UNIT 18

WEATHER FORECASTING

Structure

18.1 INTRODUCTION

In this course so far, you have studied about the fundamentals of climatology like elements and controls of weather and climate, origin and evolution of atmosphere and its composition and vertical structure. You are also aware of the atmospheric processes of insolation, heat balance and pressure systems. You know about atmospheric disturbances in the form of fronts, cyclones and difference in air masses. You have studied in detail about climatic classification of both Koppen and Thornthwaite. Under contemporary issues, you have been acquainted with climate change theories and issues like global warming.

In this unit, you will study about weather forecasting. Sec. 18.2 will give you a brief introduction to weather forecasting and its types. In section 18.3, you will get acquainted with procedures or steps required in weather forecasting. You will learn about different tools required for weather forecasting section 18.4. Sec. 18.5, you will brief you about different methods of weather forecasting. Lastly you will have a brief tour about the weather forecasting India in Sec. 18.6. In the next unit, you will study about Applied Climatology which would be the last unit of this course.

Expected Learning Outcomes

After studying this unit, you should be able to:

- define weather forecasting and discuss the different types of weather forecasting;
- explain the procedure of weather forecasting;
- describe the tools used for weather forecasting;
- differentiate between different methods of weather forecasting; and
- discuss histogenesis of weather forecasting and its development in India.

18.2 DEFINITION AND SIGNIFICANCE

Weather forecasting involves predicting atmospheric conditions such as air temperature, humidity, sky conditions, air pressure, and the overall atmospheric circulation in a specific location or region. This prediction utilises scientific tools and technological knowledge, serving as a means to anticipate atmospheric conditions before they occur. The process is supported by various statistical and empirical techniques, and forecasts can be made at different temporal levels, such as daily, weekly, or monthly, depending on available information sources. Conducting weather prediction requires extensive research in atmospheric sciences.

In contemporary times, there is a growing demand for weather forecast data across various segments of society. For instance, tourists planning a week-long trip need a comprehensive weather forecast to make informed plans and take necessary precautions. Similarly, fishermen require forecasts tailored to different time frames, ranging from a few hours to several days, depending on the duration of their fishing trips. Sports events are also significantly influenced by weather conditions, with the success of outdoor games or tournaments relying on favorable weather and accurate forecasts.

Weather forecasting plays a crucial role in agricultural activities, spanning from the initial stages of sowing to the application of fertilisers, the need for irrigation, and the eventual harvesting of crops. It also aids in the storage and transportation of crops. In essence, weather forecasting is a scientific product that impacts various aspects of our daily lives.

Now, let's familiarise ourselves with various types of weather forecasting based on different time scales.

18.2.1 Types of Weather Forecasting

Weather forecasting is categorised into four types based on different time scales, each serving distinct purposes with varying accuracy parameters. Let's explore them briefly:

Long Range Weather Forecast

- Extends over periods like a fortnight, month, season, or even a year.
- Presented as statements or estimates due to lower accuracy compared to shorter forecasts.
- Considers departures from normal atmospheric conditions based on past observations.

- Important for predictions like monsoon success or failure.

Medium Range Weather Forecast

- Provided for 3 days to 3 weeks, offering greater accuracy than long-range forecasts.
- Crucial for weather-sensitive activities such as farming, flood forecasting, and transportation.
- Made possible by global forecasting models developed at various meteorological centers.

Short Range Weather Forecast

- Encompasses a few hours to a day or 72 hours, with high accuracy, especially for the first 12 hours.
- Applied in day-to-day activities like aviation, transport, tourism, and disaster management.
- Relies on maps, weather charts, satellite imagery, or changes in atmospheric conditions.

Nowcast

- A brief forecast for a few hours, focusing on current weather details and extrapolated forecasts.
- Enables detailed predictions of individual storms for small areas using radar, satellite images, and observational data.
- Offers pre-warnings for extreme weather events like cyclones, thunderstorms, and tornados.
- Essential for disaster management, aviation, marine safety, and various industries.

Nowcasting proves valuable in preventing casualties, minimizing property loss, and safeguarding the economy. Its applications extend to aviation, marine safety, water and power management, offshore oil drilling, construction, and leisure industries.

SAQ I

a) What is weather forecasting and why is it important in our daily lives?

b) List the different types of weather forecasting based on time scales?

18.3 PROCEDURES OF WEATHER FORECASTING

Today, the field of weather forecasting has evolved into a highly scientific endeavor, encompassing a series of well-defined steps. These include the meticulous recording, collecting, transmitting, compiling, plotting, analyzing,

and ultimately forecasting of weather-related information. Let's briefly acquaint ourselves with each of these steps.

