सत्यमेव जयते

भारत मौसम विज्ञान विभाग
INDIA METEOROLOGICAL DEPARTMENT

आदित्यात् जायते वृष्टिः

वार्षिक प्रतिवेदन
ANNUAL REPORT
2019

भारत मौसम विज्ञान विभाग
INDIA METEOROLOGICAL DEPARTMENT
पृथ्वी विज्ञान मंत्रालय, भारत सरकार
Ministry of Earth Sciences, Govt. of India

IMD Annual Report 2019

Compiled and Edited

by

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(Formerly Publication Section)
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वार्षिक प्रतिवेदन

ANNUAL REPORT

2019

INDIA METEOROLOGICAL DEPARTMENT

(MINISTRY OF EARTH SCIENCES)

(GOVT. OF INDIA)

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Published in India

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Document Control Sheet

India Meteorological Department

Ministry of Earth Sciences (MoES)

1.	Document Title	Annual Report 2019
2.	Document type	Technical
3.	Issue No.	MoES/IMD/Annual Report 2019/2020/01
4.	Issue Date	10.07.2020
5.	Security Classification	Open
6.	Control Status	Open
7.	No. of Pages	154
8.	No. reference	Nil
9.	Distribution	Open
10.	Language	English & Hindi
11.	Originating Division/Group	India Meteorological Department, New Delhi [Information Science & Knowledge Resource Development Division (IS&KRDD) (Formerly Publication Section)]
12.	Reviewing and Approving Authority	Director General of Meteorology
13.	End Users	Open to all
14.	Abstract	This report highlights the progress made by the department during the year 2019. The Department has continuously augmenting its observational, forecasting and information systems to render better services in areas of agriculture, aviation, shipping, fisheries, environment, water, health, energy, transport etc. Some significant achievements during 2019 include Sub-basin wise Quantitative Precipitation Forecast (QPF), Location specific forecast for capital cities, New climate and climate change products and reports, New website of IMD entitled MAUSAM (www.mausam.imd.gov.in), A mobile application for farmers named MEGHDOOT for Agrometeorology Advisory Services, A web-based Centralized Data Entry System (CDES) package etc. His Royal Highness Prince Charles visited IMD and appreciated the accurate predictions during cyclone FANI & Bulbul. The departmental journal MAUSAM (Formerly Indian Journal of Meteorology, Hydrology & Geophysics) has entered into 70th year of its publications. The department organized several users' conferences, workshops, seminars and symposia to create awareness about the weather among the people. Agromet. Advisories Services (AAS) are disseminated under PPP mode and through mKisan Portal of Ministry of Agriculture and Farmer's Welfare to 40.2 million farmers. IMD has imparted training to the personnel from developing counties. The department also brought out research publications in national and International journals.
15.	Key Words	IMD Annual Report 2019, MoES, Publication, Mausam, Weather

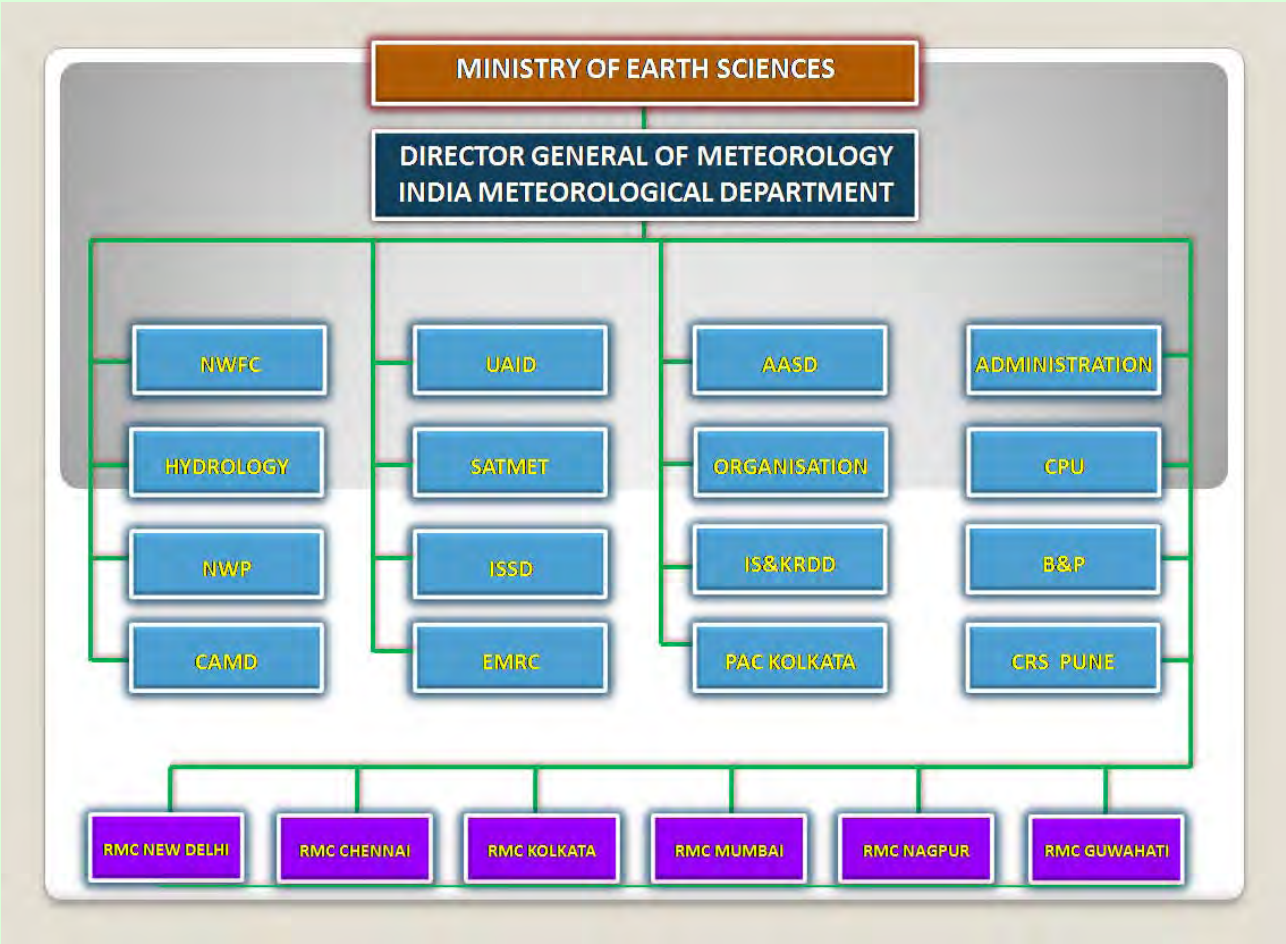
IMD ORGANIZATION CHART

INDIA METEOROLOGICAL DEPARTMENT
MINISTRY OF EARTH SCIENCES
GOVERNMENT OF INDIA

Dr. Harsh Vardhan
Hon'ble Union Minister
of Science & Technology,
Minister of Health &
Family Welfare
and Earth Sciences

Dr. Madhavan Nair Rajeevan
Secretary,
Ministry of Earth Sciences,

Dr. Mrutyunjay Mohapatra
Director General of Meteorology
India Meteorological Department



FOREWORD

It gives me immense pleasure to bring out the Annual Report of India Meteorological Department (IMD) for the year 2019. 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 meteorological services and contributing to safety of life, property and socio-economic development since its establishment in 1875. 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, environment, water, health, energy, transport etc. IMD's services 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 range (monthly and seasonal) and severe weather (cyclones, thunderstorms, extreme rainfall, heat wave, cold wave, fog) forecasts have improved to meet the demands of the user agencies, disaster managers, emergency response groups and other stakeholders.

All India Severe Weather forecast (24 hrs) skill for 2019 has improved as compared to that of 2002-18. The Probability of Detection (POD) for 2019 had been 74%, 92%, 85% and 85% for heavy rainfall, heatwaves, cold waves and nowcast respectively. Annual average track forecast errors in 2019 for 24, 48 and 72 hours has been 69, 104 and 149 km against the mean forecast errors during 2014-18 of 86, 132 and 177 respectively Similarly, the track forecast skills in 2019 also improved substantially and were 68, 79 and 77% for 24, 48 and 72 hours against the average of 58, 70 and 74% during the period of 2014 to 2018.

During 2019, IMD achieved some significant milestones like induction of High Resolution Ensemble Global Forecast System (GEFS) (≈ 12 km) for medium range forecast, NWP model based Sub-basin wise Quantitative Precipitation Forecast (QPF) and new climate products and reports for various users. The annual mean temperature for the country during 2019 year was +0.36 °C above the 1981-2010 average making it as 7th warmest year since 1901. Higher mean temperatures during the pre-monsoon season (Mar-May, with anomaly 0.39 °C and monsoon season (June-September, with anomaly 0.58 °C, warmest since 1901) mainly accounted for the above normal annual temperature for the year. Rainfall during the principal rainy season [Southwest (summer) monsoon season (June-September)] for the country as a whole was normal [110% of Long Period average (LPA)]. The seasonal rainfall during the Northeast monsoon season (October - December) over the NE Monsoon core region of the south peninsula was 109% of its LPA.

IMD launched its new website entitled *MAUSAM* (*www.mausam.imd.gov.in*) and a mobile application for farmers named *MEGHDOOT* for Agrometeorology Advisory Services. A Data Supply Portal was also made operational for automation of activities related to data enquiry, retrieval and supply (Supply of Meteorological Data at National Data Centre, IMD, Pune). A portable X-Band Doppler Weather Radar mounted on mobile platform also received at Sonmarg under Integrated Himalayan Meteorology Programme (IHMP) for Western and Central Himalayas.

A web-based Centralised Data Entry System (CDES) package was launched on 8th August, 2019 to replace the outdated (data entry) DATEN9 software. At present, 91 surface stations, 40 airports and 11 PBO Observatories started sending data through this system. Two Hundred Sixty One (261) more stations were added on Nowcast Warning Page of Newly launched IMD website for issue of three hourly nowcast warnings for severe weather, thereby increasing the total number of three

hourly nowcast stations to 832. IMD installed thirteen (13) additional GPS based RS/RW stations. Special emphasis was given to establish a network in North East India. Further, 341 no. of new raingauge stations added in the District Rainfall Monitoring Scheme. WMO recognized 5 observatories of IMD - Chennai (Nungambakkam), Mumbai (Colaba), Panjim, Pune and Thiruvananthapuram as a long-term observing station for more than 100 years.

It is noteworthy that His Royal Highness Prince Charles visited India Meteorological Department on 13th November, 2019 and was fascinated with the pin point accuracy of monitoring of cyclone FANI. His Royal Highness appreciated the accurate predictions during cyclone FANI & Bulbul and specially complemented IMD which also acts as Regional Specialised Meteorological Centre, New Delhi for providing the advisory services to the countries in the region to effectively mitigate disaster associated with cyclones. IMD earned appreciations from United Nations and Hon'ble President of India for accurate prediction of cyclone FANI. Appreciation letters were also received from the State Governments of Gujarat, West Bengal, Tripura and Odisha for exemplary services provided by the IMD.

It is a great opportunity for IMD that departmental journal MAUSAM (Formerly Indian Journal of Meteorology, Hydrology & Geophysics) has entered into 70th year of its publications and on the occasion of glorious seventieth (70th) year, all the issues of MAUSAM with effect from 1950 to till date have been uploaded on IMD website (MAUSAM web page http://metnet.imd.gov.in/ imdmausam/) for the benefit of scientists, researchers, students, forecasters and planners in the field of Meteorology, Hydrology, Geophysics and Allied Sciences.

The department organized several users' conferences, workshops, seminars and symposia to create awareness about the weather among the people. The implementation of officials languages policy in popularizing use of Hindi in day-to-day officials works pursued and encouraged. The growth towards publishing research finding in national and International journals has embarked a new high by publishing one hundred twenty five research papers/publications during the year.

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 40.2 million farmers. In addition to above Crop Specific Weather based Agromet Advisories for the country on daily basis are being telecasted through DD Kisan Channel, on real time in programs like 'Kisan Samachar' and 'Mausam Khabar' in Hindi and in regional languages of Gujarati, Marathi, Malayalam and Tamil. At present 662 Agromet Advisory Service (AAS) districts bulletins are being prepared and issued to cater to the needs of farmers in the country.

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 and credibility of the department at national and international level. My special thanks to Dr. S. D. Attri, Head [Information Science & Knowledge Resource Development Division (IS&KRDD) (Formerly Publication Section)] and his team of publication unit for their sincere efforts in compilation, editing and publication of this annual report & various divisions and offices of IMD for providing requisite inputs

(Dr. Mrutyunjay Mohapatra)
Director General of Meteorology

Contents

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 2019.

INDIA METEOROLOGICAL DEPARTMENT

Milestones (1793-2019)

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.

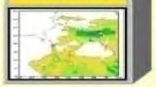
The first DWR was commissioned at Chennai.

2003 — Launch of Meteorological Data and INSAT Imagery through World Space Digital Data Broadcast System.

2006 — Moderization of observing system

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

2014

- Developed a Web based visualisation & Analysis tool Real-Time Analysis of Products and Information Dissemination (RAPID) for INSAT data
- Established Customized Rainfall Information System (CRIS)
- SMS based Cyclones Alert/ Warning initiated.

2015

- An MoU signed between IMD and POSOCO for better management of Indian Power system from generation to distribution and to increase overall efficiency.
- 3 to 5 days forecast initiated.
- ISO 9001:2008 Certification awarded in 10 offices of IMD

2016

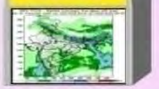
- Operationalization of Coupled modeling system for extended range forecast
- High resolution global model (≈ 12 km) for medium range forecast
- Established Regional Climate Centre of WMO and O/o Climate Research and Services (CRS) at Pune

2017

- Implemented Global Ensemble Forecasting System (GEFS SL) in medium range at 25 km resolution.
- Operationalisation of Coupled modelling system for extended range forecas

2018

- Distric Level color coded impact based forecast
- Global Ensemble Prediction System (GEPS) model at 12 km resolution
- Satellite & Lightning merged products
- Air quality early warning system for Delhi
- Block level experimental agromet advisories initiated

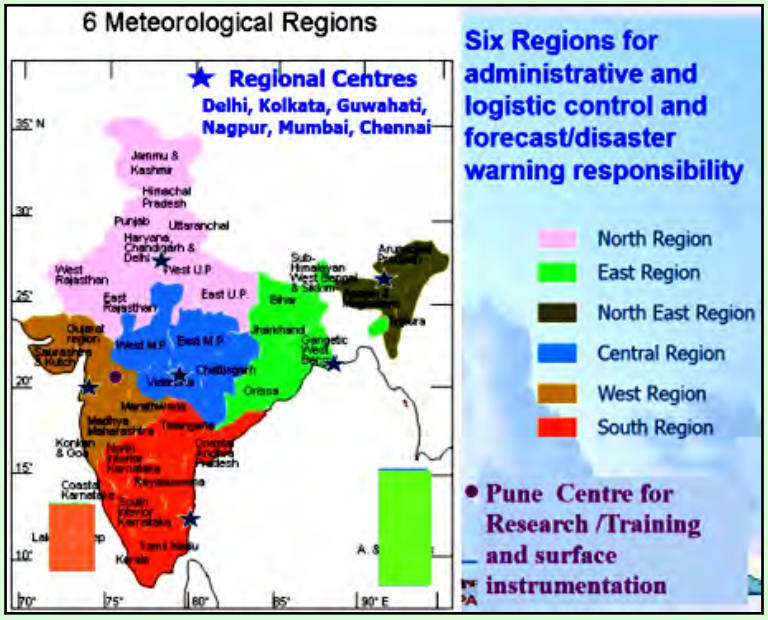


2019

- Glorious seventy (70) years of publication of Journal 'MAUSAM'
- Probabilistic Quantitative Precipitation Forecast (QPF)
- MEGHDOOT App launched
- Online Data Supply Portal
- Lightning forecast & Warning
- Location Specific Forecast for capital cities

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 2019. 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 2019. Its short, medium, extended & long range and cyclone forecasts were appreciated all over the world.

Climate over India during 2019 was above average with respect to temperature. The annual mean temperature for the country this year was +0.36 °C above the 1981-2010 average, thus making the year 2019 as the seventh warmest year on record since the nation-wide records commenced in 1901. Higher mean temperatures during the pre monsoon season [Mar-May, with anomaly 0.39 °C and monsoon season (Jun-Sep), with anomaly 0.58 °C, warmest since 1901] mainly accounted for the above normal annual temperature for the year 2019.

Rainfall during the principal rainy season [Southwest (summer) monsoon season (JuneSeptember)] for the country as a whole was normal [110% of Long Period average (LPA)]. The seasonal rainfall during the Northeast monsoon season (October – December) over the NE Monsoon core region of the south peninsula was 109% of its LPA. The Northeast monsoon rainfall activity, over the south peninsula (core region of northeast monsoon rainfall activity comprising of 5 subdivisions *viz.*, Coastal Andhra Pradesh & Yanam, Rayalaseema, Tamil Nadu, Puducherry & Karaikal, South Interior Karnataka and Kerala & Mahe) was normal [109% of Long Period Average (LPA)].

During 2019, 8 cyclonic storms formed over the Indian seas. Arabian Sea contributed 5 out of these 8 cyclones against the normal of 1 per year, which equals the previous record of 1902 for the highest frequency of cyclones over the Arabian Sea. This year also witnessed development of more intense cyclones over the Arabian Sea. Considering the past data (1891-2018), the highest number of cyclones formed in both the Indian Seas together was 10 during the four years (1893, 1926, 1930 and 1976). The year 2019 also witnessed development of more intense cyclones over the Arabian Sea. Out of 5 systems formed in the Arabian Sea, there have been two very severe cyclonic storms, one extremely severe cyclonic storm and one super cyclonic storm. However, the cyclone activity over the Bay of Bengal during 2019 has been found subdued as only 3 cyclones formed against the normal of 4 per year.

Among the significant weather events of the year 2019: Heavy rain & flood related incidents reportedly claimed over 850 lives from different parts of the country during the pre-monsoon, monsoon & post-monsoon seasons. Of these, 306 lives were reported from Bihar alone, 136 from Maharashtra, 107 from Uttar Pradesh, 88 from Kerala, 80 from Rajasthan and 43 from Karnataka. Heat wave conditions which prevailed over the northeastern & central parts the country during the period March to June claimed about 350 lives. Of these, 293 lives were reported from the worst affected state of Bihar alone during June and 44 lives were reported from Maharashtra. Lightning & Thunderstorm reportedly claimed over 380 lives from central, northeastern, northwestern and peninsular parts of the country during pre-monsoon, monsoon & post-monsoon seasons. Of these, 125 lives were reported from Jharkhand, 73 from Bihar, 51 from Maharashtra and 24 each from Madhya Pradesh & Rajasthan. Snowfall and avalanche related incidents claimed 33 lives from Jammu & Kashmir & 18 from Leh. Cold wave claimed 70 persons from northern parts of the country during 15th to 31st December. Of these, 28 lives were reported from Uttar Pradesh, 19 from Bihar, 13 from Jharkhand & 10 from Madhya Pradesh.

SUMMARY OF MAJOR ACHIEVEMENTS IN 2019

Observations

- **WM**O recognized 5 observatories of **IMD - Chennai (Nungambakkam), Mumbai (Colaba), Panjim, Pune and Thiruvananthapuram** as a long-term observing station for more than 100 years.
- **27 Doppler Weather Radars** are operational across the country including one portable **DWR** at Sonemarg, J&K meant for **Shri Amarnathji Yatra**.
- **13 Radiosonde/Radio Wind** stations commissioned in 2019 taking the total number from 43 to 56 stations enabled with twice a day ascents.
- Three (3) Nos. **transmissometer - RVR (Drishti System)** installed at Kochi, Thiruvananthapuram and Bhubaneswar making it to a total of 44 transmissometer - RVR (Drishti System).
- Preparation of **realtime rainfall statistics** was enhanced from 681 to 683 numbers of districts.
- New Aeronautical Meteorological Stations commissioned under **RCS-UDAN** Scheme.
- 341 no of new **raingauge stations** are added in the District-wise Rainfall Monitoring Scheme (DRMS).
- Agromet Observatories have been installed at Five (5) **AMFUs** in Roorkee, Bhubaneswar, G. Udaigiri, Pusa and Agwanpur, thus total becoming 122.

- 138 **District Agrometeorological Units** have been established in comparison to earlier 130 units.

- **Monthly Meteorological Register (MMR)** - Online was made operational at all surface observatories w. e. f. 1st October, 2019.

- Air Pollution Section, IMD participated in **60th and 61st Laboratory Inter-comparison programme of WMO**.

Modelling & Forecasting

- **IMD's North Karnataka Agro Meteorological Forecasting Centre (NKAFC)** established at University of Agriculture (UAS) Dharwad (Karnataka) on 14th February, 2019.

- **Global Forecast System (GFS)** model upgraded and run 4 times a day to generate 10 days forecast.

- Regional **WRF** mesoscale model upgraded from **9 km to 3 km resolution**.

- **Hurricane WRF** was run as a coupled model at a **resolution of 2 km** in collaboration with **INCOIS**.

- NWP Model based gridded rainfall data (WRF & GFS) are provided operationally to **CWC for their flood forecasting model**.

- **SWIRL application Nowcasting software** has been installed at 12 DWR stations.

- IMD in collaboration with NCMRWF & IITM implemented **Thunderstorm and Lightning Modelling and Warning System**.

- **Impact based forecast** initiated for different severe weather events.

- Two Hundred Sixty One (261) more stations were added on **Nowcast Warning Page of Newly launched IMD website for issue of three hourly nowcast warnings for severe weather**, thus increasing the total number to 694.

- **Within city local forecast and nowcast initiated for 100 places**.

Communication System Networks

- IMD launched its **new website: www.mausam.imd.gov.in** for general public and Mobile App '**MEGHDOOT**' for Agromet Advisory Services.

- In Collaboration with IITM, **a webpage, web application and mobile application** developed for providing weather forecast for **Kumbh Mela** during 2019 along with **current weather information.**

- New website of **Air Quality Early Warning System for Delhi** has been launched during 2019.

- **A Data Supply Portal, http://dsp.imdpune.gov.in** has been made operational for automation of activities related to data enquiry, retrieval and supply.

- A new Web page made operational for **INSAT-3D** and **INSAT-3DR** in stagger mode.

- A web-based **Centralised Data Entry System (CDES)** package was launched on 8th August, 2019 to replace the outdated DATEN9 software. At present, 91 surface stations, 40 airports and 11 PBO Observatories started sending data through this system.

- **Agro-Meteorological Advisory Services (AAS)** bulletins are disseminated under PPP mode and through Kisan Portal to about 40.2 million farmers.

Improvement in Forecast Accuracy

- Significant **improvement in forecast** accuracy of severe weather events by 15 to 35% during the last 5 years.

- All India **Severe Weather forecast (24 hrs) skill for 2019** has improved as compared to that of 2002-18. The Probability of Detection (POD) for 2019 had been 74%, 92%, 85% and 85% for heavy rainfall, heatwaves, cold waves and nowcast respectively.

- **Annual average track forecast errors in 2019 for 24, 48 and 72 hours has been 69, 104 and 149 km against the mean forecast errors during 2014-18 of 86, 132 and 177 respectively.** Similarly, the **track forecast skills in 2019** also improved substantially and were 68, 79 and 77% for 24, 48 and 72 hours against the average of 58, 70 and 74% during the period of 2014 to 2018.

Awards and Appreciation

- **Dr. M. Mohapatra, DG, IMD** has been elected as **Member Executive Council, WMO** for 2019-2023.

- **National Geographic Channel** aired a story on "The Mega Cyclone FANI" on 7th October, 2019 highlighting the role of IMD in early warning services for '**FANI**'.

- **Fascinated with the pin point accuracy of monitoring of cyclone FANI, Prince Charles visited the IMD, Delhi** on 13th November, 2019. Dr. M. Rajeevan, Secretary, Ministry of Earth Sciences and Dr. Mrutyunjay Mohapatra, Director General of Meteorology, India Meteorological Department welcomed His Royal Highness Prince Charles to IMD.

- IMD earned **appreciations** from **United Nations** and **Hon'ble President of India** for accurate prediction of **cyclone FANI**.

- Appreciation letters received from the **State Governments of Gujarat, West Bengal, Tripura and Odisha for exemplary services provided by the IMD**.

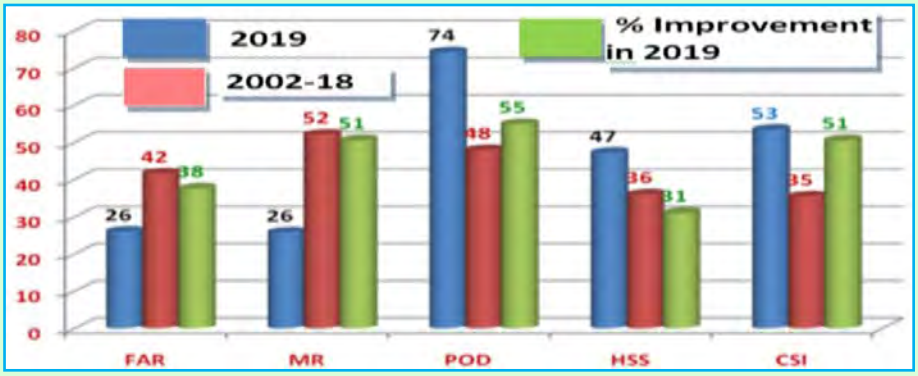
- **President of India appreciated IMD** for providing accurate forecast for Independence Day celebrations of 2019.

- **Dr. M. Mohapatra, DG, IMD** honoured with Bharat Gourav Award, 2019 by Jay Bharat Foundation and felicitated by Hon'ble Chief Minister of Odisha for outstanding contribution to Disaster Management.

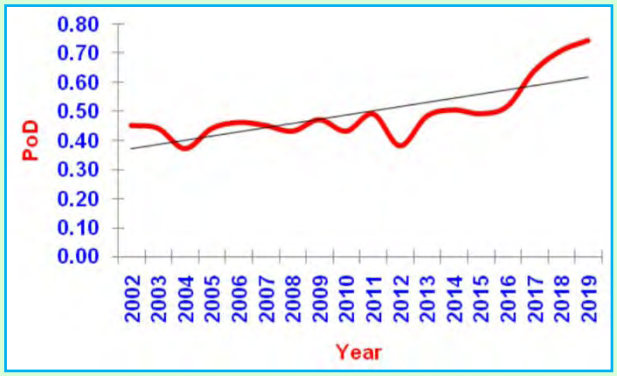
- **Dr. M. Mohapatra DG, IMD** was conferred with Fellowship of IMS & Indian Climate Congress in 2019.

- Indian Meteorological Society awarded **Dr. H. R. Biswas** for the **best research paper published in 2019 in Weather & Climate Services.**

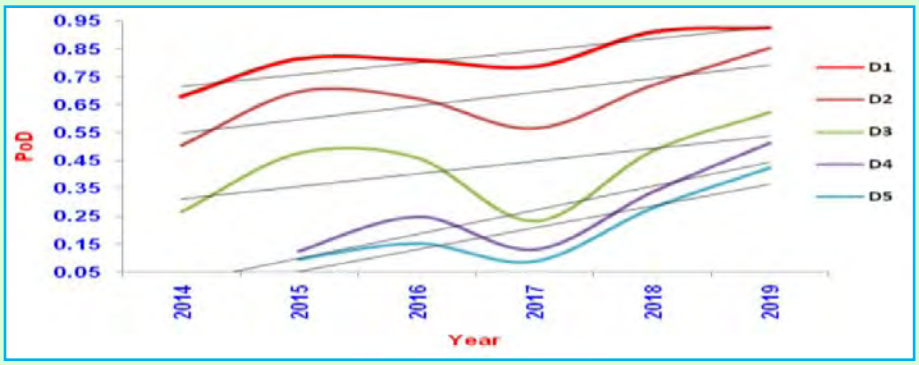
Recent improvements in skill of severe weather forecasts in IMD



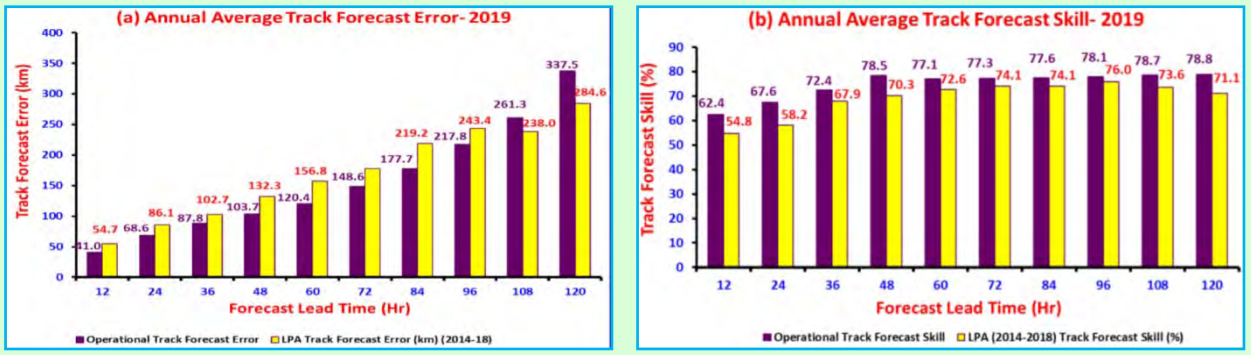
Improvement in heavy rainfall prediction in terms of False Alarm Ratio (FAR), Missing Rate (MR), Probability of Detection (POD), Heidke Skill Score (HSS) and Critical Success Index (CSI); for 24 hours lead period in 2019, in comparison with past 5 years



Probability of Detection of heavy rainfall events, 24 hours in advance showing steady improvement during 2002 - 2019



Probability of Detection of Heatwave, 5 days in advance showing steady improvement during past 5 years



Substantial improvement in the track forecast errors & skill, compared to past 5 years

CHAPTER 2

WEATHER SUMMARY DURING 2019

1. Winter Season (January & February)

Rainfall Features

Rainfall during the season was third highest since 2001. Rainfall over the homogeneous hregion of northwest India and northeast India was 2nd and 6th highest respectively since 2001.

Rainfall realized during the season was 125.7% of LPA. It was 96.4% of LPA during January and was 148.2% of LPA during February. During the season, out of 36 meteorological subdivisions, 9 received large excess rainfall, 4 received excess rainfall, 4 received normal rainfall, 12 received deficient rainfall, 5 received large deficient rainfall and two subdivisions received no rain (Fig. 1). Andaman & Nicobar Islands, northern parts and some subdivisions of south peninsula received large excess/excess/normal rainfall.

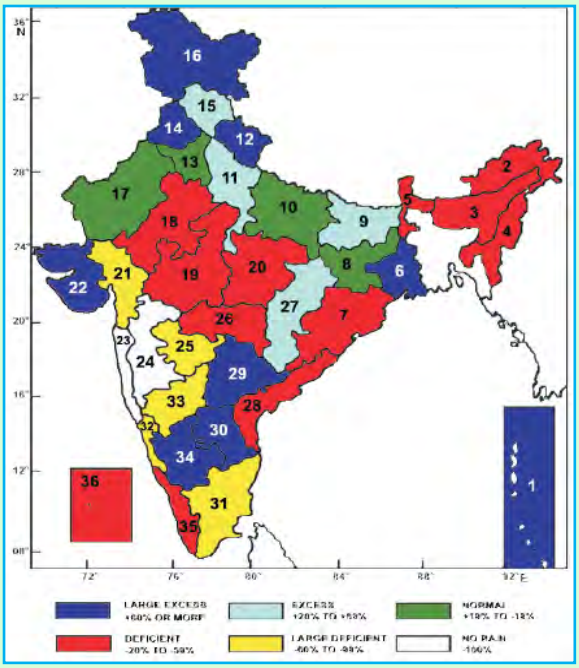


Fig. 1. Sub-divisionwise rainfall percentage departures

The spatial pattern of rainfall (mm) received during the seaso [Fig. 2(a)]. Rainfall activity was confined to Northern, northeastern, east central, south peninsular region, Andaman & Nicobar Islands and Lakshadweep. Parts of Arunachal Pradesh, Jammu & Kashmir, Uttarakhand, Himachal Pradesh, Punjab and Andaman & Nicobar Islands received more than 200 mm rainfall. Parts of Arunachal Pradesh, Jammu & Kashmir, Himachal Pradesh and Uttarakhand received more than 300 mm rainfall.

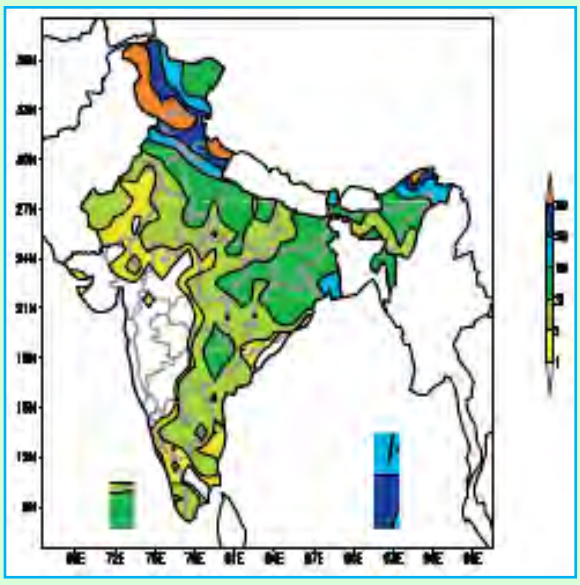


Fig. 2(a). Seasonal rainfall (mm)

The spatial pattern of rainfall anomaly (mm) during the season [Fig. 2(b)]. Positive rainfall anomaly exceeded 100 mm over parts of Uttarakhand, Jammu & Kashmir, Himachal Pradesh, Punjab, Gangetic West Bengal and Andaman & Nicobar Islands. It exceeded 200 mm over parts of Uttarakhand and Jammu & Kashmir. Magnitude of negative rainfall anomaly exceeded 25 mm over parts of Arunachal Pradesh, Nagaland, Manipur,

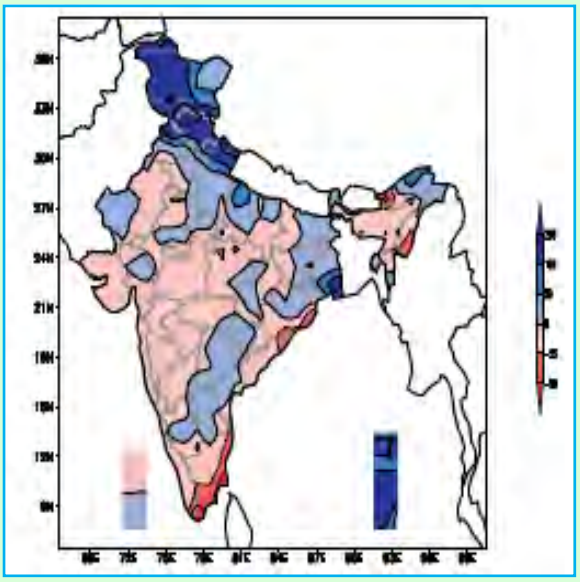


Fig. 2(b). Seasonal rainfall anomaly (mm)
(Based on 1951-2000 Normals)

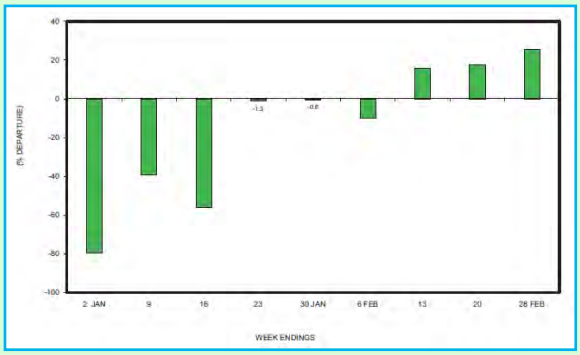


Fig. 3. Accumulated percentage departure of area weighted weekly rainfall over the country as a whole

Mizoram & Tripura, coastal Andhra Pradesh and Tamil Nadu & Puducherry.

The area weighted cumulative weekly rainfall percentage departure over the country as a whole during the season (Fig. 3).

The all India area weighted rainfall series for the season since 1951 (Fig. 4). The area weighted rainfall for the season this year was 51.4 mm was third highest since 2001 after the years 2005 (69.9 mm) and 2003 (53.2 mm).

The area weighted rainfall series for the season over the four homogeneous regions since 1951 was 157.9% of LPA over Northwest India, 85.2% of LPA over East & North East India, 72.7% of LPA over Central India and 84.3% of LPA over south peninsula.

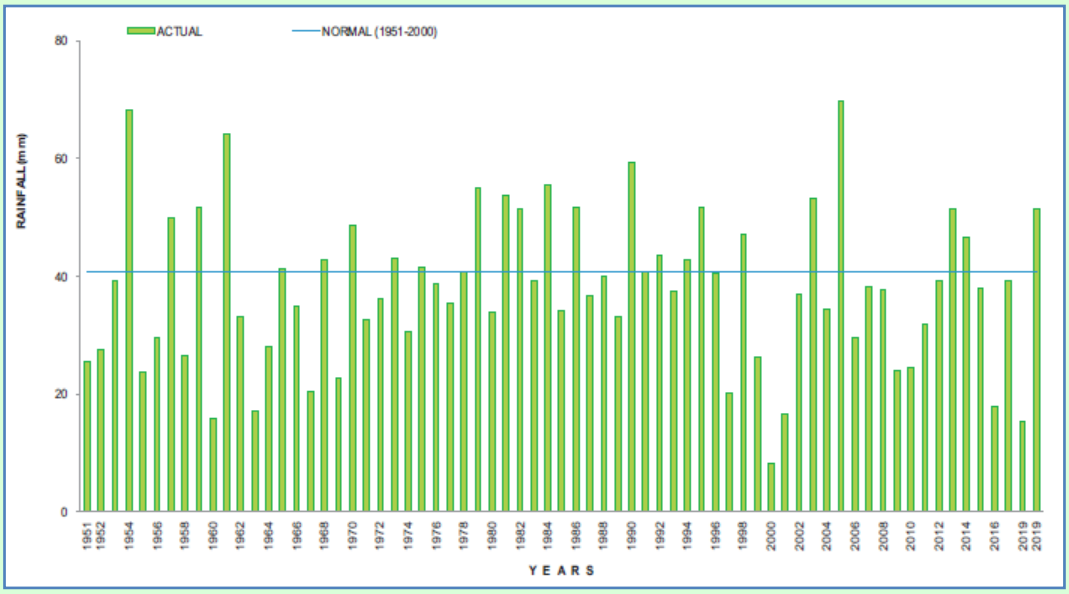
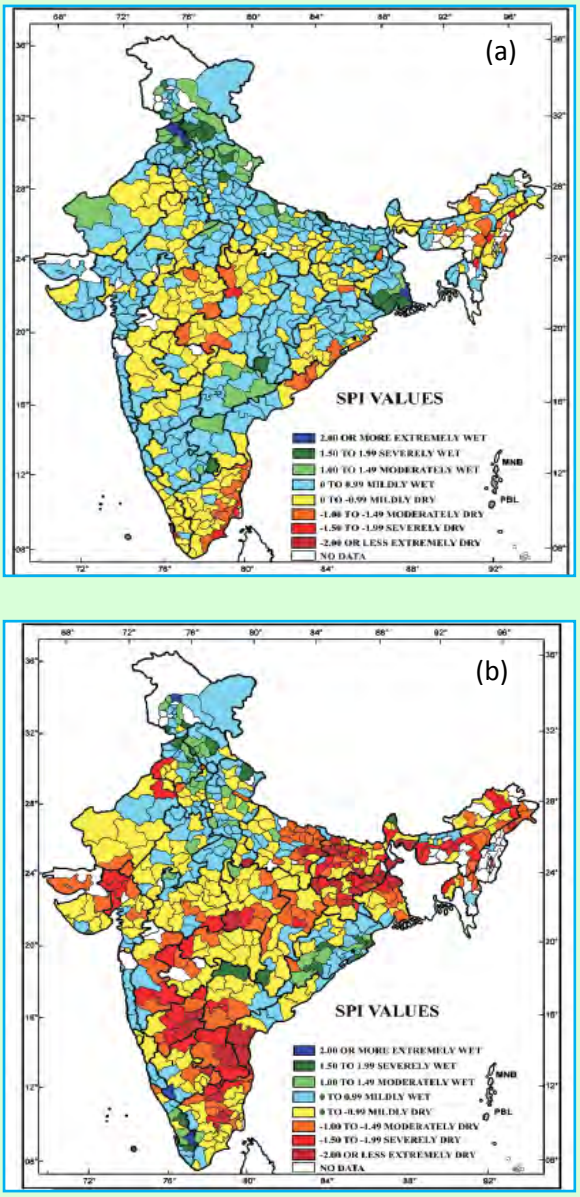


Fig. 4. Time series of area weighted rainfall over the country as a whole (1951 - 2019)

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 respectively. Figs. 5 (a&b) show the SPI values for the winter season 2019 (Jan-Feb, 2 months cumulative) & period from June 2018-February 2019 (nine months cumulative) respectively.



Figs. 5(a&b). Standardized Precipitation Index (SPI) cumulative for (a) two months (Jan-Feb, 2019) and (b) nine months (June 2018-Feb 2019)

Cumulative SPI values of the past two months January and February) indicate that extremely wet/severely wet conditions were observed over parts of Gangetic West Bengal, Bihar,East Uttar Pradesh, West Uttar Pradesh, Uttarakhand, Punjab, Himachal Pradesh, Jammu & Kashmir, Chhattisgarh and South Interior Karnataka, while extremely dry/ severely dry conditions were observed over parts of Nagaland, Manipur, Mizoram & Tripura, East Madhya Pradesh, Tamil Nadu and Kerala.

Cumulative past nine 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, 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, East Uttar Pradesh,West Uttar Pradesh, Punjab, West Rajasthan, West Madhya Pradesh, East Madhya Pradesh, Gujarat Region, Madhya Maharashtra, Marathawada, Vidarbha, Chhattisgarh, Coastal Andhra Pradesh, Telangana, Rayalaseema, Tamil Nadu, North & South Interio Karnataka.

Pressure and Wind

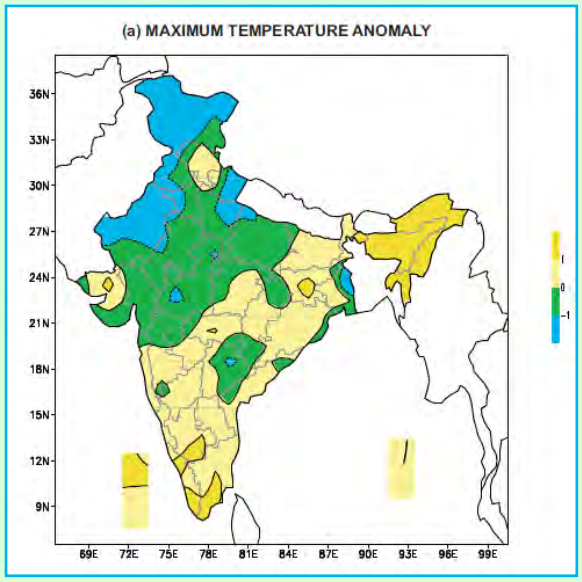
The pressure anomaly was positive almost throughout the country and was of the order of 1.0 to 2.0 hPa except over some parts of West Rajasthan.

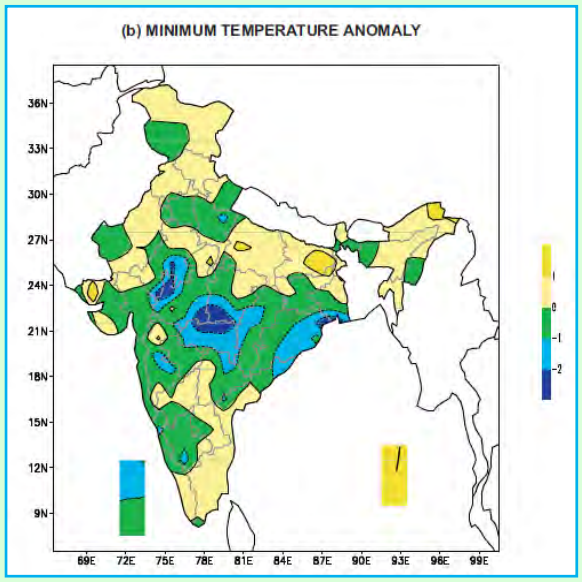
The mean circulation pattern at 850 hpa level an anomalous NW to SE trough from extreme northwest region to westcentral parts were observed. At 500 hPa level, an anomalous trough was more marked and it even extended upto NW Bay of Bengal. At 250 hPa level, an anomalous cyclonic circulation was observed over most parts of the country.

Temperature

Mean seasonal maximum and minimum temperature anomalies are shown in Figs. 6(a&b) respectively.

The maximum temperature was below normal over most parts of the country except north/northeast region, east central, peninsular region and both the islands. Maximum temperature anomaly was more than 1 °C over extreme northeast, Tamil Nadu & Puducherry, Kerala, south interior Karnataka and Lakshadweep. Magnitude of





Figs. 6(a&b): Mean seasonal maximum and minimum temperature anomalies

maximum temperature anomaly was less than 1 °C over parts of Jammu & Kashmir, west Rajasthan, west UP, Uttarakhand & Gangetic West Bengal.

Minimum temperature was above normal over parts of north/northeastern region, eastern parts of peninsula and Andaman Nicobar Islands. Minimum temperature anomaly was more than 1 °C over parts of Arunachal Pradesh and Bihar. Magnitude of minimum temperature anomaly was less than 1 °C over parts of Odisha, coastal Andhra Pradesh, east Rajasthan, Madhya Pradesh state, Vidarbha and Chhattisgarh. Magnitude of minimum temperature anomaly was less than 2 °C over parts east Rajasthan, Madhya Pradesh state and Vidarbha.

Outgoing Longwave Radiation (OLR)

OLR anomaly (W/m^2) over the Indian region and neighbourhood is shown in Fig. 7. OLR anomaly was negative over almost entire country and was positive over the Arabian Sea and Bay of Bengal. Magnitude of negative OLR anomaly exceeding 10 W/m^2 was observed over northwestern parts of the country.

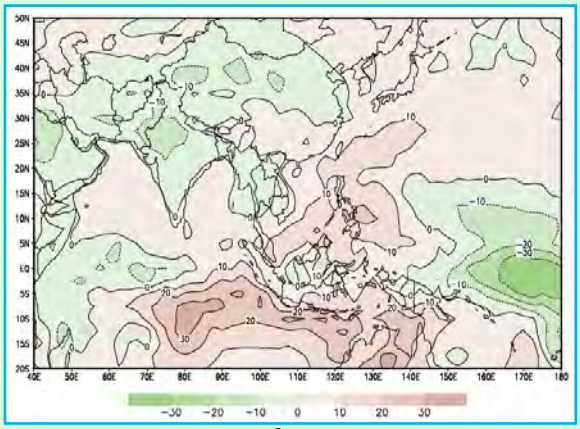


Fig. 7. OLR anomaly (w/m^2) for the winter season 2019 (*Source* : CDC / NOAA, USA) (Based on 1981 - 2010 climatology)

Low Pressure Systems

One cyclonic storm "**Pabuk**" formed in January. It originated as a low pressure area (LPA) over South China Sea on 28th December. It concentrated into a tropical depression on 31st December, 2018. At around 0600 UTC of 1st January, it further intensified into a tropical storm "**Pabuk**". It weakened into deep depression on 6th January at 0600 UTC. The system crossed Andaman Islands as a deep depression close to south of Port Blair between 1300 UTC and 1500 UTC on 6th January.

Besides this cyclonic storm, one low pressure area formed in January and 3 short lived low pressure areas formed in February.

2. Pre-Monsoon Season (March-May)

Heat Wave Conditions

During the season, heat wave/severe heat wave conditions were observed in all the months of the season. In the month of March and April, it was observed during 26-31 March, 1-16 April, 26-30 April at a few places in some parts of central, northwest India. Heat wave conditions again re-emerged in the last week of the month of April over some parts of central India and Maharashtra. During the month of May, its spatial extent increased as it was observed on few days in isolated parts of the entire country except over northeast, extreme north & west coast of India. Vidarbha experienced heat to severe heat wave conditions throughout the month of May.

Rainfall Features

Rainfall activity during the season was rather subdued. During the season, out of 36 meteorological subdivisions, one received large excess rainfall, 3 received excess rainfall, 9 received normal rainfall, 13 received deficient rainfall and 10 received large deficient rainfall (Fig. 8). The subdivision wise rainfall statistics (mm) for the Pre-monsoon season (March-May 2019) shown in Table 1.

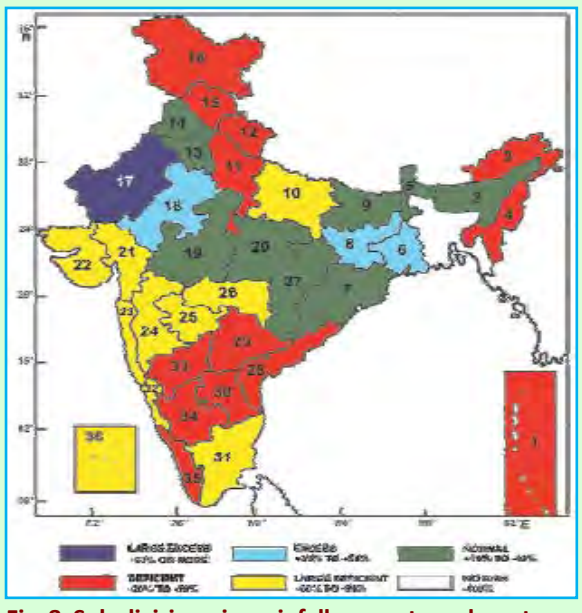


Fig. 8. Sub-divisionwise rainfall percentage departures

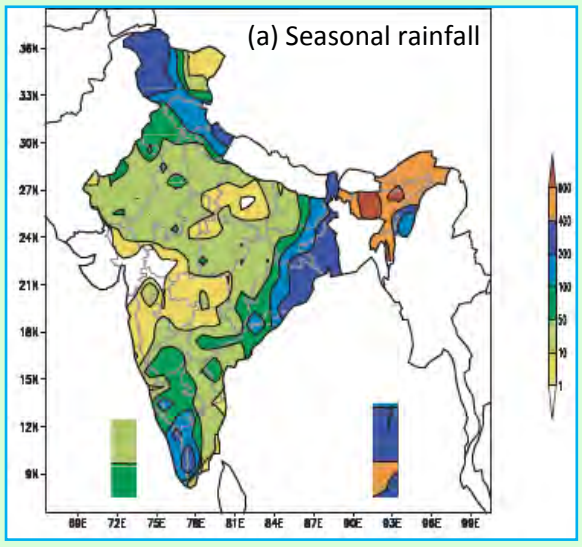
TABLE 1

Meteorological sub-divisionwise rainfall statistics for the pre monsson season 2019 (Based on operational data)

S. No.	Met. Subdivision	Actual (mm)	Normal (mm)	Dep (%)
1.	A & N Islands	282.0	465.0	-39
2.	Arunachal Pradesh	549.3	750.4	-27
3.	Assam & Meghalaya	589.7	590.2	0
4.	Nag., Mani., Mizo., Trip	283.4	494.1	-43
5.	S.H.W.B. & Sikkim	431.5	457.1	-6
6.	Gangatic W.B.	226.8	164.8	38
7.	Odisha	148.7	134.7	10
8.	Jharkhand	105.6	79.4	33
9.	Bihar	69.6	77.5	-10
10.	East U. P.	9.7	31.7	-69
11.	West U. P.	17.6	29.1	-40
12.	Uttarakhand	101.2	156.0	-35
13.	Har., Chandi., Delhi	36.7	34.2	7
14.	Punjab	55.2	53.5	3
15.	Himachal Pradesh	134.5	244.9	-45
16.	Jammu & Kashmir	219.1	326.0	-33
17.	West Rajasthan	31.6	19.1	65
18.	East Rajasthan	25.9	17.4	49
19.	West M. P.	13.4	13.5	-1
20.	East M.P.	24.6	25.1	-2
21.	Gujarat Region	1.1	6.7	-83
22.	Saurashtra & Kutch	0.4	4.0	-90
23.	Konkan & Goa	0.7	37.2	-98
24.	Madhya M'rashtra	8.3	37.8	-78
25.	Marathawada	6.1	30.3	-80
26.	Vidarbha	6.9	30.9	-78
27.	Chattisgarh	38.7	46.8	-17
28.	Coastal A.P.	57.5	97.0	-41
29.	Telangana	27.6	56.3	-51
30.	Rayalaseema	44.9	82.0	-45
31.	Tamil Nadu & P'cherry	51.5	128.1	-60
32.	Coastal Karnataka	47.4	178.8	-73
33.	N. I. Karnataka	44.2	85.1	-48
34.	S. I. Karnataka	116.0	145.2	-20
35.	Kerala	170.7	379.7	-55
36.	Lakshadweep	37.9	232.4	-84

The spatial pattern of rainfall (mm) received during the season is shown in Fig. 9(a). Parts of Odisha, Gangetic West Bengal, coastal Andhra Pradesh, Sub-Himalayan West Bengal & Sikkim, Jammu & Kashmir, Andaman & Nicobar Islands, Tamil Nadu & Puducherry and adjoining Kerala, Assam & Meghalaya, Arunachal Pradesh, Nagaland, Manipur, Mizoram & Tripura received more than 200 mm rainfall Parts of Assam & Meghalaya, Arunachal Pradesh, Nagaland, Manipur, Mizoram & Tripura and Andaman & Nicobar Islands received more than 400 mm rainfall. Parts of Assam & Meghalaya received more than 800 mm rainfall.

The spatial pattern of rainfall anomaly (mm) during the season Positive rainfall anomaly of more than 50 mm was observed over parts of Odisha, coastal Andhra Pradesh, Gangetic West Bengal, Assam & Meghalaya and Arunachal Pradesh. Positive rainfall anomaly of more than 100 mm was observed over parts of Odisha, Assam & Meghalaya and Arunachal Pradesh [Fig. 9(b)]. Magnitude of negative rainfall anomaly was more than 100 mm over parts of Nagaland, Manipur, Mizoram & Tripura, Sub-Himalayan West Bengal & Sikkim, Jammu & Kashmir, Tamil Nadu & Puducherry, Andaman & Nicobar Islands, Kerala, coastal Karnataka and Lakshadweep.



Figs. 9(a&b). (a) Seasonal rainfall (mm) (b) Seasonal rainfall anomaly (mm) (*Based on 1951-2000 Normals*)

The area weighted cumulative weekly rainfall percentage departure during the season for the country as a whole [Fig. 10(a)]. Cumulative rainfall departure was negative during all the weeks of the season except first week. For the Pre-monsoon season 2019, rainfall realized was 75.3% of its LPA value. It was 59.3% of LPAduring March, 78.1% of LPA during April and 81.9% of LPA during May.

The area weighted seasonal rainfall over the country as a whole for the period 1951-2019 [Fig. 10(b)]. Rainfall received over the country as a whole (99.0 mm) was third lowest since 2001 after the years 2012 (90.5 mm), 2009 (95.3 mm).

The time series of area weighted seasonal rainfall over the four homogeneous regions for the period 1951-2019. During the season this year, rainfall realized over central India was 81.8% of its LPA, over Northwest and East & Northeast India (70.0% of LPA, 86.1% of LPA respectively) and over South peninsular India was (53.2% of LPA). Rainfall received over homogeneous region of the south peninsular India (65.8 mm) was lowest since 2001.

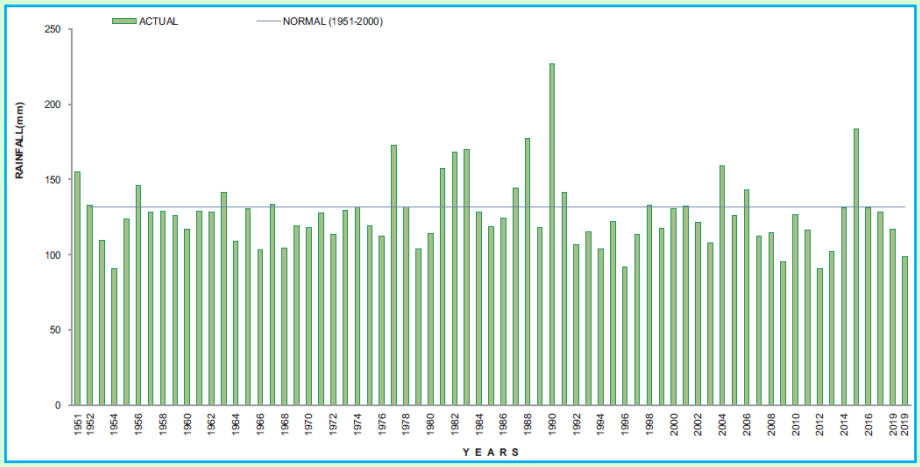
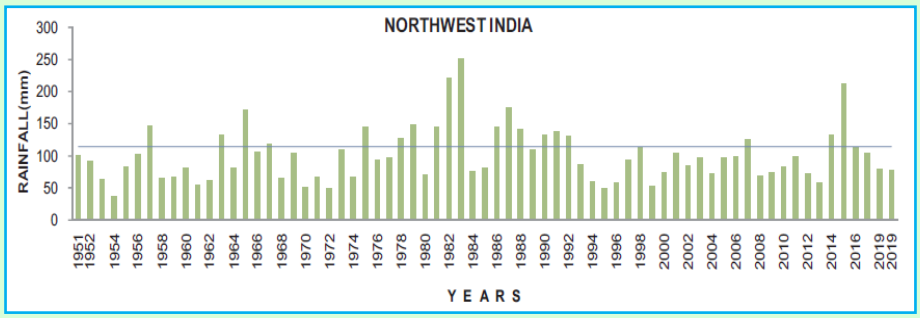
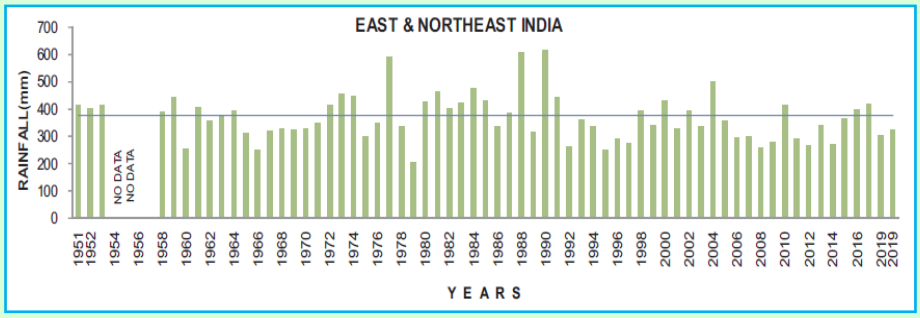
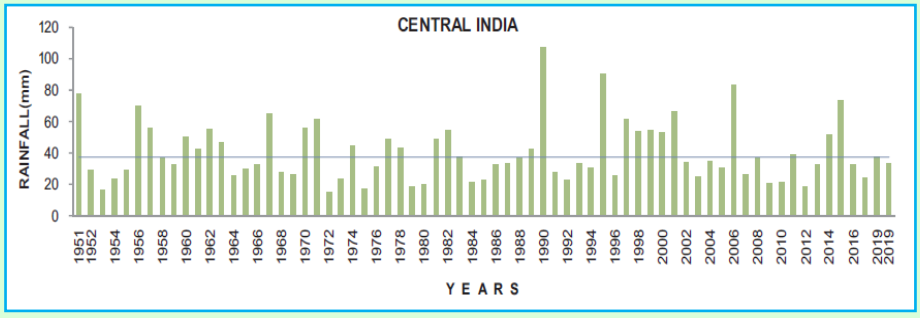


Fig. 10(a). Time series of area weighted rainfall over the country as a whole (1951 - 2019)







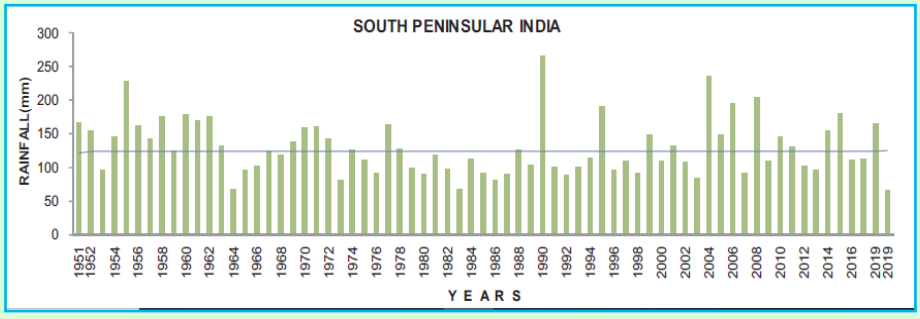


Fig. 10(b). Time series of area weighted rainfall over the four homogeneous regions (1951 - 2019)

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 and positive for wet conditions. As the dry or wet conditions become more severe, the index becomes more negative or positive. Fig. 11 gives the SPI values for the Pre-monsoon season this year.

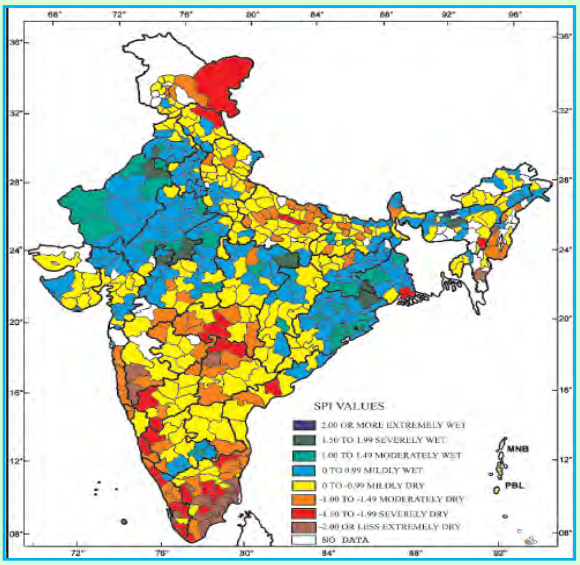


Fig. 11. Standardized precipitation index (SPI) cumulative for pre monsoon season (Mar-May, 2019)

Outgoing Longwave Radiation (OLR)

OLR anomaly (W/m) over the Indian region and neighbourhood is shown in Fig. 12. It was negative over northern and extreme peninsular region and adjoining Arabian Sea. Over extreme northeastern regions and Bay of Bengal, positive OLR anomaly exceeding 10 W/m was observed.

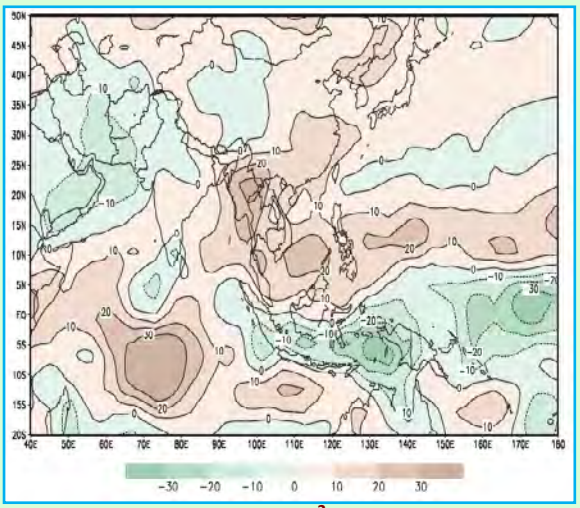
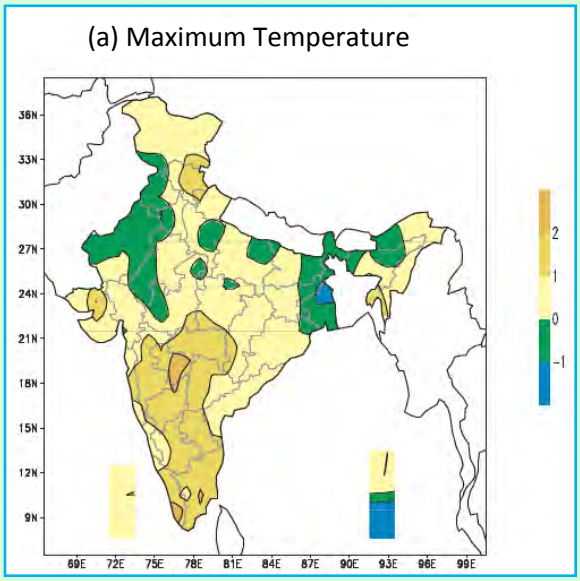


Fig. 12. OLR anomaly (w/m^2) for the season 2018 (*Source* : CDC/NOAA, USA) (Based on 1981-2010 Climatology)

Temperature

Mean seasonal maximum and minimum temperature anomalies during the season are shown in Figs. 13(a&b) respectively.



