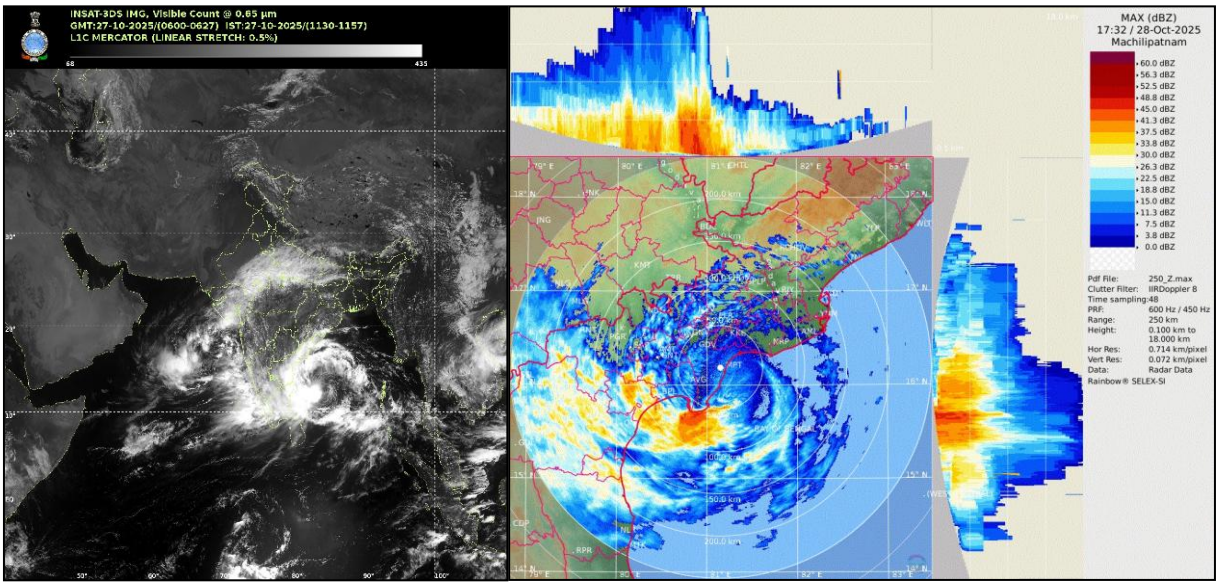
WMO/ESCAP PANEL ON TROPICAL CYCLONES

ANNUAL CYCLONE REVIEW 2025



SATELLITE AND RADAR IMAGERY OF SEVERE CYCLONIC STORM, MONTHA OVER BAY OF BENGAL

WMO

ESCAP

WORLD METEOROLOGICAL ORGANISATION
AND ECONOMIC AND SOCIAL COMMISSION
FOR ASIA AND THE PACIFIC

PREFACE

First commenced in 1997, the publication of ***WMO/ESCAP Panel*** - *Annual Review* has entered **twenty-third** year of issue for the year 2024. Considerable efforts have gone into producing this document in order to make it useful scientifically and informative for the members of panel. Panel Members are encouraged to make more contributions for further improvement of this publication.

WMO and ***ESCAP*** have played a commendable role in disaster mitigation efforts in the Panel region through continued interaction with the governments of the member countries. There is increasing realization that disaster mitigation effort must encompass all spheres including scientific research on natural hazards, establishment of integrated-all-hazard early warning system and most importantly, empowering communities to be self-reliant for timely and proper response to warnings. Despite rapid technological advances made in the recent past, the problem of generating accurate weather forecasts and associated warnings/ advisories and their timely dissemination to the communities at highest risk continues to be a great challenge. In order to make the early warning system more effective, it is essential that the Panel Members take new initiatives. The basic aim of the panel is to improve the quality and content of cyclone warnings, devise methods for quick dissemination of warnings and flood advisories and ensure proper response by concerned agencies and the community.

This review highlights the achievements made during the year, 2025 in the region in pursuance of the goals set out by the ***WMO / ESCAP*** *Panel* and the activities of other international and national organizations in support of the above tasks, within the overall objective of mitigating the impact of natural hazards. I would like to express my sincere thanks to all the Panel Members for their valuable input and contributions and hope for thesame in the future.

Chief Editor

WMO AND THE WMO / ESCAP PANEL ON TROPICAL CYCLONES
WORLD METEOROLOGICAL ORGANIZATION (WMO)

The World Meteorological Organisation (WMO), of which 193 States and Territories are Members, is a specialised agency of the United Nations. The objectives of the organisation are:

- To facilitate international co-operation in the establishment of networks of Stations and Centres to provide Meteorological and Hydrological services and observations;
- To promote the establishment and maintenance of systems for the rapid exchange of meteorological and related information;
- To promote standardisation of meteorological and related observations and ensure the uniform publication/circulation of observations and statistics;
- To further the application of meteorology to aviation, shipping, water problems, agriculture and other human activities;
- To promote activities in operational hydrology and to further close co-operation between Meteorological and Hydrological Services and
- To encourage research and training in meteorology and, as appropriate, in related fields and to assist in co-ordinating the international aspects of such research and training.

ECONOMIC AND SOCIAL COMMISSION FOR ASIA AND THE PACIFIC (ESCAP)

The Economic and Social Commission for Asia and the Pacific (ESCAP) aims to initiate and participate in measures for concerted action towards the development of Asia and the Pacific, including the social aspects of such development, with a view to raising the level of economic activity and standards of living and maintaining and strengthening the economic relations of countries and territories in the region, both among themselves and with other countries in the world. The commission also:

- Provides substantive services, secretariats and documentation for the Commissionand its subsidiary bodies;
- Undertakes studies, investigations and other activities within the commission's termsof reference;
- Provides advisory services to Governments;
- Contributes to the planning and organisation of programmes of technical co-operations and acts as executing agency for those regional projects decentralised to it.

WMO / ESCAP PANEL ON TROPICAL CYCLONES

Huge loss of human life, damage to property and unbearable sufferings of human beings caused by tropical cyclones in coastal areas in various parts of the globe likeAtlantic, Pacific, China Sea and North Indian Ocean (NIO) coast are regular features.

The disaster potential due to cyclones is particularly high in the NIO comprising of theBay of Bengal & the Arabian Sea region, which is being associated with high storm surge, which is the greatest killer in a cyclone. This region has the distinction of having experienced the world's highest recorded storm tide of 41 feet (1876 Bakherganj cyclone near Megna estuary, Bangladesh) followed by 13 meters over West Bengal coast on 7th October, 1737 in association with another super cyclone. Past records show that very heavy loss of life due to tropical cyclones have occurred in the coastal areas

surrounding the Bay of Bengal. In the recent past, during the year 1998, the state of Gujarat in India experienced the impact of a very severe cyclonic storm, which crossed coast north of Porbandar (42830) on June 9, 1998 and caused huge damage to public property near Kandla Port (42639). A Super Cyclonic Storm that crossed east coast of India near Paradip (42976) in Orissa state on October 29, 1999 took a toll of 9885 lives and caused huge damage to property in 12 districts of the state. Apart from causing large-scale devastation to agriculture and plantation crops, it also affected entire infrastructure on communication, power and transport. The storm surge of 5-6 m height was experienced in areas close to and southwest of Paradip. This cyclone was century's most intense cyclone and its unusual feature was that it remained practically stationary after crossing coast and battered the State of Orissa for 36 hours. In June, 2007 another super cyclone 'Gonu' developed over southeast Arabian Sea, moved north-westward, crossed Oman coast and then entered into Gulf of Oman and made second landfall over Iran coast. It caused huge damage to the property and loss of lives in Oman and Iran. The very severe cyclonic storm, 'Nargis' crossed Myanmar coast near Irrawaddy delta on 2nd May 2008 and caused loss of about 138,000 lives in Myanmar.

Realizing the importance of an effective cyclone warning and disaster mitigation machinery in the region, WMO and ESCAP jointly established the Panel on Tropical Cyclones (PTC) in 1972 as an inter-Governmental body. Its membership comprises the countries affected by tropical cyclones in the NIO. Its member countries are Bangladesh, India, Maldives, Myanmar, Pakistan, Sri Lanka, Sultanate of Oman and Thailand.

The Panel is one of the six regional tropical cyclone bodies established as part of the WMO Tropical Cyclone Programme (TCP) namely Miami, Honolulu, Tokyo, New Delhi, La Reunion and Nadi that aims at promoting and coordinating the planning and implementation of measures to mitigate tropical cyclone disaster.

It also aims to initiate and participate in measures for concerted action towards the development of Asia and the Pacific including social aspects of such developments, to raise the level of economic activity and standards of living and maintain and strengthen the economic relations of countries and territories in the region, both among themselves and with other countries in the world.

The first session of WMO/ESCAP Panel on Tropical Cyclones was convened in Bangkok, Thailand in January 1973. The functions of the Panel are:

- To review regularly the progress in various fields of tropical cyclone damage prevention;
- To recommend to the member countries plans and measures for the improvement ofcommunity preparedness and disaster prevention;
- To promote, prepare and submit to member countries plans for co-ordination ofresearch programmes and activities on tropical cyclones;
- To facilitate training of personnel from member countries in tropical cyclone forecasting and warning, flood hydrology and its control within the region;
- To plan for co-ordination of research programmes and activities concerning tropical cyclones within member countries;
- To prepare and submit, at the request and on behalf of the member countries requests for technical, financial and other assistance offered under United Nations Development Programme (UNDP) and by other organizations and contributors and
- To consider, upon request, possible sources of financial and technical support for

such plans and programmes.

In carrying out these functions, the PTC committee maintains and implements action programmes under the five components of meteorology, hydrology, disaster prevention and preparedness, training and research with contributions and co-operation from its members and assistance from the UNDP, ESCAP, WMO and other agencies.

The Panel at its twelfth session in 1985 at Karachi (Pakistan) adopted a comprehensive cyclone operational plan for this region. The basic purpose of the operational plan is to facilitate the most effective tropical cyclone system for the region with existing facilities. The plan defined the sharing of responsibilities among Panel countries for the various segments of the system and recorded the co-ordination and co-operation achieved. The plan also recorded the agreed arrangements for standardization of operational procedures, efficient exchange of various data and its archival related to tropical cyclone warnings, issue of a tropical weather outlook and cyclone advisories from a central location having the required facilities for this purpose, for the benefit of the region and strengthening of the operational plan. Further the Panel agreed upon the issue of tropical cyclone advisory bulletin for use of aviation as per recommendation No. 1/21 of International Civil Aviation Organisation (ICAO) in its 12^{th} meeting of 161^{st} session held at Montreal, Canada during 09-26 September, 2002

The operational plan is evolutionary in nature. Its motivation is to update or raise the text of the plan from time to time by the Panel and each item of information given in the annexes of the plan to be kept up to date by the member country concerned.

RSMC- Tropical Cyclones, New Delhi:

Regional Specialized Meteorological Centre (RSMC) - Tropical Cyclones, New Delhi, which is co-located with Cyclone Warning Division of IMD and came into existence in 1988 as per the recommendation of first session of WMO/ESCAP Panel on Tropical cyclones held in January,1973. It has the responsibility of issuing Tropical Weather Outlook and Tropical Cyclone Advisories for the benefit of the countries in the World Meteorological Organization (WMO)/ Economic and Social Co-operation for Asia and the Pacific (ESCAP) Panel region bordering the Bay of Bengal and the Arabian Sea, namely, Bangladesh, Maldives, Myanmar, Pakistan, Sultanate of Oman, Sri Lanka and Thailand. It has also the responsibilities as a Tropical Cyclone Advisory Centre (TCAC) to provide Tropical Cyclone Advisories to the designated International Airports as per requirement of International Civil Aviation Organization (ICAO).

The area of responsibility of RSMC- New Delhi covers Sea areas of north Indian Ocean (north of 10^0S between 45^0 E and 100^0 E) and includes the member countries of WMO/ESCAP Panel on Tropical Cyclones viz. Bangladesh, India, Maldives, Myanmar, Pakistan, Sri Lanka, Sultanate of Oman, Thailand and Yemen. The Yemen became member of the Panel in 2016. Iran, Saudi Arabia, United Arab Emirates and Qatar joined in 2018.

The broad functions of RSMC- Tropical Cyclones, New Delhi are as follows:

- Round the clock watch on weather situations over the entire north Indian Ocean. Analysis and processing of global meteorological data for diagnostic and prediction purposes.
- Detection, tracking and prediction of cyclonic disturbances in the Bay of Bengal and the Arabian Sea.
- Running of numerical weather prediction models for tropical cyclone track and storm surge predictions.
- Interaction with National Disaster Management Authority and National Disaster Management, Ministry of Home Affairs, Govt. of India to provide timely information and warnings for emergency support services. RSMC-New Delhi also coordinates with the National Institute of Disaster Management (NIDM) for sharing the information related to cyclone warning.
- Implementation of the Regional Cyclone Operational Plan of WMO/ESCAP Panel. Issue of Tropical Weather Outlook and Tropical Cyclone Advisories to the Panel countries in general.
- Issue of Tropical Cyclone advisories to international airports in the neighboring countries for international aviation.
- Collection, processing and archival of all data pertaining to cyclonic disturbances viz. wind, storm surge, pressure, rainfall, damage report, satellite and Radar derived information etc. and their exchange with Panel member countries.
- Preparation of comprehensive annual reports on cyclonic disturbances formed over North Indian Ocean every year.
- Preparation of annual review report on various activities including meteorological, hydrological and disaster preparedness and prevention activities of panel member countries.
- Research on track, structure and intensity monitoring and prediction techniques as well as associated adverse weather including storm surge, heavy rain and gale wind.

COMMITTEE ON WMO/ESCAP PANEL ON TROPICAL CYCLONES (2025)

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Chairman drafting committee:	**Dr. D. R. Pattanaik (India Meteorological Department)**

TECHNICAL SUPPORT UNIT (TSU)New Delhi, INDIA

Co-ordinator	**: Dr. D.R. Pattanaik**
Meteorologist	**: Ms. Monica Sharma**

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INTRODUCTION

Publication of "WMO/ESCAP Panel on Tropical Cyclones–Annual Review commenced with the review for the year 1997. This was as per the decision of the Second Joint Session of the WMO/ESCAP Panel on Tropical Cyclones and Typhoon Committee held at Phuket, Thailand 20-28, February 1997. The present Annual Review: 2025 contains primary contribution from the Panel member countries.

Chapter I contains detailed information on national programmes and activities related to meteorology, hydrology, disaster prevention and preparedness, training and research as supplied by Panel Members. Technical and administrative support provided and activities undertaken by the Panel.

A summary of Tropical Cyclones during 2025 is given in the first part of Chapter II. Earlier, tropical cyclones were identified by their geographical locations. From post-monsoonseason 2004, the practice of naming each tropical cyclone individually has been adopted in the north Indian Ocean basin also. Tropical disturbances are classified as per the practice introduced at Regional Specialized Meteorological Centre (RSMC)–Tropical Cyclones New Delhi. The classification of disturbances is shown in the following Table. The term "Cyclone" used in the present text is a generic term for the five categories of cyclonic disturbances (S.N. 4 to 8) in the Table.

Classification of low-pressure systems at RSMC–Tropical Cyclones, New Delhi

S No.	Maximum sustained surface wind Speed in knot (kmph)	Nomenclature
1.	Less than 17 (31)	Low Pressure Area (L)
2.	17 to 27 (31-49)	Depression (D)
3.	28 to 33 (50- 61)	Deep Depression (DD)
4.	34 to 47 (62 –88)	Cyclonic storm (CS)
5.	48 to 63 (89 – 117)	Severe Cyclonic Storm (SCS)
6.	64 to 89 (118 –166)	Very Severe Cyclonic Storm (VSCS)
	90-119 (167-221)	Extremely Severe Cyclonic Storm (ESCS)
7.	120 and above (222)	Super Cyclonic Storm (SuCS)

The second part of Chapter II contains a brief report on tropical cyclones affecting Panel countries during 2025. Based on the real-time and climatological data available with the India Meteorological Department (IMD), India, special features of the 2016 tropical cyclone season are highlighted. It also contains realized weather and damages caused by cyclones. All units used in the chapters are as per standard norms.

In the context of Chapter II, sustained winds refer to wind speeds averaged over a period of 3 minutes. Kilometer per hour (kmph) / knot is the unit used for wind speed as well as the speed of movement of tropical cyclones. The S.I. unit of hecta-Pascal (hPa) is used for atmospheric pressure. Reference time used is primarily in Universal Time Coordinate (UTC). Wherever possible, station names contained in WMO Weather Reporting-Observing Stations (WMO/OMM-No.9 Volume A) are used for geographical reference with code.

Chapter III consists of the 4 years coordinated plan (2025-28) and COORDINATED TECHNICAL PLAN (CTP) 2024-2027

Chapter IV consists of Annual Operational Plan

CHAPTER-I

WMO/ESCAP PANEL ACTIVITIES IN 2025

1.1 METEOROLOGICAL ACTIVITIES

Activities of member countries on WMO/ESCAP Panel, WMO and UN-ESCAP for the year 2025 were presented at the **52nd Session** of the WMO/ESCAP Panel on tropical cyclones hosted virtually by Qatar Meteorology Department, **from 28th April to 01st May, 2025**. Under this item, matters relating to the basic observational network, the telecommunication links and data-processing systems established in the region to fulfill the WMO's World Weather Watch Programme requirements were reviewed.

1.1.1. WMO

The WMO representative emphasized strengthening the meteorological component of the Panel through improved operational standards, harmonized forecasting practices, technical guidance and sustained capacity development across the North Indian Ocean region. Under the Early Warnings for All (EW4All) initiative, WMO highlighted continued progress in the observations and forecasting pillar of multi-hazard early warning systems, while noting that important gaps remain in impact-based forecasting, integrated warning services and the operational use of probabilistic information. WMO further noted that advances in high-performance computing, satellite observations, numerical weather prediction (NWP), data-sharing platforms and artificial intelligence (AI) provide significant opportunities to enhance tropical cyclone forecasting and warning services.

With regard to tropical cyclone forecasting over the North Indian Ocean, WMO reported ongoing work through the Advisory Group on Tropical Cyclones (AG-TC) to develop and operationalize impact-based and probabilistic tropical cyclone forecast products. It informed the Panel that tropical cyclone forecast parameters are being incorporated as mandatory products within the WMO Integrated Processing and Prediction System (WIPPS), which is expected to improve the consistency, interoperability and availability of forecast products generated by WMO Regional Specialized Meteorological Centres (RSMCs) and National Meteorological and Hydrological Services (NMHSs).

WMO also highlighted ongoing initiatives to facilitate the operational adoption of artificial intelligence in tropical cyclone forecasting through a series of technical webinars, training activities and knowledge-sharing programmes. In addition, WMO successfully organized the Fourth International Workshop on Satellite Analysis of Tropical Cyclones, providing a platform for exchanging best practices on the application of satellite observations and advanced analysis techniques for tropical cyclone monitoring and forecasting. Capacity development under the WMO Tropical Cyclone Programme continues to support forecaster competency, standardized operational procedures and the adoption of emerging forecasting technologies across regional forecasting centres.

Overall, the WMO placed greater emphasis on strengthening forecasting methodologies, operational coordination among WMO centres, standardization of forecast products, implementation of impact-based and probabilistic forecasting, implementation of interoperability, enhanced forecaster competencies, and the application of artificial intelligence and satellite-based techniques, rather than on expansion of observational infrastructure or development of new numerical forecast models.

1.1.2 India

A brief description of the observational network of IMD and types of observations collected from the network are given below:

1.1.2.1. Surface Observations

IMD has a good network of surface observatories satisfying the requirement of World Meteorological Organization. There are 547 surface observatories in IMD. Of these, 209 observatories are manned by IMD staff. 141 out of 209 observatories are called Class – 1 observatory where all 8 synoptic observations are taken and all autographic instruments are available and remaining 68 observatories are called Class – 2 observatories where autographic instruments are not available. There are 338 surface observatories which are manned by non-departmental staff. Such observatories are called Part Time Observatories where 2 synoptic observations are taken daily. The data from these stations are used on real time basis for operational, monitoring and forecasting. A number of moored ocean buoys including Meteorological Buoy (MB), Shallow Water (SW), Deep Sea (DS) and Ocean Thermal (OT) buoys have been deployed over the Indian Sea, under the National Data Buoy Programme (NDBP) of the Ministry of Earth Sciences, Government of India. As a routine, a large number of ship observations over Indian seas from about 50 ships per day, both Indian and International are also received and are assimilated in the analysis.

In order to augment the manned surface observational network, IMD has established a network of Automatic Weather Stations (AWS) and Automatic Rain Gauge (ARG) Stations. As on date there are 1008 AWS installed across India. The sensors for parameters, Air Temperature, Relative Humidity, Rainfall, Pressure, Wind and Solar Radiation are interfaced with these stations. In addition to these sensors, 200 AWS called as Agro-AWS are equipped with sensors for Soil Temperature, Soil Moisture at different depths, sunshine duration sensor. These stations have been installed uniformly in different agro-climatic zones of India and cater to the requirements of agricultural sector for issuing agro-meteorological advisories to the stake holders. This is in addition to the conventional (manual) agromet observatories of IMD. For monitoring of rainfall, IMD has established a network of over 1382 ARG stations. ARG stations are subset of AWS with sensor for only rainfall interfaced with the system. Some stations are also equipped with additional sensor for Air Temperature and Relative Humidity. Satellite and Mobile telemetry are being used for data communication from field stations to central data receiving server. Data are available at measurement interval of 1 hr for satellite telemetry and 15 min for mobile telemetry. About 5860 rain gauges are considered for real time monitoring of daily rainfall at district level. 37 HWSR systems have been installed along the east and west coasts of India for continuous monitoring of high wind speed.

1.1.2.2. Upper Air Observatories

There are at present 62 Pilot Balloon Observatories, 56 Radiosonde/ Radio wind observatories. All the 56 stations are GPS based observatories. Out of 56, six RS/RW stations at Regional Meteorological Centre (New Delhi, Mumbai, Kolkata, Chennai, Guwahati and Nagpur) are of WMO-GUAN (Global Climatological Observations System Upper Air Network) standards. Out of 56 stations, there are 18 Nos. of stations situated

along the Sea coast. The details are given in Table 1.1 and fig 1.1.

To monitor the daily ascent status and the stock of various consumables there is observatory performance monitoring system has been started on the intra IMD portal. The upper air meteorological data collected all over the country are used on real time basis for operational forecasting. The PBOs at New Delhi, Mumbai and Lucknow have been upgraded with GPS based PBO.

IMD has a network of 62 pilot balloon (PB) observatories. At these stations a smaller balloon is tracked for upper air wind data i.e Wind direction and wind speed profiles. Presently these stations are taking manual observations by tracking the balloon using optical theodolites and some of these stations are GPS based. The details of PB observatories near the coast are given in Table 2.2 and fig 2.2.

Future Plans:

- Sustenance of 6 Nos of high-quality GPS based system- WMO-GUAN standard network.
- Expansion of GUAN standard network from 6 to 12 stations by up-gradation of 6 operational RS/RW stations to GUAN standard.
- Continuation of all 56 RS/RW stations with twice a day observation.
- Further expansion of operational RS/RW stations from 56 to 63
- Up-gradation of PB network from manual (optical theodolite based) observations to fully automatic GPS based observations.
- To create an additional buffer stock of consumables for upper air observations dedicated to the cyclone monitoring.

Table 1.1: List of RS/RW stations along the coast

	Name of the station
1	Bhuj
2	Mumbai
3	Ratnagiri
4	Goa
5	Mangaluru
6	Kochi
7	Thiruvananthapuram
8	Amini Divi
9	Minicoy
10	Karaikal
11	Chennai
12	Kavali
13	Machilipatnam
14	Visakhapatnam
15	Gopalpur
16	Bhubaneshwar
17	Kolkata
18	Port Blair

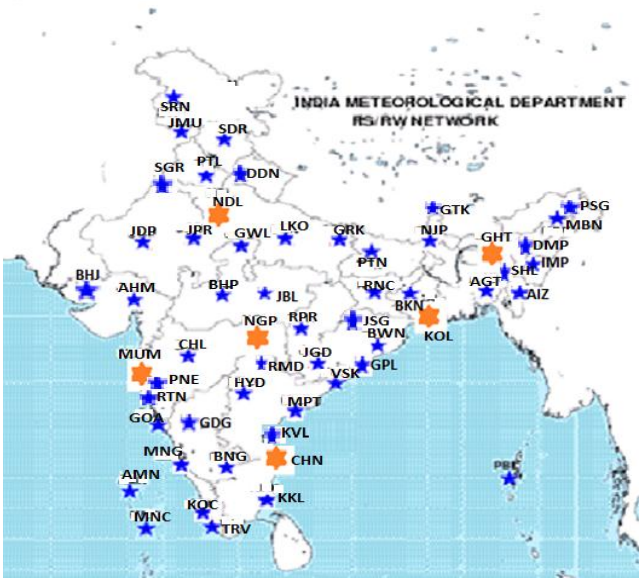

Fig. 1.1 RS/RW network of India Meteorological Department

Table 1.2: List of PB stations near the coast

	Name of the station
1	Bhuj
2	Veraval
3	Surat
4	Mumbai
5	Ratnagiri
6	Mangaluru
7	Thiruvananthapuram
8	Amini Divi
9	Minicoy
10	Karaikal
11	Chennai
12	Machilipatnam
13	Visakhapatnam
14	Gopalpur
15	Bhubaneshwar
16	Balasore
17	Kolkata
18	Port Blair

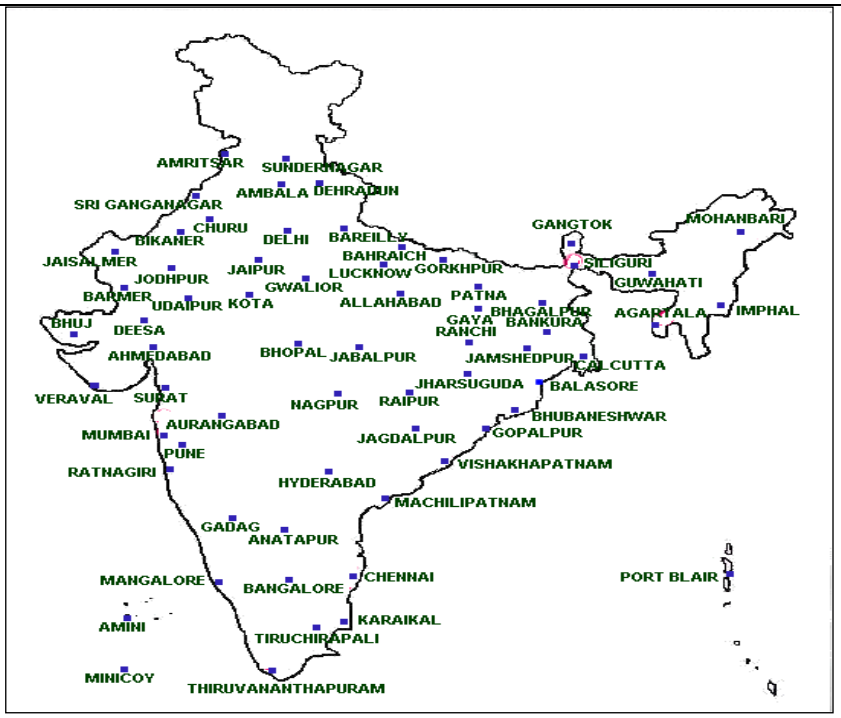

Fig. 1.2 PB station network of India Meteorological Department

1.1.2.3. Radars

1.1.2.3.1. Current Status

Weather radar network of India is managed by IMD, and consists of 47 Doppler Weather Radars (DWRs) presently, spreading across the country (Fig. 1.3). RADAR network includes 3 ISRO and 7 IITM RADARs.

- India has a network of 16 RADARs covering the Indian Coast line. Eight radars (Chennai, Kolkata, Machilipatnam, Visakhapatnam, Paradip, Gopalpur, Sriharikota, Karaikal) on the East Coast and five radars (Kochi, Goa, Mumbai, Bhuj, and Thiruvananthapuram) on West Coast. Recently, two more indigenously developed DWRs: one X-band DWR at Pallikarnai, Chennai and one C-band at Veravali, Mumbai have been added in IMD radar network. Thus, there are 16 radars along the coast.
- IMD also utilizes the data inputs from DWRs of ISRO located at VSSC Thiruvananthapuram (C-Band), Sohra / Cherrapunji (S-Band) and SHAR (Sriharikota-S Band) and radar set up by India Institute of Tropical Meteorology, Pune at Silkheda (Madhya Pradesh), Juhu, Panvel, Dombivali, Vasai and Solapur, (Maharashtra).

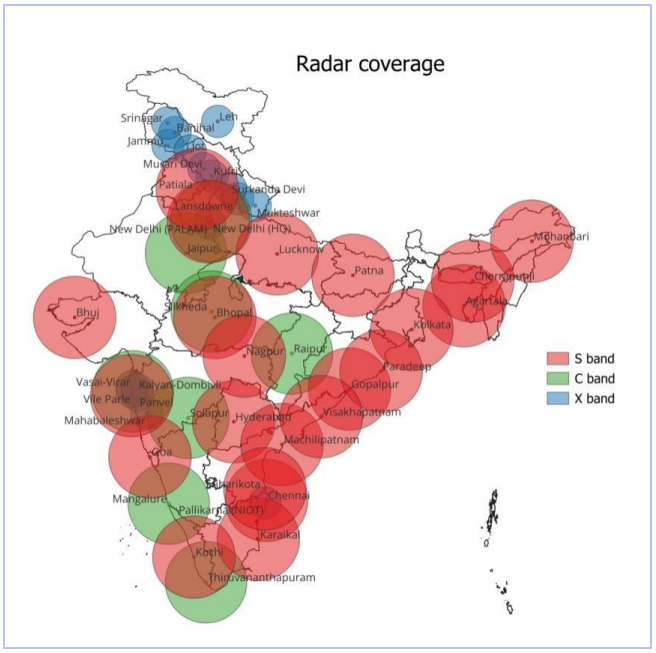

Fig. 1.3 Network of Doppler Weather Radar used for weather monitoring and forecasting (47 Nos.)

Radars of IMD are being used for detection of rainfall, hail storm, thunderstorms and for tracking of cyclonic storms. Various meteorological and hydrological products derived from radar data using software algorithms are extremely useful to the forecasters for estimating the storm's center, direction of movement, structure and intensity. The existing radars have also been networked to provide near real time data to super computers for ingesting into numerical weather prediction (NWP) models for short range forecasting. Composite images are also being generated centrally. Data is also converted to scientific formats such as NetCDF (Network Common Data Format), HDF5 (Hierarchical Data Format version 5), and Opera BUFR (Binary Universal Form for Representation) for assimilation in NWP models. A national Radar data centre has been established at IMD, New Delhi for archival and retrieval of radar data. Radar data products are also provided to various users. Open source GIS (Geographic Information System) platforms are used to display the radar data on the web pages. The radar data are combined with lightning data and satellite imagery for a unified display on the website using GIS platform. This now provides accurate positional information of the location of the storm cells.

Location specific information of lightning is also being generated in the radar data center and is available in the web page. A unique audio alert system announces the location and number of lightning occurrences district wise which alerts the forecaster and other end users to severe weather events.

1.1.2.3.2. Future Plan:

The Radar division is involved in implementation of modernization of Radar Network by replacing old conventional Radars with state of art DWRs. IMD plans to install 85 more number of DWRs and 19 numbers of wind profiler radars under Mission Mausam Scheme in the phased manner to bring entire Country and coasts under radar coverage. For improved efficient management, there are also plans, to establish a Weather Radar Operation Center, which would be responsible for weather radar related activities of the department. It will manage radar network, archival, dissemination of data, development of algorithms, network planning and related Research & Development. IMD has also planned the procurement of Wind profilers under MoU with ISRO, Bangalore. The information on wind profilers improves the weather prediction in the tropics. Therefore,

wind profilers are planned to be installed at nine locations. Further, 10 wind profilers have been proposed under mission Mausam scheme in different locations in India. The total number of 19 wind profilers network is as shown in Fig. 1.5.

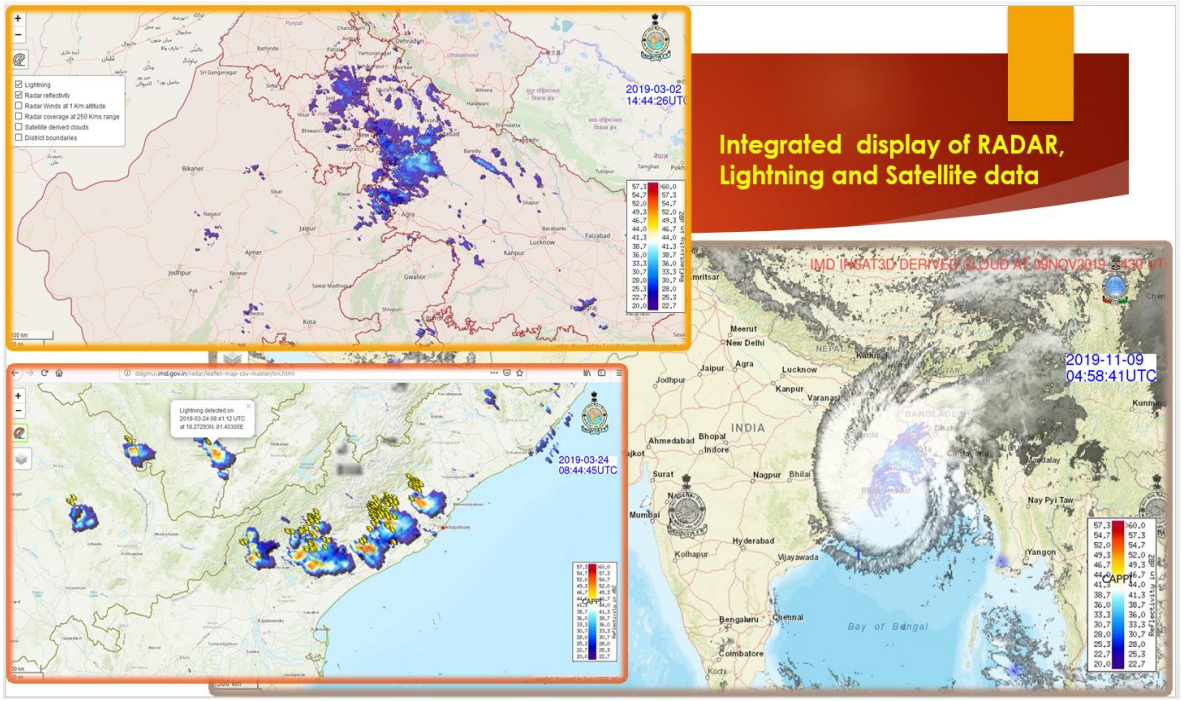

Fig. 1.4: Integrated display using RADAR, Lightning and Satellite data

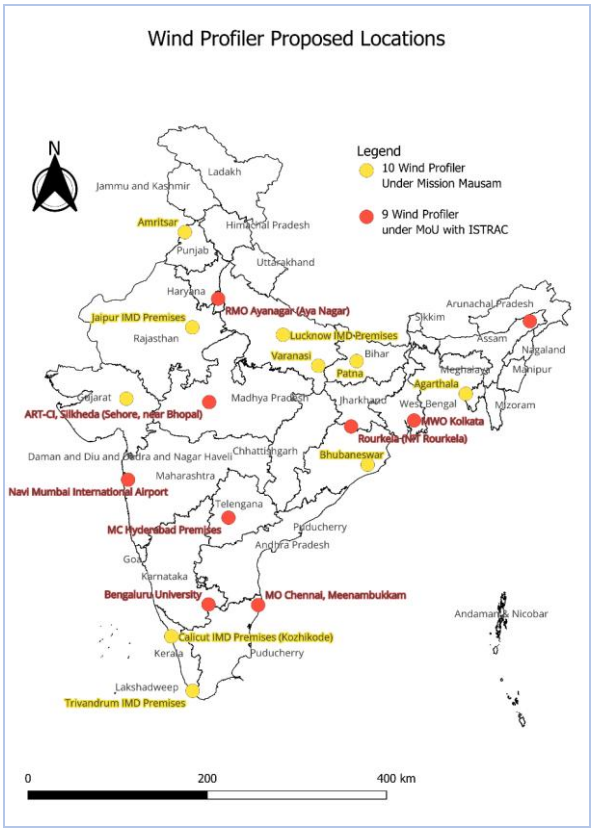

Fig.1.5: Wind profilers planned across the country (19 Nos.).

Further under Mission Mausam, 53 Radars and 10 wind profilers will be procured and added to the network. Total Radar coverage of DWRs is shown under Fig. 1.6.

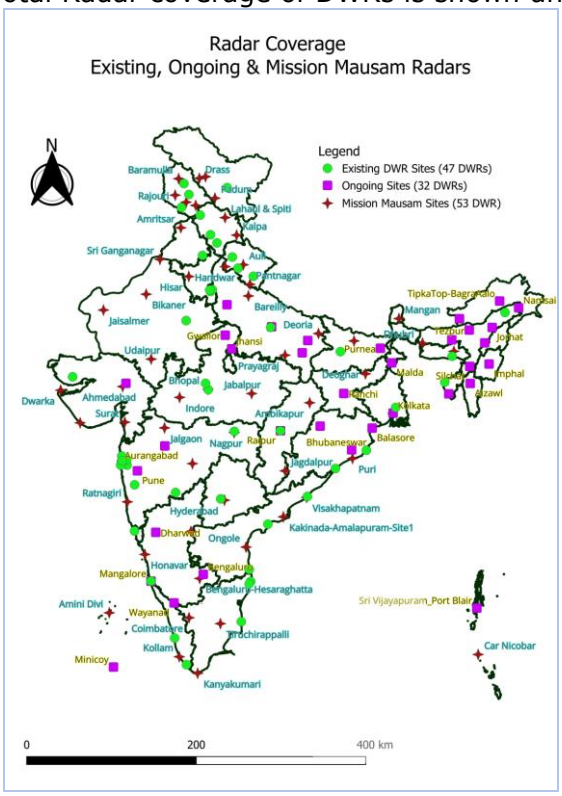

Fig. 1.6: Total DWRs Network after implementation of Mission Mausam

1.1.2.4. Meteorological Satellite

At present, IMD is receiving and processing meteorological data from two Indian geostationary satellites namely, INSAT-3DS & INSAT-3DR. INSAT-3DS was launched on 17th February, 2024 and is positioned at 82°E since 19th June, 2024, while INSAT-3DR launched on 8th Sep, 2016 is located at 74°E. INSAT-3DS and INSAT-3DR have an advanced imager with six imagery channels [Visible (0.55-0.75 µm), Short wave Infra-Red (SWIR, 1.55-1.70 µm), Medium Infra-Red (MIR, 3.80-4.00 µm), Thermal Infra-Red-1(TIR-1, 10.2-11.3 µm), TIR-2 (11.5-12.5 µm), & Water Vapour (WV, 6.50-7.10 µm)] and a nineteen channel sounder (18 IR & 1 Visible) for derivation of atmospheric temperature and moisture profiles. The imagers onboard INSAT-3D and INSAT-3DR provide imageries at 1 km spatial resolution in visible and SWIR bands, at 4 km spatial resolution in MIR and IR bands, and at 8 km spatial resolution in WV band.

At present, about 48 nos. of satellite images scans are taken daily from Imager payload of each satellite (INSAT-3D and INSAT-3DR). Imager payload of these satellites is operated in a staggered mode to get images every 15 minutes. Currently, sounder onboard the INSAT-3DR satellite is providing data at hourly interval. It provides hourly data 20 times a day for Sector A (Indian land region) and 4 times a day for Sector B (Indian ocean region) for generating multi-level imageries and vertical profiles of humidity and temperature. The Multi-mission Meteorological Data Receiving and Processing System (MMDRPS) is used on an operational basis to receive, process and disseminate meteorological data from INSAT-3D and INSAT-3DR satellites on round the clock basis in Satellite Meteorology Division of IMD. Cloud Imageries and derived products are disseminated to forecasting offices of the IMD as

well as to the other users in India and foreign countries through dedicated web pages, and online analysis and visualization tool known as RAPID, and through file transfer protocol (FTP) etc. All the received and processed data from the satellite are archived on a dedicated storage of the MMRDPS.

The following products derived from the satellite are useful for monitoring of tropical cyclones

(i) Enhanced grey scale imagery of cyclone.
(ii) Enhanced coloured imagery of cyclone.
(iii) Outgoing Long wave Radiation (OLR) at pixel resolution
(iv) Quantitative Precipitation Estimation (QPE)
- Three hourly accumulated precipitation at 1x1 degree resolution,
- Hydro estimator (HE) at pixel level
- INSAT Multi-spectral Rainfall (IMR) at 0.1x0.1 degree resolution
- Corrected IMR (IMC) at pixel level.

(v) Sea Surface Temperature (SST) at pixel resolution
(vi) Upper Tropospheric Humidity (UTH) at pixel resolution
(vii) Cloud Motion Vector (CMV)
(viii) Water Vapour Wind (WVW)
(ix) Vis/MIR wind
(x) Wind derived products such as: Lower level Vorticity, Upper level Divergence, Lower level convergence, Vertical wind shear & Wind shear tendency
(xi) Temperature, Humidity profiles
(xii) Value added parameters from INSAT-3DR sounder
- Geo-potential Height
- Layer Precipitable Water
- Total Precipitable Water
- Lifted Index
- Dry Microburst Index
- Maximum Vertical Theta-E Differential
- Wind Index
- Ozone

At present, Dvorak technique is used but manually applied. Recently, efforts have been made for automation of this technique. Automated Dvorak technique version (8.2.1) is running in experimental mode at Satellite Application Unit. Satellite Application Unit is also using microwave imageries operationally from NOAA, NASA-GPM, AMSR2, Metop, DMSP satellites for locating the tropical systems. Satellite Application Unit issues three hourly bulletins in general, and hourly and half hourly bulletins in case of tropical cyclones and other severe weather events.

ISRO successfully launched EOS-06 in November 2022. Satellite Meteorology Division, IMD had started receiving operational Scatterometer data from ISRO from May 2023. Satellite division, IMD, has indigenously devised a software module for operational handling of the Scatterometer data. Data are fetched between dual swath mode in a calendar day through file transfer protocol (FTP) and end products are generated by utilizing various Python libraries on a real time basis. Satellite division has also established a direct file transfer protocol access to the NRSC data repositories for seamless data transfer and product generation. The data output is currently generated in jpg format. The software code for this visualization has been exclusively made at SATMET division for the forecasters and end users. Typical OceanSat imagery during cyclone "SHAKHTI" is presented in Fig. 1.7.

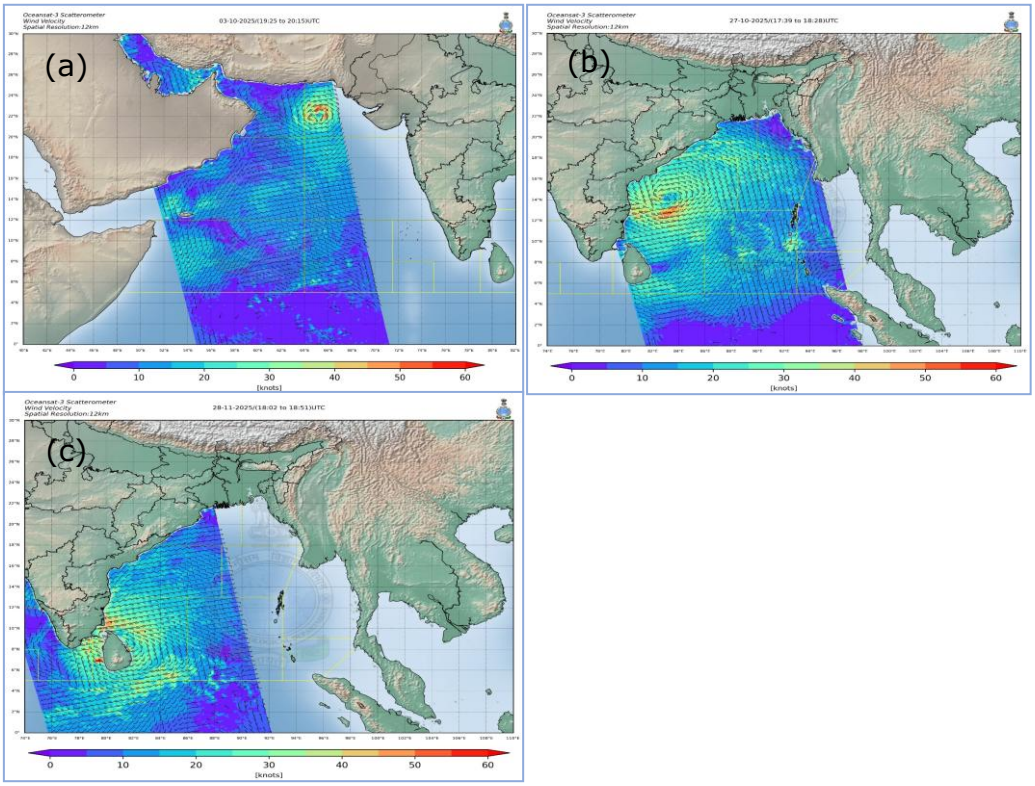

Fig.1.7: Oceansat-3 image of cyclones (a)Shakhti, (b)Montha & (c) Ditwah during 2025

Satellite based Land Surface temperature product is currently generated on a pilot mode for Delhi-NCR region. The region-specific land surface temperature values from INSAT 3D and 3DR are generated for improved understanding of the urban hotspots over the city. This module is also planned for other smart cities in near future. An example is presented is Fig 1.8.

