सत्यमेव जयते

Years of Service to the Nation
राष्ट्र सेवा के 150 वर्ष

IMD celebrating 150 years of service to the Nation

HAR-HAR MAUSAM
HAR-GHAR MAUSAM

Years of Service to the Nation
राष्ट्र सेवा के 150 वर्ष

MINISTRY OF
EARTH SCIENCES
GOVERNMENT OF INDIA

भारत मौसम विज्ञान विभाग
जय गीत

आदित्यात् जायते वृष्टिः आदित्यात् जायते वृष्टिः
मौसम विभाग वन्दे, मौसम विभाग वन्दे

हम हर मौसम पढ़ने वाले, मानव जीवन के रखवाले
वसुधा परिवार हमारा है, मौसम विज्ञान सहारा है
पृथ्वी की गतियों का विधान, ऋतुओं का शाश्वत संविधान
जलवायु औ पर्यावरण के, परिवर्तन का ध्यान
आपदाओं से हों सतर्क सब, आई एम डी अभियान
ये मौसम ज्ञान पुरातन, नवल विज्ञान प्रभावन

जल थल अम्बर हर गाँव नगर, पर्वत, घाटी, जंगल, सागर
जीते हम संग फिजाओं के, लाते संदेश हवाओं के
सहयोगी मित्र किसानों के, जन जीवन की मुस्कानों के
कर्तव्यनिष्ठ मौसम प्रहरी, जनसेवा में आस्था गहरी
करते अध्ययन तूफानों के, नव चक्रवात अनुमानों के
जन धन जीवन रहे सुरक्षित, मंथन अनुसंधान
मानवता के लिए समर्पित, मौसम का विज्ञान, मानसून संज्ञान,
है अपना ज्ञान पुरातन, नवल विज्ञान सुहावन

वैदिक संस्कृति का नव-विहान, ऋषि चाणक्य का अर्थज्ञान
कवि कालिदास के मेघदूत, आदित्य प्रभा के अग्रदूत
मौसम उपग्रह का दिग्दर्शन, ऋतुचक्र प्रवर्तन विश्लेषण
भारत के स्वर्णिम कल के लिए, शुचि मन में दृढ़ संकल्प लिए
साक्षी समृद्ध विरासत के, हम गौरव प्यारे भारत के
पूरब पश्चिम उत्तर दक्षिण शुभ कर्मयोग संधान
सीमाओं के पार हमारी, करुणा की पहचान, सहयोगी गुणगान
ये मौसम ज्ञान पुरातन, अमर विज्ञान पुरातन
मौसम विभाग वन्दे, मौसम विभाग वन्दे
मौसम विभाग वन्दे, मौसम विभाग वन्दे

हर-हर मौसम, हर-घर मौसम

IMD celebrating 150 years of service to the Nation

15 January, 2024

INDIA METEOROLOGICAL DEPARTMENT
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Lodi Road, New Delhi - 110 003

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डॉ. मृत्युंजय महापात्र
मौसम विज्ञान विभाग के महानिदेशक,
विश्व मौसम विज्ञान संगठन में भारत के स्थाई प्रतिनिधि
विश्व मौसम विज्ञान संगठन के तीसरे उपाध्यक्ष

Dr. Mrutyunjay Mohapatra
Director General of Meteorology,
Permanent Representative of India to WMO
Third Vice President of WMO

भारत सरकार
पृथ्वी विज्ञान मंत्रालय
भारत मौसम विज्ञान विभाग
मौसम भवन, लोदी रोड़
नई दिल्ली–110003
Government of India
Ministry of Earth Sciences
India Meteorological Department
Mausam Bhawan, Lodi Road
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Preface

The India Meteorological Department (IMD) was formally established on 15 January 1875, although the meteorological observatories were established in India much earlier with first observatory in Madras in 1793, Colaba in 1823 and Calcutta in 1829. During 150 years of its existence, IMD has contributed immensely for the development of meteorology in the country. The long journey of IMD has been a journey of scientific innovation, technological adaptations and journey of science to serve the society. New products and services have developed over the years to provide the effective weather & climate forecast and early warning services to cater to the needs of different sectors. The sesquicentennial celebration provides an opportunity to remember IMD's story demonstrating growth and evolution, and to set the stage for the future.

The social progress and economic development of a country is judged through its resilience and capacity to mitigate the adverse impact of disastrous weather events and to ensure safety, security and wellbeing of people. India is one of the few countries in the world which is impacted by natural disasters of almost all kinds, such as tropical cyclones, heavy rainfall/snowfall, floods, droughts, thunderstorms, dust storms, lightning, hailstorms, frost, high winds, fog, heat & cold waves, landslides and avalanches etc. Meteorological services therefore assume great significance in mitigating the impact of such disasters by providing accurate and timely forecasts and warnings.

Early warning system is a cost-effective tool that saves lives, reduces economic losses, and provides manifold return on investment. The Early Warnings for Every Household initiative is a groundbreaking effort by IMD to ensure everyone in the country to be protected from hazardous weather through response actions based on early warning.

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With human-induced climate change leading to more extreme weather conditions, the need for early warning system is more crucial than ever. Behind every warning lies the pivotal role of meteorological observations, data communication, modelling and weather forecasting. IMD is determined to ensure that whole country has robust meteorological monitoring, data communication and modelling system and enable policies to support optimization and sustainability of weather monitoring and early warning. Also it aims at management of natural resources and optimal utilization of weather and climate information for socio-economic development of individuals, organizations and the country as a whole.

The souvenir on 150 years of IMD contains all important milestones of India Meteorological Department since 1875. The developments in organization structure and different services of IMD are also presented in the souvenir as it evolved over the years. The souvenir also contains the most significant scientific and technological developments of IMD during its journey of 150 years and the significant achievements in recent decade.

On behalf of entire meteorological fraternity, I express my deep gratitude to Hon'ble President and Hon'ble Vice President of India for blessing us through the message published in Souvenir. I also express my deep gratitude to all other high dignitaries for sharing their blessings through their messages included in this Souvenir.

I congratulate the entire meteorological fraternity in India and outside who are/were the partners in the journey of IMD. I especially congratulate all present and past colleagues of IMD whose hard work, commitment and dedication has enabled IMD to scale this height. I am sure that IMD and allied organizations dealing with meteorology and allied sciences will create new history in this Amrit Kaal by providing better services to human kind.

(Mrutyunjay Mohapatra)

New Delhi

15-01-2024

सत्यमेव जयते

राष्ट्रपति
भारत गणतंत्र
PRESIDENT
REPUBLIC OF INDIA

Message

I am happy to know that India Meteorological Department (IMD) is celebrating 150 years of its establishment from 15th January, 2024 to 15th January 2025. A souvenir is also being published to mark the occasion.

Since its establishment in 1875, IMD is playing an important role in building climate-resilient societies. IMD, as one of the nation's oldest government institutions has been helping Indians make informed decisions for the protection of their lives and properties. Climate change is also increasing the risk of heavy rains and floods. IMD is the authoritative voice of the country in making the statement on climate change every year. We can reduce risks related to weather and climate through multi-hazard early warning systems that provide timely alerts to decision-makers, socio-economic sector and to the public. The IMD not only provides services to India but also to the countries in South Asia, Southeast Asia and Middle East.

I extend my warm greetings and felicitations to all officers and staff of IMD on this occasion and wish them all success in their future endeavours.

(Droupadi Murmu)

New Delhi
January 02, 2024

सत्यमेव जयते

उपराष्ट्रपति
भारत गणराज्य

VICE-PRESIDENT
REPUBLIC OF INDIA

MESSAGE

On this remarkable journey of one and a half century, I extend my heartiest congratulations to the India Meteorological Department (IMD) for providing authoritative, timely and quality weather information. As one of our country's oldest scientific institutions, IMD is a unique national organization which has a long and proud history of providing services not only to our country but to the world. IMD is the authoritative source of every weather information, forecast and warning service in India.

Since 1875, IMD has continuously adapted and harnessed the latest development in science and technology to meet the needs of the country. Today, the IMD provides round-the-clock weather forecasts and other meteorological and hydrological services to India and the region year-round through a wide variety of channels. Weather and climate information has played a vital role in enhancing our economy especially through its use in agriculture, water, power & energy, disaster and environment management.

In view of the ongoing climate change and its impact in India through more frequent and intense extreme weather events, access to vital information such as weather predictions and air quality are more important than ever before to make decisions about our safety, security, health and wealth. The success of IMD in predicting severe weather especially cyclone, heavy rains leading to flood, heat/cold waves is really praiseworthy. It has made each Indian proud as it earned laurels for the country from the world for successful cyclone warning.

I hope IMD will continue to evolve to serve the nation and the world and bring laurels to country in future.

Once again I congratulate all IMD employees and entire meteorological fraternity for achieving this milestone.

Jagdeep Dhankhar

Jagdeep Dhankhar

New Delhi
11th January, 2024

अमित शाह

गृह मंत्री एवं सहकारिता मंत्री
भारत सरकार

सत्यमेव जयते

संदेश

मुझे यह जानकर हार्दिक प्रसन्नता हो रही है कि **भारत मौसम विज्ञान विभाग** अपना 150वां स्थापना दिवस मना रहा है। इस अवसर पर एक स्मारिका का प्रकाशन भी किया जा रहा है।

भारत मौसम विज्ञान विभाग अपनी स्थापना से ही समकालीन उन्नत पद्धतियों और तकनीकों को आत्मसात कर मौसम संबंधी सूचनाओं और आपदा प्रबंधन में उल्लेखनीय भूमिका निभा रहा है। विभाग की मौसम संबंधी त्वरित और विश्वस्त सूचनाओं ने देश की कृषि, आपदा प्रबंधन, विमानन और अन्य क्षेत्रों को सशक्त और समय शेष रहते कार्ययोजना बनाने में सक्षम बनाने का महत्त्वपूर्ण कार्य किया है।

माननीय प्रधानमंत्री श्री नरेंद्र मोदी जी के नतृत्व में IMD ने अपनी विशेषज्ञता को और अधिक व्यापक बनाते हुए ब्लॉक स्तर पर कृषि-मौसम संबंधी सलाहकार सेवा देना शुरू किया है, जिससे देश के शहरी एवं ग्रामीण क्षेत्रों के मौसम आधारित उद्यम, विशेष तौर पर किसान लाभान्वित हुए हैं। भारत सरकार आज मौसम विज्ञान के अत्याधुनिक तकनीक को अपना रही है और साझा सूचनाओं से संभावित आपदाओं का पता लगाकर देश और दुनिया में जीवन और संपत्तियों की रक्षा कर रही है।

मुझे विश्वास है कि यह स्मारिका भारत में मौसम विज्ञान के विकास, चुनौतियों और संभावनाओं को एकीकृत करेगा और मौसम विज्ञान के विद्यार्थियों, शिक्षकों और अन्य संबंधित लोगों व संस्थाओं के लिए एक प्रमुख दस्तावेज सिद्ध होगा। मैं इस अवसर पर भारत मौसम विभाग के सभी कार्मिकों को अपनी शुभकामनाएँ प्रेषित करते हुए स्मारिका के सफल प्रकाशन की कामना करता हूँ।

(अमित शाह)

डॉ. मृत्युंजय महापात्र,
महानिदेशक, मौसम विज्ञान विभाग

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किरेन रीजीजू
KIREN RIJIJU

मंत्री
पृथ्वी विज्ञान
भारत सरकार
MINISTER
EARTH SCIENCES
GOVERNMENT OF INDIA

MESSAGE

I congratulate India Meteorological Department (IMD) for the significant accomplishments made in tropical meteorology over the last 150 years.

The India Meteorological Department (IMD) founded in 1875 is the nation's premier scientific organization promoting and disseminating information about the weather forecast, early warning and related services. During the 150 years of its existence, incredible progress has been made in several fundamental areas of weather forecasting and early warning services. The remarkable improvement in the quality of weather forecasts is one of the great successes of IMD, which continues at a sustained pace. This is due to the progress of numerical weather prediction systems and the increasing number and variety of quality observation network of IMD, including observations from Earth Observation Satellites and above all the human knowledge. IMD has played a significant role to ensure food security and sustainability through its agro-meteorological advisory services provided to the farmers in local language through online and offline communication channels. It has also played a pivotal role in disaster risk reduction (DRR) through efficient early warning and also in management of natural resources.

IMD is diligently working on providing accurate and reliable forecast and early warning for some of society's most critical challenges, including climate change, extreme weather events, air quality, power and water management to better serve the needs of diverse communities. We look forward to celebrating our 150th anniversary and using this major milestone to reflect on how far we have come, as well as how to build on one and half century of accomplishments to make the most impact. With a focus on the future, we aim to empower IMD to continue serving the decision makers, disaster managers, other scientists, and communities across this Nation and around the world.

(Kiren Rijiju)

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धर्मेन्द्र प्रधान
ଧର୍ମେନ୍ଦ୍ର ପ୍ରଧାନ
Dharmendra Pradhan

सत्यमेव जयते

आज़ादी का अमृत महोत्सव

मंत्री
शिक्षा; कौशल विकास
और उद्यमशीलता
भारत सरकार

Minister
Education; Skill Development
& Entrepreneurship
Government of India

MESSAGE

I am pleased to know that the **India Meteorological Department (IMD)** is celebrating its 150th Anniversary and a Souvenir is being brought out to commemorate this historic occasion.

Capacity building in the ever expanding field of meteorology to meet the dynamic needs of education and professional development in this sector remains a formidable challenge. Increasing demand for improved weather, climate and water services including early warning for disaster risk reduction calls for greater domain specific professional knowledge and competencies. The exemplary role of IMD in executing its core mandate besides engaging with various institutions, colleges and universities to meet the needs of human resource development and capacity building has been well acclaimed. At a time when there is a growing demand for disaster management, risk reduction and better application of weather forecasts and warnings, it will be imperative to have more advisory roles for meteorologists in providing emergency services for seamless use of the weather forecasts and warnings in protecting lives and property besides improving the economic well-being of the nation.

I am happy to learn that IMD is creating a Competency Framework to help the institutions better plan for education and training activities in the field of meteorology to deliver high quality climate services in accordance with world class standards and regulations, especially those defined by the World Meteorological Organization Framework. The advances expected in weather forecasting and climate predictions, I am sure, will enable a next generation of weather and climate services that help people, businesses, and governments to better mitigate risks and reduce losses.

I extend my heartiest congratulations to India Meteorological Department (IMD) for their relentless efforts in taking the weather forecast and early warning system to greater heights.

(Dharmendra Pradhan)

सबको शिक्षा, अच्छी शिक्षा — स्वच्छ भारत — कौशल भारत, कुशल भारत

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ज्योतिरादित्य मा. सिंधिया
JYOTIRADITYA M. SCINDIA

सत्यमेव जयते

नागर विमानन एवं इस्पात मंत्री
भारत सरकार
Minister of Civil Aviation and Steel
Government of India

Message

I convey my heartiest greetings and warm wishes to India Meteorological Department on the occasion of 150th years of its establishment. In the 1970s, IMD as well as all Domestic and International Airports in India functioned directly under the Union Ministry of Tourism and Civil Aviation.

It is well known that meteorological information and forecasts are required for aircraft operations. IMD provides crucial meteorological services to the National and International Civil Aviation sectors in fulfilment of the requirements prescribed by the International Civil Aviation Organisation (ICAO) and the Director General of Civil Aviation (DGCA) of India. In this regard, IMD plays an important role towards the safety, economy regularity and efficiency of air navigation through Aviation weather services.

I congratulate IMD for achieving the rare milestone of completing 150th years of its establishment and believe that Civil Aviation services continue to get best of the meteorological services of IMD.

(Jyotiraditya M. Scindia)

Ministry of Civil Aviation : Room No. 291, B-Block, Rajiv Gandhi Bhawan, Safdarjung Airport, New Delhi-110003
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आर. के. सिंह
R. K. SINGH

सत्यमेव जयते

विद्युत मंत्री एवं
नवीन और नवीकरणीय ऊर्जा मंत्री
भारत सरकार
Minister of Power and
Minister of New & Renewable Energy
Government of India

MESSAGE

I congratulate the India Meteorological Department (IMD) on the occasion of completing 150 years of its establishment.

Power demand is affected by the weather and climate. Renewable Energy generation and scheduling is entirely dependent on nature. Therefore, accurate and constantly updated weather information and forecast is vital to power generation and distribution companies.

India is well on its way to achieving its ambitious goal of having 50 percent of its installed power generation capacity sourced from non-fossil fuel options by the year 2030 as announced by Hon'ble Prime Minister Shri Narendra Modi ji at COP26 Summit in Glasgow. Weather information and forecasts optimized for energy applications is essential to achieve this target. To support the power sector, IMD has partnered with Grid-India (earlier POSOCO) to provide the system operators across the country with accurate weather forecasts and real time weather information which has enabled better power system operation of the country. Over the last several years, the weather forecasts provided by IMD has helped in handling extreme weather conditions such as cyclones, thunderstorms, duststorms, high winds, heat / cold waves for advance operational planning, secure system operation and early restoration.

I am sure that the partnership with India Meteorological Department would further pave way for enhanced weather and climate information support which would help in reliable, secure and economic operation of the energy generation and distribution. I extend my best wishes to IMD.

(R.K. Singh)

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आज़ादी का
अमृत महोत्सव

नित्यानन्द राय
NITYANAND RAI

सत्यमेव जयते

भारत 2023 INDIA
वसुधैव कुटुम्बकम्
ONE EARTH • ONE FAMILY • ONE FUTURE

गृह राज्य मंत्री
भारत सरकार
नार्थ ब्लाक, नई दिल्ली – 110001
**MINISTER OF STATE FOR
HOME AFFAIRS
GOVERNMENT OF INDIA
NORTH BLOCK, NEW DELHI - 110001**

Message

Warm greetings to IMD on completion of 150 years. The period of 150 years is an obvious history of immense achievements of India Meteorological Department.

Today, as we are celebrating 150 years of IMD, it is necessary to remember the circumstances that formed the basis of its establishment. These circumstances had decades of experience behind it to serve the nation through better weather forecast and early warning in order to save the lives and livelihood. IMD is playing an important role to build a Weather-Ready Nation that is ready, responsive and resilient to hydro-meteorological extreme events by providing forecasts and early warning in a way to support disaster managers, first responders, governments, businesses and the public to make timely and smart decisions to save lives and property and enhance livelihoods. For effective management of disasters, we need adequate, reliable and timely warnings which can be formulated only on the basis of accurate forecasts. IMD has demonstrated its capability to provide early warning for Cyclones with high precision and has earned accolades globally and nationally. Early warnings provided by IMD gave ample time for NDRF and SDRF to complete the evacuation process as well as relief & rescue operations and minimise the loss of human life. With increasing frequency and severity of weather related hazards because of climate change, the role of IMD will become increasingly important in respect of early warning and disaster risk management.

When you are celebrating the sesquicentenary with big resolutions and new thinking then the stories of the past should be inspiration and trail for the days to come, and new energy to move forward at a faster pace. My sincere regards to every person who has raised IMD to this height; I congratulate them.

(Nityanand Rai)

New Delhi.
8 January, 2024

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डॉ. पी. के. मिश्र
प्रधान मंत्री के प्रधान सचिव
Dr. P. K. Mishra
Principal Secretary to Prime Minister

सत्यमेव जयते

प्रधान मंत्री कार्यालय
साउथ ब्लॉक, नई दिल्ली - 110 011
Prime Minister's Office
South Block, New Delhi - 110 011

MESSAGE

I congratulate India Meteorological Department (IMD) on the occasion of 150 years of its establishment. Weather and Climate services can help countries and communities build greater resilience against floods, droughts, cyclones and other hydro-meteorological hazards.

Coalition for Disaster Resilient Infrastructure (CDRI) aims to enhance global understanding and action on climate and disaster resilient infrastructure. The formation of the CDRI is inspired by Prime Minister Shri Narendra Modi in a bid to focus on a resilient infrastructure that can withstand and recover quickly from natural disasters.

With climate change causing extreme weather events more frequent and intense, the role of the IMD becomes even more critical as countries brace for record warming, floods, and droughts that can disrupt critical infrastructure and cripple the system. India Meteorological Department has a big role to play in making disaster resilient country through timely and accurate impact based weather forecasting.

IMD has established a robust early warning system. With its continuous efforts, it has significantly improved the weather forecast and warning services, especially with respect to cyclones, heavy rain and heat/cold waves. I convey my best wishes to all employees of IMD and the entire meteorological fraternity for achieving this milestone. I believe that IMD, in the coming days, will harness the latest technologies in the domain and continue to provide timely inputs which will be crucial in saving lives and infrastructure.

[**P.K. Mishra**]
11 January 2024

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अजय के. सूद
भारत सरकार के प्रमुख वैज्ञानिक सलाहकार
Ajay K. Sood
Principal Scientific Adviser to the Govt. of India

सत्यमेव जयते

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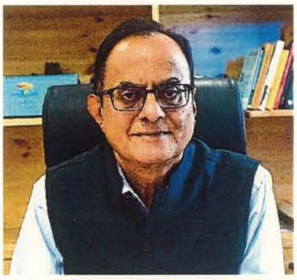

MESSAGE

It is with great pride that I extend my heartiest congratulations to India Meteorological Department (IMD) as it marks its 150th anniversary.

Weather forecasting in India has evolved over the past one and half century from being an empirical, analog-based process with little skill to an increasingly high-tech processes demonstrating tremendous prediction accuracy. This transformation has been enabled by remarkable advances in IMD's observational network, by application of rigorous physical principles to understanding atmospheric phenomena, and subsequent enormous increase in digital computing capability. The extreme weather events such as cyclone, floods, thunderstorms, heat and cold waves etc threaten human life and property, as well as affecting the economy and inflicting significant societal hazards. Our ability to predict these events accurately with sufficient lead times enables people to prepare for them. With the current trajectory of changing climate, our country is facing increased frequency and intensity of extreme weather events. Enhanced attention is being paid to climate and disaster risk assessment, strengthening systems for early warning and early action, and identifying options for adaptation, mitigation and risk reduction.

I would like to express my sincere appreciation of IMD for effective weather predictions and their dissemination to save lives, protect infrastructure, improve public safety and the quality of life, protect the environment, safeguard economic sectors, and increase socio-economic benefits.

I applaud IMD's 150 years of achievement and look forward to continued timely and quality weather information from them in future.

Ajay K. Sood

(Ajay K. Sood)

Dated: 26th December, 2023

आज़ादी का अमृत महोत्सव

सत्यमेव जयते

अजय भल्ला, भा.प्र.से.
AJAY BHALLA, IAS

भारत 2023 INDIA
वसुधैव कुटुम्बकम्
ONE EARTH • ONE FAMILY • ONE FUTURE

गृह सचिव
Home Secretary
भारत सरकार
Government of India
नॉर्थ ब्लॉक/North Block
नई दिल्ली/New Delhi

MESSAGE

I am happy to know that IMD is completing 150 years of its establishment. I congratulate IMD and all meteorological community for achieving this milestone which very few institutions could achieve in the world. Weather related disasters usually exert huge impacts on the development of both human society and the economy. Our country has been one of the most severely affected by natural disasters mainly caused by a variety of high frequency meteorological events such as cyclone, thunderstorms, floods, heat/cold waves, drought, landslides and avalanches. The climate is changing, and those changes also manifest themselves in a changing risk from weather-related hazards in India. The intensity and frequency of hazards will change with climate change. For this reason, the role of IMD is becoming increasingly important in monitoring, forecasting and early warning of meteorological phenomena. Meteorological services are also important to foster adaptation to climate risks and in reducing vulnerability in developing and under-developed world.

2. I compliment IMD in making significant stride in tracking and forecasting extreme weather events especially tropical cyclones which helped reducing the loss of lives and livelihood in India and neighbouring countries. The impact-based weather forecasting and risk-based warning of IMD is helping state and national disaster management agencies to act before disasters to minimise the socio-economic costs of weather and climate hazards.

3. I once again congratulate IMD for achieving rare milestone of completing 150 years of service to the nation and hope IMD will continue to fulfill the increasing need for better hydro-meteorological data and services in future.

25/12/23

(Ajay Bhalla)

Place : New Delhi
Dated : 25.12.2023

सत्यमेव जयते

डॉ. एम. रविचंद्रन
Dr. M. Ravichandran

सचिव
भारत सरकार
पृथ्वी विज्ञान मंत्रालय
पृथ्वी भवन, लोदी रोड, नई दिल्ली–110003

SECRETARY
GOVERNMENT OF INDIA
MINISTRY OF EARTH SCIENCES
PRITHVI BHAWAN, LODHI ROAD, NEW DELHI-110003

Message

I congratulate the India Meteorological Department as it celebrates its 150th anniversary which marks an important milestone in its illustrious history. It is indeed a pride and a great sense of joy for me. India Meteorological Department is one of the oldest scientific organizations in the country. It had many distinguished scientists who have made outstanding contributions to the development of tropical meteorology in the sub-continent. Meteorological Services have a mandate to provide services that protect lives and livelihoods from the adverse effects of weather related events. Today, weather and climate affect society more than at any other time, with different sectors vulnerable to even small changes in environmental conditions. At the same time, societies are becoming more capable of mitigating the adverse consequences of weather and climate phenomena, provided the relevant and timely information are made available. Weather-related disasters are becoming increasingly avoidable through early prediction, warning and action on the part of those at risk and those responsible for public safety and security. Early warnings, accurate identification of vulnerable areas and timely evacuations during cyclones have helped in minimizing the major loss of lives in the country.

Weather affects almost every aspect of society, from daily life to the economy. It is crucial for country like India to have accurate forecasts of the risks, and with sufficient lead times to implement early actions and allow disaster managers to reach more people. As more widespread extreme weather events occur frequently associated with climate change, IMD has more responsibility to continue improving forecasting and modelling, not only for accuracy, but also to provide enhanced lead time as possible.

Once again I congratulate all IMD employees and entire meteorological fraternity for rare milestone of 150th year of services to the nation.

(M. Ravichandran)

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CONTENTS

Evolution of IMD

1. Evolution of IMD

IMD is the principal government agency of the Government of India for all weather and climate services. It functions under the Ministry of Earth Sciences (MoES) with its headquarters at Mausam Bhawan, Lodhi Road, New Delhi. IMD is proud to be manned by more than 4000 scientific personnel and is a house to advanced meteorological instruments, state-of-the-art computing platforms, weather and climate prediction models, information processing and forecasting systems and warning dissemination systems.

IMD works in a coordinated manner with headquarters in Delhi and 6 Regional Meteorological Centers (RMCs) catering to 6 different regions of the country. These RMCs are further assisted by 26 Meteorological Centers (MCs) at the state level that are specialized for observing and disseminating information, advisories and warnings about regional weather. The different dedicated divisions in IMD headquarters like the National Weather Forecasting Center (NWFC), Numerical Weather Prediction (NWP), Satellite Meteorology Division, Upper Air Instrument Division, Hydrology Division and Information System & Services Division (ISSD) and Climate Research & Services Division of IMD Pune support the overall forecasting, monitoring and dissemination services of IMD.

IMD since its foundation has undergone several phases of evolution and has been a testament of progress, glory and service to the nation since 1875. The salient features of the evolution of IMD in different phases are described below:

1.1 Upto 1875 (Birth of India Meteorological Department)

The importance of weather and climate was understood by human civilisation in the very beginning, as we can find out the description highlighting the importance of weather & climate and attempt for its prediction since the ancient era as mentioned in Vedas and Epics. Upanishads are found to deliberate on the reasons for cloud formation, rain and seasonal cycles. During the past few centuries also, India has been at the forefront of scientific knowledge concerning meteorology and allied subjects. It is followed by the attempt in the Medieval Era as mentioned in Kalidas Meghdoot and Chanakya's Artha Shastra, highlighting the importance of weather and climate and the attempt for the prediction. In terms of infrastructure, India has some of the oldest Meteorological Observatories in the world. However, the instrumental era of Science and Meteorology in India commenced with the establishment of the 1st Meteorological and Astronomical Observatory in Madras in 1793. While the number gradually increased since then, the standards of instruments, and the time of observations were not fixed and the observations could not be utilized for predicting purposes. While on the one hand, the first war for independence was being fought by the Indians, popularly known as the "Sepoy Mutiny" in 1857, on the other hand, a group of Scientists in Asiatic Society of Bengal was also following up a Scientific revolution to establish a national meteorological Committee for standardising the instruments, exchanging data and utilising data for cyclone & flood disaster management and find out the relationship between the diseases and weather in India.

Accordingly, the Asiatic Society of Bengal represented to the Governor General in 1857. It was followed up by the formation of Sanitation Committee in 1860 and finally the Meteorological Committee at Provincial level was set up. Considering the limitations of provincial committees as the data were not exchanged and no guidance was generated in all India level and there was no uniformity and standardisation, Asiatic society of Bengal again reiterated the need of National Meteorological Committee. Finally, Governor General

Council agreed to form the National Committee. The India Meteorological Department was established in 1875 with HF Blanford as Meteorological Reporter.

1.2 1875-1890 (Nascent age)

With the establishment of IMD, all meteorological work in India was brought under its ambit. Subsequently, the meteorological observatory was established at Alipore, Kolkata in 1877.

Major breakthroughs came in the form of
(i) Integration of Meteorological observations
(ii) Standardisation of observations
(iii) Exchange of observations, not only in India but also with the World

Scientists at that time understood that weather and climate have no boundaries. Hence to monitor & predict weather & climate, they realised that observations should be taken across the globe. IMD became a member of the World Meteorological Organisation.
Communication was the key to the success of the above initiative, with the first postal service for the collection of observation on a daily basis implemented in 1876, and telegraphic weather code in 1878, the telephone switchboard in 1882 and the Introduction of the express telegram (XXW) in 1887.

By the end of 1886, a system of port warnings which commenced for Kolkata Port in 1865 was extended to all Indian ports.

IMD became the Rainfall Registration Authority and the adoption of the common type of rain gauge was carried out in 1890 with a resolution passed by the Government of India.

1.3 1891-1946 (Growth before independence)

Major breakthroughs towards the end of the 19^{th} century included:
(i) Preparation of the first chart in 1877
(ii) Preparation of the first Daily Weather Report in 1878
(iii) Preparation of climatology based on long-term observational data

As the world was moving towards a conflicting era, with World War- I during 1914-19 and World War II during 1939-1945, everybody felt the need for weather information from the upper atmosphere for managing the war. It gave a boost to understanding weather & climate, development of climatology, analogs, and statistical methods. The observations from the upper atmosphere commenced with the release of the Pilot Balloon in 1905 from Shimla. By 1905 upper air observations began using theodolites for tracking balloons. Surface Instruments Division was established in 1920 to ensure the maintenance of instruments. The first aviation forecast was issued from Shimla in 1921. Aviation service expanded with the establishment of many aviation forecasting centers due to World War I & II. RS/RW observations commenced in 1930 in India. Thus, India had three-dimensional information about weather by 1930.

- The first climatological data in the form of a meteorological atlas of the Indian Seas was published in 1908. Atlas of storm tracks in the Bay of Bengal and Arabian Sea was prepared in 1925.
- The communication technology also improved with the adoption of radio communication for the collection of data from ships and transmission of warnings through coastal radio stations at Karachi and Mumbai in 1912 and the wireless exchange of weather information in 1929. All India Radio started broadcasting the weather bulletin in 1936.

- The first formal training on General Meteorology was introduced in IMD in 1943. Later it was extended to training on Meteorological Instrumentation.
- To give special emphasis on Agriculture meteorology a separate Division in 1932 was carved out within IMD to cater to Agromet research activities. Farmer's Weather bulletins from Regional Meteorological Centres and Coordinated Crop Weather Watch Scheme commenced in 1945.
- During this period the IMD HQ shifted from Kolkata to Shimla in 1905, to Pune in 1928 and to Delhi in 1944. 7 Regional Meteorological Centres were established at New Delhi, Bombay, Madras, Nagpur, Kolkata, Karachi and Lahore.
- On the other hand, it was also felt necessary to monitor the earth's environment. The first observation of total column ozone was taken in 1928 from Kodaikanal.

1.4 1947-1959 (Commencement of Radar age & Flood Met. Services)

With the country's independence, the progress of meteorology accelerated in the country with many interventions. Major breakthroughs are given below:

(i) IMD saw a quantum jump in its observational infrastructure with the introduction of radar to support aviation services and for tracking storms in 1954. The first wind-finding Radar was established in Dum Dum in 1954 followed by indigenous radar at Safdarjung Delhi in 1958 from the remnants of the 2nd World War. Scientists of IMD under the leadership of then DG IMD, Dr. LS Mathur developed this indigenous radar for detecting winds and thunderstorms.
The 1950s also saw the beginning of advanced Numerical Weather Prediction research and development activities in the department under the leadership of Dr. P. K. Das, Former DG IMD.

(ii) During this period another new service started for the management of floods and reservoirs. Damodar Valley Corporation Meteorological Unit was established in 1949 for Dam safety measures. Policy statement on flood was adopted by Govt of India in 1954. First High Level Committee on Floods recommended flood plain zoning, flood forecasting and warning for the management of floods in 1957.

(iii) Following up on the environmental monitoring initiated in the previous period, first atmospheric turbidity monitoring network was established in 1957. IMD also started emphasis on environmental meteorology with the setup of the first ozone measurement in 1957.

(iv) Another chapter was added to the services of IMD with the establishment of the Positional Astronomy Center at Kolkata which published the Panchang in 1955.

1.5 1960-1970 (Commencement of Global Satellite Era & Establishment of ITM)

- The USA launched TIROS-1 satellite in April, 1960. A receiver was provided to IMD Colaba to receive the satellite imagery from this Polar Orbiting satellite. This was the dawn of an era when the missing of cyclones over the Bay of Bengal and the Arabian Sea could be minimized with better estimation of location, intensity and the study of structure of cyclone as well as the monsoon, clouds and circulation features. IMD started using the satellite images provided through US satellites since December, 1963. The first cyclone detection radar (CDR) was set up in Visakhapatnam in 1970.
- To encourage research, Institute of Tropical Meteorology (ITM) was established in 1962 in IMD, Pune which later became an autonomous institution, Indian Institute of Tropical Meteorology (IITM).
- The First Precipitation Chemistry Network for monitoring rainfall quality, a self-recording rain gauge (SRRG) was established in 1970. The first Indian ozonesonde

was developed in 1964 and surface ozone recorder in 1970. The first runway visual range was established in 1966 to measure visibility along the runway.

- A radio teletype link was established between India and Moscow on 1st January 1960 and with Tokyo in 1961 creating New Delhi as one of the Northern Hemispheric Exchange Center (NHEC) of the world for WMO. 1961 also saw the establishment of a directorate of seismology and a Northern Hemispheric Analysis Centre (NHAC). New Delhi became an Area Forecast Centre along with Tokyo, Cairo, Melbourne and Moscow to prepare and transmit actual and forecast charts for international use in Aviation. The Directorate of Telecommunication was established in 1970 along with high-speed switching computers in 1970 and Delhi became the Regional Telecommunication Hub.
- To augment the numerical modeling of weather, first NWP research group was set up in IMD, Delhi in 1969 under the leadership of Dr. P. K. Das.
- The services of IMD further expanded. The Storm Analysis Unit was established in 1963 to support flood forecasting. Marine Weather Service commenced in 1966. Crop weather diagram was prepared in 1961 to provide crop weather advisories to farmers and crop weather forecasting commenced in 1967. Study commenced on drought climatology over India in 1967.
- Capacity building was another important initiative during the period with the establishment of RS/RW Meteorological Training Centre in 1962 and the commencement of Training to Naval and Air Force Officers in 1963. The 1st batch of foreign training candidates commenced in 1967. The training Directorate was established in Pune in 1969.

1.6 1971-1983 (Global monitoring and better forecasting up to 24 hours)

Major breakthroughs during the period are as follows:

- The Bhola cyclone killed 300,000 people in Bangladesh in 1970, 10,000 people died in Andhra Pradesh in the same year and another 10,000 in Odisha in 1971 due to cyclones. A Cyclone Disaster Mitigation Committee under the Chairmanship of Cabinet Secretary was formed in 1971 which recommended an institutional mechanism, like the establishment of Cyclone Warning Centres in addition to Area Cyclone Warning Centres. Specific cyclone warnings could be provided for all coastal states. 11 Cyclone Detection Radar were established by 1974 to cover the entire east and west coasts. Hence no landfalling cyclone for India went undetected since 1974.
- First indigenous X band radar was installed in Delhi in 1975.
- A directorate of satellite was created in 1971. The geostationary satellite images from foreign satellites commenced in 1974. IMD could receive satellite-based cloud images every three hours covering entire globe. Thus, since 1974, the technology enabled IMD could detect all the synoptic scale (100 km to 1000 km diameter) weather systems and could provide better accuracy 24 hours forecast. The first time a ceilometer was established to estimate the height of the base of the cloud in 1975. INSAT Series of satellites commenced in 1982 by ISRO and monitoring of cyclones by Indian satellite in 1983. INSAT provided a Geostationary platform for remote sensing of the atmosphere and automatic data collection in 1982. 100 data collection platforms were established in 1980s.
- Alphanumeric data exchange commenced in 1974 with the advent of a message-switching Computer in 1974 (2400 BPS speed). Numerical modelling which commenced in 1958 and under the leadership of Dr. P. K. Das, got a major boost and India started running the models providing forecasts upto 24 hours.

- This period also saw a major expansion in organisational network. In 1971, IMD came under the Ministry of Tourism and Civil Aviation. IMD established Hydrometeorology Division in 1971, Cyclone Warning Research Centre in 1972, WMO recognised regional Meteorological Centre (RMC) for Tropical Cyclones in 1973 and several Meteorological Centres at LKN, HYD, TRV, BBN, Bengaluru, Patna, AHD, Bhopal, Chandigarh, Sri Nagar during 1972-1981. Nine Flood Meteorological Offices were established during 1973-1980 to improve flood forecasting. The first quantitative precipitation forecast for the river sub basin commenced in 1975.
- The environment monitoring further expanded with the establishment of first ozone sonde in Dakshin Gangotri, Antarctica in 1982. Environmental monitoring for Mathura commenced in 1981. The first Indian expedition to Antarctica commenced in 1981. IMD also expanded its wings in polar research with the establishment of the First Meteorological station in Antarctica in 1983.
- IMD also placed a lot of emphasis on the up-gradation of human resources and for this purpose meteorological training facility created in 1942 was upgraded to a directorate in 1969 and is now functioning as the Regional Meteorological Training center of WMO. A Regional Area Forecast Center (RAFC) was created at NHAC in 1971 to cater to the needs of South Asia. 1977 saw the establishment of the National Data Center at Pune for scrutinizing and archiving all meteorological data.

1.7 1984-1990 (Indian Satellite era)

(i) Regular reception of satellite images commenced in 1984 from Indian satellites. Further, the derived products from satellites including wind, precipitation, Sea surface temperature commenced during 1984-86.

(ii) WMO recognised the training services of IMD as Regional Meteorological Training Centre (RMTC) in the year 1986.

(iii) In the environmental monitoring front, total column ozone was observed in Antarctica in 1987, Met Station Maitri was established in Antarctica in 1989, Radio Theodolite was developed in 1989. Vertical distribution of ozone commenced in 1990. For better monitoring of rainfall and hence floods, droughts in high spatial resolution, district wise rainfall monitoring commenced in 1989.

(iv) National Centre for Medium range Weather Forecasting (NCMRWF) was established in 1988 and Super computer came to India in 1989.

(v) There was further re-organisation of IMD as IMD came under Ministry of Science and Technology in 1985. Global role of IMD in providing daily tropical cyclone advisories got enhanced with Regional Meteorological Centre (RMC) Tropical cyclones, New Delhi becoming Regional Specialised Meteorological Centre (RSMC) in 1988. Cyclone Warning Centre was established in Ahmedabad in 1988 to provide warnings to Gujarat, Daman and Diu. Total number of Area Cyclone Warning Centres (ACWCs) and Cyclone Warning Centres (CWCs) became six to provide cyclone warnings for entire east and west coasts of India.

(vi) Cyclone Warning Directorate was established in 1990 in Delhi to bring uniformity in cyclone warning work in the country and to carryout national and international coordination.

1.8 1991-2005 (Commencement of Automatic of observations)

(i) First dedicated meteorological satellite Kalpana was launched in 2002 by ISRO.

(ii) 127 Automated Weather Stations (AWS) were established in 2005.

(iii) To improve environmental monitoring, Aerosol Optical Depth monitoring commenced in 2004.
(iv) Because the land-ocean-atmosphere interacts together, leading to weather & climate variations, Govt. of India launched the Data Buoy Programme through Department of Ocean Development in 1997. The computing system also improved.
(v) The failure to provide accurate and timely forecast for the Odisha Super Cyclone in 1999 led to intervention of new tools & technology like first Doppler Weather Radar in Chennai in 2002. By 2006, there were 4 Doppler weather radars along the east coast.
(vi) Resolution of Limited Area Model increased to 150 km and lead period increased to upto 2 days by end of 2005.
(vii) The services of IMD got further expanded and improved during the period. Hydrology Project was taken up by Government of India with participation of IMD and Ministry of Water Resources to better monitor the rainfall and manage floods & droughts in 1996. Mountain Weather Services for Himalayan region started in 1998.
(viii) Tropical Cyclone Advisory for International Civil Aviation commenced in 2003 from IMD New Delhi and it acted as one of the seven Tropical Cyclone Advisory Centre (TCAC) as per the requirement of ICAO.
(ix) Naming of Cyclones over the North Indian Ocean commenced over North Indian Ocean in 2004 and the first name was ONIL for the cyclone over the Arabian Sea in September, 2004.
(x) VSAT system for communication was introduced in 2000
(xi) The Organisation further expanded with establishment of Regional Meteorological Centre (RMC), Guwahati in 1997. Meteorological Centres were established in Jaipur, Dehradun, Raipur, Shimla, Ranchi, Gangtok and Agartala during 2001-2003 to provide State Level Weather & Climate Services.

1.9 2006-13 (Age of Modernisation of IMD)

Major breakthroughs during this period are highlighted below:

(i) In 2006, IMD came under the umbrella of the Ministry of Earth Sciences (MoES) with an ambition that Earth, Ocean, and Atmosphere should be considered integrally to improve the weather & climate services.
(ii) The modernisation programme of IMD was taken up during 2007-12 which paved the way for the transition from analog & subjective to an objective method of forecasting & warning services equipped with a Decision Support System (DSS) in a digital platform. The forecasters could compare, comprehend and analyse the observations and the model guidance to provide the forecast for the next 3 days by the end of 2009 and 5 days by 2013.
(iii) No. of models increased for short to medium range forecast upto five days from a single regional model of IMD to 6 global models (viz. IMD GFS, NCEP GFS, ECMWF, NCMRWF Unified Model, JMA & Meteo France) and other regional models (viz. IMD WRF and Hurricane WRF). The assimilation and modelling activities at NCMRWF, Noida and IITM, Pune of MoES and other institutions of the country got accelerated during this period.
(iv) Monsoon Mission was taken up to improve the forecast in all spatial and temporal scales.
(v) Workstation of 600 GB data exchange was established in 2009.
(vi) The High-Power Computing System (HPCS) was installed in 2010. Dynamical Statistical Modelling of tropical cyclones, Ensemble Prediction systems, Multi Model Ensemble were introduced during 2009-11.

(vii) The digitisation helped in introduction of new services like Online Aviation Meteorological Briefing System in 2007, electronic Atlas of cyclonic disturbances in 2008, Web Atlas in 2011, District Level Agrometeorological Advisory Services in 2008, Multi-hazard Early Warning System (MHEWS) in 2009, Gramin Krishi Mausam Sewa (GKMS) in 2012, SMS service in 2009 to disaster managers, to fishermen and farmers by 2013.

(viii) Major breakthrough came during cyclone Phalin which hit Odisha coast on 12th October, 2013 near Gopalpur. Entire world went wrong and India proved right, when the Extremely Severe Cyclonic Storm, Phailin hit the Odisha coast on 12th October, 2013. India wrought the history. It was monitored and predicted under the leadership of Dr. M. Mohapatra, Director Cyclone warning Division. Entire World appreciated IMD and IMD emerged as a global leader in tropical cyclones monitoring and forecasting.

1.10 2014-23 (Rapid advancement in observation, communication and modelling facilities, paradigm shift in forecasting accuracy and Services)

(i) There was significant improvement in all fronts including meteorological observations, communication, modelling and infrastructure. Accordingly, there was rapid enhancement of weather and climate services and also the forecast accuracy improved by 40-50%.

(ii) From the modest beginning in 1875 to at present, IMD boasts of 39 Doppler Weather Radars for better observation and prediction of extreme events across the country by 2023, along with INSAT 3D/3DR dedicated weather satellites providing every 15 minutes cloud imagery. About 200 Agro-Automated Weather Station (Agro-AWS), 806 Automatic weather stations, 1382 Automatic Rain gauges, 83 lightning sensors along with 63 Pilot balloon upper air observation stations serve as the backbone of weather observation services of IMD throughout the country.

(iii) Development of new monitoring and forecast products including rapid assessment of severe weather through satellite in 2015, rapid scanning of cyclones every 6 minutes from 2018, every 15 minutes products from INSAT 3D/3D(R) since 2016, sea surface winds from scatterometer from SACTSAT-1 in 2016, Ocean Sat-3 in 2023 are some of the major interventions. Installation of Multi Mission Data Reception & Processing System (MMDRPS) in 2017 and upgraded system in 2021. Deployment of 25 Global Navigation Satellite System (GNSS) for total columnar water vapour management.

(iv) Numerical Weather Prediction modelling capabilities of IMD have also reached new heights with improved dynamical models operationally run in a seamless manner from nowcast for a few hours to long range weather predictions with forecast upto a season. There was the introduction of 12 km resolution global model in 2016, ensemble prediction model in 2018, extended range forecast system in 2017, dynamic MMCFS for seasonal forecasting in 2017 followed by multi model ensemble based seasonal forecasting model in 2021 were the major backbone improvement for weather & climate forecasting. Introduction of ocean atmosphere coupled cyclone specific model (HWRF) in 2017 & 2019. Meso-scale WRF Model with 3 km resolution in 2019. WRF Polar Model for Antarctica in 2019. Hy-SPLIT Model for trajectory forecasting in 2021. Nowcast model High Resolution rapid Refresh (HRRR) 2 km resolution in 2021 and Electrical WRF (EWRF) for lightning prediction in 2022, integrated urban flood warning system in 2020, South Asia Flash Flood Guidance system in 2020, Severe Weather Forecasting System in 2016 were the major interventions for regional and location specific forecasting.

(v) The introduction of multi-model ensemble in 2022 for cyclone and other severe weather events in 2022 at high resolution helped in decision making and improving the forecast accuracy.

(vi) Indigenous development of the GIS platform and Decision Support System along with impact-based forecasting technique enabled IMD to enter into a new era of service.

(vii) The lead period of the forecast for river catchments increased from 3 days to 5 days in 2020, and to 7 days in 2023. The lead period of cyclogenesis forecast improved from 24 hours to 3 days in 2014, to 5 days in 2018 and 7 days in 2023. The pre-genesis track & intensity forecast was issued in 2022 and extended-range forecast valid for 2 weeks was introduced in 2018. The daily weather forecast validity increased from 5 days to 7 days in 2023.

(viii) Forecast accuracy for all types of severe weather events increased by about 50% in 2023 as compared to 2014. The 5 day ahead forecast accuracy in 2023 is the same as 1 day forecast accuracy in 2017. There is an increase in lead period by 4 days in the last 5 years. While there has been pinpointed forecast accuracy for the landfall point of the cyclones with zero error in most cases (20 km in 24 hours ahead forecast). The 24 hours forecast accuracy for heavy rainfall is about 80%, thunderstorms 86%, heat waves & cold waves about 88%.

(ix) The period was witnessed with Digital India Programme launched in IMD in December, 2014 with SMS service to farmers, public & disaster managers in 2014, launching of dedicated website for cyclone in 2014, for severe weather over South Asia in 2016 & website for public in 2019, customised rainfall information at district, state, river catchment at All India level on daily, weekly, monthly and seasonal scale from 2015, Social media implementation in 2016, observed and forecast products in GIS platform in 2020 and other weather parameters in 2021, Dynamic Risk Atlas for Cyclones in 2021, climate hazards in GIS in 2021, the introduction of Mobile App in 2021, Automatic Programme Interface in 2022, introduction of audio visual forecast message in 2021. As a part of the digital India program, various reports and weather charts including reports on cyclonic disturbances since 1990 were digitised. The Climate Data Portal was developed in 2020. Climate Data Supply Portal for easy access and availability of Climate Data in 2020.

(x) IMD with its extensive network of observatories, telecommunication systems and newly added forecasting offices provides weather data for nation-building activities, issues forecasts and warnings for the prevention of any loss of life and property and also helps in optimum planning for economic development of the country. IMD's forecasting reach has now increased significantly covering almost all sectors of life in one way or another. IMD services have expanded enormously during this period be it Agriculture, Aviation, Shipping, General Weather, Hydrology, Power, Health, Transport etc. It won’t be an exaggeration for IMD services if we say that it symbolizes Har-Har Mausam; Har-Ghar Mausam.

(xi) At present, IMD is providing the nowcast for about 1200 stations, city forecasts for about 1200 stations apart from district level and sectoral forecast and warning services throughout the country. IMD is not only catering to the Indian region but also provides Cyclone forecast and warning services to 13 north Indian Ocean countries along with forecast and warning services to SAARC nations. IMD has helped the growth and development of different sectors of the country by making them weather-ready and climate-smart by providing them timely and skilled forecast and warning services. Farmers use Agro-met advisories for weather information-based management like sowing, irrigation, fertilizer and pesticide application, and harvest.

The IMD also provides support for an integrated flood warning system for Mumbai and Chennai, flash flood guidance services for India, Bangladesh, Bhutan, Nepal and Sri Lanka, winter fog forecasts for IGI airport, New Delhi etc.

(xii) IMD introduced, customised location specific forecast for offshore & onshore industries, airports, ports, Indian Air Force, Indian Oil corporation, Nuclear Power Corporation of India, marine weather forecast, cyclone forecast, heatwave forecast, thunderstorm forecast in text, graphic & GIS platform with socio economic attributes, hazard & impact modelling as well as risk assessment in 2021.

(xiii) The Agro-met services were extended to block level reaching upto 3 crore farmers during the period. Guidance could be provided for all types of floods including riverine, urban and flash floods. Urban meteorological services were extended to 1200 cities and towns with 150 cities being provided geospatial services with sub-city forecast.

(xiv) Collaboration with Power Sector and provision of forecast enabled to improve Power Sector Economy and harness renewable energy. The service to the health sector commenced during the period for implementation of the Heat Action Plan in 23 Heat wave prone states and UTs and guidance for vector-borne diseases like Malaria & Dengue. The air quality forecast commenced during the period along with the monitoring.

(xv) The aviation sector got massive extension under the Govt of India projects like UDAAN and Green Field Projects. Accordingly, IMD provided aviation services to more than 100 airports with instrumental observations and forecasts.

(xvi) Because of the Blue Economy, IMD extended its Marine Weather Services catering to the needs of all service providers and providing impact-based forecast.

(xvii) The Indian railways and National Highways were also provided specific forecasts during this period. IMD worked with the Incredible India Programme to provide forecasts for tourism in the country.

(xviii) The IMD’s focus on impact-based forecasting has opened a new vista for disaster risk reduction by providing impact-based information. The dynamic composite risk information in the case of Tropical Cyclones has helped disaster managers to plan and execute timely action for disaster responses. IMD’s affinity with the latest technologies has enabled the shifting of forecast products to newer platforms like Geographic Information Systems (GIS) leveraging the technologies for the benefit of mankind.

(xix) To make weather services omnipresent, IMD has leveraged technology to bring out innovative solutions like the dynamic Meteogram “**MAUSAM GRAM**” which provides weather information at all locations at any time (Har Har Mausam, Har Ghar Mausam).

(xx) IMD as an organisation also expanded during this period with the establishment of Meteorological Centres in, Shillong in 2018, Amravati in 2019, Leh in 2021, Port Blair, Imphal, Kohima & Aizawl in 2023.

(xxi) IMD’s history has been a story of precision and continuous progress. The IMD has come a long way with unprecedented improvements in its forecast accuracy, lead time and spatial & temporal resolutions which also reflect in the demands and aspirations of the general public. IMD is looking forward to developing its capabilities further and playing a very important and constructive role in nation-building by transforming India into a weather-ready and climate-smart nation, disaster resilient society and a Global Leader in meteorological science and service to society.

First two Indians in IMD

1885: First Indian Lala Ruchi Ram Sahni joined in IMD at Calcutta to assist Blanford in his scientific work.

1887: Lala Hem Raj was appointed in IMD at Shimla to assist Blanford in his scientific work.

World Meteorological Organization (WMO)
Vice-Presidents of WMO from India

Dr P. Koteswaram was elected vice-president of WMO in 1972.

Dr N. Sen Roy was elected vice-president of WMO in 1996.

Dr. M. Mohapatra was elected vice-president of WMO in 2023.

Padma Award received by IMD Scientists

Dr. K. R. Ramanathan was awarded Padma Bhushan in 1965 and Padma Vibhushan in 1976

Dr. P. C. Mahalanobis was awarded Padma Vibhushan in 1976

Dr. P. Koteswaram was awarded Padma Bhushan in 1975.

Dr. M. K. Vainu Bappu was awarded Padma Bhushan in 1981.

Dr. L. A. Ramdas was awarded Padma Shri in 1958.

Dr. R. Ananthakrishnan was awarded Padma Shri in 1969.

Dr. P. R. Pisharoty was awarded Padma Shri in 1970.

