Recent Advances in Cyclone Forecasting

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भारत मौसम विज्ञान विभाग
INDIA METEOROLOGICAL DEPARTMENT

TYPES OF POTENTIAL DAMAGES ACCOMPANYING TROPICAL CYCLONES

CYCLONE

LOCAL TIDES

LOCAL COASTAL CONFIGURATION

STORM SURGE

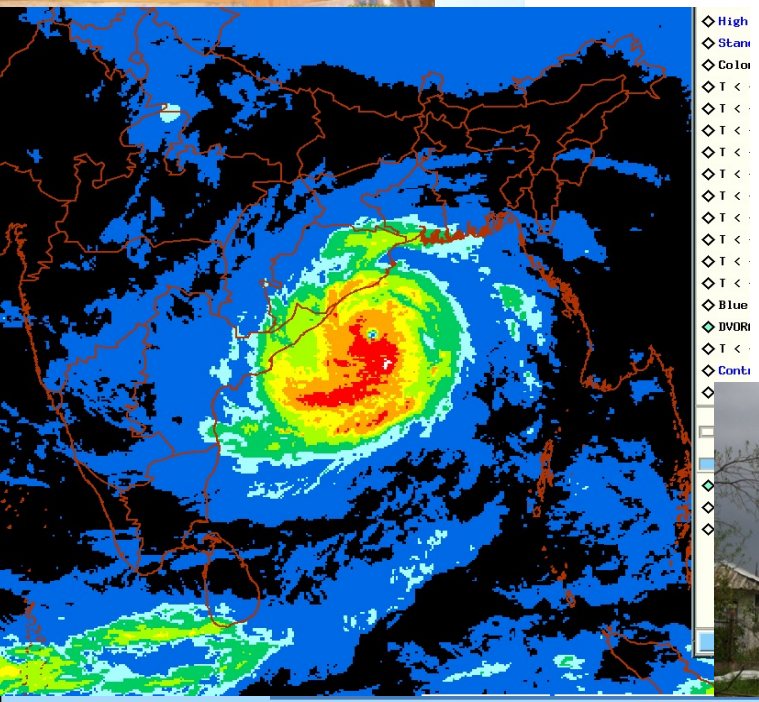
- FLOODING OF COASTAL AREAS
- EROSION OF BEACHES
- LOSS OF SOIL FERTILITY FROM SALINE INTRUSIONS

WIND

- DAMAGE TO STRUCTURES
- LOSS OF POWER/COMMUNICATION
- INJURIES & LOSS OF LIFE
- DESTRUCTION OF CROPS, VEGETATION, LIVE-STOCK

RAIN

- CONTAMINATION OF WATER SUPPLY SYSTEM
- LAND SUBSIDENCE
- FLOODING OF INLAND AREA



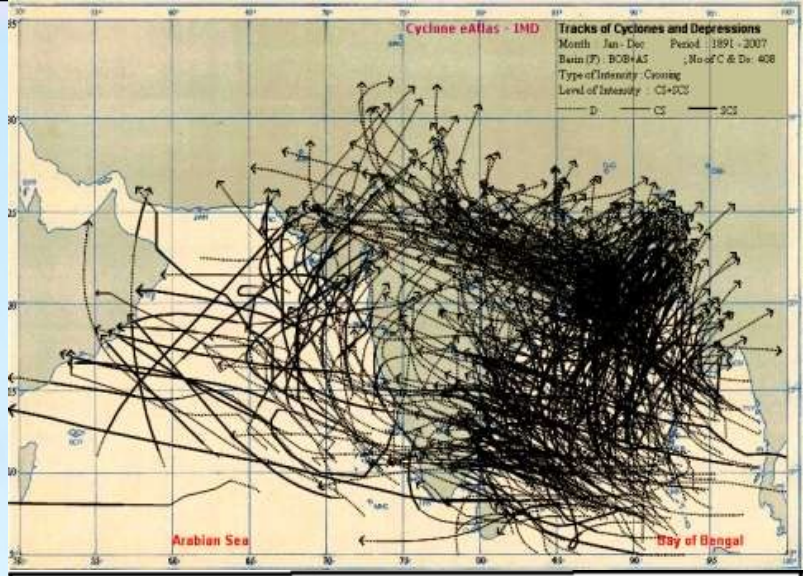
A Few Facts about Tropical Cyclones(TCs)

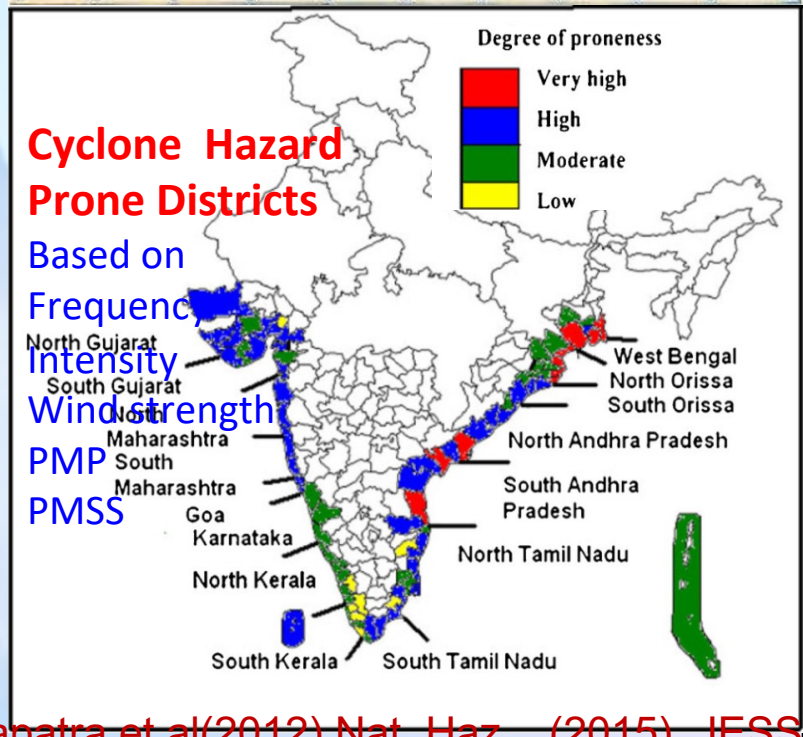
- During 1970-2019, 33% of hydro meteorological disasters are caused by TCs.
- One out of three events that killed most people globally is TC.
- Seven out of ten disasters that caused biggest economic losses in the world from 1970-2019 are TCs.
- It is the key interest of 85 WMO Members prone to TCs
- Casualties of 300,000 in Bangladesh in 1970 is still ranked as the biggest casualties for the last five decades due to TC;
- Cyclone Monitoring, forecasting and warning services deals with application of all available modern technologies into operational services.

Cyclone in India

- Out of 80 forming over the globe, five form over north Indian Ocean
- Ratio of TCs between Bay of Bengal and Arabian Sea – 4:1
- Bay of Bengal is a vast warm pool.
- The ocean currents in Bay of Bengal are quite complex. Bathymetry of this coast is very complex due to many rivers, deltaic regions & orography

- ✓ In order to build an effective response mechanism, we need to assess our vulnerability & Risks.
- ✓ Post-landfall impact assessment is integral part of Cyclone warning,
- ✓ Based on data collected, IMD issus impacts expected over coastal Districts
- ✓ Satellite since plays dominant role in (i) development of climatology(genesis, track, intensity) of TC, hazard, vulnerability and risk analysis

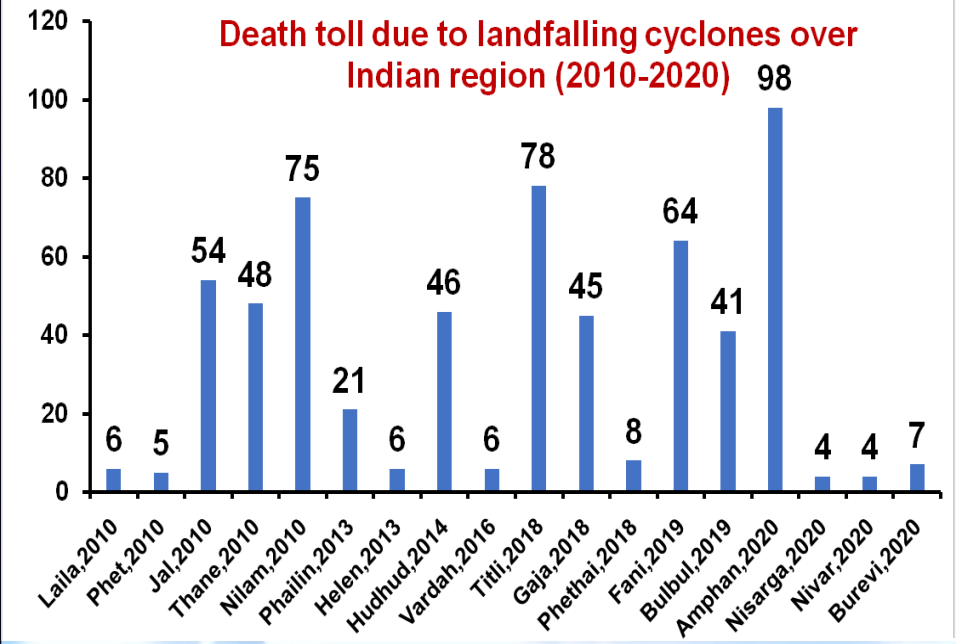


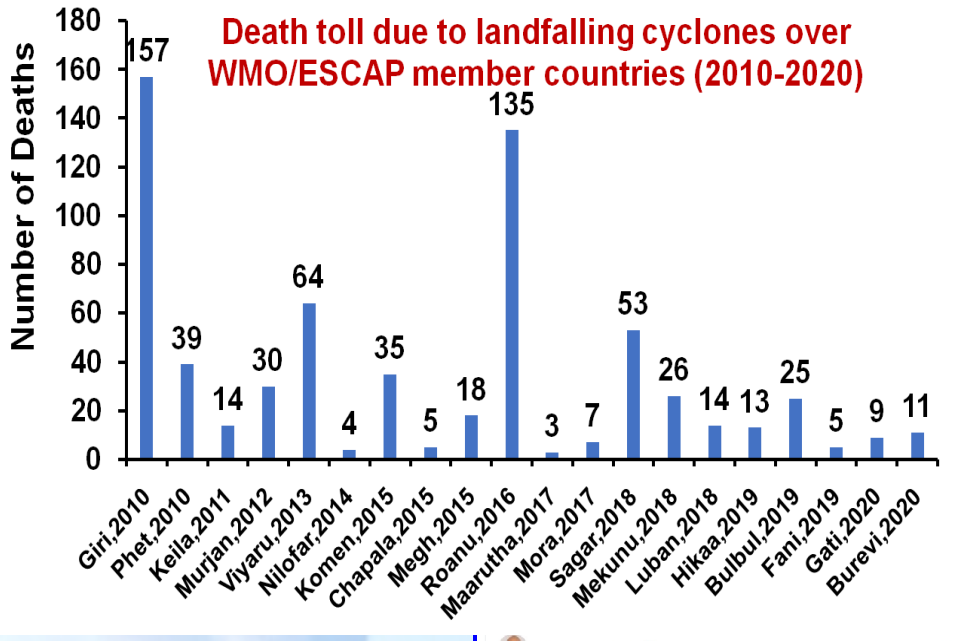


Mohapatra et al(2012) Nat. Haz., (2015), JESS

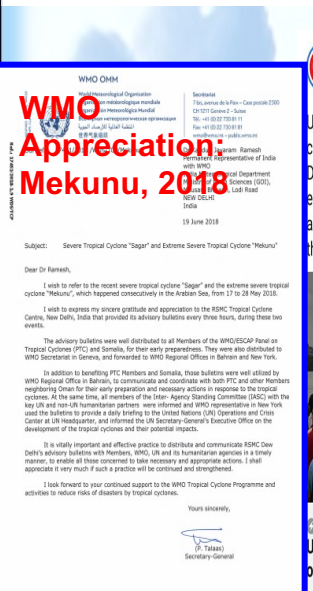
Outcome of Improved Early Warning System

- Improved confidence of disaster managers/general Public
- Enabled disaster managers and public to minimize loos of lives and properties





WMO Appreciation: Mekunu, 2018


WMO OMM

Subject: Severe Tropical Cyclone "Sagar" and Extreme Severe Tropical Cyclone "Mekunu"

Dear Dr Ramesh,

I wish to refer to the recent severe tropical cyclone "Sagar" and the extreme severe tropical cyclone "Mekunu", which happened consecutively in the Arabian Sea, from 17 to 28 May 2018.

I wish to express my sincere gratitude and appreciation to the RSMC Tropical Cyclone Centre, New Delhi, India that provided its advisory bulletins every three hours, during these two events.

The advisory bulletins were well distributed to all Members of the WMO/ESCAP Panel on Tropical Cyclones (PTC) and Somalia, for their early preparedness. They were also distributed to WMO Secretariat in Geneva, and forwarded to WMO Regional Offices in Bahrain and New York.

In addition to benefiting PTC Members and Somalia, those bulletins were well utilized by WMO Regional Office in Bahrain, to communicate and coordinate with both PTC and other Members neighboring Oman for their early preparation and necessary actions in response to the tropical cyclones. At the same time, all members of the Inter- Agency Standing Committee (IASC) with the key UN and non-UN humanitarian partners were informed and WMO representative in New York used the bulletins to provide a daily briefing to the United Nations (UN) Operations and Crisis Center at UN Headquarter, and informed the UN Secretary-General's Executive Office on the development of the tropical cyclones and their potential impacts.

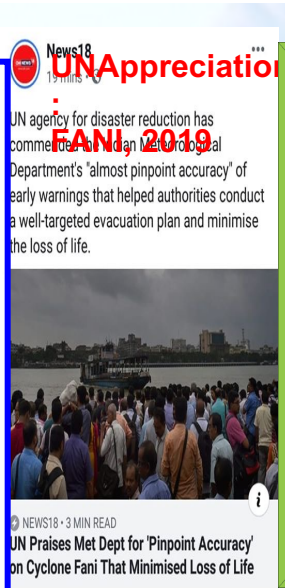
It is vitally important and effective practice to distribute and communicate RSMC Dew Delhi's advisory bulletins with Members, WMO, UN and its humanitarian agencies in a timely manner, to enable all those concerned to take necessary and appropriate actions. I shall appreciate it very much if such a practice will be continued and strengthened.

I look forward to your continued support to the WMO Tropical Cyclone Programme and activities to reduce risks of disasters by tropical cyclones.

Yours sincerely,

(P. Taalas)
Secretary-General

UNAppreciation : FANI, 2019

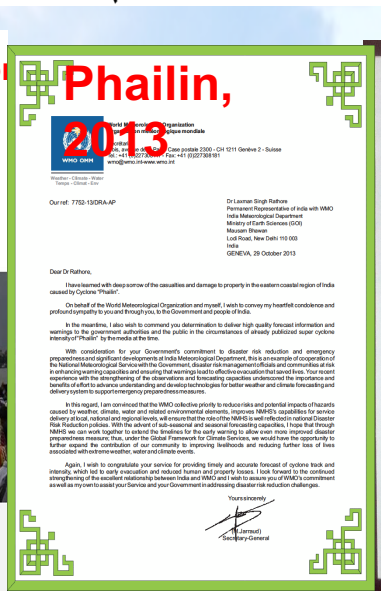

News18
19 MINS AGO

UN agency for disaster reduction has commended the Indian Meteorological Department's "almost pinpoint accuracy" of early warnings that helped authorities conduct a well-targeted evacuation plan and minimise the loss of life.

NEWS18 • 3 MIN READ

UN Praises Met Dept for 'Pinpoint Accuracy' on Cyclone Fani That Minimised Loss of Life

Phailin, 2013


WMO OMM

Our ref: 7752-3/DRA-AP

Dear Dr Rathore,

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

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

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

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

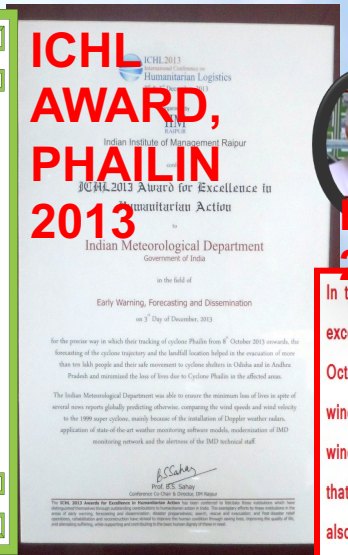
In this regard, I am convinced that the WMO collective priority to reduce risks and potential impacts of hazards caused by weather, climate, water and related environmental elements, improves NMHS's capabilities for service delivery at local, national and regional levels, will ensure that the role of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

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

Yours sincerely,

(M. Jarraud)
Secretary-General

ICHL AWARD, PHAILIN 2013


ICHL 2013
Humanitarian Logistics
Award

Indian Institute of Management Raipur

ICHL 2013 Award for Excellence in Humanitarian Action

to

Indian Meteorological Department
Government of India

in the field of

Early Warning, Forecasting and Dissemination

on 3rd Day of December, 2013

for the precise way in which their tracking of cyclone Phailin from 8th October 2013 onwards, the forecasting of the cyclone trajectory and the landfall location helped in the evacuation of more than ten lakh people and their safe movement to cyclone shelters in Odisha and in Andhra Pradesh and minimized the loss of lives due to Cyclone Phailin in the affected areas.

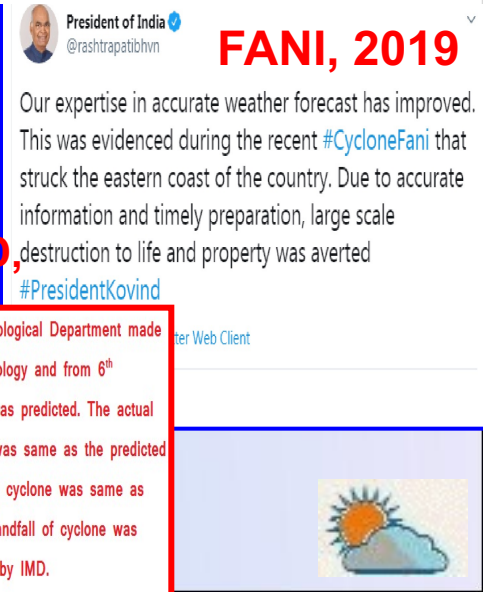
The Indian Meteorological Department was able to ensure the minimum loss of lives in spite of several news reports globally predicting otherwise, comparing the wind speeds and wind velocity to the 1999 super cyclone, mainly because of the installation of Doppler weather radars, application of state-of-the-art weather monitoring software models, modernization of IMD monitoring network and the alertness of the IMD technical staff.

Prof. JES Sahay
Conference Co-Chair & Director, IIM Raipur

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.