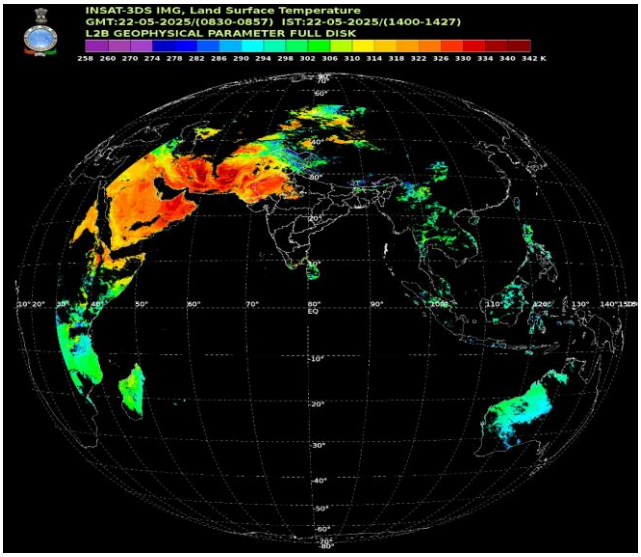

Fig 1.8: Satellite based land surface temperature

Real-time Analysis of Product and Information Dissemination (RAPID) is a visualization tool developed jointly by IMD & ISRO for monitoring and analysis of satellite imageries and products of INSAT 3DS and INSAT 3D(R). A satellite based nowcast tool for its prediction is also available in RAPID. As RAPID is a geo-reference platform, it provides real time information on genesis, growth and decay along with its location and

other geo-physical parameters to help forecasters to provide more objective nowcast. This tool is available in IMD website at the link: http://www.rapid.imd.gov.in/

With the Web Archival System developed at IMD, INSAT-3DS and INSAT 3DR products & imageries are archived. Spectral Band images and product images are archived online for last 6 months. The generation of around ten new products has been put in operational chain of MMDRPS to meet the NWP, Forecaster and Agromet services requirement.

INSAT-3DR Imager payload is used to conduct rapid scans during active cyclones following a standard operating procedure. Each Rapid scan cover up 3 degree in N-S direction (6 Blocks/240 scan lines) in 4.5 minutes. Rapid scan data are being used to track these cyclones in real time basis. The processed data is being disseminated on a dedicated webpage (http://satellite.imd.gov.in/ rapid/rapid_scan.htm).

A web page for real time display of T-Phi gram images derived from Sounder payload of INSAT 3DR/3DS for most of the districts of the country is available. It gets updated for clear sky pixels in near real time at the link: https://satellite.imd.gov.in/tphigram.htm

The occurrence of lightning in India is being monitored with the help of lightning detectors established by the Ministry of Earth Sciences and Indian Air Force. Currently, there are about 300 nos. of lightning detectors in the country. The area of lightning during preceding 5 min, 10 min and 15 min are superimposed with satellite and radar imageries. It helps in enhanced monitoring of thunderstorm and lightning activities and nowcasting of similar extreme events.

Capabilities of Modern Indian Satellites:

Modern Indian satellites are equipped with sophisticated instruments that provide comprehensive atmospheric observations. These instruments include:

- Multispectral Imagers: These imagers capture images in multiple spectral bands, allowing for detailed analysis of cloud cover, land surface conditions, and ocean features.
- Sounders: Sounders measure the temperature and moisture profiles of the atmosphere, providing crucial information for weather forecasting and climate studies.

The recently launched INSAT-3DS, with its improved blackbody calibration and advanced sounder payload, further enhances India's capabilities in satellite meteorology.

By harnessing the power of satellite technology, India has significantly improved its weather forecasting and climate monitoring capabilities, contributing to the safety and well-being of its citizens and the global community.

INSAT-3DS, launched on February 17, 2024, is the latest addition to India's geostationary satellite fleet. It is designed to provide enhanced meteorological observations and monitoring of land and ocean surfaces, significantly improving weather forecasting and disaster warning capabilities.

Key Features of INSAT-3DS:

- Advanced Payloads: Similar to INSAT-3D and INSAT-3DR, INSAT-3DS carries a 6-channel imager and a 19-channel sounder.
- Improved Capabilities: The satellite incorporates advancements in radiometric accuracy, black body calibration, thermal management, and imaging throughput.
- Enhanced Data Quality: Provides higher-quality data for more precise weather analysis and forecasting.
- Real-time Monitoring: Contributes to real-time monitoring of weather systems, including cyclones, thunderstorms, and fog.

- Improved Disaster Warning: Helps in early warning systems for extreme weather events like floods, droughts, and heatwaves.

Contribution to Weather Forecasting:

INSAT-3DS, along with INSAT-3D and INSAT-3DR, plays a crucial role in:

- Accurate Weather Prediction: Provides high-resolution imagery and atmospheric profiles for precise weather forecasting.
- Tropical Cyclone Tracking: Enables real-time monitoring of cyclone formation, intensification, and movement.
- Monsoon Monitoring: Helps in understanding and predicting the Indian monsoon, a vital weather system for the country.
- Extreme Weather Event Monitoring: Detects and tracks extreme weather events like heatwaves, cold waves, and heavy rainfall.
- Climate Studies: Contributes to long-term climate studies and monitoring climate change impacts.
- By leveraging the capabilities of these advanced satellites, India is strengthening its capacity to monitor weather patterns, issue timely warnings, and mitigate the impacts of natural disasters

1.1.2.5. Performance of operational NWP models during 2025

1.1.2.5.1 Global Forecast System

The Global Forecast System (GFS), adopted from National Centre for Environmental Prediction (NCEP) USA is operationally run at India Meteorological Department (IMD), New Delhi on Cray XC40 based High Power Computing Systems (HPCS). The IMD-GFS (T1534/L64) global model is run with ~12 km horizontal resolution and 64 hybrid sigma-pressure layers with Ensemble Kalman Filter (ENKF) based Grid Point Statistical Interpolation (GSI) scheme as the global data assimilation to generate 10 days forecast. The model is run four times in a day (00, 06, 12 and 18 UTC). The real-time outputs are made available to the national web site of IMD (https://mausam.imd.gov.in/ under Short to Medium Range Model Guidance).

IMD also makes use of NWP products prepared by some other operational NWP Centers like, European Center for Medium Range Weather Forecasting (ECMWF), GFS (NCEP) USA, Japan Meteorological Agency (JMA), UK Meteorological Office (UKMO) model etc.
(b) Bharat Forecast System (Bharat FS) global model of about 6 km horizontal resolution operationally started using by IMD in 2025 May. The model uses novel grid structure Triangular cubical Octahedral grid (TCO) to achieve high resolution forecasts about size of cluster of Panchayats/villages. The Bharat Forecast system will significantly enhance predictive capabilities across a wide range of sectors, including public safety, energy, transportation and agriculture. Its high resolution forecast will support timely decision-making, improve preparedness, optimize resource allocation and in critical situations help save human lives.

1.1.2.5.2. Regional Forecast System

IMD operationally runs regional models Weather Research Forecast Advance Research for Weather Forecasting (WRFARW) (v3.9) with regional GSI based data assimilation, and Atmosphere-Ocean coupled Hurricane Weather Research and Forecast (HWRF) modelling system for short-range prediction during cyclone.

1.1.2.5.2.1 Non-hydrostatic mesoscale modeling system WRF-ARW with regional GSI based Data Assimilation system

The mesoscale Weather Research and Forecast WRF (version 3.9.1) with 3DVAR data assimilation is being operated daily twice to generate mesoscale analysis at 8 km horizontal resolution using IMD GFS-T574L64 analysis as first guess and forecasts as boundary condition. Using analysis and updated boundary conditions from the WRFDA, the WRF (ARW) is run for the forecast up to 3 days with 3 km and 45 Eta levels in the vertical 4 times a day at 06 hourly interval.

The model domain covers the area between lat. 5ºS to 40ºN long 50ºE to 102ºE covering India and neighbouring south Asian countries. The model runs with its own regional data assimilation (Com GSI V3.7_EnKF1.3).

1.1.2.5.2.2. Hurricane WRF Model (HWRF)

Since 2011, time to time the HWRF modelling system is developed and customized atmospheric and ocean models with other associated pre-processing and post-processing components are implemented in IMD under the framework of MoU between Ministry of Earth Sciences (MoES) India and National Oceanic and Atmospheric Administration (NOAA) USA. The HWRF version H217 has been ported on the MHIR HPCS with horizontal resolution of 18 km for parent domain and 6km & 2 km for intermediate and innermost nested domains following the center of cyclonic storm. The model is running with 61 vertical levels with parent domain, intermediate and innermost domain covering area of 80^{o}x80^{o}, 24^{o}x24^{o} and 7^{o}x7^{o} respectively. The special feature modified for tropical cyclone forecasting includes vortex initialization and correction, GSI based regional data assimilation, coupler for two-way coupling between atmosphere and ocean components and fine-tuned physical parameterization schemes. This model is customized specifically to forecast the track, intensity and structure of tropical cyclones. The HWRF modelling system uses the dynamics and infrastructure from the Non-Hydrostatic Mesoscale Model (NMM) WRF modelling system. It uses physics that are proven to be better for the tropics. Also, at this time, it is an Ocean coupled model system with a Moving two-way interactive nest, and advanced data assimilation. IMD is operationally running ocean coupled HWRF models during Tropical Cyclone (TC) events with two ocean models viz. Princeton Ocean Model (POM-TC) and Hybrid Coordinate Ocean Model (HYCOM). HYCOM initial conditions are provided through Indian National Centre for Ocean Information Services (INCOIS) whereas POM-TC is initialized based on climatology.

It is run 4 times a day in cyclic mode with GSI based (hybrid-Ensemble Variation (EnVar)) assimilation (80 members) with 6 hourly cycles in cycling mode with full physics configuration. The Unified Post-Processor (UPP) coverts raw model outputs from all three domains into standard GRIB1/2 format. Moreover, Global Fluid Dynamics Laboratory (GFDL) tracker generates track and intensity information in a standard Automated Tropical Cyclone Forecasting System (ATCF) format processing all GRIB files with a specified time interval (3 or 6 hours) as per requirement.

The modeling system was fully operational and predicted all cyclones during the years. Whenever any low-pressure system intensified and became depression over both sub-basins of North Indian Ocean, the cyclic run of the modelling system had been initiated. The model utilized ocean initial state from the INCOIS Tendral Ocean Prediction System

– Indian Ocean Model (ITOPSI) during each cycle to initialize the HYCOM ocean component. All available observed data including conventional and satellite observations were assimilated into the regional GSI system to improve further the initial condition after the vortex initialization of the atmospheric first guess state of the model forecast from previous cycle (except first cycle).

The ocean model provides the SST field to the atmospheric component through coupler during the model integration to update the effect of mixing, cooling as well as advection effect on SST field, whereas the atmospheric component provides the heat fluxes, wind stress, precipitation and surface pressure fields to the ocean model through coupler. The coupled HWRF model uses GFDL vortex tracker and diagnostic software to provide the graphic and text information on track, intensity as well as structure of tropical cyclones for real time operational requirements. The HWRF physics scheme upgrades include updated Scale-Aware Simplified Arakawa-Schubert (SASAS) scheme, Ferrier-Aligo microphysics, GFS Hybrid-EDMF PBL, partial cloudiness for RRTMG scheme, and surface-exchange coefficients in the surface layer.

Within coupled framework of HWRF modeling system, the POM is initialized based on the climatological data whereas the HYCOM is initialized based on the ocean fields from Real-Time Ocean Forecast System (RTOF) of INCOIS, Hyderabad. The atmospheric component of HWRF is initialized based on the analysis and forecast from IMD-GFS (T1534L64) and associated GDAS analysis. The HWRF model uses 3D-EnVAR-GSI as its data assimilation component. The coupled HWRF model is run every 6 hours on real time basis in cyclic mode based on 00, 06, 12, 18 UTC initial conditions to provide track and intensity forecast along with surface wind, rain swaths and other diagnostic products for up to 126 hours.

The coupled HWRF system with both ocean models viz, POM-TC and HYCOM was operational simultaneously and model guidance products were provided from both the configurations. The coupled HWRF model uses TC Vital parameters generated by RSMC, New Delhi every six hour from Deep depression state till landfall of TC

1.1.2.5.2.3. High Resolution Rapid Refresh Modeling System (HRRR)

The High Resolution Rapid Refresh (HRRR) system based on Weather Research and Forecast (WRF-ARW) model with WRFDA (3DVAR-FGAT) data assimilation is operationalized in IMD in collaboration with Space Application Center (ISRO) from beginning of 2021. The HRRR is hourly updated atmospheric model with horizontal resolution of 2km. The model uses forecast of IMD-GFS (T1534L64) model as first guess and forecast as boundary during cold start and is then cycled providing hourly updates based on Radar Data assimilation. Using analysis and updated boundary conditions from the WRFDA, the HRRR is run to produce forecasts up to 12 hours and forecasts are made available after every two hours on NWP website of IMD.

The model is run in three different domains covering Indian mainland. The three domains are North-West domain, East & North-East domain and South-Peninsular domain. HRRR with hourly updates provide frequent and updated precipitation and reflectivity forecasts with respect to the TC's which could be very useful in planning effective and immediate disaster mitigation strategies in very short range.

1.1.2.5.2.4. Dynamical statistical models

The method comprises of five forecast components, namely (a) Cyclone Genesis Potential Parameter (GPP), (b) Multi-Model Ensemble (MME) technique for cyclone track prediction, (c) Cyclone intensity prediction, (d) Rapid intensification and (e) Predicting decaying intensity after the landfall.

a) Genesis Potential Parameter (GPP)

A cyclone genesis parameter, termed the genesis potential parameter (GPP), for the North Indian Sea is developed (Kotal et al, 2009). The parameter is defined as the product of four variables, namely relative vorticity at 850 hPa, middle tropospheric relative humidity, middle tropospheric instability, and the inverse of vertical wind shear. The parameter is operationally used for distinction between non-developing and developing systems at their early development stages. The composite GPP value is found to be around three to five times greater for developing systems (T 3.0) than for non-developing systems. The analysis of the parameter at early development stage of a cyclonic storm found to provide a useful predictive signal for intensification of the system.

The grid point analysis and forecast of the genesis parameter up to seven days is also generated on real time. Higher value of the GPP over a region indicates higher potential of genesis over the region. Region with GPP value equal or greater than 30 is found to be high potential zone for cyclogenesis. The analysis of the parameter and its effectiveness during cyclonic disturbances in 2022-2023 affirm its usefulness as a predictive signal (4-5 days in advance) for cyclogenesis over the North Indian Ocean.

b) Multi-model ensemble (MME) technique

The multi model ensemble (MME) technique (Kotal and Roy Bhowmik, 2011) is based on a statistical linear regression approach. The predictors selected for the ensemble technique are forecasts latitude and longitude positions at 12-hour interval up to 120-hour of five operational NWP models. In the MME method, forecast latitude and longitude position of the member models are linearly regressed against the observed (track) latitude and longitude position for each forecast time at 12-hours intervals for the forecast up to 120-hour. The 12 hourly predicted cyclone tracks are then determined from the respective mean sea level pressure fields using a cyclone tracking software. Multiple linear regression technique is used to generate weights (regression coefficients) for each model for each forecast hour (12hr, 24hr, 36 hr, 48hr, 60hr, 72hr, 84hr, 96hr, 108hr and 120 hrs) based on the past data. These coefficients are then used as weights for the ensemble forecasts. 12-hourly forecast latitude (LATf) and longitude (LONf) positions are defined by multiple linear regression technique. A collective bias correction is applied in the MME by applying multiple linear regression based minimization principle for the member models GFS (IMD), GFS (NCEP), ECMWF, UKMO and JMA. ECMWF data are available at 24h intervals. Therefore, 12h, 36h, 60h, 84h, 108h forecast positions of ECMWF are computed based on linear interpolation. All these NWP products are routinely made available in real time on the IMD web site: www.rsmcnewdelhi.imd.gov.in.

New MME since 2021: With the latest version of different models & EPS as well as different tracker used for tracking the centre of TC in models, the IMD has developed

another MME for track, intensity & landfall forecasts since 2021. It performs better than the individual models. Since 2021, IMD has also implemented IFS TC Tracker (available from ECMWF) for all available TIGGE models (9 in numbers). These 9 models are from Bureau of Meteorology, Australia (BoM), Environment and Climate Change Canada (ECCC), European Centre for Medium-Range Weather Forecasts (ECMWF), India Meteorological Department (IMD), Japan Meteorological Agency (JMA), Korea Meteorological Administration (KMA), Met Office - UK (UKMO), and National Centers for Environmental Prediction, USA (NCEP), and National Centre for Medium Range Weather Forecasting (NCMRWF) are nine International Institutes model outputs (contributing to the TIGGE) are chosen based on availability at the ECMWF-TIGGE web data portal https://apps.ecmwf.int/datasets/data/tigge/levtype=sfc/type=cf/ as on December 2021.

c) Statistical Dynamical model for Cyclone Intensity Prediction (SCIP)

A statistical-dynamical model (SCIP) (Kotal et al, 2008) has been implemented for real time forecasting of 12 hourly intensity up to 120 hours. The model parameters are derived based on model analysis fields of past cyclones. The parameters selected as predictors are: Initial storm intensity, Intensity changes during past 12 hours, Storm motion speed, Initial storm latitude position, Vertical wind shear averaged along the storm track, Vorticity at 850 hPa, Divergence at 200 hPa and Sea Surface Temperature (SST). For the real-time forecasting, model parameters are derived based on the forecast fields of IMD-GFS model. The method is found to be provided useful guidance for the operational cyclone forecasting.

The MME based all available NWP models on EPS is also developed by IMD since 2021 for intensity prediction.

d) Rapid Intensification (RI) Index

A rapid intensification index (RII) is developed for tropical cyclones over the Bay of Bengal (Kotal and Roy Bhowmik, 2013). The RII uses large-scale characteristics of tropical cyclones to estimate the probability of rapid intensification (RI) over the subsequent 24-h. The RI is defined as an increase of intensity 30 kt (15.4 ms-1) during 24-h. The RII technique is developed by combining threshold (index) values of the eight variables for which statistically significant differences are found between the RI and non-RI cases. The variables are: Storm latitude position, previous 12-h intensity change, initial storm intensity, vorticity at 850 hPa, divergence at 200 hPa, vertical wind shear, lower tropospheric relative humidity, and storm motion speed. The probability of RI is found to be increases from 0% to 100% when the total number of indices satisfied increases from zero to eight. The forecasts are made available in real time from 2013.

e) Decay of Intensity after the landfall

Tropical cyclones (TCs) are well known for their destructive potential and impact on human activities. The Super cyclone Odisha (1999) illustrated the need for the accurate prediction of inland effects of tropical cyclones. The super cyclone of Odisha maintained the intensity of cyclonic storm for about 30 hours after landfall. Because a dense population resides at or near the Indian coasts, the decay forecast has direct relevance to daily activities over a coastal zone (such as transportation, tourism, fishing, etc.) apart from disaster management. In view of this, the decay model (Roy Bhowmik et al.

2005) has been used for real time forecasting of decaying intensity (after landfall) of TCs.

1.1.2.5.3. Ensemble Prediction System

1.1.2.5.3.1. Tropical Cyclone Ensemble Forecast based on Global Models Ensemble (TIGGE) Data

The THORPEX Interactive Grand Global Ensemble (TIGGE, Philippe Bougeault et al. 2010) is an implementation of ensemble forecasting for global weather forecasting and is part of THORPEX, an international research programme established in 2003 by the World Meteorological Organization (WMO) to accelerate improvements in the utility and accuracy of weather forecasts up to two weeks ahead.

1.1.2.5.3.2. Global Ensemble Forecast System

The Ministry of Earth Sciences (MoES) has commissioned two very high resolution (12 km grid scale) state-of-the-art global Ensemble Prediction Systems (EPS) for generating operational 10-days probabilistic forecasts of weather. The EPS involves the generation of multiple forecasts using slightly varying initial conditions. The forecast products from these two prediction systems are available at the following links (http://nwp.imd.gov.in/gefspro.php) and (http://www.ncmrwf.gov.in/product_main.php). The frameworks of the new EPSs are among the best weather prediction systems in the world at present. Very few forecasting centres in the world use this high resolution for short-medium range probabilistic weather forecasts.

1.1.2.5.3.3. The Ensemble Mean and Spread

The ensemble spread is a measure of the difference between the members and is represented by the standard deviation (SD) with respect to the ensemble mean (EM). On average, small (high) spread indicates a high (low) forecast accuracy.

- The ensemble spread is flow-dependent and varies for different parameters.
- It usually increases with the forecast range, but there can be cases when the spread is larger at shorter forecast ranges than at longer ranges. This might happen when the initial days are characterized by strong synoptic systems with complex structures but are followed by large-scale "fair weather" high pressure systems.

1.1.2.5.4. Models run at NCMRWF

(a) Mithuna Forecast System (Mithuna-FS)

NCMRWF has recently upgraded its operational global forecasting system, moving from the atmosphere–land model NCUM-G to a fully coupled Earth system model known as Mithuna-FS. This model is India's first fully coupled numerical weather prediction system operational for routine short to medium-range forecasting, developed under the MOMENTUM, India-UK partnership. The new system incorporates dynamic exchange processes of heat, momentum, and moisture across the atmosphere, ocean, sea-ice, land components. Solar and terrestrial radiation govern the system's overall energy balance, while hydrological processes further intensify the coupling pathways between the atmosphere and the land surface. Mithuna-FS is operationalized since November,

2025 and routine short- to medium-range forecasts are now being delivered to IMD and other Government agencies, which will further strengthening national forecasting services. The Mithuna-FS suite encompasses modules for pre-processing, observation handling and monitoring, weakly coupled data assimilation, the coupled model components systems. Arunika, petascale high-performance computing (HPC) platform hosts an advanced software ecosystem built to support this **modelling system.**

(b) Weakly Coupled Data Assimilation (WCDA)

In a weakly coupled data assimilation (WCDA) system, Atmospheric, oceanic, land, and sea-ice components assimilate their respective observations independently using separate data assimilation systems. The updated component states are then combined within a coupled forecast model, where interactions among atmosphere, ocean, land, and sea ice occur only during the model integration step. No cross-component error covariances are used during the assimilation. The atmospheric deterministic DA system employs a hybrid 4D-Var scheme that blends static and flow-dependent background-error covariances. The ensemble DA system uses a hybrid En-4DEnVar method, in which ensemble-derived covariances are incorporated directly within a four-dimensional variational framework. Ocean and sea-ice analyses are performed using NEMO v4, configured with the SI3 sea-ice model. The system uses 75 vertical levels, a 20-minute time step, and 1/4° horizontal resolution on the ORCA025 tripolar grid. A 3D-Var FGAT scheme assimilates SST, SSH, T/S profiles, and Sea Ice Concentration, ensuring balanced updates of both oceanic and cryospheric states. The land surface and atmosphere are weakly coupled in the DA cycle: each system computes analysis increments independently but remains linked through the coupled model forecast. The JULES land-surface model, together with a simplified EnKF (sEnKF), enhances soil-moisture analyses and improves the representation of land–atmosphere energy and moisture exchanges.

(c) Mithuna FS: Deterministic

Mithuna-FS is based on the GC5 global coupled configuration (Xavier et al., 2025) comprising Global Atmospheric and Land system (GAL9) , Global Ocean and Sea (GOSI9) with the field exchanges passed through OASIS3 coupler. GOSI9 contains the NEMO 4.0 where Sea Ice-modelling Integrated Initiative (SI3) uses the same grid as the oceanic mesh where the transfer process is more robust and steady. The atmospheric and land component is using UM version 12.1 and the JULES version 7.1 respectively, and is set up with a horizontal resolution of 12 km and 70 vertical levels that span about 80 km. Major science advancement in the UM part is the modification in the mid-level convection to represent both surface-driven deep convection and elevated convection; bimodal cloud scheme and dust based heterogeneous ice nucleation thresholds. Whereas in the JULES, change in the tuning of the surface tile albedo values, and the changes in the soil water retention parameterization. The conductive coupling approach is replacing the default standard bulk formulation used in the NEMO.

(d) Mithuna FS: Ensemble

In the Mithuna-FS, forecast uncertainty is represented through ensemble-based methodologies, with the overall framework derived from the Met Office Global and Regional Ensemble Prediction System–Global. Recent system developments have transformed this framework into a fully coupled atmosphere–ocean ensemble configuration that employs weakly coupled data assimilation and stochastic physics perturbations. A hybrid ensemble–variational approach (En-4DEnVar) provides flow-dependent background-error covariances, leading to improved analysis accuracy.
The Mithuna-FS incorporates these advances by allowing each ensemble member to assimilate nearly all observations used in the deterministic system. Improvements in ensemble spread–skill relationships, particularly in the tropics, are achieved through

advanced ensemble data assimilation techniques, including the use of multiple inflation schemes, spatial localisation, and perturbation of observations, which together enhance the representation of initial-condition uncertainty. Additional gains in ensemble spread and reliability are obtained through the application of stochastic physics and parameter- or tendency-perturbation schemes.

The current operational ensemble is integrated at N640L70 resolution, corresponding to an approximately 20-km horizontal grid spacing with 70 vertical levels extending up to a model top of about 80 km. Collectively, these developments enable the Mithuna-FS to generate dynamically consistent, weakly coupled initial states and to deliver robust probabilistic forecasts of high-impact monsoon weather. The system operates with a 44-member ensemble in each assimilation cycle, starting from background states at T–6 h. A mean update is first performed, after which ensemble perturbations are applied to represent initial-condition uncertainty. Each perturbed member undergoes analysis by assimilating atmospheric observations together with soil analysis and perturbations, as well as sea surface temperature (SST) analysis and SST perturbations. The resulting ensemble analyses are used to initialise the EPS forecasts, which consist of a combination of short-cycle members and long-cycle members, thereby enhancing ensemble spread and improving the reliability of probabilistic forecasts.

1.1.2.5.5. Models run at IITM Pune

Since 2018, Global Ensemble Forecast System (GEFS) T1534 (~12 km) is used for operational short-range probabilistic weather forecast system including cyclone prediction at IITM. It is based on Global Forecast System (GFS v14.1) which is a part of the 'Operational Model' developed at NCEP, USA in 2018. This is a spectral model with semi lagrangian dynamics and semi implicit time scheme. It has a horizontal resolution of 12.5 km. The total number of 21 Ensembles (20 perturbed forecasts + 1 control forecast) constitutes the ensemble system. These 20 ensembles analysis are generated by Ensemble Kalman Filter (EnKF) method from the forecast perturbation of the previous cycles four times a day (00, 06, 12 and 18 UTC) at all 64 model vertical levels. These analysis perturbations are added to the reconfigured analysis obtained from the hybrid four-dimensional Ensemble variational data assimilation system (GDAS-Hybrid4DEnsVar) as part of the suite. The 243 hour forecast of GEFS is routinely generated based on 00UTC and 12UTC initial conditions which include a control forecast starting from GDAS assimilation and 20 (20 perturbations) ensemble members with each perturbed initial conditions.

1.1.2.5.6. Probabilistic forecasts of quantitative precipitation

- In these charts, the probability that 24-hour precipitation amounts over a 2.5x2.5 lat-long grid box will exceed certain threshold values is given. The forecast probability is estimated directly from the 20-member global ensemble.
- At each grid point the number of ensemble members having a 24-hour precipitation amount within a specified range (e.g. 1-2cm, 2-5cm etc) is counted (M) and the probability is expressed as 100*(M/20).

1.1.2.5.7. Storm surge forecasting

Storm surge forecasting is the responsibility of the National Meteorological Services. However, storm surge guidance is issued and incorporated in the Tropical Cyclone Advisory bulletin by RSMC- New Delhi based on IIT, Delhi Storm Surge prediction model and INCOIS Advanced Circulation model (AdCirc).

1.1.2.5.8. Coastal inundation forecasting

The coastal inundation forecast by RSMC, New Delhi commenced from 2013 experimentally with cyclone Phailin. This forecast is provided to disaster managers. It is mainly based on coastal inundation model run by Indian National Centre for Ocean Information Services (INCOIS) Hyderabad. This is ADCIRC model is adapted from USA. This forecast guidance is also provided all member countries.

1.1.2.5.9. Seasonal Prediction of cyclonic disturbances

Seasonal prediction of cyclonic disturbances is being issued experimentally for the post monsoon season (Oct.-Dec.) since 2014. This contains information about the frequency of cyclonic disturbances (depression and above) over the Bay of Bengal and number of cyclonic disturbance days over the north Indian Ocean. However, it has not been operationalised considering the large inter-annual & intra-seasonal variability and less number of cases over north Indian Ocean region. The accuracy of this prediction system is low.

1.1.2.6. Operational forecast and warning production

1.1.2.6.1 Analysis and Prediction system

Various strategies have been adopted in recent years for improvement of analysis and prediction of cyclone. The tropical cyclone analysis, prediction and decision-making process is made by blending scientifically based conceptual models, dynamical & statistical models, meteorological datasets, technology and expertise. Conventional observational network, automatic weather stations (AWS), buoy & ship observations, cyclone detection radars and satellites are used for this purpose. A new weather analysis and forecasting system in a digital environment is used to plot and analyse different weather parameters, satellite, Radar and Numerical Weather Prediction (NWP) model products. An integrated fully automated forecasting environment facility is thus set up for this purpose.

The manual synoptic weather forecasting has been replaced by hybrid systems in which synoptic method could be overlaid on NWP models supported by modern graphical and GIS applications to produce

- high quality analyses
- Ensemble of forecasts from NWP models at different scales - global, regional and mesoscale
- Prediction of intensity and track of tropical cyclone

A schematic representation of the monitoring and analysis, forecast and warning procedure is given in Fig.1.9.

The **indigenously developed decision support system has** following facilities.

- Analysis of all synoptic, satellite, radar and NWP model products for genesis, intensity and track monitoring and prediction
- Preparation of past and forecast tracks upto 120 hrs
- Depiction of uncertainty in track forecast
- Preparation of quadrant wind radii forecast upto 120 hrs.

All the available data and products from various national and international sources are systematically considered for analysis and prediction of cyclones. Various data and products utilized for this purpose are as follows:

- Data and analysis Products through digitized system as mentioned above.
- Radar data and products from IMD's radar network and neighbouring countries
- Satellite imageries and products from IMD and international Centers
- Dynamical and statistical Model products from various national and international Centers.
- Data, analysis and forecast products from various national and international Centers through internet.

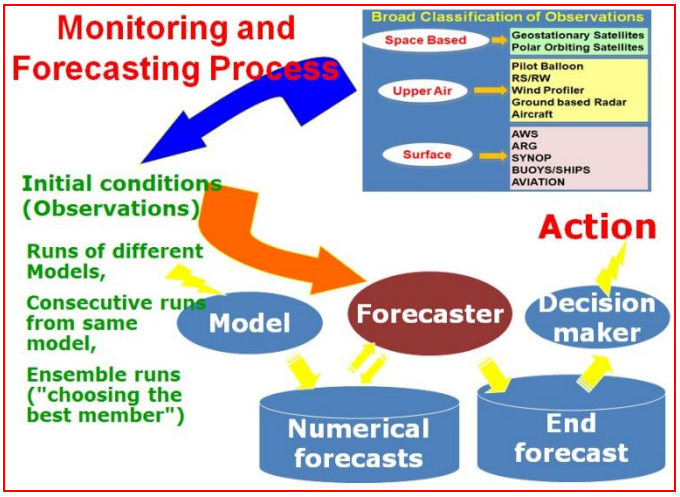

Fig.1.9. Strategy adopted for cyclone analysis and forecasting

Cloud imageries from Geostationary Meteorological Satellites INSAT-3D and INSAT-3D (R) are the main sources of information for the analysis of tropical cyclones over the data-sparse region of north Indian Ocean. Data from scatterometry based satellites and Ocean buoys also provide vital information. Ship observations are also used critically during the cyclonic disturbance period. When the system comes closer to the coastline, the system location and intensity are determined based on hourly observations from Radar as well as from coastal observatories. The AWS stations along coast are also very useful as they provide hourly observations on real time basis. The WVW and CMV in addition to the conventional wind vectors observed by Radio Wind (RW) instruments are very useful for monitoring and prediction of cyclonic disturbance, especially over the Sea region. The direction and speed of the movement of a tropical cyclone are determined primarily from the three hourly displacement vectors of the center of the cyclone. The consensus forecast that gather all or part of the numerical forecast and used synoptic and statistical guidance are utilised for issue of official forecast.

In addition, IMD has developed GIS based decision support indigenously which has the facility to overlay various model products at a single platform. It is utilized by the forecasters to generate probabilistic area of cyclogenesis, multi model based warnings for fishermen, probabilistic area of winds exceeding 25 knots and 34 knots, probabilistic heavy rainfall warning maps etc.

1.1.2.7. Bulletins and Products Generated by RSMC, New Delhi

RSMC, New Delhi prepares and disseminates the following bulletins:

1.1.2.7.1. Extended Range Outlook

IMD started issuing Extended Range Outlook for cyclogenesis during next two weeks every Thursday from 22nd April, 2018. It contains information about large scale features over the region, model guidance on probable cyclogenesis from various global/regional models, probability of cyclogenesis as LOW (0-33%), MODERATE (34-67%) and HIGH

(68-100%) alongwith verification of forecast issued during last two weeks. The product is available on RSMC website at http://www.rsmcnewdelhi.imd.gov.in/images/bulletin/eroc.pdf and is also transmitted by email to WMO, WMO/ESCAP panel member countries and various scientists and researchers in the country. The ERF is generated based on consensus approach utilizing the forecast guidance from different deterministic and probabilistic NWP models, ERF models and the large scale processes like convectively coupled equatorial waves such as Maden Julian Oscillation (MJO), Equatorial Rossby waves, Kelvin waves, low background waves. For details kindly refer SOP of cyclone warning services in India available on RSMC website at https://rsmcnewdelhi.imd.gov.in/report.php?internal_menu=NjE=).

1.1.2.7.2 Tropical Weather Outlook

Tropical Weather Outlook (TWO) is issued daily at 0600 UTC based on 0300 UTC observations in normal weather for use of the member countries of WMO/ESCAP Panel. This contains description of synoptic systems over NIO along with information on significant cloud systems as seen in satellite imageries. It also provides probabilistic genesis forecast (formation of depression) over Bay of Bengal and Arabian sea separately for day 1 (up to 24 hrs), day 2 (24 – 48 hrs), day 3 (48 – 72 hrs), day 4 (72-96 hrs), day 5 (96-120 hrs), day 6 (120-144 hrs) and day 7 (144-168 hrs). The forecast is issued in probabilistic terms like Nil, Low, Moderate and High probability corresponding to expected probability of occurrence of 00, 01 – 33, 34 – 67 and 68 – 100 %. It is based on the consensus developed from various NWP and dynamical statistical guidance coupled with guidance from observations and analyses. This forecast has been introduced since 1st June 2014 upto 72 hrs lead period. The lead period of cyclogenesis forecast has been extended to 120 hrs since 22nd April, 2018 and upto 168 hours since September, 2023. The area of genesis is also marked graphically.

The outlook is generated based on consensus approach utilizing the forecast guidance from different deterministic and probabilistic NWP models, the large scale processes like convectively coupled equatorial waves such as Maden Julian Oscillation (MJO), Equatorial Rossby waves, Kelvin waves, low background waves and the guidance on genesis potential parameters. For details kindly refer SOP of cyclone warning services in India available on RSMC website at https://rsmcnewdelhi.imd.gov.in/report.php?internal_menu=NjE=.

1.1.2.7.3 Pre-Genesis Forecast:

India Meteorological Department has commenced pre-genesis forecast of probable date, time and location of expected cyclogenesis (formation of depression) over the NIO along with 12 hourly forecast of track, intensity and structure upto next 72 hours, once daily from the stage of low pressure area on 17th March, 2022. Typical example of pre-genesis forecast issued during cyclone "MONTHA" is presented in Fig. 1.10.

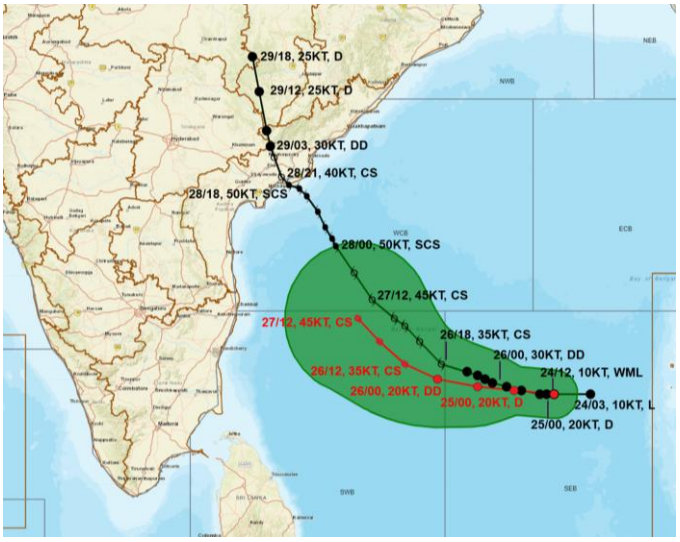

Fig. 1.10: Pre-genesis forecast issued at the stage of well marked low pressure area based on 1200 UTC of 24th October, 2025

The pre-genesis forecast is generated based on consensus approach utilizing the forecast guidance from different deterministic and probabilistic NWP models, and the large scale processes like convectively coupled equatorial waves such as Maden Julian Oscillation (MJO), Equatorial Rossby waves, Kelvin waves, low background waves and regional scale process as well as genesis potential parameters. For details kindly refer SOP of cyclone warning services in India.

1.1.2.7.4. Special Tropical Weather Outlook

The Special Tropical Weather Outlook is issued at +03 hours based on observations of 0000, 0300, 0600, 1200 & 1800 UTC observations when a tropical depression forms over NIO. These bulletins contain the current position and intensity, past movement, central pressure of the cyclone, description of satellite imageries, cloud imageries, expected direction and speed of movement, expected track and intensity of the system up to 72 hrs in case of depression and upto 120 hrs in case of a deep depression. It also includes the description of sea condition. It also includes discussion on various diagnostic and prognostic parameters. The 72 and 120 hours track and intensity forecasts are being issued from the stage of depression and deep depression respectively since 2009 and 2018. The track and intensity forecast are issued for +06, +12, +18, +24, +36, +48, +60, 120 hours or till the system is likely to weaken into a well marked low pressure area. IMD has initiated to give the quantitative forecast of track & intensity from depression stage for lead period of +12, +24, +48, +72 hours since April 2018. The time of issue of this bulletin is HH+03 hours. The cone of uncertainty in the track forecast is also included in the graphical presentation of the bulletin. Tropical weather outlooks are transmitted to panel member countries through global telecommunication system (GTS) & e-mails and are also made available on real time basis through internet at IMD's website: **www.mausam.imd.gov.in, www.imd.gov.in and www.rsmcnewdelhi.imd.gov.in**. RSMC, New Delhi can also be contacted through e-mail (**cyclonewarningdivision@gmail.com**) for any real time information on cyclonic disturbances over NIO.

1.1.2.7.5 Tropical Cyclone Advisories

Tropical cyclone advisory bulletin is issued when a deep depression intensifies into a tropical cyclone (wind speed= 34 knots or more). It replaces the 'special tropical weather outlook' bulletin. Tropical cyclone advisories are issued at 3 hourly intervals based on 00, 03, 06, 09, 12, 15, 18 and 21 UTC observations. The time of issue is HH+03 hrs. These

bulletins contain the current position and intensity, past movement, central pressure of the cyclone, description of satellite imageries, cloud imageries, expected direction and speed of movement, expected track and intensity of the system up to 120 hours like that in special tropical weather outlook. The expected point and time of landfall, forecast winds, squally weather and state of the Sea in and around the system are also mentioned. Storm surge guidance is provided in the bulletin as and when required. Tropical cyclone advisories are transmitted to panel member countries through e-mails & GTS and are also made available on real time basis through internet at IMD's website: www.mausam.imd.gov.in and www.rsmcnewdelhi.imd.gov.in. RSMC New Delhi introduced confidence level in current and forecast location & intensity as low, moderate and high wef post monsoon cyclone season 2025. Track and Intensity estimate is based on multiple data sources including satellite, scatterometer, multi-satellite based winds, radar, synoptic, guidance from other centres etc. Considering the variation in the estimate by different sources, probability or confidence in estimation of intensity and location is decided as given in Table 1.3 and Table 1.4 respectively.

Table 1.3: Confidence level for estimation of intensity

Range	Confidence Level
<10 kt	High
10-20 kt	Moderate
>20 kt	Low

Table 1.4: Confidence level for estimation of location corresponding to various lead period

Lead time (hr)	Confidence level		
	Low	Moderate	High
0	>0.5	0.3 - 0.5	0.3
+24	>1.0	0.5 - 1.0	0.5
+48	>1.5	1.0 - 1.5	1.0
+72	>2.0	1.5 - 2.0	1.5
+96	>2.5	2.0 - 2.5	2.0
+120	>3.0	2.5 - 3.0	2.5
+144	>3.5	3.0 - 3.5	3.0
+168	>4.5	4.0 - 4.5	4.0

1.1.2.7.6 Storm Surge Guidance

RSMC New Delhi is providing storm surge guidance to the panel member countries since 2009 based on IIT Delhi Storm Surge model and. Recently INCOIS Hyderabad has developed an ADvanced CIRCulation (ADCIRC) Storm Surge and Coastal Inundation model which is running experimentally since 2013. In future it will be used as an input for providing storm surge guidance to member countries. RSMC New Delhi also commenced probabilistic storm surge guidance from Severe Cyclonic Storm "Remal" in May 2024. Typical guidance product is placed at Fig. 1.11.

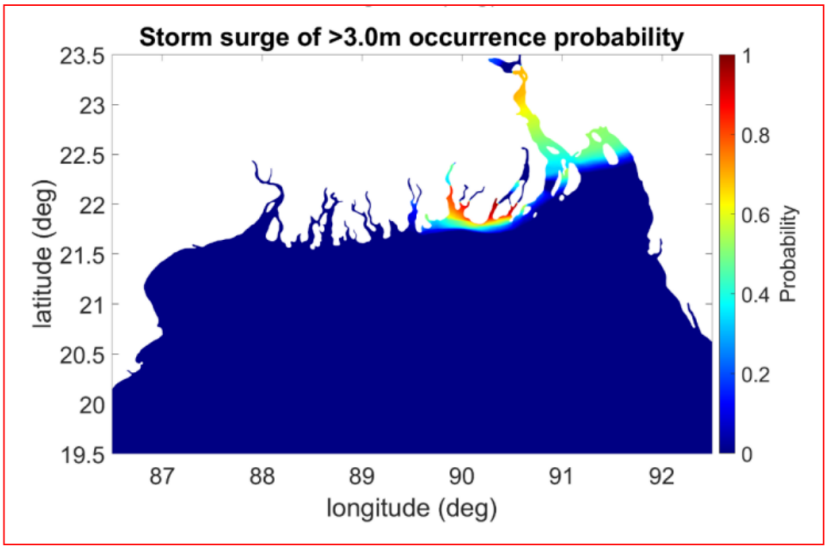

Fig. 1.11: Probabilistic Storm Surge during SCS REMAL

1.1.2.7.7 Maritime forecast bulletins

Under Global Maritime Distress and Safety System (GMDSS) Scheme, India has been designated as one of the 16 services 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, sea area bulletin, coastal weather bulletins are also issued for broadcast through NAVTEX transmitting stations. Fleet Forecasts for Indian seas are also issued for Indian Navy twice a day with validity period of twelve hours.