Change of Designation of the Head of India Meteorological Department

1875: Mr. H. F. Blanford "Imperial Meteorological Reporter"

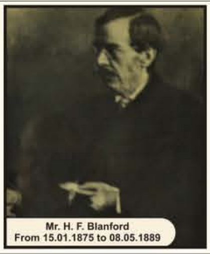
1899: John Eliot "Director General of Observatories".

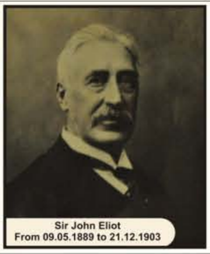
1975: Y. P. Rao "Director General of Meteorology".

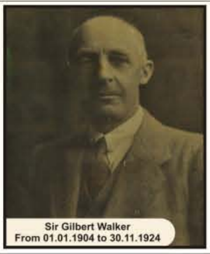
भारत मौसम विज्ञान विभाग
INDIA METEOROLOGICAL DEPARTMENT
पृथ्वी विज्ञान मंत्रालय, भारत सरकार
Ministry of Earth Sciences, Govt. of India

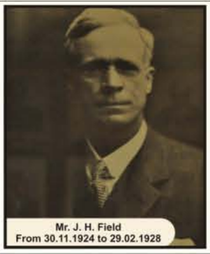
150 Years of Service to the Nation
राष्ट्र सेवा के 150 वर्ष

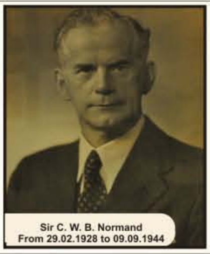
List of Director General of Meteorology


Mr. H. F. Blanford
From 15.01.1875 to 08.05.1889

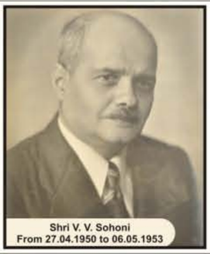

Sir John Eliot
From 09.05.1889 to 21.12.1903

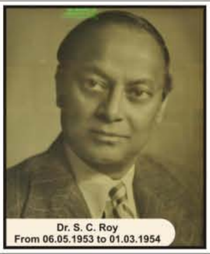

Sir Gilbert Walker
From 01.01.1904 to 30.11.1924


Mr. J. H. Field
From 30.11.1924 to 29.02.1928


Sir C. W. B. Normand
From 29.02.1928 to 09.09.1944

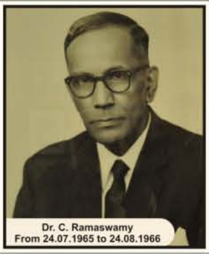

Dr. S. K. Banerji
From 10.09.1944 to 27.04.1950

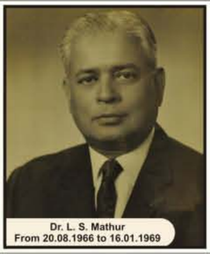

Shri V. V. Sohoni
From 27.04.1950 to 06.05.1953

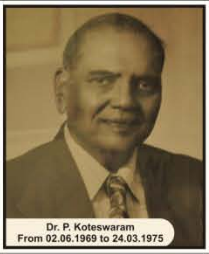

Dr. S. C. Roy
From 06.05.1953 to 01.03.1954

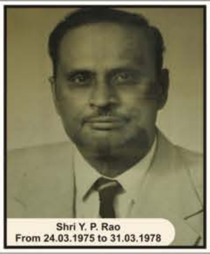

Shri S. Basu
From 01.03.1954 to 23.10.1959

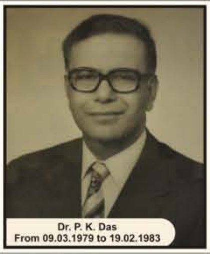

Shri P. R. Krishna Rao
From 23.10.1959 to 24.07.1965

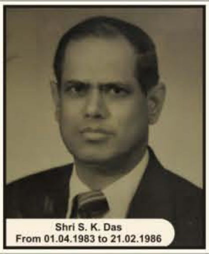

Dr. C. Ramaswamy
From 24.07.1965 to 24.08.1966

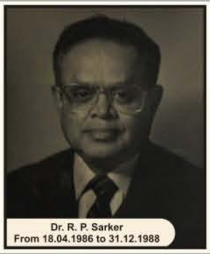

Dr. L. S. Mathur
From 20.08.1966 to 16.01.1969


Dr. P. Koteswaram
From 02.06.1969 to 24.03.1975

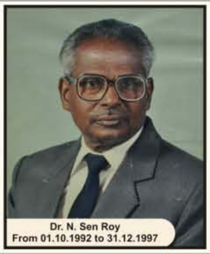

Shri Y. P. Rao
From 24.03.1975 to 31.03.1978


Dr. P. K. Das
From 09.03.1979 to 19.02.1983


Shri S. K. Das
From 01.04.1983 to 21.02.1986


Dr. R. P. Sarker
From 18.04.1986 to 31.12.1988


Dr. S. M. Kulshrestha
From 12.07.1989 to 01.05.1992

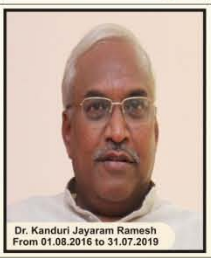

Dr. N. Sen Roy
From 01.10.1992 to 31.12.1997


Dr. R. R. Kelker
From 01.01.1998 to 31.12.2003


Dr. S. K. Srivastav
From 01.01.2004 to 15.01.2005


AVM (Dr.) Ajit Tyagi, VSM
From 11.03.2008 to 31.01.2012


Dr. L. S. Rathore
From 01.02.2012 to 31.07.2016


Dr. Kanduri Jayaram Ramesh
From 01.08.2016 to 31.07.2019


Dr. M. Mohpatra
From 01.08.2019

Major Milestones of IMD (1875 - 2023)

2. Major Milestones of IMD (1875-2023)

ORGANISATION

Journey of Head Quarters of India Meteorological Department

1875: Established Meteorological Department at Calcutta (now Kolkata).

1905: Headquarters of India Meteorological Department shifted to Shimla.

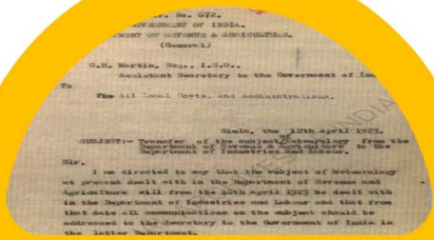
1928: Headquarters of India Meteorological Department shifted to Poona (now Pune).

1944: Headquarters of India Meteorological Department shifted to Delhi.

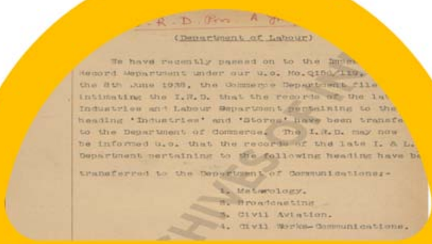
1976: Mausam Bhavan was established as Headquarters.

Journey of India Meteorological Department under different Ministries

1875: Established Meteorological Department at Calcutta under the department of Revenue, Agriculture, and Commerce.



1923: India Meteorological Department functioned directly under the Department of Industries and Labour.



1938: India Meteorological Department functioned directly under the Department of Communication.

पर्यटन एवं नागर विमानन मंत्रालय
MINISTRY OF TOURISM AND CIVIL AVIATION
सत्यमेव जयते

1971: India Meteorological Department functioned directly under the Union Ministry of Tourism and Civil Aviation.

विज्ञान एवं प्रौद्योगिकी मंत्रालय
MINISTRY OF SCIENCE AND TECHNOLOGY

1985: India Meteorological Department functioned directly under the Ministry of Science and Technology.

पृथ्वी विज्ञान मंत्रालय
MINISTRY OF EARTH SCIENCES

2006: India Meteorological Department functioned directly under the Ministry of Earth Science (MoES).

Journey of Division in India Meteorological Department

1913: India Meteorological Department (IMD) started taking upper air observation in Agra to support Aviation.

1920: Surface Instrument Division, Pune was established with the objective of inspection and maintenance of surface meteorological instruments.

1932: Agricultural meteorology branch started in Poona

1942: Beginning of formal training Courses for IMD personnel as an outcome of World War II

1955: Established Positional Astronomy Centre (PAC)

1960: Establishment of New Delhi as one of the five Northern Hemisphere Exchange Centre (NHEC) of the World over WHO scheme

1961: A Northern Hemispheric Analysis Centre (NHAC) established.

1966: IMD is the nodal agency to provide Marine Weather Services.

1970: A Directorate of Telecommunications was established

1971: Hydrometeorological Division established in IMD

1972: Satellite Meteorology Division established in IMD

1976: Commencement of Agro-meteorological Advisory Service (AAS).

1981: Mathura Refinery Unit (MRU) established in IMD for special observatories at Mathura subsequently renamed as Environment Monitoring and Research Centre (EMRC).

1982: Antarctica Project Evaluation Cell (APEC) established in IMD which has renamed as Polar Meteorology and Research Division (PMRD).

1988: Regional Specialized Meteorological Centre (RSMC) New Delhi was established

1990: Cyclone warning Directorate was established.

1998: Mountain Weather Services introduced in IMD.

2011: National Weather Prediction (NWP) which was part of Northern Hemispheric Analysis Centre (NHAC) started working as individual division.

2011: Northern Hemispheric Analysis Centre (NHAC) renamed as National Weather Forecasting Centre (NWFC).

2011: Climate Research and Services (CRS) Division established in IMD

2012: Central Aviation Meteorological Division (CAMD) was started in DGM's Office, New Delhi.

2019: Urban Meteorology and Climate Cell (UMCC) established in IMD.

2019: Power, Health and Transport (PHT) sector established in IMD.

2021: Geospatial section established in IMD.

Journey of Regional Meteorological Centers in India Meteorological Department

1945: Established seven regional meteorological centers (New Delhi, Bombay, Madras, Nagpur, Calcutta, Karachi, Lahore)

1997: Regional Meteorological Center established in Guwahati.

Journey of Meteorological Centers in India Meteorological Department

1972: Meteorological Centre established on Lucknow.

1973: Meteorological Centre established on Hyderabad.

1973: Meteorological Centre established on Bengaluru.

1973: Meteorological Centre established on Thiruvananthapuram.

1973: Meteorological Centre established on Bhubaneswar.

1974: Meteorological Centre established on Ahmedabad.

1974: Meteorological Centre established on Patna.

1976: Meteorological Centre established on Bhopal.

1980: Meteorological Centre established on Chandigarh.

1981: Meteorological Centre established on Srinagar.

2001: Meteorological Centre established on Jaipur.

2002: Meteorological Centre established on Ranchi.

2002: Meteorological Centre established on Gangtok.

2002: Meteorological Centre established on Dehradun.

2002: Meteorological Centre established on Raipur.

2002: Meteorological Centre established on Shimla.

2002: Meteorological Centre established on Ranchi.

2002:Meteorological Centre established on Gangtok.

2003: Meteorological Centre established on Agartala.

2004:Meteorological Centre established on Itanagar.

2007: Meteorological Centre established on Goa.

2014: Meteorological Centre established on Amaravati.

2018: Meteorological Centre established on Shillong.

2021: Meteorological Centre established on Leh.

2023 : Meteorological Centre established on Port Blair.

2023: Meteorological Centre established on Imphal.

2023: Meteorological Centre established on Kohima.

2023: Meteorological Centre established on Aizawl

National & International activities in India Meteorological Department

1908: Meteorological Divisions of India (Monthly weather review; IMD)

1911: First flight in India from Allahabad to Naini was made successful for current weather information and forecast was felt very much by the aviators.

1921: First aviation forecast was issued from Shimla for the Royal Air Force (RAF) operations in Waziristan which was part of the then northwest India.

1928: First Observations of Total Column Ozone in India at Kodaikanal using Dobson Spectrophotometer with the permission of the DGO in India

1929: The first air mail service from England to India commenced and Delhi and Karachi meteorological forecasting offices were empowered with the responsibility of issuing adverse weather warnings for the air mail service.

1943: Commencement of organized training school at Pune


THE MONSOON EXPERIMENT (MONEX)
P. K. DAS
Current Science
Vol. 48, No. 5 (MARCH 5, 1979), pp. 187-189 (3 pages)

1959 - 1965: International Indian Ocean Expedition (IIOE) was conducted.

1960: Establishment of New Delhi as one of the five Northern Hemisphere Exchange Centre (NHEC) of the World over WHO scheme which has renamed as Information Systems and Services Division (ISSD) in 2009.

1966: The Indian Ocean and Southern Hemisphere Analysis Centre (INOSHAC) establied at Pune, IMD.

1971: Regional Area Forecast Centre (RAFC) started functioning at NHAC New Delhi Under the ICAO Scheme.

1973: Indo-Soviet Monsoon Experiment (ISMEX-73) was conducted.

1973: Establishment of Regional Meteorological Centre (RMC) New Delhi to provide Tropical Cyclone (TC) guidance to WMO/ESCAP/neighbor country.


THE MONSOON EXPERIMENT (MONEX)
P. K. DAS
Current Science
Vol. 48, No. 5 (MARCH 5, 1979), pp. 187-189 (3 pages)

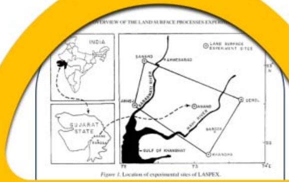
1979: Monsoon Experiment (MONEX) was conducted during the First Global GARP (Global Atmospheric Research Program) Experiment (FGGE).

1981: First Indian Scientific Expedition to Antarctica (ISEA) with IMD participates.

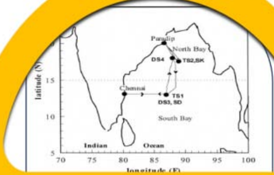
1983: First Meteorological station established in Dakshin Gangotri, Antarctica by IMD

1989: Meteorological Station established in Maitri, Antarctica by IMD

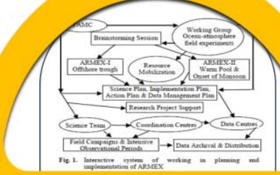
1990: Monsoon Trough Boundary Layer Experiment (MONTBLEX) was conducted.



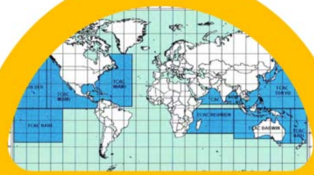
1997-98: Land Surface Processes Experiment (LASPEX) was conducted.



1999: Bay of Bengal Monsoon Experiment (BOBMEX) was conducted.



2002-05: Arabian Sea Monsoon Experiment (ARMEX) was conducted.



2003: Tropical Cyclone Advisory Centre (TCAC) was established in IMD to provide Tropical Cyclone forecast.

2008-10: Continental Tropical Convergence Zone (CTCZ) programme was the sequel to the BOBMEX and ARMEX.

2012: Meteorological station established in Bharti, Antarctica by IMD

2015: Severe Weather Forecasting programme (SWFP).

2017: The India Meteorological Department, Pune, was designated as Regional Climate Centre (RCC) Pune

2023: WMO Global Producing Centers of Long-Range Forecasts (GPCs-LRF) and the WMO Lead Centre for Long Range Forecast Multi-Model Ensemble (LC-LRFMME).

OBSERVATIONS

Surface instruments/observations

1875: Non Recording Rain Gauge (Symon's type)

1962: Wind Vane tells us about which direction the wind is blowing.

1962: Natural Syphon Recording Rain gauge

1962: This pan evaporimeter also known as modified Class A Pan, consists of a pan 1207 mm in diameter with 250 mm of depth.

1962: Thermograph provide a continuous record of air temperature. The recording is done on a graph mounted on a drum.

1962: Different types of thermometers

1962: Stevenson screen is a shelter to meteorological instrument and allows air to circulate freely around them.

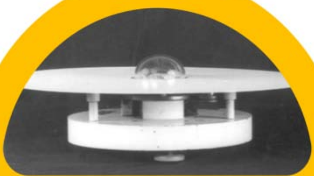
1962: Heliostat

1962: Hygrograph.

1962: A barometer is a scientific instrument used to measure atmospheric pressure.

1962: Diffuse shading ring

1962: A Sunshine recorder is a device that records the amount of sunshine at a given location at any time.



1962: Pyranometer is made for measurement of Solar Radiation

1962: Cup type anemometer consists of four hemispherical cups mounted on horizontal arms.

1970: Aneroid Barometer

1970: Dynes pressure tube Anemograph for measurement and recording of high wind speed and direction.

1970: An aneroid barograph is a portable instrument for automatic and continuous recording of atmospheric pressure.

1980: Tipping bucket rain Gauge is an event type sensor.

1980: Snow Gauge (manual)

2000: Digital barometer to serve as standard for surface pressure at Meteorological stations.

2006: Automatic Weather Stations (AWS) IMD has established 2000 AWS and ARG network.

2015: Wall mounted Digital Barometer

Upper Air Observation

1913: India Meteorological Department (IMD) started taking upper air observation in Agra to support Aviation.

1930: Pilot Balloon Observations were taken for Wind Data measurements.

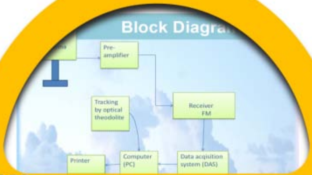
1964: Weather Bureau Radio Theodolite (WBRT) imported from USA.

1970: METOX Radiotheodolite Ground System was based on old Vacuum Tubes Technology.

SAMEER

1977: Special Microwave Product Unit (SMPU) was developed by SAMEER, Mumbai for IMD.

1989: SAMEER Radiotheodolite was developed by SAMEER, Mumbai for IMD



1989: RSGE was developed by the firm Digital Electronics Ltd. for IMD to collect temperature, pressure and humidity data. This system operated on a frequency of 403MHz on 39 stations.

2002: IMS Radiotheodolite was imported from USA. This system was based on the Digital Technology.

2002: System Reception (SR2K2) is a ground instrument for reception of data from sonde.

2008: IMD procured new GPS-based technology to introduced for the radio sounding system from France.

2023: IMD has a network of 56 Radiosonde Radiowind (RS/RW) stations.

2023: IMD has a network of 62 stations having pilot balloon observations.

World Meteorological Organization
Recognition of Centennial Observatory

1792: First astronomical and meteorological unit started at Madras.

1841: Establishment of Mumbai (Colaba) Observatory.

1853: Thiruvananthapuram Observatory established.

1856: Central Agro - Meteorological observatory (CAgMo) was established at the campus of Agriculture college, Pune.

1860: Panjim Observatory established

1866: Port Blair Observatory established

1867: Patna Observatory established.

1867: Cuttack hydrological station established.

1877: Alipore Observatory established.

1881: Gopalpur Observatory established.

1888: Puri Observatory established.

1889: Cuddallore Observatory established.

1891: Minicoy and Srinagar Observatory established.

1892: Bahraich Observatory established.

1893: Ahmedabad Observatory established.

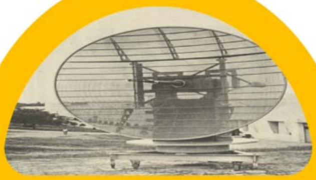
1890: Veraval hydrological station established.

1899: Kodaikanal Observatorv

1901: Dwarka hydrological station established.

1902: Shillong Observatorv

Radar Observation



1954: Radars were pressed into aviation weather service at Dum Dum (Calcutta) Airport

1958: IMD adopted radar technology for meteorological applications at Safdarjung airport, New Delhi

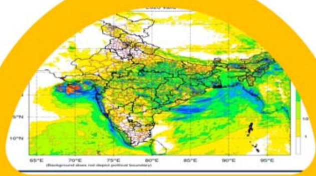
1970: First S-band radar was installed at Visakhapatnam

1975: First indigenously designed and developed X-Band storm detection radar was installed in Delhi

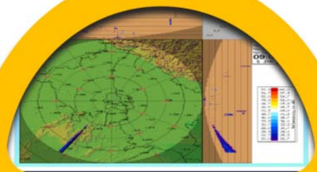
2002 - 2006: Four numbers of S-band Doppler Weather Radars (DWR) were installed at Chennai, Kolkata, Machilipatnam and Visakhapatnam.

2004: One indigenous S-band Doppler Weather Radar (DWR) developed by ISRO was installed at Sriharikota.

2007: Under modernization of IMDs observational network 13 old obsolete analogue radars were replaced with DWRs

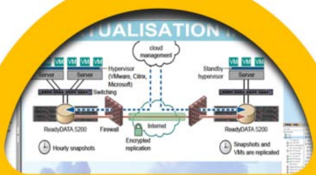


2010: First time Radar data used in NWP model (ARPS and WRF) to improve the initial condition.



2010: Implementation of Nowcast based on RADAR data.

2011: IMD procured two C-band Polarimetric DWRs from Finland and installed at Delhi and Jaipur in 2012.

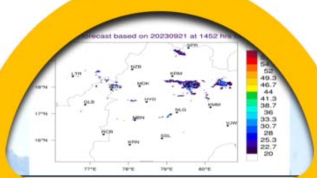


2011: RADAR data centre started in IMD

2014: Warning Decision Support System (WDSS-II) for nowcast service based on RADAR started in IMD.

2015: Two DWRs from M/s BEL Bangalore based on ISRO technology were installed at Mumbai and Bhuj in 2016.

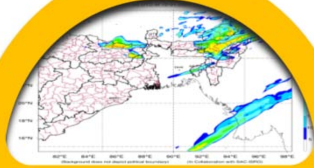
2015: Indigenous S-band polarimetric DWRs developed by ISRO (Indian Space Research Organization) were installed at Gopalpur.



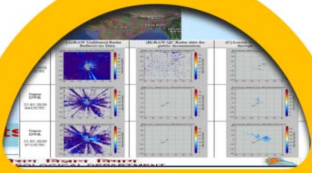
2016: Short Range Warning of Intense Rainstorms in Localized System (SWIRLS) software was developed by the Hong Kong Met Office.

2017: Indigenous S-band polarimetric DWRs developed by ISRO (Indian Space Research Organization) were installed at Kochi.

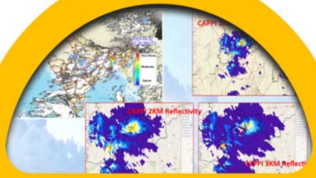
2018-2023: Under the Integrated Himalayan Meteorology Programme (IHMP) for Western and Central Himalayas, 10 X-Band polarimetric DWRs have been installed.



2020: High Resolution Rapid Refresh (HRRR) model used RADAR data to improve the initial condition.



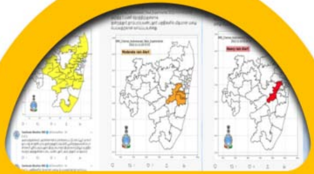
2020: Capture the Locust signature and extracted from radar reflectivity data.



2020: Radar Mosaic products on WebGIS.

2021: A transportable X-band Doppler Weather Radar mounted on a mobile platform was installed at Leh. The Leh DWR installed by IMD is at the highest altitude in India.

2021: First time plot the Radar reflectivity in 3D visualization.



2022: Taluk level auto-nowcasting for Greater Chennai Region using probabilistic ensemble nowcast for 2-3 hours.

2023: IMD's operational Doppler Weather Radar (DWRs) network comprises of 39 Radars all over India.

Satellite Observations

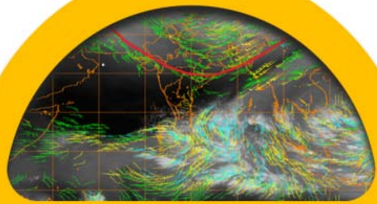
1960: On April first 1960 the USA launched its first meteorological satellite, TIROS-1
IMD started receiving satellite images from US Satellites in 1963

1972: Establishment of Satellite Meteorology Division in IMD New Delhi

1982: Launch of INSAT-1A geostationary satellite
Resolution of visible (2.75 Kms) & IR (11 Kms)

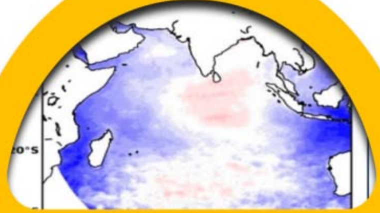
1982: India's first multipurpose geostationary satellite INSAT-1A provided a unique opportunity to observe the data-sparse Tibetan region.

1983: INSAT-1B launched on 30 Aug 1983
Resolution of visible (2.75 Kms) & IR(11 Kms)



1984: With the operationalization of INSAT-1B in October 1983-1984 extraction of CMVs from half-hourly.

1986: INSAT-1B based Quantitative precipitation estimates (QPE) algorithm and outgoing longwave radiation (OLR) product are developed



1986: Retrieval of sea surface temperature from INSAT-1B radiometer measurements using a multi-channel simulation approach.

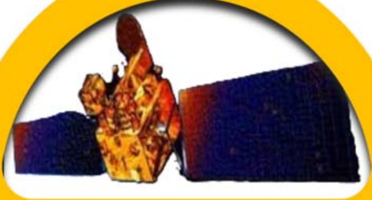
1988: INSAT-1C launched in July 1988 INSAT-1C satellite failed in Nov 1989 Resolution of visible (2.75 Kms) & IR (11 Kms)

1990: Launch of INSAT-1D Resolution of visible (2.75 Kms) & IR (11 Kms)

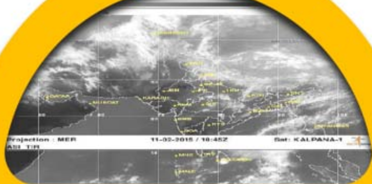
1992: Launch of INSAT-2A, the first indigenous geostationary satellite with resolution of visible (2 Kms) & IR (8 Kms) channels.

1993: Launch of INSAT-2B Satellite with Improved resolution of imaging instruments

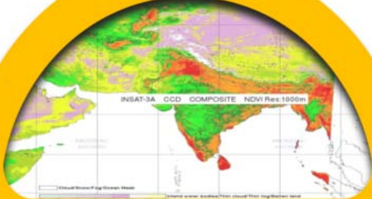
1999: Launch of INSAT-2E geostationary satellite, carried CCD payload for the first time with 1 Km resolution and data used for NDVI product



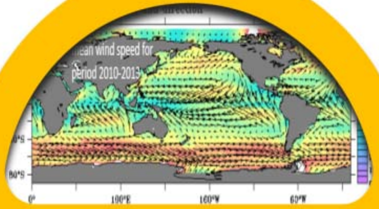
1999: Launch of OCEANSAT-1 first polar orbit satellite for meteorology and Oceanography



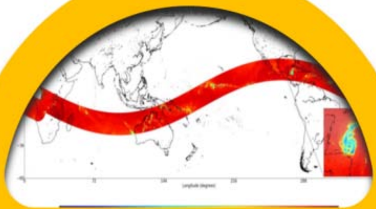
2002: Launch of first dedicated geostationary meteorological satellite (METSAT) & later renamed as KALPANA-1



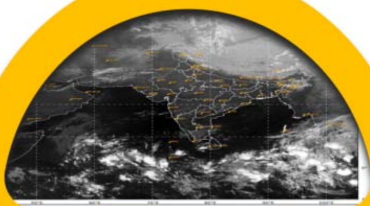
2003: Launch of INSAT-3A geostationary satellite



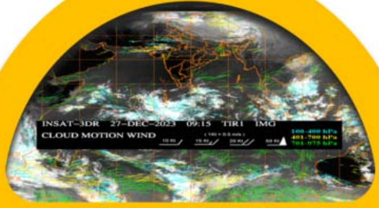
2009: Launch of OCEANSAT-2 satellite



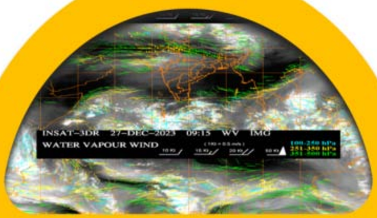
2011: MEGHA-TROPIQUES provide info on the water cycle, with information on condensed water in clouds, water vapor in the atmosphere.



2013: Launch of INSAT-3D with 6-channel imager and 19-channel atmospheric sounder provides high resolution: 1 Km (VIS & SWIR), 4Km(MWIR), 8km(WV) and 4km(TIR1 & TIR2) information

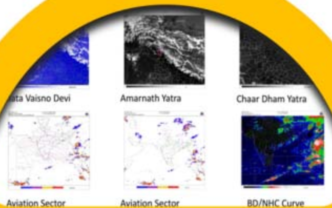


2014: First time radiances are being assimilated to the NWP models.



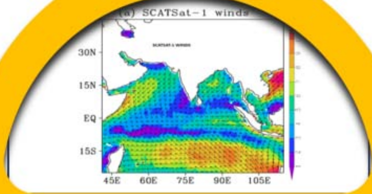
2015: First time winds (CMV/WVW) are being assimilated to the NWP models

2015: Launch of RGB & RAPID Visualization tool



2015: Generation of special sector satellite cloud images such as Amarnath Yatra, Char Dham Yatra and Mata Vaishno Devi Shrine

2016: With the launch of INSAT-3DR, data reception interval was increased to 15 mins.

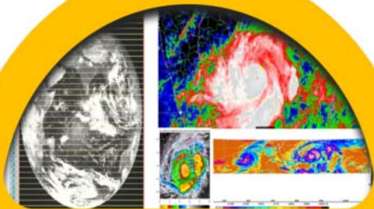


2016: Launch of SCATSAT-1 & used for sea surface wind monitoring

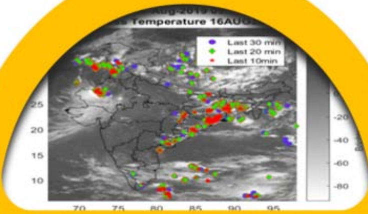
2016: A dedicated Cal-Val site for carrying out the vicarious calibration activities in respect of INSAT-3D/3DR Satellite was identified at Bhuj

2017: 25 Numbers GNSS Stations project for "Earth and Atmospheric studies" is commissioned and installed

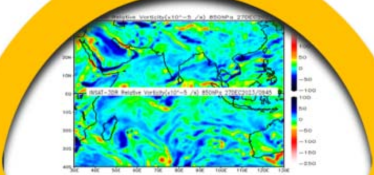
2017: A multi-Mission Data reception and processing system (MMDRPS) for INSAT-3D/3DR/INSAT-3DS Satellite has been established



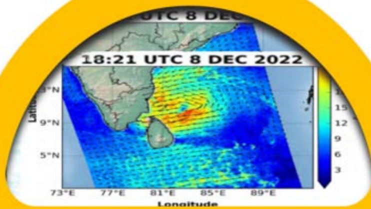
2017: Standard operating procedure (SOP) has been finalized in consultation with ISRO to conduct Rapid scan mechanism during extreme weather events.



2018: First time the INSAT-3D satellite and ground lightning data was merged and product made operationalized at IMD website

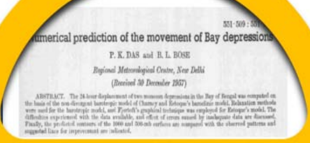


2020: Wind derived product started. (Vorticity, Convergence, Wind shear)



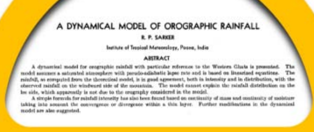
2022: Launch of OCEANSAT-3 & used for sea surface wind monitoring.

Numerical Weather Prediction

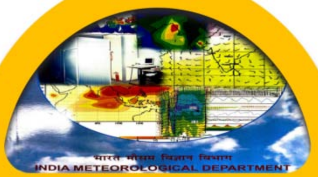


1958: First paper publication on numerical weather prediction model by Dr. P. K. Das, former DGM, IMD.

1961: A Northern Hemispheric Analysis Centre (NHAC) established.

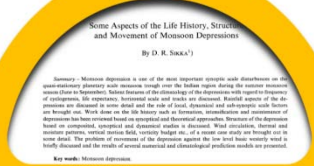


1966: Development of simple dynamical models of orographic rainfall over Western Ghats by R. P. Sarkar.



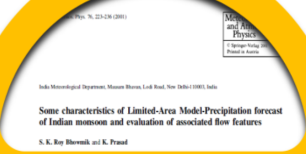
1969: Initial Numerical Weather Prediction (NWP) research group was setup in IMD, New Delhi.

1973: IBM 360/44 used for processing MONEX data. It had memory of 512KB with CPU speed–4MHz along with storage capacity of 64MB.

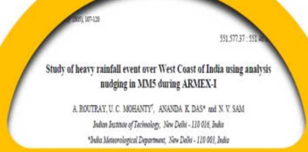


1977: NWP modelling to forecast movement of monsoon depressions and tropical cyclones.

1987: VAX-11/730 running of Q.G. and early P.E. Models. Memory-4MB, CPU Speed-3.7 Mhz, Storage-456MB.



1990: Operational implementation of Limited Area Analysis & Forecast Model (LAM) on cyber computing system and Quasi-Langrangian Model (QLM) for cyclone track prediction.

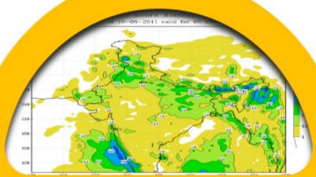


2000: Operational implementation of regional modelling system, MM5.

2001: SGI Origin 200 computing systems implemented in IMD.

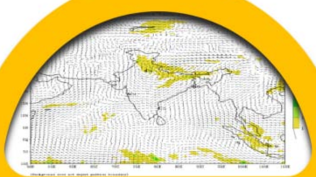
2004: SGI Alti 350 computing systems implemented in IMD.

2010: IBM-P5 HPCS implemented in IMD and Global Forecast System (GFS) Model IMD-GFS (T-254 at ~60 km resolution) and Mesoscale model WRF (27 km resolution) operationalized.

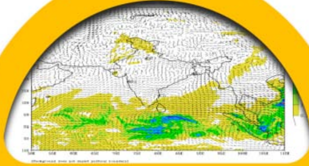


2010: Global Forecast System (GFS) model upgraded to T382 (~ 38 km) resolution.

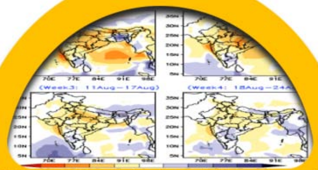
2011: National Weather Prediction (NWP) which was part of Northern Hemispheric Analysis Centre (NHAC) started working as individual division.



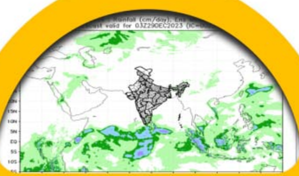
2013: Global Forecast System (GFS) model upgraded to T574 (~ 25 km) resolution.



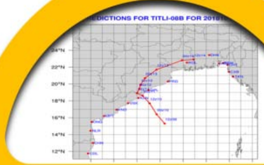
2016: Global Forecast System (GFS) model upgraded to T1534 (~ 12 km) resolution.



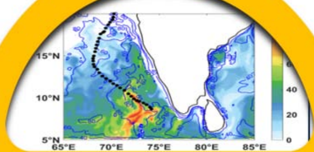
2017: Operational implementation of coupled modelling system (CFSv2) at a horizontal resolution of ~38 km with 16 ensemble members for real time extended range forecasts (upto 4 weeks).



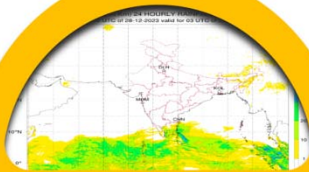
2018: High resolution Global Ensemble Forecast System (GEFS) IMD-GEFS at T1534 (~ 12 km resolution) with 21 members ensemble is operationalized.



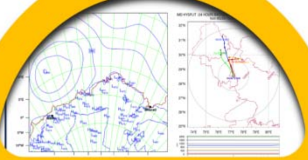
2018: Hurricane WRF (HWRF) modelling system coupled with POM-TC ocean model operationally implemented for Tropical Cyclone Forecasting.



2019: Ocean Model HYCOM coupled with HWRF model implemented for Tropical Cyclone Forecasting.

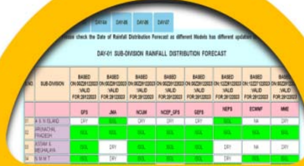


2019: Mesoscale WRF model at 3 km resolution.

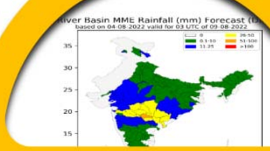


2019: WRF-Polar model for Antarctica.WRF HYSPLIT model for trajectory forecasting was implemented.

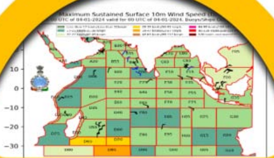
2021: Nowcast to very short range High Resolution Rapid Refresh (HRRR) model (2km resolution) implemented.



2021: Implemented Multi-Model Ensemble (MME) based forecast for met-subdivision, district, city and river basin scales.

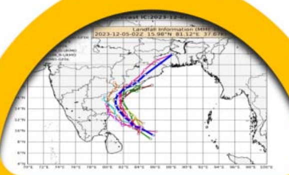


2021: Operationalized Multimodal Ensemble based River Sub-Basinwise Quantitative Precipitation Forecast (QPF).



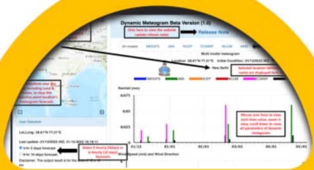
2022: Implemented Multimodel Ensemble based Fleet Forecast for Indian Navy encompassing weather forecast in Extended Domain.

2022: Electric WRF (E-WRF) model (at 3km resolution) with lightning data assimilation.



2022: Implemented Multi-Model Ensemble based cyclone tracker

2023: Experimental Heat index using model forecasts.



2023: Multi-Model Ensemble based Block level forecast and Dynamic Meteogram for location specific forecast.

Weather Forecasting Services

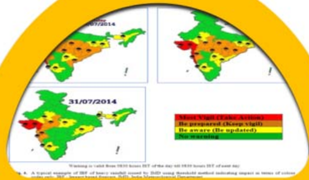
1961: A Northern Hemispheric Analysis Centre (NHAC) established.

1877: First Surface Weather Charts

1878: Preparation of first daily weather report

1998: commencement of Mountain weather bulletin.

2000: Shifted from Manual plotting of weather charts to automatic plotting using NHEC computer Ultrix-origin-200.



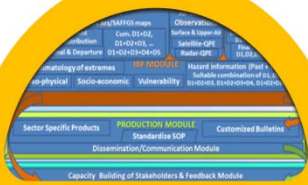
2010: Multi-hazard early warning maps (Green, Yellow, Orange, Red) colors included for three days

2013: commencement of Forecast Demonstration Project (FDP) of thunderstorm.

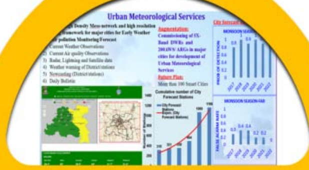
2013: commencement of Operational Nowcast

2017: commencement of FDP Heat Wave

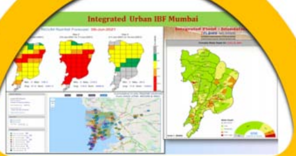
2019: IBF and risk based warning (RBW) stage 1 to stage 2 implemented for cyclone, heavy rainfall, TS/DS, Cold wave, heat wave & fog.



2020: Commencement of Impact based flash flood forecasting.



2020: Commencement of Integrated Urban Weather, Climate and Environmental Services.



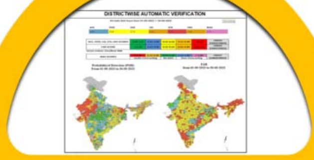
2021: District and sub-city levels (urban modules-I-flows, C-flows) IBF and risk warning (RBW) implemented stage-II & STAGE-III

2023: IBF and Risk Based Warning (RBW) implemented stage-1 threshold and consensus base heavy rainfall, TS/DS, Cold wave, heat wave & fog

2023: Commencement of Indigenous Decision Support System (DSS) for all severe weather events.

2023: Commencement of forecast warning extend to 7-days.

2023: Commencement of heat wave indices.



2023: District-wise auto verification of nowcast.

2023: GIS based heat wave and cold wave warning.

Cyclone Warning Services

1864: Severe cyclonic storm struck Kolkata in which in quick succession hit the east coast of India, causing enormous loss of human lives.

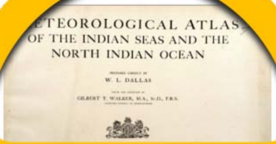
1865: Kolkata became the first port where a storm warning system was organised

1875: Establishment of India Meteorological Department.

1886: System of early warnings against cyclones was extended to cover all Indian ports

1891: Publication of India Weather Review containing details of depressions and storms.

1898: Uniform system of storm warning signals was introduced at all the Indian ports



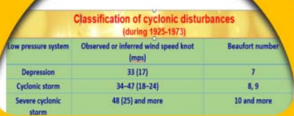
1908: Meteorological Atlas of the Indian Seas and the North Indian Ocean published

1915: First PB observatory at Pune

1919: Second PB observatory at Kolkata

Normand, C.W.B., 1925, "Storm Tracks in the Bay of Bengal" – Ind.Met.Dept

1925: Atlas of "Storm Tracks in the Bay of Bengal published.



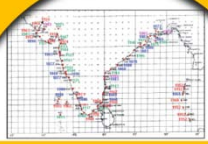
Classification of cyclonic disturbances (during 1925-1973)

Low pressure system	Observed or inferred wind speed knot (mps)	Beaufort number
Depression	33 (17)	7
Cyclonic storm	34-47 (18-24)	8, 9
Severe cyclonic storm	48 (25) and more	10 and more

1925: Classification of cyclones into cyclonic storms and severe cyclonic storms

1945: The storm warning work for the Bay ports on the east coast from Kalingapatnam Southwards was transferred to Chennai.

1947: Responsibility for the Arabian Sea ports was taken over by the Meteorological Office at Santacruz (Mumbai).



1952: First Surface Observatory over

1956: Separate storm warning centres came to be established at Colaba (Mumbai)

1960: First Surface Observatory in Lakshadweep and Kerala

1963: APT system donated by USA for receiving the satellite imagery from GOES satellites was established at Bombay

1964: Revised Storm Atlas published for 1877-1890 and 1891-1960

1969: Separate storm warning centres came to be established at Nungambakkam (Chennai).

1969: The responsibility for the ports on the west coast from Karwar to south was also transferred from Mumbai to Chennai

1969: CDMC for Andhra Pradesh was established to mitigate human suffering and reduce loss of life and property due to cyclonic storms.

1970: First cyclone detection radar was set up at Visakhapatnam in 1970.

1971: CDMC for Andhra Pradesh recommended IMD to establish Storm Warning Centre at Visakhapatnam for issuing cyclone warnings to coastal Andhra

1972: CDMC for Odisha recommended IMD to establish storm warning centre at Bhubaneswar for issuing cyclone warnings to coastal Odisha.

1972: Establishment of CWC at RMC, Chennai to carry out research as per operational requirement

1973: Storm warning centre was set up at Bhubaneswar for catering to the needs of Odisha

1973: RMC for Tropical Cyclones, New Delhi came into existence with the formation of WMO/ESCAP Panel

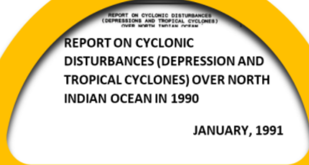
1974: Storm warning centre was set up at Visakhapatnam for catering to the needs of Andhra Pradesh.

1983: Cyclone monitoring by Indian satellite, INSAT

1988: Storm Warning Centre was established at Ahmedabad for catering the needs of Gujarat, Union Territory of Diu, Daman, Dadra and Nagar Haveli

1988: RSMC Tropical Cyclones, New Delhi and assigned the responsibility of issuing Tropical Weather Outlooks and Tropical Cyclone Advisories.

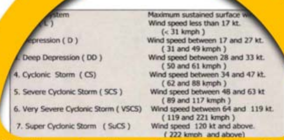
1990: Cyclone Warning Directorate to co-ordinate the cyclone warning work in the country in totality and act as RSMC Tropical Cyclones, New Delhi.



1991: First Annual RSMC Report on cyclonic disturbances over north Indian Ocean was published for the year, 1990

1996: Addendum to Storm Atlas for the period of 1971-1990 was published.

1997: Deployment of 12 Meteorological Buoys by NIOT over the NIO



1999: Introduction of super cyclonic storm category and change of nomenclature from severe cyclonic storm with core of hurricane wind to very severe cyclonic storm

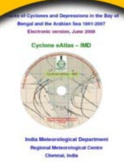
2002: First Doppler Weather Radar established at Chennai

2003: Cyclone Warning Division acted as Tropical Cyclone Advisory Centre, New Delhi as per requirement of International Civil Aviation Organisation

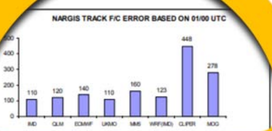
2004: Naming of cyclones over north Indian Ocean was introduced. First name was ONIL by Bangladesh.

2005: Area of responsibility of RSMC New Delhi extended to cover entire North Indian Ocean from 2005

2005: RSMC New Delhi Organised first bi-weekly training for Tropical Cyclones Forecasters of WMO/ESCAP Panel member countries



2008: Publication of Electronic Atlas for the period of 1891 onward

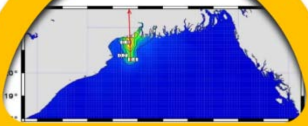


2008: Introduction of verification of Operational forecast for cyclone Nargis

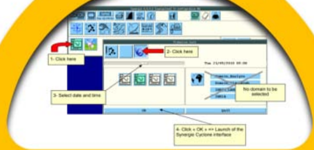
2008: Issue of 72 hr forecast with forecast of Cone of Uncertainty from cyclone WARD

2008: Forecast Demonstration Project started for the period 15-October to 30 November

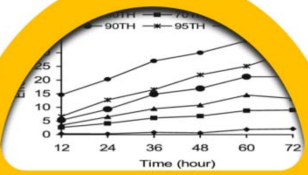
2008: Introduction of press release and press briefing.



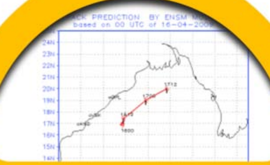
2009: Operationalisation of IIT- D Storm Surge Model & issue of storm surge guidance for WMO/ESCAP member countries from cyclone "BIJLI"



2009: Warning system was modernised with introduction of Digitised Decision Support System



2009: Introduction of Dynamical Statistical Model for Intensity Prediction

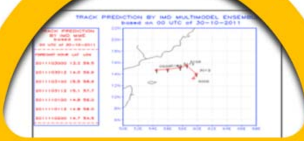


2009: Introduction of Multi Model Ensemble Model for track prediction Introduction of Dynamical Statistical Model for Intensity Prediction

2010: Forecast of Quadrant Wind Radii from cyclone "GIRI"

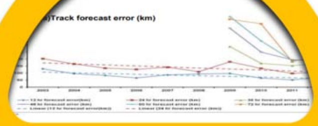
2010: Introduction of Quadrant Wind Bulletin from cyclone "GIRI"

2010: Introduction of HWRF Model for north Indian Ocean region from cyclone "MURJAN"

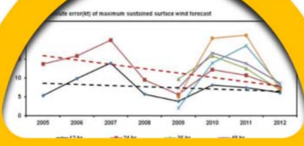


2011: Introduction of Ensemble Prediction System Model for Track Prediction

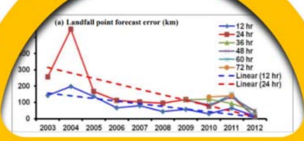
2011: Web enabled E-Atlas developed



2012: Verification of Track forecast errors from 2003 onwards

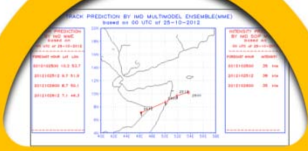


2012: Verification of Intensity forecast errors from 2003 onwards

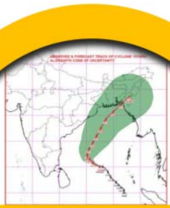


2012: Verification of Landfall forecast errors from 2003 onwards

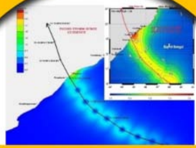
2012: Introduction of SMS to Disaster



2012: Introduction of MME



2013: Extension of forecast upto a lead period of 120 hours from cyclone



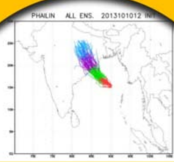
2013: Introduction of experimental coastal inundation forecast with experimental run of Advanced Circulation (AdCirc) model by INCOIS from cyclone

Example:
IMD 01B MAHASEN 20130515 0000 160N 0870E 030
040 0996 1003 0250 020 060 0170 0170 0120 0140 M

2013: Introduction of coded TC Vital from cyclone

```
#
0005
THANE
2011122706 12.0 087.0 O
2011122712 12.5 086.5 O
2011122718 12.5 086.0 O
2011122800 12.5 086.0 O
2011122806 12.5 085.0 O
2011122812 12.5 084.3 F
2011122818 12.7 083.7 F
2011122900 12.8 083.1 F
2011122906 12.8 082.5 F
```

2013: Introduction of ADRR text bulletin for civil aviation



2013: Introduction of Ensemble Prediction System (EPS) collaboration with Japan Meteorological Agency (JMA).

ESSO- Indian National Centre for Ocean Information Services

2013: Introduction of SMS to fishermen through INCOIS network from cyclone

2013:
- IMD got appreciation worldwide for accurate prediction of cyclone
- Appreciation from WMO

2013:
- IMD got appreciation worldwide for accurate prediction of cyclone
- Appreciation from RA II President

2014: Launching of a dedicated website for RSMC

During VSCS HUDHUD about 19 Lakh SMS were sent to farmers of Andhra Pradesh, Odisha from 9th October onwards and for the states of Telangana, Bihar, Chattisgarh, Jharkhand, East Uttar Pradesh, East Madhya Pradesh

2014: SMS to farmers through farmers portal from cyclone

India Meteorological Department
(Ministry of Earth Sciences)

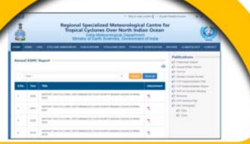
HOURLY UPDATE ON CYCLONIC STORM 'HUDHUD' OVER BAY OF BENGAL

BULLETIN NO. 01

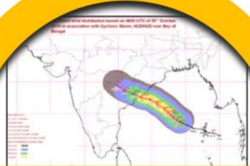
DATE: 1 TIME OF ISSUE: 0400 HRS IST

DATE/TIME (IST) OF OBSERVATION	BASED ON 12.10.2014 (0230 HRS IST)
LOCATION LATITUDE/LONGITUDE	THE VERY SEVERE CYCLONIC STORM 'HUDHUD' LAY CENTRED AT 0230 HOURS IST OF 12TH OCTOBER 2014 NEAR LATITUDE 16.8°N AND LONGITUDE 84.4°E, ABOUT 160 KM SOUTHEAST OF VISAKHAPATNAM AND 280 KM SOUTH-SOUTHWEST OF GOPALPUR.
CURRENT INTENSITY NEAR CENTRE	160-170 KMPH GUSTING TO 185 KMPH

2014: Hourly updates around the time of landfall from cyclone HUDHUD



2014: Digitisation of Annual RSMC Report on Cyclonic Disturbances since 1990 available on RSMC website



2014: Modified Redii of cone of Uncertainty in Track forecast due to improvement in track forecast from cyclone Hudhud

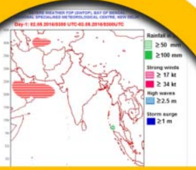
2014: Probabilistic forecast for cyclogenesis for next 3 days from 1st June 2014

Press Information Bureau
Government of India
Ministry of Earth Science

Weather Alert System based on SMS

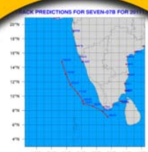
The Earth System Science Organization-India Meteorological Department (ESSO-IMD) had launched an SMS-based alert system for general public for dissemination of weather and disaster-related (cyclone, severe weather storms, heavy rains) information. Under this round-the-clock web-based operational system, the ESSO-IMD will send SMS to individuals who would register themselves at the weather forecaster's official website (www.imd.gov.in) for this purpose. Besides giving information about natural calamities, the system will also suggest what action needs to be taken.

