# UNIT 1 UNDERSTANDING NATURAL DISASTERS

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* 1. **INTRODUCTION**

Disasters can arise from both natural and human causes. They cannot be predicted, and once they occur, they need to be dealt with in a mature, tactful and responsible manner. A lot of on-the-spot decisions need to be taken and relief activities need to be organized and coordinated. In this unit, you will learn about various disasters and their impact on the living beings and the environment.

## UNIT OBJECTIVES

After going through this unit, you will be able to:

* + - Discuss the meaning of disasters and its various types
    - Describe the causes and consequences of floods, draughts, and cyclones
    - Discuss the different types of geographical disasters
    - Explain heat and cold wave
    - Discuss the impact of climate change such as global warming, rise in sea level and ozone depletion

## DISASTER AND ITS TYPES

A disaster is a mishap or hazard which causes huge loss of life and property and disrupts the balance of the economy. It is a tragic event with drastic consequences for living beings as well as social and individual development. A disaster can be caused by either natural or man-made factors. Both these factors need to be taken care of to prevent a disaster or lessen its impact. Disasters also arise due to inefficient management of risks. If a safety net is devised to address the potential risks, it would lead to reduction in damages triggered by disasters. Developing countries are more vulnerable to disasters.

An environmental disaster is a mishap or hazardous event which directly influences the environment, bringing serious alterations in the same. These alterations become the root cause of

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failures or damages that would occur following a disaster. Since the environmental disasters have direct impact on the environment, they could stunt economic growth, lead to socio-economic failures, deteriorate environmental conditions or threaten life.

Apart from heavy immediate effects or damages, the environment also suffers from the long-term consequences of a disaster, which can prove to be costly. As these long-term effects alter the ecosystem, they can lead to more deaths over the next few years by giving rise to certain diseases and ailments. They may also hinder tree growth or stop cultivation in a particular area, almost instantly.

When a disaster strikes, the economy needs to divert all its resources towards the affected areas to try and save its elements from damage to the maximum extent possible. However, it takes high costs to recover the elements which been lost in or damaged by the disaster.

Given below are some of the disasters which had taken place across different countries.

#### Agricultural

* Salinity in Australia
* Salinization of the Fertile Crescent
* The Dust Bowl in Canada and the United States (1934–1939)
* The Great sparrow campaign: sparrows were eliminated from Chinese farms, which caused locusts to swarm the farms and contributed to a famine which killed 38 million people
* Africanized bees, known colloquially as ‘killer bees’
* Mismanagement of the Aral Sea
* ‘Dirty dairying’ in New Zealand

#### Biodiversity

* Introduction of the Nile perch into Lake Victoria in Africa, decimating indigenous fish species
* The Saemangeum Seawall
* Emerald Ash Borer
* Environmental threats to the Great Barrier Reef
* 2006 Zakouma elephant slaughter
* Invasive species in New Zealand
* The loss of biodiversity of New Zealand

#### Human health

* Introduction of the Bubonic Plague (the Plague of Justinian) in Europe from Africa in the 7th century resulting in death of about 60 per cent (100 million) of the population.
* Introduction of the Bubonic Plague (the Black Death) in Europe from Central Asia in the 14th century resulting in the death of up to 60 per cent (200 million) of the population and recurring until the 18th century.
* Introduction of infectious diseases by Europeans causing death of indigenous people during European colonization of the America.
* Health effects arising from the September 11 attacks

#### Industrial

* Minamata disease—mercury poisoning in Japan (1950s and 1960s)
* Ontario Minamata disease in Canada
* Itai-itai disease, due to cadmium poisoning in Japan
* Love Canal toxic waste site
* Seveso disaster (1976), chemical plant explosion, caused highest known exposure to 2,3,7,8- tetrachlorodibenzo-p-dioxin (TCDD) in residential populations
* Bhopal disaster (3 December 1984, India)
* Sandoz chemical spill into the Rhine river (1986)

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#### Air

* The Donora Smog of 1948 in Donora, Pennsylvania in the United States
* The Great Smog of 1952, which killed 4,000 Londoners
* The 1983 Melbourne dust storm
* The 1997 Southeast Asian haze
* The 2005 Malaysian haze
* Yokkaichi asthma in Japan

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#### Land

* + The Dust Bowl of Canada and the United States
  + Contaminated soils in Mapua, New Zealand due to the operation of an agricultural chemicals factory
  + Basin F, a disposal site in the United States for contaminated liquid wastes from the chemical manufacturing operations of the Army and its lessee Shell Chemical Company
  + 2006 Côte d’Ivoire toxic waste dump

#### Water

* + Sandoz chemical spill, severely polluting the Rhine in 1986
  + Selenium poisoning of wildlife due to farm runoff used to create Kesterson National Wildlife Refuge, and the artificial wetland
  + The Jiyeh Power Station oil spill in the Mediterranean region
  + Coral bleaching
  + The artificial Osborne Reef off the coast of Fort Lauderdale, Florida in the United States
  + Dumping of conventional and chemical munitions in Beaufort’s Dyke, a sea trench between Northern Ireland and Scotland
  + Marine debris

#### Causes of Environmental Disasters

The common causes of environmental disasters are as follows—haphazard population growth, poor planning and environmental deterioration.

* + **Haphazard population growth:** Population explosion is a disaster in itself. To enable the growing population lead a healthy and satisfied life, it is necessary to fulfil its essential needs such as food, housing, employment, educational and health facilities. However, governments, particularly in developing countries, find it difficult to fulfil these needs of all their citizens. The non-fulfilment of essential human needs makes developing countries more vulnerable to natural disasters.
  + **Poor planning:** Planners and developers have not been able to plan effectively to take care of the essential needs of the growing population. It is for this reason that more and more people have been left unprotected and vulnerable to disasters.
  + **Environmental deterioration:** Gradual deterioration of the environment and the tools that nature has provided us as protection against disasters has also emerged as a major cause of disasters. If natural remedies for and protections against disasters are removed, then man-made protections need to be provided.

The intensity of a disaster in an area is inversely proportional to the natural and man-made protection the area has, and thus it becomes necessary to ensure that such a protection remains intact.

**1.2.1 Types of Disasters**

Broadly, disasters have been categorized as natural and man-made disasters on the basis of their causes. The cause-based disaster classification facilitates altering or stopping altogether such activities that lead to a disaster. Taking such steps would help in reducing the impact of a disaster even if it strikes. The magnitude of a disaster also decides the kind of damage it would cause and the steps required to avoid or lessen the damage. Therefore, disasters are also classified on the basis of their magnitude. Disasters

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which cause large-scale loss are called major disasters while those which do not cause heavy devastation are called minor disasters.

#### Natural disasters

Natural disasters are those hazardous events which occur naturally. They are caused by sudden changes in the environment. Natural disasters include earthquakes, cyclones, volcanic eruptions, forest fires, tornadoes. They can cause heavy loss of life and damage to physical structures, leading to huge financial losses. The magnitude of these disasters may vary. Every area is susceptible to its own set of natural disasters and thus it is important to take preventive measures accordingly. For example, the areas where tectonic plates are too close would be susceptible to earthquakes, whereas areas near volcanic formations would be more likely to suffer from volcanic eruptions. Governments must make necessary arrangements to protect people from area-specific natural disasters. This would ensure minimum damage. One effective way to reduce the impact of disasters is to use latest technology. For example, infrastructure and buildings can be strengthened to withstand natural disasters by using new construction technology and materials. Natural disasters are also known as geographical disasters, which are discussed ahead in detail.

Natural disasters can be of various kinds, the most prominent of which, have been listed as follows:

* **Land-movement disasters:** These kinds of disasters can further be classified into the following: o Avalanches
  + Earthquakes
  + Landslides and mudflows
  + Volcanic eruptions
* **Water disasters:** The various water disasters are:
  + Floods
  + Limnic eruptions
  + Tsunamis
* **Weather disasters:** The disasters caused by weather disturbances are:
  + Blizzards
  + Cyclonic storms
  + Droughts
  + Hailstorms
  + Tornadoes

#### Natural fires (like forest fire)

* **Health and diseases:** The hazards that can be caused due to health problems are as follows:
  + Epidemic
  + Famine

#### Man-made disasters

As is clear from their name, man-made disasters are caused by human intervention or activities. These may be dangerous to life, physical elements or economic components of the environment and the resultant damage could prove disastrous for the whole economy. Man-made disasters occur due to a variety of reasons. One reason is the hardened human attitudes and approaches to view things and situations in certain ways. These lead to man-made disasters such as big crimes, arson, civil disruption, war, and terrorism. Another type of man-made disasters includes those hazardous events which are caused by technological faults or breakdowns. These disasters include industrial fires, structural collapse, chemical or gaseous release and accidents involving transport means such as cars, planes, ships, trains or space shuttles. Better technology, sufficient precautions and careful working with technology are the only steps which can prevent or lessen the damage from technology-related disasters.

With the growing climatic changes and unstable landforms all over the world, human beings are

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becoming more vulnerable to disasters and hazards. The drastic changes in the weather patterns have also led to a number of occurrences of the disasters. Technological advancements and the growing population density have also contributed to the world becoming increasingly unsafe.

#### Anthropogenic disasters

Anthropogenic disasters are threats that have an element of human intent, negligence or error or have witnessed failure of a man-made system. They are also known as man-made disasters since they are the result of a failing or error on the part of humans.

Anthropogenic disasters can be classified into the following categories:

* **Sociological hazards:** The disasters that are caused due to sociological factors are: o Crime
  + Arson
  + Civil disorder
  + Terrorism
  + War
* **Technological hazards:** Technological advancements can lead to the following disasters:
  + Industrial hazards
  + Structural collapse
  + Power outage
  + Fire
* **Hazardous materials:** The chemical substances that can cause disasters are as follows:
  + Radiation contamination
  + CBRNs

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**Check Your Progress**

1. Define disaster.
2. What is an environmental disaster?
3. Mention the two types of disasters.
4. What is meant by anthropogenic disasters?
   1. **FLOODS**

Floods are caused by too much rain or water in a location, when the excess water surpasses the limits of its confines. Generally, occurrences of floods are more frequent in low-lying lands. Some plains may periodically flood; known as a flood plain. Ancient Egypt relied on these floods for agriculture. Floods present a significant danger with enough force to sweep away massive objects such as houses, cars and trees.

