

सत्यमेव जयते



Years of Service to the Nation
राष्ट्र सेवा के 150 वर्ष



Early Warning Services of India Meteorological Department

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Ministry of Earth Sciences (MoES)

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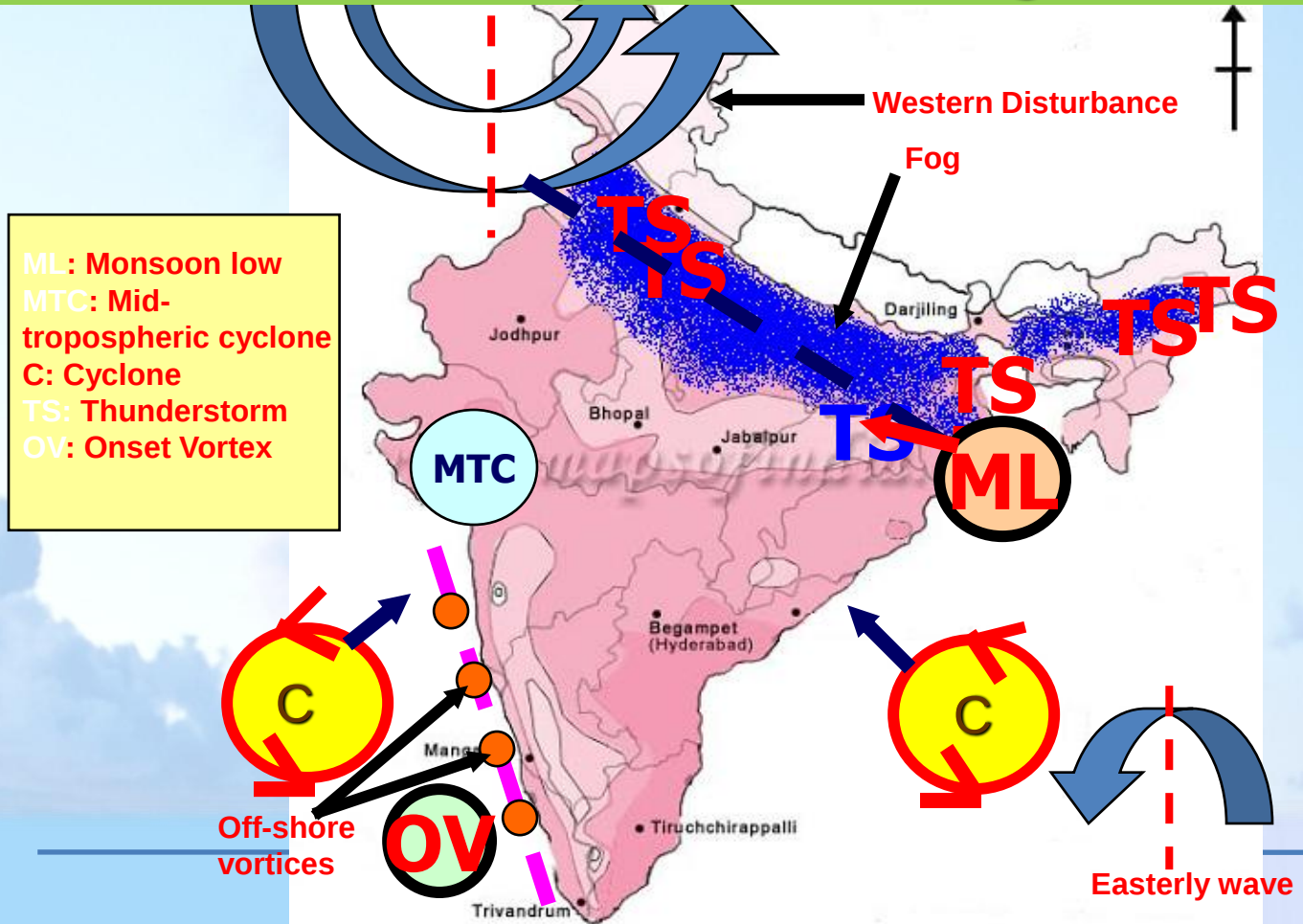
IWM-8 (17-21 March 2025), IITM Pune



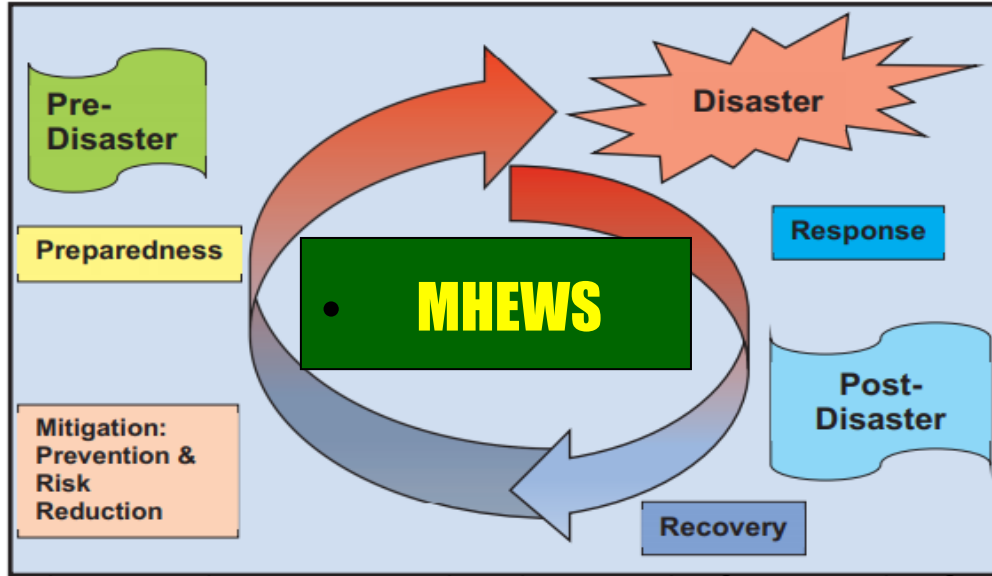
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INDIA METEOROLOGICAL DEPARTMENT



Weather Systems causing hazards



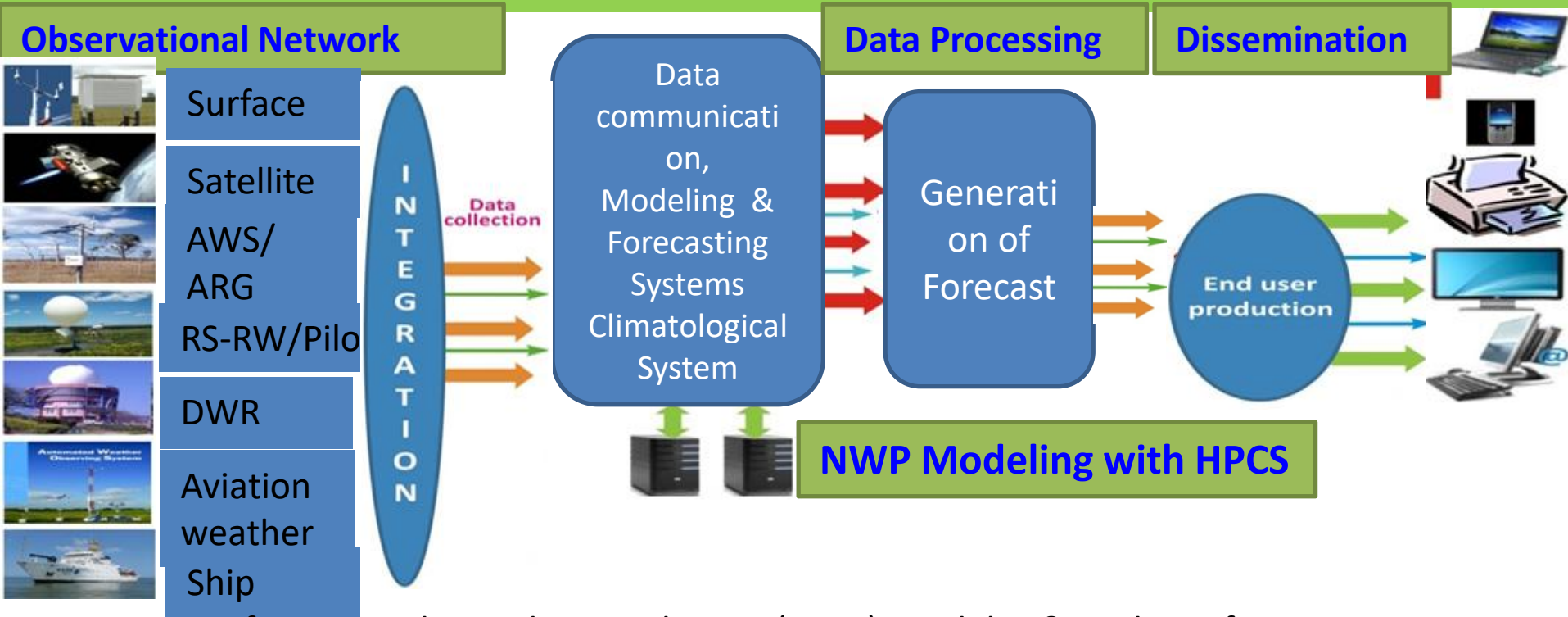
MHEWS in India for Disaster Risk Reduction



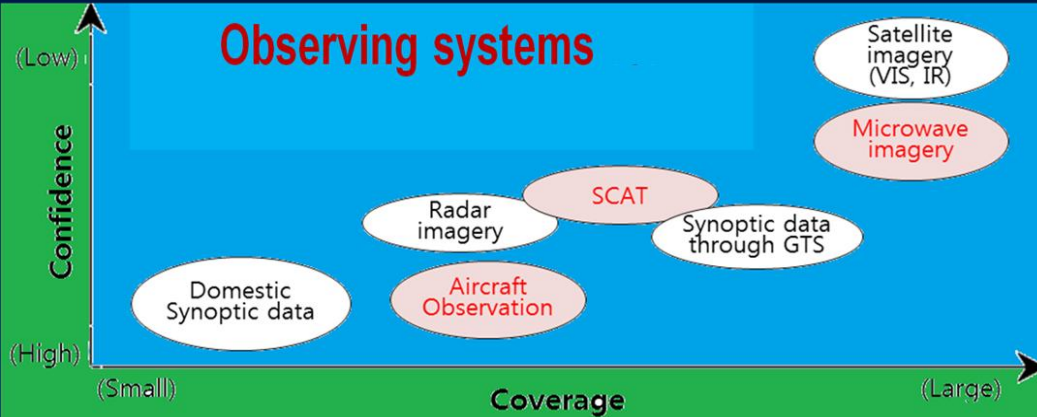
- **National Policy**
- **National DM Act**
- **National DM Plans**
- **National Guidelines**
- **Institutional mechanism**