2015: Introduction of Public SMS under digital India Program

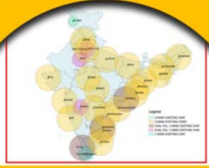


2016: Severe Weather Forecast Demonstration Project Bay of Bengal (SWFDP-BoB) started since May

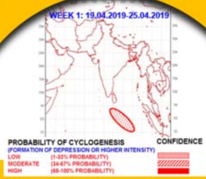
2016: Dissemination of cyclone warnings through Social Media Site



2017: Introduction of Coupled HWRF Model, Princeton Ocean Model (POM) from cyclone 'Ockhi'



2018: Entire coast is covered with Doppler Weather Radar (DWR)



2018: Introduction of Extended Range forecast of cyclogenesis for next 2 weeks

2018: Probabilistic forecast extended to 72 to 120 hrs

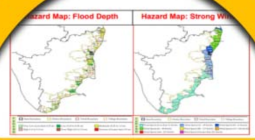
2018: Started Track forecast from Depression stage instead of Deep Depression stage

2018: Establishment of Cyclone Warning Centre at MC Thiruvananthapuram

2019: King Charles visited IMD fascinated with pin pointed accuracy of cyclone FANI

2020: Introduction of cyclone track on interactive GIS platform

2020: New list of names for cyclonic storms from June, 2020 with "Nisarga" (Bangladesh)



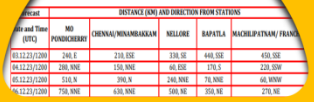
2021: Web-DCRA Tool for generating dynamic impact-based forecast and loss to different exposure elements

2021: Development of decision support system for rainfall, winds, wave height on GIS platform indigenously for forecasters

2021: Development of fishermen warning graphics based on multi model guidance

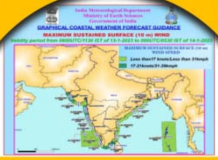
2021: Introduction of probabilistic guidance for area of maximum sustained wind speed exceeding 25 knots and 35 knots

2021: Introduction of pre-genesis forecast of track, intensity & structure

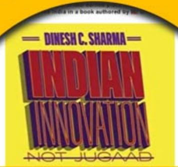


2021: Introduction of distance from forecast track and nearest time of arrival since March, 2022

2021: Introduction of customized location specific bulletins for offshore industries



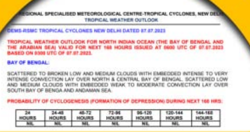
2021: Availability of marine bulletins in textual, graphical and interactive GIS platform for users for easy decision making



2021: Cyclone Warning Services earned place among 100 innovations that transformed India

2022: Development of Marine Forecast Products in GIS and QGIS platform

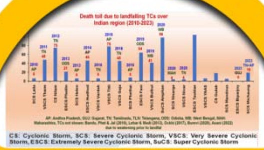
2022: Cyclone Bulletins dissemination through whatsapp to WMO and WMO/ESCAP PTC members



2023: Extension of lead period of cyclogenesis forecast to next 7 days

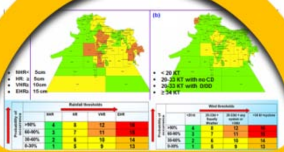
2023: Extension of customised forecast to other sectors Indian Oil Corporation Limited, Indian Air Force

2023: IMD and INCOIS to jointly act as RSMC for Marine Emergency Response and Search and Rescue (RSMC MER-SAR)



2023: Zero casuality achieved during cyclone Biparjoy: A success story of monitoring, prediction, dissemination and disaster mitigation.

2023: The documentary film highlighting the "Cyclone Warning System: An End-to-End System" was screened during 76th Session of WMO Congress.



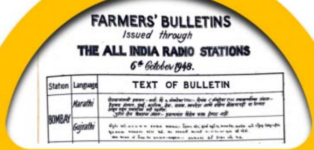
2023: Impact based forecast for 98 sub-divisions under Severe Weather Forecasting Programme.

2023: India was elected to host PTC Secretariat in PTC-50 Session (19-23 December, 2023) at Bahrain.

Agricultural Meteorology Services

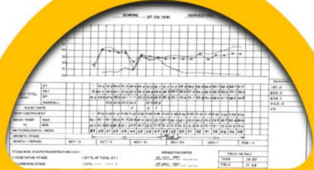
1856: Central Agro-Meteorological Observatory (CAgMo) was established at the campus of Agricultural College, Shivajinagar Pune.

1932: Agricultural meteorology branch started in Poona under the leadership of Dr. L. A. Ramdas.



1945: Commencement of Farmers' Weather Bulletins from Regional Meteorological Centres and Initiation of "Co-ordinated Crop Weather Scheme".

1951: Commencement of recording of phenological observations by voluntary observers



1961: Issue of first volume of Crop Weather Diagram.

1967: Commencement of studies on drought climatology and crop-yield forecasting

1971: Commencement of evapotranspiration measurements through lysimeters and Commencement of efforts to provide weather aids for the forecasting and control of locust outbreak.

1976: Commencement of training of teachers and research workers of Agricultural universities in advanced Agricultural Meteorology.

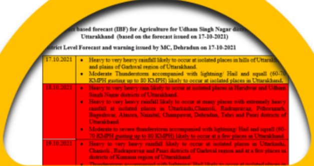
1977: Commencement of Agrometeorological Advisory Services at State level.

1991: Agrometeorological Advisory provided to the farmers at district level through a network of existing 130 Agro-Met Field Units (AMFUs) located in each Agro Climatic Zone (ACZ).

2008: Agrometeorological Advisory Services at District Level under 'Integrated Agromet Advisory Services (IAAS)' scheme.

2012: Launching of 'Gramin Krishi Mausam Sewa (GKMS)' scheme

2018: Agrometeorological Advisory Services at Block Level.



2021: Launching of Impact based forecast based Agromet advisories and Agrometeorological Advisory Services for all districts and 3100 blocks by establishing the network of Agromet Field Units (AMFUs) and District Agromet Units (DAMUs).

Aviation Services

1911: First flight in India from Allahabad to Naini was made successful for current weather information and forecast was felt very much by the aviators.

1913: India Meteorological Department (IMD) started taking upper air observation in Agra to support Aviation.

1921: First aviation forecast was issued from Shimla for the Royal Air Force (RAF) operations in Waziristan which was part of the then northwest India.

1923: Daily upper wind was sent telegraphically to the RAF HQ for the regional military operations at Waziristan and Dardoni. The services rendered by IMD was well appreciated by the War Department, Washington, United States.

1925: IMD opened the specialized aviation forecast offices at Peshawar and Quetta.

1926: IMD opened the specialized aviation forecast office at Karachi.

1929: The Calcutta Meteorological office was catering to the aviation forecasting needs of Eastern India and Burma (Myanmar) for flying boat service for the route Singapore – Kolkata.

1929: The first air mail service from England to India commenced and Delhi and Karachi meteorological forecasting offices were empowered with the responsibility of issuing adverse weather warnings for the air mail service.

1932: The Tata and Sons' flights Karachi – Chennai and air taxi service between Chennai and Kolkata were catered to by Pune weather office. Wireless communication system was set up for the quick dissemination of current weather information.

1939: During World War-II, numerous airfields were opened all over India, and the Delhi forecasting office was revived.

1941: A special air force meteorological office was opened at Lahore.

ICAO: International Civil Aviation Organization

1944: India became a member of the International Civil Aviation Organization (ICAO).

1952: The first civil aviation aircraft (BOAC Comet I) flew through Bombay (Mumbai) and Calcutta

1954: Radars were pressed into aviation weather service at Dum Dum (Calcutta).

1958: IMD adopted radar technology for meteorological applications at Safdarjung airport, New Delhi.

1964: Non-stop flights from India to Hongkong, Cairo etc were commenced with establishment of Extended Analysis and Prognostication Centres (EAPC)

1966: At Dum Dum airport (Calcutta) was installed Transmissometer to assess the runway visual range (RVR).

1971: IMD as well as all domestic and international airports in India functioned directly under the Union Ministry of Tourism and Civil Aviation.

1974: Ceilometer was installed to estimate the height of the base of the low clouds at Mumbai.

1975: The fastest mode of telecommunication system, the teleprinter, telex and automatic message switching system (AMSS) have been installed

1985: First analogue Current Weather Instruments System (CWIS) was installed at major airport.

1990: First Automatic Visual Range Assessor (AVRA) installed at major airport.

2003: Tropical Cyclone Advisory Centre (TCAC) was established in IMD to provide Tropical Cyclone (TC) forecast for international civil aviation as par the requirement of ICAO.

2005: First Digital Current Weather Instruments System (CWIS) was installed at major airport.

2007: Online aviation meteorological briefing system (OLBS) has been introduced in Chennai.

2010: Digital Distant Indicating Wind Equipment (DIWE) installed at major airports.

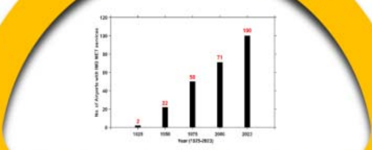
2011: First Drishti Transmissometer Runway Visual Range (RVR) systems installed at New Delhi.

2020: Integrated Automatic Weather Observing System (AWOS) installed at major airport.

2021: Current Weather Instruments System (CWIS) on frangible mast installed at Tirupati airport.

2021: Forward scatterometer type RVR system installed at New Delhi airport.

2022: Heliport Aviation Weather Observing Systems (H-AWOS) installed by IMD over a heliport.



2023: IMD is providing aviation MET services at 100 airports through 4 Meteorological Watch Offices (MWO), 18 Aerodrome Meteorological offices (AMO), and about 82 Aeronautical Meteorological Stations (AMS).

Hydro - Meteorological Services

1890: Govt. of India passed the Rainfall Resolution of India. The adoption of a common type of rain gauge (Symon's) for rainfall registration throughout India.

1949: Established Damodar Valley Corporation (DVC) Met Unit in IMD, Kolkata to prepare water balance for Dams safety measures.

1954: Policy statement for Flood adopted by Govt. of India.

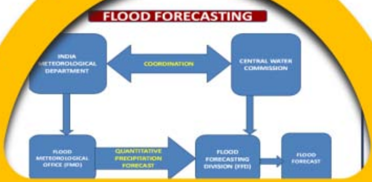
1957: High Level Committee on Floods' made major recommendations on flood management including Flood plain zoning, flood forecasting and warning etc.

1963: Storm Analysis Unit established in IMD as per Khosla Committee's recommendations.

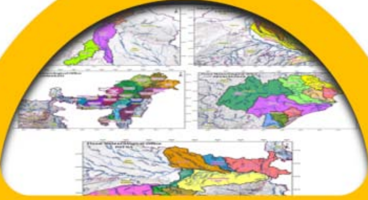
1964: Ministers' Committee on Flood Control made major recommendations on flood management including Flood warning and forecasting, flood plain zoning, flood insurance etc.

1970: Self-recording raingages (SRRG) record the rainfall depth in the form of a continuous plot.

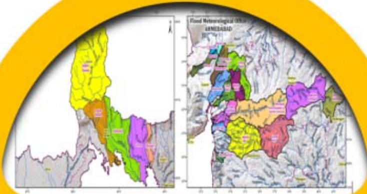
1971: Hydrometeorological Division established in IMD.



1972: Ministerial Committee on Floods & Flood Relief suggested to establish Flood Forecasting Centres, Flood Meteorological Offices (FMOs).



1973: IMD established FMOs at New Delhi, Lucknow, Guwahati, Bhubaneswar and Patna.



1974: FMOs established at Jalpaiguri and Ahmedabad.

1975: Sub-basin-wise Quantitative Precipitation Forecast (QPF) for 24 hours.

1977: FMO Hyderabad established.

1980: FMO Asansol established.

1985: FMO Agra established.

1989: Commencement of District Wise Rainfall Monitoring Scheme.

1996: Commencement of Hydrology project Phase-I supported by world bank.

2005: Installation of Automatic Weather Station (AWS)/ Automatic RainGage (ARG).

2006: Commencement of Hydrology project Phase-II supported by world bank.

2013: Sub-basin-wise Quantitative Precipitation Forecast (QPF) for 48 hours.

2015: Customized Rainfall Information System (CRIS) for preparation of Real Time Rainfall Statistics and FMO at Srinagar established.

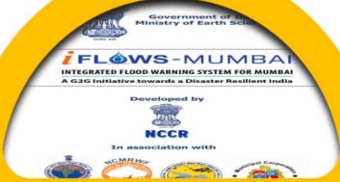
2015: FMO at Srinagar established

2015: Sub-basin-wise Quantitative Precipitation Forecast (QPF) for 72 hours.

2016: FMOs established at Bengaluru and Chennai.

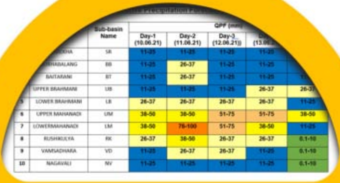
2016: Commencement of National Hydrology project.

2018: Commencement of Chennai Flood Warning System (C-FLOWS).



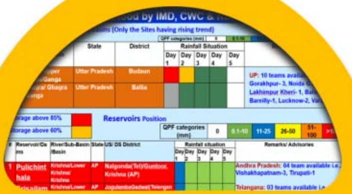
2020: Commencement of Integrated Flood Warning System for Mumbai (i-FLOWS MUMBAI).

2020: South Asia Flash Flood Guidance System in coordination with WMO.



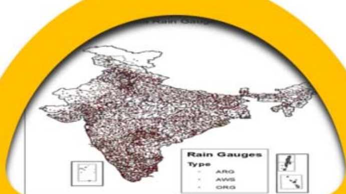
2020: Sub-basin-wise Quantitative Precipitation Forecast (QPF) for 5 days.

2021: FMO Thiruvananthapuram established



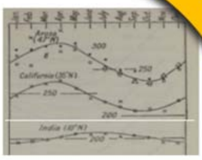
2021: Joint bulletin on the flood status in the country by IMD, CWC and NDRF.

2023: Sub-basin-wise Quantitative Precipitation Forecast (QPF) for 7 days.



2023: DRMS network enhanced to 6095 stations.

Environment Monitoring and Services

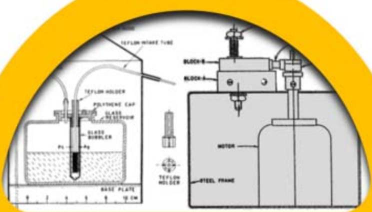


1928 – 1929: First Observations of Total Column Ozone (Sep 1928 – Aug 1929) in India at Kodaikanal by Dr. Roycls and Dr. Narayan.

1940: IMD acquired first Dobson Spectrophotometer.

1957: First atmospheric turbidity network in India.

1964: Indian balloon - borne electrochemical Zonesonde developed by instrument division, Pune, IMD.



1966: First Indian surface ozone recorder developed by instrument division, Pune, IMD.

1970: Establishment of Precipitation Chemistry network and Lab.

1981: First Indian Scientific Expedition to Antarctica (ISEA) with IMD participates.

1981: Mathura Refinery Unit (MRU) established in IMD for special observatories later renamed as Environment Monitoring Unit (EMU) subsequently as Environment Monitoring and Research Centre (EMRC).

1987: First total column ozone measured by Dobson ozone spectrophotometer at Dakshin Gangotri, Antarctica.

1990: First vertical distribution of atmospheric column ozone using Brewer spectrophotometer.

2004: Establishment of Aerosol optical depth monitoring network using Microtops-II sunphotometer.

2010:

- Sky-radiometer Network established.
- Air quality monitoring under System of Air Quality and Weather Forecasting and Research (SAFAR) programme.

2013: Total columnar ozone observation at every 50 km from INSAT-3D.

2015: Ozone observation started at Bharti station at Antractica using ozone sonde.

2016: Establishment of Aethelometer monitoring network for Black Carbon monitoring.

2018: Commencement of air quality modelling Using SILAM & ENFUSER model and Introduction of Air quality early warning system (AQEWS) for Delhi

Polar Meteorological Services

1911- 1912: Sir George Clarke Simpson was appointed to the IMD in 1906 and was given leave to serve as meteorologist with Scott's Antarctic expedition. He sailed in Terra Nova and arriving at McMurdo Sound on 4th January, 1911 and left Antarctica in March 1912.

ATMOSPHERIC STRUCTURE : EXPLORATION OVER ANTARCTICA AND INTERHEMISPHERIC COMPARISON

THESIS
Submitted to the
GUJARAT UNIVERSITY
for the degree of
DOCTOR OF PHILOSOPHY
(Science)
by
PARMJIT SINGH SEHRA
October 1976

1971 - 1973: First Indian Dr. Paramjit Singh Sehra participated in the 17th Soviet Antarctica Expedition (SAE) under a joint Indo-Soviet agreement.

1981: First Indian Scientific Expedition to Antarctica (ISEA) with IMD participates.

1982: Antarctica Project Evaluation Cell (APEC) established in IMD which is renamed as Polar Meteorology and Research Division (PMRD).

1982: First ozonesonde observation at Dakshin Gangotri, Antarctica.

1982: First Automatic Recording Weather Station installed in Antarctica at Dakshin Gangotri.

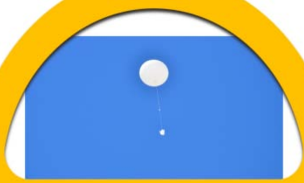
1983: First Meteorological station established in Dakshin Gangotri, Antarctica by IMD.

1989: Meteorological Station established in Maitri, Antarctica by IMD.

2000: First woman member from IMD joined the 20th Indian Summer Expedition to Antarctica.

2012: Meteorological station established in Bharti, Antarctica by IMD.

2015: Ozone observation started at Bharti station at Antractica using ozone sonde.



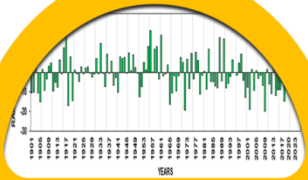
2023: Upper Air Observations started at Maitri, Antarctica by IMD.

Climate Services

1886: First attempt of seasonal forecast for the southwest monsoon rainfall over India region including Burma as a whole based on Himalayan snowfall by Sir H F Blandford, who was the first Chief Reporter of IMD.

1889-1904: Subjective methods such as analogue and curve parallels for issuing forecasts by Sir John Eliot .

1892: Commencement of long-range forecasts (LRF) for the monsoon season and winter precipitation.



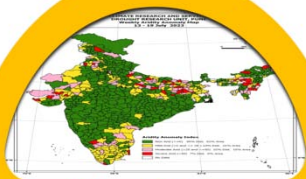
1909: Commencement of monsoon forecast for the rainfall over the entire India by Sir Gilbert T. Walker.

1922: Identification of three homogenous regions for monsoon forecast namely Northeast India, Northwest India and the Peninsula.

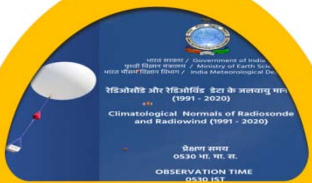
1935: Commencement of forecasts for Northeast India.

1959: Commencement of Climatological Publication.

1962: Publication of Monthly and Annual Rainfall Normal and Rainy days.

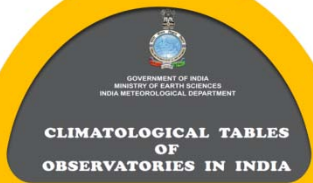


1967: Drought Research Unit Established.



1968: Publication of " Areological Data of India" commenced with inclusion of Upper Air and Radiation data.

1969: Commencement of Quantitative Crop Yield forecast.



1971: Publication of Climatological Atlas .

1987: Commencement of forecasts for Northwest India and the Peninsula.

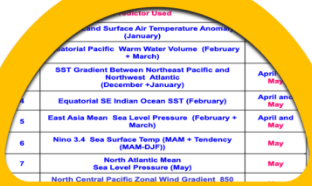
1988: Adoption of the 16-parameter power regression and parametric models for southwest monsoon rainfall forecasts for the entire country.

1994: National Climate Centre (NCC) established in IMD, Pune.

1996: Commencement of Climate Diagnostic Bulletin (CDBI).

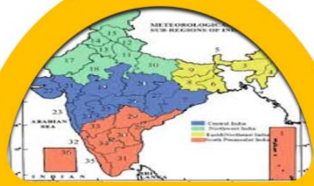
1999: Reintroduction of forecasts for three geographical regions namely Northwest India, Peninsular India, and Northeast India.

2003: Introduction of LRF strategy, namely June to September and April rainfall over the country.



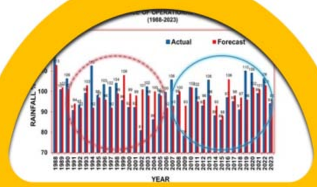
2003: Utilization of the eight-parameter power regression and Linear Discriminant Analysis models for forecasts.

2004: Publication of Annual Climate Summary.



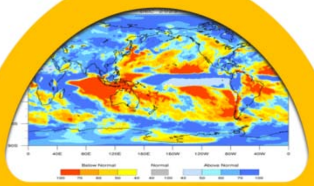
2004: Reclassification of the country into four sub-geographical regions.

2005: Commencement of Onset of monsoon over Kerala.



2007: Adoption of a new statistical forecasting system based on ensemble techniques (SEFS) for the southwest monsoon season rainfall forecast.

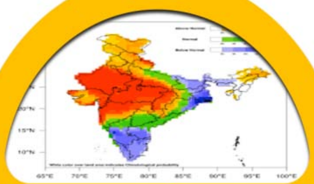
2010: Commencement of South Asia Climate Outlook Forum (SASCOF) and issued outlook for South Asia Region.



2012: Commencement of forecasts for monsoon rainfall generated by Monsoon Mission Coupled Forecasting System (MMCFS) developed by IITM, Pune.

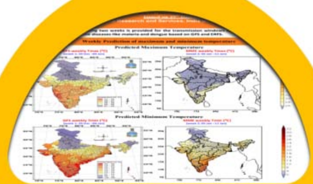
2014: Introduction of a second update for seasonal rainfall in August, covering four homogeneous regions.

2015: Commencement of ENSO/IOD forecast by IMD



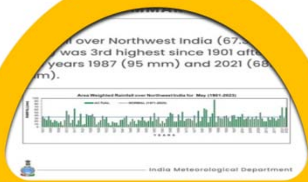
2016: Commencement of temperature outlook using MMCFS for hot and cold weather seasons.

2016: The India Meteorological Department, Pune, was designated as WMO Regional Climate Centre (RCC) Pune.

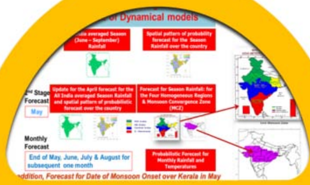


2017: Commencement of Weekly Health Bulletin.

2020: Revision of Monsoon onset and withdrawal normal dates.

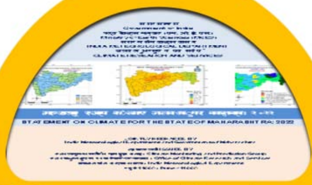


2021: Commencement of monthly climate summary over India.



2021: Commencement of rainfall forecast using Multi Model Ensemble (MME) for the entire country.

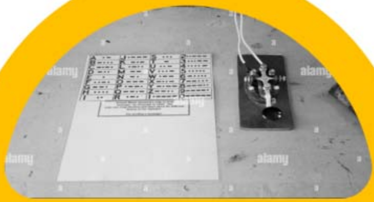
2021: Generation of GIS based Climate Hazard and Vulnerability atlas.



2022: Commencement of State-wise annual climate statement.

2023: IMD Pune recognized as the WMO Global Producing Centres of Long Range Forecasts (GPCs-LRF)

Communication/Dissemination



1877:First telegraphic weather report for storm warning

1878:A telegraphic weather code based on the system in use in the American Weather Signal Service consisted of only 6 words in the use of Telecommunication for weather service in India.

1878:Magneto (Cordless): In India first of all telephone exchanges were setup at 3 metropolitans.

1882:A Telephone Switchboard was a device used to connect circuits of telephones to establish telephone calls between users or other switchboards.

1887: The Telegraph Department recognized weather telegrams.

1911: A teleprinter is used first time in IMD.

1912:The Coastal Radio Station at Karachi and Bombay started communicating weather bulletins to shipping at sea on December 10, 1912.

1921:First aviation forecast was issued from Shimla for the Royal Air Force (RAF) operations in Waziristan which was part of the then northwest India.

1923: Daily upper wind was sent telegraphically to the RAF HQ for the regional military operations at Waziristan and Dardoni.

1926: Telex was a major method of sending written messages electronically between businesses in the post World War-II period.

1929: With the installation of shortwave wireless by the Director General, Post & Telegraph at the Karachi civil W/T station, wireless sharing of synoptic weather data was possible.

1936: All India Radio started broadcasting in India and included weather news to citizens as part of regular news bulletin.

1950: In 1950 a start was made to transfer upper air observational data to cards

1960: Hollerith Sorter & Tabulator were the only means for the preparation of sums and averages for climatological

1968: The IBM 1620 computer at Indian Institute of Tropical Meteorology, was brought into use for preparation of various climatological statistics.

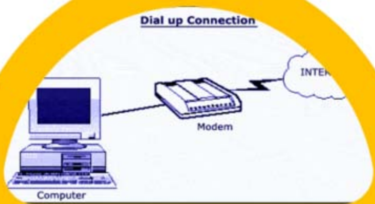
1970: High-speed switching computers LUCH was introduced in IMD.

1970: Under the voluntary assistance program (V.A.P.) of the WMO for Regional Telecommunication Hub (RTH) at New Delhi, high-speed switching machines are

1974: Message switch computer Philips DS-714 with circuit capacity of 2, Max handling speed of 2400bps with a few KB alphanumeric data exchange per day in a Telegram message.

1980: Fax (short for facsimile), is used to transfer meteorological data.

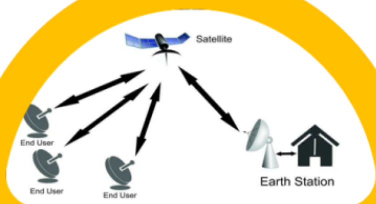
1988:A family of 32-bit superminicomputers, running the Virtual Address eXtension (VAX) instruction set architecture (ISA) is used for communication.



1995: IMD started using first public internet service

2000:NETSYS SUN E-250 with circuit capacity of 128, Max handling speed of 128 Kbps with 4GB Charts/File/ Alphanumericdata exchange per day via VSAT system.

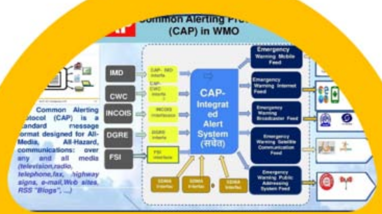
2000:IMD offices at the national, regional, and state level maintain websites with dedicated pages for weather forecasting services which contain both static as well as dynamic pages.



2000:IMD started using VSAT(Very Small Aperture Terminal) for data exchange

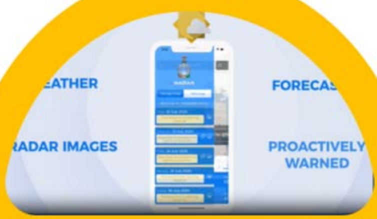
2000: NETSYS SUN E-250 with circuit capacity of 128, Max handling speed of 128 Kbps with 4GB Charts/File/ Alphanumeric data exchange per day via VSAT system.

2000: IMD offices at the national, regional, and state level maintain websites with dedicated pages for weather forecasting services which contain both static as well as dynamic pages.



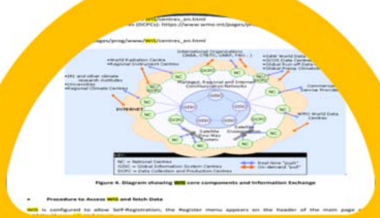
2004: IMD is also working with WMO and NDMA for disseminating the warning through CAP (Common Alerting Protocol).

2009-AMSS TRANSMET: Any number of circuit capacities, with any practical speed, with 600GB of different modes of data exchange per day via digital platform is equipped.



2009: Weather forecasts and warnings especially agromet advisories and nowcasts related to thunderstorms etc. are disseminated through SMS facility.

2010: Use of social media and bulk SMS also have been put into use in the dissemination of weather forecasts and warnings.



2016: The WIS portal-GISC New Delhi is a system for cyclone warning dissemination. IMD has also started issuing NAVTEX bulletins for the coastal region as well as the operation of lightships and fishermen.

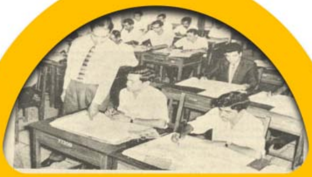
2019: IMD has prepared mobile Apps for the use by general public to get the latest weather information on their mobile.

2020: APIs for various forecast scales have been prepared for the use of sectorial applications.

2021: IMD launched a crowd-sourcing web interface and the link is available https://city.imd.gov.in/citywx/crowd/enter_th_datag.php

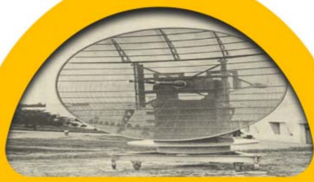
2021: IMD started Geospatial Portal

Training and Capacity Building



1942: Begining of formal training Courses for IMD personnel as a outcome of World War II.

1943: Commencement of organised training school at Pune.



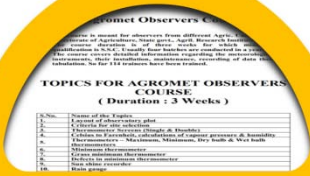
1952: A training Programme in Radio Sonde and Radar started at New Delhi.

1962: Establishment of regular Radio Sonde and Radio Meteorlogical Training Centre.

1963: Started training to Naval and Air force Officers.

1967: First foreign trainee admitted.

1969: Training Directorate came in existence.



1976: Establishment of Agro Meteorological Training Unit.

1977: Establishment of training Centre for telecommunication at New Delhi.

1986: Recognition of Training Centre at Pune and New Delhi as WMO Regional Meteorological Training Centre (RMTC)

1988: Agreement concerning the New RMTC signed by WMO Secretary General & DG of Meteorology.

1999: Re-designation of the training division as Central Training Institute.

2004: Introduction of modern teaching aids.

2009: Syllabi of subjects of all training courses revised by panel of experts and implemented.

2023: MOU between WMO and IMD for hosting RTC to all RTC components, including MTI and ICITC.

Institutions related to India Meteorological Department

In 1962 IMD established the Institute of Tropical Meteorology at Pune as its own unit, with Dr. P. R. Pisharoty as its Director. In 1971 it became an autonomous institution.

In 1971 Indian Institute of Geomagnetism (IIG) was carved out of IMD as an autonomous body with full-scale mandate to pursue geomagnetic and allied field research.

In 1971 IMD's astrophysics activity was separated into an autonomous institution with Dr. M. K. Vainu Bappu as Director.

National Centre for Medium Range Weather Forecasting was established as a mission mode project of the Government in 1988 with the mandate to provide medium range weather forecasts.

In 1979, during the tenure of Dr. P. K. Das, IMD sponsored the establishment of a Centre for Atmospheric Sciences in IIT Delhi.

Seismology Division has now been carved out as National Center for Seismology (NCS) in New Delhi.

Dr. K. R. Ramanathan joined IMD in 1925 and did pioneering work in the measurement of atmospheric ozone. After retirement from IMD in February, 1948, he joined Physical Research Laboratory, Ahmedabad as its first Director in March 1948.

Dr. P. C. Mahalanobis, Meteorologist at Alipore between 1922 and 1926, established the Indian Statistical Institute in Calcutta in 1931.

Major Science Innovation

3. Major Science Innovation

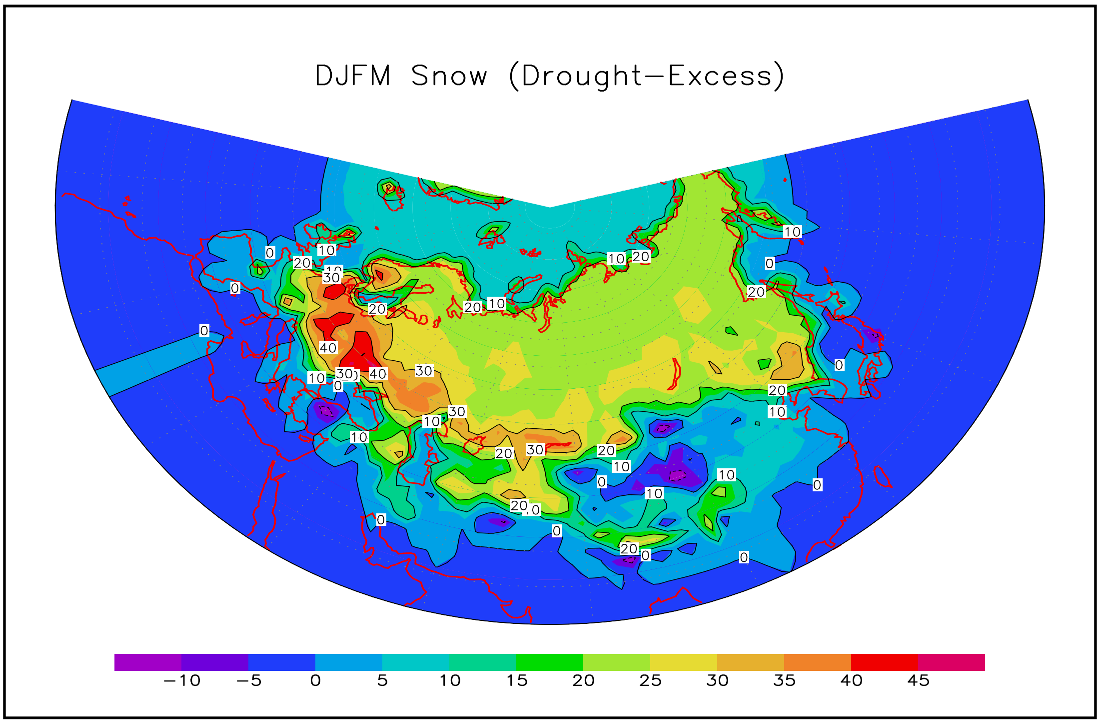
3.1 *Major Innovation in the Science of Meteorology*

(i) Winter Snow Cover and Indian Summer Monsoon

The long-range forecasting (LRF) of the summer monsoon rainfall over India started following a devastating famine in India during 1860s and 70s. It has been one of the first systematic endeavours at seasonal climate forecasting. The first operational LRF of Indian summer monsoon rainfall for the region covering the whole of India and Burma was issued on June 4th, 1886 using an empirical method developed by Blandford who was the first Head of the India Meteorological Department (IMD). This forecast was based on the inverse relationship between Himalayan winter and spring snow accumulation and subsequent summer monsoon rainfall over India. It was assumed that, in general, varying extent and thickness of the Himalayan snow has a great and prolonged influence on the climate conditions and weather of the plains of northwest India. After this, the LRF of the monsoon rainfall became one of the important operational responsibilities of IMD and efforts for better forecasts continued.

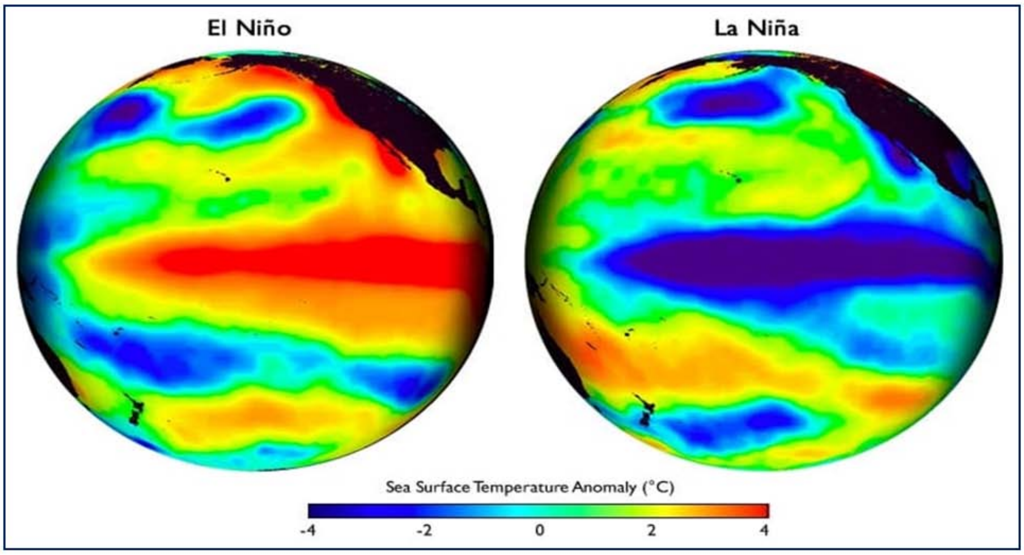
This was later confirmed by many other scientists using additional observational data both from surface as well as satellite and model studies. It was observed that the Indian monsoon-snow teleconnection is derived from snow cover over the entire Eurasian region. These studies also suggested two main physical processes, which are responsible for the time-lag relationship between winter/spring Eurasian snow cover and ISMR. One is the albedo effect which impacts the monsoon through the changes in the land surface heating resulting in anomalous land-sea thermal contrast and changes in the strength of the monsoon circulation. The latter effect involves the melting of an anomalous snow mass, anomalous moistening of the soil and anomalous evaporation, which subsequently increases/reduces the heating of the atmosphere from the ground surface in the warmer season.

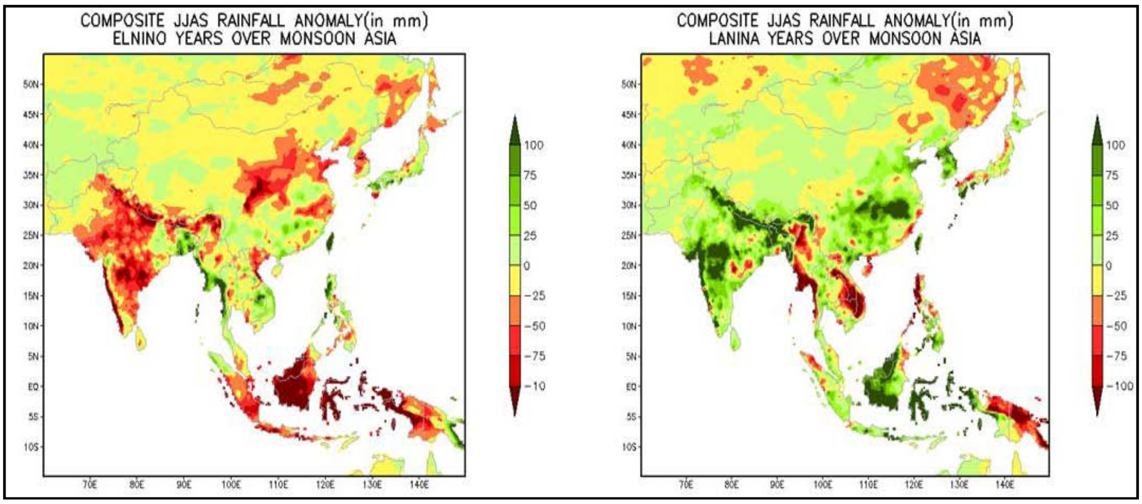
Composite Snow Cover over Eurasia -December to March:
(Deficient – Excess) Monsoon Rainfall Years



(ii) El Niño-Southern Oscillation (ENSO)

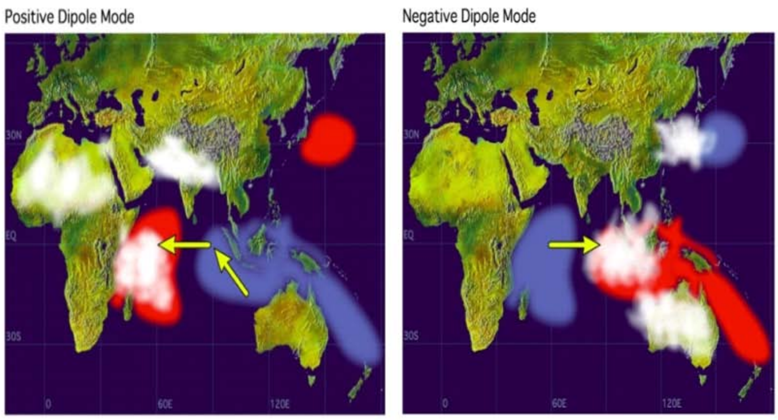
Sir Gilbert T. Walker who took over as the Director General of IMD in 1904 started systematic studies for the development of objective techniques for LRF (Walker, 1908). Search for the potential predictors led Walker to identify three large-scale seesaw variations in the global pressure patterns. These are Southern Oscillation (SO), North Atlantic Oscillation (NAO), and North Pacific Oscillation (NPO). Among these, SO was found to have the most significant influence on the climate variability of India as well as many parts of the globe. The SO, a see-saw between the sea level pressure at Tahiti (an island over the equatorial Pacific) and Darwin, was later linked to the unusual warming of sea surface waters in the eastern tropical Pacific Ocean or El Niño by Jacob Bjerknes in 1960s. Bjerknes and other climatologists later defined these linked phenomena as El Niño-Southern Oscillation (ENSO). Today, most scientists use the terms El Niño and ENSO interchangeably though El Nino is the warm phase of ENSO. After this in the 1980s, the terms *La Niña (cold phase of ENSO)* and *Neutral* also gained prominence. The opposite phases of ENSO have significant and opposite impacts on the temperature and precipitation patterns across the globe but primarily in tropical regions. It is also recognized that the combined ocean–atmosphere ENSO phenomenon is the dominant mode of Earth's interannual climate variability.

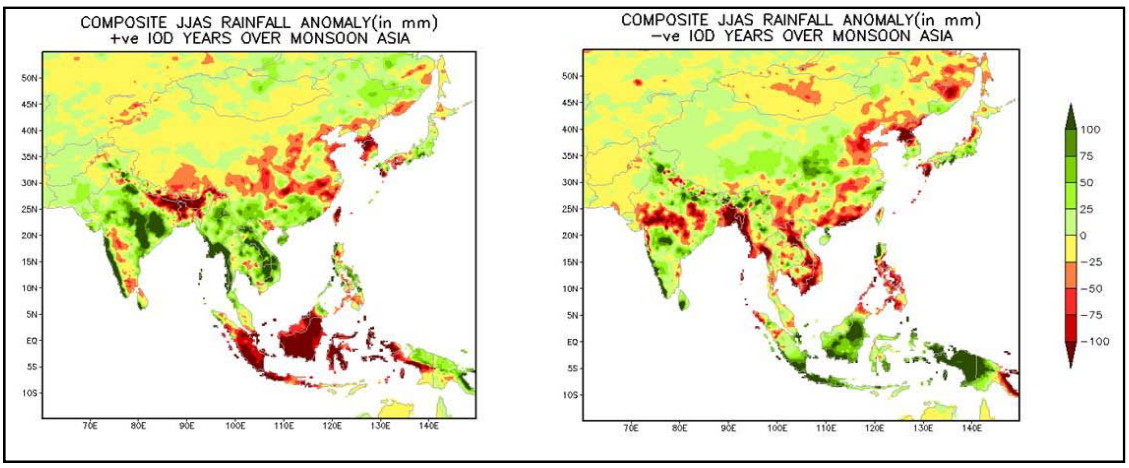




(iii) Indian Ocean Dipole (IOD)

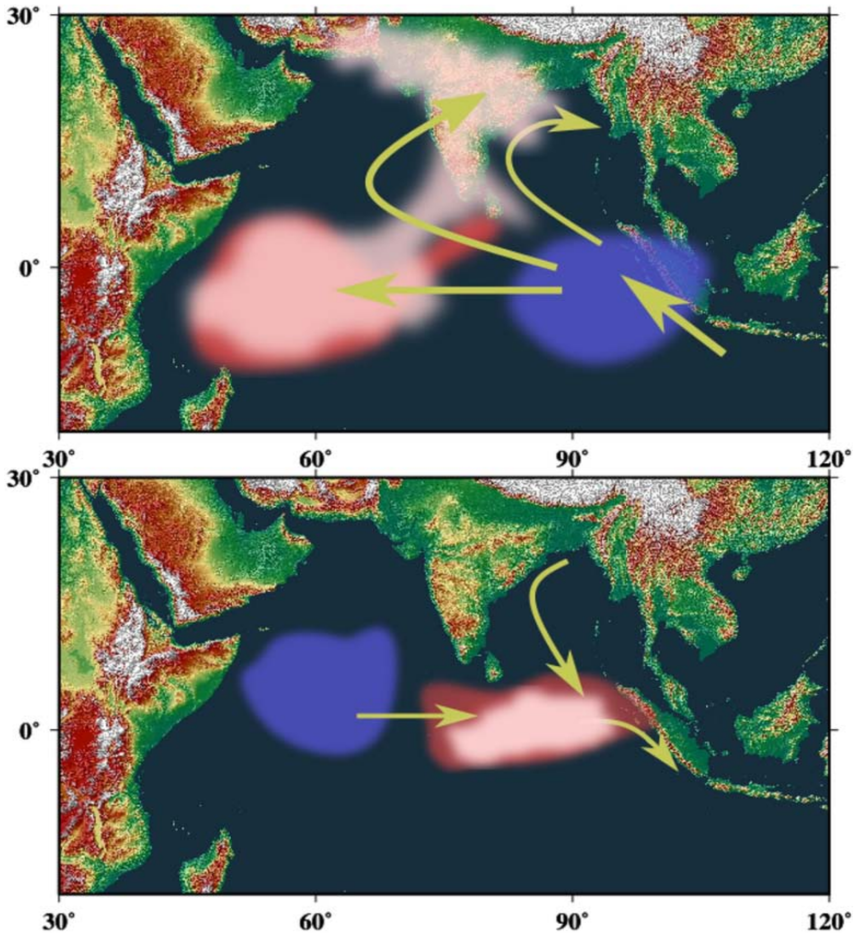
The Indian Ocean Dipole (IOD) phenomenon was first identified by climate researchers including Indian meteorologist Shaji N Hameed in 1999. The Indian Ocean Dipole (IOD) also known as the Indian Nino is a coupled ocean and atmosphere phenomenon and is characterised by an irregular oscillation of sea-surface temperatures in which the western Indian Ocean becomes alternately warmer and then colder than the eastern part of the ocean. A positive IOD period is characterised by cooler than normal water in the tropical eastern Indian Ocean and warmer than normal water in the tropical western Indian Ocean (see map below for an example of a typical positive IOD SST pattern). Generally, the dipole begins to be evident in early to mid-summer, reaches its peak in late fall to early winter, and then rapidly decays during the boreal spring. The negative phase has similar timing, magnitude, and decay. The IOD affects the climate of India and other countries that surround the Indian Ocean basin. The IOD is commonly measured by the Dipole Mode Index (DMI) which is the difference between sea surface temperature (SST) anomalies in the western and eastern equatorial Indian Ocean. In general, associated with the positive IOD, normal convection situated over the eastern Indian Ocean warm pool shifts to the west and brings heavy rainfall over east Africa and severe droughts/forest fires over the Indonesian region. It has been observed that the dipole mode event is independent of the ENSO in the Pacific Ocean. However, the IOD and the ENSO were found to have complementary influence over the Indian Summer Monsoon Rainfall (ISMR) in recent decades with the association of ENSO-ISMR being low when the association between the IOD-ISMR was high and vice versa.





(iv) Equatorial Indian Ocean Oscillation (EQUINOO)

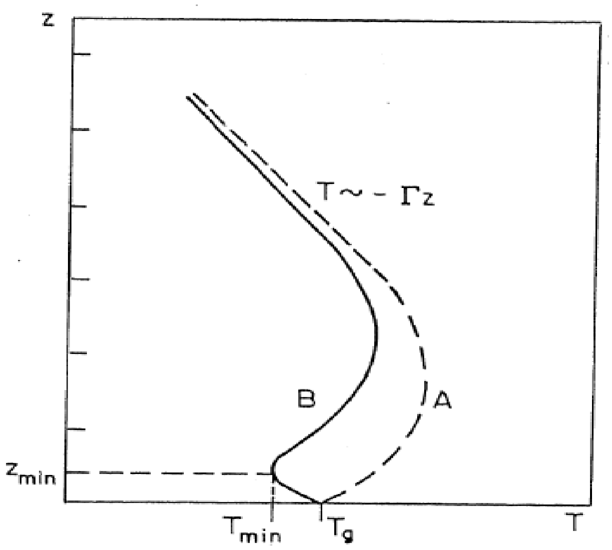
The Equatorial Indian Ocean Oscillation (EQUINOO) is an east-west oscillation manifested as the sea saw in the convection anomalies over the western and eastern equatorial Indian Ocean. It plays an important role in the interannual variation of Indian summer monsoon rainfall. It is considered to be the atmospheric component of the Indian Ocean dipole mode and was first introduced by Sulochana Gadgil an Indian meteorologist and her colleagues in 2004. Initially, an index based on the standardized zonal component of the surface wind averaged over the central equatorial Indian Ocean was used to represent the EQUINOO. Later the difference in the anomaly of outgoing longwave radiation (OLR) or precipitation between eastern and western parts of the equatorial Indian Ocean was used. In general, the positive phase of EQUINOO is favourable for stronger than normal Indian summer monsoon and vice versa. Recent studies have shown that though most of the latest state-of-the-art Ocean–atmosphere global coupled models successfully simulate the ENSO–Monsoon link realistically to some extent; cannot reproduce the EQUINOO-Monsoon link realistically. Some scientists are of the view that the inability of the models to simulate the EQUINOO is one of the reasons for these models not achieving their potential monsoon predictability.



Schematic diagrams showing positive (top panel) and negative (bottom panel) phases of Equatorial Indian Ocean Oscillation (EQUINOO). The anomalies of SST (red: warmer and blue: colder), direction of prevalent surface winds (yellow arrows) and cloudiness (silver shade) as proxy for organized convection/rainfall associated with the two phases, are also shown; (Source: Rajendran, et al. (2022). Climate Dynamics.)

(v) Lifted Minimum Temperature or Ramdas Layer

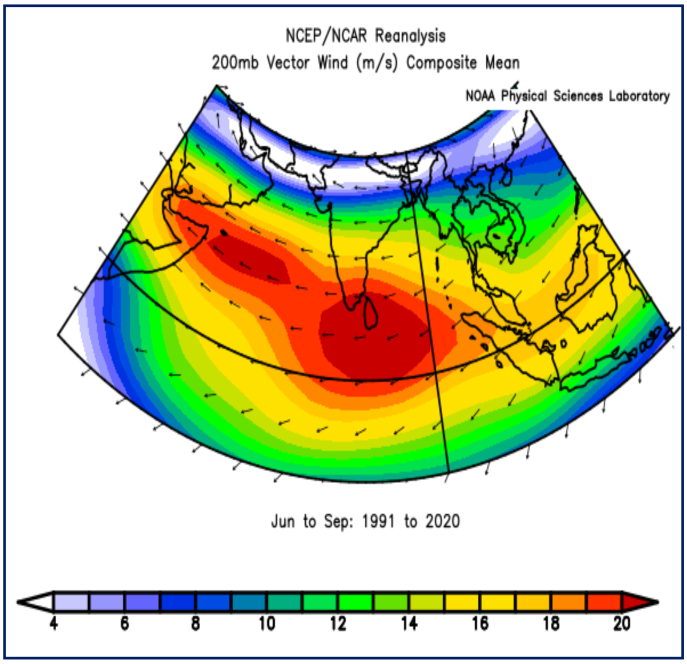
The phenomena of the Lifted Temperature Minimum were first reported in 1932 by Indian scientists L. A. Ramdas and S. Atmanathan. It was observed that on clear windless nights, the lowest temperature is not on the ground but is lifted by a height between 20 and 50 cm. The phenomenon has been named the Ramdas Layer, and is attributed to the interaction of thermal radiation effects on atmospheric aerosols and convection transfer close to the ground. This can be seen in thin layer fogs which are at some height above the ground. Later Kalus Raschke, a young German agronomist who worked as a researcher with Ramdas repeated the study with more accurate air temperature observations using special thermoelectric sensors and established the existence of the Ramdas layer without any doubt. This discovery is very important in understanding observed sub-micro climatology and predicting weather and climate in the lowest meter of the atmosphere and its impact on crops. L. A. Ramdas is known as the father of agricultural meteorology in India because of his significant contributions to the field of agricultural meteorology, including the development of crop weather calendars that examined detrimental weather in the phases of crop growth in various agro-climatic regions of India. He also studied microclimate in crop ecosystems, pest and disease relationships with weather apart from soil-water relationships.

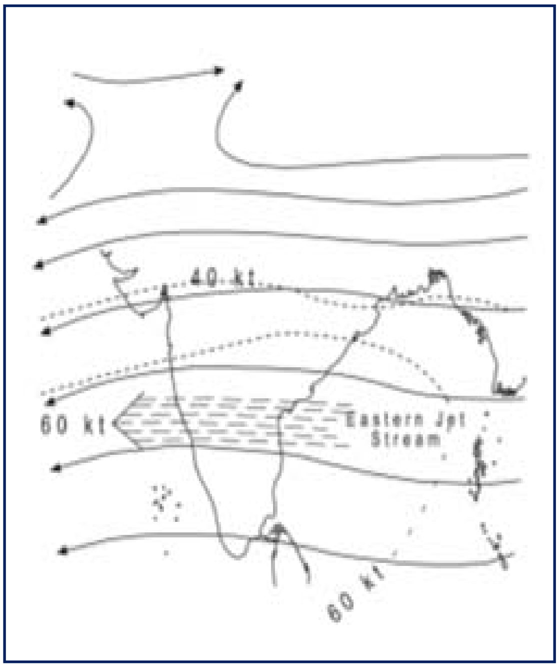


The temperature distribution near ground at night as generally expected (Curve A) and as found by Ramdas under calm, clear conditions (curve B)

(vi) Tropical Easterly Jet Stream During Southwest Monsoon Season

The Tropical Easterly Jet Stream (TEJ) is an important upper air circulation feature of the Indian summer monsoon manifested as a band of strong easterly airflow centred about 15°N, 50-80°E and extends from South-East Asia to north Africa across the Indian Ocean and south Indian peninsula. Over most of the Atlantic Ocean, continental America and Pacific Ocean, the easterly jet is not generally found. The term easterly jet was given by the Indian meteorologists P. Koteshwaram and P.R. Krishnan in 1952. Over the Indian region, the Tropical Easterly Jet (**TEJ**) appears just after the Sub Tropical westerly Jet (STWJ) shifts to the north of the Himalayas around late June and continues until early September. The strongest development of the jet is observed at about 15 Km with wind speeds of up to 40m/s over the Indian Ocean. Many subsequent studies have shown that the intensity and duration of heating of the Tibetan Plateau have a direct bearing on the amount of rainfall in India by the monsoons. When high air temperatures develop over Tibetan region for a sufficiently long time, it strengthens the TEJ resulting in heavy rainfall over the Indian monsoon region. On the other hand above normal snowfall during winter and spring a season delays formation of the TEJ and weakens the rainfall activity over India.