Many reasons could lead to a flood, including prolonged rainfall from a storm, thunderstorms, rapid melting of snow, overflowing rivers from excess rain, bursting of man-made dams or levees. Monsoon rainfalls can also cause floods, such as in Bangladesh due to extended periods of rainfall. There is a growing feeling that the incidence and intensity of floods has grown alarmingly over the years. A major cause is the increased encroachment of flood plains because of development and population pressure. The damage caused by floods can at best be minimized and not altogether eliminated or in other words, there can really be no such thing as ‘fool proof protection’ or ‘absolute flood control’ for all magnitudes of floods. The concept of flood management, therefore, aims for such planned measures which ensure profitable and economic utilization of the flood plains for the benefit of mankind and at the same time emphasizing that during high floods, there is no severe damage as far as possible. An essential part of a disaster preparedness plan is education for those who may be threatened by disaster.

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#### Types of Floods

1. **Flash floods:** If extremely heavy rainfall occurs for some time and the ground loses its absorbing capacity then this type of flood generally takes place. These types of floods last for a short duration with a relatively high peak discharge.
2. **River floods:** If due to heavy rain the water level of river flows much above the danger mark, this type of flood occurs.
3. **Storm surge:** Low-pressure storm associated with strong wind causes the sea level to rise suddenly. If strong winds are directed towards the shore, they drive the seawater onto the land. The storm that produces the surge can also give rise to heavy rainfall, resulting in coastal areas being subjected simultaneously to flooding due to incessant rains and seawater.

#### Factors that cause floods

Some of the factors responsible for causing floods are listed below:

* + - Rivers in spate due to heavy and continuous rain for a long period such as few days or weeks
    - Flowing of water much above its danger level due to inadequate capacity within the banks of the river to contain high flows
    - Breaching of embankments
    - Breaching of water reservoir
    - Storm surges
    - Snowmelt
    - River bank erosion and silting of riverbeds
    - Landslides leading to obstruction of flow and change in the river course
    - Poor natural drainage
    - Flow retardation due to tidal and backwater effects
    - Deforestation
    - Cyclone
    - The resistance to the flow of water due to various reasons

Among all the natural disasters affecting India, frequent river floods are the most devastating, which cause maximum damages of life and property. Total flood prone areas in India are 40 million hectares, out of which 9.4 per cent falls in Assam. Besides draught, about 90 per cent damages to crops are only due to flood.

**Check Your Progress**

1. What are the three types of floods?
2. List some of the factors that cause floods.

## DRAUGHTS

A drought is an extended period of months or years when a region notes a deficiency in its water supply. Although droughts can persist for several years, even a short, intense drought can cause significant damage and harm the local economy.

#### Causes

Generally, droughts occur when a region receives consistently below-average precipitation. It can have a substantial impact on the ecosystem and agriculture of the affected region. This global phenomenon has a widespread impact on agriculture. Generally, rainfall is related to the amount of water vapour in the atmosphere, combined with the upward forcing of the air mass containing that water vapour. If either of these are reduced, the result is a drought. This can be triggered by an above average prevalence of high pressure systems, winds carrying continental, rather than oceanic air masses (ie. reduced water content), and ridges of high pressure areas form with behaviours which prevent or restrict the developing of

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thunderstorm activity or rainfall over one certain region. Oceanic and atmospheric weather cycles such as the El Niño-Southern Oscillation (ENSO) make drought a regular recurring feature of the Americas along the Pacific Coast and Australia.

Human activity can directly trigger exacerbating factors of droughts such as over-farming, excessive irrigation, deforestation, and erosion adversely impacting the ability of the land to capture and hold water. While these tend to be relatively isolated in their scope, activities resulting in global climate change are expected to trigger droughts with substantial impact on agriculture throughout the world, especially in developing nations. Overall, global warming will result in increased world rainfall. Along with drought in some areas, flooding and erosion will increase in others. Paradoxically, some proposed solutions to global warming that focus on more active techniques, solar radiation management through the use of a space sunshade for one, may also carry with them increased chances of drought.

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*Dry Earth as a result of drought (Source: Wikipedia)*

#### Consequences

Periods of drought can have significant environmental, agricultural, health-related economic and social consequences. The effect varies according to vulnerability. For example, subsistence farmers are more likely to migrate during drought because they do not have alternative food sources. Areas with population that depend on subsistence farming as a major food source are more vulnerable to drought-triggered famine. Drought is rarely, if ever, the sole cause of famine; socio-political factors such as extreme widespread poverty play a major role. Drought can also reduce water quality, because lower water flows reduce dilution of pollutants and increase contamination of remaining water sources. A few common consequences of drought include:

* Diminished crop growth or yield productions and carrying capacity for livestock
* Dust bowls, themselves a sign of erosion, further erode the landscape
* Dust storms occur when drought hits an area suffering from desertification and erosion
* Famine due to lack of water for irrigation
* Habitat damage, affecting both terrestrial and aquatic wildlife
* Malnutrition, dehydration and related diseases
* Mass migration, resulting in internal displacement and international refugees
* Reduced electricity production due to insufficient available coolant for power stations and reduced water flow through hydroelectric dams
* Shortages of water for industrial users
* Social unrest
* War over natural resources, including water and food
* Wildfires, such as Australian bushfires, are more common during times of drought

## CYCLONES

A tropical cyclone is a storm system characterized by a large low-pressure centre and numerous thunderstorms that produce strong winds and heavy rain. Tropical cyclones feed on heat released when moist air rises, resulting in condensation of water vapour contained in the moist air. The term ‘tropical’

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refers to both the geographic origin of these systems, which form almost exclusively in tropical regions of the globe, and their formation in maritime tropical air masses. The term ‘cyclone’ refers to such storms’ which are cyclonic in nature, with counterclockwise rotation in the Northern Hemisphere and clockwise rotation in the Southern Hemisphere. Depending on its location and strength, a tropical cyclone is referred to by names such as hurricane, typhoon, tropical storm, cyclonic storm, tropical depression, and simply cyclone. In the Atlantic and northern Pacific, the storms are called ‘hurricanes,’ after the Caribbean god of evil, named Hurrican. In the northwestern Pacific, the same powerful storms are called ‘typhoons.’ In the southeastern Indian Ocean and southwestern Pacific, they are called ‘severe tropical cyclones’. In the northern Indian Ocean, they’re called ‘severe cyclonic storms.’ In the southwestern Indian Ocean, they’re just ‘tropical cyclones.’



*Hurricane Isabel (2003) seen from the International Space Station (Source: Wikipedia)*

#### Why do cyclones occur?

* When warm air rises from the earth and condenses to form clouds, a great amount of heat is released. The combination of this heat and moisture often leads to thunderstorms, from which a tropical storm can develop.
* The trigger for most Atlantic hurricanes is an easterly wave, a band of low pressure moving westwards, which may have begun as an African thunderstorm.
* Typhoons in the Far East and Cyclones in the Indian Ocean often develop from a thunderstorm in the equatorial trough. During the hurricane season, the Coriolis Effect of the Earth’s rotation leads to the winds in the thunderstorm spinning in a circular motion.

#### Effects

While tropical cyclones can produce extremely powerful winds and torrential rain, they are also able to produce high waves and damaging storm surge as well as spawning tornadoes. They develop over large bodies of warm water, and lose their strength if they move over land. This is why coastal regions can receive significant damage from a tropical cyclone, while inland regions are relatively safe. Heavy rains, however, can produce significant flooding inland, and storm surges can produce extensive coastal flooding up to 40 kilometres from the coastline. Although their effects on human population can be devastating, tropical cyclones can also relieve drought conditions. They also carry heat and energy away from the tropics and transport it toward temperate latitudes, which make them an important part of the global atmospheric circulation mechanism. As a result, tropical cyclones help to maintain equilibrium in the Earth’s troposphere, and a relatively stable and warm temperature worldwide.

Tropical cyclones out at sea cause large waves, heavy rain, and high winds, disrupting international shipping and, at times, causing shipwrecks. Tropical cyclones stir up water, leaving the air cooler behind them, which causes the region to be less favourable for subsequent tropical cyclones. On land, strong winds can damage or destroy vehicles, buildings, bridges, and other outside objects, turning loose debris into deadly flying objects. The storm surge, or the increase in sea level due to the cyclone, is

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typically the worst effect from tropical cyclones, historically resulting in 90 per cent of tropical cyclone deaths. The broad rotation of a tropical cyclone, and vertical wind shear at its periphery, spawns tornadoes.

Over the past two centuries, tropical cyclones have been responsible for the deaths of about 1.9 million people worldwide. Large areas of standing water caused by flooding lead to infection, as well as contributing to mosquito-borne illnesses. Crowded evacuees in shelters increase the risk of disease. Tropical cyclones significantly interrupt infrastructure, leading to power outages, bridge destruction, and the hampering of reconstruction efforts.

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**Check Your Progress**

1. Define drought.
2. What is a cyclone?
   1. **NATURAL/GEOGRAPHICAL DISASTERS**

Natural/geographical disasters have already been discussed in the earlier section. In this section, we will discuss the different types of geographical disasters.

### Earthquakes

Earthquakes are caused by a sudden shift or movement deep underground in the Earth’s tectonic plates, causing the Earth’s crust to shake violently, with vibrations varying in magnitude. On the surface, we see this as the shaking of the ground, causing damage to poorly built structures. Earthquakes occur unpredictably along fault lines and are capable of killing thousands of people. The most powerful earthquakes can destroy even the best built structures. Earthquakes can also cause other disasters including tsunamis and volcanic eruptions. Seismometers can detect the strength of an earthquake. In the past, seismologists used to estimate earthquake intensity using the Richter scale devised by Charles Richter. However, today, the moment magnitude scale, which is an improved version of the Richter scale, is used by seismologists to measure the size of earthquakes in terms of the energy released.



*Picture taken in the aftermath of the 1964 Alaska Earthquake, the second most powerful earthquake in recorded history (Source: Wikipedia)*

An earthquake has point of origin underground called ‘focus’. The point directly above the focus on the surface is called the ‘epicentre’. Earthquakes by themselves rarely kill people or wildlife. It is usually the secondary events that they trigger, such as building collapse, fires, tsunami (seismic sea waves) and volcano. Many of the disasters related to an earthquake are actually human disasters and

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could be avoided by better construction, safety systems, early warning and evacuation planning, the term unnatural disaster is not unwarranted.

Some of the most recent and disastrous earthquakes in recent times are:

* The 2011 Japanese Earthquake, registering a magnitude of 9.0, triggered a massive tsunami.