- MHEWS plays a dominant role during, before and after the disasters in all phases of preparedness, prevention and risk reduction
- India is **self reliant with respect to weather and climate services** in terms of contribution to economy, development of system and infrastructure, socio-economic applications and disaster risk reduction
- In terms of forecast accuracy and service delivery, **it is at par with leading centres**

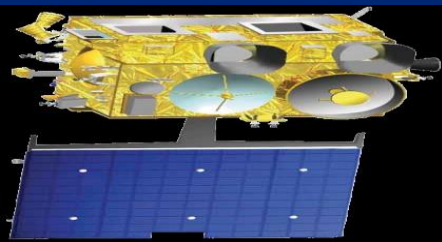
INTEGRATED MHEWS



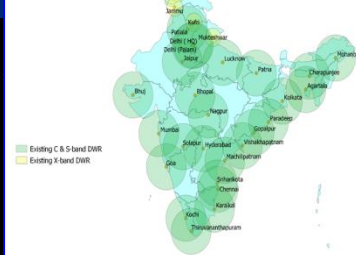
- An Array of numerical Weather Prediction (NWP) models & High performance Computing System in India for **Seamless Forecast** from a few hrs(nowcast) to short to medium range forecast (upto seven days), extended range forecast (upto 4 weeks) and seasonal forecast
- **Impact based forecast and early warning** upto five days (120 hrs) for all severe weather



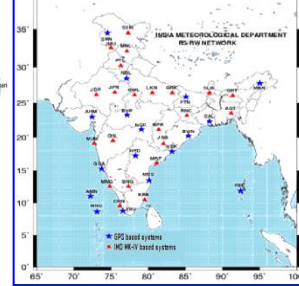
INSAT-3D & 3DR



40 DWRs

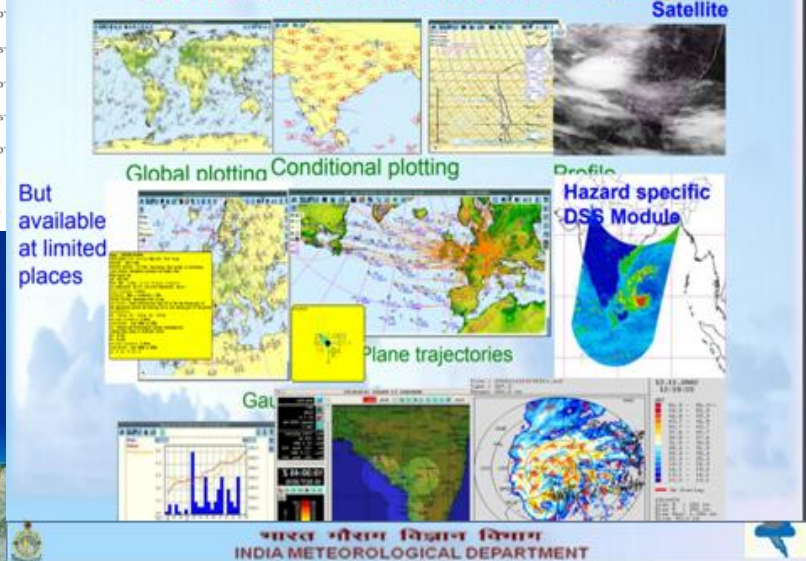


56 RS/RW Stations

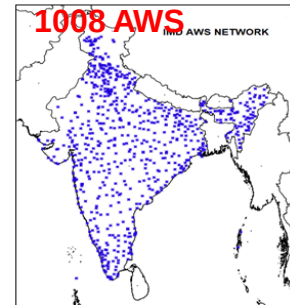


Decision Support System for cyclone forecasting:

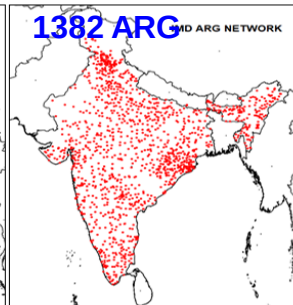
Geospatial Application in decision making



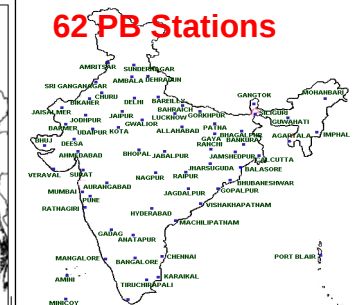
1008 AWS



1382 ARG



62 PB Stations



Seamless Weather and Climate Forecasting Strategy

- IMD has a seamless forecasting strategy. IMD issues forecasts and warnings on different time scales and for different spatial scales:
- Nowcasting- up to six hours for all types of severe weather at all districts and 1206 stations
- Short to medium range forecasts for rainfall over cities, blocks, districts and meteorological subdivisions range (up to 10 days)
- Extended range (up to 4 weeks) forecasts for All India, homogenous regions and meteorological sub-divisions
- Seasonal Forecasts (one season in advance) for All India and homogenous regions and Monsoon Core Zone.



Suite of operational NWP and Climate Models

Nowcasting
to Very Short
range

12 hours forecast

**HRRR (High
Resolution Rapid
Refresh)**
2 km
2 hourly update
3 domains over
India

**Electric WRF for
Integrated Lightning
Forecast
WRF**
3 km
12 hourly update

Short range

3 days forecast

**Weather Research
and Forecast
(WRF)** 3km
6 hourly update

NCUM regional
4 km
12 hourly update

**NCUM regional
ensemble**
4 km
Once in a day

Medium range

10 days forecast

**Global Forecast System
(GFS) ~ 12 km**
6 hourly update

**Global Ensemble Forecast
System (GEFS) ~ 12 km**
21 members
12 hourly update

NCUM Global
~12 km
12 hourly update

**NCUM Ensemble
Prediction System (NEPS)**
~ 33 km
12 hourly update
44 members

Extended
Range

32 days

**Climate
Forecast System
(CFS) ~ 38 km**
Weekly update
Coupled model
16 members
ensemble
16 yrs hindcast
(2003-2019)

**NCUM Coupled
Model ~ 60 km**
Weekly update
44 members

Seasonal

4 to 7
months

**Climate
Forecast
System (CFS)**
~ 38 km
Weekly
update

**NCUM
Coupled
Model ~ 60 km**
Weekly
update
44 members

New Strategy for Long Range Forecast Based on MME of Dynamical models

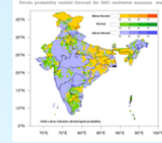
**1st Stage
Forecast**

April

**All India averaged Season
(June – September)
Rainfall**



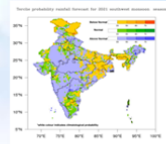
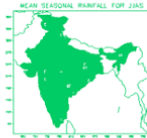
**Spatial pattern of probability
forecast for the Season
Rainfall over the country**



**2nd Stage
Forecast**

May

**Update for the April forecast for the
All India averaged Season Rainfall
and spatial pattern of probabilistic
forecast over the country**



**Forecast for Season Rainfall: for
the Four Homogeneous Regions
& Monsoon Convergence Zone
(MCZ)**

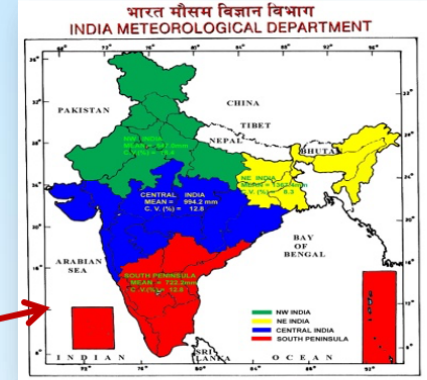
■ NW India
■ NE India
■ Central India
■ S. Peninsula



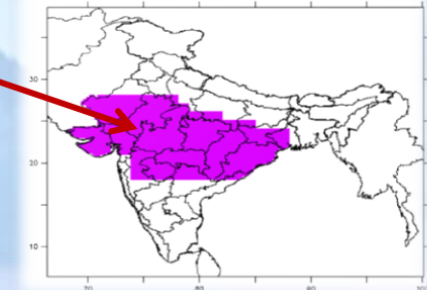
**Monthly
Forecast**

**End of May, June, July & August for
subsequent one month**

**Probabilistic Forecast for
Monthly Rainfall and
Temperatures**



Core Monsoon Zone



In addition, Forecast for Date of Monsoon Onset over Kerala in May

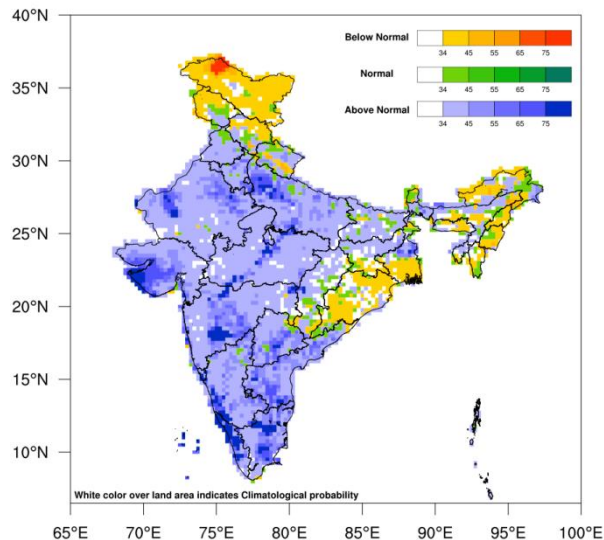


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Probability Forecast of the 2024 SW Monsoon Seasonal (June- Sept) Rainfall over India:

Tercile probability rainfall forecast for 2024 southwest monsoon season



Normal to above normal rainfall:
Most part of the country.

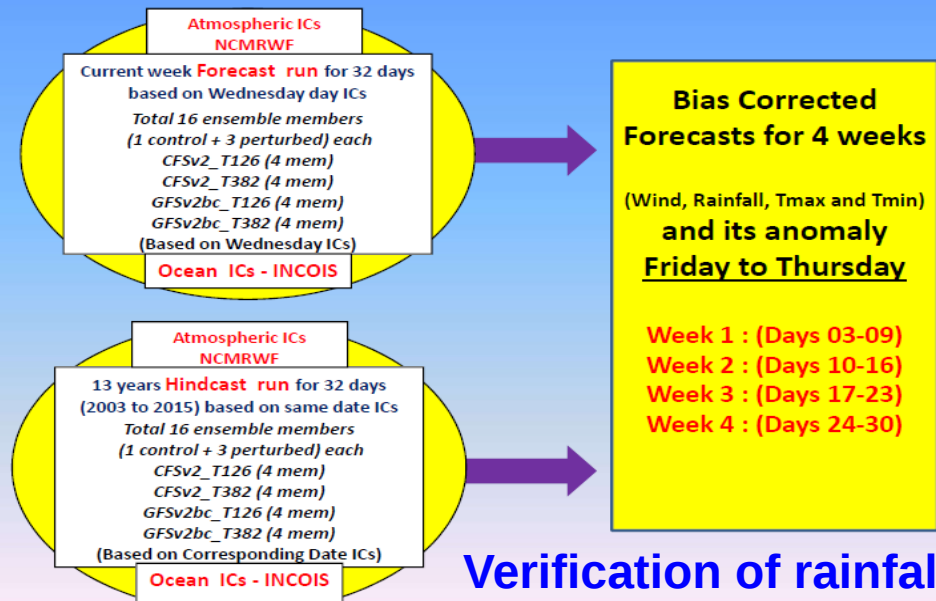
Normal to below normal rainfall:
Many areas of northern part of Northwest India, Northeast India and eastern part of the Central India

The white shaded areas within the land areas represent climatological probabilities.