The recording of weather data, such as temperature, pressure, wind speed and direction, and precipitation, is carried out using an array of instruments and tools at weather and meteorological stations worldwide. These stations, situated on both land and water surfaces, conduct recordings at various times throughout the day, specifically at 6 a.m., 6 p.m., 12 a.m., and 12 p.m. Additionally, satellite imagery is employed to capture and document weather-related information.

The collection of weather-related information is facilitated by numerous weather recording centers and stations strategically positioned across different global locations, including mountains, plains, plateaus, oceans, and seas. These centers gather meteorological, climatological, hydrological, and oceanographic data from a vast network, including over 15 satellites, 100 moored buoys, 600 drifting buoys, 3000 aircraft, 7300 ships, and around 10,000 land-based observation stations, all constituting the World Meteorological Organisation (WMO).

Following the recording and collection processes, the transmission of weather-related data takes place. The World Meteorological Organisation, a scientific body under the United Nations founded in 1950, boasts 191 member countries and a substantial network of observatories and stations. The WMO collaborates with the National Meteorological and Hydrological Services of its member countries, sharing weather-related data internationally through the World Weather Watch. Three primary collection centers, situated in Washington D.C. (USA), Melbourne (Australia), and Moscow (Russia), facilitate the transmission of information from local and regional centers. This system ensures the dissemination of daily weather forecasts and timely warnings for significant weather and climate events.

Following the recording, collection, and transmission processes, climatological experts take on the tasks of compiling and analyzing the data. Computers play a crucial role in this final analysis, with experts utilizing various models, which will be explored in subsequent subsections. Finally, after the analysis, the data is interpreted in the form of a weather forecast.

18.4 TOOLS IN WEATHER FORECASTING

You are already acquainted with various instruments utilised for collecting weather-related data, such as thermometers, barometers, hygrometers, and rain gauges, which provide localised measurements of weather variables. The advent of satellite climatology has extended the capability to obtain weather-related information over larger areas and measure upper air weather conditions. Instruments like radiosondes, satellites, and radars play crucial roles in gathering upper atmospheric data. Let's delve briefly into the details of these instruments.

Radiosondes, illustrated in Fig. 18.1, are instruments lifted by balloons equipped with radio transmitters. The term "radiosonde" combines "radio" for the onboard transmitter and "sonde," an old English term meaning

messenger. These instruments contain sensors capable of directly measuring pressure, temperature, and wet bulb temperature up to an altitude of approximately 30 km. The collected data is promptly transmitted to ground stations via the onboard radio transmitter, with ground-based antennas tracking the motion of the radiosonde for measurement purposes.

Fig: 18.1: Radiosonde.
(Source: https://en.m.wikipedia.org/wiki/File:Radiosonde-wx-balloon.jpg, cc: Public Domain)

Rawinsondes, akin to radiosondes, offer wind speed and direction at various altitudes through radar tracking. These balloons, filled with hydrogen and featuring a metal target, reflect radar signals, allowing horizontal drift measurements in addition to ascent.

Both airplanes and satellites contribute to capturing images of earth's atmosphere at different levels. Airplanes provide aerial photos of cloud covers, particularly at lower altitudes, while satellites, categorised as geostationary and polar orbital satellites, play a crucial role in capturing images and recording atmospheric data. Geosynchronous satellites, positioned at extremely high altitudes (about 36,000 km), cover larger areas, while polar satellites, due to their lower altitudes (about 800 km), capture detailed information on smaller areas like cloud cover and water vapor.

Satellites are equipped with two types of sensors: sounding sensors, exemplified by AVHRR (Advanced Very High Resolution Radiometer), which provide information on thermal conditions, cloud cover, and water vapor and are attached to polar satellites; and imaging sensors, attached to high-altitude geosynchronous or geostationary satellites, offering insights into thermal and

humidity conditions, as well as capturing images of the physical and cultural landscape.

Radars, operating on microwave wavelengths, are active remote sensing systems. Unlike passive systems, radars can capture images during day or night, and in various weather conditions, including clouds and precipitation. The fundamental principle involves transmitting a microwave signal toward a target object, detecting the backscattered radiation, and measuring the strength of the signal to discern different targets. The time delay between transmitted and reflected signals determines the distance or range of the target object from the radar. Refer to Fig. 18.2 to understand better.

