Earth and Atmospheric Disasters Management

Natural and Man-made

Navale Pandharinath
C K Rajan

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Dedicated to My Parents

Late Smt. Narasubai R. Navale
Late Shri. Rukmaji Rao Narsoji Rao Navale
and
to all My Teachers

Navale Pandharinath

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Preface

Tales about human loss and miseries due to natural/man made disasters, like cyclones, earthquakes, floods, wars, droughts are found plenty in epics, folklores and ancient writings of many civilizations. This indicates disasters are not new to the man. Ancient Babilonian epic describes about a disastrous flood that followed with a prolonged spell of torrential rain. Ramayana describes that Sita was swallowed by an earthquake, Mahabharata describes the terrible loss of life in war. Man has been endeavouring to subjugate the natural disasters with an effort to conquer the natural phenomena but realized that it is futile. With the advancement of science and technology, man realized though it is futile effort to conquer the natural disaster phenomena, but it is definitely possible to reduce the loss of life to a large extent by preventive steps, and creating awareness and mass education among the people. The number of disasters that are occurring now will continue to be the same, if not more, but a lot can be done to reduce the ill-effects, particularly human loss. This is precisely the aim of disaster management.

No army, no campaign, no plan can function without the statistics of past data. Facts and figures are necessary as they tell us all about the past historic disasters and their magnitudes. Critical survey of these data provide us some clues how to negotiate with the disasters. The Freedom from Hunger Campaign launched in 1960 by FAO of UN is achieved through Green Revolution. It is hoped that Disaster Management Act 2005 and its campaign lead us to subjugate at least the ill effects of natural disasters.

Natural disasters are associated with Geological, Atmospheric, Biological and Ecological phenomena. The most common natural hazards are Tropical Cyclones, Tornadoes, Earthquakes, Floods, Droughts, Tsunamis, Local Severe Thunderstorms, Landslides, Avalanches and Climate Change.

The authors undertook to write on Earth and Atmospheric Disasters Management after decades of experience in weather forecasting, delivering talks on AIR, DD and writing articles in news papers about cyclones, floods, droughts, tsunamis and environmental pollution. The first author delivered lectures on natural disasters at Engineering Staff College of India, Hyderabad. He delivered lecture on Role of Weather and Forecasting in a seminar at Artillary Centre Hyderabad (in Feb 1994). The seminar was held on Disaster Management, after the killer earthquake that rocked Latur district in Maharastra in September 1993. The seminar gave him tremendous input on disaster management and in particular the role of defence services. He was a member of Internal Review Committee in Government of Andhra Pradesh, Andhra Pradesh Hazard Mitigation and Emergency Cyclone Recovery Project 1999-2005 (a World Bank funded project). Under this project two studies were undertaken (i) Watershed and Delta Management including Flood Modeling – study 'A', (ii) Coastal Zone Management including modeling of Wind, Rainfall and Storm surge- Study 'B'. During this project studies he has gone through various literatures pertaining to natural disasters and had interaction with scientists from WL/Delft Hydraulics-the Netherlands, Bobtie International UK, NEERI Nagpur, NIOT Chennai, AP State Remote Sensing applications Centre, Shore Area Development Authority (SADA), NRSA, CWC etc.

-Authors

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In writing this book relevant material was collected from various sources, published papers, books particularly WMO Publications, DGCA (India)/ICAO/Rules/ Publications and IMD forecasting manuals, met-monographs, cyclone tracks. Though a few references are given but they are incomplete. We express our sincere thanks to the IMD Director General and S/Shri. Y.P. Rao, K. Ramamurthy, G.S. Mandal, G. Appa Rao for using their published material; and to Prof. S.K. Dube, Prof. U.C. Mohanty IIT New Delhi, Dr. Y.S. Ramakrishna, Director (Retd.) CRIDA and Dr. R.R. Kelkar, Director General IMD (Retd).

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Abbrevations and Acronyms

AAI	=	Airport Authority of India
AASR	=	Airport & Airways Surveillance Radar
AC	=	Alternate Current
ACAS	=	Airborne Collision Avoidance System
ADS	=	Automated Dependence Surveillance
ADC	=	Air Data Computer
AIR	=	All India Radio
AP	=	Andhra Pradesh
APT	=	Automatic Picture Transmission
ART	=	Accident Relief Trains
ASR	=	Airport Surveillance Radar
ATC	=	Air Traffic Control
ATCOs	=	Air Traffic Control Officers
AWR	=	Airborne Weather Radar
AFS	=	Aeronautical Fixed Service
ATS	=	Air Traffic Service
BAPMoN	=	Background Air Pollution Monitoring Network
BOD	=	Biological Oxygen Demand
BSNL	=	Bharath Sanchar Nigam Limited
CAT	=	Clear Air Turbulence
CBRI	=	Central Building Research Institute
CBRN	=	Chemical, Biological, Radiological and Nuclear
CDA	=	Command Data Acquisition
CDR	=	Cyclone Detection Radar
CG	=	Central Government

CMW	=	Cloud motion winds
CPU	=	Central Processing Unit
CSO	=	Central Seismological Observatory
CWC	=	Central Water Commission
CWDS	=	Cyclone Warning Dissemination System
DCP	=	Data Collection Platform
DCT	=	Data Collection Transponder
DD	=	Doordarshan
DDMA	=	District Disaster Management Authority
DDMP	=	District Disaster Management Plan
DM Act	=	Disaster Management Act 2005
DGCA	=	Director General of Civil Aviation
DOT	=	Doctrine Organization and Training
DT Network	=	Department of Telephone Network
DMU	=	Disaster Management Unit
DRT	=	Data Relay Transponder
DRM	=	Disaster Risk Management
DRU	=	Drought Research Unit
DST	=	Department of Sciences and Technology
DRDO	=	Defence Research and Development Organisation
DFMD	=	Defence Forensic Metal Detectors
EASA	=	European Aviation Safety Agency
ECHO	=	European Commission Humanitarian Aid Office
EFIS	=	Electronic Flight Instrument System
ELT	=	Emergency Locator Transmitter
EPA	=	Environmental Pollution Act
EACAP	=	Economic and Social Commission for Asia and Pacific
ESSA	=	Environmental Science Services Administration
EU	=	European Union
EREC	=	Earthquake Risk Evaluation Centre

FCI	=	Food Corporation of India
FAA	=	Federal Aviation Administration
FIC	=	Flight Information Centre
FIR	=	Flight Information Region/Far Infrared Region
FL	=	Flight Level
FOQA	=	Flight Operations Quality Assurance
GAGAN	=	GPS Aided GeoAugmented Navigation
GAW	=	Global Atmospheric Watch
GDP	=	Gross Domestic Product
GESAMP	=	Group of Experts on Scientific Aspects of Marine Pollution
GIS	=	Geographical Information System/Geophysical Information System
GPS	=	Global Positioning System
GOI	=	Government of India
GMDSS	=	Global Maritime Distress and Safety System
GMS	=	(Japan's) Geostationary Meteorological Satellite
GNSS	=	Global Navigation Satellite System
GSI	=	Global Seismological Institute
GPWS	=	Ground Proximity Warning System
GTS	=	Global Telecommunication System
GOES	=	Geostationary Operational Environment Satellites
GOMS	=	(USSRs) Geostationary Operational Meteorological Satellite
HQ	=	Headquarters
HRPT	=	High Resolution Picture Transmission
HFRT	=	High Frequency Radio Telephony
IAF	=	Indian Air Force
IAS	=	Indicated Air Speed
ICAO	=	International Civil Aviation Organization
IFF	=	Identify friend or foe
IFR	=	Instrument Flight Rules
IHS	=	International Hurricane Scale
ILS	=	Instrument Landing System

IIT = Indian Institute of Technology
IMD = India Meteorological Department
INSAT = Indian National Satellite
INOSHAC = Indian Ocean Southern Hemispheric Analysis Centre
IMDPS = INSAT Meteorological Data Processing System
IPCC = Intergovernmental Panel on Climate Change
IR = Infrared
IS = Indian Standards
ISC = International Seismological Centre
ISRO = Indian Space Research Organization

JRCC = Joint Rescue Coòridnation Centre

Kt = Knots (Nautical miles per hour)

LAN = Local Area Network
LPA = Long Period Average (Normal)
LUT = Local User Terminal

MDD = Meteorological Data Dissemination
MIR = Midwave Infrared
MSSR = Monopulse secondary surveillance Radars
MRO = Mandal Revenue Officer
MTN = Main Telecommunication Network
MSD = Meteorological Sub-division

NAAQS = National Ambient Air Quality Standards
NASA = National Aeronautical Space Administration
NCC = National Cadet Corps
NDMA = National Disaster Management Authority
NDMP = National Disaster Management Plan
NCRMP = National Cyclone Risk Mitigation Project
NDRF = National Disaster Response Force
NDVI = Normalised Difference Vegetation Index
NEC = National Executive Committee
NFIP = National Flood Insurance Programme

NGO	=	Non-governmental Organization
NGRI	=	National Geophysical Research Institute
NIDM	=	National Institute of Disaster Management
NIAR	=	National Institute of Amateur Radio
NIR	=	Near Infrared
NOAA	=	National Oceanic and Atmospheric Administration
NSDI	=	National Spatial Data Infrastructure
OLR	=	Outgoing Longwave Radiation
PLB	=	Planetary boundary layer
PCB	=	Polychlorinated bicarbon
PHC	=	Primary Health Centre/Public Health Centre
PPI	=	Plan Position Indicator
PRA	=	Participatory Rural Appraisal
PRI	=	Panchayat Raj Institution
PSI	=	Pollutions Standard Index
PSR	=	Primary Surveillance Radar
RACES	=	Radio Amateur Communication Emergency Service
R&B	=	Roads and Buildings
RCC	=	Rescue Coordination Centre
RDD	=	Radar Digitised Display
RSC	=	Rescue Sub-centre
RTH	=	Regional Telecommunication Hub
RTS	=	Radio Times Signal
Rx	=	Receiver
SASE	=	Snow and Avalanche Study Establishment
SAR	=	Search and Rescue
SARSAT	=	Search and Rescue Satellite
SDMA	=	State Disaster Management Authority
SDMEC	=	State Disaster Management Executive Committee
SDMP	=	State Disaster Management Plan
SDMU	=	State Disaster Management Unit
SIGMET	=	Significant Meteorological Information

SHG	=	Self Help Group
SMR	=	Scanning Microwave Radiometer
SR	=	Scanning Radiometer
SSR	=	Secondary Surveillance Radar
SST	=	Sea Surface Temperature
SRS	=	Search and Rescue Services
SWAN	=	State Wide Area Network
TCAS	=	Traffic and Collision Avoidance System
TA	=	Traffic Advisory
TARs	=	Terminal Area Surveillance Radars
TAWS	=	Terrain Awareness and Warning System
TIR	=	Thermal Infrared
TIROS	=	Television Infrared Observational Satellite
TSP	=	Total Suspended Particulate
TSPM	=	Total Suspended Particulate Matter
Tx	=	Transmitter
UNEP	=	United Nations Environmental Programme
UNDP	=	United Nations Development Programme
UNO	=	United Nations Organization
USAID	=	United States Agency for International Development
UVB	=	Ultra Violet (Band) radiation
VDMC	=	Village Disaster Management Committee
VDMP	=	Village Disaster Management Plan
VDMT	=	Village Disaster Management Team
VFR	=	Visual Flight Rules
VHF	=	Very High Frequency
VHRR	=	Very High Resolution Radiometer
VIS	=	Visible
VSAT	=	Very Small Aperture Terminals
VTPR	=	Vertical Temperature Profile Radiometer

WDF	=	Watershed Development Fund
WEDC	=	Women's Economic Development Corporation
WHO	=	World Health Organization
WMO	=	World Meteorological Organization
WV	=	Water Vapour

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Introduction

According to WHO, "A disaster is an event that causes damage, economic disruption, loss of human life and deterioration of health and the health of societies on a scale sufficient to warrant an extra-ordinary response from outside the effected community or area".

Most of the severe floods are caused by the rivers that originate in the Himalayas. To combat floods the Rashtriya Barh Ayog was established in 1978, Task Force on flood management and Erosion control in 2004. The primary responsibility of flood control rests with State Governments. The responsibility of NDMA (2005) is (i) prevention, (ii) preparedness, (iii) mitigation, (iv) rehabilitation (v) reconstruction (vi) recovery and (vii) formulation of appropriate policies and guidelines for disaster management.

Flood management includes structural measures like flood embankments, dams, reservoirs, channel improvement, drainage improvement, diversion of flood waters, afforestation, catchment area treatment and anti-erosion works. Flood management courses being introduced in professional institutions.

On an average annually 5 to 6 cyclones form in the Indian seas of which 2 to 3 become severe. East coast is more vulnerable to cyclones than west coast of India. 13 coastal States and Union Territories with 84 coastal districts are directly effected by cyclones. India Meteorological Department provides four stage cyclone warnings. Under NDMA, National Cyclone Risk Mitigation Project (NCRMP) drawn up to mitigate cyclone risk in all coastal districts. The project is being financed by

World Bank assistance. NDMA shall arrange : (i) Mass awareness, (ii) mock drills for community capacity building to combat cyclone disaster. Government of India undertaken a comprehensive Disaster Risk Mitigation (DRM), a programme with UNDP in 169 hazard prone districts to train the people at grass root level.

According to Atlas prepared by the Building Materials Technology Promotion Council (BMTPC), 229 districts from 21 States and Union Territories, comprising 58.6% of geographical area of India is vulnerable to moderate to severe earthquakes. The NDMA proposes to launch the National Earthquake Risk Mitigation Project (NERMP) during the 11^{th} five years plan, to identify critical gaps and formulate guidelines for management of earthquakes. The NDMA and the Government of India seek the support and cooperation of various stakeholder groups, NGOs and common people, in ensuring for the institutionalization of earthquake risk reduction initiatives in the country.

According to a UN report the incidence of natural catastrophics have increased from about 100 per year in 1975 to 395 in 2006. It shows the urgency of an institutionalized mechanism for disaster management with a well organised elaborate medical preparedness in every country. In view of recent chemical tragedies and terrorism explosions, the medical preparedness for CBRN (Chemical, Biological Radiological and Nuclear) management requires Standard Operating Procedures (SOPs) for CBRN management at the incident site for triage (Sorting), personal protection, decontamination, resuscitation, casuality evacuation followed by treatment of exposed victims at the hospital level. The critical infrastructure for medical management includes CBRN casuality treatment centres/wards and training facilities for specialised response to deal with covert CBRN attacks. NDMA, Government of India with all stakeholders and experts in the country taking a proactive initiative for institutionalization of medical management by formulating national guidelines for all stakeholders and in the public domain. The main object of medical preparedness is to convert over capabilities in terms of human resource and supportive infrastructure into capacities for quick and efficient medical response.

The estimate annual loss due to natural disasters in about 2 to 3 percent of National income, 85% of the country is prone to natural disasters. It is highest in Southeast Asia. Drought prone area is about 68% of the cultivable area. Flood prone area is about 12 to 13 percent of the geographical area. About 2000 sq. km area in India is exposed to avalanches and landslides. According to US State Departments annual report, global terrorism fatalities increased from bout 15000 in 2005 to 20500 in 2006 (about 40% rise).

During 20th century global industrial activity increased 20 to 25 folds, global population grown about 2.5 billions to about 6 billions, fossil fuel consumption increased 30 to 35 folds, water demand increased enormously. All this lead to the destruction of green lungs of the earth, increased agricultural activity, use of toxic pesticides, increased greenhouse gases in the atmosphere, pollution of air, water and soil, acid rain, ozone hole and global warming and climate change. It is projected India would become to worlds most population country with 1.7 billion people by 2050.

According to intergovernmental panel on climate change 20 to 30 species face extinction due to temperature rise, glaciers retreat in the Himalays, due to sea level rise millions in control areas will be at risk, production of wheat, maize and rice will drop in India and China and more than one billion people may face fresh water shortage by 2020.

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CHAPTER - 1

Disaster Management Plan (DMP) – General

Disasters both natural and man made and climate change are much older than the oldest epics on the globe. Many of the epics mostly deal with the natural or man made disasters and climate change. However in recent times the frequency and intensity of disasters (natural and man made) show an increasing trend. The basic cause for this is attributed to human explosion, rapid industrialisation, urbanisation, global warming, environmental pollution and religious fanaticism. A world conference on Natural Disaster Reduction held recently (Jan 2005) at Kobe, Japan adopted the Hyogo Frame work of action plan by 168 Governments, India is one of them. In pursuance of this action plan, Government of India passed Disaster Management Act in both houses of parliament in 2005 and it was approved by the President of India on 23rd Dec 2005. Under this Act, National Disaster Management Authority (NDMA) was created under the Chairmanship of Prime Minister. In accordance with this Act, National Disaster Response Force (NDRF) and National Institute of Disaster Management (NIDM) are to be created, the later will work under the guideline of NDMA. At the behest of NDMA, State Governments creating State Disaster Management Authority at the State HQ, under the Chairmanship of respective State Chief Ministers, (Lt Governors for Union Territories). At district/ mandal/village level, DMA shall work under District Collector, Mandal Revenue Officer, Serpanch respectively, roping in workers both from government and NGO's. NDMA aim to build a safer, holistic, proactive, multi-displinery disaster management system. Local committees shall be formed involving stakeholders, NGOs, Corporate Sector, Voluneers, Indian Red Cross Society, NCC, Scout and Guides, Civil Defence, Home Gaurds, District, Mandal and Local Panchayat Representatives and Prominent Doctors, retired Teachers, Postman etc.

For the purpose of disaster management a specialised response force will be developed with a deputation of eight battalion well trained force which will be positioned at vulnerable locations. These NDRF units maintain close liaison with various local State Department and other stakeholders. These NDRF units provide training to other local units in the state of the art equipments. For disaster mitigation a number of disaster mitigation projects shall be initiated in respect of cyclones. earthquakes, floods, droughts, medical preparedness, mass casuality management, National mitigation reserves, Information and Communication Networks, shall be developed using the latest technologies. Research and development shall be encouraged on microzonation, risk assessment and vulnerability analysis. High priority will be given for strengthening early warning system using latest technologies like Radar, Satellites and Communication system.

NDMA provides guidelines to the states in coordination with stakeholders on preparedness and mitigation of floods, cyclones, earthquakes, chemical (industrial) disaster, medical preparedness, biological hazards, Insurance and disaster preparedness involving local people.

Most of the severe floods are caused by the rivers that originate in the Himalayas. To combat floods the Rashtriya Barh Ayog was established in 1978, Task Force on Flood Management and Erosion Control in 2004. The primary responsibility of flood control rests with State Governments. The responsibility of NDMA (2005) is (i) prevention, (ii) preparedness, (iii) mitigation, (iv) rehabilitation, (v) reconstruction, (vi) recovery and (vii) formulation of appropriate policies and guidelines for disaster management.

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According to WHO, "A disaster is an event that causes damage, economic disruption, loss of human life and deterioration of health and the health of societies on a scale sufficient to warrant an extraordinary response from outside the effected community or area".

Any extreme hazard event becomes a disaster when it severely affects the human habitation, its social, economic activities and health services on a large scale and badly requires mitigating response from outside the affected community or area. Natural disasters cause havoc to life and property every year the world over. Disasters are triggered by natural events or man made, in either case the event casts ill effects on man, animal or environment. Natural hazards have no political boundaries and no one can stop them. However it is certainly possible to reduce the ill effects to a large extent by mass education, preparedness and response.

The Ministry of Agriculture, Government of India set up a High Power Committee (2004-05) at the behest of the Prime Minister of India, to review disaster management machinery in the country and to formulate a model plan for disaster management at the National, State, District and Mandal levels. The Ministry of Home Affairs taken up a comprehensive programme for prevention, mitigation and preparedness on disaster management. One of the crucial areas needs to be built up is the area of warning protocols for cyclones. Cyclone monitoring and mitigation group will consist of :

(a) representatives of the States vulnerable to cyclones,

(b) the IMD (India Meteorological Department)

(c) National Remote sensing Centre (NRSC) and

(d) Indian Space Research Organisation (ISRO).

Cyclone Monitoring and Mitigation Group constituted and is headed by the Secretary (BM), Ministry of Home Affairs. The aim of Monitoring and Mitigation group is to strengthen the existing cyclone tracking, monitoring and early warning and its dissemination mechanism at National, State, District and Community level. This shows the urgency and to appraise the community, particularly students, to know about natural hazards and when they turn into disasters, what should be the contingency plans to face them with minimum loss of life and property?

Natural hazards are associated with geological, atmospheric, ecological and biological events. These can be categorized as:

(i) meteorological (including hydrological) and (ii) other types.

The most common natural hazards associated with meteorological events are: Tropical cyclones, Hurricanes, Typhoons, Tornadoes, Waterspouts, Thunderstorms, Hailstorms, Norwesters, Sand/Dust storms, Heat waves, widespread snowfall, smog, fog and climate change. The hydrological hazards are floods, droughts, avalanches, tsunamis. The other types of hazards include earthquakes, landslides, volcanoes, forest fires, infestations etc. Man made disasters include accidents (like train, bus, plane etc.), big fires, bomb explosions, caving of mines, food poisoning, hooch tragedies, chemical contamination (pollution of air, water and soil), nuclear accidents, human suicide bombs, extremist attacks, hostages and killings, mutiny, war, communal flares, mass exodus, weapons of mass destruction etc. The root cause of many of man made disasters are attributed to social evils, supremacy of one man or society over the other, ignorance, revenge and hatred. Some known examples are:

(i) *Nuclear/ atomic bomb explosions* – Atom bomb explosions over Nagasaki, Hiroshima cities in Japan.

(ii) *Biological chemical* – Pathogens, Bird flue, Madcow disease, Anthrox.

(iii) *Radioactive chemicals* – Chernobyl (Russia 1986) nuclear accident, Bhopal (India) Isocyanide gas fumes tragedy (1998).

(iv) *Smog tragedy* – Over London (1952), Mouse valley Belgium (1930), Los Angeles (1944)

(v) *Human suicide bombs* – 9/11 aircraft explosions over World Trade Centre, Perumbadoor (India, TamilNadu) Rajiv Gandhi assasination etc.

(vi) History provides unending tragedies of wars.

In recent times both natural and man-made disasters are in the increasing trend, which is attributed to population explosion, ignorance, pervertedness and negligence. It is forecasted that the occurance of natural and man-made hazards shall remain the same in future as they are at present if not more. However a great deal can be done to minimise the losses of life and property. This is exactly the aim of disaster management. A bank report indicates, an investment of one Dollar for disaster prevention saves forty Dollars, but ironically most people think an investment as cost and not as benefit.

According to World Bank estimates, the global natural disaster damage between 1950-1990 rose from $ 400 lakh to $ 6520 lakh. The number of natural disasters between 1975-2005 rose from 100 to 400 (four times) and it is said "Nature creates hazards but man makes them disasters". According to one study (emergency data base) of the world natural disasters, the most frequent are in India, which ranks fourth among top ten considering human casualities. If we consider number of people affected, India stands third in rank after China, Bangladesh. The statistics of natural disasters in India during 1900 to 2005 indicates that there had been 160 floods, 21 droughts and 24 earthquakes. The statistics of ten major global natural disasters during 1947-1980 is given in the Table 1.1 ranking by virtue of their ferosity (Bindi V. Shah 1983).

Table 1.1

S.No.	Types of Disaster	No.of deaths nearest thousand	Approximate percentage of total deaths
1.	Tropical cyclones, Hurricanes Typhoons	4,99,000	41%
2.	Earthquakes	4,50,000	37%
3.	Floods (other than associated with cyclones)	1,94,000	16%
4.	Thunderstorms and Tornadoes	29,000	2.4%
5.	Snowstorms	10,000	1%
6.	Valcanoes	9,000	0.7%
7.	Heat waves	7,000	0.6%
8.	Avalanches	5,000	0.4%
9.	Landslides	5,000	0.4%
10.	Tidal waves including Tsunamis	5,000	0.4%

Important world's worst natural disasters are given in the Table 1.2.

Table 1.2

S.No.	Year	Types of disaster	Place	Approximate No.of Deaths
1.	526 B.C	Earthquake	Syria	250000
2.	1556	Earthquake	Shanxi, China	830000
3.	1703	Earthquake	Japan	200000
4.	1737	Earthquake and cyclone	Calcutta, India	300000
5.	1976	Earthquake	Tianjin, China	242000
6.	1943-44	Famine	Bengal, India	1500000
7.	1969-71	Famine	Northern China	20000000
8.	1642	Flood	Huanghe River, China	300000
9.	1887	Flood	Henan, China	900000
10.	1939	Flood	Henan, China	1000000
11.	1450	Bubonic Plague (Black death)	Europe and Asia	75000000
12.	1918	Influenza	World wide	22000000
13.	1888	Typhoon	Vietnam, Haiphong	3000000
14.	1876	Cyclone	Bakerganj, India	100000
15.	1970	Cyclone	Bangladesh	200000
16.	2004	Tsunami and Earthquake	Sumatra, Indian Ocean	300000

In all disasters atmospheric (meteorological and hydrological), geological, ecological, biological events, weather plays an important role, that it adds fuel to the fire. About 90% of all natural disasters account to (Cyclones, floods and droughts) hydrometeorological events, which cause heavy devastation to property and loss of life account about 65% of total damage of natural disasters.

Disaster management is a part of government and it is coming down from the ages. To handle any type of natural or man-made crisis a thorough contingency plan exists at National and State level. At the National level organisation for different crisis is given in Table 1.3.

Table 1.3

S.No.	Disaster Event	Nodel Ministry
1.	Natural disasters-cyclones, floods, droughts, earthquakes etc.,	Agriculture
2.	Nuclear disaster	Department of Atomic Energy
3.	Nuclear, Biological, chemicals	Environment & Forest, Health and Family welfare
4.	Law and order	Ministry of Home Affairs
5.	Endangering Security	Ministry of External Affiairs
6.	Mutiny	Ministry of Defence and Ministry of Home Affairs
7.	Mass exodus, and Breakdown	Ministry of Home Affairs of Services
8.	Terrorist hijack	Ministry of Civil Aviation
9.	Extremist attack, hostage and assasination	Ministry of Home Affairs
10.	Oil spill	Ministry of Ocean Development

The estimated annual loss due to natural disasters is about 2 to 3 percent of National income. 85% of the country is prone to natural disasters. It is highest in southeast Asia. Drought prone area is about 68% of the cultivable area, Flood prone area is about 12 to 13% of the geographical area. Every year floods are experienced in about 2% of the geographical area. More than 50% of the geographical area is vulnerable to seismicity, about 2000 sq.km area in India is exposed to avalanches and landslides, and most part of northwest India is attacked by desert locust. According to US State Departments annual report, "Country Reports on Terrorism", global terrorism fatalities rose from 14618 in 2005 to 20498 in 2006, that is, rose by 40%. It is noteworthy that long term investment in disaster management is wiser than an isolated emergency investment just before the onset of disaster.

Increased use of the knowledge of weather and climate certainly will contribute to the protection of life and property, mitigation of natural disasters and side by side promotes sustainable development. Sustainable development means the use of natural resources to meet all the needs of present generation without causing any harm to the natural resources so that the future generation also fully enjoy their needs. In recent decades, the application of the science of meteorology and environment provided the man a key for faster development both in food production and national economy. However its abuse or inadverant use causing global warming, climate change, environmental damage and natural resources for future generation. This is the concept against depletion (abuse) of natural resources without recourse to substitute (that is environmental sustainability).

The prediction of atmospheric hazards achieved tremendous progress or nearly precise, however the prediction of geological and biological hazards is still far away from the practical use. In advanced countries (like America, European countries, Japan, India) loss of life due to cyclones, tornadoes, floods have been decimated in recent times through accurate weather forecasts, timely warnings, disaster preparedness, awareness among the masses and prompt action. During 1977 November, Andhra Deeviseema cyclone more than 10,000 people lost their lives, while in 1990 May Andhra cyclone of the same intensity the loss of life reduced to less than 1000, this is because of mass awareness and preparedness. The devastation of weather hazards and other natural hazards can be further reduced both in loss of life and property, using the advanced technologies of satellite based data, geophysical information system, hazard zoning, by construction of cyclone shelters, protection barriers, dykes against floods and storm surge inundation, diversion of flood waters, percolation tanks, watershed management, plantation of mangroves etc., in coastal areas. It is highlighted here that even 100% correct forecast is of no use if it is not reached in time to the concerned persons (officials) in a language clearly understood by them and if they are not equipped with men and material to combat the situation. It is therefore necessary to have pre-plan to train the officials, and volunteers/NGOs about the meaning of the forecasts to enable them not to draw any conclusion of their own about the gravity of the situation or bypass the forecasts but to act on it as advised.

United Nations focused the National Meteorological and Hydrological services to anticipate, avert and minimize the impacts of extreme natural events, desertification and other threats to human safety and security to the global environment including climate change, global warming, ozone depletion and increased pollution.

We shall learn briefly about the natural hazard events and associated disaster management, which differs from one type of natural hazard event to another type. First we shall learn about cyclones and associated disaster management plan in detail, which will be a guiding principle in respect of other natural disaster event management. The standard operating procedures (SOPs) of cyclone disaster management plan are:

1. Disaster preparedness-longterm, like construction of shelter belts, cyclone shelters, education etc.
2. Disaster preparedness-just before the event, like alerting the people, storing food, water, machinary etc.
3. Action after receipt of warning – like evacuation of people from low-lying vulnerable areas which are likely to be affected, cancelling the leave of officials and ask them to proceed to their assigned work etc.

4. Rescue operations before impact of cyclone.
5. Actions during impact phase of cyclone.
6. Rescue operations after impact of cyclone.
7. Relief operations after disaster (that is after dewarning of cyclone)
8. Rehabilitation operation
9. Reconstruction operation.

Disaster Preparedness Involves

(i) Understanding the hazards associated with the type of event – like cylcone, flood, drought, earthquake etc.

(ii) Understanding the ways how the type of event inflicts losses. In case of cyclone the losses occur due to heavy rains, strong winds, storm surges.

(iii) Vulnerability or susceptibility. In case of cyclone low lying coastal areas are susceptible to inundation and wind fury, which inflicts damage to life and property like assets (Government and private), roads, bunds of tanks and rivers, uproots or damages trees, telegraphs and electric lines etc.

(iv) Vulnerability reduction. Actions and measures that reduces vulnerability. In case of floods and cyclones strengthening of bunds, coastal flood embarkments, shelter belts, wind breakers etc.

Vulnerability assessment depends on the frequency of hazards (in a specified area), density of population, vocation of the majority of the people. In case of cyclone the proximity to the coast, river, low-lying areas, transport and communication.

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CHAPTER - 2

Cyclones and their Hazard Potential

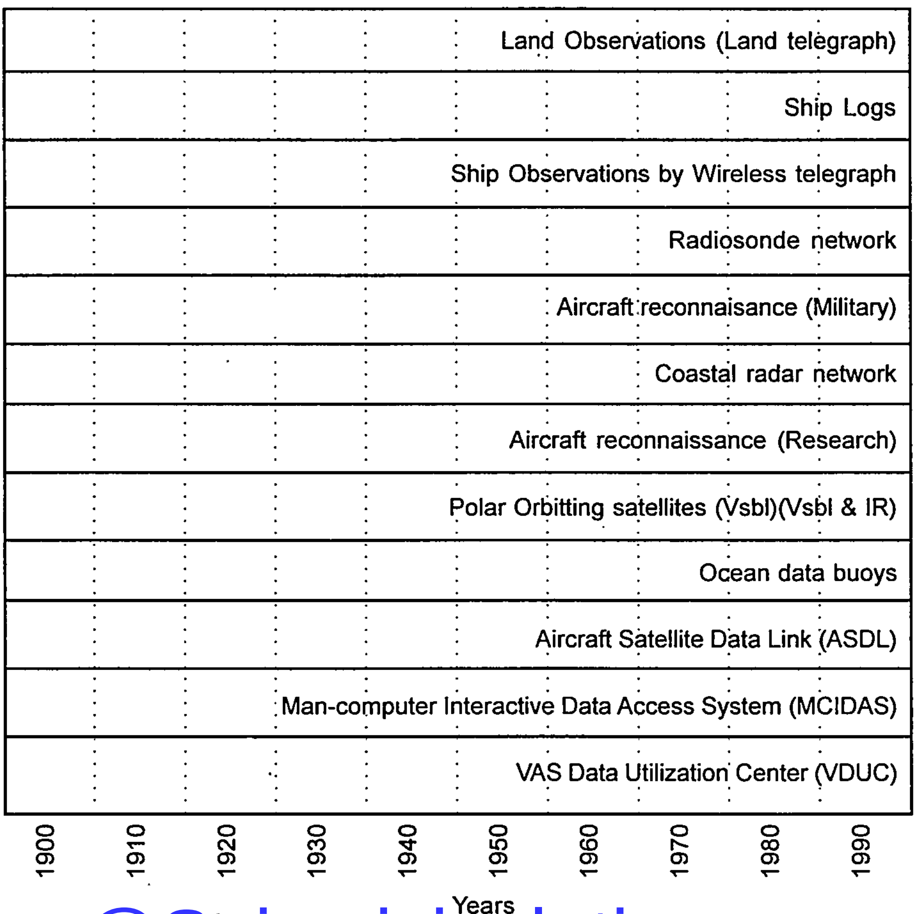
Tropical cyclones are the most destructive phenomena of atmospheric nature. They are foremost in their violence, destruction and duration. They generally form over the sea, strike the coastal areas with their ferocity of winds, torrential rains and inundate the area with storm surges. Compare with other natural disasters, an earthquake short lived (one or two minutes) but cause much more devastation to life and property. Tornadoes are the most violent storms on earth but they are small in size and cause destruction in their narrow path for a short period. Extra-tropical cyclones of winter are the largest phenomena of the atmosphere but they are very mild as compared to tropical cyclones. In addition to the loss of life and property, the tropical cyclones leave behind them the trail of difficulties in constructions even after their passing away. It was estimated that a normal cyclone precipitates water about 2 giga tons (2×10^9 tons) in an hour and dissipates about 36×10^{10} kwh of kinetic energy. A moderate cyclone releases large amounts of energy, of which about 3% is in the form of wind and wave energy. This energy is sufficient for all the needs of 100-150 million people for a year. With all its ferocity and destruction the blessings of a cyclone is that it gives large quantities of fresh water, which fills lakes, reservoirs, ponds without which many places would have been arid.

Tropical cyclones are known by different names over different parts of the globe. Over Indian seas they are called cyclones. In western Pacific they called Typhoons (when wind speed exceeds 118 kmph or 64 kt), in Atlantic and eastern

Pacific they are called Hurricanes. In Australia they are named Willy-Willies, in Philippines as Baguios and in Maxico Cordonazo. Our knowledge of cyclones has been built up gradually as and when more and more sophisticated instruments were invented. Initially the knowledge of cyclones based on ship reports and coastal meteorological observations when they approached the coast. Subsequently it was built on aircraft reconnaissance flight reports and then Radar observations. Since 1960, weather satellite observations greatly contributed to our knowledge and now with these satellite observations none of the cyclones over seas escape detection.

Technical advances in systems for observing Tropical cyclones is given in Table 2.1 and cyclone dectection and observation given in Fig. 2.1.

Table. 2.1 Technical advances in system for observing tropical cyclones.



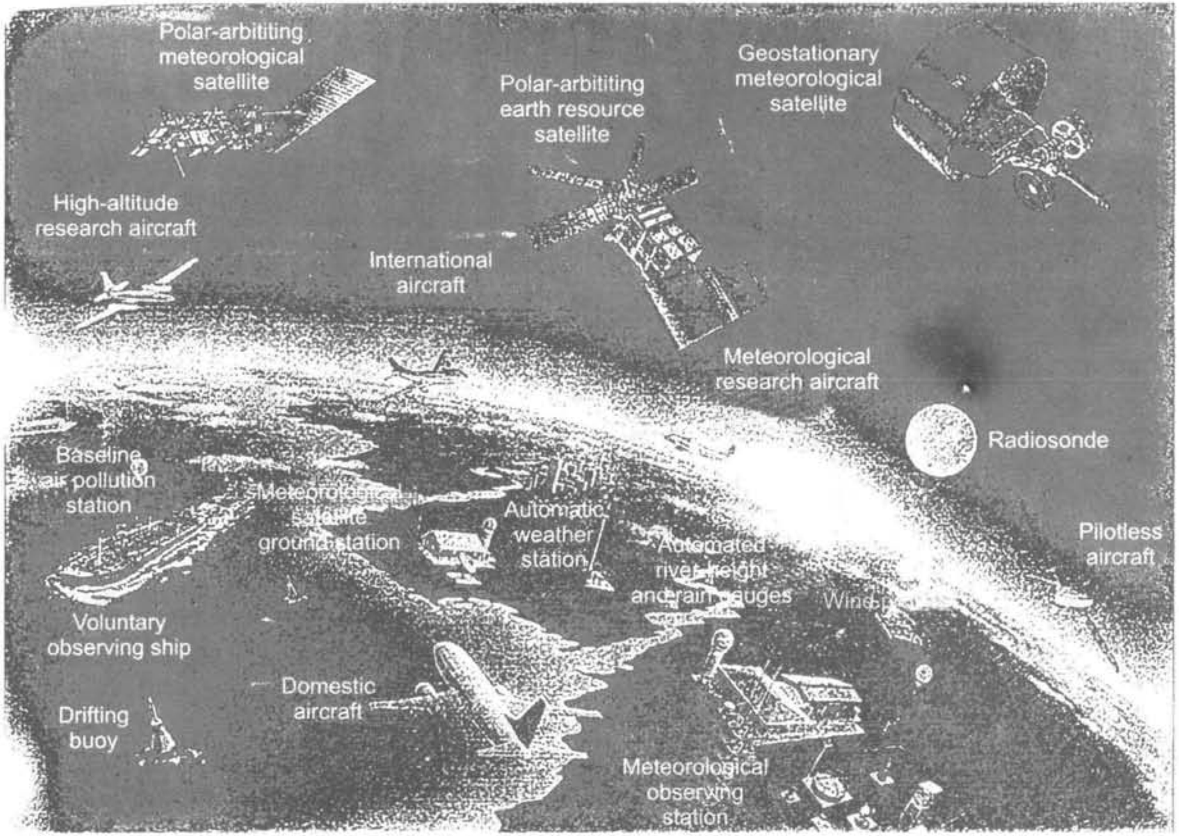


Fig. 2.1 Cyclone detection and observation.

The essential elements of an integrated global observing system for the atmosphere based on the contribution of national Meteorological Services of WMO Member Countries.

2.1 Classification of Low-Pressure Systems

Tropical cyclones are the intense atmospheric low pressure systems that form over the sea, where sea surface temperature is more than 26 ^{o}C. They germinate as tropical distrurbances or low pressure areas. IMD classified these low pressure systems based on surface wind speed over sea area is given in Table 2.2.

Table 2.2 Classification of tropical disturbances.

S. No.	Pressure system	Beaufort Scale	Surface wind speed Kt	Kmph	Satellite picture current intensity	Pressure defect at the centre (hPa)
1.	Low pressure area	4	less than 17	19-28 (10-17)	-	-
2.	Depression	5,6	17-27	29-49	1.5	4.0
3.	Deep Depression	7	28-33	50-61	2.0	4.5
4.	Cyclonic storm	8,9	34-47	62-88	2.5 to 3.0	6.1 to 10
5.	Severe cyclonic storm	10, 11	48-63	89-117	3.5 to 4.0	15 to 21
6.	Very severe cyclonic storm	12 or (a) more (b)	64-90 91-119	118-167 168-221	4.0 to 4.5 5.0 to 6.0	29-80 29-80
7.	Super cyclone	more than 12	120 or more	more than 221	6.5 or more	more than 80

1kt = 1.86 kmph

The Table 2.3 gives the International Hurricane Scale (IHS)

Table 2.3 International Hurricane scale.

IHS number	Wind speed mps	Kt	IHS number	Wind speed mps	kt
1.0	33	64	6.0	80	156
1.5	40	78	6.5	83	162
2.0	46	90	7.0	87	168
2.5	52	100	7.5	90	174
3.0	57	110	8.0	93	180
3.5	61	119	8.5	95	185
4.0	65	127	9.0	98	191
4.5	69	135	9.5	101	196
5.0	73	142	10.0	103	201
5.5	77	149			

The Table 2.4 gives the description of the state of sea.

Table 2.4 Description of the state of sea.

S.No	Wave height in meters	Wind speed kt	Description of sea	
1.	0	0	Calm	glassy
2.	0-0.10	1-3	Calm	ripples
3.	0.10-0.50	4-5	Smooth	wavelets
4.	0.50-1.25	6-10	Slight	
5.	1.25-2.50	11-21	Moderate	
6.	2.50-4.00	22 - 27	Rough	
7.	4.00-6.00	28-41	Very Rough	
8.	6.00-9.00	41-47	High	
9.	9.00-14.00	48-63	Very High	
10.	14 or more	64 or more	Phenomenal	

The Table 2.5 gives the Beaufort Scale with estimation of wind speed.

The Table 2.6 gives Hurricane scale damages.

Tropical cyclones generally form over warm sea waters (temperature 26 °C or more).They dissipate when moved over to cold waters or crossed coast or recurved over to subtropics. The breeding region of tropical cyclones is shown in Fig 2.2, and Fig. 2.2(a) Equatorial regions between lat 5°N or 5°S are not favourable for the formation of cyclones. The average life span of a cyclone is about six days until they land or recurve into temperate latitudes. Some have life of few hours, while others may last for about two weeks. In northern hemisphere the wind and cloud bands spiral in anticlockwise sense while in southern hemisphere they spiral in clockwise sense. This phenomenon clearly seen in satellite pictures in Fig. 3.1.

Tropical cyclones have four stages of life cycle. Formative, immature, mature and decaying stage. There is no set duration that a storm may be in one stage. The storm may skip any stage or go through in such a short period that it is not possible to distinguish with synoptic available data. On some occasions it is difficult to say in any stage of development.

Table 2.5 Beaufort scale.

Baufort number	Description	Wind speed mps	Wind speed knots	Wind speed estimation	
				Overland	Over sea
0	Calm	0-0.2	Less than 1	Smoke rises vertically	Sea looks like mirror
1	Light	0.3-1.5	1-3	Smoke drift indicates wind direction (wind vane does not move)	Ripples with the appearance of scales but no foam crests
2.	Light breeze	1.6-3.3	4-6	Leaves rustle ordinary vanes moved by wind	Small wavelets - More crests have a glassy appearance but do not break
3.	Gentle breeze	3.5-5.4	7-10	Leaves with small twigs in constant motion. Wind extends light flag.	Large wavelets – crests begin to to break. Foam of glassy appearance. Scattered white horses.
4	Moderate breeze	5.5-7.9	11-16	Small branches are moved, raises dust and loose papers	Small waves becoming longer. Fairly frequent white horses
5	Fresh breeze	8.0-10.7	17-21	Small trees in leaf begins to sway. Orested wavelets form on inland waters	Moderate waves taking a more pronounced long form. Many white horses are formed.

Table 2.5 *Contd....*

Baufort number	Description	Wind speed mps	Wind speed knots	Wind speed Estimation	
				Overland	Over sea
6.	Strong breeze	10.8-13.8	22-27	Large branches in motion, whistling sound heard in telegraph wires, umbrellas used with difficulty	Large waves begin to form, the white foam crests are more extensive everywhere, probably some spray.
7.	Moderate gale or Near gale	13.9-17.1 (T 2.0)	28-33	Whole tree in motion, inconvenience felt when walking against the wind	Sea heaps up and white foam; breaking waves begin to be blown in streaks along the direction of the wind (spindrift begins to be seen)
8.	Fresh gale or gale	17.2-20.7 (T 2.5)	34-40	Breaks twigs off trees, generally impedes progress	Moderate high waves of greater length, edges of crests break into spindrifts; the foam is blown in well marked streaks along the direction of the wind
9.	Strong gale	20.8-24.4 (T 3.0)	41-47	Slight structural damage occurs (chimney pots and slates removed)	High waves; dense streaks foam along the direction of wind. Crests of waves begin to topple, tumble and rollover. Spray may affect visibility.
10.	Storm	24.5-28.4 (T 3.5)	48-55	Rarely experienced inland, trees uprooted; considerable structural damage occurs.	Very high waves with long overhanging crests. The resulting foam in great

Table 2.5 *Contd....*

Baufort number	Description	Wind speed mps	Wind speed knots	Estimation	
				Overland	Over sea
					Patches is blown on dense white steaks along the direction of the wind. On the whole, the surface of sea takes white appearance, the rolling of the sea takes white appearance. The rolling of the sea becomes heavy and shock like Visibility affected.
11.	Violent storm (T3.5 to 4.0)	28.5-32.5 (T4.0 to 4.5)	56-63	Very rarely experienced on land Accompanied by widespread	Exceptionally high waves. Small and medium sized ships might be for a time lost behind the waves. The sea is completely covered with long white patches of foam lying along the direction of wind. Everywhere the edges of waves, crests are blown into forth. Visibility badly affected.
12.	Hurricane	32.7 and more T5.0 to 6.0	64 or more 64-90 (T4 to 4.5) 91-119 (T5.0 to 6.0) 120 or more (T6.5 or more)	Severe extensive damage	The air is filled with foam and spray. Sea is completely white with driving spray. Visibility is very seriously affected.

Table 2.6 Hurricane scale damages (WMO TCP R.L. Southern)

S.No.	IHS	Wind speed kmph	Storm surge height above astronomical tide level		Potential damage to property and flooding along the coast
			meters	feet	
1.	one	119-153	1.2 to 1.5	4-5	No real damage to building structures. Damage to mobile homes (unanchored), shrubbery and trees. Flooding of coastal roads and minor damage to pier
2.	Two	155-177	1.8-2.4	6-8	Some roofing material, door and window damage to buildings; considerable damage to vegetation, exposed mobile houses and piers. Coastal and low-lying escape routes flood 2 to 4 hrs before arrival of Eye (centre). Small craft in unprotected anchorage break moorings.
3.	Three	179-194	2.7-3.7	9-12	Small structural damage to small residences, and utility buildings with a minor amount of curtain wall failures. Mobile homes are destroyed. Flooding near the coast destroys small structures while large structures damaged by floating debries. Terrain continuously lower than 1.5 m (5 ft) may be flooded inland extending to about 13 km (8 miles) or more
4.	Four	195-233	4-5.5	13-18	More extensive curtain wall failures with some complete roof structure failure on small residences. Major damage to lower floors of structures near the shore. Terrain flooded inland as far as 10 km (5 miles).
5.	Five	≥233	≥5.5	≥19	Complete roof failure on many residences, and industrial buildings. Some complete building failures with small utility buildings blown off. Major damage to lower floors of all structures located below 4.6 m (15 ft) above sea level and within 460 m (500 yds) of the shore line.

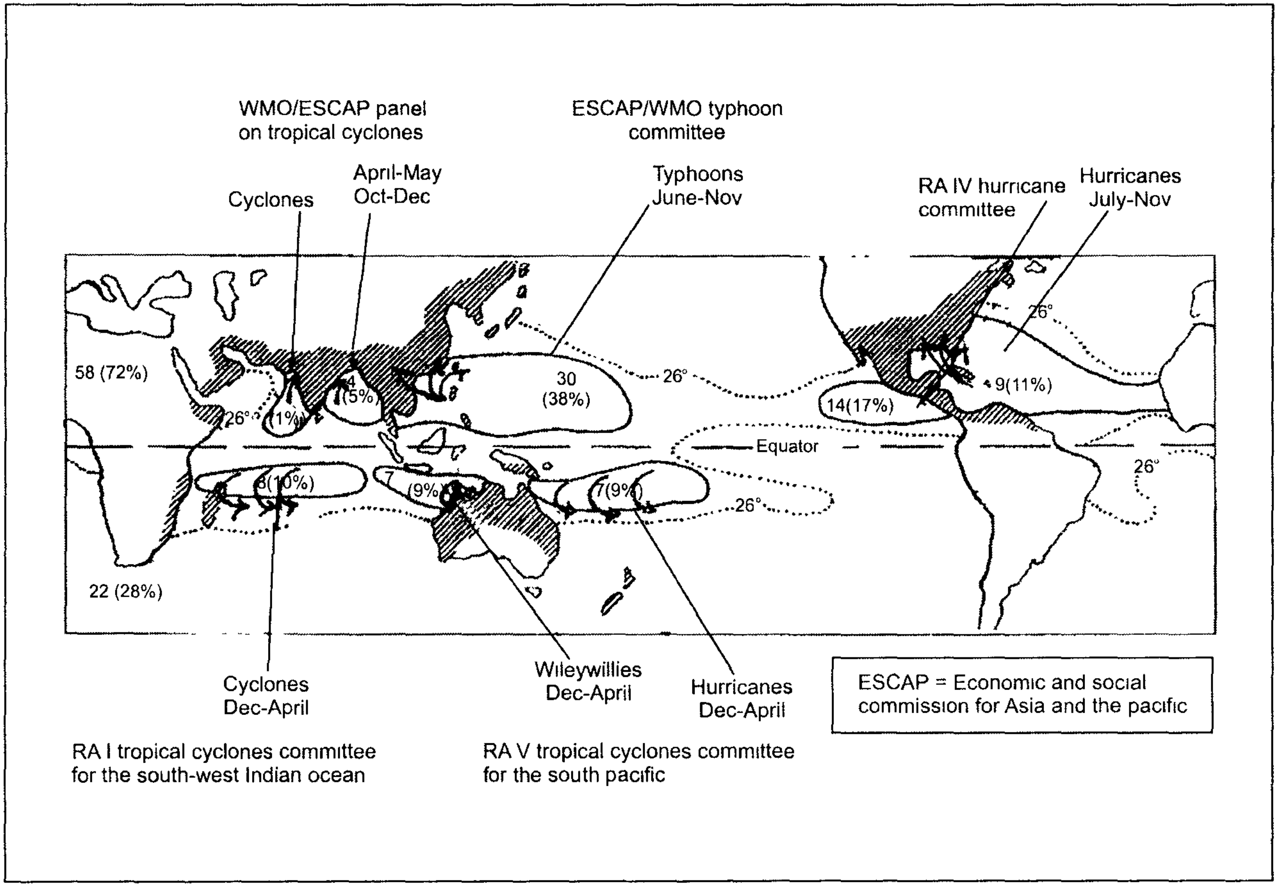


Fig. 2.2 Bredding regions of tropical cyclones

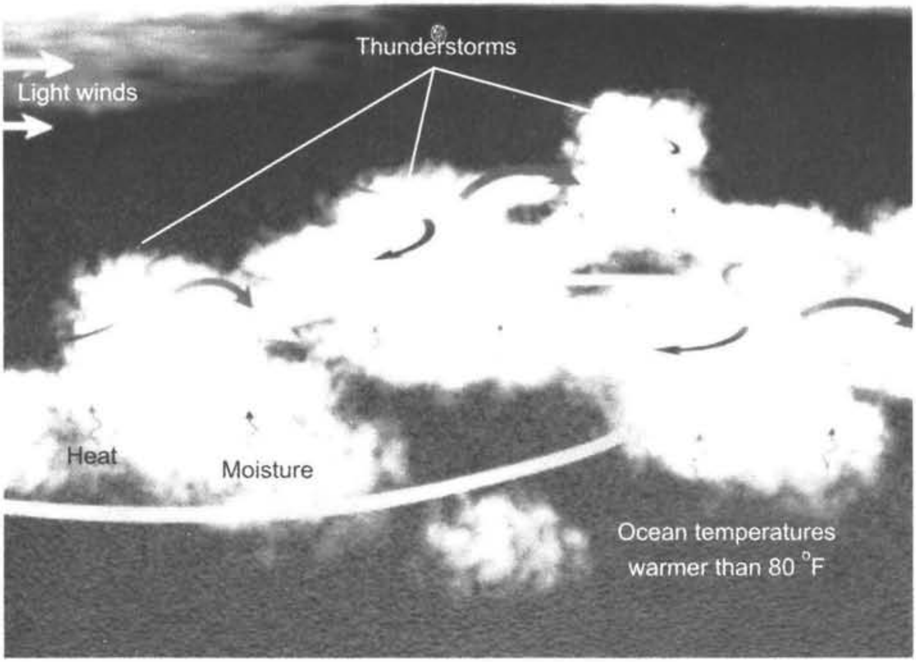


Fig. 2.2(a) Birth of a tropical cyclone.

A fully developed cyclonic storm can be divided horizontally at surface level into four regions. (See Fig. 2.3). The central area (radius 20 to 50 km) with calm or light winds and generally clear sky, is called the Eye of the cyclone. The eye-wall cloud mass is shown in Fig. 2.4. The adjacent ring shaped area (ring width 10 to 20 km) with virtually overcast sky, towering cumulus and cumulonimbus clouds is called Wall-cloud Region. The third region of ring shaped area, radius extending upto 80 km from the centre, with strong hurricane winds (speed 118 kmph or more) is called a belt of hurricane winds. The fourth, last region extending 200 to 500 km radius from the centre is called outer ring region. The diameter of a tropical cyclone is of the order 100 to 1000 km or more. Some may have diameter as small as 30 km. The greatest damage caused by a cyclone is its hurricane winds and storm surges (tides). At sea, some storms produce distinctive heavy swell, that effects ocean shipping. As storm travels and approaches the coast, the piling up of water by strong winds produce a disastrous storm surge (tidal wave) which inundate coastal areas, particularly river mouth deltoic areas.

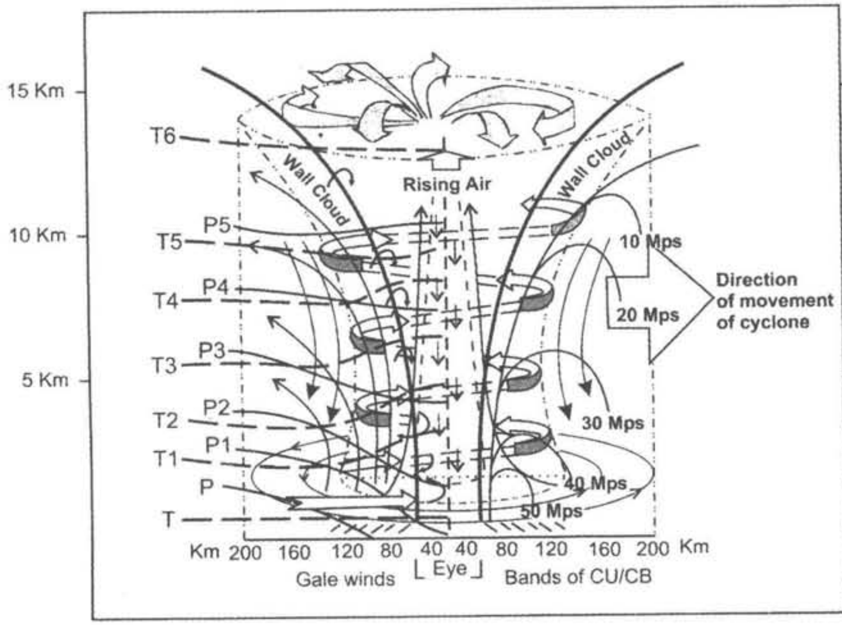


Fig. 2.3 Schematic diagram of a mature cyclone, with cloud, temperature and wind distribution.

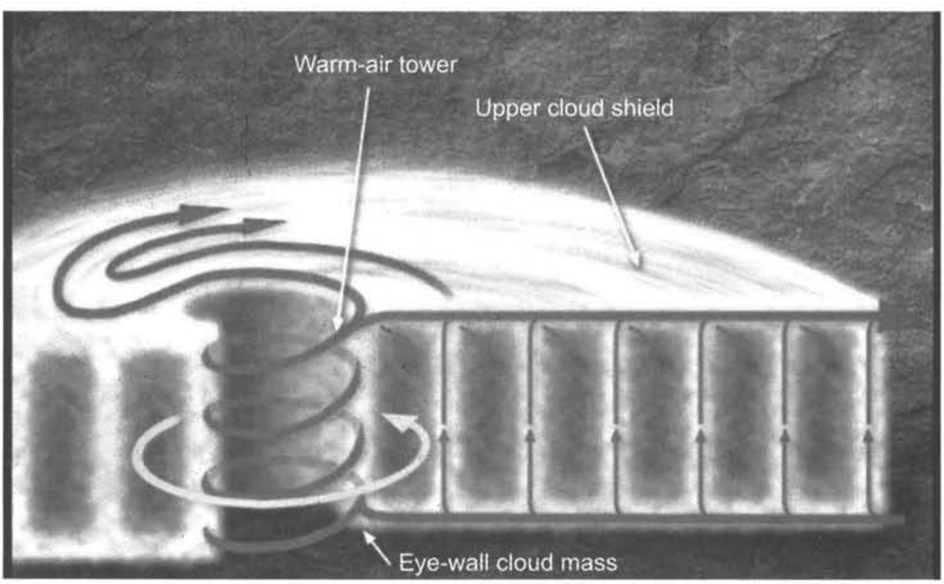


Fig. 2.4 Profile through a tropical cyclone.

2.2 Statistics of Cyclonic Storms Over Indian Seas

Studies of past historical cyclone data indicate that about 85% of depressions intensify into cyclonic storms withing 48 hours of their formation and within 12 to 24 hrs on 40% of the occasions. Cyclonic storms attain severe intensity within 36 hours on 75% of the occasions. More than 50% of cyclonic distrubances that form in the Bay of Bengal in the months of March, April, May, November and December intensify into cyclonic storms.

The Table 2.7 gives the statistics of cyclonic storms over Indian seas of 100 years (1891 to 1990) and Table 2.6 gives Statistics of CS and SCS crossing the coast during 1891-2000.

Table 2.6 Statistics of CS and SCS crossing Indian coast during 1891-2000.

S.No.	Name of coast	No.of CS+ SCS)	Bay of Bengal	Arabian sea
1.	West Bengal	69		
2.	Orissa	98		
3.	Andhra Pradesh	79	308	
4.	Tamilnadu	62		
5.	Karnataka	02		
6.	Maharashtra	18		51
7.	Gujarat	28		
8.	Kerala	03		
9.	**Total**	**359**		

It follows from the Table 2.7 (1891-1990 data):

1. The annual average of depressions (D) in (Bay of Bengal and Arabian sea)

   Indian seas $= \dfrac{767}{100} \simeq 8.$

2. The annual average of cyclonic storms (CS + SCS) over Indian seas

   $$= \frac{551}{100} \simeq 6.$$

3. The annual average of Depressions and cyclonic storms $= \dfrac{1318}{100} \simeq 13.$

4. The annual average of SCS in Indian seas $= \dfrac{248}{100} \simeq 2.5.$

5. The annual average of monsoon depressions in Indian seas $= \dfrac{533}{100} \simeq 5.5.$

Table 2.7 Statistics of cyclonic storms over Indian seas 1891-1990.
D = Depression, CS = cyclonic storms, SCS = severe cyclonic storms

S.No.	Month	No.of depressions (D)	No.of cyclonic storms (CS)	No.of severe cyclone Storms (SCS)	Total (CS + SCS)
1.	January	9	5	2	16 (7)
2.	February	3	-	1	4 (1)
3.	March	1	2	2	5 (4)
4.	April	10	13 } 35	14 } 66	37 (27)
5.	May	29	20	50	99 (70)
6.	June	87	40	17	144 (57)
7.	July	131 } 533	37 } 137	8 } 45	176 (45)
8.	August	171	30	3	204 (33)
9.	September	144	30	17	191 (47)
10.	October	99	54	45	198 (99)
11.	November	53 } 182	46 } 126	68 } 134	167 (114)
12.	December	30	26	21	77 (47)
13.	Total	767	303	248	1318 (551)

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6. The annual average of monsoon (CS+ SCS) cyclonic storms in Indian seas $= \frac{182}{100} \simeq 2.$

   Of the total annual depressions that form in the Bay of Bengal and Arabian sea ($\left(\frac{551}{1318}\right)$ or about 42% become cyclonic storms, $\left(\frac{248}{1318}\right)$ or about 11% become severe cyclonic storms and $\left(\frac{767}{1318}\right)$ or 58% remain as depressions.

   Of the total depressions that form in the Bay of Bengal and Arabian sea during pre (M.A.M) and post (O.N.A) monsoon period $\left(\frac{361}{583}\right)$ or 62% become cyclonic storms, $\left(\frac{200}{583}\right)$ or 34% become severe cyclonic storms.

The above statistics are useful in disaster management planning.

The global annual average of tropical cyclones is 80, which affect about 50 countries and its annual variation is about 8 (that is 10%). Year to year variation of cyclonic disturbances and cyclonic storms are large. The average life period of cyclone storm is 6 days. In indian seas the annual average of cyclonic disturbances is about 16 (Bay of Bengal 13) and standard deviation is 3.1. Its variation is 7 in 1984 and 23 in 1927. The annual average of tropical cyclones (in indian seas) is about 6 (that is about 7% of global total), standard deviation is 1.85. Its variation is 1 in 1949 and 10 in each of the years 1893, 1926, 1930 and 1976. The average life period of cyclones in Indian seas is 1.5 days. The worlds longest record life period of tropical cyclone is 31 days, in case of Hurricane Ginger formed in Atlantic ocean in 1972, while in Indian seas 14 days (2-15 Nov 1886 and 16-19 Nov 1964). The radius of global tropical cyclones vary 50-100 km to 2000 km, while a large number of cyclones in Indian seas had diameter less than 100 km. The maximum number of tropical cyclones form in western parts of north Pacific (about 33% of the global storms) while the southern parts of eastern Pacific, south Atlantic are free from tropical cyclones.

The lowest pressure in a tropical cyclone occurs in its Eye (central) region. The global lowest pressure of 870 hPa was recorded in Typhoon Tip in Pacific on 12 october 1979, which had sustained wind speed of 165 kt. The most intense cyclone in Indian seas was Falsepoint Orissa cyclone, which recorded the central pressure (Eye) of 918.9 hPa on 22 september 1885, and sustained wind speed 136 kt, tidal height 6 to 7 meters. In case of Diviseema Andhra cyclone of 19 November 1977, the estimated central (Eye) pressure was 911 hPa and maximum sustained wind speed was 140 kt with tidal height 5 meters.

The maximum sustained wind speed for cyclones in Indian seas is given by the emprirical formula

$$V_{max} = 14.2 \sqrt{P_n - P_0}$$

where V_{max} = Maximum sustained wind speed in kt

P_n = Peripheral pressure of cyclone in hPa

P_0 = lowest central pressure in the cyclone Eye in hPa

A hurricane wind speed of 100 kt creates roughly a wave height of about 30 m and kinetic energy about 10^{19}J. The liberation of this much of energy and its conversion into heat does not warm the ocean surface water but instead cools it. It mixes the ocean water to a depth of about 200 m to 400 m in an area of about 50 to 100 km of radius.

2.3 Movement of Cyclones in Indian Seas

Prediction of the movement of a cyclone is a very difficult job because it is erratic. However the past data of more than 100 years reveal the climatic movement.

The number of cyclones that cross or accost or skirt the east coast of Srilanka, Tamilnadu, Andhra Pradesh and Bangladesh is highest during October, November, December, while that affect Orissa, West Bengal, Arakan coasts is maximum during mansoon (June, September) months and March, April, May.

Most of the cyclonic storms (about 65%) form in the months of April, May and in October, November and December. During January, February and March cyclones do not form in Arabian sea, while in Bay of Bengal they are a few and far between. In these months they originate between lat 5°N and 8°N, move in a westerly or northwesterly direction and hit the coast of north Tamilnadu and east coast of Srilanka.

During April, May they form between lat 8°N and 15°N, move initially in a northwesterly or northerly direction and then recurve. In Bay of Bengal the whole east coast of India, coastal areas of Bangladesh and Arakan coast of Myanmar are prone to the incidence of cyclones. In Arabian sea, they move towards the coast of Arabia. A few move in northerly direction towards Maharastra, Gujarat coasts. Tracks of storms during May is shown in Fig. 2.5 and during November is shown in Fig. 2.6

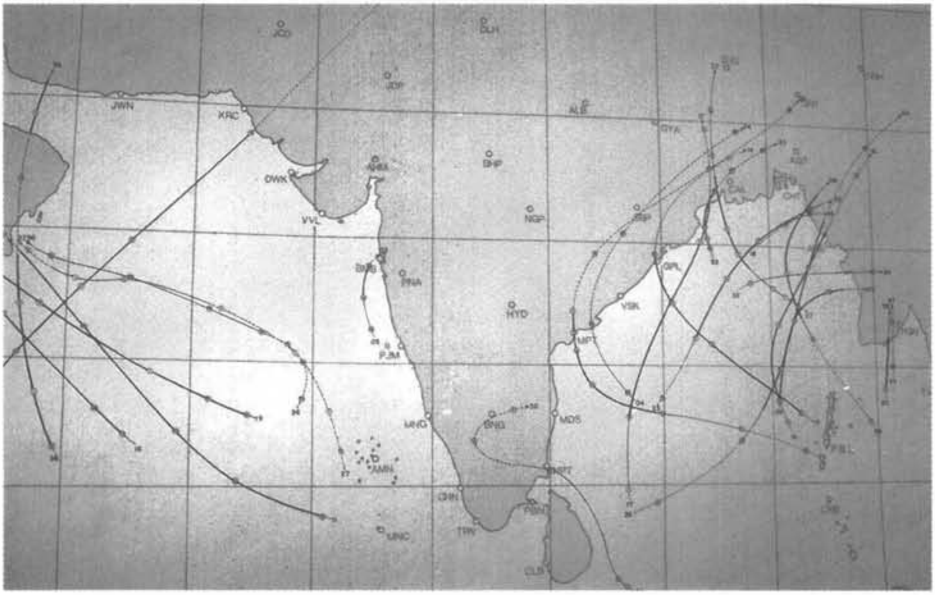

Fig. 2.5 Track of Storm - May (40 years).

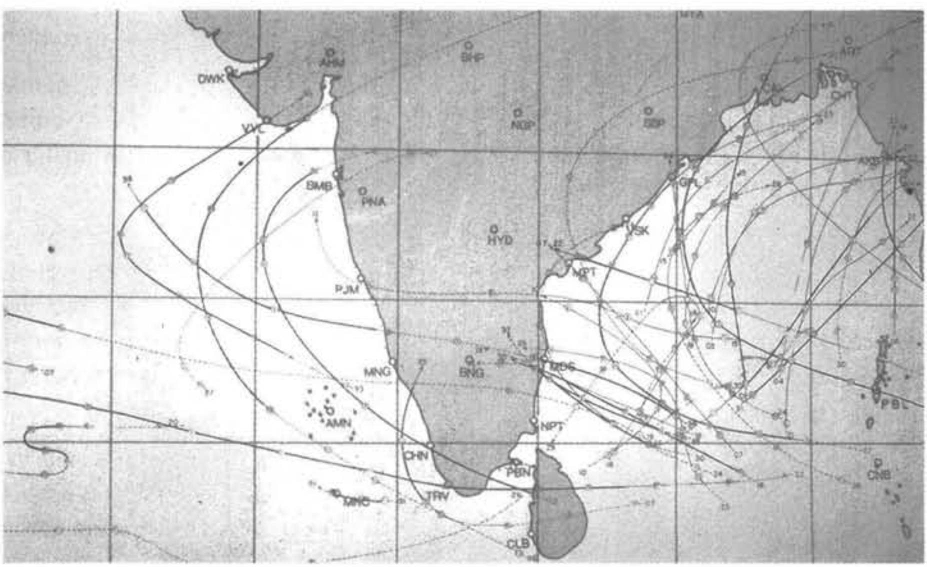

Fig. 2.6 Track of Storm - November (40 years).

During June to September (monsoon months) there will mostly be monsoon depressions and rarely cyclonic storms. During June, in Bay of Bengal, they originate between lat 16°N and 21°N and west of long 92°E, move in a northwesterly direction, cross coast and weaken. During July, August, in Bay of Bengal, they originate between lat 16°N-21°N and west of long 92°E, move in a northwesterly or west north-westerly direction and cross coast between the zone of lat 20°N - 25°N. In Arabian sea there is abrupt fall from June to almost nil in July, August, September. During September Bay storms originate north of lat 15°N and west of long 90°E, move initially in west or northwesterly direction, later recurve towards north-north-east.

During October, November the Bay cyclonic storms originate between lat 8°N and 14°N, move initially in northwesterly or west-north-westerly direction. Most of them later recurve north-eastwards. During these months north coastal Tamilnadu, Andhra, Bangladesh coasts are vulnerable to the incidence of cyclones. In Arabian sea they move initially west or northwesterly direction upto lat 15°N then recurve northeast wards and hit Maharashtra, Gujarat coasts.

During December the frequency of storms fall. Most of the Bay cyclones originate between lat 5°N-10°N and move initially in a northwesterly direction, strike Tamilnadu coast or northeast coast of Srilanka. A few of these cross south peninsula and enter into Arabian sea. The position of formation of Tropical storms migrate with the movement the sun both northwards and southwards.

2.4 Storm Surges

Storm surge means the rapid rise in the sea level water due to winds, pressure changes (falls), ocean waves and ocean currents associated with a single storm at the time of storm crossing the coast. Storm surges inundate coastal low lying areas, cause havoc to life and property. More than 75% loss of life and property in tropical cyclone is attributed to storm surges.

All storm surges are associated with severe cyclones but all severe cyclones are not accompanied by storm surges. Hurricanes, Typhoons are much severe than the cyclones of Bay of Bengal but the storm surges developed by the former in general are not so high as the Bay severe cyclones. It appears Bay of Bengal is the worst with regard to storm surges. A typical cyclone storm surge is shown in Fig. 2.7 and storm surge risk shown in Fig. 2.8.

Storm surges may occur before, during or after storm crossed the coast. There seems no precise method of predicting storm surges. However in India an empirical model nomograms were developed by Ghosh (1977), which are being used successfully with minor modifications. The Table 2.8 gives the storm surge heights associated with Bay of Bengal cyclones along with some other features and Table 2.9 gives the probable maximum storm surge heights.

According to empirical storm surge model, the maximum storm surge heights along east coast of India at important locations are given in the Table 2.9.

Fig. 2.9 shows the vulnerable areas for storm surges along the coast and Fig. 2.10 shows the distribution incidence of cylonic and severe ccylonic storms.

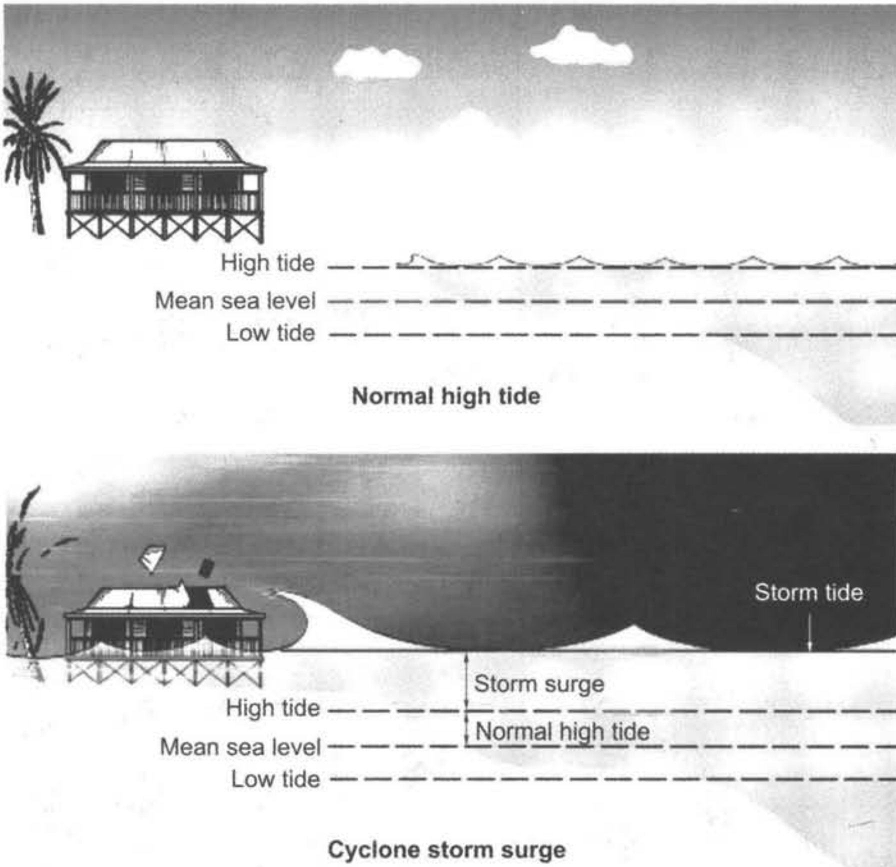

Fig. 2.7 Storm surge.

Fig. 2.8 Storm surge risk.

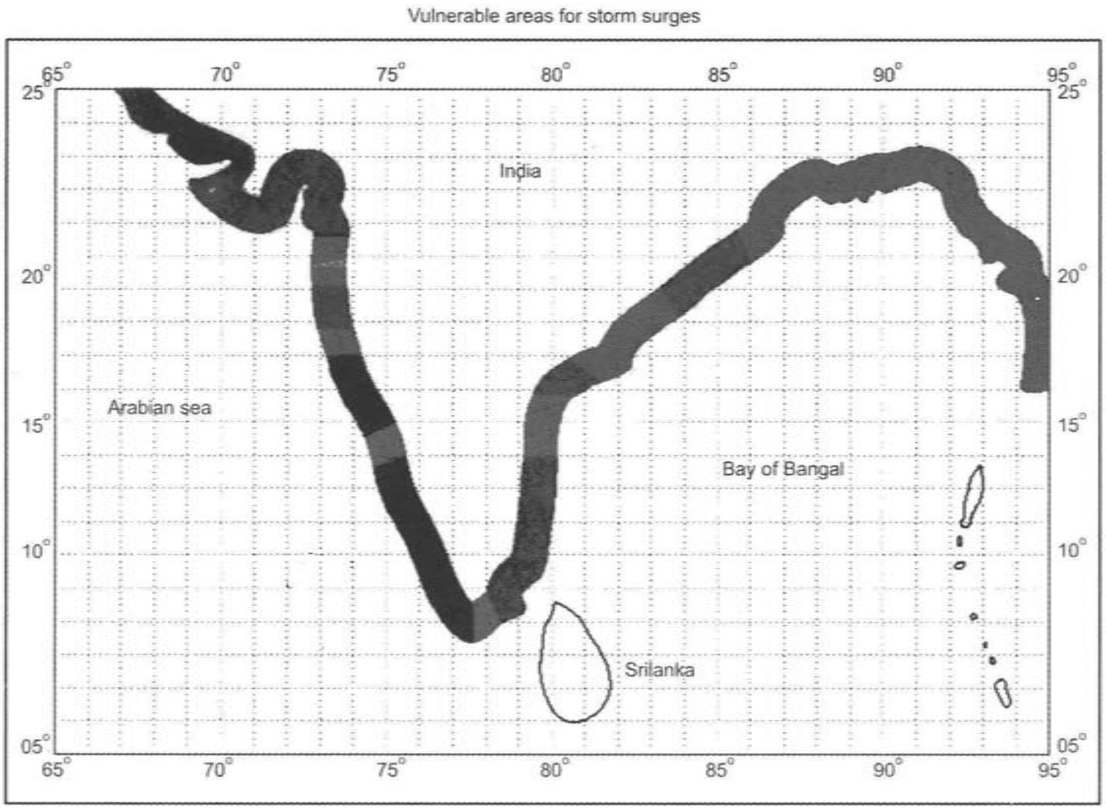
Vulnerable areas for storm surges
India
Arabian sea
Bay of Bangal
Srilanka
65°
70°
75°
80°
85°
90°
95°
25°
20°
15°
10°
05°

Fig. 2.9

Table 2.8 Storm surge heights.

S.No.	Name/Place of severe cyclone	Date of crossing Coast	Lowest central pressure	T-number hPa	Tidal height meters	Approximate No.of deaths
1	Orissa, Paradeep	29 oct 1999	924	6.5	3-5	10,000
2.	Andhra, Machilipatnam	5-10 May 1990	921	7.0	4-5	1000
3.	Andhra, Diviseema	14-20 Nov 1977	911	7.0	5	10,000
4.	Orissa, Falsepoint	Sept 1885	919	-	6-7	--
5.	Bangladesh, Bhola	11-12 Nov 1970	-	-	12	-
6.	Bangladesh, Backergunj	1 Nov 1876	-	-	12-13 2,00,000	more than
7.	West Bengal, Calcutta Hoogli river mouth	7 Oct 1737	-	-	12	-
8.	West Bengal, Midnapur	1864	-	-	2	75,000.

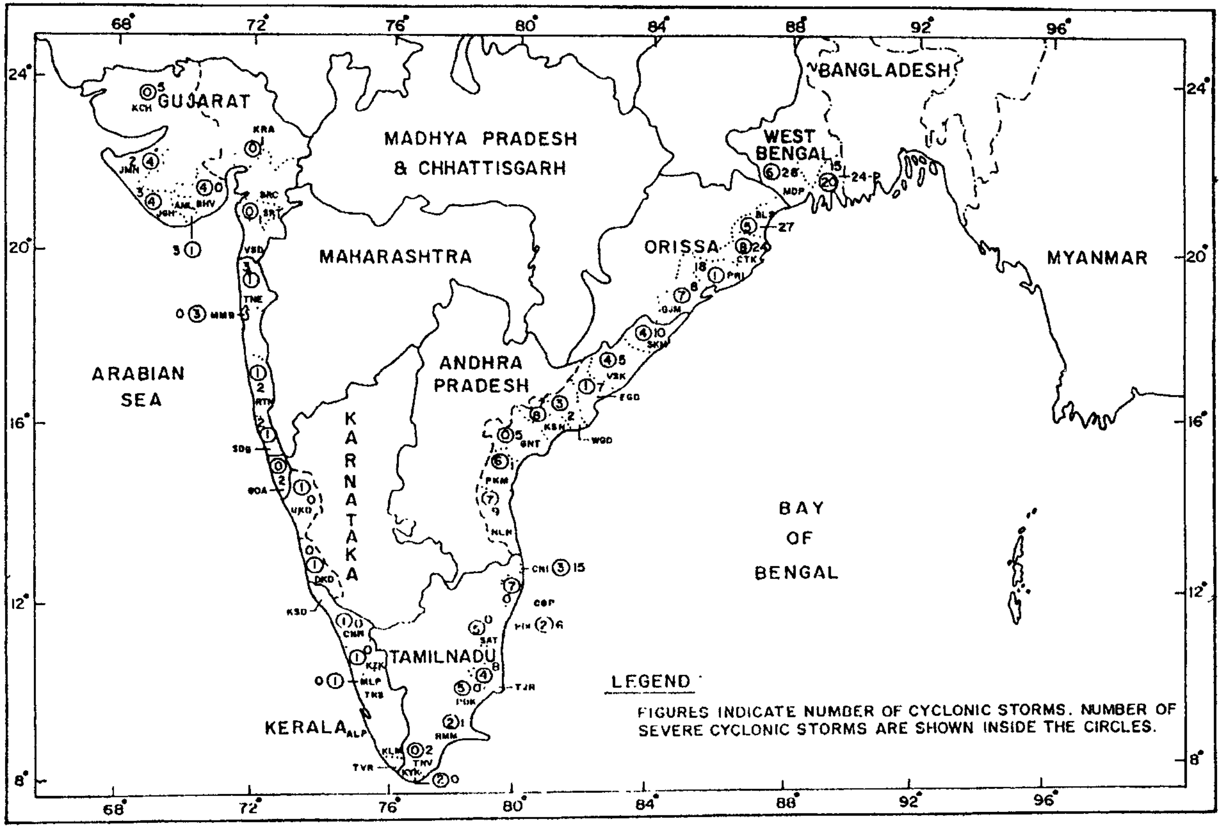
GUJARAT
MADHYA PRADESH
& CHHATTISGARH
BANGLADESH
WEST
BENGAL
MAHARASHTRA
ORISSA
MYANMAR
ARABIAN
SEA
ANDHRA
PRADESH
KARNATAKA
BAY
OF
BENGAL
TAMILNADU
KERALA
LEGEND
FIGURES INDICATE NUMBER OF CYCLONIC STORMS. NUMBER OF SEVERE CYCLONIC STORMS ARE SHOWN INSIDE THE CIRCLES.

Fig. 2.10

Table 2.9 Emprirical storm surge height along east coast of India.

S.No.	Name of location	Probable maximum surge height in meters	S.No.	Name of location	Probable maximum surge height in meters
1.	Nagapatnam (TN)	5.5	13.	Paradeep (Orissa)	4.5
2.	Pondicherry (TN)	3.0	14.	Balasore (WB)	9.8
3.	Chennai (TN)	3.0	15	Contaı (WB)	12.5
4.	Nellore (AP)	2.8	16.	Sagar Island (WB) Morelgam	11.5
5.	Ongole (AP)	4.5	17.	Dakhin Shahabazpur	8.5
6.	Kavali (AP)	6.8	18.	Patuakhali	12.5
7.	Machilipatnam (AP)	5.5	19.	Hatia	13.5
8.	Kakinada (AP)	3.0	20.	Sandwip	12.5
9. 10.	Visakhapatnam (AP) Kalingapatnam (AP)	2.6 2.8	21. 22.	Chittagong CoxBazar	8.0 7.5
11.	Gopalpur (Orissa)	2.6	23.	Taungya Taung	5.0
12.	Puri (Orissa)	3.2			

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@Seismicisolation

Chapter - 3

India Meteorological Department and Cyclone Warnings in India

In october 1864 two severe cyclonic storms in Bay of Bengal hit Calcutta and Machilipatnam in quick succession. A great storm surge swept over river Hoogly and drowned more than 80,000 people and the other took a toll of about 40,000 people in Machilipatnam. Consequent to this a provincial Meteorological organisation was set up in 1867 for providing warnings to ships in Bay of Bengal and storm warning signals for ports was introduced in 1880. India Meteorological Department (IMD) was established in 1875. During 1914 transmission of weather sea bulletins by W/T to ships was introduced and broadcast of coastal weather bulletins introduced in 1964. In 1969 storm warning bulletins for coastal areas was introduced through AIR broadcast for the benefit of coastal shipping and fishing community.

IMD is the National Meteorological services of the country. It is the principal Government Agency and the designated authority in all matters relating to Meteorology, Seismology and allied subjects (Agricultural Meteorology, Aeronautical Meteorology, Flood Meteorology etc).

The Mandate of IMD are

1. Register Meteorological observations, provide current and forecast meteorological information to all weather sensitive activities (like Agriculture, Aviation, Shipping, Irrigation etc).
2. Warn against severe weather phenomena (like Tropical cyclones, heavy rains, snow, frost, Norwesters, Kalbaisakhi, sandstorms, dust storms, hail storms, floods, droughts, heat and cold waves etc.) which cause damage and destruction to life and property.

3. Provide meteorological statistics required for agriculture, water resources management, industries, tourism, oil exploration and other national building activities.
4. Conduct and promote research in meteorology and allied disciplines.
5. Detect and locate earthquake and evaluate seismicity in different parts of the country for developmental projects. Make study of earthquakes, identify the potential consequences in relation to the existing structures and for locating new structures in the planning.
6. Publish the National calendar and Rashtriya Panchang and data on planetary positions. Conducts study in Positional Astronomy, bring out related publications and issue Radio Times Signals (RTS).
7. *Cyclone detection and warning* : Earlier cyclone detection was based on surface and upper air (synoptic) data of coastal meteorological observatories and ship weather observations. Subsequently with the invention of Radars, cyclones were detected by coastal Radar observations when they moved within their radar range (about 400 km). At present in addition to the above observations, satellite based imageries (images or pictures) are used when they are far away from the coast (beyond the radar range). Subsequently cyclones are tracked by radars, coastal synoptic observations besides satellite based imageries. Fig 3.1 and 3.2 show the cyclone as seen from satellite and Rader scope.A network of cyclone detection radars exist along east and west coast of India. At present the occurrence of cyclonic storms cannot be prevented but a great deal can be done to mitigate loss of life and property

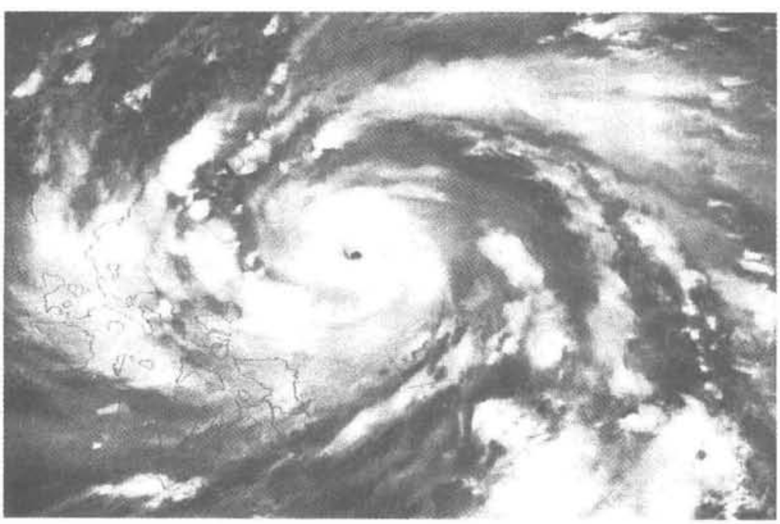


Fig. 3.1 Cyclone as seen from satellite.

that are associated with them. In this respect the IMD's four stage warnings were found to be very useful. IMD is the nodal agency of Govt of India for issue of cyclone warnings in India. The inputs for this are:

(i) surface and upper air synoptic charts,

(ii) the network of Cyclone Detection Radar (CDR) observations and

(iii) satellite imageries.

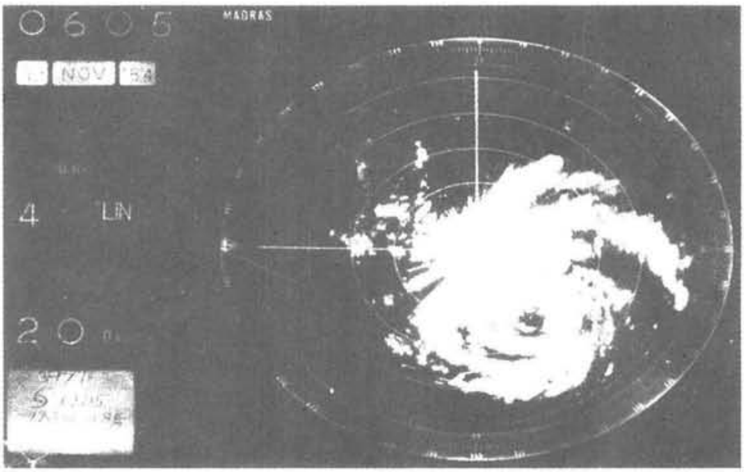


Fig. 3.2 Cyclone as seen from the weather radar.

The CDRs are located at Kolkata, Paradeep, Visakhapatnam, Machilipatnam, Chennai, Karaikal on the east coast and at Cochin, Goa, Mumbai and Bhuj on the west coast. See Fig. 3.3. The cyclone warning centres are established (for tracking and forecasting) at Kolkata, Bhubneshwar, Chennai, Visakhapatnam, Mumbai and Ahmedabad. The four stage cyclone warnings are issued as given below.

Stage 1

Pre-cyclone watch : Special bulletin issued to indicate the development of cyclonic disturbance which is likely to become cyclone. This bulletin is issued by Director General of Meteorology, New Delhi. It is addressed to Cabinet Secretary and other senior officers of Govt of India, which include Chief Secretaries of concerned Maritime States.

Stage 2

Cyclone Alert : As soon as the depression formed and expected to become a cyclone, Cyclone Alert is issued at least 48 hours in advance to designated State and Central Govt. officials. The messages are sent by landline P&T telegrams to

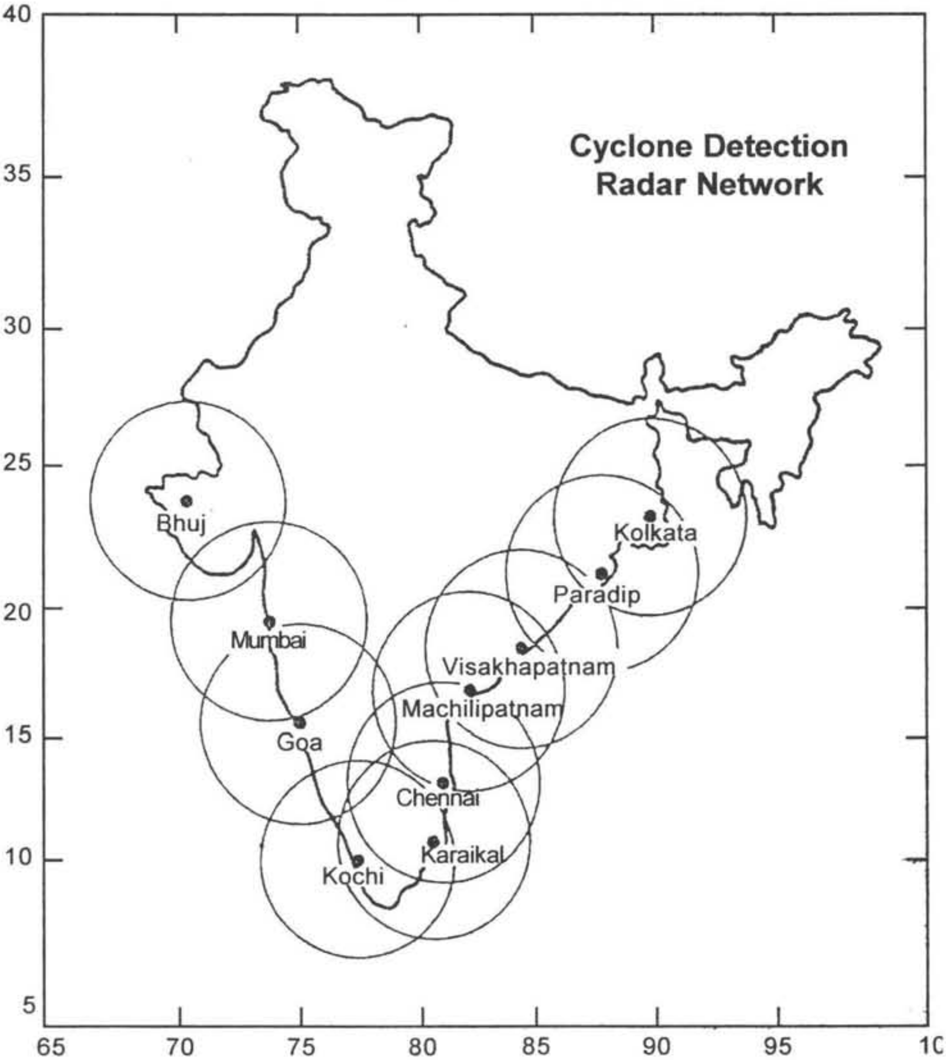


Fig. 3.3

the State Chief Secretary, Relief commissioner and concerned collectors of coastal districts of Maritime States. In addition to these, designated Defence, Railways, Irrigation officials are also supplied these warnings. For general public the warnings are broadcast by AIR, Doordarshan at regular intervals to appraise the coming adverse weather.

Stage 3

Cyclone Warning : Cyclone warning issued at least 24 hours in advance of the commencement of bad weather. This warning is addressed to all officials to whom 'Cyclone Alert' was sent. After this message, officials are advised to monitor further cyclone bulletins issued on AIR and Doordarshan. Tracking the cyclone on radars, satellite imageries and special synoptic charts, three hourly bulletins are issued as and when the system intensified, otherwise daily two minimum cyclone bulletins are issued, one in the morning at about 0600 hrs UTC (1130 IST) and another at about 1500 hrs UTC (2030 IST).

Stage 4

Post-landfall Scenario : This bulletin is issued about 12 hours before landfall and continue till such time the cyclone force winds expected to prevail in the interior areas. At this stage the district collectors of all interior districts besides the coastal areas likely to be affected are included in the issue of bulletins.

De-warning : After weakening of the cyclone into Depression a final message on "Cyclone De-warning" is issued to the all concerned.

The Table 3.1, Fig 3.4 gives the distribution of cyclonic storms during 1891 to 2000 district wise. This statistics may be used for giving weightage to the hazard zoning of coastal districts.

Table 3.1 Distribution of cyclone incidence in the coastal districts during 1891-2000.

