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Evolution of surface meteorological observations systems in India

R. R. MALI

India Meteorological Department, MoES, India (Retired)

C-704, Mohite Township Sinhagad Road, Pune – 411 051, India

e mail : rajesh132002.rm@gmail.com

सार– लेख में उन विकासों का वर्णन किया गया है जिनके कारण भारत मौसम विज्ञान विभाग (आईएमडी) में सतही मौसम विज्ञान अवलोकन प्रणालियों की स्थापना हुई। आईएमडी राष्ट्र की सेवा में पिछले 150 वर्षों से सतही मौसम विज्ञान उपकरण नेटवर्क का निरंतर उन्नयन और आधुनिकीकरण कर रहा है।

ABSTRACT. The article describes the developments that led to the establishment of the Surface meteorological Observation systems in India Meteorological Department (IMD). IMD is continuing upgrade & modernize the surface meteorological instrument network through the last 150 years in the service of the nation.

Key words – India, Observatories, Meteorology, IMD, History.

1. Basic surface observatory

The meteorological services all over the world have set up a network of weather observation stations in their countries to provide meteorological support to various government and other user agencies engaged in implementing diverse national development programmes. The vast global network of these observation stations makes use of a very large number and variety of instruments for every measurement of different atmospheric parameters near ground and in the free atmosphere and collect vital meteor logical data required by the organizations to carry out their day-to-day activities. The surface instruments permanently installed in the field, most of them completely open to the atmosphere, while some are placed within specially designed instrument shelters or screens where they are required to be in continuous operation round the clock. It is equally important, that the large volume of data generated from network stations every day, round the year, is consistent and comparable both nationally and globally in order that it can be satisfactorily used, with high degree of confidence, for day-to day precise weather analysis and weather predictions activities and for climatological purposes. This depends, not only on the instrument's accuracy and performance but equally on the care and considerations the weighed while setting up an observation station/network and the procedures and practices followed in making measurements which ensure that data obtained are representative of true state of the atmosphere at the time of observation.

The World Meteorological Organization (WMO) has thus laid great stress on the standardization of observational procedures to adopt uniform practices in establishing surface observation stations and making reliable measurements of different weather elements.

The surface meteorological observatories are established to monitor surface weather parameters at regular interval for various meteorological parameters. The WMO has recommended that the surface meteorological stations should generally be located at distances not exceeding 150 Km. The objective of establishing such a vast network is that to have adequate spatial coverage to obtain a more representative state of the atmosphere over the country. The national network established they can provide support for daily weather analysis and forecast activities. The information obtained can also provide support and meet the needs of various other user agencies. The large volume of data generated also helps to build up the national & global data base which can be used to establish long-term climatology of the country.

In addition, most often, the meteorological services are also called upon to provide support to various other national resource development programmes being undertaken by the countries like developments in agriculture, aviation, and hydrology. These have led to the establishment of specific purpose surface observational networks of what are known as agrometeorological, hydrological and aviation weather stations which cater especially to these requirements in the countries.

1.1. *Surface observation set up and their basic instrument set up.*

The meteorological services need to establish a network of observation stations to monitor at regular intervals, various meteorological parameters that may determine the state of the atmosphere over the country at the time of observation. This information obtained is fundamental to meet one of the primary obligations of a national meteorological services. A denser observational network would thus help to derive a more accurate picture of the atmosphere and its variation with time, as the observed data pours in at the forecast centres at periodic intervals. These stations which make surface measurements at regular intervals for the daily weather analysis and forecast purposes are more commonly known as principal observation stations or synoptic stations. (Fig. 1) The services are thus continually engaged in augmentation and upgrading the network to have adequate spatial coverage.

The basic meteorological parameters required to be measured at these stations and the instrument most used for the purpose are given in the Table 1.

TABLE 1

Sr. No	Weather element to be measured	Instruments used for the purpose
1.	Atmospheric pressure	Barometer, Barograph, Solid state sensor
2.	Wind Speed & Direction	Anemometer, Windvane, Anemograph, Optical anemometers, shaft encoders, Ultrasonic sensors.
3,	Atmospheric Temperature	Thermometer and thermographs, Solid state sensor
4.	Atmospheric Humidity	Psychrometer, Hygrograph, Solid state sensor
5.	Precipitation (rain and snow)	Rain gauge, Snow gauge, Self-recording rain gauge, Tipping bucket rain gauge.
6.	Evaporation	Evaporimeter and automatic evaporimeter
7.	Soil Temperature	Soil thermometer, Solid state sensor
8.	Sunshine and solar radiation	Sunshine recorder and radiometers.

1.2. *Some special characteristics features of Surface Meteorological Instruments*

India meteorological Department (IMD) placed scientific instruments to measure any variable parameters, with two most important consideration.

Fig. 1. Typical synoptic observatory site photograph.

(*i*) The 'accuracy' with which the instruments can measure (and indicate/record) the true value of the parameters at the time of measurement, and

(*ii*) Its 'sensitivity' or response to sudden, sharp changes in the magnitude of the variable.

The two characteristics features – 'accuracy and sensitivity' in respect of any instruments used for the measurement of physical quantity. Ideally, a measurement value is said to be accurate, if it is as close to the "true value". IMD has made special efforts to measure various weather parameters values from these instruments as close as "true value", by identifying the various possible sources of errors in the measurement like instrumental errors and personal errors and apply necessary correction to obtain a value which could be the best approximation to the "true value".

For example, the true surface air temperature values obtained depend not only on the type of thermometer used but also on several factors other than thermometer characteristics that affect the measurement – like proper exposure of thermometer, actual procedure followed for taking the readings *etc*. Similarly, the 'sensitivity' or response of an instrument to a sudden change in the variable, needs to be considered in the context of the data requirement. For example, a large response time of an instrument could give rise to lag errors, so that instrument fails to measure/indicate changes in the variable which may be considered significant for some specific program.

Hence, due to the varying nature of the data requirement for synoptic/ climatological purposes the two instrumental characteristics 'accuracy' and 'sensitivity', acquire a somewhat different perception in respect of conventional surface instrument used for routine measurements than what is normally understood by scientific instruments users.

1.3. *Standard observational practices*

Having good reliable instruments and installing them correctly at carefully selected observations sites with desired exposure conditions need not necessarily results in data quality as desired by the IMD. Manual observations are taken by the number of personnel, spread over the entire national network follow uniform, standardised, measurement practices. If this is not ensured, the data obtained from the entire national network may not be mutually comparable and may indicate unexplained anomalies/ discontinuities as compared to the international network observations. IMD follows WMO guidelines while making routine observations.

1.4. *Training & skill of observational personnel*

Since the comparability and utility of the data collected from the IMD network of stations depends very much on the correct, established procedures followed by the entire observer community, and the care taken in reading the instruments with the required accuracy, it is apparent that several personnel, subjective factors, like the skill of the observer and his overall understanding of the data requirement play a significant role in ensuring the data quality. It is thus extremely important that the personal at each station are appropriately trained, preferably at the regular Training Centres established by the IMD, emphasizing in all detail, the standardized observational procedures laid down by WMO for the entire international community of observational personnel.

