वार्षिक प्रतिवेदन

ANNUAL REPORT

2015

भारत मौसम विज्ञान विभाग

INDIA METEOROLOGICAL DEPARTMENT

पृथ्वी विज्ञान मंत्रालय, भारत सरकार

Ministry of Earth Sciences, Govt. of India

Annual Report 2015

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ANNUAL REPORT

2015

INDIA METEOROLOGICAL DEPARTMENT

(MINISTRY OF EARTH SCIENCES, GOVT. OF INDIA)

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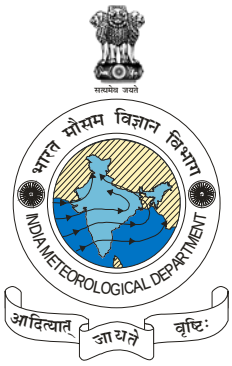

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16.	Abstract	This report highlights the progress made by the department during the year 2015. The department has taken major initiatives in augmenting its observational, computational, forecasting and dissemination mechanism in recent years. The department has taken lead in development and installation of LED Drishti Transmissometer Systems at different airports, Automated Weather Observing System, Radio Sonde and DTH based Digital Cyclone Warning Dissemination System under “Make in India”. There has been systematic improvement in the management of various extreme weather events by providing timely warning and guidance to the Government, various stakeholders and public at large. IMD Long Range Forecasts (LRF) for the S-W Monsoon 2015 were widely appreciated. The department continued co-operation with many national agencies like ISRO, ICAR, NCMRWF, INCOIS, IITM, NIDM, Indian Air Force, etc. Several National & International MoUs including an MoU between ESSO-IMD and Power System Operation Corporation Ltd. (POSOCO) have been signed. The department organized several national and international conferences, workshops, seminars and symposia to improve its skills and R&D activities. IMD has imparted training to the personnel from developing counties. The department also brought out research publications in national and International journals.
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FOREWORD

I feel privileged in presenting the 'IMD Annual Report 2015' which highlights the accurate meteorological services rendered to various stakeholders of the society and the progress made by the department during the year. The department has taken major initiatives in augmenting its observational, computational, forecasting and dissemination mechanism in recent years. IMD services are now counted among the best in the world.

IMD has augmented its observation organization with addition of new Doppler Weather Radars, GNSS stations, GPS based Solar Trackers, UV-B radiometers, Pyranometers, WMO compliant GPS Sondes, Automated Rain Gauges (ARGs), Air quality monitoring system, Nephelometers and Aethalometers networks in the country in 2015. It has taken lead in development and installation of LED Drishti Transmissometer Systems at different airports, Automated Weather Observing System, Radio Sonde and DTH based Digital Cyclone Warning Dissemination System under "Make in India".

The year 2015 has been an eventful year exhibiting unseasonal rain in north India during rabi season, severe floods in Chennai and other parts of the country, heat waves in Andhra Pradesh, Telangana and Odisha, drought, and other extreme events throughout the year. There has been systematic improvement in the management of these episodes by providing timey warning and guidance to the Government, various stakeholders and public at large. Number of stations for forecasting and periodicity have also been increased. Four (4) cyclones observed over north Indian Ocean during the year were forecasted well in advance and warnings were provided to disaster management authorities and public by different modes of communications including SMS Alerts.

The first stage forecast for the South West Monsoon Season (June-September) rainfall over the country as a whole issued on 22nd April, 2015 was 93% of LPA (below normal) with a model error of ± 5% of LPA, which was updated to 88% ± 4% of LPA (deficient) on 2nd June, 2015. The actual seasonal rainfall realized for the country as a whole turned out to 86% of LPA. IMD long range forecasts were widely appreciated.

IMD took new initiative towards systematic use of Meteorological Information for better management of Indian Power System from generation to distribution and to increase overall efficiency of the power system operations. An MoU has been signed between ESSO-IMD and Power System Operation Corporation Ltd. (POSOCO), a wholly owned subsidiary of Power Grid Corporation of India Ltd. to harness the benefits. The department continued co-operation with many national agencies like Indian Space Research Organization, Indian Council of Agricultural Research, Indian Air Force, Indian Navy, Army, Geological Survey of India, Central Water Commission, NCMRWF, INCOIS, NIOT, NCAOR, IITM SAC, NIDM, National Aeronautical Laboratory, Airport Authority of India, SASE, etc and signed several MoUs.

The department organized several national and international conferences, workshops, seminars and symposia to improve its skills and R&D activities and also to enhance e awareness among the masses. IMD has imparted training to 52 personnel from developing counties. The department supported bilateral and multi-lateral programmes with WMO, Geneva. The collaboration with US, Australia, U.K., China and Finland, has opened a path ahead for technical and scientific cooperation under various exchange programmes. The department also brought out 175 research papers/publications in national and International journals during the year.

The credit for providing state of art world class meteorological services and progresses made by the department goes to all dedicated IMD personnel who work round the clock to observe the atmosphere and issue weather forecasts to various stakeholders.

I compliment Dr. S. D. Attri, Dr. S. I. Laskar, Shri U. P. Singh and Shri M. K. Bhatnagar for bringing out the publication with support from S/Shri S. C. Sharma, Raj Kumar Verma, Dinesh Khanna, Brij Bihari and Gopi Chand of Publication section and inputs from different divisions/offices of IMD.

Dr. Laxman Singh Rathore
Director General of Meteorology

IMD ORGANIZATION CHART

INDIA METEOROLOGICAL DEPARTMENT

MINISTRY OF EARTH SCIENCES

GOVT. OF INDIA

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and Earth Sciences

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Director General of Meteorology

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(Weather Forecasting)

CHAPTER 1

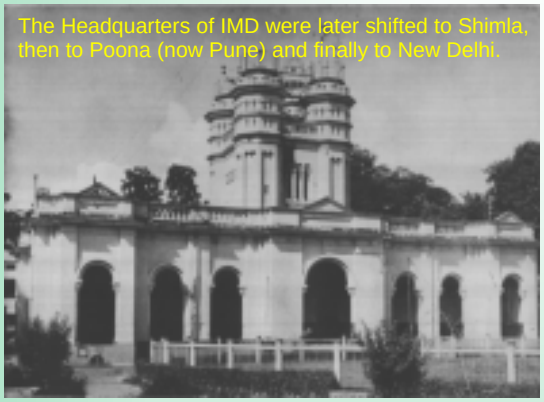
INDIA METEOROLOGICAL DEPARTMENT-OVERVIEW

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.

Its 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.



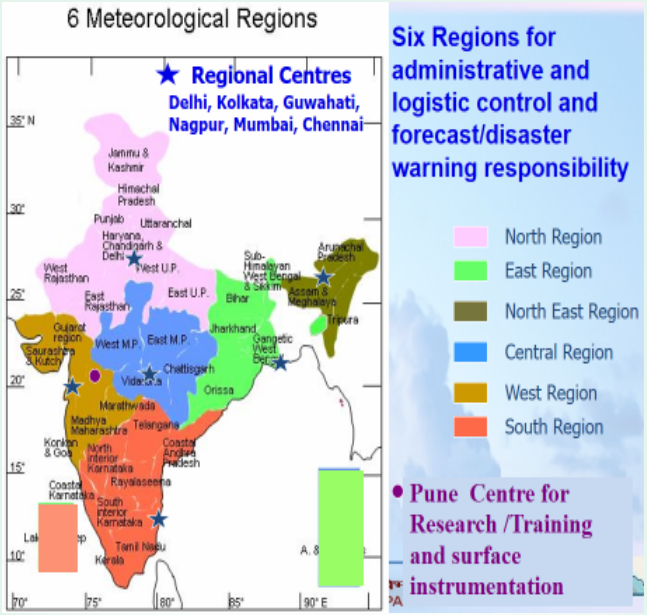
Alipore Observatory, Kolkata founded in 1877

India Meteorological Department, New Delhi

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 140 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.

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 06 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, Agrimet. Advisory Centres, Flood Meteorological Offices and Cyclone Detection Radar Stations.



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

IMD has continued its efforts in improving observational, forecasting and dissemination mechanism in 2015. Its short, medium and long range and cyclone forecasts were appreciated all over the world.

The 2015 has been an eventful year exhibiting drought, flood and extreme events throughout the year. World Meteorological Organization has described 2015 as one of the warmest year on record with strong El-Nino. South-West Monsoon was deficit, while North-East Monsoon was excess. Extreme events like unseasonal rainfall in March, 2015 in North west parts of India adversely affected Rabi crop production, sizzling heat wave sweeping many parts of the country particularly Andhra Pradesh, Telangana and Odisha reporting more than 2200 deaths, extremely heavy rainfall occurred over Gujarat, hailstorms over south Uttar Pradesh, Madhya Pradesh, Maharashtra & Chhattisgarh and floods in many parts of the country. Southeast India, especially Tamil Nadu and Puducherry also experienced unprecedented rainfall activity during November and early December 2015 leading to devastating flood over Tamil Nadu. The megacity of Chennai was worst affected during the end of November and early part of December 2015.

Accurate forecast, warnings and advisories issued by IMD during the year for extreme events has greatly helped a large number of users from various sectors, thus made a significant contribution to the national economy. Deficit monsoon forecast of 2015 was appreciated all over the world and helped the country and society to tide over the unprecedented looming food crisis by adaption of short duration, low water requirement and efficient farm management practices. Extreme event forecast and warnings were also equally effective in safeguarding life and property losses.

IMD took many initiatives to further improve its observational, analysis, forecasting and dissemination capability. It also organized many training programmes for international and national meteorological personnel to enhance their skills in meteorology and environment. The forecasting service has been extended to 324 cities with validity from 5 days to 7 days , while 5-day tourism forecast for 88 tourist destinations across the country has also been extended to 106 tourist destinations with 7-day forecast.

At the international front, the year had been very fruitful as Dr. L. S. Rathore, DGM has been elected as Member, Executive Council of WMO and Vice-Chair of IBCS and its National Climate Centre is being upgraded to Regional Climate Centre of WMO. It also hosted many international events and provided leadership and contribution to WMO programmes and projects.

SUMMARY OF MAJOR ACHIEVEMENTS IN 2015

OBSERVATION

- Doppler Weather Radars : (2 installed, 4 under installation)
- GNSS stations : 25 (6 installed, 19 under installation)
- GPS based Solar Trackers : 4, UV-B radiometers : 2 & Pyranometers : 4
- RS stations upgraded to WMO compliant GPS Sondes : 39
- Automated Rain Gauges (ARG) : 47 added
- Nephelometers : 12
- Aethalometers : 16
- Skyradiometers : 12

} SAMAR for Aerosol and Black carbon monitoring

- Installation of SAFAR at Mumbai
- Visualization of AWS data of ISRO network on IMD RAPID introduced

PREDICTION

- Accurate prediction of SW Monsoon 2015 (Actual : 86%, Forecast : 88% of LPA)
- Accurate prediction of NE Monsoon 2015 (Actual : 132%,Forecast : >111% of Long Period Average)
- Accurate prediction of Extreme events (2015 : Heavy Rainfall Warnings, Probability of Detection & Critical Success Index were 80%, 59% & 41%, respectively)
- Accurate prediction of cyclones (forecast error reduced by 13, 13, 17 km for 1, 2, 3 days, respectively in 2015 over 2010-2014

SERVICES

- Provided Weather forecast for 324 stations, tourism forecast for 106 stations and nowcast for 156 stations
- Increased forecasts period from 3 to 5 days over India and introduced sector wise 7-days special forecast & warnings for Western Himalayan Region for Indian Army
- Revenue of Rs.55.40 crores from aviation and data/services
- Environmental Impact assessment of 1546 Development projects
- Model based QPF for river basin and design storm analysis of 17 projects

DIGITAL INDIA

- Development of New Website of IMD
- Dissemination of Agromet advisories to 115 lakh farmers (SMS, Agri-portal, Website)
- Establishment of SMS based 'Cyclone Alert/Warning System'
- Generation of soil moisture maps through GIS
- Dissemination of Nowcast, Fog, Earthquake through SMS

MAKE IN INDIA

- Development and installation of 20 LED Drishti Transmissometer Systems at airports (Installed : 12, under installation : 8)
- Development of AWOS for aviation operations
- Development of RS with SAMEER
- DTH based Digital Cyclone Warning Dissemination System (CWDS) for 222 stations

HRD

- Capacity building : 52 personnel from Asia, Pacific and Africa regions and 359 from India
- Career advancement : 35 Group'A',170 Group 'B'(Gazzated) and 520 Group 'B' (Non Gazated) and 12 Group 'C' official in IMD
- MoUs with universities and research institutions

PUBLICATION

- 175 Research Papers/books/Met monographs

QUALITY ASSURANCE

- ISO9001:2008 Certification - 10 offices of IMD

CHAPTER 2

WEATHER SUMMARY DURING 2015

1. Winter Season (January & February)

Cold Wave conditions

Cold wave conditions prevailed over parts of central India during second and third week of January and over parts of peninsular India during the second week. These conditions again prevailed over most parts of the country (except south peninsula) during last few days of January and first week of February. Cold day conditions were observed over the plains of northern India after the second week of January and continued till the end of the month. Foggy conditions prevailed at isolated places over northern parts of the country almost throughout the month of February. Both maximum and minimum temperatures were below normal by 5 °C or more at many stations over the plains of northern India during January. However, during second fortnight of February, both maximum and minimum temperatures were substantially above normal over northern and central parts of the country.

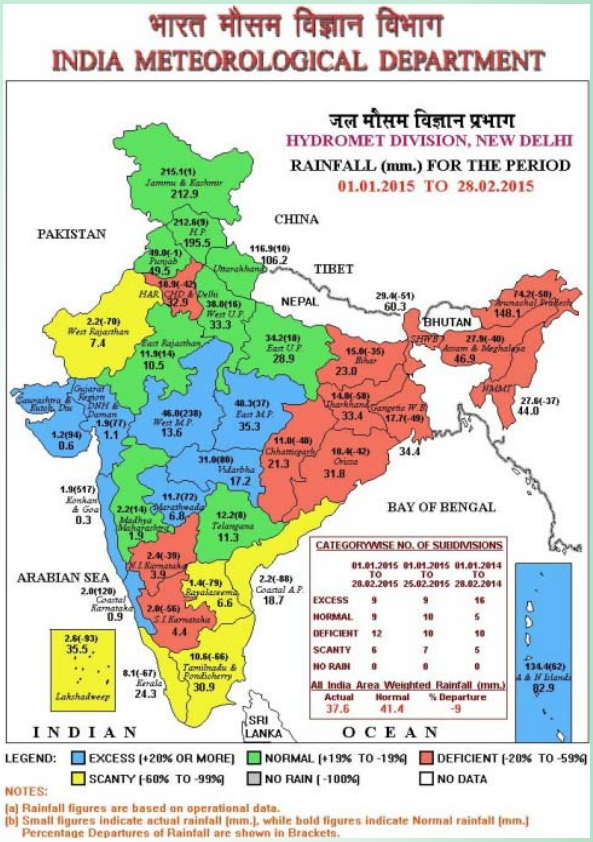


Fig. 1. *Meteorological sub-division wise rainfall (mm)*

Rainfall Features

Rainfall activity over the country as a whole was near normal during the season. It was near normal during both the months of the season (89% of LPA during January and 93% of LPA during February). Northern, Central and adjoining north peninsular parts of the country in general received excess/normal rainfall while, eastern/northeastern and south peninsular parts of the country received deficient/scanty rainfall. During the season, out of 36 meteorological sub-divisions, 9 received excess rainfall, 9 received normal rainfalls, 12 received deficient rainfalls and remaining 6 sub-divisions received scanty rainfall.

Northern, central and eastern/northeastern parts of the country in general received more than 20 mm of rainfall. Central parts of Madhya Pradesh and adjoining southern parts of Uttar Pradesh and parts of coastal Odisha received 50 to 100 mm of rainfall. Extreme northern parts of the country, parts of Arunachal Pradesh and Andaman & Nicobar Islands received 100 to 200 mm of rainfall, while rainfall over parts of Jammu & Kashmir, Himachal Pradesh and Uttarakhand exceeded 200 mm (Fig. 1).

The rainfall for the country as a whole for the winter season has been recorded as 37.5 mm

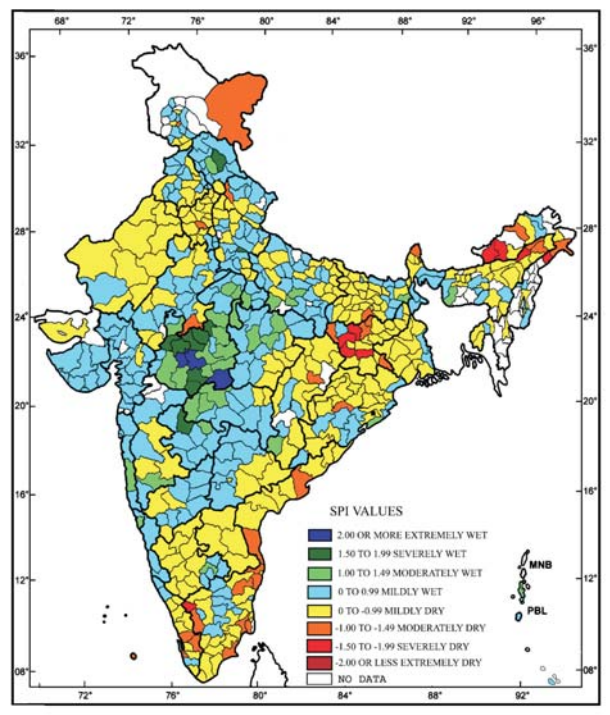


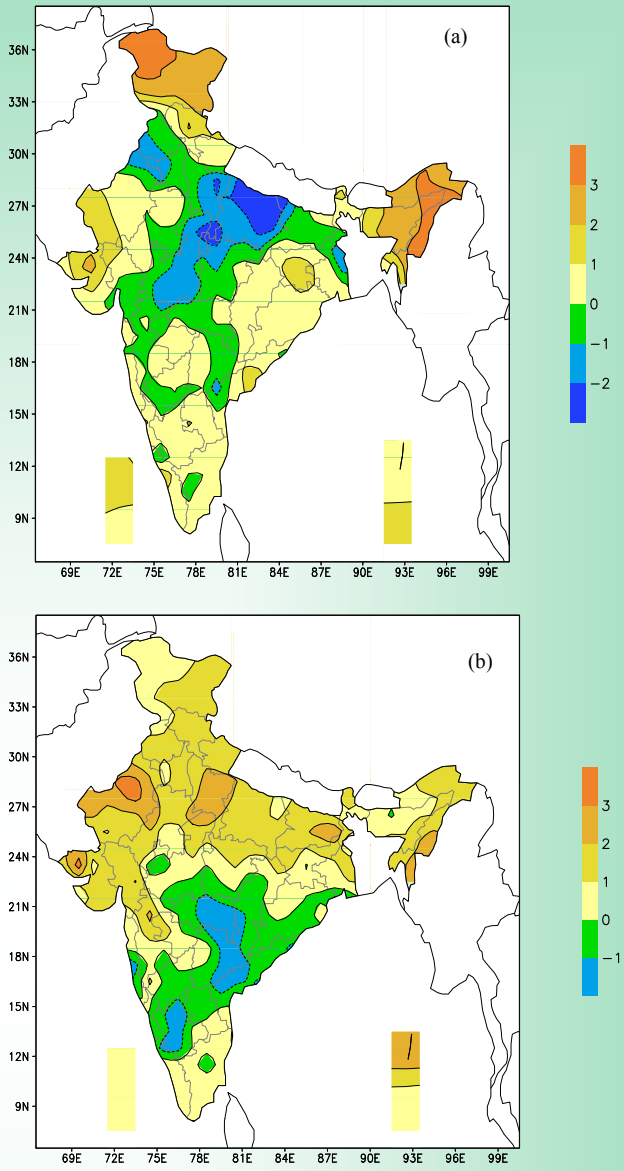
Fig. 2. *SPI for winter season (JF)*

(-08%) against the normal rainfall 40.9 mm for the season.

For the winter season 2015, rainfall for the country as a whole was 92% of its Long Period Average (LPA) value. The rainfall for the season was above normal over the central India (132% of LPA), normal over the northwest India (102% of LPA) and below normal over the east & north east India (53% of LPA) and the south peninsula (50% of LPA).

Standardized Precipitation Index (SPI)

The Standardized Precipitation Index (SPI) is an index used for measuring drought and is based only on precipitation. Cumulative SPI values indicate extremely wet/severely wet conditions over parts of Himachal Pradesh, West Uttar Pradesh, West Madhya Pradesh and Marathwada while extremely dry/severely dry conditions were observed over parts of Jharkhand, Tamil Nadu, Arunachal Pradesh and Assam (Fig. 2).



Figs. 3(a&b). *Mean seasonal temperature anomaly (°C) (a) Maximum and (b) Minimum [Based on 1971-2000 NORMAL(S)]*

Temperatures

Maximum temperature was below normal over the plains of northern India and some adjoining central and north peninsular parts of the country, and was generally above normal over remaining parts of the country. It was below normal by about 1 to 2°C over parts of Uttar Pradesh, Madhya Pradesh, southern parts of Punjab and adjoining northern parts of Rajasthan and western parts of Haryana and some parts of Gangetic West Bengal. Over the hilly areas of western Himalaya's, viz., parts of

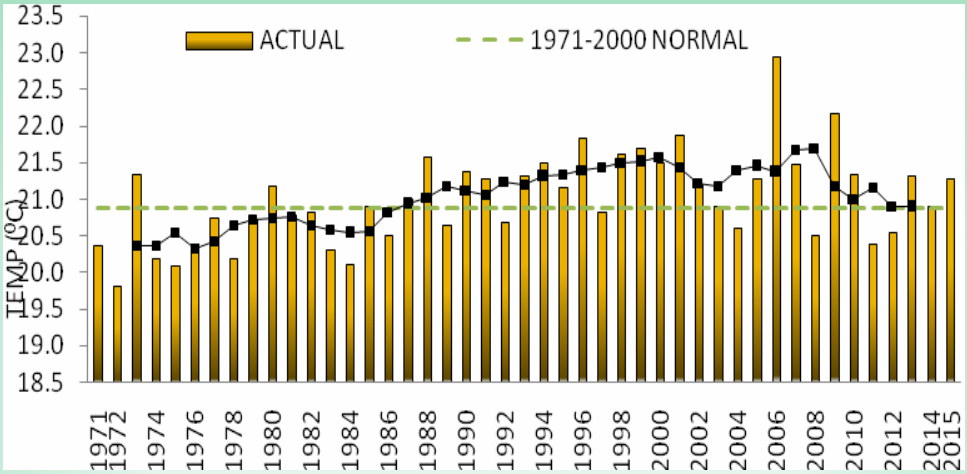


Fig. 4. *Mean temperature & five year running mean for Winter Season (1971-2000)*

Jammu & Kashmir and adjoining Himachal Pradesh and over parts of extreme northeastern region, maximum temperature was above normal by about 2 to 3 °C.

Minimum temperature was above normal over most parts of the country except some parts of central/eastern region and adjoining north peninsula. Over plains of northern India and western region, it was above normal by 1 to 2°C. Over some parts of West Rajasthan, maximum temperature was above normal by about 2 to 3 °C [Figs. 3(a&b)].

The mean temperature for the country as a whole for the season since 1971 has been shown in the Fig. 4. During this year the mean temperature for the season was near normal.

The minimum temperature series for the country as a whole and the four homogeneous regions during the season since 1971 has been shown in the Fig.5. In the year 2015 the minimum temperature was above normal over the India as a whole and over the four homogeneous regions. It was above normal by about 0.5 °C over the northeast and South Peninsular India and by about 1 °C over the Northwest India

Warm days/cold nights

Figs. 6(a&b) show the percentage of days when maximum (minimum) temperature was more (less) than 90th (10th) percentile. Over parts of Jammu & Kashmir, maximum temperature was greater than 90th percentile for more than 40% of the days of the season and over parts of Nagaland, Manipur, Mizoram and Tripura and Lakshadweep Islands, it exceeded 60%. For minimum temperature, no significant distribution was observed.

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

Severe and widespread heat wave conditions were observed over most parts of north/northwestern, central, eastern and southeast peninsular India during second fortnight of May. During rest of the season these conditions prevailed only at isolated places over western, central and north peninsular parts of the country for short period of time. Moreover, March and April months witnessed well below normal maximum temperature almost throughout the country. Maximum temperature was below normal by about 5 to 10° C over some stations of north, northwest, north east and central India on many occasions during these two months in succession.

Rainfall features

Rainfall activity over the country during the season as a whole was above normal. It was substantially above normal during March and

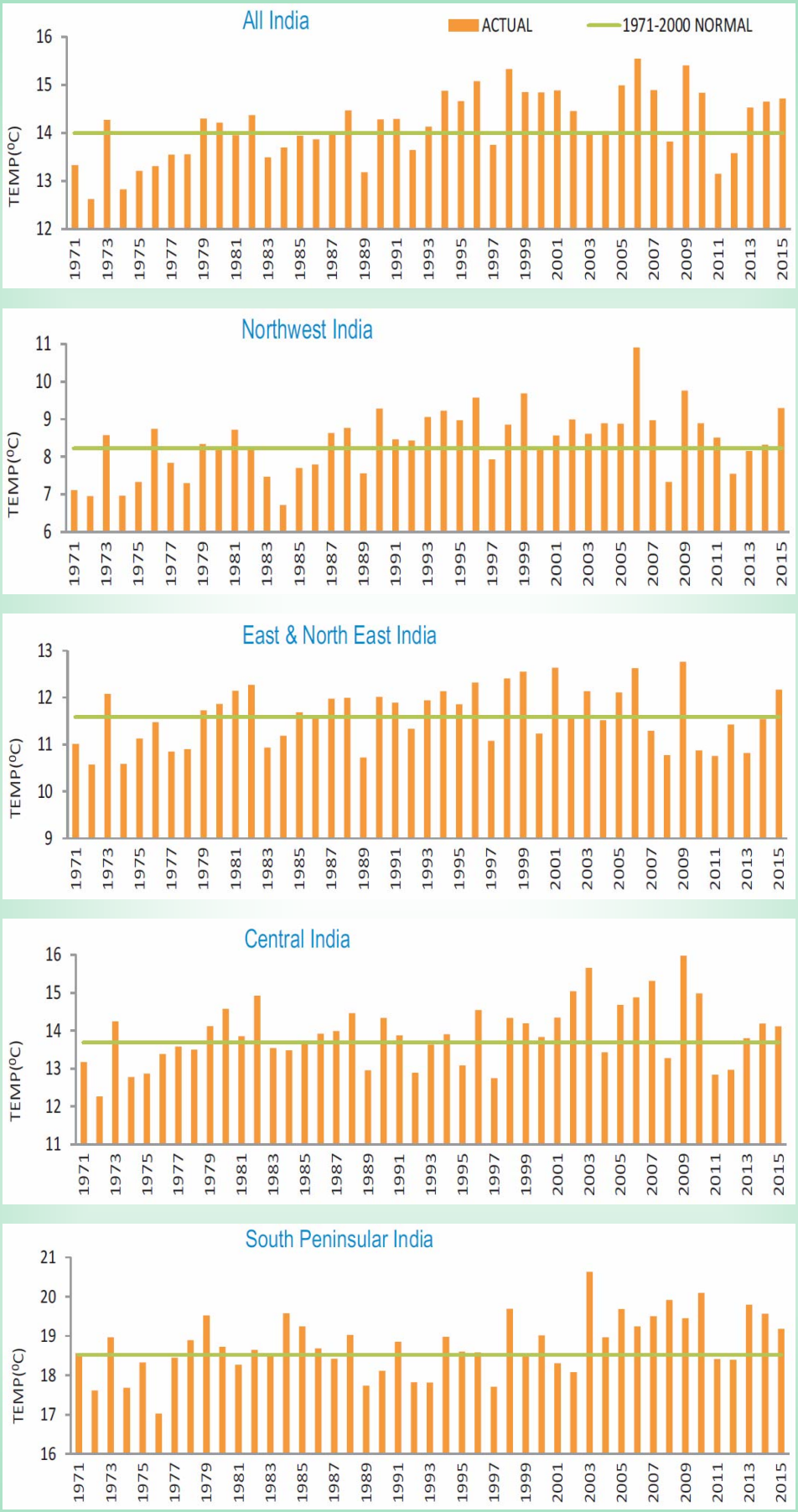
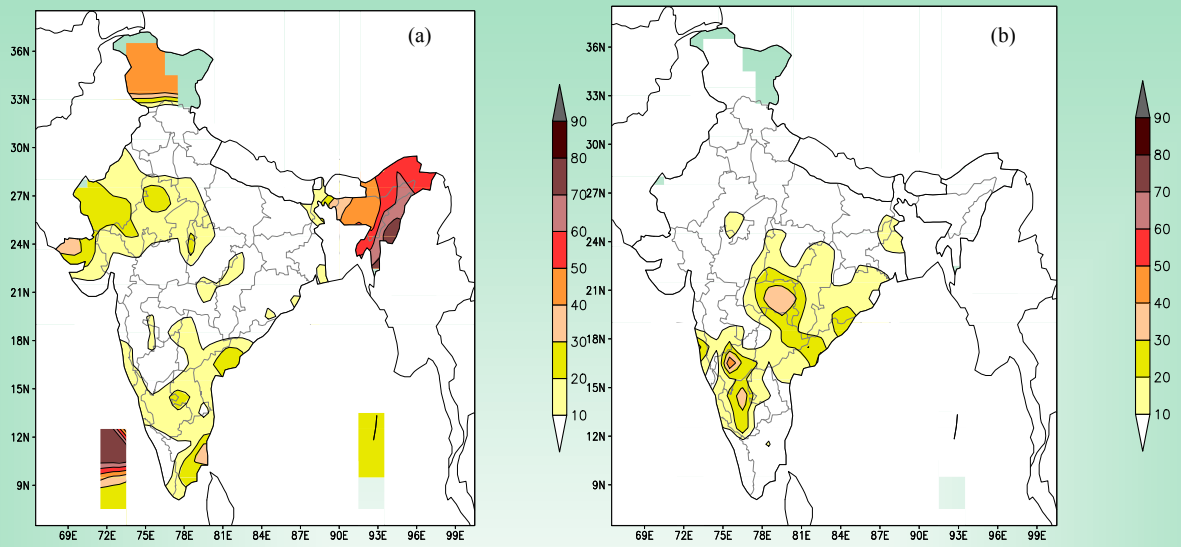


Fig. 5. *Minimum temperature for four homogeneous regions (1971-2015)*



Figs. 6(a&b). *Percentage of days with (a) maximum temperature more than 90th Percentile (b) minimum temperature less than 10th Percentile*

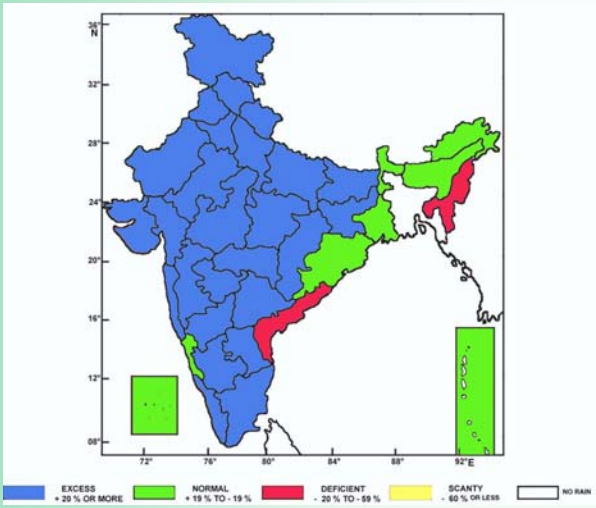
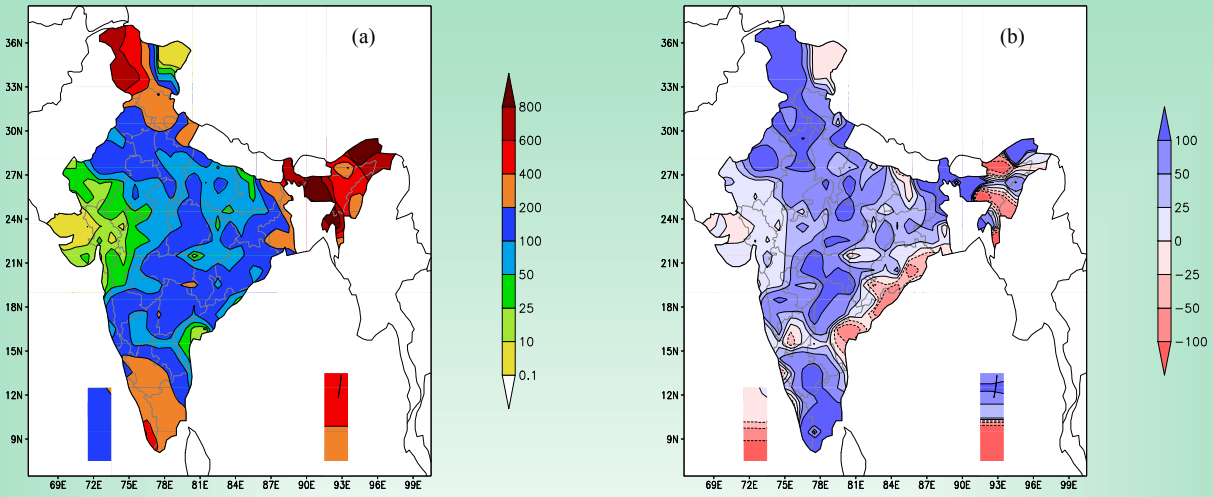


Fig. 7. *Sub-division wise rainfall percentage departure for the pre-monsoon season 2015*

April (198% and 174% of LPA respectively) and below normal during May (88% of LPA). Except for the meteorological sub-divisions of east coast, extreme northeastern region and the Islands, almost entire country received excess rainfall. Some subdivisions of north/northwest and central India, viz., West Uttar Pradesh, Haryana, Chandigarh & Delhi, East &West Rajasthan, East & West Madhya Pradesh and Vidarbha received more than three times of their respective normal rainfall. During the season, out of 36 meteorological subdivisions, 26 received excess rainfall, 8 received normal rainfall and 2 received deficient rainfall (Fig. 7).

Fig. 8(a) shows the spatial pattern of rainfall (mm) received during the season. Except for western region, most parts of the country received rainfall of the order of 50 to 200 mm. Extreme northern parts of the country, parts of south peninsula, northeastern region of the country and Andaman & Nicobar Islands received more than 200 mm of rainfall. Rainfall over some parts of extreme northeastern region of the country was more than 800 mm.

Fig. 8(b) shows the spatial pattern of rainfall anomaly (mm) during the season. Rainfall anomaly was positive over most parts of the country except for some parts of east coast, extreme northeastern region and the Islands. Positive rainfall anomaly of the order of 50 to 100 mm was observed over most parts of northern, northeastern, central and south peninsular region. Negative rainfall anomaly of the order of 25 to 50 mm was observed over most parts of east coast and over parts of extreme northeastern region of the country and the Islands it exceeded 100 mm.



Figs. 8(a&b). (a) *Seasonal rainfall (mm) and (b) Seasonal rainfall anomaly (mm) [Based on 1951-2000 NORMAL(S)]*

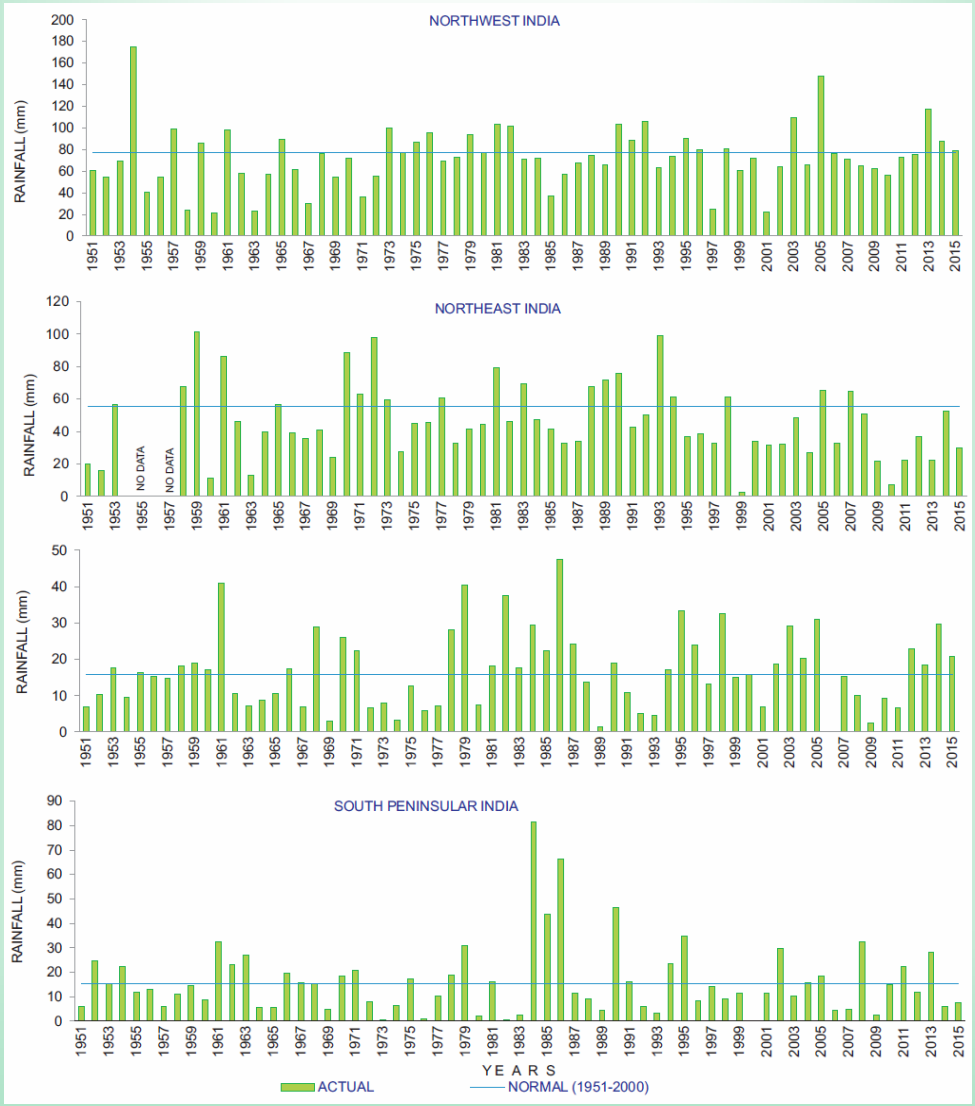


Fig. 9. *Time series of area weighted seasonal rainfall over the four homogeneous regions for the period, 1951-2015*

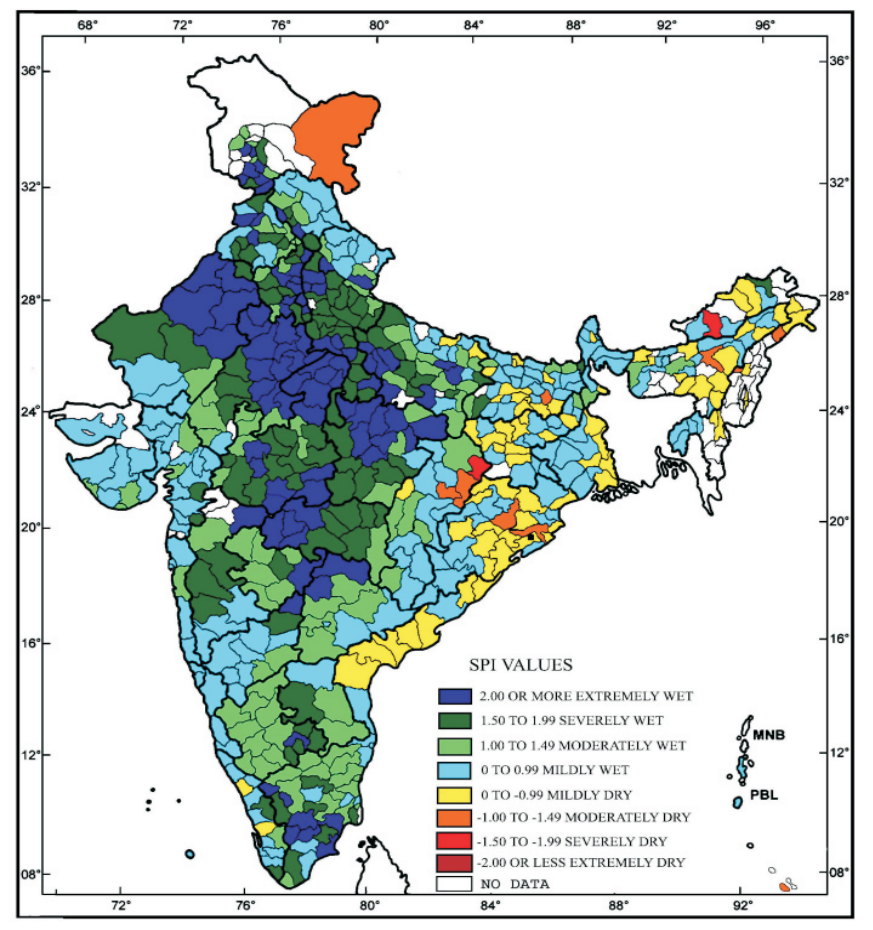
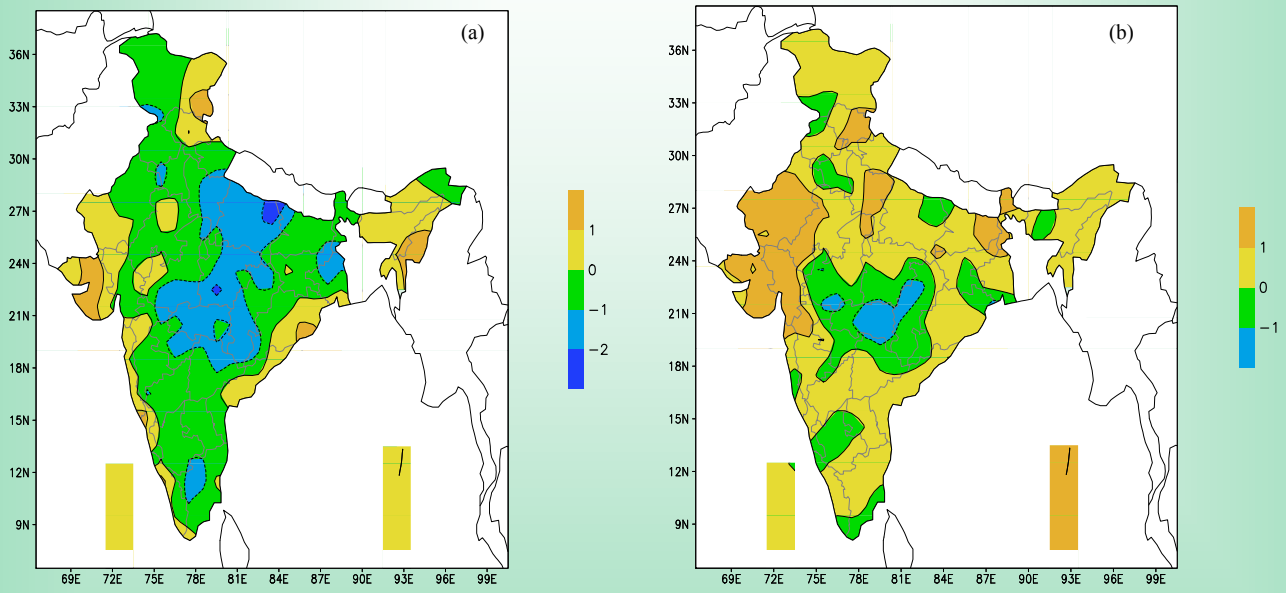


Fig. 10. *Standardized Precipitation Index (SPI)*



Figs. 11(a&b). *Mean seasonal temperature anomaly (°C) (a) Maximum and (b) Minimum [Based on 1971-2000 NORMAL(S)]*

The Cumulative rainfall departure was positive during all the weeks of the season. It exceeded twice its normal value during the mid of the season (15 April). However, this high positive anomaly reduced gradually due to subdued rainfall activity during May.

Rainfall for the country as a whole was 138% of its Long Period Average (LPA) value during the season.

The area weighted seasonal rainfall (181.5 mm) over the country as a whole for the season was the second highest since 1901 after the year 1990 (226.9 mm) for the period, 1951-2015.

Fig.9 shows the time series of area weighted seasonal rainfall over the four homogeneous regions for the period, 1951-2015. During the season, northwest and central India received nearly twice of its respective normal rainfall, south peninsula received about one and half times of its normal rainfall while northeast India received normal rainfall.

Standardized Precipitation Index

Cumulative SPI values during the pre-monsoon season indicate, extremely wet/severely wet conditions over parts of Arunachal Pradesh, Bihar, Uttar Pradesh, Uttarakhand, Haryana, Chandigarh & Delhi, Punjab, Himachal Pradesh, Jammu & Kashmir, Rajasthan, Madhya Pradesh, Gujarat region, Madhya Maharashtra, Marathwada, Vidarbha, Telangana, Rayalaseema, Tamil Nadu, North & South Interior Karnataka and Kerala, while extremely dry/severely dry conditions were observed over parts of Arunachal Pradesh and Chhattisgarh (Fig. 10).

Outgoing Longwave Radiation (OLR)

Negative OLR anomaly exceeding 5 to 10 W/m^2 was observed over the south peninsula & adjoining seas and parts of extreme northeastern region.

Temperature

Mean seasonal maximum and minimum temperature anomalies are shown in [Figs. 11(a&b)] respectively. Maximum temperature was below normal over most parts of the country except some parts of Jammu & Kashmir, Himachal Pradesh, Gujarat, Rajasthan, west coast, east coast, parts of extreme northeastern region and the Islands. Over some parts of central and adjoining northern region, viz., Vidarbha, Marathwada, Telangana, Chattisgarh, Madhya Pradesh and Uttar Pradesh, it was below normal by about 1 to 2 °C.

Minimum temperature was above normal over most parts of the country, except some parts of central region. Over parts of Gujarat, Rajasthan, Himachal Pradesh, West Uttar Pradesh, Bihar, Jharkhand, West Bengal and Andaman & Nicobar Islands, it was above normal by about 1 to 2°C. Over parts of Vidarbha and adjoining Chhattisgarh minimum temperature was below normal by about 1 to 2 °C.

As per the time series of mean temperature for the country as a whole during the pre monsoon season (1971-2015) [Figs. 12(a&b)] mean temperature for the season during the year was near normal. Maximum temperature was below normal by more than 1°C over the homogeneous region of northwest and northeast India during the season. Similarly, minimum temperature was above normal over the south peninsular India by about 1°C.

Percentage of Warm days/Cold nights

Over parts of coastal Gujarat, Konkan & Goa and adjoining northern parts of coastal Karnataka, maximum temperature was greater than 90^{th} percentile for more than 40% of the days of the season. Figs. 13(a&b) show the percentage of days when maximum (minimum) temperature was more (less) than 90^{th} (10^{th}) percentile.