(vii) IMD's Contribution to Atmospheric Ozone research and Monitoring

India Meteorological Department has long history of ozone research using measurements of all the three components of Ozone i.e. Total Columnar Ozone (TCO), Vertical Distribution and Surface Ozone measurement. The TCO measurements in India were first made during September 1928 to August 1929 by Dr Royds and Dr Narayan at Kodaikanal during 1928-29, as part of Dobson's programme of world-wide total ozone measurements with Dobson's spectrograph. The same instrument was used for daily ozone measurements at the Colaba Observatoryduring October 1936 to September 1938. The measurements at Kodaikanal and Bombay established the existence of low values of total ozone over tropical region. The IMD acquired its first Dobson spectrophotometer in 1940 for regular measurements. In 1940's ozone observations from Kodaikanal, Pune, Delhi and Shimla using Dobson Ozone Spectrographs were taken. The observations devised ways of correcting the Ozone observations for atmospheric scattering by aerosols. Professor K. R. Ramanathan evolved and extended the use of the Gotz Umkehr method of finding the vertical distribution of ozone in the atmosphere. Ramanathan, Anna Mani and their associates did pioneer investigations of atmospheric ozone in India and carried out detailed measurements of total ozone and its vertical distribution in the atmosphere and established the main features of the horizontal and vertical distribution of ozone over the tropics. The studies from India presented the fact that the day-to-day variations in the ozone amounts in the tropics are small and showed that the level of maximum ozone is higher (25-28 km) in the tropics than at higher latitudes. The major contribution in the studies of atmospheric ozone are (i) the discovery of the quasi biennial oscillations of total ozone in the tropics, (ii) the dependence of ozone distribution on meteorological phenomena such as jet streams and their location, tropopause discontinuities and inter-latitudinal air exchange, and (iii) on the whole its relationship with the general circulation of the atmosphere. These studies led to a large number of theoretical investigations by several authors on the behaviour and transport of ozone in the upper atmosphere. The systematic ozone monitoring in India was started by IMD from first International Geophysical Year 1957-58.

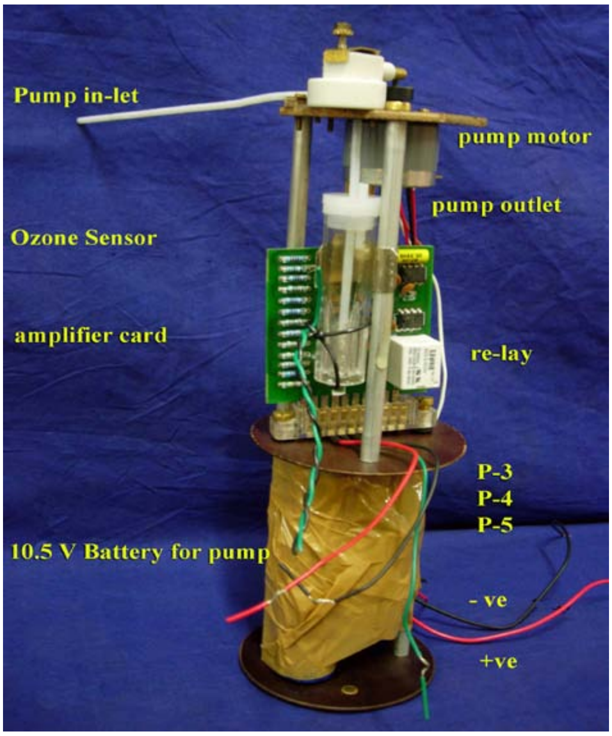
IMD tested the first successful ozone-sounding from Pune in September 1964 using IMD make Ozonesonde. During the next five years the sonde was improved to such an extent that systematic soundings were started from Thiruvananthapuram, Pune and New Delhi. In 1970 the Indian ozone-sonde was intercompared in the International Ozone-sonde inter-comparisons held in Germany. IMD started ozone monitoring over Antarctica since second expedition(1982-83) during which Ozonesonde ascents were taken to obtain the vertical profile of ozone at the Indian station using IMD make electro-chemical ozonesonde. IMD further strengthened the ozone observations at Dakshin Gangotri to join the international efforts for Antarctica Ozone-Hole Investigation. In 1974, Molina and Rowland published their theory about catalytic destruction of ozone involving CFCs. In 1985, Joe Farman, Brian Gardiner and Jonathan Shanklin reported large decreases in stratospheric ozone levels over the Antarctic stations of Halley and Faraday which led to the discovery of Ozone Hole. Global efforts were mobilized for the systematic measurement of atmospheric ozone. The ozone soundings had become a routine part of the Indian scientific expeditions to Antarctica from second expedition (1982-83) onwards almost three years before discovery of ozone hole. The Indian ozone sounding clearly showed the 'ozone hole' over Antarctica and corroborated Farman's discovery. The soundings have yielded an accurate assessment of the vertical distribution of ozone in the tropics and its temporal and spatial variations.The soundings over Antarctica provided clear evidence of the dramatic ozone depletion. Subsequently, Montreal Protocol, came in to existence in 1987, to protect the stratospheric ozone layer by phasing out the production and consumption of ozone-depleting substances.Regular ozone profile measurement continued at Dakshin Gangotri till it was abandoned in 1989. The surface and profile ozone observations started at second station Maitri. Brewer Spectrophotometer was operated at Maitri, from 1999 to 2011 for the measurement of TCO. The ozone measurement programme startedat third Indian Antarctic stations Bharati from 2015. The Indian ozone soundings assume special significance because India is the only country conducting systematic ozone measurements from the tropical and Antarctic region. All other countries that make ozone soundings do it from the middle and high latitudes. Surface ozone is also measured at Indian stations in Antarctica. As anthropogenic pollution is almost negligible at Maitri, the in-situ photochemical production of ozone may not be very significant. Depletion in the stratospheric ozone during ozone hole period gives way to highly energetic UV radiation to reach to the surface layer and initiate photolysis of oxygen and NOx molecules in the surface boundary layer leading to production of surface ozone. The NOx is produced from surface snow pack. Moreover, the surface ozone concentrations can also be increased by the downward transport of stratospheric ozone rich air during deep convection and stratosphere-to-troposphere exchange event. Episodes of high surface ozone in the Antarctica region associated with stratospheric intrusion have been reported at Maitri.

First Indian station in Antarctica “Dakshin Gangotri”

Ozone sonde launch at Maitri

3.2 Major Innovation in Technology

(i) IMD Make Electrochemical Ozonesonde

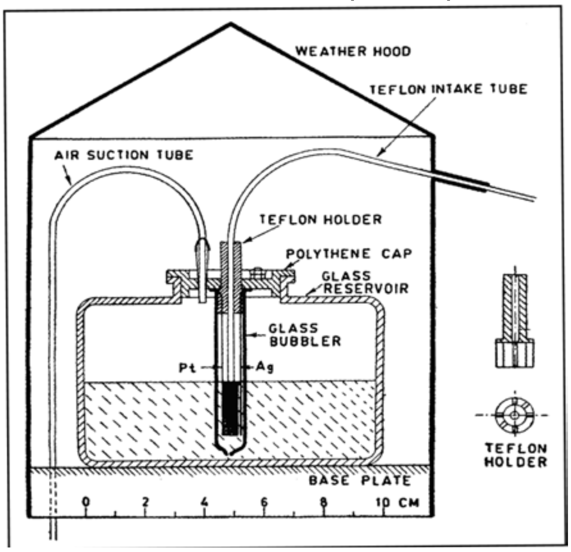


Schematic diagram of IMD Ozonesonde

The first Indian balloon-borne electrochemical ozonesonde was developed under the supervision of Ms Anna Mani in 1964 and the first surface ozone recorder in 1970 at the Instruments Division of the Meteorological Office at Poona (now Pune). The IMD make ozonesonde is a modified version of the Brewer electrochemical sonde The ozone sensor transmits values of air temperature, air pressure, relative humidity, detector current, detector temperature, and pump speed to a ground receiving station. The air containing the ozone sample is pumped through Potassium Iodide solution which is oxidized by ozone producing an electrical current. The electrical current is proportional to the flow of ozone. The instrument became operational at the India Meteorological Department in 1971 and from Antarctica from 1983.

(ii) Modification of IMD Ozonesonde for measuring Surface Ozone

The electrochemical bubbler ozone sensor used in ozonesonde was modified and used as surface ozone recorder which consists of (a) a bubbler ozone sensor with reservoir, (b) a non-reactive teflon pump unit to bubble air through the sensor, (c) an electrical network for supplying a polarising potential to the bubbler, and (d) a continuous chart recorder capable of full scale deflection for two (2) microampere output. Later the chart recorder was replaced with the data logger and online display system. The ozone current is read directly from the record and ozone partial pressure.



Bubbler for Surface Ozone Recorder

(iii) IMD Make Thermo electric Pyronometer

The First Indigenous and IMD make Solar Radiation sensor was designed and developed at Radiation Lab, IMD, Pune during 1972. The sensor gives Solar Radiation in Watts per Square Meter.

The sensor uses a thermocouple junction. A copper constantan Thermo junction is created on top and bottom surface. The Top surface is coated with optically black paint for absorbing 98% of solar Radiation with reference to black body. The Top surface absorbs solar Radiation and acts as a hot junction. The bottom surface in shadow acts as a cold junction. A hemispherical glass dome on the sensor allow only short wave Radiation coming from Sun.

(iv) Madras huts or Bengal huts for housing Thermometers

In tropical regions, thermometer sheds were constructed to protect thermometers from radiation from the sun and sky, precipitation and any invasion of birds and animals. They could also allow free circulation of air around the thermometers. Thermometer sheds were first used in India in the last quarter of the nineteenth century. They were called Madras huts or Bengal huts. The construction varied from place to place and the thermometers were mounted in a cage suspended in the shed. The shed normally had double leaf roof with a 6-inch air space between the two roofs.

Though these huts have been replaced with Stevenson Screens all across India, Hong Kong Observatory (HKO) still maintains a hut in its HQs. A comparison of temperature readings taken from the thermometer shed, from a Stevenson screen and from a rotating thermometer was carried out in 1978; and the differences were very low.

Photograph of Temperature Shed (Photograph taken by Shri S.C. Bhan at HKO on 20 December, 2018)

(v) IMD make snow depth sensor

IMD designed and developed a snow depth sensor during year 2021. The first sensor was installed at Tawang Arunachal Pradesh during February 2022. The System record and sends snow depth in meters through Automatic Weather station. The Data are available in AWS server every 15min interval along with other parameters.

The basic sensor is an ultrasonic Transducer emitting sharp ultrasonic sound pulse at 40 KHZ frequency. The pulse is reflected by the snow and returned back to the Transceiver. A micro controller PCB control Ultrasonic Transceiver for Transmission/reception of sharp sound pulse and Timer circuit in micro controller counts Travel time. Micro controller computes the level of snowfall using Speed of sound at prevailing temperature. The current level is subtracted from the level where there was no snow fall and it computes the snow depth in meters.

Snow Sensor installed at Tawang, Arunachal Pradesh

3.3 Major Innovation in Services

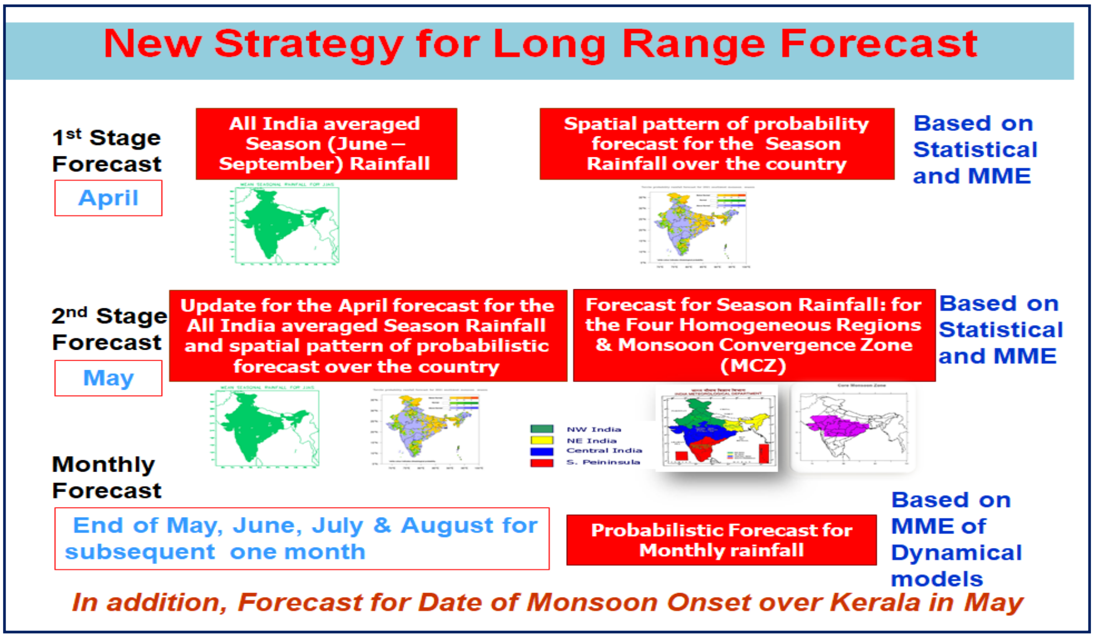
(i) Long Range Forecasting of Monsoon Rainfall over India

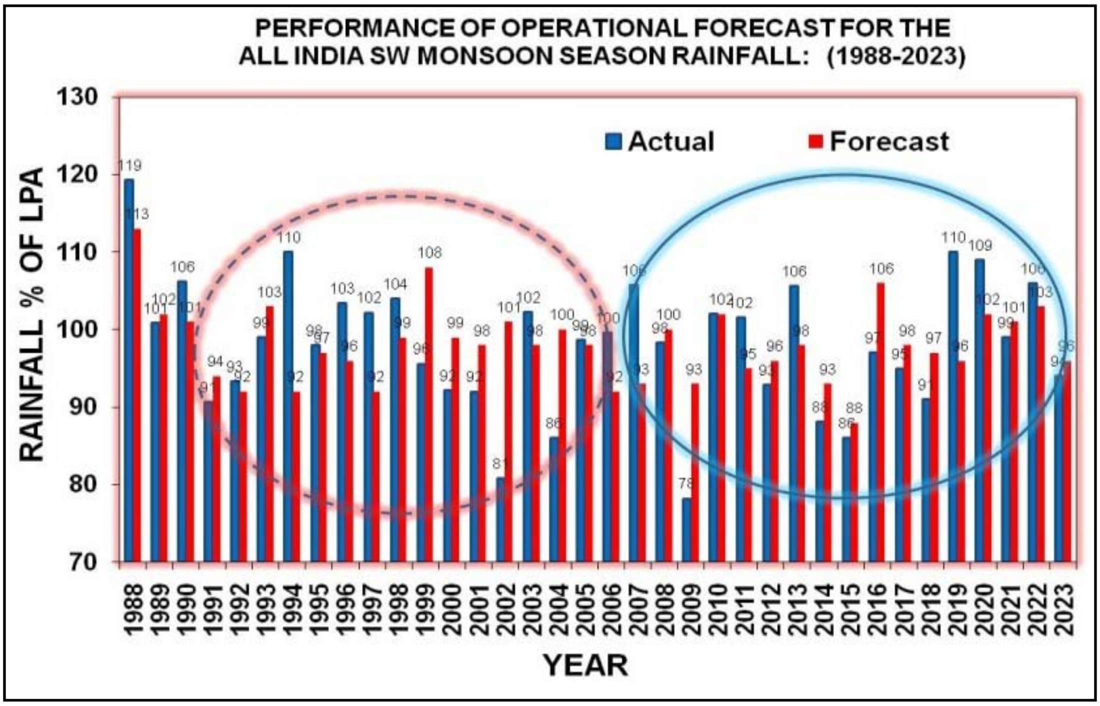
First attempt for the operational forecasting of seasonal rainfall was made for the 1886 southwest monsoon season for the Indian subcontinent including Burma (now Myanmar) using empirical subjective method by Sir Hendry Blandford. Over the years, the operational long range forecast (LRF) system in India underwent many changes in its approach and scope. The first operational objective forecast was issued in 1909 based on regression technique, resulted from the extensive and pioneering work of Sir Gilbert Walker. Later, on realizing that the entire country cannot be taken as homogenous rainfall region, operational forecasts during 1924 to 1987 were issued for Northwest India and Peninsular India using regression models initially developed by Walker and updated time to time. Forecast for the geographical regions was discontinued during 1988-1998. During 1988-2002, operational forecast for the season rainfall over the country as a whole was based on the 16 parameter power regression and parametric models. In view of increasing user demands, the operational forecasts for three geographical regions of the country namely, Northwest India, Peninsular India and Northeast India were reintroduced in 1999. The areas of these geographical regions were however different from that of Walker's geographical regions with the same names.

From 2003, the lead time for issuing seasonal monsoon rainfall forecast was increased. The first forecast for the seasonal rainfall over the country as a whole was issued in April and update was issued in June along with seasonal rainfall forecast for the four geographical sub regions of the country and monthly rainfall forecast for the country as a whole. During 2003 to 2006, the operational first and update long range forecasts for the seasonal rainfall over the country as a whole was issued using the 8 and 10 parameter models based on power regression and probabilistic discriminant analysis techniques. In 2004, the country was reclassified into 4 sub geographical regions (Northwest India, Northeast India, Central India and South Peninsular India). In 2005, forecasting of date of monsoon onset over Kerala was introduced. In 2007, a new state of the art statistical ensemble forecasting system (SEFS) was introduced for the seasonal rainfall forecasting over the country as a whole.

The new strategy implemented since 2021 uses a Multi-Model Ensemble (MME) forecasting system developed by IMD based on coupled global climate models (CGCMs) from different global climate prediction and research centers including IMD's Monsoon Mission climate Forecast system (MMCFS) coupled model developed by IITM-MoES. The MME is a universally accepted technique, which is used to improve skill of forecasts and reduce forecast errors when compared to a single model-based approach. MME is also used to issue spatial distribution of the probabilistic monthly and seasonal rainfall forecast over country, which is the first in the history of the operational seasonal forecasting in the country. IMD also has extended this methodology to prepare climate outlook summary over south Asia under the South Asia Seasonal Climate Outlook Forum (SASCOF) activities recognized by the World Meteorological Organization (WMO).

Since the introduction of Statistical Ensemble Forecasting System (SEFS) in 2007 and use of dynamical models for the seasonal forecasting, IMD operational forecast for the monsoon rainfall has shown noticeable improvement. For example, the absolute forecast error in forecasting all India seasonal rainfall reduced by about 22% during the recent 17 years (2007-2023) compared to the previous period (1990-2006). Similarly, the anomaly correlation between the observed and forecast Indian Summer Monsoon Rainfall (ISMR) during 2007-2023 was 0.5 compared to -0.25 during 1990-2006. It may be noted that IMD was able to correctly forecast the twin deficient monsoon years of 2014-2015.

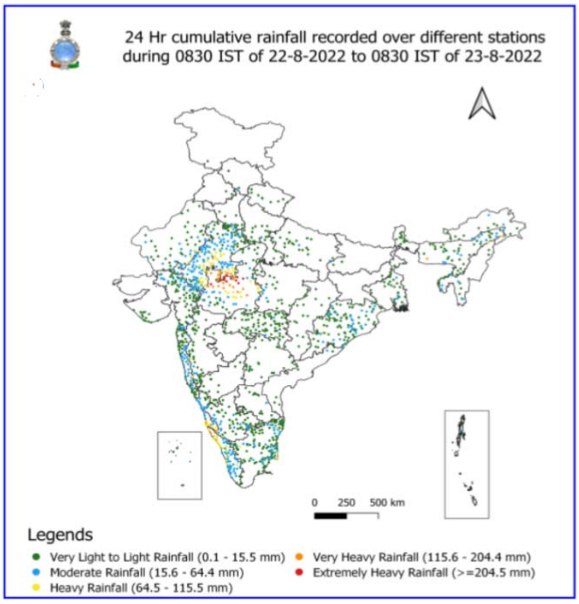


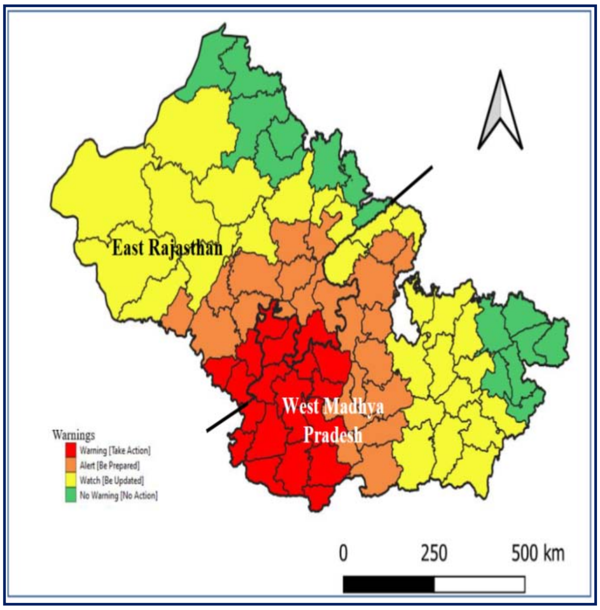


(ii) Innovation in Impact Based Forecasting in India

There have been major advances in the last few decades in our understanding of severe weather due to substantial progress in both observation and numerical modelling. All these resulted in more accurate forecasts of severe weather in the short to medium range (upto five days) with 40% improvement in accuracy in recent five years (2019-2023) as compared to the previous five years. However, improvement of forecast and warning skill is not sufficient to minimize damage to lives and property. It is essential to extend to hazard forecast systems (hazard models) and then to impact and risk with stakeholder interaction for risk-based warning (RBW) and response action to protect lives and livelihoods.

Considering all these, India Meteorological Department (IMD) has introduced impact-based forecast (IBF) at the district and city scale since August 2019 in its short to medium-range forecasts and nowcasts indicating the likely impact of the heavy rainfall in different sectors and required response actions. Since then IBF has undergone several changes. Currently, the IBF provided by IMD includes (i) meteorological hazards like cyclones, heavy rainfall, heat and cold waves, thunderstorms, and fog, (ii) secondary hazards, (iii) geospatial applications and (iv) socio-economic conditions. It utilises a web-GIS based decision support system (DSS). It has been successfully implemented in a dynamic platform in a collaborative mechanism with other organizations like National Disaster Management Authority (NDMA), National Remote Sensing Centre (NRSC), Indian Space Research Organisation (ISRO), state Governments etc. The success of IBF enhances the management of critical resources like agriculture, water & power and supports urban & disaster management sectors among others while reducing loss of life and property. While issuing the warning suitable colour code is used to bring out the impact of the severe weather expected and to signal the Disaster Management about the course of action to be taken concerning impending disaster weather events. The green color corresponds to no warning hence no action is needed, yellow colour corresponds to be watchful and get updated information, orange colour to be alert and be prepared to take action whereas red colour signals to take action.





Left figure: One-day cumulative rainfall recorded on 23rd Aug 2022 and; Right figure: Districtwise IBF issued for East Rajasthan and West MP for 22nd August, 2022.

(iii) Agricultural Meteorological Services

Given the dependence of Agriculture mostly on rainfall before independence, the government realized, as early as in 1920s, that a thorough understanding of the relationship between weather and crops was necessary to improve crop growth and productivity where monsoon rainfall was uncertain. As a result, as per the recommendation of the Royal Commission on Agriculture, the Agricultural Meteorology Division was established in 1932 in Pune. During the formative years, initiative was taken to carry out research activities in collaboration with various organizations to understand crop stresses and related remedial measures led by Dr. L. Ramdas, IMD, Senior Scientist.

To cater to the needs of the farming community, weather services for Agriculture commenced in IMD with “Farmers’ Weather Bulletin (FWB)” in 1945 to provide district-wise weather forecast twice a day. Following that, as it was difficult for the farmers to interpret weather forecasts, provided through FWBs, in their day-to-day farm operations, IMD started issuing agrometeorological advisories based on state-level short-range weather forecasts in July 1977 from the then-Madras (now RMC, Chennai), by the recommendations of the National Commission on Agriculture (1971). National Centre for Medium-Range Weather Forecasting (NCMRWF) started NWP model forecast-based Agromet Advisory Services (AAS) at the Agroclimatic Zone level in collaboration with IMD, Indian Council of Agricultural Research (ICAR) and various State Agricultural Universities (SAUs) since 1991 which was later extended in a phased manner to all the 127 Agroclimatic zones spread all over India.

In 2007, AAS provided by two organizations were integrated into a single window system and brought under IMD, named as “Integrated Agrometeorological Advisory Services (IAAS)”. Subsequently in June 2008, led by Dr. L. S. Rathore, Former DGM IMD, District level AAS was initiated in collaboration with ICAR and SAUs through the network of 130 Agrometeorological Field Units (AMFUs) located across the country to provide more relevant weather information and location and crop specific advisories.

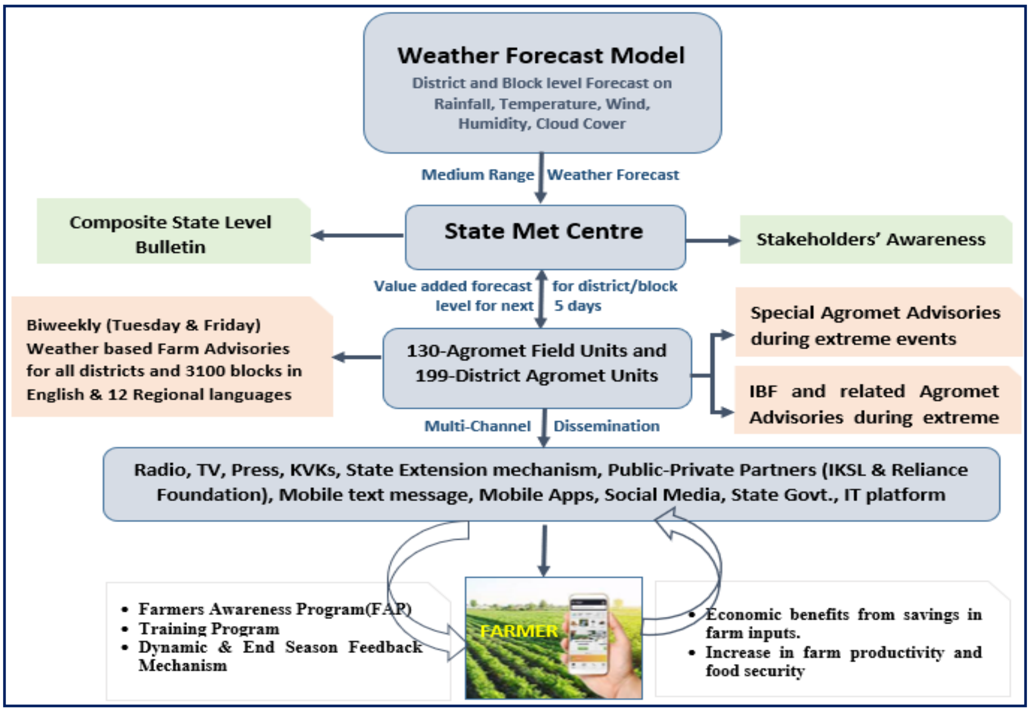
IAAS scheme has been extended in XII[th] Five Year Plan as 'Gramin Krishi Mausam Sewa (GKMS)' scheme to improve the District level AAS and extend to the Block / Sub-district level. With the introduction of upgraded high-resolution models, the service has been further extended to the block level from 2018 with the establishment of District Agro-Met Units (DAMUs).

Presently agreement advisories are being prepared at the district and block level, every Tuesday and Friday, by 130 AMFUs, co-located with SAUs, institutes of ICAR, Indian Institute of Technology (IIT) etc., and 199 DAMUs established in the premises of Krishi Vigyan Kendras (KVKs) under the network of ICAR. Block-level weather forecasts and Agromet Advisories aid the farmers in deciding on day-to-day agricultural operations at the micro-level. Thus, the main emphasis of the AMFUs and DAMUs under the existing AAS system is to collect and organize climate/weather, soil and crop information, and to amalgamate them with weather forecasts to assist farmers in making decisions on day-to-day farm operations.

Agromet Advisories are disseminated to the farmers through multichannel dissemination systems like print and electronic media, Door Darshan, radio, internet etc. including SMS using mobile phones through m-Kisan Portal, launched by the Ministry of Agriculture and Farmers' Welfare (MoA & FW), and through private agencies under Public Private Partnership (PPP) mode. More than 30 Million farmers are receiving weather information through different dissemination channels.

It is revealed from the recent studies, conducted by the National Council of Applied Economic Research (NCAER) in 2019, on the assessment of the economic impact of weather forecast-based advisories that an additional annual income was estimated at Rs. 12,500 per agricultural household belonging to Below Poverty Line category in rain-fed areas, while total income gain was estimated at Rs. 13,331 crore per annum in rain-fed districts.

Existing Agromet Advisory Service System under GKMS is presented below.



Existing Agromet Advisory Service System under GKMS

This innovation in agro-meteorological services has led to Socio-economic gain of individual farmer and the economy of the country.

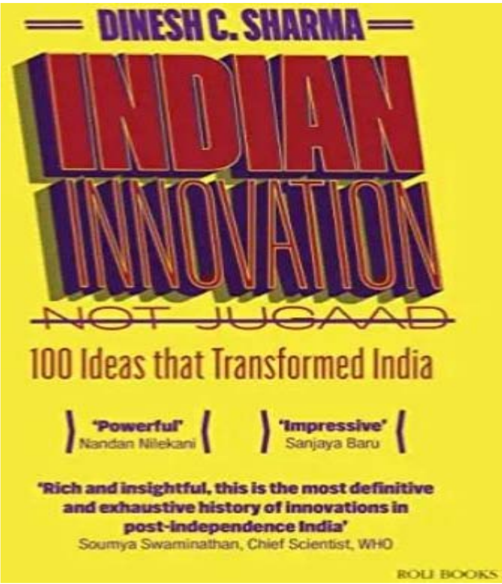
(iv) Innovation in Cyclone Forecasting Services in India

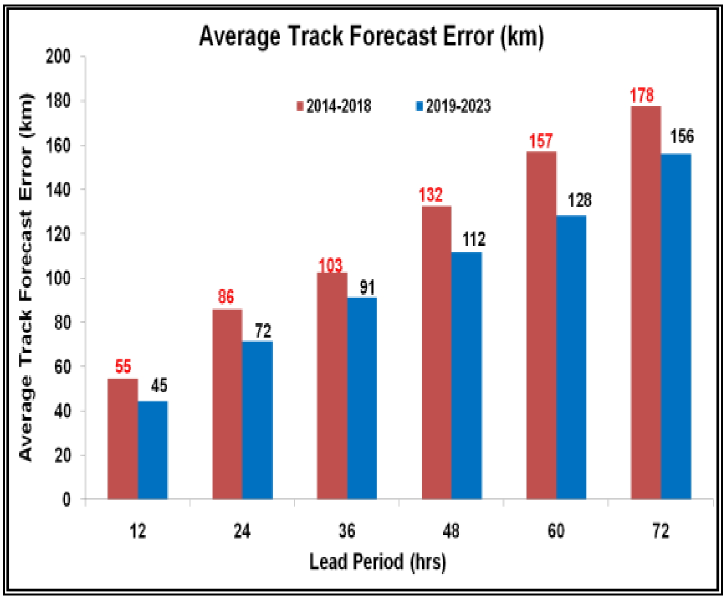
The tropical warm north Indian Ocean (NIO), like the tropical North Atlantic, the South Pacific and the NW Pacific, is a breeding ground for the disastrous tropical cyclone (TC). Historically, in terms of loss to human life, the Bay of Bengal (BoB) TCs accounted for deaths exceeding thousands. However, during recent years, there has been a significant reduction in loss of life, cost of evacuation and loss in government exchequer towards payment of exgratia etc. through the proactive involvement of three-tier disaster management agencies at central, state, and district levels based on accurate and timely warnings by India Meteorological Department (IMD). It has been possible due to the continuous upgradation of all the components of early warning based on the latest technology for effective management of TCs. The early warning component includes skill in monitoring and prediction of TCs, research and development leading to the introduction of scientific methods, tools and technology, effective warning products generation and dissemination, coordination with emergency response units and the public perception about the credibility of the official predictions and warnings.

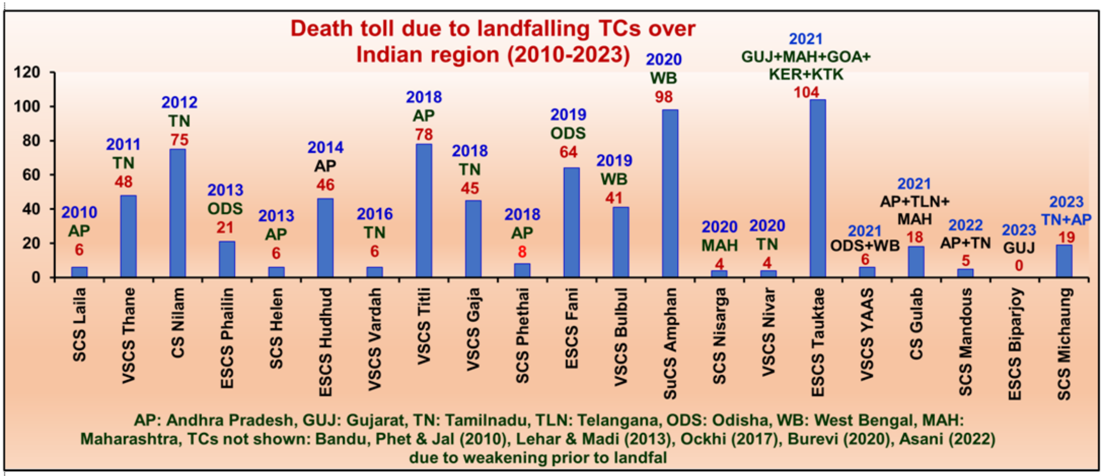
- The cyclone warning helped in better management of cyclones by disaster managers leading to minimum loss of human lives (double digits) since 2010, a decrease in area of evacuation by 300 km in 20 years, evacuation cost by 60 percent and exgratia payments by 99 percent compared to Odisha Super Cyclone (1999) and Kandla Cyclone (1998).
- Accurate prediction of Biparjoy cyclone (2023) enabled disaster managers to achieve zero deaths over Gujarat.
- India received worldwide accolades due to remarkable improvement in cyclone warning services by IMD enabling a reduction in human deaths to less than 100 due to any landfalling cyclone since 2010.
- Commencing with the era of Henry Edington who coined the word Cyclone in 1840, the dedicated research and innovation along with the intervention of Science and Technology helped continuous improvement in cyclone warning services from 1865 with port warning to dynamic impact-based warning in 2020.
- The significant achievement in recent years was possible with the highly exceptional contribution of IMD led by Dr. M. Mohapatra. The upgradation of early warning services for severe weather including cyclones, impact-based forecast (IBF) and risk-based warnings (RBW) was addressed holistically through (i) policy, (ii) planning, (iii)vision, (iv)strategy, (v) observations, (vi) monitoring, (vii) analysis, (viii) modelling, (ix)forecasting, (x)early warning generation, (xi)dissemination, (xii) capacity building, (xiii)confidence building and (xiv) outreach. It led to the development and modernization of end to end cyclone warning system in India which is better than many leading centres of the world today.
- For improvement in policy and planning, the Vision-2020 in 2010 and Vision-2030 documents in 2015 were prepared. It helped in planning of cyclone observational, monitoring, analysis, modeling and forecasting system. There is an improvement in cyclone track (path) forecast accuracy by 60 to 70 percent and landfall forecast accuracy by 70 to 80 percent by 2020 compared to 2010. While 48-hour track forecast accuracy was 50% less than that of USA in 2010, it is better than USA by 30% in 2020.
- IMD standardized the procedure in accordance with the National and International Guidelines for monitoring and prediction of cyclones and updated the annual cyclone operational plan every year for WMO ESCAP Panel countries (since 2010). IMD

developed NDMA guidelines for Cyclone Management (2008) and revised these guidelines in 2018. IMD introduced an indigenously development Decision Support System (DSS) for cyclone monitoring and forecasting.

- Many new technologies were introduced like (i) automated weather stations, high wind speed recorders, buoys, Doppler weather radars, satellite-based monitoring tools, (ii) digitised forecasting platforms, (iii) new global and regional deterministic and ensemble prediction models, storm surge model. Further, IMD and MoES introduced high-resolution models and implementation of multi-model ensemble techniques for cyclone and associated adverse weather prediction.
- IMD also introduced scientific methodology like (i)extension of lead period of cyclogenesis forecast from 1 day (2008) to 3 days (2014), 5 days (2018), 7 days(2023), (ii)cyclone track and intensity forecast from 24 hrs (2009) to 120 hrs(2013), (iii)2 weeks advance forecast for cyclogenesis (2018), (iv)fishermen warning for next 5 days for entire North Indian Ocean(2018) against previous one day forecast along Indian coast, (v)impact based forecast(IBF) and risk-based warning(RBW) upto district level for severe weather(2019), (vi)web GIS tool, (vii)customized objective sectoral forecast for ports, shipping, offshore operations, fisheries, power, urban, hydrology, health, transport and agriculture.
- The cyclone warning services of IMD were adjudged as one of the 75 most important innovations (Sharma 2022).







Appreciation from WMO Secretary General for successful prediction of Phailin in 2013

World Meteorological Organization
Organisation météorologique mondiale

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Weather - Climate - Water
Temps - Climat - Eau

Our ref: 7752-13/DRA-AP

Dr Laxman Singh Rathore
Permanent Representative of India with WMO
India Meteorological Department
Ministry of Earth Sciences (GOI)
Mausam Bhawan
Lodi Road, New Delhi 110 003
India
GENEVA, 29 October 2013

Dear Dr Rathore,

I have learned with deep sorrow of the casualties and damage to property in the eastern coastal region of India caused by Cyclone "Phailin".

On behalf of the World Meteorological Organization and myself, I wish to convey my heartfelt condolence and profound sympathy to you and through you, to the Government and people of India.

In the meantime, I also wish to commend you determination to deliver high quality forecast information and warnings to the government authorities and the public in the circumstances of already publicized super cyclone intensity of "Phailin" by the media at the time.

With consideration for your Government's commitment to disaster risk reduction and emergency preparedness and significant developments at India Meteorological Department, this is an example of cooperation of the National Meteorological Service with the Government, disaster risk management officials and communities at risk in enhancing warning capacities and ensuring that warnings lead to effective evacuation that saved lives. Your recent experience with the strengthening of the observations and forecasting capacities underscored the importance and benefits of effort to advance understanding and develop technologies for better weather and climate forecasting and delivery system to support emergency preparedness measures.

In this regard, I am convinced that the WMO collective priority to reduce risks and potential impacts of hazards caused by weather, climate, water and related environmental elements, improves NMHS's capabilities for service delivery at local, national and regional levels, will ensure that the role of the NMHS is well reflected in national Disaster Risk Reduction policies. With the advent of sub-seasonal and seasonal forecasting capacities, I hope that through NMHS we can work together to extend the timelines for the early warning to allow even more improved disaster preparedness measure; thus, under the Global Framework for Climate Services, we would have the opportunity to further expand the contribution of our community to improving livelihoods and reducing further loss of lives associated with extreme weather, water and climate events.

Again, I wish to congratulate your service for providing timely and accurate forecast of cyclone track and intensity, which led to early evacuation and reduced human and property losses. I look forward to the continued strengthening of the excellent relationship between India and WMO and I wish to assure you of WMO's commitment as well as my own to assist your Service and your Government in addressing disaster risk reduction challenges.

Yours sincerely

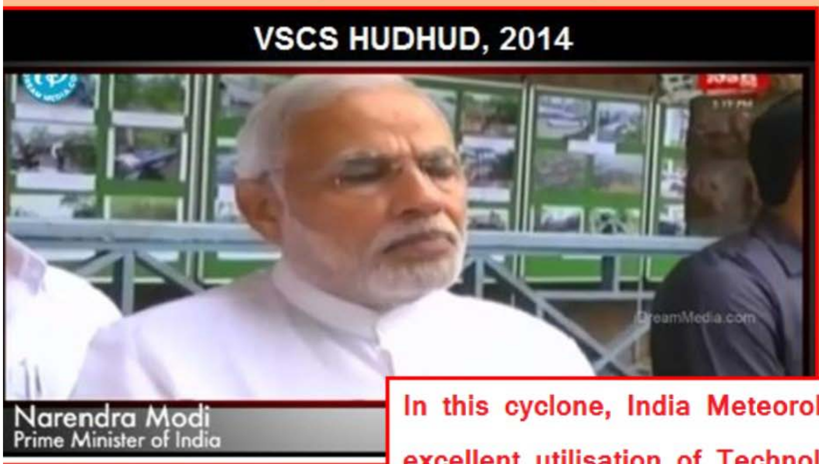
(M. Jarraud)
Secretary-General

Excerpt of Appreciation:

I wish to congratulate your service for providing timely and accurate forecast which led to early evacuation and reduced loss of human lives.

M. Jarraud
Secretary General, WMO

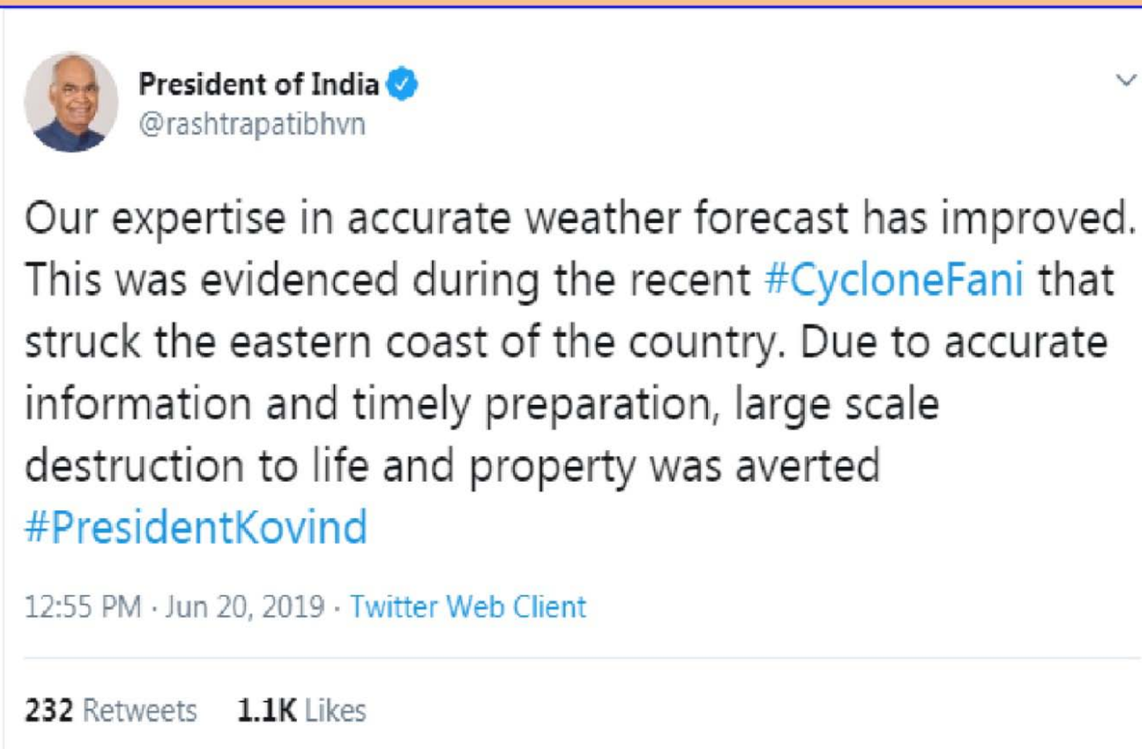
Appreciation from Hon'ble Prime Minister of India for successful prediction of cyclone "Hudhud (2014)"



In this cyclone, India Meteorological Department made excellent utilisation of Technology and from 6th October itself, this cyclone was predicted. The actual wind speed due to cyclone was same as the predicted wind speed. The track of the cyclone was same as that predicted. The time of landfall of cyclone was also same as that predicted by IMD.

Appreciation from 104th Indian Science Congress for cyclone Vardah in 2016

Appreciation from Hon'ble President of India for cyclone FANI (2019)



Appreciation from the World Meteorological Organisation for accurate prediction of Super Cyclonic Storm "AMPHAN" that immensely helped in early response and actions. The services provided by IMD/RSMC New Delhi, showcased excellent lesson and best practices in tropical cyclone forecasting & warning services and response actions for effective mitigation of disaster.

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Our ref.: 10944/2020/S/DPS/TCP-Storm-Amphan

Dr Mrutyunjay Mohapatra
Permanent Representative
of India with WMO
India Meteorological Department
Mausam Bhawan, Lodi Road
110003
NEW DELHI
India

2 June 2020

Subject: On Provision of RSMC New Delhi Tropical Cyclone Advisories for Super Cyclonic Storm "Amphan" in the Bay of Bengal, 16–21 May 2020

Dear Dr Mohapatra,

I refer to the recent super cyclonic storm "Amphan" , which happened in the Bay of Bengal, from 16 to 21 May 2020.

I wish to express my sincere gratitude and appreciation to India Meteorological Department and especially the RSMC Tropical Cyclone Centre, New Delhi, India, that provided its advisory bulletins every three hours, during the super cyclonic storm "Amphan".

The advisory bulletins were well distributed to all Members of the WMO/ESCAP Panel on Tropical Cyclones, in particular Bangladesh, to provide accurate and consistent forecasting information from genesis until the demise of the super cyclonic storm "Amphan'.
The accurate prediction of genesis, track, intensity, landfall point and time, as well as associated adverse weather like storm surge, rainfall and wind, by IMD/RSMC New Delhi with lead period of more than three days, has immensely helped in their early response and actions. The services thus provided by concerned Members have been showcased as excellent lesson and best practice in tropical cyclone forecasting and warning services and response actions leading to sufficient preparedness for mitigation of losses and damages.

The advisories were also distributed to the WMO Secretariat in Geneva, and shared with the WMO Regional Offices in Singapore, Bahrain, and the WMO Coordination Hub. WMO Secretary-General used the information extracted from the bulletins to communicate with the UN Secretary-General about "Amphan." Those bulletins were also well utilized by the WMO officer in New Yorkto daily brief the relevant entities of the United Nations (UN) at its Headquarter on the status and potential impacts of the cyclone "Amphan."

Evidently, it is vitally important and effective practice to distribute and communicate RSMC Dew Delhi's advisory bulletins with Members, WMO, the United Nations and its humanitarian agencies in a timely manner, thus enabling all those concerned to take necessary and appropriate actions. I should appreciate it very much that such a practice be continued and strengthened.

I would like to express my appreciation, and look forward to your continued support to the WMO Tropical Cyclone Programme and activities to reduce risks of disasters due to tropical cyclones.

Yours sincerely,

(E. Manaenkova)
for the Secretary-General

Appreciation from WMO for accurate forecast during Super Cyclone Amphan

Excerpt of Appreciation:

I express my sincere appreciation and gratitude to RSMC New Delhi for regular bulletins during Super Cyclone Amphan. The advisories were well distributed and shared with WMO, UN, Wmo Co-ordination Hub, WMO Regional Office in Bahrain & Singapore and PTC member countries including Bangladesh.

WMO, Secretary General

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Our ref.: 16097/2023/S/DPS/PTC

Dr Mrutyunjay Mohapatra
Permanent Representative of India with WMO
India Meteorological Department
Mausam Bhawan, Lodi Road
110 003 New Delhi
India

17 July 2023

Subject: Appreciation letter

Dear Dr Mohapatra,

I wish to express my deepest appreciation to you and your government for the invaluable meteorological services provided to the region by the India Meteorological Department (IMD), specifically in relation to the accurate forecasting of Tropical Cyclone Mocha. I would also like to extend my gratitude to the Regional Specialized Meteorological Centre (RSMC) New Delhi and your staff, in particular Dr Ananda Kumar Das and Dr Monica Sharma. Your timely and precise forecast continues to play a pivotal role to trigger early action, preparedness and response.

Your support to the WMO Coordination Mechanism (WCM) with shared guidance, information and expert advice enabled the WCM to deliver a timely update on Tropical Cyclone Mocha to the United Nations and humanitarian agencies. Your contribution to the analysis, monitoring and forecasting of Mocha, first cyclone of the year in the Bay of Bengal, has proven to be instrumental in protecting lives and livelihoods in the region.

IMD contribution to early action continues to be a reference for the region and the world. I am grateful for your commitment to share and disseminate authoritative information ahead of severe weather, which allows to build a more resilient society capable of withstanding current and future challenges in a changing climate.

I am confident IMD will continue its exceptional work in advancing meteorological science, improving forecast accuracy, and enhancing collaborations with stakeholders. Your efforts hold the potential to save more lives, reduce damages, and make meaningful

I look forward to your continued support to the WCM and warmly extend an invitation to you to explore the possibility to make international, regional and national data sharing simple, effective and inexpensive via the WMO Information System (WIS 2.0).

Yours sincerely,

Dr Elena Manaenkova
for the Secretary-General

Appreciation from WMO for accurate forecast during Extremely Severe Cyclonic Storm "MOCHA"

Excerpt of Appreciation:

I express my deepest appreciation for Government of India and IMD for the invaluable meteorological services during cyclone MOCHA. Your support to WMO Co-ordination mechanism and expert advice helped WMO provide timely updates to UN and other humanitarian agencies. It played an instrumental role in protecting lives in the region.

WMO, Secretary General

Recent achievements of IMD in the last decade (2014-2023)

4. Recent achievements of IMD in the last decade (2014-2023)

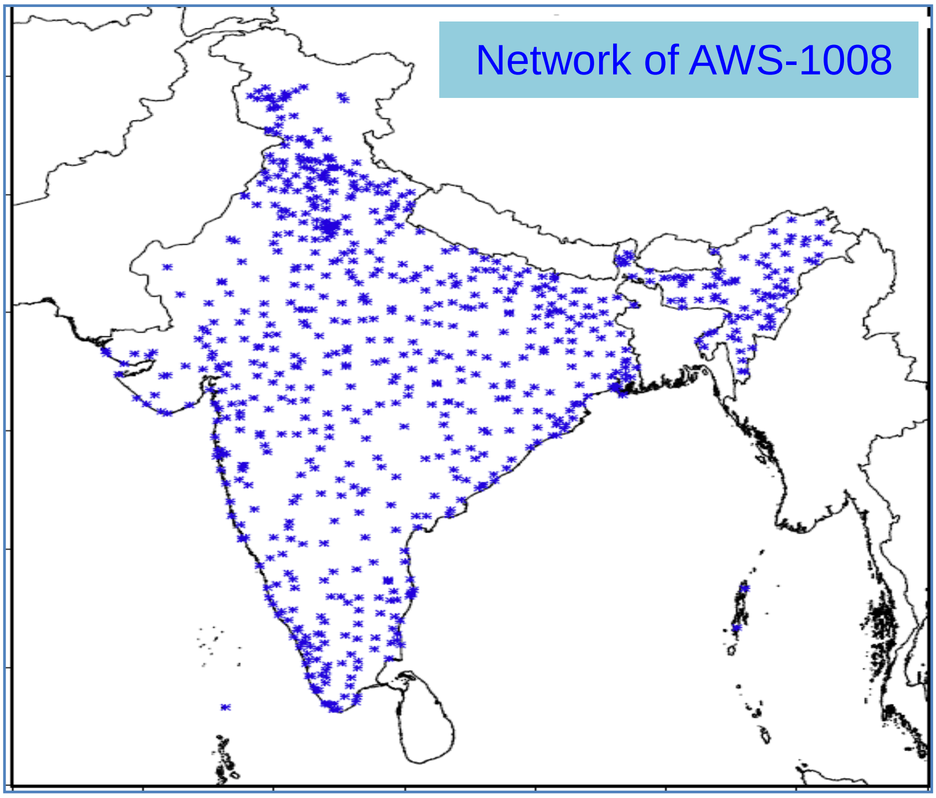
There have been significant improvements in early warning systems and weather forecasting services in India with the augmentation of observational networks, data communication systems, high-performance computing systems, modeling and forecasting systems, and warning dissemination systems. The improvement in all these aspects in recent ten years is given below :-

4.1. Observation Network

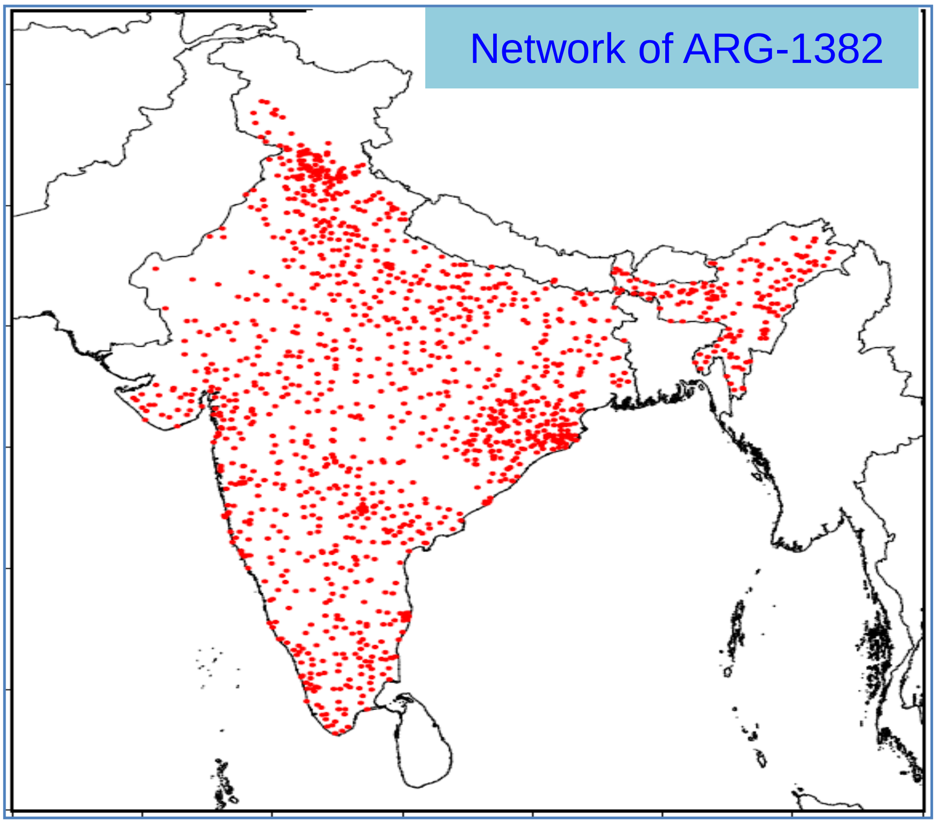
Many additional and new observatories have been introduced in the last 10 years. A comparative analysis of the same is given below.