Probability forecast of tercile categories* (below normal, normal, and above normal) for the seasonal rainfall over India during the 2024 southwest monsoon season (June - September). The figure illustrates the most likely categories as well as their probabilities. The white shaded areas within the land area represent climatological probabilities. The probabilities were derived using the MME forecast prepared from a group of coupled climate models. (*Tercile categories have equal climatological probabilities, of 33.33% each).



IMD's Operational Extended Range Forecast (ERF) System

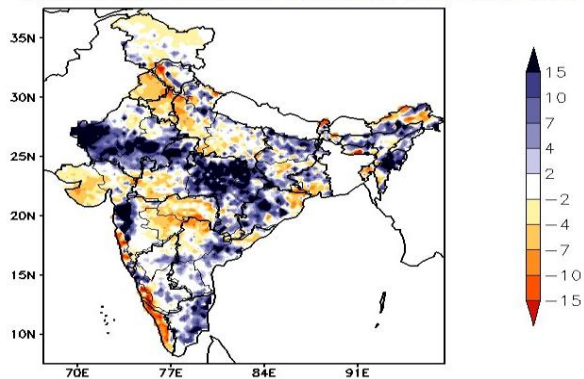


Extended Range Forecast of Rainfall:

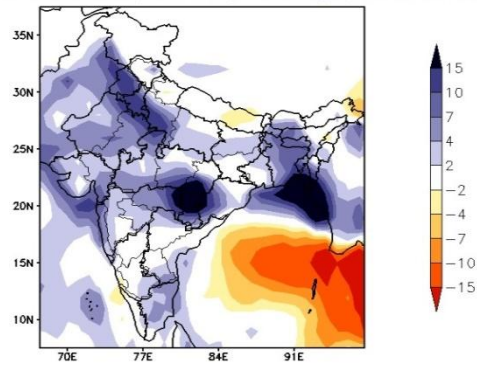
- Issued every Thursday valid for next four weeks
- Reasonable skill upto 2 weeks

Verification of rainfall forecast for the week **01-08 Aug 2024**

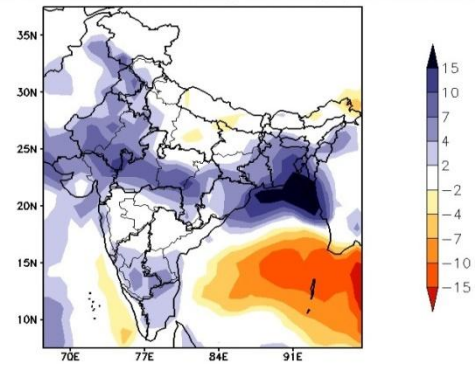
(Obs Anomaly: 00Z01Aug-00Z08Aug) (00Z=0530 hrs IST)



(FCST week1 Anomaly: 00Z01Aug-00Z08Aug) (00Z=0530 hrs IST)

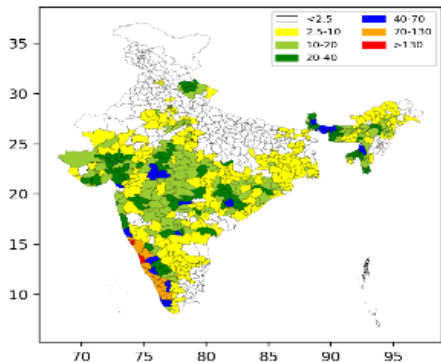


(FCST week2 Anomaly: 00Z01Aug-00Z08Aug) (00Z=0530 hrs IST)

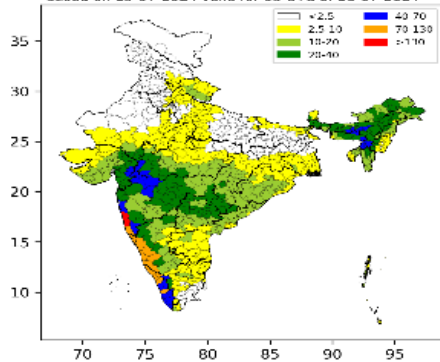


Multi Model Ensemble based district level Rainfall forecastFor next 7 days

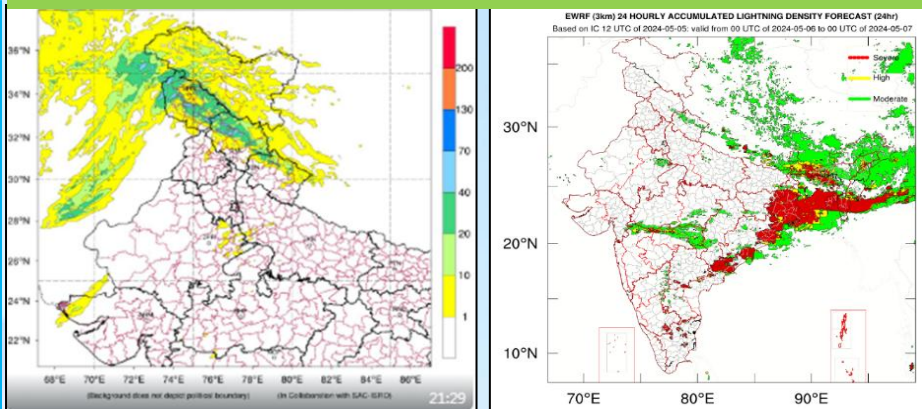
IMD Observed Rainfall (mm) 16-07-2024



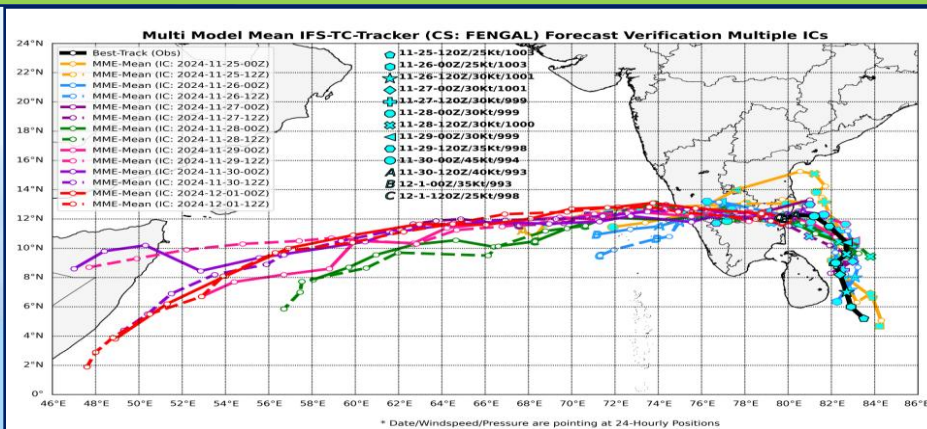
IMD MME Rainfall (mm) Forecast (Day 1)
based on 15-07-2024 valid for 03 UTC of 16-07-2024



HRRR-WRF (2 km) and EWRF (3 km) rainfall, lightning & Max Ref. Product

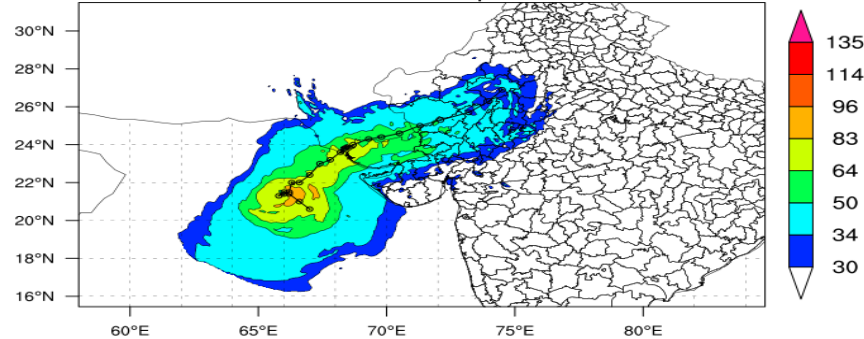


MME Tropical Cyclone Tracks Forecasts based on different Initial Conditions with Best track for FENGAL 2024-11-25-06Z to 2024-12-01-18Z



IMD-HWRF ocean coupled model run 4 times a day with resolution of 2 km during cyclones to give 5 day forecast

IMD:HWRF 10m Maximum Wind Speed(kts)
based on 2023061300 Valid upto 2023061806 UTC



Multimodel dynamic Meteogram (mausamgram)

Lat,Long: 35.68°N 74.90°E

31st Dec 2024 0 UTC ▾ lat: 28.61 lon: 77.21 Go

Forecast: ☐ 1-hr 1.5 day ☒ 3-hr 5 days ☐ 6-hr 10 days

Models Update time Pincode GP Code Search

imdghs: 2024123100, 31-12-2024 10:30:40

jma: 2024123100, 31-12-2024 11:03:55

ncep: 2024123100, 31-12-2024 11:06:33

ecmwf: 2024123100, 31-12-2024 10:59:28

ncumg: 2024123100, 31-12-2024 11:08:50

mme: 2024123100, 31-12-2024 12:10:56

Disclaimer: The output result is for the area of 12 x 12 km

Dynamic Meteogram Beta Version (1.0)



[Release Note](#)