Figs. 13(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

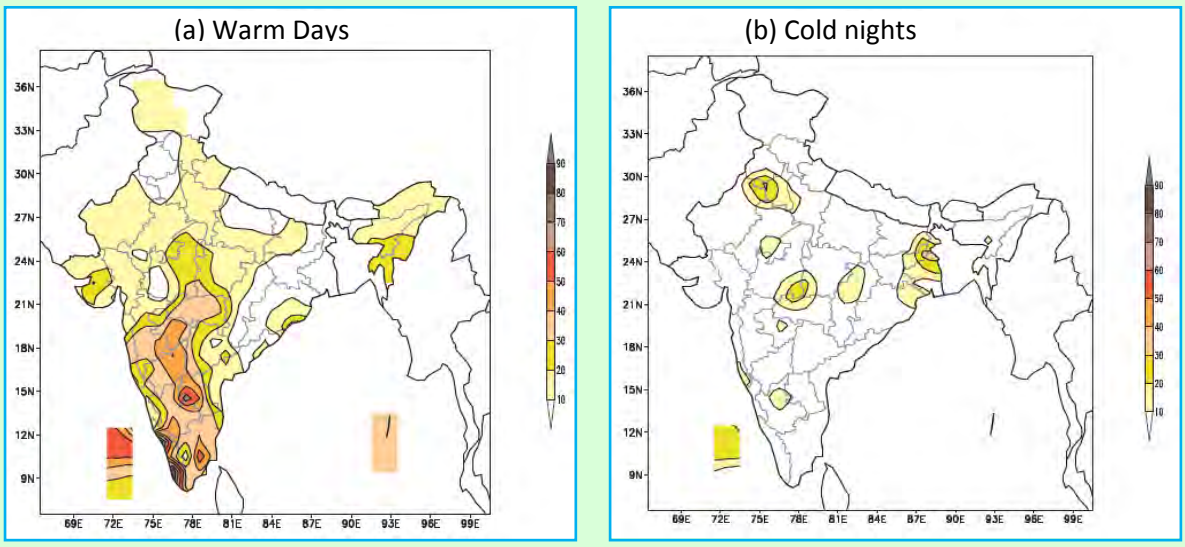
parts of northeastern, northwestern region and Andaman and Nicobar Islands. Maximum temperature anomaly was more than 2 °C over parts of Marathwada and Kerala. Minimum temperature was also above normal over most parts of the country except some northern and central parts and Lakshadweep. Minimum temperature anomaly was more than 2 °C over parts of Telangana and north interior Karnataka.

Percentage of Warm days/Cold nights

The percentage of days when maximum (minimum) temperature was more (less) than 90th (10th) percentile are shown in Figs. 14(a&b).

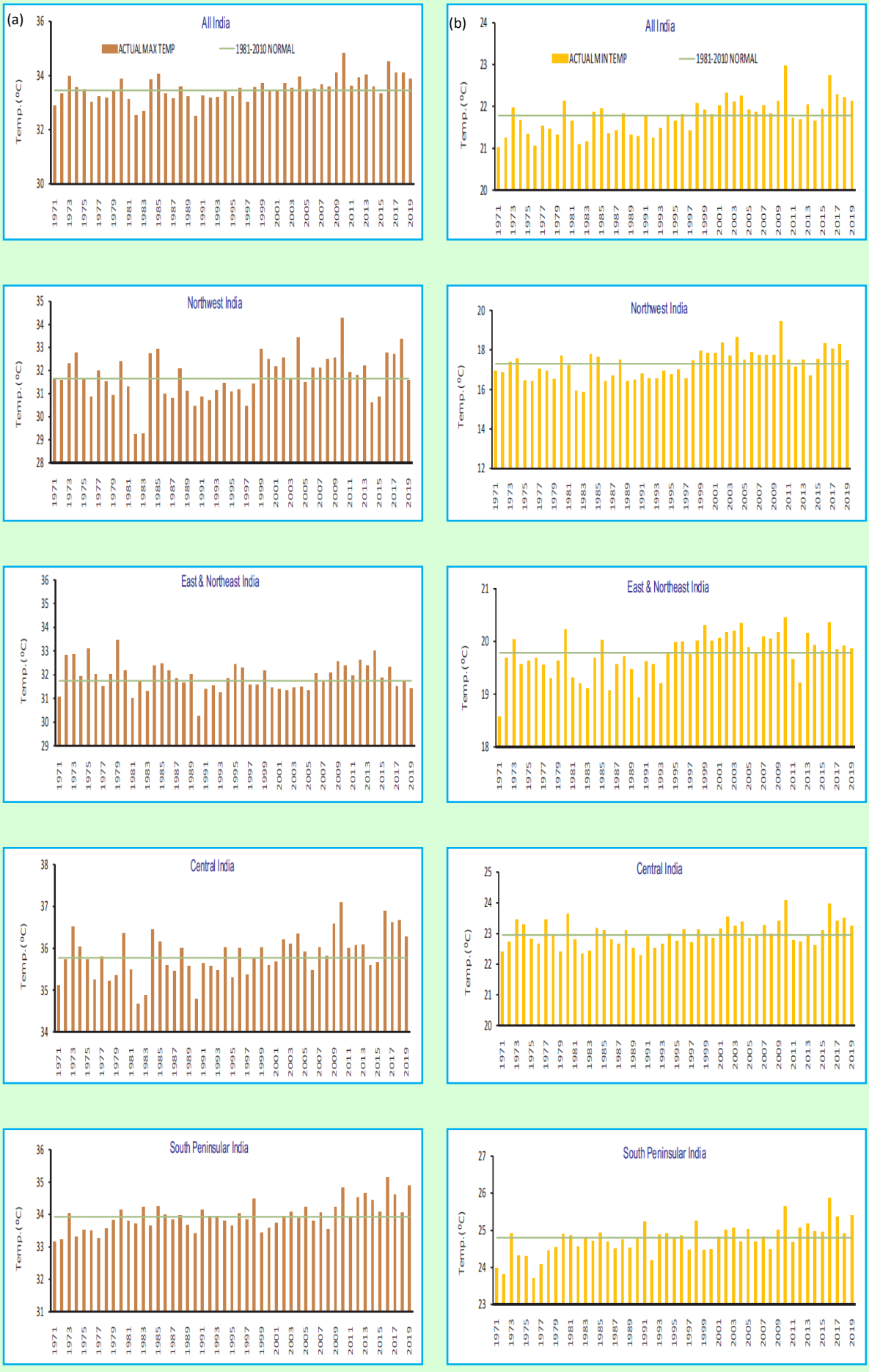
Over parts of Tamil Nadu & Puducherry, Rayalaseema, Kerala and Lakshadweep islands, maximum temperature was greater than 90th percentile for more than 50% of the days of the season. For minimum temperature, no significant distribution was observed. Fig. 15 shows the time series of mean temperature for the country as a whole during the Pre monsoon season (1971-2019). Five years moving average values are also shown. The mean temperature for the season this year (28.0 °C) with anomaly of 0.4 °C.

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. 16(a&b)]. Maximum temperature was above normal over all the homogeneous regions except northwest India and East & northeast India. Minimum temperature was above normal over all the homogeneous regions. Maximum temperature (34.9 °C) over south peninsula was second highest since 1901 after the year 2016 (35.14 °C).



Figs. 14(a&b). Percentage of days when (a) Max. temperature > 90th Percentile (b) Min. Temperature < 10th Percentile

Fig. 15. Time series of mean temperature averaged over india (vertical bars) and five years running mean (continuous line) for the pre monsoon season (1971 - 2019)



Figs. 16(a&b). Time series of temperature for the country as a whole and the four homogeneous regions (1971 - 2019) (a) Maximum (b) Minimum

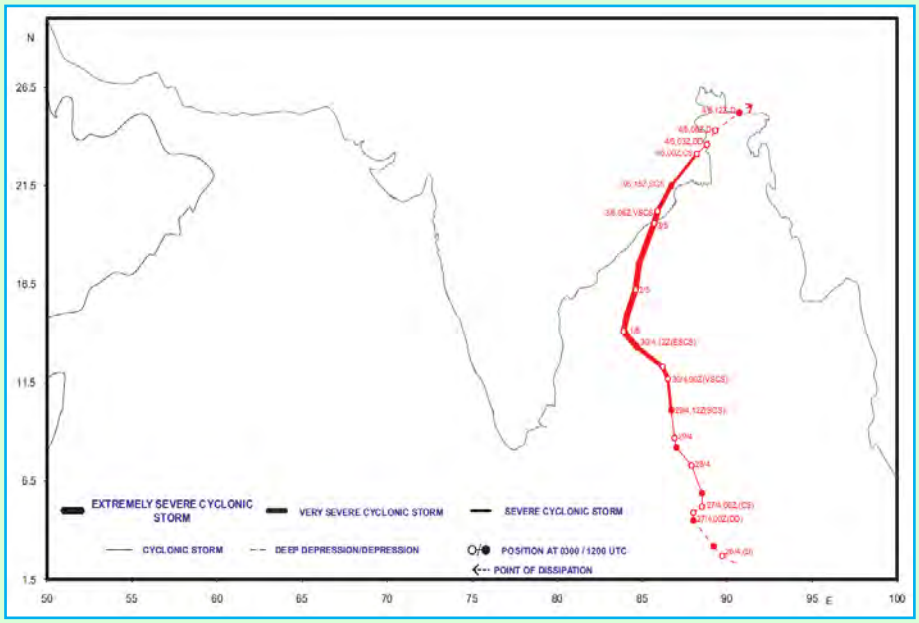


Fig. 17. Track of intense low pressure systems formed during the month (April-May, 2019)

Low Pressure Systems

During the season, an Extremely Severe Cyclonic Storm (ESCS, Fani, 26 April-4 May, 2019) formed over Bay of Bengal. Besides this ESCS, one short lived low pressure area formed on 30th May over southwest Arabian sea off Somalia coast which dissipated on 31st May. The track of intense low pressure systems formed during the month (April-May, 2019) is shown in Fig. 17.

Significant Weather events during the season

Hailstorm : Due to hailstorm, around 1,102 birds killed in Madhya Pradesh in March.

Sunstroke: As per media reports, three suspected sunstroke deaths were reported in Kerala in March.

Rain: 21 people were reportedly claimed dead from Rajasthan, 15 from Madhya Pradesh, 10 from Gujarat and 3 from Maharashtra during the month of April due to rain related incidents. One person reportedly claimed dead in Coimbatore district of Tamil Nadu during third week of May due to falling of tree associated with continuous rain.

Cyclonic Storm: Due to extremely severe cyclonic storm "Fani", total 64 people were reportedly claimed dead from different districts (39 from Puri, 9 from Khurda, 6 from Cuttack, 4 from Mayurbhanj and 3 each from Jajpur and Kendrapara) of Odisha during first week of May.

Lightning/Thunderstorm: At least 60 people were reportedly claimed dead across northern and western India, 50 people in Rajasthan, Madhya Pradesh, Gujarat and Maharashtra, 4 people from Maharashtra and 3 from Manipur during the month of April and 8 persons were reportedly claimed dead in Uttar Pradesh during first week of May.

Heat Wave: One person reportedly claimed dead during first week of April in Aurangabad district of Maharashtra and Two persons reportedly claimed dead during first week of May in East Godavari district of Andhra Pradesh.

Landslide: 5 people were reportedly claimed dead and 9 injured from Jammu & Kashmir's Doda district during April and 2 persons were reportedly claimed dead and 1 injured from Baramulla district of Jammu & Kashmir during third week of May.

3. Monsoon Season (June-September)

Onset and advance of SW Monsoon

Onset of the southwest monsoon had taken place over Andaman Sea on 24th May. It had covered some more parts of Bay of Bengal upto 30th May. On 30th May, the Northern Limit of Monsoon (NLM) passed through Lat. 5° N/Long. 75° E, Lat. 5° N/Long. 80° E, Lat. 10° N/Long. 87° E, Lat. 13° N/Long. 90° E & Lat. 16° N/Long. 94.5° E. The NLM continued to be in the same position upto 2nd June.

It further advanced into southern most parts of Arabian Sea, some more parts of Maldives - Comorin area, some parts of Bay of Bengal on 3rd June. It continued to be in the same position on 4th June. It further advanced into some more parts of south Arabian Sea, most parts of Maldivescomorin area and some more parts of Bay of Bengal. It continued to be in the same position upto 7th June. The southwest Monsoon further advanced into some more parts of south Arabian sea, most parts of Lakshadweep area, some parts of Kerala and south Tamil Nadu, remaining parts of Maldives Comorin area, most parts of Bay of Bengal on 8th June, 2019. Thu,s the southwest Monsoon set in over Kerala on 8th June, 2019. It further advanced into entire south Arabian Sea & Lakshadweep area, most parts of Kerala and some more parts of Tamil Nadu, most parts of Mizoram and some parts of Manipur on 10th June. On 16th June, it further advanced into remaining parts of Bay of Bengal, remaining parts of northeast India and some parts of eastern India. During 20-28 June, the monsoon steadily progressed, covering entire Arabian Sea, peninsular India, northeast India and some parts of central India, Gujarat, Uttar Pradesh and Uttarakhand. It further advanced into some parts of Rajasthan, most parts of Uttar Pradesh, most parts of Uttarakhand and some parts Himachal Pradesh and Jammu & Kashmir during 1 to 2 July. It further advanced into some more parts of Gujarat, Rajasthan, Madhya Pradesh and Uttar Pradesh on 3rd July.

The Southwest Monsoon has further advanced into remaining parts of North Arabian Sea, Gujarat, Madhya Pradesh and some more parts of Rajasthan on 4th July. It further advanced into some more parts of Rajasthan, remaining parts of Uttar Pradesh, Himachal Pradesh, Uttarakhand and Jammu & Kashmir and some parts of Punjab, Haryana, Chandigarh and entire Delhi on 5th July. It further advanced into remaining parts of east Rajasthan, most parts of Haryana and some more parts of West Rajasthan & Punjab on 9th July, 2019. The Northern Limit of Monsoon Barmer, Jodhpur, Churu, Ludhiana, Kapurthala (NLM) continued to pass through Lat. 25° N/ Long. 60° E, Lat. 25° N/Long. 65° E, Southwest Monsoon has further advanced into most parts of Haryana and Punjab on 15th July, 2019. It further advanced into remaining parts of Punjab and Haryana and some more parts ofWest Rajasthan on 17th July. Southwest Monsoon has further advanced into the remaining parts of West Rajasthan and thus has covered the entire country on 19th July. Fig. 18 depicts the advance of southwest monsoon 2019.

Rainfall Features

Most sub-divisions of the country received large excess/excess/normal rainfall except a few from northern/northeastern regions. During the season, out of 36 meteorological subdivisions, 2 subdivisions received large excess rainfall, 10 subdivisions received excess rainfall, 19 received normal rainfall and the remaining 5 subdivisions received deficient rainfall (Fig. 19).

The subdivision wise distribution of rainfall percentage departures for the four months of the monsoon season (June to September) 2019 is shown in Figs. 20(a-d).

Figs. 21(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

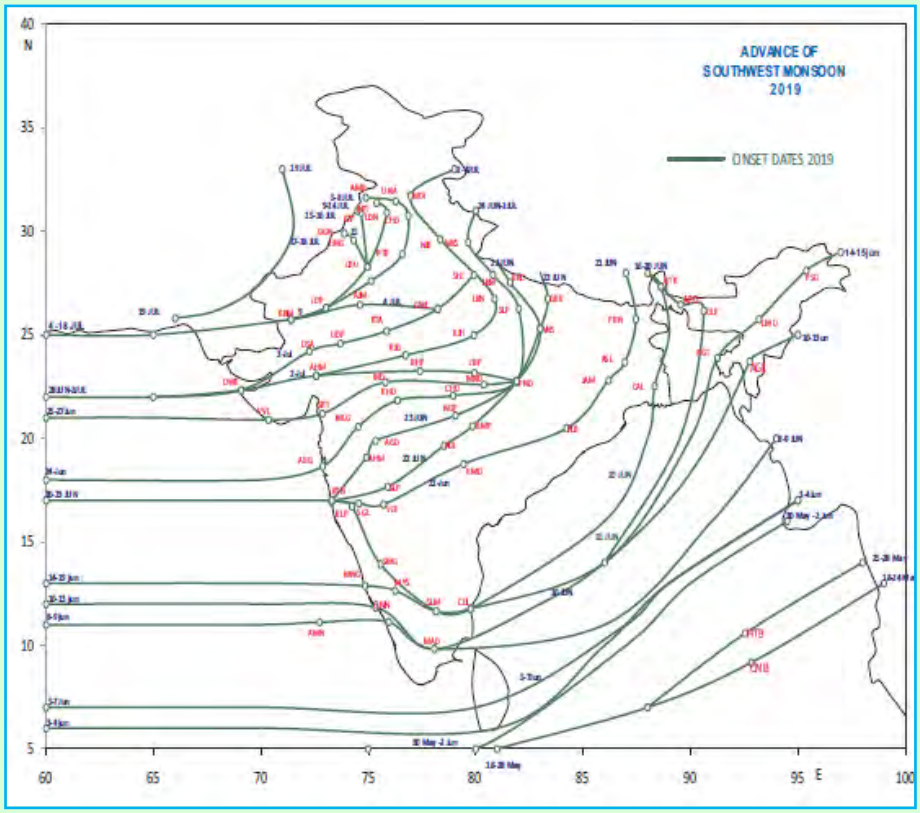


Fig. 18. Advance of southwest monsoon 2019

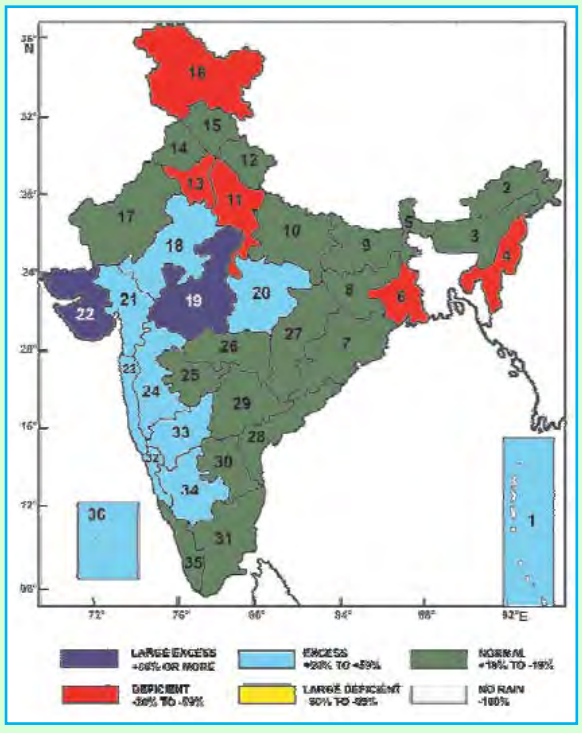
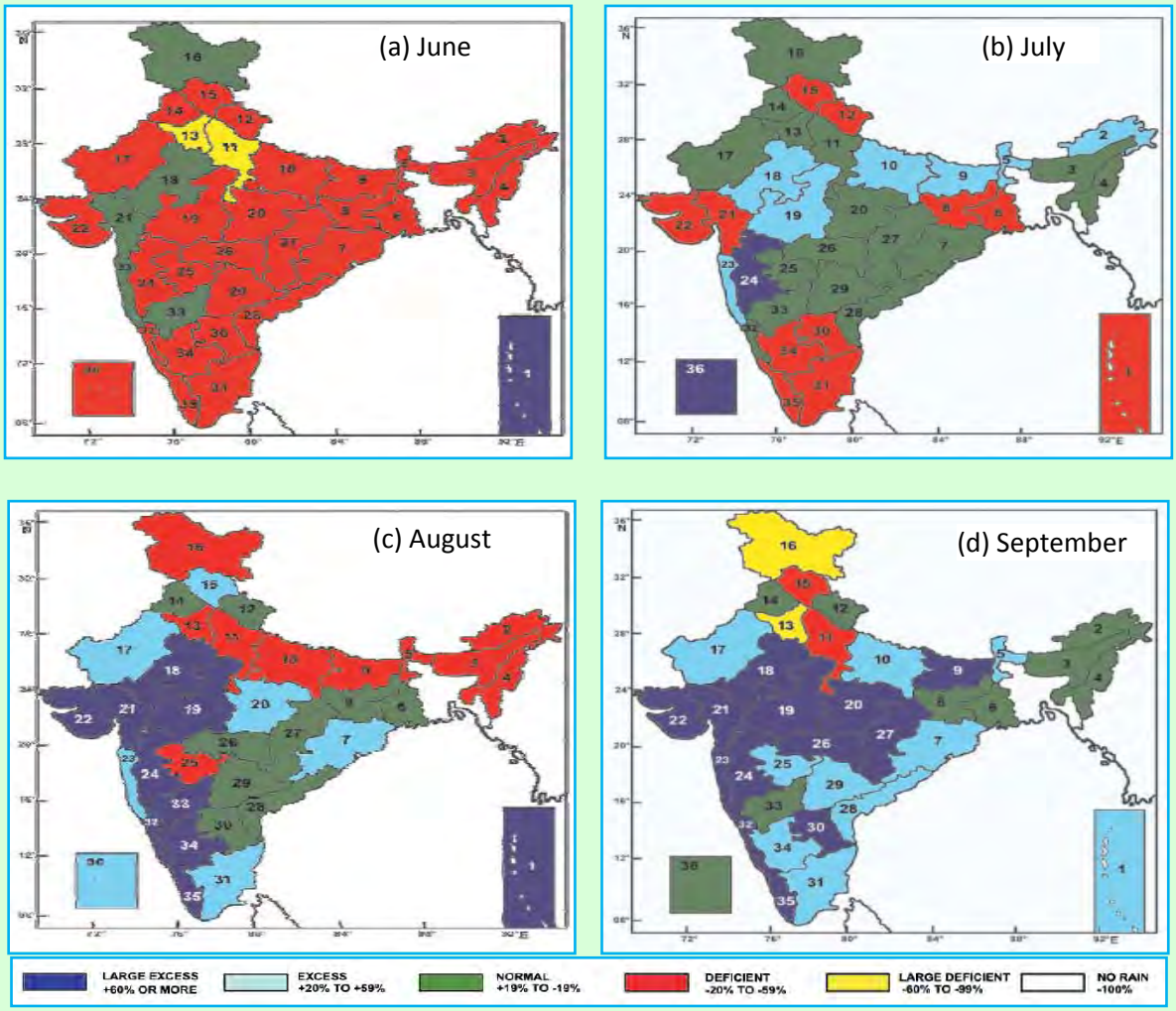
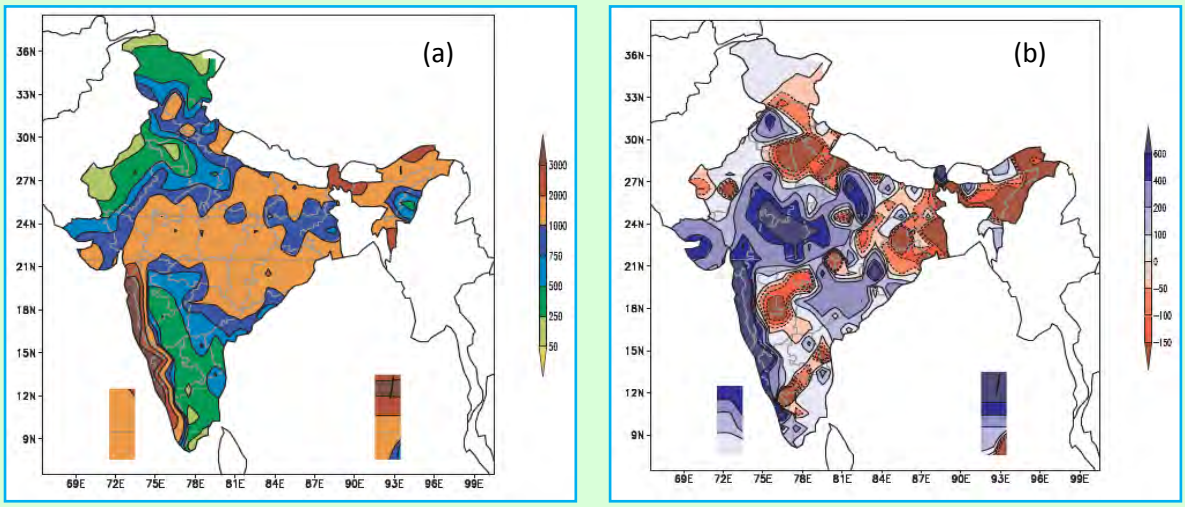


Fig. 19. Sub-divisionwise rainfall departures for te monsoon season

of the country, entire west coast and both the Islands received rainfall of the order of 750-2000 mm. Parts of Arunachal Pradesh, Assam & Meghalaya, Sub-Himalayan West Bengal & Sikkim, Nagaland, Manipur, Mizoram & Tripura, Konkan & Goa, Madhya Maharashtra, coastal Karnataka, Kerala and Andaman & Nicobar Islands received more than 2000 mm of rainfall. Parts of Konkan & Goa, coastal Karnataka and Andaman & Nicobar Islands received more than 3000 mm of rainfall. Rainfall anomaly was positive over parts of northwestern India, central India, entire west coast and both the Islands. Positive rainfall anomaly exceeding 400 mm was observed over parts of Sub-Himalayan West Bengal & Sikkim, Punjab, east Uttar Pradesh, Odisha, Madhya Pradesh, east Rajasthan, Saurashtra & Kutch, Gujarat Region, Konkan & Goa, Madhya Maha rashtra, coastal Karnataka, Kerala & Mahe and both the islands. Positive rainfall anomaly exceeding 600 mm was observed over parts of Sub-Himalayan West Bengal & Sikkim, east Uttar Pradesh, Madhya Pradesh, Odisha, Gujarat Region, Konkan & Goa, Madhya Maharashtra, coastal Karnataka and Andaman & Nicobar Islands. Magnitude of negative rainfall anomaly was more than 150 mm over parts Arunachal Pradesh, Assam



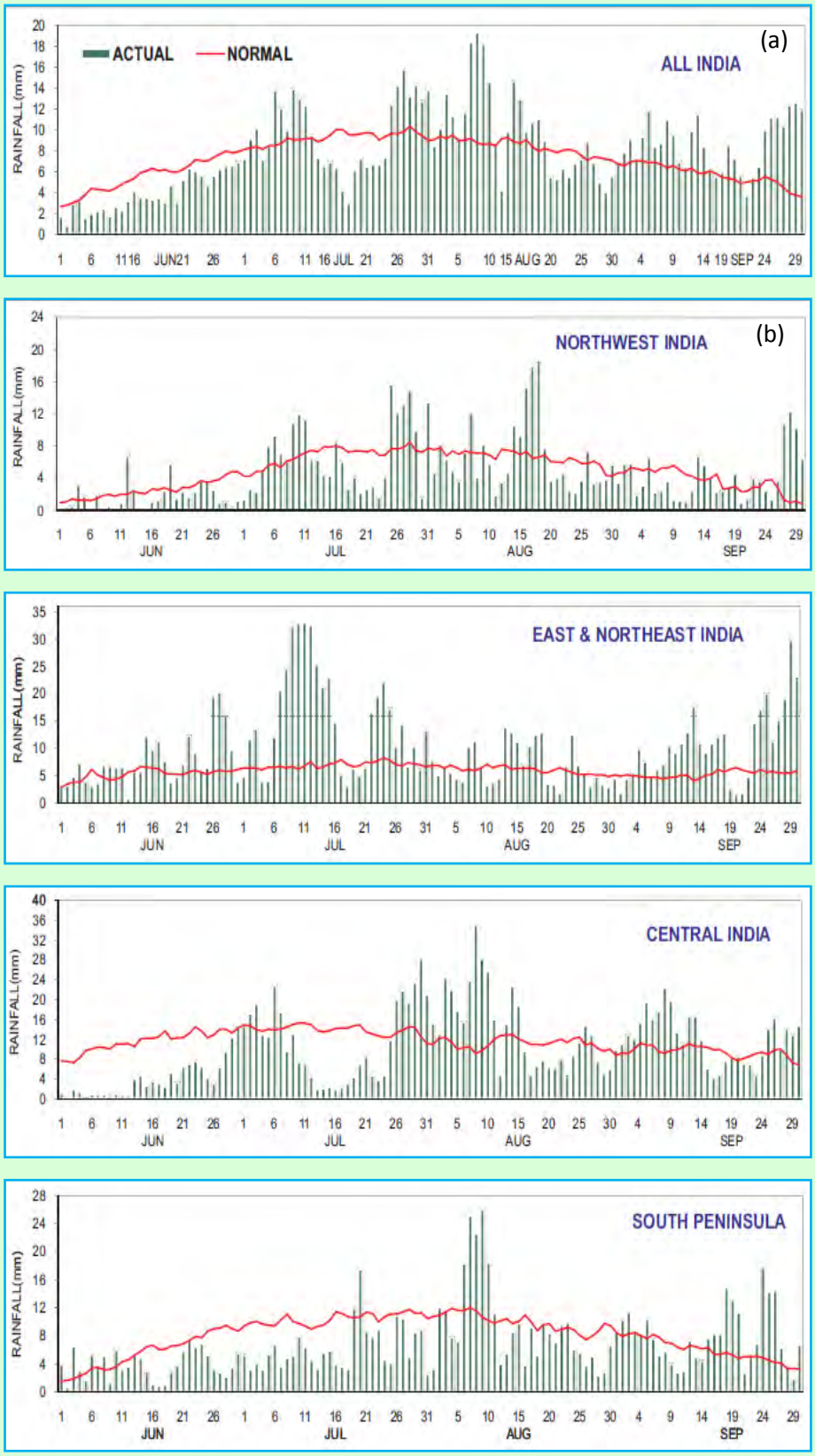
Figs. 20(a-d). Monthly sub-divisionwise distribution of rainfall percentage departures



Figs. 21(a&b). (a) Seasonal rainfall (mm) (b) Seasonal rainfall anomaly (mm) (*Based on 1951-2000 Normals*)

& Meghalaya, Nagaland, Manipur, Mizoram & Tripura, GangeticWest Bengal, Jharkhand, west Uttar Pradesh, Haryana, Chandigarh & Delhi, Uttarakhand, west Rajasthan, Marathwada, coastal Andhra Pradesh & Yanam, south interior Karnataka and Andaman & Nicobar Islands.

The all India area weighted rainfall series for the season since 1951 is shown in Fig. 22(a) and the area weighted rainfall series for the season over the four homogeneous regions since 1951 is shown in Fig. 22(b). The rainfall for the season was near normal over the

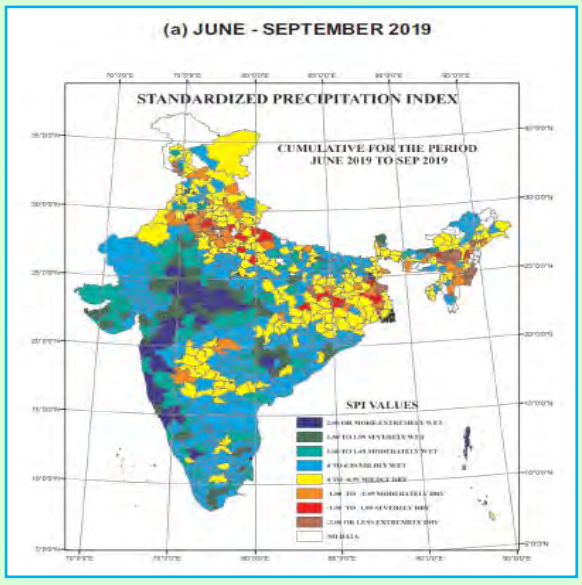


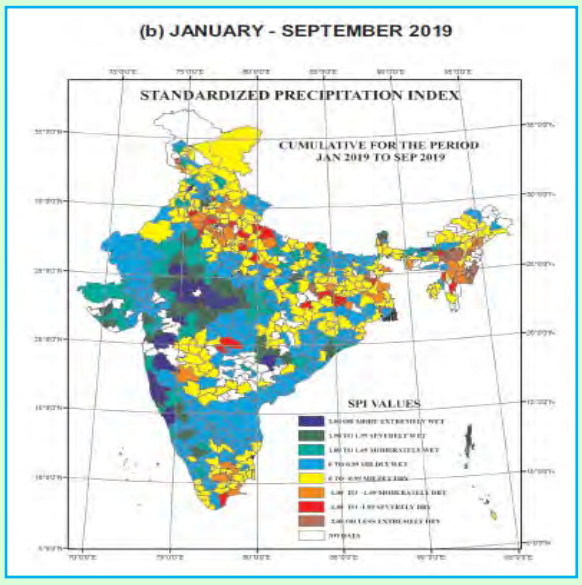
Figs. 22(a&b). Time series of area weighted rainfall over the (a) country as a whole (b) four homogeneous regions, for the monsoon season (1951 - 2019)

Northwest (97.8% of LPA), below normal over east and northeast India (88.0% of LPA), above normal over Central India (129.3% of LPA) and south peninsula (115.8% of LPA). Rainfall over the homogeneous region of Central India (1262.8 mm) was the third highest since 1901 after the years 1994 (1311.3 mm) and 1961 (1297 mm).

Standardized Precipitation Index

The Standardized Precipitation Index (SPI) is an index used for monitoring drought and isbased 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. 23(a&b) give the SPI values for the monsoon season (four months) and the year since January, 2019 (nine months) respectively.





Figs. 23(a&b). SPI values for the monsoon season (a) four months and (b) the year since January 2019 (nine months)

Cumulative past four months SPI values indicate extremely wet/severely wetconditions over parts of Andaman & Nicobar Islands, Assam & Meghalaya, Sub Himalayan West Bengal & Sikkim, Odisha, Jharkhand, Bihar, East Uttar Pradesh, Punjab, East Rajasthan, Madhya Pradesh, Gujarat State, Konkan & Goa, Madhya Maharashtra, Vidarbha and Chhattisgarh, while extremely dry/severely dry conditions were observed over parts of Assam & Meghalaya, Nagaland, Manipur, Mizoram & Tripura, West Bengal & Sikkim, Jharkhand, Uttar Pradesh, Haryana, Chandigarh &Delhi, Jammu & Kashmir and Chhattisgarh. Cumulative SPI values of the past nine months indicate extremely wet/severely wet conditions over parts of Andaman & Nicobar Islands, Assam & Meghalaya, Sub Himalayan West Bengal & Sikkim, Odisha, East Uttar Pradesh, Punjab, East Rajasthan, Madhya Pradesh, Gujarat State, Konkan & Goa,Madhya Maharashtra, Vidarbha and Chhattisgarh, while extremely dry/severely dry conditions were observed over parts of Assam & Meghalaya, Nagaland, Manipur, Mizoram & Tripura, West Bengal & Sikkim, Jharkhand, Uttar Pradesh, Haryana, Chandigarh & Delhi, Jammu & Kashmir, Vidarbha and Chhattisgarh.

Pressure & Wind

The wind anomaly at 850 hPa level shows anomalous cyclonic circulation over northwest Arabian Sea indicates the above normal cyclonic activity over the Arabian Sea. At 500 hPa level, strong cross equatorial flow over Arabian Sea indicates above normal low level jet stream during the season. At 200 hPa level, easterly wind anomaly over peninsular region indicate strong tropical easterly jet stream during the monsoon season.

Outgoing Longwave Radiation (OLR)

OLR anomaly (W/m^2) over the Indian region and neighbourhood is shown in Fig. 24. OLR anomaly was negative throughout the country except over northwest India, Gangetic West Bengal, Odisha and adjoining Bay of Bengal. Magnitude of negative OLR anomaly exceeded 10 W/m^2 over parts of central Bay of Bengal, Gujarat Region and SW Arabian Sea.

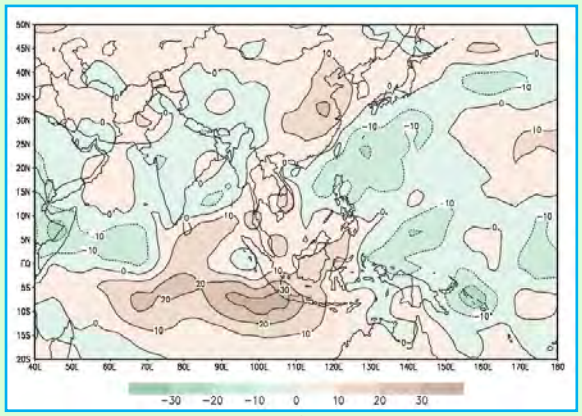


Fig. 24. OLR anomaly (W/m^2) for the monsoon season 2019 (*Source* : Cdc / Noaa, Usa)
(*Based on 1981 - 2010 Climatology*)

Low Pressure Systems

During the season, fourteen low pressure systems (2 cyclonic storms, 1 Deep depression, 1 Depression, 2 well marked low pressure areas & 8 low pressure areas) were formed.

The first intense system of the season formed as a VSCS "VAYU" during 10-17 June, the second system as deep depression formed during 6-9 August, the third system as a VSCS "HIKAA" during 22-25 September and the fourth system as a depression during 29 September - 1 October formed.

Fig. 25 shows the number of depressions and cyclonic storms formed during the monsoon season since last 10 year period (2010-2019).

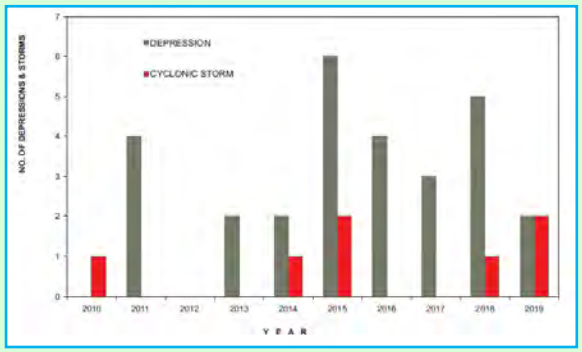


Fig. 25. Number of depressions & cyclonic storms formed during the SW monsoon season (2009-2019)

Significant Weather events

Heat wave : 293 people were reportedly claimed dead from different parts of Bihar during 15-18 June.

Lightening : 5 people were reportedly claimed dead from Rajasthan. Out of this, 3 from Bhilwara and Udaipur on 19, 21, 27 July and 2 from Banswara and Bundi on 20 September. 3 people were reportedly claimed dead from Madhya Pradesh (Burhanpur) on 28 June. 6 people were reportedly claimed dead from Maharashtra. Out of this 3 from Solapur on 1 July, 1 from Thane on 20 July, one from Pune on 29 July and one from Jalgaon on 3 August.

Thunderstorm : 34 people were reportedly claimed dead from Bihar. Out of this, 7 from Gopalganj, Siwan, Chapra on 10 June, 15 from Patna, Nalanda, East Champaran on 12 June, 6 from Khagaria, Jamui, Banka, Buxar on 21 June, 6 from different parts of Bihar on 26 June. 71 people were reportedly claimed dead from Jharkhand. Out of this, 1 from Ranchi on 2 July, 34 from Chatra, Lohardaga, Gadwa, Dumka Jamtara, Latehar, Ramgarh, Pakud, Giridih, Gumla, Palamu, Bokaro, Deoghar, Ranchi on 23 and 24 July, 7 from Gadwa, Giridih, Palamu on 26 July, 1 from Ranchi on 6 August, 1 from Khunti on 11 August, 1 from Ranchi on 12 August, 8 from Ranchi, Garhwa on 11-12 September, 9 from Deoghar, Giridh on 16 September, 3 from Chatra on 21 September, 2 from Latehar on 23 September, 1 from Ranchi on 26 September, 3 from Gadwa on 6 July. 14 people were reportedly claimed dead from Rajsthan (Barmer) on 23 June.

Heavy Rain : During the season heavy rain & flood related incidents reportedly claimed at least 528 lives from different parts of the country. Out of this, 99 people were reportedly claimed dead from Bihar, 29 people from Himachal Pradesh, 21 people from Madhya Pradesh, 92 people from Maharashtra, 81 people from Rajasthan, 33 people from Uttar Pradesh during the season. 9 people from Jammu & Kashmir during July, 12 people from Uttarakhand during August, 6 people from Assam & Meghalaya during 1-5 August, 27 people from Gujarat Region on 10 August, 31 people from Karnataka on 11 August and 88 people from Kerala during 11-12 August were reportedly claimed dead.

4. Post Monsoon Season (October-December)

The homogeneous region of northwest India was abnormally cooler in respect of maximum temperature during the season as a whole. Maximum temperature was below normal by -2.1 °C during the season. Abnormal cold day conditions during second half of December mainly contributed to this. During 11-14 December the plains of north and central India experienced unusual cold day, cold wave and dense to very dense foggy conditions during second half of December. The season also witnessed enhanced cyclogenesis over the Arabian sea. Five intense low pressure systems (3 CS, 2 D) formed over the Arabian Sea which is a record for the season over the Arabian Sea since 1891.

Northeast Monsoon Activity

The southwest monsoon withdrew from the entire country on 16th October and northeast monsoon rains subsequently commenced on the same day. Rainfall activity over core region of the South Peninsular India (comprising of 5 subdivisions *viz*., Coastal Andhra Pradesh, Rayalaseema, Tamil Nadu & Puducherry, South Interior Karnataka and Kerala) during the season as a whole was normal [109% of Long Period Average (LPA)]. It was above normal during October and December (142.8% of LPA and 115% of LPA respectively) and was below normal during November (54.6% of LPA).

Rainfall Features

Rainfall realized over the country as a whole during the season was 129% of LPA. It was 144.3%, 103.2% and 110.5% of its LPA during October, November and December months respectively. Except for 3 subdivision of Northeast India *viz*., Arunachal Pradesh, Sub-Himalayan West Bengal & Sikkim, Bihar and Andaman & Nicobar Islands all the subdivisions received large excess/excess/ normal rainfall during the season.

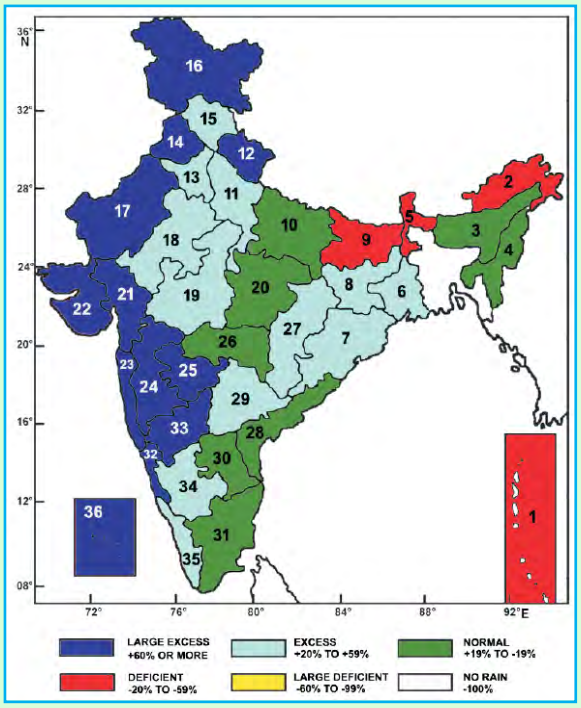
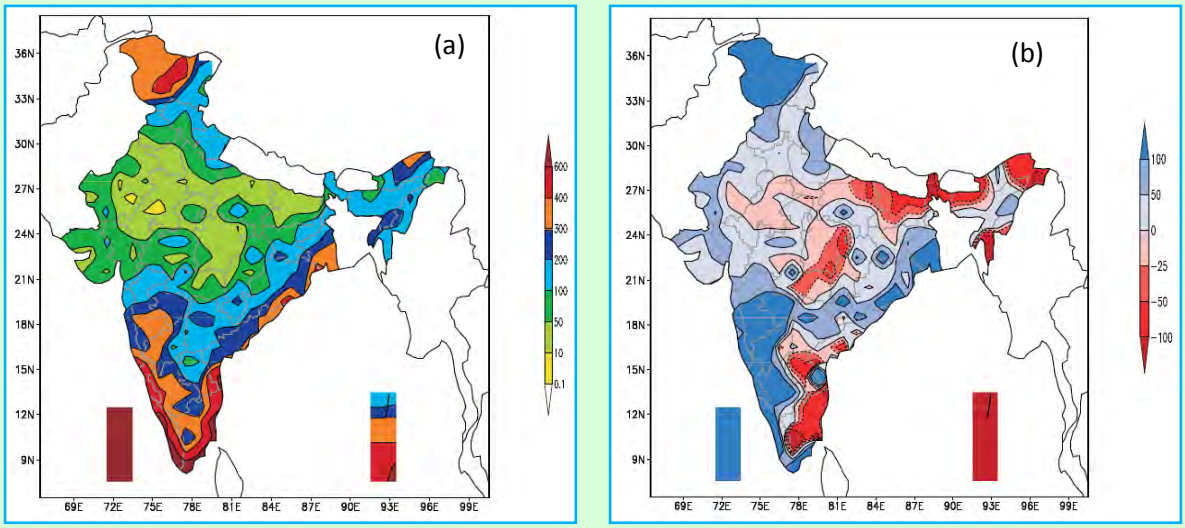


Fig. 26. Sub-divisionwise rainfall percentage departures

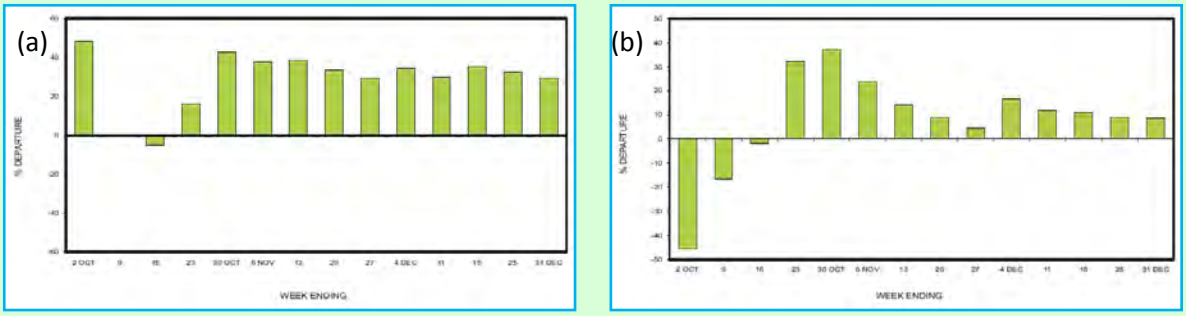
During the season, out of 36 meteorological subdivisions, 12 received large excess rainfall, 12 received excess rainfall, 8 received normal rainfall and 4 received deficient rainfall (Fig. 26).

Figs. 27(a&b) show the spatial pattern of rainfall (mm) received during the season and its anomaly respectively. Parts of Jammu & Kashmir, Arunachal Pradesh, Nagaland, Manipur, Mizoram & Tripura, Gangetic West Bengal, Odisha, coastal Andhra Pradesh & Yanam, Telangana, Rayalaseema, Tamilnadu, Puducherry & Karaikal, Konkan & Goa, Madhya Maharashtra, Marathwada,Karnataka state, Kerala & Mahe and both the islands received more than 200 mm rainfall. Parts of Jammu & Kashmir, Tamilnadu, Puducherry & Karaikal, coastal Andhra Pradesh & Yanam, Rayalaseema, coastal Karnataka, Kerala & Mahe and both the islands received more than 400 mm rainfall.

Rainfall anomaly was positive over most parts of the country except some northeastern region, central region, eastern part of peninsular region and Andaman & Nicobar Islands. Rainfall anomaly was more than 100 mm over parts of Jammu & Kashmir, Gangetic West Bengal, Odisha, coastal Andhra



Figs. 27(a&b). (a) Seasonal rainfall (mm) and (b) Seasonal rainfall anomaly (mm) (*Based on 1961-2010 Normals*)



Figs. 28 (a&b). Accumulated percentage departure of area weighted weekly rainfall over the (a) country as a whole (b) core region of south peninsula

Pradesh & Yanam, Tamilnadu, Puducherry & Karaikal, Konkan & Goa, Madhya Maharashtra, Marathwada, Kerala and Lakshadweep islands. Magnitude of negative rainfall anomaly was more than 100 mm over parts of Andaman & Nicobar Islands, Nagaland, Manipur, Mizoram & Tripura, Sub-Himalayan West Bengal & Sikkim, Tamilnadu, Puducherry & Karaikal.

The area weighted cumulative weekly rainfall percentage departure during the season for the country as a whole [Fig. 28(a)]. Cumulative rainfall departure which was negative till mid October became positive during fourth week and was constant above 120% till end of the season. At the end of the post-monsoon season 2019, the rainfall for the country as a whole was 129.3% of its LPA. The area weighted cumulative weekly rainfall percentage departure during the season for the northeast monsoon region of south peninsula [Fig. 28(b)]. Cumulative rainfall departure was positive since fourth week till end of the season. At the end of the post-monsoon season 2019, the rainfall over the northeast monsoon region of south peninsula was only 109 % of its LPA.

The all India area weighted rainfall series for the season since 1951 shown in Fig. 29(a). The rainfall this year was the highest since 2001.

The area weighted rainfall series for the season over the four homogeneous regions since 1951 shown in Fig. 29(b). The rainfall for the season was above normal for all the homogeneous region except northeast India (92.6% of LPA). It was 176.4%, 163.1%, 116.4% of LPA respectively over homogeneous regions of northwest India, Central India, south Peninsular India.

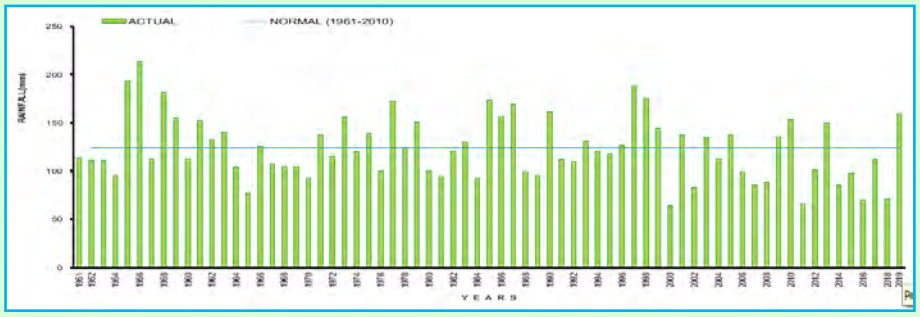


Fig. 29(a). Time series of area weighted rainfall over the country as a whole (1951 - 2019)

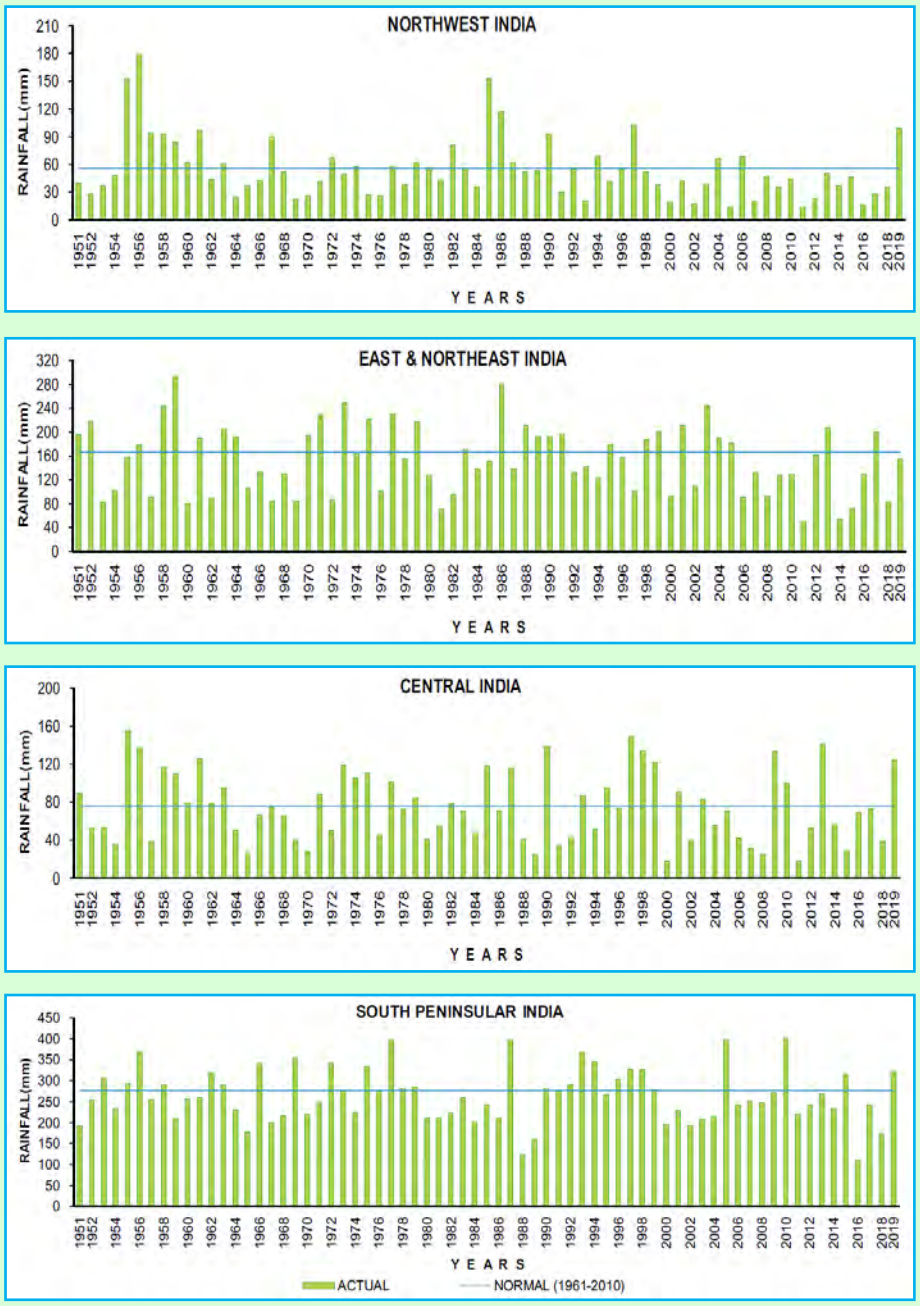
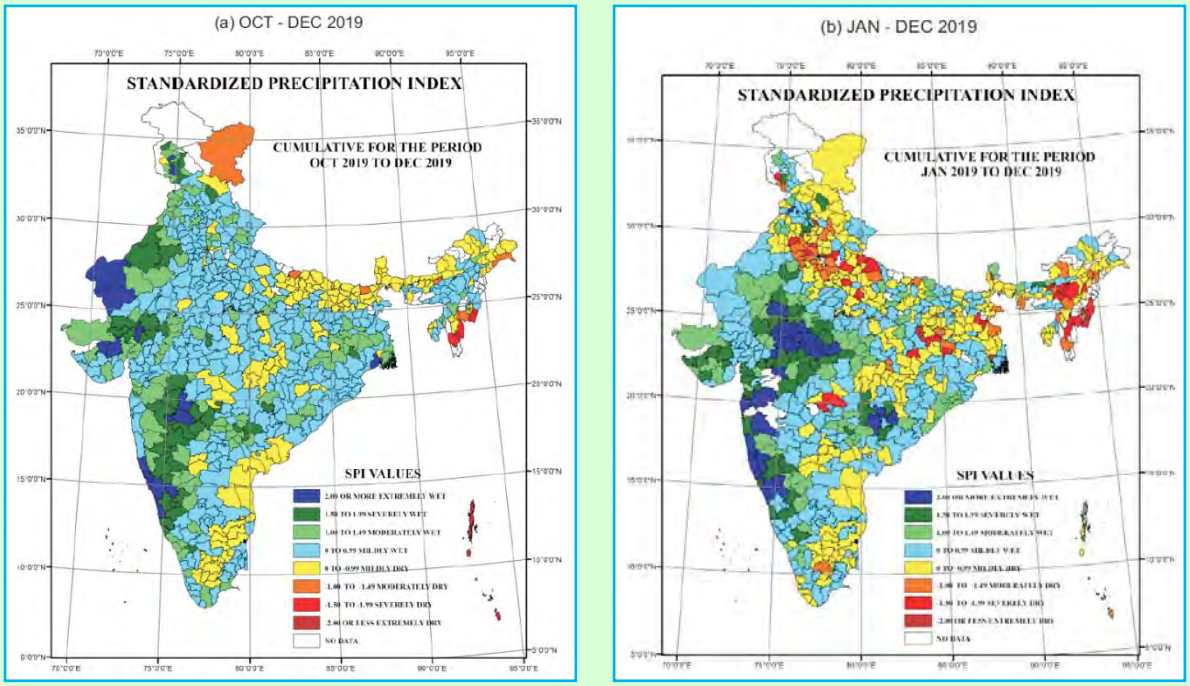


Fig. 29(b). Time series of area weighted rainfall over the four homogeneous regions (1951 - 2019)

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. 30(a&b) give the SPI values for the northeast monsoon season (October to



Figs. 30(a&b). Standardized Precipitation Index (SPI) cumulative for (a) Three months (b) Twelve months

December 2019 *i.e.*, 3 months cumulative) and the year (January-December 2019, *i.e.*, 12 months cumulative) respectively.

Cumulative SPI values of the past three months indicate extremely wet/severely wet conditions over parts of Gangetic West Bengal, Jharkhand, Himachal Pradesh, Jammu & Kashmir, Rajasthan state, West Madhya Pradesh, Gujarat state, Konkan & Goa, Madhya Maharashtra, Marathawada, Chhattisgarh, Telangana and Tamil Nadu, while extremely dry/severely dry conditions were observed over parts of A & N Islands, Nagaland, Manipur, Mizoram & Tripura.

Cumulative SPI values of the past twelve months indicate, extremely wet/severely wet conditions over parts of Assam & Meghalaya, Punjab, Himachal Pradesh, Jammu & Kashmir, East Rajasthan, Madhya Pradesh state, Gujarat state, Konkan & Goa, Madhya Maharashtra, Vidarbha, Chhattisgarh and Telangana, while extremely dry/severely dry conditions were observed over parts of Assam & Meghalaya, Nagaland, Manipur, Mizoram & Tripura, Sub Himalayan West Bengal & Sikkim, Gangetic West Bengal, Jharkhand, Uttar Pradesh state, Haryana, Chandigarh & Delhi, Jammu & Kashmir, Vidarbha and Chhattisgarh.

Pressure & Wind

The mean sea level pressure & its anomaly respectively. The pressure anomaly was near normal (± 0.5 hPa) over most parts of country. However, over parts of northern and extreme northeastern region it exceeded 1.0 to 1.5 hPa.

Wind anomaly at 850 hPa shows anomalous cyclonic circulation over southwest Arabian Sea, which indicate above normal cyclonic activity during the seasn. An anomalous anti cyclonic circulation at 500 hPa level was observed over east Central India. Anomalous westerlies at 250 hPa level indicate stronger than the normal subtropical westerly Jet.

Outgoing Longwave Radiation (OLR)

Outgoing Longwave Radiation (OLR) anomaly (W/m^2) over the Indian region and neighbourhood is shown in Fig. 31. Negative OLR anomaly exceeding 10 W/m^2 was observed over most parts of the country and adjoining Arabian Sea. Over parts of southeast and eastcentral Arabian Sea and adjoining west peninsula negative OLR anomaly exceeded 20 W/m^2.

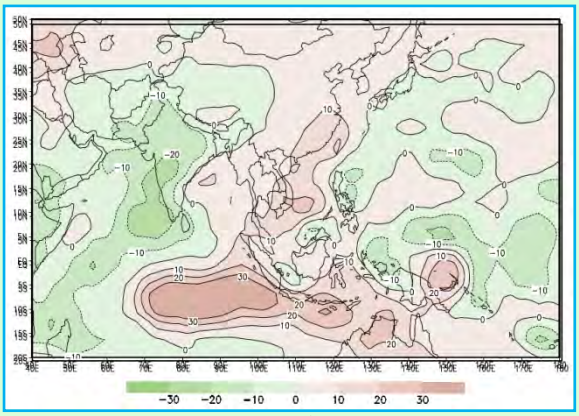


Fig. 31. OLR Anomaly (W/m^2) for the post-monsoon season 2019 (*Source* : CDC / NOAA, USA) (Based on 1981 - 2010 Climatology)

Temperature

Mean seasonal maximum and minimum temperature anomaly is shown in Figs. 32(a&b) respectively.

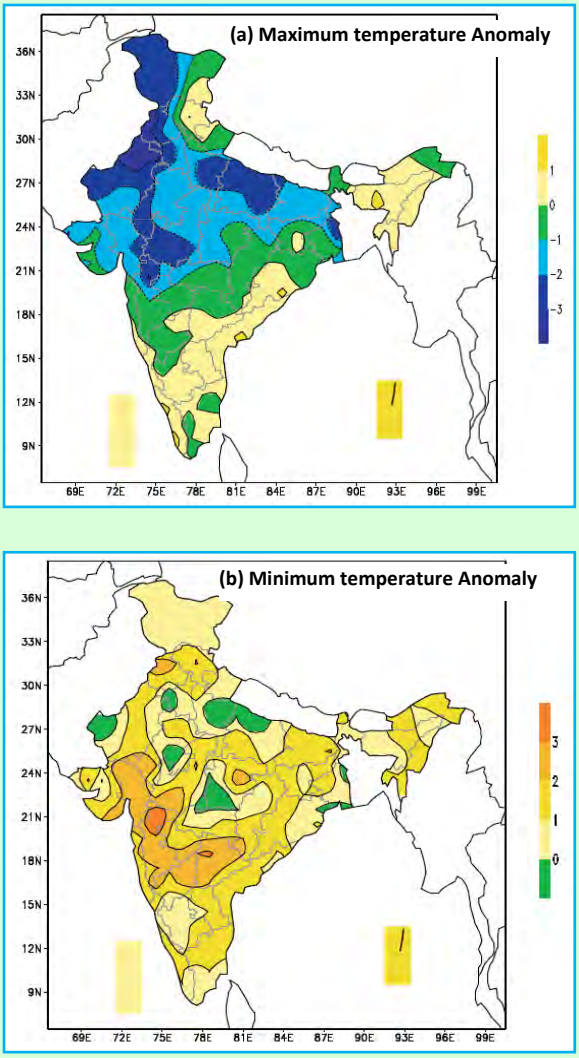


Fig. 32. Mean seasonal temperature anomalies (°C) (a) Maximum (b) Minimum (Based on 1981-2010 Normals)

Maximum temperature was below normal over most parts of the country except for parts of northeastern region, peninsular parts some eastern part of Jammu & Kashmir, Uttarakhand and both the islands. Maximum temperature anomaly less than -2 °C was observed over parts of Gangetic West Bengal, Uttar Pradesh, Jammu & Kashmir, Punjab, Haryana, Chandigarh & Delhi, Rajasthan, Madhya Maharashtra, Gujarat Region and west Madhya Pradesh. Maximum temperature anomaly less than -3 °C was observed over parts of west Rajasthan and Punjab.

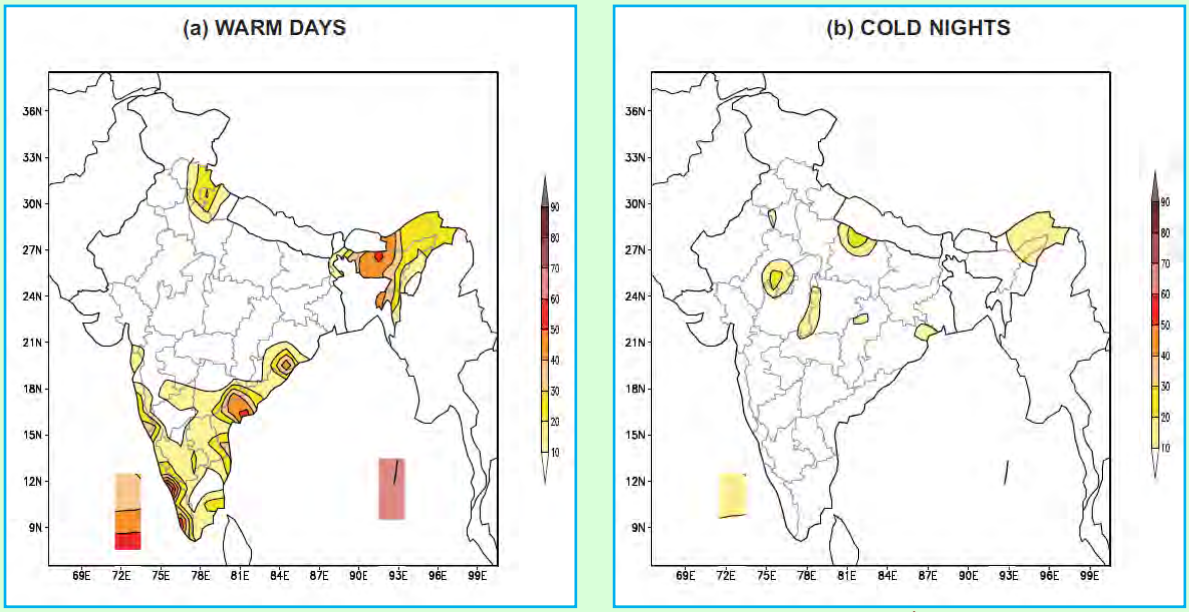
Minimum temperature was above normal over almost entire country. Minimum temperature anomaly was more than 2 °C over parts of Gujarat Region, west Madhya Pradesh, Madhya Maharashtra, Marathwada, Telangana & north interior Karnataka. It was more than 3 °C over parts of Madhya Maharashtra and Telangana.

