सत्यमेव जयते

भारत मौसम विज्ञान विभाग
INDIA METEOROLOGICAL DEPARTMENT

आदित्यात् जायते वृष्टिः

2018

वार्षिक प्रतिवेदन

ANNUAL REPORT

भारत मौसम विज्ञान विभाग

INDIA METEOROLOGICAL DEPARTMENT

पृथ्वी विज्ञान मंत्रालय, भारत सरकार

Ministry of Earth Sciences, Govt. of India

IMD ORGANIZATION CHART

INDIA METEOROLOGICAL DEPARTMENT

MINISTRY OF EARTH SCIENCES

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(MINISTRY OF EARTH SCIENCES, GOVT. OF INDIA)

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FOREWORD

It gives me immense pleasure to bring out the Annual Report of India Meteorological Department (IMD) for the year 2018. The report highlights significant activities of the department during the year. The department has been playing a leading role in the field of Earth and Atmospheric Sciences by providing efficient services in meteorology and contributing to safety of life and property. By all means this contribution is a major towards the cause of national development.

The celebration of 144th IMD's Foundation Day on 15th January, has provided ample opportunity to commemorate past glory and a reflection of the future vision. The Department's progressive strides towards modernization of scientific infrastructure in the fields of meteorological observations and information systems has helped to render better services in areas of agriculture, aviation, shipping, fisheries, energy and transport. Numerical Weather Predictions (NWP) has established its credibility in giving medium and short range forecasting of severe weather phenomenon like cyclones, heavy rains, thundershower, cold and heat waves.

During 2018, IMD achieved some significant milestones like implemented Global Ensemble Forecasting System (GEFS SL) for ensemble forecasts in the medium range time scale. The GEFS SL at semi-Lagrangian resolution T1534 in horizontal resolution (~12 km) with 64 hybrid sigma-pressure layers was made operational in June, 2018. The operational coupled modelling system for the extended range forecast and the very high resolution global model (GFS T1534) for short to medium range weather forecasts continued in 2018 also. In addition, various new climate products are prepared for providing services to Health Sector, Power Sector, Agriculture sector etc. based on the operational extended range forecast. IMD is in the process of further enhancing the quality of climate services to different users. IMD in collaboration with IIT Gandhinagar has recently implemented a well calibrated Variable Infiltration Capacity Model (VIC) for land surface products such as Soil moisture, Runoff etc for application in Agriculture and also for hydrologic assessment. During 2018 IMD has also operationalised Air Quality Early Warning System for Delhi.

IMD has continued its efforts for the improvement of observing, warning and dissemination systems all through 2018. With regard to the upper air observing system all 43 RS/RW stations are working on GPS based sounding system. The merged lightening & satellite products as a joint collaboration of IMD, IITM & IAF has been operationalised in IMD. IMD's improved services rendered in respect of very short (up to 6 hrs), short (up to 3-days in advance), medium (up to 7-10 days in advance), extended (up to 15 to 20 days in advance), long (monthly and seasonal) range and severe weather (cyclones, thunderstorms, extreme rainfall, heat wave, cold wave, fog) forecasts have been built to meet the demands of the user agencies, disaster managers, emergency response groups and other stakeholders in an organized manner.

Climate over India during 2018 was significantly warm in respect of temperature. The annual mean temperature for the country was +0.40 °C above the 1971-2000 average, thus making the year 2018 as the sixth warmest year on record since 1901. Higher mean temperatures during the winter season (January-February, with anomaly +0.59 °C, fifth warmest since 1901) and the pre-monsoon season (Mar-May, with anomaly +0.55 °C, seventh warmest since 1901) mainly accounted for the above normal annual temperature for the year 2018.

Cold wave conditions took a toll of 279 lives throughout the country during 2-14 January, 2018 mainly over Uttar Pradesh and Bihar. Dust Storm took a toll of 225 lives throughout the country mainly over Uttar Pradesh and Rajasthan. Lightning reportedly claimed over 198 lives from different parts of the country mainly over Uttar Pradesh, Odisha, Madhya Pradesh, Maharashtra and Rajasthan. Thunderstorm reportedly claimed over 496 lives throughout the country during pre monsoon season, Jun and July mainly over Andhra Pradesh and Jharkhand. Heavy Rain & Flood related incidents during the monsoon season claimed at least 612 lives from different parts of the country mainly over Kerala and Uttar Pradesh. 77 lives were claimed dead due to Cyclone (SCS) "TITLI" during 12 to 14 October. 45 lives reported dead due to Cyclone (SCS) "GAJA" during 10 to 17 November.

Doppler Weather Radar (DWR) installed at Goa in 2018. The inauguration of S-Band DWR at Goa was done in June, 2018. IMD is in the process of installing more DWR to its network. Augmentation in DWRs network will definitely enhance the accuracy of nowcast of concerned areas.

In 2018, instruments of Dust Storm and Fog Monitoring system have been straightened at airports of north India. In addition, HWSR, Drishti Transmissometer, DIWE, DCWIS, Laser Ceilometer, etc. have been commissioned at different airports. Two Meteorological Center, Amaravati (M. C., Amaravati) and Andhra Pradesh has established full fledge conventional Surface Met. Observatory with 10 meter wind mast in the month of November 2018.

Dissemination of agromet advisories to the farmers through different multi-channel system of All India Radio (AIR) and Doordarshan, private TV and radio channels, newspaper and internet, SMS and IVR (Interactive Voice Response Technology) etc. is being made on wider scale. Agromet Advisories Services (AAS) are disseminated under PPP mode and through Kisan Portal to 40.1 million farmers. At present 658 Agromet Advisory Service (AAS) districts bulletins are being prepared and issued to cater to the needs of farmers in the country.

A large number of Workshops, Symposia and Conferences were organized this year by covering such diverse themes as Gramin Krishi Mausam Seva (GKMS), TROPMET 2018, Weather, Climate & Natural Hazards, Flood/Drought Monitoring, Annual Cyclone/Monsoon Review Meeting, State level stake holders, SASCOF-12, etc. The Annual Report makes an interesting reading on the plethora of activities pursued in this Department in this vibrant area of science.

In conclusion, I am availing this opportunity to thank all the members of IMD for their true dedication and strive to further enhance the reputation of the department with strong national and international credibility. My special thanks to Dr. D. R. Pattanaik and his team of Publication Unit for their sincere efforts in compilation, editing and publication of this annual report.

Dr. K. J. Ramesh
Director General of Meteorology

CHAPTER 1

INDIA METEOROLOGICAL DEPARTMENT - OVERVIEW

India Meteorological Department, Ministry of Earth Sciences is the National Meteorological Service of the country and the principal Government agency in all matters relating to Meteorology, Seismology and allied discipline and provides weather and climate services to the public and specialized sectors.

It's mandate is:

- To take meteorological observations and to provide current and forecast meteorological information for optimum operation of weather-sensitive activities like agriculture, irrigation, shipping, aviation, offshore oil explorations, etc.

- To warn against severe weather phenomena like tropical cyclones, norwesters, duststorms, heavy rains and snow, cold and heat waves, etc., which cause destruction of life and property.

- To provide meteorological statistics required for agriculture, water resource management, industries, oil exploration and other nation-building activities.

- To conduct and promote research in meteorology and allied disciplines.

- To detect and locate earthquakes and to evaluate seismicity in different parts of the country for development projects.

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.

From a modest beginning in 1875, IMD has progressively expanded its infrastructure for meteorological observations, communications, forecasting and weather services and it has achieved a parallel scientific growth. IMD has always used contemporary technology. In the telegraph age, it made extensive use of weather telegrams for collecting observational data and sending warnings. Later IMD became the first organization in India to have a message switching computer for supporting its global data exchange. One of the first few electronic computers introduced in the country was provided to IMD for scientific applications in meteorology. India was the first developing country in the world to have its own geostationary satellite, INSAT, for continuous weather monitoring of this part of the globe and particularly for cyclone warning. IMD has continuously ventured into new areas of application and service, and steadily built upon its infra-structure in its history of 144 years. It has simultaneously nurtured the growth of meteorology and atmospheric science in India. Today, meteorology in India is poised at the threshold of an exciting future.

India had some of the oldest meteorological observatories of the world and the first astronomical and meteorological unit started at Madras in 1793. Thus, meteorological observation in India was taken even prior to the establishment of the department in 1875. Since then IMD has achieved many milestones during the period from 1793 to 2018.

INDIA METEOROLOGICAL DEPARTMENT

Milestones (1793-2018)

1793 

India has some of the oldest Meteorological Observatories of the world.

First Astronomical and Meteorological Unit started at Madras in 1793.

1875 

All meteorological work in the country was brought under a central authority with the establishment of IMD.

First Headquarters-The Alipore Office at Calcutta, started in 1875.

1878 

Advent of telegraphy enabled centralised data reception and publication of the Indian Daily Weather Report (IDWR) since 1878.

The first weather charts were printed in the IDWR in 1887.

1882 

Seismological activity started in India with the establishment of the first observatory at Alipore, Calcutta.

Seismogram of the disastrous Quetta Earthquake, 1935.

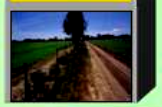
1886 

First Long Range Forecast of Monsoon was issued

1905 

Upper air measurements of winds started in 1905 by the method of tracking balloons with theodolites.

The launching of the Pilot Balloon.

1932 

A separate division was created in 1932 for research activities in the field of Agricultural Meteorology.

The first field unit at Pune.

1954 

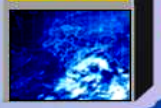
Radars were pressed into aviation weather service as early as 1954.

First Cyclone Detection Radar was installed at Vishakhapatnam in 1970.

1957 

Environmental Meteorology took shape in India with the first Ozone measurements at Kodaikanal in 1957.

The Kodaikanal observatory.

1964 

IMD started receiving satellite images from US Satellites in 1964.

Image received from India's own satellite INSAT.

1969 

Meteorological training facilities were created in 1942 and in 1969 upgraded to a Directorate.

A training class at the Central Training Institute in Pune.

1970 

Directorate of Telecommunication was set up in 1970 to rapidly exchange information amongst various centres.

The maze of current communication network.

1973 

The Telecom age ushered in the prospects of global data assimilation and numerical weather forecasting.

View of the Northern Hemispheric Analysis Centre, New Delhi.

1977 

The National Data Centre at Pune was created in 1977 for scrutinising and archiving all meteorological data in computerised form.

The control room of NDC, Pune.

1982 

INSAT provided a Geo-stationary platform for remote sensing of the atmosphere and automatic data collection.

An unmanned Data Collection Platform.

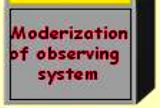
2002 

Doppler Weather Radars (DWR) inducted in the cyclone detection network which enable precise estimate of intensity of cyclone.

The first DWR was commissioned at Chennai.

2003 

Launch of Meteorological Data and INSAT Imagery through World Space Digital Data Broadcast System.

2006 

The Department took a major initiative to modernize its observational and forecasting infrastructure to deliver a whole range of new services.

2008 

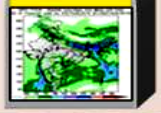
New forecast services were introduced in the country addressing specific needs of individual Districts. It has been specifically designed for providing Agricultural advisories.

2010 

- Integrated Forecasting & Communication System (IFCS)
- Setting up of National Weather Forecasting Centre (NWFC) at Delhi
- Operational global model
- Operational extended range forecast
- Nowcasting

2012 

- Agromet advisories through SMS to 3.3 million farmers.
- Nowcasting of Thunder-storms over 117 cities
- ISO 9001-2008 certification to (i) Met. services of IGI airport (ii) Met. centre Hyderabad, (iii) DWR Palam, (iv) RS/RW Aaya Nagar and (v) Synoptic station at Safdarjung, New Delhi

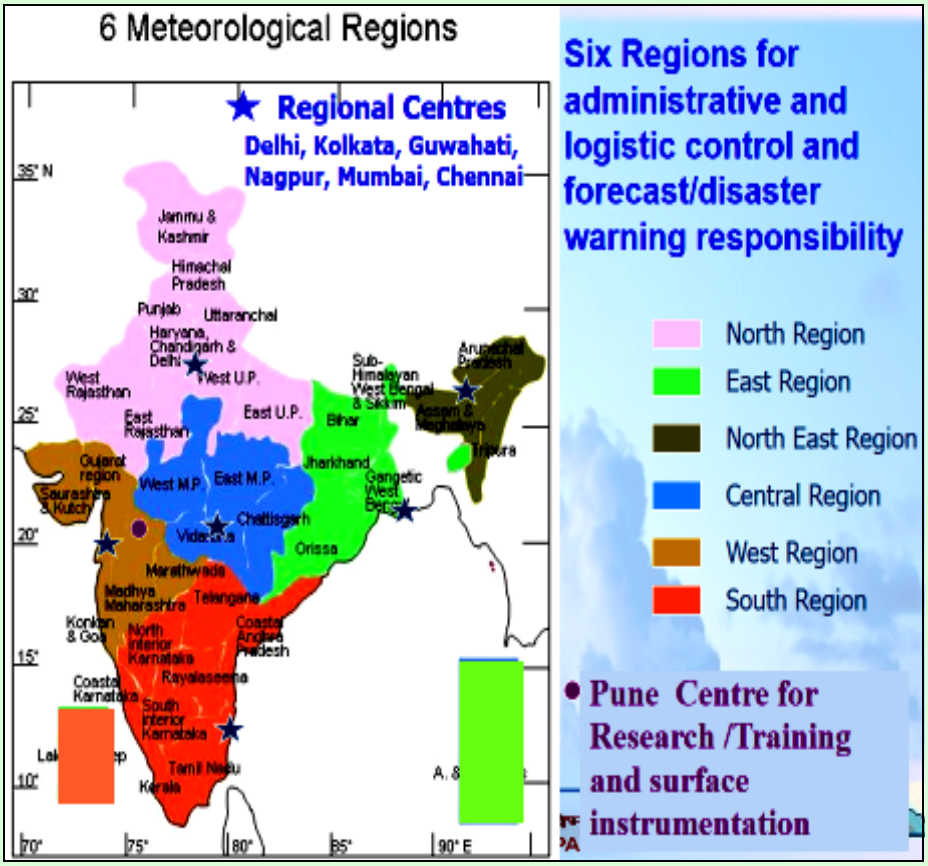
2018 

Implemented in IMD :

- Global Ensemble Prediction System (GEPS) model at 12 km resolution
- Land Surface Hydrology Products using VIC models
- Satellite & Lightning merged products
- Air quality early warning system for Delhi

In service of the Nation since 1875

The Director General of Meteorology is the Head of the India Meteorological Department, with headquarters at New Delhi. For the convenience of administrative and technical control, there are 6 Regional Meteorological Centres, each under a Deputy Director General with headquarters at Mumbai, Chennai, New Delhi, Kolkata, Nagpur and Guwahati. Under the administrative control of Deputy Director General, there are different types of operational units such as Meteorological Centres, Forecasting Offices, Agromet. Advisory Centres, Flood Meteorological Offices and Cyclone Detection Radar Stations.



In addition, there are separate divisions to deal with specialized subjects, which are:

India Meteorological Department has continued its efforts for the improvement of observing, warning and dissemination mechanism/systems all through 2018. Its improved services rendered in respect of very short (up to 6 hrs), short (up to 3-days in advance), medium (up to 7-10 days in advance), extended (up to 15 to 20 days in advance), long (monthly and seasonal) range and severe weather (cyclones, thunderstorms, extreme rainfall) forecasts have been built to meet the demands of the user agencies, disaster managers, emergency response groups and other stakeholders in an organized manner in 2018. Its short, medium, extended & long range and cyclone forecasts were appreciated all over the world.

Climate over India during 2018 was significantly warm in respect of temperature. The annual mean temperature for the country was +0.40 C above the 1971-2000 average, thus making the year 2018 as the sixth warmest year on record since 1901. The other 9 warmest years on record in order were: 2016 (anomaly +0.707 C), 2009 (0.552), 2017 (0.541), 2010(0.539), 2015(0.424), 1958(0.250), 2002(0.245), 2014(0.238), 2006(0.228). Higher mean temperatures during the winter season (January-February, with anomaly +0.59 C, fifth warmest since 1901) and the pre-monsoon season (Mar-May, with anomaly +0.55 C, seventh warmest since 1901) mainly accounted for the above normal annual temperature for the year 2018.

Rainfall during the southwest monsoon season from June to September, 2018 for the country as a whole was normal [91 % of Long Period average (LPA)]. The Northeast monsoon rainfall activity during October to December, 2018 over the south peninsula (core region of northeast monsoon rainfall activity comprising of 5 subdivisions viz. Coastal Andhra Pradesh, Rayalaseema, Tamil Nadu & Pondicherry, South Interior Karnataka and Kerala) was below normal (66 % of Long Period Average (LPA)). Among the significant weather events of the year 2018: 279 persons were reported dead due to Cold Wave during 2-14 January. Of these, 135 persons were reported from Uttar Pradesh and 121 from Bihar. Dust Storm took a toll of 225 lives throughout the country. Of this 150 were reported from Uttar Pradesh during the period 6 May to 13 Jun, 74 from Rajasthan and one from Madhya Pradesh. Snowfall reportedly claimed more than 18 lives from Jammu and Kashmir of which 11 were reportedly claimed dead on 5 Jan 2018. Lightning reportedly claimed over 198 lives from different parts of the country. Of these, 74 deaths were reported from Uttar Pradesh, 61 in Odisha, 16 in Madhya Pradesh, 11 each from Maharashtra and Rajasthan. Thunderstorm reportedly claimed over 496 lives throughout the country during pre monsoon season Jun and July, of which 87 were reported dead from Andhra Pradesh, 121 from Jharkhand and 163 from Jharkhand. Heavy Rain & Flood related incidents during the monsoon season claimed at least 612 lives from different parts of the country. Of these,149 persons were reported dead from Kerala and 189 persons from Uttar Pradesh. 77 lives were claimed dead due to Cyclone (SCS) “TITLI” during 12 to 14 October. 45 lives reported dead due to Cyclone (SCS) “GAJA” during 10 to 17 November.

SUMMARY OF MAJOR ACHIEVEMENTS IN 2018

- The inauguration of S-Band Doppler Weather Radar (DWR) at Goa on 12th June, 2018 was done by Dr. M. Rajeevan, Hon’ble Secretary, MoES in presence of Dr. K. J. Ramesh, DG, IMD.

- IMD jointly received “Awards for Excellence in Climate Change Mitigation & Adaptation” under the category “Leadership in Urban Climate Action” on 17th April, 2018 at New Delhi for the development & implementation of Heat Action Plan in the country for the city of Ahmedabad contributing to the UN sustainable development Goal on Climate.

- IMD and POSOCO have launched a web portal dedicated exclusively to energy sector. A Reference Document on Weather Portal for Energy Sector was launched by Hon’ble Minister of State (IC), Ministry of Power and New & Renewable Energy, Shri R. K. Singh in the presence of Dr. K. J. Ramesh, DGM on 29th August, 2018.

- The processed data of INSAT-3DR Imager and Sounder is being obtained from SAC, Ahmedabad. The satellite products are being used extensively for weather forecasting services.

- License agreement has been signed between India Meteorological Department and EUMETSAT Germany for obtaining data and product generated by EUMETSAT Geostationary Satellites and its Polar orbit Metop Satellites and Terrestrial link has been set at NCMRWF, Noida.

- Air Quality Early Warning System for Delhi was launched on 15th October, 2018 by Dr. Harsh Vardhan, Hon’ble Union Minister for Earth Sciences. The System is designed to predict extreme air pollution events and give alerts to take necessary steps as per Graded Response Action Plan (GRAP) of the Government of India.

- Supply order for procurement of 10 X-band DWRS for installation in three states J&K, H.P and Uttrakhand has been issued in September, 2018.

- In June 2018 IMD has implemented high resolution (12 km grid scale) state-of-the-art global Ensemble Prediction Systems (EPS) for generating operational 10-days probabilistic forecasts of weather.

- All 43 RS/RW stations working on GPS based sounding system.

- Six IMD upper air station included in GCOS-GUAN network.

- Five New Aeronautical Met. Stations (AMS) were commissioned at Jagdalpur, Hisar, Jharsuguda, Pakyong and Pithoragarh under RCS-UDAN Scheme.

- Eleven indigenously developed new Drishti RVR systems at Amritsar, Mumbai, Chennai, Kannur, Cochin, Hyderabad and Delhi. These RVR systems are developed indigenously by CSIR-NAL.

- Three Laser Ceilometers were installed at Mangalore (Bajpe), Delhi and Kolkata airport.

- Current Weather Instrument Systems (CWIS) were commissioned at Shamshabad, Hyderabad and Patna airport.

- Distant Indicating Wind Equipment (DIWE) instruments were installed at Pantnagar, Port Blair (Command Office), Lengpui, Kadapa, Bhuntar, Hissar, Pithoragarh airports and M. C., Amravati.

- Augmentation of Skyradiometer network by commissioning of 8 sky radiometer at Jaipur, Raipur, Gangtok, Minicoy, Pondicherry, Aurangabad, Sagar and Amaravati.

- 189 new stations were included in District-wise Rainfall Monitoring System (DRMS).

- WMO appreciated IMD for tropical cyclone advisory services during VSCS Luban and VSCS Titli. There were 14 cyclonic disturbances (depressions and cyclones) over the north Indian Ocean (NIO) and adjoining land regions during 2018. Out of 14 CDs, 7 intensified into tropical cyclones (Cyclonic Storm (CS); Severe Cyclonic Storm (SCS); Very Severe Cyclonic Storm (VSCS); and Extremely Severe Cyclonic Storm (ESCS)) against the normal frequency of 4.5 cyclones per year over north Indian Ocean (NIO) based on LPA. RADAR imagery from DWR Vishakapatnam & Gopalpur for VSCS “Titli over Bay of Bengal near landfall time.

- Surface ozone recording system was installed at New Delhi.

- Agro-Meteorological Advisory (AAS) Services are disseminated under PPP mode & through Kisan Portal to 40.1 million farmers. At present 658 Agromet Advisory Service (AAS) districts bulletins are being prepared and issued to cater to the needs of farmers in the country.

- IMD in collaboration with IIT Gandhinagar has recently implemented a well calibrated Variable Infiltration Capacity Model (VIC) for land surface products such as Soil moisture.

- 114 Research Papers/books/Met. Monographs published.

Chapter 2

Weather Summary during 2018

1. Winter Season (January & February)

Cold Wave conditions

Cold wave conditions were rather moderate during the season and prevailed only for few days during the season. Rainfall during the season was third lowest since 1901. Over Northwest region, maximum temperature (22.32 °C) was above normal by 2.14 °C, which is second highest for the region since 1901, over central India it was fourth highest since 1971.

Cold Wave / foggy conditions

Cold wave conditions were moderate during the season. Severe Cold wave conditions were observed over parts of Bihar during first fortnight of the January.

Dense to very dense foggy conditions prevailed at a few places over the northern parts of the country during February. Dense to very dense foggy conditions prevailed at a few places over Assam and Meghalaya one or two days during last week of the February.

Rainfall Features

Rainfall activity over the country as a whole during the season was substantially below normal (38%of LPA). It was very much below normal during January (15% of LPA) and below normal during February (57% of LPA). Rainfall activity was mainly observed over Andaman & Nicobar Islands, parts of Marathwada and Vidarbha.

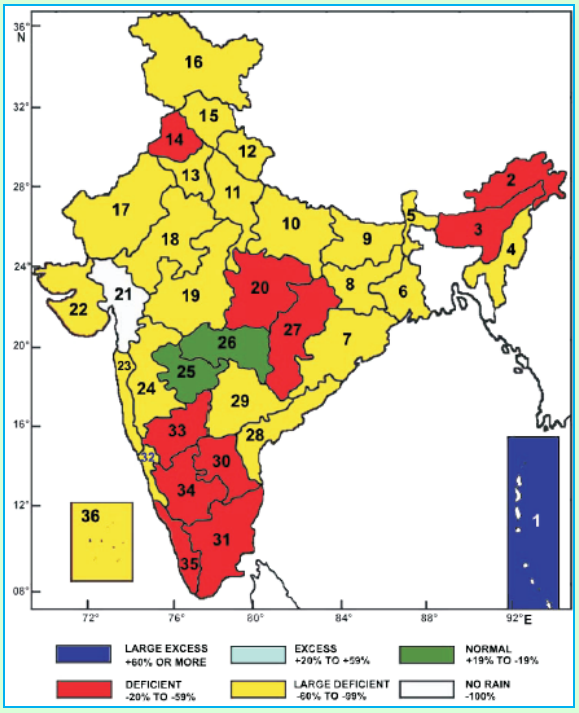
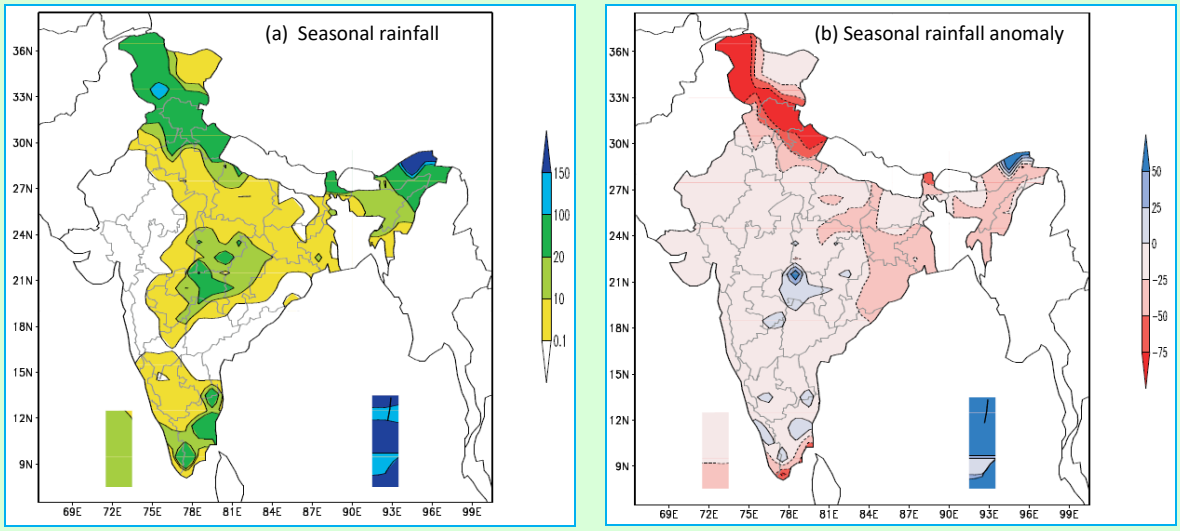


Fig. 1. Sub-divisionwise rainfall percentage departures

During the season, out of 36 meteorological subdivisions, 1 received large excess rainfall, 2 received normal rainfall, 10 received deficient rainfall, 22 received large deficient rainfall. One subdivisions did not receive any rain. (Fig. 1). Except Andaman & Nicobar Islands, Marathwada and Vidarbha all subdivisions of the country received deficient/large deficient or no rainfall.

The spatial pattern of rainfall (mm) received during the season [Fig. 2(a)]. Northern, extreme northeastern parts of the country, central India, eastern parts of south peninsular India and Andaman & Nicobar Islands received more than 20 mm of rainfall. Parts of Arunachal Pradesh, Jammu & Kashmir and Andaman & Nicobar Islands received more than 100 mm rainfall.



Figs. 2(a&b). (a) Seasonal rainfall (mm) (b) Seasonal rainfall anomaly (mm)
(*Based on 1951-2000 Normals*)

The spatial pattern of rainfall anomaly (mm) during the season is shown in Figs. 2(b). Except for some parts of extreme northeastern region, few parts of Central India and south peninsula and Andaman & Nicobar Islands the rainfall anomaly was negative over most parts of the country. Negative rainfall anomaly was more than 50 mm over parts of Jammu & Kashmir, Himachal Pradesh, Uttarakhand, Tamil Nadu & Puducherry and Sub-Himalayan West Bengal & Sikkim.

Standardized Precipitation Index (SPI)

The Standardized Precipitation Index (SPI) is an index used for measuring drought and is based on only precipitation. This index is negative for drought, and positive for wet conditions. As the dry or wet conditions become more severe, the index becomes more negative or positive. Fig. 3 gives the SPI values for the winter season 2018 (January-February, 2 months cumulative).

Cumulative SPI values of the past two months (January and February) indicate that extremely wet/severely wet condition was not present over any part of the country, however extremely dry/severely dry conditions were observed over parts of Assam & Meghalaya, Nagaland, Manipur,

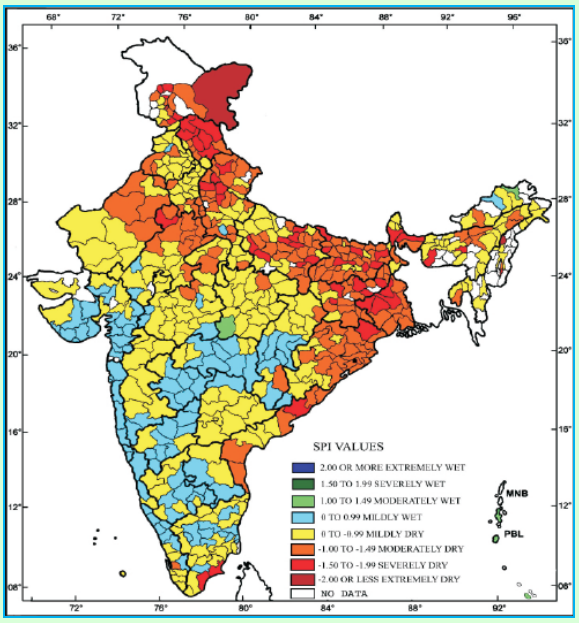
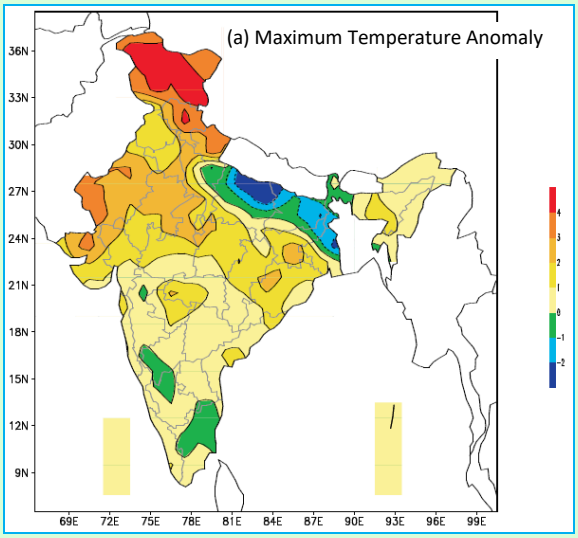


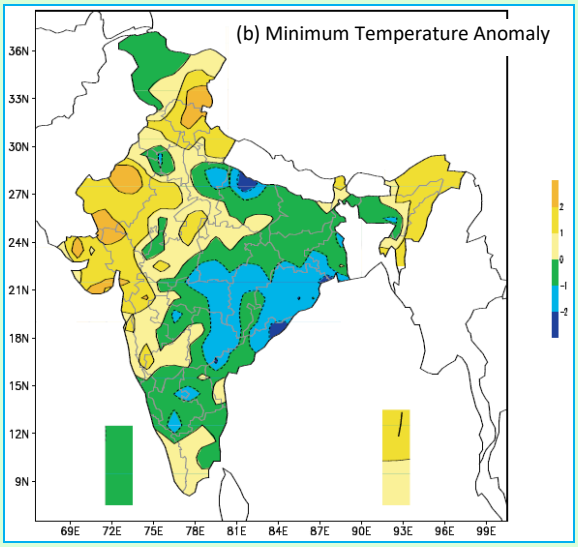
Fig. 3. Standardized Precipitation Index (SPI) cumulative for two months

Mizoram & Tripura, Sub-Himalayan West Bengal & Sikkim, Gangetic West Bengal, Odisha, Jharkhand, Bihar, East Uttar Pradesh, West Uttar Pradesh, Uttarakhand, Himachal Pradesh, Jammu & Kashmir, East Rajasthan, Coastal Andhra Pradesh and Tamil Nadu.

Temperatures

Mean seasonal maximum and minimum temperature anomalies are shown in Figs. 4(a&b) respectively.





Figs. 4(a&b). Mean seasonal temperature anomalies (°C) (a) Maximum (b) Minimum (*Based on 1981-2010 Normals*)

Maximum temperature was above normal over most parts of the country, except some parts of northern plains, eastern parts and some isolated places of peninsular India. It was above normal by 3 °C over extreme northern and extreme northwestern parts. Maximum temperature was below normal by more than 1-2 °C over parts of Gangetic West Bengal, Jharkhand, Bihar and east Uttar Pradesh.

Minimum temperature was above normal over parts of the west central, northwestern, and extreme northeastern region, while it was below normal over parts of eastern region, northern plains and extreme south peninsula and Lakshadweep. Minimum temperature was above normal by 2 °C over parts of east Jammu & Kashmir and adjoining north Himachal Pradesh, parts of West Rajasthan, north Gujarat region and Saurashtra & Kutch. It was below normal by 1-2 °C over parts of Odisha and adjoining Gangetic West Bengal, Vidarbha, south East Madhya Pradesh, Chhattisgarh, northern parts of Coastal Andhra Pradesh, Telangana, East and West Uttar Pradesh.

Outgoing Longwave Radiation (OLR)

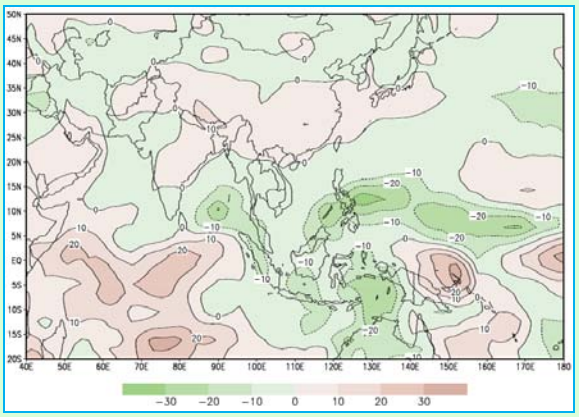


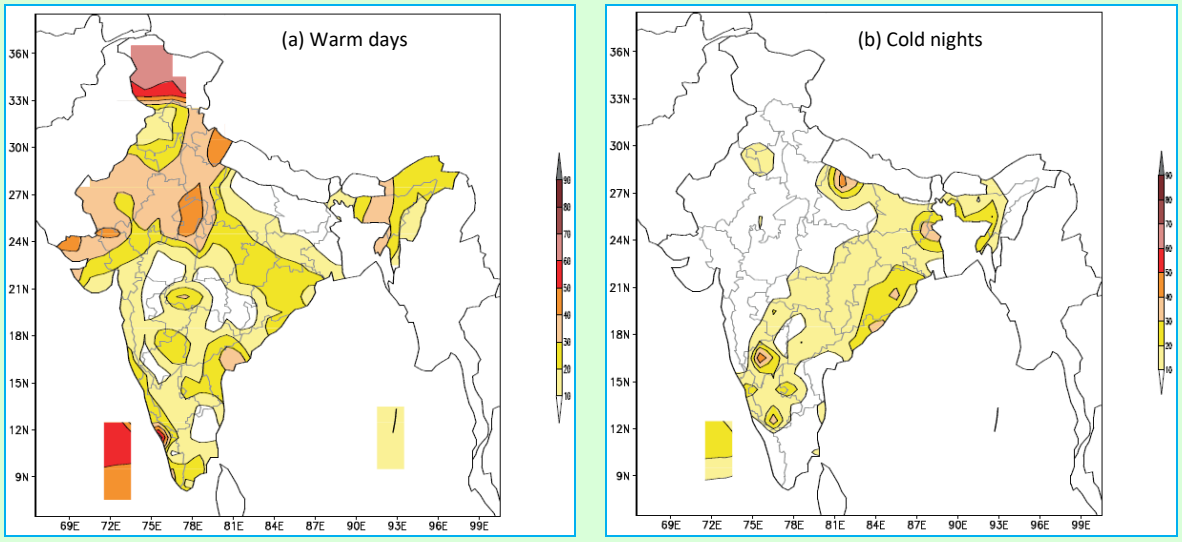
Fig. 5. OLR anomaly (w/m^2) for the winter season 2018 (*Source* : CDC / NOAA, USA) (*Based on 1981 - 2010 climatology*)

OLR anomaly (W/m^2) over the Indian region and neighbourhood is shown in Fig. 5. OLR anomaly was near normal (within ± 10 W/m^2 range) over most parts of the country and adjoining seas. However, over some parts of south central Bay of Bengal, negative OLR anomaly exceeding 10 to 20 W/m^2 was observed. Over most parts of equatorial Indian Ocean region, positive OLR anomaly exceeding 10 to 20 W/m^2 was observed.

Warm days/cold nights

Figs. 6(a&b) show the percentage of days when maximum (minimum) temperature was more (less) than 90th (10th) percentile.

Over northern parts of Saurashtra & Kutch, Gujarat region, northern parts of East Madhya Pradesh and adjoining West Uttar Pradesh and East Rajasthan, Uttarakhand, maximum



Figs. 6(a&b). Percentage of days when (a) maximum temperature > 90th percentile (b) minimum temperature < 10th percentile

temperature was greater than 90th percentile for more than 40 to 50% of the days of the season and over parts of Kerala, Lakshadweep Islands and Jammu & Kashmir, it exceeded 50%. For minimum temperature, it was less than 10th percentile for more than 40 to 50% of the season over parts of East Uttar Pradesh and North Interior Karnataka.

Low Pressure Systems

A low pressure area formed over the Bay of Bengal in the month of January. It formed over southeast Bay of Bengal and adjoining south Andaman Sea in the month of January on 6th and became less marked on 9th January.

2. Pre-Monsoon Season (March-April-May)

Heat Wave Conditions

During the season, heat wave conditions were rather moderate. These conditions were observed over northern, northwestern, western and central parts of the country during the last week of March (26 -31 March). In the month of April, heat wave conditions were observed over some parts of west Rajasthan and Saurashtra & Kutch only on few days during the first three weeks. From 28 April to 31 May, these conditions prevailed over parts of west Rajasthan, Madhya Pradesh and Vidarbha on many days. These conditions were also observed over some parts of west Uttar Pradesh, Haryana, Chandigarh & Delhi and Saurashtra & Kutch on few days in the second fortnight of the May.

Rainfall Features

Rainfall activity over the country during the season as a whole was normal (89% of Long Period Average (LPA) value). It was below

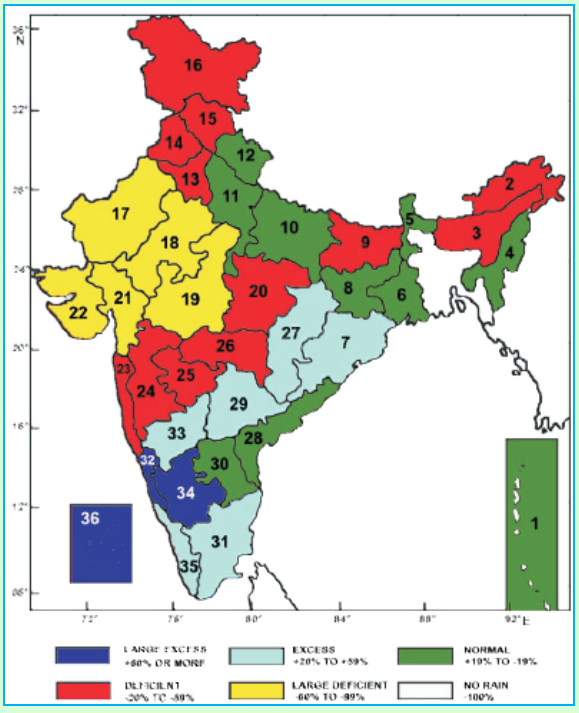
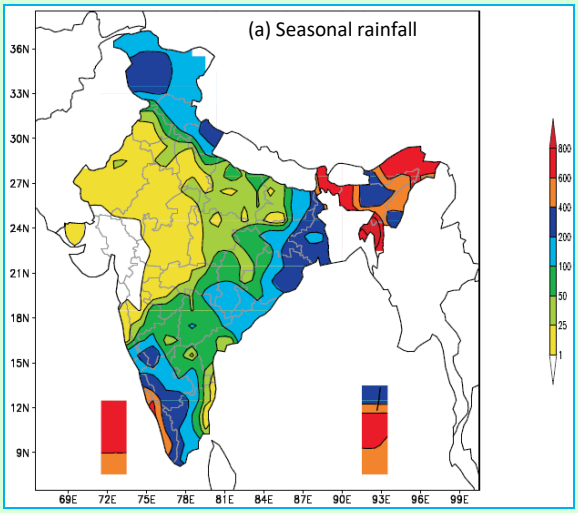
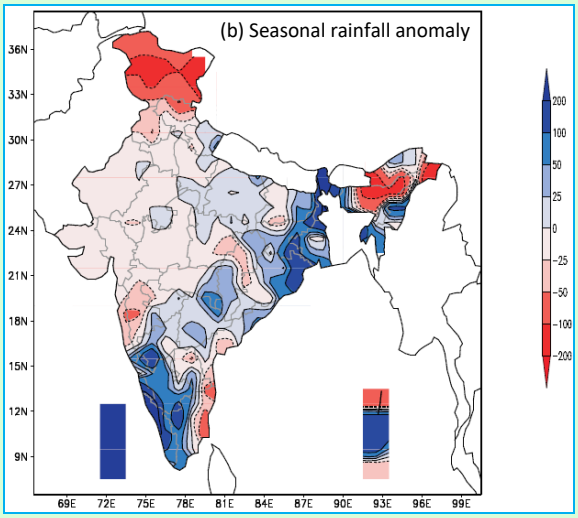


Fig. 7. Sub-divisionwise rainfall percentage departures





Figs. 8(a&b). (a) Seasonal rainfall (mm) (b) Seasonal rainfall anomaly (mm) (*Based on 1951-2000 Normals*)

normal during March (52% of LPA) and normal during April and May (100%, 101% of LPA respectively). Coastal Karnataka, south interior Karnataka and Lakshadweep received about one and half times of their respective normal rainfall. During the season, out of 36 meteorological subdivisions, 3 received large excess rainfall, 6 received excess rainfall, 10 received normal rainfall, 12 received deficient rainfall and 5 received large deficient rainfall (Fig. 7). Table 1 shows the subdivision wise rainfall statistics (mm) for the Pre-monsoon season (March-May 2018).

Fig. 8(a) shows the spatial pattern of rainfall (mm) received during the season. Northern, eastern/northeastern and south peninsular parts of the country including the Islands received more than 100 mm of rainfall. Parts of Jammu & Kashmir, Uttarakhand, Bihar, Jharkhand, West Bengal and adjoining north Odisha, Assam & Meghalaya, Gangetic West Bengal, south interior Karnataka, Kerala, Andaman & Nicobar Islands and Tamil Nadu received rainfall of the order of 200 to 400 mm. Parts of Andaman & Nicobar Islands, Arunachal Pradesh, Assam & Meghalaya, Nagaland, Manipur, Mizoram & Tripura, Sub-Himalayan West Bengal & Sikkim, coastal Karnataka, Kerala, Lakshadweep received rainfall of the order of 400 to 800 mm. Some parts of Mizoram & Tripura received rainfall more than 800 mm.

Fig. 8(b) shows the spatial pattern of rainfall anomaly (mm) during the season. Positive rainfall anomaly of more than 100 mm was observed over parts of Andaman & Nicobar Islands, Nagaland, Manipur, Mizoram & Tripura, Sub-Himalayan West Bengal & Sikkim, Gangetic West Bengal, Orissa, Jharkhand, south interior Karnataka, Kerala, Lakshadweep. Over parts of Tripura and Sub Himalayan West Bengal & Sikkim, Tamil Nadu & Puducherry, north interior Karnataka Kerala, Lakshadweep positive rainfall anomaly was more than 200 mm. Negative rainfall anomaly of the order of 100 to 200 mm was observed over parts of Assam & Meghalaya, Arunachal Pradesh, Himachal Pradesh, Jammu & Kashmir and extreme eastern parts of Tamil Nadu & Puducherry.

Fig. 9(a) shows the area weighted seasonal rainfall over the country as a whole for the period, 1951-2018.

Fig. 9(b) shows the time series of area weighted seasonal rainfall over the four homogeneous regions for the period, 1951-2018. During the season this year, South peninsular India received above normal rainfall (132.8% of LPA), normal rainfall over central India (93.2% of its LPA) and below normal rainfall over Northwest and East & Northeast India (71.0% of LPA, 80.5% of LPA respectively).

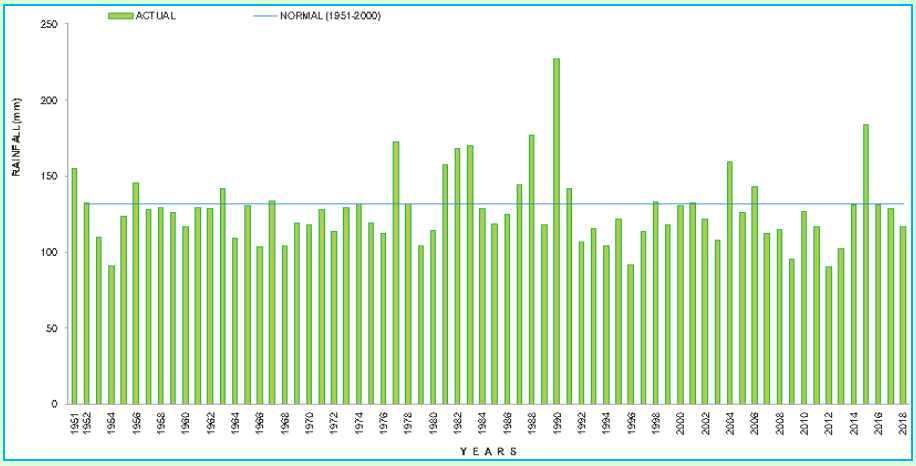


Fig. 9(a). Time series of area weighted rainfall over the country as a whole (1951 - 2018)

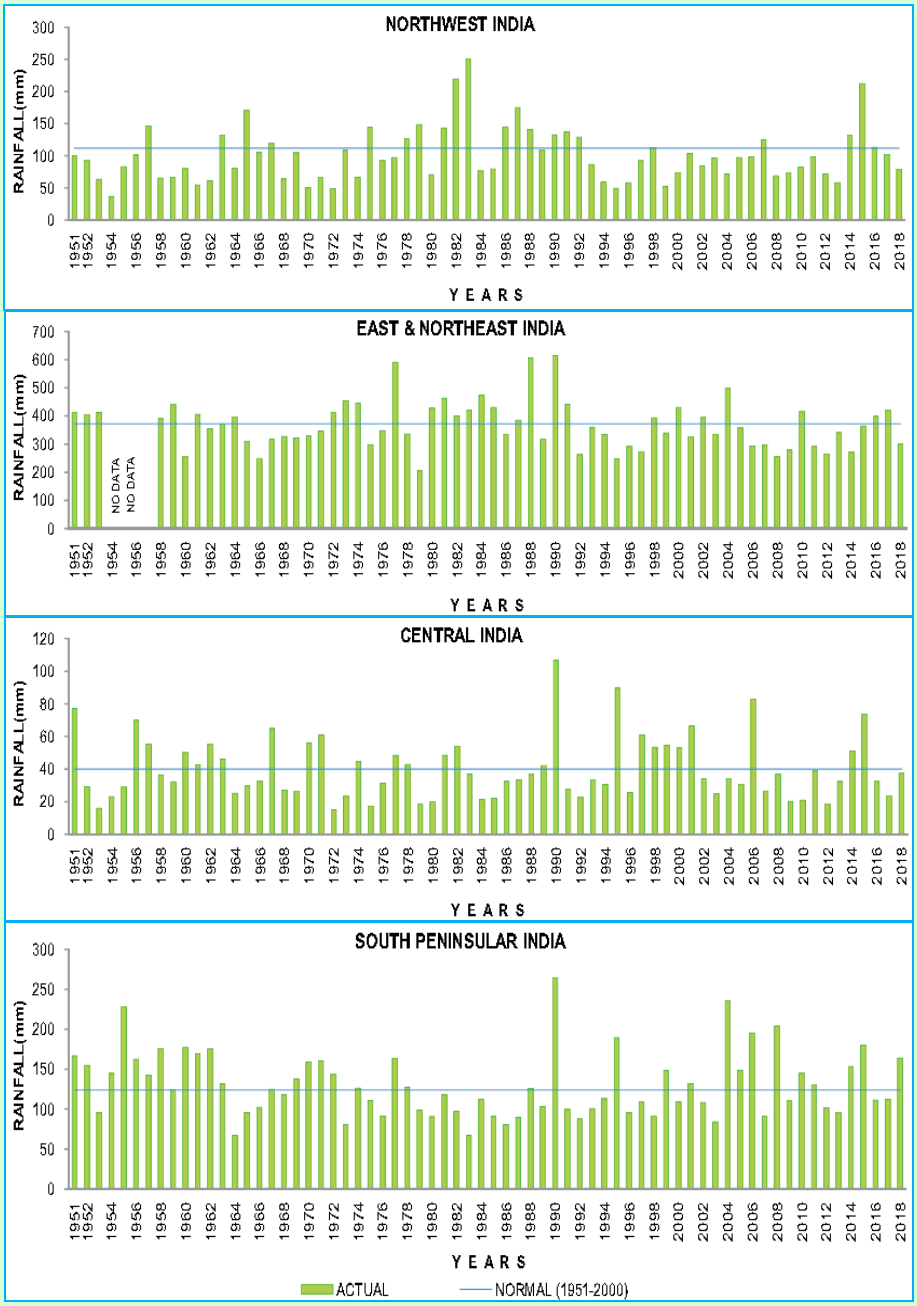


Fig. 9(b). Time series of area weighted rainfall over the four homogeneous regions (1951 - 2018)

Standardized Precipitation Index

The Standardized Precipitation Index (SPI) is an index used for monitoring drought and is based on only precipitation. This index is negative for dry & positive for wet conditions. As the dry or wet conditions become more severe, the index becomes more negative or positive. Fig. 10 gives the SPI values for the Pre-monsoon season this year (March-May, 2018).

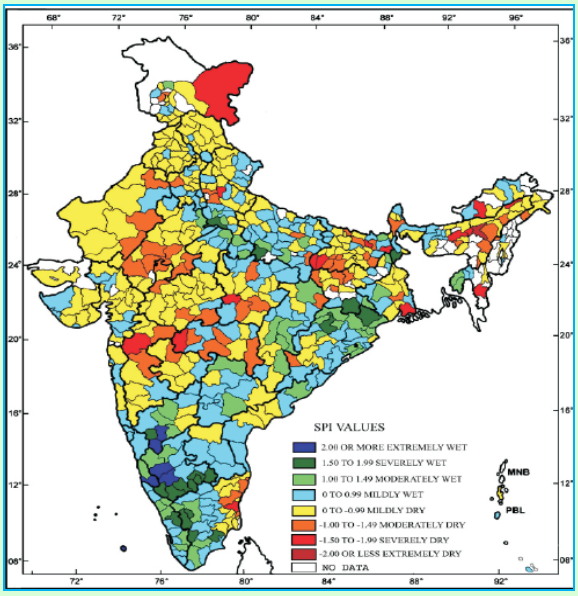


Fig. 10. Standardized precipitation index (SPI) cumulative for pre monsoon season (Mar-May, 2018)

Outgoing Longwave Radiation (OLR)

OLR anomaly (W/m^2) over the Indian region and neighbourhood is shown in Fig. 11. It was negative over most parts of the country, Arabian Sea and equatorial Indian Ocean. It was positive over northwestern region and most parts of Bay of Bengal. Negative OLR anomaly exceeding 20 to 30 W/m^2 was observed over extreme southern parts of the country and adjoining Indian Ocean.

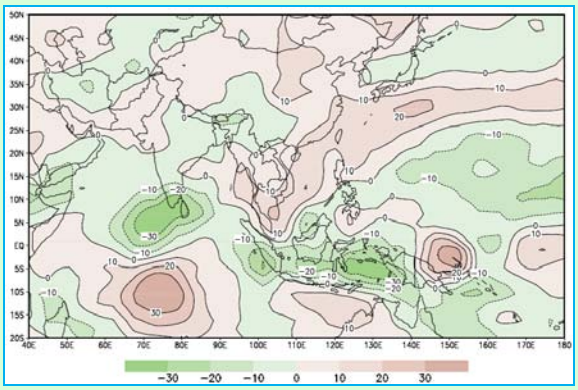
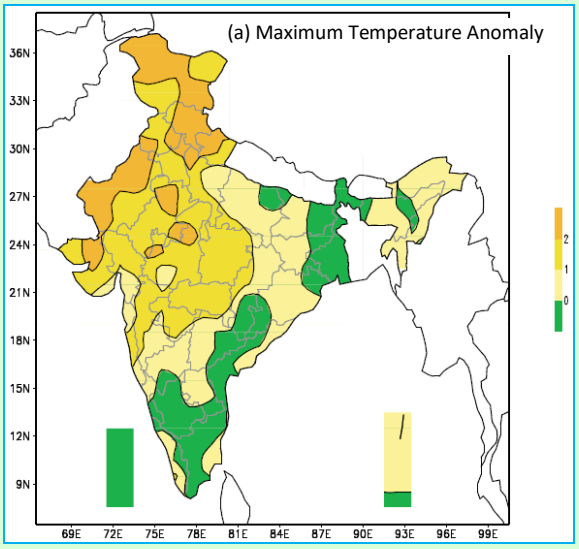
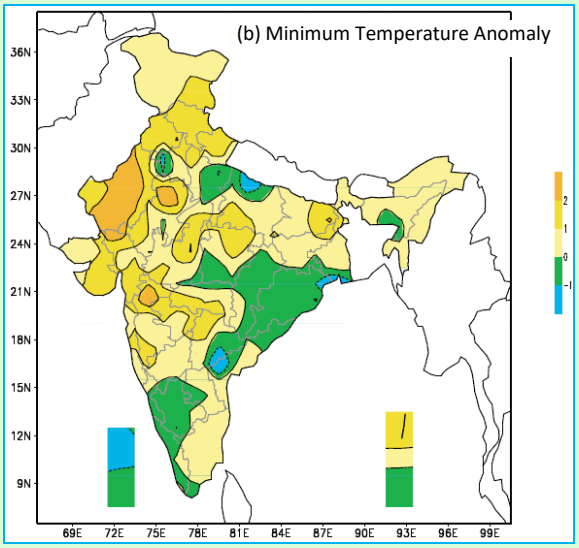


Fig. 11. OLR anomaly (w/m^2) for the season 2018 (*Source* : CDC / NOAA, USA) (*Based on 1981-2010 Climatology*)

Temperature

Mean seasonal maximum and minimum temperature anomalies during the season are shown in Figs. 12(a&b) respectively.





Figs. 12(a&b). Mean seasonal temperature anomalies (°C) (a) maximum (b) minimum (*Based on 1981-2010 normals*)

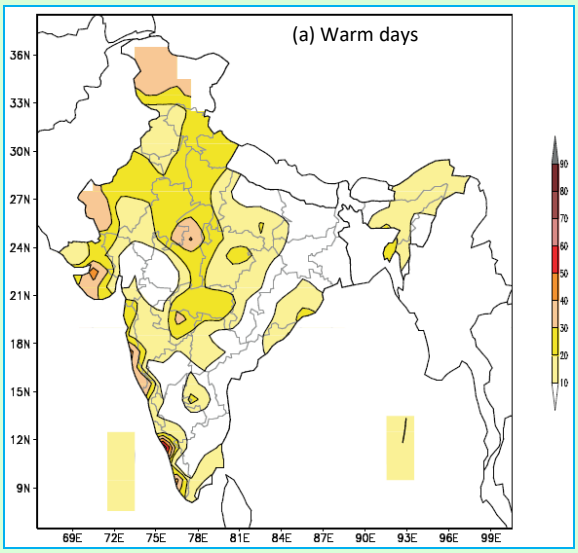
Maximum temperature was above normal over most parts of the country except for the parts of northern, peninsular and island region. Over parts of northern, northwestern,

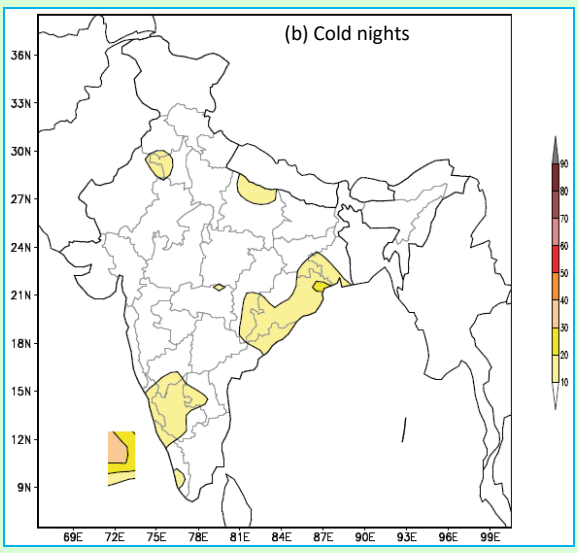
central India it was above normal by 1 °C. It was more than 2 °C over parts of J&K, HP and adjoining Uttarakhand and west Rajasthan.

Minimum temperature was also above normal over most parts of the country except for some parts of UP, Odisha, Chhattisgarh, Telangana, north interior Karnataka, Kerala & Lakshadweep. It was more than 2 °C over parts of west & east Rajasthan, Madhya Maharashtra.

Percentage of Warm days/Cold nights

The percentage of days when maximum (minimum) temperature was more (less) than 90th (10th) percentile [Figs. 13(a&b)].





Figs. 13(a&b). Percentage of days when (a) maximum temperature > 90th Percentile (b) Minimum Temperature < 10th Percentile

Over parts of Saurashtra & Kutch and Kerala maximum temperature was greater than 90th percentile for more than 40 to 50% of the days of the season. For minimum temperature, no significant distribution was observed.

The maximum and minimum temperature series respectively for the country as a whole and for the four homogeneous regions during the season since 1971 [Figs. 14(a&b)]. Both maximum temperature and minimum temperature were above normal over northwest India and central India and was near normal over south peninsular India and northeast India. Maximum temperature over northwest India (33.44 °C) was third highest after the years 2010 (34.66 °C) and 2004 (33.69 °C) and over central India (36.82 °C) was also third highest since 1901 after the years 2010 (37.41 °C) and 2016(36.91 °C).

Low Pressure Systems

One Depression formed during the March over the Arabian Sea. The Depression was first seen as a low pressure area over south west Bay of Bengal off Sri Lanka-south Tamil Nadu coasts on 10th March and it became well marked low pressure area on 12th and became depression on 13th March.

During the month of April, a low pressure area formed over the Andaman Sea on 29th April and it became less marked on 2nd May.

During the month of May, an extremely severe cyclonic storm (ESCS, Mekunu, 21-27 May) and a Cyclonic Storm (CS, Sagar, 16-20 May) over the Arabian Sea and a deep depression (29-30 May) over the Bay of Bengal, formed during the month. All the three systems moved away from the Indian coast. Apart from these three systems, one low pressure area (27-29 May) also formed over southeast Arabian Sea off Kerala-Karnataka coast during the month. Fig. 15 shows the tracks of these intense low pressure systems.

Figs. 14(a&b). Time series of temperature for the country as a whole and the four homogeneous regions (1971 - 2018) (a) Maximum (b) Minimum

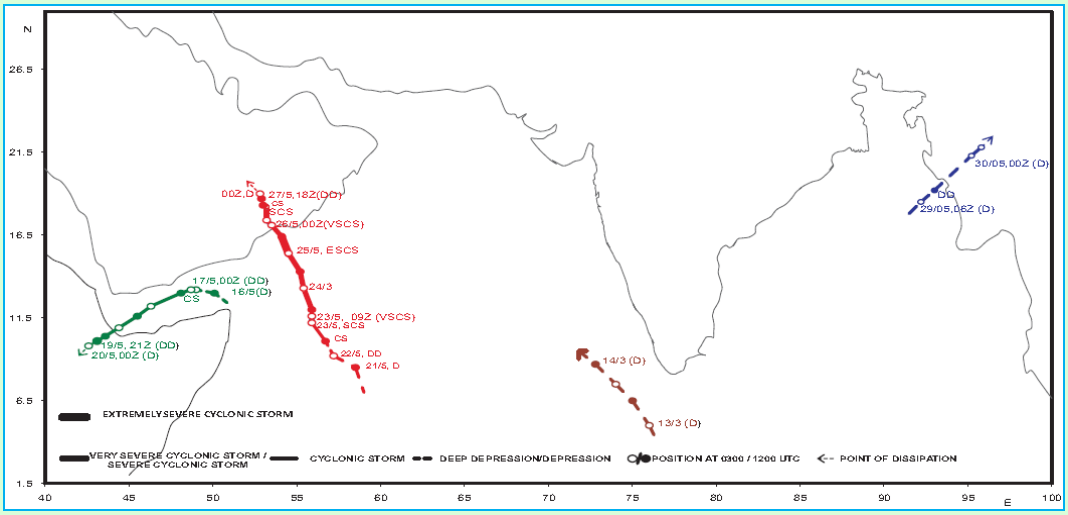


Fig. 15. Tracks of the low pressure systems

Significant Weather events during the season

Duststorm: Total 180 persons reportedly claimed dead due to duststorm from northern & northeastern states of the country during the season. Total 92 persons reportedly claimed dead from 24 districts of Uttar Pradesh (2nd & 6th May). Of which, 90 persons died from 22 districts (maximum death from Agra-50) of Uttar Pradesh on 2nd May. While 68 persons reportedly claimed dead from Alwar, Bharatpur, Bhilwara, Dholpur districts of Rajasthan (10th & 11th April and 2nd May). While on 2nd May, 8 persons reportedly claimed dead from West Bengal, 6 each from Uttarkhand & Madhya Pradesh.

Thunderstorm: Thunderstorm activities reportedly claimed 215 lives during the season. Of these, 166 persons reportedly claimed dead from 56 districts of Uttar Pradesh during the period of 6th April to 31st May. While 19 persons reportedly claimed dead from Bharatpur, Dhoplur districts of Rajasthan(12th April). 15 persons reportedly claimed dead from Bihar (28th May), 7 from West Bengal (9th May). 4 persons reportedly claimed dead during the month April in Assam. While 2 persons each reportedly claimed dead from Jharkhand (20th May) & Punjab (3rd May). Huge amount of standing crops & houses were also damaged in Assam and Uttar Pradesh.

