Regional Specialised Meteorological Centre-Tropical Cyclones, New Delhi

Area of responsibility of RSMC New Delhi

“Enabling resilience against Cyclone Disasters”

RSMC New Delhi,
India Meteorological Department,
Ministry of Earth Sciences

August, 2024

Regional Specialised Meteorological Centre-Tropical Cyclones, New Delhi: A Souvenir

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Preface

A tropical cyclone (TC) is a multi-hazard weather phenomenon, as it leads to heavy rainfall, gale wind, storm surge and high waves during the landfall. Though the North Indian Ocean experiences about 7% of cyclones developing over the globe, it has faced some of the deadliest cyclones like Bhola Cyclone in 1970 causing the death of about 300000 people. However, during recent decades, there has been a paradigm shift in IMD's early warning system of TC which enabled the disaster managers, stakeholders and general public to take adequate response actions. As a result, there has been significant reduction in the loss of lives due to any cyclone over the region.

The capacity building programmes play a pivotal role to improve the competency of forecasters and hence the TC monitoring & forecasting accuracy as well as the cyclone warning services delivery. Over the years, the India Meteorological Department (IMD) has built up a credible Cyclone Warning System for the region which utilizes augmented observational network, satellites, radars, array of various global & regional numerical weather prediction (NWP) models, information & communication technology and Decision Support System for monitoring, analysis, forecasting and warning products generation & dissemination to various stakeholders.

I am happy that the Regional Specialized Meteorological Centre (RSMC), New Delhi is organizing 20th Attachment Training for Tropical Cyclone Forecasters in the region. On this momentous occasion, RSMC New Delhi has brought out a Souvenir for Tropical Cyclones Forecasters in the region. It brings out journey of RSMC New Delhi since its establishment in 1973, international obligations, its services, achievements and the future plans. RSMC New Delhi has played a very significant role in capacity building and improving the competency of forecasters in the region through organization of regular trainings, workshops, conferences, outreach activities and development of annual tropical cyclone operational plan. I hope this Souvenir would motivate operational forecasters, researchers and decision makers to improve the services.

I appreciate WMO, UN-ESCAP, the meteorological fraternity of all the PTC member countries including Thailand, Myanmar, Bangladesh, Sri Lanka, Maldives, Pakistan, Iran, United Arab Emirates, Qatar, Saudi Arabia, Sultanate of Oman and Yemen for their support and confidence in the services of RSMC New Delhi. I also congratulate various Global, National & Regional Centres, financial supporters, researchers, developers and forecasters for the success of RSMC New Delhi. I would also like to place on record my deep appreciation to various sub-offices & Divisions of IMD and sister organizations under the Ministry of Earth Sciences (MoES) for their relentless support in improving the early warning system of TCs over the region.

I deeply appreciate the Scientists and Staff of Cyclone Warning Division and RSMC New Delhi for significant improvement in TC advisory services to the WMO/ESCAP Panel member countries. I express my deep appreciation to RSMC, New Delhi especially Mrs. Monica Sharma, Scientist-D for preparing this Souvenir. I also appreciate Dr. PLN Murty, Mr. Anshul Chauhan, Dr. T. Arulalan, Dr. M. Iyappan, Dr. A. K. Das and Dr. D.R. Pattanaik for their support in preparing this Souvenir. I acknowledge contribution of Ms. Neeru Barak, Mr. Ashish Rawat, Mr. Vijay Kumar Singh, Mr. Mukesh Kumar, Mr. Santosh Singh, Mr. Vishal Maurya, Mr. Gulvez Mohd, Ms. Neelam Meena, Ms. Vineeta Bhardwaj and Mr. Yashasvi of Cyclone Warning Division for their contribution in preparation of this document.

Mrutyunjay Mohapatra
Director General of Meteorology

16th August, 2024

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Chapter 1
Introduction

Origin of WMO/ESCAP Panel on Tropical Cyclones over the Bay of Bengal and Arabian Sea

Huge loss of human lives, damage to property and unbearable sufferings of human beings are caused by tropical cyclones in coastal areas of tropical oceans like Atlantic, Pacific and Indian Oceans. The disaster potential due to cyclones is particularly high in the North Indian Ocean (NIO) comprising of the Bay of Bengal (BoB) & the Arabian Sea (AS) region, primarily due to associated high storm surge and poor socio-economic conditions. 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 metres over West Bengal coast on 7th October, 1737 in association with another 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 1970, Bhola cyclone struck East Pakistan (now Bangladesh) and the West Bengal region of India on November 12, 1970. The cyclone caused an estimated 300,000 to 500,000 deaths, making it one of the deadliest natural disasters in recorded history (Randall et al., 2017). Similarly, there were huge loss of lives due to cyclones in other countries.

Realizing the need for an effective cyclone warning and disaster mitigation machinery in the region, World Meteorological Organisation (WMO) and United Nation's Economic and Social Commission for Asia & Pacific (UN-ESCAP) jointly established the Panel on Tropical Cyclones (PTC) in 1972 as an inter-Governmental body. Its membership comprised the countries affected by tropical cyclones in the NIO. Initially, Bangladesh, India, Myanmar, Pakistan, Sri Lanka and Thailand joined the Panel in 1972. Later Maldives joined the Panel in 1982 followed by Sultanate of Oman in 1997, Yemen in 2016 and Saudi Arabia, United Arab Emirates, Qatar and Iran in 2018. The PTC has thus now 13 countries bordering BoB and AS as the members.

Role of WMO/ESCAP PTC

The PTC is one of the five regional tropical cyclone bodies established as part of the WMO Tropical Cyclone Programme (TCP) namely Panel on Tropical Cyclones (PTC), Typhoon Committee, RA I Tropical Cyclone Committee, RA IV Hurricane Committee and RA V Tropical Cyclone Committee (Fig. 1.1).

The PTC aims at promoting and co-ordinating 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, 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 first session of WMO/ESCAP Panel on Tropical Cyclones was convened in Bangkok, Thailand in January 1973.

The functions of the PTC 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 of community preparedness and disaster prevention;
- To promote, prepare and submit to member countries plans for co-ordination of research 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 organisations and contributors and

❖ To consider, upon request, possible sources of financial and technical support for such plans and programmes.

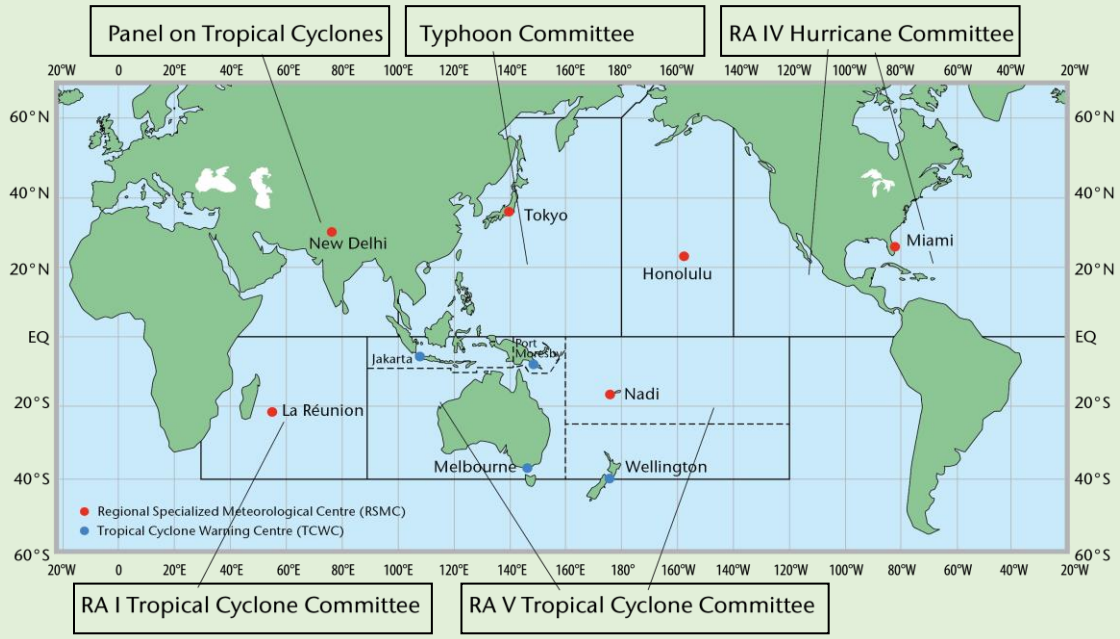

Fig. 1.1: Regional Tropical Cyclone Bodies

The Secretariat of PTC was initially located in Bangkok, Thailand in 1973. Currently IMD, New Delhi hosts the PTC Secretariat for the period of 2024-2027.

Origin of Regional Specialized Meteorological Centre (RSMC), New Delhi

It was further decided that under the umbrella of WMO/ESCAP PTC, IMD will act as a Regional Meteorological center (RMC) to provide Topical Cyclone Advisories to the Member Countries. IMD New Delhi acted as RMC New Delhi during 1973-1987. In 1988, it was designated as Regional Specialized Meteorological Centre (RSMC) for tropical cyclones to provide the daily Tropical Weather Outlook, Special Tropical Weather Outlook during depression and Tropical Cyclone Advisory during cyclones over the Bay of Bengal and Arabian Sea, covering the area of latitude 5^0 N to 35^0 N and longitude 60^0 E to 100^0 E. The area of responsibility has been extended from original latitude 5^0–35^0 N & longitude 60^0–100^0 E to latitude 0^0–35^0 N & longitude 45^0–100^0 E in 2005 and to latitude 0^0–35^0 N & longitude 40^0–100^0 E in 2018.

Chapter 2

Operational Activities of Regional Specialised Meteorological Centre-Tropical Cylones, New Delhi

Regional Specialized Meteorological Centre (RSMC) - Tropical Cyclones, New Delhi, is co-located with Cyclone Warning Division of India Meteorological Department (IMD) at New Delhi in the office of Director General of Meteorology. It is one among the six WMO recognized RSMCs in the world as shown in Fig. 2.1. These are RSMC Honolulu covering North Eastern Pacific, RSMC Tokyo covering North West Pacific, RSMC Miami covering North West Atlantic, RSMC La Réunion covering South West Indian Ocean, RSMC Nadi covering South East Indian Ocean.

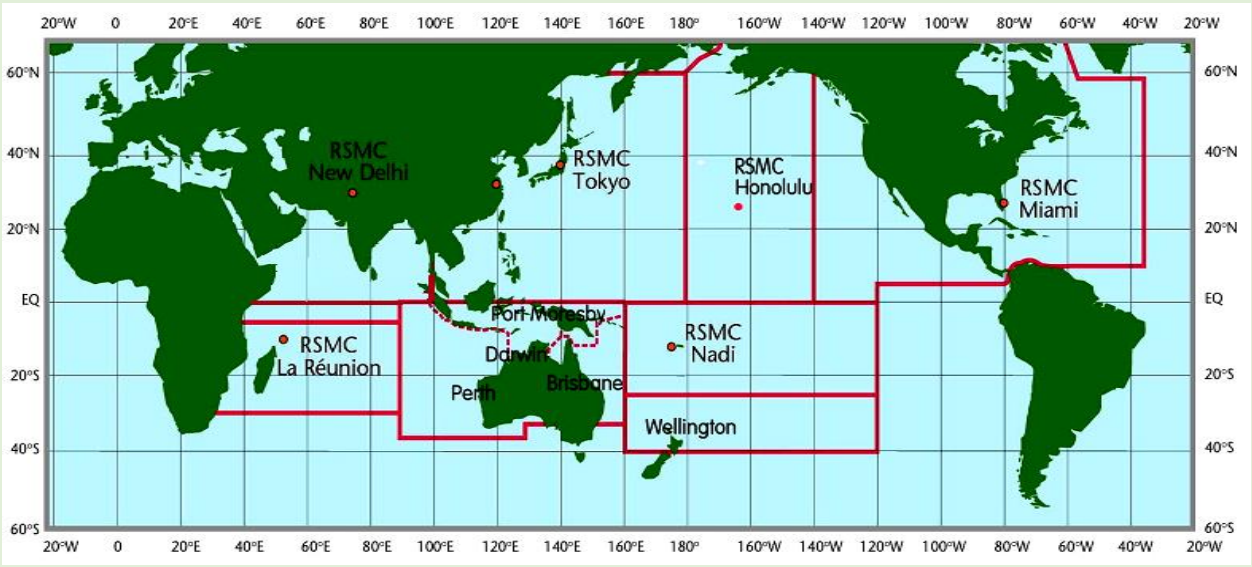

Fig.2.1: WMO's recognized Regional Specialised Meteorological Centres globally

In addition to Six RSMC's, there are five Tropical Cyclone Warning Centers (TCWC) viz. TCWC Perth, Brisbane, Wellington, Jakarta, Port Moresby.

Area of Responsibilities of RSMC New Delhi

RSMC has the responsibility of issuing Tropical Weather Outlook, Special Tropical Weather Outlook and Tropical Cyclone Advisories for the benefit of the countries in the WMO)/ ESCAP Panel region bordering the BoB and the AS, namely, Thailand, Bangladesh, Myanmar, India, Sri Lanka, Maldives, Pakistan, Iran, Sultanate of Oman, United Arab Emirates, Saudi Arabia, Qatar and Yemen. The current area of responsibility of RSMC New Delhi is presented in **Fig. 2.2**.

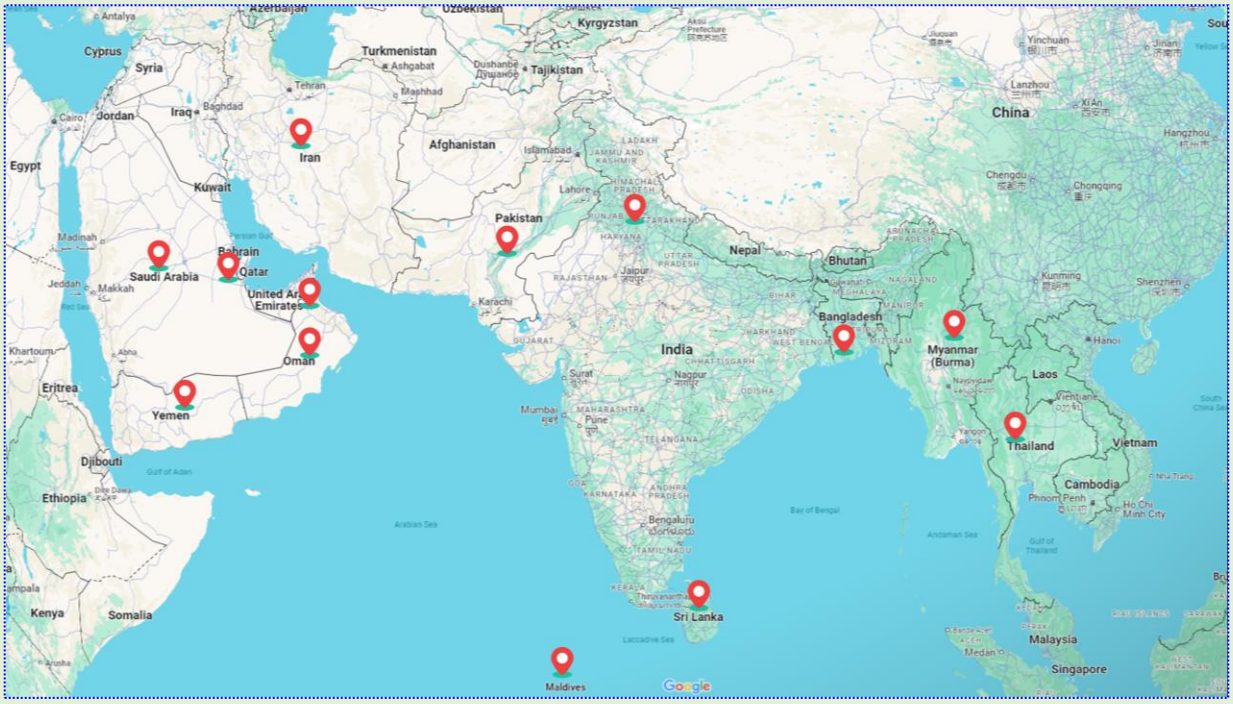

Fig.2.2: Area of responsibility of RSMC New Delhi

Functions of RSMC- Tropical Cyclones, New Delhi

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. The depression & cyclones (with maximum sustained wind speed (MSW) of 17 knots or more) are called as cyclonic disturbances.
- Running of numerical weather prediction models for tropical cyclone track, intensity, landfall and associated severe weather like rainfall, wind and storm surge predictions.
- Implementation of the Regional tropical Cyclone Operational Plan (TCP) of WMO/ESCAP Panel.
- Issue of daily Tropical Weather Outlook, Special Tropical Weather Outlook (during depression) and Tropical Cyclone Advisories (during cyclonic storm) to the Panel countries.

- Issue of Tropical Cyclone advisories to International airports in the neighbouring countries for International civil aviation as per the requirement of International Civil Aviation Organization (ICAO). Cyclone Warning Division, IMD, New Delhi acts as Tropical Cyclone Advisory Centre (TCAC) for this purpose.
- Collection, processing and archival of all data pertaining to cyclonic disturbances viz. wind, pressure, rainfall, storm surge, damage report, satellite and Radar derived information etc. and their exchange with Panel member countries.
- Preparation of report on each cyclonic disturbance after their dissipation and sharing of the report with PTC member countries.
- Preparation of comprehensive annual reports on cyclonic disturbances formed over North Indian Ocean every year and sharing of the report with PTC member countries.
- Preparation of annual review report on various activities including meteorological, hydrological, disaster risk reduction (DRR), Research and training activities of panel member countries.
- Research on tropical cyclones over North Indian Ocean and storm surge and track & intensity prediction techniques among others.
- Organisation of annual trainings on tropical cyclone monitoring and prediction as well as associated severe weather forecasting and warning services for WMO/ESCAP Panel member countries.

Outlooks and Advisories issued by RSMC, New Delhi to the member countries:

(a) Extended Range Outlook:

The RSMC New Delhi 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. Typical example of extended range outlook issued during cyclone MOCHA is presented in Fig. 2.3.

