

**TOPIC: -
WEATHER ANALYSIS AND WEATHERFORECASTING.**

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WEATHER ANALYSIS AND WEATHERFORECASTING.

INTRODUCTION: -

In this course so far, you have studied about the atmospheric processes in general as well as few extreme weather events. You are also well acquainted with classification of climates given by some of the leading scholars. You have also learned about the processes that have brought about a change in climate. In this module, you will study about the processes of recording weather data which leads to forecasting of weather. Today weather prediction has become the need of the hour. Almost all sections of society need weather forecasts directly or indirectly, whether they are general public, administrators, farmers, businessmen or industrialists etc. This module will take you to the journey of weather forecasting since ancient times to the modern era when satellite remote sensing and GIS have brought about a revolution in weather forecasting methods and techniques. You will be introduced to different procedures and tools used in weather forecasting as well different types of weather forecasting.

DEFINITION AND MEANING: -

Weather forecasting simply means 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. In other words, it is a way of predicting the atmospheric conditions before they actually happen and is supplemented by a variety of statistical and empirical techniques. The weather prediction or forecast is done at different temporal levels like daily, weekly, monthly etc. depending upon different sources of information. It requires a lot of high level research work in atmospheric sciences.

As already mentioned, now-a-days there is an increasing demand of weather forecast data for different sections of the society. For example, if tourists plan a trip to a destination for a week, they will require a complete weather forecast for that duration, so as to plan accordingly. This would also enable them to take necessary precautions well in advance. Similarly, fishermen also need forecast but their need varies in different temporal ranges of forecast, ranging from only a few hours to a few days depending upon the time they go for fishing. If they come back within a day, they would need forecast of few hours. If their crew go for fishing for few days, then in that case they need forecast for that many days. Sports events also depend a lot on weather. The success of any major outdoor game or tournament depends on favourable weather conditions and of course weather forecast. Weather forecasting is highly required for all farming activities right from sowing to applying fertilizer, need for irrigation and harvesting of crops. It also helps in the storage and transportation of crops.

So in a way we can say that weather forecasting is a product of science that impacts us in all walks of life.

HISTOGENESIS OF WEATHER FORECASTING: -

In module 32, related to Progress in Climatology, you have already studied that even in ancient times much before the advent of modern tools and satellite technology, weather forecasting was prevalent in the society. Please refer to that section as it is related to the histogenesis of weather forecasting. However, we discuss that in brief here.

During ancient times, much of the forecasting was done in a crude manner by just looking at the sky and general atmospheric conditions, like sky colour, wind direction, cloud colour and its cover, lightening, thunder etc. Behaviour of some animals and birds were also marked as an indication of change in weather conditions. Certain folklores were also in use during early periods of history as a method of weather forecasting.

Systematic weather data recording started with the invention of instruments like thermometer by Galileo in 1593 and barometer by Torricelli in 1686. You must be knowing that thermometer is used for measuring air temperature while barometer is used for air pressure. The invention of telegraph in the year 1840 further helped in the collection and propagation of weather data and reports to each and every part of the world. Then with the advent of radiotelegraphy it became easier to collect climatic data. Then came the air-craft sounding technique which further revolutionised the method of weather data collection. Then with the help of radar technology, it became possible to determine upper winds with greater accuracy as well as track tropical cyclones, thunderstorms and other extreme weather events.

The first meteorological satellite, TIROS 1 was launched by United States in 1960. You have also studied that there are two types of weather satellites, namely sun synchronous and geosynchronous satellites. Also the invention of high speed electronic computers also revolutionized the method of analyzing climatic data. It helped to solve various complex mathematical problems with ease which is very important in various weather predicting models.

PROCEDURES OF WEATHER FORECASTING: -

Today weather forecasting has become very scientific and involves some well-defined steps like recording, collecting, transmitting, compilation, plotting, analyzing and then the final forecasting of the weather related information. Let us get acquainted with them in brief.

Recording of weather data like temperature, pressure, wind speed and direction, precipitation etc. is done with the help of several instruments and tools in weather and meteorological stations. These stations are located around the world be it land or water surface. These recordings are done at different times of the day, especially during the four times, that is, 6 a.m., 6 p.m., 12 a.m. and 12 p.m. Satellite imageries are also studied to record weather related information.

