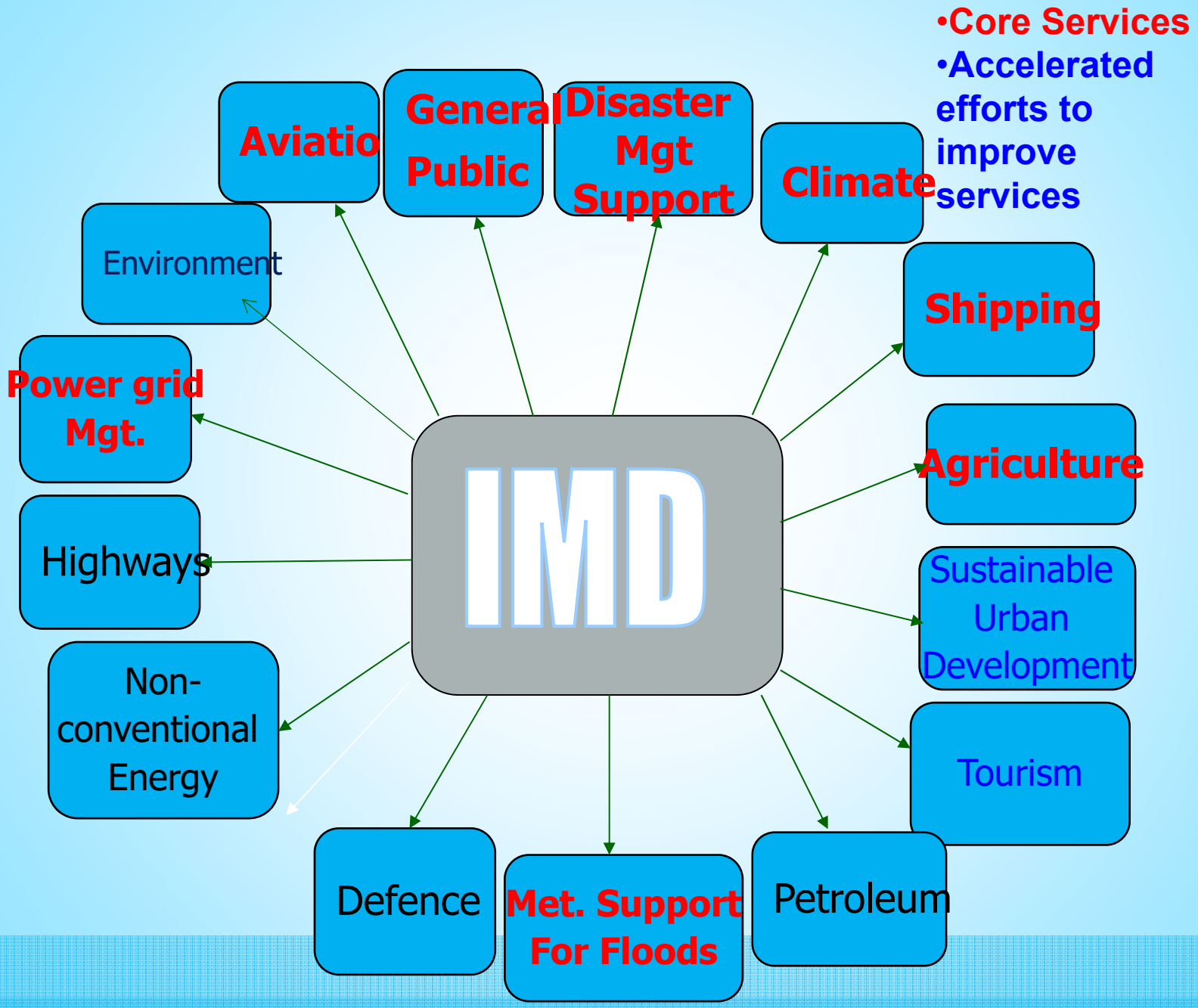
EMMDA

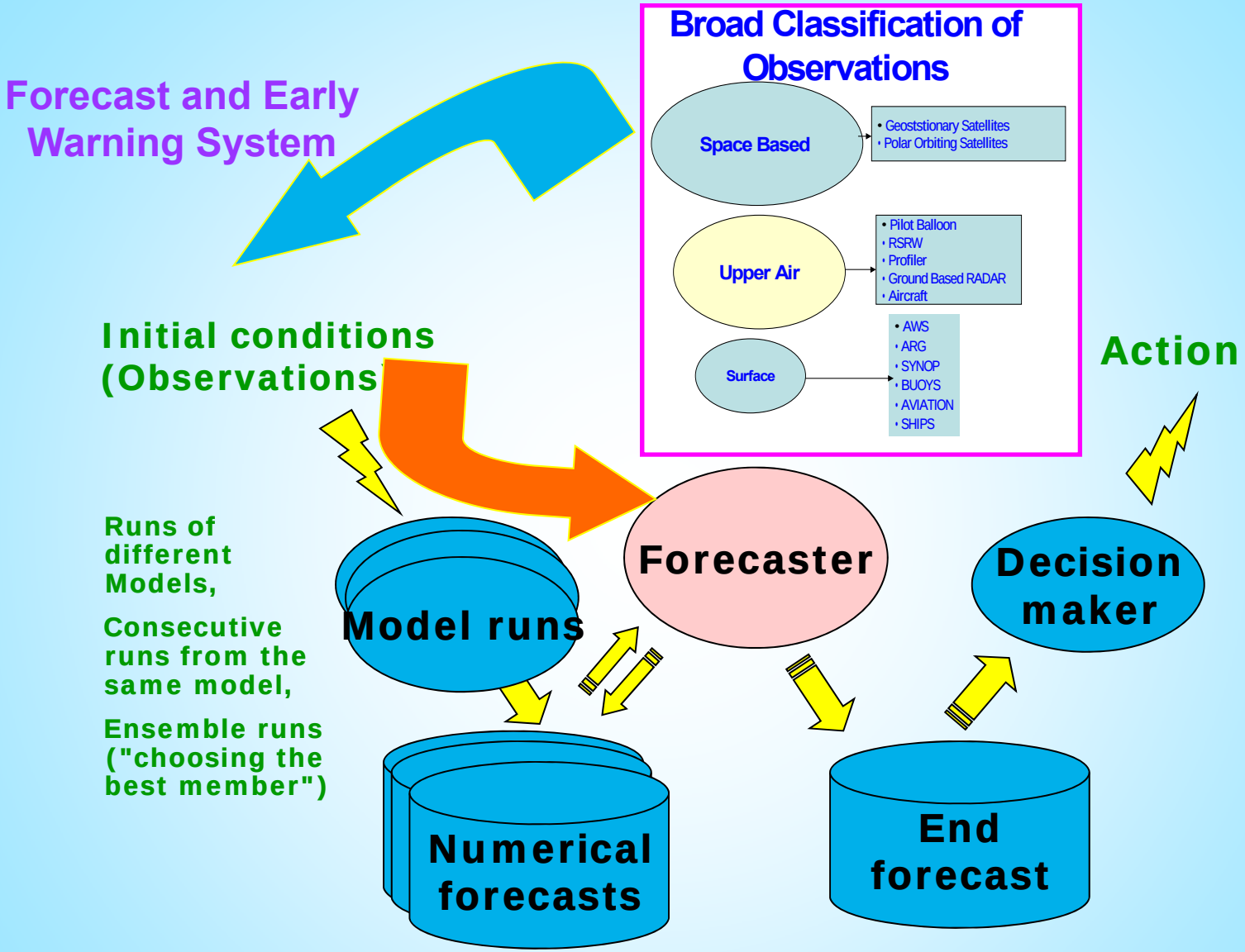
Probabilistic Forecasting in IMD: Current Status and Future Scope

M. Mohapatra
DGM, IMD
भारत मौसम विज्ञान विभाग
INDIA METEOROLOGICAL DEPARTMENT

Major science themes/applications/services of IMD



Major science themes/applications/services of IMD



Improved Forecast and Early warning system with respect to all the above components

Deterministic Forecast

- **Determinism:** Every event is the inevitable result of antecedent causes.
- A perfect **deterministic (or categorical) forecast** can only be as good as

  (a) the meteorologist's interpretation skills.

  (b) degree of his understanding of the forecast models and how good these models are at estimating things.

  (c) degree to which original observations are accurate @ so on.
- Entrenched preconceived notion held by forecasters is that a deterministic or a categorical forecast is the best forecast.
- However, the further out from present time one goes, the more important it is that a forecaster integrates "probabilistic" language either into actual forecast wording, or at least into intellectual underpinning for his forecast.

"Not to do so is to not produce a state of the art forecast"

Probabilistic Forecast at IMD : Current Status

- **Probabilistic forecasting** is a technique for weather forecasting that relies on different methods to establish an event occurrence/magnitude probability.
- It represents an estimation of the respective probabilities for all the possible future outcomes of a random variable. In contrast to single-valued forecasts, such as median time-series forecasts or quantile forecasts, the probability forecast represents a probability density function.
- **IMD** is issuing the probabilistic forecast in spatial as well as temporal domains by incorporating different terminologies in its forecasts.

Forecasts for spatial distribution & weather events

Spatial Distribution of Rainfall	Descriptive term used	Criteria as per reported rainfall
Dry	Dry	No station
Isolated	One or two Places	≤ 25% of stations
Scattered	At a few Places	(26–50)% of stations
Fairly Widespread	At many Places	(51–75)% of stations
Widespread	At most places	(76–100)% of stations

Intensity of Snowfall (in 24 hours)

Terminology	Snowfall depth (cm)	Percentile
Light Snowfall	**10.4 cm or less**	**Less than 50th percentile**
Moderate Snowfall	**10.5 - 64.4 cm**	**50 – 95**
Heavy Snowfall	**64.5 - 115.5 cm**	**95 – 99**
Very Heavy Snowfall	**115.6 - 204.4 cm**	**99.0 - 99.9**
Extremely heavy Snowfall	**204.5 cm or more**	**> 99.9**

Probability forecasts of rainfall or weather

Term	Probability
Unlikely	probability of occurrence less than 25%
Likely	probability of occurrence between 25 & 50%
Very likely	probability of occurrence between 51% & 75 %
Most likely	probability of occurrence above 75%

Sample Forecast & Warning of 19th February 2020.

राष्ट्रीय मौसम पूर्वानुमान केन्द्र
भारत मौसम विज्ञान विभाग
पृथ्वी विज्ञान मंत्रालय

National Weather Forecasting Centre
India Meteorological Department
Ministry of Earth Sciences

Table-1

5 Day Rainfall Forecast (MID-DAY)

19-February-2020

Met-Sub-Division	19-Feb Today	20Feb Thu	21Feb Fri	22Feb Sat	23Feb Sun
1. Andaman & Nicobar Islands	SCT	ISOL	ISOL	DRY	DRY
2. Arunachal Pradesh	SCT	ISOL	ISOL	SCT	SCT
3. Assam & Meghalaya	ISOL	ISOL	ISOL	ISOL	SCT
4. N. M. M. & T.	ISOL	DRY	DRY	DRY	ISOL
5. S.H. West Bengal & Sikkim	ISOL	ISOL	ISOL	SCT	SCT
6. Gangetic West Bengal	DRY	DRY	DRY	DRY	ISOL
7. Odisha	DRY	DRY	DRY	DRY	ISOL
8. Jharkhand	DRY	DRY	ISOL	SCT	SCT
9. Bihar	DRY	DRY	ISOL	SCT	SCT
10. East Uttar Pradesh	DRY	ISOL	SCT	ISOL	ISOL
11. West Uttar Pradesh	DRY	ISOL	ISOL	ISOL	ISOL
12. Uttarakhand	ISOL	FWS	FWS	SCT	ISOL
13. Haryana, Chd & Delhi	ISOL	SCT	SCT	ISOL	DRY
14. Punjab	ISOL	FWS	SCT	ISOL	DRY
15. Himachal Pradesh	SCT	FWS	SCT	ISOL	ISOL
16. J & K and Ladakh	SCT	SCT	ISOL	ISOL	DRY
17. West Rajsthan	DRY	ISOL	DRY	DRY	DRY
18. East Rajasthan	DRY	DRY	DRY	DRY	DRY
19. West Madhya Pradesh	DRY	DRY	ISOL	DRY	DRY
20. East Madhya Pradesh	DRY	DRY	ISOL	ISOL	ISOL
21. Gujarat Region	DRY	DRY	DRY	DRY	DRY
22. Saurashtra & Kutch	DRY	DRY	DRY	DRY	DRY
23. Konkan & Goa	DRY	DRY	DRY	DRY	DRY
24. Madhya Maharashtra	DRY	DRY	DRY	DRY	DRY
25. Marathawada	DRY	DRY	DRY	DRY	DRY
26. Vidharbha	DRY	DRY	DRY	DRY	DRY
27. Chhattisgarh	DRY	DRY	ISOL	ISOL	ISOL
28. Coastal A. P. & Yanam	DRY	DRY	DRY	DRY	DRY
29. Telangana	DRY	DRY	DRY	DRY	DRY
30. Rayalaseema	DRY	DRY	DRY	DRY	DRY
31. T.N.,Puducherry & Karaikal	DRY	ISOL	SCT	SCT	ISOL
32. Coastal Karnataka	DRY	DRY	DRY	DRY	DRY
33. North Interior Karnataka	DRY	DRY	DRY	DRY	DRY
34. South Interior Karnataka	DRY	DRY	DRY	DRY	DRY
35. Kerala & Mahe	DRY	DRY	ISOL	ISOL	DRY
36. Lakshadweep	DRY	DRY	DRY	DRY	DRY

% Station Reporting Rainfall

% Stations	Category	% Stations	Category
76-100	Widespread (WS/Most Places)	26-50	Scattered (SCT/ A Few Places)
51-75	Fairly Widespred (FWS/ Many Places)	1-25	Isolated (ISOL)
No Rain	Dry		

20 February (Day 2): ♦ **Dense fog** very likely in isolated parts over Sub-Himalayan West Bengal & Sikkim.

♦ **Thundersquall (speed reaching 50-60 kmph)** accompanied with **lightning & hail** very likely over Uttarakhand. **Thunderstorm** accompanied with **lightning & gusty wind (speed reaching 30-40 kmph)** very likely over Himachal Pradesh, West Uttar Pradesh, Punjab and Haryana, Chandigarh & Delhi.