For Maximum Temperature

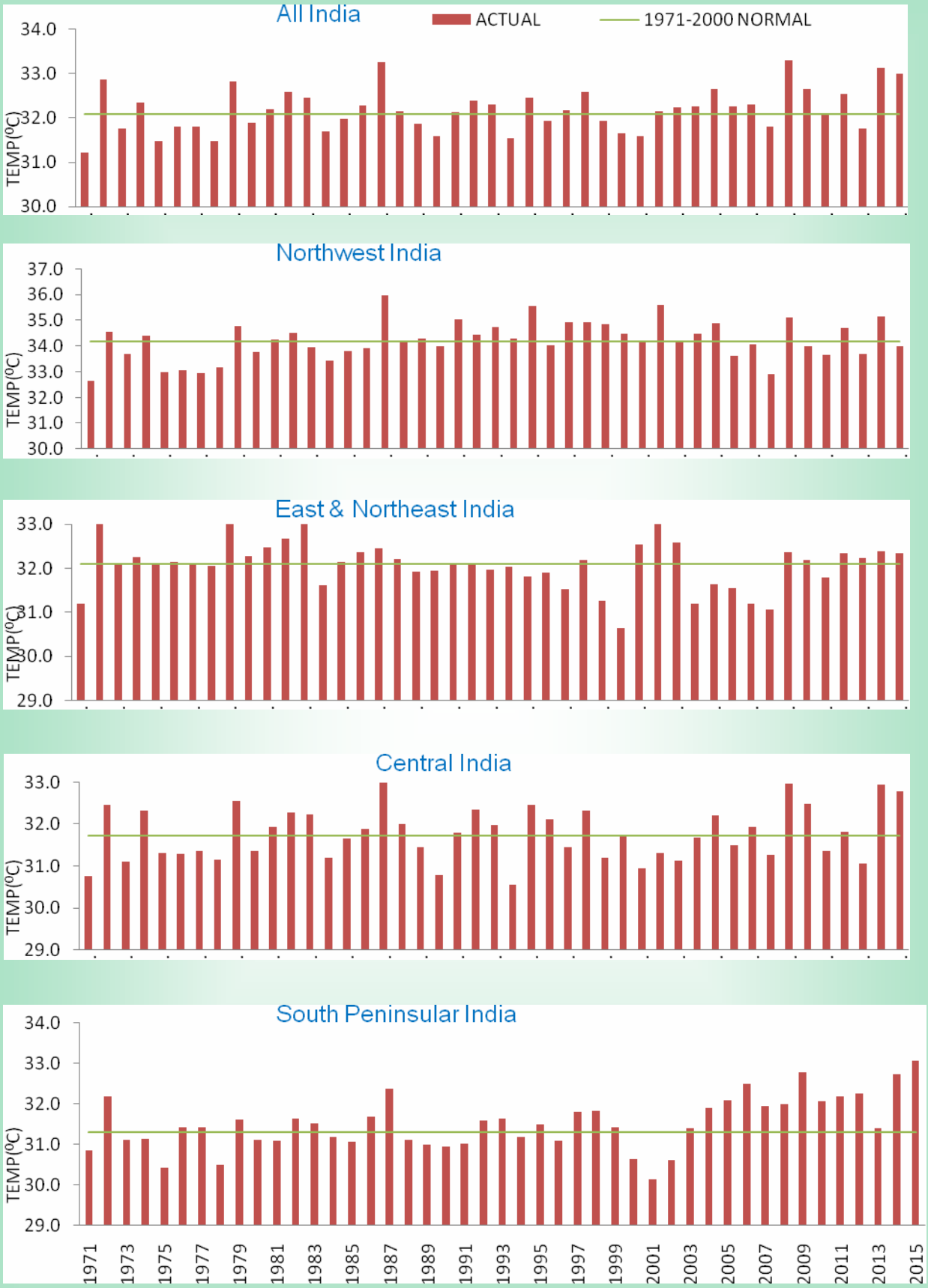


Fig. 12(a). *Time series of maximum temperature for the country and four homogeneous regions (1971-2015)*

For Minimum Temperature

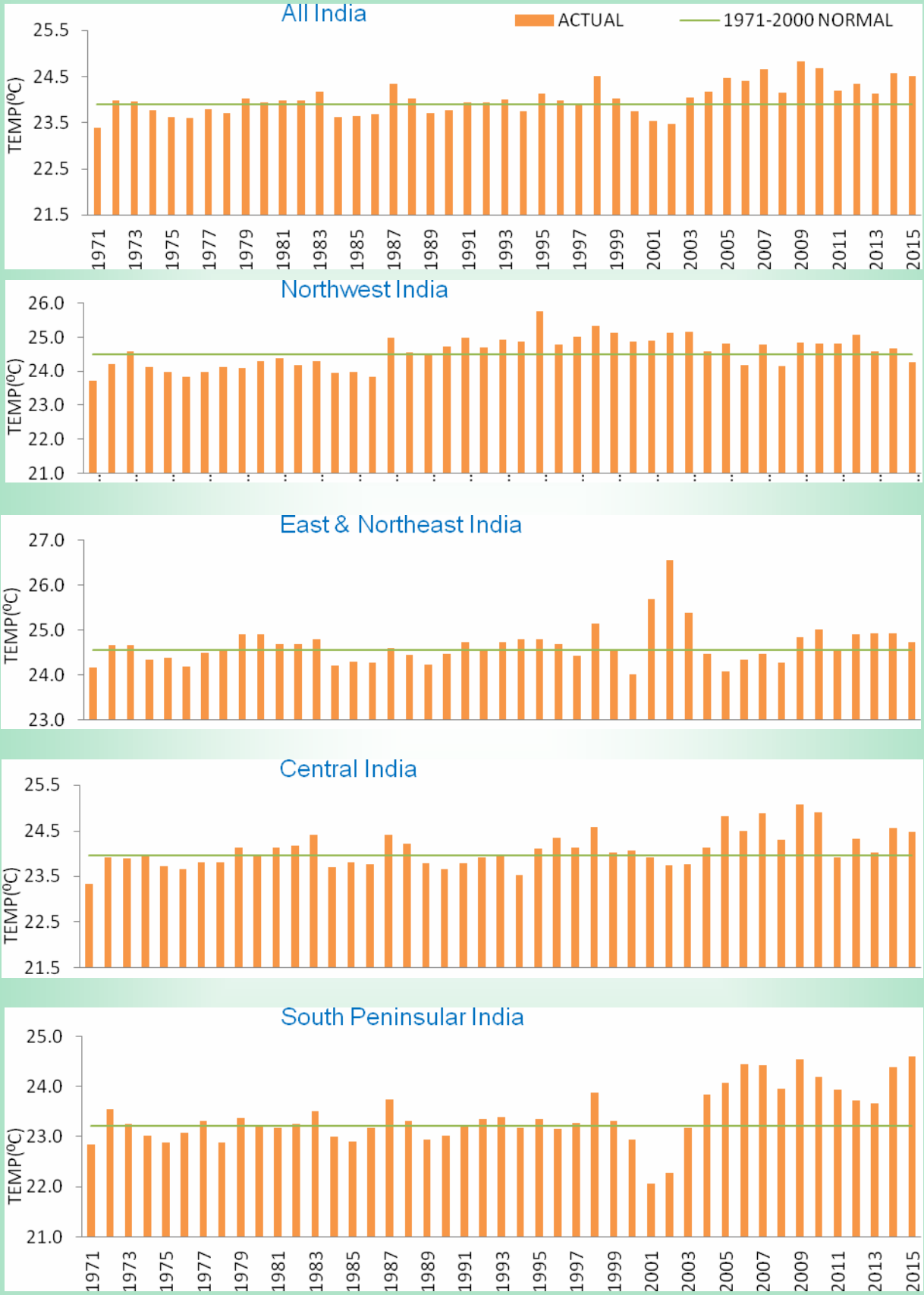
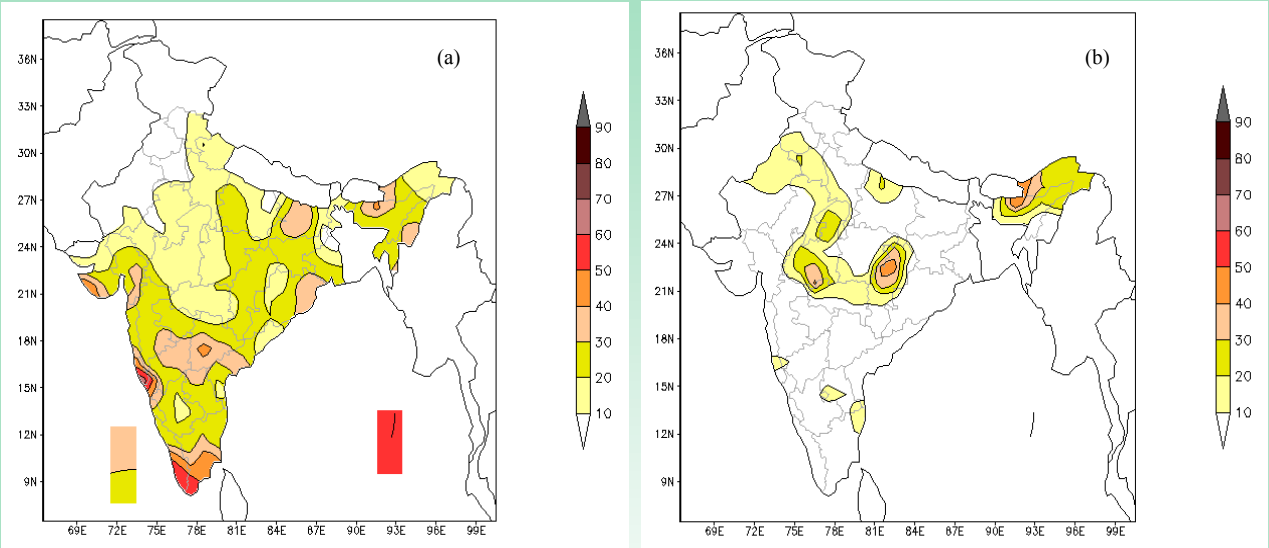


Fig. 12(b). *Time series of minimum temperature for the country and four homogeneous regions (1971-2015)*



Figs. 13 (a&b). *Percentage of days with (a) maximum temperature more than 90th Percentile (b) minimum temperature less than 10th Percentile*

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

Onset and advance of SW Monsoon

The conditions which were favorable for onset of monsoon over Kerala coast follows:

The rainfall over Kerala had been fairly widespread on 4th and 5th June. Out of the 14 rainfall monitoring stations for Monsoon onset over Kerala, more than 70% of stations reported rainfall more than 2.5 mm for consecutive two days *i.e.* on 4th June and 5th June (Fig. 14).

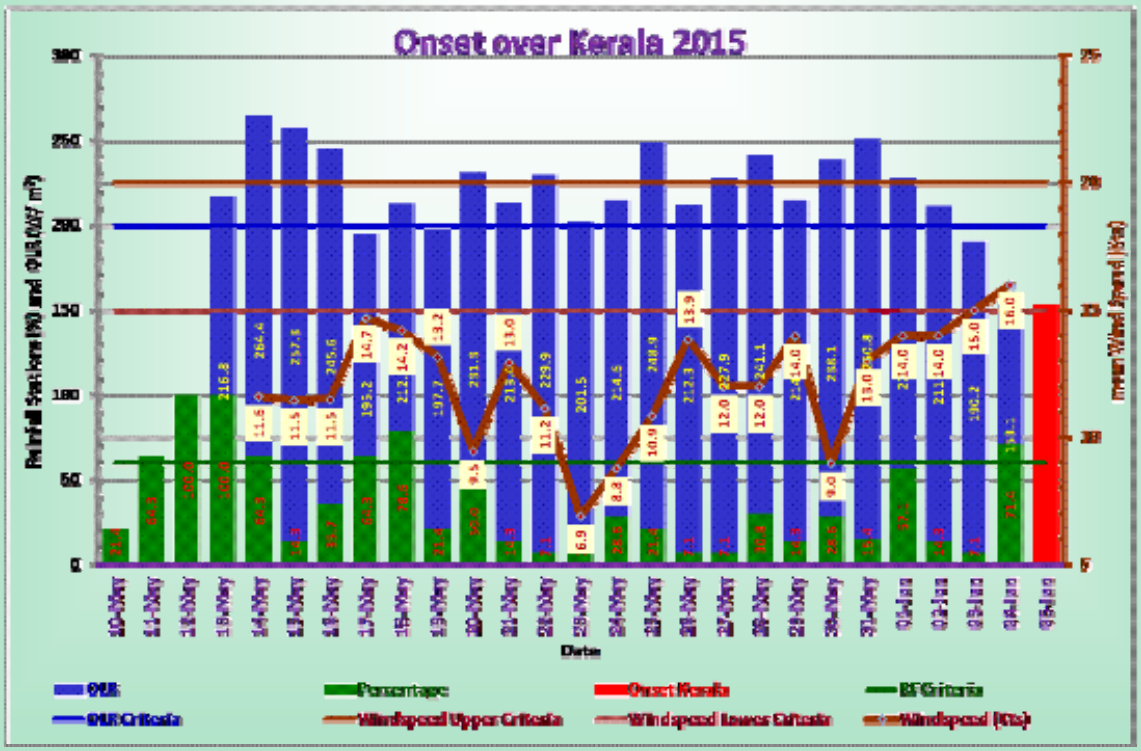


Fig. 14. *Percentage of stations reporting rainfall ≥2.5 mm*

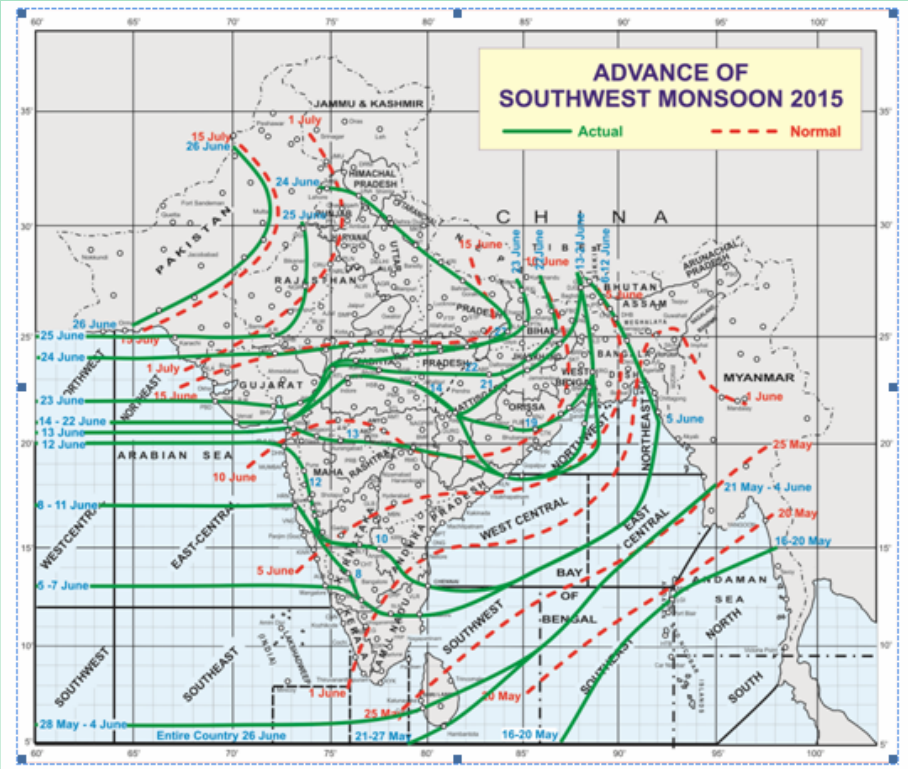


Fig. 15. *Advance of SW monsoon 2015*

The depth of the southwesterlies upto 600 hPa was seen from 14th May onwards. The wind / Outgoing Longwave Radiation (OLR) criteria and the rainfall criterion were satisfied on 4th & 5th June. The average wind speed at 925 hPa over the area bounded by Latitudes 5-10° N and Longitudes 70-80° E was 16 knots. The INSAT-3D derived OLR value in the box confined by Lat. 5-10° N, Long. 70-80° E was 153.1 W/m^2 on 4th June and 191.5 W/m^2 on 5th June.

The onset of southwest monsoon over Kerala signals the arrival of monsoon over the Indian subcontinent and represents beginning of rainy season over the region. The normal date of onset of monsoon over Kerala is 1st June. The monsoon was set over Kerala on 5th June, 2015.

Strong southwesterly surface winds crossing over to the Bay of Bengal across the equator, caused increase in cyclonic shear vorticity over the southern parts of Bay of Bengal and Andaman Sea, which in turn caused enhanced convection over the region. As a consequence, the rainfall activity increased over the Andaman & Nicobar Islands indicating the arrival of southwest monsoon over most parts of Andaman Sea and some parts of southeast Bay of Bengal on 16th May, 4 days before the normal date of 20th May.

Active phase of the Madden Julian Oscillation (MJO) aided in the further advance of southwest monsoon over Kerala on 5th June. At the same time, it also aided in the intensification of the 'onset vortex' over the Arabian Sea into Cyclonic Storm (Ashobaa). The Arabian Sea branch of the monsoon current was aided by the formation of a Cyclonic Storm (Ashobaa). Thus southwest monsoon further advanced into entire south Arabian Sea, some parts of central Arabian Sea, entire Lakshadweep area and Kerala, some parts of coastal & south interior Karnataka and Tamil Nadu, most parts of southwest Bay of Bengal, remaining parts of southeast Bay of Bengal, some more parts of central Bay of Bengal and some parts of northeast Bay of Bengal on 5th June, 4 days later than its normal date of 1st June (Fig. 15)

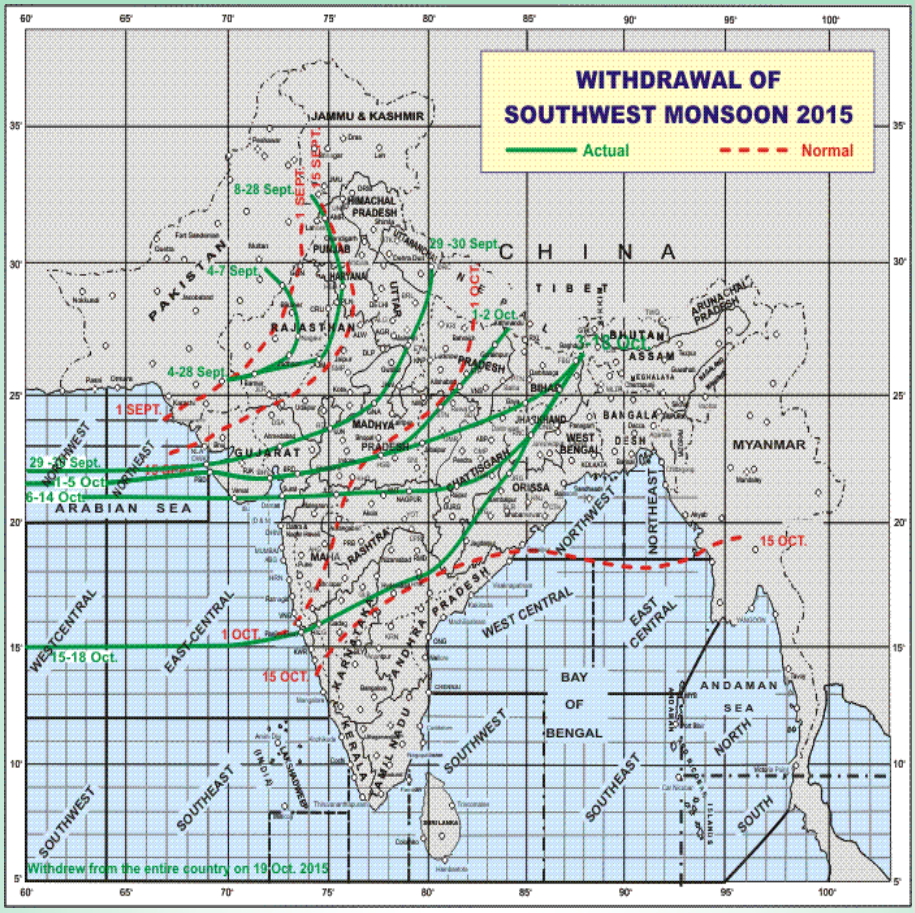
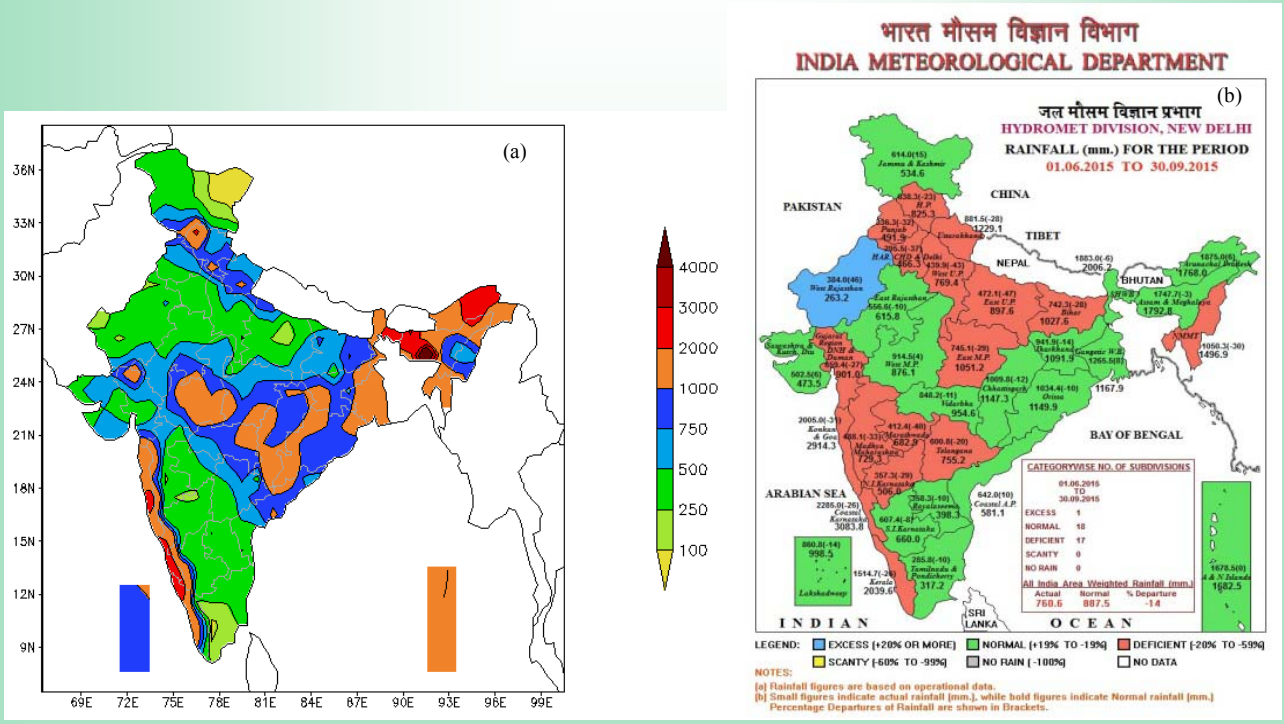


Fig. 16. *Isochrones of withdrawal of Southwest Monsoon 2015*



Figs. 17 (a&b). *(a) Seasonal rainfall (cm) and (b) All India area weighted rainfall*

Active MJO led to favourable convective environment and resultant rainfall. This helped to the further advance of southwest monsoon. It consistently advanced and covered central Arabian Sea, some parts of north Arabian Sea, entire south peninsula, and most parts of central and northeast India by 15th June. The formation of couple of intense pressure systems one each in Arabian Sea (Deep Depression) and in Bay of Bengal (Depression) towards the end of third week caused rapid advance and covered entire country by 26th June 2015.

Withdrawal of southwest monsoon

The rainfall activity over the northwestern parts of Rajasthan remained subdued since last week of August. A change over in the lower tropospheric circulation pattern over the region from cyclonic to anti cyclonic indicated the beginning of the withdrawal of southwest monsoon from the region. Hence the withdrawal of southwest monsoon commenced from 4th September and the withdrawal line passed through Anupgarh, Nagaur, Jodhpur and Barmer. It withdrew from some more parts of Rajasthan and some parts of Punjab and Haryana on 9th September and the withdrawal line passed through Amritsar, Hissar, Ajmer and Barmer. Further withdrawal had been stalled due to the formation of Deep Depression over Odisha and neighborhood and easterly winds associated with the above system and consequent moisture incursion from the Bay of Bengal. With the eastward extension of the ridge, more drying of the lower and middle troposphere took place over northwest India and accordingly, the southwest monsoon further withdrew from remaining parts of Rajasthan, Punjab, Haryana, Chandigarh & Delhi, entire Jammu & Kashmir, Himachal Pradesh, Uttarakhand, most parts of west Uttar Pradesh and some parts of West Madhya Pradesh, Gujarat state and north Arabian Sea on 29th September.

The southwest monsoon withdrew from remaining parts of West Uttar Pradesh, most parts of East Uttar Pradesh and some more parts of Madhya Pradesh, Gujarat state and north Arabian Sea on 1st October; from remaining parts of East Uttar Pradesh, most parts of Bihar, some more parts of East Madhya Pradesh and some parts of north Chhattisgarh on 3rd October and from some more parts of Bihar, Chhattisgarh & Gujarat state, remaining parts of Madhya Pradesh, some parts of Jharkhand, Vidarbha, Madhya Maharashtra and some more parts of north Arabian sea on 6th October. A Deep Depression formed over the Arabian Sea and dissipated in-situ during 9th - 12th October. The moisture incursion and rainfall caused by this Deep Depression over the Arabian Sea and a well marked low pressure area over the north Bay of Bengal halted the further withdrawal of southwest monsoon till 15th October and then it further withdrew from some more parts of Jharkhand, most parts of Chhattisgarh, remaining parts of Vidarbha, Madhya Maharashtra, Gujarat state and north Arabian Sea, entire Marathwada and Konkan & Goa and some parts of Odisha, Telangana, North Interior Karnataka and central Arabian Sea.

On 19th October the SWM further withdrew from remaining parts of the country, Bay of Bengal and Arabian Sea. The northeast monsoon rains commenced over Tamil Nadu, Kerala and adjoining areas of Andhra Pradesh and Karnataka on 28th October (Fig. 16).

Rainfall Features

The southwest monsoon season rainfall over the country as a whole was below normal. Moreover, it was characterized by pronounced spatial and temporal variability. Eastern/ northeastern region of the country received normal rainfall, while central, peninsula and northwestern region of the country received deficient rainfall. Rainfall deficiency over West & East Uttar Pradesh and Marathwada exceeded 40%, while that over Haryana, Chandigarh & Delhi, Punjab, Konkan & Goa and Madhya Maharashtra exceeded 30%. Also, during the first half of the season (1st June to 31st July) country received near normal rainfall (95% of its LPA value), while during second half of the season (1st August to 30th September) it received deficient rainfall (only 77% of LPA).

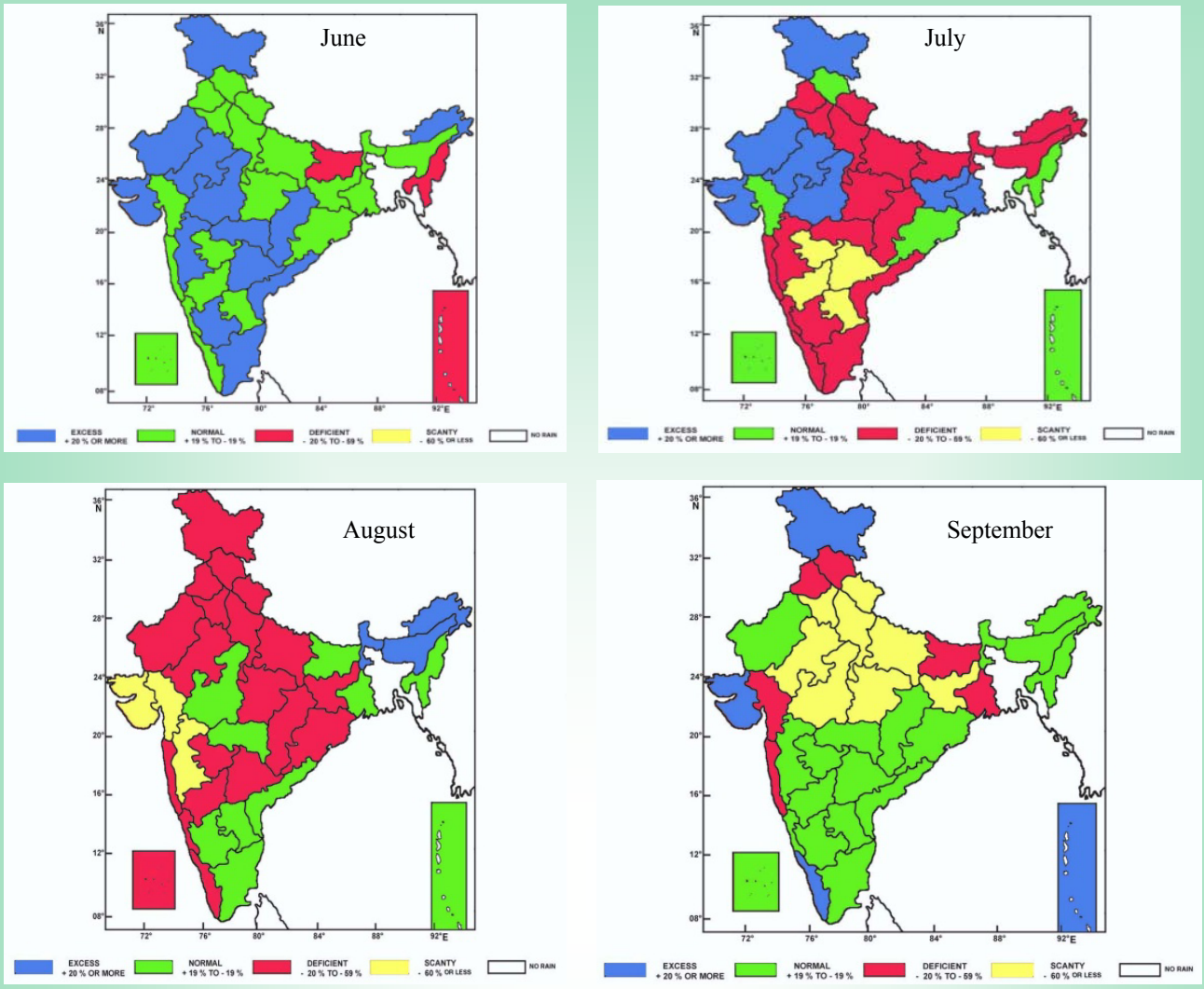


Fig. 18. *Monthly sub-divisions wise distribution of rainfall percentage departures*

During the season, out of 36 meteorological sub-divisions, only one sub-division (West Rajasthan) received excess rainfall, 18 received normal rainfall and the remaining 17 sub-divisions received deficient rainfall. [Fig. 17(b)].

Fig. 18 shows the sub division wise distribution of rainfall percentage departures for the four months of monsoon season (June to September) 2015. The figures also represent number of sub-divisions receiving excess, normal, deficient and scanty rainfall during each month of the season and monthly rainfall received as the percentage of LPA for each month.

Central, west central, eastern/northeastern and some northern parts of the country and parts of west coast received rainfall of the order of 500-1000 mm. Rainfall received by parts of Konkan & Goa, Coastal Karnataka, north Kerala, Sub-Himalayan West Bengal & Sikkim, Assam & Meghalaya and Arunachal Pradesh was more than 2000 mm. Parts of Meghalaya received more than 4000 mm of rainfall. Rainfall anomaly was negative over most parts of the country except for some parts of northern/northwestern, central, east peninsular and eastern/northeastern region. Magnitude of negative rainfall anomaly over most parts of northern/northeastern region, west coast and Marathwada & adjoining areas was more than 200 mm. Over parts of East Uttar Pradesh and adjoining north Bihar, Sub-Himalayan West Bengal & Sikkim, Arunachal Pradesh, most parts of west coast and Gujarat region, magnitude of negative rainfall anomaly was

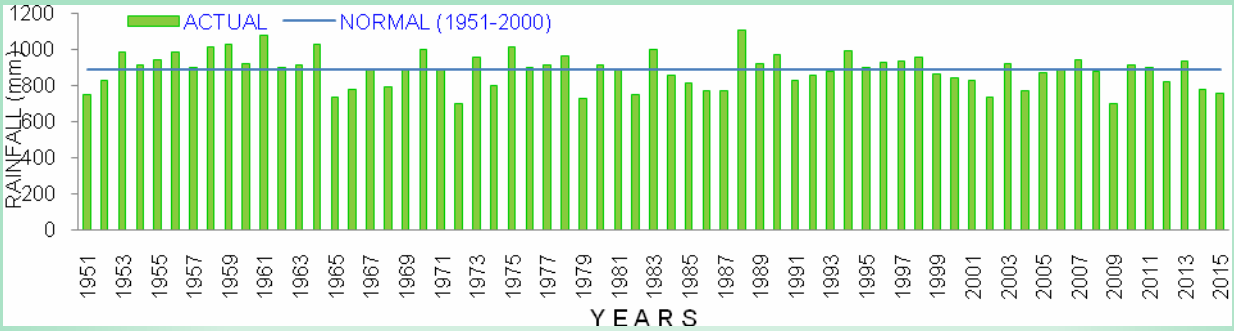


Fig. 19(a). *Time series of area weighted rainfall over the country as a whole for the monsoon season (1951-2015)*

more than 600 mm. Similarly, positive rainfall anomaly over parts of Chattisgarh & adjoining south Odisha, Coastal Andhra Pradesh, south Rajasthan and adjoining north Gujarat, Gangetic West Bengal and Assam & Meghalaya was more than 200 mm.

Fig. 19(a) shows the area weighted rainfall (in mm) and its long term normal over the country as a whole and the Fig. 19(b) shows the area weighted rainfall (in mm) and its long term normal over the four homogeneous regions during the season. For the country as a whole (except for the month of June) rainfall average was below normal on most of the days during the season. On about 30 occasions, it was nearly half its normal value. However, on few occasions (of relatively shorter duration) it was above normal, viz., for the period from 20-25 June, 23-27 July and again from 16-23 September.

Of the seventeen weeks of monsoon season, rainfall was above normal only on four occasions. Cumulative rainfall departure was positive only till end of June. There after, magnitude of negative rainfall departure continuously increased due to subdued rainfall activity during rest of the season. The area weighted rainfall for the season this year was 86% of its LPA value.

Fig. 19(a) shows the all India area weighted rainfall series for the season since 1951. Rainfall for the season (761 mm) was the third lowest since 2001 after the years 2009 (698 mm) and 2002 (737 mm). Fig. 19(b) shows the area weighted rainfall series for the season over the four homogeneous regions since 1951. The rainfall for the season was near normal over east & northeast India (92% of LPA) and below normal over northwest India (83% of LPA), central India (84% of LPA) and south peninsular India (85% of LPA). The rainfall over central India (815 mm) was the second lowest since 2001 after the year 2009 (795 mm). Similarly, the rainfall over the south peninsular India (606 mm) was also the second lowest since 2001 after the year 2002 (506 mm).

Temperature

Mean seasonal maximum and minimum temperature anomaly is shown in Figs. 20(a&b) respectively.

Maximum temperature was above normal over most parts of the country during the season except for parts of northern/northwestern region. It was above normal by about 1 °C over most parts of peninsula and some parts of northern/ northeastern region viz. eastern parts of Jammu & Kashmir, Himachal Pradesh, East Uttar Pradesh and adjoining northern parts of Madhya Pradesh and parts of Bihar, Jharkhand and north Odisha.

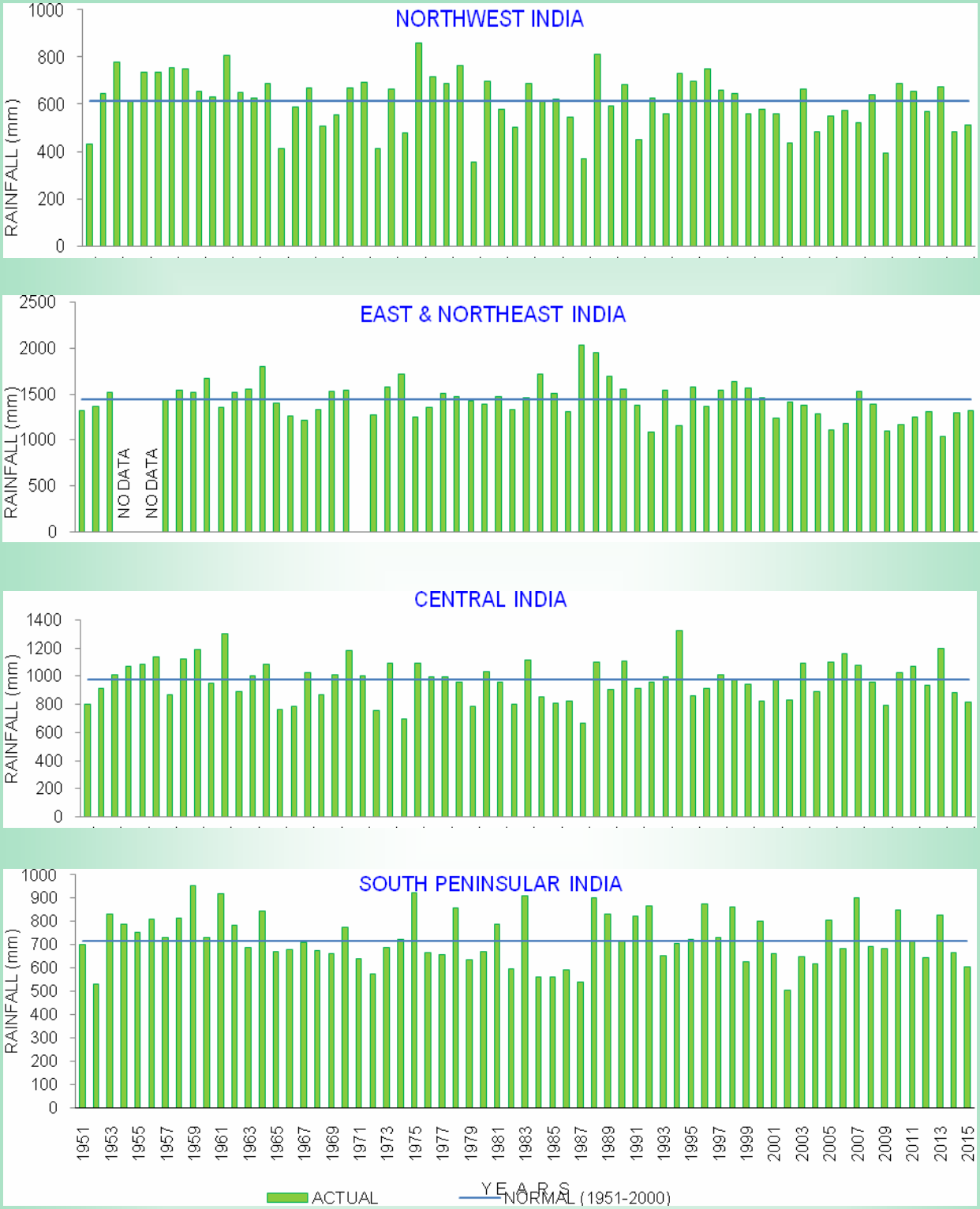
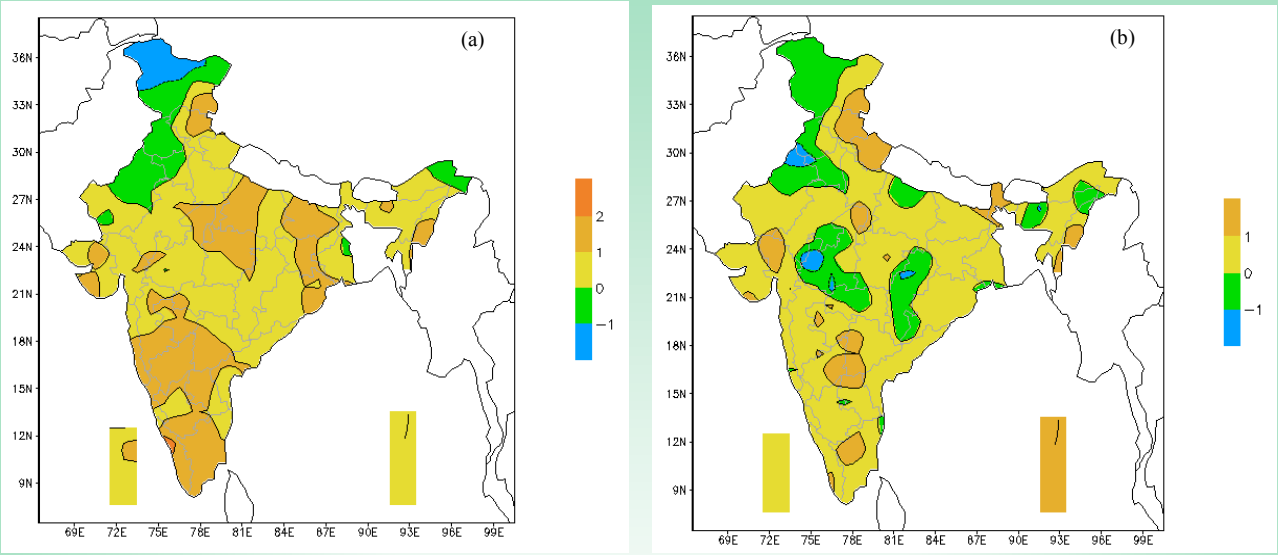


Fig. 19(b). *Time series of area weighted rainfall over the fourhomogeneous regions for the monsoon season (1951-2015)*

Minimum temperature was also in general above normal over most parts of the country except for parts of northern/northwestern and central region. It was above normal by more than 1 °C over parts of Jammu & Kashmir, Himachal Pradesh, Uttarakhand, West Madhya Pradesh, Gujarat region, Telangana and adjoining parts of North Interior Karnataka and



Figs. 20(a&b). *Mean seasonal temperature anomaly (°C) (a) Maximum and (b) Minimum [Based on 1971-2000 NORMAL(S)]*

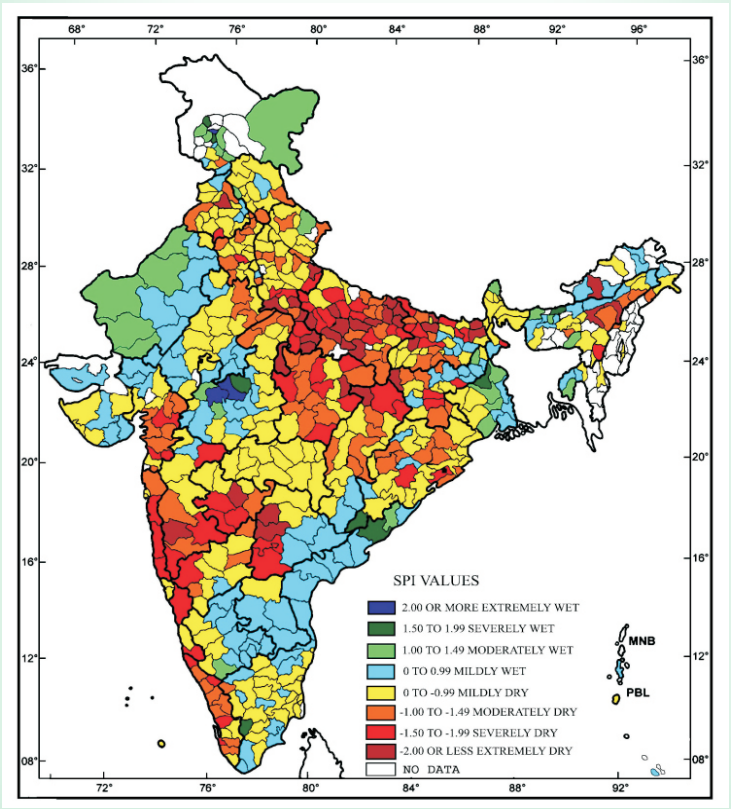


Fig. 21. *Standardized Precipitation Index (SPI)*

Rayalaseema, Sub-Himalayan West Bengal & Sikkim, Nagaland, Manipur, Mizoram & Tripura and Andaman & Nicobar Islands.

The mean temperature (28.7 °C) for the season during this year since 1971 was above normal by about 0.75 °C and thus this season was the fourth warmest since 1971 after the years 2009 (29.04°C), 2014 (28.82°C) and 1987 (28.74 °C).

Maximum temperature was above normal by about 1° C over the central India and by about 1.7°C over the south peninsular India. The maximum temperature (33.0°C) for the country as a whole was above normal by about 0.9 °C

which is the fourth highest since 1971 after the years 2009 (33.30°C), 1987 (33.26°C) and 2014 (33.1°C). Minimum temperature was above normal over the central India by about 0.5°C and over the south Peninsular India by about 1.4 °C. Both maximum (33.1°C) and minimum temperature (24.61°C) over the south peninsular India during this season was the highest since 1971.

Standardized Precipitation Index

Fig. 21 gives the SPI values for the monsoon season 2015. Cumulative SPI values of the season indicate, extremely wet/severely wet conditions over parts of Assam & Meghalaya, Gangetic West Bengal, Odisha, Jammu & Kashmir, West Madhya Pradesh, Coastal Andhra Pradesh and Tamil Nadu, while extremely dry/severely dry conditions were observed over parts of Arunachal Pradesh, Assam & Meghalaya, Sub-Himalayan West Bengal &Sikkim, Odisha, Jharkhand, Bihar, East Uttar Pradesh, West Uttar Pradesh, Haryana, Chandigarh & Delhi, Punjab, East Madhya Pradesh, Gujarat Region, Konkan & Goa, Madhya Maharashtra, Marathwada, Chhattisgarh, Telangana, Coastal Karnataka, North Interior Karnataka and Kerala.

Pressure & wind

The pressure anomaly was positive throughout the country. Over peninsula and central parts of the country it was of the order of 1 hPa and over northern/northeastern parts of the country it exceeded 1.5 hPa.

At 850 hPa level, anomalous ridge was observed over the south peninsula. At 500 hPa level, an anomalous cyclonic circulation was observed over north Arabian Sea and adjoining Pakistan and extreme northwest region of India. This anomalous circulation was more marked at 250 hPa level with westward shift. At 250 hPa level, anomalous westerlies (indicating weaker than the normal Tropical Easterly Jet) prevailed over the peninsular India.

Outgoing Longwave Radiation (OLR)

OLR anomaly (W/m^2) over the Indian region and neighbourhood was positive over most parts of country (except for parts of extreme northeastern region) and adjoining seas. Over most parts of the country, positive OLR anomaly exceeding 10 W/m^2 was observed and over parts of south peninsula it exceeded 20 W/m^2.

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

Post monsoon 2015 was the warmest post monsoon season since 1901.Northeast monsoon commenced over the south peninsular India on 28th Oct. with a delay of 8 days from its normal date despite the withdrawal of southwest monsoon from the country on 19th October.

Northeast monsoon activity

Rainfall activity over the core region of south peninsula (comprising of 5 subdivisions viz. Coastal Andhra Pradesh, Rayalaseema, Tamil Nadu & Puducherry, South Interior Karnataka and Kerala) during the season as a whole was substantially above normal [132% of Long Period Average (LPA)]. It was subdued during October (68% of LPA) and substantially above normal during November and December (227% and 152% of LPA respectively). November month was one of the rainiest month for the northeast monsoon rainfall region since 1901.

Out of the above five subdivisions, Tamil Nadu & Puducherry, Rayalaseema and Kerala received excess rainfall while Coastal Andhra Pradesh and South Interior Karnataka received normal rainfall. Tamil Nadu & Puducherry and Rayalaseema received more than one and half times of their respective normal rainfall.

Rainfall features

Rainfall activity over the country as a whole was subdued during the season. It was subdued during October (53% of LPA), above normal

during November (134% of LPA) and near normal during December (90% of LPA). Except for some sub-divisions of south Peninsula, Jammu & Kashmir and the Islands, which received excess/normal rainfall, most parts of the country received deficient/scanty rainfall.

During the season, out of 36 meteorological subdivisions, 5 sub-divisions received excess rainfall, 5 received normal rainfall, 8 received deficient rainfall and remaining 18 sub-divisions received scanty rainfall (Fig. 22).