Lightning: During the season, 75 deaths were reportedly claimed from different parts of the country. Of these, 17 deaths were reported from Andhra Pradesh, 13 from Uttar Pradesh, 12 each from Jharkhand, Karnataka & Maharashtra. While 2 deaths were reportedly claimed from each Jammu & Kashmir, Madhya Pradesh, Rajasthan & Telangana.Also one person reportedly claimed dead from Tamil Nadu.

Heat Wave: 14 persons reportedly claimed dead from Maharashtra & Uttar Pradesh during 27th April to 31st May. Of these, 9 persons reportedly claimed dead from Fatehpur, Kanpur, Mathura districts of Uttar Pradeshand 5 persons from Ahmednagar, Beed, Gondia, Nashik, Solapur districts of Maharashtra.

Hailstorm: Hailstorm affected northern & central parts of the country during the season. The affected states are Jammu & Kashmir, Madhya Pradesh, Maharashtra, Rajasthan and Uttar Pradesh. Extensive damage to orchards, vegetables & crops reported from Anantnag, Bandipora, Baramulla, Budgam, Kulgam districts of Jammu & Kashmir. Damage to Soyabean, Gram, Onion, Vegetables including fruits, like Mango, Pomegranate, Watermelon, Papaya crops reported from Hingoli, Latur, Nanded, Osmanabad, Parbhani, Pune, Sangali districts of Maharashtra. Damage upto 70% of Wheat crops reported from Agra, Mathura districts of Uttar Pradesh in the first fortnight of the month April.Damage to Wheat, Gram crops reported in Raigarh, Madhya Pradesh. Huge amount of rabi crops damaged in Alwar, Jaipur, Jhunjhunu, SawaiMadhopur, Sikar districts of Rajasthan.

Heavy Rain: Rain related incidents affected northeastern, central & peninsular parts of the country during the season. Total 10 persons reportedly claimed dead. Of these, 9 persons died due to landslide in Agartala, Tripura on 12th & 20th May. While one person died due to heavy rain from Salem district of Tamil Nadu on 20th May. In Latur district of Maharashtra, 200 hens perished & crops were damaged due to Heavy rain on 15th April. Also, damage to crops were reported from different districts of Andhra Pradesh, Uttar Pradesh, Telangana, Jammu& Kashmir.

Gale: Total 2 persons reportedly claimed dead due to Gale during the month of May. One from Baramulla district of Jammu & Kashmir (12th May) and the other from National Capital Delhi on 15th May.

3. Southwest (SW) Monsoon (June-July-August-September)

Onset and advance of SW Monsoon

The Southwest Monsoon set in and advanced into some parts of southeast Arabian Sea, Maldives Comorin area, Bay of Bengal, Andaman Sea and Andaman & Nicobar Islands in stages during 25-28 May. On 29th May, monsoon further advanced into remaining parts of Southeast Arabian Sea & Comorin, Maldives area, entire Lakshadweep, most parts of Kerala, some parts of Tamil Nadu and some more parts of southwest, central & northeast Bay of Bengal. Thus, the southwest monsoon set in over Kerala, on 29th May (three days prior to its normal date, i.e., 1st June). The Southwest Monsoon further advanced into some parts of central Arabian Sea, remaining parts of Kerala, most parts of coastal Karnataka and some parts of South Interior Karnataka and some more parts of interior Tamil Nadu on 30th May. As on 30th May, the Northern Limit of Monsoon (NLM) passed through Lat. 14° N/ Long. 60° E, Lat. 14° N/ Long. 70° E, Shirali, Hassan, Mysuru, Kodaikanal, Thoothukudi, Lat. 9° N/ Long. 80° E, Lat. 13° N/ Long. 85° E, Lat. 18° N/ Long. 90° E and Lat. 21° N/ Long. 93° E.

It further advanced into some parts of northeastern states and northeast Bay of Bengal on 1st June. During 2-9 June, monsoon covered some parts of Odisha, some more parts of central Arabian Sea, peninsular & northeast region and northwest Bay and entire central and northeast Bay. By 12th June, it covered some more parts of Odisha, Gangetic West Bengal, remaining parts of northwest Bay, entire Arunachal Pradesh and most parts of Assam & Meghalaya and Sikkim. As on 12th June, the Northern Limit of Monsoon (NLM) passed through Lat. 19° N/ Long. 60° E, Lat. 19° N/ Long. 70° E, Thane (including Mumbai), Ahmednagar, Buldhana, Amraoti, Gondia, Titlagarh, Cuttack, Midnapore, Lat. 24° N / Long. 89° E, Goalpara, Baghdogra and Lat. 27° N / Long. 87° E. Subsequently, there was a hiatus of 10 days during 13 - 22 June in the advancement due to weakening of the monsoon flow. The advance of southwest monsoon was sluggish during the next few days and it covered entire central Arabian Sea, West Bengal and Assam and some more parts of Maharashtra, most parts of Bihar and Jharkhand, some parts of north Arabian Sea, Gujarat State and Odisha by 26th June. As on 26th June, the Northern Limit of Monsoon (NLM) passed through Lat. 21° N / Long. 60° E, Lat. 21° N / Long. 65° E, Veraval, Amreli, Ahmedabad, Khandwa, Amraoti, Gondia, Bolangir, Jharsuguda, Daltonganj, Chapra and Lat. 28° N / Long. 84° E. During 27-28 June, it covered entire central, east and most parts of north India. The Southwest monsoon advanced into remaining parts of Gujarat State, Rajasthan and north Andaman Sea on 29th June and thus it covered the entire country on 29th June, sixteen days earlier than its normal date (15th July). Fig. 16 depicts the isochrones of advance of southwest monsoon.

Withdrawal of Southwest Monsoon

The withdrawal of southwest monsoon from west Rajasthan commenced on 29th September with a delay of over three weeks from its normal date (1st Septemer). The formation of a Cyclonic storm (DAYE) over east central Bay and its west-northwestward movement during 19-22 September delayed the commencement of withdrawal from west Rajasthan. The SW monsoon withdrew from some parts of Rajasthan, Kutch & north Arabian Sea on 29th September 2018. Withdrawal line of SW monsoon passed through Anupgarh, Nagore, Jodhpur, Jalore, Nalia, Lat. 23.0 °N/ Long. 68.0 °E, Lat. 23.0° N/ Long. 65.0° E and Lat. 23.0° N / Long. 60.0° E on 29th and 30th September.

Rainfall Features

The southwest monsoon season rainfall over the country as a whole was normal. Most of the subdivisions of the country received

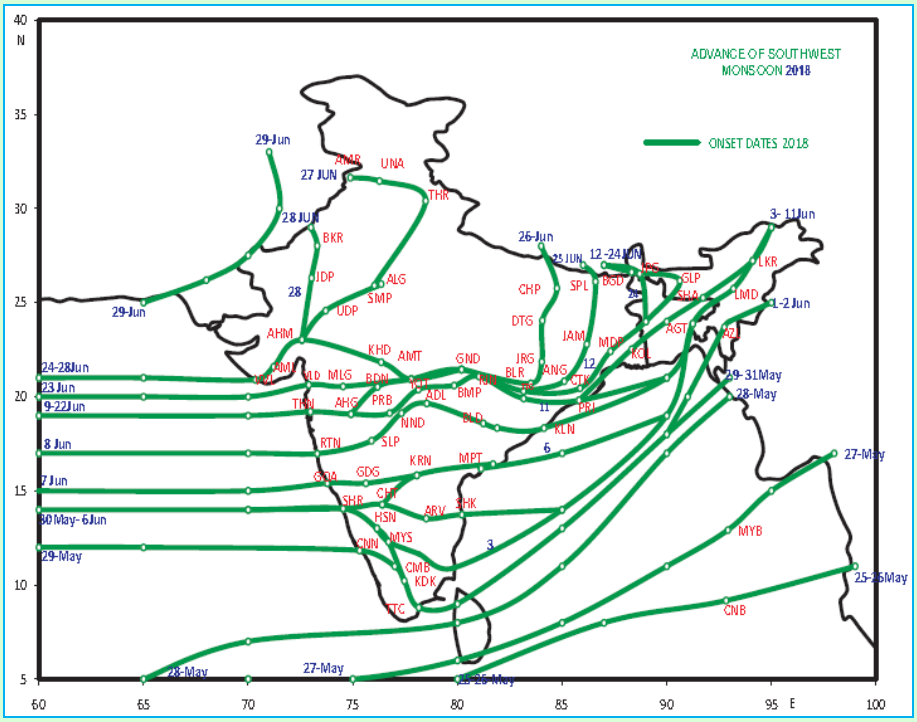


Fig. 16. Advance of southwest monsoon 2018

normal rainfall. However, some subdivisions of western, peninsular and east and northeastern India received deficient rainfall.

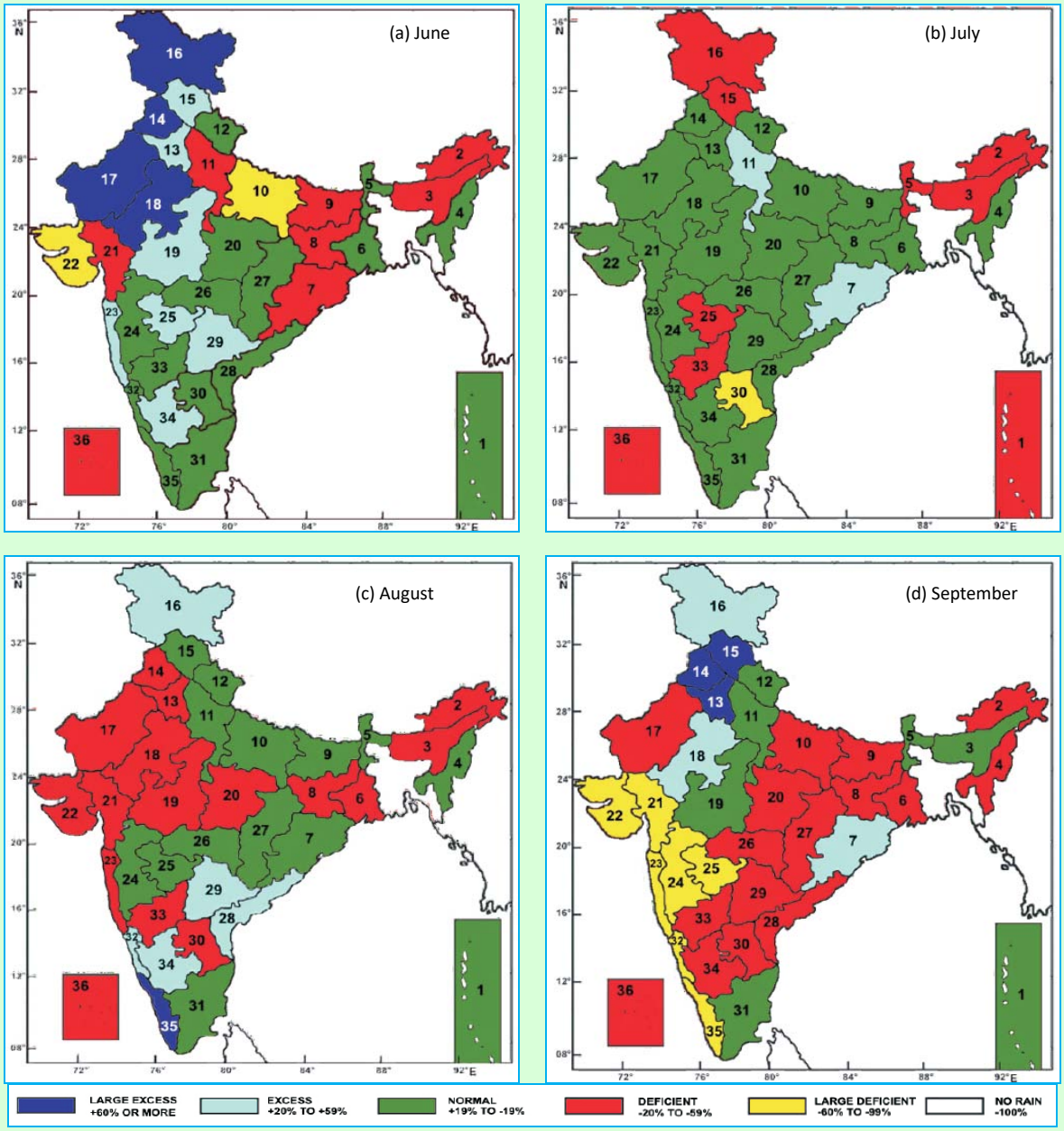
Fig. 17 shows the subdivision wise distribution of rainfall percentage departures for the four months of the monsoon season (June to September) 2018.

Figs. 17(a-d) shows the subdivision wise distribution of rainfall percentage departures for the four months of the monsoon season (June to September) 2018.

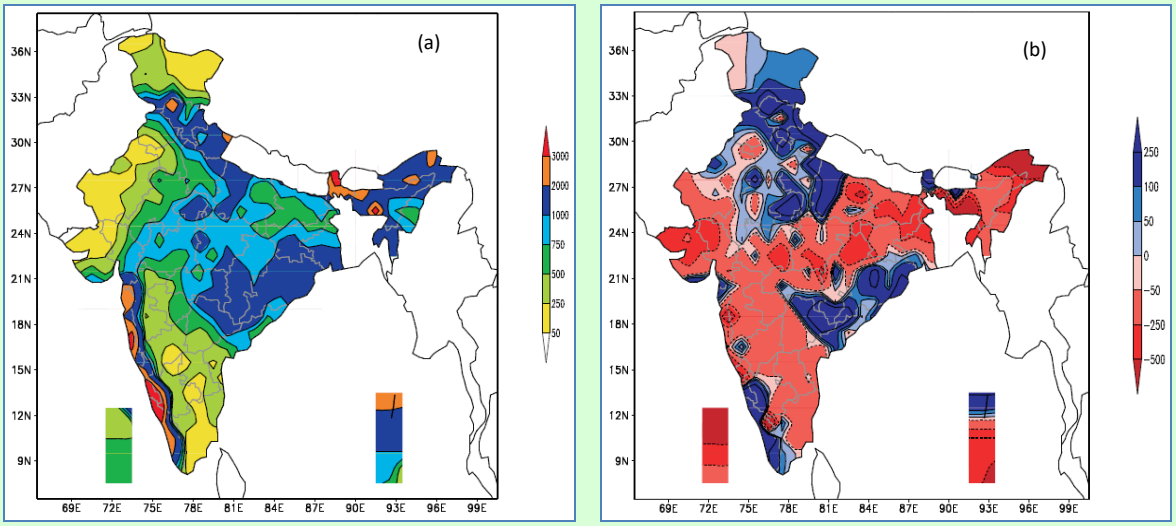
Figs. 18(a&b) show the spatial pattern of rainfall received during the season and its anomaly (mm) respectively.

Parts of Central, eastern/northeastern and some northern parts of the country, parts of west coast and the Islands received rainfall of the order of 750-2000 mm. Parts of Arunachal Pradesh, Assam & Meghalaya, Sub-Himalayan West Bengal & Sikkim, Konkan & Goa, coastal Karnataka, Kerala and Andaman & Nicobar Islands received more than 2000 mm of rainfall. Parts of Sub-Himalayan West Bengal & Sikkim, Assam & Meghalaya, coastal Karnataka and Kerala received more than 3000 mm of rainfall.

Rainfall anomaly was positive over parts of northern India, east central India, western parts of south peninsula and Andaman & Nicobar Islands. Positive rainfall anomaly over parts of Sub-Himalayan West Bengal & Sikkim, Assam & Meghalaya, Uttar Pradesh, Uttarakhand, Himachal Pradesh, Jammu & Kashmir, Madhya Pradesh, Odisha, Chhattisgarh, Telangana, coastal Karnataka, south interior Karnataka and Kerala was more than 250 mm. Magnitude of negative rainfall anomaly of more than 250 mm was observed over parts of Arunachal Pradesh, Assam & Meghalaya, Nagaland, Manipur, Mizoram & Tripura, Gangetic West Bengal, Jharkhand, Bihar, East Uttar Pradesh Gujarat Region, Saurashtra & Kutch, Konkan & Goa, Madhya Maharashtra, Vidarbha, Madhya Pradesh, Kerala and both the islands. Magnitude of rainfall anomaly of more than 500 mm was observed over parts of Arunachal Pradesh, Assam & Meghalaya and Lakshadweep islands and some isolated places.



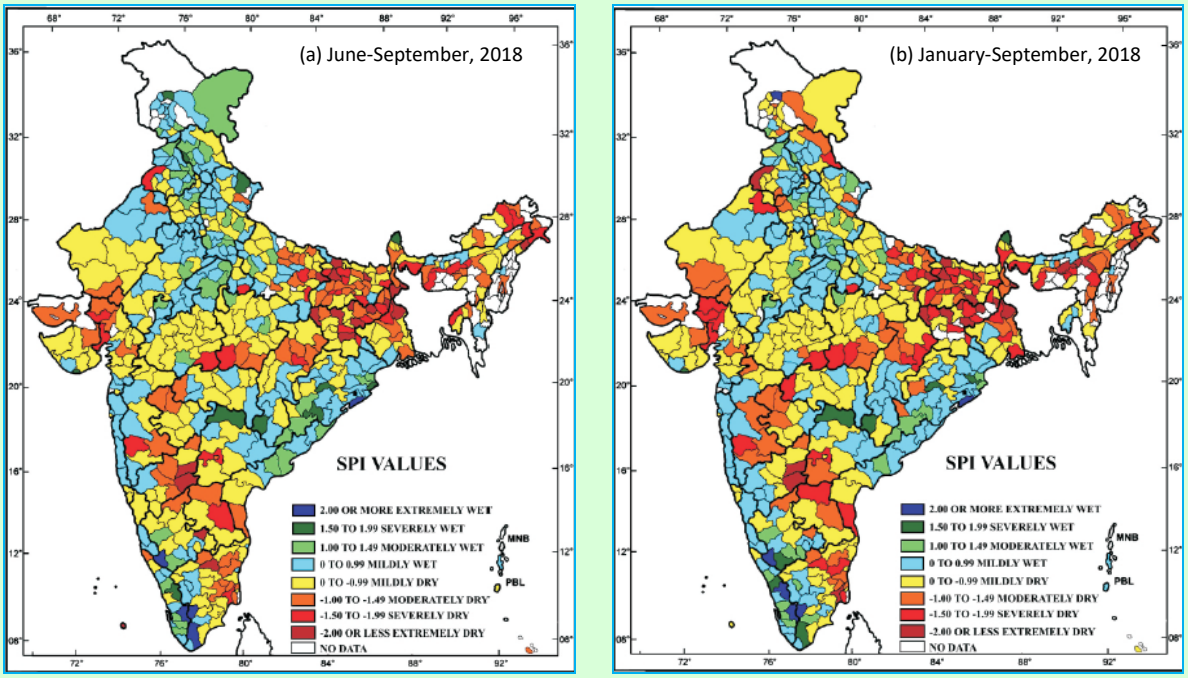
Figs. 17(a-d). Monthly sub-divisionwise distribution of rainfall percentage departures



Figs. 18(a&b). (a) Seasonal rainfall (mm) (b) Seasonal rainfall anomaly (mm) (*Based on 1951-2000 Normals*)

Figs. 19(a&b). Time series of area weighted rainfall over the (a) country as a whole (b) four homogeneous regions, for the monsoon season (1951 - 2018)

Figs. 19(a&b) show the all India area weighted rainfall series for the season since 1951 and area weighted rainfall series for the season over the four homogeneous regions since 1951 respectively. The rainfall for the season was normal over the Northwest, Central and



Figs. 20(a&b). Standardized Precipitation Index (SPI) for (a) Four months (b) Nine months

South peninsular India (98%, 93% and 98% of LPA respectively) and below normal over the Northeast India (76% of LPA). Rainfall over the homogeneous region of east and northeast India (1087.5 mm) was the second lowest since 2001 after the year 2013(1037.9 mm).

Standardized Precipitation Index

The Standardized Precipitation Index (SPI) is an index used for monitoring drought and is based only on precipitation. This index is negative for dry and positive for wet conditions. As the dry or wet conditions become more severe, the index becomes more negative or positive. Figs. 20(a&b) give the SPI values for the monsoon season and the year since January 2018 respectively.

Cumulative past four months SPI values indicate, extremely wet/severely wet conditions over parts of Sub Himalayan West Bengal & Sikkim, Odisha, Uttarakhand, Punjab, Himachal Pradesh, Jammu & Kashmir, Saurashtra & Kutch, Chhattisgarh, Telangana, Tamil Nadu, South Interior Karnataka and Kerala while, extremely dry/severely dry conditions were observed over parts of Arunachal Pradesh, Assam & Meghalaya, Nagaland, Manipur, Mizoram & Tripura, Sub Himalayan West Bengal & Sikkim, Gangetic West Bengal, Jharkhand, Bihar, Uttar Pradesh, Madhya Pradesh, Gujarat Region, Madhya Maharashtra, Chhattisgarh, Telangana, Rayalaseema, Tamil Nadu, North and south Interior Karnataka .

Cumulative SPI values of the past nine months indicate, extremely wet/severely wet conditions over parts of Sub Himalayan West Bengal & Sikkim, Odisha, Punjab, Jammu & Kashmir, Saurashtra & Kutch, Chhattisgarh, Telangana, Tamil Nadu, South Interior Karnataka and Kerala while, extremely dry/severely dry conditions were observed over parts of Arunachal Pradesh, Assam & Meghalaya, Sub Himalayan West Bengal & Sikkim, Gangetic West Bengal, Jharkhand, Bihar, Uttar Pradesh, Punjab, Himachal Pradesh, West Rajasthan, Madhya Pradesh, Gujarat Region, Madhya Maharashtra, Vidarbha, Chhattisgarh, Andhra Pradesh, Tamil Nadu and North Interior Karnataka.

Pressure & Wind

The pressure anomaly was near normal (within + 0.5 hPa) over most parts of the country.

At 850 hPa level, stronger than the normal wind (southwesterly/westerly) were observed over west/east Arabian Sea. These anomalous winds slowed down over the peninsular India. At 500 hPa level also stronger than the normal westerlies were observed over the Arabian Sea and peninsula. At 250 hPa level, an anomalous anti cyclonic circulation was observed over the eastern, northeastern and northern parts of the country.

Outgoing Longwave Radiation (OLR)

OLR anomaly (W/m^2) over the Indian region and neighbourhood is shown in Fig. 21. OLR anomaly was positive throughout the country except over east and northeast region. It exceeded 10 W/m^2 over parts of northwest India, south west peninsular and adjoining Arabian Sea and Odisha. Negative OLR anomaly exceeding 10 W/m^2 was observed over central Bay of Bengal.

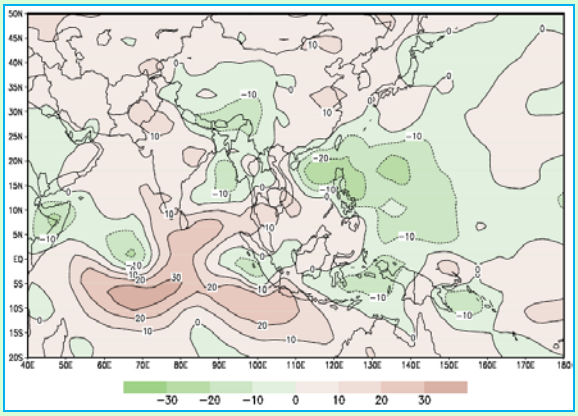


Fig. 21. OLR anomaly (W/m^2) for the monsoon season 2018 (*Source* : Cdc / Noaa, Usa)
(*Based On 1981 - 2010 Climatology*)

Low Pressure Systems

During the season, eleven low pressure systems (1 cyclonic storm, 1 Deep Depression, 4 Depressions, 1 well marked low pressure area & 4 low pressure areas) were formed. The frequency and place of origin of these low pressure systems formed over the Indian region during the monsoon season.

The first intense system of the season formed as a Depression (10-11 June) the second depression formed during (21-22 July). In the month of August two depressions formed (7 -8 August) and (15-17 August). In the month of September one Deep Depression (6-7 Sept.) and one cyclonic storm "DAYE" (19-22 Sept.) formed. All these systems formed over Bay of Bengal & moved westward across central India.

Fig. 22 shows the number of depressions and cyclonic storms formed during the monsoon season since last 10 year period (2009-2018).

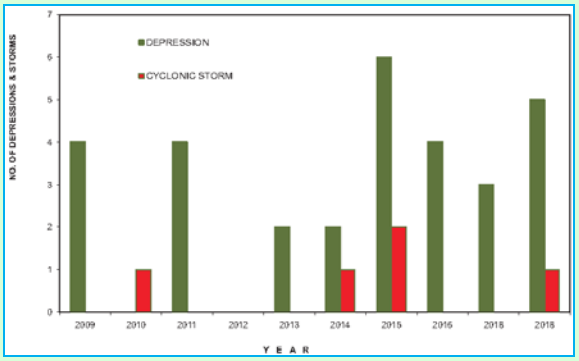


Fig. 22. Number of depressions & cyclonic storms formed during the SW monsoon season (2009-2018)

Significant Weather events

Heavy rain, lightning and thunderstorm related incidents were the most high impact weather events of the season which reportedly claimed over 792 lives mostly from northern, eastern/north-eastern, central and north peninsular parts of the country.

Thunderstorm: Thunderstorm activities reportedly claimed 76 lives during the season mostly from different parts of the country. Of these, 75 deaths were reported from Jharkhand during the month of June and July and one reportedly claimed died in Rajasthan.

Lightning: As per reports in local newspaper 114 people were struck & killed by lightning from different parts of the country during the season. Out of 114 persons 39 were from districts of Uttar Pradesh, 22 persons from Odisha, 11 each from Maharashtra andRajasthan, 4 each from Andhra Pradesh and Bihar, 5 from west Bengal and 6 from Uttarakhand state. 12 persons were reportedly claimed during September.

Heavy Rain: During the season heavy rain & flood related incidents reportedly claimed at least 536 lives from different parts of the country.

Deaths of 246 people were reported from Kerala of which 223 were during the period 8-23 August and 9 in the month of June and 14 in the month of July. 158 persons were reported dead in Uttar Pradesh during the season (of which 64 in the month of July and 66 in month of September), 34 from Assam, 26 from Maharashtra, 17 from Himachal Pradesh, 18 from Rajasthan, 7 from Manipur, 6 from Jammu and Kashmir, 5 from Gujarat, 4 each from Arunachal Pradesh and Odisha, 3 each from Punjab, West Bengal and Andhra Pradesh and 2 from Tamilnadu state.

4. Post Monsoon Season (October-November-December)

Maximum temperature anomaly over central India (0.78 °C) was fourth highest since 1901.

Northeast Monsoon Activity

The southwest monsoon withdrew from the entire country on 21st October and the northeast monsoon rain commenced over the south peninsula on 1st November.

Rainfall activity over core region of the south peninsula (comprising of 5 subdivisions viz. Coastal Andhra Pradesh, Rayalaseema, Tamil Nadu & Puducherry, South Interior Karnataka and Kerala) was below normal [66% of Long Period Average (LPA)]. It was below normal during October November and December (65% of LPA, 72% of LPA and 55% of LPA respectively).

Rainfall Features

Rainfall over the country as a whole during the season was below normal (56% of LPA). It was 44%, 71% and 89% of its LPA during October, November and December month respectively. Except both the islands, Odisha, Jammu & Kashmir and Kerala, all the subdivisions received deficient/large deficient rainfall.

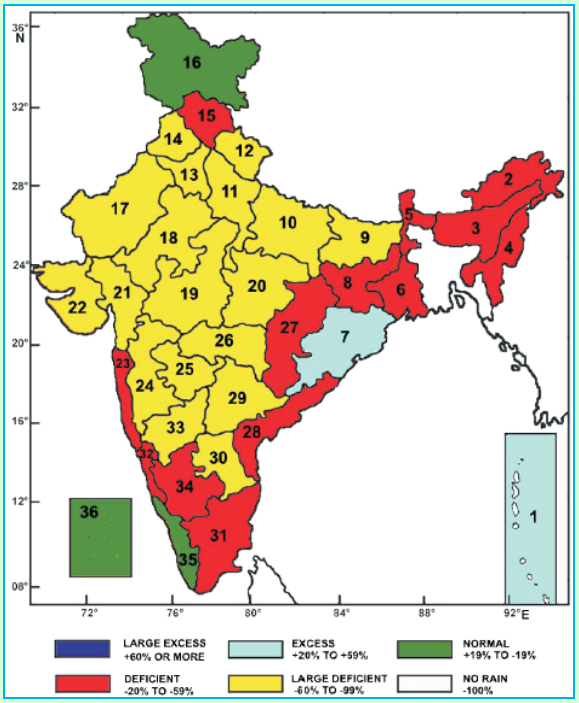
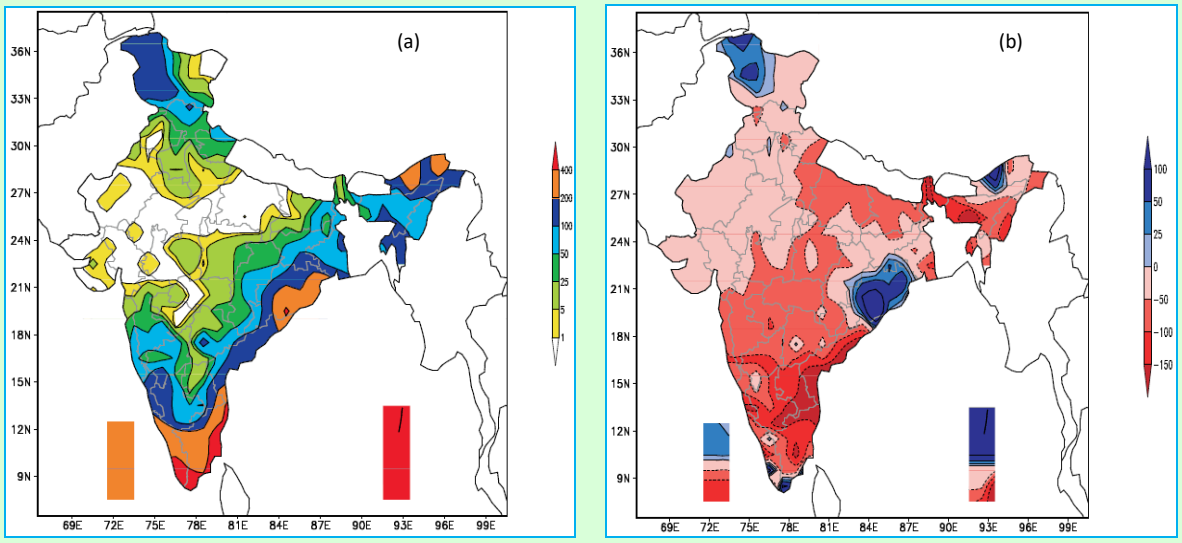


Fig. 23. Sub-divisionwise rainfall percentage departures

During the season, out of 36 meteorological subdivisions, 2 subdivisions received excess rainfall, 3 subdivisions received normal rainfall, 13 subdivisions received deficient rainfall and remaining 18 subdivisions received large deficient rainfall (Fig. 23).

Figs. 24(a&b) show the spatial pattern of rainfall (mm) received during the season and its anomaly respectively. Parts of Odisha, Arunachal Pradesh, Tamil Nadu, Kerala, and both the Islands received more than 200 mm rainfall. Coastal parts of north Tamil Nadu & Puducherry, southern parts of Kerala and Andaman & Nicobar Islands received more than 400 mm rainfall.

Rainfall anomaly was negative throughout the country except over some parts of Odisha, Arunachal Pradesh, both islands, Kerala and Jammu & Kashmir. Magnitude of negative rainfall anomaly exceeded 100 mm was observed over parts of Assam & Meghalaya Sub-Himalayan West Bengal & Sikkim, Coastal Andhra Pradesh, Rayalaseema, Tamil Nadu & Puducherry, Karnataka state and Andaman & Nicobar Islands, while positive rainfall anomaly more than 100 mm was observed over parts of Odisha, Arunachal Pradesh and A&N Islands.



Figs. 24(a&b). (a) Seasonal rainfall (mm) (b) seasonal rainfall anomaly (mm)
(*Based on 1951-2000 Normals*)

Figs. 25(a&b) show the all India area weighted rainfall series for the season since 1951 and area weighted rainfall series for the season over the four homogeneous regions since 1951 respectively.

The rainfall for the season was below normal over all the four homogeneous regions. It was 55.5%, 49%, 48.6% and 63.5% of LPA over northwest India, east and northeast India, central & south peninsular India respectively.

Standardized Precipitation Index

The Standardized Precipitation Index (SPI) is an index used for measuring drought and is based only on precipitation. This index is negative for dry and positive for wet conditions. As the dry or wet conditions become more severe, the index becomes more negative or positive. Figs. 26(a&b) give the SPI values for the northeast monsoon season (October to December 2018, i.e., 3 months cumulative) and the year (January-December 2018, *i.e.*, 12 months cumulative) respectively.

Cumulative SPI values of the past three months indicate extremely wet/severely wet conditions over parts of A & N Islands, Odisha, Haryana, Chandigarh & Delhi and Jammu & Kashmir, while extremely dry/severely dry conditions were observed over parts of Arunachal Pradesh, Assam & Meghalaya, Nagaland, Manipur, Mizoram & Tripura, S.H. West Bengal & Sikkim, Bihar, Uttar Pradesh state, Madhya Pradesh state, Marathawada, Vidarbha, Chhattisgarh, Andhra Pradesh state, Telangana, Tamil Nadu, North Interior Karnataka and South Interior Karnataka.

Cumulative SPI values of the past twelve months indicate extremely wet/severely wet conditions over parts of S.H. West Bengal & Sikkim, Odisha, Punjab, Jammu & Kashmir, Saurashtra & Kutch, Telangana, Tamil Nadu, South Interior Karnataka and Kerala, while extremely dry/severely dry conditions were observed over parts of Arunachal Pradesh, Assam & Meghalaya, S.H. West Bengal & Sikkim, Gangetic West Bengal, Jharkhand, Bihar, Uttar Pradesh state, Punjab, Himachal Pradesh, West Rajasthan, Madhya Pradesh state, Gujarat state, Madhya Maharashtra, Marathawada, Vidarbha, Chhattisgarh, Andhra Pradesh state, Telangana, Tamil Nadu, North Interior Karnataka & South Interior Karnataka.

Pressure & Wind

The pressure anomaly was positive throughout country. The positive anomaly was generally of the order of 0.5 to 1.0 hPa over most parts of the country.

At 850 hpa level an anomalous cyclonic circulation was observed over the southern

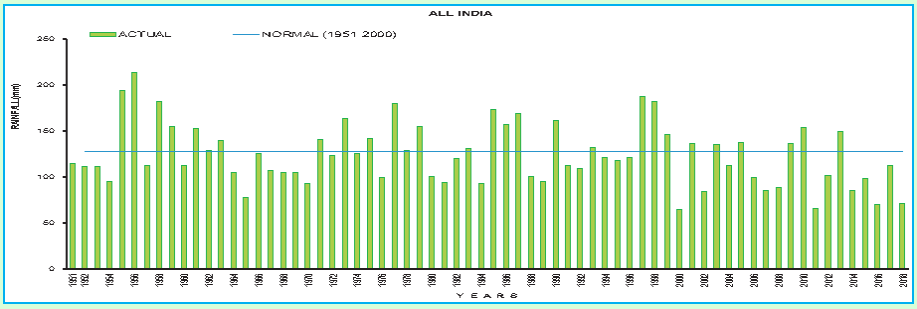


Fig. 25(a). Time series of area weighted rainfall over the country as a whole (1951-2018)

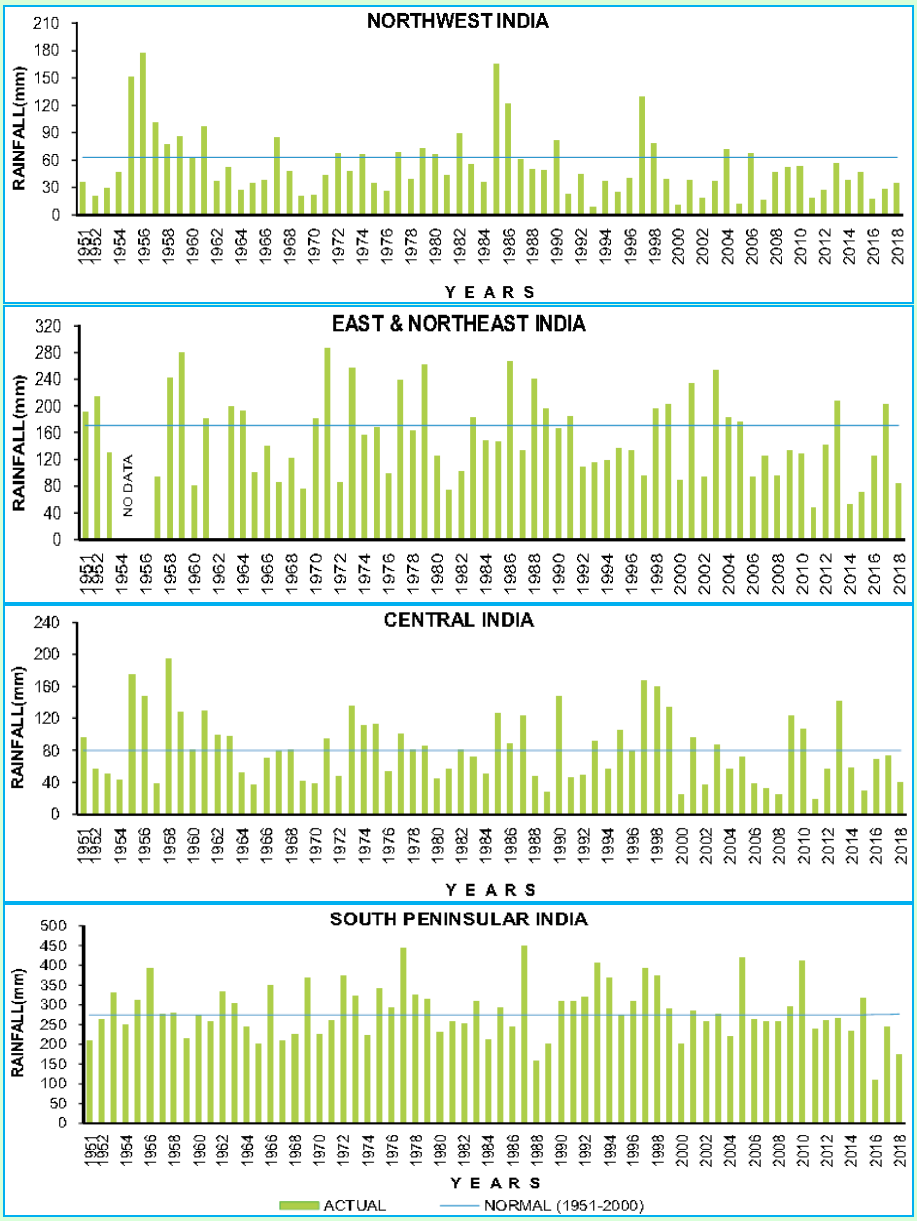


Fig. 25(b). Time series of area weighted rainfall over the four homogeneous regions (1951 - 2018)

equatorial Arabian Sea. At the same level anomalous easterlies prevailed over the peninsula. At 500 hpa level an anomalous anti cyclonic circulation was observed over the northwestern parts. At 250 hPa level, anomalous westerlies prevailed throughout the country.

Outgoing Longwave Radiation (OLR)

OLR anomaly (W/m^2) over the Indian region and neighbourhood is shown in Fig. 27. OLR anomaly was positive over most parts of the country except northwestern & east and north-east region. OLR anomaly more

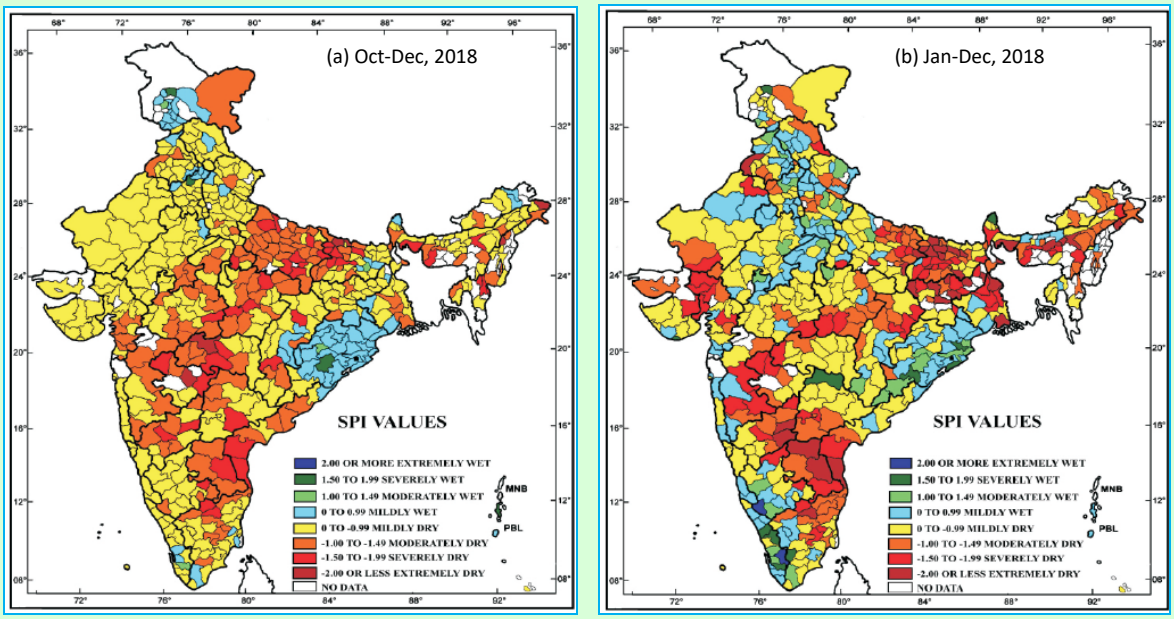


Fig. 26(a&b). Standardized Precipitation Index (SPI) cumulative for (a) Three months (b) Twelve months

than 10 W/m^2 was observed over eastern part of south peninsula.

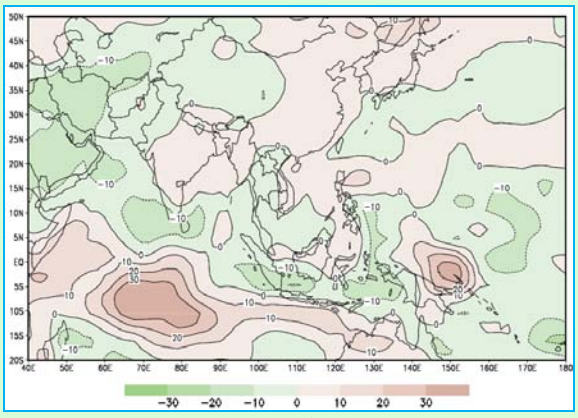
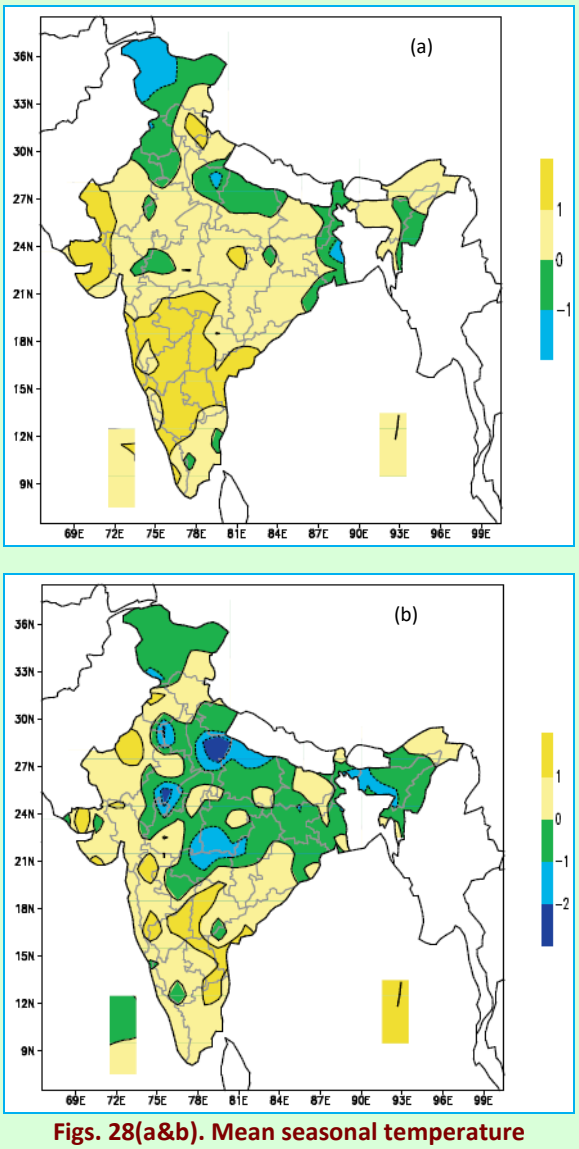


Fig. 27. OLR Anomaly (w/m^2) for the post-monsoon season 2018 (*Source* : CDC / NOAA, USA) (*Based on 1981 - 2010 Climatology*)

Temperature

Mean seasonal maximum and minimum temperature anomaly is shown in Figs. 28(a&b) respectively. Maximum temperature was above normal over most parts of the country except for parts of Uttar Pradesh state, Jammu & Kashmir, Punjab, Haryana, Chandigarh & Delhi and parts of east and northeastern region. Maximum temperature anomaly was more than 1 °C over parts of Himachal Pradesh, West Rajasthan, Saurashtra & Kutch, Maharashtra state, Karnataka state, Kerala and Andhra Pradesh state.



Figs. 28(a&b). Mean seasonal temperature anomalies (°C) (a) Maximum (b) Minimum (*Based on 1971-2000 Normals*)

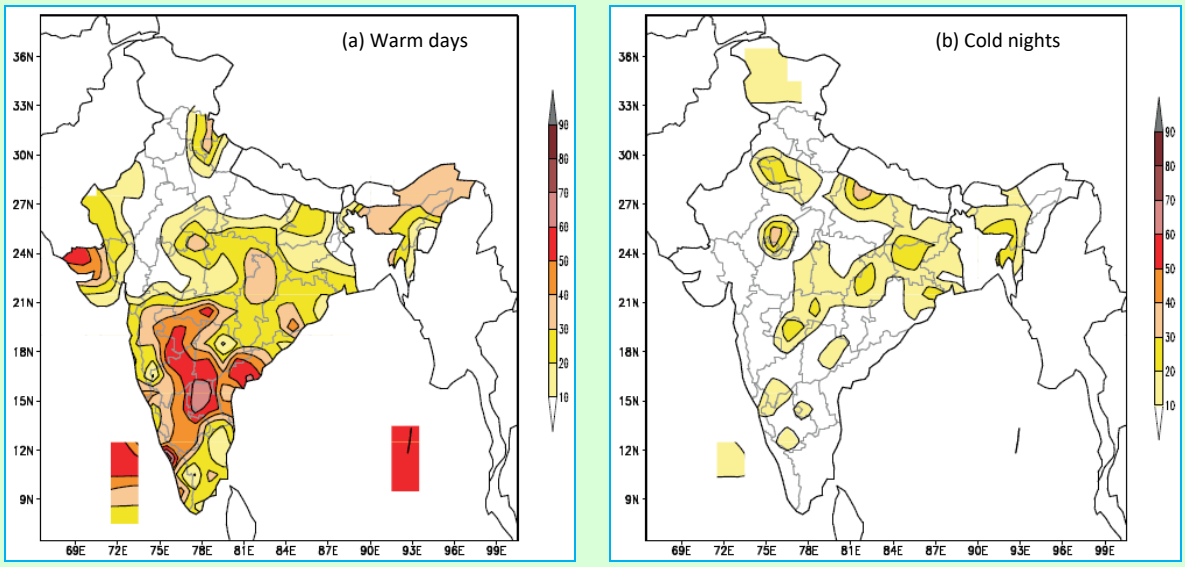
Percentage of Warm days/Cold nights

Figs. 29(a&b) show the percentage of days when maximum (minimum) temperature was more (less) than 90th (10th) percentile.

Over parts of Saurashtra & Kutch, Coastal Andhra Pradesh, Telangana, Rayalaseema, Marathawada, Madhya Maharashtra, Vidarbha, North Interior Karnataka, Kerala and both the Islands the maximum temperature was greater than 90th percentile for more than 50% of the days of the season. However, for minimum temperature, no significant distribution was observed.

Fig. 30 shows the mean temperature for the country as a whole for the season since 1971. Five year moving average values are also shown. The mean temperature (23.9 °C) for the season this year was above normal by about 0.3 °C.

Figs. 31(a&b) show the maximum and minimum temperature series respectively for the country as a whole and the four homogeneous regions during the season since 1971. Maximum temperature over central India and south peninsular India was above normal by about 0.7 °C and minimum temperature over south peninsular India was above normal by about 0.6 °C and it was below normal over northeast India by 0.6 °C. Maximum temperature over central India (31.69 °C) was fourth highest since 1901 after the years 2015(32.18 °C), 2000 (32.10 °C) and 2002(31.71 °C). Both maximum and minimum temperatures over south peninsula were fifth highest since 1901.



Figs. 29(a&b). Percentage of days when (a) maximum temperature > 90th percentile (b) minimum temperature < 10th percentile

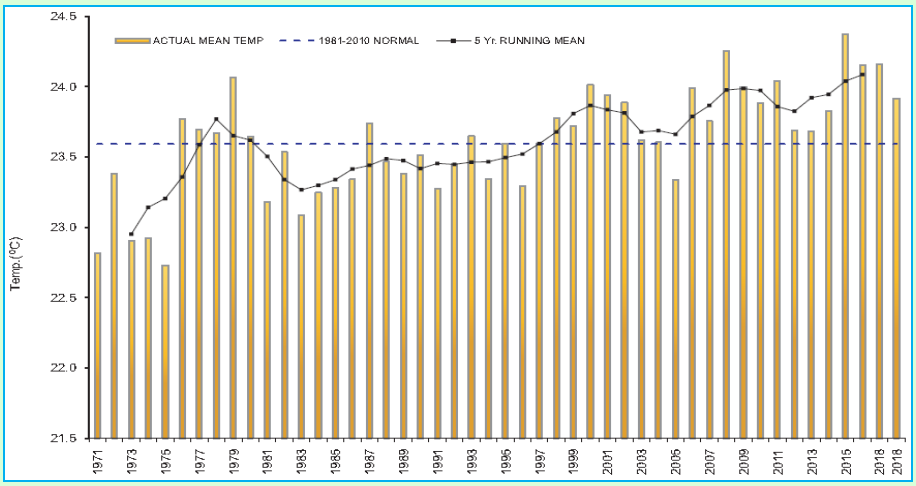
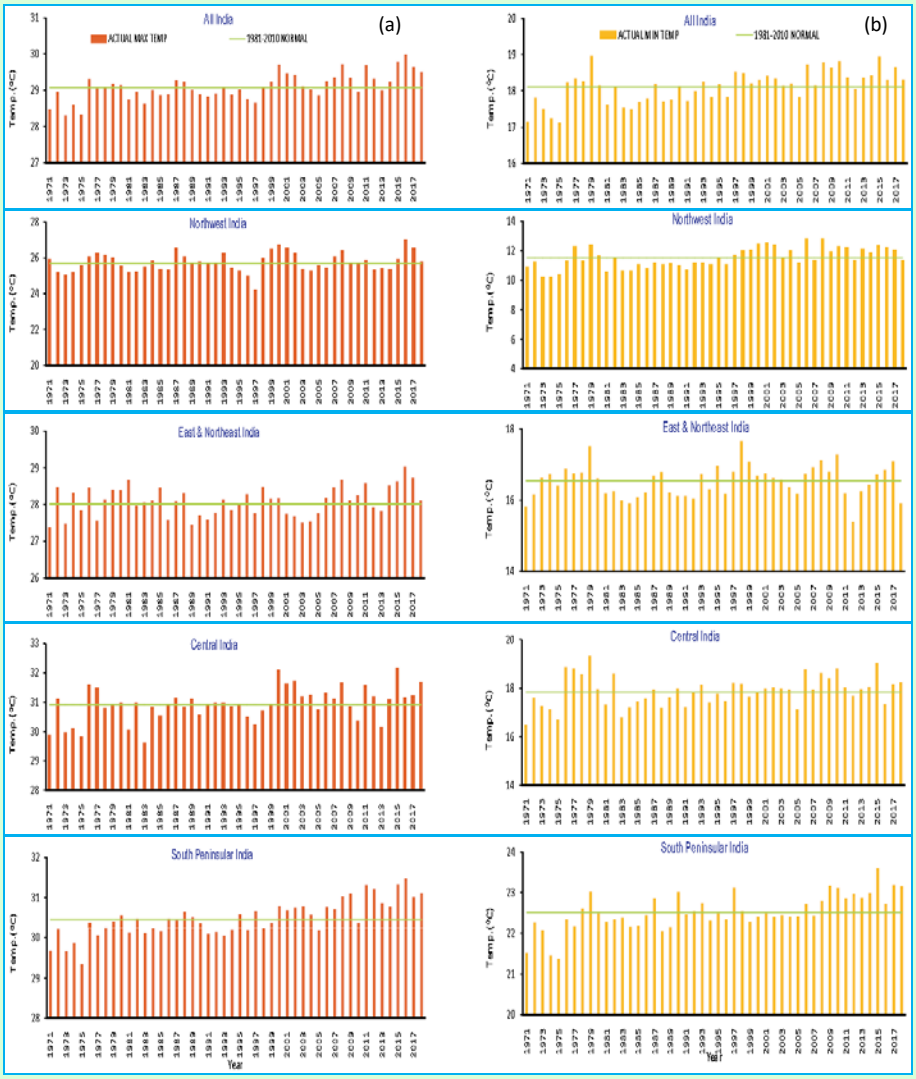


Fig. 30. Time series of mean temperature averaged over India (vertical bars) and five year running mean (continuous line) for the post monsoon season (1971-2018)



Figs. 31(a&b). Time series of temperature for the country as a whole and the four homogeneous regions (1971-2018) (a) Maximum (b) Minimum

Low Pressure Systems

A very severe cyclonic storm "Titli" formed during October and two severe cyclonic storms "Gaja" and "Phetai" formed in November and December month respectively. The tracks of these systems are shown in Fig. 32.

Fig. 33 shows the number of depressions & storms formed over the Bay of Bengal during the post-monsoon season (1951-2018).

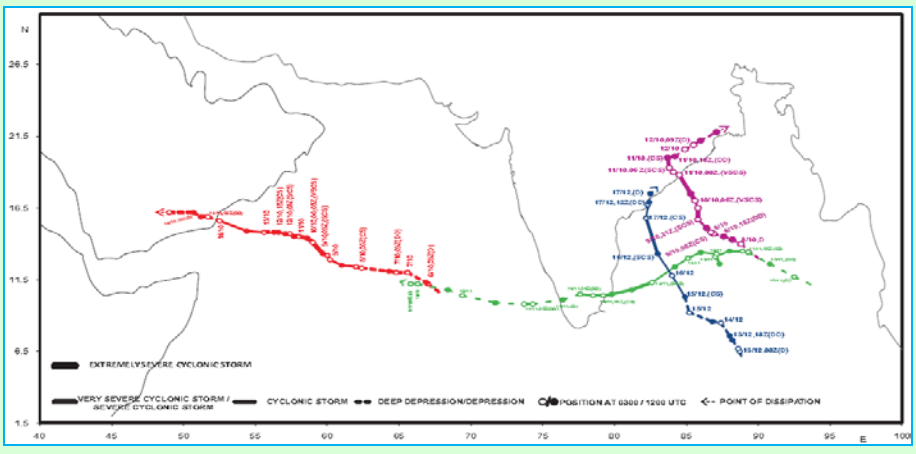


Fig. 32. Tracks of intense low pressure systems formed during the post-monsoon season

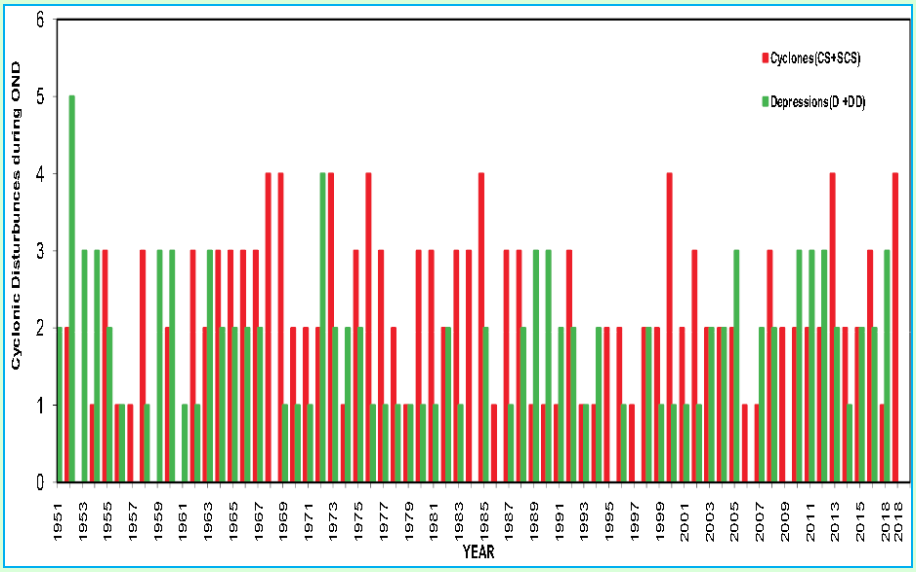


Fig. 33. Frequency of depressions / cyclonic storms formed over the Bay of Bengalduring the post-monsoon season (1951-2018)

Significant Weather events

Cyclonic Storm : Due to very severe cyclonic storm Titli Total 77 people were reportedly claimed dead from different districts (Gajapati, Ganjam, Khurda, Puri, Jagatsinghpur, Kendrapara, Bhadrak, Balasore) of Odisha during 8-14 October and 12 people were reportedly claimed dead from different districts of Odisha and Andhra Pradesh (Srikakulam and Vizianagaram) during 10-11 October. Due to Cyclone Gaja 45 people were reported claimed dead in different districts of Tamil Nadu during 10-17 November.

Rain : Due to heavy rains 5 people were reportedly claimed died in Villupuram and Thanjavur districts of Tamil Nadu during 23-25 November.

Squally winds : As per media report a woman died in Godavari district of Andhra Pradesh due to squally winds on 17th December (Hindustan Times e paper).

Low Visibility / Dense Fog : One person died in an accident on the Yamuna Expressway on 22nd December in Agra district due to low visibility. As reported, due to dense fog accident occurred and 24 persons died in Haryana on 24th December, 2018. Similarly on 30th December, 2018 in Chandigarh (Haryana) 7 people died due to fog.

CHAPTER 3

NUMERICAL WEATHER PREDICTION

Global modeling, coupled modeling and Regional Modelling

(*i*) Global Forecasting System (GFS T1534L64 SL) model run operationally at India Meteorological Department (IMD) twice in a day (00 & 12 UTC) to give deterministic forecast in the short to medium range upto 10 days. The forecast model has a resolution of approximately 12 km in horizontal and has 64 levels in the vertical. The initial conditions for this GFS model is generated from the four-dimensional (4D) ensemble-variational data assimilation (DA) system (4DEnsVar) building upon the gridpoint statistical interpolation (GSI)-based hybrid Global Data Assimilation System (GDAS) run on High Performance Computing Systems (HPCS) at National Center for Medium Range Weather Forecasting (NCMRWF). The real-time GFS T1534L64 model outputs are generated daily at IMD. This 4DEnsVar data assimilation system has capabilities to assimilate various conventional as well as satellite observations including radiances from different polar orbiting and geostationary satellites.

Global Ensemble Forecast System (GEFS) is a Semi-Lagrangian T1534 L64 (about 12 km on equator) and 64 hybrid sigma-pressure layers with 21 ensemble members. This high resolution GEFS model is being run once in a day (00 UTC) at IMD to give 10 day operational probabilistic prediction in the short to medium range since June 2018. The initial conditions are generated from the NCEP based Ensemble Kalman Filter (EnKF) component of hybrid Global Data Assimilation System (GDAS).

The state of Kerala received a Heavy rainfall during 15 to 16 August 2018; the rainfall hugely exceeded the daily climatology. The spatial observed and forecast rainfall from the deterministic (GFS) and ensemble (GEFS) models over kerala is shown in the in Fig. 1. The model 24 hour forecast based on 15th August 2018 initial condition is able to demonstrate the inner core of heavy rainfall and the outer rain bands as seen in the observations over kerala. Both the deterministic and ensemble models predicted the Heavy rainfall over Kerala during 15 -16 August 2018 reasonably well

(*ii*) The extended range forecast (ERF) system with a suite of models from CFSv2 coupled model have been developed, implemented and operationalized in IMD during July 2016 for generating operational Extended Range Forecast (ERF) products for different users. This suite of models are (*i*) CFSv2 at T382 (≈ 38 km) (*ii*) CFSv2 at T126 (≈ 100 km) (*iii*) GFSbc (bias corrected SST from CFSv2) at T382 and (*iv*) GFSbc at T126. The Multi-model ensemble (MME) of the above suite is run operationally for 32 days based on every Wednesday initial condition with 4 ensemble members to give forecast for 4 weeks for days 2-8 (week1; Friday to Thursday), days 9-15 (week2; Friday to Thursday), days 16-22 (week3; Friday to Thursday) and days 23-29 (week4; Friday to Thursday). The ERF of monsoon rainfall and extreme temperatures are being used by various user agencies during the year 2018. As seen in Fig. 2 the skillful forecast of monsoon rainfall for 3 weeks are having significant correlations with observed rainfall departure for the country as a whole.