21 February (Day 3): ♦ **Thundersquall (speed reaching 50-60 kmph)** accompanied with **lightning & hail** very likely over Uttarakhand. **Thunderstorm** accompanied with **lightning & gusty wind (speed reaching 30-40 kmph)** very likely over Uttar Pradesh, Punjab and Haryana, Chandigarh & Delhi and with **lightning** over East Madhya Pradesh.

♦ **Strong wind (speed reaching 45-55 kmph)** very likely to prevail over South Andaman Sea, Gulf of Mannar, Comorin area & South Bay of Bengal. Fishermen are advised not to venture in the above areas.

ENSEMBLE modelling for probabilistic forecasting

- **Main sources of uncertainty in NWP due to:**

❖ **Incomplete knowledge of exact state of atmosphere (initial conditions)**

❖ **Unavoidable simple representation of complex nature in NWP models.**

- **Despite advances in observational network (satellite, Radar, conventional land, Ocean & atmosphere based observations), it remains impossible to describe state of the atmosphere without any uncertainty.**
- **Whole complexity of all atmospheric processes & their interactions with Ocean & land surface cannot be captured in NWP model.**
- **Ensemble prediction system offers most consistent method of**

❖ **identifying predictable scale,**

❖ **estimating overall confidence and**

❖ **drawing attention to possible alternative developments,**

in particular those which involve extreme or hazardous weather events.

IMD Operational Models

Temporal scales	Numerical NWP/Climate Models	Resolutions and Frequency of Update
Up to short range forecasting	• Weather Research Forecast (WRF) regional models • HWRF – HYCOM/POM modeling system for Tropical Cyclones.	• 03 km run for 3 days (Run twice a day) • 2,6,18 km triple nested (Run four times a day ; 00, 06, 12 & 18 UTC) for 126 hours.
Medium range forecast	• Global Forecast System (GFS) atmospheric model • Global Ensemble Forecast System (GEFS) atmospheric model (20 members)	• 12 km (Run four times a day ; 00, 06, 12 & 18 UTC) for 10 days • 12 km (Run once a day) for 10 days
Extended range forecast (ERF)	• Climate Forecast System (CFS) coupled models (16 members)	• 38 km (Run once in a week) for 32 days with 16 years hindcast (2003-2018)
Seasonal forecast	• Climate Forecast System (CFS) coupled models (20 members)	• 38 km (Run once in a month) for 4 to 7 months

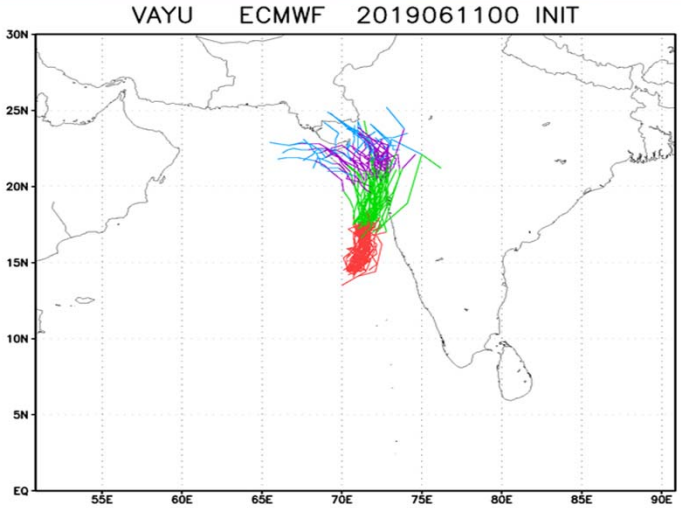
Different Ensemble Models and Methods In IMD For Probabilistic Forecast

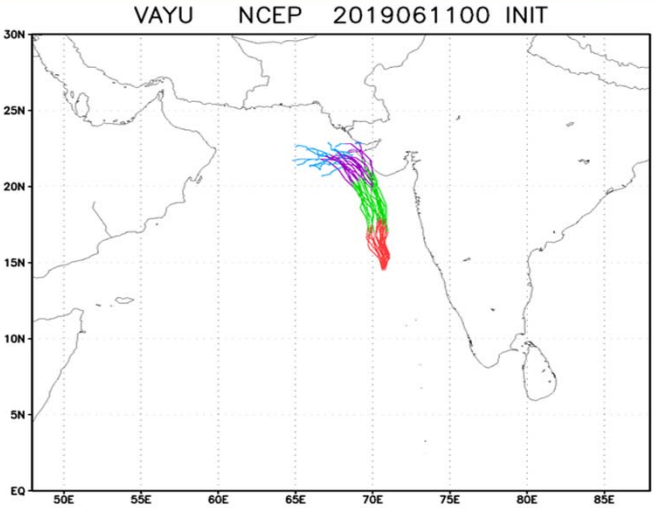
- *Ensemble Prediction System (TIGGE-EPS).*
- *HWRF Ensemble System (Experimental).*
- *IMD Tropical Cyclone Cone of Uncertainty.*
- *IMD Global Ensemble Forecast System.*
- *IMD Probabilistic Quantitative Probabilistic Forecast.*
- *IMD Extended Range Probabilistic Forecast.*

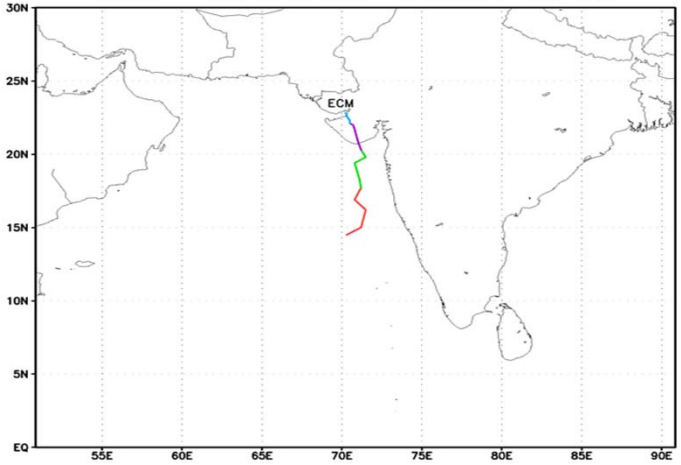
Ensemble Prediction System (TIGGE-EPS).

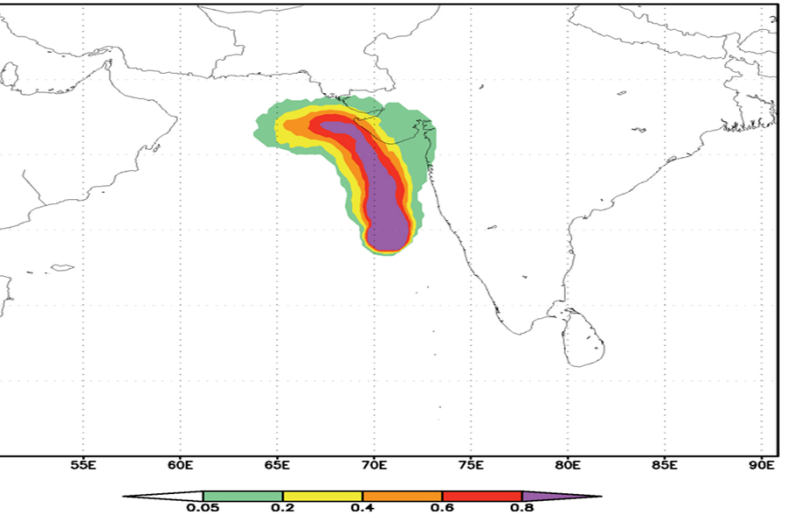
- TIGGE consists of ensemble forecast from 10 global NWP centers, since Oct. 2006. Available from data archive portals at ECMWF/ JMA.
- TC data generated in CXML format from deterministic and Ensemble (all Members) Forecasts in Lat, Long positions, MSLP, Vmax from Initial 00 to 120 hr Forecasts from ECMWF, NCEP, UKMO are available in real –time from Depression stage onwards for NIO region.
- JMA software generates Graphic Products using CXML files on :Deterministic and Ensemble TC Track forecasts, Strike Probability Maps, Strike probability within the range of 120 kms 4 days in advance
- TIGGE helps in research projects on ensemble forecasting, predictability and development of products to improve severe weather prediction.

Ensemble Prediction System (TIGGE-EPS).



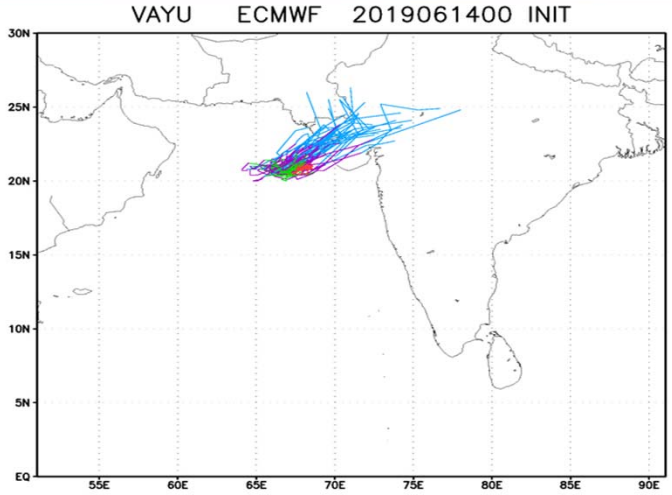


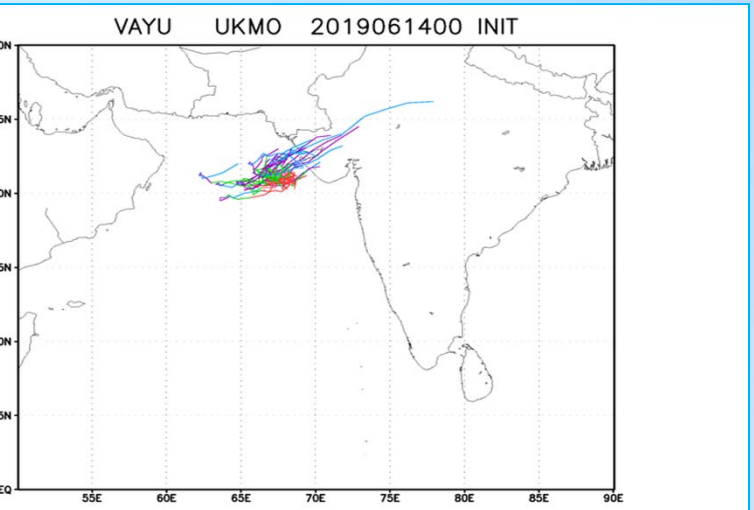


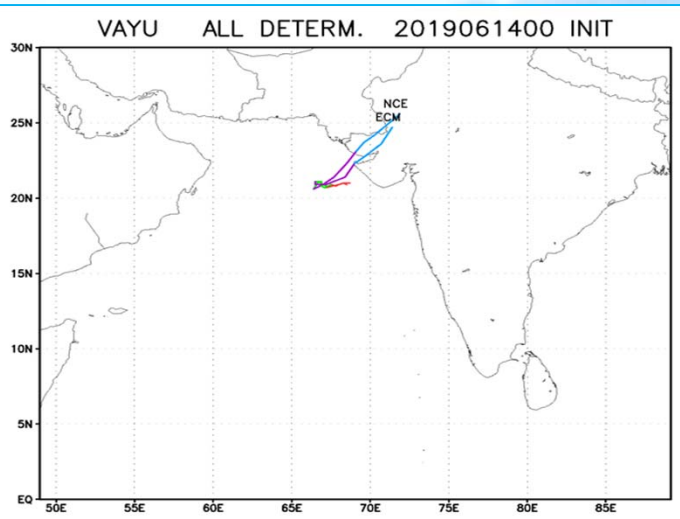


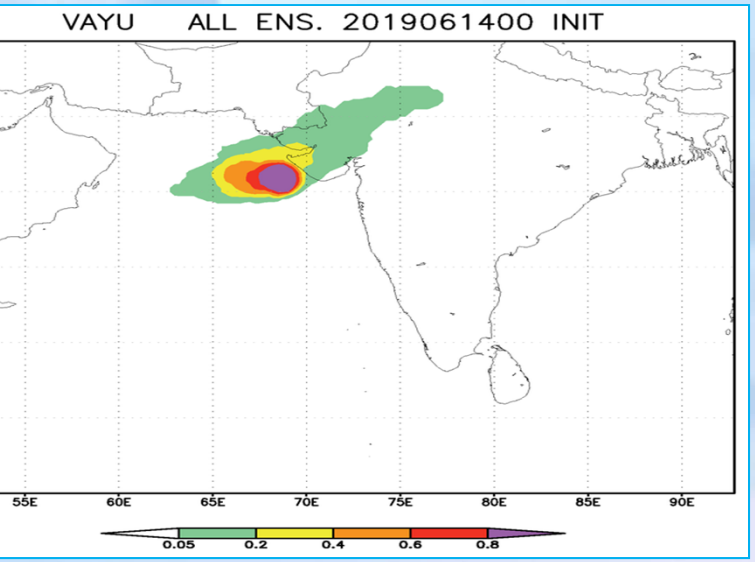
भारत मौसम विज्ञान विभाग
INDIA METEOROLOGICAL DEPARTMENT

Ensemble Prediction System (TIGGE-EPS).