Specification	**2014**	**2023**
Doppler Weather Radar (DWR) network	15	39
Geostationary Satellites	1 (INSAT 3D)	2 [INSAT 3D (R)]
Automatic Weather Stations (AWS)	675	1208
Automatic Rain Gauges (ARG)	1350	1382
High Wind Speed Recorders	➢ 19 ➢ Imported	➢ 37 ➢ Indigenous
Upper-Air Observation Systems		
Radio Sonde/Radio Wind Stations	➢ 43 ➢ Non GPS	➢ 56 ➢ All GPS
Pilot balloon stations	➢ 62 Total ➢ Non GPS	➢ 62 Total ➢ 23 GPS based
Airport Instruments		
Runway Visual Range (RVR) Instruments	33	156
No. of airports with RVR	12	82
Digital Current Weather Indicating Systems (DCWIS)	32	117
No. of Airports with DCWIS	21	83
Heliport Weather Observing Systems (HAWOS)	Nil	10
No. of Airports provided with weather services	74	100
Rainfall Monitoring Systems		
District-wise Rainfall Monitoring Scheme	3955	5896

(i) Increase in the number of **Automatic Weather Stations (AWS)** from **675 in 2014** to **1008 in 2023**.



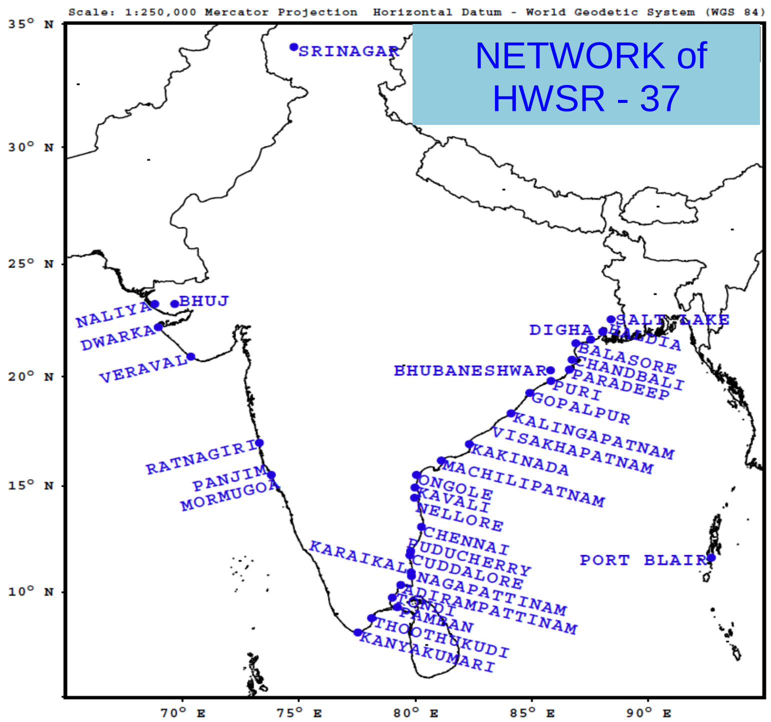
(ii) Increase in the number of **Automatic Rain Gauges (ARG)** from **1350 in 2014** to **1382 in 2023**.



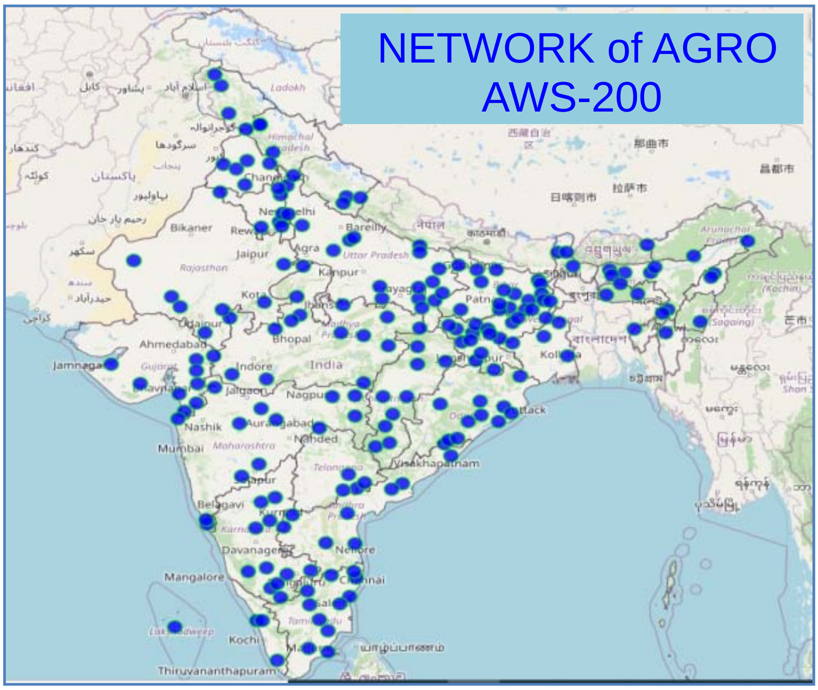
(iii) In the year 2014, IMD had a **meso-network of AWS** only in the **NCR of Delhi**. **By** 2023, IMD has a Meso-network of AWS and ARG stations in Mumbai, Pune and some more parts of India.

(iv) In 2014 IMD had **Mercury Barometers** at all Class I observatories (200 Nos.). **By** 2023, IMD has replaced all Mercury Barometers with **Digital Barometers** by the UNEP Minamata convention (as mercury is hazardous to human health).

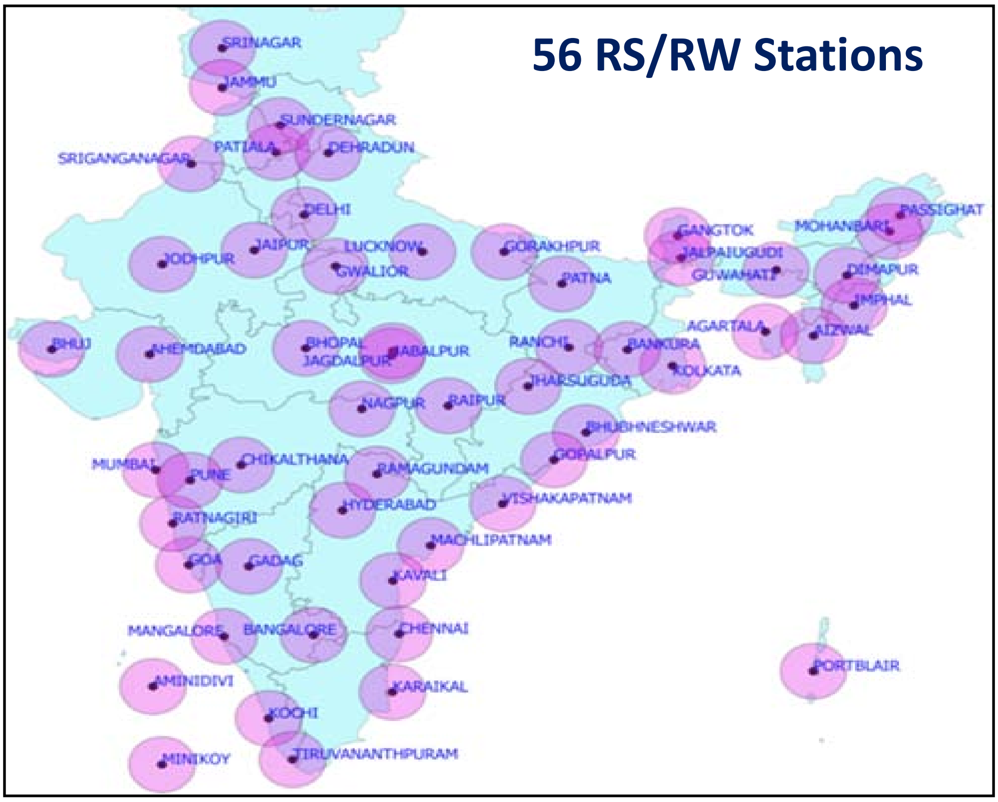
(v) Increase in **High Wind Speed Recorders** from **19 in 2014** to **35 in 2023**.



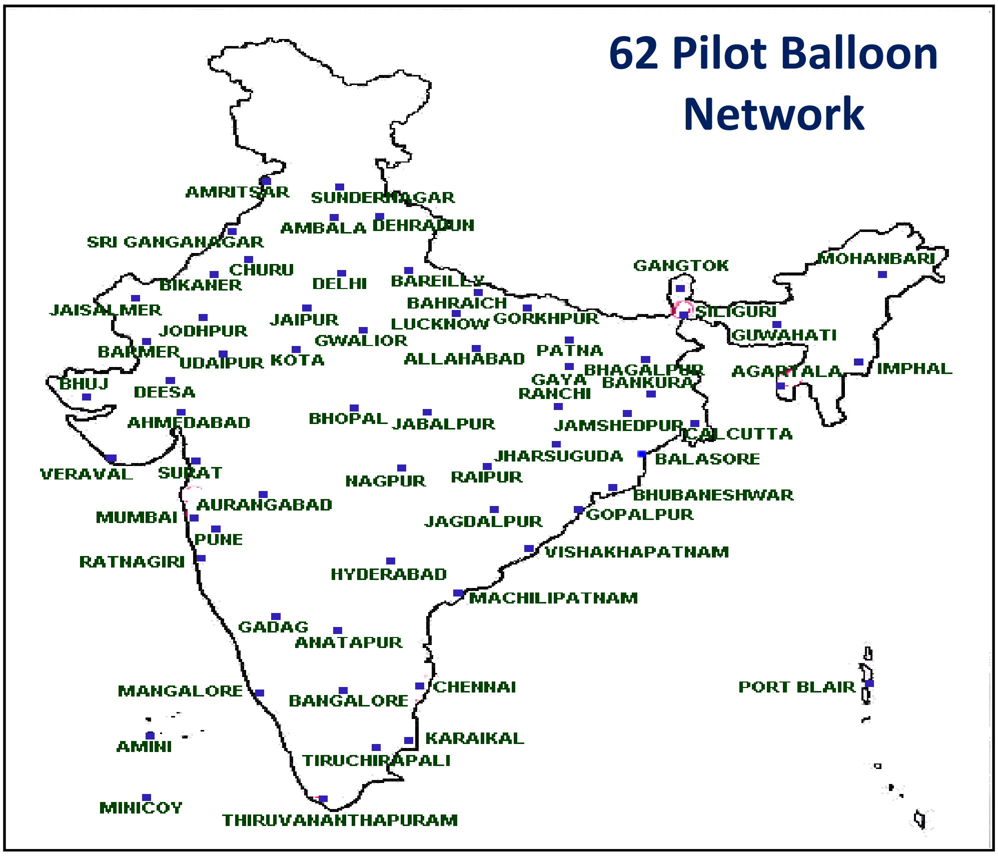
(vi) **At present**, there are **200 AGRO AWS** whereas **there were no AGRO AWS in 2014.**



(vii) Increase in **upper air observation systems** from **43 in 2014** to **56 in 2023**.



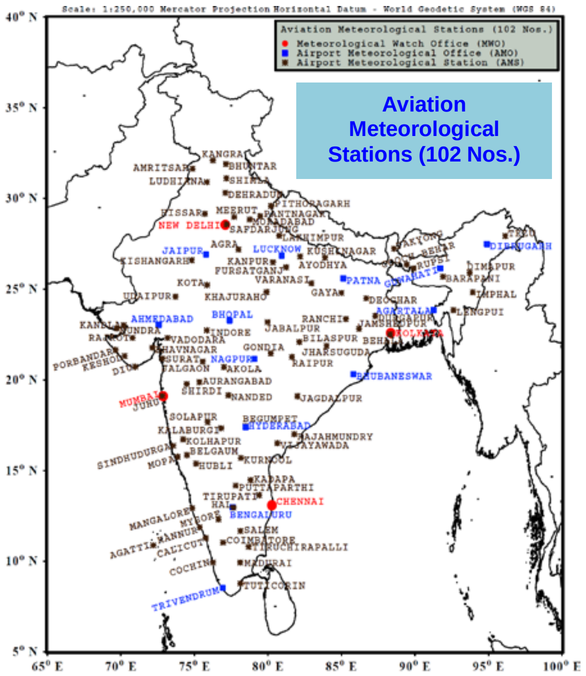
(viii) 62 PB stations 23 Manual stations upgraded to GPS-based stations while there was **no GPS-based PB station in 2014.**

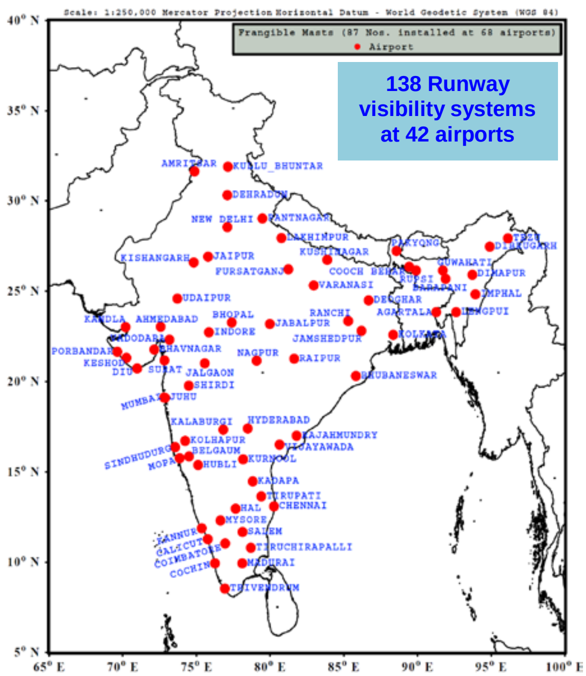


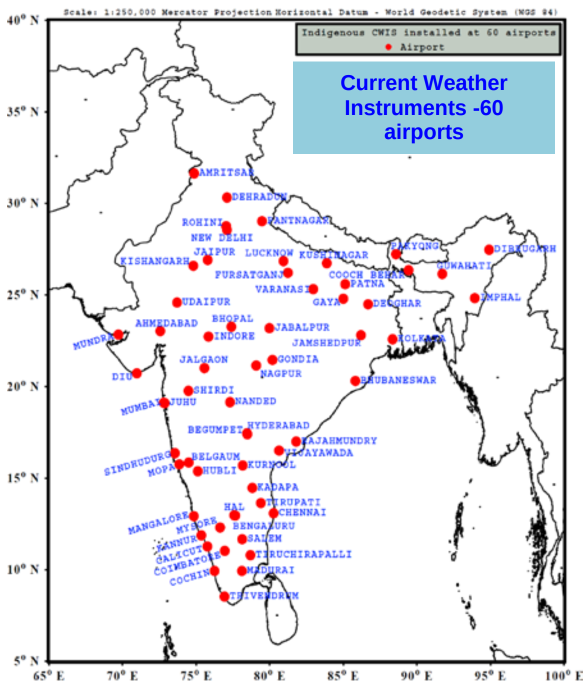
(ix) In the year **2014**, IMD had about **20 RVR** systems at different airports. **By 2023**, IMD has installed **138 RVR systems** at **airports across the country**.

(x) Till **2014**, IMD had **Digital Current Weather Systems at 29 airports**. **By 2023**, IMD has installed 107 **Indigenous Current Weather Indicating Systems** at about **74 airports** across the country.

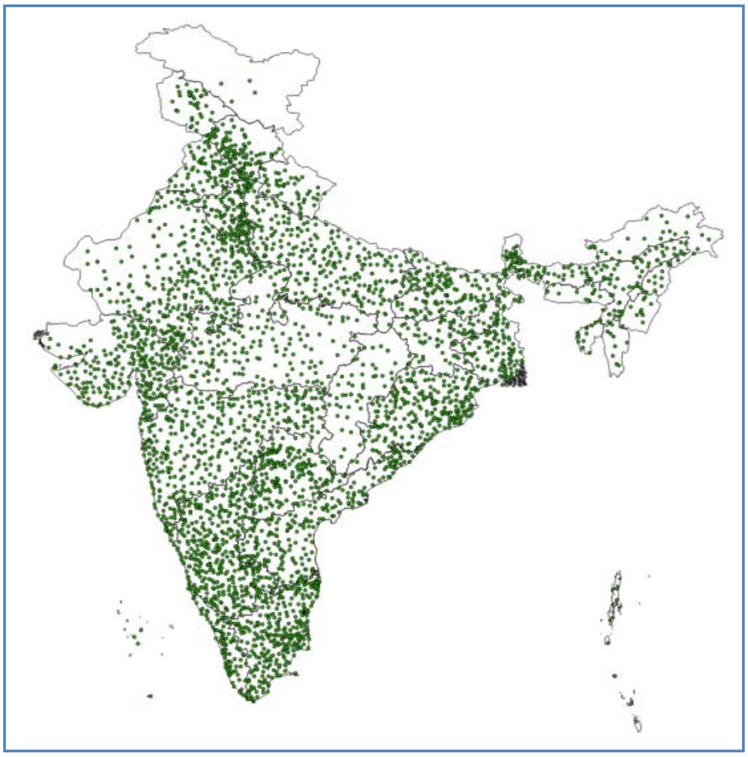
(xi) By **2023**, **8 No. of Heliport Weather Observing Systems (HAWOS)** have been installed at various heliports across the country, while there was **no HAWOS in 2014**.







(xii) Increase in the number of **District-wise Rainfall Monitoring Scheme (DRMS)** stations from **3955 in 2014** to **5896 in 2023**.



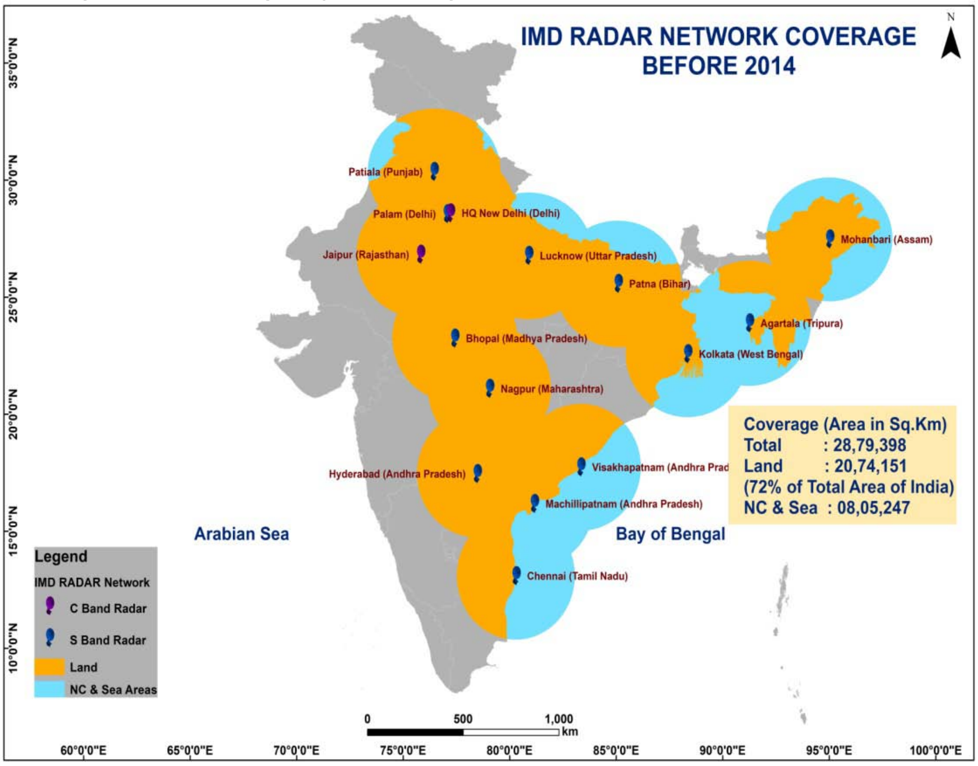
Network of **District-wise Rainfall Monitoring Scheme (DRMS)** stations - 5896

(xiii) There are **two geostationary satellites**, viz., **INSAT-3D and INSAT-3DR in 2023** against only **one such satellite INSAT-3D in 2014**. A comparison is given below.

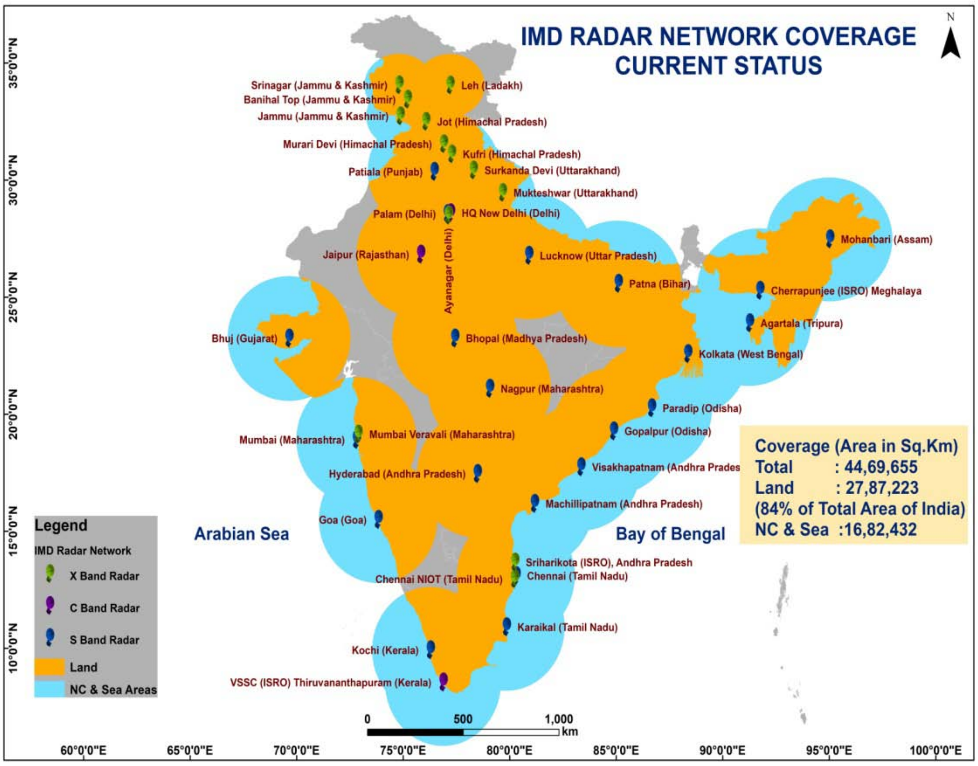
2014	2023
• INSAT-3D (2013) • Oceansat2 (Sea Surface Winds)	• INSAT-3D/3DR (2016) • Oceansat3 (Sea Surface Winds)
Temporal resolution • Half Hourly	Temporal resolution • Half hourly/15 Minutes (3D+3DR) • RAPID SCAN (Less than 5 Minutes) since 2018.
Derived Products • CMV/QPE/OLR/SST/UTH ((Half Hourly) • Imageries for VIS/IR/WV (Half Hourly) •	Derived Products • OLR/QPE/IMR/HEM/IMC/UTH/SST/LST/WDP/INS/NER/ • NHC/CTBT/AET/PET/LSA/DMP/NMP/RBG/FIRE/SMOKE/ • Vorticity/Shear/Convergence/Divergence • OLR/SST/AOD/CTT/CPP/LST/Insolation • Vertical Profile (Temperature/Humidity) • Cyclone Enhancement Images

(xiv) Expansion of **Doppler Weather Radar (DWR)** network from **15 in 2014** to **39 in 2023 with land area of coverage increased by about 35% from 2014**.

2014 (Area coverage by Radars)



2023 (Area coverage by Radars)

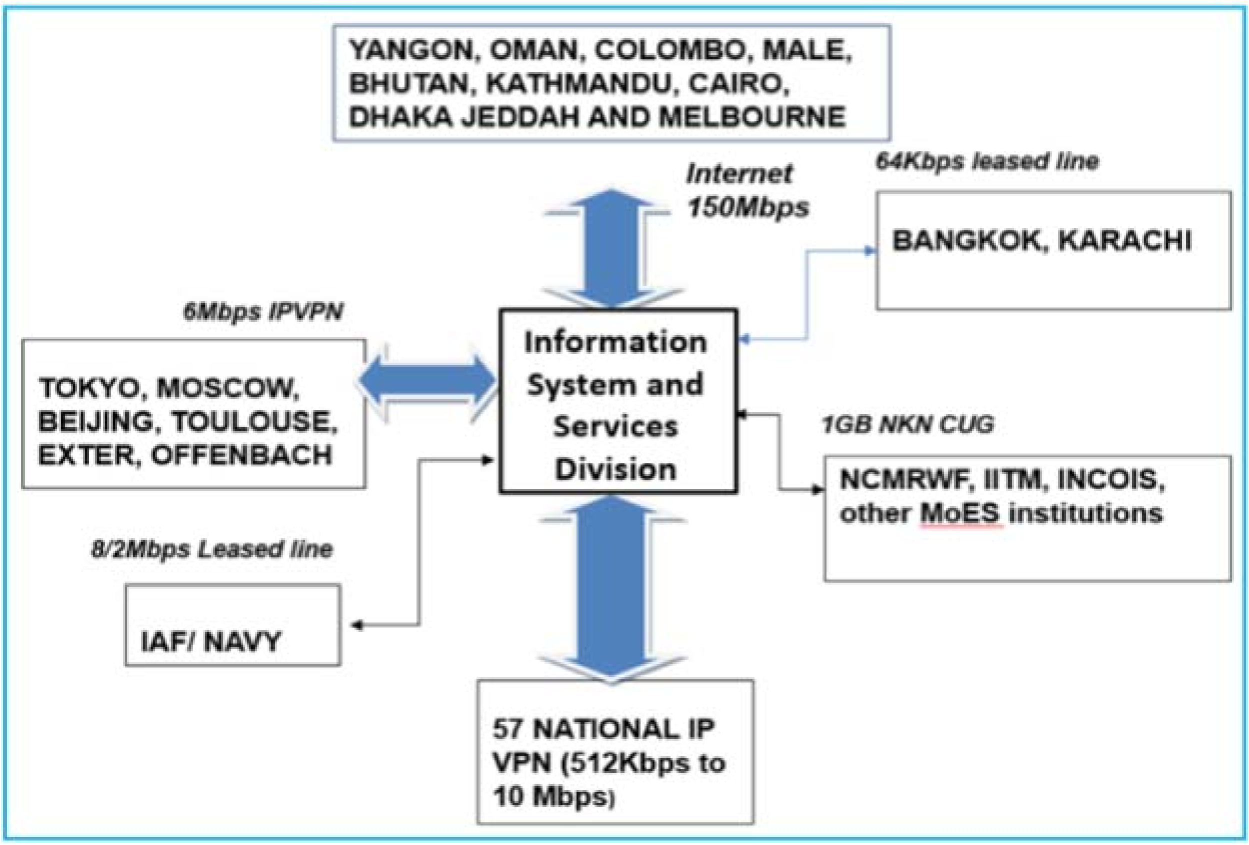


4.2 Communication

There has been significant improvement in data communication with regard to volume of data exchanged, speed, modes of communication etc in recent decade.

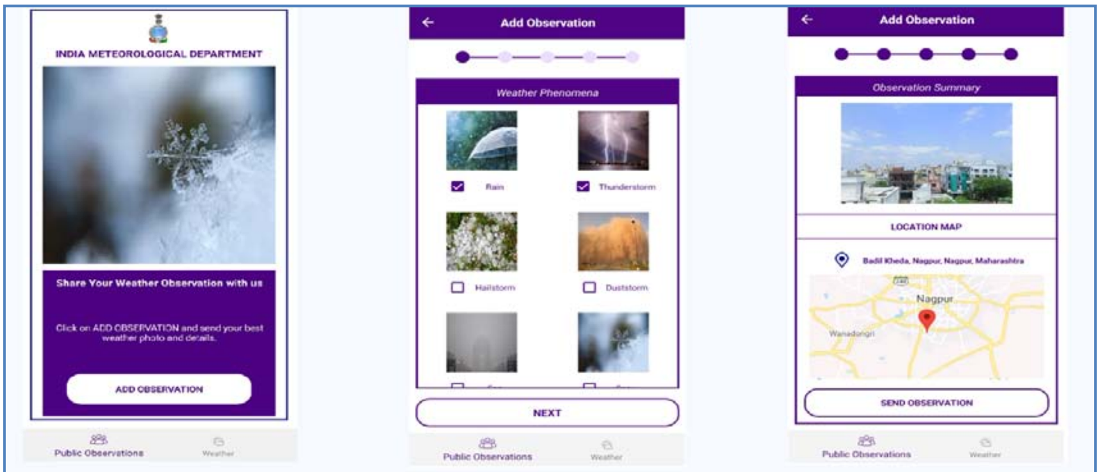
Specification	2014	2023
Data Collection	conventional method (phone, email with more manual intervention	Manual intervention has been reduced by implementation of latest art of technology with upgrading maximum bandwidth of the order of Gbps which has reduced the time of data exchange.
Role in regional and global exchange	Regional Telecommunication Hub	Global Information Service Centre WMO Information System (WIS) **WIS2.0** implemented in 2023 for regional and global exchange of data. **IMD status improved from Regional to Global data dissemination centre**
Internet Bandwidth	60 Mbps	1000 Mbps (16 times Increase in bandwidth)
National Data communications	8 Mbps	10 Mbps
Exchange of Data Volume/Day		
(a)Observational Data	150 MB	250 MB (1.7 times increased)
(b)Radar Data	32 GB	420 GB (14 times increased)
(c)Satellite	296 GB	1780 GB (6 times increased)
(d)NWP	300 GB	2500 GB (8.2 times increased)
Data collection through Public Involvement	No facility	Crowd Sourcing implemented in 2021
Common Alerting Protocol	Nil	For cyclone alerts and other severe weather warnings since 2022.
Forecast and Warning Dissemination	Conventional methods, Web site and SMS only	• Weather Apps such as Meghdoot, Mausam, Damini, • Social media platforms like Facebook, Twitter, WhatsApp, YouTube, Instagram etc. • Daily/weekly weather video. • Dedicated websites for different purposes like cyclone, severe weather, climate, etc • APIs for various weather observations and forecast products used by more than 60 government and private organizations

Data Communication Framework for two ways exchange of data



Crowdsourcing

- India Meteorological Department launched its Crowdsource web interface in January 2021 and the mobile App "Public Observation" on 14th January, 2022 to allow users to to provide their weather feedback at anytime from anywhere.
- IMD launched its crowd-sourcing mechanism through web interface to collect all observed weather phenomena like rain, thunderstorm, squall etc., from public which were not available till 2014.



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4.3 Numerical Weather Prediction Models

IMD/MoES runs a seamless modelling system to cover forecasts at all time scales from a few hours to a season as mentioned below. At present 7 NWP models are run for the products generated for day-to-day forecasting covering timescales from MoES Institutions like NCMRWF, Noida; IITM, Pune; INCOIS Hyderabad, etc from Nowcasting to seasonal forecast as given below.

- Nowcast to Very Short Range (up to 3 to 12 hrs)
- Short Range (Up to 3 days)
- Medium Range (Up to 10 days
- Extended Range (Up to 4 weeks)
- Seasonal forecast (Up to a season)

There has been a paradigm shift in types of Models, Model Resolution, Lead period, Update frequency, Model products prepared, volume of data and products for different sectoral applications in the last 10 years.

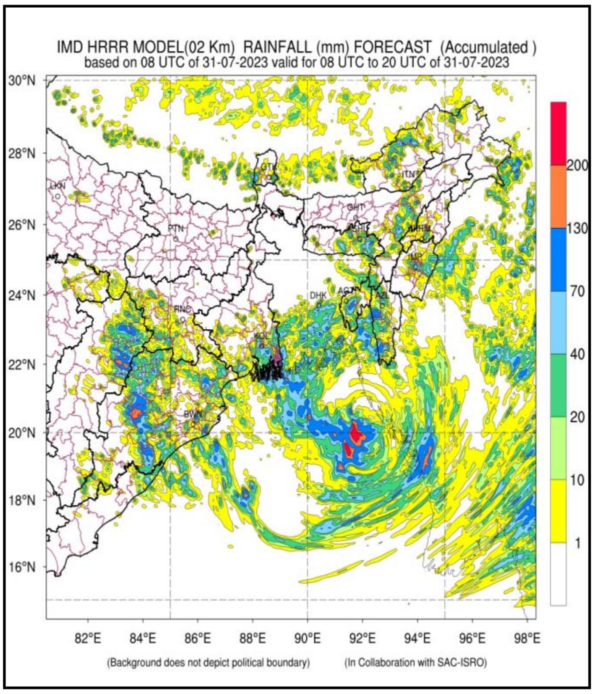
Models	2014	2023
Nowcast model For very short-range forecast (Up to 12 hrs)	Not available	• Electric WRF (EWRF) model at 3 km with lightning data assimilation • High-Resolution Rapid Refresh (HRRR) at 2 km with Radar data assimilation
Regional model For short range (3 days forecast)	• Resolution- 9 km • Forecast period – 3 days • Run 2 times a day	• Resolution- 3 km (3 times) • Forecast period – 3 days • Run 4 times a day
Global Model for medium-range deterministic forecast	• Resolution- 25 km • Data assimilated – 50 GB per day • Forecast period – 5 days • Run 2 times a day • Guidance products - 59	• Resolution- 12 km (2 times) • Data assimilated – 500 GB per day (10 times increase) • Forecast period – 10 days • Run 4 times a day • Guidance products – 84 (42% increase)
Coupled Hurricane WRF (HWRF) model for cyclone	• Resolution- 27x9 km • Forecast period – 3 days • No Ocean model	• Resolution- 18x6x2 km • Forecast period – 5 days • With coupled ocean model
Global ensemble model for medium-range probabilistic forecast	Not available	• Resolution- 12 km • Forecast period – 10 days • Run 2 times a day
Multi-model ensemble (MME)	For cyclone track only	• MME for cyclone track, intensity, landfall point & landfall time. • MME-based forecast based on 7 global model outputs • Seven variables : Rainfall, temperature, wind direction,

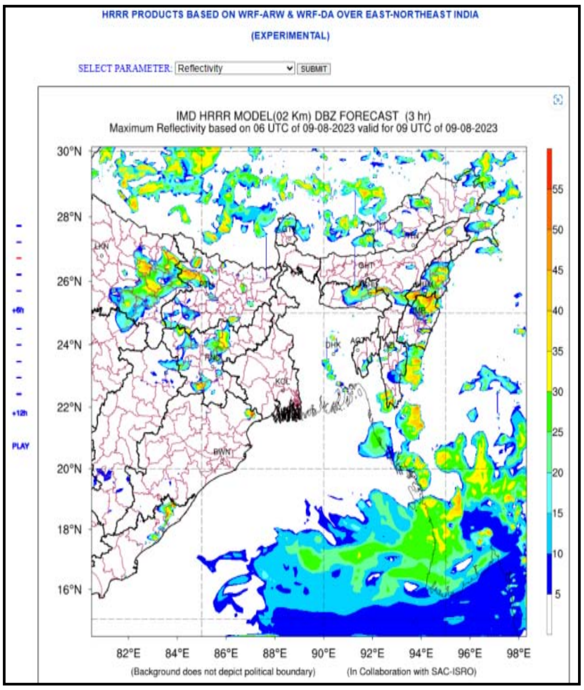
		wind speed, humidity, cloud cover • For 7 days • At Met-subdivision, district, river basin, city and block level.
Extended Range Model up to 4 weeks	Not available	• Since 2017 : to provide forecasts for the next 4 weeks for cyclogenesis, rainfall and temperature, wind, MJO etc • This is developed through the Monsoon Mission program of MoES through collaborative efforts of IITM, NCMRWF, INCOIS and IMD, which is operational at IMD. • Run on the fly with hindcast for 20 years (2003-2022) • Run for 32 days with the weekly update • Sectoral application products available for : Agriculture, Water, Disaster Risk Reduction, Power and Health
Dynamical monthly and seasonal forecast	Not available	The forecast is updated every month for the next month and next season.
NWP Data supplied to users	37.62 TB	97.3 TB (2.5 times increase)

Operational NWP models in as on January 2024 (Nowcast to Extended Range Forecast)

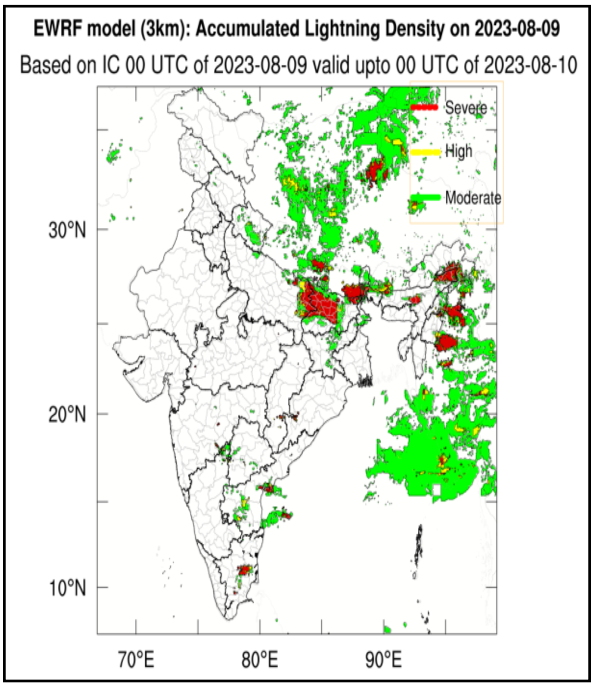
Temporal scales	Operational Numerical NWP/Climate Models	Resolutions and Frequency of Update
Nowcasting to short range forecasting	• Weather Research Forecast (WRF) regional models • HRRR (with radar data assimilation) • E-WRF (with lightning data assimilation) • Coupled Hurricane WRF (HWRF)	• 03 km run for 3 days (Run 4 times a day) 00, 06, 12 & 18 UTC) • Run for 3 domains, 2 km resolution with forecast for 12 hours. (every 2 hrs) • Run 2 times a day (2 km Resl. 24 hr forecast • 18x6x2 km (During cyclone time) for 5 days
Medium range forecast	• Global Forecast System (GFS) Model • Global Ensemble Forecast System (GEFS)	• 12 km (Run four times a day ; 00, 12 UTC) for 10 days and 06 & 18 for 3 days) • 12 km (00 UTC) for 10 days; 20 Members
Extended range (ERF)	• Climate Forecast System (CFS) coupled models (16 members) with hidcasts of 20 Years (2003-2022).	• 38 km (Run once in a week) for 32 days. Run based on every Wednesday and forecast is prepared for 4 weeks.
Multi-Model Ensemble (MME)	• MME forecast based on 6 Global models. (IMD-GFS, IMD-GEFS, NCEP-GFS, NCUM, JMA and ECMWF) • MME based track & intensity with 8 models – IMDGFS, ECMWF, NCEP, NCUM-G, NCUM-R, HWRF, UKMO, ECCC	• Regridded into 12km x12km and customized products are prepared based on all 6 models for 7 days. • Prepared during the cyclone time and used for operational forecast.

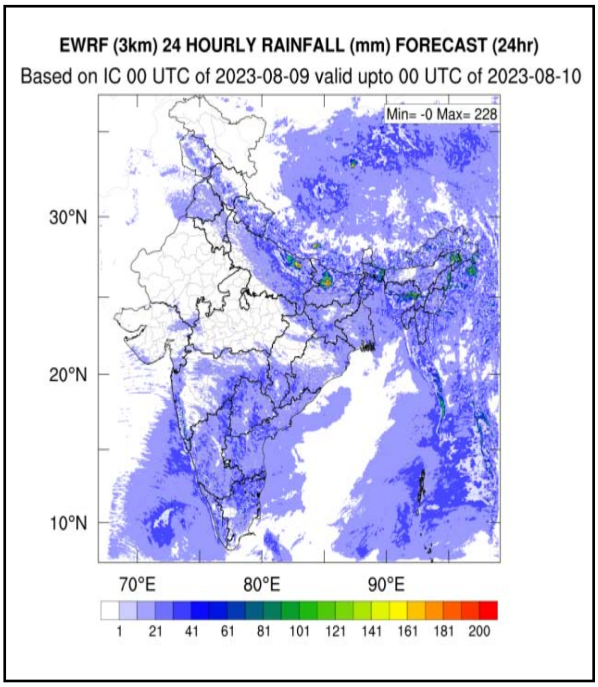
High-Resolution Rapid Refresh (HRRR) model for Nowcasting of Rainfall & Reflectivity forecasts



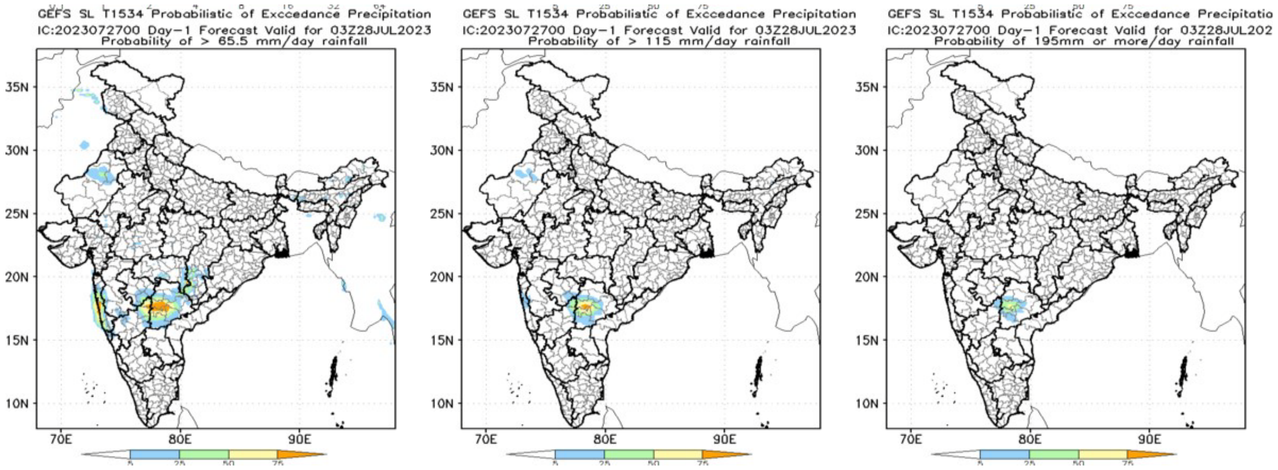


EWRF model for Nowcast of Lightning density & Accumulated Rainfall forecasts





Global Ensemble Forecast System (GEFS) day -1 forecast products (available through joint efforts of IITM, Pune; NCMRWF Noida and IMD) with the probability of different rainfall thresholds (65.5 mm, 115 mm and 195 mm/day)



Rainfall accumulated over 24 hours valid for 03 UTC of 28 July 2023 based on GEFS model forecast based on 00 UTC of 27 July 2023.

MME Based Met sub-division wise (36) rainfall intensity forecast for 7 days

NUMERICAL WEATHER PREDICTION DIVISION

HOME | ARCHIVE | SWFP-SA | PUBLICATIONS | ALL MODELS >> | NOWCAST >> | SHORT RANGE FORECAST >> | MEDIUM RANGE FORECAST >> | EXTENDED RANGE FORECAST >> | SEA

DAY-01 | DAY-02 | DAY-03 | DAY-04 | DAY-05 | DAY-06 | DAY-07

Please check the Date of Rainfall Intensity Forecast as different Models has different updation time

DAY-01 SUB-DIVISION HEAVY RAINFALL FORECAST

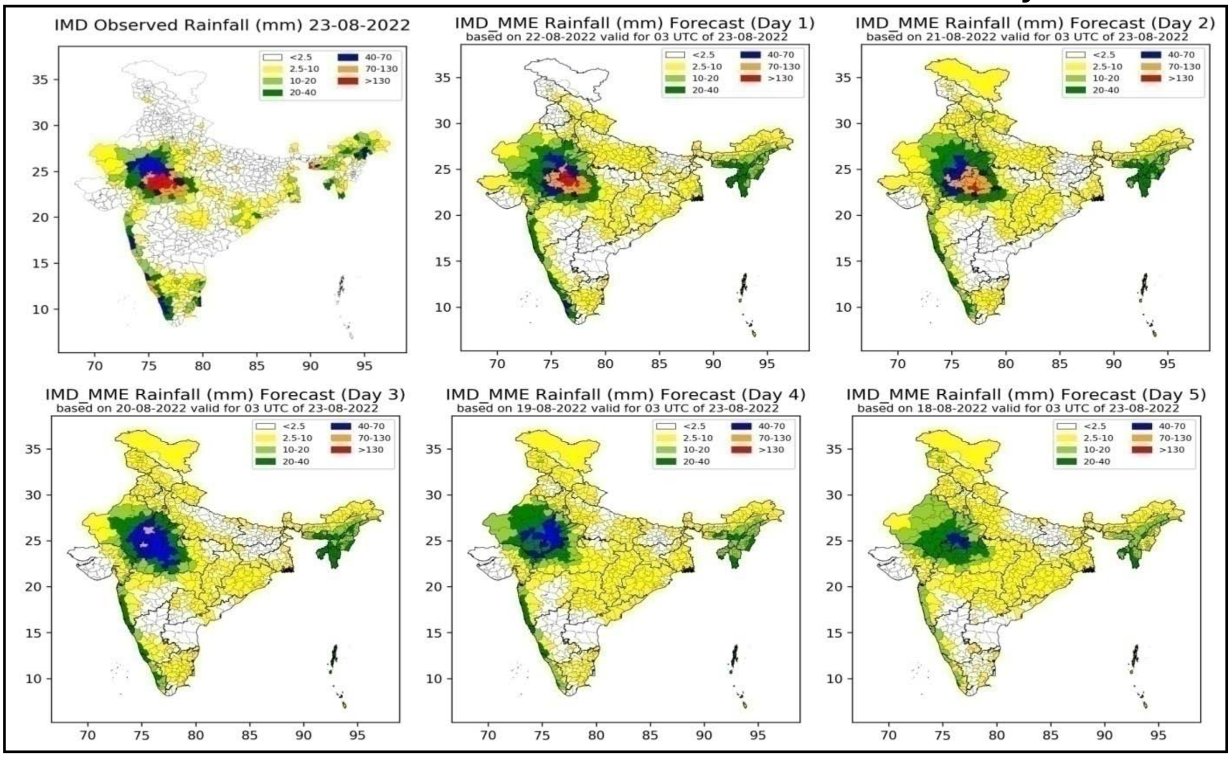
S.NO.	SUB-DIVISION	BASED ON:00Z09082023 :VALID FOR:10082023	BASED ON:00Z09082023 :VALID FOR:10082023	BASED ON:00Z09082023 :VALID FOR:10082023	BASED ON:00Z09082023 :VALID FOR:10082023	BASED ON:00Z09082023 :VALID FOR:10082023	BASED ON:12Z08082023 :VALID FOR:10082023	BASED ON:00Z09082023 :VALID FOR:10082023	BASED ON:00Z09082023 :VALID FOR:10082023
		GFS MEAN(MAX)	JMA MEAN(MAX)	NCUM MEAN(MAX)	NCEP_GFS MEAN(MAX)	GEFS MEAN(MAX)	NEPS MEAN(MAX)	ECMWF MEAN(MAX)	MME MEAN(MAX)
01	A & N ISLAND	7 (24)	4 (9)	8 (21)	7 (15)	7 (14)	9 (13)	6 (20)	6 (16)
02	ARUNACHAL PRADESH	17 (225)	10 (119)	18 (274)	15 (151)	11 (81)	17 (66)	22 (91)	17 (147)
03	ASSAM & MEGHALAYA	16 (89)	6 (38)	17 (147)	19 (93)	13 (65)	15 (73)	11 (58)	15 (85)
04	N M M T	19 (131)	12 (79)	11 (75)	14 (60)	17 (75)	11 (42)	11 (48)	13 (71)
05	SHWB & SIKKIM	15 (86)	15 (82)	14 (76)	7 (18)	9 (31)	12 (29)	18 (48)	15 (57)
06	GANGETIC WEST BENGAL	4 (15)	17 (48)	7 (32)	5 (16)	5 (12)	8 (23)	9 (33)	9 (31)
07	ORISSA	3 (43)	1 (10)	3 (15)	3 (19)	3 (27)	4 (21)	2 (14)	2 (21)
08	JHARKHAND	5 (22)	11 (78)	6 (36)	5 (28)	7 (18)	9 (41)	6 (45)	6 (41)
09	BIHAR	10 (41)	27 (78)	24 (328)	19 (92)	14 (32)	26 (64)	25 (114)	19 (101)
10	EAST UTTAR PRADESH	34 (281)	16 (46)	29 (403)	11 (88)	28 (74)	21 (88)	29 (504)	23 (174)
11	WEST UTTAR PRADESH	3 (48)	4 (28)	5 (191)	3 (19)	5 (28)	6 (101)	2 (20)	4 (61)
12	UTTARAKHAND	11 (91)	12 (74)	11 (99)	10 (29)	8 (42)	12 (67)	6 (32)	10 (66)
13	HAR. CHD & DELHI	1 (2)	1 (3)	2 (14)	2 (5)	1 (25)	2 (6)	1 (4)	1 (8)
14	PUNJAB	3 (29)	1 (4)	4 (22)	1 (6)	3 (20)	3 (14)	5 (18)	3 (18)
15	HIMACHAL PRADESH	3 (50)	1 (8)	3 (54)	2 (9)	3 (33)	3 (15)	2 (10)	2 (25)
16	JAMMU AND KASHMIR	1 (69)	1 (31)	1 (50)	1 (6)	1 (21)	1 (21)	1 (9)	1 (30)
17	WEST RAJASTHAN	1 (4)	1 (1)	1 (3)	1 (2)	1 (6)	1 (1)	1 (3)	0 (2)
18	EAST RAJASTHAN	1 (4)	1 (7)	1 (4)	1 (3)	1 (3)	1 (4)	1 (10)	0 (4)
19	WEST MADHYA PRADESH	1 (4)	1 (6)	2 (13)	1 (4)	1 (4)	2 (8)	2 (13)	1 (6)
20	EAST MADHYA PRADESH	1 (22)	1 (4)	2 (5)	1 (3)	2 (27)	3 (11)	2 (4)	1 (11)
21	GUJARAT REGION	2 (6)	4 (12)	2 (7)	2 (5)	2 (7)	2 (5)	3 (7)	2 (7)
22	SAURASHTRA & KUTCH	2 (4)	2 (7)	1 (2)	2 (3)	2 (4)	1 (3)	2 (6)	1 (4)

AMOUNT	CATEGORY		AMOUNT	CATEGORY	
NIL	NO RAIN		64.5-115.5	HEAVY	
1-15	LIGHT		115.6-204.4	VERY-HEAVY	
15.1-64.4	MODERATE		>=204.5	EXTREMELY-HEAVY	

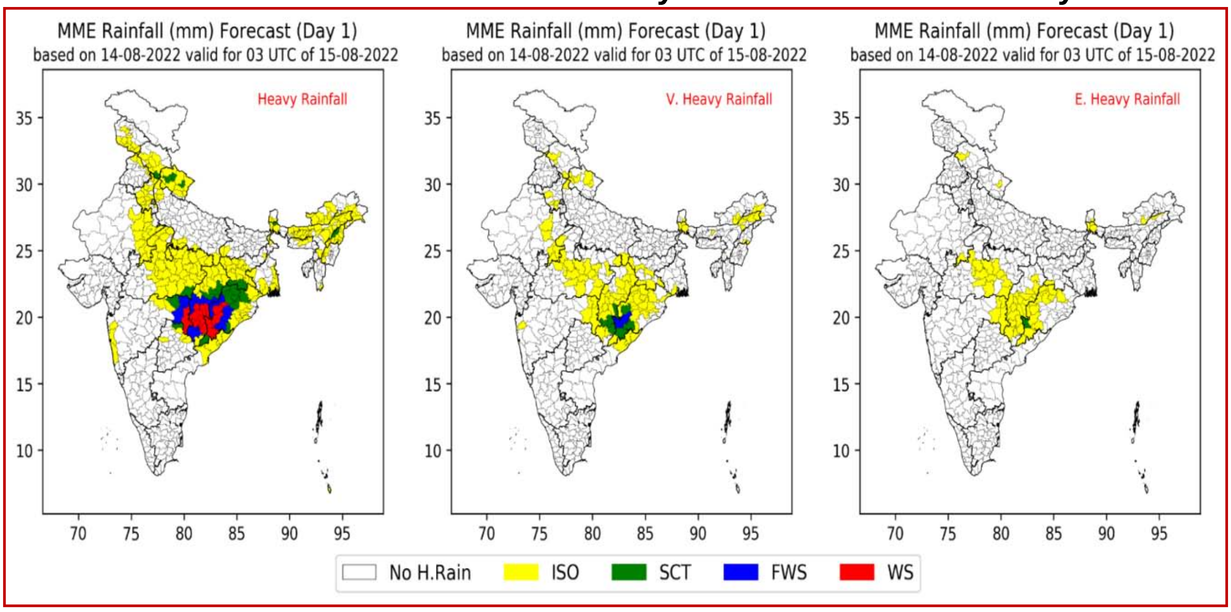
Rainfall Intensity : Mean (Maximum) rainfall over the subdivision for 7 days based on 7 NWP models and MME with different colour indicating different rainfall intensity.