S.No.	District Name	No.of CS	No.of SCS
	Gujarat		
1.	Kutch	5	0
2.	Jamnagar	2	4
3.	Junagarh	3	4
4.	Amreli	3	1
5.	Bhavnagar	0	4
6.	Kheda	1	0
7.	Surat	1	0
	Total	**15**	**13**
	Maharashtra		
8.	Valsad	-	-
9.	Thane	3	1
10.	Mumbai	0	3
11.	Ratnagiri	2	1
12.	Devdurg	2	1
13.	Goa	2	0
	Total	**9**	**6**

Table 3.1 ***Contd...***

S.No.	District Name	No.of CS	No.of SCS
	Karnataka		
14.	Uttar Kanada	0	1
15.	Dakshin Kanada	0	1
	Total	**0**	**2**
	Kerala		
16.	Kannanur	0	1
17.	Kozikodi	0	1
18.	Mallapuram	0	1
	Total	**0**	**3**
	Tamilnadu		
19.	Kanyakumari	0	2
20.	Tirunalveli	2	0
21.	Ramanathapuram	1	2
22.	Pudukottai	0	5
23.	Thanjavur	8	4
24.	SAT	0	5
25.	Pondicherry	6	2
26.	Cuddalore	0	7
27.	Chennai	15	3
	Total	**32**	**30**
	Andhra Pradesh		
28.	Nellore	9	7
29.	Prakasham	1	6
30.	Guntur	5	0
31.	Krishna	7	8
32.	West Godawari	2	3
33.	East Godawari	7	1
34.	Visakhapatnam	5	4
35.	Srikakulam and Vijayanagaram	10	4
	Total	**46**	**33**
	Orissa		
36.	Ganjam	8	7
37.	Puri	18	1
38.	Cuttak	24	8
39.	Balasore	27	5
	Total	**77**	**21**
	West Bengal		
40.	Midnapur	28	6
41.	24 Parganas	15	20
	Total	**43**	**26**

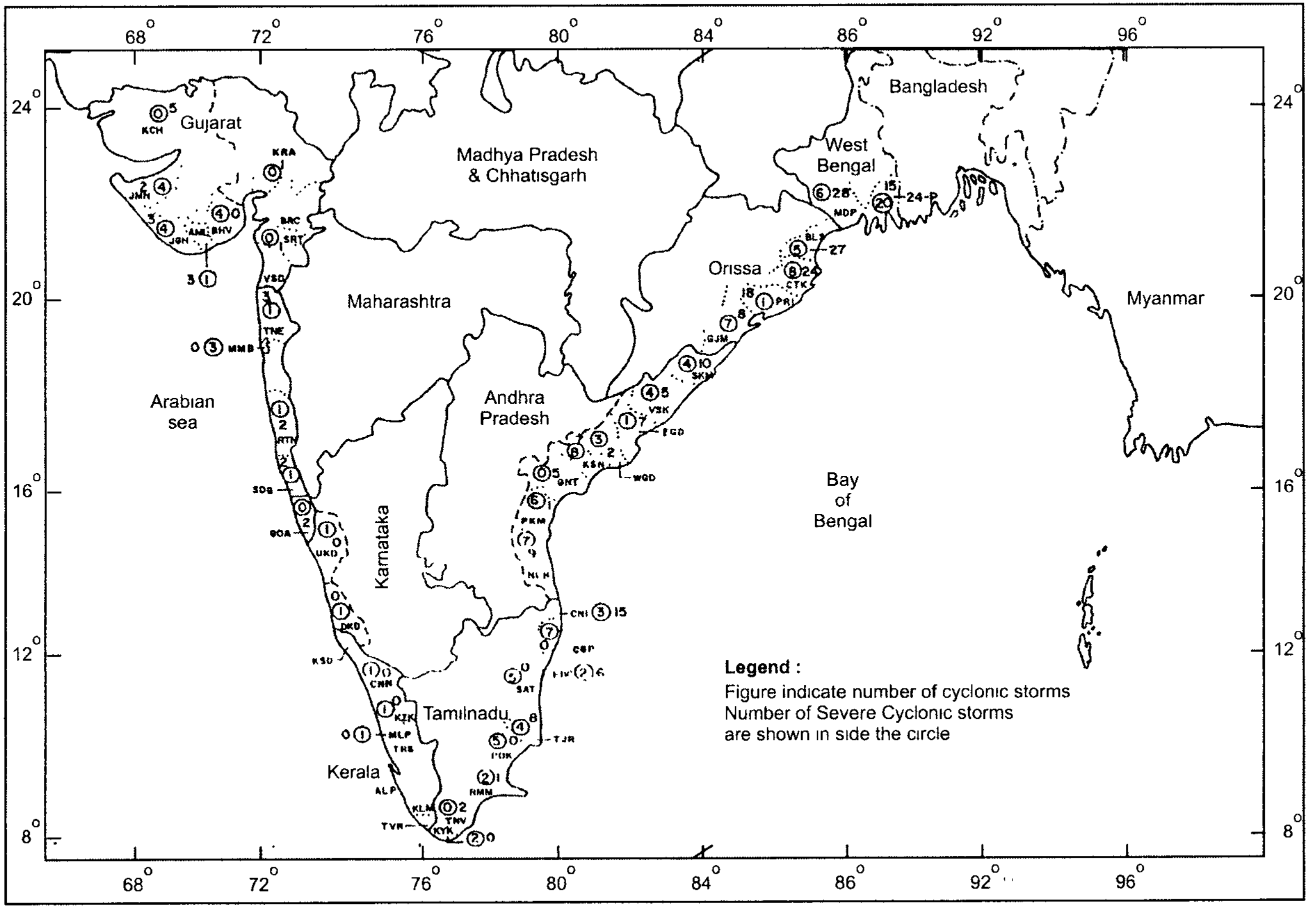


Fig. 3.4 Districtwise distribution of cyclonic storms (1891-2000).

The distribution of cyclone incidence statistics shows that Orissa (98) and Andhra Pradesh (79) are more prone to the incidence of cyclones, while Kerala, Karnataka are least.

3.1 Hazard Potential of Cyclonic Storms

According to IMD Convention the hazard potential of cyclonic storms in the Indian seas is given in Table 3.2.

Table 3.2 Hazard potential of cyclonic storms.

S.No.	Type of storm Satellite T-number	Wind speed Kt/Kmph	Description of damage potential
1.	Deep depression T-2.0	$\frac{28-33}{(52-61)}$	Overall minor damage. Minor damage to kutchcha/unsecured structures. Some breaches in kutchcha roads due to flooding. Banana trees be damaged. Coastal agricultural land may be affected by salt spray. Damage to ripe paddy crops. Minor damage to kutchcha embankments. *state of sea :* very rough, sea waves height 4 to 6 m. Fishermen advised not to venture into sea.
2.	Cyclonic storm T 2.5 to 3.0	$\frac{34-47}{62-87}$	Overall minor to moderate damage. Damage to thatched huts. Minor damage to power communication lines due to breaking of tree branches. Major damage to kutchcha roads and minor damage to pucca roads. Some damage to paddy crops, Banana, Papaya plantation and orchards. *State of sea* : High to very high. Wave height 6 to 9 m. Surface sea water inundation in low-lying areas after erosion of kutchcha embankments. Fishermen advised not to venture intosea.
3.	Severe cyclonic T3.5	$\frac{48-63}{88-117}$	Damage to thatched houses/huts. Roof tops may blow off. Unattached metalsheets, asbestos sheets may fly off. Minor damage to power and communication lines and kutchcha roads. Some damage to pucca roads. Flooding of escape routes. Uprooting avenue trees, breaking of tree branches. Moderate damage to Banana, Papaya plantation.

Table 3.2 ***Contd...***

S.No.	Type of storm Satellite T-number	Wind speed Kt/Kmph	Description of damage potential
		$\frac{48-63}{88-117}$	Large dead limbs blown off from trees. *State of Sea* : Phenomenal with wave heights 9-14 m. Movement in motor boats unsafe. Major damage to coastal crops. Storm surge upto 1.5m (area specific) causing to damage embankments and salt pans. Inundation in specific areas upto 5 km in land. Fishermen warned not to venture into sea. Coastal hutment dwellers advised to move to cyclone shelters or safer places. Other people in the affected areas advised to remain indoors.
4.	(a) Very severe cyclonic storm T 4.0 to 4.5	$\frac{64-90}{118-167}$	Total destruction of thatched houses, extensive damage to kutchcha houses and some damage to pucca houses. Potential threat from flying missiles (objects). Bending or uprooting of power and communication poles. Major damage to both kutchcha and pucca roads. Flooding of escape routes. Widespread damage to standing crops, plantations, orchards. Breaking of green coconut trees, tearing of palm fronds, blowing down of bushy trees like mango. Minor disruption of railway tracks, overhead power lines and signalling system. *State of Sea* : Phenomenal with wave heights exceeding 14 meters. Severe deterioration of visibility and unsafe movement of motor boats and small ships. Storm surge height about 2 meters and inundation upto 10 km interior of coast in specific areas. Detachment of small boats, country crafts from their moorings. Fishermen warned not to venture into sea. People residing close to coastal areas have to be evacuated. People advised to remain indoors or in cyclone shelters. Rail, road traffic to be regulated after confirmation of safety of roads and rails.

Table 3.2 *Contd...*

S.No.	Type of storm Satellite T-number	Wind speed Kt/Kmph	Description of damage potential
5.	(b) Very severe cyclonic storm T 5.0 to 6.0	$\frac{91-119}{168-221}$	Overall extensive damage. Extensive damage to old and Kutchcha sturctures. Great hazard from flying missiles. Large scale uprooting of power and communication poles. Widespread disruption of rail, road links. Extensive damage to standing crops, plantations, orchards. Blowing down of palm and coconut trees, uprooting of large bushy trees. *State of Sea* : Phenomenal with wave heights exceeding 14 m. Storm surge height 2 to 5 m. Movement of motor boats and small ships perilous. Inundation may penetrate upto 10 to 15 km in specific areas. Large boats and ships may be snapped from their moorings and torn. Fishermen warned not to venture into sea. Coastal people from the vulnerable areas must be evacuated. Diversion or suspension of rail, road traffic from vulnerable areas is essential.
6.	Super cyclonic storm T6.5 or more	$\frac{120 \text{ or more}}{222 \text{ or more}}$	Overall damage is catastrophic. Extensive damage to non-concrete residential and industrial buildings and structures. Aerial surroundings will be full of missile debris. Total disruption of power and communication system with large scale uprooting of poles. Widespread damage to rail and roads. Large scale submergence of roads, low-lying areas due to flooding and sea water inundation. Total disruption of rail, road traffic with heavy damages to bridges, culverts. Widespread washing away of rail, road links. Complete destruction of standing crops, orchards, uprooting of large trees, blowing away of palm and coconut crowns, stripping of tree barks.

Table 3.2 *Contd...*

S.No.	Type of storm Satellite T-number	Wind speed Kt/Kmph	Description of damage potential
			State of sea : Phenomenal with wave heights exceeding 14 m. All shipping activity perilous. Widespread damage to port installations. Storm surge height more than 5 m. coastal inundation extends upto 40 km in specific areas with widespread beach erosion. All ships torn of their mooring. Complete flooding of escape routes. Fishermen strictly warned not to venture into sea. Large scale evacuation of coastal people in the likely affected area. Complete stoppage of rail and road traffic in hazard prone areas.

3.2 Cyclone Prediction and Dissemination of Warnings

IMD has three Area Cyclone Warning Centres located at Kolkatta, Chennai (for Bay of Bengal) and Mumbai (for Arabian sea) and three cyclone warning centres at Bhubneshwar, Visakhapatnam and Ahmedabad. Cyclone detection, its intensification and movement, landfall is done in coordination by these centres for their respective areas. Prediction of cyclone intensity (intensification or dissipation), movement (track of cyclone), storm surge and location of landfall are really very complicated processes. Prediction of these depend on several factors like availability of data (synoptic, radar, satellite) on real time, past climatology and experience of meteorologist in understanding the behaviour of the system. It must be noted that no two cyclone behave alike both in time and space. Past climatological data are used as guiding factors in the assessment of the behaviour of a cyclone. A blind assertion is 50% climatalogy and 50% persistancy. Climatology indicates that some cyclones exhibit their fury of destruction through winds, some by heavy to very heavy rains and others by storm surge. Thus a cyclone, for a commn man, is a combination of these in a single or combination of these byproducts. Landfall of a cyclone depends on angle of approach of the cyclone to the shore line, bathymetry of the ocean floor, diurnal and seasonal state of astrominal tides and nature of the coastal terrain including riverine watershed. Limitations exist in the forecast that the typical cyclone track line forecast 24 hours in advance is 100 km error, 48 hours forecast error 250 km and 72 hours forecast error about 360 km. Inspite of all drawbacks cyclone warning achieved nearly precise for all practical purposes.

Cyclone Warning Division at IMD HQ New Delhi provides cyclone warning information to the control Room and Crisis Management group set up in the Ministry of Agriculture Government of India, which is finally responsible for coordination with various Central Government Agencies as listed in Contingency Action Plan of Government for effective cyclone disaster mitigation. Cyclone Warning Division at HQ also caters the needs of International responsibilities such as issue of cyclone advisories to the neighbouring countries.

The cyclone warning user Agencies are : 1. Commercial shipping and Indian Navy, 2. Port Authorities 3. Fisheries officials 4. Officials of State and Central Govts. 5. Album page warnees (special warnees who are registered with IMD), 6. Commercial Aviation, 7. Special interests and 8. General public.

3.3 Dissemination of Cyclone Warnings

Cyclone Warning Bulletins are normally issued every 3 hours, but more frequently issued when development warrens. The warning bulletins are sent by any of the following modes of communication to the user agencies.

1. Landline telegrams under highest priority - XXW.
2. Police W/T.
3. Telex, Telephone, Fax depending on the facilities available.
4. Broadcast through AIR, Telecast through DD-TV channel.
5. Bulletins to the press
6. INSAT based Cyclone Warning Dissemination system (CWDS)
7. Internet on IMDs website www.imd.ernet.in.

Warning to ships : Daily weather forecasts to coastal areas of Bay of Bengal and Arabian sea are issued by IMD. The cyclone warning centres at Kolkatta (Alipore), Mumbai (Colaba), Chennai (Nungambakam), Ahmedabad, Bhubneshwar and Visakhapatnam provide to ships, Government Departments-Maritime State and public ports, Forecast Weather and cyclone warnings for Bay of Benal, Arabian Sea, Coastal areas.

Daily two bulletins are issued for the benifit of ships in the high sea. They are called, "Daily one" and "Daily two". These are broadcast by P&T Coastal Radio stations at fixed times on fixed wavelengths. "Daily one" issued at 0600 hrs UTC, valid for the next 12 hrs, "Daily two" issued at 1500 hrs UTC again valid for next 12 hrs. During cyclone situations other bulletins called "Extra", "Storm" and "Special" are issued upto six times a day or as and when required. These bulletins are also broadcast by AIR and Coastal Radio Stations.

Cyclone warning centres at Mumbai, Kolkatta and INOSHAC (Indian Ocean Souther Hemispheric Analysis Centre) Pune provide to Indian Navy, Fleet forecast twice a day, frequency of bulletins increases to four times during cyclone period for Arabian sea, Bay of Bengal and Indian Ocean upto lat 10°S long 60° E to 100° E.

Global Maritime Distress and Safety System (GMDSS) : Area Cylone Warning Centres (ACWC) Mumbai, Kolkatta, and INOSHAC Pune provide to all ships: Weather bulletins twice a day are issued for Meteorological Area VIII N, for Arabian sea, Bay of Bengal and Indian Ocean to the North of Equator. The frequency increases to six during storm period. Under GMDSS scheme India designated as one of the 16 services in the world for issuing sea-area bulletins twice in a day. Six times during Tropical storm period for broadcasting on GMDSS for Meteorological Global region VIII (which covers entire North Indian Ocean and some parts of southern Indian Ocean). Bulletins are issued from ACWCs Kolkatta, Mumbai and INOSHAC Pune. It is meant for the use of all ships.

WMO/ESCAP Panel Region : WMO and the Economic and Social Commission for Asia and Pacific (ESCAP) jointly established the Panel on Tropical Cyclones in 1972 as an Inter-Governmental body with the aim to promote measures to improve Tropical Cyclone Warning System in the Bay of Bengal and Arabian sea. The members of the Panel are (1) India, (2) Bangladesh (3) Pakistan, (4) Myanmar (5) Srilanka (6) Thailand and (7) Maldives.

Global Teclecommunication System (GTS): Under GTS (organised as part of World Weather Watch plan), New Delhi is functioning as a Regional Telecommunication Hub (RTH) on the Main Telecommunication Network (MTN) connecting the two World Meteorological Centres Moscow directly and Washington via Tokyo. The automated centre of RTH, New Delhi is the principal Meteorological Telecommunication Centres in South Asia and its area of responsibility extends from Saudi Arabia in the west to Thailand in the east and adjoining sea areas. It collects meteorological observational data from these areas and feeds on to the GTS for Global and Regional Exchange. Other Meteorological Services in the Middle East and South East Asia also depend for their data requirements on RTH New Delhi. Accordingly New Delhi maintains telecommunication circuits with Moscow, Tokyo, Cairo, Jeddah, Bangkok, Colombo, Dhaka, Tehran, Karachi, Male, Yangon and Kathmandu. The circuits with Tokyo, Moscow and China operate on Frame Relay, Jeddah and Karachi at 64 kbps (kilobytes per second), Dhaka at 9.6 kbps and in addition Malbourne and Muscat operate via internet.

3.4 Cyclone Warnings through INSAT

It was stated earlier that cyclone warning messages are originated at ACWCs Chennai, Kolkatta, Mumbai or Cyclone warning centres at Bhubneshwar, Cochin, Ahmedabad and Visakhapatnam to provide cyclone warning service to Maritime States. The centres issue adverse weather warnings of cyclones to various users like port authorities, commercial shipping, Indian Navy, Fishermen and Fisheries officials. During cyclone adverse weather most of the landline telecommunications breaksdown, as a result of this actual warnings are not received by the recipients in time or not at all delivered. Many a time AIR stations also face similar situations since the mode of communication of cyclone warnings is by XXW Telegrams

Teleprinters, Telex, W/T and landline telephone. In view of this hazardous obstacle, a dependable scheme of dissemination of cyclone warning messages directly to the area of the affected people is achieved through INSAT TV broadcast. This is called INSAT-CWDS (INSAT - Cyclone Warning Dissemination System, previously called Disaster Warning System (DWS).

In this method, warning messages originated at cyclone warning centre is transmitted to the satellite, which in turn, broadcasts it for instantaneous reception by Receiving Sets located at the coastal stations. By the method of Selective Addressing, warning messages are received only by the addressed receivers. The Selective Addressing is done by first transmitting a digital code which is followed by the actual warning message in the Local Vernacular Language. Each coastal district is alloted a seperate code number. By this process only those receivers will be activated which are going to be affected to receive the warning messages. A Loud Siren (alaram sound) will follow for about one minute, in the identified code receiver (which attracts the attention of the people around), this will be followed by a gap of a few seconds to minute, then the actual warning message will be broadcast for about nine minutes. Arrangements made in some receivers to receive warning messages meant for more than one district. The Receiver located at the State HQ will receive all warning messages issued to all its districts.

Some important features of INSAT-CWDS are :

1. Cyclone warning centre originates disaster warning messages and area code of the districts.
2. The earth-station located near the cyclone warning centres with uplink facility in C-Band and suitable communication links with the cyclone warning centre.
3. The C/S Band transponder put on board of INSAT.
4. The INSAT - CWDS Receivers installed in cyclone prone coastal areas.

This method was found most successful in practical operation in Andhra Pradesh, Tamilnadu where this method initially tried. Subsequently this method is extended to all Cyclone Warning Centres.

3.5 Port Warnings with Day and Night hoisting Signals

Area cyclone warning centre Mumbai issues warnings to ports in the Arabian sea. Chennai ACWC is responsible for warning the ports south Kalingapatnam in Bay of Bengal and ACWC Kolkatta for the remaining ports in the Bay of Bengal.

When ports are threatened by a Cyclone, Port Warnings are issued to port officers to hoist appropriate visual siganals during day and light signals at night for the information to the ships and fishermen about the imminent danger. The system of Port Warnings are three types.

(i) The General system

(ii) The Brief system and

(iii) The extended system.

The General system has 11 signals, two of which signify the existence of distant disturbed weather, eight indicate that the port is threatened by local bad weather and the last one signifies that communication system with the Meteorological Dept broken down and that in the opinion of the Local Officer, there is a danger to the port due to bad weather.

The Brief system consists of five of the above signals. This is used at ports which are mainly frequented by smaller vessels engaged in local traffic.

The Extended System consists of all the 11 signals of the general system and also sectional signals to indicate the position of the disturbance. This system is in use only at certain ports in the Bay of Bengal.

The General System with day and Night Signals

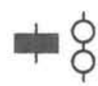
Signals

Day Night

Distant Signals indicate that ships may be exposed to danger after they left the harbour

1. **Distant Cautionary DC-I**

   There is a region of squally weather in which a storm may be forming

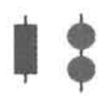


2. **Warning - DC II**

   A storm has formed. This signal is hoisted when there is no immediate danger

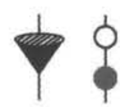
   Local signals :

   These indicate that the port itself and the ships in it are threatened.



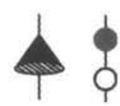
3. **Cautionary LC III**

   The port is threatened by squally weather



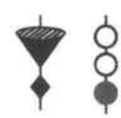
4. **Warning LW IV**

   The port is threatened by a storm, but it does not appear that the danger is as yet sufficiently great to justify extreme measures of precaution

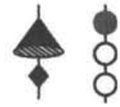


5. **Danger D V**

   The port will experience severe weather from a storm of slight or moderate intensity that is expected to cross the coast to the south of the port (or east in case of Veraval, Hoogly ports and Port blair).

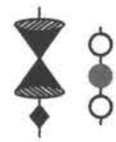


6. Danger D VI



The port will experience severe weather from a storm of slight or moderate intensity that is expected to cross the coast to the north of the port (or to the west in case of Veraval, Hoogly ports and Port blair)

7. Danger D VII



The port will experience severe weather from a storm of slight or moderate intensity that is expected to cross over or near to the port.

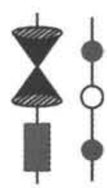
8. Great Danger D VIII

The port will experience severe weather from a storm of great intensity that is expected to cross the coast to the south of the port (or to the east in case of Veraval, Hoogly, and Port Blair.

9. Great Danger D IX

The port will experience severe weather from a strom of great intensity that is expected to cross the coast to the north of the port (or to the west in case of Veraval, Hoogly port and Port blair.

10. Great Danger D X



The port will experience severe weather from a storm of great intensity that is expected to cross over or near the port.

11. **Failure of Communication XI**

Communications with the meteorological warning centre have broken down, and the local officer considers that there is danger of bad weather.

Brief System

In the brief system only one of the five following signals is hoisted and the port officers are kept informed of the prospects of local bad weather associated with any disturbance in the sea, for the general information of shipping.

Cautionary	LC	III	
Warning	LW	IV	
Danger	D	VII	
Great Danger	D	X	
Failure of communication	D	XI	

Extended System

Special signals, in addition to those of the General System are exhibited at certain ports in the Bay of Bengal. If the port itself is threatened, only the appropriate local signals of the General System are hoisted.

But, if there is an area of squally weather or a storm that does not threaten the port, the distant cautionery or Distant warning signals of the General System is hoisted and one or more of the locality signals(given below) are hoisted under the Distant signals to indicate the position of the disturbance in the Bay.

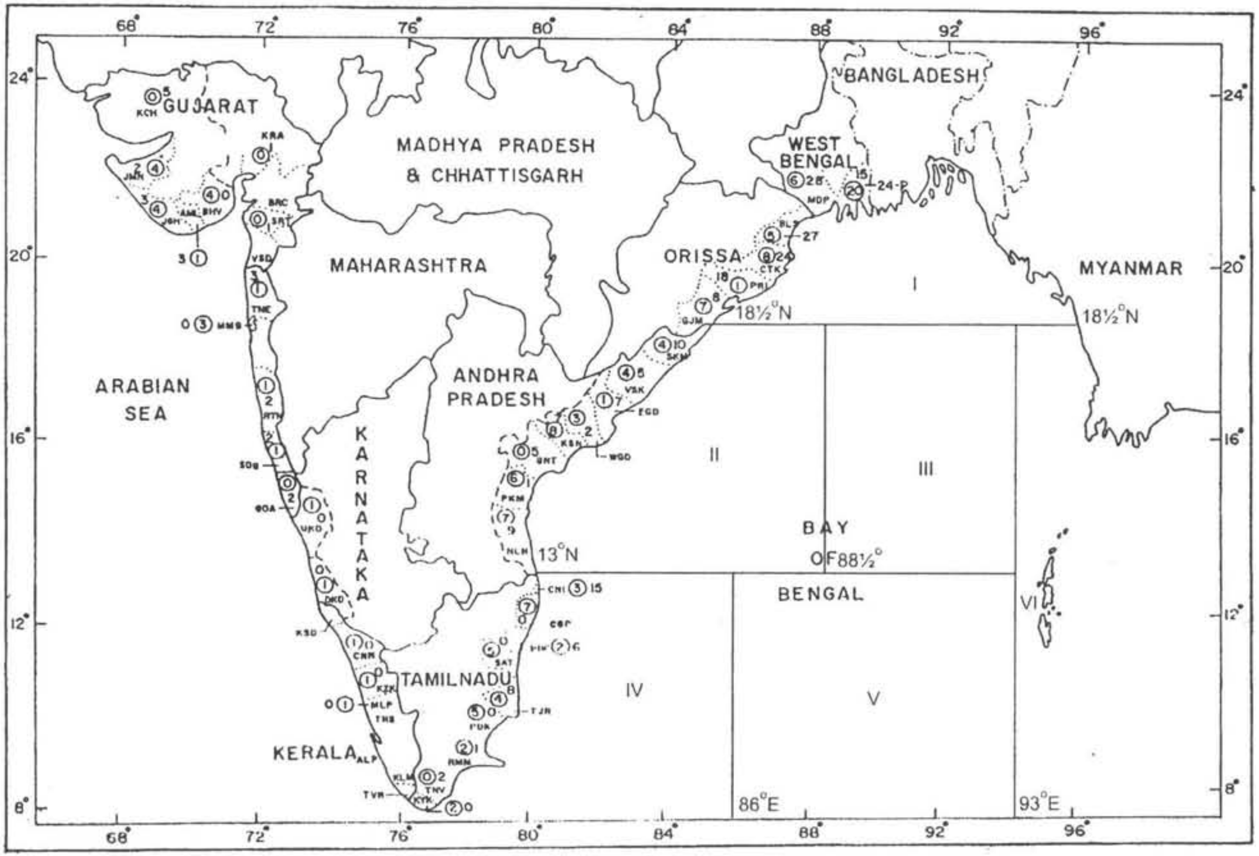
The following shapes, when hung below a Distant Cautionary or Warning signal become locality signal indicating the six divisions into which the Bay of Bengal has been divided for this purpuse.

Signal

Section I II III IV V VI

Division of Bay of Bengal

I	North Bay	II	West central Bay
III	East central Bay	IV	Southwest Bay
V	Southeast Bay	VI	Andaman Sea



Division of Bay of Bengal

Safety Measures to be taken at Ports

When storm signals are hoisted the following safety measures to be taken.

1. Lower the masts of all vessels and be moored firmly in a sheltered water.
2. Electrical installations (such as substations) should be blocked its doors, windows and other openings.
3. Power should be switched off to avoid electrical short circuiting and casualities due to falling of eletrical poles, exposure to live wires. Strengthen the supports to the transmission towers and transformers.
4. Lower the booms of all cranes and lay them on the ground.
5. Firmly block the doors, windows and other openings of all godowns.

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@Seismicisolation

CHAPTER - 4

Cyclone Disaster Management – Plan

In all disasters/crisis management. the working groups involved: (i) Government (Cental/State) officials (ii) Voluntary organisations besides the victims. We shall discuss the overall responsibilities of various Government Departments and the roles of NGOs (Non Governmental Organisations).

Disaster/Crisis management mainly depends on the awareness about the disaster event, crisis event, preparedness and the help provided to the affected people (i) before the event, (ii) during the event and (iii) after the disaster.

Before disaster : (a) Long term preparedness plan, (b) just before the disaster/ crisis season:

Actions

(i) Timely accurate warnings,

(ii) Community preparedness to meet the eventuality,

(iii) Awareness about the disaster/crisis or education about natural disasters,

(iv) Construction of cyclone shelters (long term plan),

(v) Protection barriers against floods, storm surges, lightning,

(vi) Plantation of shelter belts,

(vii) Stocking of food, emergency medicines and potable water,

(viii) Evacuation of the people, who are likely to be affected to safer places.

During Disaster

(i) Organising the affected people to be shifted to the cyclone shelters or camps,

(ii) Motivate the people to be bold and organise them to help one another.

After Disaster

(i) Conduct survey of the affected area to assess loss of life and damage to property. Recommend assistance.

(ii) Organise the affected people staying in the camps/cyclone shelter to send them back to their places .

(iii) Render help/assistance to the affected to rehabilitate.

Cyclone Disaster Management Plan (CDMP)

The broad procedure of cyclone disaster management plan model at the National. State, District, Mandal and Panchayat levels are described below.

I At the National Level Organisation

HeadQuarters (HQ)	-	At the Cabinet Secretariat (Delhi)
Chairman	-	Cabinet Secretary
Members	-	Secretary to the Prime Minister
	-	Secretary, Ministry of Home Affairs
	-	Secretary, Concerned Crisis Ministry
	-	Director Information and Broadcasting
	-	Secretary RAW (Research and Analysis Wing)
Crisis Ministry	-	1. Secretary (Nodal Ministry) located in Control Room of Ministry
		2. Ministry of Defence-Concerned Service HQ

II At the State Level Organisation

The model Department for formulating, controlling, monitoring and directing measures for disaster preparedness, organising rescue, relief and rehabilitation is the responsibility of Revenue Department of the State Secretariat. A State level High Power Standing Committee (HPSC) functions under the chairmanship of Chief Secretary with members to deal (or act) with the situations arising out of disasters (calamities/crisis) including preparedness.

The Composition of HPSC consists of

Chairman	-	Chief Secretary of the State Govt.
Members	-	Commissioner of Land Revenue
	-	Principal Secretary of Government Revenue Department
	-	Commissioner of Civil Supplies.
Member - Secretary	-	Commissioner for Relief
Other Members	-	All concerned Deparments (about 50)
		India Meteorological Department, Central Water Commission, NGRI, Army, Health, Railways, P&T, DD, AIR, R&B etc.

Sub-Committees : During disaster period one sub-committee will work under the Head of Chief Secretary, which will monitor the daily current situations and order to the concerned officials to act suitably to the existing situation. A second sub-committee works under the chairmanship of Principal Secretary or Revenue Secretary or Commissioner for Relief to coordinate the activities of all agencies (both official and non-official) involved in the disaster relief operations.

Commissioner for Relief will be the overall incharge of rescue, relief and rehabilitation operations in the State.

Liaison Officers from other Departments : A Senior officer from each of the following departments would be nominated to liaise with Commissioner for Relief.

Liaison Departments : The Departments of Food and Agriculture, Irrigation and power, Transport, Roads and Buildings, Education, Social welfare, Medical and Health, Finance and Planning, Forest, Animal Husbandary and Fisheries, Panchayat Raj, Municipal Administration, Home Departments and other concerned Departments of the Secretariat involved in the Relief works, Rehabilitation, Reconstruction in the affected area by cyclone, natural calamity. Liaison officers would responsible to get the work done by the field officers with suitable instructions.

Control Room (General) : In disaster management, Control Room is a nodal centre for collecting and disseminating latest information to the affected area and to the concerned persons for appropriate action. Infact, Control Room is a joint control room with a team of selected officers/members who are involved in local decision making based on the reports received/collected. It is the responsibility of Control Room to communicate warnings to the concerned people, collection of relevant information, monitoring the situation and issue of advisories for implementation. Control Room functions round the clock under all circumstances.

Control Room at the State HQ : Control Room will be located in the State General Administration Department, which works round the clock throughout the year. Control Room functions as joint control room with a team of officers from Revenue, Police and Army. Control Room functions under the supervision of Commissioner for Relief. It is connected via satellite with all Districts, Mandals and important coastal villages. Provision has been established in some States for video conferencing from HQ Control Room to Districts and Mandal levels. Control Room will have up-to-date information of different organisations, like Army, Air Force, Navy, Transport, squads, Police, Red Cross etc. It will be in constant touch with the State Meteorological centre, Cyclone Warning Centre and obtain the running commentary of cyclone intensification, movement, wind strength and storm surge information. The Chief Engineer Major Irrigation would maintain a round the clock monitoring cell at State HQ and provide up-to-date flood situation and indicate the areas inundated or likely to inundate throughout monsoon season and during cyclone warnings.

District Level Committees : All the districts of the Maritime States are prone to cyclone impacts in various degrees. In all the Coastal districts, District level Committees will work under the chairmanship of District collector. Under disaster management plan, collectors should prepare suitable plan to meet the most frequent disasters that affect the district. In case of cyclones, collectors should be in constant touch with Meteorological Centre for latest position of cyclone and also with the State HQ Control Room. Collectors are responsible for disseminating warnings to Mandals and Coastal Fishermen and other local bodies like Municipalities to Village Panchayats. Arrange storages of food, first-aid medical kits (with medicines). Similarly Mandal level and Village level Committees function under MRO (Mandal Revenue Officer) and Sarpanch.

District Control Room : District Control Room will be set up at District HQ (in all Coastal districts), function round the clock during cyclone period.

Mandal Control Room : It will be set up at Mandal HQ and will function at MRO's office.

Village Control Room : It will be set up at Village Panchayat Hall and will function under Sarpanch.

4.1 Hazard Potentials Associated with Cyclones

We have learnt that cyclones cause damage through strong wind, heavy rains and storm surges, either in single or in combination. Table 3.2 gives the salient features of cyclone damages due to wind and storm surges. The strength of the wind in a cyclone depends on the pressure deficiency (Δp) between the centre (Eye) of the cyclone and its periphery. The storm surge and rainfall depend on several parameters. It seems there is no fool-proof method of predicting storm surges. Table 2.9 gives the probable maximum storm surge heights along east coast of India. The maximum sustained wind in Indian seas is given by the empirical formula.

$$V_{max} = 14.2\sqrt{P_n - P_0}$$

Where V_{max} = Maximum sustained wind speed in kt

P_n = Peripheral pressure in a cyclone in hPa

P_0 = lowest pressure in the cyclone Eye in hPa

INSAT digital inputs may be used for better disaster management associated with extreme events of rainfall. The application of satellite data at a pixel by pixel resolution along with conventional data would help in better prediction of very heavy rains. Outgoing Longwave Radiation values ranging 80-260 W/m^2 by pixel by pixel resolution provides rainfall intensity and coverage of severe weather event of cyclones. To draw hazard zone maps, the analysis of extreme weather events (Heavy rainfall, Maximum day temperature, Strongest wind, Extreme flood level etc.) have to be made. Though rainfall in a cyclone causes flash–floods, floods cause damage to life and property, yet its distribution is not symmetric or highly variable.

According to Herbert Tidemann (1989) (modification) the disaster potential is a function of :

1. Human failure
2. Hydrological (floods, droughts, inundation, ground water)
3. Cyclonic storm (which depends on strong wind, heavy rain, storm surge)
4. Local severe thunderstorm (includes snowfall, hailstorm, dust/sand storm, Andhi, Kalbaisaki, Tornado)
5. Heat waves, cold waves
6. Earthquakes (intensity)
7. Volcanoes
8. Avalanches
9. landslides (includes Rockfalls, settlements, expansive soils).
10. Forest Fires
11. Accidental Fire
12. Explosions (9/11, WTC)
13. Transport accidents (includes air, land and sea)

14. Product liability,
15. Environmental contamination
16. Burglary, Robbery, thefts
17. Terrorism (kidnapping, beheding, hijacking planes, buses, cars etc)
18. Human Bombs (like the assasination of Rajiv Gandhi or suicide bombs)
19. Nuclear bombs (Little Boy, Fat man explosions on Nagasaki, Hiroshima cities in Japan)
20. Droughts and agricultural problems (includes desertification, soil salinity and fertility, pests and diseases)
21. Epidimical problems (includes widespread prevelent in community in season).

Risk due to a particular hazard = Disaster potential $\times$ probability of its occurance

Risk rate per mile (%)

$$= \frac{\text{expected loss} \times \text{overhead factor} \times \text{safety factor} \times \text{Period of exposure in years}] \times 1000}{[\text{Return period in years} \times \text{value at risk}]}$$

It must be noted that human beings are a part of nature and coexists along with it by his adoptative nature.

Any extreme natural event which surpases the normal capacity of man to reflect or absorb or buffer it is a hazard. Thus natural hazards are a part and parcel of human life but its management is the second greatest concern of man after war in terms of loss of life, property and economy. The characteristic behaviour of disaster management is that devours a substantial resources of finance and other normal developmental works. At least temporarily halts all developmental activity of the affected community.

Explanation of some Terms

Hazard : Any event that is likely to cause damage to life, property, injury to health, damage to environment, sustainability may be viewed as hazard. Hazard also refers to the probability occurence of a potentially damaging event over a specified space and time. Estimation of hazard of an event can be made with the help of past historical data (statistics of the event). Estimation is also made by the nature of event. In case of cyclone the potential damage effect can be gauged by the pressure anomaly, radius of maximum wind, speed of movement of cyclone and place of landfall (orography). Similarly we can estimate hazards of other natural events. In case of drought, environmental pollution, global warming (these are spread over a longer space and time) it is difficult to estimate. Man made hazards come under this category. Some natural hazards have potential benevolence effect. In such cases the net hazard damage would be accounted only after subtracting benefits.

Vulnerability : The capacity of a community or society to anticipate, cope with, resist and recover from any hazard event may be termed vulnerability. People living in lower reaches of rivers mostly vulnerable to floods. Similarly people living in coastal areas are vulnerable to cyclone fury, people living on the slopes of foot of the Himalayas are vulnerable to avalanches, landslides, snowstorms. The degree of proneness for loss of life and property due to natural hazard at a given place and time is vulnerability due to that particular hazard event. Vulnerability is a function of physical, social and economic aspects of a community or society.

Physical Vulnerability : It is a function of buildings, habitats (kutchcha, pucca houses, huts etc) and infrastructure. Magnitude of this vulnerability is that its ability or effort required for restoration of the place to normalacy after the hazard event passed over it (effected it).

Social Vulnerability : It is a function of livelihood, housing, age, disaster awareness, education, community services and social unity.

Economic vulnerability : It is related to monetary/economic losses at a particular place.

Risk : It is defined as the product of hazard and vulnerability or estimate of overall expected loss for a given area and hazard event.

Exposure to a natural hazard may be taken as constant but the vulnerability depends on societal character, social behaviour, availability of technologies and policies. It is found rich nations are less prone to hazards than poor nations. Thus Risk reduces depending on preparedness, mitigation, timely warning (with lag time) and relief. For example the effect of drought reduces with understanding of drought, preparedness to go for alternate drought resisting crops and the ability of government to create emergency jobs (Food for Work Yojana) to desist exodus or migration to other places.

Preparedness : A series of protective measures or actions taken to minimize the likely damages to life and property in all the three phases of disaster (before, during and after the hazard event) is called preparedness for that particular type of hazard event.

For this purpose first we have to learn about the hazards associated with certain events (like cyclones, floods, droughts, earthquakes etc). Secondly it is required to know how losses occur. For example in case of cyclones the losses are caused by strong winds, heavy pours and storm surges. The third factor is vulnerability. In case of cyclones houses, assets, roads, river/tank bunds, power and telephone, telegraph lines, damages to standing crops, orchards, inundation of low lying coastal areas etc. The fourth factor is approximate actions or measures to minimize the vulnerability. For example in case of cyclones strengthening of bunds, errection of wind breakers, coastal flood embankments, cyclone shelters etc.

The important steps involved in disaster preparedness for cyclones are :

(i) Adequate timely cyclone warnings for mariners in the high seas,

(ii) Port Warnings (distant signals DC I, DC II) for the safety of ships leaving the ports,

(iii) Port warnings for the safety of the port, ships and crafts plying on the coastal areas and the ships at the port,

(iv) Fishermen warning for the safety of fishermen,

(v) Cyclone warning to the State Government authorities for the safety of coastal population.

All these steps taken before cyclone crossing the coast comes under preparedness.

Preparedness Plan : Setting up action committees at District, Mandal and village level. Assignment of jobs to responsible persons, sequencing of work, training them to act according to the emergency situation, storing of food material at cyclone shelters, keeping ready transportation, acessories, propaganda machinary, medicines, geographical information system.

Prevention Planning : Preventive actions that are taken before the commencement of cyclone may be regarded as prevention and preparedness. The term prevention here implies to the long term policies and actions designed to prevent or reduce the impact of the disaster. Preparedness implies to the action plans which minimizes the loss of life and damage and side by side it facilitates rescue, relief and rehabilitation during cyclone. For example evacuating shipping from ports, progressive closure of transportation on sea, road, rail , air and inland river water, power supplies, water storages, closure of schools and using them as cyclone shelters, commercial activity, evacuation procedures, seeking army assistance, emergency food, clothing and medical supplies. All these activities require special meteorological assistance.

Cyclone Disaster prevention planning consists of :

(i) a technical evaluation of the climatological risk of cyclone and its effects in selected coastal zone,

(ii) an assessment of relative vulnerability of population in this selected zone to the effects of stated cyclone intensity,

(iii) Establishment of structural design codes, regulator controls and minimum safety standards under authoritative legislation,

(iv) Educational programmes for community acceptance of the cost of cyclone disaster prevention.

Mitigation : Providing help to alleviate the suffering or reducing the miseries of the affected people. This involves short term and long term actions and policies implementation to lower the risk to life and property.

Disaster Mitigation efforts depend on the strengthening of local committees, preparedness, cooperation and involvement of NGOs, Government and local authorities. Training and teaching of disaster mitigation in schools and colleges and preparing self help group activities.

For the mitigation of cyclone effected people the following emergency actions to be taken in the order of preference.

(i) Assess the losses and damages

(ii) Provide medical aid,

(iii) Disposal of dead bodies and caracases,

(iv) Immediate repairs to breaches in tanks, river bunds and other water bodies,

(v) Preventive measures against spreading of epidemics, like cholera, diarrhoea, flue etc.

(vi) Arrange safe drinking water and food

(vii) Mobilise building materials,

(viii) supply cattle feed and fodder,

(ix) Distribution of relief materials including building materials for repairs of dwellings.

(x) Arrange to send back the evacues to their homes.

Relief : Help (both material and physical) provided to the affected people (after the event) by government, or NGOs to minimize the damage or shortening the post disaster recovery period (or process).

Authoritative Warning : The authority to issue "Warnings" in impending natural hazards lies exclusively with Government of India, namely India Meteorological Department (IMD), Central Water Commission (CWC for floods) and National Geophysical Research Institute (NGRI). Warnings issued by these Departments carry Statutory Force. In other words, it is the responsibility of Government of India (IMD, CWC, NGRI) to study, (collect analyse and interpret) and forecast natural hazards.

Line Departments in Cyclone Disaster Mitigation : All Government Departments, (Central or State) which have some bearing in cyclone mitigation are called line departments. It must be noted that some departments may have a major role to play while others may have minor roles in mitigation work. In general the following departments have some role or the other in cyclone mitigation. [CG = Central Government, SG = State Government. This list not included the NGOs].

1. IMD, 2. CWC 3. Defence services, 4. P & T, 5. DD 6. Information and Broadcasting 7. Railways, 8. Disaster Management Unit (DMU) 9. General Administration 10. Commissioner of Relief, Rev Department, 11. Commissioner Civil Supplies, 12. Finance Department (Treasury), 13. Home Department Police 14. Medical and Health department. 15. Environment and Forest department 16. Roads and Buildings 17. Road Transport Department 18. Panchayat Raj Department 19. Electricity Department 20. Animal Husbandary and Fisheries Department 21. Irrigation and Command Area Department 22. Agricultural Department 23. Information and Public Relations 24. Housing and Rural Development 25. Fire services 26. Ports.

In addition to the above the Non-Governmental Organisations (NGOs) like NIAR (National Institute of Amateur Radio), Indian Red Cross Society, Rama Krishna mission, Helpage India, Satyasai Seva Samiti etc., to be involved in for distress mitigation.

Stake Holders : All parties involved in disaster management or interest in it are termed stake holders.

In disaster management the main stake holders are :

(i) Originators (the technical staff of Disaster Management unit)

(ii) Intermediaries (the Government staff through whom warnings are sent and external departments or units employed for dissemination of information)

(iii) Receivers and Responders (senior district level government officials and originators coming under Disaster Management Committees)

(iv) The affected people (or the public at risk). The identified stake holder in disaster management are : NGOs, Religious Groups, Prominent citizens, Self Help Groups, Public and Private industry, Traders, Civil and Defence, Homeguards, NCC, Bharat Scouts and Guides, National Service Scheme (NSS), Insurance, Government of India, International Relief Agencies, International Funding Agencies, Governments of other countries.

Insurance : Insurance in general a safety belt against any loss due to any hazard. People should be educated to go for insurance against natural hazards for the safety of life, property, crops, orchard plantation etc. In recent times in India many farmers committed suicides unable to repay loans taken for growing crops due to crop failures (because of the monsoon failures). The best solution for averting such sucides is compulsory crop insurance while taking bank loan. It is most surprising and unfortunate that there is hardly any education and encouragement about crop insurance. Small farmers become the victims of money lenders which is a social evil, still coming down from ages. In western countries suicides on account of crop failures is unheard. In recent times only in Goa, disaster related insurance is seen, in Kerala, the tribal people are insured against natural hazards.

The following are some of existing main Risk Insurance in India.

Standard Fire and Material damage, Agricultural Insurance, Household Insurance, Hut Insurance (single or group), Bankers Indemnity, Special contingency, Package Insurance for Credit Society, contractor plant Machinary, Motor Insurance, Personal Accident Insurance and Social Security Scheme, Commercial Insurance, Public Liability Insurance Act.

Risk Insurance Schemes : Standard Fire Insurance and material damage. General Insurance corporation covers storm, cyclone, hurricane, tornado, flood and inundation.

Household Insurance policy covers the risks due to fire, lightning, explosion of gas cylinders and domestic appliances, flood, cyclone, earthquake, aircraft damage, landslide damage, terrorism, riot, strike (Bandh), bursting and overflowing of water tank, apparatus or pipe.

Hut Insurance - individual or group, Bankers Indemnity, package insurance for credit society etc., as given above.

Some International Insurance Practices

National Flood Insurance Programme NFIP (USA) : A flood policy protects the community from flood. Stock insurance companies, Mutual Insurance Companies, Blue Cross, Blue Shield provide insurance for hospital and surgical expenses and physician expenses. Social security system, All risk crop insurance, Flood insurance.

The Insurance system is well regulated and controlled by the Government. Insurance is considered as business concerning public interest. There are regulations for approval of premium rates. Premium rates are supported by statistical data.

Crop Insurance existed in Australia since 1918 but new schemes were introduced in 1960's. According to FAO report non-hail insurance tend to be private initiated by growers, growers associations, mutuals, cooperatives or marketing groups. Predominant crop insurance arrangements are : Growers pool or mutual fund. Commercial insurer working with grower associations.

Commercial insurer providing cover for a grower marketing association. Commercial insurer operating through brokers to individual large scale growers as clients. Commercial insurer linked with grower cooperatives of smaller scale growers.

In Japan agricultural insurance scheme was established in 1947. The present scheme has 6 programs.

1. Rice, Wheat and Barley insurance
2. Livestock insurance
3. Sericulture insurance
4. Fruit and Fruit tree insurance
5. Field crop insurance
6. Greenhouse Insurance

The first three are compulsory, who cultivate over a certain specified area. The Central Government subsidizes farmers with part of their office expenses.

4.2 Vulnerability Reduction

We study recorded extreme events with an aim to bring out some results. These results shall be useful to handle or prevent similar extreme events or to mitigate their ill effects.

Extremes of any distribution in statistics is of great interest. The statistics of extremes provide the range of variables. The extremes in natural hazards (say, temperature, wind, flood height, lowest pressure in a cyclone, earthquake intensity, Tsunami wave height, Tornado intensity etc) are expected to repeat their occurence again. In design of engineering structures, the most extreme value has significant importance. Dams must be constructed to withstand the maximum flood anticipated in that location, skyscrapers must be designed to withstand the most severe earthquake occured or anticipated in the locality, chimneys errected should withstand the strongest gale that occured or anticipated in that area. In all such natural hazards the distribution of extremes is of great importance. Thus in disaster reduction the long term climate records of potential natural hazard events like climate change, severe cyclones, floods, droughts, Tornadoes, Tsunamis, earthquake etc., provide vulnerability of these events on communities/ areas. They also provide clues for preparedness, planning guidelines, response strategies to handle the future extreme events. Past experience of cyclones show that the effective preparedness, early warning, community awareness contributes a lot in disaster mitigation. By the projected climate change, global warming and their impacts on sea level (rise) Arctic and Antarctic ice cap melting, rise in number of cyclones, Tsunamis, spreading of deserts etc., can be made use of in long-term sustainable development plan. Global warming is likely to cast shadow in the existing hazard zoning because it causes change in environment. Flood prone areas may increase, some places/ islands may be submerged under sea, number of extreme events are likely to shootup (like severe thunderstorm activity, hailstorm, lightning discharges to ground, point heavy rainfall amounts, frequency of fog/smog, flash floods in rivulets and in urban areas.

4.3 Early Warning

Early warning of any severe weather depends on comprehensive programme of surface and space based (satellite images) observations, their unrestricted exchange of data together with derived products. The backbone of weather monitoring system, namely some 10,000 land weather observatories, 1000 upper air observatories, several hundred storm and cyclone detection radars, more than 7000 voluntary observing ships, about six polar orbiting and an equal number of geostationary satellites, a global network of river gauges and about 250 Global Atmospheric watch stations (monitoring atmospheric chemical composition –

greenhouse gases, ozone, pollutants). The data contribution from environmental satellites for monitoring natural weather hazards contribute to the disaster management. All coordinated and cooperative efforts in collection and exchange of observational data in time, processed information exchange through Global Telecommunication System will add to the effective, timely disaster warning system.

Long term preparedness and prevention measures will help in predicting climate change and variability and early warning. Further it will help in long term vulnerability analysis, risk assessment, preparedness and protection of community from natural hazards. WMO (World Meteorological Organisation) cooperates in the implementation of International Strategy for Disaster Reduction. WMO has entered into partnership with other UN organisations for this purpose, particularly WHO, FAO, Forestry, Water-resource management, humanitarian relief and Tourism. The organisations cooperate through building multidisciplinary approach to integrate scientific knowledge of physical, chemical, biological processes of the Earth System. Making impact assessments, develop preparedness and response strategies for a range of extreme weather events, climate and water related events.

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CHAPTER - 5

Action Plan for Cyclone Disaster Management

Action Plan for cyclone disaster management is dealt in three phrases.

(i) Before the commencement of cyclone effect,

(ii) During the cyclone effect and

(iii) After cyclone crossing the coast and weakening.

***Action Plan Phase* I :** As soon as the Cyclone Alert (48 hrs in advance of cyclone effect) issued by IMD, Maritime State district collectors in turn should communicate Cyclone Alert to MROs, Division officers, District Heads by all modes of communication (Telegram, Telephone, Cellphone, W/T even through messengers) available. MROs in turn communicate to Village Local committees, Sarpanchs, Local village level officers. Immediately mass publicity be done by drum beats (Tom Tom method) or Blares, particularly in vulnerable areas. All district officers on leave should return to HQ duty automatically (cancelling leave) and report to the collector. No officer should be on tour or leave after cyclone warning issued. Collector should convene the District level Committee to take stock of the situation. Local NGOs/ voluntary organisations be asked to extend their cooperation. The following immediate actions have to be taken by the committee.

1. Procure and stock adequate quantities of food grains, (rice, wheat flour, dals), cooking fuels (kerosene, LPG cylinders) dry foods (biscuits, drybread or tosh, powder milk, beaten rice etc) for distribution to victims.
2. All government vehicles be kept in working condition.
3. The list of working generators available in the district (including cinema theatres) may be given.

4. Medical and Veterinary Departments should store essential drugs and vaccines for preventive use (to arrest the spread of diseases or epidemics).
5. *Cyclone stores have to stock the following materials* : Large cooking vessels for use in relief camps/cyclone shelters. Identity slips with serial numbers for issuing to victims in emergency camps. Fire service department should keep hooks for clearing debris, Floats (lorry rubber tubes, empty plastic drums) to wade through inundated water. Tents for emergency camps, strong ropes, wires, chains, steel poles, bamboos, asbestos/GC sheets, sloted stripes of metal, double handle saws for cutting fallen trees, electrical saws, shovels to lift and throw, loud Hails (for anouncing), Hose pipes, First Aid Kits, torch lights, candles, kerosene/gas lanterns, gunny bags, sand bags, polythene bags (for food dropping packets), buckets, VHF sets with batteries. Fodder, pumps for bailing out water along with hose, spades, crowbars, hand gloves, gum boots, eucalyptus oil, phenyl, naphthalene balls, chlorine tables, bleaching powder, potassium permanganate granules (for water cleaning), bamboo mats, nylon mats, phenyl slate line etc., useful for burying the dead bodies.

Police department should set up VHF mobile sets for better communication. Electricity department disconnect power supply in areas where gales and squally winds are expected. Installation of mobile power generators at crucial places like Municipal / Panchayat buildings. Geographical information along with toposheet maps of vulnerable areas, list of working generators (both government and private) for emergency use.

Municipal/ Block Development/ Panchayat authorities should store maximum quantity of drinking water in safe overhead tanks, cleaned mobile tankers and working diesel generators be set up near overhead water works. Working transport vehicles (like jeeps, lorries, vans) be filled with diesel/ petrol be placed on duty at District, Mandal, Block, Panchayat Raj Head Quarters to enable to draft for transport of materials or evacuation. Weak locations of river banks, tank bunds and other water bodies be strengthened. Weak, delapidated houses, buildings etc., be repaired or completely destroyed. Intense patrolling be ordered to inspect the weak spots to avert breaches. People living in low-lying areas and in other vulnerable places be warned by drum beats/ blairs and other public address systems about the impending danger and advise them to move to safer places or cyclone shelters. In villages and Panchayats school teachers, doctors, eminent people be made committee members and they should be informed about the latest position of cyclone and safety measures to be taken.

Officials of Road and Building Department order immediate inspection of bridges, culverts, diversion roads, old buildings and repair where necessary for free flow of traffic on roads. They should store necessary materials to repair any emergecy breach.

Executive Engineer Irrigation Department should be in touch with his counterparts of river upstream districts and obtain first hand information of inundation, flash flooding and flooding in their areas. He should be in readiness to combat the situation without much damage. Prohibit temporarily plying of buses, lorries, trains etc., in cyclone track areas and other critical vulnerable areas of flooding, and old kutchcha roads. This will prevent stranding of passengers in flooded areas. Designated team officials must be in readiness with adequate lorries/ vehicles for transporting men and material from endangered localities. If required big cargo boats from port officers may be used. Similarly pre-designated team of Fisheries Department move to coastal vulnerable areas (likely to be affected by cyclone) advise the fishermen not to venture into sea and tie their boats, stores, nets etc., at safer places. Fishermen in low-lying coastal areas and shore be warned to move to the safer areas or to nearest cyclone shelters. Agro Industries corporation may be asked to keep their buldozers at the disposal of collector for necessary use.

The designated team of Agricultural Department should advise the local farmers suitably, who are likely to be affected, how to save their crops.

Doctors of District Medical and Health team should stock essential medicines and chlorinate the waters of wells and tanks for drinking purpose.

District civil supplies officer arrange to draw sufficient quantity of rice, wheat flour, pulses (dals) etc., from Food Corporation of India godowns. Similarly the designated team stock adequate petrol, diesel, kerosene, LPG cylinders along with stoves from local outlets on government account. These will be used in emergency camps/cyclone shelters. Post and Telegraph Department team must be in readiness (with technical men and accessories) to move into the communication disrupted areas to restore the communication.

Designated team at district collectorate, under the natural calamities act. "Instructions on Aid to Civil Authorities by the Armed Forces, 1970", alert the Defence Services to provide Army assistance at short notice in rescue, relief operations by way of Helicopters, winged aircrafts in aerial survey of flooded area, in rescue of marrooned people, in air dropping of food and also provide assistance in wireless communications.

It is a must that all District, Mandal, Block Development, Municipal and Village Panchayat Committee members to be in constant touch (online) with State Head Quarters Control Room and seek decision support orders and strictly adhere to weather warnings, by monitoring them on AIR, TV broadcasts.

***Action Plan Phase* II :** As soon as the cyclone warning (24-hrs in advance) received, the Joint Control Room (at state HQ) located in General Administration Department (GAD), the members of Revenue, Police and Army have to act. GAD should alert Air force to be in readiness with helicopters for aerial survey to assess damages, to rescue the marooned people. It is the primary responsibility of army to help the Civil Authorities in case of natural calamities. GAD would be incharge of seeking Defence help and to coordinate with Army, Navy and Air force. Air force along with Civil authorities should survey cyclone hit area and submit report of inundation.

Evacuation **:** It is the responsibility of Revenue Department to evacuate coastal people vulnerable to gales, storm surges and inundation. By sending lorries, buses or with the help of Army, vulnerable people in coastal areas and in low-lying areas who are likely to be affected by cyclone should be evacuated. These people may be accommodated in cylone shelters, available schools, temples, churches, mosques, railway waiting halls and other public safe buildings or in army camps. The evacuated people be given identity slips and be provided food, safe water and medical aid as required. Children be supplied milk, bread, biscuits and preventive inoculation. In cyclone affected areas, collectors are empowered to declare holiday for schools. State Road Transport Corporation operate special bus services (free of cost) in cyclone affected areas from Railway station or stranded place to cyclone shelters for stranded passengers. Railway safety unit should survey the track fitness in the affected area before allowing the trains to pass through. Similar action to be taken by Revenue, Irrigation Departments about the safety of roads, culverts etc. Holiday may be declared to all local government offices except the line department officials involved in disaster management duty, viz Police, Revenue, Fire services, Road Transport, Food corporation of India, Nationalised Banks, AIR, DD etc. The designated officials of these Departments must be on duty (even cancelling their leave). It is the responsibility of district civil supplies officer to supply (pre-arranged from FCI) food stock for running emergency community Kitchen at cyclone shelters and to military rescue camps. Dry durable foods like bread, buns, Tosh, boondi, beaten rice etc., be kept ready on hand in sufficient quantity for air dropping to the marooned people. In cyclone hit area, all trains, bus services and other transport traffic be stopped temporarily at suitable places, particularly during night to avoid accidents and likely to be stranded at odd places (in forests etc).

Vehicles like Jeeps, tractors (with wheel handle) etc., which kept ready for use at Revenue, Police and Road and Building Department may be pressed into service to pull out the stranded vehicles. Similarly buldozers of Agro-industries be used to clear road blocks.

P&T Departments keep its Telephone exchange units open and tacitly allow the use of phones to cyclone duty staff and in emergency cases to all civilians who are caught in the disaster. Efforts will be made to inform the well being of the people living in camps to their relatives. Similarly Police Department set up mobile wireless sets at District/ Mandal Control rooms for transmitting emergency messages. All such arrangements be made at Mandal Head Quarters.

Executive Engineer R & B Department should take steps to evacuate movable equipments, vehicles and other accessories from cyclone vulnerable areas and prohibit plying of vehicles on sections of roads, bridges, culverts which are likely to be affected by cyclone.

Divisional Engineer Electricity Departments should place generators at crucial locations like General Hospitals, Municipal/Panchayat Water Works, District/ Mandal Office to provide emergency power supply in the event of power failure. Mandal Parishads, Village Sarpanch, Assistants arrange sound blairs (Sirens, trumpets, Tom Tom), ringing of temple bells, churches as an indication of cyclone warning to the common man and take protective steps.

***Action Plan Phase* III:** Soon after the anouncement of cyclone dewarning by IMD or passing away of cyclone over the area even without formal intimation of dewarning, the local disaster management committee members meet immediately (before 6 A.M in case cyclone passed or crossed over the coast and weakened in the night) decide the action of rescue of the affected people, evacuation, damage assessment, emergency relief camps and relief work.

***Rescue Operation* :** A meteorologist from the IMD may be involved in assessing the strength of the cyclone and its damages in the team of survey. The pre-assigned relief team armed with GIS maps along with or without a meteorologist should make an aerial survey of inaccessible areas, high flood zones or places of communication failure and prepare a list of marooned areas requiring food droppings and rescue. In case of people marooned, immediate assistance may be sought from the IAF or the Navy to rescue people if their lives are in danger, otherwise air dropping of food packets, water bottles be arranged. Concerned village teams be contacted or involved in relief operations. In the event of civil groups of state government unable to handle, army be involved in the rescue operation. First contact be made with the affected people (villages), collect exact location, and information of their requirement of help, it is then rescue and relief operations be undertaken on war footing.

***Relief*:** Collectors are empowered to pay reasonable cash gratuities to the affected people in transparent listed mode (collectors are also empowered to draw any amounts from treasury towards relief). In case of house, property damages, the unfortunate people may be given rice, wheat flour, pulses etc., for immediate relief. Relief teams should arrange disbursement involving local people and committees with prescribed procedures and documents be got signed by the beneficiaries to avoid allegations of fraud later.

***Rescue Operation from debries and disposal of dead and animal carcasses* :** It is the responsibility of Police Department to undertake the removal of people trapped under debris. In case of deaths, they should make panchanama and then the dead bodies and animal carcasses be disposed before they are decomposed. This is really a tough job because of rains, strong winds, road blockings, road breaches and inundation. The Police team is empowered to engage local labour on spot payment. Wherever possible, after identification by local committees, mass burial or burning of dead including animal carcases be undertaken. Collector should arrange adequate fuel (Coal, kerosene, firewood etc.,) for burning (pyres) the dead bodies and animal caracases. Generally this is done in consultation with the Police Superintendent. Though from the point of view of hygene burning is recommended but it is followed as a last resort when the mass burial is not possible.

***Health and Sanitation*:** There will be chance of spreading of epidimics related to water borne disease after the passage of cyclone. District level Medical and Health team should take steps to arrest them by undertaking mass vaccination, distribution of antimalarial and flue tablets, vitamins and other essential drugs to the affected people. In Municipalities, Blocks, Mandals, Panchayats Health teams should undertake similar action in their respective affected areas. District Medical and Health Officers enlist the local doctors, both government and private practitioners and utilise their services in any emergency. Army medical units will work in their relief camps, however there should be active cooperation and consultation in these units. Ambulences (both government and private), vans, cars be kept ready with drivers for transporting the affected/ injured to the medical camps.

***Restoration of trains, roads traffic* :** After the passage of a cyclone the railway track in the area be inspected and repaired immediately as required. Train services should be restored immediately. It is the responsibility of R & B Department Committee to undertake the clearance of roads and restore traffic immediately. The team should arrange removal of obstacles (fallen trees, mud slides, stones etc.) on roads and repair the damaged roads, culverts etc. Local villagers may be involved in clearance of road blocks, fallen trees and they may be allowed to take away the wood for themselves. Police team should help the civilians with their mobile squads in clearing of large trees fallen by gales, stone blocks of landslides on roads. Electricity Department should clear immediately roads, lanes that are fallen by electric poles to avoid any kind of shock hazards and restore the power supply at the earliest possible.

MROs with the help of Public Relation Officers (PROs) and other revenue officers, Panchayat Raj, Municipal Officials should prepare cyclone damage photograph album (with names, damage description) and send it to the District Collector.

Revenue Divisional Officers with their teams survey and enlist the damages of houses, crops, orchards, sand casting, breaches in roads/ river bunds etc., with supporting photographs. This work should involve the cooperation of village level committees and NGOs. The damage and loss enumeration should give the following details.

Loss of human lives with complete enquiry. Loss of livestock, loss of property with details, loss of government property including local bodies enlisted as:

(i) Educational Institutions

(ii) Other buildings

(iii) Electrical

(iv) Damage to irrigation sources

(v) Damages to drains and related work.

Damages to Municipal properties, loss to Agricultural Department stores, loss to industries, loss to standing crops. Damage to lands (erosion, sand casting etc.). Damage to fishing equipments may be given.

***Distribution of Relief*:** After aerial survey, evacuation of people to cyclone shelters or relief camps, the district supply officer should arrange and supply of food grains to each of the relief camps. The supply of stock should be based on population in the camp. The main items would be rice, wheat flour, Rawa, Pulses, Chilli powder, Tamarind, Vegetables, Oils, milk powder, LPG (gas) cylinders along with stoves, firewood and other daily cooking articles. Food articles drawn from FCI generally despatched and stored in cyclone shelters or camps just after the III stage cyclone warning anounced. At the local relief centres the food grains and other articles would be distributed to the people based on the identity slips issued and recorded on a proforma sheets with signatures of the beneficiaries babe in arms be given seperate slips.

Team members engaged in rescue, relief operations should submit status position pertaining to their area of operation to the concerned Mandal Revenue Officer, who in turn submit to the District Collector of the area, and from there to the State HQ.

After passing away of the cyclone or weakening Control Rooms at Panchayat, Mandal and District HQ coordinate in various relief and rehabilitation works. District Public Relation Officers regularly brief the press, AIR, DD and T.V channels all about the development relief, rescue and rehabilitation operations for news, public broadcast to the nation.

In the event of extensive loss of life and property voluntary donations in cash and kind may be appealed, which may be received, stored and distributed with proper accounting by a senior officer involving NGOs.

· ***Disaster Reports*** : All officers, NGOs (requested) involved in rescue, relief and rehabilitation works should submit detailed report on losses together with the difficulties faced and suggestions for improvement in the operation of future work. It is important to note that these reports of damage are documents, based on which State and Central Government relief assistance will be given. The reports should be correct, unbiased assessments of the field situations and damages to the crops, properties (both public and private), loss of human lives, head of cattle, flooding, breaches, inundations etc., should be prepared in minimum possible time and sent to State HQ Control room within the following proforma.

Disaster Report Proforma - 1

Statement showing the loss of property, human lives etc., caused by natural disasters - indicate the type of calamity (cyclone, flood, earthquake, Hailstorm, Tornado, storm surge, Gale wind etc.) to be submitted to the District HQ, to the State HQ.

1. S.No
2. Type of Calamity
3. Location
4. Date from to Date, duration
5. No. of villages affected
6. Area affected (in km^2)
7. Population affected
8. Population evacuated, extent of loss
9. Number of human lives lost
10. Number of cattle lives lost
11. Estimated value of cattle lost
12. Number of other animals lost
13. Estimated value of other animals lost
14. Number of huts damaged or destroyed
15. Estimated value of the huts lost
16. Number of houses damaged/destroyed
17. Estimated value of houses damaged and destroyed.

    Damage to crops

18. Name of crops destroyed
19. Area of crops destroyed (in acres)
20. Potential loss of yield (tonnage)
21. Estimated value of crop damage

    Damage to public utility works

22. Name of work damaged
23. Nature of damage
24. Remarks: (Difficulties faced and suggestions for improvement)

Proforma - 2

Statement of loss of property and human lives to be submitted by State Government to Government of India.

1. S.No.
2. Names of the Districts (s)
3. Number of affected villages
4. Number of people affected (in lakhs)
5. Total area affected (in km^2 or in lakh hectares)
6. Cropped area affected (in km^2 or in lakh hectares)
7. Value of the crops damaged (in Rs Crores)
8. Number of houses/huts damaged or destroyed
9. Value of the houses/huts damaged or destroyed (in Rs crores)
10. Loss of Human lives
11. Loss of Cattle lives
12. Loss of other animals
13. Value of damage to public utility (in Rs crores)
14. Total value of damage (7+9+12, crops, houses, huts and public utilities - in Rs crores).
15. Expenditure incured on relief operations
16. Remarks :

Another form of Cyclone Damage Assessment

S. No.	Particulars
1.	Number of people affected
2.	Number of villages affected
3.	Area affected in km^2 (area)
4.	Number of human deaths
5.	Number of human injuries
6.	Number of cattle dead
7.	Cropped area damaged km^2 (area)
8.	Area saline inundated km^2 (area)
9.	Number of houses collapsed/damaged
10.	Telephone/power lines damaged km (length)
11.	Number of power sub-stations damaged
12.	Number of canals breached

13. Number of embankments breached
14. Embankments/canals damaged km (length)
15. Number of irrigation projects damaged
16. Road damaged km (length)
17. Number of public buildings damaged/collapsed
18. Number of schools collapsed/damaged
19. Number of tube wells damaged
20. Number of drinking water wells damaged
21. Fields/orchards area sandcast km^2
22. Area of plantation destroyed km^2

CHAPTER - 6

Role of Different Institutions in Natural Disaster Management

Effective Disaster Management involves the coordination of many institutions/ departments, some may have greater role to play than others. The principal Agencies/ Institutions/ Departments that involve (play role) in Natural Disaster Management are : India Meteorological Department, Central Water commission, National Geophysical Research Institute, Defence, Revenue, Medical and Health Department, Police, Irrigation, Panchayat Raj, Electricity. Civil Supplies, P & T etc. We shall study the role of a few important line department except Defence which will be dealt separately.

Role of Panchayat Raj **:** The Panchayat Raj bodies include Zilla Parishad, Mandal Parishad and Gram Panchayat. The important contribution of these Parishads in disaster management are: Sanitation and Health, Drinking water, Transport and Communication, Street lighting and educating the local people about natural hazards. The Primary duty of Panchayat Raj institutions to create awareness among the coastal people, about the cyclone disasters and their adherence of do's and dont's during cyclones.

Gram Panchayats play a role at the gross root level.

Preparedness Action Plan : *B*efore the onset of a cyclone or during phase I, Gram Panchayat councillors, ward members be made in-charge of receiving the cyclone warning messages. A VHF set/Radio set / Community TV be kept in working condition to monitor the warnings.

Dissemination of Warnings : As soon as the warnings are received from Mandal Control Room or District Control Room or State HQ Control Room or monitored on Radio, T.V, Sarpanch should call local committee members and dissemination action should commence with the beat of Tom Tom or Blairs or through Public Address system of mobile blair fitted to the jeeps. Hazard warnings should be spread like wild fire in all lanes, by lanes and nearby hamlets. Villiage ward members/ Councilors shall be responsible to inform the people of their wards and nearby hamlets. They shall be made responsible evacuating the people who are likely to be affected, to safer places or cyclone shelters. They will be responsible for arranging transport for evacuation and return.

Gram Panchayats should procure or stock bleaching powder, lime powder, phenyl, broomsticks, drain clearing bamboos and other clearing materials. In camps/ cyclone shelters they should provide safe drinking water, cleanliness, spraying lime powder, phenyl or bleaching powder. They should arrange temporary latrines.

Preparedness for Drinking Water **:** Panchayats should keep hand pumps in good working condition and store spare parts (for emergency repairs). Panchayat Water Supply (PWS) schemes procured and kept in readiness. Leakage of pipeline, if any, be attended well in advance. To remove fallen trees on roads double handle cutting saws, ropes, gunny bags, sand bags, bamboo sticks or poles, hose pipes be kept ready. All overhead water service, mobile water tankers be filled in with fresh water and duly chlorinated. All drinking water sources (lakes, wells etc) should be protected and repaired where necessary. Tanks and river bunds be inspected, weak spots be strengthened. Generators/mobile generators be kept in good working condition with spare tins of diesel.

Transport and Communication **:** Panchayat Raj engineers should inspect, weak bridges, culverts, road breaches and repair them. Lorries, vehicles, boats, motor launches/local wooden sailing planks be kept ready for transporting disaster victims to cyclone shelters and other relief camps.

At village level, different committees be formed (involving local people--teachers, doctors etc) such as alerting people, awareness, food, rescue, relief committees. Sanitation supervision committee, swimmers, divers, vehicle drivers. The committees should train them if needed and arrange when required.

Food **:** Rice, Wheat flour, dals, tamarind, chilli powder, salt, milk powder, LPG cylinders (cooking gas) with stoves, kerosene, lighters, diesel oil, edible oils for cooking food at relief camps be procured at Panchayat level.

Role of Mandal Parishad

Mandal Parishad shall be responsible : Establish Control Room. Designate people to monitor warnings received from State/District Control rooms and directly from AIR/DD. Communicate warnings to the concerned officials and Committees. Arrange to estimate the potential of disaster and resources required to meet the contingency. Send assessed requirements to Zilla Parishad for repairs of Roads, bridges, culverts, water works, strengthening of bunds of tanks, rivers, reservoirs etc. Select a temporary helipad site and inform to Zilla parishad with clear marks of identification. Select sturdy buildings for temporary cyclone shelters like schools, Cinema theatres, Municipal / Mandal community halls, temples, mosques, churches etc., or arrange erect relief camps (with tents). Keep in readiness boats, motor launches, gunny bags, sand bags, ropes, transport vehicles, bamboo poles etc. Designate relief teams of men and women.

***Preparedness action Plan at Mandal level*:** Activate Control Room for round the clock vigilance and working. Warning messages immediately send to the concerned people positively. Arrange transport and order evacuation of people from most vulnerable areas. Pool required resources. Procure water tankers with safe chlorinated water, identify drinking water resources and take steps to chlorinate them before supply. Procure materials and accessories for damage repairs

***Action Plan during Disaster* :** Arrange temporary shelters or errect tents to lodge victims. Assess damages/losses to life and property. Coordinate in relief camps with materials, Health and Sanitation. Prevent epidemics. Assess storages/ omission, inform to district administration. Arrange helicopter for evacuation of marooned people or located in hazardous area.

***Action Plan during Post Disaster* :** Make assessment of all items realistically. Provide some short period work (under Food for Work) to the most needy, serve food, rice, wheat flour etc. Help in restoration of public and community assets. Make a review of all items of work entrusted. Find the needs and arrange necessary equipments required by all teams engaged in relief work. With the current experience name the programmes of works for future hazard resistance/ prevention and community development. Document the events in order (if possible with photographs) and submit the report to the Mandal Officer.

6.1 Role of Zilla Parishad

The role of Zilla Parishad in all the three phrases of disaster briefly described below.

Preparedness before the Onset of Cyclones

1. Chief executive officer/Chairman Zilla Parishad call an emergency meeting of the parishad members. Take stock of the situation and take important decisions on matters of urgency.
2. Establish Control Rooms.
3. Make publicity of the seriuosness of the hazard situation.

4. Instruct executive engineers/ Dy E.E to tour and identify the weak and vulnerable points of roads, bridges, culverts, schools, public buildings, public water supply schemes and strengthen or repair where it is necessary.
5. Assign work to the enlisted officers and hold them responsible for execution.

Action on Receipt of Cyclone Alert

1. Activate Control Room or joint information centre to work round the clock.
2. Coordinate or liaise with neighbouring district Control Rooms for mutual sharing of information and aid.
3. Pool all resources at the command at a central place for easy catering.
4. Coordinate the resources received from outside.
5. Order to move the spare parts of hand pumps and public water supply schemes and power generators to the identified centres.

Action Plan when Cyclone Warning received or during Disaster

1. All concerned engineering staff be alerted and asked to attend urgent repairs of breaches of bunds of rivers, tanks etc.
2. Liaise with the neighbouring district counter parts and seek mutual assistance in grave situations.
3. Coordinate relief operations of evacuation, establishing camps etc.
4. Mobilise sufficient funds from treasury to meet the situation.
5. Coordiante with various line departments including army.
6. Arrange prompt distribution of relief materials and spares.
7. Make prompt/instant cash payment to all labours/contractors.
8. Arrange disposal of dead bodies and animal carcases after local identification. This should be done at the earliest (before they are decomposed).
9. To acertain the status position of cyclone coordinate with other Zilla Parishads and district administration.

Action Plan when Cyclone dewarning received (or during post disaster) :

1. All officers involved in disaster mitigation, relief work should submit a detailed report of their work, including short comings, deficiencies faced without exaggeration.
2. Document about disaster in detail and the mitigation works.
3. Critical assessment of damages may be prepared groupwise which will be useful in future contingency plan.
4. Experience in coordination and monitoring of post disaster actions may be reported.

5. Experience and difficulties faced in reaching vulnerable places or inaccessible places may be reported.
6. Based on the experience gained in disaster mitigation, training may be given to line departments staff and NGOs, stake holders for future benefit.

Response : In any natural disaster management work, the effective coordination and mitigation depends on the response from the local people, volunteers, self help groups and government officials. The following actions contribute to the good response in cyclone disaster management.

1. Establishment of Control Room, organisation and activation.
2. Organised Information Centre for coordination.
3. Receipt of clear/unambiguous warnings and prompt dissemination to the concerned people.
4. Evacuation of the people from the most vulnerable areas.
5. Actions of individual and families towards the safety of vulnerable persons like aged, sick persons, children, pregnant ladies and single member families.
6. Effective management of cyclone shelters/camps, first aid kits, emergency medical aid, clean drinking water and hygenic food arrangement.
7. Stocking of relief materials and receiving relief materials from outside sources. Prompt delivery of these and distribution to the affected needy people.
8. Aerial survey, search and rescue operation.
9. Extrication of the people from debris, collection of dead and their identification and quick disposal by either mass burial or burning.
10. Similarly collection of the dead animal carcases and their quick disposal.
11. Damage assessment and recommendation of relief assistance.
12. Organising relief, rehabilitation, repair and reconstruction of collapsed houses.
13. Organising training to volunteers, self help groups, NGOs, school children and government line department officials.

Contingency Action Plan

Contingency action Plan is a good procedure for the management of natural disasters. The features are given below.

1. Enlisting the past historical natural disasters with details of loss of life and property, time and space.
2. Identification of vulnerable locations (villages, towns, specific areas).
3. Geographical Information of locations (topographical features like roads, tanks, rail links, river mouths etc).

4. Acessories or assets useful for protection, prevention of disasters (like ropes, sand bags, boats, big logs, double handle saws, VHF sets, generators, buldozers etc).
5. Responses during recent past disasters from the Government Agencies, Army, NGOs, Self Help Groups, Red Cross, Local representatives (MLAs, MPs, Councillors).
6. Weaknessess identified in warning (accuracy, lead time), dissemination of warnings, propaganda, and other features during the past disasters and remedial suggestions.
7. Pictorial representation of participation of local people / Self Help Groups, awards given to Self Help Groups or individuals in recognition of exemplory work by State or Central Government. Such data presentation on location map for publicity and encouragement of their participation.
8. Formation of local voluntary groups (which include village respected elders, doctors, teachers etc) for the smooth execution of different activities in disaster management entrusted to the designated groups.
9. Supply of accessories (tools) and training to the identified work groups.
10. Assignment of work to the executive groups and coordination among them.

6.2 Role of PRA Groups in Disaster Management

The basis of Participatory Rural Appraisal groups is the involvement of local people for development activities of the village/ Mandal and to find their pressing needs. The PRA group generally consists village elders, prominent men, ward members, councilors, teachers, doctors etc. PRA groups involvement in disaster management greatly help in all phases of disaster. Participation of PRA groups will enhance the efficiency, confidence in the disaster management work. The PRA groups would be able to provide the authentic information of the following critical points.

PRA groups would be able to provide history of past disasters faced by them. The group can provide information of vulnerable locations, vulnerable communities, number of houses, huts, number of families resideing, their socio economic status, their proneness to disasters and their help in disaster mitigation work. The PRA groups can provide the statistics of individual/community assets which were affected during the past disaster events. The PRA groups would provide the information of retired teachers, doctors, officials, ex-servicemen, Policemen, Paramedical staff. Identified selfless individual persons may be honoured for their work on the occassion of local celebration of Independance Day, Republic Day and other local community festivals. The groups would prodvide the response of Govt. officials, Panchayat Raj members, NGOs, in the previous disasters. Based upon this, relief can be sought from the Government. These groups would provide the information of adequacy and or deficiencies of rehabilitation measures in the earlier implementations. Further these groups would provide adequacy of warnings, accuracy, lead time or the usefulness of the warnings in the earlier disaster events. This information would help in improving the warning system. The groups would provide the information about the necessity or adequacy of timely evacuation measures in the earlier disaster events and simultaneously provide the scope for improvement in evacuation policy.

***Application of PRA Groups* :** UNO observed 1990-99 decade as International Decade for Natural Disaster Reduction, which stressed the need to improve early warning system, Disaster resistant structures, to disseminate information or forecast at fastest speed to the affected people. Awareness of hazard events, their education and preparedness to meet the eventuality. Keeping these points in view the application of PRA groups is given below.

Community or people be informed the basic aim of collection of information. The sharing of information with them should be friendly and in helpful atmosphere. Encourage the people to share their information and advisories in their own way. Complete freedom be given to express their views and which shall be noted. They should not be restricted to express their views. Each PRA group may be composed of 5 to 6 members. Selection of members in a group in different areas may be composed of different strata of community. To extract or collect information frame the questions in different ways.

The involvement of local people (in PRA groups) in hazard preparedness, a number of activities have to be planned, organised, monitored and executed by the role players and stake holders to reduce the loss of life and damages.

6.2.1 Disaster Management GoI-UNDP Programme

According to GoI-UNDP DRMP Programme

Disaster suppress/threat sustainable development. They destroy decades of human endeavors, development and earnings. According to UNDP study during 1991-2000, of the globally affected population by disasters, Asia has accounted 83% and within Asia, 24% of deaths occur in India (due to disasters). The Indian sub-continent is highly vulnerable to natural disasters. Floods and cyclones affect 40×10^6 hectares of the land, 59% of the land area is vulnerable to earthquakes.

The GoI and UNDP Disaster Risk Management Programme provides support to the Government (State) to establish institutions/agencies to address disaster preparedness, response, prevention and mitigation. The programme objectives are given below.

1. Capacity building to institutionalize systems for disaster management in the government.

2. Support preparation of participatory multi-hazard preparedness plans, through preparation of response and mitigation plans for disaster risk management at State, District, Block (mandal) and Village and ward level in 176 most multi-hazard prone districts of 17 selected States (covering about 30% of India's population).
3. Awareness generation and education programmes in disaster risk reduction and recovery.
4. Networking knowledge on effective approaches, methods and tools for disaster risk management, developing and promoting policy frame works at State and National levels.

   The disaster management programme is being funded under multidonor framework of $ 41 million. Apart from UNDP other donors such as European Union (IEU), the United States Agency for International Development (USAID), the Government of Japan, the Australian Agency for International Development (AUSAID). Department of International Development, the European Commission Humanitarian Aid Office (ECHO) and United Nations International Strategy for Disaster Reduction (UNISDR) are part of this framework

The Role of Women as Self Help Groups (SHG)

Disaster Risk Management Programme is aimed to establish and sustain partnership linkages with important stakeholders.

In order to reduce disaster risks, the involvement of Women and Girls has been specially advocated through government programmes and departments like Sarvasiksha Abhiyan, Integrated Child Development Scheme, Mahila Samakhya, National Service Scheme and Education, Health and Industry departments. The departments assumed the responsibility, Media played active role in creating mass awareness.

The devastating Super Cyclone that hit Orissa in 1999, led to a surge in community response and participation in development interventions. DRM programme interventions aimed at developing the capacities of institutions and individuals to play lead roles. These citizen leaders play direct role in increasing local resilience and addressing root causes of vulnerability.

DRM awareness among school children about disaster preparedness through streat theaters have proved to be very effective in creating awareness campaigns. The people of Killari village in Latur district welcomed the DRM programme but with a poor response. The formation of Self Help Groups initiated by the Women's Economic Development Corporation and their representatives given guidance to the SHGs. This initiative successfully ensured increased participation of Men and Women from the Platform of Participatory Rural Appraisal (PRA) to the formation and training of the "first Aid" team and the "Search and Rescue" team. The SHG membership in Killari shows widespread network which offers the additional benefit of effective Channel of Communication. DRM programme in Killari was successful due to the active participation of women.

ASHA

Assam is prone to natural hazards like earthquakes, floods, landslides, cyclones. DRM Programme was launched to reduce the vulnerability of communities to natural disasters in this multi-hazard disaster prone areas.

ASHA (Accredited Social Health Activities), who are link between the public health centres and the villagers. They are drawn from the community where they serve and are fully aware of the needs and availability resources. This network put up their common needs, concerns and the views of the community.

6.3 Role of NGOs, Self Help Groups in Disaster Management

In a widespread disaster it is practically impossible for Government machinary to attend all services and no individual group or organization would function effectively. Consequently it is important to enlist the services of NGOs, Charitable Institutions, PRA Groups who have strong committed people and volunteers. Thus participatory, collabarative action plan would be most efficient for disaster management.

It is the responsibility of every citizen to render their help in calamities. This implies the collective effective effort by all agencies both Government and Non-governements to formulate priority actions like early warning, restoring the ecological balance with the available resources, infrastructure and communication system.

The role of NGOs in disaster management is well appreciated by the Health and Medical Services. Community participation in disaster management will boost the morale of the affected people. The Human Resources Development wing should encourage to involve them actively in disaster relief and reconstruction work. In India the prominant NGOs include : Helpage India, Ramakrishna mission, RSS, Christian Missionaries, Satya Sai Seva Samiti etc.

Peoples participation in disaster management have several advantages both effective and economic. It promotes awareness of natural hazards among the local people. NGOs and Self Help Groups be trained in civil defence, which would pave the way for their self dependency. It will help in locating hazard prone localities due to the perception of the threat. In case of distribution of scarce materials and water management it will be smooth sailing.

During natural disasters generally it is found that transportation and communication services are badly hit. In such situation unconventional communication system provides a valuable service. Amateur Radio proved to be one such important tool in post disaster management. Developed countries have

RACES (Radio Amateur Communication Emergency Services) wing, with the advent of mobile cell phones its importance is waning.

When a calamity occurs Amateur Radio operators in the affected locality or neighbourhood, inform about it to their local club station. They form relif committees and go on air, help civil authorities. Amateur Radio is a purely personal hobby. The involvement of Amateur Radio network does not cost any expenditure to government. The network clubs are willing to work day-in-and day out, at any place and under any circumstances. In recognition of this valuable talented service, United Nations Organisation established its own HAM Wing with a call sign of 401 UN. During natural disasters 401 UN HAM takes the help of local HAM and does yeomen service by establishing contacts with outside the world. It organises relief operations. HAM fraternity plays important role in communication sector under all adverse conditions. All schools and colleges may be provided with a HAM equipment which will work as hobby in fair weather but act as a frontline communication system in adverse situations.

In India, National Institute of Amateur Radio (NIAR) established HAM Radio Network along east coast belt. NIAR actively participates in major events of Melas, Pushkars, Rallies etc. These activities earned the good name and confidence from the public and government for selfless service in the hour of need. Presently this system is being linked through satellite communication and works efficiently except during solar flares and magnetic storms.

6.4 Role of Red Cross in Disaster Management

Jean-Henry Dunant, a swiss humanitarian established the Red Cross in June 1859 at the Battle of Solferimo organising emergency aid service to the French and Austrian wounded soldiers. Based on this humanitarian experience the first national voluntary relief societies came into existence in 1864. The Geneva Convention adopted Red Cross with commitment of signatory Govt. to (look after or nurse) care for the war wounded soldiers, irrespective of their affliation in army as friend or foe. This convention was revised later (1907, 1929, 1949) to meet the various contingencies. Though Red Cross started for the care of war wounded soldiers but eventually it became humanitarian organisation to help in the prevention and relief of human sufferings.

The main activities of Red Cross during peace time are : First Aid, Blood Banks, Medical Clinics, Meternal and Child Welfare Centres, Accident Prevention, Water safety.

The Indian Red Cross Society has its Head Quarters in Delhi and each State has its chapters. The President of India is President of National Society and Governers of each State is the president of that State chapter. District Magistrate/District Collector is the president of the District Red Cross. The membership of a district Red Cross may vary from 5 to 25 thousand, however 10% of these members regarded as Active in times of crisis. The membership drive or resources depend on the leadership, preparedness plan, coordination between Government and voluntary organisations.

Red Cross pays visit and enquires about the welfare of prisoners in war camps and provide relief supplies, mail letters and information to their relatives. The League of Red Cross Societies has a Secretariate in Geneva, which helps to provide relief in natural disasters and also helps in the development of National Red Cross Societies. The World-wide structure of the International Red Cross consists of International Committee of the Red Cross, the League of Red Cross Societies and National Red Cross Societies.

Benefits of Involvement of Red Cross in Natural Disasters

Red Cross motivates the voluntary workers for manual labour in times of crisis, provides skill workers (like doctors, nurses etc). It provides food, blankets, clothing, emergency shelters, medicines, blood supplies, first aid, life saving drugs and procedures, transportation, counselling the affected people to boost their morale, cooking and distribution, rehabilitation and reconstruction of housing colonies.

The other advantages of Red Cross involvement in natural disaster management is that it has country wide membership, high credibility in general public, it can get relief help from all the countries through the League of Red Cross Societies. It has large network of blood banks and voluntary blood doners. National Red Cross has always been in the forefront in rendering help to the effected in times of natural calamities. International community prefers giving its voluntary aid to Red Cross agencies for distribution to the effected people. Red Cross has universal recognition for identification and deployment in disaster relief work.

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CHAPTER - 7

The Role of Defence and other Services in Disaster Management

The services of Army is called upon only during emergency and in exceptional circumstances, when it is beyond the control of civil government to handle and /or when the civil resources of men and material are inadequate to meet the situation. The policy procedures and general guidelines for seeking assistance is given in Government of India publication, "Instructions on aid to Civil Authorities by the Armed Forces, 1970". Thus, it is one of the roles of Armed Forces to assist the Civil Government during natural disasters and other extreme contingencies. The Defence Services provide assistance to civil authorities with the approval and on orders of the Central Government. In case of emergency nature (when it is not possible to refer the matter to the Central Government, local military authorities may comply with a request at their discretion and refer the matter to the Central Government through proper channel at the earliest possible.

Each service (Army, Air Force and Navy) is independently responsible to render all assistance for maintaining essential services during natural disasters. The primary responsibility of disaster relief lies with the civil authorities who will control and coordinate all relief operations. The Defence services operations will be of supplement in nature which at that time civil efforts may not be sufficient or ineffective, but the army will not take over the entire relief work, which has to be controlled by the civil administration only. The main contribution of Defence Services would be during "Emergency stage", though not exclusively so.

Generally Chief Secretary of a State acts as a coordinator for all relief operations through a State HQ Control Room (centre), which involves all line departments, Government Agencies including Defence Services. However, actual relief plan will be executed at District level under the Control of District Collector, who will be the main coordinator. As said earlier the District level committee includes Deputy Commissioner, District Superintendent of Police, District Medical Officer, Executive Engineer, representative members from electricity Department, Post & Telegraph, Civil Supplies, Fire Services, Municipal, Block Development and NGOs.

The chain of Liaison Military and Civil authorities correspond to the following levels.

State Government	-	HQs command /Area
Division	-	HQs Area/ Sub-Area
District	-	Station HQs

In case of Navy and Air Force liaison will be at State level unless specifically ordered at lower levels.

The responsibility for coordination at various levels are as follows :

(a) Inter Service coordination at Centre level

- Cabinet Secretary (Military Wing)

(b) Service HQs

(i) Military Operations Directorate at Army HQs

(ii) Director of Naval Operations at Naval HQs

(iii) Directorate of operations (Transport and Maritime) at Air HQs.

(c) Command and Lower Formation HQs

(i) Senior General Staff Officer (operation) – Army

(ii) Chief of Staff / Fleet Operations Officer – Navy

(iii) Senior Air Staff Officer – Air Force

(d) State level – Service liaison officers deputed to form part of Joint Central Centre.

(e) Local level – Nominated Commander of troops and Senior Civil Administrator incharge of Relief.

The chief Secretary of State may initiate a direct request for emergency assistance, like helicopter for aerial survey to a Local Service HQ (Naval Base or Air Force Station). In case no station exists the request should go to Commands HQ of that jurisdiction area. The three Services, particularly the Army and the Air Force have a role in peace time in associating the Maritime State Government during cyclone disaster management. The Air Force helicopters play a major role in rescue of marooned people. Both helicopters and winged aircraft (of Air Force) are engaged for air dropping of supplies (in disaster affected areas), transportation and rescue mission. In case of chemical and nuclear fallout it helps in assessing them. The Navy play a role in rescuing fishermen in the high seas and in providing instant aid to derelict ships and fishing boats.

Indian Army is highly disciplined, organised and equipped. It possesses and controls some of the major resources required for rescue, relief and mitigation operations like boats, bridging equipment, mobile medical facilities, tents, engineering plants such as bulldozers, transport and para dropping equipment and trained manpower to operate these resources. Some of these resources are not available with civil administration to combat holocaust.

In case of cyclones, floods and earthquakes, landslides Army plays crucial role in post disaster relief and rescue operations, like extrication of men, dead bodies from the debris of buildings, cremation or burial of the dead, retrieval of personal belongings from debris, shifting of the wounded to camps, providing temporary accommodation in tents, medical aid, distribution of relief materials through voluntary organisations, providing food in camps, emergency preparation of helipads etc.