Collection of weather related information and data is done through various weather recording centres and stations scattered at different places around the world. These centres are distributed in various landscapes, that is, mountains, plains, plateaus as well as water areas in the oceans and seas. They collect meteorological, climatological, hydrological and oceanographic data from over 15 satellites, 100 moored buoys, 600 drifting buoys, 3000 aircraft, 7300 ships and some 10,000 land-based observation stations which are a part of World Meteorological Organisation (WMO).

Transmission of weather related data is done after the recording and collection. World Meteorological Organisation is a scientific body of United Nations established in 1950 and having 191 member countries with a huge network of observatories and stations as mentioned above. WMO coordinates with National Meteorological and Hydrological Services of its member countries through which weather related data is shared internationally through the World Weather Watch. There are three major collection centres of WMO where the information from local and regional centres are transmitted. They are located at Washington D.C. in USA,

Melbourne in Australia and Moscow in Russia. This enables in the dissemination of daily weather forecasts and early and reliable warnings of high-impact weather and climate events.

After the processes of recording, collection and transmission of data comes the work of compilation and analysis of data which is done by climatological experts. Computers are used in the final analysis work and various models are in use by the experts which we would learn in the coming subsections. Lastly after the analysis, final interpretation is done which is in the form of weather forecast.

TOOLS IN WEATHER FORECASTING: -

You are already familiar with several instruments that are used to collect weather related data. These instruments are thermometers, barometers, hygrometers, rain gauge etc. that measures weather variables locally. With the advent of satellite climatology, it has been possible to get weather related information for a relatively larger area and also measure upper air weather conditions. So radiosondes, satellites, radars, etc. help in collection of upper atmospheric data. Let us learn about the other instrument in brief here.

Radiosondes are instrument that are carried aloft by a balloon as shown in Figure 1 and has radio transmitting capabilities. It is a combination of two words "radio" which is for the onboard radio transmitter and "sonde", which means messenger from old English. It contains sensors capable of making direct in-situ measurements of pressure, temperature and wet bulb temperature upto an altitude of approximately 30 km. The observed data is transmitted immediately to the ground station by a radio transmitter located within the instrument package. The ground based antenna tracks the motions of the radiosonde and measurements are taken.

Rawinsondes are similar to radiosondes but they provide wind speed and direction at various altitudes based on radar tracking. This is because the balloon is filled with hydrogen and is released with a metal target to reflect radar signals. So apart from ascending, the balloon also drifts horizontally as per wind speed.



Fig. 1: Radiosonde.

Both aeroplanes and satellites are used for taking pictures of the earth's atmosphere at different levels. **Aeroplanes** provide aerial photos of cloud covers at probably lower altitudes. **Satellites** on the other hand are of two types basically geostationary and polar orbital satellites that are important for taking imageries and recording atmospheric data. You have already read about them in module 32 of this course. You may recall that geosynchronous satellites because of the extremely high altitudes (about 36,000 km) are capable of taking imageries of a relatively larger area compared to the polar satellites. Polar satellites on account of their low altitudes (about 800 km) are capable of recording minute atmospheric details of relatively smaller area like cloud cover, water vapour etc.

There are two types of sensors attached with satellites. One is the sounding sensor and another is the imaging sensor. An example of sounding sensor is AVHRR (Advanced Very High Resolution Radiometer) that provides useful information about thermal conditions of the atmosphere, cloud cover, water vapour etc. They are attached with polar satellites. On the other hand, the imaging sensors are attached with high altitude geosynchronous or geostationary satellites and provide information about thermal conditions and humidity conditions of the atmosphere. They are also capable of taking pictures about physical and cultural landscape of the region.

Radars (Radio Detection and Ranging) are active remote sensing systems operating at microwave wavelengths. You have already studied about active and passive remote sensing

system. The primary advantage of active remote sensing system or radar is that, it can take imageries during any time, whether it is daylight or night or in any weather condition whether it is cloudy or precipitating in the form of rain or snowfall. The basic principle underlying a radar is that the sensor in this transmits a microwave (radio) signal towards a target object and detects the backscattered radiation. The strength of the backscattered signal is measured to discriminate between different targets and the time delay between the transmitted and reflected signals determines the distance (or range) of the target object from the radar. There are different modes of operation of the radar, that is *constant wave mode* which is continuous and *pulsed mode* which transmits electromagnetic waves in short pulses. Refer to Figure 2 to get a clear picture of Radar.