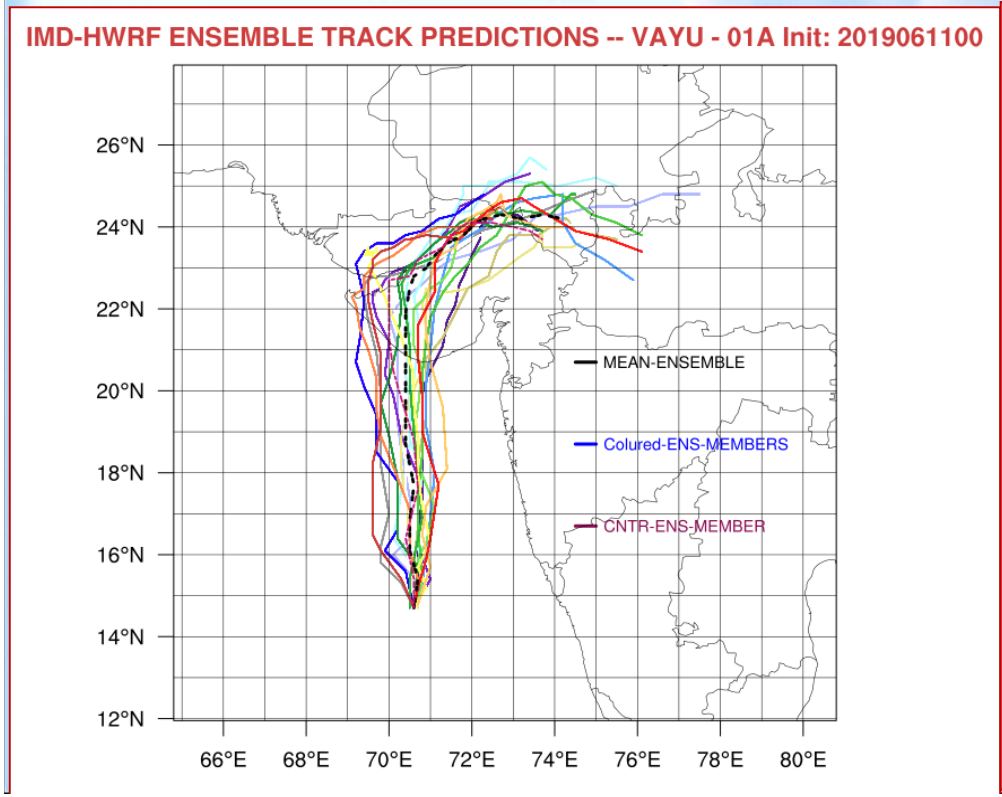


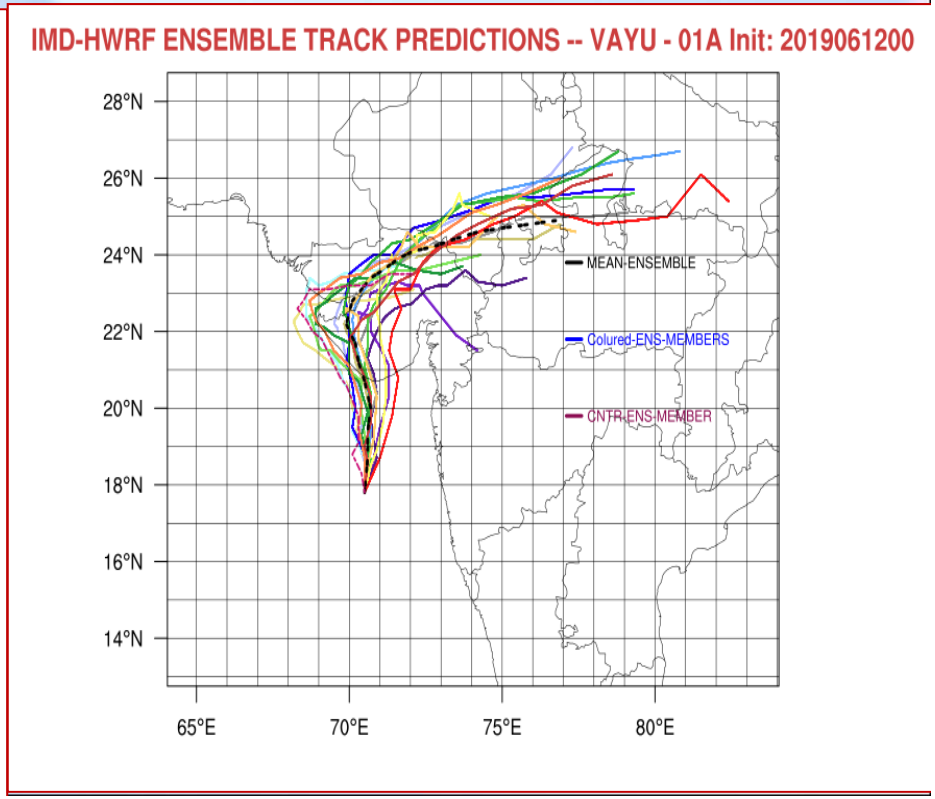


HWRF Ensemble System (Experimental).

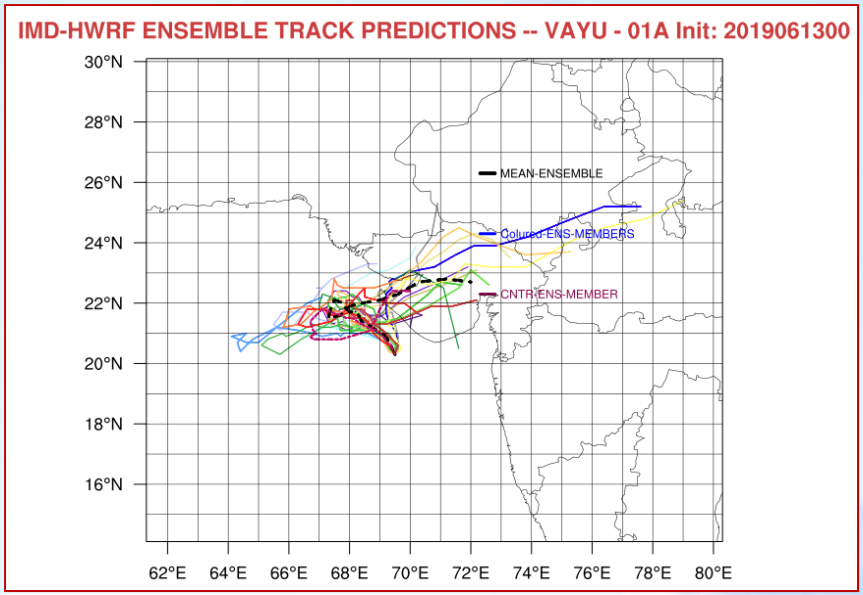
HWRF coupled modeling system based on H217 configuration of NCEP is operationally run with triple nest (18x6x2 km) and 61 vertical levels 4 times a day in cyclic mode with data assimilation.

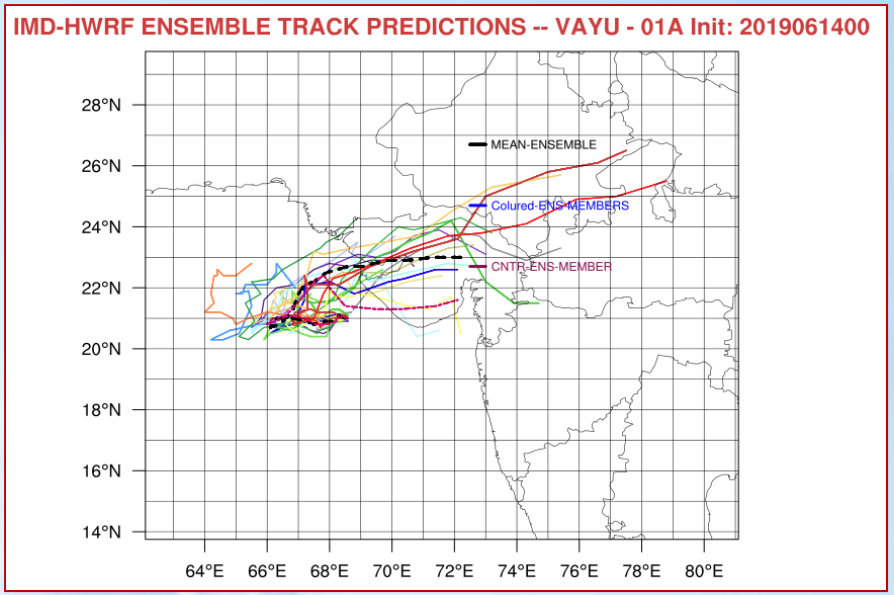
HWRF ensemble forecast (expt) based on IC from NCEP GEFS for Tropical Cyclone "VAYU"

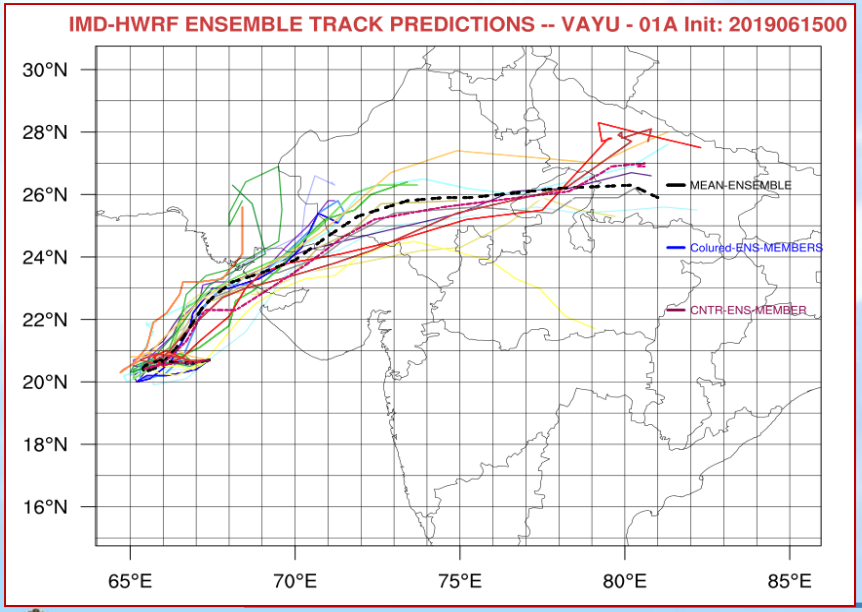


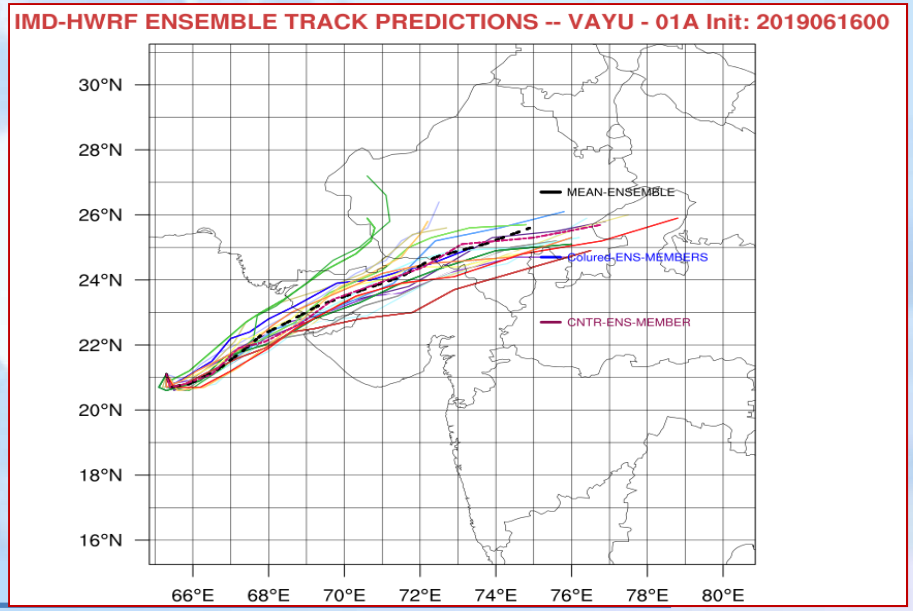


HWRF Ensemble System (Track Forecast).