In order to use the extended range forecast for agromet applications, the forecast for 36 met subdivisions of India is prepared for two weeks with categorising the subdivisions as below normal (BN), normal (NN) or above

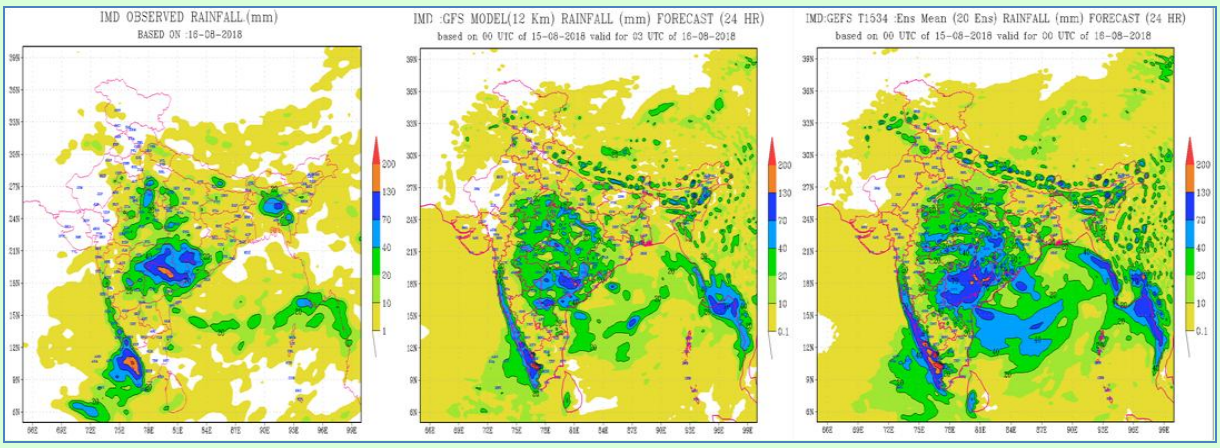


Fig. 1. The observed and 24 hr forecast rainfall associated with Heavy Rainfall from GFS T1534 and GEFS T1534 model valid for 0300 UTC of 15 August to 0300 UTC of 16 August 2018

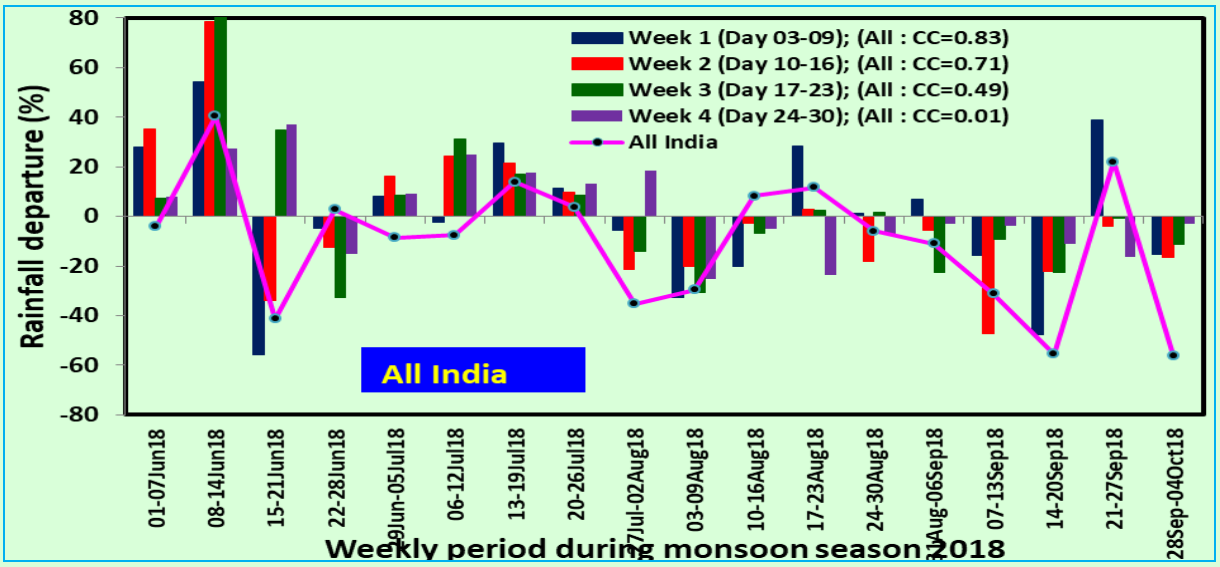
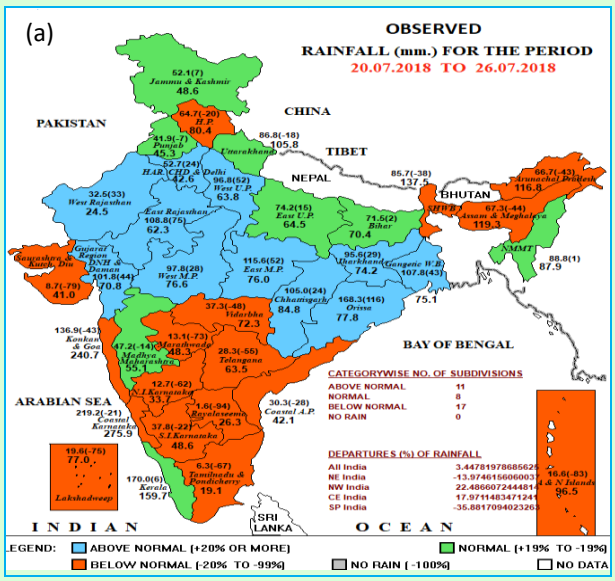
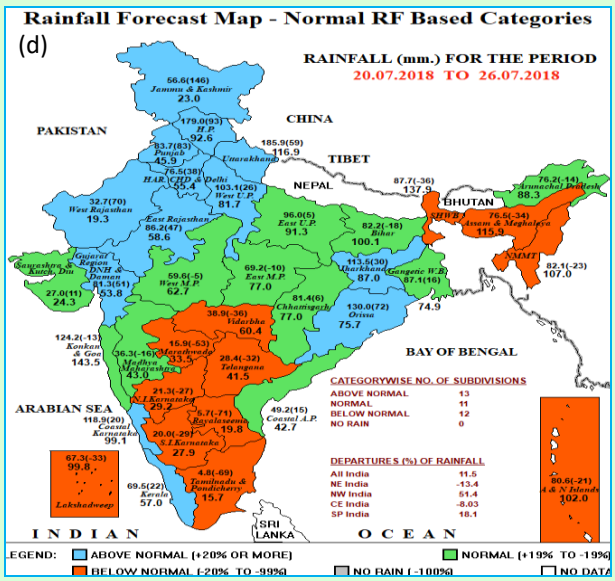


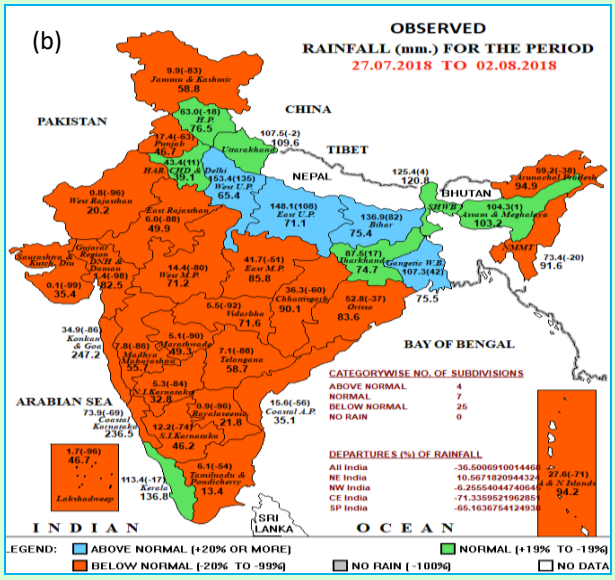
Fig. 2. Weekly observed all India weekly rainfall departure during the monsoon season 2018 along with corresponding extended range forecast rainfall departure with lead time of week 1 week 4

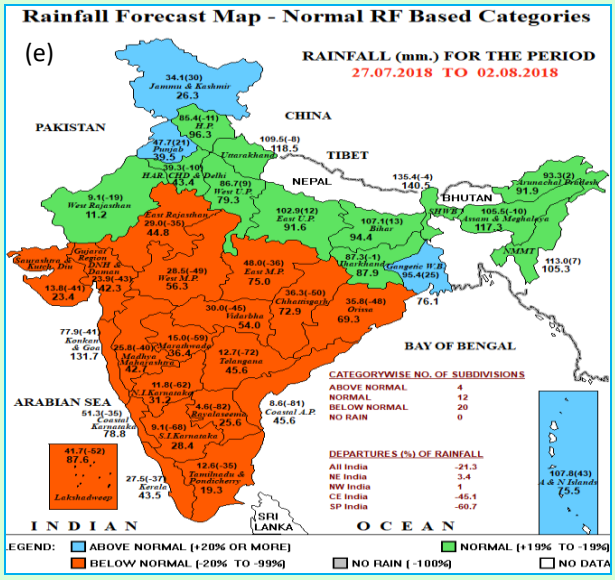
normal (AN) category depending on the rainfall departure during the week. As per the classification a met-subdivision is considered to be 'AN' if rainfall departure ≥ 20%; 'NN' if it is between +19% to -19% and 'BN' if it is ≤ -20%. The active to break transition of monsoon from above normal week of 20-26 July to below normal weeks of 27 July-2 August and 3-9 August, 2018 can be seen in Fig. 3. The observed met-subdivision level rainfall for this three weeks period is shown in Figs. 3(a-c). The corresponding forecast rainfall for two weeks based on the ICs of 18 July, 25 July and 1 August, 2018 is shown in Figs. 3(d-f). As seen from Figs. 3(a-c) the observed rainfall departure over most of the meteorological subdivisions in central and northwest India changed from AN/NN categories during 20-26 July into BN category during 27 July-2 August and 3-9 August, 2018 indicating the transition from active phase of monsoon into break phase of monsoon. The MME ERF based on ICs of 18th July and valid for next two weeks (20-26 July and 27 July-2 August) well captured this transition and hence was very useful in providing Agromet advisory to farmers [Fig. 3(d&e)].

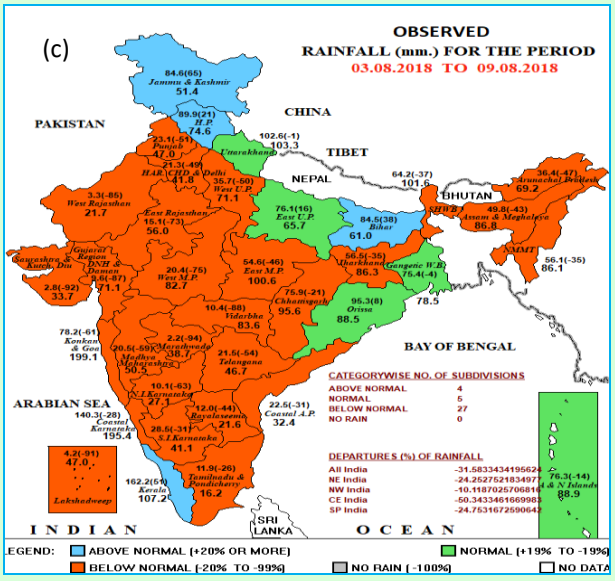
(*iii*) The triple nested (18, 6 and 2 km) coupled version (v3.8a) of Hurricane WRF (HWRF) model has been implemented with two different ocean models POM (Princeton Ocean Model) and HYCOM (HYbrid Cordinate Ocean Model) simultaneously for the cyclone "PHETHAI". Both the prototypes of coupled HWRF model have been established with three

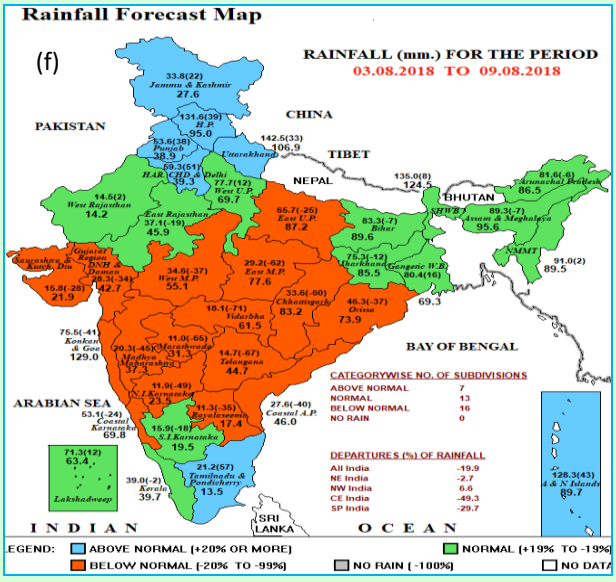




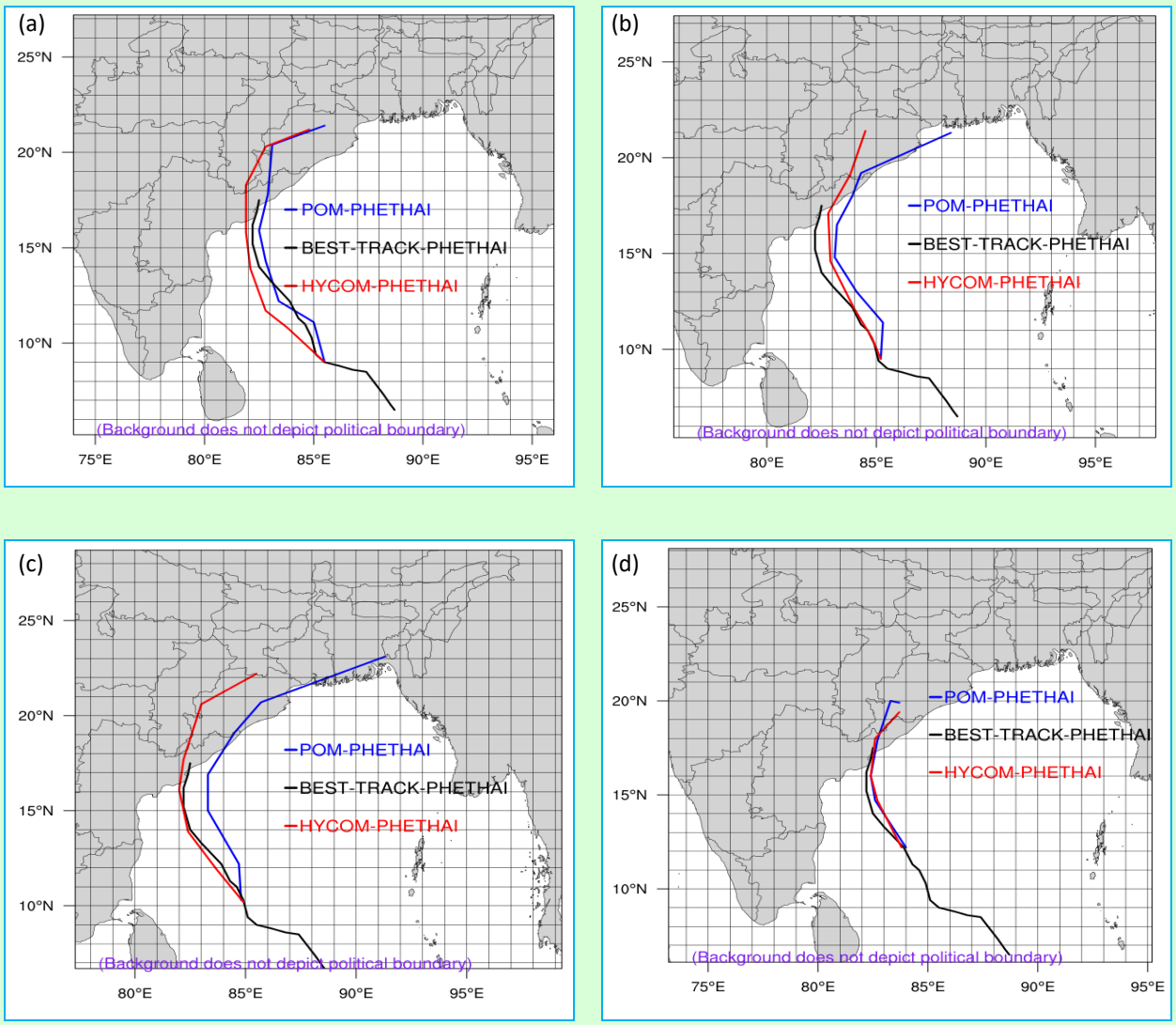








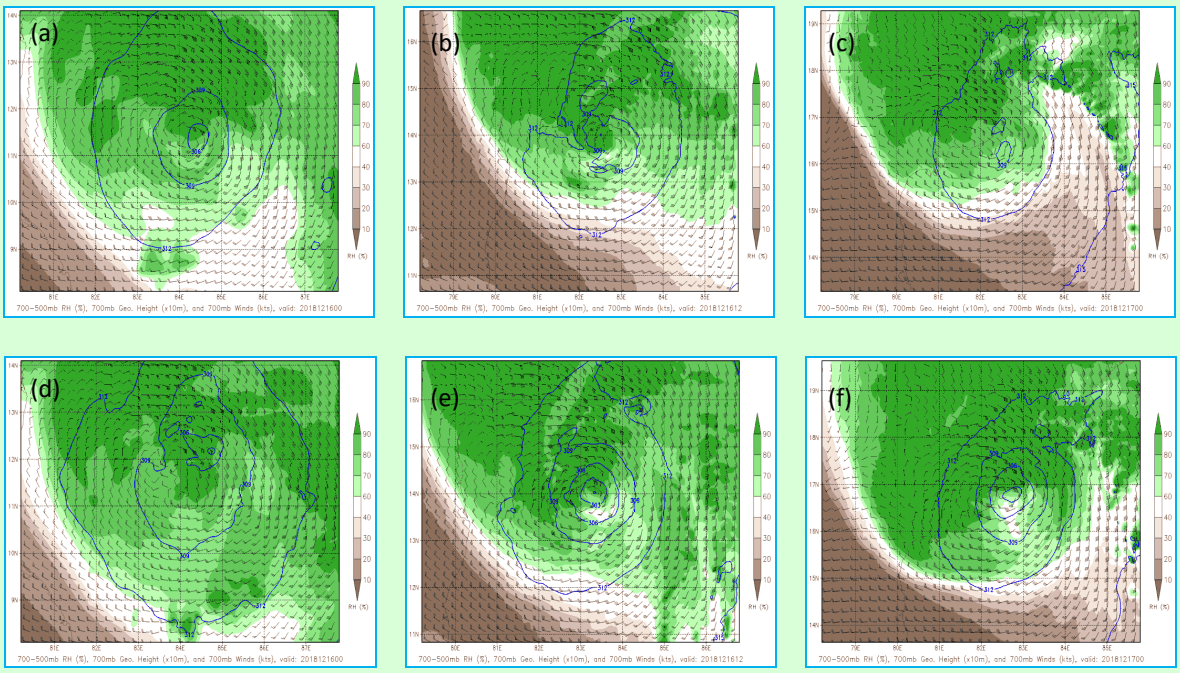
Figs. 3(a-f). (a-c) Observed met-subdivision level rainfall with three categories, (d-e) MME ERF based on 18th July and valid for week 1 and week 2 forecasts coinciding with 20-26 July and 27 July-2 August and (f) Week 2 forecast based on IC of 25th July and valid for 3-9 August, 2018



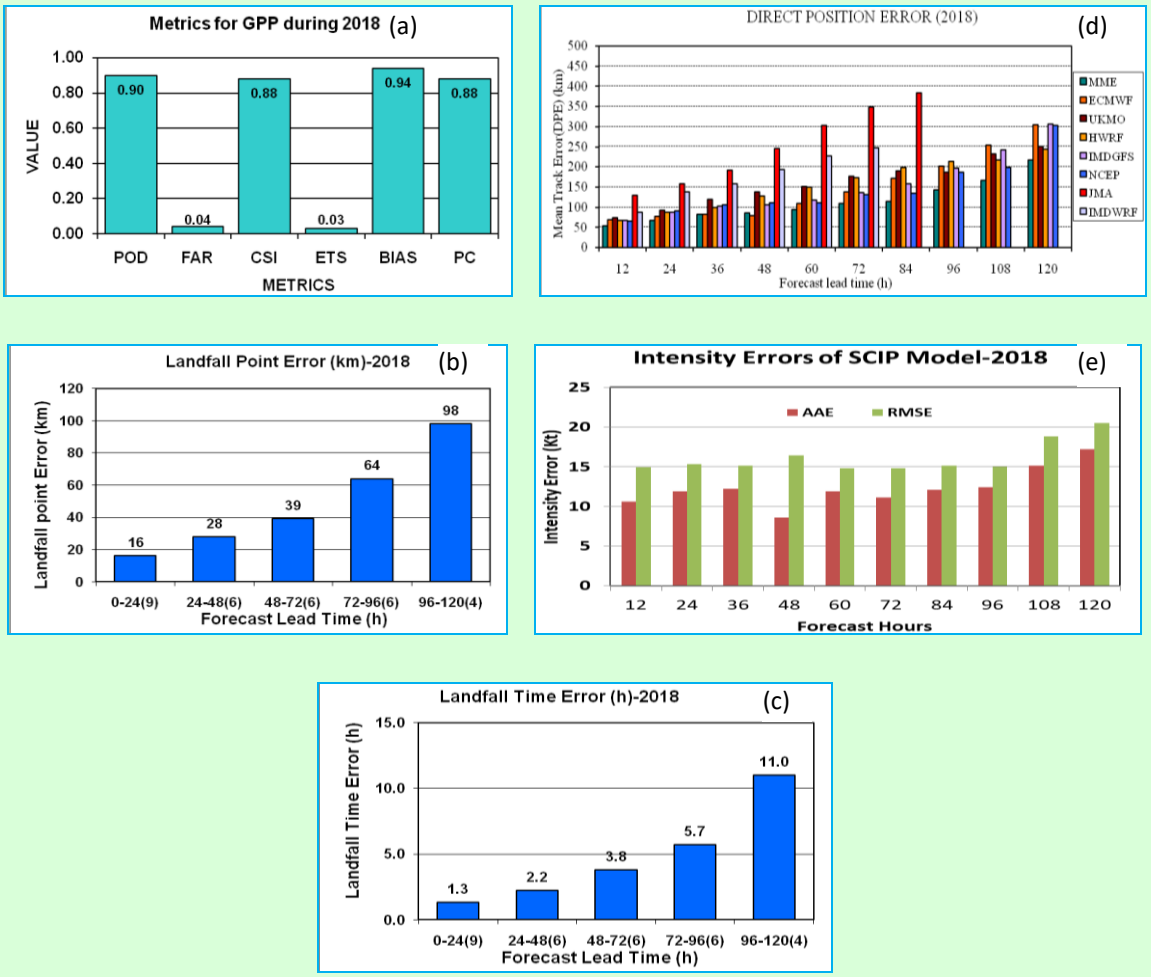
Figs. 4(a-d). Combine domain 126 hours track forecasts for cyclone PHETHAI from both HWRF-POM and HRWF-HYCOM models based on four different cycles of 15 December 2018 valid at (a) 0000 UTC, (b) 0600 UTC, (c) 1200 UTC and (d) 1800 UTC

dimensional ensemble variational (3D-EnVar) assimilation in 0600 hourly cyclic-mode for the forecasting of cyclone over North Indian Ocean. The model predicted clustered tracks and intensity during the cyclone PHETHAI in the Bay of Bengal from 13 December to 17 December 2018. The coupling with POM utilizes the climatology as a initial consition for the ocean whereas the HWRF-HYCOM coupling exploits the ocean state generated from Real Time Ocean Forecast System (RTOFS) of INCOIS (Indian National Centre for Ocean Information Services), Hyderabad based on HYCOM model. The both versions of the model have been prepared for real-time forecasting of the cyclones over North Indian Ocean (including Bay of Bengal and Arabian Sea). The Figs. 4(a-d) show the 126 hours combine domain track forecasts of HWRF model coupled with both POM and HYCOM based on the initial conditions of four different cycles at 0000, 0600, 1200 and 1800 UTC of 15 December 2018. Figs. 5(a-f) show the analysis and forecast of horizontal structure of the cyclone based on same initial time at 0000 UTC on 16 December 2018 from both versions of HWRF. The comparison between upper panels [5(a) to 5(c)] and the lower panels [5(d) to 5(f)] it is evident that the HWRF-HYCOM could represent the storm structure evolution in a better way compared to HWRF-POM.

(iv) In addition to several NWP models, IMD also run operationally "NWP based Objective Cyclone Prediction System (CPS)". The method comprises of five forecast components,



Figs. 5(a-f). The analysis and forecasts of the structure of PHETHAI cyclone based on the initial condtion at 0000 UTC of 16 December 2018. The plots in (a), (b) and (c) are the analysis, 12 and 24 hours forecasts respectively shwoing layer humidity between 700 and 500 hPa, geopotential height and wind at 700 hPa from HWRF-POM model. The plots in (d), (e) and (f) are similar to the plots in (a), (b) and (c) but from HWRF-HYCOM model



Figs. 6(a-e). Error statistics of GPP, tracks and intensity for all cyclonic systems during 2018 using NWP-based objective techniques. (a) GPP scores, (b) Landfall point error, (c) Landfall time, (d) direct position track error and (e) SCIP intensity error

namely (a) Cyclone Genesis Potential Parameter (GPP), (b) Multi-Model Ensemble (MME) technique for cyclone track prediction, (c) Cyclone intensity prediction, (d) Rapid intensification and (e) Predicting decaying intensity after the landfall. Genesis potential parameter (GPP) is used for predicting potential of cyclogenesis and forecast for potential cyclogenesis zone. The multi-model ensemble (MME) for predicting the track (at 12 h interval up to 120 h) of tropical cyclones for the Indian Seas is developed applying multiple linear regression technique using the member models IMD-GFS, GFS (NCEP), ECMWF, UKMO and JMA. The SCIP model is used for 12 hourly intensity predictions up to 120-hours. Error statistics of GPP, tracks and intensity for all cyclonic systems during 2018 using NWP-based objective techniques is shown in Figs. 6(a-e).

CHAPTER 4

OBSERVATIONAL NETWORK

One of the mandates of IMD is to take meteorological observations for use by different users. Strengthening of atmospheric observational network and its regular maintenance is absolutely required to sustain and improve skill of weather forecasts. IMD has been augmenting its observing system networks over the past years.

4.1. UPPER AIR OBSERVATIONAL NETWORK

Radiosounding Radiowind (RS/RW) network

India Meteorological Department (IMD) has 43 operational Radiosonde radiowind stations in their upper air network, as a part of global observing system (GOS) network of WMO. These stations take observations for measuring the vertical profile of the Atmosphere, *viz*., Temperature, Pressure, humidity, Wind Speed and Direction, the upper air observations are taken by using balloon borne soundings. These stations are engaged in taking the radiosounding observations twice a day at 0000 UTC and 1200 UTC hours (Fig. 1).

As a subset of Global Observing System (GOS) network, World Meteorological Organization (WMO) in collaboration with the Inter-governmental Oceanographic Commission

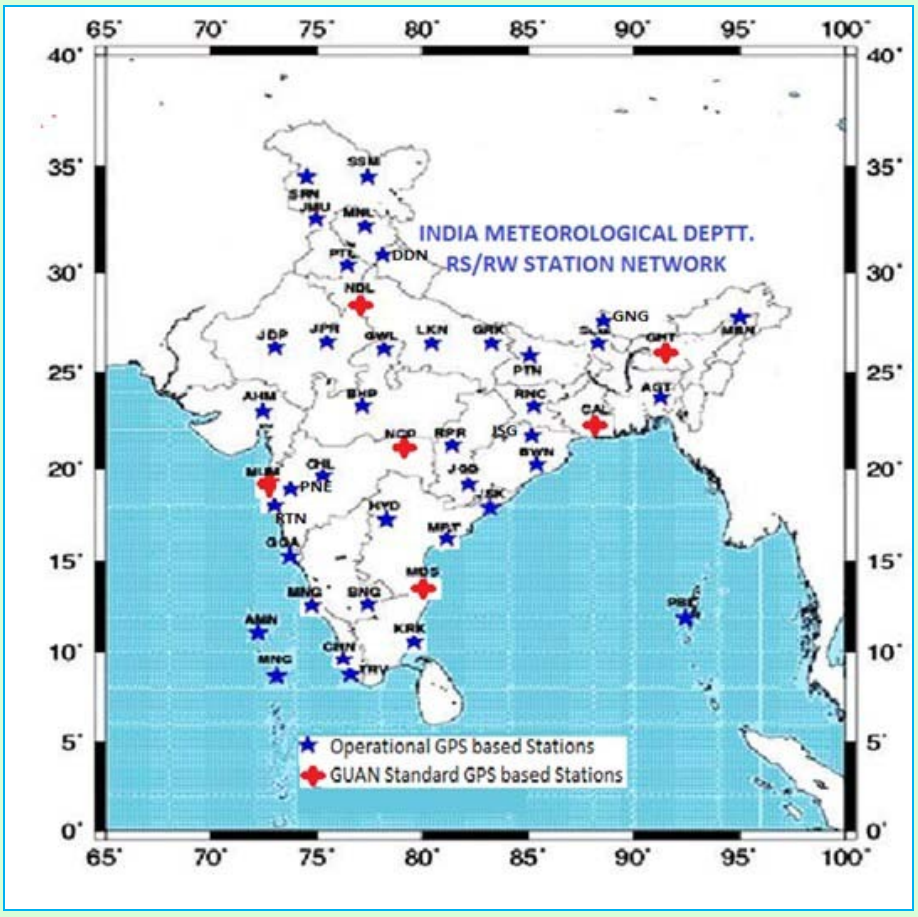


Fig. 1. RS/RW Network of India Meteorological Department

(IOC) of the United Nations Educational, Scientific and Cultural Organization (UNESCO), the United Nations Environment Programme (UNEP) and the International Council for Science (ICSU) established Global Climate Observing system (GCOS) network in 1992, as an outcome of 2nd World Climate Conference. In the upper air domain of GCOS, aiming on further improvement of upper air data quality, IMD established GUAN standard radiosounding observations at its 6 Regional Meteorological Centres (New Delhi, Mumbai, Kolkata, Chennai, Guwahati and Nagpur). The performance of these stations was presented at WMO Technical Conference on Instruments and Methods of Observations (TECO-2016) and a formal claim was made to Secretary General WMO for inclusion of these stations into the GCOS Upper Air Network (GUAN). Based on the sustained performance, these stations have been included in the WMO-GUAN standard network by GCOS Secretariat, and their performance indicators figures in the summary of NOAA's monthly report with effect from June 2017 on regular basis.

A. Achievements during the year 2018

(*i*) Continuation of 6 Nos. of WMO GCOS Upper Air Network (GUAN) standard RS/RW stations at New Delhi, Mumbai, Kolkata, Chennai, Guwhati and Nagpur equipped with GPS based high quality radiosounding systems (make M/s GRAW Germany).

(*ii*) Sustenance total network of upper air radiosounding (RS/RW) of 43 stations with GPS based radiosounding systems.

(*iii*) The production of indigenous Pilot-sonde in IMD Workshop at New Delhi. The system has been implemented at PB stations of New Delhi, Mumbai and Lucknow.

(*iv*) The process started for extension of RS/RW network from 43 to 55 and likely to be completed by May, 2019.

(*v*) Twice a day (0000 and 1200 UTC) Radisounding (RS/RW) observations continued at all 43 stations.

B. Pilot Balloon (PB) network

IMD is operating 62 PB observatories taking 2 to 4 observations for upper air wind profiles at0000, 0600, 1200 and 1800 UTC hrs of observations. PB stations are using optical theodolites for balloon tracking manually (Fig. 2). Efforts have been made to switch over

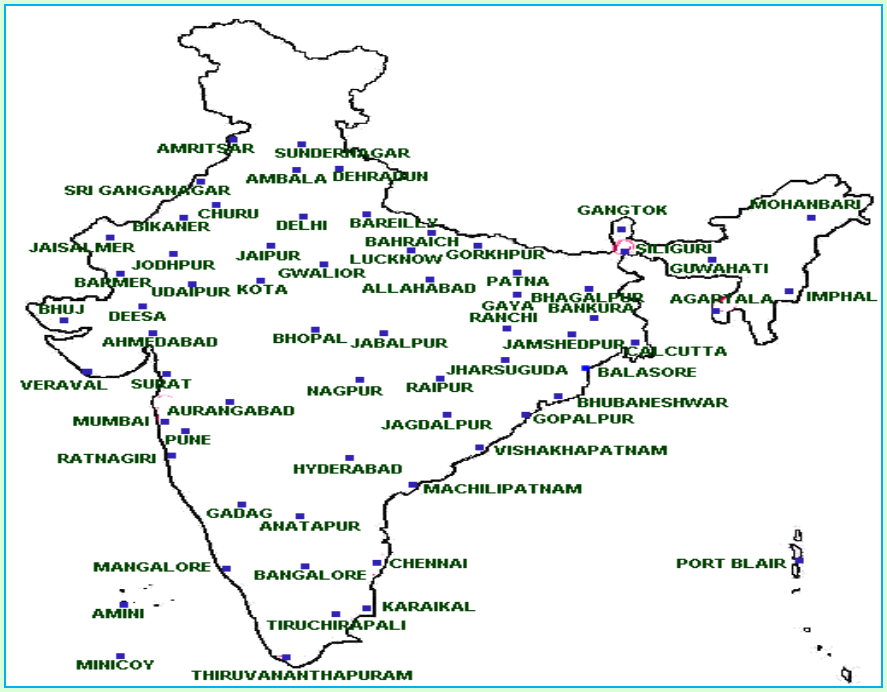


Fig. 2. Upper Air Pilot Balloon (PB) Network of IMD

to GPS based fully automatic PB systems from conventional optical theodolite based observations. For this, GPS based pilot-sonde has been developed and being manufactured in-house in IMD Workshop. The same has been implemented in the PB network at PB stations of New Delhi, Mumbai and Lucknow.

4.2. SURFACE OBSERVATIONAL NETWORKS

New Installation and Up-gradation of Airport Instruments

The new installation and up-gradation of airport instruments from April 2018 to March 2019 are shown in Table 1 and Figs. 3&4.

TABLE 1

List of New Installation and upgradation of airport Instruments

S. No.	Station	System Installed
1.	Kakinada	HWSR
2.	Bhubaneswar Mumbai, Chennai, Amritsar, Kannur, Hyderabad, Kochi and Guwahati airports	Drishti Transmissometer
3.	Lengpui, Kadapa, Hissar, Bhuntar and M. C. Amravati	DIWE
4.	Shamshabad, Gaya,Patna and Vijaywada Airports	DCWIS
5.	New Delhi.	Surface ozone recording system
6.	Delhi,Kolkata, Mangalore(Bajpe), Bengaluru and Guwahati airports	Laser Ceilometer
7.	Hyderabad airport	Drishti at Runway 9 & 27
8.	New Delhi IGI Airport	Met. Instruments to New ATC building
9.	Antartica	Supplied new instruments
10.	Hissar& New Delhi	DIWE Installation, maintenance/inspection work

Fig. 3. New Installation and upgradation of airport Instruments

DIWE System at Hissar | Laser Ceilometer at Guwahati

Fig. 4. DIWE System at Hissar and Laser Ceilometer at Guwahati

Established full fledge conventional Surface Met. Observatory with 10 meter wind mast at newly formed Meteorological Center, Amaravati (M. C., Amaravati) and Andhra Pradesh in the month of November 2018 (Fig. 5)

Amaravati (M. C., Amaravati) | Andhra Pradesh

Fig. 5. Amaravati (M. C., Amaravati) and Andhra Pradesh Surface Met. Observatory

4.3. SATELLITE OBSERVATIONS

Atmospheric Observations and Services

INSAT-3D Meteorological data system was established in 2009 through a MoU signed between M/S Antrix Corporation limited and IMD and since then the system being used to receive process and disseminate images and derived products operationally from INSAT-3D satellite. The performance of the system during the current year has been maintained to the level of 99% operation efficiency (24 × 365 bases). The output generated by the system is used for efficient and successful forecasting.

INSAT-3DR has been launched successfully 8th September, 2016 by GSLV -F05 and placed at 74° East in place of Kalpana-1 which has been shifted at 73.2° East. INSAT-3DR similar to INSAT-3D, is an advanced meteorological satellite of India configured with an imaging System and an Atmospheric Sounder. At present the Processed data of INSAT-3DR Imager and Sounder is being obtained from SAC, Ahmedabad through dedicated NKN connectivity and images generated at IMDPS, are disseminated on IMD website on real time basis.

INSAT-3D & DR carries a six spectral band Imager, 19 channel Sounder, Data Relay Transponder and Search and Rescue Transponder payloads. IMD is in action to establish Multi-Mission Meteorological Data Receiving and Processing System (MMDRPS) for INSAT-3D, INSAT-3DR and INSAT-3DS in collaboration with M/s Antrix Corporation Ltd., ISRO for which a MOU has been signed between IMD & ISRO on 6th March, 2017. The installation of project is in progress & being monitored closely for implementation. After installation of this project, the data and image processing time will be reduced to 5 minutes.

INSAT-3D/3DR imager and sounder data is being supplied to NCMRWF Noida for assimilation in NWP model on operational basis. These data is also being supplied to Indian Air Force & KDMA in real time basis.

Modified scan strategy of INSAT-3D and INSAT-3DR sounder payload has been implemented with effect from 12th August, 2017. INDIAN region sector data is now available on hourly basis and Ocean region data is available on one and half hourly basis. Rapid scan strategy of Imager payload of INSAT-3DR has been finalized and conducted during Luvan, Titli and Gaja cyclone for monitoring them more closely with five minute temporal resolution.

RO Data of ROSA payload of Megha-Tropics is being disseminated via GTS in BUFR format since last week of September 2017. Scatsat-1 wind data is being disseminated on GTS since April 2018. INSAT-3D derived Winds (IR/WV/Vis) as in BUFR format is also being provided to UKMET Office through GTS.

The products derived from the satellite data include: Cloud images in the Visible, Short wave Infra-red, Mid Infra-red, Thermal Infra-red, Water Vapour Channels and special enhanced images, Atmospheric Motion Vectors (IR Wind, Water Vapour Winds, MIR and Visible Winds), Sea Surface temperature, Outgoing Long-wave radiation, Land Surface Temperature (LST), Insolation, Quantitative Precipitation Estimates, Night time Fog, Smoke, Fire, Snow Cover, Aerosol Optical Depth, Upper Tropospheric Humidity, Cloud top Temperature, Cloud top Pressure, Temperature & Humidity profiles, Total ozone, Total/Layer Precipitable Water Vapour, Stability Indices. In addition to these, IMD has also started generation of Wind derived products such as Vorticity (at 850 hPa, 700 hPa, 500 hPa, 200 hPa levels), Wind Shear, Mid-level Wind Shear, Shear Tendency, Low level Convergence and Upper Level Divergence using Imager Wind product and NCEP forecast file and T-phi gram at all district locations using Sounder data. All these images and products are disseminated in a real time basis through dedicated IMD website. Satellite observed radiances and winds are now being assimilated in NWP models to improve their forecast ability. Satellite images are used in monitoring Cyclones. Intensity and position of cyclones is given to forecasters in real time using Dvorak technique. Satellite data and images are also used in monitoring various other significant weather phenomena such as Fog and thunderstorms.

The validation of atmospheric Motion Vector (wind products), sea surface temperature (SST), outgoing long wave radiations (OLR) vertical Profile of temperature and humidity has been carried out for the period of January, 2018 to December, 2018 and the feedback are used for fine tuning of algorithm of these products and calibration coefficients.

IMD's Area Cyclone Warning Centres generate special warning bulletins and transmit them every hour in local languages to the affected areas. During Recent past, in cases of Luvan, Titli and Gaja cyclones warnings were disseminated to all stake holders which resulted in minimum loss to human life. Advanced Dwork Technique (ADT) software has been customized for INSAT-3D and implemented to determine the intensity of Tropical Cyclones.

To improve navigation accuracy, Fixed Grid Navigation and Automatic Template Based Registration package for INSAT-3D Imager was developed and operationalized at Space Application Centre, Ahmedabad and IMD, New Delhi. The Ancillary Data Products Generation Software (ADPS) capability enhanced to include HRIT/LRIT products, AWS (Automatic Weather Station) Data Decoding, archival and report generation. Generation of Day Time Microphysics using Visible, SWIR and TIR1 spectral band and Night time Microphysics using MIR, TIR1 and TIR2 RGB composite Images have been started which are being used for cloud classification, operationally.

Space Application Centre, Ahmedabad has developed the Real Time Analysis Product & Information Dissemination (RAPID) which is a

web based quick visualization and analysis tool for satellite data on a real-time basis and IMD has hosted it operationally since January 2015. This introduces Next Generation Weather Data Access & Advanced Visualization Application that touch the life of common man in one or other way ranging from weather events to atmospheric phenomenon. This has capability to visualize the Fog presence over railway track and highways & a pilot can see the position of clouds and fog of the entire route in real time basis interactively. This also have capability to generate, time series plot of different products derived from satellites along with measuring capability of distance, area of any cloud system and to display the digital value of different parameters over different types of maps. The following additional features have been added in RAPID such as Taluk boundaries, India Sub-Basins and FMO Basin and the following enhancement (Aviation colour enhancement (AVN), Funktop enhancement-to highlight intense areas of precipitation, Rainbow, *i.e*., Colourful enhancement for a pretty image, New variation on the Rainbow enhancement curve - Colourful enhancement(RBtop)) are integrated in RAPID.

IMD has set up a countrywide network of 25 nos. Global Navigation Satellite System (GNSS) stations for "Earth and Atmospheric studies" have been Installed and commissioned to drive integrated precipitable water vapor (IPWV). The IPWV data is being used for now casting and assimilated in NWP models to improve the weather forecasting. A dedicated website has been developed to access IPWV data of 25 GNSS site in real time. Graphical user Interface was also provided to visualize 15 min, hourly, daily, weekly and monthly IPW data along with Meteorological data and minimum and maximum value of IPW etc.

Interpretation of the lightning data with respect to the occurrence and intensity of convective clouds. The occurrence of lightning with respect to area of occurrence and intensity of convection can be further interpreted by considering the animation of satellite imagery superimposed with lightning data. As the lightning data are very frequent, it can be analysed better with rapid scan images of INSAT 3D /3DR.

It is stated that satellite technology is of great use in meteorology and plays a very significant role in the improvement of weather forecasting and dissemination. In fact, the improvement in weather forecasting is mainly attributed to increasing use of satellite data.

4.4. ENVIRONMENT MONITORING AND RESEARCH CENTER (EMRC)

Environment Monitoring and Research Center, a division of IMD conducts monitoring and research related to atmospheric constituents that are capable of forcing change in the climate of the Earth, and may cause depletion of the global ozone layer, and play key roles in air quality from local to global scales. EMRC also provides specific services to Ministry of Environment and Forest & Climate Change and other Government Agencies in the assessment of air pollution impacts. IMD contributes in the field of atmospheric environment to the World Meteorological Organization (WMO) Global Atmosphere Watch (GAW) programme. The main objective of GAW is to provide data and other information on the chemical composition & related physical characteristics of the atmosphere and their trends, required to improve understanding of the behavior of the atmosphere and its interactions with the oceans and the biosphere.

Ozone Monitoring Network

National Ozone Centre of IMD is designated as secondary regional ozone centre for Regional Association II (Asia) of World Meteorological Organization. The centre maintains a network of ozone monitoring stations (Fig. 6) including Maitri and Bharati in Antarctica:

- Total Columnar ozone measurement using Dobson spectrophotometer.

- Surface Ozone monitoring network

- Measurement of Vertical Distribution of Ozone.

Fig. 6. Ozone monitoring network

Precipitation and Particulate Matter Chemistry Monitoring

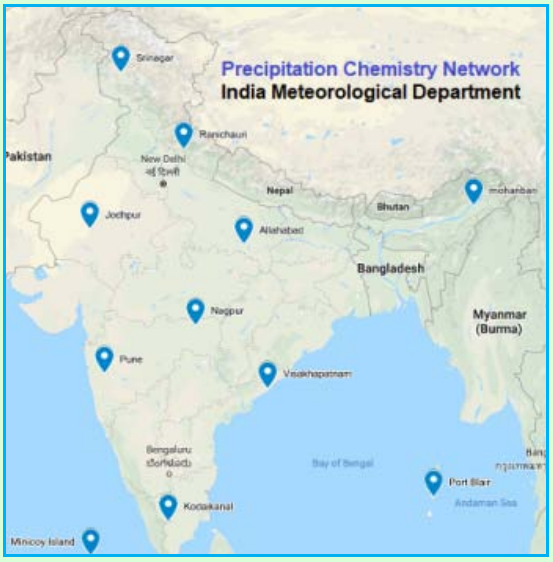


Fig. 7. Precipitation chemistry network

IMD is monitoring Precipitation Chemistry through a network of eleven stations since 1970s (Fig. 7). The rainwater samples collected from these stations are analyzed in Air Pollution Chemistry Laboratory at IMD, Pune (Fig. 8) which is equipped with Ion-chromatograph, UV-VIS Spectrophotometer, Atomic Absorption Spectrophotometer, Semi-micro Balance, pH & Conductivity Meter, Ultra-pure Deionized Water Purification System.

Fig. 8. Air Pollution Laboratory at IMD, Pune

Aerosol Monitoring Network

IMD has established Aerosol Monitoring Network covering different geographic regions of India (Fig. 9). The Aerosol Monitoring Network consists of following sub-networks:

Fig. 9. Aerosol Monitoring network of IMD

- **Sun-Skyradiometer Network**

Environment Monitoring and Research Center, India Meteorological Department has established Aerosol Monitoring Network by installing skyradiometer at twenty locations. The network is used to measure optical properties of aerosols such as Aerosol Optical

Depth, Single Scattering Albedo, Size Distribution, Phase Function etc.

- **Black Carbon Aerosol Monitoring Network**

Black Carbon Monitoring Network of 25 stations for measurement of Spectral Aerosol Absorption Coefficient, Equivalent Black Carbon Concentration and bio-mass burning component is operational.

- **Multi-wavelength Integrating Nephelometer Network**

IMD has established a network for measurement of aerosol scattering coefficient at twelve locations is operational at New Delhi, Ranichauri, Varanasi, Nagpur, Pune, Port Blair, Visakhapatnam, Guwahati, Kolkata, Jodhpur, Bhuj, Thiruvananthpuram.

- **Chemical Characterization of Aerosols**

High Volume Samplers for collecting PM_{10}, $PM_{2.5}$ and Total Suspended Particulate Matter have been installed at Delhi, Ranichauri, Pune and Varanasi (Fig. 10). The filter papers are being analyzed for chemical characterization of aerosols at Air Pollution Section, O/o CRS, IMD, Pune.

Fig. 10. High volume sampler for collecting PM10, PM2.5 and Total Suspended Particulate Matter

Air Quality Forecasting and Research

Under the FMI-IMD Collaborative project, System for Integrated modeLling of Atmospheric coMposition (SILAM) model is operational at IMD for Air Quality Forecast. IMD issues AQ Early Warning bulletins based on SILAM and WRF-Chem (IITM) models.

For city scale air quality forecasting, a very high resolution FMI-ENFUSER model will be implemented during 2019-20.

The System for Air quality Forecasting and Research (SAFAR) is operational to monitor and forecast air quality in Delhi. This is a joint project of IITM and IMD. The system is also operational at Pune, Mumbai and Ahmedabad. All major air pollutants (PM2.5, PM10, Ozone, CO, NOx (NO, NO2), SO2, BC, Methane (CH4), Non-methane hydrocarbons (NMHC), VOC's, Benzene, Mercury), solar radiation and meteorological parameters are measured at ten air quality station installed in each city. SAFAR provides location specific information on air quality in near real time and its forecast 1-3 days in advance.

High Altitude Background Climate Monitoring Station

IMD maintains a Background Climate Monitoring Station Ranichauri, Uttarakhand (Fig. 11). Skyradiometer, Aethalometer, Differential Mobility Particle Sizer, Nephelometer, Solar Radiation monitoring equipment, Precipitation Chemistry and Surface Ozone Analyzer have been installed at the station. The site is being developed for monitoring aerosol-cloud interaction & GHGs monitoring.

Fig. 11. IMD Climate Monitoring Station Ranichauri, Uttarakhand

POLAR METEOROLOGICAL RESEARCH DIVISION (PMRD)

India Meteorological Department has been an integral part of all the Indian Scientific Expedition to Antarctica (ISEA) since the very first expedition during 1981. IMD started meteorological and ozone observations at Maitri station from January, 1990 (from 9th ISEA) and are ongoing till date. A meteorological observatory was commissioned in 2015 by IMD at Bharati, another Indian station in Antarctica (Fig. 12). The observations vertical profile of ozone is also carried out at Bharati regularly (Fig. 13). Polar WRF model is implemented to provide day-to-day 48 hours weather forecast for the Maitri and Bharati region in the Antarctica. The NWP products are routinely made available on the IMD web site to support of Antarctic Expedition.

Fig. 12. Meteorological Observatory at Bharati

Fig. 13. Launch of Ozonesonde at Bharati

4.5. RADAR OBSERVATIONS

(a) **Network of Radars**

IMD monitors and maintains vast network of 23 DWRs all over india alongwith DWR images being received from 3 ISRO and 1 IITM DWRs (Fig. 14).

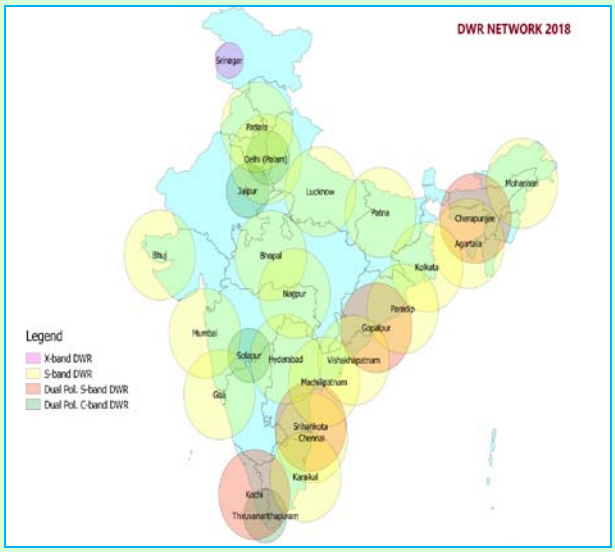


Fig. 14. Network of Radars

Proposed Dual Polarized 10 X- Band DWRs

10 Dual Polarized X-Band DWRs will be installed by March 2020 at locations shown in following map (Fig. 15):

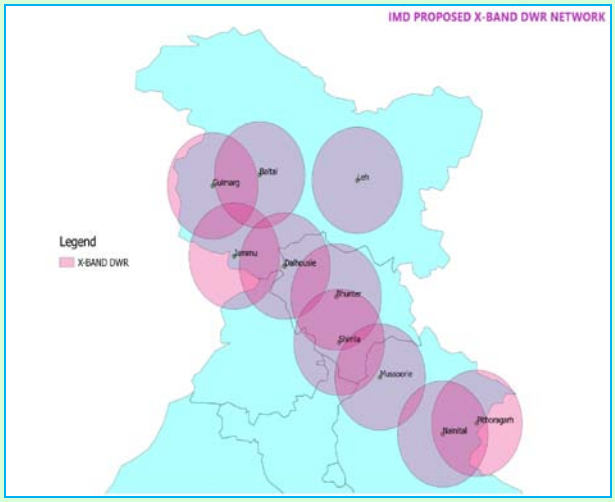


Fig. 15. 10 Dual Polarized X-Band DWRs

Proposed Dual Polarized 11 C-Band DWRs:

11 Dual Polarized C-Band DWRs to be installed at locations shown in map (Fig. 16).

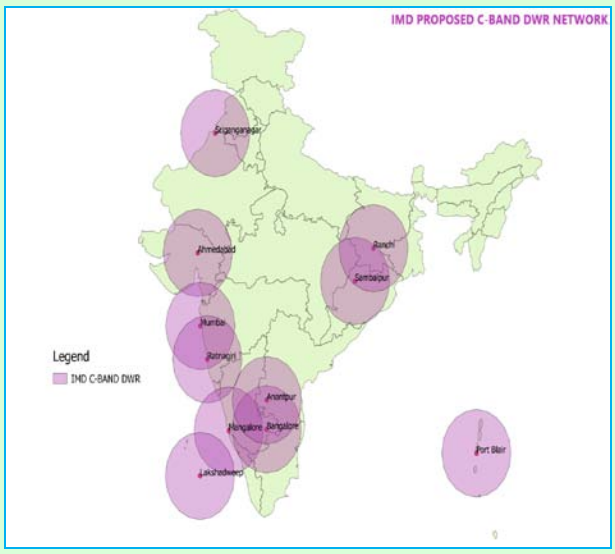


Fig. 16. 11 Dual Polarized C-Band DWRs

GIS APPLICATIONS

- A Web-Based GIS application has been developed which overlays Radar Refelectivity, Wind, Radar Coverage and Lightning Data Over GIS based map in real time for Observation and Nowcasting.

- The URL for application is http://ddgmui.imd.gov.in/radar/leaflet-map-csv-master/mosaic.php.

- The application is available for national as well as for regional level.

- The webpage is visualized as (Fig. 17).

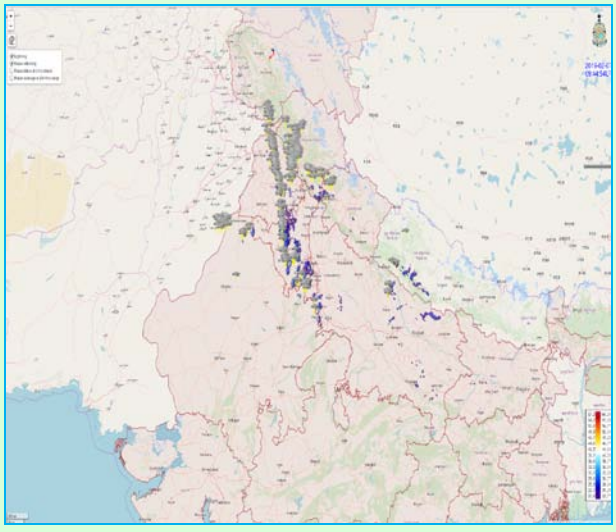


Fig. 17. Webpage of GIS application

4.6. SAARC STORM PROJECT – 2018

A. Short-range Warning of Intense Rainstorms in Localised Systems (SWIRLS)

Warning Decision Support System Integrated Information (WDSSII) for automated nowcasting of thunderstorms has been replaced by SWIRLS adopted from Hong Kong Observatory during 2018. SWIRLS is based on the extrapolation of radar echoes using the TREC (Tracking Radar Echoes by Correlation) technique. With a suitable choice of pixel array size on the radar reflectivity maps, the TREC vectors derived can be used to monitor and extrapolate echo motion right across the mesoscale spectrum, from individual convective cells, to supercells and clusters, and to groups of rain bands or squall lines.

On the basis of TREC, quantitative precipitation forecast (QPF) algorithms have been developed to produce high resolution forecast rainfall distribution maps over the local area. These maps provide useful objective guidance for forecasters to assess the likely rain scenario in the next 30, 60 & 120 minutes along with analysis and to facilitate decision-making in operating the Rainstorm Warning System. The first SWIRLS was installed and made operational at Delhi in Oct, 2018. At present the SWIRLS software is operational at 11 stations viz; Delhi, Mumbai, Goa, Patna, Machilipatnam, Bhopal, Agartala, Mohanbari, Visakhapatnam, Patiala and Hyderabad DWR stations [Figs.18(a&b)].

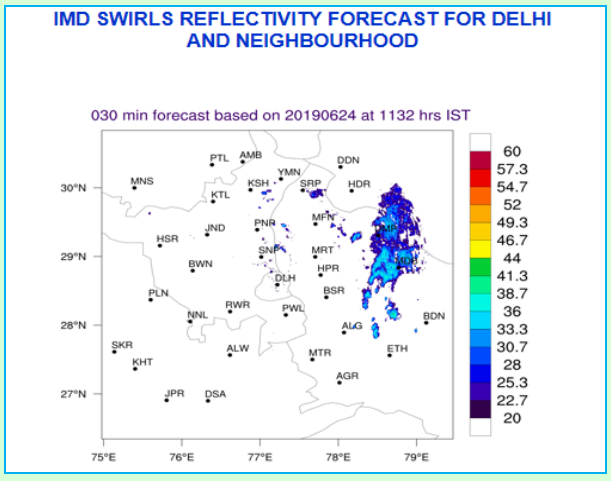


Fig. 18(a). SWIRLS Reflectivity Delhi & Machilipatnam

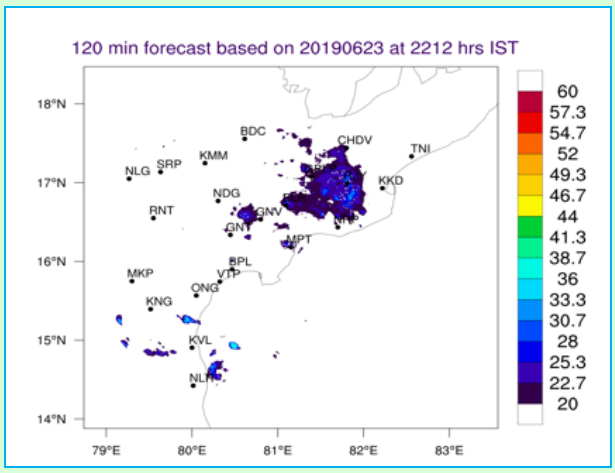


Fig. 18(b). IMD SWIRLS forecast for Delhi and Machilipatnam

B. STORM Forecast Demonstration Project - 2018

The STORM program was conceived as a multidisciplinary nationally co-ordinated research and development programme and has been carried out as a multi-year observational-cum modelling campaign with an objective to build appropriate operational early warning systems for highly damaging severe thunder storms over various parts of India. In order to develop methods for improving the accuracy of nowcasting of Severe Thunderstorms, Hailstorms, Squalls & other associated phenomenon, India Meteorological Department conducts field experiments over entire country under STORM Forecast Demonstration Project (FDP STORM) during March to June every year.

Broad objectives of the FDP STORM can be put forward as follows:

(a) To understand the genesis, development and propagation of severe thunderstorms.

- To enhance the knowledge of dynamical and thermo-dynamical structure and the role of micro-physical processes on intensification of these severe storms.

- To study the behaviours of atmospheric electrification during intensification of these storms and their interaction with cloud microphysical processes.

- Development/customization of mesoscale prediction systems with improved forecast skill for prediction of these severe thunderstorms.

The programme was started in 2009 & STORM Field Experiments were conducted jointly in Bangladesh, Bhutan, east and northeast India and Nepal under the name SAARC STORM Programme. In 2012, Afghanistan, Northwest India and Pakistan were also included under this programme to focus on deep convective moist and dry storms over these areas and in 2013 STORM field experiments were also conducted in Southern Peninsular India, Maldives and Sri Lanka to study maritime and continental convective storms during pre-monsoon season and thus whole India was covered under this project. Since then, the project is being conducted successfully every year during pre-monsoon season. At present this programme is being run under the name FDP STORM. At the end of every FDP programme, STORM Reports containing region wise detailed analysis of observed significant weather events, case studies and verification of Intensive Observation Periods (IOPs) issued during the FDP, are prepared and published.

This year also STORM Fields Experiments covered the whole India. The monitoring period was uniform for entire country from 7 March to 30 June, 2018.

Under this project, FDP Bulletins were issued on daily basis with updated one if required. The FDP Bulletin consists of four sections:

1. Current Synoptic situations and satellite current and past 24 hrs observations over India,

2. NWP model Guidance from IMD GFS, IMD WRF and NCUM (NCMRWF) Models,

3. Summary of 1 & 2 above and

4. Intensive Observation Period for thunderstorm and rainfall occurrence during next 24 hrs and 24-48 hrs for meteorological

subdivision and image display of the same. The bulletin also contains satellite imageries, Radar and Thunderstorm Reports.

A total of 116 FDP Bulletins were issued during the STORM Period-2018.

C. Nowcast Guidance Bulletins

In addition to FDP Bulletins during March to June-2018, Nowcast Guidance Bulletin containing current Synoptic features and depicting potential areas for Severe Weather (Heavy Rainfall/Thunderstorm & Associated Phenomenon/Fog) for next 24hours, in text as well as visual form based on 0830IST observations were issued once/twice (if needed) a day throughout the year. This bulletin provides significant guidance to the forecasters working at different RMCs/MCs, in keeping a watch over their areas of responsibility as mentioned in the Guidance Bulletin and issue Nowcast Bulletins accordingly.

D. Location Specific three hourly Thunderstorm (TS) Nowcast

Nowcasting of Severe Weather (thunderstorms, squalls and hailstorms, heavy rainfall etc.) has benefited from the recent improvement in monitoring and forecasting due to introduction of (*i*) digital and image information at 10 mins interval from a network of 18 Doppler Weather Radars, (*ii*) half hourly satellite observations from RAPID Satellite imagery, (*iii*) dense automatic weather station (AWS) network (*iv*) better analysis tools in synergy system at forecaster's workstation and (*v*) availability of mesoscale models, (*vi*) computational & communication capabilities.

TS nowcast of major towns is uploaded every 3 hourly interval utilizing Synoptic Data, Model outputs, Satellite products and finally various Radar outputs by the respective RMCs/MCs/RWFCs under whose jurisdiction these stations are situated. During the year-2018, 126 new stations were added on All India Nowcast Warning page of IMD website for issueing three hourly thunderstorm nowcast, thereby, increasing the total number of nowcast stations to 433 under 20 Nowcast Centres (RMC/RWFC/MC/CWC). Considering the importance and reliability of DWR based information for nowcast of severe weather all district headquarters/major towns/tourist places in India are to be included for nowcasting of severe weather during the year-2019. Fig. 19 indicates the year-wise cumulative number of stations added on Nowcast Warning page for three hourly thunderstorm Nowcast. Fig. 20 depicts the screen shot of Nowcast Warning Page on IMD website.