In Army operations, the cyclone affected area is divided into sectors (for convenience which may include one or more States). Each sector is allotted to one or more Task forces to conduct relief operations. Each sector may put up a number of evacuation camps and relief centres. Each relief centre may provide the following essential relief services.

Rescue – Team of Boats, Helicopters operating from boat points/landing sites.

Reliable communication – Radio, telegraph, telephone etc.

Medical assistance – Set up medical camps for evacuees, injured, provide life saving drugs, immunisation against epidemics.

Emergency Supplies – Rations, emergency clothing, blankets, medicines etc.

Rehabilitation – this includes errecting shelters/tents, clearing of roads, debris, fallen trees, running temporary schools for children.

The above operations are more or less common in case of cyclones, floods, earthquakes etc. Coordination between Army and Civil authorities is very essential. This begins with the top level and reaches down to jawans and village Sarpanch/ voluntary organisation members involved in the operation.

Army Medical Service **:** This varies from the type of disaster. In case of major accident (like Railway disaster, earthquake) a large number of concerns to save the lives and limbs. Special arrangements are required by the medical authorities to deal with the contingency cases. Medical contingent unit includes Surgeon, Dental officer, JCOs and Medical operators, ambulance vehicles.

Command and Control **:** Disaster management requires a firm leadership with quick decision ability without any hesitation and loosing nerve. The command officer will be away from taking care of patients. There will be an administrative officer for disaster relief. Errect field hospitals with mobile X-ray, laboratory. Laboratory facility includes dental chair. A mobile army medical team go round the affected villages, attend the patients, cases requiring hospital admission, radiological investigation would be shifted or referred to Field Surgical Centre immediately. In case of inundation/ flooding, preventive vaccination (like cholera) be given to prevent any outbreak of epidemic. It will be advisable that all ill-equipped civil Rural Medical Officers be attached to army medical contingency to help them wherever possible or Civil Health Officers run parallel treatment where army cannot undertake. Political, civil, national, international leaders may be advised to postpone their visits to the affected area to avoid inconvenience to the affected people, or the dignitories themselves.

Allotment of Tasks **:** A task force may be grouped as Functional or Composite. For example for bund repair the task force will have engineering regiment grouped with supporting elements of signals, Infantry and Administrative services. Medical task force is another example. A composite task force is a suitable mix of such units and act as a unit HQ and provide a number of relief teams. Each team may operate one or more mobile detachments in boats or helicopters.

Army troops may be asked to provide any or all the relief services. Navy may be called for transportation of troops, relief stores upto a safe anchorage. Boats and helicopters operate to ferry personnel and supplies as far inland as possible, to establish radio communications, providing divers or under water teams, for sea rescue of survivors.

7.1 Role of Air Force in Disaster Management

Air Force may be asked to make :

(i) An aerial survey for disaster assessment or visual and photographic reconnaissance,

(ii) Air landing or dropping of relief supplies (food, water etc.), personal and task teams,

(iii) Aerial evacuation of marooned people or entrapped in fire in multistoried building,

(iv) To supplement long distance communication facilities,

(v) Air lift of relief material and personnel to the nearest Air-HQ.

IAF provides assistance mainly with helicopters and fixed wing aircraft which have inbuilt flexibility suited for quick response. IAF will be asked to provide assistance to civil authorities in natural disasters like cyclone, flood, earthquake relief work.

IAF helicopters are capable of performing many roles, tasks, relief and mercy missions. IAF is most useful to rescue people trapped in snowclad Himalayan heights, trapped people in a cable car, fire in sky scrapers (multi storied buildings), flood marooned people, earthquake victims who are totally cut-off from rest of the world. IAF has light helicopters (Chetak) medium lift MI-8, MI-17 and high lift MI-26 helicopters.

India has five Air Force regions. HQ Central Air Command, based at Allahabad is responsible for providing relief to UP, MP, Bihar, Chattisgarh, Jharkhand, Maharastra, Andaman and Nicobar Islands. Eastern Air command located at Shillong responsible to all States east of Bihar. HQ Training Command based at Bangalore, responsible for Andhra Pradesh, Tamilnadu, Kerala, and Karnataka. HQ Western Command based at Delhi, responsible for Jamuu and Kashmir, Punjab, Haryana, Himachal Pradesh, Uttaranchal, Chandigarh, Delhi. South Western Air Command located at Jodhpur, responsible for Rajasthan, Gujarat, Saurastra and Kutch.

Helicopters for VIPs **:** This has to be cleared by the Ministry of Defence, then at Air HQs. DD (VIP) cell processes these demands. Operating units are informed through concerned HQ Command and Controlling Stations.

Helicopter lift for Relief**:** For disaster relief the requirements can be addressed to AOC/Station Commander, who will launch the helicopter and inform command HQ for regularisation. It would be better to contact Commander HQ and Chief Operations Officer or Station Commander/AOC of the operating base.

GIS (Geographical Information System) : For effective quick helicopter/plane service, accurate information of location, namely Latitude, Longitude of the place, District, Mandal name, nearest prominant town and other land marks like Railway station are essential.

Some features of Helicopters

MI-8 is a 12 ton medium lift helicopter. It can carry a load of 3 tons or it can accomodate about 24 passengers or 12 stretchers with lying cas. It's cruise speed varies 210 kmph to 420 kmph. It requires landing ground size 75 m × 35 m at sea level. There should not be any tall building or tree in the vicinity of the helipad. Chetak is a light helicopter, which can carry load upto 300 kg or upto 4 passengers or two stretchers with lying cas. Its cruise speed is about 160 kmph. It requires a landing ground size 25 m × 15 m with clear direction for take-off and approach into wind.

7.2 Role of Medical and Health Department in Cyclone Disaster Management

In disaster mitigation health aspects mainly include :

(i) First Aid to the injured,

(ii) Treatment to the casualities,

(iii) Postmortem (autopsies), burial/creamation of the dead,

(iv) Disposal of dead livestock,

(v) Providing medical facilities (treatment to the injured, ailing and fting to the medical camps if required),

(vi) Maintaining the records of the dead people in the disaster,

(vii) Providing safe drinking water, (chlorinated or bleached water),

(viii) Disinfection of the polluted surroundings (with phenyl, lime/bleaching powder).

In disaster management, all government agencies including Medical and Health Departments should coordinate vertically through the departmental structures and horizontally through coordination committees by way of periodical meetings.

The responsibility of District Medical Officer is to constitute Health teams associating with one or two medical officers for Every Public Health Centre (PHC). Medical teams with the staff and medicines should proceed to Mandal HQs. As soon as the cyclone warning received, the District Medical Health Officer should assess and send sufficient medicines, medical accessories to each PHC.

Preparedness Plan at District level **:** Identification of vulnerable villages prone to cyclones, floods under each PHC. A medical team should consist of one male and one female multipurpose health assistant, one medical supervisor. District Medical Health Officer should discuss with the District Collector and seek his approval of arrangement (men and material). He should procure adequate essential medicines, equipment, stock them and arrange to send them to the pre assigned places (PHCs). He should issue specific instructions to Dy. Civil Surgeons of identified Government Hospitals, which are to be used as referral hospitals, to cooperate with PHC in cyclone prone areas.

Preparedness plan at PHC level **:** Health supervisors at PHC should prepare a list of cyclone/flood prone villages with GIS (Geographical Information System) of water resources, cyclone shelters and population size. Responsibilities be assigned to the Health Supervisor and his health team to take charge of specific villages for implementing Medical Relief measures in those villages during cyclone. It is the responsibility of Health Supervisor to store adequate drugs, disinfectants, chlorination tablets etc. He should maintain buffor stock of essential drugs at PHC and should inspect cyclone shelters, find the amenities available and supply essential medicines and First Aid Kit.

At PHC level para-medical teams, staff, village health guides, councillors, village officers etc., be trained to meet the emergency medical services demands during cyclone. Medical Officer should conduct special training to combat cholera to the medical teams, district Health Educator and paramedical assistants at each PHC.

Disaster Mitigation activities during and Post cyclone period at District / Divisional level : District collector communicates the cyclone warnings to the Divisional Officers and immediately call District level Committee meeting. Under the supervision and control of District Medical Health Officer, medical teams would be sent to Mandals with adequate medicines and depute to move to the cyclone affected areas.

The responsibilities of Divisional Officer of Medical and Health services are :

Daily inspection of cyclone affected areas, coordinate with other Divisional cyclone, flood control officers particularly Revenue and Police, procure boats, motor launches, pump sets for bailing out of stagnant water, collect daily reports from PHCs, regulation of relief activities at PHC level including diversion of vehicles and manpower where required.

At PHC Level : The responsibility of Medical Officer (Family Welfare) to supervise and organise the work. Medical officer (Regular) with the help of Health supervisor should visit and survey at least half the area covered by PHC and the other half to be covered by Medical Officer (child health welfare) with the help of Block Extension Educator. Field level assistance would be provided by multipurpose health supervisor, multipurpose worker, village health guide and voluntary organisations.

The activities of Medical Officer at PHC accompanied by health supervisor, should visit the affected villages, assess damages and supervise the PHC staff activities. He should visit cyclone shelters, relief camps, arrange First aid, medical aid, referral services and similar arrangements. Collect daily activity reports from para-medical teams (incharge of cluster villages), consolidate and submit to the Divisional Officer daily. He should coordinate and cooperate with block level cyclone relief officers.

Post Cyclone activities : After stabilization and rehabilitation work, Medical and Health Department should continue its work for a prescribed number of days independently. District Health Educator should provide field publicity and Health education through mass media. He should tour the affected areas and address the people with film projections, pamphlets on hygiene and personal health care against water borne diseases and the likely epidemics. Pasting of door slips may also be undertaken. At PHC level and Divisional level the activities performed during the cyclone period would be continued for specific period. At village level Public Health Services are continued. Village level health workers should undertake antimalarial operations.

7.3 National Disaster Response Force (NDRF)

Disaster Management Act (2005) was passed by both houses of parliament and secured the assent of the President of India on 23rd December 2005. Under this act, the National Disaster Management Authority (NDMA) was created, under the chairmanship of Hon'ble Prime Minister of India as a Apex body for Disaster Management in the country, similarly State, Union territories disaster Management Authorities are chaired by the respective Chief ministers/Lt Governors as the case may be. The Act provides a paradigm shift from the erstwhile response-centric syndrome to a pro-active, holistic and integrated management of disasters with emphasis on prevention, preparedness and mitigation, which are aimed at conserving developmental gains, minimizing losses to lives, properties and livelihood. The Act mandates the creation of the National Disaster Response Force (NDRF) for specialized response and the National Institute of Disaster Management (NIDM) for institutional capacity development.

NDRF is a specilised response to any disaster situation. The general superintendence, direction and control of this force has been vested in the National Disaster Management Authority. At present NDRF has eight battalions, of which seven are located at Guwahati, Kolkata, Mundali (Bhubaneshwar), Arakonam (Chennai), Talegoan (Pune), Gandhinagar (Gujarat) and Chandigarh. This force has specially chosen personnel from Central Para Military Forces, who have the high skill training and the state-of-the art equipment. The personnel are specially trained in (i) collapsed structure search and rescue, (ii) water rescue and diving, (iii) Medical First Response, (iv) Heli-slithering (Helicopter based resene operations) and (v) Chemical, Biological, Radiological and Nuclear (CBRN). All the eight battalions are equipped and trained for all natural disasters. Four of these battalions are specially trained for CBRN emergencies. NDRF is to be trained to meet the above situation at BARC (Bhaba Atomic Research Centre), Mumbai, DRDE (Defence Research Development Establishment), Gwalior, and CME (College of Military Engineering), Pune. NDRF is a multidisplinary, multi-skilled, hi-tech force for all types of disasters capable of insertion by land, air and sea. The NDRF personnel are being trained for heli-insertion in impact areas with the help of IAF (Indian Air Force). The institutions and infrastructure of NDRF battalion would be available to impart training in after response to the state police force and other stakeholders. NDRF units shall maintain liaison with state administration and shall be available to them proactively in the event of any serious disaster contingence developing. In any disaster situation the first responder is community consequently community capacity building, public awareness is very important towards saving life and property. NDRF is being trained and equipped to build community capacity, public awareness programme (particularly for the vulnerable groups).

In any natural or man-made disasters/situations the state police personnel are the first responders and hence they should be trained in the state-of-the-art equipment. It is envisaged to train at least one battalion equivalent of some Armed Police battalions in each State and named State Disaster Response Force (SDRF) on the lines of NDRF. It is known that Centre provides 10% of the calamity relief fund to the States, which amount is suggested to utilize for procuring specialist equipment. State police personnel should be familiarised with the basics of Disaster Management and setup Disaster Management training facilities in their respective Police Training Colleges. A basic and inservice courses of Disaster Management for all ranks of police personnel may be included.

Fire Services, Civil Defence Services are primarily responsible to respond to any major disaster/contingency situation these personnel should be trained the basics of Disaster Management. Civil Defence is a community based voluntary organisation as such will play an important role in Community Capacity Building and response at the grass root level (District, Mandal, and even at village level).

For the success of both natural and man-made disaster mitigation, response it is necessary to provide on the similar lines of NDRF training and equip agencies like Police, Civil Defence, Home guards, Fire Services and youth organisations like NCC, NSS, NYKS to play complementary role as force multiplier in Disaster Response towards building disaster resilence in the country.

7.4 Role of Remote Sensing in Disaster Management

The process of observing an object with the aid of electromagnetic spectra (band of radiation wavelengths) that human eye cannot see may be called remote sensing. In meteorology this term is used for observing meteorological parameters with radiometers on board satellites. Thus remote sensing is the measurement of returned or back radiation from the earth atmosphere system (which is achieved by radiometers).

Satellite based radiation measurements are found to be useful in infering ground surface/atmosphere features. We know that natural disasters are caused by phenomena of severe weather events, earthquakes, volcanoes, landslides, avalanches, floods and droughts. All these phenomena are detected by satellite imageries. Satellite remote sensing of severe natural events aid in detecting, tracking of the phenomena and lends support in disaster management. The configuration of satellite network in use is shown in Fig 7.1.

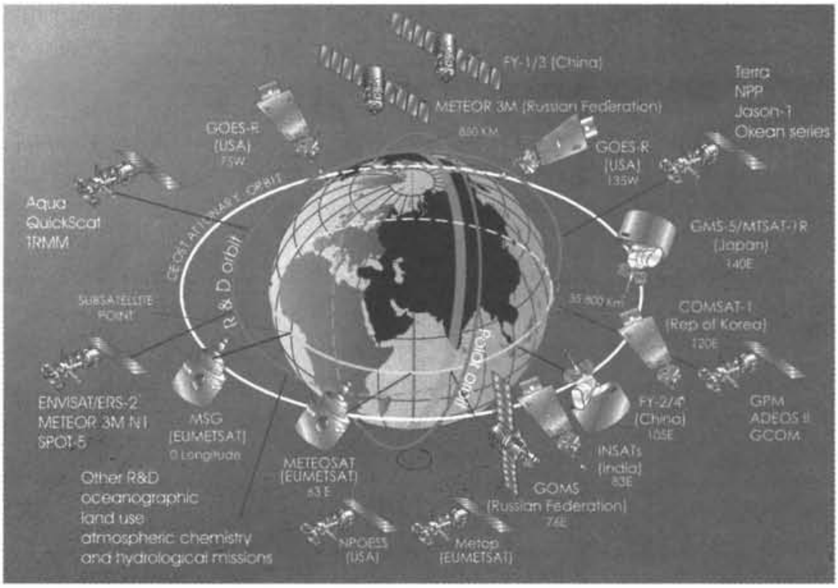


Fig. 7.1 Satellites.

Satellite based data are useful in:

(i) Detection of severe events,

(ii) Earth observation,

(iii) Delivery of warnings directly to the people of the affected area,

(iv) Data relay and communication capabilities.

Satellite imageries are useful in detection and monitoring of cyclones over seas particularly when they are beyond the range of radars of coastal areas. The imageries are useful in detection of cyclone Eye, wall cloud region, line squalls, estimating cloud-top temperatures, cloud motion winds (CMW), vertical temperature profiles (VTPR), humidity profiles, sea surface temperature (SST), Tropical easterly jet (TEJ). Satellite imageries are received either from polar orbitting satellite or geostationary satellites. Earth resources satellites such as IRS, LANDSAT, NOAA, GOES, INSAT, KALPANA-1 are used for infering ground features cyclone impact on coastal areas. Thermal measurement data are used for detection of flood inundation. OLR (outgoing longwave radiation) data may be used for detect heavy to very heavy rainfall zones. Thus satellite data is useful in flood mapping, flood monitoring, cyclone impact on coastal areas and hence useful in cyclone, flood mitigation work.

It is to be noted that till now it has not been possible to prepare a synoptic chart with remote sensing (satellite) data, but it proved to be a boon in assessing weather over oceans, mountains, dense forests and inaccessible areas. Large weather systems like tropical cyclones, Tornadoes, mid-latitude cyclones, Anticyclones, Monsoon circulation etc., are clearly identified with satellite images. A space-borne precipitation radar can make direct measurements of rainfall over the sea areas. Vertical profiles of temperature and humidity are made globally with sounders on NOAA and GOES satellites but the retrieval is a very complex process over hot and humid tropics. The capabilities of weather satellites to observe and monitor weather systems depend on factors like number, type and resolution of spectral channels of radiometers, the period of satellite orbit, height of the satellite above the earth, the inclination of the orbit which delineates the geographical coverage.

Satellite Imageries

The photographs taken by the satellites are called imageries. They are basically of two types.

(i) visual (visible band) which are obtained by TV cameras and

(ii) Infrared (IR band) which are obtained by scanning radiometers.

Visual channel imageries look black and white and represent what we could see with our eyes from a satellite. This imagery is a measure of earth's (or surface) albedo. IR-channel imagery represents the temperatures of the surface and temperature contrasts (warm or cold, clouds at different heights).

Visual imageries measure radiation in the spectrum range of 0.4 to 0.7 μm. These imageries are possible only from the sunlit portion of the earths surface and clouds. IR imageries measure radiation (by scanning radiometer) in the spectrum band of 8-13 μm. This represents long wave radiation emitted by the earth, atmosphere (cloud, fog etc), water bodies (round the clock).

Atmosphere is virtually transparent to incoming solar radiation (short wave radiation) but readily absorbs terrestrial (long wave or IR) radiation. Atmosphere is thus selectively absorbs and emits radiation and hence called selective absorber. The main atmospheric gases absorption bands are watervapour at 6.7 μm, CO_2 (Carbon-dioxide) at 15 μm and O_3 (ozone) at 9.6 μm. There are other minor absorption bands pertaining to Methane, Nitrous oxide and other gases.

Water vapour channel imagery measures emitted radiation in the watervapour (WV) band centred at 6.7 μm (5.7 to 7.1 μm) round the clock. WV imageries have different appearances in VIS and IR imageries. These imageries show the moisture boundaries in the form of plumes or tongues or streams of moisture. These pictures provide a clue of zones of very heavy precipitation and movement of tropical cyclones.

Grayscale **:** In satellite images, the brightness of a pixel is assigned a value on a scale (256 points) ranging from 0 to 255. This is called gray scale. The scale '0' stands for pure black (higher temperature) and the number 255 stands for pure white (ice, snow etc., lower temperature).

IRS, LANDSAT, SPOT satellite data are effectively used in monitoring Meteorological, Hydrological elements such as stream flow, water storage levels etc. By way of Satellite based multi-stage monitoring data standing crop position, crops sown area and other agricultural indicators may be estimated.

Satellite imagery shows ITCZ as a series of cloud clusters interspersed with clear areas. Thunderstorms appear as bright white in satellite imagery in all channels (VIS, IR, WV bands). Dust storms can be detected in VIS images, MODIS (Moderate Resolution Imaging Spectro- Radiometer) images give clear view of dust raised if there is a satellite pass at the time of the storm has occured. However Dust storms cannot be located in IR images due to lack of temperature difference between the surface and the dust layer.

Tornadoes can be located by continuous monitoring the satellite pictures. Mountain waves may be identified as a series of gray or white cloud bands with intervening clear areas running parallel to the mountains. Mountain waves are hazardous for aviation. Onset of Monsoon can be identified from the satellite VIS, IR and WV imageries. WV imageries clearly indicate the boundary of onset of monsoon over Kerala. Oceansat-1, MSMR (Multi Spectral Microwave Radiometer) clearly indicate northward movement of monsoon with the area of maximum moisture and windspeed movement northwards.

Satellite VIS imagery indicates the low level cloud motion wind which clearly depicts Low Level Jet along the East African coast associated with the Indian SouthWest monsoon.

Tropical Easterly Jet will be more clear in IR images than in VIS images due to associated cumuliform clouds. Extended cirriform cloud bands parallel to jet axis is seen.

Low OLR (Outgoing Longwave Radiation) indicates cold surface temperatures or presence of clouds or precipitation.

High OLR indicates warm surface temperatures and absence of convection or clear sky or major deserts, oceanic Subtropical Highs.

INSAT-2A and 2B were fitted with a Search and Rescue Transponders (SRT) operating in 406 MHz band. This transponder picks up any distress signal beacon operating in this band and thus alerts. Fishing vessels over sea should carry 406 MHZ contingency beacons, and in case of any danger they can send distress messages, which will be picked up by the Control Mission Centre and arrange Rescue Power boats. This system is compatible with international COSPAS and SARSAT (Search and Rescue Satellite) system.

Meteorological satellites are useful in effictive monitoring (on line monitoring) stream flow, water storage levels etc. By way of multi stage monitoring the satellite data is useful in knowing the position of standing crops, crops sown area and other agricultural indicators. In other words the data is useful in combating drought. Similarly satellite imageries are useful in water resources management, agriculture, land resources, fodder resources, integrated natural resources, socio-economic and demographic data base. Based on these inputs soil, land use, forest cover mapping, integrated water recharge mechanism, types of crop grown, vegetation cover, snow cover, waste land mapping can be prepared. Based on these outputs of remote sensing it can be effectively planned to contain adverse impacts of drought by way of upgradation of land, afforestation, soil erosion arrrest by fodder growth, wasteland reclamation. Through information system of high imagery Cartosat-2 satellite (2007), ISRO plans to map 137 major cities in India, then extend to 5000 towns and eventually to prepare cartographic map of the entire country (India). The cartographic maps will be useful for urban development planning. Cartosat-2 satellite can beam imageries required for infrastructure development, disaster management and watershed development. The resolution of images in one meter, but intend to fine tune to half-meter resolution. The life of Cartosat-2 is upto 2012 AD (i.e., five years).

IMD broadcasts (three hourly) on world space "Asia Star" satellite, the INSAT, Kalpana imageries in visible, IR and water-vapour bands. IMD is receiving and processing satellite based meteorological data from Kalpana-1, INSAT-3A and NOAA series of satellites.

Kalpana-1 was launched on 12 September 2002, located in equatorial (geostationary) orbit at long 74^0 E. INSAT-3A was launched on 10 April 2003, located in the equatorial orbit at long 93.5^0E.

There are more than 100 AWS (Automatic Weather Stations) in India. An Earth station was established at Pune for reception and processing the data. Hourly meteorological data from all AWS received at Pune Earth Station via satellite. A network of 500 Automatic Raingauge Stations are being installed.

INSAT Meteorological Data Processing System (IMDPS)

IMDPS is receiving and processing Met (meteorological) data from AWS. An AWS station records, stores hourly data and transmits the same to Kalpana-1 through INSAT DATA RELAY TRANSPONDER (DRT). Cloud imageries are supplied and also transmitted through INSAT-3C satellite to various forecasting offices of IMD and also to other users through Meteorological Data Dissemination (MDD) scheme.

IMDPS generates cloud imageries and thereby derives the following Met products.

1. *Cloud Motion Winds (CMW)*–using three hourly consecutive half hourly images from the operational Kalpana-1 satellite at 0000 hrs UTC and 0730 hrs UTC and sends to users through GTS, IMD website.

2. *Sea Surface Temperatures (SSTs)* are computed from INSAT-IR imagery from 0000 and 1200 hrs UTC. SSTs are also computed from NOAA satellites using multichannel algorithem.
3. *Outgoing Longwave Radiation (OLR) and quantitative precipitation* estimates at $1.0^0 \times 1.0^0$ grid is computed from INSAT -IR data on three hourly/Daily/ weekly/ monthly basis.
4. *Atmospheric soundings* are generated from US Polar Orbitting (satellite) NOAA series. The soundings include temperature and humidity profiles and standard level geopotentials.
5. *Meteosat-5 satellite* is located in equatorial orbit at 63^0 E and covers India and adjoining area.

Primary Data Utilisation Centre was installed in 2000 for reception of data from Meteosat-5. This data is received in VIS, IR and WV channels at 30 minute intervals.

7.5 Role of Broadcast, Educational Media in Disaster Management

Media plays an important role in disaster management particularly in preparedness, warning and mitigation. For very effective disaster management community must be educated about the natural hazards, preparedness and make them aware of the dangers associated with each hazard and implicitly adhere to dos and dont's during disasters. Public education and awareness decimates the impact of any disaster. Education begins at schools and continues to university. However but these are lacking. However the education of natural disasters were introduced recently (2006-07) at the insistence of judiciary. As regards mass awareness it depends on media, particularly news papers, Radio and TV broadcasts. All India Radio (AIR) and Doordarshan (DD) are the main National Broad casting system of Governmnet of India and these media is responsible for immediate broadcasting of official warnings, dos and donts in any emergency situations. In all events media should shun from broadcasting hearsay. Private telecasting channels also have the same responsibility in telecasting warnings and gain mass credibility by focusing the attention of Government in disaster relief and rehabilitation work. This was amply illustrated during recent (26 July 2005) Mumbai phenomenal rain deluge scenes telecast. Newspaper media (daily, weekly, fortnightly etc.,) also play important role in educating people about natural disasters, preparedness, do's and dont's during natural calamities. Though Government responds to the ill effects of natural disasters but in many cases the urgency of relief requirement is brought to the notice of the Government and NGOs by media broadcast, news publication during or just after the calamity.

The Director General of Information and Broadcasting and Public Relations Officer should arrange natural hazard programmes in connection with the celebrations of Science Day, World Water Day, World Health Day, World

Meteorological Day etc. These occasions may be used to broadcast on AIR, TV-channels relating to natural hazards particularly about Cyclones, Earthquakes, Floods, Droughts, Tsunamis, Avalanches, landslides, Heatwaves, Coldwaves, Local Severe Thunderstorms, Tornadoes etc., to focus the attention of the people about the hazards associated with these events and make them aware how to face them or prevent their ill effects. Expert Meteorologists, Hydrologists, Seismologists and other reputed scientists, teachers be invited to deliver talks on natural disasters and the same may be published/propagated through newspapers, Radio, T.V broadcasts to educate the people on the lines of propagation / publicity of Family planning, Adult Education, AIDS, Polio eradication etc. Such educative talks may be frequently arranged just before the commencement of the season (for Monsoons, thunderstorms, hailstorms, Tornadoes, heatwaves during February, March, April, May, for cyclones during Feb, March and August, September etc). Posters depicting natural hazards and the precautions to be taken by the affected people be exhibited at prominent places like Railway/Bus stations, Airports, Market yards, Cinema houses, large play grounds, schools. colleges, libraries, stadiums, Highways etc. Publicity department should make films on natural disasters and arrange film shows through voluntary organisations, educational institutions. Distribute the hand outs of Dos and Dont's during natural disasters. Education department should encourage the teachers for conducting essay writing competitions, and teachers be encouraged to become local Disaster Management committee members.

Role of AIR **:** It is the primary responsibility of AIR to receive warning messages from IMD and broadcast them immediately in the local language. AIR should obtain the latest warning bulletins and broadcast them every 15 to 30 minutes interrupting in normal broadcast. This should continue till dewarning is issued (in case of cyclone). During disaster phase AIR should broadcast evacuation messages in local language issued by the District Collector of the concerned area. Warning messages should not be broadcast soon after dewarning issued. Similarly old warning messages should not be broadcast. Efforts be made to obtain latest warnings from IMD and broadcast it, otherwise the credibility of forecast may be lost. It will be more effective if the latest warning are directly broadcast through mouth of local incharge or Duty Officer of IMD in the local language or which may be followed by translation in local language.

Role of DoorDarshan **:** DD is the Government of India's National TV broadcasting organisation. It operates on similar lines of AIR. During emergency situations like cyclones, floods IMD warning bulletins be telecast as news bulletins. DD instructed to broadcast official emergency bulletin news and pictures at anytime of day or night. Where possible DD arrange to take snapshots of actual emergency situations and project them in telecast. Due importance be given to telecast the authoritative warnings directly from the mouth of local IMD officer incharge or Duty Officer and not the political leaders and research institute staff who have no responsibility except projecting individuals. It has been the past experience that in emergency situations such individual projections cause more harm than benifit. Under preparedness plan both AIR and DD should invite experience IMD officers (serving or retired) to deliver talks on severe weather events with appropriate past data and pictures.

Do's and Don'ts during cyclones **:** As soon as cyclone alert issued by IMD the following precautions are to observed.

1. Check houses and make necessary repairs of doors and windows. Secure loose tiles by cementing. Zinc and asbestos sheets be fastened firmly lest they will be blown off by gales/strong winds.
2. Check the area around the house. Remove dead and fallen trees. Anchor removable objects like lumber piles, loose bricks, garbage cans, sign boards etc.
3. Keep ready some sturdy wooden boards to block / cover the glass windows or nail them down with wooden strips from inside.
4. Keep ready hurricane lanters filled with kerosene, candles and good match boxes, tarch lights with cells and few extra dry cells.
5. Demolish delapidated or condemned unsafe houses.
6. Keep your radio/transistor sets in working condition along with batteries and some extra cells. Be listening to the cyclone warnings and advisories to act.
7. Keep ready First Aid Kit. Secure personal belongings, jewellary, cash, documents of property, bank account books, identity/ ration cards, certificates etc.

Precautions to be taken during Cyclones or Imminent

1. Do not remain on the top open floors. People living in multi-storied buildings are advised to come down and shelter on first/ground floor. All doors and windows and openings be firmly secured and barricated.
2. Store extra drinking water in covered vessels.
3. Stock food grains and other essential consumer goods both for children and adults sufficient for a week, particularly those foods which do not require cooking like beaten rice, bread, tosh etc.
4. Keep within easy reach the items, candles, hurricane lanterns filled with kerosene, match boxes. Stock kerosene or LPG gas cylinder, Torches with dry cells.
5. Don't take shelter near or under tall trees, old trees, old houses, unsafe weak structures. Electrical discharges in thunderstorms generally take place over tall trees.

6. Do not move outside when cyclone hit the coast and passing over the area or nearby. "Calm before a storm", when the cyclone moves over your area or closeby, surface wind becomes light or calm, sky appears temporarily clear or mainly clear. Do not move during such storm period, because shortly after that strong cyclone winds from the opposite direction (as compared to earlier direction) may invade your area as a surprise and cause havoc.
7. Do not believe in false rumours. Keep listening to the authentic AIR/DD broadcasts of weather warnings. Convey these authentic news to others.
8. When cyclone warnings are issued, evacuate the cattle to safer places from low-lying areas in good time, else you may be caught or stuck up in the low-lying area on the way.
9. Keep boats, crafts securely tied in safer places.
10. Keep secure house implements furniture, kerosene tins, plastic barrels etc., otherwise they act as missiles in gales and hurricane winds.
11. If your house is old, insecure to cylone or located in low lying flooding area, move to safer elevated area to cyclone shelters, temples, schools or pucca buildings.
12. During all stages of cyclone bad weather, remain clam and poised. Encourage others to remain composed. This will help the management both at cyclone shelters and in the affected area.
13. Keep off from electric broken wires and power lines. To save a person struck with a live electric wire use only dry long wooden stick to push the wire off. Do not use metal rods or wet stick. If you find any electric wire hanging, immediately inform to eletricity department officials to remove and warn other people to be cautious.
14. Be alert while walking or driving on road or on road under water. Road may be eroded or washed off. Be away from the vicinity of poles, trees, culverts or bridges. It is possible that a tree and its braches may fall or move over.

The following rules may be observed when advised Evacuation

1. Proceed to the proper cyclone shelter or evacuation point indicated to your area.
2. Do not worry about your house and belongings. The evacuated area will be patrolled by police to prevent thefts.
3. While at cyclone shelter follow the instructions of in-charge or volunteers.
4. Remain in cyclone shelter till the in-charge asked you to go home.
5. Keep yourself cool and calm at all times in evacuation camp and follow the instruction of in-charge, there is no personal danger involved. Observe all sanitory precautions like clean hands, drink boiled or chlorinated water. Keep clean surroundings.

The Safety Precautions to be taken at Ports

When the storm signals are hoisted at ports, the following precautions are to be observed.

1. Lower the masts of all vessels, they may be firmly tied in a sheltered water.
2. Electrical installations in port (such as sub-station) should be barricated its doors, windows and other openings.
3. Switch off the power to avoid electrical short circuting and casualities due to falling electrical poles and exposure to live wires. Strengthen the supports to the transmission towers and transformers.
4. Lower the booms of all cranes and keep them on ground.
5. Secure firmly the doors, windows and other openings of all godowns by barricating.

Chapter - 8

Floods

Introduction

In the history of the earth, Rivers are much older than Man and they have been continuously working to level all the land. Rocks are continuously eroded by weather and water into smaller and smaller fragments and finally reaching the sea as sand, clay, silt, forming deltas at the river mouths. When river moves down from the mountain ranges to the plains it becomes an alluvial river. The bed of the river consists of boulders, gravel, shingle and sand. Rivers tend to be straight, sluggish with shallow bed and shifting. The beds of alluvial rivers may be stationary or aggrading because of obstructions or degrading. In general the course of a river system is dependent on the structural patterns of the rocks in the area.

River water contains a number of inorganic salts due to weathering of rocks and soil. The presence of carbonate or calcium in water indicates the presence of abundance of limestone and Vegetation. The presence of sulphates and chlorides in the water indicates pollution. The total soluble salt content of a river water is generally low and increases slightly during lean flow. The Chambal and the Yamuna rivers show considerable variation of salt content during the year with rise in lean flow, while the Kaveri river does not show any variation in salt content during the year because of the influence of both Southwest and Northeast monsoons. Rivers flowing through black cotton soils (Narmada, Tapi, Chembal, Godavari, upper Krishna) have higher soluble salt content than rivers flowing through each of alluvial, laterite and red soils (Ganga, Brahmaputra, Kosi, Goundak, Kaveri). The Alkalinity of river water changes pH 7.6 to pH 8.9, during lean period being higher.

Water is a precious gift of nature to all living beings. In Sanskrit water is called Amrita, meaning it has no death. Water is required in a number of human activities like drinking, irrigation, industries, power generation, navigation and recreation. Water contains three kinds of impurities: 1. Physical, 2. Chemical and 3. Microbiological. Physical impurities are colours, taste, odour and sediments. Chemical impurities are dissolved minerals and organic mater. Microbial impurities consists of water borne micro organisms. Any of these impurities could be harmful or undesirable depending on the nature and amount of impurity. According to WHO recommendation every man requires five liters of water for drinking, cooking and domestic activity per day.

The Ministry of Water Resources plays an important role in the utilisation, distribution and management of water resources in the country. National Water Policy (NWP) lays emphasis on integrated water resources development and management for optimal and sustainable utilisation of available surface and ground water. Demand and conservation of water have been recognised in the policy making. Among diverse uses of water first priority has been given to drinking water allocation.

The volume of global water is estimated to be 1455×10^6 km^3 (cubic kilometers), about 1370×10^6 km^3 (94% of global water) is estimated to be in the oceans and seas (which occupies 70.8% of global surface area). While Global fresh water estimated to be 85×10^6 km^3 (or 6% of the global water) which accounts waters of rivers 1200 km^3 (or 0.0001% of global water), lakes 750×10^3 km^3 (or 0.05% of global water), glaciers 2.4×10^6 km^3 (or 4.11% of global water). Water in the atmosphere is 14×10^3 km^3 or 0.001% of global water. Water in the ocean and seas is not usable by man without extensive treatment. Water supplies available to man are (i) Ground water (wells, springs) and (ii) surface water (lakes, rivers, streams, reservoirs).

The prosperity of any country depends on its water resources and their judicious use. If rivers are properly controlled they yield better prosperity than any gold mine. Controlled rivers boost the cropped area by irrigation, helps in generation of power, provides cheap transportation and in reduction of flood damages. The rivers wealth is derived through rivers, dams, tunnels, canal system and power houses. Irrigation is the largest climatic change devised by man for his welfare. This helped him for his dependable food, to produce more yield from crops grown, enabled him to raise two or more crops in a year. Vegetation accounts 50% of all water consumed and irrigation has a major share. At present cities and industries are also claiming equal share of consumption of water. The aim of irrigation is to provide the cultivated plants with water that required at different stages of plants growth. In Africa, the Niger River basin is the most fertile area. By controlling the flood waters of the Niger, rice and maize can be grown almost continuously. This is an example of waking sleeping lands. Cultivation of 20% of unused land by irrigation, it is possible to increase the world crop output by 45%. History suggests that man helped to create many deserts over the globe. A large part of Rajasthan desert has been developed over the centuries through mismanagement of man.

8.1 Water Wealth of India

The land surface area of India is about 3.3×10^6 km^2 and has second largest arable land in the world (after United States). It has many fresh water resources, which include 12 major rivers with catchment area about 258×10^6 hectares (ha). The Indo-Gangetic plain which occupies about 6.5×10^5 km^2 and extends from northern Rajasthan desert to high rainfall zone of West Bengal. Annual rainfall depth varies from less than 100 mm to more than 4000 mm, that is arid to humid. Thus India is prone to both droughts and floods. Most part of the country gets major amount of rain during mansoon period, however parts of North India, North-east India gets rain due to Western Disturbances, while Tamilnadu and parts of South Coastal Andhra Pradesh, Rayalseema gets considerable rain during Northeast Monsoon period.

India has many fresh water resources of which total utilisable water resources assessed as 1123 BCM (Billion Cubic meters) 60% of the total. Surface water 690 BCM (about 37% of total) and ground water 433 BCM (about 23% of total). The percapita availability of water at national level has been reduced to 35% from about 5177 m^3 in 1951 to the estimated level of 1820 m^3 in 2001. This is attributed to population growth and variation of water availability in different river basins. With the development of irrigation through major, medium and minor irrigation projects, the irrigation potential increased from 22.6 million hectares in 1951 to about 98.84 Mha (about 4.4 times) at the end of the year 2004-05. According to 1988 CWC publication the average annual run-off over India is about 1880×10^9 m^3 (1880 BCM). Of this total 600 BCM (32%) is generated in Brahmaputra and Meghna (Barak) basins, about 500 BCM (27%) in the Ganga basin and the remaining 780 BCM (41%) accounts to the remaining basins (Godavari, Krishna, Mahanadi, Narmada, Tapi, Kaveri and other small rivers) which occupy about 56% of the country's land surface area. The surface water runoff is mostly seasonal. Most of the rivers carry about 80% of their annual flow during southwest monsoon (June to September) and 90% of their annual flow during June to November and very low flow during December to May. There is year to year large variation in rainfall both in time and space. For example the 32 year (1948-79) annual rainfall series of Narmada basin shows annual average flow 45 BCM and ranged 21 BCM to 76 BCM (47% to 169% of average).

The replenishable ground water resources in India excluding Brahmaputra and Meghna basins, is about 450 BCM, per year. According to National Water

Development Agency, India has plan to utilise about 660 BCM of water and can utilise another 222 BCM of water which will benefit 35 million hectare of land area, generate 40 million kw of power, provide perenial inland navigation and mitigate floods. Of this, water could be transferred from perenial sources to others by gravity flow in small reaches by about 120 million cubic meters (MCM). Monsoon flood water, which goes to the sea, should be conserved in storage reservoirs and can be used for irrigation, power generation etc. Peninsular river development envisages the diversion of surplus flows of the Mahanadi to the Godavari system and further transfer of surplus water to water shortage of Krishna, Pennar and Kaveri basins.

The second part is to construct storages and interlink small rivers flowing along the westcoast south of Tapi to north of Mumbai for supplies to Mumbai. Partial release of Narmada, Tapi waters to Saurashtra, Kutch areas.

Third part envisages interlinking of the southern tributaries of Yamuna, a dam on Yamuna at Panchanand and construction of small storages to benefit west MP and Bundelkhand region of UP.

The fourth part of the proposal is to divert a part of the west flowing rivers of kerala and karnataka to east of the Western Ghats.

8.2 Definition of Flood

When river water over tops or bursts its banks and comes in conflict with the activities of the man on flood plains it is called flood. See Fig. 8.1.

Fig. 8.1

Floods may be classified as :

Flash floods, River floods, Storm surge floods and man made floods.

Floods are assessed by river gauge heights, peak discharges and volume of flow. Of these gauge heights at fixed locations along the river are more realistic, since other parameters of flood are derived from it. Flood forecasting includes mapping of river system, its drainage basin, assessment of the runoff of rainfall or snow melt and the capacity of river channels to drain water from its basin area and time. Flood preparedness includes flood frequency analysis of various magnitudes with the help of past historical flood data, return period analysis of floods, probable maximum precipitation, probable maximum storm, storm transposition. Flood forcecasting models are based on anticident rainfall, real time rainfall, gauge heights and quantitative precipitation forecasts. Watershed management is necessary for hazard reduction in vulnerable areas prone to the incidence of cyclones, floods and droughts. Construction of contour bunds, percolation tanks, afforestation, pasture development, soil and moisture conservation are all include in preparedness measures. According to National Flood Commission report, India has about 40 million hectare area is prone to floods. About 20% of this area (8 million hectares) is incident to floods every year, of this 3.5 Mha is a cropped area. Annual human casualities due to floods is 1400 to 1450. Indo Gangetic–Brahmaputra plains are susceptible to floods every year. In general lower reaches of all river basins in India are flood prone areas.

Flood Plain stands for land adjoining to river channel which inundates during high floods. Flood levels are generally marked as Warning level, Danger level. Flood management aims at suitable mix of structure and non-structural measures for reducing flood damage potential. Since flood plain is fertile and suitable for agriculture and industries, the construction in these areas should take care of warning and Danger levels. Hospitals, water supplies, telephone exchange, schools, residential houses etc.,should be located above river danger level of that area or flood height correspond to one in hundred year frequency to 25 year frequency. Flood plain management is governed by flood frequency, population density, and property situated in the area. Flood frequency study provides land use planning with maximizing productivity and minimizing risk to life and property. It helps in design flood control structures and water use projects. Land use development decreases flood hazard risk, at the same time risk increases with the increase in population density. Flash flooding risk increases with the expansion of urbanization, particularly in areas where storm drainage is poor. Periodic review of land use pattern helps in minimizing flood hazard risk, simultaneously helps in combating drought. Preventive measures of coastal flooding may be achieved by construction of dykes, barrages, plantation belts, wind and wave breakers.

Factors of vulnerability to Floods

1. Low-lying areas
2. Flood zones
3. Lack of education about floods
4. Areas of maximum surface flow and minimum percolation into soil
5. Weak structures with shallow foundations.
6. Standing crops, livestock, food stocks in unprotected and open areas
7. Construction of structures with water soluble material

Factors that are Potential to Flood Damages

1. Depth of flood water and speed of water flow
2. Soil slope which contributes to speed of water flow and mud slides
3. Season – cyclone season, Active / Vigorous monsoon
4. Time occurence – after sunset more risk
5. Speed of onset of flood – Flash flood due to heavy / very heavy rain in steep mountainous areas, poor drainage rivulets, city streets.
6. Duration of flood and type of area affected–low lying areas with large duration makes the area cut-off, heavy inundation.

Flood Control Techniques

1. Construction of reservoirs for flood water storage
2. Fairly widespread canal system with free flow capacity or drainage
3. Sufficiently high pucca embankments toward off breaches in flood prone areas
4. Diversion of flood waters by interlinking canals
5. Flood zoning
6. Accurate timely forecast with dissemination of warnings
7. Local action committees with accessories
8. Afforestation, planting of trees either side of river embankment
9. Flood plain land use management or watershed management
10. Flood frequency analysis
11. Flood models – depends on collection, compilation of past recorded historical data, thematic mapping of river basin.

Thematic Mapping of River Basins

Collection of data pertaining to basin geomorphology, contour slopes (using toposheets), land use for various purposes (agriculture, forestry, industry etc.), land cover, rainfall (averages/ daily/ weekly/ monthly seasonal maps), river runoff (gauge data, discharge data), drainage canal network, dykes and barriers locations, types of soils, settlement locations, administrative boundaries (States, Districts, Mandals), transport network (railway lines, road lines, air routes, water routes etc.), power line network, reservoirs, minor irrigation tanks, percolation tanks, cropping patterns (dry, wet crops), basin probable maximum precipitation maps, probable maximum storms and flood frequency return period analysis.

Watershed Management

This includes district wise action plan using thematic information of land use, soils, hydromorphology, status of ground–surface water, land development, rainfall actual and departure from normal, basin slopes, socio-economic aspects for watershed management on 1 : 50000 scale be developed.

Advanced technologies are available for monitoring floods. This includes Multiple Satellite data from IRS series, Landsat, Radarsat, Kalpana, GOES. Data from these sources are useful in flood mapping, flood damage control/assessment, river configuration mapping, flood hazard zoning. IR, WV channel satellite data, OLR data, microwave data are useful, however VIS data is not useful during cloudy weather.

8.3 Role of Central Water Commission

CWC (Central Water Commission) a Central Government Agency attached to the Ministry of Water Resources is the premier technical organisation in the field of water Resources. It carries the responsibilities of initiating, coordinating and furthering the schemes for control, conservation and utilisation of water resources throughout the country in consultation with State Governement. Water utilisation may be for flood control, irrigation, navigation, water supply and hydropower generation. It undertakes the investigation, consultation and execution of such schemes.

CWC has a network of gauge and discharge measurement stations and surface water monitoring sites. The discharge and water levels are measured at the selected site stations transmitted through HF/VHF radio link. CWC has a network of Flood Forecasting stations and hydrometeorological stations in river basins of flood prone areas. CWC also has a network of raingauge stations. The data of these stations obtained on real time basis. CWC and IMD rainfall data and IMD weather forecast put together flood forecast and warnings are issued for major rivers and tributaries by CWC flood forecasting stations. The forecast issued upto 18 hours ahead.

CWC issues daily, weekly and fortnightly flood bulletins together with a flood forecasting appraisal report.

Floods are associated with tropical cyclones, extra tropical depression, Active / Vigorous monsoons, snow melting of mountain ranges. Historically the worst catastrophes were caused by river bursting their banks. The Yangtze River of

China has acquired notority in this respect, taking death toll in millions. During 1851-1866 (15 years) the estimated death toll was between 40 to 50 millions. Flood plains are tempting farmers because of its fertile soil for agriculture but at the same time it is potentially risky for human habitation and factories.

The river forecasts demand a close collaboration between meteorologists and hydrologists. The lead time of flood warning depends on meteorological weather forecasts, online rainfall amounts every three hours, river stage gauge data and time taken by a flood wave to travel downstream. For small rivers, tributaries even a single storm is enough to cause flash flood in a matter of hours, so also in urban low-lying areas where it matters even in minutes. It is therefore required a well prepared plan involving inhabitants and line departments. Longer scale preparedness plan definitely helps in bringing down its frequency and intensity of damage.

Dissemination of Forecasts

Flood forecast bulletins are disseminated within half-an-hour to one hour after formulation by Radio, Telephone, e-mail, Fax, messenger to concerned officials which include District Collectors, Revenue Divisional Officers, Mandal Revenue Officers. Inflow forecasts issued to irrigation and Command Area Development Department-Engineers-in-charge of several dam projects to help them decide on spilway releases. General Public is warned through broadcasts on AIR and DD telecast and other private channels.

Floods are caused mainly surface runoff of water, which is associated with cyclones, active/vigorous monsoon conditions, local severe thunderstorms, snow melt. We have studied about cyclones, now we shall learn briefly about monsoons and local severe thunderstorms.

8.4 Monsoons

The word monsoon is derived from the Arabic word mousam, meaning season. It connotes seasonal reversal of wind, relief from sweltbering heat and plenty of rainfall. The characteristic features of monsoon air mass is moist maritime and extends vertically to a depth of 3 to 9.5 km above sea level. From ancient times the economy of our country is dependent on agriculture, which in turn heavily dependent on monsoon rainfall. More than 80% of the annual rainfall occurs in monsoon period (June to September), which is a blessing of nature in this region due to its cyclic behaviour. Monsoon is an annual oscillation of atmosphere with great regularity. The description over land and sea areas differ. According to IMD convention, the strength of monsoon over sea and land areas is given below.

Over sea area

Description	Wind speed reported or estimated to be existing
Weak monsoon	upto 12 kt (23 kmph)
Moderate monsoon	13 to 22 kt (24-42 kmph)
Strong monsoon	23 to 32 kt (43-60 kmph)
Vigorous monsoon	33 kt or more (61 kmph or more)

Over land Area

Description	Rainfall compared with long period average called normal at a place or sub–division
Weak monsoon	RF less than half the normal
Normal monsoon	RF half to less than 1½ times the normal
Active monsoon	(i) RF 1½ to 4 times the normal
	(ii) RF in at least two stations should be 5 cm if the sub-division is along west coast and 3 cm if it is elsewhere in India.
	(iii) RF in that sub-division should be FWD or WD.
Vigorous monsoon	(i) RF more than 4 times the normal
	(ii) RF in at least two stations should be 8 cm if the sub-division is along west coast and 5 cm if it is elsewhere in India.
	(iii) RF in that sub-division should be FWD or WD.

Normal RF : It is the average RF of long period (morethan 30 years) of a station.

Isolated (one or two places) means RF over a sub-division is less than 25% of the stations of the sub-division reporting rainfall.

Scattered RF (at a few places) means 25 to 50% of the station of the sub-division reporting rainfall.

Fairly wide spread (FWD or at many places) stands for 50 to 75% of the stations of the sub-division reporting RF.

Widespread (WD or at most places) stands for 75 to 100% of the stations of the sub-division reporting RF.

A rainy day is defined when 24 hrs (0830 to 0830 hrs IST) is 2.5 mm or more.

Rainfall intensity in 24 hrs

RF	Description
0.1-2.4 mm	Very light rain
2.5-7.5 mm	Light rain
7.6-64.9 mm	Moderate rain
65.0-124.9 mm	Heavy rain
125.0 mm or more	Very heavy rain

The time and space variation of RF during monsoon is an inherent phenomena. Monsoon dynamics is viewed (like land and sea breeze circulation) as the cause of differential heating of vast land (Asian continent) on the north and the sea (Indian ocean) in the south. There is a great rhythm or cyclicity of onset and withdrawal of mansoon phenomena. The normal dates of onset of southwest mansoon and withdrawal are shown in Fig 8.2(a) & (b). The mansoon rainfall over India and its variation are shown in Figs. 8.3(a) & (b).

Monsoon rainfall over India varies from more than 800 cm to less thaan 40 cm. The coefficient of variation is 20% in Northeast India and Konkan to 60% (maximum 80%) in Rajasthan and south Tamilnadu.

Inter-Monsoon Rainfall Variability

Inspite of regular annual recurrence of summer monsoon there are large variation of rainfall within the season. These variations are attributed to synoptic scale disturbances, oscillations of monsoon trough, mid-latitude effects. Synoptic scale disturbances such as Lows, Depressions, Cyclonic storms, mid-tropospheric cyclones, off shore vortices cause rainfall variations in periods of 5-7 days. The intensity, frequency of disturbances have dominant role in floods. The oscillation or meandering of monsoon trough (on sea level chart) from its normal position causes rainfall variability in periods of 10-15 days. Shifting of the eastern end of monsoon trough to the foot hills of Himalayas generally cause floods in Brahmaputra, while most part of the country receives scanty rainfall. On the contrary if the monsoon trough shifts south of its normal position widespead rainfall occurs over most part of the country.

There are five semi permanent features of monsoon which are described below.

(i) ***Heat Low :*** The formation of heat low over Pakistan and adjoining Rajasthan is a semi-permanent feature of Indian monsoon. Heat low is very shallow extends upto 1.5 km asl. Above the heat low there exists a marked ridge (part of Sub-Tropical High). Rainfall associated with this low is very

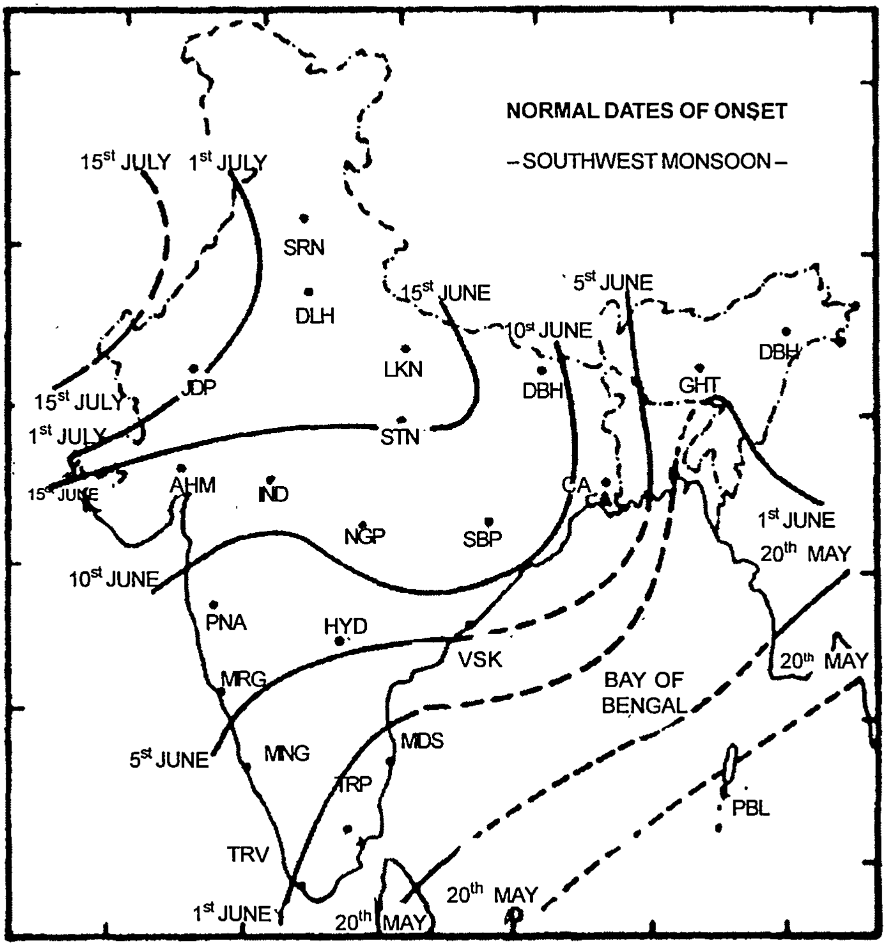


Fig. 8.2(a) Normal dates of onset of southwest monsoon over India (Rao Y.P 1976).

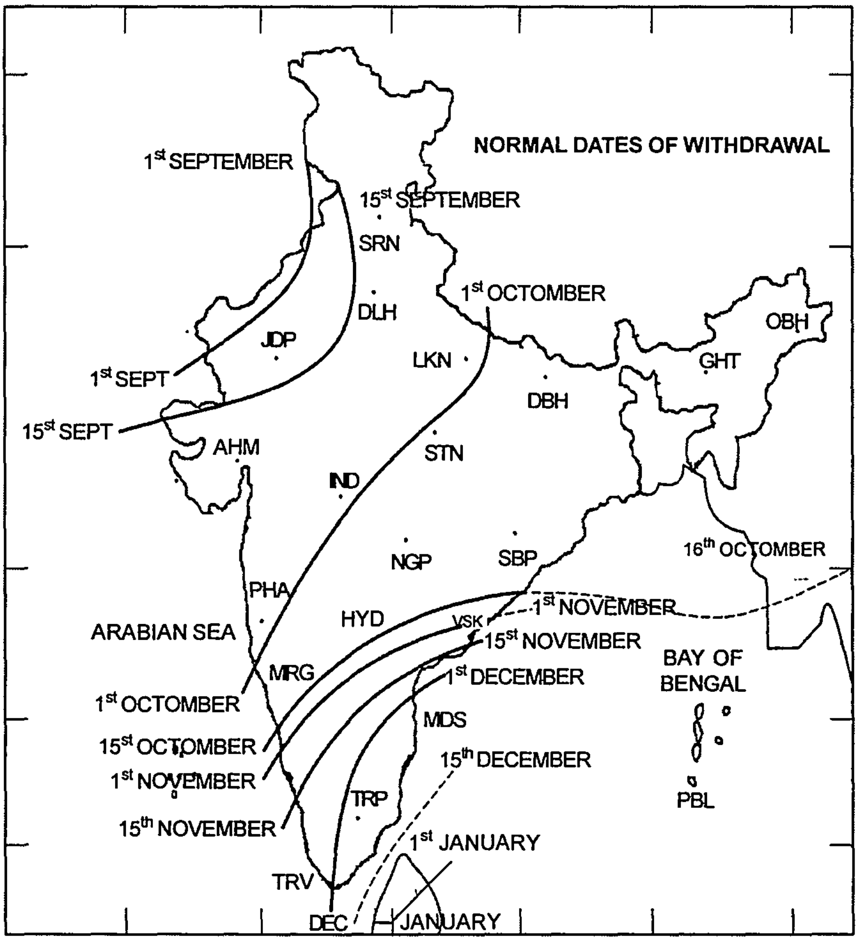


Fig. 8.2(b) Normal dates of withdrawal of southwest monsoon over India (Rao Y.P. 1976).

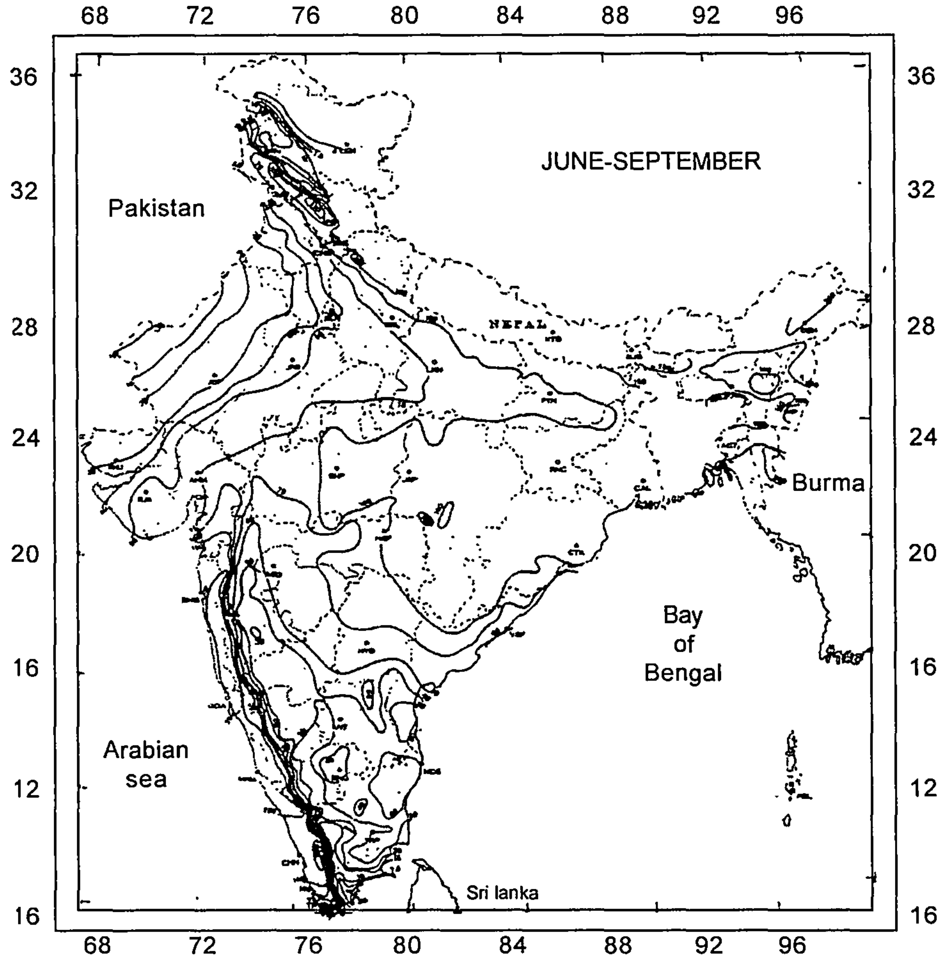


Fig 8.3(a) Monsoon Rainfall over India.

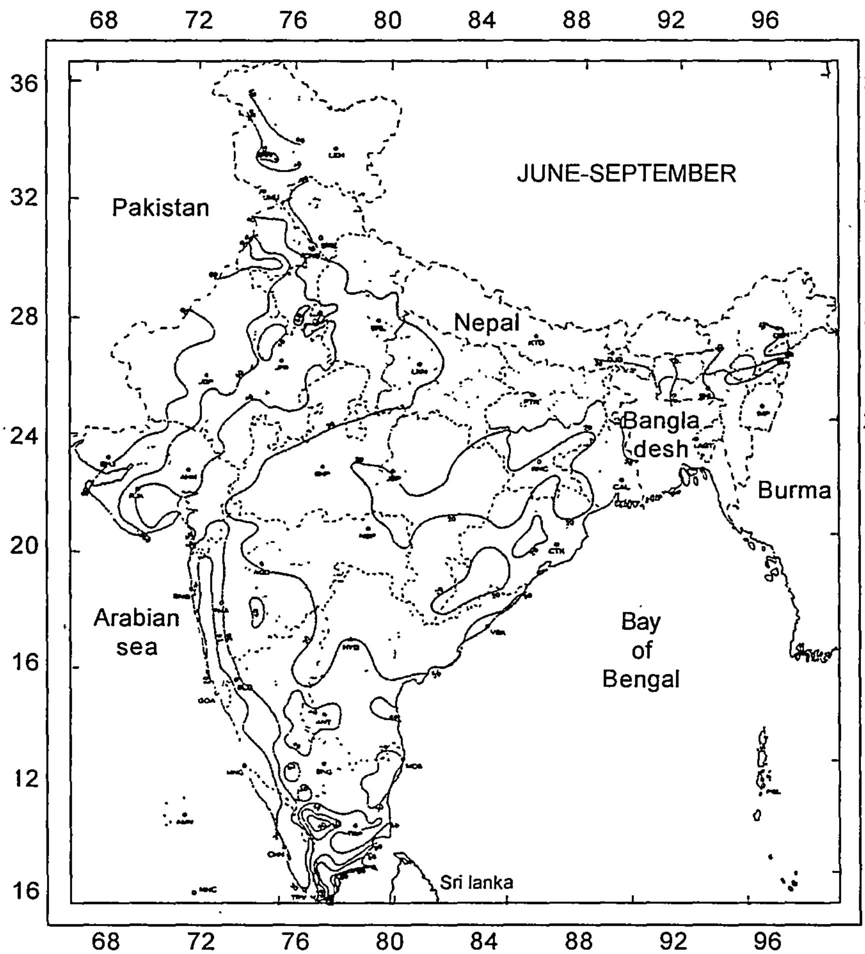


Fig 8.3(b) Coefficient of variation of rainfall.

small in that area and is the cause of formation of Thar desert in Rajasthan. The surface air temperatures in the area are high which evaporates the moisture. However the intense heat low acts on a suction devise of moist air along the monsoon trough to some extent related to good monsoon over India. During weak heat low monsoon rainfall over most part of India is deficient or scanty.

(ii) ***Monsoon Trough :*** During monsoon period an elongated low pressure area extends from heat low over Pakistan to Head Bay of Bengal. This is called monsoon trough. This is a semi-permanent feature of monsoon circulation. It migrates sometimes southwards and sometimes northwards. Southward migration results in active/vigorous monsoon conditions over major part of the country, while its migration northwards leads to break monsoon conditions over major part of the country, however heavy rains occur along the foot hills of Himalayas.

(iii) ***Mascarene High :*** During monsoon period a High pressure area is located around Mascarene Islands (in South Indian Ocean). This is responsible for cross-equatorial flow and acts as a southern hemispheric linkage. The variation in the intensity of high pressure causes monsoon surges across equatorial flow which is responsible for heavy rains along west coast of India.

(iv) ***Tibetan High :*** It is a large warm anticyclone situated over Tibetan Plateau (Centre at lat 28^0 N, long 98^0 E) in middle/upper troposphere during June-September. Shifting its position east or west causes variation in monsoon activity over India. West movement causes monsoon transients from Bay to northwards.

(v) ***Somali Jet :*** Low-level (upto 1.5 km asl) inter-hemispheric cross equatorial flow of air attains jet speed at the west end of monsoon regime along the east coast of Africa. The jet originates near Mauritius and northern part of Madagascar in the southern hemisphere. The jet reaches Kenya Coast (about 3^oS) covers the plains of Kenya, Ethiopia and to Somali coast at about 9^0 N. During May it moves further north into eastern Africa, then into Arabian sea and reaches west coast of India in June. It attains maximum strength in July. The Low Level Jet gives rise to strong monsoon over peninsular India.

Monsoon Disturbances

During monsoon (June - September) a series of low pressure systems (called monsoon disturbances) form over Head Bay of Bengal and generally move in a west-north-westerly direction along the monsoon trough and weaken over west

MP or Rajasthan. On their way these system give copious rain. Some of these pressure systems intensify into Depressions or Deep Depressions and rarely become cyclones (Def. of the systems refer to Table 2.1). The average occurrence of monsoon disturbances is 2-3 per month or 10 per season. The frequency of these disturbances in the Bay of Bengal is much more compared to Arabian sea and over land. Monsoon Depressions generally move in west-north-westerly direction and weakens over Northwest India. Along the path of these disturbances monsoon strengthens to active/vigorous conditions and cause floods.

8.5 Flood Warning Signals and Precautionary Actions

Chief Engineer Major Irrigation demarks the flood warning stages on all rivers in the State. Depending on the degree of danger, preparedness required by the concerned people. Yellow, Amber, Red signals alaram are given.

Yellow Signal indicates the approach of floods in the river in the concerned area. It is an alert signal for the incoming high flood.

Amber signal indicates requiring greater alertness by the concerned people in the river reach area.

Red signal is a warning meant for flood control or approach of high flood.

District authorities should disseminate the warning of impending flood to the people by drum beat and organise evacuation of people to safer places (shelters).

Based on previous historic data flood inundation area corresponding to river stage be kept ready (flood zoning maps and GIS) for evacuation of people. Areas likely to be affected by flood be demarked by errecting bounday pillary. Special flood warnings will be broadcast on AIR/DD indicating the towns, villages that are likely to be flooded with approximate inundation depth. Evacuation and Relief Organisations, flood fighting organisations should report for duty immediately.

Concerned authorities Irrigation and Power, Road and Buildings, Panchayat Raj, State Electricity Board etc., should survey the area of their work charge before the onset of monsoon/cyclone season and report to the High Power Committee the weak positions requiring repairs/ precautionary measures. Concerned departments should take appropriate remedial measures before the onset of the season.

Actions to be taken

1. **By Irrigation Department :** The head regulators of the irrigation system in coastal areas to be closed and water be allowed to pass through the river course. Irrigation Department authorities should undertake general survey of all works including Flood Banks and report with requiring precautions

before the onset of the season. Empty cement bags, sand, metal, stone balls etc., should be stocked adequately in flood stores for use in times of emergency or exigency. The river mouths of major rivers joining sea, river drains be cleared before the onset of monsoon season to drain off the maximum flood discharges.

Note :

(i) Obstructions at the river mouths cause high storm surge water inundation across the banks of rivers. High river discharges occur during cyclone movements, active/vigorous monsoon conditions. For example the Godavari river discharged maximum of about 1 lakh m^3/s during 1986 floods, while Krishna river discharged maximum about 34000 m^3/s during 1903 floods.

(ii) Hydrology may be defined as the science that governs the processes of depletion and replenishment of surface water and ground water resources.

(iii) Deforestation, erosion of soil aids flood.

2. **Revenue Department :** Revenue Department should alert the village assistants, Sarpanches to patrol the river banks, irrigation tanks and report the weak points to the concerned engineers. The flood/cyclone duty officers of irrigation departments should keep ready sufficient power launches at the disposal of Collector/MROs/ Revenue authorities for rescuse and relief operations of flood marooned people in lankas.

   For dissemination of flood / cyclone warning messages, wireless stations of the river and canal telephone system be used.

   Officers of Chief Engineer, Major Irrigation HQ should set up control room to work round the clock (in Superintending Engineers Office), which would inform all emergency messages to HQ Control room (in State Secretariat).

   Flood stores have to be established in all major river deltas and one flood store under district collector. Flood stores should stock empty sand bags, pump sets, for dewatering, diesel generators, loud hailers, tarpaulin tents.

Do's and Don'ts

Do's : (i) listen to autentic news of warnings and advisories on AIR/DD.

(ii) Keep vehicles, instruments, chemicals at a higher place.

(iii) Disconnect all electrical appliances, switch off gas connection.

(iv) Switch off electricity and close gas before leaving house.

Don'ts : Don't allow the children to play in or near flood waters. Don't allow anyone to move in the submerged areas in the floods.

Some Greatest observed Point Rainfall Depths given in the Table 8.1.

Table 8.1

S.No.	Duration	R.F depth in mm	Location	Date
1.	One minute	38	Barot Guadeloupe	26 Nov 1970
2.	15 minutes	198	Plumb-point, Jamaica	12 May 1916
3.	2 hrs 10 minutes	483	Rockport, WVa	18 July 1889
4.	12 hrs	1,340	Belouve, Reunion	28, 29 Feb 1964
5.	24 hrs	1,870	Cilaos, Reunion	15-16 March 1952
6.	8 days	4,130	Cilaos, Reunion	11-19 March 1952
7.	15 days	4,798	Cherrapunji, India	24 June to 8 July 1931
8.	31 days	9,300	Cherrapunji, India	July 1861
9.	One year	26, 461	Cherrapunji, India	August 1860 to July1861
10.	24 hrs	944.2	Mumbai, Santacruz,	26 July 2005 India

8.6 Water Purification Technologies in Flood Affected Areas

Disaster Management Community : It is a group of professionals from various organizations and disciplines concerned with Disaster preparedness, mitigation, response, recovery and rehabilitation issues. Members of this community share their knowledge and experience in the day-to-day challenges they face.

Environment – Water Community : This community helps to promote sustainable and equitable access to water, particularly drinking water and environmental sanitation in urban and rural areas. It promotes to reverse unsustainable exploitation of water resources.

A few water purification technologies useful in flood affected areas, recommended by the above communities are given below.

1. *Solar Water Disinfection (SODIS) :* In this method contaminated/flood water first filtered with fine cloth (8 folds). It is then put in a closed PET bottles and exposed to sunlight for few hours (7 to 8 hours). Bottles are kept inclined at 45^0 on roof tops, and can be partly painted black to increase heat gain. Solar UV-radiation disinfects. In cloudy conditions exposure time has to be increased.

   PET bottles can be found in recycling and solid waste sector. It is the cheapest method. Technical information on photocatalytic destruction of water pollutants is available with University of Massachusetts – Peru.

2. *Na DCC tablets :* 33 mg tablet can purify about 20 liters of non-turbid water.

   Na DCC tablets are manufactured by water Chemical Laboratories, Kattedan Hyderabad – 500 277.

3. *Use of Ferric Alum, Lime and Bleaching powder sachets:* Three separate sachets containing Ferric alum powder 64 mg, lime powder 32 mg and bleaching powder 4 mg (total 100 mg) purifies about 20 liters of turbid water when dipped and stirred. This method widely used in Assam.

   Note : Ferric Alum, lime and bleaching powder should not come in contact with one another inside the sachet.

4. *Sodium Hydrochloride Solution:* It is available in liquid form packed in small plastic bottle, which is sufficient to purify 1000 liters of water. It is very effective in removing microbial contamination.

5. *Calcium Hypochlorite :* It is mainly used to purify water for combating during diarrhea outbreaks in health camps.

   Details Calcium Hypochlorinate (65-70% active chlorine): It can be used in dealing with diarrhoeal outbreaks, both for water purification and also Hospital Management (having diarrhea patients) Health camp management.

   Preparation of Stock Solution : Mix 15 gms (1 level table spoon or 3 level tea spoons) of calcium Hypochlorite 70% in one liter of water. This stock solution will last for about 1 month. For water purification, mix 0.6 ml or 3 drops of solution in one liter of raw water.

6. *Vani :* Traditional system followed by the Jain community. Equal parts of Cow Dung and wood is burnt to ash, which is called Vani. 100 gm of this ash can purify 20 liters of water. After mixing with ash water is kept under sun for about one hour and then filtered with plain cloth (about 8 folds). This makes water as pure as zero-bacteria. The ash acts as a catalyst to kill bacteria.

7. *Fuel wood ash* : Finely ground fuel wooden ash is mixed in the proportion 96 gm to 11 liters of water, stirred and kept for two hours in sunlight, then filtered. It provides safe water for consumption in emergencies. This method can be used even during cloudy weather.

8. *Drumstick Seeds Powder (Moringa Olefiera Seeds)* : It is cheap way to purify water. The seeds treat water in two ways. It acts as a coagulant and as antibacterial agent.

9. *Chlorination* : There are three methods of chlorination (i) Shock chlorination, (ii) Pot chlorination (iii) Dip chlorination which are used during floods and disasters.

   Shock Chlorination : In this method chlorine powder, bleach or liquid bleach added to the water body, say well, only once at the ratio of 5-10 mg/liter and left unused for a period of few hours (say 6 to 8 hours). Before chlorination solid waste has to be removed. After that the first water drawn from the well after disinfection period is discarded, and then normal use resumed. Shock chlorination eliminates transit threat to water quality by contamination and flooding.

Pot Chlorination : In this method a two liter plastic (mineral water) bottle is filled with bleach (chlorine powder) and gravel mixture. The bottle will have a few holes. This bottles is placed in a big vessel or mud pot, which has also few holes. The number and size of holes in the vessels control the disinfectant dose must match volume of water in tank / well or rate of runoff of water from the source.

Drip Chlorination : The principle is similar to the hospital intravenous drip set. The water body must be in continuous flow like running stream. A small check dam or bund diverts water flow through a pipe into a tank (which has provision for an overflow when there is no usage). Liquid chlorine is filled in the plastic bottle from which liquid chlorine drips is regulated by a squeeze valve on its outlet. The outlet needle is kept well submerged in the tank by an anchor. This type of chlorination is suitable for small tanks which can supply to limited number of houses.

10. *INDION mobile Disaster Management Unit (DMU)* : This unit can treat water of any kind and quality of surface or high salinity. This unit consists of a membrane process and ozonation modules, which can be used in combination depending on the quality of water to be treated.

    The DMU is compact, containerized and skidmounted. It can be mounted on truck and portable. It can also work on diesel generator. The capacity of DMU is 1 m^3/hour or 2 m^3/hour. DMU was developed by Ion Exchange India.

11. *NCL National Chemical Laboratory* Pune developed water purification kit, which is membrane based. It is completely manually operated. It provides water free from biological contamination (microbial free water), can avoid any epidemic like situation.

12. *"NEERI ZAR"*: It is a portable instant water filter, developed by NEERI (National Environmental Engineering Research Institute), Nagpur.

    The unit is easy to fabricate and simple to operate and maintain. The unit cost is low. It provides the onsite treatment to available flood water under emergency situations to remove the organic contamination, suspended solids and bacterial load to produce safe portable water within few hours, using locally available material and without using electricity.

    NEERI-ZAR patented in Jan 29, 2007, Ref. No. 0268 NF 2006/IN.

Warning : Maximum hourly intake of water should not be more than 1.03 liters not more than 11.35 liters per day. One should not eat snow, as this will expend more energy melting it in the mouth and can be fetal. Sea water even if diluted with fresh water and drunk in small quantities leads to death. Drinking flooded and Marooned waters could be potential health hazard, many a times fetal. Under normal conditions a person requires to drink 1.5 to 2.5 liters or 8 glasses of water per day.

CHAPTER - 9

Drought

Introduction

According to US weather Bureau, drought is defined as "Lack of rainfall so great and long continued as to affect injuriously the plant and animal life of a place to deplete water supplies both for domestic purpose and for the operation of power plants, especially in those regions where rainfall is normally sufficient for such purpose".

The term drought has different connotations in different parts of the globe. In Egypt, any year the river Nile does not flood is a drought year irrespective of rainfall. In Bali, a period of six days without rain is a drought. In parts of Lybia, droughts are recognised only after two years without rain. The definition of drought varies from the use of water and its scarcity. Based on this a few standard varieties of droughts are : Meteorological, Hydrological, Agricultural and Socio-Economic.

Aridity and Drought

Aridity is a permanent climatic feature of a region of low rainfall and high temperature, while drought is a temporary feature related to rainfall variability when the rainfall is appreciably below normal.

Aridity is both low precipitation and low effective precipitation, where,

low effective precipitation = precipitation – Evaporation.

Index precipitation effectiveness = r/t

where r = annual rainfall in mm

t = mean annual temperature ^{o}C

If $\frac{r}{t} < 40$; it is arid

If $\frac{r}{t} > 160$; it is per humid

Drought may occur in any rainfall or temperature regime. It may be confined to a single area (or river basin) or may be widespread invading over many states, even in case of widespread it may be severe only on a small area compared to the total area affected. It is found that drought occurs frequently in that area where the coefficient of annual rainfall is more than 35% and less frequent where the coefficient of variation is less than 25%. The occurrence of drought is frequent where annual rainfall is small and coefficient of variation is high and they seem to go together. The affect of drought varies from one area to another.

No rain for a few days is of little consequence but if it continuous for weeks or months or seasons (or years) with deficient rain it may lead to disaster. Prolonged droughts cause total crop failures, decimation of livestock, widespread starvation and deaths. Drought and famine generally go hand in hand each abbeting the other. Famine is extreme lack of food. Definition of drought is not unique. The causes of droughts are many and complex. They may commence at any time and may last for a longtime and attain many degrees of severity. As yet the occurence, cessation, continuation and recurrence of drought cannot be predicted reliably or stopped. However it can be reasonably inferred using statistics of past data which may be helpful to government and local authorities to combat it. From the past data of any locality it is possible to indicate the probability occurrence of drought of various intensities at different times of a year. This information is useful for planning land use, water use and agricultural development by way of using drought resistant crops, short duration crops, design of irrigation projects, emergency planning for the next drought when it occurs (which is of course certain).

The causes of drought appears to be general climatic fluctuations associated with persistant large scale aberrations of atmospheric circulation which favoured subsidence over the region. The likely factors are air-sea interaction, pumping or dispersal of large scale ash and dust into the atmosphere, changes in the composition of atmosphere, particularly water vapour, carbondioxide, ozone (which are selective absorbers of (short and long wave) radiation that could modify the heat balance of the earth).

Drought is a creeping phenomena, its beginning is subtle progress is treacherous and effects can be devastating. Impacts of drought are cumulative, drives the people out of job, makes them apart and brings conflict between people, communities and government, stiff compitition for water resources, migration of people with livestock in search of livelihood, food, water, fodder. All these may lead to famines, thefts, robberies, unstable socio-economic condition in the area and even it may reflect into political instability.

9.1 Meteorological Drought

According IMD convention India has been divided into 35 Meteorological subdivisions (now it is changed) (MSD). An MSD is declared as drought affected if it receives monsoon (seasonal) rainfall less than 75% of LPA (long period average, called normal). It is further classified as moderate drought if it receives seasonal rainfall 50 to 74% of LPA and severe drought if it receives less than 50% of LPA. In any year the total affected area by drought of the above two categories exceeds 20% area of the country, that year is considered as a drought year for whole of the country. Based on this criteria the years of drought during 1875 to 2002 is given below (data taken from IMD) in descending order of magnitude and its probability of occurence by ranking method.

Fa(m) = Probability level = (100 m)/(n+1) (in percent)

where m = ranking number, n = no.of year of data used .

Year	Percentage area of the country affected	Ranking number m	Probability level Fa(m)
1918	70	1	0.78
1899	68.4	2	1.55
1877	59.5	3	2.33
1987	47.7	4	3.1
1972	40.4	4	3.8
1965	38.3	6	4.65
1920	38.0	7	5.42
1905	37.2	8	6.2
1941	35.5	9	6.97
1966	35.4	10	7.75
1951	35.1	11	8.52
1979	34.8	12	9.30
1904	34.4	13	10.07
1974	34.0	14	10.85
1985	32.3	15	11.62
1901	30.0	16	12.4

Table *Contd...*

Year	Percentage area of the country affected	Ranking number m	Probability level Fa(m)
1907	29.1	17	13.17
1982	29.1	17	13.17
2002	29.0	18	13.95
1939	28.5	19	14.75
1911	28.4	20	15.50
1913	28.4	21	16.27
1891	22.7	22	17.05
1915	22.2	23	17.83
1968	21.9	24	18.60
1925	21.1	25	19.37

During these 128 years (1875-2002) none of the 35 MSD affected by drought as defined above for 35 years and thus we have probability of a drought free year for the whole country (all MSD) is 0.27. This means the whole of India is likely to be drought free for 27 years out of 100 years. The annual average of drought affected MSD is 3.81 (about four sub divisions), of these 0.55 MSD likely to be affected by severe drought (on an average every year half a Met sub division will be affected by severe drought). 29% of total geographical area is drought prone.

The probability of 50% (about 18 MSD) area of the country may be affected by drought is 3% (3 times in 100 years). The probability of 20% (about 7 MSD) area of the country may be affected by drought is 20% (once in five years), that is country as whole may be affected by drought once in five years.

The probability occurrence of two consecutive years of drought over (whole of) India is one in sixty as seen from 60 year cycle. During last 128 years two consecutive years of drought over whole of India (20% of area or more) occured during 1904, 1905 and 1965, 1966. As a precursor another two consecutive years of drought likely over (20% or more area) whole of India during 2026, 2027 A.D. (assuming little climatic change). It is worth noting in 1904 four MSD namely west Rajasthan, Gujarat region, Sourastra and Kutch, Rayalseema were affected by severe drought while 1905 two MSD west and east Rajasthan were affected by severe drought. In 1965 and 1966 none of the 35 MSD were affected by severe droght. There seems a down trend in drought severity incidence, which may be attributed to improved irrigation. The above example suggests drought can be softened if not rooted out, which is the main purpose of drought monitoring and mitigation studies.

9.2 Breaks in the Monsoon

Monsoon fully establishes over India by the end of June and thereafter sustained monsoon conditions prevail over whole of India during July and August. Withdrawal begins in September middle. However during July, August months there were occasions of short period, say about a week, when rainfall over most part of the country is absent. This low rainfall activity is termed "Breaks in monsoon" which is associated with change in established monsoon circulation. A convention is followed that if the monsoon trough is absent on sea level chart and at 850 h Pa level for more than two days then it is called break in monsoon. According to this convention the longest break of 20 days occurred in 1906 (29 July to 18 Aug). A statistical study of 80 years data (1887-1967) shows that the average period of breaks in July 5.8 days and August 6.5 days and most frequent duration in these months 4 and 3 days respectively and the longest period in these months being 17 and 20 days respectively. Standard deviation is about 3 days. There was no break in 12 years out of 80 years indicating the probability of occurrence of break is surface 0.85. A typical surface chart of break monsoon is shown in Fig. 9.1 and weak/break monsoon condition trough axis are shown in Fig. 9.2.

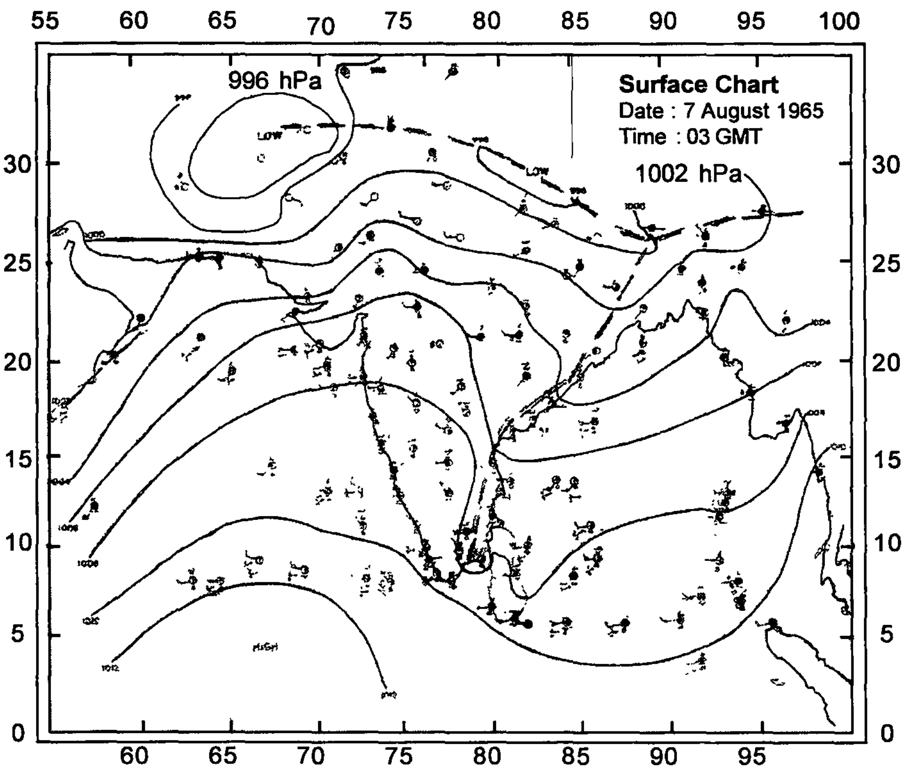


Fig. 9.1 Break monsoon conditions typical surface chart.

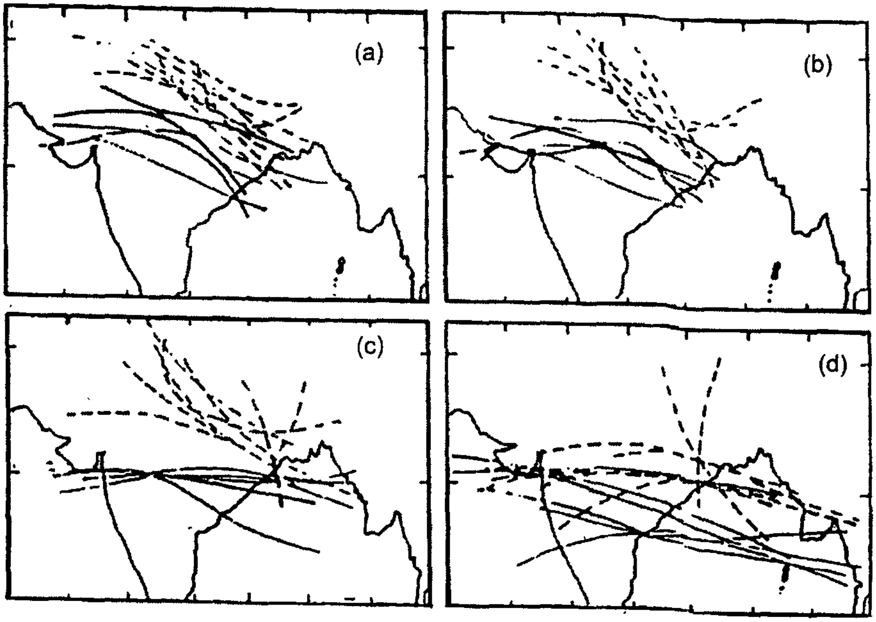


Fig. 9.2 Mean positin of the monsoon trough during strong (normal) and weak (break) monsoon; (a) at 900 hPa, (b) at 850 hPa (c) at 700 hPa (d) 500 hPa.

Synoptic Situations During Breaks

Shifting of Monsoon trough to the foot hills of the Himalayas causes break. This may be caused by :

(i) the eastward movement of active western disturbance north of the country,

(ii) pronounced low index westerly circulation in middle latitudes,

(iii) Eastward movement of large amplitude trough in westerlies (between 500-300 h Pa) over north of India across Tibetan Plateau,

(iv) movement of Bay depression northwards to foot hills of the Himalayas,

(v) movement of a western Pacific Typhoon to north of 30°N over China or its recurvature northeastwards.

Break in monsoon may be caused by the formation of a low in lower latitudes which moves westwards along lat 10 °N over south peninsula or by the formation of High pressure ridge at 500 h Pa level over Central India.

During break monsoon conditions mid-latitude upper tropospheric ridge (at 300 h Pa) shifts southwards to about 26 °N, mean sea level pressure falls to below normal over south peninsula (south of 13 °N) where surface temperature becomes above normal. This warming is observed in the entire troposphere. Over central parts of India sea level pressure rises to the order of 4 h Pa.

During break monsoon, heavy rains occur along foot hills of the Himalayas and over southern parts of India (Tamilnadu, south Andhra Pradesh), while rainfall activity drastically reduces over western and central parts of India. In upper troposphere easterly Jet shifts northwards as far as 23 ^{0}N (normal position is 13 ^{0}N). Two Jet core maxima are located, one at about 12 ^{0}N (south of its normal position) and another at about 22 ^{0}N. Two westerly jet cores are also observed, one at about 32 ^{0}N and another at about 40 ^{0}N.

9.3 Drought Management Plan

Drought prone area programme was introduced in 1973-74. The programme is funded equally by Central and State Governments. The activities of this programme include :

(i) Soil conservation,

(ii) Water resources development,

(iii) Afforestation,

(iv) Waste land developement (fodder, grass land development).

Watershed development includes contour bunding, construction of micro level check dams, percolation tanks, afforestation, pasture development, soil and moisture conservation measures which are to be taken up by the communities themselves through watershed association.

In 1999-2000, NABARD (National Agricultural Banking and Rural Development) established Watershed Development Fund (WDF) to enable States to access credit for treatment of under Watershed Development – Wasteland development, large scale Agro-forestry and Social forestry programme.

Prime Ministers 12 point programme for the management of drought. The salient points are given below:

1. ***Full time Relief Officers*** **:** Full time Relief officers to be appointed to assist the District officers since the district is likely to be seriously affected by scarcity of food, employment and drinking water. Relief operations should involve all departments.
2. ***Monitoring*** **:** Daily monitoring of the situation with regard to food, employment, starvation and drinking water should be conducted (i) at the State level for each district and (ii) at the district level for each village or Panchayat and timely action taken.
3. ***Availability of Food Grains*** **:** All godowns of the Food Corporation of India (FCI) should stock adequate food grains. The State Government should open buffer godowns in seriously affected blocks and ensure that no area suffers from non-availability of food grains. Movement and dispatch plans

for food grains should be finalised in consultation with the State Government by the representatives of FCI and followed up daily in joint meeting by the representatives of the State Government, the FCI and the local Railways.

4. ***Fair Price Shops*** : Fair Price shops at the rate of one shop for 2000 persons should be established through private or public agencies and supplies of food grains, sugar, edible oil and kerosene arranged through them. Assistance of banks should be ensured.

5. ***Anti-social Elements*** : Continuous legal, administrative and social pressure should be mounted against law breakers, black-marketers, profiteers and hoarders and deterrent and domonstrative action taken against all such anti-social elements who try to exploit the scaricity situation.

6. ***Food for Work*** : Continuity of food for work (FFW) should be ensured by a shelf of schemes at the Panchayat circle level and continuity of payment within a week ensured by availability of food grains and "on account payment" if measurement of work done is likely to be delayed.

7. ***Afforestation*** : A plan for massive plantation of trees should be mounted as a campaign in the drought affected States. This should comprise arranging nurseries and digging of trenches, pits, boundary walls etc., for afforestation. The campaign should be given a high priority in the FFW scheme. Enhanced targets for plantation in the degraded areas of the reserved and protected forests and also on community land, canal-side and road-side areas should be taken up on the date of onset of monsoon in continuation of the scheme of employment.

8. ***Food for Nutrition Programme*** : Free food grains had been offered for the States for feeding the destitutes, etc., but very little of these has been utilized. Every Panchayat circle must have a feeding centre for children, nursing mothers, pregnant women and the destitutes who cannot be employed. Skimmed milk powder and edible oil should also be utilized.

9. ***Contingency Plans*** : Contingency plans for supply of water to the identified village should be drawn up and advance action taken for arranging tankers, trucks, drums, diesel etc.

10. ***Public Health Measures*** : All available public and private sources of water should be protected, impounded, disinfected and expanded to cover as many villages as possible.

11. ***Rigs for boring drinking water wells*** : Rigs of all the departments and of all types along with the crew should be mobilized on a war footing and used for boring and deepening of wells in the most seriously affected areas.

12. ***Cattle Camps and Relief Camps*** : Sites of Cattle Camps and Relief Camps near water sources should be identified and advance action taken for opening them at short notice.

Protection from Famine

Persistant drought results in famine. Indian Irrigation Commission was appointed in 1900, which toured whole of India for about two years and at its advise a number of protective works – barrages, storage reservoirs, massonary/concrete dams, construction of canals, weirs, tanks were undertaken. These works aimed at the protection against famine. These constructions helped in irrigating more land area for agriculture.