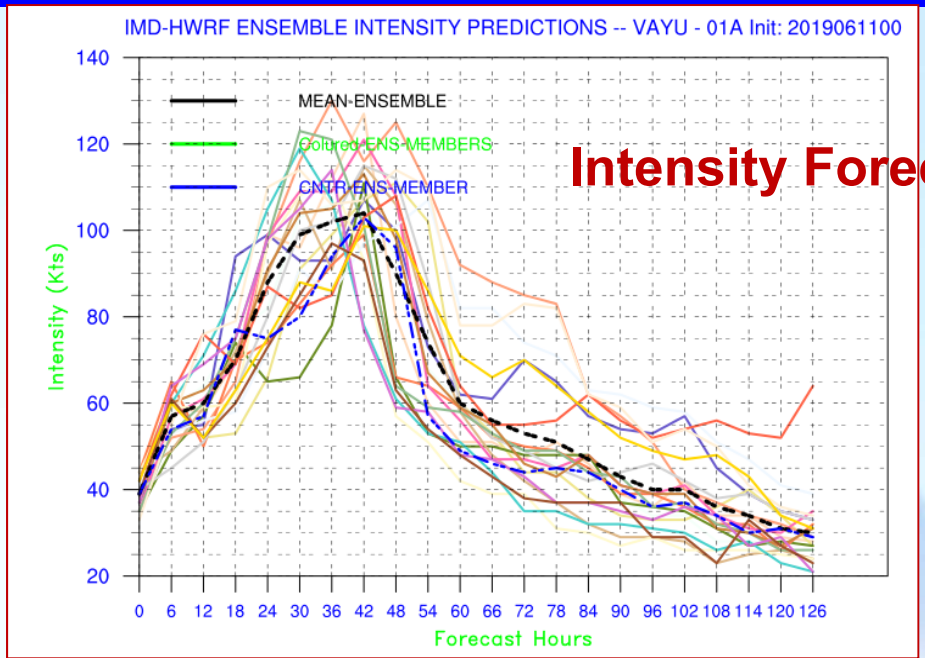




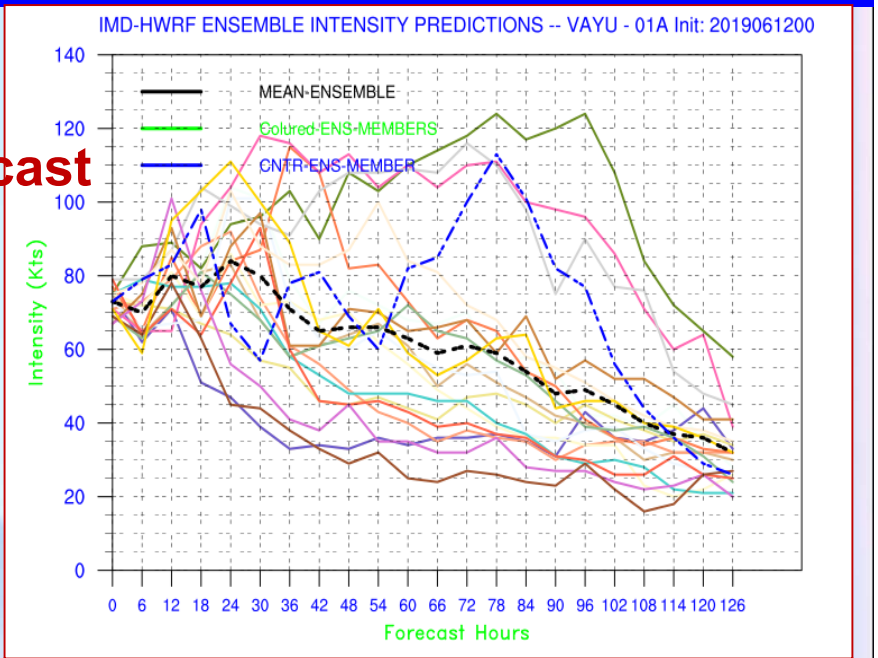
भारत मौसम विज्ञान विभाग

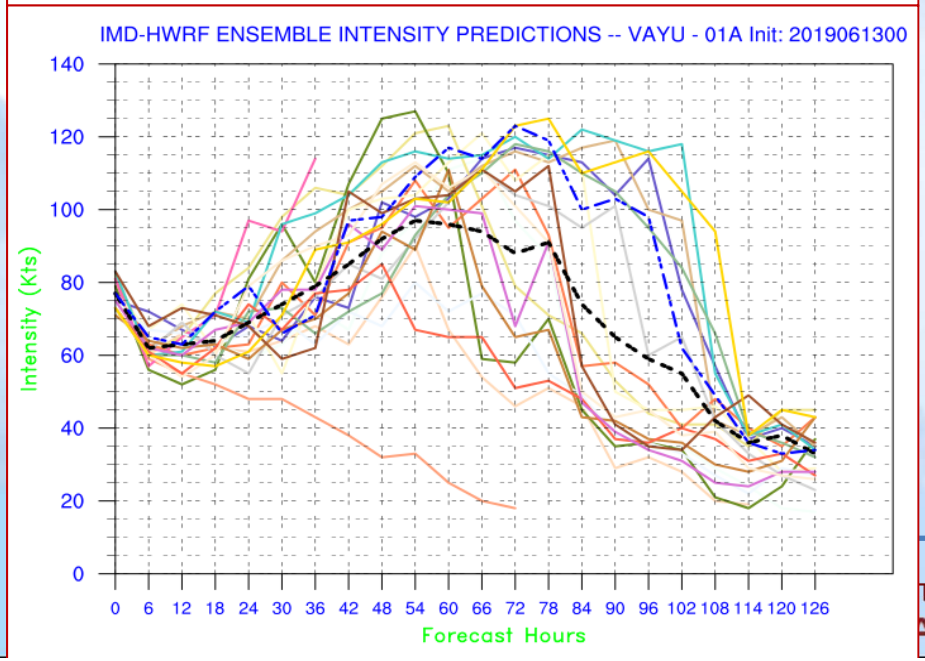
INDIA METEOROLOGICAL DEPARTMENT

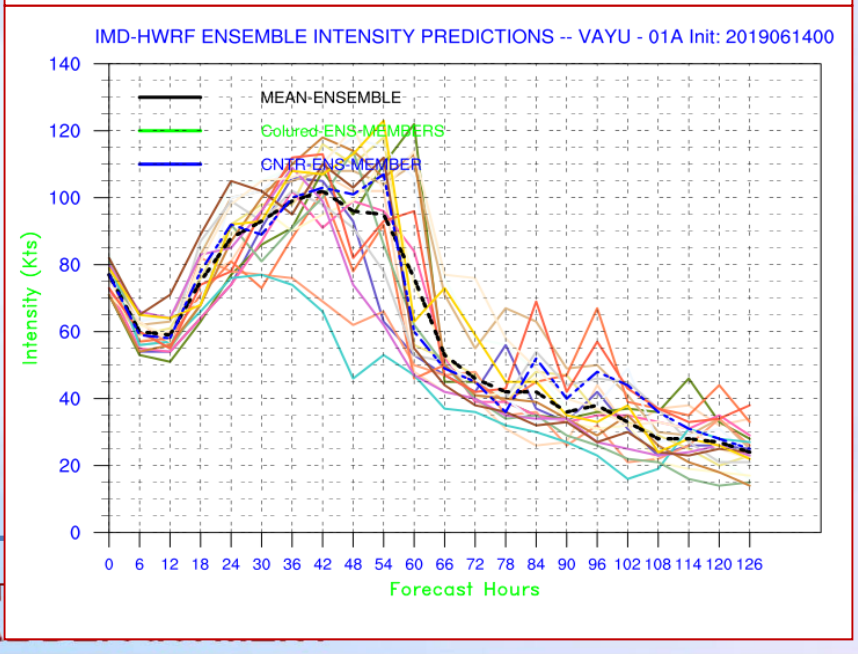
HWRF Ensemble System (Experimental).



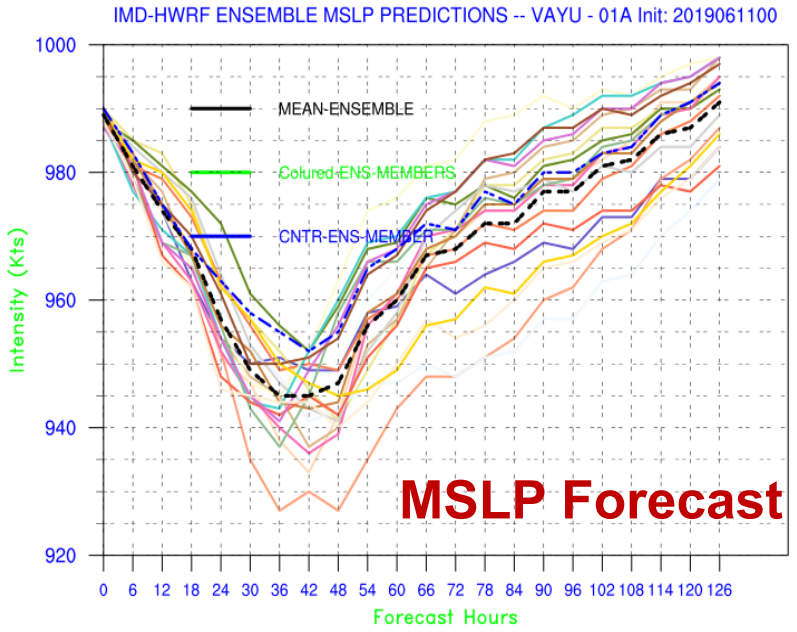
Intensity Forecast

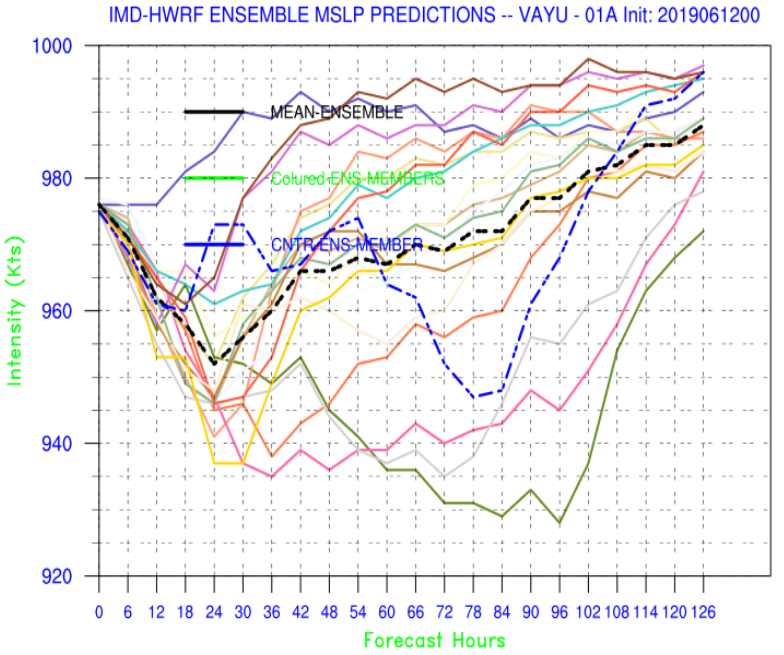


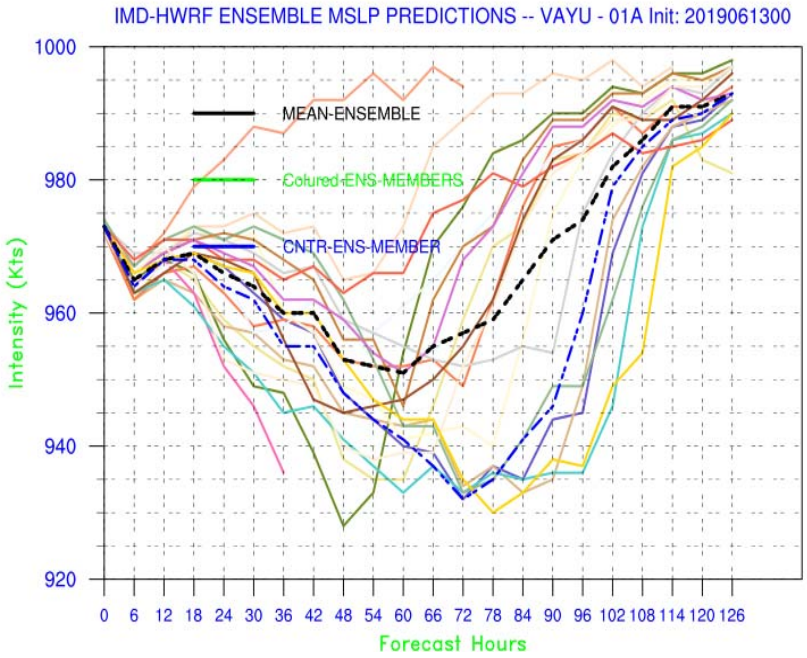


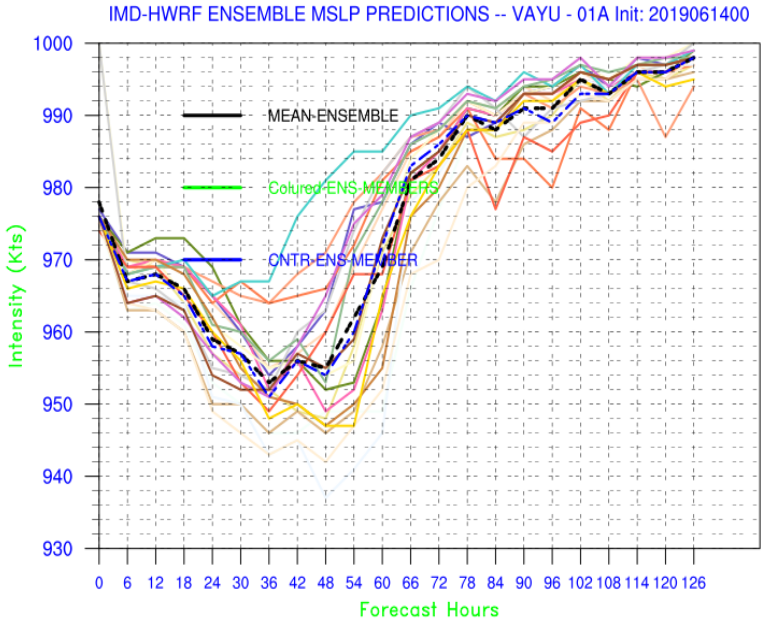


HWRF Ensemble System (Experimental).