1.5. *Periodic maintenance and calibration of instruments in the network*

Since the instruments the observation sites are continuously exposed to all kinds of weather conditions and are handled/operated several times every day by different observing personnel, it is extremely important that a close is maintained on their performance. Any fault or malfunction of the instruments that may be creeping in with time and which may gradually deteriorate the data quality is detected and rectified without delay, so that data reliability is always assured. IMD has established National Surface Instrument Division for the upkeep of the stations. The Regional Meteorological Centres and Meteorological Centres also take the responsibility for the stations under their charge centres at periodic intervals to the observation stations to check the instrument performance at site.

1.6. *Standardization of all operational instruments*

While instruments at the field are compared and checked by the respective maintenance centres, using travelling standards, it is important that all operational instruments at the field stations, in IMD and also National standards at the Surface Instrument Division are periodically checked and calibrated against National standards, in order to achieve uniformity and comparability of the data obtained from the entire network stations.

A standard instrument determines the accuracy of measurement and thus exhibits a high degree of repeatability by giving identical value of the measured quantity during the successive measurements made under identical conditions.

(*i*) Primary Standard: A standard which has the highest measurement qualities whose accuracy is determined by laboratory measurements and model calculations of the physical properties of its various components (that may give rise to source of errors). The accuracy of a primary standard is thus determined without reference to or comparison with other standards.

(*ii*) Secondary Standard: It is a standard of the highest quality whose value is assigned by or indirect comparisons with the primary standard. This is normally used for calibrating other types of instruments. Such ‘Secondary standard’ is located at Surface Meteorological Institute Division, CR&S, Pune, IMD.

(*iii*) Travelling Standard**:** This standard is carried to different locations/observation stations, for *in situ calibration/comparison* of the instruments installed for routine measurements at the sites. These standards are thus specially designed and constructed to withstand transportation and rough handling during transit without changing their calibration.

2. History of surface meteorological observatories network of IMD

2.1. *History meteorological observatory*

India is fortunate to have some of the oldest meteorological observatories of the world. The British East India Company established several such stations, for example, those at Calcutta in 1785 and Madras (now Chennai) in 1796 for studying the weather and climate of India. The Asiatic Society of Bengal founded in 1784 at Calcutta, and in 1804 at Bombay (now Mumbai), promoted scientific studies in meteorology in India. Captain Harry Piddington at Calcutta published 40 papers during 1835-1855 in the Journal of the Asiatic Society dealing with tropical storms and coined the word "cyclone", meaning the coil of a snake. In 1842 he published his monumental work on the "Laws of the Storms". In the first half of the 19th century, several observatories began functioning in India under the provincial governments.

A disastrous tropical cyclone struck Calcutta in 1864, and this was followed by failures of the monsoon rains in 1866 and 1871. In the year 1875, the Government of India established the India Meteorological Department, bringing all meteorological work in the country under a central authority. Mr. H. F. Blanford was appointed Meteorological Reporter to the Government of India. The first Director General of Observatories was Sir John Eliot who was appointed in May 1889 at Calcutta headquarters (Fig. 2). The headquarters of IMD were later shifted to Shimla, then to Poona (now Pune) (Fig. 3) and finally to New Delhi (Fig. 4).

Fig. 2. Calcutta (HQ) office photograph (1889)

Fig. 3. Poona (HQ) office photograph (1928)

Fig. 4. Delhi (HQ) office photograph of (1944)

2.2. *Journey begins for surface instrument division (SID), IMD.*

Ms. Mani established surface instruments manufacturing unit at Pune, is the first manufacturing indigenous unit after independence. She joined India Meteorological Department (IMD) in 1948 and worked on an ambitious program that made India self-sufficient by designing and manufacturing its own weather instruments. Her first job was to construct recording rain gauges, hygrographs, thermographs, barographs, barometers, anemographs and so forth. Thanks to her leadership in the field, India was in the forefront of countries where meteorological data, especially of solar radiation and wind, were used for studies of alternative sources of energy. Introduction The Surface Instrument Division (SID) was conceived and established at Pune after India becomes an independent country. Conventional surface Meteorological instruments are manufactured at SID Workshop.

Earlier upper air Ozone sonde and Radiosonde instruments were manufactured at SID Workshop. These instruments are manufactured at well- equipped and self-sufficient worship which is ISO 9001-2008 certified in 2010 and maintained by the division. All manufactured instruments are tested and calibrated in an in-house calibration laboratory. Workshop also carries out research and development in instrumentation and brings out new designs. The division maintains the detailed instruction manuals and engineering drawings for all the instruments.

In addition, the division also established and maintains a large network of Automatic Weather Station (AWS-Laboratory), Radiation Observatories (Radiation Laboratory), Airport Meteorological Instruments, Ozone measurements, Ozone-sonde, Radiometer Sonde, Antarctica supply etc. (Electronic-Laboratory), Testing and Calibration of all types surface meteorological instruments for departmental & non-departmental users, Seismology instruments (Surface Laboratory) and Design, development, manufacturing and testing of all types of surface meteorological instruments (Workshop-Unit)

Workshop division cited at Pune is the unique, vital, and nodal section available IMD and intended for the manufacturing of conventional meteorological instruments. This office is responsible to manufacture, calibrate, maintain all meteorological instruments and then after supply to departmental and non-departmental networks of Agro-met, upper air, automatic weather section, airports, marine stations, seismological stations, *etc*. These instruments have also been provided to various governmental sectors *viz*. defence organizations (such as Air-Force and Navy) airlines, scientific and research institute, colleges, universities, private sectors, *etc*.

These activities have contributed towards the Indian Meteorological Department (IMD), Pune being designated as the Regional Training Centre for instruments by the World Meteorological Organization. The Division is headed by the Head (Surface Instruments Division).

2.3. *History of Surface Observation in IMD*

The observatory set up in Calcutta in 1829 was in the compound of the Office of the Surveyor General of India on Park Street. In 1852, Radhanath Sikdar, then 'Chief Computrol' of the Great Trigonometric Survey of India, was given charge of this observatory in addition to his surveying work. Sikdar was the first Indian to occupy such a position in British India. He managed the observatory exceedingly well until his retirement in 1862.

2.4. *Some of the oldest observations (Source IMD data)*

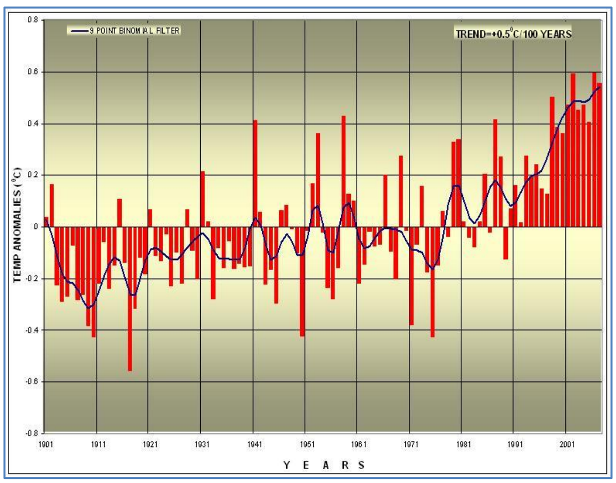


Fig. 5 Graphical representations of Historical Temperature records

2.5. *Historical data collection record in manuscript form are as shown in (Fig. 6 to Fig.10).*