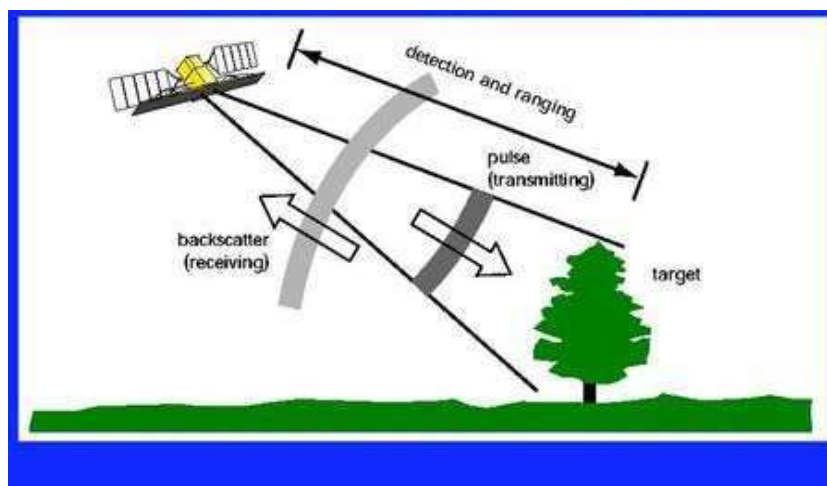


Fig. 2: Fundamentals of Radar.

Now let us get acquainted with different types of weather forecasting based on different time scales.

TYPES OF WEATHER FORECASTING: -

As mentioned above, weather forecasting is done for different temporal scales which has different uses and have different parameters for accuracy. So on the basis of different time scales, there are four types of weather forecasting. They are listed below:

- i. Long Range Weather Forecast
- ii. Medium Range Weather Forecast
- iii. Short Range Weather Forecast
- iv. Nowcast

LONG RANGE WEATHER FORECAST: -

Long range forecast as the name suggests is done for a longer temporal range. These are not forecasts in true sense but are given in the form of statements or estimates for the period ranging from a fortnight, month, season or even a year. As these are given in the form of statements and is for a longer period, the level of accuracy is definitely lesser compared to the shorter ranges of weather forecasting. Such forecasts give due consideration to the departures of temperature and pressure and other atmospheric conditions from normal atmospheric conditions for a particular season or period of time. These departures are seen from an average of past observations regarding the different elements of weather or atmospheric conditions. Long range forecasts are considered important if the forecaster believes that the forecasting is accurate and his level of confidence is high. For instance, if a forecaster says that it would rain next Monday with a 90% level of confidence, then it is considered important. Similarly, long range forecasts are given for a season, like for predicting the success or failure of monsoons in case of India. These are based on several parameters like Southern Oscillation, El Nino, or both, that is ENSO (El Nino and Southern Oscillation). You must have watched on television news channels regarding predictions for the success of forthcoming monsoons by climatic experts very often.

MEDIUM RANGE WEATHER FORECAST: -

Medium range weather forecasting is given for the time interval ranging between 3 days to 3 weeks. These have greater accuracy compared to long range weather forecast but have lesser accuracy in comparison to short range weather forecasts. Like long range weather forecasts they are also given considering the mean weather conditions for the extended period based on past and present weather conditions. This is important for various weather sensitive activities such as farming operations, flood forecasting, water resource management, sports, transport etc. Medium-range forecasts were impossible before the advent of satellites remote sensing for climatological purposes. Global forecasting models developed at the U.S. National Center for Atmospheric Research (NCAR), the European Centre for Medium Range Weather Forecasts (ECMWF), and the U.S. National Meteorological Center (NMC) became the standard during the 1980s for making medium-range forecasting a reality. India Meteorological Department (IMD) has operational mandate to provide day to day forecasts on short to medium range for various user specific application such as, public weather services, aviation, agriculture, hydrology, disaster management etc.

SHORT RANGE WEATHER FORECAST: -

Short range forecast is made for the time period ranging from few hours to a day or even 72 hours. The purpose of short-range weather forecasting today is to provide various users with the information on anticipated weather conditions for forthcoming two or three days. It covers areas of a few million square kilometers. The prime objective is to take necessary precautions

beforehand so as to reduce the inconvenience or damage caused by adverse weather conditions. Short range weather forecasting has a high level of accuracy compared to the two types discussed above and is based on maps, weather charts, satellite imageries or any change in atmospheric conditions over a particular location. About 80-90% accuracy is seen in forecasts that is done for smaller duration, say 12 hours. These have greater application in day-to-day activities, for example in aviation, transport, tourism, sports, health, adventure activities and for managing the disasters. This is because such forecasts are weather specific and predict specific weather phenomenon like fog, thunderstorms, cyclones, dust storms, hailstorms etc. and the information is transmitted in the form of weather report through both print (newspapers) and electronic media (radio or television channels) to the people.