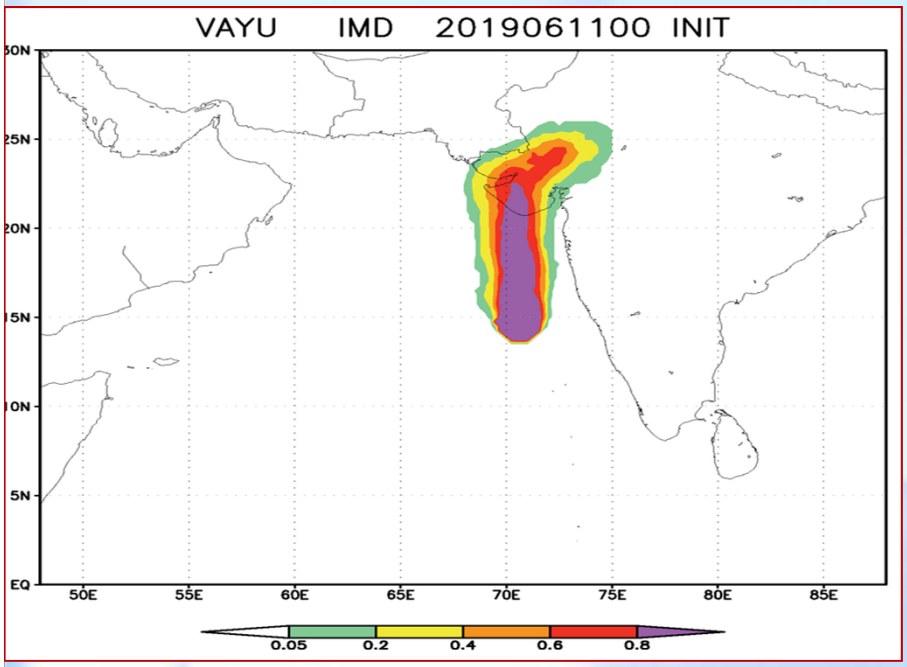


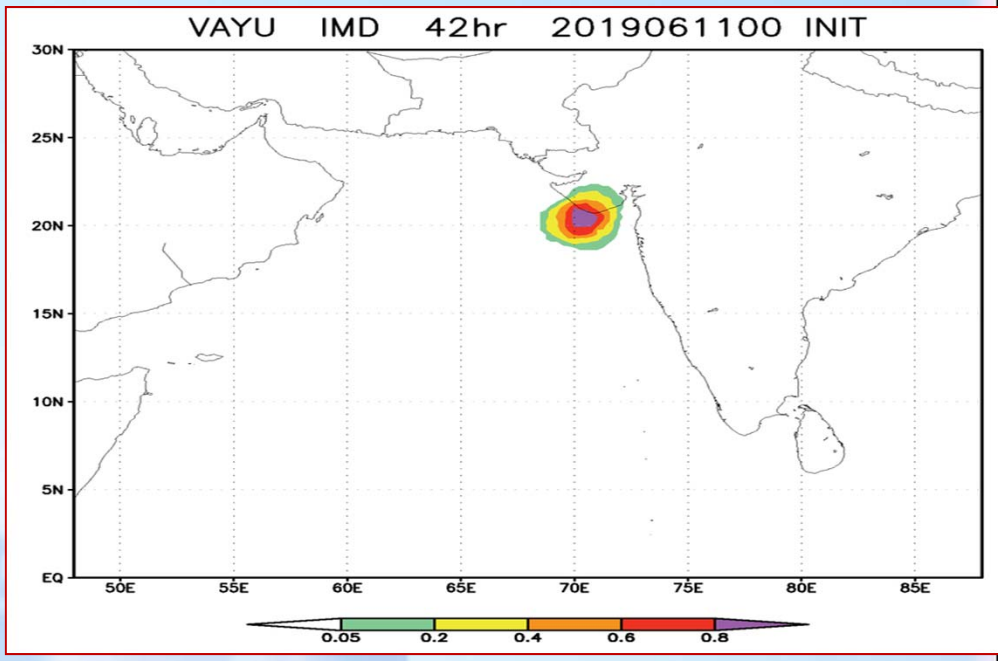


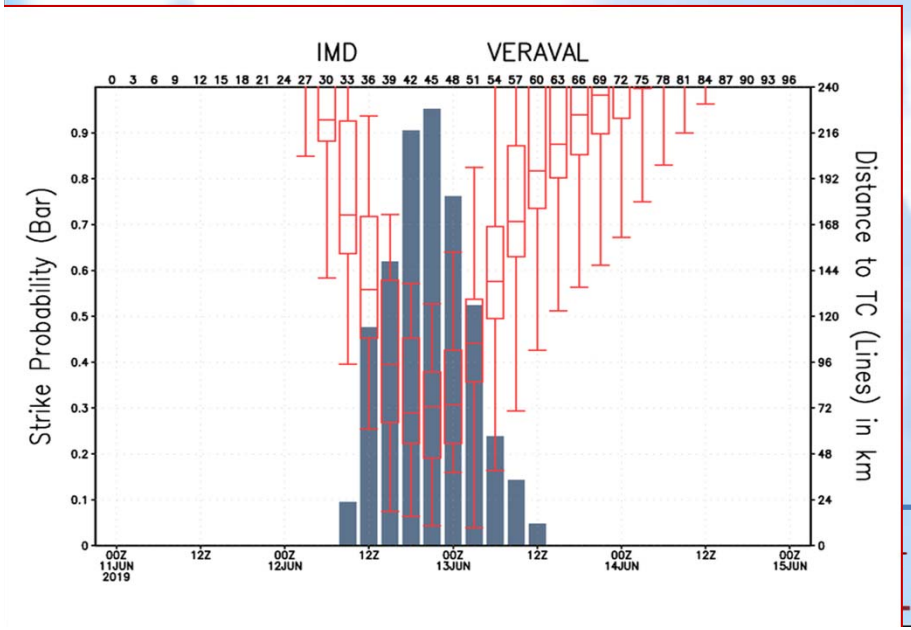


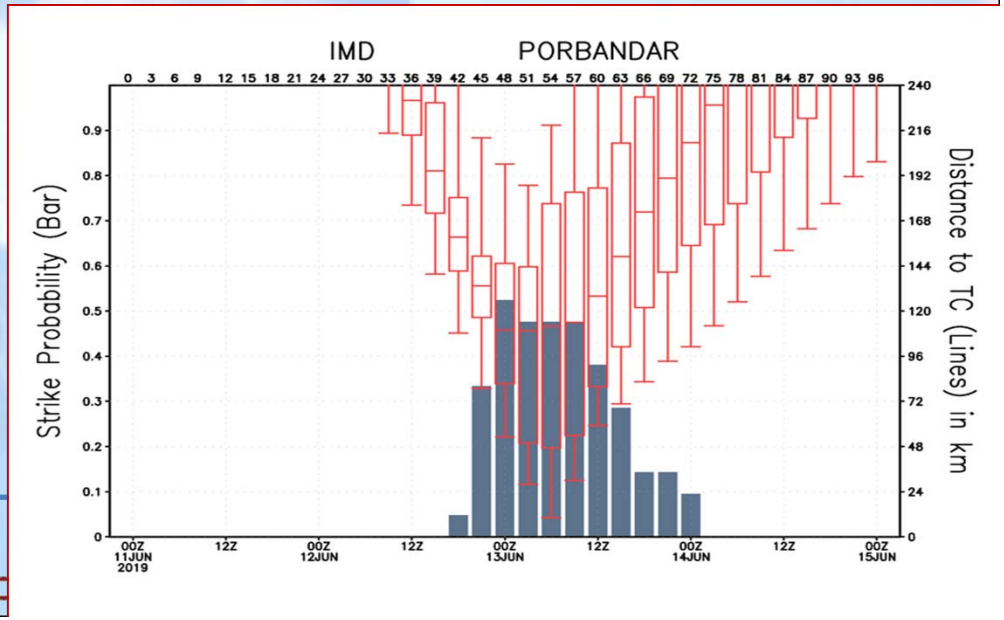


HWRF Ensemble run utilization using TIGGE EPS

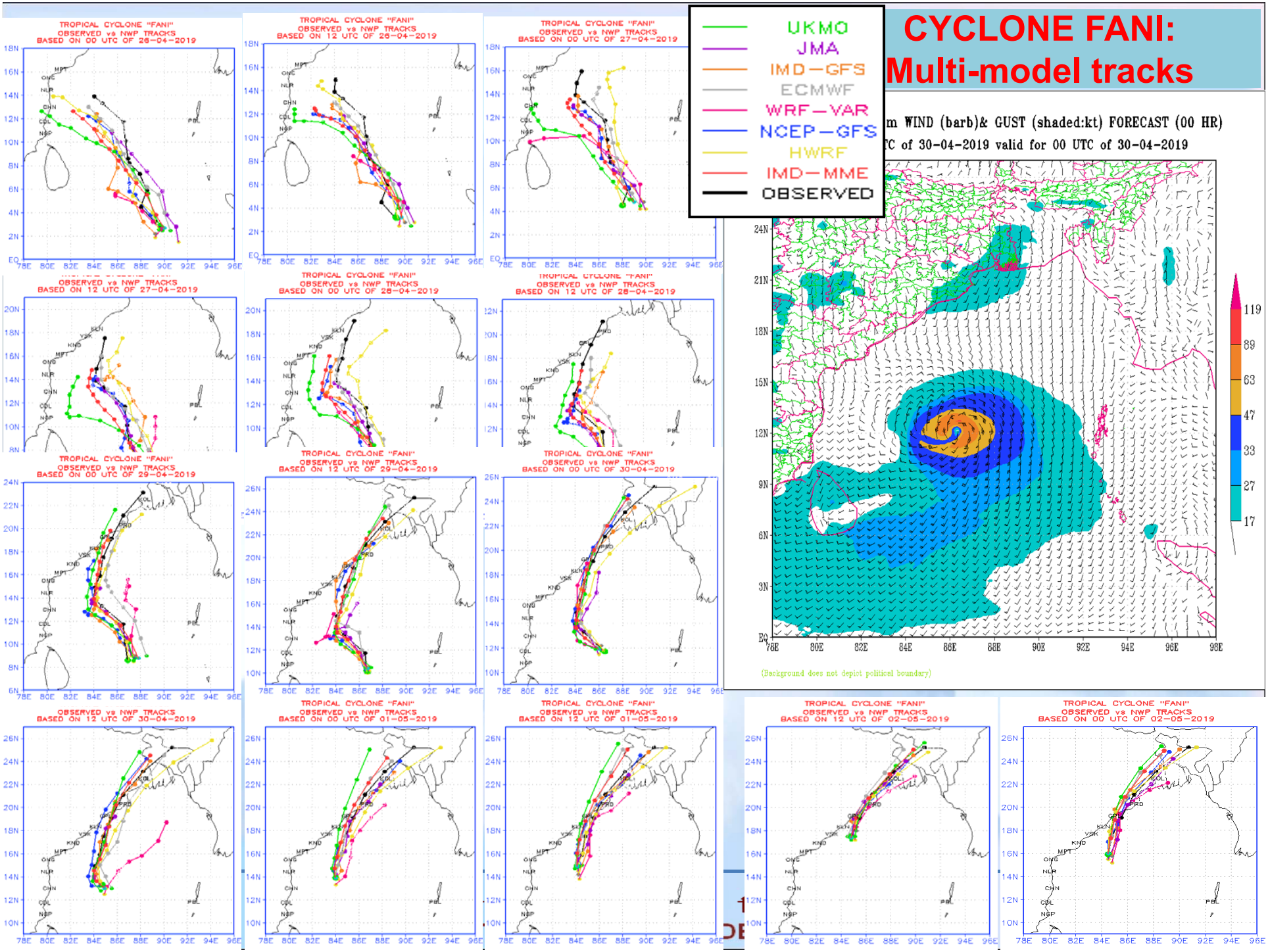




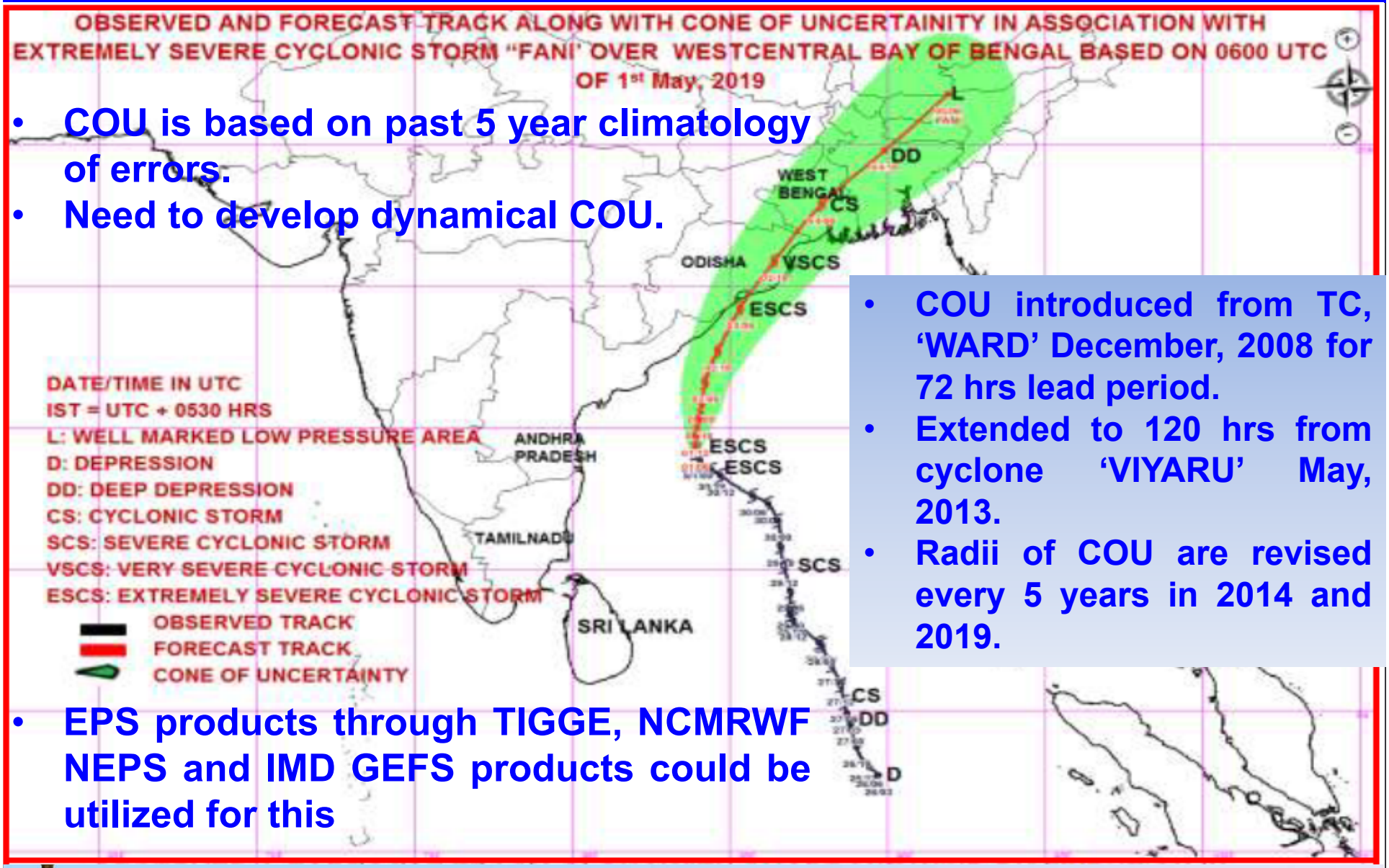




CYCLONE FANI: Multi-model tracks



IMD Tropical Cyclone Cone of Uncertainty (COU)



- COU is based on past 5 year climatology of errors.
- Need to develop dynamical COU.

- COU introduced from TC, 'WARD' December, 2008 for 72 hrs lead period.
- Extended to 120 hrs from cyclone 'VIYARU' May, 2013.
- Radii of COU are revised every 5 years in 2014 and 2019.

- EPS products through TIGGE, NCMRWF NEPS and IMD GEFS products could be utilized for this

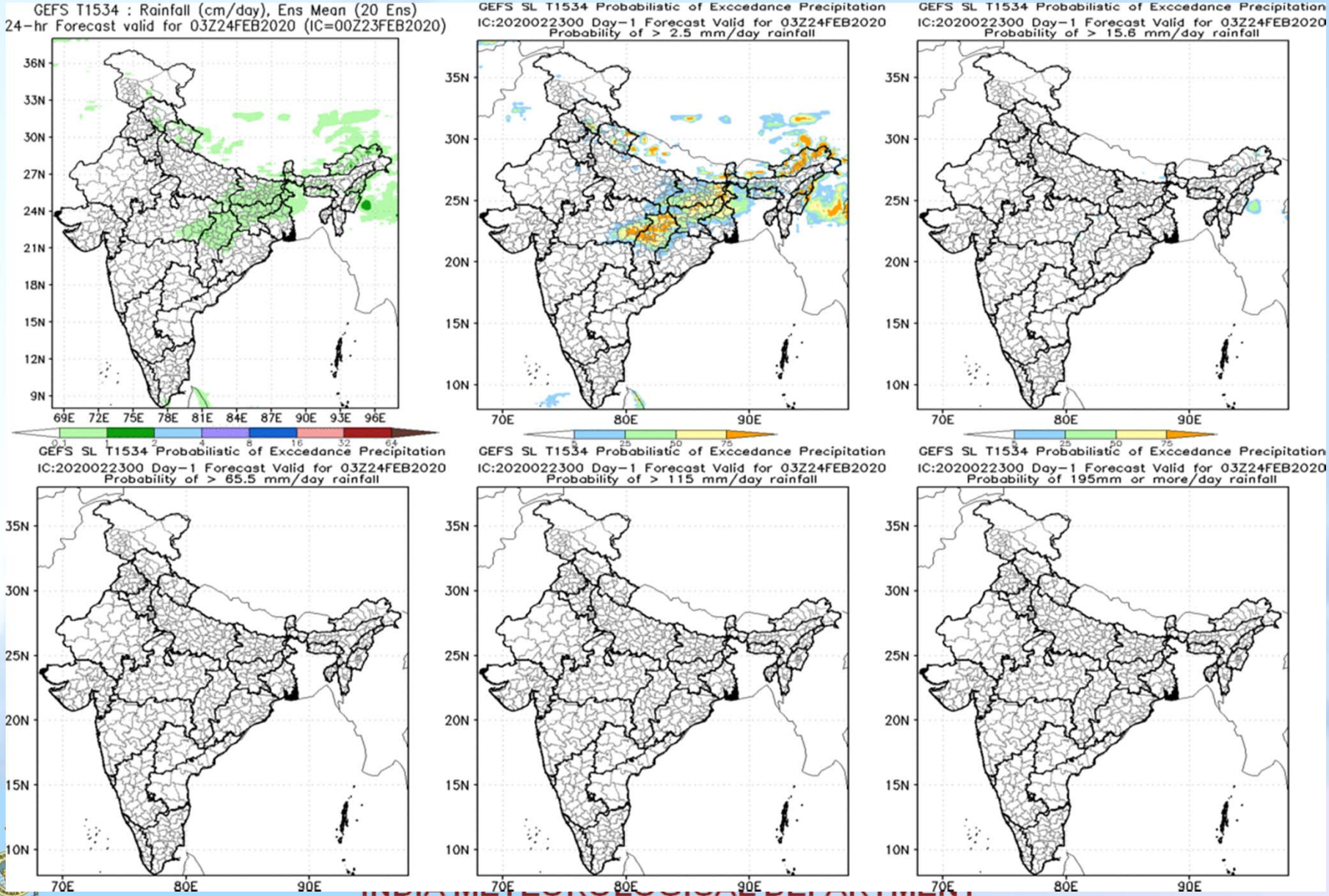