All models IMDGFS JMA NCEP ECMWF NCUMG MME



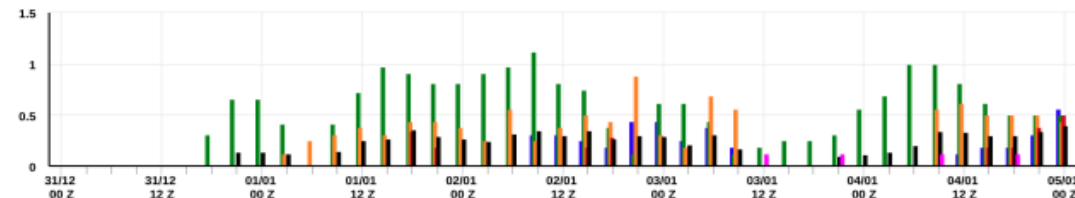
Multi model meteogram

Location :35.68°N 74.90°E Initial Condition :31/12/2024 00Z

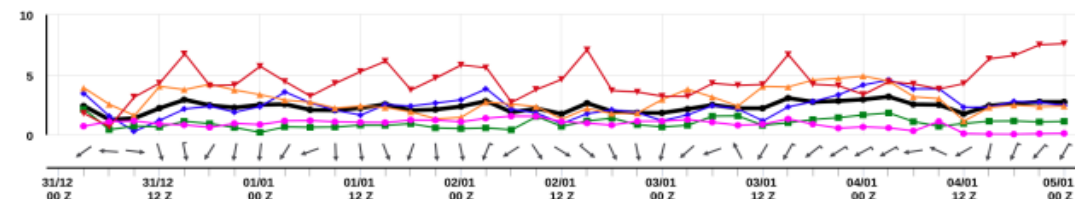
IMDGFS JMA NCEP NCUMG ECMWF MME

District Warning: Day 1 Day 2 Day 3 Day 4 Day 5

Rainfall (mm)



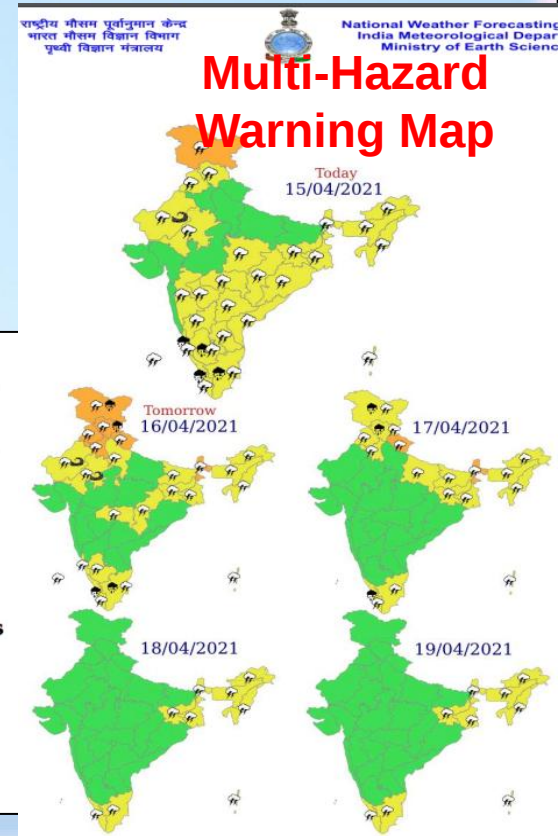
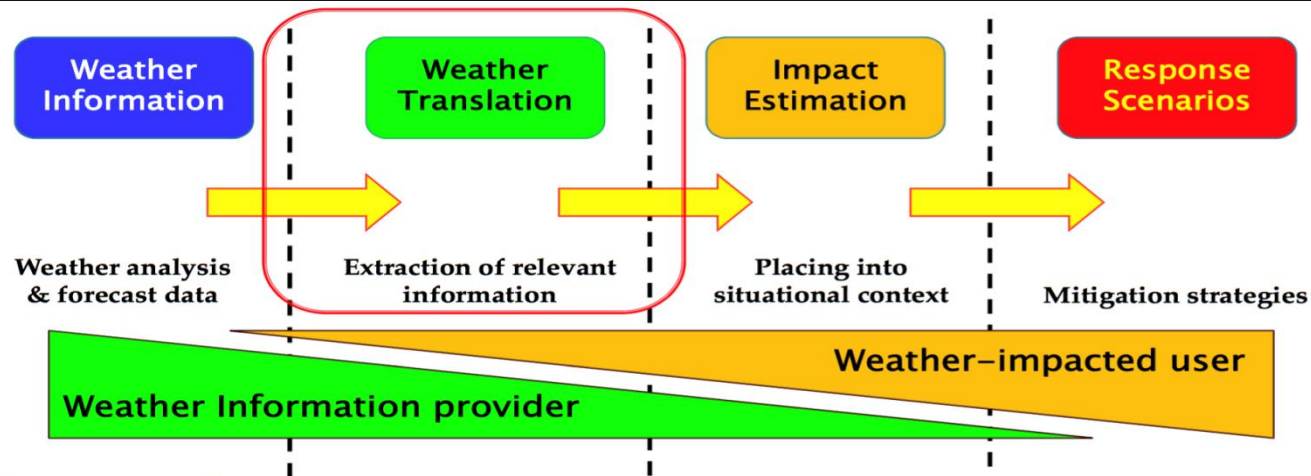
Wind Speed (m/s) and Wind Direction



For location specific forecast click anywhere and visualize the forecast upto next 1.5 days (1-hourly), next 5 days (3-hourly) & 10 days (6-hourly).

Impact-based Forecasting in India

- Relevant information from weather forecast is extracted and placed into situation context to produce impact estimations;
- With potential impact information, response scenarios are set-up
- Geospatial information plays a key role along with hazard, vulnerability, exposure and risk analysis

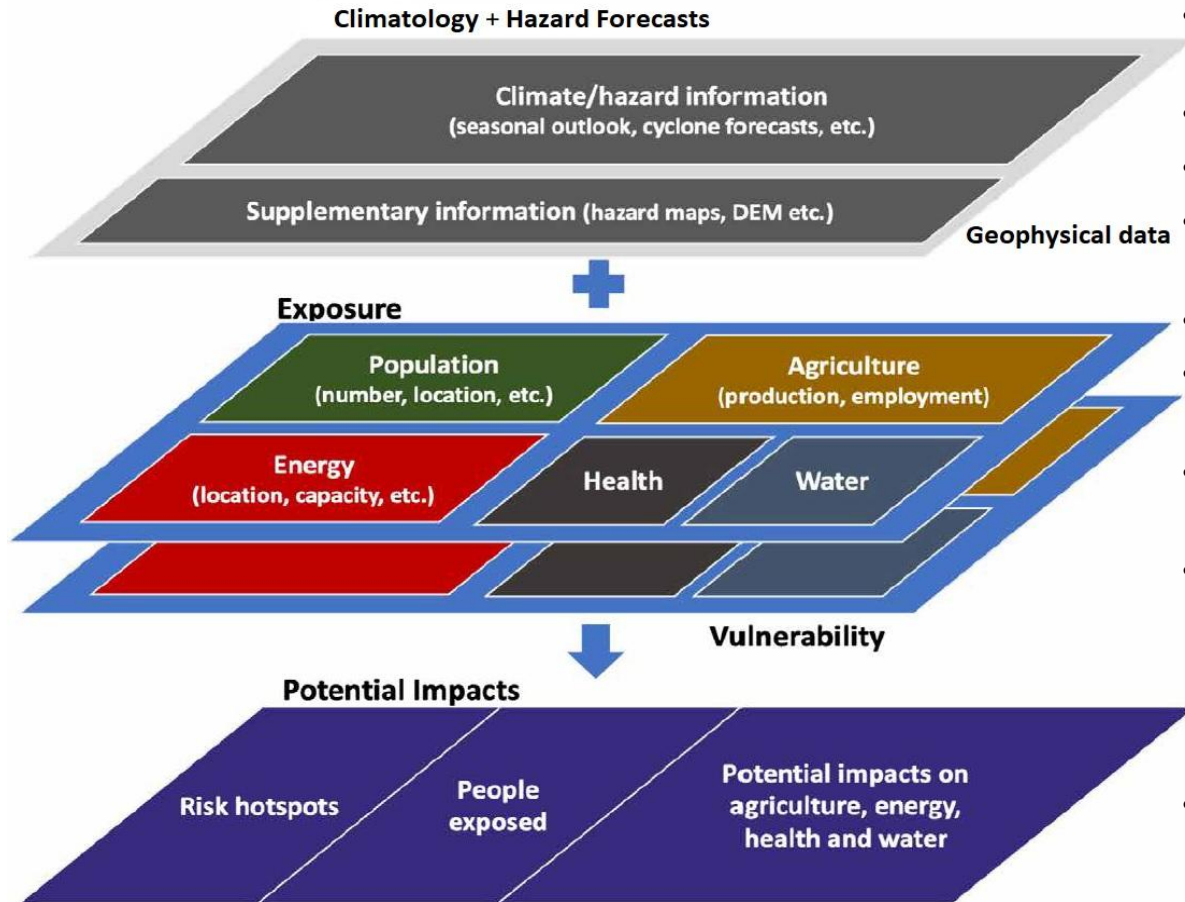


Source: Baode Chen and Xu Tang (2014) Translating weather forecasts into impact-relevant information

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Impact Based Forecasting based on Web-GIS Decision Support system



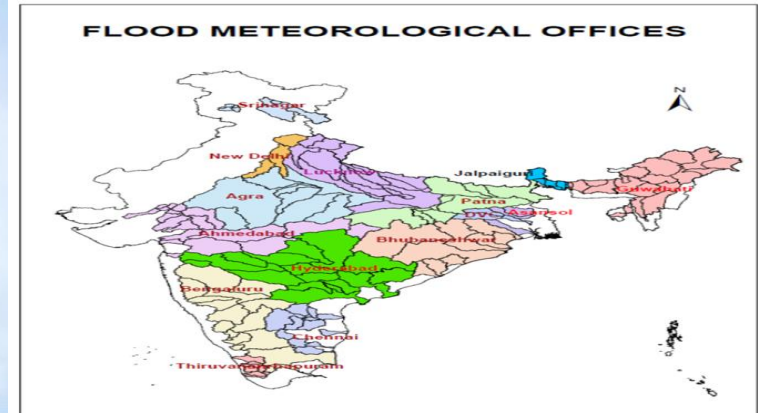
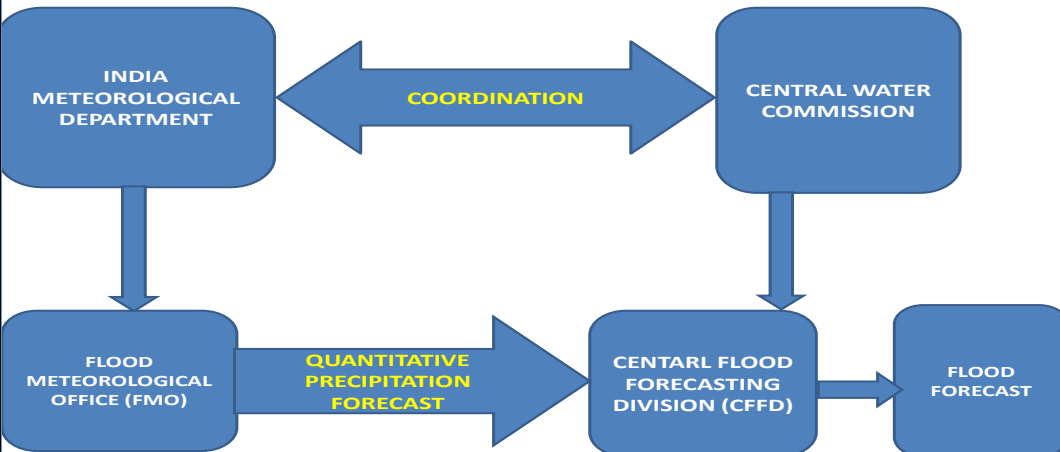
- **Administrative layers** (State, district, city, ward boundary & etc.)
- **Digital Elevation Model Data**
- Land Use Land Cover
- **Meteorological data** (Observation and Forecasts)
- Climatology,
- **Infrastructure layers** (Rail, Road, Buildings & etc)
- **Demographic Data** (Population, livestock & etc)
- **Major Point of Interest (POI)**- School, college, hospital, Airport, bus stand, Telcom. towers, Major industries, water resources, structures, shelters & etc.
- **Impact Matrices for Hazards** (Rainfall, Cyclone, Wind, Storm Surge, Heat/Cold Wave, Thunderstorm, Lightning)