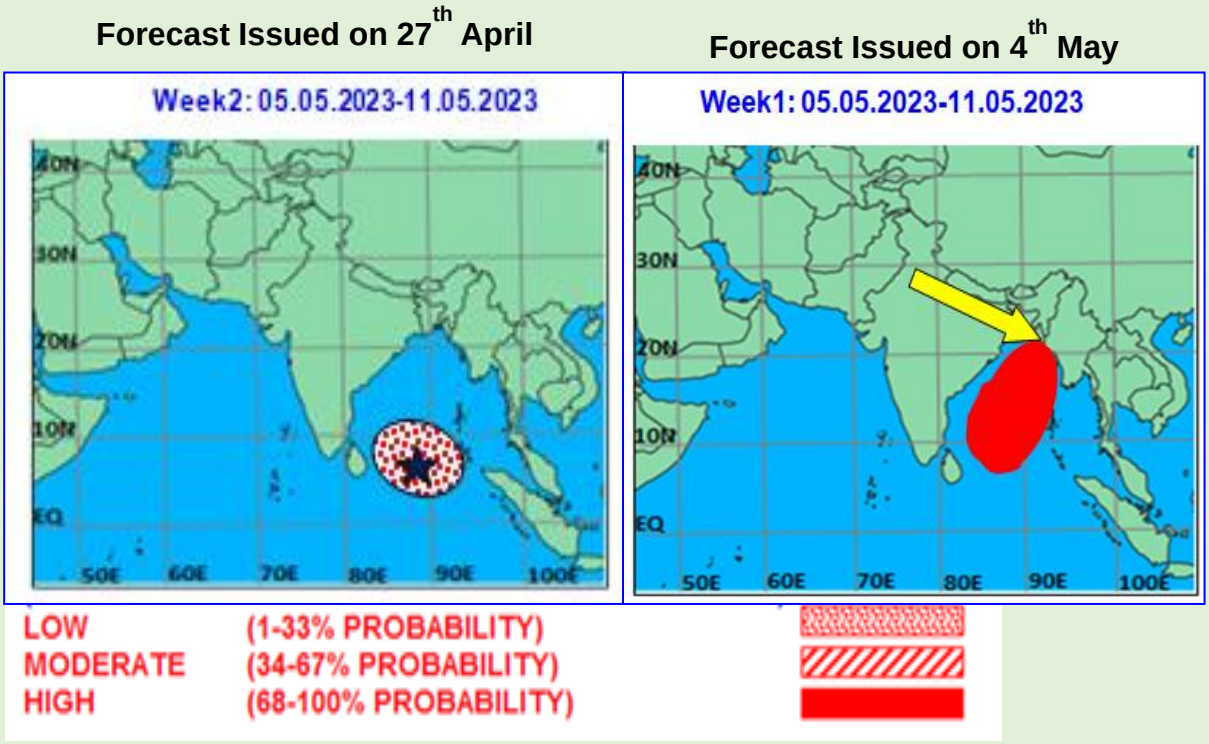

Fig. 2.3: Extended range outlook issued on (a) 27th April, about 12 days prior to formation of depression on 9th May and (b) 4th May, about 5 days prior to formation of depression on 9th May and about 10 days prior to landfall over Myanmar-Bangladesh coasts

(b) Tropical Weather Outlook:

The Tropical Weather Outlook 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) since July 2023. It was issued upto 24 hrs till 2013, upto 3 days from 2014 and upto 5 days from 2018. 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 & 68–100 %. Typical example is presented in Fig. 2.4.

PROBABILITY OF CYCLOGENESIS (FORMATION OF DEPRESSION) DURING NEXT 120 HRS:

24 HOURS	24-48 HOURS	48-72 HOURS	72-96 HOURS	96-120 HOURS
NIL	NIL	NIL	LOW	HIGH

Fig.2.4: Extract of daily tropical weather outlook issued on 4th May indicating High Probability of formation of depression around 9th May.

(c) Pre-Genesis Forecast:

The RSMC New Delhi commenced pre-genesis forecast of probable date, time and location of expected cyclogenesis (formation of depression) over the NIO along with 12 hourly forecasts of track, intensity and structure upto next 48 hours, once daily from the stage of low pressure area in March 2022. It was extended upto 72 hours in 2023. Typical example of pre-genesis forecast issued during MOCHA on 9th May at the stage of well marked low pressure area is presented in **Fig. 2.5**.

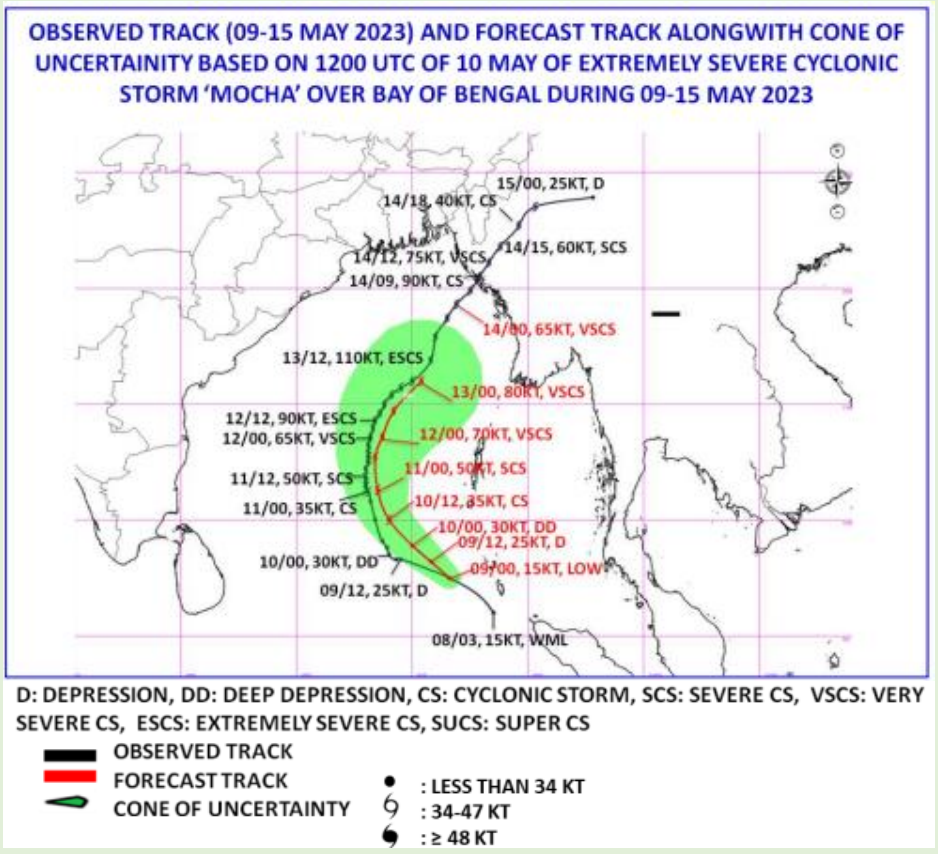

Fig. 2.5: Pre-genesis track and intensity forecast issued on 9th May morning at the stage of well marked low pressure area

(d) Special Tropical Weather Outlook:

The Special Tropical Weather Outlook is issued at 0300, 0600, 0900, 1500 & 2100 UTC based on observations of 0000, 0300, 0600, 1200 & 1800 UTC 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 and discussion on various diagnostic and prognostic features.

(e) Tropical Cyclone Advisories:

Tropical cyclone advisory bulletin is issued when a deep depression intensifies into a tropical cyclone (wind speed≥ 34 knots). 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. These bulletins contain the current position and intensity, past movement, central pressure of the cyclone, description of satellite and radar based cloud imageries, expected direction & speed of movement and expected track & intensity of the system up to 120 hours similar to that in special tropical weather outlook. The expected point & 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 expected. Typical track, intensity and structure forecast issued during cyclone MOCHA on 11th May is presented in Fig. 2.6.

(f) Storm Surge Guidance:

RSMC New Delhi commenced storm surge guidance to the panel member countries in 2009 in association with cyclone Bijli based on IIT Delhi Storm Surge model and Storm Surge & Coastal Inundation based on INCOIS Hyderabad, ADvanced CIRCulation (ADCIRC) model since 2013. IMD commenced Probablistic storm surge guidance experimentally in May 2024 during cyclone REMAL.

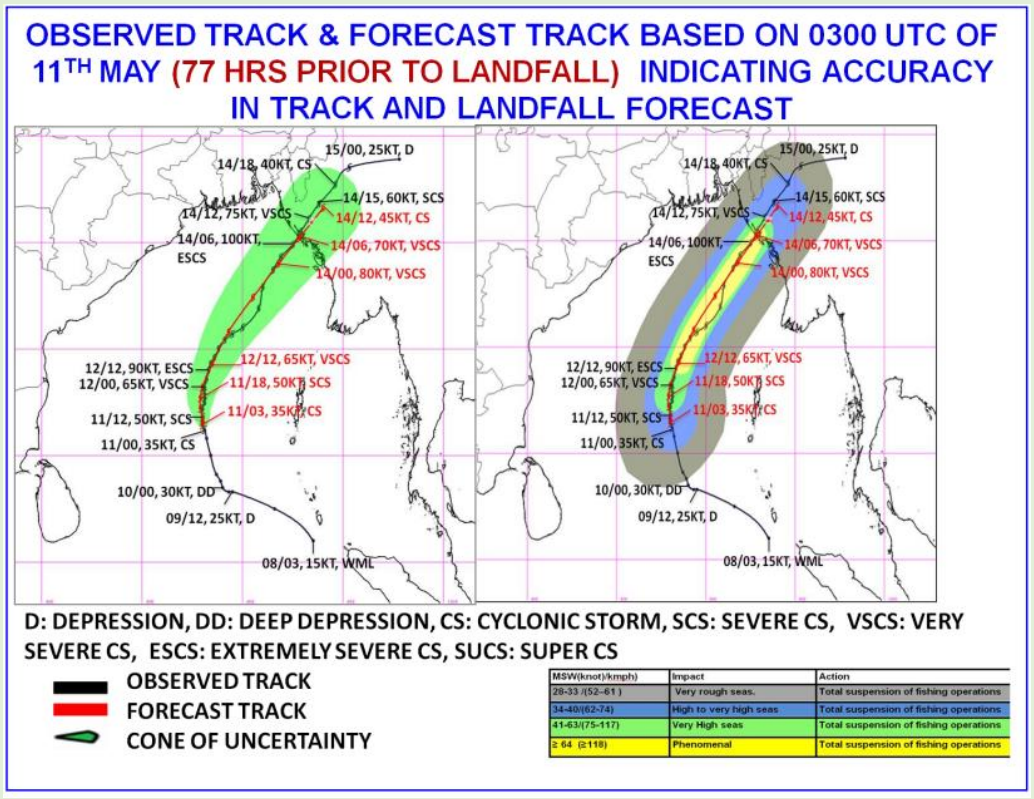

Fig. 2.6: Typical track and intensity forecast issued on 11th May/0300 UTC demonstrating accuracy in track and landfall prediction (about 77 hours prior to landfall)

(g) Tropical Cyclone Advisories for international civil aviation

IMD acts as one among 7 WMO recognized Tropical Cyclone Advisory Centres (TCAC) to provide cyclone advisories to Asia Pacific countries and Middle East countries for civil aviation as per International Civil Aviation Organisation guidelines **(Fig.2.7**).

Tropical Cyclone Advisories for aviation are issued as soon as any disturbance over the NIO attains or is likely to attain the intensity of cyclonic storm (maximum sustained surface wind speed ≥ 34 knots) within next 24 hours. These bulletins are issued within three hours of observation based on 00, 06, 12, 18 UTC observations. 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 being sent in graphics in png format through GTS. The text and graphical bulletins are also uploaded on RSMC website. These bulletins are used to issue Significant Meteorological Information (SIGMET) warnings by the Meteorological Watch Offices

(MWOs) for their respective area of responsibilities. Typical advisory issued during TC MOCHA is presented in **Fig. 2.8**.

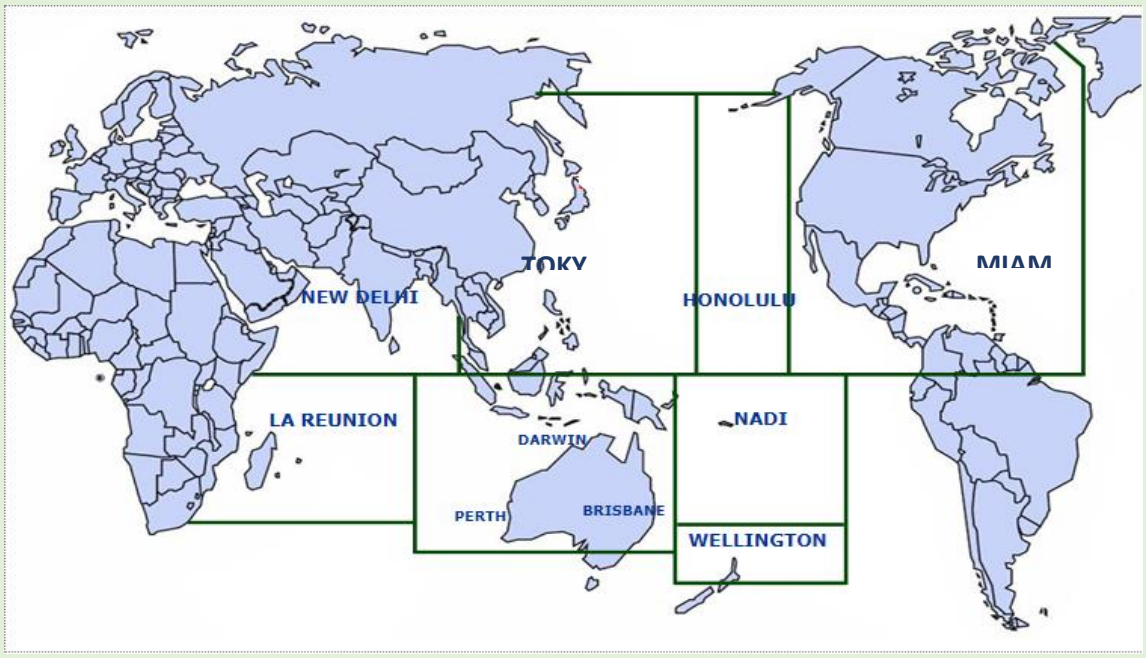

Fig.2.7: Area of responsibility of various Tropical Cyclone Advisory Centres

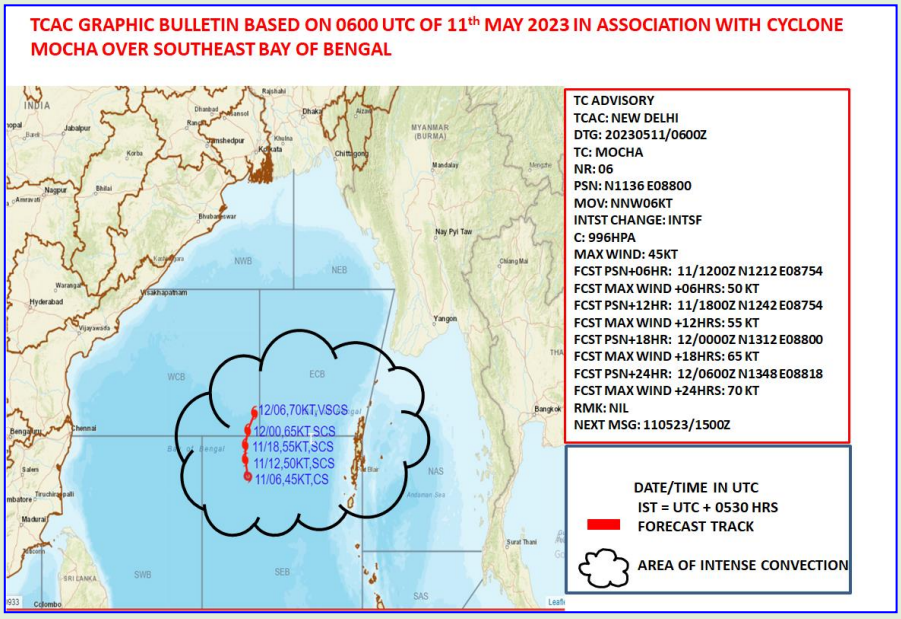

Fig.2.8: Typical TCAC bulletin issued on 11th May/0600 UTC during TC MOCHA.

(h) Advisory to International Shipping Community for Met Area (VIII N) under Global Maritime Distress and Safety System:

As part of it's international obligation, India Meteorological Organisation (IMD) is one among 16 services in the world for issuing Sea Area bulletins for broadcast through GMDSS for MET AREA VIII (N). The METAREA VIII (N) is the area of the Indian Ocean enclosed by lines from the Indo-Pakistan frontier in 23°45'N 68°E to 12°N 63°E, thence to Cape Gardafui; the east African coast south to the equator, thence to 95°E, to 6°N, thence northeastwards to the Myanmar/ Thailand frontier in 10°N 98°30'E. (**Fig. 2.9**).

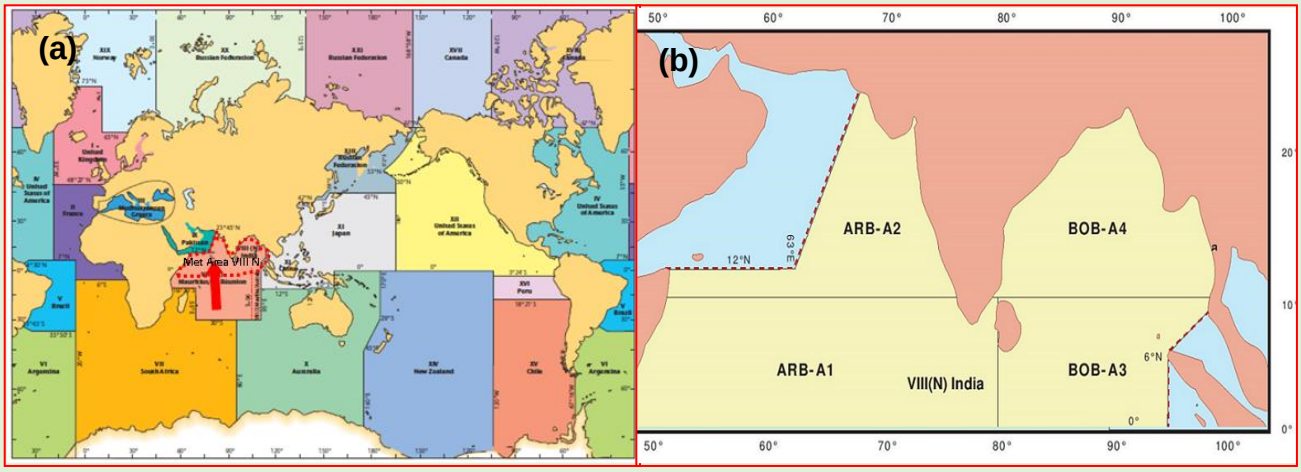

Fig.2.9: (a) Area of responsibility for GMDSS Bulletin and (b) Met Area VIII (N) subdivisions

Under normal weather conditions, these advisories are issued twice daily at 0900 UTC and at 1800 UTC valid for next 24 and 48 hours. During Cyclone period additional bulletins (4) are also issued based on 00, 03, 06, 12 & 18 UTC for GMDSS broadcast depending on the requirement. This bulletin is transmitted to Tele-communication Division (Regional Telecommunication Hub (RTH), New Delhi) for further transmission by e-mail to the Local Earth Station (LES) of VSNL in Ghaziabad. They in turn transmit the message to INMARSAT. This bulletin is also sent to Naval Headquarter and Navy Western Command and uploaded on various websites of IMD.