NOWCAST: -

Nowcast is a weather forecast for a very short duration and comprises of detailed description of the current weather along with forecasts obtained by extrapolation usually for a few hours, say about 0-6 hours. Through nowcast, it becomes possible to forecast even the minute details of individual storms with reasonable accuracy. In this case, the forecast is done for a relatively small area like a city and minute weather details are covered with the help of radar, satellite images and observational data. It is predominantly given as a pre-warning against any extreme weather event like, cyclone, thunderstorms and tornados which has the possibility of causing flash floods, lightning strikes and destructive winds. One important feature of nowcast is that, it provides location-specific forecasts of storms right from initiation, its growth and movement to final dissipation. This location specific information helps the local people to cope with any such extreme weather events. Extrapolating radars are used for nowcasting. Nowcasting systems use the combination of radar extrapolation techniques along with satellite and Numerical Weather Prediction (NWP) model products to produce an extended short-period forecast. You will learn about NWP models in the next section of this module.

Thus, nowcast is helpful in three ways. Firstly, it prevents casualties of the population vulnerable to these extreme weather events. Secondly, it helps to minimize the loss of property either public or private in an event of any such weather related disaster. Thirdly, it also prevents the loss in economy by improving the savings for sectors that could be directly affected by weather. Besides being used for disaster management, nowcast is also used for aviation purposes. Here weather related information is given for both terminals, that is, the source and the destination as well as en-route environmental conditions are also provided. Nowcast also provides information for marine safety, water and power management, off-shore oil drilling, construction industry and leisure industry.

So far, you have learnt about different types of weather forecasting. Now, let us get acquainted with different methods of weather forecasting.

METHODS OF WEATHER FORECASTING:-

There are several different methods used for weather forecasting. The method chosen by forecasters depends upon their experience, the amount of information available to them and the level of difficulty posed by the forecast situation. Weather forecasting requires a lot of atmospheric research and includes numerous mathematical and statistical techniques and models and is done by professional weather scientists and forecasters as mentioned.

Let us study some of well-defined forecasting methods used by climatologists. They are as follows:

- A. Persistence Method
- B. Trends Method
- C. Climatology Method
- D. Analog Method
- E. Numerical Weather Prediction Method

Describe the methods.

PERSISTENCE METHOD: -

This is the simplest of all the methods listed above and as the name suggests it is based on the phrase **“today equals tomorrow”**. In this method, it is assumed that the atmospheric conditions would persist tomorrow like the way it is today. For example, if it is sunny today with the temperature of 37°C, then tomorrow also, it would be the same if prediction is done as per this method. This method works best for places where weather conditions do not change much for a particular season or time. For example, in Southern California during summers predictions can be made with the help of persistence method as there are very few changes in day-to-day weather conditions at that time there. It might appear that, this method is generally used for short range forecasts, but it is more suitable for long range weather forecasts, for example monthly or seasonal forecasts like a cold and dry month would be followed by another cold and dry month.

TRENDS METHOD: -

This method as the name suggests, is based on certain trends on the basis of which prediction is made. These trends could be like speed and the direction of winds in a cyclonic condition which could precisely predict the time when the cyclone would hit a particular place. For example, if a cyclone is at 1000 km west from a region “X” and is advancing eastwards with a velocity of 200 km per day, it would hit the place “X” in five days. Trends method is also applicable for nowcasts if the prediction is made for a few hours. For example, if a thunderstorm is located about 60 km north-west of a place and is moving in south-easterly direction at the rate of 30

km/hour, then it would reach the place in just 2 hours' time. This method is useful if there is consistency in the speed and direction of a particular weather system.

CLIMATOLOGY METHOD: -

As the name suggests, the climatology method involves the predictions of weather of a particular place and time by finding out the average weather conditions of that particular place and time accumulated over many years. For example, if one has to make predictions of weather conditions of Mumbai for 10th of June, then all weather data recorded in previous years for Mumbai for June 10, would be taken into consideration. This method works well if the weather conditions are more or less similar for that particular place for that particular time. If the weather conditions are erratic at that time, then this method will not work.