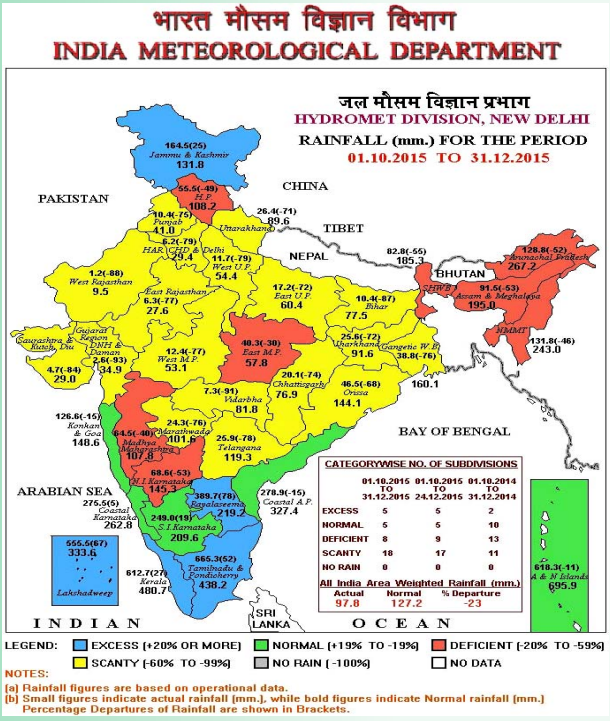
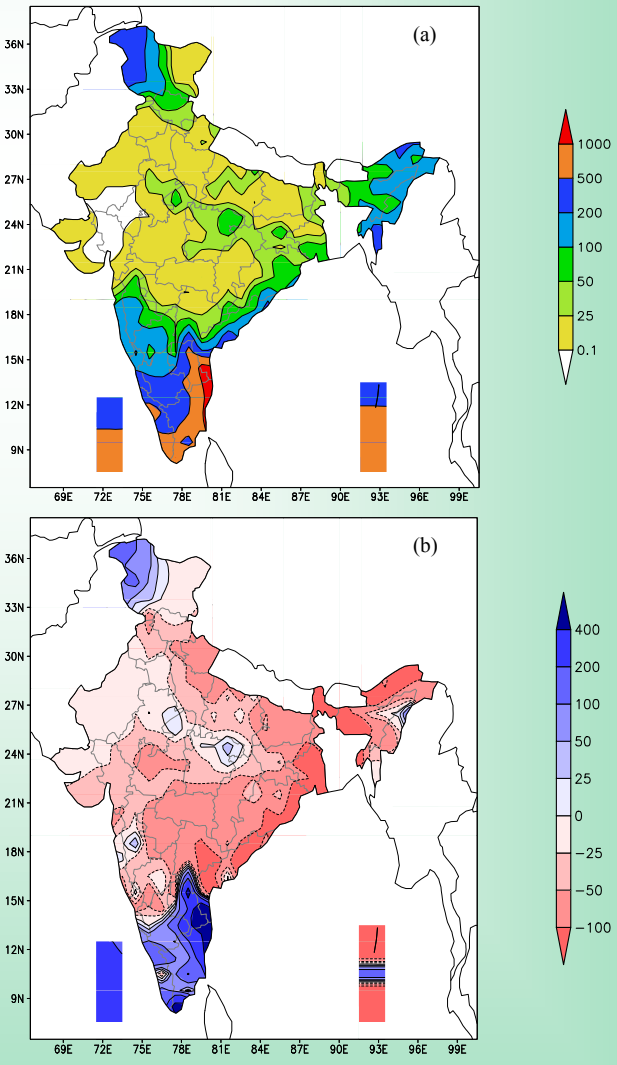


Fig. 22. *Sub-division wise rainfall percentage departures for the post monsoon season 2015*

Figs. 23(a&b) show the spatial pattern of rainfall (mm) received during the season and its anomaly respectively. Parts of south peninsula, Jammu & Kashmir, extreme northeastern region of the country and the Islands in general received more than 100 mm of rainfall. Parts of Kerala, Tamil Nadu, Rayalaseema, south Coastal Andhra Pradesh and the Islands received more than 500 mm of rainfall. Rainfall over parts of north coastal Tamil Nadu and adjoining Rayalaseema & south coastal Andhra Pradesh exceeded 1000 mm.

Rainfall anomaly was negative over most parts of the country except for parts of extreme south peninsula, the Islands, parts of Jammu & Kashmir and some isolated places. Positive rainfall anomaly over parts of south peninsula viz. Tamil Nadu, Rayalaseema, south Coastal Andhra Pradesh and Kerala, Lakshadweep Islands and parts of Jammu & Kashmir was more than 100 mm. Over parts of north coastal Tamil Nadu and adjoining Rayalaseema and south coastal Andhra Pradesh it exceeded 400 mm. Magnitude of negative rainfall anomaly over parts of northeast peninsula and eastern/ northeastern parts of the country was more than 50 mm, while over parts of north coastal Andhra Pradesh, Telangana, Coastal Odisha, West Bengal and parts of extreme northeastern region it exceeded 100 mm.



Figs. 23(a&b). *(a) Seasonal rainfall (mm) and (b) Seasonal rainfall anomaly (mm) [Based on 1951-2000 NORMAL(S)]*

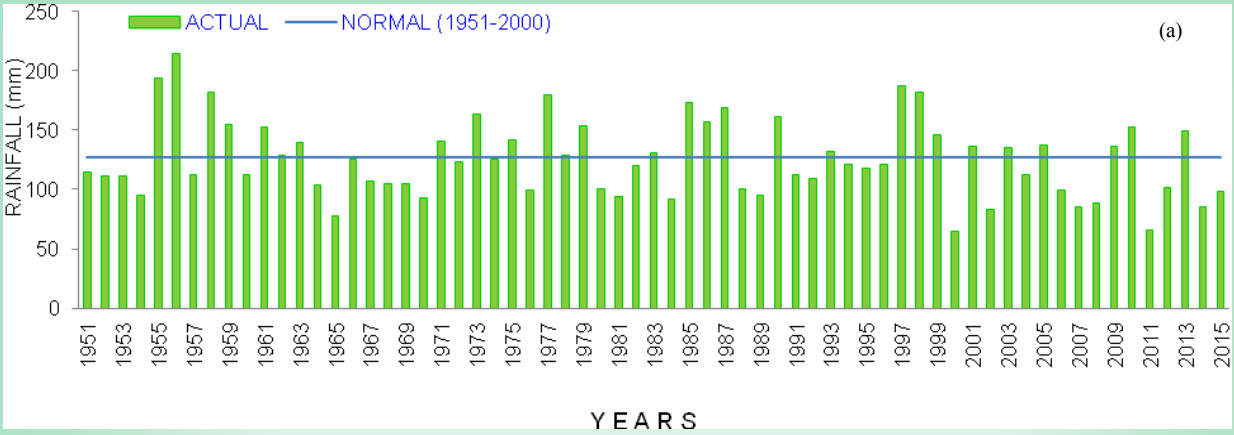


Fig. 24(a). *Time series of area weighted rainfall over the country as a whole (1951-2014)*

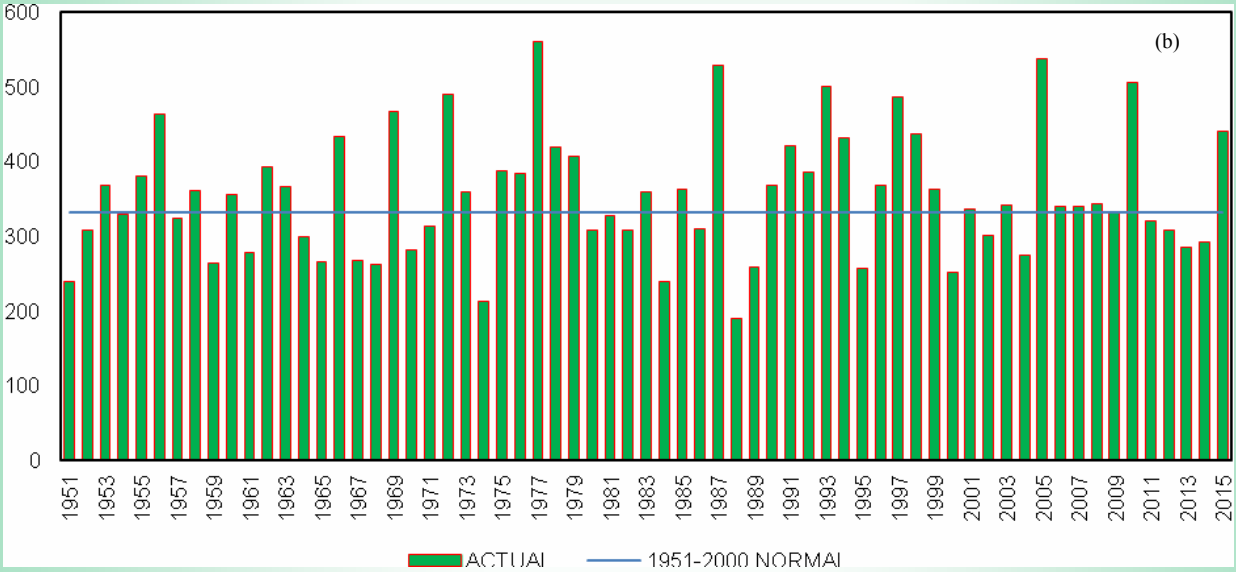


Fig. 24(b). *Time series of area weighted rainfall over the south peninsula (1951 - 2014)*

Fig. 24(a) shows the all India area weighted rainfall series for the season since 1951. Similarly, Fig. 24(b) shows the area weighted rainfall series for the season since 1951 over the northeast monsoon region of south peninsula. Rainfall over the south peninsula this year (439.7 mm) was the third highest since 2001 after the years 2005 (533.9 mm) and 2010 (504.8 mm).

Fig. 25 shows the area weighted rainfall series for the season over the four homogeneous regions since 1951. The rainfall for the season was above normal over the south peninsular India (116% of LPA) and below normal over the other three homogeneous regions. It was 74% of LPA over the northwest India and only 42% and 37% of LPA respectively over the east & northeast and central India.

Standardized Precipitation Index

Fig. 26 gives the SPI values for the post monsoon season 2015. Cumulative SPI values of the past three months (i.e. the Post-Monsoon season) indicate, extremely wet/ severely wet conditions over parts of Coastal Andhra Pradesh, Rayalaseema and Tamil Nadu & Puducherry while extremely dry/severely dry conditions were observed over parts of Arunachal Pradesh, Assam & Meghalaya, Nagaland – Manipur – Mizoram – Tripura,

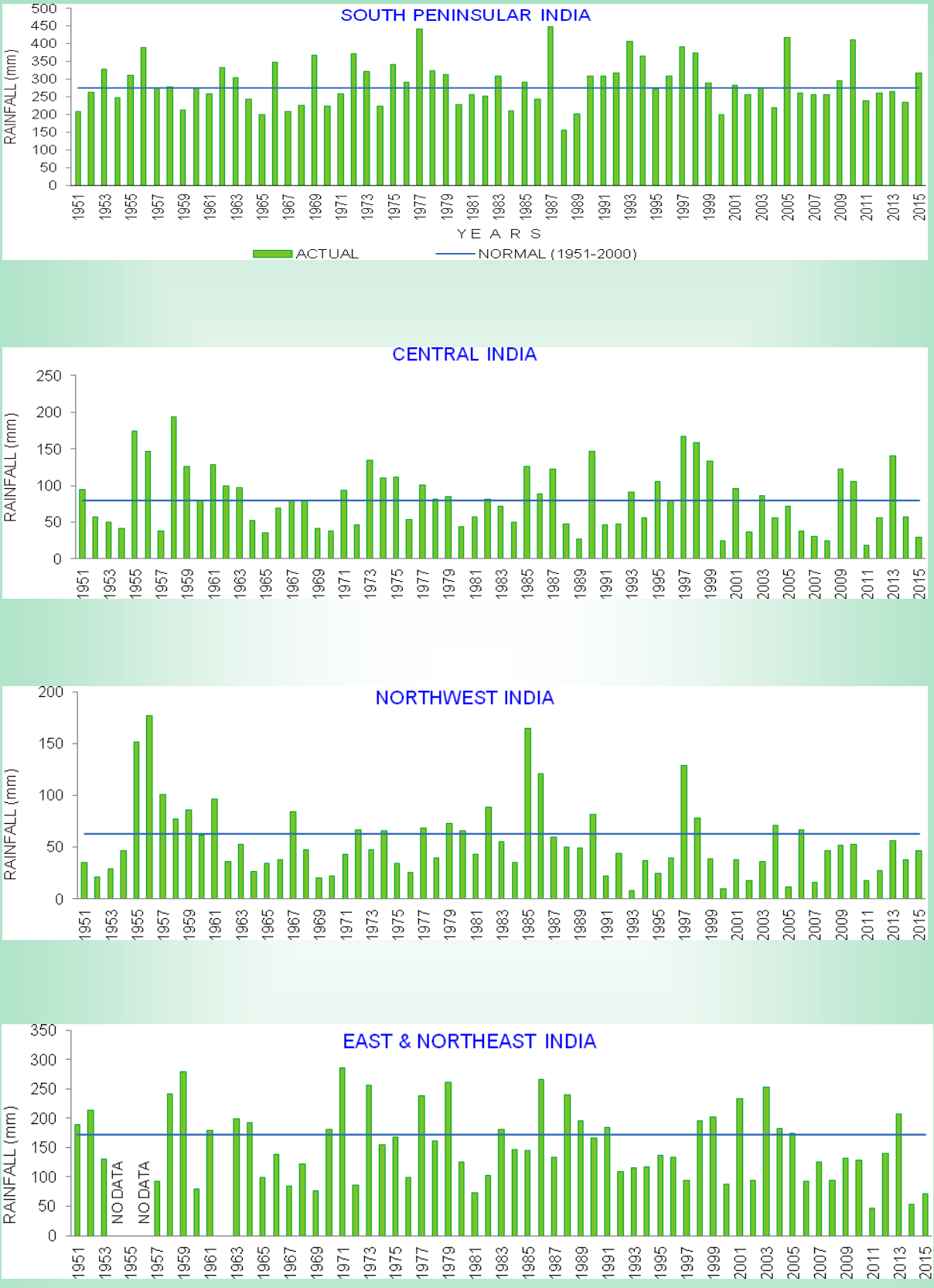


Fig. 25. *Time series of area weighted seasonal rainfall over the four homogeneous regions for the period, 1951-2015*

Gangetic West Bengal, Odisha, Jharkhand, Bihar, Vidarbha, Chhattisgarh and Telangana.

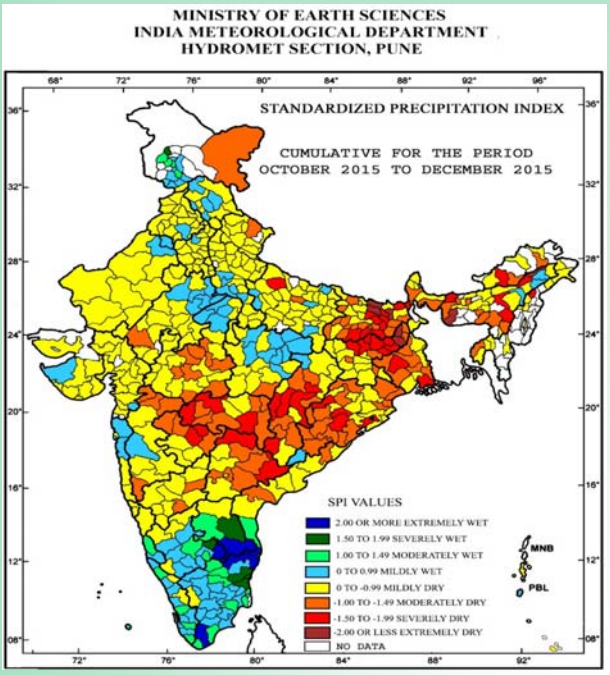


Fig. 26. *SPI for Post- monsoon season 2015*

Outgoing Longwave Radiation (OLR)

OLR anomaly (W/m^2) over the Indian region and neighbourhood is shown in Fig. 27. Positive OLR anomaly was observed over most parts of the country and adjoining Bay of Bengal. Over the Arabian Sea and equatorial Indian Ocean region, negative OLR anomaly with magnitude exceeding 10 W/m^2 was observed.

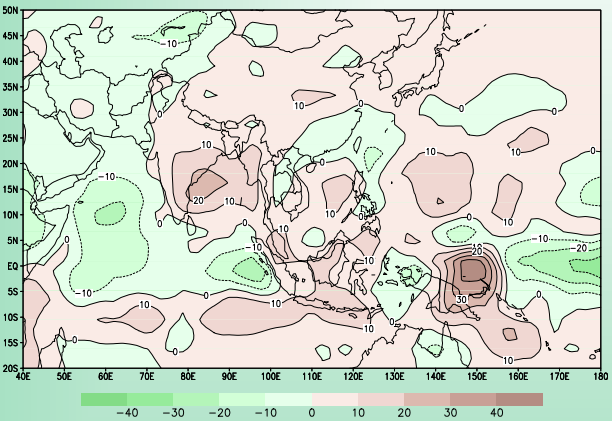
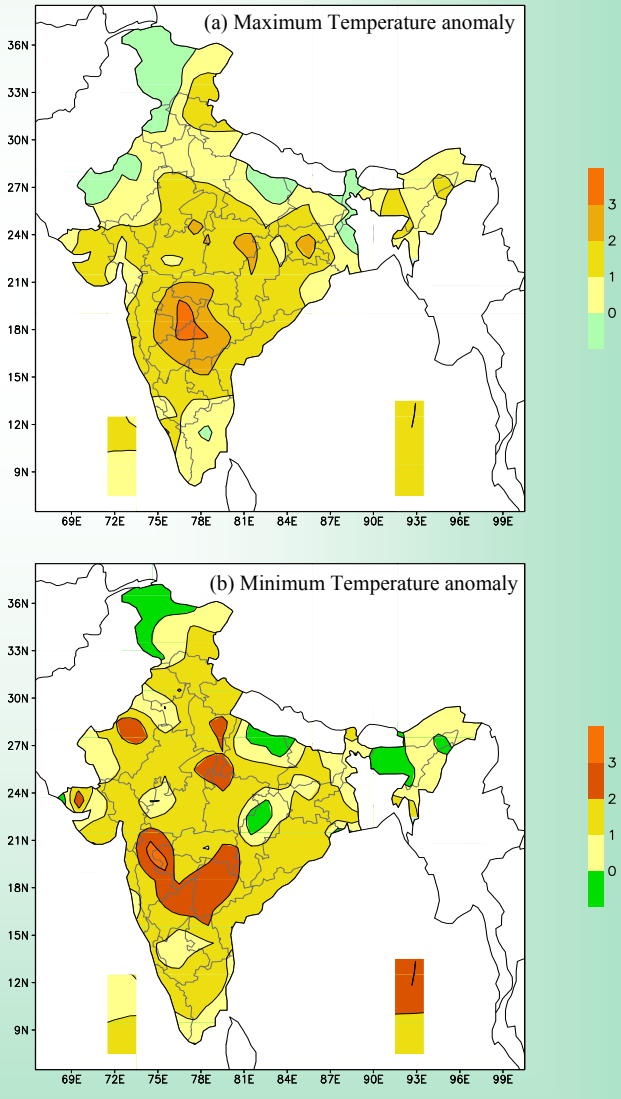


Fig. 27. *OLR anomaly (W/m^2) for the post-monsoon season 2015 (Source : cdc / noaa, usa) (based on 1981 – 2010 climatology)*

Temperature

Mean seasonal maximum and minimum temperature anomaly is shown in Figs. 28(a&b) respectively. Both maximum and minimum temperature was above normal over most parts of the country by about 1 to 2°C. Over parts of central peninsula, viz., Marathwada, Vidarbha, Telangana, Rayalaseema, north Interior Karnataka and south Madhya Maharashtra, both maximum and minimum temperature was above normal by 2 to 3°C. However, at some isolated places over the northern/northeastern region, both maximum and minimum temperature was slightly below normal.



Figs. 28(a&b). *Mean seasonal temperature anomaly (°C) (a) Maximum and (b) Minimum [Based on 1971-2000 NORMAL(S)]*

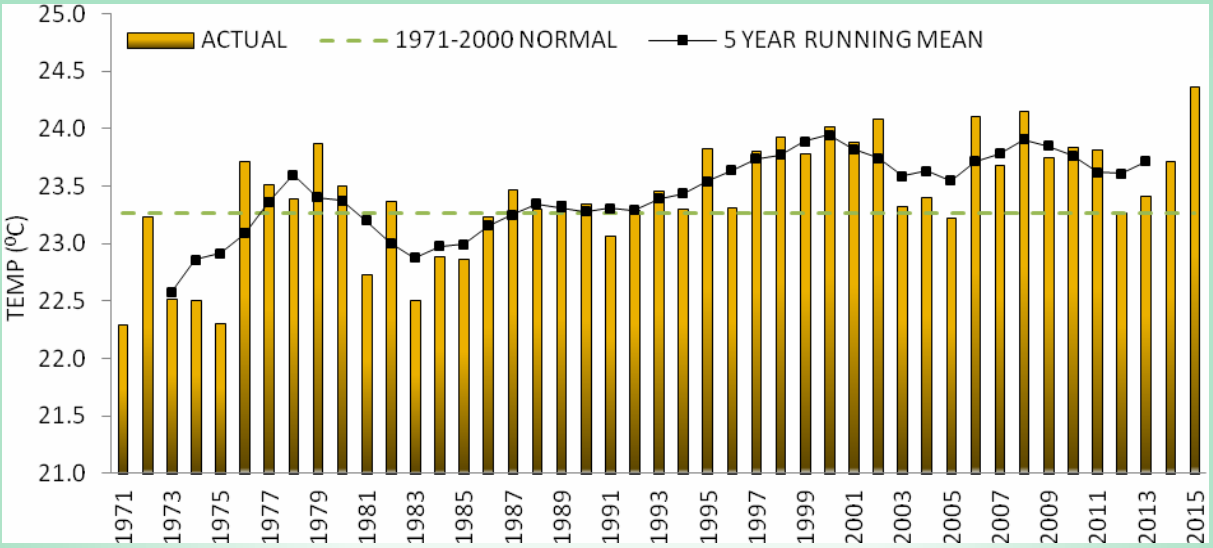
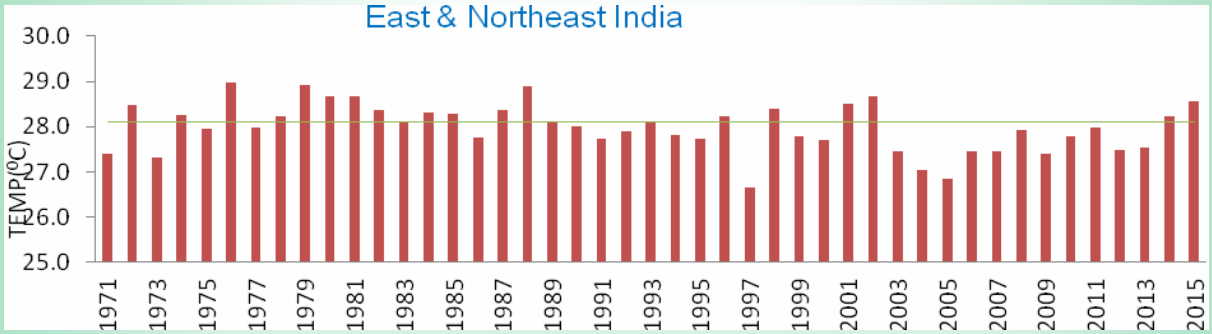


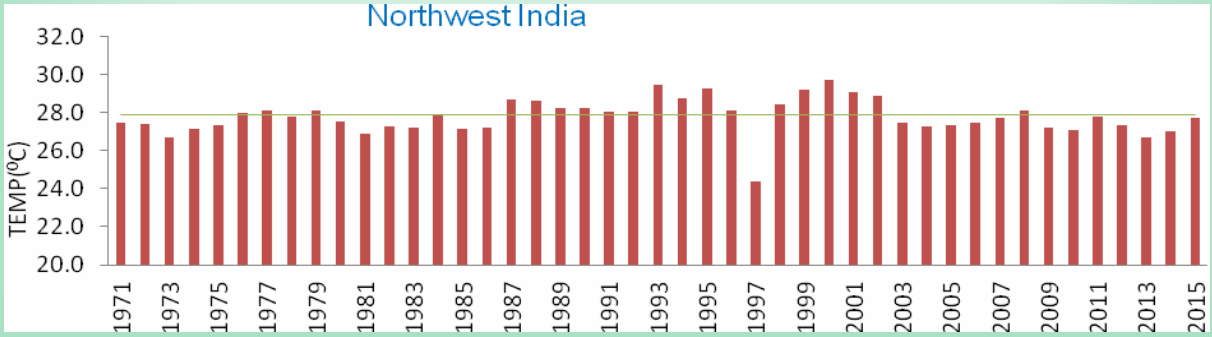
Fig. 29. *Time series of mean temperature averaged over India (vertical bars) & five year running mean (continuous line) for the monsoon season (1971-2015)*

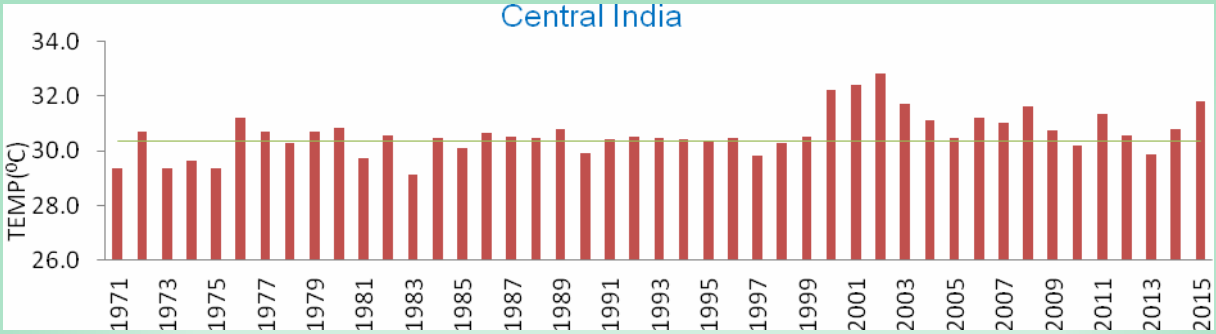
Fig. 29 shows the mean temperature for the country as a whole for the season since 1971. Five year moving average values are also shown. The mean temperature (24.4° C) for the season this year was above normal by about 1.1° C which is the highest since 1971.

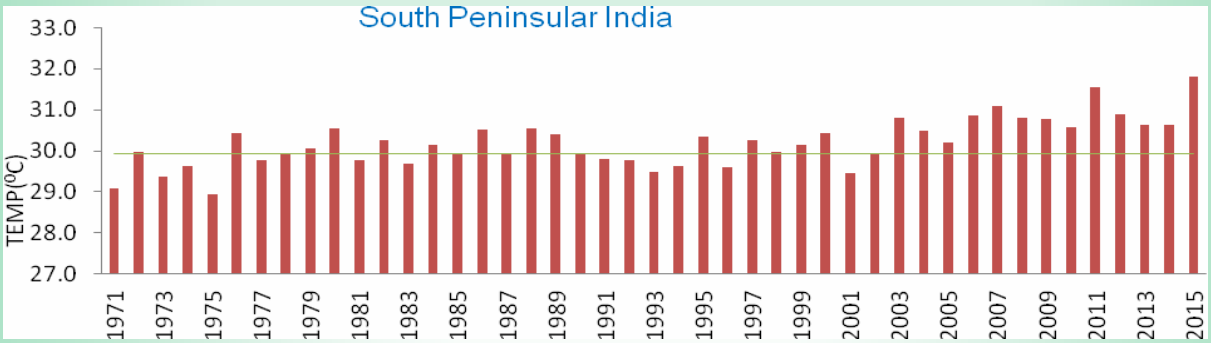
Figs. 30(a&b) show the maximum and minimum temperature series respectively for the country as a whole and the four homogeneous regions during the season since 1971. Both maximum and minimum temperature was above normal over the central India by about 1.5 °C and over the peninsular India by about 2 °C.

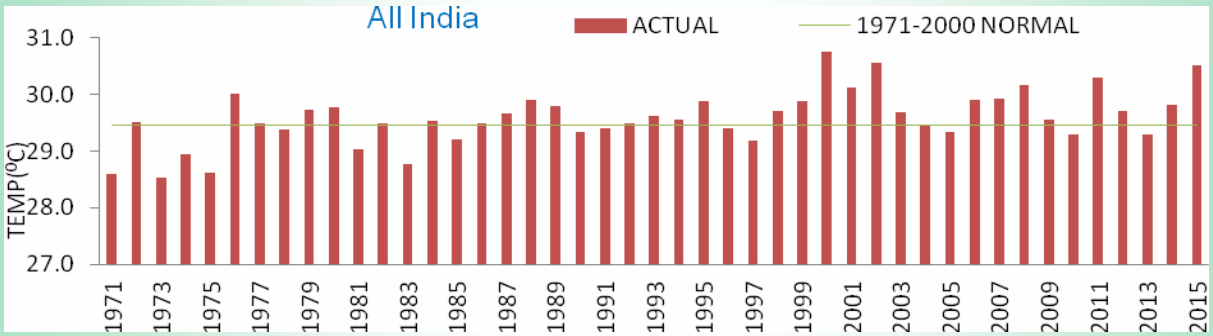
(a)



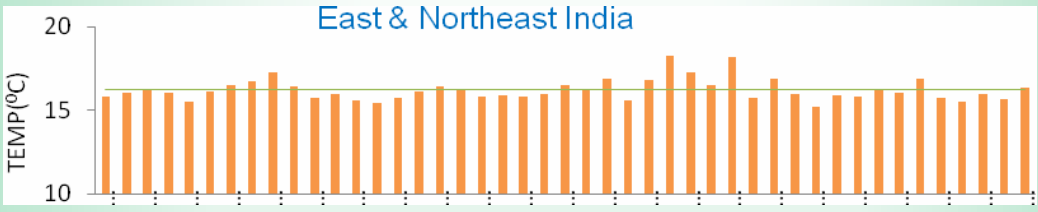


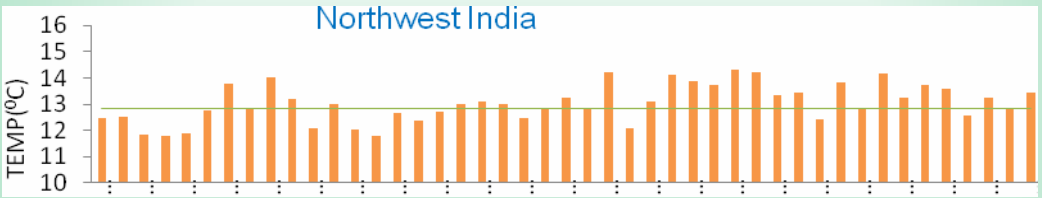

Central India
TEMP(°C)
34.0
32.0
30.0
28.0
26.0
1971 1973 1975 1977 1979 1981 1983 1985 1987 1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011 2013 2015

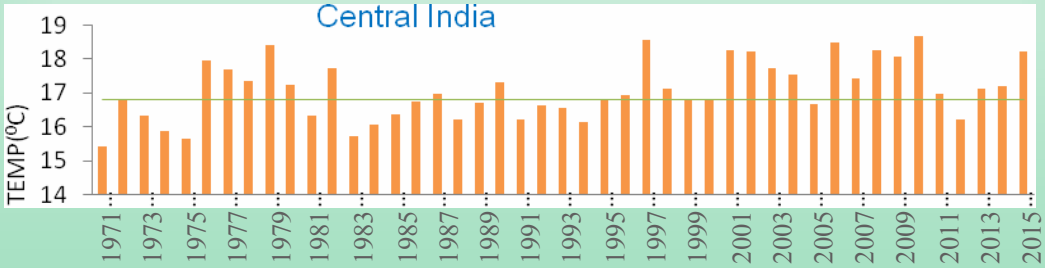

South Peninsular India
TEMP(°C)
33.0
32.0
31.0
30.0
29.0
28.0
27.0
1971 1973 1975 1977 1979 1981 1983 1985 1987 1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011 2013 2015


All India
ACTUAL
1971-2000 NORMAL
TEMP(°C)
31.0
30.0
29.0
28.0
27.0
1971 1973 1975 1977 1979 1981 1983 1985 1987 1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011 2013 2015

(b)


East & Northeast India
TEMP(°C)
20
15
10


Northwest India
TEMP(°C)
16
15
14
13
12
11
10


Central India
TEMP(°C)
19
18
17
16
15
14
1971 1973 1975 1977 1979 1981 1983 1985 1987 1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011 2013 2015

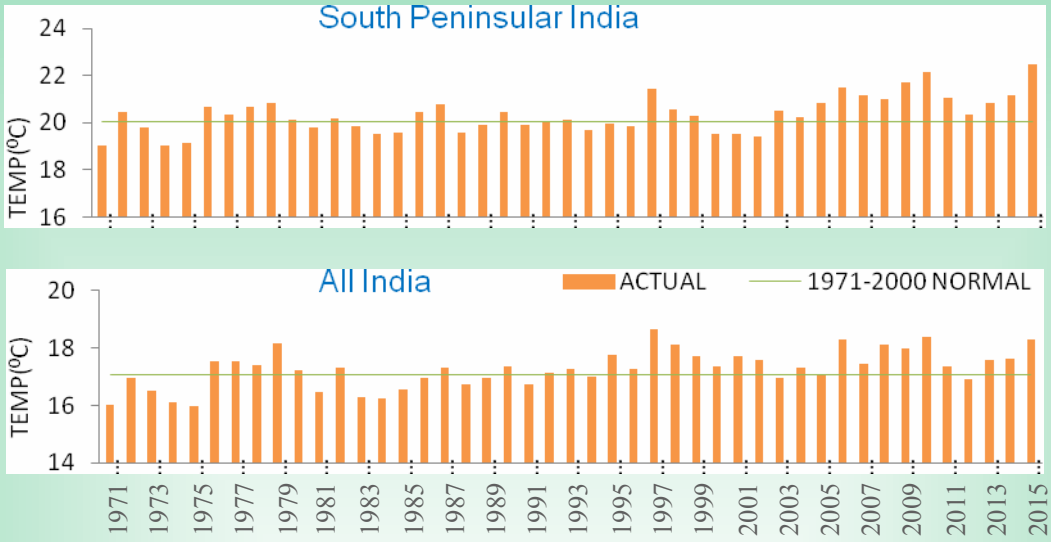
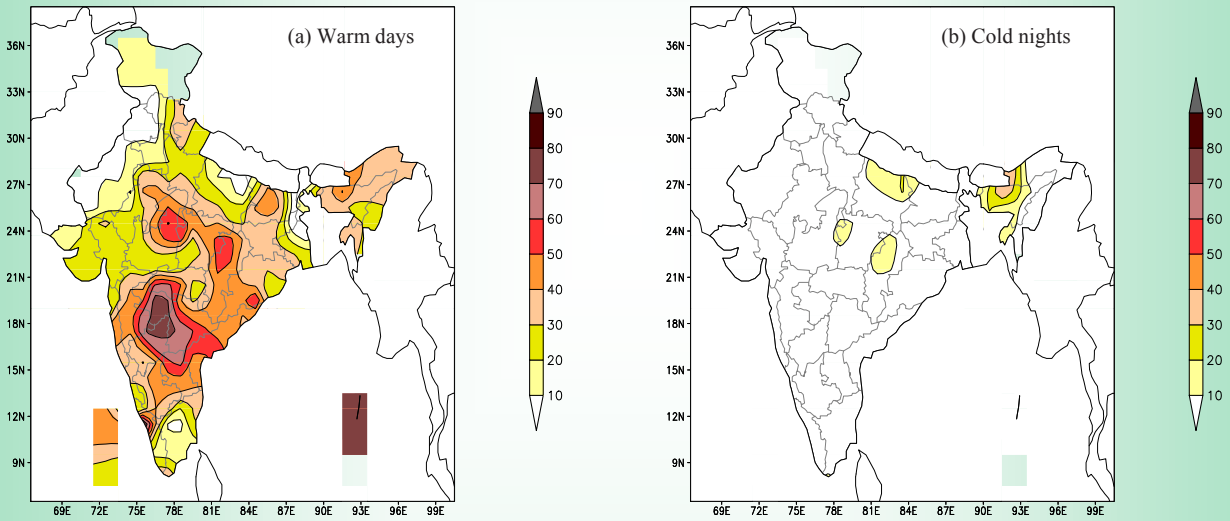


Fig. 30. *Time series of temperature for the country as a whole and for four homogeneous regions (1971-2015) (a) Maximum (b) Minimum*



Figs. 31(a&b). *Percentage of days when (a) maximum temperature more than 90th Percentile (b) minimum temperature less than 10th Percentile*

Percentage of Warm days/Cold nights

Figs. 31(a&b) show the percentage of days when maximum (minimum) temperature was more (less) than 90th (10th) percentile.

Over some parts of central peninsula viz. Marathwada, Vidarbha, Telangana, Rayalaseema, north Interior Karnataka and south Madhya Maharashtra, parts of north coastal Kerala and Andaman & Nicobar Islands, the maximum temperature was greater than 90th percentile for more than 60% of the days of the season, while, over parts of coastal Odisha, north Chattisgarh and north Madhya Pradesh, it exceeded 50%. However, for minimum temperatures, no significant distribution was observed.

Low Pressure systems

Post-monsoon season was cyclogenically active with successive formations of two

Extremely Severe Cyclonic Storms (ESCS) (CHAPALA and MEGH) over Arabian Sea (one each in October and November) and two Deep Depressions each over the Arabian Sea in October and the Bay of Bengal in November.

The Deep Depression which formed over east central Arabian Sea on 9th November dissipated over the Sea itself on 12th due to intrusion of dry air from northwest and western parts of Arabian Sea.

The first cyclonic storm of the season 'CHAPALA' which formed over the southeast Arabian Sea on 29th October, moved away westwards away from the Indian region. It intensified into an extremely severe cyclonic storm on 30th and crossed the Yemen coast on 3rd November.

The second cyclonic storm 'MEGH' of the season which formed over the central Arabian Sea on 5th November, moved away westwards, away from the Indian region. It intensified into an extremely severe cyclonic storm on 8th and crossed the Yemen coast after recurving on 10th November.

The Deep Depression which formed over southwest Bay of Bengal was first seen as a low pressure area over the southwest and adjoining southeast Bay of Bengal and neighbourhood on 7th November. It concentrated into a depression near Lat. 10.7°N / Long. 83.7°E at 0300 UTC of 8th. Moving west-northwestwards it intensified into deep depression a near Lat. 11.5°N / Long. 80.7°E, 0000 UTC of 9th. It moved west-northwestwards and then northwards and lay over southwest Bay of Bengal centred near Lat. 12.1°N / Long. 80.0°E 1200 UTC of the same day. It then moved westwards and crossed the Tamil Nadu coast and weakened into depression a over north Tamil Nadu near Lat. 12.4°N / Long. 79.3°E, 0300 UTC of 10th. Moving westwards, it weakened into a well marked low pressure and then into a low pressure area over north Tamil Nadu and adjoining south interior Karnataka by the evening of 10th & became less marked on 11th. This Deep Depression caused scattered to widespread rainfall activity over south peninsula. Fig. 32 shows the tracks of these systems.

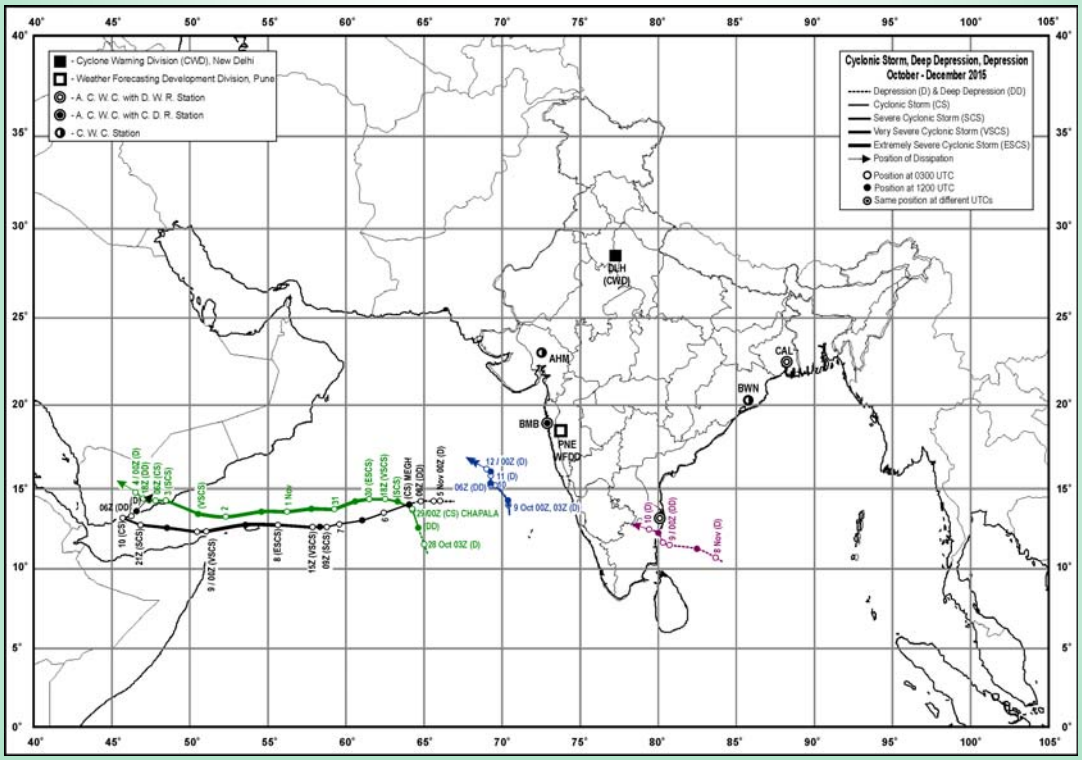


Fig. 32. *Tracks of intense low pressure systems formed during the post-monsoon season 2015*

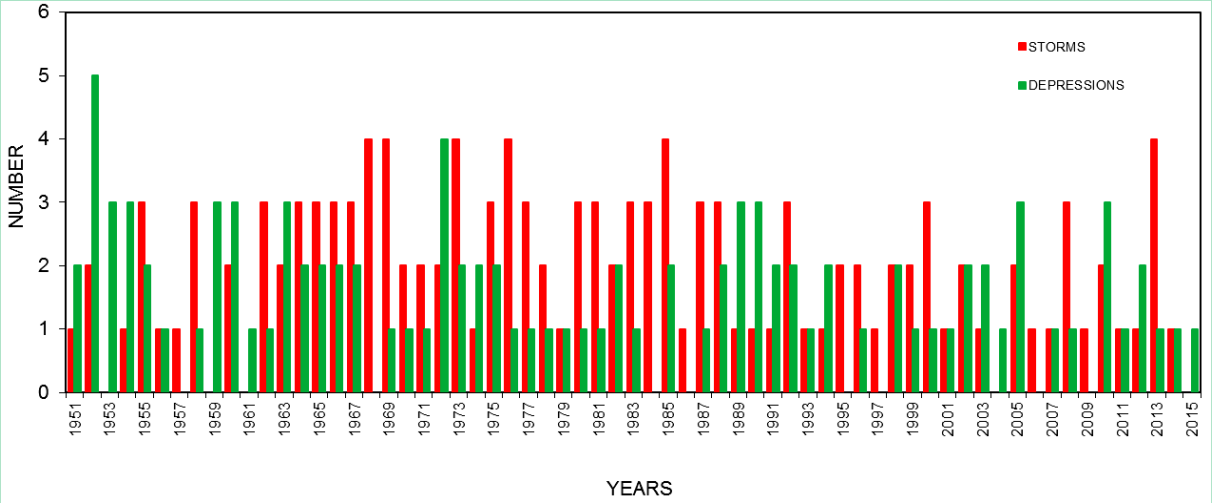


Fig. 33. *Frequency of depressions / cyclonic storms formed over the Bay of Bengal during the post-monsoon season (1951 - 2014)*

Apart from these systems, 6 low pressure areas (4 over Bay of Bengal and 2 over Arabian Sea) formed during the season. The first low pressure area formed over the north Bay of Bengal & neighbourhood on 7th October. It became well marked over the same region on 8th October. It lay over Myanmar & adjoining areas of Mizoram and Tripura on 9th October. It moved away eastwards and became less marked on 10th October. The second low pressure area formed over the southwest Bay of Bengal off Sri Lanka coast on 25th October. It persisted there on 26th - 27th October and over southwest Bay of Bengal and adjoining Sri Lanka on 28th October and became less marked on 29th October. Three low pressure areas formed during the November month. Of which, two formed over the south Bay of Bengal (during 13-18 and 19-24 November) and one over the Arabian sea (during 12-14 November). The two low pressure areas over the Bay of Bengal caused active to vigorous northeast monsoon over the east coast of peninsular India. The remaining low pressure area (3rd -6th December) formed over southwest Bay of Bengal and adjoining Sri-Lanka off Tamil Nadu coast.

Except for one well marked low formed over north Bay of Bengal, all others formed over southern region of Indian Sea and generated good amount of rainfall over south peninsular India.

Fig. 33 shows the number of Depressions formed over Bay of Bengal during the post-monsoon season (1951-2015).

CHAPTER 3

LONG RANGE FORECASTS

Southwest monsoon (June-September)

1. Background : The onset of southwest monsoon over Kerala signals the arrival of monsoon over the Indian subcontinent and represents beginning of rainy season over the region. From 2005 onwards ESSO-India Meteorological Department (IMD) has been issuing operational forecasts for the date of monsoon onset over Kerala using an indigenously developed statistical model, which uses the following six predictors: (i) Minimum Temperature over North-west India, (ii) Pre-monsoon rainfall peak over south Peninsula, (iii) Outgoing Long wave Radiation (OLR) over south China Sea, (iv) Lower tropospheric zonal wind over southeast Indian ocean, (v) upper tropospheric zonal wind over the east equatorial Indian Ocean, and (vi) Outgoing Long wave Radiation (OLR) over south-west Pacific region. The operational forecasts for the event issued during all the last nine years (2005 to 2014) were correct as seen in the table given below :

Year	Actual Onset Date	Forecast Onset Date
2005	7th June	10th June
2006	26th May	30th May
2007	28th May	24th May
2008	31st May	29th May
2009	23rd May	26th May
2010	31st May	30th May
2011	29th May	31st May
2012	5th June	1st June
2013	1st June	3rd June
2014	6th June	5th June

2. SW Monsoon 2015

Onset and Advance of monsoon

Advance of southwest monsoon over the Andaman Sea normally takes place around 20th May with a standard deviation of about one week. During the last few days, prior to onset of monsoon enhanced convection and increased rainfall activity was observed over the Bay of Bengal and the Andaman Sea. The cross equatorial flow was likely to strengthen and deepen over the area. As such, conditions were becoming favourable for advance of southwest monsoon over the Andaman Sea and adjoining sea areas during the next 3- 4 days. Past data suggested absence of any one to one association of the date of monsoon advance over Andaman Sea with the date of monsoon onset over Kerala or that with the seasonal monsoon rainfall over the country.

Based on an indigenously developed statistical model, it was predicted on 15th May, 2015 about the onset of monsoon over Kerala on 30th May with a model error of ±4 days. However, the actual monsoon onset over Kerala took place on 5th June, 2 day later than the upper forecast limit. It advanced into entire country by 26th June against normal date of 15th July

Long Range Forecast of SW Monsoon 2015

2.1. First Stage

This year, the long range forecast for the 2015 southwest monsoon rainfall was issued in two stages. The first stage forecast was issued in April and the second stage forecast was issued in June. The ESSO-IMD's Ensemble Statistical Forecasting system for the April forecast uses the following 5 predictors.