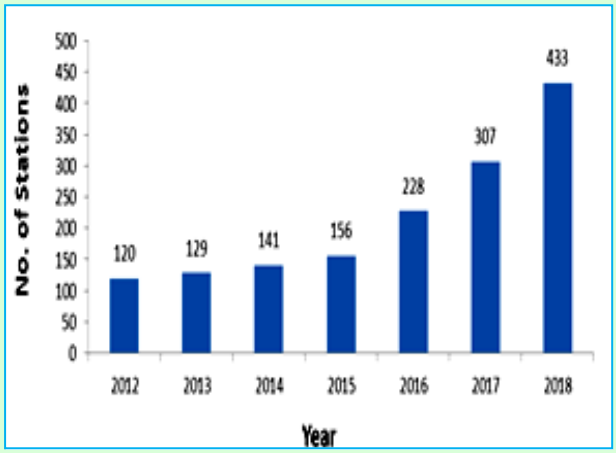


Fig. 19. Year-wise cumulative number of stations for three hourly thunderstorm Nowcast

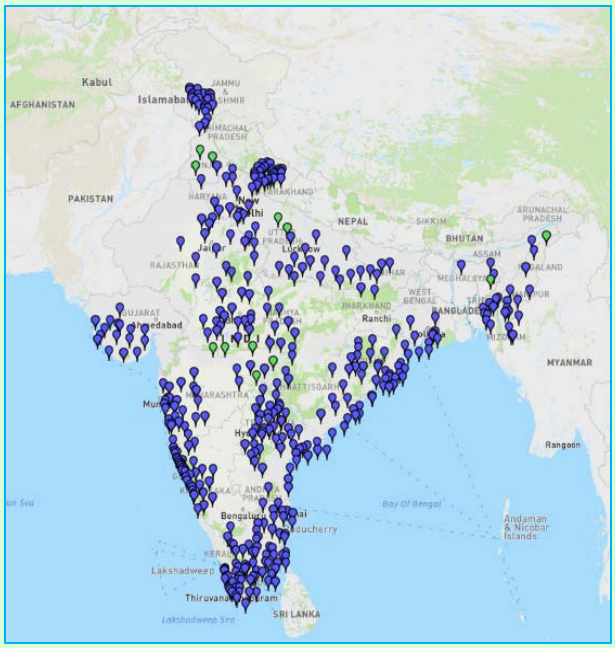


Fig. 20. Thunderstorm Nowcast Warning Page on IMD website

E. Verification of IOPs/TS Nowcast - 2018

(*i*) FDP Bulletins

The thunderstorm and rainfall forecast issued for 24 hours during FDP STORM-2018 were verified with realised thunderstorm and rainfall data. The verification results for thunderstorm forecast are shown in Table 2 and graphically by Fig. 21, while verification results for various forecasted rainfall categories are given in Table 3 and graphically by Fig. 22.

TABLE 2

Skill Scores for Thunderstorm Verification for FDP STORM – 2018

Skill Scores	March	April	May	June	Season-2018
Ratio Score	0.85	0.71	0.66	0.61	0.71
POD	0.48	0.7	0.75	0.42	0.6
FAR	0.47	0.39	0.39	0.36	0.39
CSI	0.34	0.48	0.5	0.34	0.43
ETS	0.26	0.25	0.2	0.12	0.23

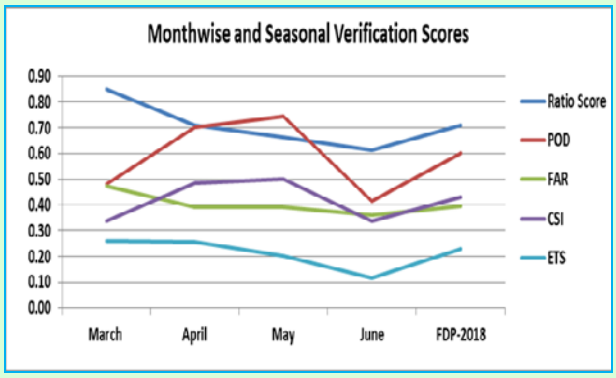


Fig. 21. Monthly and Sesonal Thunderstorm verification Scores during FDP STORM – 2018

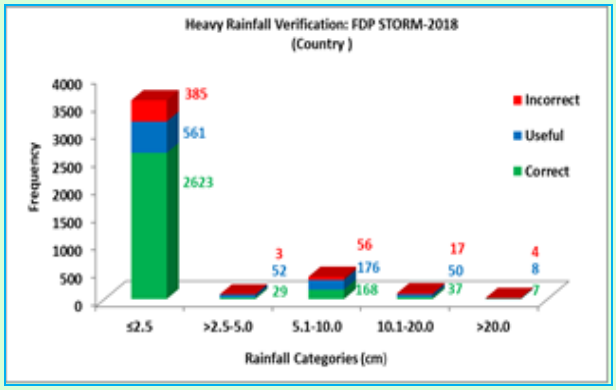


Fig. 22. Category-wise Rainfall Verification for FDP STORM - 2018 (March to June)

TABLE 3

Category wise Rainfall Verification for FDP STORM - 2018 (March to June)

Country: FDP STORM-2018				
Rainfall Category	Within Range	Out by one Range	Out by two or more Range	Total RF Forecasts issued
	Correct	Useful	Incorrect	
≤2.5	2623	561	385	3569
>2.5-5.0	29	52	3	84
5.1-10.0	168	176	56	400
10.1-20.0	37	50	17	104
>20.0	7	8	4	19
Total	2864	847	465	4176

(*ii*) Three Hourly TS Nowcast

Figs. 23 to 27 indicate respectively the Ratio Score, FAR, POD, ETS and CSI of three hourly TS Nowcast issued by various RMCs/ MCs during FDP STORM (March to June) for the year-2018 and Fig. 28 indicates All India Scores of the same.

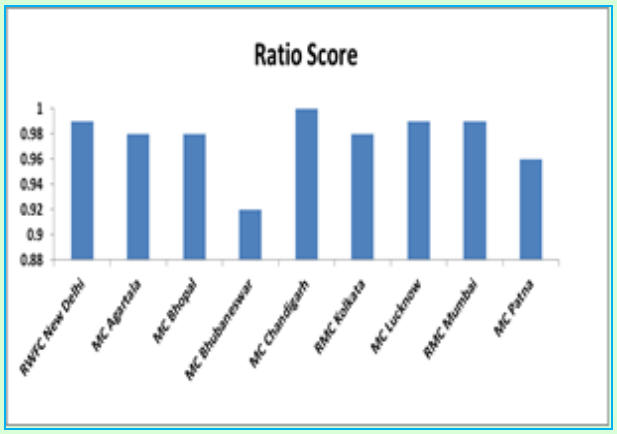


Fig. 23. MC-wise Ratio Score of Three Hourly TS Nowcast Verification during FDP Period-2018

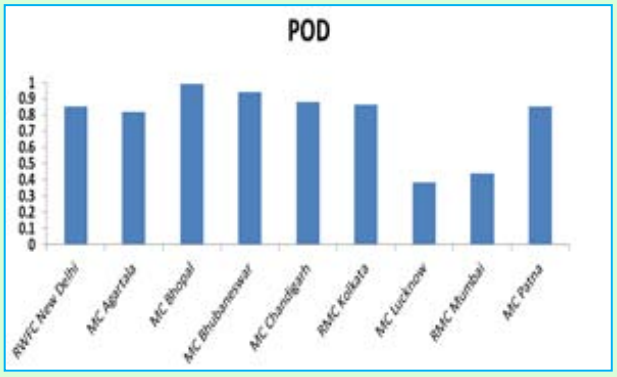


Fig. 24. MC-wise Probability of Detection (POD) of Three Hourly TS Nowcast Verification during FDP Periood-2018

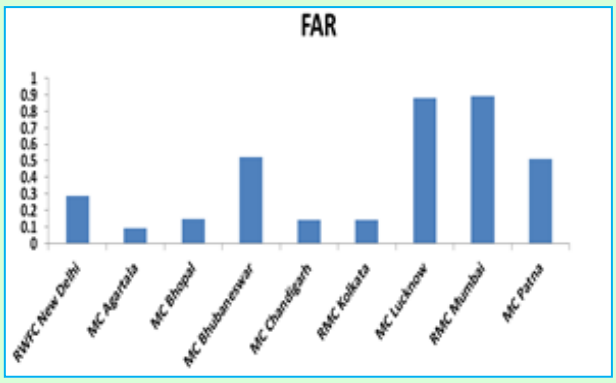


Fig. 25. MC-wise False Alarm Ratio (FAR) of Three Hourly TS Nowcast Verification during FDP Period-2018

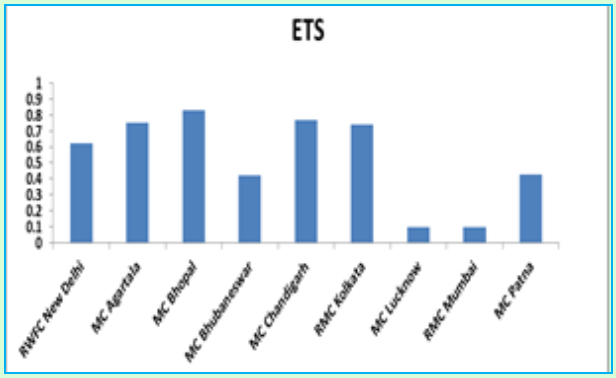


Fig. 26. MC-wise Equitable Threat Score (ETS) of Three Hourly TS Nowcast Verification during FDP Period - 2018

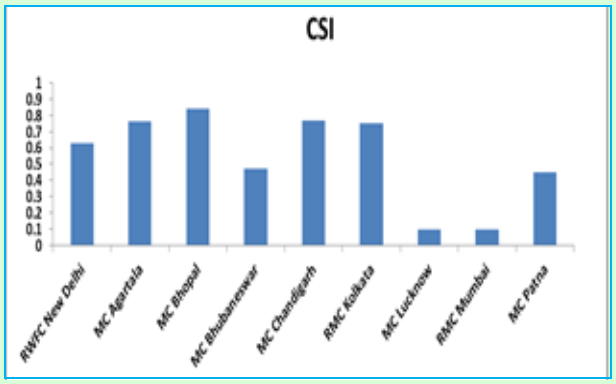


Fig. 27. MC-wise Critical Success Index (CSI) of Three Hourly TS Nowcast Verification during FDP Period-2018

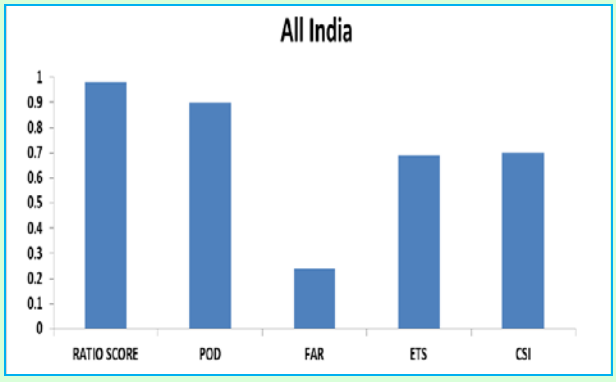


Fig. 28. All India TS Nowcast Verification Scores during FDP Period-2018

F. FDP STORM Report - 2018

A detailed Storm Report document, based on thunderstorm activities observed over India during March to June-2018, is being prepared by Nowcast Division. It contains information on daily weather situation, important weather charts, severe weather events all through the campaign period, case studies and the bulletins issued during the period. The report is expected to be completed and published soon. Figs. 29 to 35 represent some of the salient features of the Storm Report-2018.

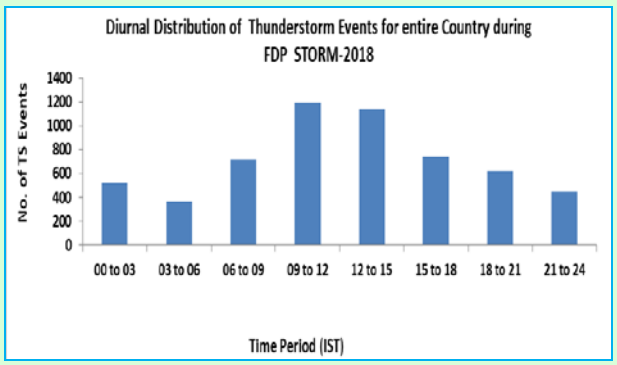


Fig. 29. Diurnal distribution of TS events over the country during FDP STORM -2018

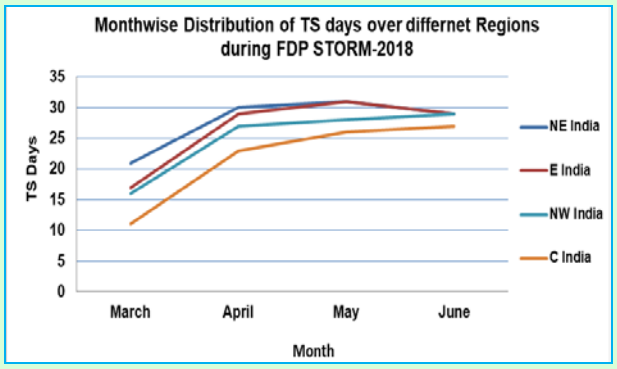


Fig. 30. Monthwise distribution of TS Days over different regions of India during FDP STORM-2018

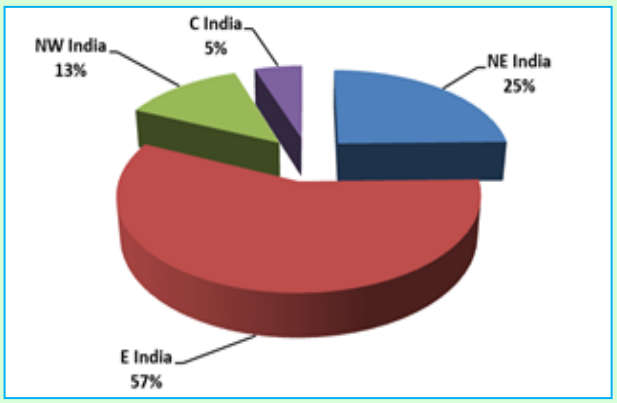


Fig. 31. Regionwise Distribution of Thundersquall events over the country during entire FDP STORM-2018

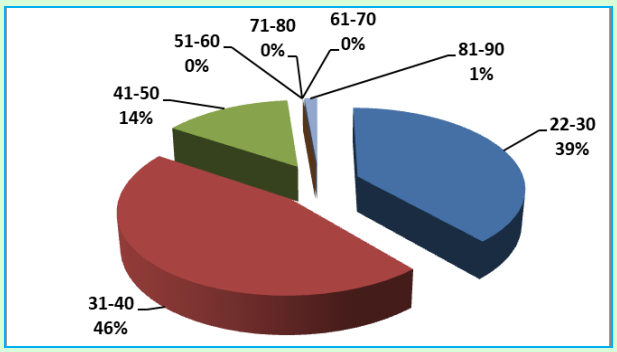


Fig. 32. Distribution of thunder squalls over the country based upon max wind speed (Kt) during FDP STORM -2018

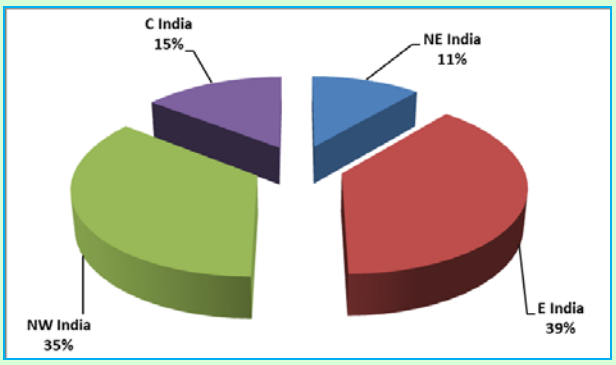


Fig. 34. Regionwise distribution of hailstorm events during FDP STORM-2018

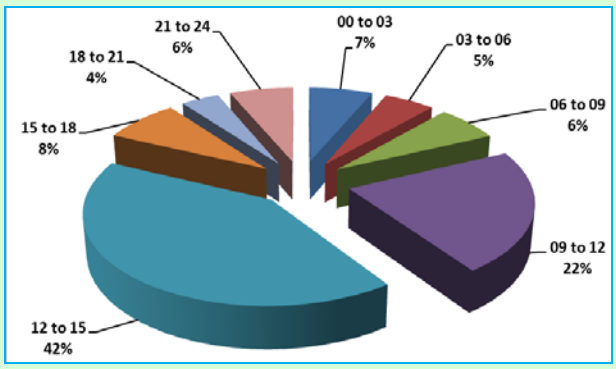


Fig. 33. Diurnal distribution of thundersqualls during FDP STORM-2018

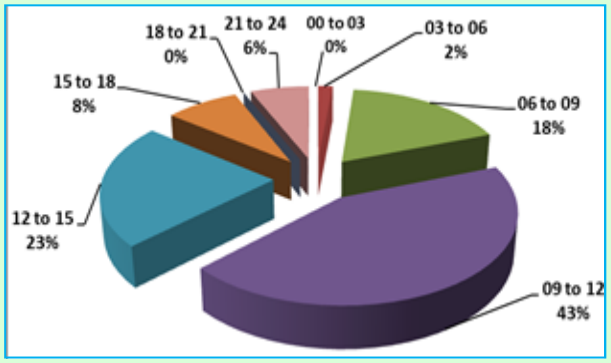


Fig. 35. Diurnal Distribution of Hailstorm Events over the Country during entire FDP STORM-2018

CHAPTER 5

WEATHER AND CLIMATE SERVICES OF IMD

5.1. HYDROMET SERVICES

The Hydro-meteorological Division is providing the necessary technical and operational support to various Central/State Govt. organization and other agencies in the field of flood forecasting, rainfall monitoring and hydro met design for water management and agricultural planning purposes etc.

Major achievements

1. NWP model based Sub basin wise QPF (WRF and GFS) is extended for the following river basin areas:

(*i*) 7 River sub basins over Kerala state as per request of Central Water Commission.

(*ii*) Ranjit Sagar dam catchment area as per request of the Dam Authority

2. "South Asia Flash Flood Guidance system" is running in experimental mode for providing Flash flood guidance in South Asia Region *viz.*, Nepal, Bhutan, Bangladesh, Sri Lanka & India under the WMO project of Hydrological Research Centre (HRC), San Diego, USA (Fig. 1).

3. NWP model output forecast are operationally provided by IMD to CWC for the use in Hydrological modelling;

(*i*) GFS: spatial resolution 12 km x 12 km for Day-1 to Day-7.

(*ii*) WRF: spatial resolution 3 km x 3 km and 9 km x 9 km for Day-1 to Day-3.

4. Daily monitoring of Flood Situation & QPF issued by IMD provided to Central Agencies.

5. Enhancement of raingauge network in the Unrepresentative districts. 341 no. of new raingauge stations are added in the DRMS.

6. Daily Rainfall Statistics is started to prepare throughout the year on spatial domain of district, Subdivision, state wise & country as a whole during the year.

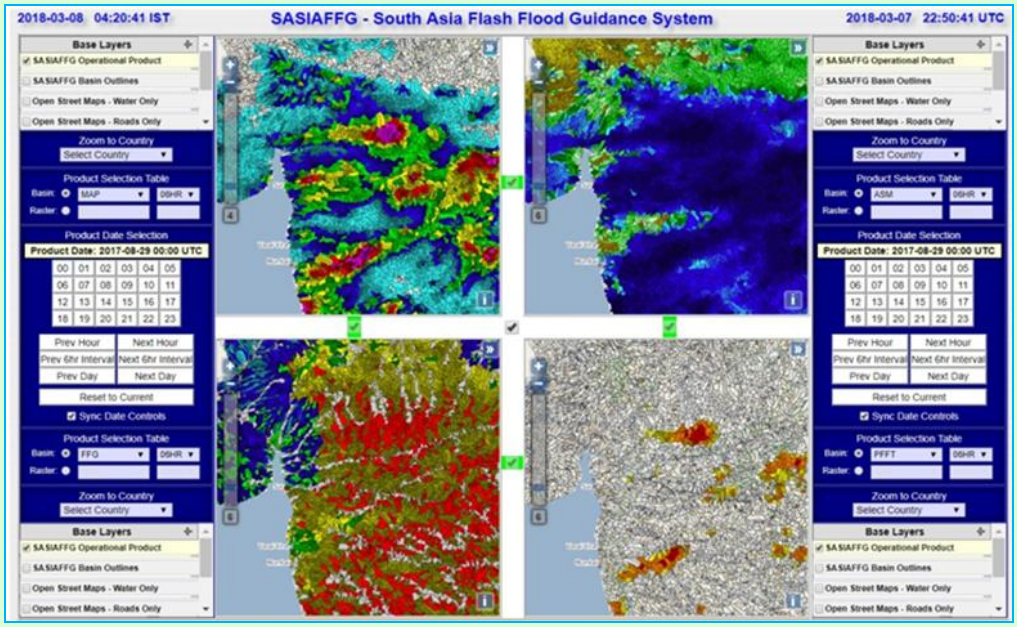


Fig. 1. South Asia Flash Flood Guidance system

Flood Meteorological Services

The sub-basin wise QPFs were issued (daily on operational basis) by FMO Agra, New Delhi, Asansol, Ahmedabad, Bhubaneswar, Guwahati, Jalpaiguri, Hyderabad, Lucknow, Patna, DVC Met Unit Kolkata, MC Srinagar, RMC Chennai and MC Bengaluru during the monsoon season 2018 for their area of jurisdiction (from 1st June to October 2018). RMC Chennai and MC Bengaluru continued to issue QPFs upto 31st December, 2018. These operational QPF were provided to the field offices of Central Water Commission for the use in their Flood Forecast Model.

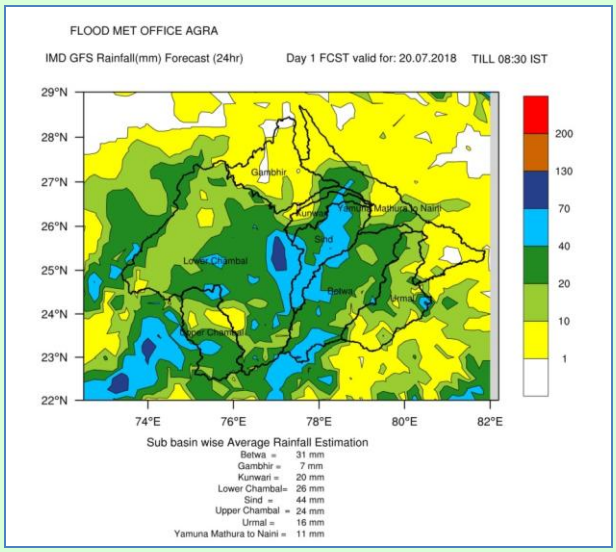


Fig. 2. IMD GFS Rainfall forecast - Agra

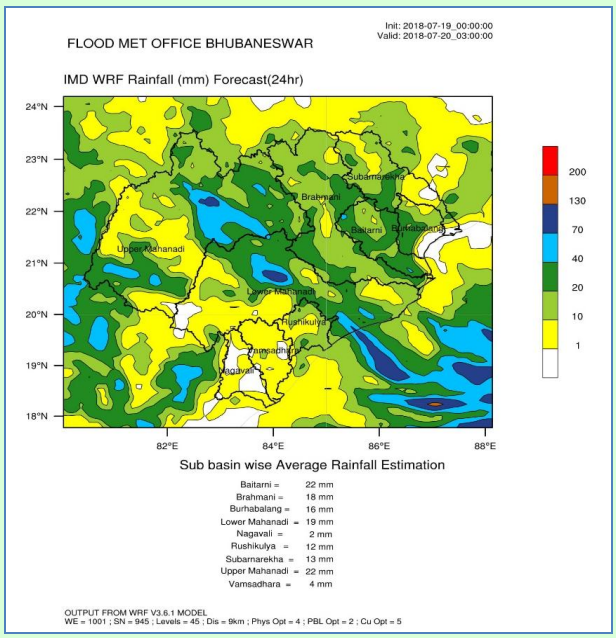


Fig. 3. IMD WRF Rainfall forecast - Bhubaneshwar

Sub basin-wise Quantitative Precipitation Estimate for Day-1, Day-2, Day-3, using WRF ARW (9 km x 9 km) based on 0000 UTC & 1200 UTC, for Day-1 to Day-5 MME (0.25° x 0.25°) based on 0000 UTC and Day-1 to Day-7 using GFS (0.25° x 0.25°) based on 0000 UTC run by IMD are computed and uploaded on IMD website operationally.

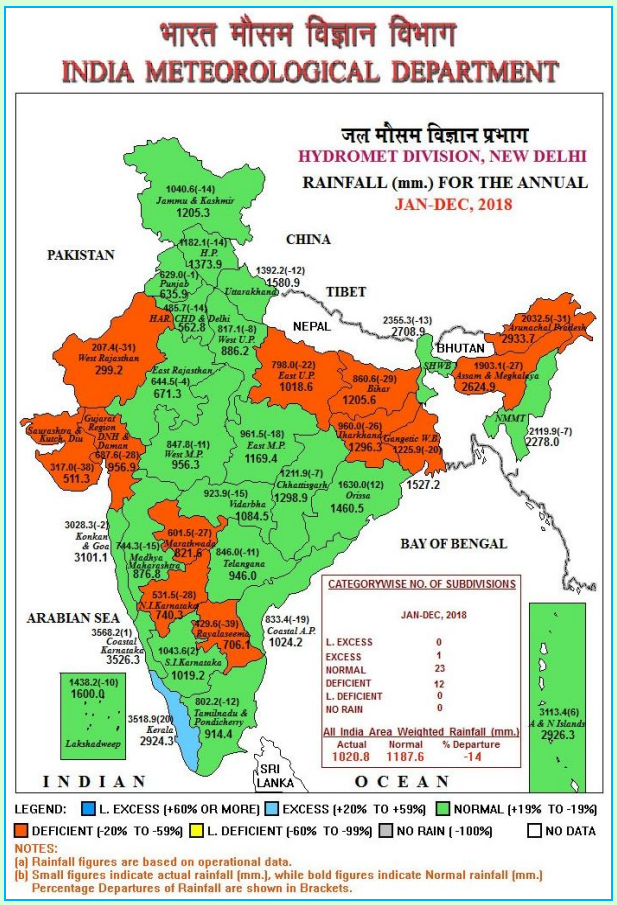
Design storm Estimates

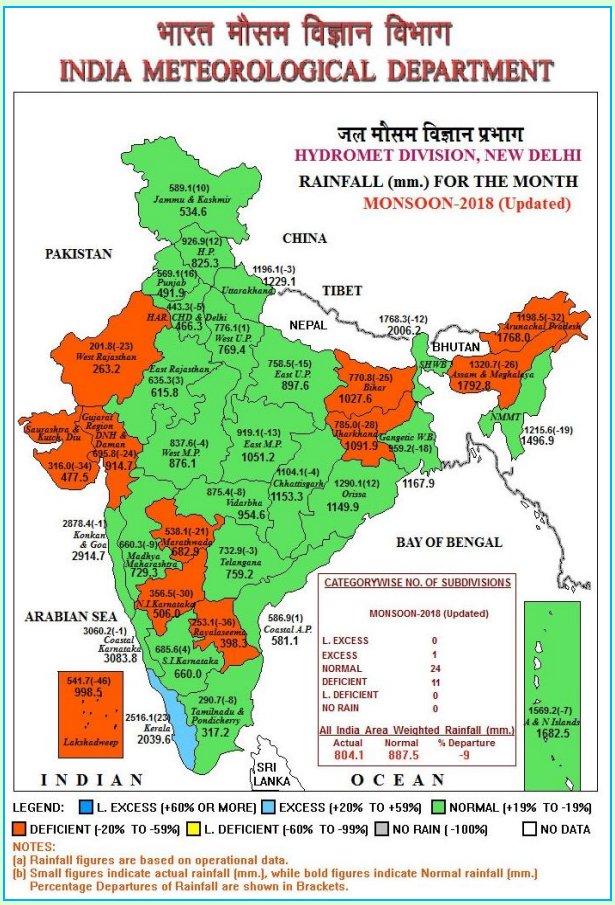
Design Storm Studies are being conducted to evaluate design storm estimates (rainfall magnitude and time distribution) for various river catchments/ projects in the country, for use as main input for design engineers in estimating design flood for hydraulic structures, irrigation projects, dams etc. on various rivers. This estimation of design values is required for safe and optimum design of storage and spillway capacity. On the request of Central Govt./State Govt., Private Agencies, design storm values (Standard Project Storm, Probable Maximum Precipitation along with Time Distribution) are being provided for users as main input. For Govt. agencies, these studies are being carried out and supplied free of cost where as for private / profit earning agencies on payment basis. The project reports containing the design storm studies are being sent in respect of the projects on payment basis.

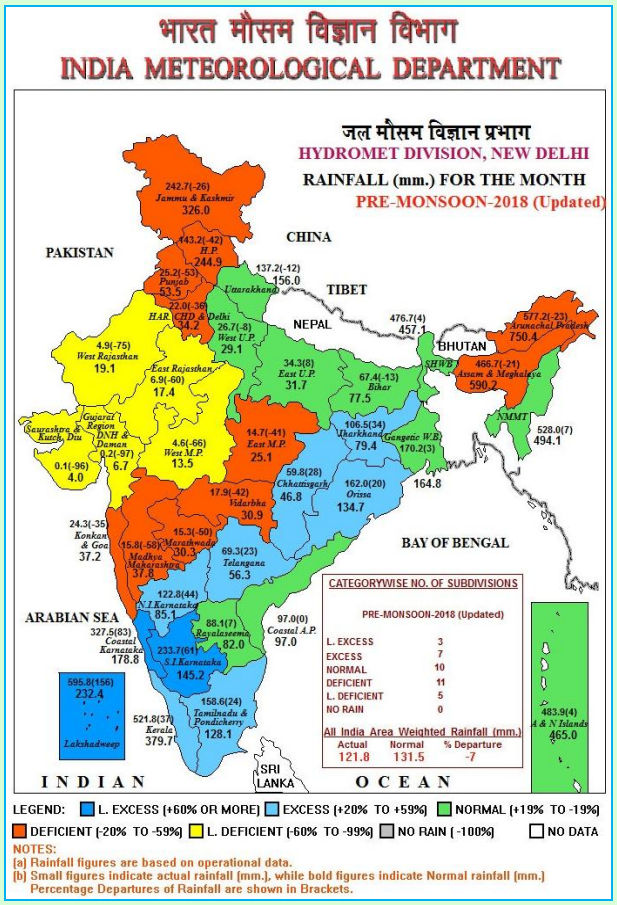
During the year 2018, design storm studies of twelve projects have been completed and results communicated to the concerned project authorities. An amount of Rs.23,63,589/- (Rupees Twenty Three lakh Sixty Three Thousand Five Hundred Eighty Nine only)has been deposited in IMD's A/c for carrying out the design storm studies in respect of projects received from private/profit earning agencies.

Rainfall Monitoring

Hydromet Division brings out real-time rainfall summary every week from Thursday to Wednesday and also for months. During Monsoon season, the same is prepared on daily basis for 660 Districts, 36 Met. Sub







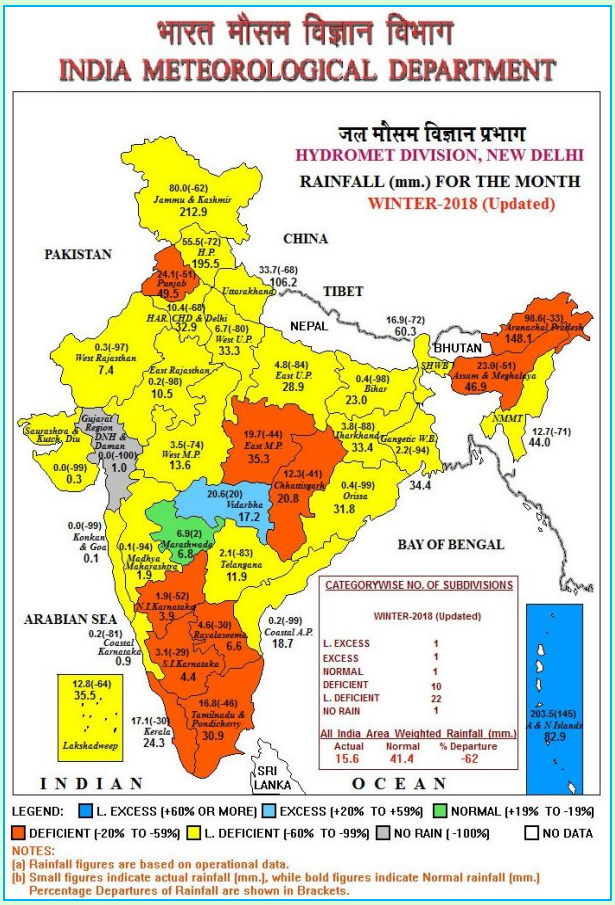


Fig. 4. Subdivision-wise rainfall map of India during 2018

TABLE 1

Subdivision-wise rainfall (mm) distribution

S. No.	Meteorological Sub-divisions	Annual (Actual)	January-December, 2018		
			Normal	% Dep.	Cat.
	EAST & NORTH EAST INDIA	1561.5	2037.8	-23%	
1.	Arunachal Pradesh	2032.5	2933.7	-31%	D
2.	Assam & Meghalaya	1903.1	2624.9	-27%	D
3.	N M M T	2119.9	2278.0	-7%	N
4.	SHWB & Sikkim	2355.3	2708.9	-13%	N
5.	Gangetic West Bengal	1225.9	1527.2	-20%	D
6.	Jharkhand	960.0	1296.3	-26%	D
7.	Bihar	860.6	1205.6	-29%	D
	NORTH WEST INDIA	745.4	866.9	-14%	
1.	East U.P.	798.0	1018.6	-22%	D
2.	West U.P.	817.1	886.2	-8%	N
3.	Uttarakhand	1392.2	1580.9	-12%	N
4.	Haryana, Chandigarh & Delhi	485.7	562.8	-14%	N
5.	Punjab	629.0	635.9	-1%	N
6.	Himachal Pradesh	1182.1	1373.9	-14%	N
7.	Jammu & Kashmir	1040.6	1205.3	-14%	N
8.	West Rajasthan	207.4	299.2	-31%	D
9.	East Rajasthan	644.5	671.3	-4%	N
	CENTRAL INDIA	999.7	1111.0	-10%	
1.	Odisha	1630.0	1460.5	12%	N
2.	West Madhya Pradesh	847.8	956.3	-11%	N
3.	East Madhya Pradesh	961.5	1169.4	-18%	N
4.	Gujarat Region	687.6	956.9	-28%	D
5.	Saurashtra & Kutch	317.0	511.3	-38%	D
6.	Konkan & Goa	3028.3	3101.1	-2%	N
7.	Madhya Maharashtra	744.3	876.8	-15%	N
8.	Marathwada	601.5	821.6	-27%	D
9.	Vidarbha	923.9	1084.5	-15%	N
10.	Chhattisgarh	1211.9	1298.9	-7%	N
	SOUTH PENINSULA	1049.2	1128.3	-7%	
1.	A & N Island	3113.4	2926.3	6%	N
2.	Coastal Andhra Pradesh	833.4	1024.2	-19%	N
3.	Telangana	846.0	946.0	-11%	N
4.	Rayalaseema	429.6	706.1	-39%	D
5.	Tamilnadu & Puducherry	802.2	914.4	-12%	N
6.	Coastal Karnataka	3568.2	3526.3	1%	N
7.	N. I. Karnataka	531.5	740.3	-28%	D
8.	S. I. Karnataka	1043.6	1019.2	2%	N
9.	Kerala	3518.9	2924.3	20%	E
10.	Lakshadweep	1438.2	1600.0	-10%	N
	Country as a whole	1020.8	1187.6	-14%	

Divisions, 36 States including UTs, 4 Regions and for the country as a whole. Besides this, rainfall statistics is also prepared for **61 selected River basins** of India and the maps are uploaded on IMD website. The Unit also brings out updated monthly, seasonal and annual rainfall statistics after incorporating the late receipt data. Rainfall Monitoring Unit also publishes Annual Rainfall Report.

The rainfall summary is used by various stake holders for multiple purposes like Agricultural planning and advisories, Crop yield forecast, Agricultural pricing, Estimation of irrigation requirements, Relief measures, Hydro-power Planning and many other economical and research activities.

Recipients of rainfall statistics include higher authorities like Office of Hon. Prime minister, Secretary MoES etc.

Updated rainfall statistics for the Annual- 2018 has been prepared. The rainfall for the country as a whole for the annual rainfall has been recorded as 1020.8 mm against the normal rainfall for the annual as 1187.6 mm (departure -14%). In all, 01 met sub-divisions remained in category of Excess rainfall, 23 in Normal and 12 in Deficient rainfall. The subdivision-wise updated rainfall map for the annual, 2018 is given in Fig. 4 & Table 1.

5.2. AGROMETEOROLOGICAL ADVISORIES SERVICES

Agromet Advisory Services (AAS) under Gramin Krishi Mausam Seva (GKMS) scheme:

(a) Preparation of Agromet Advisory Service (AAS) bulletins

(*i*) AAS bulletins have been prepared and issued at district and state level on every Tuesday & Friday and National level on every Friday to cater to the needs of users at various levels. The district level AAS bulletins are prepared and issued by 130 Agromet Field Units (AMFUs) located in State Agricultural Universities, ICAR institutes, IITs etc. The bulletins include past weather, medium range weather forecast for next 5 days and specific advisories on field crops, horticultural crops, livestock etc. At present these bulletins are issued for 658 districts in the country.

(*ii*) IMD in collaboration with CRIDA, Hyderabad issued Operational AAS bulletin based on Extended Range Weather Forecast on every Friday to help farmers to cope with climate risks and uncertainties.

(b) Dissemination of agromet advisories

(*i*) Dissemination of agromet advisories to the farmers through different multi-channels like All India Radio (AIR) and Door Darshan, private TV and radio channels, newspaper and internet, SMS and IVR (Interactive Voice Response Technology) etc. is being carried out on wider scale. Under Public Private Partnership (PPP) mode, Reliance Foundation, IFFCO Kisan Sanchar Limited (IKSL), Mahindra Samriddhi, Kisan Sanchar etc. are disseminating agromet advisories in SMS and IVR format to the farming community. Agromet Advisories are being disseminated in both Regional and English languages through "Kisan SMS", a portal (http://farmer.gov.in/advs/login.aspx) launched by the Ministry of Agriculture, Government of India. In addition to that, numbers of AMFUs have been sending agromet advisories through SMS in collaboration with Agricultural Technology Management Agency (ATMA)/ KVKs. At present 40.1 million farmers are receiving SMS and benefitted by this service directly. Weather forecast and advisories under alerts and warnings during extreme weather events are also issued through SMS which enable the farmers in planning appropriate farming operations to minimize damage of crops under adverse weather conditions.

(*ii*) In addition to above, Crop Specific Weather based Agromet Advisories for the country are being telecast on Tuesday and Friday through DD Kisan Channel in programs like 'Kisan Samachar' and 'Mausam Khabar' in Hindi and Marathi.

(*iii*) **Disaster Support:** During the recent Cyclonic storms **Daye** (19-22 September), **Titli** (8-11 October) and **Gaja** (14-16 November), alerts were issued by Agromet Field units **Anakapalli, Bhubaneshwar and Karaikal** to

the farming community in the form of SMS thorough mkisan Portal of Ministry of Agriculture. **13,40,669** farmers were benefited from this service.

(c) Agromet Products

Agrimet Division has started generation of following agromet products for operational use in AAS. All these products are being generated under PAN India modeusing geospatial technology and areuploaded in the Division's website and communicated to the AMFUs for preparation of more accurate agromet advisories at district level.

(*i*) Soil Moisture: Realized (Daily) and Forecasted (twice a week on Tuesday & Friday).

(*ii*) Spatial variation of weather parameters at different temporal scales (Fig. 5).

(*iii*) Soil temperature and evaporation on daily and weekly scale (Fig. 6).

Satellite products: Agrimet Division is generating following satellite products (Fig. 7).

(*i*) Normalized Difference Vegetation Index (NDVI)

(*ii*) Reference Evapotranspiration and Insolation mapsin collaboration with SAC Ahmedabad

(*iii*) Vegetation Condition Index (VCI)

(*iv*) Vegetation Health Index (VHI)

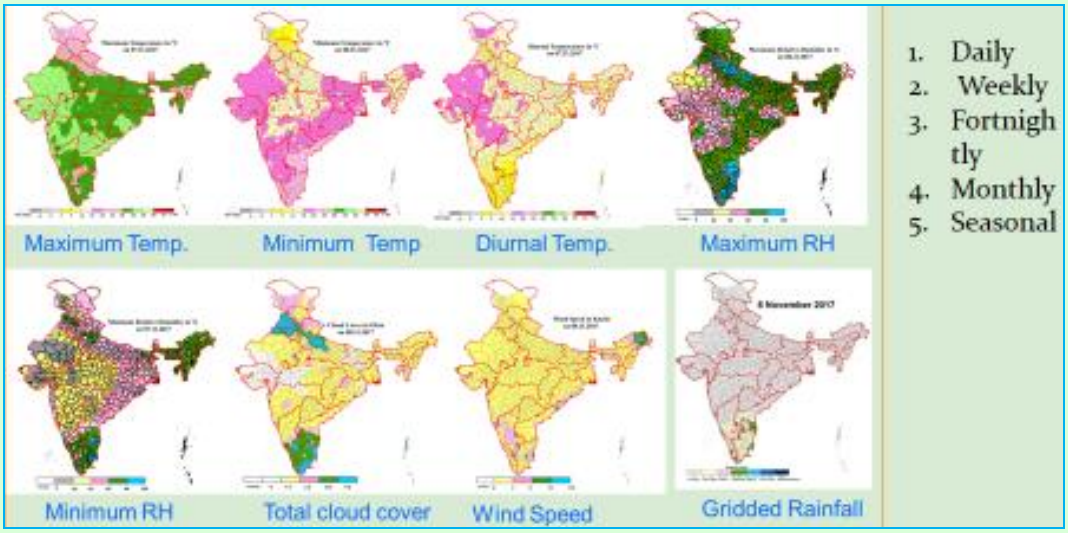


Fig. 5. Spatial Variation of Weather Parameters at different temporal scales using surface observatory Data

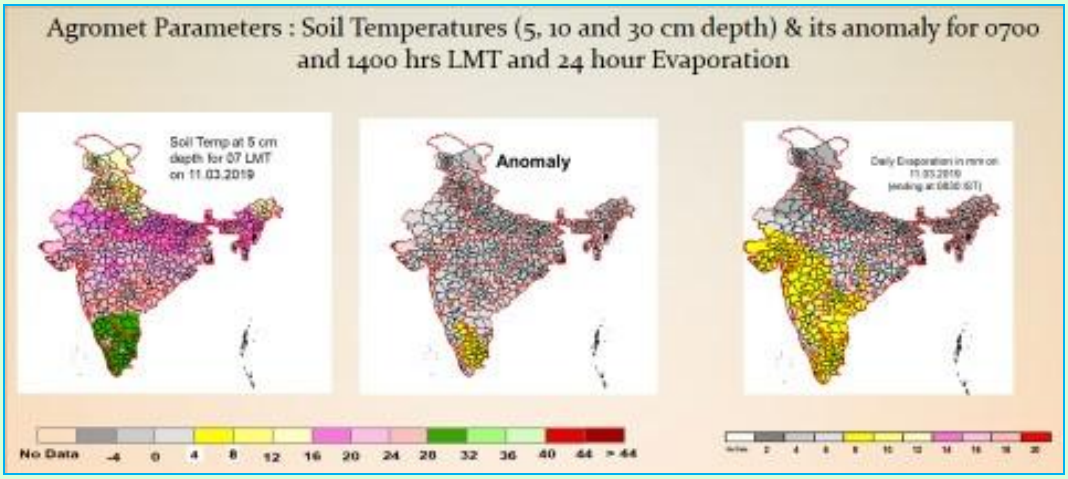


Fig. 6. Soil temperature and Evaporation

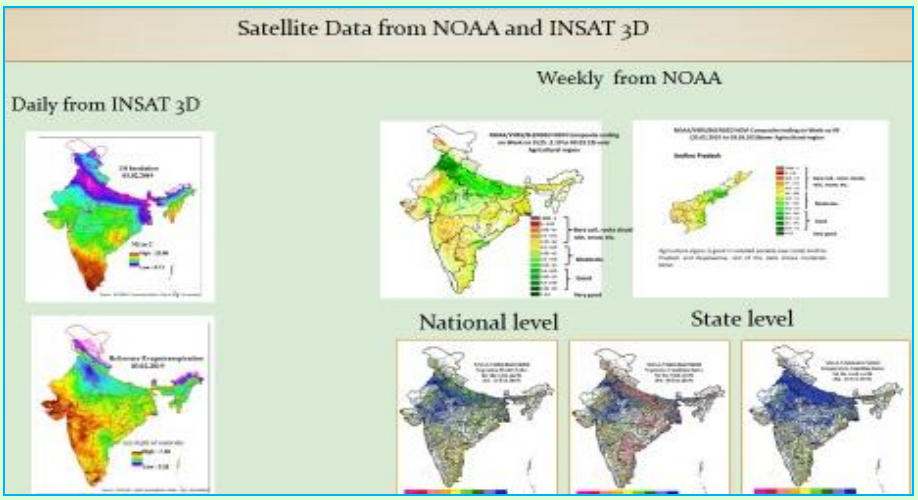


Fig. 7. Satellite Data Products

Fig. 8. Display of Spatial Weather parameters in Bhuvan Portal

(d) Display of Agromet Products in BHUVAN Portal of NRSC, Hyderabad

Agrimet Division started display of spatial distribution of weather parameters at different temporal scales in BHUVAN Portal developed by National Remote Sensing Centre, Hyderabad on daily basis (Fig. 8).

(e) Research & Development Project on AAS

(*i*) Agrimet Division, IMD Pune in collaboration with NIC, Pune developed software for online verification of value added forecasts on experimental mode. Presently gridded rainfall (0.25 × 0.25) and Temperature (0.5 × 0.5) is used for verification (Fig. 9).

(*ii*) Agromet Decision Support System: Agromet-DSS-software has been developed by Agromet Advisory Services Division (AASD) of IMD powered by RIMES (The Regional Integrated Multi-Hazard Early Warning System for Africa and Asia) for value addition of district level weather forecast by RMCs/MCs (Fig. 10). It has been made operational from 1st September, 2018.

12th Annual Review Meeting (ARM) under "GKMS projectin the country was organized from 3rd to 5th December, 2018, jointly by India Meteorological Department (IMD) and Acharya N.G. Ranga Agricultural University at Regional Agricultural Research Station (RARS), Tirupati andhra Pradesh for strategic planning for improvement of Agromet advisory services.

Fig. 9. On line verification of district level weather forecast

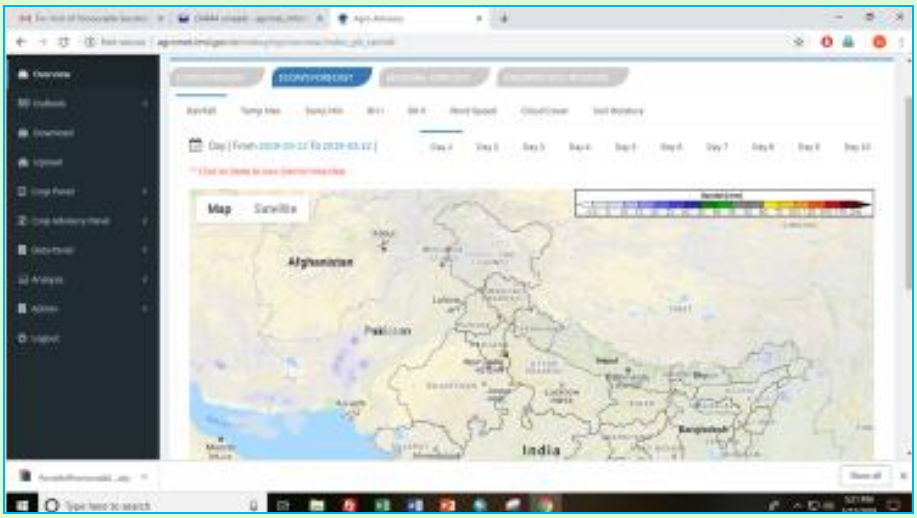


Fig. 10. Agromet Decision Support System

5.3. POSITIONAL ASTRONOMY SERVICES

With a view to developing astronomical and astrophysical studies in India as envisaged by the planning committee constituted by the Govt. of India in 1945, a small unit, known as Nautical Almanac Unit, was set up under CSIR at Calcutta. Although the Govt. of India used Gregorian calendar for official use, divergent practices of calendar keeping were in vogue during the period of post independence of the country. A need was felt by the Government to develop a unified National Calendar on the basis of the most accurate modern astronomical data in the interest of national integrity. Keeping these in view, a Calendar Reform Committee was formed in 1952 under the CSIR with Late Prof. Meghnad Saha as the Chairman. The Committee recommended preparation of the Indian Ephemeris and Nautical almanac (renamed as Indian Astronomical Ephemeris from 1979 issue) incorporating therein usual astronomical data calculated with most modern astronomical formula, to publish the National Calendar of India (using Saka Era) in the form of Rashtriya Panchang with Solar Calendar system for civil use and Luni solar Calendar system for religious use. It was decided that these works should be done by the Nautical Almanac Unit. This Unit was taken over by the India Meteorological Department from CSIR on 1st December, 1955 and put under Regional Meteorological Centre, Calcutta. On 1st December, 1979, following the recommendations of Dr. Ramanna Committee, the centre was made an independent centre and renamed as Positional Astronomy Centre. It was then brought under the direct administrative control of DGM. A standing advisory committee consisting of eminent experts in the field of astronomy advices DGM on technical matters and future scientific programs of the centre.

Positional Astronomy Centre is the nodal office of the Govt. of India to generate data on Positional Astronomy and to publish the same in the form of annual publications *viz.*, The Indian Astronomical Ephemeris. It is also performing pivotal role in implementing the recommendations of two committees, one already mentioned earlier as Calendar Reform Committee and other one constituted later on and named as Peer Review Committee, through publication of Rashtriya Panchang in 14 languages. India is one of the 7 countries in the world having an ephemeride office like this centre and publishing the Indian Astronomical Ephemeris. The centre issues the following 16 publications annually.

(i) The Indian Astronomical Ephemeris

(ii) Tables of Sunrise-Sunset, Moonrise-Moonset

(iii) Rashtriya Panchang in 14 languages namely-English, Hindi, Urdu, Sanskrit, Assamese, Bengali, Gujrati, Kannada, Malayalam, Marathi, Oriya, Punjabi, Tamil& Telegu.

The centre also fixes up dates of all India festivals for all communities for declaration of holiday by Central & State Govt.

The centre also meets specific data requirements of a large number of users including Govt. organizations, non Govt. organizations, professional astronomers, research scholars, various panchang makers, general public etc.

This centre also provides five years advance accurate calendric data to many leading panchang makers of the country for preparation of their own Panchangs.

The centre also contributes to a great extent in popularizing astronomy through publication of monthly astronomical bulletin and star charts (presently star charts are being prepared on computer), issuing press release on different astronomical events through various print media, attending live discussions on various electronic media etc.

This centre also takes observation on special astronomical events from time to time with the help of its portable telescopes at different places of the country.

ACTIVITIES DURING THE YEAR 2018

1. The Indian Astronomical Ephemeris for the year 2019, an annual publication of Positional Astronomy Centre, which mainly contains positional data of the Sun, Moon and planets, basic data on yearly positions of fundamental stars, diary of celestial events, calendric data, eclipse data, explanatory text and other useful information on astronomy has been published both in hard copy and soft copy format.

2. Fourteen language editions of Rashtriya Panchang of 1940 SE (2018-19 AD) and Sunrise-Sunset and Moonrise-Moonset tables for 2019 have been published during the year 2018. These are important regular publications of the centre catering to daily need of users of almanac, Panchang makers and other users.

3. Web based service has been started by the centre by creation of electronic versions of 14 language editions of Rashtriya Panchang and Indian Astronomical Ephemeris which can be accessed by the users through the PAC Kolkata website.

4. A pocket-type, card-size calendar containing brief information on important celestial events during the year 2018 has been published in for benefit of users.

5. The centre has prepared monthly star charts and astronomical bulletins for 12 months during the year 2018 for giving useful guidance for watching celestial objects in the night sky. The bulletins contain brief texts explaining positions of objects in the sky and celestial diagrams showing positions for practical demonstrations.

6. The 26th Standing Advisory Committee meeting of PAC, Kolkata was held on 5th February, 2018 at PAC Kolkata office under chairmanship of Prof. G. M. Ballabh, Retd. Prof., Osmania University, Hyderabad. The meeting was attended by other distinguished members of the Committee. The Committee made some important recommendations for overall improvement in the functioning of the Centre.

7. A four day refresher course on Astronomy was organized by PAC Kolkata during 6 to 9 February, 2018 at PAC, Kolkata for officers of PAC and RMC Kolkata for imparting knowledge on Positional and Calendric Astronomy to the officials.

5.4. FOG FORECASTING SERVICES

Fog Monitoring

- Total 18 number of RVR of IGIA
- Five numbers of AWOS/DCWS
- RAPID-INSAT 3-D of IMD at each 30-minute gap using various Channels or their combination in RGB and day-night cloud-fog detection mciro-physics
- Data from following instruments especially deployed under winter fog experiment (WIFEX) since mid November 2017 at IGI Airport Delhi jointly by IITM-IMD under Ministry of Earth Sciences, Govt of India was also fully used
- Radiometer
- SODAR
- Ceilometer (newly added and functional in 2017-18)

Fog forecast /Early warning system

- Past real time events over an area at Synop or large-scale-A Process based forecast system based upon Climatological and synoptic Spatial pattern types (Self triggering phase with STR-Wind conditions, High low pollution phase, WD phase, CS/Easterly wave related blocking/Phase
- Location based Threshold and checklist based
- Threshold table using IMD surface and upper air of local data e.g., min. temp, RH etc.
- Climatological and Synop spatial based Checklist/Pattern method by ridge line and winds, etc using GFS products (FDP-Winter products, GFS Fog products and GFS forecast of large-scale/local wind and other parameters)
- Real time Trends from real time data (RAPID, Surface, UA inversion data)
- Location based trend using Rapid online analysis system using Reflectivity/BTD/RGB values
- IITM Fog campaign data-MARGA, Radiometer and Cileometer data
- Trends of require parameters from DWR/RVR/AWS/Synop network of Delhi

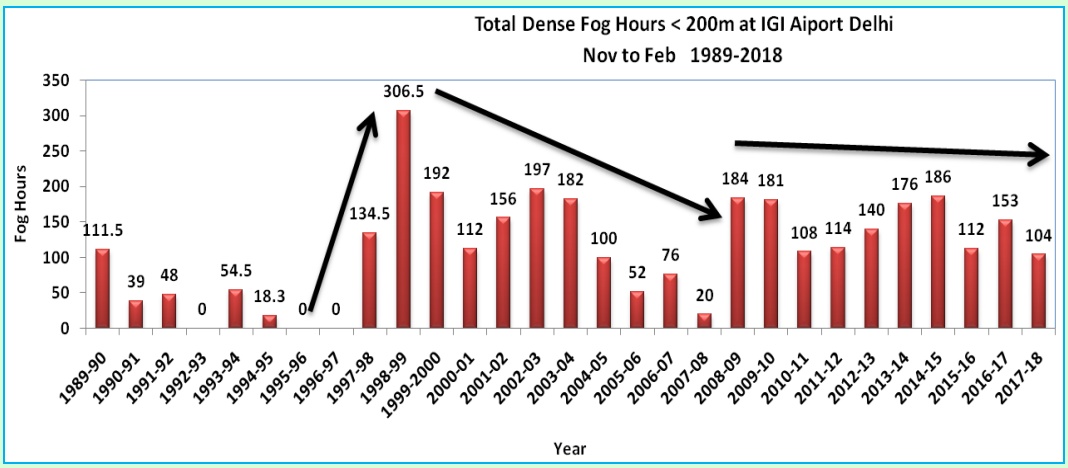


Fig. 11. Overall trends of total occurrences of season dense fog hours for Nov-Feb at IGIA 1989-2018

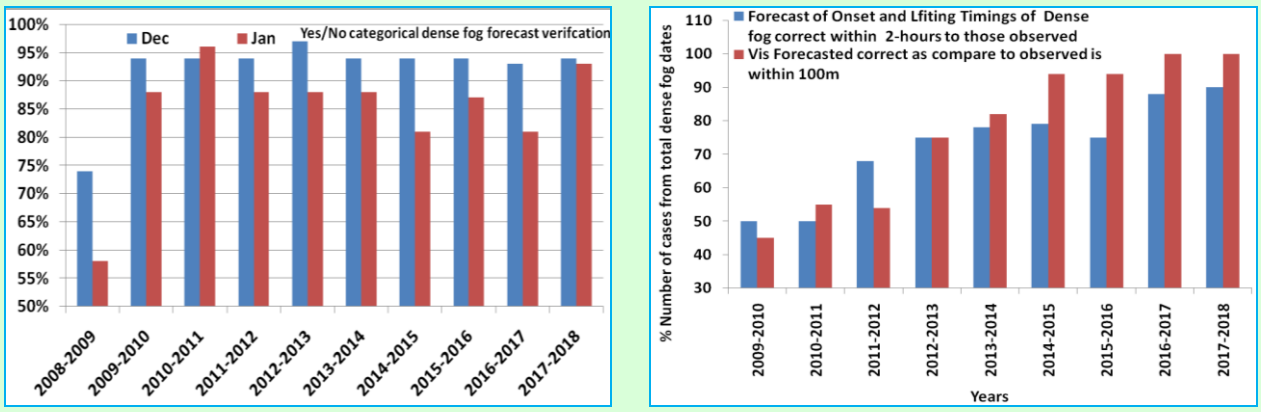


Fig. 12. On progress 2008-2018 categorical fog forecast (dense fog) and 2009-2018 timings of onset/lifting and min visibility forecast

Objective/NWP based fog forecasts using fog Models

- IMD Empirical Fog model of intensity and duration based fog forecast System.
- Experimental spatial intensity based NCUM spatial fog forecast map from NCMRWF for 24, 48, 72 hours.
- IITM WRF based Fog Model for 24 hours Visibility forecast at 2 Km resolution Delhi Region at 24 hours lead time.

Occurrences of fog events in 2017-18 at IGIA Palam Delhi and Performance of its real time fog forecast system

The MWO Delhi has been successful in adopting a new web based Fog monitoring, nowcasting, forecasting and dissemination system in Winter of 2017-18 with achieving of higher skill in fog forecast and in robustness of RVR functioning with backup system, live RVR and RAPID-RGB based night time fog detection. Occurrences of fog events and Skill of fog forecast in winter 2017-18 at IGIA shows in November, December, January, February of 2017-18, IGIA had reported total number of CAT-III ILS dense fog events as 2/10, 5/19, 12/73 and 1/2 of days/hours respectively with all winter total of 20 days and 104 hours of dense fog.

Comparison of WIFEX 2015-18-WRF Delhi fog model based forecast products with those observed at IGIA also undertaken for 2015-18 and it shows Yes/no dense fog forecast at 4-12 hours lead time in 2015-18 has huge improvement (from 30% to 74%). The skill in % correct for daily forecast issued at real time for aviation use by MWO Delhi for IGIA on occurrences and non occurrences of dense fog (yes/no forecast the categorical verification), for peak months Dec-Jan, 2017-18 is 94% and for timing of onset and lifting against those observed timings within 0-2 hours is 90% of dates while the skill of Lowest visibility forecasted against observed has been 100%, for both were within 100 m range. In overall progress in the skill of fog freocast for whole 2008-18, shows forecast skill during 2008-2018 (Figs. 11&12) for yes/no dense fog forecast and onset lifting timings forecast have improved from 54% (54%) to 94% (93%) for Dec(Jan) with respective onset/lifting timings with 2-h of range and lowest vis forecasting to observed from 50% (45%) to 90% (100%) respectively while in terms of impact on air traffic, during the period of 2009-2017, total observed hours of CAT-III dense fog at IGIA fluctuated within 130-200 hours while flight diversion reduced from 200 to just 10-30 numbers. This impact is so higher that such reduction of flight impact observed irrespective of increase of air traffic from 450 operations to 1300 during this 8-winter fog period All such Fog information systems has also helped in improvement of MET-ATFM-Airline utility impact through right stake holders coordination system such as Fog-CDM cell operational at AOCC, minimizing air traffic - A rare in IMD history in this service sector.

Major Achievements by MWO IGIA Palam Delhi in 2018

- **In QMS and ISO Certification:** MWO IGIA Delhi is the first Airport Met office in India to get ISO 9001-2015 class of certification.

- First Airport Met office in India started Terminal weather information display system in collaboration with airport operator.

- First Airport Met office in India implemented MET-ATFM integration at real time operational since January 2018 by starting AAI-MET-ATFM-DIAL-Airlines-Airsides collaboration decision making (CDM) during severe weather by timely providing early weather warning and trend at lead time 2-6 hours and latest airport MET report for early traffic measures/ restriction from likely bad weather thorough operational of CDM cell at AOCC building and ATFM cell operational at IGIA.

- MWO Delhi has made availability of all METARS of IAF stations to civil airlines operational under IMD OLBS from Oct 2018.

- **Record number of Flight weather briefings in 2018 at IGIA by MWO IMD IGIA Delhi to Scheduled/Non Scheduled flights and to respected VVIP flights:** Analysis of Past Records stored at OLBS of MWO Delhi at http://olbs.amssdelhi.gov.in/ shows, it has delivered successfully briefings to a total of 52000 number of flight for Jan-Nov, 2018 through OLBS covering all scheduled and non-scheduled flights operated in Delhi region.

- **In carrying out safety inspection of AMO/AMS from time to time which are under its responsibility:** Completed Safety Audit of a record number of seven Airports (IGIA Palam Delhi, Lucknow, Jaipur, Babatpur, Pantnagar, Dehradun, Udaipur) in the region which helped further to improve aviation met services as per ICAO standards. It was conducted as per ICAO Format of Safety Audit checklists (total 27 pages) for each airports.

- **In conducting GPS based visibility landmark field survey at AMO/AMS routinely which are under its responsibility and updating of Visibility polar diagram a key to airport operation:** In 2017-18, it has completed at total of now twelve numbers of major Airports in the region (IGIA Delhi of MWO Palam, Rohini, Shimla, Hisar, Pithoragara, Lucknow, Jaipur, Babatpur, Pantnagar, Dehradun, Udaipur, Kishangarh). In all case, we use GPS based system upto 10-12 km around each airports and prepared excellently well plotted hard copy with all of them glass bonded photo type.

- In helping new airport operations and providing aviation met service under RCS-UDAN Project.