Port Warnings & fishermen warnings are also issued for the entire Indian coast as and when the coast is likely to be affected due to disturbances in seas. IMD has initiated to issue the fishermen warning for entire BoB and AS since April, 2018. Further a graphics based fishermen warning is being generated for entire BoB and AS since 26th April 2019. Sample fishermen graphics is placed at Fig. 1.12.

The fishermen warnings for next 5 days based on multi-model ensemble and probability of exceedance of winds ≥ 45 kmph and 35 knots are available at www.rsmcnewdelhi.imd.gov.in.

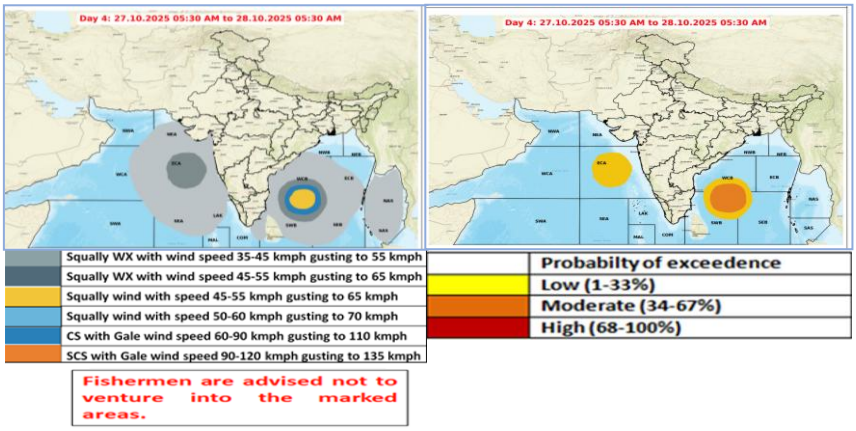

Fig. 1.12: Typical (a) fishermen warning graphics and probabilistic map for wind exceeding 45 kmph issued on 24th October, 2025 for 27th October during cyclone Montha

IMD has also commenced preparation of marine weather bulletins in graphical format using QGIS tool and these graphical products are also available over GIS platform since January, 2021 based on multi model ensemble guidance. During the cyclonic disturbance period the frequency of these bulletins increase. Kindly refer SOP for detailed information available on RSMC website (www.rsmcnewdelhi.imd.gov.in).

1.1.2.7.8 Tropical Cyclone Advisories for Aviation

Tropical Cyclone Advisories for aviation are issued for international aviation as soon as any disturbance over the NIO attains or likely to attain the intensity of cyclonic storm (maximum sustained surface wind speed ≥ 34 knots) within next six hours. These bulletins are issued at six hourly intervals based on 00, 06, 12, 18 UTC synoptic charts and the time of issue is HH+03 hrs. These bulletins contain present location of cyclone in lat./long., maximum sustained surface wind (in knots), direction of past movement and estimated central pressure, change in intensity, forecast position as Lat./Long (in degree & minutes), and forecast winds in knots valid at HH+6, HH+12, HH+18 and HH+24 hrs. The tropical cyclone advisories are transmitted on real time basis through GTS & AFTN channels to designated International Airports of the region prescribed by ICAO and ftp to ADRR, Hong Kong (WMO's Aviation Disaster Risk Reduction) in coded form. It is also sent in graphics form in **png** format through GTS. The text and graphical bulletins are also uploaded on www.rsmcnewdelhi.imd.gov.in

1.1.2.7.9. National bulletin

These bulletins are issued from the stage of low pressure area as a "Special Message", once daily. During the stage of depression/deep depression; it is issued 5 times daily based on 00, 03, 06, 12, and 18 UTC observations. When the system intensifies into a cyclonic storm over NIO, these bulletins are issued every three hourly based on 00, 03, 06, 09, 12, 15, 18 and 21 UTC (every three hourly interval) at +03HH. This bulletin contains present status of the system i.e. the location, intensity; past movement and forecast track & intensity for next 120 hours or till the system weakens into a low pressure area, likely landfall point & time and likely adverse weather including heavy rain, gale wind & storm surge. Expected damage and action suggested are also included in these bulletins. This bulletin is completely meant for national users and these are disseminated through various modes of communication including Email, Telephone/FAX, All India Radio, Doordarshan (National TV), SMS and Print & electronic media. It is also posted on cyclone page of IMD website and RSMC website. These are also posted on social networking sites like facebook, tweeter and WhatsApp.

1.1.2.7.10. Cone of uncertainty forecast

The Cone of uncertainty (COU) represents the uncertainty in forecast centre of a CD/TC's and is made by drawing a set of circles centered at each forecast point—06, 12, 18, 24, 36, 48, 60, 72, 84, 96, 108 and 120 hours for a five-day forecast. IMD introduced COU forecast upto a lead period of 72 hours in 2009 from Cyclone "WARD". The lead period was further extended to 120 hours in 2013 from Cyclone "VIYARU". COU values were revised in 2014 from cyclone "Hudhud" based on the errors during 2009-13. From cyclone FANI, 2019, the COU values have been revised based on the errors during 2014-18. Thereafter, again, the COU values have been revised from post monsoon season 2025 based on the operational errors during 2020-24. The standard errors (nm) as radius of the circle around the forecast position (lat/long) so as to construct the cone of uncertainty in the track forecast for 00, +06, +12, +18, +24, +36, +48, +60, +72,

+84, +96, +108 and +120 hrs lead period have been fixed as 10, 20, 25, 35, 40, 50, 60, 70, 85, 100, 115, 130 and 145 nm since April, 2025. Typical observed and forecast track alongwith cone of uncertainty demonstrating accuracy in track forecast during Severe Cyclonic Storm "MONTHA" is presented in Fig. 1.13. This product is uploaded on various websites of IMD viz. www.rsmcnewdelhi.imd.gov.in and www.mausam.imd.gov.in in .png format and appended with the national and tropical cyclone advisory bulletins. Since, severe cyclonic storm "Nisarga" in June, 2020, this product was also made available on GIS based platform at www.rsmcnewdelhi.imd.gov.in

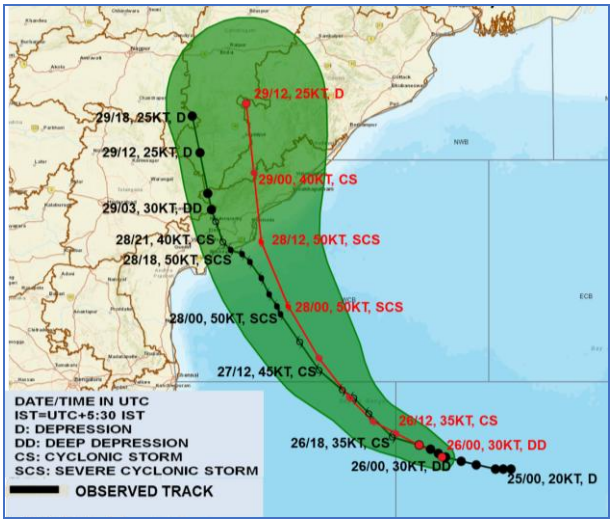

Fig.1.13: Observed track and forecast based on 25th Oct./ 0000 UTC (0530 IST) demonstrating accuracy in track & intensity forecast

1.1.2.7.11 Wind forecast for different quadrants

The forecast of the radius of maximum sustained wind in four quadrants of a cyclone commenced with effect from the cyclone, GIRI during October 2010. In this forecast, the radius of 28, 34, 50 and 64 knot winds are given for various forecast periods like +06, +12, +18, +24, +36, +48, +60, … 120 hrs. A typical graphical presentation of this forecast is shown in Fig.1.12 (b). This product is uploaded on various websites of IMD viz. www.rsmcnewdelhi.imd.gov.in and www.mausam.imd.gov.in in .png format and appended with the national and tropical cyclone advisory bulletins. Since, severe cyclonic storm "Nisarga" in June, 2020, this product was also made available on GIS based platform at www.rsmcnewdelhi.imd.gov.in. It is also uploaded on RSMC, New Delhi website in textual form.

1.1.2.7.12. Hourly Update

On the day of landfall IMD issues hourly updates on the landfalling cyclone over the Indian coast since October, 2014. It contains information about the centre, it's distance & direction from the station, landfall point and time, current maximum sustained wind speed (MSW), MSW at the time of landfall. These bulletins are available at http://www.rsmcnewdelhi.imd.gov.in/images/bulletin/hourly.pdf on the day of landfall.

1.1.2.7.13. TC Vital

The TC Vital is issued by RSMC New Delhi to various NWP Centers in coded form for their use in creating the synthetic vortex in NWP models and running storm surge and coastal inundation model. It is issued 4 times a day based on 00, 06, 12 and 18 UTC. This bulletin contains the information on location (Latitude/Longitude), intensity (MSW and

estimated central pressure), movement (Speed/Direction), size, the radius of maximum wind and wind radii of 34kts wind in 4 geographical quadrants namely NE, NW,SE and SW quadrants etc. This bulletin has been introduced in 2012.

1.1.2.7.14 Impact Based Forecast and Risk Based Warning for heavy rainfall over cities and districts

India Meteorological Department introduced impact based forecasts (IBF) & warnings for cyclonic Storms since long. Recently, since 2014, IMD introduced colour coded IBF for other severe weather events as per WMO guidelines. However, since 2019, IMD started issuing IBF & suggested actions for severe weather events at District level. It was further enhanced for all severe weather events at city & District level in 2020. It is a four stage warning system which includes advisories, alert and warnings in a pre-defined colour coded format. It has also provision of 3-hourly updates of the bulletin during the warning stage that includes a record of realised rainfall, probable impacts and action suggested. It has been made mandatory to provide 3-hourly observations and warnings information to disaster authorities and other state users through WhatsApp group, website, E-mail and all other possible means of communication.

- Stage - 1 comprises of Heavy rainfall advisory (Watch) issued with a lead time of often 3-4 days, with 12 hourly updates and is disseminated mainly to the disaster managers of the City.
- Stage -2 is the Heavy rainfall Alert, issued nearly 48 hours prior to the occurrence of the event with 12 hourly updates. Alert will be disseminated via E-Mail, website, Social media, WhatsApp etc.
- Stage -3 will contain the Heavy rainfall warning issued 24 hours prior to the commencement of the event with frequent updates (06 hourly or as the situation demands). This bulletin will be disseminated to all user communities including local media using web page, e-mails, various social media, WhatsApp, etc.
- Stage-4 warning bulletins are issued 12 hours prior to the occurrence of the maximum rainfall spell. In this, warnings and all accompanying information including situation reports are updated to the users on a 3 hourly or hourly basis depending on the situation. This will also contain more specific information like which part of the city is likely to have intense rain spells in the ensuing three hours etc.

1.1.2.7.15 Web Based Dynamic Composite Risk Atlas (Web-DCRA) & DSS Tool

Web-DCRA&DSS Tool for Cyclone impacts forecasting for the area falling within 10 m elevation above mean sea level in 13 Coastal States/UTs of the Country has been developed under National Cyclone Risk Mitigation Project (NCRMP) Phase II and is installed/hosted at IMD, HQ, New Delhi. The responsibility for operating the DSS Tool at central level has been entrusted to IMD, being Nodal Agency for cyclone warning, while outputs of Web-DCRA & DSS Tool is being accessed by States through State specific credentials and utilized by Disaster Management Deptt. in all 13 coastal States/UTs for mitigation planning and decision making during cyclonic event. The Web-DCRA & DSS Tool has been operationalized during the cyclone 'Biparjoy' in 2023.

The outputs of Web-DCRA & DSS Tool are probabilistic and real-time hazard layer of cyclonic wind, storm surge and cyclone induced rainfall flooding, which can be used by

Disaster Management Authorities of the 13 cyclone-prone States and Union Territories (UTs) of India in advance mitigation planning as well as dynamic response during a real time cyclonic event. Using this Tool, dynamic and impact-based cyclone warnings will be release by IMD aiming to minimize economic losses and damage to property due to the intense weather system. The Offline version of Web-DCRA has been installed in State Disaster Management Authority (SDMA) for routine updation of exposure database by the coastal States.

1.1.2.8. Tele-communication Network in IMD

Telecommunication Division was set up in IMD at New Delhi in 1969 to cater the need of National Meteorological Service and strengthen the meteorological telecommunication in India. It has been renamed as Information System and Services Division (ISSD) in 2009.

It provides the support needed for exchange of meteorological data and processed weather products to the users, both national and international (including aviation data/ products) round the clock in near real time. It also provides administration of IT systems including management, processing and storage of operational data, workflow and system integration. A WMO recognised international training centre named as International Communication and Instrumentation Training Centre (ICITC) was established in New Delhi in 1977 for imparting training to departmental and extra-departmental (national/ international) officials in Meteorological Telecommunication.

1.1.2.8.1. Present Status of Circuits in the GTS connected with RTH, New Delhi

India Meteorological Department has its National Meteorological Telecommunication Centre (NMTC) with an Automatic Message Switching computer System (AMSS) which is connected to WMO Centers on the GTS. The existing RTH switching system "TRANSMET" is the state-of-the-art technology system. It consists of two Separate Automatic Message Switching System (AMSS) for National and International data exchange. Each AMSS works in hot standby mode for 100% redundancy in case of any failure.

1.1.2.8.2. RMDCN Link

RMDCN link has been upgraded to 6 Mbps RMDCN-NG (Next Gen) which handles 6 circuits viz. Tokyo, Moscow, Beijing , Germany, Exeter and Toulouse. This has improved the data exchange between these GTS centres.

1.1.2.8.3. VPN Circuits

MPLS VPN link at HQ New Delhi has been upgraded to 10 Mbps for smooth catering of data requirements to the national users. This will help in faster data reception at Head Quarter from DWR stations & NWP Centres to various users. Fifty five, IMD stations are connected with MPLS VPN connectivity speeds ranging from 512 kbps to 10 mbps. These VPN circuits are connected with forecasting Systems at various out stations, Doppler Weather Radar Stations, AMSS Centres and Regional Centres.

1.1.2.8.4. Internet Services

At present IMD has two independent Internet leased links of 150 Mbps from different

Internet service providers. IMD is also connected to 1 Gbps NKN (National Knowledge Network) link of NIC for internet, data exchange within Close User Group (CUG), Video conferencing & Telepresence services.

1.1.2.8.5. GMDSS

India has been designated as an issuing authority under the GMDSS program for Meteorological Area VIII (N). This covers the area of the Indian Ocean enclosed by the lines from Indo-Pakistan frontier in 23°45'N 68°E; 12°N 63°E, thence to Cape Gardafui; the east African coast south to equator, thence to 95°E to 6°N, thence to the Myanmar / Thailand frontier in 10° N 98° 30' E.

India Meteorological Department is transmitting daily two GMDSS bulletins for Met. Area VIII (N), one at 0900 UTC and other at 1800 UTC. During the period of cyclonic storms, upto four additional bulletins are also issued for GMDSS broadcast depending on the requirement. GMDSS bulletins are transferred to Earth Station of Bharat Sanchar Nigam Ltd (BSNL) at Ghaziabad through email and is also uploaded on IMD Website at URL:https://www.mausam.imd.gov.in and http://www.rsmcnewdelhi.imd.gov.in/. Ghaziabad Earth Station uplinks this information to INMARSAT for broadcast to all ships on high seas in Met Area VIII(N).

1.1.2.8.6. Regional Telecommunication Hub (RTH)

Regional Telecommunication Hub (RTH), New Delhi came into existence in the year 1971. The latest system has been installed in the year 2009 by Meteo France International (MFI). This is connected to WMO Centres on the GTS. The existing RTH computer system is driven primarily by dual HP server working on the state-of-the-art distributed networking technology. The whole system has been designed to handle high speed data circuits, message exchange through web interface, SMS & Email. It has also fax interface and audio alarm. NMTC New Delhi is connected to HPCS of NCMRWF Noida, IITM Pune through NKN and the HPCS computer at Regional Specialised Meteorological Centre (RSMC) New Delhi for instantaneous transmission of global observational data and processed information received via GTS. Moreover, NWP division of IMD is utilizing the resources of IITM HPCS to run their various models for product generations through CUG link of NKN. As regards the Meteorological Telecommunication Networks within the GTS, New Delhi telecommunication center is a designated RTH located on the Main Trunk Network (MTN). The MTN is the core network of GTS. It links together three World Meteorological Centers (WMCs) and 15 other RTHs on the MTN. The Centre is also a National Meteorological Centre (NMC) for telecommunication purposes within the framework of GTS. RTH New Delhi is directly connected with Tokyo, Exeter, Offenbach, Cairo, Jeddah, Beijing, Dhaka, Bangkok, Karachi, Male, Moscow, Oman, Colombo, Melbourne, Toulouse, Tehran, Katmandu, Bhutan and Yangon with different protocol and speed. Automatic Message Switching Systems (AMSS) are also operational at the major International airports of India viz. Mumbai, Delhi, Kolkata, Chennai, Nagpur and Guwahati. The circuits linking New Delhi (Palam), Mumbai, Kolkata, Chennai, Nagpur and Guwahati Airport computers with the NMTC New Delhi are working at 1 mbps speed.

The Mirror RTH at Pune is functional to act as Disaster Recovery Centre (DRC) which would be able to take over all the responsibilities of RTH New Delhi in case of any catastrophe at RTH New Delhi. This will also function as WMO WIS GISC for South East Asia and cater to all data needs for Indian users and all other WMO GISC centres in real time with 24 hours

1.1.2.8.7. Open WMO Information System (WIS)

The WMO Information system (WIS) is the single coordinated global infrastructure responsible for the telecommunications and data management functions. It is the pillar of the WMO strategy for managing and moving weather, climate and water information in the 21st century. WIS provides an integrated approach suitable for all WMO Programmes to meet the requirements for routine collection and automated dissemination of observed data and products, as well as data discovery, access and retrieval services for all weather, climate, water and related data produced by centers and Member countries in the framework of any WMO Programme. WIS is an enhanced information system capable of exchanging large data volumes, such as new ground- and satellite based systems, finer resolutions in numerical weather prediction and hydrological models and their applications.

GISC New Delhi is operational from 2016. This can be access through url http://wis.imd.gov.in. As per Resolution 51(Cg-XIV), following two centres have been designated as WIS DCPC under the principal GISC New Delhi: RTH (New Delhi) and RSMC- Tropical Cyclones New Delhi. The India Meteorological Department has joined the OpenWIS Association AISBL as Strategic Partner in July 2018. In coordination with KMA OpenWIS has been implemented in India. WIS 2.0 Strategy was approved at EC-69 in 2017(revised at EC-70). Under WMO WIS2 pilot project India also participated and installed the wis2.0 box. The urls are http://demo.wis2box.wis.wmo.int and http://wis2box.imd.gov.in. **IMD started deployment by ingesting SYNOP data into WIS 2 Box. Synoptic stations** in Aug 2023 **-** Around 419 stations data integrated in WIS 2 Node. Later, IMD added TEMP. After inclusion of software update with WIS 2.0 1.07b version, Satellite data is incorporated in WIS2BOX.

1.1.2.8.8. On line Briefing System at Chennai & Delhi (Palam)

IMD being only authorised meteorological service provider, provides the meteorological services to all the aviation operators at all the major airports. Earlier the service was provided manually and switched to online services w.e.f. 2008 on test basis. As the service got well appreciation from Aviation operators, IMD started Online Meteorological services through dedicated OLBS from AMO Palam and AMO Chennai since 2012-2013.

1.1.2.8.9. Weather Forecast Decision Support System:

IMD has introduced an in-house **Web-GIS-based Decision Support System (DSS)** designed to deliver tailored meteorological products and enhance dissemination methods.

Key Features of DSS:

- **Advanced Visualization Platform**
  It is a visualization platform to compare, comprehend and analyse various meteorological observations, prediction model products and arrive at a decision with respect to current status of weather system, their past evolution and the future characteristics, especially with respect to severe weather phenomenon and their socio economic impact.
- **Four-Layer Architecture**
  DSS has four-layer structure, comprising the Meteorological Information Communication System, Data Information and Processing System , Synthesized Integrated Visualization System, and Public Weather Information System. It has been developed by IMD entirely with open-source technologies
- **Sector-Specific Applications**

Adhering to the principle of **"Sarvajan Hitay, Sarvajan Sukhay"** (For the welfare of all), DSS supports socio-economic sectors under the umbrella of **UPHHEATT** (Urban, Power, Hydrology, Health, Energy, Agriculture, Transport, and Tourism). Tailored tools for weather-sensitive sectors, including agriculture, energy, health, transport, and urban planning have been developed as the part of DSS.

- **Accessibility for All**
  Dissemination of forecasts through platforms like Twitter, Facebook, YouTube, RSS feeds, SMS, email, and mobile apps are improved through DSS.
- **User-Centric Modules**:
  The "Mausamgram" feature provides localized observations, forecasts, and warnings based on user inputs such as place name, pin code, or geographic coordinates.

Future Directions

IMD envisions a robust upgrade of its forecasting and warning services to meet national needs through cutting-edge technologies and improved outreach mechanisms:

1. The DSS incorporates impact-based forecasting for severe weather events like cyclones, heatwaves, thunderstorms, etc with sufficient lead time.
2. **Enhanced Dissemination** through multilingual and multimedia formats (text, 2D, 3D, 4D visuals) across platforms accessible to all, including specially-abled users.
3. **Impact-Based Forecasts and Risk based** customized bulletins and warnings for the general public, disaster management authorities, and stakeholders with higher spatiotemporal resolution and better accuracy.
4. **Adoption of AI/ML and Big Data Analytics** for precise weather predictions and better understanding of weather impacts.
5. **Automation** in streamlined generation of forecast and waring bulletins and products, forecast verification, and dissemination of forecasts and warnings to all stakeholders.
6. **Data Archival and Retrieval**: Long-term storage and accessibility of products as per data retention policies to ensure easy access of data to all stakeholders including students, scientists, researchers.
7. **Feedback Mechanism**: Continuous improvement of services based on user inputs will be ensured through automated feedback mechanism including submission of feedback by users, its evaluation and report generation.

1.1.2.8.10. Short Message Service (SMS)

India Meteorological Department has taken various initiatives in recent years for improvement in dissemination of weather forecast and warning services based on latest tools and technologies. Since 2009, IMD has started SMS based weather and alert dissemination system through AMSS (Transmet) at RTH New Delhi. To further enhance this initiative, India Meteorological Department has taken the leverage of Digital India Programme to utilise "Mobile Seva" of Department of Electronics and Information Technology (DeitY), Ministry of Communication and Information Technology, Govt. of India for SMS based Warnings /Weather information for wide range of Users through the URL: https://services.mgov.gov.in/logout.do. Since 2014. Services Portal provides three modes of sending SMS depending on the user's needs. These modes are Quick SMS, Group SMS and Bulk SMS

1.1.2.8.11. Website of IMD

Website of IMD is operational since 1st June, 2000. A new redesigned IMD website has been made operational w.e.f.15.12.2015 It contains static & dynamically updated information on all India Weather and forecasts, special monsoon report, local weather forecasts for 300+ cities, satellite cloud pictures (updated every half an hour), animated satellite cloud pictures, NWP models like GFS, WRF etc. and prognostic charts, special weather warnings, tropical cyclone information and warnings, daily, weekly and monthly rainfall distribution maps, etc. This also contains a brief overview of the activities and services rendered by India Meteorological Department. This site can be accessed round the clock with the URL: http://www.imd.gov.in by the registered users. The list of email addresses of senior officers is available at IMD website.

The new IMD website dedicated to general public of URL: https://mausam.imd.gov.in/ was launched by Hon'ble Minister of Earth Sciences, Dr Harsh Vardhan on 27th July at the eve of Foundation Day Function of Ministry of Earth Sciences. It is designed in such a way that the information can be communicated without any technical failure to meet the requirement of general public.

There is a dedicated website http://www.rsmcnewdelhi.imd.gov.in/ for Regional Specialized Meteorological Center (RSMC), New Delhi. The Regional Meteorological Centres and meteorological centers have also their own websites. IMD is also providing 100 Indian city forecast on the WMO Website daily at http://worldweather.wmo.int/066/m066.htm .

India Meteorological Department developed its own intranet website with the address https://metnet.imd.gov.in exclusively for the use of IMD officials. All employees can access this site using their login ID. This is a very useful site and all IMD officials are accessing this site all over the country for numerous applications on official matters.
Apart from the national website Mausam, dedicated website are also being available for the respective Meteorological and Regional Meteorological centers all over India.

Since 2022, IMD is also providing severe weather guidance for all severe weather events including cyclone, heavy rainfall, wind, storm surge, heat/cold wave, thunderstorm, marine weather etc in GIS platform through dedicated web pages.

1.1.2.8.12. Mobile App

India Meteorological Department, Ministry of Earth Sciences has taken various initiatives in recent years for improvement in dissemination of weather forecast and warning services based on latest tools and technologies. To further enhance this initiative, the mobile App "Mausam" was launched by Hon'ble Minister of Earth Sciences, Dr Harsh Vardhan on 27th July 2020 at the eve of Foundation Day Function of Ministry of Earth Sciences.

IMD has also taken the leverage of Digital India Programme to utilise "UMANG App". The weather Services from IMD is also now available on "UMANG" App- Users can access observed weather, forecasts, radar images and be proactively warned of impending weather events."Meghdoot" App for Agrometeorological advisories is linked to Mausam website.

On the occasion of 150th year of establishment and service to the Nation at Vigyan Bhawan. Honorable Vice President of India Shri Jagdeep Dhankar Ji graced the occasion

and launched unified mobile app Mausam caters to the need of all categories of services including urban, power, health, hydrology, environment, agriculture, surface, transport, aviation, navigation and tourism sectors. The mobile app provides specialised services on current weather including temperature, humidity, wind, rainfall, sunrise/sunset, moonrise/moonset and AQI. MAUSAM app is freely available on mSeva AppStore, Google Play store, Apple App store. This app also have the **Crowd sourcing module also.**

1.1.2.8.13. Application Programming Interface (API's)

API stands for Application Programming Interface. It is like messenger that takes our request to a system and returns a response back to us via seamless connectivity. IMD has developed API's for cyclone forecast, Nowcast warning, Rainfall warning, City & district weather forecast/warning and Current weather. API's of IMD are being used by various stakeholders to extract data from our server and utilize the same for further applications developed by them. The stakeholders who are using IMD API's are Uttar Pradesh Government, Telangana Government, Kerala Government, Umang App, DD News, NDMA, Incredible India, KRC Network, NITI Aayog, Kerala State Disaster Management, Chandigarh Smart City Limited, Apple.com, Tomorrow.io, Uttarakhand Toursim, National Rice Research Institute Odisha, Madhya Pradesh Government, RMSI private limited, TV-9, CDAC etc.The details of the APIs can be found at the following link:- https://mausam.imd.gov.in/imd_latest/contents/api.pdf

1.1.2.8.14. Introduction to Crowd sourcing Interface

India Meteorological Department has launched its Crowd source web interface in the month of January 2021 to allow users to make their own observations. This feature can be found in the "Public Observation" section of Mausam website of IMD (https://city.imd.gov.in/citywx/crowd/enter_th_datag.php). There is no need to register to send observations and the associated weather damages caused. User can report their observations along with their state, district, location and time of the events. Following weather phenomena such as **Rain, Thunder/lightning, Hailstorm, Duststorm, Fog, Snow, Gusty wind** and the associated damage caused such as breaking of tree branches, uprooting of small/big trees, Telephone pole / Transmission tower damaged by bending, Telephone pole / Transmission tower uprooting, Damage to Kutcha structures (houses, cowsheds), Damage to Pukka structures (houses, shelters), Flooding of land, Damage/Death to livestock, Damage/Death to Humans, Damage to vegetation/crops.
User can share their location (lat./lon) by allowing the location through browser. Each phenomenon also includes additional information field that can be filled with free text. It is also possible to attach photos in jpg, jpeg, png & gif format.

1.1.2.8.15. Implementation of Common Alert Protocol (CAP)

India Meteorological department has started the dissemination of weather information through Common Alerting Protocol (CAP). These feeds automatically aggregated to the WMO Alert Hub at https://cap-sources.s3.amazonaws.com/in-imd-en/rss.xml. These alerts are also disseminated to Google, AccuWeather, Global Multi-Hazard Alert System (GMAS) portal (https://gmas.asia/).
IMD also participates as one of the alert generating agencies for the CAP alert projects of NDMA developed by CDOT. CAP has been implemented in India. During the cyclone 'Biparjoy' 32.67 cr, 'Michaung' 6.7 cr messages were disseminated through this CAP platform.

1.1.2.8.16. Information Technology Applications

Considering the ever growing influence of Information Technology in day–to-day affairs of the department, IT cell carries out the following activities:-

a) Coordination of IT initiatives of the department.
b) Supervise various IT projects to be implemented.
c) Asserting the IT literacy and imparting suitable mechanisms for its improvement.
d) Development of various in-house softwares for routine activities.
e) Dealing with the issue related to cyber security.

Conforming to these objectives, IT Division has developed an intra - IMD Portal, which is considered as the first step towards e-governance implementation in the department.

f) The e-office has been implemented to enable better environment friendly administration with an objective of paperless work.

1.1.2.8.17. Video Conferencing System

IMD has also implemented desktop video conferencing solution of NIC for all offices.

1.1.2.8.18. Social Networking sites

IMD has started its social media services through
Facebook (https://www.facebook.com/India.Meteorological.Department/) and
Twitter (https://twitter.com/Indiametdept),
Instagram (https://www.instagram.com/mausam_nwfc/),
Youtube:
https://www.youtube.com/channel/UC_qxTReoq07UVARm87CuyQw/featured?view_as=subscriber) and
Blog (https://imdweather1875.wordpress.com/)
accounts to disseminate its forecast and warnings etc. timely to the public as well as get back their feedback which may be used to know their needs to further improve the weather services. These accounts provide general information such as highlights of weather bulletins, satellite and Radar images, air quality of some major Indian cities and earthquake information. The social media platform is being used by IMD only for sharing the information among the public.

1.1.2.8.19. LAN Upgradation

In Upgraded LAN, several networking devices are being installed and integrated. The system connectivity is required to be made available to various units at HQ over LAN. Keeping in view of the operational requirement, new upgraded LAN with latest state-of-the-art technology to cover future requirement of more than 1500 nodes parallel to present setup to accommodate increased voluminous data/product flow un-interruptedly over LAN at IMD HQ. A 10 Gbps optical fibre backbone support is used to provide high availability of LAN as well as high volume of data flow.

1.1.2.8.20. Video Wall

The video wall system has been installed in all forecasting offices of IMD for visualization of weather observations, forecasts and products.

1.1.2.8.21. Cyber Security –

Load Balancer – IMD has installed the load balancer with WAF (Web application Firewall) which prevents the website from the attack of Web application security parameters tampering, cookie poisoning, SQL injection, Session Hijacking, Cross site scripting (XSS), Cross site Request Forgery (CSRF).

SSL Certificate - An SSL certificate is a digital certificate that authenticates a website's identity and enables an encrypted connection. SSL stands for Secure Sockets Layer, a security protocol that creates an encrypted link between a web server and a web browser. IMD has installed the SSL certificate to all the national websites of IMD. All websites are running on HTTPS.

1.1.2.8.22. Ongoing projects:

Provision of adequate communication system for data and product transmission:

a. Up Gradation of AMSS (Automatic Message Switching Systems) at Delhi-Palam, Kolkata, Mumbai and Chennai.

c. Implementation of cloud based services at IMD.

d. Implementation of all mode of communications including GPS Aided Geo Augmented Navigation-(GAGAN) Message Service (GAMES) for warning Dissemination through CAP (Common Alerting Protocol).

e. Early Warning Dissemination System (EWDS).

f. Upgradation of LAN with 100 Gbps optical fibre backbone support.

g. Implementation of SIEM and SOAR services at IMD.

h. Transmission of GMDSS bulletins through IRIDIUM satellite

1.1.3. Myanmar

During November 2024 to March 2025

During November to December 2024, 4 times low pressure areas totally formed over the Bay of Bengal. Out of them, some further intensified into one Well Marked Low Pressure Area, one Depressions, and one Cyclonic Storms. In monthly details, two low pressure area formed in November and one further intensified into a Cyclonic Storm "FENGAL". Two low pressure area formed in December and one intensified into a depression. During January to March 2025, no low- pressure areas formed over the Bay of Bengal.

1.1.3.1. Meteorological Component

a. Weather Summary

i. During November to December 2024

In the first week of November, Northeast Monsoon prevailed in the whole country. New rainfall records were observed at some stations in Bago, Ayeyarwady and Tanintharyi Regions, Southeastern Shan States. In December, new maximum temperature records were observed at Heho in Southern Shan State. New recorded Minimum Temperatures were observed at Myitkyina in Kachin State during the month of November and December 2024.

ii. During January to March 2025

Generally, January and February are winter period and the weather is cool and dry in the whole country. In month of February, the new rainfall record observed one station in Naypyitaw, and Yangon, two stations in Ayeyarwady Region. New minimum temperature record observed one station in Kachin on month of February and new maximum temperature record observed two stations in Southern Shan State during this period.

b. New Records of Meteorological Parameters

Rainfall, Maximum and Minimum Temperature Records from November to December 2024

Sr No	Date of New Record	Station	New Rainfall Record		Old Rainfall Record		Date of Old Record	Past Years of opening station
			(mm)	(inches)	(mm)	(inches)		
1.	7-11-2024	Phyu	209	8.23	78	3.07	10-11-2014	40
2.	7-11-2024	Namsam (Southern Shan)	154	6.06	79	3.11	1-11-1999	30
3.	7-11-2024	Zalun	123	4.84	72	2.83	1-11-1996	36
4.	7-11-2024	Pinlaung	104	4.09	71	2.80	2-11-2001	58
5.	7-11-2024	Gyobingauk	85	3.35	75	2.95	18-11-1988	40
6.	14-12-2024	Kawthaung	156	6.14	140	5.51	5-12-1972	78

New Maximum Temperature Records in 2024 (November and December)

Sr No	Date of New Record	Station	New Maximum Record		Old Maximum Record		Date of Old Record	Past Years of opening station
			(°C)	(°F)	(°C)	(°F)		
1.	14-11-2024	Gangaw	36.4	97.5	35.8	96.4	3-11-2019	60
2.	4-12-2024	Heho	30.8	87.4	30.6	87.1	15-12-2020	46

New Minimum Temperature Records in 2024 (November and December)

Sr No	Date of New Record	Station	New Minimum Record		Old Minimum Record		Date of Old Record	Past Years of opening station
			(°C)	(°F)	(°C)	(°F)		
1.	30-11-2024	Myitkyina	8.2	46.8	9.5	49.1	30-11-2006	58
2.	18-12-2024	Myitkyina	4.6	40.3	6.5	43.7	30-12-1999	58

Rainfall, Maximum and Minimum Temperature Records during January to March 2025

New Rainfall Records

Sr No	Date of New Record	Station	New Rainfall Record		Old Rainfall Record		Date of Old Record	Past Years of opening station
			(mm)	(inches)	(mm)	(inches)		
1.	25-2-2025	Hmawbi	39	1.54	37	1.46	22-2-1996	71
2.	26-2-2025	Labutta	34	1.34	10	0.39	3-2-2015	11
3.	26-2-2025	Ngathaing chaung	23	0.91	18	0.71	18-2-2023	36
4.	26-2-2025	Ela	17	0.67	8	0.32	15-2-2017	19

New Minimum Temperature Records

Sr No	Date of New Record	Station	New Minimum Record		Old Minimum Record		Date of Old Record	Past Years of opening station
			(°C)	(°F)	(°C)	(°F)		
1.	5-2-2025	Myitkyina	7.0	44.6	7.2	45.0	9-2-1997	59
2.	5-3-2025	Myitkyina	9.8	49.6	10.0	50.0	1-3-1983	59

New Maximum Temperature Records

Sr No	Date of New Record	Station	New Maximum Record		Old Maximum Record		Date of Old Record	Past Years of opening station
			(°C)	(°F)	(°C)	(°F)		
1.	21-1-2025	Heho	31.8	89.2	30.6	87.1	27-1-2023	46
2.	30-3-2025	Loilin	35.5	95.9	33.7	92.7	21-3-2021	58

c. Warning Issued for Meteorological Situation

Storm warnings, untimely rainfall warnings, heavy rainfall warnings, situation of increasing Day Temperature and decreasing of Night Temperature News and special weather news were issued for the whole country in accordance with the occurrences of weather disturbances in the Bay of Bengal (low pressure area, depression, cyclonic storm, etc), western disturbances and easterly waves conditions and remnants of Typhoon from the South China Sea. The warning issues are showing in the following tables:

I During November to December 2024

No.	Type of Warning	Frequency of issue
1.	Low Pressure Area	24
2.	Depression	6
3.	Deep Depression	11
4.	Cyclonic Storm	4
5.	Rainfall Record	1
6.	Maximum Temperature Record	2
7.	Minimum Temperature Record	2
8.	Rainfall Record	2
9.	Special Weather News	6

II During January to March 2025

No.	Type of Warning	Frequency of issue
1.	Untimely Rainfall Warning	7
2.	Rainfall Record	2
3.	Maximum Temperature Record	2
4.	Minimum Temperature Record	2

d. Significant weather conditions

i. During November to December 2024

In the first week of November, due to the clouds of remnant Typhoon "Yinxing" in the South China Sea moving towards the Gulf of Thailand through the South China Sea, and the interaction of warm air from the Andaman Sea and the Bay of Bengal with cold air moving from the high pressure area over China, and atmospheric instability condition in the Andaman Sea and southeastern Bay of Bengal, new rainfall records were observed 8.23 inches in Phyu, 6.06 inches in Namsam (Southern Shan), 4.84 inches in Zalun, 4.09 inches in Pnlaung and 3.35 inches in Gyobingauk. In the third week of November, due to the Cyclonic Storm "FENGAL" which crossed North Tamil Nadu & Puducherry coasts caused heavy rainfall in West Coast, Northern, Deltaic and Central Myanmar Areas. In the second week of December, it was observed fairly widespread to widespread rain in Eastern, Deltaic and Southern Myanmar Areas, due to the easterly wave, clouds moving from the Andaman Sea and Bay of Bengal, and development of convective clouds.

ii During January to March 2025

In January, it was observed that isolated rainfall occurred only in Northern and extreme Southern part of Myanmar, and observed below normal condition in the whole country. In February, due to the convergence of warm air from the Andaman Sea and Bay of Bengal and cold air from the China high pressure system, the western disturbances and eastern disturbances, untimely rain occurred in most parts of the country during 24th to 27th February 2025 and new rainfall records were observed 1.54 inches in Hmawbi, 1.34 inches in Laputta, 0.91 inche in Ngathaungchaung and 0.32 inch in Naypyitaw (Ela) on 25th -26th February. During this period, maximum temperature was recorded two stations in Southern Myanmar and minimum temperature was recorded at Myitkyina in Kachin State.

1.1.4. Oman

The Directorate General of Meteorology (DGMET) in Oman operates under the Civil Aviation Authority, which serves as the regulatory body overseeing its functions. The directorate comprises three distinct departments: Research and Development Department, Technical Services Department, and Weather Forecasting and Early Warning System Department. Additionally, the National Multi-Hazard Early Warning Center, within the directorate, plays a key role in providing essential services related to weather and tsunami monitoring and alerting.

Since the beginning of 2023, the center has undergone substantial development through the Muzn Strategic Program, which is driven by six primary objectives that align with 17 strategic goals and over 100 strategic initiatives. Furthermore, the program encompasses 12 major projects that are instrumental in accomplishing these goals. The core purpose of this program is to build the center's capacity by enhancing the competence of its personnel, improving systems and products, and strengthening its infrastructure.

In July 2024, DGMET successfully renewed its quality certifications for the next three years, achieving ISO 9001, ISO 27001, and ISO 17025. The directorate also ensures compliance with the standards set by various international and regional organizations, including the International Civil Aviation Organization (ICAO), the World Meteorological Organization (WMO), the Intergovernmental Oceanographic Commission (IOC-UNESCO), and others.

1.1.4.1. Weather Forecasting and Early Warning System Services:

The Weather Forecasting and Early Warning Department provides the following services:

- Daily public weather bulletins
- Marine bulletins and marine maps
- Special forecast bulletins for over 10 contracted entities
- City forecasts
- Governorate bulletins
- Road-to-Salalah bulletins
- Weather updates through social media platforms, including satellite and radar images
- Weather reports, alerts, and warnings for surface and upper-air lows, troughs, and tropical systems
- Weekly seasonal weather outlooks for cloud formations over the Al Hajar mountains, tropical depressions over the Arabian Sea, and the Dhofar Governorate's Kharif (monsoon) season
- Hourly METAR reports for 78 locations and TAF reports for 14 airdromes
- FIR SEGMET, SIGWX, and regional QNH updates
- Airdrome warnings
- Earthquake and tsunami monitoring, as well as tsunami advisories and warnings

1.1.4.2. Research and Development Department Services:

The Research and Development Department focuses on the following activities:

- Provision of advanced numerical weather prediction models, along with the necessary analysis and fine-tuning
- Conducting research and case studies on weather-related phenomena
- Providing training for weather forecasters and other key stakeholders
- Hosting the 7th Center of Excellence for Satellite Applications, which includes the organization of training programs and monthly forums
- Conducting climatological studies and producing relevant climatological bulletins
- Offering climatological data services

1.1.4.3. Technical Services and Maintenance Department Responsibilities:

The Technical Services and Maintenance Department is responsible for the following services:

- Installation and maintenance of both hardware and software components related to tsunami and meteorological systems
- Installation and maintenance of weather stations, tidal stations, GPS stations, wave radar stations, weather radars, and other equipment
- Providing support and supervision for stakeholders' weather-related projects
- Overseeing DGMET's projects
- Calibration of weather stations and sensors

1.1.4.4. Platforms for Disseminating Services:

DGMET uses the following platforms to effectively communicate its bulletins and services:

1. Official DGMET website
2. DGMET mobile application
3. Social media platform X (formerly Twitter)
4. SMS, email, and fax communication
5. Cell Broadcasting Services (CBS)
6. Call center
7. Radio and TV interviews

1.1.4.5. Recent and Ongoing Projects:

The following key projects are currently underway:

- Upgrade of the flash flood guidance system
- Upgrade of DGMET CPUs and monitors
- Revamping the DGMET website and mobile app (scheduled for launch in 2025)
- Installation of five new weather stations
- Upgrade of the PC cluster, increasing computational power to 80 teraflops
- Enhancement of the local numerical model to improve resolution to 6.5 and 2.1
- Introduction of additional global weather models, including Unified10, ECMWF, and ICON

1.1.4.6. DGMET Stations:

The Directorate General of Meteorology operates the following stations:

- 78 weather stations
- 10 tide gauge stations
- 5 wave radar stations
- 5 weather radar stations (with plans to install an additional radar in 2025-2026)
- 10 GPS stations
- 26 seismic stations (data sharing with the Earthquake Monitoring Center)
- 2 radiosonde stations

1.1.4.7. Public Awareness Activities:

DGMET has actively engaged in public awareness initiatives, including:

- A national campaign to raise awareness about the risks associated with weather phenomena and tsunami waves, which took place in North Al Batinah Governorate from May 12 to May 15, 2024. This campaign featured:
- Meetings, lectures, and field seminars with 1,108 participants
- Awareness lectures and practical exercises attended by 1,163 participants
- An accompanying exhibition across 12 schools, attracting 415 visitors
- Awareness publications and media coverage targeting residents of the governorate and the Sultanate at large
- The second national campaign, focusing on similar topics and objectives, was held in the Dhofar Governorate from September 29 to October 7, 2024.
- The third national campaign, was conducted during mid-April 2025 targeting

another governorate including Masirah island .
- Participation in three additional exhibitions throughout the year
- Conducting a weather forecasting workshop for the public, specifically targeting weather enthusiasts.