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 stormy conditions had developed in an area after a warm afternoon, then if similar temperature conditions persist in the afternoon, one can predict the arrival of storm. 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 (NYP) METHOD: -

Numerical weather prediction method uses the power of computers and complex computer programmes and equations concerning atmospheric variables like temperature, pressure, humidity etc. These equations are used by models which are run on supercomputers with the help of which weather forecasting is done. The equations used for this method has to be very precise, otherwise when the models are run, the errors multiply and give erroneous results. The errors are also due to certain gaps in the data received before which forms the basis of equations and are run in a model. However, it is worth mentioning that despite these flaws, this method is considered the best of the methods discussed above and gives precise day-to-day weather forecast. It also requires tremendous expertise and only experienced forecasters use this model to give precise weather information.

WEATHER FORECASTING IN INDIA: -

IMD was established in 1875 as a National Meteorological Service of the country which brought all meteorological work in the country under a single authority. It has the prime objective of taking meteorological observations and act as a governmental agency of forecast related to certain weather sensitive activities like agriculture, water resource management, industries, oil exploration, shipping, aviation etc. It has a tremendous role in giving pre-warning in case of extreme weather events like cyclone, floods, thunderstorms, heat and cold waves etc. The information is disseminated to the disaster management agencies and general public so as to prevent the loss of life and property if any such extreme weather condition results. One important objective of the IMD is also to prevent high end research in meteorology and related fields. It

also detects and finds out the exact location of earthquakes in different parts of the country so as to aid in some vulnerability assessment of some development projects.

Since the last 140 years, IMD has come a long way right from the telegraph age to the computer age to current times which is the era of satellites. India boasts of having its own geostationary satellites for continuous monitoring of atmospheric conditions and making precise weather predictions. The INSAT series of satellites carrying Very High Resolution Radiometer (VHRR) have been providing data for generating cloud motion vectors, cloud top temperature, water vapour content, etc., facilitating rainfall estimation, weather forecasting, genesis of cyclones and their track prediction. Oceansat-2, launched on September 23, 2009, carries Ocean Color Monitor (OCM), Ku-band Scatterometer and a Radio Occultation Sounder for Atmospheric studies (ROSA).

ISRO (Indian Space Research Organisation) has also designed and developed ground based observation systems such as, Automatic Weather Station (AWS), Agro-meteorological (AGROMET) Tower and Doppler Weather Radar (DWR) as well as Vertical Atmospheric Observations System such as GPS Sonde and Boundary Layer LIDAR (Light Detection and Ranging) whose short form is BLL. These ground based system would augment the space based observations and validating the outcomes pertaining to various earth system processes. Refer to Figure 3 to get an idea of forecast performance in terms of accuracy of IMD with respect to cyclone Hudhud which came in 2014. The red line represents the forecasted tract while the black line represents the actual observed track followed by the cyclone. There is a very little difference between the two, which suggests the high level of accuracy attained by IMD in forecast these days. In future even higher precision would be obtained.

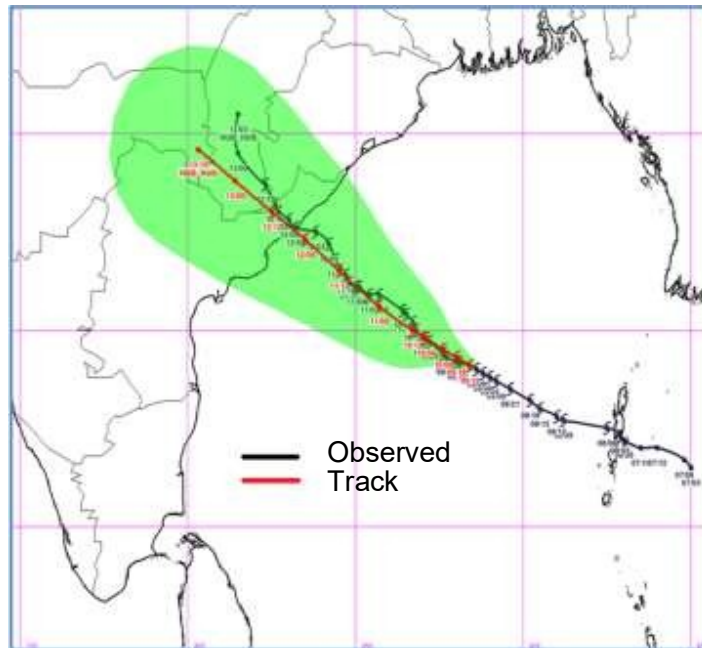


Fig. 3: Forecast Performance of IMD Regarding Cyclone Hudhud.

CONCLUSIONS: -

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.