5.5. CYCLONE MONITORING & PREDICTION

5.5.1. Annual Characterstics of Cyclonic disturbances during 2018

There were 14 cyclonic disturbances (CDs), *i.e.*, depressions and cyclones over the north Indian Ocean (NIO) & adjoining land regions during 2018 against the long period average (LPA) of 12 disturbances per year based on satellite era during 1961-2017. Out of 14 CDs, 7 intensified into tropical cyclones against the normal frequency of 4.5 cyclones per year over north Indian Ocean (NIO) during satellite era (1961-2017). Last such development of seven cyclones in a year occurred in 1985 (33 years before). It included including 2 cyclonic storms (CS), 1 severe cyclonic storm, 3 very severe cyclonic storms (VSCS) and 1 extremely severe cyclonic storm (ESCS). Arabian Sea was more active with 3 cyclones against an average of 1 per year. In May, back to back cyclones Sagar and Mekunu formed over Arabian Sea within a week. Last such development of two cyclones over Arabian Sea in quick succession occurred in 2015 (Chapala and Megh). The cyclonic storm, Sagar was the first cyclone to cross the coast to the west of 45° East and travelling upto Ethiopia across Gulf of Aden and western Somalia. The cyclone, Mekunu was an extremely severe cyclonic storm,

which crossed Oman coast. It was the most intense cyclone which crossed Oman coast during satellite era. It had maximum sustained wind speed of 95 knots at landfall over Oman coast. The Cyclonic Storm, Daye developed in monsoon season (in the month of September). The last cyclone in September formed in 2005. During October, two very severe cyclonic storms, Luban and Titli formed over Arabian Sea and Bay of Bengal simultaneously. Such activity of simultaneous occurrence of two severe cyclonic storms over the Bay of Bengal and Arabian Sea was last observed in November 1977. The cyclone Titli had northeastward recurvature across Odisha after landfall over north Andhra Pradesh and adjoining south Odisha coasts as a very severe cyclonic storm with maximum sustained wind speed of 80 knots. The very severe cyclonic storm, Luban had multiple recurvature and weakening before landfall over Yemen coast. It crossed Yemen and adjoining Oman coast as a cyclonic storm with wind maximum sustained wind speed of 40 knots. In November very severe cyclonic storm Gaja with an anticlockwise recurving track, southwestward recurving track after the loop and with one of the longest tracks with a life period of about 10 days developed over Bay of Bengal and dissipated over Arabian Sea. The last such recurving track over the Bay of Bengal occurred in 1996. It had rapid intensification before landfall reaching upto 70 knots at the time of landfall over Tamil Nadu and Puducherry coasts. The Cyclonic storm Phethai developed in December with a recurving track. It recurved during and after the landfall over Andhra Pradesh coast and moved along the coast causing two landfalls over Andhra Pradesh coast (near south of Yanam at 0900 UTC followed by another landfall near Tuni at 1430 UTC of the same day, *i.e.*, 17th December, 2018). Thus, the year 2018 witnessed cyclones with all types of unusual characteristics like northeastward and southwestward recurving tracks, looping tracks, cyclogenesis in very quick succession, simultaneous development of two severe cyclones, rapid intensification before landfall and weakening before landfall.These cyclones are:

- ***Cyclonic storm, Sagar over Arabian Sea (16-21 May)***
- ***Extremely Severe Cyclonic storm, Mekunu over Arabian Sea (21-27 May)***
- ***Cyclonic storm, Daye over eastcentral Bay of Bengal and adjoining Myanmar (19-22 September)***
- ***Very Severe Cyclonic storm, Luban over eastcentral Arabian Sea (6-14 October)***
- ***Very Severe Cyclonic storm, Titli over eastcentral Bay of Bengal (8-13 October)***
- ***Very Severe Cyclonic storm, Gaja over eastcentral Bay of Bengal (10-19 November)***
- ***Severe Cyclonic storm, Phethai over Southeast Bay of Bengal (13-18 December)***

Regular bulletins were issued to disaster management agencies of central level and concerned states during the life period of various cclonic disturbances with frequent updates by sms and social networking sites.

Every three hourly TC Advisories were also issued to central & state level disaster managers, media, general public and WMO/ESCAP member countries, WMO and United Nations.

5.5.2. Characterstics of Cyclonic Storms during 2018

5.5.2.1. Cyclonic Storm, Sagar

The Cyclonic Storm (CS) Sagar originated over southwest Arabian Sea in the morning (0300 UTC) of 14th May. The observed track of the CS Sagar is shown in Fig. 13. The peak maximum sustained surface wind speed (MSW) of the cyclone was 80-90 kmph gusting to 100 kmph (45 knots) during 0000 UTC of

18th to 0300 UTC of 19th May. It crossed Somalia coast near latitude 10.65° N and longitude 44° E as a cyclonic storm with maximum sustained wind speed (MSW) of 70-80 kmph gusting to 90 kmph between 1330 and 1430 IST of 19th May. The CS, Sagar was the first cyclone to cross coast to the west of longitude 45° E during satellite era (since 1965).

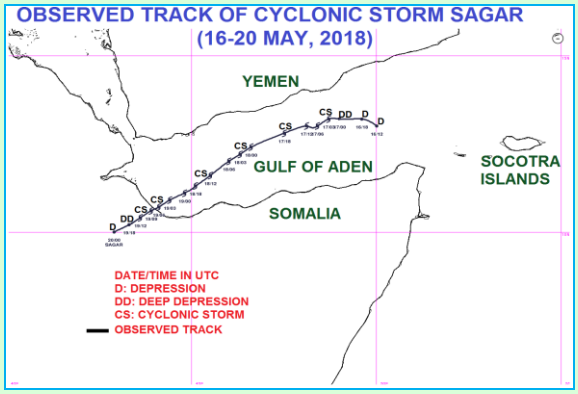


Fig. 13. Observed track of CS, 'Sagar' over Arabian Sea during 16-20 May, 2018

Forecast Performance

- First information regarding formation of a low pressure area over the central parts of south AS and adjoining central AS around 15th May and it's movement towards Yemen coast with further intensification into D in subsequent 48 hrs was predicted in Tropical Weather Outlook issued at (1130 IST) 0600 UTC of 11th May (72 & 108 hours in advance of formation of low pressure area & D respectively).

- First information regarding landfall of system near northwest Somalia (near 11.30° N/43.10° E) around 0900 UTC of 19th was issued at 1400 UTC of 17th May (42 hours in advance of actual landfall). The system crossed Somalia coast near 10.65° N/44.0° E between 0800-0900 UTC of 19th May.

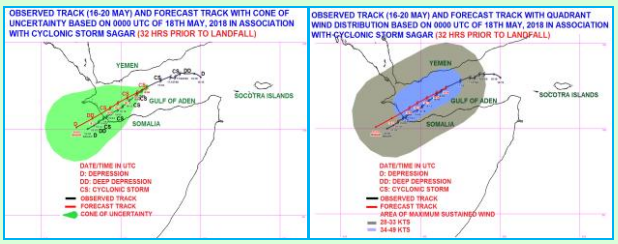
- First bulletin issued at 1500 UTC observations of 16th May indicated that the system would move west-northwestwards towards Yemen coast during next 24 hours and then west-southwestwards during subsequent 48 hours. The track shows that the system moved west-northwestwards upto 0300 UTC of 17th (for 15 hours) and then west-southwestwards till its weakening into a WML at 0300 UTC of 20th May (for subsequent 72 hours). Thus the track of the system including its west-southwestward recurvature was well predicted.

- The warning issued at 0200 UTC of 18th indicated that the system would cross Somalia coast as a CS with MSW of 65-75 kmph (37 knots) (32 hours in advance). The system crossed Somalia coast as a CS with MSW of 40 kts.

- The landfall point forecast errors for 12, 24 and 36 hrs lead period were 6.6, 40.4 and 100.5 km respectively and the landfall time forecast errors for 12, 24 and 36 hrs lead period were 1.0, 1.0 and 5.5 hrs respectively.

- The track forecast error for 12, 24 and 48 hrs lead period were 42.7, 49.6 and 117.2 km respectively, which is significantly less than the average track forecast errors of 57, 93 and 144 km during last five years (2013-17). The track forecast skill was about 18%, 53% and 64% against the long period average (LPA) of 45%, 55% and 68% during 2013-17 for 12, 24 and 48 hrs lead period respectively.

- The absolute error (AE) of intensity (wind) forecast for 12, 24 and 48 hrs lead period were 2.2, 7.0 and 10.8 knots against the LPA of 6.3, 10.4 and 15.5 knots respectively. The skill in intensity (wind) forecast based on AE for 12, 24 and 48 hrs lead period was 34.3, 17.6 and 46.3% against the LPA of 22.3, 37.1 and 56.8% respectively [Figs. 14(a&b)].



Figs. 14(a&b). Observed track of CS Sagar (16-20 May, 2018) and forecast track based on 0000 UTC of 18th May alongwith (a) Cone of uncertainty and (b) Quadrant wind distribution

5.5.2.2 Extremely Severe Cyclonic Storm, 'MEKUNU'

Extremely Severe Cyclonic Storm (ESCS) Mekunu originated from a low pressure area which formed over southeast Arabian Sea (AS) in the morning (0300 UTC) of 20th May. Under favourable environmental conditions, it concentrated into a Depression (D) over southwest AS in the evening (1200 UTC) of 21st May. Moving west-northwestwards it intensified into a deep depression (DD) in the morning (0300 UTC) of 22nd May. It then moved north-northwestwards and intensified into a cyclonic storm (CS) **"Mekunu"** in the evening (1200 UTC) of same day over southwest AS. It further continued to move north-northwestwards, intensified into a Severe Cyclonic Storm (SCS) in the morning (0300 UTC) and into a Very Severe Cyclonic Storm (VSCS) in the afternoon (0900 UTC) of 23rd May over Westcentral AS. Moving further north-northwestwards, it intensified into an Extremely Severe Cyclonic Storm (ESCS) in the morning (0300 UTC) of 25th, It attained its peak intensity on the day of landfall while lying close to coast and crossed south Oman coast near 16.85° N/53.75° E around midnight (between 1830-1930 UTC) of 25th May as an ESCS with an estimated wind speed of 170-180 kmph gusting to 200 kmph. It moved north-northwestwards and weakened into a VSCS over Oman in the early hours of 26th May (2100 UTC of 25th May). Continuing to move north-northwestwards, it weakened into an SCS in the early morning (0000 UTC), into a CS in the afternoon (0900 UTC) and into a DD around midnight (1800 UTC) of 26th May. It further weakened into a D in the early morning (0000 UTC) and into a well marked low pressure area over Saudi Arabia and adjoining Oman & Yemen in the morning (0300 UTC) of 27th May. Observed track of ESCS MEKUNU is shown in Fig. 15(a).

Forecast Performance

- It formed (at 1200 UTC of 21st May) just 5 days after the formation of CS Sagar (at 1200 UTC of 16th May) over Arabian Sea. Such cylogenesis in quick succession within a week last occurred over AS in post-monsoon season of 2015 (ESCS Chapala followed by ESCS Megh).

- The track length of the cyclone was 1385 km.

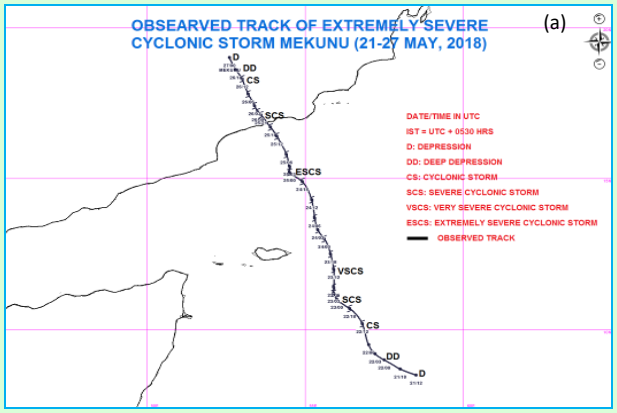


Fig. 15(a). Observed track of ESCS MEKUNU

- First information regarding formation of a low pressure area over southeast AS was given in Tropical Weather Outlook issued in the morning (0600 UTC) of 20th May with moderate probability (51-75%) of it's intensification into a D during next 24-48 hours (36 hours in advance of formation of D). D formed over southwest AS at 1200 UTC of 21st.

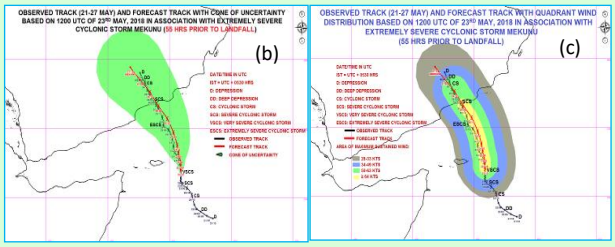
- First bulletin issued around noon (0600 UTC) of 20th May indicated that the system would move towards south Oman-southeast Yemen coasts (about 138 hours in advance of actual landfall).

- The landfall point forecast errors for 24, 48 and 72 hrs lead period were 17.2, 12.5 and 29.0 km respectively and the landfall time forecast errors for 24, 48 and 72 hrs lead period were 7.0, 8.0 and 7.0 hrs respectively.

- The track forecast error for 24, 48 and 72 hrs lead period were 48.8, 63.3 and 79.4 km respectively, which is significantly less than the average track forecast errors of 93, 144 and 201 km during last five years (2013-17). The track forecast skill was about 54.9%, 68.3%

and 71.6% against the long period average (LPA) of 45%, 55% and 68% during 2013-17 for 24, 48 and 72 hrs lead period respectively. The observed and forecast tracks of Mekunu are shown in Figs. 15(b&c).

- The absolute error (AE) of intensity (wind) forecast for 24, 48 and 72 hrs lead period were 5.5, 14.1 and 14.7 knots against the LPA of 10.4, 15.5 and 15.4 knots respectively. The skill based on AE of intensity (wind) forecast for 24, 48 and 72 hrs lead period was 74.9, 56.7 and 71.7% against the LPA of 37.1, 56.8 and 69.3% respectively.



Figs. 15. (b&c). Observed track of ESCS MEKUNU (21-27 May, 2018) and forecast track based on 1200 UTC of 23rd May alongwith (a) Cone of uncertainty and (b) Quadrant wind distribution

5.5.2.3. Cyclonic Storm, '*DAYE*'

Cyclonic Storm (CS) **Daye** originated from a low pressure area (LPA) which formed over eastcentral Bay of Bengal (BoB) and adjoining Myanmar in the afternoon (0900 UTC) of 18th September. It lay as a well marked low pressure area (WML) over the same region in the morning (0300 UTC) of 19th September. Under favourable environmental conditions, it concentrated into a Depression (D) over eastcentral BoB in the night (1500 UTC) of 19th September. Moving nearly west-northwestwards, it intensified into a deep depression (DD) over westcentral BoB in the morning (0300 UTC) of 20th September and further into a cyclonic storm (CS) "Daye" in the same night (1500 UTC). It crossed south Odisha and north Andhra Pradesh coast close to Gopalpur (Odisha) as a cyclonic storm with a wind speed of 60-70 kmph gusting to 80 kmph during 1900-2000 UTC of 20th September. It continued to move west-northwestwards, weakened into a DD in the early morning (0000 UTC) of 21st, into a D in the same evening (1200 UTC) and into a WML over west Madhya Pradesh and adjoining east Rajasthan in the evening (1200 UTC) of 22nd September. It lay as a WML over southeast Rajasthan in the morning (0300 UTC) of 23rd. It lay over north Rajasthan and adjoining southwest Uttar Pradesh & south Haryana in the early morning (0000 UTC) of 24th and lay as an LPA over south Haryana and neighbourhood on 24th morning. It became less marked on 25th morning. Observed track of CS DAYE is shown in Fig. 16.

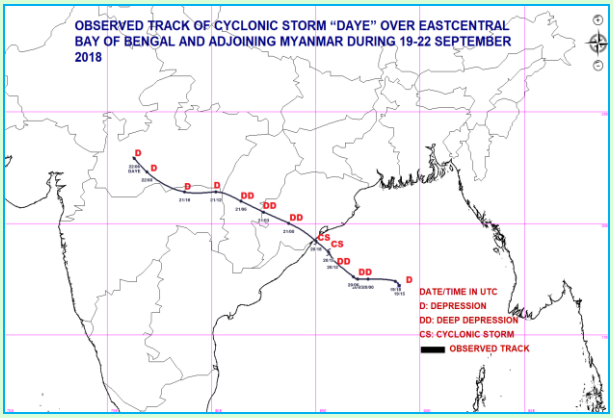


Fig. 16. Observed track of CS DAYE

- It is the first cyclonic storm to develop over the north Indian Ocean in the month of September after 2005 when the cyclonic storm, Pyarr crossed Andhra Pradesh coast near Kalingapatnam on 21st September, 2005.

- The track length of the cyclone was 1550 km.

- First information regarding formation of an LPA over the central & adjoining north BoB around 18th and low (1-25%) probability of it's intensification into depression around 19th was issued in the Tropical Weather Outlook at 0600 UTC of 16th September (about 54 hours in advance of formation of LPA & 84 hours in advance of formation of depression). Thereafrer, the probability of formation of depression was upgrated to moderate and high in the tropical weather outlook issued on 17-18 September. The LPA formed over eastcentral BoB and adjoining Myanmar at 0900 UTC of 18th and depression

formed over eastcentral BoB in the night (1500 UTC) of 19th.

- First information regarding west-northwestwards movement of system towards south Odisha-north Andhra Pradesh coasts was issued in Tropical Weather Outlook issued at 0600 UTC of 17th September (about 30 hours prior to landfall).

- The error in landfall point for 12 hours lead period was 39.7 km against long period average (LPA) (2013-17) of 29.7 km and the error in landfall time for 12 hours lead period was 3.5 hours against LPA of 2.3 hours.

- The track forecast error for 24 and 48 hrs lead period were 63.1 and 58.5 km respectively, which is significantly less than the average track forecast errors of 93 and 144 km during last five years (2013-17). The track forecast skill was significantly higher being about 85% and 93% against the long period average (LPA) of 55% and 68% during 2013-17 for 24 and 48 hrs lead period respectively. The observed and forecast tracks of Daye are shown in Fig. 17.

- The absolute error (AE) of intensity (wind) forecast for 24 and 48 hrs lead period were 1.1 and 6.1 knots against the LPA of 10.4 and 15.5 knots respectively. The skill in intensity (wind) forecast based on AE for 24 and 48 hrs lead period was 92.3 and 81.3% against the LPA of 37.1 and 56.8% respectively.

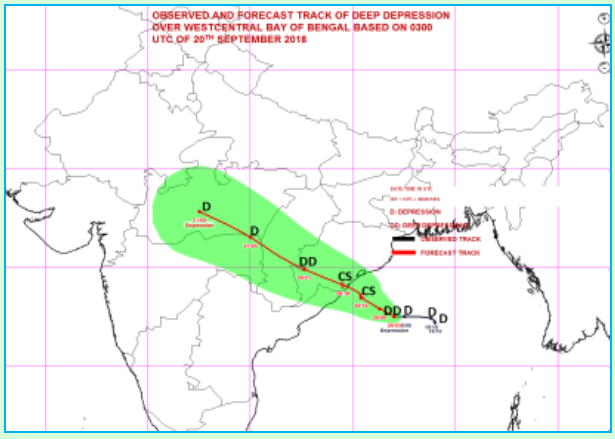


Fig. 17. Observed track and forecast track of CS DAYE based on 0300 UTC of 20th September alongwith Cone of uncertainty

5.5.2.4. Very Severe Cyclonic Storm, 'LUBAN'

Very Severe Cyclonic Storm (VSCS) Luban originated from a low pressure area (LPA) which formed over southeast Arabian Sea (AS) and neighbourhood in the morning (0830 IST/0300 UTC) of 5th October. It lay as a well marked low pressure area (WML) over southeast and adjoining eastcentral AS in the morning (0530 IST/0000 UTC) of 6th October. Under favourable environmental conditions, it concentrated into a Depression (D) over southeast and adjoining eastcentral AS in the afternoon (1430 IST/0900 UTC) of 6th October. Moving west-northwestwards, it intensified into a deep depression (DD) over the same region in the afternoon (1430 IST/0900 UTC) of 7th October. It further intensified into a cyclonic storm (CS) "Luban" in the early morning (0530 IST/0000 UTC) of 8th October over westcentral and adjoining south & eastcentral AS. Moving further west-northwestwards it intensified, into a severe cyclonic storm (SCS) in the afternoon (1430 IST/0900 UTC) of 9th over westcentral AS. It then moved northwestwards and further intensified into a very severe cyclonic storm (VSCS) in the early morning (0530 IST/ 0000 UTC) of 10th over westcentral AS. It attained it's peak intensity of 75 kts around noon (1130 IST/0600 UTC) of 10th. It maintained it's peak intensity till early morning (0530 IST/ 0000 UTC) of 11th. Thereafter, it experienced unfavourable environment like colder sea and dry & cold air advection from Arabian Peninsula and hence, it started weakening. It weakened into an SCS in the morning (0830 IST/0300 UTC) of 12th and into a CS in the same midnight (2330 IST/1800 UTC). It crossed Yemen and adjoining south Oman coasts near 15.8° N and 52.2° E during 1100-1130 hrs IST (0530 to 0600 UTC) of 14th as a CS with the wind speed of 70-80 gusting to 90 kmph. After landfall, it weakened quickly into a DD in the afternoon (1430 IST/0900 UTC) of 14th, into a D in the same midnight (2330 hrs IST/ 1800 UTC) and into a WML over Yemen and adjoining Saudi Arabia in the morning (0830 IST/ 0300 UTC of 15th). Observed track of VSCS LUBAN is shown in Fig. 18.

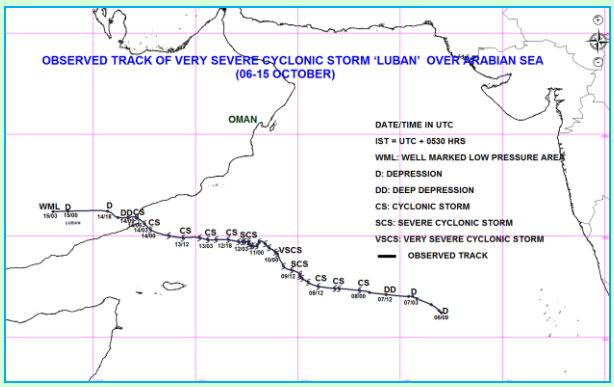


Fig. 18. Observed track of VSCS LUBAN

Forecast Performance

- There had been three landfalling cyclones over Arabia & African coasts during 2018 against 8 such cyclones during the entire satellite era (1961-2017). Hence, the frequency of landfalling cyclones over the region has been significantly higher this year.

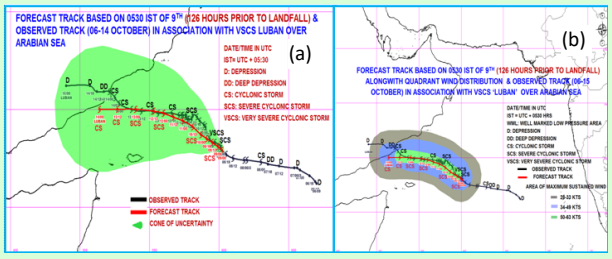
- Just after the genesis of VSCS, Luban over Arabian Sea, another cyclonic storm Titli developed over Bay of Bengal simultaneously. It was one of the rarest of rare events that simultaneously two very severe cyclonic storms developed over Arabian Sea and Bay of Bengal. Simultaneous occurrence of such two VSCSs last occurred in November 1977, *viz*., (*i*) Bay of Bengal Super Cyclonic Storm (14-20 Nov, 1977) which crossed Andhra Pradesh coast near Chirala on 19th Nov and (*ii*) Bay of Bengal VSCS (9-23 Nov, 1977) which crossed Tamil Nadu coast close to south of Nagapattinam on 12th Nov and then emerged into Arabian Sea, made a looping track, intensified into an SCS, weakened thereafter and crossed Karnataka coast to the north of Mangalore on 29th Nov as a depression.

- First information about formation of low pressure area (LPA) over southeast AS around 5th was issued in Tropical weather outlook dated the 3rd October at 0600 UTC (about 45 hours in advance of formation of LPA). The LPA formed over southeast AS & neighbourhood at 0300 UTC of 5th October. In the same bulletin, it was also forecast that the LPA would concentrate into a depression by 7th October (about 69 hours in advance of formation of D). Depression formed over southeast & adjoining eastcentral AS in the afternoon (0900 UTC) of 6th October.

- First information that the system crossing Yemen and adjoining Oman coasts around 1200 UTC of 13th was near 15.20° N/51.40° E was issued in the Tropical Cyclone Advisory issued at 1600 UTC of 8th October (about 5 days and 15 hours prior to landfall). The system crossed coast near 15.80° N/52.20° E between 0530-0600 UTC of 14th.

- The landfall point forecast errors were about 172.2, 103.8 and 103.8 km for 24, 48 and 72 hrs lead period against past five year (2013-17) average errors of 42.3, 94.8 and 122.1 km respectively. The landfall time forecast errors were about 1.0, 1.0 and 1.0 hours for 24, 48 and 72 hrs lead period against past five year (2013-17) average errors of 3.6, 5.4 and 3.8 hours respectively. The landfall point error was significantly less than long period average (LPA) of past five years for all lead periods.

- The track forecast errors were about 83.1, 125.9 and 140.8 km for 24, 48 and 72 hrs lead period against past five year (2013-17) average errors of 93, 144 and 201 km respectively. The track forecast skill was about 55.7, 67.4 and 74.7 km for 24, 48 and 72 hrs lead period against past five year (2013-17) average errors of 54.9, 68.3 and 71.6% respectively. The observed and forecast tracks of Mekunu are shown in Figs. 19(a&b).



Figs. 19. (a&b). Observed track of ESCS LUBAN (6-14 October, 2018) and forecast track based on 0000 UTC of 9th October alongwith (a) Cone of uncertainty and (b) Quadrant wind distribution

- The absolute error (AE) of intensity (wind) forecast for 24, 48 and 72 hrs lead period were 9.9, 13.5 and 16.2 knots against the LPA of

10.4, 15.5 and 15.7 knots respectively. The skill in intensity (wind) forecast based on AE for 24, 48 and 72 hrs lead period was 24.4, 46.5 and 59.0% against the LPA of 37.1, 56.8 and 69.3% respectively.

5.5.2.5. Very Severe Cyclonic storm Titli

Very Severe Cyclonic Storm (VSCS) Titli originated from a low pressure area (LPA) which formed over southeast Bay of Bengal (BoB) and adjoining north Andaman Sea in the morning (0830 IST) of 7th October. It lay as a well marked low pressure area (WML) over the same region in the same evening (1730 IST). Under favourable environmental conditions, it concentrated into a Depression (D) over eastcentral BoB in the morning (0830 IST) of 8th October. Moving nearly west-northwestwards, it intensified into a deep depression (DD) over eastcentral BoB in the mid-night (2330 IST) of 8th October and further into a cyclonic storm (CS) **"Titli**" around noon (1130 IST) of 9th October. It then moved northwestwards and intensified, into a severe cyclonic storm (SCS) in the early hours (0230 IST) of 10th. It then moved north-northwestwards and further intensified into a very severe cyclonic storm (VSCS) around noon (1130 IST) of 10th. It crossed north Andhra Pradesh and south Odisha coasts near Palasa (18.8° N/84.5° E) to the southwest of Gopalpur during 0430-0530 IST of 11th as a VSCS with the wind speed of 140-150 gusting to 165 kmph. Moving further west-north westwards, it weakened into an SCS around noon (1130 IST) of 11th and a CS in the same evening (1730 IST). Under the influence of southwesterly winds at middle and upper tropospheric levels, the system recurved northeastwards from 11th evening. It weakened into a DD over south Odisha in the mid-night (2330 IST) of 11th. It further weakened into a D in the afternoon (1430 IST) of 12th into a WML over Gangetic West Bengal and adjoining Bangladesh & north BoB in the early hours (0530 IST) of 13th and into an LPA over the same region in the morning (0830 IST) of 13th. Observed track of VSCS TITLI is shown in Fig. 20.

Forecast Performance

- Titli was the most destructive cyclonic storm to strike Indian coast during 2018.

- The genesis of VSCS, Titli over Bay of Bengal took place 45 hours after the genesis of VSCS, Luban over Arabian Sea. It was one of the rarest of rare events that simultaneously two VSCSs developed over Arabian Sea and Bay of Bengal.

- Considering the data during satellite era (1961 onwards), simultaneous occurrence of such two VSCSs last occurred in November 1977, *viz*., (*i*) Bay of Bengal Super Cyclonic Storm (14-20 Nov, 1977) which crossed Andhra Pradesh coast near Chirala on 19th November and (*ii*) Bay of Bengal VSCS (9-23 November, 1977) which crossed Tamil Nadu coast close to south of Nagapattinam on 12th November and then emerged into Arabian Sea, made a looping track, intensified into an SCS, weakened thereafter and crossed Karnataka coast to the north of Mangalore on 29th November as a depression.

- The peak maximum sustained surface wind speed (MSW) of the cyclone was 140-150 kmph gusting to 165 kmph (80 knots) during 1200 UTC of 10th to 0000 UTC of 11th October. The lowest estimated central pressure was 972 hPa 1200 UTC of 10th to 0000 UTC of 11th October.

- First information about formation of low pressure area (LPA) over south Bay of Bengal and neighbourhood around 8th was issued in Press Release dated the 5th Oct at 1310 IST (about 45 hours in advance of formation of LPA). LPA formed at 0300 UTC of 7th.

- First information about that the system would cross Odisha and adjoining north Andhra Pradesh coasts between Gopalpur and Kalingapatnam around 11th morning was given in the bulletin issued at 0900 hrs IST of 9th October (about 43 hours prior to landfall). The system crossed north Andhra Pradesh

and south Odisha coasts near Palasa (18.80° N/84.5° E) to the southwest of Gopalpur during 0430-0530 IST of 11th.

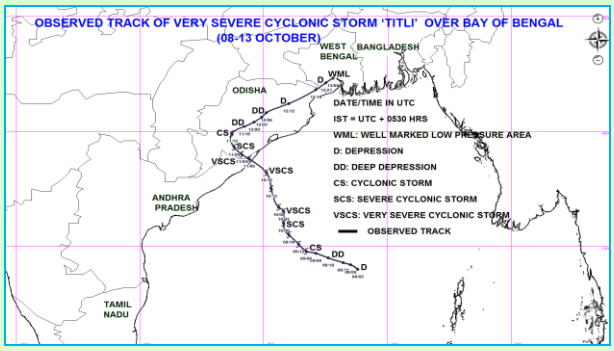


Fig. 20. Observed track of VSCS TITLI

- The landfall point forecast errors were about 15.6, 15.6 and 46.7 km for 24, 48 & 60 hrs lead period against past five year (2013-17) average errors of 42.3, 94.8 and 115.4 km respectively. The landfall time forecast errors were about 5.0, 3.0 and 3.5 hours for 24, 48 and 60 hrs lead period against past five year (2013-17) average errors of 3.6, 5.4 and 4.6 hours respectively. The landfall point error was significantly less than long period average (LPA) of past five years for all lead periods.

- The track forecast errors were about 98, 114 and 113 km for 24, 48 and 72 hrs lead period against past five year (2013-17) average errors of 93, 144 and 201 km respectively. For all the lead periods beyond 36 hours, the track forecast errors were less than the past five years average. For 12 & 24 hours lead period, it was comparable to past five years average. The observed and forecast tracks of Titli are shown in Fig. 21.

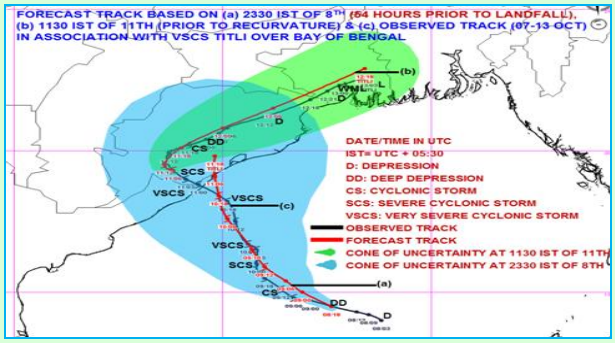


Fig. 21. Observed track of VSCS Titli (7-13 October, 2018) and forecast track based on 1800 UTC of 8th October and 0600 UTC of 11th October alongwith Cone of uncertainty

- The absolute error (AE) of intensity (wind) forecast for 24, 48 and 72 hrs lead period were 10.8, 10.3 and 2.0 knots against the LPA of 10.4, 15.5 and 15.7 knots respectively. The skill in intensity (wind) forecast based on AE for 24, 48 and 72 hrs lead period was 69.7, 85.3 and 96.0% against the LPA of 37.1, 56.8 and 69.3% respectively.

5.5.2.6. Very Severe Cyclonic storm, Gaja

Very Severe Cyclonic Storm (VSCS) Gaja originated from a low pressure area (LPA) which formed over Gulf of Thailand and adjoining Malay Peninsula in the morning (0830 IST) of 8th November. It lay as a well marked low pressure area (WML) over north Andaman Sea and neighbourhood in the evening (1730 IST) of 9th November. Under favourable environmental conditions, it concentrated into a Depression (D) over southeast BoB in the morning (0830 IST) of 10th November. Moving west-northwestwards, it intensified into a deep depression (DD) over southeast & adjoining central BoB in the same evening (1730 IST). Moving further west-northwestwards, it intensified into cyclonic storm (CS) "Gaja" over eastcentral and adjoining westcentral & southeast BoB in the early morning (0530 IST) of 11th November, 2018. It then moved nearly westwards till early morning (0530 IST) of 12th. Thereafter it recurved south-southwestwards and followed an anticlockwise looping track till 13th morning. It then moved west-southwestwards and intensified, into a Severe Cyclonic Storm (SCS) over southwest BoB in the morning (0830 IST) of 15th November and into a very severe cyclonic storm in the same night (2030 IST). Moving further west-southwestwards it crossed Tamilnadu & Puducherry coast between Nagapattinam and Vedaranniyam near latitude 10.45° N and longitude 79.8° E with wind speed of 130 kmph gusting to 145 kmph during 0030 to 0230 hours IST of 16th November. Thereafter, it moved nearly westwards and weakened rapidly into an VSCS in the early morning (0530 IST), a CS in the morning (0830 IST) and

into a DD over interior Tamil Nadu in the forenoon (1130 IST) of 16th November. It then moved west-southwestwards and weakened into a D in the same evening (1730 IST) over central Kerala. Moving nearly westwards, it emerged into southeast Arabian Sea (AS) in the same midnight (2330 IST). Moving nearly westwards, it intensified into a DD over southeast AS in the early morning (0530 IST) of 17th November. Thereafter, it moved nearly west-northwestwards and crossed Lakshadweep Islands in the 17th afternoon (1400-1700 hrs IST) as a deep depression. It continued to move west-northwestwards and weakened into a D over southeast AS around noon (1130 IST) of 19th & into a WML over southwest & adjoining southeast AS in the same midnight (2330 IST). It lay as a low pressure area over southwest Arabian Sea on 21st and became less marked over the same region on 22nd (Fig. 22).

Forecast Performance

- First information about formation of LPA over southeast Bay of Bengal and adjoining Andaman Sea around 9th was issued in the Tropical Weather dated 7th November at 1200 IST (around 48 hours in advance of formation of LPA). LPA from Gulf of Thailand emerged in Andaman Sea in the afternoon of 9th.

- In the first bulletin issued on 10th (issued at 1230 IST), it was mentioned that, the system would move west-northwestwards during next 48 hours and then west-southwestwards towards north Tamil Nadu – south Andhra Pradesh coasts (about 5 days in advance of actual landfall).

- The landfall over Tamil Nadu coast during evening hours of 15th (around 1330 IST) was predicted on 11th early morning (0930 IST) more than 4 days in advance. At 1430 IST of 12th November (around 81 hours in advance of actual landfall), it further indicated the landfall of the cyclonic storm over Tamil Nadu coast between Cuddalore and Pamban, around Nagapattinam.

- The landfall point forecast errors were about 31, 43 and 70 km for 24, 48 and 72 hrs lead period respectively against past five year (2013-17) average errors of 42.3, 94.8 and 122 km respectively. The landfall time forecast errors were about 3.0, 8.5 and 14.5 hours for 24, 48 and 72 hrs lead period against past five year (2013-17) average errors of 3.6, 5.4 and 3.8 hours respectively. The higher landfall time error for 48 and 72 hrs lead period were mainly due to the fact that the system followed a looping track during 11th night to 13th morning leading to delay in landfall time.

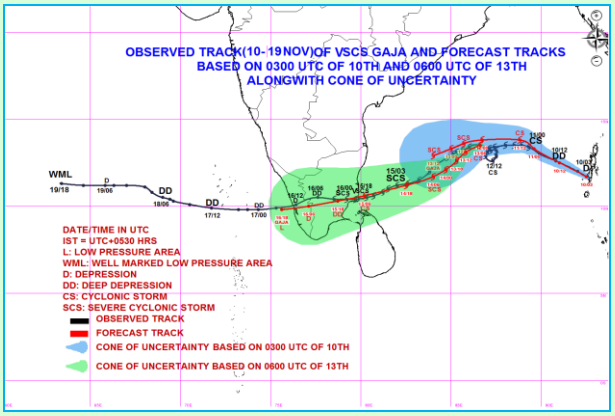


Fig. 22. Typical forecast and observed tracks of VSCS, Gaja demonstrating accurate track and landfall point forecast

- The track forecast errors were about 121, 185 and 195 km for 24, 48 and 72 hrs lead period against past five year (2013-17) average errors of 93, 144 and 201 km respectively. The track forecast skills were about 49, 68 and 82% for 24, 48 and 72 hrs lead period against past five year (2013-17) average skills of 55, 68 and 72% respectively.

- The absolute error (AE) of intensity (wind) forecast for 24, 48 and 72 hrs lead period were 9.1, 11.0 and 14.6 knots against the LPA of 10.4, 15.5 and 15.7 knots respectively. The skill in intensity forecast based on AE for 24, 48 and 72 hrs lead period was 22.0, 37.5 and 22.0% respectively.

5.5.2.7. Severe Cyclonic Storm, '*PHETHAI*'

The Severe Cyclonic Storm (SCS) Phethai originated from a low pressure area (LPA)

which formed over Equatorial Indian Ocean and adjoining central parts of south Bay of Bengal (BoB) in the evening (1730 IST) of 9th December. It lay as a well marked low pressure area (WML) over central parts of south BoB and adjoining EIO in the morning (0830 IST) of 11th December. Under favourable environmental conditions, it concentrated into a Depression (D) over southeast BoB in the early morning (0530 IST) of 13th December. Moving north-northwestwards, it intensified into a deep depression (DD) over southeast BoB in the same mid-night (2330 IST) of 13th December. It intensified into a cyclonic storm (CS) "Phethai" (Pronounced as Pay-ti) in the evening (1730 IST) of 15th December and into a severe cyclonic storm (SCS) in the afternoon of 16th December. It maintained its intensity of SCS till early morning (0530 IST) of 17th December and weakened into a CS in the same morning (0830 IST). Continuing to move north-northwestwards and then northwards it crossed Andhra Pradesh coast near 16.55° N and 82.25° E (close to south of Yanam and 40 km south of Kakinada) during 17th afternoon (1330-1430 IST) as a cyclonic storm with maximum sustained wind speed of 75-85 kmph gusting to 95 kmph. After landfall, it moved north-northeastwards and weakened rapidly into a deep depression over westcentral BoB off Kakinada coast in the evening (1730 IST) of 17th December. Observed track of SCS PHETHAI is shown in Fig. 23.

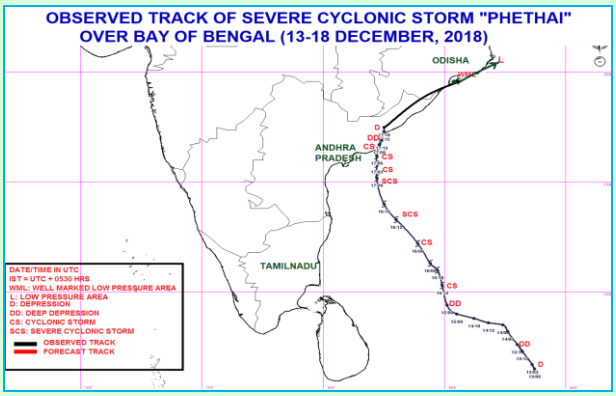


Fig. 23. Observed track of SCS *PHETHAI*

- SCS Phethai was the seventh cyclone over north Indian Ocean during 2018 against normal frequency of about 4.5 cyclones per year during the satellite era (1961 onwards).

- The track length of the system was 1525 km.

- First information about formation of low pressure area (LPA) over southeast BoB and neighbourhood around 9th December was issued in the Tropical Weather Outlook (TWO) dated the 5th December at 1230 IST (more than 4 days in advance of formation of LPA). LPA formed at 1730 IST of 9th.

- In the bulletin issued at 0830 IST of 14th December when it was a D, it was predicted that the system would cross Andhra Pradesh coast between Ongole and Kakinada during 17th December afternoon as a cyclonic storm.

- The landfall point was further specified to be between Machilipatnam and Kakinada during 17th December afternoon in the bulletin issued at 1430 IST of 16th.

- The landfall point forecast errors (first landfall) were about 15.6, 15.6 and 46.7 km for 24, 48 and 60 hrs lead period against past five year (2013-17) average errors of 42.3, 94.8 and 115.4 km respectively. The landfall time forecast errors were about 2.0, 4.5 and 2.5 hours for 24, 48 and 60 hrs lead period against past five year (2013-17) average errors of 3.6, 5.4 and 4.6 hours respectively.

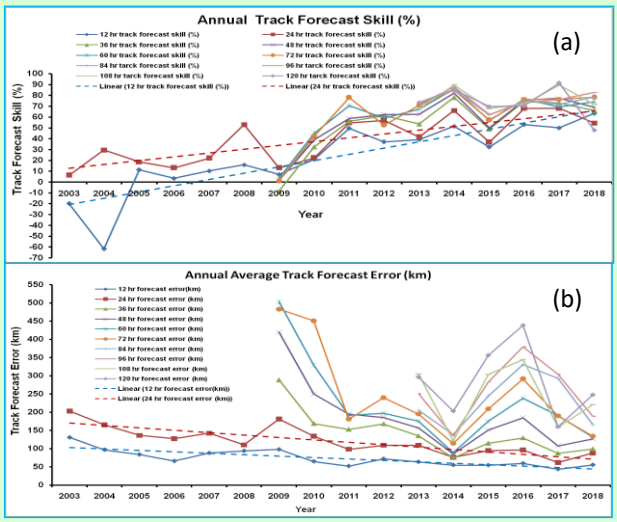
- The track forecast errors were about 100.3, 106.5 and 84.8 km for 24, 48 and 72 hrs lead period against past five year (2013-17) average errors of 93, 144 and 201 km respectively. For all the lead periods beyond 24 hours, the track forecast errors were significantly less than the past five years average. For 12 & 24 hours lead period, it was comparable to past five years average.

- The absolute error (AE) of intensity (wind) forecast for 24, 48 and 72 hrs lead period were 6.7, 7.1 and 4.8 knots against the LPA of 10.4, 15.5 and 15.7 knots respectively. The skill in intensity (wind) forecast based on AE for 24, 48 and 72 hrs lead period was 56.2, 64.4 and 31.7% against the LPA of 37.1, 56.8 and 69.3% respectively.

5.5.3. Annual Average Cyclone Forecast error and skill during 2018

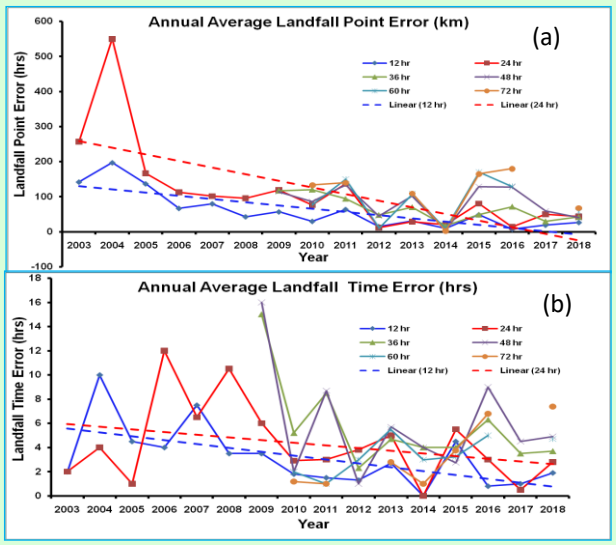
5.5.3.1. Track and landfall

The annual average track forecast errors in 2018 have been 88, 124 and 134 km, respectively for 24, 48 and 72 hrs against the past five year average error of 93, 144 and 201 km based on data of 2013-2017. The errors have been significantly lower during this year as compared to long period average (2013-17). The track forecast skills compared to climatology and persistence forecast are 54, 69 and 78% respectively for the 24, 48 and 72 hrs lead period compared to long period average of 2013-2017 (55%, 68% & 72% respectively). The annual average landfall point forecast errors for the year 2018 have been 44, 40 and 68 km for 24, 48 and 72 hrs lead period against the long period average of 42, 95 and 122 km during 2013-2017 [Figs. 24(a&b)].

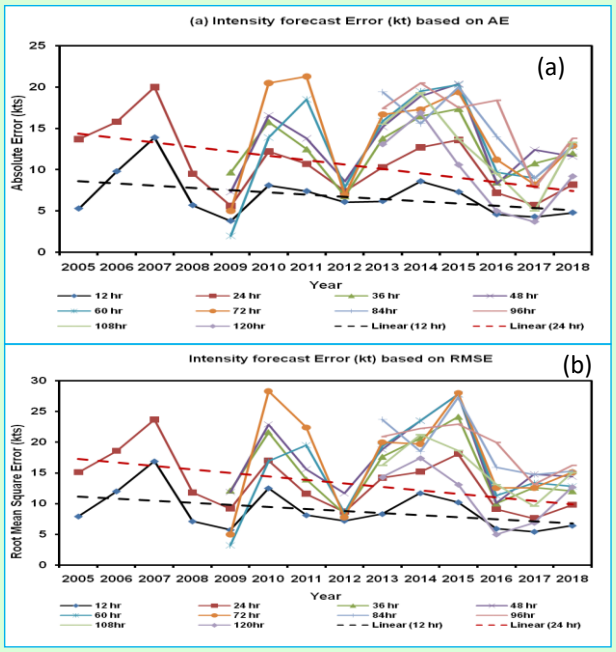


Figs. 24 (a&b). Annual Track Forecast (a) Skill (%) and (b) Error (km) of RSMC, New Delhi over North Indian Ocean

The landfall time forecast errors have been 2.8, 5.0 and 7.4 hrs for 24, 48 and 72 hrs lead period during 2018 against the average of past five years of 3.6, 5.4 and 3.8 hrs during 2013-2017. It can be seen from Figs. 25(a&b) that there has been continuous improvement in forecast accuracy with decrease in landfall and track forecast errors and increase in skill over the years. The intensity forecast error (kt) based on AE & RMSE is shown in Figs. 26(a&b).



Figs. 25(a&b). Annual average (a) Landfall Point errors (b) Landfall Time errors

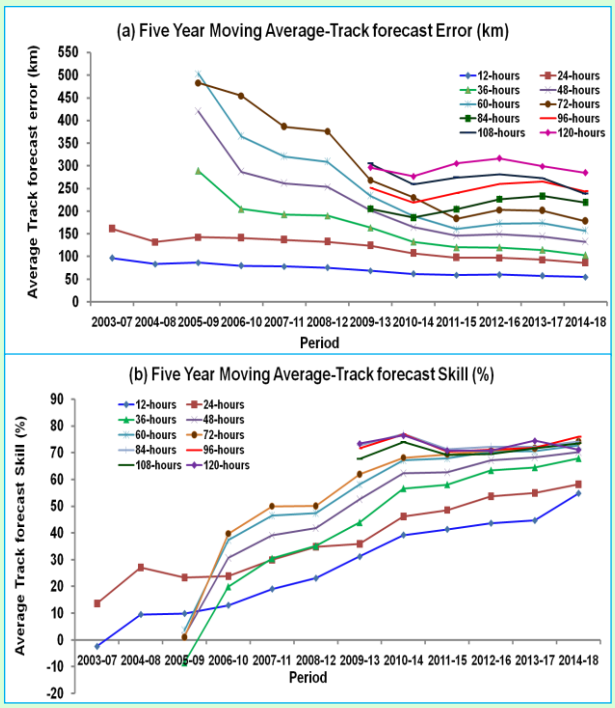


Figs. 26(a&b). Annual average Intensity forecast errors based on (a) AE (b) RMSE

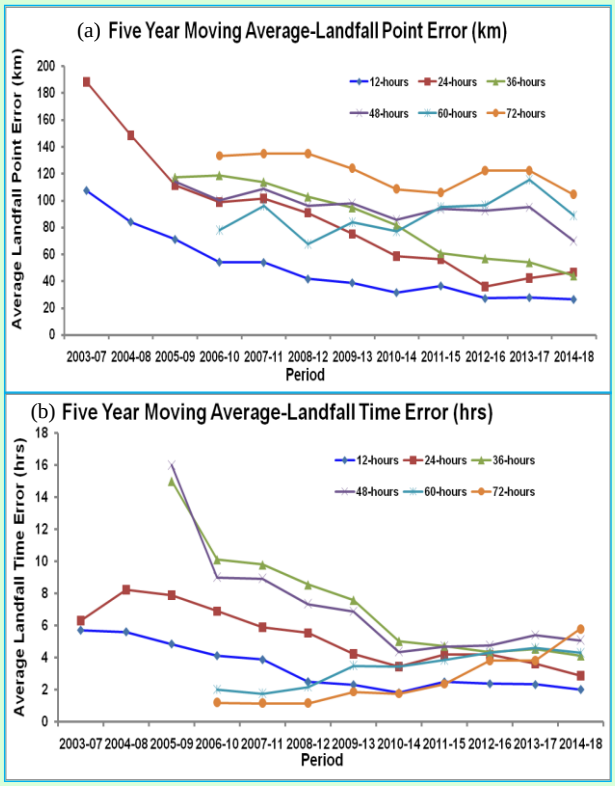
5.5.3.2. Trend in errors and skill

It can be seen from Figs. 27-29 that there has been continuous improvement in forecast accuracy with decrease in landfall and track forecast errors and increase in skill over the years.

Due to modernization programme of IMD and other initiatives of MoES, the improvement has been more significant since 2009. However, the rate of improvement in intensity forecast over the years has been marginal as can be seen from Figs. 29(a&b).

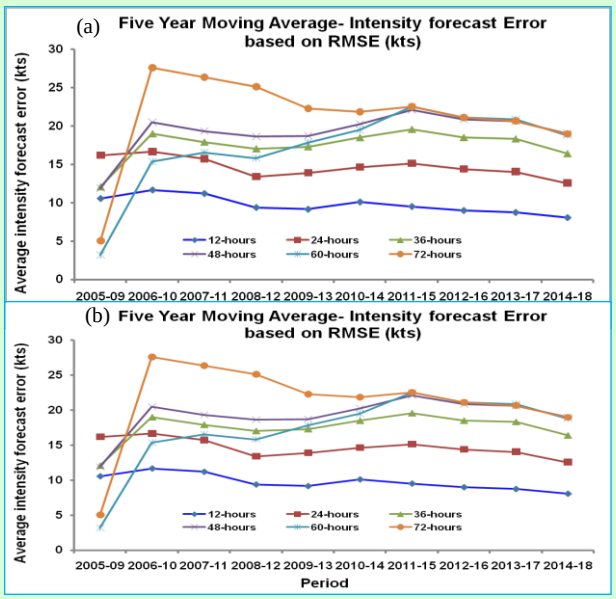


Figs. 27 (a&b). Five Year Moving Average (a) Track Forecast Error (km) and (b) Track Forecast Skill (%) of RSMC, New Delhi over North Indian Ocean



Figs. 28(a&b). Five Year Moving Average (a) Landfall Point Forecast Error (km) and (b) Landfall Time Forecast Error (hrs) of RSMC, New Delhi over North Indian Ocean

The 36-72 hours forecasts commenced from 2009 and it was further extended to 120 hrs from 2013 onwards.

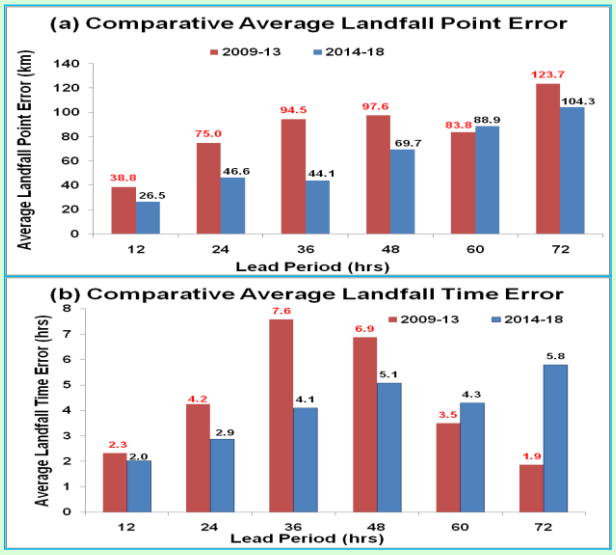


Figs. 29(a&b). Five Year Moving Average Intensity Forecast (a) Absolute Error (kts) and (b) Root Mean Square Error (kts) of RSMC, New Delhi over North Indian Ocean

5.5.3.3. Forecast accuracy in recent five years as compared to previous five years

Landfall Forecast

Significant improvement in landfall forecast errors have been observed during 2014-18 compared to that during 2009-13 due to implementation of modernisation programme in IMD in 2009. The landfall point error during 2014-18 has been 46.6, 69.7 and 104.3 km against 75.0, 97.6 and 123.7 km during 2009-13 [Fig. 30(a)] for 24, 48 & 72 hours lead period.

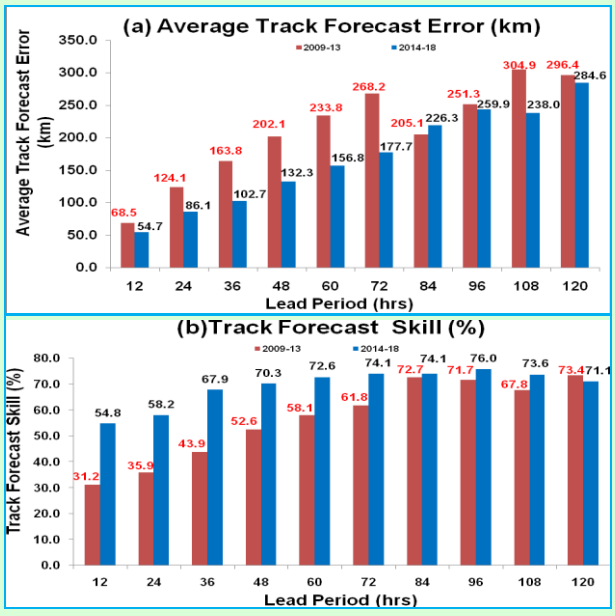


Figs. 30(a&b). Comparative average (a) Landfall Point errors and (b) Landfall Time errors

Thus, 38%, 28% and 16% improvement in landfall point error was observed during 2014-18 compared to 2009-13 for 24, 48 and 72 hours lead period. Landfall time errors [Fig. 30(b)] during 2014-18 has been 2.9, 5.1 and 5.8 hrs against 4.2, 6.9 and 1.9 hrs during 2009-13 for 24, 48 hrs lead period respectively with an improvement of 32%, 26%.

Track forecast error and skill

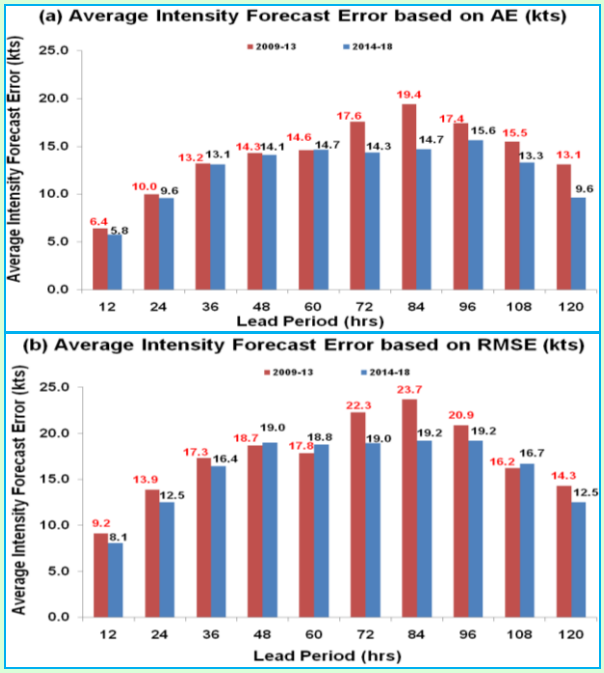
The track forecast errors during 2014-18 have been 86, 132, 178 km against 124, 202, 268 km during 2009-13 for 24, 48 and 72 hrs lead period respectively [Fig. 31(a)]. The period during 2014-18 registered a decrease in track forecast error by 31, 34 & 34% as compared to 2009-13 for 24, 48 and 72 hours lead period respectively. Similarly skill also improved significantly during 2014-18 [Fig. 31(b)] and has been 58, 70 & 74% during 2014-18 against 36, 53 & 22% during 2009-13 for 24, 48 and 72 hrs lead period respectively.



Figs. 31(a&b). Comparative average (a) Track forecast errors and (b) Track forecast Skill

Intensity forecast error and skill

Comparative analysis of intensity forecast errors and skill based on absolute error (AE) & root mean square error (RMSE) relative to persistence error is shown in Figs.32 (a&b). The intensity forecast errors based on AE during 2014-18 has been 9.6, 14.8 & 14.3 knots against 10, 14.3 & 17.6 knots during 2009-13 for 24, 48 and 72 hrs lead period respectively. The intensity forecast errors based on RMSE during 2014-18 has been 12.5, 19.0 & 19.0 knots against 13.9, 18.7 & 22.3 knots during 2009-13 for 24, 48 and 72 hrs lead period respectively.



Figs. 32(a&b). Comparative average Intensity forecast errors based on (a) AE and (b) RMSE

5.5.4. Research and Development

5.5.4.1. Forecast Demonstration Project (FDP) on Landfalling Tropical Cyclones over the Bay of Bengal

A Forecast Demonstration Project (FDP) on landfalling tropical cyclones over the Bay of Bengal was taken up in 2008. It helps us in monitoring and prediction of a tropical cyclone.

The project is operated during 15 October to 30 November every year. But during the year 2018, due to development of cyclonic storm "Phethai" over northeast BoB in the month of December, the FDP campaign was extended upto 18th December, 2018. Like previous years (2008-2018), several national institutions participated for joint observational,

communicational & NWP activities. There was an improved observational campaign with the observation from Buoys, Scatterometer based satellite and microwave imageries products. There was intense observation period for 19 days during the field phase 2018 in association with the systems over the Bay of Bengal and the Arabian Sea. The daily reports were prepared during this period to find out the characteristics of genesis, intensification and movement of the systems as well as environmental features over the NIO. The detailed report on implementation of FDP-2018 will be available in RSMC, New Delhi website (www.rsmcnewdelhi.gov.in).

5.5.4.2. SWFDP-South Asia

IMD is leading WMO's Severe Weather Forecasting Demonstration Project (SWFDP) – South Asia. Pilot project is started from 1 May, 2016 and demonstration phase started from 1 June, 2019. It provides daily severe weather guidance on heavy rainfall, strong wind, storm surge, high waves and cyclonic disturbances to the member countries including Bangladesh, India, Bhutan, Nepal, Pakistan, Sri Lanka, Maldives, Myanmar and Thailand. National Meteorological Services use this guidance to provide more specific local and regional forecast & warning against the severe weather events. IMD developed SWFDP web page for all member countries. IMD also provides training to forecasters from these countries.

5.5.5. New initiatives

OBSERVATIONS & MODELING

1. Development of new satellite based diagnostic products.

2. Rapid scanning of cyclone by INSAT-3DR during FANI.

3. Superimposition of lightning data on satellite & radar images (FANI).

4. Augmentation of radar network with coverage of entire coastal belt

5. Utilisation of DWR based specific products like wind speed at the height of 1 km for intensity determination (FANI).

6. Adaption of global models from USA and UK under the bilateral cooperation for forecasting of cyclones (2018). Global Forecasting System (GFS) with a resolution of 12 km and Global Ensemble Forecasting System (GEFS) with a resolution of 23 km have been adapted from NCEP, NOAA, USA (7 days forecast). The Unified Model (UM) and unified Model Ensemble Prediction System (UMEPS) have been adapted from UKMO, UK (7 days forecast).

7. Operationalisation of Princeton Ocean Model (POM) (2017 December) and Hybrid Co-ordinate Model (Hy-Com) (2018) of cyclone specific Hurricane Weather Research & Forecast Model (HWRF).

8. HWRF model forecast products were made available through IMD website, RSMC website and also NCEP, USA website (2019).

OPERATIONAL PRODUCTS & DISSEMINATION

1. Extension of probabilistic genesis forecast in the daily Tropical Weather Outlook from 3 days to 5 days w.e.f. 22nd April, 2018.

2. Issue of Informatory Message to disaster management agencies including MHA, NDMA, NDRF, Chief Secretaries and state disaster management agencies from low pressure stage when it has the potential to intensify into a cyclonic storm w.e.f. 22nd April, 2018.

3. Issue of quantitative track and intensity forecast from depression stage w.e.f. 22nd April, 2018 against earlier practice of issuing the same from deep depression stage when it has the potential to further intensify into cyclonic storm.

4. Introduction of probabilistic extended range outlook valid for next two weeks every Thursday w.e.f. 22nd April, 2018.

5. Issue of fishermen warning for entire Bay of Bengal and Arabian Sea valid for next five days.

6. Establishment of Cyclone Warning Centre at Thiruvananthapuram w.e.f. 1st October, 2018 to provide cyclone warnings for the states of Kerala, Lakshadweep and Karnataka.

7. Reduction in cone of uncertainty representing uncertainty in track in 26th April, 2019 by 20-30% for different lead periods due to reduction in track forecast errors during 2014- 18 as compared to that during 2009-13. Last revision was carried out in 2013 shown in Fig. 33.

8. Impact over sea area and suggested action was given in the warning graphics alongwith wind distribution around the system centre from 26th April, 2019.