1.1.4.8. Publications:

DGMET main publications:
- Monthly climatological reports with a three-month outlook
- A climatological booklet for 2023
- A climatological booklet for 2024

1.1.4.9. Main weather events

(a) Weather events during 2024:

Al-Riyan Trough: Between March 4 and March 6, 2024, the weather in the Sultanate was influenced by a trough associated with a low-pressure system. This resulted in rainfall across several governorates, including Al Dakhiliyah, North and South Sharqiyah, Dhahirah, and Al Wusta. The intensity of the rainfall varied from heavy to moderate, accompanied by active descending winds and hail in mountainous regions.

Al-Mutayr Low-Pressure System: The Sultanate experienced the effects of a low-pressure trough from April 13 to April 18, 2024, which resulted in heavy rainfall and severe flash floods. The weather event, known as the "Al-Mutayr Low-Pressure," was closely monitored and extensively reported through various media channels, including television, radio, and social media. The coverage included 85 interviews and approximately 102 social media posts, ensuring the swift dissemination of alerts and information to all segments of society. Awareness campaigns were conducted in three languages: Arabic, English, and Urdu. During this period, two reports and four alerts were issued. This weather event was deemed exceptional, as some Civil Aviation Authority stations recorded exceptionally high rainfall in a short period. For instance, the Wadi Bani Khalid station recorded 91.6 mm of rain in just one hour. Additionally, significant daily rainfall totals were noted, with the Shinas station recording 180.2 mm. The highest wind gusts were registered at the Ibri station, where wind speeds reached 69.9 knots.

Tropical Storm (Asna): The tropical system initially developed as a low-pressure area northeast of the Indian subcontinent on August 24, 2024, and strengthened into a tropical storm by August 30, 2024, with estimated wind speeds of 34-40 knots near its center. At the time, the system was approximately 920 kilometers from the coasts of the Sultanate of Oman. The storm's impact on Oman included rough wave heights ranging from 3 to 5 meters, cloud formation, and scattered rainfall in the governorates of South Sharqiyah and Al Wusta. On September 1, 2024, the storm's classification was downgraded to a tropical depression as it gradually weakened and moved southward through the Arabian Sea.

Tropical Depression and Upper Air Low Trough (Al Sayyal): Between October 14 and October 17, 2024, a weather system emerged, combining a tropical depression over the Arabian Sea, approaching the southeastern coasts of Oman, and an upper air trough over the northern parts of the Sultanate. This system brought significant rainfall, exceeding 200 mm in some areas, accompanied by severe flash floods

(b) Weather events during Jan- Apr 2025: there was no significant weather.

1.1.5. Pakistan

1.1.5.1. Observational Network:

Pakistan Meteorological Department (PMD) has around 110 surface observing stations (synoptic observatories) across Pakistan, 334 rain gauges (RGs), 28 Pilot Balloon Observatories (PBO), 85 automatic weather stations (AWSs), 34 Agromet stations, 31 Aeronautical Meteorological Offices, 7 Weather Surveillance Radars (with 2 DWR at Karachi and Islamabad) (Fig.1a-b). There are three Meteorological satellite (FY 4B, FY 2G & FY 2H, courtesy to China) receiving stations installed at Karachi, Lahore and Islamabad which provide data and products. The Numerical Weather Prediction (NWP) High-resolution Regional Model; Grapes Meso HR, WRF, ECMWF, ICON & GFS are used at PMD.

1.1.5.2. PMD Services

PMD provides services in the following fields:

- Aviation Met service (ISO 9001:2015 certified)
- Marine Meteorological Service (IMSAS audited 2022)
- Public weather forecast
- Early warnings for Meteorological hazards, torrential rains, floods, drought, heat/cold waves, Cyclone, Tsunami & etc.
- Agromet service
- Drought monitoring
- Seismic monitoring and Tsunami early warning
- Flood forecasting
- Climate data archiving
- Astronomical service &
- Provision of Trainings like Basic Forecasting Course (BIP-M), Preliminary Meteorology Course, and Initial Meteorology Course (BIP-M) to regional countries (Afghanistan, Bhutan, Bangladesh, Nepal, Maldives, Sri Lanka, Myanmar, Djibouti, Yemen, and Syria).

1.1.5.3. Significant Extreme Weather Events that affected Pakistan in 2024:

The year 2024 was climatically one of the most volatile in Pakistan's history, marked by extreme rainfall, record-breaking heat, and rare cyclonic activity. With 31% above-average annual rainfall, 2024 ranked as the 7th wettest year since 1961, including record rains in Sindh (+94%) and Balochistan (+82%), where such high rainfall is historically uncommon. The Cyclonic Storm ASNA, only the 4th August cyclone in recorded history (since 1893), struck the Northeast Arabian Sea, bringing wind gusts of 40–46 knots and triggering widespread flooding in Karachi, Thatta, and Badin.

Temperature extremes were equally alarming. The national mean temperature was 0.71°C above average, ranking 9th highest on record, while the mean minimum temperature was 1.29°C above normal—the 2nd warmest ever. Jacobabad hit 52°C in May (tying its all-time high), and Karachi recorded an unprecedented 32°C nighttime temperature in July. The months of October and November were especially warm, with Sindh's October average temperature exceeding normal by 3°C. Fog and smog crippled Punjab in January and November, causing severe transport and health issues. These events strongly underline Pakistan's increasing vulnerability to climate variability and global warming.

(a)Tropical Cyclone (TC) *ASNA* Monitoring

During the year 2024, a rare feature was the development of Cyclonic Storm, CS (ASNA) in the month of August. Usually during peak monsoon, TCs do not develop in the North Indian Ocean and ASNA proved to be the only 4th CS in the recorded history (during 1893-2023) of the North Indian Ocean, the previous ones being in 1944, 1966

and 1976. PMD's Tropical Cyclone Warning Centre (TCWC), Karachi monitored the TC ASNA and issued 10 alerts from 29 Aug - 1 Sep. The TC *ASNA* (اسنی) formed on 30th August over the Northeast Arabian Sea off Pakistan southern coast, Sindh. The CS dates back to 16 August when a monsoon low developed over the Northwest Bay of Bengal and adjoining west Bengal and Bangladesh. It located over South Bangladesh during 17-19 August and then over North and West Bangladesh during 20-23 August. Moving westward, it concentrated first into a well-marked low over Uttar Pradesh (India) and then into a Depression over Madhya Pradesh (India) on 25 Aug. It further intensified into a Deep Depression (DD) over East Rajasthan (India) on 26 Aug and moved on to north Gujarat (India) on 27 Aug and then over Rann of Kutch (India) and adjoining southeast Tharparker (Pakistan) where it remained stationary for following two days. Having moved southwest and emerging over the Northeast Arabian Sea and meeting favourable environmental conditions (warm SSTs (28-29C), low/moderate vertical wind shear, VWS, and well-organized upper-air outflow/divergence) it further intensified into a Cyclone Storm (ASNA) off Pakistan's Sindh coast on 30th at 1100PST (0600 UTC). Thereafter, the CS (ASNA) kept tracking west-southwest for next two days. Reaching over Northwest Arabian Sea and encountering unfavourable conditions of cooler SSTs, higher VWS and dry air entrainment from Arabian Peninsula it then weakened first into a DD from 1st September night and then into a Depression from 2nd Sep morning (see adjacent Fig-3).

Cyclonic Storm (ASNA) impacts over Pakistan coast

On Friday, 31 August the CS, *ASNA,* induced squally winds of 40-46kts speed over Karachi, and other adjacent southern districts, Sujawal, Thatta and parts of Badin associated with widespread rain/thunderstorm with some extremely heavy falls over Sothern Sindh which uprooted dozen of trees, smashed signboards and blown away loose structures. Apart from this, its induced circulation also produced heavy rains in Balochistan, Khyber Pakhtunkhwa (KP), Punjab, Gilgit Baltistan (GB) and Azad Jammu & Kashmir (AJK) during 25-31 August (source: pmd.gov.pk)

(b)Tropical Depression

A low-pressure area first formed over Southeast Arabian Sea on 11 October, which later turned into a Depression and moved in northwest direction towards Oman coast. PMD kept monitoring it and issued eight advisories from 11-15 October.

1. 1.5.4. Agrometeorological Service

PMD has a network of 34 agrometeorological observatories across Pakistan with five regional agromet centres (RAMCs) and a dedicated National Agromet Centre (NAMC), Islamabad which monitor and record the agrometeorological observations from dawn to dusk. NAMC, Islamabad issues the agromet bulletins on weekly, decadal, monthly basis and seasonal outlook along with seasonal crops report.

1.1.6. Thailand

1.1.6.1. Review of tropical cyclones originating over the Bay of Bengal that affected/impacted Thailand from 1 January 2024 to 31 March 2025

Thailand is situated in the middle of Southeast Asia, with its weather primarily influenced by the southwest monsoon in the rainy season (from mid-May to mid-October) and the northeast monsoon in winter (from mid-October to mid-February), along with tropical cyclones from the Andaman Sea and the South China Sea. For the period of January 2024 – March 2025, there was only one tropical cyclone named "REMAL" (01B), which originated in the Bay of Bengal and affected rainfall in Thailand during this period, as illustrated in Figure 2.6.1. (a).

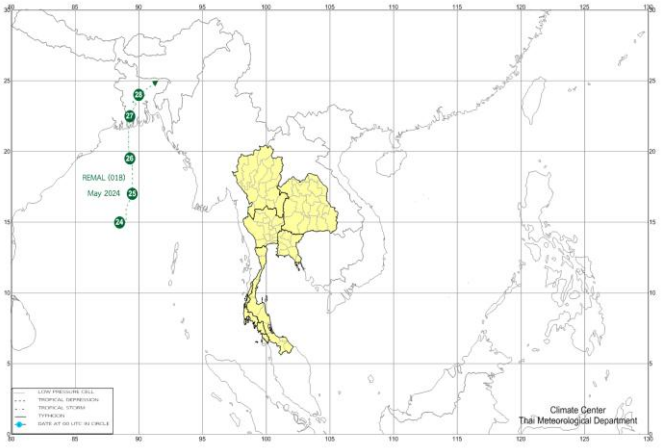

Figure 2.6.1(a): Track of the tropical cyclone "REMAL" (01B), forming in the Bay of Bengal, which partially affected rainfall in Thailand.

The tropical cyclone "REMAL" (01B) initially developed from an active low-pressure cell that intensified into a tropical depression over the central Bay of Bengal on 24 May 2024. It gradually strengthened into a tropical cyclone on 25 May 2024. It made landfall in the southern region of Bangladesh around midnight on 27 May 2024, subsequently weakening into a tropical depression and then into a remnant low-pressure cell over northern Bangladesh the following day. Due to the combined effects of Cyclone Remal and a low-pressure cell over the lower northern and central region of Thailand and the Gulf of Tonkin on 24 May 2024, along with the interaction between Remal and the rather strong southwest monsoon from 25 to 27 May 2024, widespread rain was reported, especially across the Northern region of Thailand for the period of 24 to 27 May 2024, as shown in figure 2.6.1.(b). As a result of these circumstances, Kamphaeng Phet province experienced gusty winds on 26 May 2024, flooding was reported in Tak province on 23-24 May 2024 and a landslide occurred in Mae Hong Son province in the Northern Region on 28 May 2024.

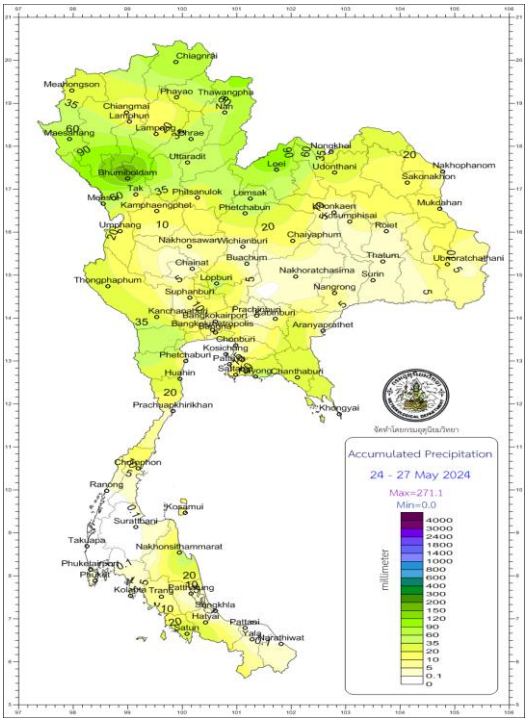

Figure 2.6.1 (b): The accumulated rainfall for the period of 24 - 27 May 2024 under the influence of REMAL (01B).

1.1.7. United Arab Emirates

The National Center of Meteorology (NCM) of the United Arab Emirates is the country's official authority responsible for weather observation, forecasting, climate monitoring, and early warning services.

NCM operates a modern and integrated meteorological infrastructure that includes over 140 automatic weather stations, 22 rain gauges, 7 weather radars, 34 air-quality monitoring stations, 18 falling-dust stations, an ozone monitoring station, satellite image reception systems, upper-air radiosonde stations, wind profilers, and a lightning detection network. All observational data are centralized in a unified national database that supports forecasting, climate services, aviation, marine operations, and environmental monitoring.

For numerical weather prediction, NCM runs six advanced forecasting models: COSMO, ICON, WRF-GFS, WRF-ECMWF, WRF-Hydro, and WaveWatch III. These models are executed four times daily and provide forecasts up to 10 days ahead with resolutions as fine as 1 km, enabling highly detailed prediction of weather, hydrological, and marine conditions.

NCM delivers meteorological services to more than 200 domestic destinations and also supports international users. Forecasts, warnings, and environmental information are disseminated through mobile applications, web portals, websites, and other digital platforms, making weather information easily accessible to the public and specialized sectors.

The center plays a critical role in disaster risk reduction and national emergency management. NCM works closely with the Ministry of Interior (MOI), the National Emergency Crisis and Disaster Management Authority (NCEMA), and the National Disaster Management Office (NDMO). Through the national Early Warning System, NCM provides timely alerts and forecast guidance to support preparedness and response to severe weather events such as heavy rainfall, floods, strong winds, dust storms, and tropical systems.

A notable example was the Arabian Sea depression of October 2024, which was continuously monitored by NCM from its formation over the Arabian Sea through its movement toward Oman and the UAE. NCM issued forecasts and warnings for strong winds, reduced visibility, and rainfall that affected parts of the UAE, particularly Al Ain, internal regions, and the Western Region. Upper-air observations and numerical model analyses helped identify high moisture levels, cooling in the mid-level atmosphere, and changes in wind patterns that supported rainfall development.
Overall, NCM represents one of the most technologically advanced meteorological services in the region, combining dense observation networks, high-resolution forecasting models, digital service delivery, and strong coordination with national emergency authorities to protect lives, property, and critical infrastructure across the United Arab Emirates.

1.1.8.Iran

The Iran Meteorological Organization (IRIMO) is the national agency responsible for weather monitoring, forecasting, severe weather warnings, and the dissemination of meteorological information. Through its Oceanic and Atmospheric Science Center, IRIMO provides continuous forecasting services to protect lives, infrastructure, and economic activities, particularly in coastal and marine regions.

Iran's meteorological system is designed to monitor and forecast a wide range of hazardous weather events, including floods, flash floods, strong winds, storm surges, lightning, and tropical cyclones. Forecasts are generated using advanced numerical weather prediction models running on supercomputers, with meteorologists analyzing model outputs to produce accurate public forecasts and warnings.
Meteorological observations are collected from multiple sources, including:

- Surface synoptic observation stations
- Coastal meteorological stations
- Weather satellites
- Weather radar systems
- Voluntary Observing Ships (VOS)
- National and international meteorological databases and observation networks

To improve forecast accuracy, IRIMO integrates domestic observations with global meteorological data received through the Global Telecommunication System (GTS) and international organizations such as NOAA, ECMWF, JMA, the Joint Typhoon Warning Center (JTWC), and other regional meteorological agencies.

The organization employs several numerical weather prediction models, including:

- Global Forecast System (GFS) for large-scale atmospheric prediction.
- Weather Research and Forecasting (WRF) model for high-resolution regional forecasts.
- SWAN (Simulating WAves Nearshore) model for forecasting wind-generated waves in the Caspian Sea, Persian Gulf, and Gulf of Oman.
- A major focus of Iran's meteorological services is marine meteorology and tropical cyclone monitoring. IRIMO issues:
- Tropical Weather Outlooks
- Cyclone Track Forecasts
- National and Hourly Weather Bulletins
- Wind and Storm Surge Warnings
- Marine Operational Forecasts for the Persian Gulf and Gulf of Oman
- Forecasts for ports and offshore oil platforms

In 2024, IRIMO produced thousands of operational marine forecasts, including daily marine bulletins, point forecasts for ports and offshore facilities, and numerous yellow- and orange-level marine weather warnings, demonstrating its extensive operational forecasting capacity.

Weather warnings are communicated through multiple channels to ensure timely disaster preparedness. Information is shared with national disaster management authorities, the Red Crescent, the Ministry of Interior, flood management agencies, local authorities, media organizations, and the general public through television, radio, newspapers, and the official IRIMO website.

Beyond operational forecasting, IRIMO contributes to meteorological research, international cooperation, and professional training by organizing scientific conferences and hosting World Meteorological Organization (WMO) Regional Training Centre courses on topics such as severe convection, drought monitoring, and early warning systems.

1.1.9. Qatar

The highlights of accomplishments in the field of training and development during the year 2024, which has been one of our top priorities. This stems from our deep belief in the importance of capacity building and enhancing technical competencies. The key points include:

1. Conducting several specialized training courses covering various fields such as meteorological observation, forecasting, and the use of modern technologies in meteorology.
2. Qatar Meteorology Department of Civil Aviation Authority (QMD) has published 'Climatological Atlas for the State of Qatar', which provides long-term statistics on various meteorological variables using observations from a well representative network of stations in Qatar spanning 30-years.
3. Climate Section of QMD has been carrying out research on assessing the impact of climate change on Qatar and the GCC region using two hundred years of climate simulations from CMIP6 models under different GHG emission scenarios.
4. Climate Section has set up a dust forecast system on an experimental basis (WRF-Chem) and is carrying out sensitivity experiments to improve its performance in the GCC region. This work is being carried out in collaboration with Indian Institute of Tropical Meteorology (IITM), Pune and the Integrated Land Ecosystem-Atmosphere Processes Study (iLEAPS). A research paper entitled 'Performance and Sensitivity Analysis of a Dust Forecast System During the 2022 FIFA World Cup in Doha, Qatar' is under review with Journal Geophysical Research
5. Increasing opportunities for staff to participate in international workshops and conferences, enabling them to stay updated with the latest trends and technologies. These efforts are part of our ongoing commitment to developing capabilities and improving performance. We will continue in this direction throughout 2025 as part of our strategic objectives.

1.1.10. Maldives

1.1.10.1. Meteorological Component

On the occasion of World Meteorological Day, 23 March 2025 with the theme "Closing the Early Warning Gap Together", the government of Maldives reaffirms its commitment in working together in closing early warning gap through investments in advanced meteorological infrastructure to provide timely and accurate warnings to the last mile of the community. Besides social media posts, MMS experts participated in some local TV talk shows to create public awareness on the occasion of World Meteorological Day.

The Government of Maldives endorsed and published the Early Warning For All (EW4All) road map for scaling up the Early Warning System to achieve the objectives of the EW4All initiative of UN Secretary General.

Maldives Meteorological Service, conducted its 9th National Monsoon Forum on 17 April 2025 in Addu City Gan with the supported from UNEP and GCF. The main objectives of the Monsoon Forum is to review the 2024 SW monsoon and 2025 NE Monsoon Season , to receive experience-based recommendations for enhancing end-to-end forecast generation and application system, to present the seasonal outlook for the 2025 NE Monsoon Season as well as the updates in the current climate conditions, to discuss potential impacts and risks as well as matrices for impact-based forecasting to inform planning, decision-making, and the inception of preparedness strategies by relevant sectors through the integration of information of various timescales, prioritize recommendations to address residual gaps in forecast generation and application. Regional Multi-Hazard Early Warning System for Asia and Africa (RIMES), National Disaster Management Authority (NDMA) participated as technical partners. A total of 52 participants including Addu City and Fuvahmulah City based government offices, CSO's, NGO's and individuals representing various user communities also participated in this forum.

1.1.10.2. Observations

Maldives has 5 meteorological stations all are manned 24 hours, both synoptic and aviation reports are made on all five stations. Only one of them is categorized additionally as upper-air station. Altogether 43 Automatic Weather Stations (AWS) have been installed throughout the country. In addition, stand-alone rainwater collectors are installed in 2 area including Capital City. However, sustaining of these stations is highly challenging due to financial limitations. Under Systematic Observation Financing Facility (SOFF), upgrade of 5 manned synoptic stations and radio sonde' upper air station work is under progress.

There is an ongoing Asian Development Bank supported project for upgrade of existing Doppler Weather RADAR and a procurement of another RADAR for southern atolls. Additionally, under grant aid fund provided by the Government of Italy, 4 X-band RADARs will be installed to fill the remaining gaps in the RADAR coverage across the country.

Long range lightning detection sensors were installed in collaboration with Chinese Academy of Science.

1.1.10.3. Meteorological Satellites.

An integrated satellite receiving system generously donated by China Meteorological Agency installed on 25 October 2012. This CMACast system receives Satellite imageries from FY2E and FY2D series of Chinese geostationary satellites at an interval of 30 minutes. There is requirement to upgrade the system for reception of higher temporal and spatial data set for better monitoring and forecasting high impact sever convective weather systems. Additionally, we utilize various satellite images and products from IMD website, Japanese (JAXA) website. Satellite data software application like RAPID (ISRO), MICAPS and SWAP (CMA) are being utilized for operational weather monitoring and forecasting.

1.1.10.4. Numerical Weather Prediction

There has been an improvement in NWP capacity with the enhancement of computation capacity under USAID climate adaptation project. Currently WRF model at 9km and 3km resolution is being tested in the HPC system for operationalization.

MMS need more of its staff time to be dedicated on research of WRF model to fine-tune on physical parameterization so that the model skills can be enhanced. MMS need to train its staff on data assimilation so that satellite radiance data, RADAR and local AWS data can be assimilated on the WRF system for a better performance.

In addition to local NWP products, Maldives Meteorological Service continues to use NWP products provided by RIMES, ECMWF, NCMRWF(India) and others customized products facilitated in the WMO-SWFP and RSMC on the web portal.

1.1.10.5 Telecommunications

The 200 mbps internet service and the computer-based telecommunication system between the local Meteorological Offices and the National Meteorological Centre (NMC), functioned very well.

NMC's Global Telecommunications System (GTS) and Message Switching System (MSS) MESSIR-COMM message switching system developed by COROBOR is a TCP/IP based multi-channel communication link that is capable of handling vast amount of data. The system is currently under maintenance.

1.1.10.6. Disaster Prevention and Preparedness Component

Maldives Meteorological Service is the authoritative organization in the country for issuing advisories and warnings related to meteorological, hydrological, tectonic, and Tsunami disasters. To accomplish these tasks, MMS has prepared the Standard Operating Procedures (SOP) to act upon any likely event of meteorological, hydrological, tectonic, and Tsunami disasters. MMS acquired a High-Resolution Satellite Image Receiving System, Doppler Weather Radar, number of Automatic Weather Stations, broadband and short-period seismometers within the framework of establishing a National Multi-Hazard Early Warning System. Maldives' sea level network comprises of three tide gauges in Hanimaadhoo, Male' and Gan to monitor low frequency changes in sea level associated with global sea level rise or decadal climate variations like other gauges in GLOSS network. They have been upgraded with more sensors such as radar/ pressure/ float-based water level sensors, and the reference level float switch sensors and with these improvements, it shall even detect any slight variations in sea level due to a tsunami wave.

1.1.10.7. Warnings and Advisories

During 2024 Cyclone Season, the severe weather monitored locally through manned Meteorological Stations, Automatic Weather Stations and CMACast satellite image-receiving system. Products of in-house WRF model output and various numerical weather prediction models and dynamical-statistical models received through internet utilized to predict the variations in the atmosphere. NWP guidance from RIMES and Bulletins from RSMC – New Delhi used to predict the intensity and track of the Arabian Sea and Bay of Bengal Systems. Maldives Meteorological Service followed the Standard Operating Procedure (SOP) and issued 365 Alert level 1 (white), 149 Alert level 2 (yellow) and 3 Alert level 3 (Orange), no alert was issued at Alert level 4 (Red).

Apart from Alerts, interviews/ personal briefings to sea travelers, fisherman, National Defense, Police, Disaster Management and various media were conducted. Apart from severe weather or tropical cyclone warnings, earthquake or tsunami warning bulletin dispatched by Regional Tsunami Service Providers – Australia, India and Indonesia, received at MMS. Similar Bulletins plus severe weather advisories received from RIMES as well. All the advisories and warnings disseminated to public satisfactorily in time.

1.1.10.8 Training

To build the capacity of MMS further and in accordance with the mandate and action plan, we urgently need to train our personnel. Training is required in general Meteorology, Aviation, and Satellite Met, WRF model, Wave model, climate, tsunami propagation modeling etc. We are thankful to regional and internation partners for facilitating some of the required training programs for operational weather forecasting. Training on weather instruments (AWS, RADAR) maintenance and calibration is also urgently required as we keep expanding our observation network.

1.1.11. Sri Lanka:

There were 6 cyclonic storms formed in the North Indian Ocean, in 2023 and 4 cyclonic storms formed in in 2024. Out of these 6 cyclonic storms occurred in 2023, 3 namely extremely severe cyclonic storms. Those are: Mocha over Bay of Bengal during 11-14 May, Biparjoy over the southeast Arabian Sea during 6-16 June and Tej over southwest Arabian Sea during 20-24 October. There was one very severe cyclonic storm named Hamoon over West central Bay of Bengal during 23-25 October. Two severe cyclonic storms named Midhili and Michaung over west central Bay of Bengal during November 10-17 and southwest Bay of Bengal during 3-5

December respectively. There was no significant impact on Sri Lanka from these cyclonic storms. Furthermore, the depression occurred in the southwest Bay of Bengal during 30 January- 2nd February moved across Sri Lanka, caused heavy rainfall in the northern half of the country.
In year 2024, there were 4 cyclonic storms formed in the Indian Ocean. One was severe cyclonic storm and named Ramel formed over Bay of Benal during 25-27 May. Other two cyclonic storms were named as Asna and Fengal were formed over Bay of Bengal during 30 August-1 September, and during 29 November -1 December respectively. Among all the above systems Fengal was the system caused maximum extreme rainfall over the island. According to Disaster Management Center (DMC) this caused many disasters particularly in northern and eastern parts of the island.

Significantly above average rainfall has received in February 2023, Below normal in July 2023. Consecutive three months observed above normal rainfall in most areas from October to December 2023. Above average rainfall was reported in January, May, August and, November 2024 while, below average rainfall was reported in most parts in February, July, and September 2024

1.1.11.1. Impacts related to tropical cyclones or other severe weather events during September 2023 and 2024

(a)Monthly rainfall from January 2023 to December 2023
Above average rainfall has received in the most parts of the island from October to November 2023 while below average rainfall was reported in July 2023. In January, below average rainfall has received in the most parts of the island except northwestern and southwestern parts where above normal rainfall received. In February, considerably above average rainfall has received in the most parts of the island except northwestern and central parts where below normal rainfall received. In March below average rainfall has received in the northern, northwestern parts and Matara and Hambantota areas while, above average rainfall has received in the other parts of the island. In April, above average rainfall has received in the most parts of the island except northwestern and southwestern parts where below normal rainfall received. In May, above average rainfall has received in the most parts of the island except southwestern parts where below normal rainfall received. In June, below average rainfall has received in the northwestern and central parts, southwestern half of the coastal regen received below normal rainfall and other areas received normal rainfall. In August, above average rainfall has received in the northern parts, while below normal rainfall received elsewhere. In September, above average rainfall has received in the southwestern quarter and Batticaloa areas, while below normal rainfall received elsewhere.

(b) Monthly rainfall from January 2024 to December 2024
Above average rainfall has received in the most parts of the island in January, May, August and November while below average rainfall has received in the most parts of the island in February, September and December. In March above average rainfall has received in Galle and Batticaloa areas while below average rainfall has received in the other parts of the island. In April, above average rainfall has received in western part and Galle areas while, below average rainfall has received in the other parts of the island. In June, below average rainfall has received in the northcentral, Central and Uwe areas and above normal rainfall received in elsewhere. In July, above average rainfall

has received in western and southwestern parts and Mannar areas while, below average rainfall has received in the other parts of the island. In October below, average rainfall has received in the Central and Uva areas and above normal rainfall received in elsewhere.

1.1.11.2. Extreme weather events

(a)Extreme Rainfall event on 1st June, 2024

Convective showers were enhanced with the formation of low-level disturbance in the vicinity of Sri Lanka on 1st June. Extreme rainfall was reported in the southwestern part of the country. This high intense rainfall reached maximum at 460 mm at rainfall station at Labugam area during 24 hours on the day. Heavy rainfall leading to flash floods and other hydrometeorological hazards in the southwestern part of the country. According to Disaster Management Center (DMC), approximately 118,000 people were affected including twenty-three deaths, seven injured and one missing in the event. The most affected areas were Rathnapura district in Sabaragamuwa province (nearly 60,000 affected), Kaluthara district in western province (nearly 32,000 affected), and Matara district in southern province (nearly 21,700 affected).

Table 1. stations received above 250 mm rainfall in 1st June 2024

Date	Station	24 hour Rainfall (mm)
01st June 2024	Kalatuwawa	490.0
01st June 2024	Labugama	464.8
01st June 2024	Elstan	307.1
01st June 2024	Padukka Estate	296.3
01st June 2024	Keragala	285.2
01st June 2024	Rathnapura	281.9
01st June 2024	Batuwangala	264.2
01st June 2024	Kukuleganga	264.0

(b)Extreme Rainfall due to cyclonic storm Fengal 25-30 November 2024

The cyclonic storm Fengal over Bay of Bengal caused heavy rainfall in the country particularly from 22nd November to 27th November. In 24th of November heavy rainfall reported from eastern parts. Rainfall activities were enhanced in the 25th of November and wide spread extreme rainfall were reported with highest rainfall during 24 hours at 311.1 mm from Ampara district in Eastern Province. In 26th of November also wide spread rainfall were reported in many areas. According to Disaster Management Center (DMC), highest number of people were affected in eastern province (149,491 individuals were affected in Ampara district, 71,618 individuals were affected in Batticaloa district, and 10,416 individuals were affected in Trincomalee district), northern province (68,103 were affected in Mannar district, 64,621 were affected in Jaffna district, 9,169 were affected in Kilinochchi district, 7,524 were affected in Mullaitivu district and 4,851 were affected in Vavuniya district) and Northcentral province (6,619 were affected in Anuradhapura district).

Table: stations received above 250 mm 24 hours rainfall during November 25th to 30th 2024

Date	Station	24 hour Rainfall (mm)
25th November 2024	Nawakiriaru Tank	256
25th November 2024	Ampara Tank	311.1
25th November 2024	Pannalgama	256.7
25th November 2024	Sagaman Tank	274.0
25th November 2024	Elkaduwa	255.0
25th November 2024	Ulhitiya	286.6
25th November 2024	Aralaganviala	259.2
25th November 2024	Girandurukotte	290.8
26th November 2024	Jaffna	253.0
26th November 2024	Thunukkai-Mullaitivu	250.5

1.1.11.3. Coordination with emergency managers and other stakeholders

- Online stakeholder meetings with Disaster Management Centre (DMC), Department of Irrigation which is responsible for flood warnings, National Building Research Organization, which is responsible for landslides warning and Department of Fisheries for dissemination of warnings to fishery community, are being arranged in a short notice and discuss the situation with them at the Department of Meteorology (DoM).
- Regular virtual meetings were conducted with stakeholder during extreme weather events. Possible adverse weather conditions and impacts were discussed. Daily briefing is being done for Minister and secretary to the ministry of Disaster Management and for the disaster mangers in a critical situation.
- Media briefing also is being done when it is required.
- Military troops are deploying with the coordination of the Disaster Management Centre (DMC) in the most affected areas. Thereafter, the District and Divisional Administration together with disaster management authorities take over the response

1.1.11.4. Early warning practice of the Early warning center of Department of Meteorology (DOM), Sri Lanka

- **Advisory/special bulletins** are issued for General public and fishing/ Navel community from the stage of low-pressure level for preparedness activities based on observations and global/IMD/ECMWF NWP model outputs.
- **Track, intensity and landfall forecast**: DoM continuously monitors, predicts and issues bulletins containing track, intensity, and landfall forecast with the guidance of RSMC New Delhi till the system move away enough /no effect.
  The frequency of issuing warnings for cyclones depends on the distance to the country and criteria is as follows. If cyclone moving towards or closer to Sri Lanka
    - •If cyclone is 600kms away from Sri Lanka ➔ Cyclone alert (every 12 hrs)
    - •If cyclone is 500kms away from Sri Lanka ➔ Cyclone Warning (every 6 hrs)
    - •If cyclone is 300Kms away from Sri Lanka ➔ Cyclone Warning (every 3 hrs)
- **Cyclone structure forecast for shipping and coastal hazard management**: The radius of maximum wind and radius of maximum sustained wind, state of sea

- **Stages of Warning**: Information/Advisory /warning /no threat
- **Adverse weather warning bulletins:**

The tropical cyclone forecasts along with expected adverse weather like heavy rain, gale wind and storm surge will be issued with update during cyclone. The bulletin also contained the suggested action for disaster managers and general public in particular for

fishermen.

• **Warning graphics**: The graphical display of the observed and forecast track with one of uncertainty and the wind forecast for different quadrants were disseminated by email and uploaded in the DoM Web site. The adverse weather warnings related to heavy rain, gale/squally wind will be presented in graphics along with color codes in the website.

Signal No	Colours	Description	Action Required
1	White Information	Potential area of possibility to development of vortex /disturbance / Cyclone has formed	Information only, Vessels at sea to be vigilant and avoid the area, Listen to media
2	Amber Alert	Cyclone has formed in the vicinity, Heavy rain and windy, sea rough, (30-40kts, 50-80kmph)	Stay away from beach/sea, vessels in danger/be inside building
3	Amber Alert	Cyclone has formed in the vicinity, very heavy rain with very strong winds, very rough seas (V> 40kts, 80kmph)	Be ready to leave weak buildings and low lying areas (flood prone areas), secure your home valuables
4	Red	Cyclone is expected to cross land,Very heavy rain/very strong winds (v>50kts,100kmph)	Evacuate to pre-designated areas
5	Green	Cyclone warning cancellation/withdrawal bulletin	

• **Warning and advisory through social media:**

Daily updates were uploaded on Facebook regularly during the life period of the system.

• **Press release and press briefing**:

Press and electronic media were given daily updates since inception of system through press release, e-mail, and website (SMS by DMC).

• **Warning and advisory for marine community**:

The Warning and advisories will be issued for fishermen, coastal and high sea shipping community.

• **Advisory for international Civil Aviation**:

Meteorological watch office in Katuanayake International airport will issue of significant meteorological information (SIGMET).

1.1.11.5. Lesson learnt and drawback

The center operates 24 hours a day, analyzing meteorological observation data, studying global numerical meteorological forecasts, preparing local numerical meteorological forecasts, preparing weather summaries, weather forecasts were issued, information about special weather conditions and early warning about bad weather conditions and tsunami conditions were carried out and this information was transmitted to the Disaster Management Center and mass media agencies on the Internet and social media networks. During the year 2023, the center issued 3434 forecasts and 119 warnings to the general public, concerning disaster management authorities and the fisheries department to prepare well in advance. In the year 2024, the center issued 4557 forecasts and 505 warnings to the general public supporting disaster management authorities and the Department of Fisheries in their preparedness efforts. In addition, 1316 forecasts have been provided to private institutions and other parties.

Department of Meteorology successfully conducted the 28th Monsoon Forum in May and 29th Monsoon Forum in October 2023. Furthermore, successfully conducted the 30th Monsoon Forum on May and 31st Monsoon Forum on

October in 2024 with technical support from the Regional Integrated Multi-Hazard Early Warning System (RIMES) to share the country specific climate outlook and to provide a platform for climate sensitive stakeholders to share experiences and requirements on application of seasonal climate outlook.

1.2. HYDROLOGICAL ACTIVITIES

1.2.1. India

1.2.1.1. Services provided by Central Water Commission

Central Water Commission (CWC) under Ministry of Water Resources, Government of India is entrusted with the task of formulating and disseminating flood forecasting in various locations in inter-state rivers. Absolute or permanent immunity from flood damage is not physically attainable by known methods of flood control. Flood Plain Zoning and Flood Forecasting and Warning and like measures do not require large capital investments. Flood forecasting is one of the effective low-cost non-structural methods for mitigating the loss due to flood. Flood Forecasting is the process of estimating the future stages or flows and its time sequence at selected points along river during flood. The prediction of water level in advance is called the Level Forecasting while the prediction of flows into Dams/ Reservoirs/ Barrages is called the Inflow Forecasting.

1.2.1.1.1. Flood Forecasting Network in India

Central Water Commission (CWC) under Ministry of Water Resources, Government of India is entrusted with the task of formulating and disseminating flood forecasting in various locations in inter-state rivers. CWC maintains 338 flood forecasting stations which include 200 level and 138 inflow forecast stations spread across 22 States and 2 Union Territory and NCT, Delhi, 20 major river systems in the country. The work of formulation and dissemination of flood forecasts under various inter-state river basins is carried out directly by 36 Flood Forecasting Divisions which are designated as Divisional Flood Control Rooms (DFCR). The forecasts formulated are issued to various User Agencies who include the Engineering and Revenue authorities of the concerned flood affected states. In addition, the hydro-meteorological data and flood forecast issued by DFCR are also sent to Central Flood Control Room (CFCR) operated in CWC Headquarters under RM wing and Flood Management Organisation. State-wise flood forecasting network in the country is as under:

Sno	Name of State/UT	Number of flood forecasting Stations		
		Level	**Inflow**	**Total**
1	Andhra Pradesh	10	10	20
2	Arunachal Pradesh	3	1	4
3	Assam	30	0	30
4	Bihar	40	3	43
5	Chhattisgarh	1	2	3
6	Gujarat	6	8	14

7	Haryana	1	1	2
8	Himachal Pradesh	1	0	1
9	Jammu & Kashmir	3	0	3
10	Jharkhand	2	15	17
11	Karnataka	1	14	15
12	Kerala	4	2	6
13	Madhya Pradesh	2	12	14
14	Maharashtra	8	14	22
15	Odisha	12	7	19
16	Rajasthan	4	11	15
17	Sikkim	3	5	8
18	Tamil Nadu	4	11	15
19	Telangana	5	10	15
20	Tripura	2	0	2
21	Uttar Pradesh	39	5	44
22	Uttarakhand	4	5	9
23	West Bengal	12	4	16
24	Daman & Diu	1	0	1
	NCT of Delhi	2	0	2
	Total	**200**	**140**	**340**

1.2.1.1.2. Flood Monitoring

Central Water Commission monitors the flood by observing hydrological and hydro-meteorological data during flood on hourly basis at about 1730 (1543 hydrological stations and 187 met stations) stations manually and transmitting it to divisional offices through HF/VHF wireless sets, mobiles, etc. Under modernization, automatic data acquisition and satellite-based transmission system for hourly data collection is being deployed. Presently, 1121 such stations are installed and installation of another 38 stations is under progress. Central Water Commission is also collecting reservoir related data from project authority under State Govt, Meteorological data from India Meteorological Department, etc. Data collected are managed by web-based application, WIMS for archival and real time display of flood trends in the web site http://ffs.india-water.gov.in.

1.2.1.1.3. Formulation of Flood Forecast:

Flood forecast is formulated by the Divisional Flood Control Room using hydro-meteorological data from various upstream locations of the flood forecasting station and rainfall forecast from India Meteorological Department. These data are processed either graphically or mathematically using computers and flood forecasts are generated. Generally, flood forecasts are issued whenever the Water Level in a river is expected to cross the Warning Level as fixed by State Authorities in consultation with CWC. Forecasts formulated from the conventional statistical correlation methodology are issued with a warning time of 6 to 24 hours while flood advisories formulated using mathematical models based forecasting methodology are being issued with the lead time of up to 168 hours. The forecasts are issued at pre-designated times to the user agencies well in advance so that sufficient time is available for the authorities to carry out mitigation works. In the case of level forecast, the expected water level at the given

location is given in the forecast and based on the topography and submergence of areas for that level, the revenue authorities take necessary action. In the case of inflow forecast the volume of water likely to be flowing into the reservoir during the succeeding period is given based on which the project authorities plan their release schedules into the canals and river.

1.2.1.1.4. Dissemination of Flood Forecast

The formulated flood forecasts have to be sent to the concerned user agencies by the quickest possible mode of communication to ensure that the forecast is useful for flood fighting measures. In CWC, the flood forecasts are disseminated by various communication methods. CWC uses various communication modes including HF Wireless Sets/ whatsapp/Fax/ Telephone/ e-mail/ updating the CWC's flood forecasting web site (http://www.india-water.gov.in), Facebook, Twitter as well as through Google platforms Google public alerts etc. In case of floods above Danger Level, SMS are issued to mobile numbers of various concerned users who are directly responsible for relief and rehabilitation measures in the State.

1.2.1.2. Services provided by India Meteorological Department

1.2.1.2.1. Rainfall Monitoring:

Real time monitoring of district wise daily rainfall is one of the important functions of IMD. A network comprising of 6495 rain gauge stations is utilized under District wise Rainfall Monitoring Scheme (DRMS) for preparing the maps and rainfall statistics. Based on real time daily rainfall data, different temporal scales such as daily, weekly, monthly, seasonal and annual and different spatial scales such as district wise, Met-subdivision wise, state wise and homogeneous region wise rainfall distribution summaries are prepared in the form of rainfall departure tables, maps and graphs. District wise, state wise and Met subdivision wise rainfall statistics provides important information to the agricultural scientists, planners and decision makers.

During the year **2025**, rainfall statistics for the **36 meteorological sub-divisions, States & UTs, districts, four homogeneous regions of India [(i) Northwest India, (ii) Central India, (iii) South Peninsula and (iv) East & Northeast India], and the country as a whole** were prepared on **daily, weekly, monthly, seasonal and annual** basis and disseminated to various stakeholders. Hydromet Division continued to provide **real-time rainfall monitoring** and published **All India Rainfall Statistics** on Daily, Weekly, Monthly, Seasonal and Annual basis.

The **annual (January–December) 2025 rainfall** over the country was **1278.2 mm**, which is **110% of the Long Period Average (LPA) of 1160.0 mm**. Out of **36 meteorological subdivisions**, **2 recorded Large Excess rainfall, 14 recorded Excess rainfall, 18 recorded Normal rainfall, and 2 recorded Deficient rainfall**, while no subdivision fell under the Large Deficient or No Rain category.

The seasonal rainfall statistics for **2025** are as follows:

- **Winter Season (January–February) 2025:** The country received **53% of its LPA (20.9 mm)**. Out of 36 meteorological subdivisions, **2 recorded Excess rainfall, 5 Normal, 8 Deficient, 16 Large Deficient, and 5 No Rainfall**.
- **Pre-Monsoon Season (March–May) 2025:** The country received **142% of its LPA (185.8 mm)**, making it the **third highest pre-monsoon rainfall since 1901**. Out of 36 meteorological subdivisions, **22 recorded Large Excess rainfall, 7 Excess, 4 Normal, and 3 Deficient rainfall**.
- **Southwest Monsoon Season (June–September) 2025:** The country received

108% of its LPA. Among the four homogeneous regions, **Northwest India, Central India, South Peninsula and East & Northeast India received 128%, 115%, 110% and 80% of their respective LPAs**. Out of 36 meteorological subdivisions, **2 recorded Large Excess rainfall, 12 Excess, 19 Normal and 3 Deficient rainfall**.

Design Storm Studies continued to be undertaken to estimate **Standard Project Storm (SPS), Probable Maximum Precipitation (PMP), rainfall time distribution, Intensity-Duration-Frequency (IDF) curves and other design storm parameters** for river catchments and hydraulic projects. These studies support the design of dams, spillways, irrigation projects and other hydraulic structures by providing critical inputs for design flood estimation.