Percentage of Warm days/Cold nights

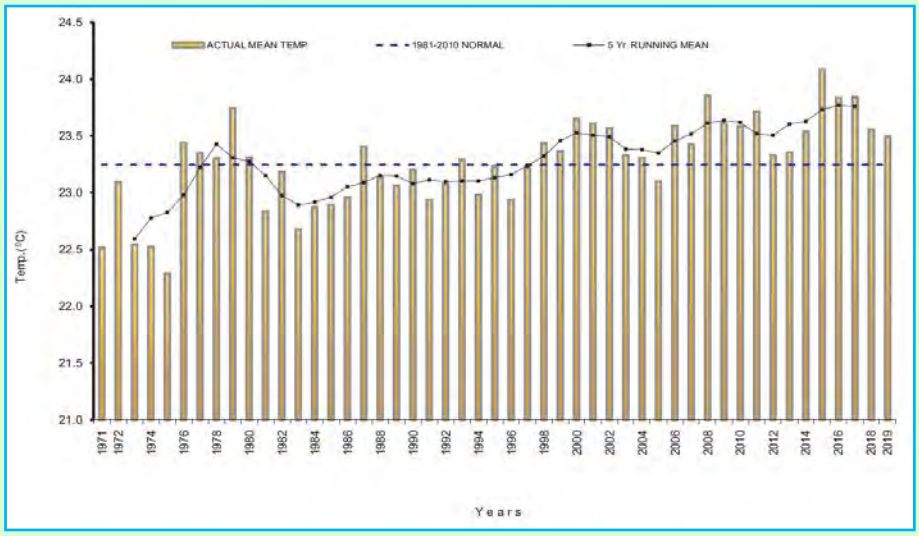
The percentage of days when maximum (minimum) temperature was more (less) than 90th (10th) percentile shown in Figs. 33(a&b). Over parts of Assam & Meghalaya, coastal Andhra Pradesh & Yanam, Andaman & Nicobar Islands and Kerala& Mahe and Lakshadweep islands the maximum temperature was greater than 90th percentile for more than 50% of the days of the season. However, for minimum temperature, no significant distribution was observed.

Fig. 34 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 (23.49 °C) for the season this year was above normal by about 0.25 °C.

Figs. 35(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 all the homogeneous regions except south peninsular India was below normal.



Figs. 33(a&b). Percentage of days when (a) maximum temperature > 90th Percentile (b) minimum temperature < 10th Percentile



Figs. 34. Time series of mean temperature averaged over India (vertical bars) and five year running mean (continuous line) for the post monsoon season (1971 - 2019)

Maximum temperature over homogeneous region of northwest India was fifth lowest since 1901. Minimum temperature over all India (18.58 °C) was the highest since 1901. Minimum temperature over all the homogeneous regions was above normal. Minimum temperature over central India (19.13 °C) and south peninsula (23.39 °C) was second highest since 1901.

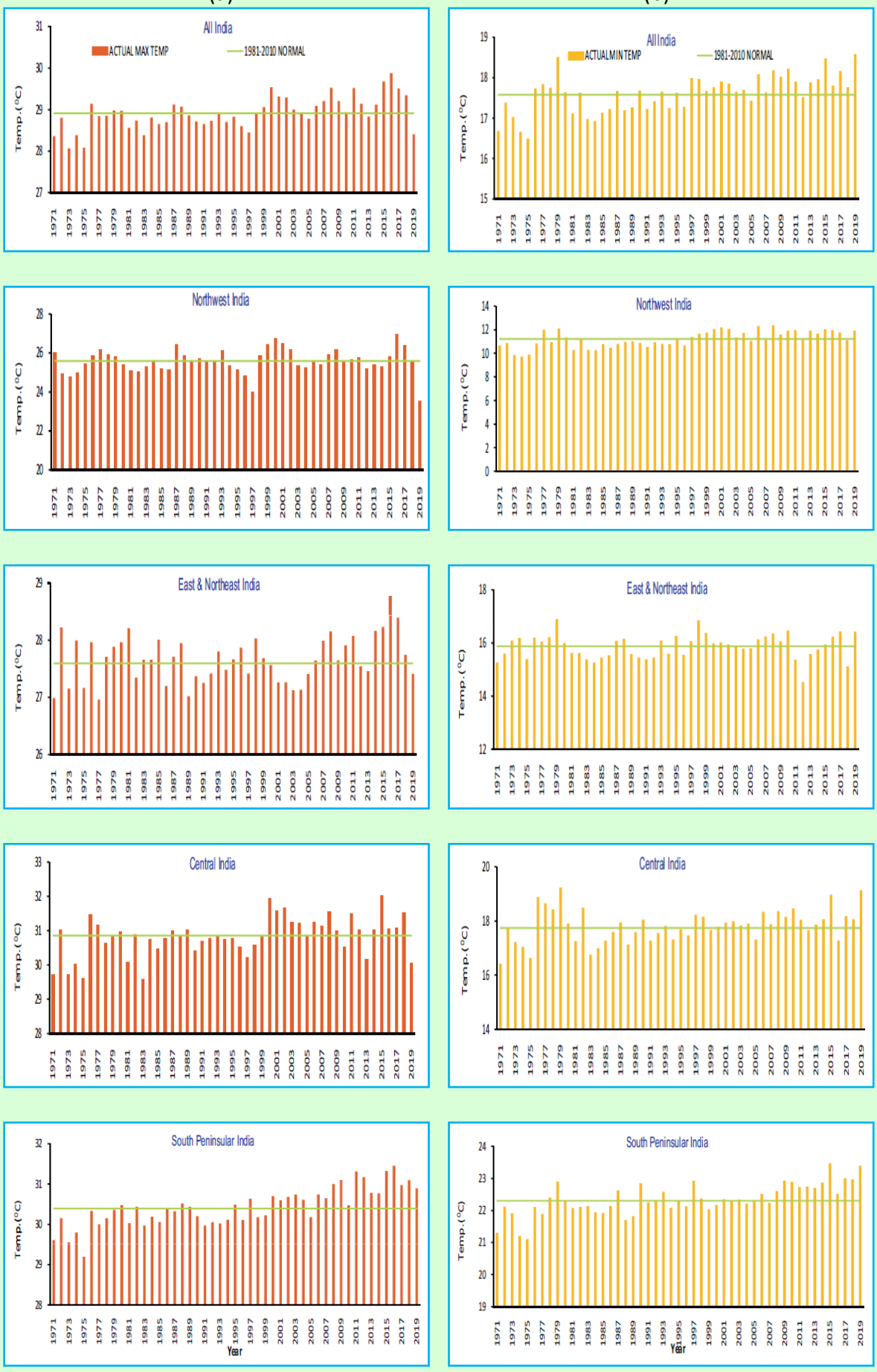
Low Pressure Systems

One super cyclone (KYAAR) over Arabian Sea and one Very Severe Cyclonic Storm (MAHA formed during October. One very severe cyclonic storm "BULBUL" formed over the Bay of Bengal during November. One cyclonic storm "PAWAN" (2-7 Dec) and two depressions (3-5 Dec) and (8-10 Dec) formed over Arabian Sea during December.

Apart from these systems two low pressure areas formed during the season. A low pressure area which formed during October became well marked low pressure area. Fig. 36 shows tracks of these systems.

Fig. 37 shows the number of depressions & storms formed over North Indian Ocean during the post-monsoon season (1951-2019).

(a) (b)



Figs. 35(a&b). Time series of temperature for the country as a whole and The four homogeneous regions (1971 - 2019) (a) Maximum (b) Minimum

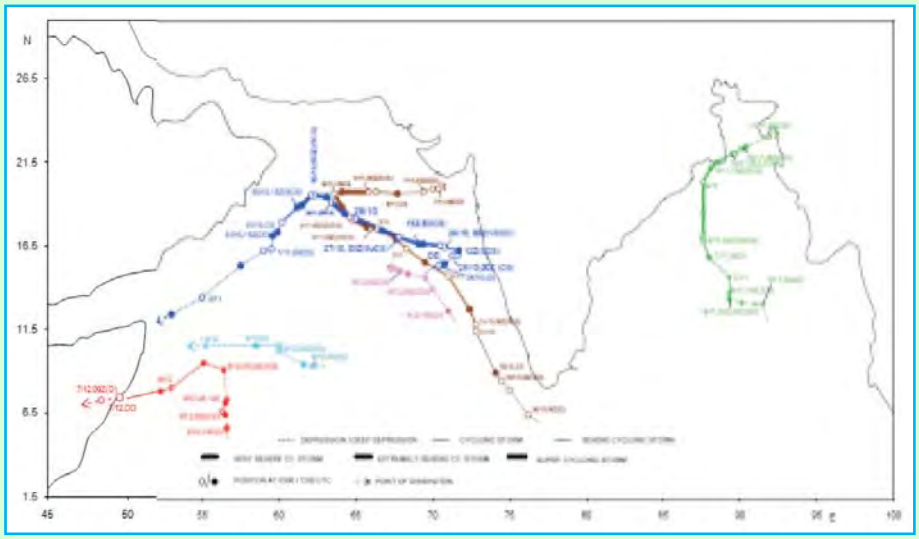


Fig. 36. Tracks of intense low pressure systems formed during the post-monsoon season

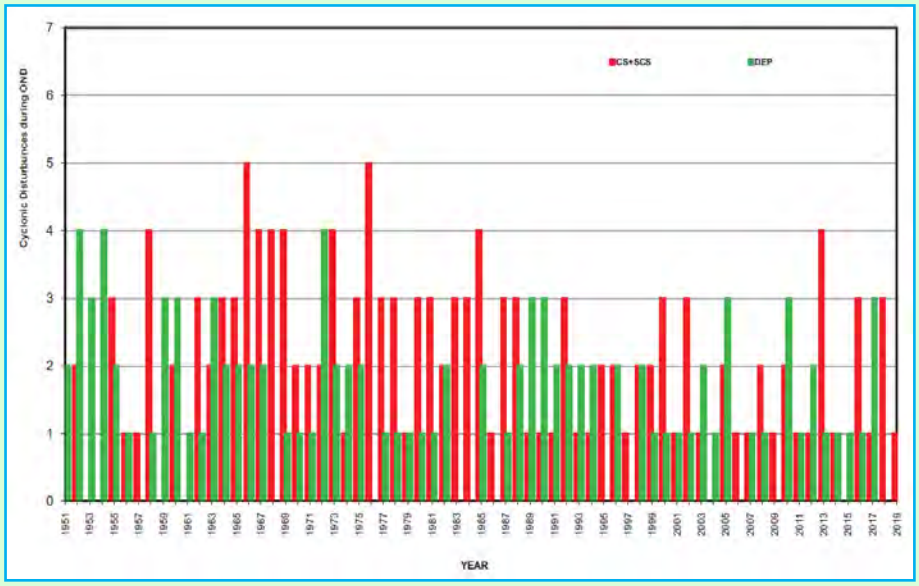


Fig. 37. Frequency of depressions/cyclonic storms formed over the Bay of Bengal during the post-monsoon season (1951 - 2019) (*Source* : Cyclone Eatlas RSMC IMD, New Delhi) Based on real time data

Significant Weather events

The country experienced cold waves, snow fall, lightening & thunderstorm, Heavy rain & floods, during the season. Total 199 persons reportedly claimed dead. The causalities mentioned here are based on the media and government reports.

Cold Wave : Total 57 persons reportedly claimed dead from northern parts of the country during 27 to 31 December. 28 persons reportedly claimed dead from Banda, Kanpur, Lucknow, Mahoba, Mainpuri, Shravasti, Varanasi districts of Uttar Pradesh. 19 persons reportedly claimed dead from Begusarai, Bhojpur, Darbhanga, East Champaran, Muzaffarpur, Nawada, Rohtas, Samastipur, Saran, Sitamarhi, West Champaran districts of Bihar on 30th December. While 10 persons reportedly claimed dead from Bhind, Datia, Guna, Harda, Mandla, Rewa, Shahdol, Shivpuri, Vidisha districts of Madhya Pradesh during the period 27-30 December.

Snowfall : Total 22 persons reportedly claimed dead during 7 November to 20 December. Out of which, 8 were reportedly claimed dead due to snow avalanche from Leh (18 & 30 November) and 14 from Bandipora,, Baramulla, Budgam, Kulgam, Kupwara, Pulwama, Ramban Srinagar districts Jammu

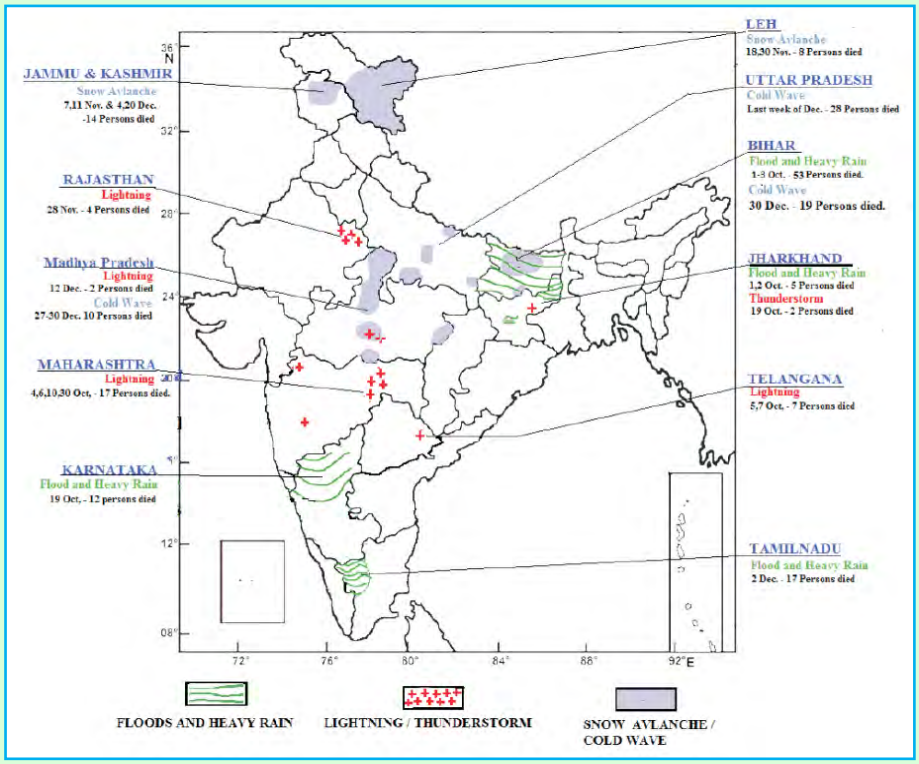


Fig. 38. Significant weather events formed during the season (Based on real time data)

and Kashmir (7 & 11 November and 4 & 20 December).

Lightning : Total 30 persons reportedly claimed dead during the season. Of which, 17 claimed dead from Akola, Amaravati, Dhule, Jalana, Nanded, Osmanabad, Pune, Satara, Yavatmal districts of Maharashtra (4, 6, 10 & 30 Oct). 7 persons reportedly claimed dead from Khamam district of Telangana (5, 7 Oct). 4 from Bharatpur district of Rajasthan on 28th November. While, 2 from Raisen, Vidisha districts of Madhya Pradesh on 12th December.

Heavy Rain : Total 88 persons reportedly claimed dead during the season. Of these, 53 persons reporetedly claimed dead from Arwal, Begusarai, Bhaglapur, Bhojpur, Buxar, Darbhanga, Jehanabad, Kathihar, Khagaria, Lakhisarai, Nawada, Nalanda, Patna, Samastipur, Siwan, Vaishali districts of Bihar during the period 1-3 October. While, 17 persons reportedly claimed dead from Cuddalore, Thoothukudi, Tirunelveli districts of Tamil Nadu on 2nd December. Also 12 persons reportedly claimed dead from parts of Karnataka, 5 from Jharkhand and one from Jammu & Kashmir.

Thunderstorm : 2 persons reportedly claimed dead from Dhanbad, Ranchi district of Jharkhand on 19 October.

The significant weather events during the season (Fig. 38) (Based on real time media reports).

CHAPTER 3

NUMERICAL WEATHER PREDICTION

Global and Regional Modelling (NWP)

(*i*) The GFS (*GSM. V14*) at T1534L64 (~12 km) in horizontal resolution and 64 hybrid sigma-pressure layers with the top layer centred around 0.27 hPa (approximately 55 km) was made operational on 1 December, 2016. It is now run twice a day (0000 & 1200 UTC) to give deterministic forecast in the short to medium range. The initial conditions are generated from the NCEP based Ensemble Kalman Filter (EnKF) component of hybrid Global Data similation System (GDAS). **Fig. 1 indicate the Heavy Rainfall on 10th August, 2019 over Gujarat region in the 48 hr forecast from GFS model.**

A coupled model with a suite of models from CFSv2 coupled model has been developed, implemented and operationalized in IMD in 2016 for generating operational Extended Range Forecast 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 09-15 (week2; Friday to Thursday), days 16-22 (week3; Friday to Thursday) and days 23-29 (week4; Friday to Thursday). As shown in Fig. 2 the ERF forecasts show useful skill upto three weeks on India level. On smaller spatial scales (homogeneous regions and met subdivision levels) the forecast shows useful skill up to two weeks. On met subdivision level the category forecasts upto two weeks are being used for agro-advisory purpose.

The delayed onset of monsoon over Kerala was well captured in the ERF forecast based on 15 May initial condition with negative anomaly in rainfall and northwesterly wind at lower level persists till first week of June, 2019 (Fig. 3).

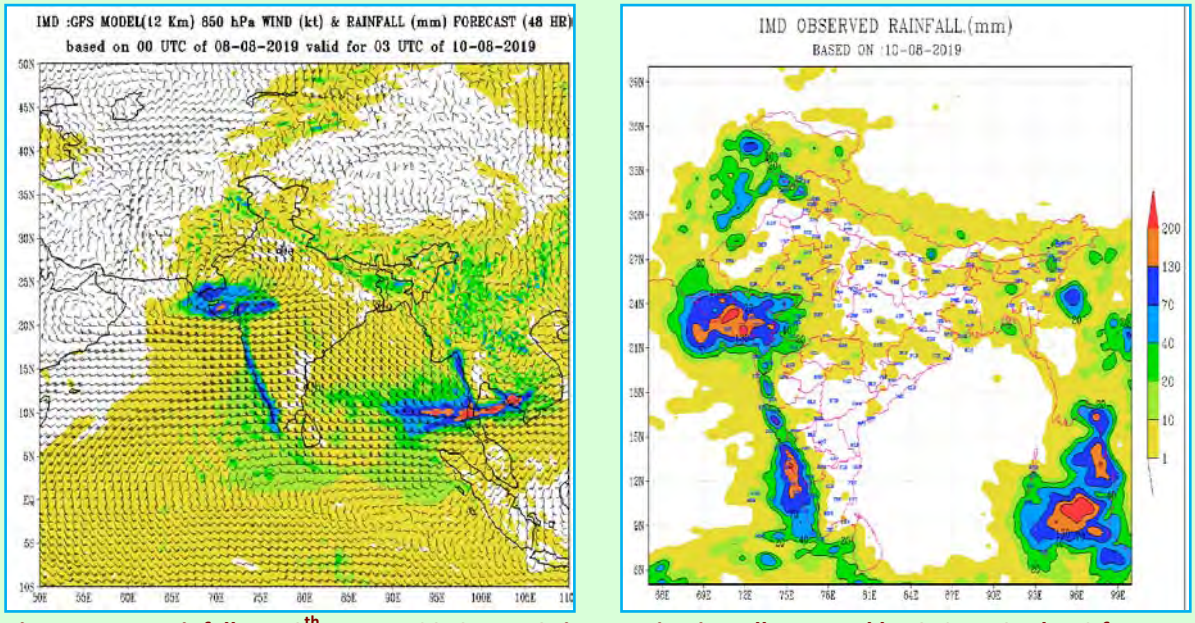


Fig. 1. Heavy Rainfall on 10th August, 2019 over Gujarat region is well captured by GFS T1534 day-2 forecast

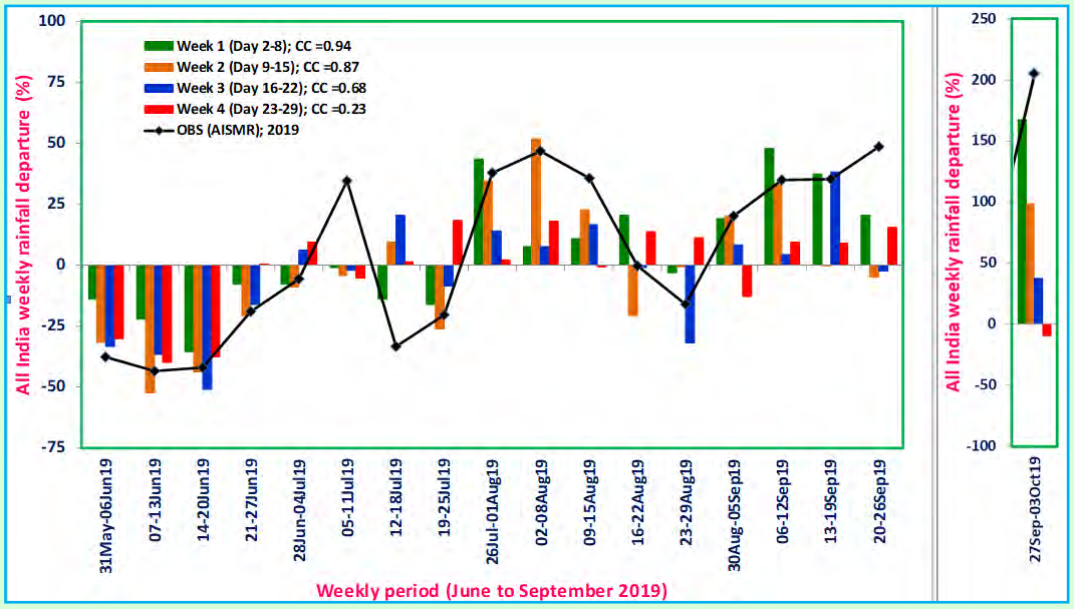


Fig. 2. The ERF forecasts show useful skill upto four weeks on India level

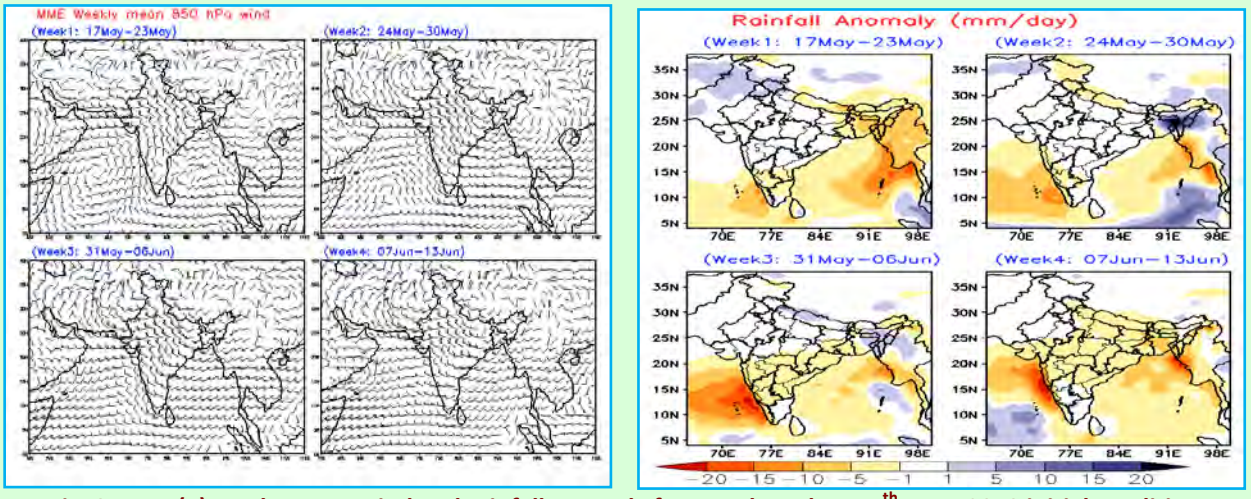
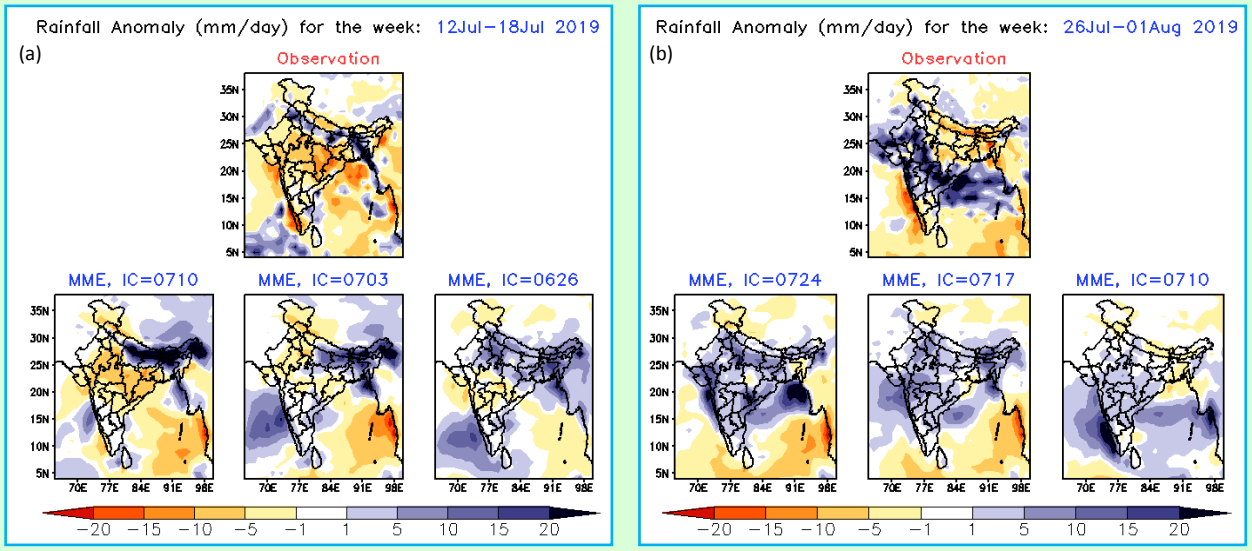


Fig. 3. Four (4) weeks mean wind and rainfall anomaly forecast based on 15th May, 2019 initial condition and forecast valid from 15 May to 13 June, 2019

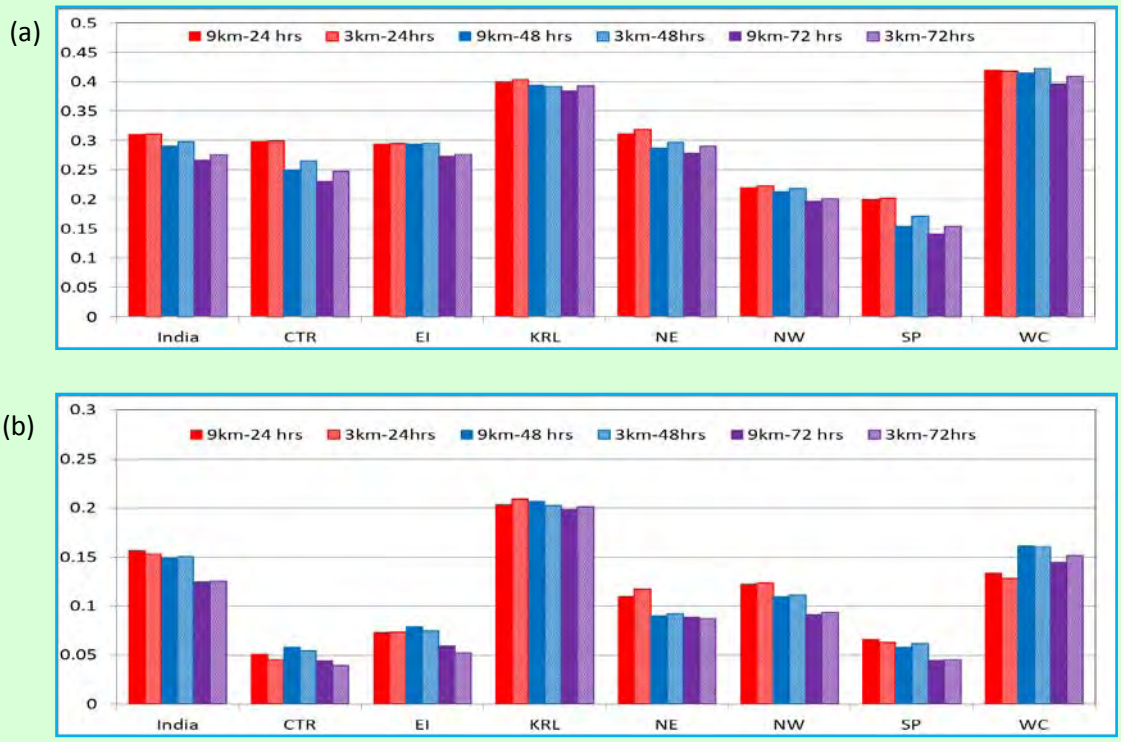
The transition from normal monsoon condition to weak monsoon and *vice versa* is also well captured in the ERF forecast. As shown in Figs. 4(a&b) the observed and forecast rainfall anomaly for the weak phase of monsoon for the target week of 12-18 July, 2019 is weak captured in the ERF forecasts with three weeks lead time (10 July, 3 July and 26 June ICs). Similarly the active target week of 26 July-01 August, 2019 the ERF rainfall is well captured with two to three weeks lead time.

(*ii*) Regional mesoscale models

The WRF model (ARW) delivered three days forecasts twice daily at 0000 UTC and 1200 UTC. The data assimilation component, WRF Data Assimilation (WRFDA) takes global GFS analysis and all other conventional quality controlled observations as its input and generates mesoscale analysis with 9 km resolution. The model mother domain (09 km) covered the area of responsibility for Regional Specialized Meteorological Center (RSMC), New Delhi (23° S to 46° N; 40° E to 120° E). The nested domain with 3 km resolution is centered at 22.5° N and 81.2° E spans nearly 4000 km in both east-west and north-south directions to cover whole Indian region. The standard verification of the rainfall forecasts with categorical skill scores during southwest monsoon season 2019 over seven different



Figs. 4(a&b). (a) Observed and forecast rainfall anomaly for the weak phase of monsoon for the target week of 12-18 July, 2019 with three weeks lead time (10 July, 3 July and 26 June ICs). (b) Same as 'a' but for the active target week of 26 July-1 August, 2019



Figs. 5(a&b). The categorical skill scores averaged over whole Indian region and seven other sub-regions during the monsoon season 2019. (a) CSI and (b) GSS respectively for Day-1 (red), Day-2(blue) and Day-3 (violet) forecasts. The solid bars represent 9 km whereas bars with pattern are for 3 km resolution

regions (*i.e.*, Kerala, West Coast, Southern Peninsula, Central India, East India, North-East India and North-West India), has been carried out for different rainfall thresholds. Fig. 5 shows two skill scores (CSI and GSS) considering a rainfall threshold of 7.6 mm in all three days forecasts with a comparison between two resolutions of the model.

The HWRF version H217 has been ported on the MHIR HPCS with horizontal resolution of 18 km for parent domain and 6 km & 2 km for intermediate and innermost nested domains following the center of cyclonic storm. The model is running with 61 vertical levels with parent domain, intermediate and innermost domain covering area of 80^{o} x 80^{o}, 24^{o} x 24^{o}

TABLE 1

HWRF ANNUAL ERRORS - 2019

Forecast Hours	12	24	36	48	60	72	84	96	108	120
Weighted Track Error (Kms)	62	86	110	136	169	209	243	264	366	425
Weighted Intensity Error (Kts)	8.8	10.7	12.8	12.2	14.3	15.4	15.1	13.8	17.8	20.9
No. of Forecast Verified	181	169	154	140	125	110	96	80	70	59

and 7^{o} x 7^{o} respectively. The special feature modified for tropical cyclone forecasting includes vortex initialization and correction, GSI based regional data assimilation, coupler for two way coupling between atmosphere and ocean components and fine-tuned physical parameterization schemes. The model was operational for all cyclonic storms (e.g., Pabuk, Fani, Vayu, Hikaa, Kyarr, Maha, Bulbul and Pawan) of 2019. The skill of the model for cyclone track and intensity forecasts is given in Table 1.

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

IMD has installed 13 additional RS/RW stations. Special emphasis was given to establish a network in North East India. Jabalpur, Bhuj, Sriganganagar, Gopalpur, Shillong, Passighat, Dimapur, Imphal, Aizwal, Kavali, Ramagundam, Gadag and Bankura are now included in the RS/RW observational network. The GPS radiosounding network now consists of 56 stations enabled with twice a day ascents (Fig. 1). India Meteorological Department (IMD) has 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.

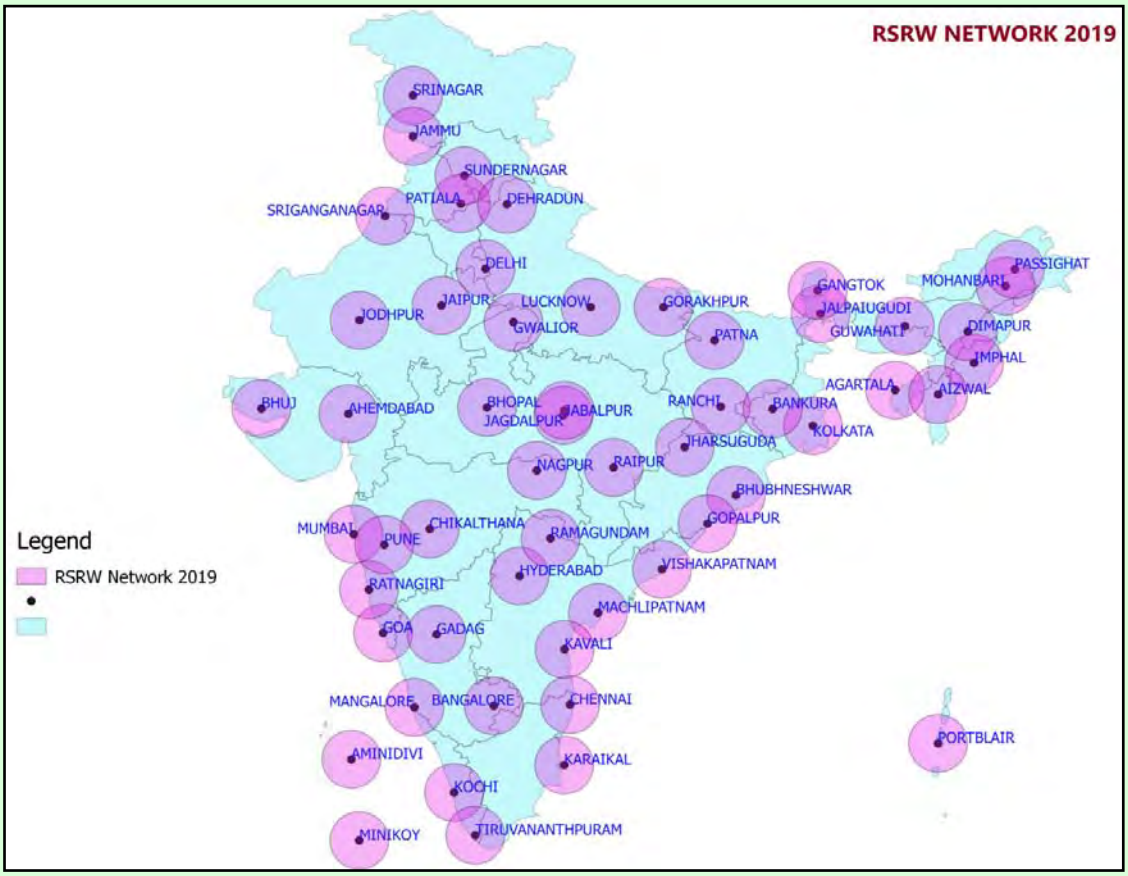


Fig. 1. Existing RS/RW Network of India Meteorological Department

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.**

Pilot Balloon (PB) Network

IMD is operating 62 PB observatories taking 2 to 4 observations for upper air wind profiles at 0000, 0600, 1200 and 1800 UTC hrs of observations (Fig. 2). PB stations are using optical theodolites for balloon tracking manually. Efforts have been made to switch over 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.

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

Major achievements during the year 2019

(*i*) Sustenance 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.

(*ii*) Further densification of network of upper air radiosounding (RS/RW) from 43 to 56 stations with fully automatic GPS based radiosounding systems. RS/RW network has been further extended at 13 new stations with a special emphasis on North East India. List of new installations is shown in Table 1 & Figs. 3-6.

TABLE 1

List of new installations

S. No.	Station	R M C	Installation date
1.	Imphal	RMC Guwahati	30.07.19 to 01.08.19
2.	Pasighat		06.09.19 to 08.09.19
3.	Shillong		13.09.19 to 15.09.19
4.	Dimapur		09.09.19 to 11.09.19
5.	Lengpui (Aizawl)		03.08.19 to 05.08.19
6.	Bankura	RMC Kolkota	10.07.19 to 12.07.19
7.	Gopalpur		29.07.19 to 02.08.19
8.	Gadag	RMC Chennai	25.07.19 to 27.07.19
9.	Ramagundam		18.09.19 to 20.09.19
10.	Kavali		12.09.19 to 14.09.19
11.	Bhuj	RMC Mumbai	16.07.19 to 18.07.19
12.	Sriganganagar	RMC New Delhi	12.09.19 to 14.09.19
13.	Jabalplur	RMC Nagpur	30.07.19 to 01.08.19

Fig. 3. Radiosonde antenna installation at RS/RW Bankura, West Bengal

Fig. 4. Preparation of Radiosonde launch at Lengpui (Aizawl), Mizoram, RS/RW station

Fig. 5. Radiosonde antenna installation at RS/RW Gadag, Karnataka

Fig. 6. Antenna installation at RS/RW Shillong, Meghalya

4.2. Surface Observational Networks

New Installation and Up-gradation of Airport Instruments

The new installation and up-gradation of airport instruments during the year 2019 are shown in Figs. 7-18.

Fig. 7. Net Radiation sensor at AET Anand

Fig. 8. DCWIS Thirupati

Fig. 9. AWS at Pahalgam

Fig. 10. AWS at Baltal, Jammu and Kashmir

Fig. 11. HWSR installed at Puri

Fig. 12. Drishti Transmissometer systems installed at Bangalore (new runway) airport

Fig. 13. DIWE System installed at Port Blair

Fig. 14. Laser Ceilometer installed at Guwahati

Fig. 15. HWSR installed at Veraval

Fig. 16. DCWIS System installed at Gaya Airports

Fig. 17. DCWIS System installed at Shirdi Airports

Fig. 18. Calibration of Digital Standard Barometer (DSB) cited at Shillong and Cherrapunji

Fig. 19. MMDRPS receiving and processing systems

4.3. Satellite Observations

Space based observation Network & Services

The meteorological satellite data of INSAT is processed and disseminated by INSAT Meteorological Data Processing System (IMDPS) of India Meteorological Department (IMD) which was installed by M/s Antrix Corporation through an MOU with India Meteorological Department. At present, INSAT-3D and INSAT-3DR (Imager, Sounder, DRT) satellites carrying meteorological payloads are supporting weather forecasting services. INSAT-3D was launched on 26th July, 2013 located at 82° East and INSAT-3DR was launched on 8th September, 2016 by GSLV - F05 and placed at 74° East in place of Kalpna-1 which has been shifted at 73.2° East and decommissioned in September 2017. INSAT-3DR similar to INSAT-3D, is an advanced meteorological satellite of India configured with an imaging System and an Atmospheric Sounder. INSAT-3D & 3DR carries a multi spectral Imager, 19 channel Sounder, Data Relay Transponder and Search and Rescue Transponder payloads. INSAT-3D Meteorological Data Processing System (IMDPS) was dedicated to the nation by the Hon'ble Minister of Science and Technology, Ministry of Earth Sciences on 15th January, 2014. The performance of the system during the current year has been maintained to the level of 99% operation efficiency (24 x 365 bases). Till September 2019, the processed data of INSAT-3DR Imager and Sounder was obtained from SAC, Ahmedabad through dedicated NKN connectivity and images generated at IMDPS and are disseminated on IMD website on real time basis.

IMD is at advanced stage for establishing Multi-Mission Meteorological Data Receiving and Processing System (MMDRPS) for INSAT-3D, INSAT-3DR and INSAT-3DS (Fig. 19) in collaboration with M/s Antrix Corporation Ltd, ISRO for which a MOU has been signed between IMD and ISRO on 6th March, 2017. The 95% work of the project has been completed. The MMRDPS system is being used to Receive & process the INSAT-3D & INSAT-3DR satellites data parallelly with IMDPS system since 1st October, 2019. The output generated by the system is used for efficient and successful forecasting the major weather events particularly major cyclones PABUK, FANI, VAYU, HIKAA & BULBUL during 2019.

The Imager payload of INSAT-3D & INSAT-3DR is being used in staggered mode so that effectively 15 minutes temporal resolution is achieved. IMD in collaboration of SAC, MCF has finalized the Standard operating Procedure (SOP) to carry out the Rapid scan strategy from INSAT-3DR Imager payload in case of severe weather events. Rapid scan has been

conducted during major cyclonic events, *i.e.*, PABUK, FANI, VAYU, HIKAA, BULBUL and KYARR. 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.

The products derived from the satellite data include: Cloud imageries in the Visible, Short wave Infra-red, Mid Infra-red, Thermal Infra-red, Water Vapour Channels alongwith special enhanced images, Atmospheric Motion Vectors (IR Wind, Water Vapour Winds, MIR / 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, 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. Two new types of satellite Imageries IR-1 BT Blended Image and IR-1 BT & Visible Sandwich Image has been made operational which will be very useful for monitoring Thunder-storm events (Fig. 20).

The imageries of rapid scan conducted during cyclonic events (Fig. 21) are being disseminated through newly developed dedicated web page (http://satellite.imd.gov.in/rapid/rapid_scan.htm).

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 April,

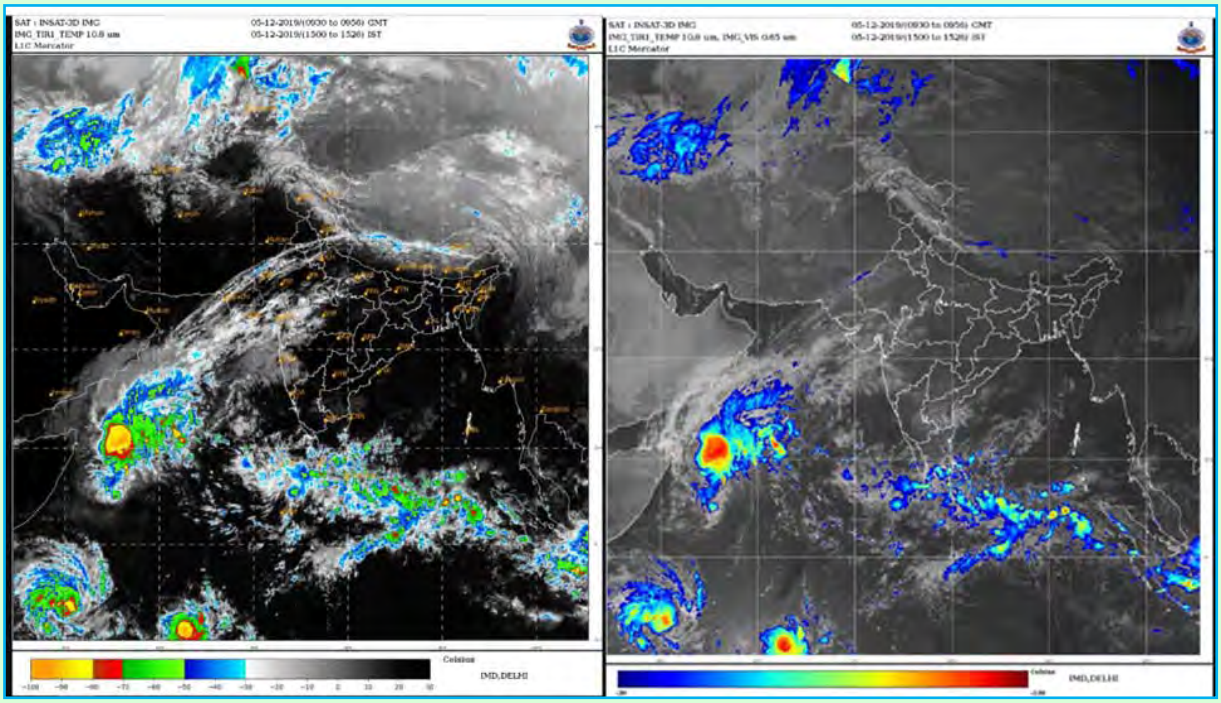


Fig. 20. Satellite Imageries IR-1 BT Blended Image and IR-1 BT & Visible Sandwich Image

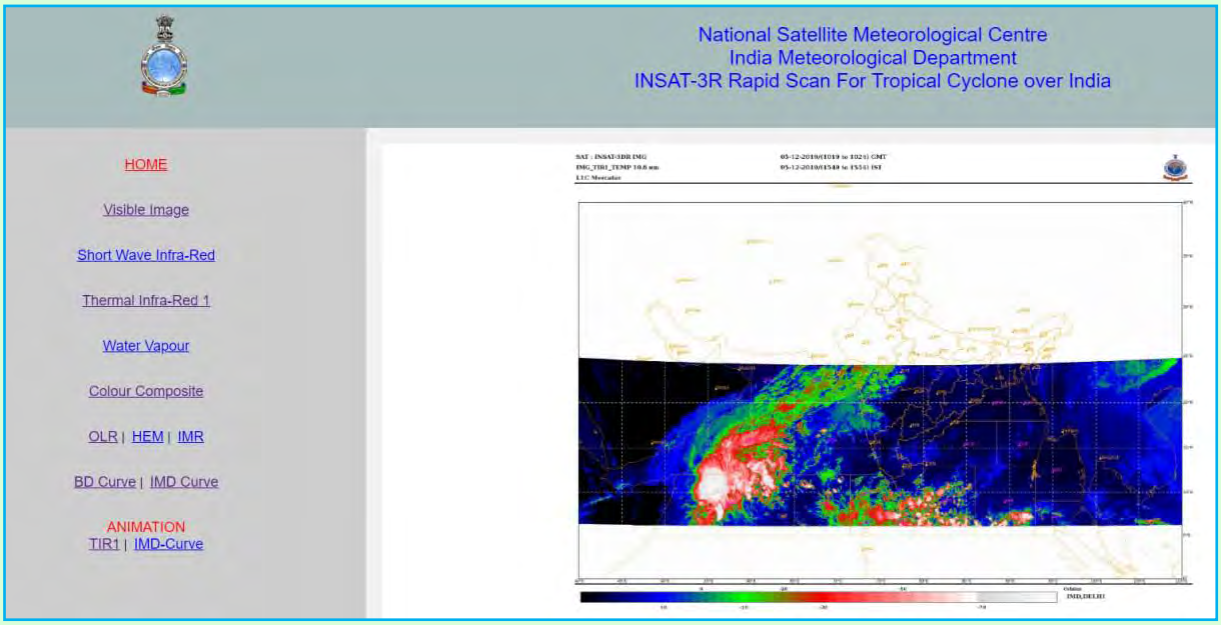


Fig. 21. The imageries of rapid scan conducted during cyclone

2018 to July, 2019 and the feedback are used for fine tuning of algorithm of these products and calibration coefficients. IPWV estimated from GNSS neatwork of nine stations has been validated with GPS Sonde IPWV data for the period of June 2017 to June 2018. Total Precipitable Water Vapour derived from INSAT-3D has been validated with GNSS-IPWV of 18 stations for the period of June 2017 to June 2018.

IMD's Area Cyclone Warning Centers generate special warning bulletins and transmit them every hour in local languages to the affected areas. During Recent past, in cases of PABUK, FANI, VAYU, HIKAA & BULBUL, KYARR Cyclones warnings were disseminated to all stake holders which resulted in minimum loss to human life. Advanced Dvorak 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

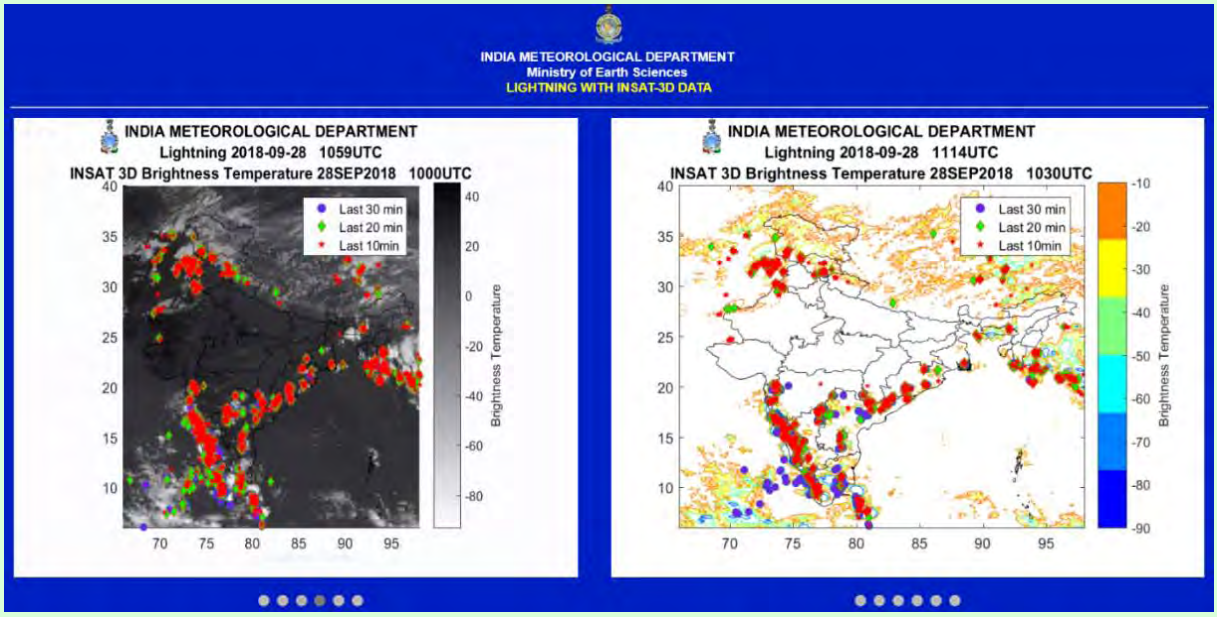


Fig. 22. Satellite and lighting merged products

precipitation, Rainbow, *i.e.*, Colourful enhancement for a pretty image, New variation on the Rainbow enhancement curve - Colorful enhancement (RBtop)] are integrated in RAPID. **INSAT-3DR data has been integrated along with rapid scans data has been integrated in RAPID in October 2019 for real time visualization and analysis of cyclonic events.**

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. IPWV data is being shared with NCMRWF in near real time basis for assimilation in NWP model.

The satellite and lighting merged products are also operationalized at IMD website (Fig. 22). The merged lightening & satellite cloud top temperature operational product is a joint collaboration of IMD, IITM & IAF. Work is going on to merged (all 3 types of instrument data) Satellite+RADAR and Lightning data for the weather forecast 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 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 behaviour 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. 23) including Maitri and Bharati in Antarctica:

- Total Columnar ozone measurement using Dobson spectrophotometer.
- Surface Ozone monitoring network
- Measurement of Vertical Distribution of Ozone.

Fig. 23. IMD Ozone monitoring network

Precipitation and Particulate Matter Chemistry Monitoring

IMD is monitoring Precipitation Chemistry through a network of eleven stations since 1970s (Fig. 24). The rainwater samples collected from these stations are analyzed in Air Pollution Chemistry Laboratory at IMD, Pune (Fig. 25)

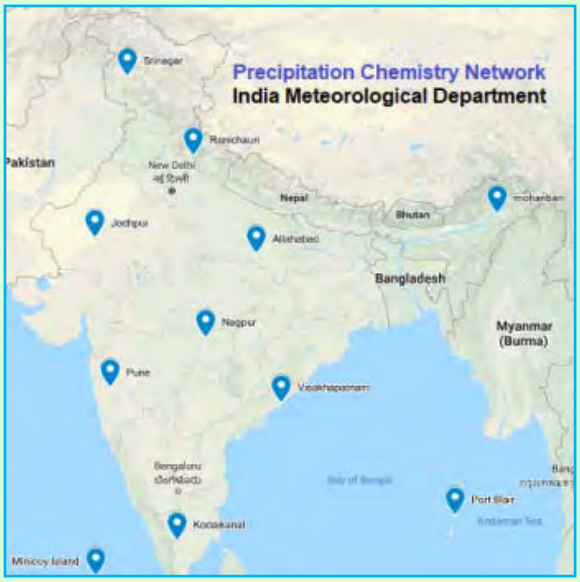


Fig. 24. IMD Precipitation chemistry network

which is equipped with Ion-chromatograph, UV-VIS Spectrophotometer, Semi-micro Balance, pH & Conductivity Meter, Ultra- pure Deionized Water Purification System. A new Atomic Absorption Spectrophotometer has been installed in the laboratory.

Fig. 25. Air Pollution Laboratory at IMD, Pune

Aerosol Monitoring Network

Fig. 26. Aerosol Monitoring network of IMD

IMD has established Aerosol Monitoring Network covering different geographic regions of India (Fig. 26). The Aerosol Monitoring Network consists of following sub-networks:

- **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. 27). The filter papers are being analyzed for chemical characterization of aerosols at Air Pollution Section, O/o CRS, IMD, Pune.

Fig. 27. High volume sampler for collecting PM_{10}, $PM_{2.5}$ 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.

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 ($PM_{2.5}$, PM_{10}, Ozone, CO, NO_x (NO, NO_2), SO_2, BC, Methane (CH_4), Non-methane hydrocarbons (NMHC), VOC's, Benzene, Mercury), solar radiation and meteorological parameters are measured at ten air quality station installed in each city.

High Altitude Background Climate Monitoring Station

IMD maintains a Background Climate Monitoring Station Ranichauri, Uttarakhand (Fig. 28). Skyradiometer, Aethalometer, Differential Mobility Particle Sizer, Nephelometer, Solar Radiation monitoring equipment, Precipitation Chemistry and Surface Ozone Analyzer have been installed at the station.

Fig. 28. IMD Climate Monitoring Station Ranichauri, Uttarakhand

The site is being developed for monitoring aerosol-cloud interaction & GHGs monitoring.

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. 29). The observations vertical profile of ozone is also carried out at Bharati regularly (Fig. 30). 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. 29. Meteorological Observatory at Bharati

Fig. 30. 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. 31).

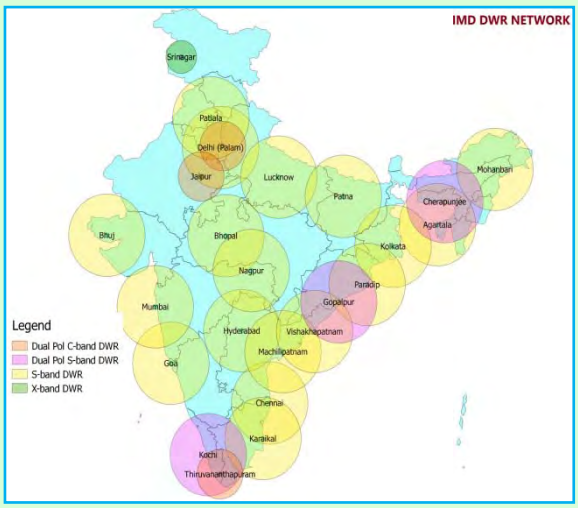


Fig. 31. Network of Radars

(b) Proposed Dual Polarized 10 X- Band DWRs

10 Dual Polarized X-Band DWRs will be installed in North-West Himalayas under Integrated Himalayan Meteorological Programme (Fig. 32).

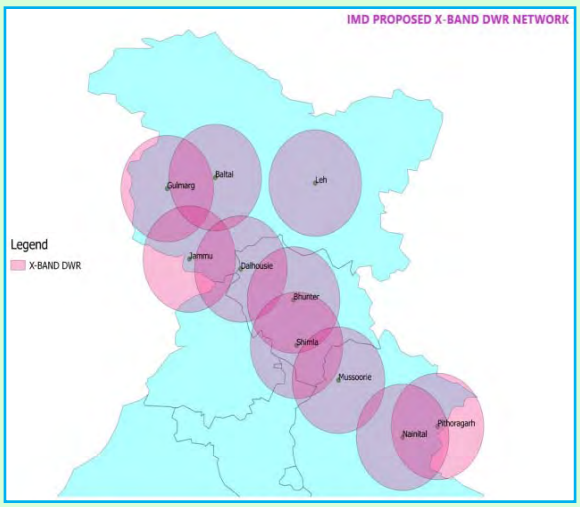


Fig. 32. Proposed X- Band DWR Network

(c) Proposed Dual Polarized 11 C-Band DWRs

11 Dual Polarized C-Band DWRs to be installed over the mainland of India (Fig. 33).

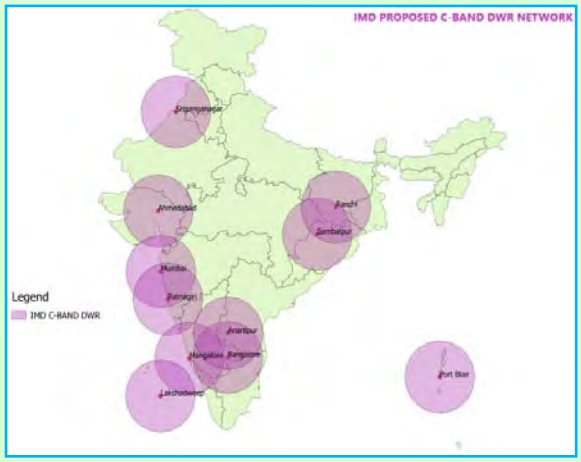


Fig. 33. Proposed C- Band DWR Network

A **portable X-Band Doppler Weather Radar mounted on mobile platform** received at Sonmarg under Integrated Himalayan Meteorology Programme (IHMP) for Western and Central Himalays (Fig. 34).

Fig. 34. Portable X-Band Doppler Weather Radar

A tower based X-Band DWR has been installed at Mukteshwar in Uttarakahnd under IHMP (Fig. 35).

Fig. 35. DWR at Mukteshwar in Uttarakahnd

IMD has completed the in house development of a Lightning Warning system which includes detailed report of occurrence of lightning events. The same has been implemented at all MCs and audio alerts are generated. This detailed report along with the audio alerts is generated in every fifteen minutes state wise and district wise.

IMD has also completed the development and implementation of An Integrated Display system showing all Meteorological Observations such as Radar, Lightning, Sounding, INSAT-3D satellite Derived clouds, Meteosat derived clouds and GFS forecasted winds etc. (Figs. 36-38).

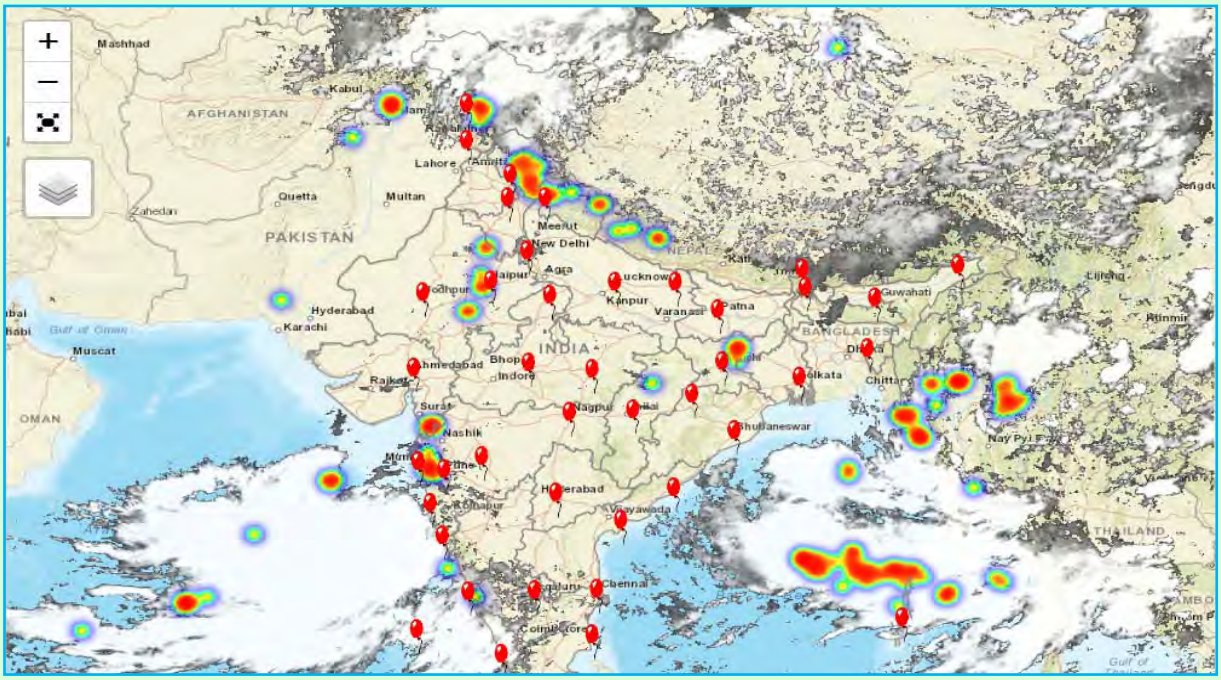


Fig. 36. An Integrated Display system

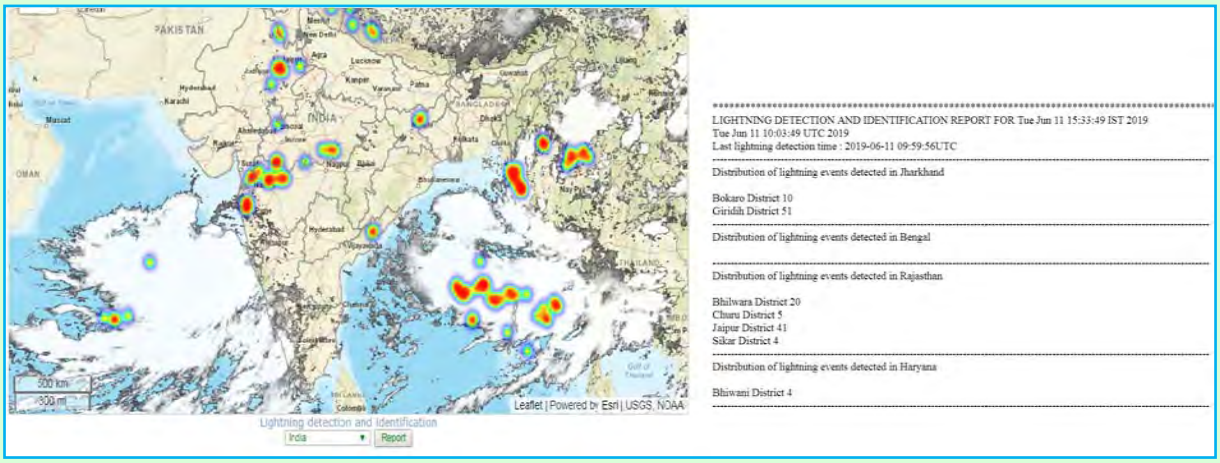


Fig. 37. Lightning Warning system

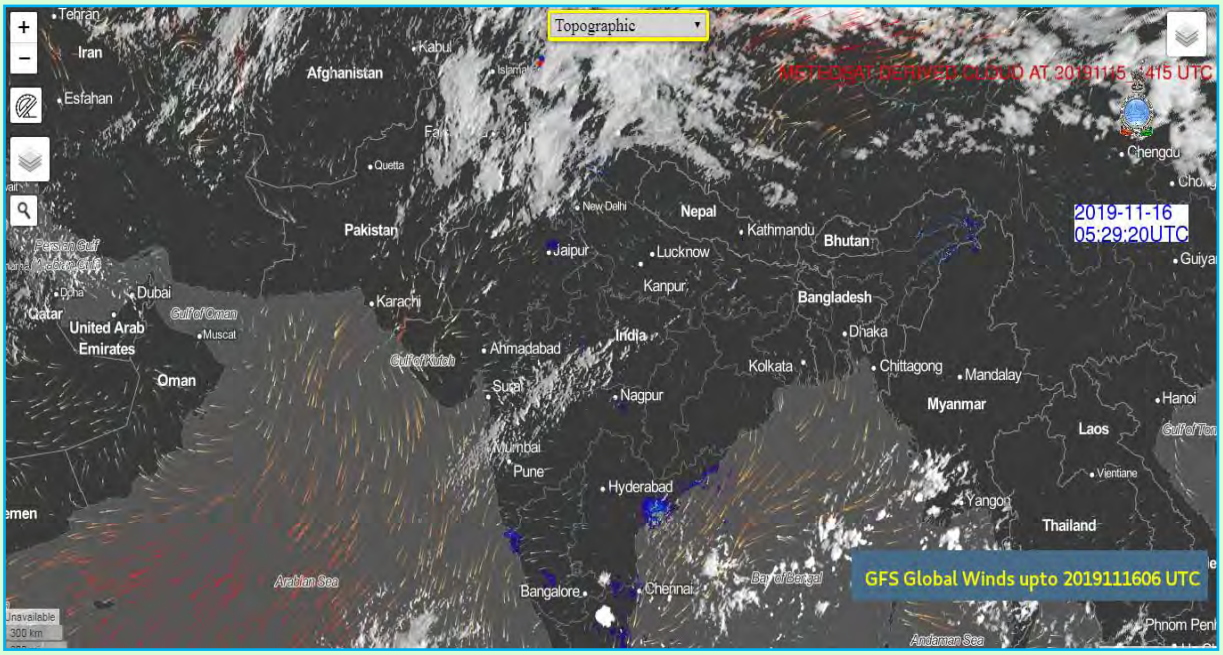


Fig. 38. Meteosat derived clouds

4.6. SAARC Storm Project - 2019

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 October, 2018. At present the SWIRLS software is operational at 12 stations, *viz*; Delhi, Mumbai, Goa, Machilipatnam, Patna, Agartala,

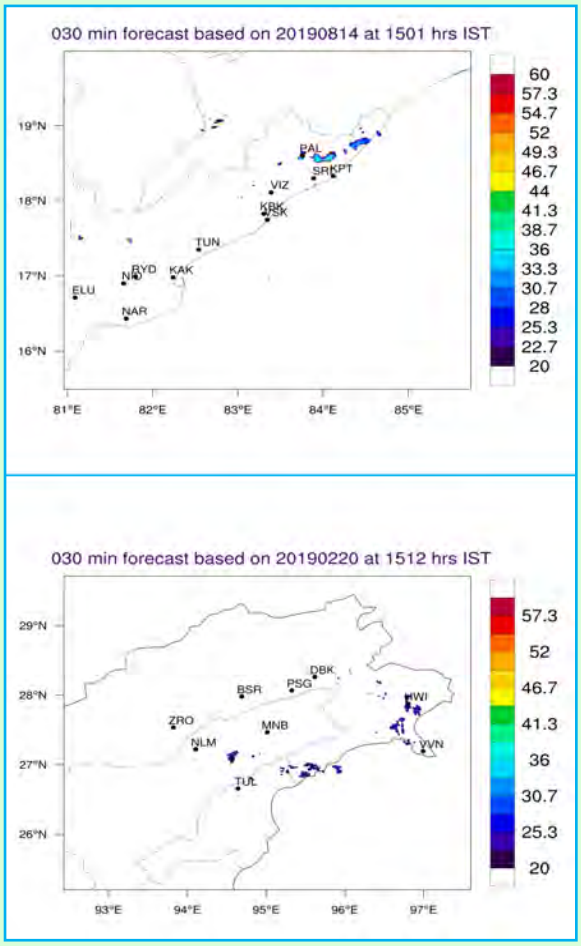


Fig. 39. SWIRLS Reflectivity Visakhapatnam and Mohanbari

Mohanbari, Visakhapatnam, Patiala, Hyderabad, Lucknow and Kolkata. Fig. 39 shows IMD SWIRLS forecast for Visakhapatnam and Mohanbari.

