Modernisation of Radiation Network

by

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ABSTRACT: The network activity on radiation measurements was initiated during IGY in July, 1957 with the 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 parameter 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. Direct solar irradiation is measured at 21 stations whereas the diffuse irradiances are monitored at 23 locations. The net terrestrial radiant energy is measured at 12 stations only. There is no UV measurement.

With increased industrialization and its associated urbanization, the skies get increasingly loaded with both particulate matter and radiatively active gaseous matter. They have deleterious effect on radiation and thermal energy. Hence a need was felt to expand radiation measurement activities quantitatively and qualitatively.

IMD has thus drawn a very extensive plan to bring about uniform measurement of various radiation parameters through out the network. The basic parameters like direct and diffuse radiations, wherever not measured, will be introduced. Net terrestrial radiation will be uniformly recorded round the clock using latest pyrgeometers. UV-A, UV-B and UV-Total measurement will also be introduced at all the station to study the impact of climate on human health, agriculture productivity, ozone depletion etc. State-of-the-art sky scanning radiometers and sunphotometers with suitable filters will also be introduced to determine particle size distribution in the atmosphere. The data thus gathered will fill the existing gap of information in radiation measurement.

Introduction:

To begin with, India started radiation measurements on a network scale from July, 1957 with a modest number of four stations viz. New Delhi, Pune, Kolkata and Chennai. All the four stations made continuous recording of global solar irradiances and instantaneous observations two times a day in the night of net terrestrial radiant energy. Besides these, New Delhi and Pune recorded the diffuse solar irradiances continuously and instantaneous direct solar irradiances in selected band pass spectral regions at the four synoptic hours during the day time (at 03, 06, 09 and 12h UT). The density of the radiation network was gradually increased over the next three decades to the present 45 stations. The increase in the network density was however not necessarily on any climatological requirements; they were started mainly to meet the requirements of different disciplines like agricultural meteorology and environmental (atmospheric pollution) studies.

Present Status of Radiation Network

The present distribution of stations in the radiation network is given in Fig. 1. There are 21 principal and 22 ordinary stations in the network. A principal station makes continuous recording of global and diffuse solar irradiances (radiant exposure) and duration of bright hours of sunshine besides measurements of direct solar irradiances either at specified times or continuously using a solar tracker. An ordinary station has to record continuous global solar irradiation and duration of bright hours of sunshine. In the Indian radiation network there are other parameters which are also monitored. Table I gives the various parameters being recorded at different locations in the network.

Instruments in use at the network stations:

Different types of instruments are in use in the network stations. They are:

(i)	Thermoelectric pyranometers	For global solar irradiances
(ii)	Thermoelectric pyranometers with Schüepp model shadow band	For diffuse solar irradiances
(iii)	Ångström pyrheliometer	For direct solar irradiances (including spectral)
(iv)	Thermoelectric pyrheliometer on solar tracker	For direct solar irradiances
(v)	Ångström pyrgeometer	For net terrestrial radiant energy in the nights
(vi)	Funk type net pyrradiometer	For net total radiant energy
(vii)	Sunphotometer	For optical depth
(viii)	Bimetallic pyranograph (SIAP model)	For global solar irradiances
(ix)	Bellani spherical pyranometer	For global solar irradiances
(x)	Campbell-Stokes sunshine recorder	For duration of sunshine
(xi)	Thermoelectric pyranometer	For reflected solar irradiance

The network has the following measurements distribution:

(i)	Global solar irradiation	43 stations 38 stations use pyranometer 2 stations use bimetallic pyranograph 3 stations use Bellani pyranometer
(ii)	Diffuse solar irradiation	24 stations
(iii)	Direct solar irradiation	14 stations six times a day
(iv)	Direct solar irradiation	10 stations using solar trackers
(v)	Reflected solar irradiation	1 station
(vi)	Global solar irradiation inclined at 45° and facing south	1 station
(vii)	Net terrestrial radiant energy	12 stations
(viii)	Net total radiant energy	6 stations
(ix)	Optical depth	12 stations

Besides, several stations compute the turbidity parameters from direct solar irradiance measurements. They are:

(i) Linke turbidity factor T – 22 stations

(ii) Ångström turbidity coefficient β - 14 stations.