Over 15,000 people were killed in the disaster.

* The 2010 Haiti Earthquake, registering a magnitude of 7.0, killed an estimated 100,000-150,000 people.
* The 2004 Indian Ocean earthquake, the third largest earthquake in recorded history, registered a moment magnitude of 9.3. The huge tsunami triggered by the earthquake cost the lives of at least 229,000 people in 14 countries.
* The 2001 Gujarat Earthquake, measuring 7.7 on the moment magnitude scale, killed at least 20,000 people.

### Landslides

Landslides are an extremely frequent geological event. They occur when masses of rock, earth, or debris move down a slope, caused by disturbances in the natural stability of a slope. They are defined as downslide of soil and rock, which happen due to natural phenomena or man-made actions. There are various kinds of movements like falls, slides, topples, lateral spreads, and flows. Landslides generally occur in hilly terrains. In India, they usually occur in the Himalayan region as the Himalayas are geologically young and susceptible to earthquakes and intensive soil erosion. Landslides also occur in the Western Ghats, Eastern Ghats and the Nilgiri hills with lesser frequency and intensity. Over the years, due to increasing human activity, the incidences of landslides have shown a disturbing upward trend of occurrence with higher damage to life and property.

Landslides take place when there are disturbances in the natural stability of a slope. They can accompany heavy rains or follow droughts, earthquakes, or volcanic eruptions. Mudslides develop when water rapidly accumulates in the ground and results in a surge of water-saturated rock, earth, and debris. Mudslides usually start on steep slopes and can be activated by natural disasters. Areas where wildfires or human modification of the land have destroyed vegetation on slopes are particularly vulnerable to landslides during and after heavy rains.

Landslides are often secondary effects of heavy storms, volcanic eruptions and earthquakes. They cause high mortality, killing many thousands by burying villages and hillside houses, by sweeping vehicles off the road into ravines. Death mostly results from trauma and suffocation by entrapment under debris. Significant damage to property is also caused like a breakdown in the water systems, constructions, and lines of communication, and damaged crops.

Factors that cause landslides are often man-made, like intense deforestation, soil erosion, construction of human settlement in landslide prone areas, roads or communication lines in mountain areas, buried pipelines, among others.

Apart from landslides there are also:

* + - * **Mudslides:** Debris flows, also known as mudslides, are a common type of fast-moving landslide that tends to flow in channels.
      * **Lahars:** A lahar is a volcanic mudflow or landslide. The 1953 Tangiwai disaster was caused by a lahar, as was the 1985 Armero tragedy, in which the town of Armero was buried and an estimated 23,000 people were killed.

### Avalanches

Avalanche can be defined as a swift flow of snow down a slope, which may have been triggered naturally or due to human activity. An avalanche typically happens in mountainous regions, and also brings down air and water along with snow. A strong enough avalanche can drag down with itself ice, and large objects like rocks, trees, and other material down the slope. While rock slides, mudslides, serac collapses and rock avalanches are all caused by icefalls, an avalanche is different from them because it is primarily composed of flowing snow. In the mountains, avalanches are one of the commonest threats faced by life and property, mainly because they are rapid and have enough power to carry down other objects with them.

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Usually, avalanches are categorized according to their size and other shape-related characteristics and rated according to the destruction they are capable of causing. Some traits of an avalanche used to categorize it include nature of the failure, sliding surface, type of snow involved, propagation mechanism of the failure, reason for trigger of avalanche, direction, slope elevation and slope angle. Avalanche size, mass, and destructive potential are rated on logarithmic magnitude scales, which usually consist of 4 to 7 categories, which vary with the system of observation being used and/or the region in which forecast is being done.

#### Classification and Terminology

There are some elements that are common to all avalanches, such as a trigger, a starting point of origin, the path along which the avalanche goes, a point where the avalanche stops and the debris that an avalanche collects along its way down, along with the mass of snow. Other things common to all avalanches are the failure layer along which the avalanche moves and the bed surface which lies at the original starting point of the avalanche. In most avalanches, the two things — failure layer and bed surface— are the same. Besides these, a slab avalanche also has a crown fracture at the top of the starting point, flank fractures on the sides of the start zones, and a shallow staunch fracture at the bottom of the start zone. Crown and flank fractures can be defined as vertical walls in the snow which distinguish the snow falling down the slope from snow remaining on the slope.

The avalanche is morphologically classified by studying the nature of the failure of the snowpack. For instance, a slab avalanche is triggered when some kind of surplus load leads to a failure of a slab lying over a weak layer of snow; the failure occurs when a fracture is formed in the slab. Similarly, loose snow, point release, and isothermal avalanches get triggered when some type of stress generates a shear failure in a weak interface, which may be at the base or within the snow pack. In case of failure at the base, it is known as a full depth avalanche. When snow is lifted by the wind and funnels into a steep drainage from the top zone of the drainage, a spin drift avalanche is triggered.

On steep terrains, loose snow avalanches are the most common because freshly fallen snow has low density and disintegrates easily. In this kind of avalanche, the avalanche starts small, from a point and then gains in size as it progresses down the slope, eventually taking on a teardrop shape, which is a complete contrast to the slab avalanche.

Slab avalanches are the most powerful and therefore most destructive—they cause nearly 90 per cent of deaths caused by avalanches. These avalanches take place when a slab of snow forms as falling snow is deposited on a lee slope by the wind or when a large amount of loose snow moves. The moment a failure occurs in a weak layer, the fracture extends very rapidly over a very large area, such that a snow slab, hundreds of meters in length and equally thick, begins to move almost immediately.

The wet snow avalanche or isothermal avalanche is triggered when a snowpack is saturated by water. Such avalanches also spread forward after they originate from a single point. If the water content is high, the avalanche is categorized as a slush flow and can move down largely shallow slopes. As far as the power and speed of an avalanche is concerned, a powder snow avalanche is known to travel with a speed upwards of 300 km/h, and be of 10,000,000 tonnes of volume. They are so powerful that they can travel over largely flat surfaces or even uphill. This kind of avalanche is formed of a powder cloud that is a result of an avalanche accelerating over a sudden change in slope, for example, a cliff band, leading the snow to mix with air. This chaotic suspension of snow powder turns into a gravity current.

#### Terrain

Terrain plays an important role in the formation and trigger of an avalanche in three ways—first, the evolution of the snowpack is determined by the meteorological surroundings of the snow pack, which are affected by the terrain. Second, the stability of the snowpack is determined by the ground composition and geometry of the slope, again functions of the terrain. Third, the down slope angle and direction of the terrain determine the route and impact of an avalanche.

An avalanche can happen on a slope only if the slope is capable both of retaining snow and also at an angle which allows snow to accelerate once it is triggered. Besides this, it also depends on the quality of the snow—whether it is ductile and has optimum shear strength, which in turn depends on the moisture content and temperature of the snow. If the snow is dry and very cold, with low shear strength and ductility, it will remain bonded only to slopes only with a lower angle slopes; and on the other hand, wet and warm snow, that has high shear strength and ductility will bound to very steep slopes. It is seen

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in coastal mountains, for instance, the Cordillera del Paine region of Patagonia, that deep snowpacks remain collected on vertical, and overhanging, rock faces.

Snow which is saturated with moisture so much that it becomes slush will flow better on shallow angled terrain; and a dense snow pack will not flow down really steep slopes, for instance, the snowpack in the Chugach Mountains of Alaska.

Snow packs that exist on slopes that are regularly exposed to the sun are also affected by the sunshine. During the day, the snow melts to a certain extent and then refreezes during nighttime. This daily cycle stabilizes the snow pack. Very strong sunshine and very cold nights lead to formation of surface crusts during the night and unstable isothermal snow during daytime. Slopes that are protected from the wind collect more snow, wind slabs and cornices which are likely triggers of avalanches when disturbed. On the other hand, a slope exposed to strong winds will not have collected snow.

The point where the avalanche originates needs to be steep enough to allow it to gain speed. Moreover, concave slopes are comparatively more stable than convex slopes, due to the difference between the tensile and compressive strength of snow layers. The nature of ground surface (composition and structure) that lies underneath the snow pack affects the stability of the snow pack, and may either provide it strength or make it weak. Big trees that have strong roots can stabilize a snow pack; and big, heavy rocks and sparse vegetation leads to weak areas deep inside the snow pack, owing to strong temperature gradients. Full depth avalanches are those which clean out a slope of snow almost entirely. They are mostly seen on slopes that have a smooth surface, like rock slabs or grass.

An avalanche usually follows the drainage path that already exists on a slope, which is very similar to a summertime watershed. The drainage routes are usually demarcated by natural vegetation boundaries in places where previous avalanches have led to low vegetation growth. Deliberately created drainage routes, such as the avalanche dam on Mount Stephen in Kicking Horse Pass, are meant to protect people and property, by naturally redirecting avalanches, which are common in the area. Large debris deposits that result from avalanches tend to rest in depressions in the ground, such as river beds and gullies.

There is less likely to be an avalanche if the slope is less than 25 degrees or steeper than 60 degrees, or if the slope is regularly exposed to sunlight or strong winds. Avalanches caused by human activity are most likely when the snow lies at an angle between 35 and 45 degrees. It has been observed that the critical angle, where human-triggered avalanches are most common, is 38 degrees. When human activity is only restricted to recreational ones, the danger is higher on steeper slopes. Usually it has been observed that if a slope is steep enough to ski and flat enough to hold snow, can potentially cause an avalanche, irrespective of its angle.

#### Weather

Avalanches take place only in a standing snow pack. It is normal in winters at high altitudes or snow to accumulate into a snow pack. The formation of a snow pack is an occurrence that is orchestrated by many meteorological conditions coming together with very narrow margin of error. The critical conditions include heating by the sun, radiational cooling, vertical temperature gradients in standing snow, snowfall amounts and snow types. Surprisingly, mild winters lead to formation of snow packs and very cold, extremely windy conditions lead to weakening of snowpacks.

When the temperature is close to 0 degrees, the freezing point for water, or even when the sun is mild, the free-thaw cycle is gentler than it is in harsher weather. During the free-thaw cycle, the snow pack is strengthened during the freezing stage and weakens when the thaw stage comes on. In such conditions, when there is a sudden elevation in temperature where it goes much higher than 0 degrees, an avalanche may be triggered due to a thaw. This happens in the spring season when temperatures rise.