STORM Forecast Demonstration Project-2019

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.

The programme is renamed as FDP STORM from 2017 onwards. 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 1 March to 30 June, 2019.

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

(*i*) Current Synoptic situations and satellite current and past 24 hrs observations over India,

(*ii*) NWP model Guidance from IMD GFS, IMD WRF and NCUM (NCMRWF) Models,

(*iii*) Summary of 1 & 2 above and

(*iv*) 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 122 FDP Bulletins were issued during the STORM Period-2019.

Nowcast Guidance Bulletins

In addition to FDP Bulletins during March to June-2019, 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 0830 IST 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 & issue Nowcast Bulletins accordingly.

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, (*v*) availability of mesoscale models and (*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-2019, 259 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 692 under 25 Nowcast Centres (RMC/RWFC/MC/CWC). Fig. 40 depicts the screen shot of Nowcast Warning Page on IMD website and Fig. 41 indicates the year-wise cumulative number of stations added on Nowcast Warning page for three hourly thunderstorm Nowcast. In addition to stationwise nowcasting, district level nowcasting for 773 districts of India has also been started from July 2019 (Fig. 42). Considering the importance and reliability of DWR and satellite based information for nowcast of severe weather, all district headquarters/major towns/tourist places and specific locations within capital cities (under Urban Meteorology and Climate project) in India are to be included for nowcasting of severe weather.

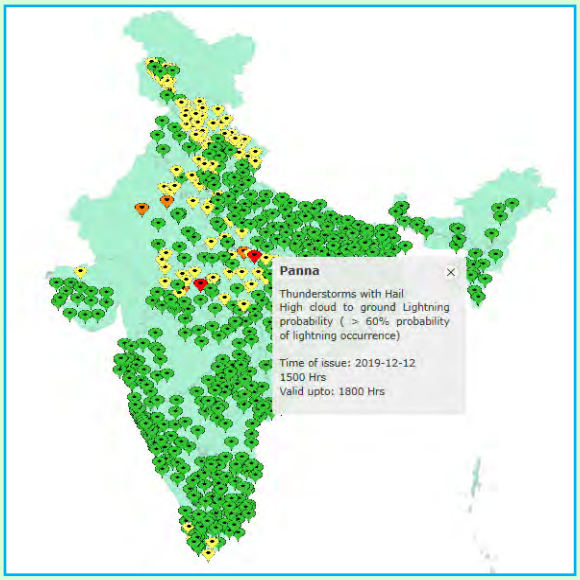


Fig. 40. Stationwise Nowcast Warning Page on IMD website

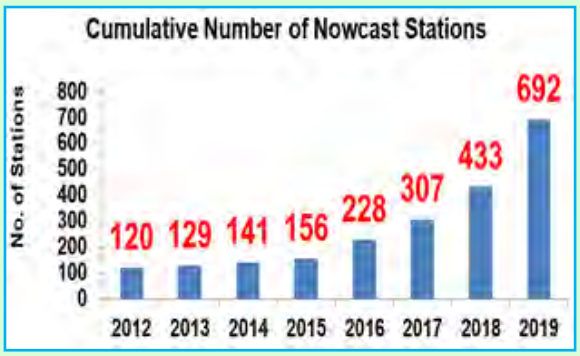


Fig. 41. Year-wise cumulative number of stations for three hourly thunderstorm Nowcast

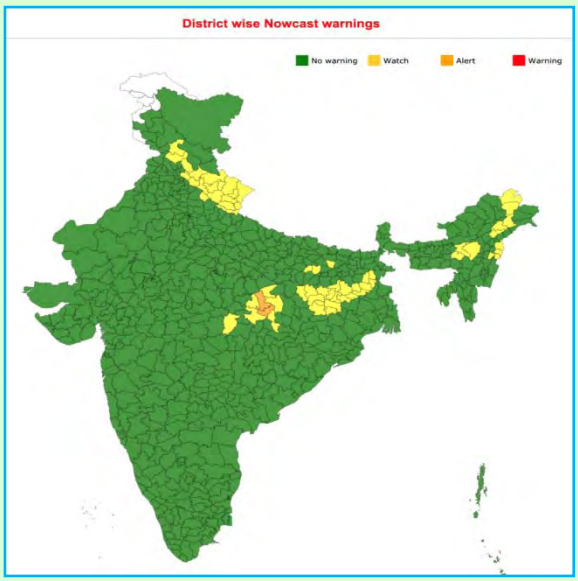


Fig. 42. Districtwise Nowcast Warning Web Page on IMD website

During this year a new thunderstorm webpage has been created (Fig. 43) that brings all products related to thunderstorm forecasting

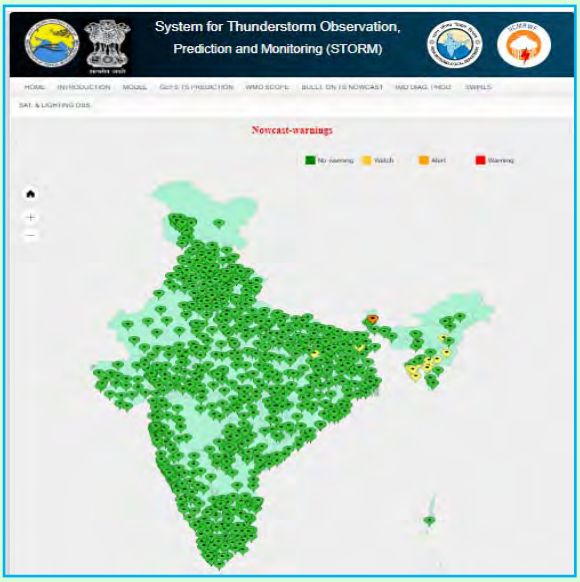


Fig. 43. New Web Page for Thunderstorm monitoring and forecasting

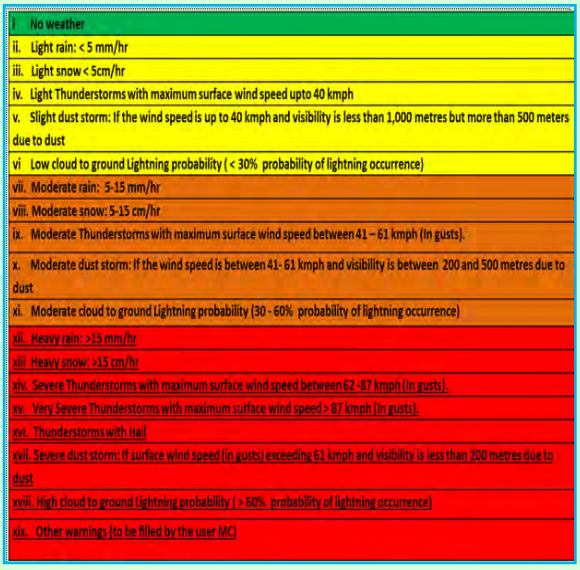


Fig. 44. Different catogories of Nowcast Warnings

and nowcasting to one platform. This includes products developed by IMD, NCMRWF and IITM scientists under the umbrella of the THUMP project under the chairmanship of Secreatry MoES**.** These new products, which provide short range forecast of weather phenomena associated with thunderstorms, have greatly aided in improving the short range forecast of thunderstorms over the Indian region. The categories of thunderstorm nowcasts have also been increased from the earlier four catgories to about nineteen categories of different kinds of weather over the India region (Fig. 44). There has simultaneously been a conscious thrust from all Meteorological centres to provide impact

Category/Wind Speed	Structures	Communication & Power	Agriculture	Suggested Actions
Light Thunderstorm <41 kmph (21 knots)	Nil	Nil	Nil	Nil
Moderate Thunderstorms 41 – 61 kmph (22-33 knots)	Minor damage to loose / unsecured structures	Nil	Minor damage to Banana trees. Damage to ripe paddy crops.	People are advised to keep a watch on the weather for worsening conditions and be ready to move to safer places accordingly.
Severe Thunderstorms 62 -87 kmph (34 -47 knots)	Damage to thatched huts.	Minor damage to power and communication lines due to breaking of branches.	Some damage to paddy crops, banana, papaya trees and orchards and Standing crops.	People are advised to take shelter in pukka structures and avoid taking shelter under trees. Farming operations to be temporarily suspended during occurrence of event. Also move away from electric poles and wires.
Very Severe Thunderstorms Greater than 87 kmph {(47Kt) in gusts/ squall}	Major damage to thatched houses/ huts. Roof tops may blow off. Unattached metal sheets may fly.	Minor damage to power and communication lines.	Breaking of tree branches, uprooting of large avenue trees. Moderate damage to banana and papaya trees. Large dead limbs blown from trees. Damage to Standing crops.	People are advised to stay away from weak walls and structures and take shelter in pukka structures. People in affected areas to remain indoors and avoid water bodies and flying projectiles. Farming operations to be temporarily suspended during occurrence of event.
Thunderstorm associated with Hailstorm	Major damage to Kutcha structures and tin and asbestos roofed houses, cars		The fruit, vegetable and field crops at maturity stages are more prone to damage. Damage to Standing crops.	People are advised to stay away from weak walls and structures and take shelter in pukka structures. People in affected areas to remain indoors.

Fig. 45. Impacts associated with various types severe weather events

based forecasts for thunderstorms over the Indian region. Generalized impacts associated with different categories of thunderstorms is also published through a forecast Circular No. 1/2019 (Fig. 45).

Verification of IOPs/TS Nowcast-2019

(*i*) FDP Bulletins

The thunderstorm and rainfall forecast issued for 24hours during **FDP STORM-2019** were verified with realised thunderstorm and rainfall data. The verification results for thunderstorm forecast are shown in Table 1 and graphically by Fig. 46. Fig. 47 indicates verification scores of 24 hr Thunderstorm IOP during 2016 to 2019 which shows a significant improvement in all the scores. Monthwise comparative Probability of Detection (POD)

TABLE 1

Skill sores for Thunderstorm verification for FDP STORM - 2019

Rainfall Category	Within Range	Out by one Range	Out by two or more Range	Total RF Forecasts issued
	Correct	Useful	Incorrect	
≤2.5	3124	433	278	3835
>2.5-5.0	40	92	14	146
5.1-10.0	137	142	55	334
10.1-20.0	16	37	9	62
>20.0	8	5	2	15
Total	3325	709	358	4392

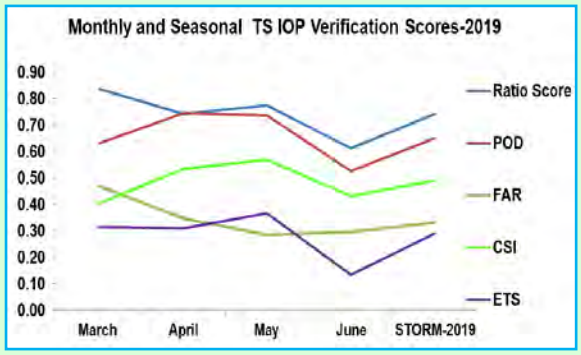


Fig. 46. Monthly and sesonal 24 hr Thunderstorm IOP verification scores during FDP STORM - 2019

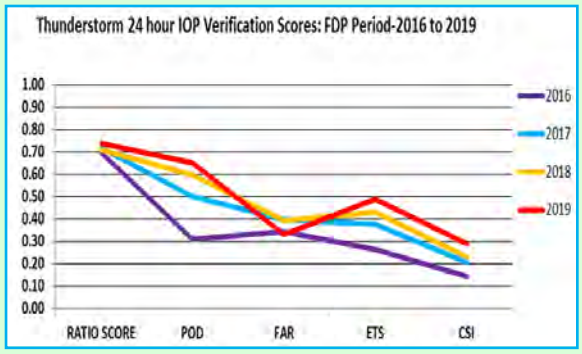


Fig. 47. Commparative 24 hr Thunderstorm IOP verification scores during FDP STORM - 2016 to 2019

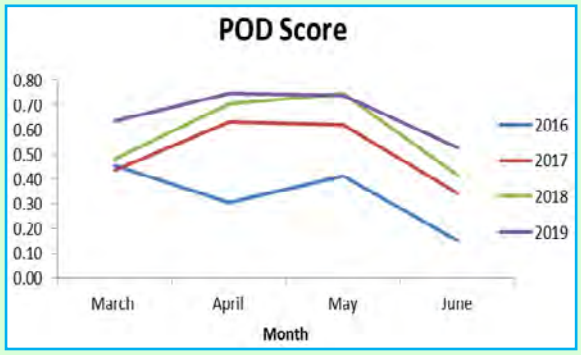


Fig. 48. Comparative POD Scores of 24 hr Thunderstormn IOP verification during FDP STORM -2016 to 2019

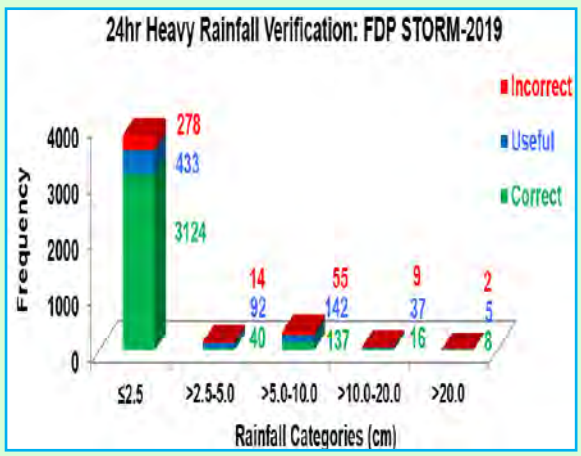


Fig. 49. Category-wise Rainfall Verification for FDP STORM - 2019 (March to June)

TABLE 2

Category wise Rainfall Verification FDP STORM - 2019 (March to June)

TS IOP Verification FDP-2019						
Month	Ratio Score	POD	FAR	CSI	ETS	BIAS
March	0.84	0.63	0.47	0.41	0.31	1.19
April	0.74	0.75	0.35	0.53	0.31	1.14
May	0.78	0.74	0.29	0.57	0.37	1.03
June	0.61	0.53	0.30	0.43	0.14	0.75
FDP-2019	0.74	0.65	0.33	0.49	0.29	0.97

scores during 2016 to 2019 (Fig. 48) indicates that this year the thunderstorms were detected more acuurately in all the months of the seasom as compared to similar result for all previous STORM seasons. The verification results for various forecasted rainfall categories are given in Table 2 and graphically by Fig. 49.

(*ii*) Three Hourly TS Nowcast

Figs. 50-54 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-2019 and Fig. 55 indicates All India Scores.

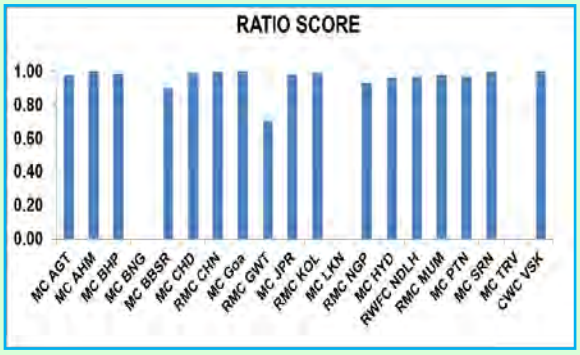


Fig. 50. MC-wise Ratio Score of Three Hourly TS Nowcast Verification during FDP STORM-2019

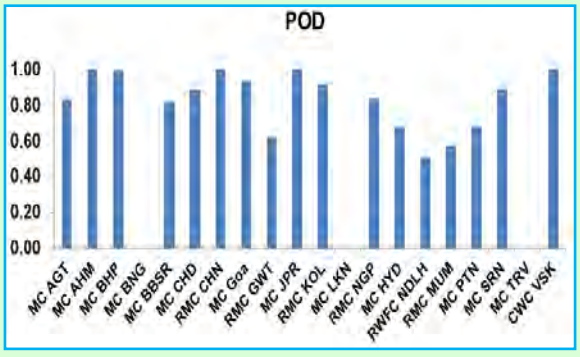


Fig. 51. MC-wise Probability of Detection (POD) of Three Hourly TS Nowcast Verification during FDP Periood-2019

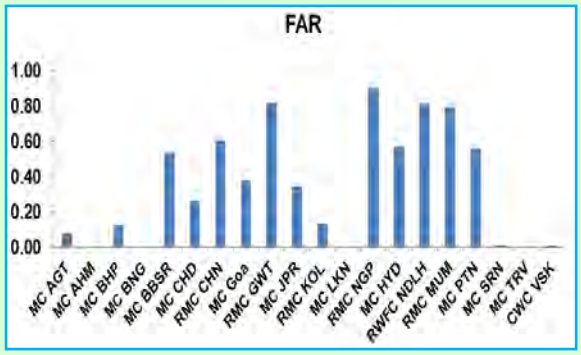


Fig. 52. MC-wise False Alarm Ratio(FAR) of Three Hourly TS Nowcast Verification during FDP Period-2019

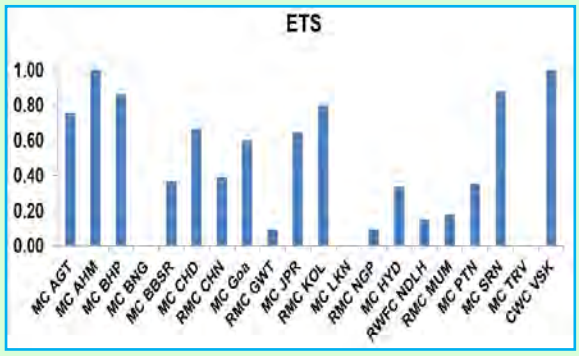


Fig. 53. MC-wise Equitable Threat Score (ETS) of Three Hourly TS Nowcast Verification during FDP Period -2019

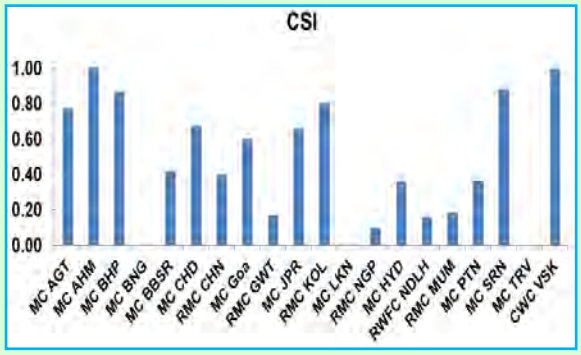


Fig. 54. MC-wise Critical Success Index (CSI) of Three Hourly TS Nowcast Verification during FDP Period-2019

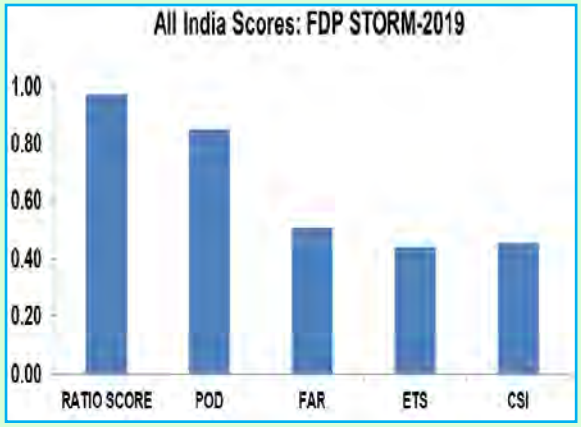


Fig. 55. All India TS Nowcast Verification Scores during FDP Period-2019

FDP STORM Report - 2019

A detailed STORM Report document, based on thunderstorm activities observed over India during March to June-2019, was 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. 56-62 represent some of the salient features of the **STORM Report-2019**.

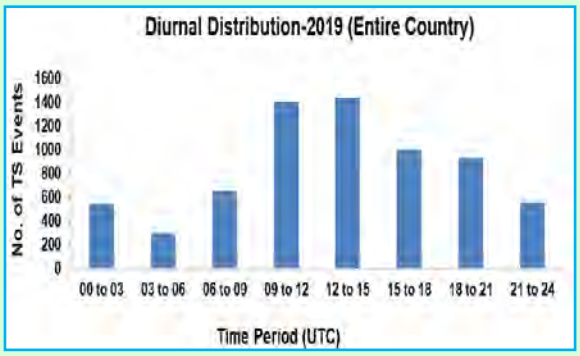


Fig. 56. Diurnal distribution of TS events over the country during FDP STORM -2019

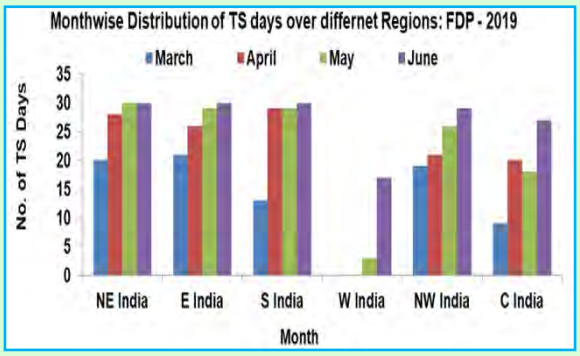


Fig. 57. Monthwise distribution of TS Days over different regions of India during FDP STORM-2019

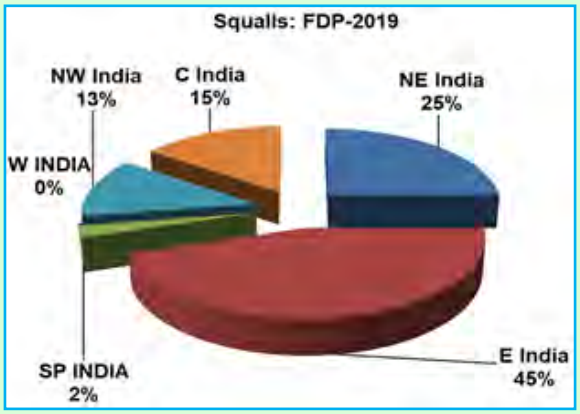


Fig. 58. Regionwise Distribution of squall events over the country during entire FDP STORM-2019

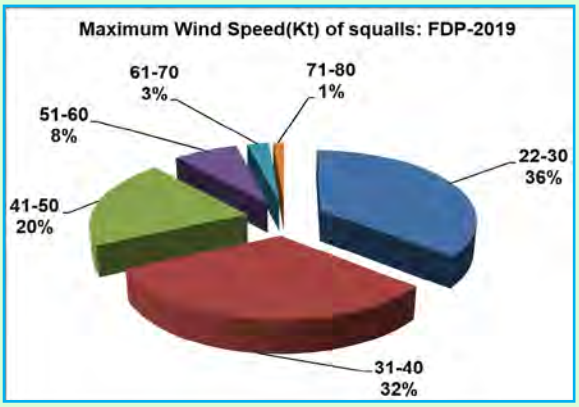


Fig. 59. Distribution of squalls over the country based upon max wind speed (Kt) during FDP STORM -2019

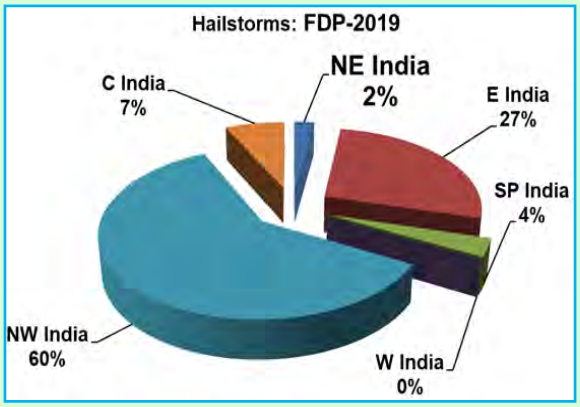


Fig. 61. Regionwise distribution of hailstorm events during FDP STORM-2019

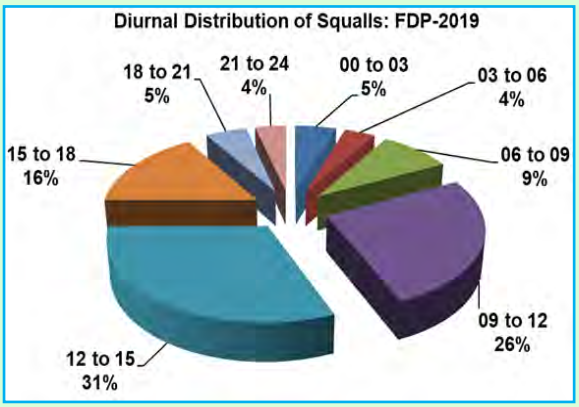


Fig. 60. Diurnal(time in UTC) distribution of thundersqualls during FDP STORM-2019

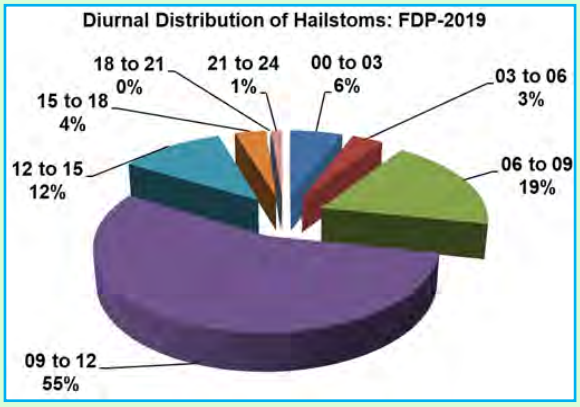


Fig. 62. Diurnal Distribution of Hailstorm Events over the Country during entire FDP STORM-2019

Awareness & Outreach and Programme

The three hourly Nowcast warnings for Severe Weather events for any area issued by IMD are automatically disseminated through mKisan portal of Govt. of India to all the registered farmers of that area in the form of local language SMS. This mKisan Portal link was successfully shifted from old window based Platform to Linux based Platform with the help of NWP Division of IMD & officers from Ministry of Agriculture.

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 hydromet design for disaster management, water management and agricultural planning purposes etc.

Major achievements

1. "South Asia Flash Flood Guidance system" is running in pre-operational mode for providing Flash flood guidance in South Asia Region *viz*., Nepal, Bhutan, Bangladesh, Sri Lanka & India under the WMO project. India is recognised as the regional centre by WMO for implementing the project in south Asia (Fig. 1).

2. Following 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 and.

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

3. Achieved 14% improvement in Day1 and 10% in Day2 in accuracy of operational River basin wise Quantitative Precipitation Forecast over NWP.

4. First time operationalization of sub basin wise Probabilistic QPF (GEFS and NEPS).

5. A new model NCUM customised for issuing of River Sub basin wise QPF.

6. Daily monitoring of river sub basin wise Severe Flood Situation & high QPF provided to Central Agencies.

7. Implementation of New rainfall normal based on 1961-2010 initiated from SW monsoon season 2019.

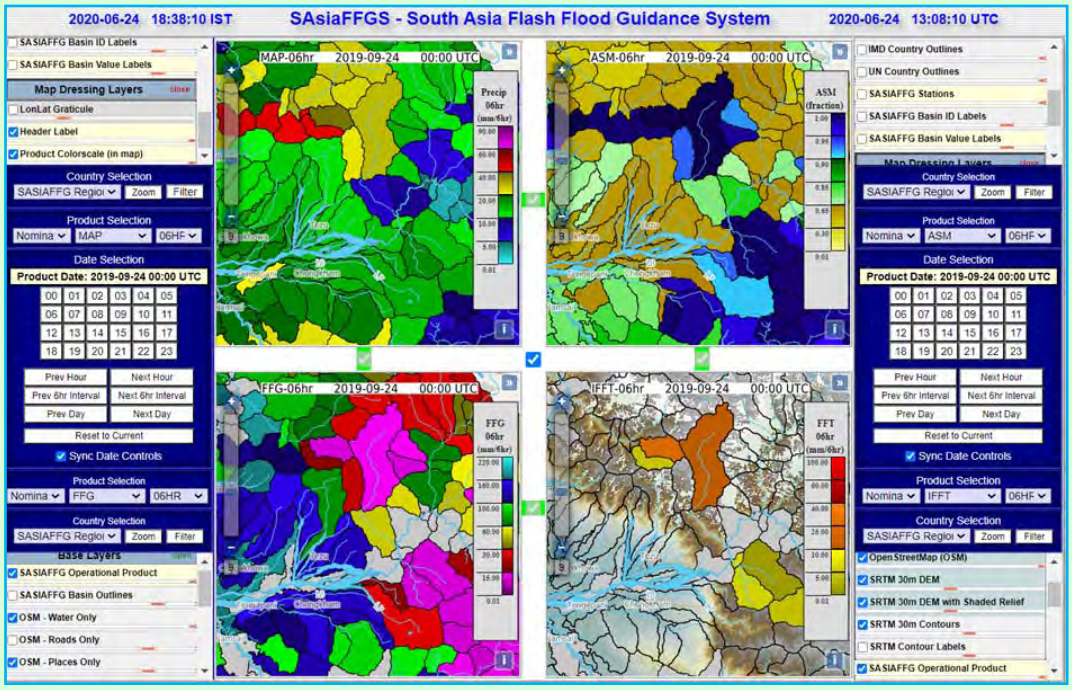


Fig. 1. South Asia Flash Flood Guidance system

8. Preparation of realtime rainfall statistics was enhanced to 683 districts.

9. Daily Rainfall Statistics in addition to weekly is prepared throughout the year.

10. 24 unrepresentative districts in respect of preparation of rainfall statistics is reduced to only 1 due to enhancement in raingauge network.

11. Ten (10) design storm study projects were completed and earned a revenue of Rs.11,25,340/- (Rupees Eleven Lakh Twenty Five Thousand Three Hundred & Forty only).

Flood Meteorological Services

(*i*) The sub-basin wise Quantitative Precipitation Forecasts (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 2019 for their area of jurisdiction (from June to October, 2019). RMC Chennai and MC Bengaluru continued to issue QPFs upto 31st December, 2019. These operational QPF were provided to the field offices of Central Water Commission for the use in their Flood Forecast Model (Figs. 2&3).

(*ii*) 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 (12 km x 12 km) based on 0000 UTC are computed and uploaded in IMD website operationally.

(*iii*) Sub basin-wise Quantitative Precipitation Estimate of NCUM (12 km x 12 km) for Day-1 to Day-7 based on 0000 UTC data was made operational for issuing QPF.

(*iv*) Sub-basinwise Probabilistic QPF based on dynamical model GEFS and NEPS was made operational in the IMD website on experimental mode (Figs. 4&5).

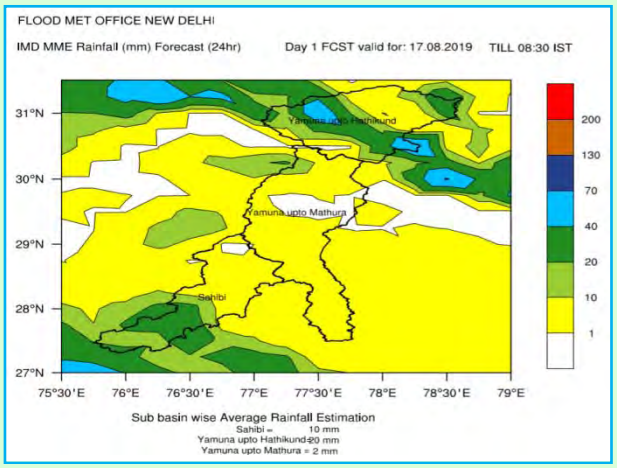


Fig. 2. IMD MME Rainfall forecast - New Delhi

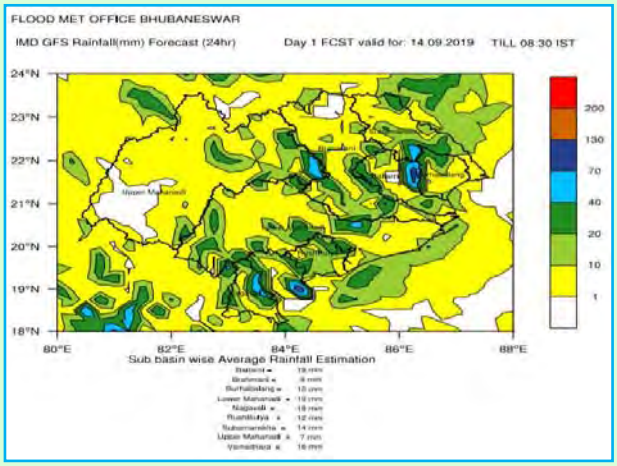


Fig. 3. IMD GFS Rainfall forecast - Bhubaneshwar

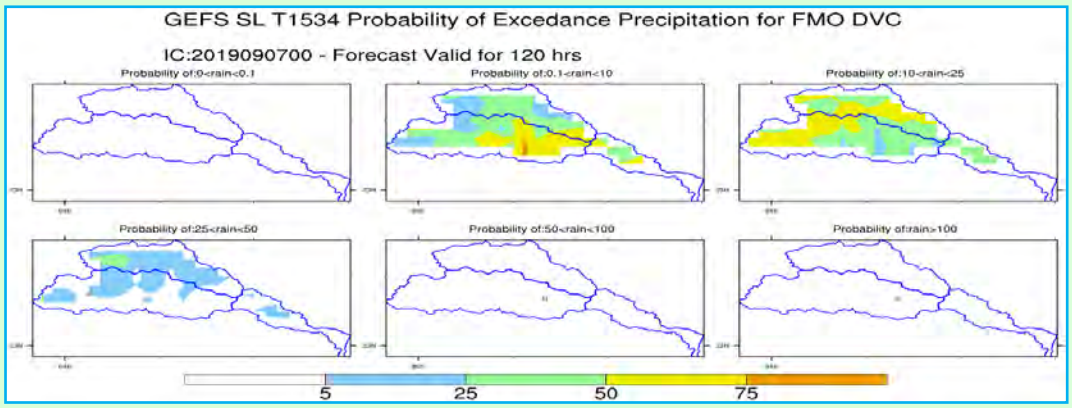


Fig. 4. Sub-basinwise Probabilistic QPF based on dynamical model GEFS

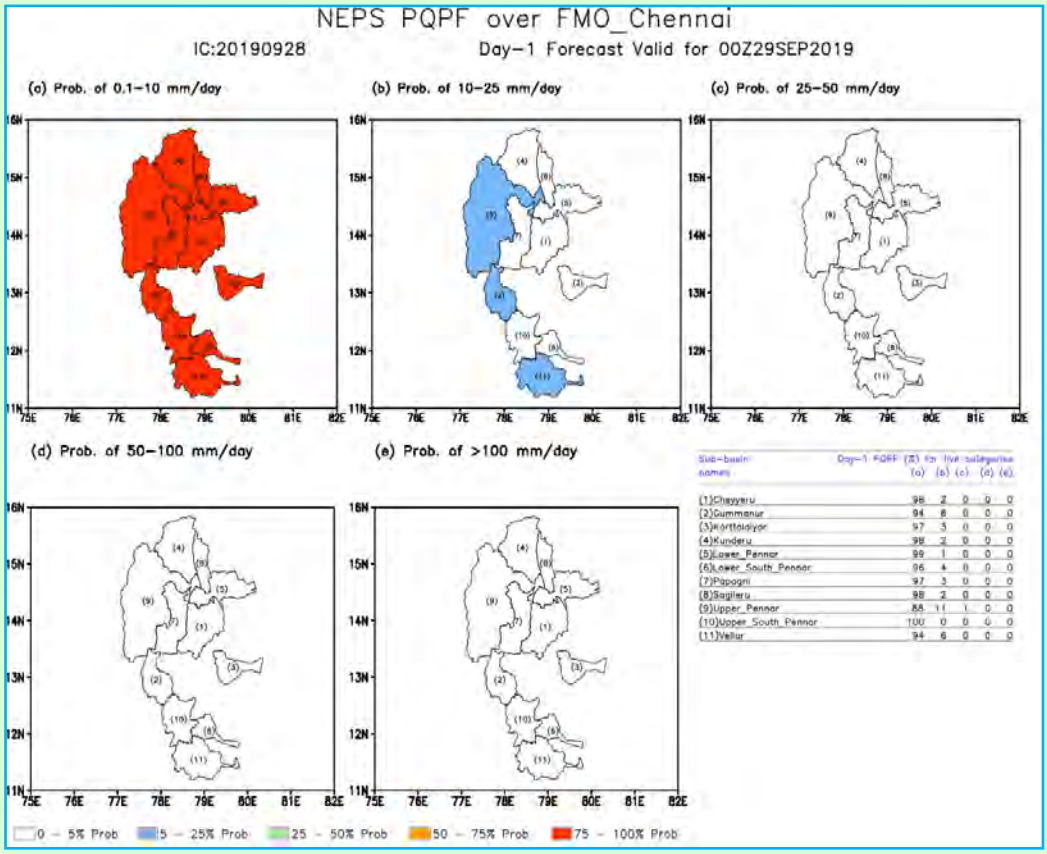


Fig. 5. Sub-basinwise Probabilistic QPF based on dynamical model NEPS

Design Storm Studies/Storm Analysis

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 whereas 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 2019, design storm studies of ten (10) projects have been completed and results communicated to the concerned project authorities (Fig. 6).

Fig. 6. Design storm studies projects

Rainfall Monitoring Services

(1) Hydromet Division brings out real-time rainfall summary every week from Thursday to Wednesday & also for months. During Monsoon season, the same is prepared on daily basis for 683 Districts, 36 Met. Sub 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 & annual rainfall statistics after incorporating the late receipt data and 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.

(2) Updated rainfall statistics for the year 2019 has been prepared. The rainfall for the country as a whole for the annual rainfall has been recorded as 1288.8 mm against the normal rainfall for the annual as 1176.9 mm (departure 10%). In all, 2 met subdivisions remained in category of Large Excess rainfall, 10 met subdivisions remained in category of Excess rainfall, 21 in Normal, 3 in Deficient rainfall and no any met subdivisions in Large Deficient and No Rain category. The subdivision-wise updated rainfall map for the annual, 2019 is shown in Fig. 7 and Table 1.

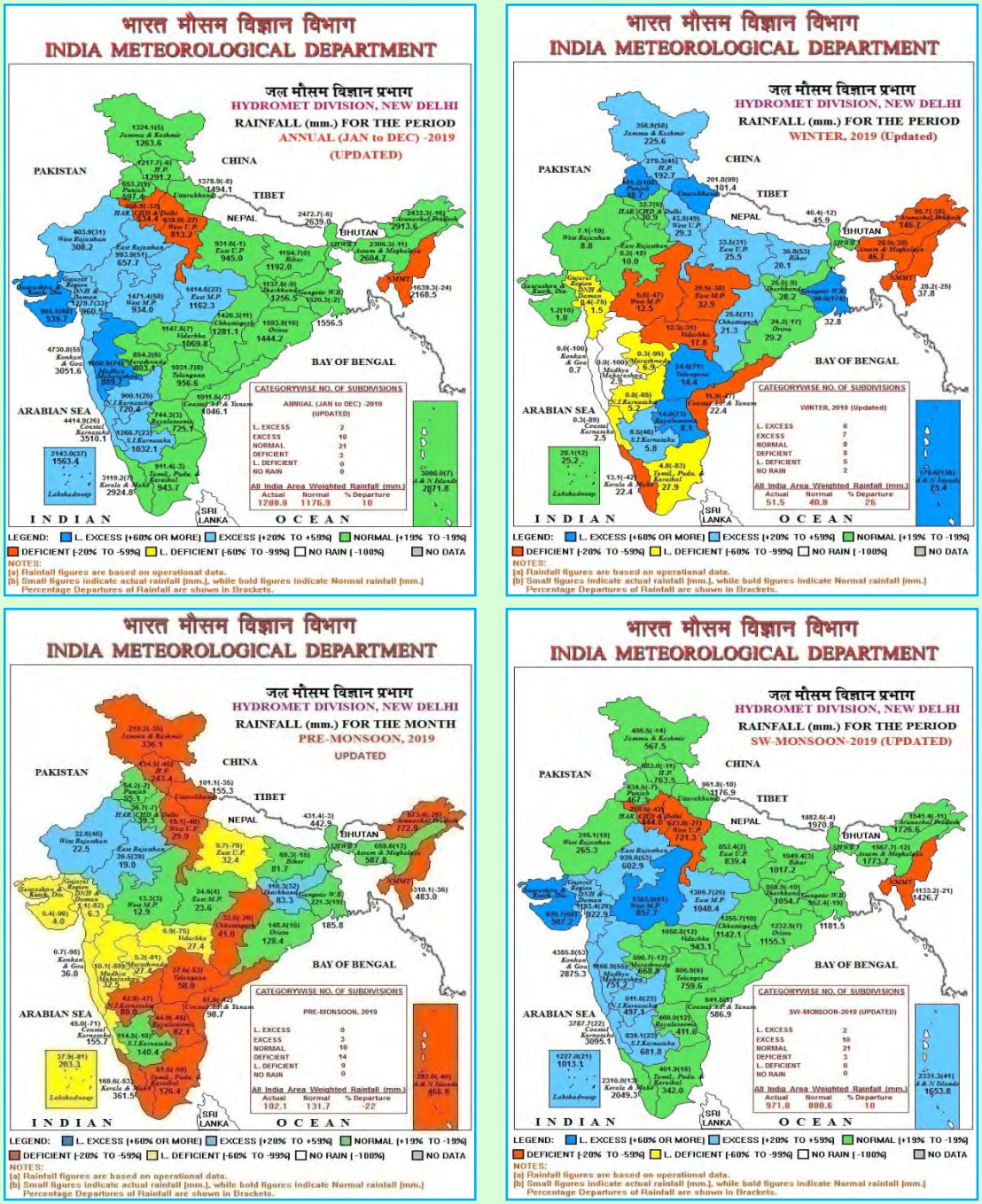


Fig. 7. Subdivision-wise rainfall map of India during 2019

TABLE 1

Subdivision-wise rainfall (mm) distribution

S. No.	Meteorological Sub-divisions	Period: Actual	Annual-2019 Normal	% Dep.	Cat.
	East & North East India	1769.3	2006.0	-12%	
1.	Arunachal Pradesh	2433.3	2913.6	-16%	N
2.	Assam & Meghalaya	2306.3	2604.7	-11%	N
3.	N M M T	1639.3	2168.5	-24%	D
4.	SHWB & Sikkim	2472.7	2639.0	-6%	N
5.	Gangetic West Bengal	1520.3	1556.5	-2%	N
6.	Jharkhand	1137.8	1256.5	-9%	N
7.	Bihar	1194.7	1192.0	0%	N
	North West India	895.5	848.7	6%	
1.	East U.P.	931.6	945.0	-1%	N
2.	West U.P.	638.0	813.2	-22%	D
3.	Uttarakhand	1378.9	1494.1	-8%	N
4.	Har. Chadigarh & Delhi	356.8	534.4	-33%	D
5.	Punjab	653.2	597.4	9%	N
6.	Himachal Pradesh	1217.7	1291.2	-6%	N
7.	Jammu & Kashmir	1324.1	1263.6	5%	N
8.	West Rajasthan	403.9	308.2	31%	E
9.	East Rajasthan	993.9	657.7	51%	E
	Central India	1448.2	1105.3	31%	
1.	Odisha	1593.9	1444.2	10%	N
2.	West Madhya Pradesh	1471.4	934.0	58%	E
3.	East Madhya Pradesh	1414.6	1162.3	22%	E
4.	Gujarat Region	1278.7	960.5	33%	E
5.	Saurashtra & Kutch	905.5	539.7	68%	LE
6.	Konkan & Goa	4730.8	3051.6	55%	E
7.	Madhya Maharashtra	1550.9	889.7	74%	LE
8.	Marathwada	854.2	803.1	6%	N
9.	Vidarbha	1147.8	1069.8	7%	N
10.	Chhattisgarh	1420.3	1281.1	11%	N
	South Peninsula	1241.6	1140.8	9%	
1.	A & N Island	3086.0	2871.8	7%	N
2.	Coastal A. P. & Yanam	1011.5	1046.1	-3%	N
3.	Telangana	1031.7	956.6	8%	N
4.	Rayalaseema	744.3	725.1	3%	N
5.	Tamil., Pudu. & Karaikal	911.4	943.7	-3%	N
6.	Coastal Karnataka	4414.9	3510.1	26%	E
7.	N. I. Karnataka	900.1	720.4	25%	E
8.	S. I. Karnataka	1268.7	1032.1	23%	E
9.	Kerala & Mahe	3119.2	2924.8	7%	N
10.	Lakshadweep	2143.0	1563.4	37%	E
	Country as a whole	1288.8	1176.9	10%	

(3) Updated rainfall statistics for the SW-Monsoon - 2019 has been prepared. The rainfall for the country as a whole for the annual rainfall has been recorded as 971.8 mm against the normal rainfall for the annual as 880.6 mm (departure 10%). In all, 2 met subdivisions remained in category of Large Excess rainfall, 10 met subdivisions remained in category of Excess rainfall, 21 in Normal, 03 in Deficient rainfall and no any met subdivisions in Large Deficient and No Rain category.

Tourism Forecast Services : A new initiative

Tourism Forecast Services is a NITI Ayog approved scheme. The scheme involves the development of tourist specific services to significantly improve the "stay experience" of both domestic and international Tourist. It would help in establishing a decision support system for other stake holder like event managers, Sports enthusiast, Hospitality industry, Highway and Railway authorities etc. the services will be enhanced through Commissioning of dedicated (UV based and Met sensor based) AWS for providing site specific hourly current weather. Higher resolution NWP models will be used for generating hourly/3-hourly (for next 24 hrs) and daily (for next 3 days) forecasts of all relevant surface meteorological parameters for dissemination of the Weather information. Provision has been made for installing outdoor display screens at major tourist locations across the country. Mobile & Web apps will be developed through outsourcing for providing customized weather and Climatic advisories to tourists. Tourist centric services (like POI mapping, Routing services) to be ensured through the use of API's paid subscription for 5 years. Open street map will be used for integrating Highway Network/Rail/Road Network (Fig. 8).

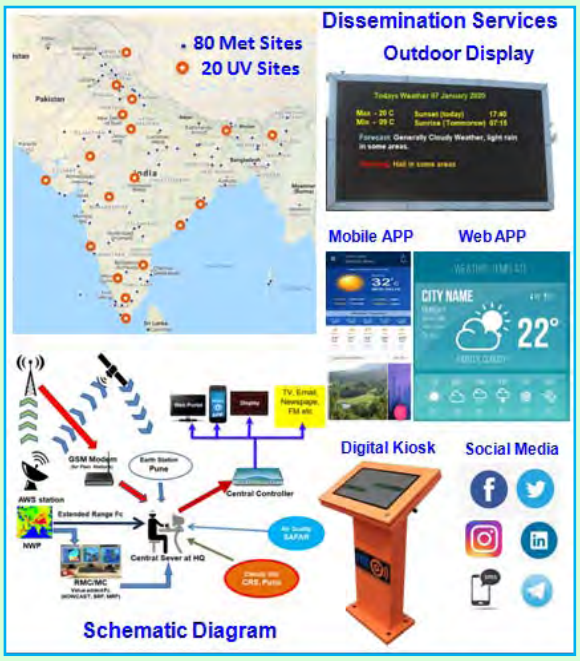


Fig. 8. Schematic diagram of Dessemination Services

5.2. Agrometeorological Advisories Services

Agrometeorological Observatories & Data Management:

(*i*) Agrimet Division maintains a network of agrometeorological observatories, dewfall and soil moisture stations. The data received through online and offline mode from these observatories are scrutinized, archived and supplied to scientists, planners etc. through NDC, Pune. Around 191 Agromet observatories are uploading on web portal of Agrimet Division.

(*ii*) Conventional Agromet Observatories at 5 AMFUs *i.e*., Agwanpur, G. Udaigiri, Pusa (RAU), Bhubaneswar, Roorkee (IIT) have been installed during the year.

(*iii*) Weather data is provided to Ministry of Agriculture for use in Kisan Suvidha app and also to NGOs and Agromet Feild Units for generation of block level AAS bulletin through web services on real time.

Weather Services under Gramin Krishi Mausam Sewa (GKMS)

a. Preparation of Agromet Advisory Service (AAS) bulletins

(*i*) AAS bulletins have been prepared and issued at district and state levels on every Tuesday & Friday and at 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 agromet advisories on field crops, horticultural crops, livestock etc. At present these bulletins are issued for 662 districts in the country.

(*ii*) IMD in collaboration with CRIDA, Hyderabad issues Operational AAS bulletin based on Extended Range Weather Forecast on every Friday to help farmers to take decision on agricultural operations and also to the planners to take policy decision.

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. Under Public Private Partnership (PPP) mode, Reliance Foundation, IFFCO Kisan Sanchar Limited (IKSL), 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, number of AMFUs have been sending agromet advisories through SMS in collaboration with Agricultural Technology Management Agency (ATMA)/KVKs. At present 40.2 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, Agromet Advisories 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:** Alerts and warning messages for the cyclones like Fani: 5937365 (Andhra Pradesh : 849809, Assam: 962312, Arunachal Pradesh: 1389, Karnataka: 66599, Odisha: 2523248, Puducherry : 10694, Tamilnadu : 646570, West Bengal: 876744), Vayu: 1767494 (Gujarat: 704279, Karnataka:

117016, Kerala: 655544, Maharashtra: 290655), Bulbul: 1819501 (Odisha: 1469608, West Bengal: 349893) and for Hailstorm: Maharashtra: 5052314 during 2019 have been issued to the farming community in the respective Agromet Field Units of the States to safeguard the crops.

c. Agromet Products

Agrimet Division has continued generation of following agromet products for operational use in AAS. All these products are being generated under PAN India mode using geospatial technology and are uploaded 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 Forecast (twice a week on Tuesday & Friday)

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

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

d. Satellite products

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

(*ii*) Reference Evapotranspiration & Insolation maps in collaboration with SAC Ahmedabad

(*iii*) Vegetation Condition Index (VCI)

(*iv*) Vegetation Health Index (VHI)

(*v*) Temperature Condition Index (TCI) (Fig. 9)

e. 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. 10).

f. Research & Development Project on AAS

(*i*) Agrimet Division, IMD, Pune in collaboration with NIC, Pune is redesigning Division's website using PHP which is user friendly and with additional features.

(*ii*) A web based Agromet-DSS-software has been developed by Agromet Advisory Services Division (AASD) of IMD in collaboration with RIMES (The Regional Integrated Multi-Hazard Early Warning System for Africa and Asia) (Fig. 11) for online generation of District and block level AAS bulletins by the scientists of AMFUs located at

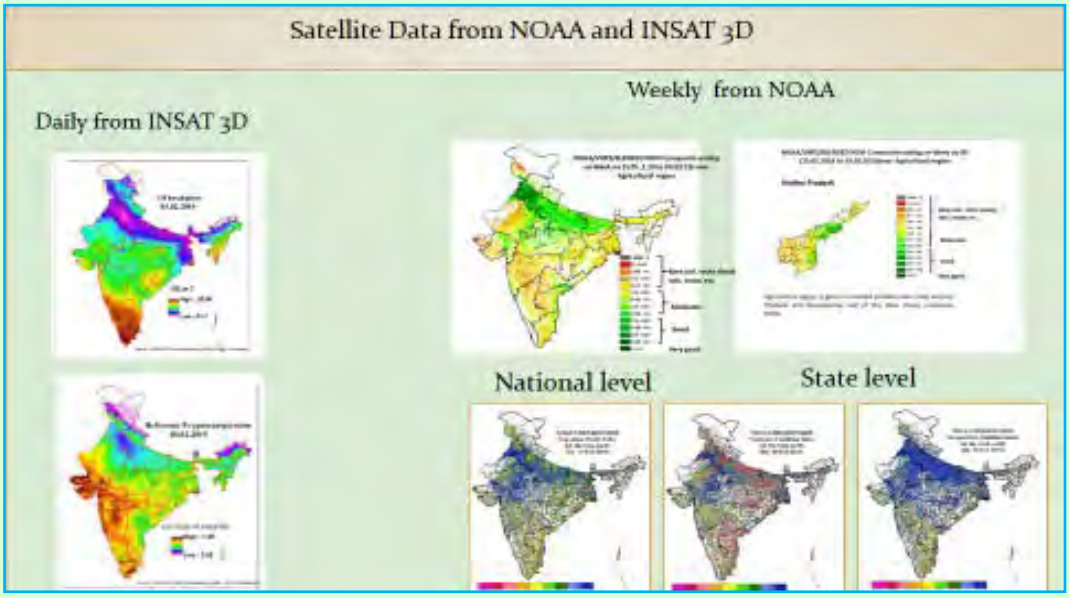


Fig. 9. Satellite Data Products

Fig. 10. Display of Spatial Weather parameters in Bhuvan Portal

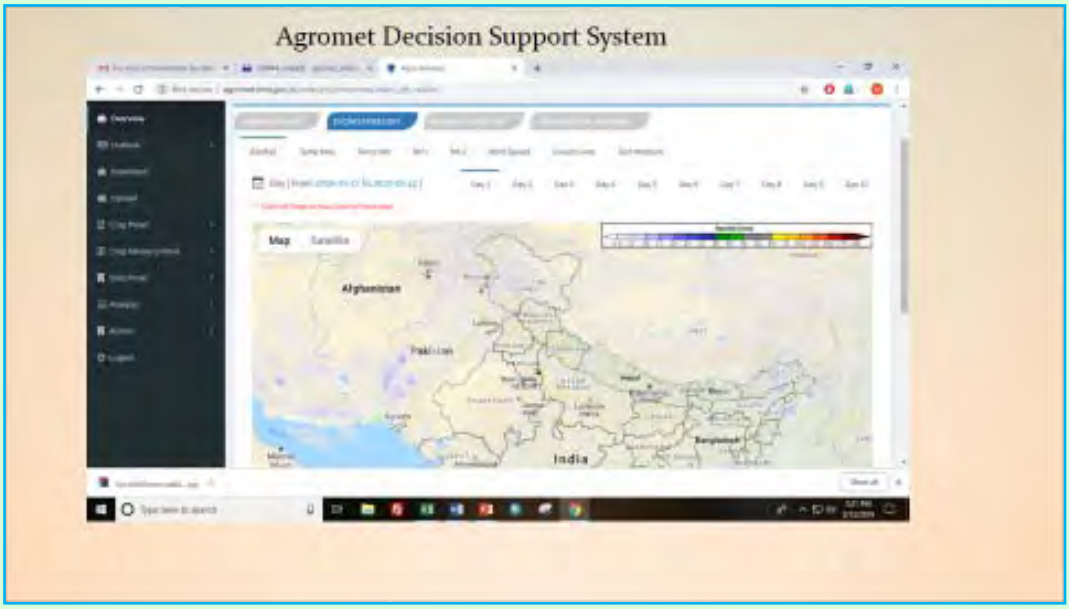


Fig. 11. Agromet Decision Support System

State Agricultural Universities, institutes of ICAR and IITs etc. Presently 25 AAS Units and 115 Agromet Field Units, 125 DAMUs are utilizing the portal for value addition of forecast and generation of district and block level weather bulletins respectively through the portal the bulletins are also being pushed to recently launched megdoot app.

g. New Initiative under Gramin Krishi Mausam Sewa (GKMS)

(*i*) India Meteorological Department (IMD) and Indian Institute of Tropical meteorology (IITM) and the Indian Council of Agricultural Research (ICAR) developed a mobile application "Meghdoot" for the dissemination of Agromet Advisories to the farmers (Fig. 12). It provides weather data and forecast relating to temperature, rainfall, humidity and wind speed and direction, which play critical role in agricultural operations and advisories to the farmers on how to take care of their crops and livestock. The information would be updated twice a week on every Tuesday and Friday. The app would provide information in the form of images, maps and pictures to help the farmers for decision making based on weather information and agromet advisories.

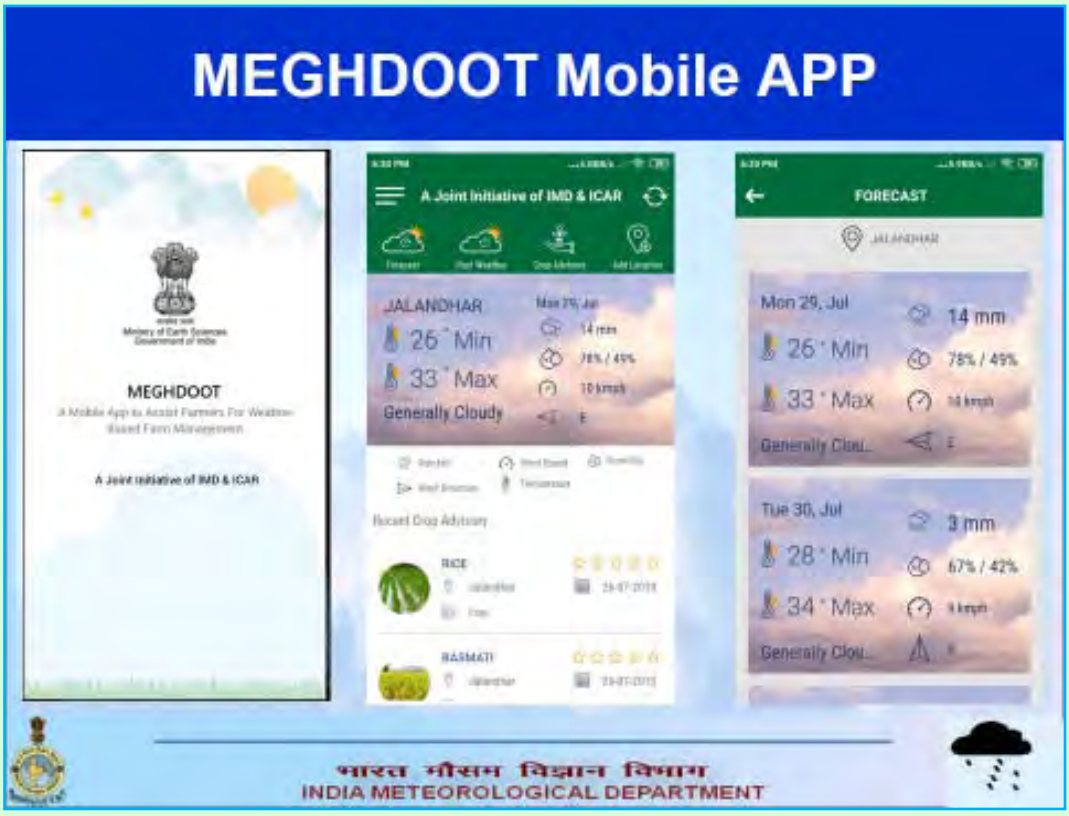


Fig. 12. Megdoot Mobile App

(*ii*) IMD in collaboration with WOTR, Pune is developing Decision Support System software for automated preparation of agromet advisories to generate locale and crop specific dynamic agromet advisories.

Implentation of District level Agromet Advisory Services through District Agro-Met Units (DAMUs) at KVKs in the Country

In order to empower the farmers with weather based agromet advisory customized at block level, IMD and ICAR are jointly extending the network to District level by setting up of District Agro-Met Units (DAMUs) at Krishi Vigyan Kendras (KVKs) in 530 districts in addition to existing 130 AMFUs. Each DAMU at KVK will be facilitated with (*i*) one Automatic Weather Station (AWS) to record changes in weather, (*ii*) Two manpower: one Subject Matter Specialist-Agrometeorology (SMS-Agrometeorology) and one Observer, (*iii*) Expert Panel consisting of Subject Matter Specialists at KVK and District Level Head of State Department of Agriculture to prepare agormet advisory at block level and (*iv*) dissemination platforms including mKisan portal for sending Agromet SMS to farmers. IMD and ICAR are jointly implementing the setting up of DAMUs at KVKs in phased manner. Till March 2020, recruitment of manpower at 153 DAMUs are completed and 125 DAMUs started to prepare block level agromet advisory bulletins in experimental mode for around 2000 blocks and disseminating through state extension services and social media (whatsapp) to selected villages and farmers.

Crop Yield Forecasting Under FASAL Scheme

Under the FASAL (Forecasting of Agricultural Output using Space Agrometeorology and Land based observation) project of Ministry of Agriculture & Farmers Welfare, IMD in coordination with 47 Agromet Field Units of FASAL network forecasted crop yield of 14 major mandate crops. Theses forecast are based on statistical models and crop simulation model based and forecasting has been carried out at 3 phenological phases in advance and provided to Ministry of Agriculture.

Economic Impacts of the Agrometeological Services

It has been reported by the farmers under different AMFUs that the weather forecast and agromet advisories are helping them in day to day farm operations like sowing, irrigation scheduling, fertilizer and pesticide applications etc. Special advisories, alerts and warnings issued during extreme weather events like heavy rain, cold wave, heat wave, hail storms etc. also helped them in minimizing the loss.

New Initiative under Gramin Krishi Mausam Sewa (GKMS)

Agrimet Division has taken special initiative under the GKMS to make agromet advisories more precise and accurate and reach maximum number of agriculture dependent farming households like:

(*i*) *Implementation of Block level AAS in the country* : After successful implementation of district level AAS, IMD in collaboration with Indian Council of Agricultural Research (ICAR) is venturing into implementation of block level weather forecast and Agromet Advisories. District Agromet Units (DAMUs) are being established in Krishi Vigyan Kendras (KVKs) under ICAR network in a phase-wise manner for rendering block level AAS. So far, 138 DAMUs have been established. Short term training programmes were conducted on "Preparation and Dissemination of Agromet Advisories at Block level under Gramin Krishi Mausam Seva (GKMS) scheme" for Subject Matter Specialists (SMS) and Observers of Krishi Vigyan Kendras (KVKs) under various ATARI zones of ICAR at New Delhi (29 July-3 August), Kolkata (6-11 August), Jorhat (26-31 August), Solapur (19-24 August), Hyderabad (14-19 October) and Jabalpur (20-25 November).

(*ii*) Experimental Block Level Agro Advisories: A total 1623 Experimental Block level advisories have been issued by both Agromet Field Units and District Agromet Units. (AMFUs:- 954 and DAMUs:-669) during 2019.

(*iii*) Agrimet Division, IMD, Pune in coordination with State Department of Agriculture, Government of Maharashtra and Agromet Field Units (AMFUs) in Maharashtra organised Video Conference to discuss southwest monsoon status and decision of *kharif* sowing and further crop management based on weather during SW monsoon 2019.

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 2019

(*i*) The Indian Astronomical Ephemeris for the year 2020, 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.

(*ii*) Fourteen language editions of Rashtriya Panchang of 1941 SE (2019-20 AD) and Sunrise-Sunset and Moonrise - Moonset tables for 2020 have been published during the year 2019. These are important regular publications of the centre catering to daily need of users of almanac, Panchang makers and other users.

(*iii*) Web based service has been continued 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.

(*iv*) A pocket-type, card-size calendar containing brief information on important celestial events during the year 2020 has been published for benefit of users.