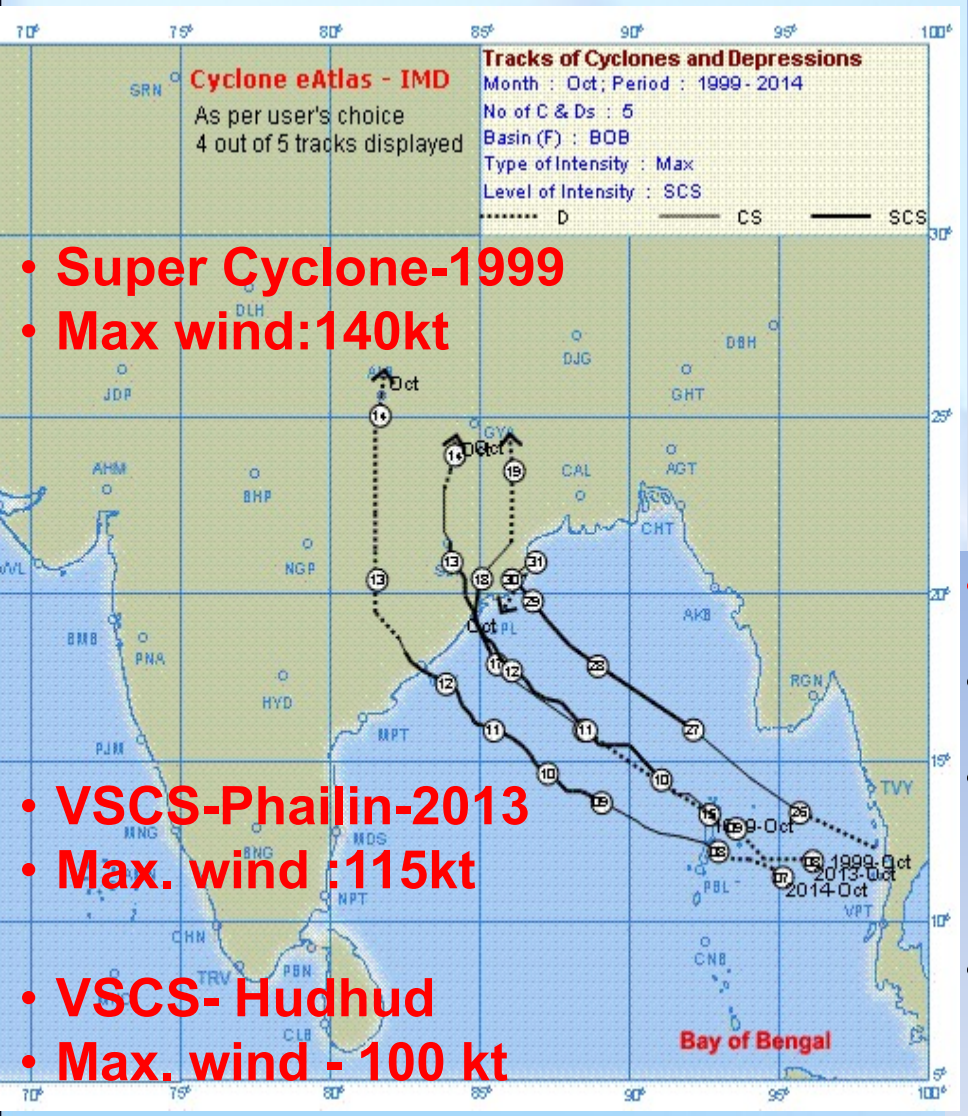
FANI, 2019


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

ter Web Client

Cyclone warning improvement over the years



- Super Cyclone-1999
- Max wind:140kt
- VSCS-Phailin-2013
- Max. wind :115kt
- VSCS- Hudhud
- Max. wind - 100 kt

- Super Cyclone-1999
- No genesis forecast
- Lead period was less (24 hrs)
- Accuracy was moderate
- Poor Warning communication and triggering mechanism

- VSCS-Phailin and Hudhud(2013-14)
- 5 day Genesis forecast
- Objective track, intensity and landfall forecast-5 day lead
- Accurate impact based warning (Rain, wind and storm surge)
- Effective communication and triggering mechanism

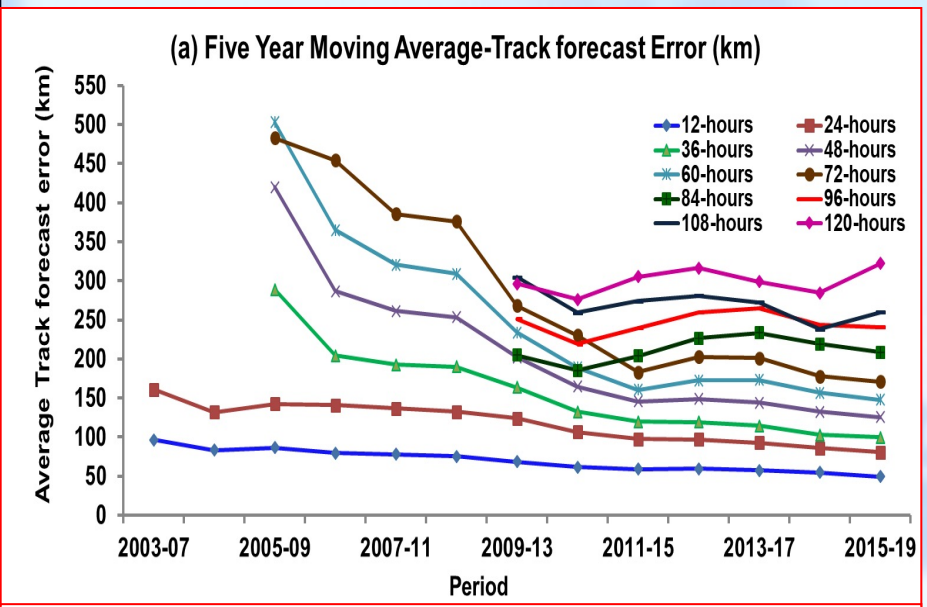
OUTCOME

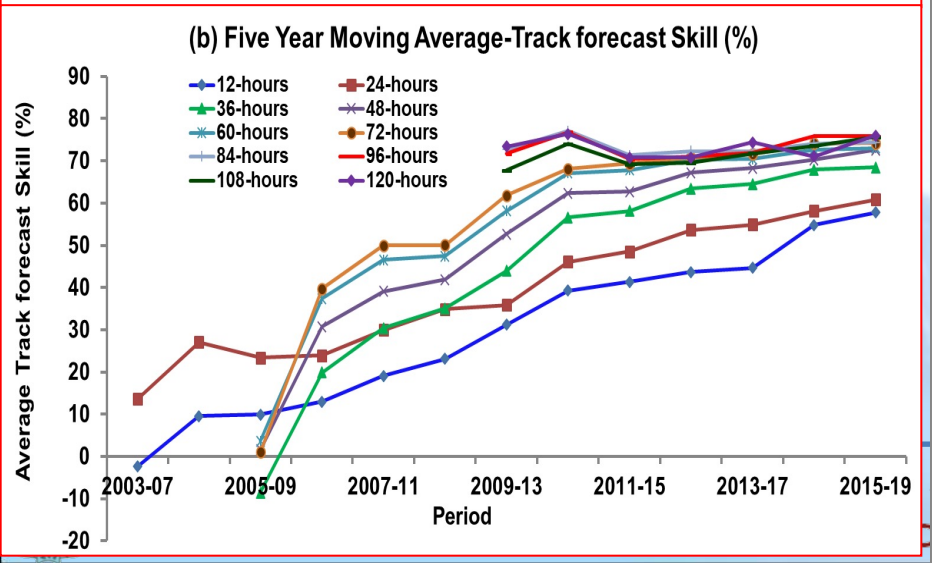
SN	PARAMETERS	PARADIP SuCS CYCLONE, 1999	VSCS PHAILIN, 2013
1.	Loss of human life	9887	21
2.	Ex-gratia paid by Govt. @ Rs 0.6 Million	Rs 5930 Millions	Rs 12.6 Mollions
3.	Area of evacuation	500 km (approx)	180 km
4.	Cost of evacuation per km (1 Million Rupees assumed)	500 Millions	180 Millions
Calculation is based on assumption that similar amounts would have been spent for evacuation and payment of ex-gratia in 1999 as in 2013			

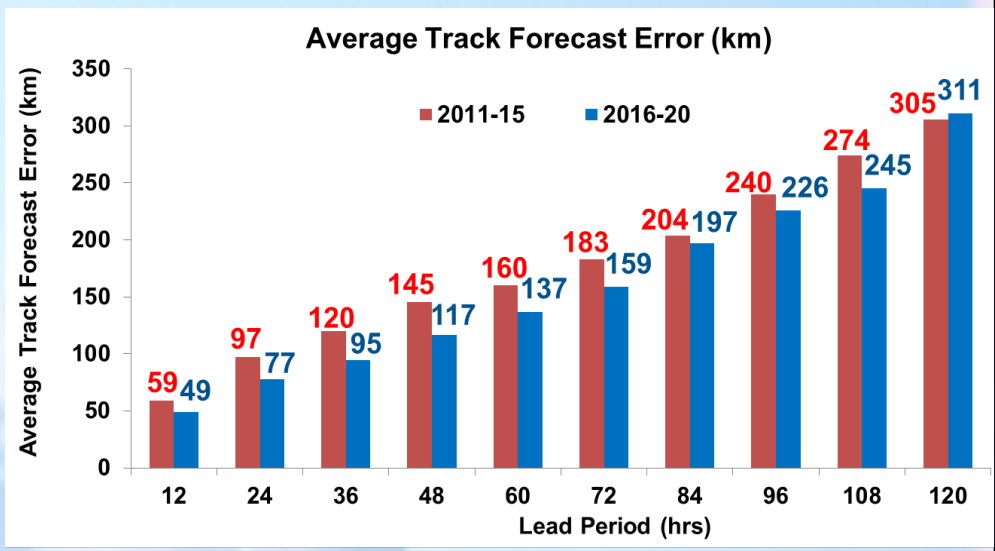
- There is decrease in area of evacuation by 300 km in 20 years and hence evacuation cost by 60 percent
- Decrease in ex-gratia paid by Govt. to survivors by about 99 percent as compared to 1999.

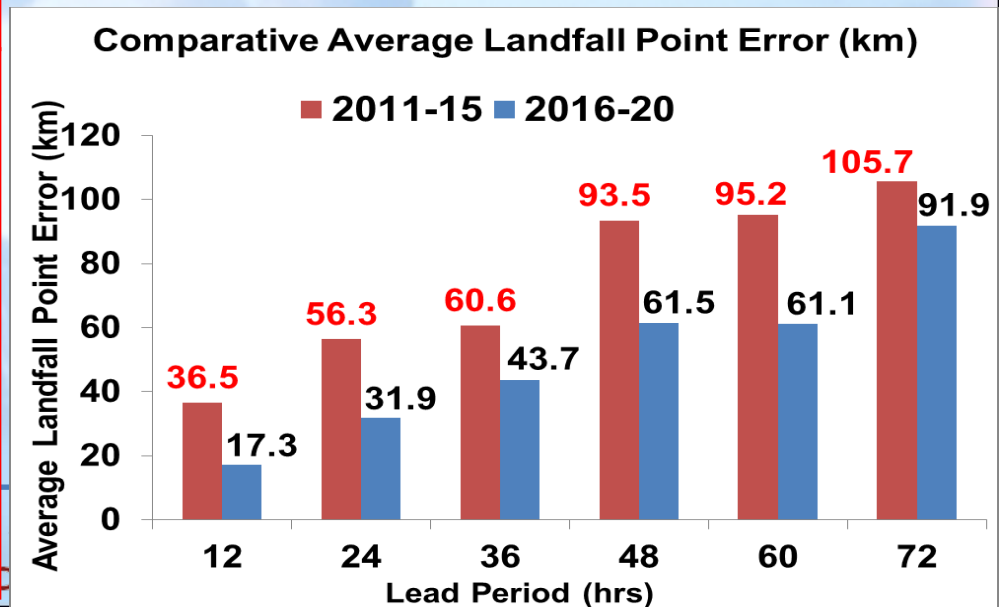
Five Year Moving Average- Track Forecast Error & Skill

- About 25% decrease in error compared to previous five years
- It is at par or better than many leading centres
- Recurving and rapidly/slow moving tracks are still challenging









HOW DID IT HAPPEN?

- What was the game changer? Is it Odisha Super Cyclone causing 10,000 human loss?
- National Cyclone Risk Mitigation Project of India-planned from 2005 with IMD as a partner
- Modernisation Programme of IMD, MoES-2007

  IMD decides to modernise cyclone warning System through its own modernisation programme
- Modernisation programme of IMD as well as cyclone warning system starts -2008
- All the aspects of cyclone warning system was addressed

HOW DID IT HAPPEN?

- Upgradation of cyclone warning services taken up in holistic manner addressing all components of early warning system including:

(i) policy and planning,

(ii) Introduction of new tools and technology for monitoring, analysis, forecasting and warning services

(iii) Introduction of new methodology for monitoring, analysis, forecasting and warning services

(iv) R&D

(v) capacity building

(vi) confidence building measures and

(vii) outreach,

IMPROVEMENT IN POLICY AND PLANNING

- Vision 2020 document was prepared in 2010
- Benchmarking to fix target of forecast accuracy of landfall, track, intensity, heavy rainfall, wind and storm surge in 2010
- 20% by 2015 and 40% improvement by 2020 with base year as 2010.

❖ Standard Operation Procedure for

- Daily Watch and Methodology
- Check list,
- impact based forecast product generation
- Dissemination mechanism and triggering

❖ DM Act and DM Plan of Govt of India

❖ National Cyclone Risk Mitigation Project by NDMA

❖ Cyclone management guidelines of NDMA in 2008.

❖ Hazard & Vulnerability Atlas as per requirement of NDMA

❖ Institutional Mechanism: Establishment of Ministry of Earth Science

Cyclone

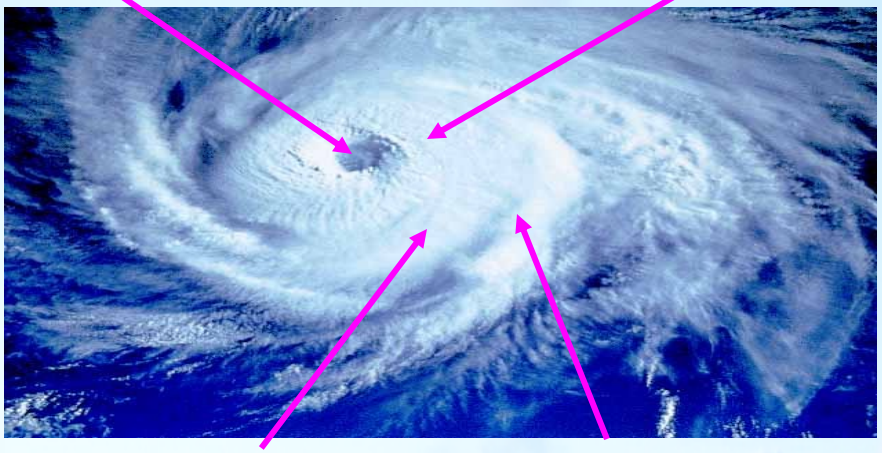
- **A low pressure system, where the wind rotates in anticlockwise (clockwise) direction in northern (southern) hemisphere with a minimum sustained wind speed of 34 knots (62 kmph)**
- **World Meteorological Organization's official definition :**

A tropical cyclone (hurricane, typhoon) **is a** synoptic scale (≥100 km) **,**

- non-frontal (no sharp gradient of temperature) **disturbance,**
- **over** tropical or subtropical **waters ,**
- **with** organized convection**, and definite** cyclonic surface wind circulation.

WESTERN PACIFIC	TYPHOONS	
AUSTRALIA	WILLY-WILLIES	
MEXICO	CORDONAZO	
PHILIPPINES	BAGIOUS	Named after a city 'BAGUIO' which experienced a rain fall of 116.8 cm in 24 hrs in July, 1911
INDIAN SEAS	CYCLONES	Derived from Greek word 'CYCLOS' – Coil of a Snake
ATLANTIC & EASTERN PACIFIC	HURRICANES	Derived from 'HURACON' - God of Evil (central American ancient aborigines call God of Evil as HURACON

Tropical cyclone



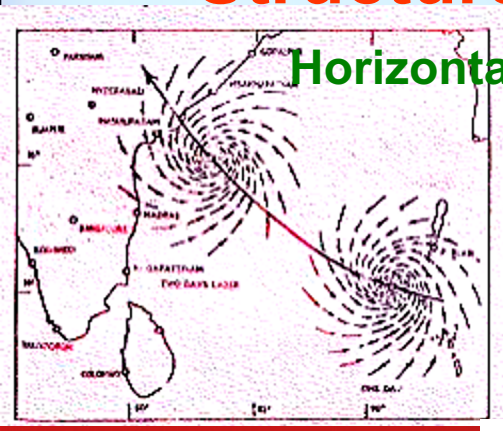
- Horizontal : 100-1000km
- Vertical :10-15 km
- Wind speed : UP to 300 km / hr
- Average storm speed : About 300 km / day

Eye Wall/ Wall Cloud : Ring of convective clouds around eye.

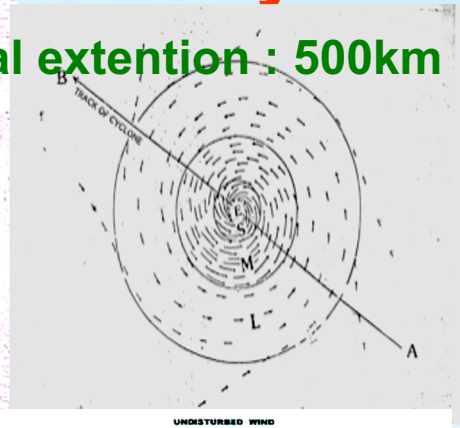
- Intense rainbands spiralling inwards. Most dangerous part of the TC.
- Width of wall cloud is about 20-100 Km.
- Region maximum pressure gradient, maximum temperature gradient, heaviest precipitation and strongest wind

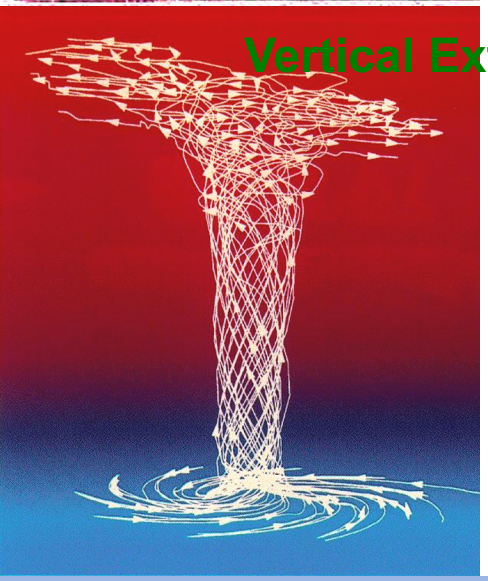
- **EYE:** Central part, is known as eye. Diameter of eye: 10 to 100 Km
- Formed by air sinking from upper levels to lower levels and is characterized by calm winds, clear sky and lowest pressure
- Abrupt cessation of precipitation when eye passes over an area.
- Shape : Circular or elliptical, Regular/diffused eye, Single/Double eye
- Eye is warmer than the surrounding.