If temperatures are consistently very low for a sustained period, it may lead to either stabilizing or destabilizing of a snow pack. When the base temperature of a snow pack is close to freezing, cold winds hitting the snow surface lead to a temperature gradient. However, if the snow pack is lying on top of a glacier, the temperature at its base will be much less than freezing point.

If the temperature gradient inside the snow pack is more than 10°C change per vertical meter for more than a day, a depth hoar would be generated in the snow pack, because moisture will move from the bottom to the top of the temperature gradient. The depth hoar causes a fundamental weakness in the

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snow pack and leads to grains being formed. If a slab lying on this weak portion is destabilized, an avalanche will be triggered.

Any reasonably strong wind will lead to quickly accumulation of snow on slopes that are downwind and sheltered. At the same time, a favorable angle of wind pressure leads to stabilization of slopes. A brittle and unstable structure which is not strongly bound to the surface it rests on is known as a wind slab. A strong wind can move this structure and lead to an avalanche in two ways—top- loading or cross-loading. Top-loading is said to happen when snow is deposited on a slope perpendicular to the fall-line and cross-loading is said to happen when snow is deposited parallel to the fall line.

The occurrence of avalanches is most likely during or just after snowstorms and rainstorms. Fresh snowfall destabilizes existing snow pack, due to the weight as well as because new snow has not had any time to bond itself to existing snow layers. Similarly, rain also causes instability in the snow pack by weighing down on the snow and reducing the friction that holds the various layers of snow together, thus triggering an avalanche.

##### Triggers

Avalanches are never random events. They always occur due to an external stress trigger on the snowpack. A few common natural triggers are heavy rain or snow, sudden rise in temperatures, and sudden impacts due to rock falls or ice falls. A more slow-moving cause is the cracks and fractures that develop over time despite constant temperatures and pressures. These cracks develop due to the gradual downward creep of the snow pack. Some human triggers are skiing, engineered explosions and snowmobiles. The stress trigger of an avalanche may be localized or remote. Common localized trigger are rocks that become warm due to sunlight. A remote trigger is when there is some transfer of stress from the slab to the origin and this initiates a fracture which propagates rapidly and triggers an avalanche. The triggering of an avalanche is always critical phenomena.

##### Prevention

Avalanches may be prevented to a certain extent. Over time, humans have come up with ways to mitigate the destructive power and incidence of avalanches. There are largely two kinds of techniques used:

1. Active techniques: Under this method, small artificial avalanches are triggered which are obviously less harmful than big avalanches. This is done by disturbing the snow deliberately using explosives like bombs or shelling or even howitzer rifles.
2. Passive techniques: Under this method, basically, snow is either slowed down, stopped or diverted or prevented from moving in large masses that could cause damage. One of the ways to block snow is to build a cemented structure blocking it.

Some classifications of avalanche control structures are:

* + Snow retention structures like snow racks, avalanche snow bridges and snow nets. These are all used in the upper path of likely avalanche routes.
  + Avalanche barriers: The key to an avalanche barrier is a strong steel wire mesh, which is extended across the slope. The support provided by the mesh helps prevent creeping within the snowpack. The avalanche is thus stopped at the starting point itself and minor snow shifts remain harmless. The stress caused by the snow pressure is absorbed into the snow nets and taken away over the swivel posts and anchor ropes into anchor points.
  + Snow redistribution structures (wind baffles, snow fences)
  + Snow deflection structures: These are used to restrict and redirect the moving snow within the avalanche path. The redirecting should be gradual and not sharp because if it is sharp they might be overpowered by the avalanche.
  + Snow retardation structures like snow breakers are usually used in small slope portions of the avalanche path, to promote its slowdown naturally
  + Snow catchment structures
  + Direct protection of important objects and structures, such as using snow sheds (avalanche sheds)

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* + Avalanche dams, ditches, earth mounds, terraces, etc. may also help in redirecting, slowing down, and engineered collection of snow. Other passive methods are:
    - Reforestation on the natural tree line because forests are the best means of retaining, redistributing, retarding and storing snow
    - Snow compaction is done mostly in ski resorts using mechanical equipment like snow groomers

#### Search and rescue equipment

People who have to go to avalanche-prone areas use certain equipment that would help rescue them in case of an avalanche. This equipment includes:

* **Avalanche cords:** These are the oldest and simplest equipment used in areas with heavy snow. They were used before beacons came into normal use. A 10-meter long red avalanche cord is attached to the belt of the skier and drags along behind the person. If the person gets caught in an avalanche, they can be traced using the red, easily visible cord. The cord is marked at every meter so that the rescue personnel know the distance to the victim. However, this is not an adequate or foolproof safety technique and no record is there of any live recoveries made using this equipment.
* **Beacons:** These emit beeps that can be traced using radio signals. They are held by every member of a party and can be used to trace a buried victim up to 80 meters away. Individuals using beacons need to be trained in their use before using them in real-life situations. The newer models also help to track a victim by indicating direction and distance from victim.
* **Probes:** These can be used to penetrate the snow up to several meters to locate buried victims. They are portable and collapsible. In case multiple individuals are buried, probes are used to decide who would be rescued first because victims in shallow snow have a better chance of survival. Probes alone may not be a very quick technique of reaching the buried victims, but if used in conjunction with beacons, they can prove to be very effective.
* **Shovels:** After an avalanche comes to rest, it becomes a hard mass of compressed snow and shovels need to be used to dig victims out. Shovels can also be used to detect hidden dangers packed in dense snow and for digging snow pits.
* **Witnesses as rescuers:** Witnesses of an avalanche should remain aware and alert and inform authorities in case they know of someone who has been buried, especially witnesses from the same party as the victim/s. A quick rescue in case of an avalanche is essential because the human body cannot stay warm enough for survival for very long when buried in snow. Sometimes just a couple of minutes can be the deciding factor between life and death for a buried victim. This is why, people who are travelling to a snow-bound mountainous area should be trained in basic life skills as preparation.

Victims who are buried in shallow snow or partially buried can be located through just visual scanning and should be provided with immediate first aid as soon as they are pulled out. Some common first aid required by avalanche victims is related to breathing, circulation/pulse, arterial bleeding, spinal injuries, fractures, shock, hypothermia, internal injuries, etc.

#### Safety in avalanche terrain

* **Terrain management:** This entails minimizing the risk factor faced by an individual while traveling in avalanche terrain by travelling only on selected slopes. Some key things to be kept in mind are—slopes should not be undercut because this removes the support of the snowpack, staying away from convex rolls because here the snowpack is under considerable stress, steering clear of sharp, exposed rocks and terrain traps like gulleys, cliff edges and heavy timber forests.
* **Group management:** This technique aims to mitigate risks related to a whole party getting buried in an avalanche. Basically, the members of a group/party are spread out over the slope rather than moving in close bunches. For instance, if there is a precarious stretch to be traversed, members do it only one by one—only after has one member reached safety does the next member start moving.
* **Route selection**: This involves mapping out the route with least risk factor of an avalanche. The camping sites are also marked out after careful consideration. There should be contingency

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plans and escape routes planned in case of an emergency. Party members should never travel singly and always take someone along even for short explorations. And finally, there should be clear communication among all party members and there should be transparency among the leaders and the rest of the members.

* **Risk factor awareness:** Before traveling to a particular area, gather basic knowledge about the area including its meteorological history, existing weather and snow conditions and the social and physical indicators of the group.
* **Leadership:** The leader of the party should be a certified trainer, well-experienced in the safety measures, risk assessment, first aid techniques specific to snow victims, and decision making protocols. Such training is offered by resource centers in Nort America and Europe. The leader should also have a calm temperament and a quick thinking ability. These are the qualities of a person and cannot be taught. A calm leader inspires confidence and can keep his wits about him in a crisis situation rather than breaking down under pressure and taking inappropriate decisions.

#### Avalanches in the Indian context

In India, Snow and Avalanche Study Establishment (SASE) has the responsibility of handling various aspects of avalanches and their hazards. The Border Roads Organization (BRO) also plays a major role enabled by its large network of roads in the high altitude snow-bound areas of Leh in Jammu and Kashmir, Sikkim, Arunachal Pradesh, Himachal Pradesh, and Uttarakhand, in the task of snow-avalanche clearance. One of the main tasks of BRO is keep communication lines open in snow-bound regions using measures like sophisticated snow cutting equipment/snow cutters/snow sweepers, conventional dozers, experienced workforce and total station survey instruments.

Every year, snow is cleared out across a 50 km stretch on the Zojilla-Pass on the Srinagar-Leh road. In fact this is the part of the road that is not open to traffic in the winter months and upto May every year. Snow is also cleared from a 100 km stretch on the Manali-Leh road across the Rohtang Pass and Baralachla Pass. There are many avalanche-prone zones in this area and need to be treated with extreme caution. Besides clearing the roads, the BRO marks and monitors the avalanche zones and updates the SASE whenever a fresh avalanche takes place. The SASE in turn keeps record of the avalanche zones and accordingly forecasts avalanches. The government of the area and the Central governments collaborate with the BRO to implement clearance and control strategies for handling the avalanches that take place.

* + 1. **Volcanic Eruptions**

An opening in the surface of the earth that allows lava, volcanic ash and gases to escape from its magma chamber below the surface is called a volcano. The sudden occurrence of a violent discharge of steam and volcanic material from a volcano is a volcanic eruption. There are essentially three meta types of volcanic eruptions. The most common are magmatic eruptions, which involve the decompression of gas within magma that propels it forward. Another type of volcanic eruptions are known as phreatomagmatic eruptions. These are driven by the compression of gas within magma, direct opposite of the process powering magmatic activity. The third type of volcanic eruption is known as phreatic eruption. It occurs as a result of the superheating of steam via contact with magma. Phreatic eruptions often exhibit no magmatic release, instead causing the granulation of existing rocks.

There are two types of volcanic eruptions in terms of activity—explosive eruptions and effusive eruptions. Explosive eruptions are characterized by gas-driven explosions that propel magma and tephra. Effusive eruptions, meanwhile, are characterized by outpouring of lava without significant explosive eruption. The most dangerous eruptions are explosive eruptions; in the history of the earth some explosive eruptions are thought to have caused climate changing events such as the Lake Toba eruption in Indonesia that occurred 69,000 years ago.