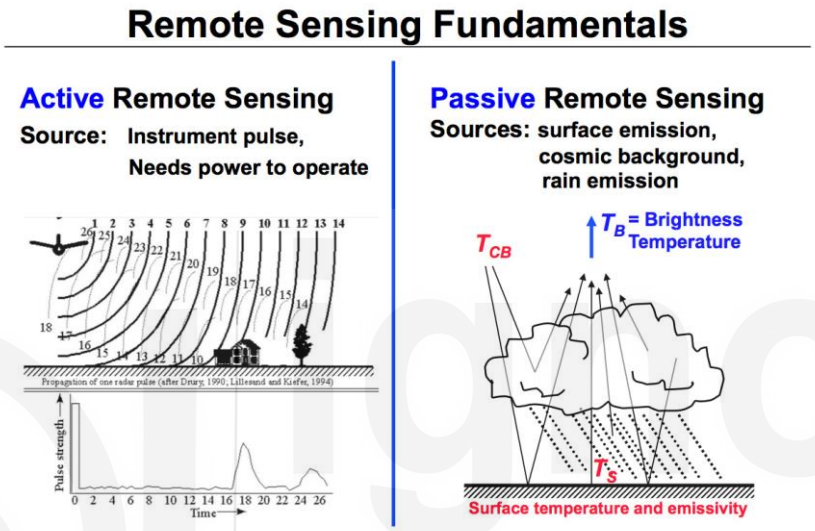

Fig. 18.2 Active and Passive Remote Sensing.
(Source: http://pmm.nasa.gov/image-gallery/active-and-passive-remote-sensing-diagram, Credit: NASA)

Before we proceed to the next section, let us answer some short answer type questions.

SAQ 2

a) What are some instruments used for collecting weather-related data on a localised level?

b) How is weather-related data transmitted internationally?

Let us now delve into different methods of weather forecasting.

18.5 METHODS OF WEATHER FORECASTING

Various methods are employed for weather forecasting, chosen based on forecaster experience, available information, and forecast complexity. Weather forecasting involves extensive atmospheric research, incorporating mathematical and statistical techniques. Professional weather scientists and forecasters employ these methods. Let's explore some well-defined forecasting methods.

Persistence Method

As its name implies, this method is the most straightforward of all those mentioned above and is predicated on the idea that "today equals tomorrow." This approach makes the assumption that the current atmospheric conditions will continue to exist tomorrow. For instance, if this form of prediction is used and it is sunny today with a temperature of 36°C, then tomorrow will likewise be the same. This approach functions well in locations where seasonal or temporal variations in the weather are minimal. For instance, predictions during the summer months in Mumbai can be produced using the persistence approach because the daily weather conditions there don't vary much at that time of year. Although this strategy seems to be more appropriate for short-range weather forecasts, but it is also suitable for long-range weather forecasts such as monthly or seasonal forecasts. In that case, a cold and dry month may be followed by another cold and dry month.

Trends Method

This method, as its name implies, bases predictions on specific *trends* that are seen. These trends could be similar to wind direction and speed during a cyclonic event, which could help forecast the weather conditions with precision as to when the cyclone would make landfall at a certain location. For instance, a cyclone that is moving West at a speed of 300 km/day and is 700 km East of a region, it will reach that particular region in five days. If the forecast is prepared for a few hours, the trends method can also be used for nowcasts. Take for example, a cyclone is located about 100 Km south-west of a place and is moving in north-easterly direction at a speed of 50 km/hr. It will take only two hours to reach the place. However one thing has to be kept in mind, that this method applies only when there is some sort of consistency in the elements of weather in a particular system.

Climatology Method

Just as climate of a place is determined by average weather conditions over a long period of time, so this method involves the predictions of weather conditions of particular place and time by finding out the average weather conditions of that particular place and time that has accumulated over a long period of time. For example if one has to make predictions of weather conditions of Chennai for 10th of December, then all weather data recorded in over the years for Chennai city for December 10, would be accounted for. As this method also relies of previous weather trends of a particle day or month, and that too for a long period of time, it works well if the weather conditions are more or less similar for that particular place for that particular time. The weather conditions at that period of time for that particular place is not uniform then the results will not be so appropriate and this method will not be suitable.

Analog Method

This method is based on regularity or periodicity of weather conditions in the past and belief of recurrence or repetition of similar weather events in future. Analog method thus finds an analogy of a particular day’s forecast scenario with a day in the past when the weather scenario looked similar. Take for example; if a cyclone had developed in an area after a warm afternoon, then

if similar temperature conditions persist in the afternoon, one can predict the arrival of a cyclone. It is however true that this method is complicated as there is impossibility to find a perfect analog. Even small differences can lead faulty results and inaccurate predictions.