Fig. 6. Historical data collection from the old surface observatories

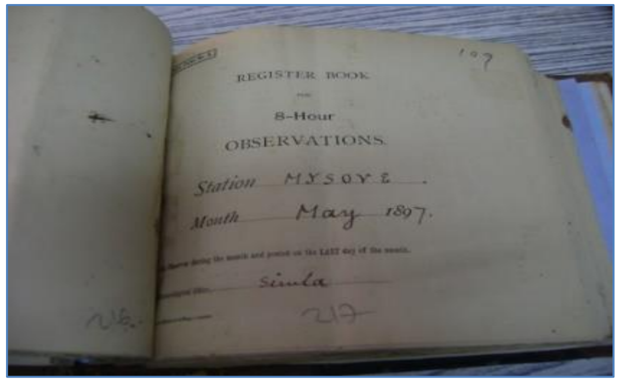


Fig. 7. Historical data collection from the old surface observatories

Fig. 8. Historical data collection from the old surface observatories

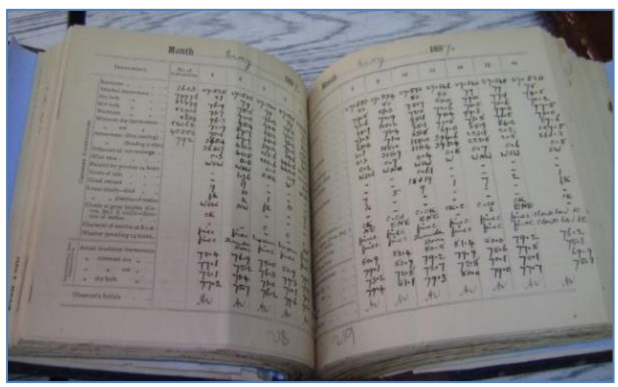
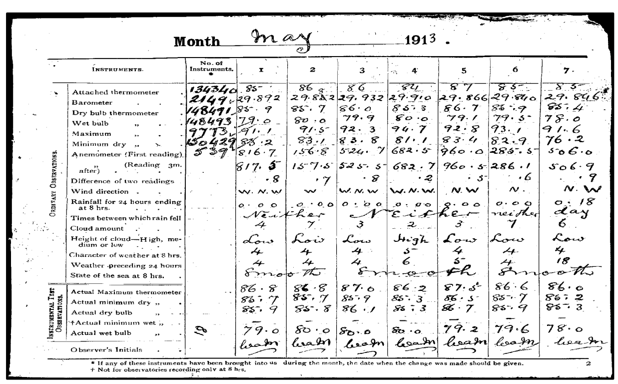


Fig. 9. Historical data collection from the old surface observatories



Month May 1913.

	Instruments.	No. of Instruments.*	1	2	3	4	5	6	7
Ordinary Observations.	Attached thermometer	134340	85	86	86	84	87	85	85
	Barometer	2149	29.892	29.882	29.932	29.910	29.866	29.840	29.846
	Dry bulb thermometer	148491	85.9	85.7	86.0	85.3	86.7	85.9	85.4
	Wet bulb "	148493	79.0	80.0	79.9	80.0	79.1	79.5	78.0
	Maximum "	9773	91.1	91.5	92.3	94.7	92.8	93.1	91.6
	Minimum dry "	150429	85.2	83.1	83.8	81.1	83.4	82.9	76.2
	Anemometer (First reading)	539	816.7	156.8	524.7	682.5	960.0	285.5	506.0
	" (Reading 3m. after)		817.5	157.5	525.5	682.7	960.5	286.1	506.9
	Difference of two readings		.8	.7	.8	.2	.5	.6	.9
	Wind direction		W.N.W	W	W.N.W	W.N.W.	N.W	N.	N.W
	Rainfall for 24 hours ending at 8 hrs.		0.00	0.00	0.00	0.00	0.00	0.00	0.18
	Times between which rain fell		Neither		Neither			neither	day
	Cloud amount		4	7	3	2	3	7	6
	Height of cloud—High, medium or low		Low	Low	Low	High	Low	Low	Low
	Character of weather at 8 hrs.		4	4	4	5	4	4	4
	Weather preceding 24 hours		4	4	4	6	5	4	18
	State of the sea at 8 hrs.		Smooth			Smooth		Smooth	
Instrumental Test Observations.	Actual Maximum thermometer		86.8	86.8	87.0	86.2	87.5	86.6	86.0
	Actual minimum dry "		85.7	85.7	85.9	85.3	86.5	85.7	86.2
	Actual dry bulb "		85.9	85.8	86.1	86.3	86.7	85.9	85.3
	†Actual minimum wet "		–	–	–	–	–	–	
	Actual wet bulb "	[illegible]	79.0	80.0	80.0	80.0	79.2	79.6	78.0
	Observer's Initials		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

* If any of these instruments have been brought into us during the month, the date when the change was made should be given.
† Not for observatories recording only at 8 hrs.

2

Fig. 10. Historical data collection from the old surface observatories

Standard Surface Observation manual recording is as shown in (Fig. 11) below:

Fig. 11. Standard surface observations (manual recording)

3. Surface instrument division, Pune IMD.

3.1. *Surface laboratory:*

Surface Laboratory, an important wing of the Surface Instrument Division, has been providing valuable services in all aspects of testing, calibration, and standardization of surface meteorological instruments. The calibration laboratory maintains National and Working standards. National standards are regularly compared and calibrated against National/WMO standards.

The calibration laboratory is recognized By Bureau of Indian standards as the Centre for certification of Indigenously made meteorological instruments including thermometers and rain measures. Each instrument is carefully assessed and evaluated before issuing certification.

3.1.1. *Test & calibration facilities:*

Various Standards and calibration equipment's are available in this Laboratory for calibration of various meteorological instruments. These include:

(*i*) Wind Tunnel for Wind Speed sensors calibration,

(*ii*) Standard Thermometers,

(*iii*) Temperature Calibration Bath

(*iv*) Pressure calibration Dead Weight Tester

(*v*) Environmental Calibration Chambers for autographic instruments.

The Laboratory is recognized by Bureau of Indian Standards as the Centre for Certification of indigenously made meteorological instruments including thermometers and rain measures. Each instrument submitted is carefully assessed and evaluated before issuing certification.

Testing, calibration and certification of all Surface meteorological instruments – Departmental and non-departmental (Defense establishments, Airlines, scientific and research institutions, private and other user organizations.

3.1.2. *Primary "Atmospheric pressure" standard.*

One of the primary pressure standards for IMD is GE RUSKA Model 2465 absolute Dead Weight Tester (DWT), is shown in (Fig. 12) below

Fig. 12. Standard surface observations (manual recording)

3.1.3. *Temperature standard*

Hart Scientific model 1521, with Digital Thermometer is a working standard thermometer used to calibrate Temperature sensors. It is shown in the Fig. 13.

3.1.4. *Wind Speed standard*

An Indigenously manufactured wind tunnel is used to calibrate all types of wind sensors and is shown in the Fig. 14.

Fig. 13. Thermometer (digital) calibration chamber

Fig. 14. Wind tunnel for the calibration of wind anemometer

3.1.5. *Surface instrument manufacturing unit (Workshop-Unit):*

All the surface meteorological instruments used in the conventional surface meteorological instruments are manufactured in the workshop units:

The following are various shops as a part of Workshop unit:

(*i*) Machine Section No 1

(*ii*) Machine Section No 2

(*iii*) Tool room section

(*iv*) Foundry section

(*v*) Carpentry section

(*vi*) Painting section

(*vii*) Packaging and forwarding section.