- **The MME forecasts** products in the medium-range time scales are also generated for Indian cities, districts, meteorological sub-divisions, Indian coastal regions, and the North Indian Ocean for various applications, such as : for general weather forecasting, severe weather forecasting, for issuing Agro-advisory.
- MME-based forecast products are also generated for entire RSMC domains, covering India along with neighbouring countries and also the north Indian Ocean, river basins, Sea areas, fleet areas etc. These forecast products are also used for the automation of different weather bulletins.

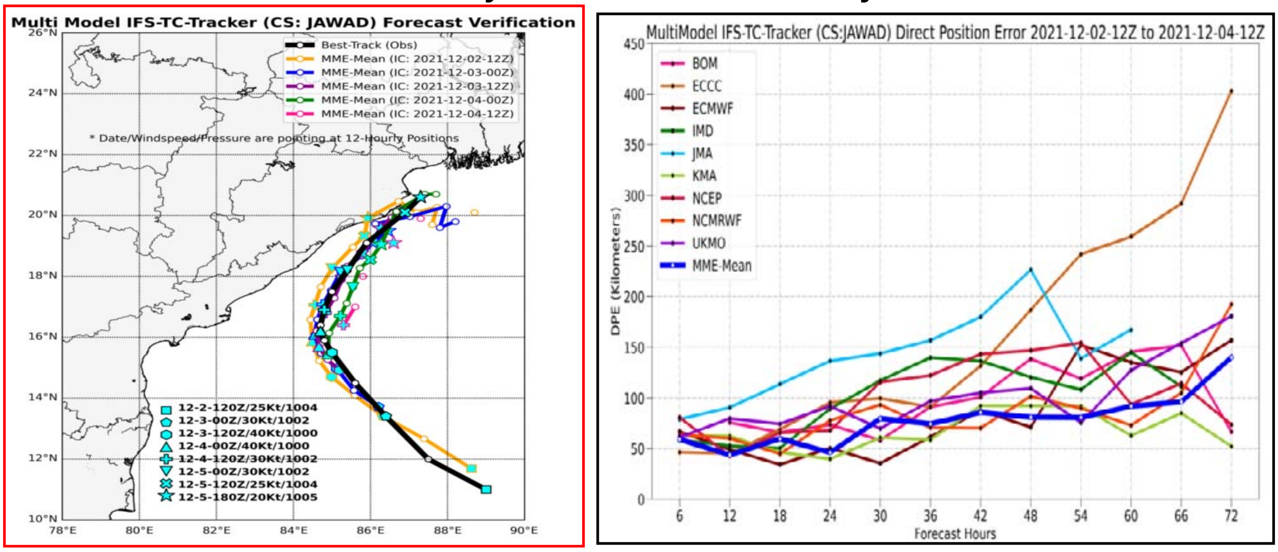
MME based district scale mean rainfall forecast for 5 days



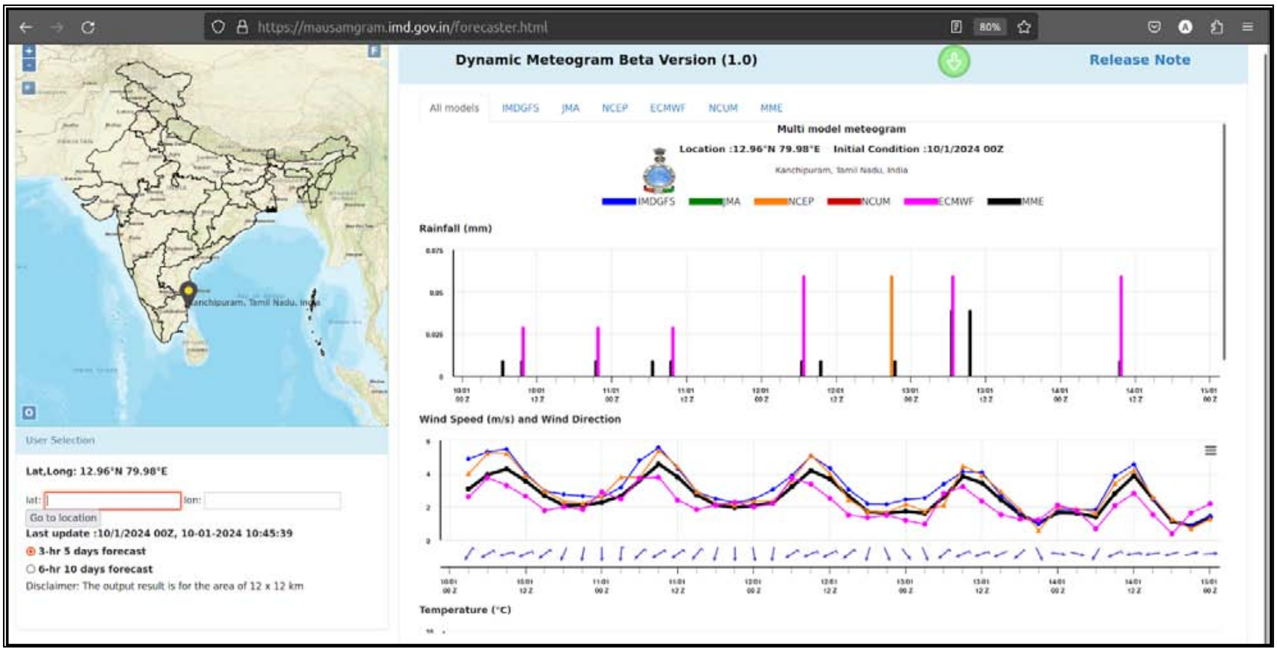
MME based district scale for Heavy Rainfall forecast for 5 days

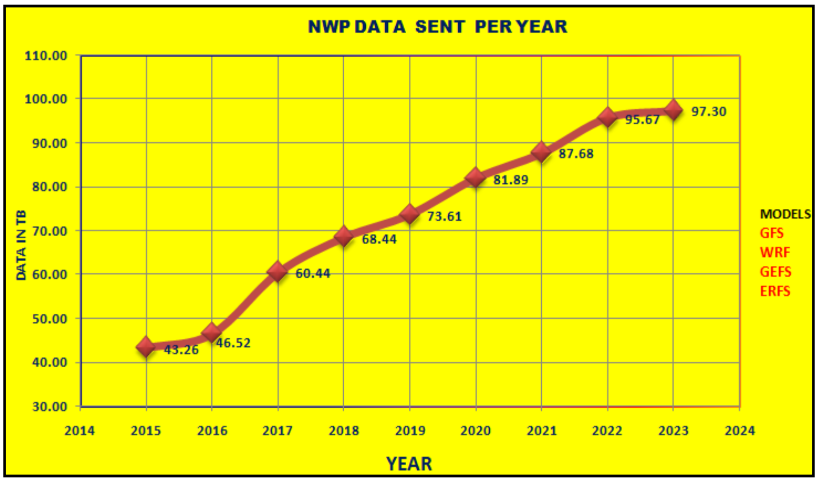


MME-based cyclone track and intensity forecast



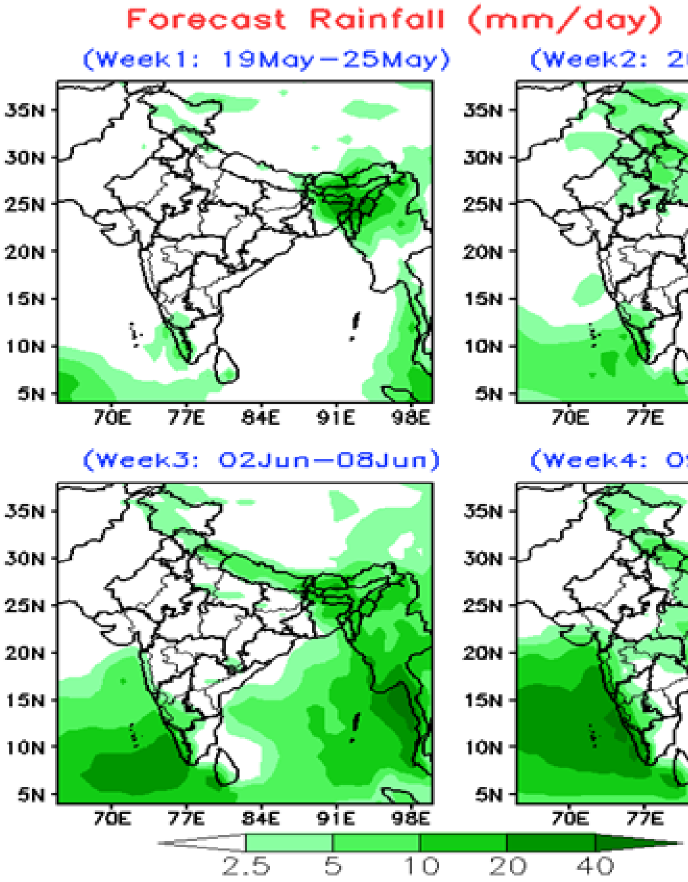
Dynamic Meteogram for weather forecast at any location

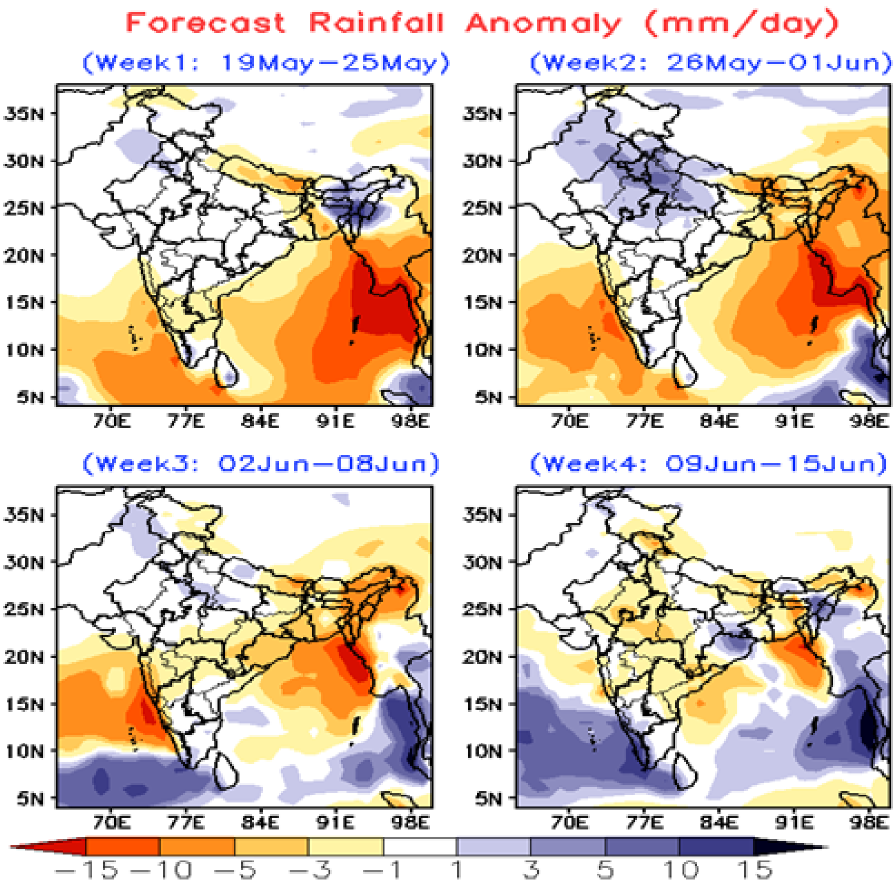




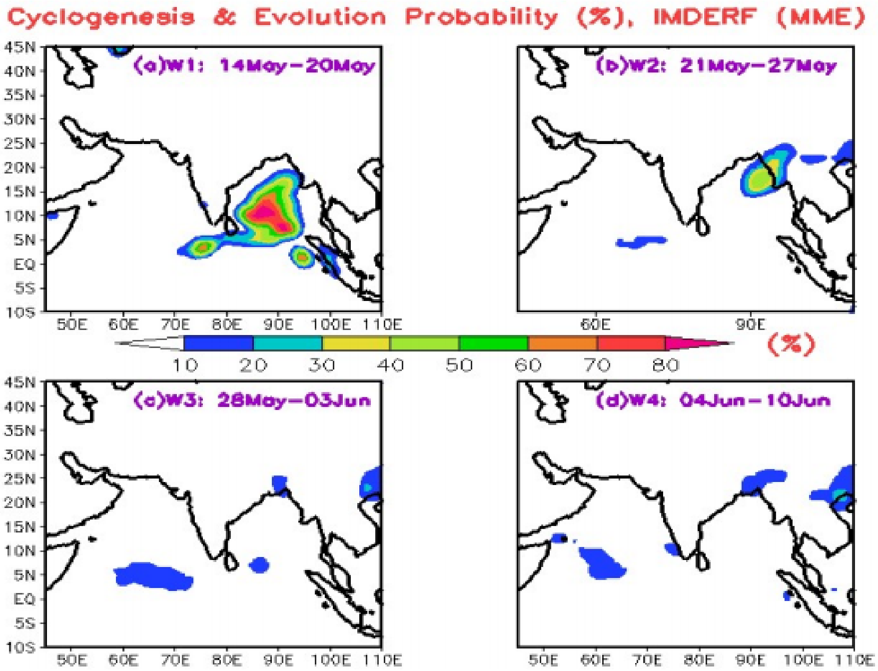
The volume of NWP data supplied to various research communities, State Emergency Operation Centres (SEOCs) and National Meteorological and Hydrological services of different countries has increased manifold in the last decade.

Extended range forecast (ERF) of rainfall and its anomaly for 4 weeks (IC : 17 May 2023)

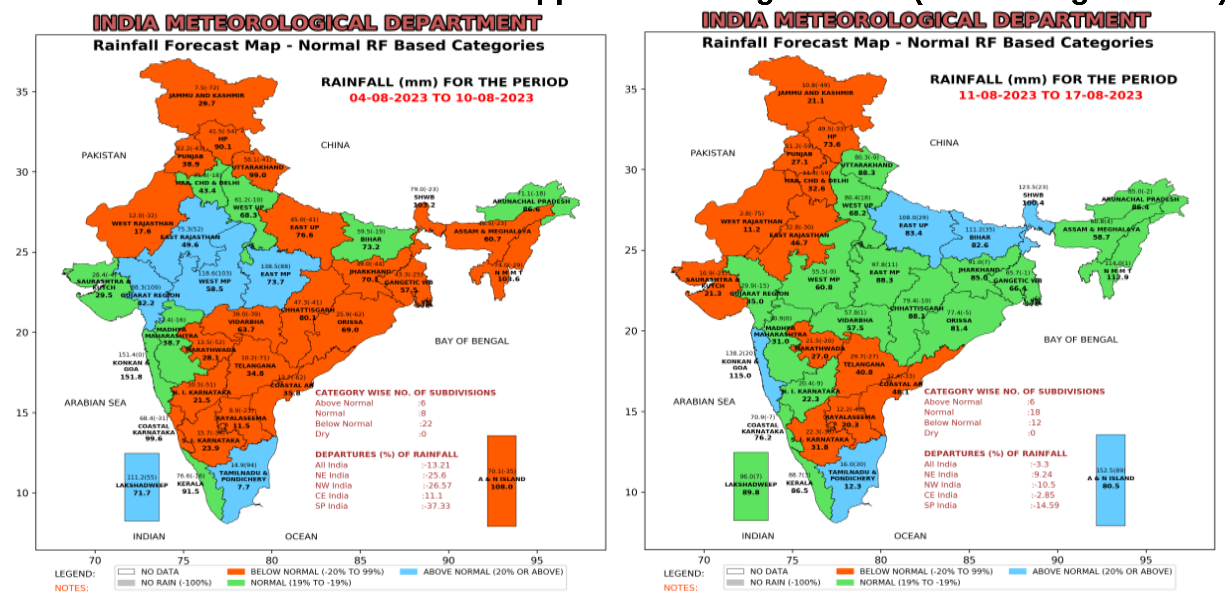




Cyclogenesis probability forecast for 4 weeks (IC : 12 May 2020)



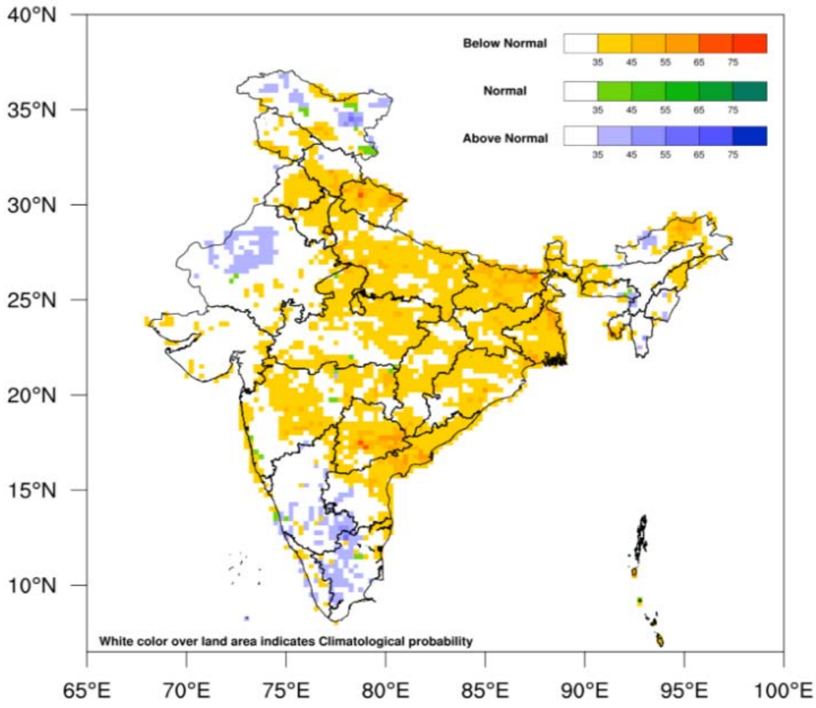
Sub-division level ERF rainfall for application in Agriculture (IC : 02 August 2023)



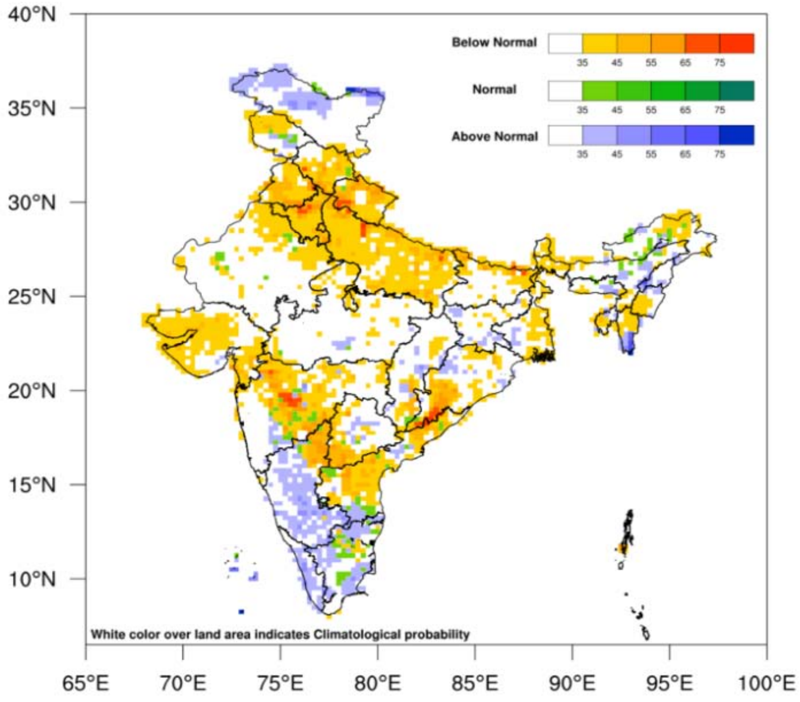
4.4 *Monthly and Seasonal Forecast*

The updated forecast for monthly forecast for June 2023 and seasonal rainfall forecast for June-September, 2023 based on the Multi-Model Ensemble (MME) by using MMCFS (Monsoon Mission Climate Forecast System) climate model and best few climate models that have the highest forecast skills over the Indian monsoon region.

Probability Monthly Rainfall Forecast for June 2023 (May ICs)



Tercile Probability of seasonal monsoon rainfall forecast for Jun-Sep 2023 (May ICs)



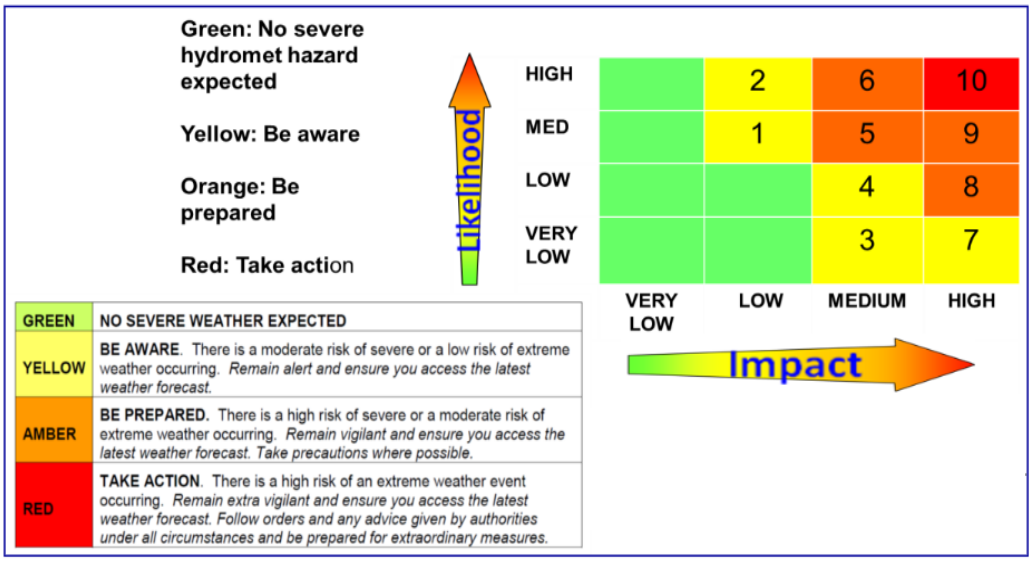
4.5 Weather Forecasting and Warning Services

Overall Forecast Accuracy improvement: 40% improvement in 2023 as compared to 2014.

IMD implemented Impact Based Forecast (IBF) in recent years at the district level since 2020. It contains the details of impacts expected from the severe weather elements and guidelines to the general public about do's and don'ts. These guidelines are finalized in collaboration with the National Disaster Management Authority (NDMA) and have already been implemented successfully for cyclones, heatwaves, thunderstorms, and heavy rainfall. Work is in progress to implement the same for other severe weather elements.

While issuing the warning suitable colour code is used to bring out the impact of the severe weather expected and to signal the Disaster Management about the course of action to be taken concerning impending disaster weather events. **The green colour corresponds to no warning hence no action is needed, the yellow colour corresponds to being watchful and getting updated information, the orange colour suggests to be alert and be prepared and the red colour advises taking action.**

- Impact-based Forecasting (IBF) is being issued for all severe weather events at district and city levels with the inclusion of exposure and vulnerability parameters and suggestions for necessary actions.



4.6 Tropical Cyclone Forecasting Services

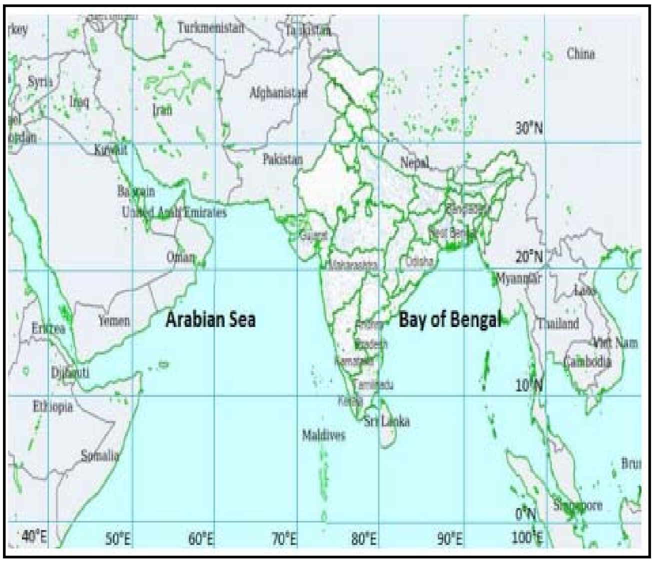
Cyclone Forecast	
First-ever initiatives	**First-time ever Initiatives:** **(i)** probabilistic forecast of cyclogenesis for the next three days in 2014, the next five days in 2018 and the next 7 days in 2023. **(ii)** extended range forecast of cyclogenesis upto two weeks in 2018, **(iii)** Pre-genesis track and intensity forecast of cyclone on the formation of a low-pressure area in 2022 against similar forecast only after the formation of deep depression before 2014. **The first country in the world to provide track & intensity forecast from low-pressure stage** **(iv)** cyclone track and intensity forecast in GIS for the public, disaster managers and other stakeholders, **(v)** Dynamic impact-based forecast (IBF) utilising Web GIS-based Dynamic Composite Risk Atlas (Web-DCRA) in 2021 enabling risk assessment at the village level against IBF based on historical

	damage database at the district level, **(vi)** Customised location-specific impact-based forecast for onshore and offshore industries, fishermen, ports, coastal and high sea shipping in 2022 against textual messages before 2014. **(vii)** Introduction of dedicated website for cyclones (2014), SMS to disaster managers (2012), SMS to general public, fishermen & farmers (2014), social media (2016), SMS, NaViC (2021), mobile apps(2020), bulletins transmission through WhatsApp (2020), Common Alerting protocol(2022), video messages in English, Hindi & regional languages (2022) for cyclone warning.	
Death Toll	Odisha Super Cyclone caused 10,000 deaths in 1999 in India The Bhola Cyclone caused 300,000 deaths in 1970, Nargis cyclone caused 1,25,000 deaths in Myanmar in 2008	The death toll has reduced significantly to double digits not only in India but also in 13 WMO/ESCAP Panel Member countries bordering the Bay of Bengal and the Arabian Sea. Graphics
Error in the track forecast	**2005-2013:** 24 hours ahead: 126 km 48 hours ahead: 200 km 72 hours ahead: 268 km	**2014-22 :** 24 hours ahead: 78 km (38% improvement) 48 hours ahead: 120 km (41% improvement) 72 hours ahead: 169 km (36% improvement)
Error in intensity forecast	**2005-2013:** 24 hrs ahead: 11.4 kts 48 hrs ahead: 14.3 kts 72 hrs ahead: 17.6 kts	**2014-22 :** 24 hrs ahead: 8.3 kts (27% improvement) 48 hrs ahead: 11.9 kts (16% improvement) 72 hrs ahead: 14.3 kts (18% improvement)
Landfall point	The 72hr landfall point forecast error in five years (2019-2023) is 73 km compared to that of 104 km in the five years (2014-2018)	
Comparison with global centres		In comparison with international agencies, IMD's cyclone track forecast accuracy is better than the leading nations including USA and Japan for all forecasts issued five days in advance
Appreciations		**(Appreciation from (i) Hon'ble Prime Minister for the accurate forecast of Hudhud (2014), (ii)** According to the NCAER report(2015), 95% of the coastal population believe in cyclone warning and take action, **(iii)** Cyclone Warning Services of IMD earned a place among 100 Innovations that transformed India after independence: published in Indian Innovation by Dinesh C Sharma, (iv) (iii)Appreciation from WMO for forecasting cyclones (a)Phailin(2013), (b)Sagar and Mekunu (2018), (c)Titli and Luban(2018), (d)Amphan,2020 and (e)Mocha2023, **(iv)** King (then Prince) Charls visited IMD in 2019 and many other

		international dignitaries appreciated IMD's cyclone warning, **(iv)** UN DRR and WMO appreciated pin pointed forecast of cyclone Fani, (2019), (v) Appreciation from Hon'ble President of India for accurate forecast of FANI, **(v)** Leading TV channels including Discovery and Animal Planet, Washington Post, New York Times, Times of India, Indian Express, PTI, National and local TVs among many others appreciated cyclone warning and management in India

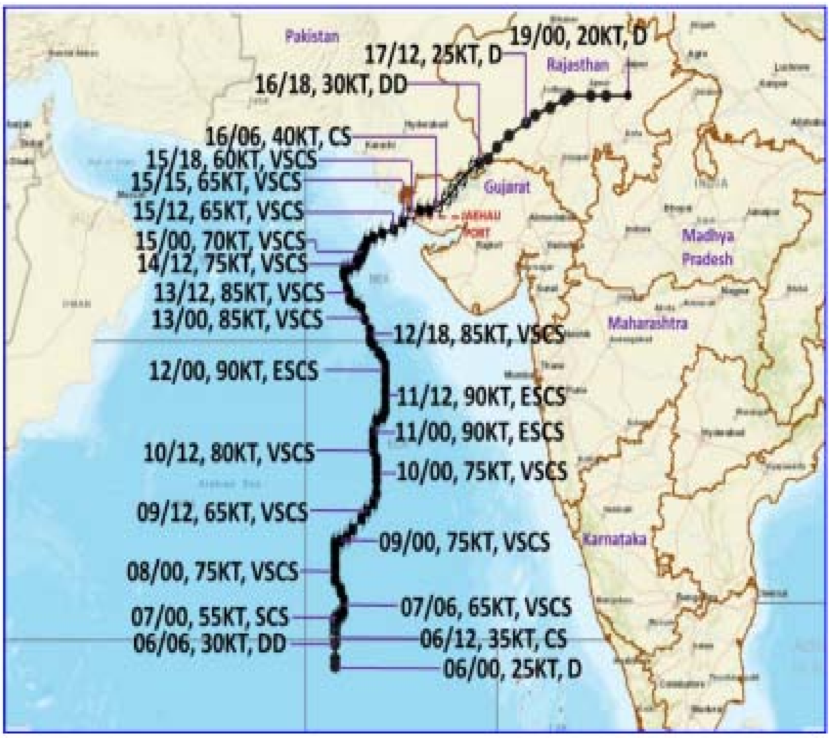
- Area Cyclone Warning Centre/Cyclone Warning Centre increased from 7 (2014) to 8 (2023) with the establishment of CWC Thiruvananthapuram in 2018 to cater to the maritime requirements of Lakshadweep, Kerala and Karnataka.
- At the National level, Cyclone Warning Division at Headquarters, New Delhi along with 3 Area Cyclone Warning Centres (ACWC) at Chennai, Mumbai, Kolkata and 4 Cyclone Warning Centres (CWC) at Bhubaneswar, Visakhapatnam, Thiruvananthapuram and Ahmedabad are responsible to cater to the cyclone warning services for the north Indian Ocean.

RSMC, New Delhi Domain



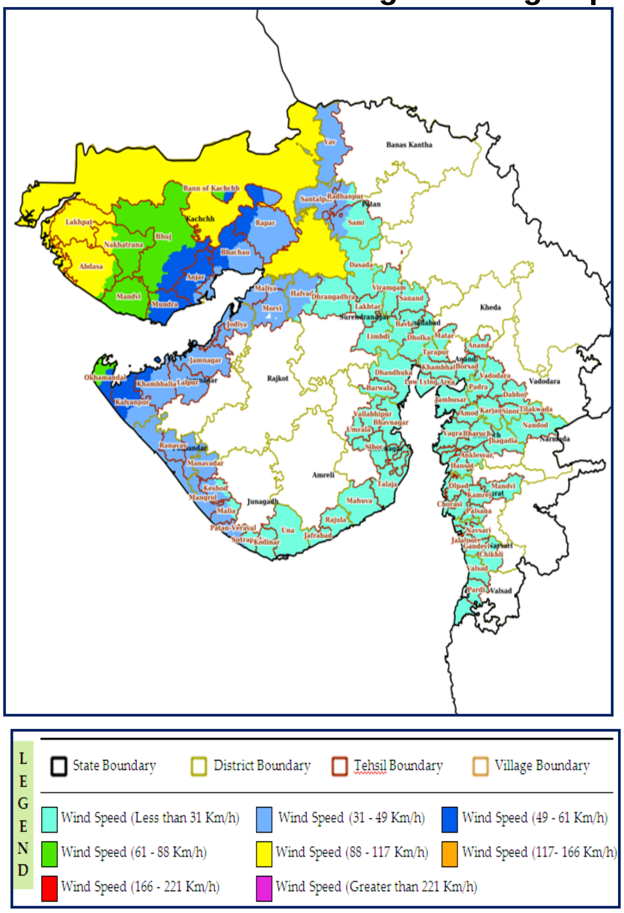
Cyclone Warning Organisational Structure of IMD

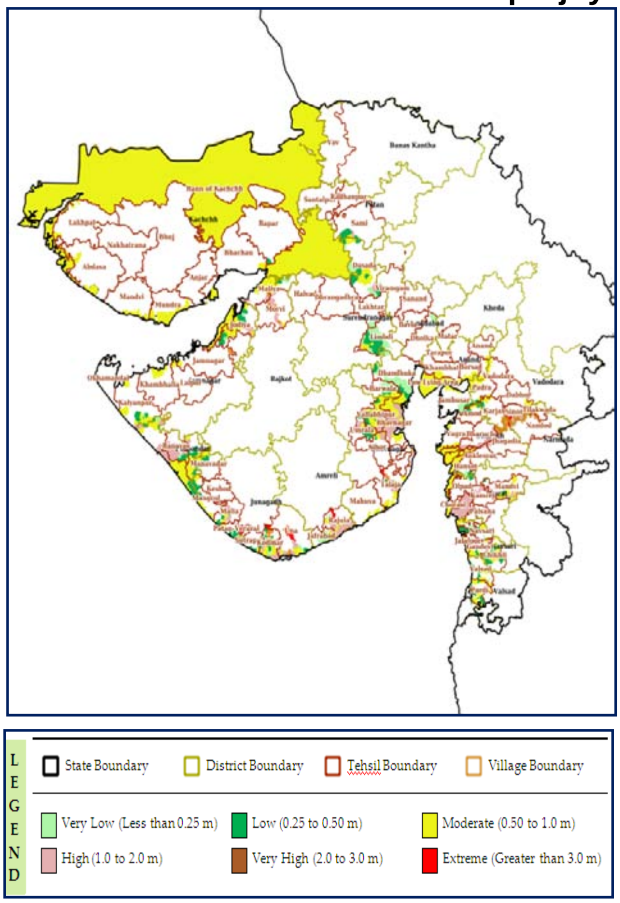
- A web-based Dynamic Composite Risk Atlas (Web-DCRA) and Decision Support System (DSS) tool for real-time Cyclone and associate impact-based forecasting in 13 coastal states (covering both eastern and western coasts) of the country was launched by National Disaster Management Authority (NDMA) on 28th of September, 2022. The Web-DCRA and DSS tools have been installed/hosted at the India Meteorological Department.

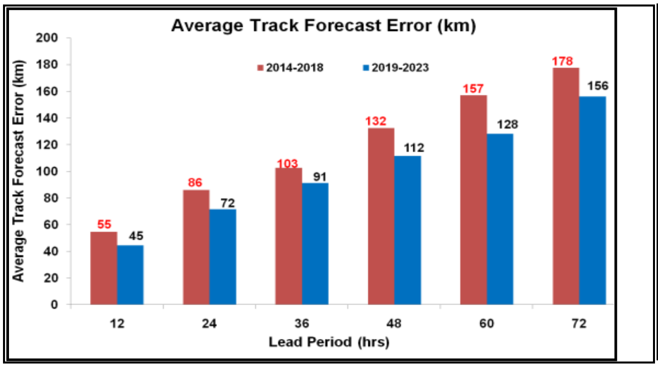


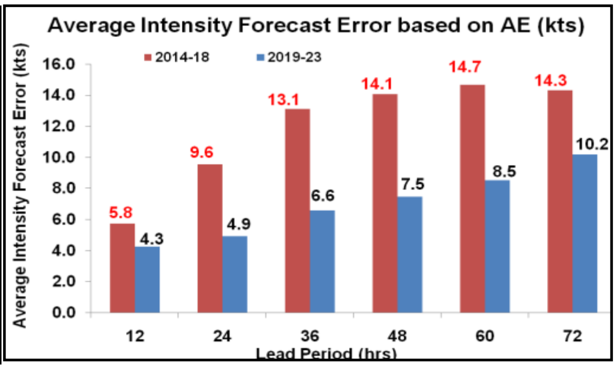
06-19 June 2023 (Extremely Severe Cyclonic Storm Biporjoy)

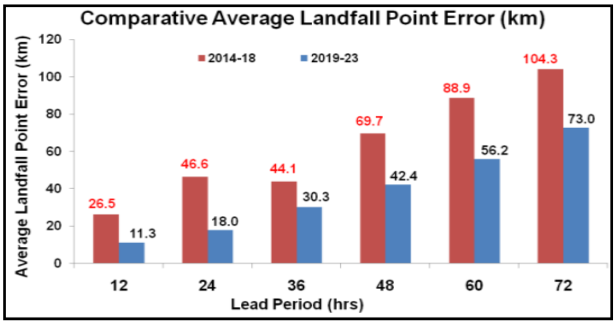
Web DCRA Tool used for generating impact based forecast at the time of Biporjoy

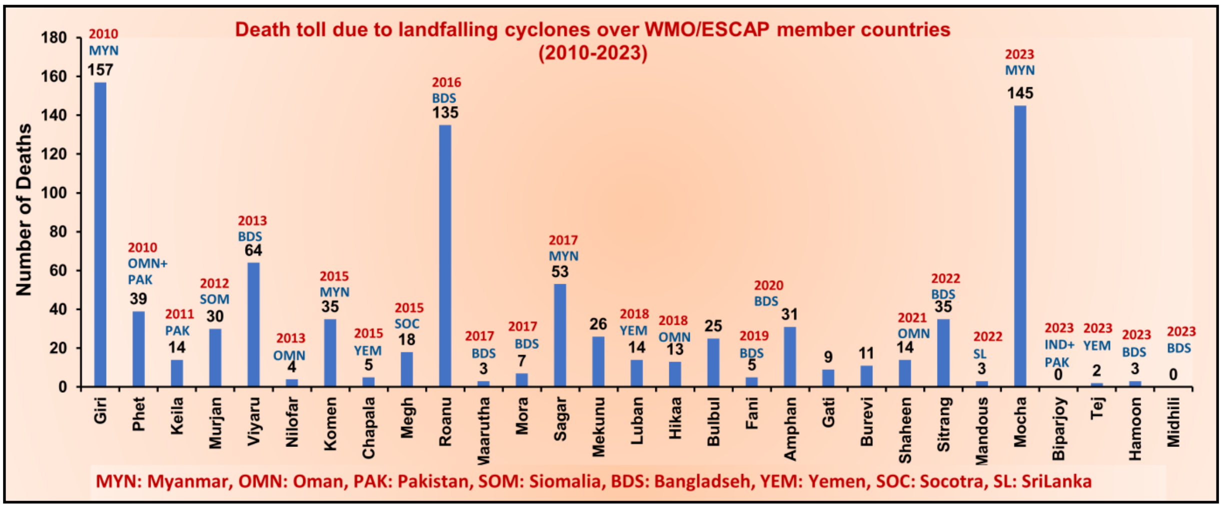












4.7 Marine Services

To safeguard human life at sea and marine assets, the India Meteorological Department has taken various initiatives in recent years as discussed below:

Initiatives for fishermen and offshore industries and ships in deep sea:

(i) At the international level, Cyclone Warning Division & Marine Services Division at Headquarters, New Delhi provide (a) the advisories concerning cyclonic disturbances over the North Indian Ocean, (b) regular bulletins to the international shipping community in Met Area VIII(N) under Global Maritime Distress Safety System with respect to weather over sea.

(ii) At National level, Cyclone Warning Division & Marine Services Division at Headquarters, New Delhi along with 3 Area Cyclone Warning Centres (ACWC) and 4

Cyclone Warning Centres (CWC) are responsible to cater to the maritime requirements.

(iii) Under Global Maritime Distress and Safety System **(GMDSS)** Scheme, India has been designated as one of the 16 service providers in the world for issuing Sea area bulletins for vessels on high seas for broadcast through GMDSS for MET AREA VIII (N), which covers a large portion of NIO. As a routine, two GMDSS bulletins are issued at 0900 and 1800 UTC. During tropical cyclones/ depressions, additional bulletins (up to 4) are issued for GMDSS broadcast. In addition, coastal weather and warning bulletins are also issued for broadcast through NAVTEX transmitting stations. Fleet Forecasts for Indian seas are also issued for the Indian Navy twice a day with a validity period of twelve hours.

(iv) Port warnings have been issued for all the 120 ports since 1865. IMD is in the process of developing a customised location-specific forecast for all the ports from 2024.

(v) Increase in the lead period of cyclogenesis forecast from 3 days (2014) to 5 days (2018) and 7 days (2023) to increase the lead period of warnings and advisories in particular for the marine community, disaster managers and forecasters (already mentioned on page 1)

(vi) Introduction of extended range outlook for cyclogenesis for the next two weeks in 2018 to increase the lead period of warnings and advisories in particular for the marine community, disaster managers and forecasters (already mentioned on page 1)

(vii) Fishermen warnings for the entire North Indian Ocean in textual and graphical format since 2019 for the next 5 days based on a multi-model technique

(viii) The graphical information about the probability of exceedance of winds exceeding 20 kts and 34 kts for the next 5 days for the entire north Indian Ocean since 2022.

(ix) Dissemination of warnings to fishermen in the deep sea through the Navik system which is an indigenous GPS system developed by ISRO to inform the fishermen in deep sea about the natural disasters on their way.

(x) Coastal area warnings (upto 40 nm off coast) and Sea area warnings (beyond 40 nm) in textual, graphical and GIS platforms since 2022

(xi) Customised location-specific colour-coded warnings and forecast for the next 5 days for offshore operators since 2022

(xii) Warnings for the extended area (Red Sea, Entire North Indian Ocean and upto 30^0S and 120^0E) for Naval Ships.

(xiii) IMD is also in the process of providing customized forecasts for Indian Navy, Indian Coast Guard locations and ship routes

(xiv) Regular posts on social media for fishermen warnings since 2023

(xv) Regular awareness campaigns are organised by the coastal offices with the fishermen

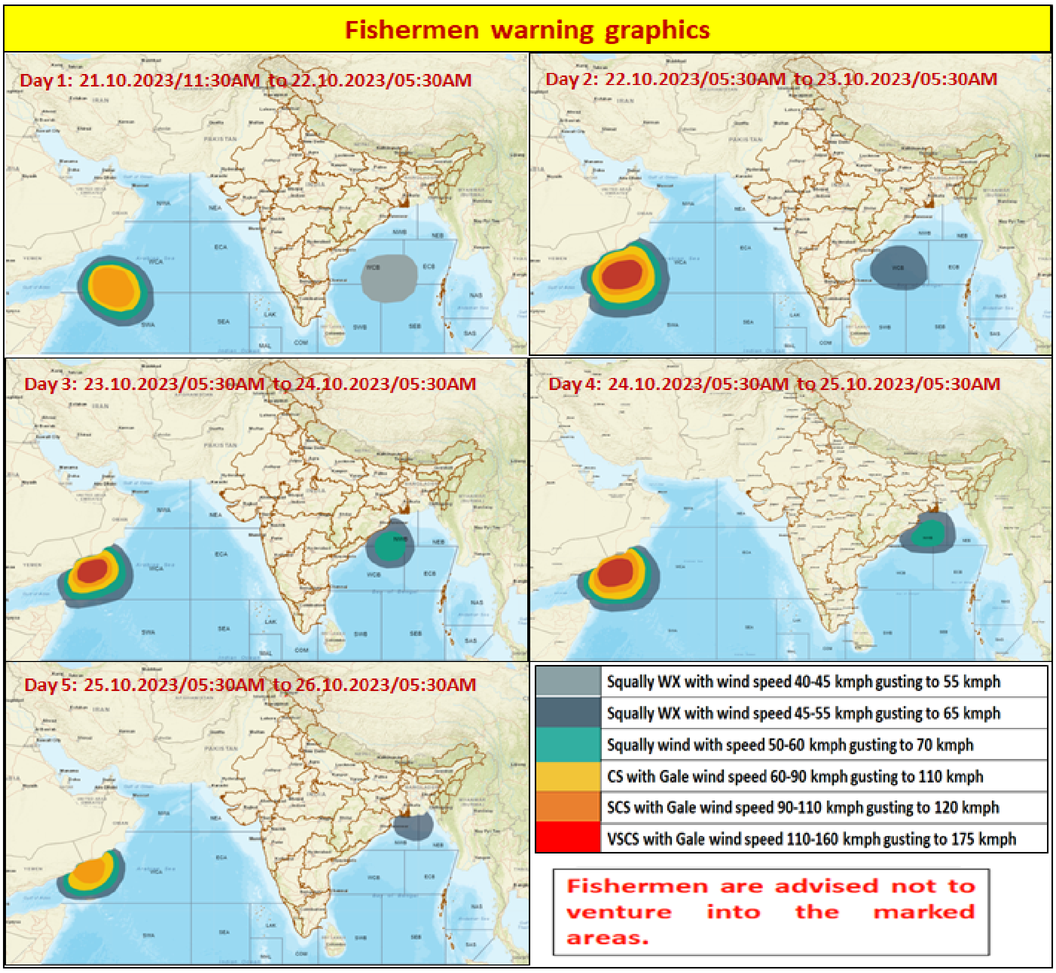
(xvi) IMD is working jointly with INCOIS to provide Met services to the oceanic region and integrating with the ocean state forecast of INCOIS for **Marine-Emergency Response (MER) for Marine Disaster Management.**

Bulletins for marine community by the India Meteorological Department

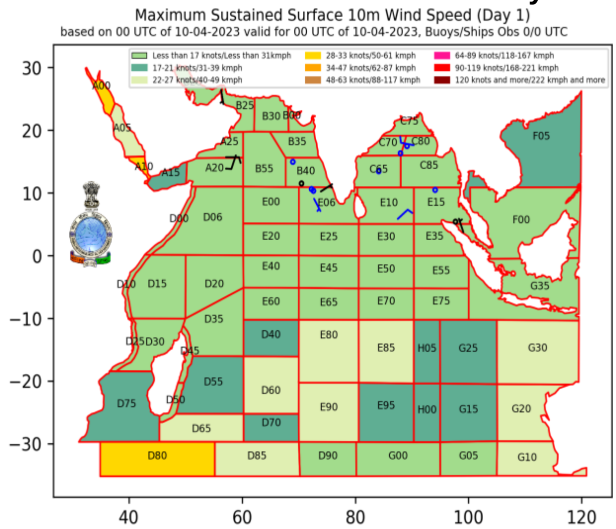
Marine Weather Forecasting and Warning Bulletins

Bulletins	GMDSS Bulletin	Cyclone Warnings	Sea Area	Fleet Forecast	Coastal Weather	Fishermen Warnings	Offshore Industries
Frequency (Normal)	2 times/day	Once/day	2 times/day	2 times/day	2 times/day	2 times/day	Once/day
Frequency (Depression)	3 times/day	5 times/day	3 times/day	4 times/day	4 times/day	4 times/day	5 times/day
Frequency (Cyclone)	5 times/day	8 times/day	5 times/day	4 times/day	5 times/day	4 times/day	8 times/day
Format	Text	Text ,graphic, GIS	Text & graphic	Text	Text & graphic	Text & graphic	Text & graphic
Area	Global Area under sub divn VIII(N)	Entire North Indian Ocean for 13 countries	Deep sea beyond 40 nm off coast	As per IN requirement	Sea area within 40 nm off coast	Entire Bay of Bengal & Arabian Sea, North of Equator)	Offshore industries as per DGH
Dissemination	INMARSAT, Website	FAX, Email, website,SMS, Facebook, Tweet, whatsapp, video, Radio, Doordarshan	NAVTEX Websites	Email, IMD website	NAVTEX websites	Radio, Doordarshan, SMS, Websites, Mobileapp, email,FAX	Email, website, whatsapp
Information	Wind, weather, visibility, wave height	Synoptic system, track, intensity, landfall forecast, associated adverse weather, damage expected, action suggested	Synoptic system, wind, weather, visibility, wave height	Wind, weather, visibility, wave height	Synoptic system, wind, weather, visibility, wave height	Winds ≥45 kmph Squally weather Rough sea Swells	Customised forecast of nearest distance, intensity & time of arrival

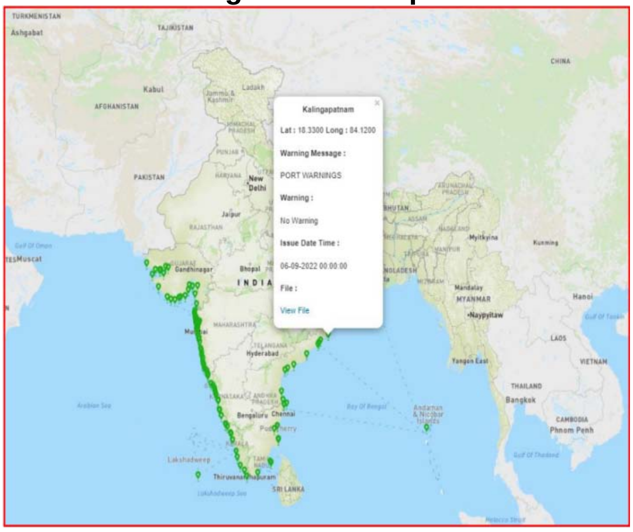
Fishermen Warning Graphics for the entire NIO valid for the next 5 days based on multi-model ensemble



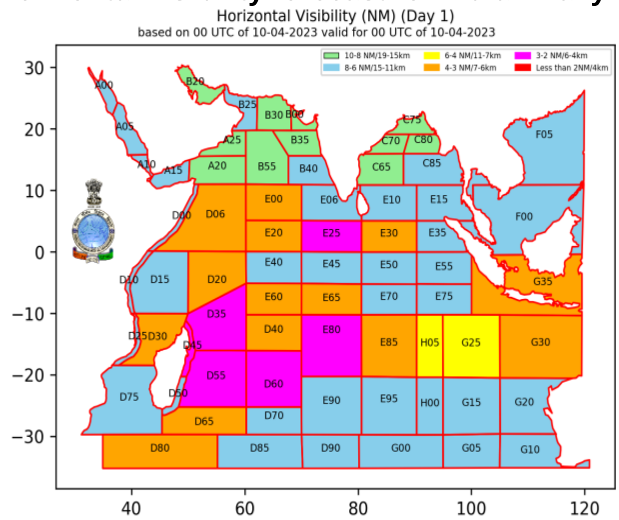
10m wind forecast for Indian Navy



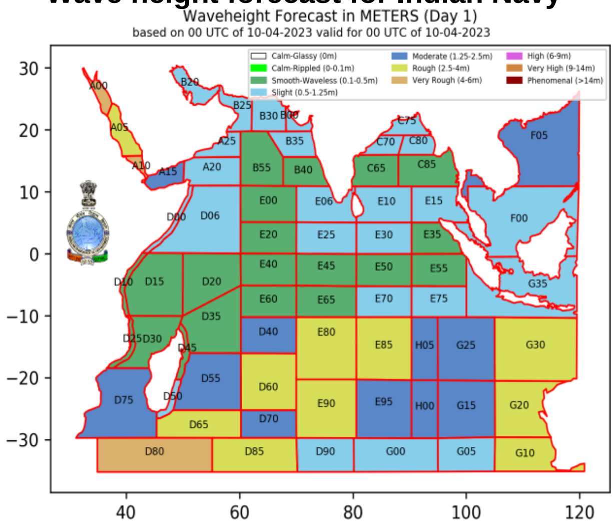
Port Warnings for Indian ports



Horizontal visibility forecast for Indian Navy



Wave height forecast for Indian Navy



Customised bulletins for Offshore/onshore industries

TABLE 4: CYCLONIC DISTURBANCE FORECAST FOR BAY OF BENGAL & MAJOR AREAS OF E&P OPERATIONS BASED ON 1130 hrs IST of 8th December, 2022

SI	DESCRIPTION Name (Lat° N/ Long° E)	LOCATION		CURRENT LOCATION FROM CENTRE OF CYCLONIC DISTURABANCE		FORECAST PARAMETERS WHEN THE INSTALLATION WOULD BE NEAREST TO THE CYCLONE PATH							
		LAT (°N)	LONG (°E)	DISTANCE (NM)	DIRECTION	DATE/ TIME (IST) OF OCCURRENCE	DISTANCE OF RIG FROM PATH	DIRECTION OF RIG FROM PATH	UNCERTAINITY IN DISTANCE OVER PATH (NM)	MSW OVER RIG(KTS)	UNCERTAINITY IN MSW OVER RIG (KT)	SIGNIFICANT WAVE HEIGHT	STATE OF SEA
BAY OF BENGAL AREA													
1.	South West Bay of Bengal (SWB) (13.25/81.50)	9.7	83.5	244	NNW	09.12.22/2030	89	NE	52.5	33	5	4 - 6	Very Rough
2.	West Central Bay of Bengal (WCB) (15.00/83.00)	9.7	83.5	320	N	09.12.22/2030	225	NE	52.5	<27	5	<4	Rough
3.	East Central Bay of Bengal (ECB) (14.25/92.00)	9.7	83.5	570	ENE	08.12.22/1130	570	ENE	10	<27	5	<4	Rough
4.	North West Bay of Bengal (NWB)-1 (18.50°	9.7	83.5	542	NNE	09.12.22/2330	479	NE	55	<27	5	<4	Rough

Color Code for generating impact based forecast:

ZONE	PARAMETERS
GREEN	NORMAL SITUATION, NO FORECAST OF CYCLONE
YELLOW	(1) A TROPICAL CYCLONE FORECAST: THE STORM CENTRE WITHIN 800 NM FROM LOCATION AND (2) THE FORECAST TRACK IS FORECAST TO BE WITHIN 300 NM FROM LOCATION
ORANGE	(1) A TROPICAL CYCLONE FORECAST: THE STORM CENTRE WITHIN 600 NM FROM LOCATION AND (2) THE FORECAST TRACK IS FORECAST TO BE WITHIN 200 NM FROM LOCATION AND (3) SUSTAINED WIND SPEED ALONG THE PATH IS FORECAST TO EXCEED 50 KTS
RED	(1) A TROPICAL CYCLONE FORECAST: THE STORM CENTRE WITHIN 300 NM FROM LOCATION AND (2) THE FORECAST TRACK IS FORECAST TO BE WITHIN 150 NM FROM LOCATION AND (3) SUSTAINED WIND SPEED ALONG THE PATH IS FORECAST TO EXCEED 65 KTS

Notes:
(1) Under each zone, all three parameters are to be fulfilled to declare the rig under that zone
(2) The distance from Forecast Track in Sl No.2 of each zone is the minimum distance of the rig from the track/path when it is passing through:i.e., when it is closest to the rig

4.8 Severe Weather Forecasting Programme of WMO

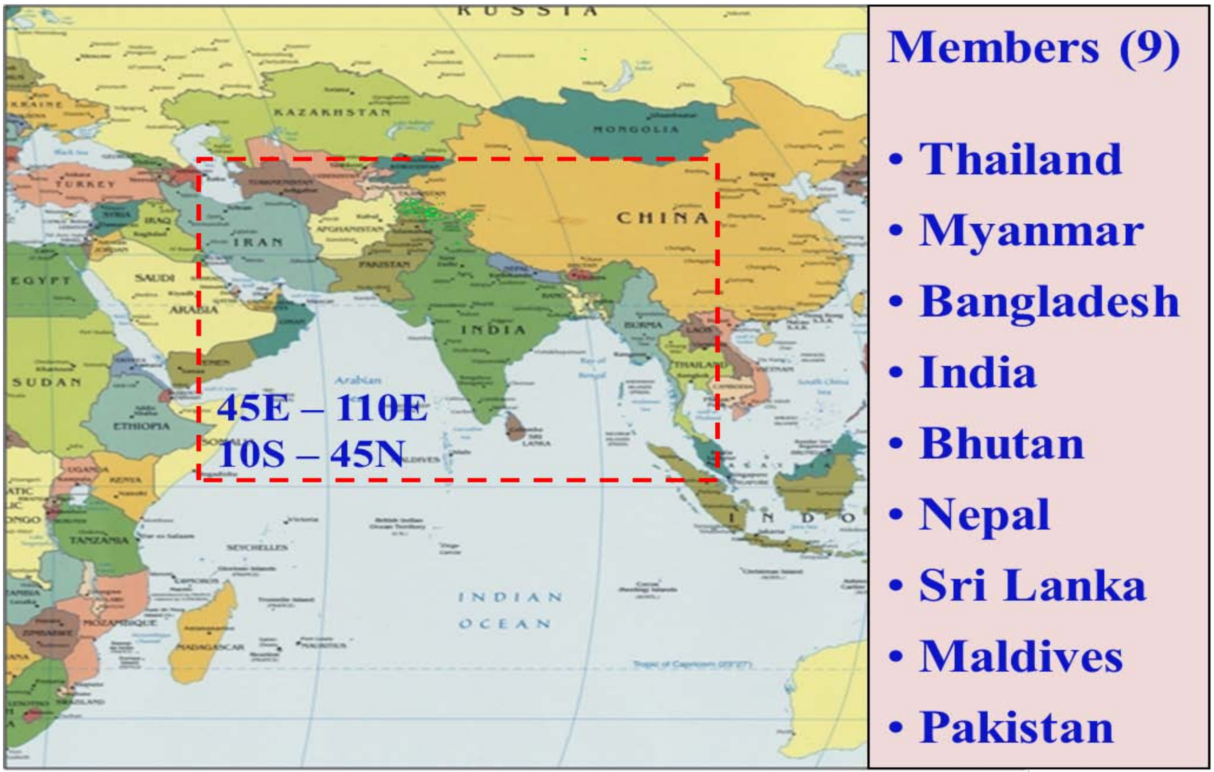
- SWFP is a three-way cascading process with Global Modeling Centres, Regional Centres and National Meteorological & Hydrological Services (NMHSs) as partners with an objective to enable the NMHSs to have greater capability to identify hazardous weather conditions in the short- and medium-range and issue forecasts and warnings accordingly.
- IMD leads WMO's SWFP-South Asia to predict severe weather viz, heavy rain, strong winds, high waves, cyclonic disturbances and storm surge for 9 member countries including Bangladesh, Bhutan, India, Maldives, Myanmar, Nepal, Pakistan, Sri Lanka, and Thailand since May, 2016 in graphical format for next 5 days.
- 2019 marked the introduction of textual products with the inclusion of guidance in short medium range, risk tables in short range and probability tables in medium range.
- 2023 marked the introduction of impact-based forecast and risk-based warnings in GIS and QGIS for heavy rainfall, strong winds, significant wave height, cyclonic disturbance and storm surge for the area of responsibility.