1. Background : ESSO-India Meteorological Department (IMD) issues various monthly and seasonal operational forecasts for rainfall during the southwest monsoon season. Operational models are critically reviewed regularly and further improved through inhouse research activities. Operational forecasts for the southwest monsoon season (June - September) rainfall are issued in two stages. The first stage

forecast is issued in April and the second stage forecast is issued in June. The ESSO-IMD's Ensemble Statistical Forecasting system for the April forecast uses the following 5 predictors.

S. No	Predictor	Period
1	The Sea Surface Temperature (SST) Gradient between North Atlantic and North Pacific	December + January
2	Equatorial South Indian Ocean SST	February
3	East Asia Mean Sea Level Pressure	February + March
4	Northwest Europe Land Surface Air Temperature	January
5	Equatorial Pacific Warm Water Volume	February + March

2. Sea Surface Temperature (SST) Conditions in the equatorial Pacific & Indian Oceans

Positive SST anomalies had been prevailing over the western and the central Pacific Ocean for the last about six months from the date of issue of forecast. However, the SSTs over eastern Pacific after remaining near to below normal between late December 2014 and mid-March 2015 became above normal. Thus currently, weak El Nino conditions were prevailing over the Pacific. The latest forecast from the IMD-IITM coupled model forecast indicated persistence of El Nino conditions during the southwest monsoon season. During April, 2015, slight negative Indian Ocean Dipole (IOD) conditions were prevailing over Indian Ocean. The latest forecast from the coupled model indicated persistence of negative IOD conditions during the monsoon season. As the extreme sea surface temperature conditions over Pacific and Indian Oceans particularly ENSO conditions over Pacific (El Nino or La Nina) are known to have strong influence on the Indian summer monsoon, IMD was carefully monitoring the sea surface conditions over Pacific and Indian oceans.

3. Experimental Coupled Dynamical Model Forecasting System - ESSO Monsoon Mission Model

The ESSO-Indian Institute of Tropical Meteorology (IITM), Pune is coordinating and working along with different climate research centers from India and abroad on the development of a coupled model for the forecasting of Indian summer monsoon rainfall under ESSO's Monsoon Mission project. The latest high resolution research version of the Coupled Forecasting System (CFS) originally developed by the National Centers for Environmental Prediction (NCEP), USA has been implemented at the ESSO-IITM. This model was used to generate the experimental update forecast for the 2015 southwest monsoon season rainfall using the February initial conditions. The model has moderate skill.

The experimental forecast based on the coupled dynamical model forecasting system suggested 91 ± 5% of long period model average (LPMA) monsoon rainfall during the 2015 monsoon season (June to September) averaged over the country as a whole.

4. Summary of the ESSO-IMD's Operational long range Forecast for 2015

Southwest monsoon rainfall (a) Quantitatively, the monsoon seasonal rainfall is likely to be 93% of the Long Period Average (LPA) with a model error of ± 5%. The LPA of the season rainfall over the country as a whole for the period 1951-2000 is 89 cm.

The 5 category probability forecasts for the Seasonal (June to September) rainfall over the country as a whole is given below:

Category	Rainfall Range (% of LPA)	Forecast Probability (%)	Climatological Probability (%)
Deficient	< 90	**33**	16
Below Normal	90 - 96	**35**	17
Normal	96 -104	**28**	33
Above Normal	104 -110	**3**	16
Excess	> 110	**1**	17

ESSO-IMD issued the update forecasts in June, 2015 as a part of the second stage forecast. Along with the update forecast, separate forecasts for the monthly (July and August) rainfall over the country as a whole and seasonal (June-September) rainfall over the four geographical regions of India was also issued.

2.2. Second Stage

Long Range Forecast Update for 2015 Southwest Monsoon Rainfall

1. Background ESSO-India Meteorological Department (IMD) issues updated forecast in June for the season rainfall over the country as well as forecasts for the monthly rainfall for July & August over the country and forecast for the season rainfall for the 4 broad geographical regions of India (NW India, NE India, Central India and South Peninsula) are issued. The update forecast for the southwest monsoon season (June-September) rainfall over the country as a whole is issued using a 6-parameter Ensemble Forecasting System. The 6 predictors used are : NE Pacific to NW Atlantic SST Anomaly Gradient (December + January), Southeast equatorial Indian Ocean Sea Surface Temperature (February), East Asia Mean Sea Level Pressure (February + March), Central Pacific (Nino 3.4) Sea Surface Temperature (March to May + tendency between March to May & December to February), North Atlantic Mean Sea Level Pressure (May) and Northcentral Pacific 850 hPa zonal wind gradient (May).

2. Sea Surface Temperature Conditions in the Pacific & Indian Oceans

Since April, 2015 weak El Nino conditions were established over equatorial Pacific Ocean. Atmospheric conditions like weakened trade winds, negative Southern Oscillation Index (SOI) values etc. generally associated with El Nino conditions were also observed. Deficient rainfall forecasted for the country as a whole for the 2015 southwest monsoon season (June to September). Forecast from IMD-IITM coupled model indicated further strengthening of El Nino and reach to moderate strength conditions during the monsoon season. There was about 90% probability of El Nino conditions to continue during the southwest monsoon season. Over Indian Ocean, slight basin wide warming along with neutral Indian Ocean Dipole (IOD) conditions was prevailing. The latest forecast from ESSO-IMD-IITM coupled model indicated about 50% probability of neutral IOD conditions to continue during the monsoon season.

3. Monsoon Mission Experimental Coupled Dynamical Model Forecast

The experimental forecast based on the ESSO-IMD-IITM coupled dynamical model suggested 86% ± 5% of long period model average (LPMA) rainfall during the 2015 monsoon season (June to September) averaged over the country as a whole. The experimental five category probability forecasts for the 2015 monsoon season rainfall over the country as a whole using the experimental dynamical prediction system were 61% (deficient), 24% (below normal), 13% (normal), 2% (above normal) and 0% (excess).

4. The second Stage Forecasts for 2015 Southwest Monsoon Rainfall

(i) Seasonal (June-September) rainfall over the country as a whole was forecasted as 88% of the long period average (LPA) with a model error of ±4%. The LPA rainfall over the country as a whole for the period 1951-2000 is 89 cm. The 5 category probability forecasts for the Season (June to September) rainfall over the country as a whole is given below.

Category	Rainfall Range (% of LPA)	Forecast Probability (%)	Climatological Probability (%)
Deficient	< 90	**66**	16
Below Normal	90 - 96	**27**	17
Normal	96 -104	**7**	33
Above Normal	104 -110	**0**	16
Excess	> 110	**0**	17

(ii) Season (June-September) Rainfall over Broad Geographical Regions.

The forecasts for season rainfall were 85% of LPA over north-west India, 90% of LPA over central India, 92% of LPA over south peninsula, and 90% of LPA over north-east India with a model error of ± 8 %.

(iii) Monthly (July & August) Rainfall over the country as a whole.

The rainfall over the country as a whole was forecasted 92% of its LPA during July and 90% of LPA during August both with a model error of ± 9%.

3. Performance of Monsoon 2015

The seasonal rainfall over the country as a whole and that over four broad geographical regions were within the limits of the forecasts issued in June and accurate. Similarly, the forecasts for the July as well as that for the rainfall during the second half of the monsoon season over the country as a whole were also accurate. However, the August forecast was an overestimate to the realized rainfall. The observed large seasonal rainfall deficiency over the country as whole (-14 % of LPA) was distributed among all the four broad geographical regions with highest rainfall deficiency (-17% of LPA) over northwest India and lowest deficiency over northeast India (-8% of LPA). Within the season, except in June, the rainfalls during all the other 3 months were below normal.

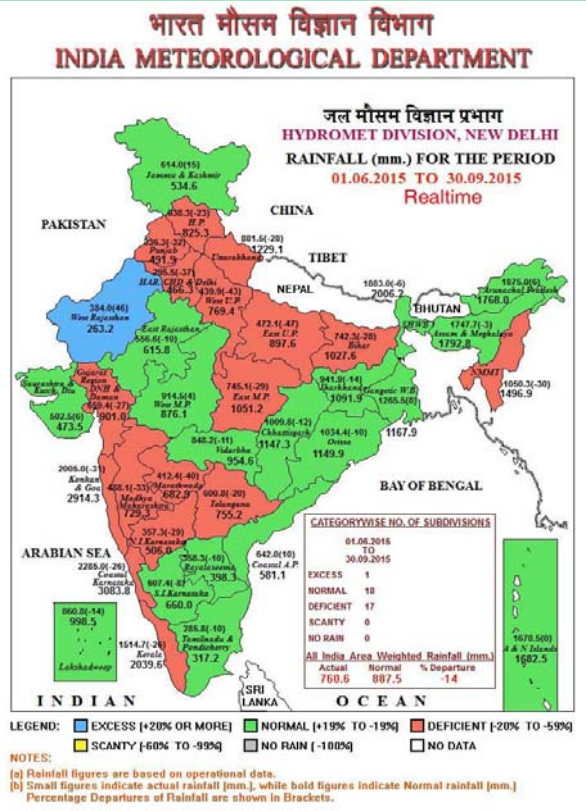
The actual monthly rainfalls during July and August were 84% & 78% of LPA respectively, which are below the forecasts by 8% and 12% respectively. Thus whereas the actual July rainfall was within the forecast limit, the actual August rainfall was 3% below the lower forecast limit. The Table below gives the summary of the verification of the long range forecasts issued for the 2015 southwest monsoon.

The actual rainfalls over northwest India, central India, northeast India and south peninsula were 83%, 84%, 92% and 85% of the LPA respectively. The actual seasonal rainfall of northwest India was 2% less than the forecast and that of northeast India is 2% more than the forecast. However, the actual season rainfalls over central India & south peninsula were less than the forecast by 6% & 7% respectively but well above the lower forecast limits. The forecast for the second half of the monsoon season (August -September) for the country as a whole was 84% with a model error of ±8% against the actual rainfall of 77% of LPA. Thus the forecast for the rainfall during the second half of the monsoon season over the country as a whole was also within the forecast limits.

Region	Period	Forecast (% of LPA)		Actual Rainfall (% of LPA)
		22th April	2th June (Update)	
All India	June to September	93 ± 5	88 ± 4	86
Northwest India	June to September		85 ± 8	83
Central India	June to September		90 ± 8	84
Northeast India	June to September		90 ± 8	92
South Peninsula	June to September		92 ± 8	85
All India	July		92 ± 9	84
All India	August		90 ± 9	78
All India	August to September		84 ± 8	77

Observed rainfall was excess over 1, normal over 18 and deficient over 17 sub-divisions as given below:

Category	Period : 1 June 2015 to 30 September 2015	
	No. Of Sub-divisions	Subdivisional % area of country
EXCESS	1	6%
NORMAL	18	55%
DEFICIENT	17	39%
SCANTY	0	0%
NO RAIN	0	0%



Sub-divisionwise rainfall for the months June- September, 2015 over the country

4. Post Monsoon Season, (October-December, 2015)

The northeast monsoon season (NEM) of October to December (OND) is the chief rainy season for the south-eastern parts of peninsular India (Tamil Nadu and Puducherry). This season is also the chief cyclone season over the North Indian Ocean and hence, low pressure systems forming over the Bay of Bengal and moving westwards contribute significantly towards the NEM rainfall over meteorological sub-division of Tamil Nadu and Puducherry (TN&PDC).

Five Meteorological Subdivisions of Southern India namely Tamil Nadu, Coastal Andhra Pradesh, Rayalaseema, Kerala and south interior Karnataka, receives about 30% of its annual rainfall during the North East monsoon season (October to December). Tamil Nadu in particular receives about 48 % of its annual rainfall during this season. The summary of forecasts for 2015 North-East monsoon season's Rainfall is given below:

1. Season's rainfall for South Peninsula (Tamil Nadu, Coastal Andhra Pradesh, Rayalaseema, Kerala and south interior Karnataka), is most likely to be above normal (>111% of Long Period Average). The Long Period Average (LPA) of the North-East monsoon season rainfall for the south Peninsula for the base period 1951-2000 is 332.1mm.

2. Season's rainfall for Tamil Nadu is most likely to be above normal (>112% of LPA). The LPA of the North-East monsoon season rainfall for the Tamil Nadu for the base period 1951-2000 is 438.2 mm.

3. The probability of above normal 2015 North-East monsoon season rainfall over south peninsula and over Tamil Nadu is 88% and 90% respectively.

During the year 2015, the onset of NEM took place on 28th October against the normal date of 20th October. The total rainfall for this northeast monsoon season over south peninsula was observed as 132% of LPA.

CHAPTER 4

NUMERICAL WEATHER PREDICTION

The NWP products are being provided to the forecasters, pubic authorities and other users regularly and on several occasions at the time of some of the episodes of the adverse weather. There have been systematic improvement in the management of these episodes of adverse weather by providing timey warning and guidance based on the NWP model forecasts, which has been improved over the year through improvement in the modeling efforts and the incorporation of new data in the assimilation cycle of the model.

NWP division at HQ (New Delhi) runs global model Global Forecast System (GFS) T574/L64 adopted from the National Centre for Environmental Prediction (NCEP) incorporating Global Statistical Interpolation (GSI) scheme as the global data assimilation system. Currently, the model runs twice in a day (0000 UTC and 1200 UTC) for 7 days forecast. In addition to this, the meso-scale forecast system WRF (ARW) with 3DVAR data assimilation is being operated daily twice, at 27 km, 9 km and 3 km horizontal resolutions for the forecast up to 3 days using initial and boundary conditions from the IMD GFS-574/L64 (horizontal resolution over the tropics ~ 22 km). At ten other regional centres, very high resolution mesoscale models (WRF at 3 km resolution) are made operational. The polar WRF is also run twice a day for short range (48 hours) weather forecast for the Maitri and Bharati stations in Antarctica. During the cyclone period the Hurricane WRF (HWRF) model is run to generate the real time cyclone track and intensity forecast. In addition, to strengthen the cyclone forecasting services the division also prepare other products used for the cyclone forecast such as : Cyclone Genesis Potential Parameter (GPP), Multi Model Ensemble (MME) technique for cyclone track prediction, (c) Cyclone intensity prediction, (d) Rapid intensification and (e) Predicting decaying intensity after the landfall. In the extended range time scale - the unit also prepare MME based bias corrected weekly forecast of rainfall and temperature forecasts for 4 weeks based on coupled models outputs available from different centers. During the monsoon season from June to September, the MME extended range forecast rainfall is prepared on met-subdivision level, which is being used for providing agromet advisories on extended range time scale. An empirical model for the forecast of seasonal frequency of cyclonic disturbance likely to be formed during October to December season is also developed. Thus, the division provides various products to the forecasters in the real time. Thus, the operational work of NWP division includes :-

- Day-to-day medium range products generation based on operational run of Global Forecasting System (GFS T574) with 6 hourly GDAS cycle.

- Meso-scale model products generation based on operational run of WRF, Polar-WRF and HWRF models for three days (72 hrs).

- Generation of multi-model based extended range forecast products on operational basis (upto 4 weeks) based on the coupled models outputs.

- Multi-model ensemble cyclone track and the Genesis potential parameter (GPP) values during the cyclone period.

- Generation of operational District and Block-Level Forecasts.

- Nowcast product generation for thunderstorm at station level.

- Prototype for Highway forecast giving near real-time weather information along with the synoptic warnings for stations along five National-Highways passing through Delhi.

Major Achievements during 2015

- Operational implementation of Global Forecasting System (GFS Version 9.0.0) at T574L64 resolution and 06 hourly cycle of Global Data Assimilation System (GDAS) with new Grid point Statistical Interpolation (GSI version 3.0.0) analysis scheme in AADITYA HPCS at IITM Pune for day-to-day operational run.

- Successful porting and operational implementation of nested (9 and 3 km) WRF model along with data assimilation on Aditya High Performance Computing System (HPCS) before monsoon 2015.

- Implementation of upgraded new version (3.6.1) polar WRF with increased horizontal resolution of 9 km.

- Operational implementation of triple nested domain (27, 9 and 3 km) Hurricane WRF (HWRF) model with improved product generation. The same modeling system has successfully provided real-time forecasts on 06 hourly intervals for recent cyclones over Bay of Bengal and Arabian Sea.

- Development of version 2 of mobile application named "Indian Weather" for Android with addition of upto 300 cities and Nowcast warning for thunderstorm.

- Development of All India Nowcasting system for thunderstorms that facilitates the forecaster at MC/RMC's to generate forecast in Nowcast mode and display on the public portal on real time basis.

- Development of dynamic pages for the IMD's website for Doppler Weather Radar Products.

- A demonstration webpage for Severe Weather Forecast Demonstration Project-Bay of Bengal (SWFDP-BoB) has been created, which will provide NWP guidance products from different modeling centres to the member countries. The web-portal was presented during the training workshop held in Bangkok, organised by Thai Meteorological Department (TMD) and WMO in Bangkok, which has been provided to the member countries.

NWP forecasts during 2015

GFS model forecast for medium range

The Global Forecast System GFS model at T574L64 (~ 23 km in horizontal) resolution is implemented at IITM Pune, on IBM based iDataPlex Supercomputer (AADITYA) in June 2015 for day-to-day operational use. The Global Data Assimilation (GDAS) cycle is a global 3-dimensional variational technique (3D- VAR) runs 4 times a day (0000, 0600, 1200 and 1800 UTC. Forecast model integrated for 7 days based on 0000 and 1200 UTC initial conditions.

Fig. 1 illustrates the spatial distribution of seasonal mean observed and day-3 forecast rainfall (mm/day) from *GFS T574* for the period from 1st June to 30th September 2015. The observed rainfall distribution shows a north south oriented belt of heavy rainfall along the west coast and Assam & Meghalaya with a peak of about 15 - 20 mm/day. The sharp gradient of rainfall between the west coast heavy rainfall and the rain shadow region to the south east, which is normally expected, is noticed both in the observed and model day-3 forecasts. In general, the day-3 forecast field of seasonal mean rainfall of GFS T574 could reproduce the heavy rainfall belts along the west coast, over the northeast Bay of Bengal and over the domain of monsoon low. However, some spatial variations in magnitude over northeast region with heavy rainfall belt extending westwards along the foothills of Himalayas are noticed during the summer monsoon season of 2015.

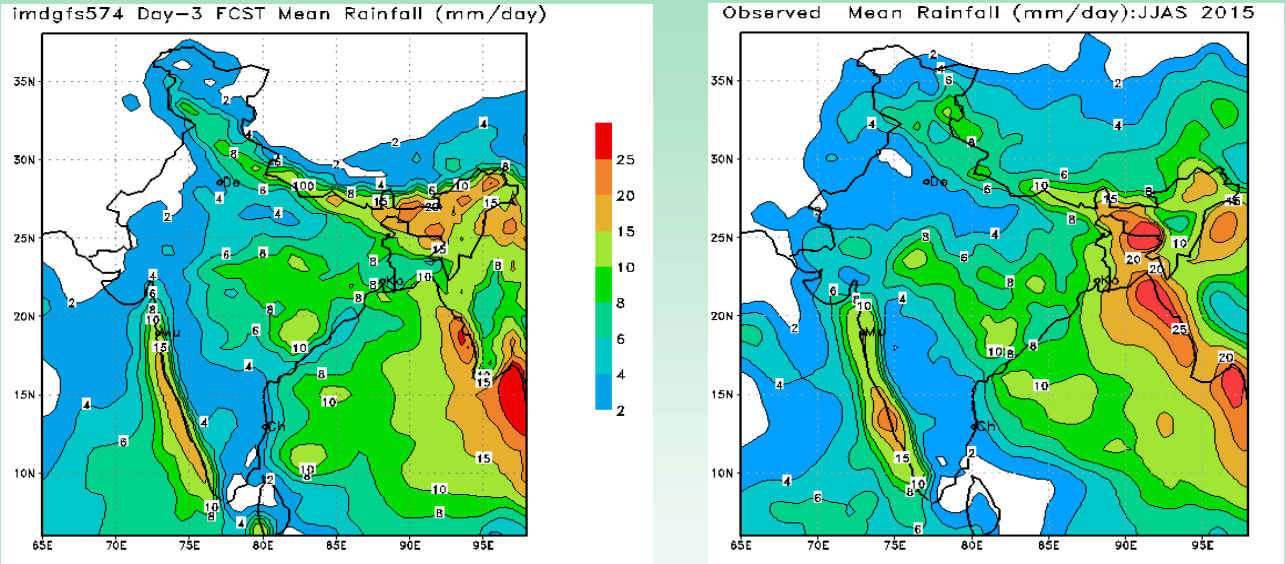
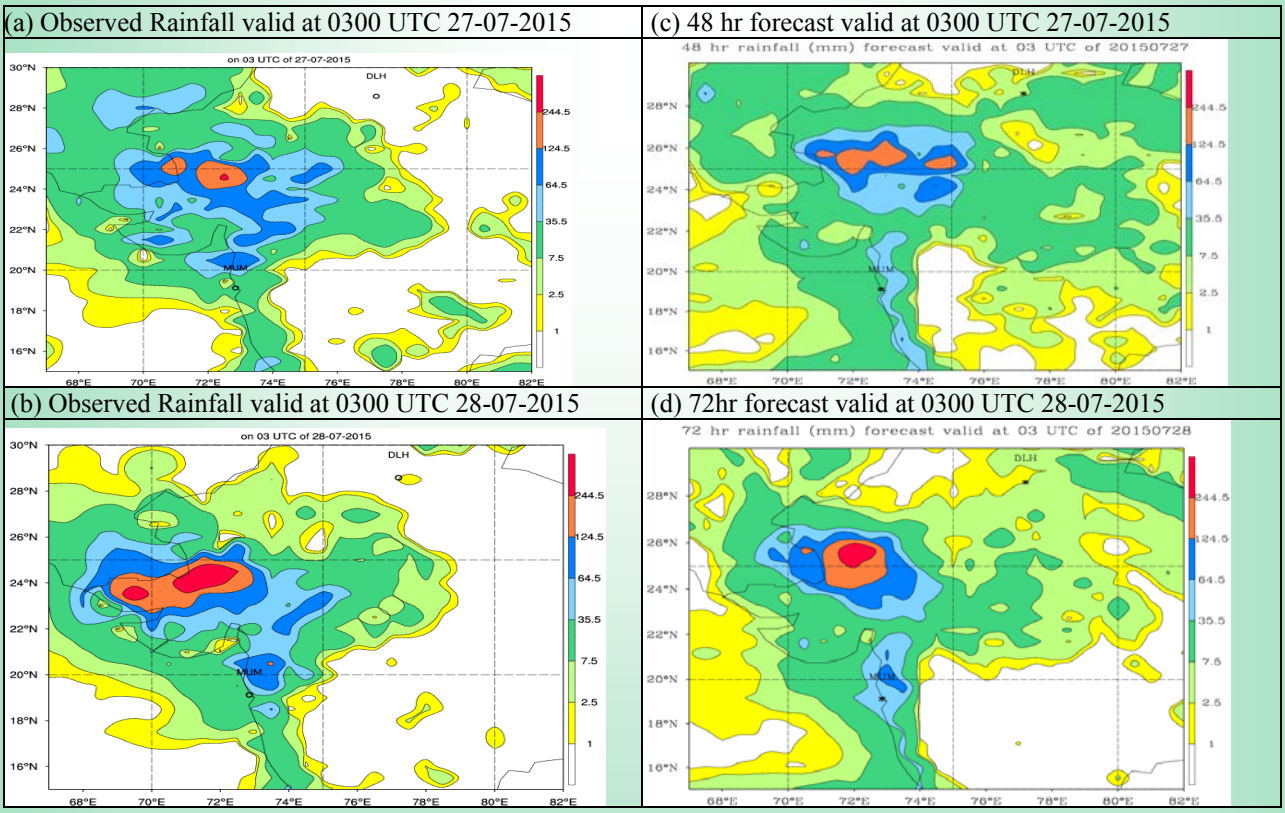


Fig. 1. *JJAS observed mean rainfall (mm/ day) along with corresponding GFS model forecast mean rainfall (mm/ day) valid for day 3 forecast*



Figs. 2(a-d). *Comparison between observed rainfall analyses and WRF model rainfall forecasts during 27 and 28 July 2015. (a) and (b) observed rainfall and (c) 48 hour forecast and (d) 72 hour forecasts valid at 0300 UTC of 27 and 28 July 2015 respectively*

Short range forecasting based on regional models (WRF, HWRF and Polar WRF)

Fig. 2 shows that the heavy rainfall occurring over Gujarat and Rajasthan during 27th and 28th July 2015 have been captured well by the 48 and 72 hours forecasts of WRF model. The specific increase of rainfall intensity within the period mentioned above has also been brought out by the model forecasts.

Fig. 3 represents the cluster of tracks provided by the real-time forecasts by HWRF model during the cyclone 'Chapala'. The forecast tracks have been provided on real-time basis with 06 hour interval. The 12 hourly real-time forecast tracks of HWRF model has been plotted in the figure for better representability. The forecast tracks of HWRF model have also been found to be useful to the forecaster during other cyclones of 2015.

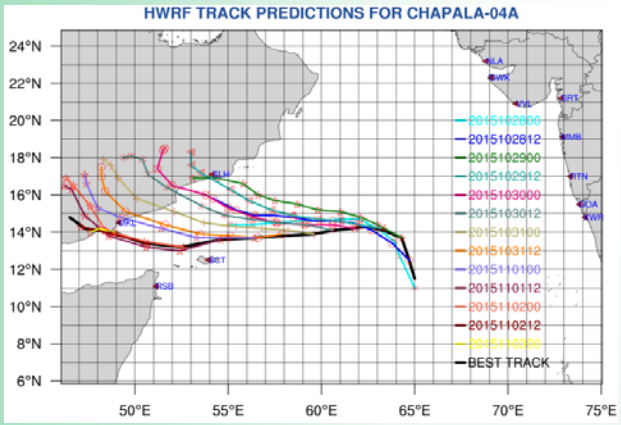
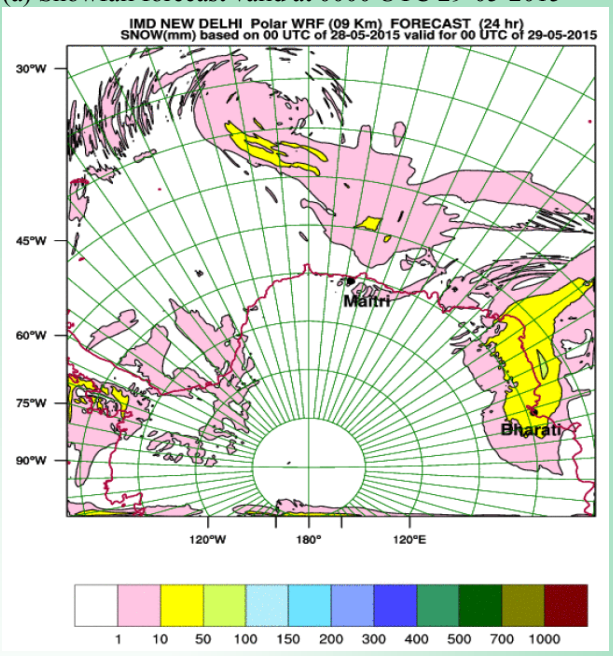


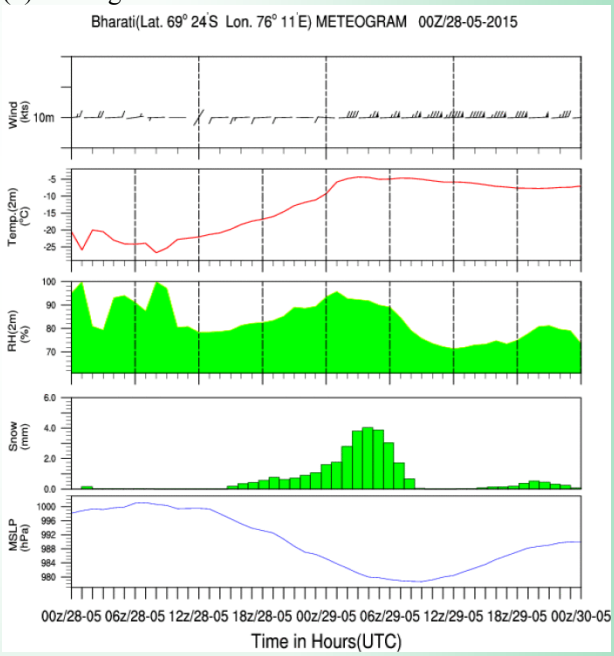
Fig. 3. *The real-time HWRF forecasts tracks from different initial conditions during the cyclone Chapala (28 October – 03 November 2015)*

The polar WRF model is producing real-time forecast for the Antarctica region more specifically for the two Indian stations Maitri and Bharati. Fig. 4 is showing the meteogram of one representative day of 29th May 2015 for Bharati. At the same time the snowfall coverage valid at 0000 UTC of the same day over the Antarctic area has also been plotted in the Fig. 4.

(a) Snowfall forecast valid at 0000 UTC 29-05-2015



(b) Meteogram for Bharati



Figs. 4(a&b). *Polar WRF forecast for Antarctica region and over Indian station Bharati on 29th May 2015*

MME based extended range forecast

With respect to the extended range forecast the Multi-model ensemble (MME) based on coupled modes outputs (IITM_CFSv2, NCEP_CFSv2 and JMA_EPS) are prepared for 4 weeks on weekly basis. Over the main monsoon belt of central India (CI) the MME forecast rainfall departure and

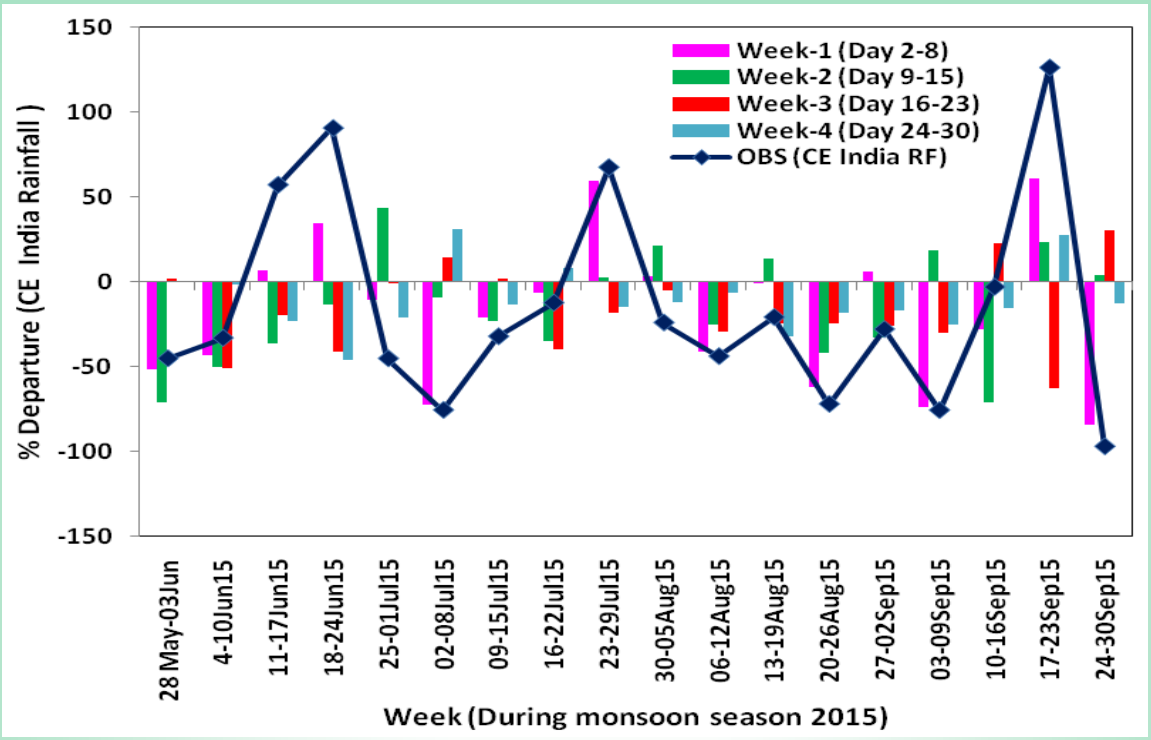
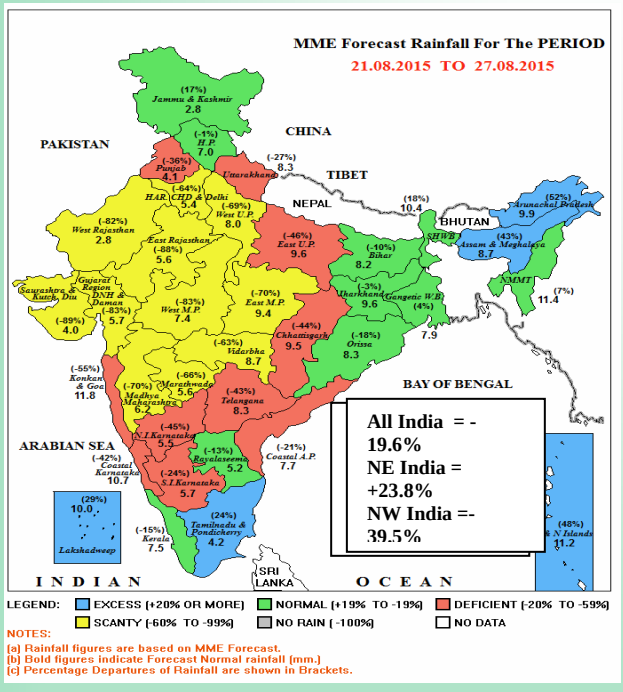
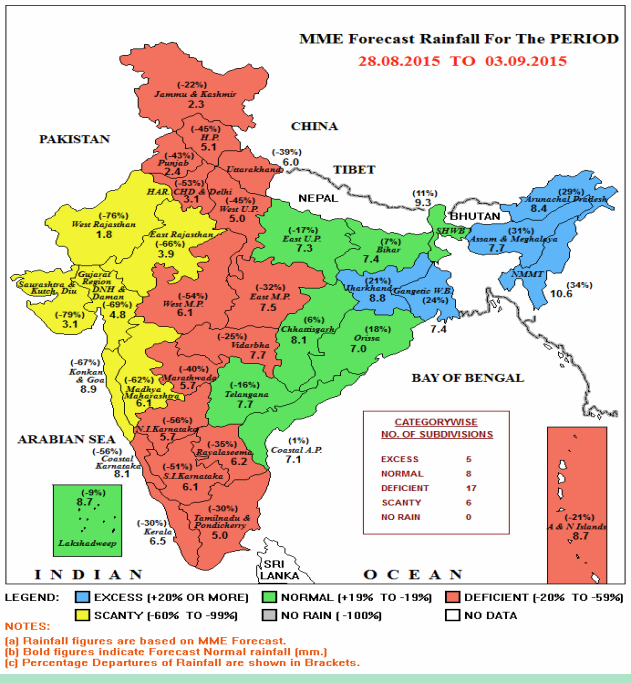


Fig. 5. *Observed and MME forecasts rainfall departure for 4 weeks over Central India (CI) during the southwest monsoon season 2015*

(a) Met. Subdivision rainfall forecast for week 1 based on 19 Aug, 2015 and valid for 21-27 Aug, 2015

(b) Met. Subdivision rainfall forecast for week 2 based on 19 Aug, 2015 and valid for 28 Aug-03 Sep, 2015





Figs. 6(a&b). *MME based met-subdivision wise forecasts rainfall departure for 2 weeks based on 19 August and valid for (a) 21-27 Aug and (b) 28 Aug - 03 Sep, 2015*

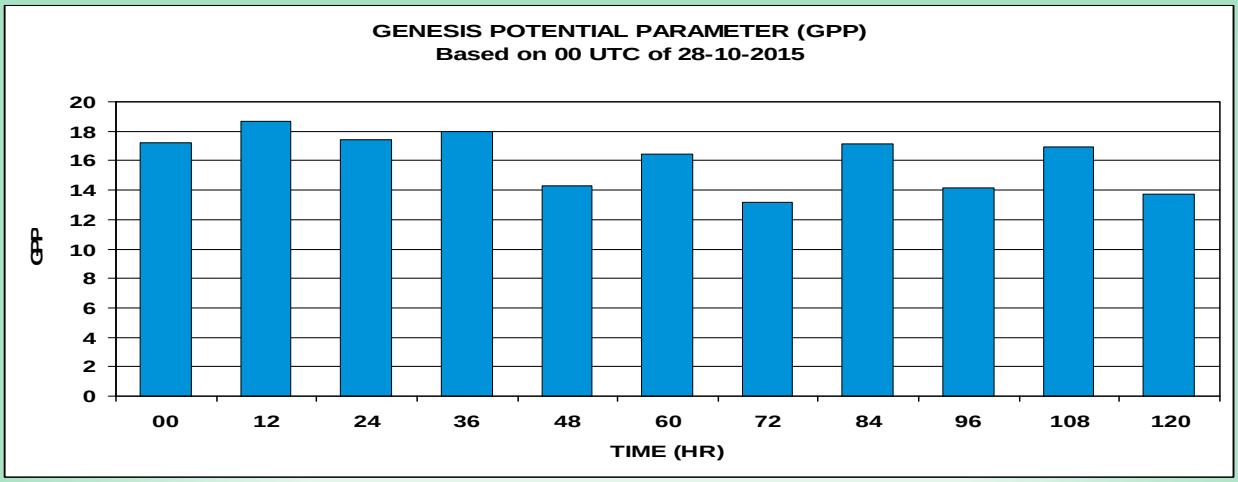


Fig. 7. *Area average analysis and forecasts of GPP based on 0000 UTC of 28.10.2015*

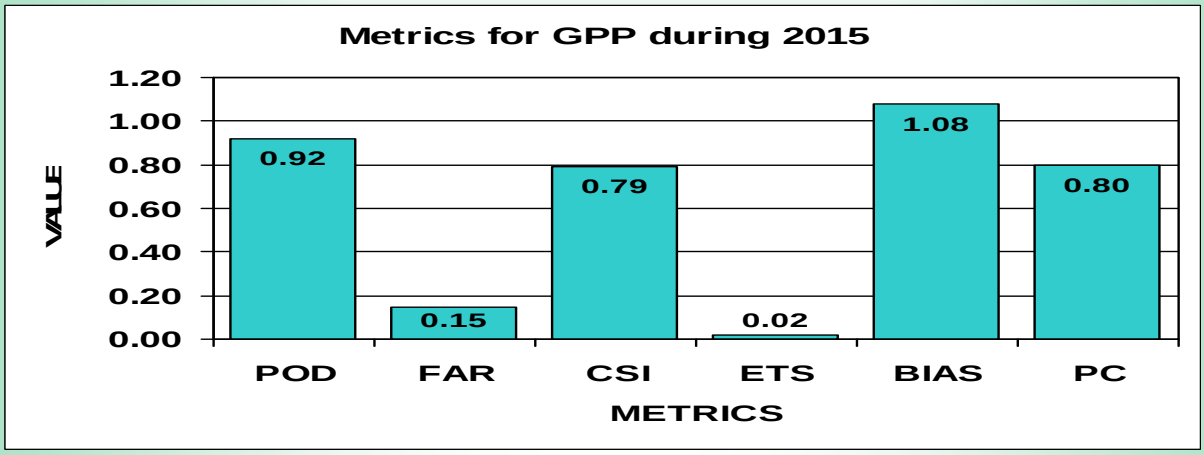


Fig. 8. *POD, FAR, CSI, ETS, BIAS and PC for all genesis forecasts of GPP during 2015*

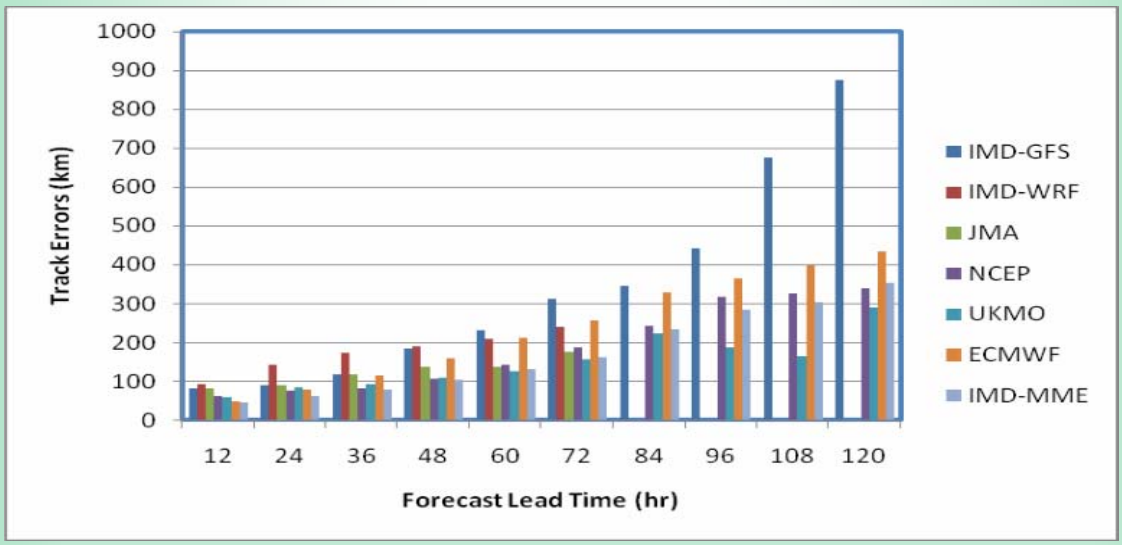


Fig. 9. *Average track forecast errors (in km) during 2015*

corresponding to observed rainfall during the 18 weeks of 2015 monsoon season is shown in Fig. 5. As seen the transition of monsoon from active to weak phase, weak to active phase and the long weak spells of July, August and early September was captured very well in the MME

forecast. The CC between observed and forecast rainfall departure over Central India (CI) is found to be significant till two weeks with CC of 0.70 during week 1 and 0.42 during week 2.

The MME forecast is also prepared on smaller spatial scales (4 homogeneous regions of India and 36 met-subdivisions). The met subdivision wise forecasts for two weeks are being used experimentally for agromet advisory to farmers. The met-subdivision wise MME forecast for two weeks based on 19th August, 2015 and valid for 21st August to 03rd September, 2015 indicating dry spell of monsoon over most parts of India (except the met subdivisions over north east India) is shown in Fig. 6. The quantitative forecast rainfall departure on all India and 4 homogeneous regions also indicate weak spells of monsoon over most parts of India except the northeast region.

Cyclone genesis potential parameter (GPP) and track forecast

Since all low pressure systems do not intensify into cyclones, it is important to identify the potential of intensification (into cyclone) of a low pressure system at the early stages (T.No. 1.0, 1.5) of development. Analysis and forecasts of GPP (Fig. 7) shows that GPP $\geq$ 8.0 (threshold value for intensification into cyclone) indicated its potential for intensification into a cyclone at early stages of development (T.No. 1.0 to 1.5).

Six metrics, such as the probability of detection (POD), the false alarm rate (FAR), critical success index (CSI), equitable threat score (ETS), frequency bias (BIAS) and percentage correct (PC) have been computed to evaluate the skill of the GPP for genesis forecasts issued during 2015. It can be seen from the Fig. 8 that the POD of the GPP was 0.92, the FAR was 0.15, CSI was 0.79, ETS was 0.02, BIAS was 1.08 and PC was 0.80 for 59 forecast events during 2015. The results show that POD was much higher than FAR and near desirable value for BIAS and also high CSI and PC indicate that the GPP was skillful for cyclogenesis prediction.

The MME based cyclone track is also prepared for each cyclone. The average track forecast errors (in km) during 2015 is shown in Fig. 9. It shows that under wide variation of track forecasts of different NWP models MME track provided very useful guidance during 2015.

CHAPTER 5

OBSERVATIONAL NETWORK

India Meteorological Department augmented its observational structure during 2015 and establishbed following major instrument/ networks.

- Doppler Weather Radars (2 installed, 4 under process).
- 25 GNSS stations (6 installed, 19 under installation).
- Installed GPS based Solar Trackers (4), UV-B radiometers (2) & pyranometers (4).
- 39 RS stations upgraded to WMO compliant GPS Sondes.
- Added Forty Seven (47) Automated Rain Gauges (ARG).
- Installation of SAMAR for aerosol and black carbon monitoring (Nephelometers : 12, Aethalometers : 16 and Skyradiometers : 12).
- Installation of SAFAR at Mumbai.
- Visualization of AWS data of ISRO networks in IMD RAPID introduced tool for the users.

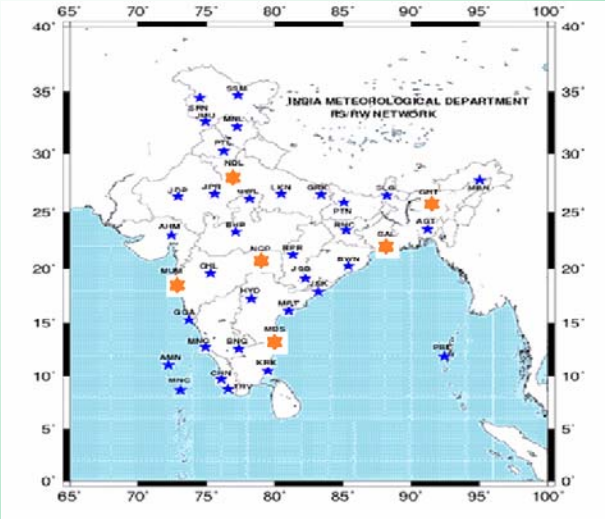
5.1. Upper Air Observational Network

Radiosounding Radiowind (RS/RW) network

As a part of global observing system (GOS) network of WMO, India Meteorological Department (IMD) has 39 operational Radiosonde radiowind stations in their upper air network. These stations are engaged in taking the radiosounding observations twice a day at 0000 UTC and 1200 UTC hours. Upper Air Observations are used to measure the vertical profile of the Atmosphere, viz., Temperature, Pressure, humidity, Wind Speed and Direction using balloon borne soundings.

As a subset of GOS network, World Meteorological Organization (WMO) in collaboration with the Intergovernmental Oceanographic Commission (IOC) of the United Nations Educational, Scientific and Cultural Organization (UNESCO), the United Nations Environment Programme (UNEP) and the International Council for Science (ICSU) established Global Climate Observing system (GCOS) network in 1992, as an outcome of 2nd World Climate Conference.

IMD, aiming on further improvement of upper air data quality, initiated the establishment of GUAN standard radiosounding observations at its 6 Regional Meteorological Centres (RMCs). These stations have been equipped with M/s GRAW radiosondes, Germany make, high quality GPS based radiosounding system, GS-E along with DFM-09 radiosondes. The ground system GS-E and radiosondes DFM-09 are compatible to be used at a standard GUAN upper air observatory for radiosounding.



GUAN standard compatible Radiosounding stations

GPS based stations

Radiosonde Radiowind (RS/RW) Network

Achievements during the year 2015

(I) 06 Nos. of GPS based systems (make M/s GRAW Germany) installed/commissioned at RMCs to upgrade these RS/RW stations as per WMO GCOS Network (GUAN) standard. Action being taken for induction of these stations into GUAN network.

(II) Pilot Balloon (PB) observatories of Sundernagar and Dehradun up-graded to RS/RW.

(III) 13 Nos. of GPS based systems (make M/s Jinyang Korea) installed/commissioned at RS/RW Agaratala, Siliguri, Gorakhpur, Lucknow, Ranchi, Karaikal, Machhilipatnam, Mangalore, Kochi, Jodhpur, Jammu, Sundernagar & Dehradun.

(IV) 7 Nos. of GPS based systems (make M/s Changfeng China) installed/ commissioned at Patiala, Gwalior, Jagdalpur, Raipur, Jaipur, Aurangabad & Bangalore to upgrade these RS/RW stations.