Structure of a Cyclone

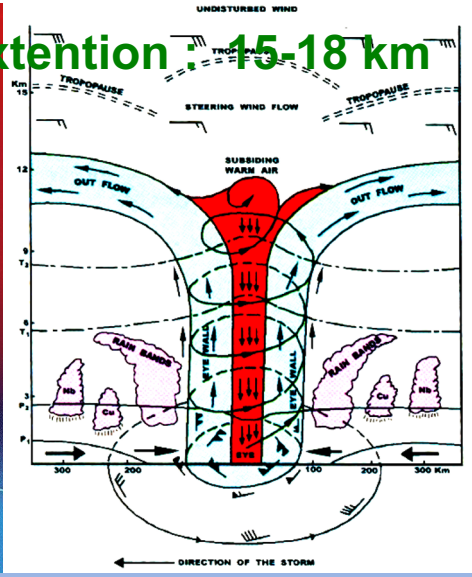


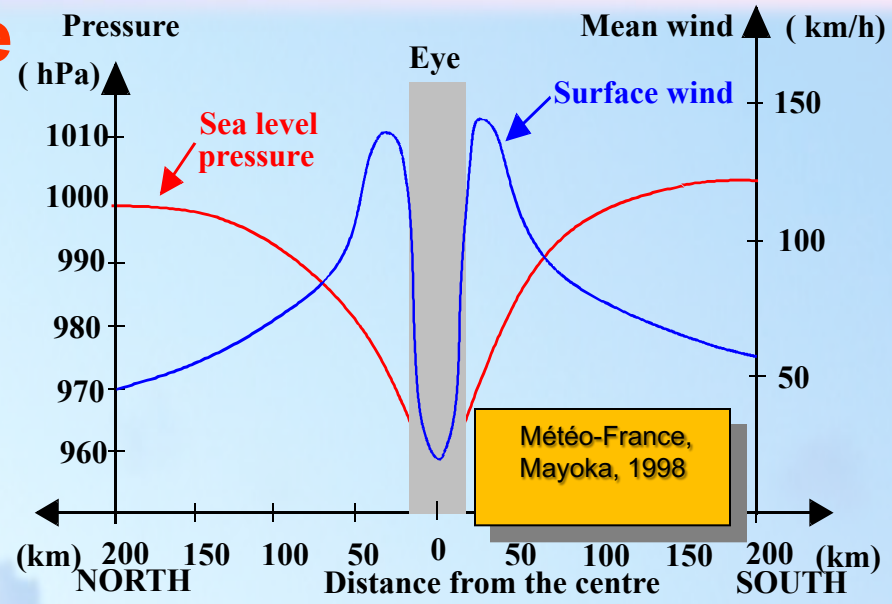
Horizontal extention : 500km





Vertical Extention : 15-18 km





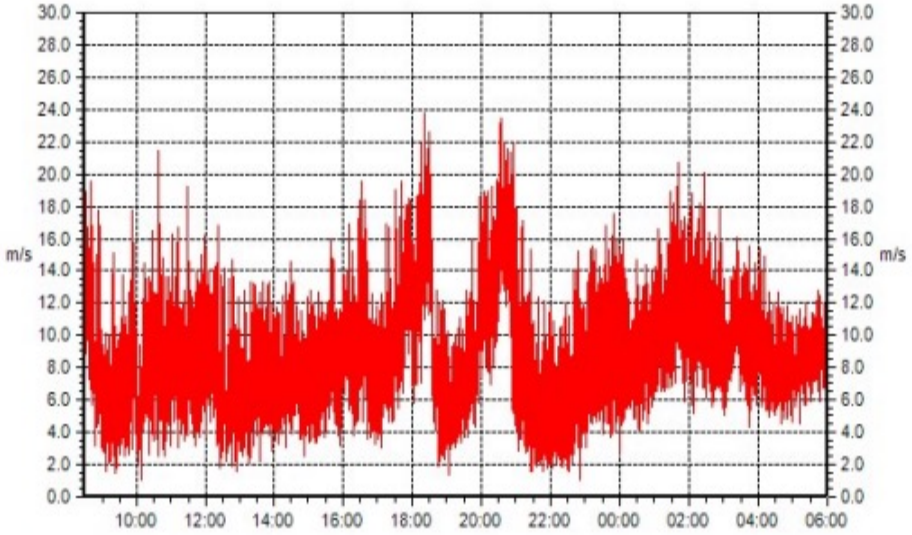
➢Vertically : three distinct layers

(i)*Inflow layer:*

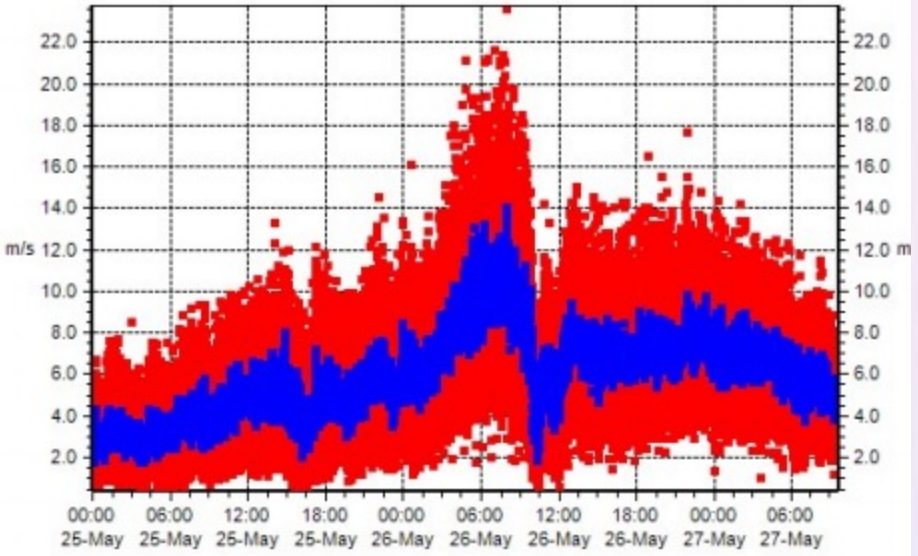
- from surface upto about 3 Kms.
- Strongest inflow : surface to 1Km.
- *Middle layer:* weak inflow, extends from 3 Km to 7.6 km.

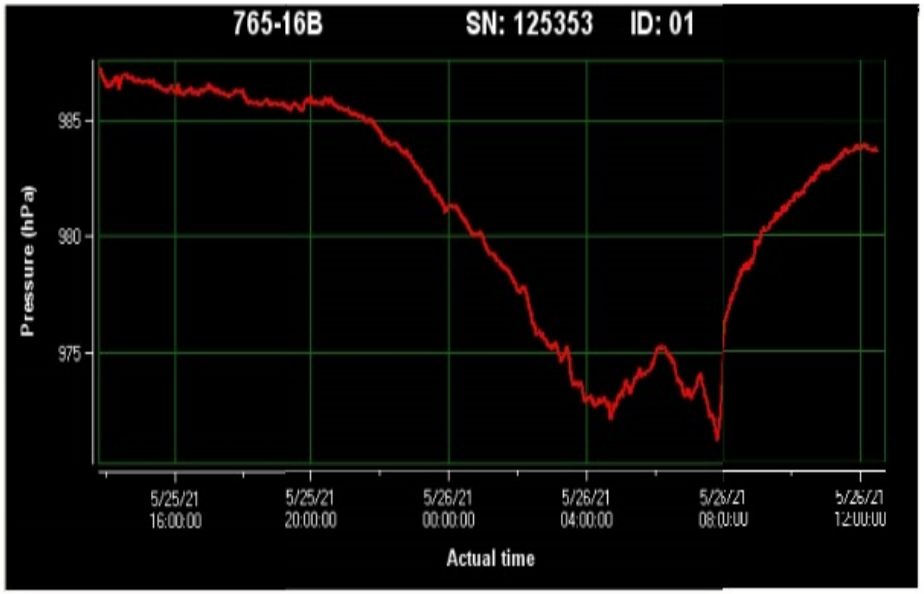
- *Outflow layer:* Above 7.6 km. Maximum outflow at 12 km height.
- Flow is cyclonic near core but anti-cyclonic further outwards.
- diameter is small and is about 1° Lat/ Long at 12 km height.

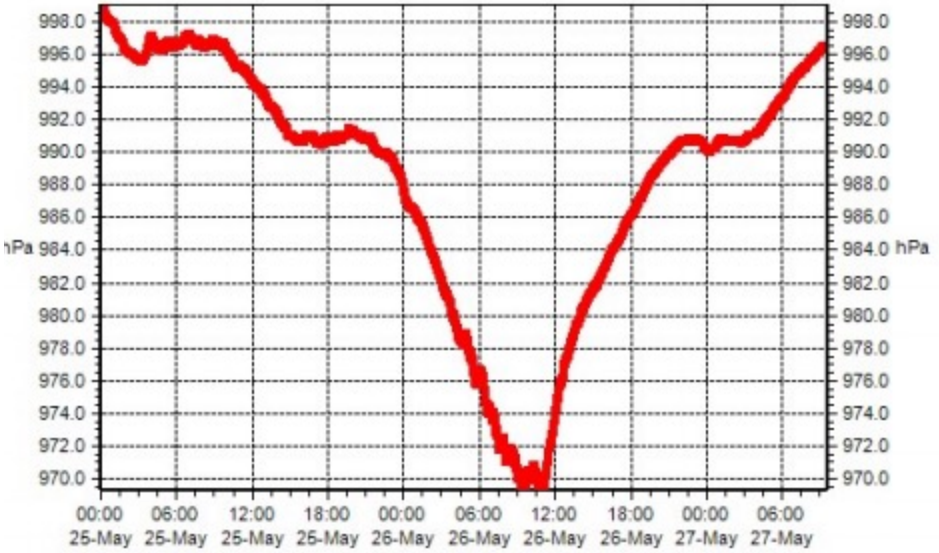
Wind and pressure: Dhamara

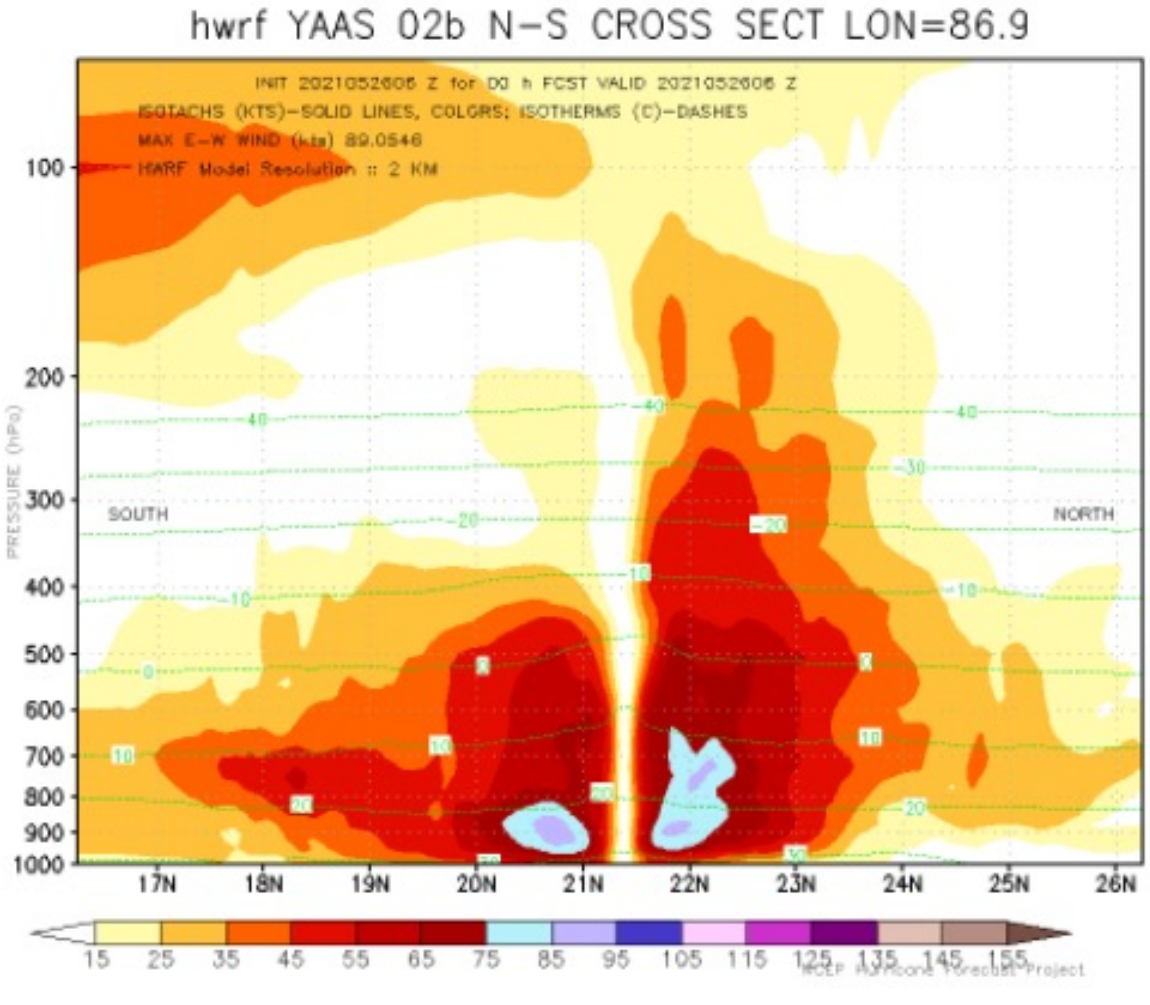


Wind and pressure: Chandipur





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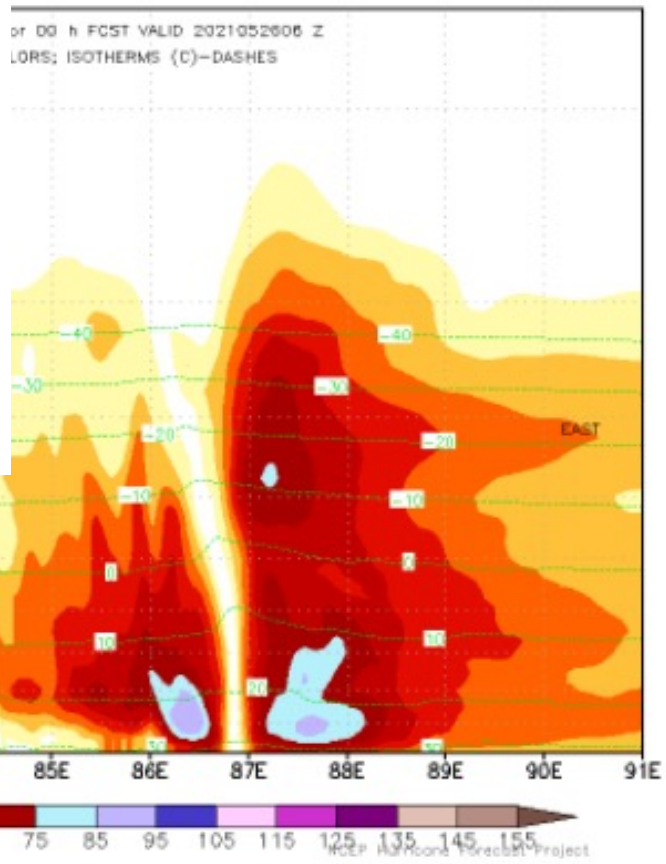
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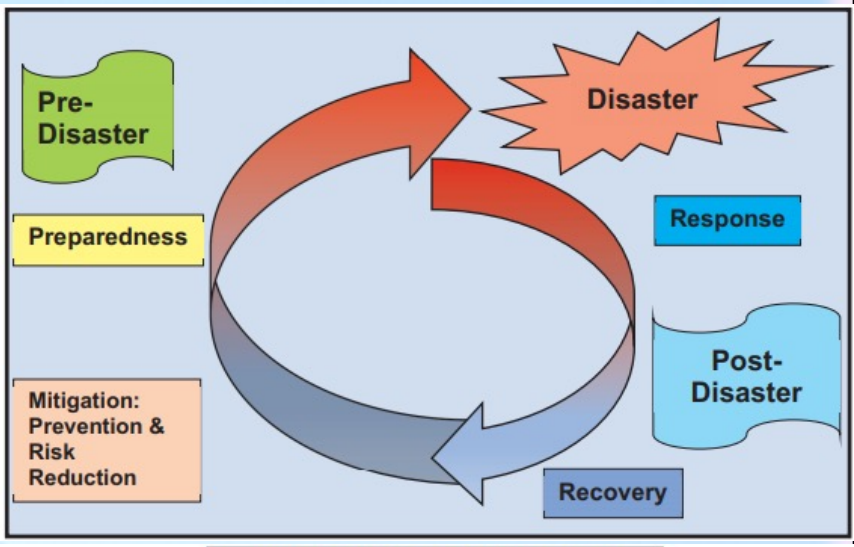
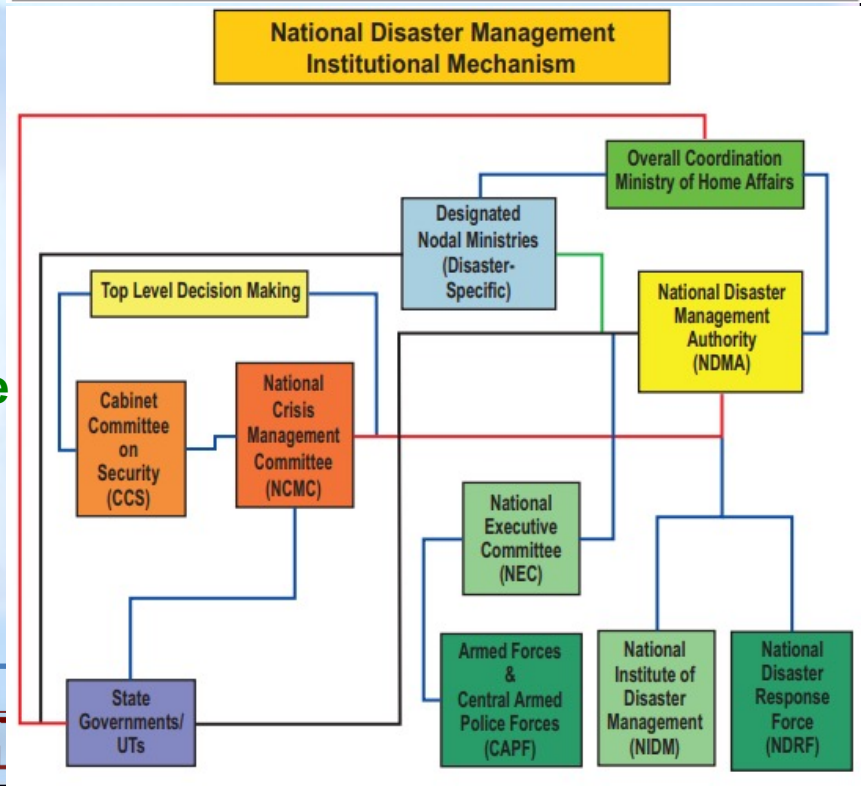
भारत
INDIA ME

Chasing the cyclone for Mitigation

- Reduction of cyclone disasters depends on several factors including
  - hazard analysis,
  - vulnerability analysis,
  - preparedness & planning,
  - early warning and mitigation.
- The early warning component includes
  - skill in monitoring and prediction of cyclone,
  - effective warning products generation and dissemination,
  - coordination with emergency response units and
  - the public perception about the credibility of the official predictions and warnings.