Flood Meteorological Activities: In 1970, India suffered number of severe floods caused huge loss of life & property and Govt. of India constituted a committee of Ministers to look into the problem. The committee in 1972 recommended that Central Water Commission (CWC) to establish Flood Forecasting Division and India Meteorological Department to establish Flood Meteorological Offices (FMO). Accordingly, India Meteorological Department's (IMD's) contribution in flood warning is mainly in the form of Quantitative Precipitation Forecast (QPF) used in the preparation of flood warning/forecast issued to Flood Forecasting Division of Central Water Commission (CWC) / State Governments. IMD caters this service through its 15 Flood Meteorological Offices (FMOs) situated in the different flood prone areas. These FMOs issue daily QPF and Hydromet Bulletin(HM) during Flood Season for respective sub-basins under their jurisdiction. HM Bulletin contains prevailing synoptic situation, average areal rainfall occurred during past 24 hrs., heavy rainfall warning, observed station-wise significant rainfall (≥5cm) and the important component, river sub-basin-wise QPF for a lead time of 7-days. QPF is also issued in case of cyclone during non-flood season. During flood season of 2023, 27,301 numbers of QPF over 157 river sub-basins are issued to Central Folld Forecasting Divisions (CFFDs) of CWC.

Model based Sub-basin-wise Quantitative Precipitation Forecast (QPF) using dynamical model WRF ARW (3kmx3km) for day-1 to day-3, NCUM-R (4kmx4 km) for day-1 to day-3, GFS (12kmx12km) for day-1 to day-7, NCUM(12kmx12km) for day-1 to day-7 are uploaded in the IMD's website. Also, Model based Sub-basin wise Probabilistic Quantitative Precipitation Forecast (PQPF) using dynamical model NEPS (12kmx12km) for day-1 to day-7 and GEFS(12kmx12km) for day-1 to day-7 uploaded in the IMD website at the link http://hydro.imd.gov.in/hydrometweb/ for all 157 river sub-basins. Also, WRF ARW and GFS gridded model rainfall forecast are shared with Central Water Commission for their flood forecasting purposes. A technical document on 'Verification of River Sub-basin-wise Quantitative Precipitation Forecast during SW Monsoon 2023' is published as Met Monograph in IMD web site.

South Asia Flash Flood Guidance System

The WMO Commission for Hydrology (CHy) jointly with the WMO Commission for Basic Systems (CBS) and in collaboration with the US National Weather Service, Hydrologic Research Center (HRC), and USAID/OFDA have developed the concept of the Flash Flood Guidance System (FFGS) with global coverage. Flash Flood Guidance System Project has global coverage of 64 countries with more than two billion people around the world gets

benefitted in saving lives and decreasing economic losses.

The South Asia Flash Flood Guidance System comprises of 5 countries (Bangladesh, Bhutan, India, Nepal and Sri Lanka) wherein India Meteorological Department (IMD) is recognised as the Regional Centre for providing the EWS guidance alerts on flash floods in South Asia. IMD commissioned this system for catering flash flood guidance services on 23 Oct 2020 and put into full operations during the flood season 2021.

Hydromet division of IMD viz. Regional Centre (SASIAFFGS) provides location specific flash flood guidance alerts every 6 hours up to watershed level on pluvial flash floods in the form of **risks with 24 hour lead time** based on deterministic numerical weather forecasts from IMD GFS (12km×12km), NCUM (4km×4km) and IMD WRF (3km×3km), and **threats with 6 hour of lead time** by integrating near real-time gauge observations along with the satellite and IMD Radar rainfall estimates. It is being recognised as an impact based forecasters' tool using a GIS based interactive dynamic MAPSERVER complimented by the outputs from the Doppler Weather based NOWCAST for issuing impact based flash flood guidance alerts at watershed level. These guidance alerts used along with the real- time socio economic data by the disaster managers would help in making effective impact-based decision management at critical times.

1.2.2. Pakistan:

1.2.2.1. Severe Weather (Flood) Monitoring

PMD monitors other severe weather phenomena like flood, drought, heatwave, heavy rains and GLOF with the network of 110 Meteorological data stations, 334 RG (Rain Gauge) stations, 85 AWSs, 34 Agromet stations, 28 Pilot Balloon Observatories (PBO), 7 Weather Surveillance Radars (with 2 DWR) installed across the country besides FY-4 satellite products. The Numerical Weather Prediction (NWP) products from the models ICON, ECMWF, GFS and JMA are also used for the purpose. For riverine flood, there are additional 100 AWS installed over river catchment areas, 45 Telemetric stations and 130 water discharge data sites (maintained by the WAPDA, water and power development authority, and Irrigation department) whose data are incorporated into a flood routing model to generate the flood alerts and warning.

1.2.2.2. Drought Monitoring

The drought monitoring and early warning is done by:

i. Meteorological Indices (Cumulative Precipitation Index, Percent of Normal of Rainfall, SPI (Standard Precipitation Index), Length of dry period, Soil moisture anomaly and monthly precipitation/soil moisture outlook),
ii. Satellite Indices (Normalized Difference Vegetation Index, NDVI, Temperature Vegetation Dryness Index, TVDI and Land Surface Temperature LST),
iii. Water availability in reservoirs and
iv. Field reports are used.

Based on these indices, the drought bulletins, reports, advisories and alerts are issued on weekly, fortnightly, monthly & quarterly basis. Two such advisories issued during 2024.

1.2.2.3. GLOF Monitoring

Meteorological & Geomorphological based GLOF (glacial lake outburst flood) alerts are issued by taking into account the:

i. Expected Precipitation events,
ii. Persistent high temperature over couple of days,
iii. Persistent high temperatures followed by rain spells in following days and
iv. Monitoring the fluctuation in the discharge from the lake level (with river and lake level sensors installed).

1.2.2.4. Heatwave

Following the WMO criteria, heatwave is declared when maximum temperature of a place rises 5°C above average temperature for consecutive 5 days. Since 2015 killer heatwave of Karachi, a new criterion is followed by the PMD as:

1. Hot Day: Tmax=>35°C but < 40°C
2. Heatwave:
   i. Tmax=>40°C
   ii. Departure from Normal = 5-6°C, persisting for at least 3-days
3. Severe Heatwave:
   i. Tmax=>40°C
   ii. Departure from Normal= 7°C or more, persisting for at least 3-days.

1.2.2.5 Impact Based Forecasting

The Pakistan Meteorological Department (PMD) has pioneered Impact-Based Forecasting (IBF) to enhance weather services for agriculture and disaster resilience. Beginning with a pilot project in 2022 focused on the Potohar region's rainfed crops (maize and groundnut), PMD collaborated with the UK Met Office, ICIMOD, and local stakeholders to develop impact tables, risk matrices, and tailored advisories. Despite coordination challenges, the pilot successfully provided actionable forecasts to farmers via webpages, WhatsApp, and radio.

Building on this success, PMD expanded IBF to cover the entire Potohar region during the 2022– 2023 Rabi season, focusing on wheat crops. Key steps included stakeholder workshops, real-time surveys (436 field responses), and impact tables for hazards like frost and drought. Farmers highlighted needs for localized forecasts, mobile-friendly services, and more met offices.

Key Outcomes & Challenges:

- Improved farmer access to crop-stage-specific forecasts.
- Identified gaps: limited coordination, data scarcity, and funding needs.
- Lessons: Early stakeholder engagement, MoUs, and incentives are critical for scalability.

Future Plans: PMD aims to extend IBF to cotton-growing regions (e.g., South Punjab) to bolster climate resilience for Pakistan's agricultural economy

1.2.3 Thailand:

Office of the National Water Resources (ONWR) has taken preparatory measures to address potential storms that may bring heavy rainfall, as follows:

1.2.3.1. Monitoring and Surveillance of Weather and Water Situations, and Risk Area Assessment

ONWR has been closely monitoring weather conditions and water situations. According to the Thai Meteorological Department (TMD):

a) From 14 to 20 May 2024, and particularly from 20 to 23 May, the southwesterly monsoon prevailing over the Andaman Sea, Thailand, and the Gulf of Thailand is expected to strengthen. Furthermore, from 22 to 26 May 2024, a low-pressure area over the Bay of Martaban (Gulf of Mottama), Myanmar, is forecast to intensify. These conditions will likely lead to heavy to very heavy rainfall in the western parts of Northern and Central Thailand, the Northeastern Region, and the western part of Southern Thailand. ONWR has assessed the water situation based on forecasts from TMD and other relevant agencies, identifying at-risk areas for flash floods, runoff, and urban flooding, especially in areas previously affected by poor drainage during 18 to 25 May 2024.

b) On 25 May 2024, a tropical depression in the central Bay of Bengal is expected to intensify into a cyclonic storm and move toward the northeastern coast of India and Bangladesh during 26–27 May 2024. This development will cause the southwesterly monsoon to strengthen, bringing heavy to very heavy rainfall to the western parts of Northern and Central Thailand, as well as the western coast of Southern Thailand. Meanwhile, a low-pressure area over the Gulf of Tonkin will result in heavy to very heavy rainfall in the Northeastern and Eastern Regions of Thailand. ONWR has assessed the water situation based on forecasts from the TMD and relevant agencies. The assessment identifies at-risk areas that require close monitoring for flash floods, runoff, and urban flooding, particularly in areas with recurring drainage issues. These risks are expected to increase during 25–31 May 2024.

1.2.3.2. Warning and Notification

The Office of the National Water Resources (ONWR) has issued notifications advising vigilance for flash floods and runoff during the periods of 18–25 May, 22–26 May, and 25–31 May 2024 across the Northern, Northeastern, Eastern, Western, and Southern Regions of Thailand.

1.2.3.3. Implementation of Water Management Measures to tackle Flood Risks

During the flood period, ONWR has coordinated with related agencies to ensure preparedness through the following actions:

(a) Closely monitoring weather and water conditions, particularly in areas where accumulated rainfall exceeds 90 millimeters within 24 hours, as well as in flood-prone zones or urban areas with recurring drainage problems.

(b) Preparing flood response plans, ensuring the readiness of personnel and equipment, removing obstructions from waterways, dredging drainage systems, and coordinating integrated response efforts for timely assistance.

(c) Disseminating water situation updates and issuing early warnings to at-risk communities so they can be prepared for potential evacuation in case of emergency.

1.2.3.4. Strategy:

ONWR is driving the implementation of the 2024 rainy season preparedness measures by encouraging responsible agencies to act in accordance with the following strategies:

a) Forecast and identify flood-prone and drought-prone areas, and issue timely warnings.
b) Review and update water management criteria for water sources and hydraulic structures through an integrated river basin approach, from pre-rainy season through the entire rainy season.
c) Ensure readiness of machinery, hydrological structures, drainage systems, telemetry networks, on-site personnel, and evacuation centers to handle both flood and drought conditions throughout the season.
d) Inspect and monitor the structural integrity of levees, dams, and flood barriers from pre-rainy season through the rainy season.
e) Enhance the efficiency of drainage systems in a systematic manner before and during the rainy season.
f) Conduct emergency drills, establish forward command centers prior to disasters, and carry out recovery operations to restore normalcy throughout the rainy season.
g) Strengthen community-based networks to support local information-sharing and response efforts from pre-season through the end of the rainy season.

1.2.3.4. Water Situation Monitoring and Assessment Meetings

ONWR has convened meetings to assess the water situation and coordinate with relevant agencies for proactive preparedness. All agencies have been instructed to integrate data, enabling the development of a rapid and efficient early warning system. Emphasis has been placed on building an extensive communication network that reaches local communities, along with planning immediate response operations to prevent and minimize impacts on the public, reducing potential damage as much as possible.

Additionally, ONWR has prepared for potential overflow in reservoirs identified as high-risk, such as Vajiralongkorn Dam, by gradually releasing water in advance to accommodate incoming rainfall and reduce the risk of downstream flooding should heavy rainfall occur.

1.2.3.5. Review of tropical cyclones that affected/impacted Thailand 2024

Weather conditions affecting Thailand in 2024 with storms and monsoon troughs moving through Thailand during June-December 2024 as follows

Monsoon winds and the climate of Thailand. Thailand is under the influence of two types of monsoons: the southwest (SW) monsoon and the Northeastern (NE) monsoon.

The Southwest (SW) Monsoon: Blows covered Thailand between the middle of May and mid-October.

The Northeast (NE) Monsoon: Happen after the influence of the southwest monsoon is gone. Around mid-October there are northeastern monsoon covering Thailand until mid-February.

Seasons in Thailand can be divided into 3 seasons as follows:

- Summer between mid-February and mid-May.

- ❖ Rainy season between mid-May and mid-October.
- ❖ Winter between mid-October and mid-February.

Storms and monsoon troughs moving through Thailand during June – December 2024 are as follows:

1.2.3.6. Event in June 2024

Affected Area: resulted in heavy to very heavy rain mostly on the western side of the southern region. Particularly in Phuket Province, continuous heavy rain occurred throughout the night of 29 June until 30 June 2024, causing the most severe flooding in 10 years.

In Tak and Chanthaburi provinces where very heavy rain caused flash floods and inundation on 9th and 10th of June 2024, respectively. In Chiang Rai and Mae Hong Son provinces, during 3-4 June 2024. In mid-June, heavy rain in PathumThani Province and eastern Bangkok caused flooding at King Kaew on 17 June 2024. On 22 June 2024, flooding occurred with water levels of approximately 30-60 cm in Trat Province. On 23 June 2024, there were flash floods in Satun Province. Additionally, flash floods and inundation occurred in Kathu and Thalang districts, Phuket Province on 29 June until 30 June 2024.

1.3. DISASTER RISK REDUCTION ACTIVITIES

1.3.1. India

1.3.1.1. Disaster Risk reduction:

At the national level, the Ministry of Home Affairs is the nodal Ministry for all matters concerning disaster management. The Joint Secretary, Disaster Management, Ministry of Home Affairs is the Central Relief Commissioner (CRC) and the nodal officer to coordinate relief operations for natural disasters. The CRC receives information relating to forecasting/warning of a natural calamity from IMD or from Central Water Commission of Ministry of Water Resources on a continuing basis. The Ministries/ Departments/ Organizations concerned with the primary and secondary functions relating to the management of disasters include:

India Meteorological Department (under Ministry of Earth Sciences), Central Water Commission, Ministry of Home Affairs, Ministry of Defence, Ministry of Finance, Ministry of Rural Development, Ministry of Housing and Urban Affairs, Ministry of Communications, Ministry of Health & Family Welfare, Ministry of Water Resources, River Development & Ganga Rejuvenation, Ministry of Petroleum & Natural Gas, Department of Agriculture Cooperation and Farmers' Welfare, Ministry of Power, Ministry of Railways, Ministry of Information and Broadcasting, NITI Aayog, Cabinet Secretariat, Ministry of Road Transport and Highways, Ministry of Social Justice & Empowerment, Ministry of Women & Child Development, Ministry of Environment, Forest & Climate Change, Department of Food & Public Distribution. Each Ministry/Department/ Organization nominates their nodal officer to the Crisis Management Group chaired by Central Relief Commissioner. The nodal officer is responsible for preparing sectoral Action

Plan/Emergency Support Function Plan for managing disasters.

1.3.1.2. National Crisis Management Committee (NCMC):

Cabinet Secretary, who is the highest executive officer, heads the NCMC. Secretaries of all the concerned Ministries /Departments as well as organizations are the members of the Committee. The NCMC gives direction to the Crisis Management Group as deemed necessary. The Secretary, Ministry of Home Affairs is responsible for ensuring that all developments are brought to the notice of the NCMC promptly. The NCMC can give directions to any Ministry/Department/Organization for specific action needed for meeting the crisis situation.

1.3.1.3. Crisis Management Group (CMG):

The Central Relief Commissioner in the Ministry of Home Affairs is the Chairman of the CMG, consisting of senior officers (called nodal officers) from various concerned Ministries/Departments. The CMG's functions are to review every year contingency plans formulated by various Ministries/ Departments/ Organizations in their respective sectors, measures required for dealing with natural disasters, coordinate the activities of the Central Ministries and the State Governments in relation to disaster preparedness and relief and to obtain information from the nodal officers on measures relating to above. The CMG, in the event of a natural disaster, meets frequently to review the relief operations and extend all possible assistance required by the affected States to overcome the situation effectively. The Resident Commissioner of the affected State is also associated with such meetings.

1.3.1.4. Control Room (National Emergency Response Centre):

A National Emergency Response Centre (Control Room) exists in the nodal Ministry of Home Affairs, which functions round the clock, to assist the Central Relief Commissioner in the discharge of his duties. The activities of the Control Room include collection and transmission of information concerning natural calamity and relief, keeping close contact with governments of the affected States, interaction with other Central Ministries/Departments/Organizations in connection with relief, maintaining records containing all relevant information relating to action points and contact points in Central Ministries etc., keeping up-to-date details of all concerned officers at the Central and State levels.

1.3.1.5. National Disaster Management Authority (NDMA)

As mandated by Disaster Management Act, 2005, the Government of India (GoI) created a multi-tiered institutional system consisting of the National Disaster Management Authority (NDMA) headed by the Prime Minister, the State Disaster Management Authorities (SDMAs) headed by the respective Chief Ministers and the District Disaster Management Authorities (DDMAs) by the District Collectors and co-chaired by Chairpersons of the local bodies. These bodies have been set up to facilitate a paradigm shift from the hitherto relief centric approach to a more proactive, holistic and integrated approach of strengthening disaster preparedness, mitigation and emergency response.

About 8% of the area in the country is prone to cyclone-related disasters. Recurring cyclones account for large number of deaths, loss of livelihood opportunities, loss of public and private property and severe damage to infrastructure, thus seriously

reversing developmental gains at regular intervals.

Broad-scale assessment of the population at risk suggests that an estimated 32 crore people, which accounts for almost a third of the country's total population, are vulnerable to cyclone related hazards. Climate change and its resultant sea-level rise can significantly increase the vulnerability of the coastal population.

1.3.1.6. Guidelines for the Management of Cyclones

The NDMA had issued Guidelines for the Management of Cyclones to assist ministries and departments of GoI and state governments to prepare their DM plans. The guidelines are presented in nine chapters as detailed below:

i. Chapter 1 provides an introductory overview that reflects the risk and vulnerability of the country to cyclones, including the dimensions and magnitude of the problem.
ii. Chapter 2 discusses the Early Warning Systems (EWS) for cyclones. In this chapter, the present status of EWSs has been discussed and the gaps have been identified. Requirement to bring them up to international standards and making them state-of-the-art systems has been recommended.
iii. Chapter 3 deals with the present status of Warning Communication and Dissemination, its gaps and future improvements required towards making it fail-proof and modern.
iv. Chapter 4 covers structural measures for preparedness and mitigation, covering cyclone shelters, buildings, road links, culverts and bridges, canals, drains, saline embankments surface water tanks, cattle mounds and communication/power transmission networks.
v. In Chapter 5, important aspects of the management of coastal zones and its relevance to CDM, including some other non-structural mitigation options have been presented. This chapter discusses issues related to coastal zone management, sustainability of coastal resources, bio-shields, coastal flood plain management, coastal erosion, natural resources management, etc.
vi. Chapter 6 deals with various aspects of awareness generation related to CDM as an important preparedness measure.
vii. Chapter 7 covers Disaster Risk Management (DRM) issues, risk assessment and vulnerability analysis, hazard zoning and mapping, data generation, including the use of GIS tools, and capacity development.
viii. Chapter 8 deals with CDM-related response and relief strategies. A detailed account of several issues related to effective response such as response platforms, linking risk knowledge with response planning, evolving disaster response capabilities, etc., is brought out in this chapter.
ix. In Chapter 9, guidelines and implementation strategies have been discussed.
x. Salient initiatives recommended for implementation as part of the National Guidelines for Management of Cyclones are listed for undertaking action by various relevant Departments.
xi. The guidelines are hosted in NDMA website at (https://ndma.gov.in/images/guidelines/cyclones.pdf

1.3.1.7. Current Status

1.3.1.7.1. National Cyclone Risk Mitigation Project (NCRMP)

Government of India has initiated the **National Cyclone Risk Mitigation Project (NCRMP)** with World Bank assistance with a view to address cyclone risks in the country. The overall objective of the Project is to undertake suitable structural and non-structural measures to mitigate the effects of cyclones in the coastal States and UTs of

India. National Disaster Management Authority (NDMA) under the aegis of Ministry of Home Affairs (MHA) is entrusted with implementation of this Project in coordination with participating State Governments.

Phase I was approved for implementation in two coastal states viz .Andhra Pradesh & Odisha at a cost of Rs.1496.71 crore in January 2011 with the date of completion as January 2016, with World Bank Assistance. It was further revised to Rs. 2541.60 Crore with the date of completion as December 2018. Phase I stands completed with an expenditure of Rs. 2,524.84 crore.

Phase II was approved for implementation in six coastal States viz; Goa, Gujarat, Karnataka, Kerala, Maharashtra, and West Bengal with World Bank assistance at an outlay of Rs. 2361.35 crore in July 2015 with the date of completion as 31st March 2020. With subsequent revisions in the light of the scheme performance, ratings, cancellation of non-started activities as well as surrendering of savings of US$ 80 Million, the outlay was finally revised to Rs. 1864.38 crore with the date of completion as 14th March 2023. Phase II stands completed with an expenditure of Rs. 1806.84 crore.

Details of the structural and non-structural measures implemented under NCRMP are as follows:

(a)Structural Measures

(i)Early Warning Dissemination System (EWDS):-The EWDS, the state-of-the-art multi-technology option (Alert Siren, Satellite Radio, Mass Messaging, etc.) to provide reliable communication by ensuring last-mile connectivity during disasters has been commissioned and is operational in coastal districts of Andhra Pradesh and Odisha. The physical work has been completed in Goa, Karnataka, and Kerala and the testing for commissioning the same is under process. The activity would be launched very soon in these three States. Further, EWDS would be taken up in Gujarat, Maharashtra and West Bengal in the next phase of NCRMP.

(ii) Cyclone Risk Mitigation Infrastructure (CRMI):- The CRMI enhances the preparedness and mitigates the vulnerability of coastal communities through investments for the construction of multi-purpose cyclone shelters (MPCS), roads, bridges, underground electric cabling and saline embankments. The infrastructure created under the project is as under:

Sub-component	**Total**
MPCS (No.)	795
Roads (Km)	1291.52
Bridge (No.)	36
Saline Embankment (Km)	118.18
Underground Electric Cabling (Km)	1387.76

(b) Non-Structural Measures

(i) Capacity Building Training (CBT)/ Shelter Level Training (SLT):
A total of 24,007 Government officials from various priority sectors viz., Health, Education, Panchayat Raj Institutions, Urban Local Bodies, and Rural Development have been trained through 925 Capacity Building Training. Similarly, 68,988 community representatives have been trained on various disaster response skills viz., First Aid, Search & Rescue, and Shelter Management through 3421 Shelter Level Training.

(ii) Technical Studies:

- **Coastal Hazard, Risk and Vulnerability Assessment (HRVA):** To analyse risk at village level, a Web-based Composite Risk Atlas (CRA) has been developed under NCRMP-I which has been shared with all 13 coastal States & UTs for mitigation planning.
- **Post Disaster Needs Assessment (PDNA):** National Institute of Disaster Management (NIDM) has developed PDNA tools under NCRMP-I with an objective to establish a standardized mechanism based on scientific approach for conducting post disaster needs assessment for long term recovery and reconstruction. The newly developed tools are based on the existing damage assessment system in India and an internationally-accepted methodology.
- **Development of Web based Dynamic Composite Risk Atlas (DCRA) & Decision Support System (DSS) Tool for Cyclones & Associated Hydro-meteorological Hazards:** A Web-DCRA & DSS Tool for Cyclone impacts forecasting covering all 13 coastal States and Union Territories of the Country has been developed which provides real-time forecast for location specific cyclonic wind and inundation level due to storm surge, cyclone induced rainfall and riverine flood.
- **Hydro-meteorological Resilient Action Plans (HmRAP):** HmRAP study has been taken up to strengthen the capacity of National/States and ULB entities to effectively plan for and respond to significant hydro-met hazards/extreme events and climate change affecting urban areas in six selected cities of the project States of NCRMP-II.
- **Design of Comprehensive Multi-hazard Risk Financing Strategy (CMhRFS):** CMhRFS has been taken up with an objective to work out risk transfer financial instruments and to develop risk financing strategies in 4 States (Gujarat, Odisha, Kerala and Uttarakhand).

1.3.1.7.2. (**DCRA Mobile App)**

A DCRA Mobile App. is also being developed for faster outreach to populations at risk. The existing mobile applications, namely, Meghdoot, Damini, Mausam, TNSMART, Thoondil as well as Navik have been studied to benchmark functionality for this application.

The DCRA Mobile App. is a hybrid application which would be available on both the IOS and Android platforms. The DCRA app will enable users to access features of Web-DCRA and cyclonic events specific to the area through location based technology. Registered users can access all the forecast, warnings and advisories through the Mobile App. This application provides live updates features such as safe / emergency shelter, raised platforms, nearest evacuation routes, additional resources if any for general public as well as for state & district administration officials and Disaster Management Authorities. It also provides local weather forecast and near real-time risk reports of an impending cyclone.

Design of the Hybrid Mobile Application has been completed with the development of modules including Registration, Login, User Management, I'm Safe, I'm not safe, Crowd Sourcing & Map Module. The Mobile App. also has Social Media feature including WhatsApp for registration process as well as sending these alerts apart from SMS.

1.3.1.8. National Disaster Response Force (NDRF)

1.3.1.8.1. Vision

To be one of the most effective & modernised disaster response forces in the world.

1.3.1.8.2. Mission

- To consistently provide effective disaster response in India (and out of India if called upon)
- To facilitate Pan-India capacity building empowerment and awareness in disaster response.
- To develop into a high-tech, modernised force with equipment, protocols and standards which are world class.

1.3.1.8.3. History

India experienced heavy loss of life & property in last three decades due to mammoth natural calamities like the Odisha Super Cyclone of 1999, Gujarat Earthquake of 2001, and Indian Ocean Tsunami of 2004 - a succession of events that demanded comprehensive disaster management. This led to the enactment of the Disaster Management (DM) Act on December 26, 2005. This Act provides for effective management of disasters and for matters connected therewith or incidental thereto. Consequently, as mandated in the DM Act, the National Disaster Response Force (NDRF) was formed in the year 2006 as a federal first-responder Force.

The multi skilled, highly professional "National Disaster Response Force" comprising of 08 Nos. of battalions (Bns) (02 Bn each from BSF, CRPF, ITBP and CISF) was raised as per Chapter VIII, Section-44 of DM Act- 2005 to tackle/mitigate all types of disaster. In a short span of time, the Force became known for its proactive approach to disaster response, ready availability and assistance to the States and its preventive pre-positioning in disaster situations, resulting in rapid response and minimal damage during natural calamities. Further, two more Bns (one each from CRPF & BSF) were added on 13 Oct' 2010 and in 2015, two more Bns from SSB were added in NDRF. In 2018, GoI approved raising of four Additional Battalions, out of which 01 Battalion of Assam Rifles is inducted in 2020, 02 Battalions of ITBP and 01 Battalion of BSF are inducted in 2021. Presently NDRF is 16 Battalion strong.

1.3.1.8.4 Roles and Responsibility

The NDRF aims toward proactive deployment in impending disaster situations, followed by specialized response during disasters. In non-disaster periods, the NDRF focuses on capability building, acquiring new skills through constant training. The force imparts basic and operational level training to State Disaster Response Forces, Police, Civil Defence and Home Guards. It also engages in Community Capacity Development, wherein it facilitates and empowers communities in disaster preparedness. Other than mock drills, activities include co-ordination with other stakeholders, reconnaissance, vulnerability and disaster mapping, and rehearsals. The NDRF consistently spreads awareness about disaster management in the community at large and amongst school children.

1.3.1.8.5 Organisational Structure

At present, NDRF has a strength of 16 Battalions including four battalions each from BSF & ITBP, three battalions from CRPF, two each from CISF & SSB and one from Assam Rifles. Each Battalion consists of 1149 personnel. Each battalion has 18 specialist search and rescue teams, which are self-contained and have specialists like engineers, technicians, electricians, dog squads and medical and paramedical personnel. Each battalion is equipped and trained for man-made and natural calamities. They are also capable of responding to chemical, biological, radiological, and nuclear emergencies (CBRN). There is an NDRF Academy at Nagpur. The National Civil Defence College also has been merged with NDRF Academy. The location of the NDRF battalions is

determined by the vulnerability profile of the country, with the intention of cutting down response times in times of disaster.

1.3.1.8.6 Working of NDRF

NDRF responds within the minimum time frame and reaches the place of disaster with the required equipment. As per the Standing Operating Procedure (SOP) for deployment of NDRF teams, approved by MHA, NDRF teams can be requisitioned for deployment during pre-disaster/ impending disaster phase as well during actual disaster. During floods, cyclones, tsunamis and other disasters where forecast or early warning is available, NDRF prepositions its team in consultation with the respective state authorities and as per the forecast of early warning agencies like IMD, CWC, INCOIS etc. In addition, when disaster is of larger magnitude, NDRF teams are mobilized even on telephonic request to save time, as timely response is of essence.

Each NDRF unit conducts FAMEx in respective Area of Operations (AOR) to provide opportunity to the personnel to acquaint themselves about topography, demography, route, terrain and availability of resources such as medical support, water points, earth moving equipment etc. It also provides opportunity to the Commanders to familiarise themselves with local inhabitants and liaise/ coordinate with the officials who invariably are the first responders or stakeholders at the time of disaster.

1.3.1.8.7 Capabilities & Strength

- CSSR (Collapsed Structure Search & Rescue) operations.
- MFR (Medical First Response).
- CBRN emergency response.
- Flood Disasters.
- Mountain Search & Rescue.
- Deep Diving Search & Rescue.
- Canine and Technical Search.
- Animal disaster response.

1.3.1.8.8. Equipment

NDRF has been equipped with latest state of the art equipment required for the rescue and relief work. An inventory of State of the art equipment have been authorized to NDRF which broadly consists of Medical First Responder (MFR) Equipment, Collapsed Structure Search & Rescue (CSSR), Flood Water Rescue, CBRN equipment and specialist vehicles etc.

1.3.1.8.9. Notable Operations

Year	Operations
2008	Kosi Floods in Bihar
2009	Cyclone Aila (West Bengal) and Building collapse Bellary (Karnataka)
2010	Train accident in Jhargram (WB), Chlorine leakage at Shiwadi Mumbai(MH), Leh Cloud Burst, Mayapuri Radiation, New Delhi.
2011	Sikkim earthquake and Triple disaster at RifuCho, Japan
2012	Shital Febric Factory Collapse (Jalandhar, Punjab) and Assam Floods
2013	Uttarakhand Flash Floods, Mumbai Building Collapse, Cyclone Phailin, and

	General Floods
2014	J&K Floods, Cyclone Hudhud, Cyclone Nilofar, Malin (Pune) Land Slide (MH), Assam Floods and Meghalaya Floods
2015	Gujarat Floods, Chennai Urban Floods, Cyclone Komen and Andhra Pradesh Floods
2016	Kolkata Flyover Collapse, Shavitri Bridge Collapse Mahad (MH), Kanpur-Dehat Train derailment (UP) and Cyclone Vardah
2017	Kanpur Building Collapse (UP), Cyclene Ockhi
2018	Murshidabad Bus accident (WB), Varanasi Flyover Collapse (UP), Shahberi (G/Noida, UP) Building Collapse, Kerala Floods, Cyclone 'Titli', Cyclone Gaja, Cyclone Phethai, Cyclone Pabuk.
2019	Ksan Coal Mine incident (Meghalaya), Gurugram Building collapse (Haryana), Pune Bore-Well incident (MH), Hissar Bore-Well incident, Dharwad (Karnataka) Building Collapse, Mathura Bore-Well incident (UP), Cyclone "FANI", Cyclone "VAYU", Kesarbai (Dongri, Mumbai) Building Collapse, Mahalaxmi Express Ops (Thane, MH), Mallapuram & Waynad Landslide (Kerala), Kerala Floods, Kachuluru Devipatnam Boat Capsize East Godavari (AP), Malda Boat capsize (WB), Sant Kabir Nagar Boat capsize (UP), Cyclone "Maha" and Cyclone "Bulbul"
2020	Gas Leakage at L.G Polymer, Vishakhapatnam (A.P), Super Cyclone 'Amphan', Cyclone 'Nisarga', Building Collapse at Mumbai (Maharashtra), Idukki Landslide (Kerala), Plane Crash, Kozhikode Airport (Kerala), Building Collapse Raigarh (Mahtrashtra), Assam Floods & Bihar Floods, Cyclone 'Nivar' and 'Burevi'
2021	Forest Fire at Dzukou Valley Manipur & Nagaland, Glacier burst & Flash Flood at Tapovan, Chamoli, Uttrakhand, Cyclone 'Tauktae' and 'Yaas', Landslide-Village-Taliye, Tehsil-Mahad, Distt.-Raigarh (Maharashtra)
2022	Train Derailment at Do-Muhani, Maynaguri, Alipurdwar (WB), Rescue of a Trekker Stranded on cliff ot Pallakad (Kerala), Building Collapse in Gurugram (Haryana), Trikut Hills Ropeway Incident, Deoghar (Jharkhand)
2023	Building collapse at Lucknow, UP, Building collapse at Thane (MH), Gas leakage at Ludhiana, Punjab, Train accident at Balsore, Odisha, Extremely Severe Cyclonic Storm Biparjoy (Gujarat, Rajasthan, Maharashtra, Karnataka, Diu), Delhi Floods, Landslide at Shimla, Severe Cyclonic Storm "Michaung", Tunnel collapse at Silkyara, Uttrakshi, Tamilnadu Flood.
2024	North Delhi, Building collapse Kolkata, West Bengal, Building collapse Rupnagar, CSSR Ghatkopar, Mumbai, Floods-Imphal, West Medinipur, Train accident Darjeeling, CSSR, Surat, Gujarat, CSSR Deogarh, Jharkhand, land Slide Wayanad, Kedarnath Landslide/Floods, Jharkhand Floods, Cloudburst Shimla, Kullu, mandi (HP), Tripura Floods, Gujarat Floods, Andhra Pradesh Floods, Bihar, West Bengal Floods.

Summary of International Operations:

2011: For the first time NDRF was deployed in Japan post Tsunami

2015: 16 USAR teams of NDRF were deployed to provide assistance in Nepal Earthquake

2023: 03 NDRF teams mobilised for Turkiye after the earthquake struck Turkiye and northwest Syria

1.3.1.8.10. Summary of operational activities (since 2006 till date)

Human lives Rescued by NDRF	1,58,700

Human lives evacuated by NDRF	8,62,084
Dead bodies retrieved	7,466
Total No. of Operation	10,471
Livestock	19,380
Familiarization exercises conducted by NDRF	2844

1.3.1.8.11. Capacity Building initiatives for disaster resilience

i) School Safety Programmes
ii) Capacity Building Programmes for states and local agencies
iii) Community Awareness Programmes
iv) Mock Exercise

1.3.1.8.12. Summary of Capacity Building initiatives

Community Awareness Programmes (CAPs)	No. of CAPs conducted	12543
	No. of beneficiaries	63,89,537
School Safety Programmes (SSPs)	No. of SSPs conducted	7310
	No. of beneficiaries	26,00,086
Mock Exercise	No of Exercise conducted	5,394
	No. of beneficiaries	17,81,999

1.3.1.8.13. Accolades

- Police Medal for Gallantry - 09
- Jeevan Raksha Padak - 10
- Prime Minister Life Saving Medal - 40
- NDRF is the first recipient of the Subhash Chandra Bose Aapada Prabandhan Medal in 2019.

1.3.1.9 National Institute of Disaster Management (NIDM)

- The National Institute of Disaster Management (NIDM) was constituted under an Act of Parliament with a vision to play the role of a premier institute for capacity development in India and the region. The efforts in this direction that began with the formation of the National Centre for Disaster Management (NCDM) in 1995 gained impetus with its redesignation as the National Institute of Disaster Management (NIDM) for training and capacity development. Under the Disaster Management Act 2005, NIDM has been assigned nodal responsibilities for human resource development, capacity building, training, research, documentation and policy advocacy in the field of disaster management.
- Both as a national Centre and then as the national Institute, NIDM has performed a crucial role in bringing disaster risk reduction to the forefront of the national agenda. It is our belief that disaster risk reduction is possible only through promotion of a "Culture of Prevention" involving all stakeholders. We work through strategic partnerships with various ministries and departments of the central, state and local governments, academic, research and technical organizations in India and abroad and other bi-lateral and multi-lateral international agencies.
- NIDM is proud to have a multi-disciplinary core team of professionals working in various aspects of disaster management. In its endeavour to facilitate training

and capacity development, the Institute has state-of-the-art facilities like class rooms, seminar hall, a GIS laboratory and video-conferencing facilities etc. The Institute has a well-stocked library exclusively on the theme of disaster management and mitigation. The Institute provides training in face-to-face, on-line and self-learning mode as well as satellites based training. In-house and off-campus face-to-face training to the officials of the state governments is provided free of charge including modest boarding and lodging facilities.

- NIDM provides technical support to the state governments through the Disaster Management Centres (DMCs) in the Administrative Training Institutes (ATIs) of the States and Union Territories. Presently NIDM is supporting thirty such centres. Six of these centres are being developed as Centres of Excellence in the specialised areas of flood risk management, earthquake risk management, cyclone risk management, drought risk management; landslides risk management and management of industrial disasters. Eleven larger states (Andhra Pradesh, Bihar, Gujarat, Karnataka, Madhya Pradesh, Maharashtra, Rajasthan, Tamil Nadu, Uttar Pradesh, West Bengal and Odisha) have been provided with additional centres to cater their needs in this area.
- The vision is to create a Disaster Resilient India by building the capacity at all levels for disaster prevention and preparedness.

1.3.2. Pakistan

In progress is the UNDP's GLOF project; AWS, water-level gauges for rivers/streams and EW equipment.

Initiative	Description	Timeline
Radar Expansion	Deployment of 4 X-band, 2 C-band, and 2 S-band radars	2025–2027
High-Performance Computing	Enhancement of computational capacity to 220	2026
Upgrade	TFLOPs for improved NWP resolution 7-10km	
Automated Weather Stations	Installation of 300 AWS stations, including 50 with agro-met sensors	

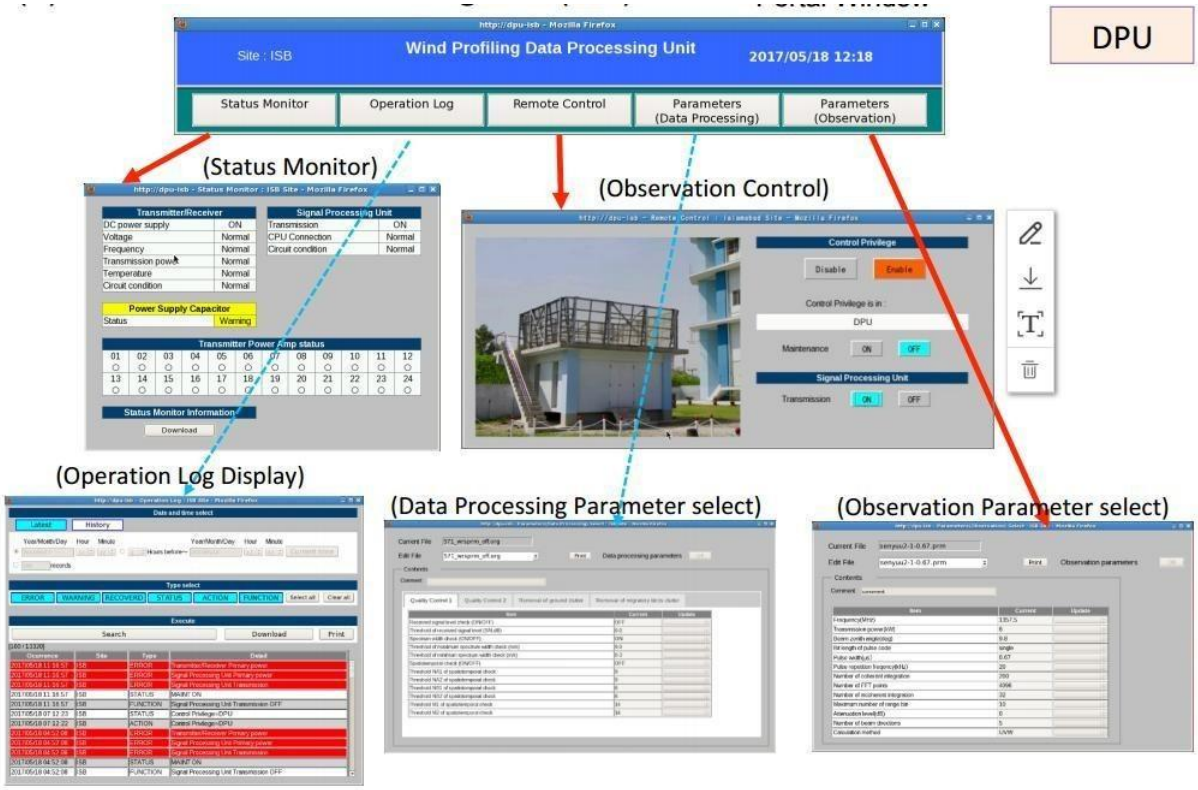

Table 3.2.1. Wind Profiler Specifications

Frequency	1.3575 GHz
Observation Elements	East-west, North-south and Vertical Components of the Wind (including the fall velocity of precipitation particles)
Resolution of Observation Data	Wind Speed (Vertical, Horizontal): 0.1 m/s, Wind Direction: 1°
Accuracy	Wind Speed: 1m/s (Horizontal), 0.2 m/s (Vertical)
Wind Direction: 15° (≤5m/s), 10° (>5m/s)	
Observation Range	Wind Speed: 0-90m/s (Horizontal), 0-30m/s (Vertical)
Receiving Sensitivity	Signal to Noise Ratio: +3dB or more (@Altitude 5.5km) Conditions: • Refractivity Turbulence Structure Constant (C_n^2): 10^-0.000276·R(m)^-13.862 • Range Resolution (ΔR): 300m • Ambient Temperature: 290K • Surface Noise Temperature: 36K

Observation Height	0.4–12.0 km

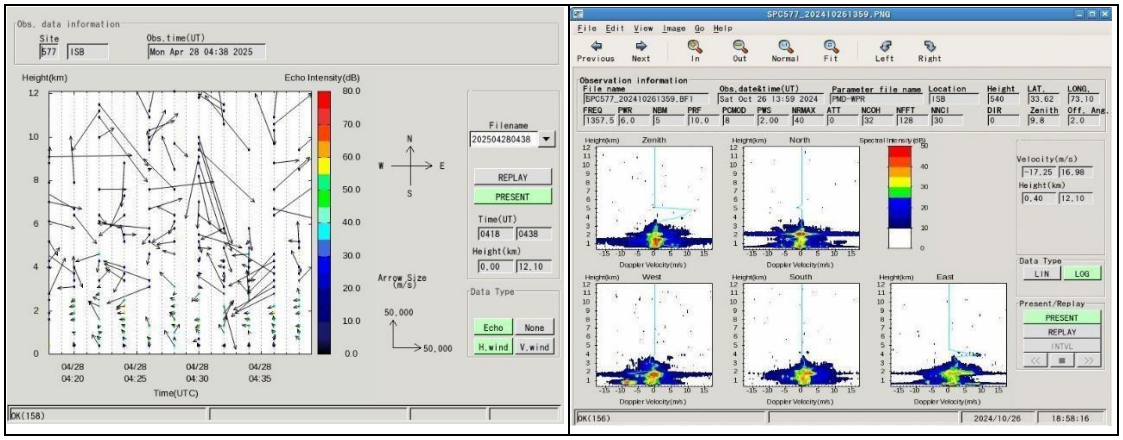

Fig.3.2.1. Wind Profiling Mechanism. Size of arrow is showing the speed of wind

Fig.3.2.2. Wind Profiler installed in Islamabad

Lightning Detectors Installation:

To mitigate the growing risks posed by lightning strikes, the Pakistan Meteorological Department (PMD), in collaboration with the Institute of Electrical Engineering, Chinese Academy of Sciences (IEE, CAS), has established a state-of-the-art **3D Lightning Monitoring and Warning System**. This network comprises **28 Very Low-Frequency/Low-Frequency (VLF/LF) sensors** strategically deployed across vulnerable regions, enabling real-time detection of lightning strikes with precise location, intensity, and spatial distribution data. The system addresses critical gaps in weather monitoring, serving as a radar proxy in areas with poor coverage while enhancing severe weather forecasting, flood warnings, and aviation safety. With an investment of **USD 1 million**, this initiative marks a significant leap in Pakistan's disaster preparedness, aiming to reduce fatalities and economic losses caused by lightning-related disasters.