(V) Total network of upper air radiosounding (RS/RW) of 39 stations has been upgraded with GPS based radiosounding, and all the stations are working at present. The details of new installation during the year are given in the adjacent table;

GPS Stations Dates of commissioning		
S. No.	Name of Station	Installation Date
1	Chennai	8/8/2015
2	Kolkata	12/8/2015
3	Nagpur	5/8/2015
4	New Delhi	1/8/2015
5	Jodhpur	24-10-2015
6	Sunder Nagar	8/10/2015
7	Jammu	29-10-2015
8	Agartala	6/10/2015
9	Machhilipatnam	24-10-2015
10	Mangalore	14-10-2015
11	Ranchi	14-10-2015
12	Gorakhpur	18-10-2015
13	Lucknow	18-10-2015
14	Bangalore	19-8-2015
15	Chikalthana	6/9/2015
16	Guwahati	18/8/2015
17	Gwalior	1/8/2015
18	Jagdalpur	27-8-2015
19	Jaipur	15-8-2015
20	Karaikal	9/10/2015
21	Kochi	19-10-2015
22	Mumbai	21-08-2015
23	Patiala	27-7-2015
24	Raipur	24-8-2015
25	Jalpaiguri	12/10/2015
26	Dehradun	3/12/2015


Radiosonde

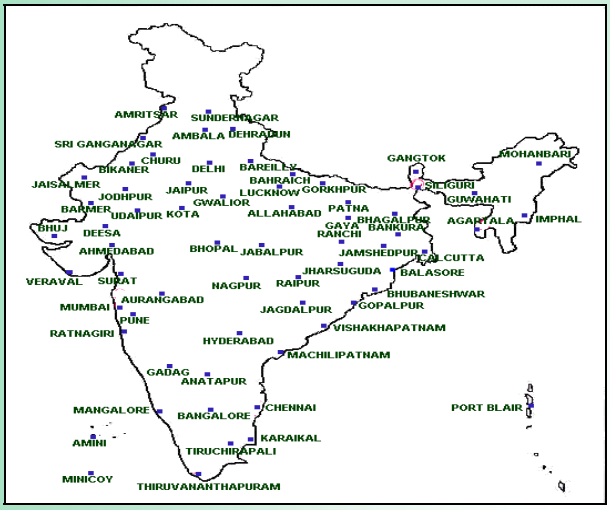
- GPS based radiosounding systems are latest in sounding.
- Fully Automatic.
- User Friendly.
- Auto tracking of balloon (transmitter)
- Auto detection of balloon launch and burst / termination.
- Minimum human interference.
- Very Light and portable type systems.
- Easy to maintain.


Radiosonding Reciever System

(VI) Indigenous GPS based radiosonde is in final stage of production. Procurement of different components in different stages-production to start on receipt of material.

Pilot Balloon (PB) network

62 stations in the upper air network of IMD have pilot balloon observations. Pilot Balloon Observations are used to measure the upper air wind speed and direction. The balloon is tracked using an optical theodolite. These observations are made every synoptic hour.



Pilot Balloon (PB) Network

Future Projects

- Induction of Indigenous GPS based radiosounding system in IMD's upper air network, and production of GPS based radiosondes in IMD workshop.
- 6 Nos of high quality GPS based system to be inducted into the WMO-GUAN network.
- To explore the use of satellite derived profiles as an alternative to radiosounding.
- Upgradation of pilot balloon stations using pilot sonde.

Upgradation of seven radiosonde observatories to GPS based radiosounding

To enable the availability of better quality upper air atmospheric data for various NWP models, upper air laboratory of the O/o DDGM(UI), New Delhi has upgraded seven more upper air observatories of the network by installing the M/S Beijing Santel make radiosounding systems.

Systems were installed at Gwalior, Patiala, Jaipur, Raipur, Jagdalpur, Bangalore and Chikalthana in the month of July - August 2015.

Establishment of network of six global upper air stations (GUAN) in India

As per the request from WMO, upper air laboratory of the O/o DDGM(UI), New Delhi has established a network of six GUAN standard observatories under the GCOS (Global Climate Observing System) scheme of WMO by installing the M/S GRAW radiosounding systems.

Systems were installed at New Delhi, Chennai, Guwahati, Kolkata, Nagpur and Mumbai in the month of August 2015. This is to ensure the availability of high quality upper air atmospheric data for use in the NWP models.

Antenna Installation of Radiosounding system

Antenna of GUAN standard Radiosounding system

DWR Mumbai Inauguration by Dr. L. S. Rathore, DGM, IMD

SAFAR Mumbai Control Room Inauguration by Dr. L. S. Rathore, DGM, IMD

Gramin Krish Mausam Seva (GKMS) Workshop at PBO Dessa, Gujarat

5.2. Satellite Observations

After successful launch of INSAT-3D Satellite in July, 2013 the INSAT-3D Meteorological data system was upgraded and also being utilized to receive and process INSAT-3D Satellite data.

In addition to this the generation of new images, BD - curve and NHC curve enhancement technique for use in determination of cyclone intensity and centre has been developed and implemented operationally. The retrieval algorithm of satellite derived wind products has been modified and implemented successfully resulting in generation of good quality wind products.

A web based analysis and visualization tool called "Real Time Analysis and Product Information Dissemination" has been developed and implemented operationally w.e.f. 15.01.2015. The tool is capable of displaying numerical values of satellite derived products, radiances brightness temperature provision of area measurement, zooming of images up to native resolution, running animation of desired sector, overlaying different products over different type of base map etc.

The performance of the system during the current year has been maintained to the level of 98% operation efficiency (24 × 365 bases). The validation of atmospheric Motion Vector (wind products), sea surface temperature, outgoing long wave radiations (OLR) vertical Profile of temperature and humidity has been carried out for the period of July, 2014 to October, 2015 and the feedback are used for fine tuning of algorithm of these products.

The satellite based technique/tools for monitoring and forecasting of evolution of clouds cluster that leads to the severe weather has been developed and implemented operationally. The method is used to generate NOWCAST Satellite images for next three hours on half hourly basis.

IMD has 352 nos. of Digital Cyclone Warning Dissemination System (DCWDS) spread over coastal boundaries of India which are used to Disseminate Cyclone warning generated from area cyclone warning centre (Chennai, Vishakhapatnam, Mumbai and Kolkata) in the affected region to carry out disaster management since 2002. The system is being upgraded with Direct to Home (DTH) based DCWDS through MoU between ISRO, Doordarshan, Bharat Elelctroinc Ltd. and IMD along with further increase in no. of stations to 500. Till date out of 500, 222 nos. have been installed in Tamil Nadu Orissa Andhra Pradesh and Pondicherry regions. Installation of remaining is in progress.

Integrated Network of GNSS (INGNSS) for IPWV Measurements

IMD is in the process for setting up the Integrated Network of GNSS (INGNSS) for IPWV Measurements by installing additional 25 GNSS receivers for atmosphere, ionosphere and Seismic studies in 2015-2016, which is an expansion project of existing 5 GPS receiver at Chennai, Mumbai, Kolkata, Guwahati and New Delhi operational since 2007 as a pilot project to detect signal from multi-constellation GNSS satellites. This Project also have provision of using other GNSS Network data of NGRI, INCOIS and other research institutes in real time basis, for augmenting the data spatial density and processing. IMD at present acquires IPWV with high temporal resolution for day to day weather forecasting and climate applications. The expected accuracy of GPS-derived IPWV is of the order of 1 mm.

The vital role of water vapour in the Earth's climate/weather system requires long-term stable and highly accurate measurements of the atmospheric Integrated Precipitable Water Vapour (IPWV). Key advantages of the current GNSS measurements is (i) that apart from the IPWV measurement the equipment is also installed with advanced meteorological sensors to measure Temperature Pressure, Humidity of the station (ii) capable of working independently in all weather condition with high temporal resolution (of the order of minutes) which is practically not possible by other existing methods.

5.3. Environment Monitoring

SAFAR

The system for air quality forecasting and research (SAFAR) has been operationalized by IMD to monitor and forecast air quality in major cities. This is a joint project of IITM and IMD. The installation of air quality monitoring and forecasting system in Mumbai has been completed. The air quality monitoring system was inaugurated on 23.06.2015 by Hon'ble Minister of Earth Sciences in the presence of Hon'ble Chief Minister of Maharashtra and Director General of Meteorology.

System of Aerosol Monitoring And Research (SAMAR)

System of 3 Aerosol Monitoring Networks (Skyradiometer, Nephelometer & Aethalometer)

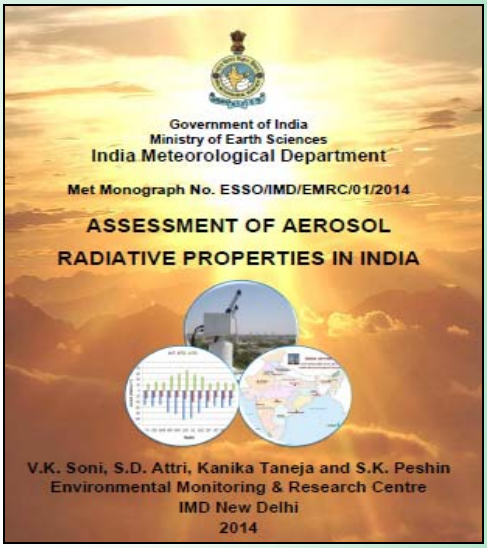
India-SkyNet

India-Skynet is a network of skyradiometers consisting of twelve stations in different locations in India.

The instrument makes measurements in eleven narrow wavebands in the ultraviolet, visible and infrared parts of the solar spectrum (315, 340, 380, 400, 500, 675, 870, 940, 1020, 1627, 2200).

The instrument enables estimation of optical parameters of aerosols such as

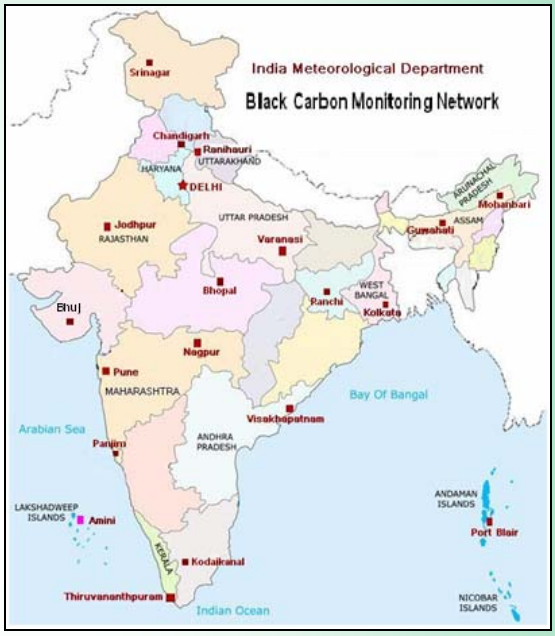
- Aerosol Optical Depth (AOD)
- Single Scattering Albedo (SSA)
- Angstrom exponent,
- Phase function
- Complex refractive index
- Columnar size distribution of aerosols.



Nephelometer Network

IMD has established a network of Nephelometers at twelve different stations in India. It has the following applications:

- Measurement of scattering coefficient.
- Determining a variety of aerosol parameters used in climate change radiative models.
- Visibility monitoring including haze, fog and smog.
- Helping to determine the effect that humidity changes have on aerosols.
- PM2.5 correlation studies.
- Dust and sandstorm monitoring.
- Bush fire and wood smoke monitoring.



The instrument makes measurements at 3 different wavelengths:

Green : 525 nm – most sensitive for the human eye best measurement for smog, fog, haze.

Red : 635 nm - interacts strongly with large particulate matter (pollen, sea salt).

Blue : 450 nm - interacts strongly with fine and ultrafine particulates (wood fires, automobiles).

Backscatter : 90-170° - measures the light reflected back towards light source.

Black Carbon Monitoring Network

➢ The network is established at sixteen locations in India.

➢ A seven wavelength Aethalometer (λ = 370, 470, 520, 590, 660, 880 and 950 nm) is used to measure the aerosol attenuation coefficient.

➢ While continuously collecting sample, the instrument measures optical absorption in real time.

➢ Converts optical absorption to mass concentration of Black Carbon (BC) and UV-absorbing particulate matter (UVPM).

Bharati Meteorological Observatory in Antarctica was augmented by installing following instruments:

(a) Digital Current Weather Instruments System (with Data Digitizer & Data logger) has been installed at Bharati Meteorological Observatory in Antarctica.
(b) Radiation data logger.
(c) Stevenson's screen for Max., Min. & dry bulb temp.
(d) Snow Gauge.
(e) UV-A & Global Radiation sensor.
(f) Radiation Data logger.
(g) The measurement of vertical distribution of ozone will commence from January, 2016. The GPS based Ozonesonde system has been sent to Bharati, Antarctica.

Precipitation Chemistry Program

Wet only precipitation samples collected at GAW stations are analyzed at Central Chemical laboratory, Pune.

Precipitation chemistry

Completed chemical analysis for pH, conductivity, major cations (Ca, Mg, Na, K, NH_4) and major anions (SO_4, NO_3, Cl) have been done for all precipitation samples received from 11 GAW stations for the year 2014.

- Air Pollution Section Laboratory, O/o ADGM(R), participated in 52nd and 53rd Laboratory Inter-comparison programme conducted by WMO in April and October 2015 and analyzed the samples for ten parameters (Ph, Conductivity, anions and cations) and sent the results to QASAC, USA.

5.4. SAARC STORM PROJECT-2015

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. The Program Implementation Committee (PIC) of the SAARC STORM Project was reconstituted by MoES in 2008. During the pilot-phase of 2009, the domain was extended to include the neighbouring countries Nepal, Bhutan and Bangladesh through a newly established lead partnership with the SAARC Meteorological Research Centre (SMRC), Dhaka. In the SAARC STORM Project so far, four STORM Field Experiments have been conducted in Phase-I focusing on Norwesters in pre-

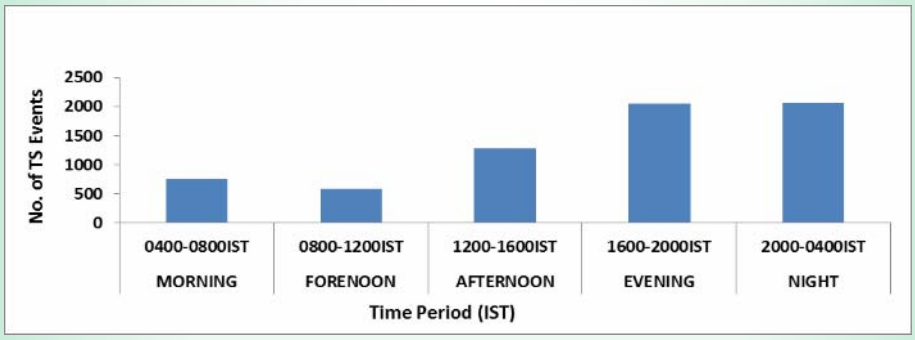


Fig. 1. *Diurnal distribution of thunderstorm events over the country during Storm Period-2015*

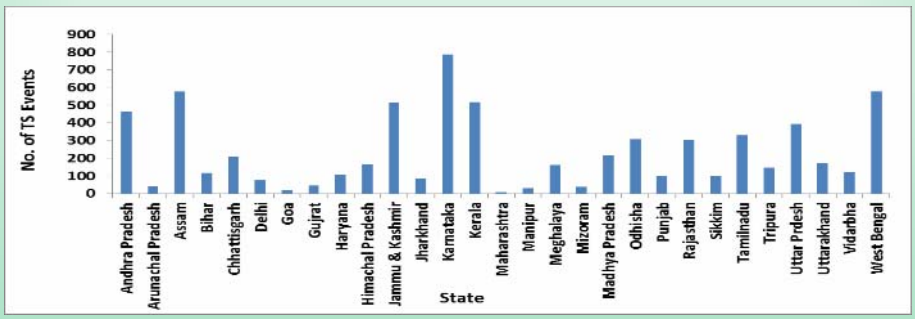


Fig. 2. *Statewise distribution of thunderstorm events over the country during Storm Period-2015*

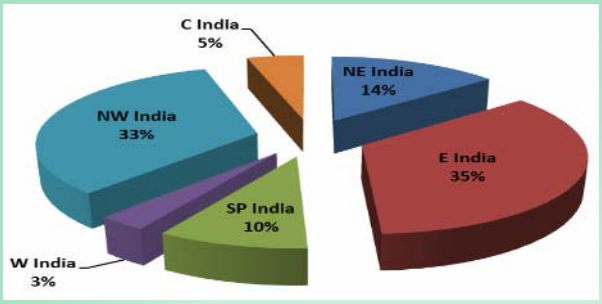


Fig. 3. *Regionwise Distribution of Thundersquall Events over the Country during entire Storm Period-2015*

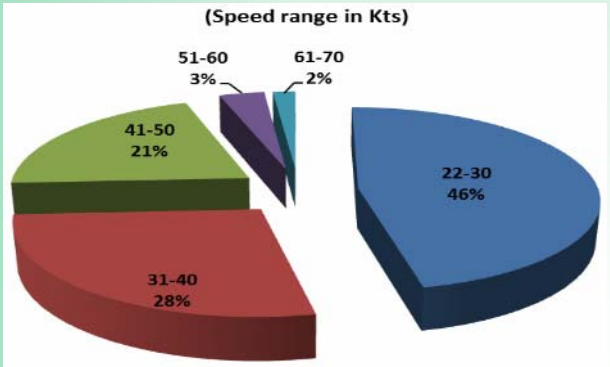


Fig. 4. *Distribution of Thunder squalls over the country based upon max wind speed (Kt) during Storm Period-2015*

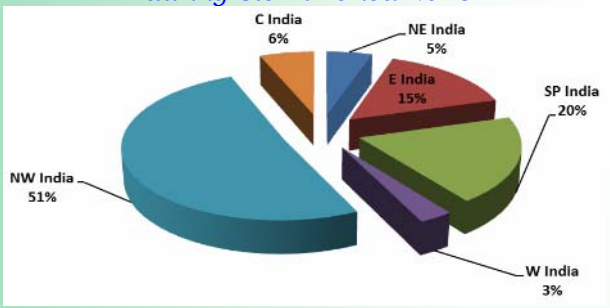


Fig. 5. *Regionwise Distribution of Hailstorm Events over the Country during entire Storm Period-2015*

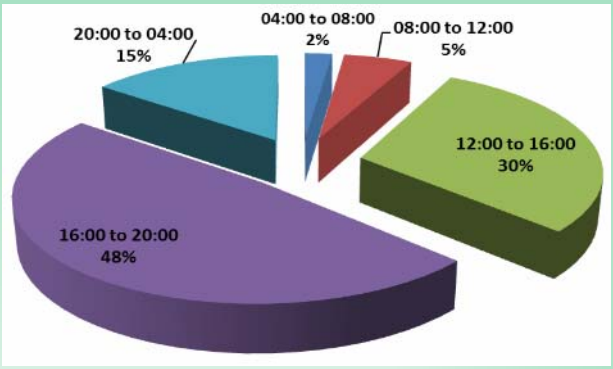


Fig. 6. *Diurnal Distribution of Hailstorm Events over the Country during entire Storm Period-2015*

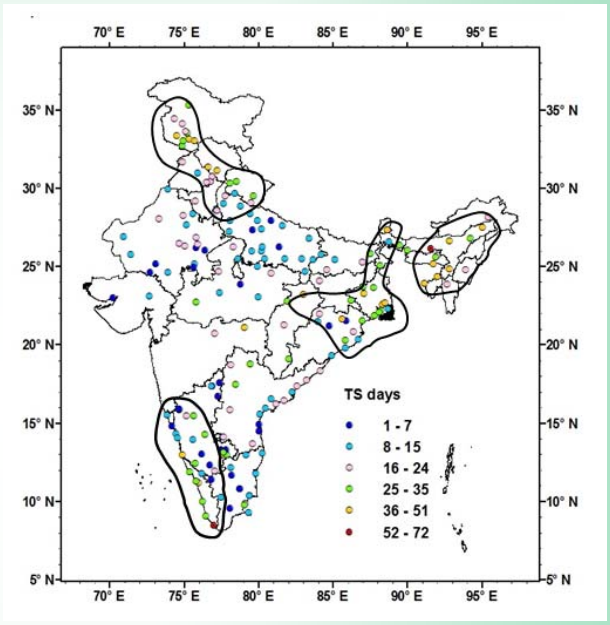


Fig. 7. *Spatial distribution of thunderstorm days over India during entire Storm Period-2015*

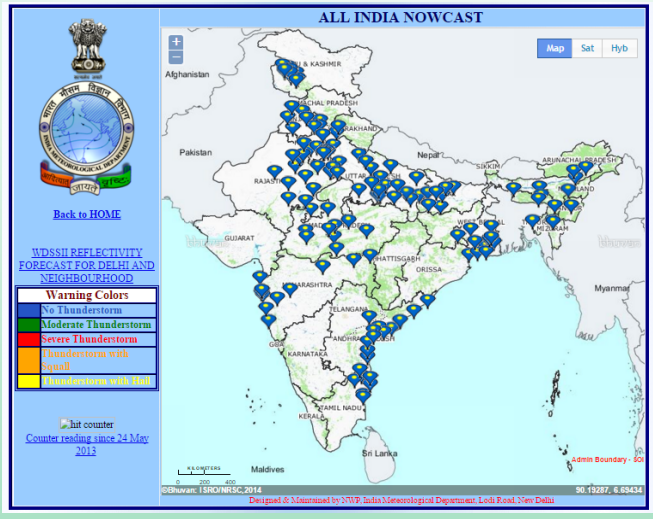


Fig. 8. *All India Nowcast*

TABLE 1

Verification of Intensive Observation Period Issued during STORM Period-2015

Region	IOP Period	Total number of days	Total no. of IOP issued	No. of times Significant Weather (TS/HS/SQ)Occurred	% age Correct
Northwest India	15-0315 to 15-06-15	93	22	22	**100**
Central India	15-03-15 to 15-06-15	93	17	16	**94**
West India	15-03-15 to 15-06-15	93	9	4	**44**
South Peninsular India	15-03-15 to 15-05-15	76	20	20	**100**
East India	01-04-15 to 31-05-15	63	23	23	**100**
Northeast India	01-04-15 to 31-05-15	63	28	28	**100**

monsoon seasons during 2009-2012. In Phase-III of SAARC STORM Programme which started in 2013, the STORM Fields Experiments covered the whole SAARC region. This year also Storm field experiments covered whole India. A Weather Advisory Group, established at the India Meteorological Department (IMD), New Delhi was set up, whose main task was to watch the development of daily weather situation over the STORM campaign area during March-June-2015, advice the various participating offices on the nature and frequency of observations required to be taken by them on day to day basis and to issue a bulletin every Monday, Wednesday and Friday.

Nowcast Nowcasting of Thunderstorms, squalls and Hailstorms

Nowcast Unit prepared a storm report document that 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 to be released on 15 January, 2016 on IMD Foundation Day. Figs. 1 to 7 represent some of the important results of the Storm Report-2015 and Table 1 gives the verification of Intensive Observation Period (IOP) issued during the storm period.

Nowcasting is based on the ability of the forecaster to assimilate great quantities of weather data, conceptualize a model that encompasses the structure and evolution of the phenomenon and extrapolate this in time. Nowcasts require high resolution of spatial and temporal meteorological data to detect and predict the occurrence of an event. Lack of data of the mesoscale imposes limit on ability to diagnose and predict an event. Nowcasting in India has benefited from major developments in observational meteorology and computer-based interactive data processing and display systems in IMD. In view of 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) dense automatic weather station (AWS) network, (iii) half hourly satellite observations from Kalpana and INSAT satellites, (iv) better analysis tools in synergy system at forecaster's workstation and (v) availability of mesoscale models, (vi) computational and communication capabilities, IMD implemented nowcasting of thunderstorms, squalls and hailstorms. Considering the importance and reliability of DWR based information for nowcast of thunderstorm and associated weather, in the first phase, major stations/cities which come under the coverage of DWR were included for nowcasting of convective weather.

This year, with installation of DWR Srinagar 15 new stations were added, thereby, increasing the total number of nowcast stations to 156 within 200 km radius of various Doppler Weather Radars. TS nowcast of these stations is uploaded every 3 hourly interval utilising Synoptic Data, Model outputs, Satellite products and finally various Radar outputs. The forecast was operational from December 2012.

Stationwise Skill Scores of Thunderstorm Nowcast Verification - 2015 is shown in Figs. 8&9.

Warning Decision Support System Integrated Information

WDSSII (Warning Decision Support System Integrated Information) installed in ACWC Chennai for nowcasting purpose. Nowcasting of Thunderstorm and Hailstorm etc. are uploaded daily in the RMC Chennai website on real time basis.

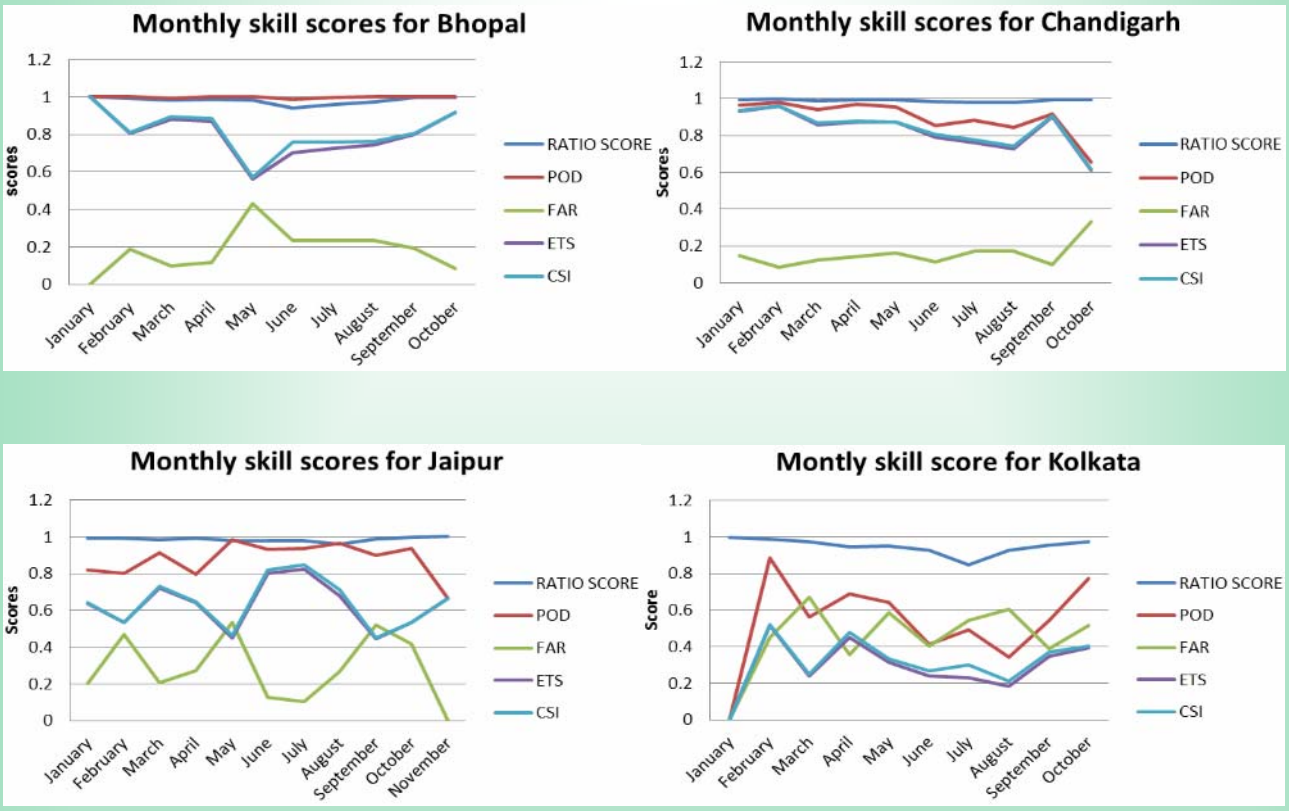
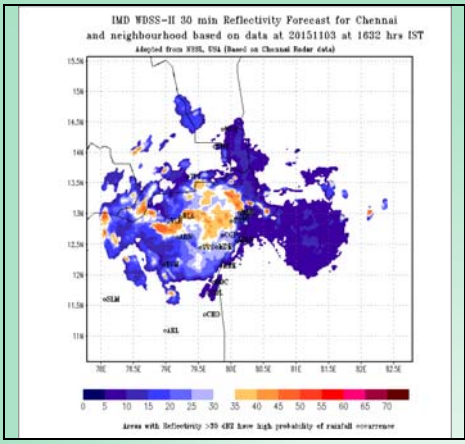


Fig. 9. *Stationwise Skill Scores of Thunderstorm Nowcast Verification - 2015*



INDIA METEOROLOGICAL DEPARTMENT

NOWCAST FOR CHENNAI

DATE OF ISSUE :	03	11	2015	TIME OF ISSUE :	1430	HOURS	IST

VALID FOR	03	HOURS	FROM	1430	HOURS	IST	TO	1730	HOURS IST

TEMPERATURE	31-29	°Celsius
WIND DIRECTION	Easterly	
WIND SPEED	02-05	KMPH
WEATHER	The sky condition would be generally cloudy. Rain or thundershowers may occur in some areas.	
SEVERE WEATHER WARNING	Nil	
NEXT UPDATE AT	1730	HOURS IST

5.5. Quality Assurance in IMD

IMD initiated process for ISO:9001-2008 certification for its various offices in the country. Standard Operating Procedures (SOPs) have been put into place for various meteorological offices in the country. 10 offices of IMD were awaded ISO:9001-2008 in 2015.

ISO certification of MWO Mumbai

CERTIFICATE

EN ISO 9001 : 2008
Quality Management System

AIB-VINCOTTE International nv/sa
Jan Olieslagerslaan 35, 1800 Vilvoorde, Belgium

This is to certify that: *India Meteorological Department (Meteorological Watch Office-Mumbai)*

Located at: *Sutar Pakhadi Road, CSI Airport, 400099 Mumbai, Maharashtra India*

has established and maintains a quality system conforming the requirements of EN ISO 9001 : 2008 "Quality Management System" for

Provision of meteorological services for aviation.

This certificate is based on the result of a quality audit documented in the audit report IMD_MDO_cert_Jan15.

Certificate number: IS QMS 5692
Valid from 9 February 2015 to 8 February 2018

Further clarifications regarding the scope of this certificate and the applicability of EN ISO 9001 : 2008 requirements may be obtained by consulting the organization.

This certificate is granted during the Certification Commission of 9 February 2015 and is subject to the General Regulations of AIB-VINÇOTTE International nv/sa

VINÇOTTE IQNet

Signed for the certification body:
Bart Janssens
Chairman Certification Committee

BELAC 016-QMS

IQNet
THE INTERNATIONAL CERTIFICATION NETWORK

CERTIFICATE

IQNet and AIB-VINÇOTTE International hereby certify that the organization

India Meteorological Department (Meteorological Watch Office-Mumbai)
Sutar Pakhadi Road, CSI Airport,
400099 Mumbai, Maharashtra (India)

for the following field of activities

Provision of meteorological services for aviation.

has implemented and maintains a

Management System

which fulfils the requirements of the following standard

ISO 9001:2008

Issued on : 9 February 2015
Validity date : 8 February 2018

Registration Number : BE-15 QMS 5692

IQNet — VINÇOTTE

Michael Drechsel
President of IQNet

Bart Janssens
Chairman Certification Committee

CHAPTER 6

MAJOR SERVICES OF THE DEPARTMENT

6.1. Operational Weather Services

Hydrometeorological Services

The Hydrometeorological Division is providing the necessary technical and operational support to various Central/State Govt. organization and other agencies in the field of hydromet design, flood forecasting, rainfall monitoring for water management and agricultural planning purposes etc. The main activities of this division are :-

Design Storm Studies: During, 2015, design storm studies of twelve (12) projects were completed. An amount of Rs.14,77,680/- (Rupees Fourteen Lakh Seventy Seven Thousand Six Hundred Eighty only) has been levied to carry out the design storm studies of the projects.

Major Services

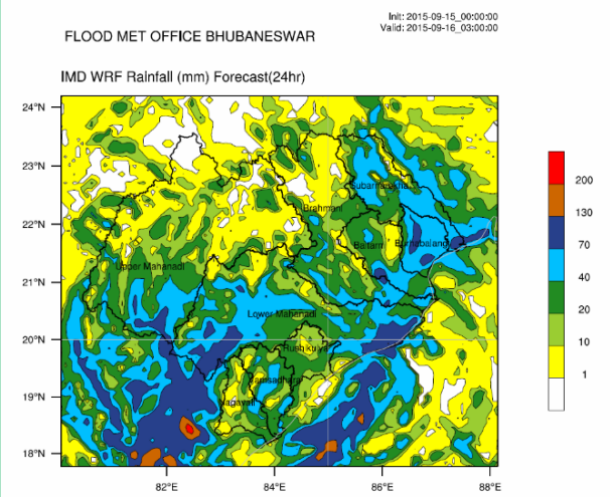
Ho'ble Union Minister of Agriculture launched the Nowcasts Extreme Weather Alerts to farmers on 18-06-2015 at Krishi Bhavan, New Delhi. The Extreme weather nowcasts uploaded by various IMD centers are being sent automatically to around 1 Crore farmers registered in mKisan portal. The function was attended by Dr. L. S. Rathore, DGM and Dr. Kamaljit Ray, Sc-E. The Extreme weather alerts issued are available at the link: http://mkisan.gov.in/nowcastreport/NowCast Consume.aspx.

Sample Rainfall Map

Flood Meteorological Service

The sub-basinwise Quantitative Precipitation Forecast (QPF) is being issued (daily on operational basis) during flood season by 10 Flood Meteorological Offices (FMOs) and MC Srinagar in flood prone areas to Flood forecasting Division (FFDs) of Central Water Commission (CWC). These FMOs are located at Ahamedabad, Agra, Bhubaneswar, Hyderabad, Lucknow, Patna, Guwahati,

Asansol, Jalpaiguri, Delhi. Besides these FMOs DVC Met. unit Kolkata also issues QPF for Damodar Velly Corporation. Total 119 sub-basins of different flood prone rivers in the country are being covered for flood forecast during the flood season. During flood season 2015-2016, six more river basins; namely Jhelum, Sankosh, Jaldhaka, Torsa, Pennar and Chambal have been included for operational forecasting from the year 2015. The lead time is also enhanced for issue of QPF from 2 days to 3 days and outlook from 3 days to 4 days. The total Nos. of QPFs issued till October 2015 is 19,793 for Day-1; 18,298 for Day-2, and 18,285 for Day-3.



Sample WRF Rainfall (mm) Forecast Map

Central Hydromet Observatory (CHO)

A Central Hydromet Observatory is situated at IMD, New Delhi for taking observations and for demonstration as a Model Observatory to visitors. During 2015-16, about 1364 students/Academia and teachers from various schools/Govt./Private institutions visited the Central Hydromet Observatory to get familiarization of India Meteorological Department and working of I.M.D. through C.H.O.

Research & Development Under the content "Research & Development Programme"

Hydromet Division, New Delhi is being computing Sub-basinwise QPF using operational NWP models, viz., WRF, MME and procedures uploaded on IMD website for 127 flood prone sub-basins of India to be used as guidance for field forecasters for issuance of operational QPF. In addition to this, similar sub-basinwise GFS model rainfall products for day1 to day7 has been made operational w.e.f. 29-06-2015 and uploaded on IMD website.

International Hydrology Programme (Under the content of "International Co-operation)

IMD is working in a "Joint Working Group" with representatives of MoWR and other associated members on co-operation in the field of Water Resources Management under the MoU signed in 2009 between the Govt. of India and the Govt. of Australia with a validity of five years which was renewed in September, 2015 for another five years.

The rainfall data from state authorities received during 2015 are as follows :

Snowfall data

IMD has 47 snow gauge stations over Jammu & Kashmir, Himachal Pradesh and Uttaranchal. Hydromet Division, Pune is keying, processing and archiving these snowfall data. Snowfall data from Himachal Pradesh and Jammu & Kashmir (till Oct 2015) has been received.

Rainfall Data

Hydromet Division at Pune has computed monthly rainfall data series for districts, states, met sub-divisions and India as a whole based on data from 1901 onwards using uniform methodology. The CD-ROM (priced) consisting of 110 years (1901-2010) monthly rainfall data series for districts, states. met sub-divisions and all India have been brought by the division. The aforesaid publication is advertised in the official websites of IMD Pune, Delhi & MoES. Daily Rainfall normals (1951-2000) for 61 river basins of India has been prepared.

6.2. Meteorological Data Services

As a custodian of all meteorological data collected from 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 261.8 million records of which around 46.1 million records have been updated to the archives in the current year.

During the year 2014-15 NDC received 1156 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 under consideration 9,46,65,864 records were retrieved and supplied to different users. An amount of Rs.96,25,644/- and US $ 381 were collected towards the supply of data. The gridded rainfall & temperature data at various resolutions and district normals in CD form were supplied to total 96 various institutes, scientists and researcher across India and abroad during 1st January 2015 till date.

Digital Photography of Analysed Weather Charts-Phase-II:

In the Phase-I, the archival of about 5 lakh analysed weather charts have been completed and made available on NAS and on a web portal with URL: http://14.139.127.85/charts for access by remote users. The photography of about 2.5 lakh charts was taken up during this year and is nearing completion..

6.3. Agro Advisories Services

District level AAS bulletins are prepared and issued by Agromet Field Units (AMFUs) located in State Agricultural Universities, ICAR institutes, IITs etc. At present these bulletins are issued for 633 districts in the country.

Agrometeorological Observatories & Data Management

Agrimet Division maintains a network of agrometeorological observatories, evapotranspiration observatories, evaporation observatories, dewfall recording observatories and soil moisture observatories. The data received from these observatories are scrutinized, archived and supplied to scientists, planners etc. through NDC, Pune.

Weather Services – Agrometeorology

a. Preparation of Agromet Advisory Service (AAS) bulletins

AAS bulletins have been prepared and issued at district, state and national levels to cater to the needs of users at various levels. The district level bulletins are prepared and issued by Agromet Field Units (AMFUs) located in State Agricultural Universities, ICAR institutes, IITs etc. The bulletins include past weather, medium range weather forecast for next 5 days and specific advisories on field crops, horticultural crops, livestock etc. At present these bulletins are issued for 633 districts in the country.

b. Operational Agromet Advisory Service Bulletin based on Extended Range Weather Forecast and National Agromet Advisory Service Bulletin based on Monthly Weather Forecast

To help farmers to cope with climate risks and uncertainties and effectively use seasonal to inter-annual climate forecasts, IMD in collaboration with Indian Institute of Tropical Meteorology (IITM), Pune and Central Research Institute for Dryland Agriculture, Hyderabad started issuing AAS Bulletins based on extended range weather forecast and monthly weather forecast on experimental mode during southwest monsoon 2015.

Agromet Advisories for Preparedness under *Kharif* Crop Campaign based on Seasonal Rainfall Forecast.

c. Dissemination of agromet advisories

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. Under PPP mode, Reuter Market Light, IFFCO Kisan Sanchar Limited (IKSL), NOKIA, Handygo, National Bank for Agricultural and Rural Development (NABARD) are disseminating agromet advisories in SMS and IVR format to the farming community. In addition to that number of AMFUs has started sending agromet advisories through SMS in collaboration with National Informatics Centre (NIC)/Agricultural Technology Management Agency (ATMA) /KVK/NABARD/Internet. Agromet Advisories are also 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 during July 2013. At present 11.50 million farmers are benefitted by this service. Weather forecast and advisories under alerts and warnings through SMS now enable farmers in planning farming operations effectively to minimise/control damage of crops under adverse weather conditions.

Dissemination of weather based Agromet Advisories to farmers under pilotmode through Reliance Foundation Information Services (RFIS) in collaboration with IMD was also started during the year. Presently it is being disseminated in 7 States (Andhra Pradesh, Gujarat, Kerala, Madhya Pradesh, Maharashtra, Odisha, Tamil Nadu and Union Territory of Puducherry) covering 61 districts, 5400 villages and 45 crops and reached to 42,000 farmers directly and broadcasted one million messages.

d. Research & Development Project on AAS : Following R & D projects have been undertaken through different institutes for use in AAS.

(i) eAgromet : Ministry of Agriculture has designed a portal to generate automated Agromet Bulletins. 130 Agromet Field Units and State Meteorological centres are utilizing the portal to moderate the district level weather forecast and district level agromet advisory services bulletin.

(ii) Experimental Surface soil moisture estimation by passive microwave sensor of Advanced Microwave Scanning Radiometer (AMSR-2) and soil moisture estimation and forecast with gridded and value added rainfall using book keeping method was started.

(iii) Sowing suitability of crops during *kharif* season is initiated using the satellite data (AMSR-2) soil moisture content INSAT 3A CCD NDVI data.

(iv) Determination of soil moisture over India using Space Borne Passive Microwave Sensors onboard SMOS in collaboration with International Centre for Radio Science (ICRS), Jodhpur. Soil moisture for nine state maps are being generated using these data.

Future Plan : Standardization and validation of multi-source soil moisture products - AMSR-2 soil moisture, bucket model output and VIC model output will be carried out and soil moisture product for 1 km spatial resolution will be developed and made available to AMFUs for preparation of AAS. High resolution soil moisture will be estimated using multi ensemble technique along with the calibration of ground observation

e. New Initiative under Gramin Krishi Mausam Sewa : Agrimet Division has taken special initiative under the project "Gram Krishi Mausam Sewa" during 12th Five Year Plan to make agromet advisories more precise and accurate.

(i) Crop Specific Weather based Agromet Advisories for the country on daily basis are being telecasted through DD Kisan Channel, New Delhi since May, 2015 on real time in programs like 'Kisan Samachar' and 'Mausam Khabar' in Hindi and in regional languages of Gujarati, Marathi, Malayalam, Tamil and Telugu from October onwards.

(ii) Nowcast services to the farmers were launched through mKisan Portal of Ministry of Agriculture. Around 1 crore farmers registered under the portal are availing these services.

(iii) IMD in collaboration with CAB International will disseminate agro advisories in six states Bihar, Haryana, Jharkhand, Madhya Pradesh, Rajasthan, Uttar Pradesh targetting around 3 lakhs farmers. This will help farmers to take informative decisions and educate the farmers for moisture conservation methods, rain-water harvesting and benefit them to overcome the impact of expected weather conditions.

(iv) This Division has developed 'Excel based softwares using Visual Basics Application (VBA)' in house for data entry, scrutiny and archival of different kinds of Agromet data in prescribed format.

f. Forecasting Agricultural output using Space, Agrometeorology and Land based observations (FASAL)

Developed and issued crop yield forecast for Kharif 2015 for Jute for 3 states and rice at F1 and F2 stages for 14 states, sugarcane at F1 stage for 5 states, and cotton at F1 and F2 stages for 8 states during kharif 2015. Developed and issued crop yield forecast for rabi 2014-15 for rapeseed and mustard for 6 states and wheat for 9 states at F1, F2 and F3 stages respectively and potato at F1 and F2 stages for 5 states, rabi rice at F1 stage for 5 states and onion for the state of Karnataka and Gujarat.

IMD in collaboration with Mahalanobis National Crop Forecast Centre, Ministry of Agriculture, State Remote Sensing Centres and State Department of Agriculture conducted Crop Cutting Experiment (CCE) at Dharwad and Solapur (sorghum), Moradabad, Allahabad and Ganganagar (wheat) and Baragarh (rice) for real time estimation of rabi rice yield in farmers' field during the year.

g. Disaster Support; Disaster Weather Events and Verification; Forecast Verification

Agricultural Meteorology Division during April 2015 disseminated advisories to minimize the crop losses due to severe thunder storm and Maharashtra, West Bengal, Odisha, Karnataka hailstorms activity to around 5151253 farmers both in English and regional language in the states of, Madhya Pradesh, Chhattisgarh, Jharkhand, Bihar, Uttar Pradesh and Telangana.

6.4. Environmental Services

IMD continued to provide environmental meteorological services to the Ministry of Environment, Forests and Climate Change and carried out environmental impact assessment of 1546 development projects (Thmermal Power: 98, Industries: 615, Mining: 692 and Coal mining: 116) in 2015 in the country. Dr. S. K. Peshin, Sc-F & Head, EMRC and Dr. S. D. Attri, DDGM (O) & Scientist-F, IMD participated in monthly meetings as IMD experts.

IMD also provided air quality forecast services to public under the project SAFAR with IITM, Pune.

6.5. Astronomical 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 then Prime Minister, Late Pt. Jawaharlal Nehru 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 2015

1. The Indian Astronomical Ephemeris for the year 2015, an annual publication of Positional Astronomy Centre, which mainly contains positional data of the Sun, Moon and planets, basic data on yearly positions of fundamental stars, diary of celestial events, calendric data, eclipse data, explanatory text

and other useful information on astronomy has been published both in hard copy and soft copy format.

2. Fourteen language editions of Rashtriya Panchang of 1937 SE (2015-16 AD) and Sunrise-Sunset and Moonrise- Moonset tables for 2016 have been published during the year 2015. These are important regular publications of the centre catering to daily need of users of almanac, Panchang makers and other users.

3. Web based service has been started by the centre by creation of electronic versions of 14 language editions of Rashtriya Panchang which can be accessed by the users through a newly developed website.

4. 25th meeting of the Standing Advisory Committee (SAC) was held on 9th September 2015 at Positional Astronomy Centre, Kolkata under the Chairmanship of Prof. G. M. Ballabh of Osmania University, Hyderabad. The committee made some important recommendations for overall improvement in the functioning of the centre.

5. A pocket-type, card-size calendar containing brief information on important celestial events during the year 2016 published for benefit of users.

6. The centre has prepared monthly star charts and astronomical bulletins for 12 months during the year 2015 for giving useful guidance for watching celestial objects in the night sky. The bulletins contain brief texts explaining positions of objects in the sky and celestial diagrams showing positions for practical demonstrations.

6.6. Weather Forecast Services

IMD provided forecast, warnings and advisories to public and specialized sectors like aviation, agriculture, water resources, environment, defence, transport, energy health etc. and the information and products were also put on website.

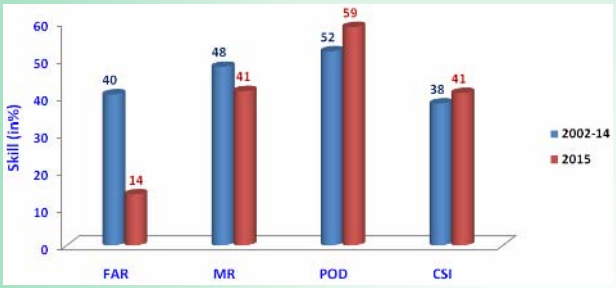
IMD website comprises of observed maximum temperature, minimum temperature, their departure from normal, 24-hour rainfall, sky condition and sunset/sunrise, moonset/ moonrise timings along-with 5-day weather forecasts of temperature, rainfall and warnings to 221 cities across the country till last year. Information on extreme weather events in the month alongwith all-time records, climatological data about mean daily maximum, minimum temperature, total rainfall, number of rainy days and mean number of days with hail, thunder, fog and squall etc. was also being provided.

In addition, to expand the dissemination of the weather forecasts to tourists, the information regarding the prevailing weather and the forecast of various cities, is also provided on toll free number 1800 180 1717 through Interactive Voice Response System (IVRS). IMD has also developed a mobile App called "Indian Weather" by which initially, current weather and 4-days forecast for 220 cities was being provided. At present 80 additional cities have been added with Graphical User Interface (GUI) totally re-designed for better navigation. Presently IMD issues thunderstorm forecast on the nowcast scale (3-hours validity) for 147 stations out of which 45 stations have been added to the App to provide thunderstorm forecast. IMD introduced Sector wise 7 days special forecast & warnings for Western Himalayan Region for Indian Army and application of forecast for generating advisory for heat wave for railways and highways has been taken up.