(*v*) The centre has prepared monthly star charts and astronomical bulletins for 12 months during the year 2019 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.

(*vi*) An observation on solar eclipse of 26th December, 2019 has been done for general public from the roof top of PAC building by setting portable telescope as a part of outreach programme (Fig. 13).

Fig. 13. Observation on Solar Eclipse of 26th Dec., 2019 from the rooftop of PAC Kolkata building

5.4. 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.

From 2017, forecasts are also prepared based on coupled forecasting system (CFS) developed under MoES's monsoon mission (MM) or MMCFS. These forecasts are prepared by the Climate Monitoring and Prediction Group in the Office of Climate Research & Services, IMD, Pune.

The original model frame work of MMCFS was developed by the National Centers for Environmental Prediction (NCEP), USA. The model was modified to provide better forecast over Indian monsoon region through mission mode research work by the Indian Institute of Tropical Meteorology (IITM), Pune in collaboration with various climate research

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

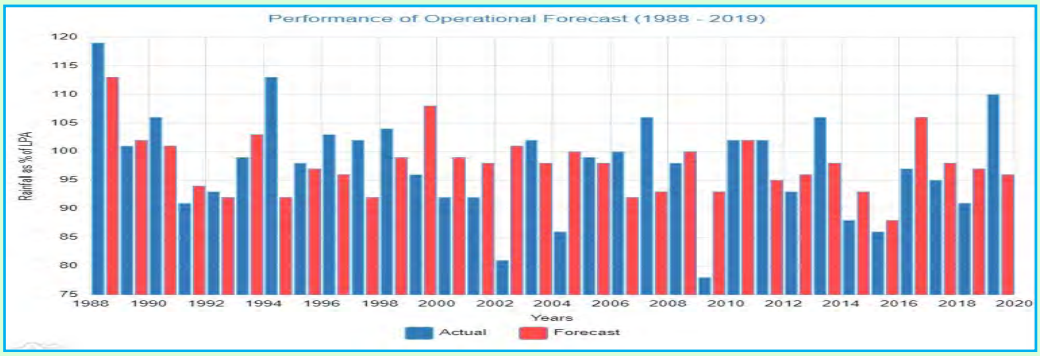


Fig. 14. Performance operational forecast (1988-2019)

TABLE 3

Verification of Long Range Forecast for 2019 Winter Season

Forecast	Actual
The 2019 winter season (Jan to March) rainfall over north India is most likely to be above normal [>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	Winter Winterrainfall in North India during the period January to March 2019 is above normal (> 115 of the LPA)

centers from India and abroad. The latest version of the high resolution [horizontal resolution of approximately 38 km (T382)] MMCFS for the seasonal forecasting of monsoon rainfall was implemented at the Office of Climate Research and Services, IMD, Pune.

In 2019, MMCFS 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).

The details of the various long range forecasts issued by IMD and their verification are discussed in this report. The Performance operational forecast (1988-2019) is shown in Fig. 14.

Verification of Operational Long Range Forecasts

(i) Winter Season (January to March, 2019) Precipitation over North India

The LRF for the 2019 winter season (January to March) rainfall over north India was prepared in the last week of December 2018. 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 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.

Table 3 shows the summary of the verification of the long range forecasts issued for the 2019 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 and thermal stress.

India Meteorological Department (IMD), Ministry of Earth Sciences (MoES) has been issuing seasonal forecast outlooks for subdivision scale temperatures over the country for both hot and cold weather seasons based on predictions from the Monsoon Mission Coupled Forecasting System (MMCFS) Model developed under MoES's monsoon mission project. The model climatology was prepared using retrospective forecasts generated for 28 years (1982-2010). The model hindcasts and forecasts were bias corrected using the probability distribution function (pdf) method.

The forecast for 2019 pre-monsoon season (March to May) was prepared using 33 ensemble member forecasts, based on the 2019 February initial conditions. IMD had issued the following seasonal forecast for March to May (MAM) 2019. The March to May, 2019 season averaged temperatures are likely to be normal over most of the subdivisions except a few subdivisions of Northwest India, Northeast India and southern part of west coast where above normal temperatures are most likely. The season averaged maximum temperatures in Himachal Pradesh, West Rajasthan, Konkan, Goa, Coastal Karnataka, Kerala and Arunachal Pradesh are likely to be warmer than normal by 0.5 °C to 1 °C. Normal to slightly above normal heat wave conditions are likely in the core heat wave zone during the season. The orecast of MAM 2019 could correctly indicate higher temperatures observed over south Peninsula. However, the observed maximum, minimum and mean temperature anomalies over some subdivisions of north and north-east India were relatively lower than that of issued forecast for MAM season.

IMD had issued seasonal forecast for Hot Weather Season (April to June) using 38 ensemble member forecasts from MMCFS based on the 2019 February initial conditions. The summary of outlook was as follows; The April to June (AMJ) season average maximum temperatures are likely to be warmer than normal by 0.5 °C over most of the meteorological subdivisions from central India and some sub-divisions from northwest India. Near normal maximum temperatures are likely in the remaining sub-divisions. The seasonal average minimum & mean temperature s over West Rajasthan are likely to be above normal by more than 1.0 °C. Above normal heat wave conditions are likely in the core heat wave (HW) zone during the season. The forecast of AMJ 2019 could correctly indicate higher temperatures observed over most parts of the country. However, the observed maximum and mean temperature anomalies over some subdivisions of north-east India were relatively higher than that of issued forecast for MAM season.

The sub-division wise maximum, minimum and mean temperatures forecast issued by IMD for the 2019 Hot weather season (April to June) is shown in Fig. 15.

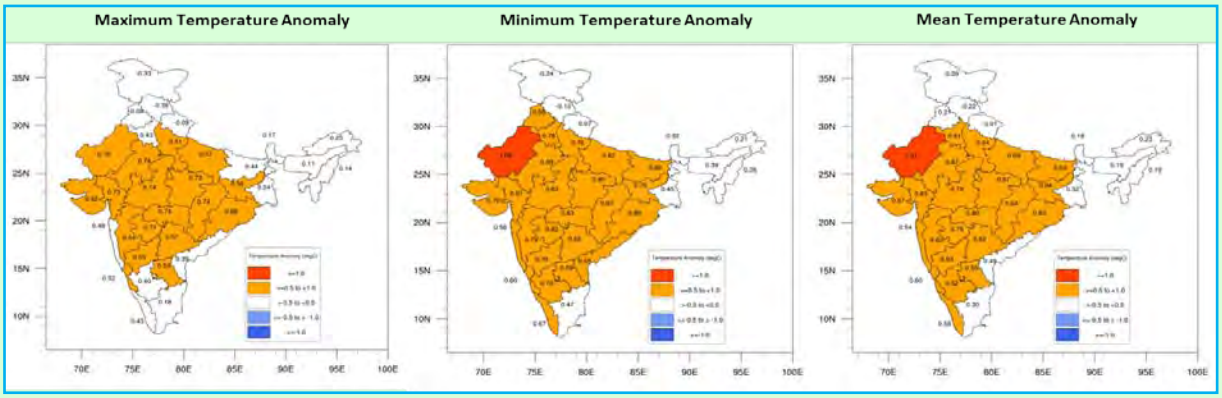


Fig. 15. Subdivision wise maximum, minimum and mean temperatures anomaly forecast duing 2019

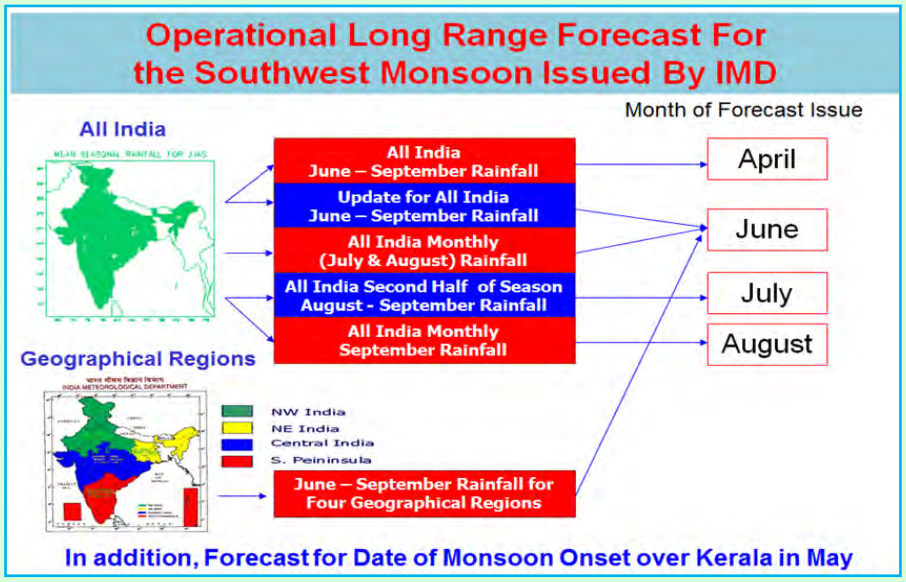


Fig. 16. Schematic diagram showing various operational forecasts for the southwest monsoon rainfall issued by IMD

(iii) Southwest Monsoon Season (June to September, 2019) Rainfall

Long range forecasts were issued seasonal rainfall over the country as a whole and for seasonal rainfall over four geographical regions (Northwest India, Central India, Northeast India and South Peninsula) and for monthly (for July, August), second half (August + September) 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. 16). The forecast for monsoon onset over Kerala for this year was forecasted on 6th June ± 4 days and the monsoon onset over Kerala took place on 8th June and it was correct. Thus the operational forecast for the monsoon onset over Kerala has been correct (within the forecast limits) during 14 of the 15 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. Table 4 gives the summary of the verification of the long range forecasts issued for the 2019 Southwest Monsoon.

(iv) Northeast Monsoon Rainfall over South Peninsula (October to December, 2019)

The long range forecast for the 2019 NE monsoon season (October to December) rainfall over South Peninsula and Tamil Nadu was issued in the last week of September 2019. The south Peninsula consisting 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

TABLE 4

Verification of the operational forecast issued for the 2019 southwest monsoon rainfall

Region	Period	Forecast (% of LPA)			Actual Rainfall (% of LPA)
		15th April	31st May	1st August	
All India	June to September	96 ± 5	96 ± 4	96	110
Northwest India	June to September		94 ± 8		98
CentralIndia	June to September		100 ± 8		129
Northeast India	June to September		91 ± 8		88
South Peninsula	June to September		97 ± 8		116
All India	July		95 ± 9		105
All India	August		99 ± 9		115
All India	August to September			100± 8	130

TABLE 5

Verification of the long range forecasts issued for the 2019 northeast monsoon season

Region	Long Range Forecast	Actual
South Peninsula	The 2019 NE monsoon (Oct-Dec) rainfall is most likely to be above normal (>111% of LPA)	The 2019 NE monsoon (Oct-Dec) rainfall was **109%** of LPA
Tamilnadu	The 2019 NE monsoon (Oct-Dec) rainfall is most likely to be normal above normal (≥112% of LPA)	The 2019 NE monsoon (Oct-Dec) rainfall was **101%** of LPA

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) 2019 Cold weather Season (December to February) Temperatures

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

IMD had issued Seasonal outlook for the subdivision averaged temperatures for the last cold weather season [December 2019 to February 2020 or (DJF 2019-2020)] on 30th November, 2019 based on IMD's Monsoon Mission Coupled Forecasting System (MMCFS) Model developed under MoES's monsoon mission project. The forecast was prepared using 36 ensemble member forecasts.

The summary of forecast was the upcoming winter season (DJF) is likely to experience warmer tha n average season minimum temperatures over most parts of the country except over north ern most parts of India. Cold Wave (CW) conditions over core CW zone of the country during the season have climatological probabilities (equal probabilities for all three categories). The observed temperatures (maximum, minimum and mean) during the cold weather season over most of the subdivisions from peninsular India were in accordance with temperature forecast outlook issued. However, observed maximum and mean temperatures over many of the sub divisions from north and central India were below normal in place of normal temperature forecast. The sub-division wise maximum, minimum and mean temperatures forecast issued by IMD for December-February is shown in Fig. 17.

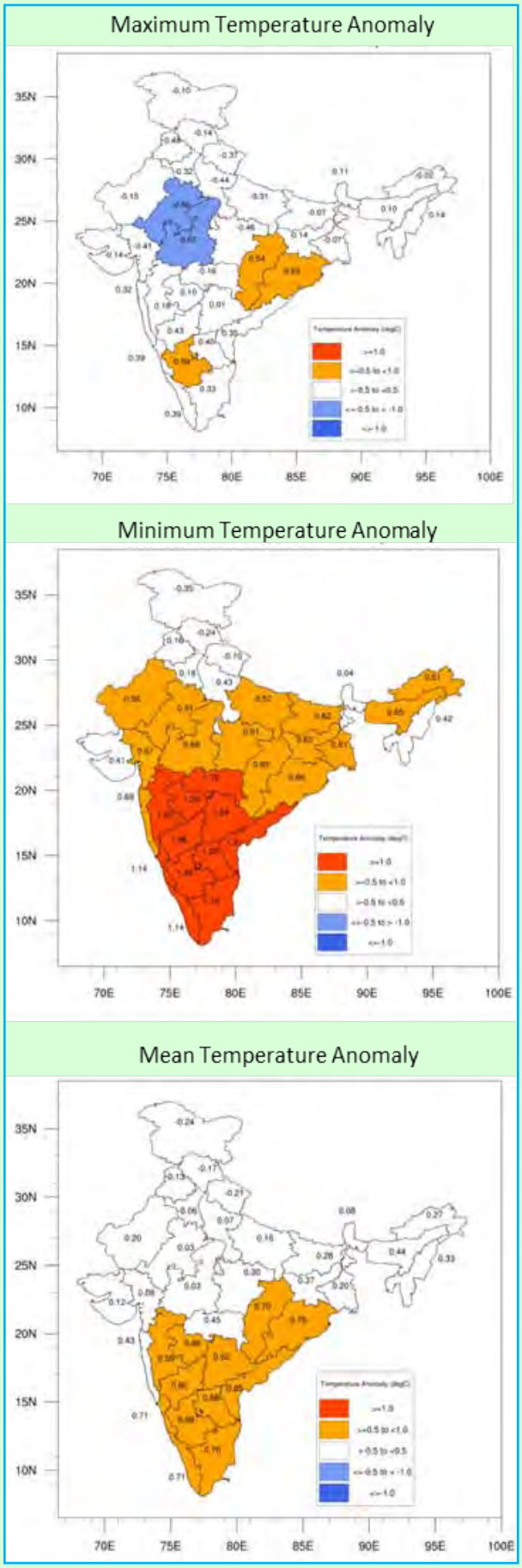


Fig. 17. Subdivision wise maximum, minimum and mean temperatures forecast issued by IMD for the 2019 cold weather season (December to February)

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 RCC long range forecasting activities.

(a) Generate global monthly and seasonal (anomaly and probability) 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 2020 JFM & FMA seasons issued in Dec 2019 is shown in the Figs. 18(a&b) and 19(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 December 2019 for Nino 3.4 and IOD plumes is shown in the Figs. 20(a&b). The corresponding probability forecast is given in Figs. 21(a&b).

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

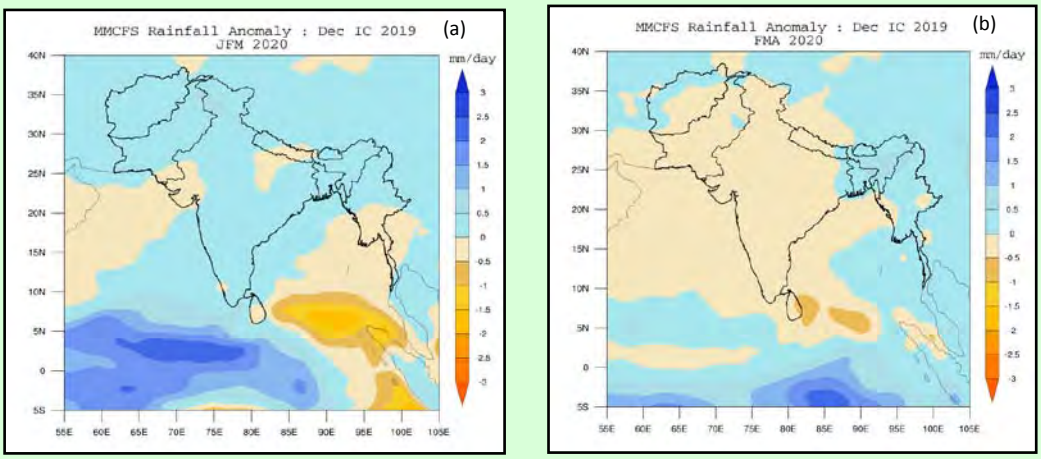
Future Plans

- Improve the skill of existing operational statistical long range forecasting system.

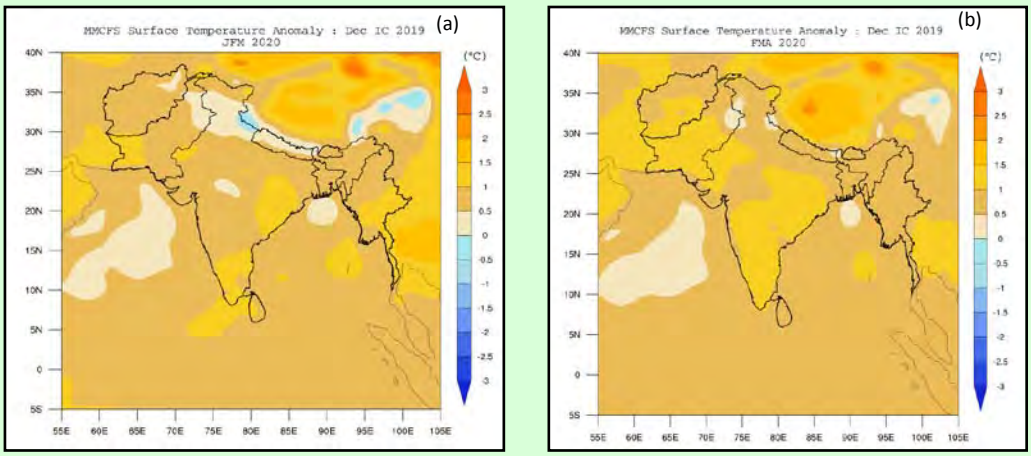
- Develop Multi-model ensemble (MME) based seasonal prediction system for sub-divisional forecast.

- Develop tools for sector specific climate prediction products.

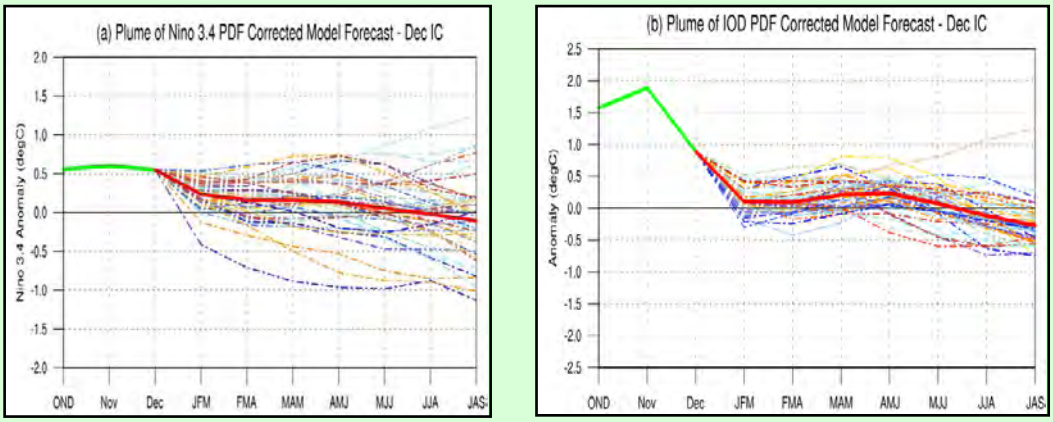
- Develop tools for verification of quantitative and probabilistic climate hindcasts and forecast products.



Figs. 18(a&b). Seasonal forecasts of precipitation anomalies (mm/day) for (a) JFM and (b) FMA based on Initial conditions of December 2019

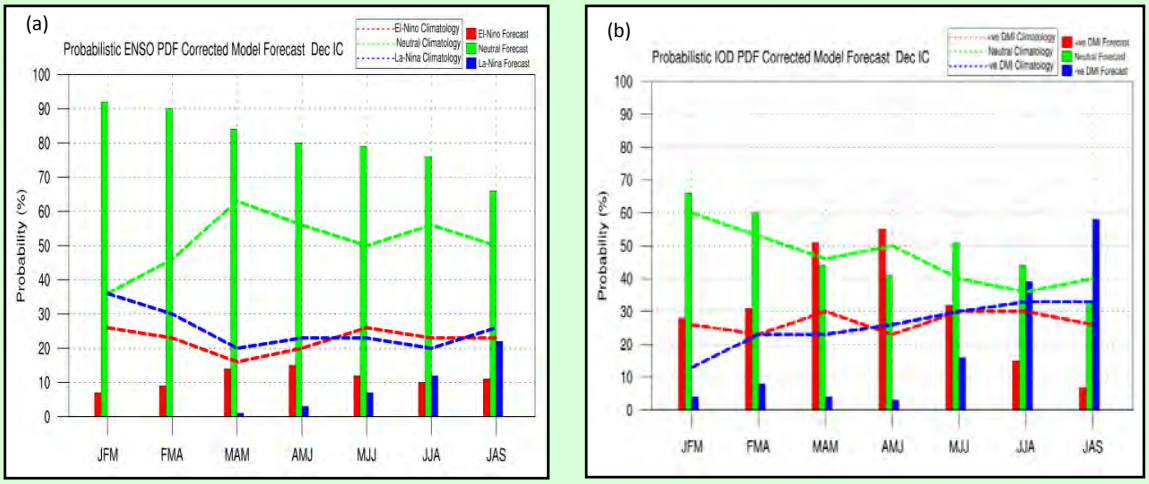


Figs. 19(a&b). Seasonal mean temperature anomalies (°C) for (a) JFM and (b) FMA based on Initial conditions of December 2019



Figs. 20(a&b). PDF Corrected Model Forecast using December IC (a) Plume of Nino 3.4 and (b) Plume of IOD

- 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.
- 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.



Figs. 21(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 V5. 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

(*vi*) Climate Monitoring & Annual Climate Statement

Climate over India during 2019 was above average with respect to temperature. The annual mean temperature for the country this year was +0.36 °C above the 1981-2010 average. Higher mean temperatures during the pre monsoon season (Mar-May, with anomaly 0.39 °C and monsoon season (Jun-Sep, with anomaly 0.58 °C, warmest since 1901) mainly accounted for the above normal annual temperature for the year.

Rainfall during the principal rainy season [Southwest (summer) monsoon season (June-September)] for the country as a whole was normal [110% of Long Period average (LPA)]. The seasonal rainfall during the Northeast monsoon season (October - December) over the NE Monsoon core region of the south peninsula was 109% of its LPA.

Temperatures

The annual mean temperature for the country was +0.36 °C above the 1981-2010 average, thus making the year 2019 as the seventh warmest year on record since 1901 (Fig. 22). The other 9 warmest years on record in order were: 2016 (anomaly +0.71 °C), 2009 (0.55 °C), 2017 (0.54 °C), 2010 (0.539 °C), 2015 (0.42 °C), 2018 (0.40 °C), 1958 (0.25 °C), 2002 (0.246 °C) and 2014 (0.24 °C).

It may be mentioned that 11 out of the 15 warmest years were from the recent past fifteen years (2005-2019). In addition, the past

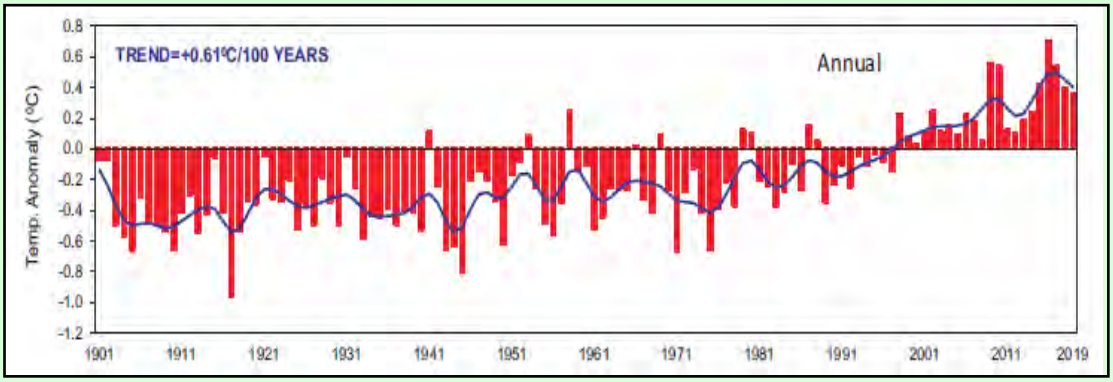


Fig. 22. Annual mean land surface air temperatures anomalies averaged over India for the period 1901-2019. The anomalies were computed with respect to base period of 1981-2010. The solid blue curve represents the sub-decadal time scale variation smoothed with a binomial filter

decade (2001-2010/2010-2019) was the warmest decade on record with anomalies of 0.23 °C / 0.36 °C above average. During 1901-2019, the annual mean temperature showed an increasing trend of 0.61 °C/100 years with significant increasing trend in the maximum temperature (1.0 °C /100 years) and relatively lower increasing trend (0.22 °C/100 years) in the minimum temperature.

Rainfall

Rainfall activity over the country as a whole was above normal (110% of LPA) during the year. Out of 36 meteorological subdivisions, two sub-division Saurashtra & Kutch and Madhya Maharashtra received large excess rainfall, 10 received excess rainfall, 21 received normal rainfall and remaining 3 subdivisions received deficient rainfall. At the end of year, of the four homogeneous regions, central India received 131%, south peninsular India received 109% and Northwest India received 106% of their respective LPA rainfall. While, East & Northeast India received 88% of their respective LPA rainfall.

High Impact Weather Events

During 2019, eight cyclonic storms formed over the north Indian Ocean. Out of these 8 systems, one system each formed during the winter (Cyclonic Storm "Pabuk") and pre-monsoon season [Extremely Severe cyclonic Storm (ESCS), "Fani"] over the Bay of Bengal. The significant weather events during 2019 & associated loss of lives are shown in Fig. 23.

The ESCS "Fani" which formed during premonsoon season, crossed the Odisha coast near Puri on 3rd May and claimed over 64 lives from different districts of the state. The monsoon season too witnessed 2 very severe cyclonic storms (VSCS) "Vayu" and "Hikka" over Arabian Sea in the month of June and September respectively. Of these, the cyclonic storm "Vayu" dissipated before crossing Gujarat coast and the cyclonic storm "Hikka" moved away from the Indian region and crossed the Oman coast. During the post-monsoon season, 3 systems formed over the Arabian Sea and 1 system over the Bay of Bengal.

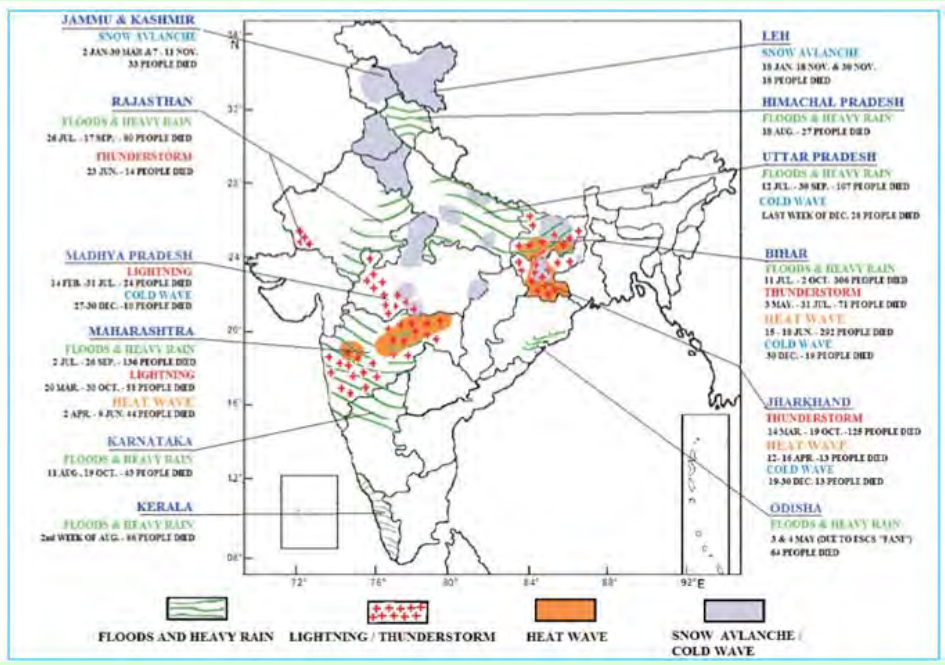


Fig. 23. Major extreme weather events occurred during 2019

The super cyclonic storm "Kyarr", ESCS "Maha" and the CS "Pawan" did not have landfall over the Indian region. The VSCS "Bulbul" which formed over the Bay of Bengal, skirted the West Bengal coast close to Sunderbans forest on 9th November, 2019.

Heavy rain & flood related incidents reportedly claimed over 850 lives from different parts of the country during the pre-monsoon, monsoon & post-monsoon seasons. Of these, 306 lives were reported from Bihar alone, 136 from Maharashtra, 107 from Uttar Pradesh, 88 from Kerala, 80 from Rajasthan and 43 from Karnataka. Heat wave conditions which prevailed over the northeastern & central parts the country during the period March to June claimed about 350 lives. Of these, 293 lives were reported from the worst affected state of Bihar alone during June and 44 lives were reported from Maharashtra. Lightning & Thunderstorm reportedly claimed over 380 lives from central, northeastern, northwestern and peninsular parts of the country during pre-monsoon, monsoon & post-monsoon seasons. Of these, 125 lives were reported from Jharkhand, 73 from Bihar, 51 from Maharashtra and 24 each from Madhya Pradesh & Rajasthan. Snowfall and avalanche related incidents claimed 33 lives from Jammu & Kashmir & 18 from Leh. Cold wave claimed 70 persons from northern parts of the country during 15-31 December, 2019. Of these, 28 lives were reported from Uttar Pradesh, 19 from Bihar, 13 from Jharkhand & 10 from Madhya Pradesh.

Drought Monitoring and Prediction

Drought Monitoring and Prediction is being done using different indices like SPI (Standardized Precipitation Index), AAI (Aridity Anomaly Index) and SPEI Drought monitoring using Aridity Anomaly Index (AAI). The SPI maps are being generated every week as well as every month to identify the regions with prevailing or beginning/ending of the extremely/severely/moderately dry/wet conditions. The detailed statistics of the SPI computed for the entire SW monsoon period helps the various state government agencies for initiating drought management. Weekly SPI maps and values is being sent to all the state authorities as demanded by them according to new Drought manual of Ministry of Agriculture (Figs. 24-26).

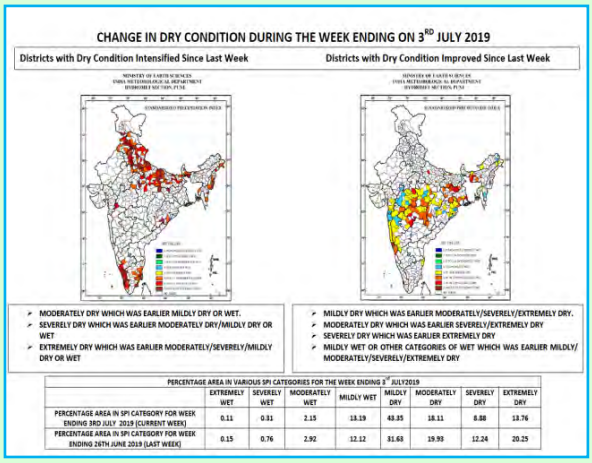
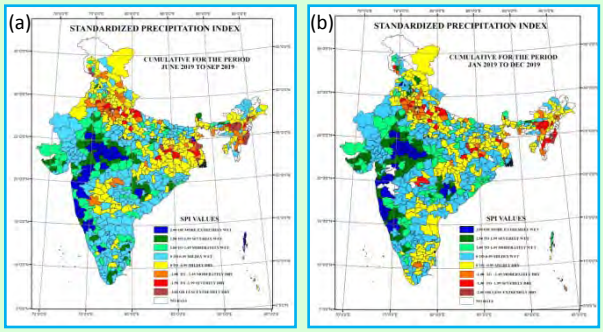


Fig. 24. Change in dry/ wet condition



Figs. 25(a&b). SPI for (a) Jun-Sep 2019 (b) Jan-Dec 2019

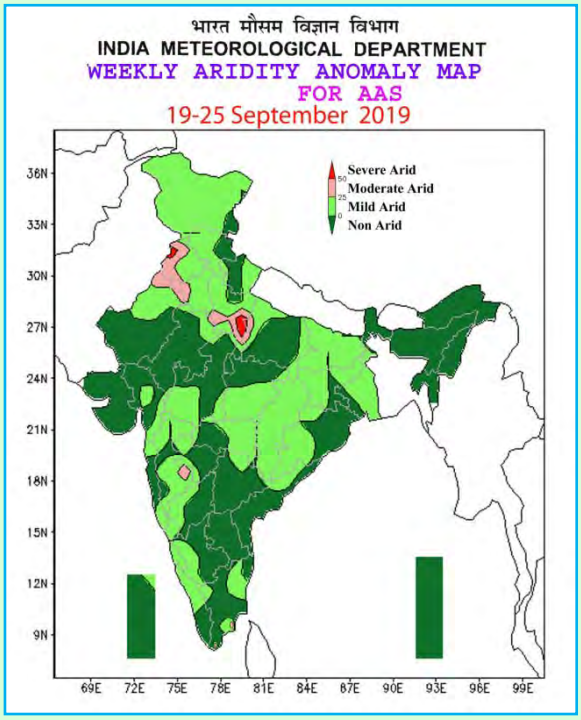
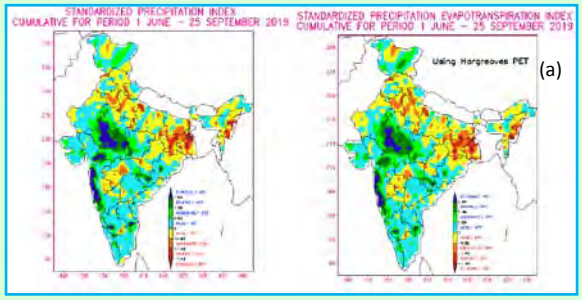
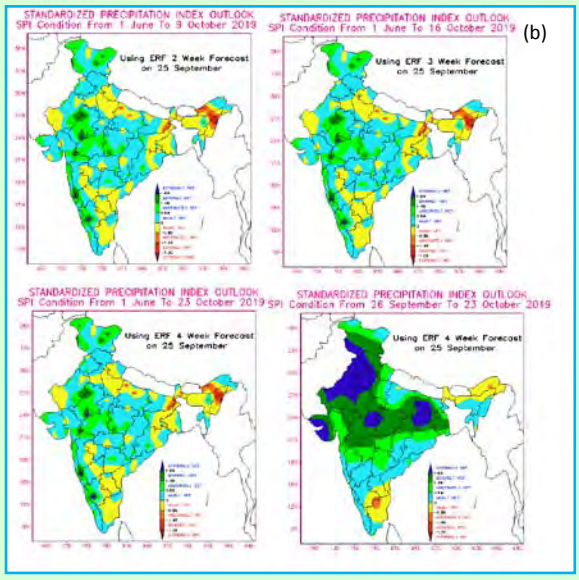


Fig. 26. Weekly Aridity Anomaly map

Weekly Drought monitoring using Standardized Precipitation Evaporation Index (SPEI) has been done in the year 2019. Prediction of one week advance SPI and AAI maps is being done during SW monsoon and NE monsoon using

IMD GFS district rainfall forecast. SPI Forecast maps for one week to four weeks are also being generated using ERFS data [Figs. 27(a&b)].





Figs. 27(a&b). (a) Cumulative weekly SPI and SPEI based on gridded data (b) Cumulative weekly SPI outlook based on gridded data

Climate services for water sector

Weekly monitoring and prediction of basin averaged rainfall and volume of water for 101 river sub basins of India based on ERF is being

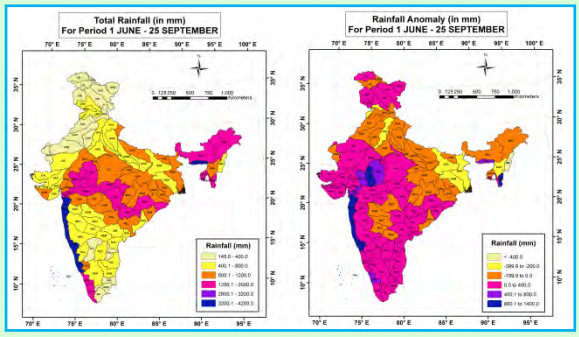


Fig. 28. Actual rainfall and rainfall anomaly

started in the year 2019 and are being regularly uploaded in IMD Pune website (Figs. 28&29).

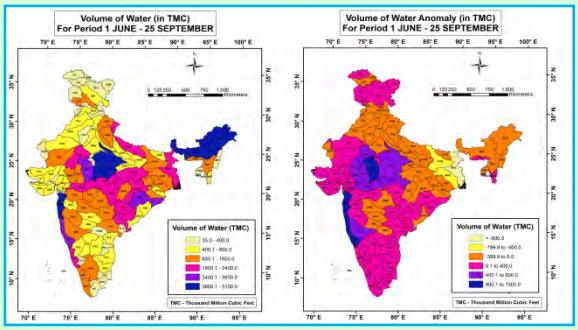


Fig. 29. Volume of water and anomaly

Climate services for Health sector

Climate information for Health bulletin *viz*., temporal evolution of spatial distribution of transmission window for Vector borne disease & probabilistic outlook about prevalence of climatic suitability for VBD occurrence based on extended range weather forecast on weekly basis started in May 2nd week 2017 is continued on every Friday. The regions which are likely to get maximum/minimum temperature within threshold maximum/minimum temperature of above VBD transmission windows during succeeding two weeks are indicated.

(*vii*) 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. The total holding of meteorological data at the data centre as of date is 5045.64 lakh records of which around. During the year 2019, NDC received 2045 (including 2 foreign parties) queries and requests for data supply from various parties that include Government, private institutions, industries, research and operational users. On receipt of requests, the required data were retrieved from the computer archives, within short time and supplied to the users on CDs, in the desired formats, following the usual formalities as per department policy. During the period, Rs.23,18,91,079 records were retrieved and supplied to different users. In the current year, 85 educational/research institutes have registered with IMD for supply of data for academic and research purposes. An amount of INR 63,24,181 and US $ 581 has been earned by sale of data.

(*viii*) Highlights of the year, 2019

(*i*) "Climate information for Health based on ERF Products" being prepared weekly on experimental basis (*ii*)Climate of 82 Smart Cities are uploaded on the official website (*iii*) Preparation of climate of cities in respect of Additional 67 important cities is in progress. (*iv*) Seasonal Outlook update for the temperatures during the Hot Weather Season (*v*) The first stage forecast for the 2019 SW monsoon rainfall for the country as a whole is issued on 15th April, 2019 (*vi*) SW monsoon seasonal (Jun-Sep) rainfall over the country as a whole is likely to be near normal (*vii*) The forecast for the date of monsoon onset over Kerala was issued on 15th May, 2019 (*viii*) LRF Update for 2019 SW Monsoon Rainfall was issued on 31st May, 2019 (*ix*) Forecast for the Rainfall during the Second Half (August - Sept.) was issued on 1st August, 2019 (*x*) The temperature Outlook, Climate forecast outlook for temperature and rainfall over South Asia for 2019-2020 Winter Season (DJF) for India were issued

5.5. Cyclone Monitoring & Prediction

5.5.1. Annual Characterstics of Cyclonic disturbances during 2019

The year, 2019 was an exceptional year with respect to cyclonic activity over the North Indian Ocean (NIO) with development of more frequent and more intense cyclones over the NIO. The Arabian Sea (AS) was more active as compared to the Bay of Bengal (BoB). In all 12 cyclonic disturbances (CDs) developed over the north Indian Ocean (NIO) including 4 over the BoB and 8 over the AS during the year 2019 against the normal of 12 CDs per year over the NIO. The maximum of 18 CDs have been observed in a year over the north Indian Ocean during 1925 and 1975. Thus, the current frequency of 12 CDs is still less than the maximum. Year 2019 witnessed 8 cyclones (3 over BoB and 5 over AS) and 4 depressions/deep depressions (1 over BoB and 3 over AS). Out of 5 cyclones over the AS, 4 were severe & above intensity cyclones and out of 3 cyclones over BoB, 2 were severe & above intensity cyclones. The maximum number of 10 cyclones developed over the north Indian Ocean during 1893 and 1930. The maximum number of 5 cyclones with 4 severe cyclones developed over AS during 1902. Thus, the frequency of cyclones over north Indian Ocean during 2019 is still less than the maximum of 10 cyclones observed in past. The frequency of cyclones and severe cyclones over the AS during the year 2019 as a whole matches the frequency during 1902.

The year 2019 also witnessed development of more intense cyclones over the Arabian Sea, as out of 5 cyclones, there have been 1 super cyclonic storm (Kyarr), 1 extremely severe cyclonic storm (Maha), 2 very severe cyclonic storms (Vayu, Hikaa) and 1 cyclonic storm (Pawan). The activity over the Bay of Bengal has been subdued this year as compared to Arabian Sea with the formation of only 3 cyclones (Pabuk, Fani, Bulbul) against the normal of 4 per year. Out of these, there were two severe cyclones (Fani & Bulbul) against the normal of 2 per year. Comparing the post and pre-monsoon cyclone seasons, the post-monsoon cyclone season has been more active over the Arabian Sea and subdued over the Bay of Bengal with the formation of 5 CDs over the Arabian Sea against normal of 0.8 per year. The BoB witnessed development of 1 CD against normal of 3.5 per year during post monsoon season. Three cyclones formed over the AS against normal of 0.6 per year and 1 cyclone over the BOB against normal of 2.1 per year. Thus, the frequency of CDs observed over the Arabian Sea during 2019 post monsoon season exceeds the past record of 1982 and 2011 when 4 CDs developed in the post monsoon season. It equals the past record of 1902 post monsoon season with formation of 3 cyclones including 2 severe cyclones. Out of eight cyclones over the NIO in 2019, there were 5 landfalling cyclones namely Pabuk, Fani, Hikaa, Bulbul and Pawan. Pabuk crossed Andaman Islands as deep depression, Fani crossed Odisha coast as an extremely severe cyclonic storm, Hikaa crossed Oman coast a very severe cyclonic storm, Bulbul

crossed West Bengal coast as a severe cyclonic storm and Pawan crossed Somalia coast as a Cyclonic Storm.

The cyclonic storm, Pabuk was the first cyclone to cross the Andaman Sea as deep depression. The year 2019 also witnessed development of super cyclonic storm (SuCS), Kyarr which was the 7th super cyclonic storm over NIO during the period 1965-2019. It was the second SuCS over Arabian Sea during this period after cyclone Gonu in June, 2007. However, Gonu crossed Oman coast as a very severe cyclonic storm while Kyarr weakened over the Arabian Sea. The year 2019, also witnessed a prolonged 19 days of continuous cyclone activity with development of three consecutive cyclones during 24 October-11 November namely Kyarr (24 October-2 November), Maha (30 October-7 November) and Bulbul (5-11 November) over AS and BoB. During 2019, seven out of eight cyclones (all including Pabuk, Vayu, Fani, Kyarr, Maha, Bulbul & Pawan except Hikaa) had recurving track.

Based on preliminary analysis, the enhanced cyclonic activity over the Arabian Sea may be attributed to the following factors:

(*i*) The above normal sea surface temperatures (SST) and favourable vertical wind shear between upper and lower tropospheric levels.

(*ii*) The positive Indian Ocean Dipole (IOD) over Equatorial Indian Ocean (EIO) (*i.e.*, warmer SST over the west EIO near Somalia coast and relatively colder SST over east EIO near Indonesia). The positive IOD is favourable for enhancing the convective activity and the lower level convergence of winds over the Arabian Sea.

(*iii*) Favourable Madden Julian Oscillation (MJO) prevailed with the enhanced phase of convection lying over the west EIO and adjoining Arabian Sea. Climatologically, about 60% of the genesis can be attributed to favourable MJO conditions.

(*iv*) The active northeast monsoon conditions prevailed during the season leading to seasonally excess rainfall activity over India as on date. The active northeast monsoon conditions help in increasing the moisture upto middle troposphere over the Arabian Sea. Also, the atmosphere becomes more unstable over the Arabian Sea, during such situation.

These cyclones are:

- ***Cyclonic Storm PABUK over Andaman Sea (04-08 January)***
- ***Extremely severe cyclonic storm FANI over the BoB (26 April-04 May)***
- ***Very severe cyclonic storm VAYU over the AS (10-17 June)***
- ***Very severe cyclonic storm HIKAA over the AS (22-25 September)***
- ***Super Cyclonic Storm KYARR over the AS (24 October-02 November).***
- ***Extremely severe cyclonic storm MAHA over the AS (30 October-07 November).***
- ***Very severe cyclonic storm BULBUL over the BoB (05-11 November)***
- ***Cyclonic Storm PAWAN over the AS (02-07 December)***

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

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

5.5.2. Characterstics of Cyclonic Storms during 2019

5.5.2.1. Cyclonic Storm, Pabuk

Cyclonic Storm (CS) Pabuk originated from a low pressure area (LPA) which formed over south China Sea on 28th December, 2018. Under favourable environmental conditions, it

concentrated into a tropical depression on 31st December, 2018. At around 0600 UTC of 1st January, it further intensified into a tropical storm "Pabuk" [Name given by Japan Meteorological Agency (JMA)]. It emerged into the north Indian Ocean region over Andaman Sea in the morning of 5th January, 2019. It moved west-northwestwards, weakened gradually into a deep depression around noon (0600 UTC) and crossed Andaman Islands near 11.6° N/92.7° E, close to south of Port Blair during night (between 1300 and 1500 UTC) of 6th January, 2018 with maximum sustained wind speed of 55-65 kmph gusting to 75 kmph. It weakened into a well marked low pressure area in the early morning (0000 UTC) of 8th January over eastcentral BoB and adjoining areas. Typical track graphics of cyclonic storm Pabuk is shown in Fig. 30.

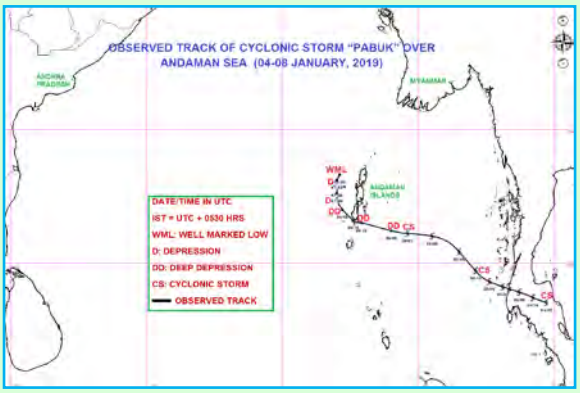


Fig. 30. Observed track of CS, 'Pabuk' over Andaman Sea during 4-8 January, 2019

Forecast Performance

- First information about the probable emergence of a cyclonic disturbance into Andaman Sea around 5th January was given in the Tropical Weather Outlook (TWO) issued at 0700 UTC of 31st December (about 5 days in advance). CS Pabuk emerged into Andaman Sea at 0300 UTC of 5th January.

- In the first bulletin issued on 3rd January (issued at 0700 UTC), it was mentioned that, the system would cross Andaman Islands around evening / night of 6th January (about b56 hours in advance of actual landfall). The system emerged into Andaman Sea at 0300 UTC (0830 hrs IST) of 5th and crossed Andaman Islands around 1400 UTC (1930 hrs IST, late evening/night) of 6th January.

- The landfall point forecast errors were about 44, 11 and 11 km for 12, 24 & 48 hrs lead period respectively against past five year (2014-18) average errors of 27, 47 and 70 km respectively. The landfall time forecast errors were about 0, 0 and 2 hours for 12, 24 & 48 hrs lead period against past five year (2014-18) average errors of 2, 3 and 5 hours respectively.

- The track forecast errors were about 57, 96 and 156 km for 24, 48 and 72 hrs lead period against past five year (2014-18) average errors of 86, 132 and 178 km respectively. The track forecast skills were about 74, 76 and 44% for 24, 48 and 72 hrs lead period against past five year (2014-18) average skills of 58, 70 and 74% respectively. The track forecast errors were less than long period average for all lead periods.

- In the first bulletin issued on 3rd January (0700 UTC), it was mentioned that, the system would move west-northwestwards till landfall. Thereafter, it would move north-northwestwards and then recurve northeastwards towards Myanmar coast during 7-8 January, 2019.

- The track forecast errors were about 57, 96 and 156 km for 24, 48 and 72 hrs lead period against past five year (2014-18) average errors of 86, 132 and 178 km respectively. The track forecast skills were about 74, 76 and 44% for 24, 48 and 72 hrs lead period against past five year (2014-18) average skills of 58, 70 and 74% respectively. The track forecast errors were less than long period average for all lead periods.

- The absolute errors (AE) of intensity (wind) forecast for 24, 48 and 72 hrs lead period were 6.6, 9.8 and 15.3 knots against the LPA of 9.6, 14.1 and 14.3 knots respectively. The skill in intensity forecast based on AE for 24, 48 and 72 hrs lead period was 41.4, 35.0 and 31.8% respectively.

5.5.2.2. Extremely Severe Cyclonic Storm, 'FANI'

Extremely Severe Cyclonic Storm (ESCS) "FANI" originated from a low pressure area (LPA) which formed over east Equatorial Indian Ocean (EIO) and adjoining southeast Bay of Bengal (BoB) in the early morning (0000 UTC) of 25th April. It intensified into cyclonic storm (CS) "FANI" around noon (0600 UTC) of 27th April over southeast BoB and adjoining east EIO. It crossed Odisha coast close to Puri as an ESCS with maximum sustained wind speed of 175-185 kmph (100 knots) gusting to 205 kmph between 0230 to 0430 UTC of the 3rd May, 2019. FANI developed near the equator (near 2.7° N and 88.7° E) and genesis of the cyclonic disturbance in such lower latitude is very rare. Last such activity was observed over the north Indian Ocean in January, 2005.

Forecast Performance

- First information about formation of LPA over EIO & adjoining south BoB during week ending 25th and beginning of week ending at 2nd May with probability of intensification into depression was indicated in the extended range forecast issued on 18th April.

- In the daily National Bulletins issued by IMD, it was consistently indicated that an LPA would form over EIO & adjoining southwest BoB to the southeast of Sri Lanka around 25th April with further intensification into depression by 26th April and into a CS by 28th April.

- On 25th, an LPA formed over EIO & adjoining southeast BoB. It concentrated into depression in morning of 26th April, 2019 and into a CS around 27th April evening while moving northwestwards.

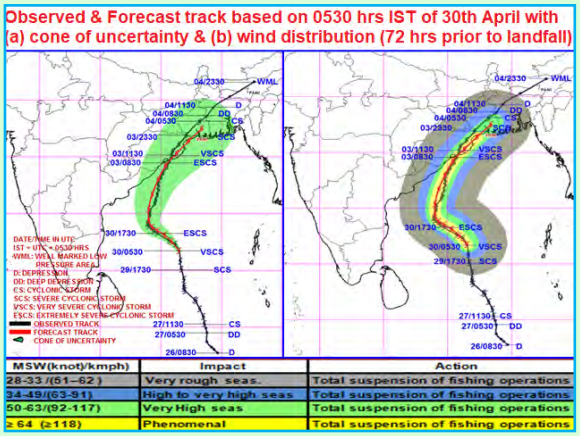
- First information issued at 1430 IST of 29th April (about 90 hrs prior to landfall) indicated that the system would move northwestwards till 1st May and recurve north-northeastwards towards Odisha coast.

- It was further indicated at 2100 hrs IST of 29th that the system would cross Odisha coast around Puri in the early morning of 4th May (about 84 hrs prior to landfall) as an extremely severe cyclonic storm with maximum sustained wind speed of 160-170 gusting to 190 kmph.

- The bulletin issued at 1520 hrs IST of 30th April indicated that the system would cross Odisha coast between Gopalpur and Chandbali, to the south of Puri around 3rd May afternoon with wind speed of 175-185 kmph gusting to 205 kmph (about 66 hrs prior to landfall).

- The bulletin issued at 2030 hrs IST of 1st May (36 hrs prior to actual landfall) indicated that the system would cross Odisha coast between Gopalpur and Chandbali, around Puri during 3rd May afternoon. The time of landfall was revised to 3rd May forenoon at 1600 hrs IST of 2nd May.

- Observed & forecast track based on 0530 IST of 30th April (72 hrs prior to landfall) of ESCS FANI indicating accurate landfall prediction near Puri is presented in Figs. 31(a&b).



Figs. 31(a&b). Observed & forecast track based on 0530 IST (0000 UTC) of 30th April (72 hrs prior to landfall) of ESCS FANI indicating accurate landfall prediction near Puri)

- The landfall point forecast errors for 24, 48 and 72 hrs lead period were 11, 11 and 15 km respectively against long period average errors of 47, 70 and 104 km during 2014-18 respectively.

- The landfall time forecast errors for 24, 48 and 72 hrs lead period were 1.5, 5.5 and 14.5 hours respectively against long period average errors of 3, 5 and 6 hours during 2014-18 respectively.

- The track forecast errors for 24, 48 and 72 hrs lead period were 77.7, 137.3 and 182.6 km respectively against the average track forecast errors of 86.1, 132.3 and 177.7 km during last five years (2014-18) respectively.

- The track forecast skill was about 57%, 61% and 58% against the long period average (LPA) of 58%, 70% and 74% during 2014-18 for 24, 48 and 72 hrs lead period respectively.

- The absolute error (AE) of intensity (wind) forecast for 24, 48 and 72 hrs lead period were 9.6, 12.6 and 13.8 knots against the LPA of 9.6, 14.1 and 14.3 knots respectively.

5.5.2.3. Very Severe Cyclonic Storm, 'VAYU'

Very Severe Cyclonic Storm (VSCS) "VAYU" originated from a low pressure area (LPA) which formed over southeast Arabian Sea and adjoining Lakshadweep & eastcentral Arabian Sea (AS) in the morning (0830 IST) of 9th June during the onset phase of the southwest monsoon. It intensified into cyclonic storm (CS) "VAYU" around midnight (1800 UTC) of 10th June, 2019 over eastcentral & adjoining southeast AS. It initially moved northwards and then skirted the coast of south Gujarat during while moving from eastcentral AS to northeast AS during 13-14 June, 2019. It moved nearly westwards away from the coast and then re-curved towards Gujarat coast once again. However, during this period, a couple of unfavourable factors including enhanced vertical wind shear caused it to weaken into a well marked low pressure area over northeast AS and adjoining Saurashtra & Kutch in the midnight (2330 hrs IST) of 17th June. Observed track is shown in Fig. 32.

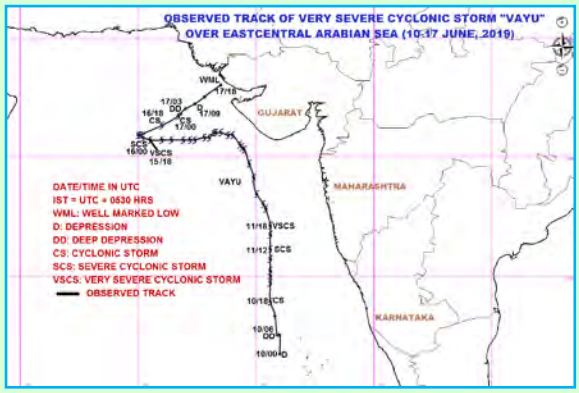


Fig. 32. Observed track of VSCS VAYU

Forecast Performance

- The extended range outlook issued on 6th June, indicated that there is moderate probability of cyclogenesis during later part of week 1 (7-13 June) over southeast & adjoining eastcentral AS and low probability of cyclogenesis during first half of week 2 (14-20 June) over northwest & adjoining westcentral AS.

- In the Tropical Weather Outlook issued on 7th June at 0600 UTC (1130 hrs IST), it was mentioned that an LPA would form over southeast AS around 9th June.

- In the first informatory message issued at 0800 UTC (1330 hrs IST) of 9th June on formation of low pressure area over Lakshadweep and adjoining eastcentral AS, it was mentioned that the system would intensify into a depression around 11th and further into a CS around 12th. The depression formed in the morning of 10th and CS formed in the midnight of 10th.

- First bulletin issued at 0700 UTC (1230 hrs IST) of 10th June indicated north northwestwards movement of the system towards Gujarat coast. The bulletin issued at 1000 UTC (1530 hrs IST) of 13th indicated that the system would not cross Gujarat coast but would skirt Gujarat coast affecting coastal districts of south Gujarat coast. On 13th June, Porbandar reported MSW of 84 kmph at 1330 hrs IST, Veraval reported 60 kmph of MSW at 1430 & 1530 hrs IST and Diu reported MSW of 41 kmph at 1430 hrs IST. On 14th June, Veraval reported MSW of 63 kmph and Diu reported 37 kmph of MSW at 0103 hrs IST.

- The track forecast errors for 24, 48 and 72 hrs lead period were 67.5, 125.9 and 264.9 km respectively against the average track forecast errors of 86.1, 132.3 and 177.7 km during last five years (2014-18) respectively.

- The track forecast skill was about 57%, 57% and 39% against the long period average (LPA) of 58%, 70% and 74% during 2014-18 for 24, 48 and 72 hrs lead period respectively.

- The absolute error (AE) of intensity (wind) forecast for 24, 48 and 72 hrs lead period were 6.6, 11.9 and 33.7 knots against the LPA of 9.6, 14.1 and 14.3 knots respectively.

5.5.2.4. Very Severe Cyclonic Storm, 'HIKAA'

Very Severe Cyclonic Storm (VSCS) "HIKAA" originated from an LPA which formed over eastcentral AS off north Maharashtra coast in the morning (0300 UTC) of 20th September. It intensified into CS "HIKAA" in the early morning (0000 UTC) of 23rd over northeast and adjoining eastcentral AS. It crossed Oman coast near latitude 19.7° N and longitude 57.7° E, close to north of Duqm in the same evening (between 1400 and 1500 UTC of 24th) as a VSCS with maximum sustained surface wind speed of 120-130 kmph gusting to 145 kmph. Typical observed and forecast track of VSCS Hikaa is shown in Fig. 33.

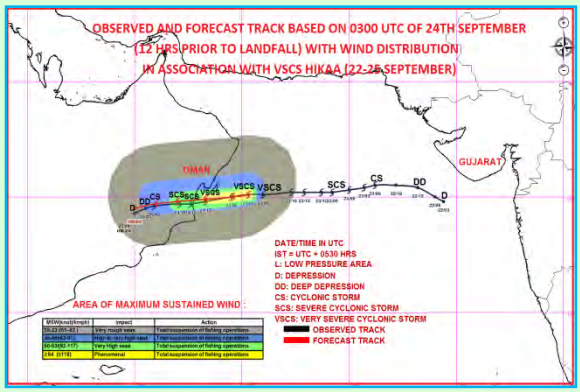


Fig. 33. Observed & forecast track of VSCS HIKKA alongwith wind distribution indicating accuracy in track, landfall and intensity forecast

Forecast Performance

- First information about possible cyclogenesis over eastcentral AS during first half of week (20-26 September) with moderate probability (34-67%) was indicated in the extended range outlook issued by IMD on 12th September (about 10 days prior to formation of depression over eastcentral AS on 22nd morning (0300 UTC).

- First information about formation of LPA over eastcentral AS & adjoining areas around 20th was given in Tropical Weather Outlook issued on 18th September (about 48 hours prior to formation of LPA in the morning (0300 UTC of 20th). It was also predicted that it would move west-northwestwards and concentrate into a depression around 22nd [about 96 hours prior to formation of depression over eastcentral AS on 22nd morning (0300 UTC)].

- In the first bulletin issued at 1115 hours IST (around 0600 UTC) of 22nd, it was indicated that the system would move towards Oman coast and cross Oman near 20° N in the night (around 2200 UTC of 24th). The system actually crossed Oman coast near 19.7° N/longitude 57.7° E in the late evening (around 1430 UTC) of 24th. Further intensification of the system was also predicted in this bulletin.

- In the bulletin issued at 2030 hours IST (1500 UTC) of 23rd, it was predicted that the system would move nearly westwards and cross Oman coast between latitude 19° N and 20° N close to Duqm during early hours of 25th September, 2019 as a Cyclonic Storm with a wind speed of 70-80 kmph gusting to 90 kmph.

- The warning was further upgraded and in the bulletin issued at 1615 IST (around 1030 UTC) of 24th that the system would cross Oman coast between latitude 19.5° N and 20° N close to Duqm around 2030 Hours IST of 24th September, 2019 as an SCS with a wind speed of 110-120 kmph gusting to 135 kmph.

- The landfall point forecast errors for 24, 48 and 60 hrs lead period were 20, 32 and 62 km respectively against long period average errors of 47, 70 and 89 km during 2014-18 respectively. The landfall time forecast errors for 24, 48 and 60 hrs lead period were 4, 11

and 7 hours respectively against long period average errors of 3, 5 and 4 hours during 2014-18 respectively.

- The track forecast errors for 12, 24 and 48 hrs lead period were 44, 56 and 195 km respectively against the average track forecast errors of 55, 86 and 132 km during last five years (2014-18) respectively.The track forecast skill was about 60%, 73% and 51% against the long period average (LPA) of 55%, 58% and 70% during 2014-18 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 10, 19 and 6 knots against the LPA of 6, 10 and 14 knots respectively.

- The skill in intensity forecast based on AE for 12, 24 and 48 hrs lead period was 33, 48 and 89% against the LPA of 29, 43 and 68% respectively.

5.5.2.5. Super Cyclonic storm KYARR

The Super Cyclonic Storm (SuCS) 'KYARR' originated as an LPA over southeast Arabian Sea & adjoining Lakshadweep area in the morning (0300 UTC) of 17th October. It intensified into CS 'KYARR' in the early morning (0000 UTC) of 25th October over eastcentral AS. It further intensified into Super Cyclonic Storm (SuCS) in the morning (0300 UTC) of 27th October over EC AS. It maintained the intensity of SuCS for 45 hours and while moving northwestwards, unfavourable environmental conditions caused it to start weakening. It weakened into a WML over westcentral & adjoining southwest AS off north Somalia Coast around the midnight (1800 UTC) of 2nd November. For a brief period, *viz*., 30 October-2 November, 2019, this system co-existed with ESCS MAHA over the AS (Fig. 34).

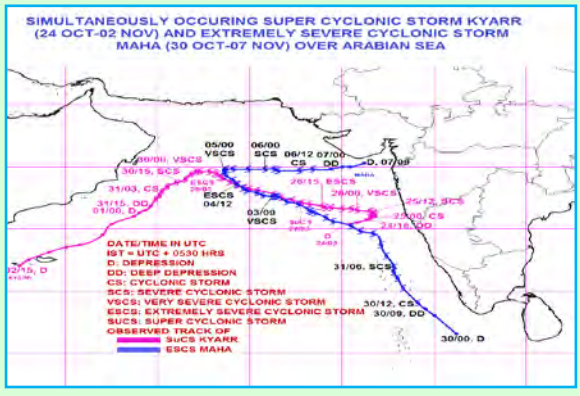


Fig. 34. Observed track of the co-existing SUCS Kyarr and VSCS MAHA

Forecast Performance

- First information about possible cyclogenesis over eastcentral Arabian Sea was given in in the extended range outlook issued on 17th October. In the extended range outlook issued on 24th, when the system lay as a depression over eastcentral Arabian Sea. The initial northeastwards movement and west-southwestwards recurvature of system towards westcentral Arabian Sea with high confidence (>75% probability) was predicted.

- At 1200 UTC of 20th, it was indicated that the system would intensify into Depression by 24th. Depression formed in the morning (0300 UTC) of 24th.

- In the first bulletin issued at 1230 hrs IST (around 0700 UTC) of 24th October, it was indicated that the system would move initially east-northeastwards till 25th October evening and then recurve nearly westwards. In the subsequent bulletin issued at 1130 hrs IST of 26th October, it was predicted that the system would move west-northwestwards till 31st October & thereafter recurve southwestwards. It was also predicted that the system would intensify further into an ESCS by 27th October. Actually, the system intensified into an ESCS in the night of 26th October (2030 hrs IST) and recurved southwestwards from 30th noon (1130 hrs IST).

- In the bulletin issued at 0530 hrs IST (around 0000 UTC) of 30th October, it was indicated that the system would reach close to Somalia as a WML in the evening of 3rd. Actually, the system weakened into a WML over westcentral & adjoining southwest Arabian Sea off North Somalia coast in the midnight (2330 hrs IST) of 2nd.

- The track forecast errors for 24, 48 and 72 hrs lead period were 27, 65 and 100 km respectively against the average track forecast errors of 86, 132 and 178 km during last five years (2014-18) respectively.