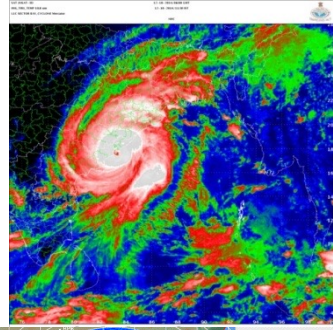


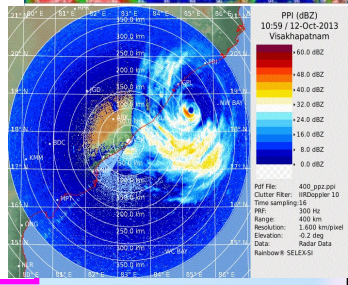


Chasing the cyclone through Early Warning System

Broad Classification of Observations

- **Space Based**
  - Geoststionary Satellites
  - Polar Orbiting Satellites
- **Upper Air**
  - Pilot Balloon
  - RSRW
  - Profiler
  - Ground Based RADAR
  - Aircraft
- **Surface**
  - AWS
  - ARG
  - SYNOP
  - BUOYS
  - AVIATION
  - SHIPS





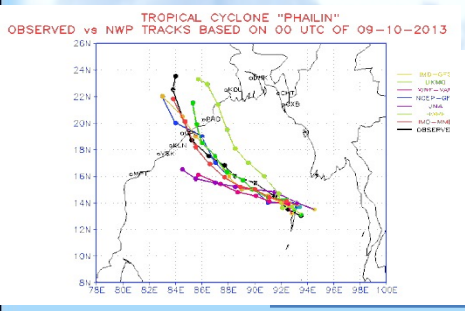
Initial conditions (Observations)

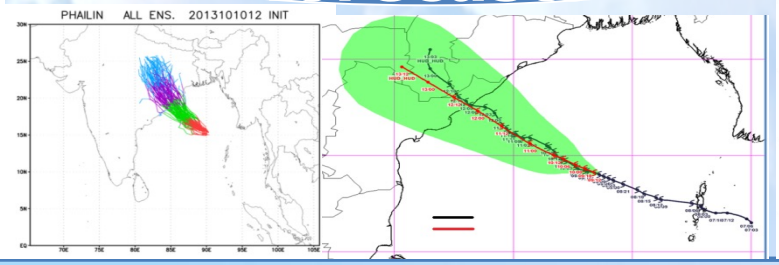
Runs of different Models,

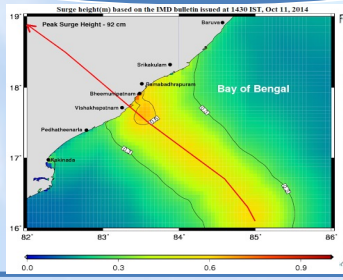
Consecutive runs from the same model,

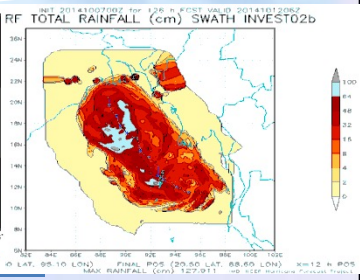
Ensemble runs ("choosing the best member")

Model → **Forecaster** → **Numerical forecasts** → **End forecast** → **Decision maker** → **Action**









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INDIA METEOROLOGICAL DEPARTMENT

Numerical Weather Prediction (NWP) Modeling in MoES: Backbone for Forecasting and Warning Services

Models in 2021 :

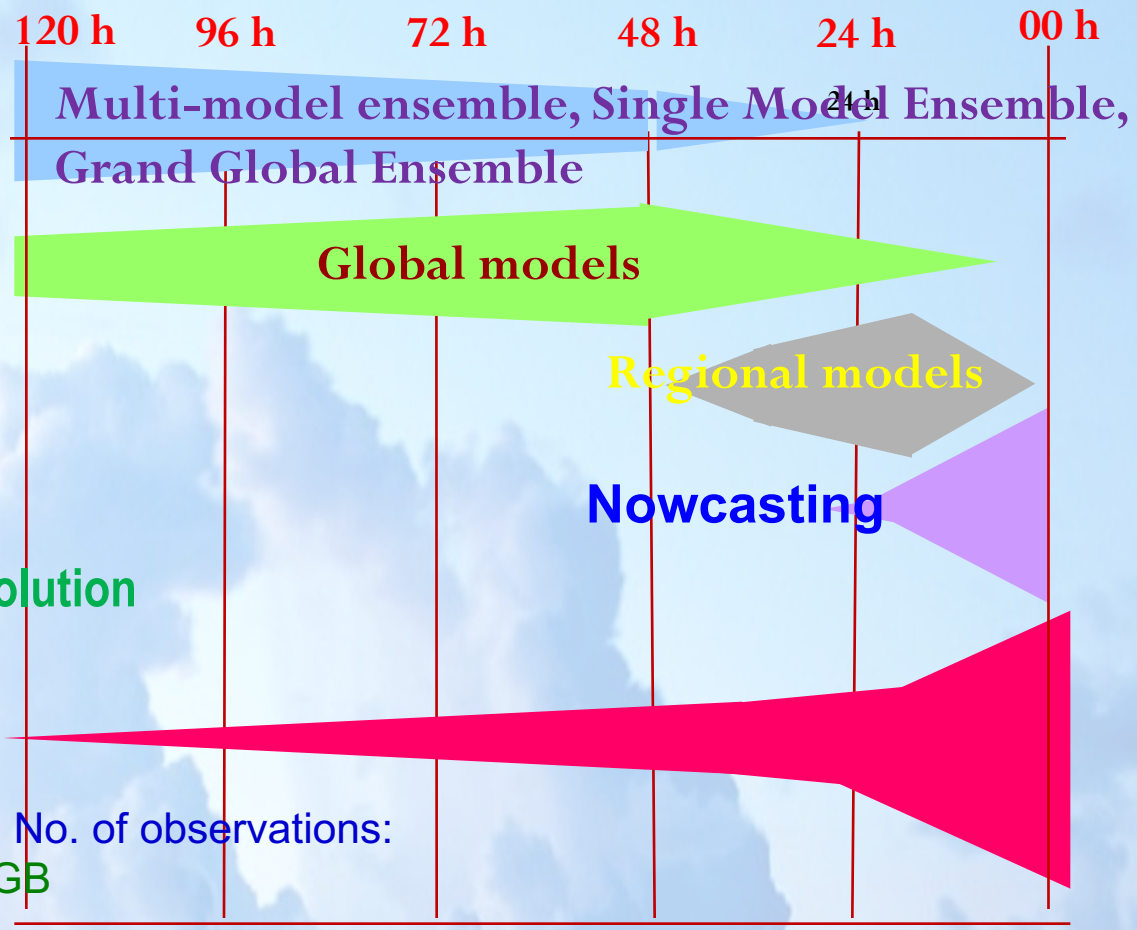
Ensemble Pred. Model
GEFS(1534/574), UMEPS

Global Models
GFS(T1534/574), Unified Model

Regional Models
WRF (3/2KM), HWRF(18/6/2kms)

Nowcasting Tools
(SWIRLS,ARPS Model, High Resolution Rapid Refresh(HRRR) model)

Warnings Activities



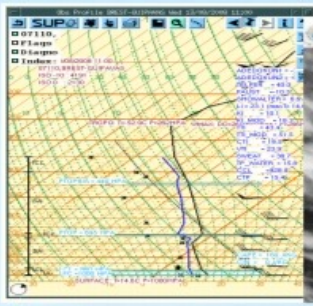
- Assimilated every 6 hours: Typical No. of observations:
- Satellite: 32 GB, Conventional: ~ 1 GB

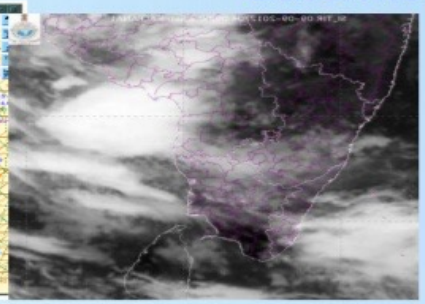
Global Model GFS T1534 (12 km/L 64); Unified Model (12 km/L 70) ; Ensemble Modelling System (GEFS-21) Member/12 km/l 64 & UMEPS – 21 Members/12 km/L70) ; Coupled NCUM-NEMO (25 KM/L70)

Decision Support System for cyclone forecasting:

Geospatial Application in decision making

Satellite



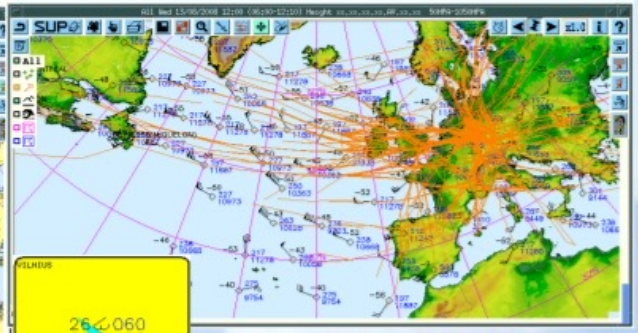


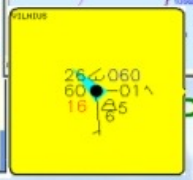
Global plotting

Conditional plotting

Profile

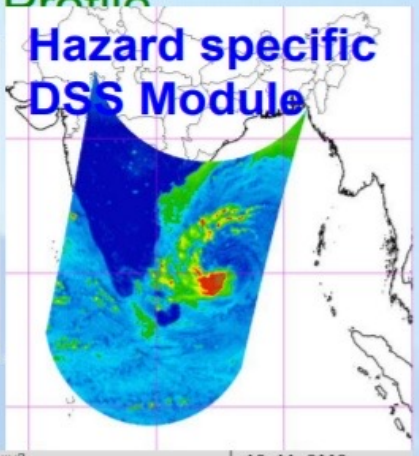
But available at limited places



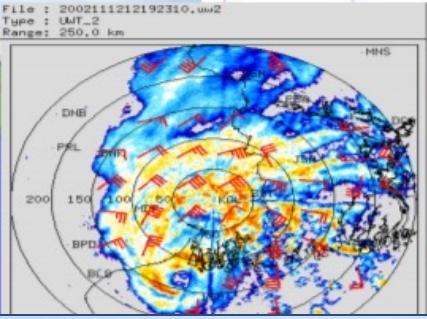


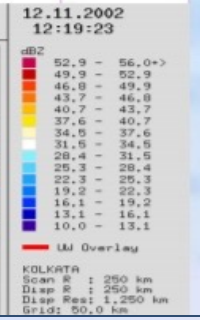
Plane trajectories

Hazard specific DSS Module



Gau





Centre and Intensity estimation of cyclones

(a) Satellite:

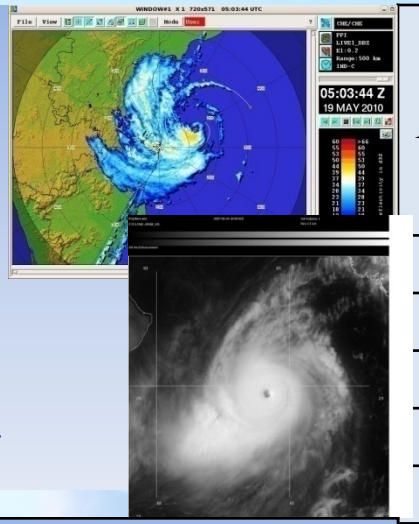
(1) INSAT-3D, 3DR, ScatSat

(2) Other international satellites

(b) Radar

(c) Synoptic analysis

(d) Consensus location and intensity



Low pressure system	T No.	Maximum sustained surface wind speed		
		knots	mps	kmph
Low (L)/ Well marked Low	LLC/T 1.0	< 17	< 9	< 31
Depression (D)	T 1.5	17-27	9-14	31-49
Deepdepression	T 2.0	28-33	15-17	50-61
Cyclonicstorm(CS)	T 2.5-3.0	34-47	18-24	62-88
Severe CS storm	T 3.5	48-63	25-32	89-117
Very Severe CS	T 4.0-4.5	64-89	33-46	118-166
Extremely Severe CS	T 5.0-6.0	90-119	47-61	167-221
Super CS	T 6.5-8.0	>119	>61	>221

C.I. Number	*Max. Wind Speed (knots)*	*Pressure depth (in mb)*
1	25	3.1
1.5	25	3.1
2	30	4.5
2.5	35	6.1
3	45	10.0
3.5	55	15.0
4	65	20.9
4.5	77	29.4
5	90	40.2
5.5	102	51.6
6	115	65.6
6.5	127	80.0
7	140	97.2
7.5	155	119.1
8	170	143.3

MENT

Centre and Intensity Forecasting of cyclones

(a) Extended Range (Two weeks) Forecast of Genesis of cyclone and its location issued every Thursday

(b) Tropical Weather Outlook (Five days) issued daily :

(c) Objective Track, intensity and structure forecast valid for next five days issued every six/three hour from depression/cyclone stage

(d) Landfall point and time forecast every three hrs during cyclone period

(e) Hourly update 12 hrs prior to landfall

(f) Adverse weather forecast at district level valid for five days

- Heavy rain
- Gale wind
- Storm surge and coastal inundation

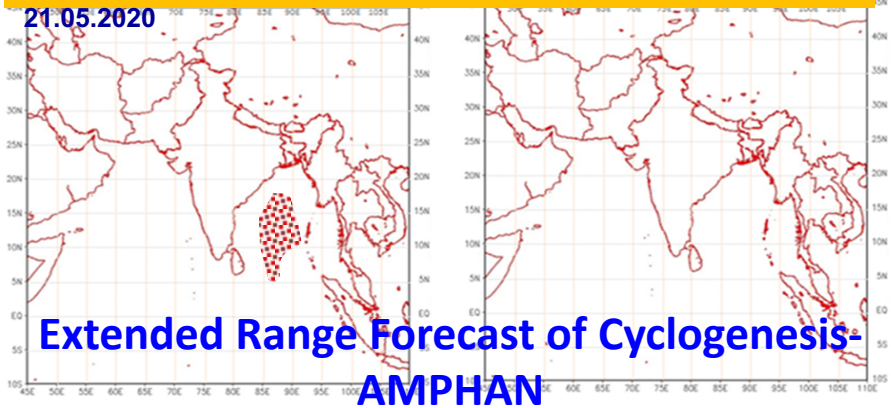
(f) Forecast of expected damage

(g) Suggested action

Extended and Short to Medium Range Genesis Forecast

NORTH INDIAN OCEAN EXTENDED RANGE OUTLOOK FOR CYCLOGENESIS

WEEK 1: 08.05.2020-14.05.2020 **WEEK2: 15.05.2020-21.05.2020**

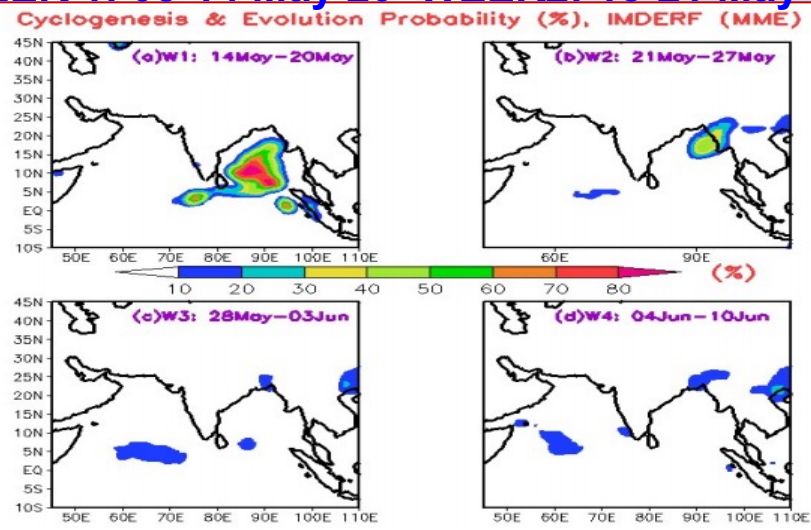


Extended Range Forecast of Cyclogenesis-AMPHAN

PROBABILITY OF CYCLOGENESIS
(FORMATION OF DEPRESSION OR HIGHER INTENSITY)
LOW (1-33% PROBABILITY)
MODERATE (34-67% PROBABILITY)
HIGH (68-100% PROBABILITY)

CONFIDENCE

WEEK 1: 08-14 May 20 WEEK2: 15-21 May 20



Medium Range Forecast of Cyclogenesis-AMPHAN

World Meteorological Organization

REGIONAL SPECIALISED METEOROLOGICAL CENTRE-TROPICAL CYCLONES, NEW DELHI
TROPICAL WEATHER OUTLOOK

DEMS-RSMC TROPICAL CYCLONES NEW DELHI DATED 13.05.2020

TROPICAL WEATHER OUTLOOK FOR NORTH INDIAN OCEAN (THE BAY OF BENGAL AND ARABIAN SEA) VALID FOR NEXT 120 HOURS ISSUED AT 0600 UTC OF 13.05.2020 BASED ON 0300 UTC OF 13.05.2020.

BAY OF BENGAL:

A LOW PRESSURE AREA HAS FORMED OVER SOUTHEAST BAY OF BENGAL (BOB) AND ADJOINING SOUTH ANDAMAN SEA WITH ASSOCIATED CYCLONIC CIRCULATION EXTENDING UPTO MID-TROPOSPHERIC LEVELS.

IT IS VERY LIKELY TO CONCENTRATE INTO A DEPRESSION OVER CENTRAL PARTS OF SOUTH BAY OF BENGAL ON 15TH MAY AND FURTHER INTENSIFY INTO A CYCLONIC STORM OVER SOUTHWEST AND ADJOINING WESTCENTRAL BAY OF BENGAL BY 16TH EVENING. IT IS VERY LIKELY TO MOVE NORTHWESTWARDS INITIALLY TILL 17TH AND THEN RECURVE NORTH-NORTHEASTWARDS.