(i) Guidance to 9 countries under Severe Weather Forecasting Programme (SWFP) for South Asia:

RSMC New Delhi provides guidance on heavy rainfall, strong winds, significant wave height, cyclonic disturbances and storm surge alongwith risk based forecast for these weather parameters for next 5 days once daily based on 0300 UTC observations to 9 countries in the South Asia region including Thailand, Myanmar, Bangladesh, Nepal, Bhutan, India, Sri Lanka, Maldives and Pakistan for 95 sub-divisions based on the multi-model guidance further modulated with current observations and forecaster's experience & expertise.

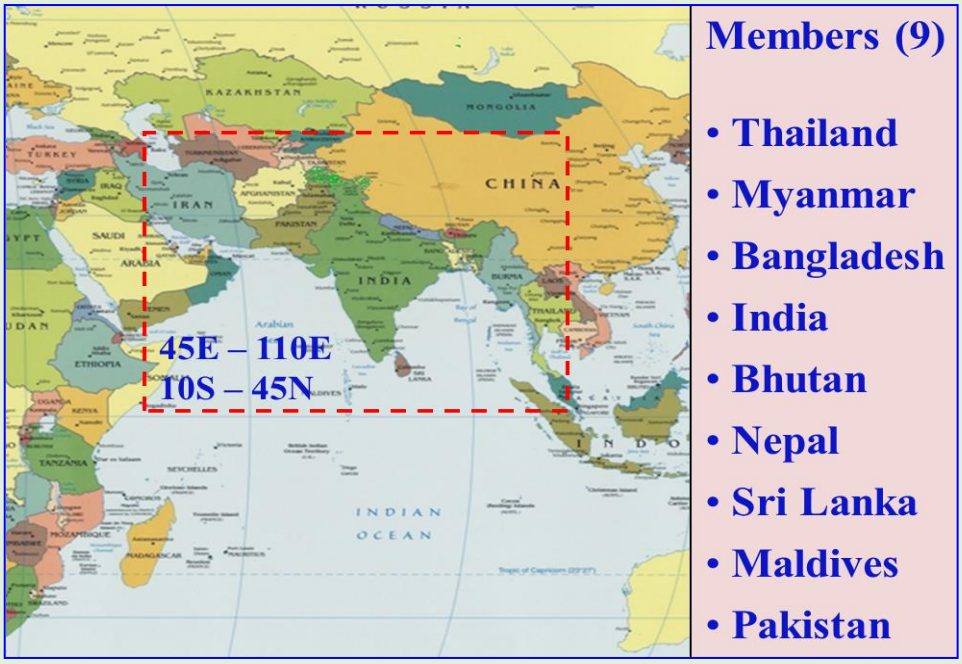

Fig.2.10: Area of responsibility under WMO's Severe Weather Forecasting Programme

Under this programme, RSMC New Delhi maintains a dedicated web page for these countries with guidance from Global Data Processing & Forecasting (GDPF) Centres, satellite based guidance and final guidance prepared by RSMC New Delhi at a single platform to enable the National Meteorological and Hydrological Services (NMHSs) better monitor and predict severe weather events. Capacity development through regular trainings on forecasting and service delivery aspects is also a critical component of this programme. 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.

Chapter 3

Major milestones of RSMC New Delhi

The major milestones of RSMC, New Delhi are listed below:

1908: Meteorological Alas of the Indian Seas and North Indian Ocean

1925: Normand CWB published Storm Tracks in Bay of Bengal Revised storm

1964: Normand CWB revised Storm Atlas for period 1871-1890 and 1891-1960

1973: Establishment of WMO/ESCAP Panel on Tropical Cyclones (PTC).

1973: Establishment of Regional Meteorological Centre, New Delhi to provide guidance/advisories to PTC member countries.

1988: Establishment of Regional Specialized Meteorological Centre (RSMC) Tropical Cyclones, New Delhi with the responsibility of issuing Tropical Weather Outlooks and Tropical Cyclone Advisories for the benefit of the countries in the WMO/ESCAP Panel region bordering the Bay of Bengal and the Arabian Sea, namely, Bangladesh, Maldives, Myanmar, Oman, Pakistan, Sri Lanka and Thailand.

1990: Establishment of Cyclone Warning Division (CWD) in the office of Director General of Meteorology, IMD at New Delhi. CWD acts as RSMC-TC, New Delhi.

1991: First Annual RSMC Report on cyclonic disturbances over north Indian Ocean was published for the year, s1990.

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

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

1999: Introduction of super cyclonic storm category (MSW ≥120 kts) and change of nomenclature from severe cyclonic storm with core of hurricane wind to very severe cyclonic storm (64-119 kts).

2003: IMD to act as Tropical Cyclone Advisory Centre (TCAC), New Delhi as per requirement of International Civil Aviation Organisation (ICAO)

Preparation of Annual Cyclone Review

2004: Introduction of Naming of cyclones over north Indian Ocean. The first name ONIL proposed by Bangladesh was introduced in Sep 2004.

2005: Introduction of annual bi-weekly training for cyclone forecasters from WMO/ESCAP member Countries

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

2008: Issue of 72 hr track & intensity forecast with forecast of Cone of Uncertainty from cyclone ‘WARD’ which crossed Srilanka in Dec, 2008.

Verification of Operational forecast

Inclusion of Prognosis & Diagnosis in RSMC Bulletin from cyclone ‘NARGIS’ which crossed Myanmar.

Introduction of Media Briefing on cyclone updates and Press Release from cyclone ‘NARGIS’ which crossed Myanmar.

Preparation of preliminary report for each cyclone commencing from cyclone ‘NARGIS’.

2009: Operationalisation of IIT- Delhi Storm Surge Model & issue of storm surge guidance for WMO/ESCAP member countries from cyclone 'BIJLI' which crossed Bangladesh.

2010: Forecast of Quadrant Wind Radii from cyclone 'GIRI' which crossed Myanmar in Nov 2010.

Introduction of Quadrant Wind text Bulletin.

2011: Introduction of Ensemble Prediction System Model for Track Prediction.

2012: Verification of Track, Intensity & Landfall forecast errors from 2003 onwards

Introduction of HWRF Model for north Indian Ocean region from cyclone 'MURJAN' which crossed Somalia in Oct 2012.

2013: Extension of forecast upto a lead period of 120 hours from cyclone 'VIYARU' which crossed Bangladesh in May 2013.

Introduction of experimental coastal inundation forecast from cyclone 'PHAILIN' which crossed Odisha coast (India) in Oct 2013.

Introduction of coded TC Vital from cyclone 'VIYARU' and

Introduction of Aviation Disaster Risk Reduction (ADRR) text bulletin for international civil aviation.

2014: Launching of dedicated website for RSMC, New Delhi (www.rsmcnewdelhi.imd.gov.in) in Dec 2014

Hourly updates around the time of landfall from cyclone 'HUDHUD which crossed Andhra Pradesh coast in Oct 2014

Digitisation of Annual RSMC Report on Cyclonic Disturbances from 1990 onwards

Head RSMC acted as Rapporteur for preparation of Annual Tropical Cyclone Operational Plan (TCP-21) since 1988

2012: Digitisation of six hourly best track data since 1982

2016: RSMC provided 5 days regional forecast of severe weather including heavy rainfall, strong winds, high waves and storm surge under Severe Weather Forecasting Programme for Bangladesh, India, Maldives, Myanmar, Sri Lanka, Thailand, Bhutan, Nepal, Afghanistan and Pakistan

Yemen joined PTC in 2016

2018: Saudi Arabia, United Arab Emirates, Iran and Qatar joined PTC

2018: Introduction of Extended Range forecast of cyclogenesis every Thursday valid for next 2 weeks.

Probabilistic forecast of genesis extended from 72 to 120 hrs in daily Tropical Weather Outlook

Track forecast from Depression stage instead of Deep Depression stage.

Special bulletin in case of formation of low pressure area over NIO which has the potential to become a cyclone.

2019: Prince Charles visited IMD and appreciated tropical cyclone advisories issued by IMD to PTC member countries.

2020: Introduction of cyclone track on interactive GIS platform

Introduction of new list of names for cyclonic storms from June, 2020 with “Nisarga” proposed by Bangladesh.

2021: Introduction of damage expected & action suggested in extended range Outlook

2022: Pre genesis forecast of track & intensity was introduced with formation of well marked Low Pressure Area.

Introduction of distance of landmarks from forecast track in nearest time of arrival

Development of fisherman warning graphics based on multi model guidance for NIO. Introduction of probability of exceedance of 25 knots and 35 knots

Probabilistic graphical guidance for Maximum Sustained Wind Speed exceeding 25 & 35 knots introduced in August, 2022 for squall & gale wind warning for ships & fishermen

2022: Introduction of new MME for track, intensity, landfall and rainfall forecast

Production of graphical and interactive website based products for marine weather services including cyclone warning services

2022: Introduction of new Decision Support System for cyclone & marine weather forecasting

2023: Extension of lead period of cyclogenesis in Tropical Weather Outlook in July to 7 days

Introduction of Marine & Oceanographic guidance jointly by IMD and INCOIS for Marine Emergency Response (MER) & Search and Rescue (SAR) in November, 2023

Introduction of verification of Genesis forecast in medium range forecast (next 5 days) and extended range forecast (next 2 weeks) for years 2019-2023 and 2018-2023 respectively from December, 2023

IMD elected to host PTC secretariat for period 2024-27 in December, 2023

2024: Introduction of experimental probabilistic storm surge forecast in May 2024

Chapter 4

Climatology of Cyclones over NIO

Climatology nearly 7 % of the global TCs form in the NIO region. About 5 to 6 TCs occur in the NIO annually. However, they prominently occur during the pre-monsoon season (March-June) and the post-monsoon season (October-December). The Bay of Bengal TCs more often strike Odisha-West Bengal coast in October, Andhra coast in November and the Tamilnadu coast in December. Over 61 percent of the TCs in the Bay of Bengal strike different parts of the east coast of India, 23 percent strike coasts of Bangladesh and Myanmar and about 16 percent dissipate over the Sea itself. The cyclones crossing different coastal states are shown in Fig.1.26. Considering Arabian Sea, a significant number of cyclones dissipate over the sea itself before making any landfall (about 46%). Gujarat coast is the most prone for the cyclones developing over the Arabian Sea, with about 34% of total cyclones developing over Arabian Sea cross Gujarat coast followed by 17% crossing Oman and 3% crossing Pakistan coasts. The tracks of cyclones over the NIO during 1965-2023 are shown Fig 4.1.

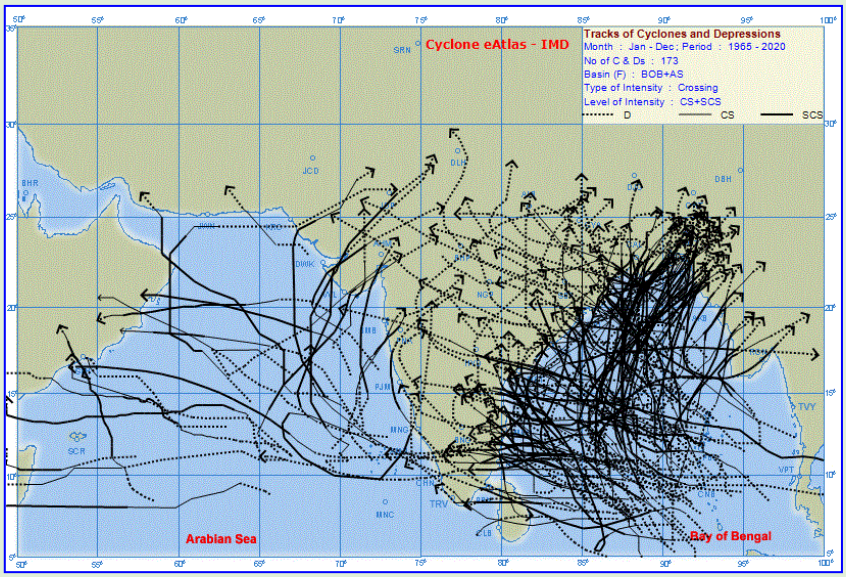

Fig. 4.1.: Tracks of cyclones (maximum sustained wind speed ≥34 kt) crossing the east & west coasts in the NIO region during 1965-2020 year as a whole

The individual frequency of TCs crossing various coastal states and countries in the BoB and AS region during 1965-2019 is shown in Fig. 4.2. The most intense TCs (ESCS & above) cross the coast maximum over Orissa (ODS) followed by Andhra Pradesh (AP)/Myanmar (MMR) & Bangladesh (BDS) and low intensity TCs (CS/SCS) cross maximum over BDS followed by AP, ODS & Tamilnadu & Puducherry (TNP) and medium intensity TCs (VSCS) cross maximum over TN/AP/BDS followed by ODS/West Bengal (WB)/ Myanmar (MMR) during year as a whole. While maximum CS/SCS cross BDS, maximum VSCS cross BDS/MMR and maximum ESCS cross MMR coast during pre-monsoon season. While maximum CS/SCS/VSCS cross AP coast, maximum ESCS

cross ODS coast during post-monsoon season. Over the AS, the landfall frequency of CS & above and SCS & above and VSCS & above are maximum over Iran, Arabia & Africa (IAA) followed by Saurashtra & Kutch during both the seasons and year as a whole.

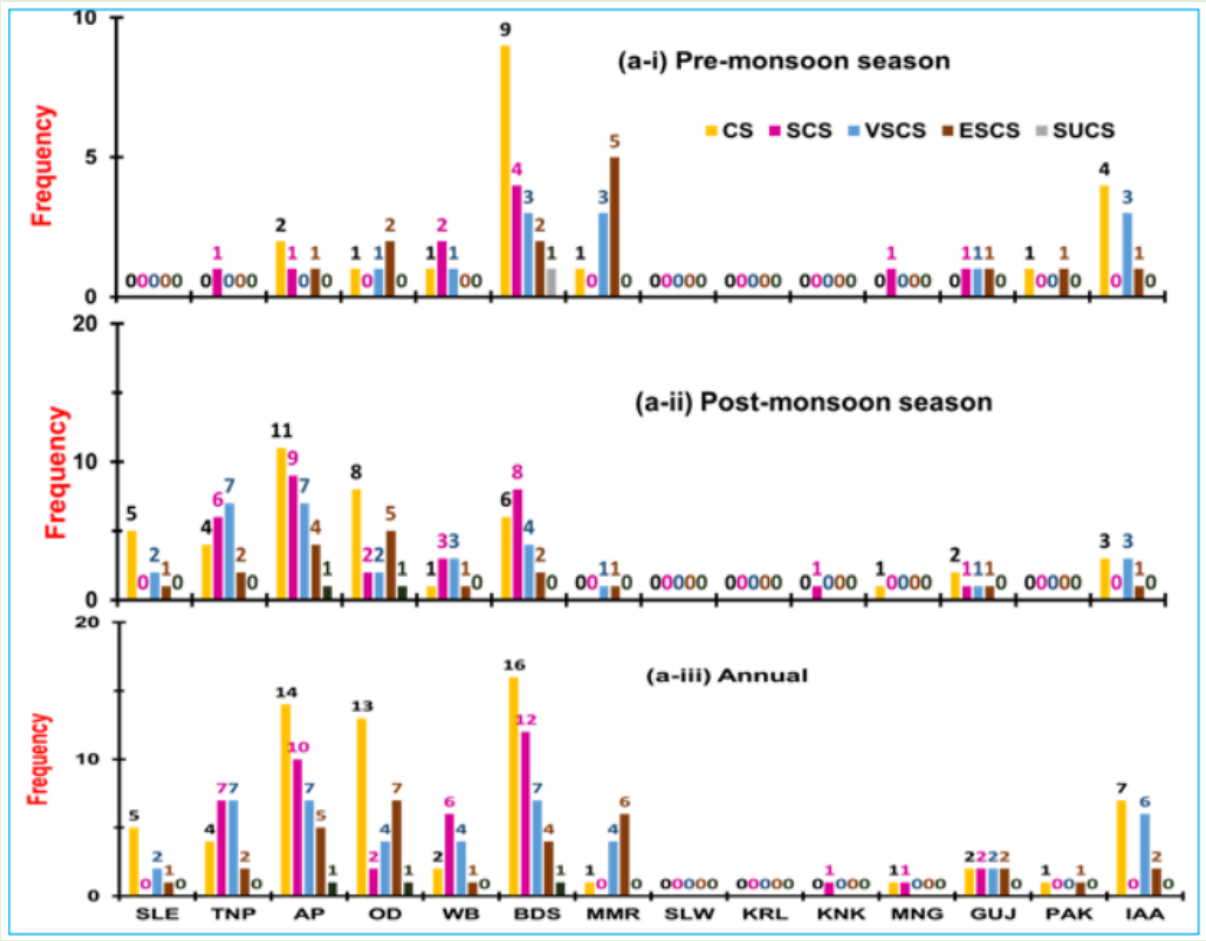

Fig.4.2: Individual frequency of various categories of landfalling TCs during (a-i) pre-monsoon, (a-ii) post-monsoon and (a-iii) year as a whole over the period 1965-2020 (Mohapatra et al., 2021)

(TC: Tropical cyclone, CS: Cyclonic storm, SCS: Severe cyclonic storm, VSCS: Very severe cyclonic storm, ESCS: Extremely severe cyclonic storm and SuCS: Super Cyclonic Storm, SLE: Sri Lanka East, TNP: Tamilnadu and Puducherry, AP: Andhra Pradesh, OD: Odisha, WB: West Bengal, BDS: Bangladesh, MMR: Myanmar, SLW: Sri Lanka West, KRL: Kerala, KNK: Karnataka, MNG: Maharashtra and Goa, GUJ: Gujarat, PAK: Pakistan, IAA: Iran, Arabia and Africa)

Chapter 5

Standard Operation Procedure

IMD follows a well-defined Standard Operation Procedure (SOP) for monitoring and prediction of various cyclonic disturbances over the NIO region.

All available observations (which are space based, upper air based and surface based) are analysed to assess the initial conditions of the atmosphere. Beginning with a wide perspective of satellite imagery, and synoptic study of surface conditions, taking pressure and wind at various levels into consideration, weather systems, such as circulations, low-pressure areas, convergence and divergence zones, troughs, ridges, and anti-cyclones are identified. The forecast is based on multi-model guidance. Monitoring and forecasting process is presented in **Fig.5.1**.