Soil Erosion

Erosion is a natural process aggravated by too much of rain or too little. Erosion is more prevelant where rainfall variation is high. Erosion destroys top fertile soil, in weeks or days the accumulation of centuries which make the few inches of fertile top soil. Dust in many cases is the direct result of erosion. Dust can originate from man-made deserts and dust bowls, abandoned after over cropping and over grazing. Erosion is one of the favourable factors of drought.

9.4 Drought Years for Different Met Subdivision of India

Based on monsoon rainfall (June-September) during 1875-2005 given below.

MSD	Years of Drought
1. Andaman and Nicobar Islands	1886, 1892, 1893, 1899, 1900, 1907, 1915, 1919, 1924, 1925, 1927, 1979, 1984, 1990, 1993, 1999, 2000
2. Arunachal Pradesh	1937, 1942, 1961, 1971, 1992, 1994, 2001
3. Assam and Meghalaya	1884, 1896, 2005
4. Nagaland, Manipur, Mizoram and Tripura	1884, 1887, 1888, 1889, 1895, 1896, 1899 1899,1907, 1972, 1980, 1981, 1986
5. Sub-Himalayan West Bengal	1890, 1891, 1896, 1904, 1908, 1972, 1994
6. Gangetic West Bengal	1895, 1966
7. Orissa	1878, 1901, 1924, 1974, 1987
8. Bihar Plateau	1903, 1966, 1979, 1982, 1992, 2005
9. Bihar Plains	1877, 1891, 1901, 1908, 1932, 1951, 1959, 1966, 1972, 1982, 1992
10. East Uttar Pradesh	* 1877, 1883, 1896, 1907, 1913, 1918, 1928, 1932, 1959, 1965, 1966, 1979, 1987
11. Plains of West UP	*1877, 1883, 1905, 1907, 1913, 1918, 1928, 1941, 1979, 1987, 2004

12.	Hills of west UP	*1877, 1883, 1905, 1907, 1913, 1918, 1941, 1951, 1965, 1972, 1976, 1980, 1982, 1987, 1991, 1992, 1997
13.	Haryana, Chandigarh and Delhi	*1877, 1883, 1898,*1899, 1905, 1907, 1913, 1915, *1918, 1920, 1928,1929, 1938, 1939, 1941, 1951, 1965, 1968, 1979, 1986, *1987, 2002
14.	Punjab	*1899, 1904, 1905, *1911, 1915, 1918, 1920, 1921, 1928, 1929, 1938, 1939, 1951, 1964, 1965, 1969, 1972, 1974, *1979, *1987, 2002, 2004
15.	Himachal Pradesh	1877, 1883, 1899, 1902, 1905, *1907, 1911, *1918, 1928, 1965, 1968, 1972, 1979, 1981, 1982, 1983, 1984, 1986, *1987, 1989, 2004
16.	Jammu and Kashmir	1878, *1879, *1883, *1884, 1885, 1886, 1887, *1889, *1891, 1895, 1896, 1898, 1900, 1902, 1911, 1918, 1920, 1937, 1949, 1951, 1965, 1971, 1972, 1979, 1982, 1992
17.	West Rajasthan	*1877, 1883, 1885, 1887, 1891, *1899, *1901, 1902, *1904 *1905, *1911, 1913, *1915, *1918, 1920, 1925, 1938, *1939, 1951, 1963, 1968, 1969, 1971, 1974, 1980; 1981, 1982, 1985, 1986, 1987, 1991, *2002, 2004.
18.	East Rajasthan	*1877, 1898, 1899, 1901, *1905, 1907, 1911, 1913, *1915, *1918, 1925, 1928, 1939, 1941, 1951, 1965, 1966, 1972, *1987, 1991, 2000, *2002.
19.	West MP	1877,1899, 1905, 1907, 1918, 1920, 1940, 1951, 1965, 1966, 1979, 1987, 2000
20.	East MP	1878, 1899, 1941, 1962, 1965, 1966, 1974, 1998, 2000
21.	Gujarat Region	*1877, 1885, 1888, 1892, *1899, 1901, *1904, *1911, *1915, *1918, 1920, 1923, 1925, 1936, 1939, *1948, 1951, 1957, 1960, 1965, 1972, *1974, 1982, *1985, *1986, *1987, 2000, 2002

22. Saurashtra and Kutch	1875, *1877, 1889, 1890, 1894, *1899, *1901, *1904, 1905, *1911, *1915, *1918, *1923, 1975, 1931, *1939, *1948, 1951, 1968, 1969, *1972, *1974,, 1982, *1985, 1986, *1987, 1991, 1993, 1995, *1999, 2000.
23. Konkan and Goa	1877, 1899, 1905, 1918, 1920, 1941, 1968, 1972, 1986
24. Madhya Maharashtra	1877, *1899, 1904, 1905, 1911, *1918, 1972, 1985, 1987
25. Maratwada	1877, 1885, 1899, 1905, 1907, 1912, 1918, *1920, 1925, 1929, 1939, 1941, 1972, 1974, 1984, 1985, 1993, 1997
26. Vidarbha	1877, *1899, 1902, 1904, 1918, 1920, 1950, 1952, 1965, 1971, 1972, 1974, 1982, 1985, 1987, 2004
27. Coastal AP (CAP)	1877, 1888, 1899, 1904, 1920, 1952, 1968, 1972, 1973, 1979, 1984, 1987, 2002
28. Telangana (TLNG)	1876, 1877, 1881, 1888, 1899, 1918, 1920, 1939, 1941, 1952, 1968, 1971, 1972, 1977, 1985, 1997, 2004
29. Rayalaseema (RYSM)	1876, 1884, 1891, 1896, 1899, 1901 *1904, 1907, 1911, 1913, 1918, 1920, *1922, 1923, 1934, 1941, 1948, 1952, 1971, 1972, 1985, 1993, 2002
30. Tamilnadu and Pondicherry	1884, 1891, 1899, 1904, 1918, 1934, 1952, 1969, 1980, 1982, 1999, 2002
31. Coastal Karnataka	1881, 1899, 1918, 1972, 2002
32. North Interior Karnataka	1876, 1891, 1899, 1905, 1937, 2002, 2003
33. South Interior Karnataka	1875, 1881, 1884, 1905, 1918, 1976, 1985, 2002, 2003.
34. Kerala	1881, 1899, 1918, 1944, 1951, 1952, 1965, 1966, 1976, 2002, 2003
35. Lakshadweep	1901, 1918, 1927, 1928, 1934, 1941, 1948, 1952, 1956, 1957, 1969, 1980, 2002

* indicates severe drought years.

The calculations of probabilities occurrence of drought over each sub-division can be done, however an example of three Met sub-divisions of Andhra Pradesh has been given. From the above data we have 1875-2005 monsoon seasons.

	No. of drought years	No. of consecutive drought years	No. of severe drought years
Coastal AP	13	1	0
Telangana	17	2	0
Rayalaseema	23	2	2

Drought over whole of AP 5 (1899, 1918, 1920, 1952, 1972)

Drought free years over whole of AP 95

The Probability of non-occurrence of drought (drought free) year over whole of AP = 95/131 $\simeq$ 0.73 (i.e., 7 drought free years out of ten)

The Probability occurence of drought over whole of AP = 5/131 $\simeq$ 0.04 (i.e., once in twenty five years)

The probability occurence of drought over CAP = 13/131 $\simeq$ 0.1 (i.e., once in ten years)

The probability occurrence of severe drought over CAP = 0/131 = 0 (that is a non-event)

The probability occurrence of two consecutive years of drought over CAP = 1/131 $\simeq$ 0.008 (twice in 250 years)

The probability occurrence of drought over TLNG = 17/131 $\simeq$ 0.13 (i.e., once in eight years).

The Probability occurrence of severe drought over TLNG = 0/131 = 0 (that is a non-event)

The probability occurrence of two consecutive years of drought over TLNG = 2/131 $\simeq$ 0.015 (i.e., fifteen years in thousand years)

The probability occurrence of drought over RYSM = 23/131 $\simeq$ 0.18 (i.e., about once in six years)

The probability occurence of severe drought over RYSM = 2/131 $\simeq$ 0.015 (i.e., fifteen years in thousand years).

The Probability occurrence of two consecutive years of drought over RYSM = 2/131 $\simeq$ 0.015 (that is fifteen years in thousand years).

Droughts over Andhra Pradesh

By virtue of area AP is the fifth largest State in India. It has population density 2.76 persons per hectare. Climatically it has arid, semi-arid and sub-humid conditions. The average annual rainfall of the State is about 91 cm. Of which monsoon season accounts 80% rainfall in CAP and TLNG, while in Rayalseema 60%. The average rainfall of the State is 602 mm during southwest monsoon and 203 mm during Northeast monsoon (October-December). 65% of the area is rainfed.

About 29% area of India is drought prone. During 1800-1996 period, there were 40 drought years, of which 5 were severe (more than 39.5% of the area affected) and 5 were phenomenal (more than 47% area affected).

9.5 Drought Assesment

Drought is a creeping process, its assessment is difficult because it does not involve in any structural damage as in case of cyclones and floods. Qualitatively the adverse effects of drought reflects in human suffering, animal health, groundwater table depletion, surface water sources drying or shrinking abnormally and resulting in shortage of drinking water, for irrigation and power generation, fall in crop and fodder production. The creeping of drought reflects in migration of agricultural labour seeking employment, steep rise of prices of commodities, increase in thefts, crimes, robberies, abnormal farmers sale of livestock, gold, silver articles at low price, falling trend in daily wages, overall subdued sale in market yards, people movement in buses and trains, fall in gathering of people in festivals, market places.

Drought Assessment through Remote Sensing

This is based on vegetation index. The pigment in plant leaves, chlorophyll strongly absorbs sunlight in visible spectrum (VIS 0.4-0.7 μm) in the process of photosynthesis. The cell structure of the leaves strongly reflects radiation in near infrared spectrum band (NIR 0.7 - 1.1 μm). Healthy plants with high leaf density absorb more incident visible light and reflect large portion of the NIR. Plants of improper growth or diseased reflect more of VIS and less of NIR radiation.

Vegetation Index defined by NDVI (Normalised Difference Vegetation Index) as

$$\text{NDVI} = (\text{NIR} - \text{VIS}) / (\text{NIR} + \text{VIS})$$

NDVI mostly derived from the satellite data of AVHRR (Very High Resolution Radiometer) on board of NOAA polar orbitting satellite for over 20 years on global scale. Long term averages of NDVI compiled which are used for finding current seasonal anomalies. Thus NDVI is used as a proxy indicator to measure the meteorological / Agricultural drought. The vegetation index condition classes for drought is given below.

Change in Vegetation Index with respect to normal year	Drought classification
Less than – 50%	Severe
Less than – 10%	Critical
+ or – 10%	No change (normal)
More than +10%	Above normal

The above method has a drawback because of cloud covereage.

The assessment of drought based on NDVI is useful to have basic overview of risk areas.

9.6 Drought Parameters

The main parameters of drought are :

(i) Rainfall, (ii) weather, (iii) crop condition, (iv) water availability for drinking and irrigation.

During drought water crisis arises – short supply of water for drinking, washing and growing food. Ground water levels fall steadily. This may be mitigated through planning of pumping wells for ground water use.

Drinking Water

Recent droughts in Andhra Pradesh showed that a lot of time of women and children wasted in procuring drinking water, the cost of fetching drinking water through labour increased abnormally (Rs 10/ per 25 litres). To mitigate drinking water permanent solution is to be sought. Recharge near domestic ground water sources and enforce restriction for irrigation, industrial use. There must be sufficient space between domestic and agricultural wells. Observe strict descipline against water pollution. Create surface and ground water reserves that suffice the domestic need during dry season and drought. Panchayat Raj institutions (PRI) should enforce collective responsibility in protecting drinking water resources and ward off for other use. Establish or increase low check dams, re-establish shallow aquifers around the water resources. De-silting and strengthening of tanks should be given priority during summer when the water is lower dried up. Community must be involved in this work.

Groundwater

Storing water underground appears to be the best solution for many water problems. Groundwater offers greatest potential for many profitable uses, particularly when water is scarce. The first few hundred meters of earth's crust contains more than million cubic kilometers (km^3) of water. These reserves are much more than the surface water. As compared to surface water, in most of the cases, groundwater safer from pollution. Generally groundwater immediately protects from failure of rain. Groundwater reservoirs are free from sedimentation, evaporation and pollution unlike the surface dams. It is wiser to replenish the groundwater by percolation pits and percolation dams as compared to river water which flows unused into the sea.

Groundwater is a renewable resource. It is mainly recharged by rain namely rainfall amount, intensity and frequency. Groundwater follows the topography, that is drainage basin coincides with groundwater basin. Groundwater is a function of topography, geology, drainage patterns and climatic conditions. Its distribution, movement and quality depends on number of aquifers, their composition, aerial extent and hydraulic parameters. Groundwater is the world's most extracted rawmaterial.

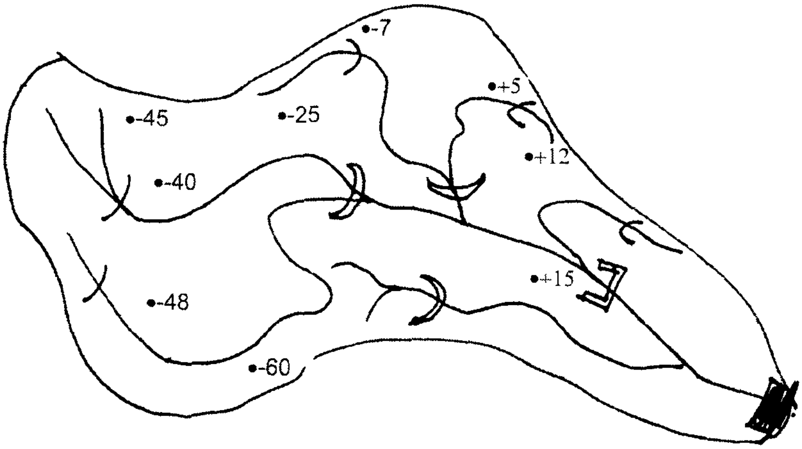
Groundwater levels decline during drought. Grooundwater management for drought mitigation is its monitoring and conservation. The basic unit of groundwater management for drought mitigation is watershed (village) or groundwater basin which is also monitoring unit. Long term monitoring indicates drought in advance, short term monitoring during drought in affected area indicates severity in association with long term data. Groundwater monitoring is done with piezometer (longterm data records) of special observation stations. Short term and close monitoring is done by measuring groundwater levels with regard to wells, which slowly dry up. Monitoring of groundwater levels and quality in a basin gives us the status, namely, decline or improvement in the area (village). This information is used to plan recharge measures for mitigation. The Fig. 9.3 shows a typical groundwater basin, monitoring and planning of rainwater harvesting structures.

Promotion of shallow wells serves as soil and water conservation unit. Diversion of run-off required to dried or defunct wells or pits. Shallow wells may be used for irrigation while deep wells may be used for Rural water supply. Groundwater recharge is a must where groundwater is freely used. Recharge structures are cost-effective. Nationwide groundwater recharge programme seems to be the unique way to combat drought and it is also a solution for the second green revolution in India. For sustainable development the participation of local people is very essential in monitoring, accounting and planning of the resource.

Watershed Development

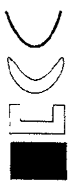
Contour bunding, construction of micro-level check dams, percolation tanks, afforestation, pasture land development, soil and moisture conservation measures to be taken up by the communities themselves through watershed association.

In 1999-2000, NABARD (National Agricultural Banking and Rural Development) established watershed Development Fund (WDF) to enable States to access credit for treatment of large areas under watershed Development (particularly wasteland development) and large scale Social Forestry and Agro-Forestry Programme, Rural water supply schemes.



-ve numbers show declining levels

+ ve numbers show above normal level



Minipercolation tank

Percolation tank

Micro Irrigation tank

Sub-surface dam.

-ve numbers indicate stations where groundwater level falling and where exploitation of groundwater needs ban.

Fig. 9.3

Contingency Agriculture Plan

In order to compensate the shortfall in Kharif production, under minor irrigation sources like tanks and wells (under Rabi) with the available water dry crops to be raised and also cash crops like groundnut, pulses be undertaken. Under contingency agriculture plan, short duration crop seeds, plant protection chemicals and fertilizers, be provided with subsidy. Similarly short duration pulse crops – redgram, greengram, blackgram be undertaken under subsidy. The Direcor Agriculture is responsible for implementation of contingency agriculture plan in the affected areas.

In addition to the above the following alternate enterprises and occupations are advised.

Enterprises : Dryland horticulture, Livestock production, Goat rearing, Poultry, Apiculture, Mushroom culture, Sericulture, Agrobased industries etc.

Occupations : Basket making, Rope making, Pot making, Carpentary, Pickle making, Broom making, Collection and sale of minor forest products etc.

9.7 Role of Banking, Insurance, Microfinance in Drought Mitigation

Bankers have a major role in providing relief and rehabilitation assistance to the drought affected people.

RBI gives instructions to provide flexibility in measures commensurate with the district situations.

The General Guidelines are :

1. Conversion of crop loans into medium term loans depending on crop damage (declared by district collector).
2. In case conversion/rescheduling of short term loan to medium term loan is pending, fresh loans are sanctioned for seasonal agricultural operations to farmers.
3. In drought affected area financing will be provided to minor irrigation activities.
4. Financing will be provided for purchase of cattle feed and fodder.

   Crop insurance scheme was started on 24 June 1999. It is now titled as "National Agricultural Insurance Scheme" or Rashtriya Krishi Bima Yojana. The scheme will cover all the farmers (including commercial and horticultural crops) recommended by General Insurance Corporation of India. The premium rates vary 1.5% to 3.5% (of sum insured) in respect of food crops and cereals, 3.5% for Bajra, and oil seeds. 2.5% for other Kharif crops, 1.5% for wheat, 2% for other rabi crops.

Note : Crops grown in southwest monsoon are called Kharif, and that are grown during post monsoon are called Rabi.

Main Kharif Crops are : Rice, Sorghum (kharif), Bajra, Maize, Ragi, groundnut, cotton.

Main Rabi crops are : Wheat, Sorghum (Rabi), gram.

Other Commercial crops : Sugarcane, tobacco, potato, Jute, tea, coffee, coconut, rubber, and other crops like spices, condiments. Some are seasonal, some are annual and some are perenial. The scheme is operative only for notified crop for widespread calamities, individual localised calamities (hailstorm, landslide, cyclone, flood). Risks covered for crop yield losses (due to non-preventable hazards) like natural fire, lightning, thunderstorm, hailstorm, cyclone, flood, landslide, drought, dry spells, pest and deseases. However the losses arising out of war, nuclear chemical accidents, malicious damage etc., are excluded. General Insurance Corporation covers for cereals and pulses. United India Insurance company Ltd covers banana crop insurance. New India insurance company Ltd operates sugarcane crop insurance.

Micro-finance is a helping hand in drought mitigation. Women Self Help Groups may be provided soft loans at nominal interest to mitigate the drought impact. With these loans, SHGs can make earnings with traditional skills in embroidary, netting, pottery, pickle making, sewing clothes, selling vegetables etc.

9.8 Drought Monitoring

Drought, particularly attracts the distress and severity situation of food, drinking water, fodder, employment and health. The District level drought monitoring has to be done for each village, The State level drought monitoring has to be done for each district. It is the responsibility of District Relief Officer or Joint Collector at the district level management and monitoring of drought. At the State level it will be responsibility of Commissioner for Relief.

Disaster Management at District level

Control room will be set up at District collector's office. District Relief officer nominates a responsible officer to be in-charge of control room, who will monitor the reports received from Mandal Officers. Control Room should prepare maps and charts showing the affected areas and severity of drought. At district level, District Relief officer monitors the situation about food, employment, drinking water, fodder and health for each village or Panchayat and takes necessary timely action.

To monitor the rainfall distribution, agricultural progress after 15 June for two months, a committee will be constituted with the following departments.

1. Drought monitoring cell
2. IMD
3. Irrigation and Command Area Development Department
4. Agriculture Department
5. Animal Husbandary Department
6. Panchayat Raj and Rural Development Department
7. Research and Development Department.

9.9 Drought Research Unit (IMD)

After 1965 and 1966 prolonged severe drought, at the instance of Planning Commission, Drought Research Unit started in 1967. The main objectives of this unit are : 1. Agroclimatic and synoptic study of droughts 2. Development of formulae for forecasting yield of principal crops in India.

To meet these objectives DRU (IMD) taken up 4 activities.

1. Preparation of Aridity Anomaly maps for the kharif season (June-September) on weekly basis, for all Met. subdivisions (MSDs) of India. Preparation of Aridity Anomaly Reports for Northeast Monsoon (October - December) for 5 Met Subdivisions of Coastal Andhra Pradesh, Rayalaseema, South Interior Karnataka, Kerala, Tamilnadu and Pondicherry. These maps and reports are disseminated to the various Agromet Advisory Services units and Agricultural specialists. These maps are useful in monitoring Agricultural droughts over the country.
2. Analysis of average daily rainfall of various districts in the Dry farming region of the country is achieved by obtaining conditional and simple probabilities of Dry and Wet spells using Markov Chain Models. In order to promote Dryland agriculture short period rainfall (weekly) probability analysis for nine States in dry farming track is done by fitting incomplete Gamma Distributrion Models by bringing out the assured rainfall of different decile levels. This information is further used to delineate different States into various rainfall pattern zones. Based on weekly assured rainfall and potential evapotraspiration nine States in the dry farming track delineated into different Agroclimatic zones to bring out crop growing period.
3. Crop yield Models developed for Wheat and Rice using corelation and regression techniques for MSDs, using an MSD as unit. This covered the entire crop growing areas of the country.
4. Using these models, monthly interim forecasts are prepared by DRU during the respective crop growing seasons, both for Rice and Wheat. These forecasts are supplied to Planning Commission, Directorate of Economics and Statistics, Ministry of Agriculture and Irrigation and other user organisations for planning purposes. The first interim forecast for Rice is issued during August and final forecast during November/ December. Similarly, in the case of wheat, the first interim forecast is issued during January and final forecast during April. Models on districtwise basis developed for crops like Jowar and Bajra grown in Dryland farming areas.

At the instance of National Commission of Agriculture, Agromet Advisory service Centres are established by IMD at the State Capitals and other crutial important places. These Centres issue Weekly or Biweekly Agromet Advisories tailored to the needs of the farmers on their field operation, which are broadcast on AIR. These bulletins are prepared in coordination with the Agricultural expert of the State Agricultural Departments and the meteorologists from Agromet Advisory Service Centres.

9.10 Rainwater Harvesting

It is amply clear that rainwater harvesting, groundwater recharging are potential drought proofings. The ultimate solution to the drinking water problem is rain-water harvesting, which is primary source of water for the past human history. In arid and dry areas of India ingenious rainwater storage tanks have served our needs. Rainwater harvesting consists of water storage and water recharging (percolation pits, Watershed management). The cost-benifit ratio is that the cost of purifying about 150 litres of water per day, per head far exceeds the cost of rainwater storage. For the WHO specified requirement of 5 liters of water for drinking and cooking exerts enormous pressure on energy resource.

Basis

1. Rainwater harvesting simply means the collection of rainwater that falls on the roof of a house, apartment, complex, commercial building, office, factory etc.
2. Roof water may be channelised through a drain pipe and allow the collected water to flow into a well or a storage tank after filtration. If it goes into the well it will add to the ground water table.
3. In coastal areas, close to the sea this process limits the sea water seeping into the groundwater table.
4. In residential complexes which are facing water supply problem, the stored water may be used for consumption.

Harvesting System

Collect the rainwater from house tops, terraces, courtyard or lawns by water flow. This catchment of water diverted to harvesting (or storage) system through pipes. It will be allowed to settle in the tanks. This will clean the rainwater from impurities and also act as buffer to store water. The insoluble impurities settle down at the bottom of the tank, from where water is purified/filtered and then allowed into storage facility or recharge. Underground tanks are made of brics/ RCC or old abondoned water tanks can be used as settling tanks. The bottom and sides of this tank should have loose rubble and bricks to allow percolation. The bottom of the tank must be filled with sand, gravel or metal to filter impurities.

Storage

A shallow depth structure (like a trench, bore, open well) is connected to the housing complex's water supply tank. A recharge pit can be constructed adjacent to a well in the compound. The well acts as a storage facility.

In order to keep water fresh

First week should be runoff, to avoid collecting dust.

Storage tank should be properly sealed.

Make sure sunlight does not enter the tank.

To keep the water tank clean chlorine or lime can be used.

Contaminants

Contaminants of water may be (i) Heavy metals (ii) POPs (Persistant Organic Pollutants) and (iii) Other Chemicals. Water contamination occurs due to dumping of chemicals, human waste, garbage in water, if water supply lines are close to the sewage lines and slums, pesticides, fertilizers, acidification of water bodies due to air pollution (like oxides of sulpher). Chemicals like Arsenic, Lead, Flouride present in the water more than critical (safe) limit is hazardous for drinking purpose. Some water bodies are becoming breeding grounds for Malaria (Dengue) and other insects that thrive in the filth. Unhygenic surroundings are the places for the growth of bacterial, viral and protozoal infections, skin ailments and respiratory problems.

Filtering water (Straining) : Any dirt or floating sediment should be first strained with clean cloth (folded at least eight layers). Then it should be boiled, filtered and chlorinated.

Solar Treatment : Exposing water to sun's rays, kills or invalidates many germs.

Boiling : Water should be boiled at least 10 minutes before drinking.

Disinfection : Chlorine, Bleaching powder etc., can help improve water quality (these are very simple, but should not exceed doses).

With all development, even now, more than a thousand people die every day due to water related ailments. According to 2004 UNICEF study of India claims that only a third of the population has access to adequate sanitation facilities. Poor water quality, sanitation and waste management leads to a plethora of maladies.

Preparation and Dissemination of Disaster Management Advisory Messages

As soon as the IMD/CWC/NGRI detects the respective field hazards and issues warning about the hazard, its intensity, location, movement and hazard associated dangers and its forecasts, the SDMA/SDM advisory committee or collectively state Disaster Management Unit (SDMU) shall prepare Disaster Management Advisory messages and disseminate to the District and local authorities.

Preparation of Disaster Management Advisory Messages by State Disaster Management Unit and it dissemination to the stakeholder is the key responsibility.

Great case has to be taken to prepare the messages in simple unambiguous language and easily understood by the recipients. The advisories are to be disseminated by fastest and most reliable channels so that even in most adverse situations they are to be delivered to the appropriate recipient groups. In general the following stakeholders are identified for the purpose.

1. ***Originators (SDMU)*** : Sate Disaster Management Unit prepares and disseminates the advisories.
2. ***Intermediaries*** : Government decision makers, who respond to the advisories, organisations employed for cascade communication including communication media.
3. ***Receivers and Responders :*** Organisation that receive the advisories and respond, and may also act as intermediate dissemination agents.
4. ***Affected***: The public at risk. Stakeholders are an important component of an affective advisory system.

The Recipients of Advisory Messages : The advisory should reach the following bare minimum administrative hierarchy of disaster management.

(i) State level Disaster Management Authority

(ii) District level Disaster Management Authority

(iii) Local Authorities of Disaster Management which include Mandal level and Panchayat level Disaster Management Authority.

The Recipients of Government Departments include: (a) Decision makers, (b) Administrators, (c) Implementing authorities. There cannot be rigid boundaries of jurisdiction of the above functionaries. It is possible that an administrator has to play the role of a decision maker.

It must be noted that different recipient groups require different levels of detail advisory messages. The State Disaster Management Unit which possesses broad information of districts at risk and level of rist like river flooding status.

At District level (District Disaster Management Authority or District Collector) (DDMA) will have names of mandals exposed to the risk with time and period of the event of occurrence (say flood).

At mandal level Mandal Disaster Management Authority or MROs) will have villages/ areas exposed to risk (say inundation, windfury, tidal waves etc). This also includes the number of people, livestock, crop area, roads, tanks, reservoirs. Public in general will have warnings about Do's and Dont's.

A model of action in dissemination of disaster management advisories in the events of floods is given below:

Recipient	Message type	Dissemination Channel/media
1. State Disaster Management Unit	D	Internet
2. National level/central, Central Water Commission, NGRI, Railways	D, 1, 4	Fax, Email
3. Sate level		
(a) Chief Minister	D, 1, 7	Fax, Email, Internet
(b) Secretariat		
(i) Secretary Finance and planning	D, 1, 7	Fax, Email, Internet
(ii) Commissioner for Relief	D, 1, 7	Fax, Email, Internet
(iii) Secreatary, Irrigation and Command Area Development (CAD)	D, 1, 7	Fax, Email, Internet
(iv) Commissioner Civil Supplies	D, 1, 7	Fax, Email, Internet
(v) Secretary, Transport ,Roads & Buildings	D, 1, 7	Fax, Email, Internet
(vi) Secretary, Energy	D, 1, 7	Fax, Email, Internet
(vii) Secretary, Information, Technology and Communication	D, 1, 7	Fax, Email, Internet
(viii) Secretary, Panchayat Raj and Rural Development	D, 1, 7	Fax, Email, Internet
(ix) Secretary, Health, Medical and Family welfare	D, 1, 7	Fax, Email, Internet
(x) Secretary, Agriculture	D, 1, 7	Fax, Email, Internet
(xi) Secretary, Animal Husbandry and Fisheries	D, 1, 7	Fax, Email, Internet
(xii) Police Department HQ	D, 1	Fax, Email
(xiii) Fire Service - HQ	D, 1	Fax, Email
(xiv) BSNL (Department of Telephones)	D, 1	Fax, Email
(xv) Irrigation Department Project sites	9, 1, 4	Voice, Fax
4 District level		
(i) District Collectors of Coastal districts and other conserned districts	D, 2, 7	Fax, E-mail, Internet
(ii) Revenue Divisional Officers	9. 2. 3	Voice, Fax, E-mail
(iii) Irrigation Department, Circles	9, 1, 4	Voice, Fax
(iv) Police Department-Districts	9, 2	Voice, Fax
5 Mandal level		
(i) Mandal Revenue Officers (MROs)	9, 2, 3	Voice, Fax
(ii) Irrigation Department-Division	9, 2, 4	Voice, Fax
(iii) Police Department-Division	9, 2	Voice, Fax
6. Public, General public	6, 10, 8	DD/AIR, Internet

In addition to the above Album page warness, particularly for coastal plain and delta areas are recipients (warned) of advisory messages.

Types of Advisory Messages : Depending on the availability of data advisory messages are prepared.

***Message D* :** Daily messages issued during the season for cyclones : April, May, October, November, December. For Floods/Heavy rains: Monsoon months, in addition to cyclone period.

***Message* 1 :** This advisory message gives details of the state-wide flood situation. On a map of state or river basin/sub basin, with demarked districts, flood inundation status will be depicted with colour codes and legend. Specific advisory messages for the rivers, giving details of water levels at different gauge stations along with other important information.

***Message* 2 :** This advisory message gives details of the flood situation in a specific district. On the district map with mandals and important villages demarked flood inundation status will be shown in colour codes with legand. The present flood status together with flood forecast for the madals for different lead times would be given in a tabular form.

***Message* 3 :** This advisory message will have the format like Message - 2 and in addition it will provide population likely to be affected, the number of livestock affected and potential damage to crops, roads, bridges etc., will be given. The recipient of a specific mandal would have to go through all neighbouring mandal data to abstract information relevant to it.

***Message* 4 :** This advisory message is meant for Central Water Commission and irrigation Departments. The message will contain details of forecasted water levels for different lead times at different forecast stations gauging points and includes Warning levels or danger levels of existing forecast stations/gauging stations.

***Message* 5 :** This message is meant for internal dissemination in the Disaster Management Unit. This message contains the details of advisory messages and instructions if any.

***Message* 6 :** This message is meant for general public, that is to be informed or tom tomed.

***Message* 7 :** This message gives web based Flood Watch output. It contains prediction information, tabular forecast data and the likely effect on the available GIS data bases like hospitals, roads, cyclone shelters, relief camps etc. This may include snapshots of forecast inundation showing principal roads, towns, mandals, railways, tanks, rivers and status of raingauges, rainfall amounts, rainfall isohytes, river stages at various gauging points, IMD predictions and districts affected.

***Message* 8 :** This message is meant for general public and contains relevant information as in Message - 7.

***Message* 9 :** This is a voice message alerting the recipient of flood advisory and instructing him/her to contact the higher officials for further information.

***Message* 10 :** This message is meant for dissemination to the general public through AIR/DD and interested or designated private TV channels (local cable TV companies or operators). The message contains the present status and forecast flood situation and Dos and Dont's in grave situation.

The Communication Channels

The Communication channels are :

1. ***Primary network*:** Communication networks of State Government, like Local Area Network (LAN) used in secretariat .
2. ***Secondary networks, Internet :***
3. ***Tertiary Networks* :** Departmental networks and the official public broadcasting media.
4. ***Other Networks*:** Private networks – cable TV companies and Cellular networks.

Primary network example LAN used in Secretariat

SWAN - State-wide Area Network

BSNL - Bharat Sanchar Nigam Ltd.

In Andhra Pradesh Secretariat Campus network and Local Area Network is in use in various Government offices at different locations.

SWAN is extended upto district Head Quarter, which may further be extended to Mandal HQs and to villages. SWAN is a backbone for voice, data and video communication throughout the State. State-wide video conferencing facility enables face to face conversation of Government functionaries from different locations of the State. This facility connects State Secretariat with all district collectorates. There exists satellite based communication network using KU-band transponder to link schools, colleges, Health care.

DoT Network (Department of Telephone Network) is most widespread and has alternate routes (Conventional cables and optical fiber cable network). This cascade connectivity extends upto village level. State Disaster Management Unit thus disseminate advisory messages upto Mandal level freely.

***Secondary* :** Internet has a wide reach. This one is one of the best mode for dissemination of advisories to general public.

Tertiary : In addition to the State Government network, some departments have their own established communication networks. For example Police Communication network by HF and VHF. State HQ is connected to District HQs by Hot lines.

Police stations within each district are connected by HF (for data/tect transfer). Police communication network is most useful of voice and text transfer during disaster period.

Irrigation and Command Area Developement Communication Network : The offices of the Chief Engineers, Superintending Engineers and Executive Engineers are equipped with Telephones and Fax facilities. In addition VHF wireless communication is available with the office of the Chief Engineers linked to various project sites (in Andhra Pradesh seven project sites at Dowleshwaram, Sriramsagar, Singoor, Nizamsagar, Nagarjunasagar, Srisailam, Prakasam Barrage are linked).

In addition to the above, there are project wireless stations under National Hydrology projects.

Railway Communication Network : This is available with the Railways, which may be pressed into service for dissemination of SDMU advisory messages.

SDMU could provide AIR/DD with the advisory messages for dissemination through their broadcasts by interuption in routine broadcasts. The AIR staff could read these SDMU advisory messages during the news programmes and also as flash messages. SDMU could provide Door Darshan with the advisory messages and the likely affected area graphics or whenever possible satellite images of cyclones, flood inundation, actual heavy rainfalls and inundation scenes for dissemination during its telecast. DD staff could read these advisory messages during News programmes and as flash messsages. In additon DD could display the advisories as running "text strings" at the bottom of the screen throughout the telecast period.

Private T.V channels and cable T.V companies may also telecast the SDMU advisory messages and running text strings at the bottom as frequently as possible during their programme breaks.

ISROS Desi Google maps of cyclones, flood inundation, flash flood etc., may be obtained and telecast with the advisory of Do's and Dont's in the likely affected area.

VSAT (Very Small Aperture Terminals)

VSAT are small software-driven earth stations, used for the reliable transmission of data, video or voice via satellite. Its working depends on to pluging into the telemetry terminal equipment. A VSAT network consists of a central hub (master earth station), many remote VSATs and the satellite transponder space segment. The hub station will be located (at SDMU) at the Command Control Centre. A

VSAT is located at each end-user location, which can be connected/linked upto several thousand sites. In communication system there are two segments in the network of transmission

(i) Earth segment, which consists of the equipment at the hub and VSAT locations and

(ii) The space segment, which is the link to-and-from the satellite.

The VSAT equipment consists of two units. One is placed outdoors for a line-of-sight to the satellite and the second is placed indoors to interface with the users communication device. The outdoor unit consists of a small antenna, mount and electronic equipment for transmission and reception. The indoor unit is a small desktop box, consisting of receiver and transmitter boards and in interface to the users equipment. Both these instruments are connected via cabling. VSAT networks provide very good performance as compared to other routes of communication.

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CHAPTER - 10

Earthquakes

Introduction

An earthquake is a detonation of a system underground that develops under suitable conditions of nature of fault and time. ChangHeng, a chinese philosopher invented the first earthquake recording instrument in 132 A.D, which detected an earthquake that occured at a distance of about 640 km (400 miles) away and it was not felt by the people at the site of the instrument. The mechanism of the instrument however was not known to others. Nowadays earthquakes are recorded by a seismographic network of intruments.

Earthquakes belongs to the natural hazards, associated with the geological events and stands first in natural disasters (see world's worst natural disasters in chapter1).

The Main Types of Earthquakes are

(i) Tectonic, (ii) Volcanic and (iii) Plutonic.

During an earthquake the slip of one plate (very huge block of rock) over another plate releases energy that causes the ground to vibrate and this process continues. In this way earthquake energy travels in a wave form.

Different aspects of an earthquake are measured by different ways, of this magnitude is the most common. It measures the size of the fault at the earthquake source which is commonly measured by Richter scale. Richter scale measures the wriggle (twist and turn) on the recording, but other magnitude scales measure the different parts of the earthquake.

Intensity is a measure of the shaking and the damage caused by an earthquake. Logarithemic magnitude scale measures the size of the earthquake, this is called ML scale (where M stands for magnitude, L stands for Local). This is eventually became the Richter scale. This scale is valid for certain frequency and distance range.

On similar lines of Richter ML Scale, bodywave magnitude - MB, and surface wave magnitude - MS are developed by Japanese. MB and MS scales are used beyond 6.5 and 8.3 magnitude respectively. It is observed, during the formation of an earthquake, temperature near the epicentre region rises. The susceptibility of matter is inversely proportional to the absolute temperature while the permeability of the matter varies with temperature. The variations of susceptibility and permeability changes the earth's horizontal magnetic field, Dip and Declination. Hourly changes of these magnetic elements and temperature may provide us a clue for forecasting the occurrence of an earthquake (which is lacking at present).

10.1 Interior Structure of the Earth

Seismology is the science of earthquakes. In order to understand the nature of seismic wave propagation and detection, a quick survey of the interior structure of the earth is essential.

The interior of the earth consists of : Lithosphere or earth's crust, Mantle and Core.

The earth's outer shell or layer is called crust or Lithosphere. Litho – means stone. Earth's crust is not monolithic but divided into strata. The top structure is made of sediments or sedimentary rocks, the second layer is made of granite rocks, and the third layer is made of basaltic rocks. The density of rocks increases, basaltic > granite > sedimentary rocks. The three crust layers, are found everywhere in continents. However under oceans the granite layer is missing (see Fig. 10.1).

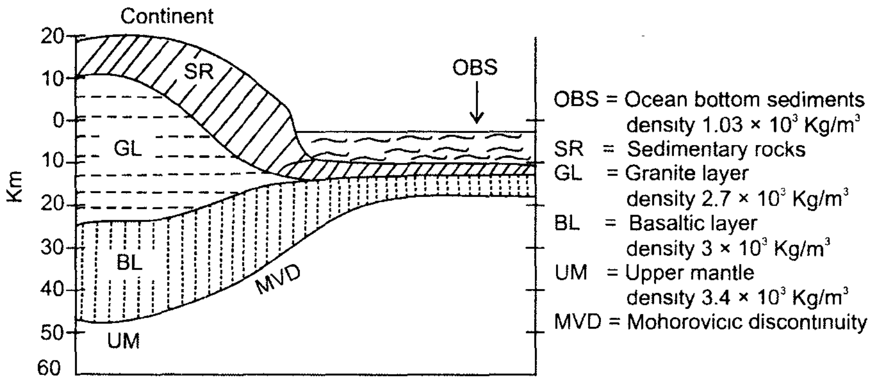


Fig. 10.1 Constituents of earth's crust.

The boundary between the sedimentary and granite rocks has not been given any name, the boundary between granite and basaltic rocks is called Konard discontinuity. The boundary under basaltic (between Crust and Mantle) is called Mohorovicic or simply Moho discontinuity.

The average thickness of the crust is about 35 km, which is very thin compared to the radius of the earth (about 6400 km). The average thickness of the earth's crust under oceans is 5-10 km, while its thickness below continental mountain ranges is about 50 km. The average density of the earth is 5.5×10^3 kg/m^3, Lithosphere 2.8×10^3 kg/m^3, Mantle 3.2 to 5.7×10^3 kg/m^3 and core 9 to 12×10^3 kg/m^3. The mass of the earth is about 6.00×10^{24} kg, Lithosphere 5×10^{22} kg, Mantle 4.05×10^{24} kg (68% of the earth) and core 1.88×10^{24} kg (31% of the earth). The depth of the Mantle is about 3000 km and Core is 3000 km.

A discontinuity means an interface and indicates marked change of material property. Below the earth's crust lies Moho discontinuity (at an average depth of 35 km, where density is 3.3×10^3 kg/m^3) which separates the earth's crust from Mantle (the interior of the earth). The Central Core (below the Mantle) probably consists of liquid outer core (thickness about 2000 km) and solid inner core (thickness about 1000 km). Gutenberg discontinuity seperates the Mantle from the central core and is located at a depth of about 3000 km, where the density is about 5.7×10^3 kg/m^3. There is still uncertainity about the composition of materials in the interior of the earth. It is generally viewed that the principal constituents of Lithosphere as oxygen (93.88%), Silica, Aluminium, Iron, Calcium, Sodium, Potassium and Magnesium (granite and basaltic rocks) all together they makeup 98.5% of the earth's crust by weight, Earth's crust mostly contains Sial (Silica, Aluminium compound) and Sima (Silica, Magnesium compound).

Mantle consists of Oxygen, Silica, Mangesium and Iron (Iron, Magnesium Silicates). The common silicate in the Mantle is probably Olivine (Formula : [$(Mg\ Fe)_2\ So_4$]). These silicates are similar to those found in stoney meteorites. The core probably consists of iron, sulphure in the combined form as FeS and nickel (Fe, FeS, Ni). Core contains nife (Nickel, Iron compound).

The building blocks of Lithosphere are rocks namely Igneous, Sedimentary, Metamorphic rocks. Sedimentary layer is thick below the continents and becomes thin in ocean area, whereas the granetic layer almost absent (in ocean area).

The temperature of the interior of the earth increases with depth. In Lithosphere it increases about 1^0C for every 30 metres of depth, however this increase will not continue to the centre of the earth. Observations indicate that the average increase in temperature is about 1°C/km. The cause of the increase of temperature with depth is suggested to be :

(i) heat generated by the pressure of overlying rocks,

(ii) primordial heat (original heat from the time of the earth's formation), and,

(iii) by the radioactive mineral disintegration.

The interior of the earth behaves like solid elastic in respect of earthquakes and earth-tides. It is known that oceans rise and fall twice in 24 hours due to gravitational attraction of the Moon on Earth. In a similar way an earth-tide occurs in the earth's crust and Mantle which causes rise and fall about 30 cm under the action of the earth-tides. Geneva based synchrotron works only during complete rest period of the crust and it will not work even if there is slightest change in earth's crust due to ebbs and flows occuring far away from the unit. It is found, the Geneva Synchrotron operates about 30 hours a week and the rest period the surface of Switzerland is vibrating. It has been scientifically proved that the entire territory of Moscow daily rises or falls about 50 cm from a certain average level. This rise and fall is caused by the gravitation of the Moon and the Sun.

10.2 Plate Techtonics

According to Indian Cosmology the earth consisted at one time of seven continents joined together. They seperated like the lotus petals (or leaves) from Mount Meru, the centre of the universe. Afterwards the continents floated and drifted away from the centre and were saperated by seven oceans. An Amateur Russian Astronomer Y.V. Bykhanov observed a remarkable coincidence of the outlines of the American and Euro-African coastlines that they fit well without a crack if these were moved together. By this observation, in 1877, he conjectured that once a uniform continent split into parts and ever since they have been moving away. In 1910, Alfred Wagener (1880-1930), a German geophysicist propounded a theory of continent Panghela (all earth) was broken up into pieces like the lotus leaves, they separated from one another and floated away giving rise to the modern continents divided by oceans. In 1960's this hypothesis was further modified by the evidence of ocean floor structure and named tectonics of plate or global tectonics (See Fig. 10.3). According to this hypothesis, instead of continental move, plates of large areas of the earth's crust containing both continents and adjoining sections of ocean floor moved.

According to this plate tectonics hypothesis there are six major plates.

1. Euro-Asiatic plate,
2. African plate,
3. Antarctic plate,
4. Indo – Australian plate,
5 American plate and
6. Pacific plate.

In addition to these major plates there are several minor plates located between them and they move to some extent independently (see Fig. 10.2).

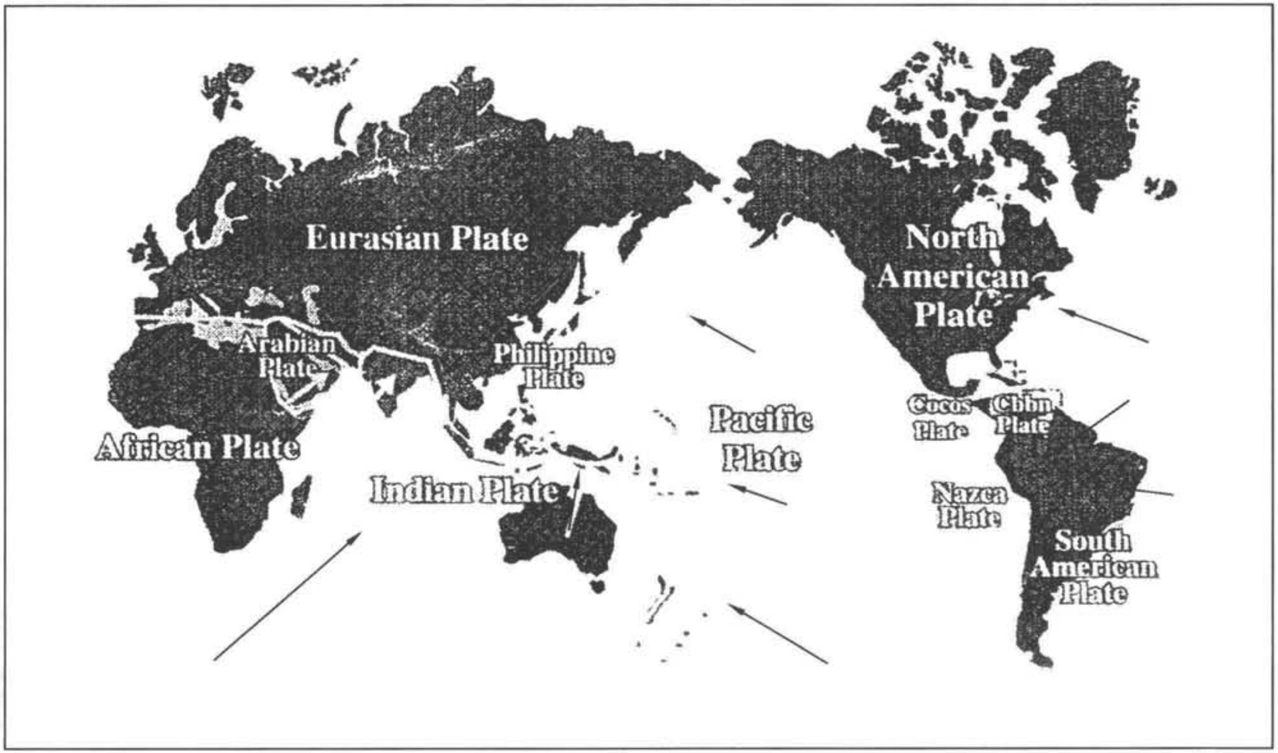


Fig.10.2 Major global tectonic plates and average direction of motion. Subduction occurs along colliding plates. After toksoz (1975).

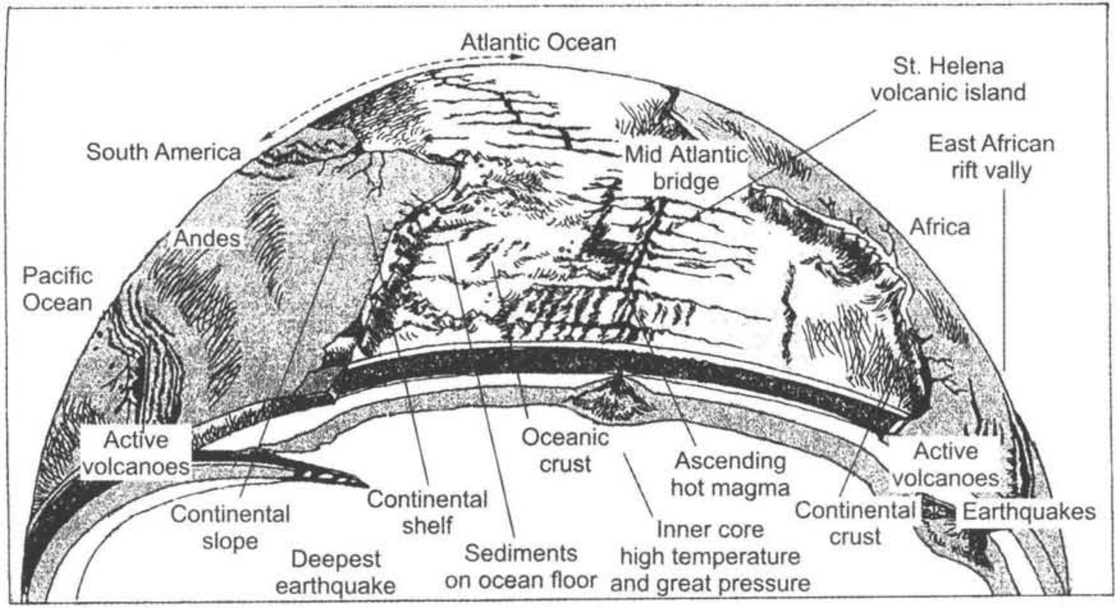


Fig.10.3 According to the sea-floor spreading theory, the splits in the mid-oceanic ridge are deep cuts in the surface of the earth (below the sea) from which molten rock gushed up to trigger earthquakes, thus moving the sea floor away from the ridge on either side.

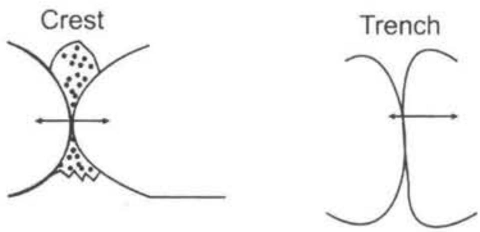
There are three types of Plate Boundaries

1. Extension or divergent boundaries
2. Compression or Convergent boundaries and
3. Transform faults.

Extension boundaries are formed when two adjacent plates move apart. Material from below swells up and a new crust is produced at the crests of the oceanic ridges. This makes both sides of the plates are added up with mass.

Compression boundaries are formed when two adjacent plates approach each other. In this case surface is destroyed. The line along which plate destruction takes place is called trench.

A third type of boundary forms when the plates move laterally relative to each other. The line along which plates move laterally is called transform faults. In this case neither crust is formed nor destroyed. It has been found that Eurasia and American plates are converging at a rate of 2 to 4 cm per year, while American, Eurasian and African plates are increasing in size and that of Indian and Antarctican plates are not changing significantly in size.



Fault : A fracture in a rock mass or rock layer whose opposite faces move independently is called a fault. The various types of fault, movements are shown in Fig. 10.4.

Folds : During tectonic movements stratified rocks develop bending. These are called folds.

Tectonics : According to one hypothesis earth's crust has large plates. These plates move due to convective forces that emanate from beneath the crust and create rifts. It is assumed that the upper Mantle consists of Newtonian Viscous fluid and the convection currents are generated due to heating from below or insitu. The lower Mantle consists of very dense fluid which inhibit convection. It is clear in case of divergent or extension boundaries a new crust is formed at the boundaries of these plates. All such boundaries are located in the oceans. The earth's crust building up towards American plate on one side and towards African and Euroasiatic plates on the other side. The plates collide at the boundaries which leads to (convergence or) submergence or subduction of one under the other plate. Such submergence taking place in case of Pacific plate under Euroasiatic plate. It is theorised that where old crusts are buried they provoke for earthquakes and volcanic eruptions. The present scientific thinking is that earthquakes are caused by the friction on the boundaries of the plates moving together. Powerful tremors are caused by the accumulated shear stresses which periodically exceed the rock strength. From the heating of the sedimentary layers of the submerging plate volcanic cruptions take place.

The various types of fault movement are shown below in Fig. 10.4.

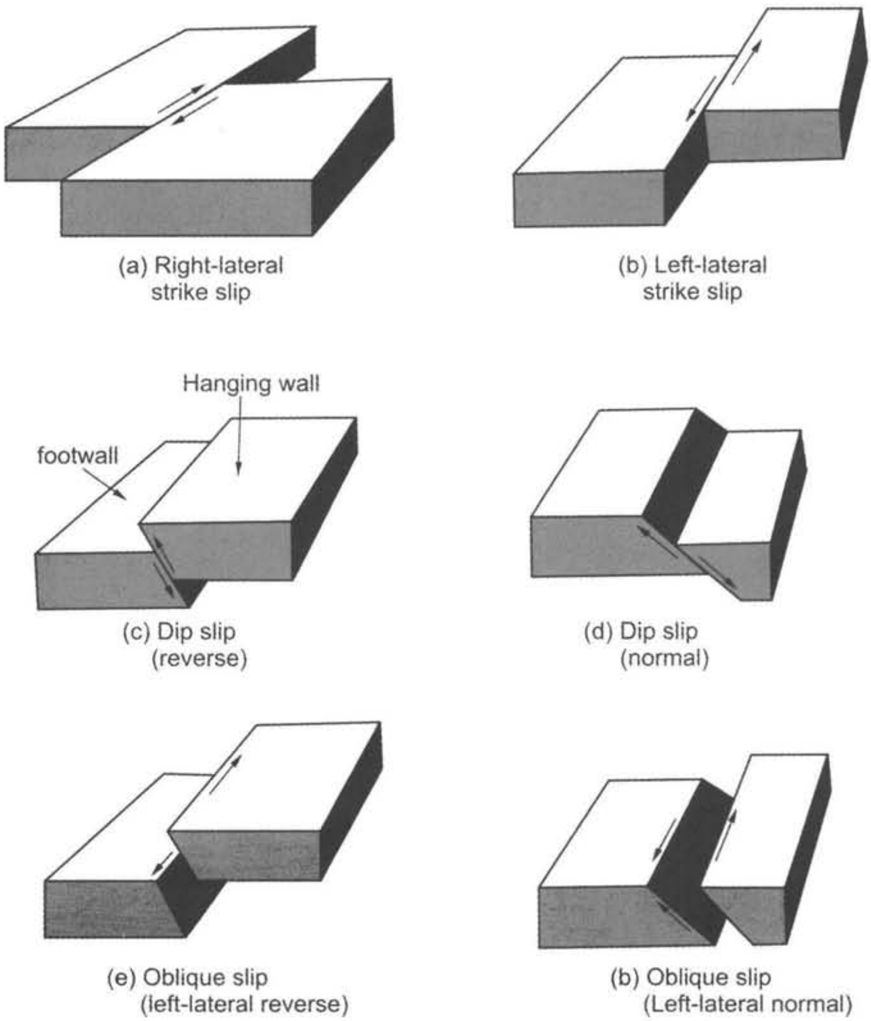


Fig.10.4 Various types of fault movement.

San Andreas is (a) type of fault; Himalayas has (c), (d), (e) and (f) types while peninsular India undergoes (d) and (f) generally. Here (c) and (e) are rare. Reverse faults are due to compression (shortening of the crust), whereas the normal faults are due to tension (stretching of the crust).

Earthquake waves

A disturbance which progresses from one point to another point in a medium with transfer of energy but without the transfer of matter is called a wave motion. Elastic waves are mechanical disturbances propagated in an elastic medium. A wave is called longitudinal or compressional if the particles of the medium vibrate in the direction of wave propagation. Longitudinal waves travel through solids, liquids and gases.

A wave motion is called transverse or shear if the particles of the medium vibrate at right angles to the direction of propagation. Transeverse waves travel through solids but not through liquids and gases.

An earthquake generates two kinds of waves. Primary or P-waves, which are compressional and travel through solids, liquids and gases. Secondary or S-waves, which are shear waves and travel only through solids. P and S-waves may not develop in actual displacement of a land mass on the surface crust.

Generation of P and S waves using springs as analogy shown in Fig. 10.5.

L-wave or long surface waves travel through surface layers of the earth.

Seismic wave motions are shown in Fig. 10.6.

The study of seismic waves produced by earthquakes provide valuable information about the nature of the matter inside the earth in its path. Seismic waves travel deep down into the earth from earthquake site and return to the earth's surface at some distant point. Seismographs are used to detect the seismic waves on their arrival at the surface of the earth. They also provide the information of type of the wave, its intensity and time of arrival. Speed of Seismic waves partly depend on the density of material through which they pass.

The markings of seismograph is shown in Fig. 10.7.

Earthquake Parameters are :

(i) **Time of origin** is the time at which earthquake has occured.

(ii) **Focus** is the point inside the earth where from the earthquake originated. See Fig. 10.8.

(iii) **Duration of an Earthquake** generally less than one minute.

(iv) **Epicentre :** the surface point vertically above the focus. It is expressed in latitude and longitude of the point. See Fig. 10.8.

(v) **Focal depth** is the depeth of the focus from the surface of the earth. See Fig. 10.8.

(vi) **Hypocentre** of an earthquake is the combination of epicentre and focal depth.

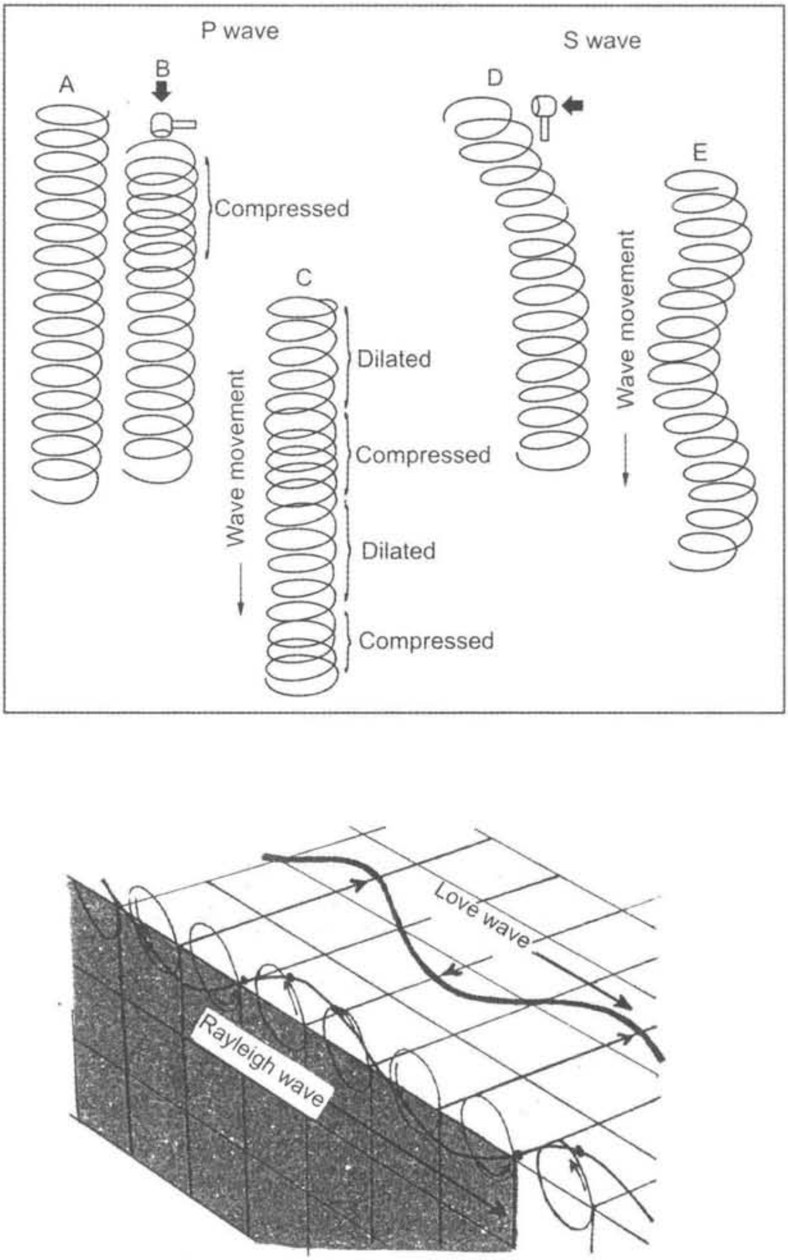


Fig.10.5 Generation of P and S waves using spring as an analogy. The figure below shows the oscillation pattern of Rayleigh and Love waves.

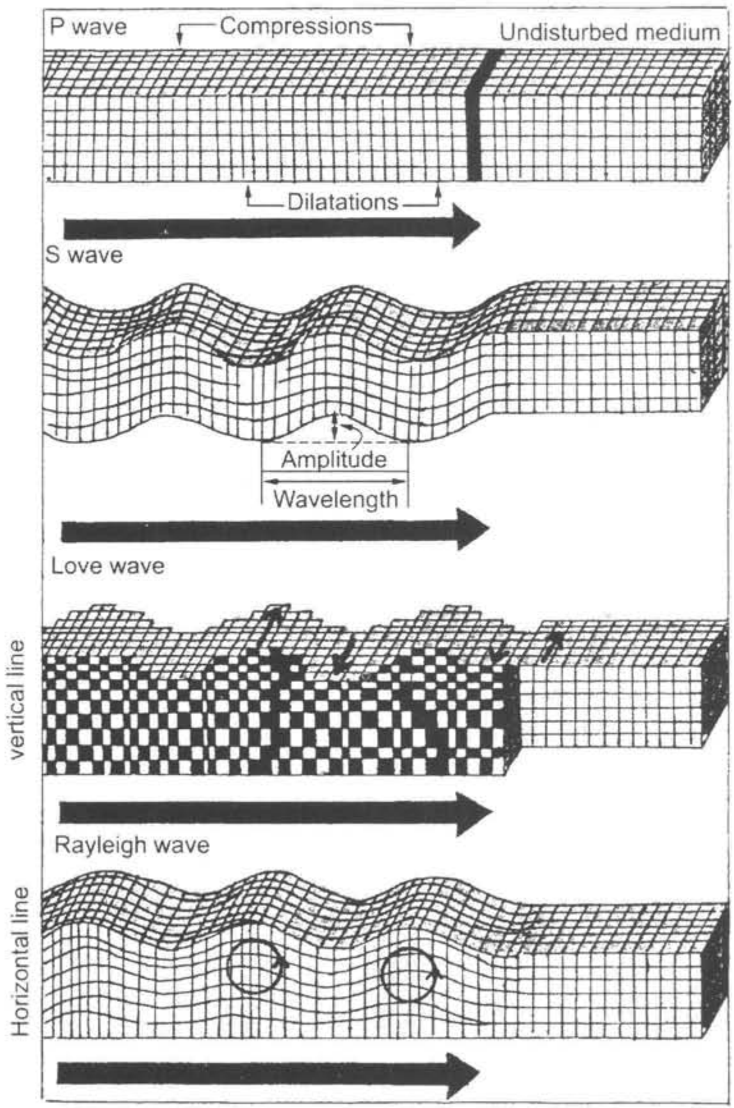


Fig.10.6 Seismic wave motions.

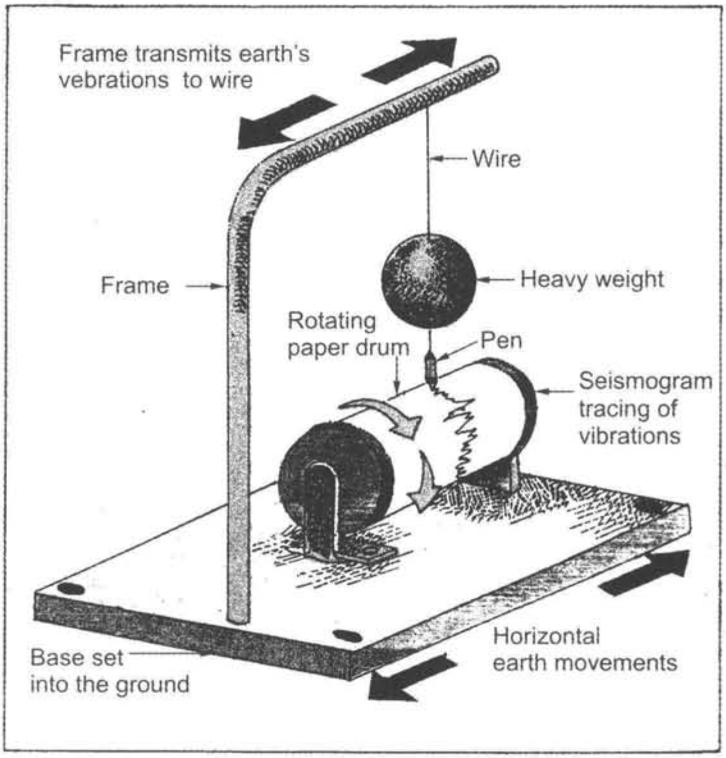


Fig.10.7 During an earthquake, the assembly together with the frame anchored into firm ground moves to and fro. A pen attached to the weight records the tremors on the paper covering the rotating drum.

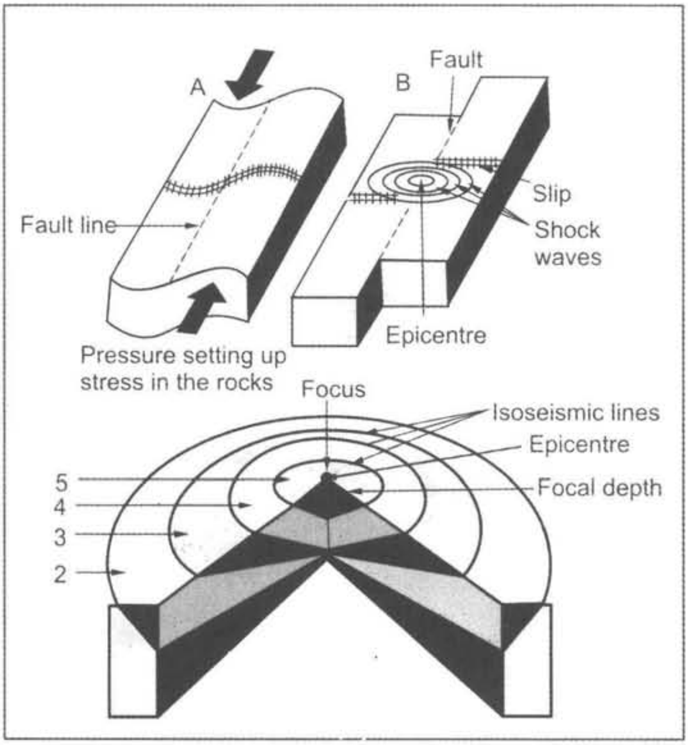


Fig.10.8 Earthquake waves begin from a point called focus located deep below the surface of the Earth. The nearest point above the focus on the Earth's surface is called the epicentre around which the maximum damage is caused. The intensity of the quake decreases as the distance from the epicentre increases. Isoseismals are imaginary lines on a map joining points of equal intensity. These are drawn based on damage survey, after an earthquake, according to modified Mercalli (MM) scale.

Classification of Earthquakes

(i) Shallow eathquakes have focal depth $\leq$ 70 km

(ii) Intermediate earthquakes have focal depth between > 70 km $\leq$ 300 km.

(iii) Deep earthquakes have focal depth > 300 km

Earthquakes have not recorded focal depth exceeding 720 km.

Magnitude (M)

The magnitude of an earthquake is a kind of instrumental measure of its size or energy (E), and is given by a linear equation

$$\log_{10} E = a + b M \qquad .....(10.1)$$

Or

$$E = 10^{(a + bM)}$$

where a and b are constants, E = Energy, M = Magnitude

The values of constants are generally found to be a = 11.8, b = 1.5

If M = 4, we have $E_1 = 10^{a+4b}$

M = 6 we have $E_2 = 10^{a+6b}$

$$\frac{E_2}{E_1} = \frac{10^{a+6b}}{10^{a+4b}} = 10^{2b}$$

or $E_2 = E_1 \times 10^{2b} = E_1 . 10^3$ (since b = 1.5)

Thus the energy radiated by earthquake of magnitude 6 (E_2) is 10^3 times the energy radiated by the earthquake of magnitude 4 (E_1).

If E_3 is the energy of magnitude of earthquake 8, then

$$E_3 = E_1\ 10^{4b} = E_1 \times 10^6$$

i.e., E_3 is 10^6 times E_1.

$\log E_s = 11.8 + 1.5$ M, where E_s in ergs, M is Richter scale magnitude.

If M = 8.25, E_s = Energy = 3.68×10^{10} kwh or 13.248×10^{23} ergs.

M = 7.5 $E_s = 2.86 \times 10^9$ kwh or 10.296×10^{22} ergs.

Seismic energy (E_s) yield for different magnitudes (M) given in Table 10.1.

Table 10.1

M	E_s in TNT	M	E_s in TNT
5 0	32000 tons	8	5 billion tons
5.5	80000 tons	9.0	32 billion tons
6.0	1 million tons	10 0	1 trillion tons
6.5	5 million tons	12 0	160 trillion tons
7 0	32 million tons	8 5	1 billion tons
7.5	160 million tons		

Intensity

It is based on effects of the earthquake on buildings, topography, land slide etc., i.e, on macroseismic effects.

The waves spreading from an earthquake centre pass through different rocks at different velocities. Seismic waves have a maximum velocity of 12.5 kmps. On passing through the Mohorovicic boundary the primary seismic waves speed up from 6.5 to 8 kmps and secondary waves from 3.7 to 4.5 kmps. However on passing from mantle into core the primary waves speed drops 12.5 to 8.5 kmps and the secondary waves from 7.5 to 5 kmps. The spreading waves from an earthquake centre pass through different rocks at different velocities. Since the waves are reflected, and refracted on their way, they reach observatories at different times. On an average more than one lakh (10^5) earthquakes of varying intensities are registered over the globe every year by the seismological observatories. The data is evaluated by using 12 grade modified Mercalli (M.M) scale. The scale can be divided into several groups :

1. ***Slight Intensity or First Group***

   It consists of first three grades which are weak and not imperceptible earth tremors. These are sensed by some animals. Most of domestic animals become restless, birds fly away from the place of earthquake. Cats fur stands on end. It is also said that second and third grade tremors are sensed by nervous people.

2. ***Moderate Intensity or Group Two***

   It consists of grades 4, 5 and 6. These shocks are felt by every one. In this group objects hanging on walls move, hanging lamps/bulbs, chandliers swing to and fro. Cracks develop in some houses. Tall factory chimneys may fall down.

3. ***Severe Intensity or Group Three***

   It consists of 7, 8 and 9 grades. The strength of this group is distructive and devasting. Tall buildings may fall down, cracks may occur in the ground and occasional human casualities are noted.

4. ***Catostrophic or Very Severe Intensity or Group Four***

   This last group consists of 10, 11 and 12 grades. The strength is described as catastrophic. Many buildings will collapse except structures on monolithic rocks which may not be affected. The shocks and yawning cracks will be very severe. These may cause eletrical fires.

Causes of Earthquakes

The most common cause of earthquake is tectonic activity. This mechanisms is shown in Fig. 10.9. The vertical dashed line (PQ) shows fissure or fault in the solid earth crust. By slow prolonged tectonic movement in the lithosphere one side X of the fault (Fig. 10.9 (a)) is displaced in relation to the other Y. This is shown in Fig. 10.9(b), by a deformation of straight lines drawn across the fault (P' Q'). This process continues until the stresses thus generated in the fault zone overcomes the friction between the two sides X and Y. Then a rupture (sudden displacement) occurs. After this the configuration is shown in Fig. 10.9(c). It is this sudden rupture constitutes an earthquake. The slow process is repeated and a new shock occurs at some time later. This mechanism of earthquake is called elastic rebound theory of tectonic earthquakes. Almost all earthquakes occur by this mechanism. However there may be some tremors by volcanic activity. Large earthquakes may occur with a volcanic explosion. The collapse of cavities can be the origin of minor tremors.

Long ago the super continent Pangea broken and drifted like the lotus leaves. A plate containing India broke away from it and drifted towards Asian land mass. When this plate collided with Euro-Asian plate sediments of ancient sea bed sqeezed together in huge folds and slowly rose to form the Himlayas.

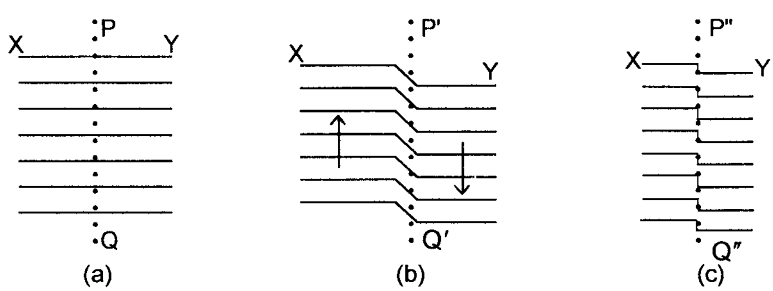


Fig. 10.9 Elastic rebound theory of tectonic earthquakes.

Indian plate consisting of India and parts of Indian ocean is moving at an average speed of 5 cm / year in the north-northeast direction and colliding with Eurasian plate along the Himalayas. This resulted in faults and fractures in the Himalayas. These are responsible for some great earthquakes in the Himalayan region in the past.

Categorisation of earthquakes	*Richter scale*
Tremor or micro-earthquake	Magnitude < 3.0
Slight earthquake	Magnitude ≥ 3 to < 5.0
Moderate earthquake	Magnitude ≥ 5 to < 7.0
Great earthquake	Magnitude ≥ 7.0

Important Seismic Belts

1. First belt, the most important Seismic belt runs along the Pacific and includes western coast of South America, North America, eastern coast of Asia, the Island of sourth coast Pacific and New Zealand.
2. Second belt runs from south Pacific Islands through Jawa, Sumatra and Central Asia mountains, further passing through Caucasus mountains to Greece, Italy and Spain.
3. Third belt which is not so important runs from north to south in the middle of the Atlantic ocean.

10.3 Seismcity of India

IMD maintains a catalogue on earthquakes in India and neighbourhood from available historical records and also instrumental data (See Fig. 10.10 and 10.11). This catalogue is continuously updated. From this records it is observed that moderate to great earthquakes have occurred all along the Himalayan region, the Rann of Kutch, Manipur, Mynmar (Burma) belt and further continuation to Andaman and Nicobar islands. Scattered earthquakes also occurred but less frequent in peninsular India with magnitude less than 6.5. Latur (Osmanabad district) earthquake had magnitude 6.3. The catostrophic earthquakes of magnitude $\geq$ 8 is given in Table 10.2.

Table 10.2

Date	Place	Magnitude
12.06.1997	Assam	8.7
15.08.1950	Arunachal Pradesh	8.5
15.01.1934	Bihar-Nepal border	8.3
26.06.1941	Andaman islands	8.1
04.04.1905	Himachal Pradesh	8.0
16.06.1819	Rann of Kutch	8.0

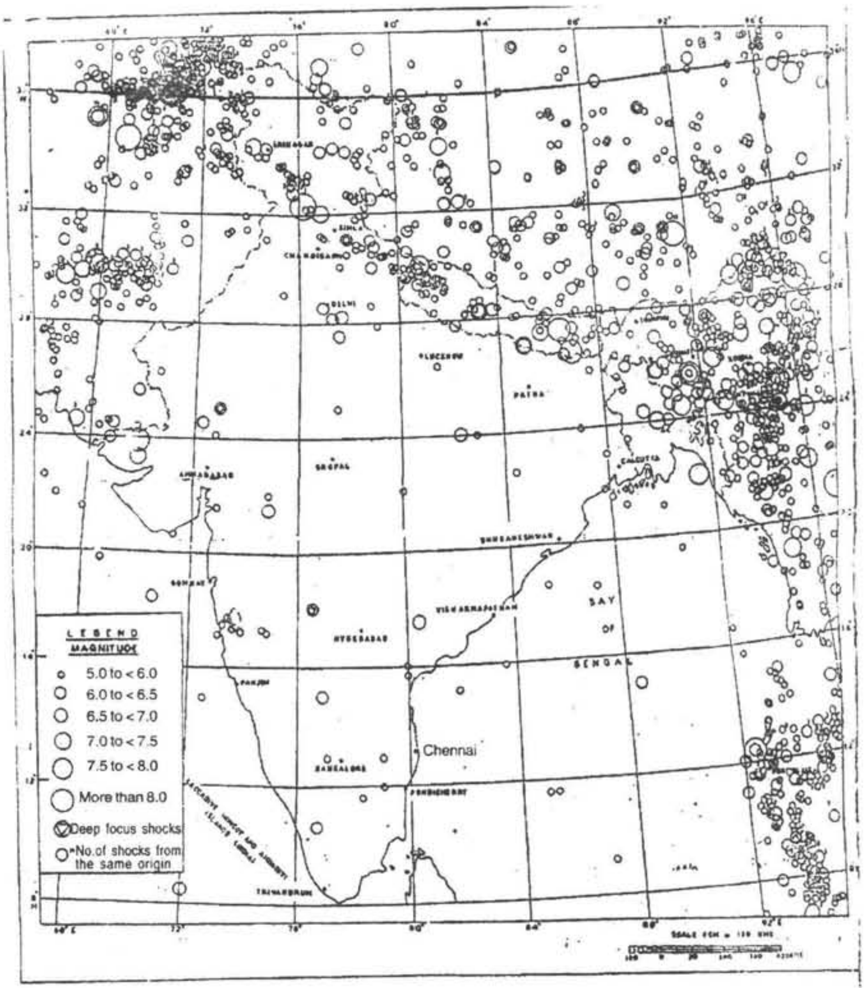


Fig. 10.10 Map of India showing epicenters (upto 1994).

Source : India Met Dept.

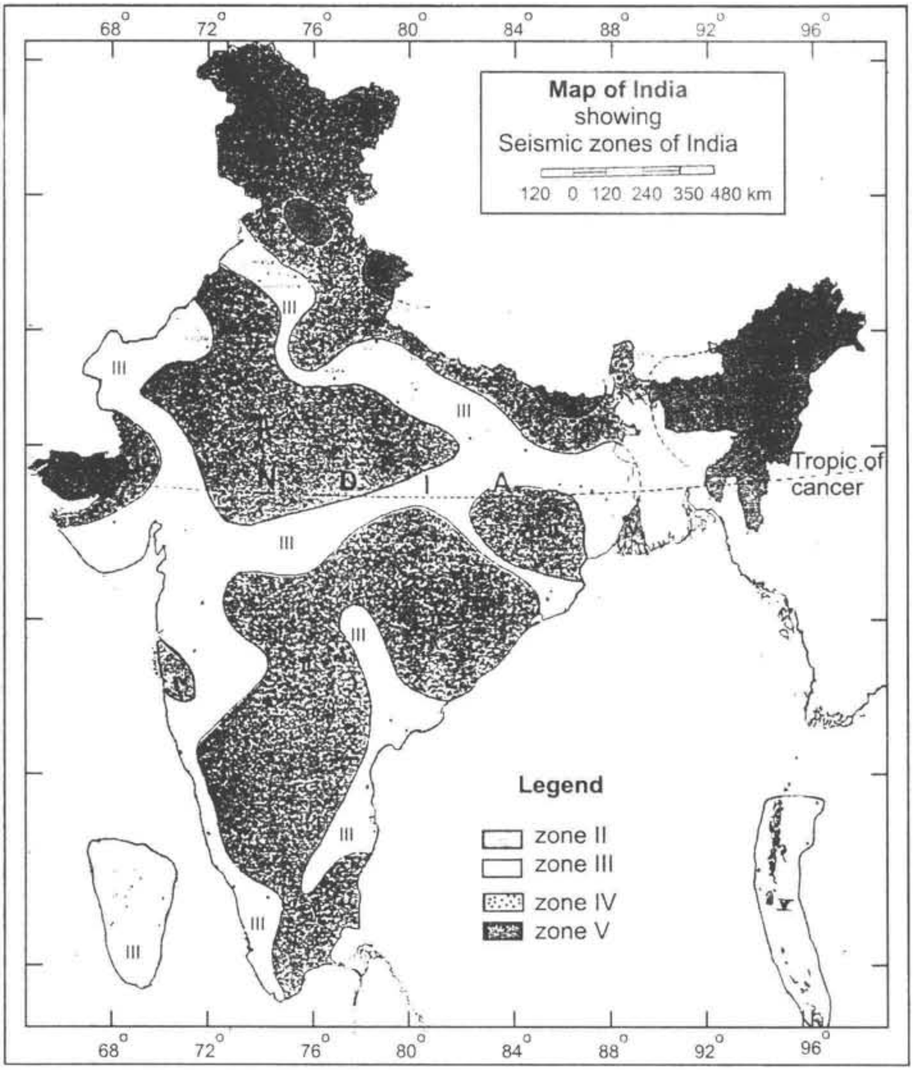


Fig. 10.11 Sketch map of India showing seismic zones (source IMD).

Research : The upgraded seismological network gave rise to useful and unique digital broad band and strong motion data sets for several significant earthquakes in the last decade including the recent great Sumatra earthquake of 26th December 2004. This helped in understanding about the earthquake process in the inter-and-intra-plate seismic regims. The Crust and upper Mantle structure of Peninsular shield region generated by the regional events. For the first time ground motions expected from future scenario earthquakes have been estimated from the Jablpur (1977) and Bhuj (2001) earthquake data.

Role of IMD

IMD is the nodal agency of Government of India, responsible for monitoring seismicity in and around India. IMD rendered more than 100 years of seismological service to the nation. The first seismological observatory of the country was set up at Kolkata in 1898. The operational task of the (IMD) department is to quickly determine the earthquake parameters immediately after the occurrence of an earthquake and disseminate the information to all the concerned State and Central Government, agencies responsible for rendering relief and rehabilitation. The information is also broadcast to public on AIR and DD and press etc.

National Seismological Network

It consists of 47 permanent observatories and 4 observatories in Northern India for special studies (See Fig. 10.12). Of the existing observatories 10 of them located at Ajmer, Bokaro, Bilaspur, Bhopal, Bhuj, Chennai, Karad, Pune, Thiruvananthapuram and Visakhapatnam, recently upgraded with global seismograph Network standard digital broadband seismograph system and 14 also been upgraded with Broad Band Seismograph systems of different makes. All 24 systems are of the state-of-art type having broadband sensors, high dynamic range (24-bit) digitizers, Global Positioning System time synchronisation and facility to access the data remotely through telephone mode or satellite communications.

A central Receiving Station has been set up at IMD HQ in New Delhi, which has the operational responsibility of keeping round the-clock watch of seismic activity, downloading the waveform data from remote field stations through dial up facility, analyse and disseminate the earthquake information to user agencies (See Fig. 10.13).

National Seismological Data base centre at IMD HQ in New Delhi, supplies a number of seismicity related reports for specific regions for establishment of Industrial units, power houses etc, and provides consultancy services to various State and Central Government Agencies on earthquake related matters. The other important activities of the division – all correspondence related to earthquake prediction, disaster management, supply of seismological data to various national and international organisations including research and academic institutions, river valley projects etc.

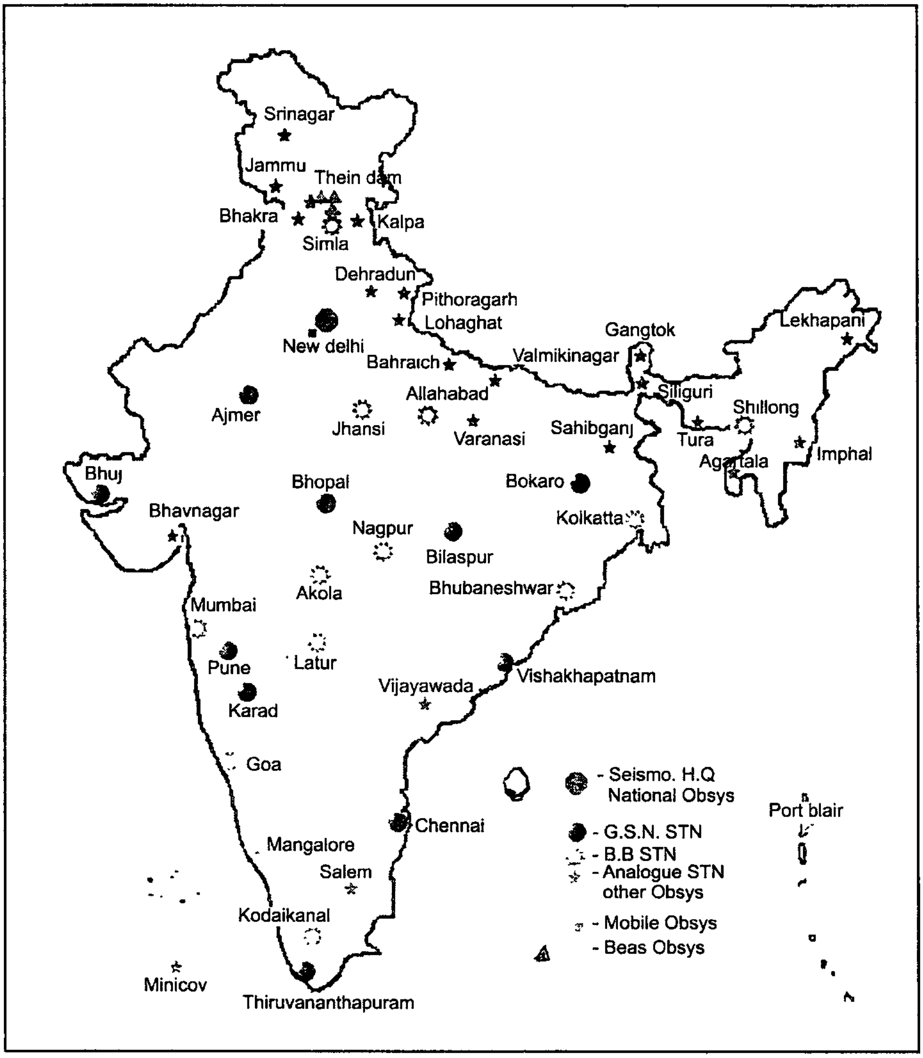


Fig. 10.12 Seismological observatories of India meteorological department.

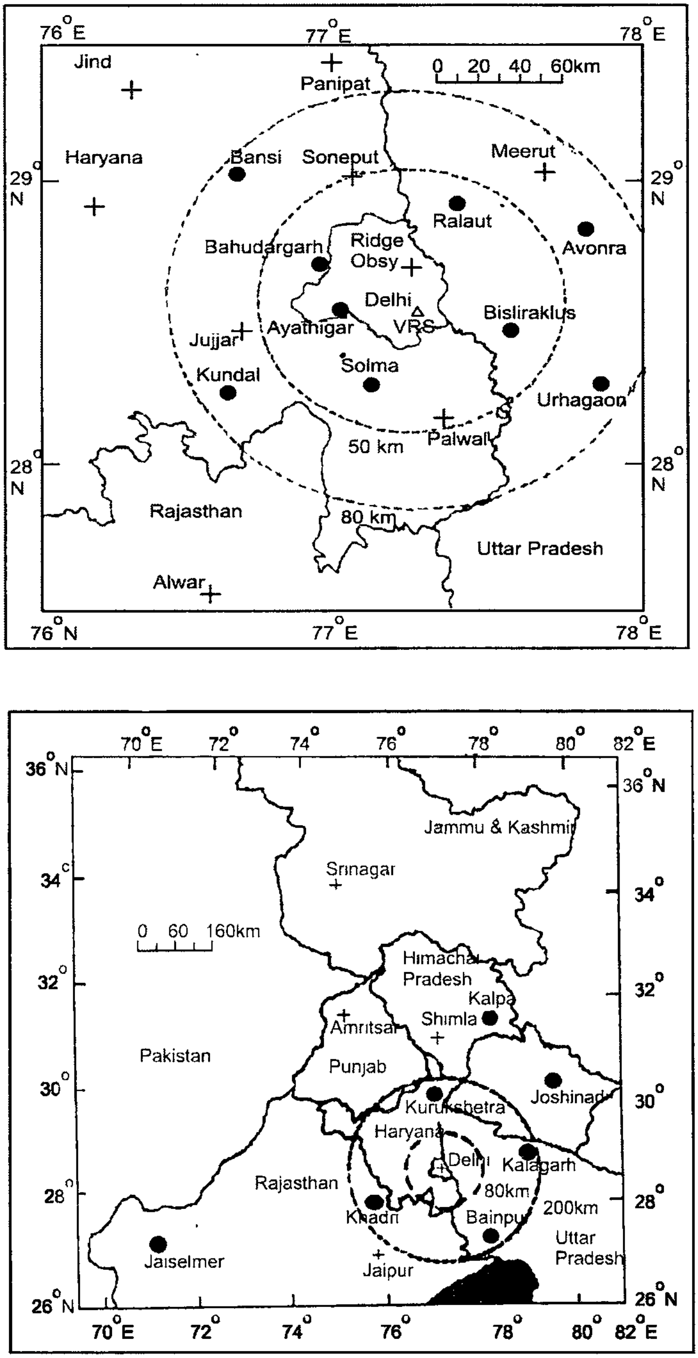


Fig. 10.13 Seismic telemetry network in and around Delhi.

The Seismological Division publishes a monthly National Seismological Bulletin which contains the phase data and the processed information on epicentral parameters of all earthquakes located by the National Seismological Network. The bulletins are periodically sent to International Seismological center (ISC) to incorporate into the global network.

IMD is a permanent Member of the International Seismological Centre UK, earthquake information, publications, bulletins are regularly exchanged by IMD and ISC.

Seismic Zoning of India : Based on Bureau of Indian standards (IS-1893 - part 1 : 2002) collection of scientific inputs from a number of agencies, the country has been divided into four Seismic zones ; Viz. zone II, III, IV and V. Of these zone V is the most Seismically active region intensity on Richter scale 9 or more, zone IV 8 to 9, zone III 6 to 8, while zone II is the least 5 or less.

Important Services of Seismological Division

Micro-earthquake surveys for monitoring after shocks, Swarm type seismic activities and site response studies by deploying portable seismographs in the affected area.

After shocks in Bhuj area is monitored at Rajkot, Surendranagar, Jamnagar for studying the explosion like blast sounds reported in the region.

As part of Tsunami warning system for the Indian ocean region, a real time Seismic monitoring and dissemination of data is in progress.

Major event in 2004 : A great earthquake of magnitude 9.3 occurred on 26 December 2004 at 06 hrs 29 minutes IST off west coast of Sumatra Island region, lat 3.3° N long 96.1°E. It generated destructive Tsunamis, took a toll of more than 3 lakh people. The Seismic belt extended from Sumatra to North Andaman Islands and caused several earthquakes of large magnitude. The main shock was followed by intense aftershocks. To study these an arry of five temporary field observatories set up in Port Blair and observatory upgraded deploying state-of-art digital broadband Seismograph system. The five field Seismological observatories are located at PortBlair, Baratang, Havelock, Hut Bay and Great Nicobar.

CSO Shillong (Central Seismological Observatory Shillong) was established in 1952 where Seismology, Meteorology and Radiation units are funtioning with the round-the-clock watch of seismology is functioning from 24-4-1989. All earthquakes of magnitude 4 or more within epicentral distance of 25 degrees transmitted to HQ New Delhi. Recording of plate motion with the help of Geographical Position System is continued from December 2001.

Earthquake Risk Evaluation Centre (EREC) was established in 2004 by Government of India to guide national effort in mitigating disastrous impact of earthquake and to evaluate earthquake risk. Microzonation of Jabalpur, Guwahati and Delhi is undertaken in collaboration with Global Seismological Institute (GSI), National Geophysical Research Institute (NGRI), IIT Roorkee and Central Building Research Institute (CBRI) Roorkee.

According to National Disaster Management Authority (NDMA) all new constructions must be earthquake resistant, particularly in cities located in seismic zones. The guidelines are selective seismic strengthening and retro-fitting of existing priority structures located in high-risk areas. Compliance of fresh building codes, revised town planning that will make it mandatory for all builders to incorporate earthquake-resistant features in their construction plans.