Fig 2 gives typical installation at one station.

Besides these 45 stations, India maintains one weather monitoring station at Maitri, Antarctica with measurements of global and diffuse solar radiation using pyranometers and of optical depth using a sunphotometer.

Maintenance of Network:

The Central Radiation Laboratory of Instruments Division at Pune of India Meteorological Department has been designated as the National Radiation Centre by Government of India. It is also one of the two designated Regional Radiation Centres for Asian Region of WMO. This Laboratory maintains an hierarchy of radiation standards to ensure the reliability in the performance of the field radiation instruments. It maintains three primary standard cavity radiometers (PACRAD, HF and PMO-6) which are inter-compared regularly to ensure the stability of these instruments performances. At least one of the three participates in the 5 yearly International Pyrheliometer Comparisons held at Davos, the World Radiation Centre and also in the regional comparisons whenever they are conducted. There are transfer and working standard pyrheliometers to calibrate other pyrheliometers and all other types of instruments like pyranometers. Reference and working standard pyranometers are also maintained here and used to standardize the pyranometers which are made in the Instruments Division at Pune and which come for repairs and calibrations. Working standard pyrheliometers and pyranometers are taken out to field stations for *in situ* standardization of field instruments. The laboratory also maintains standard electrical equipment for calibrating the recording and other auxiliary equipment used in the network.

The data collected at the field stations are sent to the Climatology Division at Pune where they are subjected to 100 per cent scrutiny and then archived. Thus all efforts are being made to ensure that the data generated in the network are well within the accuracy limits specified by WMO. The data are available on payment of relevant charges. Since the majority of data are evaluated manually they are also scrutinized in the same way. This however necessitates an unavoidable delay in archival timings.

Limitations in the present network:

(i) Since the measurement programme was started to cater to the needs of different users, the parameters measured and even the instruments used for the same parameter are not necessarily uniform. Thus instruments with lower accuracy like a bimetallic pyranograph and a Bellani spherical pyranometer are still in use. The measurement of the more important parameters like direct solar irradiances and diffuse solar irradiances are made in only about half the number of network stations. The need for the use of indigenously manufactured recording equipment has also introduced different types of recorders with differing performance characteristics.

(ii) The use of Ångström pyrheliometer limits the data to selected optical air masses, six times in a day. The use of thermopile pyrheliometers on solar trackers enables the collection of hourly and daily totals of direct solar irradiation which in turn enables the monitoring of variations in the atmospheric turbidity conditions during a day. It also enables the computation of the attenuation effected by transparent and translucent cloudy and hazy sky conditions. But pyrheliometers on solar trackers are available at ten stations only. Further Ångström pyrheliometers can be used under cloudless sky conditions only. In addition hourly or even shorter interval atmospheric transparency conditions can not be deduced from these Ångström pyrheliometers.

(iii) The measurement of net terrestrial radiant energy is of vital requirement as all living beings are permanently immersed in the field of terrestrial radiant energy. Further it is the immediate trigger in the physics of the atmosphere in the boundary layer, causing changes in the weather conditions at the place. This important parameter is measured only instantaneously two times, that too in the night time only because of the use of Ångström pyrgeometers. This instrument, by construction principles can not be used during the day. And this measurement is made at 12 stations only.

(iv) The atmospheric turbidity parameter, viz. the optical depth is measured using a sunphotometer at 12 stations. The sunphotometer used for the purpose is of an early technology using only a microammeter. The stations which use them are background air pollution monitoring stations. Of these Pune, Nagpur and Visakhapatnam no more qualify to serve as reference stations due to high incidence of atmospheric pollution over these stations.