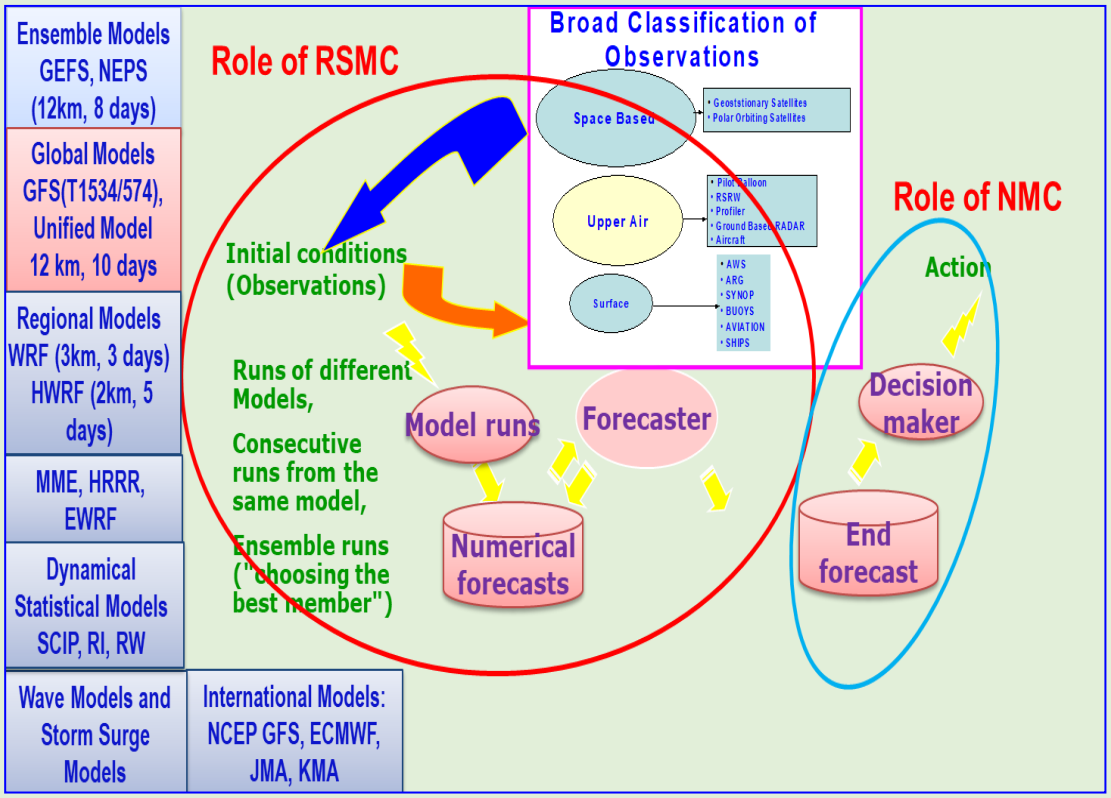

Fig. 5.1: Monitoring and forecasting process at RSMC New Delhi

(GFS: Global Forecast System, NCUM: NCMRWF Unified Model, CNCUM, Coupled NCMRWF Unified model, JMA: Japan Meteorological Agency, MME: Multi Model Ensemble, NCEP: National Centre for Enviroment Prediction, KMA: Korea Meteorological Agency, ECMWF: European Centre for Medium Range Weather Forecast, WRF: Weather Research & Forecast Model, HWRF: Hurricane WRF, EWRF: Electronic WRF, HRRR: High Resolution Rapid Refresh, SCIP: Statistical Cyclone Intensity Prediction model, RI: Rapid Intensification, RW: Rapid weakening.

Monitoring process:

The vital parameters of TC are determined based on (a) synoptic, (b) satellite and (c) Radar observations. Overall, the consensus based observations from different sources are smoothened, optimized and final parameters are fixed after consistency check. The steps involved in determination of centre, intensity, structure and shape & size of CDs are presented in Fig. 5.2-5.5)

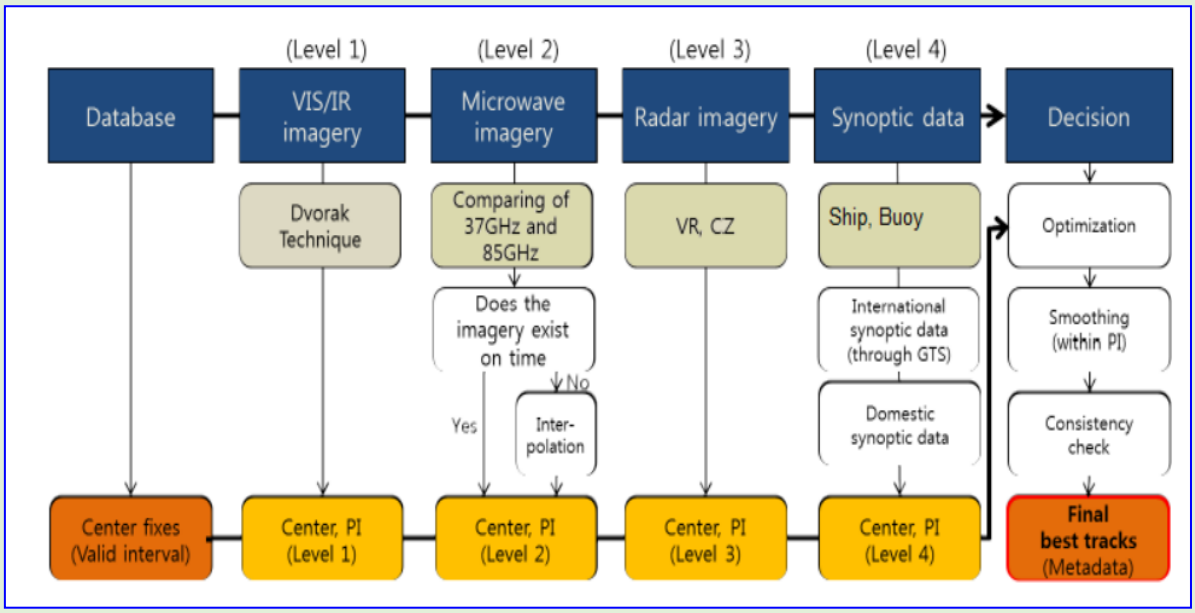

Fig. 5.2: Steps involved in determination of location

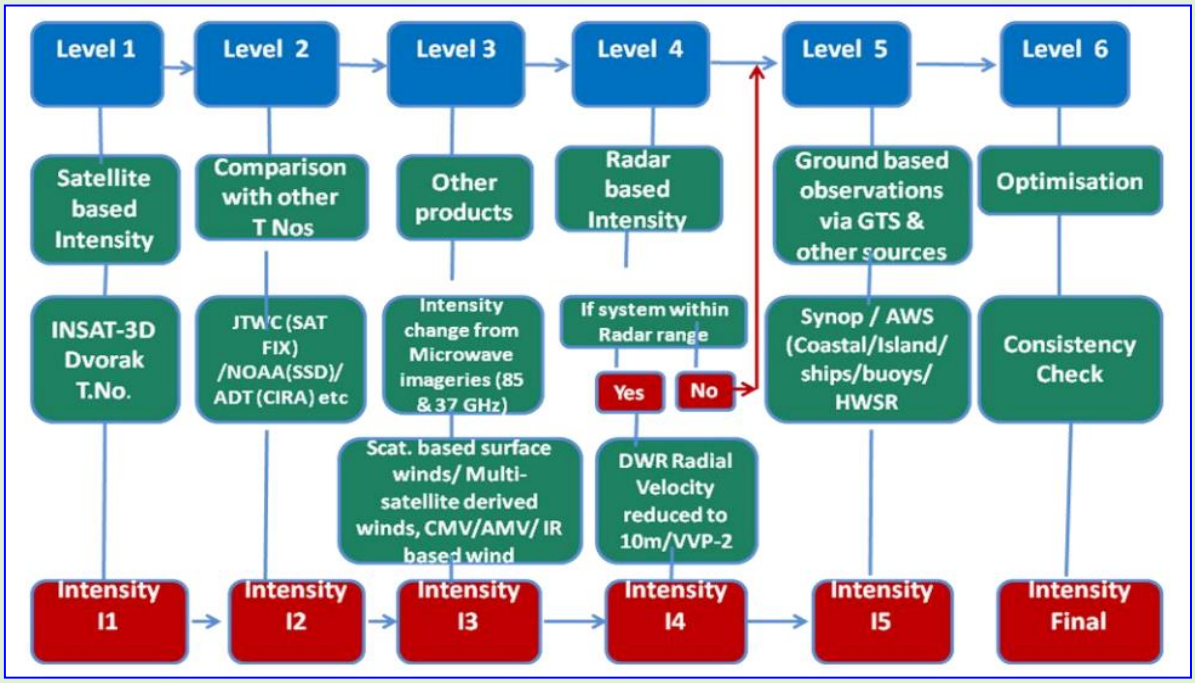

Fig. 5.3: Steps involved in determination of intensity

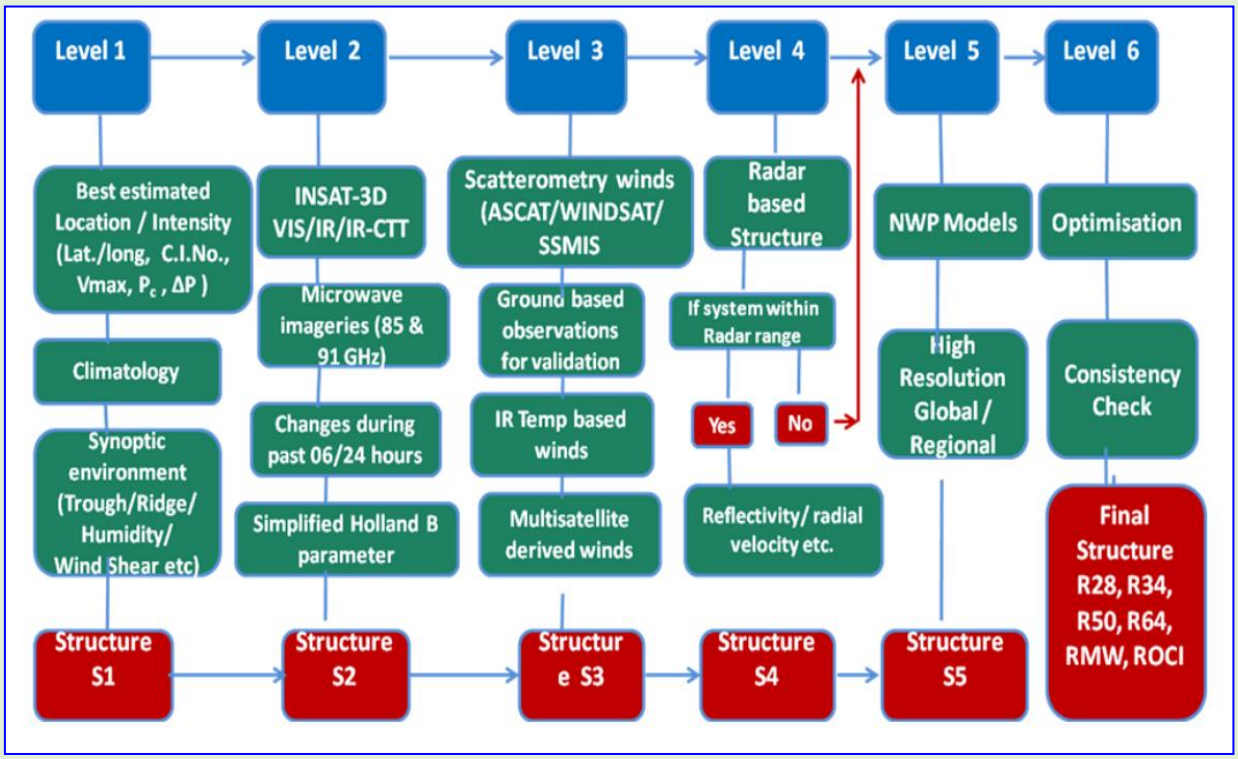

Fig. 5.4: Steps involved in determination of structure

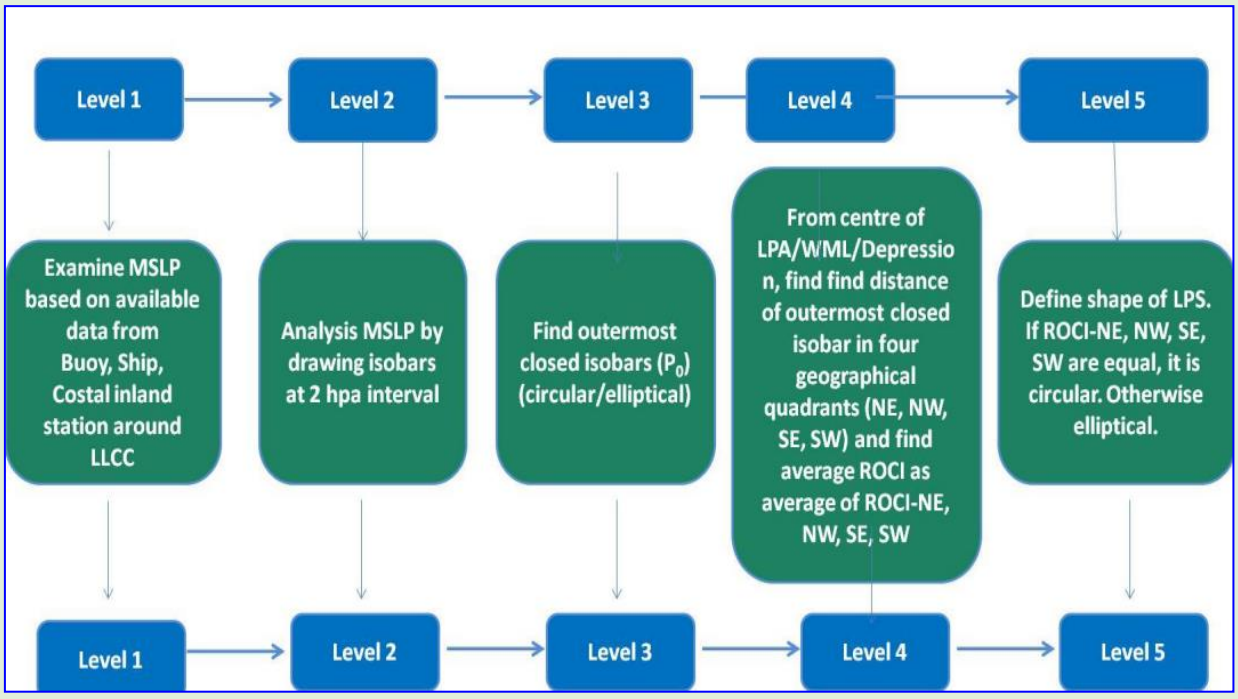

Fig. 5.5: Steps involved in determination of shape and size

(Source: Cyclone warning in India: Standard Operation Procedure published by IMD in 2024 available at www.rsmcnewdelhi.imd.gov.in**)**

Forecasting process:

RSMC New Delhi forecasts the track, intensity, landfall point & time, structure and associated adverse weather including heavy rain, strong winds, wave height and storm surge in association with cyclonic disturbances over the NIO region. The forecast of these parameters is based on multi model ensemble guidance arrived at after removing the outliers as decided by the forecaster. Weightage is given to the model that is performing best during the season, model that is picking up initial conditions the best on that day and the model that is historically the best as compared to the rest. This forecast is further modulated based on ensemble models forecast. Thereafter, based on current conditions, the consensus forecast is initialised. This is followed by a discussion among the forecasters to further modulate the forecast as per the experience, expertise and knowledge of the forecasters. Finally, guidance products are generated in textual, graphical and GIS platform in an actionable format. The steps involved in forecasting genesis, track and intensity of cyclonic disturbances over the North Indian Ocean are presented in Fig.5.6-5.9.