#### Hazards

Volcanic eruptions are extremely dangerous. Hazards during volcanic eruptions include emission of volcanic gases like carbon dioxide, sulfur dioxide, hydrogen sulfide, hydrogen, and fluorine. When sulfur dioxide gases react with water droplets in the atmosphere, it creates acid rain that corrodes vegetation. Carbon dioxide concentrations are poisonous to people and animals alike. Fluorine is a toxic gas that is absorbed onto volcanic ash which falls to the ground during eruptions. These ashes can poison livestock as well as water supplies. Along with volcanic gases, lava flows are another hazard of

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volcanic eruptions. Lava flows are molten rocks that ooze onto the earth’s surface. They are hot enough to burn everything in its path.

Pyroclastic flows, or high-speed avalanches of hot ash, rock fragments, and gas, are other hazards of volcanic eruptions. Pyroclastic flows are extremely fast moving and have temperatures that exceed 1000°C. They can cause apocalyptic devastation during explosive eruptions. For example, the eruption of Mount St. Helens on May 18, 1980, caused a huge pyroclastic surge which completely devastated an area of 230 square miles. Other dangers during volcanic eruptions are earthquakes, landslides and mudslides. When Pyroclastic flows mix with water, they can cause mudflows, also known as lahars.

Some of the most significant volcanic eruptions of recent times include:

* On May 18th, 1980, Mount St. Helens erupted in the United States causing 57 deaths and over a billion dollars in damage.
* On November 13th, 1985, an eruption on Nevado del Ruiz produced an enormous lahar that buried and destroyed the town of Armero in Tolima, killing around 25,000 people.
* On 10th April 1815, Mount Tambora on the island of Sumbawa in Indonesia erupted. The eruption was the largest in the recorded history of man. An estimated 90,000 people were killed as a direct result of the explosion or due to the aftermath. The eruption caused global anomalies in the climate. As a result of the eruption, the year 1816 came to be known as the ‘Year Without a Summer’.

**Check Your Progress**

1. What is an epicenter?
2. What is a lahar?
3. Define an avalanche.
4. What is meant by effusive eruptions?

## CLIMATIC DISASTER: HEAT AND COLD WAVE

A heat wave is a prolonged period of excessively hot weather, which may be accompanied by high humidity. There is no universal definition of a heat wave; the term is relative to the usual weather in the area. Temperatures that people from a hotter climate consider normal can be termed as heat wave in a cooler area if they are outside the normal climate pattern for that area. The term is applied both to routine weather variations and to extraordinary spells of heat which may occur only once a century. Severe heat waves have caused catastrophic crop failures, thousands of deaths from hyperthermia and widespread power outages due to increased use of air conditioning.

The definition recommended by the World Meteorological Organization is when the daily maximum temperature of more than 5 consecutive days exceeds the average maximum temperature by 5°C. A formal, peer-reviewed definition from the *Glossary of Meteorology* is a period of abnormally and uncomfortably hot and usually humid weather. To be a heat wave, such a period should last at least 1 day, but conventionally it lasts from several days to several weeks. In 1900, A.T. Burrows more rigidly defined a ‘hot wave’ as a spell of 3 or more days on each of which the maximum shade temperature reaches or exceeds 90°F (32°C). More realistically, the comfort criteria for any one region are dependent upon the normal conditions of that region.

In addition to physical stress, excessive heat causes psychological stress, to a degree that affects performance and is also associated with an increase in violent crime.

#### Incidence

Some regions of the globe are more susceptible to heat waves than others, typically inland deserts, semi- deserts and Mediterranean-type climates. According to climatologist David Jones, the likelihood of heat waves occurring is expected to increase with global warming. Heat waves are spans of extreme heat.

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#### How they occur

In the summer in warm climates, due to an area of high pressure with little or no rain or clouds, the air and ground easily heats to excess. A static high pressure area can impose a very persistent heat wave.

The position of the jet stream allows air on one side to be considerably warmer than the other side. Heat waves are far more common and more severe on the warm side and at times an unusual position of the jet stream places unusual warmth in an unusual place for hot weather, and imposes a heat wave. El Niño and La Niña (opposite reaction to El Niño) can severely disrupt the positions of the jet streams.

Large desert zones and dry areas are more likely to get extreme heat because there is rarely any high cloud cover with very low humidity.

Winds from hot deserts typically push hot, dry air towards areas normally cooler than during a heat wave. During the summer an area that has no geographic features that might cool winds that originate in the hot deserts get little mitigation, especially near the summer solstice when long days and a high sun would create warm conditions even without the transport of hot air from other locations. Should such a hot air mass travel above a large body of water, as a sirocco of Saharan origin crossing the Mediterranean sea, it is likely to pick up much water vapour with a reduction in temperature but far greater humidity that makes the original desert air little less moderate as demonstrated in a high heat index. Heat waves can also come from air originating over tropical seas penetrating far into the middle latitudes, as often occurs in the eastern United States and southeastern Canada. The heat island effects of large cities only exacerbate heat in large cities that endure heat waves because of the weakness of night-time cooling.

#### Mortality

Intense perspiration can be a sign of excess heat exposure. Heat waves are the most lethal type of weather phenomenon, overall. The 1995 Chicago Heat Wave, one of the worst in American history, led to approximately 600 heat-related deaths over a period of 5 days. Despite the dangers, Scott Sheridan, professor of geography at Kent State University, found that less than half of people age 65 and older abide by heat-emergency recommendations like drinking lots of water.

#### Underreporting and ‘harvesting’ effect

The number of heat fatalities is highly underreported due to lack of reports and misreports. Part of the mortality observed during a heat wave, however, can be attributed to a so-called harvesting effect, a term for a short-term forward mortality displacement. It has been observed that for some heat waves, there is a compensatory decrease in overall mortality during the subsequent weeks after a heat wave.

#### Impact of heat waves

* **Power outage:** Heat waves often lead to electricity spikes due to increased air conditioning use, which can create power outages, exacerbating the problem. During the 2006 North American heat wave, thousands of homes and businesses went without power, especially in California. In Los Angeles, electrical transformers failed, leaving thousands without power for as long as 5 days. The heat wave in Melbourne, Australia, also caused major power disruptions leaving over half a million people without power as the heat wave blew transformers and overloaded the power grid.
* **Wildfires:** If a heat wave occurs during a drought, which dries out vegetation, it can contribute to bushfires and wildfires. During the disastrous heat wave that struck Europe in 2003, fires raged through Portugal, destroying over 3,010 square kilometres (7,40,000 acres) of forest and 440 square kilometres (1,10,000 acres) of agricultural land and causing an estimated €1 billion worth of damage. High-end farmlands have irrigation systems to back up crops with.
* **Physical damage:** Heat waves can and do cause roads, highways to buckle, water lines to burst and power transformers to detonate, causing fires.

#### History

* The European heat wave of 2003 killed around 35,000 people. Much of the heat was concentrated in France, where nearly 15,000 people died. In Portugal, the temperatures reached as high as 48°C (118°F) in the south.
* The European heat wave of 2006 was the second massive heat wave to hit the continent in 4 years, with temperatures rising to 40°C (104°F) in Paris; in Ireland, which has a moderate maritime

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climate, temperatures of over 32°C (90°F) were reported. Temperatures of 35°C (95°F) were reached in Benelux and Germany (in some areas 38°C (100°F), while Great Britain recorded 37°C (99°F). Many heat records were broken (including the hottest ever July temperature in Great Britain) and many people who experienced the heat waves of 1976 and 2003 drew comparisons with them.

* The 2007 Bulgarian heat wave triggered wildfires leading to a state of emergency being declared in three southern towns.
* In July 2006, the United States experienced a massive heat wave, and almost all parts of the country had recorded temperatures above the average temperature for that time of year. Temperatures in some parts of South Dakota exceeded 115°F (46°C), causing many problems for the residents. Also, California experienced temperatures that were extraordinarily high, with records ranging from 100°F to 130°F (38°C to 54°C). The county of Los Angeles recorded its highest temperature ever at 119°F (48°C).
* The European heat wave of 2007 affected primarily south-eastern Europe during late June through August. Bulgaria experienced its hottest year on record, with previously unrecorded temperatures above 45°C (113°F). The 2007 Greek forest fires were associated with the heat wave.
* During the 2007 Asian heat wave, the Indian city of Datia experienced temperatures of 48°C (118°F).
* In January 2008, Alice Springs in Australia’s Northern Territory recorded 10 consecutive days of temperatures above 40°C (104°F) with the average temperature for that month being 39.8°C (103.6°F). In March 2008, Adelaide, South Australia, experienced maximum temperatures of above 35°C (95°F) for 15 consecutive days, 7 days more than the previous longest stretch of 35°C (95°F) days. The March 2008 heat wave also included 11 consecutive days above 38°C (100°F). The heat wave was especially notable because it occurred in March, an autumn month, in which Adelaide averages only 2.3 days above 35°C (95°F).
* The eastern United States experienced an early summer heat wave during June 6—10, 2008, with record temperatures. There was a heat wave in Southern California beginning late June, which contributed to widespread fires. On 6 July, a renewed heat wave was forecast, which was expected to affect the entire state.
* In early 2009, Adelaide, South Australia, was hit by a heat wave with temperatures reaching 40°C for 6 days in a row, while many rural areas experienced temperatures hovering around about mid- 40s°C (mid-110s°F). Kyancutta, on the Eyre Peninsula, endured at least 1 day at 48°C, with 46°C and 47°C being common in the hottest parts of the state. Melbourne, in neighbouring Victoria, recorded 3 consecutive days over 43°C (109°F), and also recorded its highest ever temperature 8 days later in a secondary heatwave, with the mercury peaking at 46.4°C (115.5°F). During this heat wave, Victoria suffered from large bushfires which claimed the lives of more than 210 people and destroyed more than 2,500 homes. There were also over half a million people without power as the heatwave blew transformers and the power grid was overloaded.
* In August 2009, Argentina experienced a period of unusual and exceptionally hot weather during 24–30 August 2009 during the southern hemisphere winter, just a month before spring when a unusual and unrecorded winter heat wave hit the the country. A shot of tropical heat drawn unusually far southward hiked temperatures 22 degrees above normal in the city of Buenos Aires and across the northern-centre regions of the country.
* Even though normal high temperatures for late August are in the lower 15°C (59°F), readings topped 30°C (86°F) degrees at midweek, then topped out above 32°C (90°F) degrees during the weekend.
* Temperatures hit 33.8°C (92.8°F) on 29 August and finally 34.6°C (94.3°F) on 30 August in Buenos Aires, making it the hottest day ever recorded in winter breaking the 1996 winter record of 33.7°C (92.7°F). In the city of Santa Fe, a remarkable 38.3°C (100.9°F) degrees on 30 August was registered, notwithstanding the normal high in the upper 15°C/60°F. As per the Meteorological Office of Argentina, August 2009 has been the warmest month during winter since official measurements began.
* Heat-related deaths were reported from the capital New Delhi, northern Haryana, Uttar Pradesh, Rajasthan and Madhya Pradesh. After 3 days of intense heat with temperatures hovering about

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40°C (104°F), New Delhi was relieved as the temperature slid down to 37.2°C (99°F). Meanwhile, the temperature soared to more than 46°C (115°F) at several places in northern Madhya Pradesh, with Datia turning out to be the hottest at 48°C (118°F).