IMD Global Ensemble Forecast System (GEFS)

- GEFS is a Semi-Lagrangian T1534 L64 (about 12 km on equator) and 64 hybrid sigma-pressure layers with 21 ensemble members.

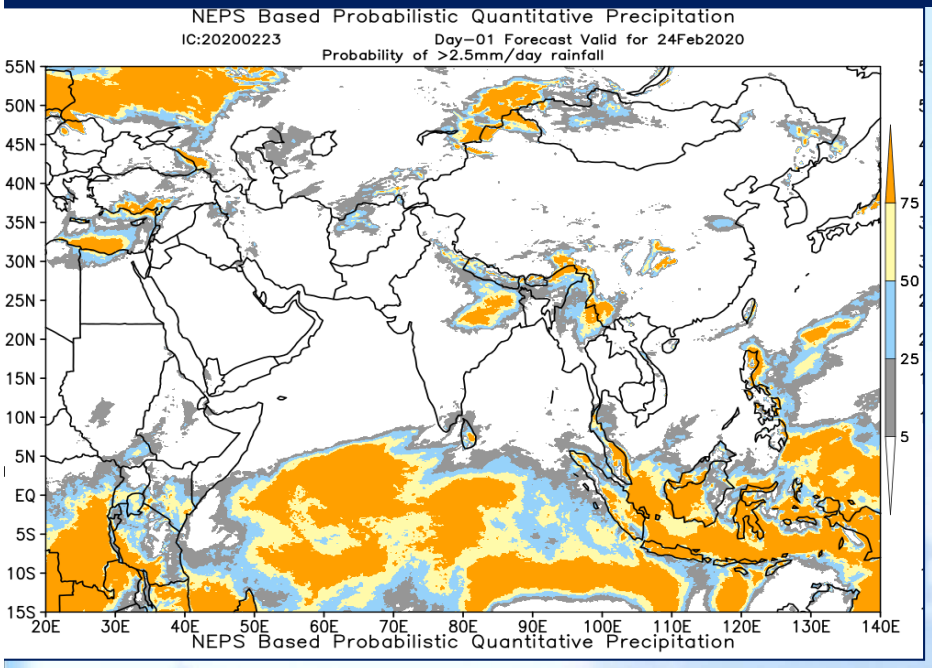
- This high resolution GEFS model is being run once in a day (00 UTC) at IMD to give 10 day operational probabilistic prediction in the short to medium range since June 2018.

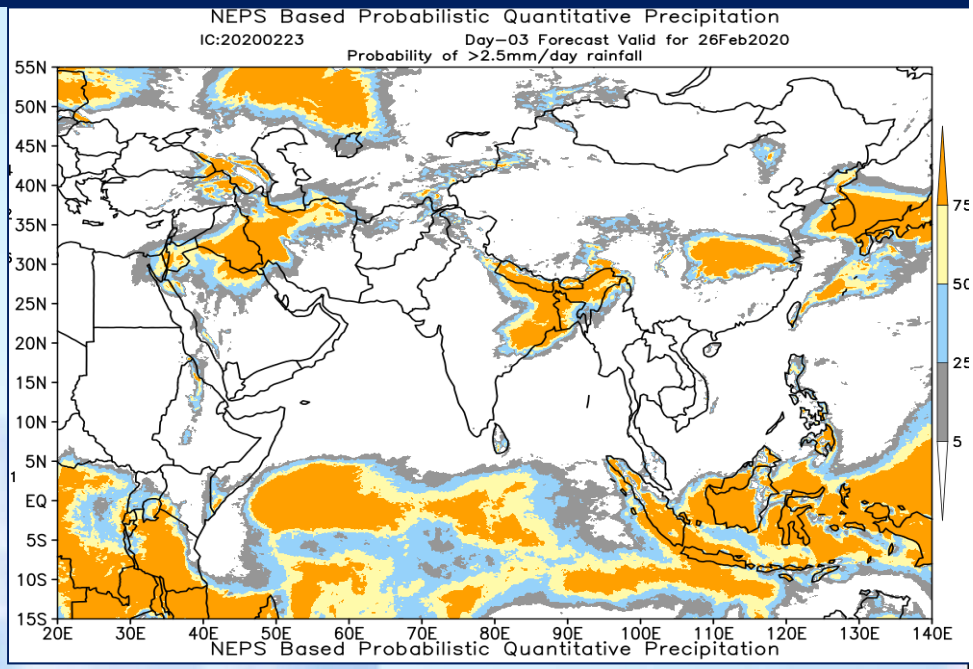
- The initial conditions are generated from the NCEP based Ensemble Kalman Filter (EnKF) component of hybrid Global Data Assimilation System (GDAS).

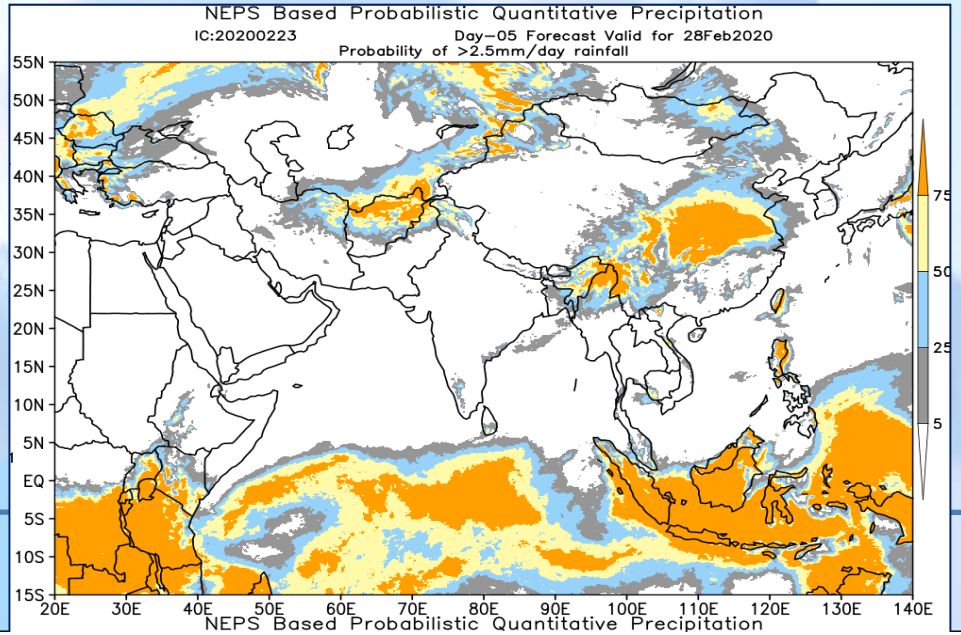
GEFS Ensemble forecast



UM Ensemble (NEPS); D1, D3 & D5 forecasts







EFI charts from ECMWF
(2m Temp, 10m wind, 10m gusts, precipitations)