(*viii*) Clock section

(*ix*) Sheet and metal cutter section

(*x*) Welding section

(*xi*) Electroplating section

(*xii*) Powder Coating Machine section

(*xiii*) CNC Machine section (Latest addition)

The various Surface meteorological instruments manufactured in workshop are given in (Fig. 15 to Fig. 26) and awarding of ISO certification for the workshop is shown in Fig. 27.

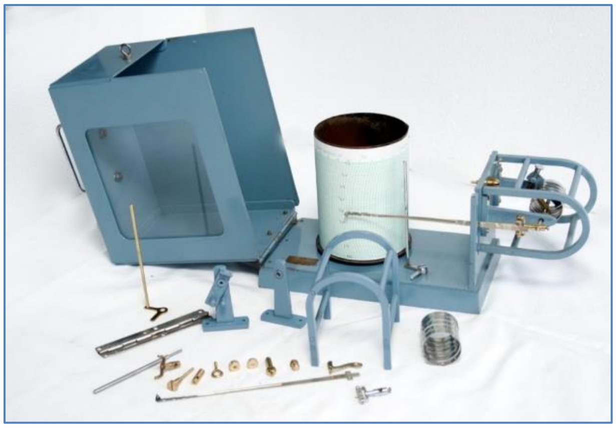


Fig. 15. Thermograph sensor manufactured in workshop

Fig. 16. Hair Hygrograph sensor manufactured in workshop

Fig. 17. Self-Recording Rain-gauge sensor manufactured in workshop

Fig.18 Tipping Bucket Rain-gauge sensor manufactured in workshop

Fig. 19. Cup Counter Anemometer sensor manufactured in workshop

Fig. 20. Anemometer sensor (Automatic) manufactured in workshop

Fig. 21. Wind Direction sensor (Automatic), manufactured in workshop

Fig. 22. Dynes Pressure Tube Anemograph sensor manufactured in workshop

Fig. 23. Stevenson's screens manufactured in workshop

Fig. 24. Open-Pan-Evaporimeter sensor manufactured in workshop

Fig. 25. Sunshine duration sensor manufactured in workshop

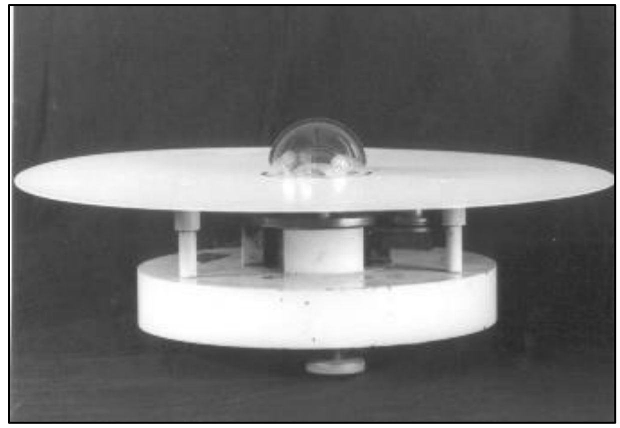


Fig. 26. Radiation sensor manufactured in workshop

3.2. *Electronic laboratory*

3.2.1. *Aviation observatories*

In order to contribute towards the safety, economy, regularity, and efficiency of air navigation, National Meteorological Services throughout the world are obliged by law to make meteorological observations and forecasts and to establish, maintained and monitored the warning systems as per the guidelines provided by World Meteorological Organization (**WMO**) and International Civil Aviation Organiztion (**ICAO**). IMD provides specialized meteorological services to the Airport Authority of India ensuing vaiation safety.

3.2.2. *The airport meteorological instruments*

Electronic laboratory is primarily involved in design, developemebt, fabrication, testing, calibration, installation, & maintenance of all airport meteorological instruments since early 60's.

First equipment deisgned and developed was Distant Indicating Wind Equioment (**DIWE**). It provides continuously & accurate Wind Direction & Wind Speed in the airport area. Many airports were equipped with the in house deleveoped products by SID, IMD.

Skopograph was a trade name of transmissometer system deisgned & developed by Impusphsik, Germany. It continuously used to measure Visibility and Runway Visiual Range(**RVR**) information in ATC. The main systems were installed near the touch down of the runway and live and continuous data of the visibility & RVR is made available in ATC on operational basis. Important airports such as Palam airport Delhi, Kolkata airport, Mumbai airport, & Chennai airport were equipped with these syatems.below:

Fig. 27. Workshop unit awarded ISO certification

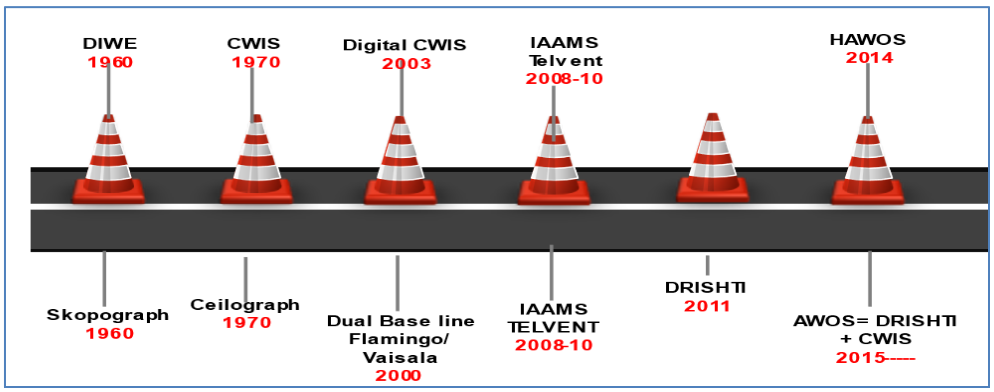


Fig. 28. Journey of modernization of airport systems

Ceilographs was a trade name of ceilometer system designed and developed by Impulsphysik , Germany. The systems are installed at few airports for monitoring height of base of low cloud.

The first version of Current Weather Instrument System(**CWIS)**, includes sensors for Wind Direction & Wind Speed, Temperature & Humidity, with digital display unit for monitoring the live data fron the runway. Atmospheric Pressure sensor (QNH/QFE) is used to measure on an anlogue meter installed on an CWIS panel deisgned and developed in house.

Subsequently the Digiatal version of CWIS was desined and developed in house and installed at many airports in India on operational basis.

The new versions of transmissometers were procured from Imulsphsik/ Vaisala and installted in late 90's, at very important airports. They are called Dual Base Line Transmissometer having two recivers.

Further the Intergrated Automatic Aviation Meteorological Syatems were procured & installed at 08 airports in India. They includes Current Weather Instrument Systems & Transmissometer integrated together. They provides Integrated display units in ATC for the operational purposes.