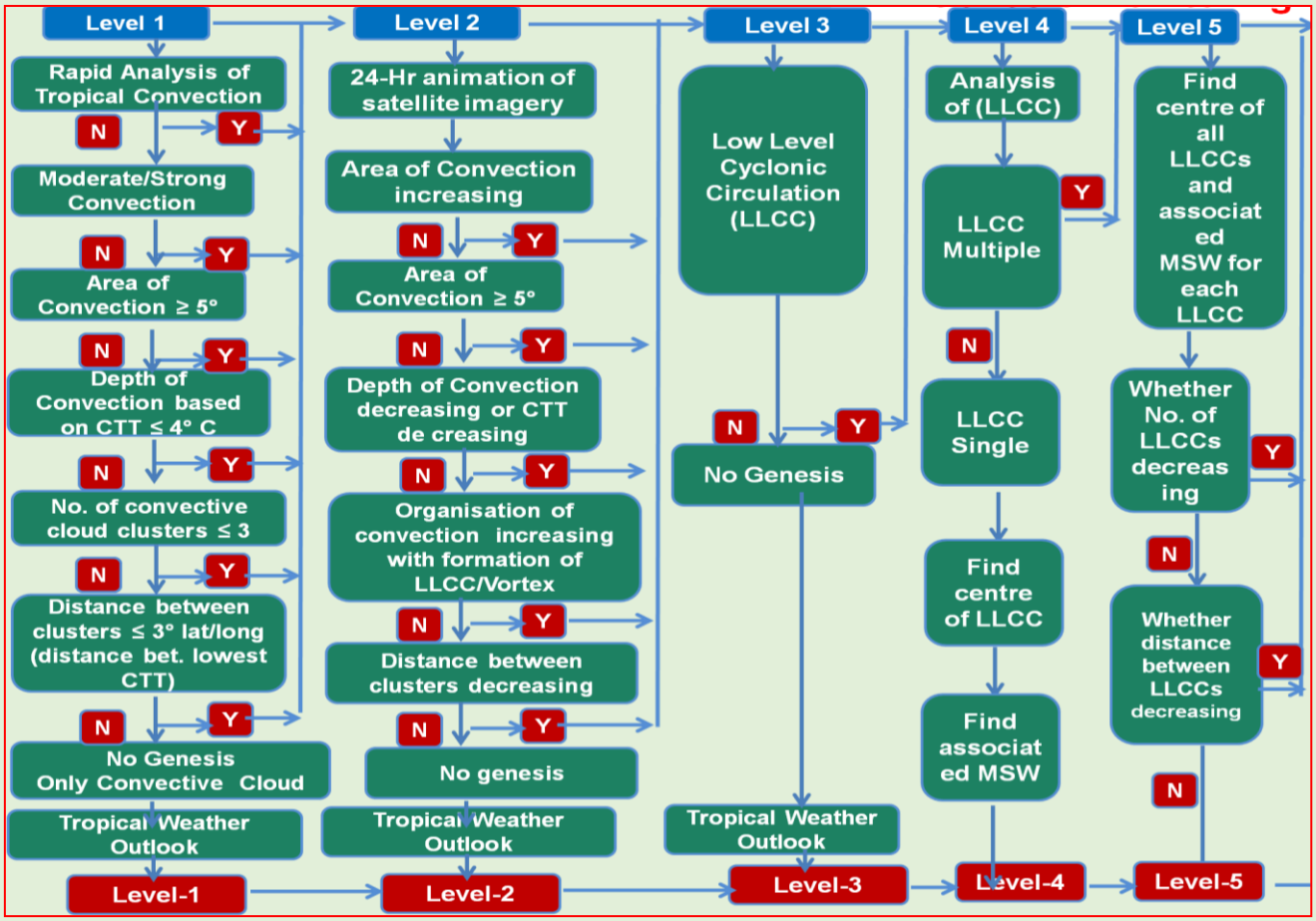

Fig. 5.6: Steps involved in forecasting genesis of cyclonic disturbance over NIO

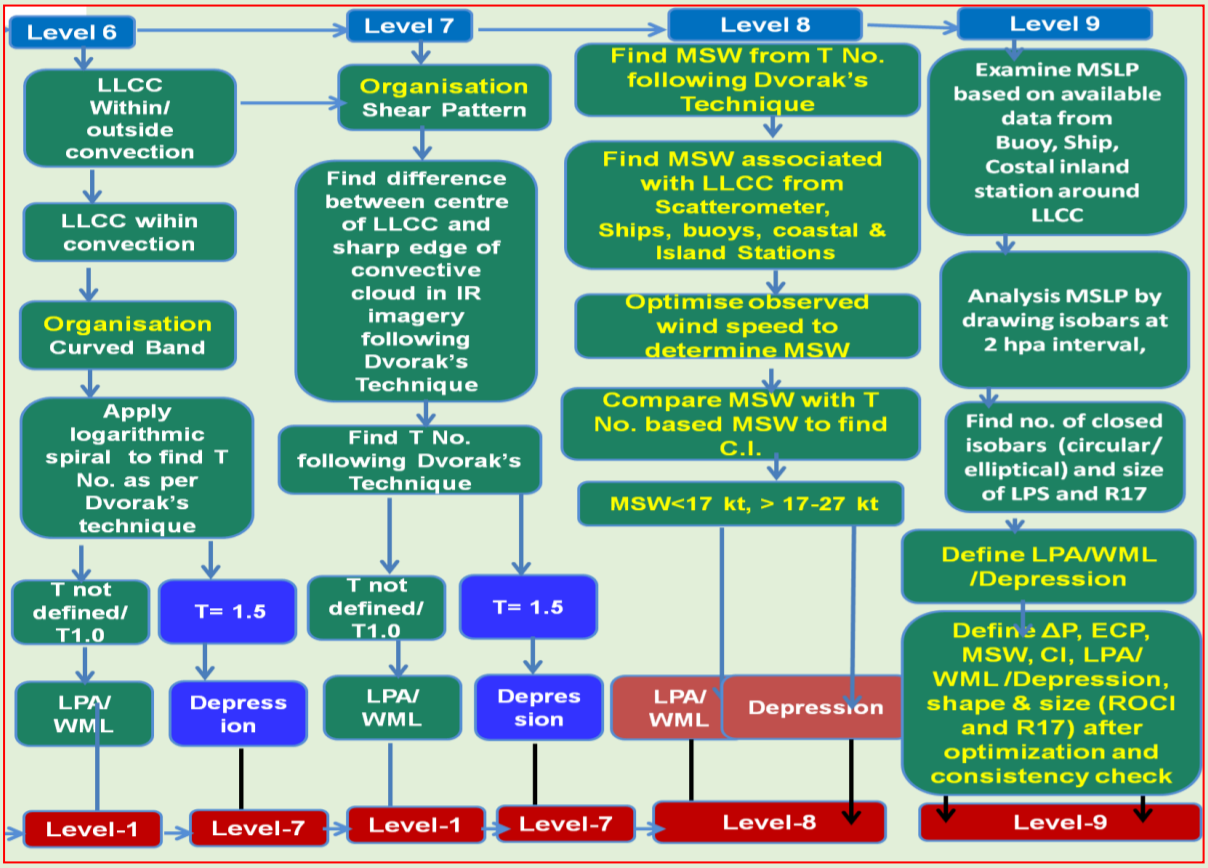

Fig. 5.6 (contd): Steps involved in forecasting genesis of cyclonic disturbance over NIO

Reference: KK Hon, Robert Ballard, Eric Blake, Steph Bond, Robb Gile, Daniel Halperin, Charles Helms, Hoang Lam, Xinyan Lyu, Mrutyunjay Mohapatra, Monica Sharma, Akira Shimokobe, Ralf Toumi, Seonghee Won, 2023, Recent Advances in Operational Tropical Cyclone Genesis Forecast, TCRR, DOI: 10.1016/j.tcrr.2023.12.001

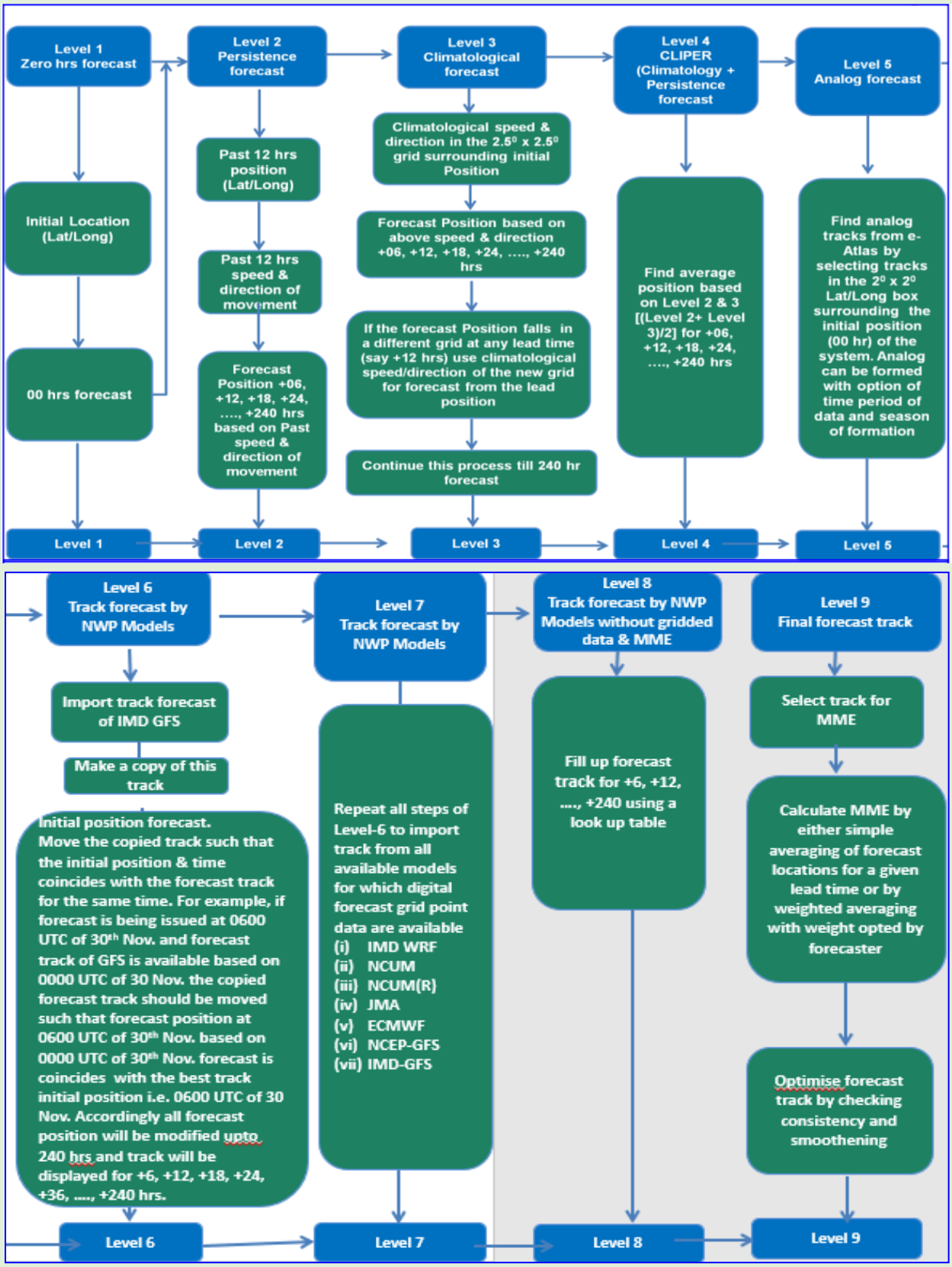

Fig. 5.7: Steps involved in forecasting track of cyclonic disturbances over NIO

Reference: Standard Operation Procedure: Cyclone warning in India published by IMD

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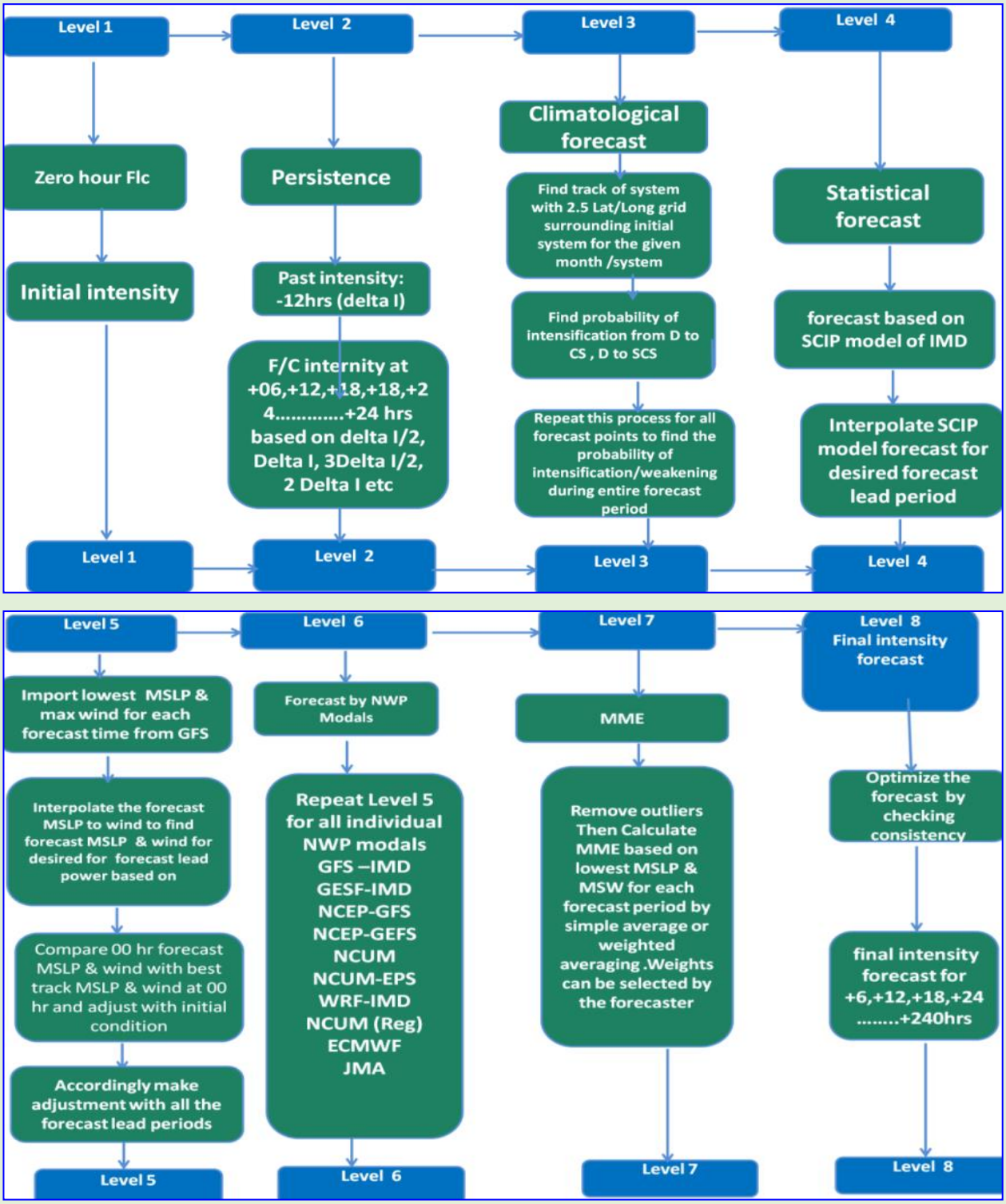

Fig. 5.8: Steps involved in forecasting intensity of cyclonic disturbances over NIO

Ref: Standard Operation Procedure: Cyclone warning in India published by IMD

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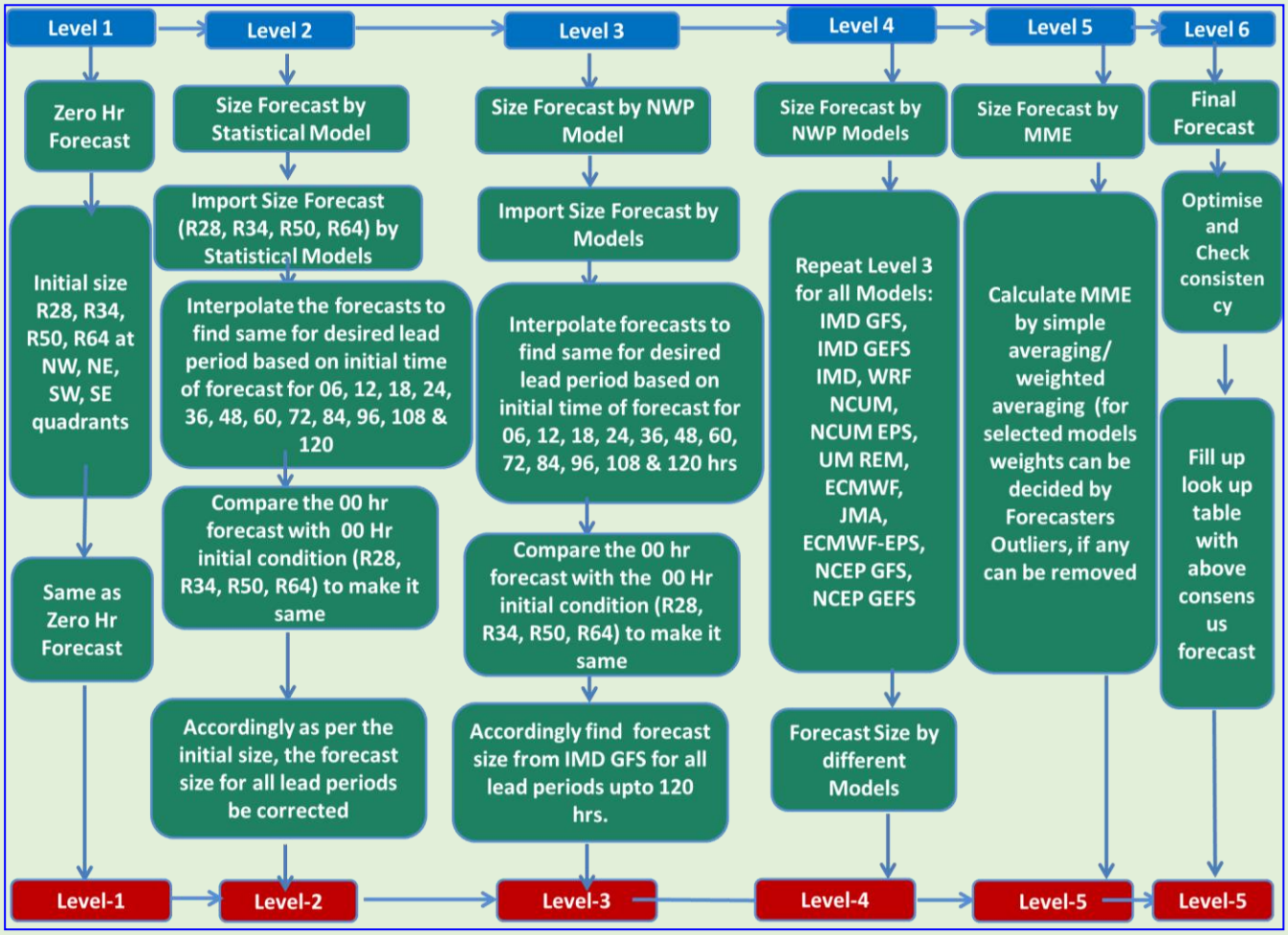

Fig. 5.9: Steps involved in forecasting structure of cyclonic disturbances over NIO

Ref: Standard Operation Procedure: Cyclone warning in India published by IMD

Available at:

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Chapter 6

Terms, terminologies and guidance criteria

Common terms and terminologies used by RSMC New Delhi to various features associated with cyclonic disturbances over the NIO are discussed in this section.

Table 6.1: Categories of cyclonic disturbances over the North Indian Ocean

Type of disturbance	Associated maximum sustained wind
1. Low pressure Area	Not exceeding 17 knots (< 31 kmph)
2. Depression	17 to 27 knots (31 – 49 kmph)
3. Deep depression	28 to 33 knots (50 – 61 kmph)
4. Cyclonic Storm	34 to 47 knots (62 – 88 kmph)
5. Severe Cyclonic Storm	48 to 63 knots (89 – 117 kmph)
6. Very Severe Cyclonic Storm	64 to 90 knots (118 – 167 kmph)
7. Extremely Severe Cyclonic Storm	91 to 119 knots (168 – 221 kmph)
8. Super Cyclonic Storm	120 knots and above (≥ 222 kmph)

Table 6.2: Criteria to describe sea condition:

Condition of Sea	Wave height (m)
1. Calm	0-0.1
2. Smooth	0.1-0.5
3. Slight	0.5-1.25
4. Moderate	1.25 – 2.5
5. Rough	2.5 – 4
6. Very Rough	4.0 – 6.0
7. High	6.0 – 9.0
8. Very High	9.0 – 14.0
9. Phenomenal	Over 14.0

Table 6.3: Reference Time used in RSMC bulletins

• EARLY HOURS	0000 - 0400 hrs IST	1830-2230 UTC
• MORNING	0400 - 0800 hrs IST	2230-0230 UTC
• FORENOON	0800 - 1200 hrs IST	0230-0630 UTC
• AFTERNOON	1200 - 1600 hrs IST	0630-1030 UTC
• EVENING	1600 - 2000 hrs IST	1030-1430 UTC
• NIGHT	2000 - 2400 hrs IST	1430-1830 UTC
• EARLY MORNING	0400 - 0600 hrs IST	2230-0030 UTC
• NOON	1100 - 1300 hrs IST	0530- 0730UTC
• MIDNIGHT	2300 - 0100 HRS IST	1730-1930UTC

Table 6.4: Dvorak's classification of cyclonic disturbances and associated maximum sustained wind speed (MSW) and pressure drop at centre

C.I.Number	*Max.Wind Speed(MSW)(knots)*	*Pressure drop(hPa)*
1.0	25	3.1
1.5	25	3.1
2 0	30	4.5
2.5	35	6.1
3.0	45	10.0
3.5	55	15.0
4.0	65	20.9
4.5	77	29.4
5.0	90	40.2
5.5	102	51.6
6.0	115	65.6
6.5	127	80.0
7.0	140	97.2
7.5	155	119.1
8.0	170	143.3

Table 6.5: Radius of circle to construct cone of uncertainty

F/C Period	Radius of the circle to construct cone of uncertainty (km/nm) w.e.f.			
	2009	2013	2014	2019
00 hr	20/10	20/10	20/10	20/10
06 hr	40/20	40/20	40/20	40/20
12 hr	75/40	75/40	55/40	55/30
18 hr	110/60	110/60	80/45	75/40
24 hr	150/80	150/80	110/60	85/45
36 hr	200/110	200/110	150/80	105/55
48 hr	250/135	250/135	185/100	130/70
60 hr	300/160	300/160	220/120	160/85
72 hr	350/190	350/190	250/135	175/95
96 hr	-	415/225	305/165	240/130
120 hr	-	490/265	360/195	295/160

RSMC New Delhi commenced Cone of Uncertainty in 2009 wef. cyclone WARD for lead period extending upto 72 hours based on track forecast errors during 2004-08.