Charts

Datasets

Quality of our forecasts

Documentation and support

Accessing forecasts

Back to charts

Related charts

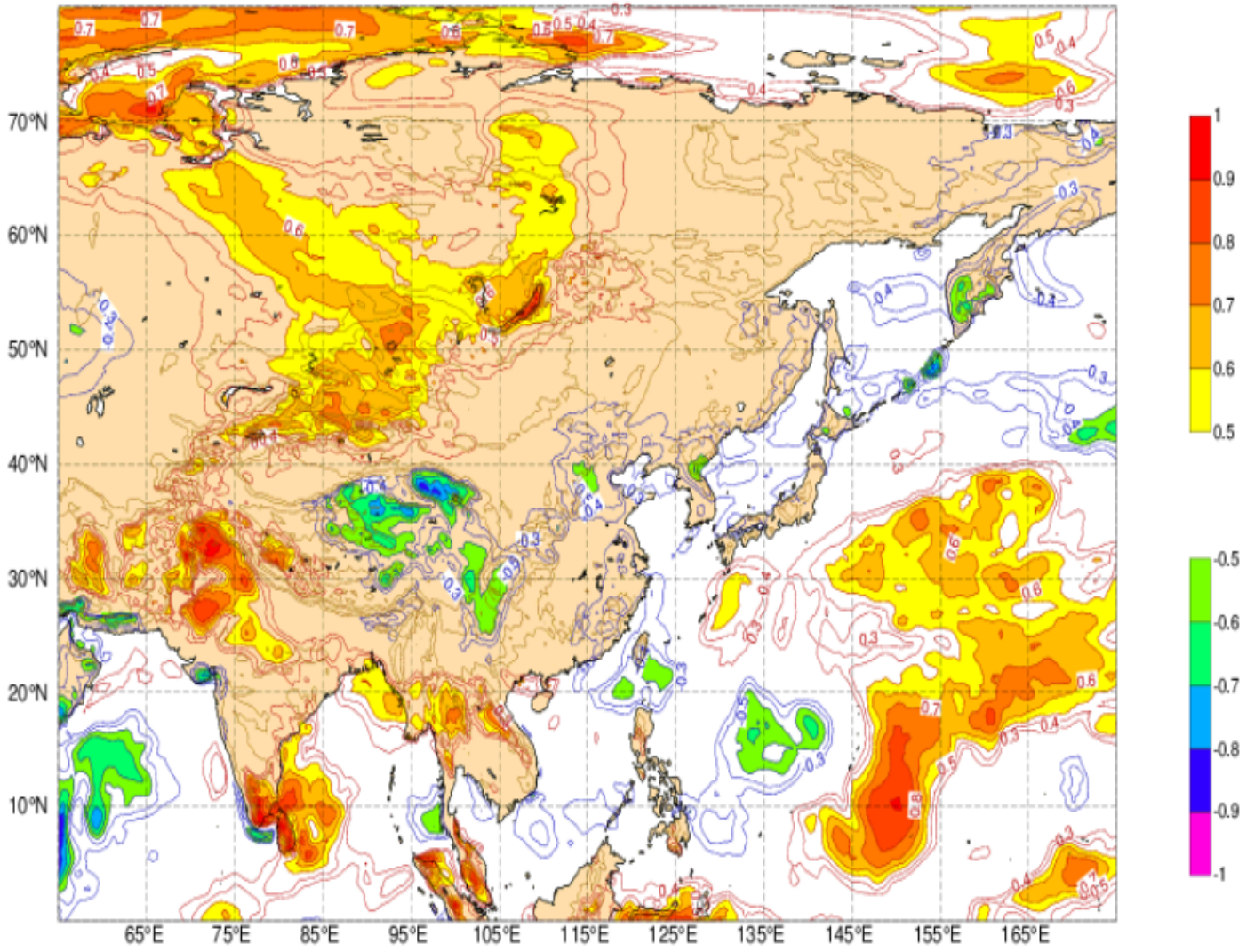
EFI 2m temperature

EFI 10m wind speed

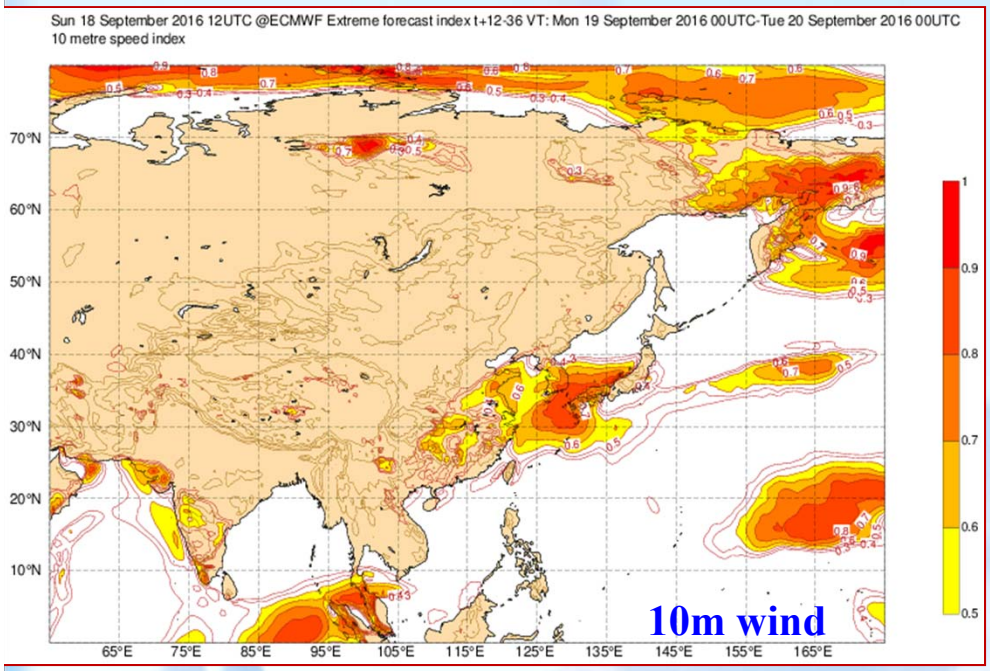
EFI 10m wind gusts

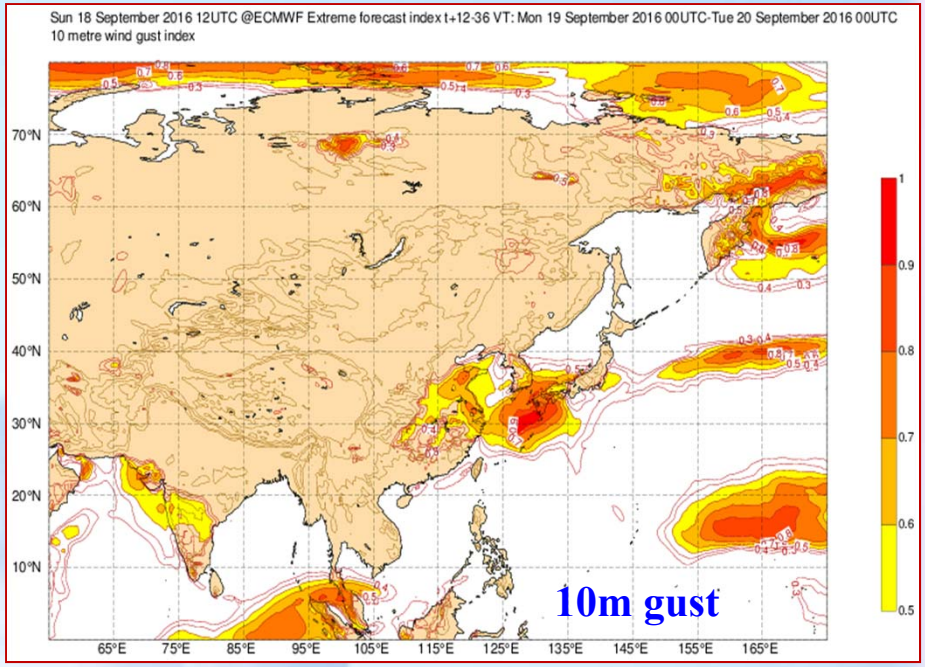
EFI precipitations

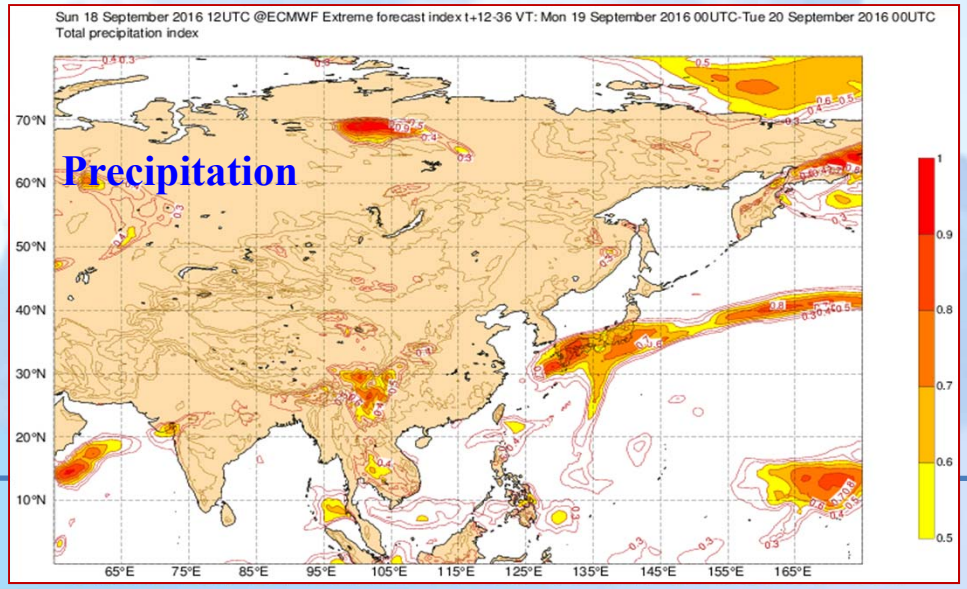
Sun 18 September 2016 12UTC @ECMWF Extreme forecast index t+12-36 VT: Mon 19 September 2016 00UTC-Tue 20 September 2016 00UTC
2 metre temperature index



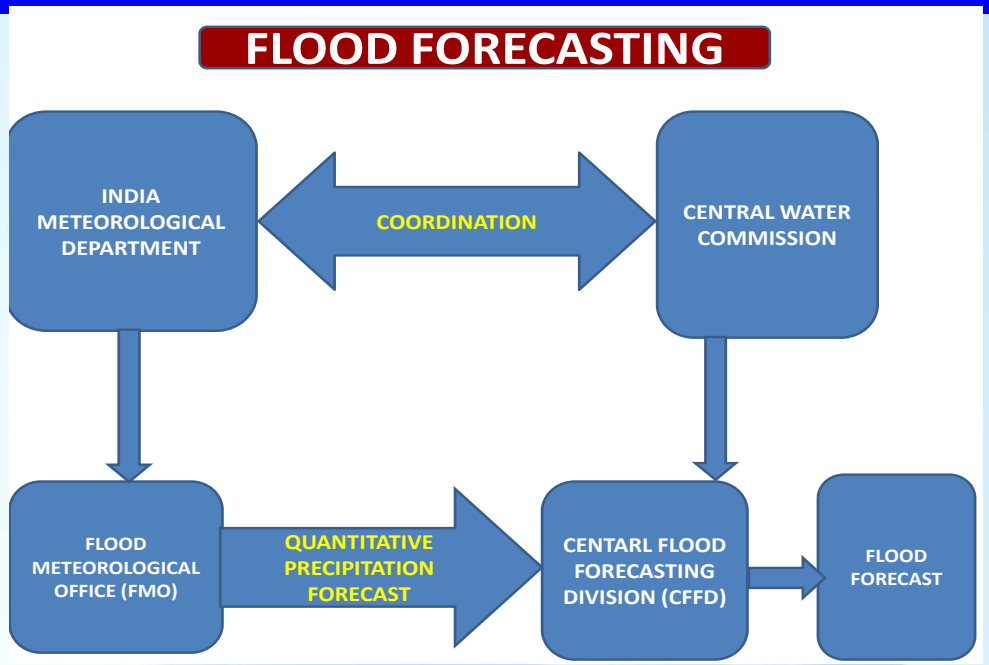
EFI charts from ECMWF
(2m Temp, 10m wind, 10m gusts, precipitations)