A joint venture between IMD (MoES) and NAL (CSIR) is the most importnant venture in the history of airport instrument modernization system is design & development of Drishti transmissometer. This is completely indegineous system and made operationally working at many airports in India. The journey of development of airport systems is given in the **(Fig. 28)**,

3.2.3. *Airport meteorological instruments:*

3.2.3.1. *Transmissometer*

The Transmissometers provides Visibility and Runway Visual Range (RVR) at each airport for the landing and take-off. The dual baseline transmissometer (name as

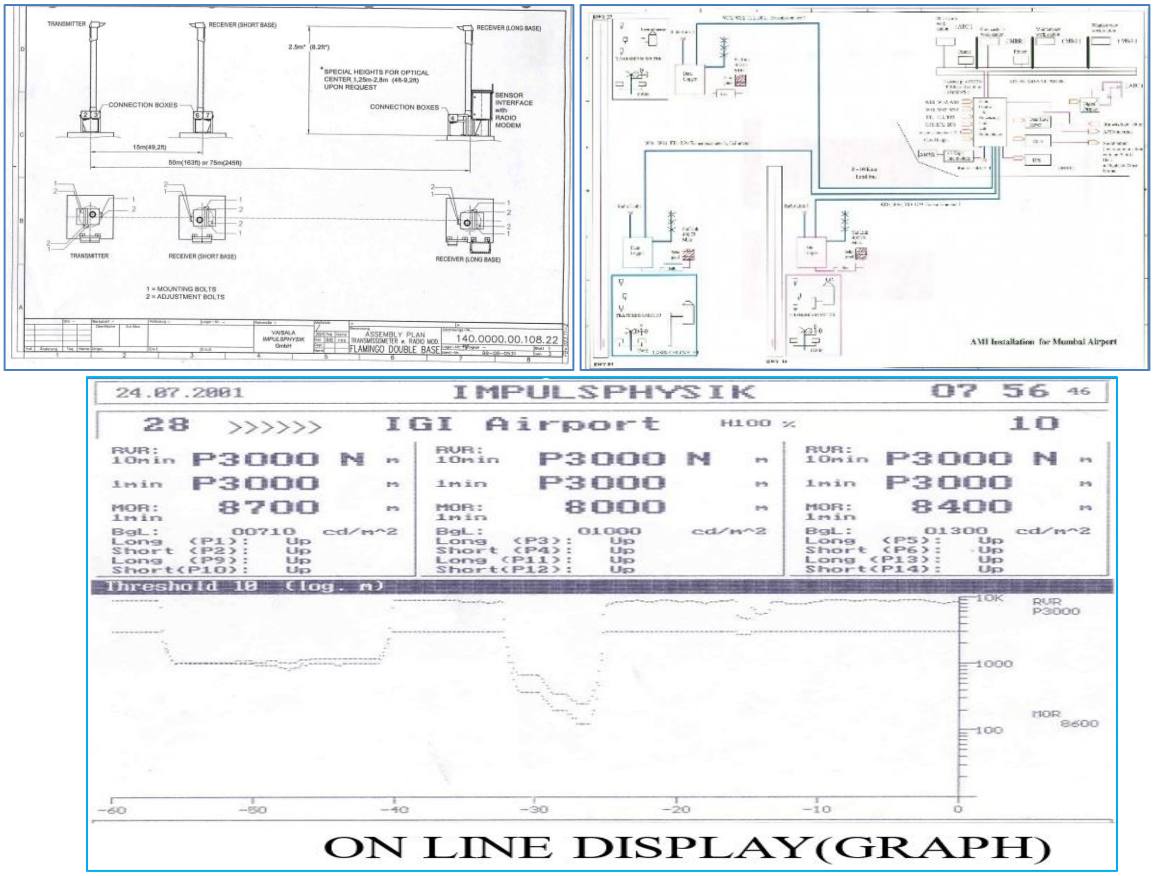


Fig. 29. First dual base transmissometer with display system

Flamingo) a complete system along with the display units, installed at IGI airport New Delhi in 1999-2000 is shown in the (Fig. 29).

3.2.3.2. *Distance indicating wind equipment (DIWE) (IMD-make)*

India Meteorological Department designed & developed DIWE and these instruments are installed at many national and international airports in India since early 80's. This provides Wind Direction and Wind Speed at the airports. The DIWE systems are shown in (Fig. 30).

Fig. 30. Indigenously developed DIWE (WD/WS) developed system

3.2.3.3. *Current weather instrument systems (CWIS) (IMD make)*

CWIS provides on-line current weather information for Wind Direction, Wind Speed, Temperature, Humidity, Dewpoint, Atmospheric Pressure (QNH/QFE) using the sensors installed at the touch down point of the runway. The CWIS data acquisition and display systems is shown in Fig. 31.

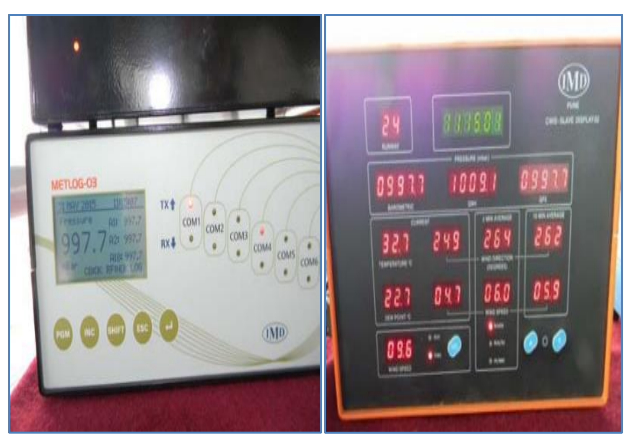


Fig. 31. Indigenously developed CWIS system with all parameters

Fig. 32. Indigenously developed modern CWIS system

Fig. 33. Typical RVR/CWIS field system of IAAMS

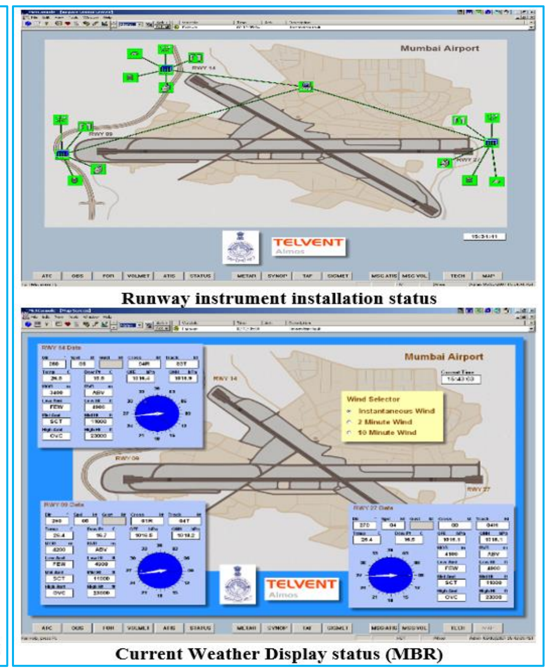


Fig. 34. Current weather display system of IAAMS

3.2.3.4. *Advance version of CWIS (IMD make)*

An advance version of CWIS was developed (PC based) with the display of analogue recording values of the selected parameters for the selected runway. The provision of sensor calibration for each sensor has also been made. The modern CWIS system is shown in (Fig. 32), below

3.2.3.5. *Integrated automatic aviation meteorological systems (IAAMS)*

A typical installation of this Integrated Automatic Aviation System at various runways at Mumbai airport is shown in the (Fig. 33 & 34).