Earthquake Safety

It is said that earthquakes do not take lives but the ill constructed structures kill the people. Bhuj (Gujarat) earthquake of 26 Jan 2001, intensity 6.5 on Richter Scale took a toll of thousands, while the earthquake of higher magnitude (about 6.5 - 7.0) shook Seattle in February 2001 without any causualitiy and there were no house collapses, because the houses were constructed with earthquake safety guidelines. During an earthquake, structures (buildings) will experience two kinds of seismic wave forces. One is lateral longitudinal waves or horizontal to and fro and the other uplift (vertical or tranverse waves). The lateral or shear forces which are horizontal they shook the buildings back and forth, while the transverse waves cause the buildings move up and down. Keeping these movements in mind, using metal connectors, shear walls and fasteners, the structural stability of the building may be strengthened. This is the basis of earthquake proofing.

Retro-fitting process is reinforcing the foundation of existing buildings to bring them to the level of the present norms of earthquake resistence. The cost of retro-fitting may take about 10% more than the actual building cost. It must be noted that a single storey or a multi-storied building are eually hazardous to earthquakes but a poorly designed structure may crumbel while a well-designed multistoried structure may only shake.

When mild earth tremors are felt rush out of the house to an open area, avoid taking shelter near walls or structures which may collapse. Even if you are in sturdy house observe the safety rule of Drop-Cover and Hold.

10.4 Earthquake Forecast and Disaster Management

The causes of earthquakes are still not clear and the forecast of earthquake parameters – place of occurrence, strenght of occurrence and period of occurrence are being monitored with the help of Seismograph network but forecasting is still in infant stage. It is said that nature itself provides man with some indicators about its disastrous attack. A study of behaviour of certain animals shows that they sense the approach of a calamity better than man. These signs being used in Russia and China. There appears to be some relation between solar activity and occurrence of earthquakes. The life period of an earthquake is about one minute. Keeping the above aspects of uncertainity of forecasting, disaster preparedness (before the event) and rescue, relief and rehabilitation (after the event) are the present required action plan. The action plan before the hazard lies in zoning, construction of houses/ structures with earthquake resisting technology. As regards post disaster action plan of rescue, relief and rehabilitation is already discussed in cyclone disaster management plan which holds good for earthquakes as well. However it is briefly repeated here about **army's role**.

Rescue Operation

This includes retrieval of bodies live/dead from debries. This is the most sensitive task requiring skill, machinery and handling the existing awesome situation immediately. This work is most efficiently handled by Army in all past earthquake disasters and deserves praise. First, the bodies have to be extricated from the debries. Live people be shifted immediately to hospitals or medical camps for treatment. The extricated dead bodies and other animal caracases have to be buried or burnt after due verification by the local civil authorities. This part of action must be completed before the bodies are decomposed.

Relief Operation

The affected people have to be evacuated to relief camps or shelters like school, temples, churches, cinema halls etc. They should be provided food, medical aid besides accomodation. The personal belongings of retrieved from debries be handed over to them in the presence of local civil authorities (Sarpanch). Arrange transport (military or civil) to be provided for evacuation of the affected people and their belongings.

Medical Aid : In widely affected areas/villages, general medical checkup may be conducted to avoid the occurrence and spread of epidemic. Civil doctors may also be involved in this work. All care be taken to provide clean water, hot food in the camps. The required foodgrains be procured from civil supplies authorities or they may be asked to supply in adequate quantity. The food articles be distributed to the affected needy people involving civil authorities.

Clearance of Debris

Army is well equipped with dozers for this purpose.

Construction of Temporary Dwellings

During severe earthquakes most of the village houses get damaged or collapsed. In such cases temporary dwellings required. These will be provided by army tents or errecting tin-sheds to provide accomodation to the victims. Temporary schools may be run by army and NGOs to keep the children engaged in acadamics.

The following are exceptes from the book "Earthquakes, Animals and Man" 1987 by Dr. B.G. Deshpande. Do's Dont's before, during and after the earthquake.

What to do before an Earthquake

It is safest to remain out of doors immediately before the onset of the earthquake, if this moment can be anticipated. One should leave the house and stay out in the open or in temporary camps till the scare is over. In short, if you take proper precautions, chances are that you will not be hurt.

- Keep cool: panic causes heavy injuries.
- Secure all top heavy objects like furniture, storage cabinets, fridges, etc. to the walls.
- Keep supplies of food, water, clothings (warm, if in winter), torches or candles, emergency medicines, radios, helmets, first-aid kits, blankets ready with you. Use plastic bottles in preference to glass bottles for carrying water or other liquids.
- Keep all combustibles and explosives at a safe distance.
- Turn off gas, electric stoves, water, etc.
- Educate all members of the family as to what to do in such emergencies.
- Avoid the risk of an epidemic, which usually follows earthquakes, by using safe water and clean food.
- Evacuate old dilapidated buildings as they are sure to tumble first.

What to do during the Earthquake

There is a drill proposed as to what to do during the earthquake. Since earthquakes last for only a few seconds to a couple of minutes, the earthquake can be all around you before you are aware of it.

- Do not panic. The ground movement is frightening to all.
- If you are in a building, stand in a strong doorway or get under a table, desk or bed; avoid standing just outside the main door or near the outside walls. This is usually an unsafe place. Watch for falling objects.
- Do not rush outside without making sure you are going to be safer there.
- If you are out of a building when on earthquake strikes, stay out. If you are in an automobile, stop at the neartest safe place, away from buildings or trees.
- Watch for falling plaster, bricks, ceiling fixtures and other loose objects.
- Do not use gas stoves, candles or matches unless you are sure there is no combustible gas around.
- Avoid escalators; even stair-cases may be crowded by escapees. Await your turn.

@Seismicisolation

What to do after the Earthquake

After the earthquake is over, there will be tremendous rush of rescue work. Those who have escaped injuries, will be trying to rescue persons who have been trapped. If you are one of the trapped, wait patiently for your turn; remain calm, conserve your energy; if possible tap with a metal piece, so that your call will reach rescuers.

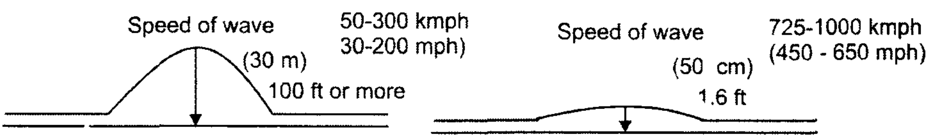
- Look for the injured in your family or neighbours' families because you know where they were and probably still are. Render such assistance as you can, unitl medical aid arrives.
- Check you electric, gas, water and sewerage connections. They may have gone haywire and damaged beyond immediate repair. You will have to live without them for some time.
- Check for fires and fire hazards, and secure fire extinguishers. Do not strike matchsticks unless you are sure that there is no gas leak around. Watch for instructions from the government rescue authorities on radio or by other means, regarding likely after-shocks and the manner in which the relief will be rushed to you.
- Keep away from hanging portions of buildings or overhanging cliffs, as they may fall due to after-shocks, which do continue for some time.

10.5 Tsunamis

In Japanese language Tsunamis meaning harbour waves. In Pacific Ocean and Hawaian Islands Tsunamis are prominent. They cause great damage to life and property in coastal areas. Tsunamis are very long waves, caused by the submarine earthquakes/explosions/volcanoes and great landslides into the oceans. Tsunami waves travel round the globe. Like Rossby waves, they have great wavelength about 600-1000 km, wave height 5.50 m and travel with a speed of about 500-1000 kmph in a circular waveform, the centre of the circle being the position of earthquake explosion/landslide. These waves show their fury in shallow waters, but not in deep water. Though they travel round the world but their destruction diminishes radially as they move further and further from the position of earthquake/explosion in the sea bed. Tsunami wave heights are mangnified when they coincide with the lunar tide. Even earthquakes also trigger more violently when they coincide with solar/lunar tides (of full moon and new moon). Any submarine earthquake intensity more than six on Richter scale may develop Tsunamis waves. Tsunami waves become more and more disastrous with the increasing intensity of the earthquake.

When a wave begins in the deep sea/ocean waters the wave height may be small, say about 30 to 60 cm (1 to 2 ft) and may look like a small rise and fall of sea surface water, but when they move to shallow waters they become very high. The following example illustrates the amplification of waves.

A Tsunami Sanriku struck Honshu, Japan on 15 June 1896. Fishermen about 35 km out at sea in deep water did not even notice the waves, height about 30 cm (1 ft) pass under their boats at that time, but when they returned to the port Sanriku they learnt about 28000 people lost their lives and about 270 km of coast line was destroyed (see Fig. 10.14).



Tsunami approaching the coast 1.5 to 30 km (500 to 10000 ft)awary from the coast

316, 800 ft away from the Coast ≃ 100 km

Fig 10. 14

Tsunami in deep water can have wavelength more than 500 km and a period of about an hour (period of wave is the time taken between two succeessive waves pass through any fixed point on their way). This is entirely different from the normal California tube, which generally has a wavelength of about 100 meters and a period of about 10 seconds. As said earlier Tsunamis are shallow water (harbour) waves such that the ratio of water depth (d) and wavelenth (λ) is very small.

$$\frac{d}{\lambda} = (\mu\text{, is very small}).$$

The wave speed (c) of these shallow water is given by the formula

$c = \sqrt{gd}$,

where $g = 9.8$ m/s^2, gravity of the earth at the place, d = depth of the water.

Thus in deeper water λ is small and c is large.

let d = 6 km, then

$$c = \sqrt{9.8 \times 6000} \simeq 873 \text{ kmph.}$$

c is comparable to the speed of jet aircrafts.

The rate of loss of wave energy E is given by

$$\frac{dE}{dt} = \frac{k}{\lambda} \text{ where k is constant, } \lambda \text{ is wavelength}$$

This shows that Tsunami waves can travel with high speed for a longer time with little loss of energy.

Some Features of Indonesian Tsunami (26-12-2004): On 26 December 2004, The Indian Plate slipped below the Burma plate at 6.29 AM IST, releasing phenominal pressure which forced the sea water rise upwards. This slipping of Plates caused earthquake of magnitude 9.0 on Richter Scale. The Seismic yield was of the order 32 billion tons of TNT. The epicentre of the quake was in the sea Northwest of Aceh Province in the Indonesian island of Sumatra. The earthquake was felt in Andaman Islands at 8.38 AM and its magnitude was 6.1 on Richter Scale. The pressure wave travelled about 1200 km in 2 hrs 08 minutes (or about 600 kmph). The Tsunami waves travelled as far as the coast of Africa-Somalia, a distance of 6500 km from the epicentre. It took a human toll of about 3 lakh people. It hit the Kerala coast and took a toll of 162 people there.

Earthquakes are highly localised phenomena, but 26 Dec 2004 earthquake/ Tsunami caused damage in 13 countries, particularly Srilanka, Indonesia, India, Thailand. This Tsunami is called the world's worst ever natural disaster because it affected 13 countries and not because of human deaths (1970 Bangladesh cyclone took a toll of 5 lakh people in a single country).

Tsunamis have been occuring occassionally in the Pacific Ocean in the past. In 1946 a Tsunami killed 165 people in Hawai. Ever since 1946 a Tsunami warning system shared by 26 countries around the Pacific Ocean. In 2004, Srilanka, Indonesia, India and Thailand shared the destruction. In 1976 Tangshan (China) earthquake killed 2 lakh people due to structural failures, while in case Sumatra Tsunami it is due to the volume of water at great speed and height that killed the people. The wave height varied 2 to 6 meters along the coast of India with great speeds. The survivor fishermen of 2004 Tsunami reported that they observed continuous line of waves looking like dark (colour) elephants with a halo of spray, a white haze above this line at a distance of about 10 km away. The waves approached very fast while the rest of sea was relatively calm and the weather was fine with normal winds. The survived fishermen, prompted by unnatural scene, immediately cut lines which held the fishing nets to the boats and aligned the boats perpendicular to the advancing tide to avoid being overturned. This instinctive action saved their lives. When the Tsunami waves passed below the boat, they reported that the boat was lifted much higher than the normal rough sea waves in a short time. The wave travelled very fast towards the shore. They observed similar waves coming towards them and passed below them very quickly. Some of them saw the waves break on the shore in a huge wall of water. People on the shore observed similar wave movement with a frightening sound. The people who were engaged pulling "AilaVala" (team of men and women 50 to 70 the ropes around their waists and drag the net with the fish catch), one person who survived the tragedy reported that the net was very light to pull. Sensing it unnatural he untied the ropes from his body and shouted others to do the same. In that short span of time the sea wave hit the shore and all hell broke loose. He was submerged under huge wall of water and carried away inland (fortunately for him the shore had elevated dunes) where he was deposited by the waves. He saw that there were bodies around him of his collegues who were still tied to the net. He went to their rescue but found all of them dead. The chance of survival from the wave breaking on the shore upto 500-1000 m of flattish area very little. The speed of the wave on the shore was many times more than the speed of a person able to run on the sandy shore.

Adverse effects of Tsunami on fisherman

Tsunami waves destroy everything in their path. Boats, thatchet houses in the coast were badly damaged. They were deposited further into the deep sea water or on the sand shore damaged. Fishing nets were sucked back into the sea or damaged critically and rendered unfit for use. Fishing community lost their livelihood.

The following precautionary measures to be observed.

1. ***GIS*** **:** Acquaint the geographical information of your house, street (height above mean sea level) and the distance from the coast.
2. ***Education*** **:** Be familiar with the Tsunami warning signals.
3. ***Signs of Warning*** **:** Coastal people should always be alert with the earthquakes. Earthquakes are the first warning signals of coming Tsunami particularly if they are violent shaking.
4. If the water in the Bay harbor or along the beach suddenly sucked or rushed out to sea, leaving fish, boats stranded, it is a sure sign of advancing Tsunami in a short time (within 5 to 30 minutes) that will hit the coast.
5. When Tsunami warning issued immediately rush to the safe top floor of the strong building 50-100 m above mean sea level (or very high elevated place) or cyclone shelter, but never venture to go towards the beach which will be inviting danger.
6. Take all precautionary measures that are recommended for storm surges.
7. Tsunami is a series of waves. First wave will be less dangerous, but subsequent waves will be progressively higher wave height and invade in a very short time. Do not leave the cyclone shelter or safe multistoried house where you have taken shelter till you hear the dewarning on Radio "All clear".
8. The hit (attack) of Tsunami will cause contamination of all food and water and cracks in structures/houses. Make sure that your house is safe before entering back into it. Be careful while wading through inundated water.
9. Monitor local Radio/DD anouncements for evacuation orders when Tsunami warning issued. Do not return to low lying areas untill the Tsunami threat has passed off and the "All clear" dewarning is anounced.

Tsunami/Storm Surge Mitigation

Tsunami waves are entirely different from storm surge (tidal) waves. The later are dependent on the central pressure defect (in the eye) and movement of the cylone, while the farmer dependent on the magnitude of the earthquake.

In addition to the basic relief measures like water, food, medical aid the administrative authorities should find means of livelihood of the affected people. Forest wing of World Bank encouraged the plantation of shelter belt to minimize the losses during storm surge and Tsunamis.

In India Forest Department encourages Social forestry along the coast within the limits of coastal Regulatory zone where Tsunami tidal waves pounded the coast in December 2004. World Bank is supporting Shelter Belt plantation programme by planting casurinas, cashewnut and palm plantations along the coast. These belts will lessen the damages of Tsunamis/storm surges. The participation of communities, Self Help Groups, NGOs, Vanasamrakshana Samities is essential for the success of Social forestry.

10.6 Landslides and Avalanches

In high mountains like the Himalayas, any disturbance in the natural balance triggers landslides and avalanches. These cause disruption of road communication, loss of property and life in hilly terrain. Landslides and avalanches are of great concern to design roads and geotechnical engineers, road users, Government administration, geologists and defence services and local inhabitants.

Landslides : A landslide or mudflow is a downward movement (in hilly region) of rock, soil or debris flow under gravity. Landslides occur when the ground is stressed beyond its frictional strength. The following main factors contribute to the landslides.

1. Erosion by rivers, glaciers or ocean waves creating over steepened slopes (soil erosion is the wearing away of land surface by natural agencies of wind and water).
2. Strength of the rock or soil.
3. Seismic zones
4. Topography, ground, water and vegetation
5. Accumulation or gathering of excess weight by rain, snow, flood and waste piles.
6. Man made causes like mining, terrain cutting and filling.

Of all these the steepness of slope and amount of water have greatest correlation with landslides. In 1920 an earthquake induced lanslide in China (Kansu province) took a huge toll of human life (about two lakh people). In Columbia (in 1985) a devastating landslide wiped out town and villages. It took a humal toll of about

20000 people. In India, Jammu and Kashmir, Himachal Pradesh, Uttaranchal, Sikkim, Siachen, Kulu, Manali (southern peripheries of the Himalayas) the incidence of landslide avalaunches are a regular phenomena every year. February 2005 witnessed very intense snowfall (15 to 45 ft or 4 to 6 m depth) in Kashmir and neighbourhood. This caused landslides and avalanches for a full one week and completely cutoff the valley from rest of India. Several hundred people lost their lives despite Army and Air force best assistance on war footing to the local administration. Similarly in December 1995 a landslide near Kulu buried about 100 people.

Project "PARVAT" : It is a joint venture of DRDO (SASE), Ministry of Defence (Army, Air force) and DST (Department of Science and Technology)–IMD and National Centre for Medium Range Weather Forecasting (NCMRWF). The aim of the project is to improve weather and Avalanche forecasting over strategic areas in western Himalayas and also to cater the needs of local people. Under this project three IMS - 1500 Radiotheodolite have been installed at Manali, Sasoma and Jammu, 22 surface Meteorological observatories and 3 upper air stations, Research and Development work, issue of weather forecasting at a resolution of 50 km, 5 days in advance with minimum accuracy of 80% in Western Himalayan region.

Landslide Preventive Measures : Preventive measures differ from place to place. Earth retaining structures, both cement masonery type and flexible type are strongly recommended. Afforestation and turfing of slopes with suitable plants / trees is a long term measure against landslides. People treading in hilly areas must be very careful in their movement just after heavy rains/ snowfall and they should monitor the weather forecast regularly.

10.6.1 Avalanches

An avalanche is the downward slide or descent of a large mass of snow/ice on slope having considerable velocity and force. It is a natural destructive force. An avalanche consist of snow, ice, air, water and soil impurities. A considerable part of our country in the foot of Himalayan region remains cut-off from the rest of the country due to avalanches. Snow avalanches occur in winter months and take heavy toll of life, a few highways remain blocked for several months (5-7) in a year. The frequency of avalanches are more where the slope is 35^0 to 45^0. Snow avalanches and landslides are grave problems in northwest and central Himalayan regions which are inhabited or frequently used by local population, for communication, winter sports, mountaineering and defence.

Avalanche Hazard Mitigation in India

In India there is no civil organization neither at the State level nor at the National level to mitigate the avalanche hazards. Recently, as described above project 'PARVAT' commenced for this purpose. Snow and Avalanche Study Establishment (SASE) of DRDO laboratory provides snow avalanche information and forecasting to armed forces. The SASE aims at to provide nowcasting and also forecasting about avalanche hazards to the population residing in landslide/avalanche prone Himalayan region. For this purpose SASE established snow measuring meteorological observatories in Jammu and Kashmir, Himachal Pradesh, Uttaranchal. These observatories communicate data to Avalanche Forecasting and Mountain Meteorological centres at (i) Srinagar - for Kashmir valley (ii) Sasoma–for Siachen and Nubra valley and (iii) Manali- for Himachal Pradesh. These centres collect data from Automatic weather stations, satellite remote sensing data pertaining to latest terrain, qualitative and quantitative snowfall information, precipitation and snow cover. Satellite based sensors provide high resolution data from visible and IR thermal wave lengths. This data facilitates identifying terrain conditions, avalanche sites, snow albedo, surface temperature and snow cover. GIS (geographical Information System) together with satellite data helps SASE forecasters to prepare Avalanche Bulletin. These bulletins are brodcast on AIR and DD regularly, which are proved to be very helpful to the local inhabitants, winter tourists, traffic regulation authority, winter sports, mountainearing department. It created great awareness among the users and thus helping in mitigating the avalanche/landslide hazard impact.

Preventive Measures : Soil stabilization by terracing geofabric, grouting etc., should be resorted. Afforestation on large scale in areas prone to landslides and all along the road on either side with large growing trees may help arrest slides.

10.7 Volcanoes

Valcanoes are believed to be caused by the plate tectonic movements. The movement of the molten rock material called magma of the earth's core causes earthquakes. In the weaker zone of earth's crust or faults the upwelling of magma takes place in association with plate boundaries divergence or convergence or transform faults. Thus weaker zones of earth's crust or faults are the principal locations of Volcanoes. It is theorised where old crusts are buried they provoke earthquakes and Valcanoes. (when plate boundaries move or transform faults). Valcanoes are classified into three types depending on the processes that cause them.

1. ***Subduction Volcanoes*** : When plates collide the boundaries submergence or subduction of one under the other plate takes place. Magma from the earth's core constantly upwells and cools along the mid-ocean ridges. This adds material to the earth's tectonic plates. At the points of collision or undercutting of the plates Volcanoes occur frequently. An arc shape belt of volcanoes or islands is often observed. 80% of the global valcanoes occur in the areas of subduction. "Ring of Fire" in Pacific Ocean is caused by the complex interaction of tectonic plates and many subduction zones. The following Table 10.3 gives the major volcanic zones and associated plate movements.

2. ***Rift Volcanoes*** : when plates are divergent magma reaches the surface directly. These are called Rift Volcanoes. 15% of the global volcanoes occur in divergent plate zones. The Iceland volcanic activity belongs to this category. Most of the earth's rift zones (7500 km) are under oceans. Many of the sub-oceanic volcanoes exist undetected.

3. ***Hot-spot Volcanoes*** : Some volcanoes occur in the interior of tectonic plates. It is theorized that local hot plumes rising from magma accounts this type volcanoes. Volcanoes in Hawaii belong to this category.

Table 10.3 Subduction zones and associated plate motions.

S.No.	Name of location	Plates Involved	Subduction rate	length km cm/year
1.	Kuriles - Kamchatka Hanshu	Pacific plate under Eurasian plate	7.5	2800
2.	Tonga-Kermadec-New zealand	Pacific under Indian	8.2	3000
3.	Middle American	Cocos under North American	9.5	1900
4.	Mexican	Pacific under North American	6.2	2200
5.	Sundra-Jawa-Sumatra - Burma	Indian under Eurasian	6.7	5700
6.	Solomon-New Hebrides	Indian under Pacific	8.7	2750
7.	Iran	Arabian under Eurasian	4.7	2250
8.	Himalayan	Indian under Eurasian	5.5	2400
9.	Ryukyu - Philipines	Philipine under Eurasian	6.7	4750
10.	Peru - Chile	Nazca under South American	9.3	6700

Note : Subduction volcanoes are associated with convergent plates.

Volcanoes are also classified as effusive or explosive. In effusive eruptions, most of volcanic matter is ejected in the form of lava (temperature 1000 to 1200^{0}C) which flows down the mountain slopes. Explosive eruptions spew out steam, rock materials, dust, smoke and ash particles. This is called Tephra. Tephra is a collection of fragments of magma, consists of rock materials of all sizes from blocks of materials to fine dust/ash.

Forecasting

Past history of well known volcanoes like that of Mt.St. Helens (in the State of Washington, USA) shows that it is not possible to forecast the volcanic eruption. However it is possible to infer that a significant event was going to occur by observing the events – earthquake tremors, volcanic tremors, growth of a bulge on volcanic cone.

Based on the frequency of eruption the volcanoes are classified as Active, Dormant and Extinct. Volcanoes which erupt constantly are called active. Strombolic volcano of Mediterranean sea, Barren Island volcano in Andaman and Nicobar islands (India) belong to this type.

Valcanoes which erupted earlier but now they are quiet without any activity are called Dormant.

Valcanoes which existed long back and are dead (like the Deccan trap) are called extinct.

It may be noted that the Dormant Volcanoes may erupt at any time and become dormant and while the extinct volcanoes have no such chance.

Some Features of Volcanoes : The highest active Volcano is Autofalla, Argentina, located at a height of 6450 m. The largest crater of volcano is Mt. Aso, Japan, whose circumference is about 115 km. The volcano of greatest eruption is Santorini (Thira) 1470 BC, in the Aegean sea, erupted about 63 km^3 of rock material. Krakatova Volcanic eruption, August 1883, debris/ash particles penetrated into lower stratosphere (32 km) and masked the sun for days and converted days into nights in the neighbourhood of the volcanic surrounding area.

Volcanic Matter : Volcanic matter may be molten lava or Tephra. The molten discharge of a volcano is called lava, consists mostly of moleten silica or rock (basaltic), while the composition of Tephra mostly consists of silicon dioxide and minor quantities of oxides of Aluminium, Sodium, Calcium, Potassium, Iron, Magnesium and water vapour. The speed of basaltic lava 10-100 kmph and temperature 1000 to 1200 °C. Tephra results from the earth's inner core (the magma) rising to surface and undergoes chemical and physical changes as it ejected into atmosphere by the force of volcano itself. The velocity of Tephra matter varies with the size of the debris (about 500 mps). The eruption ash debris may be pushed into atmosphere to an altitude of 80 km.

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Chapter - 11

Hazards associated with Convective Clouds

Introduction

For practical purposes of disaster management we treat cumulus and cummulonimbus clouds as convective clouds. The weather associated with these clouds are thunderstorms, hailstorms, dust storms, tornadoes, norwesters, kalbaisakhi, dust/sand storms. The main hazards associated with these weather conditions are :

1. Lightning discharges,
2. Hail,
3. Squalls,
4. Heavy rain,
5. Poor visibility.

Convective cloud cells develop in unsaturated air when environmental lapse rate is higher/much higher than dry adiabatic lapse rate, while in saturated air environmental lapse rate is higher than saturated adiabatic lapse rate. The presence of cumulus clouds indicate that the cloud, air mass is saturated and environment is unsaturated. In any locality instability and precipitation develops in the following process.

(i) cumulus may develop in the afternoon by the heating of the lower surface through its contact with the hot ground surface, or when a cold air mass over runs a warm ground surface,

(ii) the cooling of the middle atmosphere 4-10 km asl may initiate instability in the lower atmosphere (0-4 km asl),

(iii) cumulus clouds may persist in the presence of high humidiy and large horizontal extension of cloud,

(iv) vertical development occurs in the presence of steep lapse rate,

(v) rain/showers may occur frequently in a locality where lapse rate of 6 °C/km in the presence of large humidity. In general low level convergence of winds, high humidity with associated upper level divergence is a most favourable condition for the development of cumulus and precipitation. An inversion of temperature at the top of the moist boundary layer is favourable for the development of severe thunderstorm. Vertical wind shear in lower level aids convection cloud development. Upper level divergence exists in association with jet stream. Lines of discontinuity or dry lines also aid convection clouds.

Thunderstorm

According to WMO a thunderstorm is defined as one or more sudden electrical discharges, manifested by flash of light (called lightning) and a sharp or rumbling sound (which we call thunder).

Cloud invariably cumulonimbus and generally associated with precipitation. The sound of thunder is due to the electrical discharge. In electrical discharge enormous heat develops which heats the air channel between the cloud and earth. The conducting channel is heated upto 30000^0 K, which is five times the temperature of the surface of the Sun (6000^0 K). Because of the sudden heating of the conducting air channel in a very short period, the diameter of the channel expands abruptly from a few millimeters to a few centimeters (ten fold). This sudden expansion of conducting channel generates shock waves which spread out as sound of thunder. Thunder is generally heard upto 10-15 km and rarely beyond 25 km. At any instant there are about 2000 to 3000 active thunderstorms around the globe, most of these occur in tropics. Simultaneously at any moment there are about 100 lightning flashes per second.

A thunderstorm day is defined as a local calandar day on which thunder is heard, irrespective of the actual number of thunderstorms on that day. The highest annual average of 242 thunderstorm days was recorded at Kampala, Uganda (0°20'N, 32° 30' E) in Africa.

A thunderstorm consists of several convective cells each having distinctive convective circulation. The dynamical building block of thunderstorm is the cell. A cell is a large compact region having updrafts (about 10 mps). Most of the thunderstorm cells have short period of life. At any instant of a thunderstorm, it consists of cells which are at different stages of evolution and each interacts with neighbouring cells or outside environment. Thunderstorms are local affairs and rarely exceed diameter of 10 km (or 100 km^2 area) and duration 1 to 2 hrs.

A thunderstorm cell has three stages of life cycle. (i) Cumulus or growing stage, (ii) Mature stage and (iii) dissipating stage.

In Cumulus stage updrafts are found throughout cloud, height grows (6-10 km) and takes a shape of cauliflower type domes on the top and cloud top temperature may be about –20 to –30 °C. Updrafts of the order 10 mps are common. The life period of cumulus stage may be 10-15 minutes. Light rain may occur at the base of the cloud.

In Mature stage both updrafts and downdrafts occur in the cell. Downdrafts are prominent below the freezing level. The lowest temperature in the cloud are found in downdrafts. At the top of the cloud, false cirrus anvil develops which mostly contain ice crystals. This stage lasts for about 30 minutes when it attains maximum height (12-18 km). In this stage severe lightning, precipitation and squalls occur. The strength of the updrafts may be 10-30 mps and downdrafts 5 to 15 mps. Downdrafts below the cloud base produces divergence of cold air and in the wake of this cold divergence new cells develop and thus trigger chain action of thunderstorms. The life period of the cell in this stage is about 0-75 minutes.

In Dissipating stage only downdrafts (speed 10 mps) are found throughout the cell. Squall speed of 10-15 mps at the ground of the cloud base is common. In this stage the entire cloud mass temperature will be cooler than the ambient air temperature. No more condensation occurs. The height of the cloud dissipates along with anvil. Cold air divergence spreads below the cloud and downdrafts cease to exist. The average life of the cell in this stage is about 10-30 minutes

Condition Favourable for the occurrence of a Thunderstorm

(i) Conditional and convective instability in the atmosphere,

(ii) Adequate supply of moisture in the lower troposphere,

(iii) Suitable synoptic situation to cause low level convergence and upper level divergence,

(iv) Suitable upper airflow which may advect warm moist air in the lower troposphere and cold dry air in the upper troposphere.

In a thunderstorm energy is released mostly in the form of latent heat. An average thunderstorm over an area of 50 km^2 with average rainfall of 2 cm releases energy about 25×10^{21} ergs, which is equivalent to about 30 Hiroshina atom bomb explosions. According to C.E.P Brooks estimates there are about 44,000 thunderstorms per day, 1800 occur simultaneously at any time, and 100 flashes of lightning per second. These discharges equivalent to a continuous current of about 2000 amperes. Assuming the potential difference 10^8 volts in the vicinity of thunderstorm area, the lightning discharges world over continuously transfers energy about 268×10^6 horse power.

11.1 Climatology of World Thunderstorms

Europe and Australia have the minimum frequency of thunderstorms about 20 thunderstorm days per annum. In southeast Asia the frequency is about 60 thunderstorm days around Bangladesh (Bangladesh, India and Myanmar). South

America, Africa and Indonesia have maximum thunderstorm days. Tropical oceanic regions around 20 °N and S and semipermanent high pressure regions are relatively free from thunderstorms. Polar regions are virtually free from thunderstorms.

The accepted record of 242 thunderstorm days per year recorded over a period of 10 years at Kamapala, Uganda 0° 20'N, 32° 36' E. There are only a few stations around the world which recorded 200 thunderstorm (TS) days or more given in the Table 11.1

Table 11.1 World Recorded TS days

Name of the station	Country	Lat	Long	No.of TS days per year
Kampala	Uganda	0°20'N	32° 36' E	242
Buma	Zaire	1° 34' N	30° 13' E	228
Kamembe	Rwanda	2° 27'S	28° 54' E	221
Bandug	Indonesia	6° 54'S	107° 34' E	218
Calabar	Nigeria	4° 57'N	8° 21' E,	215
Entebbe	Uganda	0° 02'N	32° 37' E	206
Carauri	Brazil	4° 53' S	66° 54' W	206
Mamfe	Cameroon	5° 46'N	8° 20' E	201

In India the maximum of 108 TS days recorded at Sibsagar (Assam), Krishna nagar (West Bengal) and there are very few stations which have annual frequency of 100 TS days or more.

Distribution of Thunderstorms over Sea Areas

According world map of thunderstorms, the incidence of thunderstorms over sea area is less than over land. This is clearly reflected in tropics. In tropical sea regions of Panama, Ecuador, Columbia, over gulf of Guinea along African coast, along the sea areas of western coast of Indonesia and Malaysia the thunderstorm frequency is high. High frequency is also seen in the ITCZ zone of North Atlantic and North Pacific. Minimum frequency of thunderstorms observed in the Trade wind zone between lat 10° and 30°.

11.2 Lightning

In 1600 AD, William Gilbert, the physician of Queen Elizabeth, studied about static electricity. He showed that glass /amber rod when rubbed with silk/fur attract small pieces of paper. He named this phenomena electric. In 1764, Benjamin Franklin found out positive and negative electric charges. In 1752 he showed with kite experiments, that thunderstorms have electricity. In 1753 he found that thunder clouds have negative charges, but later in one experiment he also found positive charge in the thunderstorm cloud. From his experiments Franklin propounded that a majority of thunder cloud base possess negative charge but rarely positive charge may be seen. In 1756 he developed the lightning conductor for protection of buildings, which is still in use.

Charge Seperation in Clouds

In convective clouds charge is observed from the formative stage. The positive and negative charges formed in the cloud are separated by the following mechanisms. (i) By the breaking of big rain drops, (ii) by capture of ions by rain drops and ice particles in the atmosphere, (iii) by collision of ice particles at different temperatures, (iv) by freezing of supercooled water droplets.

In the cloud the charges are separated by the combination of the above mechanisms.

In a well developed convective cloud (matured stage) updrafts transport positive charge to the top of the cloud, while downdrafts and falling rain drops transport negative charge to the base. Small ice particles or ice nuclei carry positive charge to the top of the cloud while big ice particles, soft hail carry negative charge to the base of the cloud. Generally positive charge is accumulated at the top of Cb and negative charge at the base. In contrast to this classical dipole model, modern theory assumes that there can be much lateral displacement between two charges. Most lightning flashes either transfer the lower negative charge to the ground or achieve effective partial neutralization of the cloud electrification by internal cloud discharge.

The Electric Field in the Atmosphere

In a fair weather the atmosphere carries a net positive charge everywhere on earth, the average potential gradient being 150 v/m. This implies that there is negative charge on the ground and it is assumed that the electrical potential of the ground is zero. The rate of change of potential with height is called potential gradient. The gradient decreases with altitude in free air, rapidly in the first one kilometer and slowly there after. The gradient at the surface varies during the day, being maximum at 1900 UTC and minimum at 0400 UTC, and the durinal range being about 35% of the daily mean. The potential gradient near the earth in fog is about 2000 v/m. In such conditions electric sparks (or electric discharges) may take place from the extremities of metallic conductors connected to the earth.

Critical Potential Gradient

An electric discharge (spark) takes place in the atmosphere when the electrical potential between two points reaches a certain value. In clear air of normal density the critical potential gradient is about 3×10^6 v/m. Dry air is a very poor conductor of electricity and requires a large potential gradient for eletrical discharge . However the presence of water droplets in the atmosphere increases the conductivity of the atmosphere. In cloud, the lightning discharge occurs at a potential gradiant of 1.0×10^6 v/m. It is found the average field strength within a thunderstorm cell is about 10^5 v/m.

The Lightning Discharge

In a thunderstorm the lightning stroke starts from the cloud in the form of stepped leader, with average step length of 50 m. The time period of each successive step is about 50 micro (μ) seconds. The average velocity of the individual step is about 5×10^4 km/sec and the velocity of total step is about 1.5×10^2 km/sec. The total time required for stepped leader to reach the earth is about 0.01 sec. After leader reaches the earth, a reverse stroke starts from the earth to the cloud through the channel made by the leader with an average velocity of 15×10^4 km/sec. After first discharge there may be other discharges which start from the cloud but little different from that of stepped leader. It will be a continuous leader, also called dart leader, with average velocity of about 2×10^3 km/sec.

When a lightning flash strikes near an observer, about 100 m of radius, the sound consists of (i) first a click, (ii) then a crack (like that of a whip) and (iii) finally the characteristic continuous rumble of thunder. The click is caused by a discharge streamer directed upward from the ground (towards the leader stroke before commencement of the return stroke). The crack is caused by the intense return stroke in the lightning channel nearest to the observer. The rumble comes from the multiplicity of sound sources distributed along the lightning channel. When the lightning strikes away from the observer (several hundred meters) the first sound heard like the tearing of cloth.

Types of Lightning

Lightning occurs in various forms. More than 60% of the occasions lightning discharge takes place within the cloud, or cloud-to-cloud between positive and negative charges. The second type of discharge is between cloud and the earth. This is commonly called thunderbolt. The negative charge at the base of the thunder cloud induces positive charge on the earth in the vicinity of the cloud base, which repels the negative charge on the earth. The discharge between cloud and the earth takes place at a critical potential gradient.

Ribbon Lightning **:** This occurs between the cloud and the earth when the wind is very strong (speed 30 kmph or more) which displaces the conducting air channel into a ribbon form.

Sheet Lightning **:** Sheet lightning is observed due to distant thunderstorms at the horizon, which illuminates the sky by its lightning flashes.

Air Discharge **:** This occurs between the cloud base and the air below but it fails to reach the ground. Air discharge generally takes place in deserts.

Bolt from the Blue **:** The electrical discharge which begins as an air discharge but after traveling a distance away from the cloud, the leader stroke reaches the ground. The discharge may reach the ground in some cases about 15 km away from the cloud, where the sky may be completely clear. That is why it is termed Bolt from the Blue.

St. Elmo's Fire **:** This form of discharge generally takes place at the top of high masts or elevated objects. When the thunderstorm cell passes over elevated masts a positive glow will be seen at the top of the masts, while the negative charge flows down. This type of discharge observed over ship masts, on aerial masts of flying aircrafts etc.

Ball Lightning **:** There is no scientific explanation about ball lightning. Ball lightning occurs in the form of electric balls of diameter ranging 1 cm to about 2 meters. These lightning balls may fall from thunderstorm clouds and explode or the balls may roll down a hillock and strike against some objects and then explode. The electric balls appear like soap bubles. These balls sometimes may roll down into rooms through windows, doors or electrical discharges.

Lightning Discharge between Cloud and Earth

An ionized air column that is formed by the accelerated electrons in a thunderstorm electric field is a leader stroke. The stroke constitutes air channel in the form of progressive steps of 50-100 m from the base of cumulonimbus cloud to the earth.

Generally the first leader stroke is not visible but the first one which steps on the earth is visible. This looks like an illuminated river with tributaries. The speed of the leader stroke may range 160 km/s to 1600 km/s. The return stroke which goes (in the reverse direction) from the earth to the cloud base appears as a flash. This we call lightning. The speed of return stroke may be 14×10^4 km/s which is approximately half the speed of light (speed of light $C = 3 \times 10^8$ m/s). The period of lightning discharge may vary from a few micro seconds to a full second. If T seconds denotes the duration of time between the flash and thunder, then the distance of thunderstorm from the observer is approximately T/3 km, that is every three seconds is equal to one km.

Lightning

An electrically active convective cell within a thunderstorm has a life period about 30 minutes to 1 hour. During this period flashings may occur 1 to 10 per minute with maximum of 20 flashes per minute after first flash. During the life of the cell the mean flashing rate is about 3 per minute.

11.3 Some Effects of Electric Shock

Electricity produces its immediate effects on the body. It causes disturbance in body function but they do not always cause structural changes. Two principal mechanisms that cause death are : (i) Ventricular fibrillation and (ii) Respiratory arrest.

Ventricular Fibrillation

The human heart has two main pumping chambers for blood circulation. One chamber to pass blood around the body (the left ventricle) and the second to pump it through the lungs (the right ventricle). The thick walls of the ventricle consists almost entirely of muscle. It is the simultaneous contraction of all the individual muscle fibres establishes a pressure within the ventricle which is sufficient to circulate blood. An electric current passing through the heart disturbs the coordination of these individual muscle fibres so that instead of contracting simultaneously they contract individually each at its own rate. A head pressure is no longer established in the ventricles and blood circulation ceases so that death ensues within about 4 minutes. If the ventricles are viewed in this state when the muscle fibres are contracting individually, the ventricles, instead of showing forceful regular contractions "heart beats" are seem to be lying in a flacid state, with irregular twitchings, 'fibrillation'.

Respiratory Arrest

An electric shock might affect respiration in two ways. It may cause enduring arrest of respiration persisting after the shock current has ceased to flow or the path of the current may cause the chest muscles to contract and thereby preventing respiratory movement. In the later case, the effect lasts as long as the current flows and because a lightning current flows only for a very short time (a few tenths of millisecond), the effects caused by very short period respiration arrest is negligible. On the other hand, the first way in which the arrest of respiration persists even after the shock current has ceased, deserves further consideration.

These two ways (circulatory arrest or respiratory arrest) in which death might be caused are likely to be the most common. Though both cases result from changes in function unaccompanied by alteration in structure, there is nothing to prove (in post-mortem reports) that either or both had occurred. Therefore, man may die due to direct lightning stroke either by respiration arrest or due to malfunctioning of cardiac nerves. On such occasions the life of a man can be saved by heart massage or by mouth-to-mouth resuscitation.

In all types of lightning strokes only one-third of the victims loose their lives while the rest two-thirds recover partially or completely.

Types of Lightning Stroke on a Human Being

Injury/death from lightning may occur either by direct strike, by side flash over from an adjacent struck object or by ground currents. Direct strikes are the most severe which often leads to death. If the victim is struck directly, he will be initially (at least), conduct the whole current and is said to receive direct strike. His body resistance to earth may exceed that of the surrounding air, so that a flash over to the earth occurs. If the victim is near to another object which is struck, one of three things can happen. If he is actually in touch with the conducting object which is struck, he is then subject to contact voltage. If he is standing nearby, a part of the current may cross the air gap and discharge to the earth through him, in that case he is the victim of a side flash. If he is at a relatively long distance from the object which is struck, he may receive a side flash if a step voltage generated in the ground near the strike. A person in contact, generally by his feet, with two points at differing potential on the ground will receive an electric shock through the body between the two points of contact.

11.4 Favours and Frownings of Thunderstorms

(a) Favours

Thunderstorms, are also called atmospheric hot towers, are one of the main natural agency which transports sensible and latent heat energy from the surface of the earth (ocean surface or water bodies) to the atmosphere. A consequence of this is the transport of heat from equatorial region to polar regions.

Thunderstorms maintain the electrical field of the earth's atmosphere.

Fixation of atmospheric Nitrogen is mainly achieved by thunderstorms. By thunderstorm Nitrogen fixation, atmospheric Nitrogen is converted into nitrogen compounds which are brought down to earth by rain, which is utilized by the plant kingdom and aids agricultural production. Thunderstorm lightning produces about 30% to 50% nitrogen compounds in the atmosphere. In arid regions, the lower atmosphere is very dry and that the light rain or drizzle droplets which fall from clouds completely evaporate before reaching the ground (called virga). Only large drops can survive and reach the ground. Such large drops are effectively produced by thunderstorms.

(b) Frownings or Hazards

Lightning

Lightning causes death to human beings and animals and damages property by fire. To protect houses and tall buildings lightning conductors are fitted.

Hail

It causes damage to life and property, particularly crops, fruits and fruit trees. Hail storm is a severe hazard to aviation and aircrafts.

Thunder Squalls

Strong winds associated with thunderstorms are called thunder squalls. These cause damage to buildings, structures, parked and moored aircrafts, electric poles, huts and uproot even big trees.

Dust Storms

Over dry area with loose soil, thunder squalls raise lot of dust/sand into atmosphere, which may be suspended in the air for days and sometimes weeks. These are locally called Andhi (meaning blinding). This is hazardous for air and surface transportation services.

Heavy Rain and Flash Flooding

Heavy to very heavy rains are generally associated with thunderstorms, even during cyclones. These heavy falls cause flash flooding in urban areas and in small rivulets and cause havoc to life and property.

Aviation Hazard

Thunderstorm area is an aviation hazard not only for parked and moored aircraft in hangers but also for aircraft in flights due to steep wind shears, poor visibility (this is hazardous during landing and take off of aircrafts). Lightning causes radiostatic interruption in communication system. If an aircraft enters into a thunderstorm cloud, it will be tossed violently up and down (in severe cloud turbulence), causes severe icing on aircraft frames and fatigue to airframes. On small scale, severe local thunderstorms (known as Kalbaisakis) generate Tornadoes on land, and water spouts on water bodies. These cause devastating spell on life and property.

Safety Measures from Lightning Hazards during

Active Thunderstorms

1. All tall buildings, masts (minarets) must be fitted with lightning rods on their tops to discharge electric energy directly to the ground without touching beams, pillars etc.
2. ***Indoors***

   During active thunderstorm it is safer to be inside the house on an insulated bed. Keep off from electrical conductors, telephone wires, T.V. Antennas and radio aerials. Switch off radio, TV, fans, grinders, gas stoves etc. One should not touch any conducting material such as telephones, sewing machines, iron bars (picklocks, doors, grills, chains), water taps, pumps etc. Avoid smoking, better remove wrist watch, key chains etc.

3. ***Out doors***

   In open fields/areas one should not seek shelter under trees (particularly tall trees like palmer, coconut etc). It is better to lie down on the ground drenching in rain rather than seeking shelter under trees. One should avoid elevated places, rocks etc., which are the favorable places of lightning discharge. During active thunderstorm, in corn field one should not seek shelter even in a sheaf of corn. It is safer to set up two sheaves some 3 meters apart and then sit down half way between them. One should not ride on a horse/camel back, instead dismount from the horse/camel back and walk slowly.

Forecasting

Lightning may strike in a matter of seconds and as such there is no prediction of time and space of occurrence of lightning.

11.5 Hailstorms

Hail is one of the byproducts of a severe thunderstorm. Thunderstorm that is associated with hail is called hailstorm. Hail is formed in a well developed cumulonimbus cloud, which is characterized by severe updrafts. A typical hailstone when cut, shows layer structure like that of an onion. Hail is a climatic element, varies with time and space. The frequency occurrence of hailstorm is more in middle latitudes and it abruptly reduces to zero towards poles. Over the world, the western coasts of continents have maximum frequency during spring season. Hailstorms are not confined to any part of the world. Most hailstorms occur around lat 10 °N in April to September period and about lat 8 °S in October to March. However the whole of the northern hemisphere between lat 20 °N and 50 °N is prone to incidence of hailstorm in summer. Generally the size of hail is small (pea size, diameter less than 10 mm) and occurs over an area less than one square kilometer. But they cause heavy damage to fruit trees. It is estimated that on an average about 1% of the world's crop is damaged by hail. The mass of hail in general does not exceed 10% of the mass of that thunderstorm.

Hail has several shapes and is classified by its size and compared with the familiar objects. If the diameter is less than 5 mm, it is called shot, 5-10 mm is called pea size, 10-20 mm is called grape size, 20-30 mm is called walnut size, 30-50 mm is called golf ball size, 50-60 mm is called hen egg size and if it exceeds 60 mm it is called tennis ball size see Fig. 11.1. However in general the solid precipitation from cloud is classified into four types. (i) Grauple or soft hail, (ii) small hail, (iii) ice pellets and (iv) hail.

Soft Hail : They are white, opaque and conical in shape. Diameter is less than 5 mm, density 800 kg/m^3

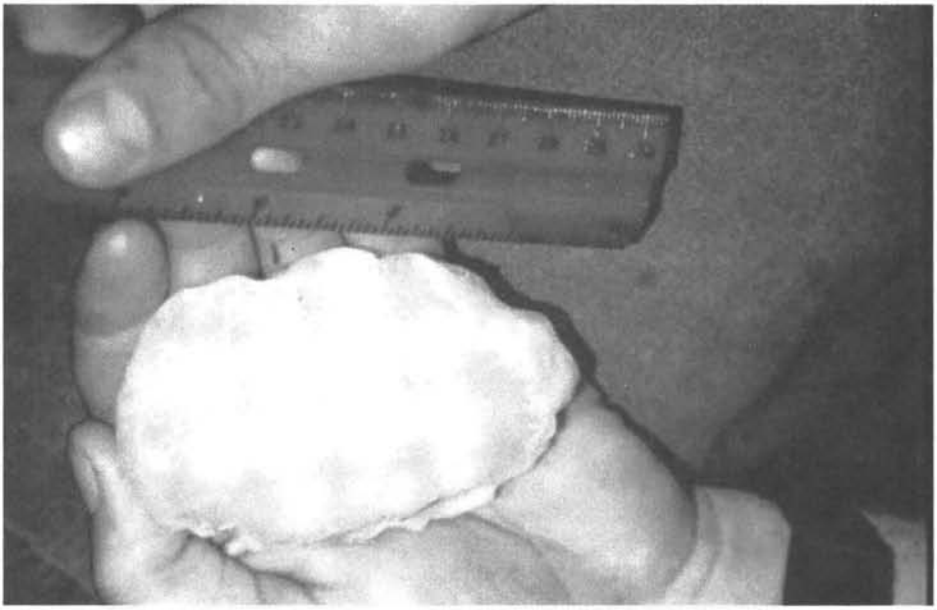

Fig. 11.1 Hail-tennis ball size.

Small Hail **:** They are partly transparent, round or conical in shape. Diameter upto 5 mm, denisity 800-900 kg/m^3.

Ice Pellets : They are transparent, spherical or irregular in shape. Diameter less than 5 mm, density the same as that of ice. They form by the freezing of rain drops.

Hail **:** They are lumps of ice or ice and water with air inclusion. Diameter more than 5 mm (up to 5 cm). They are partly transparent or opaque. They have alternating layers of ice and air babbles. Generally they are spherical or conical in shape.

Largest Hail

As mentioned earlier, the size of hail generally varies from 5 to 50 mm in diameter. But there are reports of very large size hail. On 30 April 1888, Moradabad in Bihar, India reported large hailstones of cricket ball size, which took the life of 246 human beings and 1600 goats and sheep. In Germany, in 1925, Talman measured an ellipsoidal hail 26 × 14 × 12 cm in size and weighed 2.04 kg. On 11 March 1957 Begumpet Airport (Hyderabad) India reported average hailstones of size 5-8 cm in diameter. On 27 May 1959, in Delhi, India, hail size of 200 mm diameter caused holes in aircraft frames and there were reports of hail size 250-375 mm diameter. On 3 September 1970, at Coffey Ville, Kansas, USA, a hailstone was weighed 758 gm, diameter 190 mm and circumfrence 444 mm. The substantiated reports of hail of 1.9 kg fell in Kazakisthan. 970 gm hail fell near Strasbourg, France in August 1958. The other reported hail weights are 4.5 kg recorded in China, 4 kg in

Hungary and 3.4 kg in India. These reports probably were groups of hailstones clustered or frozen together. There were also many reports of hailstones lying more than one meter deep on the ground. These consists mostly pea to walnut size and piled up drifting by wind from hill sides. During 11-13 March 1981, there were widespread hailstorm over Telangana (A.P), India which caused damage to 33000 acres standing crop, damaged 85000 houses and taken a toll of 18 human lives and 13000 live stock. The size of hail ranged 100 to 1200 gm.

Hail Formation in the Cloud

It is believed that some kind of ice nuclei when falls in the supercooled water, hail embryos are formed. It then grows by collision and accretion process. Hailstones have concentric accretions of clear and opaque ice. When embryo is carried aloft by updraft it is frozen. By repeated circular trips within updrafts of thunderstorm cell, that carry hailstone above and below freezing level, hailstone is formed. Depending on the time spent above freezing level milky hail layer forms by rapid freezing, while the clear ice layer is formed below the freezing level. The number of trips above and below freezing level (see Fig. 11.2) gives the number of layers within the hailstone. In one hailstone twenty five separate layers have been counted. Calculations show that an updraft of 95 kmph is required to support the hail of diameter 25 mm. A hailstone of 80 mm diameter requires an updraft of 200 kmph to support and a 130 mm diameter hailstone requires an updraft of 377 kmph to support.

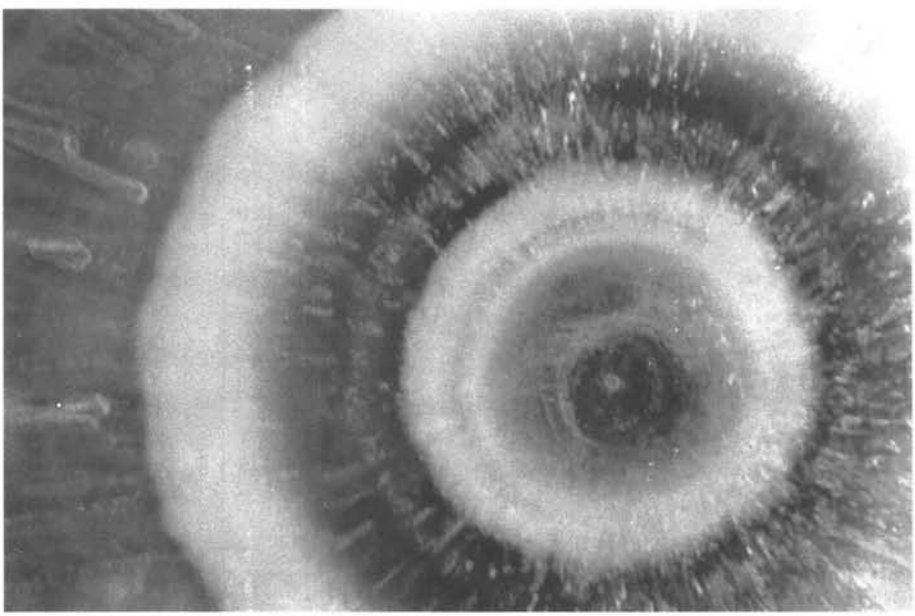

Fig. 11.2 Section of a large hail.

Favourable Synoptic Conditions

Various studies indicate the following favourable conditions for occurrence of hailstorm.

(i) Wind shear in middle troposphere (850 to 200 h Pa).

(ii) Surface high humidity and also in the lower levels.

(iii) Low level convergence of moist air masses of contrasting characteristics (such as continental and maritime air masses).

(iv) In tropics, movement of upper air trough in zonal westerlies Jet stream (200 h Pa), preferable location of hailstorm is along the axis of trough.

(v) North-South trough on sea level chart with associated wind discontinuity/ cyclonic circulation in the lower troposphere.

(vi) Steep lapse rate of temperature in the lower levels (surface to 500 h Pa).

A number of factors must be considered simultaneously and it is possible that a non-linear combination of parameters will be required. For example, wind shear plays an important role in the organization of the most severe hail storm, but it is likely that if shear is too strong, storm development will be inhibited. A major source of non-linearity in the forecasting problem is the existence of several distinct types of hailstorms.

Some principal types are:

(i) an airmass or pulsating multiple bubble storm,

(ii) a multicell strom and

(iii) a large severe super cell storm.

The first type requires great thermal instability and occurs in the absence of wind shear or strong winds. The second type requires moderate to strong instability and a proper vertical wind profile. The third type may occur without great instability, requires strong winds with a properly organized vertical wind profile and is associated with a strong organized downdraft fed by rain cooled air from the middle troposphere. It can produce very large stones, great crop damage and severe wind damage. It seems to be a type of storm associated with tornadoes.

Divergence exists from a trough to downstream crest in upper tropospheric (westerly) wave. In a sinusoidal wave, maximum upper level divergence is located about midway between trough and ridge. Its intensity is greatest for waves with short lengths and large amplitude and large wind speed in the jet stream. It seems that jet stream is a major factor in the development of severe thunderstorm.

A study revealed that wind speed from surface to 500 h Pa was very different from that compared to the wind speed from 500 h Pa to 250 h Pa. The difference between the two was related to the size of the hailstones produced. A wind shear of 65 kmph (35 kt) between the two layers correspond to heavy hail (3-5 cm diameter), 61 kmph (33 kt) to moderate hail (1-2 cm diameter) and 48 kmph (26 kt) to light hail (diameter less than 1 cm), and less than 44 kmph (24 kt) indicate no hail formation.

The terminal velocity of hail is given by an approximate formula

$$V = \sqrt{2W/C_d\, \rho_a\, A}$$

where W = weight of the hail

A = cross-section area

C_d = drag coefficient

ρ_a = density of air, which varies with height.

The fall speed of large hail stones is of the order 40-100 mps.

Low Level Wind Shear

Low level wind shear is associated with the following meteorological situations.

(i) Ground layer inversion during winter months, which results in strong jet like winds aloft.

(ii) At the boundaries of air masses.

(iii) Sea breeze circulation.

(iv) Sharp changes due to topographical features over aerodromes.

(v) In the vicinity of thunderstorm.

Microburst

Downdrafts in thunderstorms encircling horizontal gusts of large magnitude is called downburst or micro-bursts. A downburst may be defined as a localised intense down draft with vertical currents exceeding a downward speed of 3.6 mps (12 ft/sec) at an height of 91 m (300 ft) above ground. This speed is comparable to the normal descent rate of a jet aircraft during landing. This threshold speed of downburst tends to double the sinking speed of such an aircraft to adjust balance (or trimmed) for normal approach near touch down at usual 3^o glide slope below 150 m (500 ft). A microburst is a smaller but rather more intense version of the downburst. The horizontal extent of the downburst is 4-10 km and the microburst is 1-4 km. When downburst/microbursts reach the surface they spread out horizontally (see Fig. 11.3) and causes strong gusty surface winds with average maximal gusts 50 to 60 mps. In such an encounter aircraft loses balance and crashes.

Hailstorm Damages : Hailstorms damage valuable cash crops, fruits, orchards, vegetables besides damage to life and property, howver it is localised. In India highest annual frequency of hailstorm occurence is found over Vidarbha (February),

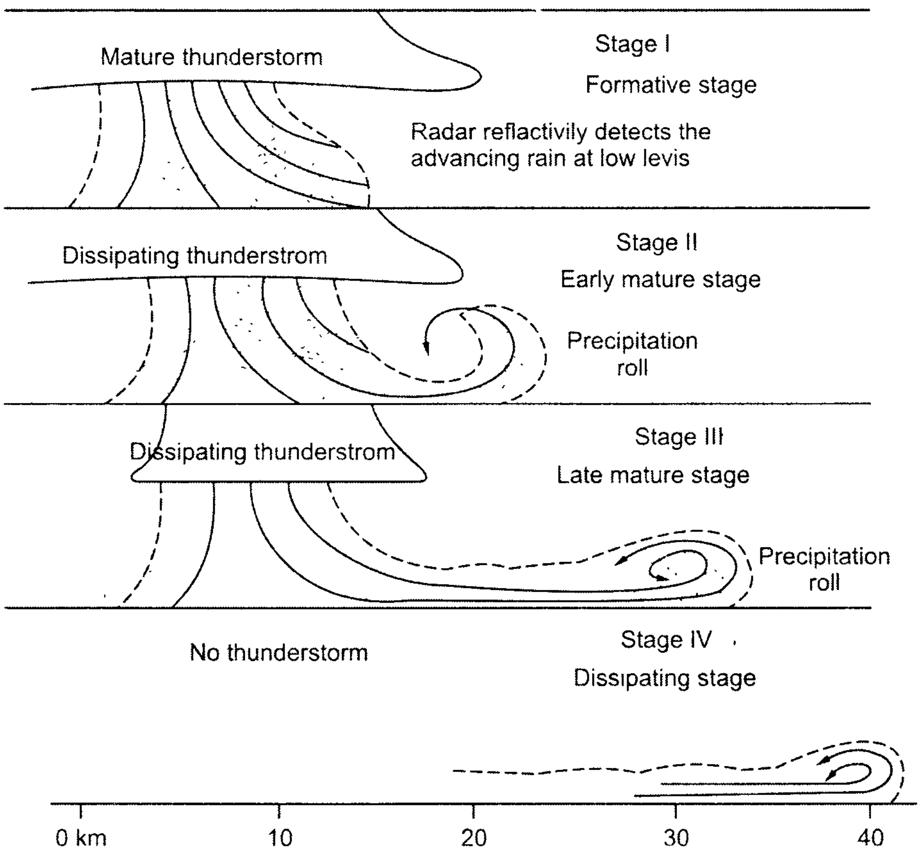

Fig. 11.3 Four stages of cold down draft air spreading ground.

Himachal Pradesh, Madhya Pradesh, Chettisgarh and Assam. Monsoon season is free from hailstorms. Hailstorms in India are mostly confined to the months of January to April. Winter months are more prone to hailstorms over Vidarbha, MP and neighbouring area. The major damages of hailstorms during February (1976-2003) are given below.

28-2-1982 Kanpur, Mathura, Unnag districts of Uttar Pradesh suffered hailstorm damage 60% of standing rabi crops. 8 persons died, 25 injured.

9-2-1986 Hailstorm around Nagpur killed 125 cattle heads, injured 16 persons, damaged standing crops worth Rs. 10 crores.

11-2-86 Hailstorm over Yavatmal District killed 4 persons, injured 5 persons and damaged property worth Rs. 2 crores.

19-2-1987 Hailstorm over Faridabad near Delhi, damaged standing crops worth Rs. 20 crores.

16-2-1988 Hailstones weighing 2 to 3 kg reported in Sambalpur, Puri districts. Several people injured and standing crops over 2000 acres damaged.

11-2-1991 Hailstorm in Delhi killed 3 persons and injured 4 persons. In Faridabad 5 killed and 4 injured.

28-2-1991 Hailstorm in Karimnager, Hyderabad (A.P.)killed hundreds of sheep and goats, damaged crops of cotton, castor and vegetables worth Rs.10 crores.

21-2-2001 Hailstorm over Bashirhat, West Bengal reported heavy hail injured 200 persons, 400 cows and many cattle.

Preventive Measures : All preventive safety measures of lightning have to be observed. In western countries particularly in Russia, Germany, rockets are fired loading with silver iodide into thunder clouds to suppress hail. Earlier long Gaigar guns were fired. Now weather modification technics with silver iodide seems more effective in suppressing hail. Such cloud seeding technology may be introduced in India for suppressing hail damage. The nowcasting and forecasting of hailstorm can be made precise using Doppler radars.

11.6 Tornadoes

Tornadoes are the most violent storms on earth, but they miss detection on synoptic chart. A Tornado is a violent rotating column (spiral motion) of air. It appears as pendent cloud extending from cumulonimbus cloud base to the ground. The column (or funnel) does not always extend to the ground and may be masked by the dust. A funnel cloud is similar to a tornado, except that the funnel does not reach the ground. The diameter of the column is about 100 m. In general tornadoes are more frequent in extra-tropics than in tropics.

The word Tornado is derived from the Spanish word Tronada, meaning thunderstorm. In northern and western parts of Africa tornado still refers to a thunderstorm. In Latin Tornare means "to turn", thus tornadoes are also called twisters. Tornadoes have different names in different parts of the world. In France and Germany they are called Trombe, in Spain and Italy Tromba, in Russia Symerch, in JapanTatsumaki, in India Hatishnura (meaning Elephants trunk)

Life Cycle of a Tornado

Tornado funnel may be seen as thin rope, conical shape, cylindrical shape or thick dense cloud mass touching the ground. Generally tornadoes rotate in an anti clockwise direction but there may be some that rotate in clockwise direction. During the life span of a tornado the funnel undergoes many changes. The life cycle of a tornado may be divided into five stages.

1. ***Dust Whirl Stage :*** In this stage whirling of dust is observed below cumulonimbus cloud but it does not touch the ground.
2. ***Organising Stage :*** In this stage the funnel from the base of Cb cloud touches the ground and intensity increases.
3. ***Mature Stage :*** In this stage funnel attains maximum diameter (100-250 m). Central pressure in the eye drops (25-200 h Pa) and attains maximum wind speed. Circulation usually stays in continuous contact with the ground through stages 3, 4 and 5. The funnel creates havoc, destroys buildings, poles, trees and sucking debris and dust raises to great heights into the air. Sometimes motor cars, animal and heavy objects sucks in, lifts aloft and thrown away at considerable distance. The destruction of buildings is also caused by explosive effect due to sudden fall of pressure (in less than a minute) by over 50 h Pa or more. The large pressure defference between inside a closed building and the outside atmosphere leads to an explosion, which bursts the walls and the ceiling outwards. According to some empirical theory, a pressure drop of 100 h Pa causes wind speed 600 kmph around the vortex.
4. ***Shrinking Stage :*** In this stage the width of the funnel decreases and tilt of vertical axis increases, fury drastically decreases.
5. ***Decay Stage :*** In this stage the shape of the funnel spreads like a spiral of rope, decreases in height and ultimately disappears.

Major tornadoes pass through all five stages while minor tornadoes abort in stages one – two – five.

Size of a Tornado

The diameter of the funnel generally varies 100-250 m, rarely reaches to 1000 m. The vertical depth of tornado circulation extends to the middle of Cb cloud (about

10 km). The average path length is 5-10 km but it may range 30 m to 500 km. Life span varies 2-3 minutes to 3 hours. Short lived tornadoes have wind speed 50 mps, path width 100 m and travel length 2 km, whereas long life period tornadoes have wind speed 100 mps, path width 200-600 m and travel length 200 km. Life period varies 15 seconds to 8 minutes at a point. An extreme duration of 7 hours along the ground observed in Illinois on 26 May 1917. They generally move in a straight line path over a flat country for a long distance. Movement becomes zig-zag when it passes through hills, tall buildings and limits speed, on some occasions dies down. The average energy of tornado is 10^{-11} times the solar energy received by the earth (3.67×10^7 cal/min).

Central Pressure Drop in a Tornado

The central pressure drop (in the eye) may 100 to 200 h Pa. On 20 Aug 1904, at Minnesota, aneroid barometer recorded a pressure fall of 200 h Pa. The eye of a tornado behaves like a vacuum, consequently strange things happen near the vortex such as, trees are stripped of their barks, sheep lose their wool, chickens lose their plumes, corks of bottles fly off, chests explode and splinters fall in all directions and bursting of closed buildings etc. People who had the experience narrated that they had the bursting experience in their chest and ears.

Synoptic Situations Favourable

The first signs of a Tornado development is a large active cumulonimbus cloud with mammatus. The cloud may acquire green and yellow colour. Green colour lightning or ball lightning also be observed. On some occasions a Tornado may occur without any thunderstorm activity but there will be heavy rain, showers and hail. Cb is associated with every tornado. It is probable a supercell type convective cloud is the genesis of a tornado. The synoptic conditions favourable for the development of a supercell type convective cloud are:

(i) Low level convergence with associated upper air divergence,

(ii) lot of moisture in low levels,

(iii) super adiabatic lapse rate in the lower-mid levels,

(iv) strong vertical shear in the horizontal wind (upto 300-250 h Pa or more).

Radar Echoes

As mentioned earlier in thunderstorms hook (6) type echo is associated with a tornado, which is an indication of meso-cyclone. It may be noted here that every hook type echo is not a tornado, it only indicates severe thunderstorm. The echo reflectivity is to the order of 4 or more.

Tornado Vortex Signature (TVS)

A pulsed Doppler Radar \when directed to a stationary cyclonic vortex, it will show particles moving away from the radar to the right (positive velocities) of the line joining the radar and the centre of vortex and the left of this line particles will appear to be moving towards the radar (negative velocities). Doppler radar will indicate positive velocities to the right of the centre of the vortex and negative velocities to the left of the vortex centre and zero along the line of the vortex centre. The velocity distribution configuration detected by Doppler Radar is called Tornado Vortex Signature (TVS). TVS is detected in the middle region of Cb. A tornado takes about 15 to 20 minutes to touch the ground after TVS is detected.

Electrical Phenomena

Increased lightning activity will be observed about half an hour before touch down of a tornado.

Acoustic Phenomena

A peculiar whining sound like buzzing of an army of bees is heard when the funnel cloud is high up in the air. When the funnel touches the ground a terrific roar, like the sound of a cannon fire, is heard for a few minutes. Snake hissing sounds heard before tornado touches the ground. This is attributed to the vibrations of the air masses rotating around the funnel.

Precipitation

Heavy rain sometimes associated with hail precede and follow a tornado. The eye of the tornado, like the cyclone eye, is generally free from precipitation.

Tornado Hazards

Prediction of a tornado is still in infant stage as its mechanism of formation is not clearly understood. However with the help of radar nowcasting is done (forecasting its movement and severity in a very short period) to alert people to save their lives. Property damage due to tornadoes seems at present inevitable (see Fig. 11.4). The average death toll in United States of America is about 150-250 per annum, but the injury seems many folds of this. This is caused by the flying objects hitting the people and the subsequent fire. The greatest loss of life due to a single day tornado was 689 people recorded on 18 March 1925, while the greatest loss on a single day was about 1200 people recorded on 19 February 1884.

Some Recorded Tornado Incidence

On 30 May 1879 an iron bridge weighing 108 tons was lifted over the River Big Blue in Irving (USA). This incident was recorded in great detail in a book by Finley (1881). A tornado in Minnesota lifted a passenger car with 117 passengers, total

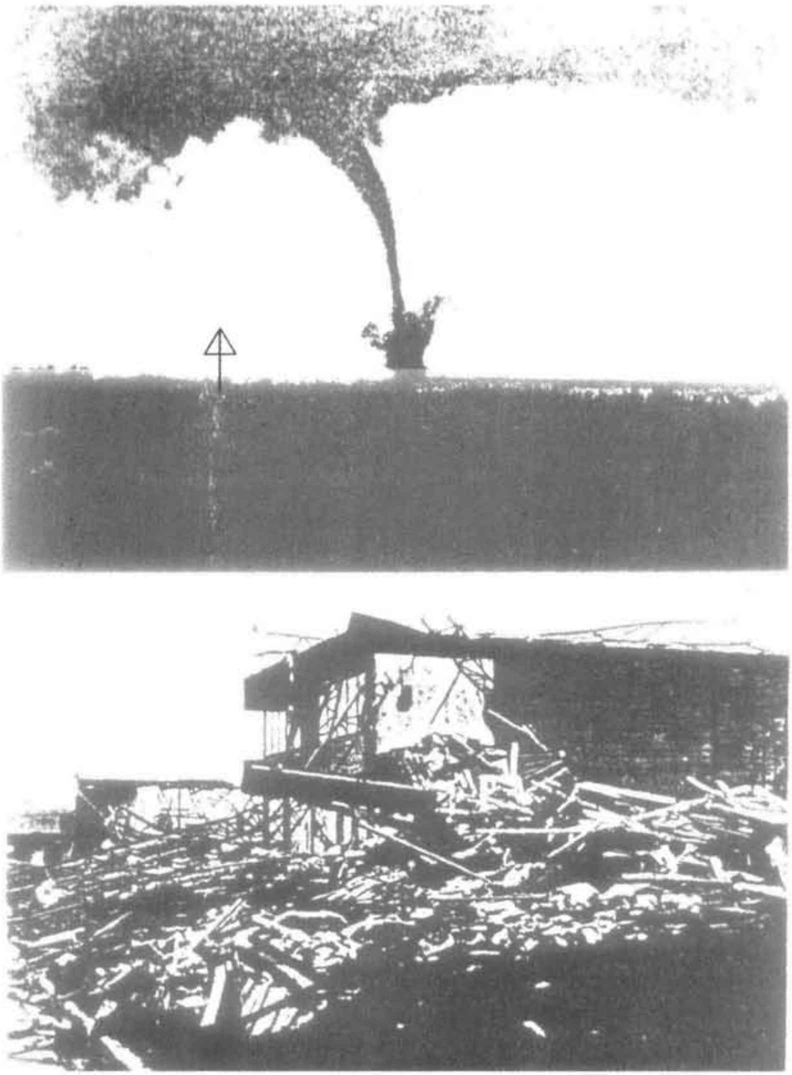

Fig. 11.4 The tornado (upper photo) which struck Edmonton, Canada on 31 July 1987 left 26 dead and cause damage amounting to US$350 million (*lower photo*)
(***Photos :*** *Atmospheric Environment Service Canada*).

weight about 72 tons. In 1879, in Missouri, a horse was lifted and carried a distance of few hundred meters and deposited without any injury. In New Delhi (India) on 17 March, 1978 a tornado in about three minutes took a toll of 28 people, caused injuries to about 700 people and damaged property worth more than one crore rupees. The same tornado lifted a passenger bus with 70 passengers and deposited twenty meters away in a canal. A tempo vehicle was also lifted from a petrol pump and thrown 100 meters away. In a Germany city market a man who was standing under the vortex was lifted high in the air, pelted with hailstones and thrown. When he came back to senses he found himself under two men, one woman and a horse. Another man who was standing close to a post in front of an emergency ward of a hospital in Lefortova was lifted five meters high in the air, carried a distance of 100 m in the garden and deposited on the lawn.

Development of Tornadoes Associated with Fire and Volcanic Eruptions

Under favourable circumstances widespread fire may develop a tornado. On 1 September 1923, a fire broke out in Tokyo after an earthquake. Within 24 hours about 120 tornadoes and smoke devils developed in Tokyo after the great earthquake. Some tornado acquired intensity of wind 50-70 m/s, picked up cars, people outside the fire line. About one lakh forty two thousand (142000) people died in Tokyo, more by fire than by earthquake itself.

Tornadoes/waterspouts may develop after volcanic eruptions over land/water surface. In 1963, there was volcanic eruption of Surtsey in the middle of the sea, off the coast of Iceland. Each intense volcanic eruption gave rise to an enormous dense cloud. From these clouds tornadoes of different sizes developed on the leeward side.

Safety Measures

People can adopt safety measures to protect themselves by listening to tornado advisory bulletins broadcast on national TV channel. The following measures to be adopted as in case of lightning strokes and cyclones. Shut off immediately, after alert, electric power, gas supplies and extinguish all fires. Seek shelter quickly in a tornado cell or in sturdy reinforced pucca concrete building. Do not drive a car which may be hit by missile debris or it may even be lifted and thrown away by strong winds. If caught in an open place, run to a nearby culvert or ditch, lie down and hold on to a fixed object to protect from being blown off. Protect your head from the injuries of flying objects.

Fujita-Pearson (FPP) Tornado Intensity Wind Scale

This was proposed by Fujita in 1971. This wind scale designed to link the Beaufort scale of Force 12 with Mach No.1 in twelve steps. The scale is derived from the formula

$$V = 6.30\,(F + 2)^{3/2}$$

where V = wind speed in mps. The scale specifications are given in Table 11.2.

Table 11.2

Scale	Wind	Damage description
F0	18-32 mps	Light damage: such as breaking of tree branches, falling of sign boards.
F1	33-49 mps	Moderate damage: Beginning of hurricane wind speed. Moving autos pushed off the roads. Peel surface off roofs. Mobile homes overturned
F2	50-69 mps	Considerable damage: Box cars pushed over; Mobile homes demolished. Large trees uprooted or snapped. Light object missiles generated.
F3	70-92 mps	Severe damage: Roofs and walls tornoff well constructed homes. Trains overturned, Heavy cars lifted off ground and thrown. Most forest trees uprooted.
F4	93-116 mps	Devastating damage: Well constructed houses levelled; cars thrown and large missiles generated, structures with weak foundation blown off some distance.
F5	117-142 mps	Incredible damage: Automobile sized missiles fly through the air beyond 100 meters; strong frame houses lifted off foundations and disintegrated at consider-able distance. Trees debarked; incredible phenomena will occur.
F6-F12	142 mps to Mach-1	The maximum wind speeds of tornadoes (=speed of sound) not likely to reach F6 wind speeds.

Tornado Statistics

Tornadoes can occur in any latitudes, but they are more frequent in extra-tropics than in tropics, and rare in equatorial belt. The annual frequency of occurrence of tornadoes in USA is about 200. The Mississippi valley has maximum occurrence in the world. Generally tornadoes move from south westerly direction (in northern hemisphere) at the average speed of 15 mps. The maximum wind speed does not exceed 142 mps. The average travel length is about 2 km (range 100 m to 600 km), in USA 7 km. The average width of track is 50 m to 250 m. There may be erratic movement as well. Average life span varies from 2 minutes-2 hours.

11.7 Waterspouts

Waterspouts are of two types. Type one that develops downward from a cumulonimbus cloud and it is also called fair-weather waterspout. Type two is simply a tornado over the water. Type two develops upwards from the surface of water and is not directly associated with a cloud. In both of these types water gets sucked up into air along with aquatic creatures such as fish, frog etc. These aquatic creatures may be found in rain associated with waterspout. In the world over Florida keys and Palm beach Florida have the highest frequency of incidence of waterspouts about five per annum per 100 sq km.

Waterspouts undergo a life cycle similar to that of tornado on land. It has five stages of life cycle which are briefly described below.

1. ***Initial or Dark Spot Development Stage :*** First visible sign of a vortex is a dark spot on the sea surface. In this initial stage a short funnel pendant may develop from the super cell (Cb cloud). The dark spots may occur in bunches of two or more, of which one may be dominating the others. The dominant one becomes waterspout and the others decay. The life span in this stage may be about 1-20 minutes. Many may dissipate after this stage. From the droppings of tracers it is gathered that the dark spots are developed by the rotation imposed from above.
2. ***Spiral Stage :*** In the second stage, formation of spiral occurs on the sea. Only one dark band (150-1000 m) comes out from a nearby shower band. Spiral bands indicate the lines of confluence or difluence on sea surface while the regions of flow away from the vortex seen along the surface.
3. ***Ring Spray Stage :*** In this stage wind strength increases beyond a critical value of about 22 mps and throws up a ring of spray from the surface. In this stage funnel increases in size and the axis of funnel tilts. It begins to move rapidly along the surface as it comes under the influence of the wind shift line. The wind shift line is believed to be associated with the cool breeze from close by shower.
4. ***Mature Stage :*** Mature stage lasts about 2 to 18 minutes. This stage is characterized by the strongest wind, funnel tilt and associated with forward wind speed 4-8 mps. In this stage the funnel may acquire double eye wall like that of cyclone and generally moves along a gentle curved path. The spray ring becomes spray vortex. Waterspout may not be visible all through from cloud to water surface. On radarscope hook echo may be seen.
5. ***Decay Stage :*** The last stage is decay stage. This stage generally lasts about 2 to 3 minutes. Spiral and funnel disappears, and rain cooled air takes over waterspout. However in decay stage spiral rain may still be seen which lasts about 5 minutes.

Waterspout Statistics

The maximum tangential wind speed estimated by photogrammetric technique is 85 mps in the lowest levels of 10-15 m (amsl). Waterspouts carry objects weighing 5 tones to a height of about 40 m over coastal waters out at sea. The helical funnel of waterspout may go upto about 300 m in air. Waterspout vortex may generate waves of moderate to high amplitude over the sea surface. According to Schroder (1977) statistics Hawaiian island has maximum incidence of water spouts about 7 per annum. Photogrammetrically estimated wind speed at an altitude of 38 m is about 55 mps and vertical velocity 25 mps.

According to aircraft penetration of waterspouts observation the principal funnel features are:

(i) A warm central core region.

(ii) Funnel core deficit 1 to 10 hPa depending on waterspout intensity.

(iii) In the core upward vertical velocities 5-10 mps.

(iv) Tangential velocities at penetration altitude of 400 m is about 30 mps.

(v) Both cyclonic and anti-cyclonic vortices encountered.

In general waterspouts are more common than tornadoes and the average frequency is about 400 per annum per 10^4 sq km in favorable locations. Compared to tornadoes, central pressure of waterspouts have higher pressure and lower pressure defect and relatively less ferocious/violent.

11.8 Dust-Devils

Dust-devils are a frequent phenomena in tropics and sub-tropics, however they can be seen at any latitude under suitable environmental conditions. Generally dust-devils are observed during scorching hot sun in deserts and semi deserts. They are generally much smaller in size and less violent than tornadoes. The funnel core is warm with temperature anomaly of 1 to 10 °C. The core has low pressure with pressure defect 1 to 4 h Pa. Dust and sand whirls in a funnel shape but no pendant cloud is involved. The rotation of wind may be cyclonic or anticyclonic. The horizontal rotation and upward flow of wind in dust-devils exceed 30 kmph with average height of column being 200 m. Duration of life varies from few minutes to 7 hours with horizontal path distance of about 50 km.

Favourable condition for formation of Dust-Devils

(i) Hot or intense insolation (ii) Dry dusty ground (iii) Steep lapse rate of temperature at the ground (iv) calm or light surface wind.

11.9 Nowcasting

In Western countries, the disaster management associated with tornadoes are successfully executed with Nowcasting method, which we shall discuss briefly.

Some hazardous weather events occur in very short periods of time and there will be no lead time for warning. Flash floods, snow avalanches, mud-slide which cause havoc in a matter of few minutes. Lightening can strike in seconds and there seems an increasing trend of thunderstorm activity and lightning hazards and deaths which is attributed to atmospheric pollution and climate change. It is next to impossible to give exact prediction of the time and place of occurrence. In such situations the best course is left with the meteorologist is to issue warnings of the risk of their occurrence in a fairly wide area over an extended period of time. The people at risk must keep an eye open and judge for themselves whether it would be wise to move to a safer location.

For effective working of National Disaster Management Agency in such events is beyond imagination. However real time information would give local authorities a vital lead time in saving lives. Nowcasting system, which is in vogue in western developed countries, providing an impetus to the forecasting value and helping in disaster mitigation work. Nowcasting aims at a six-hour city specific prediction. This system would integrate the data from Doppler radars, automatic weather stations, satellite data and wind profilers to enable meteorologist to detect a phenomena like 26 July 2005 Mumbai rainfall deluge and allow the executive authorities a critical window to evacuate the likely affected people or warn them to move to safer locations nearly in a couple of hours.

Nowcasting will be of great value to urban users, to improve long and short time forecasts which help agriculture and industry.

Improving the network of Automatic weather stations and Doppler radar network would provide real time data of temperature, precipitation, humidity and wind. Automatic raingauge stations and wind profilers provide vital information at critical times for decision making.

11.10 Summer Thunderstorms over India

During hot weather period (March-May) rapid rise of surface temperature, fall of pressure, intensification of southern Indian ocean anticyclone, Northward movement of equatorial trough, Norwesters, Dust storms, Dust raising winds, Hail storms are common features over India neighborhood. Thunderstorm activity continues in monsoon season but less marked. The main thunderstorm activity observed during the period are :

(i) The area from Northeast India to east Madhya Pradesh, east Vidarbha and adjoining Andhra pradesh.,

(ii) Southwest Peninsula (Kerala and neighborhood),

(iii) Northwest India excluding Rajasthan.

Squalls associated with summer thunderstorms are very strong/violent. They uproot trees and there were instances in the past that trains being thrown out of tracks. On an average 15 to 20 thunderstorm days recorded in the season. Assam and adjacent States, south Kerala have the highest frequency (30 to 40 days). Entire India is susceptible to thunderstorm activity but Gujarat State has the lowest frequency (about five days in whole of the season).

Thunderstorm activity progressively increases from March. During March the areas of maximum activity (frequency more than 6-days) are Assam and adjacent States and Kerala. The other areas are foot hills of the Himalaya (J & K), Punjab, Himachal Pradesh, east Madhya Pradesh, Bihar, Bengal. The lowest activity lies in Saurastra, Kutch, Gujarat and Konkan coast.

In April thunderstorm activity increases. Maximum frequency (12-14 days) lies over Assam and Kerala. The other area of high frequency (about 8 days) are east Madhya Pradesh, Vidarbha, Deccan Plateau. The lowest frequency (about one or two days) lies in south coastal Andhra Pradesh, coastal Tamilnadu, Saurastra, Kutch, Gujarat and KonKan coasts.

May is the month of peak thunderstorms activity. The maximum frequency zone runs from Assam to south Kerala. Assam and Bengal have frequency of about 16 days, while Gujarat, Saurastra and Kutch have the least frequency or no activity.

The chief atmospheric features during this season are :

(i) a number of meteorological parameters show large diurnal variation,

(ii) formation of heat low over central/interior parts of the country,

(iii) weak to moderate westerly wind flow in the lower troposphere, and

(iv) intense convective activity associated with conditional convective instability (steep lapse rate).

Thunderstorm activity continues in monsoon and post monsoon season and becomes least in winter. The highest frequency of thunderstorms (more than 80 days in a year) extends from Assam to east Madhya Pradesh. Assam and neighbouring Bengal have frequency of more than 100 days, Silchar has 101 days, Mohanbari 106 days. Gauhati 102 days and Sibsagar, Krishnanagar have 108 days. The other high frequency zone is central Kerala and hilly regions of extreme north India. The lowest frequency, less than 10 days in a year, are in coastal Saurastra and Kutch.

11.10.1 Norwesters

The severe Thunderstorms of hot weather period over Bengal and Orissa are known as Norwesters. They are locally called 'Kal Baisakhi' or the fateful thing of the month Baisakh (15 April to 15 May). These severe thunderstorms usually approach a station from northwest direction (and hence the name Norwester) and burst over a station with great violence raising clouds of dust. The squalls associated with these Norwesters reach tornadic violence (120 to 150 kmph). They cause considerable damage to life and property in their path. Tornadoes rarely occur in north east India. Assam and adjacent States are more susceptible to tornadoes locally called Hatishmura (frequency once in a few years). Generally the direction of the squalls is Northwesterly direction.

Favourable Synoptic Situations

(i) induced low over Punjab, Haryana, Rajasthan, West Uttar Pradesh or northwest Madhya Pradesh,

(ii) conditional convective instability in the lower-mid troposphere,

(iii) adequate moisture supply in the lower troposphere (Note: Horizontal distribution of moisture at the ground can be ascertained by dew point temperature of surface observations while vertical distribution of moisture is known through Radiosonde ascents),

(iv) an extension of trough east-south-east wards from induced low to Bihar Plateau and westwards,

(v) penetration of easterlies upto 850 h Pa level over Bihar plains,

(vi) in mid-and upper troposphere mainly westerly wind flow over north-east India.

Thunderstorms in Gangetic West Bengal, Bihar, Orissa have definite sequence of time. They generally develop over Bihar plateau, south Madhya Pradesh or west Orissa. They travel east or south-eastwards towards Gangetic West Bengal or Head Bay of Bengal.

The severe thunderstorms of north-east India are classified into four types.

Type A : They develop over Bihar plateau and adjoining area in the after noon and move with fury in a southeasterly direction.

Type B : They originate in submontane districts of north Bengal and move southwards. They generally form and move during night or early morning.

Type C : They originate in the hills of Nagaland, Manipur and Mizoram and move westwards.

Type D : They develop near the Khasi hills and move southwards.

In fact perturbation in the westerlies caused by a trough or jet stream or a cut-off low, deep westerly trough causes widespread thunderstorm activity over north-east India.

11.10.2 Thunderstorms and Dust-storms over north-west India

During March-June (in all months), thunderstorms occur in north-west India and Uttar Pradesh. The activity is more in western Himalayas as compared to the plains. Thunderstorm activity progressively increases from March and attains peak in May and June. Dust storms occur in plains of UP, Punjab, Haryana and north Rajasthan. They begin in April and attain peak in June. The dust storms locally called Andhi – meaning blinding.

Dust-storms are of two types :

(i) Pressure gradient type and,

(ii) convective type.

In pressure gradient type, strong winds raise loose dust from the surface of the earth into the atmosphere. In this case no Cb is involved. In convective type dust is raised into the atmosphere by strong downdrafts from Cb cloud. In convective type dust storm proceeds a thunderstorm.

The maximum frequency of dust-storms occur in Rajasthan. In pressure gradient type strong surface winds are built up due to steep gradient around low. Wind raised dust suspends in the atmosphere and reduces the visibility to below one km. Pressure gradient of 1 to 1.5 h Pa or more per degree latitude prevails over a longer

Fig. 11.5 Photo of dust wall of an advancing convective dust storm.

period. Winds of the order 30 to 50 Kt prevail upto 1.5 km (850 hpa level). Dust raising winds may commence in the morning and continue for the whole day with maximum intensity in the afternoon when the lapse rate near the ground reaches superadiabatic. In convective type dust-storms the duration of strong winds is of short duration (few minutes or fraction of an hour). Even after dust storm/dust raising winds subside, the raised dust in the atmosphere may go upto 700 hPa level and remain suspended for days together and reduce the visibility.

Favourable Synoptic Situation

Shallow heat low forms over central and northwest India. Quasi Stationary wind discontinuity in low levels run in north-south direction to Peninsula and another south-east Madhya Pradesh to Assam. A shallow anticyclone over Bay of Bengal feeds moisture from the south on one side of the wind discontinuity and contrasting dry northerly or north-westerlies prevail on the other side of the discontinuity line. Over north India in the mid-and upper troposphere sub-tropical jet stream runs, which provides upper divergence. Near the surface of the earth and in planetary boundary layer superadiabatic temperature lapse rate favours convective activity.

11.10.3 Thunderstorms over South Peninsula

During March-May high frequency of thunderstorm activity prevails over Kerala (about 15 days each month) and neighborhood. Orography plays an important role. Abundant moisture feed comes from the neighbouring sea. Kodaikanal: seasonal 34 days, annual 75 days; Trivendrum: seasonal 36 days, annual 70 days.

Hailstorms

Hailstorms in India occur in northern parts of the country. They are much less common over Peninsula. Hailstorms are always associated with Cb cloud only. Hailstorms are common in winter (Dec-Feb) over northwest India, Uttar Pradesh, Madhya Pradesh, and in premonsoon period over north-east India, Peninsula, Vidarbha and Madhya Pradesh. No hailstorm reports from any part of the country during monsoon (June-September) period. During post monsoon (October-November) there is little activity in isolated pockets north of Lat 20 ^{o}N and west of long 90^{o}E.

The annual frequency of hailstorms over northeast India is about 10 days, over Uttar Pradesh, east Bihar and Agartala about 6 days, over east Madhya Pradesh, Chattisgarh, Jharkhand is 2 to 3 days. Maximum activity over south Peninsula is 1 to 2 near Madurai. The entire west coast, south coastal Andhra Pradesh are free from hailstorm activity.

Favourable Synoptic Features

Intense convective conditional instability, large Cb cloud extending to upper troposphere (12 to 14 km). In lower and mid-troposphere high moisture content, strong vertical wind shear surface to mid-troposphere, low freezing level, lowering of trough in the jet core.

11.12 Cold Waves and Heat Waves

Introduction

Absorption of solar radiation and long IR radiation effects man in two ways.

(i) It can heat or cool (thermal effects) and

(ii) Photochemical effects.

These effects are caused through skin and eyes. Skin of white people reflects visible and near IR radiation to the extent of 40%. Radiation is accepted or rejected by the skin according to its surface properties and colour. Black skin absorbs about 44% more solar energy than white skin, but the horny layer of white skin transmits 3.5 times more UV light than that of Negroes. Irrespective of the skin colour white, yellow or black, human body radiates energy in the long wave (IR) as that of black body at 32 ^{o}C. The main wave lengths of emission are for IR at 6 and 9 mm (range 2-14 mm). The important parts of the humans body that react to severe meteorological elements are skin, lungs, throat, nose, eyes and nervous system.

Human heat balance = heat gain [(from metabolism + skin absorbed (solar radiation + long IR radiation)] – heat loss (IR radiation from body + convection + evaporation).

UV radiation (near 0.3 μm) causes photochemical inflammation of cornea of the eyes. This damage is caused by reflected solar UV-radiation by snow.

Photochemical action of the skin causes production of Vitamin-D, sunburn, early aging of the skin, strengthening of the horny layer, skin cancer through pigmentation.

Natural sunburn is caused by solar UV-radiation around 0.3 μm, which penetrates deeper into living skin layers. It first causes white skin or tender spots of the skin reddening (after 5-20 minutes of exposure), painful reddening (30-70 minutes of exposure), larger dose oedema and finally blisters. UV-radiation larger dose causes sunburn under nose, lips, nostrils, upper and inside portions of ears, eyelids, chin and cornea of the eyes.

Protection against sunburn achieved by lowering the dose (shortening the exposure time at high sun and clear sky), window glass and skin creams application (which absorb radiation below 0.32 μm) dry cloths and vegetation completely attenuates. Over dose of UV-radiation leads (after exceeding the minimum dose of reddening) to severe erythema, oedema and blistering. Frequent exposure leads to ageing of the skin and loss of elasticity in skin and causes skin cancer in exposed areas of face, neck etc. (there are about (2.3 million) 2.3×10^{6} eccrine sweat gland in human). Sunburn blocks human sweating and hence loses body cooling inbuilt capacity. Skin registers thermal conduction, convection and IR radiation. Human body does not sweat at skin temperature of 28 ^{o}C.

UV-radiation Effects

It causes increase in vitamin-D and histamines. Increases gastric acid secretion and protein metabolism. In blood, increased hemoglobin, Ca, Mg and phosphate levels. It causes direct lethal effects on bacteria and indirect effect on human.

Frostbite (freezing of tissues)

At very low temperatures when wind removes body heat faster than the body can replace it, frostbite occurs.