* + More than 120 peacocks died in Tughlakabad Fort and Surajkund due to the heat; additionally, reports of severe water shortages were common. A total of 400 peacocks died in Madhya Pradesh, about 200 of those being in Haryana and Punjab alone.
  + The cotton crop in Punjab was severely affected by the heat wave. Meanwhile, the persisting heat wave in various parts of Chandigarh rendered milk cattle dry. When the day temperature hovered around 48°C (118°F), milk supply to various milk plants of cooperative unions went down by 40,000 litres per day. In addition, milk collection by private sector plants was reduced by 1,60,000 litres during the same period.

#### Is heat wave a result of global warming?

Some facts related to heat waves and global warming are as follows:

* + The Earth is heating up by 1.4°F since 1920.
  + The ice caps are melting and the level of sea is rising.
  + The first 6 months of 2006 were the hottest since records were maintained in 1890.

The heat wave and the resultant extreme occurrences being witnessed in these recent years are consistent with what is seen as caused by global warming, even though there is no definite correlation. Until now, approximately several high-temperature records have been broken. However, scientists are researching to ensure if the global heat wave constitutes part of a longer and more intense pattern of heat waves before considering it as a part of the larger global warming picture. The movement to bring down greenhouse gas emissions is gaining international attention.

In the recent conference on climate change in Copenhagen, the deadline was determined for adopting ‘green’ policies and saving the planet from global warming. It was decided that if drastic cuts are not made in the pollution levels by 2020, it would cost the planet up to £150 per year, and we would not have virtually any chance of reducing the temperature. It was decided that geo-engineering and radical solutions would be adopted such as covering the planet with artificial trees or by reflecting sunlight back into space with mirrors. Global leaders meeting in Copenhagen are using rise in temperature issue as their target for the climate deal, which will see billions of pounds being handed down to developing countries to slow down climate change.

It is being said that a cut of 5 per cent in global emissions is the utmost even the most ambitious campaigner is possible. This means drastic changes in power generation, use of renewable energy like wind farms and solar energy, nuclear power, use of biofuels and driving electric cars. Deforestation would have to be brought down and use of fossil fuel reduced drastically.

#### Cold Wave

An unusual drop in the weather over a short period of time can be called a cold wave. Like heat waves, the term cold wave is relative to the usual weather in the area. A prolonged cold wave may be accompanied by heavy snowing. A cold wave is extremely hazardous to livestock, and also to humans. Since the exposure to cold mandates a greater intake of calories for animals, if there is snow, grazing animals may be unable to reach needed food and die of hypothermia or starvation. The 2012 European cold wave caused temperatures to fall below –35 °C and led to the deaths of 590 people.

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**Exhibit 1**

**Cold wave claims lives in north India**

Jan 10, 2013

NEW DELHI: More than twenty people lost their lives due to cold wave in Uttar Pradesh and Uttarakhand as temperature in parts of north India plummeted.

Delhi has been witnessing cold wave conditions for the past one week with both minimum and maximum remaining five degrees below normal. In the plains of Uttar Pradesh, the biting

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cold wave conditions snuffed out more than fifteen more lives in the last 24 hours as death toll due to the harsh weather touched almost 250.

Five persons died in Gorakhpur district which was the coldest place in the state yesterday, followed by four each in Farrukhabad and Barabanki, two in Sant Kabirnagar and one in Bijnore.

Met office said that Lucknow along with Najibabad in Bijnore were coldest in the state recording 0.5 (–6) degrees Celsius followed by Kheri with 1 deg C, Sultanpur 1.2 (–7) deg C and Gorakhpur 1.8 (–7) deg C.

Loss of seven lives was reported from Uttarakhand. Most of the casualties were reported from Roorkee and Haridwar districts where icy northwesterly winds continued to blow amid dense fog.

Mercury rose marginally in most places with Dehradun recording a minimum of 3.5 deg C, Pantnagar 0.2 deg C, Mukteshwar 0.2 deg C, Tehri 1.0 Pithoragarh 2.3 and Nainital 4.0 degree C, the MeT office said.

Chilly conditions prevailed in Jharkhand with Kanke on the outskirts of Ranchi recording a minimum of 3.4 degree Celsius and Ranchi’s low temperature being 8 degree Celsius today.

The minimum temperatures recorded in Jamshedpur and Palamau were 5.1 degree and 6.4 degree Celsius respectively, the sources said adding chill also prevailed in other parts of the state.

(***Source:*** Adapted from <http://articles.timesofindia.indiatimes.com/2013-01-10/india/> 36257505\_1\_degree-celsius-today-cold-wave-minimum-temperature, accessed on 29.11.13)

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**Check Your Progress**

1. What is a heat wave?
2. Define a cold wave.
   1. **CLIMATE CHANGE**

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Climate is the average weather of an area. It is the general weather conditions, seasonal variations and extremes of weather in a region. Such conditions which average over a long period of at least 30 years is called climate.

The Intergovernmental Panel On Climate Change (IPCC) in 1990 and 1992 published best available evidence about past climate change, green house effect and recent changes in global temperature. It is observed that earth’s temperature has changed considerably over the years. It has experienced several glacial and interglacial periods. However, during the past 10000 years of the current interglacial period, the mean average temperature has fluctuated by 0.51° C over 100 to 200 year period. Even small changes in climatic conditions may disturb agriculture that would lead to migration of animals and even humans beings.

Anthropogenic activities are upsetting the delicate balance that has been established between various components of the environment. Green house gases are increasing in atmosphere resulting in increase in the average global temperature. This may upset the hydrological cycle; result in floods and droughts in different regions of the world, cause sea level rise, changes in agricultural productivity, famines and death of humans as well as livestock.

### Global Warming

The average temperature of the planet has increased more than 1 degree Fahrenheit since 1900 and the speed of warming has been almost threefold since 1970. This increase in the planet’s average temperature is called *global warming*.

According to the scientists of the National Oceanic and Atmospheric Administration, period between 1998 to 2007 rank among the topmost 25 hottest years for the United States. We are considering the example of United States, because the US and China are the two biggest polluters in the world and

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have gained negative attention for their dumping policies. The planet could heat by an additional 7.2 degrees Fahrenheit during this century if we do not reduce emissions from fossil fuels such as coal and oil. This rise in the average temperature will have wide-reaching effects on the earth’s climate patterns and on all living things, and many of these changes have already begun.

#### Consequences of global warming on weather patterns

Increase in temperatures could lead to increased droughts and wildfires, heavier rainfall and a greater number of intense hurricanes. Warmer water in the oceans pumps more energy into tropical storms, making them stronger and potentially more destructive. The warning signs prevalent today are as follows:

The number of intense storms has greatly increased over the past years, in addition to ocean temperature.

* + The Atlantic hurricane season in 2005 was the most active in recorded history, with 27 named storms, of which 15 became hurricanes. Seven of the hurricanes strengthened into major storms, five became intense hurricanes and four became very intense hurricanes.
  + In August 2005, Hurricane Katrina was the costliest and deadliest hurricanes in American history.
  + Warmer temperatures have increased the possibility of droughts. Increased evaporation could increase drought conditions and increase the risk of wildfires.
  + Expenditures incurred in firefighting have consistently gone up by $1 billion per year.
  + Warmer temperatures have increased the energy of the climatic system and have increased the possibility of heavier rainfall in some areas.
  + The national annual precipitation has surged between 5 and 10 per cent since the early 20th century, largely due to heavy downpours.
  + According to the Intergovernmental Panel on Climate Change, intense rain events have increased in frequency during the last 50 years and human-induced global warming most likely contributed to the trend.
  + According to the National Oceanic and Atmospheric Administration, the northeast region of the US has had its wettest summer on record in 2006, exceeding the previous record by more than 1 inch.

#### Consequences of global warming on health

Carbon dioxide in the air aggravates asthma and allergies. More frequent and severe heat waves will result in a greater number of heat-related deaths. The warning signs prevalent today are as follows:

* + In 2003, very intense heat waves killed approximately 70,000 people in Europe. In France alone, about 15,000 people died during 2 weeks of increasing temperatures that reached as high as 104 degrees Fahrenheit.
  + Most areas of North America underwent a severe heat wave in July 2006, which led to the deaths of over 140 people.
  + In the 1995 heat wave in Chicago, 739 heat-related deaths had occurred within a week.
  + Global warming could lead to an increase in smog pollution in some areas and intensify pollen allergies and asthma. It could also increase local air quality problems.
  + Research shows that a higher level of carbon dioxide spurts the increase in the growth of ragweed, whose pollen leads to allergies and worsens asthma.
  + Diesel exhaust particles can also mix with pollen and deliver it deeper into the lungs.
  + The rise in temperatures can increase ground-level ozone smog production, which is a grave threat to asthmatics.
  + The number of mosquitoes and disease outbreaks, such as dengue and malaria increase as the climate allows them to survive in formerly inhospitable areas.
  + Higher outdoor temperatures can also lead to more outbreaks of foodborne illnesses such as salmonella, which reproduces rapidly in warm temperatures.

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#### Consequences of global warming on wildlife

Rising temperatures have destroyed coral reefs and melted the habitats of polar bears and penguins. Increasing global temperatures have disrupted ecosystems and pushed to extinction species that have not been able to adapt. A comprehensive assessment of the extinction risk from global warming found that more than 1 million species could be extinct by 2050 if the current trend continues. The warning signs prevalent today are as follows:

* + A recent analysis of about 2000 plant and animal species discovered movement towards the poles at an average rate of 3.8 miles per decade.
  + The latest Intergovernmental Panel on Climate Change report found that approximately 20 to 30 per cent of plant and animal species assessed are likely to be extinct if global average temperature increases by more than 2.7 to 4.5°F
  + The US Geological Survey has predicted that two-thirds of the world’s polar bear sub-populations will be extinct by mid-century because of melting of the Arctic ice cap.
  + In Washington’s Olympic Mountains, the sub-alpine forest has invaded higher elevation alpine meadows.
  + The mangrove forests in Bermuda are disappearing.
  + Over the past years, some Antarctic penguin populations have reduced by 33 per cent due to decline in winter sea-ice habitat.
  + The ocean has become more acidic due to carbon dioxide emissions, because of which species with hard calcium carbonate shells are vulnerable.
  + Scientists predict that an increase by 3.6°F in temperature would wipe out 97 per cent of the world’s coral reefs.