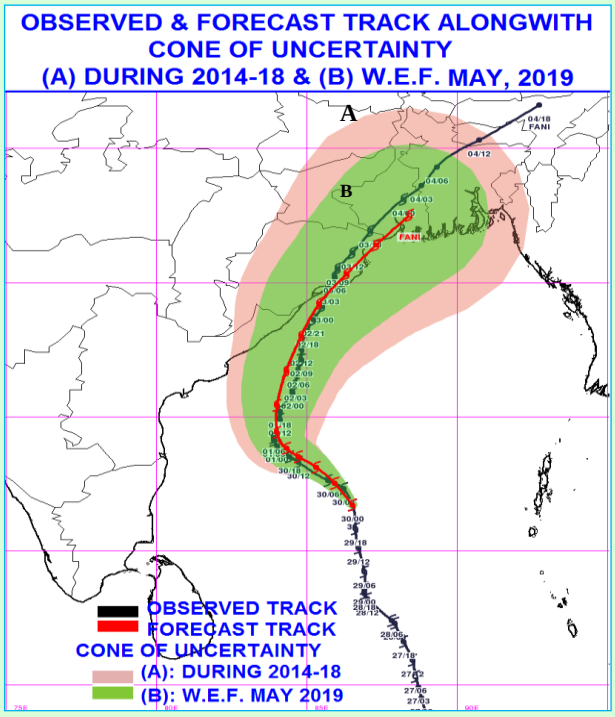


Fig. 33. Observed & Forecast Track alongwith cone of uncertainty (A) during 2014-18 and (B) w.e.f. May, 2019

9. Issue of Fishermen warnings in graphical form daily valid upto 5 days from 25th April, 2019 onwards.

10. Issue of hourly updates even 60 hours prior to landfall during cyclone VAYU.

11. Uploading of bulletins on facebook, tweeter and whatsapp hourly and SMS to disaster managers & general public hourly.

12. Uploading of IMD bulletins on INCOIS website since 2019 to facilitate easy access to bulletins.

13. Information and warning products on cyclone alongwith storm surge guidance were also provided to United Nations through WMO

5.6. CLIMATE RESEARCH & SERVICES

(*i*) Operational Long Range Forecast and its Verification

Operational LRF System

The present operational Long Range Forecasting (LRF) system for generating the rainfall/precipitation forecast is essentially based on the statistical methods and that for generating temperature forecasts is based on the coupled forecasting system (CFS). The operational LRF system based on statistical models was developed through in house research activities and regular review. IMD issues operational long range forecasts for rainfall/ precipitation during Winter (January-March), Southwest Monsoon (June-September) and Northeast Monsoon (October-December) seasons. Among these, forecast for monsoon season is most important as the rainfall received during this season accounts for 70-90% of the annual rainfall over most parts of the country and due strong positive association of monsoon season rainfall with both Kharif and Rabi crop production in the country. Table 2 shows various forecasts. Since 2012, as additional forecast guidance, IMD started to use the experimental forecasts for the monsoon rainfall generated by the dynamical model approach developed by Indian Institute of Tropical Meteorology (IITM), Pune. The present dynamical model forecasting system is based on the global climate forecasting system CFS) version 2. The CFS is a fully Coupled General Circulation Model (CGCM) implemented by IITM under Monsoon

Mission project launched by the Ministry of Earth Sciences (MoES) (Saha *et al.*, 2014). The global monthly and season forecasts for rainfall and temperature prepared using Monsoon Mission CFS (MMCFS) is updated 15th of every month is now available through IMD, Pune (www.imdpune.gov.in) and IITM (www.tropmet.res.in) websites. In 2018, CFS was used for issuing an outlook for seasonal temperatures over India during the hot weather seasons (March to May & April to June) & cold weather season (December to February).

Details of the various long range forecasts issued by IMD and their verification are discussed in this report.

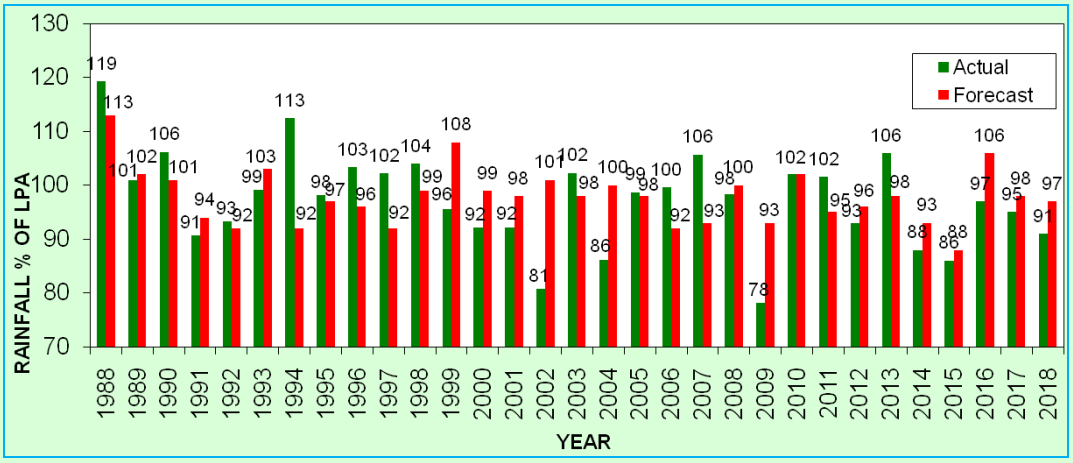


Fig. 34. Performance operational forecast (1988-2018)

TABLE 2

Various operational forecasts issued by IMD

S. No.	Forecast for	Region for which forecast issued	Issued in	Method / Model
1.	Winter Season (Jan- March) Precipitation	Northwest India	December	Statistical
2.	Hot Weather Season Temperature for (March- May) & (April-June) seasons	Subdivision wise	March	MMCFS
3.	SW Monsoon Season (June to September) Rainfall	Country as a whole	April	Statistical/MMCFS
4.	SW Monsoon Season (June to September) Rainfall	Country as a whole	June	Statistical/MMCFS
5.	South-West Monsoon Onset	Kerala	May	Statistical
6.	SW Monsoon Season (June to September) Rainfall	Four broad geographical regions: Northwest India, Northeast India, Central India and South Peninsula	June	Statistical
7.	SW Monsoon Monthly Rainfall for July and August	Country as a whole	June	Statistical/MMCFS
8.	SW Monsoon Second half of the Season (August-September) Rainfall	Country as a whole	July	Statistical/MMCFS
9.	September Rainfall	Country as a whole	August	Statistical/MMCFS
10.	NE Monsoon Season (October to December) Rainfall	South Peninsula	September	Statistical/MMCFS
11.	Cold Weather Season (December - February) Temperature	Subdivision wise	November	MMCFS

The Performance operational forecast (1988-2018) is shown in Fig. 34.

Verification of Operational Long Range Forecasts

(i) Winter Season (January to March, 2018) Precipitation over North India

The LRF for the 2018 winter season (January to March) rainfall over north India was prepared in the last week of December 2017. North India consisting of seven subdivisions (East U.P., West U.P., Uttaranchal, Haryana, Punjab, Himachal Pradesh, Jammu & Kashmir) receives about 17% of its annual rainfall during the winter season (January to March). The Jammu & Kashmir in particular receives about 30% of its annual rainfall during this period. The winter rainfall is very crucial for Rabi crops over the region. It is also crucial for the water management of the region. In view of these

TABLE 3

Verification of Long Range Forecast for 2018 Winter Season

Forecast	Actual
The 2018 winter season (Jan to March) rainfall over north India is most likely to be normal [(≥ 85 to ≤ 115 of the Long Period Average (LPA)]. The LPA of the winter rainfall over North India for the period 1951-2000 is 183.1 mm	WinterWinterrainfall in North India during the period January to March 2018 is below normal (< 85 of the LPA)

reasons, India Meteorological Department (IMD) has been issuing long range forecast outlook for thewinter rainfall over north India. IMD also continuously works to improve the skill of the forecasting models. This year, for preparing the quantitative and probabilistic forecasts for winter season rainfall over the North India, a 4-parameter Principle Component Regression (PCR) has been used.

The Table 3 below shows the summary of the verification of the long range forecasts issued-for the 2018 winter season.

(ii) 2018 Hot Weather Season Temperature Forecast for Hot Weather (March- May) & April - June) Seasons

The country experiences hot weather primarily during March to July. March to May season is known as the pre-monsoon season and April to June is known as Hot weather season. During these seasons, many parts of the country experience heat wave conditions (days with abnormally warmer temperatures) with many adverse consequences. Abnormally above normal temperatures can have devastating effects on human health, water resources and power generation and outage. There is a marked relationship between human mortality andthermal stress.

The forecast of 2017 could correctly indicate highest temperatures observed over northwest India. However, the observed maximum temperature anomalies over many subdivisions from Peninsula and east central India were relatively higher than that of forecasted. On the other hand, the observed minimum temperature anomalies of some subdivisions form north Peninsula and neighbouring central India were less than that of the forecasted anomalies.

During the 2018 Pre-monsoon Season (March to May), warmer than normal temperatures are likely in allmeteorological sub-divisions of the country. Seasonal (March - May) averaged temperatures over many of the subdivisions from northwest neighbouring central India are likely to be above normal by more than 1 °C. Normal to above normal heat wave (HW) conditions are likely over core heat wave zone of the country. India Meteorological Department, MoES issued a seasonal outlook for summer temperatures over the country based on the predictions from MMCFS. The model climatology was prepared using retrospective forecasts generated for 28 years (1982-2010).

The forecast for 2018 pre-monsoon season (March to May) was prepared using 34 ensemble member forecasts, based on the 2018 February initial conditions.

During the 2018 Hot Weather Season (April to June), warmer than normal (maximum, minimum and mean) season averaged temperatures are likely in most of the meteorological sub-divisions of the country with exception of subdivisions from eastern, east central and southern parts for the country where normal to slightly below normal maximum temperature are most likely. Season averaged temperatures in most of the subdivisions are likely to be cooler than March to May. Climatological probabilities are most likely for Heat wave (HW) conditions over core heat wave zone of the country.

The forecast for 2018 pre monsoon season (March to May) was prepared using 41 ensemble member forecasts, based on the 2018 March initial conditions.

The sub-division wise maximum, minimum and mean temperatures forecast issued by IMD for

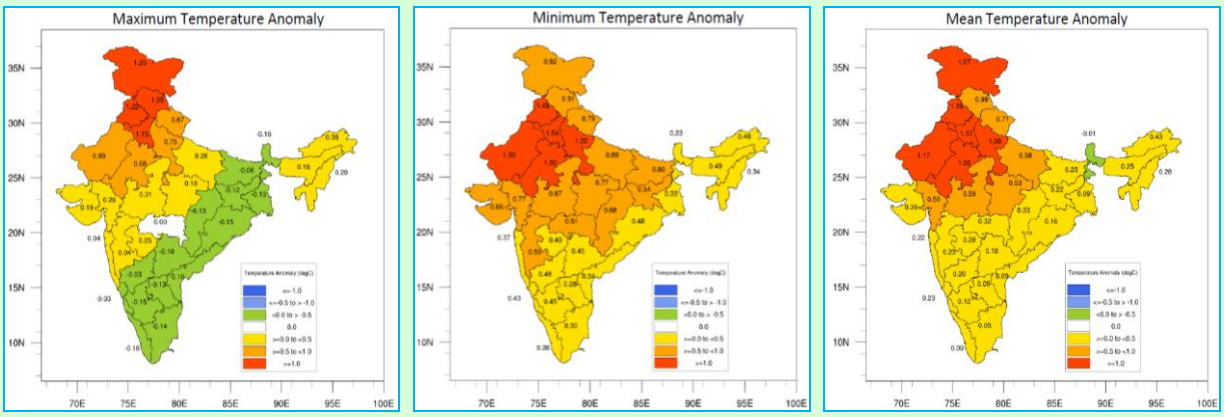


Fig. 35. Subdivision wise maximum, minimum and mean temperatures forecast issued by IMD for the 2018 Pre monsoon season (March to May) along with actual subdivision wise temperature anomalies

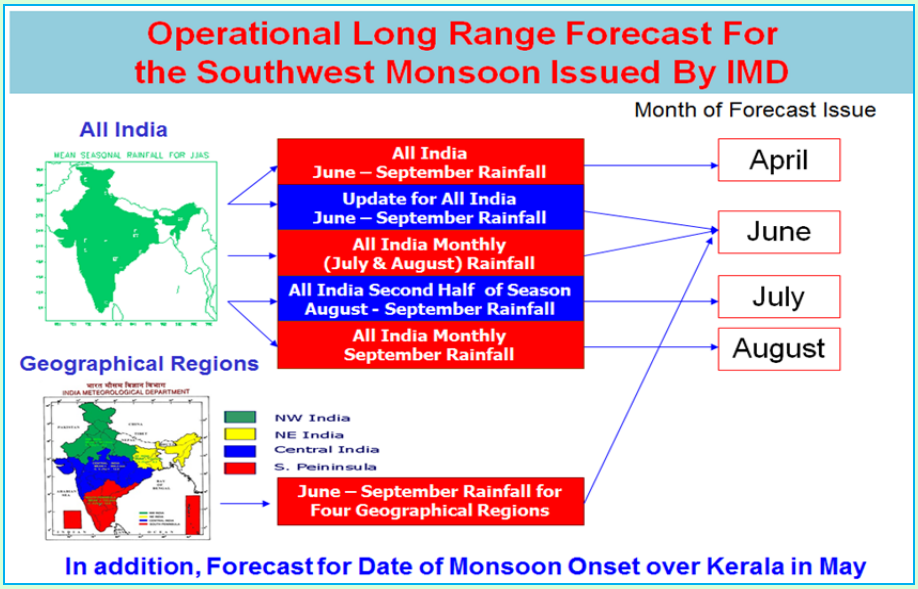


Fig. 36. Schematic diagram showing various operational forecasts for the southwest monsoon rainfall issued by IMD

the 2018 Pre monsoon season (March to May) along with actual subdivision wise temperature anomalies are shown in Fig. 35.

(iii) Southwest Monsoon Season (June to September, 2018) Rainfall

Long range forecasts were issued for monthly (for July, August), second half (August + September) andseasonal rainfall over the country as a whole and for seasonal rainfall over four geographical regions (Northwest India, Central India, Northeast India and South Peninsula) with useful skill. In addition to the above long range forecasts, an operational forecast for the monsoon onset over Kerala was issued in May. For the forecasting of the south-west monsoon season (June-September) rainfall over the country as a whole, the newly introduced statistical ensemble forecasting system based on 8 parameters were used. Multiple Regression models based on separate parameters sets were used for the forecast of the monsoon season rainfall over four geographical regions (NW India, NE India, Central India and South Peninsula) of the country and forecast for the rainfall over the second half of the monsoon Season over the country as a whole. Principal Component Regression Models were used for the forecast of monthly rainfall for the months of July & August over the country as a whole.

The operational forecast for the onset of monsoon over Kerala was prepared using a 6-Parameter principal component regression (PCR) method (Fig. 36). The forecast for monsoon onset over Kerala for this year was

TABLE 4

Verification of the operational forecast issued for the 2018 southwest monsoon rainfall

Region	Period	Forecast (% of LPA)			Actual Rainfall (% of LPA)
		16th April	30th May	3rdAugust	
All India	June to September	97 ± 5	97 ± 4		91
Northwest India	June to September		100 ± 8		98
CentralIndia	June to September		99 ± 8		93
Northeast India	June to September		93 ± 8		76
South Peninsula	June to September		95 ± 8		98
All India	July		101 ± 9		94
All India	August		94 ± 9	96 ± 9	92
All India	August to September			95 ± 8	86

TABLE 5

Verification of the long range forecasts issued for the 2018 northeast monsoon season

Region	Long Range Forecast	Actual
South Peninsula	The 2018 NE monsoon (Oct-Dec) rainfall is most likely to be normal (89% -111% of LPA) with a strong tendency to be in the positive side of the normal	The 2018 NE monsoon (Oct-Dec) rainfall was 66% of LPA
Tamilnadu	The 2018 NE monsoon (Oct-Dec) rainfall is most likely to be normal above normal (≥112% of LPA)	The 2018 NE monsoon (Oct-Dec) rainfall was 77% of LPA

correct, as the monsoon onset over Kerala took place on 29th May, on the same day as forecasted on 29th May ± 4 days. Thus the operational forecast for the monsoon onset over Kerala has been correct (within the forecast limits) during 13 of the 14 years since issuing of operational forecast for the event started in 2005. Only in 2015, the forecast for monsoon onset over Kerala was not correct, as the monsoon set over Kerala on 5th June ±4 days against the forecast of 30th May.

The Table 4 below gives the summary of the verification of the long range forecasts issued for the 2018 Southwest Monsoon. In 2018, As seen in the table, the forecasts for the season rainfalls over three of the four broad geographical regions as well as that for the July & August rainfall over the country as a whole were correct. However, the forecasts for the season rainfall over the country as a whole & that over the Northeast India and the rainfall during second half of the monsoon season over the country as a whole were not correct.

(iv) Northeast Monsoon Rainfall over South Peninsula (October to December, 2018)

The long range forecast for the 2018 NE monsoon season (October to December) rainfall over South Peninsula and Tamil Nadu was issued in the last week of September 2018. The south Peninsulaconsisting of five subdivisions (Tamil Nadu, Coastal Andhra Pradesh, Rayalseema, Kerala and south interior Karnataka) receives about 30% of its annual rainfall during the NE monsoon season October to December). Tamil Nadu in particular receives about 48% of its annual rainfall during this season. Due to this important fact, IMD has been preparing experimental forecasts for NE monsoon season rainfall over south Peninsula since 1998 using statistical models. IMD also continuously works to improve the skill of the forecasting models. This year, for preparing the quantitative and probabilistic forecasts for NE monsoon season rainfall over the south Peninsula, a 5-parameter Principle Component Regression (PCR) has been used. Similarly a 4- Parameter PCR model has been used for the forecasting season Rainfall over Tamil Nadu. The summary of the verification of long range forecasts for NE monsoon season shows in Table 5.

(v) 2018 Cold weather Season (December to February) Temperatures

The country experiences cold weather primarily during December to February. During

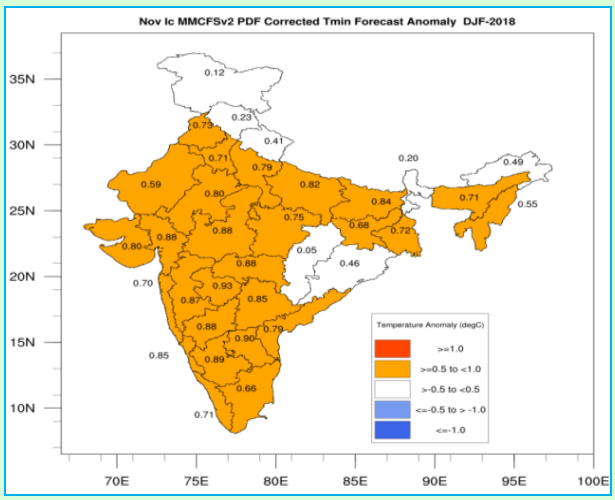


Fig. 37. Minimum Temperature

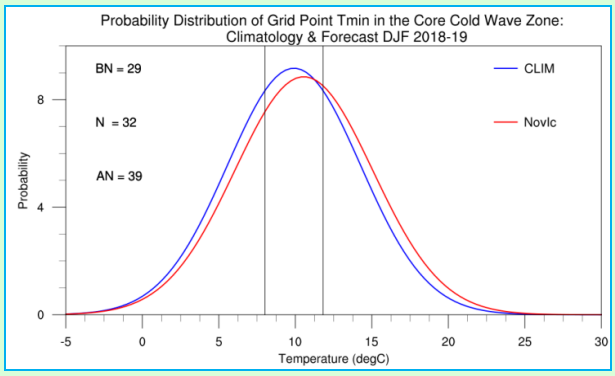


Fig. 38. Climatological probability distribution of grid point maximum temperatures during December 2018 to February 2019 over Core Cold wave Zone (CCZ) is shown along with forecast probability distribution of the same for December 2018 to February 2019

this season, many parts of the country experience cold wave conditions (days with abnormally cooler temperatures) with many adverse consequences. In an average about 780 deaths particularly of homeless people take place due to cold waves during each year.

The forecast suggests that above normal seasonal minimum temperatures (>0.5 °C) are most likely over most of the meteorological subdivisions of the country except Jammu & Kashmir, Himachal Pradesh and Uttarakhand in the north, Sub-Himalayan West Bengal & Sikkim and Arunachal Pradesh in the northeast, Odisha in the east and Chhattisgarh in Central India, where normal (between 0.5 °C & -0.5 °C) seasonal minimum temperatures are most likely (Fig. 37).

The seasonal temperature forecast December 2018 to February 2019 was prepared based on the 2018 November initial conditions. The forecast was prepared using 40 ensemble member forecasts. The model hindcasts and forecasts were bias corrected using the probability distribution function (pdf) method. The model showed moderate skill over many subdivisions over northwest and central India during the period 1982-2008.

There is about 39% probability of minimum temperatures in the core cold wave (CW) zone to be above normal during the November 2018-January 2019 season. Core CW zone covers states of Punjab, Himachal Pradesh, Uttarakhand, Delhi, Haryana, Jammu & Kashmir, Rajasthan, Uttar Pradesh, Gujarat, Madhya Pradesh, Chhattisgarh, Bihar, Jharkhand, West Bengal, Orissa & Telangana and met subdivisions of Marathwada, Vidharbha, Sourashtra and Madhya Maharashtra (Fig. 38).

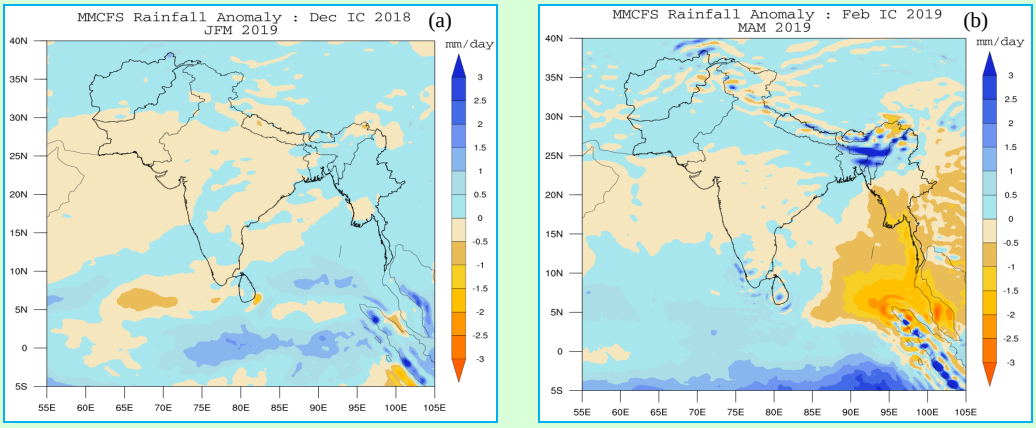
Regional Climate Center (RCC) Activities

The CRS office of IMD, Pune is also recognized as the WMO Regional Climate Center (RCC) for south Asia. Presently the MMCFS is used for the following the RCClong range forecasting activities.

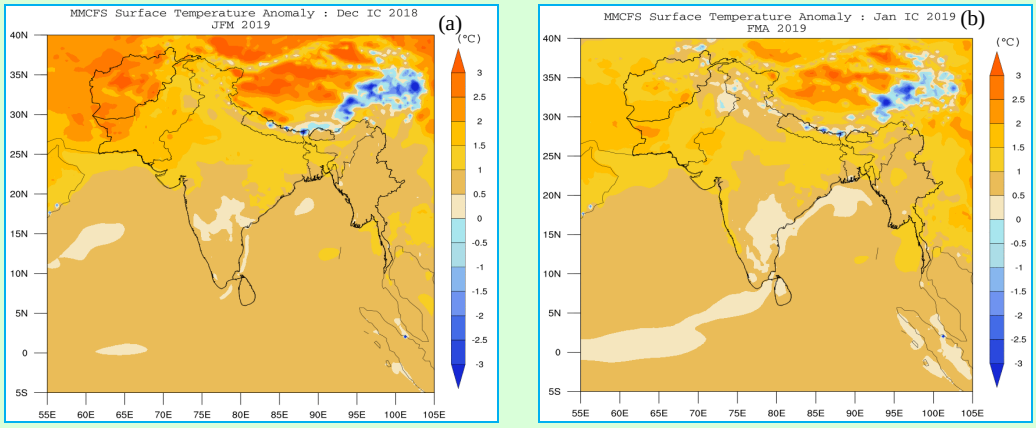
(a) Generate global monthly and seasonal forecasts for the temperature and rainfall. This is updated every month.

(b) Prepare Seasonal Climate Outlook for rainfall and temperatures over south Asia for the next 2 moving 3 month seasons (total 4 months) with monthly update. Seasonal rainfall and temperature for the 2019 JFM & FMA seasons issued in Dec 2018 is shown in the Figs. 39(a&b) and 40(a&b) respectively.

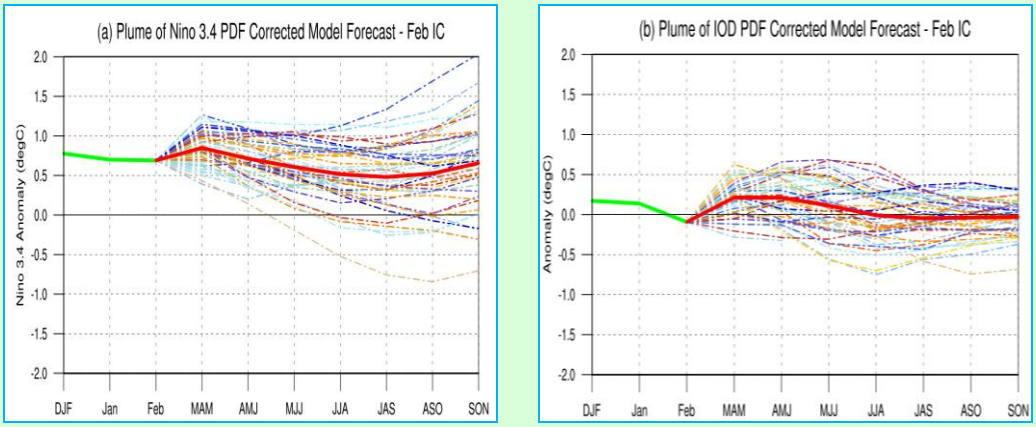
(c) Prepare ENSO & IOD bulletin every month providing statement on the global SST anomalies forecast with emphasis on the ENSO and IOD conditions for the next 9 months prepared based with monthly update. Forecast issued in March 2019 for Nino 3.4 and IOD plumes is shown in the Figs. 41(a&b). The corresponding probability forecast is given in Figs. 42(a&b).



Figs. 39(a&b). Seasonal forecasts of precipitation anomalies (mm/day) for (a) JFM (left) and (b) FMA (right) based on Initial conditions of December 2018



Figs. 40(a&b). Seasonal mean temperature anomalies (°C) for (a) JFM (left) and (b) FMA (right) based on Initial conditions of December 2018

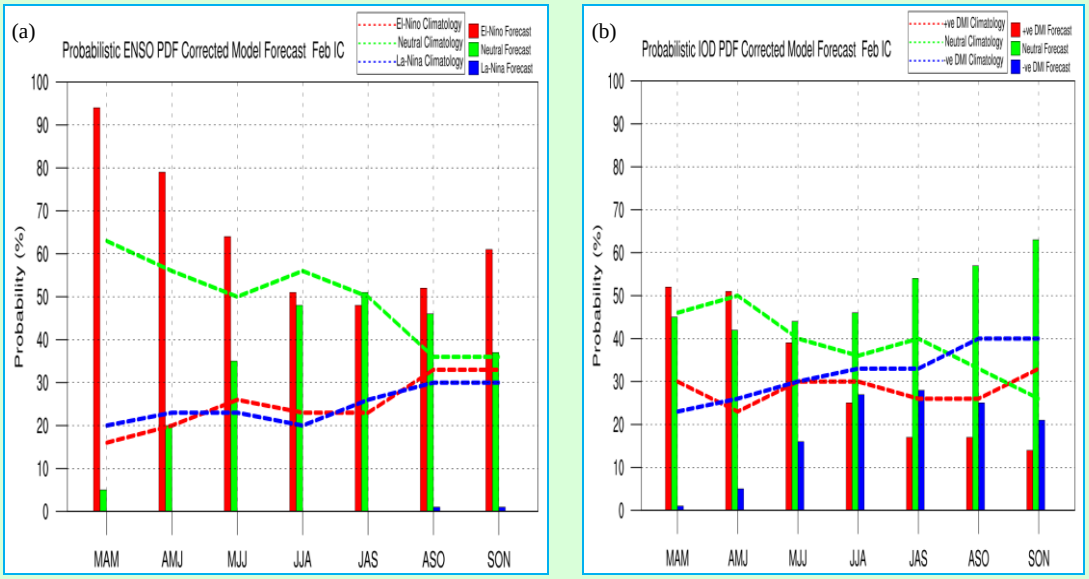


Figs. 41(a&b). PDF Corrected Model Forecast using FEB IC (a) Plume of Nino 3.4 and (b) Plume of IOD

(d) Take lead role in preparing consensus forecast outlook for the monsoon season rainfall, northeast monsoon rainfall and winter rainfall over south Asia.

Future Plans

- Improve the skill of existing operational statistical long range forecasting system.
- Develop Multi-model ensemble (MME) based seasonal prediction system.
- Develop tools for sector specific climate prediction products.
- Develop tools for verification of quantitative and probabilistic climate hindcasts and forecast products.



Figs. 42(a&b). Probability forecast along with climatological probabilities of (a) Niño 3.4 and (b) Indian Ocean Dipole Mode Index from high resolution MMCFSv2. Data source for Climatology probabilities: NOAA Extended Reconstructed SST V4b. Criteria used for Probabilistic ENSO Forecast: ≤ -0.5 La Niña, >0.5 to <-0.5 neutral, ≥ 0.5 El Niño. Criteria used for Probabilistic DMI Forecast: ≤ -0.2 negative DMI, >0.2 to <-0.2 neutral, ≥ 0.2 positive DMI

- Generate regional and sub-regional tailored climate prediction products.

- Generate regional and sub-regional tailored products, relevant to RCC User needs, including seasonal outlooks etc.

- Provide on-line access to products/services to different users.

- Assess use of climate prediction products and services through feedback from users.

- Development of tools for LRF at various spatial scales using statistical recalibration of the dynamical model outputs.

- Development of tools for drought prediction.

- Perform verification of RCC quantitative LRF products, including the exchange of basic forecasts and hindcast data.

(*ii*) Climate Monitoring & Annual Climate Statement

In line with the warmer than normal observed global temperatures during 2018, mean temperature over India was significantly higher during the year. During 2018, the annual mean land surface air temperature, averaged over the country, was +0.40 °C above the 1981-2010 average, thus making the year 2018 as the sixth warmest year on record since nation-wide records commenced in 1901. The winter and pre monsoon seasons (January-February, with anomaly of +0.59 °C, fifth warmest and Mar-May, with anomaly +0.55 °C, seventh warmest, since 1901) mainly accounted for the above normal annual temperature for the year.

The 2018 annual rainfall over the country as a whole was 85.9% of Long Period Average (LPA) value for the period 1951-2000.

Temperatures

The 2018 annual mean land surface air temperature for the country was +0.40 °C above the 1981-2010 average, thus making the year 2018 as the fourth warmest year on record since 1901 (Fig. 43). The other nine warmest years on record in order were: 2016 (+0.707 °C), 2009 (+0.552 °C), 2010 (+0.539 °C), 2015 (+0.424 °C), 1958 (+0.250 °C), 2002 (0.245 °C), 2014 (0.238 °C), 2006 (0.228 °C). It may be mentioned that 11 out of 15 warmest years were during the recent past fifteen years (2004-2018). Past decade

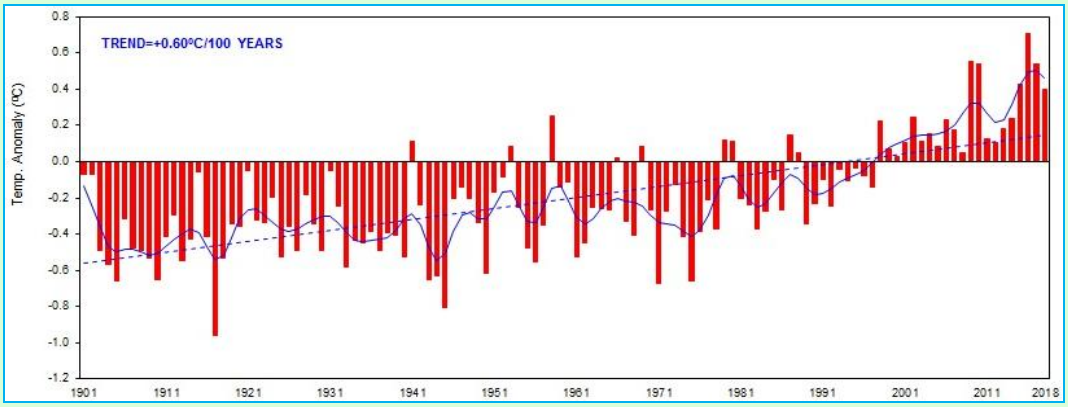


Fig. 43. Annual mean land surface air temperatures anomalies averaged over India for the period 1901-2018. The anomalies were computed with respect to base period of 1981-2010. The dotted line indicates the linear trend in the time series. The solid blue curve represents the sub-decadal time scale variation smoothed with a binomial filter

(2001-2010/ 2009-2018) was also the warmest decade on record with anomalies of 0.23 °C/ 0.38 °C above average. The annual mean temperature during 1901-2018 showed an increasing trend of 0.60 °C/100 years (Fig. 43) with significant increasing trend in maximum temperature (1.0 °C/100 years) and relatively lower increasing trend (0.20 °C/100 years) in minimum temperature. The country averaged season mean temperatures were also above the average during all the four seasons with the post-monsoon season (October-December, +0.31 °C) being the 13th warmest and the winter season (January-February, +0.59 °C) being the 5th warmest since 1901. Monsoon season (June-Sept) this year with anomaly +0.26 °C was the 10th warmest since 1901 and the pre monsoon season (March-May, with anomaly +0.55 °C above average) being the 7th warmest ever since 1901. The country averaged mean monthly temperatures were warmer than the normal during all the months of the year with mean temperatures in the range ± 1.0 °C above average except below normal in December (-0.08 °C).

Rainfall

The annual rainfall over the country was 85.9 % of Long Period (1951-2000) Average (LPA). Rainfall over the country as a whole during the SW monsoon season, which is the principal rainy season was normal (91% of LPA). During this season, among the four large geographical regions of the country, South Peninsula and NorthwastIndia received highest rainfall (98% of LPA) and East & Northeast India received lowest rainfall (75% of LPA). Central India received seasonal rainfall of 93% of LPA.

The northeast monsoon season rainfall over the country as a whole was below normal (56.1% of LPA). The seasonal rainfall over northeast monsoon region of the south peninsula (comprising of 5 subdivisions viz. Coastal Andhra Pradesh, Rayalaseema, Tamil Nadu & Puducherry, South Interior Karnataka & Kerala) was also below average (66% of LPA).

High Impact Weather Events

During 2018, 7 cyclonic storms formed over the north Indian Ocean. Out of these 7 systems, 3 systems forming over the Arabian Sea (2 during the pre-monsoon season and one during the postmonsoon season), did not have landfall over the Indian region. One cyclonic storm formed over Bay of Bengal in monsoon season (September) and crossed north Andhra Pradesh-Odisha coast near Gopalpur on 20 September. The remaining three systems, which formed over the Bay of Bengal during the post monsoon season crossed Indian coast. The first system VSCS “Titli” formed over the east central Bay of Bengal on 8 October and crossed Odisha coast on 11. The second one SCS “ Gaja” which formed over the east central Bay on 10 November, crossed Tamil Nadu coast on 15 and after moving across the south peninsula, it

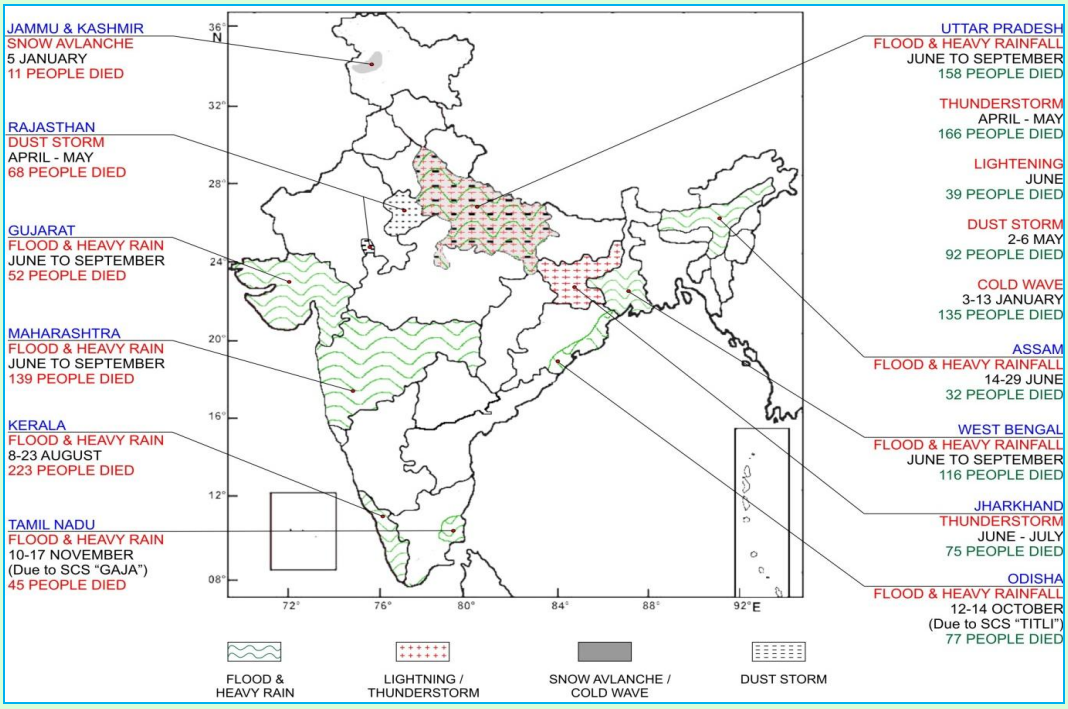


Fig. 44. Major extreme weather events occurred during 2018

re-emerged into Arabian Sea as a deep depression. The last cyclonic storm of the year SCS "Phethai", which formed over the southeast Bay of Bengal on 13 December, crossed the Andhra Pradesh coast on 17. The country also experienced other high impact weather events like, extreme heavy rainfall, heat and cold waves, snow cover, dust storm, lightening, floods etc. (Fig. 44). The causalities mentioned here are based on the media and government reports.

Lightning reportedly claimed over 198 lives from different parts of the (central, northeastern, peninsular & northwestern parts of the) country during pre-monsoon, monsoon & post-monsoon seasons. Of these deaths, maximum deaths were reported from Uttar Pradesh and Odisha.

Heavy rain & flood related incidents during the monsoon season claimed at least 612 lives from different parts of the country. Of these, 149 persons were reported dead from Kerala and 189 persons from Uttar Pradesh. 77 lives were claimed dead due to Cyclone (SCS) "TITLI" during 12 to 14 October. 45 lives reported dead due to Cyclone (SCS) "GAJA" during 10 to 17 November.

Snowfall reportedly claimed more than 18 lives from Jammu and Kashmir of which 11 were reportedly claimed dead on 5 Jan, 2018. 279 persons were reported dead due to Cold Wave during 2-14 Jan. Of these, 135 persons were reported from Uttar Pradesh and 121 from Bihar. Dust Storm took a toll of 225 lives throughout the country. Of this 150 were reported from Uttar Pradesh during the period 6 May to 13 June, 74 from Rajasthan and one from Madhya Pradesh. Severe heat wave/heat wave conditions prevailed over parts of north and central India during March to May and then extended spatially to east India in the month of June. The heat wave conditions got abated from the entire country by 26 June.

(*iii*) Supply of Meteorological Data

As a custodian of all meteorological data collected different stations of the country, National Data Centre (NDC) keyed, processed and archived them in standard format from time to time. During the period 2,50,24,315 records were retrieved and supplied to different users. In the current year, 8 educational/research institutes have registered with IMD for supply of data for academic & research purposes. An amount of Rs.29,74,450/- has been earned by sale of data.

CHAPTER 6

CAPACITY BUILDING, PUBLIC AWARENESS & OUTREACH PROGRAMME

IMD's major initiative in 2018 was to provide capacity building for its officers and staff, personnel from the other organizations in the country as well as from foreign countries particularly personnel from Asia pacific regions through organised training programmes, user workshops, conferences etc. Salient details are as under.

6.1. CONFERENCES & SYMPOSIUM

Dr. S. K. Peshin, Scientist 'G' attended the Fukuoka - Delhi Friendship Agreement 10th Anniversary commemorative Event "Environmental Seminar on Air Pollution" on 17th January, 2018 at Le-Meridien, New Delhi organized by Government of NCT Delhi, India Fukuka Perfectural Government, Japan and Japan International Cooperation Agency.

Shri S. M. Metri, Scientist 'E' and Shri N. Ramdoss, Met. 'B' attended seminar on "Savings Lives and Property through Severe Weather Alerting" based on Total Lightning Detection by the U.S. Commercial Service Bengaluru, U. S. Consulate General, Chennai and Earth Networks, USA with support from Skymet Weather Services on 8th February, 2018 at Plumeria, Taj West End, Race Course Road, Bengaluru.

Dr. S. Y. Khedikar, Scientist 'B' attended Farmer Awareness Program (FAP) held at Kurle, Taluka Sangamner, Distt. Ahmadnagar on 24th February, 2018 organised by AMFU, Rahuri. He gave talk on Application of weather forecast in agriculture to the farmers.

Dr. Kripan Ghosh, Scientist 'E' participated in a State Level Seminar on "Climate change and farmers: Impact on agriculture" organised by People's Participation, a NGO in West Bengal at "Institute of Co-Operative Management for Agriculture & Rural Development (ICMARD)", Kolkata, West Bengal, supported by Government of India, Ministry of Earth Sciences, on 27th February, 2018 and interacted with the farmers for their awareness regarding use of agromet advisory services for improvement of crop production.

Dr. K. J. Ramesh, DG, IMD along with Dr. M. Mohapatra, Scientist 'G', Dr. (Ms.) K. Sathi Devi, Scientist 'F' and Shri B. P. Yadav, Scientist 'F' attended Annual Conference of Relief Commissioners/Secretaries, Department of Disaster Management of States/UTs to review the status of preparedness for "SW Monsoon and to discuss other disaster management related issues" on 18th May, 2018 at Vigyan Bhawan, New Delhi. Dr. M. Mohapatra made a presentation on IMD's preparedness for ensuing monsoon and cyclone season.

Dr. S. D. Attri, Scientist 'F' delivered inaugural talk as Chief Guest in the National Conference

Dr. S. Y. Khedikar, Sc. 'B' during FAP

Dr. S. D. Attri, Sc. 'F' during the National Conference

on "Beating the plastic hazard : Challenge and Strategies" organised by DTU, New Delhi on 4th June, 2018 on the occasion of World Environment Day.

Dr. S. L. Singh, Sc. 'F', Shri Kuldeep Srivastava, Sc. 'E' and Shri Shankar Nath, Sc. 'E' took part in the seminar on the "Steering Committee of Open WIS Association" on 9th August, 2018.

Dr. Kripan Ghosh, Sc. 'E' and Mrs. Priyanka Singh, Sc. 'B' participated in Orientation Programme on "Preparation & dissemination of Agromet Advisories at Block level under Gramin Krishi Mausam Seva (GKMS) scheme" for Nodal Officers of Krishi Vigyan Kendras (KVKs) of ATARI Zone IV (Bihar and Jharkhand States), Patna, Bihar during 20-21 August, 2018.

Dr. K. Ghosh, Sc. 'E' and Shri R. Balasubramanian, Sc. 'D' attended the Orientation Programme as resource persons for the capacity building on "Preparation and Dissemination of Agromet Advisories at Block level under Gramin Krishi Mausam Seva GKMS) scheme" for Nodal Officer's of Krishi Vigyan Kendras (KVKs) for the state of 'Rajasthan' from 11-12 September, 2018 at Maharana Pratap University of Agriculture and Technology (MPUAT), Udaipur.

Shri Kuldeep Srivastav, Sc. 'E' participated in the seminar on the "Technical Committee of Open WMO Information System (WIS) Association" on 12 and 27 September, 2018.

Shri Bikram Singh, Sc. 'E' inspected Chinyalisaur Airport (District Uttarkashi) for "Provision of Aeronautical Met. Services under UDAN Scheme" on 21st September, 2018.

Dr. S. D. Attri, Sc. 'F', attended the Orientation Programme for the capacity building on "Preparation and Dissemination of Agromet Advisories at Block level under Gramin Krishi Mausam Seva (GKMS) scheme" for Nodal Officer's of Krishi Vigyan Kendras (KVKs) have been conducted for ATARI Zone Bengaluru (Karnataka, Kerala and Lakshdweep) on 28th September, 2018.

Dr. Shirish Y. Khedikar, Sc. 'B' attended the Young Scientist's Conference under "India International Science Festival 2018" from 5-8 October, 2018 held at Indira Gandhi Pratisthan, Lucknow, Uttar Pradesh.

Dr. A. K. Sahai, Sc. 'G', Dr. A. Kashyapi, Scientist 'F', Dr. S. L. Singh, Sc. 'F', Dr. Vijaya Bhaskar, Sc. 'E', Shri Manish Ranalkar, Sc. 'E', Mrs. Samanti Sarkar, Sc 'E', Shri R. Balasubramanian, Sc. 'D', Shri M. Danish, Sc. 'B', Dr. D. M. Rase, Met. 'B', Smt. Sandhya Ravikiran, Met. 'B' etc. participated in National Symposium on "Understanding Weather and Climate Variability : Research for Society - TROPMET 2018" organised by Indian Meteorological Society (IMS) in association with Department of Geophysics, Banaras Hindu University (BHU), Varanasi during 24-27 October, 2018.

Dr. K. J. Ramesh, DG, IMD, was the Guest of Honour in the "Valedictory Session of 10th National Seminar on Climate Change and World Peace (10th Indian Climate Congress)" from 27-29 December, 2018 at OUAT, Bhubaneswar. Dr. Shashi Kant, Sc. 'B', Shri Uma Shankar Das, Sc. 'B', Shri L. D. Mohapatra, Met. 'B' and Shri P. K. Nath, Met. 'A' were also participated in Seminar.

Participants attending orientation programme under GKMS

Dr. K. J. Ramesh, DG, IMD and others during the seminar

6.2. WORKSHOP

Dr. A. K. Sahai, Scientist 'G' attended the workshop in connection with "India UK Water Centre Workshop on "Improving Fresh Water Monitoring Frameworks for Data and Research Management" from 23-25 January, 2018 at Kochi.

Dr. Sanjib Bandyopadhyay, Scientist 'F' attended Workshop on "A climate change resilient and carbon neutral West Bengal" on 30th January, 2018 at Saltlake, Kolkata organized by Department of Environment, Government of West Bengal.

Dr. G. N. Raha, Scientist 'D' attended a workshop on "Developing Disaster Resilience Action Plan for Gangtok" on 6th February, 2018, at Gangtok organized by Integrated Research and Action for Development (IRADe) and North-Eastern Space Applications Centre (NESAC), with support from Ministry of Environment, Forests & Climate Change (MoEFCC) under National Mission on Himalayan Studies.

Shri S. C. Bhan, Scientist 'F' attended National workshop on "Preparedness, Mitigation and Management of Heat wave" held at Vijayawada on 21-22 February, 2018 and delivered an invited talk on "Operational issues: Temperature threshold cooperation and dissemination".

Dr. K. K. Singh, Sc. 'F' and Dr. S. D. Attri, Sc. 'F' participated in "KVK Workshop 2018" held during 16-17 March, 2018 which was inaugurated by Hon'ble Prime Minister of India.

Dr. M. Mohapatra, Scientist 'G' and Dr. Sathi Devi, Scientist 'F' participated in the Indo-Japan Workshop on "Disaster Risk Reduction" during 19-20 March, 2018 at Vigyan Bhawan.

Dr. S. C. Sahu, Scientist 'F', participated in the workshop on "Regional Environment and Climate in Odisha: Lighting, Thunderstorm and Heat wave (RECO 2018)" jointly organized by Indian Meteorological Society (IMS), Bhubaneswar Chapter and Centre for Environment and Climate, ITER, Siksha 'O' Anusandhan University, Bhubaneswar on 23-24 March, 2018.

Dr. S. C. Sahu, Scientist 'F' during the workshop

Dr. N. Chattopadhyay, Scientist 'F' attended the work-shop on "Agromet Decision Support System for automation of Agromet Advisories services (AAS)" and Brainstorming meeting on "Preparation of Road Map for successful Implementation of Block Level Advisory Services" during 3-4 May, 2018 in New Delhi organized by Agromet Advisory Service Division(AASD), IMD, New Delhi.

Shri N. T. Niyas, Scientist 'D' has been deputed for participation in a workshop on "Climate change and Agriculture in Local self Governments in Kerala" organised by the Kerala Institute of Local Administration, Thrissur, Kerala during 18-19 May, 2018.

Dr M. Mohapatra, Sc. 'G' participated as a Panelist in the Panel discussion in the National Workshop on "Forging Partnership" Capacity Building for DRR organized by NIDM at its Vijayawada campus on 21st May, 2018 and delivered a presentation on Capacity building for Early Warning and its Dissemination.

A one day workshop in Hindi was held at RMC Chennai on 21st May, 2018 under the chairmanship of **Shri S. Bagulayan Thampi**, DDGM, RMC Chennai. Dr. C. Annapurna, Prof. & Head of Hindi Department, University of Madras was the Chief Guest and Shri Udaykumar Meghani, Announcer, All India Radio gave a lecture on "Correct pronunciation of some Hindi words". The following lectures in Hindi were presented in the workshop:

Smt. S. Stella, Scientist 'E', AMO Chennai - on Aviation Meteorological Services.

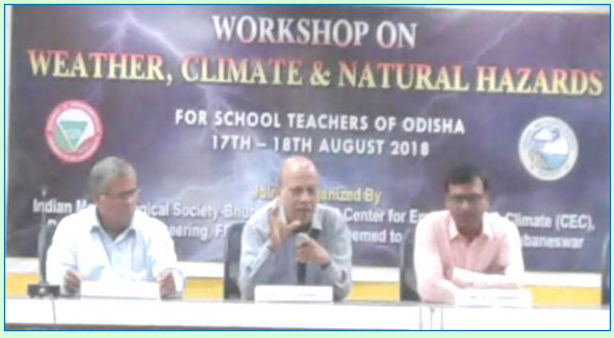
Shri R. Balasubramanian, Scientist 'D', Dr. S. Y. Khedikar, Scientist 'B', Smt. K. Malathi, Met. 'A', Shri K. G. Kanade, Met. 'A' and P. S. Pranjali, Scientific Assistant attended the two days hands-on workshop on "Use of Software for Automated Generation of Agromet Advisories during Kharif season by all the Agromet field Units" organized by Watershed Organization Trust (WOTR), Pune during 28-29 May, 2018 at Pune.

Shri S. Sengupta, Scientist 'E' from MC Patna, Dr. G. K. Das, Scientist 'E' from ACWC Kolkata, Dr. G. N. Raha, Sc. 'D' from MC Gangtok and Shri R. S. Sharma, Scientist 'B' from MC Ranchi, attended a workshop on "Interpretation of Satellite Imageries and Products" at DGM, New Delhi during 18-23 June, 2018.

Shri H. R. Biswas, Sc. 'E', M. C. Bhubaneswar attended the workshop conducted by South Asia Sustainable Impact Platform on "Scaling Climate-Smart Agriculture in Odisha-Practices, Policies and Institutions" on 18th July, 2018 held at The New Marrion, Janpath, Bhubaneswar.

Shri Bikram Singh, Sc. 'E', attended a workshop on 2nd August, 2018 at UCOST, Vigyan Dham, Dehradun in connection with "Understanding Mountain People's - approach and Practices to Combating Climate Change in the Indian Himalayan Region" organized by SDFU and IMI, Govt. of Uttarakhand.

Shri H. R. Biswas, Sc. 'E' M. C. Bhubaneswar participated in the workshop on "Weather, Climate & Natural Hazards" organized by India Meteorological Society (Bhubaneswar Chapter) at Siksha 'O' Anusandhan (Deemed to be University) during 17-18 August, 2018 and addressed the Valedictory Session.



H. R. Biswas, Sc. 'E' during the workshop

Shri Bikram Singh, Sc. 'E' attended a workshop in connection with "Sendai framework" on 20th August, 2018, organized by Dept. of Disaster Management, Govt. of Uttarakhand.

Shri Shankar Nath, Sc. 'E' participated in a workshop on 29th August, 2018 with the subject "SDWAN Security & Next Generation Firewall". This workshop was organized in CERT-In, New Delhi.

Dr. S. Balachandran, Sc. 'F', RMC Chennai, accompanied by Dr. R. Puviyarasan, Sc. 'D', ACWC Chennai, participated in the workshop on the "Programme for Water as Leverage for Resilient Cities Asia" in which Special Envoy for International Water Affairs of the Netherlands Government and other experts participated on 6th September, 2018.

Shri Bikram Singh, Sc. 'E' attended one day workshop in connection with "Disaster Risk Assessment" on 12th September, 2018, organized by Deptt. of Disaster Management, Govt. of Uttarakhand.

Dr. K. K. Singh, Sc. 'F', Dr. S. D. Attri, Sc. 'F' and Mrs. Priyanka Singh, Sc. 'B' attended workshop for "CHAMAN phase II launch" on 20th September, 2018 at NRL, IARI, New Delhi.

Shri Bikram Singh, Sc. 'E' attended one day workshop in connection with "Use of Technology for Reducing Landslide Induced Losses" on 24th September, 2018, organized by Dept. of Disaster Management, Govt. of Uttarakhand.

Dr. Kripan Ghosh, Sc. 'E' attended the "Extended Range Forecast Systems (ERFS) Training Workshop" as resource person and delivered lectures and hands on training to the participants from 8-10 October, 2018 at Indian Institute of Technology, Bhubaneswar, Odisha.

Dr. Somenath Dutta, Sc. 'F' participated in the two day workshop organized by The Energy & Resources Institute (TERI) on "Climate and Health" held at India Habitat Centre, Lodhi Road, New Delhi, from 23-24 October, 2018 and gave a presentation on the recent initiatives taken in IMD towards Climate Services for health.

Shri H. R. Biswas, Sc. 'E' attended the Final Dissemination Workshop of "Deltas, Vulnerability and Climate Change: Mitigation and Adaptation (DECCMA) Project (PADIF)" at New Marrion Hotel, Bhubaneswar on 1st November, 2018.

Mrs. Priyanka Singh, Sc. 'B' participated in "Kick-Off Workshop of the International Cooperation Project East Africa Peru India Climate Capacities - EPICC" held at India Habitat Center, New Delhi during 1-2 November, 2018.

Dr. K. K. Singh, Sc. 'F' participated in one day workshop on "Enhancing Climate Services in Agriculture in Bihar State" on 2nd November, 2018 at Patna, Bihar.

Dr. A. K. Sahai, Sc. 'G' attended one day workshop and technical aspect of "Climate Forecast" held at New Delhi on 3rd November, 2018.

Dr. S. D. Attri, Sc. 'F' attended IAAPC National Workshop on "Impact of Air Pollutionon Monuments and Conservation" and gave a talk on "Impact of Meteorological/climatic factors on monuments" on 3rd November, 2018 at New Delhi.

Dr. Pulak Guhathakurta, Sc. 'F' attended workshop on "Improving Flood & Drought Risk Estimation and Prediction in data sparse region" organised by Centre for Ecology and Hydrology, UK at IIT Powai, Mumbai on 26th November, 2018 and gave a presentation on "Suitability of Ideal Method in estimation of PET in real time flood/drought monitoring in India".

Dr. Pulak Guhathakurta, Sc. 'F' during the Workshop

Dr. S. L. Singh, Sc. 'F' participated in workshop on "Cloud Security" at Cert In, Shastri Park, Delhi on 20th December, 2018.

6.3. MEETINGS

Dr. A. K. Sahai, Scientist 'G' was on tour to IISc, Bangalore to attend a meeting on 4th January, 2018 regarding "Planning possible future collaborations between USA and Indian scientists to study the sub-seasonal variability in the Monsoons".

Dr. Jayanta Sarkar, Scientist 'F' attended meeting with participants from SAARC Member States to discuss the training on "SAARC Disaster Management Centre" at GIDM, Gandhinagar on 4th & 9th January, 2018.

Shri Bikram Singh, Scientist 'E' attended a meeting on "Review of seismic threat in Uttarakhand and recent earthquake tremors" at Uttarakhand Secretariat organized by Disaster Management Department, Govt. of Uttarakhand on 4th January, 2018.

Dr. K. J. Ramesh, DG, IMD participated in the Parliamentary Standing Committee meeting on "Science and Technology, Environment and Forest (Air Pollution in Delhi NCR)" at Rajya Sabha Secretariat, New Delhi on 9th January, 2018.

Dr. Devendra Pradhan, Scientist 'G' and Shri Bikram Singh, Scientist 'E' attended a meeting with Chief Secretary, Govt. of Uttarakhand in connection with "Status of Radar procurement and site finalization for installation of Radars in Uttarakhand on 11th January, 2018.

Dr. K. J. Ramesh, DG, IMD was guest of honour in the Brainstorm Meeting on "Establishment of Bay of Bengal Coastal Observatory (BoBCO)" at IIT, Bhubaneswar on 17th January, 2018.

Dr. K. K. Singh, Scientist 'F', Dr. S. D. Attri, Scientist 'F', Dr. N. Chattopadhyay, Scientist 'F' and Dr. Kripan Ghosh, Scientist 'E' attended "WMO-IMD-IITM Inception Meeting on Development of Climate Services Toolkit for National Centre for Hydrology & Meteorology (NCHM), Bhutan" and support to be provided for the overall improvement in the climate services in Bhutan" at Pune, during 17-18 January, 2018.

Shri Anand Sharma, Scientist 'F', attended a meeting to develop "Contingency plans for Kharif, 2018 in regard to El Nino and Drought" on 31 January - 1 February, 2018 at Jalagam, Dehra Dun under the Watershed development program.

Dr. K. J. Ramesh, DG, IMD attended a meeting through video conference on "Weather and Climate Science for Service Partnership (WCSSP) - India" involving Ministry of Earth Sciences (MoES) and UK-Met Office on 5th February, 2018.

The **26th Standing Advisory Committee meeting of PAC, Kolkata** was held on 5th February, 2018 at PAC Kolkata office under chairmanship of Prof. G. M. Ballabh, Retd. Prof., Osmania University, Hyderabad. Dr. D. R. Pattanaik, Scientist 'E', Dr. S. Bandyopadhyay, Shri S. Sen, Scientist 'F'attended the meeting.

Officers during 26th Standing Advisory Committee meeting

Dr. K. J. Ramesh, DG, IMD and Dr. K. K. Singh, Scientist 'F' invited and participated in the session on "Science & Technology intervention" on 19-20 February, 2018 organised by Ministry of Agriculture and Farmers Welfare under "Agriculture - 2022, New initiatives" at National Agriculture Science Complex (NASC), Pusa, New Delhi.

Dr. K. J. Ramesh, DG, IMD had meeting with Professor Alan Jenkins from Centre for Ecology & Hydrology, UK on issues of "Research co-operation" on 20th February, 2018 at IMD, H.Q., New Delhi about the issues of River - basin Hydrology that will be part of joint Indo-UK Projects currently under formulation.

Dr. K. J. Ramesh, DG, IMD chaired the meeting on "Implementation of Hurricane Weather Research & Forecast - Hybrid Ocean Coupled Model (HWRF-HYCOM) Modelling System on real time basis" in IMD through collaboration of IMD, INCOIS and National Centre for Medium Range Weather Forecasting (NCMRWF) at IMD, New Delhi on 23rd February, 2018.

Dr. N. Chattopadhyay, Scienist 'F' attended a meeting with Dr. Adam Griffin, Hydrological Statistician, Centre for Ecology & Hydrology (CEH), Wallingford, Oxon, United Kingdom and his team during their visit to IMD Pune on 26th February, 2018 regarding the current progress of the project on "Flood and rainfall frequency estimation in Maharastra State" between CEH, Walliangford, Oxon, U. K., Indian Institute of Technology, Mumbai and IMD Pune.

Dr. S. C. Sahu, Scientist 'F' attended the "Technical Sub Committee Meeting of SDMC" for the Installation of AWS and ARG in the state at OSDMA, Rajib Bhawan, Bhubaneswar on 27th February, 2018.

Dr. M. Mohapatra, Scientist 'G' and Dr. A. K. Mitra, Scientist 'D' participated in 4th Meeting of Indian Space Research Organisation (ISRO) - MoES sub-committee on "Advances in Atmospheric Research" on 28th February, 2018 through video conference.

ANNUAL CYCLONE/MONSOON REVIEW MEETING

India Meteorological Department (IMD) organised **Annual Cyclone/Monsoon Review Meeting** to review it's activities on monsoon and cyclones during the past year and plan for the season ahead at Ahmadabad during 4-5 March, 2018. The participants included officers of IMD at state/regional/HQ levels and representatives from Indian Institute of Tropical Meteorology (IITM) Pune/National Centre for Medium Range Weather Forecasting (NCMRWF)/Indian National Centre for Ocean Information Services (INCOIS)/ National Institute of Ocean Technology (NIOT). Dr. M. Mohapatra, Scientist 'G' & Head (Services) made a presentation on "Lessons learnt during Cyclone Ockhi".

Dr. K. J. Ramesh, DG, IMD and officers during the meeting

Dr. S. D. Attri, Scientist 'F' participated in meeting of the "Steering Committee on Sustainable Livelihoods and Adaptation to Climate Change (SLACC) Project" held under the chairmanship of Secretary, Rural Development on 5th March, 2018 at Krishi Bhawan, New Delhi.

Dr. N. Chattopadhyay, Scientist 'F', Shri R. Balasubramanian, Scientist 'D', Dr. S. Y. Khedikar, Scientist 'B' and staff members of NAASC Section attended "State level stake holders' meeting on Agromet Advisory Services in Maharastra" held on 14th March, 2018 at College of Agriculture, Pune organised by Mahatma Phule Krishi Vidhyapith, Rahuri, India Meteorological Department, Pune and Department of Agriculture, Government of Maharastra.