3.2.3.6. Industry grade Transmissometer Drishti Designed & Developed jointly National Aeronautics Limited (CSIR-NAL) & IMD:

The Drishti system and its performance is shown in the (Fig. 35 & 36)

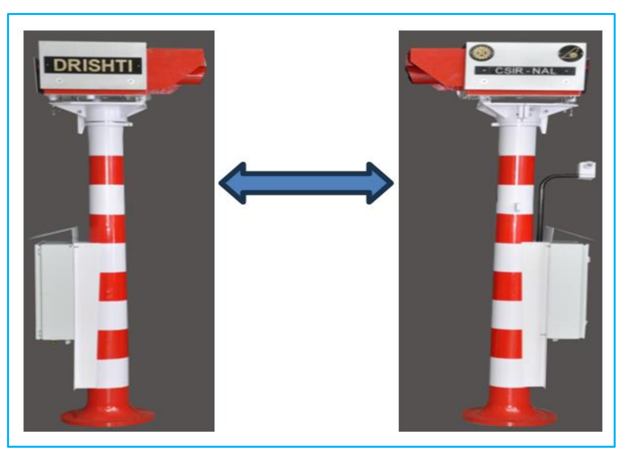


Fig. 35 Indigenous Drishti system developed jointly by IMD and NAL

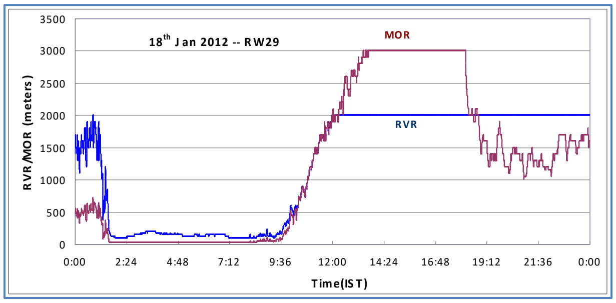


Fig. 36. Typical RVR/Visibility display from Drishti system

3.2.3.7. *Mile stones of aviation meteorological service of IMD:*

- 1921 First aviation forecast issued from Shimla for Royal Air Force flight operation over Wazaristan (now in Pakistan)
- 1930 Wireless communication systen installed for exchange of Current Weather Information and dissemination of warning and advance weather development
- 1940 Indigeneous radio-sonde developed and ascent started
- 1950 Increase in meteorological requirement due to introduction of Jet Aircraft flights
- 1954 First local storm radar installed at Dum Dum Airport Kolkata
- 1954 Creation of Director Aviation Services at New Delhi
- 1960 Ceilometers and remote sensing aviation meteorological instruments installed at International airports in India.
- 1964 Introduction of chart form of documentation
- 1966 First transmissometer installed at Dum Dum Airport, Kolkata
- 1971 Establishment of Regional Area Forecast Center at New Delhi under World Area Forecast System of ICAO
- 1981 Tailor made meteorological services due to introduction of Vayudoot & Air Taxi services
- 1986 Establishment of First computerized Automatic Message Switching Systems
- 2000 Dual base line transmissometers are comissioned at Delhi Airport to meet CAT-III compliance
- 2001 Doppler Weather Radar Syatems commissioned at Chennai & Kolkata
- 2004 World Area Forecast Systems (WAFS) products hosted on IMD website to support international & National long haul flights
- 2006 Introduction of web-based meteorological seif briefing system for pilots
- 2009 Commissioning IAAMS at 08 airports
- 2010 Live RVR informstion of IMD's website during dense fog
- 2011 Reception of AMDAR data on experimental basis.
- 2012 Drishti transmissometer systems are developed were made operational at many airports in India.
- 2014 Heliport Aviation Weather Observing System (HAWOS) are installed at the heliports (Juhu, Mumbai and Vaishno Devi, Katra)
- 2015 Deployment of Digital Standard Barometers in parallel with mercury barometers for taking atmospheric presseure at the national & international airports in India.

3.3. *AWS laboratory*

Meteorological Department is in modernization of surface observational network in a phased manner.

A network of 125 Automatic Weather Stations (AWS) has been established during the year 2006-07 under the IMD Modernization Programme Phase-I, the network is further expanded with additional 550 AWS. The sensors for parameters Air Temperature, Relative Humidity, Atmospheric Pressure, Rainfall, Wind and Global Solar Radiation are being interfaced with each AWS. Out of 550 AWS planned for installation, 127 will be Agro-AWS with additional sensors for parameters soil temperature, soil moisture, leaf temperature and leaf wetness. Meteorologically unrepresented districts of India are being considered on priority for installation of AWS.

The network is required to meet the needs of diverse services of IMD such as Weather Forecasting, Cyclone Warning and Hydrological Studies etc. The network is planned in such a way that data sparse regions of the country particularly north and northeastern states have uniform distribution of AWS.

There are 253 meteorologically unrepresented districts in India Typically one AWS is planned for installation in each unrepresented district. A meso-network of 12 AWS has also been established in and around National Capital Region. Under the modernization project phase-I, a uniform and dense surface observational network of 550 AWS is expected to be available to meet operational forecasting requirements (both synoptic and meso-scale) of the nation.

Under modernization project a network of 1350 Automatic Rain Gauge Stations all over India proposed to be installed during the period 2007-2012. To improve monitoring of district wise rainfall monitoring a network of 1350 Automatic Rain Gauge Stations is being established during Phase-I of the modernization project. Out of 1350 ARG stations, 500 stations are being equipped with additional sensors for temperature and humidity observations.

3.3.1. *IMD AWS network station*

Typical installation of IMD is shown in (Fig. 37) and various components of complete Satellite based AWS is shown in (Fig. 38).

Fig. 37. Typical site installation of AWS

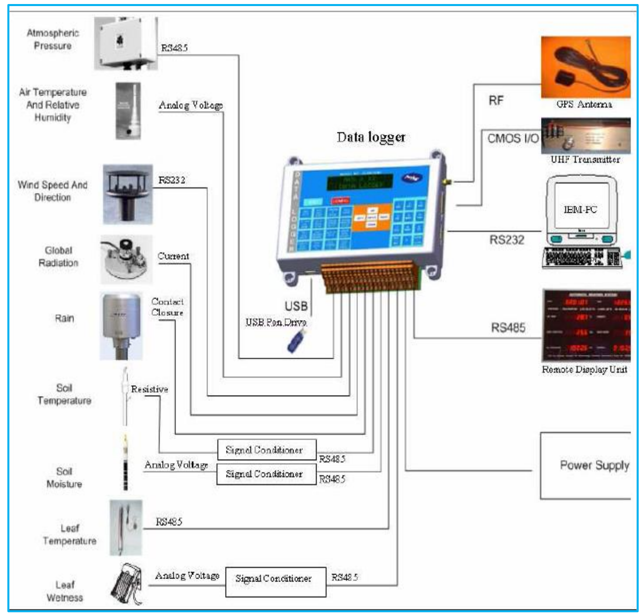


Fig. 38. Various components of satellite-based AWS system

3.3.2. *Evolution of IMD AWS network stations*:

The AWS network started with Satellite link-based stations and is as shown in the (Fig. 39), next generation telemetry type communication systems were deployed and is shown in (Fig. 40.)