2011-2014: Assessment, planning, drafting (Regional Subproject Implementation Plan) RSIP, workshops and final review of RSIP through SWFDP-Bay of Bengal

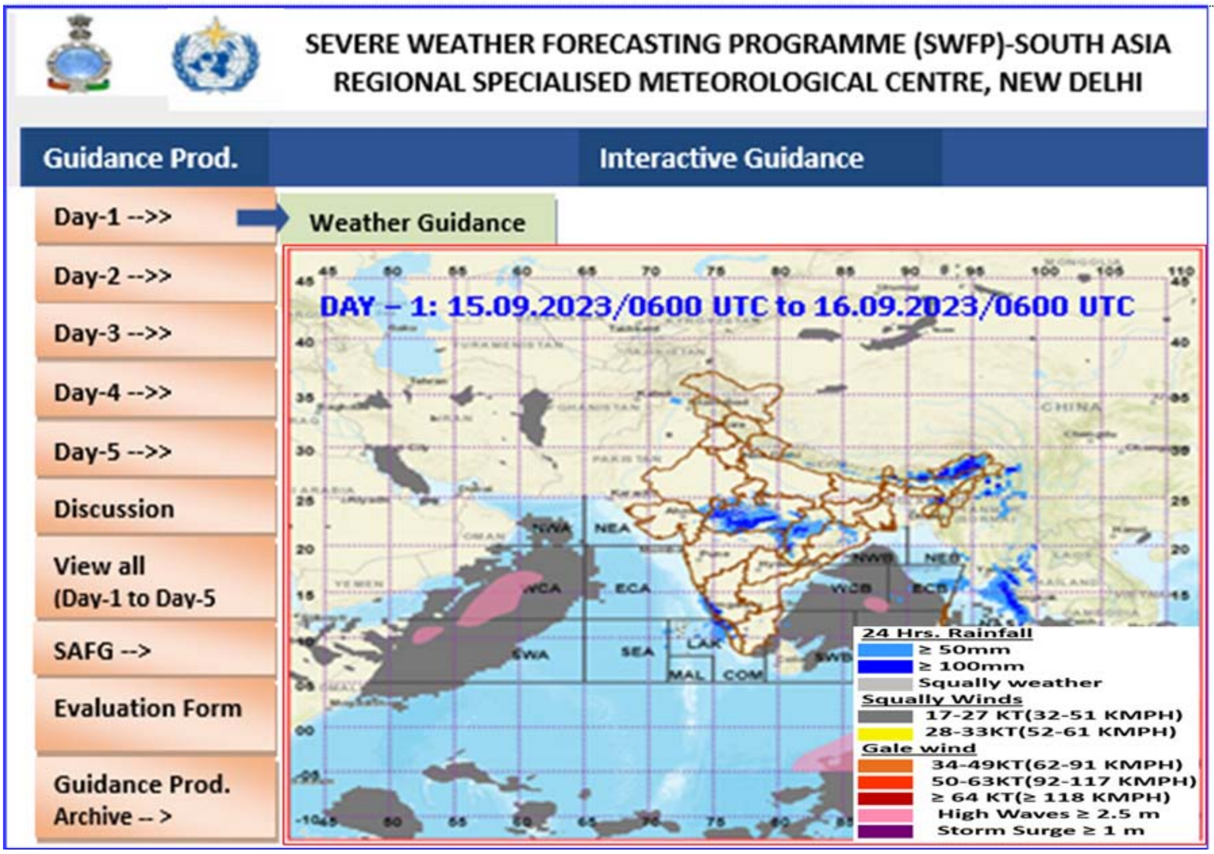
2015: Launch of RSMC New Delhi web portal for SWFP; Joint Training Workshop for both the Bay of Bengal (South Asia) and Southeast Asia sub-regions.

Regional Guidance Products by RSMC New Delhi

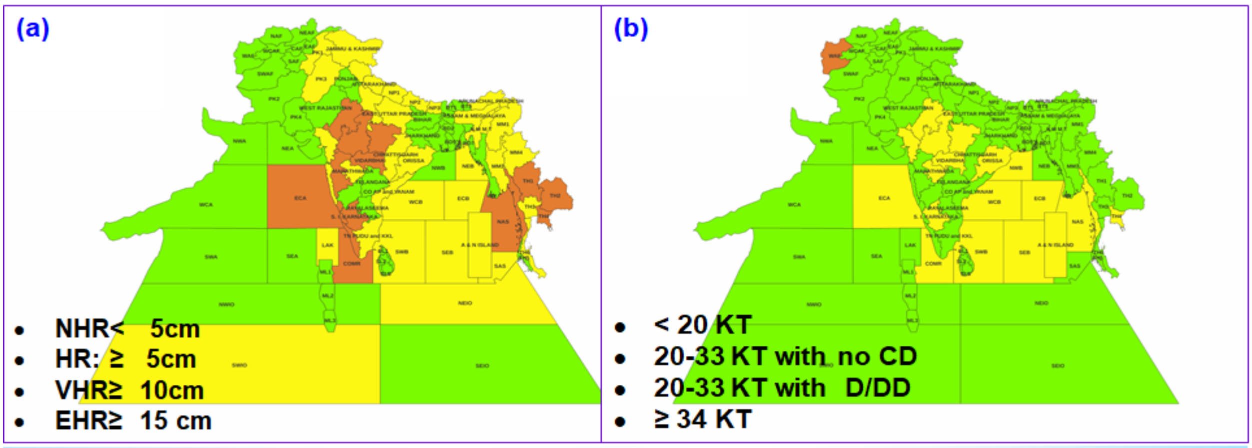
- Short Range (1-2 days) and Medium Range (3-5 days) guidance products for next 5 days:
- Graphical WX forecast products
- Risk Guidance for precipitation & winds (graphical, tabular, GIS) for all 95 sub-divisions based on MME guidance from 5 global models (New)
- Discussion of main synoptic features, satellite features and forecast of heavy rainfall & strong winds and Flash Flood Guidance



Domain of SWFP-South Asia



Severe Weather Guidance Portal on RSMC website
Risk Guidance for (a) heavy rainfall and (b) strong winds for Next 5 days (98 sub-divisions)



Probability of occurrence	Rainfall thresholds: NHR	HR	VHR	EHR
>90%	4	8	12	16
60-90%	3	7	11	15
30-60%	2	6	10	14
0-30%	1	5	9	13

Probability of occurrence	Wind thresholds: <20 kt	20-33kt + Squally Weather	20-33kt + any system or >34kt	>34 kt +cyclone
>90%	4	8	12	16
60-90%	3	7	11	15
30-60%	2	6	10	14
0-30%	1	5	9	13

4.9 Heatwave forecast and warning services

- IMD in collaboration with local health departments has started a heat action plan in many parts of the country to forewarn about the heatwaves and also advising action to be taken during such occasions. The heat action plan became operational in 2013.
- The Heat Action Plan is a comprehensive early warning system and preparedness plan for extreme heat events. The Plan presents immediate as well as longer-term actions to increase preparedness, information-sharing, and response coordination to reduce the health impacts of extreme heat on vulnerable populations. NDMA and IMD are working with 23 states prone to high temperatures leading to heat-wave conditions for supporting heat action plans.
- Considering data for the years 2016 to 2023, there has been a gradual improvement in the heat wave forecasting skill as seen from different skill scores. The Probability of Detection has improved by 20%-30% for Day 1 to Day 5 forecasts in 2023 as compared to 2016 and the POD for Day 1 forecast reached 95% in 2023 against 81% in 2016.
- After the death of about 2,000 people due to heatwaves in 2015, several actions have been taken by MoES/IMD. To minimize the loss of life due to heatwaves, during the summer session for the period from 1 April to 30 June, IMD issues colour-coded impact-based heatwave warnings for the benefit of the public and users since 2019 at the district level. The criteria for the colour code used for the purpose are given in the table;

Green (No action)	**Normal Day**	**Maximum temperatures are near normal**
Yellow Alert (Be updated)	**Heat Alert**	**Heat wave conditions at isolated pockets persists on 2 days**
Orange Alert (Be prepared)	**Severe Heat Alert for the day**	**(i) Severe heat wave conditions persists for 2 days** **(ii) Through not severe, but heat wave persists for 4 days or more**
Red Alert (Take Action)	**Extreme Heat Alert for the day**	**(i) Severe heat wave persists for more than 2 days.** **(ii) Total number of heat/severe heat wave days exceeding 6 days.**

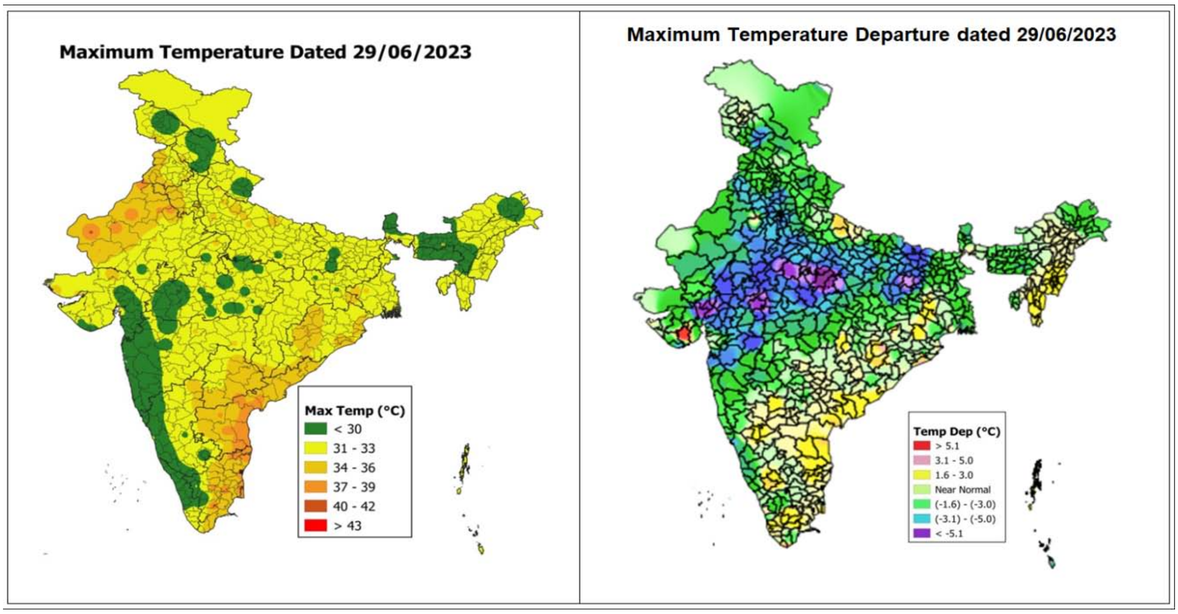
- IMD also issues the impacts and suggested actions concerning the intensity of heat waves and the colour code used for related warnings, in collaboration with NDMA. Details of the same are given in the table below;
- The seasonal and monthly forecast of maximum temperature, minimum temperature and heat wave conditions have been provided during the summer season since 2016.
- Extended range forecast bulletin (including temperature forecast and warnings for the next two weeks) has been issued every Thursday since 2017
- Many new Information in Web-GIS has been added for better interpretation of Heat Wave warnings by various users since 2020 like

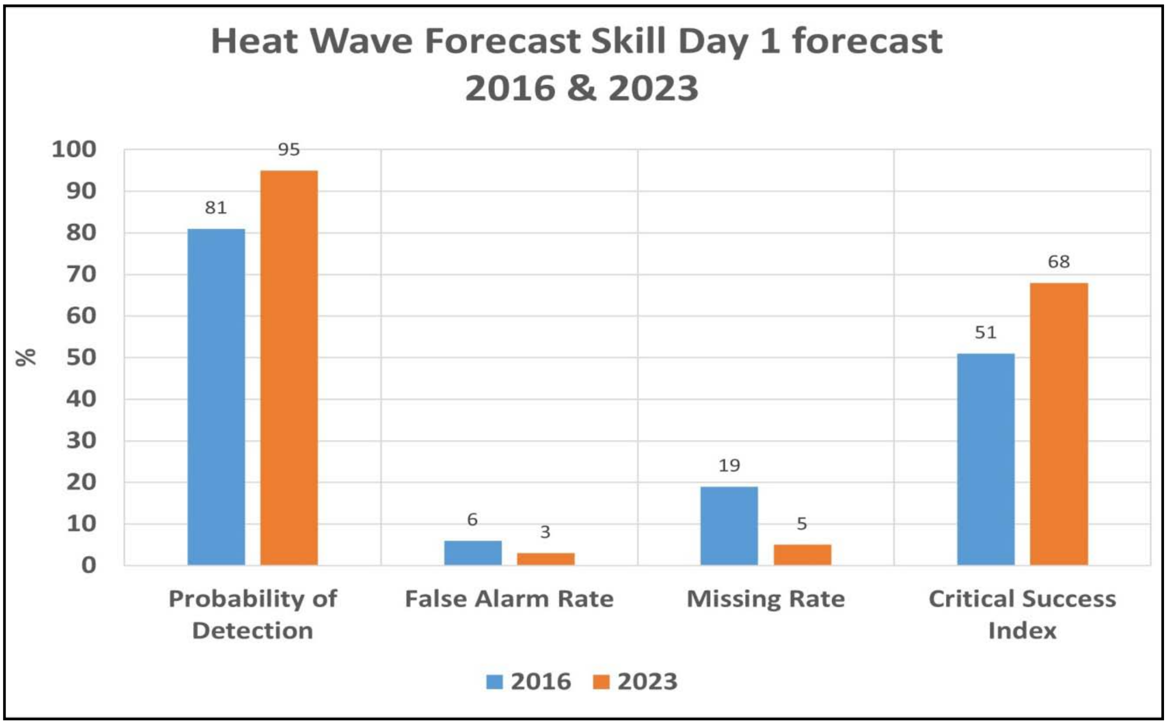
a) Interactive Map for actual Maximum temperature & its Departure from normal temperature based on the situations of the day.

b) Interactive Map for Heatwave and Severe Heatwave along with Warm Nights and very Warm Nights based on the situations of the day.

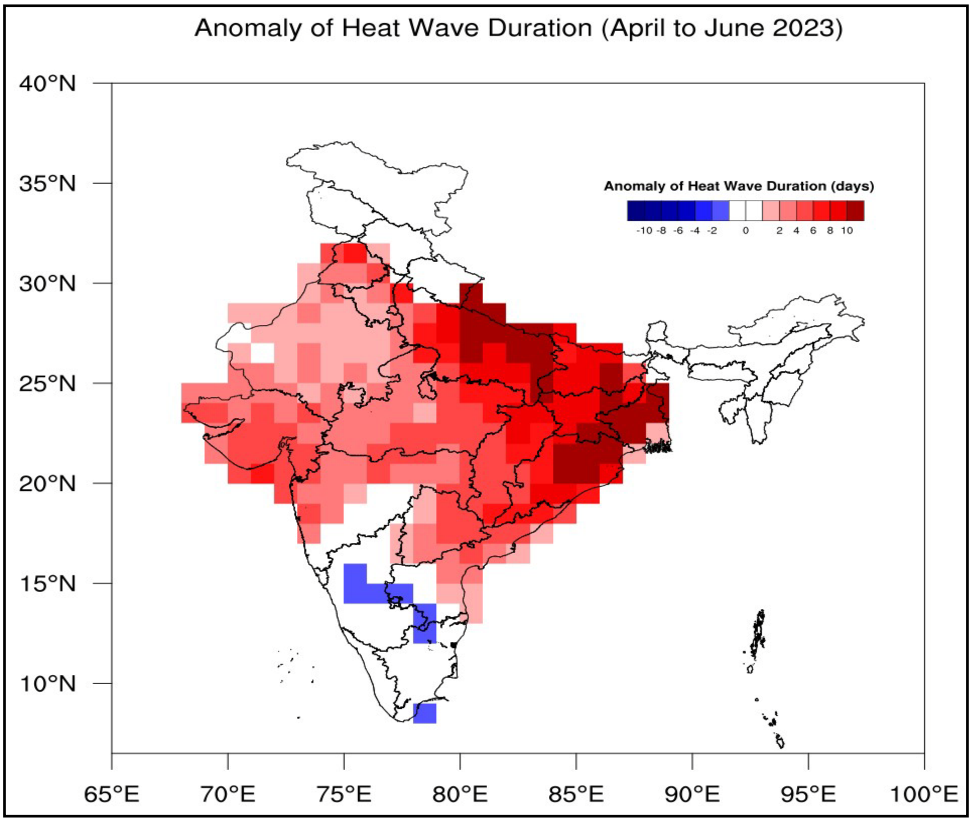
	Status in 2014	**Status as on 2023**
Heat Wave Action Plan	Nil	Commenced by NDMA and SDMAs in 2015 in collaboration with IMD and others
Accuracy	12 hours ahead: 67% 48 hours ahead: 50% 72 hours ahead: 27%	12 hours ahead: 100% 48 hours ahead: 95% 72 hours ahead: 90% Quantum jump in accuracy for all lead periods.
No. Of deaths	2000 in 2015	Double Digit by 2023

Web-GIS based plot of maximum temperature and its departure

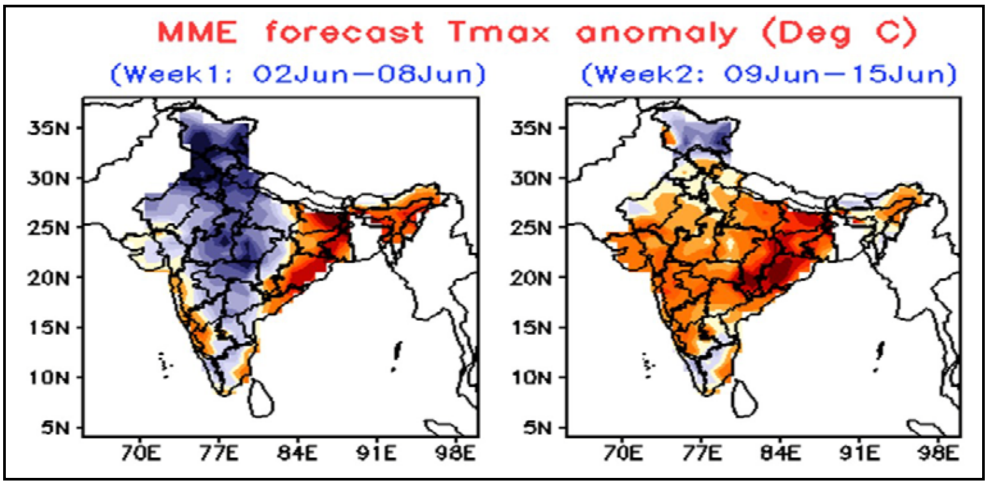




Seasonal forecast of Heatwave duration anomaly issued on 1st April 2023



Extended range forecast of maximum temperature anomaly for 2 weeks based on 30 May 2023 and valid for the period from 02-15 June 2023.



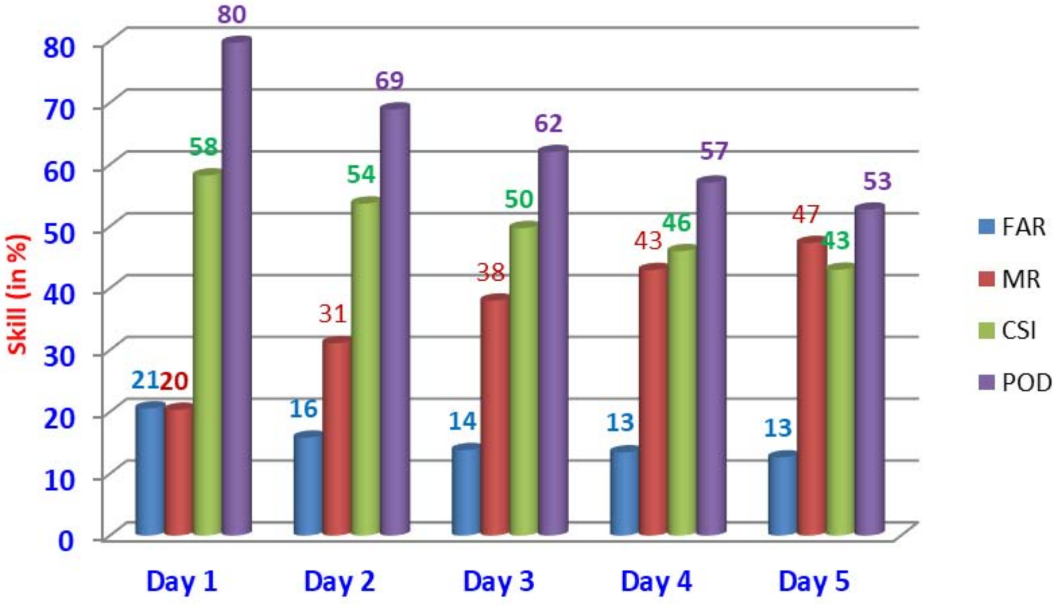
4.10 Heavy Rainfall Forecast and Warning Services

IMD issues various outlooks/forecasts/warnings for the Public as well as Disaster Management Authorities for the preparedness of extreme weather events and adaptation of various climate-related risks. IMD utilizes all its observational and forecasting systems to issue impact-based heavy rainfall warnings to state and central agencies and other stakeholders. These forecasts and warnings are issued through the National Weather Forecasting Centre, New Delhi and State Meteorological Centres for the concerned state.

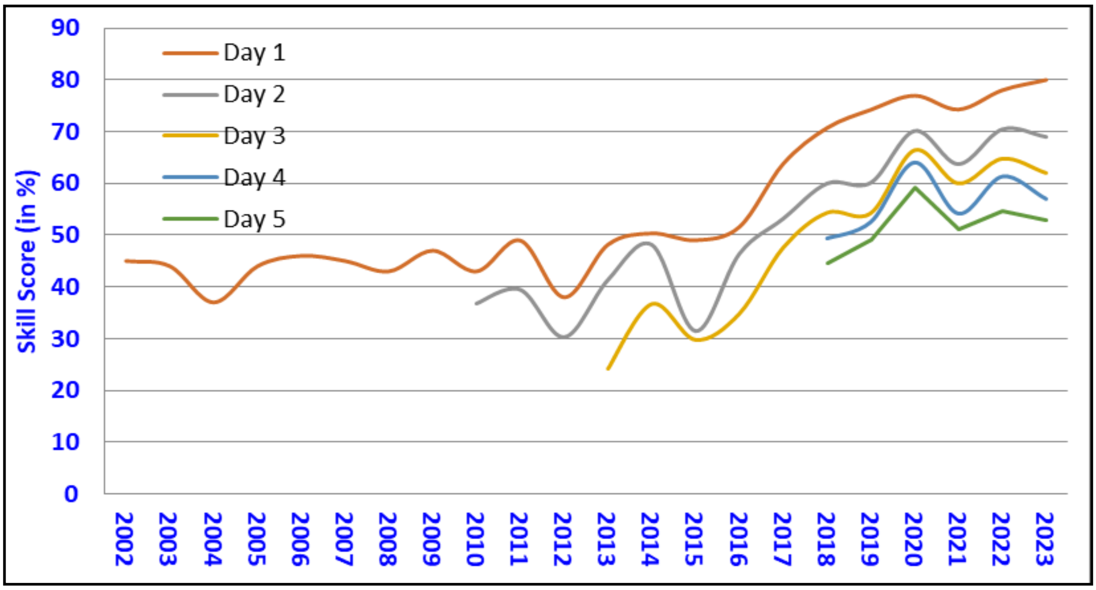
IMD issues short to medium-range forecasts and warnings daily valid for the next five days with an outlook for the subsequent two days. The short to medium-range forecast and warning at district and station levels are issued by state-level Meteorological Centres (MCs)/Regional Meteorological Centres (RMCs) with a validity of the next five days and are updated twice a day.

Category	2014	2023
Heavy Rainfall Warnings		
Stages of Warning	Single stage	4 stage heavy warning ➢ Heavy Rainfall Watch (72 hours prior to occurrence), ➢ Heavy Rainfall Alert (48 hours prior to occurrence), ➢ Heavy Rainfall Warning (48 hours prior to occurrence) and ➢ Nowcast (3-6 prior to occurrence)
Lead Period of forecast	5 days	7 days
District-wise warnings	No	For all 739 districts
Forecast Accuracy	24 hours ahead: 50% 48 hours ahead: 48% 72 hours ahead: 37%	24 hours ahead: 80% 48 hours ahead: 70% 72 hours ahead: 65% 96 hours ahead: 57 % 120 hours ahead: 53 % **By that way the disaster managers and public have got a lead period of 5 days with accuracy of > 50% for heavy rainfall management.**

The probability of Detection of heavy rainfall is between 80% to 53% from Day 1 to Day 5. False Alarm Rate (FAR) is between 21% to 13% from Day 1 to Day 5.



Verification scores of heavy rainfall forecast at meteorological sub-division level during monsoon season 2023. FAR : False Alarm Ratio; MR: Missing Rate; CSI : Critical Success Index; POD : Probability of Detection



Probability of Detection (POD) of Heavy rainfall at meteorological sub-division level from 2002 to 2023

- By 2023, Probability of Detection (POD) for southwest monsoon heavy rainfall warning is 80 for day 1, 69 for day 2 and 62 for day 3 as compared to 50 for day 1, 48 for day 2 and 37 for day3 in 2014.
- Day 5 skill in 2023 (53%) is better than Day 1 skill in 2016 (52%) and all proceeding years. Hence, there is an improvement in the lead period of the forecast by 4 days.

4.11 Urban Flood Forecasting

Urban Floods over India are mainly associated with shorter-duration heavy rainfall events. It occurs normally during active monsoon periods, triggered by major monsoonal systems when moved over a city or part of it or it may be triggered by localized thunderstorms which are convective systems.

For the implantation of appropriate Urban heavy rainfall and associated Flash flood Early warning systems, multi-intuitional efforts have been initiated by MoEs in collaboration with IITs, IISC, C-DAC, ISRO etc, and major City Municipality Corporations, concerned city disaster authorities including concerned state Govt.

In recent periods of 2019-2023, Urban rainfall monitoring networks improved significantly over major cities like Mumbai, Chennai, Delhi, Bhubaneswar, Bengaluru, Guwahati, Pune, Kolkata, Ahmedabad and additional RADARS have been installed. Meso-scale Nowcast models also are being run. Exposures and vulnerability were computed. Risk analyses are also carried out using past rain and impact data for all these major cities. Impact-based ward-wise end-to-end Dynamic NWP-based urban flood warning systems have been operational since monsoon 2020 for two major cities of Mumbai and Chennai which have been most vulnerable. These 2 new systems are Integrated Flood Warning System for Mumbai referred to as I-***FLOWS*** and Chennai Flood Warning System or **C-FLOWS**. The system can estimate floods up to 3 days in advance. The system also provides 3 hours – 6 hours nowcast (forecast up to 3 hours) and in low-lying areas forecasts up to 12 hours in advance.

Development and implementation of similar systems are in progress for other major cities of India (Delhi, Bengaluru, Bhubaneswar, Guwahati, Pune, Kolkata, Ahmedabad). These are integrated end to end system (with DSS) and it provides color coded Graphical map form and text based, actionable warnings along with likely Impacts at Ward-wise.

IMD has also implemented four-stage Impact Based early warning System using their products, to effectively help disaster mangers and other stake holders, to manage all urban Heavy Rainfall events and associated urban floods for all Major Cities of India from monsoon 2022.

Stage -1: Heavy rainfall Advisory (Watch)-(3-4 days lead time with 12-h updates,

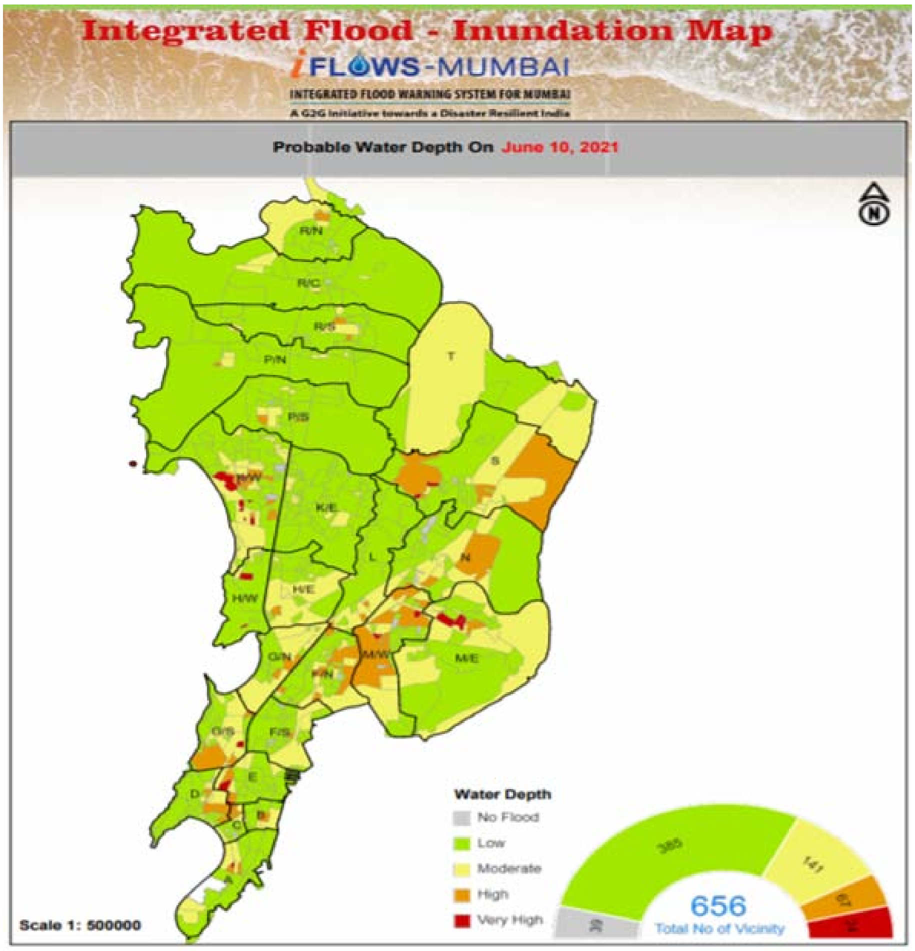
Stage-2: Heavy rainfall Alert (48 hours prior to the occurrence of the event at 12 hourly updates,

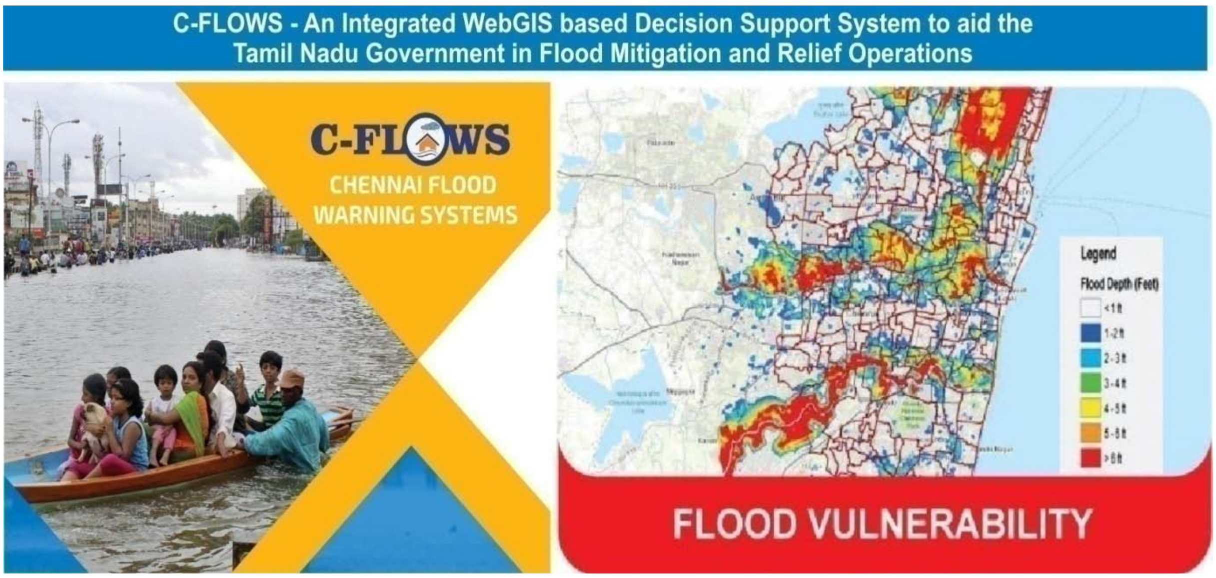
Stage-3: Heavy rainfall Warning and IBF from likely flash floods (24 hours prior to the occurrence of the event at 06/12-hourly updates,

Stage-4: 12 hours prior to occurrences of maximum rainfall spell and color-coded IBF from likely flash floods).

All this information and warnings are delivered, at the Disaster Managers Desk for timely decision in real-time, with a lead time of 3-12 hours, with guidance at 3-5 days lead period, for taking early actions e.g. action to divert the traffic/closed the flooded roads, and all other safety actions well in advance before the flood hits an area. It uses all the latest digital dissemination systems like CAP, API, WhatsApp, etc for timely dissemination to users.

By 2023, Urban Flood Forecast – IFLOWS established for the cities of Mumbai, Chennai and Kolkata, it was not available in 2014.

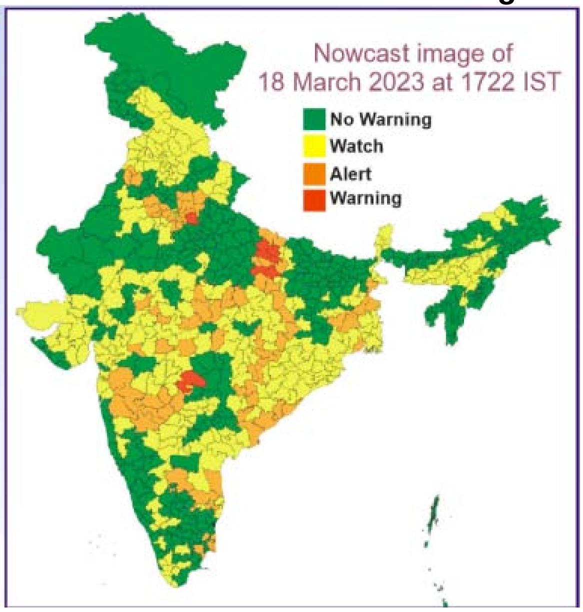


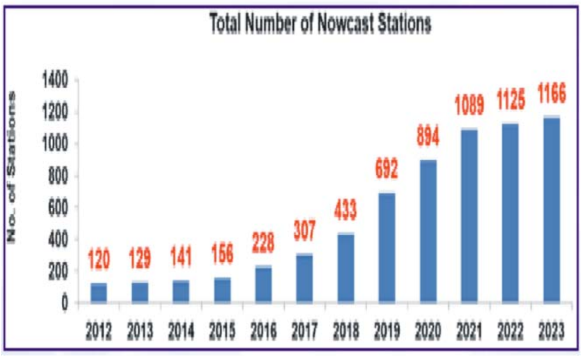


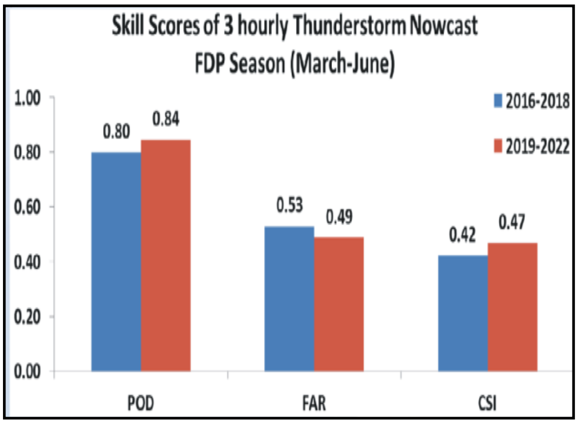
4.12 Thunderstorm and Lightning Forecasts & Warning

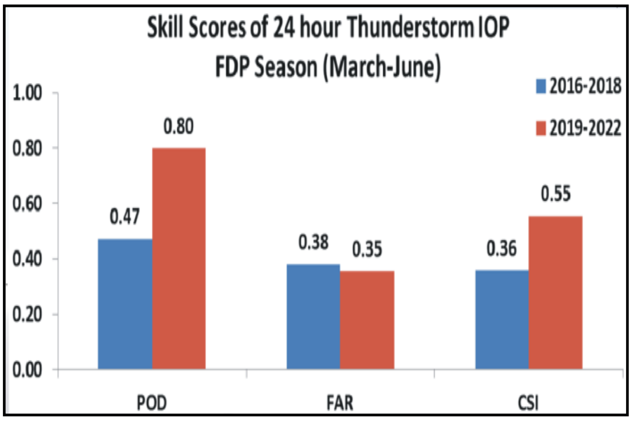
- Issued 5 days in advance presently as compared to 3 days in advance during 2014.
- Used to be issued at the Subdivision level only in 2014. By 2023, it is issued at Sub division level, district level, and station level and updated twice a day.
- Accuracy in thunderstorm nowcast has improved significantly during the recent years.
- The probability of detection for hourly thunderstorm Nowcast is 0.86 as compared to 0.50 in the year 2017.
- Three Hourly Thunderstorm Warning at 732 district level
- Nowcast of severe weather events increased from 120 to 1166 stations in 2023.
- District-level Nowcasting started in 2018.
- Lightning warning system in the country started since 2019.
- India is among the 5 countries to have a Lightning warning system.
- Multi-hazard forecast and nowcast warnings are being issued districtwise and stationwise at IMD website.
- Nowcast warnings are updated every 3 hours.

Districtwise Nowcast Warning





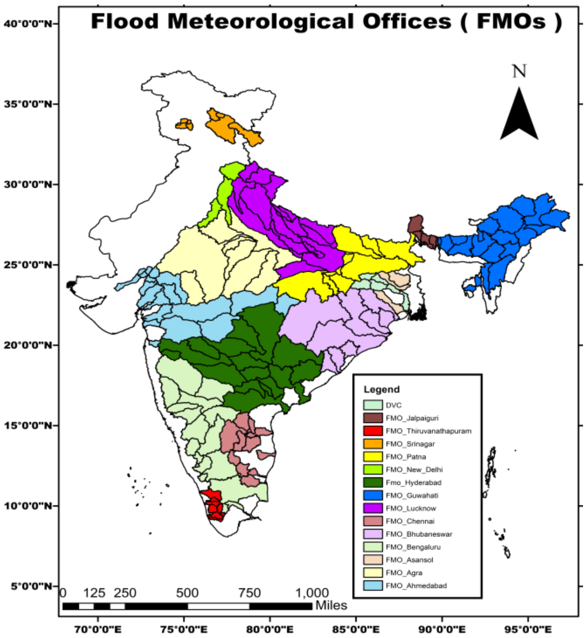




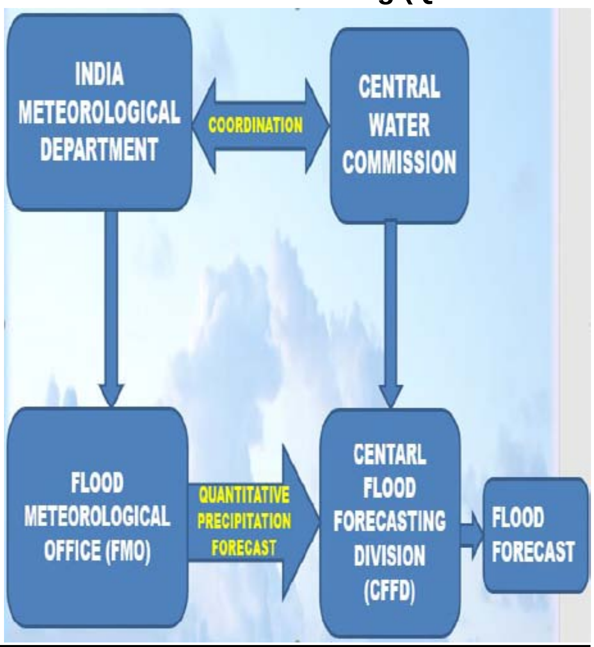
4.13 Hydromet Services & Quantitative Precipitation Forecast (QPF)

- Commissioned New Flood Meteorological Offices at Srinagar, Bengaluru, Chennai and Thiruvananthapuram which, increased the total nos of 15 FMOs.
- The validity of QPF was for 2 days and the outlook for the subsequent 3 days in 2014.
- Presently, Validity is for the next 5 days with the outlook for the subsequent two days.
- More than 10% improvement in the accuracy of QPF recorded since 2016.
- Increased the river sub-basins by 35 nos. from 121 to 156 for issuing of QPF in recent years
- Initiated the issuance of probabilistic QPF.
- Utilization of high-resolution dynamical Models for decision-making in issuing QPF.
- Initiated the Joint advisories by IMD, CWC and NDRF on the Flood Status of the country.

15 FMO with 156 River sub-basins



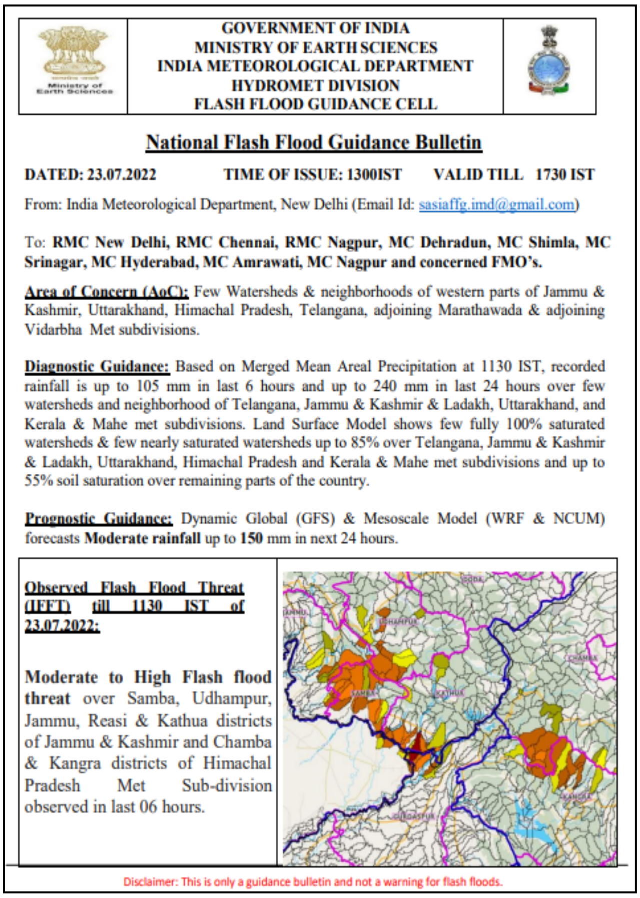
Riverine Flood Forecasting (Quantitative



South Asia Flash Flood Guidance System (SAsiaFFGS)

- ❖ IMD in collaboration with WMO jointly implemented the **South Asia Flash Flood Guidance System (SAsiaFFGS)** project and provides flash flood advisories in the form of threat and risk operationally to National Meteorological & Hydrological Centres in Nepal, Bhutan, Bangladesh Srilanka & India since October 2020. IMD is the Regional Centre for South Asia.
- ❖ Presently High Resolution (4x4 km) Flash Flood Guidance system provides flash flood guidance for >30,000 watersheds in India and the South Asian countries of Nepal, Bhutan, Bangladesh and Sri Lanka daily. It was not available in 2014.
- ❖ IMD provides location-specific Flash Flood guidance advisory up to watershed level (1 lakh watersheds) four times a day.
- ❖ Capable of issuing flash flood Threat and risk for next 6 and 24 hours respectively.

National Flash Flood Guidance Bulletins



GOVERNMENT OF INDIA
MINISTRY OF EARTH SCIENCES
INDIA METEOROLOGICAL DEPARTMENT
HYDROMET DIVISION
FLASH FLOOD GUIDANCE CELL

National Flash Flood Guidance Bulletin

DATED: 23.07.2022 TIME OF ISSUE: 1300IST VALID TILL 1730 IST

From: India Meteorological Department, New Delhi (Email Id: sasiaffg.imd@gmail.com)

To: **RMC New Delhi, RMC Chennai, RMC Nagpur, MC Dehradun, MC Shimla, MC Srinagar, MC Hyderabad, MC Amrawati, MC Nagpur and concerned FMO's.**

Area of Concern (AoC): Few Watersheds & neighborhoods of western parts of Jammu & Kashmir, Uttarakhand, Himachal Pradesh, Telangana, adjoining Marathawada & adjoining Vidarbha Met subdivisions.

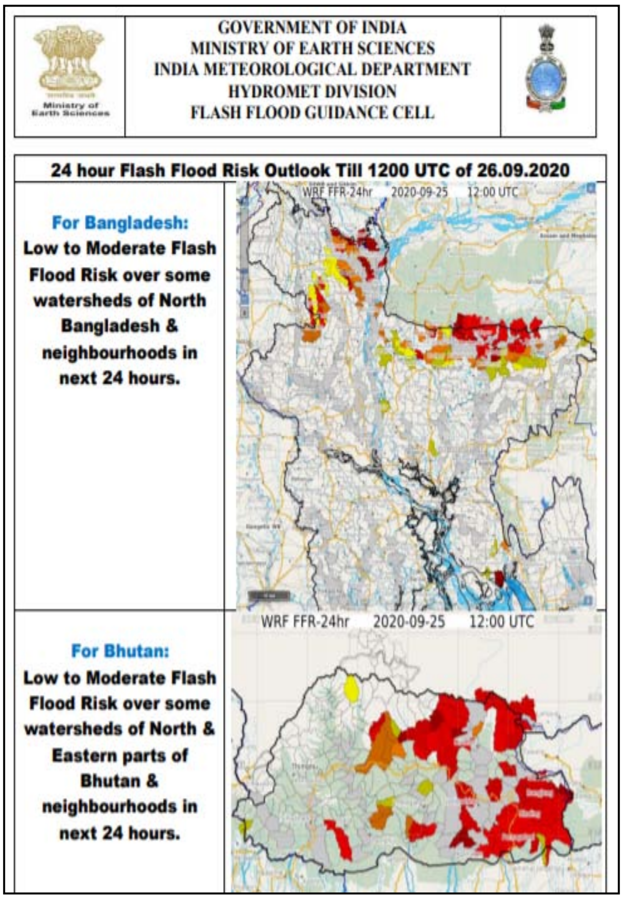
Diagnostic Guidance: Based on Merged Mean Areal Precipitation at 1130 IST, recorded rainfall is up to 105 mm in last 6 hours and up to 240 mm in last 24 hours over few watersheds and neighborhood of Telangana, Jammu & Kashmir & Ladakh, Uttarakhand, and Kerala & Mahe met subdivisions. Land Surface Model shows few fully 100% saturated watersheds & few nearly saturated watersheds up to 85% over Telangana, Jammu & Kashmir & Ladakh, Uttarakhand, Himachal Pradesh and Kerala & Mahe met subdivisions and up to 55% soil saturation over remaining parts of the country.

Prognostic Guidance: Dynamic Global (GFS) & Mesoscale Model (WRF & NCUM) forecasts **Moderate rainfall** up to **150** mm in next 24 hours.

Observed Flash Flood Threat (IFFT) till 1130 IST of 23.07.2022:

Moderate to High Flash flood threat over Samba, Udhampur, Jammu, Reasi & Kathua districts of Jammu & Kashmir and Chamba & Kangra districts of Himachal Pradesh Met Sub-division observed in last 06 hours.

Disclaimer: This is only a guidance bulletin and not a warning for flash floods.