Frostbite or hypothermia occurs either by drop in ambient air temperature or increase in wind speed.

Hypothermia

The lowering of central body temperature is called hypothermia. Normal body temperature is maintained by muscular activity (muscular metabolism) and basal metabolism. The process in which food is converted into living matter and useful form of energy is called metabolism – which depends on energy supplied by food and water as intake. Hypothermia begins when ambient environmental temperature is much lower and body loses heat as compared to what it produced. The symptoms of setting of hypothermia are :

1. Weariness and reluctant to continue moving.
2. Trembling and shivering.
3. False feeling of well-being.
4. Clumsiness and loss of judgement.

Hypothermia progress with fall temperature is given in Table 11.3.

Table 11.3

Temperature		
F	C	Symptoms
99-96	37.2-35.6	Uncontrollable shivering
95-91	35.0-32.8	sluggish thinking and violent shivering, difficult in speaking. Beginning of amnesia.
90-86	32.2-30.0	shivering decreases but shows muscular rigidity. Unclear thinking and dull comprehension of surroundings. Total amenesia begins.
85-81	29.4-27.2	Irriationality, muscular rigidity, lost contact with environment. Pulse and respiration slows down.
80-78	26.7-25.6	Victim does not respond to spoken word. Reflexes mostly cease to function, erratic heartbeat, unconsciousness begins.
Below 78	Below 25.6	Cardiac fibrillation and failure idema and hemorrhage in lungs; death.

Heat Effects

In thermal balance, the deep body temperature of man will be 98.6 °F or 37 °C. The normal skin temperature lies between 31-34 °C.

When deep body temperature increases by 2 to 3 °C (3.6-5.4 °F) i.e., 39-40 °C (102.2 to 104 °F) heat stroke occurs - circulatory failure,

at 41 °C (105.8 °F) Coma sets in,

at 41-44 °C (106-111 °F) death imminent,

at 45 °C (113 °F) certain death.

Altitude Sickness

Without proper acclimation (about a week) if people are abruptly transported to high altitude (say about 2 to 3 km from a station level) they feel over exertion, fatigue after arrival. This is called altitude sickness. After arriving at high altitudes even a few minutes of work cause them grasping for breath, chest pain. Over exertion may cause headache, nausea and vomiting, dizziness and weakness. The remedy is rest. In all such cases slow down your work till acclimated. Breath through nose (not through your month) to keep yourself free from dehydration.

11.11.1 Cold Waves in India

During the period November to March and sometimes in the months of October and April, cold dry air blows from northwesterly/northerly direction and lowers the day and night temperatures significantly. On some occasion temperature falls so much that it leads frost formation and causes damage to crops and loss of life. There is no regular periodicity of occurrence but occurs two to three times in a season. According to IMD convention the 24 hr minimum temperature changes and departure from normal (cold waves) defined as follows.

Cold Waves

A. When the normal minimum temperature of a station is $\geq$ 10 °C.

Magnitude of change °C	Description of 24 hr change	Description of departure from normal
– 1 to 1	Little change	Normal
– 2	Fall	Below normal
– 3 to – 4	Appreciable fall	Appreciably below normal
–5 to –6	Marked fall	Markedly below normal or Moderate cold wave condition
–7 or less	Large fall	severe cold wave

B. When the normal minimum temperature of a station is < 10 $^{\circ}$C

Magnitude of change $^{\circ}$C	Description of 24 hr change	Description of departure from normal
– 1 to 1	Little change	Normal
– 2	Fall	Below normal
– 3 to – 4	Marked fall	Cold wave
–5 or less	Large fall	Severe cold wave

It is obvious from the above definition, only the departure from normal (pentad normal) that defines cold wave condition. For example a station in northwest India on a winter day may record minimum temperature of the order 4 or 5 $^{\circ}$C, but it may not be a cold wave at all (because normal itself is low). On the contrary a station in Maratwada or Telangana recorded temperature may be little higher say 6 or 7 $^{\circ}$C but it may be classified as cold wave condition (normal being high). In general strong cold winds cause human discomfort. People residing in a place for a long time, they get acclimatised to the normal weather conditions of that place. Thus a person from Hyderabad (AP) feel a normal winter day at Delhi to be severe cold wave condition.

The characteristic wave aspects like amplitude, frequency, periodicity etc., are not associated with cold wave situations but it appears cold waves tend to move in a preferred directions. They move eastwards and also southwards.

In general cold waves are frequent over northwest India in comparison to other parts of the country. Cold waves do not occur over Bay islands, Lakshadweep, Tamilnadu, coastal Andhra Pradesh, Coastal and South interior Karnataka and Kerala. Jammu and Kashmir is haunted by severe cold waves (on an average four per annum) while neighbouring Punjab, Uttar Pradesh have less frequency (once in two years). This neighbouring phenomena may be attributed to adiabatic compression (warming) of cold air mass during its descent on the mountain slopes. Rajasthan, western parts of Madhya Pradesh, Saurastra and Kutch are affected by severe cold waves once in a year. Ladakh recorded maximum duration of severe cold wave for 30 days.

During October Saurastra and Kutch, Rajasthan, Bihar plateau and neighborhood are affected by a few cold waves (about 1 % of annual). During November from Jammu and Kashmir to west Madhya Pradesh (or west of long 80^{0}E) are affected by cold waves of the order of 5% annual incidence. During December, Jammu and Kashmir, Uttar Pradesh, Bihar, Maratwada, Telangana, Orissa, Rayalaseema are affected by cold waves, about 11% of annual.

January and February are the peak periods of cold waves. About 28% of the annual occur in this period and entire country is susceptible to cold waves except Tamilnadu. The main targets in these months are Jammu and Kashmir, Rajasthan, Madhya Pradesh, Gujarat, Maharastra, Telangana, Uttaranchal, Utter Pradesh, Chattisgarh.

During March and April the frequency of cold waves falls, the whole Peninsula is free from cold waves.

The lowest temperature of –45 °C (departure from normal – 9.7 °C) was recorded at Dras in Jammu and Kashmir on 28 December 1910, world record – 89.2 °C recorded at Vostok, Antarctica on 21 July 1983.

The chief synoptic features associated with cold waves are, the rear of active WD and inflow cold air from northern latitudes. Cold waves are associated with cold core troughs in which a pool of cold air mass exists. The cold pool westerly troughs are classified as severe cold core trough, moderate cold core trough and warm core trough depending on the anomaly of temperature (which is the difference of actual dry bulb and mean dry bulb temperature). In severe cold core trough the anomaly is –6 °C or less extending upto a depth of 300 h Pa level. In moderate cold core trough the anomaly is –1 to –5 °C extending upto a depth of 700 hPa level. In warm core trough the anomaly is –1 to + 5 °C extending upto a depth of 600 h Pa level. Cold waves are not generated in warm core troughs.

11.11.2 Heat Waves in India

According to IMD convention the 24 hr maximum temperature changes and departure from normal (heat waves) defined as follows.

Heat Waves

A. When the normal maximum temperature of a station is $\leq$ 40 °C

Magnitude of change °C	Description of 24 hr change	Description of departure from normal
– 1 to 1	Little change	Normal
2	Rise	Above normal
3 to 4	Appreciable rise	Appreciably above normal
5 to 6	Marked rise	Markedly above normal or Moderate heat wave
7 or more	Large rise	Severe heat wave

B. When the normal maximum temperature of a station is > 40 °C

Magnitude of change °C	Description of 24 hr change	Description of departure from normal
– 1 to 1	Little change	Normal
2	Rise	Above normal
3 to 4	Marked rise	Heat wave
5 or more	Large rise	Severe heat wave

During hot whether period (March to July) surface temperatures over many parts of India abnormally shoot up particularly over North India. This heat wave conditions progessively invades the neighbouring region. The incidence of severe heat wave occurs mostly in Uttar Pradesh, but there is no region where reccurs successively every year. Bay islands, Lakshadweep, Tamilnadu, Kerala, Coastal and South Interior Karnataka are not affected by heat waves. Rest of the country is prone to the incidence of heat waves.

During March Saurashtra and Kutch are prone to the incidence of severe heat waves (about 17% of annual). In April the frequency of heat waves fall (7%) and mostly occur in Jammu and Kashmir, Punjab, Rajasthan, Madhya Pradesh and to thence Konkan, Bihar plains, West Bengal, south Assam. In May the heat waves activity slightly increases (10%) and mostly occurs over Jammu and Kashmir, Telangana, Rayalaseema, Vidarbha and Orissa. The month of June is the peak period of heat wave activity (about 54%) particularly in places where the onset of monsoon not taken place/delayed. Uttar Pradesh, Madhya Pradesh, Chattisgarh experience severe heat waves which are locally called 'Loo". Rajasthan is the hottest part of India but rarely records heat waves. Entire west coast, Saurastra and Kutch to Kerala is free from heat waves.

The month July also records heat waves but they are confined to Uttar Pradesh and Punjab.

During severe heat wave conditions maximum temperature departure from normal goes up to 8 to 10 °C, particularly over Uttar Pradesh and Bihar. Alwar (in east Rajasthan) recorded the highest day temperature of 50.6 °C on 10 May 1956 (world record of highest day temperature is 58.0 °C recorded at Alazizyah, Libya on 13 September 1922).

Heat wave conditions in any part of the country does not last more than 5 to 6 days and severe heat waves one to two days. The maximum period of 15 days heat wave lasted over Jammu and Kashmir. Heat waves generally develop over Punjab, Saurastra and Kutch and spread to east and southwards but not westwards.

Favourable conditions for the formation of heat waves

Prevalence of dry air over the region with little or no moisture in the lower troposphere. The area should be cloud free and lapse rate may be dry adiabatic in the lower troposphere

Global Warming likely to increase the frequency and intensity of extreme weather events. It is in this context heat wave condition likely to increase during summer over the globe including India. In recent times it has been observed extreme temperature recorded at many stations over central and northwest India broken the past records. Abnormal increase in atmospheric temperature causes severe physiological stress and adversely effects the life, health of society and individuals. Many people become the victims of heat strokes/sun strokes over several interior parts of India.

Precautionary Measures : Drink water very frequently. Avoid hard physical work out doors during afternoon (say 10 A.M to 4 P.M). Wear white clothes covering whole body. Use white cap or umbrella when you move outside house in the sun during heat wave conditions or forecasted. Before leaving house drink a glass of water, when you return from hot sun do not eat sweets or lick honey. Take slightly cold lemon juice or coconut water or simple water. Do not take ice cold drinks which may effect your throat. While moving outside in the hot sun if you feel giddiness, rush to the nearby doctor for first aid against possible heat stroke or sun stroke.

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CHAPTER - 12

Environmental Pollution

12.1 Air Pollution

Definition

The presence of solid, liquid and gaseous contaminants in the atmosphere in such quantities which damage materials and property, and cause injury to human, animal or plant life or interfere unreasonably with normal human activity and enjoyment of life is called air pollution. In short any undersirable concentration of contaminants in air may be called air pollution.

Natural Contaminants

SO_2 (Sulphur dioxide), H_2S (Hydrogen sulphide), HF (Hydrogen fluoride), HCl (Hydrogen chloride) which emanate from volcanoes, due to thunderstorms, putrefication. These are considered harmful only when the concentration exceeds certain limit. Toxic gases like Nitrous oxide (N_2O), Ozone (O_3) form or evolve due to electrical discharges in the atmosphere. Natural particulate matter, such as dust from the deserts and volcanoes, ashes from forest fires, salt particles from sea, meteoritic dust, pollen from flowers are important.

Artificial Pollutants

Emission from chimneys, exhaust from automobiles, aeroplanes and other man made activities. Agricultural insecticidal, pesticidal dusting and spraying, domestic and municipal incinerators, burning of vegetation introduces pollutants into the atmosphere. Thermo-nuclear explosions introduce radioactive pollutants.

The Important Air Pollutants

CO (Carbon monoxide), Hydrocarbons, SO_2, Oxides of nitrogen, Aldehydes, Ammonia etc., photochemical process lead to further generation of harmful gases and aerosols. Hydrocarbons formed by the incomplete combustion of liquid petroleum products. Pollutants that enter the atmosphere by human activities are called Anthropogenic pollutants.

Some basic definitions are given below

A gram molecule or mole (kilogram molecule or kilomole)

It is the amount of chemical substance whose mass expressed in grams (kilogram) is numerically equal to its molecular weight.

The volume of one mole of a substance is called its molar volume.

A gram atom (kilogram atom)

It is the amount of a simple chemical substance (an element) whose mass expressed in grams (kilograms) equals to its atomic weight.

Avogadro number

For all substances,

number of molecules in a gram molecule

= the number of atoms in a gram atom = N_A

This number N_A is called Avogadro number.

$$N_A = 6.023 \times 10^{23} \text{ mol}^{-1}$$

$$= 6.023 \times 10^{26} \text{ k mol}^{-1}$$

Molar ratio (or volume ratio) **:** The number of moles of the compound per mole of air.

Mass ratio **:** The mass of the compound per unit mass of air.

Mass Cconcentration **:** The mass of compound per unit volume.

Concentration (or molecular concentration) :

The number of moles of the compound per unit volume.

$$\text{Mass ratio} = \text{molar ratio} \times \frac{M_J}{M}$$

Where $M \cong 29$ = the average relative molecular mass of air

M_J = Relative molecular mass of the compound considered.

ρ = density of air

Mass concentration = Mass ratio $\times\ \rho$

$$\text{Concentration} = \frac{\text{Mass concentration}}{M_J}$$

ppm = parts per million (10^{-6})

ppb = parts per billion (10^{-9})

ppt = parts per trillion, (10^{-12})

At temperature 15 °C, pressure p = 1013 h Pa, the air density ρ = 1.225 kg/m^3

Notation : (m) in bracket denotes mass ratio, (v) in bracket denotes volume ratio

Examples

1. ***Conversion***

(i) Given molar ratio of oxygen in dry air is 21% (v)

$$\text{Mass ratio of oxygen} = \text{Molar ratio} \times \frac{M_J}{M}$$

$$= 21 \times \frac{32}{29}$$

$$= 23.17 \text{ (m)}$$

(ii) Given mass ratio of SO_2 = 1.1 ppb (m)

Molar ratio or volume ratio of SO_2

$$= \text{Mass ratio of } SO_2 \times \frac{M}{M_J}$$

where mol wt. of S = 32

mol wt. of O = 16

mol wt of SO_2 = 64

$$= 1.1 \text{ ppb (m)} \times \frac{29}{64}$$

$$= 0.5 \text{ ppb (v)}$$

Mass concentration and molar concentrations of minor constituents of air are expressed in units μg m^{-3} (micrograms per cubic meter) or μ mole m^{-3}.

2. Consider x molecules cm^{-3}.

$$x \text{ molecules cm}^{-3} = x \, \frac{\text{mole}}{N_A} \, \text{cm}^{-3}$$

$$= x \frac{\text{mole}}{N_A} 10^6 \text{ m}^{-3}$$

$$= \frac{x}{N_A} 10^6 \ \mu \text{ mole m}^{-3}$$

$$= \frac{x}{NA} 10^{12} \text{ m mole m}^{-3}$$

3. Consider 145 ppb (v) of CO as mass concentrations and molar concentration

$$145 \text{ ppb (v)} = 145 \times \frac{28}{29} \text{ ppb (m) at T} = 15\ ^0\text{C, P} = 1013 \text{ h Pa}$$

$$= 140 \times 10^{-9} \times 1.225 \text{ kgm}^{-3}$$

$$= 140 \ \mu\text{g} \times 1.225 \text{ m}^{-3}$$

$$= 171.5 \ \mu\text{g m}^{-3}$$

$$= \frac{171.5}{28} \ \mu \text{ mole m}^{-3}$$

$$= 6.12 \ \mu \text{ mole m}^{-3}$$

$$= 6.12 \frac{N_A}{10^{12}} \text{ molecules cm}^{-3}$$

$$= \frac{6.12 \times 6.03 \times 10^{23}}{10^{12}} \text{ molecules cm}^{-3}$$

$$= 3.69 \times 10^{12} \text{ molecules cm}^{-3}$$

During 20th Century (1900-2000) Global industrial activity increased 20 to 25 folds, Global population grown from about 2.5 billion to about 6 billions. More land has been cleared for cultivation during this period than in all preceding human history, fossil fuel consumption increased 30 to 35 folds. Global demand for water increased enormously due to growth of industries, irrigation and domestic use. This resulted in water withdrawal from existing source was morethan six fold, which was more than double the population growth rate during the same period. All this resulted in destruction of green lungs of the earth (plant kingdom), burning of fossil fuels in motor vehicles, furnaces, factories, electricity producing plants. The later added carbondioxide, Sulpherdioxide and oxides of nitrogen emissions to the atmosphere together with toxic chemicals like lead, mercury. Some of these are responsible for the destruction of ozone layer in the stratosphere, acid rain, photochemical smogs. Increased agricultural activity added methane, toxic pesticides to the atmosphere. In addition to these greenhouse gases (namely CO_2, N_2O, CH_4, CFCs), tropospheric ozone have been added into the atmosphere which are responsible for the Global warming of the atmosphere.

If N_2 and O_2 were the only two constituents of the atmosphere, the average air temperature near the earths surface would have been -18 °C, that is 33 °C colder than the at present 15 °C. The gases CO_2, N_2O, O_3, CH_4, CFCs, water vapour warm the earth's surface like that of a glass house by allowing solar radiation coming to the earth and preventing the terrestrial radiation escaping from the atmosphere. These gases are called green house gases. The principal sources of green house gases are man made, such as fossil fuels, aerosol sprays, refrigerents, agriculture, deforestation. Natural sources are volcanoes and forest fires which are insignificant. During last 100 years barring water vapour all other green house gases increased in the atmosphere. In totality during last 150 years the green house gases increased in the atmosphere by an amount radiatively equivalent to a 53% increase in CO_2, although the gas (CO_2) itself increased by only 26%. The main impact of the green house gases are climate change, sea level rise and adverse effect on health.

Except the CFCs the green house gases cycle (through atmosphere, biosphere-earth system) with sources and sinks are adding to or substracting from the atmospheric concentrations. On the whole man has achieved in reducing the sinks and adding to the sources. The life time of the green house gases in the atmosphere vary from few hours or weeks to more than 100 years. Tropospheric ozone has a life period of few hours or days, CFCs have about 75 to 110 years, nitrous oxide (N_2O) 150 years, methane 7-10 years, CO_2 50-200 years. The concentration of CO_2 increased from 275 ppmv before industrialisation to 354 ppmv by the end of 20th century. The major sources of emission of this gas is burning of fossil fuels, deforestation and change in land use. The concentration of tropospheric ozone increased 15 ppbv to 35 ppbv by the end of 20^{th} Century. Ozone formed from vehicle exhausts and industrial pollutants in sunshine (photo chemical action). Ozone contribution to the green house effect is about 8%. The increased effect of CFCs to the green house effect during last 100 years is about 25%. It was non-existent in atmosphere before industrialization and it is found to the order of 0.25 to 0.45 ppbv by the end of 2000 AD. The sources of CFC's are man made chemicals used as solvents, spray can propellants making of foam and refrigeration. Nitrous oxide contributes 7-8 percent in green house effect. It is increased 228 ppbv before industrialisations to 320 ppbv by the end of 2000 AD. It (N_2O) is found in fossil fuels and burning of biomass, fertilizers and land use change. Methane contributes about 13% to the green house effect. Its concentration roughly trebled (0.7 ppmv to 2.0 ppmv) during last 100 years. The major methane producing sources are : Swamps, rice paddies, ruminants (animal cud-chewing) and fossil fuel extraction. Overall man has achieved to add green house gases and reduced the sinks.

According to WMO, No. 735 (1990) the annual carbon fluxes were : photosynthesis on land removes 100 Gt [Gt (gigaton) = one million metric tons] of carbon from the atmosphere annually in the form of CO_2, plant and soil respiration together returns 100 Gt (each 50 Gt). Fossil fuel burning and deforestation releases carbon into atmosphere 5 and 2 Gt respectively. Physicochemical processes at the sea surface releases about 100 Gt into the atmosphere and absorb about 104 Gt. The net gain by the atmosphere is about 3 Gt annually.

Of the green house gases increased by human activities 70% accounts to energy sector. Vegetation is called the green lungs of the earth is also a carbon sink. Deforestation reduced one third of forested land on the globe (six billion hectares to four billion hectares).

In addition to release of green house gases, many metals and chlorinated hydrocarbons are also released into the atmosphere by industrial activities. Some of these substances are toxic in high concentration to human beings, animals and plants. According to WMO estimates the anthropogenic toxic substances that are introduced into the air in kilotons per year are: lead 332, Cadmium 7.6, Copper 35, Nickel 56, Zinc 132, Arsenic 18 while the natural process introduces these substances 19, 1.0, 19, 26, 46 and 8 Kilotons/year respectively.

Group of Experts on the Scientific Aspects of Marine Pollution (GESAMP) established that all oceanic areas over the globe are affected by man made pollutions. Though concentrations are not high, but these toxics are deposited in the seas and on land over long periods and bio-accumulate in the food chain. From the atmosphere to sea, fluxes of metals such as Pb, Hg, Cd, Zn are estimated to be greater than or comparable in magnitude to direct discharges and transport by rivers.

By burning Coal, oil and metal smelting industry introduces mainly SO_2 and oxides of nitrogen into the atmosphere, which are largely responsible for acidic rain. Acid rain is mainly confined to local, regional scale than global. Rain and snow are acidic and have a global pH of about 5.6.

12.2 pH Value

Concept of Acids and Bases

A substance which can donate or give a pair of electrons to form a coordinate bond is called a base. A substance which can accept a pair of electrons to form a coordinate bond is called an acid. Thus base is an electron donor while an acid is an electron acceptor. pH of a solution is the negative logarithm of the concentration (in moles per liter) of hydrogen ions which it contains.

$$pH = -\log [H].$$

A neutral solution has pH =7

If pH is less than 7 the solution is acidic

If pH is greater than 7 the solution is alkaline.

The pH of lemon juice is about 2.2, Vinegar 3.0, pure rain 5.6, Distilled water 7, Ammonia 12.

Buffer Solution

A solution which resist change in its pH value on addition of an acid or a base is called Buffer solution.

LeChatelier's Principle

The state of equilibrium is affected by concentration, temperature and pressure. According to LeChateliers principle if a system at equilibrium is subjected to a change of concentration, temperature or pressure the equilibrium shifts in the direction that tends to undo the effect of the change. Thus in a chemical equilibrium, when concentration of reactants is increased the equilibrium shifts in favor of the products. Conversely when the concentration of the products is increased the equilibrium shifts infavour of the reactants.

Thus a liquid changes into vapour by absorption of heat. The vapour pressure of a liquid increases with increase of temperature. The boiling point of a liquid increases with increase of pressure. The solubility of substance increases with increase of temperature.

Methods of measurements of important pollutants are given below.

SO_2	:	Measurements are made by UV-pulsed fluorescence, flame photometry, dilution or permeation tube calibrations.
CO	:	Measured by Non-dispersive IR tank gas and dilution calibration.
O_3	:	Measured by ozone UV-generators, UV-spectrometers, Gas Phase Titration (GPT) calibrators.
NO_2	:	Measured by Chemiluminescence method, permeation, or GPT caliberation.
Pb (lead)	:	Measured by High Volume Sampler and atomic absorption analysis.
Sulphates and Nitrates	:	Measured by High volume Sampler and chemical analysis.
Hydrocarbons	:	Measured by flame ionization method or Gas Chromatograph, *calibration* with methane tank gas.

TSP (Total Suspended Particulate) Measured by High Volume Sampler and weight determination method

12.3 Pollutions Standard Index

Based on pollutants effects, pollutions standard index (PSI) is determined. Corresponding to PSI air quality, pollutants concentration are given in Table 12.1.

Table 12.1

PSI	Air Quality 24-hr	Pollutants concentration				
		TPS 24-hr μg/m³	SO_2 24-hr μg/m³	CO 8-hr μg/m³	O_3 1-hr μg/m³	NO_2 1-hr μg/m³
0		0	0	0	0	0
50	50% NAAQS	75	80	5	80	–
100	NAAQS	260	365	10	160	–
200	Alert	375	800	17	400	1130
300	Warning	825	1600	34	800	2260
400	Emergency	875	2100	46	1000	3000
500	Significant harm	1000	2620	57.5	1200	3750

NAAQS : National Ambient Air Quality Standards. μg = Micrograms

NAAQS – 1970 given in Table 12.2.

Table 12.2

Pullutant	Period of measurement	Primary standard μg/m³	ppm
CO	8–hr	10,000	9
	1–hr	4000	3
Hydrocarbons (non-methane)	3–hr	160	0.24
NO_2 (Nitrogen oxide)	1–yr	100	0.05
O_3	1-hr	240	0.12
	1–yr	80	0.03
	24-hr	365	0.14
	3–hr	none	none
SO_x	1–yr	75	–
TSP	24–hr	260	–
Pb	3–months	1.5	–

The Table 12.3 gives PSI, corresponding health effects and precautions.

Table 12.3

PSI	Air quality	Health effects and Precautions
200	Alert	Generally unhealthy. Irritation symptoms in healthy persons. Mild aggravations of symptoms in susceptible persons. Persons suffering from heart and respiratory ailments reduce physical exertion and out door activity.
300	Warning	Persons suffering from heart and lung diseases symptoms of significant aggravation and decreased exercise tolerance. Healthy persons lose excercise tolerance. Elderly persons with heart and lung ailments should stay indoors and lessen their physical activity.
400	Emergency	In ailing persons aggravation of symptoms. In eldery persons primature onset of certain diseases. In healthy persons decreased excercise tolercence. Ill and elderly persons stay indoors, avoid physical exertions. Others avoid outdoor activity.
500	Significant harm	In ill and elderly persons onset of premature death. Healthy persons experience adverse effect in their normal activity. All persons should remain indoors. Doors and windows should be closed. Minimise physical exertion. Avoid traffic.

A. The effects of Air Pollutants

The effects of air pollutants depends on the toxicity of the substance its concentration, period of exposure and individual personal/animal/plants internal resistivity.

B. Effects of Gases

Compounds

Effects of some important air pollutants are given below.

***SO_2* :** Affects health, damages to materials and ecosystem, aids acid precipitation and affects climate indirectly.

***CO* :** Directly affects health and indirectly affects climate.

***CO_2* and CFCs :** Directly affects climate and indirectly affects stratospheric ozone.

***O_3* :** Directly affects health and climate and damages materials and ecosystem.

***Hydrocarbons* :** Directly affects health and indirectly affects climate, causes damages to materials and ecosystem.

***NO, NO$_2$*:** Directly and indirectly affects health, damages to materials and ecosystem, aids acid pptn, directly affects stratospheric ozone layer and indirectly affects climate.

***NO$_2$* :** Indirectly affects stratospheric ozone layer and directly affects climate.

C. The Effects of Particulate matter

Aerosol particles directly affects health and climate. Sulphate and nitrate containing particles directly affects health and climate and damages to materials, aids acidic rain.

***SO* :** it affects climate. Particulate matter of heavy metals and radionuclides directly affects health and causes damage to ecosystem.

The above discussed pollutants are directly introduced into the atmosphere by industrial activities. However a part of N_2O and CO_2 are let into the atmosphere by agriculture and forestry activities. The primary species, like SO_2, NO and NO_2 aid for the secondary formation of tropospheric ozone, sulphate particles and some particulate matter. It may be noted here that all of these compounds barring CFCs and some radionuclides are natural constituents but they should be considered pollutants only when their anthropogenic emissions effect their concentration in air significantly.

It has been estimated that on average in a year the atmosphere is polluted by more than 200 million tons of CO, more than 50 million tons of various hydrocarbons, about 146 million tons of SO_2, 53 million tons of oxides of nitrogen, 200-250 tons of dust and 120 million tons of ash and soot. Daily 10000 tons of cosmic dust falls on the earth. Its origin is still a mystery. It may be the result of the activity of the sun or originate in zodiacal nebulae.

Suspended Particulate Matter

On an average a man breathes 22000 times in a day and inhales about 15-22 kg of air. The daily respirable particulate matter (RSPM) should be 100 Mg/m^3. If on any two consecutive two days RSPM levels cross 100 mark, it is categorised as high pollution. Delhi is the most polluted city in India and fourth in the world.

It was mentioned earlier that particulate mater in the atmosphere effects human beings and also weather system. In high concentration many kinds of air borne particles were found to be toxic. The hazards of Chernobyl radioactive fallout and Bhopal isocyanide gas leakage were well documented. The accident of Chernobyl (USSR), nuclear power plant radioactive fallout moved with the winds to Scandinavia. The fallout was scavenged by rains to render lichen and the reindeer browsing on lichen radioactive. Animals were found to carry too high, a burden of radioactivity to be consumed by the people of the region. The radioactive debris were carried over the whole of northern hemisphere by westerly wind circulation.

Dust and ash particles that spewed out of volcanoes or industrial smoke stack has cooling effect on the atmosphere. The eruptions of Tambora (1815 which took a human toll of 12000 lives) spewed out about 80 cubic kilometers of ash and rock pieces into the atmosphere. Some particles entered into stratosphere and remained there. This caused cooling. As a result there was no summer in 1816 in northern parts of US and it caused extensive crop failure. The volcanic dust, ash, water vapour reached high altitudes and were carried by winds around the globe. The precipitation of this dust back to the earth took years. The ejected particles into the atmosphere, dispersed sunlight and temporarily increased the earth's albedo. The Krakatova (in East Indies) eruption on August 27, 1883, was the most powerful volcanic eruption in the history of mankind till that date. The eruption of clouds reached the heights about 30 km. It turned day into night in Batavia, about 150 km away. A Tsunami wave, caused by the fall of broken away part of Krakatova island travelled around the world. Rare optical phenomena were observed in Europe in the end of November 1883. The sky remained purple for several hours during sunsets. This was caused by the dispersion of sunlight by a layer of dust particles (size about 2 mm) injected by the volcano into the stratosphere. The dust/ash particles did not settle down on earth for several years. Successive years of weather over the entire earth was cooler than the normal. This was due to the increase of earths albedo and partly due to the mixing of ocean waters by Tsunami waves. The violent erruption of volcano Gunung Agung in Bali in 1963 injected particulate matter into the upper troposphere and stratosphere which gave rise to the spectacular sunsets throughout the world. The eruption caused the rise in stratospheric temperature by about 5 ^{o}C in the height range of 18-20 km (60-80 hPa). The volcanic particles consisted of fragments of lava and crystalline material (Calcium and Ammonium sulphate). The ash and pumice discharges of a few reknowned volcanic eruptions are given in Table 12.4.

Table 12.4

Name of volcano	Year	Estimated amount of discharge (ash and pumice) (Cubic kilometers = km^3)
Mt. Mazama	4600 BC	42
Mt. St. Helens	1900 BC	4
Vesuvius	79 AD	3
Tambora	1815	80
Krakatova	1883	18
Mt. Katmai	1912	12

Airborne particulate matter acts as a cloud condensation nuclei and freezing nuclei. It scatters and absorbs solar radiation and this influences the weather. Sea dust (spray) caused by the surf rises into PBL and on evaporating in dry air leaves sea salt and material particles in it. Since major part of the earth's surface is covered with oceans, the concentration of salt particles in the atmosphere are found to be about 10^8 particles /m^3 over oceanic area and 10^6 particles/m^3 over land. The fallout of salt in coastal areas and islands range 10-150 kg per acre per annum with extremes as high as 1400 -1800 kg per acre per annum. Atmospheric concentrations of aerosol particles vary from less than 0.1 μg/kg in polar regions to 100 μg/kg or more in dusty continental air. On an average 1 μg/kg have been noted in the middle and upper troposphere.

Airborne particles inhaled deposit in lungs passage and lungs. This may effect the tissues and cause or aggravate lung diseases. Carcinogenic substance present in the air cause lung cancer. Airborne particles may stick to any surface and cause soiling or corrosion. In addition to the scattering of sun light, air-borne particles reduce insolation reaching earth when present in bulk and under favourable atmospheric conditions (inversion of temperature close to the surface of the earth). It causes haze and smog. This deteriorates the visibility and becomes hazardous in airports and other surface transports. Airborne particles are subjected to all sorts of chemical reactions such as photochemical action, oxidation, reduction, polymerization, condensation and catalysis. It is also possible that some of these reactions lead to the formation of substances which are more toxic.

> ***Note :*** *Precipitaion scavenging* means removal of any particulate or gaseous matter from atmosphere and depositing on the earth's surface by cloud droplets, rain, snow flakes, fog droplets (atmospheric hydrometeors).

E.g., In Hyderabad (India) normal day TSPM at important junctions found to be 220-290 μg/m^3. After continuous 3 days raining (13-15 July 2004) it was found to be 150-200 μg/m^3 due to rain washout.

Cycles denotes the circulation of the element between the reservoirs, that is individual atoms after sometime return to the same reservoir again.

Resident time is the length of time that an atom or molecule spends in each reservoir. Resident times of aerosol particles depend on the size of the particles and on meteorological factors.

Reservoir is defined by its physical characteristics such as the atmosphere, the oceans, the biosphere etc. However it also refers to the chemical form in which the element occurs. For example sulphur occurs in the atmosphere in the form of SO_2 [Most of the elements or compounds in different environments are transferred by physical or chemical transport processes between different reservoirs].

Airborne particles (aerosols) may have different size, shape, chemical properties and density. Consequently their atmospheric residence time and removal processes differ widely. Normally sea spray particles, fine dust particles size any from 2 to 20 μm, larger particles (called coarse type particles) raised by gusty strong winds have smaller residence time–minutes to hours because they are heavy and have rapid sedimentation. Coarse type particles are removed from the atmosphere mainly by sedimentation, dry deposition at the surface or by precipitation scavenging. Fine airborne particles have very low rate sedimentation and dry deposition. Their residence time in the atmosphere is governed by precipitation scavenging. Residence time of aerosol particles is a function of the size of the particles and precipitation frequency. On average the residence time of these particles vary from a few days to a few weeks. In polar regions the average residence time extend to many weeks because of low rate of precipitation and stable stratification of atmosphere. Similarly is the case with the residence time of aerosol particles in the upper troposphere.

Non-radioatcive trace gases pollutants contain mainly Carbon, Sulphur, Hydrocarbons, Nitrogen and Ozone. On global scale the natural sources of many of these trace gas pollutants and particles immensely exceed the anthropogenic emissions. However in case of industrial and urban community air pollution, anthropogenic emission are much more than natural ones. Thus hazardous air pollutants are confined to these population areas. Trace pollutant substances may be of organic or inorganic in nature. As regards radionuclid, they have three sources; (i) Natural substances from the soil and oceans, (ii) Cosmic dust, (iii) man-made nuclear bomb-debries.

Compared to anthropogenic non-radioactive trace gas pollutants, radioactive pollutants are very few but they are potentially health hazards. The consequence of nuclear radiations can be realised from the world war nuclear explosions over Hiroshima and Nagasaki. However radioactive bomb debris are used in the study of understanding stratospheric processes (they affect the electrical conductivity).

The important natural sources (earth's crust) of radio nuclides found in the atmosphere are : Uranium-U^{238}, Radon-Rn^{222}, Thorium Th^{232}, Radium -Ra^{226}, Thoron-Tn^{220}. These have half life period 4.5×10^9 yr, 3.83 days, 1.65×10^{10} yr, 1.58×10^3 yr and 54.5 sec respectively. Tropospheric residence time of U^{238}, Ra^{226}, Th^{232} is 5-30 days, Rn^{222} has 3.8 days and Tn^{220} has 50 sec. The important cosmic dust radionuclides are Beryllium - Be^{10} & Be^7 Carbon-C^{14}, Sulphur $S^{35}$and phosphorus- P^{32}. Their half-life period is 2.7×10^6 yr and $\overset{7}{Be}$ 53 days, 5.7×10^3 yr, 87 days and 14.3 days respectively. Tropospheric residence time of Be^{10} and Be^7 is 5-30 days and that of C^{14}, S^{35} and P^{32} is not known.

Important man-made sources of radionuclides in the atmosphere are nuclear weapons testing, waste from nuclear reactors and nuclear power fuel cycle. The principal emissions are Strontium-Sr^{90}, Cesium- $\overset{137}{Cs}$, Carbon- $\overset{14}{C}$, Zirconium - $\overset{95}{Zr}$, Barium- Ba, their half-life period is 27.7 yr, 28.8 yr, 5.7×10^3 yr, 65 days, 12.8 days respectively and tropospheric residence time 5-30 days for all except Ba which has 13 days. In addition to the above, Tritium-H^3(t), Krepton - $\overset{35}{Kr}$ also have anthropogenic sources and transuranium species Plutonium, Americium and Curium.

Note

1. Radioactive form of carbon is called Carbon-14 (C^{14}) .$C^{14}$is readily detectable with Geiger counter and hence it is used as a tracer. C^{14}combined with oxygen form a tell-tale carbondioxide which is used in biological research.
2. Radioactivity effects of radiation on living tissue are very complex. It mainly destroys the blood cells when exposed to it. White blood cells form the marrow of bone. Consequently radioactive emission destroys bone and marrow. Radioactive emission destroys/influences gases and cause mutation. Human mutations are fetal. It causes death of a baby before it born. People who were exposed to nuclear radiation due to atomic explosion over Nagasaki and Hiroshima became the victims of Leukemia, Cancer of Thyroid, breast, lung and stomach. It caused damage to bone marrow, the spleen, the gastrointestinal track lining and the central nervous system. Mental and physical damage was found in unborn and born infants. It was found radiation exposer causes destruction of reproduction cells, sudden increase in white blood cells count and then drop, slight drop in Red Blood Cells count, fatigue, fever, sore throat, vomiting, diarrhea, and cataract of eye.
3. Radiation energy received by an organism is called the absorbed dose. It is expressed in units of rads.

   Radiation shows effects in man when it exceeds 100 rads. Radiation commonly measured in millirads. When a group of people exposed to a single dose of 350 to 450 rads, about half of them lose their lives. This is expressed as LD 50 (Lethal Dose-50) for humans. Another unit rem (roentgen equivalent man) is defined as the product of rad and a qualifying factor, where qualifying factor is a function of tissue exposure, ionising radiation and energy associated with radiation. In general radiation absorption expressed in milli rems. An average man receives about 1 m rem per year from energy production.

   Absorbed radiation dose =

   $$\frac{\text{Radiation energy absorbed}}{\text{The mass of the substance exposed to radiation}} \text{ (J/kg)}$$

   $1 \text{ rad} = 10^{-2}$ J/Kg

It was estimated that in America, an average man receives total whole body radiation doses from all sources (natural /environmental, diagnostic and other sources) is about 180 m rem per year per person. Human body normally recovers from a maximum of an acute absorption of 250 rems.

4. Geiger-Muller counter/detector is used for radiation measurement.

   $1r = 2.580 \times 10^{-4}$ Coulomb Per Kilogram (where r = roentgen)

   The roentgen is the exposure dose which produces a total of 1 esu (esu = electro static unit) ions of each sign in one cubic centimeter of air under standard conditions.

5. *Radioactivity* is defined as the spontaneous disintegration (or transmutation) atoms of unstable isotopes of one element into isotopes of another element. The disintegration is accompanied by the emission of certain particles (helium, α, β or neutran particles, or gamma radiation).

12.4 Carbon and its Compounds

The second most pollutant of atmosphere after dust particles is carbon and its compounds. The majority of earth's living matter is contained in the green plants (or the green lungs of the planet earth) which entrap solar energy and prepare food for itself (carbohydrates and some proteins) by photosynthesis process. In this process plants absorb CO_2 and water and give out oxygen. This forms the basis for life on earth.

$$x\,CO_2 + y\,H_2O \underset{\text{respiration}}{\overset{\text{Photosynthesis}}{\rightleftharpoons}} C_x(H_2O)_y + xO_2.$$

In this process one gram molecule of CO_2 absorbs 112 k cal of energy. The first photosynthesising organism on earth probably blue-green algae. It is estimated that about 248 billion tons (metric tons) of O_2 is released into the atmosphere every year by the green lungs of the earth. Earth's biosphere contains 1.44×10^{18} tons of water, 1.18×10^{15} tons of O_2 and 2.33×10^{12} tons of CO_2.

The first geochemical history of carbon begins with volcanic eruptions of CO_2, CO and CH_4 from the mantle of the earth. Most of the atmospheric carbon occurs as CO_2 and in smaller quantity as CO, CH_4. Any living organism of the earth is mainly composed of carbon, oxygen, hydrogen and nitrogen which are also the basic chemical elements of water and atmosphere.

CO_2 (Carbondioxide)

It enters the atmosphere through fuel combustion, biological decay, deforestation, volcanoes and release from ocean waters. The mass of CO_2 in global oceans is estimated to be about 1.4×10^{17} kg while its mass in atmosphere is 2.33×10^{15} kg (the farmer is about 60 times the later). The annual fluxes of Carbon globally are as follows : Plant and soil respiration adds (100 GT) 10^{14} kg to the atmosphere, fossil–fuel burning, deforestation adds 5×10^{12} kg, 2×10^{12} kg respectively. Physio-chemical processes at sea surface releases (carbon source) about 10^{14} kg to the atmosphere while it absorbs (carbon sink) about 1.04×10^{14} kg from the atmosphere. Photosynthesis removes about 10^{14} kg of carbon in the form of CO_2 from the atmosphere. Thus in totality 3×10^{12} kg of carbon per year is added to the atmosphere which contributes to the global warming. It is estimated that during last 250 years (from middle of eighteenth century) 26% of CO_2 increased in the atmosphere which is radioactively equivalent to 53% increase in CO_2 in the atmosphere. The life time of CO_2 in atmosphere varies 2-4 years to 50-200 years. The pre-industrial concentration of CO_2 was about 275 ppmv while it was 354 ppmv during the last decade of 20th century. The background concentration of CO_2 is 320 ppm and water solubility 1.64.

CO (Carbon monoxide)

It enters the atmosphere mainly through auto exhaust and incomplete combustion, forest fires. In small amount from oceans and volcanoes. Anthropogenic pollution mass is about (4.5 to 6.4) $\times 10^{11}$ kg per year while total emission into atmosphere is about (2.2 to 6.5) $\times 10^{12}$ kg per year. The global sink is (3.3 to 5.6) $\times 10^{12}$ kg per year. Atmospheric background concentration is 0.1 ppm and residence time about 3 years. As compared to natural emission, anthropogenic emission of CO is much less.

CO is colorless and odourless gas does not support combustion, sparingly soluble in water (Water solubility is 0.00284). CO has more affinity with hemoglobin of the blood than oxygen (about 250 times) and forms Carboxyhemoglobin (COHb) and leads to carbon monoxide poisoning. COHb prevents oxygen meeting with body tissues and thus starves tissues from oxygen and causes tissue suffocation. CO poisoning is dangerous as symptoms are not readily seen. When COHb level exceeds 5% level it starts effecting the body. It starts with burning of eyes followed by headache, dizziness, throbbing of temples, weariness, nausea, ringing in the ears, fast heart beating, buckling of the knees. Some victims show irritability, obstinacy, soon paralysis sets in and death fallows due to tissue suffocation. When first symptoms are noticed victim should be shifted and oxygen be given immediately. Heart attacks likely with people suffering from angina pectoris when CO level exceeds 5%.

Hydrocarbons (CH_4)

Gasoline evaporation is the main source of hydrocarbon pollution. The other sources of hydrocarbon emission into atmosphere are combustion, biological decay, agriculture and release from ocean waters. The estimated emission of anthropogenetic origin is about 8.8×10^{10} kg per year while natural emission is about 4.8×10^{11} kg per year. Atmospheric background concentration of CH_4 is about 1.5 ppm and non-methane hydrocarbons less than 1 ppb. Atmospheric residence time of methane is about 16 years. It is removed slowly from atmosphere by photochemical reactions with oxides of nitrogen and ozone.

12.5 Sulphur (S)

According to one estimate of global sulphur cycle (mainly gaseous H_2S, dimethyl sulphur and SO_2) about 6.5×10^{10} kg per year emitted into the atmosphere by anthropogenic sources while the natural emission is about 4.0×10^{10} kg, from volcanoes (3×10^9 kg), volatile sulphur from water logged soil (3×10^9 kg) and biological decay (3.4×10^{10} kg). Sea spray emission is about 4.4×10^{10} kg. This shows that other than sea spray emission anthropogenic emissions of sulphur is more than the natural sources. The atmospheric background concentration of SO_2 is about 0.2 ppbv, residence time 1-4 days, water solubility is 11.3. It is removed from the atmosphere by photochemical oxidation by ozone. Sulphur is removed from the atmosphere by wet and dry deposition by adsorption (7.0×10^{10} kg) and gaseous adsorption (3.5×10^{10}kg).

SO_2 is colourless and non-combustible gas and has bleaching properties. Most of sulphur in the atmosphere is found as SO_2. Its toxic effects are : irritates the mucous membrane of nose, throat and eyes. Sometimes causes emphysema and swelling of throat. In acute cases it causes paralysis of respiratory track. It destroys green plantation.

12.6 Atmospheric Nitrogen and its Compounds

Nitrogen is present in the atmosphere about 78% by volume and by mass 3.865×10^{18} kg. Its atmospheric life time is about 2×10^7 yrs, consequently its global variation is negligible. In combined forms it occurs in the atmosphere as NO (Nitric oxide), N_2O (Nitrous oxide), NO_2 (Nitrogen peroxide) and NH_4 (Ammonia). Nitrogen is an essential constituent of animal and vegetable matter. It is non-poisonous, does not support combustion and respiration. It does not combine with metals and non-metals. However it combines with oxygen in (lightning) the atmospheric electrical discharges and forms oxides of nitrogen.

Fixation of Nitrogen

Combining atmospheric nitrogen to form commercial compounds nitricoxide (then nitric acid and nitrates), ammonia (ammonium formate, bicarbonate, and sulphate), cyanides and cynamids, nitrides (finally obtain ammonia) is called fixation of nitrogen.

Natural emission of oxides of nitrogen consists of decomposition of nitrite in soils, fixation by lightning and conversion from ammonia, while anthropogenic emissions involve mainly high temperature combustion processes which are associated with transportation and energy production. A large part of ammonia emission is through urea from domestic animals.

Nitrogen Cycle

Atmospheric nitrogen is a chief source for numerous nitrogen compounds. Free ammonia occurs in small quantities in air which is washed down along with rain water. Nitrous and nitric oxides are formed in the atmosphere by photochemical reactions in sunlight between nitrogen and oxygen and also during electrical discharges in air. These oxides form nitrous and nitric acids with rain. When they come down to earth they form calcium nitric and calcium nitrate in the soil which is absorbed by the plant as food. There are some bacteria in the roots of leguminous plants which directly take atmospheric nitrogen. Azotobacter (one kind of bacteria found in soil) algae, fungi and mosses also use atmospheric nitrogen directly. The dead plants give out ammoniacal compounds to the earth by nitrosifying and nitrifying bacteria. Animal wastes and urea on decomposition give out ammonia and ammonium compounds. These are formed in the animal body by the process of peptic and tryptic digestion of the nitrogenous plant proteins taken by the animals as food. There are some denitrifying bacteria which breaks up soil nitrates and nitrites and ammoniacal compounds to nitrogen and thus completes the nitrogen cycle, By photochemical and bacterial processes ammonia to nitrite, nitrite to nitrate and again nitrate to nitrogen completes the nitrogen cycle.

N_2O

It enters the atmosphere through natural process of biological action in soil. Its estimated emission of mass is about 5.9×10^{11} kg per year, background concentration is 0.25 ppm, residence time in atmosphere is about 4 years. Its water solubility is about 0.121. It is removed from the atmosphere by photodissociation and biological action in soil. When inhaled with oxygen causes nervous excitement. Pure N_2O causes unconsciousness and may be fetal.

NO/NO_2

These gases enter the atmosphere by combustion and bacterial action in soil. The estimated mass of pollution of NO is 5.3×10^{10} kg and background concentration 0.2 to 2 ppb, while the estimated pollution mass of NO_2 is 5.3×10^{10} kg and background concentration is 0.5 to 4 ppb. However their natural emission is 4.36×10^{11} kg (for NO), 6.58×10^{11} kg (for NO_2) per year, atmospheric residence time about 5 days. The water solubility of NO is 0.00618. It is removed from the atmosphere by photochemical reactions and oxidation.

$\overset{+}{N}$ (Active Nitrogen)

It exists in metastable state and not an allotropic modification of nitrogen. It shows band spectrum. Active nitrogen is produced under electrical discharges and shows bright luminescence after electrical discharge stopped. It has short life and emits phosphorescence in the presence of sulphur and sodium.

Note : Both natural and anthropogenic trace pollutant gases are removed from the atmosphere by hydrometeors viz cloud droplets, raindrops, snow flakes, fog droplets. Removal process are: Wet removal process, dry removal process and chemical transformation.

12.7 Ozone (O_3)

In the composition of the atmosphere it was briefly discussed about stratospheric ozone. Here we shall consider about its formation in stratosphere and near the earths surface. Incoming solar radiation consists (about 99%) in the wave length (λ) range of 0.15-4.0 μm with peak energy at (λ=) 0.5 μm while terrestrial radiation consists (about 99%) in λ- range of 4-80 μm with peak at 10 μm. Visible radiation consists in the range 0.4-0.7 μm. Ozone absorbs UV- radiation (UVB) between range 0.2- 0.3 μm and IR- radiation at λ = 9.6 μm.

Ozone is found in the atmosphere between altitudes 10-45 km with a maximum concentration (one ozone molecule to 10^6 molecules of normal oxygen) between altitudes 18-20 km in a globe encircling ozone layer. The temperature of top ozone layer varies – 20 to +10 °C (at altitude of about 45 km) due to powerful absorbing of UVB by this layer. Ozone is formed in the atmosphere in two stages. In the first stage NO_2 is dissociated by short wave UVB [NO_2 + hν NO_2 + hν $\rightarrow$ +NO + O where hν is the energy of a solar photon] into NO and atomic oxygen. In the second stage a recombination of atomic oxygen and oxygen molecule of air ($O + O_2 \rightarrow O_3$). Ozone is also generated in small amounts in the atmosphere by the electrical discharges (thunderstorms). In free atmosphere the life period of ozone varies from a few weeks to months. According to WMO assessment (1989) there is a decrease in stratospheric ozone content with the evidence of substantial decrease in stratospheric ozone over Antarctica in spring time (the later one is described as Antarctica ozone hole). Pre-industrial period background ozone concentration was 15 ppbv which shot up to 35 ppbv in 1990. Further it was estimated that the ozone contribution to the greenhouse effect was about 8%.

Ozone shows diurnal variation in concentration in air, over land with maxima in the day time and minima at night. Near the surface of the earth ozone is found in urban polluted atmosphere as photochemical smog which is a complex mixture of ozone and other pollutant gases. In smog, ozone is produced by the oxides of nitrogen and hydrocarbons in the presence of sunlight. These gases are emitted from vehicle exhaust and other industrial plants. Thus anthropogenic pollutants are the cause of smog and its adverse effect on nature.

Ozone has a special characteristic that it absorbs the sun's harmful UVB and prevents it from reaching the surface of the earth. UVB induces skin cancers, cataract of the eyes, suppression of immune system in humans and effects the productivity of aquatic and terrestrial ecosystems. It has been estimated that a decline of 1% ozone content in stratosphere causes 3% rise in the incidence of skin cancers in the humans. If ozone concentration exceeds 800 $\mu g/m^3$ in one hour it is harmful, particularly to elderly and ailing-persons. Ozone and photochemical smog attacks and damages rubber and various synthetic materials. Ozone concentration of 20 ppm or more is poisonous. Ozone causes impairment of lung function and acceleration of aging. The vertical distribution of ozone is changing due to the effects of man-made emissions of oxides of nitrogen and hydrocarbons. As a result there is a net decline in total ozone column which is a danger signal of decreasing protection to the life matter on earth from the lethal effects of UVB. The chlorofluorocarbons (CFCs) are powerful green house gases and they are the main cause for the decline of the stratospheric ozone.

In pursuant to the global convention for the protection of the ozone layer (Vienna, 1985), the Montreal Protocol held in 1987 to control substances (and related compounds) CFCs that deplete the ozone layer in the first global agreement for the protection of earth's atmosphere. In amending the protocol, in 1990, signatory countries have committed themselves to a complete phase out the use of chemicals that deplete the stratospheric ozone layer by the year 2000 AD.

12.8 Elementary Ways of Pollution Control

Pollution control may be accomplished :

(i) by the use of substitute materials which are less pollutants,

(ii) by diminishing the use of pollutant sources, and

(iii) by treatment for the removal of pollutants.

For example we can use natural gas instead of coal. We can use natural gas/ electricity driven autos instead of mineral oil autos. We can convert the pollutant to a harmless substance such as exhause catalytic unit to convert CO to CO_2.

Control of Suspended Particulate Matter

Incomplete burning is the cause of carbon particulates (smoke and soot), and flyash. Dust and other particulate matters are produced in industrial manufacturing processes such as grinding, crushing, cement/asphalt plants, foundaries, construction and demolition works.

Particles from combustion and dust can be filtered by air cleaning equipments such as cyclones, scrubbers, baghouses and electrostatic precipitators which are briefly given below.

In *cyclone* dust collector, dust-laden air is introduced at the top outer edge to whirl around and around inside the cylinder. Centrifugal force flung the dust particles against the outside wall where it slides down to the bottom and removed periodically. The dust cleared air escapes from a duct located in the centre of the cylinder. By this process 50 to 80% of the dust particles of size 10 μm or more are removed. Small size particles still remain in the cleared air.

Scrubbers are simple screens of water/liquid spray from which air moves up. It removes large particles of air. Scrubbing towers are used to remove particles and gaseous pollutants. Water is used if the gas is soluble in it otherwise a liquid is used in which the gas is soluble.

Bag houses consists of bags or long sleeves of fabric which withstand against high temperatures. As the air passes through the fabric to the otherside particles in the airstream are filtered out. The sleeves are periodically cleared. To prevent condensation the temperature of the bag house is maintained to be higher than dew point temperature of water. Bag houses are very effective for removal of fine particles of air.

Eletrostatic Precipitator : It consists of positively charged wires centred between plates which are negatively charged and grounded. When high electric charge is passed on wires, they create charge on air stream particles which are attracted and settled on grounded plates. Settled particles are removed periodically. This system is efficient when particles in the air are electrically charged.

Control of Oxides of Sulphur

Oxides of sulphur mostly emitted into the atmosphere by smelters, oil refineries, paper industry and burning of fuels containing sulphur. Combustion of fuels containing sulphur evolves sulphur dioxide (SO_2) and sulphur trioxide (SO_3), the farmer being in bulk. Parts of SO_2 converts into SO_3 by photochemical processes. Moisture converts SO_3 into sulphuric acid (H_2SO_4). Sulphur can be undressed from oil but with the declining of oil reserves, it is wise to use coal fuel or hydropower for power generation plants. Coal contains sulphur in organic form as iron pyrite. By crushing and washing about 30% of iron pyrite can be removed. Rest of sulphur is chemically bound in organic form to the coal. The later can be removed by gasification. Large scale coal use requires flue gas desulfurisation.

Control of CO

Most of CO enters the atmosphere through internal combustion engines. A diesel engine provides more complete combustion and emits less CO as compared to gasoline engine. Autos operating on combustion engines are to be fitted with catalytic converters to reduce CO and hydrocarbons exhaust.

Control of Oxides of Nitrogen, Hydrocarbons and Ozone

Reduction of oxides of nitrogen in the atmosphere is very difficult. Most of the hydrocarbons enter the atmosphere through evaporation of gasoline which can be reduced by proper usage of floating roofs on storages. In autos it can be reduced by the use of (PCV) Positive Crank case Ventilation systems.

12.9 Acid Rain

Man's industrial activities changed the composition of atmosphere and precipitation both locally and regionally. In industrialised region the chemical composition of precipitation is found to be acidic with pH value around 4.5.

The gas phase chemical equations of atmospheric acidic rain are given below.

$$O_3 + h\upsilon \rightarrow O_2 + O(D') \quad .....(12.1)$$

where $h\upsilon$ = energy of solar photon.

$$O\,(D') + H_2O \rightarrow OH + OH \quad .....(12.2)$$

O (D') atomic oxygen (by photo dissociation)

$$NO + O_3 \rightarrow NO_2 + O_2 \quad .....(12.3)$$

$$NO_2 + OH\,(+M) \rightarrow HNO_3\,(+M) \quad .....(12.4)$$

(+ M) indicate molecule

$$SO_2 + OH\,(+M) \rightarrow HSO_3\,(+M) \quad .....(12.5)$$

HSO_3 is oxidised to H_2SO_4 .....(12.6)

In liquid phase oxidation processes of conversion of nitrogen species into nitrate is not known clearly. Gas phase convertion to nitric acid (HNO_3) is significant. However HNO_3 (gas) $\rightleftharpoons$ HNO_3 (liquid).

Oxidation of SO_2 to sulphate (SO_4) in the liquid phase proceeds via dissolved compounds, particularly ozone and hydrogen peroxide (H_2O_2).

Most of the acidity in precipitation may be attributed to oxides of sulphur and oxides of nitrogen which enter into the atmosphere mainly from the combustion of fossil fuels and industrial processes. SO_2 oxidises to sulphuric acid in rain drops.

Sulphuric acid and nitric acid accounts most of the acidic precipitation, the former accounts two-thirds while the later one-third.

Atmospheric acid is causing erosion of priceless statues, marvellous buildings through dry deposition of sulphate particles (which become acid with rain). Similarly aquatic and terrestrial ecosystem (relationship of organisms to its environment) is being damaged through long term deposition of acidic rain and snow. A number of fresh water lakes without natural buffer are suffering from acid rain or deposition. It was found during 1960 the pH of rain water was 6 to 7 (neutral value is 7). By 2000 AD it changed to 4.5 to 4.0 in some lakes in Europe and America. This acidification resulted in heavy losses of commercial fish population, and gradual disappearance of fauna. Fat head minnows, some zoo plankton disappear at pH 5.9, algal forms, lake trout disappear at a pH value of 5.6 or less. Ground water in shallow wells and aquifers also affected due to contamination by toxic metals such as mercury, cadmium. On land forests were reported dying in Europe and north America due to acid rain, high ozone concentration and smogs. Acidity of the soil increased by ten times in Europe to a depth of about one meter.

12.10 BAPMoN

In the mid-1960s, WMO established Background Air Pollution Monitoring Network (BAPMoN) to measure the changing background chemical composition of the atmosphere near the ground, away from cities and strong polluting sources (industries/plants). A complementary Urban network is coordinated by the World Health Organisation (WHO). This network of observatories collect samples for measuring the chemical composition of rain and snow. Under Global Atmospheric Watch (GAW) it provides information on (i) global increase of greenhouse gases (namely CO_2, CH_4, Nitrous oxides, CFCs, tropospheric ozone), (ii) regional distribution of sulpher, nitrogen compounds - which result in acid rain, fog, smog and other changes in the lower level (PBL) chemical composition and (iii) radiation transmitted through the atmosphere and aerosols that were ejected from volcanoes, factories to assess their contribution in cooling the atmosphere. At a few locations toxic metals (mercury, lead etc.) and toxic organic compounds (pesticides, herbicides) are also determined. Complementary data on air pollution within cities and by the side of heavy polluting sources are coordinated through WHO and United Nations Environmental Programme (UNEP). In mid 1990's there were about 350 GAW stations operating in 70 countries. 164 stations collect sampling for measurements of precipitation chemistry (rain and snow), 95 BAPMoN stations record turbidity (transparency of air), 78 stations suspended particulate matter, 52 stations CO_2, 22 stations surface ozone, 9 stations methane (CH_4), and 5 stations measure CFCs. The atmosphere is sampled according to well defined criteria, instruments and procedures by trained personnel. Through the global ozone observing system continuous measurements of atmospheric ozone in total column, its vertical distribution and changes are made, This network has about 140 stations over the globe-complemented during 1980's by satellite remote sensing.

UNO, through its agencies WMO and UNEP, urged to monitor the quality of air and environment. WMO coordinating with national services for setting the network of air pollution monitoring stations to monitor both in time and space. Horizontal scale ranges 100 to 1000 km, vertical scale ranges 1 to 10 km and time scale few hours to a year or more. Each individual station is expected to represent space radius 5000 km, time one year. A regional station may provide hourly values representative over a circle of radius 50 km. Station should be located away from Urban areas (cities/industries), high ways, power generation station etc ; however it should experience frequent natural phenomena like heat/cold waves, cyclones, forest fires, sand/dust storms, volcanoes etc. Local influence should be as least as possible. When such conditions are satisfied the monitoring station represent the background values. An example is given below.

The Table 12.5 and 12.6 gives emissions of Singrauli thermal power plant of 2000 MW capacity, situated at Shakthinagar, Uttar Pradesh (India), during September 1992, measured over 11 days. The thermal power plant burns about 1000 tones of coal per hour and emits about 9680 kg SO_2 per hour from four smoke stacks (height about 225 m). The plant is equipped with eletrostatic precipitators for removal of particulates from the plume emission. Measurement of trace gases –SO_2, NO_2, NH_3, O_3 and TSP were made upwind of the power plant at a distance of one km north of the power plant. Daily three samples of trace gases for 3 hrs duration were collected (morning, afternoon and evening), one sample of TSP 24 hrs duration collected on Whatman 41 filter paper using high volume air sampler with a flow rate of 1.2 m^3/min.

Table 12.5 Average concentrations ($\mu g\ m^{-3}$) of trace gases and TSP at Shaktinagar.

	SO_2	NO_2	NH_3	O_3	TSP
Sept 1992	33.2	8.5	22.5	7.5	134

Table 12.6 The average chemical (ionic) composition of TSP ($\mu g\ m^{-3}$)

Cl	SO_4	NO_3	NH_4	Na	K	Ca	Mg
1.16	2.47	1.30	0.41	0.64	0.61	2.55	0.86

The conclusions drawn based on the above data was that the average concentrations of NO_2 and O_3 are of the order of background values. The maximum ground level concentration of SO_2 was due to the burning of coal in the thermal power plant. The concentrations of TSP and its water soluble components (SO_4 and Ca) are high at Shakthinagar.

A number of WMO member countries provide data to the centralized data collection centres for GAW. Canada operates the WMO World Ozone Data Centre and publishes ozone data every other month. Amercia provides a base for data on precipitation chemistry analyses, acid rain and atmospheric turbidity measurements. Russia (earlier soviet union) is responsible for the collection of solar radiation and atmospheric electricity data and Japanese Government to operate the World Data Centre for Greenhouse gases.

12.11 Smog

In the Meuse Valley (Belgium) a mysterious yellow-brown fog was formed in December 1930. It caused irritation and many become ill the next day. In 1944, an air pollution episode in Los Angeles area damaged vegetation and when it became severe it caused eye irritations and tearing. It was later found that auto exhaust gases oxidised by the sun's rays (photochemical oxidation) formed complex compounds which were responsible for irritation. This phenomena later termed of smog. Smog is a combined word of smoke and fog, represents the mixture of smoke and fog. In 5-9 Dec 1952 another air pollution episode over London took a death toll of 4000 people. This attracted the world scientist to find the cause. It was found that there was temperature inversion in the atmosphere close to the ground (PBL) and SO_2 concentration was six times than usual. Subsequently it was confirmed that all air pollution death cases were associated with temperature inversion close to the ground (that is warm air above and cold air near the ground) and smog. Further it was found that these incidence also affected the vegetation.

Smog is of two types. (i) Photochemical smog and (ii) Coal-burning smog. Photochemical smog results from the action of sun rays on contaminated organic vapours particularly unburned gasoline, and oxides of nitrogen. Coal-burning smog is a combination of coal smoke and fog. Present day smog in most cities is a combination of these two types in varying proportions. Dense coal-burning smog contains carcinogenic compounds, polynuclear hydrocarbons is one which is effective carcinogen; and 3,4-benzypyrone is another carcinogen. This exists in particles.

In photochemical smog the following reactions take place,

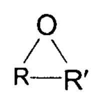
$$NO_2 + h\upsilon \rightarrow NO + O \text{ (atomic oxygen or nascent oxygen)}$$
$$\text{(photochemical dissociation)}$$

$$O + O_2 \,(+ M) \rightarrow O_3 \,(+ M)$$

$$O_3 + NO \rightarrow NO_2 + O_2$$

Atomic oxygen reacts with various hydrocarbons (such as olefines of auto exhaust) forms free radicals

$$O + \text{olefines} \rightarrow R + R'O \quad \text{or}$$



where R, R' are free radicals

$$O_3 + \text{olefines} \rightarrow \text{products}$$

$$R + O_2 \rightarrow RO_2$$

$$RO_2 + O_2 \rightarrow RO + O_3$$

Thus organic compounds such as aldehydes, acrolein or peroxyacetyl nitrate are formed. Probably these compounds are responsible for eye irritation in smogs. Smog is notorious in corrosive action. It corrodes plant cells, rubber fabrics, nylon stocking, buildings and monuments. In India Tajmahal, Redfort and other historical buildings in Agra are being targeted by smog. In 1966 Tokyo was alarmed for smog 154 days. After air pollution death episodes smog alarms are introduced in some countries.

12.12 Toxic Air Pollutants

Air pollutants that are health hazards are: asbestos, arsenic, antimony, cadmium, copper, lead, nickle, zinc, mercury, vinylchloride, benzene, radionuclides, polycyclic organic matter, ethylene chloride, methylchloroform, toluene, trichloroethylene, benzopyrene, pesticides/chlorinated hydrocarbons. Some are carcinogens. They are found in urban run-off, industrial discharge of waste water. EPA restricted the use of DDT, DDD, heptachlor, endrin, lindane, chlorodane; 3, 4- benzopyrene is a carcinogen, asbestos when inhaled may cause cancer. Toxic metals and chlorinated hydro carbons/pesticides are released into atmosphere as byproducts from industries and agriculture. During 1970's and 1980's it was found minute quantities of pesticides in melted snow, in the tissues of polar bears and in breast milk at the Arctic and in birds at the Antarctic.

Toxic some trace metals of natural processes and anthropogenic sources with global values of emission are given in Table 12.7.

Table 12.7

Metals	Sources		Remarks
	Natural in 10^6 kg/year	Anthropogenic 10^6 kg/year	
Lead	19	332	White lead is very poisonus
Cadmium	1.0	7.6	
Copper	19	35	
Nickle	26	56	
Zinc	46	132	
Arsenic	8	18	Arsenious oxides are drastic poisons, a dose of 0.125- 0.25 gm is fetal.

In the Arctic haze it was found high concentration of aerosols of sulphate, man-made pesticides like lindane, dieldrin, DDT and toxic heavy metals lead and mercury. WMO Marine pollution studies shows the presence of a number of chlorinated hydrocarbons over marine areas around the world but their concentrations are not high. According to its estimates 80% of the global chlorinated hydrocarbons in air are spread over oceanic areas. The contribution to the sea water pollution through atmosphere is of comparable magnitude (if not more) with that of contamination of sea water by highly polluted river waters particularly of fluxes of metals such as lead, mercury, cadmium and zinc whose sources are located far away from the sea areas. Examples are the pollution of Mediterranean sea, Great lakes of North America. It was found that fish in some lakes contained PCBs and were unfit for human consumption. Water pollution transmitted through atmosphere is difficult to address as pollution sources involved several countries and States that are far away.

12.13 Dispersal of Air Pollutants

Dispersal of pollutants in air depends on wind and environmental air stability and turbulence. Precipitation acts as scavenger. Thus weather effects the dispersal of air pollutants and inturn air pollutants effect the weather (particularly precipitation, visibility, acid rain, fog, smog, insolation).

Wind direction and speed at surface and also at the chimney stack level has a great bearing on the dispersal of air pollutants from stacks. Stronger the wind speed quicker the dispersal and the pollutants are carried away farther before they are settled. When the wind is light or calm pollutants concentration near the chimney stack is dense and not carried away to great distance. Gustiness dispersal covers a wide area of the chimney plume. Stable conditions of environmental air causes concentration of pollutants locally and unstable environmental air conditions causes pollutants dispersal over a large area leading to less concentration of pollutants. Based on environmental stability/instability (lapse rates) we observe six types of plumes. Looping, coning, fanning, lofting, fumigation and trapping. These cases illustrated in Figs. 12.1 and 12.2.

Precipitation and Humidity Effects

Natural scavenging of air pollutants occur by gravity fall out, rain out and wash out. In the absence of turbulence fine particles settledown by impaction with objects. Heavy particles settledown by gravity. In rain out small particles form condensation nuclei. On condensation they fall out to ground with rain drops. In wash out, rain drops while coming, sweep the pollutants in its way.

The Main Objectives of Air Monitoring

(i) Collection of basic data of air pollutants (quantitatively and qualitatively),

(ii) meteorological factors aiding pollution,

(iii) topographic influence,

(iv) climate study

(v) population.

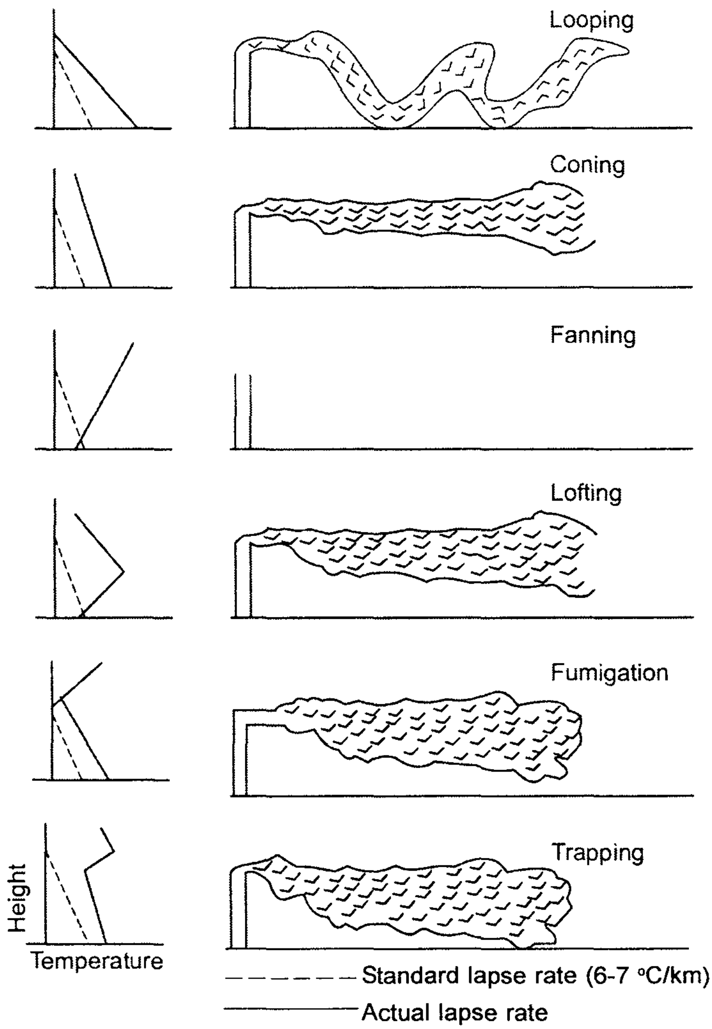


Fig. 12.1 Plume classes under different stability conditions.

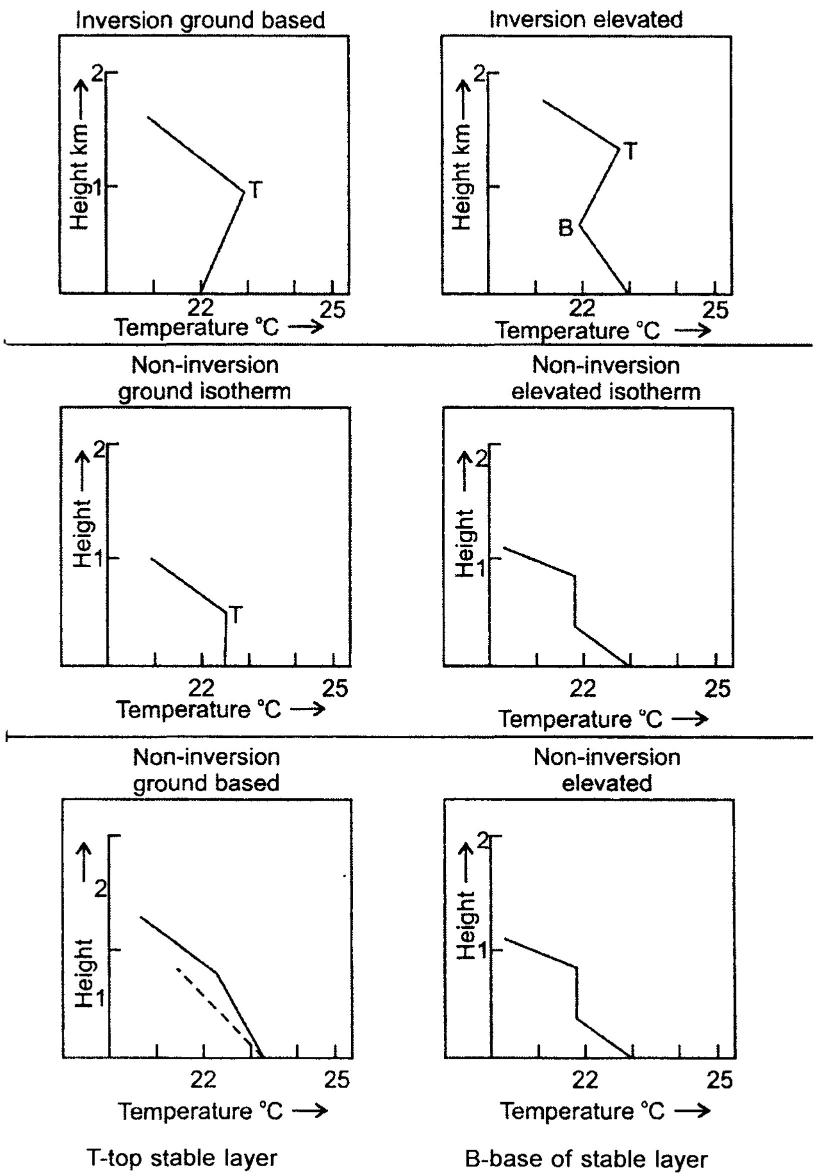


Fig. 12.2 Explanations for stable layers.

The Table 12.8 gives the methods of measurement of air pollutants.

Table 12.8 Measurement of Air pollutants.

Types of Pollutants	Sampling equipment	Analytical Method
Dust fall	Dust fall Jar	Gravimetric
Suspended particulates	High volume sampler	Gravimetric
Total sulphur compounds	Lead-candle	Gravimetric
Sulphur dioxide	Air sampling kit	West and Gaeka method
Oxides of nitrogen	Air sampling kit	Jacob and Hochneissr method
Hydrogen shulphide	Air sampling kit	Methylene blue method
Any other gaseous pollutants	Air sampling kit	–
Wind direction and speed	Wind vane recorder D.P.T recorder	Recording chart
Temperature and humidity	Stevensan screen with thermometer and evaporimeters	Instrument reading Thermographs Hydrographs

12.14 Methods of Estimation of Particulate Matter in Air

Dust-fall Jar

It is an open mouthed polyethylene jar or glass. It contains water at the bottom which is exposed to the atmosphere for a period of one month. The contents of the jar analysed for total deposits, from which deposits per unit area calculated. Dust-fall jar method used to measure the amount of settleable particles such as soot, flyash, smoke particles in the air. Dust fall is expressed as tonnes per square kilometer per month (tonnes/km^2/month) (see Fig. 12.3).

High Volume Sampler

It contains a 20 cm × 25 cm glass fibre filter, which collects sample over a period of 24 hrs. The glass fibre filtrates 100% of all particulate matter of 0.3 μm diameter or more. Air is drawn from vertically upward flow at the average speed of 19 m/min. It sucks all particulate matter upto diameter of 100 μm. Filtered particles over a period of 24 hrs is measured by weight and expressed as μg/m^3 of air. Generally air is drawn at the rate of 1-1.5 m^3/min.

Methods of Estimation of Sulphur Compounds in Air

Lead Peroxide Candle Method

Gaseous Sulphur compounds + Solid lead peroxide = lead sulphate

$$PbO_2 + SO_2 \rightarrow PbSO_4$$

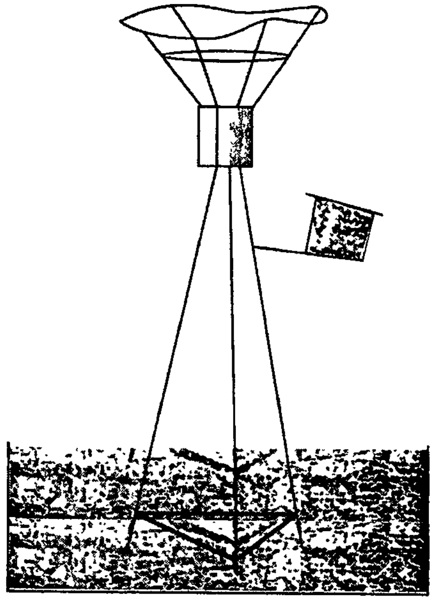


Fig. 12.3

A piece of tapestry cloth size 10 cm × 10 cm is wound round on a glass cylinder or polyethylene tube of 100 cm^2 curved surface area. Tragacanth (gum) and lead peroxide paste is made and is evenly applied on tapestry cloth surface. This is dried in a desiccator to make it a candle. This lead peroxide candle is erected in a wooden stevenson screen like box, which protects it from rain but allows the air to circulate over it. In this way the candle is exposed to air for a period of one month. Then the lead sulphate formed over the candle is estimated gravimetrically after converting into barium sulphate. The results expressed as milligrams SO_3/100 cm^2/per day.

The above lead peroxide candle arrangement generally attached to one of the legs of dust fall jar tripod.

Multi-gas Sampling Kit

It is used for sampling measurements of different gases simultaneously. Selective absorbents are kept in different impingers (generally four) to trap respective gaseous pollutants. A vacuum pump operates to suck atmospheric air which circulates over the impingers containing different absorbents and the purified air leaves the kit. Gaseous pollutants react with the absorbents. Generally air is sucked into the kit at the range of 0.1 to 3 liters per minute. Using this kit O_3, SO_2, H_2S, oxides of nitrogen, ammonia can be sampled. The results are expressed as ppm (ml/m^3) or as $\mu g/m^3$ (μg = micro grams).

12.15 Global Warming Effects

Climatic records indicate rise in global temperature by 0.3 to 0.7 °C during last one hundred years see Fig. 12.4(a). International Scientific Community agreed that there is compelling evidence of climate change and human beings are largely responsible for this. This requires adoptation to actual or expected impacts of climate change. Planning for adoption is important and which should reduce the adverse impacts of climate change and enhance beneficial effects. It is said African nations might have to spend 5 to 10% of GDP on adopting to climate change. Climate change likely to increase the frequency and intensity of extreme wheather events. It is therefore necessary to increase awareness among communities, and policy makers about the implication of climate change. See Fig. 12.4(b) and 12.4(c). Awareness campaign should focus school children and village youth in addition to normal tools like local media, street wall posters, Cinema film shows.

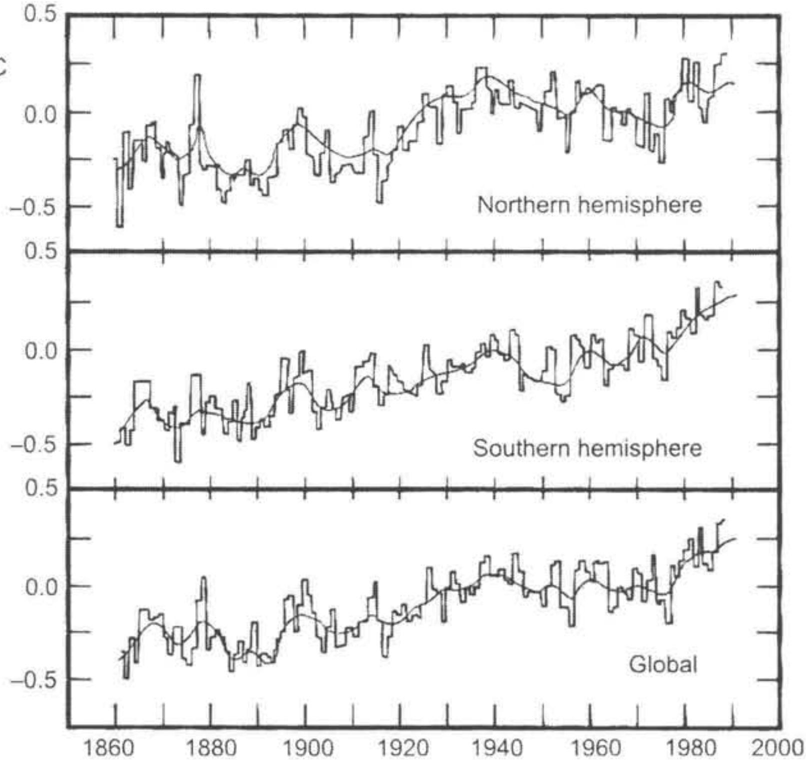
According to UN Climate Panel (Oslo / London) global warming may melt the Himalayan glaciers by 2030s, 40 animal and plant species face extinction due to rising temperatures which destroy the ecosystem that supports them. It warns that the poorest nations are likely to suffer most. Heat wave incidence may increase in US and damage to corals like the Great Barrier Reef of Australia. The rise in temperatures are blamed to the increase in greenhouse gases in the atmosphere emitted by human beings from burning fossil fuels. This would cause desertification, droughts and rising in sea levels. At the current warming rate, the Himalayan glaciers melt and shrink from the present 500,000 km^2 to 100,000 km^2 by 2030. The UN Climate Panel reports that 29×10^9 tonnes of CO_2 released into the atmosphere every year, which is acidifying the oceans. As a result it is likely to destroy coral reefs, plankton and many commercial fish species. Further it noted that the area in the equatorial belt (in Africa) may affect soil and reduce the crop yields. This may result in hundreds of millions of people hungry. The Global warming may destroy snow cover by about 70% by 2050 and destroy Alpine Ski resorts and increase in sea level water. Half a meter rise in sea level water may result in submergence of some island States and a considerable part of Bangladesh. However some good effects of global warming likely that cause Canada, Russia, New Zealand, Scandinavia become warm and help in raising crops. The UN Climate Panel study squarely blames humans for global warming saying that 90% of recent global warming attributed to human cause. See Fig. 12.5, 12.5(a) and 12.5(b).

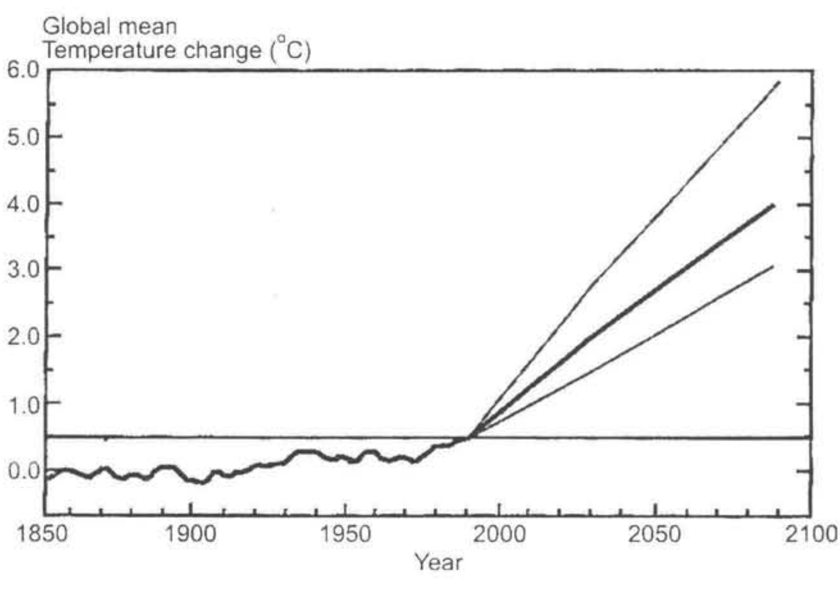
The UN Climate Panel on 6 March 2007, issued the starkest warning about impact of global warming based on the finding of 2500 scientists.

According to Intergovernmental Panel on Climate change :

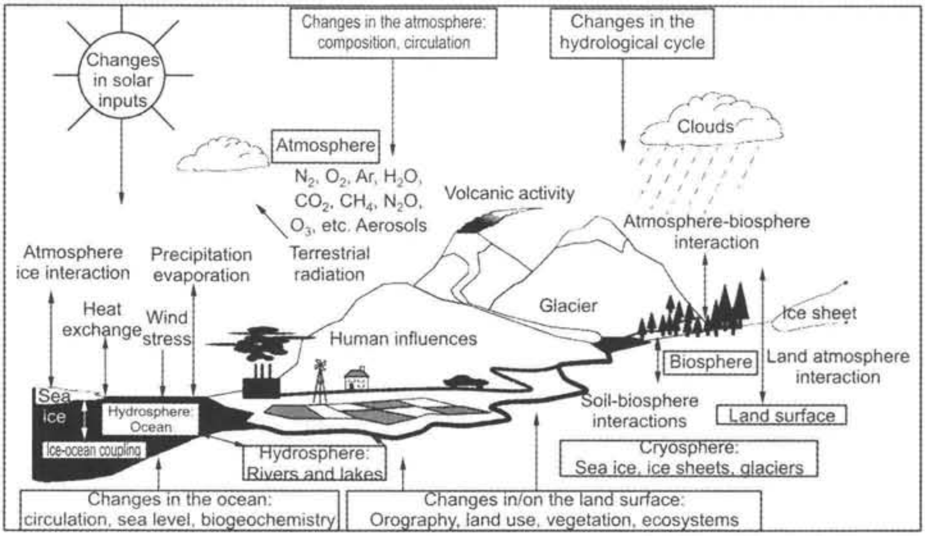
(i) 20 to 30 species face extinction if temperatures rise 2°C above average in the 80s and 90s.

(ii) Heat waves, floods, storms, fires and droughts will cause more deaths and harm.


0.5
°C
0.0
−0.5
Northern hemisphere
0.5
0.0
−0.5
Southern hemisphere
0.5
0.0
−0.5
Global
1860
1880
1900
1920
1940
1960
1980
2000

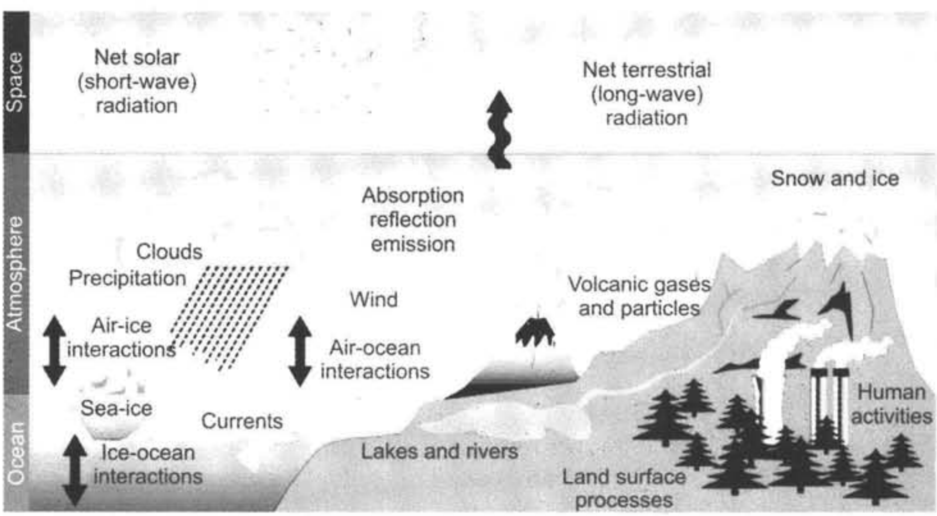

Global mean
Temperature change (°C)
6.0
5.0
4.0
3.0
2.0
1.0
0.0
1850
1900
1950
2000
2050
2100
Year

(a)



Changes in solar inputs
Changes in the atmosphere: composition, circulation
Changes in the hydrological cycle
Atmosphere
Clouds
N$_2$, O$_2$, Ar, H$_2$O, CO$_2$, CH$_4$, N$_2$O, O$_3$, etc. Aerosols
Volcanic activity
Atmosphere-biosphere interaction
Atmosphere ice interaction
Precipitation evaporation
Terrestrial radiation
Heat exchange
Wind stress
Human influences
Glacier
Ice sheet
Biosphere
Land atmosphere interaction
Sea ice
Hydrosphere: Ocean
Ice-ocean coupling
Soil-biosphere interactions
Land surface
Hydrosphere: Rivers and lakes
Cryosphere: Sea ice, ice sheets, glaciers
Changes in the ocean: circulation, sea level, biogeochemistry
Changes in/on the land surface: Orography, land use, vegetation, ecosystems

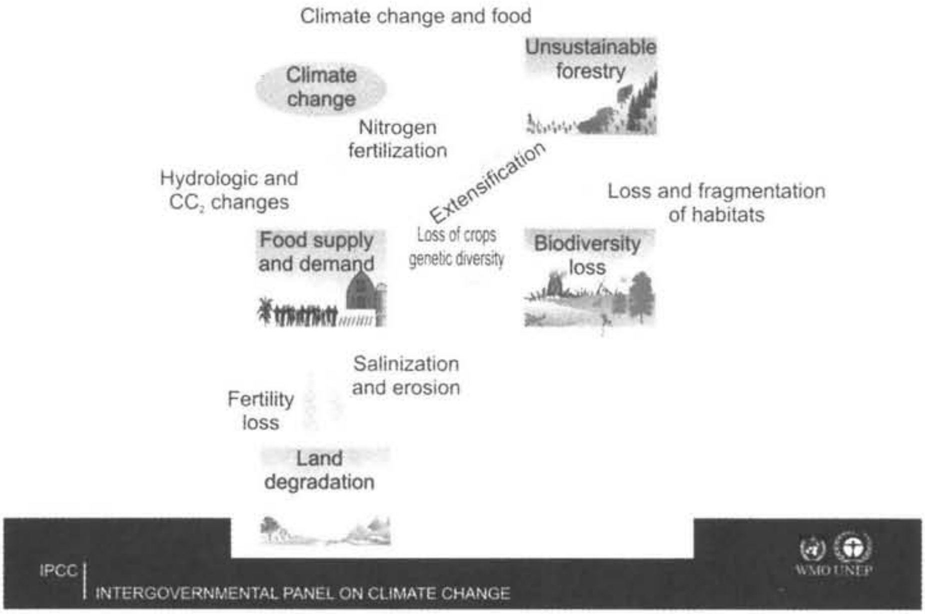
(b)



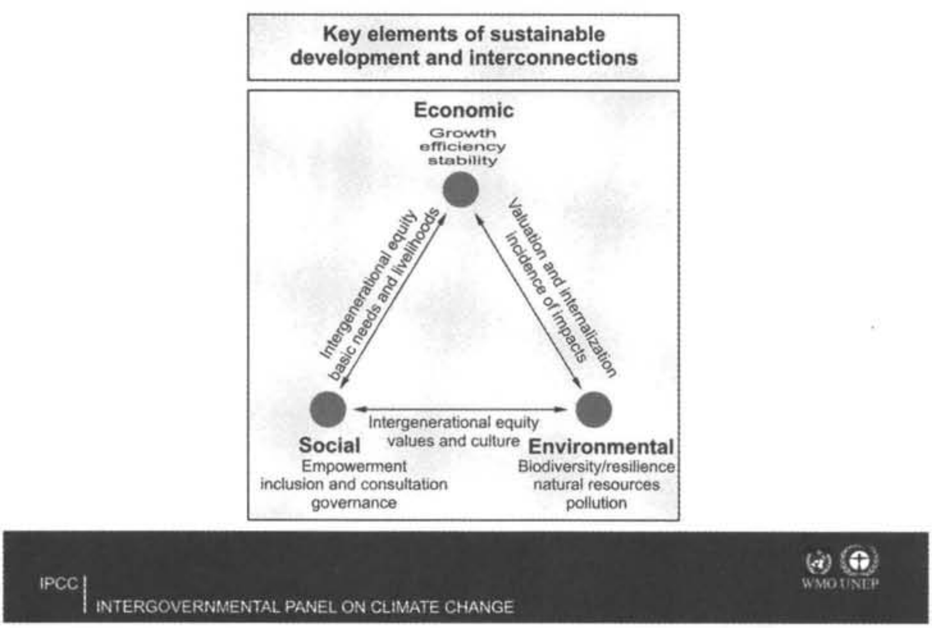
Space
Atmosphere
Ocean
Net solar (short-wave) radiation
Net terrestrial (long-wave) radiation
Snow and ice
Absorption reflection emission
Clouds
Precipitation
Wind
Volcanic gases and particles
Air-ice interactions
Air-ocean interactions
Sea-ice
Currents
Human activities
Lakes and rivers
Ice-ocean interactions
Land surface processes

(c)

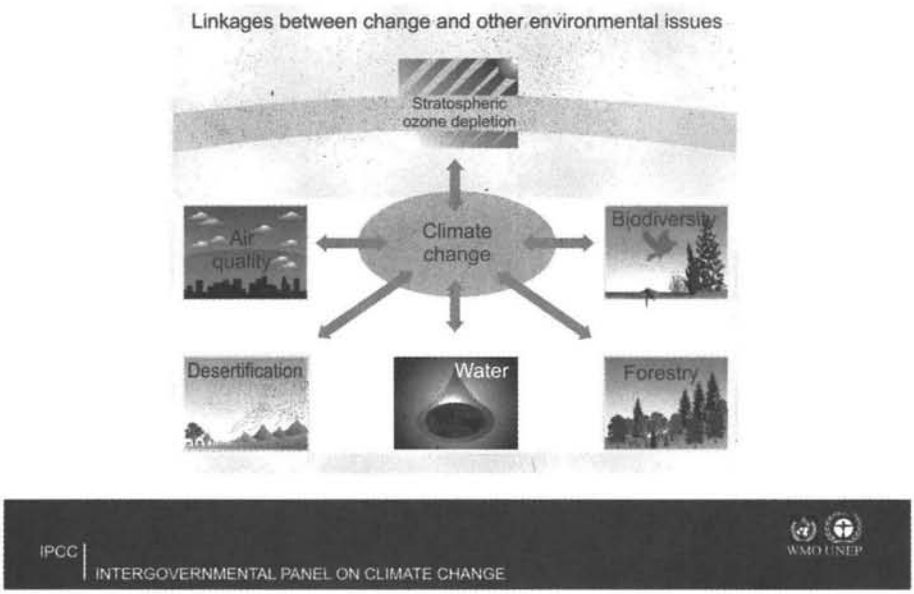
Fig. 12.4


Climate change and food
Unsustainable forestry
Climate change
Nitrogen fertilization
Hydrologic and CC, changes
Extensification
Loss and fragmentation of habitats
Food supply and demand
Loss of crops genetic diversity
Biodiversity loss
Salinization and erosion
Fertility loss
Land degradation
IPCC
INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE
WMO UNEP

(a)


Key elements of sustainable development and interconnections
Economic
Growth efficiency stability
Intergenerational equity basic needs and livelihoods
Valuation and internalization incidence of impacts
Intergenerational equity values and culture
Social
Empowerment inclusion and consultation governance
Environmental
Biodiversity/resilience natural resources pollution
IPCC
INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE
WMO UNEP

(b)



(c)

Fig. 12.5

(iii) Glacial retreat in the Himalayas will affect billions of people.