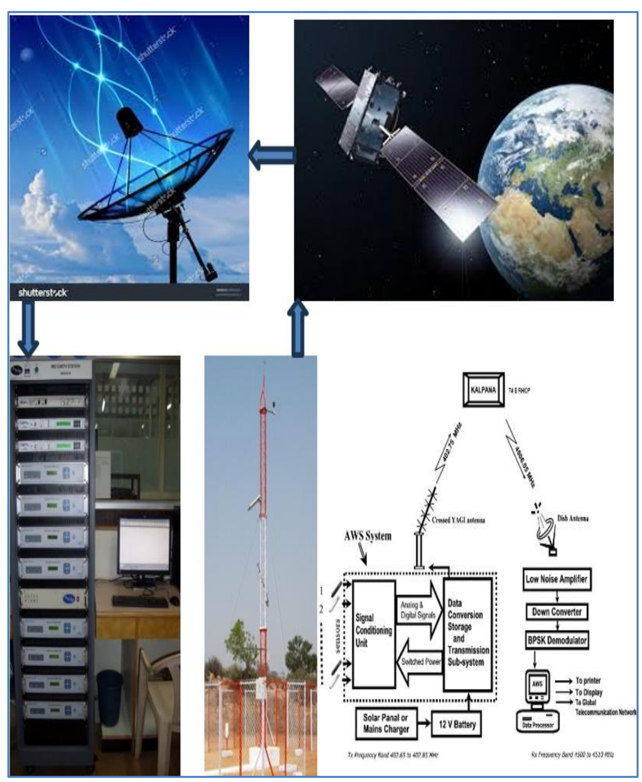


Fig. 39. Satellite based AWS/ARG data communication system

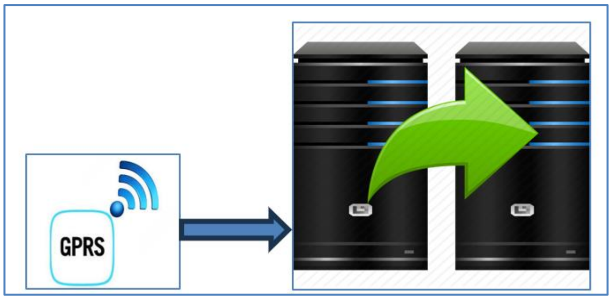


Fig. 40. Telemetry AWS/ARG data communication system

3.3.3. *AWS data retrieval and display system:*

Web-based application system developed to display online AWS/ARG network station data. (The system was developed and maintained in house by Shri M. Danish, Scientist, IMD). The details are shown in (Fig. 41) below:

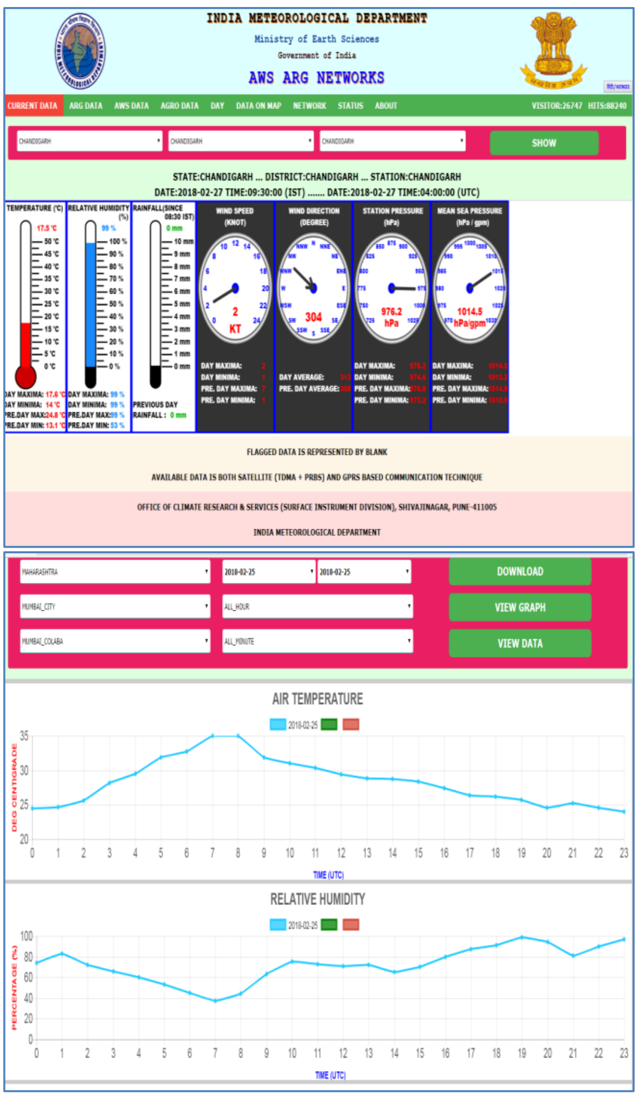


Fig. 41. Web-based AWS/ARG data display system

3.4. *Radiation Laboratory*

3.4.1. *Importance of Solar Radiation data*

The network activity on radiation measurement was initiated during July 1957, with a commissioning of 4 stations. The density of the network was gradually increased to the present level of 45 stations. The parameters measured vary from station to station, through global solar radiation is the common parameters monitored at almost all the stations. The very important components like the direct solar irradiance, diffuse solar irradiance and the net terrestrial radiant energy are not measured at many of the stations.

The earth receives a vast amount of energy from the sun in the form of solar radiation. Conversion of a small fraction of this incident radiant energy into usable forms would reduce our present-day over-dependence on the non-renewable energy sources. Solar energy can be converted into thermal energy, electrical energy and biomass and can be used in water heating, cooling, drying, cooking, desalination, pumping, lighting *etc*.

Solar radiation data for a location represents the energy per unit area and provide information on how much of the sun's energy strikes a surface at a location on earth during a particular time. It also provides the information on the significant variations occurring naturally over the course of days, months, and years. Earth's radiation budget is shown in the (Fig. 42) below:

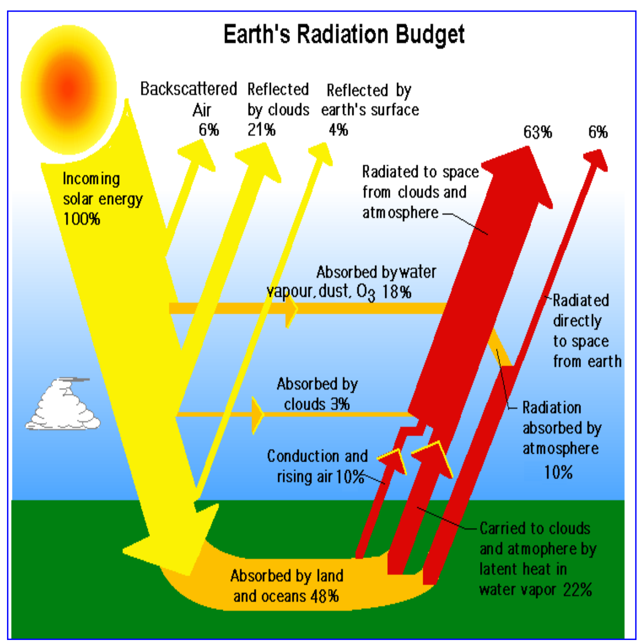


Fig. 42. Earths radiation budget

Radiation Measurements	
Parameter	**Instruments used**
Solar (0.3µm - 4.0 µm)	
Direct solar irradiance	Thermoelectric Pyrheliometers with solar tracker
Global solar irradiance	Thermoelectric Pyranometer
Diffuse solar irradiance	Thermoelectric Pyranometer with shading ring /shading disc
Reflected solar irradiance	Inverted Pyranometer
Solar spectral irradiance and turbidity	Sun photometer
Terrestrial (4µm - 50 µm)	
Net Terrestrial Radiation	Precision Infra-red Radiometer (PIR)
Total (0.3µm - 50 µm)	
Net Radiation	Net Pyrradiometer
UV-A (315-400 nm) and UV-B (280-315 nm) Radiation	
UV-A Radiation	UV-A Radiometer
UV-B Radiation	UV-B Radiometer

Direct solar irradiation (S): is the solar irradiance incident on a unit surface held normal to the incident rays.