PROBABILITY OF CYCLOGENESIS DURING NEXT 120 HRS:

0-24 HRS	24-48 HRS	48-72 HRS	72-96 HRS	96-120 HRS
NIL	NIL	MOD	HIGH	HIGH

TC TRACK & INTENSITY MONITORING AND FORECASTING

i) **Statistical Techniques**

Analogue, Persistence, Climatology, CLIPER

i) **Synoptic Techniques**

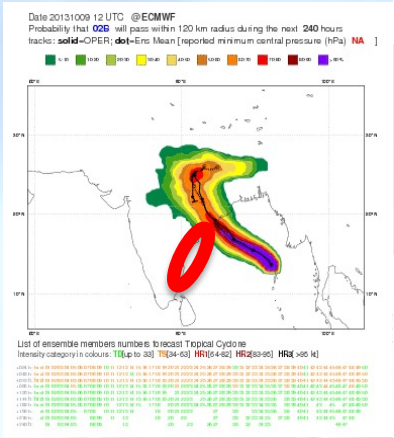
ii) **Satellite Techniques**

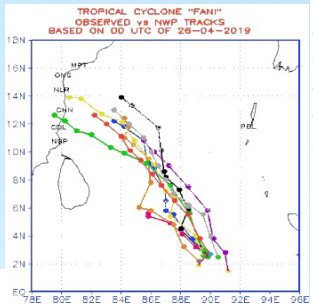
iii) **Radar Techniques**

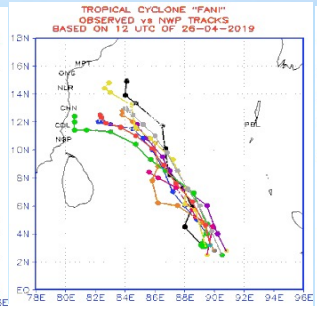
v) **NWP Models**

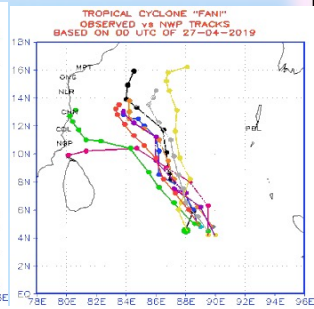
- Individual models
- IMDGFS (1534), NCUM, ECMWF Meteo-France(ARP), JMA, UKMO, NCEP, WRF, HWRF (IMD), UM-R
- Multi-model Ensemble (MME)
- **EPS (Strike probability, Location specific probability :**

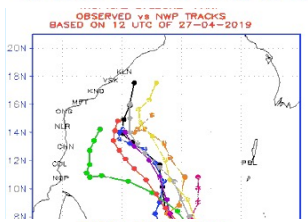
v) **Dynamical Statistical ModelS for genesis, intensity, rapid intensification and decay after landfall**

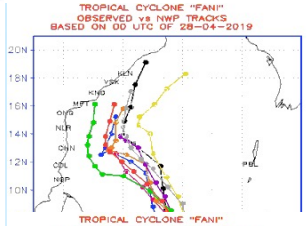


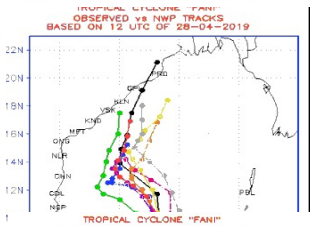


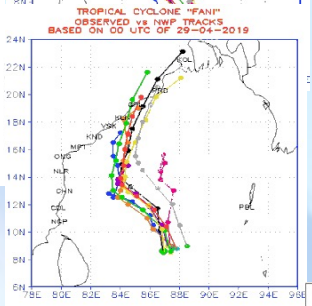


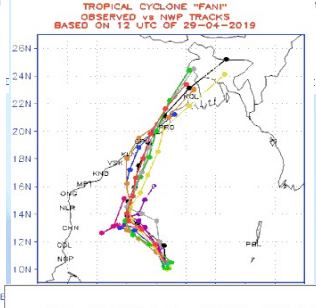


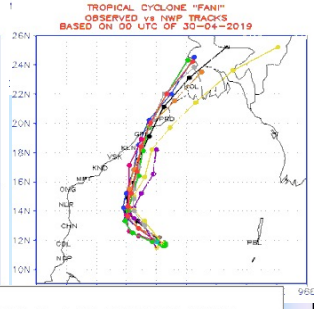


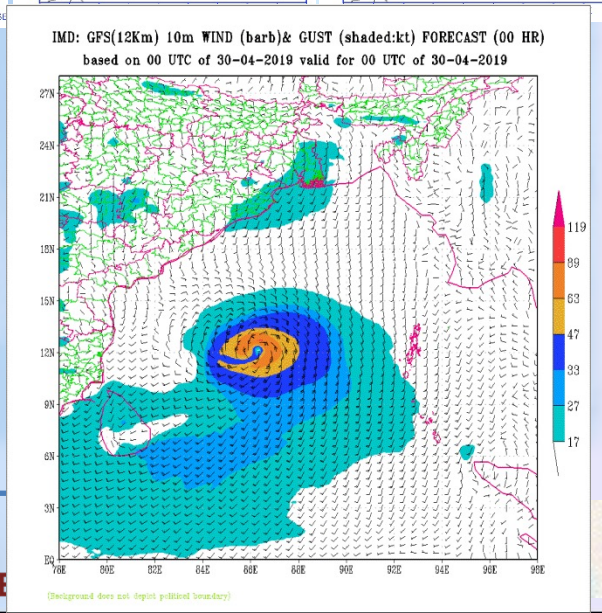












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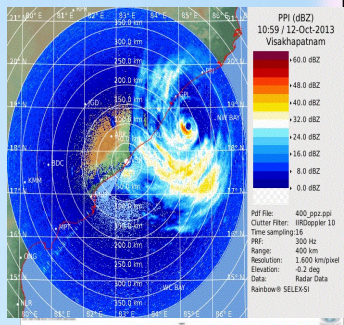
Warning Products

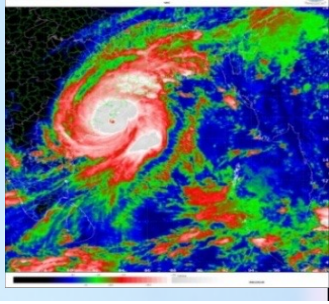
» Four stage cyclone warning

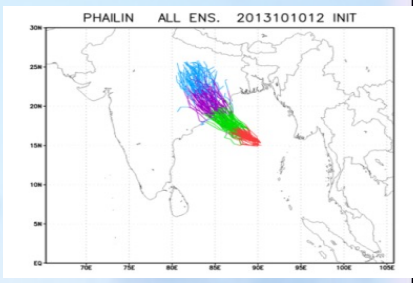
- Sea area bulletin
- Coastal weather bulletin
- Bulletins for Indian navy
- Fisheries warnings
- Port warnings
- Aviation warning
- Bulletin-for AIR/TV/ press
- Warnings for registered users.

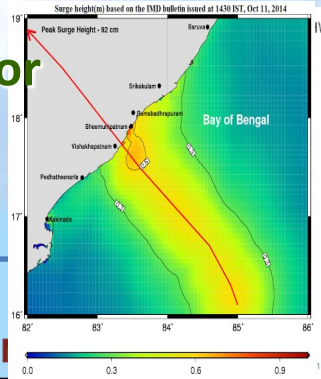
Stages of Warning

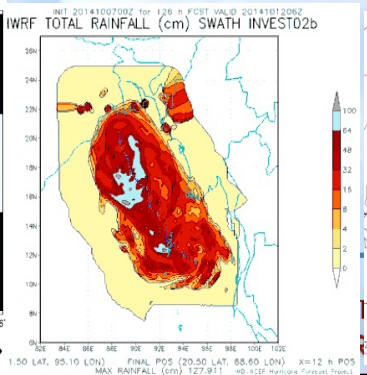
- Pre-cyclone watch (Yellow)–72 hrs in advance
- Cyclone Alert (Orange)-48 hrs in advance.
- Cyclone warning (Red)–24 hrs in advance.
- Post-Landfall Outlook- 12 hrs before landfall
- De-Warning- When Cyclone weakens.

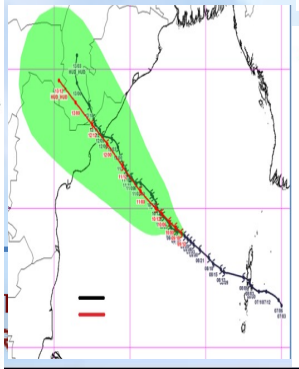


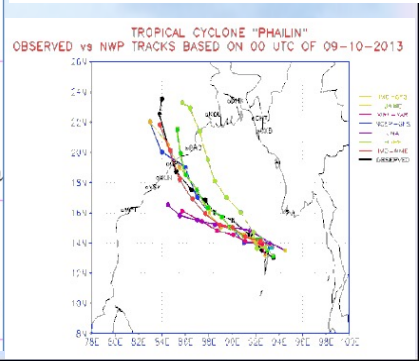




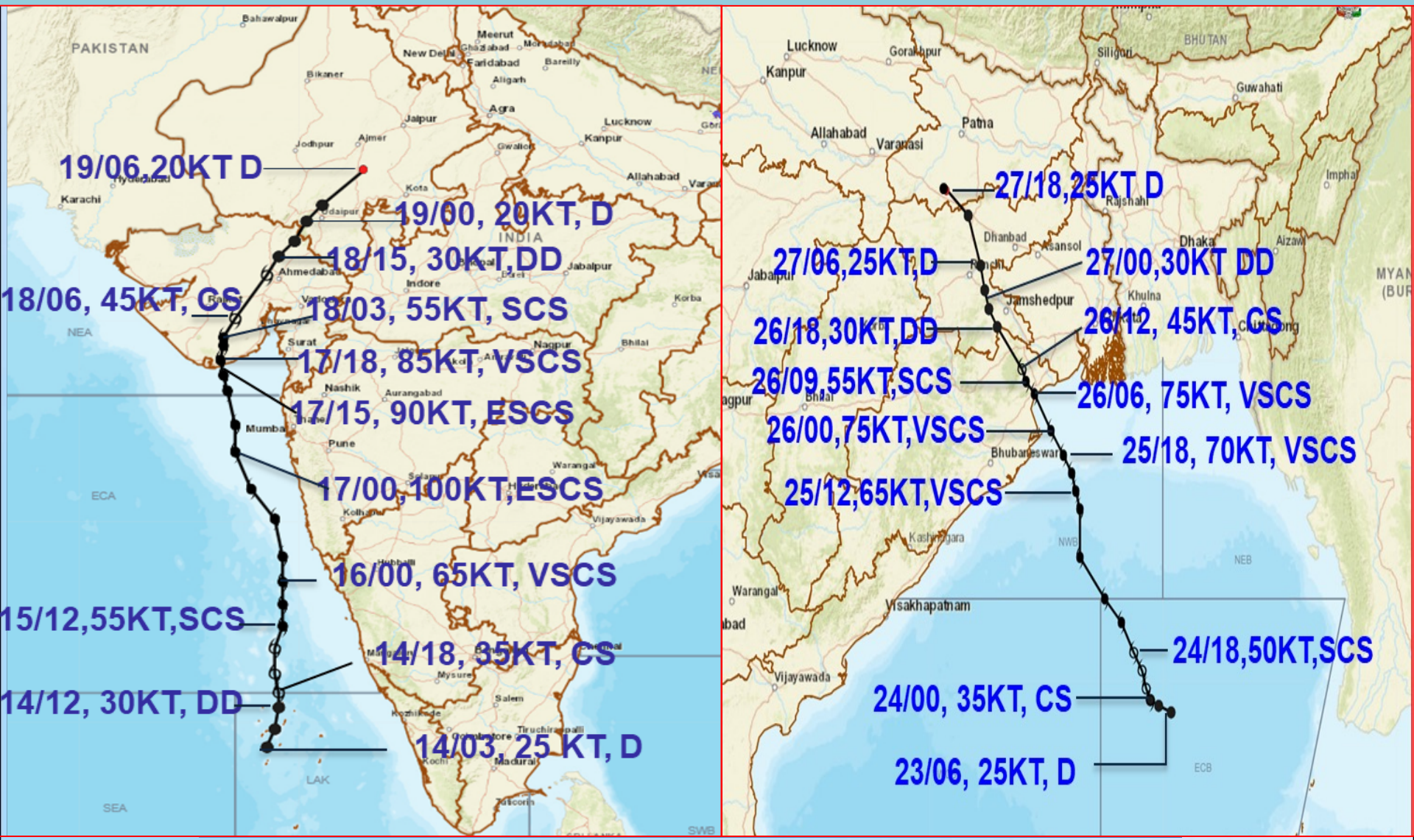








Recent Cyclone:TaukTae and Yaas



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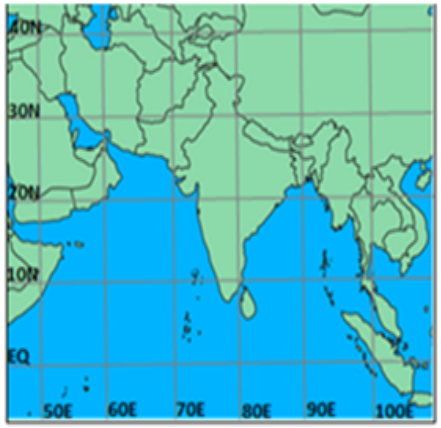
INDIA METEOROLOGICAL DEPARTMENT

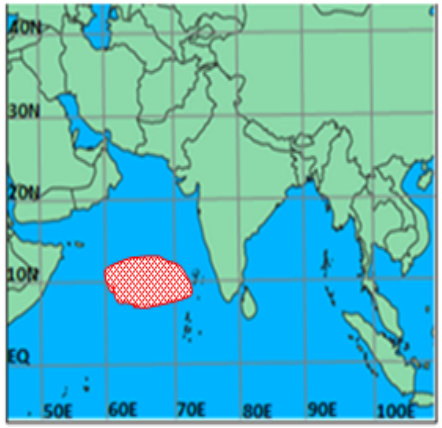
GENESIS FORECAST

NORTH INDIAN OCEAN EXTENDED RANGE OUTLOOK
FOR CYCLOGENESIS

Week1: 07.05.2021-13.05.2021



Week2: 14.05.2021-20.05.2021



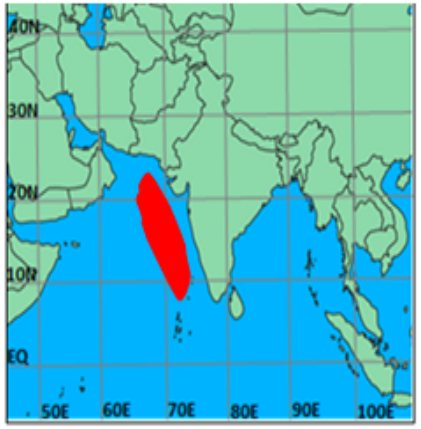
PROBABILITY OF CYCLOGENESIS
(FORMATION OF DEPRESSION OR HIGHER INTENSITY)

LOW	(1-33% PROBABILITY)
MODERATE	(34-67% PROBABILITY)
HIGH	(68-100% PROBABILITY)

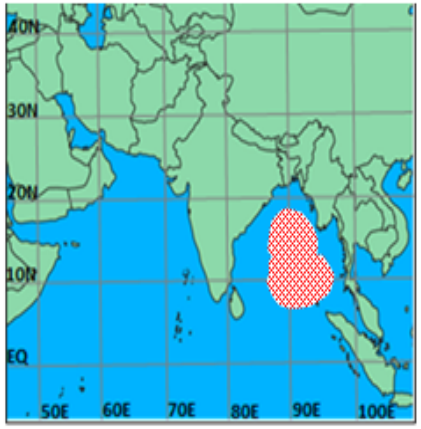
CONFIDENCE

NORTH INDIAN OCEAN EXTENDED RANGE OUTLOOK
FOR CYCLOGENESIS

Week1:14.05.2021-20.05.2021



Week2: 21.05.2021-27.05.2021



PROBABILITY OF CYCLOGENESIS
(FORMATION OF DEPRESSION OR HIGHER INTENSITY)

LOW	(1-33% PROBABILITY)
MODERATE	(34-67% PROBABILITY)
HIGH	(68-100% PROBABILITY)

CONFIDENCE

Extended range outlook dated 6th May indicated development of depression over southeast Arabian Sea and adjoining Lakshdweep during 14th-16th May

Depression formed over Lakshdweep on 14th May

Extended range outlook dated 13th May indicated HIGH probability of cyclogenesis and movement of system towards Gujarat coast parallel to West coast of India during 14-20 May. Tauktae moved parallel to West coast of India & crossed south Gujarat coast on 18th May

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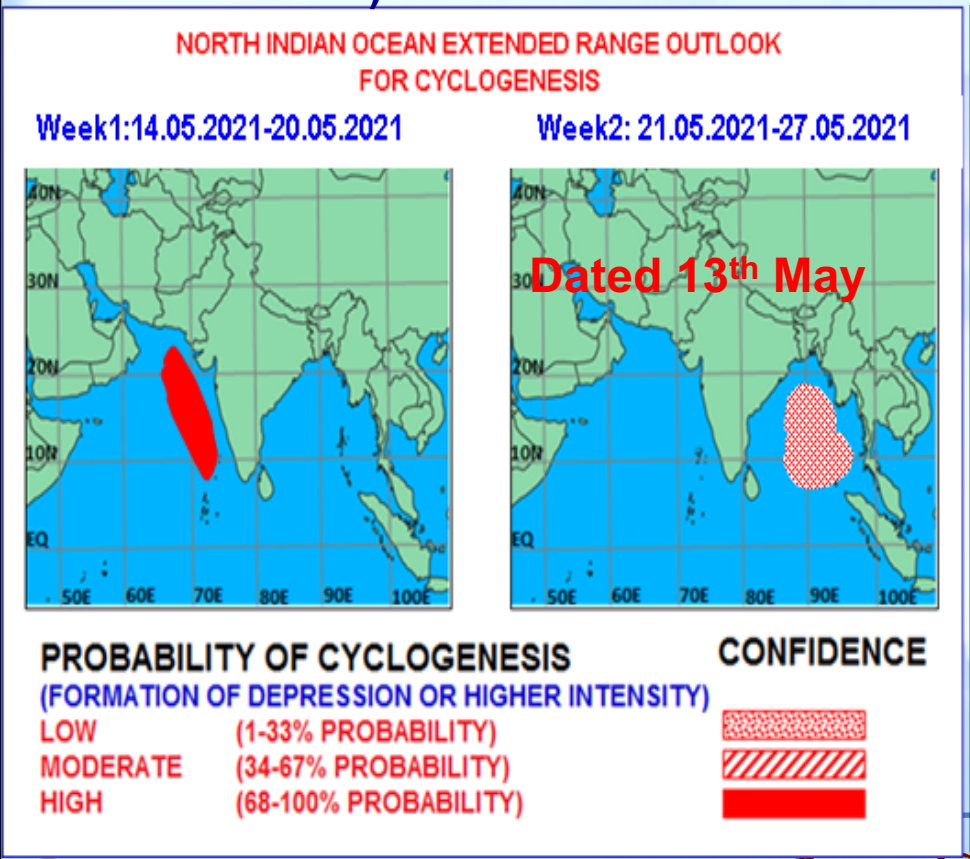
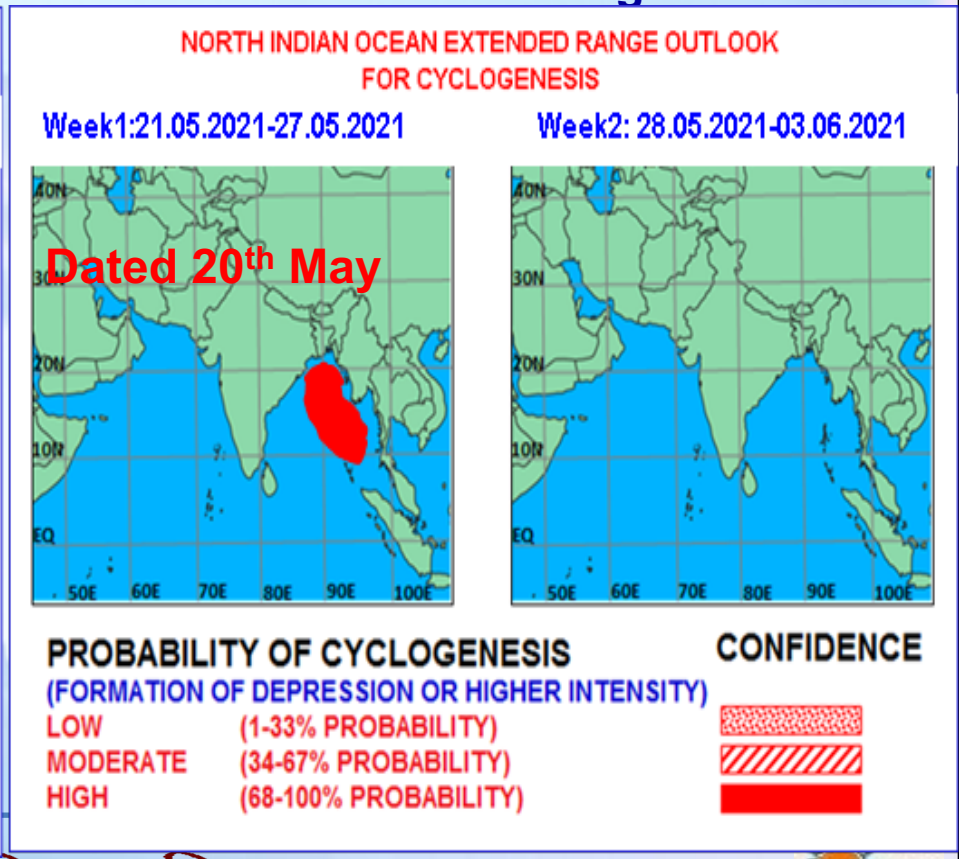
INDIA METEOROLOGICAL DEPARTMENT

GENESIS FORECAST

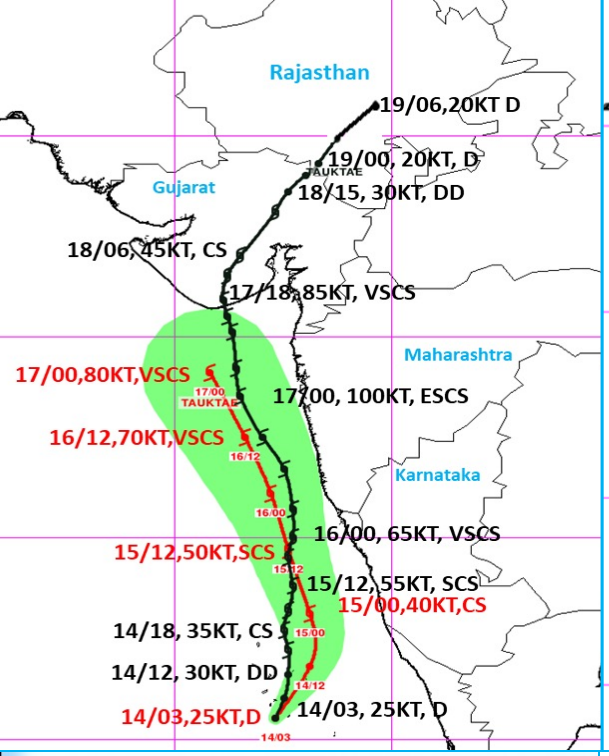
- Extended range outlook issued on 13th May indicated development of depression over eastcentral BoB with (1-33% probability) during 21st-23rd May (about 10 days prior to formation of formation of depression over on 23rd).

