ADVANCES IN HYDROMETEOROLOGICAL INSTRUMENTS, METHODS OF OBSERVATIONS AND FUTURE PROSPECTS

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ABSTRACT

The India Meteorological Department (IMD) having recognised the importance of the scientific and technological advances as major influences on the World Weather Programme, embarked upon advancements in instruments, methods of observations, fast telecommunication systems, data processing, analysis and archival, fast research and development and archival of data with specific objectives. To attain these objectives, IMD has built in the latest informatics coupled with implementation programmes backed by research work of a high quality in the respective fields. The present paper deals with the hydrometeorological instruments which are either sensory or instrumental type that are installed in the field stations viz. (a) Synoptic Stations (Surface and Upperair), (b) Climatological Stations, (c) Agrometeorological Stations, (d) Aviational Stations, (e) Special Meteorological Stations, linked with advanced regional, national, and the global telecommunication network. Instruments used in IMD national network and those developed in India or abroad have been described briefly to highlight advancement in meteorological instruments. Most advanced technologies, like satellite based Data Collecting Platform (DCP); rainfall measuring radar viz. Dual Polarisation Weather Radar, Doppler Radar, VHF-UHF Radar, Radio Acoustic Sounding System (RASS), Millimeter-Wave Radar etc. and rain estimation techniques based on direct and indirect methods using INSAT satellite data collected from 'VIS' and 'IR' have been described. Advanced hydrometeorological instruments as well as sensors that have been developed or under development have also been mentioned.

1. INTRODUCTION

The majestic snow clad Himalayas to the North, Vindhyachal in Central India, and Western Ghats on the West coast, as well as on the Arabian sea, the Indian Ocean and the Bay of Bengal have significant influence on Indian seasonal rainfall. Being predominantly an agricultural country, the behaviour of the monsoon rainfall controls the economy of the country with an impact on the Indian budget. In view of the severe consequences such meteorological events are needed to be predicted more accurately on the basis of the observations carried out with the help of meteorological instruments.

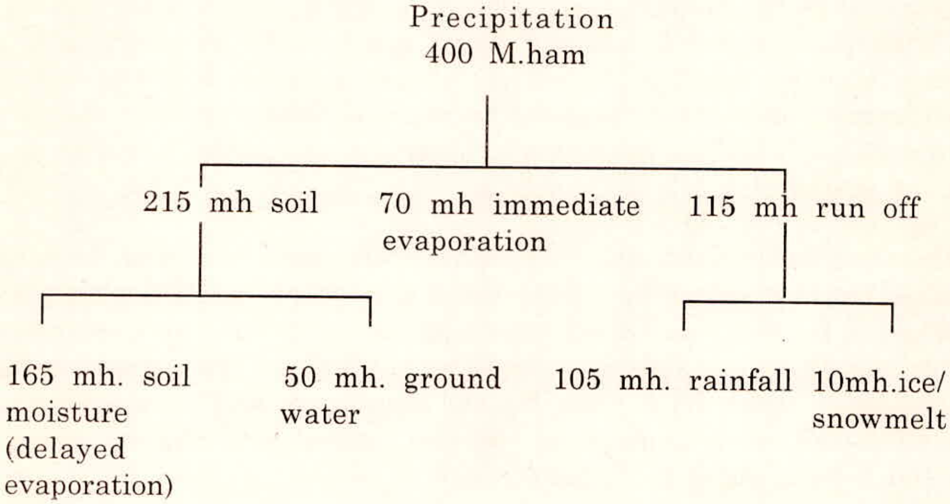
During pre-instrument era, meteorological prediction had been a premise for astrologers and their forecasts on the basis of planetery motions. A farmer was keenly watching the skies for any precursors of the coming rains. Meteorological observations in later stages were instrumental which have been further developed, and advanced sensors have been used to measure different parameters, and for recording and transmitting to distant places.

2. IMPORTANCE OF THE DEVELOPMENT OF METEOROLOGICAL INSTRUMENTATION

Staggering difficulties that forecasters faced in the early days had motivated scientists for continuous research on sensors for accuracy, quality, coverage of more areas, with fast telecommunications, developing forcasting models for prediction of the track of tropical cyclones and its landfall, needed sophisticated facilities like radar, satellite monitoring coupled with other instrument observations, to protect human life and prevent damage to property. Similarly forcasting of seasonal rainfall, snowfall and glacier melt etc. for fresh water availability round the year.