(iv) Millions in coastal areas will be at risk from sea level rises.

(v) Production of wheat, maize and rice in India and China will drop.

(vi) Over one billion (10^9) people may face shortage of fresh water by 2020.

UNs Kyoto Protocol aims to cap greenhouse gas emissions by 2012. US pulled out of Kyoto in 2001 but planned to tackle limiting CO_2 emissions on its own.

India has recorded weather data of past 150 years. Study of these records indicate that there is no change in monsoon rainfall and the extremes are in natural variation (such as floods, droughts, heatwaves etc). It is found that there is rise of 0.5 °C during last 100 years see Fig. 12.6. Model simulation shows rise in temperature by 3 to 4 °C during 21st century. Night temperatures are increasing faster than the day temperatures. Extreme precipitation appears to be on rise over large area.

Coming decades may witness warmer weather, rising sea levels, intense storms, changes in ocean currents. These will wipe some idyllic destinations off the tourist map. Global warming models indicate that the Himalayan Ski resorts may be affected due to higher temperatures. The hazards of landslides would increase. Beaches from Bondi in Sydney to Fiji, Bali, Thailand, the Phillipines and Maldives are also

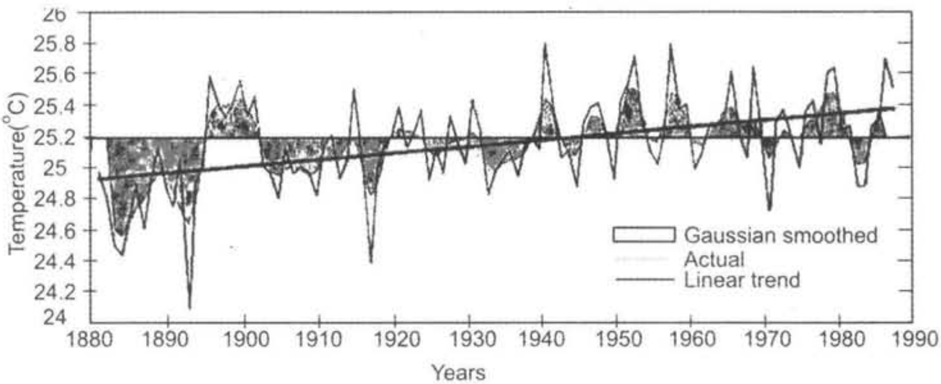


Fig. 12.6 All-India mean annual surface air temperature : 1881-1988.

under threat. In Europe the Alpine Ski resorts likely to be affected with losing about 70% of snow cover by 2050 (see Fig. 12.4). Global farm potential might increase with a rise of 3°C in temperature before sinking worldwide. Crops might grow better in nations far from the tropics (such as Canada, Russia, New zealand, Scandinavia). Mediterranean region might become arid. In the US, rising seas and storm surges could severely affect transportation along Gulf, Atlantic and Northern Coasts.

According to Andhra Pradesh pollution monitoring units: Air pollution in Hyderabad, AP, India become doulbed during 2002-2007. In 2004 the average reading of suspended particulate matter in the air was less than 150 units/m^3 of air. In 2007 it was 267 units/m^3 of air. The accepted (normal) level is 100 units /m^3 of air.

According to Dr. Yeshwant Oke (pediatriaian) noise pollution may rupture the eardrum, induce cardiac and cardrovascular changes, fatigue and cause sleep disturbances, headache and insomnia. According to Environmental Protection Act of 1986, which notified noise as a pollution. It laid down a fine of up to Rs. 100,000 or imprisonment up to five years or both.

Permissible noise level in residential areas	:	55 decibels
Loud Speakers	:	75-115 db
Drilling Machine	:	90-100 db
Vehicle - Horns	:	80-84 db
Typewriter	:	50-60 db

In 1970 there were about 80,000 vehicles plying in Hyderabad, which increased 10 lakhs in 2001 and 18.5 lakhs by the end of 2007 in the city roads.

As of January 2007 there were over 17 lakh vehicles plying in Hyderabad. The following are the pollution measurements at some important junctions in city of Hyderabad.

According to A.P pollution Control board oxides of nitrogen 26 mg/m^3 on 2 June 2007; 38 mg/m^3 on 2 June 2008.

1. Noise pollution in the city (As on 2 June 2008)

Permissible level	65 dB
Punjagutta	86.23 dB
Charminar	85.88 dB
Paradise	85.84 dB

2. CO (Carbonmonoxide)

Permissible	4 mg/m^3
Punjagutta	26 mg/m^3
Charminar	23 mg/m^3
Paradise	23 mg /m^3

3. Total suspended particulate matter

Abids	242 μg/m^3
Punjagutta	321 μg/m^3
Paradise	347 μg/m^3
Permissible	200 μg/m^3
Langer Houz	448 μg/m^3
Uppal	358 μg/m^3
Balanagar	338 μg/m^3

Notation : μg = micro grams
mg = milligrams
m^3 = cubic meter or meter cube
dB = deci Bells

Consequences of Global Warming

Climatic fluctuations are caused by large scale aberrations of atmospheric circulation. The likely factors are :

(i) air-sea interaction,

(ii) injection of large scale ash, dust into the atmosphere,

(iii) changes in the composition of atmosphere particularly water vapour, carbondioxide, ozone (which are selevtive absorbers of radiation that could modify the heat balance of the earth).

Climatic fluctuations means large departures from seasonal or annual averages, while climatic change stands for longer time scales, decades to centuries, when the average temperature of a whole hemisphere or whole globe increases or decreases significantly. Climate changes have far reaching consequences.

The study of past civilizations show how climatic changes had major impacts on human society. The last glacial period terminated about ten thousand years ago, with this the boundary of glaciers moved northwards and higher in mountains, the ocean level slowly elevated and reached the present level at about 6000 years ago. People who lived in near tropical zone moved northwards and populated over vast territories of Europe. The most significant migration was from Hindustan and Iranian Highland. The languages of the majority of European peoples have common roots with the ancient Hindustan, the Sanskrit. This is the reason why one of the major human races is called Indo-European. The everchanging earth's climate has wa.med up by 0.5 °C during previous 100 years, which is attributed to the human activities.

Atmospheric pollution, emission of greenhouse gases and the resulting impacts (on global scale) are :

(i) warming of the climate,

(ii) reduction in stratospheric ozone layer,

(iii) contamination of food chains over land and sea,

(iv) acid rains,

(v) regional photochemical smog.

(a) **General circulation,** statistical or numerical climate models take into account of air-sea interaction (at least the upper layers of the oceans), biological feed back loops, the ice and snow fields (their fluctuations) and hydrological cycle (precipitation – runoff – soil moisture – evaporation – cloud formation and back to precipitation again).

These models outputs are : For doubling of carbondioxide, the global mean temperature will increase range 2 °C to 5 °C. More warming towards poles (particularly in Northern Hemisphere but not significant change in precipitation distribution. On global basis precipitation will increase with increase in evaporation as a consequence of global warming. Intensity of tropical cyclones, extreme events of heat wave, cold waves, will increase. The inter-governmental Panel on Climate Change estimates a warming of about 3 °C by the end of (year 2100) 21st century (with range of estimates 2 °C to 5 °C with the present level of increase of greenhouse gases). The warm climate would result in 10 to 30 cm rise in mean sea level water (due to melting of glaciers, Greenland ice cap and thermal expansion of the sea water). Sea surface water temperature likely to remain the same. Island nations Maldives, Vanuatu etc. greatly reduce in size.

(b) **CFCs are powerful greenhouse gases** and they are the main destroyers of stratospheric ozone. Stratospheric ozone layer is a protecting sheild against incoming solar harmful UV-radiation (UVB). Ozone is present in the atmosphere between 10-45 km altitude with maximum concentation at altitude around 18-20 km in a globe encircling ozone layer. The total ozone column in the atmosphere sheilds the earth's surface from harmful UVB. UVB induces skin cancer, damages eye, causes suppression of immune systems in human beings. It effects the productivity of aquatic and terrestrial ecosystems. One percent decrease in ozone concentration causes three precent rise in skin cancer in humans. Stratospheric ozone decline causes stratospheric cooling, which will effect the global circulation, climate, however which is not understood. WMOs global ozone observing system concluded that use of chemicals containing Chlorine, Bromine can lead to a significant depletion of stratospheric ozone. This is the cause of ozone hole over Antarctica in spring time.

(c) **Contamination of seas, lakes and land :** Contamination of atmosphere by toxic metals and organic compounds infecting all parts of the earth. The biological communities of the water and land absorb, and the bio-accumulate these contaminants through the food webs. By the process of food chain when these substances found in higher level mammals, including humans, the trace concentrations deposited would be in harmful amounts. Arsenic, lead are known to be carcenogens. Mercury, Lead attack the central nervous system. Toxic-persistant chemicals carried through the atmosphere to land, lakes, seas and into sediments may be viewed as "time bombs". Metals and organic contaminants deposited and absorbed initially may not show any impact on the environment but after a few decades by natural process (such as microbiological methylation of mercury, and other metals) become highly toxic. The slow release of "time bomb" in soil and water can rapidly multiply in concentration at higher levels in the food webs. These affect seriously on high level predators. For example DDT caused decimation of North American eagle population during 1960s and 1970s and death and deformation of humans, the 'Minimata' condition created by ingestion of fish poisoned by methylated mercury.

(d) **Acid rains** - Discussed in Air pollution.

(e) **Smog** - Discussed in Air Pollution.

Radiocativity

The accident of nuclear power plant at Chernobyl USSR opened the eyes of scientists about its very harmful effects. They found the nuclear traces in long range transport or airborne pollutants. The cloud of radioactivity from Chernobyl accident moved with wind towards Scandinavia where rains scavanged in sufficient amounts. This rendered lichen and the reindeer browsing on lichen radioactive. The animals found to be unfit for human consumption as they were carrying very high radioactivity. After Scandinavia, the cloud trajectory moved southwards to central Europe, where radioactive particles found deposited in foodstuffs, which were banned for short period for health hazard reasons. Subsequently the radioactive debris were moved by westerly wind circulation throughout the northern hemisphere. After Chernobyl event the International Atomic Energy Agency and WMO established an international warning service forecasts by meteorological agencies regarding transport, dispersion and deposition of radioactive particles.

In 1979 the first World Climate Conference established world climate programme of four components – Data, Applications, Impact studies and Research.

(i) ***Data*** **:** Measurement, collection and exchange of data on climate and factors affecting it.

(ii) ***Application*** **:** Applying climatic information to improve the efficiency of many economic activities.

(iii) ***Impact Studies*** **:** Evaluating the Socio-economic impacts of projected changes in climate.

(iv) ***Research*** **:** Undertaking research on the climate system (atmospheric - oceans - land - biota) and the factors affecting it including predictions of effects of increasing greenhouse gas concentrations.

It is estimated that one to two billion tonnes of carbon per year could be removed from the atmosphere for each 100 million hectares of forest planted or green lungs of the earth. Under FAO/UNEPs Tropical Forest Action plan, aggressive restocking and replanting programmes in the temporate and boreal zones could restore the major biological sink for carbondioxide.

12.16 Water and its Pollution

All life on earth is sustained by water. It is the second most vital matter for life after air and then follows food, clothing, shelter etc. Man can survive without food for a few weeks but without water he cannot survive even a few days (a week) and without air even a few minutes. It is estimated nearly 70% of man by body weight is water. Water is inorganic and does not provide energy to tissues. Much of water is in body – photoplasm and in spaces between cells. Plasma (fluid part of the blood) contains 91-92 percent water. Water is essential for digestion of food, blood circulation and removal of waste products from body. Man's average daily loss of water is 2500 CC. Of which 1500 CC as urine, 500 CC in perspiration, 400 CC in exhaled air and 100 CC in faeces. Any loss of water more than 250 CC (10%) is fetal. On an average man drinks about 1500 CC of water and the remaining he gets it from food. Fruits and vegetables contain about 80% water. Kidneys remove excess water along with cellular waste.

On an average man requires 2.5 to 3 liters of water per day for drinking and cooking or one cubic meter per year. However to improve his living conditions he is using 100-200 liters per day for his household needs and a thousand times for industrial consumption. For example, production of one ton sugar requires about 100 cubic meters (m^3) of water, one ton of paper requires 250 m^3 of water, processing of 1000 liters of milk requires 5000 liters of water. Production of one ton steel requires 150 m^3, Nickel 800 m^3, Aluminium 1500 m^3 of water. In recent times man has been mining ground water for agriculture, domestic and industrial use. This is causing depletion of ground water resource which was reliably dependent through the ages. Unknowingly man has made many blunders in water use and conservation. The worst part is pollution of lakes and rivers. Pollution is the main factor that is threatening the exhaustion of fresh water resources. One cubic meter of sewage dump contaminates more than 12 cubic meters of clean water in rivers and lakes. Use of polluted water is a severe health hazard. Pollution of water is the foremost concern of mankind. Experts are of the opinion that water famine may arise only through inefficient use of natural water resources rather than lack of water in the world. Further they concluded that the water resources on the earth fully sufficient to meet all the growing needs of man for an indefinite time period provided man must practice to avoid water pollution, extend recycling of suitable water resources.

Is Ganga a Dying River

According to recent World Water Forecast, a grim prognosis is that among the worlds ten most endangered rivers include Ganga, Indus, Nile and Yangtze. Ganga basin covers one third land area of India and its fertile soil is the cradle of Indian civilization and the home of millions of people. It is a sorry state of affair that indiscriminate extraction of water with table wells from river and its basin, damming of its tributaries for irrigation purpose seriously eroded its reproduction which lead to the free flow arrest. It is said Ganga is dying due to pollution over extraction of water and serious climatic changes. According to World Water Forecast, glaciers account for as much as 30 to 40% in the case of Indus. Ganga flows through India but also drains from Nepal and China. It covers about 2500 km length and 30% of land area. As regards Indus, it flows through Pakistan, but also drains from Afghanistan, India and China. It covers 2900 km length. The main warrant threats of death is the over water extraction, pollution and drains. The endangered species in the Ganga basin besides human beings are 140 species of fishes, dolphins, fresh water shark and 90 amphibian species. In Indus the endangered species are Dolphins, about 22 species of fishes, 25 amphibian species. From source in the Himalayas to the sea Bay of Bengal the story of Ganga is India's civilization. The World Water

Forecast limits a warning the death of Ganga is not merely the river, but includes the great Hindu Civilization, Ravisingh Secretary General and Chief Executive Officer, World Water Forecast India, pleads for conservation of rivers and wet lands which are part and parcel of National Security, health and economic success and warns, people must change their mindset atleast now, lest they have to pay the heavy price in the not so-distant future.

In 1950's the world population was about 2.5 billions which shot upto 6 billions by the end of 2000 AD and it is projected to be 9.2 billions by 2050. India would become the worlds most populus country with 1.7 billion people according to UN report of 2005. Half the increase in the global population between 2005 and 2050 would be on account of rise in the over 60 years population, while the number of children under 15 will begin to decline. A 2004 UNICEF report of India said that only a third of population has access to potable water and adequate sanitation facilities. Poor water quality, sanitation and waste management lead to plethora of maladies. In 1950s about one third of the population lived in cities which rose to one-half by the end of 20th century and it is projected to rise to two thirds by 2025.

Water is essential to all lives of animals and plants. It has crucial role in industries and steam generation, plays important role in engineering. Water is used in large quantities in the production of steel, sugar, paper, rayon, chemicals, textiles, ice, drinking, bathing, washing, irrigation, fire fighting, power generation and atomic energy.

Water in the World

The volume of the global water is estimated to be 1455×10^6 cubic kilometers (km^3). About 1370×10^6 km^3 or 94% of the global water is estimated to be in the seas, which occupies 361 million km^2 (square kilometers) of the global surface area or 70.8%. 85×10^6 km^3 or 6% of global water is fresh water, which accounts water of rivers (1200 km^3 or 0.0001% of global water), lakes (750×10^3 km^3 or 0.05% of global water), glaciers (2.4×10^6 km^3 or 4.11% of global water). Water in the atmosphere is 14×10^3 km^3 or 0.001% of global water.

It is estimated that about 4.5 million km^2 or 3% of land area is occupied by inland water bodies and 16.5 million km^2 or 11% (land) area occupied by glaciers. The volume of fresh surface water is about 751200 km^3 which is very small amount compared to the volume of the oceans and seas water, yet it plays a vital role in the life of man.

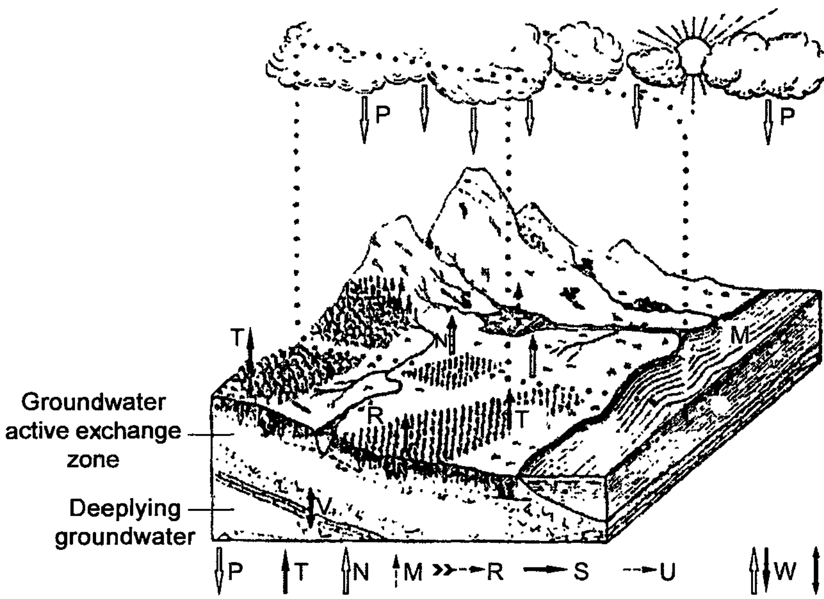
12.16.1 Hydrological Cycle

Definition

Hydrology may be defined as the science that deals with the processes governing the depletion and replenishment of surface water and ground water resources of the earth. Consequently it may be viewed as part of physical geography and hydrometeorology.

Hydrometry is the technology of water measurement spanning all aspects of water movement within hydrological cycle.

The hydrological cycle is a continuous process of movement of water from surface of earth to atmosphere (as evaporation), from atmosphere to ground (as precipitation), then to rivers, lakes, underground reservoirs and to the sea (see Fig. 12.3). Like lithosphere, the bulk composition of hydrosphere is oxygen. The composition of water has 88.9% oxygen and 11.1% hydrogen by weight. Waters of oceans, rivers, lakes have very small amounts of almost all elements of the earth's crust. Sea water has 3.5% dissolved minerals, of which NaCl (about 2.6%) is the most abundant. Consequently sea water has salty taste.



P = precipitation, T = Transpiration, N = Soil evaporation, M = Water surface evaporation R = Total river flow, S = Surface (flood) runoff, U = Ground water runoff, W = Soil mositure, V = Exchange with ground water.

Fig 12.3

About 80% of the total water vapour in the atmosphere comes from the evaporation of sea water.

Note : Steam occupies a volume of 1600 times greater than that of the liquid water. In gaseous state molecules are about 12 times apart than they are in liquid state.

Thus hydrological cycle is a God's gift to all living beings because fresh water resources on land are formed from rain water. In a sense it is a gigaintic desalination plant which converts saline sea water into water vapour and then into fresh water that falls on earth as precipitation. It may be noted that all minerals/matter transforms to other forms but water remains as water. In Sanskrit water is called Amritha, meanining deathless. At any one time the lakes and rivers contain 751200 km^3 of water which is little more than 0.05% of global water. An estimate of annual water balance of the world by M.I. LVOVICH is given in Table 12.9.

Table 12.9

	Volume in km^3	Average depth in mm
A. Over periphery of land area (116.8×10^6 km^2)		
Precipitation	106000	910
River discharge	41000	350
evaporation	65000	560
B. In land area (32.1×10^6 km^2)		
Precipitation	7500	238
Evaporation	7500	238
C. World ocean (361.1×10^6 km^2)		
Precipitation	411600	1140
Inflow river water	41000	111
Evaporation	452600	1251
D. World total (510×10^6 km^2)		
Precipitation	525100	1030
Evaporation	525100	1030

Global volume of rain water $= 4\pi R^2 h,$

$$= 4 \times \frac{22}{7} \times (6370)^2 h$$

$$= 510 \times 10^6 \text{ km}^2 \times h$$

$$= 510 \times 10^6 \times \frac{1030}{1000} \times \frac{1}{1000} \cong 525.100 \text{ km}^3$$

Where R = Mean radius of the earth 6370 km.

$$h = \text{height of pptn} = \frac{1030}{1000} \times \frac{1}{1000} \text{ km.}$$

12.16.2 Water Resources

Water resources can be divided into two categories. (i) Surface water and (ii) ground water.

Surface water resources : are Rivers, lakes, swamps, glaciers and sea water.

Underground water resources : are wells and spring water.

Rain water is the purest form of natural waters. However it contains traces of dissolved material, gaseous compounds. Rivers, lakes, swamps waters are all accumulated rain water. These have some dissolved minerals and suspended matter. Sea water contains dissolved salts about 35 gm/kg or 3.5% by weight. Six ions of sea salts together will be more than 99%. They are: ions of Chloride (55%), Sodium (30%), Sulphate (8%), Magnesium (4%), Calcium (1%) and Potassium (1%).

Water, in the form of vapour, is exchanged between sea and air. More than 80% of water vapour in the atmosphere comes from the evaporation of sea surface water. Along with water vapour energy is also transferred from sea to atmosphere in the form of latent heat of water vapour. On condensation it releases latent heat. Condensed water returns to the sea in hydrological cycle but energy remains in the atmosphere. Part of this heat energy is converted to mechanical energy (wind). Two-thirds of the precipitation on land returns to the atmosphere by soil evaporation and plants. The remaining one-third precipitation either percolates into soil or runs off on the land surface. The bulk of the fresh water on land is stored in the form of ice in glaciers (volume 24×10^6 km^3) which is about 20000 times the worlds river waters. Ice melted water flows into rivers and lakes. Water stored in lakes (750×10^3 km^3) is about 625 times the water in rivers. This water is of great importance in many parts of the world. They are the fresh water source for cities and agriculture. Because of importance artificial lakes are created by damming rivers.

Percolation of water through large pores into the soil is called gravity water. This gravity water accumulates at some depth over rocky layer and fills all cracks and pore spaces. The level below which soil and rocks are saturated with water is called water table. Water below water table is called ground water. The depth of water table varies from place to place and with season. In dry season the depth will be more than in wet season. During good rains water table slowly increases and this results in ground water flow into near by streams. When there are persistant heavy rains stream channels will be overflowing into adjacent areas. This causes floods. Surface run-off of water depends on precipitation and varies with the intensity of precipitation. Ground water flow on the other hand is more steady. The ground water (volume = 60×10^6 km^3) is about 50,000 times the volume of river water.

Artesian Wells

When rain occurs on mountain slopes water passes through the porous rock and then flows underground. If this water flows between two layers of low permeability artesian system (like water flow through a pipe) develops. The underground aquifer (water saturated zone) flow carry large quantities of water. This can be drawn through digging wells on plane area, where water comes to the surface by pressure. This type of well is called Artesian well.

Water impurities can be categorized as :

(a) suspended impurities,

(b) dissolved inorganic impurities and

(c) organic impurities.

(a) suspended impurities can be removed by filtration or settling. Suspended impurities include clay, silt, bacteria, algae, protozoa.

(b) dissolved inorganic impurities include (i) calcium, magnesium and sodium carbonates, bicarbonates, sulphates, chlorides, fluorides (ii) Metal and oxides e.g. magnesium, iron oxide, lead, Arsenic (iii) gases e.g., Oxygen, CO_2, H_2S.

(c) organic impurities include (i) Suspended (e.g., vegetables, dead animals). (ii) Dissolved (e.g., vegetables and animals).

The essentials of driking water standard in India are given in Table 12.10.

Table 12.10

Item	Desirable	Maximum permissible limit (in the absence of alteranate source)
pH	6.5 – 8.5	- - -
Alkalinity (mg/l)	200	600
Total hardness (as $CaCo_3$)	300	600
Dissolved solid material (mg/l)	500	2000
Calcium (mg/l)	75	200
Chlorides (mg/l)	250	1000
Chlorine (mg/l)	1.2	- - -
Fluroid (mg/l)	1.0	1.5
Nitrate (mg/l)	45	100
Iron (mg/l)	0.3	1.0
Copper (mg/l)	1.5	1.5
Manganese (mg/l)	0.1	0.3
Zinc (mg/l)	5	15
Arsenic (mg/l)	0.5	- - -
Cyanide (mg/l)	0.5	- - -
Lead (mg/l)	0.5	- - -
Total Coliforms	nil/100ml	10 counts/100ml
Faecal coliforms	nil/100ml	- - -

mg = milligrams l = liter

12.16.3 Hardness of Water

Water that does not produce lather easily with soap but produces white curd like form is called hard water, while water that produces lather easily with soap is called soft water. Hardness of water is of two types :

1. Temporary hardness and
2. Permanent hardness

Temporary hardness is caused by the presence of dissolved bicarbonates of calcium, magnesium and heavy metals and the carbonates of iron in the water. Temporary hardness can be removed by boiling of water which decomposes bicarbonates into insoluble carbonates and carbondioxide. Carbonates can be removed by filtration while carbondioxide escapes out.

Permanent hardness of water is caused by the presence of dissolved chlorides, sulphates of calcium and magnesium, iron and other heavy metals in the water and it cannot be removed by boiling.

Hardness of water is generally measured as parts per million (ppm). Parts per million is the parts of $CaCO_3$ equivalent hardness per 10^6 parts of water.

1 ppm = 1 part of $CaCO_3$ equivalent hardness in 10^6 parts of water.

Equivalent of $CaCO_3$ is defined as below.

$$\text{Equivalent of } CaCO_3 = \frac{\text{Mass of hardness causing substance} \times 50}{\text{Chemical equivalent of hardness causing substance}}$$

where 50 = Chemical equivalent of $CaCO_3$.

Hardness of water classified as in Table 12.11

Table 12.11

Hardness in ppm	**0-50**	**50-100**	**100-150**	**150-200**	**200-250**	**more than 250**
Nature of hardness	Soft	Moderately soft	Slightly hard	Moderately hard	Hard	Very hard

Example - 1

What is the temporary hardness in ppm and total hardness in ppm of a sample of water which have the following composition. $Ca(HCO_3)_2$ = 16.2 mg/l, $Mg(HCO_3)_2$ = 7.3 mg/l, $MgCl_2$ = 9.5 mg/l, $CaSO_4$ = 13.6 mg/l.

Solution

Where molar mass of $Ca(HCO_3)_2$ = 40 + 2 (1 + 12 + 48) = 162 etc

Substance	Mass mg/l	Molar Mass	Multiplying Factor	Equivalent of $CaCo_3$
$Ca(HCO_3)_2$	16.2	162	100/162	$16\ 2 \times \frac{100}{162} = 10$
$Mg\ (HCO_3)_2$	7.3	146	100/146	$7.3 \times \frac{100}{146} = 5$
$Mg\ Cl_2$	9.5	95	100/95	$9.5 \times \frac{100}{95} = 10$
$CaSO_4$	13.6	136	100/136	$13.6 \times \frac{100}{136} = 10$

Temporary hardness caused by dissolved bicarbonates of Ca and Mg.

∴ temporary hardness = 5 + 10 = 15 ppm.

Total hardness = 10 + 5 + 10 + 10 = 35 ppm.

Example - 2

What is the total hardness and permanent hardness in ppm of a sample of water containing $Ca(HCO_3)_2$ = 16.2 mg/l, Mg $(HCO_3)_2$ = 7.3 mg/l, $MgCl_2$ = 9.5 mg/l and $CaSO_4$ = 13.6 mg/l.

Solution

Total hardness = 10 + 5 + 10 + 10 = 35 ppm.

Permanent hardness = hardness of $MgCl_2$ and $CaSO_4$ = 10+10

= 20 ppm

Substance	Mass mg/l	Molar Mass	Multiplying Factor	Equivalent of $CaCo_3$
$Ca(HCO_3)_2$	16.2	162	100/162	$16.2 \times \frac{100}{162} = 10$
$Mg\ (HCO_3)_2$	7.3	146	100/146	$7.3 \times \frac{100}{146} = 5$
$Mg\ Cl_2$	9.5	95	100/95	$9.5 \times \frac{100}{95} = 10$
$CaSO_4$	13.6	136	100/136	$13.6 \times \frac{100}{136} = 10$

There are several disadvantages in use of hard water for domestic purpose, industries and in steam generation.

In Domestic Use

In washing and cleaning, bathing, cooking, drinking hard water causes lot of wastage of soap, skin becomes dry and dark, consumption of more fuel, gives unpleasant taste, pulses and beans etc., are not properly cooked and digestive system may be affected.

In Industrial Use

It casts bad effects in industries such as textile, sugar, dyeing, paper, laundry, concrete etc. Use of hard water in steam generation causes boiler scale, sludge formation, corrosion, priming and foaming, caustic embrittlement, boiler corrosion etc. These cause adverse effects on industrial production. Some of these terms are explained below.

Boiler Scale

When hard water is boiled, dissolved material in it forms a hard deposit on the inner surface of the boiler. This is called boiler scale.

Sludge

It is loose and slimy soft precipitate formed in the boiler, which can be removed by scrapping with brush.

Boiler Corrosion

It is the decay of boiler material caused by chemical or electro-chemical attacks by environment.

Priming

When hard water steam produced rapidly, some liquid water particles jump out along with steam. This is called priming.

Foaming

When boiling hard water contains some oily substances, it produces foam or bubbles which do not break.

Caustic Embrittlement

It is a form of boiler corrosion formed by alkaline water.

Softening of Water

To avoid ill effects of corrosion, boiler scale etc., water used in industries must be sufficiently soft. Methods used for removal of dissolved salts from water is called softening.

Lime Soda Process

In this method lime $Ca(OH)_2$, Magnesium hydroxide $Mg(OH)_2$, Soda Na_2CO_3, Calcuim carbonate $CaCO_3$ are added to the hard water. Soluble salts of Calcium, Magnesium are converted into insoluble compounds which are removed. By this method water with 10-15 ppm hardness is obtained.

Zeolite

Zeolites are complex hydrated silicates of Al, Ca, Na, K or Fe.

Permutite or Zeolite Process

In this method hard water is slowly percolated through Zeolite bed of sodium-alumino silicates. This bed converts calcium, magnesium salts into calcium, magnesium-zeolites and sodium salts. Filtered water becomes soft water with 10 ppm hardness and contains soluble sodium salts, while Ca, Mg salts are removed.

12.16.4 Drinking Water

Water for drinking purpose must be soft and clean. It should be colourless, odourless and have pleasant taste. Turbidity should be less than 10 ppm and dissolved solids should be less than 500 ppm. It should be free from micro-organisms. Natural water from rivers, lakes and underground do not satisfy these qualities and requires purification

Suspended impurities are removed by screening (passing water through screens) and by sedimentation (keeping water in big tanks without disturbing to settle down suspended particles at the bottom by gravity). Sedimentation with coagulation is used to remove suspended finer clay particles, colloidal matter. In this process chemicals, called coagulants (Alum, Ferrous sulphate etc) are added to the water before sedimentation. Coagulants are also useful for removing colour and odour and to provide pleasant taste. Alum is most widely used as coagulant. Sodium aluminate, ferrous sulphate are also used as coagulants depending on water alkalinity.

With the application of screening, sedimentation and coagulation all impurities are not removed, some will be left over which will be removed by special filtration beds. Special filteration bed removes colloidal matter, microorganisms and most of the bacteria. These filters remove 98% of bacteria and almost all suspended impurities. A typical filtered bed is shown in Fig. 12.8.

Disinfection and Sterilization

Nearly killing or destroying of all micro-organisms pathogenic bacteria to make water potable is called disinfection, while sterilization means total destruction of all living organism in water.

Removal of Micro-organisms from Water

After filteration the residual pathogenic bacteria is killed by disinfection. Water is disinfected by adding bleaching powder, by chlorination, by using chloramine, ozone, potassium permanganate and by ultraviolet light.

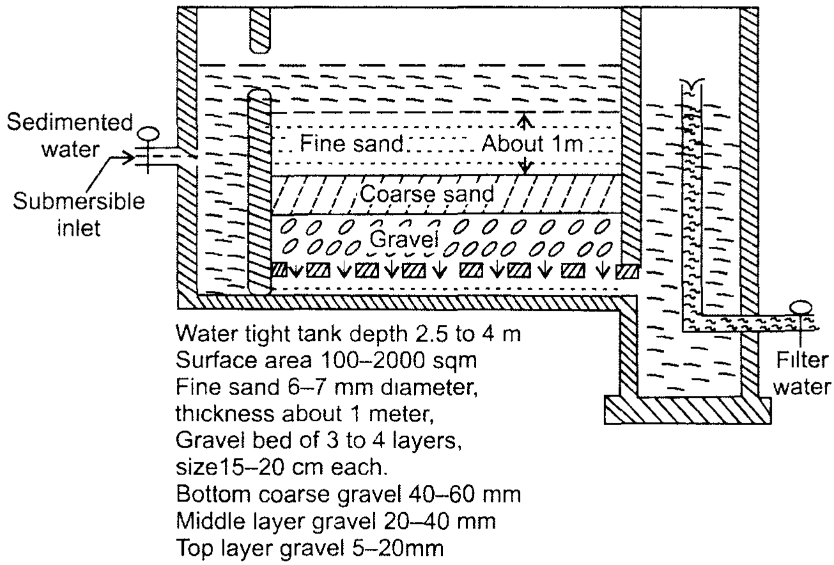


Fig. 12.8 A typical filter bed.

Chlorination

Generally level of 0.2 mg/liter of free chlorine will kill bacteria. However to kill viruses it requires 3 to 4 mg/liter and to kill protozoa it may require a level of 500 mg/lit. Disinfection by chlorination is widely used and considered safe.

Sewage

All waste waters or liquid domestic waste, industrial waste, ground waste, storm waste, human waste is called sewage. Sewage emanates gases, such as hydrogen sulphide, ammonium sulphide, phosphine etc. Some of these gases have dirty odour. Sewage contains aerobic and anaerobic bacteria which cause oxidation of organic compounds in it.

Aerobic

Living only in the presence of free molecular oxygen gas or dissolved oxygen in water.

Anaerobic

Living in the absence of free oxygen as gas or dissolved in water.

Prototrophic bacteria takes food from minerals (like nitrites, carbonates etc) present in the sewage.

Metatrophic bacteria takes food from organic compounds, nitrogenous and carbonaceous.

Important sewage characteristics : are Physical, Chemical and Biological.

Physical characteristics include colour, odour, temperature and turbidity of sewage.

Sewage contains colloidal matter, dissolved gases and suspended matter. Fresh sewage is odourless and has gray colour. In about 4 hours time it becomes stale (oxygen being exhausted) and starts emitting offensive gases like hydrogen sulphide, ammonia, methane etc. Its colour becomes dark. Temperature of sewage in general slightly higher than the water supply. Sewage contains about 99% water and the remaining solid matter such as faecial solids, matches, bits of paper, twigs, grease, vegetable matter.

Chemical Characteristics

Fresh sewage is little alkaline while stable sewage is acidic in nature. Solid sewage consists of organic (about 40%) inorganic (about 55%) matter and it contains dissolved gases like CO_2 H_2S, CH_4 etc. It is estimated that sewage consists of 0.045% solids of which 0.0225% in dissolved form, 0.0112% in suspended form and 0.0113% in settleable.

Biological Characteristics

Sewage contains large quantity of bacteria such as algae, fungi, pathogen, protozoa and other microorganisms.

Biological Oxygen Demand (BOD)

BOD of a sewage is the amount of free oxygen required for biological oxidation of the organic matter in aerobic condition at 20 °C for a period of 5 days. BOD is expressed as mg/l or ppm. An average sewage has BOD of 100-150 mg/*l*.

Sewage Treatment

To dislodge its harmful effects sewage must be treated to public health or aquatic life before it is letoff into natural water course (rivers/ponds or on land). Sewage is passed through bar screens or mesh screen which separate the large suspended floating matter and coarse solid silt, gravel etc. It is then let off into sedimentation tanks where it will be treated with chemicals before settlement. Generally alum, ferrous sulphate are used to coagulate, which also removes colloidal matter. It is then aerated or subjected to aerobic biochemical oxidation. In this process sewage is passed through special sprinklers to maintain aerobic conditions. In aerobic condition organic carbon material is converted into CO_2, the nitrogen into NH_3/ nitrites/nitrates (this forms salts). Filtering media removes micro-organisms. Treated waste sewage is removed from the bottom which is used for agriculture fertiliser etc. See flow chart in Fig. 12.9.

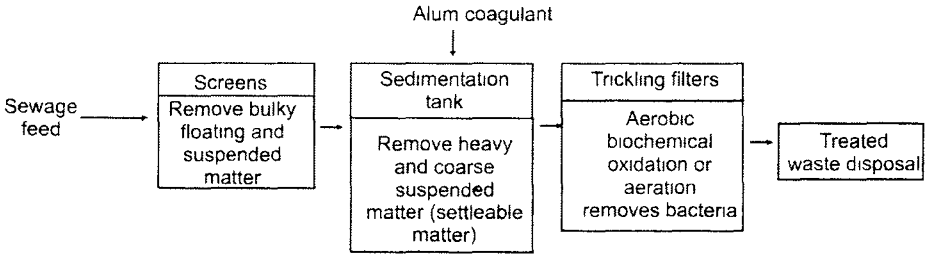


Fig. 12.9 Flow chart of sewage treatment.

Desalination of Brine

Sea water contains about 3.5% of dissolved salts and it is called brine or brackish water. Brackish water is completely unfit for drinking purpose. The removal of salts from brackish water is called desalination. Over sea areas and in coastal areas desalination is essential for getting potable water. See Fig. 12.10.

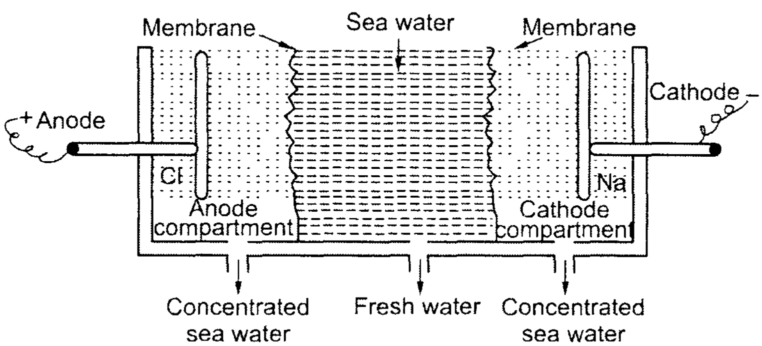


Fig. 12.10 Desalination of brine.

An age old method of desalination is boiling of sea water and then condensing the water vapor to obtain fresh water. Where electricity is easily available, the desalination is achieved by electro-dialysis. In this method direct electric current is passed through brine. By this sodium and chlorine ions are attracted at cathode and anode respectively. Fitting special compartments of permiable memebrane around cathode and anode, the central compartment gets accumulated with desalinated water, which is removed.

Reverse Osmosis

If two solutions of different concentrations of a solute are separated by a semi-permeable memebrane, by Osmosis process, dilute solution flows into concentrated solution through the membrane. This flow continues till the two sides of the membrane attains equal concentrations. If a hydrostatic pressure in excess of osmotic pressure is applied on the concentrated solution, the solvent flow reverses, that is, flow starts from concentrated to less concentrated solution across the membrane. This is called reverse osmosis. Reverse osmosis method is used for desalination of brine. This method is shown in Fig. 12.11.

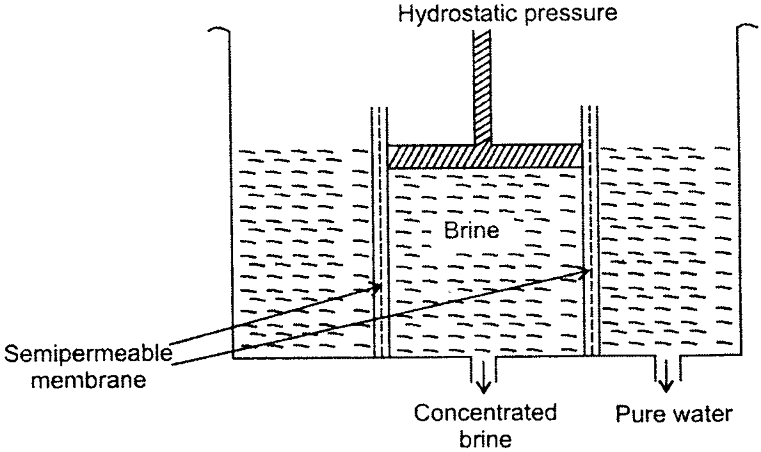


Fig. 12.11 Reverse osomosis.

12.17 Solid Wastes

Solid wastes include any garbage, refuse, sludge, air pollutants, any discarded material from domestic houses, industrial operations, mining, agriculture, construction and demolition of buildings. Solid wastes may be biodegradable or combustible. Industrial wastes include organic and inorganic chemicals, pesticides, explosives, paints and allied products, petroleum refining materials, rubber, plastic, waste oil. Some of these are toxic in nature. Municipal wastes include garbage, fats, paper, leaves, grass, wood, plastics, rubbers, rags, ash, glass, ceramic etc.

Generation of solid wastes cannot be stopped but they can be reused or recycled for use. Community refuse may contain reusable materials such as steel, aluminium, glass, paper. These materials may be collected separately and reused, which helps in reducing the cost of manufacture.

Solid waste disposal mainly carried by:

(i) land fill, (ii) incineration, and (iii) compost.

Toxic solid waste disposal by land fill may create health problems. Incinerators reduce the volume of solid waste by burning combustible materials. In this case also one must take care of air pollution. Land fill consists of depositing refuse in a low place or excavated trench. The refuse after dump is covered by earth about one feet depth.

Incinerators generally burn 85 to 90% of combustible material. Heat generated in incinerators are used for many purposes and now considered as a source of energy.

Dumping of food and agricultural waste, sewage sludge in pits to decompose by biological action is called composting. The residue of composting material is used as manure in agriculture. Micro-organisms break down the degradable material into powdery material called compost.

12.18 Fire Services (Prevention, Control and Forecasting)

Fire is one of the Pancha Bhutas. The others are Air, Earth, Water and Sky. Fire is considered as the enemy of forests, because it may rage an inferno in a short time and reduce the forest (its earned centuries savings) wealth into ash and scarred black remains. Not only vegetation but also flora and fauna destroyed and heavily damaged and make the forest land infertile for long time (by destroying top humus soil). It is a known fact that forests control soil erosion, avalanches, landslides and runoff of water which causes flash floods. Forests regulate water supply and aids in improving ground water table. All these favours are destroyed by the fire. Besides forest fires, it is a common feature, during heat wave conditions, burning of huts, haystocks, thatched houses, electrical short circuits.

In Russia, which has about 25% of world's forest area, fire danger ratings are published and warned of dangers regularly. Fire forecasters compute fire danger ratings based on maximum temperature, humidity and wind direction or speed.

In a day to day life common man uses water and sand for fire fighting. In government offices, factories, industries, fire fighting arrangements are made by use of water, sand, carbon dioxide extinguishers and making use of fire fighting services where available.

In aviation, the principal fire extinguishing agents are water and foam. The amounts of water for foam production and the complementary agents required depend on firefighting category, which is determined from Tables 12.11, and 12.12 as appropriate. The discharge rate of the foam solution shall not be less than the rates given in Table 12.12 as appropriate. The discharge rate of complementary agents are selected for optimum effectiveness of the agents used.

For example at an elevated heliport, atleast one hose sprary line capable of delivering foam in a jet spray pattern at 250 l/min.

Table 12.11 Heliport fire fighting category.

Category	Helicopter overall Length
H_1	< 15 m
H_2	≥ 15 m but < 24 m
H_3	≥ 24 m but < 35 m

Table 12.12 Minimum usable amounts of extinguishing agents for surface level Helicopters.

(1) Category	(2) Water in liters	(3) Foam Solution *l/min*	(4) Dry chemical *Powders (kg)*	(5) or Halons *(kg)*	(6) CO_2 *(kg)*
H_1	500	250	23	23	45
H_2	1000	500	45	45	90
H_3	1600	800	90	90	180

Fire fighting vehicles are used with hydraulic platforms that can extend up to 54 meters high-rise buildings.

Modern Fire Control Technology

In Classical approach firefighting is done using water sprinklers, fire alarams. Modern technology aims at prevention of fire accidents, which is named fire control technology. In this (later) system sensory devices introduced to target corporate houses and industrial units. It is aimed to fight off the fire before it breaks out. The devices heat-sensing cable, nitrogen injection and wireless system developed with the purpose of detecting and extinguishing fire at the beginning itself and eliminating the chance of casuality. For example take the case of heating cable. The optic fibre cable is made of quartz, which can detect hot gases and at the same time it is free from electromagnetic disturbances. Temperatures are recorded along the sensor cable. Depending on temperature, warning signals are delivered immediately. This helps in putting out the fire at the start itself. A German company 'Dectomat' manufacturing microprocessors with software tools for fire control panel to detect fire at any stage. The advanced electrical cables focus exclusively on detecting and preventing fire in the corporate and industrial units.

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@Seismicisolation

CHAPTER - 13

Aviation Hazards and Safety Measures

Introduction

From the dawn of civilization man has been inventing from time to time various fast moving vehicles for transportation, be it on land, water or air. In recent times the invention of fuel powered aircraft has taken the lead in the race. All types of vehicles that are used on land, sea or air are subjected to accidents, either by natural events, machine faults or huamn error man made. Hazard reduction or safety of transportation from natural hazard events is one of the key topics in disaster management. It is beyond the scope here to discuss the safety of vehicle transportation in all the three fields, namely on land (buses, cars, carts, trains etc), on sea (country boats, mechanical boats, travellers, ships etc.,) and in air (gliders, balloon flights, aeroplanes, jet aircrafts, helicapters etc). However in general, the safety elements of transportation from natural hazard events are discussed briefly. In all the three cases the natural hazard events play an important role either directly or indirectly.

The tragedies and losses that are associated in transportation can be greatly reduced by using the modern technology of communication, computers, radio and satellites. It is interesting to note that in the World Wars (I and II) this type of transporation safety began by the use of radio and radars. Here we shall discuss briefly aviation safety methods and most of these methods can be applied conveniently in case of safety of land and sea transportation.

Aviation accidents/crashes generally occur during take-off (about 15%) or landing (about 45%) phases, while a few may occur during cruising phase.

Aviation hazards associated with natural phenomenon are : Thunderstorms, squalls, gusty winds, poor visibility, low level windshear, microburst, Jetstreams, clear air tubulence, mountain waves, hail and icing. In short convective weather phenomena is hazarders to aviation.

For the safety of aircraft and passengers ICAO (International Civil Aviation Organisation) has laid down compulsory rigorous training to Pilots and Aircraft Control Officers (ATCOs). To increase the safety from human errors, recently automation and integration has been introduced. The GPS (Global Positioning System) Aided Geo Augumented Navigation (GAGAN) project was introduced to our satellite navigation system. GAGAN will help ATCOs to handle heavy air traffic with ease and enable us to handle more traffic.

In India, the Civil Aviation Training College at Allahabad provides a world class training to ATCOs. Airport Authority of India (AAI) sought the latest techniques for airspace management and safe traffic flow from US MITRE Corporation, which helps Federal Aviation Administration.

The existing routine flight safety measures in India are :

(a) 12 - Monopulse Secondary Surveillance Radars (MSSRs), installed at key locations.

(b) Automated Dependence Surveillance (ADS), which provides both pilots and the ATCOs with highly accurate air traffic data from satellites on real time basis.

(c) Instrument Landing System (ILS) at category II and category III Airports.

(d) Flight Operations Quality Assurence (FOQA) including decoding of Black Boxes to reduce human errors in flight operations.

According to ICAO's Universal Safety Oversight Audit, Indian skies (98%) are the safest in the world. In India Air Traffic is growing at the rate of 40% and Delhi, Mumbai Airports are handling traffic as some of the busiest airports of the world.

Director General of Civil Aviation (DGCA) India laid down rigorous and mandatory checks in every aircraft, which are required as for manufacturer of aircraft company. These checks are independent of the age of aircraft for its airworthiness. In order to be airworthiness, an aircraft must undergo Periodic and Preventive Maintenance. An aircraft which is 15 years or more old, it is subjected to special inspection and is kept under constant serveillance by DGCA.

Aircraft maintenance has to be carried out by DGCA approved organisation with qualified engineers, equipment and tools. The organisations should procure techinical literature and maintenance schedule of the aircraft. DGCA approved qualified engineers only can issue maintenance certificate. International guidelines are laid down by ICAO for such maintenance and certification. The maintenance organisation should be well equipped for maintenance like those European Aviation Safety Agency (EASA) of Europe and the Federal Aviation Administration (FAA) of America (USA).

The series of books, "Ground Studies for Pilots" include, Radio aids, Navigation, Flight Planning, Meteorology, Aviation law for pilots, Aircraft performance theory for pilots, Flight instruments and automatic flight control systems and Human performance and flight limitations in Aviation. These books cover virtually all topics related to Aviation syllabuses for European Joint Aviation Authorities commercial and Airline Transport Pilots licences and also all types of Aviation hazards. Keeping in view of the general awakening, inquisitiveness among general public and ever increasing, growth of Civil Aviation and recent use of aircrafts by terrorists in 9/11 World Trade Centre and White House sucide bombing, the most common hazards in aviation have been dealt here. DGCA also highlights these aviation hazard safety rules.

13.1 Air Safety – General

Air Safety is primarily putting in best use of all knowledge on aviation by pilot that he has acquired during aeronautical training and flying career. it simply means a continued concern for well being of fellow men and self and the property. The ultimate flight safety lies in knowledge, common sense, self discipline. The safety conscious of pilot should be based on good judgement of the situation rather than emotional or impulsive whims. The rules of flight are built up on the most experienced pilots and their wisdom and experts in aviation safety. Consequently pilots should practise these rules of safety at all times. The conclusions that arrived by accident investigations support these rules. It must be remembered that no one really ever graduates from a course in flying. The knowledge acquisition continues by experience and it goes on for ever. Based on new experience and accidents amendments to the rules of flight are made from time to time. Every pilot should feel the sense of responsibility to self and the fellow pilots. All Pilots have to share the same airspace and an error by one may have serious consequences and detrimental effects on others.

The flight safety rules include : Check out, Preflight, Vigilence, Control Systems, Weather, Speed / stall control, Navigation, Take-off or Landline area, Take-off or Landing limits, Wind limits, Physical condition, Starting engine.

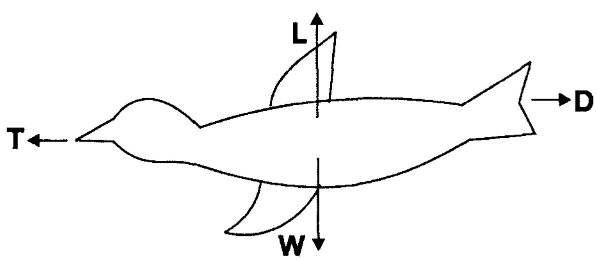
In India, Director General of Civil Aviation (DGCA) is the designated authority to look into the matters of Civil Aviation Requirements, and issue rules, circulars. These include Air worthiness, Aircraft maintanance, Certification of Aircraft, Aircraft release to service, Inspection control system, Approval of Flight and their Amendments, Aircraft equipment and Instruments, Flying training and Private work, Flight testing of aircraft, Documentation to be carried on board by Indian registered aircraft, Maintenance of Airborne Communication, Navigation and Radar equipment, Precautions during Refueling, Safety in Helicopter/Propeller driven aircraft operations. Importance of wearing seat belts/shoulder Harness, De-activation of dual controls in aircraft, Operation of under carriage system, Over loading of an aircraft, Hazards of low flying, Determination of correct maximum permisible take-off and landing, weights of the aircraft, use of Standard weights of crew and passengers for operation etc.

Definition : An aeroplane is a power-driven aircraft which is heavier than air, derives its lift in flight from aerodynamic reactions on its surfaces which are fixed (under given conditions of flight).

The flight of an aircraft mainly depends on four factors : (i) Total weight (W) of the aircraft (effect of gravity), (ii) Lift (L) (or buoyancy) of the aircraft developed by the air flow over the wings. (iii) Drag (D), which is the resistance or opposition to the forward motion caused by air. (iv) Thurst (T), which is supplied by the engines of the aircraft.

The performance characteristics of an aircraft depends on the three phases of the flight, namely

(i) Take-off, (ii) Cruise and (iii) Landing.



The importance of meteorology in civil aviation is enormous in terms of money but it is much more reflected in the air-safety records. Thanks to the excellent weather forecast that at present a very few accidents are attributed to weather. Further the efficiency of flying control decreased the danger of weather hazards, however the increase of flying speeds, size of aircraft, operating heights require meteorological inputs in planning and operation stages.

Aircraft inflight requires – safety ground operations like refuelling, passenger and luggage / freight, exposure to thunderstorm activity. Precise and timely warnings contribute to avoidance of damage, safety of passengers and comfort. An airline's major profit lies in passenger safety.

Inspite of technical advances / developments most of the aircraft severe accidents are confined to the take-off and landing phases. These accidents are caused due to windshear, severe convection, microburst, squalls, gusts, lightining strike, runway flooding and poor visibility. A lot has been done to improve sasfety by way of improving infrastructure, development work and critical training.

Piston engined aircraft (small aircraft) fly below an altitude of 3 km at speeds about 200 knots (nautical miles per hour). These flights encounter all weather conditions and terrain obstruction. These aircrafts are generally operated or short distance flights. Turbo-propeller aircraft fly between 4 to 8 km altitude at moderate speed of about 300 knots. Jet engine aircraft fly above 10 km altitude at cruise speed of 500 knots for long distance routes.

Surface wind variations considered significant in take-off, landing if it has head wind of 10 knots, tailwind of 2 knots and cross wind of 5 knots.

Vertical windshear within the final approach, take-off and initial climb out areas, particularly in the lowest 600 ft is critical or hazardous. In en-route of flight Jetstream, CAT, cumulonimbus cloud are significant hazard.

Effects of low level wind shear

Descending on an airfield where wind speeds are decreasing downwards, aircraft may undershoot. Descending on an airfield where wind speeds are increasing downwards, aircraft may overshoot. Take-off (or climb) of an aircraft into decreasing wind speed with height, the angle of climb decreases with height.

Take-off (or climb) of an aircraft into increasing wind speed with height, the angle of climb increases with height.

13.2 Clear Air Turbulance (CAT)

Clear Air Turbulance is a patchy phenomena with intensity less than the turbulence encountered in thunderstorm. The typical dimensions of CAT are : 30 km by 5-15 km across, thickness 300 to 500 m, life period 30 minutes to 3 hours. High level turbulance is associated with Kelvin Helmholtz waves. The waves are caused by vertical windshear in a statically stable layer ; which amplify, break and tumble over into chaotic motion like that of breaking ocean waves. The value of Ri (Richardson number) is less than 1 (about 0.6). There is strong association between jetstreams and CAT. CAT is frequent in the vicinity of tropopause.

CAT may cause temporarily aircraft stalling, loss of control and in severe cases may cause damage to airframe. Depending on the changes in altitude and/or attitude of aircraft CAT is defined as follows.

Light turbulence : Instant turbulence that cause changes in aircraft altitude and / or attitude without fluctuation in Indicator of Air Speed (IAS). IAS may fluctuate 5-15 kt changes in accelerometer readings less than 0.5 g at the aircrafts centre of gravity. Passengers (or occupants) may feel slight strain against seat-belts but no difficulty in walking. Losse objects may be slightly displaced.

Moderate turbulence : Instant turbulence that cause moderate changes in aircraft altitude and/or attitude but the aircraft remains in positive control at all times. IAS may fluctuate slightly 15-25 kt, changes in accelerometer readings 0.5 g to 1.0 g at the aircrafts centre of gravity. It may cause jolts and rapid bumps in aircraft. Passengers experience strain against seat belts, difficulty in walking, loose objects will move about or displaced considerably.

Severe turbulence : Large and sudden changes in aircraft altitude and/or attitude and momentarily aircraft may be out of control. IAS may fluctuate in excess of 25 kt. Changes in accelerometer readings more than 1.0 g at the aircrafts centre of gravity. Passengers are violently forced against seat belts, great strain in walking. Loose objects are tossed about.

Detection and Avoidance : Airborne weather radar (AWR) can detect CAT by locating vertical windshear at a distance of 30 km with a 20 dB improvement in sensitivity. Temperature fultuations and anomalies associated with CAT along the flight path can be measured with infrared and microwave radiometers.

To get out of CAT turn towards north or south. Climb or descend to a level where temperature lapse rate and/or vertical wind shear is less. A layer next above cirrus, cirrostratus would be free from CAT.

13.3 Airborne Weather Radar (AWR), its capabilities in detection of thunderstorm cells and avoidance

All modern aircrafts have weather radars. AWR is essentially used for navigation safety from hazardous weather. A sector scanning antenna is fitted in the nose of an aircraft behind a rodome (cover). The scan is horizontal around the aircrafts nose which gives information relative to the aircraft heading. AWR introduced to warn/ward off the dangers to the aircraft flying from cumulonimbus clouds. The radar frequency is about 10 GHz, wavelength 3 cm, conical beam width 3 - 5^{o}, tilt of the beam is about 15^{o} up or down. It can detect sufficiently large rain drops, hailstones. The intensity of the reflected (or return) signal displayed on the PPI (Plan Position Indicator) Scope (C R tube). By the shape and intensity of the return signal pilot can judge the likely severity of the weather ahead. The normal cathode Ray (CR) tube show single colour (black and white) return beam echoes. Airborne radar screen covers an angle of about 75^{o} either side of the aircraft heading, while returns indicate the reflecting of rain drops or hailstones. Strong returns indicate the presence of cummulonimbus cloud, while moderate intensity returns show non-hazardous rain-bearing clouds. Iso-echo or contour display is a devise to show levels of intensity by processing the returns above a certain strength level (datum level) which is phase changed. Intense signal returns appear as a black centre with a white surrounding. This display is called iso-echo or contour display.

Modern scope displays use different colours for different return intensities. Relative return strengths are displayed on electronic flight instrument system (EFIS) screen, Green display indicate low intensity return (non - hazardous). Yellow colours display indicate moderate intensity return (a warning signal) and Red/Megenta for very strong return (a danger signal). The range of return is measured against range rings on the C.R. display.

Turbulence Avoidance : The most severe turbulence is found in the area where the return intensity changes more rapidly. The tornado / supercell echoes often show "hooking" shape on a screen.

Below FL 200, the echoes have sharp edges, strong intensities and steep gradient, change on iso-echo contour display, avoid the area (zone) by 5 nm (nautical miles) minimum distance. If the echoes show protrusion, hooks, rapidly changing height, shape and intensity, avoid the zone by 10 nm minimum distance.

FL 200 (Flight levl 200) to FL 250, if the echoes are observed, avoid the zone by 10 nm minimum distance. Between FL250-FL 300, if the echoes are observed, avoid zone by 15 nm and for echoes observed above FL 300, avoid the zone by 25 nm.

Avoidance and Flying Techniques in Thunderstorms

(i) Take-off of an aircraft should be postponed.

(ii) Landing or approach phase be delayed or diversion be carried out on advice of Air Traffic Control (ATC).

(iii) In case of cross-country flight, ascertain possible thunderstorm areas in pre flight meteorological briefing. Avoid thunderstorm route and flight level.

(iv) Flying through thunderstorm should be avoided. If there is sufficient terrain clearance, fly around the storm keeping thunderstorm cell to your left.

In unavoidable circumstances of penetration of thunderstorm observe the following.

(i) Select a level below freezing level (FL - 100) or above FL-250. This height zone is worst for bumpiness, hail formation.

(ii) Securely fasten safety belts and loose articles lest they will be tossed about.

(iii) Most aircrafts have specified speeds of penetration. In case of the absence, select safest speed of 1.6 times the stalling speed with flaps and under carriage retracted.

(iv) Earth a trailing aerial and reel it in, otherwise there is chance of lightning strike.

(v) St Elmos Fire may be observed along the wing tips and propeller tip. This fire is awesome but generally harmless.

(vi) Inside thunderstorm cell the aircraft instruments (like Altimeter, Airspeed indicator) may not function accurately and may show eroneous readings. Hence do not depend fully on aircraft instrumental readings.

(vii) While within the storm area, maintain constant heading and avoid coarse movement of controls. It is safer to let the aircraft "ride the storm". If control is lost even temporarily, the subsequent recovery action may lead to structural failure due to combined loads of gusts and recovery action.

(viii) Do not try to control altitude or execute turns, which may increase strain on control surfaces and may lead to dangerous attitude of the aircraft.

13.4 SIGMET

SIGMET means Significant Meteorological information issued by Meteorological Watch Offices (MWOs) for their respective FIRs. In India MWOs are located in Mumbai, Kolkata, New Delhi and Chennai. SIGMET is the occurrence or expected occurrence of weather phenomena which is hazardous to the safety of aircraft operation en-route, described briefly in plain language indicating time and space. SIGMET messages are sent to Flight Information Centres/Area Control Centres, who are responsible to communicate the information to the aircraft inflight. SIGMET is valid for 4 (to 6) hours, issued every three hours or more frequently. It may be cancelled when adverse weather phenomena no longer likely. In case of Tropical Cyclones, Volcanic Ash, an outlook is included.

SIGMET is issued for one or more of the following weather phenomena. Aircraft inflight are warned when these phenomena are occurring or expected to occur on the routes ahead upto 500 nm or two hours flying time.

Table 13.1 Weather phenomena.

At subsonic cruising levels	At Tronsonic and Supersonic cruising levels This is identified by SIGMET SST
Active thunderstorm area Tropical storms Heavy hail Severe turbulence Widespread sand/dust storm	Moderate or severe turbulence cumulonimbus cloud Hail

13.5 Windshear Detection from Airborne Weather Radar

Turbulence associated with wind-shear is a major safety problem during take-off or landing / approach phase of aircraft flight. High altitude wind shear in frontal zone, mountain induced waves, CAT have considerable effect on passenger safety.

Descending of an airfield where wind speeds are decreasing downwards an aircraft may undershoot. Descending on an airfield where wind speeds are increasing downwards, an aircraft may overshoot. Take-off (or climb) of an aircraft over an airfield where wind speeds are decreasing with increasing height the angle of climb decreases with height. Take-off (or climb) of an aircraft over an airfield where wind speeds are increasing with increasing height, the angle of climb increases with height. Airspeed information can be had from ADC (air data computer), while ground speed information can be had from Navigation computer. Comparing these two we can detect the airspeed changes affecting the aircraft. Pressure altitude information from ADC, we can find the rate of ascent or rate of descent of aircraft. Coupling this with airspeed changes would indicate the effect of gust on aircraft.

Microburst detection and warning : The severe downward rush of air and its outburst near ground is called downburst, which has damaging winds. Downburst may be confined to a small area diameter 1-4 km, period 1 to 4 minutes which is called microburst or spread over large area, diameter 5 to 20 km or more, period 5 to 20 minutes.

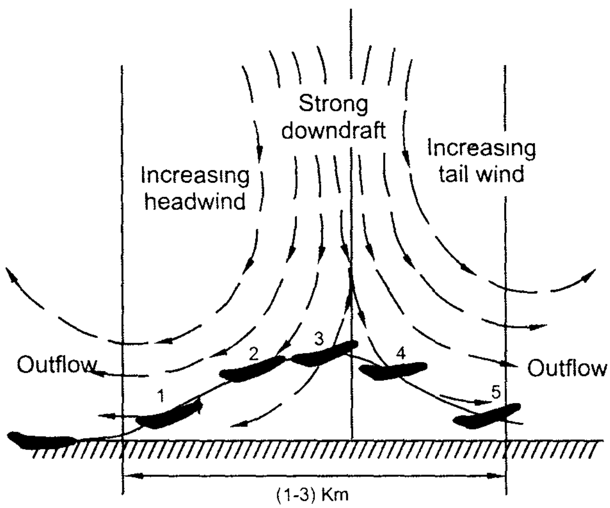


Fig.13.1

Dry microburst originate in moisture laden towering cummulus. During downdraught precipitation evaporates in air itself before reaching ground. This leads to Andhi/duststorm. In microburst, vertical downward wind speed may exceed 30 kt (6000 ft/min).

Increasing headwind (or decreasing tailwind) and/or a severe updraught exceeded a defined threshold if observed, Terrain Awareness and Warning System, (TAWS) computer on board aircraft will **alert** the crew displayed by amber light. These conditions indicate before an encounter with a microburst.

Decreasing headwind (or increasing tailwind) and/or severe downdrought conditions indicate within microburst or just afterwards and TAWS computer indicate more urgent **warning** to the crew, display red light.

'Alert' tells the pilot that he is approaching a dangerous situation, while 'Warning' tells the pilot that he is already in a dangerous situation and must take immediate action.

According to Woodfield (1990) wind changes experienced by aircraft classified into three categories (a) Turbulence (b) Windshear (c) Weather.

Turbulence are disturbances which require little or no pilot action to maintain the desired flight path within acceptable limits. Generally short duration events period less than 3 seconds.

Windshear are disturbances requiring significant pilot action to maintain flight path within acceptable limits. Generally events period 3 seconds to 40 seconds.

Weather long term and large scale events with little effect on flight path.

Stall Warning Devices : A stall occurs when the wing does not produce sufficient lift to counteract the weight of the plane, the plane ceases to fly. The stalling speed increases with the increase in weight.

Stall angle : The angle of attack beyond which the value of lift falls rapidly is called stalling angle. A stalled plane starts to loose altitude. Generally light aircrafts are fitted with stall warning device, which measures the angle of attack. When the critical angle of attack is reached, it activates the warning device in the cockpit which warns the crew with a red light, a bell or a buzzer.

The stall warning device is caliberated to perform under clean wing conditions. In case the wings are contaminated or degraded (with icing), the warning device does not activate hence it cannot be relied upon to give warning of an impending stall in icing conditions. The best stall warning device is the pilots training and experience in reaction to stalls.

Stall recovery : In order to recover from a stall, the pilot can lower the nose to decrease the angle of attack or apply more power to accelerate the plane. In case the plane is already under full power when the stall occurs, the only option left to the pilot is to lower the nose of the plane.

13.6 Fog and its Detection

In aviation Fog is one of the major hazards over an airfield. In (north and east) India severe fog conditions are mostly associated with the passing of Western Disturbances in winter months.

Fog is defind as a suspension of very small water droplets (radius 1 to 70 μm or more) that remain suspended in the air in such concentration that it reduces the horizontal visibility near the earth's surface to less than 1000 m. Fog presents impediments to pilots during take off and landing phases of an aircraft flight. Flight visibility is defined as visibility forward from the flight deck of an aircraft in flight. Pilot is interested in the visibility prevailing along the runway in use in the take-off and landing directions. When meteorological visibility is less than 1500 m, RVR (Runway Visual Range) is reported. If RVR is measured by instruments (Visibility meters, transmissometers) then it is called Instrumented Runway Visual Range (IRVR).

Fog may occur in patches or as a continuous thick or shallow layer over an extended area. Studies have been made to warn poor visibility by automation. However as yet there is no airborne instrumental warning system. Real time online RVR is achieved by IMD using the three state-of-art. Dual Base line Transmissometers installed at touch down zone, mid-point and far end of a runway. This gives short term visibility of runway with the help of the data obtained from Dual Base line Transmissometer successfully.

13.7 Impacts of Tropical Cyclones on Aviation Safety Operations

We have already studied about Tropical cyclones and associated hazards. Here we shall briefly discuss only about aviation hazards.

Aircraft operations are always affected by Tropical Cyclones mostly with associated winds, heavy rains and storm surges on coastal aerodromes. Airports can be closed for strong winds and heavy rains caused by tropical cyclones. It is interesting to note that all vehicular traffic on road and sea would be paralysed for days, even weeks due to the affect of tropical cyclone, however air transport activity can continue until the last moment before arrival of cyclone and immediately after passing over it. Thus helicopter services help in cyclone mitigation of air dropping and rescue operations.

Considering day to day meteorological conditions, planning of long haul flights made by selecting flight paths to minimise the fuel consumption by avoiding strong headwinds enroute or selecting tailwinds. In case of the presence of tropical cyclone avoid areas of wall-cloud region (convective core) and belt of strong winds and spiral bands. The impacts of tropical cyclone on enroute aircraft operations are much smaller as compared to those on operations at aerodromes. In tropical cyclones strong winds have significant impact on aeronautical operations as compared to any other severe elements associated with it. Winds parallel to the runway do not affect aircraft landing or take off, but strong cross winds will have difficulty in flight operations of take-off and landing.

The other hazards associated with tropical cyclones on aviation operations include, poor visibility in heavy showers and hydroplaning on runway and storm surges in case of coastal low level aerodrome.

Explanation of some Aviation terms

1. ***Visual Flight Rules (VFR) :*** The rules which apply when flying by means of visual reference to the ground.
2. ***Instrument Flight Rules (IFR) :*** The rules which apply when flying by means of reference to the instruments in the cockpit. Within control zones and Aerodrome Traffic Zones, under VFR flights there is weather mir ma (which is lower limit of flying over that aerodrome). Visibility not less than 3 miles (or 5 km). No cloud below 500 ft (vertically) and upto a distance of 1 mile (1.8 km) horizontally.
3. ***Survival Equipment :*** Certain surviva. equipment to be carried on board any aircraft operated over land. This is for use of rescue operations, detection by SARSAT/COSPAS system.
4. ***Transponder :*** An airborne electronic device, designed to send signal to the ground based on radar receiver to provide/confirm a positive signal of a friend (IFF) or strengthen the surveillance signal. A transponder allows positive identification of an aircraft by the ground facilities of Air Traffic Control (ATC).

   An airborne transponder will have a control, a receiver / transmitter (frequency 1090 MHz) and a small L-bank antenna fitted under side the aircraft. Ground equipment consists of transmitter (frequency 1030 MHz)/ receiver and a rotating directional antenna fixed on top of the surveillance radar antenna.

   Working of a Transponder : Ground based radar sends questioning signal to all aircraft to Identify Friend or a Foe (IFF). Only aircraft which has transponder picks up signal and automatically sends strong pulsed signal of a friend in reply. The reply signal computes distance and direction by the ground radar station and displays with the aircrafts target on the scope of Traffic Controller as one or two slashes.
5. ***Near misses :*** It indicates air proximity between two aircrafts with respect to their relative three dimensional positions and speeds. However it does not mean the aircrafts are uncomfortably/hazardously close to one another.

   Near misses may be prevented by following safety rules and concerns like the mandatory fitment of Airborne Collision Avoidance System (ACAS). ACAS provides the pilot to see all aircraft flying in his area with their relative altitude and direction.
6. ***Aborted landing :*** When a preceding aircraft is still on the runway, the oncoming aircraft is asked to go round by ATC. This is commonly called aborted landing.
7. ***Aborted take-off :*** When an aircraft is cleared to take-off and another aircraft is still on the runway or there is some obstacle on the runway then the

aircraft which was cleared to take-off is asked to not to take-off till the runway is cleared. This is called 'Aborted take off'.

The aborted landing and aborted take-off are safety procedures required to be observed universally.

8. **Surveillance Radars :** The ATC (Air Traffic Control) makes use of Surveillance Radars for continuous monitoring the aircraft flight movements and keeps the track of succession of planes landing and take-off at aerodrome.

   There are two types of surveillance radars called Primary Serveillance Radar (PSR) and Secondary Serveillance Radar (SSR).

   (i) ***Primary Serveillance Radar :*** It is based on the echo (return) principle.It does not require any equipment in the plane. Four types of PSR are in use in ATC units.

   (a) ***Airport and Airways surveillance Radar*** (AASR): It is medium range radar (150 to 200 nm), designated for Airway and Airport Surveillance applications.

   (b) ***Airport Surveillance Radar (ASR) :*** It is a short range radar used for surveillance of airport and terminal areas. It provides Range, Azimuth, if aircraft equipped with transponder it will provide altitude. ASR Controller direct the aircraft to a selected runway, if controller receives altitude information, glide path assistance can be given, otherwise pilot must judge his own descent based on distance information given by the controller.

   (c) ***Precision Approach Radar (PAR) :*** It is a short range radar used as an approach aid, it guides the aeroplane to final approach on the designated instrument runway. In addition to Azimuth, Range information glide path assistance will be provided upto the point of touch down on the runway.

   (d) ***Airport surface Detection Equipment (ASDE).*** This radar is used for surveillance of surface traffic particularly during poor visibility conditions over airfield.

   (e) ***RAMP***-Radar Modernization Project aimed at replacing existing ATC radar network by Advanced computer Technology.

   (ii) ***Secondary Surveillance Radar (SSR) :*** It requires complimentary aircraft equipment, namely transponder (an airborne system designed to send a signal to the ground based radar receiver to reinforce the surveillance singnal).

   (iii) ***Radar Digitised Display (RDD - 1) :*** A radar system that uses only transponder generated data on the ground radar display. Navigation is available only to aircraft with a functioning transponder.

9. ***Flight Information Service :*** The help assistance provided by ATC units to the pilots by supplying SIGMET and other information about known hazardous flight conditions.

10. ***Clearances and Instructions from ATC :*** An ATC clearance is an authorisation from an ATC unit for an aircraft to proceed within controlled airspace under specific conditions.

    Enroute Serveillance Radars have range 200 miles (320 km) or more. Range, Azimuth resolutions are good, pulse width short, beam width narrow, high transmitter power, frequency about 400 MHz, PPI display. Long range search radars sweep rate 12 seconds (once in 12 seconds).

    Terminal Area Serveillance Radars (TARs) used for guidance close to the aerodrome, have range 25 nm, scan 3 seconds. Controllers use search radars to guide pilots to aerodrome for smooth flow of air traffic, to avoid collisions and bad weather.

13.8 Instrument Landing System (ILS)

It was developed at the end of second world war. It allows pilots to position their aircraft in air (three dimensions) during their approach to land. If the aircraft contains airborne equipment, ATC can guide the aircraft to the runway surface.

The airborne equipment system consists of three components : (i) Localiser equipment (ii) glide path equipment and (iii) The marker beacons. Each of these have monitor systems, remote control and indicator equipment.

In this method a pilot is guided through the overcast sky to land with visual reference to instruments in the cockpit.

Emergency Locator Transmitter (ELT) : ELT is a battery operated radio transmitter that sends out distinctive distress signal on the international emergency frequency 121.5 MHz and/or 243.0 MHz. A new generation of ELTs transmit a signal on 406 MHz . A 406 MHz beacon is uniquely coded and clearly identifiable to the aircraft in which it is mounted. A 406 MHz beacon transmits about half a second for every 55 seconds, while a 121.5 MHz beacon transmits continuously.

INMARSAT (International Maritime Organisation Constellation) satellites are used for research and rescue purposes. All the INMARSAT satellites monitor signals on the international emergency frequencies 121.5 MHz and/or 243.0 MHz and alert SAR centres to emergency beacons carried by the survivors. International COSPAS - SARSAT system is dedicated for search and rescue facilities. This system uses four polar orbitting satellites to cover the whole globe. COSPAS is the Russian name while SARSAT is th US name for this joint venture.

One of these satellites can receive signals transmitted at 121.5 MHz frequency, for example from a survivors Personal Locator Beacon. The satellite re-transmits the signal to the ground station or Local User Terminal, where the exact frequency received is measured and compared with the datum 121.5 MHz. The difference is the Doppler shift. The Variation of Doppler shift gives the indication of lateral distance from the satellite path, from which the search area may be calculated.

SARSAT (Search and Rescue Satellite)

A Constellation of satellites (SARSAT) is used to detect and locate ELT signals. The SARSAT is a very efficient system. ELT signals will be detected normally within 90 minutes. In most cases a downed aircraft is located before it was reported missing. The SARSAT satellite can pickup the signal any time and relay the information to the search and rescue (SAR) aircraft. The SAR aircraft home on the signal to find you. ELT signals are affective only in line-of-sight. ELTs require an annual rectification to assure that in crash situation they will transmit a signal which will be picked up by COSPAS or SARSAT satellite. The satellite requires a coherent signal to develop the position of a crashed aircraft.

Airborne Collision Avoidance System (ACAS)

ACAS systems are an extension of the Secondary Serveillance Radar (SSR) transponder. They have sophisticated computer processor which tracks the relative position of the transponding aircraft in air (range, relative altitude and rate of change of both). If the aircrafts are within certain distance, it generates a traffic advisory (TA) to alert the crew of an aircraft about its nearness or proximity. It will ignore the signals from an aircraft which is away by 10000 ft or more of its own altitude. If the other aircraft (or intruder) comes closure within 6 nm (nautical miles) in horizontal and 1200 feet vertical, the TA symbol changes to threat (warning), and required action.

Radar Computer Display : Horizontal situation indicator (HSI) displays of all transponding traffic.

TA = Traffic Advisory, which means there is no assessed threat. It is indicated by yellow circle.

RA = Resolution Advisory, indicates threat and requires action. It is indicated by Red Square.

No threat = indicated by hollow white or blue diamond.

Proximity (means within 6 nm horizontally and/or 1200 feet vertically) = Indicated by solid white or blue diamond.

ACAS General Principle : Airborne/aircraft carries a transponder-interrogator transmitter frequency 1030 MHz and receiver on SSR frequency 1090 MHz. It gives/receives position and flight level if available. Computer assesses position, threat and necessary action-display. ACAS is ICAO requirement while TCAS (Traffic alert and Collision Avoidance System) is US commercial name. The range of replies from aircraft upto 30 nm away.

Warnings are indicated by TA (yellow circle) or RA (Red square).

Action : Pilot should take evasive action within 5 seconds of initial command and 2-3 seconds for subsequent commands. TSAS generates audio alerts to the pilots to take evasive action in the event of both aircrafts coming close to one another hazardously. Repeated voices alerts and suggests corrective actions like climb, Descend or Reduce speed to the pilot to act.

TCAS Messages

Voice Command	Action Required
(i) Traffic Traffic	(i) Identify traffic and prepare for possible Resolution Advisory.
(ii) Maintain Vertical Speed, Maintain	(ii) Maintain existing rate of climb or descent.
(iii) Climb Climb	(iii) Climb at 1500 ft/ minute
(iv) Descend Descend	(iv) Descend at 1500 ft/min
(v) Increase Climb	(v) Climb at 2500 ft/min
(vi) Increase Descend	(vi) Descend at 2500 ft /min
(vii) Climb Climb Now	(vii) Initiate change from descent into climb
(viii) Descend Descend Now	(viii) Initiate change from climb to descend
(ix) Climb Crossing Climb	(ix) Climb at 1500 ft/min through the intruder's altitude
(x) Descend Crossing Descend	(x) Descend at 1500 ft/min through the intruder's altitude
(xi) Adjust Vertical Speed, Adjust	(xi) Reduce climb or descent to the rate indicated.
(xii) Monitor Vertical Speed	(xii) No manoeuvre required, keep out of the red area
(xiii) Maintain Vertical Speed, Crossing Maintain	(xiii) Maintain rate of climb or descent while passing through the intruder's altitude.
(xiv) Clear of Conflict	(xiv) Resume normal flight, return to cleared altitude if under ATC control.

Example 1

There was near miss on 18-06-08 between Jet Airways AW-249 aircraft and an international aircraft flight at Dhaka, Bangladesh. TCAS saved the two aircrafts. AW-249 took-off from Dhaka Airport and was climbing and it was 14000 ft at 4.15 PM, while another international flight which was 17000 ft earlier was asked to descend to 1300 ft and it was at 15600 ft at 4.15 PM. When TCAS cockpit computer given alaram to international flight "Traffic Traffic" which immediately veered and levelled instantly at 15600 ft instead of descending. Simultaneously Jet Airways AW-249 also got computer cockpit alaram, immediately swung into action and levelled at 14000 ft instead of climb. This near miss occured due to lack of radar facility at Dhaka Airport.

13.9 Ground Proximity Warning System (GPWS)

Generally fetal aircraft accidents occurred under controlled flight into terrain. A computer warning system was developed to alert the pilots for imminent collision with high ground like mountain range, tall buildings, trees etc. This airborne equipment is called Ground Promixity Warning System. The inputs into the computer considered from on board aircraft equipments like Radio altitude, vertical speed sensor, glide path deviation from ILS, position of under carriage and flaps. It is now became mandatory for all aircrafts to have radioaltimeter. Subsequently it was noticed some drawbacks, and false alarams. GPWS equipment gives clearance to obstruction below (under) the aircraft but not ahead of it. This lead to the ICAO requirement for a Terrain Awareness and Warming System (TAWS). TAWS now becoming mandatory requirement for a Terrain Awareness and Warning System (TAWS). TAWS now becoming mandatory requirement safety for medium and large civil aircrafts. GPWs became mandatory for large passenger aircraft since 1990.

The GPWS outputs are : Master Indicator, Visual and Audio Warning. The Computer Central Processing unit (CPU) decides warnings under different modes which are given below.

Mode 1 Excessive rate of descent below 2500 ft

Alert : uses the words sink rate sink rate :

Warning : uses the words Pull up Pull up with whooping sound and flasing lamp.

Mode 2A High sink rate below 1800 ft, no gear or flap

Alert : uses the words "Terrain Terrain"

Warning : Same as in Mode - I

Mode 2B High sink rate below 790 ft, with gear and flap in landing configuration.

Alert : uses words "Terrain Terrain"

Warning : Same as in Mode-1

Mode 3 Sink after take-off or go-round.

Alert : uses the words "Dont sink Dont sink" or "Terrain Terrain"

Warning : uses the words same as in Mode - I

Mode 4A Below 500 ft - gear up

Alert : uses the words "Too low - gear/flaps" (as appropriate)

Warning : Same as in Mode - I

Mode 4B Below 200 ft

Alert : uses the words "Too low - gear/ flaps" (as appropriate)

warning : uses the words "Too low - terrain".

Mode 5 $\frac{1}{2}$ fly-up indicator on ILS

Alert : uses the words "Glideslope".

Mode 6 Descent below (airport) minimums

Alert : uses the words "Minimums"

In above all modes action required by the pilots for

Alert : Warning of possible hazard. Pilot must take remedial action.

Warning : Pilot must level wings and initiate maximum gradient climb to safe to en-route minimum altitude.

TAWS (Terrian Awareness and Warning System) : This equipment is an improvement of GPWS. This taken into account of obstructions ahead of aircraft. Computer inputs same as in GPWs and in addition terrain contours ahead presented on Navigation display - Red/Yellow/Green.

The first marketed TAWS called Enhanced Ground Proximity Warning System (EGPWS).

In case of GPWS the computer alerts 10-30 seconds ahead of impact, while in case of TAWS the computer alerts one minute before impact.

13.10 Jet Blast Hazard

The area behind jet planes can be dangerous to small planes maneuvering on the ground or about to take-off or land. Pilots of these small aircrafts must be careful when operating near active runways or taxiways. In places of intersecting runways, there is every possibility of Jet blast or propeller wash affecting other aircraft.

Light aircraft with high wings and narrow track undercarriages are particularly susceptible to jet blast accidents. Such aircrafts should stay atleast 600 ft away from a jumbojet when its engines are idling and 1600 feet away from it when it is full throttle for take off. There was an incidence in Jaipur (May 2008), where a jetlite Boing 737 crossed its speed and ended up damaging a King Fisher ATR aircraft parked next to it. There was another incidence of jetblast in the vicinity of Mubai airport runway. A cargo plane was readying to take-off. The Cargo Jet hot blast destroyed the roofs of 25 houses in JariMari slums adjoining Mumbai airport runway. One old person Shiwaji Khole (66) who was sleeping on the loft lost his life due to the boundary wall that fell on him, however his wife Yamuna narrowly escaped as she stepped down a few moments earlier. A Jet aircraft like Boeing 747 can produce a draft of upto 160 kmph, upto 200 ft behind it and can blow away a car when the engine is producing 40% of its maximum thurst. However during taxiing, it is about 10 to 12%.

A jet aircraft is given minimum power (thrust) while taxiing to maintain a low ground speed, and it goes full throttle with maximum thurst when it is taking-off. Even at lower thrusts, Jet engine exhaust blasts could be dangerous.

13.11 Some Aviation Safety Measures in Indian Airports

All airports in India shall be installed with latest electronic security gadgets which will be of international standards. CISF staff strength shall be increased sufficiently in Indian Airports. It is now well known that terrorists are employing aviation infrastructure to carry out their wicked plans of hijacking or damaging aviation installations. In order to check terrorist activities effectively fool proof precautions are to be established. Airport security is a highly professional and worldwide experience also expounds shows this measure. Though CISF involved in anti-hijacking and anti-intrusion measures, yet security agencies are more involved with private and external security, such as baggage and cargo screening, aircraft guarding/petrols. Airport vital installations such as Air traffic control, runway, passenger terminal building, aerobridges etc., are to be secured. In this security, private security companies are also involved. For example Delhi Airport, Hyderabad Airport, Bangalore Airport, Kochi Airport are mainly managed by private sector. With the experience of handling of security at International Airports (Heathrow, Athens, Tokyo, Amsterdam, Johannesburg etc.,) it is clear that airport security is a major task. In order to meet such stupendous job, the following important steps are visualized.

Some of the access control systems are

Tyre killers : These can be raised or lowered in seconds to destroy the wheel rims and tyres of an offending vehicle (say which has explosives). It can be installed at considerable distance from the airport, by which the damage can be minimized. Similarly these can be used in protection of banks, military installation/bases, embassies etc.

Boom barriers : It is a pole which blocks vehicles when lowered and allows to pass through when it rises vertically. These are used at entrances, manned rail way gates, tool tax gates.

Biometric identification : The following are a few commonly used biometric identifications.

(a) *Smart cards :* To avoid cheating in photo identity cards smart cards are used, which will be swiped against wall mounting readers.

(b) *Finger-printing :* This is an age old system, modified and used to accept a person into a specific area (or restricted area). It is the fastest and cheapest.

(c) *Hand-geometry reader :* This is a modified an age old system (called palmistry). Palm placed inside the instrument can distinguish between alive hand and a dead one by heat generated.

(d) *Face geometry, Retina mapping :* This is also a modified an age old system. This system is not popular due to rays falling on them besides the system is open to the vagaries of heat, dust and humidity.

(e) *Explosive trace detector :* They are very handy and highly useful in detection of explosives and harmful chemicals. The instruments can detect minute traces of TNT, dynamite, RDX and Nitroglycerin in explosives and provide results in a matter of seconds. They allow non-invasive searches of luggage using high resolution X-ray and 3D-images. CISF has deployed (about 200) in various airports.

(f) *Alarams :* These are common in banks (Burglars alaram). Latest in the series include Fire Detection Alarams. These have ionization and optical detectors, which can pinpoint the exact area of fire. Conventional fire alarams can target zones of origin of fire only.

(g) *Perimeter security :* These are common in defence and research institutes. This would involve use of fencing, like electric wire, concertina barbed wire mesh, power fence, microphonic cable mesh, infrared devices and closed circuit TVs. When an intrusion occurs, the alaram goes off in the control room, the offender is tracked on computer screens and finally be held by the guards. In private airports this work would start only when the gates and boundaries are demarked clearly.

(h) Prefabricated Watch Towers with 360 degrees swivel with high focus lights.

(i) *GPS vehicle tracking :* This system is used to track the location and speed of vehicle and to find its safe journey in case of tours/travels. Alaram signals from the vehicle during distress/emergency situations like entrapped in flood, theft or cyclone are communicated/transmitted through (via) GPRS/Global System for Mobile Communication (GSM) to a Central Monitoring Station where the Controller initiates action for rescue/response. The vehicle can be immobilized with a fuel pump and ignition immobiliser.

Other Popular Measures : (i) Routine Dog squads to track/smell out explosives, (ii) Defence Forensik Metal Detectors (DFMD), (iii) Bomb disposal squads (iv) Body Scanners.

Definitions and meaning of some tems, given below in accordance with Civil Aviation Requirement (CAR) under rule 29C and Rule 133A of the Aircraft Rules 1937 for Search and Rescue of aircraft flying in over India or of aircraft registered in India.

Alerting post : Any facility intended to serve as an intermediary between a person reporting an emergency and a rescue coordination centre or rescue sub-centre.

Alert phase : A situation where in an apprehension exists as to the safety of an aircraft and its occupants.

Distress phase : A situation wherein there is a reasonable certainty that an aircraft and its occupants are threatened by grave and imminent danger and require immediate assistance.

Ditching : The forced landing of an aircraft on water, emergency phase. A generic term meaning (as the case may be) uncertainty phase, alter phase or distress phase.

Emergency phase : A generic term meaning (as the case may be), uncertainly phase, alert phase or distress phase.

Joint Rescue Coordination Centre (JRCC) : A rescue coordination centre responsible for both aeronautical and maritime search and rescue operation.

Operator : A person, organization or enterprise engaged in or offering to engage in an aircraft operation.

Pilot-in-Command : The pilot designated by the operator, or in case of general aviation, the owner, as being in command and charged with safe conduct of a flight.

Rescue : An operation to retrieve persons in distress, provide for their initial medical or other needs, and deliver them to place of safety.

Rescue Coordination Centre (RCC) : An unit responsible for promoting efficient organization of Search and Rescue Services and for coordinating the conduct of search and rescue operations within a search and rescue region.

Rescue Sub-Centre (RSC) : A unit subordinate to a rescue coordination centre established to compliment the RCC according to a particular provision of the responsible authorities.

Search : An operation normally coordinated by a rescue coordination centre or RSC using available personnel and facilities to locate a person in distress.

Search and Rescue Service : The performance of distress monitoring, communication, coordination and search and rescue functions, initial medical assistance or medical evacuation, through the use of public and private resources including cooperating aircraft, vessels and other crafts and installation.

Search and Rescue Unit : A mobile, resource composed of trained personnel and provided with equipments suitable for expeditious conduct of search and rescue operations.

13.12 Search and Rescue Services (SRS)

Airport Authority of India is responsible for establishment and provision of search and rescue services in coordination with other agencies to ensure that assistance is rendered to persons in distress. Such services shall be provided on a 24-hour basis.