Dr. N. Chattopadhyay, Sc. 'F' and others during the meeting

Dr. K. J. Ramesh, DG, IMD, Dr. M. Mohapatra, Scientist 'G', Dr. A. K. Sahai, Scientist 'G', Dr. D. S. Pai, Scientist 'F' and Dr. Somenath Dutta, Scientist 'F' attended a meeting for "Development of collaborative mechanism for Weather and Climate Science for Service Partnership (WCSSP) India between MoES and UK Met. Office" was organised at Prithvi Bhawan during 20-21 March, 2018. Dr. M. Mohapatra gave a presentation on "Impact based forecasting & risk based warning by IMD".

Dr. K. J. Ramesh, DG, IMD, Dr. M. Mohapatra, Scientist 'G' and scientists from NWP Division participated in a meeting organised by MoES under the chairmanship of Secretary, MoES to "Plan block level forecast from this monsoon season 2018" on 26th March, 2018.

Dr. K. K. Singh, Sc. 'F' attended meeting on "High Level Monitoring Committee (HLMC) of National Innovations in Climate Resilience Agriculture (NICRA) - regarding" held on 4th April, 2018 under the Chairmanship of Secretary, DARE & DG, ICAR in NASC Complex, Dev Prakash Shashtri Marg, New Delhi.

Shri I. J. Verma, Scientist 'E' and Shri Ved Prakash Singh, Scientist 'B' participated in "16th Regional Coordination Committee meeting" at Central India Hydrology Regional Centre, Bhopal, National Institute of Hydrology on 6th April, 2018.

Shri S. C. Bhan, Scientist 'F', participated in meeting with Director NDRI and Dr. Sohanvir Singh Tomar Principal Scientist, at NDRI Karnal on 16th April, regarding the "Forecast/weather advisory for livestock owners for better comfort of livestock species and enhancing the farmers/farms income".

Dr. N. Chattopadhyay, Scientist 'F' attended a meeting for discussion on "Mechanism for implementation strategies for establishing District Agromet Units (DAMUs) observation system, outreach and feedback including the role of stakeholders" during 16-18 April, 2018 at AASD, IMD, New Delhi.

Dr. K. J. Ramesh, DG, IMD, Dr. S. D. Attri, Sc. 'F', Dr. Y. K. Reddy, Sc. 'F' and Mr. Srikanth Dashetty, Sc. 'B' participated in 2nd meeting on "Automation on Agromet Advisory Services" held on 18th April, 2018 at ICAR-CRIDA, Hyderabad. Dr. Attri also made presentation on "Agromet DSS for automation of Agromet Advisory Services".

Dr. K. J. Ramesh, DGM & other officers during the meeting

Dr. M. Rajeevan, Secretary, MoES, Dr. K. J. Ramesh, DGM alongwith scientists of IMD and foreign delegates attended the South Asian Climate Outlook Forum (SASCOF-12) meeting held during 19-20 April, 2018 at IMD, Pune.

Pre-Cyclone Exercise meet

Dr. Sanjib Bandyopadhyay, Sc. 'F' presided over **Pre-Cyclone Exercise meet** on 19th April, 2018 at RMC Kolkata, Alipore. High level Central and State govt. concerned authorities like Coast Guard, All India Radio, Doordarshan, Eastern & South-Eastern Railways, Disaster Management Department and Dept. of Fisheries, Govt. of West Bengal, DVC, representatives from office of the DMs and SPs of the Costal Districts. HAM Radio, Fishermen Associations, Kolkata Municipal Corporation, CESC, and others took part in the exercise with interactive discussions. The DDGM highlighted the importance of such meet to extend better co-ordination among the stake holders of Disaster managers to minimize loss of life and property of the people from any approaching Cyclone. Dr. G. K. Das, Scientist 'D' delivered lectures on Cyclone Warning Preparedness and Dissemination on 19th April, 2018 at Seminar hall at RMC Kolkata regarding the Pre-monsoon pre-Cyclone Exercise meeting.

Dr. Sanjib Bandyopadhyay, Sc. 'F' and other officers & staff members of IMD during the Pre-Cyclone Exercise meet

Dr. M. Mohapatra, Scientist 'G' participated in the meeting of "Inter-organizational Expert Committee" constituted by ISRO under the chairmanship of Dr. R. R. Navalgund, Distinguished Scientist, ISRO to deliberate and to consolidate the requirements for future Earth Observation Sensor Systems. **Dr. K. J. Ramesh**, DG, IMD is an expert member of this committee. The meeting convened during 20-21 April, 2018 at Bengaluru and on 25th April, 2018 in Delhi.

Dr. G. K. Das, Scientist 'D' attended a co-ordination meeting to "Ensure safety of fishermen of West Bengal Coast" on 24th April, 2018 organised by the Disaster Management Department, Govt. of West Bengal at WB Secretariat, NABANNA.

Shri Y. K. Reddy, Scientist 'F' held the "Technical Evaluation Committee meeting for procurement of Ten Nos. X-Band Dual polarized Doppler Weather Radar Systems for IMD" on 1st May, 2018.

Dr. Geeta Agnihotri, Sc. 'E' and Shri C. S. Patil, Sc. 'D' and Smt. C. A. Kameshwary, Met. 'A' attended a meeting at KSNDMC Bengalauru on 8th May, 2018 to "Explore the possibility to expand the outreach of Agro Advisiory Bulletins to farmers in Karnataka" using the call centre

facility at KSNDMC & to increase the raingauge network for calculating rainfall statistics.

Dr. S. C. Sahu, Scientist 'F' participated inthe Brainstorm Meeting on "Future strategies for the need and scope of ERFS products for robust agriculture adversaries" at IIT, Bhubaneswar during 9-10 May, 2018.

Shri K. Santhosh, Scientist 'F' attended the "Pre monsoon Meeting convened by Kerala State Disaster Management Authority" at Darbar Hall, Govt. Secretariat, Thiruvananthapuram on 14th May, 2018.

Shri R. Balasubramanian, Sc. 'D' and Shri J. P. Sabale, Met. 'A' attended the "State Level Joint AGRESCO-18" meeting hosted by Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Distt. Ratnagiri on 24th May, 2018. He gave presentation on "South west monsoon in 2018 and Activities under Gramin Krishi Mausam Seva in Maharastra".

Dr. N. Puviarasan, Sc. 'D' and Shri Rm. A. N. Ramanathan, Met. 'B' attended the meeting of stakeholders under the chairmanship of Superintendent Engineer, Central Water Commission, Chennai for the "Flood forecasting activities for the monsoon season 2018" on 25th May, 2018.

Dr. H. R. Biswas, Sc. 'E' and Shri K. Murmu, Met. 'B' attended the meeting on "Preparedness during Flood Season 2018" at Central Water Commission, Mahanadi Bhawan, Bhubaneswar on 25th May, 2018.

Dr. Sanjib Bandyopadhyay, Scientist 'F' attended meeting on "Early Warning-Interpretation & Dissemination" at Tran Bhavan, Kolkata organized by Directorate of Disaster Management, Govt. of West Bengal on 30th May, 2018.

Shri Y. K. Reddy, Scientist 'F' attended High Power meeting convened by Chief Secretary, Andhra Pradesh Government in view of "Commencement of monsoon season" on 7th June, 2018 A. P. Secretariat at Vijayawada.

Dr. G. K. Das, Sc. 'D' attended a "Monsoon preparedness" meeting organized by South 24 Parganas District Disaster Management Authorities at Alipore, Kolkata on 7th June, 2018 and also meeting on preparatory measures for monsoon 2018 organized by Chief Secretary, Govt. of WB held at Nabanna, Howrah on 12th June, 2018.

Dr. S. Bandyopadhyay, Sc. 'F' attended a meeting on "monsoon" held at RMC Kolkata, Alipore on 8th June, 2018. Senior delegates of central and state govt. concerned authorities Like Coast Guard, All India Radio, Doordarshan, Eastern & South-eastern railways, Disaster Management Department and Department of Fisheries, Govt of WB; DVC, representatives from office of the DMs and SPs of the coastal districts, HAM Radio, Kolkata Municipal Corporation, CESC and others took part in the exercise with interactive discussions.

Special Agro-Advisory Committee Meeting was held on 12th June, 2018 in Agrimet Division, Pune under the Chairmanship of Shri S. P. Singh, Commissioner of Agriculture, Government of Maharashtra to discuss "Long Range Forecast and Extended Range Rainfall Forecast issued by IMD and medium Range District level value added forecast". Dr. N. Chattopadhyay, Sc. 'F', Dr. K. Ghosh, Sc. 'E', Shri R. Balasubramanian, Sc. 'D' and State Govt. Agriculture officers attended the meeting. Based on this district level Agromet advisory prepared by 9 AMFUs State composite Agro-advisory bulletins prepared by Agrimet Division in both English and Marathi was appreciated by the commissioner of Agriculture.

Dr. M. Mohapatra, Sc. 'G' and Dr. D. R. Pattanaik, Sc. 'E' participated 4th Meeting of "National Information System for Climate & Environment Studies (NICES) - Programme Management Council" on 14th June, 2018 at ISRO Dwarka Guest House, New Delhi.

Shri Bikram Singh, Sc. 'E' attended a meeting under the chairmanship of Chief Minister, Uttarakhand on "Monsoon Preparedness" at

Secretariat, Uttarakhand on 14th June, 2018 and briefed about the South West Monsoon seasonal forecast and its progress till date.

Dr. M. Mohapatra, Sc. 'G' attended first meeting held in NDMA on 22nd June, 2018 for "Preparation of Guidelines on Thunderstorms, Squall and Lightning". Dr. Mohapatra, Sc. 'G' has also been nominated as an Expert Member of the committee constituted by NDMA.

Shri Bikram Singh, Sc. 'E' attended a meeting with Principal Chief Conservator of Forest Uttarakhand on 25th June, 2018 in connection with "Installation of Hydro-Met Network on Forest Department lands".

Shri Y. K. Reddy, Sc. 'F' attended a meeting with Agriculture Commissioner, Telangana Govt. seeking their support for "Starting Block Level Agro Advisories" at Secretariat on 3rd July, 2018.

Dr. M. Mohapatra, Sc. 'G' participated in the meeting to review inception report for "Development of Web based Dynamic Composite risk Atlas (Web-DCRA) & Decision Support System Tool for Cyclones and associated impacts including storm surge and Inland Flooding under National Cyclone Risk Mitigation Project (NCRMP) (Phase-II)" on 4th July, 2018 at NDMA Bhawan, New Delhi.

Shri Bikram Singh, Sc. 'E' participated in meeting under the chairmanship of Chief Secretary, Govt. of Uttarakhand regarding Monsoon Preparedness on 4th July, 2018. Shri Bikram Singh also gave a presentation on "Operational Products Generated by M. C. Dehradun and the Progress & Forecast for Monsoon Season-2018".

Dr. S. L. Singh, Sc. 'F' participated in the meeting on the "Use of GAGAN in non-aviation sectors/territories" held in the Ministry of Civil Aviation, New Delhi (IMG) on 9th July, 2018. It was Fourth Inter Ministerial Group (IMG) participated in the meeting on the use of GAGAN.

Dr. M. Mohapatra, Sc. 'G' chaired a meeting on 16th July, 2018 and 1st August, 2018 for reviewing of "Satellite Division Web page" to be provided to public on Internet.

Dr. A. K. Sahai, Sc. 'G' and Dr. N. Chattopadhyay, Sc. 'F' attended Farmers' Awareness Programme (FAP) organised by AMFU, Kakdwip, West Bengal on "Climate, Weather and Crops" at Namkhana Panchayet, Namkhana on 17th July, 2018. Dr. Sahai, Sc. 'G' also explained about the role of weather based Agromet Advisory Services at village level with respect to cultivation of cereal/cash crops, horticultural crops, poultry, animal husbandry and fish culture.

Dr. K. K. Singh, Sc. 'F' and Dr. S. D. Attri, Sc. 'F' attended the meeting on 18th July, 2018 at KAB, New Delhi organized by the office of the DDG (AE). ADGs (AE) and Directors from ICAR-ATARIs of all the eleven zones were present. Progress on "Steps related to setting up DAMU at KVKs was reviewed for accelerating the work and recruitment of manpower envisaged under GKMS scheme".

H. R. Biswas, Sc. 'E' attended the 2nd meeting for the year 2018-19 of the state executive committee constituted under the "Disaster Management Act, 2005" chaired by Chief Secretary, Govt. of Odisha at Odisha Secretariat on 18th July, 2018.

Dr. Jayanta Sarkar, Sc. 'F' attended a meeting, with honourable Chief Minister of Gujarat, at Gandhinagar regarding "Monsoon 2018 scenario" on 19th July 2018.

Dr. N. Chattopadhyay, Sc. 'F' attended a meeting on preparatory discussion on "Organizing Orientation Training Programme for KVKs for West Bengal and Orissa State" at Indian Council of Agriculture Research (ICAR), ATARI (Agricultural Technology Application Research Institute), Kolkata on 20th July, 2018.

Dr. K. K. Singh, Sc. 'F' and Dr. S. D. Attri, Sc. 'F' attended Consultation Meeting on "Vulnerability and Risk of Agriculture to

Climate Change and Variability: A District Level Assessment" held on 20th July, 2018 at NASC Complex, New Delhi.

Shri Anand Sharma, Sc. 'F' had a meeting with Shri Trivendra Singh Rawat, Honourable Chief Minister of Uttrakhand on 21st July, 2018 regarding organizing a workshop on users meet related to "Weather base agro advisory services to farmers of Uttrakhand".

Shri H. R. Biswas, Sc. 'E' attended the "Review Meetings on rainfall situation" chaired by Hon'ble Chief Minister, Odisha at Secretariat, Bhubaneswar on 21 and 23 July, 2018.

Shri H. R. Biswas, Sc. 'E' during the meeting

Dr. K. K. Singh, Sc. 'F' and Dr. D. R. Pattnaik, Sc. 'E' attended the meeting of Project Implementation Committee on "Development and Application of Extended Range Forecast System (ERFS-Phase II) for climatic risk management in Agriculture" chaired by the Secretary, DAC&FW on 23rd July, 2018 at Krishi Bhawan, New Delhi.

Dr. S. D. Attri, Sc. 'F' participated in Stakeholders meeting held under the Chairmanship of Additional Secretary, MoEF&CC on 23rd July, 2018 at Indira Paryavaran Bhawan, New Delhi to finalize "Government of India's response to Final Government Draft of the IPCC Special Report on the impact of Global Warming of 1.5 °C circulated by the IPCC Secretariat for Government Review".

Shri R. R. Mali, Sc. 'E' was on tour to New Delhi from 23-24 July, 2018 regarding meeting of IMD officials with IEM, in connection with "Finalisation of RFP for procurement of Agro AWS".

Shri Anand Sharma, Sc. 'F' attended meeting with Shri Radha Mohan Singh, Honourable Union Minister of Agriculture and Farmers Welfare, Government of India to "Provide inputs in connection with short debate in Parliament related to Food and Drought" on 24-25 July, 2018.

Dr. K. J. Ramesh, DG, IMD, attended a meeting with Professor Sani Abubakar Mashi, Director General/CEO Nigerian Meteorological Agency of Nigeria on 26th July, 2018 at New Delhi.

Dr. S. D. Attri, Sc. 'F' participated in meeting of Expert Committee for the preliminary selection of candidates "Raman-Chrapak Fellowship 2018" in Atmospheric Sciences, Earth Sciences and Environmental Science at Indo-French Centre for the Promotion of Advanced Research, New Delhi on 31st July, 2018.

Dr. Geeta Agnihotri, Sc. 'E' and Shri C. S. Patil, Sc. 'D' attended a meeting with the Additional Chief Secretary & Development Commissioner, Director of Agriculture, Vidhana Soudha, Bengaluru on "Preparation of contingent crop plan for kharif - 2018" on 2nd August, 2018.

Dr. Jayanta Sarkar, Sc. 'F' attended a meeting with honourable Chief Minister of Gujarat at Gandhinagar regarding "Monsoon 2018 scenario" on 7th August, 2018.

Shri Virendra Singh, Sc. 'F' attended the "Multi Mission Data Reception and Processing System (MMDRPS) incremental Algorithm Theoretical Basis Definition (ATBD)" review meeting at SAC Ahmedabad and officers from Sat Met Division and NWFC attended the same meeting via Videoconferencing at New Delhi on 8th August, 2018.

Shri K. Santhosh, Sc. 'F' attended a meeting on 9th August, 2018 convened by Hon'ble Chief Minister of Kerala in his office on "heavy rainfall situation in Kerala".

Dr. V. K. Mini, Sc. 'E' and Shri A. U. Ramesan, Met. 'B' attended a meeting called by the

Hon'ble Mayor of Thiruvananthapuram Corporation at Mini Conference Hall, Corporation Office regarding "Solar panel installation on roof top of government buildings" on 14th August, 2018.

Dr. S. Balachandran, Sc. 'F' accompanied by Dr. R. Puviarasan, Sc. 'D' attended meeting on "State Action Plan on Climate Change and Human Health" convened by State Health Society, Chennai on 16th August, 2018.

Dr. Jayanta Sarkar, Sc. 'F' and Smt. S. R. Metri, A.O. III attended the Half Yearly meeting "Nagar Rajbhasha Karyanvyan Samiti" at NID, Ahmedabad on 16th August, 2018.

Shri H. R. Biswas, Sc. 'E' participated in the Project Inception Meeting on "Operational Systems for Integrated Disaster Risk Management for Odisha" convened by OSDMA in collaboration with Regional Integrated Multi-Hazard Early warning System (RIMES) at Rajiv Bhawan on 28th August, 2018.

Dr. S. Balachandran, Sc. 'F' participated in a meeting at NIOT Chennai on 30th August, 2018 convened by National Centre for Coastal Research (NCCR) regarding operationalization of Chennai Flood Warning System (C-FLOWS) in association with NCMRWF, IMD and IIT Mumbai and Chennai.

Shri Bikram Singh, Sc. 'E' attended a meeting presided over by Honourable Chief Minister, Govt. of Uttarakhand on 5th September, 2018, at Secretariat in connection with "assessment of losses during the Monsoon season and relief work done" and briefed about the performance of the South-west monsoon for the current year.

Dr. S. Balachandran, Sc. 'F' attended meetings of Committee of Parliament on Official Languages (COPOL) at Visakhapatnam during 6-8 September, 2018.

Dr. Geeta Agnihotri, Sc. 'E' and Shri C. S. Patil, Sc. 'D' attended Cabinet sub-committee Meeting at State Emergency Operation Center, Revenue Department Disaster Management, on 11th September, 2018.

Dr. S. Balachandran, Sc. 'F' accompanied by Dr. R. Puviyarasan, Sc. 'D', participated in the "North East Monsoon 2018 preparedness meeting" convened by Corporation of Chennai under the Chairmanship of Commissioner, Corporation of Chennai on 18th September, 2018.

Dr. (Smt.) K. Naga Ratna, Sc. 'D' attended the meeting on "Development of Flood Forecasting System including inundation forecast in Godavari and Tapi Basin" conducted by NRSC on 19th September 2018 at NRSC, Balanagar, Hyderabad.

Dr. A. K. Mitra, Sc. 'E' attended the working group meeting constituted by Secretary, MoES through Video Conferencing on 20th September, 2018 to develop different "monitoring and prediction tool for Thunderstorm prediction" at MoES, New Delhi.

Dr. K. K. Singh, Sc. 'F' and Shri S. C. Bhan, Sc. 'F' attended a meeting "National Use of Weather Forecast for Livestock Management in Agro-meteorological advisory Services" held at ICAR - National Dairy Research Institute, Karnal on 24th September, 2018.

Dr. S. Balachandran, Sc. 'F' participating in the Fisheries Meeting organized by Government of Kerala on 24th September, 2018.

Shri H. R. Biswas, Sc. 'E' attended the meeting on "Pre-Cyclone Exercise and Preparedness for the Impending Cyclone" under the chairmanship of Chief Secretary, Govt. of Odisha at Secretariat, Bhubaneswar on 9th October, 2018.

Dr. Kripan Ghosh, Sc. 'E' attended the meeting for discussion on "Various activities under agromet at Pune and Delhi and its ways for enhancing technology applications in Agromet Advisory Services" from 10-12 October, 2018 at Agromet Advisory Service Division, New Delhi.

Shri H. R. Biswas, Sc. 'E' attended the review meetings on "Cyclonic Storm/Rainfall Situation" chaired by Hon'ble Chief Minister, Odisha at Secretariat, Bhubaneswar on 10-13 October, 2018.

Dr. M. Mohapatra, Sc. 'G' participated in the "19th Project Steering Committee Meeting of National Cyclone Risk Mitigation Project (NCRMP) Phase-I" held at NDMA, New Delhi on 12th October, 2018.

Shri U. R. Joshi, Sc. 'E' attended a meeting held on 12th October, 2018 at INCOIS, Hyderabad as an expert member to review the "Costing and Pricing Data and Data Products of INCOIS".

Dr. K. K. Singh, Sc. 'F' and Dr. S. D. Attri, Sc. 'F' participated in Meeting of "TTS at Ministry of Information Technology" on 14th October, 2018.

Shri Anand Sharma, Sc. 'F' attended a meeting the State Level Users Meet on "Agromet Advisory Services under the GKMS Scheme" on 15th October, 2018 and also made a presentation on "Agro-Meteorological Services by IMD: Current and Future: Gramin Krishi Mausam Seva (GKMS)" at the Technical session-1 of the Meet.

Dr. M. Mohapatra, Sc. 'G' participated in the Ministry of Earth Sciences Review Meeting at "National Centre for Earth Science Studies, Thiruvanathapuram" during 22-23 October, 2018. Dr. Mohapatra also participated in the inaugural ceremony of Cyclone Warning Centre at Thiruvanathapuram on 23rd October, 2018.

Shri H. R. Biswas, Sc. 'E' attended the 3rd meeting for the year 2018-19 of the "State Executive Committee constituted under the Disaster Management Act, 2015" at Odisha Secretariat, Bhubaneswar on 22nd October, 2018.

Dr. S. D. Attri, Sc. 'F' and Mrs. Priyanka Singh, Sc. 'B' attended meeting on "Updating weather related information on Kisan Suvidha Apps" held under Chairmanship of JS (IT) at Krishi Bhawan on 2nd November, 2018.

Dr. S. D. Attri, Sc. 'F' participated in meeting for "Finalisation of Biannual Update Reports" held under Chairmanship of Secretary, MoEF&CC on 8th November, 2018 at Indira Paryavaran Bhawan, New Delhi

Dr. K. K. Singh, Sc. 'F' participated in RAC meeting of "CRIDA" on 10-11 November, 2018 at ICAR-CRIDA, Hyderabad.

Dr. S. Balachandran, Sc. 'F' participated in a meeting convened by the Chief Secretary, Govt. of Tamil Nadu on 12th November, 2018 at Secretariat, Chennai to discuss about the "Preparedness for Gaja Cyclone".

Dr. S. D. Attri, Sc. 'F' attended a meeting and presented progress on "future plan of AASD" chaired by Secretary, MoES on 14th November, 2018 at Prithvi Bhawan, New Delhi.

Dr. S. Bandyopadhyay, Sc. 'F' attended a meeting with Secretary, Disaster Management, Govt. of WB on 19th November, 2018 for general discussion regarding "Preparedness to meet any contingencies".

"Gramin Krishi Mausam Sewa"

Officers during the meeting on GKMS

A State level Review meeting on "**Gramin Krishi Mausam Sewa**" was held on 20th November, 2018. Dr. Prabhat Kumar, IAS, APC Agriculture) (Production Commissioner was the Chief Guest of the event. Scientists/ officers of concerned departments,

viz., KVK (Krishi Vigyan kendra), Agriculture, Horticulture, AMFU (Agro Met Field Unit), National Bureau of Fish Genetics, ATARI, Remote Sensing, IISR Indian Institute Sugarcane (Research, BSNL, DD, AIR, NIC, IFFCO, Kisan Sanchar Limited, DAO District) Agriculture (Officer, Nodal Officers of various Agriculture Universities along with farmers attended the meeting.

Dr. S. L. Singh, Sc. 'F' and Shri Sankar Nath, Sc. 'E' attended a meeting on 20th November, 2018 on Subject "Meeting for finalization of draft Standard Operating Procedure (SOP) for implementation of Common Alerting Protocol (CAP) and Priority Call Routing (PCR) system in Disaster Management" at NDMA Bhawan, Safdarjang Enclave, New Delhi.

Shri H. R. Biswas, Sc. 'E' attended a meeting of "Stakeholders on finalization of flood hazards atlas for Odisha" at OSDMA, Rajiv Bhawan, Bhubaneswar on 26th November, 2018.

Dr. K. K. Singh, Sc. 'F', Dr. S. D. Attri, Sc. 'F', Shri S. C. Bhan, Sc. 'F', Dr. (Ms.) Geeta Agnihotri, Sc. 'E', Dr. Kripan Ghosh, Sc. 'E', Shri R. Balasubramanian, Sc. 'D' and Shri A. K. Baxla, Sc. 'D' participated in "12th Annual Review Meeting (ARM) and 9th Annual Review Meeting (ARM) of GKMS and FASAL" respectively at Regional Agricultural Research Station (RARS) Angravi, Tirupati, Andhra Pradesh from 3-6 December, 2018.

Dr. (Ms.) Geeta Agnihotri, Sc. 'E' attended "12th Annual Review Meeting on Gramin Krishi Mausam Seva" during 3-5 December, 2018 held at RARS, Tirupati, Andhra Pradesh.

Dr. M. Mohapatra, Sc. 'G' participated in the meeting of the "Peer Group for Updation and Revision of Vulnerability Atlas of India" at Building Materials and Technology Promotion Council, New Delhi on 12th December, 2018.

Shri H. R. Biswas, Sc. 'E' attended the meeting on "Demonstration of Common Alerting Protocol (CAP) for sending SMS to able to disseminate early warning/alert messages to targeted citizens" at OSDMA, Rajiv Bhawan, Bhubaneswar on 18th December, 2018.

Shri Bikram Singh, Sc. 'F' attended a meeting at Office of Secretary, Disaster Management, under the chairmanship of members of NDMA on 20th December, 2018 and briefed about progress of "Radar network installation in Uttarakhand and progress of Hydro-met network installation" by State Govt. under the technical guidance of IMD, Dehradun.

Dr. Sanjib Bandyopadhyay, Sc. 'F' attended a meeting on 21th December, 2018 with Shri Bratya Basu, Mininster-in-Charge, Department of Science & Technology and Bio-technology, Govt. of West Bengal to discuss on issues related to "Problems requiring solutions based on Science & Technology through collaborative programmes or otherwise".

Shri H. R. Biswas, Sc. 'E' attended the "Project Inception Meeting on Operational Systems for Integrated Disaster Risk Management for Odisha" at OSDMA, Rajiv Bhawan on 26th December, 2018.

6.4. TRAINING

25 participants of Advanced Training programme "Recent Developments in Statically Modelling and Forecasting in Agriculture" visited Satellite Meteorology Division on 9th January, 2018 for familiarization training in Satellite Meteorology.

Dr. S. C. Sahu, Scientist 'F' attended the orientation training programme for District Emergency Officers/Assistant Collectors (Emergency) on "Disaster management" convened by Special Relief commissioner, Govt. of Odisha at Gopabandhu Academy of Administration, Bhubaneswar on 10th January, 2018.

A **training workshop** on "Weather information for Power sector" was organised by Manikaran Power Limited at New Delhi on 5th February, 2018. Experts from IMD provided the technical training to this Power Sector Users during the workshop.

Dr. Lata Vishnoi, Sc. 'B' attended a Training Programme on "Agricultural Applications using Space Based Observations" course planned at SAC, Bhopal campus from 5-9 February, 2018.

Dr. Lata Vishnoi, Sc. 'B' & other participants during training

PAC, Kolkata organised a Refresher Course on "Astronomy" during 6 to 9 February, 2018 at PAC, Kolkata for officers of PAC Kolkata and RMC Kolkata, coordinated by Shri S. Sen, Sc. 'F'. Prof. G. M Ballabh, Retd. Prof. of Osmania University, Hyderabad was the Chief Guest during inaugural function. Dr. S. Bandyopadhyay, Sc. 'F' and Dr. D. R. Pattanaik, Sc. 'E' were also present during the inauguration pregramme. Shri A. K. Bhatnagar, Retd. ADGM of IMD, Dr. G. S. D. Babu, Retd. Director of M. P. Birla Planetarium, Bangalore, Prof. U. C. Joshi, Retd. Prof. of PRL Ahmedabad, Prof. Ranjan Gupta of IUCAA, Pune and Prof. Amalendu Bandyopadhyay of M. P. Birla Planeratium, Kolkata were the resource persons.

Trainees at PAC, Kolkata

A five day training workshop on "Utilisation of Numerical Weather Prediction (NWP) Model products for weather forecasting" was organised for the forecasters of IMD at Meteorological Training Institute (MTI), Pune during 12-16, February, 2018. Resource persons from IMD and other Institutes delivered the lectures during the training. The workshop was inaugurated by Prof. Ravi Nanjundiah, Director, Indian Institute of Tropical Meteorology, Pune. The Valedictory ceremony was addressed by **Dr. M. Rajeevan**, Secretary, MoES & **Dr. K. J. Ramesh**, DG, IMD.

Dr. M. Rajeevan, Secretary, MoES, Dr. K. J. Ramesh, DG, IMD and others during the Valedictory ceremony

One day Training and Familiarization on Doppler Weather Radar Products was conducted on 12th February, 2018 for officials of NESAV and RMC Guwahati, Dr. D. Pradhan, Sc. 'G' and Shri K. C. Sai Krishnan, Sc. 'F' delivered lectures as resource person.

NWP Refresher Course

Experts from IMD and other organisations like IIT Delhi, NCMWRF, INCOIS, IITM, Andhra University etc. delivered lectures to the participants. Dr. M. Mohapatra, Sc. 'G', delivered lectures on synthesis of NWP model products with other observational guidance to issue the short to medium range forecast and another lecture on utilisation of NWP models for cyclone warning during 14-15 February, 2018. Senior officers of IMD participated in said training. Dr. D. R. Pattanaik, Sc. 'E', NWP was the scientific co-ordinator for this refresher course.

Participants & resource persons during NWP refresher course

Shri Anand Sharma, Sc. 'F' delivered lectures in training workshop was organised by

Kumaon University on "Meteorological issues pertaining to Agriculture, Forestry, Transportation & Environmental Management and Climate variability/change impacts" on 15-16 February, 2018.

Shri S. C. Bhan, Sc. 'F' participated in "SAARC Training Program on Heat Wave Preparedness and Response in SAARC Region Gandhinagar, India" during 8-10 March, 2018 and delivered an invited talk on "Heat Wave Warnings: Thresholds, Customization, Dissemination and Cooperation".

Dr. K. J. Ramesh, DG, IMD inaugurated a five day training workshop on "Utilisation of Synoptic & Diagnostic Meteorology for weather forecasting" for the forecasters of IMD at Meteorological Training Institute (MTI), Pune during 12-16 March, 2018. Resource persons from IMD and other Institutes delivered the lectures during the training. The Valedictory ceremony was chaired by Dr. M. Mohapatra, Sc. 'G'. Prof. Ravi Nanjundiah, Director, Indian Institute of Tropical Meteorology, Pune and Prof. P. V. Joseph, who co-ordinated the training programme on behalf of IMD were the Guests of Honour. Dr. A. K. Sahai, Sc. 'G' also addressed the trainees. Dr. M. Mohapatra, delivered lectures on synthesis of NWP model products with other observational guidance to issue the short to medium range forecast and another lecture on Mesoscale models for short range forecasting.

Dr. K. J. Ramesh, DGM & other officers during the training

Dr. K. K. Singh, Scientist 'F' and Dr. Kripan Ghosh, Scientist 'E' participated as resource person in training conducted on "Development of Climate Risk Management Tool" during 13-20 March, 2018 at NESSC, Umian Meghalaya.

5-days national level training programme on "Challenges in Effective Communications during Disasters and its management" was organised by National Institute of Disaster Management during 19-23 March, 2018. Dr. M. Mohapatra, Scientist 'G' presented an invited talk on "Case Studies of Early Warning System for Cyclones (Phailin, Hudhud and Ockhi)" on 22nd March, 2018.

Shri Virendra Singh, Sc. 'F' attended the training on "Preparation of Parliament annual report / introduction of Parliament terminologies etc." at Parliamentary and Administrative Research Institute, New Delhi during 20-23 March, 2018.

Dr. K. Ghosh, Scientist 'E' attended the training of trainer on "Forecast Application for Risk Management in Agriculture (FARM)" during 23-27 April, 2018 in Bihar Agricultural University, Sabour.

The **Refresher Training Program** on "Agri-Business, Agricultural Advisory Services and Market Linkage for Established Agripreneurs under Agri-Clincs and Agri-Business Centers Scheme" on 25th May, 2018 at IMD, Pashan, Pune.

Summer Placement Course

Students during Summer Placement course

Four weeks **Summer Placement course** for B. Tech. (Agril. Engg.) students was conducted from 4-29 June, 2018. Total 28 candidates from different Agricultural Engineering colleges (*viz.*, Parbhani, Rahuri, Saralgaon, Jalgaon, Mandaki Palvan and Karad) participated in the training course. They were evaluated on the basis of Project presentation and viva - voce examination.

Familiarization Training Programme

Trainees dueing Familiarization Training Programme

A **Familiarization Training Programme** was held at AMO Kolkata on 15th June, 2018 for "DWR image interpretation to issue Advance Weather Warning for Aviation Purpose".

NIDM organised five days **national level training** on "Early Warning and Communication" at New Delhi. Dr. M. Mohapatra, Scientist 'G' delivered a Guest Lecture on "Case Studies of EWS of Cyclones & Storms" on 18th June, 2018.

IMD organized **a refresher course** on "Interpretation of satellite imageries and products for weather forecasting" at New Delhi during 18-23 June, 2018. There were about 40 trainees from different forecasting offices of IMD and the resource persons from IMD, NCMRWF, ISRO, SAC, IIRS, NRSC, NESAC were participated.

IMD and IIT Bhubaneswar jointly organized **training Workshop** on "Extreme Weather Events over India: Observations, Assimilation and Modeling with special focus on Tropical Cyclones" was conducted jointly by IIT Bhubaneswar and IMD during 18-25 June, 2018. There were four trainees from IMD in this workshop. **Dr. M. Mohapatra**, Sc. 'G' participated as Guest of Honour in the Workshop on 18th June.

Dr. V. K. Mini, Sc. 'E', Dr. Geeta Agnihotri, Sc. 'E' and Shri L. Ramesh Babu, Sc. 'E' participated six days refresher course on "Interpretation of Satellite Imagery and products for Weather Forecasting Services" at Prithvi Bhavan, MoES, Lodi Road, New Delhi during 18-23 June, 2018.

The WMO's Tropical Cyclones Forecasters Training 2018 was conducted by Regional Specialised Meteorological Centre (RSMC), New Delhi during 2-13 July, 2018 at India Meteorological Department (IMD), New Delhi. The training aimed at capacity building of the tropical cyclones (TCs) forecasters in the region by understanding the latest developments in observations, monitoring, modeling, prediction and warning services of TCs over the region and carrying out the case studies with practical examples in these aspects. The training also included a few lectures on Synergized Standard Operation Procedure (SSOP) by the experts from United Nations-Economic & Social Commission for Asia and the Pacific (UN-ESCAP) and RSMC, New Delhi. There were 22 participants including 2 from WMO/ESCAP Panel member countries, *viz*., Bangladesh and Thailand, 5 from Typhoon Committee member countries including Cambodia, Lao PDR, Philippines, Thailand and Vietnam, 9 from Area Cyclone Warning Centres (ACWCs), Cyclone Warning Centres (CWCs) and coastal Meteorological Centres (MCs) of IMD & 6 from RSMC New Delhi.

Participants during WMO's RSMC Training

Dr. N. Chattopadhyay, Sc. 'F', Dr. K. Ghosh, Sc. 'E' and Shri R. Balasubramanian, Sc. 'D' attended the Orientation Training on "Preparation and dissemination of Agromet Advisories at Block level" from 6-7 July, 2018 at KVK, Aurangabad, Maharashtra for sensitization of Scientists of KVKs on establishment of District Agromet Unit (DAMU) under GKMS.

Shri J. P. Sapate, S. A. and Shri A. G. Nemade, S. A. nominated for Pre Antarctic Training for 38th Indian Scientific Expedition to Antarctica commenced from 23 July to 18 August, 2018.

Dr. K. Ghosh, Sc. 'E' was on tour to RMC Nagpur on 25th July, 2018 to impart training for the officers of RMC Nagpur to use Agromet-DSS-Software developed by Agromet Division of IMD powered by RIMES (The Regional Integrated Multi-Hazard Early Warning System for Africa and Asia).

Shri Vigin Lal F., Sc. 'B' attended a National Level Training on Extreme Weather Events during 6-10 August, 2018 organized by National Institute of Disaster Management at NIDM, Andhra Pradesh.

Trainees from RMC Chennai & RMC Mumbai participated in the training on "Operation and Maintenance of Radiation Instruments" conducted at Central Radiation Laboratory, Pashan during 22-26 October, 2018.

Training on **"Operation, Maintenance & servicing of Airport Meteorological Instruments"** was imparted to 15 Air Force personnel at CRS, Pune from 22-26 October, 2018.

One day training/refresher course in "Aeronautical Meteorology" organized by IMD on 26th October, 2018 for all Airlines Operators and Flight Dispatchers at M. C., Ahmedabad.

A half-a-day capsule training course on "Doppler Weather Radar - Technology and Utilization" was conducted for the Meteorology Branch Officers of IAF from Bidar, Hakimpet, Bengalure and Dindigul stations on 29th October, 2018 at M. C., Hyderabad.

Establishment of National Centre for Coastal Research (NCCR) & Training Facility

Foundation Stone for the establishment of National Centre for Coastal Research & Training Facility (IMD & NCCR) was laid at IMD Visakhapatnam on 2nd November, 2018 by the Hon'ble Minister for Earth Sciences, Dr. Harsh Vardhan. Dr. M. Rajeevan, Secretary, MoES, Dr. K. J. Ramesh, DG, IMD, Dr. S. Balachandran, Sc. 'F' and Shri K. Ramachandra Rao, Sc. 'D', also participated in the programme.

Hon'ble Minister for Earth Sciences, Dr. Harsh Vardhan, Dr. M. Rajeevan, Secretary, MoES, Dr. K. J. Ramesh, DG, IMD and others during the Foundation stone ceremony

6.4. LECTURES/TALK

Dr. Jayanta Sarkar, Scientist 'F' delivered lecture on "Heat Wave Preparedness and Response in SAARC Region" at GIDM, Gandhinagar on 3rd January, 2018.

Dr. K. K. Singh, Scientist 'F' delivered lecture on "Overview of Yield Estimation by IMD" in the training programme organized by MNCFC (Mahalanobis National Crop Forecast Centre) in the training programme organized by MNCFC for capacity building of newly recruited analyst during 8-12 January, 2018.

Dr. S. C. Sahu, Scientist 'F' delivered lecture in refresher Course of Geography Department in Utkal University, Vani Vihar, Bhubaneswar on 18, 27 & 28 January, 2018 on "Weather Forecasting" and 24 February, 2018 on "Climate Change".

Dr. N. Chattopadhyay, Scientist 'F' invited by "The Energy and Resources Institute (TERI), Mumbai" to deliver lecture on "Overview of Changing Climate and Significance of Climate Smart Agriculture" at Agricultural College , Pune on 22nd February, 2018.

Dr. N. Chattopadhyay, Scientist 'F' during the lecture

Dr. Sanjib Bandyopadhyay, Scientist 'F' delivered a lecture on "ICT in Agriculture" at the National seminar on "Trends & Applications of ICT in Agriculture (TRACT)" organized by Centre for Development of Advanced Computing, Kolkata and IMS on 13th March, 2018.

Dr. S. C. Sahu, Scientist 'F', attended as Guest of Honour and delivered a lecture on "Coping Climate Change Impacts through Climate Resilient Agriculture" organized by DFID and CTRAN Consulting Ltd. at KIIT University Campus, Bhubaneswar on 13th March, 2018 .

Shri R. Balasubramanian, Scientist 'D' delivered lecture on "Agriculture Aspects of South West Monsoon - 2017" in monsoon workshop organized by IMSP (Indian Meteorological Society Pune) at IITM (Indian Institute of Tropical Meteorology) Pashan, Pune on 27th March, 2018.

Shri Anand Sharma, Scientist 'F', delivered an invited interactive talk on "Empowering Rural communities through Weather based agro-advisories" on 27th March, 2018 in the Faculty Development Programme of Rural Community Engagement at Jawaharlal Nehru University (JNU), New Delhi.

Shri B. A. M. Kannan, Scientist 'E' delivered lectures on the theme "Radar data streams of IMD and WMO compliance" at the South Asian Climate Outlook Forum-12 (SASCOF) held at Pune during 13-14 April, 2018.

Shri S. C. Bhan, Scientist 'F' delivered two lecture in the Training Programme on Management of Heat Wave on the topic "National Heat Wave Guideline: Salient Feature & Operationalization of Heat Wave Action Plan: Coopeartion and Dissemination issue" on 19th April, 2018 at Haryana Institute of Public Administration

Dr. N. Chattopadhyay, Scientist 'F' delivered lecture on "Application of Seasonal Weather Forecast for Agriculture" in the 12th Session of the South Asian Climate Outlook Forum (SASCOF-12) of main forum meeting hosted by IMD and IITM, Pune with support of World Meteorological Organization and RIMES held at IITM, Pune on 20th April, 2018 .

Dr. Jayanta Sarkar, Sc. 'F' delivered a lecture at GIDM, Gandhinagar on "Climate change Scenario: Future Impacts" on 12th April, 2018 and also delivered two lectures at SRTC, WALMI, Gandhinagar on "Weather Forecasting & Early warning" on 23rd & 26th April 2018.

Shri Anand Sharma, Sc. 'F' delivered key note lecture on climate variability/Change, Weather forecast and Agro Advisory at the National Seminar organized by Y. S. Parmar University of Horticulture & Forestry, Solan on 7th May, 2018.

Dr. S. C. Sahu, Scientist 'F', attended the National Technology Day Celebration at IIT, Bhubaneswar as Guest of Honour on 11th May, 2018 and delivered lecture on "Technological advancement in IMD in connection with climate change".

Shri C. S. Patil, Scientist 'D' gave a lecture on "Weather Forecasting System during Floods" to the trainee officers of Home Guards & Civil Defence Academy on 25th May, 2018.

Dr. (Smt.) Manorama Mohanty, Scientist 'D' delivered an online lecture on "Flood forecasting systems in Gujarat state" at Gujarat Institute of Disaster Management on 2nd & 6th June, 2018.

Dr. M. Mohapatra, Scientist 'G' delivered an invited talk on "Past, Present Status and Future challenges in prediction of TCs over Indian Seas and R&D Opportunities" during the inaugural session of Training Workshop on "Extreme Weather Events over India - Observations, Assimilation and Modeling with special focus on Tropical Cyclones" on 18th June, 2018 at IIT Bhubaneswar.

Shri Anand Sharma, Sc. 'F', delivered an invited lecture to farmers of Hilly areas of Garhwal, Uttrakhand on "Agro advisory: A Boon for Farming Community to Reduce

Livelihood Risks" on 21st July, 2018 at the Himalayan Action Research Center, Dehradun.

Shri K. N. Mohan, Sc. 'F' was on tour to Exitor, United Kingdom to give a lecture on "WMO Commission on Aviation Services" from 23-27 July, 2018.

Dr. S. D. Attri, Sc. 'F' delivered invited talk "Global Warming/Climate Change Perspective" in Training of Trainers' Programme on Urban Risk Mitigation: Making Cities Resilient on 25th July, 2018 at NIDM New Delhi.

Dr. M. Mohapatra, Sc. 'G' chaired the technical session in the afternoon and delivered a lecture on "Observational Programme & Severe Weather Forecasting during the Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation (BIMSTEC) centre for weather and climate workshop organized by NCMRWF, Noida on 31st July 2018. **Dr. D. R. Pattanaik**, Sc. 'E' delivered a talk on "Extended/Seasonal Scale Forecasting with coupled models at MoES" and **Dr. A. K. Mitra**, Sc. 'E' on "Satellite Products and Tools" during the workshop.

Dr. S. D. Attri, Sc. 'F' participated and delivered lead talk on "Block Level Weather Based Advisory Services at KVKs/ DAMUs" in two days "Orientation Programme for the Preparation and Dissemination of Agromet Advisories at Block Level" under Gramin Krishi Mausam Seva (GKMS) scheme for the Nodal Officers of Krishi Vigyan Kendras (KVKs) of Andhra Pradesh, Telangana, Tamil Nadu and Pondicherry under the jurisdiction of ATARI Zone X at ATARI, Hyderabad during 1-2 August, 2018.

Dr. Jayanta Sarkar, Sc. 'F' delivered online expert lecture on "Climate change: Application of Geospatial Techniques in flood Hazards, maping, monitoring & mitigation strategies" to GIDM trainees at Gandhinagar on 3rd August, 2018.

Shri Sonam Lotus, Sc. 'D' delivered a Lecture on "Role of Science in Poverty Alleviations" to students of NIT Srinagar on 8th September, 2018.

Shri Sonam Lotus, Sc. 'D' at NIT Srinagar during lecture

Dr. Jayanta Sarkar, Sc. 'F' delivered lecture on "Meteorological parameters and forecasting" to IIPH trainees at Gandhinagar on 26th September, 2018.

Shri Y. K. Reddy, Sc. 'F' delivered a lecture on "Rainfall indices and effects of Climate Change on Drought" for the trainees of a short course organised by NIDM, APHRDI, Bapatla on 22nd October, 2018. He also visited SRM University and discussed about the infrastructure requirements for establishment of MC Amaravathi on 23rd October, 2018.

Dr. O. P. Sreejith, Sc. 'D' delivered lecture on "Monsoon Variability & Climate Vulnerability" on 23rd October, 2018 during "Climate Change and Rainfed Agriculture" organized by Vasantrao Naik Marathwada Krishi Vidhyapeeth, Parbhani.

Shri Anand Sharma, Sc. 'F' delivered an invited talk on "Advances in Agro-meteorological services for farmers in India" on 26th October, 2018 at the TROPMET - 2018: National Symposium on "Understanding Weather and Climate Variability : Research and Society" at BHU, Varanasi from 23-27 October, 2018.

Dr. M. Mohapatra, Sc. 'G' delivered a talk in the "Plenary Session during TROPMET-2018" held at Varanasi on 27th October, 2018 and participated in the Panel Discussion and Valedictory Function of TROPMET 2018.

Dr. S. D. Attri, Sc. 'F' delivered lead talk on "Climate Change Over India: IMD Perspective" in Kick-Off Workshop of the International Cooperation Project "East Africa Peru India

Climate Capacities - EPICC", held at India Habitat Center, New Delhi during 1-2 November, 2018.

Shri Anand Sharma, Sc. 'F' delivered an invited talk on "Augmentation and Dissemination of Weather based Agro Advisory Services under GKMS" on 13th November, 2018 at the "National seminar on Mountain Communities & Adaptive Sustainable Livelihood Strategies" at Jawahar Lal Nehru University , New Delhi.

Shri C. S. Patil, Sc. 'D' gave a lecture on "Forecasting and Early Warning of Hydro-Meteorological disasters" at Administrative Training Institute, Mysore on 14th November, 2018.

Shri S. C. Bhan, Sc. 'F' and Shri A. K. Baxla, Sc. 'D' give lead lectures in Trainings on "Preparation of Agromet Advisories at Block Level under Gramin Krishi Mausam Sewa (GKMS) Scheme" to Subject Matter Specialist (Agrometeorology) and Agromet Observers recruited at KVKs to set up DAMUs under GKMS scheme at ATARI, Patna for 22-27 November, 2018.

Shri Anand Sharma, Sc. 'F' delivered an invited talk on "Agro advisories, Extreme Weather Events and its impact at the Disaster Risk Reduction" workshop organised by Haryana Institute of Public Administration (HIPA) on 5th December, 2018 at Gurugram.

Shri Anand Sharma, Sc. 'F' delivered an invited talk on "Weather Forecasting and Disaster Risk Reduction" at the training course on Disaster Management organised by Special Centre for Disaster Research (SCDR), Jawaharlal Nehru University (JNU), New Delhi on 19th December, 2018.

Dr. M. Mohapatra, Sc. 'G' delivered an invited talk at Lal Bahadur Shastri National Academy of Administration, Mussoorie on 20th December, 2018 during the training programme on "Disaster risk reduction" for IAS Officers.

6.5. AWARENESS & OUTREACH PROGRAMME

Farmers' awareness programmes were organised at 130 Agromet Field Units across the country *viz.*, Namakkal, Kovipatti, Ooty, Modipuram, Ranichouri, Adhuturai, Bhatinda, Brahmawar, Chennai, Chhindwara, Delhi, Diphu, Hyderabad, Jagtiyal, Kalyani, Kanpur, Kharagpur, Navile, Pantnagar, Solan, Sonitpur, Thrissur, Tikamgarh, Vellayani, Majihan, Pundibari, Lembuchera, Jahrnapani, Rajouri, Portblair, Kakdwip, Faridkot, Igatpuri, Sindewahi, Pusa, Agwanpur, Sriganganagar, Kaul, Barapani, Coimbatore, Jammu etc.

Farmer's database collected from 14 states uploaded on Farmers Portal and the number of registered farmers on the portal has increased to 3.86 crore and under Gramin Krishi Mausam Sewa, Block level advisory started on pilot basis with the existing Agromet Field Units for 50 Districts. Dissemination of Agromet Advisories to the users' community through SMS and IVR technology is being continued in the country through Kisan Portal and under PPP mode. At present Agromet Advisories are reaching to 40.1 million farmers in the country through SMS directly.

6.6. VISITORS

22 students from GMERS Medical College, Sola, Ahmedabad visited **Met. Centre, Ahmedabad** on 1st & 2nd January 2018 and they were briefed regarding the activities of IMD.

50 students from Valia Polytechnic College, Valia, Bharuch visited **Met. Centre, Ahmedabad** on 25th January 2018.

A group of 43 Students along with 3 faculty member from Banaras Hindu University, Varanasi visited **M. C. Dehradun** on 27th January, 2018. Students along with faculty members were briefed about different instruments of Meteorological observatory & a general lecture on weather and climate was given by the staff members of M.C. Dehradun.

Students along with their teachers at M. C., Dehradun

50 students from B. J. Medical College, Ahmadabad visited Met. Centre, Ahmadabad on 5th February, 2018.

A group of 11 Students alongwith 2 facultiy member from Pt. Lalit Mohan Sharma Govt. PG College, Rishikesh visited **M. C., Dehradun** on 27th March, 2018. Student's alongwith faculty members were briefed about different instruments of Meteorological observatory and a general lecture on weather and climate.

DGCA team visited **AMO Kolkata** on 5-6 April, 2018 to carry out the inspection of MET facility at MWO Kolkata.

80 students of College of Veterinary Science and Animal Husbandry, O.U.A.T., Bhubaneswar along with their teachers on Field Study Tour visited **Meteorological Centre, Bhubaneswar** on 7th and 21st April, 2018.

45 students from GMERS Medical College, Gandhinagar visited **Meteorological Centre, Ahmedabad** on 20th April, 2018 they were briefed about functions of various units and weather forecasting procedure.

Students along with their teachers during the visit

A group of **20 Students** alongwith 1 faculty member from Ramchandra Uniyal Govt. PG College, Uttarkashi visited **M. C., Dehradun** on 2nd May, 2018. Students alongwith faculty members were briefed about different instruments of Meteorological observatory and a general lecture on weather and climate.

A group of **8 Students alongwith 1 faculty** member from Rishikesh Public School visited **M. C., Dehradun** on 10th May, 2018. Students alongwith faculty members were briefed about different instruments of Meteorological observatory and a general lecture on weather and climate.

40 students along with 2 teachers from Anand Niketan school, Ahmedabad visited **Met. Centre, Ahmedabad** on 28th June, 2018. They were briefed about forecasting procedure and taking surface and u/a observation.

13 nos. of Doctors of All India Institute of Medical Sciences visited **Satellite Meteorology Division** on 5th July, 2018 for familiarization with the activity of Satellite Meteorology Division.

15 officers of NIDM visited **Satellite Meteorology Division** on 19th July, 2018 for familiarization with the activity of Satellite Meteorology Division.

Dr. John Clemens, Executives Director ICDDRB, Dr. Peter Kim Streatfield, Emeritus Scientist I/C Climate Change initiative & Dr. Quamrun Nahar, Senior Director ICDDRB visited **M. C., Ahmedabad** on 30th July, 2018. Dr. Jayanta Sarkar briefed them about the activities of IMD Ahmedabad.

45 M. Tech (Climate Science & Technology) and M.Sc. (Atmosphere & Ocean Sciences) students accompanying with Assistant Professor from School of Earth, Ocean and Atmospheric Sciences, IIT Bhubaneswar visited **M. C., Bhubaneswar** to get familiarized with different observation instruments, operational activities and weather forecasting on 14th August, 2018.

658 Students and 43 Teachers from different Schools and institutions visited **M. C., Hyderabad**. They were explained about

functioning of Met. Instruments, DWR, weather forecasting etc.

100 Participants (School Teachers from Odisha) visited **M. C. Bhubaneswar** on 17th August, 2018 for facilitating with Meteorological Observations and Forecasting Activity. Shri H. R. Biswas, Sc. 'E', M. C., Bhubaneswar gave a presentation to the visitors on Weather Forecasting and Services.

Various participants during the visit at M.C. Bhubaneswar

30 students from School of Geography, Gujarat University, Ahmedabad visited **M. C., Ahmedabad** on 20th August, 2018. Also 50 students from Sarkar school, Chandkheda, Ahmedabad visited M.C. Ahmedabad on 11th & 12th September, 2018. They were briefed about forecasting procedure, taking Surface and Upper Air Observation and the activities of IMD.

IWSU Inspection Team from DGM, New Delhi inspected **M. C., Bhubaneswar** from 24-27 September, 2018. Shri H. R. Biswas, Sc. 'E' accompanied the IWSU Inspection team as Liaison Officer inspected MO Puri on 26th September, 2018.

Scientists from National Centre for Coastal Research & National Institute of Ocean Technology, Chennai visited **IMD** and submitted RFP development of Decision Support System for Cyclones. The same has been circulated to all members for comments and suggestions, if any. NCCR has also been asked to collaborate with IMD to improve weather forecasting services of IMD.

10 persons (Unit Aircrew and Sailors) from Coast Guard Air Enclave (BSR), BPI Airport, Bhubaneswar had Familiarization visit to **M. C., Bhubaneswar** on 13-16 November, 2018.

Officers and visitors at M. C. Bhubaneswar

About 65 class XI students along with their teachers of DPS Kalinga, Bhubaneswar had a Field Study Trip to **M. C., Bhubaneswar** to be familiarized with Met Instruments and Weather Forecasting on 14th November, 2018.

Students during the visits

Students and teachers from Jawahar Navodaya Vidyalaya, Khordha, Odisha visited **M. C., Bhubaneswar** for getting information regarding National Children Science Congress on 19th November, 2018.

A group of 22 Students of B. Sc. (Agriculture) along with **2 faculty member** from Himalayan Institute of Technology, Dehradun visited **M. C., Dehradun** on 29th November, 2018. Students were shown Met. Observatory and briefed about functioning of the observatory. A lecture on Weather and Climatology and Operational Meteorological products was delivered to the students & faculty members.

Group of students with Director, M.C. Dehradun

Two M.Sc. (Atmospheric Science) students from Central University of Rajasthan, visited **M. C., Bhubaneswar** on 15th November, 2018. They visited Meteorological Observatory and learned on operational forecasting methods.

Students from BJEM Public School, Bhubaneswar visited **M.C., Bhubaneswar** on 7th December, 2018 for educational project work on earthquake proof structures.

6.7. FOREIGN DEPUTATION

Shri Akhil Srivastava, Scientist 'B' was on deputation to attend "HWRF-HYCOM training at NOAA Centre for Weather and Climate Prediction", Maryland, USA, during 23rd January, 2018 to 3rd February, 2018.

Dr. M. Mohapatra, Scientist 'G' was on deputation to Tehran, I. R. of Iran to participate as keynote speaker and presented a talk on "Monitoring, Forecasting and Early Warning System for Marine Weather Hazards in the 4th Persian Gulf Conference" during 17-18 February, 2018.

Shri Rahul Madathilath, Scientist 'B' was on deputation to Doha, Qatar to participate in "Asia Middle East Dialogue (AMED) Crisis Management Training" during 26th February, 2018 to 1st March, 2018.

Shri S. K. Asok Raja, Scientist 'B' & Ms. Hemlata Motiram Bharwani, Scientist 'B' were on deputation to San Diego, USA to attend training under "South Asia Flash Flood Guidance System (SAsiaFFGS) Operational Training (Step 3)" during 5-30 March, 2018.

Shri Chinmay Rajendra Khadke, Scientist 'B' was on deputation to Muscat, Oman to attend the "Thirteenth Satellite Application Course (SAC) focus on Tropical Cyclone" during 11-15 March, 2018.

Shri Mohammad Danish, Scientist 'B' was on deputation to Bhutan to participate in the "Installation and Training of MCH Database Management System" during 12-16 March, 2018.

Shri Vivek Sinha, Scientist 'F' was on deputation to Bangkok, Thailand to attend the "Sixteenth Meeting of Asia/Pacific Meteorological Information Exchange Working Group (Met/IE WG/16)" during 19-21 March, 2018.

Dr. D. R. Pattanaik, Scientist 'E' was on deputation to National Center for Hydrology and Meteorology (NCHM), Bhutan to participate as an "Expert for capacity building on Extended Range Prediction (ERP)" during 19-21 March, 2018.

Dr. D. R. Pattanaik, Sc. 'E' on deputation at Bhutan

Dr. Naresh Kumar, Scientist 'E' was on deputation to Kittila, Finland to participate in the "Eighth Session of the Executive Council Panel of Experts on Polar and High Mountain Observations, Research and Services (EC-PHORS-8) and meeting the Antarctic Task Team" during 20-23 March, 2018.

Dr. V. K. Soni, Scientist 'F' was on deputation to Geneva, Switzerland to "Participate in the Scoping Meeting on the Implementation of Third Pole Regional Climate Network" during 27-28 March, 2018.

Dr. O. P. Sreejith, Scientist 'F' was on foreign deputation during 24-26 April, 2018 to participate in the 14th Session of Forum on "Regional Climate Monitoring, Assessment and Prediction of Asia (FOCRAII)" held at Nanjing, China.

Shri Rakesh Kumar, Sc. 'B' was on foreign deputation to Zugspitze, Germany to participate in the "34th Global Atmosphere Watch Training & Education Centre (GAWTEC)" Training course on UV Radiation during 13-26 May, 2018.

Mr. Habibur Rahaman Biswas, Sc. 'E' was on foreign deputation to Bangkok, Thailand to participate in the "Seventh meeting of the Asia/Pacific Meteorological Requirements Working Group (MET/R WG/7)" during 21-23 May, 2018.

Shri Sourav Adhikary, Sc. 'D' was on foreign deputation to Hong Kong, China to participate in the Regional Workshop on "Aircraft Meteorological Data Relay (AMDAR)" during 29-30 May, 2018.

Dr. A. K. Sahai, Scientist 'G' and Dr. D. S. Pai, Scientist 'F' were on foreign deputation to Barcelona, Spain to participate in the "Second WMO Workshop on Operational Climate Prediction (OCP-2)" during 30th May to 1st June, 2018.

Dr. K. J. Ramesh, DG, IMD, Dr. Vipin Chandra, JS, MoES and Dr. R. K. Giri, Scientist 'E' were on foreign deputation to Geneva, Switzerland to participate in the "70th Session of World Meteorological Organisation (WMO) Executive Council and 37th Meeting of FINAC" during 18-29 June, 2018.

Dr. K. J. Ramesh, DG, IMD was on foreign deputation to Ulaanbaatar, Mangolia as a part of Indian Delegation to attend the "Asian Ministerial Conference on Disaster Risk Reduction 2018 (AMCDRR 2018)" during 3-6 July, 2018.

Shri K. N. Mohan, Sc. 'F' was on foreign deputation to Exeter, UK to participate in the "Sixteenth Session Commission for Aeronautical Meteorology (CAeM-16) & Technical Conference (TECO)" during 23-27 July, 2018.

Dr. Suman Goyal, Sc. 'F' was on foreign deputation to Tallinn, Estonia during 17-21 September, 2018 to participate in the "Conference on EUMETSAT Meteorological Satellites".

Dr. A. K. Sahai, Sc. 'G' and Dr. P. Guhathakurta, Sc. 'F' and Dr. K. Ghosh, Sc. 'E' were on deputation to attend the (India UK Water Centre) IUKWC Workshop on "Advancing Drought Monitoring Prediction and Management Capabilities" held at University of Lancaster, UK from 17-21 September, 2018 and delivered a lecture on "Monitoring drought condition and providing outlook by drought indices like SPI, SPEI and AAI from weekly to monthly scale". Dr. Ghosh delivered lecture in "Agro-meteorological Advisory Services for monitoring preparedness and management of agriculture drought".

Officers of IMD & others during IUKWC, UK

Dr. K. J. Ramesh, DG, IMD was on foreign deputation to Geneva, Switzerland during 18-20 September, 2018 to attend "Asia Weather & Climate Services Pathways for Regional Collaboration Forum".

Dr. S. L. Singh, Sc. 'F' was on foreign deputation to Casablanca, Morocco during 18-20 September, 2018 to participate in the "Meeting of the Task Team on Global Information Systems Centres (TT - GISC 2018)".

Dr. M. Mohapatra, Sc. 'G' and Chairman WMO and Economic & Social Commission for Asia & Pacific (ESCAP) panel on Tropical Cyclones was on foreign deputation to Muscat, Oman during 23-27 September, 2018 to participate in "45th Session of WMO/ESCAP Panel on Tropical Cyclones (PTC-45)". Four Arabian countries including Saudi Arabia, Qatar, United Arab Emirate and Iran joined the WMO/ESCAP Panel on tropical cyclones (PTC) in this session.

Dr. D. S. Pai, Sc. 'F' was on foreign deputation to Colombo, Sri Lanka during 26-28 September, 2018 to attend the "13th Session of South Asian Climate Outlook Forum (SASCOF-13)". Regional Climate Centre, IMD Pune issued seasonal outlook of rainfall and temperature over South Asian Countries in this Session.

Dr. K. J. Ramesh, DG, IMD was on foreign deputation to Incheon, Republic of Korea during 1-5 October, 2018 to participate in the "48th Session of Intergovermental Panel on Climate Change (IPCC)".