Hydrometeorological Support for Flood Forecasting

Flood Forecasting activity is the joint responsibility of

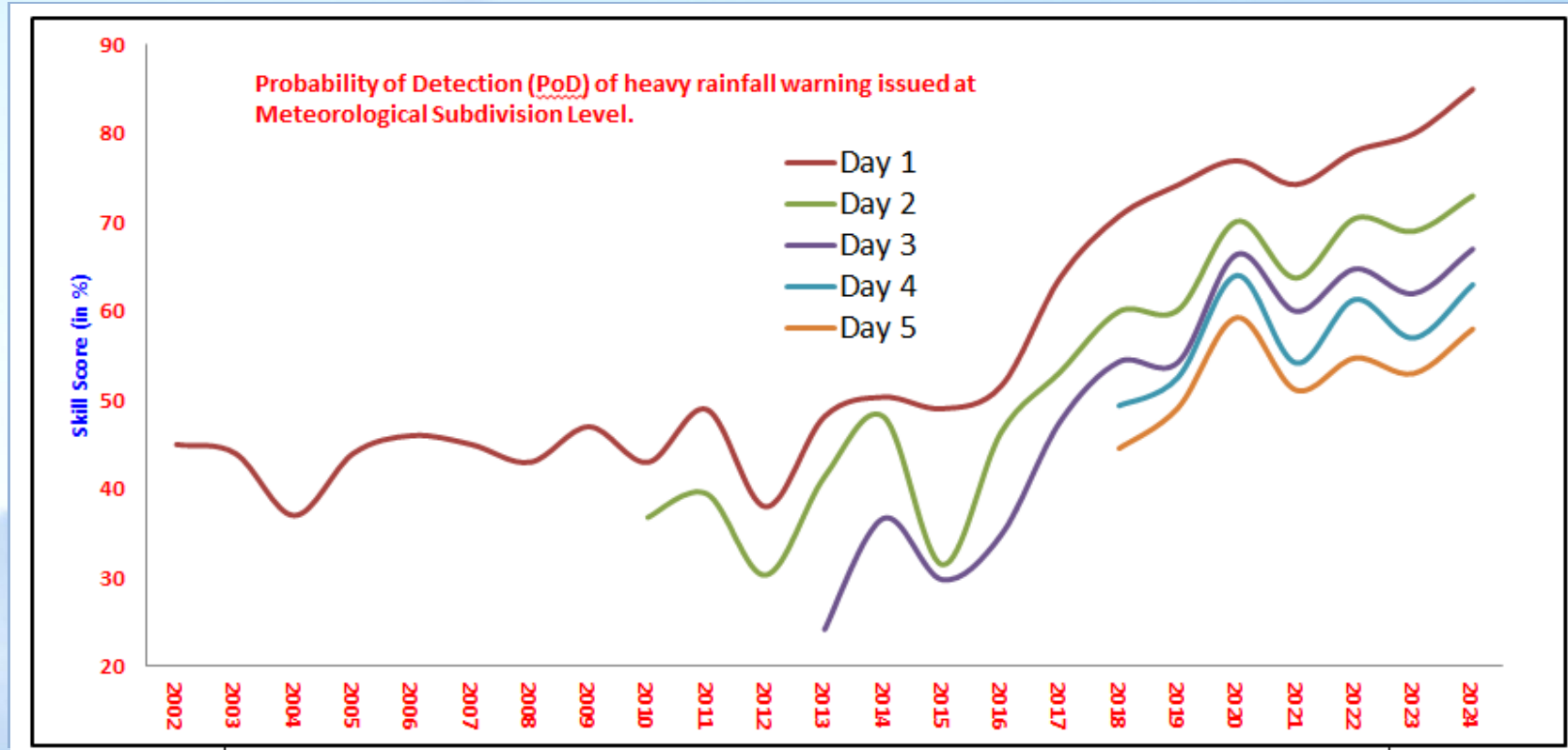
- India Meteorological Department (IMD) & Central Water Commission(CWC)
- IMD provides observed and forecast rainfall through Flood Meteorological Offices(FMOs).
- Quantitative Precipitation Forecast issued by IMD is used by CWC to forecast flood.
- Joint advisories on Flood Status of the country is issued by IMD, CWC and NDRF
- IMD Provides Flash Flood Guidance Services for India, Bangladesh, Bhutan, Nepal and Sri Lanka

FLOOD FORECASTING



Flood Meteorological Activities : 15 centres
Total No of sub basin: 156

Monsoonal Heavy Rainfall Warning Skills



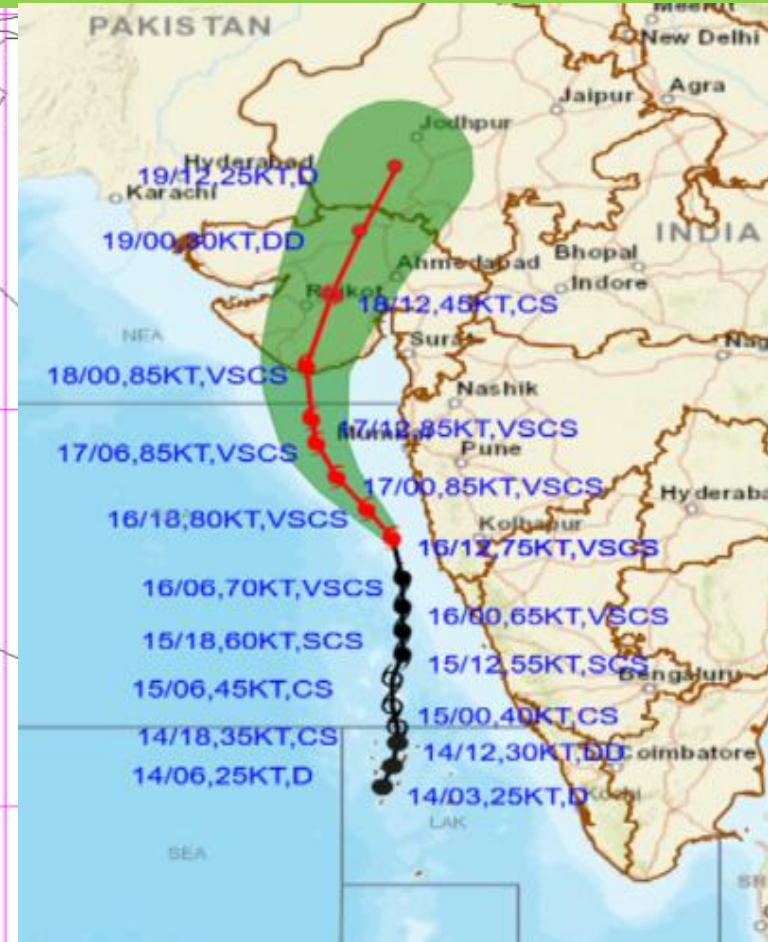
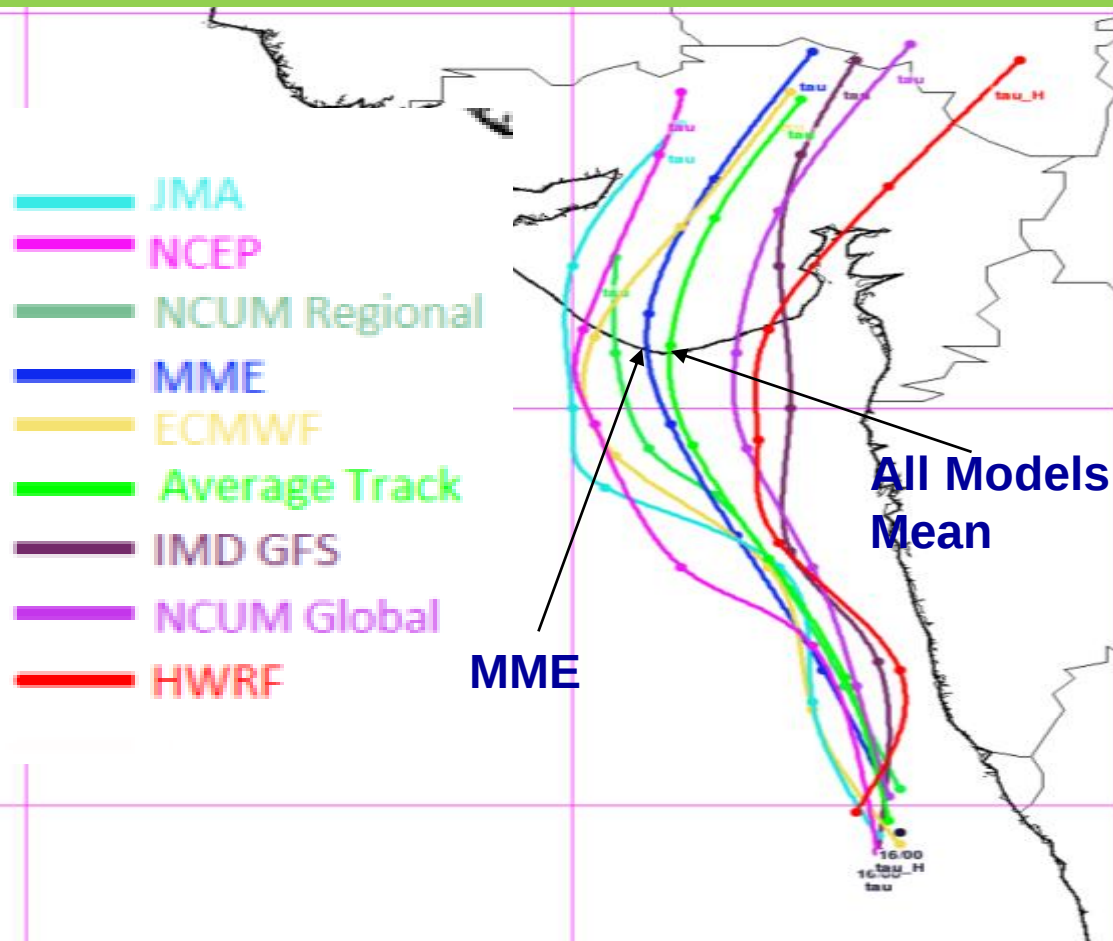
PoD for Day 5 in 2024 (58%) is better than PoD for Day 1 in 2016(52%)