Numerical Weather Prediction (NWP) Method

The numerical weather prediction method uses computers and sophisticated computer programmes and equations related to atmospheric variables such as temperature, pressure and humidity. These equations are then used by model-running on supercomputers to make weather predictions. The equations used in numerical weather prediction method must always be very precise so as to give accurate results. Otherwise, when the models are used, errors multiply and give wrong results. Errors are also caused by certain gaps in the prior data that forms the basis of the equations and are used in a model. Despite these flaws, numerical weather prediction method is considered to be the best of the above methods and provides accurate daily weather forecast. However, it also requires immense expertise and only skilled forecasters use the model to provide accurate weather information.

These methods cater to different forecasting needs and challenges. Numerical Weather Prediction, although complex, stands out for its precision. Learners are encouraged to explore additional resources for a deeper understanding of weather forecasting types and methods.

Learners can watch the following videos related to weather forecasting from the following YouTube links:

1) Observing Weather:

https://www.youtube.com/watch?v=Y6p5fGCJbtI&list=PLDCsGRRaAZqf0UAvuVbte3ZssrUXVHBcb&index=4&t=8s

2) Predicting Weather:

https://www.youtube.com/watch?v=4Nq-LGsm8_U&list=PLDCsGRRaAZqf0UAvuVbte3ZssrUXVHBcb&index=3&t=90s

SAQ 3

a) What is the Persistence Method in weather forecasting?
b) What are the challenges and advantages of the numerical weather prediction method?

18.6 WEATHER FORECASTING IN INDIA

Established in 1875, the India Meteorological Department (IMD) serves as the country's National Meteorological Service, consolidating all meteorological activities under a single authority. Its primary goals include conducting meteorological observations, acting as a governmental agency for forecast-related activities in sectors like agriculture, water resource management, industries, oil exploration, shipping, and aviation. Additionally, IMD plays a crucial role in providing pre-warnings for extreme weather events such as

cyclones, floods, thunderstorms, heatwaves, and cold waves. This information is disseminated to disaster management agencies and the public to prevent potential loss of life and property.

IMD's objectives also extend to fostering high-end research in meteorology and related fields. The department actively detects and locates earthquakes in different parts of the country, aiding in vulnerability assessments for development projects.

Over the past 140 years, IMD has evolved from the telegraph age to the computer age and, currently, the satellite era. India proudly operates its own geostationary satellites for continuous atmospheric monitoring and precise weather predictions. The INSAT series, equipped with the Very High Resolution Radiometer (VHRR), contributes essential data for cloud motion vectors, cloud top temperature, water vapor content, rainfall estimation, weather forecasting, and cyclone genesis and track prediction. The Oceansat-2 satellite, launched in 2009, carries instruments like the Ocean Color Monitor (OCM), Ku-band Scatterometer, and Radio Occultation Sounder for Atmospheric studies (ROSA).

In addition to space-based systems, the Indian Space Research Organisation (ISRO) has developed ground-based observation systems such as the Automatic Weather Station (AWS), Agro-meteorological (AGROMET) Tower, Doppler Weather Radar (DWR), GPS Sonde, and Boundary Layer LIDAR (Light Detection and Ranging), abbreviated as BLL. These ground-based systems complement space-based observations and validate outcomes related to various earth system processes.

Fig. 18.3 illustrates the forecast accuracy of IMD during Cyclone Hudhud in 2014, with the red line representing the forecasted track and the black line indicating the actual observed track. The minimal difference underscores the high level of accuracy achieved by IMD in contemporary forecasts, with expectations of even greater precision in the future.

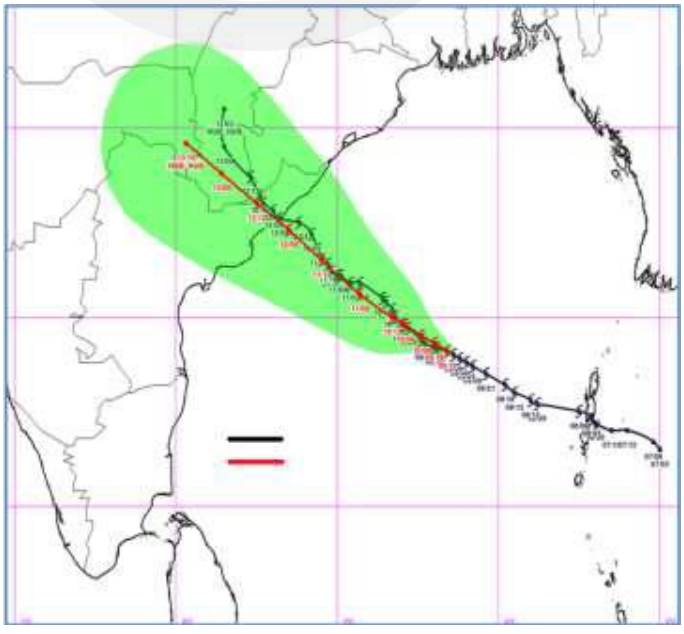

Fig: 18.3: Forecast Performance of IMD Regarding Cyclone Hudhud 2014.
(Source: IMD)