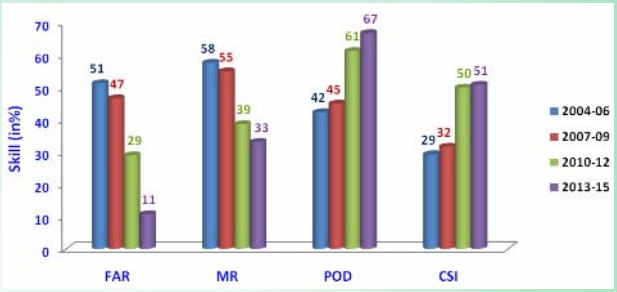
It also issued special forecasts for pilgrims of Char-Dham Yatra, Kailash-Mansarovar Yatra, Sri Amarnathji Yatra and Kumbh Mela. IMD has recently started weather information for Mata Vaishno Devi Shrine comprising of (i) Yatra Route Weather Advisory, (ii) current observations, (iii) 6-hourly low level wind and temperature forecasts for helicopter operation; and (iv) 3-day forecasts & warnings for Jammu Division.

Percentage Correct (PC) for Heavy Rainfall Warnings during monsoon 2015 was 80%.

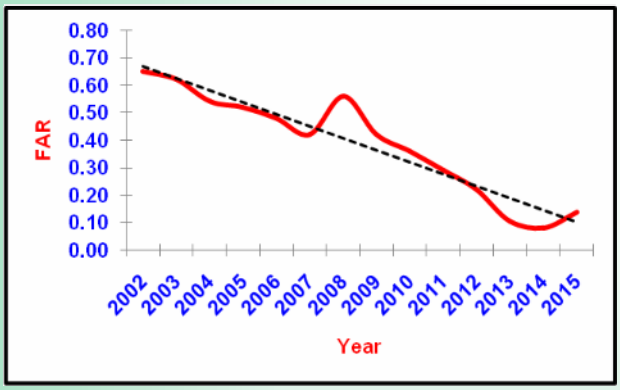
False Alarm Rate (FAR) & Missing Rate (MR) was 14% & 41%, respectively during monsoon 2015, this was 40% & 48%, respectively for the monsoon season period between 2002-14. Probability of Detection (PoD) & Critical Success Index (CSI) during monsoon 2015 was 59% & 41%, respectively. This was 52 % & 38%, respectively for the monsoon season period between 2002-14 as shown in following figure:

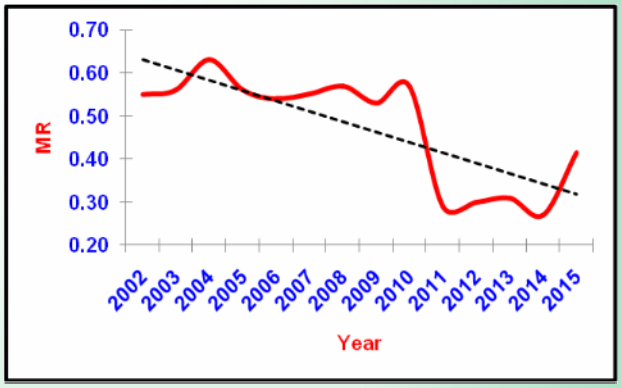


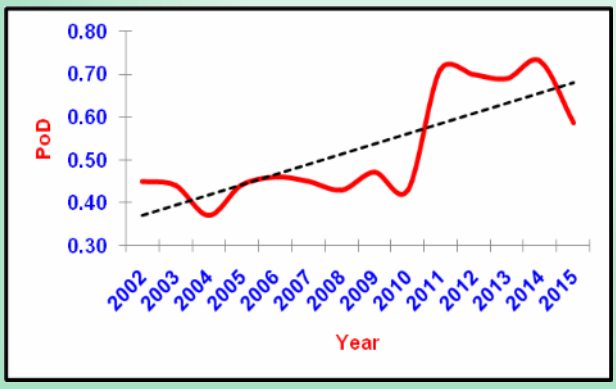
FAR & MR was 11% & 33% respectively for the period for 2013-15, was 29% & 39% respectively for the period for 2010-12 and was 47% & 55% respectively for the period for 2007-09 (as shown in Figure below). Hence, there has been significant reduction in FAR & MR in recent years (2013-15). Significant improvement is also observed in POD & CSI in recent years (2013-15) as shown in following Figure:

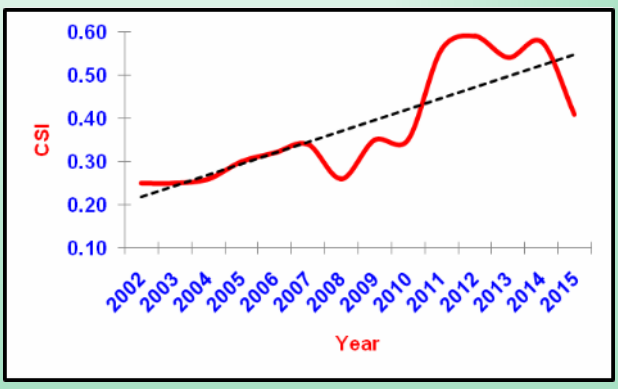


Overall for the period 2002-15, there has been consistent improvement in the accuracy and skill of operational forecasts and warnings issued by NWFC, as shown in figure given below:









Other Significant contribution

- Increased lead period of spatial weather forecasts & warnings from 72 hours to 120 hours in All India Weather Bulletin.
- Introduced Sector wise 7 days special forecast & warnings for Western Himalayan Region for Indian Army.
- Prepared and published a dedicated Meteorological Monograph, "**Forecast verification 2014**", which is first of its kind since establishment of IMD in 1875.
- Issued 10 expedition forecasts by including wind, temperature and weather forecast at different altitudes for various mountain peaks of Himalayas, which is appreciated by its users.
- Application of forecast for generating advisory for heat wave for railways and highways has been taken up.

6.7. Fog Forecasting Services

IMD continued to provide specilized fog forecasting for smooth functioning of air traffic in addition to services for the public.

Met office for IGIA has total of fifteen RVR systems made functional for real time use in December, 2015 at three RWY as per users requirements which provided live data of RWY specific fog conditions for use in flight landing/take off and CAT-ILS use by various seats at ATC at each 10-15 seconds at 24 × 7 through dual communication of land-line and wi-fi radio data link to ATC. Out of these fifteen systems, ten are from Indigenous IMD-NAL's Dristhi RVR and five are from Telvent Australian RVR systems. All Fifteen RVR instruments located at three RWY of IGI Airport worked uninterruptedly during fog of December, 2015 and provided RVR data round the clock. In fact the "newly installed five Indigenous new NAL's Dristhi RVR at RWY 29-MID-RWY 11 and at RWY 27 and RWY 27 MID" have worked smoothly. In fact, IGI airport has been the only airport in the world which has such very high number of fifteen RVR instrument working round the clock accurately during fog to guide pilots at various RWYs during take off/landing. IMD also has issued at each 30-minute current weather or MET REPORT and trend forecast on fog which were issued uninterruptedly for ATC for use in landing and take off.

Data from five new Dristhi RVRs of IMD-NAL at RWY 29-MID-11 and RWY 27, RWY 27-MID are first time successfully delivered at ATC seats for real time LVP operation at IGIA in fog/smog days in Dec 2015. All ten Dristhi RVRs are made first time live through IMD web site for all users from 30 December, 2015. Other historical new component which has been added this time for IGIA fog monitoring is for the first time is IITM-IMD, Ministry of Earth Sciences, are jointly conducting an observational campaign at IGIA Delhi since 17 December, 2015 and a total of thirty-one new instrument to monitor and to measure various fog characteristics including fog Micro-Physics have been installed successfully which are operational round the clock in the airport. Some of the instruments have been collecting data related to fog, for first time in India and for first time in Asia after China through such special fog campaign at Delhi. The observational campaign has included simultaneous measurements of surface meteorological conditions and, temp and moisture profile at each instant at lower levels by radiometer, lower level winds by LIDAR and SODAR and other instruments to measure radiation balance, turbulence, thermo-dynamical structure of the surface layer, droplet and aerosols microphysics, aerosol, fog water chemistry, to describe the complete environment in which fog develops. Some of these measurements has already been in use to improve the fog prediction skill.

Performance of fog forecasting system

The real time Fog forecast system at IGI Airport has been capable to forecast both occurrences and non occurrences of fog three categories, i.e., shallow, moderate and dense

TABLE 1

Forecast verification for fog and contingency Table 2008-2015 of December

Types	2008	2009	2010	2011	2012	2013	2014	2015
Hit	10	0	3	7	7	4	11	3
Correct Rejection (CR)	13	29	26	22	23	25	18	27
False Alarm (FA)	6	2	2	2	0	1	2	2
Under Warning / Missed (M)	2	0	0	0	1	1	0	0
Bias for occurrences (Bias Score) = (Hit+FA) / Hit+M	1.33	-	1.66	1.28	0.9	1.0	1.18	1.66
Critical Success Index (Threat Score) = Hit / (Hit+M+FA)	0.56	-	0.60	0.78	0.9	0.66	0.85	0.66
Percentage Correct	74%	94%	94%	94%	97%	94%	94%	94%

fog corresponding to visibility <1000m, <500m and <200m along with timings of their formation, lifting and lowest visibility likely to reach. Verification has been carried out only for occurrences and non occurrences Dense Fog Forecast of 18-hours validity issued at 1200 UTC evening of every day which have been operationally significant for users. Lowest visibility forecast has also been verified daily due to other fogs against realized and their timing of onset and lifting. The accuracy (percentage correct) of daily forecast of occurrences and non occurrences of dense fog, have been verified to be 94% which include 3 hits, 27 correct rejections with 2 False Alarm and not a single day has "Under warning or missed" as per contingency Table 1 enclosed. The accuracies of forecasts of timing of onset and lifting of fog reducing to a lowest visibility causing other fogs for the forecast period covering each night and morning against observed values have been verified. It shows the differences of forecasted onset and lifting timings of these dense fogs against those observed, are within 0-2 hours for 70% of dates out of total dates respectively when dense fogs were observed. The verification of lowest visibility forecasted during these dates against the lowest observed for dense fog dates shows almost 100% of these dates, an exceptional accuracy achieved during December, 2015, when their differences are within 100m.

6.8. Cyclone Warning Services

Cyclonic disturbances during 2015

During the year 2015, 12 cyclonic disturbances developed over north Indian Ocean (NIO) and adjoining land regions including 2 deep depression (DD), 1 cyclonic storm (CS) & 2 extremely severe cyclonic storms (ESCS) over Arabian Sea (AS), 1 depression (D), 1 DD & 1 CS over Bay of Bengal (BoB) and 2 D and 2 DD over land. Considering season-wise distribution, out of 12 disturbances, 8 developed during monsoon and 4 during post-monsoon season. The details of cyclonic activity over NIO during 2015 are presented in Table 2. Salient features of cyclonic disturbances during 2015 are given below:

(i) There were 4 cyclones over NIO including 3 over AS and 1 over BoB. Comparing with the long period average of 1891-2014, it was less than normal over BoB and above normal over AS. However, considering the recent years 1990-2014, the activity over NIO was normal, as normally 4 cyclones have developed during 1990-2014, though it was excess over AS and subdued over BoB.

(ii) During 2015, there has been no cyclone over BoB during both pre and post monsoon seasons and 1 and 2 cyclones developed over AS during monsoon and post-monsoon season respectively. Such type of nil cyclone activity over the BOB during both pre and post-monsoon seasons last occurred during 1959.

(iii) The significantly below normal activity over BoB may be attributed to strong El-Nino conditions during 2015 and it may be mentioned that during strong El-Nino years AS is more active as compared to BoB.

(iv) The higher activity over Arabian Sea was mainly during post monsoon season with development of 2 Extremely Severe Cyclonic Storms and 1 Deep Depression during October-November. It can be attributed to positive Indian Ocean Dipole (IOD) Index which helped in increasing the sea surface temperature over AS. Moreover, enhanced phase of Madden Jullian Oscillation (MJO) Index was over west equatorial Indian Ocean (Phase 2) with amplitude greater than 2. MJO Index greater than 1 is highly favourable for genesis and intensification of cyclones over Arabian Sea.

(v) Year 2015 has been first case after 2007 when there has been no landfalling cyclone over Indian coasts. This is mainly attributed to the fact there was no development of cyclone over BoB and the cyclones over AS moved towards Yemen coast.

(vi) 2 ESCSs developed over AS within a span of 7 days and followed almost similar tracks and crossed Yemen coast (ESCS Chapala crossed Yemen coast on 3rd Nov and ESCS Megh on 10th November). This was the first such case after 1999 when very severe cyclonic storm crossed Odisha coast near Gopalpur on 18th Oct followed by the Odisha Super Cyclone crossing Odisha coast near Paradip on 29th October (within a span of 11 days).

(vii) The total Accumulated Cyclone Energy (ACE) of the four cyclones over north Indian Ocean during 2015 was 30.95×10^4 knot^2 as against the mean of 13.1×10^4 knot^2 for the period 1990-2013 and the Power Dissipation Index (PDI) was 25.54×10^6 knot^3 as against the mean of 9.7×10^6 knot^3 for the period 1990-2013. It was mainly due to higher ACE and PDI over the Arabian Sea.

(viii) The total duration of cyclonic disturbances (Cyclones and above) during 2015 was about 26 days against the normal of about 20 days.

TABLE 2

Brief statistics of cyclonic disturbances over NIO and adjoining land areas during 2015

1.	Cyclonic Storm, ASHOBAA, over Arabian Sea (07-12 June, 2015)
2.	Depression over Bay of Bengal (20-21 June, 2015)
3.	Deep depression over Arabian Sea (22-24 June, 2015)
4.	Land Depression (10-12 July, 2015)
5.	Land Deep Depression (27-30 July, 2015)
6.	Cyclonic Storm, KOMEN, over Bay of Bengal (26 July-2 August, 2015)
7.	Land Depression (4 August, 2015)
8.	Land Deep Depression (16 -19 September, 2015)
9.	Deep depression over Arabian Sea (09-12 October, 2015)
10.	Extremely Severe Cyclonic Storm, CHAPALA, over Arabian Sea (28 October - 04 November 2015)
11.	Extremely Severe Cyclonic Storm, MEGH, over Arabian Sea (05 - 10 November, 2015)
12.	Deep depression over Bay of Bengal (08-10 November, 2015)

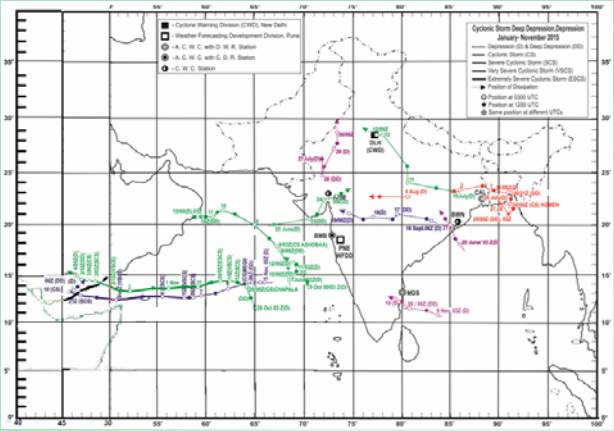


Fig. 1. *Consolidated tracks of cyclonic disturbances over NIO during 2015*

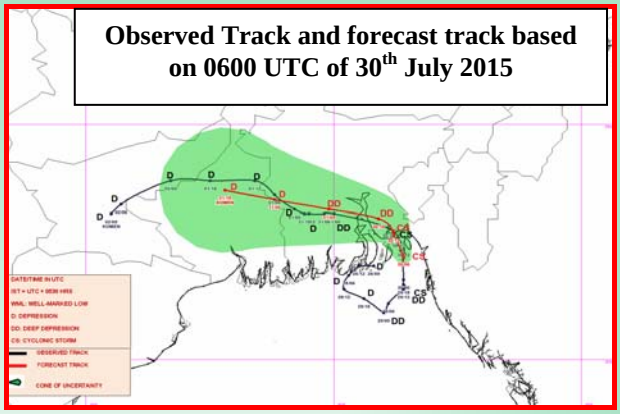
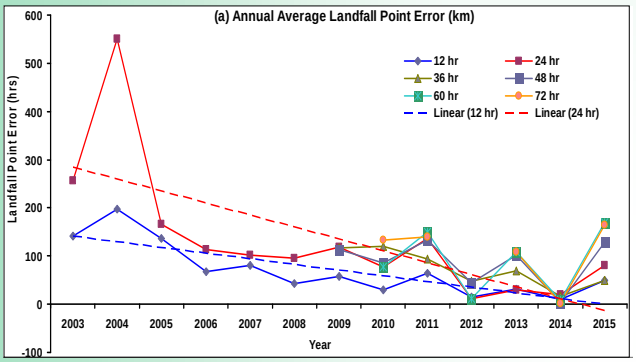
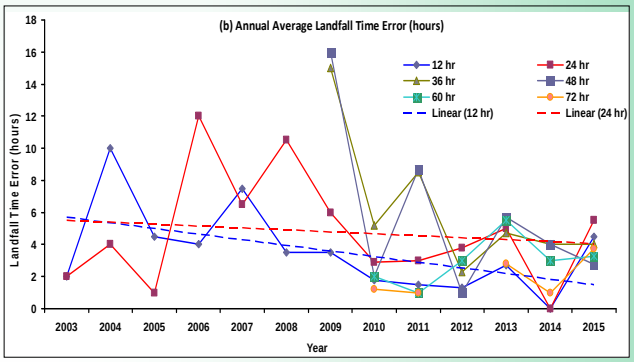


Fig. 2. *Forecast track along with cone of uncertainty issued on 0000 UTC of 30th July 2015 and the observed track of CS KOMEN during 26 Jul - 2 Aug 2015*





Figs. 3(a&b). *Annual Average (a) Landfall Point Error (km) and (b) Landfall Time Error (hours)*

Brief statistics and the consolidated tracks of the cyclonic disturbances over NIO are presented in Table 2 and Fig. 1. The life history and the characteristics features of the cyclonic disturbances during 2015 are described in following section.

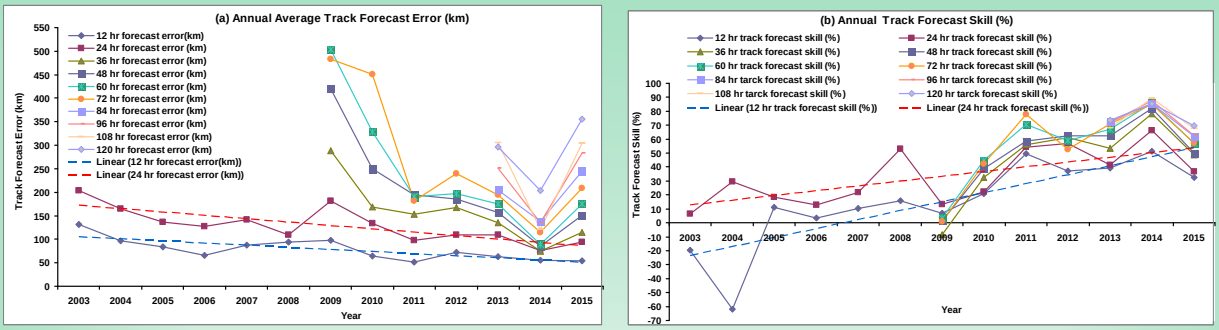
An example of forecast track along with cone of uncertainty issued on 0000 UTC of 30th July 2015 and the observed track of CS KOMEN during 26 Jul - 2 Aug 2015 is shown in Fig. 2.

Annual average track forecast error

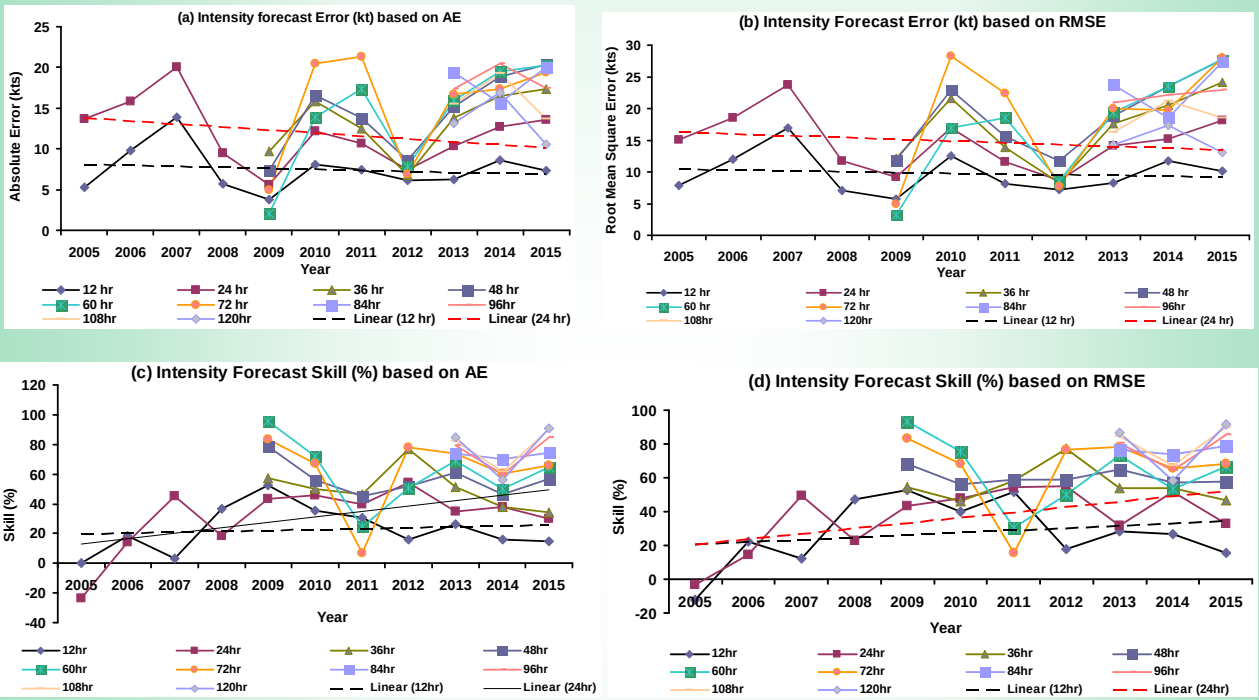
The annual tropical cyclone track forecast error has been calculated for the year 2014. The annual average track forecast error [Figs. 3(a&b)] has been 94, 151 and 209 km, respectively for 24, 48 and 72 hrs against the long period average error of 107, 164 and 230 km based on data of 2010-2014. The 96 and 120 hrs track forecast error were 283 and 356 km respectively. Also the track forecast skills compared to climatology and persistence forecast are 37%, 50% and 57% respectively for the 24, 48 and 72 hrs lead period which is lower than long period average of 2010-2014 (46%, 62% & 68% respectively) by about 10%.

Interannual variation

The landfall point and time forecast errors of cyclones over north Indian Ocean during 2003-15 are shown in Figs. 3(a&b). The track forecast errors and skills as compared to climatology and persistence (CLIPER) model based forecast errors of cyclones over north



Figs. 4(a&b). *Annual Average (a) Track Forecast Error (km) and (b) Track Forecast Skill (%)*

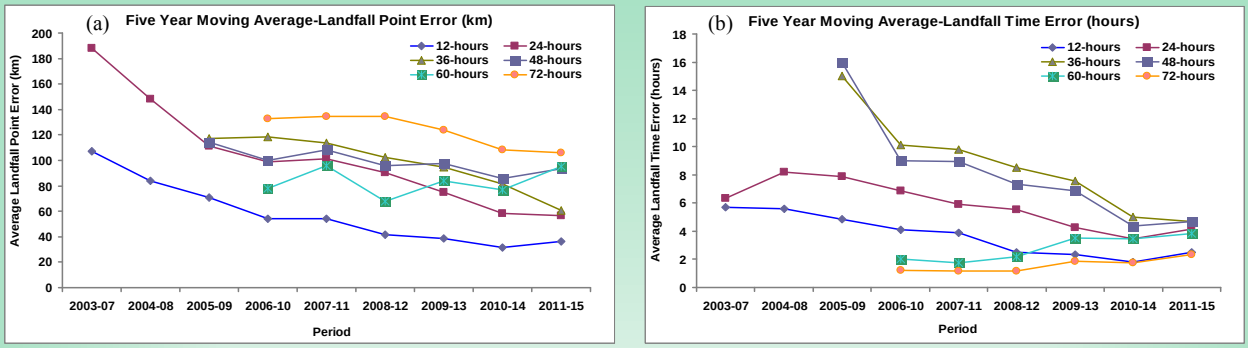


Figs. 5(a-d). *Annual Average Intensity Forecast Error (kts) based on (a) AE and (b) RMSE and Intensity Forecast Skill (%) based on (c) AE and (d) RMSE*

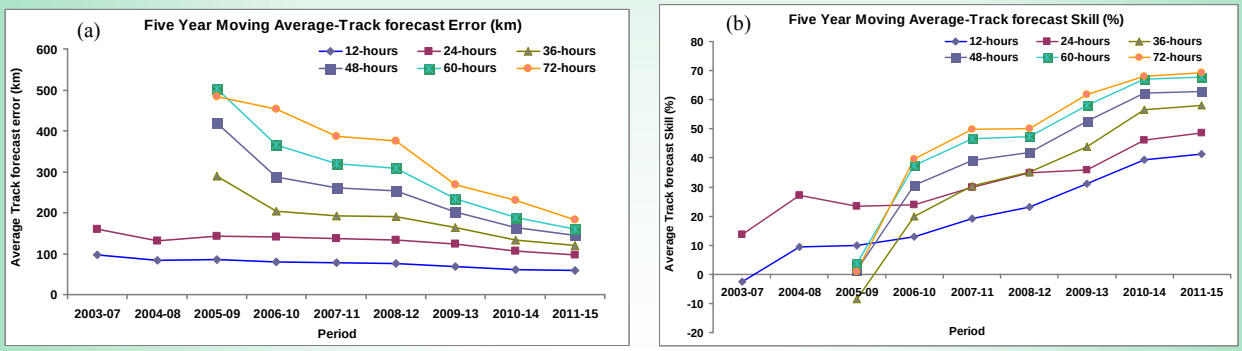
Indian Ocean during 2003-15 are shown in Figs. 4(a&b). The intensity forecast errors and skill as compared to persistence based forecast errors of cyclones over north Indian Ocean are shown in Figs. 5(a-d). It is observed that the errors are significantly less and skills are higher in recent years (2009 onwards) for all types of forecasts including track, intensity and landfall. It is mainly due to the modernization programme of Ministry of Earth Sciences and India Meteorological Department leading to enhanced observation, modeling, analysis tools and techniques and computation system. However, the rate of improvement has been highest in case of landfall point forecasts followed by track forecast. The rate of improvement in the intensity forecasts is relatively less like the other Ocean basins.

Five year moving averages of errors and skill

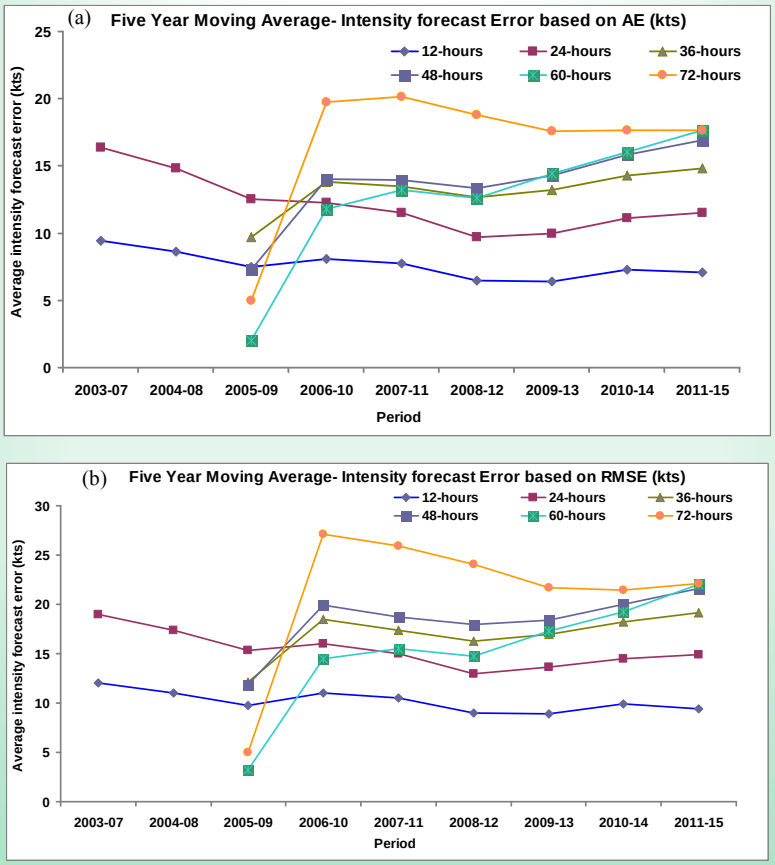
It can be seen from Figs. (6-9) that there has been continuous improvement in forecast



Figs. 6(a&b). *Five Year Moving Average (a) Landfall Point Error (km) and (b) Landfall Time Error (hours)*



Figs. 7(a&b). *Five Year Moving Average (a) Track Forecast Error (km) and (b) Track Forecast Skill (%)*



Figs. 8(a&b). *Five Year Moving Average Intensity Forecast Error based on (a) AE and (b) RMSE*

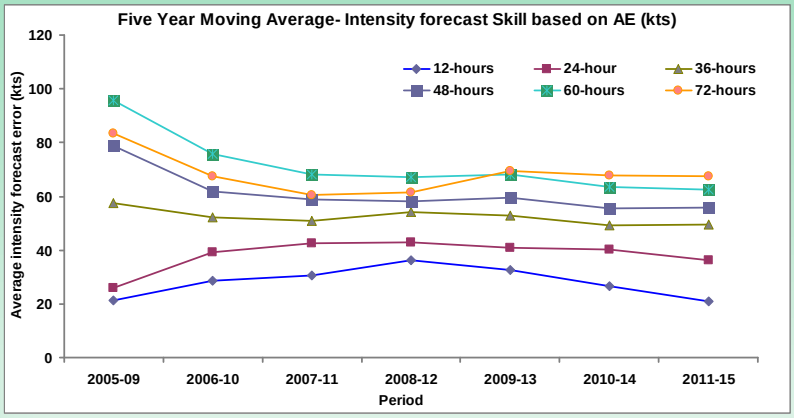


Fig. 9. *Five Year Moving Average Intensity Forecast skill based on AE compared to persistence forecast*

TABLE 3

No. of bulletins issued during 2015

S. No.	Bulletins	No. of Bulletins
1.	Press Release	13
2.	National Bulletin	110
3.	RSMC Bulletin	170
4.	DGM's Bulletin to higher officials at national and state level	7
5.	TCAC Bulletin (Text & Graphics)	71
6.	ADDR Bulletin to Hong Kong	71
7.	TC Vitals	77
8.	Quadrant Wind	71
9.	SMS to senior Govt. officials at national and state level by RSMC New Delhi	10726
10.	SMS through Kisan Portal	75125

accuracy with decrease in error and increase in skill over the years. However, due to modernization programme of IMD and other initiatives of MoES, the improvement has been more significant since 2009.

Regional Specialised Meteorological Centre

The Cyclone Warning Division/ Regional Specialised Meteorological Centre (RSMC)-Tropical Cyclone, IMD, New Delhi with all its resources for monitoring and prediction of cyclonic disturbances over the north Indian Ocean issues 3 hourly warning/advisory bulletins to national disaster management agencies including National Disaster Management (NDM), Ministry of Home Affairs (MHA), concerned state Govts and other users in regular intervals. It also issues advisories to World Meteorological Organisation (WMO) / Economic and Social Cooperation for Asia and the Pacific (ESCAP) Panel member countries including Bangladesh, Myanmar, Thailand, Pakistan, Oman, Sri Lanka and Maldives during cyclone period. For ESCS Chapala and Megh advisories were issued to Yemen and Somalia also. As Tropical Cyclone Advisory Centre (TCAC), it also issues tropical cyclone advisories with effect from the stage of cyclone for international civil aviation purpose as per the requirement of International Civil Aviation Organization (ICAO). The number of bulletins issued is given in Table 3.

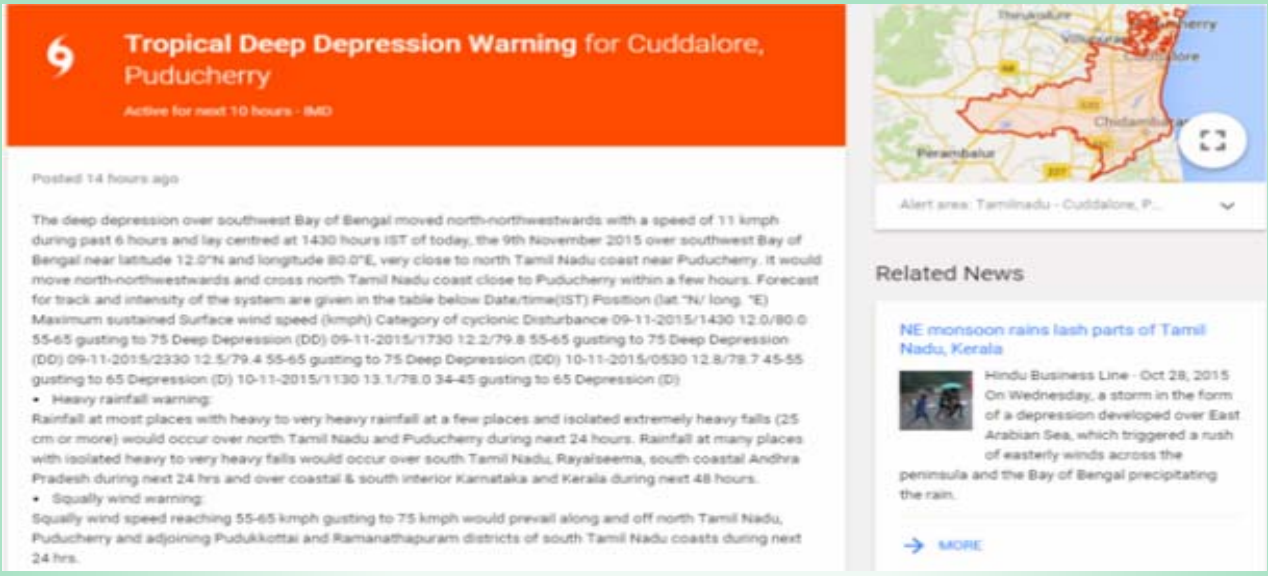


Fig. 10. *Screenshot of Google public alert in association with Deep Depression over the Bay of Bengal during 08-10 November 2015*

TABLE 4

IMD's classification of Low Pressure System from 2015

Nomenclature of Low Pressure System	Pressure defect (hPa)	T. No.	Max SurfaceWind speed in kts (kmph)
Low pressure area (LOPAR)	1.0	T1.0	<17 (<32)
Depression (D)	1.0- 3.0	T1.5	17-27 (32-50)
Deep Depression (DD)	3.0 - 4.5	T2.0	28-33 (51-61)
Cyclonic Storm (CS)	4.5- 8.5	T2.5-3.0	34-47 (62-87)
Severe Cyclonic Storm (SCS)	8.5-20.1	T3.5	48-63 (88-117)
Very Severe Cyclonic Storm (VSCS)	20.1-40.5	T4.0-4.5	64-89 (118-165)
Extremely Severe Cyclonic Storm (ESCS)	40.5-79.9	T5.0-T6.0	90-119 (166-220)
Super Cyclonic Storm (SuCS)	>79.9	T≥6.5	120 or more (≥221)

Major initiatives

Following were the major initiatives taken by IMD for monitoring, prediction and warning services during the year 2015:

(i) Observational & monitoring aspects: Based on NASA/GSFC's GPM satellite estimated rainfall data, GPM-gauge merged rainfall data at 0.25° × 0.25° resolution is generated based on a joint initiative of IMD-NCMRWF and made available for monitoring of heavy rainfall associated with Cyclonic Disturbances over the NIO.

(ii) Prediction Technique: Hurricane Weather Research Forecast (HWRF) model was run by IMD every six hrs based on 0000, 0600, 1200 and 1800 UTC during cyclone period with 27/9/3 km resolution and products were made available to Cyclone Warning Division.

(iii) Severe Weather Forecasting Demonstration Project for Bay of Bengal (SWFDP)

(iv) Introduction of extremely severe cyclonic storm category

Based on a review of IMD's classification of low pressure systems (LPS) in the light of classifications followed in other oceanic basins, IMD has introduced with effect from 2015, a new category of description of low pressure systems – Extremely Severe Cyclonic Storm (ESCS) by bifurcation of the then existing category of Very Severe Cyclonic Storm (VSCS). IMD's present classification of LPS is presented in Table 4.

(i) Warnings Dissemination technique

(a) SMS to registered general public were issued during cyclonic disturbances affecting India with effect from 2015. 10726 SMS (government officials and general public) were disseminated during 2015.

(b) Synergised Fishermen warnings

Warnings issued by IMD are included in INCOIS's Potential fishing zone information and displayed in the INCOIS's electronic display system with effect from November 2015.

(c) CAP feed for Google's Public alerts

IMD is in the process of implementation of common alert protocol (CAP), a WMO recommended standard format for multi-hazard warning dissemination through multi-platform devices. IMD has issued experimental CAP feed for CDs making landfall over Indian coasts during 2015 for Google's initiative for Public Alerts through Google search. Screenshot of the alert is shown in the Fig. 10.

(d) Coastal and sea area bulletins for shipping through NAVTEX

IMD started issue of coastal weather bulletin and sea area bulletin for coastal shipping and high sea shipping respectively through NAVTEX stations installed by Directorate General of Light house and Light Ships (DGLL) from 30th March, 2015. This replaces earlier dissemination mode through coastal radio stations which were unserviceable for last few years. This was achieved through continuous initiative of IMD with DGLL.

Severe Weather Forecasting Demonstration Project

RSMC New Delhi has been identified as the specialised meteorological centre for issuing SWFDP warnings to countries such as Bangladesh, Myanmar, Thailand, Sri Lanka and Maldives in BOB region. The project includes warnings for tropical cyclones, heavy rainfall, strong winds and sea waves. A separate web page has been developed for SWFDP (BOB) in the RSMC New Delhi web site and warning products were uploaded during the SWFDP training programme conducted at Bangkok during 14-24 September 2015. A sample SWFDP short range forecast guidance product issued based on 0300 UTC of 18th September 2015 is shown in Fig. 11.

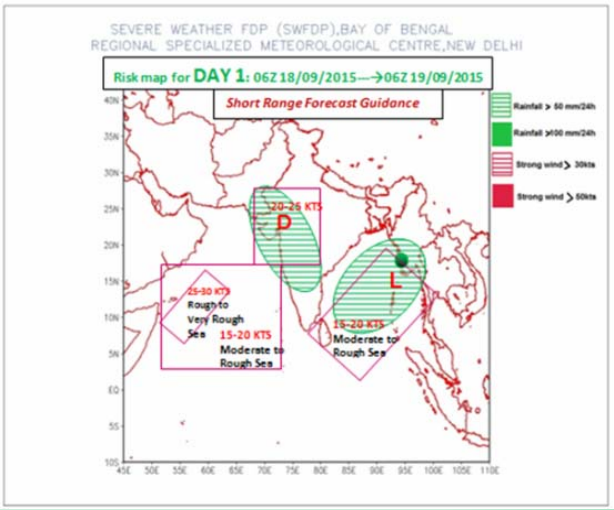


Fig. 11. *Short range forecast product generated for SWFDP based on 0300 UTC of 18 September 2015*

CHAPTER 7

EARTHQUAKE MONITORING AND HAZARDS

7.1. National Center for Seismology

National Center for Seismology (NCS) established as an attached office of Ministry of Earth Science (MoES), vide A. O. No. MoES/25/15/2012-Estt dated 20-8-2015 by reorganizing seismological related activities of India Meteorological Department (IMD) and Ministry of Earth Sciences. The broad and ultimate objectives of the NCS are:

- Provide earthquake (M:3.0 and above) related information to all user agencies in shortest possible time.

- Provide earthquake hazard and risk related products of specific regions required by various agencies as mitigative measures for design and construction of earthquake resistant structures, land use planning and for enacting building bye-laws towards minimizing damage to property and loss of lives due to earthquakes.

- Carry out research in pure and applied seismology and earthquake precursory phenomena, earthquake processes and modelling.

NCS is the nodal agency of Government of India, primarily responsible for monitoring seismic activity in and around the country. The operational task of the Center is to quickly estimate the earthquake source parameters immediately on occurrence of an earthquake and disseminate the information to all the user agencies including the concerned State and Central Government agencies responsible for carrying out relief and rehabilitation measures. The information relating to under-sea earthquakes capable of generating tsunamis on the Indian coastal regions is also disseminated to all concerned user agencies including the Indian National Centre for Ocean Information Services (INCOIS), Hyderabad for issue of tsunami related messages and warnings. The earthquake information is transmitted to various user agencies including public information channels, press, media etc. using different modes of communication, such as SMS, fax, email and also posted on Website (www.imd.gov.in). Major achievements of the Center during the year are given below, activity-wise:

A. Observational Seismology, Earthquake Monitoring & Services

NCS is maintaining a country-wide National Seismological Network (NSN) consisting of a total of 82 seismological stations. This includes: a) 16-station V-SAT based digital seismic telemetry system around National Capital Territory (NCT) of Delhi, b) 20-station VSAT based real time seismic monitoring network in North East region of the country and (c) 17-station Real Time Seismic Monitoring Network (RTSMN) to monitor and report large magnitude under-sea earthquakes capable of generating tsunamis on the Indian coastal regions. As part of an international commitment, continuous real time seismic waveform data of three seismic stations viz., Portblair, Minicoy and Shillong is being transmitted to Incorporated Research Institutions of Seismology (IRIS), Washington, USA, for early warning of tsunamis. The National Seismological Network is in successful operation.

A total of 2280 earthquake events were detected and auto-located during the period

January-November, 2014. These include 1547 events of magnitude 5 and above. Information pertaining significant events were transmitted to all concerned state and central government agencies dealing with relief and rescue operations in the region and also posted to website. A software module for issue of bulk SMS messages is functional for dissemination of (a) Earthquake hypocentral parameters (as SMS Level-1) to selected designated authorities on auto-location of an earthquake event by RTSMN system and (b) Issue of Final earthquake hypocentral parameters (as SMS Level-2) to a large number of users simultaneously in least possible time.

During this period, an earthquake of great intensity (Magnitude 7.9) occurred on 25th April 2015 at 11:.41 hrs IST in Nepal (about 80 Km NW of Kathmandu), severely felt in the epicentral and adjoining areas and caused major damage in the epicentral region and Kathmandu. About 8000 people lost their lives and about 20000 people injured in Nepal. This event was also felt in all northern, eastern and some parts of central India and some damage in adjoining UP and Bihar. The main shock was followed by number of aftershocks including two major aftershocks of Magnitudes 6.6 and 6.9 on 25th and 26th April, 2015 respectively. Till 30.4.2014 more than 70 significant aftershocks have been detected and located by the national seismological network of NCS. Another great earthquake of magnitude 7.3 occurred on 12th May 2015 at 12:35 HRS (IST) in Nepal (about 60 km East of Kathmandu), 16 days after the 7.9 magnitude mainshock which occurred 80 km northwest of Kathmandu. This earthquake further caused loss of lives and damage to structures in Nepal and some parts of adjoining UP and Bihar in India.

In addition, another great earthquake of magnitude 7.5 occurred on 26 October 2015 at 14:40 hrs IST in Afghanistan about 260 Km north-Northeast of Kabul. The event was severely felt in all northern states of India, including Delhi and NCR. This earthquake is the largest in past fifty years from the Hindukush region.

The digital seismic waveform data from the network are being uploaded into the waveform database of SeiscpmP3 software of ISGN data centre at NCS, HQ for systematic storage and archival purposes. During the year, continuous waveform data of Real Time Seismic Monitoring Network (RTSMN) for the period starting from year 2009 to 2013; NE Telemetery data for the period 2011 and 2012; and Delhi Telemetry data for the period starting from Year 2005 to 2014 have been completed. The Data Centre has a web portal (http://www.isgn.gov.in), which gives access to the registered users for downloading the waveform data for research purposes.

A project of upgradation of 44 existing seismological observatories and establishment of 34 new seismological observatories has been initiated. As on 14-12-2015, a total of 23 seismological observatories have been upgraded and one new observatory has been established. These observatories have been integrated with operational centre through VSAT communication facility established under the Integrated Seismic and GPS Network (ISGN). Upgradation work at remaining observatories is in progress.

A new webpage has been developed for online intensity survey of felt earthquakes; similar to “Did You Feel It (DYFI).” This page provides epicentral map, intensity map (simulated) and DYFI map based on a felt report along with basic parameters. The URL of the page is http://125.21.185.24/eq_info/eq.html.

DYFI maps along with other maps of Nepal earthquake of 25th April 2015 (M : 7.9) and its largest aftershock of 12th May 2015 (M : 7.3) were generated and uploaded on the webpage. Simulated intensity map and DYFI map was useful for relief and rescue purpose during Nepal earthquake. DYFI and intensity map for Nepal earthquake of 25th April 2015 (M : 7.9) is enclosed (Annex-1, 2).

The earthquake bulletins are prepared on monthly basis and archived vis-à-vis also sent to the International Seismological Center.

Seismological data and earthquake related information is supplied to various user agencies dealing with relief and rehabilitation measures, earthquake disaster mitigation and management related matters, seismic zoning, etc. Earthquake data is also being supplied to various scientific, academic and R&D institutions for research purposes. On request basis, the earthquake data and site specific seismicity reports are supplied to industrial units, power houses, river valley projects etc and a revenue worth Rs. 4.0 Lakhs was realized from different parties during January- November, 2015.

B. Earthquake Hazard and Risk Assessment:

1. Seismic hazard microzonation of NCT Delhi on 1: 10000 scale

The seismic hazard microzonation analysis of NCT Delhi on 1:10,000 scale has been completed based on a state-of-the-art Probabilistic Seismic Hazard Analysis (PSHA). Earthquake sources and parameters, considered for the area covered under 350 km radius from Delhi, (Latitude 24° – 31.5° N and Longitude 74° – 81.5° E). This area includes part of Himalayan region which recorded maximum magnitude earthquake of M:6.9 in Chamoli (1999) so for, which is about 300 km from Delhi and produced horizontal PGA of 11cm/s^2 at Delhi. After completing the field investigations for geotechnical, geophysical, laboratory tests on samples collected and data processing and analysis, a detailed report was prepared by the Expert Committee in the year 2014 and submitted to the Secretary, MoES. Subsequently, an abridged report based on main report was compiled and put on IMD and MoES website in 2015 for use to scientific community and other stake holders. This report is also provided to the **National Capital Region Planning Board** (NCRPB) for their document "Vision 2020" under Disaster Mitigation for better planning and development and reported in Chapter 15. The Product generation Hazard Index Map of Seismic microzonation of NCT Delhi on 1: 10,000 scale has been provided to the Delhi police for safe construction in Delhi to control the Disaster.

The first and foremost task in the Seismic Hazard Microzonation, study of NCT Delhi, was generation of base toposheets by Survey of India and geological map by Geological Survey of India on 1:10000 scale. NCT Delhi was presented in 75 sheets in 1:10000 scale, each covering an area of about 20 to 25sq km. Available Geological Map on 1:25,000 scale was upgraded on 1:10000 scale using high resolution old aerial photographs, quick bird satellite imagery and limited field check.

Seismic Hazard Microzonation has been carried out in six parts. Firstly, estimation of Seismic hazard at engineering bedrock (Shear wave velocity 760m/s) using seismotectonic and earthquake information within a radius of 350 km from NCT Delhi in collaboration with IIT Roorkee. Secondly, study of soil characteristics based on generated geotechnical and geophysical data at different sites. Thirdly, site characterization based on shear wave velocity evaluated from geotechnical and geophysical techniques. Fourthly, determination of Predominant frequency (Peak frequency) and Peak amplification corresponding to the peak frequency of soil columns above Seismic bedrock using experimental technique based on H/V ratio of microtremors. Fifthly, strong ground motion parameters estimation at surface at 449 sites spread over NCT Delhi by carrying out one-dimension (1-D) ground response analysis, using DYNEQ software. Sixthly, liquefaction susceptibility evaluation using Seed and Idriss simplified approach (Idriss and Boulanger 2005). Finally, all these parameters were integrated in GIS and integrated Hazard Map of NCT Delhi was developed.