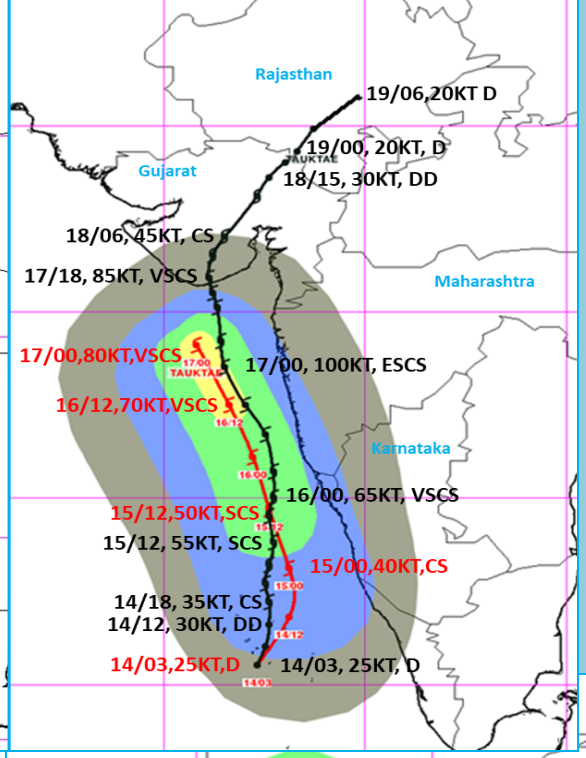
Extended range outlook issued on 20th May (3 days prior to formation of depression on 23rd and 6 days prior to cyclone reaching Odisha-West Bengal coasts on 26th) indicated high probability (67-100%) of system moving towards Odisha-West Bengal coasts.





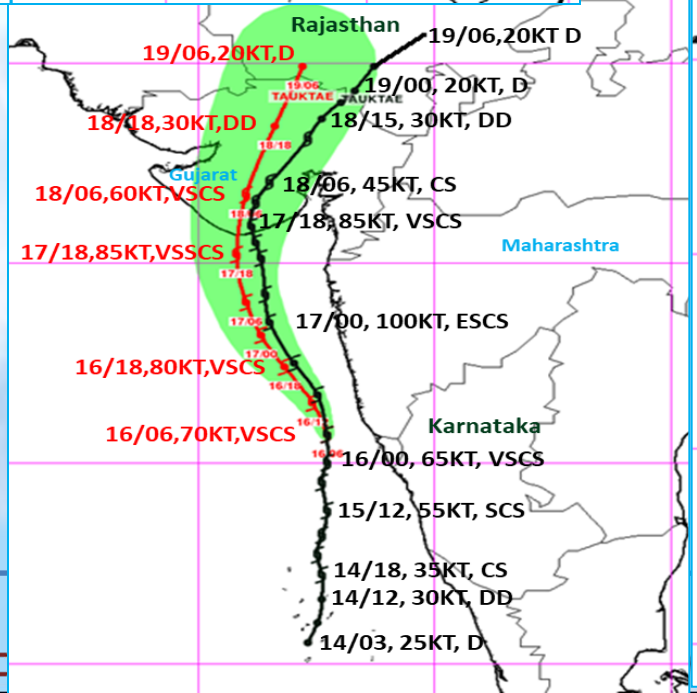
Tauktae: Forecast and actual track and intensity

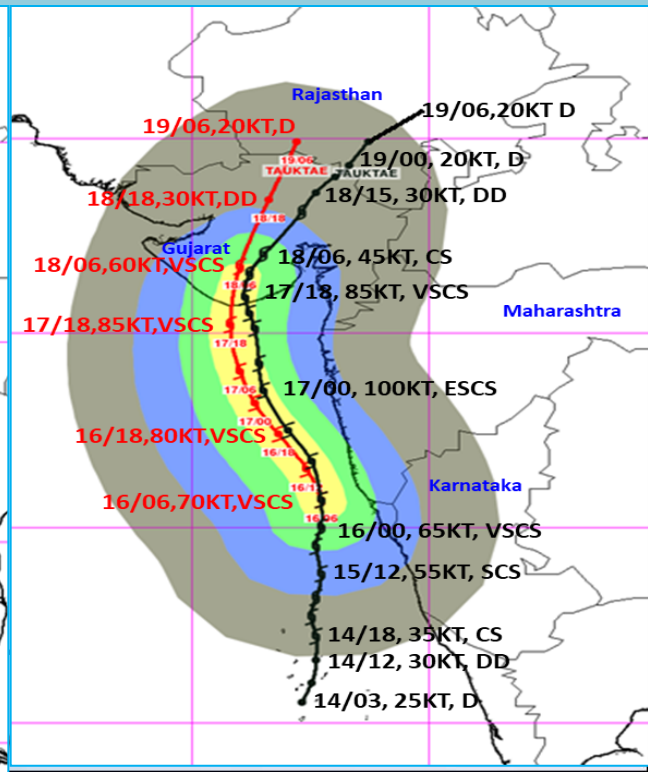




DATE/TIME IN UTC, IST = UTC + 0530 HRS, D: DEPRESSION, DD: DEEP DEPRESSION, CS: CYCLONIC STORM, SCS: SEVERE CYCLONIC STORM, VSCS: VERY SEVERE CYCLONIC STORM,

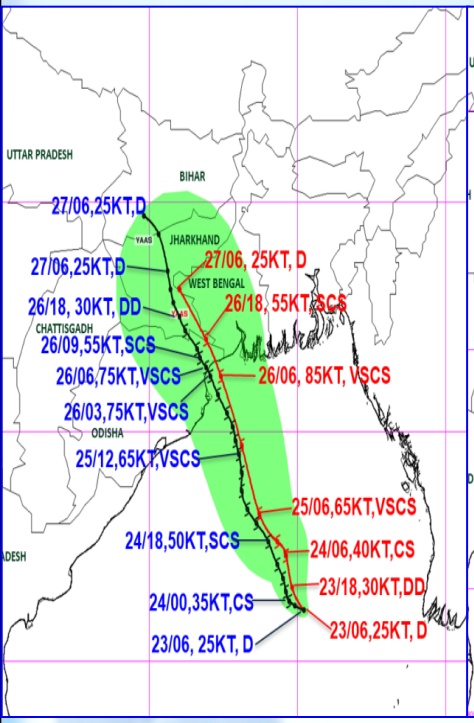
OBSERVED TRACK,
FORECAST TRACK,
CONE OF UNCERTAINTY

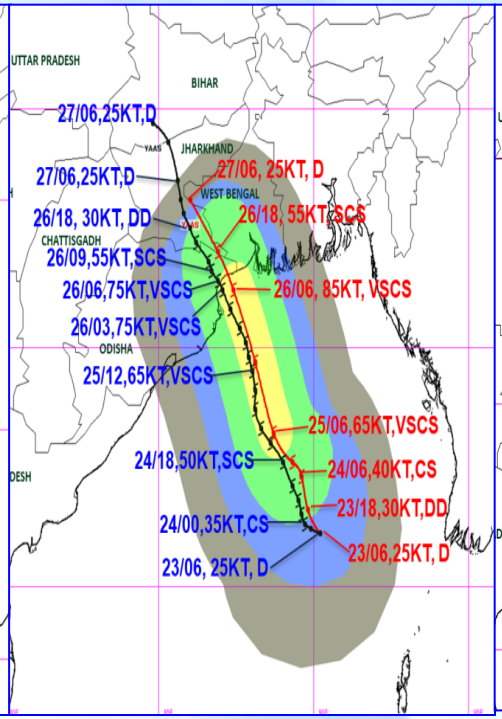




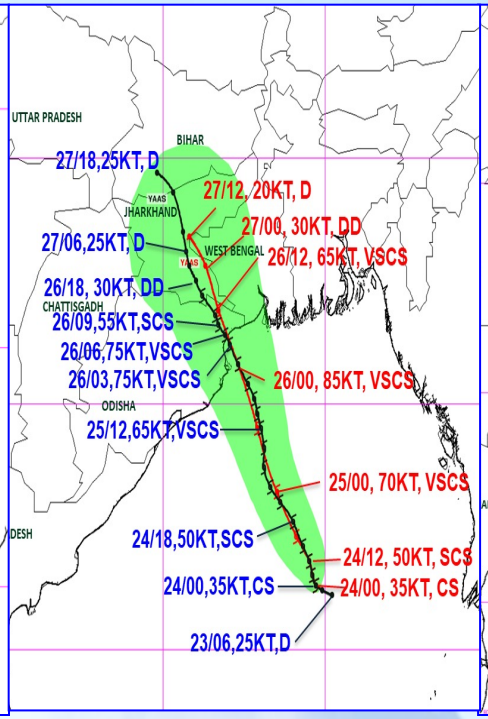
FORECAST ACCURACY- TRACK, LANDFALL & INTENSITY

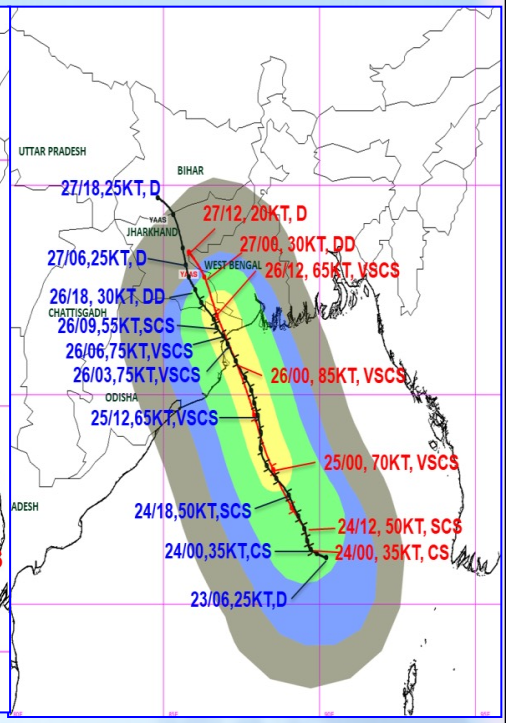
Forecast issued at 1350 hours IST of 23rd May(72 hours prior to landfall)





Forecast issued at 0900 hours IST of 24th May(54 hours prior to landfall)





From 1st Bulletin it was indicated that system would intensify upto VSCS stage, affect Odisha-West Bengal States and cross North Odisha coast on 26th A/N

Forecast issued on 24th morning demonstrating accuracy in track, landfall & intensity prediction

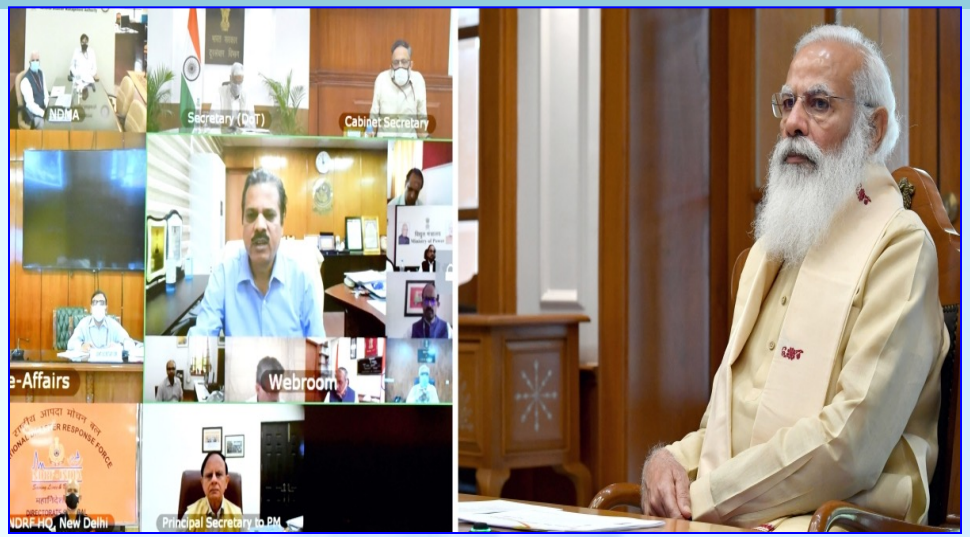
DATE/TIME IN UTC, IST = UTC + 0530 HRS, D: DEPRESSION, DD: DEEP DEPRESSION, CS: CYCLONIC STORM, SCS: SEVERE CYCLONIC STORM, VSCS: VERY SEVERE CYCLONIC STORM, OBSERVED TRACK, FORE(TRACK, CON OF UNCERTAINTY

MSW(knot)/kmph)	Impact	Action
28-33 /(52–61)	Very rough seas.	Total suspension of fishing operations
34-40/(62-74)	High to very high seas	Total suspension of fishing operations
41-63/(75-117)	Very High seas	Total suspension of fishing operations
≥ 64 (≥118)	Phenomenal	Total suspension of fishing operations

WARNING SERVICES DURING CYCLONE YAAS: AN EXAMPLE

- **1st Press Release**: **19th May (3 days prior to formation of LPA on 22nd May**). Adverse weather warnings and advisories for fishermen issued.
- **2nd Press Release & Special Message: 22nd May on formation of LPA (4 days prior to landfall**) indicating formation of cyclonic storm over Bay of Bengal and system to reach northwest BoB near north Odisha-West Bengal coasts around 26th morning.
- **Pre cyclone watch** for Odisha-West Bengal coasts issued at 1350 hrs IST of 23rd May, on development of depression over eastcentral BoB **(about 70 hours prior to landfall)**.
- **Cyclone alert** for Odisha-West Bengal coasts issued at 0830 hrs IST of 24th May, on intensification of the system into the cyclonic storm YAAS **(about 54 hours prior to landfall).**
- **Cyclone Warning** for Odisha-West Bengal coasts issued at 2030 hrs IST of 24th May, when the system was a cyclonic storm over eastcentral BoB **(about 39 hours prior to landfall)**
- **Post landfall outlook for interior districts of Odisha and West Bengal** issued at 1700 hrs IST of 25th, when system was an severe cyclonic storm over northwest and adjoining areas of BoB **(about 18 hours prior to landfall)**

MEETINGS ATTENDED BY DGM IMD

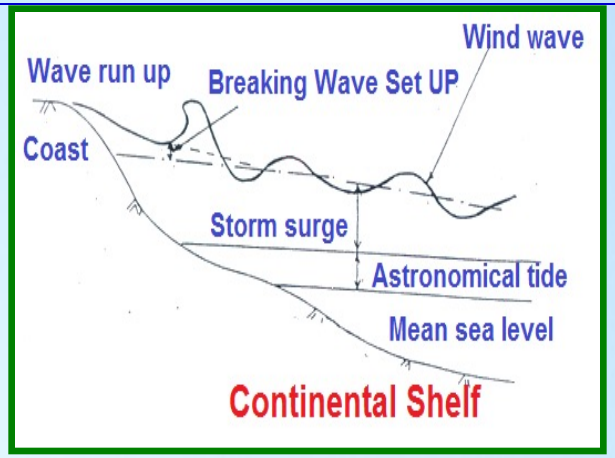


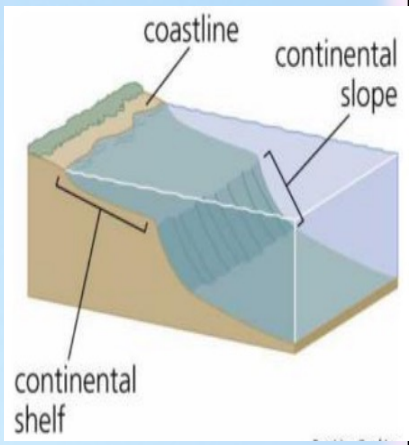
- High Level meeting chaired by Secretary, NDMA on 21st May.
- NCMC Meeting chaired by Cabinet Secretary on 21st May
- Briefing meeting under Chairmanship of Hon'ble Prime Minister on 22nd May.
- Preparedness Meeting chaired by Union Home Minister on 24th May.
- Review Meeting under joint Chairmanship of Hon'ble Ministers of State for Ports, Shipping & Waterways (I/C), Commerce & Industry and Petroleum and Natural Gas on 24th
- Briefing meeting under chairmanship of Hon'ble Prime Minister on 27th May.