The network's first sensor was successfully installed at **PMD Islamabad in 2023**, followed by rapid deployment to 22 additional locations. A **long-range lightning system** is also planned to extend coverage to neighboring countries. Supported by a

Cooperation Agreement signed in September 2023, this project underscores PMD's commitment to leveraging cutting-edge technology for public safety. By integrating lightning data into meteorological models and early warning systems, Pakistan is now better equipped to safeguard lives, infrastructure, and agricultural operations from one of nature's most unpredictable hazards.

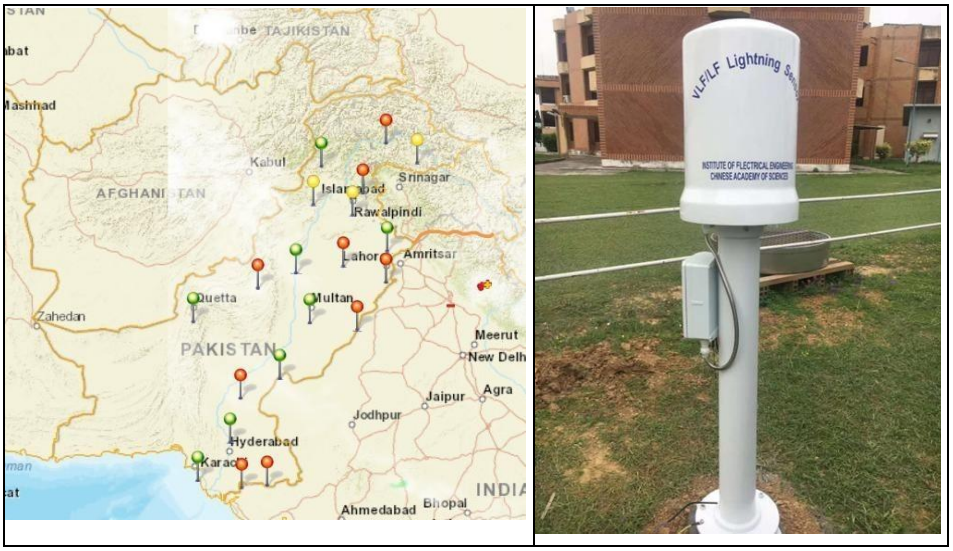

Fig.3.2.3. Lightning Detections system installed in various places all over the country

1.3.3. Myanmar

Main responsibility of Department of Meteorology and Hydrology (DMH) is to provide early warning to the higher authorities, local government, and disaster risk reduction relevant agencies, media, INGOs, NGOs, social medias and general public. Whenever the significant weather condition news and warnings are issued by DMH, the messages were sent to the respective stations by telephone or Single Side Band (SSB) transceiver, email and fax. As soon as head of the station who received the message of warning, then immediately informed the local authorities and other related departments in order to carry out the necessary actions. At the same time, the warnings and bulletin are disseminated through DMH Website, Facebook, DMRS, Radio and Television as well as through the Newspaper for general public. DMH owns weather studio for effective communication with clear understandable weather information warnings, two automatic weather answering machines and call center for the early warning system to update warnings and news. DMH cooperated with MRTV, MWD and Radio Channels for live broadcasting about early warning and advisories while Cyclone/Depression approaching Myanmar Coastal Areas. Early Warning decision making processes were accomplished with valuable support and close cooperation with WMO and its Regional office, RSMC (New Delhi), WMO GTS, GFS forecast, INCOIS, ECMWF, WMO LC, APEC, CIMSS's analysis, WMO SWFDP products and neighboring NMHSs.

During November 2024 to March 2025, DMH organized the public awareness for disaster risk reduction and participated workshop and meetings as follows;

- 33rd National Monsoon Forum organized by Department of Meteorology and Hydrology was held in Multi Hazard Early Warning Center of Department of Meteorology and Hydrology, Naypyitaw on 5th November, 2024. The forum was discussed on the reviewing of seasonal outlook for the Weather and Water Level forecasts in 2024-2025 Winter Season (Northeast Monsoon Period), condition of

Agro-meteorology, Terms and Terminology of Meteorology, Seismic Disaster in Myanmar, presenting on sectorial lessons learned during 2024 Rainy Season (Southwest Monsoon Period) and sectorial preparedness for 2024-2025 Northeast Monsoon Season and discussing on suggestions for seasonal weather forecasts.

- DMH staffs participate from 31st South Asian Climate Outlook Forum (SASCOF) and Climate Service User Forum (CSUF), from 23rd to 24th Session of the ASEAN Climate Outlook Forums (ASEANCOF) by online.
- DMH staffs attended also South Asia Hydro-met Forum (SAHF): Country-wise Working Group Meeting, Weekly SAHF Forecaster Forum, Weekly BIMSTEC Centre for Weather and Climate (BCWC) Online Map Discussion, Asean Specialized Meteorological Centre (ASMC) Fortnightly Discussion, BIMSTEC Centre for Weather and Climate (BCWC)-Scientific Advisory Committee (SAC): Science Strategy Meeting by Online.

1.3.4. Thailand

1.3.4.1. Socio-Economic Assessment (highlighting socio-economic and DRR issues/impacts)

Overview of tropical cyclones originating over the Bay of Bengal that affected/impacted Thailand from 1 January 2024 to 31 March 2025 by the Department of Disaster Prevention and Mitigation (DDPM), Thailand as per details below:

(a) Tropical cyclone "REMAL" (01B)

In May 2024, the tropical cyclone "REMAL" (01B) initially originated in the Bay of Bengal and affected rainfall in Thailand during 24 - 27 May 2024. DDPM reported that the tropical cyclone "REMAL" (01B) caused windstorm that affected 119 households across 34 districts, 62 subdistricts and 148 villages in 21 provinces including Kanchanaburi, Kamphaeng Phet, Chai Nat, Chiang Rai, Nakhon Pathom, Nakhon Phanom, Nakhon Si Thammarat, Nonthaburi, Pathum Thani, Prachuap Khiri Khan, Phichit, Phetchaburi, Maha Sarakham, Mukdahan, Ratchaburi, Lopburi, Songkhla, Satun, Samut Prakan, Sukhothai and Suphan Buri. The tropical cyclone also caused flooding that affected 294 households across 10 districts, 17 subdistricts and 71 villages in 9 provinces including Kanchanaburi, Tak, Nakhon Pathom, Phrae, Rayong, Ratchaburi, Loei, Suphan Buri, Udon Thani. There were no injuries and casualties from both accidents.

1.3.4.2. Summary of DRR Projects and Activities

During 2021 - 2022, DDPM conducted a comprehensive study of effective emergency alert systems implemented in other countries and by international organizations. The objective was to identify suitable technologies that could be adapted to Thailand's context. This exploration encompassed various communication channels, including radio, internet, and mobile applications.

In the course of this initiative, a series of consultations were held with the National Broadcasting and Telecommunications Commission (NBTC) and mobile network operators to assess the feasibility of adopting a Cell Broadcast System as a mechanism for emergency public alert dissemination. Subsequently, on August 25, 2022, the National Disaster Warning System Management Committee passed a resolution designating DDPM as the lead agency responsible for implementing mobile-based emergency alerts through Cell Broadcast System in Thailand.

In 2023, preliminary technical specifications and system limitations were developed as part of the planning process. DDPM is responsible for developing the Cell Broadcast

Entity (CBE). In parallel, the Ministry of Digital Economy and Society (MDES) is responsible for developing the necessary infrastructure and network systems to support the operational deployment of the Cell Broadcast System.

In 2024, the NBTC allocated funding to support the implementation of Cell Broadcast System by the three major mobile network operators including AIS, TRUE and NT. These funds are designated for the development and maintenance of the Cell Broadcast Centre (CBC), Core Networks, Radio Networks, and for system maintenance over a period of three years.

Thailand's Cell Broadcast System is expected to be fully operational and ready for nationwide deployment by July 2025.

1.3.4.3 Standard Operating Procedures (SOP) for Emergency Alert Systems and Standardized SMS Messages for Public Warnings

During the first half of April 2025, Thailand has established the Working Group on Development of Standard Operating Procedures (SOP) for Emergency Alert Systems and Standardized SMS Messages for Public Warnings consists of DDPM together with relevant agencies including the National Broadcasting and Telecommunications Commission (NBTC), the Meteorological Department, the Department of Mineral Resources, the Royal Irrigation Department, the Office of the National Water Resources (ONWR), the Public Relations Department, and mobile operators AIS, True, and NT. This Working Group has collaboratively developed, reviewed and refined a draft of the Standard Operating Procedures (SOP) for Emergency Alert Systems and Standardized SMS Messages for Public Warnings covering seven types of hazards: earthquakes, tropical storms, floods, landslides, cold spells, and fine particulate matter (PM2.5), in order to ensure clarity, efficiency, and inter-agency coordination in disseminating timely alerts to the public.
While full-scale deployment of Cell Broadcast System is being finalized, the interim use of Virtual Cell Broadcast System will continue. The following provides a summary of the SOP for Emergency Alert Systems.

(a) Earthquake

When an earthquake reaches the threshold for public notification (domestic earthquakes with a magnitude of 4.0 or higher), the Thai Meteorological Department (TMD) will issue the first alert message directly to mobile network operators via the Cell Broadcast System. This message is intended to inform the public immediately. Subsequently, DDPM will issue follow-up messages providing situational updates and safety instructions until the threat has passed. These alerts are issued in accordance with the Standard Operating Procedures (SOPs) for earthquake notifications, utilizing pre-approved standardized alert messages.

(b) Other Hazards

In case of other hazards such as tropical cyclones, flash floods, or riverbank overflows, relevant agencies including the Thai Meteorological Department (TMD), National Water Command Center (NWCC), Royal Irrigation Department, Department of Water Resources, Department of Mineral Resources and the Hydro Informatic Institute, will forward warning data to DDPM. These agencies then jointly assess the situation through a War Room approach. Once the alert threshold is met, DDPM will send warning messages to the public via mobile network operators using the Cell Broadcast System. The process follows established SOPs and uses standardized alert message templates prepared in advance.

(c) Current Message Dissemination via Cell Broadcast System

Until DDPM's Cell Broadcast Entity (CBE) is fully operational, the current procedure involves DDPM sending alert messages to all three mobile network operators (AIS, True, and NT) through pre-established communication channels and designated personnel (e.g., Line, telephone, and email). The mobile operators then transmit these messages via their Cell Broadcast Centre (CBC) to the mobile phones of users in the targeted areas.

1.4. Training

1.4.1. India

1.4.1.1. Trainings conducted by Meteorological Training Institute (MTI)/ Regional Training Centre (RTC), Pune, India

The Human Resource Development has always been one of the prime thrust areas of the India Meteorological Department for capacity building and to keep pace with the latest trends in various activities in the department. Meteorological Training Institute IMD Pune component of RTC India is the main centre of IMD for capacity development in the field of operational Weather and Climate Services. Training Facilities at this center has been recognized by WMO to function as a RTC in the WMO RA-II region in the disciplines of General Meteorology (Forecasting- Non-Aviation & Aviation both), Surface Instrumentation and Agricultural Meteorology, since 1986.

Like previous years, MTI Pune conducted various training programs in 2024. The course curricula of various training courses have been modified keeping in view the latest developments. In every regular training program in General Meteorology discipline, a sizable portion on Tropical cyclone is there, which consists of basic concepts on Tropical cyclone genesis, structure, life cycle, dynamics & thermodynamics aspects of tropical cyclone, different prediction & warning methods of Cyclone and techniques providing impact-based cyclone forecasting.

During 2023-24, MTI has organized 8 regular long term (2-12 months duration) certificate training courses (5 BIP-M & 2 BIP-MT), with approximately 294 national participants and 2 overseas participants from Mauritius Met. Services and during 2024-25 (till November 2024), 4 regular long term (2-12 months duration) certificate training courses (3 BIP-M & 1 BIP-MT), with approximately 164 national participants. In addition, RSMC New Delhi conducted its regular cyclone training program. Various other divisions of IMD such as Satellite Meteorological Division, Radar Division, NWP Division and Instrument division conducted training programs in their respective areas for national and international participants. Customized training course on Aviation Meteorology for Meteorological Personnel of Bhutan was conducted in virtual mode in 2023-2024. A Joint IMD-WMO group fellowship training on "Development of Competency in Weather forecasting" was conducted in Physical mode during the period 26.08.2024 to 27.09.2024. Customized training course on Basic Meteorology for Meteorological Personnel of Bhutan is going on for the period 04.11.2024 to 29.11.2024 in physical mode.

E-learning method in training program is used for some courses. Initiative is being taken up for distant learning program through virtual classroom facilities and sharing of digital content of lectures in broadcast mode.

Trainings conducted during 2023-24 along with ongoing and planned activities for 2024-25

S.N.	*Name of Training*	*No. of Trainees during 2023-24*	*No. of Trainees during 2024-25 (Till November 2024)*	*Ongoing trainees*
1.	Advanced Meteorological Training Course (AMTC)	11 (7 Indian Navy, 2 Coast Guard & 2 Mauritius) (Hybrid mode)	2 (2 Coast Guard (Physical mode)	5 (2 Coast Guard & 3 Mauritius) (Physical mode)
2.	Forecasters Training Course (FTC)	109 (E-learning & Hybrid mode)	39 (E-learning & Hybrid mode)	49 (E-learning & Hybrid mode)
3.	Integrated Meteorological Training Course (IMTC)	147 (Online / V.C.)	110 (Online / V.C.)	--
4.	Direct Recruited Scientists Training Course (DRSTC)	12 (Online / V.C.)	13 (Hybrid mode at New Delhi Centre)	--
5.	Basic / Modular Training Course	17 (Physical mode)	--	--

Future Plan:

- Customized training course on Intermediate / Advanced Meteorology for Meteorological Personnel of Bhutan will be conducted during the period 02.12.2024 to 30.12.2024 in physical mode.
- Next Batch of Integrated Meteorological Training Course (IMTC) will be conducted from 2nd December 2024.
- Next Batch of Forecasters Training Course (FTC) will be conducted from 24th March 2025.
- Next Batch of Advanced Meteorological Training Course (AMTC) will be conducted from 8th September 2025.

1.4.1.2. Trainings conducted by RSMC, New Delhi:

(a) 20th Tropical Cyclones Forecasters Training (19-30 August, 2024):

India Meteorological Department (IMD) is one of six Regional Specialised Meteorological Centres (RSMCs) in the world recognised by WMO under a global system for issue of warnings and advisories in association with cyclonic disturbances over north Indian Ocean. As an international commitment, TC advisories are issued by RSMC, New Delhi, to WMO/ Economic and Social Commission for Asia and Pacific (ESCAP) Panel member countries including Bangladesh, India, Iran, Maldives, Myanmar, Oman, Pakistan, Sri Lanka, Qatar, Saudi Arabia, United Arab Emirates, Thailand and Yemen. IMD also conducts training for cyclone forecasters in the region annually.

IMD started conducting tropical cyclones forecasters training for WMO sponsored participants from ESCAP Panel member countries since 2005. From 2008, onwards the forecasters from various Area Cyclone Warning Centres (ACWCs) and Cyclone Warning

Centres (CWCs) were also included. In 2015, International Training on Workshop on Tropical Cyclones Forecasting was organised with participants from WMO/ESCAP Panel countries, Australia, Switzerland, Cambodia, Lao PDR and Philippines.

This year, the WMO's Tropical Cyclones Forecasters Training 2024 was conducted by Regional Specialised Meteorological Centre (RSMC), New Delhi during 19-30 August in hybrid mode. This was the 20th training programme conducted every year since 2005 for the cyclone forecasters of the member countries. This year there were 106 participants including 26 International participants from Thailand, Myanmar, Bangladesh, SriLanka, Maldives, Pakistan, Iran, Oman, United Arab Emirate & Saudi Arabia, and 80 participants from various sub-offices of IMD. There are a total of 43 international participants with 9 joining in -person and remaining 34 joining online from various PTC member countries apart from the participants from India. The training aimed at building capacity of the TC forecasters in the region by understanding the latest developments in observations, monitoring, modeling, prediction and early warning services of TCs over the Bay of Bengal and the Arabian Sea and carrying out the case studies as practical examples in these aspects. The training included resource persons from UN-ESCAP, RSMC Tokyo, IMD, National Centre for Medium Range Weather Forecasting (NCMRWF), Indian National Centre for Ocean Information Services (INCOIS) and IIT Delhi. During the training special sessions were organised for storm surge & ocean state forecasts and monsoon circulations.

(b) 1st Regional Training workshop on Multi-Hazard Early Warning System (MHEWS) Interoperability Implementation

India Meteorological Department (IMD) and World Meteorological Organisation (WMO) jointly organized the 1st Regional Training workshop on Multi-Hazard Early Warning System (MHEWS) Interoperability Implementation at New Delhi during 9-13 December 2024. The training aimed to enhance the capacity of the National Meteorological and Hydrological Services (NMHSs) in South Asia on the interoperability and integration of early warning initiatives, programmes, and activities as feasible into a coordinated and sustainable, multi-hazard interoperable environment, to enhance the capacities of NMHSs. With the regional level collaboration and coordination, the participants will learn to develop a coordinated and sustainable, multi-hazard interoperable environment through:

- sharing good practices
- improve regional collaboration (e.g., among regional and national centres for guidance product, data, training etc.)
- maximizing available resources (e.g., computing, IT and manpower etc.)
- developing synergized standard operating procedures
- strengthen national institutional coordination and arrangements for MHEWS (to ensure national governance and commitment)
- sharing of data and products (in standards and formats) compatible to various systems to contribute to MHEWS interoperability
- integrate various services into one package
- minimization of number of warning bulletins and development of consolidated bulletin as per user's requirements. There were 9 international participants and 38 national participants.

1.4.1.3. Future Plan:

a) Attachment training at RSMC New Delhi during July, 2025

b) User specific training for various stakeholders

1.4.2.Iran:

(a)IRIMO conducted training on the Fluid Dynamics Conference was held by the Mechanical Engineering Department of Persian Gulf University in Bushehr in March 2024, focusing on the oil, gas, and petrochemical industries and marine currents, in collaboration with the Iranian Meteorological Organization.

(b)Conference organised:

- Laminar and turbulent flows, Compressible flows, Dilute flows, Biological flows, Flow Stability, Boundary layer,Nanofluids, Acoustics, Non-Newtonian fluids, Multiphase flows, Flows accompanied by combustion, Flow in porous media,Structure-fluid interaction, Flows accompanied by mass and heat transfer, Flow measurement and control methods,Geophysical fluid dynamics, Environmental fluid dynamics,Numerical modeling and prediction in the atmosphere and sea,Small-scale fluid flow (micro and nano),Flows with magnetic and Electric field effects,Flow in industrial equipment, Fluid dynamics in marine structural engineering and ship engineering
- Persian Gulf National Day, 30 April, 2024, was held at the Armed Forces Geographical Organization.
- Every year, a conference and exhibition is held to commemorate Persian Gulf Day in cooperation with the National Meteorological Organization and the Geographical Organization of the Marine Forces, with participation from all maritime organizations and bodies.

(c)RTC courses held at the World Meteorological Organization Regional Training Center (Tehran) 2024

Iran is a regional training center for the World Meteorological Organization, which holds training courses every year. Courses held in 2024 include:

- Integrated Drought Management: Monitoring and Early Warning
- HYDRO SOSI
- Monitoring and Now-casting of Severe Convection

WMO assessors visited RTC-Tehran this fall.

World Meteorological Organization (WMO) assessors, Mr. Mustafa Adgodzel and Ms. Mamayeva, visited the WMO Regional Training Center in Tehran to assess the quality of services and educational facilities.

1.4.3.Pakistan:

The Institute of Meteorology and Geophysics (IMG), under the Pakistan Meteorological Department (PMD), serves as one of the region's foremost centers for meteorological and geophysical education and research. Recognizing its strategic importance, the Government of Pakistan has launched an ambitious initiative to revamp and digitalize IMG, transforming it into a world-class regional training hub. This upgrade will enable IMG to address the growing demand for advanced weather and climate expertise across South Asia, Central Asia, the Middle East, and Africa.

IMG offers a diverse range of specialized courses, including **meteorology, remote sensing, GIS, artificial intelligence, seismology, aviation meteorology, marine meteorology, and satellite meteorology**. By modernizing its curriculum, infrastructure, and training methodologies, IMG aims to enhance its capacity in weather forecasting, disaster risk reduction, and climate research. A key component of this transformation is the engagement of expert consultants who will help align IMG’s

programs with international standards, introduce advanced teaching techniques, and implement performance metrics in line with ISO certification requirements. The consultants will also support infrastructure development, technology integration, and faculty training to ensure IMG becomes a center of excellence.

This initiative is not just about institutional improvement—it is a strategic investment in Pakistan's scientific leadership. A strengthened IMG will attract top researchers, foster international collaborations, and elevate Pakistan's role in global meteorological advancements. By positioning itself as a regional knowledge hub, IMG will contribute to sustainable development, improved weather resilience, and enhanced scientific diplomacy, reinforcing Pakistan's standing in the field of atmospheric and geophysical sciences.

Curricula for following courses has already been updated:
Advanced Forecasting Course (for experienced forecasters)

- Basic Forecasting Course (BIP-M),
- Preliminary Meteorology Course,
- Initial Meteorology Course (BIP-M), and
- Inspector Course

International Training/workshop regarding Tropical cyclone:

- Training Course from NUIST on Tropical Cyclone Early Warning and Forecasting (19 - 30 September 2024, Nanjing-China).
- Fourth international workshop on satellite analysis of tropical cyclones (IWSATC-4) ONLINE from 3-5 December 2024.
- CMA-CAST and visual weather analysis training were conducted in the year 2024 for all relevant sections especially forecasting and TCWC-PMD.

Asia-Pacific Typhoon Collaborative Research Center (APTCRC):
PMD works closely with AP-TCRC to utilize the STI-IBF platform, which provides probabilistic forecasts for cyclone tracks and impacts.

- The following products were analyzed in collaboration with AP-TCRC, with future plans to scale globally for predicting annual and seasonal forecast variations over the Arabian Sea.
- Impact-based forecasting has been initiated at PMD with the support of data-driven approaches. The STI-IBF system is jointly researched and developed by the Shanghai Typhoon Institute of the CMA (STI/CMA) and the Asia-Pacific Typhoon Collaborative Research Center (AP-TCRC). It integrates tropical cyclone (TC) forecast customization, multi-scale impact-based TC forecasting and prediction, as well as TC verification, offering users seamless and comprehensive TC forecast information services.

1.4.4. Myanmar

- DMH is cooperated with Yangon and Dagon Universities for B.Sc (Hons:) Met. /Hydro since 1993-1994 academic year as the recommendation of WMO Secretary General G.O.P Obasi who visited to Myanmar in year 1992. After educating B.Sc (Hons:) Meteorology, they will be served as civil services at DMH.
- DMH has conducted the Meteorology level (1) Course in Yangon from 2nd January to 31st January 2025. the Meteorology level (2) Course in Mandalay from 3rd March to 4th April 2025.
- 65th Anniversary of World Meteorological Day was celebrated in Ministry of Transport and Communications, Nay Pyi Taw on 23rd March 2025 organized by Department of Meteorology and Hydrology, and presented Research Papers Reading Sessions related with Meteorology, Hydrology, Seismology and Disasters.
- Some DMH's staffs are attending Master and PhD scholarships for Applied

Meteorology at Nanjing University of Information Science and Technology (NUIST).

- DMH's staffs attended Lecture Series on Satellite Meteorology (SAMA) and Global Greenhouse Gas Watch – eastern hemisphere from Online.

1.5. RESEARCH and publication

1.5.1. India

(a) FDP on landfalling cyclones over the Bay of Bengal:

A Forecast Demonstration Project (FDP) on landfalling tropical cyclones over the Bay of Bengal was taken up in 2008. It helps us in monitoring and prediction of a tropical cyclone. The RSMC Tropical Cyclones, New Delhi acts as National Operations Centre and Cyclone Warning Research Centre, Regional Meteorological Centre, Chennai acts as Field Operations Centre. During 2024, the project has been carried out during 15 October to 10 December this year against normal period of 15 October-30 November due to the development of cyclonic storm "MICHAUNG" during 1st-6th December. Like previous years, several national institutions participated for joint observational, communicational & NWP activities. There was an improved observational campaign with the observations from Buoys, scatterometer based satellite and microwave imageries products. The daily reports were prepared during this period to find out the characteristics of genesis, intensification, and movement of the systems as well as the environmental features over the NIO.

(b) Statistical prediction of seasonal cyclonic activity over the North Indian Ocean

An experimental outlook on the seasonal cyclonic activity over the North Indian Ocean for the period October-December is prepared on the basis of statistical model developed in-house. The prediction is validated at the end of the season. However, the seasonal forecasts is not published because of less no. of cyclones over the region and thus less accuracy. Efforts are on for improving the prediction model.

(c) Updating of *Cyclone eAtlas-IMD*

Cyclone eAtlas – IMD, a web based software for generation of tracks and statistics of cyclones and depressions over the North Indian Ocean (www.imdchennai.gov.in) was updated with the data of cyclonic disturbances during 2025.

(e) Severe Weather Forecasting Programme (SWFP):

Severe Weather Forecast Demonstration Project (SWFDP) was launched on 2nd May, 2016. During inaugural ceremony of PTC-43 Meeting held at New Delhi. It is an ambitious project taken up with the joint initiative of IMD and World Meteorological Organisation (WMO). The objective of the project is to monitor, predict and warn the public and the Disaster Managers against the Severe Weather namely heavy rain, strong wind, storm surge and high waves. RSMC New Delhi is the regional centre to provide daily Regional Severe Weather Guidance to the member countries including Bangladesh, India, Bhutan, Nepal, Pakistan, Afghanistan, Sri Lanka and Maldives. It is a 3-tier cascading process involving various NWP centres at global levels, RSMC New Delhi at regional level and the National Meteorological centres of the member countries. Under

this project 5 days forecast is issued based on initial conditions of 0300 UTC observations. The project also stresses upon the Public Weather Services and liaison with Disaster Managers, Media and others for effective management of severe weather over the region. The project continued in 2018. Various new initiatives were taken in 2019 with commencement of Pilot Phase of SWFDP Project from 1st June 2019. RSMC New Delhi introduced prognostic and diagnostics discussion, probability tables for day-1 & day-2 forecast and risk tables for day-3,4 & 5 forecasts. The SWFDP was renamed as Severe Weather Forecasting Programme (SWFP) in April, 2020. Archival of all products since 2019 has been made available on SWFP website of IMD. Since 1st September, 2023, IMD introduced risk-based warning in association with heavy rainfall and strong winds over the region based on the severity of the weather and the probability of occurrence for 95 met sub-divisions as nil, low, moderate and high.

Future Plan

- Generation of more user-friendly products / graphics for Cyclone warning.
- Development of Dynamic Cone of Uncertainty for Cyclone track forecasts.
- Automation of bulletins
- Development of customised location specific forecast for more sectors
- Dynamic impact-based forecast and risk-based warning for all types of severe weather

India Meteorological Department remained involved in extensive research activities. The major achievements during 2025 were:

- Annual RSMC Report on Cyclonic Disturbances during 2024
- Annual Tropical Cyclone Operation Plan (TCP-21) (Edition 2025)
- Annual Report of Cyclone Warning Division, IMD and MoES
- News Letters: IMD
- Preliminary and detailed reports of cyclonic disturbances during 2025
- Paper published in Mausam Journal in 2025

List of publications on cyclone in reviewed journals

- Mrutyunjay Mohapatra and M. Sharma, 2025, Cyclone Warning System in India: A journey of success over 25 years, Weather and Forecasting
- M. Sharma, M. Mohapatra and P Suneetha, 2025, Evaluation of operational extended range forecast of cyclogenesis over the North Indian Ocean, TCRR
- Litta A. J., M. Mohapatra, M. Sharma and Daisuke Abe, 2025, Tornado associated with Very Severe Cyclonic Storm "YAAS" over West Bengal on 25 May 2021, Mausam
- M Mohapatra, M Sharma and Dr Pattanaik, Evolution of Cyclone Monitoring and Forecasting System in India: A review, 2025, MAUSAM, 76 (1), 103-124
- UC Mohanty, Raghu Nadimpalli, Akhil Srivastava, Ananda K Das, Krishna K Osuri, Ashish Routray, Sudheer Joseph, PLN Murty, Dr Pattanaik, SG Gopalakrishnan, Dev Niyogi, M Mohapatra, A Journey Through Time The History of Mesoscale Severe Weather Monitoring and Forecasting in India, 2025, MAUSAM 76 (1), 79-102

- PR Naskar, GP Singh, M Mohapatra, Association of air sea heat fluxes with tropical cyclones, intensity, energy and destructiveness, 2024, Meteorology and Atmospheric Physics 136 (6), 1-10
- CR Khadke, M Mohapatra, N Nandwani, Satellite based analysis of rapid intensification of Super Cyclone Amphan, 2024, MAUSAM 75 (4), 1031-1038
- Sundar Ranganathan, Robert A Weller, Ramasamy Venkatesan, Amit Tandon, M Arul Muthiah, Mrutyunjay Mohapatra, Performance of Moored Real-Time Ocean Observations During Cyclones in the Bay of Bengal, 2024, Marine Technology Society Journal 58 (3), 56-69
- S Prakash, DS Pai, M Mohapatra, Meteorological Sub-Divisional Scale Comparison Between Two Indian Rain Gauge-Based Rainfall Datasets for the Southwest Monsoon Season, 2024, Pure and Applied Geophysics 181 (8), 2613-2630
- Nadao Kohno, Cody Fritz, Monica Sharma, Robbie Berg, Diana Greenslade, Devon Telford, Sakeasi Rabitu, PLN Murty, M Mohapatra, Maria Cristina C Uson, 2024, TCRR,
- Pravat Rabi Naskar, Mrutyunjay Mohapatra, Gyan Prakash Singh, Umasankar Das, 2024, Yerni Srinivas Nekkali, Krishna Kishore Osuri, M Mohapatra, 2024, Physical understanding of the tropical cyclone intensity and size relations over the North Indian Ocean, Climate Dynamics, pp 1-14
- Mrutyunjay Mohapatra, 2024, Climate and Weather Forewarning Systems for Disaster Preparedness and Response, Disaster Risk and Management Under Climate Change, Springer, pp 39-54
- Satya Prakash, M Mohapatra, 2024, Vertical structure of tropical cyclone precipitation over the North Indian Ocean: a space borne precipitation radar perspective, Remote Sensing Letters, 17(1), pp77

Panel News Letter

Panel News letter of PTC was released in July 2025.

1.5.2. Pakistan

Climate Data Processing Center (CDPC) of PMD published twelve monthly and one annual climate reports during the 2024 besides reports on Monsoon.

Total 10 papers were submitted by PMD scientists during 2023-2024. Two of them are:

1. Weeks, J. H., Ahmed, S. N., Daron, J. D., Harrison, B. J., Hogarth, P., Ibrahim, T.,& Sarfaraz, S. (2023). Sea-level rise in Pakistan: recommendations for strengthening evidence- based coastal decision-making. *Hydrology*, *10*(11), 205.
2. Sarfaraz, S., & Faisal, N. (2024). Climate Change and its Impacts across Pakistan: Climate Change and its Impacts across Pakistan. *International Journal of Economic and Environmental Geology*, *14*(04), 28-39.

1.5.3. Sri lanka

In the years 2023 and 2024, 27 officers working in forecasting, technical services, electronic division, accounting and administration division were participated to foreign workshops, trainings and related programs. Conducted two-day residential 'continuing training program (CET program)" in 2023 and three-day CET program in 2024 for Meteorological observer/communicators.

Research Activities in year 2023 and 2024

- Climate analysis during 1950-2020 was completed.

- In collaboration with the International Water Management Institute (IWMI), downscaling of new climate change projections for Sri Lanka by using WRF is ongoing is in the process.
- The studies to adapt the PRISM software for drought studies to Sri Lanka are being done with the support of WFP.
- Conducted verification of monthly and quarterly forecasts issued during 2020-2022.
- Preparation of climate projections for Sri Lanka based on IPCC AR 6 climate projections is underway.
- Studies on the changes in Sri Lanka's climate from 1950 to 2023 are in the final stages.
- A detailed study was conducted on the meteorological factors contributing to the heavy rainfall that occurred on 1 June 2024. Its report is being prepared.

Research Publications 2023-2024

- Research paper on "The impact of Indian Ocean warming on south-west monsoon rainfall in the wet zone of Sri Lanka during the last two decades (2001-2020)'' was published in international journal of climatology. This has done with the collaboration of University of Ruhuna.

1.6. SUPPORT FOR THE PANEL'S PROGRAMME

PTC Trust Fund

The WMO representative presented to the Panel the final statement for 2024 of the PTC Trust Fund. The Panel endorsed the statements. A detailed financial report of the Trust Fund as of 31 December 2024 as submitted by WMO to the Panel is given below**.**

1. Final Statements of Incomes and Expenditure for the Period 1 January to 31 December 2024
2. Contribution from Members from January to December 2024.
3. External auditors' auditing certificate/ report is available to PTC Members, on request

•Meeting all requirements in following WMO Financial Regulations and the Rules of PTC Trust Funds.

"In our opinion, the accompanying financial statements present fairly, in all material respects, the financial position of the Panel on Tropical Cyclone (PTC) as at 31 December 2024, and its financial performance, its changes in net asset/equity, its cash flows and its comparison of budget and actual amounts for the year then ended, in accordance with International Public Sector Accounting Standards (IPSAS) and the WMO Financial Regulations and Rules"

Final Statement of Panel's Trust Fund

WMO OMM

World Meteorological Organization
Organisation météorologique mondiale
Organización Meteorológica Mundial
Всемирная метеорологическая организация
المنظمة العالمية للأرصاد الجوية
世界气象组织

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PANEL ON TROPICAL CYCLONE TRUST FUND

Trust Fund 421313

Final Statement of Income and Expenditure
For the period 1 January to 31 December 2024
Amounts in US dollars

1.	Balance of fund at 1 January 2024				231,049
2.	Income:				
2.1	Contributions				
2.1.1	Pakistan (20 June 2024)		3,000		
2.1.2	Thailand (7 August 2024)		3,000		
2.1.3	Oman (29 August 2024)		6,000		
2.1.4	Sri Lanka (18 September 2024)		3,000		
2.1.5	Maldives (2 October 2024)		3,000		
2.1.6	Myanmar (2 December 2024)		3,000		
2.1.7	Total contributions			21,000	
2.2	Interest			4,448	
2.3	Total income				25,448
3.	Total available funds during reporting period				256,497
4.	Expenditure:				
4.1	Direct project costs				
4.1.1	Travel		5,951		
	Total Direct project costs			5,951	
4.2	Indirect project costs				
4.2.1	Project Support cost		774		
4.2.2	Unrealized loss on currency exchange	a/	17,575		
4.2.3	Bank charges		103		
4.2.4	Total indirect project costs			18,452	
4.3	Total project expenditure				24,403
5.	**Balance of fund at 31 December 2024**				**232,094**

a/ WMO's official currency is the Swiss Franc (CHF). Accordingly, all transactions completed in currencies other than the CHF are converted to Swiss Francs at the United Nations Operational Rate of Exchange (UNORE) in force on the day of the transaction. Project account balances (in CHF) are translated to applicable donor reporting currencies based on UNOREs in force at the end of the month to facilitate reporting to donors. As the Swiss Franc has been appreciating against the US Dollar (the reporting currency for the Panel on Tropical Cyclone Trust Fund), foreign exchange gains resulted from conversion of net asset balances from CHF to USD as of the reporting date. This explains the foreign exchange gain. It should be noted that the gain was not realized as of the reporting date, i.e. they were not actual, as they resulted from (a) revaluing the Fund's assets and liabilities as of that date, and (b) converting the resulting CHF balances to USD.

The financial statement has been prepared on the accrual basis of accounting in accordance with the International Public Sector Accounting Standards (IPSAS)

Certified Correct:

Krishnavarahan Adhivarahan
Chief, Finance Division
16 April 2025

Certified Correct:

Anne-Claire Fontan
Scientific Officer
16 April 2025

CHAPTER - II

CYCLONIC ACTIVITIES OVER NORTH INDIAN OCEAN DURING 2025

The salient features of the cyclonic disturbances (CDs) over the north Indian Ocean (NIO) during the year 2025, the operational forecast performance of India Meteorological Department (IMD) and new initiatives during the year are presented below:

2.1. Salient features of CDs over the NIO

The salient features of the cyclonic disturbances (CDs) over the north Indian Ocean (NIO) during the year 2025, the operational forecast performance of India Meteorological Department (IMD) and new initiatives during the year are presented below:

2.2. Salient features of CDs over the RSMC region

Following CDs developed over the RSMC region (Bay of Bengal, Arabian Sea and Land region) during 2025:

1. Depression over the Arabian Sea (24–25 May, 2025)
2. Deep Depression over Northwest Bay of Bengal off West Bengal–Bangladesh Coasts (29–30 May, 2025)
3. Depression over Southeast Gangetic West Bengal and Adjoining Bangladesh (14–15 July, 2025)
4. Depression over Central Parts of North Rajasthan (15 July, 2025)
5. Depression over Southeast Uttar Pradesh (17–19 July, 2025)
6. Depression over Northwest Bay of Bengal (25–27 July, 2025)
7. Depression over Northwest and Adjoining Westcentral Bay of Bengal (18–19 August, 2025)
8. Land Deep Depression over Southwest Rajasthan and Neighbourhood (06–10 September, 2025)
9. Depression over Northwest and Adjoining Westcentral Bay of Bengal (26–28 September, 2025)
10. Deep Depression over Westcentral Bay of Bengal (01–03 October, 2025)
11. Severe Cyclonic Storm SHAKHTI over Northeast Arabian Sea (01–07 October, 2025)
12. Depression over Southeast Arabian Sea (22–31 October, 2025)
13. Severe Cyclonic Storm MONTHA over Westcentral Bay of Bengal (25–29 October, 2025)
14. Cyclonic Storm "SENYAR" over the Strait of Malacca (25-27 November, 2025)
15. Cyclone "DITWAH" over Bay of Bengal (27th November – 03 December 2025)

Observed tracks of the CDs during 2025 are presented in **Fig. 2.1.**

- Annual activity: Year 2025 witnessed the formation of 15 cyclonic disturbances (CDs) (maximum sustained wind speed (MSW) ≥ 17 knots) i.e. depressions and cyclones over the north Indian Ocean (NIO) including 7 over the Bay of Bengal (BoB) and 3 over the Arabian Sea (AS) and 4 over land against the normal of 11.2 CDs per year over the NIO based on the data of 1965-2024. Thus, the activity of formation of CDs was above normal.
- Category-wise activity: There were 11 depressions/deep depressions (MSW: 17-33 knots) against a normal of 6.5 per year. There were 4 cyclones (MSW:≥34 knots) against a normal of 4.6 per year. It included 2 cyclonic storms (MSW:34-47 knots) and 2 severe cyclonic storms (MSW:48-63 knots) Overall, there were above normal number of depressions/ deep depressions during 2025. It was mainly due to an increased number of CDs during the monsoon season which was an above normal monsoon rainfall season.

- Basin-wise activity: There were 3 CDs over AS against normal of 2.3, 8 CDs over BoB against normal of 7.8 and 4 CDs over land against normal of 1.1. Hence higher number of CDs in 2025 was mainly due to land depressions/deep depressions during monsoon season 2025.
- Season-wise activity: There were 2 CDs during pre-monsoon season (March-May) against normal of 1.4, 7 CDs during monsoon season (June-Sep) against normal of 4.9 and 6 CDs during post-monsoon season (Oct-Dec) against normal of 4.8. Thus, the above normal genesis of CDs during 2025 was mainly during monsoon and post-monsoon seasons.
- Tracks/Paths of cyclones (Straight/recurving): All 4 cyclones (Shakhti, Montha, Senyar and Ditwah) had recurving tracks.
- Landfall of cyclones: Out of 4 cyclones, 3 crossed the coast as cyclones against normal of 3.2 per year. Shakhti dissipated over sea, Montha crossed Andhra Pradesh coast (India) as a severe cyclonic storm, Senyar crossed Indonesia coast as a cyclonic storm and Ditwah moved across Sri Lanka as a cyclonic storm. However, only 1 cyclone (Montha) crossed India coast against the normal of 2 per year.