#### Consequences of global warming on glaciers and sea levels

It is being predicted that the polar regions could be devoid of ice by 2040 and the sea levels could rise by 23 inches by 2100 if the current warming patterns continue. The rising global temperatures will speed the melting of glaciers and ice caps and cause ice to thaw early. The warning signs prevalent today are as follows:

* + The northern section of the Larsen B ice shelf in Antarctica, a section larger than the state of Rhode Island in the US, collapsed between January and March 2002 and disintegrated at a rate that astonished scientists.
  + According to NASA, the polar ice cap is melting at a rate of 9 per cent per decade. Arctic ice thickness has decreased by 40 per cent since the 1960s.
  + Over the past three decades, more than a million square miles of perennial sea ice, an area the size of Norway, Denmark and Sweden combined, has disappeared.

#### Warning signs

According to scientists at the University of Oxford, England, and the Hadley Centre for Climate Research and Prediction in Exeter, England, global warming caused by human activity has increased the possibility that Europe will witness extreme summer heat waves. It is also estimated that by the middle of this century, every second European summer will get warmer.

According to Kevin Trenberth, head of the climate analysis section at the National Center for Atmospheric Research in Boulder, Colorado, ‘the link between the current heat waves and global warming is a little complex’. According to him, ‘the immediate cause of heat waves is a weather pattern known as an anticyclone, or a high-pressure ridge. Anticyclones lead to dry conditions’. This means all the heat is getting to raise temperatures rather than evaporate moisture. For instance, if the ground is wet that usually acts somewhat as an air conditioner. However, the art lies in differentiating between climate change signals from natural variability.

According to climate experts, other signs of global warming are as follows:

* + - Spring is arriving by February in New England.
    - Glacier ice is reducing throughout the world, from the European Alps to Kenya’s Mount Kilimanjaro to Glacier National Park in Montana, United States.

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* + - The warm climate zone has shifted higher in the mountains of Central America. Several species of animals have nowhere left to move and are rapidly going extinct.
    - The National Oceanic and Atmospheric Administration recently said the first half of 2006 was the warmest ever for the US.

Almost all specialists examining the climate patterns of the earth opine that human actions, mainly releasing greenhouse gases from vehicles, industries and burning forests, are the leading causes of global warming. The gases released permit sunlight in, but stop some of the ensuing heat from radiating back to space, leading to a greenhouse effect.

#### Global warming causes

* + The major cause of global warming is the emission of greenhouse gases like carbon dioxide, methane and nitrous oxide into the atmosphere. Power plants are one of the major sources of carbon dioxide. These power plants produce carbon dioxide by burning fossil fuels for the purpose of electricity generation. Burning gasoline in vehicles contributes about 20 per cent of carbon dioxide emitted in the atmosphere.
  + Both commercial and residential buildings represent a larger source of global warming pollution. Constructing these requires a lot of fuel to be burnt which emits a large amount of carbon dioxide in the atmosphere.
  + Methane is 20 times more effectual than carbon dioxide at trapping heat in the atmosphere. It is obtained from rice paddies, bovine flatulence, bacteria in bogs and fossil fuel manufacture. When fields are flooded, anaerobic bacteria build up and the organic matter in the soil decays, releasing methane to the atmosphere.
  + Cars with catalytic converters, using fertilizers in agriculture and burning organic matter releases nitrous oxide that includes nylon and nitric acid production.
  + Deforestation caused by cutting and burning of forests for the purpose of residence and industrialization is also a cause of global warming.

#### Fight global warming

Many steps are being taken by various nations to decrease the rate of global warming. One such effort is the Kyoto agreement made between various nations to reduce the emissions of various greenhouse gases. Also, many not-for-profit organizations are working on the same cause. Al Gore has been one of the foremost American politicians to raise the alarm about the hazards of global warming. He has produced a significantly acclaimed documentary movie called *An Inconvenient Truth*, and written a book that archives his advice that the planet is rushing towards an immensely warm future. He has also given speeches to raise awareness about global warming and warned people about the ill effects of global warming and its remedies.

#### Economics of global warming

The economics of global warming refers to the economic costs and benefits of global warming, and to the economic impacts of actions aimed at the mitigation of and adaptation to global warming. Estimates come from a variety of sources, including integrated assessment models, which seek to combine socio- economic and biophysical assessments of climate change. At an Intergovernmental Panel on Climate Change (IPCC) conference in April 2007, delegates from 120 nations discussed the specific economic and societal costs of mitigating global warming, and eventually approved the IPCC Fourth Assessment Report. The IPCC Fourth Assessment Report, published in 2007, looked at the aggregate economic impacts of climate change.

Impacts of climate change are very likely (greater than 90 per cent probability) to impose net annual costs, which will increase over time as global temperatures increase. Peer-reviewed estimates of the social cost of carbon (net economic costs of damages from climate change aggregated across the globe and discounted to the specified year) in 2005 average US$ 12 per tonne of carbon dioxide, but the range from 100 estimates is large (-$3 to $95/t carbon dioxide). This is due in large part to differences in assumptions regarding climate sensitivity, response lags, the treatment of risk and equity, economic and non-economic impacts, the inclusion of potentially catastrophic losses and discount rates. Aggregate estimates of costs mask significant differences in impacts across sectors, regions and populations and very likely underestimate damage costs because they cannot include many non-quantifiable impacts.

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Aggregate impacts have also been quantified in other metrics, for example, climate change over the next century is likely to adversely affect hundreds of millions of people through increased coastal flooding, reductions in water supplies, increased malnutrition and increased health impacts.

According to the IPCC Report, ‘aggregate market sector impacts of 2°C global mean temperature increase, above the 1990 level, will be plus or minus a few percent of global GDP, with most people in the world negatively affected. Studies of aggregate economic impacts found net damages beyond temperature increases of 2 to 3°C above 1990 levels, with increasing damages at higher magnitudes of climate change.’ The report adds that ‘On balance, the current generation of aggregate estimates in the literature is more likely than not to understate the actual costs of climate change.’

In 2005, the UK House of Lords Economic Affairs Select Committee produced a report on the economics of climate change. The Report notes the complexities in making forecasts of climate change mitigation costs. The Report refers to the 2001 IPCC report for an estimate of the costs of stabilizing atmospheric CO2-equivalent at 550 ppm. The annual mitigation cost for this stabilization target is given as being between $78 billion and $1141 billion. This amounts to 0.2 per cent to 3.2 per cent of world GDP in 2005. Costs are estimated to be between 0.3 per cent and 4.5 per cent of GDP if borne by the richest nations alone. In this estimate, world income is assumed to be growing. With 2 per cent per annum growth, the worst case level of costs (with the assumption that all costs are spread over 20 years, from 2005—2025) is estimated to fall to 2.3 per cent of world income in 2035. If the costs are spread out over 50 years (2005—2055), the fraction falls to 1.3 per cent of world income. In terms of world costs per tonne of carbon, the range is estimated to be between $18 and $80 for a 550 ppm CO2-equivalent target. This figure is based on calculations using the MERGE and FUND integrated assessment models.

#### The Copenhagen Consensus

The 2004 Copenhagen Consensus assessed the problem of climate change compared to other issues such as control of diseases and malnutrition. Projects were proposed to address these problems, with each project judged by a panel of eight economists. The panel looked at three proposals, including the Kyoto Protocol, for dealing with climate change by reducing emissions of carbon. The expert panel regarded all three proposals as having costs that were likely to exceed the benefits. The panel recognized that global warming must be addressed, but agreed that approaches based on too abrupt a shift toward lower emissions of carbon are needlessly expensive. The experts expressed an interest in an alternative, proposed in one of the opponent papers, that envisaged a carbon tax much lower in the first years of implementation than the figures called for in the challenge paper, rising gradually in later years. Such a proposal however was not examined in detail in the presentations put to the panel, and so was not ranked. The panel urged increased funding for research into more affordable carbon-abatement technologies. The three climate change proposals were rated ‘bad’ and finished bottom in a ranking of all projects. In the 2008 Copenhagen Consensus, out of the 30 projects evaluated, climate change projects were ranked at number 14 (R&D in low-carbon energy technologies), 29, (R&D and mitigation) and 30 (mitigation only).

#### Stern Review

One of the most widely noted projections on this issue is the *Stern Review*, a 2006 report by the former Chief Economist and Senior Vice-President of the World Bank, Nicholas Stern, predicts that climate change will have a serious impact on economic growth without mitigation. The report suggests that an investment of 1 per cent of global GDP is required to mitigate the effects of climate change, with failure to do so risking a recession worth up to 20 per cent of global GDP. In the *Stern Review*, net monetized cost estimates of climate change were negative (i.e., net damages) for all global mean temperature increases. The Review has been criticized by some economists, saying that Stern did not consider costs past 2200, that he used an incorrect discount rate in his calculations and that stopping or significantly slowing climate change will require deep emission cuts everywhere. Some economists have supported Stern’s approach, or argued that Stern’s estimates are reasonable, even if the method by which he reached them is open to criticism. Research by Weitzman has suggested that structural uncertainty and low-probability high-impact risks are very important.

#### Kyoto Protocol

Primarily industrialized countries who ratified the Kyoto Protocol committed themselves to targets that require lowering their national greenhouse gas emissions to a specified level relative to their actual 1990 emissions. According to the IPCC report, notable achievements of the Kyoto Protocol include:

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* + Establishment of a global response to the climate problem
  + Stimulation of an array of national policies
  + Creation of an international carbon market
  + Establishment of new institutional mechanisms that may provide the foundation for future mitigation efforts

Significant differences exist between countries in meeting their Kyoto commitments. Collectively, industrial countries who ratified the treaty will probably meet their 2010 emission limitation targets. The Kyoto Protocol was the first international agreement to set mandatory limits on greenhouse gas emissions. Kyoto’s emission reduction targets have been criticized, with some saying they are too weak and others saying they are too strong. The IPCC report describes Kyoto’s emission reduction targets as being modest. It was calculated that the present value cost of the Kyoto Protocol would be $800 billion to

$1,500 billion if implemented as efficiently as possible. Some economists view Kyoto as a useful first step in responding to climate change. Climate scientists O’Neill and Oppenheimer support Kyoto’s targets, arguing that they are consistent with atmospheric carbon dioxide stabilization at 450 ppm. A 450 ppm target could forestall the disintegration of the West Antarctic Ice Sheet, but this is by no means certain, because additional warming would occur beyond 2100.