Storm Surge and Coastal Inundation Guidance

Components of sea level elevation

- Astronomical Tide, Wind waves, Wave set up, Storm surge, Tsunamis

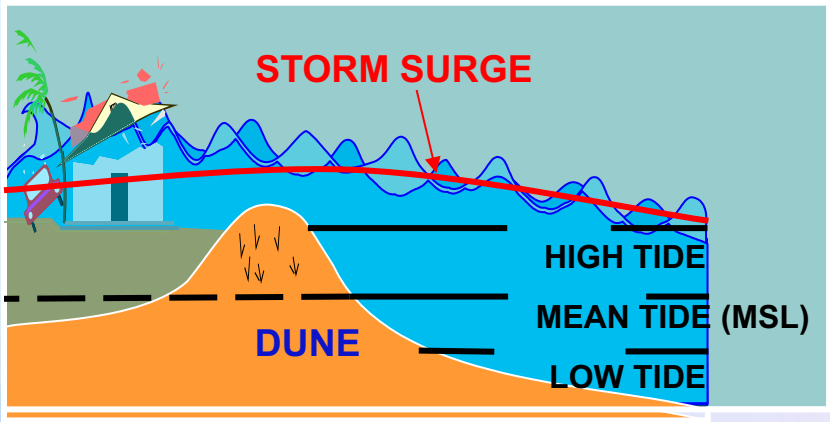




Factors affecting Storm Surge

- ❖ Meteorological factors: Intensity, wind stress, RMW, Size, Speed of storm, angle of hit.
- ❖ Hydrological factors: Past rainfall, current rainfall, soil moisture, storm tide, wave set up,
- ❖ Hydrometeorological factors: River discharge, run off
- ❖ Coastal bathymetry (shallow/deep) & coastal geometry (concave or convex towards sea)
- ❖ Topography

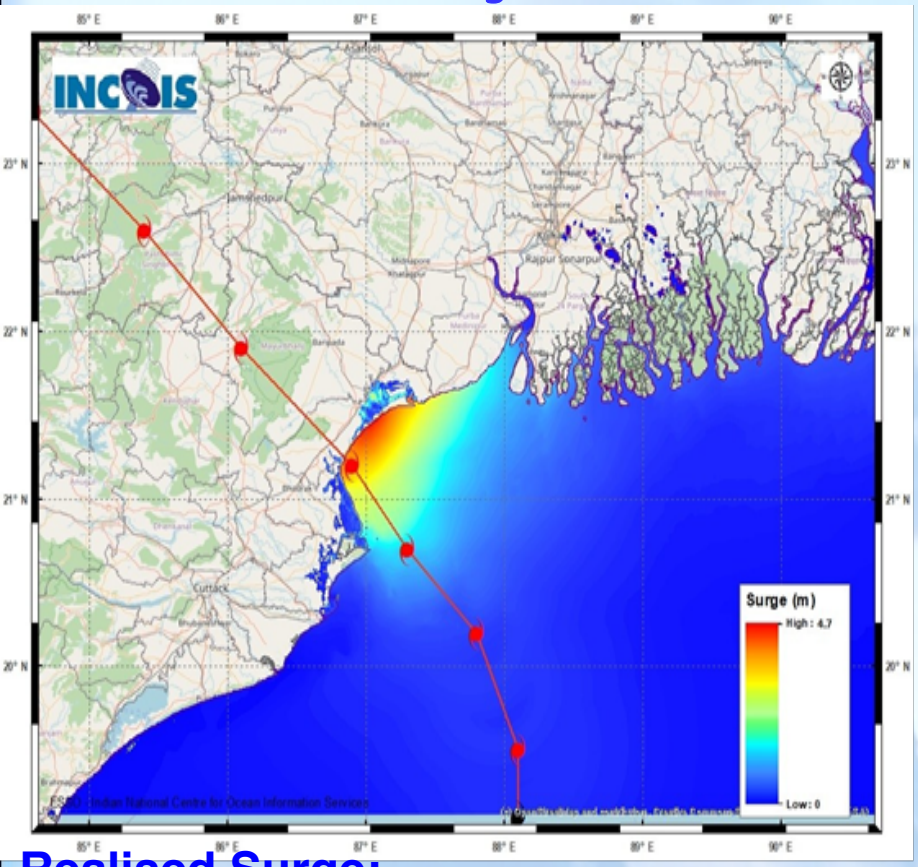
  (hills/ plains/ deltaic region)

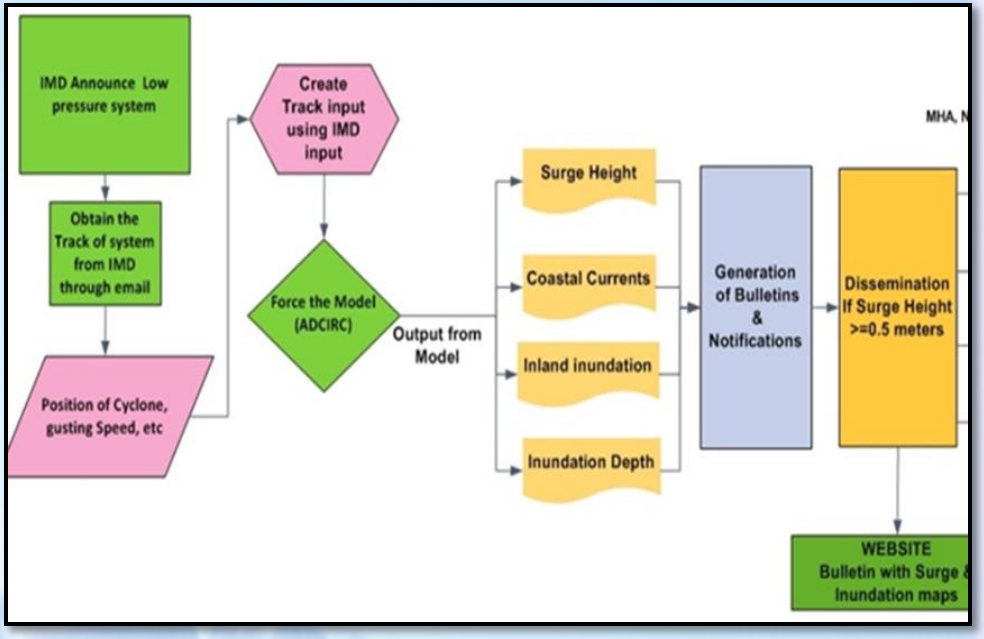


Forecast of Storm Surge

Forecasting

- ✓ Nomograms
- ✓ IITD model
- ✓ INCOIS Storm Surge Model





Forecast: Tidal waves of height 2-4 meters above astronomical tide to inundate low lying areas of Balasore, Bhadrak and 2 meters above astronomical tide to inundate low lying areas of Medinipur, 24 Parganas, Kendrapara & Jagatsinghpur Districts.

Realised Surge:

About 2-4 meters inundated low lying areas of Balasore and Bhadrak 24 parganas, medinipur districts).

Technology and Rainfall Mapping

Rainfall, Monitoring

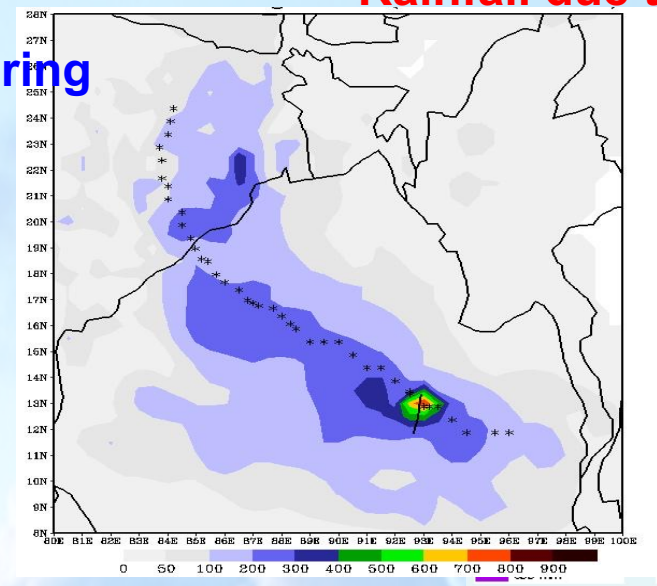
- ❖ Rain gauge based monitoring
- ❖ Satellite and Radar based monitoring

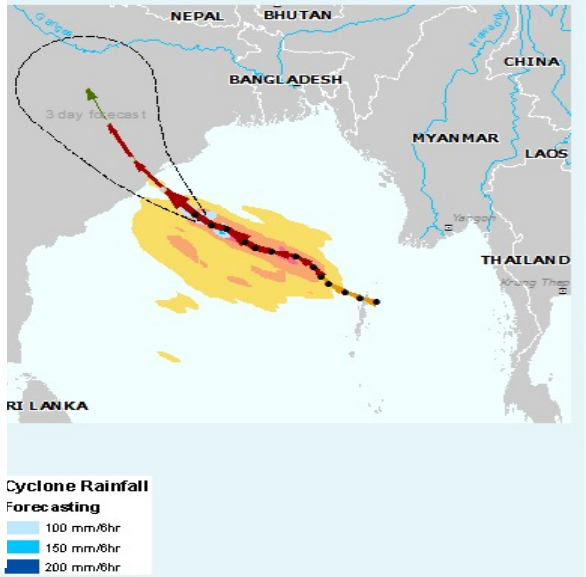
(ii) Gridded rainfall data ,

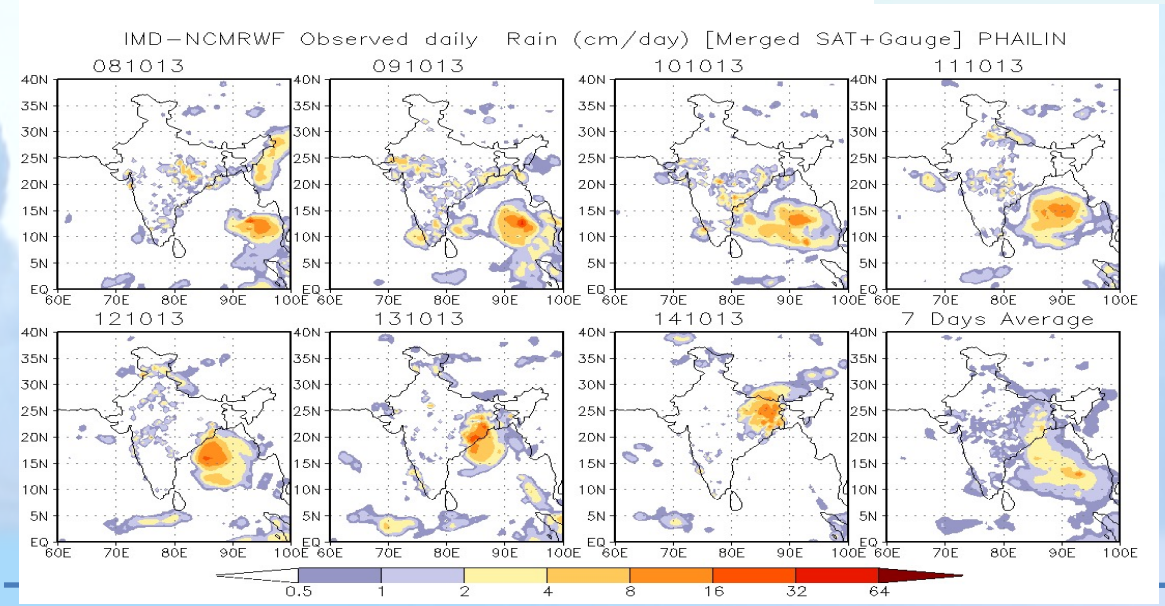
(iii) Satellite based merged gridded rainfall data

(iv) Global Precipiotation Measurement (GPM)

Rainfall due to Phailin, Oct. 2013







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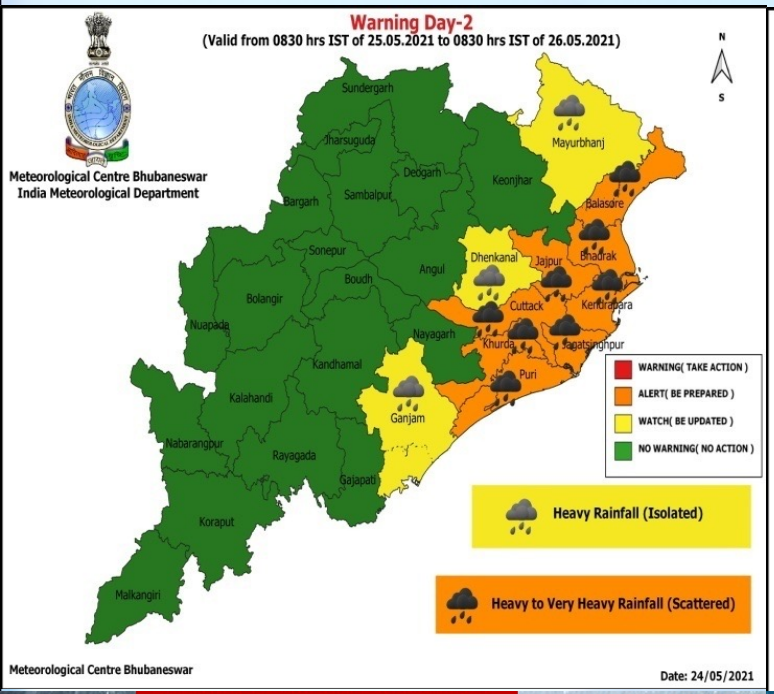
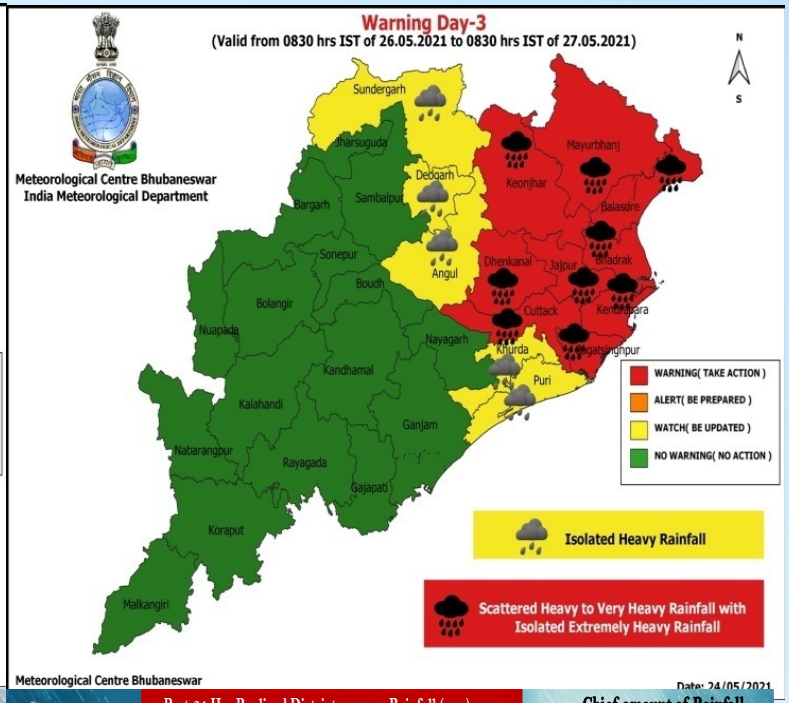
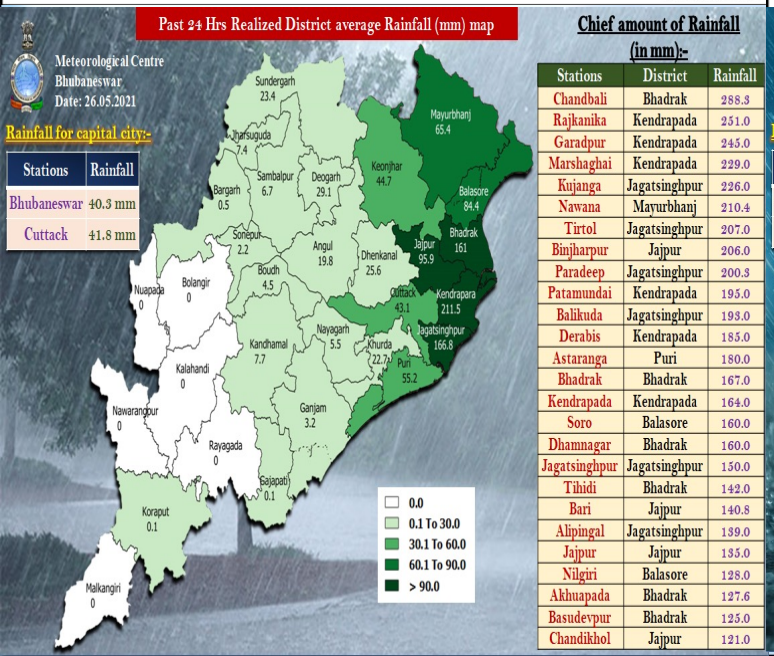
INDIA METEOROLOGICAL DEPARTMENT

Rainfall forecast Odisha





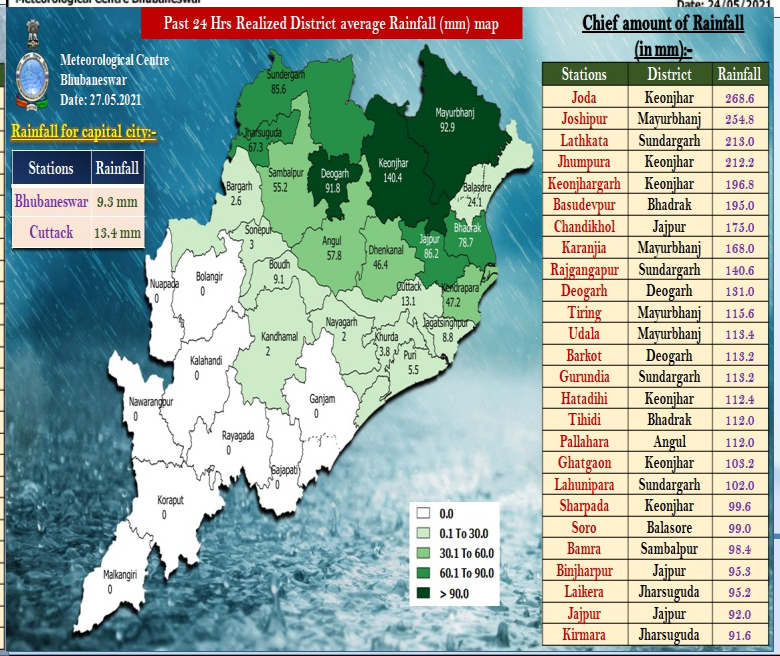


Rainfall for capital city:-

Stations	Rainfall
Bhubaneswar	40.3 mm
Cuttack	41.8 mm

Chief amount of Rainfall (in mm):-

Stations	District	Rainfall
Chandbali	Bhadrak	288.3
Rajkanika	Kendrapada	251.0
Garadpur	Kendrapada	245.0
Marshaghai	Kendrapada	229.0
Kujanga	Jagatsinghpur	226.0
Nawana	Mayurbhanj	210.4
Tirtol	Jagatsinghpur	207.0
Binjharpur	Jajpur	206.0
Paradeep	Jagatsinghpur	200.3
Patamundai	Kendrapada	195.0
Balikuda	Jagatsinghpur	193.0
Derabis	Kendrapada	185.0
Astaranga	Puri	180.0
Bhadrak	Bhadrak	167.0
Kendrapada	Kendrapada	164.0
Soro	Balasore	160.0
Dhamnagar	Bhadrak	160.0
Jagatsinghpur	Jagatsinghpur	150.0
Tihidi	Bhadrak	142.0
Bari	Jajpur	140.8
Alipingal	Jagatsinghpur	139.0
Jajpur	Jajpur	135.0
Nilgiri	Balasore	128.0
Akhuapada	Bhadrak	127.6
Basudevpur	Bhadrak	125.0
Chandikhol	Jajpur	121.0



Rainfall for capital city:-

Stations	Rainfall
Bhubaneswar	9.3 mm
Cuttack	13.4 mm

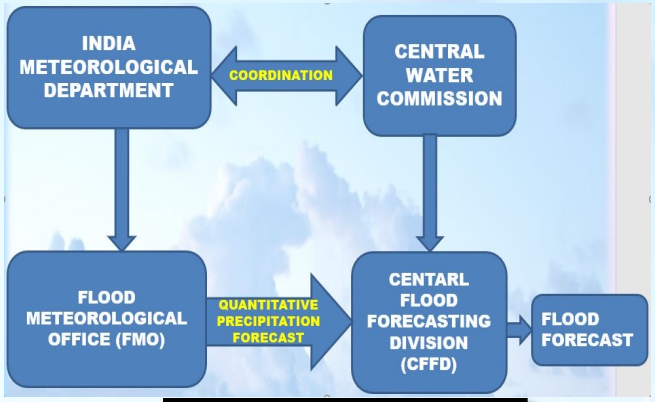
Chief amount of Rainfall (in mm):-

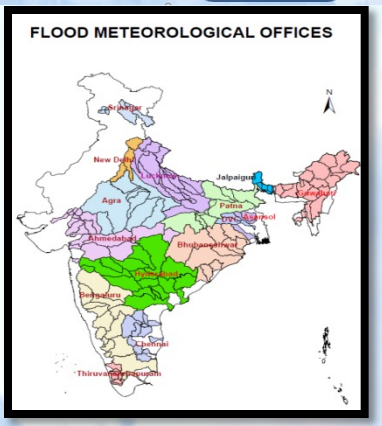
Stations	District	Rainfall
Joda	Keonjhar	268.6
Joshipur	Mayurbhanj	254.8
Lathkata	Sundargarh	213.0
Jhumpura	Keonjhar	212.2
Keonjhargarh	Keonjhar	196.8
Basudevpur	Bhadrak	195.0
Chandikhol	Jajpur	175.0
Karanjia	Mayurbhanj	168.0
Rajgangapur	Sundargarh	140.6
Deogarh	Deogarh	131.0
Tiring	Mayurbhanj	115.6
Udala	Mayurbhanj	113.4
Barkot	Deogarh	113.2
Gurundia	Sundargarh	113.2
Hatadihi	Keonjhar	112.4
Tihidi	Bhadrak	112.0
Pallahara	Angul	112.0
Ghatgaon	Keonjhar	103.2
Lahunipara	Sundargarh	102.0
Sharpada	Keonjhar	99.6
Soro	Balasore	99.0
Bamra	Sambalpur	98.4
Binjharpur	Jajpur	95.3
Laikera	Jharsuguda	95.2
Jajpur	Jajpur	92.0
Kirmara	Jharsuguda	91.6

Heavy to heavy rainfall at a few places with **extremely heavy rains (> 20 cm during 24 hour period)** at isolated places over north Odisha on 26th May

Cyclone induced heavy rainfall/flood Forecasting

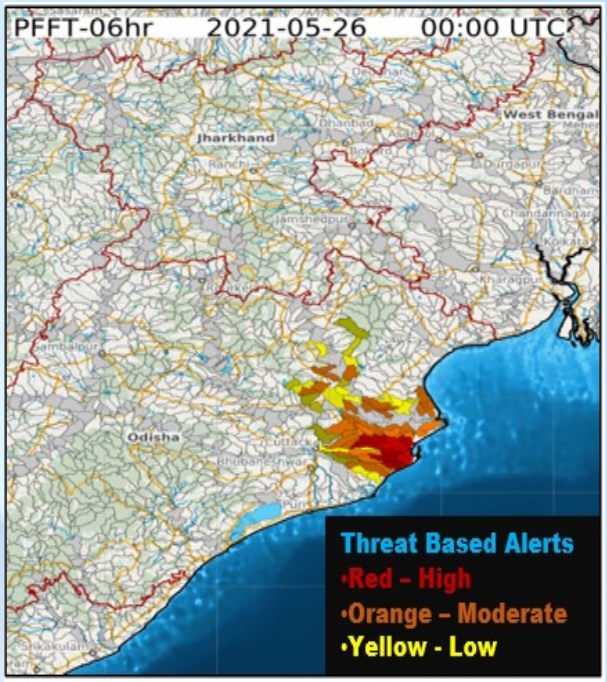
Riverine Flood Forecasting (Quantitative Precipitation Forecast)





- Hydromet services through 15 Flood Met. Offices of IMD for 153 river sub basins.
- Sub-basin-wise Quantitative Precipitation Forecast: (Deterministic/Probabilistic) and Heavy rainfall warnings for day-1 to day-5 to CWC.