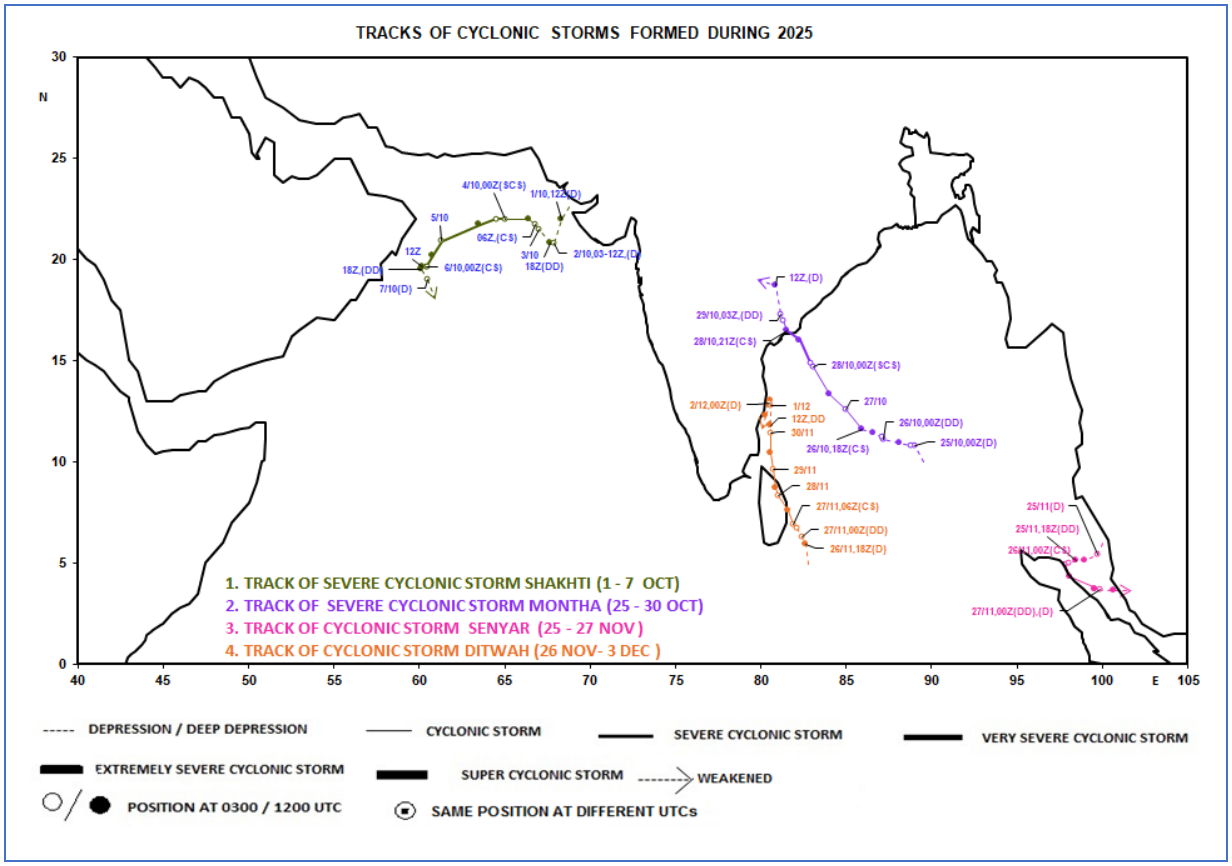

Fig 2.1: Observed Tracks of all cyclonic disturbances during 2025

Table 2.1.1 Some Characteristic features of cyclonic disturbances formed over north Indian Ocean and adjoining region during 2025

S No.	Cyclonic storm/ Depression	Date, Time& Place of genesis (Lat.°N/ Long°E)	Date, Time (UTC) Place (Lat./Long.) of Landfall	Estimated lowest central pressure, Time & Date (UTC) & (Lat°N/ Long°E)	Estimated Maximum wind speed (kt), Date & Time	Max T. No. Attained
1.	Depression over eastcentral Arabian Sea and adjoining south Konkan (24-25 May, 2025)	0000 UTC of 24th May, 2025 over eastcentral Arabian Sea and adjoining south Konkan (17.0/73.0)	crossed south Konkan coast near Ratnagiri between 1130 and 1230 hrs IST (0600 and 0700 UTC) of 24th May	998 hPa at 0000 UTC of 24th May, 2025 (17.0/73.0)	20kt at 0000 UTC of 24th May, 2025 (17.0/73.0)	T1.5
2.	Deep Depression Over Northwest Bay of Bengal off West Bengal – Bangladesh Coasts (29th - 30th May, 2025	0000 UTC of 29th May, 2025 over Bay of Bengal (20.8/88.3)	Weakened into a well-marked low-pressure area over Meghalaya and neigbourhood	986hpa at 0300 UC of 29th May, 2025 (21.3/88.3)	30 kts at 0300 UC of 29th May, 2025 (21.3/88.3)	T2.0
4.	Depression over southeast Gangetic West Bengal and adjoining Bangladesh (14th - 15th July, 2025)	0000 UTC of 14th July, 2025 over southwest Bangladesh and adjoining Gangetic West Bengal (23.0/88.8)	Weakened into a well-marked low-pressure area over north Jharkhand and adjoining south Bihar	998 hPa at 0000 UTC of 14th July, 2025 (23.0/88.8)	20 kts at 0000 UTC of 14th July, 2025 (23.0/88.8)	-
5.	Depression over North Rajasthan during 15th July-16th July 2025	0300 UTC of 15th July, 2025 over central part of northern Rajasthan (27.4/75.4)	Weakened into a well-marked low-pressure area over northwest Rajasthan	998 hPa at 0300 UTC of 15th July, 2025 (27.4/75.4)	20 kts at 0300 UTC of 15th July, 2025 (27.4/75.4)	-
6.	Depression over	0000 UTC of 17th July,	Weakened into a well-	993 hPa at 0000 UTC of	25 kts at 0000 UTC	-

	Southeast Uttar Pradesh during 17th July – 20th July, 2025	2025 over Southeast Uttar Pradesh (25.2/81.8)	marked low-pressure area over west Rajasthan and adjoining Pakistan	17th July, 2025 (25.2/81.8)	of 17th July, 2025 (25.2/81.8)	
7.	Depression over Northwest Bay of Bengal (25th July-27th July 2025)	0000 UTC of 25th July, 2025 over Northwest Bay of Bengal and adjoining areas of coastal West Bengal and Bangladesh (21.4/89.5)	Weakened into a Well Marked Low Pressure Area Over Northwest Madhya Pradesh and neighbourhood	988 hPa at 0000 UTC of 25th July, 2025 (21.4/89.5)	25 kts at 0000 UTC of 25th July, 2025 (21.4/89.5)	-
8.	Depression over Northwest Bay of Bengal during 18th - 19th August 2025	1200 UTC of 18th Aug, 2025 over northwest and adjoining westcentral BoB & north Andhra Pradesh - south Odisha coasts (18.9/85.0)	Weakened into a well-marked low-pressure area over central parts of Chhattisgarh & neighbourhood	994 hPa at 1200 UTC of 18th Aug, 2025 (18.9/85.0)	20 kt at 1200 UTC of 18th Aug, 2025 (18.9/85.0)	T1.5
9.	Deep Depression over north Gujarat and adjoining southwest Rajasthan (06th - 10th September, 2025)	1800 UTC of 06th September, 2025 over Southwest Rajasthan and neighbourhood (25.0/72.5)	Weakened into a well-marked low pressure area over northwest Arabian Sea and adjoining southwest Pakistan	995 hPa at 1200 UTC on 9th September, 2025. (24.5/71.2)	30 knots at 1200 UTC on 9th September, 2025. (24.5/71.2)	T1.5
10.	Depression over northwest and adjoining westcentral Bay of Bengal off south Odisha-north Andhra Pradesh coasts	1800 UTC of 26th September, 2025 northwest BoB (19.3/86.1)	Weakened into a well-marked low-pressure area over west Vidarbha and adjoining north Madhya Maharashtra	996 hPa at 1200 UTC on 26th September, 2025. (19.3/86.1)	25 knots at 1200 UTC on 9th September, 2025. (19.3/86.1)	T1.5

	during 26th - 28th September, 2025					
11	Deep Depression over Westcentral Bay of Bengal (01st - 03rd October 2025)	0600 UTC of 1st October, 2025 over Westcentral Bay of Bengal (15.8/86.5)	Weakened into a well-marked low-pressure area over north Chhattisgarh & adjoining areas of north interior Odisha & Jharkhand	995 hPa at 0300 UTC on 2nd October, 2025. (18.0/85.6)	30 knots at 1800 UTC of 1st October, 2025 (16.8/86.0)	T2.0
12	Severe Cyclonic Storm "Shakthi" over northeast Arabian Sea (01Oct – 07th October, 2025)	1200 UTC of 1st November, 2025 over northeast Arabian Sea (22.0/68.3)	Weakened into a well-marked low-pressure area over southwest Arabian Sea on 7th October.	986 hPa at 0300 UTC on 5th October, 2025. (20.9/61.3)	60 knots at 0300 UTC on 5th October, 2025. (20.9/61.3)	T3.5
13	Severe cyclonic storm "MONTHA" over Southeast Bay of Bengal (25th – 30th) October, 2025	0300 UTC) of 25th Nov over Strait of Malacca	Well Marked Low Pressure Area over east Vidarbha and adjoining south Chhattisgarh at 0000 UTC of 30th October 2025	990 hPa at 0000 UTC on 28th October, 2025 (4.7/83)	50 Knots at 0000 UTC on 28th October, 2025	T3.0
14	Cyclonic Storm "SENYAR" over the Strait of Malacca (25-27 November, 2025)	1200 UTC of 20th December, 2024 Over westcentral Bay of Bengal (13.7/83.5)	Weakened into a well marked low pressure area over Malacca Strait and adjoining coastal areas of Malaysia in the midnight (2330 hrs IST/ 1800	999 hPa at 0000 UTC on 26th November, 2025 (5.0/98.0)	40 Knots at 0000 UTC on 26th November, 2025 (5.0/98.0)	T2.5

			UTC) of 27th Nov			
15	Cyclone "DITWAH" over Bay of Bengal (27th November – 03 December 2025)	1800 UTC) of 26th November2025, depression over southwest BoB and adjoining Sri Lanka	Weakened into a Well Marked Low Pressure Area over North Tamil Nadu-Puducherry coasts and neighbourhood	1000 hPa at 0300 UTC on 29th November, 2025 (9.6/80.7)	40 Knots at 0300 UTC on 29th November, 2025 (9.6/80.7)	T2.5

Table 2.1.2 Statistical data relating to cyclonic disturbances over the north Indian Ocean during 2025

A) Monthly frequencies of cyclonic disturbances (C I.≥1.5)

↔ Peak intensity of the system over NIO (BoB & AS) : Land Depression

S.No	Type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1.	D					↔		↔	↔	↔	↔		
2.	DD					↔					↔		
3.	CS											↔	
4.	SCS										↔		
5.	VSCS												
6.	ESCS												
7	SuCS												

B) Life time of cyclonic disturbances during 2025 at different stages of intensity

i. For NIO Region (BoB & AS)

S.No.	Type	Life Time in (Days)
1	D	16 days 12 hours
2.	DD	5 days 12 hours
3.	CS	7 days 0 hour
4.	SCS	2 days 18 hours
	Total Life Time in (Days)	31 days 18 hours

ii. For Bay of Bengal Region

S.No.	Type	Life Time in (Days)
1	D	4 days 21 hours
2.	DD	4 days 15 hours
3.	CS	5 days 12 hours
4.	SCS	0 day 18 hours
	Total Life Time in (Days)	15 days 18 hours

iii. For Arabian Sea Region

S.No.	Type	Life Time in (Days)
1	D	11 days 15 hours
2.	DD	0 day 21 hours
3.	CS	1 days 12 hours
4.	SCS	2 days 0 hour
	Total Life Time in (Days)	16 days 0 hour

iv. For Land Region

S.No.	Type	Life Time in (Days)
1	D	7 days 12 hours
2	DD	1 days 12 hours
	Total Life Time in(Days)	9 days 0 hour

C) Frequency distribution of cyclonic disturbances with different intensities based on satellite assessment over NIO (BoB & AS)

CI No (≥)	**≥1.5**	**≥2.0**	**≥2.5**	**≥3.0**	**≥3.5**	**≥4.0**	**≥4.5**	**≥5.0**	**≥5.5**	**≥6.0**
No of Disturbances	11	6	4	3	1	0	0	0	0	0

D) Basin-wise distribution of cyclonic disturbances

Basin	**Number of cyclonic disturbances**
Bay of Bengal	8
Arabian Sea	3
Land depression	4

Table 2.1.3 Cyclonic disturbances formed over the north Indian Ocean and land areas of India during 1997-2025

Year	**Basin**	**D**	**DD**	**CS**	**SCS**	**VSCS**	**ESCS**	**SuCS**	**Total**
1997	BOB	1	4	1	1	1	0	0	8
	ARB	1	0	0	0	0	0	0	1
	Land	0	0	0	0	0	0	0	0
	Total								**9**
1998	BOB	0	3	0	1	2	0	0	6
	ARB	0	1	1	1	1	0	0	4
	Land	1	0	0	0	0	0	0	1
	Total								**11**
1999	BOB	2	2	1	0	1	0	1	7
	ARB	0	0	0	0	1	0	0	1
	Land	1	0	0	0	0	0	0	1
	Total								**9**

2000	BOB	1	1	2	--	2	0	0	6
	ARB	0	0	0	0	0	0	0	0
	Land	1	0	0	0	0	0	0	1
	Total								**7**
2001	BOB	2	0	1	0	0	0	0	3
	ARB	0	0	2	0	1	0	0	3
	Land	0	0	0	0	0	0	0	0
	Total								**6**
2002	BOB	1	1	2	1	0	0	0	5
	ARB	0	0	0	0	0	0	0	1
	Land	0	0	0	0	0	0	0	0
	Total								**6**
2003	BOB	2	2	0	1	1	0	0	6
	ARB	0	0	0	1	0	0	0	1
	Land	0	0	0	0	0	0	0	0
	Total								**7**
2004	BOB	2	0	0	0	1	0	0	3
	ARB	0	2	0	3	0	0	0	5
	Land	2	0	0	0	0	0	0	2
	Total								**10**
2005	BOB	2	3	4	0	0	0	0	9
	ARB	2	0	0	0	0	0	0	2
	Land	1	0	0	0	0	0	0	1
	Total								**12**
2006	BOB	5	2	1	0	1	0	0	9
	ARB	0	1	0	1	0	0	0	2
	Land	1	0	0	0	0	0	0	1
	Total								**12**
2007	BOB	3	4	1	0	1	0	0	9
	ARB	0	1	1	0	0	0	1	3
	Land	0	0	0	0	0	0	0	0
	Total								**12**
2008	BOB	1	2	3	0	1	0	0	7
	ARB	1	1	0	0	0	0	0	2
	Land	1	0	0	0	0	0	0	1
	Total								**10**
2009	BOB	0	2	2	1	0	0	0	5
	ARB	2	0	1	0	0	0	0	3
	Land	0	0	0	0	0	0	0	0
	Total								**8**
2010	BOB	2	1	0	2	1	0	0	6
	ARB	0	0-	1	0	1	0	0	2
	Land	0	0	0	0	0	0	0	0
	Total								**8**
2011	BOB	2	2	0	0	1	0	0	5
	ARB	1	2	1		0	0	0	4
	Land	1	0	0	0	0	0	0	1

	Total								**10**
2012	BOB	0	2	1	0	0	0	0	3
	ARB	0	1	1	0	0	0	0	2
	LAND	0	0	0	0	0	0	0	0
	Total								**5**
2013	BOB	3	0	1	1	3	0	0	8
	ARB	0	1	0	0	0	0	0	1
	Land	1	0	0	0	0	0	0	1
	Total								**10**
2014	BOB	2	2	0	0	1	0	0	5
	ARB	0	0	1	0	1	0	0	2
	Land	1	0	0	0	0	0	0	1
	Total								**8**
2015	BOB	1	1	1	0	0	0	0	3
	ARB		2	1	0	0	2	0	5
	Land	2	2		0	0	0	0	4
	Total								**12**
2016	BOB	1	2	3	0	1	0	0	7
	ARB	2	0	0	0	0	0	0	2
	Land	1	0	0	0	0	0	0	1
	Total								**10**
2017	BOB	4	1	1	1	1	0	0	8
	ARB	0	0	0	0	0	0	0	0
	Land	2	0	0	0	0	0	0	2
	Total								**10**
2018	BOB	3	2	1	2	1	0	0	9
	ARB	1	0	0	0	1	2	0	4
	Land	1	0	0	0	0	0	0	1
	Total								**14**
2019	BOB	0	1	1	0	1	1	0	4
	ARB	2	1	1	0	2	1	1	8
	Land	0	0	0	0	0	0	0	0
	Total								**12**
2020	BOB	1	1	1	0	1	0	1	5
	ARB	2	0	0	1	1	0	0	4
	Land	0	0	0	0	0	0	0	0
	Total								**9**
2021	BOB	3	1	2	0	1	0	0	7
	ARB	1	0	0	1	0	1	0	3
	Land	0	0	0	0	0	0	0	0
	Total								**10**
2022	BOB	4	3	1	2	0	0	0	10
	ARB	2	1	0	0	0	0	0	3
	Land	2	0	0	0	0	0	0	2
	Total								**15**
2023	BOB	1	1	1	1	1	1	0	6

	ARB	1	0	0	0	0	2	0	3
	Land	0	0	0	0	0	0	0	0
	Total								**9**
2024	BOB	4	2	1	2	0	0	0	9
	ARB	1	0	1	0	0	0	0	2
	Land	1	1	0	0	0	0	0	2
	Total								**13**
2025	BOB	3	2	2	1	0	0	0	8
	ARB	2	0	0	1	0	0	0	3
	Land	3	1	0	0	0	0	0	4
	Total								**15**

Table 2.1.4 Average translational speed of Tropical cyclones over the NIO during 2025

TC Name	**Basin**	**Period**	**Average Translational Speed (kmph)**		
			6 Hr	**12 Hr**	**24 Hr**
SHAKHTI	AS	01-07 October, 2025	9.9(23)	9.8(22)	9.4(20)
MONTHA	BoB	25-29 October, 2025	12.5(19)	12.4(18)	12.4(16)
SENYAR	BoB	25-27 November, 2025	10.5(9)	9.9(8)	8.3(6)
DITWAH	BoB	27 November – 03 December, 2025	6.2(22)	6.0(21)	5.9(19)
Annual Average Translational Speed (kmph)			**9.5**	**9.3**	**9.0**

Table 2.1.5 Velocity Flux of Tropical cyclones over the NIO during 2025

TC Name	**Velocity Flux (10^2 kt)**	**Accumulated Cyclone Energy (10^4 kt^2)**	**Power Dissipation Index (10^6 kt^3)**
SHAKHTI	6.8	3.4	1.74
MONTHA	4.4	1.93	0.87
SENYAR	1.5	0.57	0.21
DITWAH	0.48	1.74	0.64
Total	**13.18**	**7.64**	**3.46**

2.2 Severe cyclonic storm "SHAKHTI" over Arabian Sea (01st – 07th) October, 2025

- The severe cyclonic storm "Shakhti" originated from the remnant of a depression that formed over northwest & adjoining westcentral Bay of Bengal on 26th September which moved across Odisha, Chhattisgarh and Vidarbha and weakened into a well marked low pressure area over west Vidarbha and adjoining north Madhya Maharashtra on 28th Sep. It moved across central India and emerged into Gulf of Cambay on 29th Sep. It then moved across Gujarat and emerged into northeast Arabian Sea (AS) in the morning (0300 UTC) of 1st October as a well marked low pressure area.
- It intensified into a depression over northeast AS in the evening (1200 UTC) of 1st Oct. and into a deep depression in the midnight (1800 UTC) of 2nd Oct. Thereafter, it exhibited multiple recurvatures & changed its path about 7 times during its life period.
- It intensified into a Cyclonic Storm over northeast AS in the noon (0600 UTC) of 3rd Oct. and into a severe cyclonic storm over northeast & adjoining northwest AS in the early morning (0000 UTC) of 4th Oct. It reached its peak intensity of 60 kt in the early morning (0000 UTC) of 5th October and maintained its intensity till noon (0600 UTC) of 5th Oct.
- Thereafter, while moving south-southwestwards, it started weakening from evening (1200 UTC) of 5th October onwards.
- Continuing to move south-southwestwards till evening of 6th October over northwest & westcentral BoB, it encountered unfavourable environmental conditions (decrease in vorticity, decrease in Coriolis force, decrease in low level convergence & upper level divergence, cold dry air incursion into the core from west and increased vertical wind shear) and subsequently weakened into a cyclonic storm in the early morning (0000 UTC) of 6th Oct., into a deep depression in the midnight (1800 UTC) of 6th Oct. It moved southeastwards from the midnight of 6th Oct. and weakened into a depression in the noon (0600 UTC) of 7th Oct. and into a well marked low pressure area in the evening (1200 UTC) of 7th Oct. over the westcentral AS.
- The observed track of the system is presented in Fig.2.2.1.

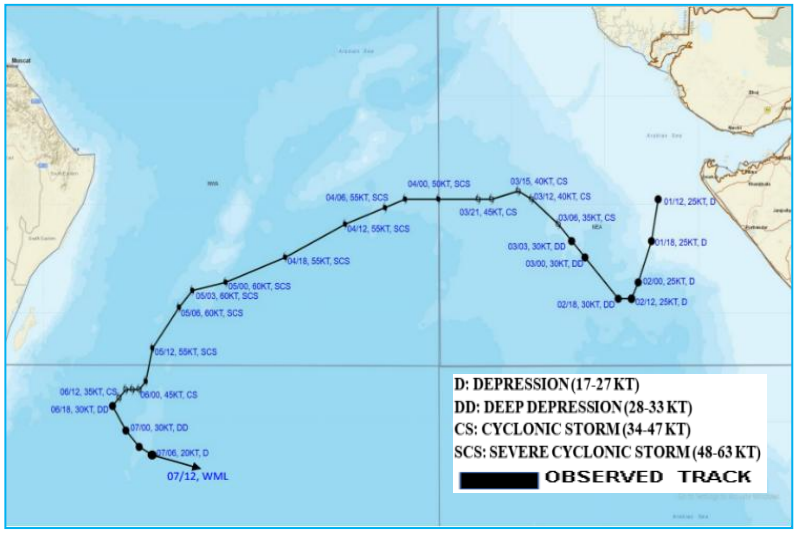

Fig.2.2.1: Observed track of Severe Cyclonic Storm Shakhti over northeast Arabian Sea

2.2 Severe cyclonic storm "MONTHA" over Southeast Bay of Bengal (25th – 30th) October, 2025

- An upper air cyclonic circulation lay over southeast Bay of Bengal (BoB) & adjoining south Andaman Sea in the evening (1200 UTC) of 23rd October, 2025.
- Under it's influence, a low-pressure area formed over southeast BoB in the early morning (0000 UTC) of 24th October, 2025.
- It lay as a well marked low pressure area over the same region in the evening (1200 UTC) of same day, the 24th October, 2025.
- It concentrated into a depression over the same region in the early morning (0000 UTC) of 25th October, 2025.
- It moved west-northwestwards and intensified into a deep depression over the same region in the early morning (0000 UTC) of 26th October.
- It then moved northwestwards and intensified into the Cyclonic Storm "MONTHA" [Pronunciation: Mon-Tha] in the same midnight (1800 UTC) of 26th October, 2025 over southwest & adjoining southeast BoB.
- Continuing to move further northwestwards, it intensified into a severe cyclonic storm in the early morning (0000 UTC) of 28th October, 2025 over westcentral BoB.
- Thereafter, it moved north-northwestwards till evening (1200 UTC) of 28th October. It then suddenly changed the track and moved west-northwestwards & crossed Andhra Pradesh and Yanam coasts between Machilipatnam and Kalingapatnam to the south of Kakinada close to Narsapur near latitude 16.35ºN and longitude 81.70º E 1800 -1900 UTC of 28th October with maximum sustained wind speed of 90-100 kmph (50 kt) gusting to 110 kmph (60 kt).
- Continuing to move further north-northwestwards, it weakened into a cyclonic storm over Coastal Andhra Pradesh in the early hours 2100 UTC of 28th October and into a deep depression over Coastal Andhra Pradesh and adjoining Telangana in the forenoon 0300 UTC of 29th October.
- Continuing to move north-northwestwards, it weakened into a Depression over south Chhattisgarh & neighbourhood in the evening 1200 UTC of 29th October.
- Further moving north-northwestwards, it weakened into a Well Marked Low Pressure Area over East Vidarbha and adjoining South Chhattisgarh in the early morning 0000 UTC) of 30th October 2025.
- The observed track of the deep depression is presented in Fig.2.3.1.

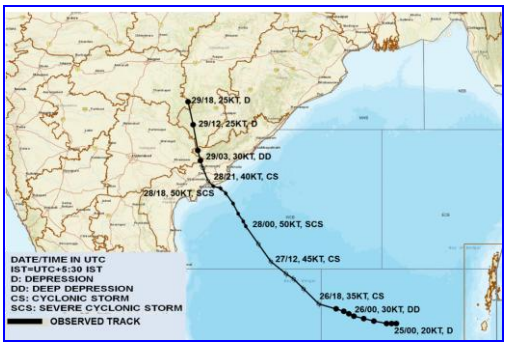

Fig.2.2.2: Observed track of severe cyclonic storm "MONTHA" over southeast Bay of Bengal during 25th-30th October, 2025

2.3 Cyclonic Storm "SENYAR" over the Strait of Malacca (25-27 November, 2025)

- An upper air cyclonic circulation lay over central parts of Strait of Malacca in the forenoon (0300 UTC) of 20th Nov.
- Under its influence, a low-pressure area developed over Strait of Malacca and adjoining South Andaman Sea in the forenoon (0300 UTC) of 22nd Nov., 2025.
- It lay as a well-marked low-pressure area over the same region in the forenoon (0300 UTC) of 23rd Nov.
- It concentrated into a depression over the Strait of Malacca in the forenoon (0300 UTC) of 25th Nov.
- It moved nearly westwards and intensified into a deep depression over Malacca Strait in the midnight (1800 UTC) of 25th Nov. and into the Cyclonic Storm Senyar over Strait of Malacca and adjoining Northeast Indonesia in the early morning (0000 UTC) of 26th Nov. while moving west-southwestwards.
- Continuing to move further west-southwestwards, it crossed Northeast Indonesia near 4.90N/97.750E in the forenoon (during 0300-0400 UTC) of 26th Nov.
- Thereafter, it gradually recurved southeastwards & emerged back into Malacca Strait in the early hours 1900-2000 UTC of 26th Nov. as a cyclonic storm.
- Thereafter, while moving nearly eastwards, it weakened into a deep depression during early morning (0000 UTC) and into a depression around noon (0600 UTC) of 27th Nov. over Malacca Strait. Continuing to move eastwards, it maintained the intensity of depression till evening (1200 UTC) of 27th Nov. and weakened into a well marked low pressure area over Malacca Strait and adjoining coastal areas of Malaysia in the midnight (1800 UTC) of 27th Nov. Thereafter, it moved across Malaysia into Northwest Pacific & adjoining Equatorial Pacific & weakened gradually.
- The observed track of the system (depression to depression) is presented in Fig.2.2.3.

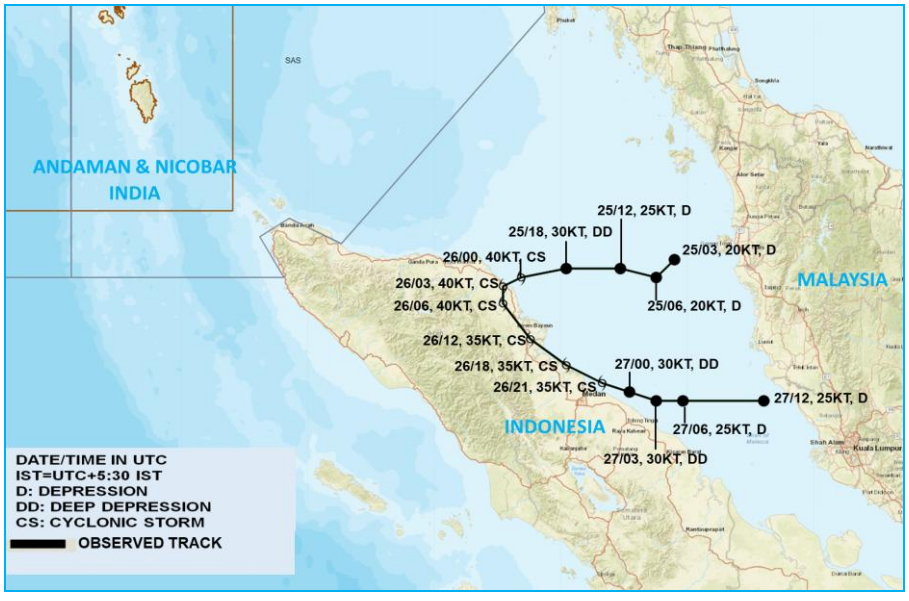

Fig.2.2.3: Observed track of cyclonic storm "Senyar" over Strait of Malacca during 25th to 27th November, 2025

2.5 Cyclonic Storm "DITWAH" over the Bay of Bengal (26th November– 03rd December, 2025)

- An upper air cyclonic circulation lay over Comorin area and neighbourhood at 0300 UTC of 23rd November, 2025.
- Under its influence, a low pressure area formed over Comorin and adjoining Southwest Bay of Bengal (BoB) & Sri Lanka at 0000 UTC of 25th November, 2025.
- It lay as well marked low pressure area over southwest Bay of Bengal and adjoining areas of Southeast Sri Lanka & Equatorial Indian Ocean at 0000 UTC of 26th November, 2025.
- It concentrated into a depression over southwest BoB and adjoining Sri Lanka at 1800 UTC of 26th November, 2025. It moved north-northwestwards and intensified into a deep depression over the same region at 0000 UTC and into the cyclonic storm "DITWAH" over the same region at 0600 UTC of 27th November.
- Continuing to move to north-northwestwards, it crossed Sri Lanka coast during 0600 UTC to 0700 UTC of 27th November as a Cyclonic Storm with the wind speed of 60 to 70 gusting to 80 kmph. Thereafter, it continued to move slowly north-northwestwards across coastal Sri Lanka & southwest BoB maintaining the intensity of 60 to 70 gusting to 80 kmph till 1500 UTC and increased marginally becoming 65-75 gusting to 85 kmph during 1800UTC of 28th to 0000 UTC of 29th November.
- Thereafter, it emerged into southwest BoB and adjoining North Sri Lanka coasts at 0000 UTC of 29th November. Thereafter, it moved nearly northwards and intensified slightly by reaching the maximum sustained wind speed of 70-80 gusting to 90 kmph during 0300 UTC of 29th to 0000 UTC of 30th November and lay centered about 50 km east of Chennai. Continuing to move further northwards over southwest BoB and adjoining Tamil Nadu-Puducherry coast, it lay about 70km east of north Tamil Nadu- Puducherry coast at 0300 UTC of 30th November and about 30km east of Chennai coast at 0600 UTC of 01st December. While moving northwards, it weakened into a deep depression at 1200 UTC of 30th November. Thereafter, it remains practically stationary till 1800 UTC of 01st December.
- Then it gradually recurved south-southwestwards & weakened into a depression in at 0000 UTC of 2nd December with its center about 25 km away from North Tamil Nadu coast and into a well-marked low pressure area over North Tamil Nadu-Puducherry coasts and neighbourhood at 0000 UTC of 3rd December. The observed track of the system is presented in Fig.2.2.4.

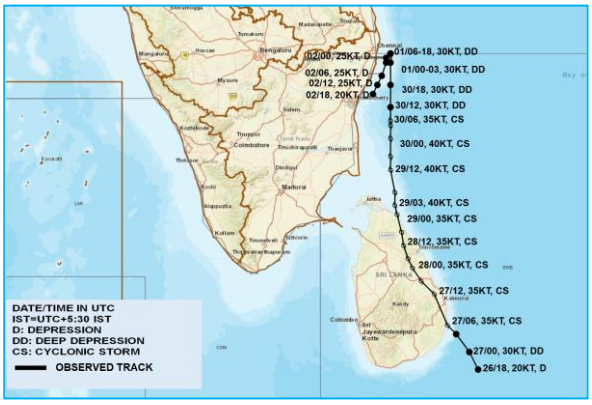

Fig.2.2.4: Observed track of cyclonic storm "DITWAH" over BoB during 26th Nov- 03rd December, 2025

CHAPTER-III
COORDINATED TECHNICAL PLAN (CTP): 2024-2027

3.1. INTRODUCTION AND BACKGROUND

Hydro-meteorological disasters account for approximately 70-80% of disaster losses in the world. Among them, tropical cyclone-associated disasters remain serious threats to people in both developed and developing countries in the tropical cyclone-prone regions. This is true for the North Indian Ocean region, where the devastating disasters repeated during the past decades proved that this region is extremely vulnerable to tropical cyclone risks.

WMO/ESCAP Panel on Tropical Cyclones for the Bay of Bengal and Arabian Sea has been exerting its effort to mitigate the impact of tropical cyclones in this region since its inauguration in 1973. The Panel's activities are a fundamental contribution to improving regional and national resilience against tropical cyclone threats.
Because of the growing demand for further mitigation of tropical cyclone disasters in this region as well as enhancement of the visibility of its activities, the CTP (2009-2011) was developed by the PTC Policy Working Group chaired by Dr. Qamar-uz-Zaman Chaudhry, Secretary of PTC and adopted by the PTC during its 36th Session (Muscat, Oman, 2-6 March, 2009).

The present CTP (2024-2027) is an updated version of previous Coordinate Technical Plans and has also taken into consideration the WMO Strategic Plan 2023-2027 and the Strategic Plan for the Enhancement of National Meteorological and Hydrological Services in Regional Association II (2023-2027).

3.1.1 Panel Region

Currently, the Panel is composed of 13 Members; Bangladesh, India, Maldives, Myanmar, Oman, Pakistan, Sri Lanka, Thailand, Yemen, Iran, Saudi Arabia, United Arab Emirates and Qatar.

The Panel region covers a vast expanse of the North Indian Ocean and contains a large and diverse range of ecosystems, including deserts, forests, rivers, lakes and seas. The desert extends from Middle East into Pakistan and northwest India. Compared to other WMO tropical cyclone regions, this region includes the highest mountains, the rainiest areas and the driest deserts, with their associated variation in culture and biodiversity. Over the long period of human occupation in the region, exploitation of natural resources, urbanization, industrialization and economic development have led to land degradation and environmental pollution. Climate change and climate variations also represent present and future stress.

Tropical cyclone warning services of Members vary in duties, size and status of advancement, geography and state of development. Therefore, they are highly differentiated in capabilities and vulnerabilities. Some Members have very advanced facilities while others have limited budgets; shortage of observation instruments, spare parts, and consumables; lack of calibration, data collection, processing and communication facilities; insufficient qualified staff; and old technology.

3.1.2. Vision and mission of the Panel

3.1.2.1. Vision of the Panel

To promote and coordinate the planning and implementation of the multi-hazard early warning based Disaster Risk Reduction system to attain sustainable development measures through minimizing loss and damage caused by tropical cyclones and associated meteorological, hydrological and other ocean hazards in the Bay of Bengal and the Arabian Sea.

3.1.2.2. Mission of the Panel

a. *To review regularly the progress made in the various fields.*
b. *To recommend measures to improve the multi-hazard early warning systems in the Bay of Bengal and the Arabian Sea, including necessary training and research, with regard to meteorological, hydrological and other ocean hazards such as storm surges and tsunamis*
c. *To recommend measures to improve information dissemination system to ensure timely provision of warnings for community preparedness and disaster risk management.*
d. *To advise on possible sources of financial and technical support for such measures.*
e. *To coordinate the activities among the Panel Members, including all other activities carried out as part of or in conjunction with the WMO and regional tropical cyclone programmes.*
f. *To encourage and carry out capacity building.*

3.1.3 Priorities of the Panel

The Panel agreed that the following are priority issues:

a. Maintenance of existing system and further development of land, Ocean and atmosphere observing and telecommunications systems and data processing facilities for better information sharing;
b. Natural disaster reduction, mitigation and prevention through the implementation of improved detection, prediction and warning systems of tropical cyclones, depressions and associated storm-surge, high waves, flash/urban floods, tsunamis etc.;
c. Implementation of CTP to provide better services to the public, governments and users, through improved infrastructure and modern technology in a user-friendly manner;
d. Enhancement of capacity building and technology transfer for early warning dissemination and response at the national and community levels to bridge the gap between the Members through bilateral and multilateral arrangements;
e. Enhancement of the collaboration and cooperation among the Members and RSMC New Delhi by exchange of information and knowledge and research studies related to tropical cyclones including numerical modeling and climate change impacts. Member countries to encourage and promote research on Multi hazards associated with tropical cyclones
f. Encouragement to improve hydrological forecasting and warning services for flood prone areas;
g. Encouragement to plan and manage water resources, including assessment of surface and ground water resources in relation to tropical cyclones;
h. Improvement of the operational linkages between hydrological and meteorological services and disaster management agencies with the aim of minimizing the impacts

of natural disasters;

i. Facilitation of tropical cyclone disaster risk assessment at the country level, especially along the coast, delta, and urban areas where risks are the highest to reach sustainable development goals
j. Increase tropical cyclone risk awareness at the community level through awareness events, school education, training, and drills where technical knowledge could be properly supplied and adopted by authorities;
k. Strengthening information exchange with various disaster-related information systems in the region;
l. Strengthening partnerships with relevant international and regional bodies, such as UN-ISDR, UNDP, UNESCO/IOC, UNEP, ESCWA, ASEAN, SAARC, IFRC, ADRC, ADPC, ICHARM, JICA, KOICA, TICA, USAID, ADB, ICAO, RIMES, BIMSTEC and WB;
m. Enhanced public & private partnerships including industries, non-governmental organizations (NGOs) etc. for awareness, feedback and information dissemination etc. aiming at disaster risk reduction (DRR);
n. Enhancement of resource mobilization activities for implementation of CTP.

3.1.4 Challenges and Opportunities

The panel is facing challenges and opportunities that have been raised in recent years in its implementation of the activities to fulfil its vision, such as rapid changes in technology, globalization, commercialization, urbanization, and emerging scientific research results. This section identifies in broad terms the challenges and opportunities of which the Panel Members could take advantage through a strategic regional approach.

3.1.4.1 Meteorology

3.1.4.1.1. Observation systems

Observation systems are fundamental to the operations of National Meteorological and Hydrological Services (NMHSs). Standardization of observation ensures that data collected by each country are compatible with other countries. This includes accuracy, instrument response times and other characteristics of instruments, frequency of observations, exposure, network densities and other related matters.

The existing gaps in the observational data coverage of the Panel region continue to be due to the deficiencies in the operations of both land, Ocean &atmosphere observing systems and telecommunication networks, high cost and therefore the lack of consumables and spare parts.

New types of earth-observing satellites including meteorological satellites which are useful for weather monitoring, forecasting, and research have been launched from time to time. However, no single receiving system is capable of receiving and processing the data from all these satellites. This poses difficulty to some Members who may not afford to have more than one satellite receiver. It would be useful if imageries and data from different satellites can be put under and distributed through one or two low-cost distribution channels.

3.1.4.1.2. Telecommunication

The WMO Information system (WIS) is the single coordinated global infrastructure responsible for the telecommunications and data management functions. It is the pillar of the WMO strategy for managing and moving weather, climate and water information in the 21st century. WIS provides an integrated approach suitable for all

WMO Programmes to meet the requirements for routine collection and automated dissemination of observed data and products, as well as data discovery, access and retrieval services for all weather, climate, water and related data produced by centres and Member countries in the framework of any WMO Programme. WIS is an enhanced information system capable of exchanging large data volumes, such as new ground- and satellite-based systems, finer resolutions in numerical weather prediction and hydrological models and their applications.

The GTS part includes the national meteorological telecommunication networks (NMTNs) and the regional meteorological telecommunication networks (RMTNs), respectively. The NMTNs are implemented and operated by each country according to both the telecommunication services available and the financial and technical capacities of each country.

3.1.4.1.3. Data-processing and forecasting systems

While there had been considerable improvements in the infrastructure and models in some WMO Integrated Processing and Production System (WIPSS) centers of the Region, there are still large deficiencies in the capabilities of some Members in their forecasting function, i.e., the production of forecasts and warnings. Some of the data processing systems of NMHSs have not been automated and the Members concerned were not able to derive full benefits from the technological advances that have taken place in the recent past. Some WIPSS centres in the Region still plot stations and produce weather charts manually.

As regards the generation and dissemination of the WIPSS products, the Regional Specialized Meteorological Centre (RSMC) New Delhi produces a large number of products on a daily basis. The availability on the Internet of high-quality products from advanced high-resolution NWP systems operated by major WIPSS centers within and outside the Region has opened up new opportunities for NMHSs to enhance their capability in providing weather forecast service to their respective users.

3.1.4.2. Hydrology and Water resources

Freshwater is a natural resource vital to the survival of all living things; however, it is limited. The sources of freshwater are river basins, groundwater reserves, lakes and manmade reservoirs. These are increasingly under pressure to meet increased domestic needs as well as demands from agriculture, industry and other human activities.

Weather is the most important factor in water availability as it determines the timing and the location of precipitation and the amount lost to evaporation. Some arid countries in the region like Oman, Yemen, Southern Pakistan and Northwest India have such low precipitation (as little as a few millimetres per year) and high evaporation, that only a small amount of freshwater can be captured for human use. By contrast, some countries receive abundant rainfall each year (thousands of millimeters). Seasonality is particularly pronounced throughout the region and, in most cases, plays a major role in water availability; those countries which receive high rainfall - Bangladesh and India for example - are inundated with rainfall during the monsoon season, but lack rainfall the rest of the year.

This seasonality problem can be tackled by preventing the precipitation during the wet season from running off into the sea. The traditional method of rain harvesting, that is, retaining water through construction of ponds/lakes etc in individual villages or towns could ensure the optimum use of precipitation. Many demonstration projects have

established that with proper storage techniques, rainfall during a season could be utilized throughout the year for agriculture and other human activities. It is such mini projects, rather than big dams, that are most cost-effective in conserving freshwater resources.

The decline of hydrological networks in the region is a challenge at a time when more high-quality hydrological data are required, often in near real-time. Hydrological networks need to be improved together with the capacity of Hydrological Services to provide relevant information to a variety of users of hydrological data. In this respect, the need for improving forecasting systems particularly to predict floods and droughts that could lead to disasters is a high priority in the region. The management of international rivers in the region is a most challenging problem as well. In the context of integrated water resources management, the joint management of river basins opens a window of opportunity for transnational collaboration in hydrology.

The potential extension of several HYCOS projects into the region are expected to foster this process and contribute to the capacity building of National Hydrological Services as well as integrated water resources management on the basis of timely, reliable hydrological data. Especially for prediction and forecasting of extreme events, the data collection and forecasting capacities of the meteorological and hydrological branches of national Services need to be integrated to provide the results required by the general public.

Likewise, the introduction of rational water resources assessment methods, promoted by WMO and the United Nations Educational, Scientific and Cultural Organization (UNESCO), are expected to enhance the capacity of National Hydrological Services in the region to act as service providers for planning, decision-making and implementation of water resources projects. A crucial issue for much needed regional collaboration between national Hydrological Services is the free exchange of hydrological data and information which has been documented in Resolution 25 of the Thirteenth Congress of WMO.

3.1.4.3 Disaster Risk Reduction

The Panel region is one of the most disaster-prone regions in the world. It has a very high frequency of disaster events and suffers from immense damage due to various types of disaster such as tropical cyclones, storm surges, floods, landslides, drought, earthquakes, volcanic eruptions, tsunamis, etc.

A large percentage of these disasters has occurred in many countries of the Region. A rapid urbanization, high population increase rates, and high population densities without reducing the poverty levels led their societies to be with high vulnerability to disasters, resulting in heavy loss of life and property damage. The Disaster Risk Reduction component of the CTP will aim at reducing tropical cyclone disaster risks at the community level by enhancing the local and institutional capacities to cope with the risks.

3.1.4.3.1. Tropical cyclone related disaster risks

In the Bay of Bengal, tropical cyclones usually form over the southern end and then move either towards the east coast of India, Myanmar or to Bangladesh and a few of them emerge into the Arabian Sea after crossing the Indian Peninsula and Sri Lanka. A few tropical cyclones form in the Arabian Sea and move to the north affecting the

western part of India, southern Pakistan, Yemen, Oman, Iran and indirectly UAE, Qatar and Saudi Arabia. These tropical cyclones can generate very heavy rainfall and cause severe flooding and landslides, high wind and waves, and are often accompanied by devastating storm surges which are the most common risk factor to the tropical cyclone deaths. Quantification of associated risks might help to plan appropriate DRR actions.

3.1.4.3.2. Regional technical coordination on tropical cyclones

Regional cooperation and coordination in disaster prevention and mitigation among the Members are gaining importance in the region. India Meteorological Department was designated by WMO a Regional Specialized Meteorological Centre (RSMC) to monitor and forecast the track and intensity of all tropical cyclones in this region, associated severe weather like high waves, storm surge and coastal inundation and heavy rainfall to provide the track and intensity information to the international community, and to provide real-time advisory information and guidance to NMSs in the region. Mechanism may be set up to foster tele conference (audio/video) for consultation among members and RSMC, New Delhi, though there has been video conferencing in recent years with individual countries by RSM and RSMC has constituted a WhatsApp group for exchange of information, data and views.

3.1.4.3.3. Inter Regional Co-operation on Tropical Cyclones

There exist a synergised SOP between the RSMC, New Delhi and RSMC, Tokyo for monitoring and prediction of cyclonic disturbances migrating into each other's area of responsibility and naming nomenclature to be followed. Additionally, both agencies also support each other in capacity-building initiatives and the resource persons from both organizations participate in the training programs organized by the RSMCs.

3.1.4.3.4. Risk assessment and management

Accurate and timely tropical cyclone forecast and warnings issued by the NMHSs is crucial information to reduce risks. The challenge is that such information needs to be reached to the communities at risk for prompt action. This is quite a challenge, especially in rural areas in developing countries where the communication system is limited. Even if reached on time, false information or technical information lacking clear directions and guidance for a specific location may mislead response to the warning and hinder people's willingness to take action for the next events. It is vital to understand the perception of individual and collective behaviors when receiving the warning. Another important issue is whether people have a safe place when responding to the warning. Without such places, people would be ended up facing the risks. Whether they can move quickly to a safe place is an additional issue, particularly, for infants, small children, the elderly, and the handicapped.

Risk level needs to be evaluated based on the tropical cyclone forecast over a region utilizing the past climatology. The assessed risk level needs to be communicated to the disaster managers for suitable actions at their levels. Post-disaster risk assessment based on loss and damage survey is also essential to identify the gaps and improve the risk assessment for the future.

3.1.4.3.5. Linkages with International Framework Initiatives

Activities of the Panel on Tropical Cyclones may be linked appropriately with important initiatives such as the ESCAP/WMO Typhoon Committee, International Network for Multi-Hazard Early Warning Systems (IN-MHEWS) established at the Third United Nations

Conference on Disaster Risk Reduction in March 2015, and the Climate Risk Early Warning System (CREWS), Early Warning for All, Impact Based Forecasting and risk-based warning initiatives of WMO and UN launched at the Conference of the Parties of the United Nations Framework for Climate Change in December 2015-2022. In this regard, WMO and ESCAP may extend institutional support the Panel on Tropical Cyclones.

3.1.4.4. Capacity Building

In considering the rapid changes in technology and the social, political and economic circumstances in addition to the global environmental issues, Members need to respond to these challenges in such a way as to enable them to properly manage their meteorological and hydrological services, and to have qualified and trained manpower and adequate facilities. Therefore, proper management, continuing training and development are important for the advancement of those services.

RSMC New Delhi, Indian National Centre for Ocean Information Services (INCOIS), Hyderabad and academic institutions to support the plans and requirements related to capacity building and transfer of technology in close cooperation with the Members.

Capacity building is to be underpinned by infrastructure and human resource development through training and technology transfer in the areas of:

Forecasting of tropical cyclone intensity and track, and associated storm surge, inland flooding and coastal inundation

- Observing and processing data and interpretation of outputs from regional centres;
- Information and communication technology (ICT);
- Equipment maintenance;
- Provision of weather services for the public, including service-oriented media/communication skills;
- Provision of weather services for aviation and shipping, including marketing of services and liaison with clients;
- Provision of climate information services;
- Application of NWP products;
- Nowcasting of severe weather; and
- High level and middle management skills.
- Climate change impacts on tropical cyclones and associated phenomenon
- Maintenance of competency standards
- Training through fellowships, seminars and workshops with assistance from outside the region needs to be also intensified.