GOVERNMENT OF INDIA
MINISTRY OF EARTH SCIENCES
INDIA METEOROLOGICAL DEPARTMENT
HYDROMET DIVISION
FLASH FLOOD GUIDANCE CELL

24 hour Flash Flood Risk Outlook Till 1200 UTC of 26.09.2020

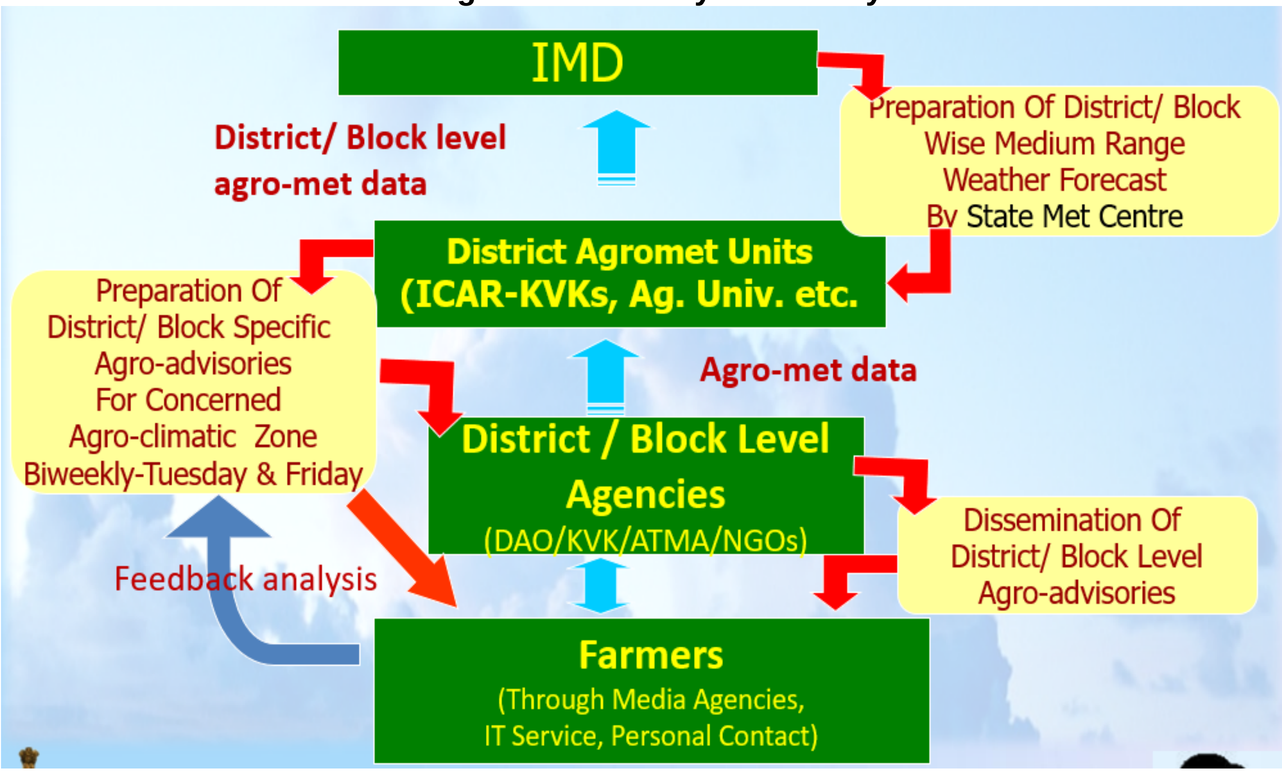
For Bangladesh:
Low to Moderate Flash Flood Risk over some watersheds of North Bangladesh & neighbourhoods in next 24 hours.

For Bhutan:
Low to Moderate Flash Flood Risk over some watersheds of North & Eastern parts of Bhutan & neighbourhoods in next 24 hours.

4.14 Agromet Advisory Services

- Gramin Krishi Mausam Sewa (GKMS) is functional for 329 districts by 2013 as compared to 130 districts in 2014.
- Weather forecast is issued for 6818 blocks and 721 districts by 2023 as compared to 608 districts in 2014.
- Agrometeorological advisory services are operational for 721 districts and 3100 Blocks in 2023 as compared to 608 districts in 2014. There were no block-level weather forecasts and agromet advisory service started in 2018 and covered the entire country in 2022.
- Dissemination of weather forecast and agromet advisory through village-level WhatsApp group started in 2020-2022.
- Impact Based severe weather forecast for agriculture started in 2020
- By 2023, 199 District Agro-Met Units (DAMUs) have been established, while there were no DAMUs in 2014.
- 54% of livestock owners reported using weather advisories twice a week in 2020 as compared to 8% of livestock owners in 2014.
- The number of Farmers awareness programs organized increased from 13 (2014) to 1133 In 2022.
- Launch of a dedicated Meghdoot Mobile App for weather forecast and agro advisory services in 2019 and extended to 13 languages
- 59% of farmers reported using weather advisories twice a week in 2020 as compared to 7% of farmers in 2014.

District/ Block Level Agromet Advisory Service System under GKMS



Dissemination of weather forecast and AAS through

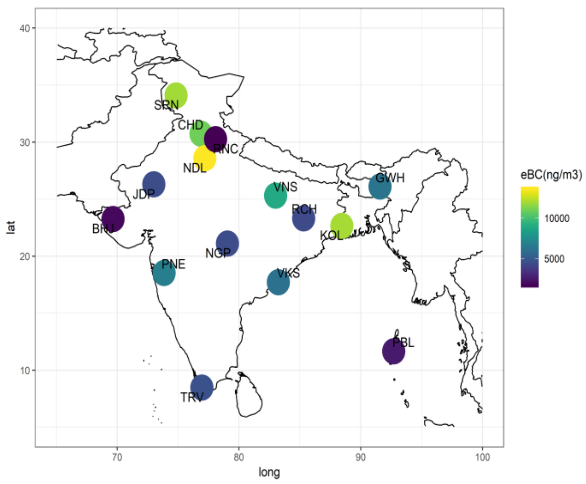
- Meghdoot Mobile App in English and 12 Indian languages (Hindi, Telugu, Assamese, Gujarati, Kannada, Malayalam, Marathi, Odia, Tamil, Mizo, Bengali and Punjabi).
- Whatsapp group: 1.6 million farmers from 3,995 blocks
- Common Service Centre (CSCs)
- Services integrated with Agriculture Produce and Livestock Market (APMC): 982 Mandis
- Farmers accessing the information from State Govt. Website/Mobile Apps: >10.48 million
- Farmers receiving SMS through PPP mode: 10.25 million
- Dissemination during extreme weather events: SMSs through **mKisan portal**

	YAAS (22-26 May 2021)	Deep Depression (9-14 Sept.2021)	GULAB (25-28 Sept.2021	Depression over Bay (10-12 Nov.2021)	JAWAD (30 Nov.-6 Dec.2021)	Deep Depression (04 Mar.2022)	SITARANG (22-25 Oct.2022)	MOCHA (10-15 May 2023)	BIPARJOY (13-15 Jun. 2023)
No.of SMS Sent (Lakh)	29.8	8.11	84.53	4.79	46.1	7.56	31.74	17.15	208.36

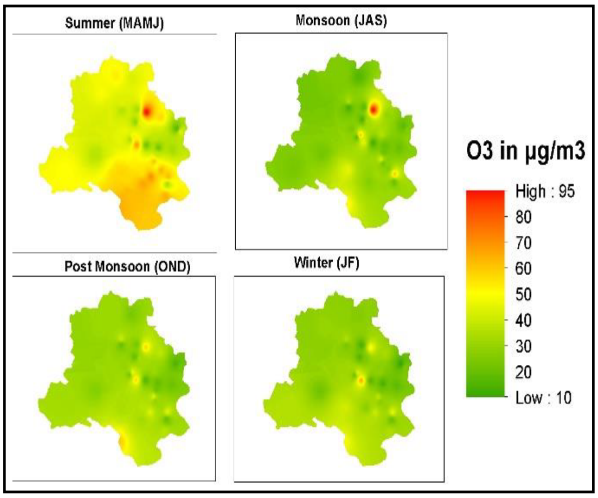
4.15 Air Quality Monitoring and Forecast Services

- The System of Air Quality Forecasting And Research to provide location-specific information on air quality in near real-time and its forecast 1-3 days in advance was launched in Delhi and Pune in 2014. Later, it was extended to Mumbai and Ahmedabad. The air quality forecast services have been extended to 40 cities since 2023.

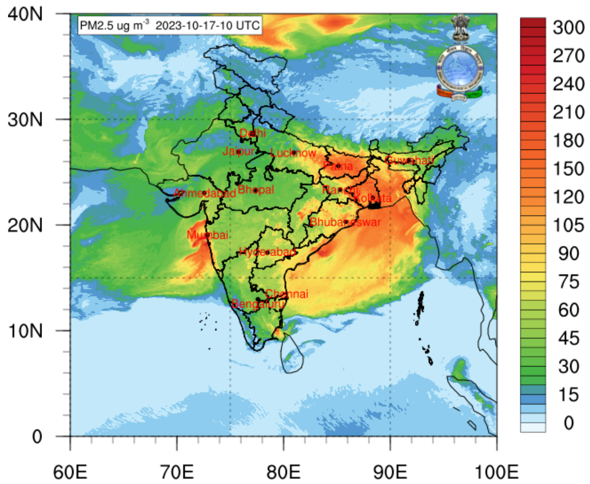
- To strengthen the forecasting services, the Air Quality Early Warning System (AQ-EWS) was developed under the aegis of the Ministry of Earth Sciences in 2018, jointly by the scientists of the Indian Institute of Tropical Meteorology (IITM), Pune, India Meteorological Department (IMD), National Centre for Medium-Range Weather Forecasting (NCMRWF).
- The Air Quality Early Warning System (AQ-EWS) has been introduced since 2018.
- New numerical models, System for Integrated Modeling of Atmospheric Composition (SILAM) and Environmental information Fusion SERvice (ENFUSER) for Air Quality Early Warning Systems have been operationalized by IMD since 2018.



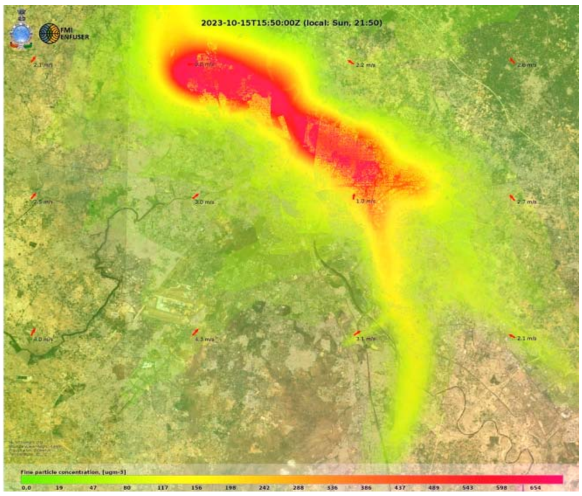
Variability of annual mean equivalent Black Carbon (eBC) aerosol concentration over India at IMD eBC aerosol observation network



Spatial distribution of Surface Ozone over Delhi during different seasons



PM2.5 Forecast using SILAM model



PM2.5 Forecast using ENFUSER over Delhi

4.16 Polar Meteorological Service

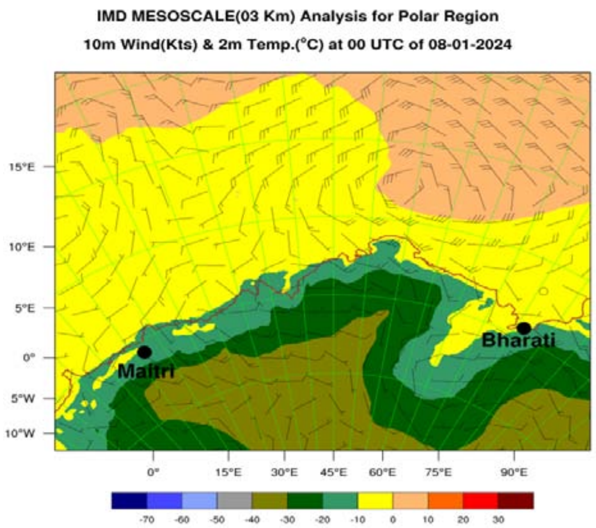
The meteorological observations, atmospheric ozone, and solar radiation are continuously monitored at Maitri and Bharati. It is well understood that the Polar Regions play a vital role in regulating the weather & climate of different continents and the world as a whole. Efforts have been made to find and establish a correlation between its weather &

its influence on India. Substantial meteorological activities are required to support logistic operations in the Antarctic and the Southern Ocean. The meteorological data bank, formed over the years of observation, is fundamental to our understanding of its climatology and its contemporary process of global relevance, ozone depletion, atmosphere pollution, climate change, melting of ice shelves, Blizzards, glaciers and sea level rise, etc.

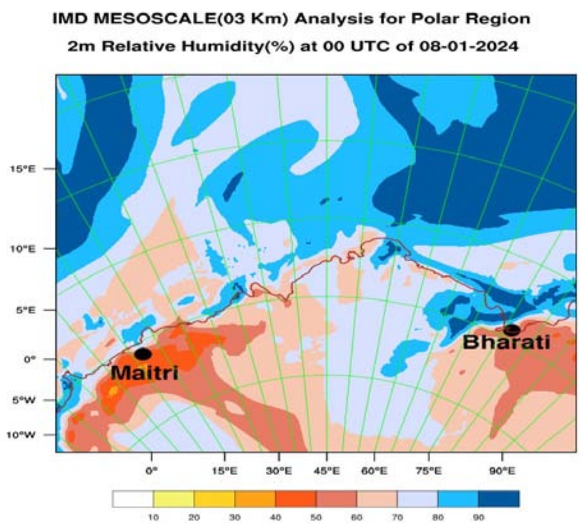
- India landed in Antarctica on 9th January, 1982 and established a base camp on the ice shelf.
- In 1983-84 during the third expedition, a permanent station Dakshin Gangotri was established and commissioned on the ice shelf, off the princess Astrid Coast in Central Dronning, Maud Land.
- India built a second permanent station Maitri on Schirmacher Oasis situated in East Antarctica, during 1988-89, as the first research Station got buried under ice.
- A third state of art Bharti Station was raised during 2011-12. It is about 3000 km from Maitri Station. But the Meteorological observatories at Bharati Antarctica were started in 2014.
- The observed and forecast weather bulletin as depicted in the figures are issued regularly to support the logistic operation at the Maitri and Bharati stations.

The Polar WRF model was operationally run by IMD at 9 km resolution over Maitri station in 2014. In 2022 the Polar WRF model was upgraded to version 4.1.1 with 3 km horizontal resolution at both places (Maitri and Bharati) and is operationalized by IMD for weather forecasting over East Antarctica mainly focusing on Maitri and Bharati.

Forecast of 10m wind and 2m temperature



Forecast of 2m Relative Humidity

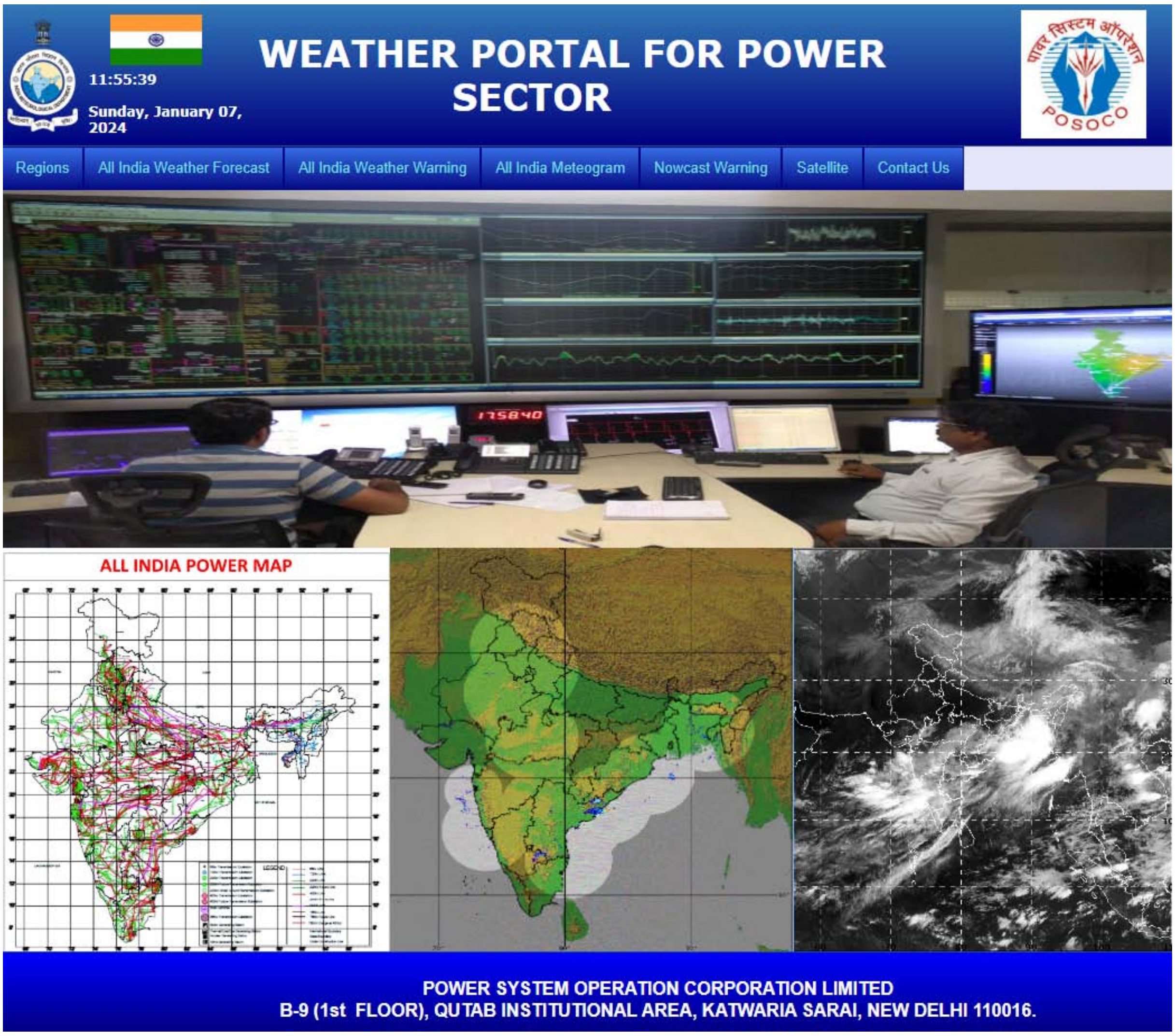


4.17 Forecast Services for Power Sector

- IMD is providing weather forecast & advisories to various organizations such as Grid-India and NHPC. IMD and Power System Operation Corporation Ltd. (POSOCO)/Grid-India had signed MoU on 18th May 2015 to take various initiatives under the aegis of this partnership like workshops at the national and regional level, development of weather portal providing information on weather for better grid management. Subsequently, a follow-up MoU was signed by IMD & POSOCO/Grid-

India on 3rd June 2022 to further enhance the scope of weather services to the power sector.

- Weather Portal for Power System has been developed using readily available products of IMD (Such as Weather forecasts, Weather warning, Radar Images, meteograms and Satellite Image). Weather information provided on the Portal is being used by the Power System Operators across India for secure, reliable and economical operation of the Indian grid.



Advisories issued by IMD have helped the power sector in the following ways:

i. IMD products are regularly being used to take proactive steps for power demand estimation and for maintaining the system reliability and security of the Indian grid.

ii. The weather portal also allows the real-time grid operator to remain more vigilant in case of heavy wind, cyclone, or heavy lightning which may lead to increased equipment tripping.

iii. Weather & rainfall forecasts for NHPC's hydro-projects at Chenab, Arunachal Pradesh, and Assam have helped in effective planning, timely warning and evacuation of man-machinery.

iv. Accurate anticipation of extreme weather conditions such as snowstorms, dust storms, high winds, thunderstorms and cyclones helps in advance operational planning, secure system operation and early restoration.

v. Solar and wind forecasting services are being provided to GRID-INDIA for effective grid management.

vi. The warnings of inclement weather help in anticipating a sudden unprecedented decrease in demand.

vii. Warning and cyclone tracking by IMD has proved to be very useful for disaster preparedness and mobilizing resources for quick recovery.

Economic Benefits

- **Grid Management:** Forecast of thunderstorm weather warning, live radar imagery enables revision of schedule for backing down of generating stations which avoids huge under drawl of power thereby also ensuring grid security.
- Hydropower generation: 5 Days of rainfall/weather forecast and alerts have helped in timely man and machinery evacuation. 4-week extended range rainfall forecast has helped in the planning and construction of Hydropower projects
- Protection from Fog: Fog forecasting helps to mitigate the adverse effect of tripping of EHV lines due to fog coupled with pollution.
- Power Infrastructure Safety: Extreme Weather Forecasting such as tropical depressions and cyclones helps in taking proactive safety measures and regulation of power generation.
- Renewable Forecasting: WRF-based Wind Forecast data is being provided for various wind power generation locations.

» **In the POWER sector accurate anticipation of extreme weather conditions i.e. snowstorms, dust storms, High winds, and thunderstorms, heavy rain, cyclones etc. facilitate advance operation planning, secure system operation and early restoration of the affected areas. There has been significant utilisation of weather and climate information by the power sector in India.**

» **Based on independent Survey by National Centre for Applied Economic Research(NCAER) in Andhra Pradesh and West Bengal in 2015, The improvements in forecast accuracy also resulted in significant gains to various sectors such as power sector saved around 500 crores each from cyclone warnings during Phailin (2013) and Hudhud (2014).**

- Meteogram, wind and rain forecast for 27/28/29-05-2017 helped in better load assessment of UP control area by U.P. State Load Despatch Centre.
- As anticipated, UP demand went down from 19000 MW to 17000 MW due to change in weather conditions.

- Accordingly, STOA & purchase from Power Exchange of the order of 2000 MW was reduced. i.e. Backing down of approximately 13 MU of costly thermal generation.

4.18 Climate Services

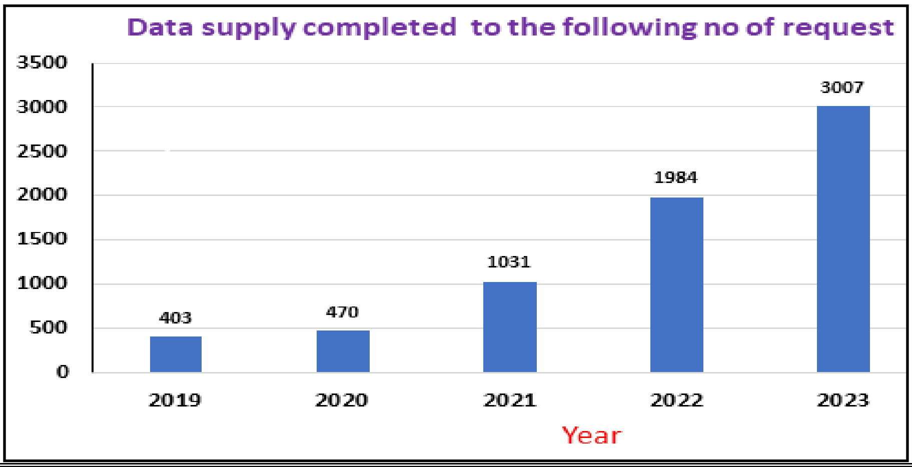
- It Is a well-accepted fact that the possible consequences of global warming and Climate Change are spreading to all spheres of life with many vital sectors will be under stress. In this scenario, the demand for climate services by society has increased manifolds.
- IMD is fortunate to have a long history and advanced capabilities of climate monitoring, research and prediction empowering its climate services, and internationally acclaimed institutions dealing with different aspects of climate and its impacts. These data set are archived and made available through the **National Data Centre, IMD Pune.**
- **Climate information, climate monitoring, climate prediction and Climate applications are the 4 major components of Climate services**.
- **Climate publications for normal and extremes at station and district levels for the recent 30 years (1991-2020) have been brought out for use by many users.**
- India Meteorological Department (IMD) provides services to weather-sensitive sectors viz. agriculture, irrigation, shipping, aviation, health, tourism, marine, offshore oil explorations, etc. as well as the general public.

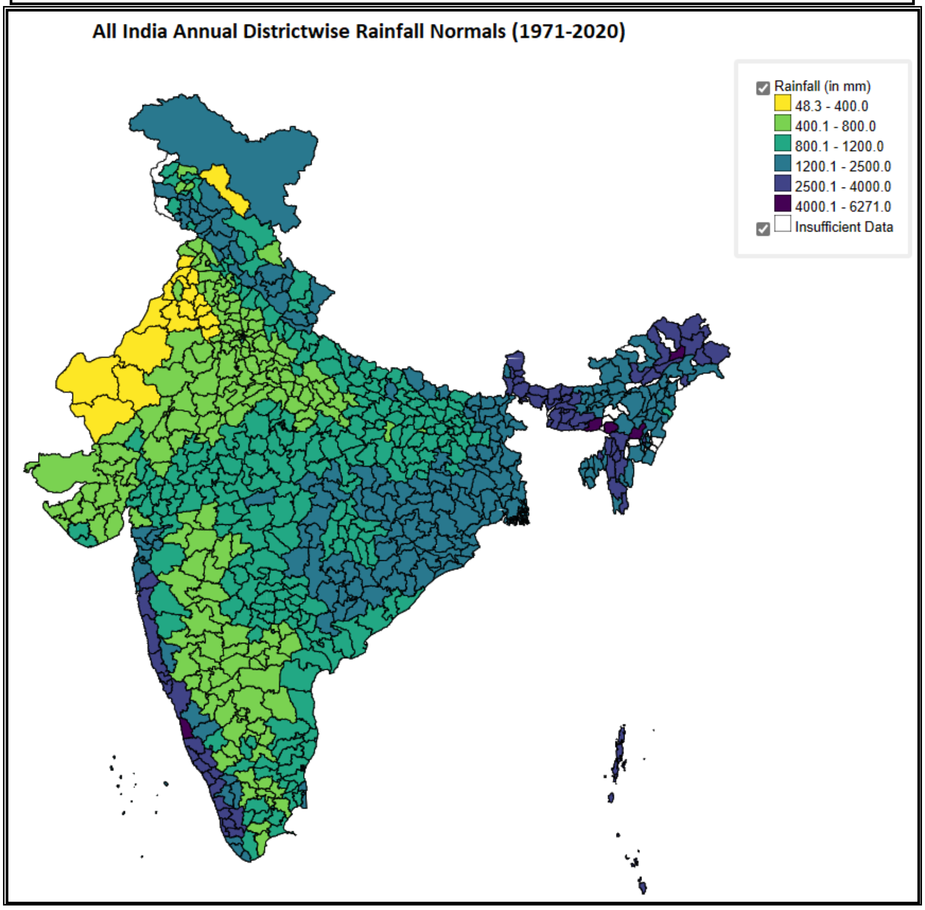
Climate Data

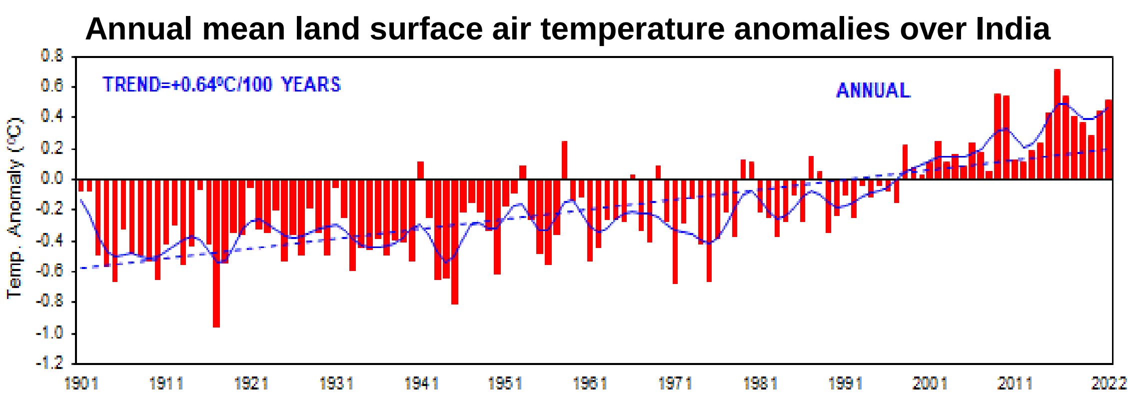
- Meteorological data from the entire country are received at the National Data Centre (NDC), IMD, Pune.
- After standard quality check process, these data are archived permanently at NDC.
- Climatological Normals and other climate products are prepared.
- The data are also made available to different users including general public
- Climate publications for normal and extremes at station and district levels

Data Supply Portal (DSP) : https://dsp.imdpune.gov.in

- IMD's Data Supply Services has been made online from 2019.
- This portal was developed in-house for online management of all activities related to the supply of meteorological data
- To enhance efficiency & transparency and
- To reduce the data delivery time.
- Four-fold increase in number of data requests after the services have been made online.
- The data delivery time has reduced from days to a few minutes.


Data supply completed to the following no of request
3500
3000
2500
2000
1500
1000
500
0
403
470
1031
1984
3007
2019
2020
2021
2022
2023
Year


All India Annual Districtwise Rainfall Normals (1971-2020)
Rainfall (in mm)
48.3 - 400.0
400.1 - 800.0
800.1 - 1200.0
1200.1 - 2500.0
2500.1 - 4000.0
4000.1 - 6271.0
Insufficient Data


Annual mean land surface air temperature anomalies over India
TREND=+0.64ºC/100 YEARS
ANNUAL
Temp. Anomaly (°C)
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
-1.2
1901
1911
1921
1931
1941
1951
1961
1971
1981
1991
2001
2011
2022

Climate Applications Products (Five Important Sectors)

❖ **Seasonal and Extended range forecast provides useful skill for applications in Agriculture, Hydrology, Energy, Health and Disaster Management.**

National Framework of Climate Services (NFCS)

- The concept of a **National Framework for Climate Services (NFCS)** that can be implemented in India, and propose collaborative efforts between various stakeholders for delivering full-value chain climate services in India. The NFCS is premised on the GFCS to strengthen the production, availability, delivery and application of science-based climate monitoring and prediction services.
- **IMD in working towards the implementation of National Frameworks for Climate Services (NFCS) – India.**

➢ Although various climate services exist in the country, the integration of climate services into government policies and decision-making processes is still limited

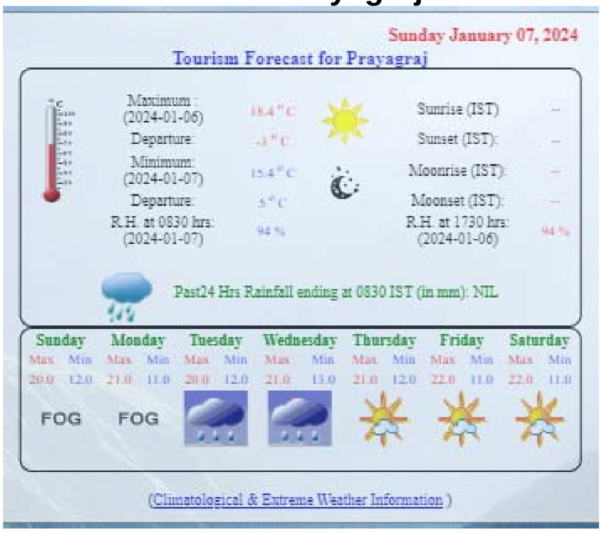
➢ Establishing an NFCS is therefore expected to be helpful to the country in terms of co-production and delivery of climate services as a sustainable multi-agency collaborative enterprise. The NFCS can play a key role by developing processes and guidelines that will assist governments, the public, and industries in integrating climate services into decision-making to manage the risks and opportunities associated with extreme climate events.

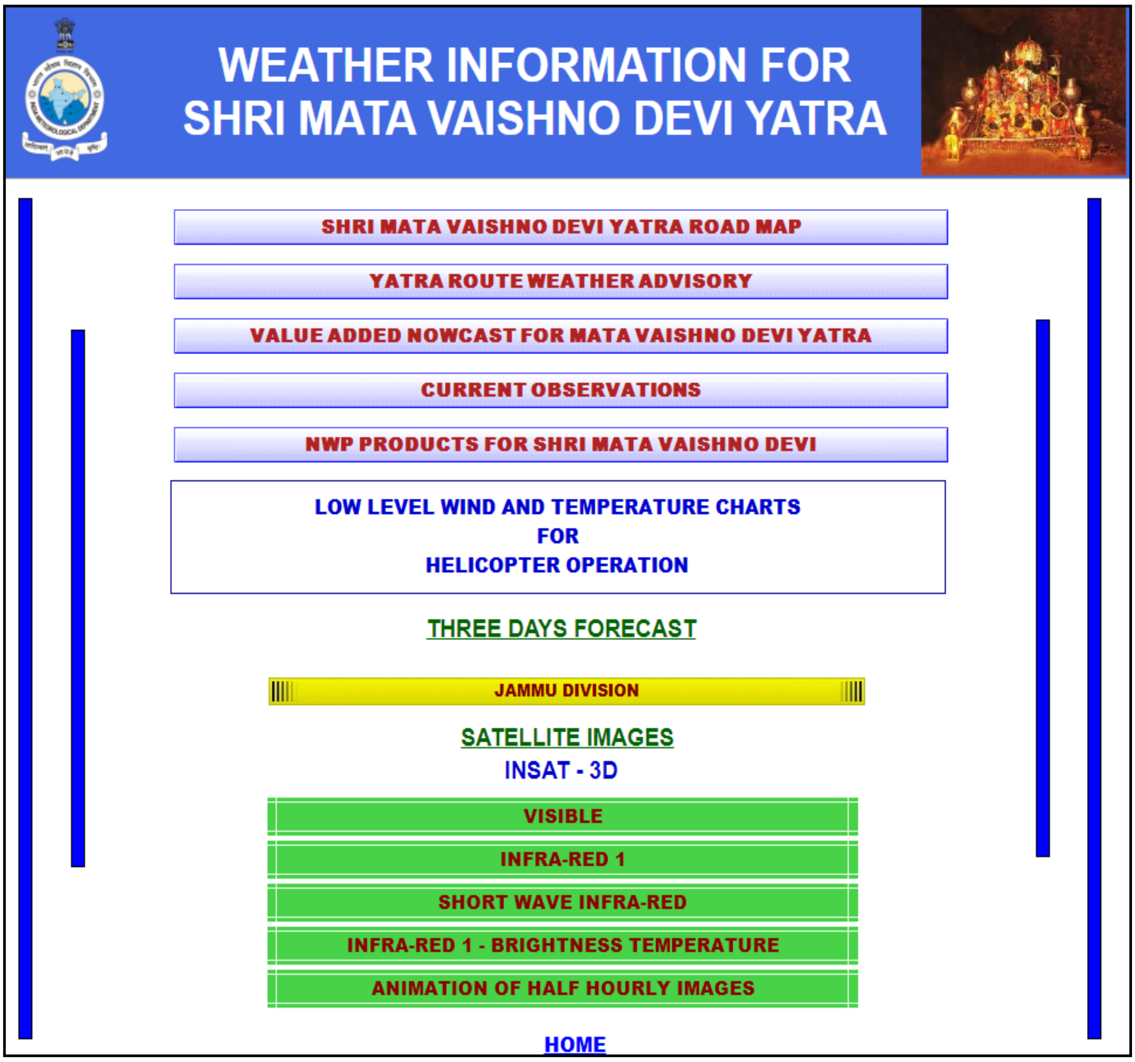
4.19 Specialized forecasts

In addition to the regular forecasts issued by IMD throughout the year, some specialized forecasts are also issued for different sectors such as Tourism, Highway, Mountain weather, Mata Vaishno Devi Yatra and Amar Shri Amarnath Ji Yatra as per the requirement.

Tourism Forecast

Forecast for Prayagraj



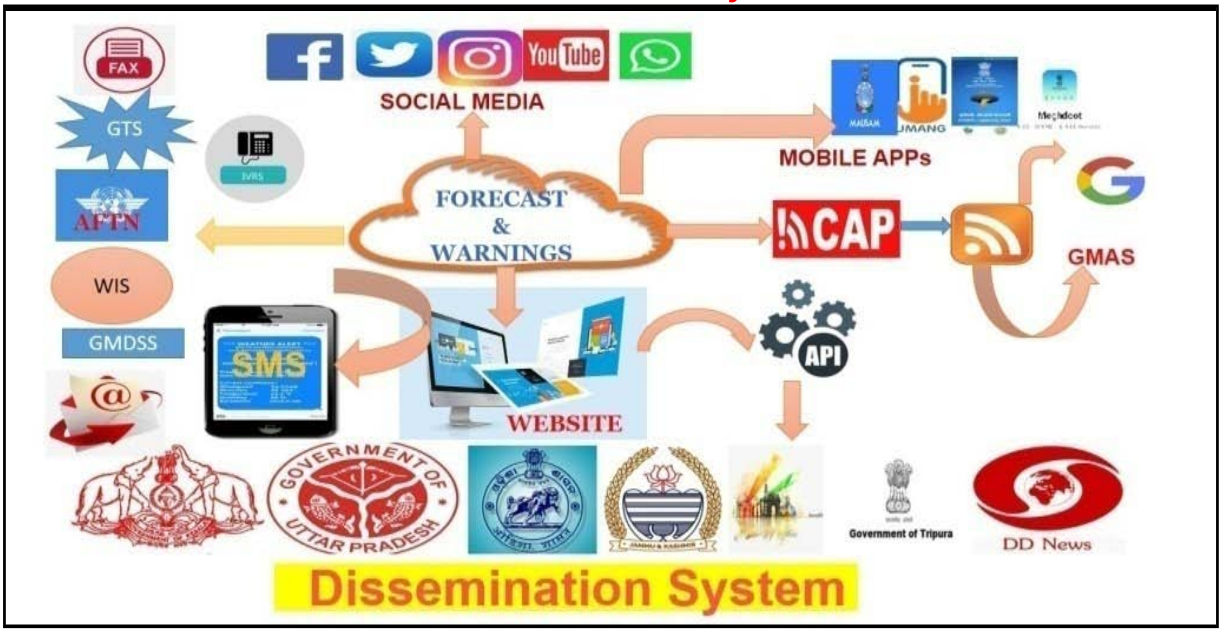


4.20 Dissemination of forecasts and warnings

- In 2014, Warning Dissemination was through Conventional methods, Websites and SMS only. By 2023, it is done through various weather Apps such as Meghdoot, Mausam, Damini and SAFAR Air, all the social media platforms, etc. The Common Alert Protocol (CAP) was implemented by 2023 with the active involvement of IMD and extensively used by different State Disaster Management Authorities (SDMAs) for cyclone alerts and other severe weather warnings. It was not available during 2014.

- Web-GIS-based service products have been introduced for providing real-time monitoring and forecasting information to the public, disaster managers and stakeholders on severe weather hazards like cyclones, heat waves, cold waves and heavy rainfall which were not available till 2014.
- More than 30 public and private organizations are using IMD's 16 Application Programming Interfaces (APIs). These include NITI Aayog, National Disaster Management Authority, Incredible Inida, eNAM, National Rice Research Institute Cuttack, SDMAs/Agriculture Dept:(AP, Odisha, Karnataka, MP, Chandigarh, Kerala, A&N Islands, Uttarakhand, J&K, UP), KRC Net Portal (MoES), Disaster Management Support Group ISRO, ICAR-NIASM, National Programme on Climate Change and Human Health, RIMES, NHAI, NHPC, C-DOT, Media, Apple.com and some other private sectors.

Data Dissemination System



Dissemination of forecast and warning, the following modes are used:

a) **Mass Media:** Radio/TV, News Paper network (AM, FM, Community Radio, Private TV): Prasar Bharati and private broadcasters

b) Weekly & Daily Weather Video

c) Internet (e-mail), ftp

d) Public Website (mausam.imd.gov.in)

e) IMD Apps: Mausam/ Meghdoot/DAMIN/RAIN ALARM

f) Social Media: Facebook, Twitter, Instagram, BLOG

Twitter: https://twitter.com/Indiametdept

Facebook: https://www.facebook.com/India.Meteorological.Department/

Blog: https://imdweather1875.wordpress.com/

Instagram: https://www.instagram.com/mausam_nwfc

Youtube: https://www.youtube.com/channel/UC_qxTReoq07UVARm87CuyQw

4.21 Research & Development and Publications

- Exploring advancements and conducting research play a crucial role in enhancing operational weather forecasting, thereby contributing to the overall improvement in the quality of weather and climate services provided to diverse users.

- Considering this. IMD brought out a quarterly journal in 1950 (presently named "MAUSAM").

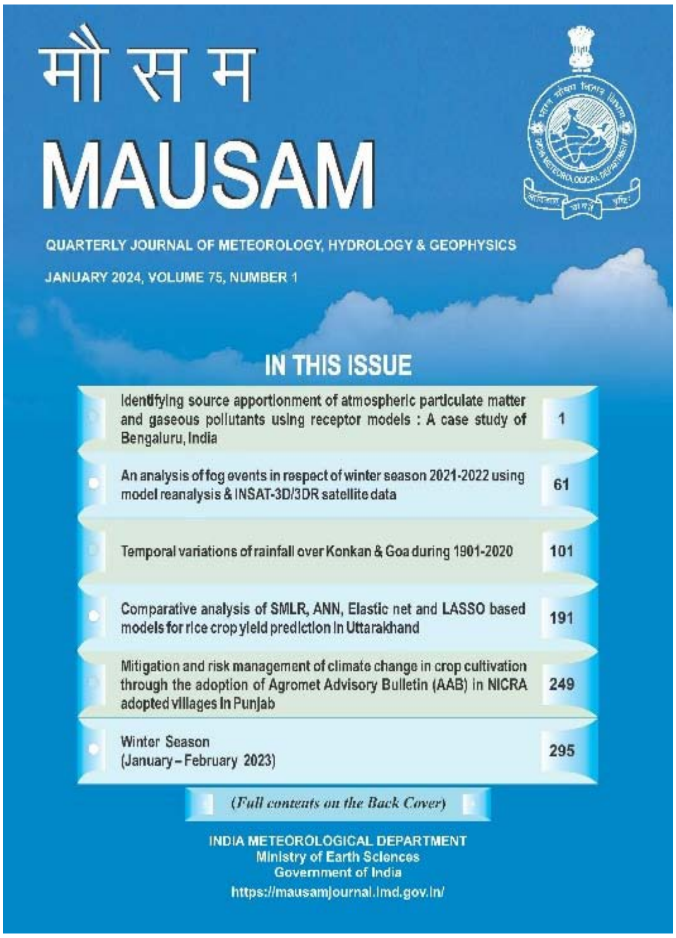
- India Meteorological Department's Quarterly International Research Journal 'MAUSAM' has been made online (https://mausamjournal.imd.gov.in/index.php/MAUSAM) since 2021. Since then, the journal has been making its way to advancement in the world of Scientific Journals.

- All the research articles (since the origin of 'MAUSAM', 1950) have been uploaded on the website and the Digital Object Identifiers (DOI's) for all of them have been activated and are working successfully.

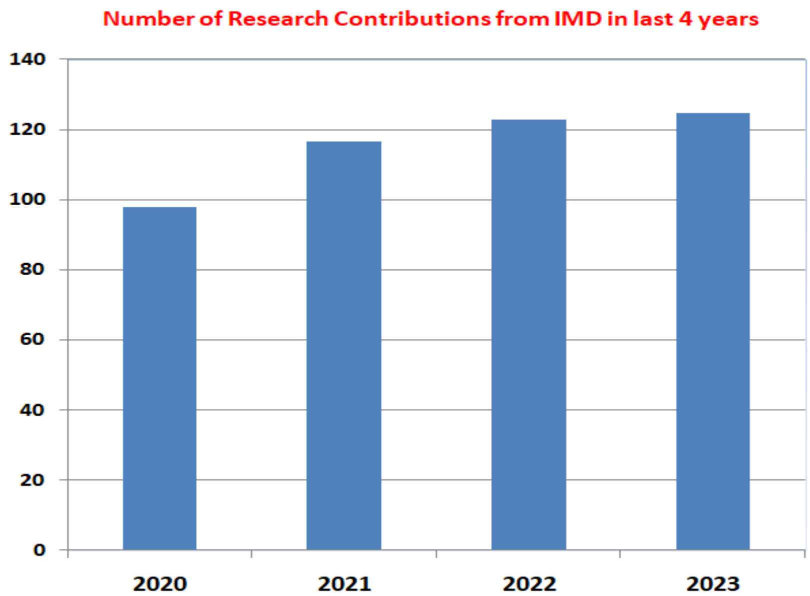
- The impact factor the journal rated by several agencies has been increased and at the maximum for the past three years. Impact factor (IF) of Journal ''MAUSAM'': **Scopus is 1.40 for 2023.**

- During the last 74 years, IMD has brought out **28 Special Issues of MAUSAM** covering various disciplines of Earth and Atmospheric Sciences with the last special issue released on 23rd March 2023 as the proceedings of the 7th International Workshop on Monsoon (IWM-7).

- Number of research papers received on MAUSAM journal portal are increasing exponentially. For the year 2023 : January to March Qtr – 70; April to June Qtr – 61; July to September Qtr – 77; October to December Qtr – 73.



- In the last 5 years IMD has signed many MoU with various research institutes, universities etc for the encouragement of collaborative research and for the expansion of meteorological services and research activities.
- Over the recent years, IMD Scientists have contributed significantly to the field, publishing a substantial quantity of research papers in both international and national journals including “MAUSAM”.

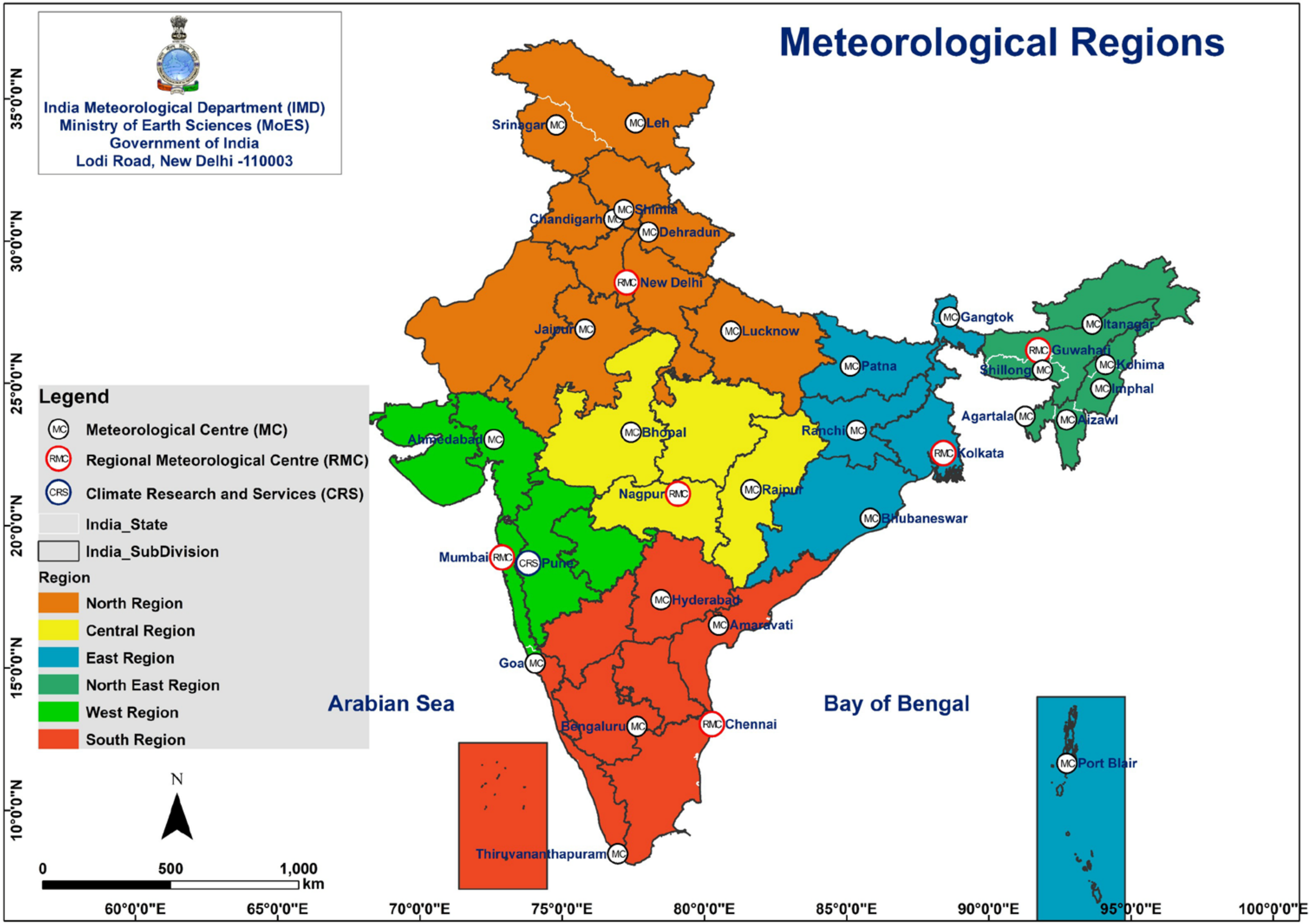


4.22 Highlights of IMD visions for 2030

There is a considerable scope for further accelerating the initiatives taken by IMD to enable the country to become a world leader in providing high quality weather and climate services, and contribute to economic and societal benefits. IMD aims to address gaps in forecast and warning services, focusing on enhancements in observational networks, improving numerical models, use of new tools and technologies, and expanding outreach to include new sectors for weather and climate services. The highlights of IMD's vision for 2030 are given below.

- The weather forecasting accuracy will further increase by 10-15% for all types of severe weather by 2030.
- IMD has introduced several new sectoral applications to cater to the present and future user requirements. A corresponding improvement in the weather forecast and service delivery will be carried out by further up-gradation of existing communication and forecasting systems. The new systems will be scalable and capable of adding new observations and modelling products.
- Outreach of Agromet Advisory Services will be further expanded from Block level to Panchayat level in next five year through state government platforms, Kisan Portal, Public–Private Partnership (PPP) and other service providers across the country.
- Impact based forecast initiated in recent years will be enhanced dynamically with hazard & impact modelling and risk assessment for all hazards.
- To set up atmospheric observational network at 25x25 km grid and upper air observations at 100x100 km, complimented by Multi-platform Satellite and air-craft based profiler observations, Doppler Radars, Wind profilers, Radiometers, Lightning detectors, and LIDARs.
- Develop an Advanced Weather Prediction System, for village level forecasts, skilful for next 3-7 days and develop advisories for sectors for like Agriculture, Disaster Management, Water resources, Power, Tourism and Pilgrimage, Smart Cities, Renewable Energy Sector and Transport, Urban, Health, Environment sectors.
- To minimize the damage due to thunderstorms and lightening, a more accurate and high spatial resolution & location-specific forecast as well as Nowcast of thunderstorms need to be enhanced by increasing lead period and accuracy. Therefore, it is aimed to develop a thunderstorm research test bed over the eastern part of India will be developed to study the dynamical, microphysical and electrical characteristics of thunderstorms.
- Application products based on extended range forecast for various sectors will continue to be developed including tailor made forecast and warning products for private industries like power sector, ONGC, aviation, energy sector & state governments.
- Develop Panchayat level weather and climate service centres for better coordination with the users and government officials for various applications including disaster management.
- Develop an Advanced National Climate Services Framework to cater to the needs of Agriculture, Water Resources, Alternate Energy Resources and Health on the basis of location specific and user specific knowledge of the climate variability and predictions of climate variables.
- Develop a State-of-the-Art Support System for Aviation Safety with the advanced meteorological instruments and advanced forecasting tools for all the civil airports in the Country.

- Improve probabilistic prediction system based on a coupled model of land-ocean-atmosphere for reliable extended range (up to 15-20 days) and seasonal (for all the four seasons) forecasts of rainfall and temperatures for smaller spatial scales at district to block levels.
- Monitor the three dimensional variability of regional hydrological cycle and assess its expected changes and impacts in the future.
- Carry out process studies of the atmosphere (aerosols, clouds, land surface processes, boundary layer, and atmospheric chemistry) through setting up of research test beds which are required for substantial improvements in dynamical models.
- Carry out cutting-edge research studies on climate variability including monsoons, meteorological droughts, desertification, land use changes using observations and modelling.
- Develop Urban Meteorology Services with dense Meso network and modelling strategy to cater to the needs of growing cities in the country.
- Implement an Integrated Himalayan Meteorology Programme for meeting the growing challenge and needs of the Himalayan States.
- Application of AI/ML in NWP for pre-processing and post-processing of data.
- Though the numerical models are improving to give better forecast skills, there is a need to utilize the Artificial Intelligence/Machine learning (AI/ML) framework for observations and NWP models for customized value-added improved forecasts for different sectors.


Meteorological Regions
India Meteorological Department (IMD)
Ministry of Earth Sciences (MoES)
Government of India
Lodi Road, New Delhi -110003
Legend
MC Meteorological Centre (MC)
RMC Regional Meteorological Centre (RMC)
CRS Climate Research and Services (CRS)
India_State
India_SubDivision
Region
North Region
Central Region
East Region
North East Region
West Region
South Region
N
0
500
1,000
km
35°0'0"N
30°0'0"N
25°0'0"N
20°0'0"N
15°0'0"N
10°0'0"N
60°0'0"E
65°0'0"E
70°0'0"E
75°0'0"E
80°0'0"E
85°0'0"E
90°0'0"E
95°0'0"E
100°0'0"E
Arabian Sea
Bay of Bengal
Srinagar
Leh
Chandigarh
Shimla
Dehradun
New Delhi
Jaipur
Lucknow
Gangtok
Itanagar
Guwahati
Shillong
Kohima
Imphal
Agartala
Aizawl
Patna
Ranchi
Kolkata
Ahmedabad
Bhopal
Nagpur
Raipur
Bhubaneswar
Mumbai
Pune
Hyderabad
Amaravati
Goa
Bengaluru
Chennai
Thiruvananthapuram
Port Blair

Years of Service to the Nation
राष्ट्र सेवा के 150 वर्ष

1875

The Meteorological Department was established at Calcutta under the Department of Revenue, Agriculture and Commerce

1905

The Headquarters of the India Meteorological Department shifted to Shimla

1928

The Headquarters of the India Meteorological Department shifted to Poona (now Pune)

1944

The Headquarters of the India Meteorological Department shifted to Delhi

1976

Mausam Bhavan established as the Headquarters

India Meteorological Department

भारत मौसम विज्ञान विभाग

https://mausam.imd.gov.in/