Shri Ashish Kumar, Sc. 'B' was on foreign deputation to Germany during 7-20 October, 2018 to participate in the "35th Global Atmosphere Watch Training & Education Centre (GAWTEC) Training course on Reactive Gases".

Dr. D. R. Pattanaik, Sc. 'E', Dr. Shirish Khedikar Sc. 'B', Shri Ved Prakash Sc. 'B' and Shri Nilish Wagh, JRF were on foreign deputation to Kathmandu, Nepal during 8-10 October, 2018 to participate in "Regional Knowledge Forum on Earth Observation and Climate Services for Food Security and Agricultural Decision Making in South and Southeast Asia".

Shri Uday Shende, Sc. 'D' was on tour to Amersterdam, Netherlands for oral & poster and presented two papers entitled "IOT based modern surface meteorological observatories" by U. K. Shende, Rakesh Kumar, M. Danish and R. R. Mali and "Calibration Facilities, standards available at IMD's renowned calibration Lab" by Shri. U. K. Shende, P. S. Budhkar, K. V. Padgalwar and R. R. Mali at TECO-2018, WMO conference from 8-11 October, 2018.

Dr. Rajendra Kumar Jenamani, Sc. 'F' on foreign deputation to Hong Kong, China during 8-12 October, 2018 to participate in "Voluntary Cooperation Programme (VCP) Contribution of Hong Kong, China Workshop on Meteorology - Air Traffic Management Integration (MET-ATM) and 4th WMO's Aviation Research Demonstration Project (AvRDP) SSC Review Meeting".

Dr. Siddharth Singh, Sc. 'E' and Dr. Ananda Kumar Das, Sc. 'E' were on foreign deputation to Finland during 8-20 October, 2018 to attend the co-operation visit at the "Finish Meteorological Institute for training on Operationalization Air Quality Models for India and Delhi/NCR".

Dr. D. Pradhan, Sc. 'G' was on foreign deputation to Amsterdam, Netherlands during 12-16 October, 2018 to attend "7th Session of Commission for Instruments and Methods of Observation (CIMO-XVII)".

Dr. K Sathi Devi, Sc. 'F' was on foreign deputation to Tokyo, Japan during 13-15 October, 2018 to participate in the "2nd Indo-Japan Workshop on Disaster Risk Reduction".

Shri Meenatchinathan Nagami, Sc. 'E' was on foreign deputation to Saint-Mande, France during 23-25 October, 2018 to participate in the 3rd meeting of "The Coordination Group for the Direct Broadcast Network for Near Real-time Relay of Low Earth Orbit Satellite Data (DBNet)".

Dr. (Mrs.) K. Sathi Devi, Sc. 'F' was on foreign deputation to Hong Kong, China during 30 October to 2 November, 2018 to participate in "Common Alerting Protocol (CAP) Training Session & CAP Implementation and Filtered Alert Hub (FAH)".

Dr. V. K. Soni, Sc. 'E' was on Ex-India deputation to Tehran during 5-6 November, 2018 to participate in the "Expert Consultation on Regional Cooperation for Building Resilience to Slow-Onset Disasters, including Sand and Dust Storms, and Information Management for Cross-border Disasters in Asia and the Pacific".

Shri Sankar Nath, Sc. 'E' was on Ex-India deputation to Beijing, China during 6-8 November, 2018 to participate in a workshop on the "WMO Integrated Global Observing System (WIGOS) in Regional Association II (RA-II)".

Dr. Arvind Kumar Srivastava, Sc. 'F' was on Ex-India deputation to Tokyo, Japan during 12-16 November, 2018 to participation in "11th Annual Atmospheric Circulation Reconstructions over the Earth (ACRE) meeting, ACRE China-3, ACRE Asia-2, ACRE Japan".

Dr. D. R. Pattanaik, Sc. 'E' and Dr. V. R. Durai, Sc. 'E' were on Ex-India deputation to Darwin, Australia during 13-16 November, 2018 to participate in the "Third Convective Scale Modelling Workshop".

Dr. D. R. Pattanaik, Sc. 'E' during the workshop

Smt. Sunitha Devi, Sc. 'E' was on Ex-India deputation to Seoul, South Korea during 19-21 November, 2018, to participate in the "Second KMA/WMO Workshop on Impact-based Forecasts in Asia".

Dr. Soma Sen Roy, Sc. 'E' was on Ex-India deputation to Tsukuba, Japan during 20-21 November, 2018 to participate in the "Sixth Meeting of the WMO SDS-WAS Regional Steering Group (RSG) for ASIA"

Dr. Somenath Dutta, Sc. 'F' was on Ex-India deputation to Geneva Switzerland during 27-30 November, 2018 to participate in "Review of Basic instructional Package for Meteorologists (BIP-MT) and Basic Instructional Package for Meteorological Technicians (BIP-MT) and WMO Global Campus initiative from at WMO, Geneva, Switzerland".

Dr. M. Mohapatra, Sc. 'G' was on Ex-India deputation to Colombo, Sri Lanka from 28 November - 8 December, 2018 to participate in the "First meeting of Regional Sub-management Team (RSMT) of SWFDP Bay of Bengal" and as an expert lecturer for one week training workshop on severe weather and impact based forecasting and delivery of warning services.

Dr. D. S. Pai, Sc. 'F' was on Ex-India deputation to Geneva, Switzerland from 3-7 December, 2018 to participate in the "Long Range Forecasting Guidance Authors Writeshop".

Dr. (Mrs.) K. Sathi Devi, Sc. 'F', Dr. S. Balachandran, Sc. 'F' and Shri Akhil Srivastava, Sc. 'B' were on Ex-India deputation to Honolulu, Hawaii, USA during 3-7 December, 2018 to participate in the "9th International Workshop on Tropical Cyclones (IWTC-9)".

Shri Krishna Mishra, Sc. 'B' and Shri Shobhit Katiyar Sc. 'B' were on Ex-India deputation to

Sri Lanka 3-8 December, 2018 to participate in "One week training workshop on severe weather and impact based forecasting and delivery of warning services".

Dr. V. K. Soni, Sc. 'E' India was on Ex-India deputation to Beijing, China during 13-14 December, 2018 to participate in the "Implementation Planning Meeting of the Third Pole Regional Climate Centre Network".

Shri S. C. Bhan, Sc. 'F' was on Ex-India deputation to Hong Kong, China during 17-20 December, 2018 to participate in the "1st Global Forum for Heat and Health held in Hong Kong, China".

6.8. FOREIGN VISITORS

Public Health experts from Colombia University visited **M. C., Ahmadabad** on 5th January, 2018 and Dr. Jayanta Sarkar, Sc. 'F' delivered lecture to them regarding "Weather Forecasting / Heat action plan Ahmedabad".

Dr. Adam Griffin, Hydrological Statistician, Centre for Ecology and Hydrology (CEH), UK visited **IMD, Pune** office with his team and had meeting with IMD and IIT Bombay on 26th February, 2018 on the subject regarding the project on "Flood and rainfall frequency estimation in Maharashtra State".

Shri Hiroshi Ishihara, Senior Forecaster, Japan Meteorological Agency visited IMD during 26-27 March, 2018 to discuss various "Trans-boundary issues between Regional Specialised Meteorological Centre-Tokyo & Regional Specialised Meteorological Centre, New Delhi and to enhance bilateral co-operation between the two RSMCs". **Dr. M. Mohapatra**, Scientist 'G' presented various activities of RSMC New Delhi to the visiting delegate. Shri Ishihara also visited various workstations of IMD during his visit to IMD. Mr. Ishihara also delivered a presentation on "Activities of RSMC Tokyo" in a seminar organised on 27th March at IMD.

6.9. IMPORTANT EVENTS 2017

IMD FOUNDATION DAY, 2017

India Meteorological Department celebrated its **143rd Foundation Day** on 15th January, 2018 at NCUI Auditorium, New Delhi. Dr. M. Rajeevan, Secretary, MoES presided over the function. Dr. K. J. Ramesh, DG, IMD delivered the welcome address and highlighted the achievements of IMD during the previous year.

Dr. M. Rajeevan, Secretary, MoES, Dr. K. J. Ramesh, DG, IMD and Shri S. C. Bhan during the Lighting of Lamp

On this occasion, Inter-school Painting, Speech and Quiz competitions were organized as part of "IMD Foundation Day" celebrations. The awards were given to winner students of the competitions during Foundation Day.

Dr. M. Rajeevan, Secretary, MoES and Dr. K. J. Ramesh, DG, IMD with the winners of Inter- school competitions

Dr. M. Rajeevan, Secretary MoES presented IMD awards for "Most Performed Regional Meteorological Centre (RMC, Guwahati), Most Performed Meteorological Centre (MC, Hyderabad)", Most Performed Meteorological Observatory (AWS/ARG Jammu, Radar Station

Mumbai, M. O. Minicoy, M. O. Chandbali, M. O. Imphal, A.M.O. Mangalore), Best Performed RS/RW Station (Nagpur). Dr S. K. Srivastav, former Director General of Meteorology was felicitated on this occasion. Dr. M. Rajeevan, Secretary, MoES released various publications including 26th Issue of IMD's Hindi magazine **मौसम-मंजूषा** & quarterly research journal **MAUSAM** Vol. 69 No. 1 (January, 2018) and also released a book entitled "Carbon Utilization: Applications for the Energy Industry" Edited by Dr. Malti Goyal and Dr. M. Sudhakar on this occasion.

143rd IMD Foundation Day was also celebrated in sub offices of IMD, Like, RMC's, MC's and MO's. On this occasion, MC, Bhubaneswar organized an exhibition to create awareness about Weather and Climate services. School Teachers, Students, General Public and Media persons visited the Exhibition. IMD officials explained the function of various instruments installed in the observatory to visitors.

IMD Officials, School Teachers and Students

NATIONAL SCIENCE DAY, 2017

National Science Day was celebrated on 28th February 2018 at **IMD HQ and sub-offices of IMD** to spread all over country. On this occasion, a large number of students, scientists, journalist and general public were attended at O/o CR&S, Pune.

Shri M. A. Pachankar, Met. 'A' and Shri S. Y. Wagmare, S. A. participated in the "**Giant Metre wave Radio Telescope (GMRT) Science Exhibition - 2018**" held on 28th February and 1st March 2018 at GMRT, Khodad, near Narayangaon, District Pune organized on the occasion of "National Science Day".

IMD officials and visitors at Science Exhibition – 2018

WORLD METEOROLOGICAL DAY, 2017

World Meteorological Day (WM DAY) - 2018 was celebrated on 23rd March, 2018 at **IMD HQ and its sub-offices all over India** on the theme "**Weather-Ready, Climate-Smart**". On this occasion a large number of students, scientists, journalist and general public were attended attended the exhibitions in CRS, Pune, RMC's, MC's offices.

IMD officials, teachers and students during WM Day - 2018

The electronic media Doordarshan, AIR, Private TV Channels including local Cable TV visited the **Observatory and various units of IMD** also and have widely published the report on the celebration in local News Papers & short video reports was telecasted in the local news channels.

Visitors at during WM Day – 2018 at RMC Kolkata

IMD officials, teachers and students during WM Day - 2018 at M.C., Bengaluru

Visitors at during WM Day - 2018 at M.C., Bhubaneswar

Visitors at during WM Day - 2018 at M.C., Dehradun

KRISHI FAIR, 2018 AT PURI

Meteorological Centre (M.C.), Bhubaneswar represented IMD, MoES at the 9th Krishi Fair, 2018 at Puri (A National level Agricultural Exhibition organized by Shree Shrikshetra Soochana, Puri) under the auspices of Ministry of Agriculture, Govt. of India during 3-7 June, 2018. MoES stall was adjusted as the best stall in the Exhibition. H. R. Biswas, Scientist 'E' received the Memento and Certificate on behalf of MoES in the Closing Ceremony on 7th June, 2018

INTERNATIONAL YOGA DAY

4th International Yoga Day Yoga Day was as celebrated on 21st June, 2018 at **IMD HQ and most of the sub-office**s spread all over India.

Officers and staff members during Yoga Day

SWACHHTHA PAKHWADA

Swachhta Pakhwada was observed during 1-15 July, 2018 at IMD HQ and sub-offices of IMD spread all over India. During Swachhta Pakhwada, the head of IMD and sub-offices suggested various steps for maintaining cleanliness in the office and cleanliness pledge was taken and entire officers and staff participated in "Shramadaan" by removing of unwanted bushes and cleaning the office/observatory and tree plantation.

Tree plantation at M. C., Ahmedabad

हिंदी पखवाड़ा / हिंदी दिवस 2018

भारत मौसम विज्ञान विभाग के महानिदेशक के कार्यालय, नई दिल्ली तथा उप-कार्यालयों में "हिंदी पखवाड़ा" 1-15 सितम्बर, 2018 के दौरान मनाया गया। भारत मौसम विज्ञान विभाग के मुख्यालय में हिंदी दिवस समारोह 14 सितम्बर, 2018 को आयोजित किया गया। रंग बिरंगे फूलों से सजे और संगीतमय वृष्टि सभागार में इस कार्यक्रम का आयोजन किया गया। हिंदी दिवस समारोह की अध्यक्षता

डॉ. मृत्युंजय महापात्र, वैज्ञानिक 'जी' ने की। इस समारोह की विशेष बात रही कि हमारे देश के प्रसिद्ध कवि एवं गज़लकार श्री नरेश शान्डिल्य जी इस समारोह के मुख्य अतिथि एवं विशिष्ट अतिथि कवि डॉ. अमरनाथ जी थे। वृष्टि सभागार में उपस्थित सभी लोगों का सुश्री रेवा शर्मा, उपनिदेशक (राजभाषा) ने स्वागत, अभिवादन और अभिनंदन किया। समारोह का शुभारंभ दीप प्रज्वलन से हुआ।

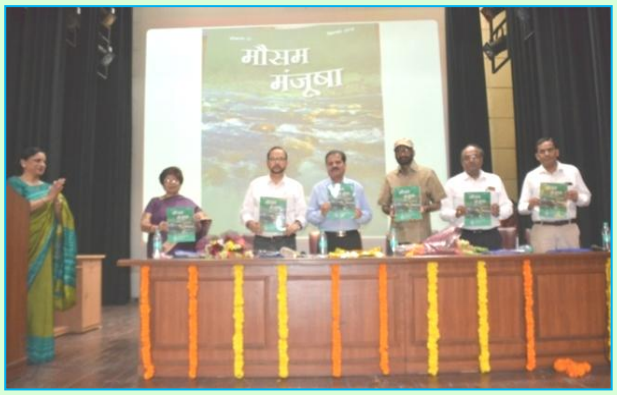
डॉ. मृत्युंजय महापात्र, वैज्ञानिक 'जी' एवं मुख्य अतिथिगण दीप प्रज्ज्वलित करते हुए

डॉ. मृत्युंजय महापात्र, वैज्ञानिक 'जी' हिंदी दिवस समारोह के दौरान संबोधित करते हुए

हिंदी दिवस समारोह का शुभारम्भ माँ सरस्वती का आशीर्वाद लेते हुए सरस्वती वंदना से की गई। सरस्वती वंदना को मधुर स्वर श्रीमती पूनम सिंह, श्रीमती वंदना, श्री अशोक कुमार और श्री कुमार प्रतीक ने दिया। इस समारोह के आयोजन के लिए मौसम विज्ञान के महानिदेशक ने डॉ. देवेंद्र प्रधान, वैज्ञानिक 'जी' (उपकरण) की अध्यक्षता में समारोह समिति का गठन किया। हिंदी पखवाड़ा के दौरान हिंदी लेखन, हिंदी टाइपिंग, हिंदी रूपांतरण, हिंदी मुहावरे एवं लोकोक्ति, हिंदी वाद विवाद तथा हिंदी स्वरचित कविता प्रतियोगिताएं आयोजित की गईं ।

हिंदी दिवस समारोह समिति के अध्यक्ष डॉ. देवेन्द्र प्रधान, वैज्ञानिक 'जी' ने स्वागत भाषण प्रस्तुत किया तथा एक वर्ष के दौरान हिंदी अनुभाग द्वारा किए गए महत्वपूर्ण कार्यों के बारे में संक्षेप में बताया। उपमहानिदेशक (प्रशासन) श्री गजेंद्र कुमार, वैज्ञानिक 'ई' ने भी मंचासीन अतिथियों के लिए स्वागत भाषण प्रस्तुत किया।

हिंदी दिवस समारोह के अवसर पर विभागीय हिंदी गृह पत्रिका '**मौसम-मंजूषा**' के 27वें संस्करण का विमोचन मंच पर आसीन महानुभावों द्वारा किया गया।



मंच पर आसीन महानुभावों द्वारा 'मौसममंजूषा' के 27वें संस्करण का विमोचन

सुश्री रेवा शर्मा, उपनिदेशक (राजभाषा) ने माननीय गृह मंत्री श्री राजनाथ सिंह द्वारा देशवासियों को भेजे गए संदेश को सभी श्रोताओं को पढ़ कर सुनाया। इस समारोह के मुख्य अतिथि श्री नरेश शान्डिल्य जी एवं विशिष्ट अतिथि डॉ. अमरनाथ जी को शॉल से सम्मानित किया गया।

वर्ष 2017-18 में हिंदी में सबसे अधिक पत्राचार करने के लिए कल्याण अनुभाग के प्रमुख श्री चरण सिंह, वैज्ञानिक 'ई' को राजभाषा चलशील्ड प्रदान की गई।

श्री चरण सिंह, वैज्ञानिक 'ई' राजभाषा चलशील्ड प्राप्त करते हुए

श्रीमती सरिता जोशी सहायक निदेशक (राजभाषा) ने सांस्कृतिक कार्यक्रम के लिए मंच का संचालन किया। सांस्कृतिक कार्यक्रम के आरंभ में श्रीमती पूनम सिंह, अशोक कुमार, दीपिका, कुमार प्रतीक, वंदना, सैमसन ने 'तेरी है जमी तेरी आसमान' गीत गाया।

सांस्कृतिक कार्यक्रम के दौरान कलाकार

सुश्री प्रतीक्षा प्रधान ने राग बहार पर शास्त्रीय गीत और डॉ. देवेन्द्र प्रधान, वैज्ञानिक 'जी' ने देश भक्ति गीत गाया। श्री अनूप कंडारी, सुमेश वर्मा, याशिका,

सांस्कृतिक कार्यक्रम के दौरान कलाकार नाटक प्रस्तुत करते हुए

देवर्ष्यान्जलि, रामनाथ गुप्ता, विवेक मित्तल, शिखा वर्मा, कुमार प्रतीक द्विववेदी, अशोक कुमार, वंदना, कुलविंदर सिंह, अरूणा चौहान ने 'लो कर दिया न कचरा' हास्य व्यंग्य नाटक प्रस्तुत किया।

डॉ. डी. आर. पटनायक ने 'ओह रे ताल मिले' गीत गाया और कार्यक्रम का अंत सभी कलाकारों द्वारा 'कंधों से मिलते हैं कंधे' समूह गीत से हुआ। दर्शकों ने सभी कार्यक्रमो का खूब आनंद उठाया और करतल ध्वनि से कलाकारों और सांस्कृतिक कार्यक्रमों को सराहा।

कार्यक्रम के अंत मे अध्यक्ष डॉ. मृत्युंजय महापात्र, वैज्ञानिक 'जी' ने विभाग में राजभाषा हिंदी की प्रगति पर अपने विचार प्रस्तुत किए और मुख्य अतिथि और विशिष्ट अतिथि का धन्यवाद किया। कार्यक्रम के सभी कलाकारों को पुरस्कार प्रदान किए गए और धन्यवाद ज्ञापन के उपरांत कार्यक्रम का समापन हुआ।

INAUGURATION OF DOPPLER WEATHER RADAR (DWR) at GOA

The inauguration of S-Band Doppler Weather Radar (DWR) at Goa on 12th June, 2018 was done by Dr. M. Rajeevan, Hon'ble Secretary, MoES in presence of Dr. K. J. Ramesh, DG, IMD.

Dr. M. Rajeevan, Hon'ble Secretary, MoES, Dr. K. J. Ramesh, DG, IMD during the inauguration of S-Band Doppler Weather Radar (DWR) at Goa

ESTABLISHMENT OF CYCLONE WARNING CENTRE (CWC) AT THIRUVANANTHAPURAM

Inauguration of Cyclone Warning Centre at Thiruvananthapuram on 23rd October, 2018

Cyclone Warning Centre started functioning at MC Thiruvananthapuram w.e.f. 1st October 2018. It was formally inaugurated on 23rd October, 2018 by Dr. M. Rajeevan, Secretary, MoES in the presence of Dr. K. J. Ramesh, DGM, Shri P. H. Kurian IAS, Addl. Chief Secretary, Government of Kerala, Dr. M. Mohapatra, Scientist 'G', Dr. S. Balachandran, DDGM, RMC Chennai and Shri K. Santosh, Sc. 'F', MC Thiruvananthapuram. The 4th Cyclone Warning Centre (CWC) in the country under Area Cyclone Warning Centres (ACWC), has been established at Meteorological Centre, Thiruvananthapuram, India Meteorological Department w.e.f. 1st October, 2018 to monitor and issue warnings about cyclones / depressions and other disastrous weather events affecting the coastal area / states of Kerala, Karnataka & Lakshadweep.

Important Events

Shri Rajnath Singh, Honourable Union Home Minister, Govt. of India, flagged off inaugural flight from Dehradun to Naini Saini Airport, Pithoragarh under UDAN Scheme on 8th October, 2018. All arrangements for aeronautical Met. Services were made by **M.C. Dehradun with the help of R.M.C. New Delhi, A.M.O. Palam and S. I. Pune**.

Shri J. P. Gupta, Sc. 'F', signed a Memorandum of understanding (MoU) with Vice-Chancellor, Narendra Dev University of Agriculture and Technology (NDUAT) Kumarganj, Faizabad on 2nd November, 2018 for providing space free of cost for PBO, Bahraich at crop research centre Bahraich.

Shri J. P. Gupta, Sc. 'F', is signing MoU with Prof. Jeet Singh Sandhu, Vice-Chancellor NDUAT

"**Met-briefing and the hourly weather forecast**" was provided for the visit of Honourable Prime Minister of India, Shri Narendra Modi, during his visit to "**Shri Kedarnathji**" on 7th November, 2018.

Dr. K. J. Ramesh, D. G., IMD and Dr. S. Balachandran, Sc. 'F' participated in the "**Mobile app release and MoU for weather forecasts for mobile app**" held at National Centre for Coastal Research, Chennai on 15th November, 2018.

Shri J. P. Gupta, Sc. 'F', signed a MOU with Airport Director, CCS Airport, Lucknow on 2nd December, 2018 regarding construction of new MC Building free of cost at DWR Complex of equivalent area as old MC building.

CHAPTER 7

RESEARCH PUBLICATIONS

MAUSAM (Formely Indian Journal of Meteorology, Hydrology & Geophysics), established in January 1950, is the quarterly research journal brought out by the department. It is a premier scientific research journal in the field of Meteorology, hydrology & Geophysics for publication of original scientific research work. MAUSAM is being indexed and abstracted by Thomson Reuter U.S.A. For the year 2017 it has an IMPACT FACTOR (IF): 0.278 and 5-year Impact factor 0.431 calculated by Thomson Reuter U.S.A. The rating score given by National Academy of Agricultural Sciences (NAAS) for the year 2017 is 6.47. IMD Scientists published 114 research paper/books in Mausam/Met. Monograph/Met Reports and National & International Journal during 2018.

7.1. RESEARCH CONTRIBUTIONS PUBLISHED IN 'MAUSAM'

B. Amudha, Y. E. A. Raj and Rm. A. N. Ramanathan, **"Differential patterns of surface winds over Bay of Bengal during the various phases of Indian northeast monsoon derived from QuikSCAT data, 1999-2008",** *Mausam*, **69**, 1, 1-18.

Arnab Hazra, Sourabh Bhattacharya and Pabitra Banik, **"A Bayesian zero-inflated exponential distribution model for the analysis of weekly rainfall of the eastern plateau region of India",** *Mausam*, **69**, 1, 19-28.

N. Chattopadhyay, K. V. Rao, A. K. Sahai, R. Balasubramanian, D. S. Pai, D. R. Pattanaik, S. V. Chandras and S. Khedikar, **"Usability of extended range and seasonal weather forecast in Indian agriculture",** *Mausam*, **69**, 1, 29-44.

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Fig. 1. Cyclonic disturbances Report

IMD Met. Monograph No. ESSO/IMD/ FDP/TCR/1/2018/06 "**Forecast Demonstration project (FDP) for improving Track, Intensity and Landfall of Bay of Bengal Tropical Cyclones Implementation Report – 2017**" Cyclone Warning Division.

7.4. OTHER PUBLICATIONS

Book Chapters

A report on "**Tropical cyclone programme report no. TCP-21 tropical cyclone operational plan for the Bay of Bengal and the Arabian Sea, edition 2018**" was published.

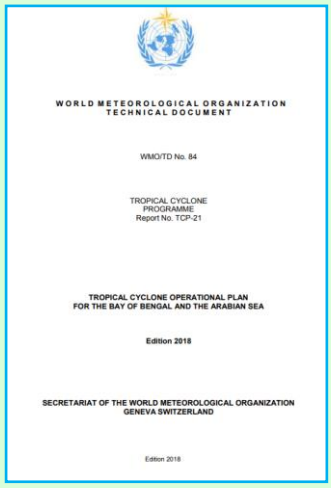


Fig. 2. TCP-21 Report 2018 edition

A report on "**WMO/ESCAP panel on Tropical Cyclones annual review 2016**" was published.

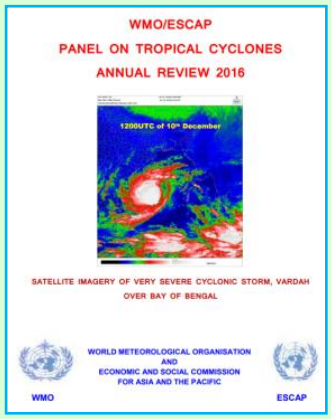


Fig. 3. Annual Cyclone Review – 2016 report

A report on "**Forecast Demonstration Project (FDP) for Improving Track, Intensity and Landfall of Bay of Bengal Tropical Cyclones: Implementation Report, 2017**" was published.

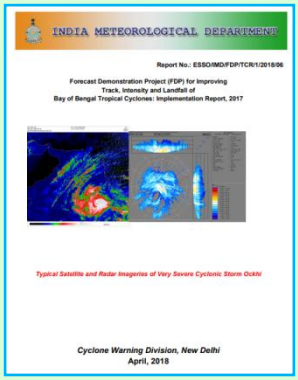
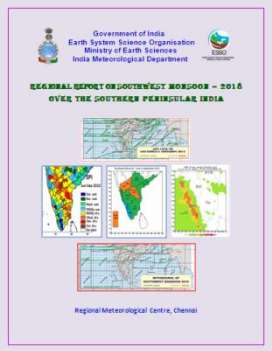


Fig. 4. FDP Implementation Report-2017

A report titled "**regional aspects of Southwest monsoon – 2018 over southern peninsular India" including heavy rainfall and associated**

flooding in Kerala" was prepared and uploaded in the RMC Chennai website.



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A report entitled **"Pre-Monsoon Thunderstorms-2017: A Report"** containing detailed analysis of the thunderstorms, hails, squalls observed during 1 March to 30 June, 2017 was prepared by Nowcast Division and was e-published during the year 2018.

Fig. 6. FDP STORM Report-2017

CHAPTER 8

FINANCIAL RESOURCES AND MANAGEMENT PROCESS

8.1. FINANCIAL RESOURCES AND MANAGEMENT

Budget Estimates/ Revised Estimates

Budget provisions for the department during the financial year 2018-19 were as follows:

Central Sector schemes (ACROSS) :

B.E. : Rs. 186.46 crores
R.E. : Rs. 185.89 crores

Establishment :

B.E. : Rs. 388.00 crores
R.E. : Rs. 394.87 crores

8.2. Atmospheric & Climate Research – Modelling Observing Systems & Services (ACROSS)

Umbrella scheme of MoES entitled "Atmospheric & Climate Research-Modeling Observing Systems & Services (ACROSS)" at a total cost of Rs. 1450.00 crore (Rupees One Thousand Four Hundred and Fifty Crore only) was approved for implementation during 2017-20.

The ACROSS scheme pertains to the atmospheric science programs of MoES. The entire gamut of weather/climate prediction involves assimilation of meteorological observations, understanding the processes, research and development of dynamical models and providing the forecast services. Each of these aspects is incorporated as sub-scheme under the umbrella scheme "ACROSS" and is carried out by different units of MoES. The overarching objective of the "ACROSS" scheme is "To conduct R & D for improving forecast of weather, climate and other hazardous events in real-time for delivery of a reliable weather and climate service". This requires:

(a) Augmentation of observations and their assimilation into weather and climate models

(b) Understanding the physical processes through field campaigns

(c) Developing and running of high resolution models for giving forecasts in all temporal and spatial scales

(d) Translating science to service and its delivery to society

(e) Improving and acquiring the required infrastructure

In order to carry out the above tasks, nine sub-schemes have been formulated with definite objectives and deliverables. Some of these sub-schemes are flagship programmes and are multi-institutional and implemented in an integrated manner through IMD, IITM, NCMRWF and INCOIS. Each institute has its designated role for accomplishing the aforesaid tasks. Considering that activities of each of the above institutes necessarily play a pivotal role in delivery of a reliable weather and climate service in real-time, and inter alia all these activities are inter-dependent, therefore all the flagship programmes of atmospheric sciences of the Ministry are integrated and are jointly implemented by the aforesaid four units. As a result these sub-schemes are put together under the umbrella scheme "ACROSS".

Sub-schemes/ activities to be carried out by IMD either exclusively or jointly with other institutes are mentioned below :

(*i*) Atmospheric Observations Network (AON)-IMD

(*ii*) Weather & Climate Services (WCS)-IMD

(*iii*) Upgradation of Forecast System (UFS)-IMD

(*iv*) Commissioning of Polarimetric Doppler Weather Radars (DWRs)-IMD

(*v*) Monsoon Mission II including High Resolution (12-km) global ensemble forecast system – IITM/NCMRWF/INCOIS/IMD

(*vi*) Monsoon Convection, Clouds and Climate Change (MC4)-IITM/NCMRWF/IMD

(*a*) Centre For Climate Change Research (CCCR) including Virtual Water Centre –IITM

(*b*) Physics & Dynamics of Tropical Clouds (PDTC)-IITM

(*c*) Atmospheric Research Testbeds (ART) for process studies and National Climate Reference Network (NCRN)-IITM

(*d*) Metro Air Quality and Weather Service (MAQWS)-IITM/IMD/NCMRWF

Aims and objectives of the programmes under ACROSS-IMD

- Sustenance and Augmentation of observational networks comprising of Doppler Weather Radars (DWRs), Automatic Rain Gauges (ARGs), Automatic Weather systems (AWSs), Upper Air, Surface and Environmental Observatories etc. Improve upon the spatial and temporal density of Radar observational network, particularly over the regions with large data gaps in the country.

- To improve and upgrade weather and climate services over northeastern region by establishing additional state of art surface and upper air observatories for real time observations and Integrated Himalayan Meteorological Programme for Western & Central Himalayas.

- Sustenance & Establishment of Multi processing, computing and communication facilities for Satellite Meteorological Applications, data and Product transmission. Development of an advanced Operational Forecast System, Delivery System for Forecast and other services.

- Establishment of DAMUs in all the districts complimentarily with existing AMFUs in the country for extension of Agromet Advisory Services (AAS). To expand the outreach of weather based agromet advisories to the farmers through multiple means of communication, collection of feedback and impact assessment of AAS.

- Major upgradation of Meteorological facilities at all airports through commissioning of semi automated Aviation Weather Observing System and establishing new Aerodrome MET Office at Greenfield airports and setting up of automated Heliport Weather Observing & Transmitting System at Heliports, Landing ground and other strategic locations to support the helicopter and low level flight operation of IAF, Indian Army, CPMF and also at important tourist and pilgrimage locations.

- Establish a state-of the-art climate data centre with integrated advanced climate data services portal for rendering national and regional climate services to provide a comprehensive set of improved and specialized climate services for the country through upgradation of the existing operational activities of climate monitoring, climate prediction, climate data management and climate application as WMO recognized Regional Climate Centre (RCC) for the region.

TABLE 1

IMD programme-wise Budget under ACROSS (Rs. in crore)

Programme	Type	2017-18	2018-19	2019-20	Total
AON	Revenue	87.46	41.10	58.60	187.16
	Capital	29.11	0.63	5.11	34.85
WCS	Revenue	21.52	51.3	79.7	152.52
	Capital	1.64	38.98	47.86	88.48
UFS	Revenue	6.10	29.51	41.27	76.88
	Capital	5.25	28.49	47.38	81.12
DWRs	Revenue	0	1.1	7.3	8.4
	Capital	0	0.9	32.7	33.6
Total	Revenue	115.08	123.00	186.87	424.95
	Capital	36.00	69.00	133.05	238.05

- Improvement of Numerical Weather Prediction System with high reliability over

- India and neighbouring regions. Establishment, maintenance & enhancement of physical, computational and associated infrastructure for carrying out research and development activities. Modeling of global and regional climate variability and change and assessments of impacts using Earth System Models and High Resolution Climate Models. Special emphasis is given on High resolution (12 km) global ensemble prediction system to enhance the capability of forecasting extremes.

8.3. Citizen's/ Client's Charter

Citizen's/ Client's Charter for the period 2018-19 uploaded on the IMD website (www.imd.gov.in).

8.4. REVENUE GENERATED DURING THE YEAR 2018

Sale of Meteorological Data

RCs/MCs	Total revenue received by sale of meteorological data during the month (Amount in Rupees)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
DGM, New Delhi												
DGM SATMET	64252	-	-	64965		-	65680	-	-		65680	-
DGM NHAC	-	-	-	-	-	-	-	-	-	-	-	-
DGM (Publication)	15925	71691	56975	16275	30340	23650	11115	450	10425	-	4050	1200
RMC, New Delhi												
New Delhi	60083	36212	35217	9481	22868	63229	18474	20284	12654	26172	28355	23767
Jaipur	28591	6662	37540	3220	12858	11117	70412	35362	58495	21212	33225	4366
Lucknow	1685	5139	16669	3424	309	10919	3660	20947	50664	8441	7338	2723
Srinagar	13135	4660	5190	6672	38405	107924	29635	6726	5428	3599	5428	4012
Chandigarh	9794	14988	2590	11324	56298	-	-	5335	4520	5143	1483	-
Shimla	52975	-	1245544	-	19605	34522	216417	-	16236	24404	23506	99622
Dehredun	7709	9559	9082	4256	30071	31440	14090	39848	76387	14169	5106	28598
RMC, Mumbai												
Mumbai	22336	68496	13156	81335	18759	85054	101492	75249	342860	71741	1506	20266
Ahemdabad	-	23609	9312	-	-	-	4024	32487	45255	16357	24185	-
RMC, Nagpur												
Nagpur	14188	38207	39365	14815	24551	86153	63956	64606	62169	10913	33932	59754
Bhopal	2294	-	1674	1191	40395	-	-	-	-	-	46953	-
RMC, Kolkata												
Kolkata	16043	54864	13462	33552	185229	39245	77491	59103	73391	29437	63707	29967
Patna	10635	-	10008	-	-	-	-	-	-	-	-	11894
Bhubneshwar	49916	41964	106252	28300	32568	18566	107566	40734	104217	22592	34622	10856
Gangtok	-	-	-	-	2266	16811	77216	41223	29492	-	21016	25638
Ranchi	21405	-	-	1255	4132	43522	15147	24269	7642	10929	-	-
RMC, Guwahati												
Guwahati	68711	10455	116191	67040	74122	32244	49494	83163	87393	44620	115714	67411
Agartala	42010	-	3926	2833	9196	-	14178	13198	5445	1149	3452	9410
RMC, Chennai												
Chenaai	39181	54319	217841	754832	70698	93173	157615	54409	166536	86284	342819	159061
Thiruvananthapuram	19357	26191	30483	59101	6870	49398	227519	182567	85849	21621	34666	128196
Hyderabad	383990	103755	33875	15931	23306	93552	61123	38322	22631	45404	13261	27059
Bangalore	25940	35884	50525	140155	37351	51024	57281	62456	56390	57640	104160	32869
ACWC Chennai	237660	5398	136975	2699	-	5398	127946	10870	2717	10868	16306	-
CWC Visakhapatnam	-	2372	-	-	15646	13152	16318	6474	4772	-	-	8760
CRS, Pune												
Pune	544492	525206	15312491 $ 2352	820640	878500	227671 $ 332	2037014	898638 $ 192	260148	318113	120282	102715

CHAPTER 9

STATUS OF SC/ST/OBC AS ON 01.01.2018

(i) Status of SC/ST/OBC as on 01.01.2018 (Group wise)

	Representation of SCs / STs / OBCs as on 1.1.2018				Appointments by Promotion during the calendar year		
Groups	No. of Employees	SCs	STs	OBCs	SCs	STs	Total
Group A	213	33	15	44	9	1	32
Group B (Gaz.)	1430	247	122	0	0	0	0
Group B (Non- Gaz.)	975	156	44	261	0	0	3
Group C	1469	455	152	173	1	0	10
TOTAL	4087	891	333	478	10	1	45

(ii) Status of SC/ST/OBC as on 01.01.2018 (Pay Scale Wise)

	Representation of SCs / STs / OBCs as on 01.01.2018				Appointments by promotion during the calendar year		
Pay Scale in Rs.	No. of Employees	SCs	STs	OBCs	SCs	STs	Total
PB-3 + GP 5400	67	9	5	19	0	0	0
PB-3 + GP 6600	1	0	0	0	0	0	0
PB-3 + GP 7600	31	5	3	12	0	0	0
PB-4 + GP 8700	62	14	5	13	5	1	23
PB-4 + GP 8900	48	5	2	0	4	0	9
PB-4 + GP 10000	3	0	0	0	0	0	0
75500-80000	1	0	0	0	0	0	0
TOTAL	213	33	15	44	9	1	32

CHAPTER 10

राजभाषा नीति का कार्यान्वयन

संसदीय राजभाषा समिति द्वारा निरीक्षण

माननीय संसदीय राजभाषा समिति की दूसरी उपसमिति द्वारा दिनांक 25 जनवरी, 2018 को विभागीय कार्यालय-मौसम केंद्र तिरूवंनतपुरम का निरीक्षण किया गया जिसमें डॉ. देवेन्द्र प्रधान, वैज्ञानिक 'जी' ने मुख्यालय के प्रतिनिधि के रूप में भाग लिया। इस निरीक्षण बैठक में उपनिदेशक (रा.भा.) सुश्री रेवा शर्मा तथा सहायक निदेशक (रा.भा.) श्रीमती सरिता जोशी भी उपस्थित रहीं।

डॉ. देवेन्द्र प्रधान, वैज्ञानिक 'जी', माननीय संसदीय राजभाषा समिति की दूसरी उपसमिति के विभागीय कार्यालय-मौसम केंद्र तिरूवंनतपुरम के निरीक्षण के दौरान

माननीय संसदीय राजभाषा समिति की दूसरी उपसमिति द्वारा दिनांक 23 फरवरी, 2018 को जलवायु अनुसंधान एवं सेवाएँ, पुणे का राजभाषायी निरीक्षण किया गया जिसमें डॉ. मृत्युंजय महापात्र, वैज्ञानिक 'जी' ने मुख्यालय के प्रतिनिधि के रूप में भाग लिया। इस निरीक्षण बैठक में उपनिदेशक (रा.भा.) सुश्री रेवा शर्मा तथा सहायक निदेशक (रा.भा.) श्रीमती सरिता जोशी भी उपस्थित रहीं।

डॉ. मृत्युंजय महापात्र, वैज्ञानिक 'जी' माननीय संसदीय राजभाषा समिति की दूसरी उपसमिति के जलवायु अनुसंधान एवं सेवाएँ, पुणे का राजभाषायी निरीक्षण निरीक्षण के दौरान

संसदीय राजभाषा समिति की दूसरी उपसमिति द्वारा दिनांक 8 सितंबर, 2018 को चक्रवात चेतावनी केंद्र विशाखापट्टनम का राजभाषायी निरीक्षण किया गया। इस निरीक्षण में महानिदेशक डॉ. के. जे. रमेश तथा उपनिदेशक (राजभाषा) सुश्री रेवा शर्मा, उपनिदेशक (रा.भा.) ने मुख्यालय के साथ-साथ पृथ्वी विज्ञान मंत्रालय के प्रतिनिधि के रूप में भी भाग लिया। श्रीमती सरिता जोशी, सहायक निदेशक (राजभाषा) तथा श्री रामहरि शर्मा, मौसम विज्ञानी 'ए' भी इस निरीक्षण में उपस्थित रहे।

मुख्यालय (राजभाषा अनुभाग) द्वारा निरीक्षण

उपनिदेशक (रा.भा.) सुश्री रेवा शर्मा, तथा सहायक निदेशक (रा.भा.) श्रीमती सरिता जोशी द्वारा प्रादेशिक मौसम केंद्र, नागपुर तथा मौसम केंद्र, रायपुर का दिनांक 20 मार्च, 2018 से 23 मार्च, 2018 तक राजभाषायी निरीक्षण किया गया तथा दोनों कार्यालयों

में 'राजभाषा नीति' तथा 'कम्प्यूटर पर हिंदी में कार्य' से संबंधित व्याख्यान व प्रेजेंटेशन दिए गए।

उपनिदेशक (रा.भा.), सहायक निदेशक (रा.भा.) तथा वरिष्ठ अनुवादक द्वारा दिनांक 11 मई, 2018 को स्थापना अनुभाग तथा दिनांक 23 मई, 2018 को सामान्य अनुभाग का राजभाषायी निरीक्षण किया गया और दोनों अनुभागों के अधिकारियों को राजभाषा नियम एवं अधिनियम के बारे में विस्तार से जानकारी दी गई और नियमों के अनुपालन के दायित्व के बारे में बताया गया।

मुख्यालय के राजभाषा अनुभाग द्वारा 25 जून, 2018 से 26 जून, 2018 तक मौसम केंद्र पटना का राजभाषायी निरीक्षण किया गया तथा पाई गई कमियों का समीक्षा पत्र आवश्यक दिशानिर्देश के साथ जारी किया गया।

मुख्यालय के केंद्रीय विमानन मौसम प्रभाग का दिनांक 28 नवंबर, 2018 तथा राष्ट्रीय मौसम पूर्वानुमान केंद्र का दिनांक 29 नवंबर, 2018 को उपनिदेशक (रा.भा.) सहायक निदेशक (रा.भा.) तथा वरिष्ठ अनुवादक द्वारा राजभाषायी निरीक्षण किया गया।

मुख्यालय की उपनिदेशक (राजभाषा) तथा सहायक निदेशक (राजभाषा) द्वारा दिनांक 14 दिसंबर, 2018 को प्रादेशिक मौसम केंद्र नई दिल्ली का राजभाषायी निरीक्षण किया गया तथा निरीक्षण के दौरान पाई गई कमियों को दूर करने के लिए आवश्यक दिशा-निर्देश दिए गए तथा इससे संबंधित समीक्षा पत्र जारी किया गया।

सम्मान

'राष्ट्रभाषा स्वाभिमान न्यास' द्वारा राष्ट्रपिता महात्मा गाँधी की 150वीं जयंती के अवसर पर 9 मार्च, 2018 को आयोजित 'राष्ट्रभाषा उद्घोष सम्मेलन' में राजभाषा हिंदी के विकास में उत्कृष्ट योगदान के लिए उपनिदेशक (रा.भा.) सुश्री रेवा शर्मा तथा सहायक निदेशक (रा.भा.) श्रीमती सरिता जोशी को 'रजत जयंती राजभाषा विकास विशिष्ट सम्मान-2018' से सम्मानित किया गया।

हिंदी कार्यशाला

राजभाषा हिंदी में कार्य करने की झिझक को दूर करने तथा विभागीय कार्मिकों को हिंदी में प्रशिक्षण देने के उद्देश्य से दिनांक 30 मई, 2018 को हिंदी कार्यशाला का आयोजन किया गया जिसमें 26 प्रशिक्षाणार्थियों ने भाग लिया। इस कार्यशाला में श्रीमती सरिता जोशी, सहायक निदेशक (रा.भा.) और श्री बीरेन्द्र कुमार, वरिष्ठ अनुवादक ने व्याख्यान दिए।

5 जून, 2019 को जलवायु अनुसंधान सेवाएं, पुणे के कार्यालय में आयोजित हिंदी कार्यशाला में सुश्री रेवा शर्मा, उपनिदेशक (राजभाषा) ने संसदीय राजभाषा समिति को प्रस्तुत की जाने वाली निरीक्षण प्रश्नावली, राजभाषा नीति और श्रीमती सरिता जोशी, सहायक निदेशक (राजभाषा) ने 'सूचना प्रौद्योगिकी और हिंदी' विषय पर व्याख्यान दिए।

मौसम केंद्र पटना में 26 जून, 2019 को हिंदी कार्यशाला का आयोजन किया गया जिसमें वरिष्ठ अनुवादक श्री बीरेन्द्र कुमार और प्रादेशिक मौसम केंद्र कोलकाता के कनिष्ठ अनुवादक श्री नीलोत्पल चतुर्वेदी ने राजभाषा नीति, नियम, अधिनियमों के संबंध में कार्मिकों को व्याख्यान दिए।

मुख्यालय में दिनांक 24 अगस्त, 2018 को हिंदी कार्यशाला का आयोजन किया गया। जिसमें 8 अधिकारियों और 9 कर्मचारियों ने भाग लिया। इसमें सुश्री रेवा शर्मा, उपनिदेशक (रा.भा), श्रीमती सरिता जोशी, सहायक निदेशक (रा.भा.) और श्री बीरेन्द्र कुमार, वरिष्ठ अनुवादक ने राजभाषा नीति से जुड़े विभिन्न विषयों पर व्याख्यान दिए।

चक्रवात चेतावनी केंद्र, विशाखापट्टनम में दिनांक 20 सितम्बर, 2018 को हिंदी कार्यशाला का आयोजन किया गया जिसमें सुश्री रेवा शर्मा, उपनिदेशक (रा.भा.) ने 'राजभाषा नीति' श्रीमती सरिता जोशी, सहायक निदेशक (रा.भा.) ने 'सूचना प्रौद्योगिकी और हिंदी' तथा श्री रामहरि शर्मा, मौसम विज्ञानी-'ए' ने 'कम्प्यूटर पर हिंदी में कार्य करने' संबंधी विषयों पर व्याख्यान दिए।

बैठक

विज्ञान और प्रौद्योगिकी और पृथ्वी विज्ञान मंत्रालय की संयुक्त हिंदी सलाहकार समिति की बैठक माननीय मंत्री महोदय डॉ हर्षवर्धन जी की अध्यक्षता में 22 जून, 2018 को सी एस आई आर, सांइस सेटर, लोदी रोड में दोपहर तीन बजे आयोजित की गई। इस बैठक में कार्यभारी महानिदेशक डॉ. मृत्युंजय महापात्रा, वैज्ञानिक 'जी' ने भाग लिया। इस बैठक में सुश्री रेवा शर्मा, उपनिदेशक (रा.भा), श्रीमती सरिता जोशी, सहायक निदेशक (रा.भा.) और श्री बीरेन्द्र कुमार, वरिष्ठ अनुवादक भी उपस्थित रहे।

व्याख्यान

राष्ट्रीय मध्यम अवधि मौसम पूर्वानुमान केंद्र, नोएडा में दिनांक 27 अगस्त, 2018 को आयोजित हिंदी कार्यशाला में सुश्री रेवा शर्मा (रा.भा.) और श्रीमती सरिता जोशी, सहायक निदेशक (रा.भा.) को व्याख्यान देने के लिए आमंत्रित किया गया। सुश्री रेवा शर्मा ने 'राजभाषा नीति' और श्रीमती सरिता जोशी ने 'कम्प्यूटर, सूचना प्रौद्योगिकी और हिंदी' विषय पर व्याख्यान दिया।

सुश्री रेवा शर्मा, उपनिदेशक (राजभाषा) ने दिनांक 28 सितंबर, 2018 को आई एस टी एम जवाहरलाल नेहरू विश्वविद्यालय (पुराना परिसर) में 'राजभाषा हिंदी की संवैधानिक स्थिति एवं संसदीय राजभाषा समिति के निरीक्षण के दौरान प्रस्तुत की जाने वाली निरीक्षण प्रश्नावली' विषय पर व्याख्यान दिया।

एम. टी. आई. पुणे के प्रशिक्षण पाठ्यक्रम में 5 दिसंबर, 2018 को राजभाषा हिंदी की संवैधानिक स्थिति एवं नियम अधिनियम के संबंध में उपनिदेशक (रा.भा.) सुश्री रेवा शर्मा एवं सहायक निदेशक (रा.भा.) श्रीमती सरिता जोशी ने व्याख्यान दिए।

CHAPTER 11

MISCELLANEOUS

11.1. HONOURS AND AWARDS

IMD Awards

Best RMC/MC/MOs Awards and Awards to IMD Scientists/employees were given on 143rd IMD Foundation Day celebrations.

Most Performed RMC : RMC Guwahati;

Most Performed MC : MC Hyderabad;

Most Performed MO : AWS/ARG Jammu under RMC New Delhi, Radar Station Mumbai under RMC Mumbai, M. O. Minicoy under RMC Chennai, M. O. Chandbali under RMC Kolkata, M. O. Imphal under RMC Guwahati and A.M.O. Mangalore under RMC Chennai.

Best Performed RS/RW : RS/RW Nagpur.

MoES AWARD 2017-2018

Ministry of Earth Sciences celebrated its foundation day on 27th July 2018 at Vigyan Bhawan, New Delhi. Various award were presented to officials from different organisations of MoES.

Certificate of Merit

1. Dr. Naresh Kumar, Sc. 'E', DGM, New Delhi.
2. Shri Sonum Lotus, Sc. 'D', M. C. Srinagar.

Dr. Naresh Kumar, Sc. 'E' receiving the certificate of merit

Shri Sonus Lotus, Sc. 'D' receiving the certificate of merit

Best Employee Award for the year 2017-18

1. Sh. Ronald john Vaz, Met. 'B', AMS Mangalore, RMC Chennai.

2. Ms. Kiran Jaswal, Met. 'A', DGM Office New Delhi.

Ms. Kiran Jaswal Met. 'A' receiving the award

3. Shri Pradeep Mishra, Sc. Asstt., M. O. Barapani, RMC Guwahati

4. Shri Shri Pramod Ramchandra Mhetre, Sc. Asstt., CRS Pune.

5. Shri Dinesh Kushwaha, Mech Gr-ll, DGM Office New Delhi.

6. Shri S. N. Satav, Radio Mechanic, DWR Mumbai.

7. Shri Ratna Babu, MTS, MC Raipur, RMC Nagpur.

8. Shri M. Sanal Kumar MTS, MC Trivandrum, RMC Chennai.

Appreciation Received

Dr. Dr. S. D. Attri, Scientist 'F' was awarded "Pride of University "by Guru Jambheshwar University of Science & Technology, Hisar.

Dr. S. D. Attri, Scientist 'F' receiving award

An Appreciation letter was received from **Hon'ble Chief Minister, Gujarat Shri Vijay Rupani** state for "Exemplary services provided by IMD Ahmedabad" during Ockhi cyclone and Monsoon - 2017.

Appreciation from WMO

WMO appreciated IMD through a letter issued by **Secretary General of WMO** for "**Tropical cyclone advisory services by Regional Specialised Meteorological Centre (RSMC), New Delhi**" during **Cyclonic Storm, Sagar** (16-20 May) and **Extremely severe cyclonic storm (ESCS), Mekunu** (21-27 May) for round the clock monitoring and providing advisories to WMO and affected countries including Oman, Yemen and Somalia.

WMO appreciated IMD through a letter issued by Secretary General of WMO for tropical cyclone advisory services by Regional Specialised Meteorological Centre (RSMC), New Delhi during Cyclonic Storm, Sagar (16-20 May) and extremely severe cyclonic storm (ESCS), Mekunu (21-27 May) for round the clock monitoring and providing advisories to WMO and affected countries including Oman, Yemen and Somalia.

Shri Sonam Lotus, Sc. 'D' was awarded "Himalayan Heroes Awards for public service" by the Naropa Community on the occasion of Naropa Festival 20th September, 2018 at Hemis, Leh-Ladakh.

Shri Sonam Lotus, Sc. 'D' receiving Himalayan Heroes Awards

11.2. MEDIA INTERACTION

Shri Anand Sharma, Scientist 'F' was interviewed by D D Kisan TV on 1st and 3rd January, 2018 on "Wrap up of weather of 2017 and Weather and Agriculture" in their Vichar Vimarsh Programme respectively.

Dr. Sanjib Bandyopadhyay, Scientist 'F' chaired a workshop with Media Personnel which was organized by ACWC Kolkata on 9th March, 2018. Dr. Sanjib Bandyopadhyay, DDGM briefed to the media personnel about the "Severe weather during all the seasons and importance of their role with regard to dissemination of weather forecast and warnings" issued by IMD in the interest of stakeholders at large. Dr. G. K. Das,

Dr. S. Bandyopadhyay, Sc. 'F' with Media Personnel

Scientist 'D' elaborately discussed in the workshop about the severe weather activity over eastern region during pre-monsoon season seasonal outlook for temperature during March to May 2018.

Shri Anand Sharma, Scientist 'F' was interviewed by AIR, Jalandhar on WMO Day, 23rd March, 2018.

Dr. Sanjib Bandyopadhyay, Scientist 'F' delivered a talk on Doordarshan on Norwester (Kalbaishakhi) related aspects on 5th May, 2018.

The DDGM delivered a lecture at Media workshop on climate change and Himalayas organized by Centre by Media Studies, New Delhi under the Indian Himalayas Climate Adaptation Programme of the Govt. of India at Darjeeling on 10th May, 2018.

The International Collective in Support of Fishermen (ICSF) Trust is preparing a documentary film, titled "**IN OCKHI's WAKE: Disaster Preparedness at Sea**" to thread through the collective learnings from Ockhi and seek solutions for the marine fisheries sector. The production team visited IMD and interviewed Dr. M. Mohapatra, Scientist 'G' about the unique features of cyclone Ockhi and future strategy to combat such disasters on 17th May, 2018.

In '**Aamchi Mati Aamchi Manse**' a programme on "Weather information and Agricultural advisories" jointly organized by India Meteorological Department, Pune, State Department of Agriculture and State Agricultural Universities in Maharashtra at Doordarshan Kendra, Kothrud, Pune on 22nd June, 2018.

Dr. M. Mohapatra, Scientist 'G' (Services) participated in live discussion on Monsoon at Lok Sabha TV on 27th June, 2018.

Team from Jamsetji Tata School of Disaster Studies, Tata Institute of Social Sciences (TISS), Mumbai visited India Meteorological Department (IMD) on 28th June, 2018 and interviewed **Dr. M. Mohapatra**, Scientist 'G' for development of a case study of Early Warning System for Tropical Cyclone with respect to a project under taken by them on "Leadership for Disaster Resilience : A Study of Current Practices and Gaps in the Indian Context".

Team from Stories Asia visited IMD and interviewed **Dr. M. Moapatra**, Scientist 'G' for a story related to thunderstorms on 28th June, 2018.

Shri Bikram Singh, Scientist 'E' was interviewed by Aaj Tak, India news, ETV, Sahara TV, Samachar Plus, Network 10, Mandakini ki Awaz, etc.

Dr. Geeta Agnihotri, Scientist 'E' answered about 20 Weather Enquiries by Electronic and Print Media during the period.

Shri S.M. Metri, Scientist 'E' answered about 5 Weather Enquiries by Electronic and Print Media during the period.

Shri L. Ramesh Babu, Scientist 'E' answered about 10 Weather Enquiries by Electronic and Print Media during the period.

Shri C. S. Patil, Scientist 'D' answered about 10 Weather Enquiries by Electronic and Print Media during the period.

Dr. Sanjib Bandyopadhyay, Scientist 'F' participated in a programme on Doordarshan on 7th June, 2018,

Dr. Sanjib Bandyopadhyay, Scientist 'F' participated in a program on Doordarshan and delivered a talk on monsoon on 23rd June, 2018.

Dr. Sanjib Bandyopadhyay, Scientist 'F' attended media workshop organized by Meteorological Centre, Ranchi at Ranchi for sensitizing the media to climatological changes on 29th June, 2018

Dr. S.C. Sahu, Scientist 'F', Director in Charge, M.C. Bhubaneswar participated in a discussion on "Kalabaisakhi and Agriculture" at Doordarshan Bhubaneswar on 8th May, 2018.

A story on "**What's behind the intense storms battering North West India?**" with expert opinions by **Dr. K. J. Ramesh**, Director General of Meteorology and **Dr. M. Mohapatra**, Scientist 'G' was published by India Climate Dialogue. The same is available at the link http://indiaclimatedialogue.net/2018/05/23/analysing-recent-high-impact-storms-in-india/A story on thunderstorm activity in northwest India was telecast on 12th May at Rajya Sabha TV with Dr. M. Mohapatra, Scientist 'G' as guest expert.

Shri Anand Sharma, Scientist 'F' was interviewed by NDTV, on 3rd July and 9th July, 2018 regarding monsoon rainfall distribution and quantum.

Dr. M. Mohapatra, Scientist 'G' participated as an Expert to review the episodes on 14th & 16th July, 2018 at Vigyan Prasar, NOIDA in connection with Vigyan Prasar is producing 26 episodes video serial entitled "Role of Science and Technology in Understanding Disaster and its Mitigation". This serial will be telecast through Doordarshan, Lok Sabha Television and Rajya Sabha Television and would be a unique resource material for awareness /training /capacity building programmes.

Shri C. S. Patil, Scientist 'D' participated in Mass Media meeting on 6th August, 2018 at Doordarshan Kendra, Bengaluru.

Ms. A. B. Bandgar, Scientist 'B' participated in discussion, special programme on "Weather Forecast and Agricultural Expert Advice" sponsored by Govt. of Maharashtra on 10th August and 24th August, 2018 broadcasted on DD Sahyadri channel.

Shri C. S. Patil, Scientist 'D' participated in live discussion in TV5 between 7 PM to 7.20 PM on 25th September, 2018.

Shri Anand Sharma, Scientist 'F' was interviewed by DD Kisan TV (Phono and live) for weather forecast on daily basis during October, 2018.

Shri C. S. Patil, Scientist 'D' gave live talk on weather in Akashwani Dharwad on 5th October, 2018.

Dr. M. Mohapatra, Scientist 'G' IMD participated in a live discussion on simultaneous occurrence of two very severe cyclonic storms over Bay of Bengal & Arabian Sea on 12th October, 2018 for Lok Sabha TV channel.

Dr. S. D. Attri, Scientist 'F' participated as Expert in one hour "Vichar Vimarsh" programme on DD Kisan, New Delhi which was telecast on 12th October, 2018.

Dr. S. D. Attri, Sc. 'F' during the programme

Dr. M. Mohapatra, Scientist 'G' was interviewed by a team from National Geographic Channel for a "Documentary film on Kerala Floods" on 18th October.

The achievement of IMD in **monitoring & prediction of cyclonic storms Luban & Titli** was telecast in the Science Express News Section in the programme Science Monitor/Gyan Vigyan on 20th October, 2018 by Rajya Sabha TV.

An article entitled "**Mohapatra: IMD's 'cyclone man' who tracked violent Titli**" was published by Press Trust of India in many newspapers on 26th October, 2018.

Dr. K. J. Ramesh, DGM, Dr. M. Mohapatra, Scientist 'G' and other senior scientists were interviewed on various aspects related to

Monsoon Mission on 5th November, 2018 for development of film on "**Monsoon Mission and Improved Prediction**".

Shri Anand Sharma, Scientist 'F' was interviewed and telecast on 7th November, 2018 by DD Kisan TV on Frost and Innovative techniques to prevent it.

Shri C. S. Patil, Scientist 'D' gave live talk in Radio City of Cyclone Gaja, its effects over Karnataka, Tamilnadu and Andhra Pradesh on 12th November, 2018.

Dr. S. D. Attri, Scientist 'F' participated in One Hour TV programme of Vigyan Prasar, DST, New Delhi on 16th November, 2018

Shri C. S. Patil, Scientist 'D' gave a live talk in All India Radio, Dharwad on Weather Forecast on 4th December, 2018.

11.3. ADDRESSES OF VARIOUS MET. CENTRES

Delhi Region

Director
Meteorological Centre,
SCO-2455-56, (First Floor),
Sector 22 C,
CHANDIGARH - 160 022.
e-mail: chandimet@yahoo.com

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Mausam Bhawan,
Budhsinghpura,
Sanganer,
JAIPUR – 302 01.
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mcjaipur2007@yahoo.com

Director
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Civil Aerodrome, Amausi,
LUCKNOW - 226 009.
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Director
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SRINAGAR – 190 015.
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Director
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Survey of India Compound,
17, E.C. Road, Karanpur,
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Chennai Region

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Mumbai Region

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Guwahati Region

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IMPORTANT NOTICE

MAUSAM (Formerly Indian Journal of Meteorology, Hydrology & Geophysics), established in January 1950, is the quarterly research journal brought out by the India Meteorological Department (IMD). MAUSAM is a medium for publication of original scientific research work in the fields of Meteorology, Hydrology, Geophysics and Allied Sciences.

This year the Journal MAUSAM has entered into 70th year of its publications. **We are glad to inform you that on the occasion of glorious seventy (70th) year, all the issues of MAUSAM with effect from 1950 to till date have been uploaded on IMD website for the benefit of scientists, researchers, students, forecasters and planners in the field of Meteorology, Hydrology, Geophysics and Allied Sciences.**

The quarterly issue of MAUSAM (January, April, July and October) contains review article, research papers, shorter contribution, letters, etc. Each year the four issues of MAUSAM also contain weather summary of previous year for winter, pre-monsoon, monsoon and post-monsoon seasons respectively. Apart from this, each July issue contain an article on "Cyclones and depressions over the north Indian Ocean" of the previous year.

Kindly visit MAUSAM web page http://metnet.imd.gov.in/imdmausam/ in IMD website for online access of the published research papers of Journal MAUSAM since 1950. For further information about the Journal MAUSAM, you may kindly contact "Publication Section", IMD (**e mail : mausamps@gmail.com**).

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भारत मौसम विज्ञान विभाग

INDIA METEOROLOGICAL DEPARTMENT

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