In 2013, lead period of forecast was extended to 120 hours from cyclone Viyaru.

In 2014, since cyclone HUDHUD, COU values were reduced based on average track forecast errors during 2009-13.

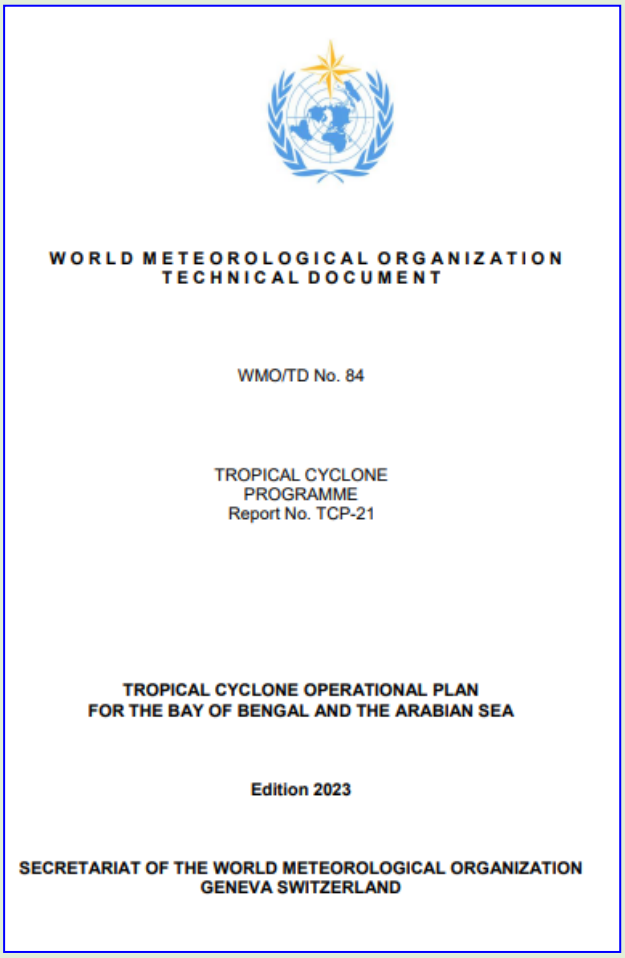
In 2019, COU was further reduced based on average track forecast errors during 2014-18 from cyclone FANI

Chapter 7

Operational Planning and Review Activities

(i) Development of Tropical Cyclone Operation Plan (TCP-21)

Every year RSMC New Delhi updates the Tropical Cyclone Operation Plan (TCP-21). The basic purpose of the TCP-21 is to facilitate the most effective tropical cyclone warning system for the region with existing facilities. TCP-21 defines the sharing of responsibilities among Panel countries for the various segments of the system and records the coordination and cooperation achieved. The plan records the agreed arrangements for standardization of operational procedures, efficient exchange of various data related to tropical cyclone warnings, issue of cyclone advisories from a central location having the required facilities for this purpose, archival of data and issue of a tropical weather outlook for the benefit of the region.



WORLD METEOROLOGICAL ORGANIZATION
TECHNICAL DOCUMENT

WMO/TD No. 84

TROPICAL CYCLONE
PROGRAMME
Report No. TCP-21

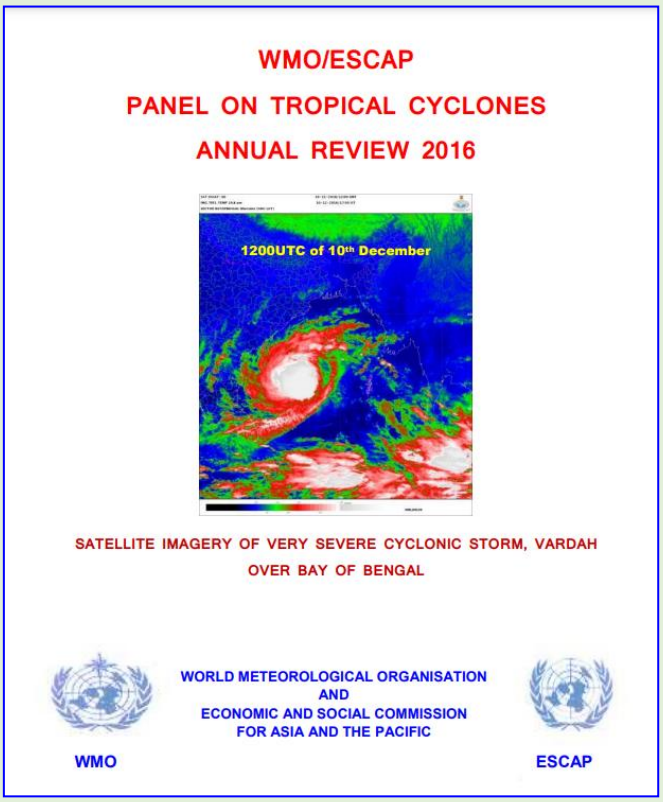
TROPICAL CYCLONE OPERATIONAL PLAN
FOR THE BAY OF BENGAL AND THE ARABIAN SEA

Edition 2023

SECRETARIAT OF THE WORLD METEOROLOGICAL ORGANIZATION
GENEVA SWITZERLAND

The operational plan contains an explicit formulation of the procedures adopted in the BoB and the AS region for the preparation, distribution and exchange of information and warnings pertaining to tropical cyclones with the member countries. It also contains updated information about the focal points. It is of great advantage to have an explicit statement of the regional procedures to be followed in the event of a cyclone, and this document is designed to serve as a valuable source of information always available as reference to the forecasters and other users, particularly under operational conditions. The operational plan is evolutionary in nature. It is updated regularly. It is updated by RSMC New Delhi with support from all the member countries and is published by WMO after approval by PTC. All versions of TCP-21 since 2010 are available on RSMC website (www.rsmcnewdelhi.imd.gov.in).

(ii) Annual Cyclone Review Report



RSMC New Delhi conducts annual cyclone review with the Member countries and brings out the Publication of "WMO/ESCAP Panel on Tropical Cyclones–Annual Review every year commencing from 1997 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 Annual Review contains contribution from the Panel member countries on national programmes and activities related to meteorology, hydrology, Disaster Risk Reduction (DRR), training and research. It includes brief report on tropical cyclones affecting Panel countries during the year. It also contains information about the realized weather and the damages caused due to cyclones. It publishes information about research articles/papers on tropical cyclones published by Member countries and scientists from various organizations and outlines of activities of PTC Secretariat during the inter-sessional period. It includes annual operational plan and five year coordinated plan for the region with respect to meteorology, hydrology, DRR research and training activities.

Chapter 8

Research & Development and Publications

IMD facilitates the research on cyclone and associated severe weather through the following.

(a) Dedicated website for RSMC, New Delhi

(b) Preparation of best track parameters

(c) Archival and retrieval of observational and forecast data on cyclone including satellite and Radar imageries

(d) Archival and retrieval of best track data through RSMC, New Delhi website

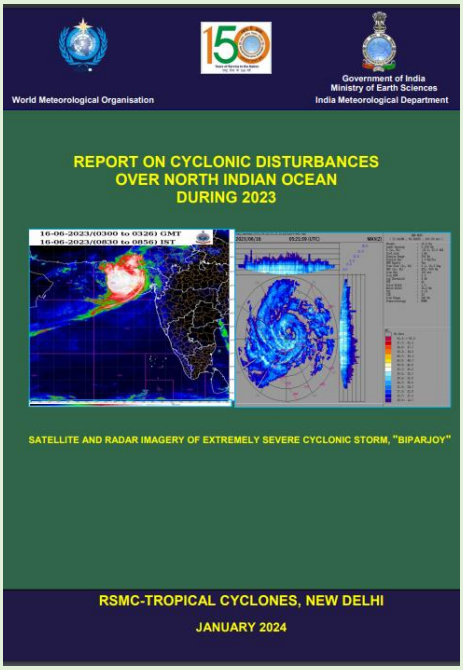
(e) Archival and retrieval of severe weather and loss data due to cyclone

(f) Preliminary report on each and every cyclonic distuirbance within seven days of dissipation of the disturbance

(g) Annual report on cyclones

(h) Conduct of Tropical Cyclone Forecasting Programme since 2008 and publication of annual report

(a) Preparation of Preliminary Reports and Annual Report on Cyclonic Disturbances over NIO region

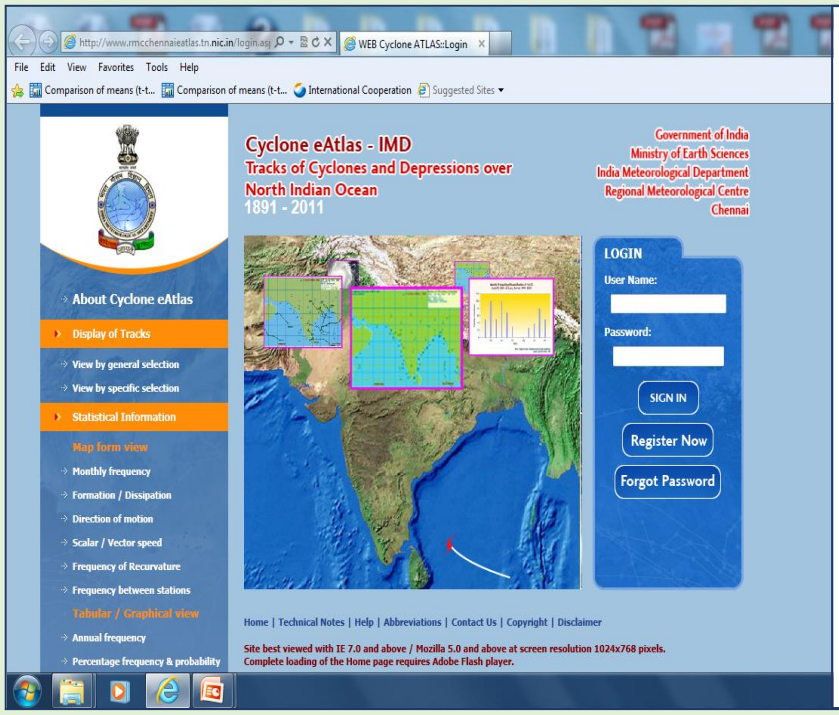


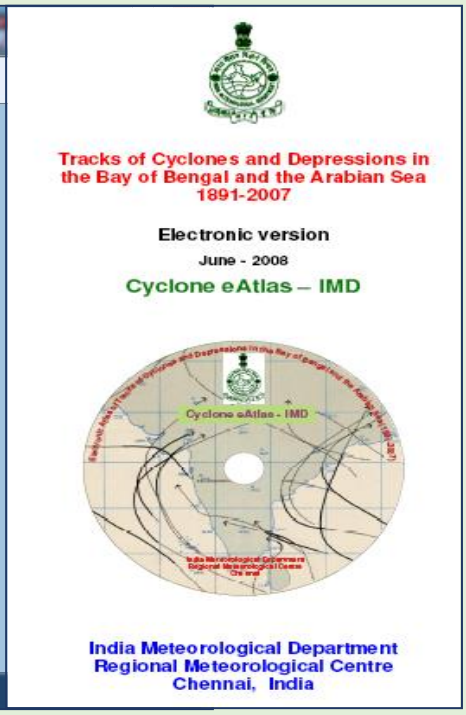
RSMC New Delhi prepares a preliminary report within one week of dissipation of the system and annual report on cyclonic disturbances over the NIO region at the end of year. All the reports since 1990 are available on RSMC website. These reports contain information about the activities of RSMC New Delhi, the life history, salient features, satellite & radar features in association with cyclonic disturbances over the NIO. It also discusses the numerical weather prediction model guidance and verification results of model forecast & operational forecast. It also includes various new initiatives and lessons learned.

(b) Archival of tracks of cyclonic disturbances since 1891

IMD maintains the archival of tracks of cyclonic disturbances since 1891.

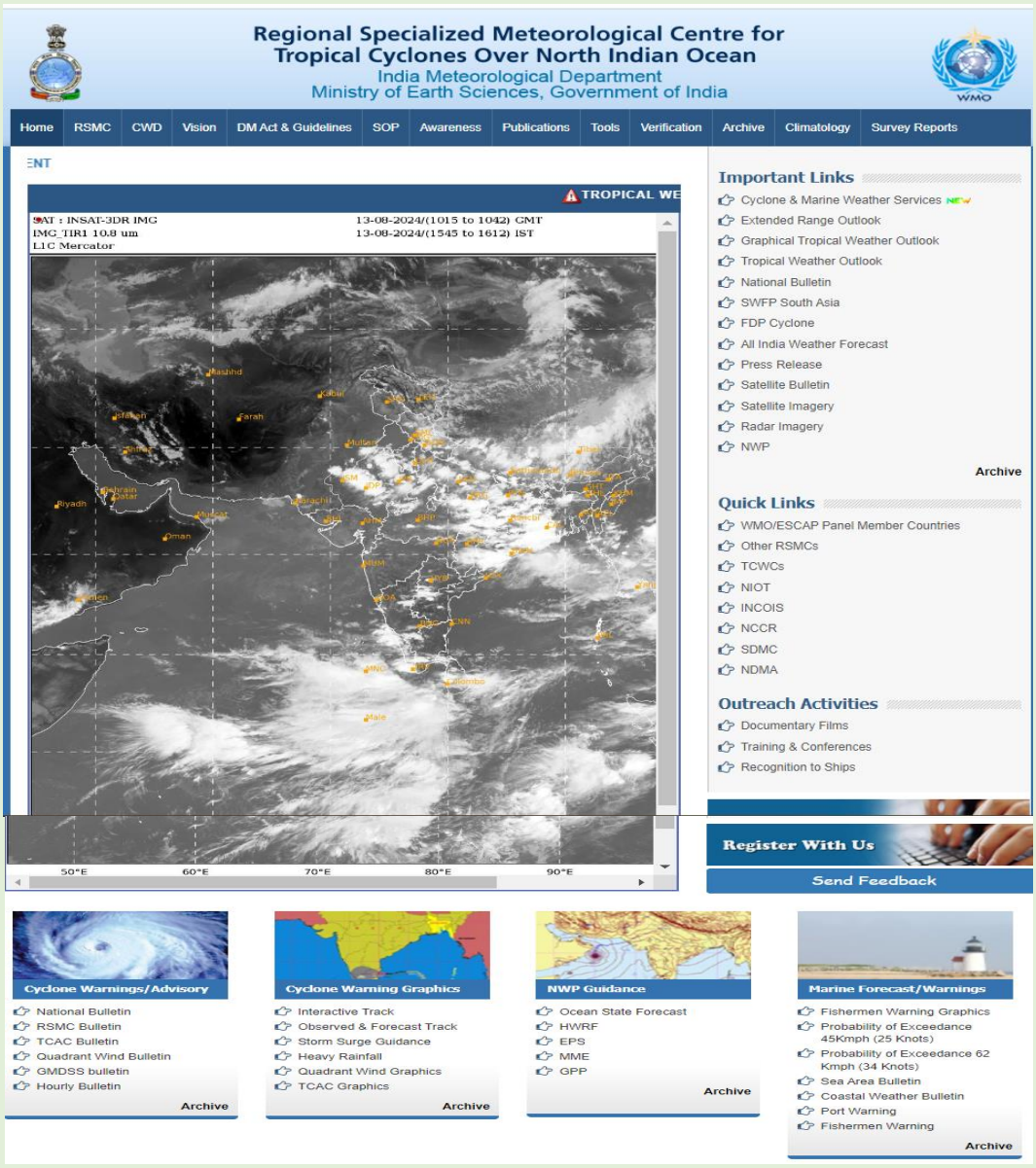
- Six hourly best track data of cyclones over north Indian Ocean since 1982 in digital form
- 12 hourly data in cyclone Atlas during 1891-2022
- Data from 1877-1890 is also available in hard copies in 1979 edition of cyclone Atlas
- Cyclone E-Atlas is available at link: http://14.139.191.203/login.aspx?ReturnUrl=%2f





(c) Dedicated website for all information about tropical cyclones since 2014

A dedicated website has been developed by IMD for the cyclone purpose. It is operational since April 2014. It consists of all static & dynamic information of cyclone, observation & modelling products, daily guidance & advisory and archived products. It is helpful for real time monitoring and forecasting as well as R&D activities on cyclones. **It can be accessed through https://rsmcnewdelhi.imd.gov.in/**


Regional Specialized Meteorological Centre for
Tropical Cyclones Over North Indian Ocean
India Meteorological Department
Ministry of Earth Sciences, Government of India
WMO
Home
RSMC
CWD
Vision
DM Act & Guidelines
SOP
Awareness
Publications
Tools
Verification
Archive
Climatology
Survey Reports
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TROPICAL WE
SAT : INSAT-3DR IMG
IMG_TIR1 10.8 um
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13-08-2024/(1015 to 1042) GMT
13-08-2024/(1545 to 1612) IST
50°E
60°E
70°E
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90°E
Important Links
Cyclone & Marine Weather Services NEW
Extended Range Outlook
Graphical Tropical Weather Outlook
Tropical Weather Outlook
National Bulletin
SWFP South Asia
FDP Cyclone
All India Weather Forecast
Press Release
Satellite Bulletin
Satellite Imagery
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NCCR
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NDMA
Outreach Activities
Documentary Films
Training & Conferences
Recognition to Ships
Register With Us
Send Feedback
Cyclone Warnings/Advisory
National Bulletin
RSMC Bulletin
TCAC Bulletin
Quadrant Wind Bulletin
GMDSS bulletin
Hourly Bulletin
Archive
Cyclone Warning Graphics
Interactive Track
Observed & Forecast Track
Storm Surge Guidance
Heavy Rainfall
Quadrant Wind Graphics
TCAC Graphics
Archive
NWP Guidance
Ocean State Forecast
HWRF
EPS
MME
GPP
Archive
Marine Forecast/Warnings
Fishermen Warning Graphics
Probability of Exceedance 45Kmph (25 Knots)
Probability of Exceedance 62 Kmph (34 Knots)
Sea Area Bulletin
Coastal Weather Bulletin
Port Warning
Fishermen Warning
Archive