#### Cost distribution

The costs and benefits of global warming are distributed quite unequally.

* + Low-lying countries’ risk of floods
  + Many countries subject to increased drought are poor African countries
  + Ability of poor countries to mitigate/adapt (margin)
  + GW increases variability of weather, which implies greater capital requirements for water storage systems, flood defenses as well as individual requirements to cope with wider variation in weather patterns

The costs of mitigation may also be distributed unequally, both within and between countries.

* + 1. **Sea Level Rise**

Over the past century, the Global Mean Sea Level (GMSL) has risen by 4 to 8 inches (10 to 20 centimeters). However, the annual rate of rise over the past 20 years has been 0.13 inches (3.2 millimeters) a year, roughly twice the average speed of the preceding 80 years.

Human activities have released enormous amount of heat-trapping gases into the atmosphere. These emissions have caused the Earth’s surface temperature to rise. The increase in temperature will result in melting of glaciers and polar ice caps. This will increase the sea level. The low-lying islands and coastal areas will be eventually submerged. The rise in sea levels is linked to three factors, all induced by this ongoing global climate change:

* + - * **Thermal expansion:** When water heats up, it expands. About half of the past century’s rise in sea level is attributed to warmer oceans simply occupying more space.
      * **Melting of glaciers and polar ice caps:** Glaciers and polar ice caps melt back a bit each summer. But in winter, the snow formed is generally sufficient to balance out the melting. Recently, higher temperatures caused by global warming have increased the level of melting of snow as well as diminished snowfall due to later winters and earlier springs. This causes the sea levels to rise.
      * **Ice loss from Greenland and West Antarctica:** Like glaciers and the ice caps, global warming is causing massive ice sheets that cover Greenland and Antarctica to melt at an accelerated pace. Higher sea temperatures are causing the massive ice shelves that extend out from Antarctica to melt from below, weaken, and break off.

#### Consequences

A small increase in sea level can have devastating effects on coastal habitats. It can cause flooding of wetlands, destructive erosion, contamination of aquifers and agricultural soils, and loss of habitat. People live in coastal areas will become vulnerable to flooding. Higher sea levels would force them to abandon their homes and relocate. Low-lying islands could be submerged completely.

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### Ozone Depletion

The highest level of ozone in the atmosphere is in the stratosphere and this zone of about 10 to 50 km is known as ozone layer. The rest 10 per cent of ozone is in the troposphere. Ozone is beneficial when it is in the stratosphere as it protects us from the harmful UV rays and is harmful, in the troposphere as it helps in formation of photo-chemical smog. It needs to be mentioned here that the photo-chemical smog formation is mainly due to human activities. Thus, ozone is mainly beneficial for us.

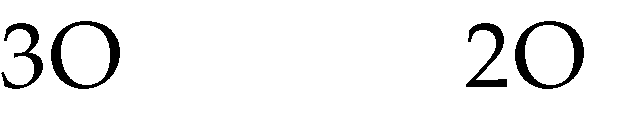
Ozone absorbs all the solar ultraviolet radiations of wavelength less than 290 nm and negligibly absorbs those in between 290 to 350 nm. Ozone is continuously created in the stratosphere and at the same time continuously removed. Thus, there is an apparent equilibrium in the ozone region with the concentration of ozone remaining constant.

The formation of ozone has been described here. In the first step, photolytic decomposition of diatomic oxygen produces atomic oxygen; the atomic oxygen reacts rapidly with diatomic oxygen in presence of third body (M, most abundant N2 or O2) to form ozone (O3).

O2 + *h*  O + O ( < 242 nm) O + O2 + M  O3 + M

O3 + *h*  O2 + O ( < 350 nm) O + O3  2O2

Equilibrium reaction can be shown as



*n*



The principal effect of the overall reaction is that most of the potentially damaging short wavelength ultraviolet radiation is absorbed as it tries to pass through stratosphere. Further, as the absorption of this radiation heats the stratosphere stable atmospheric conditions are achieved.

A satellite data, however, indicated damage to the stratospheric ozone layer over Antarctica, a hole of the size of a big continent. The main chemicals responsible for depletion of ozone layer were found to be chlorofluorocarbons (CFCs) and especially CFCl2, CF2Cl2, C2F3Cl3 and chloroflouro bromine (CF3Br). These gases are very stable (residence time: 75–185 years). They are inert in lower atmosphere but are destroyed by the UV radiation (l< 220 nm) in the ozonosphere and release atomic Cl. This atomic Cl, subsequently, destroys the ozone layer through the following processes:

CF2Cl2 + h(<220 nm)  CF2Cl + Cl The freed chlorine then act as a catalyst,

Cl + O3  ClO + O2 ClO + O  Cl + O2

O3 + O  2O2

Part of the atomic Cl, however, are removed through reaction with potent greenhouse gas CH4 and harmful NO2, producing HCl and ClO NO2 which are then removed by rain. Under these two circumstances, these gases become part of the cure.

Cl + CH4  HCl + CH3 Cl + NO2  ClO NO2

Another potent ozone depleting gas is methyl bromide (CH3Br), which is used in agriculture to sterilize soil and fumigate crops after harvesting. The released atomic bromine acts in the same way as chlorine and in the same way can be removed through reaction with CH4 and NO2.

Greater concentration of NO2 if present in the upper atmosphere (main source, jet planes) may also destroy ozone.

NO2 + O3 NO3 + O2

Hydrogen chloride (HCl) and chlorine nitrate (ClONO2) are inactive and do not destruct ozone layer. However, in the month of September (Antarctic winter) the atmosphere in the Antarctic becomes

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very cool (temperature < – 90°C) and then the small ice crystals which make up polar clouds provide the

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surface to HCl and ClONO2

to stay for a longer duration and subsequent reaction follows:

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ClONO2 + H2O  HOCl + HNO3 HOCl + HCl  Cl2 + H2O ClONO2 + HCl  Cl2 + HNO3

Once the sun rises, (Antarctic spring) the chlorine thus formed in winter gets photolyzed and forms atomic chlorine.

Cl2 + *h*  2Cl

This atomic chlorine leads to the destruction of O3. O3 + Cl  ClO + O2

In the Arctic, the combination of land and ocean maintains warmer temperature and atmospheric conditions are not as in Antarctica and, thus, there is lesser thinning of ozone layer over the Arctic in spring.

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However, it is of great concern that due to troposphere warming by greenhouse gases, there is a possibility of stratospheric cooling which ultimately might lead to same atmospheric condition in Arctic like the Antarctic and cause dramatic ozone layer depletion.

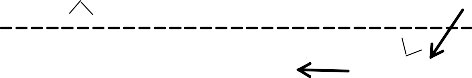
Depletion of ozone layer will lead to increase in the flux of UV radiation over the biosphere of the earth. This ultimately will lead to:

* Skin cancer
* Eye and lung irritation
* Reduced photosynthesis
* Lower crop productivity
* Change in weather patterns through interference with oxygen

The depletion of ozone (O3) molecule by CFC can be depicted as given here:

[Antarctic Spring]

UV rays



UV rays

+ HCl

Cl2

HCl + CH

+ CH4

CF2Cl2

ClONO2

3 Cl +CF2Cl

+NO2

ClO+O2

+ O3

[Antarctic Winter]

***Fig. 1.1*** *Ozone Depletion by CFC*

### Check Your Progress

1. Define climate.
2. What is global warming?
3. Why is ozone beneficial in the stratosphere and harmful in the troposphere?
4. What are the effects of depletion of the ozone layer?

## SUMMARY

* + - A disaster is a mishap or hazard which causes huge loss of life and property and disrupts the balance of the economy. It is a tragic event with drastic consequences for human life as well as social and individual development.

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* An environmental disaster is a mishap or hazardous event which directly influences the environment, bringing serious alterations in the same.
* Broadly, disasters have been categorized as natural and man-made disasters on the basis of their causes.
* Anthropogenic disasters are threats that have an element of human intent, negligence or error or have witnessed failure of a man-made system. They are also known as man-made disasters since they are the result of a failing or error on the part of humans.
* Floods are caused by too much rain or water in a location, caused by excess water surpassing the limits of its confines.
* The three types of floods are— flash floods, river floods and storm surge.
* A drought is an extended period of months or years when a region notes a deficiency in its water supply.
* A tropical cyclone is a storm system characterized by a large low-pressure centre and numerous thunderstorms that produce strong winds and heavy rain.
* Earthquakes are caused by a sudden shift or movement deep underground in the Earth’s tectonic plates, causing the Earth’s crust to shake violently, with vibrations varying in magnitude.
* An earthquake has point of origin underground called ‘focus’. The point directly above the focus on the surface is called ‘epicentre’.
* Landslides are an extremely frequent geological event. They occur when masses of rock, earth, or debris move down a slope, caused by disturbances in the natural stability of a slope.
* An avalanche is a rapid flow of snow down a slope, from either natural triggers or human activity. Typically occurring in mountainous terrain, an avalanche can mix air and water with the descending snow.
* Avalanches are always caused by an external stress on the snow pack; they are not random or spontaneous events.
* An opening in the surface of the Earth that allows lava, volcanic ash and gases to escape from its magma chamber below the surface is called a volcano.
* A heat wave is prolonged period of excessively hot weather, which may be accompanied by high humidity.
* An unusual drop in the weather over a short period of time can be called a cold wave.
* Climate is the average weather of an area. It is the general weather conditions, seasonal variations and extremes of weather in region. Such conditions which average over a long period at least 30 years is called climate.
* The average temperature of the planet has increased more than 1 degree Fahrenheit since 1900 and the speed of warming has been almost threefold since 1970. This increase in the planet’s average temperature is called global warming.
* Ozone is beneficial when it is in the stratosphere as it protects us from the harmful UV rays and harmful in the troposphere as it helps in formation of photo-chemical smog.