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Tropical Cyclone Track and intensity forecast: An example of Cyclone Tauktae, 2021



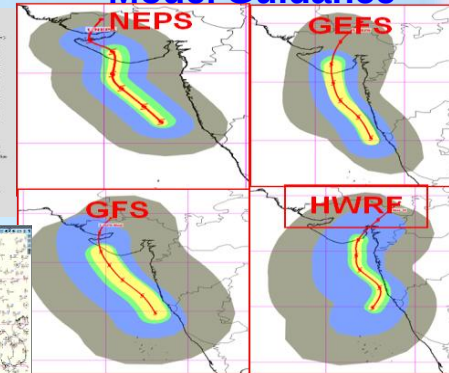
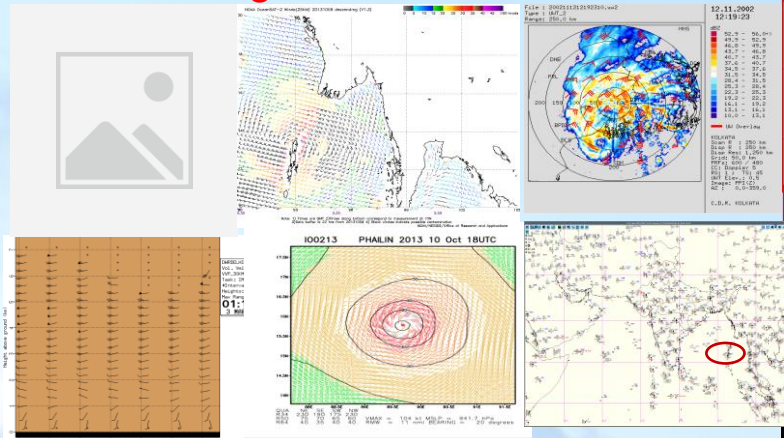
Monitoring and Prediction techniques for Cyclone wind

Observations

Monitoring Products

Model Guidance

- ❖ Surface observations (ships, buoys, GTS data, AWS, HWSR)
- ❖ Satellite observations (Scatterometer, Microwave, CIMSS, Geostationary satellites, Multi sat winds)
- ❖ DWR (when system is within the radar range)

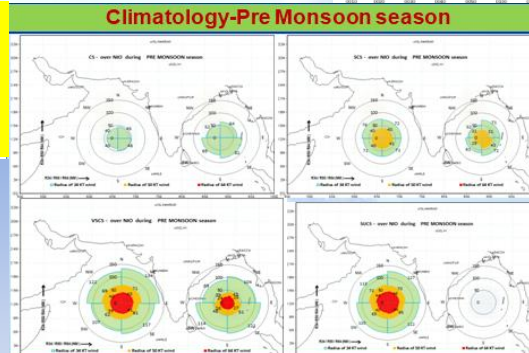


Operational Wind Prediction

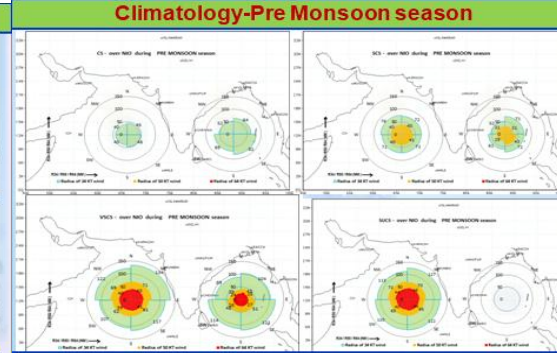
Unlike other basins IMD gives R28 forecast

Users

- ❖ Mariners
- ❖ Modeling Group
- ❖ Storm surge forecast
- ❖ Insurance Cos.
- ❖ DM agencies

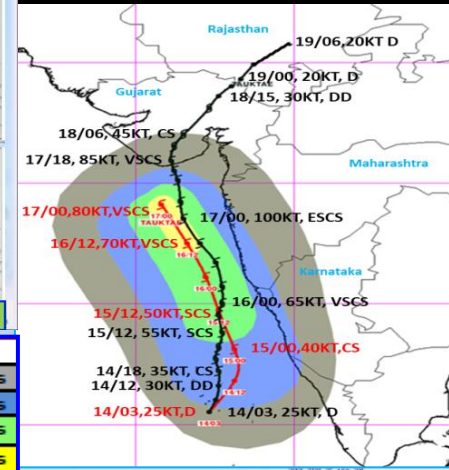


Mohapatra and Sharma, 2016, JESS (1997-2013)



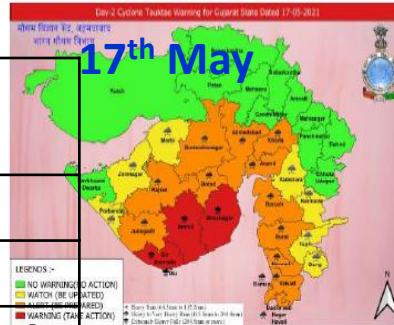
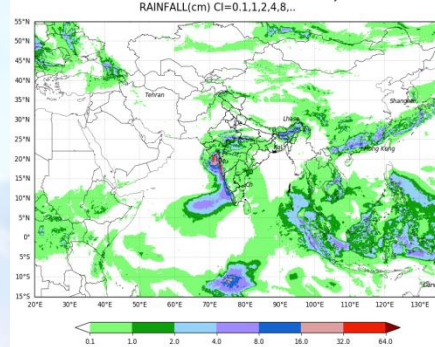
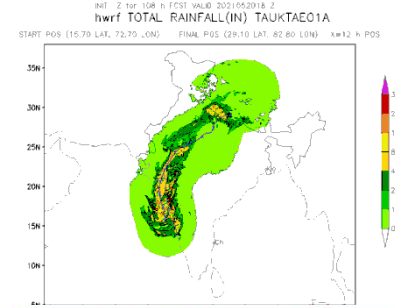
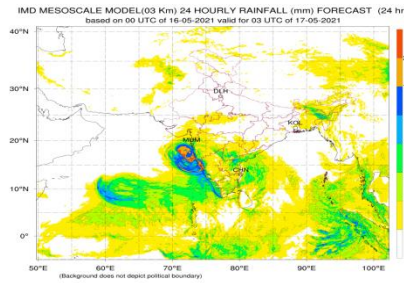
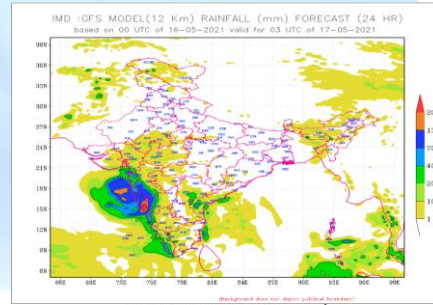
Mohapatra and Sharma, 2016, JESS (1997-2013)

MSW(knot/kmph)	Impact	Action
28-33 /(51-62)	Very rough seas.	Total suspension of fishing operations
34-49/(63-91)	High to very high seas	Total suspension of fishing operations
50-63/(92-117)	Very High seas	Total suspension of fishing operations
≥ 64 (≥118)	Phenomenal	Total suspension of fishing operations



IMPACT PREDICTION : CYCLONE RAINFALL

- ❑ Synoptic Techniques
- ❑ Satellite guidance (QPE, Sat gauge merged data)
- ❑ Radar guidance
(Reflectivity, Rain Rate, QPE)
- ❑ Thermodynamic features
(CAPE, CINE, Temperature gradient)
- ❑ Dynamic features
(Divergence, convergence, shear, shear tendency, vorticity)
- ❑ Model Guidance
(Deterministic, Cyclone Specific, Probabilistic, Multi-model)



	NO Warning (No Action)
	Watch (Be updated)
	Alert (Be prepared)
	Warning (Take action)



Impact Prediction : Cyclone Storm Surge

Storm surge Prediction (INCOIS)

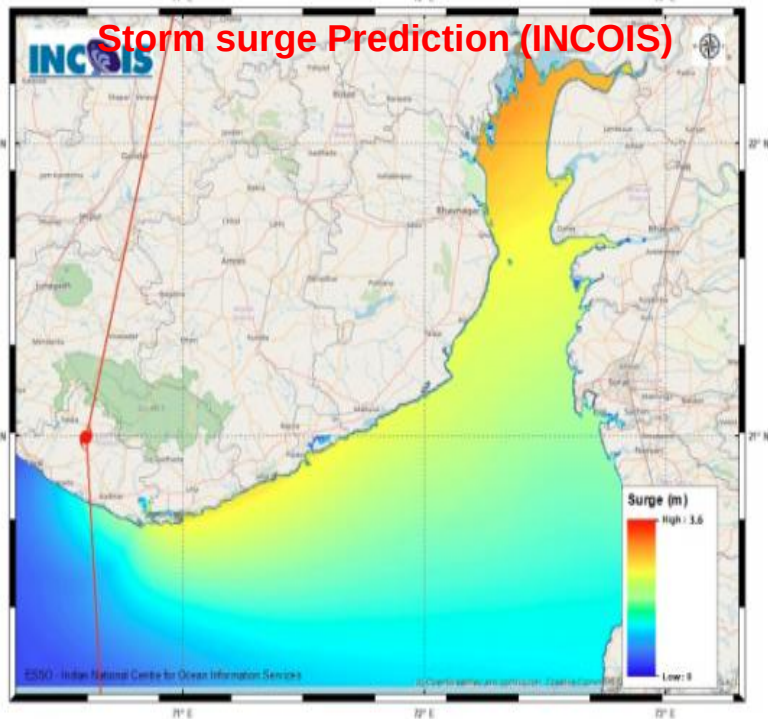
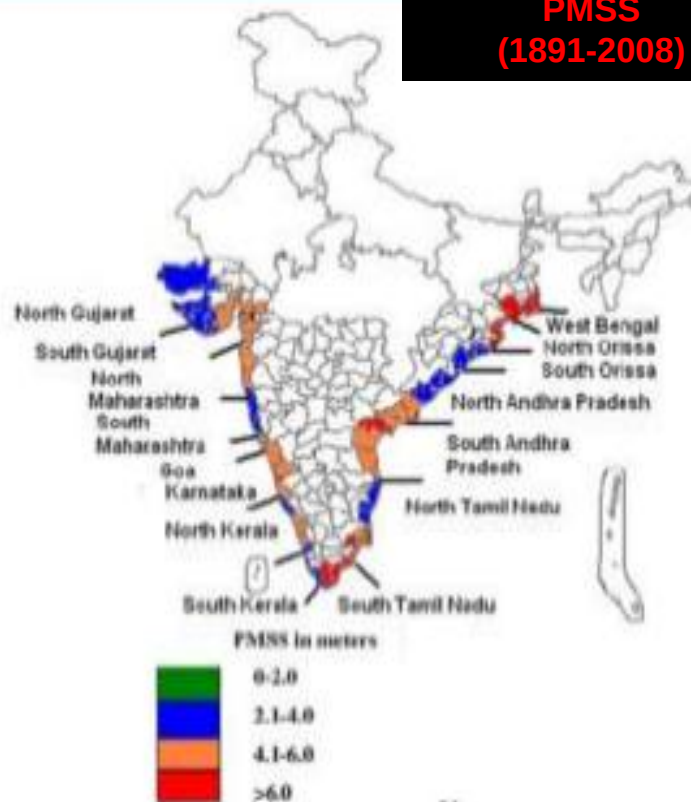