Chapter 9

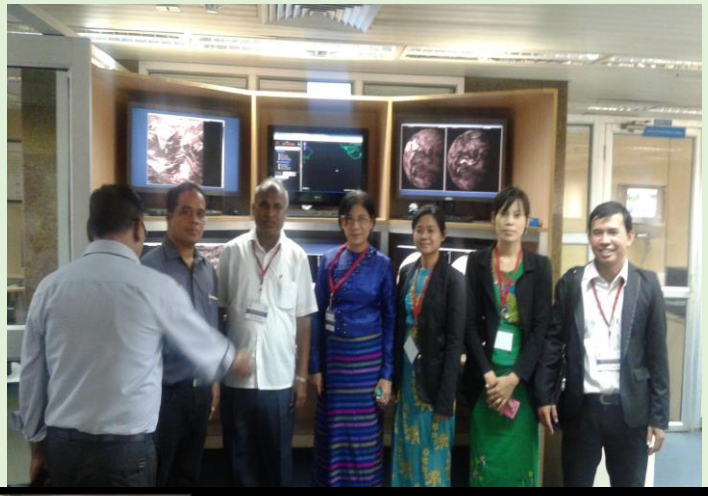
Capacity building initiatives

(a) Annual Attachment Training for Tropical Cyclone Forecasters in the region

Apart from sharing observations, model guidance and advisories, RSMC New Delhi has also played a crucial role in capacity building and enhancing competencies of forecasters through organisation of regular trainings, workshops, conferences etc. Trainings improve the competencies, productivity, accuracy and timeliness in services thereby contributing positively towards improving the early warning system. Starting with a humble beginning in 2005, with just two forecasters, over the years, the participation has increased by leaps and bounds. The details of attachment trainings conducted by RSMC New Delhi is given below:

Year	Name of Training	Period	Countries
2005	WMO's TC Forecasters Training	January, 2015	Myanmar and Thailand
2006	WMO's TC Forecasters Training	February, 2006	Maldives and Pakistan
2007	WMO's TC Forecasters Training	12-23 Feb.	Bangladesh, Myanmar and Sri Lanka
2008	WMO's TC Forecasters Training	14-25 Feb	Srilanka, Thailand
2009	WMO's TC Forecasters Training	09-20 Feb.	Bangladesh, Maldives
2010	WMO's TC Forecasters Training	1-12 Feb.	Myanmar, Srilanka
2011	WMO's TC Forecasters Training	28Feb.-11 March	Bangladesh, Oman, Myanmar, India
2012	WMO's TC Forecasters Training	20 Feb-02 March	Thailand, Srilanka, Maldives, India
2013	WMO's TC Forecasters Training	1-12 April	Bangladesh, Myanmar, Oman, India
2014	WMO's TC Forecasters Training	17-28 February	Myanmar, Sri Lanka, Thailand India
2015	International Training Workshop on Tropical Cyclone Forecasting	03-14 August	Myanmar, Sri Lanka, Thailand India, Maldives, Oman, Bangladesh, Laos, Cambodia.
2016	WMO's TC Forecasters Training	19-30 Sep	3 from Bangladesh, Maldives and Pakistan
2017	WMO's TC	11-22 Dec	3 from Myanmar, Oman and Sri Lanka

	Forecasters Training		
2018	WMO's TC Forecasters Training	03-14 July	7 from Bangladesh, Thailand, Cambodia, Lao PDR, Philippines, Thailand and Vietnam
2019	WMO's TC Forecasters Training	14-25 October	1 Bangladesh, 2 Qatar
2020	WMO's TC Forecasters Training	07-17 October	19 from WMO/ESCAP Panel member countries (online)
2021	WMO's TC Forecasters Training	06-18 October	22 from WMO/ESCAP Panel member countries (online)
2022	WMO's TC Forecasters Training	03-13 April	24 from WMO/ESCAP Panel member countries (online)
2023	WMO's TC Forecasters Training	04-14 April	26 from WMO/ESCAP Panel member countries (online)
2024	WMO's TC Forecasters Training	19-31 August	43 from WMO/ESCAP Panel member countries (9 in person)



Some memoirs of Annual cyclone forecasters trainings organized by RSMC, New Delhi

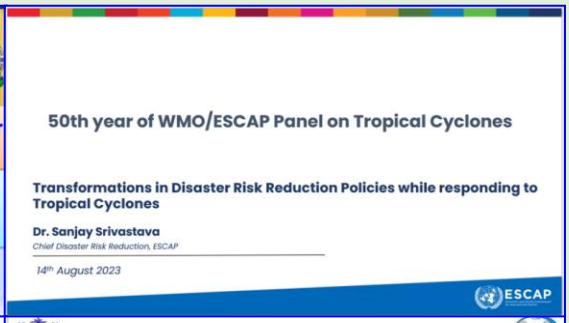
(b) Outreach Activities

To commemorate 50th Anniversary of WMO/ESCAP PTC and RSMC New Delhi in 2023, IMD with support from WMO, UN-ESCAP and PTC Member countries organized a series of activities as mentioned below:

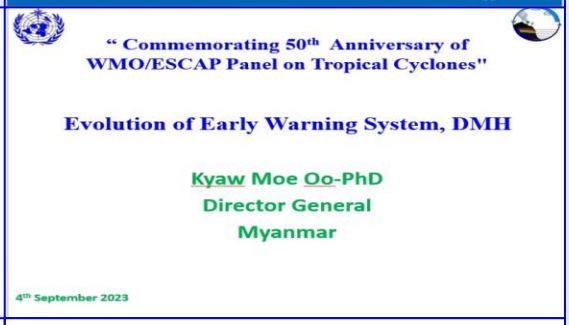
1. Organisation of international workshop, and national workshop in each country
   - Already Iran and Pakistan conducted International Workshop.
   - India Meteorological Department celebrated commenced celebration of 150 years of its foundation on 15th January 2024. IMD organised year long celebrations. IMD will organise International Conference in January, 2025.
2. RSMC started Quiz on Tropical Cyclones in September, 2023 with an objective to create awareness about activities of PTC & RSMC New Delhi and awareness about fundamentals about cyclones in the region to help public better understand the advisories.
3. RSMC New Delhi prepared a documentary film on Early Warning System of Cyclones which was screened during 18th WMO Congress, Geneva. The documentary film is available at: https://youtu.be/ET68Nozu2fo
4. RSMC New Delhi developed a logo for PTC which was approved by the PTC-50 Session in December, 2023.

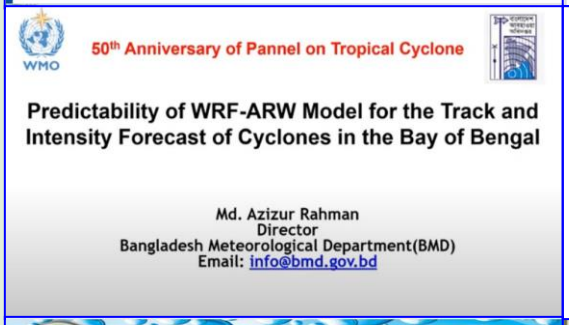
5. RSMC New Delhi organised a lecture series with eminent meteorologist and Permanent Representatives of various member countries as Expert Speakers. A total of 13 lectures were held in the series. It helped improve outreach of PTC and RSMC New Delhi and also improved liasoning among various countries. The lectures from eminent speakers are available on YouTube and also on RSMC website.
6. RSMC New Delhi will bring out a Special Edition on the talks of various eminent speakers in TCRR.

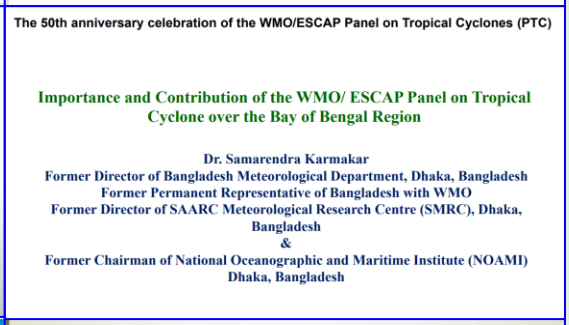

Commemorating 50th Anniversary of WMO/ESCAP Panel on Tropical Cyclones
and
Regional Specialised Meteorological Centre- New Delhi
Evolution of Tropical Cyclones Monitoring & Forecasting over North Indian Ocean
Dr. Mrutyunjay Mohapatra
Director General of Meteorology
India Meteorological Department
भारत मौसम विज्ञान विभाग
INDIA METEOROLOGICAL DEPARTMENT


50th year of WMO/ESCAP Panel on Tropical Cyclones
Transformations in Disaster Risk Reduction Policies while responding to Tropical Cyclones
Dr. Sanjay Srivastava
Chief Disaster Risk Reduction, ESCAP
14th August 2023
ESCAP


Introduction to
WMO Tropical Cyclone Programme (TCP)
Taoyong Peng
Head, DTD Division,
DMPS Branch, Services Department,
World Meteorological Organization
0830-0930 UTC, 21 August 2023
IMO-WMO
WMO OMM

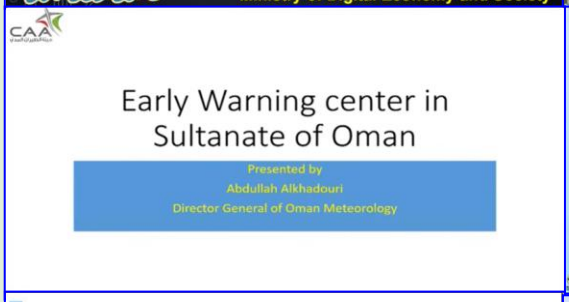

" Commemorating 50th Anniversary of
WMO/ESCAP Panel on Tropical Cyclones"
Evolution of Early Warning System, DMH
Kyaw Moe Oo-PhD
Director General
Myanmar
4th September 2023

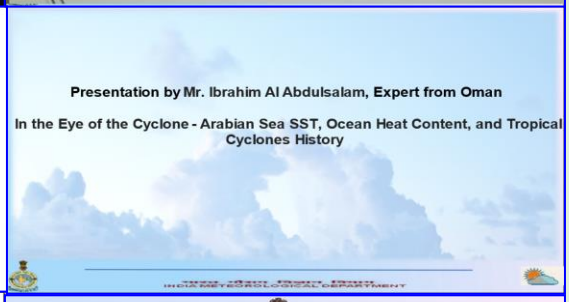

WMO
50th Anniversary of Pannel on Tropical Cyclone
Predictability of WRF-ARW Model for the Track and Intensity Forecast of Cyclones in the Bay of Bengal
Md. Azizur Rahman
Director
Bangladesh Meteorological Department(BMD)
Email: info@bmd.gov.bd


The 50th anniversary celebration of the WMO/ESCAP Panel on Tropical Cyclones (PTC)
Importance and Contribution of the WMO/ ESCAP Panel on Tropical Cyclone over the Bay of Bengal Region
Dr. Samarendra Karmakar
Former Director of Bangladesh Meteorological Department, Dhaka, Bangladesh
Former Permanent Representative of Bangladesh with WMO
Former Director of SAARC Meteorological Research Centre (SMRC), Dhaka, Bangladesh
&
Former Chairman of National Oceanographic and Maritime Institute (NOAMI)
Dhaka, Bangladesh


50th Anniversary of Panel on Tropical Cyclones
"PTC- 50 Years and TMD's services in response to Topical Cyclones and Natural Disasters
Thailand Report
Speaker : Somkuan Tonjan
Director of Meteorological Observation Division
28 August 2023
thailand
Thai Meteorological Department
Ministry of Digital Economy and Society


Celebrating PTC's 50th Anniversary –
PMD Hydromet Services & EWS
Mahr Sahibzad Khan
DG-PMD, Islamabad


CAA
Early Warning center in Sultanate of Oman
Presented by
Abdullah Alkhadouri
Director General of Oman Meteorology


Presentation by Mr. Ibrahim Al Abdulsalam, Expert from Oman
In the Eye of the Cyclone - Arabian Sea SST, Ocean Heat Content, and Tropical Cyclones History


National activity in the field of Indian Ocean's tropical cyclone warning
Behzad Layeghi, Vice President of IRIMO, PTC-50 Lecture series, 30 October 2023
IRIMO


Regional Specialised Meteorological Centre, New Delhi
Commemorating
50th Anniversary of PTC &
50th Anniversary of RSMC New Delhi
Concluding Presentation
Monica Sharma
भारत मौसम विज्ञान विभाग
INDIA METEOROLOGICAL DEPARTMENT

(c) Naming of cyclones over the NIO

The WMO/ESCAP Panel on Tropical Cyclones at its twenty-seventh Session held in 2000 in Muscat, Sultanate of Oman agreed in principle to assign names to the tropical cyclones in the Bay of Bengal and Arabian Sea. After long deliberations among the member countries, the naming of the tropical cyclones over north Indian Ocean commenced from September 2004, by RSMC New Delhi. The first name was 'ONIL' which developed over the Arabian Sea (30 September to 03 October, 2004). According to approved principle, a list of 64 names in eight columns of a table has been prepared. The names of Panel members who contributed cyclone names, have arranged in rows. The RSMC (tropical cyclones) New Delhi gives a tropical cyclone an identification name from the table of names. The Panel member's name is listed alphabetically country wise in each column. The names are used sequentially column wise. The first name starts from the first row of column one and continues sequentially to the last row in column eight. The names are not rotated every few years unlike that over the Atlantic and Eastern Pacific lists. All the names in the first list effective from September 2004 have been used. The second list in the series was released in April, 2020 with representation from all the 13 WMO member countries having a total of 169 names. Till the end of year 2023, a total of 18 names have already been utilized for naming the Tropical Cyclones over North Indian Ocean.

New list of tropical cyclone names adopted by WMO/ESCAP Panel Member Countries in April 2020 for naming of tropical cyclones over North Indian Ocean including Bay of Bengal and Arabian Sea

(To be used after the name 'Amphan' from the previous list is utilised)

WMO/ESCAP Panel Member countries	Column 1		Column 2		Column 3		Column 4	
	Name	Pron'	Name	Pron'	Name	Pron'	Name	Pron'
Bangladesh	Nisarga	Nisarga	Biparjoy	Biporjoy	Arnab	Ornab	Upakul	Upokul
India	Gati	Gati	Tej	Tej	Murasu	Murasu	Aag	Aag
Iran	Nivar	Nivar	Hamoon	Hamoon	Akvan	Akvan	Sepand	Sepand
Maldives	Burevi	Burevi	Midhili	Midhili	Kaani	Kaani	Odi	Odi
Myanmar	Tauktae	Tau'Te	Michaung	Migjaum	Ngamann	Ngaman	Kyarthit	Kjathi
Oman	Yaas	Yass	Remal	Re-Mal	Sail	Sail	Naseem	Naseem
Pakistan	Gulab	Gul-Aab	Asna	As-Na	Sahab	Sa-Hab	Afshan	Af-Shan
Qatar	Shaheen	Shaheen	Dana	Dana	Lulu	Lulu	Mouj	Mouj
Saudi Arabia	Jawad	Jowad	Fengal	Feinjal	Ghazeer	Razeer	Asif	Aasif
Sri Lanka	Asani	Asani	Shakhti	Shakhti	Gigum	Gigum	Gagana	Gagana
Thailand	Sitrang	Si-Trang	Montha	Mon-Tha	Thianyot	Thian-Yot	Bulan	Bu-Lan
United Arab Emirates	Mandous	Man-Dous	Senyar	Sen-Yaar	Afoor	Aa-Foor	Nahhaam	Nah-Haam
Yemen	Mocha	Mokha	Ditwah	Ditwah	Diksam	Diksam	Sira	Sira

WMO/ESCAP Panel Member countries	Column 5		Column 6		Column 7		Column 8	
	Name	Pron'	Name	Pron'	Name	Pron'	Name	Pron'
Bangladesh	Barshon	Borshon	Rajani	Rojoni	Nishith	Nishith	Urmi	Urmi
India	Vyom	Vyom	Jhar	Jhor	Probaho	Probaho	Neer	Neer
Iran	Booran	Booran	Anahita	Anahita	Azar	Azar	Pooyan	Pooyan
Maldives	Kenau	Kenau	Endheri	Endheri	Riyau	Riyau	Guruva	Guruva
Myanmar	Sapakyee	Zabagji	Wetwun	We'wum	Mwaihout	Mwei'hau	Kywe	Kjwe
Oman	Muzn	Muzn	Sadeem	Sadeem	Dima	Dima	Manjour	Manjour
Pakistan	Manahil	Ma-Na-Hil	Shujana	Shu-Ja-Na	Parwaz	Par-Waaz	Zannata	Zan Naa Ta
Qatar	Suhail	Es'hail	Sadaf	Sadaf	Reem	Reem	Rayhan	Rayhan
Saudi Arabia	Sidrah	Sadrah	Hareed	Haareed	Faid	Faid	Kaseer	Kusaer
Sri Lanka	Verambha	Ve-Ram-Bha	Garjana	Garjana	Neeba	Neeba	Ninnada	Nin-Na-Da
Thailand	Phutala	Phu-Ta-La	Aiyara	Ai-Ya-Ra	Saming	Sa-Ming	Kraison	Krai-Son
United Arab Emirates	Quffal	Quf-Faal	Daaman	Daa-Man	Deem	Deem	Gargoor	Gar-Goor
Yemen	Bakhur	Bakhoor	Ghwyzi	Ghwayzi	Hawf	Hawf	Balhaf	Balhaf

WMO/ESCAP Panel Member countries	Column 9		Column 10		Column 11		Column 12		Column 13	
	Name	Pron'	Name	Pron'	Name	Pron'	Name	Pron'	Name	Pron'
Bangladesh	Meghala	Meghla	Samiron	Somiron	Pratikul	Protikul	Sarobor	Sorobor	Mahanisha	Mohanisha
India	Prabhanjan	Prabhanjan	Ghurni	Ghurni	Ambud	Ambud	Jaladhi	Jaladhi	Vega	Vega
Iran	Arsham	Arsham	Hengame	Hengame	Savas	Savas	Tahamtan	Tahamtan	Toofan	Toofan
Maldives	Kurangi	Kurangi	Kuredhi	Kuredhi	Horangu	Horangu	Thundi	Thundi	Faana	Faana
Myanmar	Pinku	Pinnku	Yinkaung	Jin Gaun	Linyone	Lin Joun	Kyeekan	Kji Gan	Bautphat	Bau'hpa
Oman	Rukam	Roukaam	Watad	Wa Tad	Al-jarz	Al-Jarouz	Rabab	Ra Bab	Raad	Raad
Pakistan	Sarsar	Sar-Sar	Badban	Baad-Baan	Sarrab	Sarrab	Gulnar	Gul-Nar	Waseq	Waa-Seq
Qatar	Anbar	Anbar	Oud	Oud	Bahar	Bahar	Seef	Seef	Fanar	Fanaar
Saudi Arabia	Nakheel	Nakheel	Haboob	Haboob	Bareq	Bariq	Alreem	Areem	Wabil	Wobil
Sri Lanka	Viduli	Viduli	Ogha	Ogha	Salitha	Salitha	Rivi	Rivi	Rudu	Rudu
Thailand	Matcha	Mat-Cha	Mahingsa	Ma-Hing-Sa	Phraewa	Phrae-Wa	Asuri	A-Su-Ri	Thara	Tha-Ra
United Arab Emirates	Khubb	Khubb	Degl	Degl	Athmad	Ath-Md	Boom	Boom	Saffar	Saf-Faar
Yemen	Brom	Brom	Shuqra	Shuqrah	Fartak	Fartak	Darsah	Darsah	Samhah	Samhah

Note:

1. Panel Members name are listed alphabetically country wise
2. The names will be used sequentially column-wise
3. The first name will start from the first row of column one and continue sequentially to the last row in the column thirteen
4. Table will be used only once

Chapter 10

Achievements

The holistic development of all the components of early warning system led to paradigm shift in cyclone warning services in the region. The achievements of RSMC New Delhi are discussed in following sections.