The PGA for Delhi region obtained from PSHA analysis at engineering bedrock varies from 0.18g to 0.31g for MCE and 0.09g to 0.16g for DBE. The Peak Ground Acceleration after free surface correction at engineering bedrock varies from 0. 067g to 0.114g for MCA and from .035g to .058g, for DBE.

A comprehensive programme of geotechnical, geophysical investigations was taken up for site characterization, and ground response study. At 449 sites geotechnical data were collected by drilling boreholes, mostly up to 30m depth and DS/UDS soil sampling at each 1.5 m depth. Index properties of soil from all collected soil samples were evaluated in laboratories. On a few samples special tests such as triaxial /cyclic triaxial and Resonant Column tests have also been performed for evaluation of c, Ø, Shear modulus reduction and damping curves etc. Geophysical investigations such as MASW at 110 sites and CHT/DHT at 25 sites were also carried out for evaluation of in-situ shear wave velocity. On the basis of in-situ shear wave velocity and N values collected at a few common sites local empirical relations were developed for different types of soil, to make use of N value for evaluation of shear wave velocity.

Making use of the above data and input time histories generated based on UHRS, ground response study were performed at all the 449 sites, using DYNEQ software. Based on ground response study, PGA at surface, PGA at different depth, Amplification factor, Peak frequency, Peak amplification, were evaluated at all the 449 sites. Site specific different types of response spectra were also generated at all the 449 sites. Based on response spectra, spectral acceleration values at different periods were evaluated for all the 449 sites.

Discrete site specific values of different parameters evaluated at all the 449 sites were converted in continuous surface using Inverse Distance Weighted (IDW) interpolation technique. Making use of this continuous data different thematic maps have been generated for (i) 2% probability of exceedance in 50 year (based on MCE) and for (i) 10% probability of exceedence in 50 year (based on DBE). Site specific values can be picked up from these GIS base maps and may be used for design of buildings at those particular sites.

PGA at surface obtained from the ground response study for 2% probability of exceedance in 50 years (MCE) for 5% damping varies between 0.168g to 0.479 g. The lower PGA values less than 0.18 were estimated in a very small area of ridge. PGA values at most of the sites are within 0.42g except at two sites, where PGA values are 0.47g and 0.44g respectively due to high impedance contrast between first two layers below ground surface. PGA values for 10% probability of exceedance in 50 year (DBE) for 5% damping varies between 0.089g and 0.255g. PGA values at most of sites is below 0.21g except at a few site where PGA is between <0.21 to 0.255g. Uncertainties in evaluation of PGA at surface have also been worked out which are ± 0.06g for MCE and ±0.03g for DBE.

Peak frequency (Natural frequency) and Peak amplification of soil column above seismic bedrock were evaluated at 500 sites using Nakamura technique based on noise survey and Peak frequency and Peak amplification of soil column above engineering bedrock were also evaluated at 449 sites using numerical technique, to be used for deciding sites for construction of buildings of appropriate height to avoid resonance. Liquefaction susceptibility of soil at different depths were also carried out and site specific factor of safety have been evaluated using a simplified procedure based on empirical correlations with Standard Penetration Tests (SPT).

Based on the different investigations and assigning weightages, a seismic hazard microzonation map of Delhi on 1:10,000 scale is prepared (Fig. 1). A few other important maps are also attached.

2. Seismic hazard microzonation of targeted cities

NCS has taken an initiative to carry out the seismic microzonation studies for proposed 30 Indian cities having population more than half a million and lying in the seismic zone III, IV and V. In this regard, the collaboration work among Survey of India (SoI), Geological Survey of India (GSI) and some other departments are initiated.

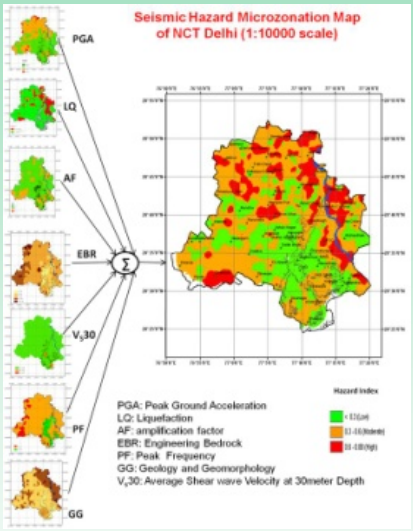
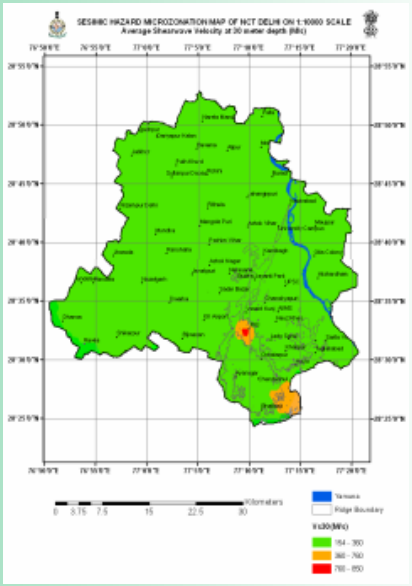
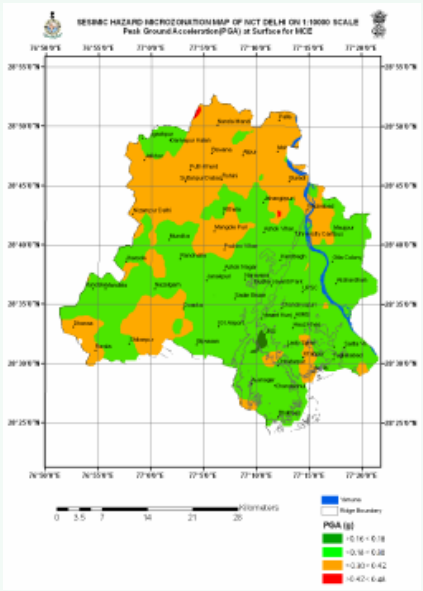


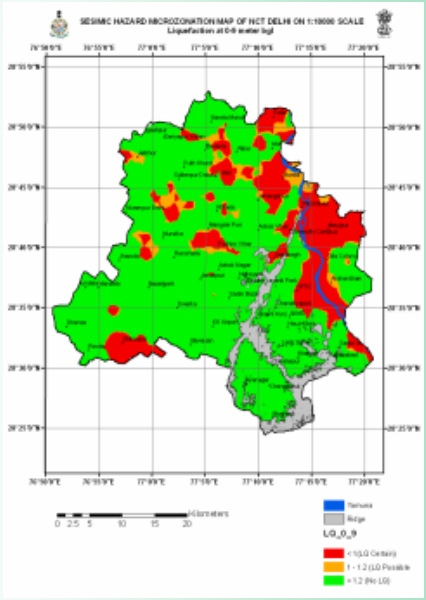
Fig. 1. *Seismic hazard microzonation map*



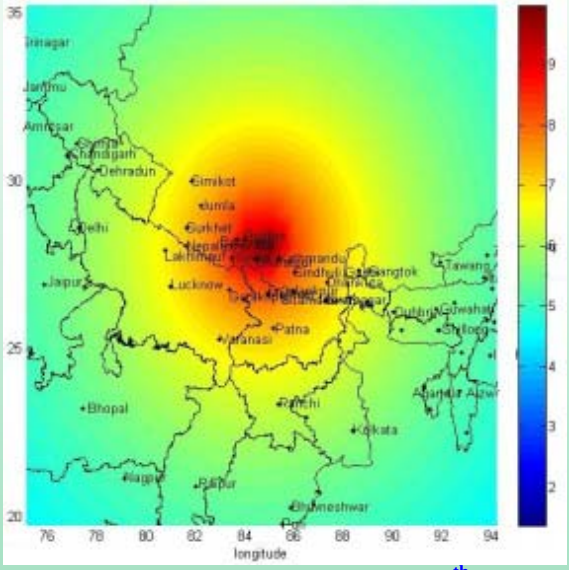
Average shear wave velocity up to 30m depth



Peak Ground Acceleration at the surface for MCE



Liquefactions map for NCT Delhi Region



Simulated Intensity Map of Nepal earthquake of 25th April 2015 (M : 7.9)

CHAPTER 8

CAPACITY BUILDING, PUBLIC AWARENESS & OUTREACH PROGRAMME

IMD initatited major initiative in 2015 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 and organised training programmes, user workshops, conferences etc. Salient details are as under.

IMD participated in the "102nd Indian Science Congress" at Mumbai and received the '**Most Innovative Pavilion' and a 'Appreciation Letter'.**

8.1. Workshop & Conferences

One day workshop (Farmer-Scientist interaction) at Doiwala, Dehra Dun on 21st January, 2015 was organized jointly by AMFU at IIT Roorkee and IMD to get feedback from the farmers to serve them in a better way. Farmers appreciated the weather forecast issued by Meteorological Centre, Dehra Dun and gave examples of saving the Toria crop based on our weather forecast.

A training workshop on "**Improvement in District Level Weather Forecast**" was organized by MC, Thiruvananthapuram on 28-29 September, 2015 at Banquet Hall, Govt. Guest House, Thiruvananthapuram. DDGM (Agrimet), DDGM (NWP), DDGM RMC Chennai and officers involved in DLWF of all State Agro Meteorological Centres (SAMC) participated in the programme.

Training Workshop on Improvement of value added daily weather forecast conducted to the Agromet Unit Incharges of all RMCs and MCs during 28 - 29 September, 2015 at Thiruvananthapuram.

DDGM, RMC Chennai addressing the participants

RMC, Chennai conducted one day IMD Website familiarization workshop on 27th October, 2015 at RMC Chennai for 15 No.'s of Power System Operation Corporation Limited (POSOCO) officials from Southern Regional Load Dispatch Centre (SRLDC), Bangalore. The training concentrated on utility of weather information and forecast products in the IMD website and on their impact on the power systems load and generation management.

Shri B. Mukhopadhyay, Sc. 'F'ADGM(R) attended the conference on "10th Biennial Flagship Conference Agri Corp 2015 as a Chairman and Panel Member for Session "Emerging Technologies for Value Addition and Risk Mitigation" at Mumbai on 3rd November, 2015.

8.2. ACR & AMR Meeting

Dr. Medha Khole, Sc. 'E' & DDGM (WF), Pune and Smt. Sunitha Devi S., Sc. 'D' participated in the Annual Cyclone Review & Annual Monsoon Review meetings were held

at Regional Meteorological Centre, Kolkata, during 22 - 23 January, 2015. The technical work of the said meetings such as preparation of working papers, monitoring the progress of recommendations of the last year's Annual Review Meetings, their circulations to all delegates and other allied work was co-ordinated.

8.3. Training

IMD training division imparted training to 539 personnel from IMD and defence forces in 2015 in Delhi and other offices, details of which are as under:

Long term training of 4-12 months : 179
Short term training of 1-2 weeks : 41
Ongoing training (4-12 months) : 119

Other training activities

Summer training of 6-8 weeks was provided to B Tech / M Tech / M Sc students in 2015 at HQ and other offices.

IMD Pune in association with IMS Pune Chapter and IITM Pune organised the five day "Training Workshop for Teachers" during 4-8 May, 2015.

Online training on E-agromet system was imparted to all Agromet Field Units (AMFUs) of the country during the period February to March 2015 for demonstration on generation of advisories using farmers portal through video conferencing by the officers of Agricultural Informatics Division, NIC, New Delhi.

"Use of Multiple Crop Models and Decision Support System in Agrometeorological Advisory Services" was conducted during 22-27 March, 2015, at PJTSAU, Rajendra nagar, Hyderabad.

DSSAT Training course on "Cropping System Models for Application in Land Resource Management" at ICRISAT, Hyderabad during 23-27 March, 2015.

AMFU, Srinagar, SKUAST-K, J & K organized a training program/working group meeting (GKMS/ FASAL) on "Use of Crop Simulation Model and Decision Support System in Agromet Advisory Services" during 8-14 June, 2015. Thirty one participants from Jammu and Kashmir, Himachal Pradesh and New Delhi attended the training programme.

Crop Simulation Model based Crop Yield Forecasting system for sorghum with special reference to Karnataka and Maharashtra was organized during 22-26 June, 2015 at AMFU,

Navile, University of Agricultural and Horticultural Sciences (UAHS), Shimoga, Karnataka.

Agromet Observers' course of 2 weeks duration was conducted for newly recruited observers at various Agrometeorological Field Units (AMFUs) from 24th August, 2015 to 4th Spetember, 2015. Total 19 participants from various AMFUs participated in this training Course.

Four weeks' Summer Placement course for B. Tech. (Agril. Engg.) students was conducted during 1-26 June, 2015. Seventeen students from different Agricultural Engineering colleges (viz., Parbhani, Rahuri and Karad) attended the training course.

Agro-meteorological aspects of sustainable agriculture and food security: Regional initiatives and challenges' on 8th September, 2015 in the Training programme on "Use of remote sensing and GIS for Crop Growth Monitoring and Yield Prediction" was conducted at IIRS, Dehradun during 31st August - 20th September, 2015.

A training workshop on "Improvement in District Level Weather Forecast (DLWF)" was conducted at M.C. Thiruvananthapuram on 28-29 September, 2015.

Trainees from Anna Institute of Management, Chennai visited RMC Chennai on 30th January, 19th February and 5th March, 2015 as part of Induction Training program for familiarization and exposure. Field visit to units were arranged for 155 trainees.

A lecture cum demonstration class for training programme on "Disaster Management" for Deputy Collector Trainees on 24th June, 2015 on "Role of IMD in Early warning & Disaster Preparedness".

8.4. Awareness & Outreach Programme

The National Science Day was celebrated in IMD office premises, Shivajinagar, Pune on 27th February, 2015. All the offices in IMD, Pune participated in the celebration. On this occasion an exhibition was arranged in the main building of IMD Pune. ADGM(R) inaugurated the exhibition. It was attended by a large number of students, scientists, scholars, journalist and general public. All visitors marked their comments with great enthusiasm in feedback register.

Farmers' Awareness Programme: Farmers' awareness programmes were organised at 51 AMFUs across the country namely Sonitpur, Ambikapur, Lam, Akola, Bharatpur, Bikaner, Pundibari, Agwanpur, Bhawanipatna, Bhatinda, Kharagpur, Imphal, Rajouri, Dapoli, Delhi, Jagtiyal, Coimbatore, Diphu, Gurdaspur, Brahmavar, Kaul, Sabour, Shillongani, Tirupati, Majihan, Dantiwada, Roorkee, Junagarh, Jaipur, Allahabad, Anand, Bangalore, Bhubaneswar, Hisar, Jorhat, Kalyani, G. Udaigiri, Parbhani, Pilicode, Palampur, Udaipur, Ranchi, Ranital, Thrissur, Pusa, Sehore, Vellayani, Morena, Lamphelpat, Kanpur and Navile. Besides, the Nodal Officers/Technical Officers participated in number of awareness programme and taken active initiatives in popularising the GKMS. AMFUs also arranged field visits, field demonstration, farmers' interaction and also participated in Kisan Mela

IMD officials participated in Project evaluation study in respect of dissemination of weather, crop and advisory to the Farmers' Club member through KVKs in Maharashtra State. Jointly with NABARD.

Officials from Agricultural Meteorology Division participated in the first edition of the Krushik Live Demos & Agri Expo held from 6-8 November, 2015 at Baramati, Pune, Maharashtra.

Important Visitors

Dr. M. Jerraud, Secretary-General, World Meteorological Organization in March 2015.

Dr. B. N. Satpathy, Sr. Advisor, NITI Aayog (Planning Commission) visited ATC Met/MBR/Area Control facilities of AMO

Palam on 8 February. He took special interest on functioning and performance of Drishti provided by NAL-IMD.

Professor Robert James Wasson from National University of Singapore visited Met. Centre, Dehradun, on 19 March and discussed about weather forecast and warning during Kedarnath disaster-2013.

Prof. Lucy J. Robertson, Head of Parasitological Deptt. of Food Safety and Infection Biology, Norway, along-with faculty of PGI, Chandigarh visited Met Centre, Chandigarh on 19 March and discussed the weather and climate services provided by this office.

Shri N. N. Vohra, Hon'ble Governor of J&K visited Met. Centre Srinagar on 31st March in connection with inspection of Doppler Weather Radar. He was briefed about the functioning of Radar.

A delegation of six scientists from Finnish Meteorological Institute visited IMD with FMI and IMD scientists was held during 28-29 January, 2015 to discuss the project work under the ambit of cooperation agreement.

3-Member delegation led by Director, DRA, WMO visited IMD in July 2015 in South East Asia.

Korean Delegation led by Administrator, KMA had a meeting with DGM, IMD in March 2015 regarding MoES-KMA bilateral co-operation.

United States ambassador to India Mr Richard Verma and U.S. Permanent Representative to the United Nations Dr. Samantha Power visited Air Quality Monitoring facility in India Meteorological Department, New Delhi on 19.11.2015.

Delegation from **International Monetary Fund** (IMF) met DGM to discuss climate change issues on 7th December 2015.

8.5. IMD Foundation Day 2015

The 140th Foundation day of India Meteorological Department was celebrated on 15th January, 2015 at H. Q., New Delhi. This day is celebrated with a view to highlight the achievements of the department and to promote awareness about new initiatives taken and also to focus on the future plans for improving the weather and climate services.

Celebration of 140th IMD Foundation Day 2015

On this occasion Dr. Shailesh Nayak, Secretary, MoES welcomed the Hon'ble Minister Dr. Harsh Vardhan, Minister for Science & Technology and Earth Sciences. Dr. Harsh Vardhan, dedicated the Web based analysis and visualization of Insat-3D data products software, the Real Time Analysis of Products & Information Dissemination (RAPID) System and Customised Rainfall Information System (CRIS) to the Nation on this occasion.

Hon'ble Minister of Science & Technology and Earth Sciences Dr. Harsh Vardhan expressed weather prediction of India at par with best country in the world. Accurate and timely predictions made by IMD in the recent times not only helped our farmers and fishermen but also saved the lives during cyclones.

The Minister felicitated Dr. N. Sen Roy, Ex. DGM. On this occasion. DG, IMD, Dr. L. S. Rathore, highlighted the yearly achievements of the organization and told that 35 weathermen from different countries were imparted meteorological training to expertise them. The department provided accurate landfall and intensity prediction of cyclone Hudhud which led to saving the lives of many.

IMD Foundation day was also celebrated at Pune office also. Dr. R. R. Kelkar, Ex. DGM was the chief guest of the function. On this occasion selected officers and staff, of IMD Pune office were given memento and certificate of merit for their excellent service.

8.6. World Meteorological Day 2015

World Meteorological Day was celebrated on 23rd March, 2015 at DGM's Office New Delhi and other offices of the department. On this occasion an Exhibition was organized in the premises of Pune office. The theme for this year WMO Day was "**Climate Knowledge for Climate Action**".

National Seminars / workshops on the theme were organised at IMD HQ and other offices in the country. Special Programmes on Radio and TV on the theme were also broadcast / telecast all over the country.

World Meteorological Day function and Aakhri Dubki Play on 23 March 2015, IMD, New Delhi

World Meteorological Day at RMC Chennai

World Meteorological Day at MC Bangalore

WMO day Celebrations at Met Centre Goa

The National Science Day and the **Earth Day** were celebrated at IMD HQ and field offices on 28th February, 2015 and 22 April, 2015 respectively all over the country.

CHAPTER 9

COLLABORATIVE ACTIVITIES

National

IMD signed Memorandum of Understanding for augmenting its observational mechanism, and enhancing research and meteorological services with the following agencies in 2015:

(i) An MoU has been signed between Earth System Science Organization-India Meteorological Department (ESSO-IMD) and Power System Operation Corporation Ltd. (POSOCO), a wholly owned subsidiary of Power Grid Corporation of India Ltd. in respect of "Use of weather information for better management of Indian Power System" on 18th May, 2015 at Shram Shakti Bhawan, New Delhi. MoU was signed by Dr. L. S. Rathore, DG, IMD and Shri S. K. Soonee, CEO, POSOCO in the gracious presence of Shri Pradeep Kumar Sinha, Secretary, Ministry of Power and other senior officers from Ministry of Power and Ministry of Earth Sciences. This MoU aims towards systematic use of Meteorological Information for better management of Indian Power System from generation to distribution and to increase overall efficiency of the power system operations.

(ii) India Meteorological Department and Laxmi Devi Institute of Engineering and Technology, Alwar.

(iii) MoU between Earth System Science Organization-India Meteorological Department (ESSO-IMD) and Power.

(iv) Power System Operation Corporation Ltd. (POSOCO), a wholly owned subsidiary of Power Grid Corporation of India Ltd. in respect of "Use of weather information for better management of Indian Power System" at Shram Shakti Bhawan, New Delhi.

(v) India Meteorological Department and University of Allahabad Krishi Vigyan Kendra, Baramati, District Pune, State Maharashtra.

(vi) India Meteorological Department and University of Allahabad.

International Activities

Hon'ble President of India ratified MoU between India and Qatar in the field of Atmospheric and oceanic sciences in November, 2015.

17th WMO Congress

Indian delegation was led by the Hon'ble Minister of Science & Technology and Earth Sciences, Shri Y. S. Chowdary and consisting of Dr. Shailesh Nayak, Secretary, Ministry of Earth Sciences. Shri Ajit Kumar, Ambassador & PR of India to the U N at Geneva, Dr. L. S Rathore, DGM, India Meteorological Department, Dr. S. D. Attri, DDGM (O), India Meteorological Department, Shri K. Balaji Majumdar, PS to HMOS for Earth Sciences, Dr. R. Krishnan, Sct-G, Indian Institute of Tropical Meteorology, Shri B. N. Reddy, Deputy Permanent Representative of India and Dr. Vishnu Reddy, Second Secretary (HR), Permanent Mission of India to UN offices participated in 17th WMO Congress during 25 May-12 June 2015. **Dr. L. S. Rathore, DGM was elected as Member of Executive Council of WMO.**

Dr. L. S. Rathore, DGM and Co-Vice Chairman of Inter-governmental Board on Climate Services of World Meteorological Organization steered the Management Committee Meeting of IBCS of GFCS (WMO) in Geneva.

Dr. L. S. Rathore, DGM participated in 3rd United Nations World Conference on Disaster Risk Reduction at Sendai Japan led by Hon'ble Union Home Minister of India in March 2015.

An International Training Workshop of seven countries, on Tropical Cyclone Forecasting (ITWTCF-2015) was organised during 3-14, August, 2015 at New Delhi. 11 nos of representatives from Bangladesh, Maldives, Myanmar, Srilanka, Thailand, Cambodia, and Australia were participants in Workshop.

Dr. Y. S. Chowdary, Hon'ble Minister of State for Science & Technology and Earth Sciences inaugurated Third Workshop (3-days) on "WMO/WWRP Monsoon Heavy Rainfall" held during 22-24 September, 2015 in New Delhi.

The inception session **Winter South Asian Climate Outlook Forum (WinSASCOF-1)** and the **Climate Services Users Forum for Agriculture (CSUF-Ag1)** was held during 14-16 October 2015 at Chennai which was hosted by IMD, Regional Meteorological Centre, Chennai. Govt. of Canada, World Meteorological Organization (WMO) and Regional Integrated Multi-Hazard Early Warning System for Africa and Asia, (RIMES) supported the event through funds available from the Government of Canada. The forum meeting was attended by several experts from India and various other countries of South Asia such as Afganistan, Bangladesh, Bhutan, Maldives, Myanmar, Nepal, Pakistan, Phillipines and Sri Lanka and also from Australia and Korea.

International Conference on Atmospheric Chemistry and Agricultural Meteorology during 2-4 November 2015.

Workshop on Global Centres of Research and Excellence in Agrometeorology on 5 November & Meeting on CAgM Expert Team on Agrometeorological Products from 6-7 November, 2015.

Meeting of Regional Association II Expert Group on Agrometeorology from 9-10 November.

Improving Climate Services

Agrimet division, IMD, Pune in collaboration with United States Agency for International Development (USAID), Washington DC, USA jointly organized international workshop on "Improving Climate Services for Farmers in Africa and South Asia (ICSFASA)" during 2-3 February at Hotel Ramee Grand, Pune.

Global Space based Inter Calibration System

IMD organized WMO's "Global Space based Inter Calibration System (GSICS) Research and Data Working Group Meeting 2015 during 16-20 March 2015" at MoES New Delhi.

Participants from different member countries/ organizations (European Meteorological Satellite (EUMETSAT), CNES France, JMA, NASA, NOAA, NESDIS, ISRO, KMA,WMO and IMD attended the meeting**. Secretary General, WMO** was also present in valedictory function.

RTH Operational training of two weeks during 16-27 February, 2015 for officials of IMD was organized by M/s COROBOR France and CMC Ltd., New Delhi at IMD, Pune.

IMD provided two months Meteorological training to 12 personnel from Meteorological Office, Bhutan in Kolkata during June-July 2015.

IMD provided 10-day training in Aviation Meteorology to 18 personnel from Meteorological Office, Oman, 4 personnel from Civil aviation, Bhutan in addition to IMD officials during December 2015.

CHAPTER 10

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 2014 it has an IMPACT FACTOR (IF): 0.181 and 5-year Impact factor 0.249 calculated by Thomson Reuter U.S.A. The rating score given by National Academy of Agricultural Sciences (NAAS) for the year 2014 is 6.15. IMD Scientists published 175 research paper/books in Mausam/Met. Monograph/Met Reports and National & International Journal during 2015.

10.1. Research contributions published in 'MAUSAM' during 2015

S. S. Chinchorkar, F. G. Sayyad, V. B. Vaidya and Vyas Pandye **"Trend detection in annual maximum temperature and precipitation using the Mann Kendall test – A case study to assess climate change on Anand of central Gujarat"** *Mausam*, **66**, 1, 1-6.

B. Geetha and Y. E. A. Raj, **"A 140 year data archive of dates of onset and withdrawal of northeast monsoon over coastal Tamil Nadu : 1871-2010 (Re-determination for 1901-2000)",** *Mausam*, **66**, 1, 7-18.

D. R. Pattanaik, C. S. Tomar and S. C. Bhan, **"Delayed withdrawal of southwest monsoon 2010 – A diagnostic study",** *Mausam*, **66**, 1, 19-32.

S. Meganathan and T. R. Sivaramakrishnan, **"A technique for spot weather forecasting", 66**, 1, 33-42.

Sunit Das, K. Bhattacharjee, G. C. Hazarika, P. Ali, M. P. Luitel, A. Choudhury, S. O. Shaw and Awadhesh Kumar, **"Quantitative precipitation forecast for the Brahmaputra and the Barak basins by synoptic analogue technique",** *Mausam*, **66**, 1, 43-76.

Sartajvir Singh and Rajneesh Talwar, **"Assessment of different CVA based change detection techniques using MODIS dataset"**, *Mausam*, **66**, 1, 77-86.

Farah Naz, Naureen Aziz Qureshi and Noor Us Saher, **"Spatial and temporal assemblage of Potamides cingulatus (Gmelin) found in the mangrove creek area of Karachi, Pakistan"**, *Mausam*, **66**, 1, 87-92.

M. R. Ranalkar, A. Anjan, R. P. Mishra, R. R. Mali and S. Krishnaiah, **"Development of operational near real-time network monitoring and quality control system for implementation at AWS data receiving earth station",** *Mausam*, **66**, 1, 93-106.

S. C. Bhan, A. K. Devrani and Vivek Sinha, **"An analysis of monthly rainfall and the meteorological conditions associated with cloudburst over the dry region of Leh (Ladakh), India",** *Mausam*, **66**, 1, 107-122.

A. T. Adediji, M. O. Ajewole, J. S. Ojo, A. G. Ashidi, M. Ismail and J. S. Mandeep, **"Influence of some meteorological factors on tropospheric radio refractivity over a tropical location in Nigeria",** *Mausam*, **66**, 1, 123-128.

V. Vizaya Bhaskar, **"Hydro-climatic characteristics of hill stations of India",** *Mausam*, **66**, 1, 129-138.

Ashutosh Mishra**, "Cloudburst and landslides in Uttarakhand : A nature`s fury?",** *Mausam*, **66**, 1, 139-144.

B. N. Vishnoi, R. C. Gupta, Anand Nagar and Kalu Ram Sharma**, "Temperature variability and trend over Rajasthan",** *Mausam*, **66**, 1, 145-150.

Remya. K, A. Ramachandran, S. Jayakumar, Divya Subash Kumar, Radhapriya. P. and Malini. P **"Rainfall trend analysis of Kolli hill, Tamil Nadu, India",** *Mausam*, **66**, 1, 151-154.

P. Vijaya Kumar, V. U. M. Rao, O. Bhavani, Rajendra Prasad, R. K. Singh and B. Venkateswarlu**, "Climatic change and variability in mid-Himalayan region of India",** *Mausam*, **66**, 2, 167-180.

K. Shimola and M. Krishnaveni**, "Sensitivity of SWAT simulated reservoir inflow to climate change in a semi arid basin",** *Mausam*, **66**, 2, 181-186.

R. Asokan and B. Amudha**, "Temperature variations and trends in the lower atmosphere over Indian longitudes, 1948-2011",** *Mausam*, **66**, 2, 187-200.

Praveen Kumar Verma, J. L. Chaudhary and M. R. Chandrakar**, "Comparative economic assessment of kharif paddy with and without agro-advisory services under AICRPAM-NICRA at Mahasamund district of Chhattisgarh",** *Mausam*, **66**, 2, 201-204.

D. T. Meshram and S. D. Gorantiwar**, "Evaluation of pan coefficient for estimating reference crop evapotranspiration in Solapur station, Maharashtra",** *Mausam*, **66**, 2, 205-210.

Ranjan, Rajeev and Nain, A. S., **"Predicting yield of Lahi (Brassica campestris var. toria) crop using remote sensing in Tarai region of Uttarakhand",** *Mausam*, **66**, 2, 211-216.

Prasanta Neog, Kushal Sarmah, Rijumani Rajbongshi and M. K. Kalita**, "Development of weather based forewarning models for Downy mildew and Alternaria blight diseases of Rapeseed (Brassica campestris) in north bank plain zone of Assam",** *Mausam*, **66**, 2, 217-224.

Ji-Long Chena, Bei-Bei Xiaod, Chun-Di Chena, Zhao-Fei Wena, Yi Jianga, Ming-Quan Lva, Sheng-Jun Wua and Guo-Sheng Li**, "Estimation of solar radiation using two-step method in Yangtze River basin in China",** *Mausam*, **66**, 2, 225-236.

G. P. Singh, Medha Khole and D. M. Rase**, "Some Characteristics of intra-seasonal variability of southwest monsoon rainfall",** *Mausam*, **66**, 2, 237-246.

A. K. Jaswal, S. C. Bhan, A. S. Karandikar and M. K. Gujar**, "Seasonal and annual rainfall trends in Himachal Pradesh during 1951-2005",** *Mausam*, **66**, 2, 247-264.

Naeem Sadiq**, "Markov Modelling of daily rainfall over different cities of Khyber Pakhtunkhwa (KPK), Pakistan",** *Mausam*, **66**, 2, 265-272.

A. Majumder, S. G. Patil, Md. Noman and S. Biswas**, "Application of L- moments for regional frequency analysis of maximum monthly rainfall in West Bengal, India",** *Mausam*, **66**, 2, 273-280.

Mohd. Azfar, B. V. S. Sisodia, V. N. Rai and Sunil Kumar**, "A study on impact of climate change on rice production in Faizabad district of Uttar Pradesh",** *Mausam*, **66**, 2, 281-286.

U. K. Choudhary, G. P. Singh, O. P. Singh and R. K. S. Maurya**, "Impact of changes in sea surface temperature over southern equatorial Indian Ocean on Indian summer monsoon : A model study",** *Mausam*, **66**, 2, 287-298.

Rajan Kumar and G. S. Yadav**, "Detection of fractured zones in part of hard rock area of Mirzapur District, Uttar Pradesh, using integrated geophysical method",** *Mausam*, **66**, 2, 299-3.

R. P. Kane**, "Antarctic ozone hole status- An update",** *Mausam*, **66**, 2, 311-312.

P. G. Gore**, "Droughts over Andhra Pradesh",** *Mausam*, **66**, 2, 313-316.

Satya Prakash, Ashis K. Mitra, I. M. Momin, R. M. Gairola, D. S. Pai, E. N. Rajagopal and Swati Basu**, "A review of recent evaluations of TRMM Multisatellite Precipitation Analysis (TMPA) research products against ground-based observations over Indian land and oceanic regions",** *Mausam*, **66**, 3, 355-366.

M. I. Ansari, Ranju Madan and S. Bhatia**, "Verification of quality of GPS based radiosonde data",** *Mausam*, **66**, 3, 367-374.

Raghavendra Ashrit, Kuldeep Sharma, Anumeha Dube, Gopal Iyengar, Ashis Mitra and E. N. Rajagopal**, "Verification of short range forecasts of extreme rainfall during monsoon",** *Mausam*, **66**, 3, 375-386.

Saji Mohandas and Harvir Singh**, "Spatial verification of rainfall forecasts for very severe cyclonic storm 'Phailin'",** *Mausam*, **66**, 3, 387-402.

Ananda Kumar Das, Mansi Bhowmick, P. K. Kundu and S. K. Roy Bhowmik**, "Verification of WRF forecasts with TRMM rainfall over India during monsoon 2010 : CRA method",** *Mausam*, **66**, 3, 403-414.

Kuldeep Sharma, Raghavendra Ashrit, Elizabeth Ebert, Gopal Iyengar and Ashis Mitra, **"NGFS rainfall forecast verification over India using the contiguous rain area (CRA) method",** *Mausam*, **66**, 3, 415-422.

Geeta Agnihotri**, "Evaluation of operational forecasts from weather research and forecasting model during southwest monsoon 2011 using MET 3.0",** *Mausam*, **66**, 3, 423-432.

Soma Sen Roy, Subhendu Brata Saha, Ananda Kumar Das, S. K. Roy Bhowmik and P. K. Kundu**, "Diurnal cycle of rainfall as predicted by WRF model : Verification using model evaluation tools software",** *Mausam*, **66**, 3, 433-444.

C. Matsudo, Y. Garcia Skabar, J. J. Ruiz, L. Vidal and P. Salio**, "Verification of WRF-ARW convective-resolving forecasts over Southeastern South America",** *Mausam*, **66**, 3, 445-456.

Nathan Faggian, Belinda Roux, Peter Steinle and Beth Ebert**, "Fast calculation of the fractions skill score",** *Mausam*, **66**, 3, 457-466.

S. I. Laskar and S. K. Roy Bhowmik**, "Temporal and spatial characteristics of systematic errors of WRF predicted location specific maximum and minimum temperature over Indian region",** *Mausam*, **66**, 3, 467-478.

V. R. Durai, Rashmi Bhardwaj, S. K. Roy Bhowmik and Y. V. Rama Rao**, "Verification of quantitative precipitation forecasts from operational ensemble prediction systems over India",** *Mausam*, **66**, 3, 479-496.

S. D. Kotal, Sumit Kumar Bhattacharya, S. K. Roy Bhowmik and P. K. Kundu**, "Verification of forecasts of IMD NWP based cyclone prediction system (CPS) for cyclones over the north Indian seas during 2013",** *Mausam*, **66**, 3, 497-510.

Anumeha Dube, Raghavendra Ashrit, Amit Ashish, Gopal Iyengar and E. N. Rajagopal**, "Tropical cyclone forecast from NCMRWF global ensemble forecast system, verification and bias correction",** *Mausam*, **66**, 3, 511-528.

Y. V. Rama Rao, K. Nagaratna, D. Joardar, Arun Sharma and Anil Kumar**, "Evaluation of short range forecast for tropical cyclones over north Indian Ocean using TIGGE data",** *Mausam*, **66**, 3, 529-540.

Zied Ben Bouallègue**, "Assessment and added value estimation of an ensemble approach with a focus on global radiation forecasts",** *Mausam*, **66**, 3, 541-550.

D. R. Pattanaik, D. S. Pai and B. Mukhopadhyay**, "Rapid northward progress of monsoon over India and associated heavy rainfall over Uttarakhand : A diagnostic study and real time extended range forecast",** *Mausam*, **66**, 3, 551-568.

Wondimu Tadiwos Hailesilassie and Gizaw Mengistu Tsidu, **"Empirical statistical modeling of March-May rainfall prediction over southern nations, nationalities and people's region of Ethiopia",** *Mausam*, **66**, 3, 569-578.

B. P. Yadav, Naresh Kumar and L. S. Rathore, **"Skill of operational forecast of heavy rainfall events during southwest monsoon season over India",** *Mausam*, **66**, 3, 579-584.

Kushal Sarmah, Prasanta Neog, R. Rajbongshi and A. Sarma, **"Verification and usability of medium range weather forecast for north bank plain zone of Assam, India",** *Mausam*, **66**, 3, 585-594.

Kamaljit Ray, B. K. Bandopadhyay and S. C. Bhan, **"Operational nowcasting of thunderstorms in India and its verification",** *Mausam*, **66**, 3, 595-602.

Aditi, John P. George, M. Das Gupta, E. N. Rajagopal and Swati Basu**, "Verification of visibility forecasts from NWP model with satellite and surface observations",** *Mausam*, **66**, 3, 603-616.

Subekti Mujiasih and Danang Eko Nuryanto**, "Utilization of categorical and continuous combination for wave model verification",** *Mausam*, **66**, 3, 617-624.

Tobias Pardowitz, Thomas Kox, Martin Göber and Alexander Bütow**, "Human estimates of warning uncertainty : Numerical and verbal descriptions",** *Mausam*, **66**, 3, 625-634.

Tressa L. Fowler, Barbara G. Brown, John Halley Gotway and Paul Kucera**, "Spare Change : Evaluating revised forecasts",** *Mausam*, **66**, 3, 635-644.

Daniel Cattani, Anna Faes, Marianne Giroud Gaillard and Michel Matter**, "Global forecast quality score for administrative purposes",** *Mausam*, **66**, 3, 645-656.

Somenath Dutta, Prakash Khare and Avinash Tathe, **"Isolated heavy rainfall over Sylhet, Bangladesh and convective instability",** *Mausam*, **66**, 4, 675-686.

A. K. Mitra, S. C. Bhan, A. K. Sharma, Nithesh Kaushik Shailesh Paihar, Riddhi Mahandru and P. K. Kundu**, "INSAT-3D vertical profile retrievals at IMDPS, New Delhi : A preliminary evaluation",** *Mausam*, **66**, 4, 687-694.

P. Kumar and Deba Prasad Pati, **"Radar imageries information extraction and its use in pre-hail estimation algorithm",** *Mausam*, **66**, 4, 695-712.

K. N. Mohan, A. Arul Paligan, G. Sivakumar, R. Krishnamurthy, V. Shubha, Uday Shinde, R. R. Mali and M. K. Bhatnagar, **"Performance study of Drishti transmissometer at CAT III B airport",** *Mausam*, **66**, 4, 713-718.

B. Amudha, P.A. Subadra and V. Radhika Rani, **"Perspectives on land breeze characteristics over Chennai",** *Mausam*, **66**, 4, 719-728.

Sunita G. Maral and Tapati Mukhopadhyay**, "Signal of urban heat island (UHI) Effect: A case study of Mumbai metropolitan region",** *Mausam*, **66**, 4, 729-740.

Charan Singh and Ramesh Chand**, "Exceptionally heavy rainfall over Uttarakhand during 15-18 June, 2013 - A case study",** *Mausam*, **66**, 4, 741-750.

Neeraj Kumar, S. S. Patel, A. L. Chalodia, O. U. Vadaviya, H. R. Pandya, R. R. Pisal, K. K. Dakhore and M. L. Patel**, "Markov chain and incomplete Gamma distribution analysis of weekly rainfall over Navsari region of south Gujarat",** *Mausam*, **66**, 4, 751-760.

Mohd. Azfar, B.V.S. Sisodia, V.N. Rai and Monika Devi**, "Pre-harvest forecast models for rapeseed & mustard yield using principal component analysis of weather variables",** *Mausam*, **66**, 4, 761-7.

Harsh VardhanPuranik, A.S. Nain and N.S. Murty**, "suitability analysis of fast growing tree species under wastelands of Uttarakhand for carbon credit",** *Mausam*, **66**, 4, 767-776.

Annu Priya, Adlul Islam, A. K. Nema and A. K. Sikka**, "Assessing sensitivity of reference evapotranspiration to changes in climatic variables : A case study of Akola, India",** *Mausam*, **66**, 4, 777-784.

M. Abdel-Wahab, Khaled S. M. Essa, M. Embaby and Sawsan E. M. Elsaid**, "Analytical and numerical solutions of crosswind integrated concentration by using different eddy diffusivities methods",** *Mausam*, **66**, 4, 785-792.

K. Seetharam, **"Trends in equatorial Pacific sea surface temperatures",** *Mausam*, **66**, 4, 793-802.

Naeem Sadiq, **"Modeling of rainfall extremes through the application of Extremal Type Theorem (ETT)",** *Mausam*, **66**, 4, 803-808.

Sukumar Lala (Roy) and Nabajit Chakravarty, **"Rainfall day and Heavy rainfall day prediction of Kolkata (22.53° N, 88.33° E), India during June to October using linear discriminant analysis technique",** *Mausam*, **66**, 4, 809-814.

Pallvi Goyal, K. K. Gill, Rajan Aggarwal, and Chetan Singla, **"Probability distributions for long term rainfall data in Ludhiana - A case study"**, *Mausam*, **66**, 4, 815-824.

G. P. Singh, Medha Khole and D. M. Rase**, "Extreme rainfall events and urban floods in the growing cities of India",** *Mausam*, **66**, 4, 825-840.

Ranjit Kumar Paul, P. S. Birthal, Amrit Kumar Paul and Bishal Gurung, **"Temperature trend in different agro-climatic zones in India",** *Mausam*, **66**, 4, 841-846.

Bishal Gurung, **"An exponential autoregressive (EXPAR) model for the forecasting of all India annual rainfall",** *Mausam*, **66**, 4, 847-849.

Neeraj Kumar, R. R. Pisal, S. P. Shukla, S. S. Patel, **"Analysis of climatic variability at heavy rainfall zone of south Gujarat",** *Mausam*, **66**, 4, 850-856.

10.2. Research contributions published in extra departmental journals (Indian and Foreign journals)

Agnihotri, Geeta and Dimri, A. P., 2015, **"Vertical structure of atmosphere in pre-monsoon season over Bangalore",** *Journal of Earth System Science*, **24**, 7, 563-1573.

Anjit Anjan and R.R.Mali **"Monitoring and Data Archival of India Meteorological Department's Radiation Network in real time",** have been submitted for technical presentation at International Pyrheliometer Comparison-XII,2015 at World Radiation Centre, Davos, Switzerland.

Bakthavathsalu, Amudha and Merrouchi, Rabia, 2015, **"Survey on alternatives for dangerous and obsolete instruments - Evaluation of the questionnaire and recommendations for alternatives",** Web site of WMO on 26 January 2015 (http://www.wmo.int/pages/prog/www/IMOP/publications-IOM - series. html and http://www.wmo.int/pages/prog/www/IMOP/documents/IOM_ 117_ mercury_final2.pdf).

Bhaskar, Vizaya, 2015, **"Implication in Radiative Forcing",** *Atmospheric Environment Journal.*

D. S. Pai, Latha Sridhar and M. R. Ramesh Kumar, **"Active and Break Events of Indian**

Summer monsoon during 1901-2014", Climate Dynamics, 1-19, First Online: 4 September 2015. DOI 10.1007/S00382-015-2813-9" **(IMPACT FACTOR: 4.763).**

Bisht, D. S., Dumka, U. C., Kaskaoutis, D. G., Pipal, A. S., Srivastava, A. K., Attri, S.D., Soni, V. K. and Tiwari, S., 2015, **"Carbonaceous aerosols and pollutants over Delhi urban environment: temporal evolution, source apportionment and radiative forcing",** *Science of Total Environment*, 521-522, 431-445, Impact Factor 3.28.

Durai V. R. and Bhardwaj, Rashmi and Rama Rao, Y. V., 2015, **"Prediction Skill of Global Numerical Weather Prediction Model Deterministic Forecast over India during North East Monsoon",** *Vayumandal*, **40**, 1-2, 182-191.

Giri, R. K., Pradhan, D. and Sen, A. K., 2015, **"Dust Storm – A case study over Patna & Neighbourhood",** *Indian Journal Science Research & Tech*., **3**, 2, 51-60. ISS-2321-9262.

Giri, R. K., Pradhan, D. and Sen, A. K., 2015, **"Rainfall Comparison of Automatic Weather Stations and Manual Observations over Bihar Region",** *Internal Journal of Physics & Mathematical Sciences*, **5**, 2, April-June, 1-22.

Guhathakurta, P. and Rajeevan, M., 2015, **"Observed changes in southwest monsoon rainfall during 1901-2011",** *American Meteorological Society*, Special symposium on South Asia Monsoon from 4th to 8th January, 2015 at Phoenix, Arizona, USA.

Kundu, Bhaskar, Vissa, Naresh Krishna and Gahalaut, V. K., 2015, **"Influence of anthropogenic groundwater unloading in Indo-Gangetic plains on the April 25, 2015 Mw 7.8 Gorkha, Nepal Earthquake",** *Geophysical Research Letters*, 42, doi: 10.1002/2015GL066616.

M. Mohapatra & Monica Sharma, 2015, **"Characteristics of surface wind structure of tropical cyclones over the north Indian Ocean",** *Journal of Earth System Science*, **124**, 7, 1573-1598. DOI:10.1007/s12040-015-0613-6, Impact Factor 1.04.

Mandal, M., Singh, K. S., Balaji, M. and Mohapatra, M., 2015, **"Performance of WRF-ARW model in real-time prediction of Bay of Bengal cyclone 'Phailin'",** *Pure and Applied Geophysics*, 1-19, DOI: 10.1007/S00024-015-1206-7. Impact Factor 1.618.

Manjunath S. Tyalagadi, Alaka S. Gadgil and Krishnakumar, G., **"Monsoonal Droughts in India – A recent assessment",** *IGBP*, papers on Global Change, **22**, 19-36.

Mohanty, U. C., Osuri, Krishna K., Tallapragada, Vijay, Marks, Frank D., Pattanayak, Sujata, Mohapatra, M., Rathore, L. S., Gopalakrishnan, S. G. and Niyogi, Dev, 2015, **"A Great Escape from the Bay of Bengal - Super Sapphire-Phailin" Tropical Cyclone: A Case of Improved Weather Forecast and Societal Response for Disaster Mitigation",** *Earth Interactions*, 11/2015; DOI:10.1175/EI-D-14-0032.1, Impact Factor 1.84.

Mohapatra, M., 2015, **"Cyclone hazard proneness of districts of India",** *Journal of Earth System Science*, **124**, 3, 515-526, DOI:10.1007/s12040-015-0556-y.

Mohapatra, M., 2015, **"Tropical cyclone forecast verification by India Meteorological Department for North Indian Ocean: a review",** *Tropical Cyclone Research and Review*, **3**, 1-14.

Mohapatra, M., Geetha, B., Balachandran, S. and Rathore, L. S., 2015, **"On the Tropical cyclone activity and associated environmental features over North Indian Ocean in the Context of Climate change",** *Journal of Climate Change*, **1**, 1-2, 1-26, DOI : 10.3233/ JCC-150001.