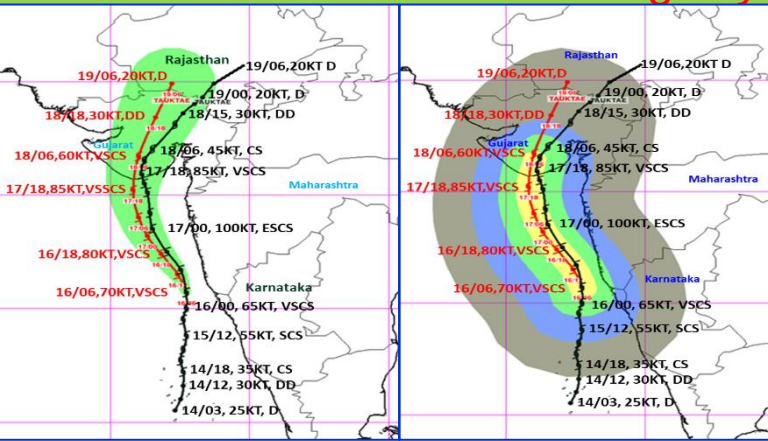
Figure: Storm Surge Map

PMSS (1891-2008)



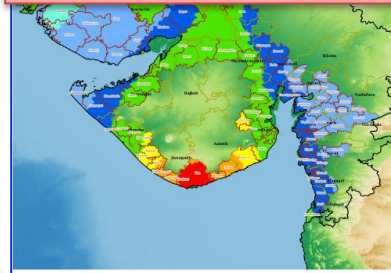
Way ahead: Probabilistic storm surge forecast

Dynamic impact based forecasting (IBF) of Cyclone Hazards, vulnerability and risk based warning: Cyclone Tauktae- May 2021 an example

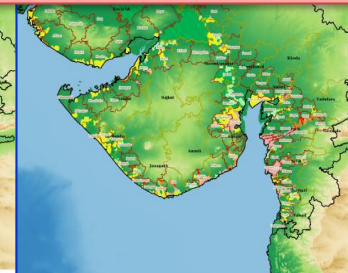


Hazard, vulnerability and risk Analysis (Meteorological data over vulnerability and exposure data)

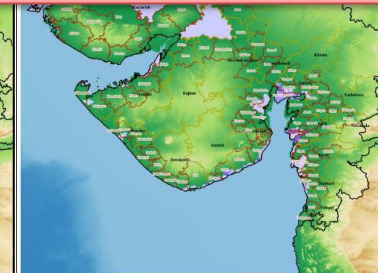
Flood



Wind

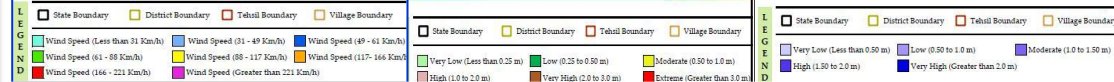


Surge



Damage Expected (Historical data)

- Total destruction of thatched houses/ Extensive damage to kutchha houses/some damage to pucca houses.
- Threat from flying objects. Bending/uprooting of power/ communication poles.
- Major damage to roads. Escape routes flooding.
- Minor disruption of railways/overhead power lines/signaling systems.
- Widespread damage to salt pans/standing crops, bushy trees.
- Detachment of small boats, crafts.



Loss By Category	GUJARAT STATE				
Exposure Type	Exposure (INR Cr)	Wind Loss (INR Cr)	Flood Loss (INR Cr)	Surge Loss (INR Cr)	Combined Loss (INR Cr)
Agriculture	15,766.08	276,3.63	1.20	0.00	2,763.63
Building	5,48,125.92	854.70	19.42	110.71	862.06
Essential Facilities	26,647.94	16.07	2.51	9.87	19.03
Transport	3,76,787.99	15.77	1,127.47	40.83	1,128.32
Utilities	1,37,099.35	86.68	2.56	563.93	570.59

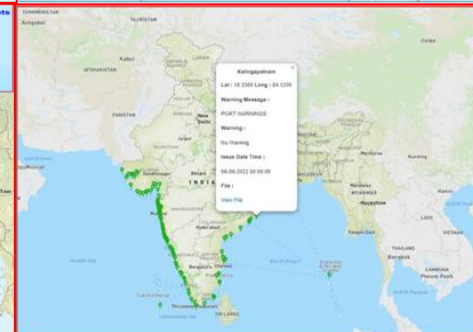
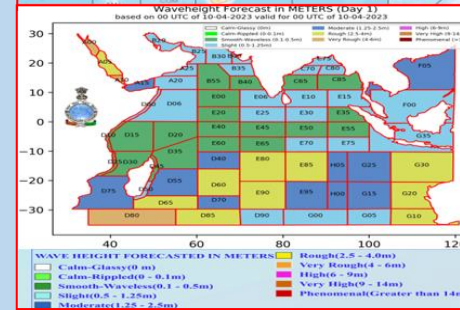
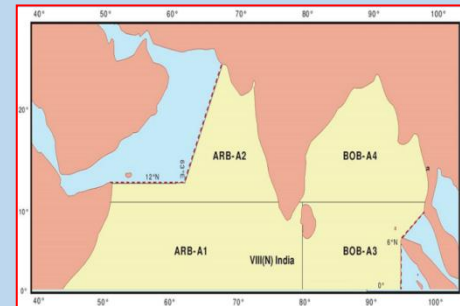
Weather services for marine community



Maritime Forecasting services provided:

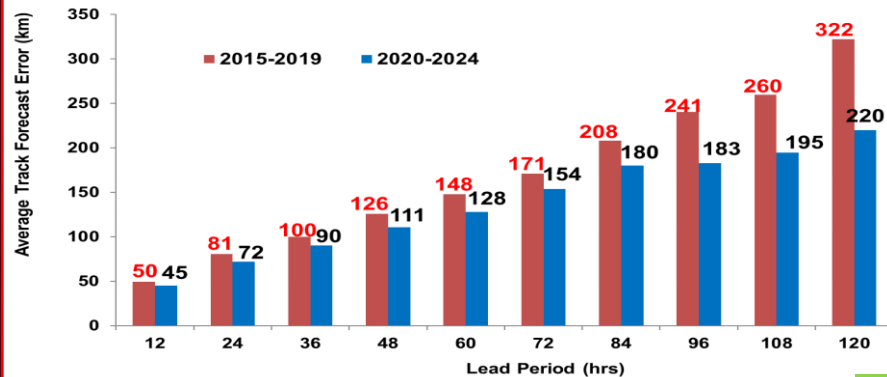
(wind speed and direction, Weather, Significant wave height, Visibility, Swells Cyclonic disturbance / depressions and Storm surge guidance):-

- GMDSS Bulletins
- Sea area bulletins (Outside 75km)
- Coastal weather Bulletins (within 75 km)
- Port warnings (120 Ports)
- Bulletins for the Indian Navy
- Fishermen Warnings (Entire North Indian Ocean)
- Warnings for Onshore and Offshore installations.

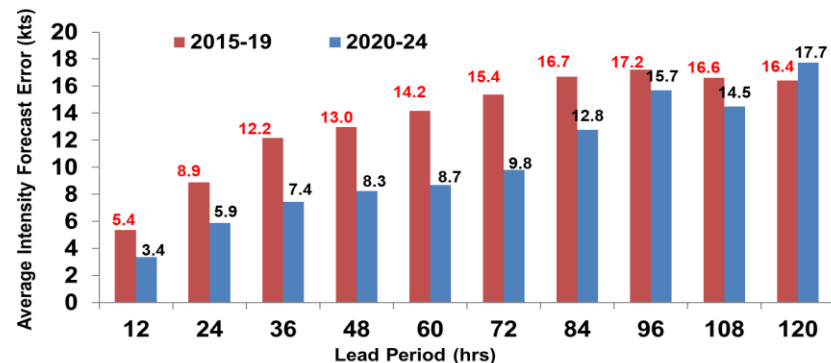


Improvement in track & intensity forecast accuracy by 20-25% and landfall forecast accuracy by 40-70% during 2020-24 compared to 2015-19

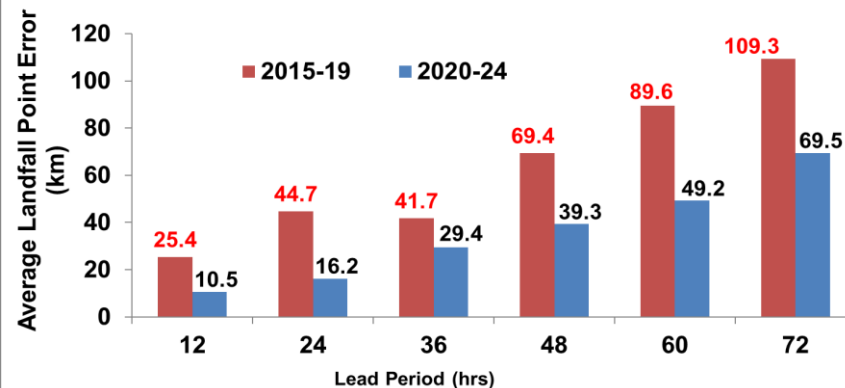
(a) Average Track Forecast Error (km)



(b) Average Intensity Forecast Error based on AE (kts)