India receives an average of 117cm. of rain annually, more than the global average of 100cm. This amount produces 400 million ham. of fresh water which is sufficient to meet all our requirements. However, the distribution in time and space is highly erratic ranging from less than 10cm. in the Thar area to more than 1000cm. in Meghalaya. A brief water budget follows; During the monsoon months (June to Sept) 770 M.Ham of moisture is transported over India from the Arabian

Sea and 340 M.Ham from the Bay of Bengal. About ¼th of it falls as precipitation (88cm). The annual normal for the country is 116.6cm. with a coefficient of variation of 30 percent over the country's land surface of about 329 hect., generating about 400 M.Ham of water in a year.



Of the total usable water of 130 M.Ham, about 1/3rd is being utilised for the present–90 percent in irrigation and 10 percent for other uses.

3. PRESENT STATE-OF-ART OF HYDROMETEROLOGICAL INSTRUMENTS

Meteorological stations on land or the seas are spatially distributed to cover the whole country and connected by fast telecommunications to disseminate the quality of controlled data to a centralised data bank. Hydromet stations are subjected to periodic inspection to ensure the high quality of data.

1. IMD's Hydromet Network.
2. State Network.

Weather Elements

a) Atmospheric Pressure

Atmospheric pressure which is equal to the weight of a vertical column of air to an unit cross sectional area above the earth's surfaces, extending to the outer limits of the atmosphere, are measured in hecta pascal unit, by Mercury barometer—(Fortin and Contracted, Aneroid barometer—(Analog and Digital), Hypsometer, Altimeter and through DCP.

b) Measurement of atmospheric humidity

The measurment of absolute humidity, relative humidity and dew point are made through dimensions of hygroscopic materials, like hair, horn, gold-beater's skin etc. Electricl resistance method, thermodynamic method, condensation method, diffusion method, absorption method, and electrical capacitance method are used.

c) Measurement of Surface Wind Direction and Speed

Wind direction is measured by mechanical and electrical wind-vanes; wind speed is measured by mechanical anemometer, thermoanemometer, anemograph etc. Measurements of humidity, wind speed and direction, and sunshine are also done through satellite based data collection platforms.

d) Measurement of Rainfall

The precipitation reaching the ground is either in liquid form (rain, drizzle, etc.) or solid form (snow, hail, etc.), the depth of which is measured in millimeters. Following are the instruments used for collecting and measuring precipitation:

Ordinary rain gauge (ORG), Self recording raingauge (SRRG), Tipping bucket precipitation recorder, Automatic weather stations (AWS-DCP) and Data collection platforms.

e) Measurement of Snow

Snow observations can be made either qualitatively or quantitatively. Qualitative observations include the following:

i) Dry snow- When a ball is not made, when a handfull of snow is pressed in the fist.

ii) Moist snow- When a ball is made but water does not stick to the palm.

iii) Wet - When water sticks to the palm.

iv) Very wet - When palm gets wet.

v) Slush - When water starts dripping on pressing the snow. Hardness of snow can be observed qualitatively by the following methods:

Type	Simple hard test
Very soft	When fist enters the layer
Soft	When fist does not enter, but forefinger does
Medium hard	When forefinger does not enter but a pencil does
Very hard	When pencil does not enter, but a knife does
Ice	When knife does not enter.

Quantitative observations are made through the use of a number of instruments, among them are:

i) Snow ruler – Measures the depth of snow cover

ii) Snow gauge – Measures liquid water content

iii) Snow sampler – Measures liquid water content

iv) Snow pillow – Measures liquid water content

v) Game-ray snow monitor – Measures liquid water content

vi) Weighing balance precipitation recorder – It is based on the principle as an ordinary counter weight letter-balance used for solid precipitation in cold climates.

4. ADVANCED TECHNIQUES IN METEOROLOGICAL OBSERVATIONS

Remote Sensing

In remote sensing, information is acquired by detecting and measuring changes that the object impresses on the sounding field, such as an electromagnetic field or perturbations of the sounding gravity or magnetic potential field.

i) **Satellite Techniques:** Information about the precipitation using satellite data is obtained indirectly as the VIS and IR sensors of the satellite "See" clouds only and not the precipitation embedded in them. Rain estimation techniques use the satellite data estimated by direct and indirect methods. Microwave techniques are used in direct methods to obtain instantaneous rain rate over the oceans. Cloud characteristics in the VIS and IR channels are used as indicators of the occurence of PP data in the indirect method. Cloud type, cloud temperatures (CTT) and cloud area extent are considered to estimate the precipitation rate and duration. Indirect techniques can again be subdivided into (a) Life history and (b) Cloud indexing and bispectral techniques. India at present has two series of satellites, INSAT-I and INSAT-II and a series of polar orbital (Sun Synchronous) IRS satellites.