Mohapatra, M., Nayak, D. P., Sharma, Monica, Sharma, R. P. and Bandyopadhyay, B. K., 2015

"Evaluation of official tropical cyclone landfall forecast issued by India Meteorological Department", *Journal of Earth System Science*, **124**, 4, 861-874, DOI:10.1007/s12040-015-0581-x, Impact Factor 1.04.

Pai, D. S., Latha Sridhar and Ramesh Kumar, M. R., 2015 **"Active and Break Events of Indian Summer monsoon during 1901-2014",** *Climate Dynamics*, 1-19, DOI 10.1007/ S00382-015-2813-9" (IMPACT FACTOR : 4.673).

Naresh Kumar, Attri, S.D and Laskar, S. I, 2015, **"Quantification in variation in temperatures over Northeast India during last century",** *International Journal of Earth and Atmospheric Science, International Journal of Earth and Atmospheric Science*, **1**, 2, 58-64.

Pattanaik, D. R. and Mohapatra, M., 2015 **"Seasonal Forecasting of Tropical Cyclogenesis over the North Indian Ocean",** *Journal of Earth System Science*, Impact Factor 1.04.

Pattanaik, D. R. and Das, Ashok Kumar, 2015, **"Prospect of application of extended range forecast in water resource management: A case study over the Mahanadi River basin",** *Natural Hazards*, **77**, 575-595.

Pattanaik, D. R. and Kumar, Arun, 2015, **"A hybrid model based on latest version of NCEP CFS coupled model for Indian monsoon rainfall forecast",** *Atmospheric Science Letters*, 16, Jan-Mar, 10-21.

Pattanaik, D. R., 2015, **"Operational extended range forecast activity in IMD and its application in different sectors",** *Vayu Mandal*, **40**, January-December, 1-2, 44-70.

Pradhan, D. and Sen, A. K., 2015, **"Role of Satellite Derived Products in Monitoring the Fog at JPNI Airport Patna",** *International Journal of Geology, Earth & Environmental sciences*, **5** (I), January-April, 79-88, ISSN:2277-2081.

Pradhan, D. and Sen, A. K., 2015 **"Study of Intra Seasonal Variability of District Wise Monsoon Rainfall over Bihar Region",** *India Journal Science Research & Tech*., **3**, 3, 31-42. ISSN-2321-9262.

Nath, Sankar, Kotal, S. D. and Kundu, P. K., 2015, **"Seasonal prediction of tropical cyclone activity over the North Indian Ocean using the Neural Network Model",** *Atmósfera*, **28**, 4, 271-281.

Pradhan, D., 2015, **"Simulation of Severe Local Strom by Mesoscale Model MM5 and Validation Using Data from Different Platforms",** *International Journal of Atmospheric Sciences*, Aricle ID 19804, p23.

Pradhan, D., Sen, A. K. and Giri, R. K., 2015, **"Study of Bio-Climate Indices over Bihar Region",** *International Journal of Advance Research in Engineering & Applied Science*, ISSN :2278-6252. Impact factor: 5.795.

Pradhan, D., Sen, A. K. and Giri, R. K., 2015, **"Study of Extreme Weather Events (Hot & Cold day wave) over Bihar Region",** *International Journal of Latest Research in Engineering & Science*, **1**, 2, June-2015.

Pradhan, D., Sen, A. K. and Parbat, Sandeep Kumar, 2015, **"Role of Weather Parameters in Crop Yield Forecasting of Wheat over Bihar Region",** *International Journal of Latest Research in Engineering & Science*, **1**, 1/May 2015.

Prakash, Rajesh and Srivastava, H. N., **"Thermal anomalies in relation to earthquakes in India and its neighbourhood",** *Current Science*, **108**, 11, June, 2015.

Ranalkar M.R., Chaudhari H.S., Hazra A., Sawaisarje G.K., Pokhrel S., 2015, **"Dynamical features of incessant heavy rainfall event of June 2013 over Uttarakhand, India",** *Natural Hazards*, online, October 2015, DOI:10.1007/s11069-015-2040-z, 1-23.

Rizwan Ahmed, Sagnik Dey and manju Mohan, 2015, **"A study to improve night time fog detection in the Indo-Gangetic Basin using satellite data and to investigate the connection to aerosols",** Meteorol. Appl., **22**, 689-693.

Samanta, S. K., Roy, Debasis, Mukherjee, Subrotoand, Sarkar, Ranjan, 2015, **"Climate in Environment and their effects on Meteorology",** *Indian Journal*, **4**, 6, June 2015.

Sharma Alankar and Peshin S. K., 2014, **"Study of air pollution trends at Lodhi Road, New Delhi through online monitoring",** *International Journal of Environmental Sciences* , **5**, 2, 217-235.

Sharma, Babita, Chingtham, Prasantha, Sutar, Anup K., Chopra, Sumer and Shukla, Haldhar P., 2015, **"Frequency dependent attenuation of seismic waves for Delhi and surrounding area, India",** *Annals of Geophysics*, **58**, 2, doi:10.4401.

Sharma, Babita, Chopra, Sumer and Kumar, Vikas, 2015, **"Simulation of strong ground motion for 1905 Kangra earthquake and a possible megathrust earthquake (Mw 8.5) in western Himalaya (India) using Empirical Green's Function technique",** *Natural Hazards*, DOI 10.1007/s11069-015-1979-0.

Shukla, H. P., **"Vector digitization of historical seismograms",** *International Research Journal of Natural and Applied Sciences*, **2**, 8, August 2015 IF- 2.818 ISSN: (2349-4077).

Sonawane, Kailas, Sreejith, O. P., Pattanaik, D. R., Benke, Mahendra, Patil, Nitin and Pai, D. S., 2015, **"Simulation of Indian summer monsoon using the Japan Meteorological Agency's seasonal ensemble prediction system",** *Journal of Earth System Science*, **124**, 321-333.

Srinivasa Kumar, T., Murty, P. L. N., Pradeep Kumar, M., Krishna Kumar, M., Padmanabham, J., Kiran Kumar, N., Shenoi, S. S. C., Mohapatra, M., Nayak, Shailesh and Mohanty, Prakash, **"Modeling storm surge and its associated inland inundation extent due to Very Severe Cyclonic Storm 'Phailin'",** *Marine Geodesy*, **38**, 4, 345-360, DOI: 10.1080/01490419.2015.1053640. Impact Factor 1.31.

Tiwari S., Pandithurai G., Attri S. D., Srivastava A. K., Soni V. K., Bisht D. S., Kumar, V. A. and Srivastava M. K., 2015, **"Aerosol optical properties and their relationship with meteorological parameters during wintertime in Delhi, India",** *Atmospheric Research*, **153**, 465-479, doi:10.1016/j.atmosres. 2014.10.003.

Tiwari S., Hopke, P. K., Pipal, A. S., Srivastava, A. K., Bist, D. S., Tiwari, Shani, Singh, A. K., Soni, V. K. and Attri, S.D., 2015, **"Intra-Urban variability of particulate matter (PM2.5 and PM10) and its relationship with optical properties of aerosols over Delhi**", India**",** *Atmospheric Research*, **166**, 223-232.

Tongdi Jamir and Krishnakumar. G, **"Assessment of Extreme Temperatures over North east and West Coast Regions of India",** *GEOADRIA*, July 2015, Vol. 20 Issue 1, p1.

V. Vizaya Bhaskar, **"Long term Characterization of Aerosol Optical Thickness over Jodhpur-Implication in Radiative Forcing",** *Atmospheric Environment Journal*.

Walsh, K. J. E., McBride, J. L., Klotzbach, P. J., Balachandran, S., Camargo, S. J., Holland, G., Knutson, T. R., Kossin, J., Lee, T. C., Sobel, A. and Sugi, M., 2015, **"Tropical cyclones and climate change",** *WIREs Clim Change*, doi: 10.1002/wcc.371.

Yadav, Rajeev Kumar, Nankali, H., Kundu, Bhaskar, Patel, Paisnee and Gahalaut, V. K., 2015, **"Finite fault slip models for the 11 August 2012 Varzaghan-Ahar, NW Iran earthquakes (Mw 6.4 and 6.3) from near-field GPS measurements of coseismic offsets",** *Journal of Asian Earth Sciences*, **115**, 268-272.

10.3. Other publications

A report on Cyclonic Disturbances over north Indian Ocean during 2014 was prepared for WMO/ESCAP member countries.

Aeronautical Climatological summary for Kollata airport for the period 2006-2010 in the form of CD has been released.

Aeronautical Climatological Summary for the period 2006 – 2010, for stations Mumbai, Kolkata and Chennai.

Annual Cyclone Review for the year 2014 was prepared by RSMC, New Delhi and published by WMO.

Annual Report on Cyclonic disturbances over north Indian Ocean during 2014 has been published and circulated to WMO/ESCAP panel member countries, various research institutes/Universities and disaster management agencies in the country.

Climate Diagnostics Bulletin of India for February to April 2015 and Winter Season 2015 (January-February) and Annual Summary 2014 have been published.

Climate Diagnostics Bulletin of India for May to August 2015 and Pre-Monsoon Season (March-May).

Climate of Chattisgarh.

Climate of Telangana.

Climatological tables of Observatories in India (1981-2010).

Cyclonic Disturbances over north Indian Ocean During 2014 : A Report.

"Cyclone Hazard Prone of India", published in Journal of Earth System Sciences.

Daily all India Weather Summary and Weekly Weather Reports.

Disasterous Weather Events – 2013.

Disasterous Weather Events – 2014.

Drought Outlook Maps for the month of July to September, Weekly aridity reports and maps for the month of July to September were prepared and uploaded on IMD, Pune website. Biweekly Aridity anomaly reports and maps for the month of July to September have been issued.

Drought Outlook Maps for the month of June, four weekly aridity reports and maps for the month of June were prepared and uploaded on IMD Pune website. Two Biweekly Aridity anomaly reports and maps for the month of June has been issued.

ENSO bulletin for the month of July to September 2015 were issued.

Forecast Demonstration Project - Implementation report for the year 2014.

Generation of daily 0.5 × 0.5 degree gridded data in respect of maximum & minimum temperature.

Climate of Uttarakhand.

Mukherjee, Subroto, *et al*., 2015, "A study on variation of Bright Sunshine hours in Kolkata and Portblair", Issue of PARIPEX- Indian Journal of Research.

Polar Science Programme, Meteorological Weather Observation at Antarctica.

Preliminary Reports on various cyclones and Deep Depressions forming over Bay of Bengal and Arabian Sea have been prepared and uploaded in RSMC, New Delhi website.

Probable Maximum Precipitation (PMP) Atlases of the following River Basins have been published, which is a joint venture of Central Water Commission & India Meteorological Department.

Probable Maximum Precipitation (PMP) Atlases of the river basins Mahanadi, Brahmaputra Narmada, Tapi, Sabarmati and Luni river basin and rivers of Saurashtra and Kutch regions including Mahi and west flowing rivers of Western Ghats have been published under a joint venture of Central Water Commission & India Meteorological Department.

Seasonal Climate Outlook of South-Asia for the period August-November 2015.

Tropical Cyclone Operational Plan (TCP-21) 2015 edition has been prepared by RSMC, New Delhi and published by WMO.

Weekly and Cumulative Standardized Precipitation Index (SPI) maps were prepared for all the weeks during April, May and June 2015 were supplied for use in Agromet Advisory Services Bulletin.

Weekly and Cumulative Standardized Precipitation Index (SPI) maps were prepared for all the weeks during July to September 2015 were supplied for use in Agromet Advisory Services Bulletin.

Met. Monograph

IMD Met. Monograph No. ESSO/IMD/CLI/01(2015)/27 entitled, "Spatial variation of Potential Evapotranspiration (PE) values over India" by P.G. Gore and V. Vizaya Bhaskar

IMD Met. Monograph No. ESSO/IMD/ EMRC/01/2014 "Assessment of Aerosol Radiative Properties in India" by V. K. Soni, S. D. Attri, Kanika Taneja, S. K. Peshin.

IMD Met. Monograph No. ESSO/IMD/PMRD/ CLI/01(2014)/26 "Climatology of Maitri, Antarctica" by V. K. Soni, M. Sateesh, S. K. Peshin.

IMD Met. Monograph No. ESSO/IMD/ SYNOPTIC MET/(2015)/17 "Monsoon 2014- A Report" edited by D.S. Pai and S.C. Bhan.

IMD Met. Monograph No. ESSO/IMD/CLI/ 01(2015)/27 entitled, "Spatial variation of Potential Evapotranspiration (PE) values over India" by P.G. Gore and V. Vizaya Bhaskar.

IMD Met. Monograph No. ESSO/ IMD/SYNOPTIC MET/(2015)/17, "Monsoon 2014- A Report" edited by D. S. Pai and S. C. Bhan.

IMD Met. Monograph on southwest monsoon 2014, "Validation of automatic Weather Station data for monitoring & prediction of low pressure system during the monsoon season".

IMD Met. Monograph: Synoptic Meteorology No.: ESSO/IMD/SYNOPTIC MET/02-2014/16], 46-79, "Verification of operational tropical cyclone forecast over north Indian Ocean during 2014 by India Meteorological Department", M. Mohapatra, B. K. Bandyopadhyay, B. Geetha, Bharati S. Sabade, D. P. Nayak, Monica Sharma, R. P. Sharma, P. S. Chinchole, R. G. Bali, S. V. J. Kumar and V. Vijayakumar.

IMD Met. Monograph: ESSO Document No.: ESSO/IMD/SYNOPTIC MET/01(2015)/17, pp171-188, "Validation of automatic weather station (AWS) data for monitoring and prediction of the low pressure systems during the monsoon season", M. Mohapatra, M.R. Ranalkar & S. Sunitha Devi.

IMD Met. Monograph ClimatologyNo.ESSO/ IMD/CLI/01(2015)/27. "Spatial variation of potential evapotranspiration over India", P.G. Gore and VizayaBhaskar.

IMD Met. Monograph Hydrology No.15/2013 "Rainfall profile of Udaipur", M.C. Jaipur.

IMD Met. Monograph Mono Satellite Meteorology No. ESSO/IMD/ Sat. Met./01 (2014)/7 "Calibration/ validation of Insat-3D Satellite: First joint campaign in Jaisalmer

during 14-23, Dec. 2013", A. K. Sharma, A. Senthil Kumar, A. K. Mitra, A. T. Jayaseelan, ShaileshParihar, H. P. Bhatt, S. Mishra, Rajesh Agnihotri, V. Gopal Krishnan and B. N. Bisnoi.

IMD Met. Monograph Cyclone Warning No. No.ESSO/IMD/CWD/01(2015/13 "Report on cyclonic disturbances over north Indian oclean during 2014", Cyclone Warning Division.

RSMC No. ESSO/IMD/RSMC/Tropical Cyclones Report/01(2015)/6 "Report in cyclonic disturbances over north Indian Ocean during 2014", RSMC Division, New Delhi.

No. ESSO/IMD/CWD-1(2015)/13, "Cyclonic activities over north Indian ocean during 2014" and "Performance of track and intensity predication of cyclones by IMD during 2014", M. Mohapatra, B. K. Bandyopadhyay, B. Geetha, Bharati S. Sabade, D. P. Nayak, Monica Sharma, R. P. Sharma, P.S. Chinchole, R. G. Bali, S. V. J. Kumar &V. Vijayakumar.

No. ESSO/IMD/EMRC(Ozone)/01(2015)/02 "Assessment of surface ozone trend over Delhi, Pune and Thiruvanathapuram", S. K. Peshin and Priyanka Sinha.

No. ESSO/IMD/SMRC Storm Project-2015/ (01)(2-015)/4.

"Monitoring and prediction of tropical cyclones over north Indian ocean", by M. Mohapatra, - Springer, Netherlands and Capital Publishing Co., New Delhi, Monitoring and prediction of tropical cyclones.

Probable Maximum Precipitation (PMP) Atlases of the following River Basins were published, which is a joint venture of Central Water Commission & India Meteorological Department:

(a) Brahmaputra River Basin

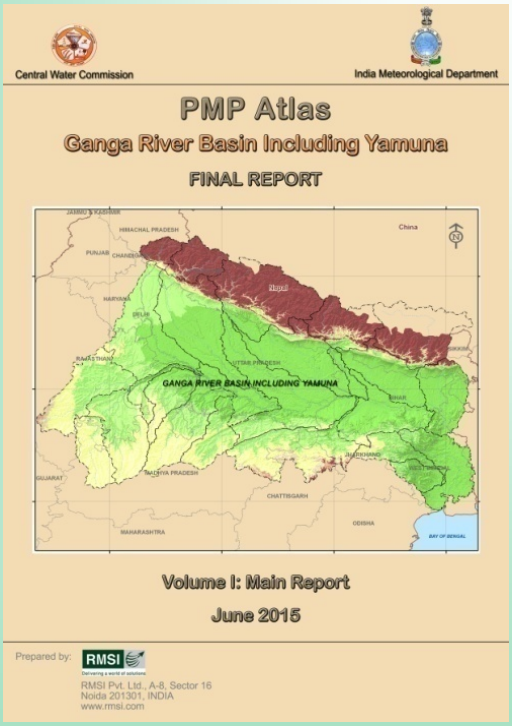
(b) Mahanadi and Adjoining River Basins

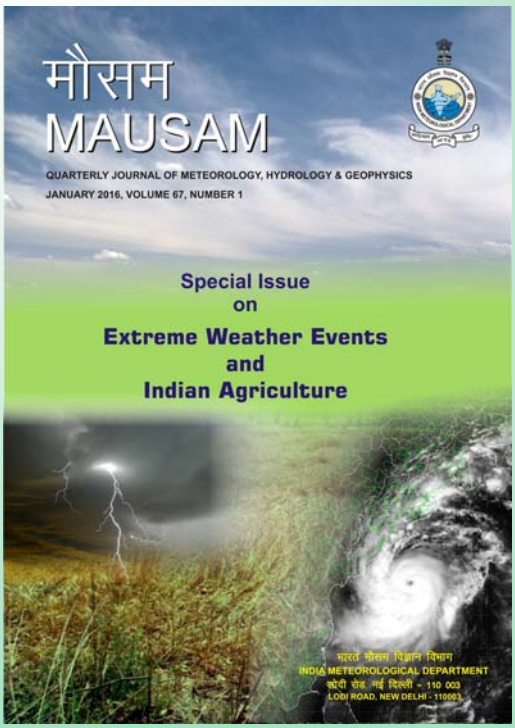
(c) Narmada, Tapi, Sabarmati and Luni River Systems and Rivers of Saurashtra and Kutch Regions including Mahi

(d) West flowing Rivers of Western Ghats

(e) Ganga River Basin including Yamuna

(f) Cauvery and other East flowing River Basins.





CHAPTER 11

FINANCIAL RESOURCES AND MANAGEMENT PROCESS

11.1. Financial resources and management

Budget Estimates

Budget provisions for the department during the financial year 2015-16 were as follows:

Budget Estimates (Plan)

B.E. (Revenue)	Rs.82.88 Crores
B.E. (Capital)	Rs.70.00 Crores

Plan Schemes

To upgrade the forecasting capabilities, various plan schemes being implemented during XII Five Year Plan as follows:

1. The scheme **"Atmospheric Observations Systems Network"** being implemented at total estimated cost of Rs. 700 Crore to deal with :

- Operation & Maintenance and sustenance of observational networks covering Doppler Weather Radars (DWRs), Automatic Rain Gauges (ARGs), Automatic Weather systems (AWSs), Upper air, surface and environmental observatories etc. on 24×7 basis.
- Provision of adequate communication system for data & product transmission.
- Maintenance of operational forecast system, delivery system for forecast and other services.
- Conduct of special campaigns for improving Cyclone, Thunderstorm and Fog forecasting, etc.

2. The scheme **"Satellite meteorology"** being implemented at total estimated cost of Rs.70 Crore.

- Receive, process, derivation of products from imager and sounder payloads data of INSAT-3D, INSAT-3A, KALPANA-1 & polar satellites.
- Establishment of state-of-art National satellite data centre.
- GPS stations for measurement of Integrated Precipitable Water Vapor (IPWV).

3. The scheme **"Gramin Krishi Mausam Sewa"** being implemented at total estimated cost of Rs.165.25 Crore.

- Improvement of the existing district level Agromet Advisory Services (AAS) to sub district level and in pilot mode at block level.
- Operationlization of block level forecast, ERFS & Climate Bulletin and e-Agromet for preparation of Agromet Bulletins.
- Creation of cell for Research Excellence in Agro-Meteorology.

4. The scheme **"Augmentation of Aviation Meteorological Services"** being implemented for continuation at total estimated cost of Rs. 115 Crore.

- Upgradation of Airport Meteorological Instruments (AMIs) at runway locations for the major airports by commissioning of Airport Weather Observing Systems, Transmissometers, Aviation Weather Decision Support Systems etc.

5. The scheme **"Climate Services"** being implemented at total estimated cost of Rs.55.40 Crore.

- Creation of facilities for providing Climate Services through the establishment of a Regional Climate Centre (RCC)-South to cater to the need of a comprehensive set of specialized climate services for the country and for South Asia region.

6. The scheme **"Metropolitan Air Quality and Weather Service"** being implemented at total estimated cost of Rs. 90 Crore jointly with IITM.

- Provide near real time and 1-2 day advance forecast for weather and air quality information for several Metropolitan cities.

- Forecast weather in now-cast and short range scales over different sections of the Metropolitan cities including severe weather warnings.

7. New scheme **"Modeling of changing water cycle and climate"** being implemented at total estimated cost of Rs.89.90 Crore jointly with NCMRWF.

- To understand the water cycle process.

8. The Scheme **"Training in Operational Meteorology"** being implemented at total estimated cost of Rs.55.81 Crore.

- Upgradation of training & capacity building to provide essential knowledge base in atmospheric science.

9. The scheme **"Integrated Himalayan Meteorology Programme for Western & Central Himalayas"** being implemented at total estimated cost of Rs.117.7 crores covering four states namely Jammu & Kashmir, Himachal Pradesh, Uttarakhand and Sub Himalayan West Bengal.

- Improvement of mountain weather and climate monitoring and forecast services over the Himalayan region.

10. New scheme **"Severe weather warning system"** being implemented at total estimated cost of Rs.88.0 Crores.

- Development of state-of-art high resolution modeling framework for predictions of high-impact weather systems including Thunderstorms, Cyclone, Fog, Cloudburst & Heavy Rainfall for public safety and economic growth of the country.

Plan Scheme Monitoring

Plan Scheme Procurement Monitoring package implemented for online monitoring of the schemes and various stages of procurements under approved plan schemes. All the Project Directors/ Associated Project Directors of the schemes can enter the procurement details and keep updated their status on the METNET till the final payment is made.

In addition, a Project/Procurement Monitoring Board constituted for clearance of bottlenecks in procurement process as well as speedy clearance and to review & recommend measures to streamline all the procurement above Rs. one Crore.

11.2. Citizen's/Client's Charter

Citizen's/Client's Charter in English language has already been displayed at all offices upto the level of AMOs highlighting the standards of service delivery that it subscribes to, availability of choice for public and avenues for grievance redress and other related information. In order to promote Hindi Language, Citizen's/Client's Charter has also been printed in Hindi for displaying (duly framed) adjacent to English version.

11.3. Revenue Generated during the year 2015

(i). Sale of Meteorological Data

RCs/MCs	Total revenue received by sale of meteorological data during the month (Amount in Rupees)											
	Jan	Feb	Mar	April	May	June	July	August	Sep	Oct	Nov	Dec
DGM New Delhi												
DGM NHAC												
DGM (Pub.)	72425	56665	70325	42725	14375	27070	13400	18975	13005	30035	5890	-
RMC New Delhi		54589				32466	11628	20857				-
Jaipur	21041	14082			42485	38322	89889	62254				-
Lucknow						15107	5850	17876	3534		1482	-
Srinagar	3000	2700	12750	46420	9100		19900		15100	10720		-
Chandigarh	5281	8163	14308	5586	18234	3876		5983	7528			-
Shimla	3615	12437	6264	87059	17242	7221	11510					-
Dehredun							1014					-
RMC Mumbai		85425	377450	106894	125791	53324			94173		47330	-
Ahemdabad			5846				47899				9088	-
RMC Nagpur	65215	67364	75924	61138	57333	401405	37904	66674	51962	35852	49216	-
Bhopal		20262					26052	4048	17314			-
RMC Kolkata	15656	2525	21595		18256	6578	27770		6203	3679	4372	-
Bhubneshwar	39268	21167	88601	33577		24027	124450	31863	4629	57639	14384	-
Agartala	4696		29170	3563	1174	3867	2899	1214				-
Gangtok	13323	1708	14021			3445	1824					-
RMC Guwahati	20217	98212	68072	30482	105866	161179	164146	16431	314985	47529		-
RMC Chennai	**70084**	**68439**	**179310**	**219944**	**125835**	**186447**	**158711**	**157412**	**126113**	**96343**	**126834**	-
Thiruvananthapuram	**202929**	**30218**	**58598**	**110913**	**187956**	**42938**	**301331**	**6480**	**46514**	**17016**		-
Hyderabad	**25000**	**29335**	**27530**	**340285**	**52140**	**33680**	**24880**	**21020**	**17311**	**25295**	**45925**	-
Bangalore	**25966**	**23371**	**75186**	**16897**	**55166**	**104886**	**68141**	**65500**	**46048**	**82102**	**45620**	-
ACWC Chennai	**6741**	**24717**	**6741**	**4494**		**13482**	**4680**	**2340**				-
CWC Visakhapatnam	**10115**	**9634**	**Nil**	**7417**	**11215**	**6792**		**16686**			**5130**	-
O/o ADGM (R)	13335367	104873	2889871	1456955	744726	312220	1049590	2179310	535868	767067	268370	-
Grand Total												

CHAPTER 12

STATUS OF SC/ST/OBC AS ON 01.01.2015

(i) Status of SC/ST/OBC as on 01.01.2015 (Group wise)

	Representation of SCs / STs / OBCs as on 1.1.2015				Appointments by Promotion during the calendar year		
Groups	No. of Employees	SCs	STs	OBCs	SCs	STs	Total
Group A	170	24	10	25	3	1	35
Group B (Gaz.)	1040	178	81	-	41	14	211
Group B (Non- Gaz.)	2182	268	94	356	6	1	13
Group C	1235	525	116	40	3	-	9
TOTAL	4527	995	301	421	53	16	268

(ii) Status of SC/ST/OBC as on 01.01.2015 (Pay Scale Wise)

	Representation of SCs / STs / OBCs as on 01.01.2015				Appointments by promotion during the calendar year		
Pay Scale in Rs.	No. of Employees	SCs	STs	OBCs	SCs	STs	Total
PB-3 + GP 5400	-	-	-	-	-	-	-
PB-3 + GP 6600	4	-	1	3	-	-	-
PB-3 + GP 7600	68	13	5	20	-	-	6
PB-4 + GP 8700	73	11	3	2	3	1	14
PB-4 + GP 8900	23	-	1	-	-	1	15
PB-4 + GP 10000	-	-	-	-	-	-	-
75500-80000	1	-	-	-	-	-	-
TOTAL	169	24	10	25	3	2	35

CHAPTER 13

राजभाषा नीति का कार्यान्वयन

राजभाषा नीति का कार्यान्वयन 2015 - *सम्मान*

➢ भारत मौसम विज्ञान विभाग की हिंदी गृह पत्रिका मौसम मंजूषा को वर्ष 2014 -15 में प्रकाशित 19वें और 20वें संस्करण के लिए ***राजभाषा विभाग, गृह मंत्रालय द्वारा 'राजभाषा कीर्ति सम्मान (द्वितीय)*** से सम्मानित किया गया। महामहिम राष्ट्रपति महोदय द्वारा हिंदी दिवस समारोह 2015 के अवसर पर यह पुरस्कार मौविउमनि (प्रशा.एवं भंडार) श्री ए. के. शर्मा ने ग्रहण किया। यह विभाग के लिए अत्यंत गर्व का क्षण रहा।

➢ भारत मौसम विज्ञान विभाग की हिंदी गृह पत्रिका मौसम मंजूषा में प्रकाशित प्रादेशिक मौसम केंद्र चेन्नै के तमिल भाषी अधिकारी श्री के. वी. बालसुब्रह्मणयन को हिंदी में लेख लिखने के लिए ***राजभाषा विभाग, गृह मंत्रालय द्वारा 'राजभाषा गौरव सम्मान'*** के प्रथम पुरस्कार से सम्मानित किया गया। महामहिम राष्ट्रपति महोदय द्वारा हिंदी दिवस समारोह - 2015 के अवसर पर यह पुरस्कार श्री के. वी. बालसुब्रह्मणयन, सहायक मौसम विज्ञानी ने ग्रहण किया।

➢ ***राजभाषा सेवा संस्थान*** द्वारा आयोजित 'राजभाषा सम्मेलन व चिंतन शिविर में डॉ. प्रसन्न कुमार पाटसाणी, माननीय संसद सदस्य तथा गोवा सरकार के माननीय मंत्री श्री राजेन्द्र आरलेकर द्वारा मौसम विभाग में राजभाषा हिंदी के सर्वांगीण विकास के लिए महानिदेशक महोदय को ***'राजभाषा श्री'*** पुरस्कार से सम्मानित किया गया। साथ ही हिंदी पत्रिका 'मौसम मंजूषा' में प्रकाशित वैज्ञानिक एवं तकनीकी प्रकार के लेखों के लिए डॉ. एस. के. पेशिन वैज्ञानिक 'एफ' सुश्री रेवा शर्मा, वरिष्ठ हिंदी अधिकारी, श्रीमती सरिता जोशी, हिंदी अधिकारी और श्री रामहरि शर्मा, वैज्ञानिक सहायक को ***'विशिष्ट पुरस्कार'*** से सम्मानित किया गया है।

संसदीय राजभाषा समिति द्वारा निरीक्षण

प्रादेशिक मौसम केंद्र चेन्नै का संसदीय राजभाषा समिति की दूसरी उपसमिति द्वारा

दिनांक 13.02.2015 को राजभाषायी निरीक्षण किया गया जिसमें भारत मौसम विज्ञान विभाग के महानिदेशक डॉ. लक्ष्मण सिंह राठोड़, प्रादेशिक मौसम केंद्र चेन्नै के उपमहानिदेशक श्री एस. बी तंपि और वरिष्ठ हिंदी अधिकारी सुश्री रेवा शर्मा ने भाग लिया। निरीक्षण के दौरान मुख्यालय की हिंदी अधिकारी श्रीमती सरिता जोशी और कनिष्ठ अनुवादक श्री बीरेंद्र कुमार भी उपस्थित रहे।

समिति के संयोजक डॉ प्रसन्न कुमार पाटसाणी का स्वागत करते हुए महानिदेशक डॉ. लक्ष्मण सिंह राठोड़

चक्रवात चेतावनी केंद्र - विशाखापट्टनम का संसदीय राजभाषा समिति की दूसरी उपसमिति द्वारा दिनांक 10.04.2015 को राजभाषायी निरीक्षण किया गया जिसमें भारत मौसम विज्ञान विभाग के वैज्ञानिक "एफ" डॉ. सोमेश्वर दास, उपमहानिदेशक (प्रशासन एवं भंडार) श्री ए. के शर्मा, चक्रवात चेतावनी केंद्र - विशाखापट्टनम के निदेशक श्री रामचंद्र राव और वरिष्ठ हिंदी अधिकारी, सुश्री रेवा शर्मा ने भाग लिया। निरीक्षण के दौरान मुख्यालय की हिंदी अधिकारी श्रीमती सरिता जोशी और वरिष्ठ अनुवादक श्रीमती एम. अनुराधा भी उपस्थित रहे।

निदेशक श्री रामचंद्र राव संयोजक से राष्ट्रपति के आदेशों से संबंधित पुस्तक लेते हुए

अनुवाद कार्य

➢ राजभाषा हिंदी के प्रगामी प्रयोग के संवर्धन के लिए भारत मौसम विज्ञान विभाग का हिंदी अनुभाग राजभाषा नीति के कार्यान्वयन के साथ-साथ प्रमुख रूप से अनुवाद का कार्य करता है। अनुवाद के सभी प्रमुख नेमी कार्यों के अलावा विभागीय वैज्ञानिक शोध पत्रिका 'मौसम' के लगभग 50 शोध पत्रों के सारों, भारत मौसम विज्ञान विभाग के मौसम प्रेक्षक श्रेणी-I, श्रेणी-II और श्रेणी-III के भर्ती नियमों, नागरिक/ग्राहक चार्टर, राज्य सभा में उत्तर दिए जाने के लिए तारांकित/ अतारांकित प्राथमिकता प्रश्न डायरी सं. 5436, मौसम विज्ञान के उपमहानिदेशक (उ.वा.उ) नई दिल्ली से प्राप्त हुए मानक मसौदे, कार्मिक एवं प्रशिक्षण विभाग के कार्यालय आदेश सं. ए. बी-

2009/6/1417स्था.(भर्ती नियम), माननीय प्रधानमंत्री के स्वच्छ भारत मिशन का संदेश, स्थापना अनुभाग के नेमी प्रकार के आदेशों के अंग्रेजी फॉर्मेट, नागरिक उड्डयन प्राधिकरण, दोहा, कतर और पृथ्वी प्रणाली संगठन, पृथ्वी विज्ञान मंत्रालय, नई दिल्ली के मध्य वैज्ञानिक और तकनीकी सहयोग हेतु समझौता ज्ञापन, केंद्रीय विमानन मौसम प्रभाग से प्राप्त हुई 'मौसम विज्ञान सेवाएं' विषय से संबंधित सामग्री, आई एम डी की वेबसाइट www.imd.gov.in के भूकंप विज्ञान से संबंधित वेब पृष्ठ, विशाखापट्टनम की वेबसाइट के पृष्ठ, सूचना प्रणाली सेवाएं प्रभाग से प्राप्त विभागीय वेबसाइट के 14 लिंक की सामग्री, चक्रवात चेतावनी प्रभाग से प्राप्त 'उष्णकटिबंधीय चक्रवातों से संबंधित 'अक्सर पूछे जाने वाले प्रश्न', विभागीय इंट्रा पोर्टल मेटनेट के होम पेज का अनुवाद, सतर्कता अनुभाग से प्राप्त परिपत्र, माननीय केंद्रीय प्रशासनिक अधिकरण (कैट) एवं अन्य न्यायालयों में लंबित मामलों पर प्रभावी कार्रवाई करने के संबंध में विधि प्रकोष्ठ से प्राप्त मसौदे, मंत्रालय से प्राप्त वार्षिक रिपोर्ट की सामग्री के 30 पृष्ठ, संसद प्रश्न आदि का अनुवाद कार्य किया गया ।

उपकार्यालयों का निरीक्षण

➢ मुख्यालय की वरिष्ठ हिंदी अधिकारी सुश्री रेवा शर्मा तथा हिंदी अधिकारी श्रीमती सरिता जोशी द्वारा दिनांक 08.01.2015 को मौसम कार्यालय उदयपुर, दिनांक 15.02.2015 को मौसम कार्यालय कडलूर एवं मौसम कार्यालय पुदुच्चेरी, दिनांक 16.02.2015 को डी. डब्ल्यू. आर. चेन्नै, दिनांक 17.02.2015 को मौसम वेधशाला मीनाम्बक्कम एवं विमानन मौसम कार्यालय चेन्नै का निरीक्षण किया गया तथा दिनांक 2015-04-09 को चक्रवात चेतावनी केंद्र - विशाखापट्टनम, दिनांक 2015-04-11- को मौसम कार्यालय-कलिंगपट्टनम और दिनांक 2015-04-13 को डॉप्लर वेदर रेडार–विशाखापट्टनम तथा दिनांक 15-05-05 को प्रादेशिक मौसम केंद्र – कोलकाता, दिनांक 15-05-06 को खगोल विज्ञान केंद्र – कोलकाता, दिनांक 15-05-07 को चक्रवात संसूचन रेडार – कोलकाता का वरिष्ठ अनुवादक के साथ राजभाषायी निरीक्षण किया गया।

मौसम कार्यालय कडलूर मौसम कार्यालय पुदुच्चेरी

संगोष्ठी /कार्यशाला / सम्मेलन

राष्ट्रीय हिंदी वैज्ञानिक संगोष्ठी

1. मुख्यालय की वरिष्ठ हिंदी अधिकारी सुश्री रेवा शर्मा तथा हिंदी अधिकारी श्रीमती

सरिता जोशी ने राष्ट्रभाषा स्वाभिमान न्यास के तत्वावधान में दिनांक 6 व 7 जनवरी 2015 को श्रीनाथद्वारा (राजस्थान) में आयोजित 19वें ***अखिल भारतीय राजभाषा सम्मेलन*** में भाग लिया।

अखिल भारतीय राजभाषा सम्मेलन श्रीनाथद्वारा (राजस्थान)

2. ***प्रादेशिक मौसम केंद्र - कोलकाता*** में दिनांक 08.05.2015 - को एक हिंदी संगोष्ठी आयोजित की गई जिसमें डॉ. देवेंद्र प्रधान, वैज्ञानिक "ई" ने "प्रादेशिक मौसम केंद्र कोलकाता की पर, श्री जी. के. दास वैज्ञानिक 'डी' ने "चक्रवात" पर, वरिष्ठ हिंदी अधिकारी सुश्री रेवा शर्मा ने 'राजभाषा हिंदी व निरीक्षण प्रश्नावली "विषय पर, तथा श्रीमती एम .अनुराधा ने 'वार्षिक कार्यक्रम' पर व्याख्यान दिए।

3. ***चक्रवात चेतावनी केंद्र, विशाखापट्टनम*** में दिनांक 13.04.2015- को एक कार्यशाला आयोजित की गई जिसमें वरिष्ठ हिंदी अधिकारी सुश्री रेवा शर्मा ने 'राजभाषा हिंदी व निरीक्षण प्रश्नावली" विषय पर, श्रीमती सरिता जोशी, हिंदी अधिकारी ने 'कम्प्यूटर और हिंदी तथा यूनिकोड' विषय पर तथा श्रीमती एम . अनुराधा ने 'वार्षिक कार्यक्रम' पर व्याख्यान दिए।

4. ***मौसम केंद्र - श्रीनगर*** में दिनांक- 05.06.2015 को एक कार्यशाला आयोजित की गई जिसमें विशेष रूप से आमंत्रित राजभाषा विभाग के निदेशक श्री केवल कृष्ण जी ने कम्प्यूटर पर हिंदी में आसानी से कार्य करने से संबंधित तकनीकी व्याख्यान दिया। वरिष्ठ हिंदी अधिकारी सुश्री रेवा शर्मा ने 'राजभाषा हिंदी व निरीक्षण प्रश्नावली "विषय पर, श्रीमती सरिता जोशी, हिंदी अधिकारी ने 'कम्प्यूटर और हिंदी तथा यूनिकोड' विषय पर तथा श्रीमती एम. अनुराधा ने 'वार्षिक कार्यक्रम' पर व्याख्यान दिए।

- वरिष्ठ हिंदी अधिकारी सुश्री रेवा शर्मा तथा हिंदी अधिकारी श्रीमती सरिता जोशी ने दिनांक 03.09.2015 को ए. एम. ओ. कोयम्बटूर में एक हिंदी कार्यशाला का आयोजन किया। हिंदी अधिकारी श्रीमती सरिता जोशी ने **ए. एम. ओ. कोयम्बटूर** के कार्मिकों को कम्प्यूटर पर यूनिकोड में कार्य करने का प्रशिक्षण भी दिया गया।

Honours and Awards

IMD Awards

Best RMC/MC/MOs Awards and Awards to IMD Scientists/employees were given on 140th IMD Foundation Day celebrations.

Best RMC : RMC Mumbai; Best MC : MC Dehradun

Best MO : M.O. Meerut, RMC New Delhi; M.O. Port Blair, RMC Kolkata; DWR Visakhapatnam, RMC Chennai; AMS North Lakhimpur, RMC Guwahati; M.O. Nasik, RMC Mumbai

Best Seismo. Observatory :
Seismo. Salem (Tamil Nadu)

Best Group' A' Officers :
Dr. S.O'Neill Shaw, Scientist D, RMC Guwahati; Dr. S. I. Laskar, Scientist D, NWP/Estt. DGM office, New Delhi.

Best Group 'B' Officials:
Shri Parmod Kumar, Sc. Asst., ISSD DGM; Smt. Geetha Harikumar, Asst., SI Pune; Shri S. Sainadha Reddy, Sc. Asst. MO Bapatla, RMC Chennai; Shri Ajay Verma, Sc. Asst., Seismo. Ridge

Best Group 'C' Officials:
Shri Vijay Kumar, Mech.Gr.l, UI New Delhi; Shri Benny Augustine, Mech.Gr.1, RMC Kolkata; Shri Robert W. Fernandes, Mech.Gr.1, MC Goa, RMC Mumbai; Shri Kamlesh Joshi, Staff Car Driver, MC Bhopal, RMC Nagpur

Best MTS
Shri Rajesh Kumar, Hydrology, DGM; Shri Madan Prasad, DGM Secretariat, New Delhi; Shri Veer Chand, AMO Kangra, RMC New Delhi; Shri D.K. Gaikwad, DDGM (SI) Pune

MoES Awards

Ministry of Earth Sciences celebrated its foundation day on 27th July 2015 at Vigyan Bhawan, New Delhi. Various award were presented to officials from different organisations of MoES. Best Employee Award for the year 2014-15 were conferred to the following.

1. Shri Ram Kumar, Asst. Met.-I, DGM Office, New Delhi

2. Ms. Latha Sridhar, AM-II, ADGM(R) Pune

3. Shri Jyotirmay De, Sc. Asstt., MC Gangtok (RMC Kolkata)

4. Shri Dinesh Khanna, Sc. Asstt., DGM's Office (Publication), New Delhi

5. Shri Sudip Majumdar, Mech. Gr-I, DDGM (UI), New Delhi

6. Shri K. K. Sikdar, Staff Car Driver, DGM Sectt., New Delhi

7. Shri Mahendra Singh, Driver, MC Jaipur (RMC New Delhi)

APPENDIX

IMPORTANT TELEPHONE LINKS AT IMD, NEW DELHI

NAME	DESIGNATION/OFFICE	EPABX New Delhi	OFFICE TELEPHONE NO. / FAX
Dr. L. S. Rathore	DGM	4201	011-24611842
Shri J. P. Sharma	Senior PS to DGM	4253	011-24611842
Shri A. K. Sharma	DDGM (A&S and Sat. Met.)	4210	011-24621472
Shri M. K. Bhatnagar	DDGM & Sc. 'F' (ISSD)	4314	011-24616051
Dr. S. K. Roy Bhowmik	Scientist 'F', DDGM (NWP)	4482	011-24615815
Dr. (Smt.) S. Kaur	DDGM & Sc. 'F', (Hydrology)	4223	011-24619167
Dr. S. K. Peshin	HEAD & Sc. 'F' (EMRC/PMRD)	4405	011-24611305
Dr. R. Suresh	Head & Sc. 'F' (CAMD)	4513	011-24611710
Shri A. K. Sharma	DDGM & Sc. 'F' (RMC)	4213	011-24690279
Dr. S. D. Attri	DDGM & Sc. 'F' (O)	4309	011-24640701
Dr. D. Pradhan	DDGM & Sc. 'F', (UI)	4245	011-24611451
Shri S. C. Bhan	Head & Sc. 'F', (HRD/DGM Sectt.)	4513	011-24611710
Shri B. P. Yadav	DDGM (NWFC) & Sc. 'F'	4398	011-24629798
Dr. M. Mohpatara	Head RSMC & Sc. 'F'	4385	011-24652484
Shri S. B. Tyagi	Scientist 'E' (Vigilance)	4254	011-24652318
Shri Manik Chandra	Scientist 'E', (CPU)	4236	011-24698147
Shri U. P. Singh	Scientist 'E', (Works)	4487	011-24697640
Shri R. P. Lal	F. O. & Sc. 'E' Planning	4502	011-24623210
Dr. S. I. Laskar	Director (Publication)	4262	011-24651287
Shri Sanjay Bist	Director (Admn.)	4204	011-24602480
Caretaker, Mausam Bhawan	-	4372	
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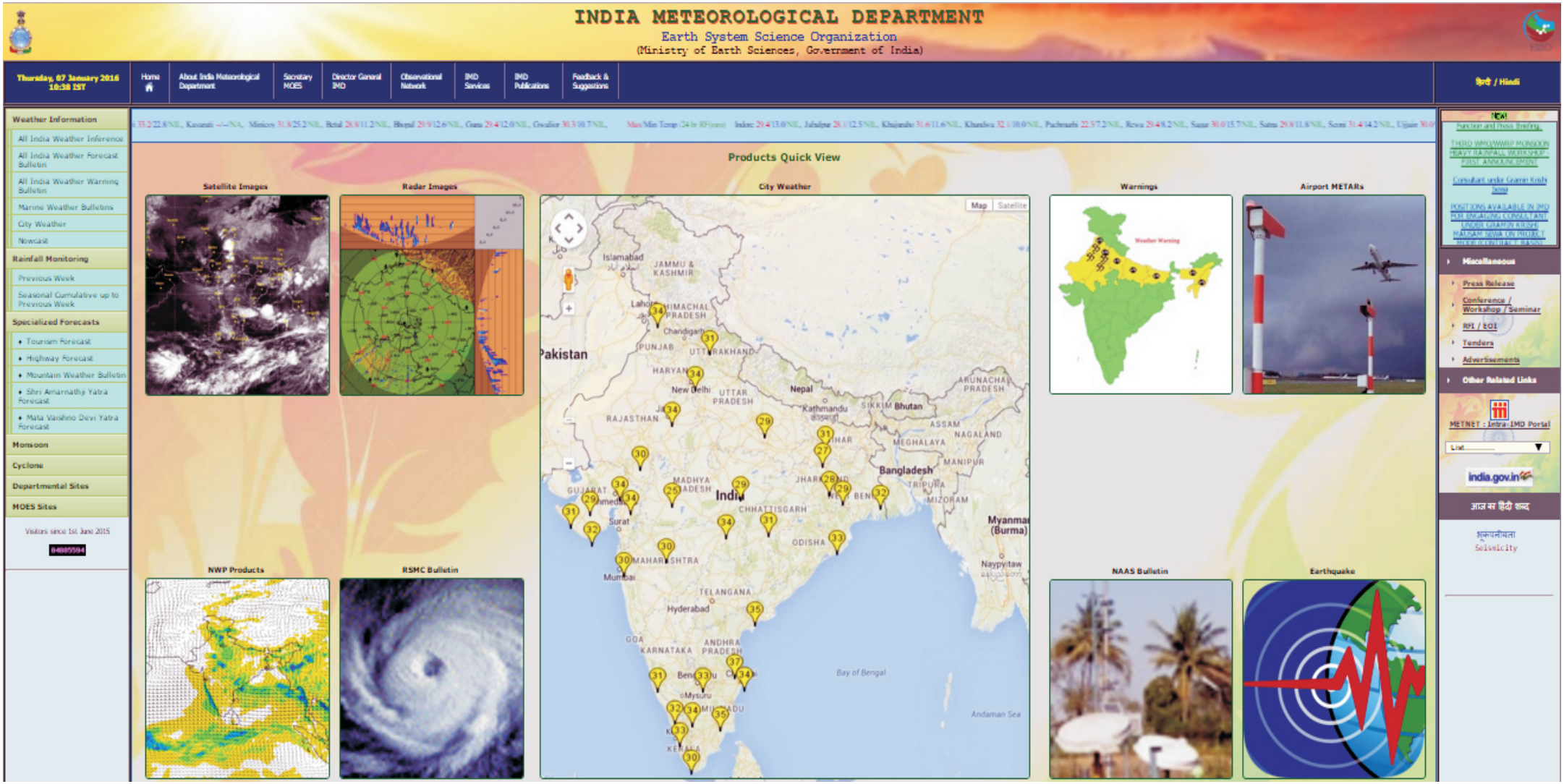

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INDIA METEOROLOGICAL DEPARTMENT

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