(v) A very vital part of the electromagnetic spectrum viz. ultra violet irradiances are not being measured in the network. This is a major lacuna in the network programme. Another important parameter not measured is the daylight illumination, though it is a difficult parameter to monitor.

(vi) Two parameters, reflected solar irradiance and net total radiant energy are measured at one and six stations respectively. These are extremely important for any study involving albedo and in agricultural sciences. However, these measurements need open spaces at ground level and hence it may not be feasible within the scope of the present network.

(vii) The radiation data are being collected on potentiometric recorders and extracted by manual evaluation. This introduces a certain subjectivity in the estimated values from the recorded charts. Though the data thus extracted undergo a hundred per cent scrutiny at the station itself and again in the Climatology Division before they are archived, the subjectivity element can not be eschewed totally.

Perspective plans for modernization:

The need for modernization of the network measurement methodology requires no stress. Fig. 3 gives the futuristic network proposals. Some of the salient features will be:

1. The sensors for global, diffuse or reflected irradiances will be made uniforme by the use of same detector principles. All the bimetallic pyranographs and spherical pyranometers are to be replaced by thermoelectric pyranometers preferably with provisions for temperature compensation.

2. The present Schüepp model or for that matter, any diffuse shading band (ring device are made using a basic assumptions, viz. the scattering processes is isotropic. It is well known that the scattering process is anisotropic even on cloud

free sky conditions. The process becomes more complicated in the presence of clouds. The diffuse irradiances are therefore to be monitored using a shading disc. Then there is no need for the computation of corrections in the irradiances based on assumptions.

3. Ångström pyrheliometers are capable of very high accuracy and actually they are treated as secondary standards. They can not however be used for continuous measurements of direct solar irradiances. The network Ångström pyrheliometers are therefore being replaced by the use of thermoelectric pyrheliometers which can be mounted on suitable solar trackers as is being done at present at ten stations. This would also ensure the continuous monitoring of direct solar irradiances and enable the computations of hourly turbidity parameters for the entire network stations.

4. The net terrestrial radiant energy is being measured only two times instantaneously during the night times. This parameter is of utmost importance. Modern solar blind pyrgeometers are to be installed at each of the 45 stations and continuous recording of the parameter is to be made. Unlike net pyrradiometers these do not need installations in the open field and hence can be installed at the pyranometer site itself.

5. The single filter sunphotometers would be replaced by narrow band multispectral sunphotometers with necessary self-computing software. They are to be provided at 24 stations which need not be background stations. Thus the optical depth measurements due to some of the important attenuating constituents of the atmosphere can be monitored with great ease and accuracy.

6. State of the art sky scanning radiometers with dedicated software would be introduced at selected 21 stations so the variations in the particle size distribution in the atmosphere can be studied and used in the environmental control applications.

7. One of the most important parameters to be monitored is the ultra violet irradiance which have far reaching consequences on the health of all living beings including the humans. With the industrial developments and consequent urbanization taking place, the possibility of damages to the delicate balance of the ozone concentrations is great, which may result in higher dosages of the incident ultraviolet radiant energy. Besides, their applications in physiological, biological, dyeing and textile fields are great. It is proposed to measure total UV, UV-A and UV-B at all the radiation stations.

8. At present, the recording of radiation data is generally being made using potentiometric recorders. At some places the galvanometric recorders are still in use. These recorders are being phased out with the latest designs of data loggers. The use of data loggers also ensures a better objectivity in data collection and higher reliability.

9. It is also envisaged to utilize satellite link facilities so that the data can be made available at the National Radiation Centre without any delay. It will also ensure to keep a check on the health of every instrument at each station from Pune by the Central Radiation Laboatory.