- The track forecast skill was about 80%, 92% and 86% against the long period average (LPA) of 58%, 70% and 74% during 2014-18 for 24, 48 and 72 hrs lead period respectively.

- The track forecast errors and skill were significantly better than long period average during 2014-18, despite the fact that the system exhibited multiple recurvatures.

- The absolute error (AE) of intensity (wind) forecast for 24, 48 and 72 hrs lead period were 09, 20 and 24 knots against the LPA of 10, 14 and 14 knots respectively.

- The skill in intensity forecast based on AE for 24, 48 and 72 hrs lead period was 45, 53 and 67% against the LPA of 43, 68 and 72% respectively.

5.5.2.6. Extremely Severe Cyclonic Storm, 'MAHA'

The Extremely Severe Cyclonic Storm (ESCS) 'MAHA' originated as an LPA over Equatorial Indian Ocean off south Sri Lanka coast in the forenoon (0600 UTC) of 28th October. It intensified into CS 'MAHA' in the evening (1200 UTC) of 30th October over Lakshadweep and adjoining Southeast Arabian Sea & Maldives Area. It moved initially north-northwestwards till 1st, northwestwards till 5th, recurved eastwards and weakened into a WML over northeast AS & adjoining coastal Saurashtra in the evening (1200 UTC) of 7th November. The typical observed and forecast tracks alongwith cone of uncertainty are presented in Fig. 35.

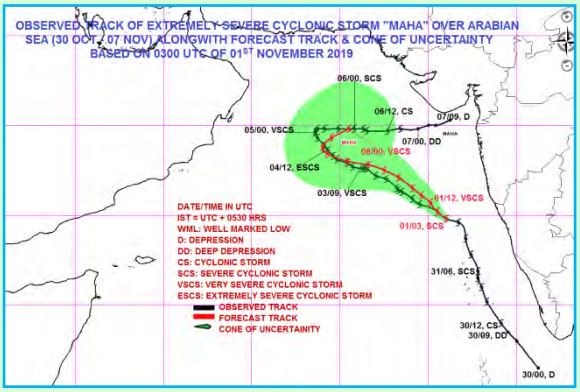


Fig. 35. Graphics showing the skill of forecasting the re-curvature of Extremely Severe Cyclonic Storm MAHA

Forecast Performance

- First information about formation of LPA over equatorial Indian Ocean off south Sri Lanka was provided in the Press Release issued at 1330 hrs IST (0800 UTC) of 28th October. It was also indicated that the system would concentrate into a depression over southeast Arabian Sea and adjoining Lakshadweep & Maldives area around 30th October. Depression formed over Maldives-Comorin area in the early morning (0000 UTC) of 30th October. Thus, genesis was predicted around 40 hours in advance.

- Pre-Cyclone Watch was issued for Lakshadweep Islands at 1500 hrs IST (0930 UTC) of 30th when the system was a depression at 1130 hrs IST (0600 UTC) of 30th over Maldives-Comorin area.

- Cyclone Alert for Lakshadweep Islands was issued at 1750 hrs IST of 30th, when it lay as a deep depression at 1430 hrs IST (0900 UTC) of 30th over Lakshadweep and adjoining southeast Arabian Sea & adjoining Maldives area.

- Cyclone Warning for Lakshadweep Islands was issued at 2000 hrs IST of 30th, when it lay as a cyclonic storm at 1730 hrs IST (1200 UTC) of 30th over Lakshadweep and adjoining south-east Arabian Sea and adjoining Maldives area.

- Dewarning message for Lakshadweep Islands was issued at 0900 hrs IST of 1st November when the system lay over eastcentral Arabian Sea at 0530 hrs IST (0000 UTC) of 1st November as a severe cyclonic storm, after it has moved away from Lakshadweep Islands.

- In the first bulletin issued at 1230 hrs IST (around 0700 UTC) of 30th October, it was indicated that the system would move initially

north-northwestwards and then re-curve west-northwestwards from 1st early morning (0000 UTC). Actually, system started recurring west-northwestwards from 1st early morning (0000 UTC). Thus, first re-curvature of the system could be correctly predicted around 2 days (45 hours) in advance.

- In the bulletin issued at 1130 hrs IST (0600 UTC) of 1st November, second re-curvature of the system was predicted (around 4 days in advance). The bulletin indicated that the system would re-curve northeastwards from 5th evening. Actually, from 5th early hours (0030 hrs IST/around 2100 UTC), it moved northwards for some time and then gradually re-curved northeastwards from noon (around 0600 UTC) of 5th November. Thus, the track was well predicted despite multiple re-curvatures.

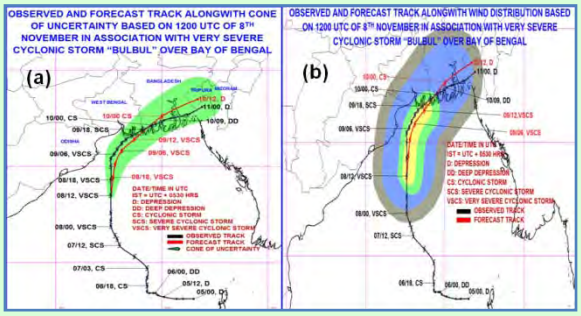
- The track forecast errors for 24, 48 and 72 hrs lead period were 72, 92 and 122 km respectively against the average track forecast errors of 86, 132 and 178 km during last five years (2014-18) respectively.

- The track forecast skill was about 71%, 89% and 83% against the long period average (LPA) of 58%, 70% and 74% during 2014-18 for 24, 48 and 72 hrs lead period respectively.

- The absolute error (AE) of intensity (wind) forecast for 24, 48 and 72 hrs lead period were 09, 12 and 10 knots against the LPA of 10, 14 and 14 knots respectively.

5.5.2.7. Very Severe Cyclonic Storm, 'BULBUL'

The Very Severe Cyclonic Storm (VSCS) "BUL BUL" originated from the remnant of Severe Tropical Storm 'MATMO' (28 October-2 November) over west Pacific Ocean that emerged into north Andaman Sea. It lay as an LPA over north Andaman Sea in the early morning (0000 UTC) of 4th November. It intensified into CS "BUL BUL" in the late night (1800 UTC) of 6th November over eastcentral and adjoining southeast BoB. It crossed West Bengal coast, close to Sunderban Dhanchi Forest near 21.55° N/88.5° E during the night (1500 to 1800 UTC) of 9th November as a Severe Cyclonic Storm with maximum sustained surface wind speed of 110-120 kmph gusting to 135 kmph. Track graphics showing the skill of the forecast is shown in Figs. 36(a&b).



Figs. 36(a&b).Observed and forecast track of VSCS 'BUL BUL' along with (a) cone of uncertainty and (b) wind distribution indicating accuracy in landfall, track & intensity predictions near West Bengal coast

Forecast Performance

- First information about possible cyclogenesis over eastcentral BoB during later half of week (01-06 November) with low probability (01-33%) was indicated in the extended range outlook issued by IMD on 24th October, 2019 [about 12 days prior to formation of depression over eastcentral & adjoining southeast BoB on 5th November, early morning (0000 UTC)].

- First information about formation of LPA over north Andaman Sea & neighbourhood around 4th November was given in Tropical Weather Outlook issued on 31st October [about 120 hours prior to formation of LPA in the early morning (0000 UTC) of 5th]. It was also predicted that it would move west-northwestwards and concentrate into a depression around 5th [about 72 hours prior to formation of depression over eastcentral BoB on 5th early morning (0000 UTC)].

- In the bulletin issued at 0630 UTC of 6th November, it was predicted that the system would move towards west Bengal - Bangladesh coasts, *i.e.*, nearly 3 days in advance of landfall.

- Foreseeing the likely impacts in terms of Gale force winds and rainfall, Cyclone watch for West Bengal north Odisha coasts was issued at 0900 UTC of 7th November (about 60 hours in advance of landfall). Also, the

fishermen warnings were issued for Odisha & West Bengal coasts since 4th November.

- In the Cyclone alert issued for West Bengal coast at 0000 UTC of 8th November (40 hours in advance of landfall), indication was given that the system is very likely to cross West Bengal - Bangladesh coasts between Sagar Islands (West Bengal) & Khepupara (Bangladesh) during the early hours of 10th November. Bulbul actually crossed West Bengal and adjoining Bangladesh coast, between Sagar Islands & Khepupara, close to Sunderban Dhanchi Forest near 21.55° N/ 88.5° E during the night (1500 to 1800 UTC) of 9th November.

- The warning was further refined and in the bulletin issued at 0900 UTC of 8th November and it was indicated that the system would cross west Bengal - Bangladesh coasts, between Sagar Islands & Khepupara across Sunderban Delta, around the mid-night of 9th November as a Severe Cyclonic Storm with sustained wind speed of 110-120 kmph gusting to 135 kmph. The system crossed West Bengal coast, close to Sunderban Dhanchi Forest, during 1500-1800 UTC, as a SCS with maximum sustained surface wind speed of 110-120 kmph gusting to 135 kmph.

- The landfall point forecast errors for 12, 24 and 48 hrs lead period were 11.2, 49.9 and 50.5 km respectively against long period average errors of 26.5, 46.6 and 69.7 km during 2014-18 respectively.

- The landfall time forecast errors for 12, 24 and 48 hrs lead period were 1, 3 and 5 hours respectively against long period average errors of 2.0, 2.9 and 5.1 hours during 2014-18 respectively.

- The track forecast errors for 24, 48 and 72 hrs lead period were 67, 77 and 131 km respectively against the average track forecast errors of 86, 132 and 178 km during last five years (2014-18) respectively.

- The track forecast skill was about 55%, 73% and 71% against the long period average (LPA) of 58%, 70% and 74% during 2014-18 for 12, 24 and 48 hrs lead period respectively.

- The absolute error (AE) of intensity (wind) forecast for 24, 48 and 72 hrs lead period were 8.6, 8.1 and 8.9 knots against the LPA of 9.6, 14.1 and 14.3 knots respectively.

- The skill in intensity forecast based on AE for 24, 48 and 72 hrs lead period was 54, 81 and 83% against the LPA of 43, 68 and 72% respectively.

- The skill in intensity forecast based on RMSE for 24, 48 and 72 hrs lead period was 56, 83 and 85% against the LPA of 49, 59 and 85% respectively.

5.5.2.8. Cyclonic Storm, 'PAWAN'

It formed from an equatorial wave trough when twin cylogenesis took place over north & south Indian Ocean. A well marked low pressure area concentrated into a Depression over southwest Arabian Sea in the evening (1200 UTC) of 2nd December. It intensified into CS PAWAN over southwest AS, by early morning (0000 UTC) of 5th December. It moved west-northwestwards for some time, till the early morning of 7th December, thereafter, it started re-curving west-southwestwards / westwards. It crossed Somalia coast near

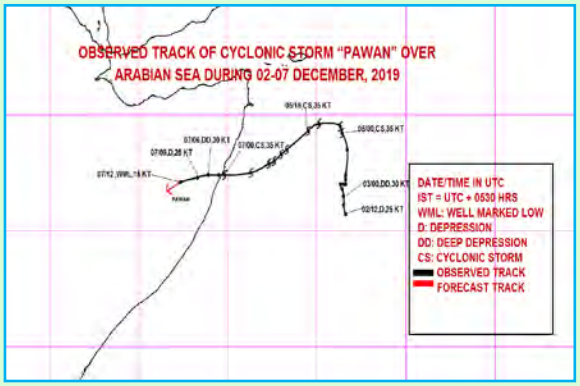


Fig. 37. Observed track of Cyclonic Storm PAWAN over south Arabian Sea

Lat. 7.4° N and Long. 49.6° E during 0200 to 0300 UTC of 7th December as a CS with wind speed of 60-70 kmph, gusting to 80 kmph. It weakened into a WML over north Somalia and adjoining Ethiopia by the evening of 7th December. Observed track is shown in Fig. 37.

Forecast Performance

- First information about the expected cyclogenesis over southwest AS and adjoining EIO around 3rd December and movement of the system towards Somalia coast was indicated in the extended range outlook issued on 28th Nov. Further, in the Tropical Weather Outlook (TWO) issued at 0600 UTC of 29th November, it was indicated that a LPA would form over EIO and adjoining southwest AS by 1st December. Actually, the LPA formed over southwest AS & adjoining EIO at 0300 UTC of 30th November.

- Thus, cyclogenesis could be predicted about 5 days in advance since 28th November.

- In the bulletin issued at 0900 UTC of 3rd December, first information about the landfall of the system over Somalia coast near 7.1° N / 49.4° E around 1800 UTC of 6th was predicted. Actually, system crossed Somalia coast near 7.5° N / 49.6° E around 0730 hrs IST/0200 UTC of 7th. Thus, landfall of the system was predicted about 89 hrs in advance.

- The track forecast errors for 24, 48 and 72 hrs lead period were 99, 139 and 183 km respectively against the average track forecast errors of 86, 132 and 178 km during last five years (2014-18) respectively.

- The track forecast skill was about 69%, 75% and 70% against the long period average (LPA) of 58%, 70% and 74% during 2014-18 for 24, 48 and 72 hrs lead period respectively.

- The landfall point forecast errors for 24, 48 and 72 hrs lead period were 69, 69 and 45 km respectively against the average forecast errors of 46, 70 and 104 km during last five years (2014-18) respectively.

- The landfall time forecast errors for 24, 48 and 72 hrs lead period were 0.5, 1.0 and 7.0 hrs respectively against the average forecast errors of 3.0, 5.1 and 5.8 hrs during last five years (2014-18) respectively.

- The absolute error (AE) of intensity (wind) forecast for 24, 48 and 72 hrs lead period were 07, 05 and 11 knots against the LPA of 10, 14 and 14 knots respectively.

- The skill in intensity forecast based on AE for 24, 48 and 72 hrs lead period was 02, 51 & 01% against the LPA of 43, 68 and 72% respectively.

- For all lead periods the skill in intensity forecast was less than the LPA. It is mainly due to the fact that the system would maintain CS intensity for nearly 2 days could not be captured well.

The salient features of the eight cyclones during 2019 are presented in Table 6 and their composite tracks are presented in Fig. 38.

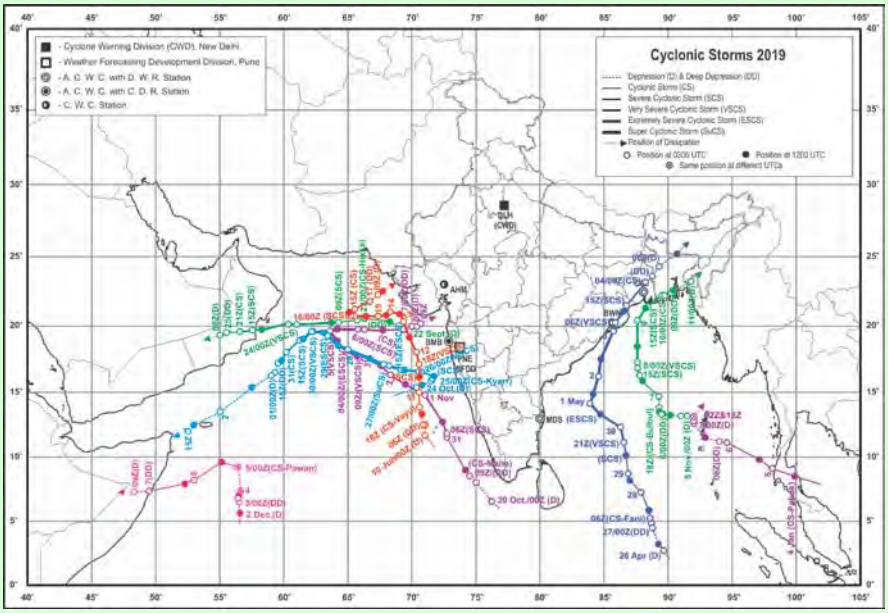


Fig. 38. Composite tracks of cyclones during 2019

TABLE 6

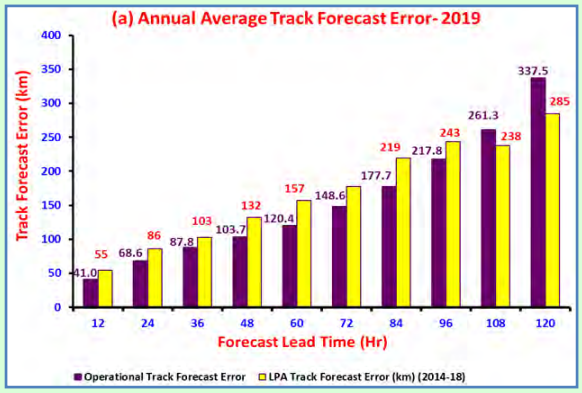
Characteristics of cyclones during 2019

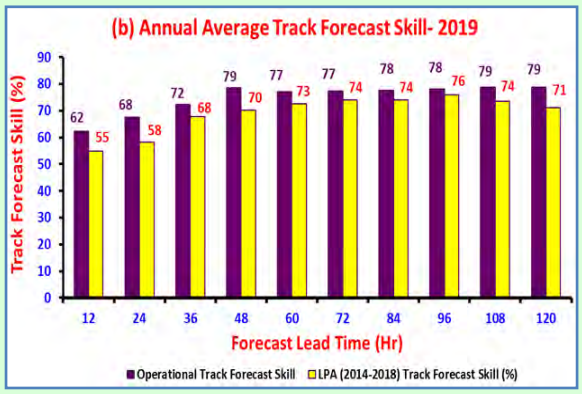
S. No.	Cyclonic storm	Date, Time & Place of genesis (Lat. N/Long. E)	Date, Time (UTC) Place (Lat. N/Long. E) of Landfall	Estimated lowest central pressure, Time & Date (UTC) & Lat. N/Long. E	Estimated Maximum wind speed (kt), Date & Time	Max T. No. Attained
1.	Cyclonic Storm (CS) PABUK over Andaman Sea during (4-8 January)	Emerged into Andaman Sea from Gulf of Thailand near (8.5/99.7)	Crossed Andaman Islands near (11.6/ 92.7) close to south of Port Blair, between 1300 & 1500 UTC of 6th January	998 hPa during 1200-2100 UTC 4th January near (8.5° N/99.7° E to 8.8/99.0)	45 knots during 1200 -2100 UTC 4th January	T 2.5
2.	Extremely Severe Cyclonic Storm FANI over the Bay of Bengal during (26 April-4 May)	26th April, 0300 UTC over East Equatorial Indian Ocean near (2.7/89.7)	Crossed Odisha coast close to Puri (near Lat. 19.75 and Long. 85.7) between 0230 & 0430 UTC of 3rd May	932 hPa during 0900-1200 UTC 2nd May 2019 near (17.1/84.8)	115 knots during 0900 to 2100 UTC 2nd May near (17.1/84.8 to 18.6/85.2)	T 6.0
3.	Very Severe Cyclonic Storm VAYU over the Arabian Sea during (10-17 June)	10th May, 0000 UTC over southeast Arabian Sea (11.7/71.0)	Weakened into a Well Marked Low Pressure Area over Northeast Arabian Sea and adjoining areas of Saurashtra & Kutch	970 hPa during 0900 UTC 12th May to 0000 UTC of 14th May near (18.8/69.9 to 21.0/68.5)	80 knots during 0900 UTC 12th May to 0000 UTC of 14th May near (18.8/69.9 to 21.0/68.5)	T 4.5
4.	Very Severe Cyclonic Storm HIKAA over the Arabian Sea during (22-25 September)	22nd September, 0300 UTC over eastcentral Arabian Sea near (19.8/69.4)	Crossed Oman coast near Lat. 19.7° N and Long. 57.6° E between 1400 and 1500 UTC of 24th September	978 hPa during 0300 to 1200 UTC of 24th September near (20.1/60.3 to 19.8/58.3)	75 knots during 0300 to 1200 UTC of 24th September near (20.1/60.3 to 19.8/58.3)	T 4.5
5.	Super Cyclonic Storm KYARR over eastcentral Arabian Sea during (24 October-2 November)	24th October at 0300 UTC over Southeast Arabian Sea & adjoining Lakshadweep near (15.4° N/70.4° E)	Weakened into a Well Marked Low Pressure Area over westcentral & adjoining southwest Arabian Sea off North Somalia coast	922 hPa during 0900 - 1800 UTC of 27th October (17.4/67.0 to 17.8/66.3)	130 knots during 0900-1800 UTC of 27th October (17.4/67.0 to 17.8/66.3)	T6.5
6.	Extremely Severe Cyclonic Storm MAHA over the Arabian Sea during (30 October-7 November)	30th October, 0000 UTC over Equatorial Indian Ocean off south Sri Lanka coast (6.5° N/76.2° E)	Weakened into a Well-Marked Low Pressure Area over northeast Arabian Sea and adjoining south Gujarat coast	956 hPa during 1200-2100 UTC 4th November, near (18.9/64.1 to 19.5/63.6)	100 knots during 1200-2100 UTC 4th November, near (18.9/64.1 to 19.5/63.6)	T 5.5
7.	Very Severe Cyclonic Storm BULBUL over the Bay of Bengal during (5-11 November)	5th November, 0000 UTC over north Andaman Sea near (13.1/91.5)	Crossed West Bengal Coast close to Sunderban Dhanchi forest near 21.55° N/ 88.5° E during 1500 to 1800 UTC of 9th November	976 hPa during 1200 UTC 8th November to 0000 UTC of 9th November near (18.5/87.6 to 20.0/87.6)	75 knots during 1200 UTC 8th November to 0000 UTC of 9th November near (18.5/87.6 to 20.0/87.6)	T 4.5
8.	Cyclonic Storm PAWAN over the southwest Arabian Sea during (2-7 December)	2nd December 2019, 1200 UTC southwest Arabian Sea near (5.7/56.6)	Weakened into a well marked low pressure area over north Somalia and adjoining Ethiopia	998 hPa at 1200 UTC 5th December 2019 near (9.6N/55.1E)	40 knots at 1200 UTC 5th December 2019 near (9.6° N/55.1° E)	T 2.5

5.5.3. Annual Average Cyclone Forecast error and skill during 2019

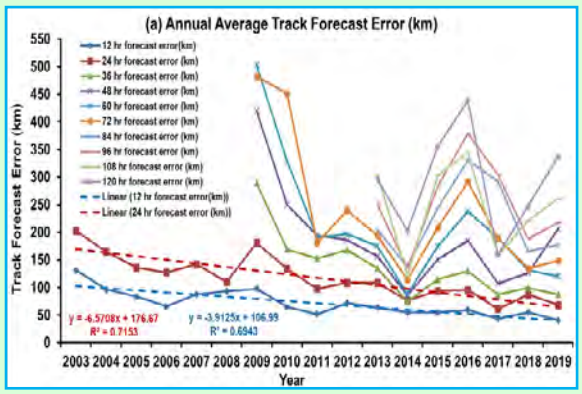
5.5.3.1. Annual Track, landfall and intensity forecast error

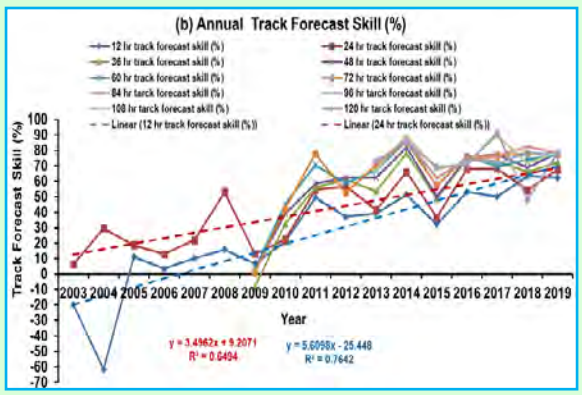
The annual average track forecast errors in 2019 have been 69 km, 104 km and 149 km, respectively for 24, 48 and 72 hrs against the past five year average error of 86, 132 and 178 km based on data of 2014-2018 [Fig. 39(a)]. The track forecast skills during 2019 compared to climatology and persistence forecast were 68%, 79% and 77% respectively for the 24, 48 and 72 hrs lead period against the long period average skill during 2014-2018 (58%, 70% & 74% respectively) [Fig. 39(b)]. The track forecast skill was higher than the long period average skill for all lead periods despite the fact that during 2019, seven out of eight TCs (all including Pabuk, Vayu, Fani, Kyarr, Maha, Bulbul & Pawan except Hikaa) had recurving track.





Figs. 39(a&b). Annual track forecast error and skill during 2019 as compared to that during 2014-18

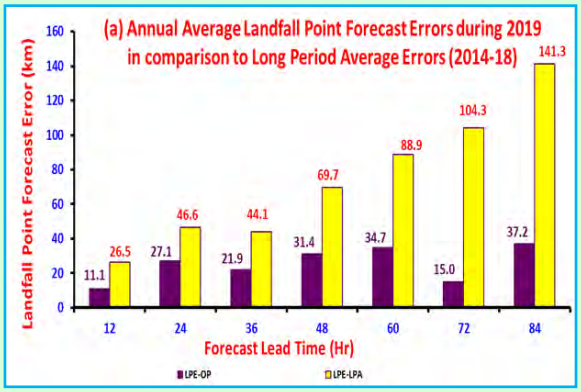


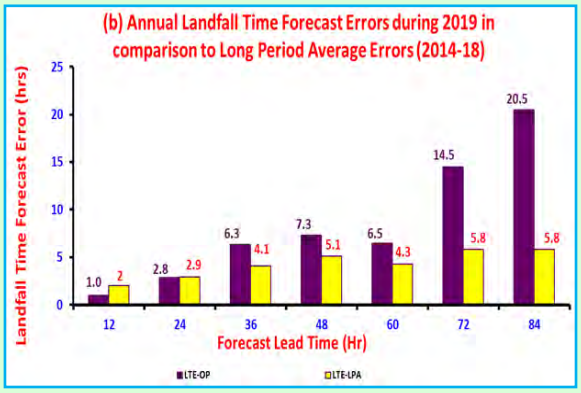


Figs. 40(a&b). Annual Track Forecast error & skill (%) of RSMC, New Delhi over North Indian Ocean

Comparing the track forecast errors during 2003 to 2019, there has been significant improvement in annual average track forecast errors and skill [Figs. 40 (a&b)] due to modernisation programme of IMD in 2009 with respect to observation, analysis and prediction tools & techniques which has been further augmented through improvement in observations, mainly from DWR and satellite and in terms of improved numerical modelling including enhanced data assimilation, higher resolution, improved physics etc.

The annual average landfall point forecast errors [Fig. 41(a)] for the year 2019 have been 27 km, 31 km and 15 km for 24, 48 and 72 hrs lead period against the long period average of past five years during 2014-18 of 47 km, 70 km and 104 km. The landfall time forecast errors [Fig. 41(b)] have been 2.8, 5.0 and 7.4 hrs for 24, 48 and 72 hrs lead period during 2019 against the average of past five years of 3.6, 5.4 and 3.8 hrs during 2014-2018.

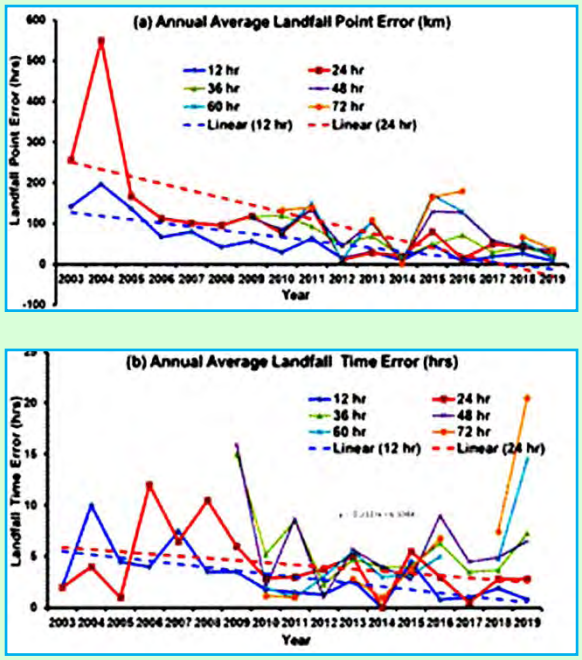




Figs. 41(a&b). Annual landfall point and time forecast errors during 2019 as compared to that during 2014-18

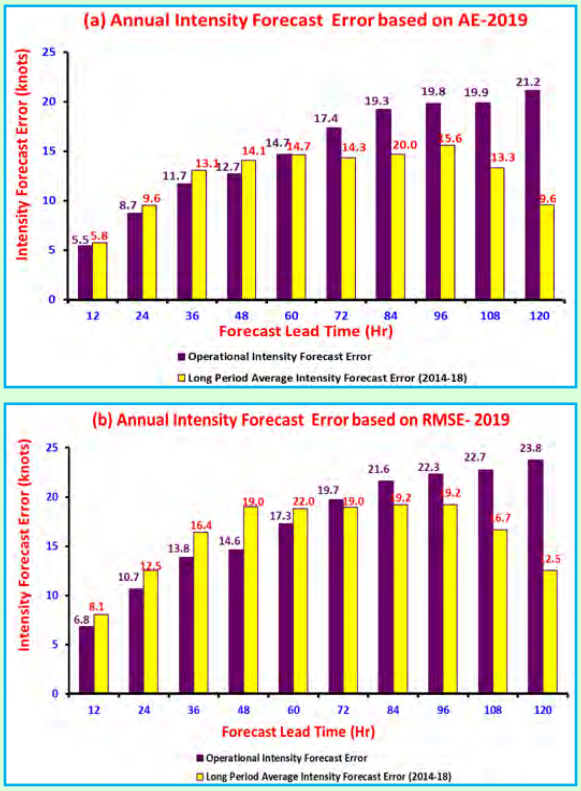
The annual landfall point errors during 2019 were significantly less than the long period average errors for all lead periods. The annual landfall time errors during 2019 were less than the long period average upto 24 hrs lead period. The higher errors in landfall time

prediction may be attributed to the fact that three out of four landfalling cyclones had recurving track It can be seen from Figs. 40(a&b) and 42(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.

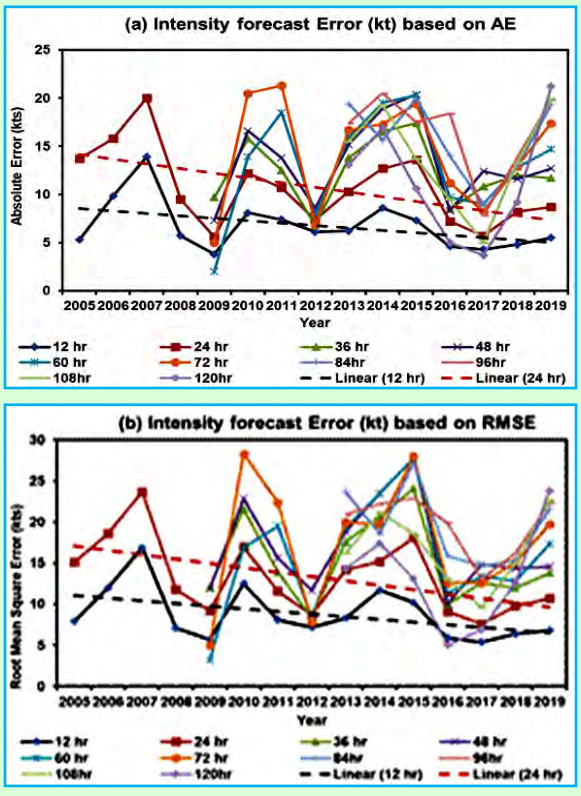


Figs. 42(a&b). Annual average (a) landfall point and (b) landfall time errors during 2003 to 2019

The average absolute errors of intensity forecast during 2019 have been 8.7 knots, 12.7 knots (KT) and 17.4 knots respectively for 24, 48 and 72 hrs lead period of forecast against the past five year average of 9.6, 14.1 and 14.3 knots [Figs. 43(a&b)]. The root mean square errors in intensity forecast have been 10.7 knots, 14.6 knots and 19.7 knots respectively for 24, 48 and 72 hrs lead period of forecast against the past five year average of 12.5, 19.0 and 19.0 knots. The errors in intensity forecast have been less than the long period average upto lead period of 60 hrs. The higher errors for lead period of 72 hrs and above is mainly attributed to the fact that during 2019, Arabian Sea (AS) was highly active and there were 5 cyclonic storms over AS against the normal of 1 per year. AS being a data sparse region, higher errors were observed in intensity forecast beyond 72 hrs lead period.



Figs. 43(a&b). Annual average intensity forecast errors during 2019 as compared to that during 2014-18

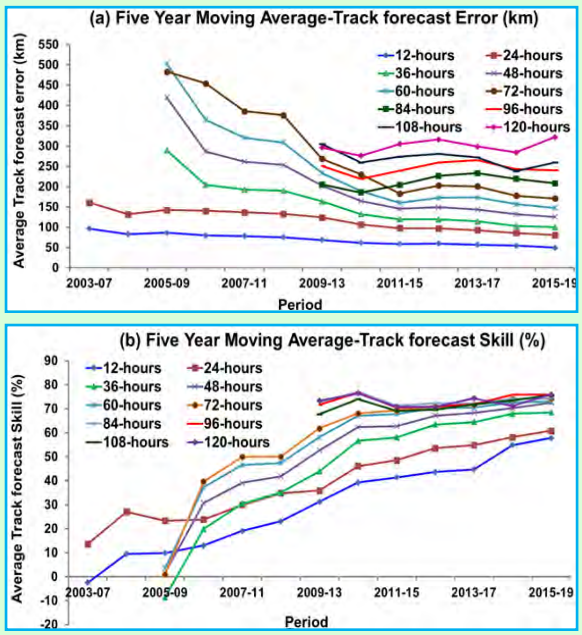


Figs. 44(a&b). Annual average Intensity forecast errors based on (a) AE (b) RMSE

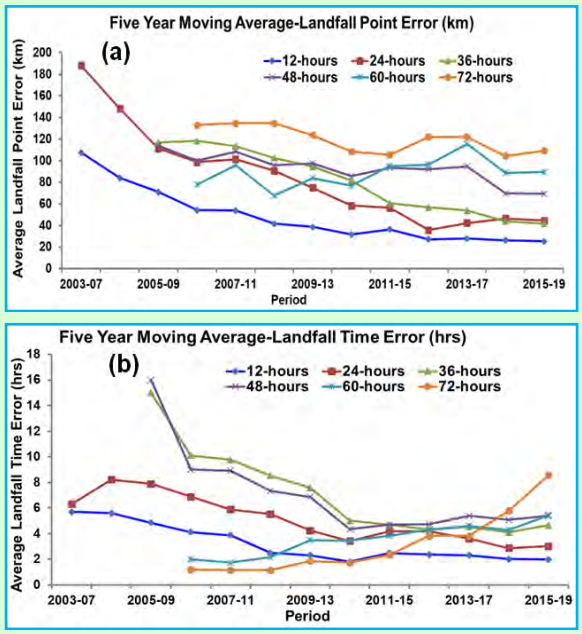
The Figs. 44(a&b) shows that the rate of improvement in intensity forecast has been less that that of track and landfall forecast.

5.5.3.2. Trend in errors and skill

It can be seen from Figs. 45&46(a&b) that there has been continuous improvement in forecast accuracy with decrease in landfall and track forecast errors & increase in skill over the years.



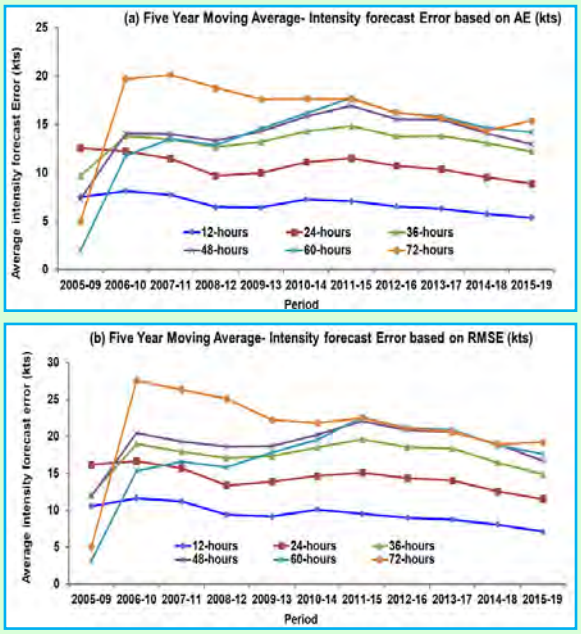
Figs. 45 (a&b). Five Year Moving Average (a) Track Forecast Error (km) & (b) Track Forecast Skill (%) of RSMC, New Delhi over North Indian Ocean



Figs. 46(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.

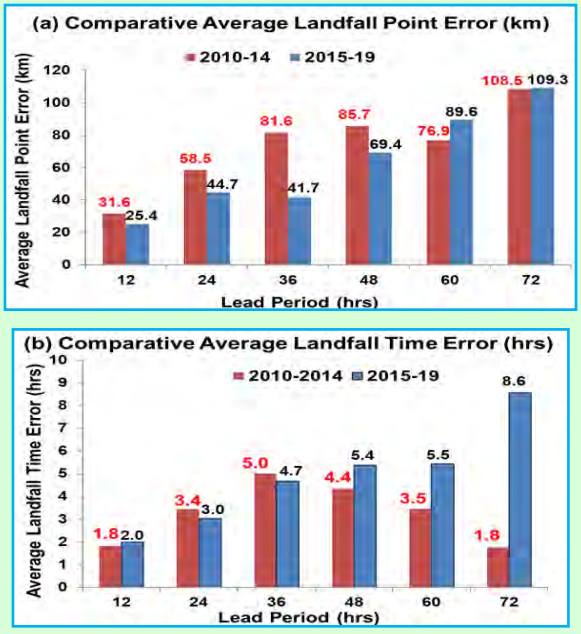
Due to modernization programme of IMD and other initiatives of MoES, the improvement has been more significant since 2009. However, the rate of improvement in intensity forecast over the years has been marginal [Figs. 47(a&b)].



Figs. 47(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 2015-19 compared to that during 2010-14 due to

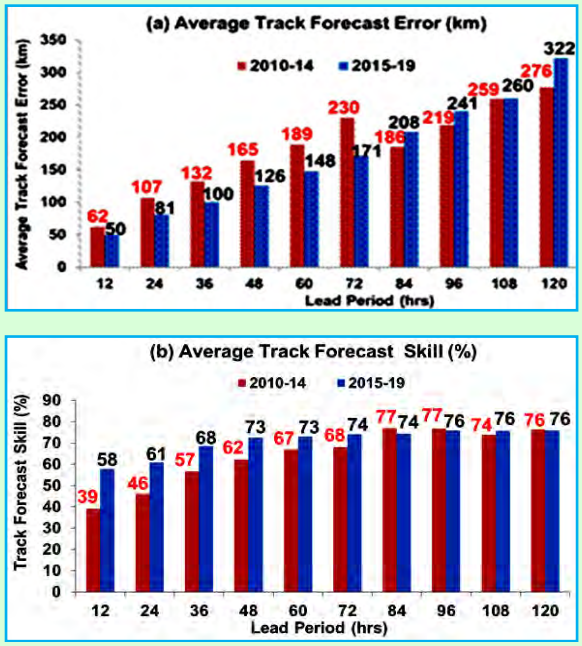


Figs. 48 (a&b). Comparative average (a) Landfall Point errors and (b) Landfall Time errors

implementation of modernisation programme in IMD in 2009. Comparative analysis of LPE and LTE during 2015-19 *vis-à-vis* 2010-14 is presented in Figs. 48(a&b). The 12 and 24 hr LPEs during 2015-19 were 25.4 km and 44.7 km against 31.6 km and 58.5 km respectively during 2010-14. There has been an improvement of 20% and 24% in 12 and 24 hr LPE during 2015-19 as compared to 2010-14.

Track forecast error and skill

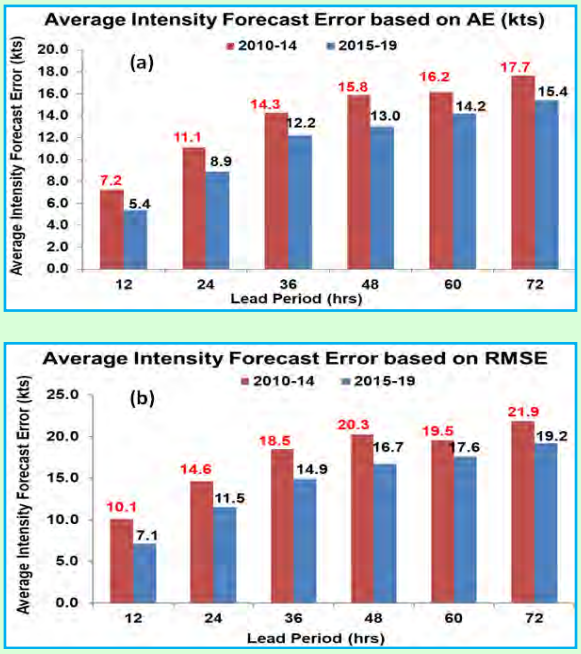
There is an improvement in track forecast error by about 25% for all lead period upto 72 hrs during 2015-19 as compared to errors during 2010-14. The 24, 48 & 72 hr track forecast skill improved by 15%, 10% and 6% respectively during 2015-19 compared to 2010-14 [Figs. 49(a&b)].



Figs. 49 (a&b). Comparative average (a) Track forecast errors and (b) Track forecast Skill

Intensity forecast error and skill

There has been an improvement in intensity forecast error by about 20%, 18% and 13% in AAE and by about 20%, 18% and 13% in RMSE for 24, 48 and 72 hours lead period respectively during 2015-19 as compared to 2010-14 respectively [Figs. 50(a&b)]. The improvement in intensity forecast has been marginal during recent five years (2015-19) as compared to previous five years (2010-14).



Figs. 50(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 & prediction of a tropical cyclone.

The project is operated during 15 October to 30 November every year. But during the year 2019, due to development of cyclonic disturbances over Arabian Sea in the month of December, the FDP campaign was extended upto 20th December, 2019. 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. 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-2019 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 1st May, 2016 and demonstration phase started from 1st 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. HWRF model forecast products were made available through IMD website, RSMC website and also NCEP, USA website (2019).

OPERATIONAL PRODUCTS & DISSEMINATION

1. 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. 51.

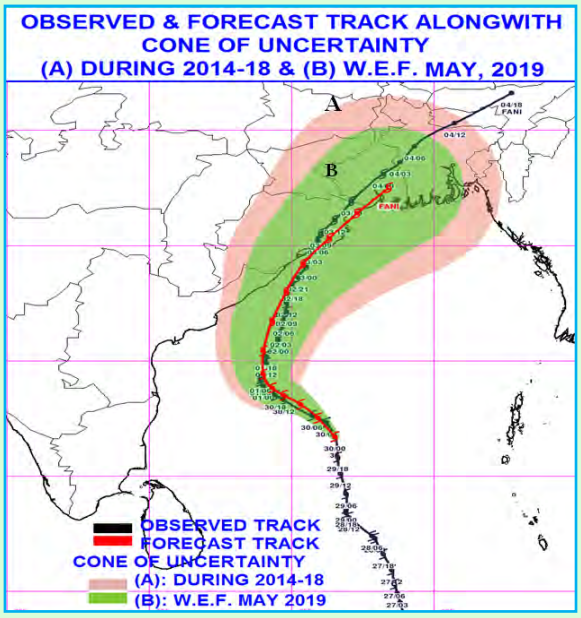


Fig. 51. Observed & Forecast track alongwith cone of uncertainty (A) during 2014-18 & (B) w.e.f. May, 2019

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

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

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

5.6. Fog Forecasting Services

Fog Monitoring

- Trend of Wind and Temp(Ta, Td) from 6 AWOS and RVR trends from 16 number of RVR

- INSAT 3D (VIS/SWIR-1KM, RGB fog products(MIR-TIR-4 km), MIR TIR/TIR2-ALL 4 km, WV-8KM

- WIFEX data Data from various instruments deployed under winter fog experiment (WIFEX) since mid November 2019 at IGI Airport Delhi jointly by IITM-IMD under Ministry of Earth Sciences, Govt of India was also fully used:

(*i*) A Microwave Radiometer (MRM) and Cileometer for low cloud and fog

(*ii*) MARGA - Monitor for AeRosols and Gases in ambient Air

(*iii*) A 20 meter Flux tower with three level observations of fluxes

(*iv*) Aerosol, gases and fog water Analyzer, Eddy covariances data, etc. as available from Winter Fog experiment Project data (About 25 number of additional equipment for special campaign deployed in every winter) (Table 7)

TABLE 7

List of major Instruments/Sensors used during the WiFEX 2018-19 at IGI Airport

S. No.	Name of Instrument/Sensor	Measuring Parameter
1.	Radiometer	Temp/Rh/LWC up to 10km
2.	Ceilometer	Cloud base height
3.	Aethelometer	Aerosol scattering coefficient
4.	Nephelometer	Black carbon
5.	MARGA	Aerosol/Gas chemistry
6.	Soil Moisture/ Temperature sensors	SM/ST
7.	Eddy Covariance (EC) 12 m	TKE/KE/Sensible Heat Flux
8.	All in one sensors (10,20 m)	Temp/Rh/WS/WD/Pressure
9.	FM120	Fog droplet spectrum measurement

Fog forecast /Early warning system

Process based using Analogues method (Formation types, scale and period) using past cases:

- Radiation fog-basic predictors (Ta-Td, winds, clouds, inversion) for localized or synop-scale fog
- Advection and large-scale fog
- Different Analog technique of localized, synop and large-scale types fog events.

Synop based Fog forecast system

- Slower level east-west sub-tropic ridge line called fog ridge line/Subsidence and calm winds at lower levels and establishment of fog ridge line using *GFS winds Analysis and Forecast at D1-D5*
- *GFS Diagnostic/prognostic products of Fog and Pollution products*
- Sudden wind changes -advection fog
- WD location asbed fog forecst-Ahead and Behind
- Certain synoptic systems - Easterly wave, Cyclone at south Bay etc.

Climatological data based Threshold and checklist :

- Threshold table using surface and UA at the location (TA, Td, RH and Wind) with Upper air Inversion depth and intensity
- Min temp *vis-à-vis* dense fog occurrences curve

Objective/NWP based fog forecasts using fog Models

- IMD Empirical Fog model of intensity and duration based fog forecast System
- Experimental spatial and Airport based intensity based NCUM Global/Regional spatial Visibility based fog forecast map from NCMRWF for 24, 48, 72 hours and further validity
- Probability NEPS Fog forecast valid for 2 days
- NCUM 12 km Global fog model from NCMRWF valid for 10 days
- NCUM 4 km Regional fog model from NCMRWF valid for 3 days
- IITM WRF chem Products spatial and Airport based Visibility based Fog Model at 4 km resolution Delhi Region and at 2 km for Delhi Airport.

Occurrences of fog events in 2018-19 at IGIA Palam Delhi and Performance of its real time fog forecast system

The MWO Delhi has further modified its web based Fog monitoring, nowcasting, forecasting and dissemination system in Winter of 2018-19 by adding by adding products from 2 km WRF Chem fog forecst system and GFS based fog guidance products to achieve fruther 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 2018-19 at IGIA

The Airport has recoreded a subdued dense fog occurrances in the season as during months of November, December, January, February of 2018-19, CAT-III ILS dense fog event total occurrances were of 0/0, 3/9, 5/24 and 4/17 days/hours respectively at IGIA with seasonal all total of 12 days and 50 hours of dense fog occurrances against normal of 25 days and 140 hours. The main cause is movement of WDs in the region at regular intervals [total of 12 numbers moved in Nov-Feb (2018-19)] which had disturbed the lower elvel stable boundery layer pattern. Most often, they have also triggered stronger winds both at their ahead and followings of movements. Lower level ridge line never gets consolidated and aligned for some longer period as Narrow east-west fog Ridge line at lower levels say 925 hPa onwards.

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, 2018-19 is 90% 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 (Figs. 52&53).

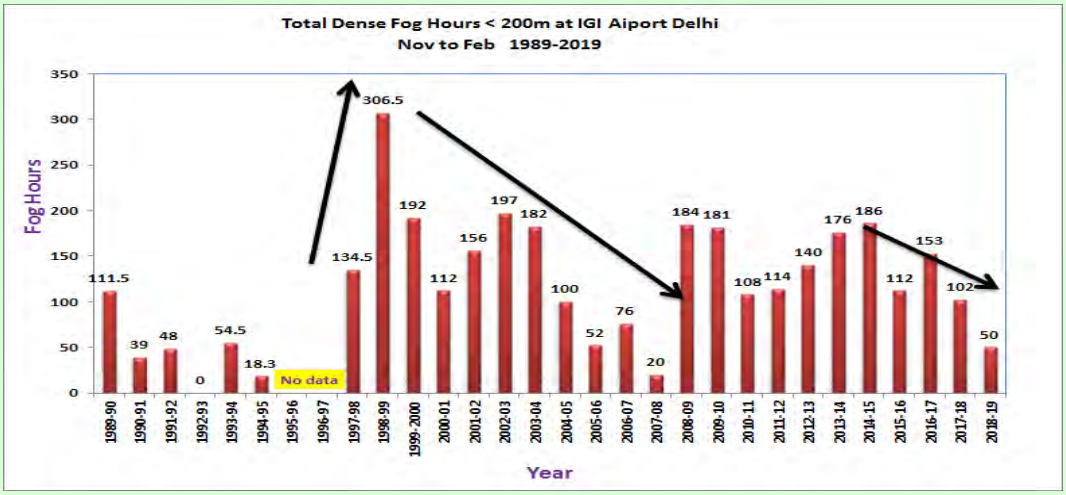


Fig. 52. Overall trends of total occurrences of season dense fog hours for Nov-Feb at IGIA 1989-2019

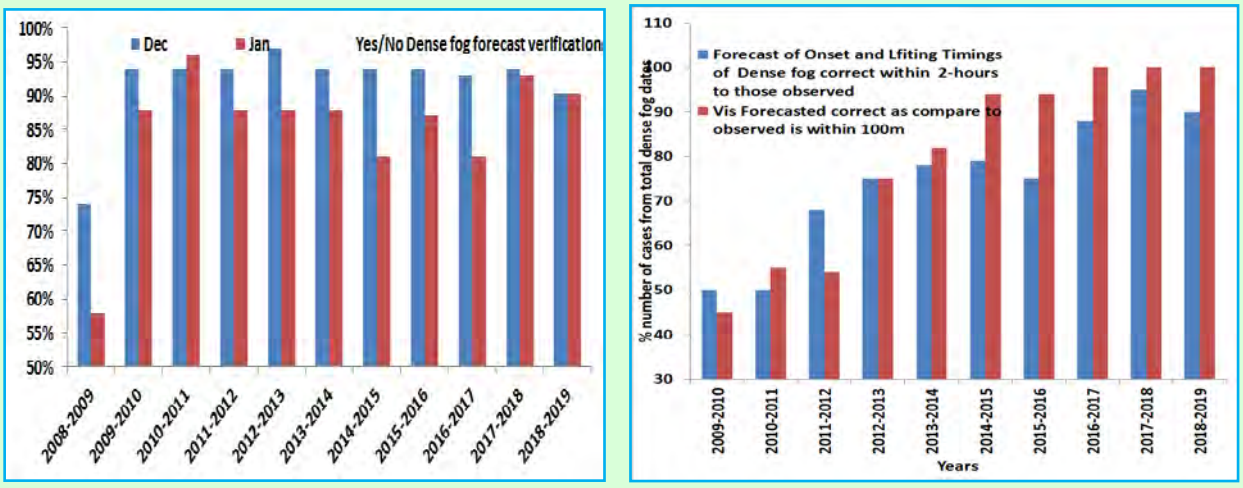


Fig. 53. On progress 2008-2019 categorical fog forecast (dense fog) and 2009-2019 timings of onset/lifting and min visibility forecast

Major Achievements by MWO IGIA Palam Delhi in 2019

Fig. 54. New ATC building IGI Airport

MWO Palam shifted its services and strated funcational Independently at the new ATC from August 2019. IMD timely planned and executed all logistic, civil, electrical and met data communication works (OFC Cable based and Wi-Fi Radio modem works) at new ATC building IGI Airport in coordination with AAI, for shifting its services of MWO Palam from old ATC building. It also shited and occupied its new office space at this new ATC in August 2019 (Fig. 54). It also successfully and timely provided all Met service support at different operational desk of ATC including live data from various sensors functional with sixteen RVR and six AWOS/DCWIS Systems from 11 number of sites located along three RWYs using both OFC cable based as well as Wi-Fi, MET REPORT/warning Display facilities etc for both test based Parallel operation started in March, 2019 and for final operation started in mid August, 2019.

- First Airport Met. office in India implemented WMO Aviation Research Development project (AvRDP) by implementing MET-ATM integration aspects through generation of impact based forecast and early warnings for fog and TS/DS season and progress were discussed in the concluding WMO SSC meeting to be held at Johannesburg, South Africa, 19-22 August, 2019.

WIFEX 2018-19 successfully completed at IGIA Delhi for 4th successively season-a 1st in Asia and 3rd in the world after France and USA. Besides total of around 25 sensors installed, which measured fog - micro-physics and BL parameters, the special was - MARGA Monitor for AeRosols and Gases in ambient Air - Continuous Measurements of Aerosols and Gases, the state of the art system for monitoring air quality 24 X 7. This year the project was operational from Nov last week for smog period and for fog period during 1 December, 2018 to 15 February, 2019.

Ministry's Aviation Modernization Expert committee 2019 submitted its report to secretary MoES in June 2019: A high level committee was formed by Secretary MoES during January 2019 for reviewing critically the available services along with Instruments and forecast status as availbe at all airports where IMD provides its services (Fig. 55). The committee headed by AVM Dr. Ajit Tyagi retired DGM and Dr. R. K. Jenamani Sc. 'F' as convenor completed the mammoth task, collected airport wise inputs where IMD provides its met services and reviewed airport met services of other major airports of the world. It has compiled status of all airports where IMD provides met services and their key aviation operational information covering all 88 airports and submitted a comprehensive report covering all aspects of modernisation and upgradation of its present services at its both interim and final report of 173 pages document.

Fig. 55. Ministry's Aviation Modernization Expert committee 2019

CHAPTER 6

CAPACITY BUILDING, PUBLIC AWARENESS & OUTREACH PROGRAMME

IMD's major initiative in 2019 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. D. S. Pai, Sc. 'F', Shri Y. K. Reddy, Sc. 'F', Shri P. Sunil, Sc. 'D', Shri R. Bibiraj, Sc.'B', Shri Prayek Sandepogu, Sc. 'B', Dr. Shirish Khedikar, Sc. 'B' and Shri Elphin T. Andrews, S. A. participated in "**India Conference on Radar Meteorology (IRAD 2019)**" at IITM, Pune during 9-12 January, 2019. Dr. Shirish Khedikar, Sc. 'B' presented a paper in the conference and received 3rd Best presentation Award.

International Conference on Thunderstorm and Lighting (ICTLT 2019)

Dr. M. Rajeevan, Secretary, MoES, Dr. K. J. Ramesh, DG, IMD, Dr. H. R. Biswas, Sc. 'E' during conference

Dr. M. Rajeevan, Secretary MoES, Dr. K. J. Ramesh, DG, IMD, Dr. H. R. Biswas, Sc. 'E' and other delegates from IMD, attended the **International Conference on Thunderstorm and Lighting (ICTLT 2019) at Siksha 'O' Anusandhan** (Deemed to be University), Bhubaneswar from 17-19 January, 2019 at M.C. Bhubaneswar.

Dr. M. Mohapatra, Sc. 'G' and Dr. Shirish Khedikar, Sc. 'B' participated in the **International Symposium on Advances in Agro-meteorology for Managing climate risks of farmers (INAGMET-2019)** at JNU, New Delhi from 11-13 February, 2019. **Dr. M. Mohapatra**, Sc. 'G' presented a Plenary Talk on "**Meteorological Support for Agriculture**" during the symposium.

Dr. S. D. Attri, Sc. 'F' addressed the gathering as Chief Guest in Valedictory function of national seminar "**Global Climate Change: Concerns & amp; Solutions**" on 16th February, 2019 at MDU, Rohtak.

Shri C. S. Patil, Sc. 'D' participated in national seminar on "**Strategies for disaster management: A multi disciplinary approach**" held on 19th February, 2019 at Govt. First Grade College, Madikeri organized by Govt. First Grade college, Madikeri and Department of Collegiate Education, Govt. of Karnataka, Bengaluru jointly.

Shri C. S. Patil, Sc. 'D' during the seminar

Dr. S. Balachandran, Sc. 'F' participated in the national level conference on "**Flood and Drought Management Practices and Future Challenges**" organized by Department of Geology, Periyar University, Salem during 20-22nd February, 2019 and delivered an invited talk on IMD's services in flood and drought management.

Shri C. S. Patil, Sc. 'D' participated in the national seminar on "**Extreme weather events: Drought and floods over Karnataka State**" organized by Govt. First Grade College, Yelburga and Deptt. of Collegiate Education, Govt. of Karnataka, Bengaluru and delivered lectures on "Services of IMD and extreme weather events; Drought and floods over Karnataka State" on 23rd February, 2019.

A local seminar on "**Monsoons-2018**" was organised jointly by RMC Chennai and Indian Meteorological Centre, Chennai Chapter on 25th February, 2019 at RMC Chennai. **Dr. S. Balachandran,** Sc. 'F', RMC Chennai presented the salient features of Northeast Monsoon-2018 and **Dr. N. Puviarasan**, Sc. 'E', RWFC Chennai presented the regional aspects of Southwest Monsoon-2018. **Shri B. A. M. Kannan,** Sc. 'E', DWR Chennai and **Shri R. Bibiraj**, Sc. 'B', DWR Visakhapatnam reviewed the tracking of cyclones during 2018 by DWRs Chennai and Visakhapatnam. About 100 participants including students, media and the general public attended the programme.

Dr. S. D. Attri, Sc. 'F' delivered lead talk on "**Weather and climate services for Indian Agriculture**" in FAI's (Fertilizer Association of India) programme on "**Recent Developments & Challenges in Fertilizer Sector**" organised at Haridwar, Uttarakhand during 8-11 May, 2019.

Shri Y. K. Reddy, Sc. 'F' and Dr A. Sravani, Sc. 'B' attended National seminar on "**Flood Early Warning for disaster risk reduction**" organized by NRSC & National Hydrology Project at Hyderabad on 30-31 May, 2019.

Shri C. S. Patil, Sc 'D' delivered a talk on "**Landslide vulnerability and risk mitigation in Karnataka**" for the training held for officers of State Government at Administrative Training Institute, Mysuru on 19th June, 2019.

Dr. Mrutyunjay Mohapatra, Sc. 'G', participated in the Annual Conference on capacity building of SDRF's during 29-30 June, 2019 held in New Delhi and presented an invited talk on "**Disaster Forecasting: Current status & prediction capacity building roadmap**".

Shri S. K. Manik, Sc 'C' attended the "**6th Water Talk to promote information sharing among participants on variety of water related topics**" on 23rd August, 2019 at Dr. Aambedkar Auditorium, Telengana Bhawan, New Delhi. The seminar is organized by National Water Mission, MoWR.

Dr. S. Bandyopadhyay, Sc. 'F' attended a "**International Conference on Sustainability Education (ICSE)**" at Bidhan Chandra Krishi Vishwavidalaya, Kalyani on 3rd September, 2019.

Dr. M. Rajeevan, Secretary, MoES, Dr. M. Mohapatra, DG, IMD and other higher officers of IMD attended the National Seminar on "**Lightning Early Warning: It's Operationalisation & Safety Cum Awareness**" at India Meteorological Department (IMD), Lodi Road, New Delhi during 3-4 October, 2019 organised by Indian Meteorological Society (IMS) in collaboration with IMD and Climate Resilient Observing-Systems Promotion Council (CROPC). Hon'ble Secretary, MoES inaugurated the event and **Dr. Mrutyunjay Mohapatra**, DG, IMD delivered the Key Note address during the event.

Dr. M. Rajeevan, Secretary, MoES and Dr. M. Mohapatra, DG, IMD and others during the seminar

Shri B. P. Yadav, Sc. 'F' attended the seminar regarding "**Lightning Early Warning, its Operationalization and Safety cum Awareness**" on 3-4 October, 2019 at IMD, New Delhi.

Dr. D. E. Surendran, Sc. 'C' and Dr. S. Y. Khedikar, Sc. 'B' participated in "**Young Scientists' Conference - 2019**", a part of India International Science Festival, held from 5-7 November, 2019 at Biswa Bangla Convention Centre in Kolkata and presented a poster on the topic "**Seasonal Prediction of Rainfall and Temperature: Role and impact on various**

sectors affecting economy" and "Hiwayther- An advanced Intelligent Road & Transport Management System" respectively.

Dr. Mrutyunjay Mohapatra, DG, IMD attended two day Regional conference on "**Jal Shaktiand Disaster Management**" organised by Governments of Tamil Nadu, Jammu & Kashmir and Ladakh during 30th November to 1st December, 2019. Dr. M. Mohapatra, DG, IMD also participated in the workshop and delivered an invited talk on "**Urban Flooding: Forecasting and Early Warning Emergency Responses**". During the Valedictory Session, Shri Farooq Khan, IPS and Advisor to Lt. Governor, Jammu & Kashmir applauded **Dr. Mohapatra**, DG, IMD for **accurate early warning services in association with various severe weather events, particularly, cyclones**.

Dr. S. D. Attri, Sc. 'F' participated in International Seminar on "**Climate Smart Farming Systems**" for BIMSTEC countries on 11th December, 2019 at NASC Complex, New Delhi.

Dr. M. Rajeevan, Secretary, MoES, Dr. M. Mohapatra, DG, IMD and other higher officers of IMD and other departments participated in National Symposium on "**Land, Ocean and Atmosphere Interactive Processes in the Context of Weather and Climate**" Jointly hosted by Indian Meteorological Society, Visakhapatnam Chapter and Department of Meteorology & Oceanography Andhra University, Visakhapatnam during 11-14 December, 2019 at Andhra University, Visakhapatnam, Andhra Pradesh.

Dr. Mrutyunjay Mohapatra, DG, IMD was conferred the "**Honorary Fellowship of the Indian Meteorological Society**" on 11th December, 2019 during TROPMET - 2019 at Visakhapatnam for his brilliance & expertise in "**Cyclones prediction that has led to significant reduction in loss of lives due to cyclones in recent years**".

Dr. M. Rajeevan, Secretary, MoES, Dr. M. Mohapatra, DG, IMD & other senior officers during TROPMET-2019

Dr. M. Mohapatra, DG, IMD attended as chief speaker in the Valedictory session in the National seminar organized by 11th Indian Climate Congress on "**Climate change and world peace**" on 27-29 December, 2019 at OUAT, Bhubaneswar.

Dr. M. Mohapatra, DG, IMD and other officers during the seminar

Dr. Mohapatra, DG, IMD has been awarded with the **9th Satyasai Samman** in a ceremony of the seminar. Dr. A. Kashyapi, Sc. 'F', Shri H. R. Biswas, Sc. 'E', Shri Umasankar Das, Sc. 'C', Shri P. K. Bal, Met. 'B', Shri P. K. Patra Met. 'A' and Ms. Anamika Mandal, S.A. also attended the seminar. **Dr. A. Kashyapi** presented W. S. keynote address entitled "**Study of extreme rainfall events during Monsoon 2019 - An eye opener towards climate resilient planning**".

6.2. Workshop

Dr. Pulak Guhathakurta, Sc. 'F' participated in the workshop on "**Building an Operational Composite Drought Monitoring Index for India**" at ICAR, Pusa, New Delhi from 22-23 January, 2019.

Shri H. R. Biswas, Sc, 'E' attended the workshop on "**Policy Dialogue on Environment and Climate Change**" conducted by Integrated Research and Action for Development IRAD at Bhubaneswar on 29-30 January, 2019 .

M. C., Hyderabad organized a half-day workshop on "**Eco-Weather Watch**" in collaboration with IMS Hyderabad Chapter and Earth Watch Institute, Gurgaon on 30th January, 2019.

Dr. M. Mohapatra, Sc. 'G' participated in the "**Knowledge Workshop on Climate Change and Disaster Management**" organised by Ministry of Environment and Forests at Paryavaran complex, New Delhi on 12th February, 2019.

Smt. S. Stella, Sc. 'E' and Shri V. H. Arun Kumar, Sc. 'B' participated in a "**3-day International Skynet Workshop**" organised by IMD at New Delhi during 13-15 February, 2019.

An international workshop on "**Earth Observations for Agricultural Monitoring**" was jointly organized by International Society of Photogrammetry and Remote Sensing (ISPRS), Group on Earth Observations Global Agricultural Monitoring (GEOGLAM) and Indian Society of Remote Sensing (ISRS) in New Delhi during 18-20 February, 2019.

Dr. M. Mohapatra, Sc. 'G' participated in a scoping workshop to explore collaborative observations and research on "**Northern Arabian Sea aimed to discuss and understand the Ocean Circulation & Air-Sea Interaction process that influences the Asian Monsoon**" was organised at INCOIS, Hyderabad during 25-26 February, 2019. The participants from Ministry of Earth Sciences (MoES), National Oceanographic & Atmospheric Administration (NOAA) and Office of Naval Research, USA. **Dr. M. Mohapatra**, Sc. 'G' chaired the technical session on "**Large scale processes and Ocean dynamics for Arabian Sea**".