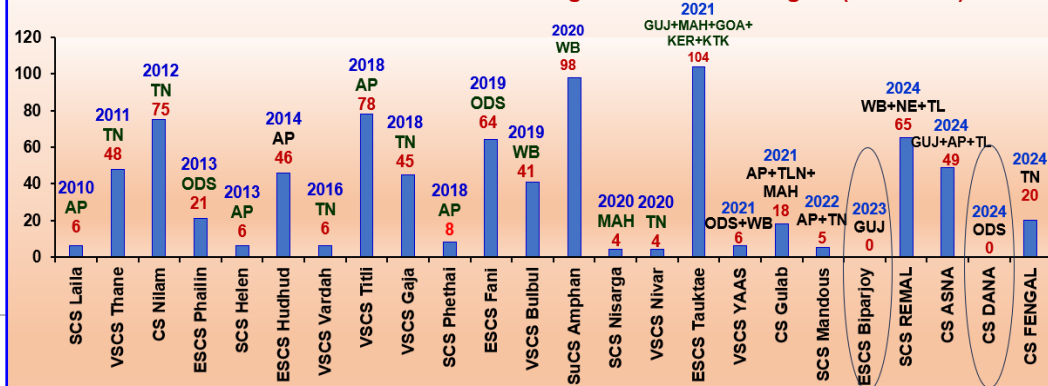


(c) Comparative Average Landfall Point Error (km)



Reduction in death toll to double digit,

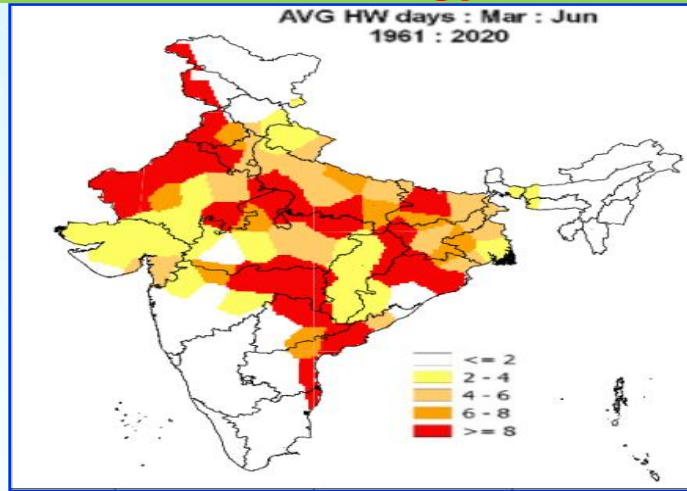
Death toll due to landfalling TCs over Indian region (2010-2024)



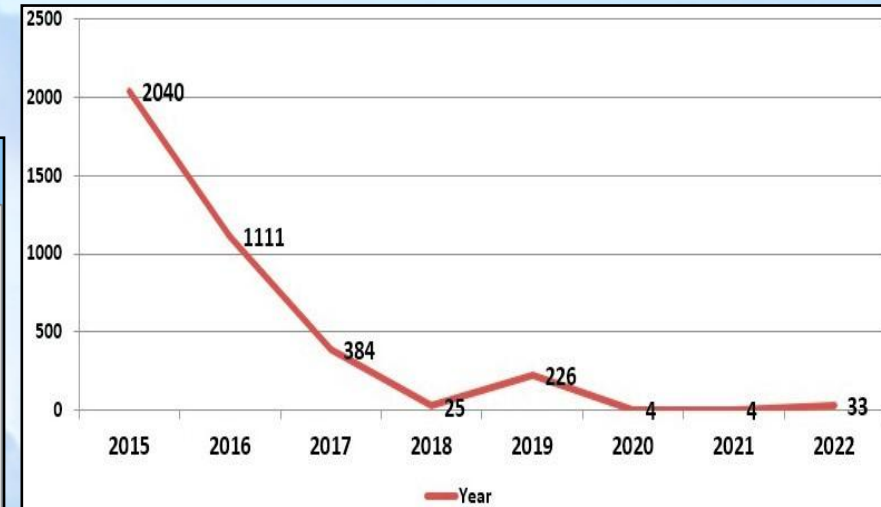
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AP: Andhra Pradesh, GUJ: Gujarat, TN: Tamilnadu, TLN: Telangana, ODS: Odisha, WB: West Bengal, MAH: Maharashtra, TCs not shown: Bandu, Phet & Jai (2010), Lehar & Madi (2013), Ockhi (2017), Burevi (2020), Asani (2022) due to weakening prior to landfall

Heat Wave Climatology, Colour coded warnings with forecast skill

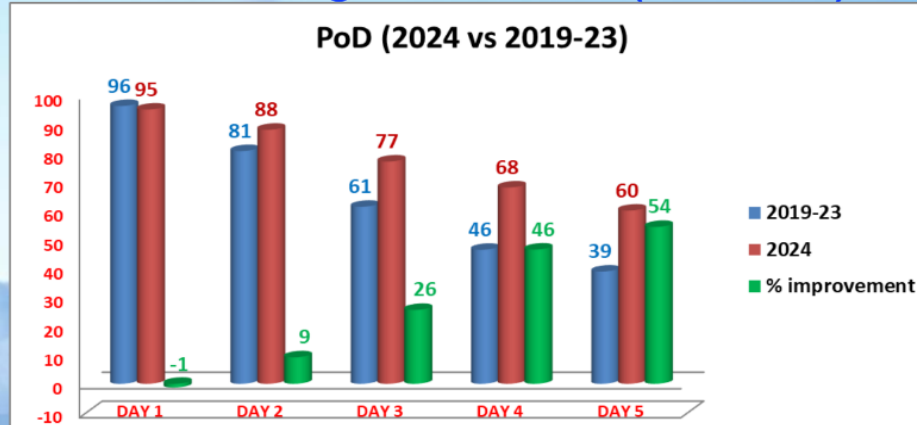


Number of Deaths due to Heat waves

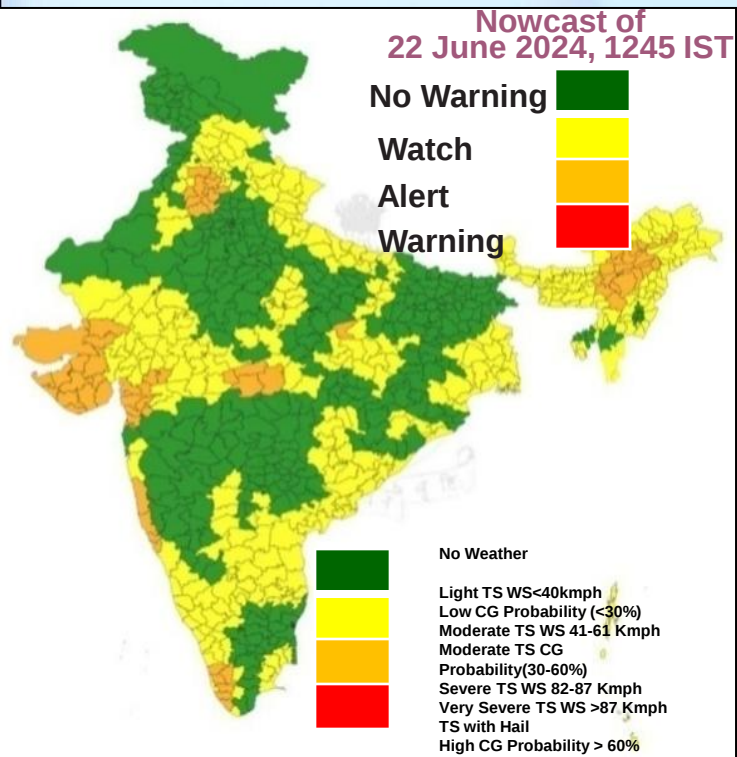


(Source: NDMA)

Heat Wave Warning Skills 2024 vs (2019-2023)



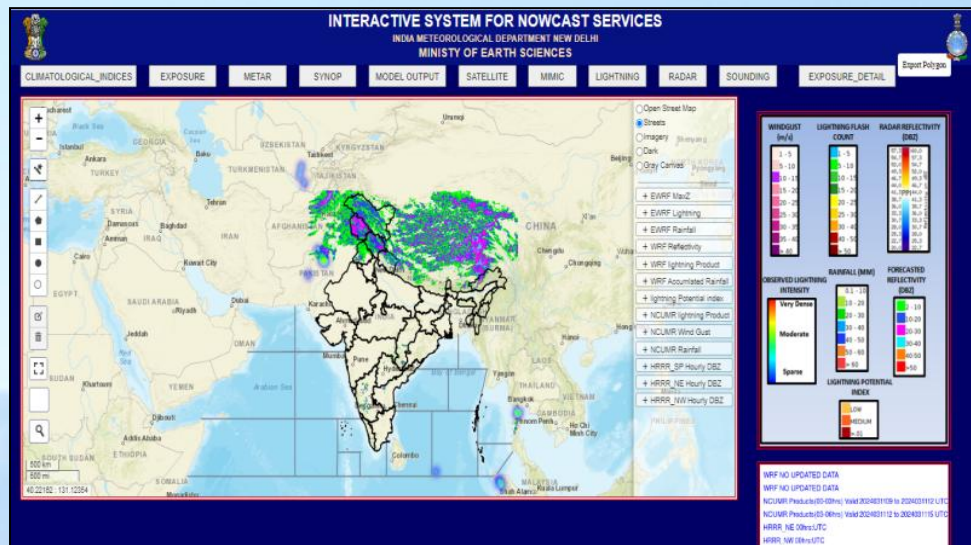
Districtwise Nowcast Warning GIS based Thunderstorm Decision Support System



24-Hourly TS Nowcast verification scores from March-June 2016-24



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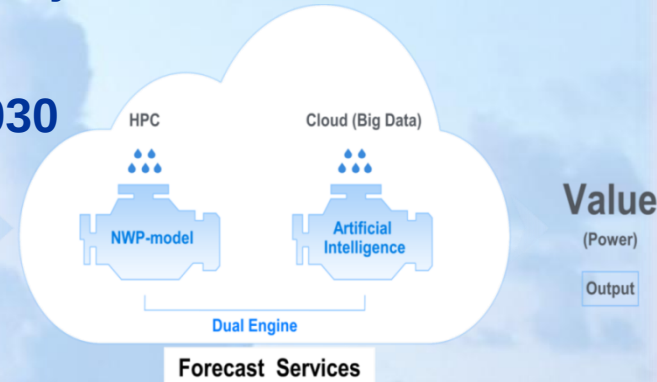
FUTURE PLAN

- Significant improvement in Cyclone MHEWS and DRR in recent years leading to drastic reduction in loss of lives
- Scope for weather hazard monitoring and forecasting to meet Early Warning for All based on following:
 - » Improved Value Chain (Observation→Modeling→ Forecasting → Severe weather warning→Sectoral Applications) including R&D.
 - » Dual engine concept : AI/ML application in conjunction with Numerical Weather Prediction (NWP) modeling
 - » Improvement in forecast accuracy by 10-15% by 2030
 - » **Mission Mausam (2024-2026)**
 - **Forecasting** of severe weather Hazards at (5x5km) by 2030
 - **Dynamic Impact based forecasting** & risk based warning for all severe weather
 - **Last mile connectivity** to meet early warning for all (Early warning to each household 2030)

Data

(Petroleum)

for



THANK YOU



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