(a) Improvements in Forecast Accuracy

Accuracy in both Cyclone track and intensity forecast registered an overall improvement of 20-30% and landfall point forecast improved by 30-60% upto 72 hours lead period during 2019-23 as compared to 2014-18 (**Fig. 10.1**).

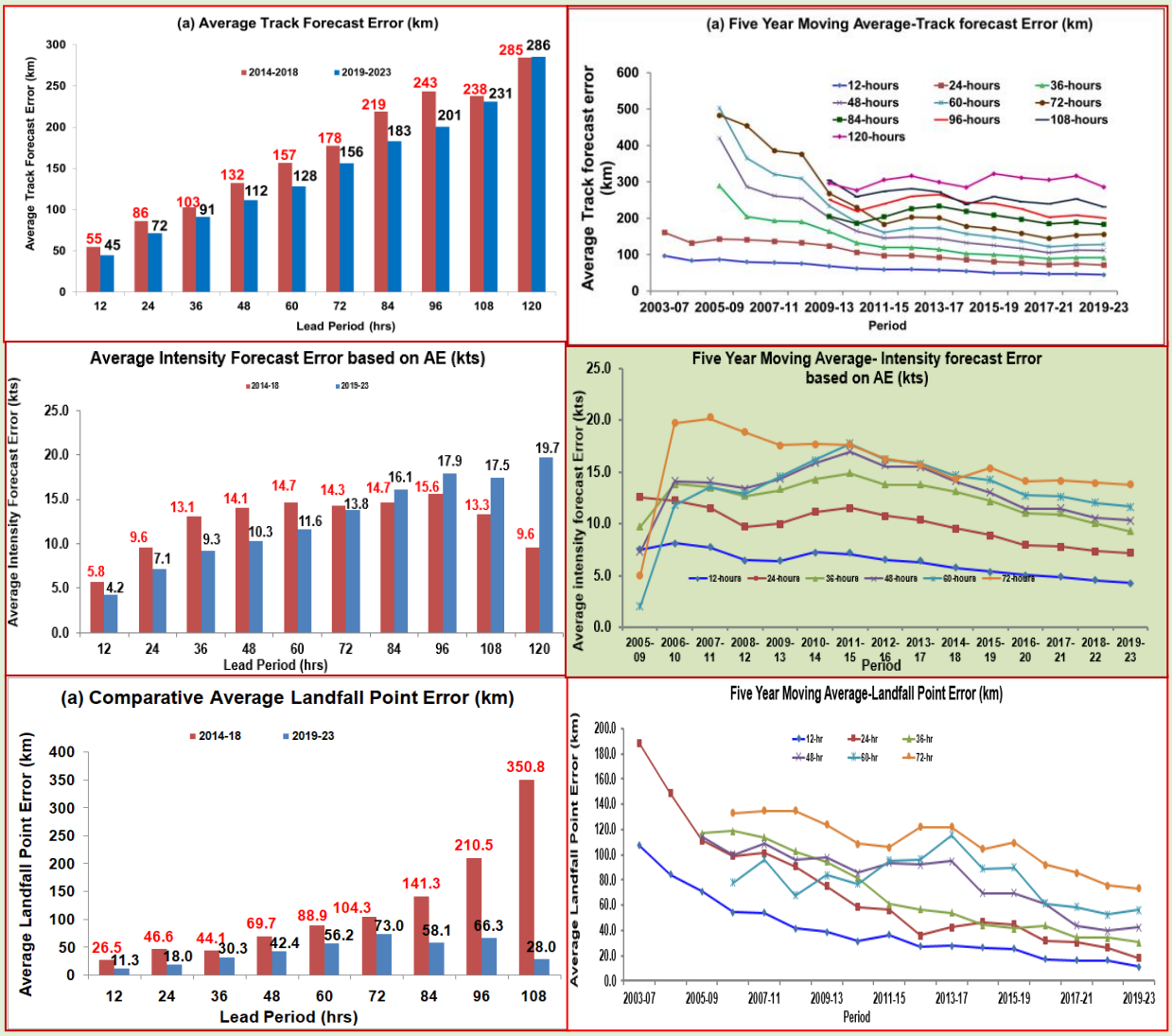


Fig. 10.1. Comparative analysis of track, intensity & landfall point forecast errors during 2019-23 vis-à-vis 2014-18 (left column) and corresponding five year moving average errors during 2003-2023 (right panel)

(b) Significant reduction in death toll over the region due to any cyclone in recent decades compared to 10,000 in 1999

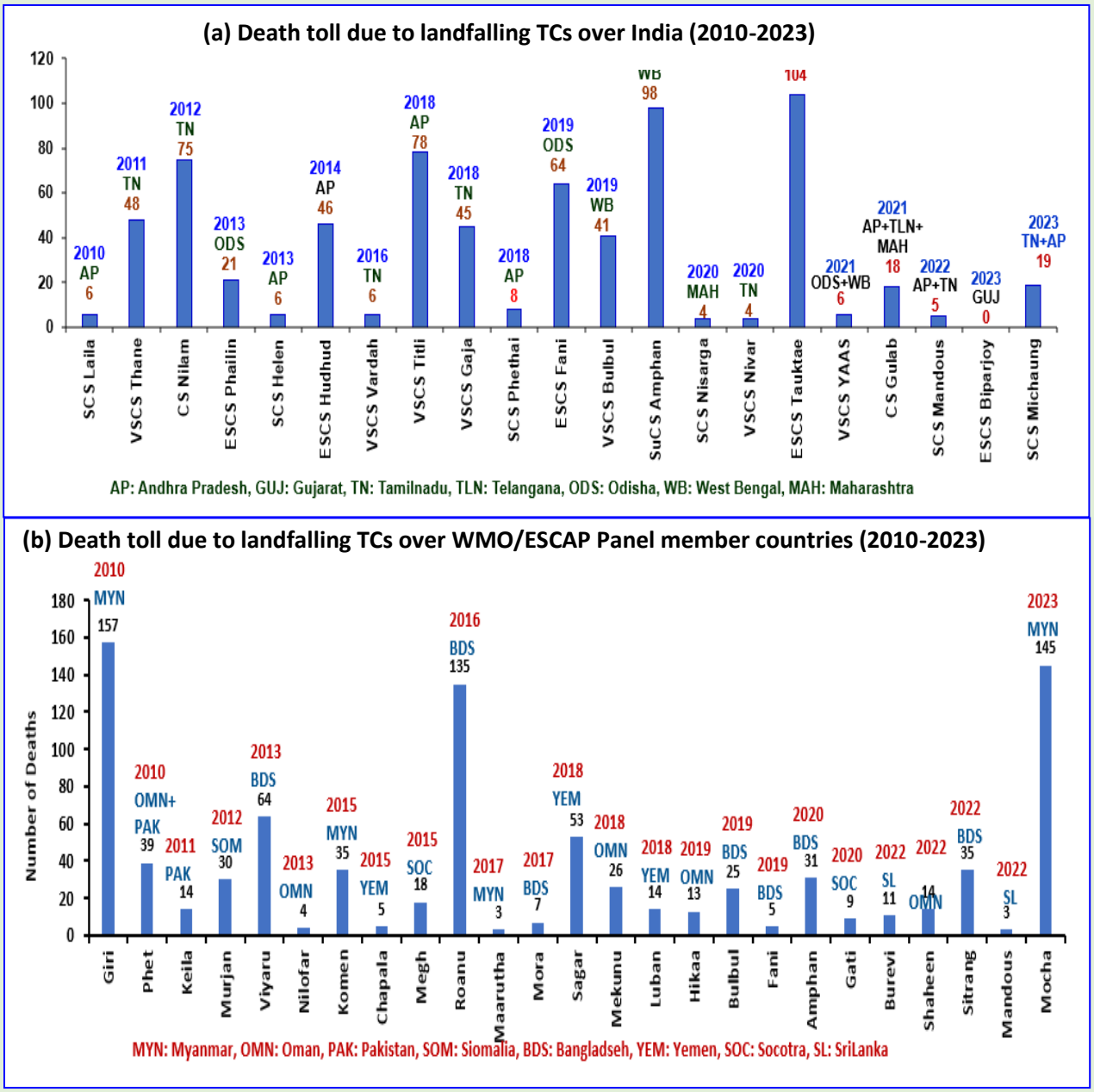
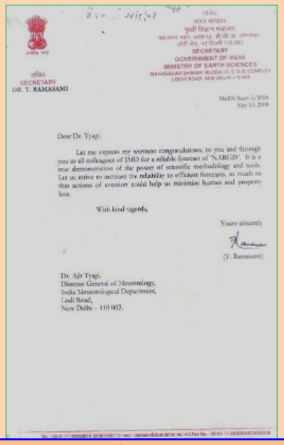


Fig. 10.2: Death toll over (a) Indian region and (b) PTC member countries during 2010-2023

(c) Awards and Appreciations

Appreciation for cyclone warning services during cyclone, Nargis in 2008



Excerpt of Appreciation from Secretary MoES:

Forecasting of cyclone "NARGIS" is a true demonstration of the power of scientific methodology and tools.

ACHIEVER'S AWARD FOR SUCCESSFUL PREDICTION OF PHAILIN, 2013

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

Excerpt of Appreciation:

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

M. Jarraud
Secretary General, WMO

International Conference on Humanitarian Logistics Award - 2013 for Excellence in Humanitarian Action for prediction of Phailin by IIM Raipur

Excerpt of Appreciation:

ICHL AWARD to IMD for the precise way in which their tracking of Phailin from 8th October onwards, the forecasting of the cyclone trajectory and landfall location helped in evacuating more than 10 kakh people in Odisha and Andhra Pradesh, minimizing loss of life.

Appreciation from WMO -Regional Association -II for prediction of Phailin

Excerpt of Appreciation:
The success of the evacuation operation was possible due to the development of IMD's infrastructure & communications system. The effective management of this calamity will be a landmark success story and a good lesson to all other countries.

Ahmed Abdullah Mohammed
President of RA II

Appreciation from Hon'ble Prime Minister of India for successful prediction of cyclone "Phailin (2013)"

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

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

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

Appreciation by Parliamentary Standing Committee on Science & Technology, 2017 for successful cyclones Hudhud (2014) & Vardah (2016)

Excerpt of 294th Report of the Department-related Parliamentary Standing Committee on Science & Technology.

The track record of the Ministry has been above par in the case of cyclone predictions which has been seen in the case of Hudhud and Vardah

Appreciation from WMO for forecast of cyclones Sagar and Mekunu, 2018

Excerpt of Appreciation:
I express my sincere appreciation and gratitude to RSMC New Delhi for regular bulletins on cyclones Sagar & Mekunu. In addition to benefitting PTC countries and Somalia, the bulletins were also utilised by WMO, RA Office Bahrain and United Nations.

P Tallas
WMO, Secretary General

Appreciation from WMO for monitoring of VSCS Titli and Luban, 2018

WMO appreciates IMD for tropical cyclone advisory services during VSCS Luban (06 -15 October) and VSCS Titli (08-13 October).
The excerpt of the twitter message of WMOdated the 16th October is given below:
Cyclonic storms #Titli and #Luban recently hit India, Oman and Yemen. Accurate warnings and forecasts from WMO Specialized Meteorological Centre New Delhi @Indiametdept helped minimize impact and save lives
https://bit.ly/2yE12sU

Appreciation from United Nations for accurate forecast during ESCS FANI

Excerpt of Appreciation from United Nations Office for Disaster Risk Reduction

The government's zero casualty policy for natural disasters and the near accuracy of the India Meteorological Department's early warning system have helped reduce the possibility of deaths from cyclone "FANI".

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

President of India
@rashtrapatibhvn

Our expertise in accurate weather forecast has improved. This was evidenced during the recent #CycloneFani that struck the eastern coast of the country. Due to accurate information and timely preparation, large scale destruction to life and property was averted #PresidentKovind

12:55 PM · Jun 20, 2019 · Twitter Web Client

232 Retweets 1.1K Likes

Appreciation from WMO for accurate forecast during Super Cyclone Amphan

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

WMO, Secretary General

WMO OMM

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

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

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

17 July 2023

Subject: Appreciation letter

Dear Dr Mohapatra,

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

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

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

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

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

Yours sincerely,

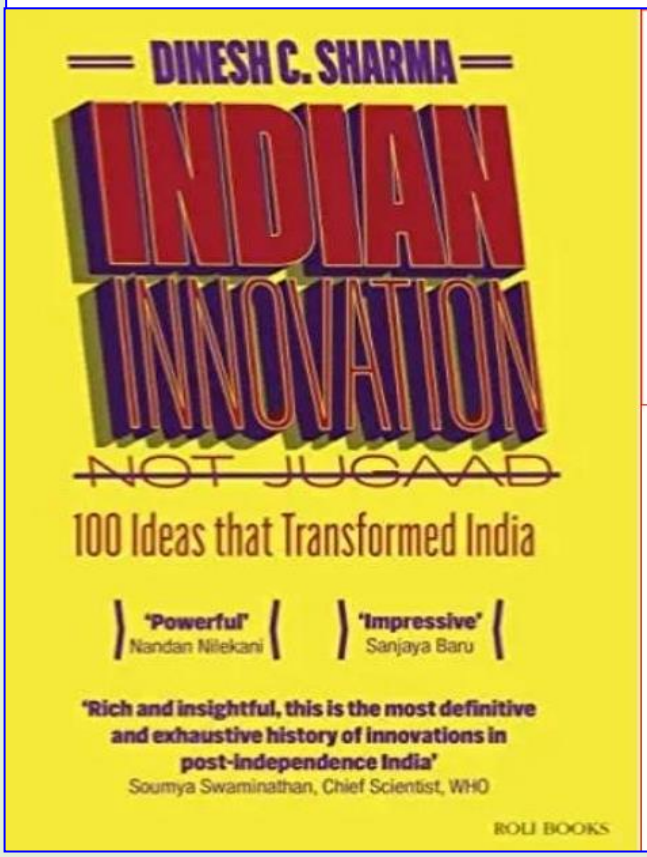
Dr Elena Manaenkova
for the Secretary-General

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

Excerpt of Appreciation:

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

WMO, Secretary General



Cyclone Warning Services of IMD earned place among 100 Innovations that transformed India in a book authored by Mr. D.C. Sharma

Chapter 11

Future Plans

RSMC New Delhi is committed to deliver world-class cyclone warning services to all the members in the region through holistic development of all four pillars of early warning services, including (i) observations, (ii) modelling, (iii) forecasting (iv) early warning products generation and dissemination. Specifically, it aims at achieving the following by 2030:

- No low pressure system should go undetected and unpredicted at least 10 days in advance.
- Sustainable development of cyclone warning services of IMD to achieve zero death toll and minimal to property through accurate impact based forecast and risk based warnings for cyclones track, intensity, landfall and associated adverse weather. It would enable the Government to minimize death and damage due to TCs and thus build a disaster resilient society through accessible and actionable cyclone warnings at each household.
- IMD to be a major contributor to Govt. exchequer by saving expenditure towards disaster management and rehabilitation activities and contributing to the prosperity of the nation through sector specific, accurate and actionable advisories
- Development of a cyclone warning system which can combat the impact of climate change through accurate forecast, at desired spatio-temporal scales and for implementation of various adaptation & mitigation measures
- IMD to emerge as a global leader in providing cyclone warning and capacity building services to the world community
- Improvement in forecast accuracy of genesis, track intensity, landfall point and time and associated adverse weather including heavy rainfall, wind and storm surge leading to further reduction in error by 20% during next 5 years.
- To enable public and disaster managers to realize zero death and drastic reduction in loss of property due to any cyclone over the region.
- Develop a society which is well familiar with actions prior to, during and post every cyclone, thereby enabling a cyclone disaster resilient society in WMO/ESCAP Panel region.

References:

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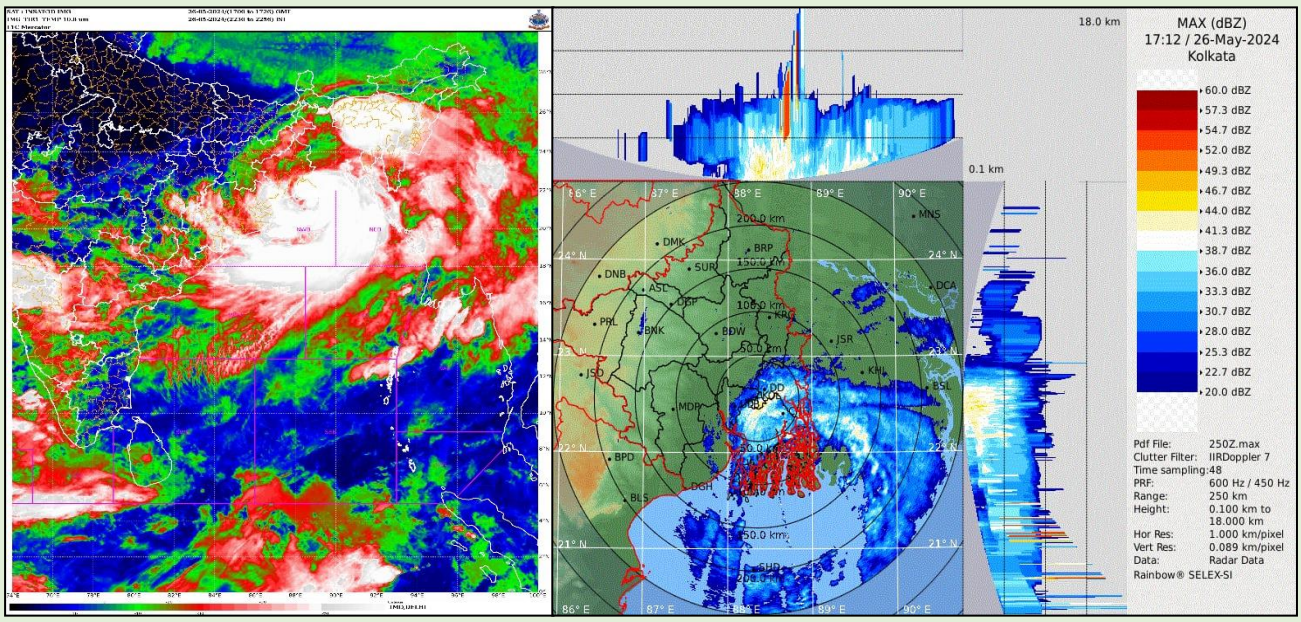

Typical enhanced color imagery from INSAT 3D(R) and reflectivity imagery from Doppler Weather Radar, Kolkata during the life cycle of severe cyclonic storm "REMAL"

(A success story of accurate and timely monitoring and prediction)

(Brief report is available at https://rsmcnewdelhi.imd.gov.in/archive-report.php?internal_menu=MjY=&year=MjAyNA==)