Global solar irradiation ($E_g\downarrow$): is the radiant exposure received by a unit horizontal surface from the hemisphere comprising of the direct beam and the scattered radiation received in diffuse form. This is given by:

$$E_g\downarrow = S.\cos Z + E_d\downarrow$$

where Z is solar zenith angle and $E_d\downarrow$ is the diffuse solar irradiance.

Diffuse solar irradiation ($E_d\downarrow$): is the radiation received diffusely from the hemisphere due to scattering and reflection from air molecules, aerosols, and clouds.

Reflected solar irradiation ($E_r\uparrow$):is the radiant energy reflected by the earth's surface or any surface under study.

Albedo of a surface (α): is the ratio of reflected solar irradiation $E_r\uparrow$ to the incident global solar irradiation $E_g\downarrow$.

Therefore $\alpha = (Er\uparrow) / (E_g\downarrow)$

Net solar radiant exposure (H_g^*): is the algebraic sum of the global solar Irradiation and the reflected solar irradiation.

$$H_g^* = E_g\downarrow - E_r\uparrow = E_g\downarrow - \alpha\ E_g\downarrow = E_g\downarrow\ (1-\alpha)$$

Thermoelectric Pyranometer : (*i*) Measures solar irradiance from 0.3 m to 4.0 m. (*ii*) Sensor: Blackened copper-constantan thermopile covered with two concentric glass domes which are transparent to radiation from 0.3 m to 4.0 m. (*iii*) Generated e.m.f. by thermopile is proportional to incident radiation. (approx. 5V $W^{-1}m^2$). (*iv*) Used for instantaneous measurement and continuous recording of Global irradiance, Diffuse irradiance and reflected solar irradiance. (Fig. 43).

Fig. 43. Thermoelectric Pyranometer

Thermoelectric Pyranometer with shading ring: (*i*) Used for diffuse solar radiation measurements. (*ii*). Pyranometer is mounted on the rectangular platform. (*iii*). The ring shades the pyranometer sensor throughout the day so as to cut direct solar radiation. (*iv*). Arms of the assembly are adjusted for latitude of the place. (*v*). Ring is adjusted according to the daily declination of the sun. (Fig. 44).

Fig. 44. Thermoelectric pyranometer with shading rung

Pyrheliometer with solar tracker: (*i*). Measures direct solar irradiance from 0.3 m to 4.0 m at normal incidence. (*ii*). Sensor: Blackened copper-constantan thermopile. (*iii*). Sensor mounted in along metallic tube to avoid diffused radiation. (*iv*). Solar tracker/Heliostat maintains the pyrheliometer directed towards the sun. (*v*) Generated e.m.f. by thermopile is proportional to incident radiation. (approx. 5V $W^{-1}m^2$). (*vi*) Used for instantaneous measurement and continuous recording of direct solar irradiance. (Fig. 45)

Fig. 45. Pyrheliometer with solar tracker

Precision Infra-Red Radiometer : (*i*) Measures net terrestrial irradiance from 4.0 m to 50 m. (*ii*) Sensor: Wire-wound thermopile detector and temperature compensation circuitry. (*iii*). To shield the thermopile from shortwave radiation, silicon hemisphere with a vacuum deposited filter on the inside dome. (*iv*) Generated e.m.f. by thermopile is proportional to incident radiation. (approx. 5V $W^{-1}m^{2}$). Used for continuous measurement of net terrestrial irradiance. (Fig. 46).

Fig. 46. Precision Infra-red radiometer

UV-A Radiometer: (i). Measures ultra-violet radiation in the range 315 to 400 nm. (ii) Sensor: Silicon photodetector. (iii) Sensitivity: 25 mV $W^{-1}m^{2}$. (iv). Used for continuous measurement of UV-A radiation. Fig. 47.

Fig. 47. UV-A radiometer

UV-B Radiometer: (*i*) Measures ultra-violet radiation in the range 280 to 315 nm. (*ii*) Sensor: Silicon photodetector. (*iii*) Sensitivity: 20 mV $W^{-1}m^{2}$. (*iv*) Used for continuous measurement of UV-B radiation As given in Fig. 48.

Fig. 48. UV-B radiometer

Net Pyrradiometer: (*i*) Measures net radiation *i.e.*, difference between total downward radiation (solar and terrestrial) and total upward radiation (reflected solar and upward terrestrial) from 0.3 m to 50 m. (*ii*) Sensor: Blackened copper-constantan thermopile - both sides exposed to radiation and covered with polythene domes, which are transparent to radiation from 0.3m to 50.0m and kept inflated by injecting dry air. (Fig. 49) (*iii*) Generated e.m.f. by thermopile is proportional to difference of radiation incident on both sides. (approx. 15V W-1 m2). (*iv*) Used for instantaneous measurement and continuous recording of net irradiance (incoming - outgoing)

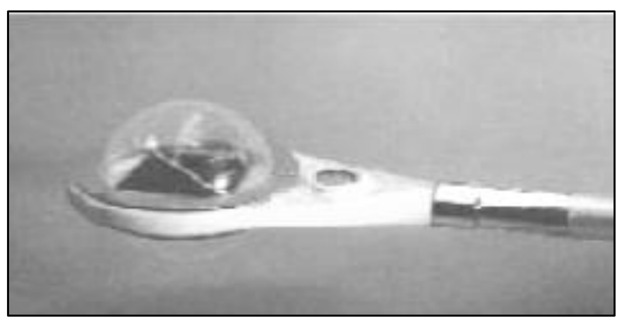


Fig. 49. Net Pyrradiometer

3.4.2. *Sunshine recorder:*

(*i*) For recording hours of bright sunshine. (*ii*) Diameter of Glass Sphere: 100 mm (*iii*) Diameter of a semi-circular metallic bowl: 160 mm. (*iv*). The bowl is provided with three sets of grooves in which suitable paste board cards of 0.4 mm thickness for recording the sunshine can be inserted. (Fig. 50).

Fig. 50. Sunshine recorder

3.4.3. *IMD Primary radiation standard*

Primary Radiation standard sensor used for secondary radiation comparison is available in the Radiation Lab Pune. The primary standards are compared with word radiation standard at Davos, Switzerland, once in every five 5 years. The standard is as shown in (Fig. 51). The calibration hut and various sensor comparison is as shown in (Fig. 52 & 53).

Fig. 51. RA-II radiation standard

Fig. 52. Radiation calibration hut

Fig. 53. Calibration & comparison of radiations sensors

Acknowledgement

At this time, I would like to acknowledge the contribution made pioneer in surface instrumentation in India, Anna Mani I am establishing a unique facility in the IMD for in-house manufacture, standardization, and maintenance of all types of surface meteorological instruments.

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Disclaimer: The contents and views presented in this research article/paper are the views of the authors and do not necessarily reflect the views of the organizations they belongs to.

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