Cloud Indexing Methods: A grid is superimposed on the satellite image and the numerical values or indices are assigned to each square of the predetermined grid. These indices are related to cloud cover within each square in the grid and to cloud type. They are assigned on the basis of probability and intensity of the rain depicted from each type of cloud. Correlation for the local terrains are made.

Follamesthee (1973) technique: Using this technique over a broad study area, through a relationship, we can calculate the daily average rainfall (R) as

$$R = \left(X\ K1\ A1 + K2\ A2 + K3\ A3\right) / Ao$$

Where, ***A0*** is the area under study. ***A1***, ***A2*** and ***A3*** are areas of ***A0*** covered by most important types of rain producing clouds and ***K1***, ***K2***, ***K3*** are the empirical coefficients related to rain rate of the concerned cloud type.

Using Kilansky and Ramage's (1976) method, rainfall estimation is done in the VIS-band over large areas and time by relating Highly Reflective Cloud (HRC) with the average rainfall over the area as

$$R_{i,j} = a + b\ {}^{*}N_{i,j}$$

where, R = mean monthly rainfall at point (i, j), Ni,j is the number of days/months with HRC at point (i, j)

a = intercept point and b = regression coefficients

IMD's (Rao et al., 1989) method: It is designed at the Meteorological. Data Utilisation Centre (MDUC) of IMD and covers from 35 N to 25 S and 40 E to 10 N. This domain is sub divided in 2.5x2.5cms (latitude/ longitude) boxes. The gray shade value of each pixel in a box is read and converted into its corresponding temperature. The whole image is scanned and the high gain classes of each box are filled by placing the pixel in a box and using predetermined 16 class histogram for all eight images of the day and the total number of pixel each in each class of histogram are calculated by addition and such total is done for the regained period. Fractional area, in each box, covered by clouds having cloud top temperature colder than a given threshold temperature is calculated by:

$$fe = \frac{\text{Sum of pixels of colder than threshold temperature}}{\text{Total number of pixel in a box}}$$

Precipitation Index (PI) = K * fe * Ne

where K = constant, related to daily rain rate = 071.2 mm/day and threshold temperature = 235K

fe = Fractional Clouding

Ne = Number of days over which accumulation is carried out.

(ii) *Radar Meteorology*: Radar meteorology is the discipline of trying to use back scattered electromagnetic radiation to gain information about the state of atmospheric specially with respect to cloud and precipitation. Radar sends out a powerful/beam of electromagnetic radiation which on meeting an object is partly absorbed and partly scattered in all directions, and part of that energy is received by the radar at a time 't,' which is related to the distance 'r' of the objects as:

$$r = c\,t/2$$

where c = velocity of the electromagnetic wave.
t = time from the moment of transmission.

The rate of precipitation (R in mm/hr) falling to the ground is a function of volume of liquid water and the fall velocity and, therefore, is proportional to D. Reflectivity factor (Z) is proportional to the sixth power of drop diameter:

$$z = a\,R^{b}$$

where a, b are constants.

The power (P) received from a unit volume at distance 'r' from the radar can be written as:

$$P = c\,Z\,/\,r^{2}$$

where, c = constant and P is related to r and by measurements of P, one can measure the rainfall rate. This is the principle of quantitative estimation of precipitation by radar. The types of radar that are in use now are:

Dual Polarisation Radar: It has the capability of transmitting the polarised waves in either the vertical or horizontal state. It utilises the nonspherical shape and high degree of orientation of hydrometeors. Zdr is measured by illuminating the volume successively at two linear polarisations for small and larger size hydrometeor, at vertical (V) aligned along the symmetry axis and horizontal (H) aligned along the major axis of oblate drops. The back scattered power is received in the same sense as transmitted.

Zdr (in decibels) =10 log (Zh/Zr)

Rainfall rate = R = 0.0068 Zh (Zdr = 0.474)$^{-2.45}$

Where Zh = back scattered power at horizontal polarisation (in millimeter to the sixth power).