10. Central Radiation Laboratory also has to undergo modifications to meet the above needs.

(a) A data acquisition system is being planned for the intercomparison of standard pyrheliometers and for the calibration of field pyrheliometers.
(b) A Laboratory calibration facility for the calibration of pyranometers for their characteristics is being organized. With this established, it would be possible to determine the cosine error, tilt error, temperature and spectral responses and linearity of pyranometers in the Laboratory.
(c) The installation of the UV-VIS-NIR spectrophotometer and another of IR spectrophotometer is to be done for carrying out various checks on filters, painted surfaces etc.
(d) A good and reliable calibration facility in infrared wavelengths for pyrgeometers and net pyrradiometers is to be established.
(e) Establishing a photometric calibration facility for illumination measurements is also being planned.
(f) Similarly the calibration of UV measuring instruments using double monochromators and if possible a Brewer Spectrophotometer is to be planned and organized.

It is envisaged that the entire activity of radiation data collection in India will be completely modernized in the next 3 to 4 years.

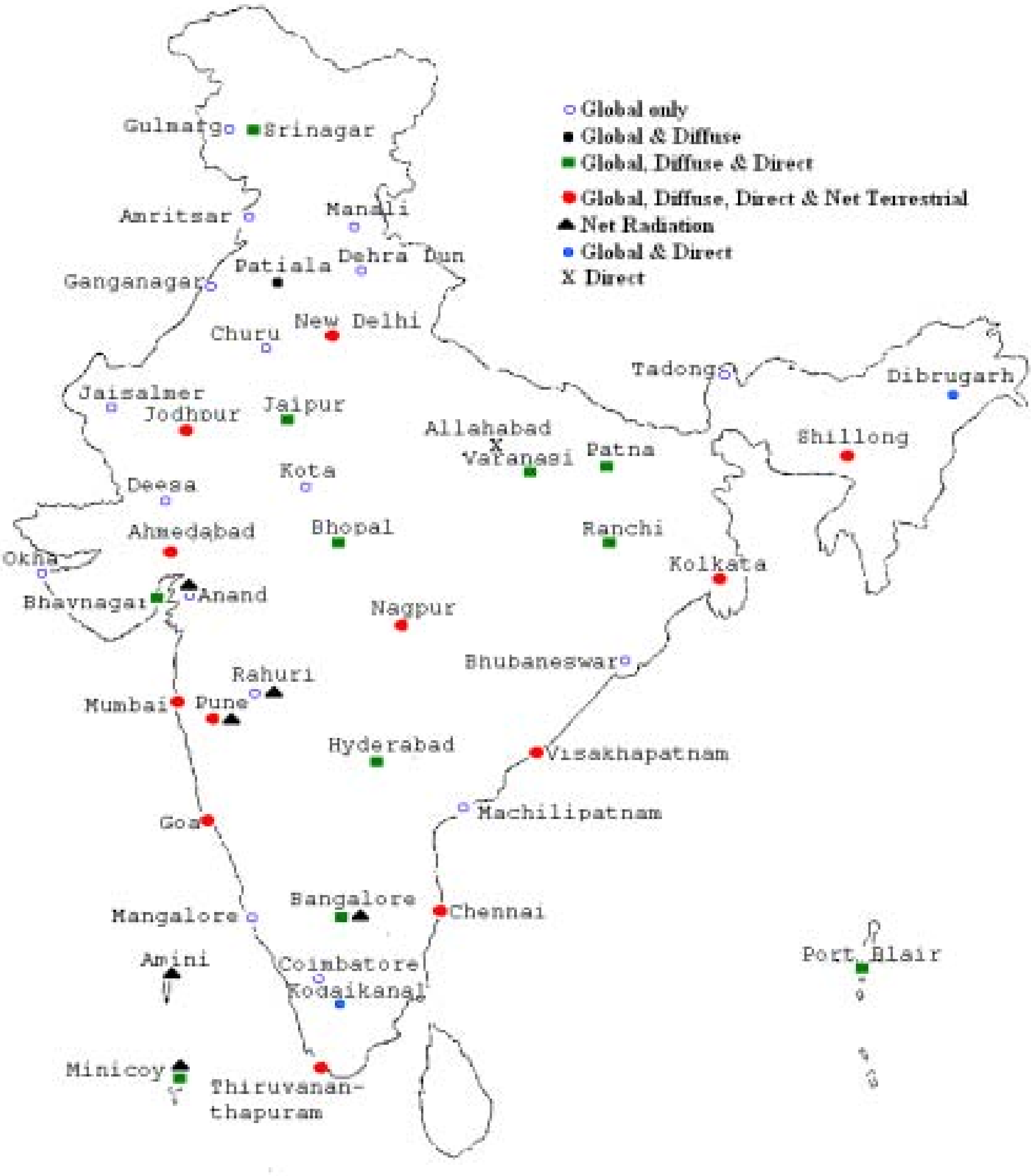

Fig 1: Existing radiation network

Fig 2: Radiation site at Varanasi

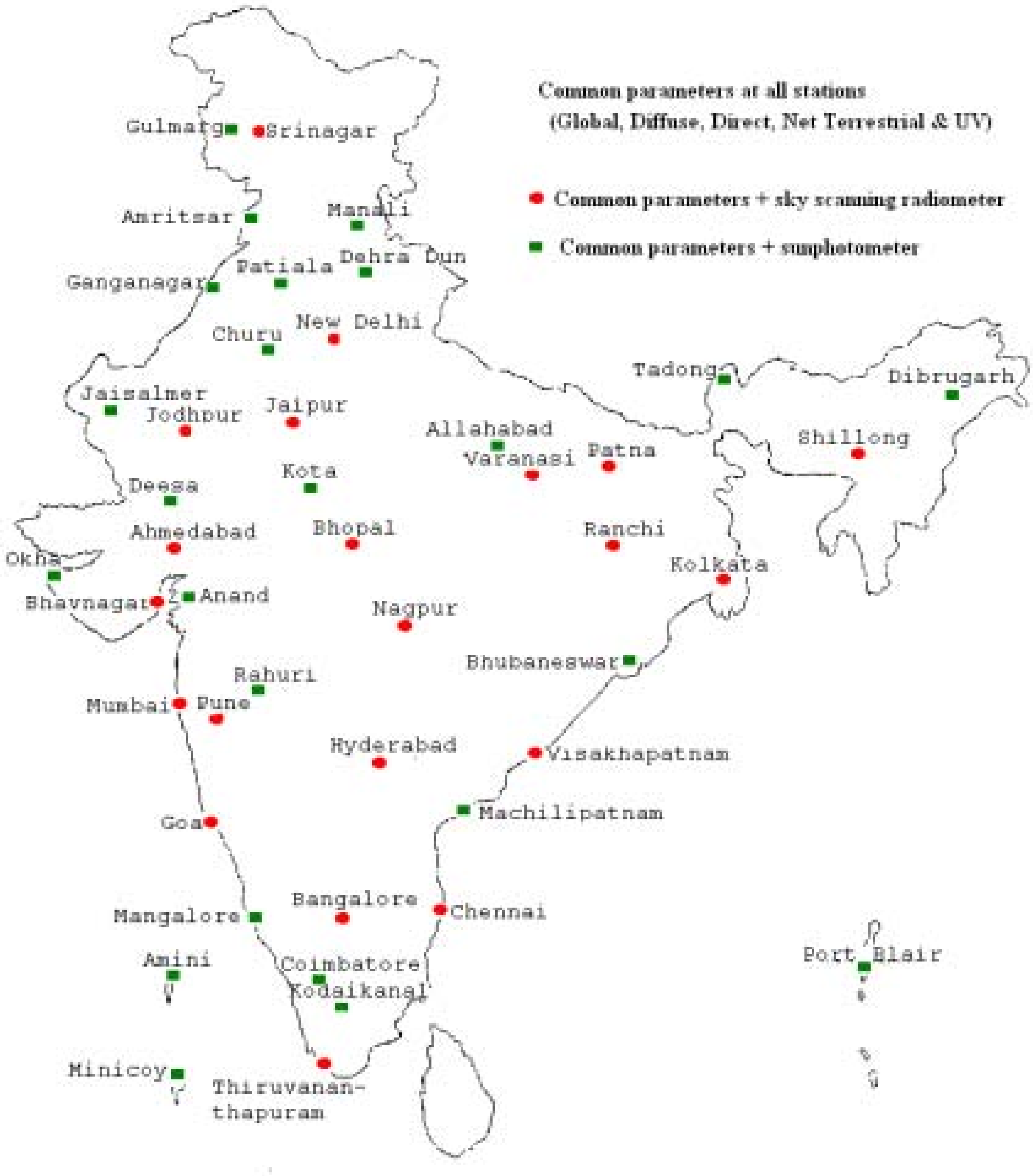

Fig. 3: Futuristic radiation network

Table 1. Details of radiation measurements at the existing network stations of IMD

S.No.	Station Name	Global Irradiance (Pyranometer)	Diffuse Irradiance (Pyranometer)	Direct Irradiance (Pyrheliometer)	Optical Depth (Sun photometer)	Net Terretrial radiation (Ångström Pyrgeometer)	Net radiant energy (Net Pyradiometer)	Upper air net radiant energy
Principal Station								
1	Ahmedabad	✓	✓	Ångström		✓		
2	Bangalore	✓	✓	Thermopile				
3	Bhavnagar							
4	Bhopal	✓	✓	Thermopile				
5	Mumbai	✓	✓	Ångström		✓		
6	Kolkata	✓	✓	Ångström		✓		✓
7	Goa	✓	✓	Ångström		✓		
8	Hyderabad	✓	✓	Thermopile				
9	Jaipur	✓	✓	Thermopile				
10	Jodhpur	✓	✓	Ångström	✓	✓		✓
11	Chennai	✓	✓	Ångström		✓		
12	Nagpur	✓	✓	Ångström	✓	✓		✓