SRS shall be provided within the entire Indian Territory including territorial waters. Such services shall also be provided over those portions of the high seas or areas of undetermined sovereignty for which responsibility of providing Air Traffic Services (ATSs) has been deligated to India.

SRS include organized available resources, communication facilities and a workforce skilled in coordinated and operational functions. SRS shall establish processes to improve service provision, including the aspects of planning, domestic and international cooperative arrangements and training.

Assistance to aircraft in distress and to survivors of aircraft accident shall be provided irrespective of the nationality or status of such persons or the circumstances in which such persons are found. SRS shall use search and rescue units and other available facilities to assist any aircraft or its occupants that are, or appear to be, in a state of emergency.

Coordination between the aeronautical and maritime rescue coordination centers shall be ensured. Maintenance of close cooperation between aeronautical and maritime search and rescue services is desirable where practical, joint rescue coordination centres be established to coordinate aeronautical and maritime search and rescue operations.

13.13 Search and Rescue Communications

Each rescue coordination centre shall have means of rapid and reliable two-way communication with:

(i) associated air traffic services unit (AATS Unit);

(ii) associated rescue subcentres, where provided;

(iii) where appropriate coastal radio stations capable of alerting and communicating with surface vessels in the region;

(iv) the head quarters (HQs) of search and rescue units in the region;

(v) all maritime rescue coordination centres in the region and aeronautical, maritime or joint rescue, coordination centres in adjacent regions;

(vi) a designated meteorological office or meteorological watch office;

(vii) search and rescue units;

(viii) alerting posts; and

(ix) the COSPAS-SARSAT Mission Control Centre serving and the search and rescue regions.

Responsible authority : The search and rescue service in India is organised by the Airport Authority of India in Collaboration with the Ministry of Defence which has the responsibility for making the necessary facilities available. The Postal and the Telegraphic address of Airports authority of India Rescue Coordination Centres are given below.

Name of Rescue Coordination centres

(i) Mumbai, (ii) Calcutta, (iii) Guwahati, (iv) Delhi and (v) Chennai .

Postal Addresses

(i) AAI (NAD), CSI Airport Mumbai - 400099

(ii) AAI (NAD), CSI Airport Calcutta – 700052

(iii) AAI (NAD), LGBI Airport Guwahati – 781015

(iv) AAI (NAD), IGI Airport Delhi – 110037

(v) AAI (NAD), Chennai Airport, Chennai – 600027

Telegraphic Addresses

(i) (AFS) : VABBYCYX
(Commercial) : Aerodrome, Mumbai

(ii) (AFS) : VECCYCYX
(Commercial) : Aerodrome, Calcutta

(iii) (AFTN) : VEGTYUYU
(Commercial) : Aerodrome Guwahati

(iv) (AFS) : VIDDYCYX
(Commercial) : Aerodrome, Delhi

(v) (AFS) : VOMMYCYX
(Commercial) : Aerodrome, Chennai.

Area of responsibility : The Search and Rescue Service is responsible for entire Indian territory, including territorial water as well as airspace over high seas encompassed by Calcutta, Mumbai and Chennai Flight Information Regions (FIRs).

Type of service : The details of the Rescue Coordination Centres are given above. The related search and rescue units are given below.

In addition to the above, other departments of the Central and State Governments viz. Railways, P and T, All India Radio, Police and District Collector/Magistrates etc., Municipal and Local Bodies, Airline Operators, Flying Clubs, Professional Pilots, Mercantile Marine, Port Trust and Armed Forces are available for Search and Rescue Missions when required.

The Search and Rescue Units

Sl. No	Name and search area	Location/ Responsible	Facilities	Remarks
1.	Mumbai, Mumbai FIR	Flight Information Centre (FIC), CSI Airport Mumbai - 400099	Aircraft, Rescue Vessels, Rescue boats, Land Rescue Units	ELR (Extra Long Range) Aircraft available for air-sea search only. Radius of operation 1500 NM from the coast. MRG (Medium Range) Aircraft, Radius of operation 400 NM. Deployment from various Military bases.
2.	Calcutta, Calcutta FIR	FIC CSI Airport Calcutta –700052	Aircraft, Rescue Vessel, Rescue Boats, Land Rescue Units	MRG aircraft, radius of operation 400 NM. Deployment from various Military bases.
3.	Guhawathi, Guhawathi FIR	FIC, LGBI Airport Guhawathi – 781015	Aircraft, Land Rescue Units.	MRG Aircraft, radius of operation 400 NM. Deployment from any Military bases Sunrise to Sunset.
4.	Delhi, Delhi FIR	FIC, Indiara Gandhi International Airport New Delhi – 1100037	Aircraft, Rescue Airport Vessels, Land Rescue Units	MRG Aircraft, radius of operation 400 NM. Deployment from various Military bases.
5.	Chennai Chennai FIR	FIC, Chennai Airport Chennai – 600027	Aircraft, Rescue vessels, Rescue boats, Land Rescue Units	ELR aircraft available for air-sea search only. Radius of operations 1500 NM from the coast. MG aircraft, radius of operations of 400 NM. Deployment from various military bases.

Satellite Aided Search and Rescue

India has evolved a Satellite Aided Search and Rescue Programme participation in COSPAS/SARSAT system (discussed separately). It operates on 121.5 MHz, 243.0 MHz, and 406 MHz. The location accuracy on the first two frequencies (viz 121.5 MHz, 243.0 MHz). is within 20 km and 5 km on the last frequency (406 MHz). The system will detect transmission on these three frequencies throughout the Indian Search and Rescue Region (SRR) and also Bangladesh, Myanmar, Bhutan, Indonesia, Kenya, Malaysia, Maldives, Mauritius, Nepal, Seychelles, Singapore, Somalia, Srilanka and Thailand.

Under this programme two Local User Terminals (LUT) have been established, one at Bangalore and the other at Lucknow, with the India Mission Control Centre (MCC) at Bangalore. The MCC would be responsible for coordination with Rescue Coordination Centres and other International Mission Control Centres.

The Mission Control Centre at Bangalore is connected/linked with the Rescue Coordination Centres at Mumbai, Delhi, Calcutta and Chennai through Aeronautical Fixed Service (AFS) network and any distress alert received from the areas covered is automatically transmitted to the Rescue Coordination Centre.

Search and Rescue Agreements

At present India has no SAR agreement with other countries.

Requests for the entry of aircraft, equipment and personnel from other states (countries) to engage in search for aircraft in Disasters and Rescue Survivors of crashed aircraft should be transmitted to the Director General of Civil Aviation New Delhi. Instructions as to the Control which will be exercised on entry of such aircraft and/or personnel will be given by the Rescue Coordination Centre of the relevant FIR (Flight Information Region).

The postal address of Director General of Civil aviation is given below.

Director General of Civil Aviation

Sri Aurbindo Marg, opposite Safdarjang Airport, New Delhi – 110003

The search and rescue areas are :

(i) Mumbai FIR

(ii) Calcutta FIR

(iii) Guwahati FIR

(iv) Delhi FIR

(v) Chennai FIR

The responsible Air Traffic Service Units are :

(i) Flight Information Centre (FIC), Mumbai

(ii) FIC Calcutta

(iii) FIC Guwahati

(iv) FIC Delhi

(v) FIC Chennai

Modern Security System for Crowded Places

With the aid of some rogue states, terrorists are freely using modern methods and technology in their attacks on crowded places. It would be practically impossible to enforce individual access control at crowded places like railway stations, religious/festival gatherings, Bus stations, Airports etc. Government of India planned to acquire ultra modern security system to protect the masses from the terrorist nefarious activities of mass attacks. This system consists of a computerized Central Command that could control sub-systems that would be assigned to a particular security parameter (like cable network cameras, biometric, narcotic detection, explosive detection etc., or any weapons of destruction). The system is non-intrusive and would not require frisking. Any security violation by an individual would immediately be spotted by the system and communicated to the Central Command, after which action can be taken. The system aim to ensure fool proof monitoring of individual baggage whether carried or booked in some transport service.

CHAPTER - 14

Modern Aids of Communication and Detection

Introduction

In this chapter we shall discuss the presently available technology in communication, search and rescue operations. In order to understand the subject, the basics of radio, radar, satellites and transponders have been given, which are principally used in aviation. It is well known that the development of radio, TV, aircraft, satellites brought revolution in the field of communication, aviation and laid way for detection and rescue in hazards. These technologies have invaluable role in natural hazard/disaster detection and disaster management.

Heinrich Hertz conducted experiment in 1887 and proved the existence of electromagnetic waves and showed that these waves propagate in vacuum and can be stopped by a metalic screen. Radio waves are produced by changing fields in alternating current (AC). The electron flow alternately forwards and backwards (thus implies continuous changing of current) which produces fields along the wire.

An AC current can induce in an open circuit with a bare wire at the end. In this case electric and magnetic fields propagate outwards at right angles to the wire. If the wire is of the correct length, the fields will resonate and send continuous alternating waves of energy outwards. This outward propagation of fields form the transmitted radio waves. If a wire of same length is placed in the same direction in space as the transmitting aerial, the fields will affect the wire and induce and AC in it, so a receiver at a faraway distance can receive the transmitted signal exactly. This was exactly Marconi achieved in his experiments. The traditional aerial is called a halfwave dipole shown in Fig. 14.1:

The speed of propagation of electromagnetic wave is 3×10^8 m/s. The transmitted waves from a simple system with a single wire aerial travel in all directions around the antenna.

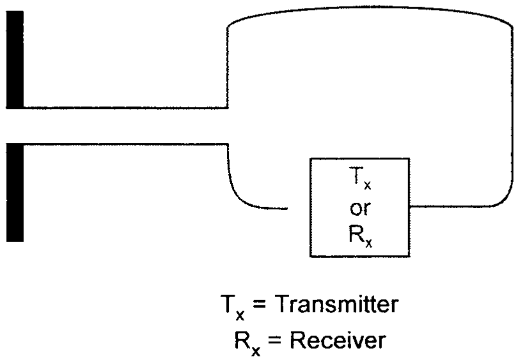


Fig. 14.1 A half-wave dipole aerial.

The magnetic field propagates at right angle to the electric field. The wave is polarised in the direction of the electric field.

The propagation of an alternating electromagnetic field in space constitutes electromagnetic waves. Electromagnetic waves are transverse waves because the electric and magnetic intensity vectors $\vec{E}$ and $\vec{H}$ of the wave fields are mutually perpendicular (shown in Fig 14.2) and lie in a plane perpendicular to the velocity vector $\vec{V}$ of wave propagation.The Vectors $\vec{V}, \vec{E}$ and $\vec{H}$ form a right handed system.

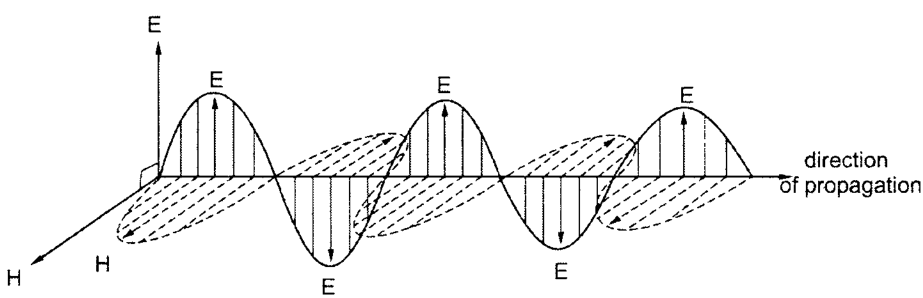


Fig. 14.2 Radio wave polarisation.

According to classical electrodynamic theory electromagnetic waves originate by the accelerated electric charges. A frame or loop antenna is a closed AC circuit.

Radio communication includes transmission of any type of information by means of radio waves, that is electromagnetic waves of frequency less than 3×10^5 MHz. Radio broadcasting in transmission of speach, music, telegraphic signals by means of radio.

Television broadcsting in transmission of images by means of radio.

Radio communications are the transmission of modulated electromagnetic waves by the radio transmitter and their demodution in a radio receiver.

The alteration or change of parameters of electromagnetic waves is called modulation. The wave which is modulated is called carrier wave and its frequency is called carrier frequency.

Depending upon the parameter of carrier wave that is altered in modulation we have:

Amplitude modulation see Fig. 14.3 (in which amplitude of the wave is changed).

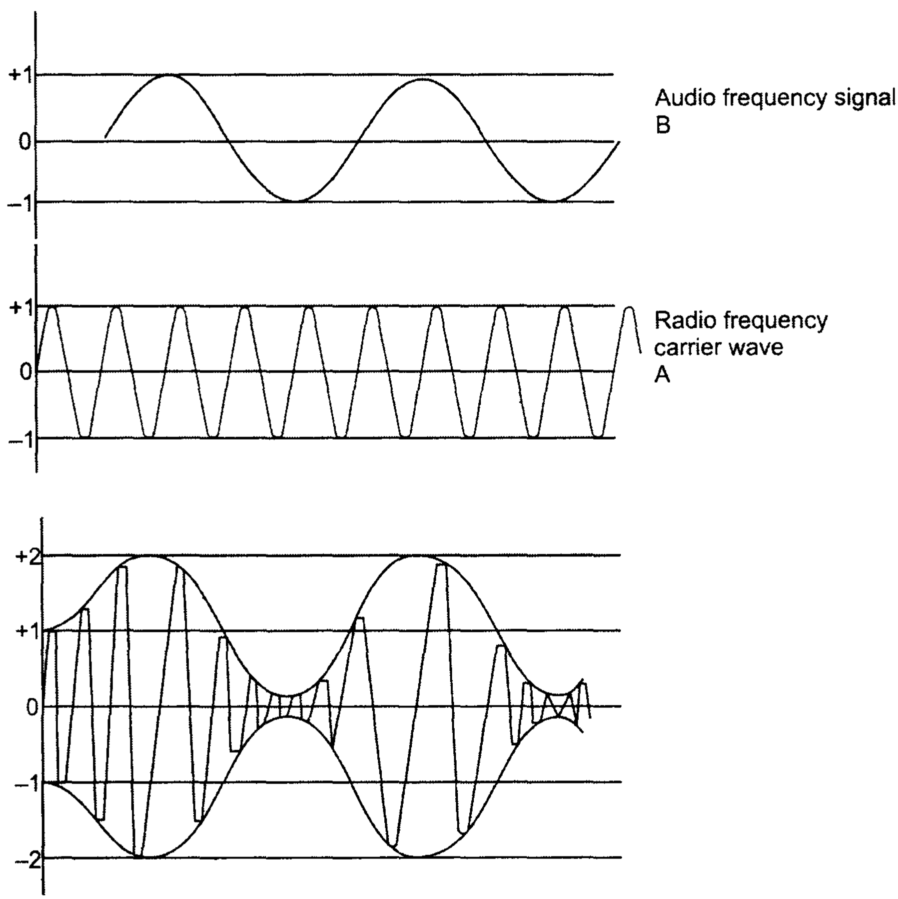


Fig. 14.3 Amplitude modulated signal.

Keying

The receiver requires a beat frequency oscillator facility.

(i) It consists of starting and stopping the continuous carrier wave, breaking it up into dots and dashes. This is generally called wireless telegraphy or interrupted carrier wave (ICW). The communication is by morse code.

(ii) Frequency modulation (in which only the frequency of the wave is changed). (See Fig. 14.4).

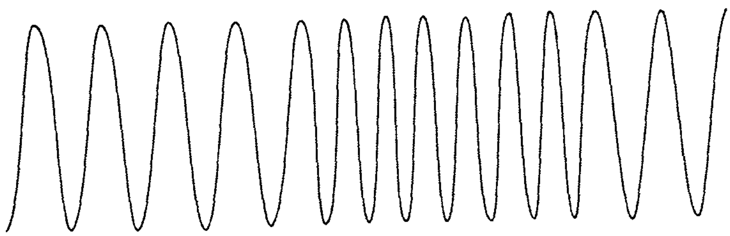


Fig. 14.4 Frequency modulated signal.

(iii) Phase modulation (in which the initial phase of the wave is changed). (See Fig. 14.5).

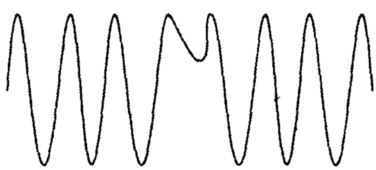


Fig. 14.5 Phase modulation-reversing the phase.

In radio broadcasting, the modulation frequency is low because the audible sounds frequency range is 16 to 20000 Hz, consequently there are no restriction to the choice of a carrier frquency. Thus the radio wave broadcast is acomplished on

	Long radio waves	[$\lambda = 10^3$ to 10^4m, f = 30 to 300 kHz]
	Medium audio waves	[$\lambda = 10^2$ to 10^3 m, f = 0.3 to 3 MHz]
and	Short radio waves	[$\lambda = 10$ to 10^2 m, f = 3 to 10 MHz]

$C = \lambda f$, or $f = \dfrac{C}{\lambda}$ or $\lambda = \dfrac{C}{f}$ where C = speed of radio waves, λ = wave length, f = frequency

An AC voltage in a wire reverses its direction in a number of times every second. The graph of radio wave is a sinusoidal curve as shown in Fig. 14.6.

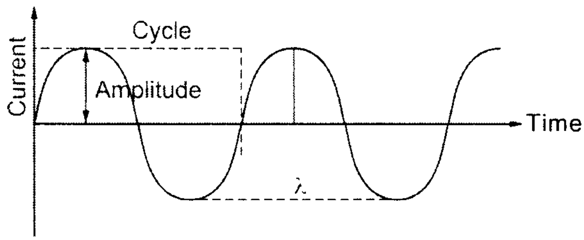


Fig. 14.6 Radio wave.

Cycle **:** A cycle is one complete process or one complete series of values.

Hertz **:** One hertz is one cycle per second

Number of cycles per second is expressed in hertz (Hz).

f = frequency, of an AC or radio wave, is the number of cycles occurring in one second, expressed in hertz.

1 cycle per second = 1 Hz (hertz)

1000 Hz = 1 kHz (kilohertz)

1000 kHz = 1 MHz (mega hertz)

1000 MHz = 1 GHz (gigahertz)

λ = wavelength : The physical length travelled or covered by radio wave in one complete cycle of transmission (distance between two consecutive troughs or ridges) .

***Ex*:** Given λ = 3m, find f

$$f = \frac{C}{\lambda} = \frac{3 \times 10^8}{3} = 10^8 \text{ Hz or } 100 \text{ MHz}$$

***Ex*:** Given f = 100 kHz, find λ in meters

$$\lambda = \frac{C}{f} = \frac{3 \times 10^8 \text{ m/s}}{100 \times 1000 \text{ Hz}} = 3 \times 10^3 \text{ m} = 3000 \text{ m}$$

Ex: Given f = 325 kHz, find λ

$$\lambda = \frac{C}{f} = \frac{3\times10^8 \text{ m}/\text{s}}{1000\times325 \text{ Hz}} \cong 923 \text{ m}$$

Ex: Given λ = 3520m, find f

$$f = \frac{C}{\lambda} = \frac{3\times10^8 \text{ m/s}}{3250 \text{ m}} = 92307 \text{ Hz or } 92.307 \text{ kHz}$$

Ex: Given λ = 3.41 cm, find f

$$f = \frac{C}{\lambda} = \frac{3\times10^8 \text{ m}/\text{s}}{341 \text{ m}}\times10^4 \quad \cong 90 \text{ GHz}$$

$$= 87.976 \times 10^9 \text{ Hz}$$

$$= 87976 \text{ MHz}$$

Ex: If a transmission is f = 100 MHz, find number of wavelengths in 60 ft. (given 1m = 3.28 ft)

$$\lambda = \frac{C}{f} = \frac{3\times10^8 \text{ m}/\text{s}}{100\times10^6 \text{ Hz}} = 3 \text{ m}$$

$$\therefore \text{ no.of wavelengths in 60 ft } = \frac{60 \text{ ft}}{3.28\times3} \cong 6\,\lambda$$

Modulation **:** Radio waves act as a vehicle (commonly called carrier waves) for the information. The waveform of information which is impressed upon the carrier wave is called modulating wave.

Oscillator **:** The radio frequency carrier wave is generated in the oscillator, whose frequency may be controlled by one or combination of several quartz crystals, a magnetron valve, or a semi conductor circuit incorporating varactor (or variable capacitor) diodes. These oscillations are of low frequency.

Transmitter **:** A radio transmitter consists of the following principal parts.

(i) A generator of sustained electromagnetic oscillations of the carrier frequency.

(ii) A modulator.

(iii) A transmitting antenna (which emits radio waves in the required direction).

Receiver : A receiver is a set consisting of :

(i) A receiving antenna.

(ii) A radio receiver.

Receiving antenna converts the energy of radio waves into the energy of high frequency electromagnetic oscillations. From these oscillations, the radio receiver chosenly separates those excited by the required transmitter and then amplifies and demodulates them. After amplification, the modulating oscillations are fed to the (reproducer) telephone/ loud speaker / TV kinescope etc.

A cathode ray tube is called kinescope, which is used to reproduce the picture in TV receiver.

In case of TV, the sending image is acomplished by modulating a carrier electromagnetic wave in proportion to the brightness of the various small spots (or portions) of the picture that is being transmitted. This is achieved by extrinsic or intrinsic photo-effect. The image (frame) is transmitted in continuous sequence line after line, and element after element in each line by scanning the image with the exploring spot. In Russian system, the Frame is divided into 625 lines with 833 picture elements per line. During each second 25 frames (distinct and separate pictures) are transmitted. The frequency of video signals (or modulation frequency) is about 6.5 MHz. To avoid distortion of video signals, the carrier frequency is used about ten times greater the ultrashort waves of meter band $\lambda = 1$ to 10 m and frequency more than 30 MHz are used.

Transmitter flow Diagram (See Fig. 14.7).

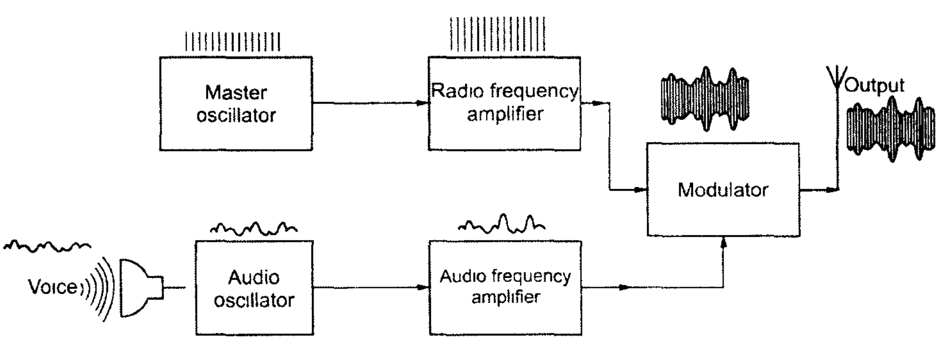


Fig. 14.7 Audio modulated transmitter.

Radio Frequency Amplifier: When the signal is at the correct frequency, it is amplified to the extent that it is strong enough to pass through the remainder of the transmitter components. Such amplifiers are semiconductor circuits.

Microphone and Audio frequency amplifier: The audio frequency signal may be produced by the operators microphone and/or audio oscillator such as a recording device that again has to be amplified. After amplification any speech part of an audio signal will be processed in a "speech processor" before modulation takes place.

14.1 Radio Spectrum

The whole of electromagnetic spectrum consists of radiation gamma rays ($\lambda < 10^{-10}$ m, $f \geq 10^{18}$ Hz), X-rays, UV-radiation, Visible light radiation, IR-radiation, Microwave (or very short radio waves), UHF (Ultra High Frequency), VHF (Very High Frequency), short and long radio waves ($\lambda \geq 10^{2}$ m, $f > 10^{5}$ Hz). Thus radio waves is only a part of this spectrum at the bottom. The spectrum of electromagnetic waves used for radio is divided into bands. Voice frequencies (audible range 16 Hz to 20 KHz). Sound waves are pressure waves and are propagated differently from electromagnetic waves. The internationally recognised radio frequency bands are given in Table 14.1.

Table 14.1

Frequency Band name	Abbreviation	f = frequency	λ = wavelength
Very low frequency	VLF	3 - 30 kHz	100 - 10 Km
Low frequency	LF	30 - 300 kHz	10 - 1 Km
Medium frequency	M	300 - 3000 kHz	1000 - 100 m
High frequency	HF	3 - 30 MHz	100 - 10 m
Very high frequency	VHF	30 - 300 MHz	10 - 1 m
Ultra high frequency	UHF	300 - 300 MHz	100 - 10 cm
Super high frequency	SHF	3 - 30 GHz	10 - 1 cm
Extremely high frequency	EHF	30 - 300 GHz	100 - 10 mm

Radar Frequency Band names given in Table 14.2.

Table 14.2

Frequency Band name	Frequencies
L - band Radar	1 - 2 GHz
S - band Radar	2 - 4 GHz
C - band Radar	4 - 8 GHz
X - band Radar	8 - 12.5 GHz

Voice Communication**:** This is achieved by voice modulation of radio waves.

Long-Range Communication (on the basis of Global Distance)**:** This lies in the frequency bands between VLF and HF. The frequency bands above HF is useful in direct wave or line of sight propagation (see Fig. 14.8). However these frequency bands are used in satellite technology. HF communication is superior for the following reasons.

- Aerials are shorter and less expensive to install.
- Static noise is less than MF and tolerable.
- For relatively less power very long range communication achieved by using sky waves during day and night.
- HF suffers less attenuation in the ionosphere.

Fig. 14.8 Ideal line of sight propagation.

Increased efficiency obtained by beaming the radiation in the direction of the receiver.

Static Interference**:** Static interference is caused by electrical disturbances in the atmosphere. The word 'noise' is used for interference from electrical components in transmitters and receivers.

HF communication**:** HF communication depends on the ionospheric conditions (Efficiency lies on the ionosphere conditions that will produce the first return at the required skip distance from the transmitter).

The HF frequency band allocated for commercial avaiation purpose ranges 2 MHz to 22 MHz.

A low power is sufficient for transatlantic voice communication.

HF range depends on the following factors.

- Transmission power
- Time Day (this effects the electron density)
- Season of the year (this effects the electron density)
- Ionospheric disturbances (depends on solar activity)
- Geographical location
- Frequency in use (this determines the critical angle and the depth of ionospheric penetration)

HF Datalink **:** HF Datalink is a facility used in oceanic control to send and receive information over normal HF frequencies (using upper sideband of the selected frequency). The signal is phase modulated to send digital information. Modern instruments convert voice signals into digital information (like a digital cell phone) and vice versa, to provide digital/voice communications.

Short-range Communication: This will provide communication upto 80 nm range with an antenna altitude of 500 ft and 200 nm range at 20,000 ftm antenna short range communication frequency bands range from VLF (3-30 kHz) to HF (3-30 MHz). However these bands have shortcomings of complexity and static interference. The VHF band provides a working practical facility but aerial requirement is complicated.

The signal strength received by a simple antenna at a given range is proportional to the wavelength. Longer wavelength (lower frequency) will provide better reception.

VHF Communication**:** The VHF band used for Radio Telephoney (R/T) communication (at short range) lies between 117.975 MHz to 137.00 MHz. Within this band communication channels are available at 8 KHz seperation intervals. It requires transmitter producing 20 W power.

VHF is free from static but some background noise is picked up (due to vertically polarised receiver aerials). A frequency modulated UHF signal would provide absolute clarity of reception (however the equipment is complex and expensive). The VHF transmission range depends on the following factors.

- Transmission power
- Height of Transmitter
- Height of the Receiver
- Obstacles at or near the transmission site (that will block the signals or scatter them and cause attenuation).

14.2 Satellite Communication

The most familiar Television pictures and sound is the gift of satellite communication. In aviation, the satellite communication is achieved through Inernational Maritime Organisation Satellite constellation (of four satellites) INMARSAT (see Fig. 14.9). The four satellites are positioned in geostationary equatorial orbit at a height of about 36000 km. The sensors based on these satellites provide communications by accepting transmissions of digital siganals in the 6 GHz band. The signals from the satellites cover almost all the area of the earth between latitudes 80 ^{o}N and 80 ^{o}S (see Fig. 14.9). The signals are not affected by the meteorological conditions (or static). This system requires special aerials for transmission and reception on these frequencies. It is noted that satellites do not reflect the signals. They receive the signals in 6 GHz band frequency and re-transmit them in different frequency of 4 GHz while those to the airborne aircraft in 1.5 GHz band. This reduces the attenuation of the signal.

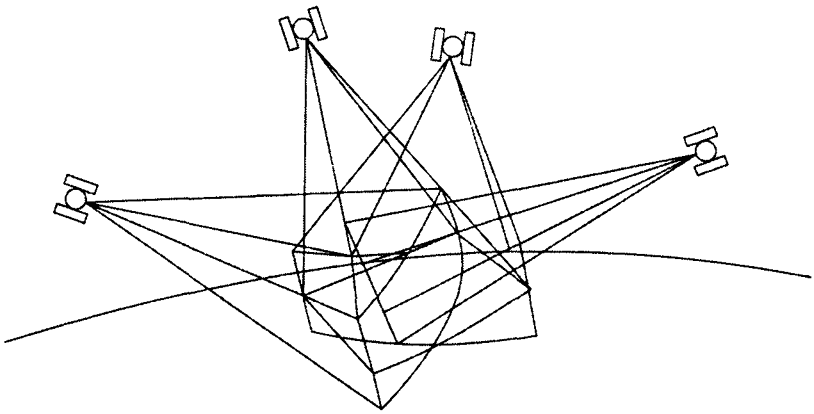


Fig. 14.9 Position fixing.

Ground based receiving stations are located in a network, which serve each of the four satellite region (or segments) and connect to the conventional public and private telephone networks. In aviation, a pilot using satellite communication system in reality using an ordinary telephone, and airborne passengers as well use this system. The aircraft satellite communication (satcom) receivers operate on frequency between 1544 to 1555 MHz, while aircraft (satcom) transmitters use frequencies between 1626.5 MHz and 1660.5 MHz. Voice messages are digitised by the equipment on ICAO laid specific algorithms.

Search and Rescue Satellites

INMARSAT constellation of 4 satellites are used for search and rescue operations (Aircrafts, Ships, Fisheries Naval Boats etc). INMARSAT satellites receives the signals on international emergency frequencies (121.5 MHz and/or 243.0 MHz) and alerts Search and Rescue (SAR) centres to emergency beacons carried by survivors.

The international COSPAS - SARSAT (Satellite Constallation) system is dedicated to the provision of Search and Rescue facilities. This system uses four polar orbiting satellites to cover whole of the earth. It is a joint venture-COSPAS is the Russian name, SARSAT is the US name. One of these satellites (of constellation) can receive signals transmitted at 121.5 MHz, for example from a survivors Personal Locator Beacon (PLB). The satellite re-transmits the signal to a ground station, called a Local User Terminal (LUT), where the exact frequency measured and compared with the datum 121.5 MHz. The difference gives the Doppler shift. The variation of Doppler shift gives an indication of the lateral distance from the satellite path. From this the search area is determined.

Marine Beacon **:** Marine radio beacons transmit in the Low and Medium frequency bands (a signal consisting of several letters in code). Some marine radio beacons operate continuously during navigation season (commercial mechanised boats, ships, fisheries boats etc) and can be used by ships, boats etc., over seas and by aircraft for navigation purposes.

Kinescope **:** A cathode ray tube called kinescope, is used to reproduce the picture in TV receiver. The priciple of kinescope is based on cathode - luminiescence. A special device scans the kinescope screen horizontally and vertically in synchronism with transmission of the corresponding picture elements by the T.V broadcast station. The different brightness (intensities) at the various points of the viewing screen are obtained by modulating the intensity of the electron beam in proportion with the electro-magnetic waves received.

Ionosphere **:** The upper atmosphere (50 - 500 km altitude) is characterised by the presence of dense ions and free electrons is called Ionosphere. These ions cause reflection of radio-waves.

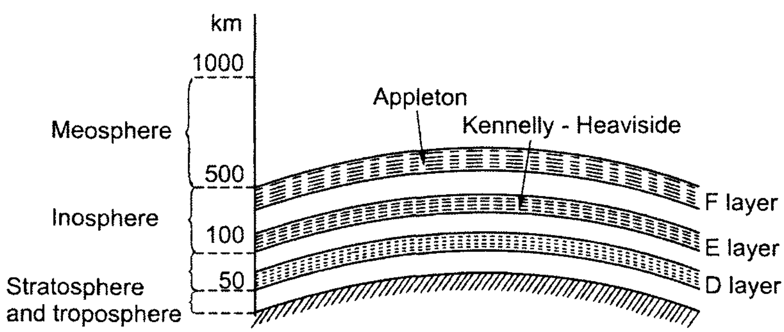


Fig. 14.10 Ionosphere layers.

Ionosphere is divided into D-region 50-90 km, E = region 90- 50 km, F-region 150-500 km. F-region is further divided into F_1-region 150-250 km, F_2-region 250-500 km.

D-Region **:** Reflects low frequency radio-waves, absorbs medium and high frequency radio waves. D-region depends on solar radiation and disappears during nights.

D-region is well developed during solar flares, during which complete break-down of Medium and High frequency radio communication takes place. This is called sudden ionospheric distrubance (SID).

E-region : Strongly reflects Medium and High frequency radio waves. E-region begins to weaken after sunset but does not completely disappear. It disappears completely during polar nights.

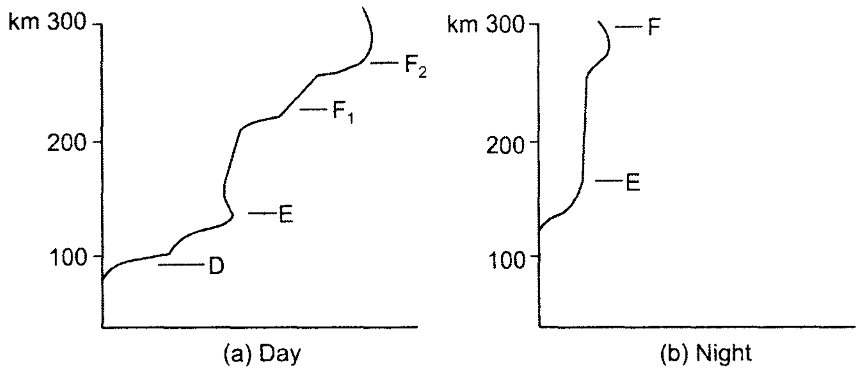


Fig. 14.11 Ionosphere diurnal effects.

F_1-region : Found only during day time when the sun is fairly high. However when the sun is low and during night it merges with F_2 region. F_1-region is important for Medium and High frequency radio waves.

F_2-region : It is important in long distance radio communication. Upper F_2 region contains protons and electrons (mobile telephone) and vice versa, to provide digital voice communication.

Propagation of Radio Waves in the Atmosphere

The Principal features of propagation of radio waves in the atmosphere are given below.

- Diffraction of radio waves at the earths surface.
- Absorption of Radio waves in the atmosphere and the surface of the earth.
- Reflection of radio waves from the surface of the earth
- Absorption, refraction and reflection by ionosphere. Inosphere is strongly charged by the ultraviolet rays, X-rays and corpuscualar radiation of the sun.

During normal conditions ultra short radio waves ($\lambda < 5$ m) are not reflected by the ionosphere. Direct waves propagated near the earth's surface are strongly absorbed by the earth. Consequently reliable reception of these waves (for example in T.V broadcasting) is possible only within the range of direct visibility, that is the distance within sight of the transmitting antenna. Long-distance T.V broad casting requires consecutives successive chain of relay stations called T.V. Station link; which receive, amplify and transmit signals along the chain work.

Radar

The word Radar is derived from RAdio Detection And Ranging. The working principle of radar is based on reflection and scattering of radio waves by various objects. In this radio waves are used to detect the presence of an object, to find its location (distance and direction) and velocity.

A radar station consists of an ultra shortwave radio transmitter and a receiver with a single (i.e., common) transmitting and receiving antenna which produces a radio pencil beam (a narrow direction beam)

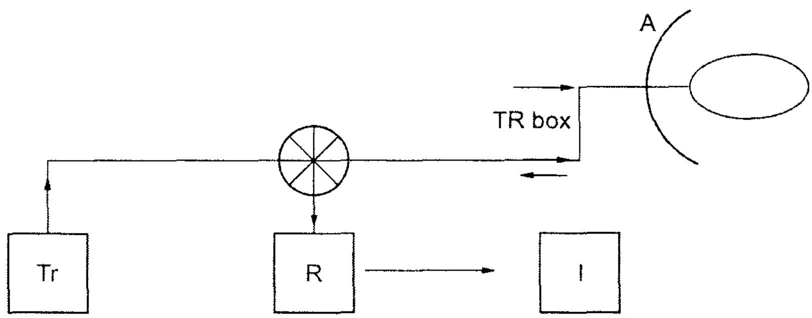


Fig. 14.12 Black diagram of a radar. T_r = Transmitter; R = Receiver; A = Antenna; T_R = Transmitter Receiver; I = Indicator

Transmission is in the form of short pulses of period of 10^{-6} sec (μs). During the interval between successive (consecutive) pulses the antenna is automatically switched over to reception of the echo-signal reflected from the target (object or obstacle). The distance of the target (radial distance from the antenna) is determined from the time interval between each transmitted pulse and the reception of the echo-signal. Radar uses ultra short waves (in the decimeter, centimeter and millimeter bands). The most successful operation (detection) depends on the size of the target (object) being detected, it should be many times larger than the wavelength (of radar or transmission wavelength λ). Radars are used efficiently and profitably in air navigation, detection of hazardous weather (like cyclones, tornadoes, thunderstorms, microbursts, clouding and precipitation etc.)

14.3 Satellite Meteorology

Introduction

Satellite meteorology is the result of combination of science, satellite technology, computers and communications. Space age has began with the launching of sputlik-I by the Soviet Union on 4th October 1957. It may be regarded as communication satellite by virtue of radio beacon.

Observing the weather from space began with the launching of TIROS-I (Television Infrared Observational Satellite) by USA on 1st April 1960, since then 27 meteorological satellites have been launched by USA. The first weather satellite Cosmos-122 was launched by Soviet Union in June 1966 and 13 followed thereafter. INSAT-1, the first Indian national satellite was launched on 18th July 1980. INSAT-I series, is a multiple concept consisting of communication, television, radio broadcasting and meteorological services. METSAT launched by India in 2002, later renamed as Kalpana-1, is exclusively dedicated to meteorological services. INSAT-3D launched in 2007 contains a sounder.

All objects in the universe emit radiant energy as long as their temperature is more than $0°K$, but cease to radiate when it is $0\ °K$ or less. The link between the distant stars and the earth is the electromagnetic radiation emitted by them. Radiant energy travels in space / vaccum in the form of electromagnetic waves, which travel in all directions away from the souce with speed of light, 3×10^8 m/s.

The range of all possible radiation wavelengths constitutes electromagnetic spectrum. It consists of gamma rays, X-rays, ultraviolet radiation, visible light radiation, infrared radiation, microwaves and short and long radio waves.

The wavelength (λ) and frequency (f) are related by the formula

$$C = f\lambda$$

where, C is velocity of light and associated energy (E) is given by the formula

$$E = h\nu,$$

where h = Planksconstant,

ν = frequency.

The electromagnetic spectrum is given in Table 14.3

Table 14.3 Eelectromagnetic spectrum.

Wavelength		Wavelength	
10^{-6} nm		1mm	Millimeter waves (mm)
10^{-5} nm	Gamma rays	1 cm	Microwaves
10^{-4} nm	(MeV)	10 cm	(cm, GHz)
10^{-3} nm		1 m	
10^{-2} nm		10 m	
10^{-1} nm		100 m	
1 nm	X-rays (A°)	1 km	
10 nm		10 km	

Wavelength		Wavelength	
100 nm	Ultra-violet (nm)	100 km	Radio waves
1 mm	Visible Near	1000 km	(MHz, kHz)
	Infrared µm	1000 km	
	Thermal Infrared		
10 µm	(µm)	10000 km	
100 µm	Far Infrared (µm)	100000 km	

nm = nanometer = -10^{-9}m, mm = micometer = 10^{-6} m.

Wavelength range of visible radiation, nomenlecture of microwave and radiowave frequencies, microwave bands are given in Tables 14.4, 14.5 and 14.6 respectively.

Table 14.4 Wavelength range of visible colours

Colour	nm	µm
Violet	380 - 430	0.38 - 0.43
Indigo	430 - 500	0.43 - 0.50
Blue	500 - 520	0.50 - 0.52
Green	520 - 565	0.52 - 0.565
Yellow	565 - 590	0.565 - 0.59
Orange	590 - 625	0.590 - 0.625
Red	625 - 740	0.625 - 0.740

Table 14.5 Nomenclature of microwave and radiowave frequencies.

Observation	Full form	Frequency	Wavelength
EHF	Extremely high frequency (microwaves)	30-300 GHz	1 mm-1 cm
SHF	Super high frequency (microwaves)	30-3 GHz	1 cm-10 cm
UHF	Ultra-high frequency	3 GHz-300 MHz	10 cm-1 m
VHF	Very high frequency	300-30 MHz	1 m-10 m
HF	High frequency	30-3 MHz	10 m-100 m
MF	Medium frequency	3 MHz-300 kHz	100 m-1 km
LF	Low frequency	300-30 kHz	1-10 km
VLF	Very low frequency	30-3 kHz	10-100 km
VF	Voice frequency	3 kHz-300 Hz	100-1000 km
ELF	Extremely low frequency	300-30 Hz	1000-10000 km

Table 14.6 Microwave bands.

Band	(Wavelength)	f (frequency)
mm - band	1-7.5 mm	40-300 GHz
ku - k - ka band	0.75-2.5 cm	12-40 GHz
X - band	2.5-4 cm	8-12 GHz
C - band	4-8 cm	4-8 GHz
S - Band	8-15 cm	2-4 GHz
L - Band	15-30 cm	1-2 GHz

Satellite Orbits

They are two kinds

(i) Sun-synchronous or near polar orbiting (elliptical or circular orbits), Tropical orbit.

(ii) Geostationary or geosynchronus (circular orbits)

The *polar orbitting satellite* crosses the equator at the same local time and views any given place under comparable lighting conditions. They cover the whole earth and see every location of the earth twice a day at the same approximate time. Generally the altitude of the satellite varies 500-1500 km.

The satellite based sensors can provide :

(i) Atmospheric vertical temperature profile of the globe.

(ii) High resolution picture transmission (HR PT)

(iii) Automatic picture transmission (APT)

(iv) Collection and transmission of data from automatic weather stations to the ground stations.

Geostationary satellites move west to east in a circular orbit in the equatorial plane at an altitude of about 3600 km and have the circular velocity (464 m/s) same as the that of the earth. Consequently they appear sationary to a fixed ground object on equator. These satellites provide continuous weather data round the clock over fixed area from about 60^0 N to 60^0 S (but it will not see the polar regions). A constellation of 5 or 6 geostationary satellites spaced around the equator will provide the near global pictures. The satellite based sensors provide vertical temperature profiles, cloud motion, wind vectors and sea-surface temperature. They act as a platform for reception of data from automatic weather stations and transmit to the ground stations.

14.3.1 Satellite Pay Loads, TV Camera

The payload carried by the TIROS-1 satellite in 1960 was a TV camera that relayed to the ground, whatever it observed of land, oceans and clouds.

Depending on the application besides TV cameras, the following are the common meteorological payloads.

(i) A scanning radiometer (SR)

(ii) Very high resolution radiometer (VHRR)

(iii) Vertical temperature profile radiometer (VTPR)

(iv) Scanning microwave radiometer (SMR)

(v) Data collection transponder (DCT)

(vi) Tape recorders

(vii) Solar cells

SR : Scanning radiometer has two channels

(i) Visible channel 0.5 to 0.17 μm

(ii) Infrared channel (window) 0.7 to 10.5 μm

Scanning radiometer functions like TV camera, transmits strip image along the orbital track. It takes continuous images of earth's atmosphere and surface. The resolution of visible channel is 4-12 km and IR channel 25 km.

VHRR : It acts like SR with better resolution of visible channel 1 km and IR channel 8 km.

> ***Note :*** Radiometer is an instrument used to measure electromagnetic radiation energy. Satellite based radiometers can provide radiation budget of surface – air system, sea surface temperature (SST), cloud cover distribution and cloud top temperatures.
>
> Radiometer operates in visible, IR and microwave regions.

***Spectrometer*:** A satellite based spectrometer provides:

(i) Chemical composition of the surface layers in the atmosphere and ocean

(ii) Measures the atmopheric concentrations of water vapour.

Resolution of an instrument is the smallest area on the ground that the given instrument is able to identify.

VTPR : It determines the temperature profile of the atmosphere on realtime operational basis over oceans and other regions (where the ground based upper air sounding station network is scanty or absent).

SMR : It operates on microwave bands and can provide global coverage of surface temperature data with an accuracy of $1^{o}C$.

DCT : It is used for collection of meteorogical and oceanographic data from remote uninhabited places on land and at sea by means of land based, ocean based data collection platforms (DCPs).

Tape Recorder : To store data before transmission to ground station. Such data storage on board makes provision for acquiring the global data at CDA (command data acquisition) station. CDA are managed by satellite launching countries.

CDA **:** A ground based station (on earth) at which various functions to control the satellite operations and to obtain data from the satellite are performed. The CDA transmits programming signals to the satellite, and commands transmission of data to the ground. Processing of data (by electronic machines and by hand) is accomplished at the CDA station. Raw and processed data are disseminated from CDA stations.

Solar Cells **:** Used for power. The sides and top of the satellite are studded with more than 9000 of these solar cells.

14.3.2 Remote Sensing

The process of observing an object with the help of electromagnetic spectra (band of radiation wavelengths) that an human eye cannot see is called remote sensing. In meteorology this term is used for observing meteorological parameters with the aid of radiometers on board satellites. Infact remote sensing is measurement of returned (or back) radiation from the earth-atmosphere system. The satellite based sensors are used for the detection of earth observation (both atmosphere and sea), detection of severe events like cyclones, tornadoes, tsunamises etc, delivary of warnings directly to the people of the affected area and for data relay and communication capabilities.

Microwave remote sensing is a powerful tool in application of meteorology and oceanography. It has the ability to measure water vapour and liquid water even in the presence of most clouds. Land surface emissivity in microwave region is high and is variable. It must be noted that microwave sensors reception signal strength on board geostationary satellites is poor and hence not useful, while its reception on polar low orbit altitudes is fairly good and hence mostly used.

TV Carmeras **:** TIROS-1 was operational for 78 days but it clearly demonstrated beyond doubt the potential use of satellites for surveying global weather conditions from space.

TIROS-1 has two TV cameras one with low resolution and the other one high resolution. The cameras were operating only in the portion of the earth which was sunlit.

TIROS-8 was launched on 21st December 1963, equipped with APT (Atutomatic picture transmission) capability, which provided satellite pictures world over to meteorological agencies in real time as the satellite passed over their region. There were 50 ground stations including one at Mumbai, India.

The successor TIROS series was ESSA (Environmental Science Services Administration) series initiated in 1966 by U.S. ESSA series transmitted thousands of space based weather system images which were received by more than 300 APT reception stations in 45 countries by 1970.

NASA (National Aeronautical and Space Administration) US launched Nimbus series satellites which had on board very advanced instruments for mapping ozone, sea ice, radiation budget components, coastal zone properties and sea surface temperature. The series carried improved Vidicon Camera system for daylight coverage, which were transmitted through the APT system.

Another APT service was provided parallelly by the Russian METEOR series of satellites.

NOAA, AVHRR: TIROS next generation satellite programme, name TIROS-N launched on 13th October 1978 followed by many satellites in the series. This followed by NOAA (National Oceanic and Atmospheric Administration) series by US. This series till 2005 had NOAA - 18 (series).

All NOAA satellites placed in near circular polar orbit. It carried on board Advanced Very High Resolution Radiometer (AVHRR) which had 4-channel radiometer initially, subsequently by 6 channel radiometer. One in visible (VIS), two in near infrared (NIR), one in mid-wave infrared (MIR) and two in thermal infrared (TIR) wavelength regions (See Table 14.7). All channels had resolution 1.09 km at the sub-satellite point.

Table 14.7 NOAA AVHRR channel specifications

Channel Number	Spectral Band	Wave length Range (um)	Uses
1	VIS	0.58 - 0.68	Daytime cloud and surface mapping
2	NIR	0.725 - 1.00	Land-water boundary delineation
3A	NIR	1.58 - 1.64	Snow and ice detection
3B	MIR	3.55 - 3.93	Night time cloud mappin SST retrieval
4	TIR	10.3 - 11.3	Night cloud mapping, SST retrieval
5	TIR	11.5 - 12.5	SST retrieval

14.3.3 Geostationary Satellites

The first US Geostationary Operational Environment Satellite (GOES) was launched on 16^{th} October 1975, the first new generation (GOES-8) launched on 13 April 1994. GOES-12 or GOES-East is located on equatorial orbit at 75^{0}W and GOES-10 or GOES-west is located at 135°W.

The current GOES satellites have 5 channel imaging radiometers whose specification are given in the Table 14.8.

Table 14.8 GOES channel specifications.

Channel Number	Spectral Band	Wave length range (um)	Resolution
1	VIS	0.55 - 0.75	1
2	SWIR	3.80 - 4.00	4
3	WV	6.50 - 7.00	8
4	FIR	10.20 - 11.20	4
5	TIR	11.50 - 12.50	4

(SWIR : shortwave infrared)

INSAT : (Indian National Satellite)

INSAT 1 **:** was launched on 18th July 1980, (India became the seventh nation after Soviet Union, USA, France, Japan, China and UK in satellite launching).

INSAT was a multipurpose satellite used for long distance telecommunication, meterorological earth observation and data relay, and direct TV broadcasting.

INSAT-1 A launched on 10th April 1982 was deactivated on 6th September 1982 due to malfunctioning. INSAT - IB launched on 30th August 1983 was a geostationary satellite, located at 74^{o}E.

India launched METSAT on 12th September 2002, which was renamed Kalpana - I, is an exclusive meteorological satellite.

INSAT - 3D launched 2007 carried a sounder.

The other geostationary satellites are:

METEOSAT of Europe locate at 0^{0} meridian

INSAT - ID of India located at 85^{0}E

GMS of Japan located at 140^{0}E

14.3.4 IMDPS (INSAT Meteorological Data Processing System)

IMDPS is receiving and processing Meteorological data from AWS (automatic weather stations). An AWS station records, stores hourly data and transmits the same to Kalpana - 1 through INSAT Data Relay Transponder (DRT). Cloud imageries are supplied and transmited through INSAT-3C to various IMD forecasting offices and also to other users through MDD (Meteorological Data Dissemination) scheme.

IMDPS generates cloud imageries and thereby derives the following meteorological products.

1. Cloud Motion Winds (CMW), using 3 hourly consecutive half-hourly images from the operational Kalpana-1 satellite at 0000 UTC and 0730 UTC and sends to users through GTS, IMD website.

2. SSTs are computed from INSAT - IR imagery from 0000 and 1200 UTC. SSTs also computed from NOAA satellite data using multichannel algorithm.
3. OLR (Outgoing Longwave Radiation) and quantitative precipitation estimates at $1.0^0 \times 1.0$ grid is computed from INSAT - IR data on 3 hourly / daily / weekly/ monthly basis.
4. Atmospheric soundings are generated from US polar orbiting (satellite) NOAA series. The soundings include temperature and humidity profiles and standard level geopotentials.
5. METEOSAT - 5, satellite is located in equatorial orbit at long 63°E. and covers India and adjoining area.

Primary Data Utilization Centre was installed in 2000 AD for reception of data from METEOSAT-5. The data is received in VIS, IR and WV-channels at 30 minute intervals.

14.4 Global Positioning System

Introduction

Satellite navigation is the concept of instrument navigation. It was developed as military system by the US and the Soviet Union. This system further developed with the computer system and provides more accurate position fixing for aviation purposes. ICAO calls this system as "Global Navigation Satellite System" (GNSS). The US calls this system "Global positioning System" (GPS). While the Russians call it "Glonass" system which is commercially available with suitable receiver equipment. The concept of satellite navigation is basically the principle of distance measurng equipment. The receivers measure the time that it takes radio signal to travel from satellite based transmitter at a known point in space. Knowing the speed of radio wave propagation and time taken for its journey from transmitter to the receiver the distance can be calculated.

Space Segment

The GPS consists of constellation of satellites (upto 29) that transmit L-Band radio signals. The satellites are all moving in a circular orbit of 26,500 km radius with inclination of 55° to the earth's spin axis and period of revolution of 12 hours around the earth. The satellites move in six different orbital planes with identical orbital characteristics. Each GPS satellite broadcasts signals in two L-band frequencies L1 at 1.57542 GHz (or 19 cm wavelength) and L2 at 1.22760 GHz (or 24.4 cm wavelength). The L1 carries the coarse acquisition or CA code, which can be received and interpreted by all receivers. The transmission from every satellite includes the orbit that each satellite is following and its position in the orbit as an almanac. The receiving computer uses that almanac to calculate where each satellite should be in its orbit. This provides which one will be in view and approximate range from each one. The ranges received at the receivers are not exact and hence called "pseudo-ranges". The satellite transmits its own exact position and path, called the "ephemeris". Each satellite carries a very accurate atomic clock which is in agreement with those in the constellation of satellites. This helps in measuring the true ranges (from the satellites instead of pseudo-ranges.)

The satellites (constellation) are supported by ground stations, which receive signals from all the satellites in turn as they pass overhead. The ground stations monitor the signals, and amend the almanac and ephemeris messages transmitted from the satellites.

Control Segment

The Control Segment consists of the ground stations. The Master station does all the calculations and the other ground stations provide communications between the satellites and the Master station.

User-Segment (Aircraft Equipment)

The GPS receiver is a simple device consisting of a small screened aerial mounted on the skin of the aircraft. Hand-held devices are also capable of showing position accurately. The computers and their associated software are the complex parts of the aircraft equipment. Computers can calculate actual track and groundspeed made good and required track and ETA (Expected time of arrival) to the intended waypoints. Given inputs from flight instrument or an air data computer, the GPS computers can make all navigational calculations.

The receiver can be any one of the three categories ; multi-channel, multiplex or sequential. Sequential receivers lockon to one satellite at a time, measure the pseudo range, then reach and lockon to the next. This system is not useful in aviation. Multi channel receivers are very expensive but they receive the signals from all the satellites in view independently and simultaneously (preferred type for aviation). Multiplex receivers 'time share' their receiving and computing time between all the satellites in view. A multiplex receiver can store the information from each while it is receiving information from others.

Pilot interface with some GPS instruments is by means of a numeric keypad, but those designated for light aircraft tend to use a menu system. A full computer or alpha-numeric keyboard controls the flight management system of airlines, and is ued to interface with the GPS equipment.

GPS Accuracy

The course acquisition (CA) signal is assumed to be accurate in the horizontal plane to within 30 m for 95% of the time. It is assumed accurate within 300 m for 99.99% of the time. The computed vertical position is however less accurate. The 95% position should be within 156 m (500 ft) vertically and 99.99% position within 500 m (1600 ft).

GLONASS

The Russian satellite navigation is called GLONASS. It uses separate frequencies for each of its active satellites which have orbital incliation at 60°, to transmit navigational data. All GLONASS satellites orbit the earth every 12 hours at an altitude of around 19000 km.

Some Applications of Global Positioning System (GPS)

Electromagnetic-surveillance technology is used in USA to monitor habitual / repeated offenders. Coast to coast authorities are using electronic monitoring devices to fight crime (this include gang members who were released on bail or probation, people accused of committing repeated violence against women etc).

i-Secure track corporation, based in Omaha, Neberska is manufacturing these devices and leasing them to Police and courts. It is said in Massachusetts, about 700 offenders were fitted with electronic bracelets which send signals via satellite to computer services to know their where abouts or if they go to the places which were debared (exclusion zones). The local law allows judges to impose electronic monitoring offenders. This system is cost-effective alternative to prison. GPS is also used in air navigation in search and rescue operations. A similar device is prepared by Indian Railways to locate railway accident sites promptly.

14.5 Geophysical Information System (GIS)

In India National Spatial Data Infrastructure (NSDI) forging digital links to construct information Highway, that could place data secreted in official vaults to be available on a personal computer. The data may be from diverse fields (like street maps, forest areas, hospitals, tax collection etc).

NSDI aims to use geophysical information system to mold satellite imagery and Survey of India Toposheets, superimposing data on water resources, flooding, rainfall, crop patterns, civic layouts etc., to produce three dimensional (3-D) digital maps. These maps will be of great use in disaster management besides in agriculture, irrigation, townplanning etc. As a first step major cites in India will be mapped on a scale 1:1000 and subsequently entire country will be mapped in a phased manner (similar to the google-earth)

GIS enables us to use (any one with a personal computer) to face several layers of data such as forest cover, taxes collected from a region or area affected by epidemic (like cholara, bird flue etc) on to a base map of the region and then carryout geographic and cartographic analysis. NSDI will act as online database to maintain such data layers and base maps in easily retrievable form.

Defence Ministry cleared 1600 Survey of India maps (given no objection certificate for use). GIS unshakling information technology (IT) and space technology for everyday use. Some of the classical Survey of India maps will be in public domain on a designated website. Work on 3-D digital "live" maps of major cities will progress as given below.

(i) NSDI will use GIS to fuse satellite imagery (photographs) to create database of urban and rural areas.

(ii) Satellite images will help in preparation of maps of major cities on scale 1 : 1000. Data on municipal plans, forests, ground water, roads will be superimposed. 4800 Survey of India maps on scale 1 : 50,000 will be open to public (many for the first time).

(iii) Maps will be updated using satellite aereal photography. Public private partnership will be encouraged. Commercial use will include vehicle navigation and data integration. User shall have any of the four controls. (a) Hand-held cellphone (or PADS), (b) Computers (laptop and desktop), (c) Internet kiosks in rural areas, (d) Printouts and Television.

14.5.1 Some applications of GIS

GIS is a poweful tool to disclose what actually lies on the ground.

High Resolution GIS Surveillance helps in tracking terror activities. Recently (2007 - 08) in Birmingham anti-terror arrests made by the use of High Resolution Surveillance. Indian army uses GIS to track terrorist infiltration across Indo-Pakistan border.

Service providers can deliver updates on road blocks and traffic congestions. On a rainy day planning a driveout of town can be simpler.

GIS helps accurately in assessing standing crops. It can provide changes in cultivated areas and also quality of gram.

GIS based 3-D maps will deliver the civic bodies authorities the truth on the ground, helps in tracking car thieves, it gives existence of a road or street or any area has been encroached, water logged, fields inundated.

GIS softwares can be applied to the tasks of locating sites for tubewells, percolation tanks in accordance with a set of parameters. Example : No well should be more than 500 m from a habitation.

Groundwater in a specific area, say north of Secunderabad adjacent to National Highway-7, can be mapped accurately using GIS.

Using GIS, medical team/health professionals can track geographic links of a disease outbreak (like birdflue) and act to control it.

GIS is of great help in disaster management, for example in flooding. It can provide information on roads, hospitals, railway tracks etc., and diret the rescue team in a pinpointed manner.

Using GIS and personal computer (PC) by a click of mouse one can superimpose physical and geographical data. GIS scheme will be profitably rolled out through public private partnerships. Any citizen, including academics, can use the data by paying fee. Besides use in disaster management, digital maps loaded with data are useful in various economic activities. The pilot project on Chandini Chowk (Delhi) had clearly shown that even crowded places can be accurately reconstructed with the help of GIS. Some map making companies are developing detailed urban maps useful in tourism and transport, entertainment, health, education and business.

Government of India considering a mechanism through GIS to enable investigation of certain types of terror incidents and other offences having inter-state and international linkages by a central agency. At present such matters are probed by CBI (Central Bureau of Investigation) only when they are referred to it by States concerned or by courts. Since "law and Order" comes under the control of States within the federal set up, the CBI or any Central Agency cannot take-up the cases of investigation on its own.

Use of Satellite (VSAT hub) by Indian Railways in Disaster Management

Indian Railways run about 12000 trains everyday, that carry more than 125 lakh passengers across the country of about 65000 km railway tracks. Available statistical records show the highest rate of railway accidents 300 per year.

In order to help the disaster victims an efficienct communication has been planned through VSAT hub in Delhi to receive updated reports from the accident sites. The Railway VSAT is connected to INSAT 4CR launched by ISRO (Indian Sapce Research Organisation). The VSAT hub was designed and commissioned by Hughes communication Ltd through its satellite broadband services. Indian Railways will install mobile satellite terminals in about 100 Accident Relief Trains (ART) which will be stationed across the country. Earlier ARTs would reach the accident site with sole purpose of rescue operations. With this satellite terminal in ARTs there will be instant Vedio and voice data connectively with bigger Railway Stations on route which will facilitate quick rescue, relief operation. The satellite terminal in ART will be in contact with the VSAT hub in Delhi via INSAT 4CR within minutes. The satellite terminal also allows connectivity with normal BSNL (Bharat Sanchar Nigam Ltd) phones and Railways Administrative lines near the accident site to other stations. With this conncectivity standard passengers can get in contact with their homes/relatives.

Arrangements are also being made for using the VSAT hub to provide internet connectivity on trains by installing portable antenna as roof of outstation trains. The antenna will continuously track signals with INSAT 4 CR and the VSAT hub at Delhi. This will ensure wireless connectivity to passengers with laptop in the train.

Some uses of Cartosat 2 Satellite High Resolution Imageries

Indian Space Research Organisation (ISRO) launched Cartosat-2 in January 2007. The resolution of imageries is one meter, but trying to improve to half meter resolution. With the cartosa-2 imageries it is planned to prepare cartographic map of India. The data will be used in urban development. The imageries could provide information required for infrastructure development, disaster management and watershed development. The imageris can help building a national database which will be very useful for a long term disaster management. The life of Cartosat-2 is five years that is upto 2012.

India has the world's largest constellation remote sensing satellites. Seven satellites in orbit provide imagery of the earth in a variety of spectral bands with a resolution of one meter (even less). The satellites provide remote sensing data, which are received at about 20 ground stations across various parts of the globe including US and Europe. Village Resource Centres established in 2004 are providing a variety of space based products and services including tele-education, tele-medicine and information on natural resources. There are about 400 Village Resource Centres in the country.

Consists of starting and stopping the continuous carrier wave, breaking up into dots and diesels. This is generally called wireless telegraphy or interupted carrier wave (I.C.W). The communication is by Morse code. The receiver requires a beat frequency oscilltor facility.

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@Seismicisolation

CHAPTER - 15

A Glance at Disaster Management Act – 2005

Disaster Management Act-2005 was passed on by Parliament (Act No. 53 of 2005 dated 23-12-2005) and notified in official gazette in 2006 (wef 28-7-2006). The motto of this Act is to provide for the effective management of disaster and for matters connected therewith. The Act is applicalbe to the whole of India including Jammu and Kashmir.

According to this Act, Disaster mean a catostrophe, mishap, calamity or grave occurrence in any area, arising from natural or man-made causes, or by accident or negligence which results in substantial loss of life, human suffering or damage to property and destruction, or damage to or degradation of environment. It is of such nature of magnitude which is beyond the coping capacity of the community of the affected area.

Disaster management is a continuous and integrated process of planning, organising, coordinating and implementing measures which are necessary. The necessary measures/steps include:

(i) Prevention of danger or threat of any disaster.

(ii) Mitigation or reduction of risk of any disaster or its severity or consequences.

(iii) Capacity building. Like, (a) Identifying the existing resources/acquiring or created (b) Organisation and training of personnel and co-ordination.

(iv) Preparedness (to be in a state of readiness to tackle with any disaster).

(v) Response (a quick response to any disaster or impending disaster situation).

(vi) Assessment (assessing the magnitude of effects or severity of disaster).

(vii) Evacuation. (Moving the people to safer areas from the threatening disaster situation or disaster area)

(viii) Rescue

(ix) Relief, Rehabilitation and reconstruction.

***Note*:** Resources include manpower, services, materials and provisions.

15.1 National Disaster Management Authority (NDMA)

National Disaster Management Authority or simply National authority, consists of the following members.

(i) Prime Minister of India, as ex-officio Chairman and

(ii) Nine members, nomiated by chairperson including Vice-chairperson.

The Central Government (CG) provides the National Authority with officers, consultants and employees, as necesary to carryout the functions. It is the responsibility of NDMA to laydown the policies, plans and guidelines for disaster management to make sure the timely and effective response to disaster.

Disaster Management Plans are prepared by the Ministries or Departments and integrate the measures for prevention of disaster or to mitigate its effects in their respective Department plans and projects.

NDMA constitutes an Advisory Committee consisting of experts in the field of disaster management and having practical experience, who can recommend on different aspects of disaster management.

***The National Executive Committee*:** It consists of the following members, who will assist the NDMA. The Secretary to the Government of India incharge of the Ministry or Departments having administrative contról of the Agriculture, Atomic Energy, Defence, Drinking water supply, Environment and Forests, Finance (expenditure), Health, Power, Rural Development, Science and Technology, Space, Telecommunication, Urban development, Water resources and the Chief of the Integrated Defence Staff of the Chiefs of Staff Committee – (all ex-officio).

The Secretaries of the above referred Ministries or Departments are ex-officio members of the National Executive Committee.

Working of the National Executive Committee (NEC)

The NEC acts as the coordinating, the monitoring body for disaster management. It prepares National Disaster Management Plan, which will be approved by NDMA. NEC helps and coordinates in executing the National Policy, laydown guidelines for preparing Disaster Management Plan by respective Ministries or Departments. It provides technical assistance to the State Governments for preparing their plans.

NEC monitors the implementation of the guidelines laid down by NDMA. It evaluates the preparedness and/or gives directions to improve preparedness. Arranges men and material in case of emergency response, rescue and relief. In general it promotes Disaster Management education and awareness (among masses).

15.2 National Disaster Management Plan/(NDMP) or simply National Plan

NDMP is applicable to whole of the country and is mandatory. NDMP is prepared by NEC and mainly includes:

(i) Disaster Preventive measures or mitigating their effects.

(ii) Disaster preparedness and Capacity building to respond to any hazardous situation or disaster.

(iii) Roles and responsibilities of different Ministries or Departments.

(iv) Upgrading the NDMP.

(v) To make provisions for Central Government financing to carryout the plan.

(vi) Based on the NDMP, the Ministries and Departments of Government of India should draw up their own plans.

***Guidelines for Minimum Standards of Relief*:** Persons affected by disaster should be provided:

(i) Minimum standards of relief in relief camps in relation to shelter, food, drinking water, medical help and sanitation.

(ii) Special provisions for widows and Orphans.

(iii) Exgratia assistance on account of loss of life, assistance on account of damage to property and for restoration of means of livelihood.

(iv) Any other relief that is necessary

***Relief in Loan Repayment*:** In the events of severe disasters, relief in repayment of loans or grant of fresh loans to persons affected with concessional terms of repayment may be allowed (as applicable).

15.3 State Disaster Management Authority (SDMA)

SDMA consists of:

(a) The Chief Minister of the state as ex-officio Chairman,

(b) Nine members nominated by the Chairperson of SDMA (including Vice-Chairman)

(c) The chairperson of the State Executive Committee, ex-officio.

The Chairperson of the State Executive Committee is the Chief Executive Officer of the SDMA.

In case of Union territory, except Delhi, the Chairperson of the State Disaster Management Authority is Lieutenant Governor or the Administrator. In case of Delhi, the Chief Minister is the SDMA Chairperson.

The State Government provides the SDMA with experienced officers in the field, consultants and employees as necessary for carryingout the functions of SDMA.

State Advisory Committee

It consists of experts in the field of disaster management and having practical experience so as to make recommendations on different aspects of disaster management.

The responsibility of State Advisory Committee is to prepare:

(i) Plans and policies for disaster management of the state.

(ii) Approve SDMPs (State Disaster Management Plans) under the guidelines laid down by the NDMA.

(iii) Approve Disaster Management Plans prepared by the Sate Government Departments.

(iv) Integration of measures, actions for prevention of disasters and mitigation in the State Development Plans and Projects.

(v) Coordinate in the implementation of State Plan.

(vi) Recommend for the provision of funds for preparedness and disaster mitigation.

(vii) Review the Development Plans of State Departments and see the disaster prevention and mitigation measures are integrated therein.

(viii) Issue guidelines to State Departments as necessary after reviewing the measures taken for disaster preparedness, mitigation and capacity building.

Minimum Standard Relief: The SDMA provides guidelines for minimum standard relief which will not be less than the minimum standard relief laid by the NDMA.

State Disaster Management Executive Committee (SDMEC)

SDMEC is also called State Executive committee. It assists the SDMA to function smoothly and efficiently.

The SDMEC consists of the following members.

(i) The Chief Secretary of the State Government and acts as a chairperson, ex-officio.

(ii) Four Secretaries of the State Goverment (belonging to Revenue, Home, Irrigation and Panchayat Raj) as ex-officio.

(iii) The SDMEC holds some powers which were delegated by the SDMA.

The functions and the Working of the SDMEC

(i) It is responsible for implementing the National Disaster Management Plan (NDMP). It is the coordinating, monitoring body for the State Disaster Management and the implementing body for the National Policy, the National Plan and the State Plan.

(ii) After examining the vulnerability of different parts for different natural hazards in the state, the committee specifies measures for the prevention or mitigation of disasters.

(iii) It lays down guidelines for preparation of disaster management plans by the State Departments and District Authorities.

(iv) It monitors the implementation of disaster management plans by the State Government Departments and District Authorities.

(v) It integrates the measures for prevention of disasters and mitigation in the departmental plans and projects.

(vi) It gives guidelines for improving preparedness after evaluating all governmental and non-governmental disaster preparedness. It coordinates in response to any alarming disaster situation or disaster and directs the concerned departments regarding actions to be taken.

(vii) The executive committee promotes general Disaster Management Education, Awareness and Training to different disasters to which the different parts of the State are vulnerable. For example the coastal people will be trained how to meet the cyclone disasters, its preparedness to prevent cylone adverse effects and its mitigation.

(viii) It cooperates and advises to all stake holders in the disaster preparedness and effective management. It provides necessary information about various disasters in the State both to National Disaster Management Authority, all state holders and NGOs as well.

(ix) It will laydown the state level Response Plans, review and update it. It provides guidelines to the district level plans preparation, review and updation.

(x) It ensures proper dissemination of warnings to the district authorities and helps in execution of disaster mock drills.

State Disaster Management Plan (SDMP)

SDMP will be prepared by the State Disaster Management Executive Committee under the guidelines of National Disaster Mamangement Authority. The plan includes:

(i) Vulnerability of different parts of the State to different disasters.

(ii) Measures to be adopted for prevention and mitigation in respect of different disasters. These measures will be integrated in the State Development Plans and Projects.

(iii) Capacity building measures with respect to each disaster.

(iv) The plan will include the roles and responsibilities of different Government Departments and Agencies. It also includes Response of different Government Departments and Agencies in the face of threatening disasterous situation or disaster.

(v) The State Plan has to be reviewed and updated with experience and additional knowledge gained every year.

(vi) Appropriate budgetry/ plan expenditure measures to be made in the State Plan. The Plan copies to be distributed to the concerned departments for necessary implementing action.

15.4 District Disaster Management Authority (DDMA)

DDMA consists of

(i) Chairperson (District Collector or Distric Magistrate or and District Commissioner), ex-officio and six members (prescribed by the State Government) which include:

(ii) Elected representative of the local authority – Co-chairperson, ex-officio (Zilla Parishad Chairman as Co-chairperson)

(iii) The chief executive officer of the District Authority, ex-officio member.

(iv) The Superintendent of Police, ex-officio member.

(v) The District Chief, Medical officer, ex-officio member.

(vi) Two other district level officers to be appointed by the State Government.

The Chief Executive Officer of District Authority may be Additional District Collector, or Additional District Magistrate or Additional Deputy Commissioner, who will be delegated with powers by the District Authority.

The District Disaster Management Authority hold meetings when necessary at a time and place as directed by the Chairman.

District Disaster Management Advisory Committees

Depending on the necessity, the District Authority may constitute one or more Advisory Committees to discharge the functions efficiently.

The Advisory Committee consists of members of which one will be nominated as Chairperson.

Responsibilities of District Disaster Management Authority

In accordance with the guidelines laid down by the National Authority and the State Authority, District Disaster Management Authority (DDMA) acts as the district planning, coordinating and implementing body for disaster management and take necessary measures in this regard. The following are the main:

(i) DDMA prepares disaster management plan including District Disaster Response Plan.

(ii) It coordinates and monitors the implementation of National and State policy and Plan and District Plan.

(iii) It identifies vulnerable areas of disasters and takes necessary actions for prevention, against recurrence, preparedness and mitigation of its adverse effects by collaborating with local district authorities.

(iv) DDMA directs the different district level and local authorities to take necessary actions for prevention and mitigation of disasters in accordance with the district disaster management plan. Also it lays down guidelines for integration of these measures in their departmental, developmental plans and projects and provides necessary technical assistance.

(v) It monitors and reviews implementation measures and recommends upgradation if necessary.

(vi) DDMA organises and coordinates in specialised Training and Awareness programmes to various officers, staff and vountary organisations involved in disaster management.

(vii) It sets up and upgrades the dissemination of warnings to the concerned and to the common man.

(viii) It prepares, reviews, upgrades district level Response Plan and guidelines and ensures prompt Response from Government concerned officials, local authorities to any impending disaster situation or disaster.

(ix) It advises, assists and coordinates with all statutory bodies, Government and Non-Government Organisations involved in the disaster management. It works for the prevention or mitigation of the disaster situation or disaster.

(x) It reviews the Developmental Plan and makes provisions for prevention of disaster or mitigation. It directs the concerned authorities for necessary constructional works for disaster prevention. It identifies the buildings, localities and other constructions which are in bad shape or hazardous and arranges to evacuate the people to the relief camps during disaster situation or disaster. It arranges water supply, sanitation in the relief camps. It provides/establishes sufficient relief and rescue materials at a short notice. It encourages the participation of non-governmental organisations in the rescue, and relief work right from the grass root level to district level.

District Disaster Management Plan (DDMP)

District Disaster Managment Plan will be prepared by the District Authority in consultation with local authorities, keeping in view of the National Plan and State Plan and which will be approved by the State Authority.

The district plan includes:

(i) Areas in the district vulnerable to different disasters.

(ii) Action to be taken to prevent the disasters and in the events of disaster, mitigation of adverse effects by the Departments of the Government at the district level and local authorities in the district.

(iii) Capacity building and preparedness on the part of Government. Departments at district level and to respond promptly to any threatening disaster situation or disaster.

(iv) The Response plans and procedures in the event of disaster, distribution of responsibilities to various Government Department at district level, entrusting responsibilities, immediate response to disaster by way of evacuation, relief, supply of essential food articles and resources, safe communication links and dissemination of information to the public.

(v) The District Plan to be reviewed and updated annually. The copies of the plan to be supplied to all concerned Government Departments in the district.

The district authority shall send the copy of the district plan to the State Authority, who in turn send it to the State Government. The district authority shall review the plan from time to time and issue instructions for its implementation

Note : All State and Central Government Offices should prepare disaster management plan for prevention and mitigation of disasters concerned to their respective departments. Take measures to capacity building, preparedness, response, coordination and implementation of District Plan (approved by the district authority) by the concerned authorities at the district level including local authority and other stakeholders. The plan to be reviewed periodically and updated.

Functions of District Disaster Management Authority

The principal objective of DDMA is to render help by protecting and providing relief to the community in response to any disastrous situation or disaster.

DDMA can give directions to any Government Department or local authority. The following are the main:

(i) It can direct to release and use the resources available with them; can order to divert or stopping of vehicular traffic or restrict movement of people to and from the affected area or vulnerable to disaster.

(ii) To remove debries (like fallen trees, collapsed houses etc), conduct research and perform rescue operations, provide temporary shelter (relief camples), food, drinking water, essential food grains/provisions,, medicines and health services.

(iii) To establish emergency communications (like police wireless).

(iv) Arrange for the disposal of dead bodies (en-mass) to prevent epidemics chlorination of water and to keep relief camps clean.

(v) If required arrange experts advise to assist the field workers as seemed necessary.

(vi) To provide preferential use of amenities or procure if from any authority (for children, pregnant ladies etc).

(vii) Order construction of temporary bridges or essential structures or demolish precariously held structures that might effect the working in the affected areas.

(viii) To monitor or ensure selfless, equitable, impartial activities in the relief or take necessary action that is warranted in the affected situation.

15.5 The Role of Central Government in Disaster Management

(i) Coordination action of the Ministries or Departments of the Government of India, State Governments, National Authority, State Authority, Governmental and NGOs in relation to disaster management.

(ii) Ensure the integration of measures for prevention of disasters and mitigation by the Ministries or Departments of India into their developmental plans and projects.

(iii) Ensure allocation of funds for prevention of disaster, mitigation, capacity building and preparedness by Ministries or Departments of GOI (Government of India).

(iv) Ensure the Ministries or Departments of GOI to take necessary measures for preparedness to promptly and effectively respond to any threatening disaster situation or disaster.

(v) Cooperates and assits State Governments suitably to the occasion.

(vi) GOI deploys Naval, Military and Air force and other Armed Forces or other civil personnel as required to the occasion.

(vii) Under the Disaster Management Act of 2005, GOI seeks coordination with United Nations Agencies, Knowhow etc., as required to the occasion.

(viii) Central Government establishes research institution, training and other developmental programmes in the field of disaster management

(ix) For effective and prompt implementation of the provisions of DM Act 2005, Central Government takes up necessary steps as required to the occasion.

(x) Under the provisions of DM Act 2005, Central Government will extend any support as required to the occasion to other countries affected by major disaster.

Responsibilities of Central Ministries and Departments:

Under this includes:

(i) Necessary measures for prevention, mitigation, preparedness and capacity building in accordance of the guidelines of National Disaster Management Authority (NDMA).

(ii) To integrate into development Plans and Projects,

(iii) To respond promptly, effectively to any threatening disaster situation or disaster.

(iv) In the light of experience and improved technologies to review the provisions of existing rules and regulations for the prevention of disaster and mitigation, preparedness.

(v) Provide/allocate necessary funds for NDMA which will be used for mitigation, preparedness, response plans, capacity building and disaster preparedness, relevant data collection, identification of causes, training personnel to meet the grave occasions, to rescue and relief operations, to assess the disaster damage, to habilitate and reconstruct the affected. Responding to any grave situation or disaster it should provide or make available resources to National and State Executive Committees. The Executive Committees at National, State level may use the resources provided for emergency communication, transporting men and relief goods in vulnerable or affected area. It may be used for setting up temporary bridges, jetties and helicopter landing places (runways) or providing drinking water, essential provisions, medicines, health care and services and other necessary purposes in an affected area.

15.6 Role of GOI Ministries and Departments in preparation of Disaster Management Plan

Every Ministry and Department of GOI prepares disaster management plan specifying particular aspects to be included in the plan. The plan includes:

Prevention, mitigation of disasters, integration of mitigation measures in developmental plan under the guidelines of National Authority (NDMA), National Executive Committee. The plan should be such that it should act promptly and effectively in respect to any grave situation or disaster, and build capacity to deal with any grave situation. It should provide annual review and updating of the plan by National Authority. It should contain provision for financing the various activities in the plan and a status report in respect of implementing the plan.

The Role of the State Governments in Disaster Management

It is mandatory for the State Governments to take all measures under the guidelines of National Authority (NDMA) which are necessary for the purpose of disaster management. The measures include:

(i) ***Coordination*** of different Departments of the State Government, State authority (SDMA), District Authority, local authority and other NGOs (Non-governmental organisation).

(ii) ***Cooperation and assistance*** in disaster management to the National Authority, National Executive Committee, State Authority, State Executive Committee and the District Authorities. Also to the Ministries and Departments of GOI.

(iii) ***Allocation of funds*** for prevention of disaster, mitigation, capacity building and preparedness by Departments of State Government in accordance with the provisions of the State Plan and District P.

(iv) ***Integration*** of measures for prevention of disaster mitigation, capacity building and preparedness by the various State Departments and also to integrate in the State Development Plan to reduce or mitigate the vulnerability of different parts of the State to different disasters.

(v) State Government make sure that adequate warnings reach to the level of communities vulnerable and with appropriate preparedness by the State and District Authorities. Also make sure the availability of resources for the purposes of effective response, rescue and relief in case of threatening disaster situation or disaster. Provide rehabilitation and reconstruction assistance to the victims of any disaster.

Responsibilities of the State Government Departments

Specification of the responsibilities of State Government Departments in reagard to prevention, mitigation, preparedness and responses to the disasters:

It is the responsibility of every State Government Department to take and necessary measures for prevention of disasters, mitigation, preparedness and capacity-building under the guidelines laid down by the National Authority and the State Authority. All departments should integrate the measures for prevention of disaster and mitigation into to development plans and projects appropriately; allocate funds for prevention of disaster, mitigation, capacity-building and preparedness. Respond effectively and promptly to any threatening disaster situation or disaster appropriately. Review the enactments administered by it, its policies, rules and regulations and incorporate necessary provisions for prevention of disasters, mitigation or preparedness. The State Government Departments provide assistance for drawing up mitigation, preparedness and response plans, capacity-building, relevant data collection and identification and training personnel in relation to disaster management. Concerned departments assess the damage of disaster and carry out rehabilitation and construction. In consultation with the State Disaster Management Authority, Government Departments make provisions for implementation of the district plan at the district level. The state government of departments should make available its resources for responding promptly and effectively to any disaster in the state and include the following measures:

(i) providing emergency communication with a vulnerable or affected area,

(ii) transporting personnel and relief goods to and from the affected area,

(iii) providing evacuation, rescue, temporary shelter or other immediate relief,

(iv) carrying out evacuation of persons or live-stock from an area of threatening disaster situation or disaster,

(v) setting up temporary bridges, jetties and landing places,

(vi) providing drinking water, essential provisions, health care and services in an affected area.

And any such actions that are necessary for disaster management.

Disaster Management Plans by the State Departments

It is mandatory for every Department of State Government to prepare disaster management plan and make of provisions for financing the plan in conformity with the guidelines laid down by the State Disaster Management Authority. These plans include:

(i) the types of disasters that affect or the areas vulnerable,

(ii) integration of strategies for prevention of disaster or the mitigation of its adverse affects or both the development plans and programmes by the department,

(iii) the roles and responsibilities of the State Department in the event of any hazardous situation or disaster and emergency support that it requires to perform,

(iv) present status of its preparedness to execute roles or responsibilities or emergency help that it can do,

(v) the capacity building and preparedness measures proposed to execute and

(vi) furnish the copy of the plan to the State Disaster Management Authority.

In addition to the above, it should provide annual review and update the plan, and furnishing of a status report on its implementation to the State Executive Committee and to the State Government for financing the activities.

Functions of the local authority

Under the directions of the District Disaster Management Authority, a Local Authority (Local Disaster Management Authority) performs its function. The functions include

(i) Officers and employees working under it are trained for disaster management work.

(ii) Ensure the resources meant for disaster management readily available to use in case of any hazardous situation or disaster.

(iii) Ensure all construction projects under its jurisdiction conform to the standards laid down.

(iv) Carryout relief, rehabilitation and reconstruction activities in the affected areas as per State Plan and the District Plan.

(v) Local authority may take such other measures that are necessary for disaster management.

15.7 The National Institute of Disaster Management (NIDM)

The National Institute of Disaster Management consists of a number of members as prescribed by the Central Government. The governing body will be constituted by Central Government from among the members of the National Institute of Disaster Management as prescribed. NIDM exercises powers and discharges the functions prescribed by regulations. NIDM functions within the broad policies and guidelines laid down by National Disaster Management Authority. It will be responsible for:

(i) planning, promoting, training and

(ii) research in the area of Disaster Management,

(iii) documentation and development at national level information base relating to disaster management policies, prevention mechanism and mitigation measures.

The broad functions of the NIDM are :

(i) Develop training modules, undertake research and documentation in disaster management and organize training programmes.

(ii) Formulate and implement human resources development plan covering all aspects of disaster management.

(iii) Provide assistance in national level policy formulation.

(iv) Provide required assistance to the training and research institutes for development of training and research programmes for stake holder (including government functionaries) and undertake training of faculty members of the state level training institutes.

(v) Provide assistance to the State Government and State Training Institutes in the formulation of State Level policies, strategies in disaster management frame work and any other assistance as required (by the State Government or State Training Institutes) for capacity building of stakeholders including government functionaries, civil society members, corporate sector and people's elected reprentatives.

(vi) Preparation of educational materials for disaster management including academic and professional courses.

(vii) Promote awareness among stakeholders including college or school teachers and students, technical personnel and other associated with multihazard mitigation, preparedness and response measures.

(viii) Undertake, organize and facilitate study courses, conferences, lectures, seminars, within and outside the country to promote above said (aforesaid) objects.

(ix) Undertake and provide for publication of journals, research papers and books and establish and maintain libraries in promoting the above said (aforesaid) objects.

(x) To attain above objectives, it will perform all such other lawful things that are conducive to the objective.

(xi) Undertake any other function that may be assigned to it by the Central Government.

Note : NIDM constituted by the Central Government to fix the responsibilities and possible functions of the Institute.

The Central Government provides the NIDM with officers, consultants and other employees as deemed necessary for carrying out its functions.

15.8 National Disaster Response Force (NDRF)

This will be constituted for the purpose of specialist response to a threatening disaster situation or disaster. The NDR Force will be constituted in such a manner and, the conditions of service of the members of the Force, including disciplinary provisions therefor, be such as may be prescribed.

The general superintendence direction and control of the Force lies with the National Disaster Management Authority and the Command and Supervision of the Force will be with an officer appointed by the Central Government and called the Director General of the National Disaster Response Force.

The Central Government constituted a fund called the National Disaster Response Fund to meet a hazardous situation or disaster, which may be given as grants to any person or institution for the purpose of disaster management. The National Disaster Response Fund will be made available to the National Executive Committee towards expenses of emergency response, relief and rehabilitation in consultation with the National Disaster Management Authority.

The Central Government constituted a fund called National Disaster Mitigation Fund for projects exclusively made for the purpose of disaster mitigation while the National Disaster Management Fund will have to be applied by the National Disaster Management Authority.

Similarly, the State Government constituted the funds called :

(i) The State Disaster Response Fund, the District Disaster Response Fund and

(ii) The State Disaster Mitigation Fund, the District Disaster Mitigation Fund. The funds established will be available to the State Executive Committee, the State Disaster Management Authority and to the District Disaster Management Authority.

Emergency Procurement and Accounting

In emergency situation (in any threatening disaster situation or disaster) the National Disaster Management Authority or the State Disaster Management Authority or the District Disaster Management Authority if satisfied for the procurement of provisions or materials or immediate application of resources are necessary for rescue or relief can authorize the concerned department or authority to make the emergency procurement by waving standard procedure of inviting tenders. However a certificate about utilization of provisions or materials by the controlling officer has to be submitted which will be deemed as document or voucher for the purpose of emergency procurement of such provisions or materials.

Offences and Punishments

If any person obstructs in the discharge of duties/functions of authorized government employee or designated person then the person will liable punishment with penalties and even imprisonment. Similarly, it will be as offence in terms of obstruction for false claim of relief, misappropriation of relief funds or materials issuance of false warning, failure of an officer to perform the allotted duty or absenting without permission or his connivance.

15.9 The Disaster Management (National Institute of Disaster Management Rules, 2006)

The compositions of the National Institute of Disaster Management.

It consists of the following members.

(i) ***President:*** The ex-officio, Minister in change of the Ministry or Department of the Central Government having administrative control of disaster management.

(ii) ***Vice-president:*** ex-officio, is the Vice-Chairperson of the National Disaster Management Authority (NDMA)

(iii) One member of the National Disaster Management Authority

(iv) *Chairperson* of the National Disaster Management-executive Committee-ex-officio, Secretary to the Government of India in-charge of Min/ Department of CG having administrative control of disaster management

(v) *Secretary* to the Government India having administrative control of expenditure ex-officio,

(vi) Secretary to Government of India, Ministry of Agriculture ex-officio.

(vii) Secretary to GOI Ministry of External Affairs, ex-officio

(viii) Secretary to GOI Ministry/Department of Health, ex-officio.

(ix) Secretary to GOI Ministry/Department Science and Technology, ex-officio.

(x) Secretary of GOI ministry Department Atomic Energy, ex-officio.

(xi) Secretary to GOI Ministry/Department Space, ex-officio.

(xii) Secretary to GOI Ministry/Department Ocean Development, ex-officio.

(xiii) Secretary/Special Secretary/Additional Secretary/Joint Secretary as the case may be, to GOI dealing with disaster management in the Ministry/Department of CG of disaster management, ex-officio.

(xiv) The Additional Secretary and Financial Advisor/Joint Secretary and Financial Advisor, as the case may be, to GOI dealing with finance of the Ministry/Department of CG of disaster management, ex-officio

(xv) Secretary/Additional Secretary, as the case may be, of the National Disaster Management Authority, ex-officio

(xvi) Director General of the National Disaster Response Force, ex-officio

(xvii) Deputy Chief of Integrated Defence Staff, Doctrine Organization and Training (DOT), HQ Integrated Defence Staff, Ministry of Defence, ex-officio.

(xviii) Two Secretions of State Governments incharge of disaster management.

CG = Central Government

GOT = Government of India

HQ = Head Quarter

Mm = Ministry

Dept. = Department

References

Avalanche and Landslide Forecasting and Mitigation Intromet-2004, May. S.S. Sharma, KC. VSM. And Snehmani

Climatology of India and Neighbourhood Y.P. Rao, K.S. Ramamurthy FMU No. 1.2.

Cyclones, Dr. G.S. Mandal ADGM, IMD (Retd)

Disaster Management : Shifting axis from visible to invisible, Prof. Santhoshkumar, Prof. Policy Planning and Community Issues; National Institute of Disaster Management, New Delhi.

Disaster Management Plan for Cyclones (Draft) Volume-10. DMP at a glance. Centre for Atmospheric Sciences IIT New Delhi-2003.

Draft final Report on Development of Long-term Hazard Planning Management and vulnerability reduction. Action plan in respect droughts, Central Institute for Dryland Agriculture-2004 Santhoshnagar Hyderabad.

Earthquake Risk Mitigation in India, Prof. N. Vinod Chandra Menon, Member NDMA Dr. A.S. Arya, Ph.D. F.NA, F.N, A.E, National Seismic Advisor, Government of India.

Earthquake-NDMA, GOI (WWW. ndmagov.in)

Earthquakes A.K.R. Hemmady-1996 National Book Trust of India.

Environmental Science Purdom and Anderson.

Flood Management-an overview, S.K. Agarwal, Central Water Commission.

Ground studies for pilots, Radio Aids R.B. Underdowns David Cockburn, Blackwell publishing

IMD-Track of cyclonic storms 1891-1970.

Medical Preparedness for Disaster Management, Lt. (Gen) (Dr) J.R. Bhardwaji, Member NDMA.

Origin and Chemical evolution of the Earth G. Voikevich, Mir Publishers Moscow-1988

Paradigm shift in Disaster Management in India, Gen. N.C. Vij (Retd), Vice chairman, NDMA.

Role of Laboratory in Disaster Management, Dr. Shashi Khare, National Institute of Communicable Diseases, New Delhi.

SAARC-Training Seminar-cum workshop on monsoon forecasting, January 8-19, 1990 IMD.

Satellite Meteorology R.R. Kelkar, B.S. Publications, Hyderabad.

Storm surges in the Bay of Bengal "J.R. Met Society 100, 437-449, Das, P.K, M.C. Sinha and V. Balasubramanyam 1974.

Strengthening Disaster Response in India, K.M. Singh, Member NDMA.

Summer Norwesters and Andhis, and large scale convective activity over peninsular and central parts of the country. Srinivasan, K. Ramamurthy and Y.R. Nene.

The Science of Weather and Environment, Navale Pandharinath, B.S Publications Hyderabad.

Tropospheric Chemistry and Air Pollution WMO TN. 176 WMONO 583

Urban Flood Disaster Management, M.S.R. Reddy, Member NDMA.

Western Disturbances and associated Weather FMU No. 111, Y.P. Rao, V. Srinivas.

WMO No. 113 TP 50 Geneva-Weather and Food.

WMO No. 143 TP 67 Geneva 1964, Weather and Man.

WMO No. 183 TP 92 Geneva 1966, World Weather Watch.

WMO No. 204 TP 107 Geneva 1996, Weather and Water.

WMO No. 220 TP 117 Geneva 1967, Harvest from Weather.

WMO No. 735 Geneva 1990, the Atmosphere of the living planet Earth.

WMP No 624 Geneva, 1984, Meteorology Aids Food Production.

World's water MI Lvovich, Mir Publishers Moscow-1973

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