Zv = B..k scattered power at vertical polarisation

0.5 < Zdr <4.8 dr.

Doppler Radar: The Doppler radar utilises the phase property of electromagnetic radiation for estimating speed of scatters. Over a scatter is moving the back radiation from a moving droplet and will have its frequency shifted in proportion to the speed of movement of the droplet.

VHF-UHF Radar:.It is a new generation Doppler radar that can observe wind, turbulence, stable atmosphere layers in the troposphere, stratosphere and mesosphere via scattering from clear air irregularities and mesosphere via scattering from clear air irregularities in the radian irrespective of the radar.

Radio Accoustic Sounding System (RASS): It is a remote sensing equipment to provide the temperature in the lowest kilometer of the planetary boundary layer with an accuracy of = 0.3 C.

5. DEVELOPMENTS IN HYDROMETEOROLOGICAL INSTRUMENTATION

Basic Synoptic Weather Stations - Developed by China to measure temperature, humidity, pressure, wind speed and direction, precipitation, radiation and soil temperature.

Multipurpose Telemetric Meteorological System - Developed by China in 1990 to record meteorological parameters as above.

Humidity - HMT 35 D, AWS electronic sensors/transducers, with improved polymer in HUMICAP capacitive sensor for humidity and improved temperature compensation of measurements developed by Finland in 1988. Similarly, electronic tensiometer 8403 gives measurement of soil suction tension by ceramic cell and Piezoresistive transducer used for agrometeorology, soil moisture measurements and was developed by Germany in 1991.

Precipitation - SL-1 tipping bucket raingauge - China (1979), DRD 11 precipitation detector (Finland 1990) based on capacitative detection of signal change due to droplets, heating for melting snow, rain detector sensor (German 1990) based on infra-red light barrier system "Yes/No" signal, weather station with optical precipitation sensors and freezing point sensors (Sweden 1991), are the few newly developed technologies in use.

Similarly, many more new technologies are in use to measure evaporation (Electromagnetic Evaporation Meter, German–1992); radiation measurements based on diffuse radiation (Finland–1990), luminescence of sky (France 1992) thermopile pyranometer for global radiation (France) etc.

6. TECHNOLOGY UNDER DEVELOPMENT FOR METEOROLOGICAL INSTRUMENTS

There are many new technologies which are still in the laboratory experimental stage to attain the required precision and accuracy.

Syresol (France) – To recognise the principle state of the ground (dry, humid or wet or covered with snow).

"Schuman" and "Smash" (France) – To detect, identify, qualify the principle of precipitating and suspending hydrometeors.

Atmospheric Pressure – Measurements based on Remote Video Observing System (Canada), PTB 100 Analog Barometer (Finland), Digital Sensors (Russia) etc., and many more are in the process of development.

(I) Data Collection and Exchange

To study the global atmosphere and issue accurate weather predictions, the World Meteorological Organisation (WMO) has launched a programme known as World Weather Watch (WWW). Under this programme, World Meteorological Centres (WMC) in Washington, Moscow and Melbourne are linked with the Global Meteorological Centres (GMC), and Regional Meteorological Centres (RMC) through Regional Telecommunication Hubs (RTH). GTS is a three tier telecommunication system -- Main Telecommunication Network (MTN), Regional Meteorological Telecommunication Network (RMTN) and the National Meteorologcial Telecommunication Network (NMTN).

Domestic data are collected first at the observatory and passed on to the regional centres (RCs) to RTH – New Delhi. To do this in a faster way on high speed Automatic Switching System (AMSS), computers have been installed in three RCs and installation of AMSS at Chennai and Guwahati is under progress. RTH New Delhi is situated on the Main Telecommuncation Network (MTN) of GTS, WMCs and 13 International Capitals have point-to-point link with RTH New Delhi through which the RTH collects global data and puts them into the GTS for distribution.

(II) Archival and Analysis

Raw data collected every day are recorded on a magnetic tape from AMSS and the telecommunication computer. Real time data collected through GTS are filtered by software to remove the unwanted and rejected data and the same are plotted on charts and analysed through computers. The same data are plotted and analysed manually in the Northern Hemisphere Analysis Centre (NHAC) New Delhi to study and forcast Regional and Global Weather System. Regional data collected from RCs are sent to the National Data Centre (NDC) at IMD–Pune to filter the data with the help of suitable software and archive for future utilisation.

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