South Asia Flash Flood Guidance System (SAsiaFFGS)



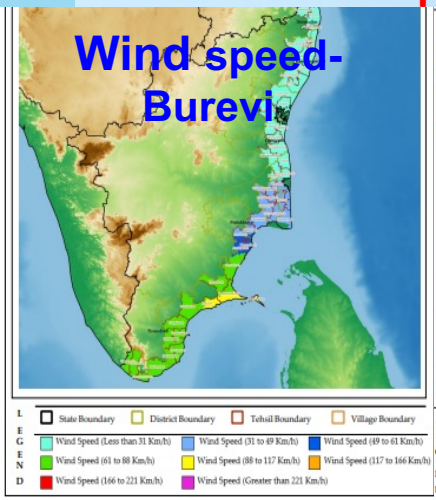
- First of its kind in South Asia (Bangladesh, Bhutan, India, Nepal, Sri Lanka).
- High resolution (4X4 km) and 30000 watersheds over Indian region.
- Capable of issuing flash flood Threat and risk for next 6 and 24 hours respectively.

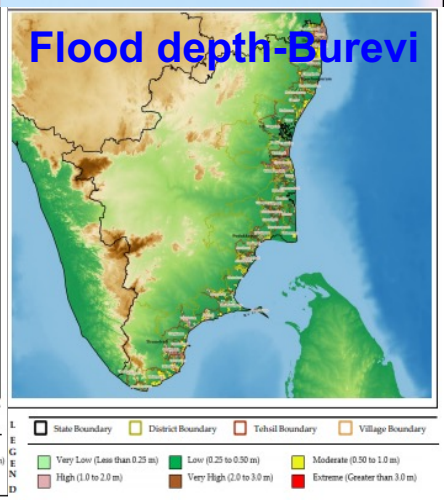
Introduction of cyclone track on GIS Platform (June, 2020)

Observed & forecast track of CS Burevi over SW BoB based on 0000UTC of 01st Dec, 2020

https://ddgmui.imd.gov.in/dwr_img/GIS/previewcyclone.html

Translating hazard information into impact





Hazard

Exposure

Vulnerability

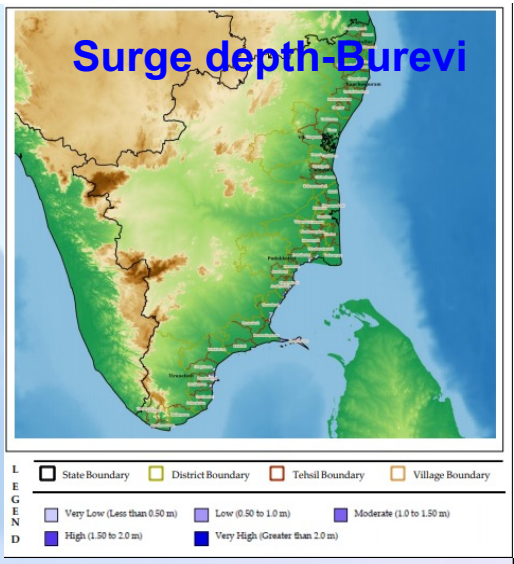
Impact/Risk

Value at Risk

Statistical - census and survey data

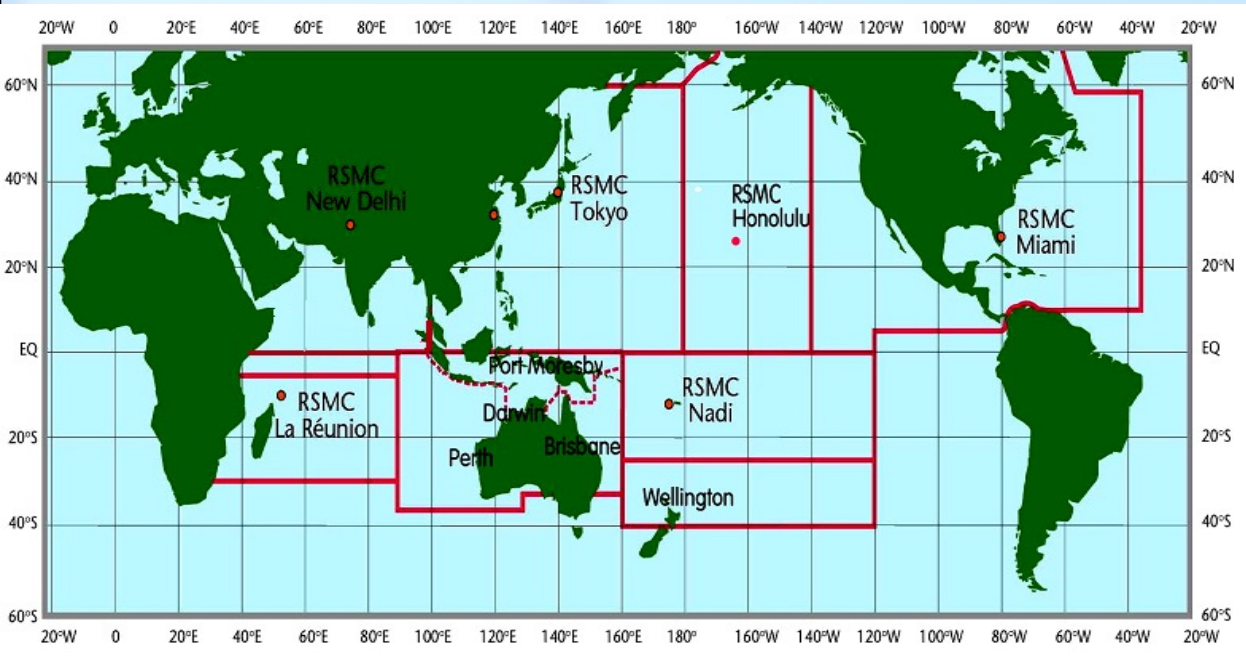
GIS/Geospatial– Infrastructure, settlements, land use..

Cartographic, Geological, Hydro-meteorological ..
Geospatial Data – Vector and Raster



Cyclone Warning Organisation

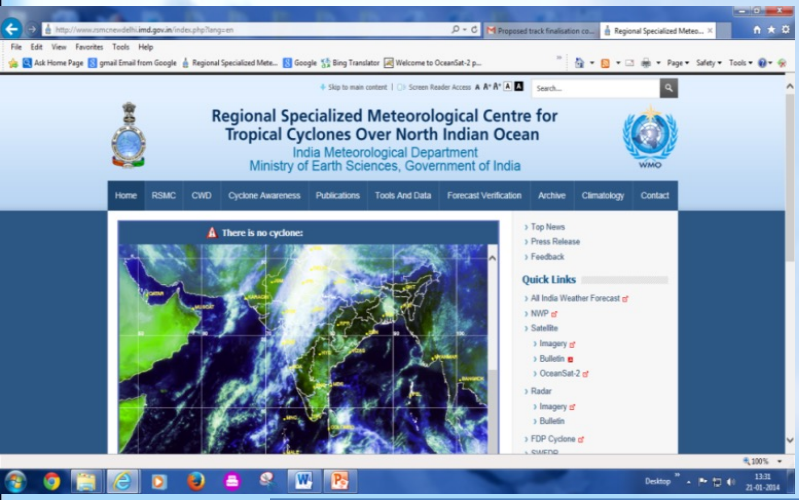
Institutional Mechanism



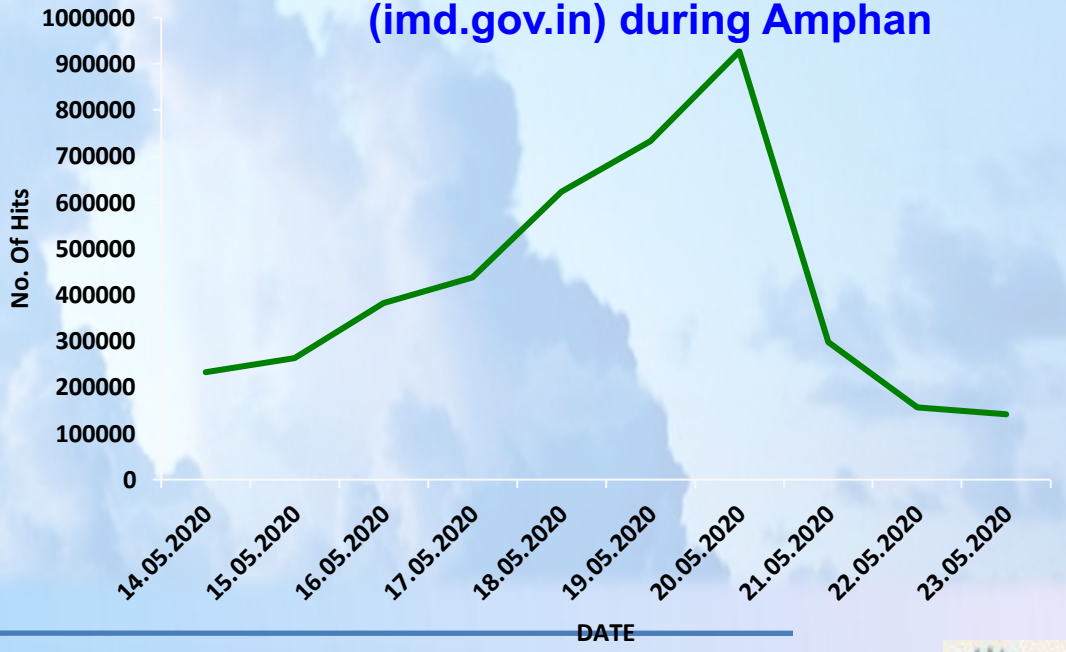
- IMD is mandated to monitor and issue warnings regarding tropical cyclones over the north Indian ocean for the country.
- International Responsibility:
  - IMD also acts as RSMC to provide tropical cyclone advisories to 13 countries under WMO/ESCAP Panel (Bangladesh, India, Maldives, Myanmar, Oman, Pakistan, Sri Lanka, Thailand, Yemen, UAE, Saudi Arabia, Qatar, Iran.
  - Acts a Tropical Cyclone Advisory Centre for international civil aviation
  - Provides Global maritime Distress Support System (GMDSS) over NIO.

Advances in Warning Dissemination Mechanism

- Telephone, Tele-fax, Mobile Phones (SMS) through IMD severe weather network, Agromet Network, INCOIS network.
- VHF/HFRT/Police Wireless
- Satellite based cyclone warning dissemination System
- Aeronautical Fixed Terminal Network
- Global telecommunication system (GTS), Mobile App : Mausam, Damini, Meghdoot,
- Websites, Dedicated website for cyclone (rsmcnewdelhi.imd.gov.in)
- Radio/TV, News Paper network (AM, FM, Comminity Radio, Private TV) : Prasar Bharati and private broadcasters
- NAVTEX , Internet (e-mail), ftp
- GAMES and NAVIK



Number of unique visitors on IMD website (imd.gov.in) during Amphan



R&D AND CAPACITY BUILDING

(i) Forecast demonstration projects on landfalling cyclones

(ii) Data bases for R&D activity:

(a) Cyclone E-Atlas and Web-Atlas

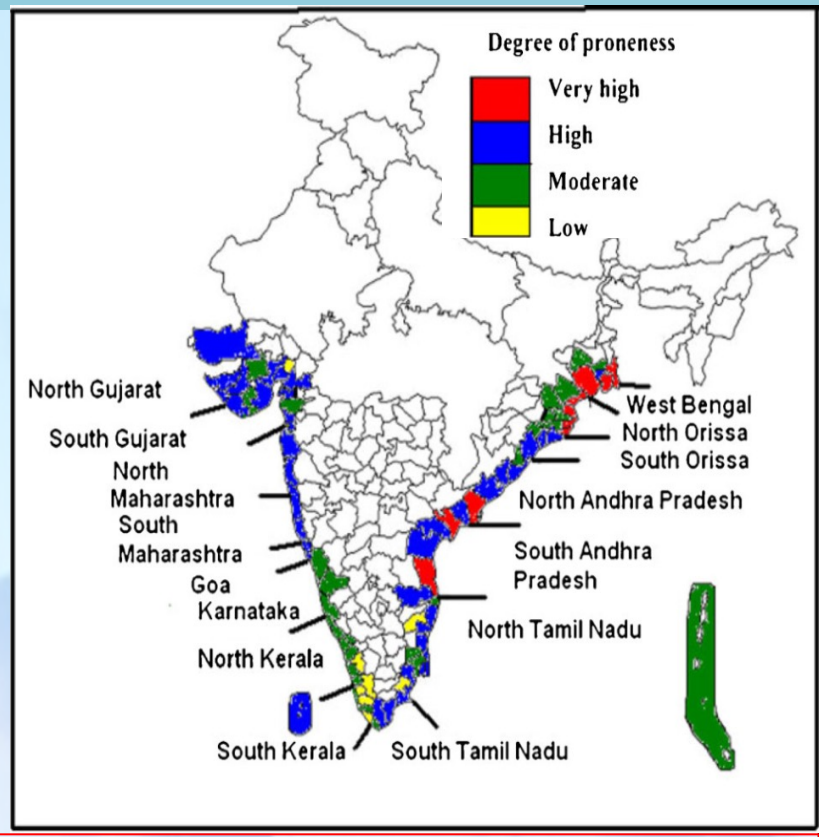
(b) Cyclone Characteristics (Three/Six hourly best track, Energy Metrix, Life Cycle, Structure, Movement, Landfall characteristics

(c) Digitisation of Annual RSMC Reports during 1990-2018,

(d) Hazard proneness of coastal districts,

(iii) Organisation national/international Conference and Workshops

(iv) National and international networked programmes



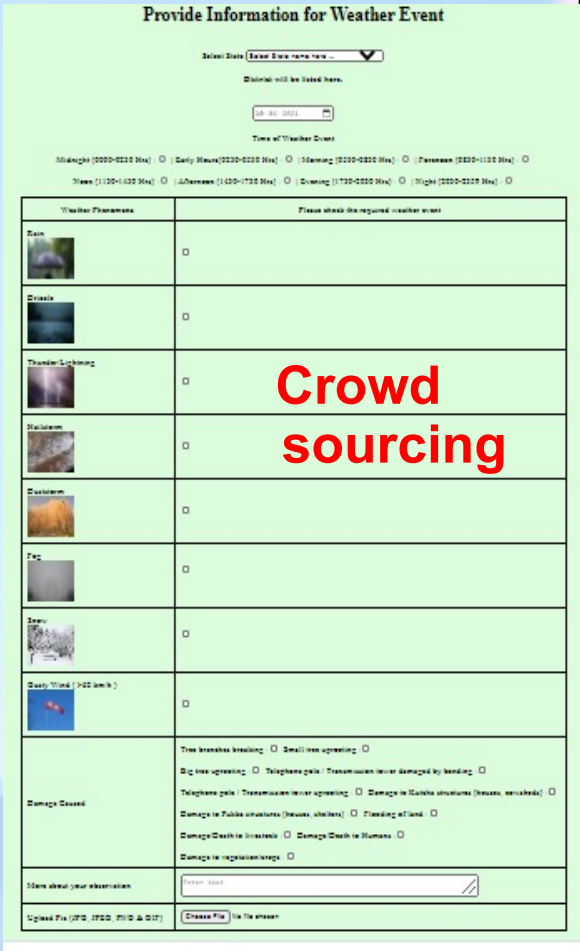
Cyclone Hazard Prone Districts based on Frequency, Intensity, Wind strength, Precipitation and storm surge

Way Ahead

- Still there are gaps in technology vis-a-vis capibility.
- Gap in scientific understanding & representation in NWP modeling:
  - Detailed structure and dynamics of cyclones
  - Interaction between cyclone, Ocean, the surrounding environment
  - Internal physical and dynamical processes in clouds.
- Still scope for improvement in Forecast skill. Intensity forecast is still challenging. 20-25% improvement in accuracy is targeted by 2030
- Dynamical impact based forecast & risk based multi-hazard early warning utilising digital information on geo-physical hazards, geo-spatioal information and socio-economic indicators
- Warning dissemination to improve with Common Alert Protocol and for most vulnerable groups in remote areas (e.g. fishermen at deep sea)
- MoES is continuously upgrading its plan and strategy for all the above
- Lessons learnt from past cyclones will be used for future

Way Ahead

- Technology plays a dominant role.
- Scope for Improvement with technology
  - High resolution & improved sensor tech.
  - Crowd sourcing observations, AI/ML
  - Digital forecasting
  - Dynamic IBF & risk based warning
- Regular dynamic update of digital data base in Web DCRA –DSS.
- CAP and mobile App to serve various strata of Community & Users in Local Language
- Space based communication, GAMES and NAVIC
- GIS based Cyclone Hazard, vulnerability & risk Atlases



Thank you