Dr. M. Mohapatra, Sc. 'G' participated in a national workshop on "**Heat Wave**" organized by National Disaster Management Authority at Nagpur during 27-28 February, 2019. **Dr. M. Mohapatra**, Sc. 'G' presented an invited talk on "**Early Warning and Communication Strategy for effective intervention for heat prone areas**" during the technical session on "**Early warning, forecasting and Preparedness for heat wave**". He also chaired a technical session on "**Climate Change impact on heat wave**".

Dr. K. K. Singh, Sc. 'F' participated in multi stakeholder consultative workshop on "**Food security for Himalayan Farmers-Lesson learnt and best practices**" on 5th March, 2019 at India Habitat Centre, New Delhi.

M. C., Hyderabad conducted a workshop on "**Extreme Weather Events with reference to Heat Wave over Telangana State**" organized by Telangana State Disaster Management, TSDPS, UNICEF Hyderabad, India Meteorological Department (IMD) & IMS, Hyderabad Chapter on 6th March, 2019.

A media Workshop on "**IMD's Role and Technological Advances made by the Department**" was organized at RMC, Kolkata on 8th March, 2019.

Dr. S. D. Attri, Sc. 'F' participated and served as Chair of Working Group in "**India-Denmark Workshop**" on "**Digital agriculture for accelerated climate risk management in India**" held during 12-13 March, 2019 at ICRISAT, Hyderabad.

Dr. Kripan Ghosh, Sc. 'E' and Shri R. Balasubramanian, Sc. 'D', attended one day workshop on "**Dissemination of weather based agricultural advisories to the farmers under Mahavedh Project**" organized by Commissioner of Agriculture, Pune on 19th March, 2019 at Agricultural College, Pune.

Shri H. R. Biswas, Sc. 'E', attended the Media Workshop on "**Nowcast and Weather Services**" was organized at M.C., Bhubaneswar on 14th March, 2019 under the chairmanship of various electronic and print media personnel from Odisha and officers and staff members of IMD.

Dr. M. Mohapatra, Sc. 'G' participated in the Brainstorming workshop on "Climate Services:

Stake holder perspectives" organised by IMS on 23-24 March, 2019. Dr. Mohapatra presented a talk on "**Early warning and impact based forecast**" during the session on "**Climate Services for Disaster Risk Reduction**".

Dr. D. S. Pai, Sc. 'F' and Senior Officers of IMD attended "**Annual Monsoon Workshop (AMW-2018)**" and Prof. D. R. Sikka Memorial National Symposium on "**Role of Weather and Climate Observation and Forecasting on Increasing Agricultural Productivity and Risk Management**" from 28-30 March, 2019 at IITM, Pune.

Shri N. T. Niyas, Sc. 'D' attended a workshop on "**Environment, Climate Change-Biodiversity Conservation and Capacity building**" organised by Kerala Institute of Local Administration at Thrissur, Kerala on 20th May, 2019.

Dr. S. D Attri, Sc. 'F' attended MoEF & CC workshop to celebrate **"World Day to Combat Desertification"** to mark the 25th anniversary of the UN Convention to Combat Desertification (UNCCD) on 17th June, 2019 which was inaugurated by Ho'ble Minister of MoEF & CC at Vigyan Bhawan, New Delhi.

Shri Anand Sharma, Sc. 'F' invited as Chief Guest at the National Workshop on 17th June, 2019 by R. K. Goel Institute of Technology and Management, Ghaziabad and delivered lead talk on **"Role of weather and Climate in Sustainable Development**".

Shri Anand Sharma, Sc. 'F' during the Workshop

Dr. S. Bandyopadhyay, Sc. 'F' attended workshop on "**Developing Model for Forecasting Climate-Sensitive Waterborne Diseases**" and delivered a lecture on the topic "**Current Perspectives on Climate Change**". The workshop was organized by ICMR-National Institute of Cholera and Enteric Diseases on 19th June, 2019.

Dr. K. J. Ramesh, DG, IMD, Dr. K. K. Singh, Sc. 'G', Dr. S.O. Shaw, Sc. 'E' and Shri Sanjay Bist, Sc. 'E' attended workshop cum "**Interaction meeting in Lightning Resilient India Campaign and Agromet Advisory Services in NER of India at NESAC**", Umium, Barapani, near Shillong on 22nd June, 2019.

M. C. Hyderabad conducted a awareness workshop for Media Persons on 24th June, 2019 in which 26 media persons participated. Shri Rajeshwar Tiwari, IAS, Principal Secretary to Govt. of Telangana and Relief Commissioner addressed the gathering and appreciated **IMD for improved forecasting and conducting awareness workshop**.

Dr. Pulak Guhathakurta, Sc. 'F' attended a workshop on "**Safe & Sustainable Technologies and Strategies for integrated Fresh water Resource management**" at JSS Academy of Higher Education and Research, Mysuru from 25- 28 June, 2019.

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

Dr. Mrutyunjay Mohapatra, Sc. 'G' co-chaired the session on "**Flood Forecasting - New Initiatives by Central Water Commission**" during the workshop on "Flood Management" on 26th June, 2019 at New Delhi.

Dr. Jayanta Sarkar, Sc. 'F' attended interactive Stakeholders workshop for evolving Rajkot "**Heat Stress Action Plan**" organized by IIPH, Gandhinagar at Rajkot on 26th June, 2019.

Dr. Kripan Ghosh, Sc. 'E' attended the workshop on "**Soil Moisture Estimation**" chaired by Joint Secretary (IT/Crops/FW), DAC&FW in Ministry of Agriculture & Farmers Welfare, Krishi Bhavan, New Delhi on 26th June, 2019.

Dr. M. Mohapatra, Sc. 'G' was invited as a Guest of Honour in the Valedictory Function of the "**National Training Workshop on Disaster Risk Reduction organized by VV Giri National Labour Institute (VVGNLI), Noida**" and **NIDM, MHA**, New Delhi on 28th June, 2019 and delivered a talk on cyclone warning services.

Dr. S. Balachandran, Sc. 'F' participated in the workshop on Technical Assistance on Coastal Resilience "**Developing New and Innovative Approaches in India and Bangladesh along the Bay of Bengal**" held at NIOT, Chennai on 17th July, 2019

Dr. M. Mohapatra, Sc. 'G' participated as an expert in the one day workshop organized by Vigyan Prasar for planning the layout of science programme "**Vigyanika**" on 23rd July, 2019 at New Delhi.

Shri H. R. Biswas, Sc. 'E' attended as Guest of Honour in the workshop on "**Restoration Strategies for Cyclone-affected Horticultural Crops**" at Central Horticultural Experiment Station (ICAR-Indian Institute of Horticultural Research), Aiginia, Bhubaneswar on 25th July, 2019.

Dr. O. P. Sreejith, Sc. 'E' attended workshop on "**Data Simulation**" on 9th August, 2019 at NCMRWF, New Delhi.

Smt. S. Sunitha Devi, Sc. 'E' participated in the India-UK workshop on Science for disaster & emergency management on 29-30 August, 2019 at New Delhi and presented "**Science for Disaster/emergency risk management: Capabilities, Institutional landscape, Science-Policy interface, opportunities & challenges, special reference to Cyclone Fani**".

South Asian Climate Outlook Forum (SASCOF-15)

Dr. M. Mohapatra, DG, IMD and Senior officers of IMD attended a "**South Asian Climate Outlook Forum (SASCOF-15)**" workshop

Dr. M. Mohapatra, DG, IMD, senior officers of IMD and foreign & Indian delegates during SASCOF-15 workshop

during 23-25 September at Thiruvananthapuram, India. Consensus Statement on the Forecast for the 2019 October to December (OND) Season Rainfall and Temperatures over South Asia was issued in 15th Session of the South Asian Climate Outlook Forum (SASCOF-15).

A half-a-day Hindi workshop was organized at **M.C. Bengaluru** on 26th September, 2019. **Shri Damodaran**, Dy Director, Hindi Cell, Coffee Board delivered speech on importance of Hindi in official Language.

Shri B. P. Yadav, Sc.'F' and Dr. A. K. Das, Sc.'E' attended the one day workshop on "**Management of Floods: Reservoir Management and other Preventable Measure**" on 18th October, 2019 at New Delhi. Shri Yadav, Sc. 'F' delivered a lead talk on "Localised Hydrometeorological Services of IMD for Flood Forecast".

Dr. M. Mohapatra, DG, IMD, Shri H. R. Biswas, Sc. 'E' and other Officers of M.C. Bhubaneswar attended 2nd National Conclave on "**Climate Change and Water**" at IITM, Bhubaneswar during 19-20 October, 2019.

Dr. M. Mohapatra, DG, IMD & other officers of IMD during the workshop

Dr. D. S. Pai, Sc. 'F' , Dr. O. P. Sreejith, Sc. 'E' and Dr. D. E. Surendran, Sc. 'C' participated in one day National Workshop organized by

Directorate of monsoon Mission on "**CFS Modelling Approaches**" at IITM, Pune on 29th October, 2019.

Shri H. R. Biswas, Sc. 'E', Shri N. P. Kulkarni, Sc. 'B', Shri S. H. Bhagwat, Met. 'A' and Shri D. H. Dolas, S.A. attended "**4th IMD Upper Air Network performance (UANP) Workshop - 2019"** at New Delhi on 18-19 November, 2019.

Shri Anand Sharma, Sc. 'F' delivered the lead talk on "**Kedarnath Disaster**" at "**Asia Pacific Hydrology Workshop**" and was also co-chairman of technical session-2 on 20-21 November, 2019. The workshop was organised by Indian Institute of Technology, Roorkee.

Dr. Mrutyunjay Mohapatra, DG, IMD participated in the the International Workshop on "**Prediction of extreme precipitation events and Tropical Cyclones: Present status and future prospects (IP4) and Annual Climate Workshop**" at Indian Institute of Tropical Meteorology (IITM), Pune on 28th November, 2019. During the workshop, Dr. Mohapatra presented a talk on cyclone warning system in India.

Dr. M. Mohapatra, DG, IMD during the workshop

Dr. Kripan Ghosh, Sc. 'E' attended the workshop on "**WCSSP- WP3 Impacts-based Forecasting (IBF)**" and gave presentation on "**Impact Based Agromet Advisory Services in India**" held at Indain Institute of Tropical Meteorology (IITM), Pune from 29-30 November, 2019.

Dr. A. K. Das, Sc. 'E' attended the 2nd Workshop of **Central Board of Irrigation and Power (CBIP)** on 9th December, 2019 at SJVN (CBIP), Chandigarh.

6.3. Meetings

Dr. V. K. Mini, Sc. 'E' attended meeting on "**State Level core committee"** convened by EARAS, Thiruvananthapuram on 1st January, 2019 in the Chamber of Principal Secretary (Planning), Government of Kerala.

Shri Bikram Singh, Sc. 'F' attended a meeting under the chairmanship of Honourable Governor, Uttarakhand on 10th January, 2019 in connection with "**Basantotsav 2019**" and provided climatological information of temperature and rainfall for the event.

Shri C. S. Patil, Sc. 'D' attended the "**20th Executive committee**" meeting of Karnataka state NDMC on 11th January, 2019.

Dr. M. Mohapatra, Sc. 'G' participated in the 1st quarterly meeting chaired by Secretary, MoES to "**Evaluate and monitor the progress of implementation of programmes of IMD"** on 21st January, 2019.

Dr. S. Balachandran, Sc. 'F' participated in the committee meeting constituted by Secretary, MoES to accomplish various programmes of IMD under the Umbrella Scheme '**ACROSS**' on 21st January, 2019 at New Delhi.

Shri B. Arul Malar Kannan, Sc. 'E' participated in the **Critical Design Review** meeting held at M/s. Astra Microwave Products Ltd, Hyderabad from 22-23 January, 2019 in connection with "**Supply/development of 10 nos. of X-band radars**" for IMD.

Dr. M. Mohapatra, Sc. 'G' participated in the review meeting to study **"Development of Web-DCRA & DSS Tool for cyclone and associated impacts"** under NCRMP (Ph. II) at NDMA on 28th January, 2019.

Dr. S. D. Attri, Sc. 'F' attended a meeting of Committee for preparation on "**Agriculture Disaster Management Plan under Disaster Management Act 2005"** at MoAg New Delhi on 28th January, 2019.

Shri Y. K. Reddy, Sc. 'F' and Shri Vivek Sinha, Sc. 'F' attended a meeting on 29th January,

2019 with M/s GHIAL and AAI, Hyderabad for deciding the "**MET equipment required for converting the Secondary Runway to Cat-1 capability**".

Dr. M. Mohapatra, Sc. 'G' participated in the 6th Meeting of "**Cauvery Water Regulation Committee**" at Bengaluru on 31st January, 2019.

Dr. N. Puviarasan, Sc. 'E' and Dr. B. Geetha Met. 'A' attended 42nd meeting of "**State level co-ordination committee on crop Insurance (SLCCCI) finalization and floating of tender, for the implementation of Pradhan Mantri Fasal Bima Yojana in Tamilnadu for the period 2019-2020 and 2021-2022**" on 31st January, 2019 at Agriculture Department, Secretariat, Chennai.

Dr. S. Balachandran, Sc. 'F' participated in the first meeting of the "**Committee for preparation of RFP for a comprehensive visualization platform and Decision Support System for weather forecasting & Dissemination**" on 1st February, 2019 at IMD New Delhi.

Dr. M. Mohapatra, Sc. 'G' participated in the meeting of the "**Committee constituted for preparing Protocol, Work Plan and Press Release**" on 4th February, 2019 at MHA, New Delhi for the 10th Meeting of Heads of departments of disaster prevention of SCO states.

Shri L. Ramesh Babu, Sc. 'E' participated in the meeting of "**Fog Management MOU between BIAL & JNCASR**" held at JNCASR, Bengaluru on 4th February, 2019.

Shri H. R. Biswas, Sc. 'E' attended 4th meeting for the year 2018-19 of the "**State Executive Committee constituted under the Disaster Management Act, 2005**" at Secretariat, Bhubaneswar on 5th February, 2019.

Dr. M. Mohapatra, Sc. 'G' participated in the 13th Research Advisory Committee (RAC) meeting of "**Indian National centre for Ocean Information & Services (INCOIS)"** held at INCOIS, Hyderabad on 15th February, 2019.

Dr. S. D. Attri, Sc. 'F' attended a meeting of "**NATCOM Workshop"** held at Ministry of Environment, Forests and Climate Change on 15th February, 2019.

Shri Y. K. Reddy, Sc. 'F' conducted OLIC meeting on 27th February, 2019 at MC Hyderabad and discussed to "**Improve the usage of Rajbhasha in all official correspondence**".

Dr. M. Mohapatra, Sc. 'G', Shri R. Bibiraj, Sc. 'B' participated in the "**Brainstorm Meeting on application of Artificial Intelligence & Machine Learning**" on 25-27 March, 2019 at IITM Pune.

Dr. V. K. Mini, Sc. 'E' attended a State Level Core Committee meeting for preparing advanced estimate of "**Chief crops and their yield**" during 2017-18 at the chamber of Additional Secretary on 28th March, 2019.

Shri G. N. Raha, Sc. 'D' attended meeting organized by Sikkim State Disaster Management Authority, Govt. of Sikkim on 4th April, 2019 for formulation of detailed Project Report for "**Glacial Lake Outburst Flood risk management**" at Tashiling Secretariat, Gangtok, East Sikkim.

Shri B. P. Yadav, Sc. 'F' attended a meeting for "**Developing Hydro-meteorological Resilient Action Plans (HmRAP) - Constitution of Consultants Evaluation Committee**" on 5th April, 2019 at NDMA Bhawan, New Delhi.

Dr. Jayanta Sarkar, Sc. 'F' attended a meeting on "**Heat Action Plan**" at Ahmedabad Municipal Corporation on 5th April, 2019.

Shri K. V. Singh, Sc. 'E' and Dr. A. K. Das, Sc. 'E' attended a meeting on "**Fourth Inter Ministerial Co-ordination meeting of Yarluns Tsangpo (Brahmaputra) River**" at Sardar Patel Bhawan, New Delhi on 8th April, 2019.

Dr. S. O. Shaw, Sc. 'E' attended meeting of "**Flood Preparedness**" called by the Chief Secretary of Assam on 12th April, 2019.

Shri D. K. Borthakur Met. 'B' and Mrs. R. B. Gayary Met. 'A' attended a meeting for "**Flood**

Forecasting preparedness" related activity held on 12th April, 2019 at CWC Adabari Guwahati under the chairmanship of Engineer B & BBO, CWC Shillong.

Dr. S. O. Shaw, Sc. 'E' attended meeting of "**Core Group committee constituted for data sharing amongst stake holders**" at Brahmaputra Board, Guwahati on 16th April, 2019.

Smt. Manorama Mohanty, Sc. 'E' and Shri K. G. Kacha, Met. 'A' attended a meeting with Shri Manoj Gangal, Airport Director Ahmedabad regarding "I**nstallation of DWR"** at M.C. Ahmedabad on 18th April, 2019.

Dr. Devendra Pradhan, Sc. 'G', Shri K. C. Sai Krishnan, Sc. 'F', Shri K. S. Hosalikar Sc. 'F' and Dr. Jayanta Sarkar, Sc. 'F' attended a meeting with CPWD officials and the Airport Director on 22nd April, 2019 regarding "**DWR installation**" at Ahmedabad and construction of new M.C. Ahmedabad building.

S/Shri S. M. Metri, Sc. 'E' and C. S. Patil, Sc. 'D' attended a meeting on Progress of "**Brahut Bengaluru Mahanagar Palike"** works under the chairmanship of Chief Secretary, Bengaluru on 23rd April, 2019.

Dr. Kripan Ghosh, Sc. 'E' attended board of studies meeting in "**Agricultural Meteorology Discipline at Centre for Advanced Faculty of Training in Agricultural Meteorology (CAFT), Pune**" on 24th April, 2019.

Dr. S. Bandyopadhyay, Sc. 'F' attended a meeting with Hon'ble Mayor of Kolkata Municipal Corporation in connection with "**Removal of water and to combat flood**" during the period of ensuing monsoon on 29th April, 2019.

Dr. Shashi Kant, Sc. 'B' attended a "**Pre-Cyclone Exercise**" meeting at Secretariat chaired by Chief Secretary, Odisha on 29th April, 2019.

Dr. S. Bandyopadhyay, Sc. 'F' and Dr. G. K. Das, Sc. 'D' attended a meeting with Chief Secretary, Govt. of West Bengal at Nabanna to apprise him regarding the **"Latest situation of very severe Cyclonic Storm 'FANI' and its impact over West Bengal**" on 30th April, 2019.

Shri H. R. Biswas, Sc. 'E' attended the Review Meeting on Cyclone **"FANI"** on 1st and 3rd May, 2019 at Secretariat chaired by Hon'ble Chief Minister, Odisha.

Shri K. Santhosh, Sc. 'F' attended a meeting with the Chief Secretary of Kerala on 4th May, 2019 at Govt. Secretariat, Thiruvananthapuram, in connection with the **Visit of Hon'ble Prime Minister** on 8th June, 2019.

Dr. S. D. Kotal, Sc. 'E' and Shri S. C. Mondal, Met 'A' attended a meeting at B. M. Airport, Ranchi organized by SPG regarding "**Security and Weather related matter**" on 6th May 2019.

Dr. S. D. Attri, Sc. 'F' attended a meeting on "**Policy Review of SMS Dissemination through m-Kisan portal of MoAg & FW"** at Krishi Bhawan on 14th May, 2019 held under the chairmanship of JS (IT).

Dr. Jayanta Sarkar, Sc. 'F' attended a state level pre monsoon meeting chaired by the chief secretary, Govt. of Gujarat, at Gandhinagar regarding "**Monsoon 2019 preparedness"** on 15th May, 2019 and gave a presentation.

Shri H. R. Biswas, Sc. 'E' attended the 1st & 2nd Meeting for the year 2019-20 of the State Executive Committee constituted under the "**Disaster Management Act, 2005**" under the chairmanship of Chief Secretary at Secretariat, Bhubaneswar on 16 & 24 May, 2019 respectively.

Dr. Shashi Kant, Sc.'B' attended the State Level Coordination Committee on "**Crop Insurance (SLCCCI) for implementation of PMFBY**" during 2019-20 at Odisha Secretariat on 18th May, 2019.

Shri Anand Shankar, Sc. 'B' attended a meeting on "**Urban flooding organized by BSDMA**" Govt. of Bihar, chaired by Chairman, BSDMA on 21st May, 2019.

Dr. A. K. Das, Sc. 'E' attended the 72nd meeting of "**Technical Advisory Committee of NIH**" on 3rd June, 2019 at Committee Room, Sewa Bhawan, CWC, New Delhi.

Dr. Pulak Guhathakurta, Sc. 'F' attended the meeting for the revision of "**Mission Document, National Water Mission"** under the chairmanship of Secretary Ministry of Water Resources, River Development & Ganga Rejuvenation on 6th June, 2019 at Shram Shakti Bhawan, New Delhi.

Dr. S. D. Kotal, Sc. 'E' attended a meeting organized by "**Disaster Management"** Govt. of Jharkhand at Nepal House, Doranda, Ranchi on 11th June, 2019.

Dr. Jayanta Sarkar, Sc. 'F' attended meetings with Hon'ble Chief Minister of Gujarat Shri Vijaybhai Rupani at Gandhinagar regarding cyclone "**VAYU**" on 11-14 June, 2019.

Dr. Jayanta Sarkar, Sc. 'F' attended meetings, with Hon'ble Chief Minister of Gujarat Shri Vijaybhai Rupani

Dr. Shashi Kant, Sc. 'B' attended the meeting of the "**16th State Level Monitoring Committee (SLMC)"** for implementation of PMFBY in the state at Krushi Bhawan, Bhubaneswar on 11th June, 2019.

Dr. Jayanta Sarkar, Sc. 'F' attended a "**Weather watch group**" meeting at State Emergency Operation Cell, Govt. of Gujarat, at Gandhinagar regarding **VAYU cyclone** on 18th June, 2019.

Mr. R. S. Sharma, Sc. 'B' attended a meeting at Project Bhawan, Ranchi in connection with "**Crop weather watch group (CWWGDM) VC**" on 19th June, 2019.

Dr. Jayanta Sarkar, Sc. 'F' attended a meeting, with ICAR, Govt. of Gujarat & CRIDA under chairmanship of Additional Chief Secretary (Agril.) regarding better preparedness to handle "**Weather Aberrations During Kharif Season-2019"** at Gandhinagar on 21st June, 2019.

Dr. K. J. Ramesh, DG, IMD, Dr. S.O. Shaw, Sc. 'E' and Shri Sanjay Bist, Sc. 'E' attended meeting with senior officials of POSOCO at Shillong on 21st June, 2019, regarding "**Weather Services Provided By IMD"** and installation of AWS in their sites.

Dr. K. J. Ramesh, DG, IMD & officers of IMD at Shillong

Shri H. R. Biswas, Sc. 'E' attended a meeting on "**Flood Atlas Release of Odisha"** under the Chairmanship of Hon'ble Chief Minister on 22nd June, 2019 at Odisha Secretariat, Bhubaneswar.

Shri Virendra Singh, Sc. 'F' participated in the meeting of "**RSMC Tokyo and RSMC New Delhi**" to discuss the activities and finalization of SOP for Tropical Cyclone border and enhancement of co-operation between two RSMC during 2-3 July, 2019 at IMD New Delhi.

Dr. N. Puviarasan, Sc. 'E' attended the "**Interview meeting for the selection of Observer**" as a committee member to represent IMD held on 4th July, 2019 at Madras Veterinary College, Chennai under GKMS Scheme.

Dr. Jayanta Sarkar, Sc. 'F' attended "**Weather watch group meetings**" at State Emergency Operation Centre, Govt. of Gujarat, Gandhinagar regarding "**Monsoon - 2019**" on 2nd, 9th, 16th and 24th July, 2019.

Dr. Kripan Ghosh, Sc. 'E' and Shri R. Balasubramanian, Sc. 'E' attended the meeting with the team members from National Council

of Applied Economic Research (NCAER), New Delhi regarding the "**Assessment of India Meteorological Department Services**", particularly the impact of Gramin Krishi Mausam Sewa (GKMS) scheme on the livelihood of farmers in the country at Head CR&S chamber, IMD, Pune on 15th July, 2019.

Shri B. P. Yadav, Sc. 'F' and Dr. A. K. Das, Sc. 'E' attended "**4th meeting of Expert Committee on Scientific Assessment of Flood Prone Areas of India**" on 26th July, 2019 at CWC, Sewa Bhawan, New Delhi.

Shri R. Balasubramanian, Sc. 'E' and Shri S. S. Mairal, Met. 'B' attended the meeting under the Chairmanship of Hon'ble Minister of Agriculture, Government of Maharashtra, on the subject of opening "**India Meteorological Department, Regional Centre for Agromet Field unit (AMFU)**" at Mantralaya, Mumbai on 30th July, 2019.

Dr. Jayanta Sarkar, Sc. 'F' attended interview at AMFU, Dantiwada as a member of interview panel for recruitment of Research Associate under "**GKMS Project of IMD**" on 31st July, 2019.

Brainstorming Meet at RMC, Chennai

Officers during Brainstorming meet at RMC Chennai

Under the joint auspices of Indian Meteorological Society, Chennai Chapter and Regional Meteorological Centre, Chennai, a "**Brainstorming Meet**" on Chennai Water Management was held on 3rd August, 2019 at RMC Chennai.

Shri Virendra Singh, Sc. 'F' attended the meeting to "**Explore the possibility to open Asia Agro Meteorological centre**" chaired by DG, IMD on 14th August, 2019.

Shri Bikram Singh, Sc. 'F' attended the meeting presided over the Chief Secretary, Government of Uttarakhand with the Inter-Ministerial Central Team constituted at the Government of India level in connection with the recommendation of grant from the "**National Disaster Relief Fund**" on 30th August, 2019.

Dr. M. Mohapatra, DG, IMD and H. R. Biswas, Sc. 'E' attended the meeting with State Government Officers was conducted regarding "**Met. Services in the state of Odisha**" on 2nd September, 2019 .

Shri Virendra Singh, Sc. 'F', Dr. R. K. Giri, Sc. 'E' and Shri Amit Kumar, Sc. 'C' attended the meeting on 3rd September, 2019 with Delegation of Scientists from Finish Meteorological Institute on "**Planning Air Quality Forecasting using FMI-SILAM and ENFUSER**" under the Chairman ship of DG, IMD at conference hall, Mausam Bhawan, New Delhi.

Dr. S. D. Attri, Sc. 'F' participated in meeting on "**Hydro-climate services to improve decision - making on drought**" at COP-14 of United Nations Convention to Combat Desertification organised by Centre for Ecology & Hydrology, Oxfordshire, UK and ADPC Bangkok on 12th September, 2019 at Greater Noida, Uttar Pradesh.

Shri Anand Kumar Sharma, Sc. 'F' attended a meeting with Vice Chancellor, Y. S. Parmar University of Horticulture and Forestry, Solan on 17th September, 2019 regarding recruitment of staff for AMFU, Seobagh and Solan and also delivered lectures to M.Sc./ Ph. D students of the university on weather and climate issues.

Dr. S. D. Kotal, Sc. 'E' attended a meeting with Additional Chief Secretary, Department of Disaster Management, Govt. of Jharkhand regarding "**Declaring drought as a result of weak monsoon in 2019**" on 25th September, 2019.

Dr. A. K. Das, Sc.'E' and Shri A. Raja, Sc. 'C' attended the 5th Inter-Ministerial

Coordination meeting of "**Brahmaputra river monitoring in TAR segment"** on 3rd October, 2019 at Kailash Hall NSCS, New Delhi.

Dr. S. L. Singh, Sc. 'F' participated in the meeting of LITD 22 held on 16th October, 2019 at BIS Headquarters, New Delhi to discuss the "**Various International and National Geospatial standards**".

Dr. P. Guhathakurta, Sc. 'F' attended a "**State Level Governing Body and Task Force**" for "**Climate Change and Human Health (CCHH)**" meeting held at Mumbai on 17th October, 2019.

Shri B. P. Yadav, Sc.'F', Dr. A.K. Das, Sc. 'E' and Shri S. K. Manik, Sc. 'C' attended the meeting on "**Upgradation of Hydromet Services under Chairmanship of DGM"** on 23rd October, 2019 at New Delhi.

Shri H. R. Biswas, Sc. 'E' attended meeting on "**Construction of Doppler Weather Radar Building at Balasore**" convened by SRC Govt. of Odisha at, Rajiv Bhawan, Bhubaneswar on 25th October, 2019.

Dr. O. P. Sreejith, Sc. 'E', Dr. D. E. Surendran, Sc. 'C' and Smt. A. B. Bandgar, Sc. 'C' attended meeting organized by SRMC of "**Monsoon Mission on Physics of the monsoon and its interannual Variability**" on 4-5 December, 2019 at IITM, Pune.

Dr. S. D. Attri, Sc. 'F', Dr. A. K. Baxla, Sc. 'E' and Mr. Sanjiv Kumar Sagar, Met. 'A' participated in "**Fasal Review Meeting (Value for Money)**" held under the chairmanship of CEO, NRAA on 5th December, 2019 at Krishi Bhawan, New Delhi.

Dr. Kripan Ghosh, Sc. 'E' participated as a member in Technical Evaluation Committee (TEC) meeting on 12th December, 2019 for "**Evaluation of performance of Agro AWS systems**" of the vendors for procurement of two hundred Agro AWS systems under Gramin Krishi Mausam Sewa.

Smt. S. Sunitha Devi. Sc. 'E' attended meeting on "**Synoptic systems of the southwest monsoon**" held under the National monsoon mission programme & presented "**Nature of the synoptic systems during the summer monsoon**" on 17th December, 2019 at IITM, Pune.

6.4. Training

Dr. Suman Goyal, Sc. 'F', Shri H. R. Biswas, Sc. 'E', Officers and Staff members participated in the training programme on **"Interpretation of Satellite Imageries and Products"** was conducted on 21st January, 2019.

Familiarization Training for taking **"Meteorological Observations"** was conducted at M. C., Bhubaneswar during 11-15th February, 2019. Six Observers from AMFU Bhubaneswar, G. Udaygiri, Kirei, Chipilima, Mahisapat and Keonjhar in Odisha attended the Training classes.

Participants in Meteorological Observations training

Shri Elphin T. Andrews, S. A., was deputed for "**ISRO-BEL S-Band Doppler Weather Radar training"** at SDSC, SHAR, Sriharikota during 24 February-2 March, 2019.

Dr. Rajavel Manickam, Sc. 'D' and Smt. N. Saraswati, S.A. conducted a training programme on "**Block level advisories**" on 16th May, 2019 at KSNDMC, Bengaluru.

Dr. S. Bandyopadhyay, Sc. 'F' inaugurated "**Integrated Meteorological Training**" batch No.VI at Salt Lake Training Centre, Kolkata for new recruited SAs on 11th June, 2019.

Dr. S. Bandyopadhyay, Sc. 'F' during training

Dr. S. L. Singh, Sc. 'F' attended "**Deep Dive Training Programme**" during 19-22 June for security of IT systems organized by Ministry of Electronics and Information Technology.

A half day training programme was organized for 35 Members of Pragya in connection with use of "**Agrimet Weather Forecast Products for farmers**" and other services being provided by IMD in Uttarakhand. **Shri Bikram Singh**, Sc.'F' and Shri Rohit Thapliyal, Sc. 'C' delivered the lectures to the participants.

One-week training course on "**Maintenance and Servicing of Systems - Distant Indicating Wind Equipment (DIWE) and Digital Current Weather Indicating System (DCWIS)"** was conducted for IMD staffs working at different airports under RMCs - Chennai, Guwahati, Mumbai, Kolkata and Nagpur from 16th September to 4th October, 2019 in three batches.

Trainees during Maintenance and Servicing of Systems

Dr. (Smt.) K. Naga Ratna, Sc. 'E' attended the Environment Projection, Training Research Institute (EPTRI)'s workshop on "**State Action Plan on Climate Change (SAPCC) for the Telangana**" on 19th September, 2019.

Dr. A. K. Mitra, Sc. 'E' attended the training programme on "**Application of Geographic Information System in Disaster Risk Management**" during 19-20 September, 2019 at Indian Institute of Surveying and Mapping, Hyderabad, Telengana.

Dr. Kripan Ghosh, Sc. 'E' and Shri R. Balasubramanian, Sc. 'E' attended and delivered lectures on "(*i*) **Agromet Advisory Services and Agromet Product**' and (*ii*) **Use of crop simulation models in crop yield forecasting**" to the students of **National Training Programme** on "**Recent Advances in Crop Micrometeorology**" at Mahatma Phule Krishi Vidyapeeth, Department of Agricultural Meteorology, Centre of Advanced Faculty of Training in Agricultural Meteorology (CAFT), College of Agriculture, Pune on 1st & 3rd October, 2019.

Dr. M. Mohapatra, DG, IMD addressed the **trainees of District Agro-Meteorological Unit (DAMU)** and also reviewed the work of **M.C. Hyderabad** on 15th October, 2019. Training was imparted to **SMS Agrimet and Agromet observers** from 15-17 October, 2019 at M.C. Hyderabad.

Shri H. R. Biswas, Sc. 'E' delivered lecture on the subject "**TAF writing using recently developed NWP products for Aviation application**" in the **Refresher Training Course on Aviation Meteorology** at MTI, Pune on 20th November, 2019.

Dr. M. Mohapatra, DG, IMD, addressed and **Dr. Pulak Guhathakurta**, Sc. 'F', Dr. D. S. Pai, Sc. 'F', Dr. Kripan Ghosh, Sc. 'E', Dr. D. E. Surendran, Sc. 'C', Smt. A. B. Bandgar, Sc. 'C' and Latha Sridhar Met. 'A' delivered lecture to the trainees in the "**International Training workshop on Operational Climate Service**" jointly organized by India Meteorological Department and Regional Integrated Multi-Hazard Early Warning System, Bangkok, Thailand held at Meteorological Training Institute (MTI), Pashan, Pune 9-20 December, 2019.

Dr. M. Mohapatra, DG, IMD and others during the Training workshop

6.5. Lectures/Talk

Dr. S. Balachandran, Sc. 'F' delivered lectures on "**Synoptic Meteorology in Advanced Meteorological training course (AMTC)**" at IMD Pune, during 6-7 February, 2019.

Shri C. S. Patil, Sc. 'D' delivered lectures on "**Services of IMD and extreme weather events; drought and floods over Karnataka State**" at the National seminar held at Government First Grade Degree College, Yelburga on 23rd February, 2019. The seminar was jointly organized by Govt. First Grade College, Yelburga and Department of Collegiate education, Govt. of Karnataka, Bengaluru.

Dr. A. K. Srivastava, Sc. 'F', Dr. A. Kashyapi, Sc. 'F', Dr. Pulak Guhathakurta, Sc. 'F' and Dr. O. P. Sreejith, Sc. 'E' delivered lectures in the training program for "**Hydro-Met (HM) Cadre of CWC (PAMET)**" at Central Water Commission National Water Academy, Pune from 3-7 June, 2019.

Shri Rohit Thapliyal, Sc. 'B' delivered a lecture on "**Weather and Climate**" on 9th June, 2019 to the newly promoted PGT (Geography) teachers of Kendriya Vidhyalaya in K. V., ITBP, Dehra Dun.

Shri Anand Sharma, Sc. 'F' delivered an invited lecture on "**Role of weather forecast and warning in disaster management**" on 15th June, 2019 at the HRDC, Kumayun University, Nainital.

Dr. Jayanta Sarkar, Sc. 'F' delivered a lecture on "**Flood Early Warning System**" at GIDM, Gandhinagar on 5th July, 2019.

Dr. Sanjib Bandyopadhyay, Sc. 'F' Kolkata delivered a lecture on **"Functions of IMD**" on 5th July 2019 to 40 number of participant of input dealers undergoing 1 year course of "**Diploma in Agricultural Extension Services for input Dealers (DAESI)**" alongwith faculty members and staffs.

Shri Bikram Singh, Sc. 'F' delivered a lecture to officers of S.D.R.F Uttarakhand on establishment of "**Hydro-Met Network**" on 12th July, 2019.

Shri Virendra Singh, Sc. 'F' delivered lecture to the trainees of "**Forecasters Training course Batch-18**" at Pune during 15-17 July, 2019.

Dr. D. S. Pai, Sc.'F' and Ms. A. B. Bandgar, Sc. 'C' participated and deliver lecture in the workshop on "**Onset of Indian Summer Monsoon: Theory and Prediction**" organized by Indian Institute of Science (IISc), Bengaluru, India on 25 & 26 July, 2019. The workshop was sponsored by the Future South Asia Regional Office at the Divecha Centre for Climate Change.

Dr. Jayanta Sarkar, Sc. 'F' delivered a lecture on "**Climate Profile of India and Gujarat and trends of Weather Events**" at GIDM, Gandhinagar on 25th July, 2019.

Shri Amit Kumar, Sc. 'C' delivered lecture to the trainees of "**IMTC training course Batch-6**" at Pune during 6-9 August, 2019.

Dr. Jayanta Sarkar, Sc. 'F' delivered lectures on "**Introduction to IMD weather forecast and strom & Cyclone forecast in Training on Flood Forecast**" at SRTC, Gandhinagar on 19th August, 2019.

Shri C. S. Patil, Sc. 'D' delivered a Lecture on "**Intensity and distribution of rainfall over the country**" on 27th August, 2019 at The Institution of Engineers (India) Karnataka State Centre, Bengaluru.

Shri Anand Kumar Sharma, Sc. 'F' delivered an invited lecture on "**Challenges of weather prediction in the mountains**" on 5th September, 2019 at the Senior Met Officers conference at Shillong. The training program was organised by Head Quarters Eastern Air Command, Shillong.

Shri Anand Sharma, Sc. 'F' delivered an invited lecture on Atmospheric Science Education program - IMPLORE on 9th September, 2019 at the "**International Conference on Sustainable Education**" at India Habitat Centre, New Delhi.

Dr. Geeta Agnihotri, Sc. 'E' delivered a lecture on "**Weather Forecasting System During Floods**" to Home Guards and Civil Defence Academy, Bengaluru on 19th September, 2019.

Dr. S. D. Attri, Sc. 'F' attended and delivered talk in National Round Table Meet on "**Doubling of Income of Farmers - Role of Stakeholder**" chaired by Secretary, DARE and DG, ICAR and attended by Senior Officials from Centre and State Govt. Universities, PSUs, Co-operatives, NGOs etc. on 21st September, 2019 at Ahmedabad.

Shri Y. K. Reddy, Sc. 'F' delivered a lecture at MANAGE, Rajendra Nagar, Hyderabad, on "**AGROMET Services & FASAL Crop Forecasting**" on 25th September, 2019.

Smt. S. Stella, Sc. 'E' as permitted to deliver lecture on "**Weather and Environment**" to the trainees of three-day training programme on "**Environment Laws and Enforcement**" organised by AP Human Resource Development Institute (APHRDI) at Bapatla on 25th September, 2019.

Dr. S. D. Attri, Sc. 'F' delivered lead talk on "**Sustaining Climate Change Impacts-Challenges & Opportunities**" in **6th India Water Week** on 27th September, 2019 at Vigyan Bhawan, New Delhi and served as Co-chair also.

Dr. S. D. Attri, Sc. 'F' during the talk

Dr. M. Mohapatra, DG, IMD convened a special session on "**Natural Hazards**" on 15th October, 2019 during the "**2nd Triennial Congress of Federation of Indian Geosciences Associations (FIGA)"** at CSIR- National Geo-physical Research Institute (NGRI), Hyderabad.

Dr. O. P. Sreejith, Sc. 'E' delivered lecture on SASCOF-A mechanism for preparing Consensus Climate Forecast outlook during training programme on "**Regional Service & Flash Flood Hazard Early Warning Mechanism**" conducted by SAARC Disaster Management Centre (IU) at Gandhi Nagar, Gujarat on 16th October, 2019.

Dr. Soma Sen Roy, Sc 'E' participated in the release of "**Monsoon 2019 Lightning Report**" followed by a lecture during the two day National Lightning Symposium on Lightning Resilient India Campaign on 7-8 November, 2019 at IMD, Lodi Road, New Delhi.

Dr. M. Mohapatra, DG, IMD delivered a talk at an event hosted by Department of Physics, Utkal University, Bhubaneswar on 17th November, 2019. Shri H. R. Biswas, Sc. 'E' also attended the programme.

Dr. M. Mohapatra, DG, IMD during the event

Shri P. S. Biju, Sc. 'E' delivered lecture on "**AWS/Radiation**" to the Officers from NAVY at MTI, Pune on 3rd December, 2019.

6.6. Awareness & Outreach Programme

Farmers Awareness Programme (FAP)

Farmers' awareness programs were organized at 28 AMFUs (Jharnapani, Srinagar, Anand, Portblair, Sindewahi, Majihan, Gossaigaon, Brahmavar, Raipur, Jammu, Pundibari, Kakdwip, Kharagpur, Lamphalpet, Kalyani, Roorkee, Sonitpur, Jorhat, Chintapalli, Diphu, Ranichauri, Lembucherra, Basar, Barapani, Navsari, Raipur , New Delhi and Majhian).

Farmers' awareness programs

AMFU, Raipur, Chhattisgarh and **Krishi Vigyan Kendra, Durg** jointly organized one day FAP by Department of **Agrometeorology, IGKV, Raipur** on 1st October, 2019 at Santra village. Shri J. L. Chaudhary, Nodal Office informed about weather forecasting & GKMS activities.

Shri J. L. Chaudhary durig FAP at Raipur

AMFU, Basar, Arunachal Pradesh organized FAP on "**Current erratic climate and role of Agromet Advisory Services**" at Soi village, Leparada district, Arunachal Pradesh on 28th November, 2019.

AMFU, Basar, Arunachal Pradesh at Soi village

AMFU, Kalyani, West Bengal organised FAP at Krishi Mela, Dhaniakhali Krisak Mandi, Block - Dhaniakhali on 29th December 2019 to explained objectives of **GKMS project**. Dr. Mahasweta Bhowmick Dutta, Technical Officer explained weather forecasting, weather based Agromet Advisory, usefulness of Bulletin, SMS and special forecast.

Dr. Mahasweta Bhowmick Dutta during FAP at Krishi Mela

6.7. Indian Visitors

Forty two (42) students & teachers attending "**Environment cum Mineral awareness Programme**" conducted by Society of Geoscientists and allied Technologists (SGAT), Bhubaneswar had a field visit to M.C., Bhubaneswar on 12th January, 2019.

A group of **15 Students** of B. A. Third Year (Geography) alongwith 3 faculty member from Shri Haripal Shastri Smarak, Feena, District Bijnor, Uttar Pradesh visited **MC, Dehradun** on 20th January, 2019. Students were shown Met-Observatory and briefed about functioning of the observatory.

Twenty five (25) students from Muktangan Engineering College have visited the **Air Pollution Laboratory, CRS, Pune** on 24th January, 2019. They were explained about the activities of APS.

Twenty (20) mid career Indian Civil Service Officials under Govt. of India visited **India Meteorological Department (IMD)**, New Delhi on 6th February, 2019. The team familiarized with various observational/forecasting/ dissemination work/services of IMD.

Dr. Chhaya Shukla, Member, Uttarakhand Public Service Commission and Member Managing Committee, Indian Red Cross Society, State Branch of Uttarakhand alongwith 15 volunteers of Red Cross Society visited **Met. Centre Dehradun** on 16th February, 2019.

Shri Bikram Singh, Sc.'F', alongwith volunteers

19 Indian sailors and 2 Indian coast Guard Naviks and 1 instructor from School of Naval

Oceanology and Meteorology (SNOM), Naval base, Kochi visited **Meteorological Training Institute (MTI), Pune** on 26th February, 2019.

An educational tour group comprising **10 students** of M. Sc. Agricultural Meteorology & M. Sc. Environmental Sciences with one faculty member from Department of Environmental Sciences and NRM, SHUATS, Allahabad visited **MC, Bhubaneswar** on 26th February, 2019 .

Twenty eight (28) M.B.B.S. (6th Semester) students alongwith 2 faculty members from Govt. Doon Medical College, Dehradun visited **MC, Dehradun** on 26th March, 2019.

Twenty five (25) M.Sc (II year) students from Wadia college and 30 students from Tolani Institute, Talegaon have visited the **Air Pollution Section, CRS, Pune** on 28th February, 2019.

A group of Scientist from DRDO, headed by Dr. A. K. Rajdan, Sc. 'G' along with Shri B. Sinha, Sc. 'F' and Shri Gajendra Kumar, Sc. 'E' from IMD visited **AMO Kolkata** for conducting "**Thunderstorm related experiment-LIDAR**" from 4-9 April, 2019.

Thirty Five (35) students of MBBS along with two Professors, from Sola medical college GMERs, Ahmedabad visited **Met. Centre, Ahmedabad** on 5th April, 2019. They were briefed regarding taking **Surface & u/a observation, Forecasting procedure and the activities of IMD**.

About **Sixty (60)** students with faculty members from Kejriwal Management institute of Ranchi visited **M. C., Ranchi** on 15th April, 2019. They were briefed by IMD officials about basics of **forecasting, observatory sites, RS/RW observation** etc.

Fifty (50) no's of student from Veterinary College, Khanapara Guwahati on 29th April, 2019 and another 50 no's of student on 30th April, 2019 visited **RMC Guwahati**.

Twenty two (22) Met. trainees and an Instructor from SNOM Kochi visited **DWR Chennai** on 6th May, 2019 as a part of their curriculum. They were explained about the principles and working of DWR and utilities of products.

Forty (40) B.Sc/M.Sc students of Manav Rachna Vishvidyalya, Faridabad visited **Satellite Meteorology Division** at IMD, H.Q., New Delhi on 6th May, 2019 for familiarization with the activity of satellite Meteorology Division.

Nineteen (19) Students from Naval base Kochi visited **MTI, Pune** on 10th May, 2019. Shri R.K. Oke, Met. 'A' and Shri Y.S. Visale, Met. 'A' explained the different activities of MTI such as observatory.

Twenty Eight (28) M.B.B.S. (6th Semester) students along with 2 faculty members from Govt. Doon Medical College, Dehradun visited **M.C., Dehradun** on 16th May, 2019 and shown Met-Observatory and briefed about functioning of the observatory by Shri Man Mohan Saklani, Met. 'B' and a lecture was delivered by Shri Rohit Thapliyal, Sc. 'B' on **Weather & Climate** to the students.

Thirty Four (34) Met. Trainees along with two Instructors (IPT COURSE IPT 01/18) from Air Force Station, Tambaram visited **DWR Chennai** on 28th May, 2019 as part of their curriculum. They were explained about the principles of **DWR and utility of products in weather forecasting**.

One hundred sixty (160) Students of Modern High School, Kolkata visited in **RMC Kolkata** for Educational Tour, on 18-19 June, 2019. Various section of this office had familiarized them about departmental activities.

Dr. L. S. Rathore, Retired DG, IMD consultant World Bank visited satellite meteorology Division along with four World Bank officers on 25th June, 2019 to familiarize the officers with the activity of satellite meteorology division.

Eighty (80) students (40 students each day) of Jaipuria School, Vaundhara, Ghaziabad visited **IMD, H.Q.** during 8-9 July, 2019 for

familiarization with the activity of "**Satellite Meteorology Division**".

Fourteen (14) students of Institute of Public Administration visited **IMD, H.Q.** on 11th July, 2019 for familiarization with the activity of "**Satellite Meteorology Division**".

Seven (7) Doctor Students of AIIMS visited **IMD, H.Q.** on 15th July, 2019 for familiarization with the activity of "**Satellite Meteorology Division**".

Ten (10) newly commissioned officers of Indian Air Force Meteorological Branch visited **IMD, H.Q.** on 16th July, 2019 for familiarization with the activity of "**Satellite Meteorology Division**".

Hon'ble Minister of Agriculture (Govt. of Maharashtra) Dr. Anil Bonde visited **CR&S, Pune** office on 19th July, 2019 and had meeting with senior officials of IMD.

Twenty Five (25) M.B.B.S. (6th Semester) students along with 2 faculty members from Govt. Doon Medical College, Dehradun visited **M.C., Dehradun** on 22nd July, 2019. Students were shown "**Met. Observatory & briefed about functioning of the observatory**".

M.B.B.S. students at M.C., Dehradun

Twenty Five (25) students along with 2 teachers of Grade V from Pragati school, Ahmedabad visited **Met. Centre, Ahmedabad** on 23rd July, 2019.They were briefed about forecasting procedure and taking "**Surface and u/a observation**".

Forty Seven (47) students along with 2 faculty members from Gyananda School for Girls Dehradun visited **M.C., Dehradun** on 22nd August, 2019. Students were shown "**Met. Observatory and briefed about functioning of the observatory**".

Fifteen (15) sailors from School of Naval Oceanography & Meteorology, Kochi visited **CR & S Pune** for "**Familiarization**" on 23rd July, 2019.

Fifty (50) Graduate/Post Graduate students of Manav Rachna Vishavvidyalaya, Faridabad visited **IMD, H.Q.** on 26th July, 2019 for familiarization with the activity of "**Satellite Meteorology Division**".

Sixty One (61) Forecasters course trainees of Air Force Administrative College Coimbatore visited **IMD, H.Q.** on 1st August, 2019 for familiarization with the activity of "**Satellite Meteorology Division**".

Thirty Five (35) students along with 2 teachers of Botany, School of Science, Gujarat University, Ahmedabad visited **Met. Centre, Ahmedabad** on 8th August, 2019. They were briefed about "**Forecasting procedure and taking Surface and u/a observation**".

Twenty One (21) students of Delhi Public school visited **IMD, H.Q.** on 20th August, 2019 for familiarization with the activity of Satellite "**Satellite Meteorology Division**".

Eighteen (18) class VII students of Vega Gurugram Haryana **IMD, H.Q.** on 28th August, 2019 for familiarization with the activity of "**Satellite Meteorology Division**".

Twenty Five (25) students along with 2 teachers from River Side School, Ahmedabad visited **Met. Centre, Ahmedabad** on 25th September, 2019. They were briefed about "**Forecasting procedure and taking surface and u/a observation**".

Shri M. Ramachandrudu, I.A.S, Additional secretary and **Shri Amod Kumar Sharan**, Additional secretary, of Disaster Management Department, Govt. of Bihar visited **Doppler Weather Radar** on 28th September, 2019.

Shri Anand Shankar, Sc. 'B' briefed them about the "**Weather forecasting service provide by India Meteorological Department (IMD) along with functioning of DWR**".

Mr. Sanjeev Kumar Jindal, IAS, Joint Secretary (Disaster Management), Ministry of Home Affairs and his team visited National Weather Forecasting Centre (NWFC), IMD at H.Q., New Delhi to have an overview of monitoring of **VSCS Bulbul** on 9th November, 2019. **Dr. M. Mohapatra**, DG, IMD explained the **overall monitoring and forecasting procedure for monitoring and prediction of tropical cyclones and various types of bulletins issued from the centre**.

Dr. M. Mohapatra, DG, IMD, Mr. Sanjeev Kumar Jindal, IAS, MHA and officers of IMD

A delegation from **Govt. of Odisha** led by **Principal Secretary, Disaster Management, Managing Director, OSDMA and Special Relief Commissioner, Odisha, Shri Pradeep Kumar Jena**, IAS visited **IMD, New Delhi** on 16th November, 2019 and held meeting with IMD Scientists led by **Dr. M. Mohapatra**, DG, IMD to enhance the **"Collaboration between IMD and Odisha state for early warning services"**. On this occasion, **the Principal Secretary appreciated the forecast and warning issued by IMD during last cyclone Bulbul**.

An educational tour group comprising (Fifty Five) 55 students of B. Sc. Hons. of **Department of Environmental Science, Berhampore Girl's College, Murshidabad, West Bengal** along with faculty members visited **MC, Bhubaneswar** on 22nd November, 2019.

Forty Nine (49) Met. Trainees along with two Instructors (IPT COURSE IPT 02/ 18) from Air Force Station, Tambaram visited **DWR Chennai** on 26th November, 2019 as part of their curriculum. They were explained about the **principles of DWR and utility of products in weather forecasting**.

Dr. M. Rajeevan, Secretary, MoES visited **RMC Mumbai** office to review the ongoing projects of **CFLOWS-Mumbai, Veravali IMD Doppler Radar and 4 X-band radar for Mumbai** through IITM. A detailed **presentation of all the activities (achievements) along with future plans of RMC Mumbai was made by Shri K. S. Hosalikar**, Sc. 'F' & officials from IITM, Pune participated in his Review meeting on 14th December, 2019.

6.8. Foreign Visitors

Two (2) Russian scientists visited **MC, Bengaluru** on 16th January, 2019.

Thirteen (13) students from seven countries in the **Asia-Pacific region**, doing a nine month PG course in "**Satellite Meteorology and Global climate**" at Centre for Space Science and Technology Education in Asia Pacific (CSSTEAP), a United Nations recognized organization under SAC, Ahmedabad, ISRO visited **DWR, Chennai** on 25th January, 2019.

Ms. Manal Alhashmi, research scholar from **Oman** visited **IMD H.Q., New Delhi** during 21-28 February, 2019 to consult with **Dr. M. Mohapatra**, Sc. 'G' Services on her research project, entitled El Nino and Southern Oscillation (ENSO), Indian Ocean Dipole (IOD) on Tropical Cyclone activity over Arabian Sea with special emphasis on Oman.

Shri Jothiraman Vivekanandan, a renowned Radar Scientist from **NCAR, USA** visited **DWR, Chennai** on 14th March, 2019 and shared his presentation with DWR team on the recent advancements in Airborne wind profilers and LIDARs and rainfall correction techniques.

Two scientists from RSMC Tokyo visited **IMD, H.Q.** during 2-3 July, 2019 to discuss the "**Standard operating procedure for cyclones migrating into other's domain area**

and to explore bilateral understanding between the two RSMCs w.r.t. sharing of knowledge".

Mr. Sunao Sato and Mr. Chaiki Kudo from **Japan Meteorological Agency (National weather service of Japan)** visited **IMD, H.Q.** on 19th July, 2019 for familiarization with the activity of "**Satellite Meteorology Division**".

Delegation from National Centre for Meteorology, United Arab Emirates visited **MoES & IMD, New Delhi** on 8th November, 2019 for initiating bilateral collaboration between the two agencies.

Dr. M. Mohapatra, DG, IMD alongwith senior officers of IMD and delegation from United Arab Emirates

Visit of His Royal Highness Prince Charles to India Meteorological Department

Dr. M. Rajeevan, Secretary, MoES and Dr. M. Mohapatra, DG, IMD welcomes His Royal Highness Prince Charles

His Royal Highness Prince Charles visited India Meteorological Department (IMD) on 13th November, 2019 for fascinated with the pin point accuracy of monitoring of cyclone FANI. **His Royal Highness** was in India during 13-14 November, 2019 for celebrating British-India connections. **Dr. M. Rajeevan, Secretary, MoES** and **Dr. Mrutyunjay Mohapatra, DG, IMD** welcomed His Royal Highness Prince Charles.

Dr. Mohapatra presented cyclone warning system of IMD which showcases India's technological abilities in monitoring of severe weather events including tropical cyclones and their +3 prediction and warning services. **His Royal Highness** appreciated the accurate predictions during **cyclone FANI** which crossed Odisha coast in May, 2019 and recent cyclone Bulbul which crossed West Bengal-Bangladesh coast on November, 2019. He specially complemented IMD which also acts as Regional Specialised Meteorological Centre, New Delhi for providing the advisory services to the countries in the region to effectively mitigate disaster associated with cyclones.

A Delegation from Mozambique led by **Mr. Aderito Celso Felix Aramuge, Director General of Mozambique National Meteorology Institute (INAM) and PR of Mozambique with WMO** visited **Ministry of Earth Sciences (MoES) & India Meteorological Department (IMD), New Delhi** to learn about "**India's best practices on Cyclone Forecasting and end to end Early warning system for effective disaster management"** on 6th December, 2019.

Dr. M. Rajeevan, Secretary, MoES & Dr. M. Mohapatra, DG, IMD alongwith Delegation from Mozambique

6.9. Foreign Deputation

Dr. Ambikapathy Ammani, Sc. 'B' (National Centre for Seismology) is on Ex-India deputation to **Japan** from 14 January, 2019 to 9 March, 2019 to participate in knowledge co-creation program on "**Global Seismological Observation**".

Shri Charan Singh, Sc. 'F' was on Ex-India deputation to **Kathmandu**, Nepal during 29-31 January, 2019 to participate in the workshop on "**Future Climate Projection and their Application in South Asia**".

Dr. D. S. Pai, Sc. 'F' and Dr. Divya E. Surendran, Sc. 'B' participated in training workshop on "**Operational Seasonal Prediction for South Asia Region**" from 25-28 February, 2019 at Regional Integrated Multi-Hazard Early Warning System (RIMES), **Bangkok, Thailand**.

Shri K. N. Mohan, Sc. 'F' Pune was on Ex-India deputation to **Tokyo, Japan** during from 6-9 March, 2019 to participate in the "**RA-II WIGOS Workshop - Regional WIGOS Centre (RWCs) and its Services**".

Dr. S. L. Singh, Sc. 'F', was on Ex-India deputation to **Bejing, China** during 12-15 March, 2019 to participate in joint meeting of "**CBS Expert Team on WIS Centres (ET-WISC) and Task Team on WIS Data Centres (TT-DC)**".

Shri Rahil Akram, S.A. was on Ex-India deputation to **Germany** for the period 31 March - 13 April, 2019 to participate in the "**36th Training Session at Global Atmosphere Watch Training and Education Centre (GAWTEC-36)**".

Dr. N. Puviarasan, Sc. 'E' was on Ex-India deputation to **Abu Dhabi** during 2-4 April, 2019 to participate in the **"CCL-17 FOCUS AREA-4"** Meeting.

Dr. V. Vizaya Bhaskar, Sc. 'E' was on Ex-India deputation to **Vienna (Austria)** during 7-12 April, 2019 to attend the "**European Geosciences Union (EGU) - General Assembly-2019 - 30th anniversary of Global Atmospheric Watch (GAW) Meeting"**.

Dr. D. R. Pattanaik, Sc. 'E' was on Ex-India deputation to **Ankara, Turkey** during 15-26 April, 2019 to participate in the "**Eleventh International Training Workshop Climate Variability & Prediction (11th ITWCVP)**".

Dr. D. R. Pattanaik, Sc. 'E' during the Workshop

Shri Sanjay Bist, Sc. 'E' was on Ex-India deputation to **Shenzhen, China** from 16-18 April, 2019 to participate in the "**4th WMO Monsoon Heavy Rainfall Workshop"**.

Dr. D. S. Pai, Sc. 'F' and Dr. O. P. Sreejith, Sc. 'E' as resource persons and Dr. Nahush Prakash Kulkarni, Sc. 'B' as operational expert were on Ex-India deputation to **Nepal** during 18-23 April, 2019 to participate in the pre-COF Training Workshop & "**14th Session of South Asian Climate Outlook Forum (SASCOF)**".

Dr. D. S. Pai, Sc. 'F' was on Ex-India deputation to **Geneva, (Switzerland)** during 29th April to 1st May, 2019 to participate in the WMO CCI/CBS Inter-Programme Expert Team on "**Regional Climate Activities**".

Dr. (Ms.) V. K. Mini, Sc. 'E' was on Ex-India deputation to **University of Warwick, UK** during 8-10 May, 2019 to participate in the workshop on "**Science and Innovation for Catchment Management**".

Dr. K. J. Ramesh, DG, IMD & P.R. of India with WMO was on Ex-India deputation to **Kyoto, Japan** during 8-12 May, 2019 as a member of Indian delegation to participate in the "**49th Session of Intergovernmental Panel on Climate Change (IPCC)**".

Shri Charan Singh, Sc. 'F' was on Ex-India deputation to **Geneva, Switzerland** to participate in the WMO's Second Multi-Hazard Early warning Conference (MHEWC-II) & Sixth Session of the Global Platform for "**Disaster Risk Reduction**" during 13-17 May, 2019.

Dr. Ashim Kumar Mitra, Sc. 'E' was on Ex-India deputation to **Sochi, Russian** Federation for participation in "**20th Session of the Global Space-based Inter-calibration System Executive Panel (GSICS-EP)**" on 16-17 May, 2019.

Dr. V. S. Prasad, Sc. 'G' along with Shri Virendra Singh, Sc. 'F' AND Dr. R. K. Giri Sc. 'E' were on Ex-India deputation at Sochi-Russian Federation for participation in the "**47th Meeting of Coordination Group of Meteorological Satellites (CGMS-47)"** during 19-23 May, 2019.

Shri N. Nigam, Sc. 'F' was on Ex-India deputation to **Singapore** for participation in "**ICAO Asia/Pacific Meteorology/Air Traffic Management (MET/ ATM)"** Seminar during 27-29 May, 2019 and Eighth Meeting of the "**Meteorological Requirements Working Group (MET/RWG-8)**" during 30-31 May, 2019.

Shri Sunil G. Kamble, Sc. 'F' was on foreign deputation to **Washington-USA** during 17-21 June, 2019 to participate in "**Command Centre CDM"** workshop as familiarization and training week at **Federal Aviation Administration (FAA)**.

Dr. Siddhartha Singh, Sc. 'E' was on foreign deputation to **Huelva, Spain** during 17-21 June, 2019 to participate in the "**17th WMO/GAW BREWER OPERATOR COURSE-ASIA/PACIFIC".**

71st Meeting of Executive Council of WMO

Indian delegation led by **Dr. M. Rajeevan, Secretary, MoES** was on foreign deputation to attend the 18th World Meteorological Congress during 3-14 June, 2019 and "**71st Meeting of Executive Council of WMO**" during 17-19 June, 2019 at **Geneva, Switzerland**. Delegation includes **Dr. M. Rajeevan**, Secretary, MoES [3-5 June, 2019 (Cg-18)], **Dr. K. J. Ramesh**, DGM, P. R. of India with WMO and Member of Executive Council of WMO [3-14 June, 2019 (Cg-18)], **Dr. M. Mohapatra**, Sc. 'G', [10-19 June, 2019 (Cg-18 & EC-71)], **Dr. Gopal Iyengar**, Sc. 'G', MoES [10-14 June, 2019 (Cg-18)], **Dr. R. K. Giri**, Sc. 'E' [3-19 June, 2019 (Cg-18 & EC-71)].

Shri Bibraj Raj, Sc. 'C' is on foreign deputation to **USA (Colorado State University)** for the period 15th July, 2019 to 14th October, 2019 to attend the three month's training course on "**Advanced Dual Polarisation Radar**".

Dr. S. L. Singh, Sc. 'F' was on foreign deputation to **Offenbach, Germany** during the period 26-29 August, 2019 to participate in the Meeting of the Task Team on "**Global Information System Centres (TT-GISC)**".

Dr. V. K. Soni, Sc. 'E' was on foreign deputation to **Bangkok, Thailand** during the period 27-28 August, 2019 to participate in the "**Asian and Pacific Centre for the Development of Disaster Information Management (APDIM) Side Event on Sand and Dust Storms in United Nations Conference Centre (UNCC)**".

Dr. Rajendra Kumar Jenamani, Sc. 'F' was on foreign deputation to **Bangkok, Thailand** during 24-27 September, 2019 to participate in Meeting of the Regional Sub-project Management Team (RSMT) for "**Severe Weather Forecasting Demonstration Project Southeast Asia (SWFDP-SeA)**".

Mrs. S. Sunitha Devi, Sc. 'E' was on foreign deputation to **Myanmar** during 9-13 September, 2019 to participate in 46th Session of "**WMO/ESCAP panel on Tropical Cyclones (PTC-46) at Nay Pyi Twa**".

Dr. Siddhartha Singh, Sc. 'E' was on foreign deputation to **Irene, South Africa** during 7-18 Oct, 2019 to participate in "**WMO/UNEP 5th Southern Africa Dobson Spectrophotometer Inter-comparison (IC) Meeting"**.

Mrs. Sunithadevi Santhamma, Sc. 'E' was on foreign deputation to **Tokyo, Japan** during 10-11 October, 2019 to participate in the "**Conference regarding High-Level Dialogue on Tropical Cyclone"**.

Ms. K. Sathi Devi, Sc. 'F' was on foreign deputation to **Pretoria, South Africa** during

14-18 Oct, 2019 to participate in the Meeting of the "**Steering Group for Severe Weather Forecasting Demonstration Project (SWFDP)**".

Mrs. Sampada Mahesh Lohogaonkar, S.A. was on foreign deputation to **Hopenpeissenberg (Zugspitze), Germany** during 14-25 October, 2019 to participate in the "**37th GAWTEC Training Course on Total Atmospheric Deposition at Environmental Research Station Schneefernerhaus and the Observatory".**

Dr. Sankar Nath, Sc. 'E' was on foreign deputation to **Mexico** city during 16-18 October, 2019 to participate in "**Common Alerting Protocol (CAP) 'Train the Trainers' Session and CAP Implementation Workshop**".

Dr. D. R. Pattanaik, Sc. 'E' was on foreign deputation to **Kathmandu, Nepal** 22-23 October, 2019 to participate in the **Regional Knowledge Forum on Early Warning for Flood and High Impact Weather Events** in "**The International Centre for Integrated Mountain Development (ICIMOD)**".