13	New Delhi	✓	✓	Ångström & Thermopile	✓	✓		✓
14	Patna	✓	✓	Thermopile				
15	Pune	✓	✓	Ångström	✓	✓	✓	✓
16	Ranchi	✓	✓	Thermopile				
17	Shillong	✓	✓	Ångström		✓		
18	Srinagar	✓	✓	Thermopile	✓			✓
19	Thiruvananthapuram	✓	✓	Ångström & Thermopile		✓		✓
20	Varanasi	✓	✓	Thermopile	✓			
21	Visakhapatnam	✓	✓	Ångström	✓	✓		
22	Amritsar	✓						

S.No.	Station Name	Global Irradiance (Pyranometer)	Diffuse Irradiance (Pyranometer)	Direct Irradiance (Pyrheliometer)	Optical Depth (Sun photometer)	Net Terretrial radiation (Ångström Pyrgeometer)	Net radiant energy (Net Pyradiometer)	Upper air net radiant energy
23	Anand	✓					✓	
24	Bangalore A.R.U.	✓					✓	
25	Bhubaneshwer	✓						✓
26	Dehradun	✓						
27	Gulmarg							
28	Jaisalmer	✓						
29	Kodaikanal	✓		Ångström	✓			
30	Kota	✓						
31	Machilipatnam	✓						
32	Manali	✓						
33	Mangalore	✓						
34	Minicoy	✓	✓		✓		✓	
35	Mohan Bari	✓			✓			
36	Okha	✓						
37	Patiala	✓	✓					
38	Port Blair	✓	✓		✓			
39	Rahuri	✓					✓	
40	Tadong	✓						
41	Allahabad				✓			
42	Amini						✓	
43	Churu							
44	Coimbatore	✓						
45	Deesa	✓						
46	Sri Ganganagar	✓						