3.1.5 International and regional projects relevant to the Panel's activities

The following international/ regional projects with significant potential benefits to Members especially the developing ones are worth pursuing:

3.1.5.1. Early Warning System for Tsunamis

After the devastating tsunami which affected most of the countries of the Panel towards the end of December in 2004, there has been an urgent need to establish an Early Warning System for the Panel region. In this connection, WMO, along with other

International Organizations, worked towards bringing the countries of the region to work together in identifying an ideal mechanism that will support an Early Warning System for the region. The Panel should take advantage of this situation and participate in all the forums that are called upon by WMO in this regard.

It is important that the Panel collaborates with the adjacent regions in establishing this project. It should then draw up a plan for implementation having all the Members participate.

3.1.5.2 Storm Surge Watch Scheme

In view of the fact that storm surges associated with the recent tropical cyclones Sidr and Nargis in the Bay of Bengal, which caused widespread flooding in the exposed coasts of Bangladesh and Myanmar, were the major cause of devastation and loss of lives in the most populous and low-lying areas of these countries, the WMO Executive Council, at its 60th session in 2008 (EC-LX), addressed the need for the provision of storm surge guidance information to the WMO Members exposed to these risks as a matter of priority.

The Council therefore agreed that a storm surge scheme attached to the tropical cyclone advisory arrangements would help to increase advisory lead-time and thus contribute to saving lives and properties, and would be the first step towards a comprehensive and integrated marine multi-hazard forecasting and warning system for improved coastal risk management. It appealed to all the regional tropical cyclone bodies to develop Storm Surge Watch Scheme (SSWS) that will make available to WMO Members concerned with the storm-surge advisories including daily marine processed data and information they require for real-time uses.

In the Panel region, efforts have to be continued under CTP for attachment training on country-specific advanced storm surge forecasting and inundation modeling.

3.1.5.3 Hindu Kush-Himalayan Hydrological Cycle Observing System (HKH-HYCOS) Phase II project

The Hindu Kush-Himalayan Hydrological Cycle Observing System (HKH-HYCOS) Phase II project, which was funded by the government of Finland, was successfully completed on December 31, 2015. The HKH-HYCOS Phase III project proposal has been prepared and is being circulated to potential donors.

3.1.5.4. Mekong-HCOS project

The Mekong-HCOS project was successfully completed on 30 November 2012. The project was financially supported by the Agence Francaise de Developpement (AFD). AFD is further supporting additional efforts with the Mekong River Commission on extending the MRC-HYCOS network and improving its sustainability, as well as improving data usage based on statistical hydrological analyses

3.1.5.5. WMO's Severe Weather Forecasting Programme (SWFP)

The World Meteorological Organization's (WMO's) Severe Weather Forecasting Programme (SWFP) previously known as Severe Weather Forecasting Demonstration Project (SWFDP) is aimed to enable all National Meteorological and Hydrological Services (NMHSs) to issue effective severe weather warnings to disaster management and civil protection authorities in their respective countries. Using a 'Cascading Forecasting

Process', the Programme makes global-scale products from Global Data Processing & Forecasting System (GDPFS) Centres available to Regional Centres. The Regional Centres in turn interpret model guidance and provide guidance products to National Meteorological and Hydrological Services (NMHSs). These NMHSs liaise with regional centres, disaster management agencies & media and issue advisories for general public. The primary objective of this programme is 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. Capacity development through regular trainings on forecasting and service delivery aspects has also been a critical component of the subproject. Forecasters need to know how to make optimal use of the various numerical weather prediction (NWP) products and satellite information coming from the contributing centres. First ever SWFDP regional subproject was initiated in 2006 with involvement of just five countries in south-eastern Africa. The success story of this subproject provided basis for expansion of SWFDP into whole Southern Africa in 2009 with involvement of sixteen countries and later into other sub-regions of the world including Eastern Africa and South Pacific. Currently, SWFP involves over 85 developing countries, least developed countries (LDCs) and small island developing states (SIDS) in nine sub-regions of the world including Southern Africa, Eastern Africa, West Africa, Central Africa, Southeast Asia, South Asia, Central Asia, Eastern Caribbean and South Pacific, with contributions from the WMO Centers, Regional Centers and support from development partners and donors. There are three SWFP regional subprojects in WMO Regional Association (RA) II (Asia) region Viz., SWFP-Southeast Asia; SWFP-South Asia; and SWFP-Central Asia.

India Meteorological Department (IMD), New Delhi is acting as a Regional Specialised Meteorological centra (RSMC), leading WMO's SWFP-South Asia to predict the severe weather namely heavy rain, strong winds, high waves, cyclonic disturbances and storm surge. IMD issues forecast for 9 member countries including Bangladesh, Bhutan, India, Maldives, Myanmar, Nepal, Pakistan, Sri Lanka, and Thailand since May, 2016. The domain covered for monitoring, analyzing and predicting various severe weather events under RSMC New Delhi is bounded by 10°S to 45°N and 45°E to 110°E. In 2019, textual products were also added with 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 95 met-subdivisions in the region covering the land areas of member countries and the entire Bay of Bengal and Arabian Sea.

3.1.5.6. Flash Flood Guidance System with Global Coverage (FFGS)

In collaboration with NOAA-National Weather Service, the US Hydrologic Research Centre, WMO, and USAID/OFDA, this project is currently being implemented in the Mekong River Basin in collaboration with MRC. Other areas under development for the implementation of the project are South Asia, southern Africa and near/middle East. The reference project has been implemented over the past years in Central America. The success of the project there was the basis to expand it globally where feasible. The core of the project is to provide flash flood guidance (not forecasting!) to disaster managers based on real-time satellite-derived precipitation estimates merged with resolution GIS and hydraulic conditions of rivers that trigger an alert once "bankful" flow conditions are to be expected based on the precipitation estimate for a given time under prevailing ground and hydraulic conditions. The first Steering Committee meeting held in New Delhi

recommended linking flash flood guidance provided by regional flash flood guidance centers for South Asia with SWFDP-BOB. The South Asian flash flood guidance system, New Delhi has been operational since 2020.

3.1.5.7. WMO Programme for the Least Developed Countries (LDCs)

This Programme was established by the Fourteenth Meteorological Congress in May 2003 to contribute efficiently and in a timely manner to the social and economic development efforts of LDCs through the enhancement of the capacities and capabilities of their NMHSs. A number of activities are being carried out in support of NMHSs of most of the 50 LDCs under the WMO Programme for LDCs and through the other WMO scientific and technical programmes. This includes the development and implementation of Internet connection projects in LDCs; provision of fellowships; supporting the participation of experts from LDCs in WMO meetings; carrying out special advocacy and project-formulation activities; and the organization of innovative capacity-building initiatives including workshops on good practices in the beneficial and effective use of weather-, climate-, and water-related services in sustainable socio-economic development.

Planned activities include the following:

- Development and organization of demonstration/pilot projects on the contribution of meteorological and hydrological and related environmental information, products and services to the sustainable development of the LDCs and Small Island Developing States (SIDS), especially in poverty alleviation, disaster risk reduction, environmental protection, food security, health, energy and water resources management;
- Organization of capacity-building activities for senior- and middle-level staff of LDC NMHSs, particularly in leadership, management, resource mobilization, strategic planning, marketing and communication;
- Preparation and implementation of development and modernization plans of NMHSs of LDCs and SIDS, including projects that are of relevance to, and consistent with, national development strategies and programmes and of high impact value to the relevant commitments enshrined in the Brussels Programme of Action for the LDCs;
- Promoting the awareness of policy- and decision-makers and other stakeholders of the socio-economic benefits of weather-, climate- and water-related services;
- Preparation of guidelines for promoting the contributions of NMHSs and WMO towards the attainment of internationally agreed development goals including those contained in the Millennium Declaration.

3.1.6. WMO Programmes and other Regional/International Programmes in support of the Panel Members

3.1.6.1. WMO Programmes

The major WMO Programmes concerned are the World Weather Watch (WWW), the World Climate Programme (WCP), Tropical Cyclone Programme (TCP), PWS (Public Weather Service), DPFS (Data Processing and Forecasting System), MMO (Marine Meteorology and Oceanography), DRR (Disaster Risk Reduction), SP (Satellite Program), AEM (Aeronautical Meteorology), HWR (Hydrology and Water Resources), RAP (Regional Office for Asia and the Pacific), ETR (Education and Training), WWRP (World Weather Research Programme), Global Framework for Climate services (GFCS).

3.1.6.2. Regional and international programmes

Programmes of the following organizations are of interest:

ESCAP; the ASEAN Subcommittee on Meteorology and Geophysics (ASCMG); the Interstate Council on Hydrometeorology of the Countries of the Commonwealth of Independent States (ICH CIS); the Coordinating Committee on Hydrometeorology and Pollution Monitoring of the Caspian Sea (CASPCOM); the UNESCO Intergovernmental Oceanographic Commission (IOC); the United Nations Environment Programme (UNEP); UNDP; the Global Environment Facility (GEF); the Economic Cooperation Organization (ECO); the Economic and Social Commission for Western Asia (ESCWA); the South Asia Association for Regional Cooperation (SAARC); the League of Arab States (LAS); the Permanent Meteorological Committee; (BIMSTEC);Regional Integrated Multi- hazard Early Warning System (RIMES);(ADPC); and the Regional Organization for the Protection of the Marine Environment (ROPME).

3.1.7. Agreements and conventions

Members are encouraged to undertake national responsibilities or contribute to national obligations under many regional and international agreements and conventions. Some of the most important ones are the WMO Convention; Agenda 21 adopted at the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro in 1992; the 1994 Global Conference which adopted the Barbados Programme of Action for Sustainable Development of Small Island Developing States; Resolution 40 of Twelfth Congress (1995) on the policy and practice for the exchange of meteorological and related data and products including guidelines on relationships in commercial meteorological activities; Resolution 25 of Thirteenth Congress (1999) on the exchange of hydrological data and products; the Geneva Declaration of Thirteenth Congress (1999); Millennium Development Goals (2000); Sustainable Development Goals 2015-2030; Hyogo Framework for Action 2005-2015; Sendai Framework for Disaster Risk reduction (2015-2030); the United Nations Framework Convention on Climate Change (UNFCCC); the United Nations Convention to Combat Desertification (UNCCD); the Convention of the International Civil Aviation Organization (ICAO); the Convention of the International Maritime Organization (IMO); the International Convention for the Safety of Life at Sea (SOLAS); and the Convention on the Protection of the Ozone Layer and most recent and important Paris agreement on Climate Change 2015.

There are also a number of United Nations programmes and agencies having activities related specifically to meteorology, climate or hydrology or providing financial support to countries. These include UNEP, the United Nations Development Programme (UNDP), the Food and Agriculture Organization (FAO) of the United Nations and others.

3.2. DEVELOPMENT OF COORDINATED TECHNICAL PLAN

3.2.1 Purpose of Coordinated Technical Plan

The coordinated Technical Plan aims to promote and coordinate the planning and implementation of the measures required to minimize damages caused by tropical cyclones and associated floods and storm surges in the Bay of Bengal and the Arabian Sea. It is expected to establish an effective integrated regional early warning system for those hazards in the region covering all five components; meteorology, hydrology, disaster prevention and preparedness, training and research.

Specific purposes of the Coordinated Technical Plan are:

- To develop an understanding among the Panel Members on the priorities and objectives for their individual development and the overall development of the Panel region through cooperation; and to guide the implementation of Panel's programmes and activities for achieving these objectives;
- To develop and provide access to appropriate databases, resources and expertise to produce appropriate advice and products required for forecasting and warning services to the private and public sectors as well as to the decision-makers and ordinary people;
- To encourage the development of joint projects by all Members or some of them with the projects under formulation and/or consideration by the Members;
- To raise general awareness of the status of the work of the Members and to have a framework under which development assistance would be provided and coordinated among the Members and the various contributing agencies; and
- To develop a system for training specialists of the Members, transferring and exchanging experience in observation and data processing, and taking advantage of advances in science and technology.

3.2.2 Institutional Arrangement

A coordinated Technical Plan needs institutional arrangements for successful implementation. Such arrangements should include a mandate, program management, human resources, funding, sectoral and organizational linkages, and reporting. These are to be considered when formulating the Plan.

3.2.2.1 Countries and organizations involved

Members will work together to contribute towards the implementation of joint programs and activities, deriving benefits from the pooling of resources within the region with the support of WMO and ESCAP.

3.2.2.2 Duration of the Coordinated Technical Plan

Coordinated Technical Plan is to cover a four-year term to keep pace with the financial periods of WMO (4 years) and ESCAP (2 years). The present Coordinated Technical Plan, therefore, covers the period from 2016- to 2019 to coincide with the financial periods of WMO and ESCAP as mentioned above. Coordinated Technical Plan is a live document and continues to be reviewed and updated by the PTC every four years.

3.2.2.3. Regional programmes and projects

Regional programmes or projects involved in the Plan are those that address problems that are common to the whole Panel region. Initial pilot phases may be undertaken in a limited number of countries only. Sub-regional programmes and projects are those which address problems that are common to only a few Members. Country-specific projects are those that are specifically required by a particular Member to address a problem in that country, given its particular circumstances. Country-specific projects are unique to individual countries and are identified through in-country consultations.

3.2.2.4. Steps for the implementation of the Coordinated Technical Plan

The steps for implementing the Coordinated Technical Plan include:

a. Panel, WMO and ESCAP, through cooperative efforts to assist and/or support the

implementation of the Coordinated Technical Plan;

b. Development of projects for implementation by Panel and its Members, and other regional and sub regional economic groups and institutions to implement effectively the Coordinated Technical Plan to enable Members to play their full role in sustainable socio-economic development of their countries.

3.2.3 Reporting

As part of implementation of the Coordinated Technical Plan, Members will report on progress on the implementation of the Plan to the PTC at annual sessions.

3.3. EXPECTED RESULTS AND STRATEGIC ACTIONS

3.3.1 Meteorology

3.3.1.1 Expected Result 1

- *Developed capabilities of Members to produce and provide impact-based forecasts and risk-based warnings of tropical cyclones, storm surges and associated hazards*
- This is expected to be achieved based on the development of an efficient and expanded observation and telecommunication network and with the acquisition of the latest forecasting technology, improved exchange of data and development of skills of personnel through national, bilateral and regional programs.

3.3.1.2 Strategic Actions

1-a To further improve and expand the observing system of surface, upper-air, ship, buoy, aircraft, radar and satellite observations in the Member countries.

1-b To ensure the real-time operational use of the WMO Information System (WIS) for operation-critical data exchange through dedicated telecommunication means of the GTS, and through broadband Internet access for Data Discovery, Access and Retrieval service.

1-c To further increase the accuracy, timeliness and usefulness of tropical cyclone forecasts and warnings.

1-d To develop the capacity of member countries for providing impact-based forecasts and risk-based warnings

1-e To extend the operational use of ensemble prediction techniques and probabilistic forecasts for more effective disaster risk assessment and management.

1-f To continue to upgrade the computing facility of RSMC New Delhi and NMHSs so as to facilitate efficient data processing and data assimilation from different observing systems/platforms to suit the national and regional needs.

1-g To ensure the operational use of the recently established a regional storm surge watch scheme to provide Members with the storm-surge advisories including daily marine processed data and information they require for real-time uses

3.3.2 Hydrology

3.3.2.1 Expected Result 2

- Enhanced capabilities of Members to produce and provide better hydrological forecasts and assessments

Members will formulate accurate and timely forecasts and warnings on floods and other water related hazards with a view to supporting preparedness and response mechanisms of their governments and the public.

3.3.2.2 Strategic Actions

2-a To further improve regional cooperation in real time monitoring and exchange of relevant data and information, forecast/products and technical expertise related to hydrological hazards.

2-b To improve flood forecasts and warnings particularly in deltaic and coastal areas by coupling meteorological storm surge forecasts with river flow forecasting.

2-c To enhance regional capabilities relating to flood hazard mapping in delta and coastal regions through continued interaction with the user agencies.

2-d To further improve management of water resources, including assessment of surface and ground water resources in relation to cyclonic disturbances;

3.3.3 Disaster Risk Reduction (DRR)

3.3.3.1 Expected Result 3

- Enhanced capabilities of Members to promote tropical cyclone disaster resilient communities through providing guidance on multi-hazard early warning dissemination and response mechanism

Disaster risk reduction in the region will be improved through the establishment of institutional and legal frameworks at the country level involving improved multi-hazard early warning and Decision Support Systems (DSS) of vulnerability and community-based disaster risk management (CBDRM) initiatives aiming at enhanced public awareness, and participation of stakeholders to be more effective. These are expected to be achieved through improvement in standard procedures on DRR and the exchange of national and international experiences and information on disaster management among the Members.

3.3.3.2 Strategic Actions

3-a To improve regional cooperation in policies and strategies on DRR, especially those related to tropical cyclones, coastal hazards and other extreme weather events.

3-b To establish a regional information system to support the development of policies and strategies on DRR as well as interfacing with the national level systems by creating an updated comprehensive database on disaster information and best practices on DRR.

3-c To further enhance public awareness and appreciation of the impacts of tropical cyclones and other extreme weather events, for possible mitigation and response actions through effective communication with the media before, during, and after such events.

3-d To further strengthen coordination and interaction between meteorological/hydrological services on the one hand and emergency management/disaster response agencies on the other through integrated emergency management, disaster response and preparedness programmes.

3-e To strengthen regional cooperation on DRR information exchange through networking by making available disaster preparedness and mitigation information through Internet web sites, involving web GIS tools and other means.

3-f To enhance disaster risk management, especially those related to cyclone-related disaster preparedness by developing and implementing pilot projects on multihazard disaster risk management programmes into the development plan of the Panel Members in the next four years.

3.3.4 Training

3.3.4.1 Expected Result 4

- Development of a strategic approach to capacity building with a regional perspective

Training activities will be enhanced by strengthening the skills of personnel engaged in various aspects of cyclone prediction and early warning through regular training programs including the organization of workshops, seminars, etc.

3.3.4.2 Strategic Actions

4-a To promote training programs on the use of NWP model products and their application in cyclone (track and intensity) and storm surge prediction.

4-b To promote training programs on media coordination during disasters and their effectiveness on "human response".

4-c To promote training programs on the use of remote sensing data including satellite and Doppler Weather Radar products in cyclone forecasting.

4-d To promote visits of experts among Member countries to share their experiences and expertise in cyclone-related fields.

4-e To enhance WMO's fellowship support on tropical cyclones and other multi-hazard risk reduction-related programs.

To set up a small group of its Members to develop a draft training plan. The training plan could identify the training needs and available opportunities as well as the gaps that will need to be addressed to support the successful implementation of the Coordinated Technical Plan.

4-f To develop TC Forecasting Competency as per the recommendation of EC-65 & EC-66.

The Panel noted that the Executive Council at its 66th session stressed the need for, and urged the Secretariat to support the, development of TC forecasting competencies in all tropical cyclone basins by regional tropical cyclone committees under the initiativeof RSMCs. Implementation of tropical cyclone competencies is an essential component of improving service delivery as it sets common global recommended practises providing a safety net of "our staff are trained to at least the minimum recommended standards" and providing a leverage for members to obtain funding of "we need to train our staff to at least the minimum recommended standards" to provide quality services. Development and implementation of a competency framework is part of a quality approach to ensuring service delivery as it requires parallel reviews of policies and forecasting processes and procedures to be successful.

The Panel also noted that Members in RAI, RA IV and RA V and the ESCAP/WMO Typhoon Committee have already undertaken considerable work in the development and implementation of tropical cyclone forecasting competencies at national and regional level. The Panel was informed that RSMC New Delhi had developed a set of tropical cyclone forecasting competencies, and circulated among the Panel Members a draft version of the tropical cyclone forecasting competencies for the Panel. The Panel is invited to discuss further this document and provide recommendations to implement these competencies.

3.3.5 Research

3.3.5.1 Expected Result 5

- Enhanced capabilities of Members to cope with high-impact weather through research

The collaboration will be promoted on research activities related to updating forecasting technologies, including NWP, storm surge and flood forecasting models.

3.3.5.2 Strategic Actions

5-a To assess the impact of climate change on tropical cyclones in the region.

5-b To further improve monitoring capabilities to characterize physical and dynamical characteristics of tropical cyclones.
5-b To further improve regional NWP models for tropical cyclone track, Intensity and structure predictions.
5-c To develop and further improve the storm surge and river flood coupling model over specific river basins for forecasting of coastal inundation.
5-d To update vulnerability maps for various parameters like wind force/peak storm surge etc., based on latest available database.
5-e To identify research issues and develop research proposals for technical and funding support

3.3.6 Partnership

3.3.6.1. Expected Result 6

- *Enhanced cooperation among Members and with partner organizations in the provision of forecasts and warnings for tropical cyclones and storm surges*
- Partnerships will be further developed both within and outside the region to take advantage of experience, expertise, infrastructure and other resources, and for future initiatives and development projects.

3.3.6.2 Strategic Actions

a To promote the exchange of information and data among Members and with regional bodies to enhance regional cooperation in the five components: meteorology, hydrology, DRR, training and research.
b To enhance cooperation with other regional bodies, organizations, service providers and sectors for more effective provision of the forecasts and warnings.
c To develop and implement joint projects in the areas of the above five components and resource mobilization.

3.3.7 Management and Governance

3.3.7.1 Expected Result 7

- *Effective management and functioning of the Panel.*

Effective management and governance will be pursued to ensure the fulfilment of Panel's vision, mission and strategic objectives.

3.3.7.2 Strategic Actions

a To further improve the coordination and decision-making process of the Panel.
b To enhance effectiveness in the implementation of CTP and AOPs.
c To continue to ensure effective and collaborative relationships among working groups of Meteorology, Hydrology and DRR.
d To further improve the coordinated technical planning process as well as monitoring and evaluation.

3.5. CONCLUSION

Coordinated Technical Plan (CTP) for the WMO/ESCAP Panel on Tropical Cyclones for the Bay of Bengal and Arabian Sea (2024-27) has been developed based on the general framework of CTP adopted at the 31st session and the draft CTP submitted to the 50th session by the CTP Working Group, as well as suggestions from the Panel Members. It also took into account Sendai Framework for Disaster Risk Reduction (2015-2030) adopted during the World Conference on Disaster Reduction in 2015.

CHAPTER-IV
Annual Operational Plan (2025-26)

Expected Result	Strategic Goal	Activity
ER-1 (Meteorology) Enhanced capabilities of Members to produce better forecasts and warnings of tropical cyclones and storm surges.	1-a To improve and expand the observing system of surface, upper-air, ship, buoy, aircraft, radar, wave radar and satellite observations in the Member countries.	To strengthen the cooperative relationship with the Airlines for the development of the regional Aeronautical Meteorological Data Relay (AMDAR) programme (WMO).
	1-b To implement and operate adequate Members' connection to the WMO Information System (WIS) for operation-critical data exchange through dedicated telecommunication means.	Members to implement plans to deploy WIS functionality.
	1-c To increase the accuracy, timeliness and usefulness of tropical cyclone forecasts and warnings.	1) To establish and enhance the communication between the operational forecasters in RSMC and the Members (RSMC, PTC-S). 2) To develop collaborative links with the Severe Weather Forecasting Programme and the Coastal Inundation Forecasting Programme of WMO (Members, RSMC, BMD, PTC-S, WMO) 3) To promote implementation of Common Alerting Protocol (CAP) in partnership with WGDRR (WMO, Members). 4) To implement TC Landfall Forecast programme (RSMC, Members) 5) To prepare an assessment report on the current status and needs of the Members with respect to data, products, analytical and forecasting procedures (Working Group on Meteorology in association with RSMC, New Delhi) 6) To arrange the training on Dvorak's technique, microwave imageries & products and application of Ensemble Prediction System (EPS) for tropical cyclone monitoring and prediction with the support of WMO. 8) WMO/PTC may facilitate training on the utilization of INSAT-3DR and S data and products including RAPID and Nowcasting tools among the Member

		countries. (in conjunction with some other training activity of WMO).
	1-d To upgrade the computing facility of RSMC New Delhi and NMSs so as to facilitate efficient data processing and data assimilation from different observing systems/platforms to suit the national and regional needs.	RSMC New Delhi may inform the Panel Member countries about the changes/upgradation in their telecommunication systems so that necessary measures taken by the members.
ER-2 (Hydrology) Enhanced capabilities of Members to provide better hydrological forecasts and assessments.	2-a To improve regional cooperation in real-time monitoring and exchange of relevant data and information, derived (forecasting) products and technical expertise related to hydrological hazards.	1) To develop and implement a regional information exchange strategy during 2025-2026. 2) To organize regional workshops on data transmission mechanisms with special reference to water-related hazards. 3) To collaborate with the Commission for Hydrology (CHy) and RA-II to carry out the activity on actions 1 and 2.
	2-b To improve flood forecasts and warnings, particularly in deltaic and coastal areas by coupling storm surge forecasts with river flow forecasting.	1) To develop delta hydraulic models for river forecasting by coupling any hydrodynamical model being used in the countries) with the storm surge forecasts for at least one river delta in each country. 2) Developing/application of coastal flood models and associated flood hazard and risk maps in the line as mentioned above. 3) To organize workshops for enhancing the capabilities of the countries (in conjunction with WMO training etc.)
	2-c To enhance regional capabilities relating to urban floods/ riverine flood risk reduction in delta and coastal regions through continued interaction with the member countries and user agencies.	1) To undertake flood hazard mapping at least in one major delta/coastal area in each country during the next four years. 2) To organize workshops for capacity building (in conjunction with WMO training activity etc). 3) To collaborate and share experiences with the Typhoon Committee (WMO, ESCAP, PTC-S)

ER-3 (DRR) Enhanced capabilities of Members to promote tropical cyclone disaster resilient communities through providing guidance on multi-hazard early warning dissemination and response mechanism.	3-a To improve regional cooperation in policies and strategies on DRR, especially those related to tropical cyclones, coastal hazards and other extreme weather events.	1) ESCAP, WMO and PTC to organize capacity development training programme for PTC member countries particularly in the areas of impact-based forecasting, risk-based warning. 2) ESCAP and WMO to work with PTC member countries for developing a regional component of International Network of Multi Hazard Early Warning System (IN-MHEWS) and implementation of MHEWS Interoperability Environment (MIE)
	3-b To establish a regional information system to support development of policies and strategies on DRR as well as interfacing the national level systems by creating an updated comprehensive database on disaster information and best practices on DRR.	1) To strengthen regional cooperation on DRR information exchange through networking by making available disaster preparedness and mitigation information through Internet websites, involving web GIS tools and other means. The web link may be provided to GMAS. WMO will provide a guideline to the member countries. 2) ESCAP to support PTC member countries in attending regional co-operation related activities including IN-MHEWS, Asian Pacific Centre for Development of Disaster Information Management (APDIM).
	3-c To improve public awareness and appreciation of the impacts of tropical cyclones and other extreme weather events, for possible mitigation and response actions through effective communication with the media before, during, and after such events.	ESCAP and WMO to support strengthening multi-stakeholder forums such as monsoon forums, and national climate outlook forums in PTC member countries.
	3-d To improve coordination and interaction between meteorological/hydrological services on the one hand and emergency management/disaster response agencies on the other through integrated emergency management, disaster response and	ESCAP and WMO to continue supporting initiatives such as Common Alerting Protocol (CAP) in PTC member countries.

	preparedness programmes.	
	3-e To improve disaster risk management, especially those related to cyclone-related disaster preparedness by developing and implementing pilot projects on multi-hazard disaster risk management programmes into the development plan of the Panel Members in the next four years.	WMO and ESCAP to support piloting a standard methodology project on impact based forecasting and risk based warning in PTC member countries.
ER-4 (Training) Training plan for capacity building with a regional perspective.	4-a An expert group of members (Bangladesh, India, Maldives & Sri Lanka) to prepare a draft training plan from 2025-26.	1) Expert Group (Sri Lanka, Oman and Thailand) to produce a training plan including a prioritized list of training needs and opportunities of PTC Members through a survey and advise WMO for reporting, planning and implementation purposes. PTC will write to member countries regarding the constitution of the expert group and request for the nomination of experts and focal persons. 2) The plan is to be submitted to PTC Secretariat by the end of December 2024. PTC will forward the report to WMO with a request to organize training as per the plan.
	4-b To arrange training programmes on the use of NWP model products and their application in Cyclone (track and intensity) and storm surge prediction.	1) To continue the attachment training programme in RSMC, New Delhi for cyclone forecasters. 2) PR of India with WMO to arrange training on storm surge forecasting in India for the PTC member countries.
	4-c To arrange training programmes on the use of Satellite and Doppler Weather Radar (DWR)data & products in Cyclone forecasting as well as DWR calibration and maintenance	3) To continue to organize a training programme at INCOIS, Hyderabad in India on the utilization of Ocean data and wave forecasting. 4) ESCAP to continue supporting training programme for information dissemination and media coordination in multi-hazard early warning system.

	4-d To arrange training programmes on information dissemination tools and media coordination during disasters and their effectiveness on "human response".	
	4-e To exchange visits of experts among Member countries to share their experiences and expertise on cyclone & related disaster management aspects.	-
	4-f To enhance WMO's fellowship support on tropical cyclone related programmes.	-
ER-5 (Research) Enhanced capabilities of Members to cope with high impact weather through research.	5-a To produce regional assessment of the impact of climate change on tropical cyclones.	To collect data/materials/papers from the Member countries which are relevant to the regional assessment.
	5-b To develop storm surge and river flood coupling model over specific river basins for forecasting of coastal inundation.	-
	5-c To update vulnerability maps for various parameters like wind force/peak storm surge etc., based on latest available database.	-
ER-6 (Partnership) Enhanced use of forecasts and warnings for tropical cyclones and storm surges for decision making and implementation by Members and partner organizations.	6-a To promote exchange of information and data among Members to enhance regional cooperation in meteorology, hydrology, DRR, training and research.	-

	6-b To enhance cooperation with other regional bodies, organizations, service providers and sectors for more effective provision of the forecasts and warnings.	-
	6-c To develop proposals for joint projects in the areas of five components including resource mobilization.	-
ER-7 (Management and Governance) Effective management and functioning of the Panel.	7.a To improve the coordination and decision-making process of the Panel.	-
	7.b To enhance effectiveness in implementation of CTP and AOPs.	-
	7.c To ensure effective and collaborative relationships among working groups of Meteorology, Hydrology and DRR.	-
	7-d To improve coordinated technical planning process as well as monitoring and evaluation.	-

CHAPTER V

TERMS OF REFERENCE OF THE PTC WORKING GROUPS

5.1 Terms of Reference as adopted in 52nd session of the PTC Working Group on Advisory Working Group (AWG)

Terms of reference of Advisory Working Group were proposed in 49th Session of PTC. Due to the various development in recent years the terms of reference have been updated as mentioned below based on the decision of 52nd session of PTC.

Guidance
In establishment of the Advisory Working Group, the PTC provided the following guidance for their assistance in planning and implementation of measures required for mitigation of Tropical Cyclone-related disasters*.*

- To improve the efficiency and effectiveness of the PTC, the PTC, and PTC Secretary.
- To promote international cooperation in the three components of Meteorology, Hydrology, and Disaster Risk Reduction.
- To promote the use of advanced information technology and resource sharing among Members of the Tropical Cyclone Committee.
- To facilitate the implementation of the Strategic Plan, Annual Operating Plan, and Annual Budget.
- To enhance resources mobilization.

Terms of Reference (ToR)
The Advisory Working Group (AWG) will assist the Chairperson of the PTC and the PTC Secretary to coordinate the implementation of PTC decisions. The AWG will also act as a "Think Tank/Steering Group" function to advise and offer options or proposals, as required, to the PTC Members, the PTC, the PTC Chairperson, and PTC Secretary.

- To monitor, review, and evaluate the Strategic Plan's Key Results Areas, Strategic Goals, and Activities; the objectives/action of the Annual Operating Plan; and Annual Budget and make proposals concerning these documents and the evaluation of the results achieved to the Committee.
- To provide overall direction and oversight for the Associated Activities – Integrated listed in the Strategic Plan.
- To provide options and proposals to enhance the effectiveness of the PTC, PTC Chairperson, and the PTC Secretary.
- To assist in the consideration and coordination of prioritizing project proposals and their budgets provided by the three components of PTC. Training and Research are incorporated as part of each of these three.
- To provide options and assistance on collaborative activities among the three components and priority options to the PTC.
- To provide options and assistance on mechanisms aimed at improving the implementation of the Strategic Plan and Annual Operating Plan.
- To assist in mobilizing resources to achieve the goals and objectives as determined by the PTC in the Strategic Plan and Annual Operating Plan.
- Coordinate and harmonize activities among WGs, TRCG, and PTC secretary.
- Monitor and ensure that the projects/activities authorized by the PTC are being accomplished in a timely manner.
- Development, review and propose the format of the Members' written reports and Members' oral reports at the PTC Sessions to focus on the results achieved on the Strategic Plan and Annual Operating Plan.
- Perform missions as required on strategic planning and project/grant proposals to selected Members.

Members

- Chairperson and Vice-Chairperson(s) of AWG as appointed by PTC.
- Chairpersons of the four working groups (i) meteorology (ii) hydrology (iii) DRR (iv) Research & Training and the Head of RSMC, New Delhi, and
- Representatives of WMO and ESCAP (as ex-officio members)

Term of Service of the Chair and Vice-chair(s) of the AWG

The term of service of the Chair of the AWG is two years subject to extension authorized by PTC. The limit of service for the Member providing the Chair shall be two consecutive terms.

The term of service of the Vice-chair(s) of the AWG is two years subject to extension authorized by the PTC. The limit of service for the Vice-Chair(s) shall be three consecutive terms.

Operational modalities

In view of the limited financial resources of the PTC Trust Fund, AWG is expected to perform most of its work, coordination and communication through correspondence including e-mail, video conferencing and other means which would be supported by regular reporting from the PTC Secretariat. As described in the above Terms of Reference of AWG, considerable number of important issues and projects for PTC and its Members will be discussed and accomplished by AWG. To enhance the efficiency of the operation of PTC, it is recommended that an AWG meeting be held at least every year. At the request of the PTC or PTC Chairperson, the AWG will investigate and review issues, make recommendations and proposals, assist in implementing approved projects, activities, etc.

5.2 Terms of Reference of the PTC Working Group on Meteorology

In order to coordinate efforts in the implementation of various programmes and activities related to meteorology with the aim to better support the socio-economic development process in the PTC region and to help accomplish the strategic goals and objectives as mentioned under the Meteorological Component of the Coordinated Technical Plan of the WMO/ESCAP Panel on Tropical Cyclones (PTC) for the Bay of Bengal and the Arabian Sea, the PTC has established the Working Group on Meteorology (WG-M) as decided during 39th Session of PTC (Myanmar, 5-9 March, 2012) with the following Terms of Reference and operational modalities.

Terms of Reference:

The WG-M will promote cooperation among the Members in the implementation of various programmes and activities under the Meteorological Component of the PTC"s Coordinated Technical Plan with the aim to support the socio-economic development process and enhance cooperation among the Members in all the five major components towards this end.

The WG-M is expected to advise and assist the PTC in:

- Identifying priority issues and areas of cooperation in the Meteorological Component;
- Promoting and facilitating the exchange of experiences and knowledge on the latest developments and techniques related to the above issues and areas;
- Coordinating and implement priority activities and programmes of the PTC aiming at strengthening capacity of the Members in meteorology;
- Mobilizing resources to carry out priority activities of the PTC related to the Meteorological Component;
- Developing Annual Operating Plan (AOP) for meteorology and reporting on the activities under the AOP;
- Reporting overall progress in the implementation of the Meteorological

Component of the PTC"s Coordinated Technical Plan;

- Recommending to the PTC"s priority areas, programmes and activities for cooperation in meteorological research by related experts of the Members; and
- Performing any other task as assigned by the PTC. Membership

Membership:
Chairperson
Vice-Chair
Member countries
The PTC invites WMO and ESCAP to continue their involvement in the work of WG M. The PTC also requests the other concerned agencies to participate in the activities of WG-M. The term of service on the WG-M is 1 year, which shall be automatically extended for similar durations unless modified or terminated by the PTC.
Operation modalities in view of the limited financial resources of the PTC Trust Fund, the WG-M is expected to perform its work through email and other means. The WG-M shall hold meeting during the annual Session of PTC. The WG-M members, however, may also meet during the inter-sessional period, if so necessary.
Reporting requirements The Chairperson of the WG-M is required to report to the PTC on overall progress in the implementation of the Meteorological Component of the Coordinated Technical Plan as well as on the activities with regards to the AOP for meteorology through the PTC Secretariat to the PTC Chairperson and the PTC Members for their consideration under the framework of the PTC. This report may also include recommendations related to priority activities to be undertaken in the coming years.

5.3 Terms of Reference of the PTC Working Group on Hydrology

In order to coordinate efforts on the implementation of various programmes and activities related to hydrology with the aim to better support the socio-economic development process in the PTC region and to help accomplish the strategic goals and objectives as mentioned under the Hydrological Component of the Coordinated Technical Plan of the WMO/ESCAP Panel on Tropical Cyclones (PTC) for the Bay of Bengal and the Arabian Sea, the PTC has established Working Group on Hydrology (WGH), as decided during 39th Session of PTC (Myanmar, 5-9 March, 2012) with the following Terms of Reference and operational modalities.

Due to the various development in recent years the terms of reference has been updated as mentioned below.

Terms of Reference (ToR):

The WGH will promote cooperation among the Members in the implementation of various programmes and activities under the Hydrological Component of the PTC`s Coordinated Technical Plan with the aim to support the socio-economic development process and enhance cooperation among the Members in all the five major components towards this end. The WGH is expected to advise and assist the PTC in:

- Identifying priority issues and areas of cooperation in the Hydrological Component
- Promote and facilitate the exchange of experiences and knowledge on the latest developments and techniques related to the above issues and areas;
- Coordinating and implement priority activities and programmes of the PTC aiming at strengthening capacity of the Members in hydrology and water resources;

- Mobilizing resources to carry out priority activities of the PTC related to the Hydrological Component;
- Developing Annual Operating Plan (AOP) for hydrology and reporting on the activities under the AOP;
- Reporting overall progress in the implementation of the Hydrological Component of PTC`s Coordinated Technical Plan;
- Recommending to the PTC`s priority areas, programmes and activities for cooperation in hydrological research by related experts of the Members; and
- Performing any other task as assigned by the PTC

Membership;

All Member countries will be represented at the WGH.

The PTC invites WMO and ESCAP to continue their involvement in the work of WGH. The PTC also requests to other concerned agencies to participate in the activities of WG-H. The term of service on the WGH is 1 year subject to extension authorized by the PTC.

Operation Modalities:

In view of the limited financial resources of the PTC Trust Fund, the WGH is expected to perform its work through email, video conferencing and other means. The WG members shall meet if necessary. The WGH can have the physical meeting during the PTC session.

Reporting Requirements:

The Chairperson of the WGH is required to submit annual report on WGH activities with regards to the implementation of Coordinated Technical Plan through PTC Secretariat to the PTC Chairperson and the PTC Members for their consideration under the framework of the PTC. This report will include recommendations related to priority activities to be undertaken in the coming years.

The working group will suggest fund requirement for the activities to be carried out during next one year. It will be submitted to the intermediary group to evaluate the proposal of various working groups. The report of the intermediary group will be examined and approved by the PTC.

5.4 Terms of Reference of the PTC Working Group on DRR

In order to coordinate efforts on the implementation of various activities under the Disaster Risk Reduction (DRR) Component to better support the socio-economic development process in the Panel on Tropical Cyclones (PTC) Area and to help accomplish the DRR related goals and objectives in the Coordinated Technical Plan (CTP) 2009-2011, PTC established the Working Group on Disaster Risk Reduction (WGDRR), with the following Terms of Reference and operational modalities.

Due to the various development in recent years the terms of reference has been updated as mentioned below.

Terms of Reference (ToR):

The WGDRR will promote cooperation among the PTC Members in the implementation of activities under the DRR Component of the PTC's Coordinated Technical Plan to support the socio-economic development process and enhance cooperation among the Members in all the five components towards this end, the WGDRR is expected to advise and assist the PTC:

- Identifying priority issues and areas of cooperation in the DRR Component;
- Promoting and facilitating the exchange of experiences and knowledge on the latest developments and techniques related to the above issues and areas;
- Coordinating and implementing priority activities of the AOP and programmes of the PTC aiming at strengthening capacity of the Members in DRR;
- Mobilizing resources to carry out priority activities of the PTC related to the DRR Component; Monitoring and evaluating overall progress in the implementation of the DRR Component of the Coordinated Technical Plan;
- Recommending to the PTC priority areas, programmes and activities for cooperation in DRR research by experts of the Members;
- Promoting measures for more effective cooperation with other components of work of the Panel, including the development of the conceptual framework on multi-hazard early warning systems and public outreach programs; and,
- Reporting overall progress in the implementation of the DRR component of the CTP.
- Monitoring and promoting the early action based on early warning in short to medium range multi-hazard monitoring, impact-based forecasting and risk-based warning for DRR.
- Monitoring and promoting the anticipatory actions based on extended range/monthly/seasonal forecast.
- Monitoring and promoting the implementation of Common Alert Protocol for early warning dissemination.
- Monitoring and promoting multihazard inter-probability for DRR.

Membership

The WGDRR will consist of the following members:

Chairperson:

Vice Chairperson:

Members:

The PTC invites ESCAP and WMO to continue their involvement in the work of WGDRR. The PTC also requests the other concerned agencies to participate in the activities of WGDRR. The terms of service on the WGDRR are 1 year subject to extension authorized

by the PTC.

Operation modalities:

In view of the limited financial resources of the PTC Trust Fund, the WGDRR is expected to perform its work through email, video conferencing and other means. The WG members shall meet if necessary. Physically, they can meet during the PTC session or side events.

Reporting requirements

The Chairperson of the WGDRR is required to submit an annual report on DRR activities with regards to the implementation of Coordinated Technical Plan through the PTC Secretariat to the PTC Chairperson and the PTC Members for their consideration under the framework of the PTC. This report will include recommendations related to priority activities to be undertaken in the coming years.

The working group will suggest fund requirement for the activities to be carried out during next one year. It will be submitted to the intermediary group to evaluate the proposal of various working groups. The report of the intermediary group will be examined and approved by the PTC.

5.5 Terms of Reference of the PTC Working Group on Training, Research and Publication

In order to coordinate efforts on the implementation of various activities under the capacity building initiatives through training and research, the Working Group on training and research (WGTR) will have the following Terms of Reference and operational modalities:

Due to the various development in recent years the terms of reference have been updated as mentioned below.

Terms of Reference:

WGTR is to promote research and training activities on various aspects of tropical cyclone analysis and forecasting, including assessment of tropical cyclones' impacts on Members' socio-economic development processes, and to encourage cooperation of efforts among Members.

Towards this end, WGTR is expected to:

- assist in identifying scientific and technical problems in the analysis and forecasting of tropical cyclones and their impacts on water resources and measures for disaster prevention and preparedness;
- facilitate the exchange of experience and knowledge on the latest development and techniques related to the above problems;

- coordinate training and research programmes, including activities in support of cross-cutting initiatives and other collaboration programmes among Members such as twinning and mentoring arrangement, aimed at improving the technical capacity and capability of Members to better serve the people in the region;
- evaluate the effectiveness of training and research activities undertaken by WGTR, and
- provide support to other working groups in performing such evaluation;
- recommend to the Committee priority areas and long-term plans for cooperation in research and training in support of the targets and strategic plans.
- Suggest and promote training on IBF, RBF, CAP and AI/ML etc in the WMO/ESCAP Panel region.
- Prepare the list of research papers and share annually to all members relevant to the region.
- Support the publication of PTC Newsletters & other publications.

Membership:

Chair:

Vice Chair:

Members:

Operation modalities:

In view of the limited financial resources of the PTC Trust Fund, the WGTR is expected to perform its work through email and other means. The WG members shall meet if necessary online.

Reporting requirements:

The Chairperson of the WGTR is required to submit an annual report on training & research activities with regards to the implementation of Coordinated Technical Plan through the PTC Secretariat to the PTC Chairperson and the PTC Members for their consideration under the framework of the PTC. This report will include recommendations related to priority activities to be undertaken in the coming years.

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