18.7 SUMMARY

Weather forecasting is defined as prediction of atmospheric conditions like air temperature, humidity, sky conditions, air pressure and general circulation of the atmosphere of a particular place or a region using scientific tools and technological knowledge. During ancient times, much of the forecasting was done in a crude manner like sky colour, wind direction, cloud colour and its cover, lightening, thunder, behaviour of some animals and birds, certain folklores etc. Systematic weather data recording started with the advent of instruments like thermometer, barometer, telegraph, radiotelegraphy, radar technology and finally satellites namely sun synchronous and geosynchronous satellites.

Weather forecasting involves some well-defined steps like recording, collecting, transmitting, compilation, plotting, analyzing and then the final forecasting of the weather related information. The tools used in weather forecasting are thermometers, barometers, hygrometers, rain gauge, radiosondes, rawinsondes, aeroplanes, satellites and radars etc.

Weather forecasting is done for different temporal scales which has different uses and have different parameters for accuracy like long range weather forecast, medium range weather forecast, short range weather forecast and nowcast.

There are several different methods used for weather forecasting. Some of the well-defined forecasting methods used by climatologists are persistence method, trends method, climatology method, analog method, numerical weather prediction method

18.8 TERMINAL QUESTIONS

1. Define weather forecasting? What are the different types of weather forecasting based on different time scales?
2. Describe briefly different methods of weather forecasting.
3. What procedures are followed in forecasting of weather?
4. Which organisation or department provides meteorological services in India. Explain briefly how weather prediction is done in India

18.9 ANSWERS

Self-Assessment Questions (SAQ)

1. a) Weather forecasting involves predicting atmospheric conditions such as air temperature, humidity, sky conditions, air pressure, and overall atmospheric circulation in a specific location or region. It utilises scientific tools and technological knowledge to anticipate atmospheric conditions before they occur. This is important as it allows individuals and various sectors of society to make informed plans, take necessary precautions, and optimise their activities based on weather conditions.

b) Weather forecasting is categorsed into four types based on different time scales. These include:

- Long Range Weather Forecast
- Medium Range Weather Forecast
- Short Range Weather Forecast
- Nowcast

2 a) Thermometers, barometers, hygrometers, and rain gauges are commonly used instruments for collecting weather-related data on a localised level.

b) Weather-related data is transmitted internationally through the World Weather Watch, which is facilitated by the World Meteorological Organisation (WMO). The WMO collaborates with the National Meteorological and Hydrological Services of its member countries and operates three primary collection centers in Washington D.C., Melbourne, and Moscow. These centers receive data from local and regional centers and ensure the dissemination of daily weather forecasts and timely warnings for significant weather and climate events

3. a) The Persistence Method is a straightforward approach that assumes the current weather conditions will continue to exist in the future. It works well in locations with minimal seasonal or temporal variations in weather, such as predicting daily weather in Mumbai during the summer months.

b) The numerical weather prediction method requires precise equations to ensure accurate results, as errors can multiply and lead to incorrect predictions. Additionally, gaps in prior data used in the equations can also introduce errors. However, despite these flaws, the method is considered the best and provides accurate daily weather forecasts when used by skilled forecasters.

Terminal Questions

1. Your answer should contain definition of weather forecasting and a little bit of explanation. Then discuss all the types of weather forecasting as in Sec. 18.2
2. You can start with a paragraph briefing the meaning of weather forecasting and its types. Then you can elaborate on different methods of weather forecasting as given on sec. 18.5.
3. Refer to Sec. 18.3 and answer.
4. Refer to Sec. 18.6 and answer.

18.10 REFERENCES AND FURTHER SUGGESTED READING

1. Lal, D. S. (2013): Climatology, Sharda Pustak Bhawan, Allahabad.
2. Singh, S. (2005): Climatology, Prayag Pustak Bhawan, Allahabad.

Web Links

- Observing Weather: https://www.youtube.com/watch?v=EKWrrkI1xrY
- (IGNOU SOS YouTubevideo)
- Predicting weather: https://www.youtube.com/watch?v=ZJE2VrdFxDg
- (IGNOU SOS YouTubevideo)
- https://en.m.wikipedia.org/wiki/File:Radiosonde-wx-balloon.jpg
- http://pmm.nasa.gov/image-gallery/active-and-passive-remote-sensing-diagram

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