Dr. S. D. Attri, Sc. 'F' was on foreign deputation to **Singapore** during 29-31 October, 2019 to participate in the **"Joint Management Group Meeting for Asia & the South-West Pacific**".

Dr. S. D. Attri, Sc. 'F', during "Joint Management Group Meeting for Asia & the South-West Pacific"

S/Shri Brahm Prakash Yadav, Sc. 'F' and **Asok Raja**, Sc. 'C' were on ex-India deputation to **Antalya, Turkey** during 3-8 November, 2019 to participate in "**Flash Flood Guidance System Regional Centres meeting & Global Flash Flood Guidance System Workshop**".

Dr. Sankar Nath, Sc. 'E' was on ex-India deputation to **Tokyo, Japan** during 13-15 Nov, 2019 to participate in the "**OSCAR/Surface updated activities and training course for RA-II National Focal Points (East Asia)"**.

Dr. Mrutyunjay Mohapatra, DG, IMD was on ex-India deputation to **Kathmandu, Nepal** during 19-21 November, 2019 to participate in "**South Asia Hydromet Forum-II"**. **Dr. Mohapatra** participated in a **Panel Discussion with Heads of National Meteorological & Hydrological Services of South Asian countries and World Bank Representative during South Asia Hydrometeorological Forum** aimed to explore and promote pathways for regional collaboration on 19th November, 2019.

Dr. M. Mohapatra, DG, IMD at Kathmandu, Nepal

Dr. S. Balachandran, Sc. 'F' was on ex-India deputation to **Tokyo, Japan** during 27-29 November, 2019 to deliver lecture in "**ESCAP/WMO Typhoon Committee Attachment Training at RSMC"**.

Shri M. I. Ansari, Sc. 'E' was on ex-India deputation to **Lindenberg, Germany** during 3-5 December, 2019 to participate in the meeting of "**WMOs CIMO Task Team on Upper Air Inter-compression (TT-UAL-2021)"**.

Dr. Suman Goyal, Sc. 'F' and **Mr. H. R. Biswas**, Sc. 'E' was on ex-India deputation to **Melbourne, Australia** during 2-7, December, 2019 for participation of "**10th Asia/Oceania Meteorological Satellite Users Conference (AOMSUC-10)"**.

Dr. O. P. Sreejith, Sc. 'E' was on ex-India deputation to **San Francisco, CA, USA** during 7-13 December, 2019 to participate in "**WCRP Climate Science Week – AGU Fall** Meeting".

6.10. Important Events 2019

IMD FOUNDATION DAY, 2019

"**144th IMD Foundation Day 2019**" was celebrated on 15th January, 2019 at Dr. Ambedkar International Centre (DAIC), Janpath, New Delhi. The event was inaugurated by **Dr. Harsh Vardhan, Hon'ble Union Minister of Science & Technology, Earth Sciences and Environment, Forests & Climate Change**. Welcome address was delivered by **Dr. K. J. Ramesh DG, IMD** wherein he highlighted the achievements of IMD during the previous year and future plans. **Hon'ble Union Minister Dr. Harsh Vardhan and Padma Shri A. S. Kiran Kumar**, distinguished Professor, Vikram Sarabhai Space Centre and Ex. Chairman, ISRO delivered Key Note Addresses on the occasion. **Dr. M. Rajeevan, Secretary, MoES** presided over the function. **Dr. S. D. Attri**, Chairman, Organising Committee delivered Vote of Thanks. Inter-school Painting, Speech and Quiz competitions and IMD Exhibition were organized as part of "IMD Foundation Day" celebrations. The awards were given to best RMC, MCs, MOs and RS/RW stations and winner students of the competitions during Foundation Day by the Hon'ble Minister. Seven distinguished scientists from different organisations and

Hon'ble Union Minister Dr. Harsh Vardhan, Dr. M. Rajeevan, Secretary, MoES, Dr. K. J. Ramesh, DG, IMD, Padma Shri Prof. A. S. Kiran Kumar and Dr. S. D. Attri, Sc. 'F' during the Lighting of Lamp

SAFFGS team from Hydrology were felicitated for their contribution to the services of IMD.

A documentary film titled "**Early warning Services of IMD**" showcasing achievements of IMD during 2014-18 was telecasted during the Foundation Day ceremony of IMD on 15th January, 2019.

On this occasion, **Inter-school Painting, Speech and Quiz competitions** were organized

Prize distribution to the winners

of "IMD Foundation Day" celebrations. The awards were given to winner students of the competitions during Foundation Day.

NATIONAL SCIENCE DAY, 2019

National Science Day was celebrated on 28th February 2019 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 various offices of IMD.

WORLD METEOROLOGICAL DAY, 2019

World Meteorological Day (WM DAY) - 2019 was celebrated on 23rd March, 2019 at IMD HQ and its sub-offices all over India on the theme "**The Sun, the Earth and the Weather**".

On this occasion of WMO Day on 23rd March, 2019 Vigyan Prasar telecast a programme on **Weather, Climate & Water** at DD Science. **Dr. M. Mohapatra, Sc. 'G'** participated in the programme as an expert from IMD.

World Meteorological Day was celebrated at **RMC Chennai**, M. C. Bengaluru, M. C. Hyderabad, M. C. Thiruvananthapuram, M. C.

Amravati and DWR Kochi on 22-23 March, 2019 with the theme - "**The Sun, The Earth and The Weather"**. On this occasion offices were kept open for general public and students and wide publicity of the event was given to media. Guest lecture was given by **Dr. P. P. Nageswara Rao, retired from ISRO, Dr. Krushna Chandra Gouda, Senior Scientist in CSIR, Bengaluru, Shri. S. Patil, Sc. 'D' and by ex-Director-in-charges of M. C. Bengaluru at M. C. Bengaluru.** Many retired officers and staff alongwith general public participated the session. An open house and "M**eteorological Exhibition"** was arranged at DWR Kochi on 23rd March, 2019 as a part of WM day celebration. Exhibition showcased different meteorological instruments including thermometers, barometer, phsychrometer, Radar testing equipments like Spectrum analyzer, Signal Generator, Oscilloscope, waveguides etc. Exhibition also included different types of radio sonde instruments, hydrogen filled balloons etc. Posters depicting different working areas of India Meteorological Department. A small video presentation showing the modernization and achievements of IMD and working of the Doppler Weather Radar was also arranged in the exhibition hall using LED TV. More than 75 general public including students visited the open house and exhibition. Local TV channel, "**Cochin Channel**" covered the open house, exhibition and broadcasted the event.

Celebration of W M Day at M. C., Bengaluru

Celebration of W M Day during exhibition

An open house Exhibition and Demonstration on Meteorological Instruments and Weather Forecasting Techniques etc. was organized by **M. C. Bhubaneswar** for the public, especially for the students. More than 150 students with their teachers from local Schools and Colleges, general public & media persons visited the Exhibition on the WMO day.

Celebration of W M Day at M. C. Bhubaneswar

LONG RANGE FORECAST 2019

Dr. M. Rajeevan, Secretary, MoES, Dr. K. J. Ramesh, DG, IMD, Dr. M. Mohapatra, Sc. 'G' and Dr. D. S. Pai, Sc. 'F' in a Press Conference

Long Range Forecast of the 2019 Southwest Monsoon Seasonal Rainfall was issued on 15th April, 2019 in the presence of Dr. M. Rajeevan, Secretary, MoES, Dr. K. J. Ramesh, DG, IMD, Dr. M. Mohapatra, Sc. 'G' and Dr. D. S. Pai, Sc. 'F' through a Press Conference on the "1st stage Long Range Forecast (LRF) for Southwest Monsoon rainfall for 2019" at Prithvi Bhawan, New Delhi. The summary of the Forecast Assessments are "**Southwest monsoon seasonal (June to September) rainfall over the country as a whole is likely to be near normal. Quantitatively, the monsoon seasonal (June to September) rainfall is likely to be 96% of the Long Period Average (LPA) with a model error of ± 5%**".

"ANNUAL MONSOON REVIEW/ANNUAL CYCLONE REVIEW MEETING 2019"

Dr. K. J. Ramesh, DG, IMD and other officials during AMR/ACR meeting

Dr. K. J. Ramesh, DG, IMD and other officers of IMD were attended "**Annual Monsoon Review (AMR)/Annual Cyclone Review (ACR) Meeting 2019**" during 27-28 April, 2019 at Mahatma Gandhi State Institute of Public Administration (MGSIPA) Punjab, Sector - 26, Chandigarh. Sixty Seven (67) delegates from all over India participated in the meeting.

ANTI-TERRORISM DAY

Pledge on anti-Terrorism Day at M.C., Bengaluru

Pledge on Anti-Terrorism Day was administered to **all officers and staff members of IMD** at H. Q. and sub offices of IMD on 21st May, 2019.

WORLD ENVIRONMENT DAY

"**World Environment Day**" was celebrated at **IMD, H.Q. and sub offices of IMD** on 5th June, 2019. On this occasion, Dr. V. Vizaya Bhaskar, Sc. 'E' delivered a lecture on Acid Rains at M/s Tata Motors at Pune.

World Environment Day at RMC Guwahati

हिंदी पखवाड़ा / हिंदी दिवस 2019

भारत मौसम विज्ञान विभाग के महानिदेशक के कार्यालय, नई दिल्ली तथा उप-कार्यालयों में हिंदी पखवाड़ा 2-16 सितम्बर, 2019 के दौरान मनाया गया। भारत मौसम विज्ञान विभाग के मुख्यालय में हिंदी दिवस समारोह 16 सितम्बर, 2019 को आयोजित किया गया। हिंदी दिवस समारोह की अध्यक्षता महानिदेशक डॉ. मृत्युंजय महापात्र ने की। इस समारोह के मुख्य अतिथि संयुक्त हिंदी सलाहकार समिति के पूर्व सदस्य तथा श्रीराम कॉलेज ऑफ कॉमर्स दिल्ली विश्विविद्यालय के हिंदी विभाग के विभागाध्यक्ष डॉ. रवि शर्मा मधुप थे।

समारोह का **शुभारंभ दीप** प्रज्वलन से हुआ। रंग बिरंगे फूलों से सजे और संगीतमय वृष्टि सभागार में इस कार्यक्रम का आयोजन किया गया। हिंदी दिवस समारोह के दौरान सांस्कृतिक कार्यक्रम का भी आयोजन किया गया। वृष्टि सभागार में उपस्थित सभी लोगों का सुश्री रेवा शर्मा, उपनिदेशक (राजभाषा) ने स्वागत, अभिवादन और अभिनन्दन किया। वर्ष 2018-19 में हिंदी में सबसे अधिक पत्राचार करने के लिए **राजभाषा चलशील्ड सामान्य अनुभाग** को प्रदान की गई।

डॉ. मृत्युंजय महापात्र, वैज्ञानिक 'जी' एवं मुख्य अतिथिगण दीप प्रज्ज्वलित करते हुए

श्रीमती सरिता जोशी सहायक निदेशक (राजभाषा) ने सांस्कृतिक कार्यक्रम के लिए मंच का संचालन किया।

सांस्कृतिक कार्यक्रम के दौरान कलाकार

SWATCHH BHARAT CAMPAIGN

Swatchh Bharat campaign at RMC, Chennai

Swatchh Bharat Abiyaan was organised at RMC Chennai and Meteorological centres at Bengaluru, Hyderabad and Thiruvananthapuram in July, 2019. Swachata Pakhwara was observed at MC Bengaluru in September, 2019.

SWACHHATA HI SEVA (SHS)

Swachhata Hi Seva (SHS) was observed at M.C., Bhubaneswar during 11 September-2 October, 2019. Dr. H. R. Biswas, Sc. 'E', M.C. Bhubaneswar, Officers and Staff Members participated in the cleanliness drive for office rooms & premises, public places, like, Airport Main gate & Road in front of Office Main gate.

ANTARCTIC EXPEDITION

Dr. M. Rajeevan, Secretary, MoES, Shri Rohit Thapliyal, Sc. 'C' and other officers during participated in Antarctic expedition

Shri Rohit Thapliyal, Sc. 'C', MC, Dehra Dun participated in **debriefing function for 36th (winter)/ 37th (Summer/Winter) and 38th (summer) Antarctic expedition on 20th August, 2019 at NCPOR, Goa**.

7th INDIAN NATIONAL EXHIBITION CUM-FAIR 2019

Officials of RMC, Kolkata during exhibition

On behalf of **MoES, RMC, Kolkata** has participated in "**7th Indian National Exhibition Cum - Fair 2019**" organized by Bengal Human Resource Development Foundation, held in Kolkata Metropolitan Development Authority (KMDA) Ground, Patuli, Garia, Kolkata, from 25-29 September, 2019.

DESTINATION UTTARAKHAND 2019

Shri Rohit Thapliyal, Sc. 'C' participated in the exhibition

Shri Rohit Thapliyal, Sc. 'C' participated as exhibitor in "**Destination Uttarakhand 2019**" exhibition in Dehradun from 18-20 July, 2019 organized by Friends Exhibition and Promotion Private Limited, New Delhi.

National Symposium on "Meteorological Advancement and its Utilisation based on Seventy years of Accomplishment of Mausam (MAUSAM)"

Publication Section, DGM office organized a 1-day National Symposium on the Theme "**Meteorological Advancement and its Utilisation based on Seventy years of Accomplishment of Mausam (MAUSAM)**" on

Dr. M. Rajeevan, Secretatry, MoES, Dr. M. Mohapatra, DG, IMD, Prof. S. K. Dube and Dr. D. R. Pattanaik, Sc. 'E' during lighting of lamp

24th December, 2019 to commemorate completing seventy (70) glorious years of research journal Mausam in December, 2019 at Mahika Hall, Ministry of Earth Sciences, Lodi Road, New Delhi. **Dr. M. Rajeevan, Secretatry**, MoES graced the occassion as **Chief Guest**. **Dr. Mrutyunjay Mohapatra**, DG, IMD & Chief Editor, MAUSAM and **Prof. S. K. Dube**, IIT Delhi addressed the distinguished delegates during the inaugural ceremony of the symposium.

The symposium concluded with a decision that Roadmap for next five years should be prepared for improving (*i*) **Impact Factor** & (*ii*) **Citation Index of "MAUSAM"**.

On this occassion a special issue of MAUSAM containing review articles and research papers and a Souvenir containing the overview of journey of the journal "**MAUSAM**" in last seven decades and the summary of the main research findings/papers published in the journal "**MAUSAM**" in the fields of Meteorology, Geophysics, Hydrology, Seismology and other allied subjects were released.

SHRAMDAN PROGRAMME

Dr. Mrutyunjay Mohapatra, DG, IMD **led Shramdan Programme** on 2nd October, 2019. IMD employees participated in the programme in a huge number. On this occasion, **Dr. Mohapatra** highlighted the importance of cleanliness in all spheres of life. Special drive for cleaning the Mausam Vibhag campus and surrounding Lodi Road area was carried out by the employees. Dr. Mohapatra also urged the staff members to avoid using plastic items in day to day life to preserve environment.

Dr. M. Mohapatra, DG, IMD & other officials during led Shramdan Programme

10th KRISHI FAIR, 2019

10th Krishi Fair, 2019 at Puri

MC, Bhubaneswar represented IMD, MoES at the 10th Krishi Fair, 2019 at Puri (a National

level Agricultural Exhibition organized by Shree Shrikshetra Soochana, Puri) under the auspices of **Ministry of Agriculture, Govt. of India** during 21-25 October, 2019. **Shri R. K. Mohapatra**, Met. 'A' and **S. K. Mallick**, Met. 'A' represented from M.C. Bhubaneswar. **MoES Stall was awarded as the 3rd best Stall in the Exhibition**.

Dr. M. Mohapatra, DG, IMD attended the **National Day** for **Disaster Reduction** and **Odisha State Disaster Preparedness Day** on 29th October, 2019 convened by **Govt. of Odisha** at Ravindra Mandap, Bhubaneswar. He was felicitated by **Hon'ble Chief Minister, Odisha, Shri Naveen Patnaik** on the occasion. Mr. H. R. Biswas, Sc. 'E' also attended the function.

Hon'ble Chief Minister, Shri Naveen Patnaik and Dr. M. Mohapatra, DG, IMD during the function

INTERACTIVE WORKSHOP WITH RENEWAL ENERGY INDUSTRY

An Interactive Workshop with Renewal Energy Industry (Solar and Wind) on use of **Weather Information** was conducted by **India Meteorological Department in association with ASSOCHAM** on 22nd November, 2019 at MoES, New Delhi. The objective of the workshop was to better understand industry's issues and concerns, implementation challenges, requirements from the Government of India, recent developments, current status and future plans of weather & climate services in context of RE sector and way forward for smooth integration of RE (Solar and Wind) power into the grid so that the weather forecasts and products can be appropriately customized for application specifically to the RE sector.

Dr. M. Mohapatra, DG, IMD and other senior officers during the Interactive Workshop

The workshop was inaugurated by **Dr. M. Mohapatra**, DG, IMD and attended by senior officers / Scientists / Executives from MoES, IMD, NCMRWF, MNRE, NIWE, POSOCO, NTPC, RE Industry, ASSOCHAM etc. Shri S.C. Bhan, Head, Power Sector Applications, IMD welcomed the participating officers and other dignitaries in the Interactive Workshop. Government stakeholders such as MNRE, POSOCO, CERC, RLDCs/SLDCs, NTPC, CEA joined the interaction.

GRAMIN KRISHI MAUSAM SEWA (GKMS) and FASAL

Dr. Mrutyunjay Mohapatra, DG, IMD participated in the 13th Annual Review Meeting of "**Gramin Krishi Mausam Sewa (GKMS) and FASAL"** as Chief Guest at Gwalior on 18th December, 2019. While addressing the participants, he highlighted the role of agromet advisory services in recent years in managing the crop/live stock. These **advisories help the farmers take the advantage of benevolent weather and minimize the adverse impact of malevolent weather**. These services have contributed significantly in enhancing farm productivity and thus improved the food security in India.

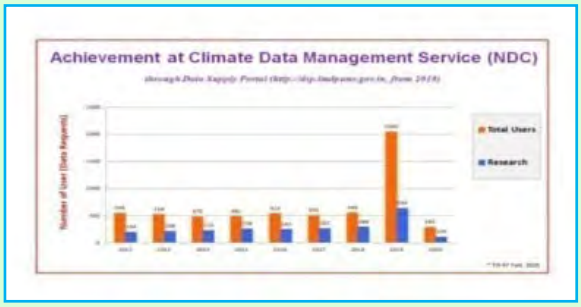
Dr. M. Mohapatra, DG, IMD and other dignitaries during the meeting

WMO RECOGNITION

World Meteorological Organisation (WMO) has recognised IMD - Chennai (Nungambakkam) observatory as a long-term observing station for more than 100 years of meteorological observations.

ACHIEVEMENTS / NEW INITIATIVES

A Data Supply Portal, http://dsp.imdpune.gov.in has been made operational for automation of activities related to data enquiry, retrieval and supply. The objective of this package is to enhance the efficiency and transparency and to reduce the service delivery time. This has led to (a) improved data delivery period from about 4 weeks to less than 1 day and (b) increase in number of users.



A Web-based Centralised Data Entry System (CDES) package was launched on 8th August 2019 to replace the outdated DATEN9 software. MMR-Online was made operational at all surface observatories w.e.f. 1st October, 2019.

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 2019 it has an IMPACT FACTOR (IF): 0.370 and 5-year Impact factor 0.659 calculated by Thomson Reuter U.S.A. The rating score given by National Academy of Agricultural Sciences (NAAS) for the year 2019 is 6.28. IMD Scientists published approx. 110 research paper/books in Mausam/Met. Monograph/Met Reports and National & International Journal during 2019.

7.1. Research Contributions Published in 'MAUSAM' during 2019

Kelkar, R. R., "**Satellite meteorology in India: Its beginning, growth and future**", *Mausam*, **70**, 1, 1-14.

Joseph, Porathur V., "**Six decades of research in diagnostic meteorology of the Asian tropics**", *Mausam*, **70**, 1, 15-30.

Chattopadhyay, Rajib, Joseph, Susmitha, Abhilash, S., Mandal, Raju, Dey, Avijit, Phani, R., Ganesh, Saranya, Kaur, Manpreet, Pattanaik D. R., and Sahai, A. K., "**Understanding the intraseasonal variability over Indian region and development of an operational extended range prediction system**", *Mausam*, **70**, 1, 31-56.

Mohanty, U. C., Nadimpalli, Raghu, Mohanty, Shyama and K. Osuri, Krishna, "**Recent advancements in prediction of tropical cyclone track over north Indian Ocean basin**", *Mausam*, **70**, 1, 57-70.

Dash, S. K., Paliwal, Manish, Panda, S. K. and Karri Srinivasarao, "**Comparison of Indian summer monsoon rainfall anomalies in response to changes in snow depths and SSTs in a GCM**", *Mausam*, **70**, 1, 71-86.

Behera, Swadhin, "**The Indo-Pacific climate dynamics and teleconnections with a special emphasis on the Indian summer monsoon rainfall**", *Mausam*, **70**, 1, 87-110.

Hon, K. K. and Chan, P. W., "**Applying simulated satellite pictures based on a sub-kilometre scale numerical weather prediction model to gain insights into the formation mechanism of quasi-2 dimensional cloud features**", *Mausam*, **70**, 1, 111-120.

Debnath, G. C., Das, G. K., Devi S., Sunitha and Singh, Charan, "**Summer monsoon onset over Andaman & Nicobar Islands: Objective criteria for operational forecaster**", *Mausam*, **70**, 1, 121-132.

Shivhare, Nikita, Rahul, Atul Kumar, Bihari Dwivedi, Shyam and Kumar Singh Dikshit, Prabhat, "**ARIMA based daily weather forecasting tool : A case study for Varanasi**", *Mausam*, **70**, 1, 133-140.

Raja, K. P. Pradeep and Reddy, Suresh Ramaswaamy, "**Regression analysis between mean daily intensity, rainy days and seasonal rainfall in normal, excess and deficient years: A case study**", *Mausam*, **70**, 1, 141-158.

Srinivasareddy, G. S., Shivakumarnaiklal, H. S., Keerthy, N. G., Garg, Prasad, Jyoti, Emily Prabha and Challa, O., "**Drought vulnerability assessment in Karnataka: Through composite climatic index**", *Mausam*, **70**, 1, 159-170.

Nandankar, P. K., "**Air quantity impact assessment due to Koradi thermal power plant**", *Mausam*, **70**, 1, 171-174.

Kumari, Pragyan, Tirkey, Deepak A., Wadood, A. and Kumar, Ramesh, "**Rainfall and temperature extreme over different sub zones of Jharkhand**", *Mausam*, **70**, 1, 175-180.

Rao, Dodla Venkata Bhaskar, "**Numerical prediction of tropical cyclones : A review of research at Andhra University**", *Mausam*, **70**, 2, 195-214.

Kar, S. C., "**On the reliability of medium-range probabilistic rainfall predictions over river basins in India**", *Mausam*, **70**, 2, 215-232.

Pattanaik, D. R., Sahai, A. K., Mandal, Raju, Phani Muralikrishna, R., Dey, Avijit, Chattopadhyay, Rajib, Joseph, Susmitha, Deep Tiwari, Amar and Mishra, Vimal, "**Evolution of operational extended range forecast system of IMD : Prospects of its applications in different sectors**", *Mausam*, **70**, 2, 233-264.

A. Rao, Suryachandra, Pillai, Prasanth A., Pradhan, Maheshwar and Srivastava, Ankur, "**Seasonal prediction of Indian summer monsoon in India: The past, the present and the future**", *Mausam*, **70**, 2, 265-276.

Robertson, Andrew W., Moron, Vincent, Vigaud, Nicolas, Acharya, Nachiketa Greene, Arthur M. and Pai, D. S., "**Multi-scale variability and predictability of Indian summer monsoon rainfall**", *Mausam*, **70**, 2, 277-292.

Salvi, Kaustubh and Ghosh, Subimal, "**A kaleidoscopic research memoir on Indian summer monsoon rainfall**", *Mausam*, **70**, 2, 293-298.

Balasaraswathi, P. and Srinivasalu, S., "**Seasonal influence on Cuddalore shoreline change: Remote sensing, GIS and statistical approach**", *Mausam*, **70**, 2, 299-308.

Kumar, Amit, Singh, Virendra, Mukherjee, Sunil and Singh, Randhir, "**Quality assessment of Outgoing Longwave Radiation (OLR) derived from INSAT-3D Imager: Impact of GSICS correction**", *Mausam*, **70**, 2, 309-320.

Wanhe, Lu and Wenxiang, Cai, "**Temporal trends features in consecutive days of extreme precipitation over China, 1951-2017**", *Mausam*, **70**, 2, 321-328.

Qiao, Chen, Decheng, Hao, Jiuchuan, Wei, Cuiping, Jia, Hongmei, Wang, Longqing, Shi, Songliang, Liu, Fangzhu, Ning, Yuhan, Ji, Fangying, Dong and Zhiwen, Jia, "**Geo-chemical processes during the mixing of seawater and fresh water in estuarine regions and their effect on water fluorine levels**", *Mausam*, **70**, 2, 329-338.

Kumar, Suraj and Roshni, Thendiyath, "**NDVI-rainfall correlation and irrigation water requirement of different crops in the Sone river-command, Bihar**", *Mausam*, **70**, 2, 339-346.

Samanta, Suman, Banerjee, Saon, Mukherjee, Asis, Patra, Pulak Kumar and Chakraborty, Pramitik, "**Deriving PAR use efficiency of wet season rice from bright sunshine hour data and canopy characteristics**", *Mausam*, **70**, 2, 347-356.

Kimothi, S., Kumar, A., Thapliyal, A., Ojha, N., Soni, V. K. and Singh, Narendra, "**Climate predictability in the Himalayan foothills using fractals**", *Mausam*, **70**, 2, 357-362.

Sahu, Mohan Lal and Dewangan, Poshan Lal, "**Case study on severe thunderstorm activity over Chhattisgarh on 21st May, 2016**", *Mausam*, **70**, 2, 363-370.

Mohanty, U. C., Sinha, P., Mohanty, M. R., Maurya, R. K. S., Rao, M. M. Nageswara and Pattanaik, D. R., "**A review on the monthly and seasonal forecast of the Indian summer monsoon**", *Mausam*, **70**, 3, 425-442.

Ashok, Karumuri, Feba, F. and Teja Tejavath, Charan, "**The Indian summer monsoon rainfall and ENSO**", *Mausam*, **70**, 3, 443-452.

Pattnaik, Sandeep, "**Weather forecasting in India: Recent developments**", *Mausam*, **70**, 3, 453-464.

Roy, Soma Sen, Mohapatra, M., Tyagi, Ajit and Roy Bhowmik, S. K., "**A review of Nowcasting of convective weather over the Indian region**", *Mausam*, **70**, 3, 465-484.

Gadgil, Sulochana, Rajendran, K. and Pai, D. S., "**A new rain-based index for the Indian summer monsoon rainfall**", *Mausam*, **70**, 3, 485-500.

Das, Ananda Kumar, Kundu, P. K., Roy Bhowmik, S. K. and Rathee, M., "**Performance evaluation of WRF model with different cumulus parameterizations in forecasting monsoon depressions**", *Mausam*, **70**, 3, 501-522.

Yadav, Seema, Bhattacharya, Prodyut and Srivastava, Kuldeep, "**Analysing long term seasonal and annual trends for precipitation and temperature in Central India**", *Mausam*, **70**, 3, 523-532.

Obot, Nsikan Ime, "**Comparison between ground measured and satellite estimates of downward longwave radiation at Ilorin, Nigeria**", *Mausam*, **70**, 3, 533-540.

Singh, Ved Prakash, Khedikar, Shirish and Verma, I. J., "**Improved yield estimation technique for rice and wheat in Uttar Pradesh, Madhya Pradesh and Maharashtra States in India**", *Mausam*, **70**, 3, 541-550.

Patel, Sangram Kishor, Mathew, Bincy, Nanda, Ankit, Pati, Sanghamitra and Nayak, Hiralal, "**A review on extreme weather events and livelihood in Odisha, India**", *Mausam*, **70**, 3, 551-560.

Patil, S. G., "**Application of Change Point Analysis (CPA) to monthly temperature in Tamil Nadu, India**", *Mausam*, **70**, 3, 561-568.

Sattar, A., Khan, S. A. and Banerjee, Saon, "**Climatic water balance for assessment of growing season in the eastern Indian state of Bihar**", *Mausam*, **70**, 3, 569-580.

Singh, Charan, Das, Sunit and Akre, Ravindra, "**Unprecedented extremely heavy rainfall over Gujarat during 20-26 June, 2015**", *Mausam*, **70**, 3, 581-588.

Pawar, P. S., Waikar, A. U. and Khodke, U. M., "**Dry and wet spell probability by Markov chain model for agricultural planning at Parbhani**", *Mausam*, **70**, 3, 589-592.

Pattanaik, D. R., "**Journey of MAUSAM during last seven decades (1950-2019)**", *Mausam*, **70**, 4, 625-634.

Mohapatra, M. and Sharma, M., "**Cyclone warning services in India during recent years: A review**", *Mausam*, **70**, 4, 635-666.

Gopalakrishnan, Sundararaman G., Osuri, Krishna K., Marks, Frank D. and Mohanty, U. C., "**An inner-core analysis of the axisymmetric and asymmetric intensification of tropical cyclones : Influence of shear**", *Mausam*, **70**, 4, 667-690.

Mohanty, U. C., Nayak, H. P., Sinha, P., Osuri, K. K. and Niyogi, D., "**Land surface processes over Indian summer monsoon region : A review**", *Mausam*, **70**, 4, 691-708.

Kishtawal, C. M., "**Use of satellite observations for weather prediction**", *Mausam*, **70**, 4, 709-724.

Srinivasan, G., Agarwal, Anshul and Sawant, Mitesh, "**Enhancing climate services in south Asia**", *Mausam*, **70**, 4, 725-730.

Gnanaseelan, C. and Chowdary, Jasti S., "**The Indo-Western Pacific climate variability and the impacts on Indian summer monsoon : Two decades of advancement in India**", *Mausam*, **70**, 4, 731-752.

Chakraborty, Arindam, "**Zonally symmetric vs asymmetric North Pacific Ocean sea surface temperature influence on Indian summer monsoon through modulation of upper tropospheric circulation**", *Mausam*, **70**, 4, 753-766.

Sonawane, Kailas, Pattanaik, D. R. and Pai, D. S., "**Inter-annual variability of Indian monsoon rainfall in the JMA's seasonal ensemble prediction system in relation**", *Mausam*, **70**, 4, 767-780.

Zhou, Xiao and Li, Ning, "**Characteristics of landfalling tropical cyclones in the Asia-Pacific region during 2007-2017**", *Mausam*, **70**, 4, 781-786.

Sasane, Sapana Ashok, Jadhav, A. S., Barik, Rabindra K., Krishnakumar, G. and Raghavswamy, V., "**Application of spatial technology in malaria information infrastructure mapping with climate change perspective in Maharashtra, India**", *Mausam*, **70**, 4, 787-806.

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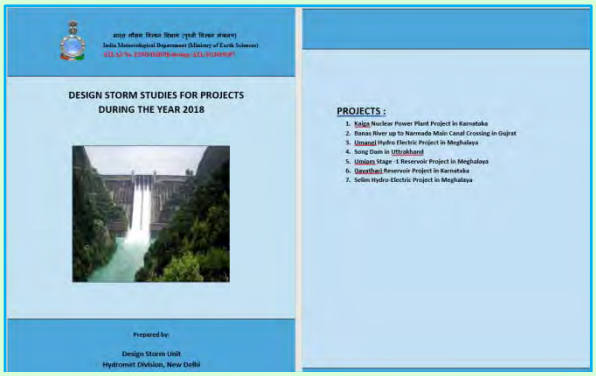
7.3. IMD Met. Monograph and Other Publications

Technical report entitled '**Design Storm Studies for projects during the year 2018**' has been published.



Technical report entitled "**Annual Rainfall Statistics of India - 2018**" has been published.

Technical report entitled "**Probable Maximum Precipitation Atlas of Indus Basin**" has been published. "

"**Monsoon 2018 - A Report**" released on 27th April, 2019 published during ACR/AMR meeting at Chandigarh.

A report entitled **"Pre-Monsoon Thunderstorms During 2019: A Report"** containing detailed analysis of the thunderstorms, hails, squalls observed during 1 March to 30 June, 2019 was prepared & published by Nowcast Division.

Guhathakurta, Pulak, Niyas, N. T., Sreejith, O. P. and Nusrath, A., 2019, "**Analysis of Hydromete-orological features of Kerala flood 2018**", Chapter 8, Monsoon 2018- A report", IMD Met Monograph: ESSO/IMD/ Synoptic Met./01 (2019), National Climate Centre.

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Ved Prakash Singh, "**Approximation of Hazardous Winds using ML and theHypothesis of Mixing length/Ekman layer from Doppler Weather RADAR**" Young Scientist Congress, Madhya Pradesh Council of S & T, Bhopal, 34, Abst. Book, 2019.

CHAPTER 8

FINANCIAL RESOURCES AND MANAGEMENT PROCESS

8.1. Financial Resources and Management

Budget Estimates/Revised Estimates/Actual Expenditure

Budget provisions and Actual Expenditure (A.E.) of the Department during the financial year 2019-20 were as given below :

- **Central Sector schemes (ACROSS-IMD)**

B.E. : Rs.207.17 Crores
R.E. : Rs.224.73 Crores
A.E. : Rs.206.04 Crores

- **Establishment (3455 Meteorology)**

B.E. : Rs.423.55 Crores
R.E. : Rs.423.73 Crores
A.E. : Rs.416.49 Crores

8.2. Atmospheric & Climate Research – Modelling Observing Systems & Services (ACROSS)

To upgrade the forecasting capabilities, various programs were implemented in IMD during 2017-20 (14th Finance Commission period) under the umbrella scheme **"Atmosphere & Climate Research-Modelling Observing Systems & Services (ACROSS)**" of the MoES as follows:

S. No.	Name of the Scheme/Project	Budget Outlays (Rs.in Crores)
1.	Atmospheric observations Network (AON)	222.0
2.	Upgradation of Forecast System (UFS)	158.0
3.	Weather & Climate Services (WCS)	241.0
4.	Commissioning of Polarimetric DWRs	42.0
	Total	663.0

The projects under ACROSS-IMD are continuing programs from previous Plan periods encompassing various activities in an integrated manner to ensure the sustenance & augmentation of observations & enhancement of facilities required for the weather forecasting services. The programs are being implemented by various Offices/Divisions across the country having long and requisite experience in the required fields. Various scientists have been assigned for implementation of the activities. With the Delegation of Enhanced Financial Powers to Heads of RMCs, MCs and CDRs/DWRs etc. & stand-alone offices headed by Group 'A' officers and Remote Offices in India Meteorological Department, execution of the scheme is being done at all offices across the country and expenditure is incurred by RMCs, MCs and other offices of the Department for successful implementation of the scheme. The implementation of the activities is under the overall guidance of the Director General of Meteorology and other senior scientists.

As per the directive of the Department of Expenditure OM No: 66(59)/PFC-II/2018 dated 17thSeptember 2018, Ministry of Earth Sciences constituted an Independent Review committee (IRC) to evaluate all nine sub-schemes under the umbrella scheme "Atmosphere and Climate Research: Modelling, Observing Systems and Services (ACROSS)" in qualitative and quantitative terms for continuation from 14th Finance commission (2017-20) to next Finance Commission Cycle. The committee evaluated the sub-schemes in terms of importance of the schemes in the context of national development, mechanism of implementation, achievements corresponding to the objectives of the scheme, key bottlenecks/issues &challenges surfaced

during the implementation, assets created/ services provided to the beneficiaries and Direct/indirect employment generation. Financial review on allocation and expenditure of the scheme was also made.

The committee appreciated the work being done under the ACROSS scheme and commented that that the activities under the nine sub-schemes under ACROSS are immensely contributing towards the delivery of a reliable and skillful weather and climate services. In view of the importance of the umbrella scheme ACROSS in the national context, the committee recommended the continuation of all the nine-schemes under ACROSS from the 14th Finance commission (2017-20) to the 15th Finance Commission.

Furthermore, in accordance with MoES Administrative Order dated 30th March, 2020, all the activities/ sub-schemes under ACROSS-IMD have been continued/ extended during Financial Year 2020-21 at an estimated cost of **Rs. 249.57 Crore**. IMD programme-wise budget during FY 2020-21 is as follows :

IMD programme-wise budget during FY 2020-21

Programme	Type	Allocation (Rs. in Crore)
AON (including MAQWS)	Revenue	**53.71**
	Capital	**39.00**
WCS	Revenue	**47.33**
	Capital	**35.50**
UFS (including Monsoon Mission-II)	Revenue	**27.15**
	Capital	**33.50**
PDWRs	Revenue	**1.88**
	Capital	**11.50**
Total	Revenue	**130.07**
	Capital	**119.50**

AON - Atmospheric Observations Network; WCS - Weather & Climate Services; UFS - Upgradation of Forecast System; PDWRs - Commissioning of Polarimetric Doppler Weather Radars

8.3. Revenue Generated during the Year 2019

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	5900	-	65680	-	-	65680	-	-
DGM (Publication)	26300	62925	25575	35825	15800	4450	33350	4450	225	4000	0	46000
RMC, New Delhi												
New Delhi	49990	33282	16039	35661	28157	50339	28430	18026	8499	12130	13920	8610
Jaipur	33243	41924	5009	22665	27413	36482	147071	123383	39913	83367	21908	34236
Lucknow	14080	2006	11254	7592	38470	17350	23986	11856	6874	12123	1585	24943
Srinagar	6644	86364	122735	29944	4867	21012	21160	40478	38410	14684	27625	10870
Chandigarh	8186	11909	18140	62432	12953	7016	20209	26293	11748	37207	27527	39682
Shimla	NIL	5382	11589	33253	14643	7434	9906	NIL	NIL	2832	4012	1416
Dehredun	14493	19985	27025	8803	17202	7005	2537	21519	4838	6837	11621	9724
RMC, Mumbai												
Mumbai	35430	12638	50395	3108	22731	36895	23311	49517	13349	21280	68115	38291
Ahemdabad	80583	27816	109973	12174	101552	33498	69392	31975	16806	33775	79093	5521
RMC, Nagpur												
Nagpur	37829	17546	36993	27450	16135	68751	46221	67751	40950	36679	67788	48850
Bhopal	9199	Nil	Nil	Nil	Nil	Nil	Nil	Nil	3813	Nil	Nil	Nil
RMC, Kolkata												
RMC Kolkata	40421	44813	0	71420	68309	78571	17578	15057	39506	26827	9311	9440
PAC Kolkata	0	0	0	2953	6046	0	0	5640	5910	6297	13981	0
Patna	0	0	0	21303	0	0	0	0	14278	9441	4720	6908
Bhubneshwar	15458	35125	11085	37409	10959	12100	48375	30294	6789	27836	31901	23120
Gangtok	2266	8638	7640	2302	0	0	11838	13924	0	4089	18926	0
Ranchi	8614	0	3241	0	7838	46396	6962	9560	12859	9727	-	6305
RMC, Guwahati												
Guwahati	35637	22954	69387	90540	67059	77810	48317	39727	81087	61355	27565	31008
Agartala	6042	18873	2041	12002	-	11608	18339	3916	1546	-	4500	9577
RMC, Chennai												
Chenaai	47033	66772	20791	74070	46279	29816	76868	84209	83020	57249	58878	154417
Thiruvananthapuram	56910	25815	46096	33154	19561	116598	32683	30979	20086	62645	63393	504695
Hyderabad	210782	29738	61881	21990	40666	30988	142362	34623	78955	59145	41369	48920
Bangalore	93187	50556	122140	10595	69513	34312	90384	77953	124439	32620	62517	59462
ACWC Chennai	10870	16304	5434	-	13585	-	54516	63726	54280	110920	54401	56050
CWC Visakhapatnam	1559	1564	7909	-	4888	21881	-	1353	2596	15576	21851	-
CRS, Pune												
Pune	520339	1225751 $548	414546	569578	290381	276450	225086	914663 $33	277918	309888	615042	963761

CHAPTER 9

STATUS OF SC/ST/OBC AS ON 01.01.2019

(i) Status of SC/ST/OBC as on 01.01.2019 (Group wise)

	Representation of SCs / STs / OBCs as on 1.1.2019				Appointments by Promotion during the calendar year		
Groups	No. of Employees	SCs	STs	OBCs	SCs	STs	Total
Group A	195	33	14	41	8	4	61
Group B (Gaz.)	1275	229	120	89	0	0	0
Group B (Non- Gaz.)	942	154	36	272	0	0	0
Group C	1395	430	147	177	0	0	0
TOTAL	3807	846	317	579	8	4	61

(ii) Status of SC/ST/OBC as on 01.01.2019 (Pay Scale Wise)

	Representation of SCs / STs / OBCs as on 01.01.2019				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	8	5	18	0	0	0
PB-3 + GP 6600	1	0	0	0	4	2	44
PB-3 + GP 7600	17	2	2	6	0	0	0
PB-4 + GP 8700	63	17	5	16	3	1	13
PB-4 + GP 8900	44	6	2	1	1	1	4
PB-4 + GP 10000	2	0	0	0	0	0	0
75500-80000	1	0	0	0	0	0	0
TOTAL	195	33	14	41	8	4	61

CHAPTER 10

राजभाषा नीति का कार्यान्वयन

संसदीय राजभाषा समिति द्वारा निरीक्षण

संसदीय राजभाषा समिति की दूसरी उपसमिति द्वारा दिनांक 15 जनवरी, 2019 को प्रादेशिक मौसम केंद्र, मुंबई का राजभाषायी निरीक्षण किया गया। इस निरीक्षण में मुख्यालय की ओर से डॉ. मृत्युंजय महापात्र, वैज्ञानिक 'जी' तथा सुश्री रेवा शर्मा उपनिदेशक (रा.भा.) ने भाग लिया।

डॉ. मृत्युंजय महापात्र, वैज्ञानिक 'जी', सुश्री रेवा शर्मा उपनिदेशक (रा.भा.) संसदीय राजभाषा समिति के सदस्य

संसदीय राजभाषा समिति की दूसरी उपसमिति द्वारा दिनांक 19 जनवरी, 2019 को प्रादेशिक मौसम केंद्र, नई दिल्ली का राजभाषायी निरीक्षण किया गया। इस निरीक्षण में मुख्यालय की ओर से डॉ. देवेन्द्र प्रधान, वैज्ञानिक 'जी' तथा सुश्री रेवा शर्मा उपनिदेशक (रा.भा.) ने भाग लिया। श्रीमती सरिता जोशी, सहायक निदेशक (रा.भा.) भी निरीक्षण के दौरान उपस्थित रही।

अखिल भारतीय विभागीय हिंदी संगोष्ठी

भारत मौसम विज्ञान विभाग (मुख्यालय) द्वारा दिनांक 28 मई, 2019 से 29 मई, 2019 की अवधि में हैदराबाद में दो दिवसीय सातवीं

डॉ. देवेन्द्र प्रधान, वैज्ञानिक 'जी' एवं अन्य विभागीय हिंदी संगोष्ठी के दौरान

अखिल भारतीय विभागीय हिंदी संगोष्ठी का सफलतापूर्वक आयोजन किया गया जिसमें 40 प्रतिभागियों ने भाग लिया।

राजभाषा अनुभाग द्वारा निरीक्षण

मुख्यालय की उपनिदेशक (रा.भा.) सुश्री रेवा शर्मा तथा वरिष्ठ अनुवादक श्री बीरेन्द्र कुमार द्वारा दिनांक 16 जनवरी, 2019 एवं 17 जनवरी, 2019 को मौसम कार्यालय सांताक्रुज एवं जुहू स्थित कार्यालयों का राजभाषायी निरीक्षण किया गया।

मुख्यालय की उपनिदेशक (रा.भा.) सुश्री रेवा शर्मा तथा सहायक निदेशक (रा.भा.) श्रीमती सरिता जोशी द्वारा दिनांक 21 फरवरी, 2019 एवं 22 फरवरी, 2019 को क्रमश: मौसम केंद्र भुवनेश्वर और मौसम कार्यालय पुरी का राजभाषायी निरीक्षण किया गया।

उपनिदेशक (राजभाषा) सुश्री रेवा शर्मा एवं सहायक निदेशक (राजभाषा) श्रीमती सरिता जोशी द्वारा दिनांक 30 मई, 2019 को मौसम केंद्र हैदराबाद का राजभाषायी निरीक्षण किया गया।

उपनिदेशक (रा.भा.) सुश्री रेवा शर्मा एवं सहायक निदेशक (रा.भा.) श्रीमती सरिता जोशी ने दिनांक 19 सितम्बर, 2019 से 22 सितम्बर, 2019 तक रेडियो सौंदे/रेडियो विंड जोधपुर कार्यालय का निरीक्षण किया।

उपनिदेशक (रा.भा.) सुश्री रेवा शर्मा, सहायक निदेशक (रा.भा.) श्रीमती सरिता जोशी एवं अन्य जोधपुर कार्यालय का निरीक्षण के दौरान

उपनिदेशक (राजभाषा) सुश्री रेवा शर्मा दिनांक 16 दिसंबर, 2019 से 19 दिसंबर, 2019 तक प्रादेशिक मौसम केंद्र चेन्नै के दौरे पर रही। इस दौरान प्रादेशिक मौसम केंद्र चेन्नै, विमानन मौसम कार्यालय मीनाबक्कम, डी डब्ल्यू आर चेन्नै, मौसम वेधशाला मीनाबक्कम का राजभाषायी निरीक्षण किया।

उपनिदेशक (रा.भा.) सुश्री रेवा शर्मा और सहायक निदेशक (रा.भा.) श्रीमती सरिता जोशी द्वारा दिनांक 24 जनवरी, 2019 को उपग्रह मौसम प्रभाग का राजभाषायी निरीक्षण किया गया।

सुश्री रेवा शर्मा, उपनिदेशक (रा.भा.) तथा श्रीमती सरिता जोशी, सहायक निदेशक (रा.भा.) द्वारा दिनांक 8 फरवरी, 2019 को संगठन अनुभाग का निरीक्षण किया।

सुश्री रेवा शर्मा उपनिदेशक (राजभाषा) तथा श्रीमती सरिता जोशी, सहायक निदेशक (राजभाषा) द्वारा दिनांक 6 मार्च, 2019 को ई. एम. आर. सी. एवं दिनांक 26 मार्च, 2019 को कृषि मौसम प्रभाग का निरीक्षण किया गया।

सुश्री रेवा शर्मा, उपनिदेशक (रा.भा.) तथा श्रीमती सरिता जोशी, सहायक निदेशक (रा.भा.) द्वारा केंद्रीय क्रय एकक का दिनांक 9 अप्रैल, 2019 को राजभाषायी निरीक्षण किया गया।

दिनांक 12 जुलाई, 2019 को उपरितन वायु उपकरण प्रभाग का सुश्री रेवा शर्मा, उपनिदेशक (रा.भा.), सहायक निदेशक (रा.भा.) और वरिष्ठ अनुवादक द्वारा राजभाषायी निरीक्षण किया गया।

सम्मान

दिनांक 18 फरवरी, 2019 से 20 फरवरी, 2019 तक परिवर्तन जन कल्याण समिति द्वारा पुरी, ओडिशा में आयोजित 'अखिल भारतीय विशेष राजभाषा हिंदी कार्यशाला एवं संगोष्ठी में श्रीमती सरिता जोशी सहायक निदेशक (रा.भा.) को इस्पात मंत्रालय की हिंदी सलाहकार समिति के विशेष आमंत्रित सदस्य, श्री देशपाल सिंह राठौर द्वारा 'राजभाषा हिंदी प्रचार-प्रसार रत्न सम्मान' से सम्मानित किया गया।

श्रीमती सरिता जोशी सहायक निदेशक (रा.भा.) 'राजभाषा हिंदी प्रचार-प्रसार रत्न सम्मान'

हिन्दी दिवस / हिन्दी पखवाड़ा

मुख्यालय में दिनांक 2 सितम्बर, 2019 से 16 सितम्बर, 2019 तक हिंदी पखवाड़े का आयोजन किया गया। इस दौरान 6 हिंदी प्रतियोगिताओं का आयोजन किया गया। मुख्यालय में दिनांक 16 सितम्बर, 2019 को हिंदी दिवस समारोह का आयोजन किया गया।

डॉ. मृत्युंजय महापात्र, वैज्ञानिक 'जी', डॉ. देवेन्द्र प्रधान, वैज्ञानिक 'जी', डॉ. रवि शर्मा मधुप

इस समारोह के मुख्य अतिथि संयुक्त हिंदी सलाहकार समिति के पूर्व सदस्य तथा श्रीराम कॉलेज ऑफ कॉमर्स दिल्ली विश्विविद्यालय के हिंदी विभाग के विभागाध्यक्ष डॉ. रवि शर्मा मधुप थे। हिंदी दिवस/हिंदी पखवाड़ा 2019 के दौरान आयोजित की गई 6 प्रतियोगिताओं के 30 विजेताओं को पुरस्कार एवं प्रमाण-पत्र प्रदान किए गए।

हिंदी दिवस समारोह का आयोजन के दौरान

16 सितम्बर, 2019 को आयोजित हिंदी दिवस समारोह में वर्ष 2018-19 के लिए राजभाषा चलशील्ड सामान्य अनुभाग को प्रदान की गई।

राजभाषा चलशील्ड सामान्य अनुभाग को प्रदान

हिंदी कार्यशाला

दिनांक 16 जनवरी, 2019 एवं 17 जनवरी, 2019 को मौसम कार्यालय सांताक्रुज एवं जुहू स्थित कार्यालयों में एक दिवसीय हिंदी कार्यशाला का आयोजन किया गया।

उपनिदेशक (रा.भा.) सुश्री रेवा शर्मा तथा सहायक निदेशक (रा.भा.) श्रीमती सरिता जोशी द्वारा दिनांक 21 फरवरी, 2019 एवं 22 फरवरी, 2019 को क्रमश: मौसम केंद्र भुवनेश्वर और मौसम कार्यालय पुरी में हिंदी कार्यशाला आयोजित की गई।

एक दिवसीय हिंदी कार्यशाला के दौरान

मुख्यालय में दिनांक 27 मार्च, 2019 को एक दिवसीय हिंदी कार्यशाला का आयोजन किया गया। इस कार्यशाला में केंद्रीय हिंदी प्रशिक्षण संस्थान के श्री रामसकल सिंह, सहायक निदेशक ने अतिथि

वक्ता के रूप में 'प्रयोजनलक हिंदी' तथा उपनिदेशक (रा.भा.) सुश्री रेवा शर्मा ने 'हिंदी वर्तनी' सहायक निदेशक (रा.भा.) श्रीमती सरिता जोशी ने कम्प्यूटर और हिंदी विषय पर व्याख्यान दिए ।

मौसम केंद्र हैदराबाद के कार्मिकों को हिंदी में कार्य करने का प्रशिक्षण देने के लिए दिनांक 30 मई, 2019 को हिंदी कार्यशाला का आयोजन किया गया। इस कार्यशाला में कल्पना श्रीवास्तव, वरिष्ठ अनुवादक, श्री बीरेन्द्र कुमार, वरिष्ठ अनुवादक, श्री रामहरि शर्मा, मौसम विज्ञानी 'ए' तथा श्रीमती अपर्णा खेडकर, कनिष्ठ अनुवादक ने अलग-अलग विषयों पर व्याख्यान दिए।

बैठक

विज्ञान और प्रौद्योगिकी मंत्रालय तथा पृथ्वी विज्ञान मंत्रालय की संयुक्त हिंदी सलाहकार समिति की 29वीं बैठक माननीय मंत्री डॉ. हर्षवर्धन की अध्यक्षता में दिनांक 1 मार्च, 2019 को आयोजित हुई इस बैठक में विभाग के कार्यभारी महानिदेशक डॉ. देवेन्द्र प्रधान, वैज्ञानिक 'जी' ने भाग लिया। कार्यभारी महानिदेशक के सहयोग के लिए राजभाषा अनुभाग से सुश्री रेवा शर्मा, उपनिदेशक (रा.भा.) श्रीमती सरिता जोशी, सहायक निदेशक (रा.भा.) और श्री बीरेन्द्र कुमार, वरिष्ठ अनुवादक भी इस बैठक में उपस्थित रहे।

व्याख्यान

दिनांक 18 फरवरी, 2019 से 20 फरवरी, 2019 तक परिवर्तन जन कल्याण समिति द्वारा पुरी, ओडिशा में आयोजित 'अखिल भारतीय विशेष राजभाषा हिंदी कार्यशाला एवं संगोष्ठी में उपनिदेशक (रा.भा.) सुश्री रेवा शर्मा तथा सहायक निदेशक (रा.भा.) श्रीमती सरिता जोशी ने भाग लिया जिसमें सुश्री रेवा शर्मा उपनिदेशक (रा.भा.) ने 'कार्यालयी अनुवाद' तथा श्रीमती सरिता जोशी सहायक निदेशक (रा.भा.) ने 'सूचना प्रौद्योगिकी एवं ई टूल्स' विषय पर संकाय सदस्य के रूप में व्याख्यान दिया।

प्रकाशन

विभागीय हिंदी गृह पत्रिका 'मौसम मंजूषा' के 28वें संस्करण का विमोचन भारत मौसम विज्ञान विभाग के स्थापना दिवस के अवसर पर दिनांक 15 जनवरी, 2019 को तथा 29वें संस्करण का विमोचन हिंदी दिवस के अवसर पर किया गया।

महानिदेशक महोदय 'मौसम मंजूषा' के 29वें संस्करण का विमोचन करते हुए

'राजभाषा नीति सिंहावलोकन' के तृतीय संस्कमरण की डिजिटल प्रति मेटनेट पोर्टल पर राजभाषा पटल में अपलोड की गई।

CHAPTER 11

MISCELLANEOUS

11.1. Honours and Awards

IMD Awards

Hon'ble Union Minister Dr. Harsh Vardhan presented **IMD awards** for Best RMC/MC/MOs Awards and Awards to IMD Scientists/ employees were given on 144th IMD Foundation Day celebrations.

Most Performed RMC : RMC Kolkata;

Most Performed MC : MC Agartala;

Most Performed MO : MO, Kurnool; MO, Jammu; MO, Sagar; AMO, Chennai; AMO, Lucknow; AMO, Mumbai;

Best Performed RS/RW : RS/RW Gorakhpur;

Best Performed DWR Station : Gopalpur.

MoES AWARD 2018-2019

Ministry of Earth Sciences celebrated its foundation day on 27th July, 2019 at Vigyan Bhawan, New Delhi. Various award were presented to officials from different organisations of MoES.

Certificate of Merit

1. Dr. S. Bandyopadhyay, Sc. 'F', RMC Kolkata;

2. Dr. Ram Kumar Giri, Sc. 'E', DGM Office, New Delhi.

Best Employee Award for the year 2018-19

1. Shri A. Prasad, Met. 'A', RMC Chennai;

2. Shri Pramod Kumar, S.A., DGM Office, New Delhi;

3. Shri Srimanta Halder, S.A., RMC Kolkata;

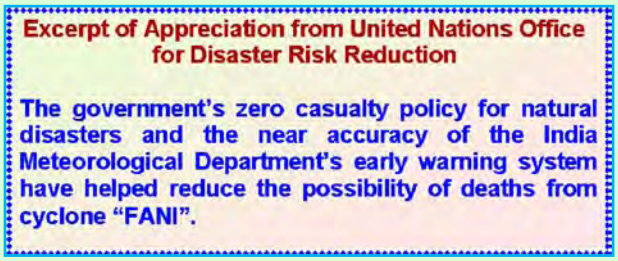
4. Shri Vivek Dhawan, S.A., MC Chandigarh;

5. Shri I. D. Sharma, M.O. Gr. 'I', HMO Kalpa;

6. Shri Ajay Shakti, Mech. Gr. 'I', MC Lucknow;

7. Shri G. J. Kazi, MTS, MO Parbhani;

8. Shri S. K. Bhoi, MTS, MC Raipur.



Dr. Mrutyunjay Mohapatra, Sc. 'G' elected as a member of Executive Council, WMO for the period 2019-23. Dr. Mohapatra won 110 out of 143 polled votes, resounding Victory for India.

Dr. M. Mohapatra, Sc. 'G' elected as a member of EC, WMO

Dr. M. Mohapatra, DG, IMD was awarded "**Bharat Gaurav Samman-2019**" at the 20th Bharat Prativa Samman Ceremony organized by Jay Bharat Foundation, Cuttack, Odisha on 2nd September, 2019.

Dr. M. Mohapatra, DG, IMD awarded "Bharat Gaurav Samman-2019"

IMDs Mumbai office received "Letter of Appreciation" from Indian Air Force (IAF), Mumbai Base, for "**Weather Forecasting Support Services rendered during last monsoon season for severe weather**".

Dr. Mrutyunjay Mohapatra, DG, IMD was conferred the "**Honorary Fellowship of the Indian Meteorological Society**" on 11th December, 2019 during **TROPMET - 2019** at Visakhapatnam for his brilliance & expertise in cyclones prediction that has led to significant reduction in loss of lives due to cyclones in recent years.

Dr. Mrutyunjay Mohapatra, DG, IMD receiving IMS Fellowship Award

Dr. Mrutyunjay Mohapatra, DG, IMD was conferred (a) the Satyasai Samman-2019 and (b) the Honorary Fellowship of Indian Climate Congress during the valedictory ceremony of the National Seminar on Climate Change and World Peace organised at the 11th Indian Climate Congress by Satyasai Charitable and Education Trust at Odisha University of Technology during 27-29 December, 2019.

Shri H. R. Biswas, Sc. 'E' was awarded "IMS Bhavanarayana Award" for best research paper in the Inaugural session of TROPMET-2019.

Shri H. R. Biswas, Sc. 'E' receiving award

Shri Ranjan Phukan, Sc. 'B' has received an Award for Recognition of Disaster Management Activities 2018-19 on Best Early Warning Dissemination - State Level from Government of Tripura.

The Executive of The Society of Earth Scientists (SES) has selected to **Shri Raja Acharya,** Met. 'A' as a Fellow of the SES. Dr. K. J. Ramesh, D.G., IMD and Dr. Mrutyunjay Mohapatra, Sc. 'G' has congratulated him on this achievement.

11.2. Media Interaction

Shri Anand Sharma, Sc. 'F' was interviewed by Lok Sabha TV & RajyaSabha TV on "G**lobal warming & Weather forecast & Weather base agro advisory"** on 24th January, 2019

Dr. Geeta Agnihotri, Sc. 'E' answered about "**24 Weather Enquiries by Electronic & Print Media**" during Jan-Mar, 2019.

Shri C. S. Patil, Sc. 'D' answered about "**110 Weather Enquiries by Electronic and Print Media**" during Jan-Mar, 2019.

Dr. S. Bandyopadhyay, Sc. 'F' attended a telecast of Live Program on "**Tornado**" under Hello DD Basundhara. (Environmental Program) on 16th February, 2019**.**

Shri Anand Sharma, Sc. 'F' was interviewed by All India Radio, Dehra Dun on 27th February, 2019 on "D**isaster management and National Science day".**

Dr. D. Pradhan, Sc. 'G' and Dr. S. D. Kotal, Sc. 'E' briefed media in a press conference in connection with installation of "**C-band DWR radar at Ranchi & preparedness for severe weather warning**" on 14th March, 2019.

Dr. S. D. Attri, Sc. 'F' participated in programme on "**Climate Change and Agriculture"** at AIR New Delhi on 14th March, 2019.

Shri Bikram Singh, Sc. 'F' interviewed by Aaj Tak, India news, ETV, Sahara TV, Samachar Plus, Network 10, Mandakini ki Awaz, etc. on 22nd March, 2019.

Shri Bikram Singh, Sc.'F', during interacting with media

Dr. S. D. Kotal, Sc. 'E' and Shri R. S. Sharma, Sc 'B' visited Doordarshan, Ranchi and participated in discussion on subject "**Climate Change**" on 10th May, 2019.

Dr. D. S. Pai, Sc. 'F' and Shri R. Balasubramanian, Sc. 'D' visited Doordarshan Kendra, Kothrud, Pune on 24th May, 2019 and participated in "**Amchi Mati Amchi Manse**" programme on "**Weather forecast and Agromet Advisory Services for Maharashtra**" jointly organized by India Meteorological Department, State Department of Agricultural & State Agricultural Universities in Maharashtra.

Shri S. M. Metri, Sc. 'E' participated in a live programme in a live phone-in programme on Doordarshan, Bengaluru on 4th June, 2019.

Dr. S. D. Attri, Sc. 'F', participated in one-hour Vichar Vimarsh programme on "**Monsoon 2019 and Agriculture**" at DD Kisan New Delhi on 10th June, 2019.

Dr. S. D. Attri, Sc. 'F' during Vichar Vimarsh programme

Dr. Geeta Agnihotri, Sc. 'E' and Shri C. S. Patil, Sc. 'D' participated in a live phone-in programme in "**Kannada on weather forecast**" on Doordarshan, Bengaluru on 25th June, 2019 at 6.30 pm.

Dr. Geeta Agnihotri, Sc. 'E' and Shri C. S. Patil, Sc. 'D' during live phone-in programme on Doordarshan

Mr. N. P. Kulkarni, Sc. 'B' delivered a talk on 26th June, 2019 on All India Radio, "**Satara on Agricultural Advisories"** Planning with respect to monsoon 2019.

Shri Anand Sharma, Sc. 'F' was one of the panelist for Lok Sabha TV interview on Glaciers and the programme was on telecast on 29-30 June, 2019 respectively. The other panelist was Dr. Gausain, Emeritus Professor, IIT, Delhi.

A team from Vigyan Prasar visited IMD on 13th July, 2019 to shoot a documentary film on **Dr. M. Mohapatra**, Sc. 'G' on "**Vigyan Ki Baat - Dr. M. Mohapatra Ke Saat**". The film was

telecast on Doordarshan on 1st August on the occasion of Dr. Mohapatra assuming the charge of Director General of Meteorology. The film aims to showcase the achievements of Dr. Mohapatra and vision for next 5 years for developing a Weather & Climate Smart Organisation.

Dr. Geeta Agnihotri, Sc. 'E' and Shri C. S. Patil, Sc. 'D', **M.C., Bengaluru** attended State Level Mass Media Core Committee Meeting on 2 August, 2019.

Dr. Mrutyunjay Mohapatra, DG, IMD participated as expert in the special programme on flood fury in Bihar at DD news. The programme is available at the link: https://www.youtube.com/watch?v=5roUEMV8UrY&feature=youtu.be&fbclid=IwAR0tZ3Gm2I_4l1S5mI21r46Nw6U6rbu56sfFIDUv0dOs7gLNuEU-8dH8tIw.

Dr. Mrutyunjay Mohapatra, DG, IMD in Bihar at DD news

National Geographic Channel aired a story on "**The Mega Cyclone FANI**" on 7th October, 2019. The story highlighted the role of **Dr. Mrutyunjay Mohapatra**, DG, IMD in monitoring of cyclone FANI and the role of Odisha State Government in mitigating the disaster associated with FANI cyclone.

Dr. Mrutyunjay Mohapatra, DG, IMD on National Geographic Channel

Dr. D. R. Pattanaik, Sc. 'E' took part in the discussion on "**El-Nino, La-Nina and Monsoon**" in Rajya Sabha TV (RSTV) in the programme Desh Deshantar on 2nd November, 2019.

Dr. D. R. Pattanaik, Sc. 'E' and others during media discussion

A **documentary film** of 30 minutes duration was released in "**DISHA**" on Naxatra News highlighting experiences of **Dr. Mrutyunjay Mohapatra**, DG, IMD & future plans of IMD.

In connection with International Training Workshop on "**Operational Climate Services**" at MTI Pune, a **Press release**, duly approved by DG, IMD was circulated among media. Media personnel also attended the inauguration of the **International Workshop** and gave publicity in local newspaper.

State Government (G.O.M.) Flood committee alongwith Shri K. S. Hosalikar, Sc. 'F', Dr. R. R. Kelkar, former DGM, Dr. Deshpande, Scientist from IITM visited CRS, Pune and had a meeting with similar scientist of IMD, *viz*., Shri K. N. Mohan, Sc. 'F', Dr. P. Guhathakurta, Sc. 'F', Dr. A. Kashyapi Sc. 'F', and Dr. O. P. Sreejith, Sc. 'E', on 15th October, 2019 regarding usefulness of new activity *viz*., "**River basin rainfall monitoring and prediction in flood**" monitoring of Maharashtra.

A half day meeting with officers of "**DD Kisan and senior officers and Heads of various divisions of IMD"** was organised on 4th November, 2019 to increase outreach of IMD products and services. The meeting was chaired by **Dr. M. Mohapatra**, DG, IMD, New Delhi. **Shri Anil Shrivastava**, ADG, DD Kisan also participated.

11.3. Addresses of various Met. Centres

Delhi Region

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Meteorological Centre,
SCO-2455-56, (First Floor), Sector 22 C,
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e-mail: chandimet@yahoo.com

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Civil Aerodrome, Amausi,
LUCKNOW - 226 009.
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17, E.C. Road, Karanpur,
DEHRADUN – 248 001.
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Bibra House,
Cliffend Estate,
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Chennai Region

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Mumbai Region

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