Hydromet Services for flood provided by IMD



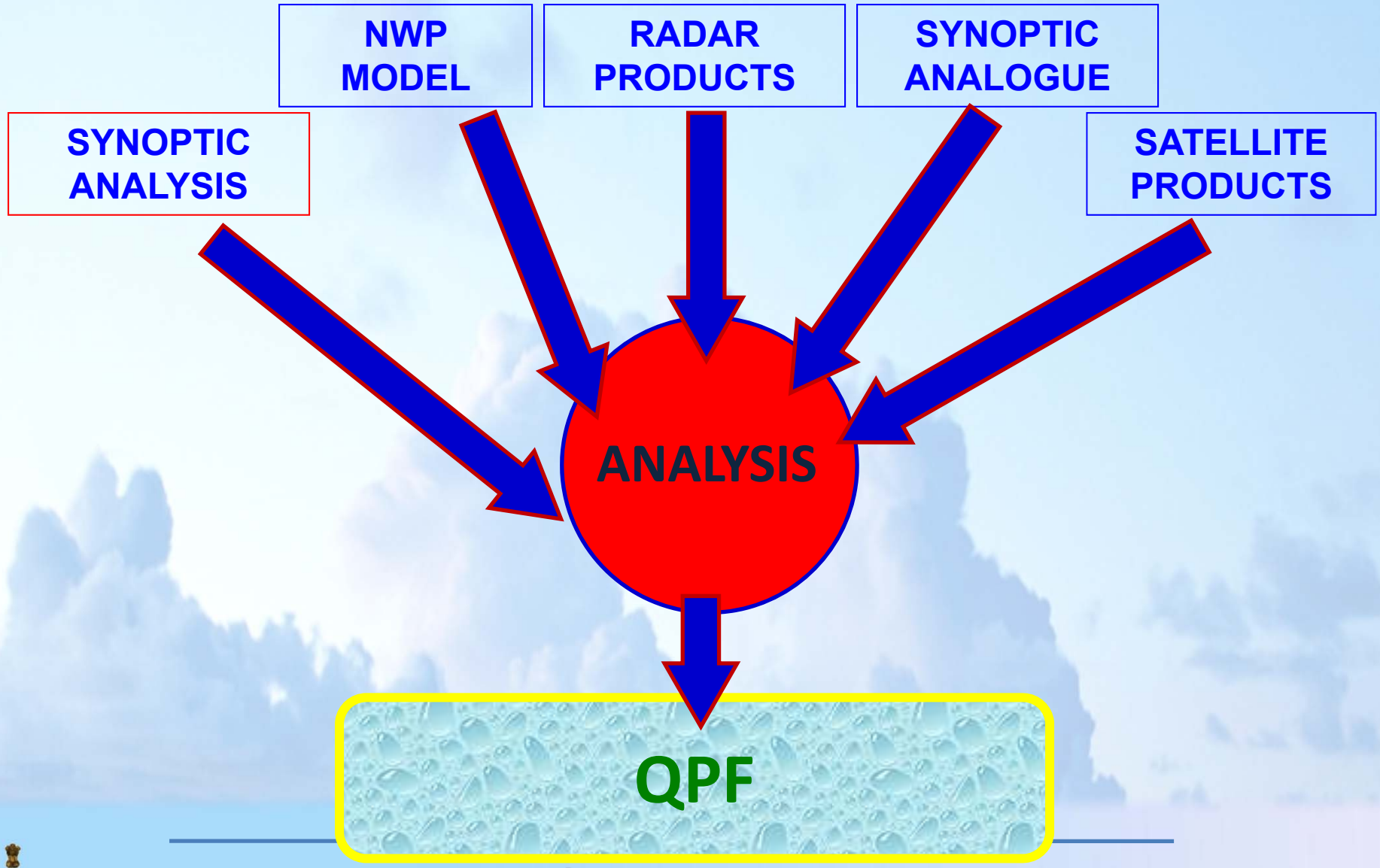
- Sub basin wise Quantitative Precipitation Forecast (QPF) in different ranges for the next three days and outlook for further four days

  0 mm , 0.1-10 mm, 11-25 mm, 26-50 mm, 51-100 mm, >100 mm

- prevailing synoptic situations
  - sub basin wise areal rainfall occurred during past 24-hours
  - Station wise significant rainfall during the past 24-hours
  - heavy rainfall warning for the next 72-hours

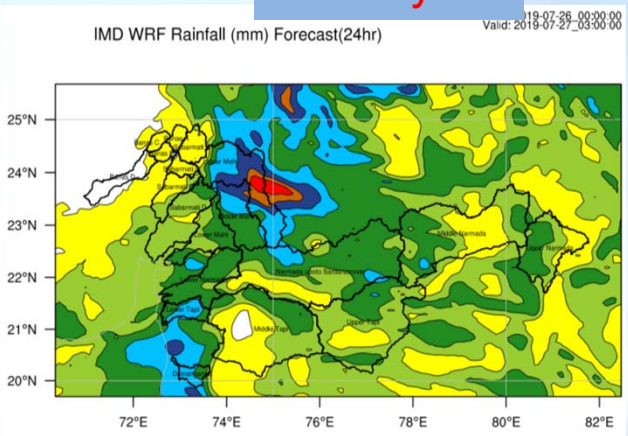
If heavy rainfall is expected during non-flood season or in the event of formation of Cyclone, concerned FMO will issue QPF Bulletins

Inputs for issuing of QPF

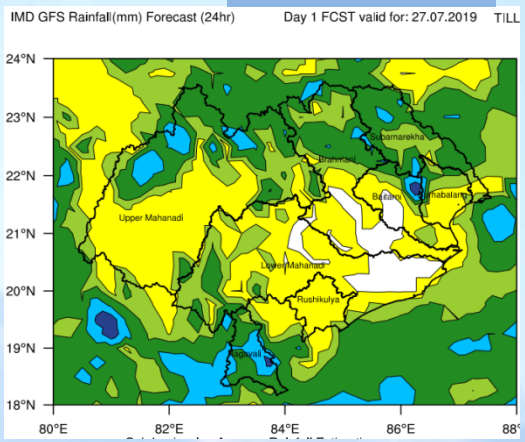


NWP based Sub Bain wise Rainfall Forecast: WRF, GFS, MME, NCUM

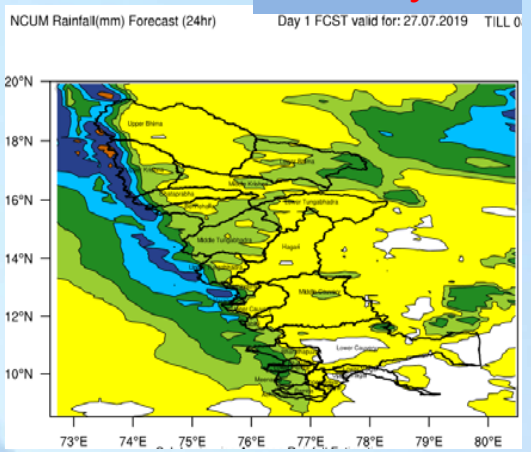
1-3 days



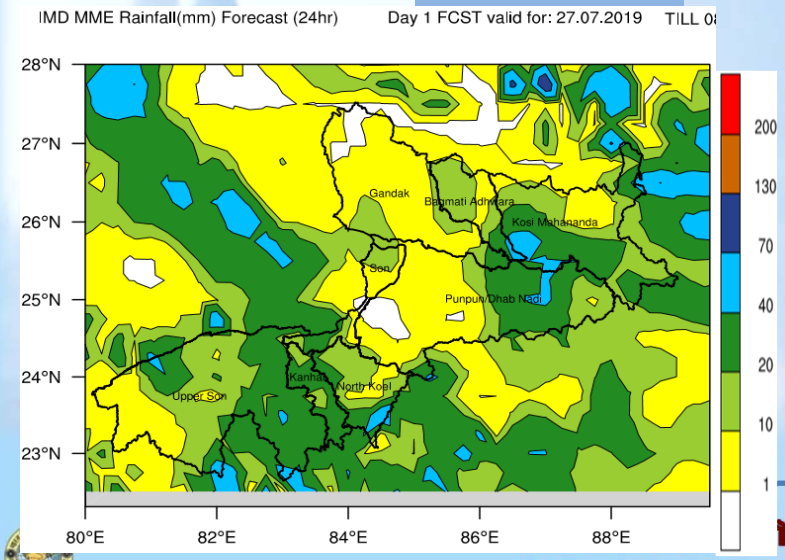
1-7 days



1-7 days



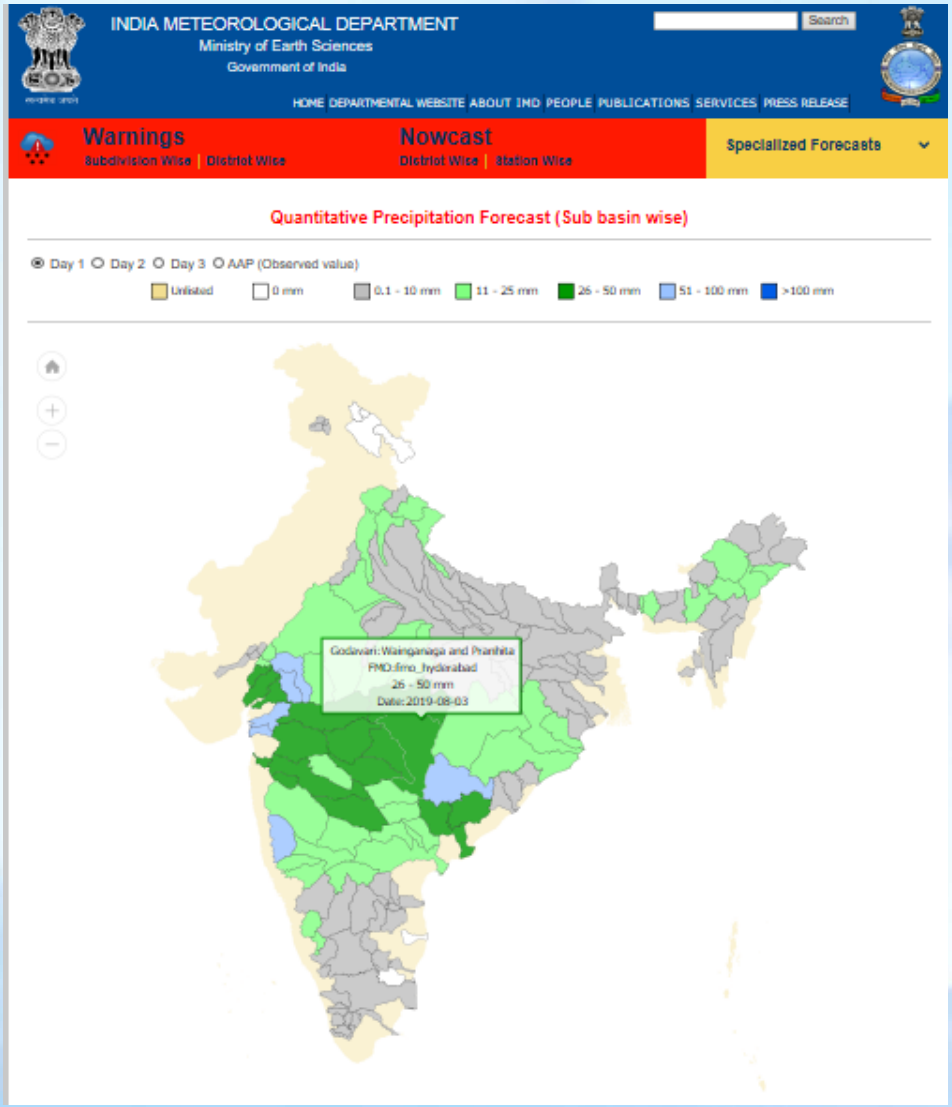
1-5 days

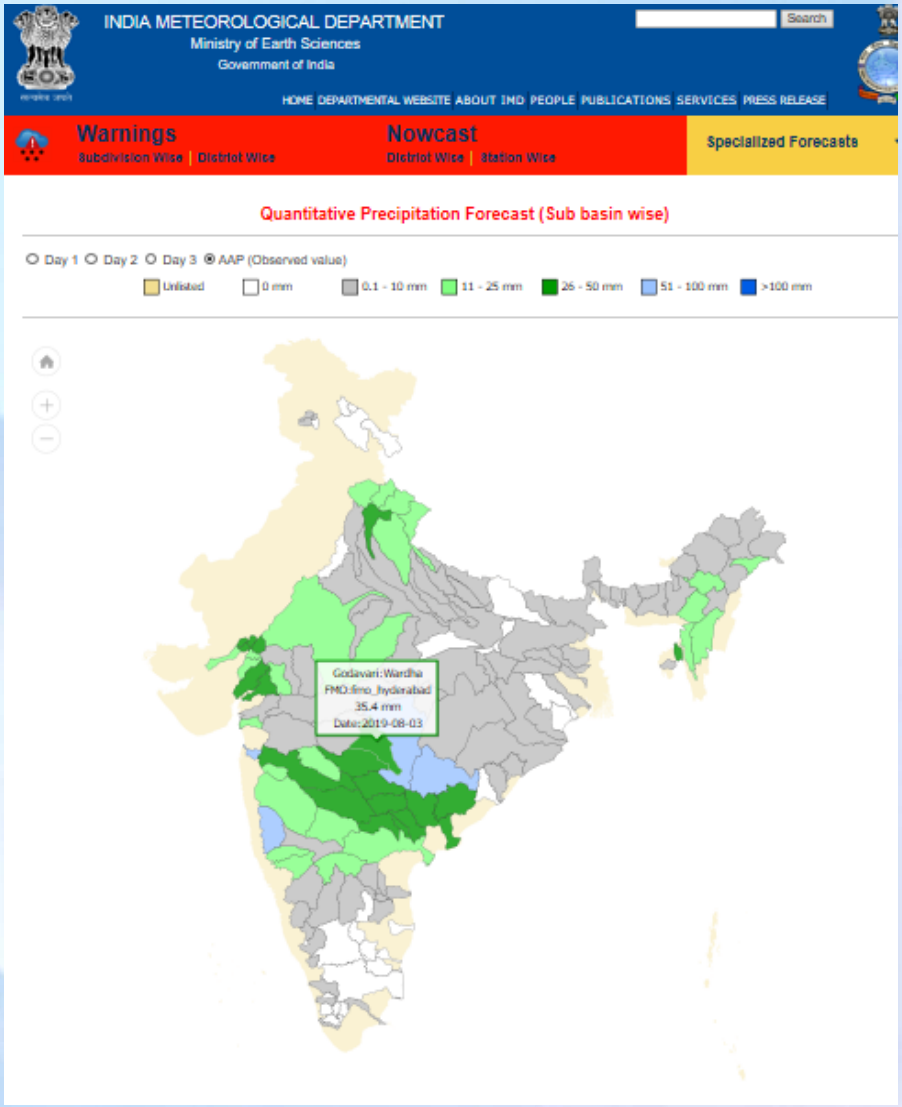


Sub basin wise Average Rainfall Estimation

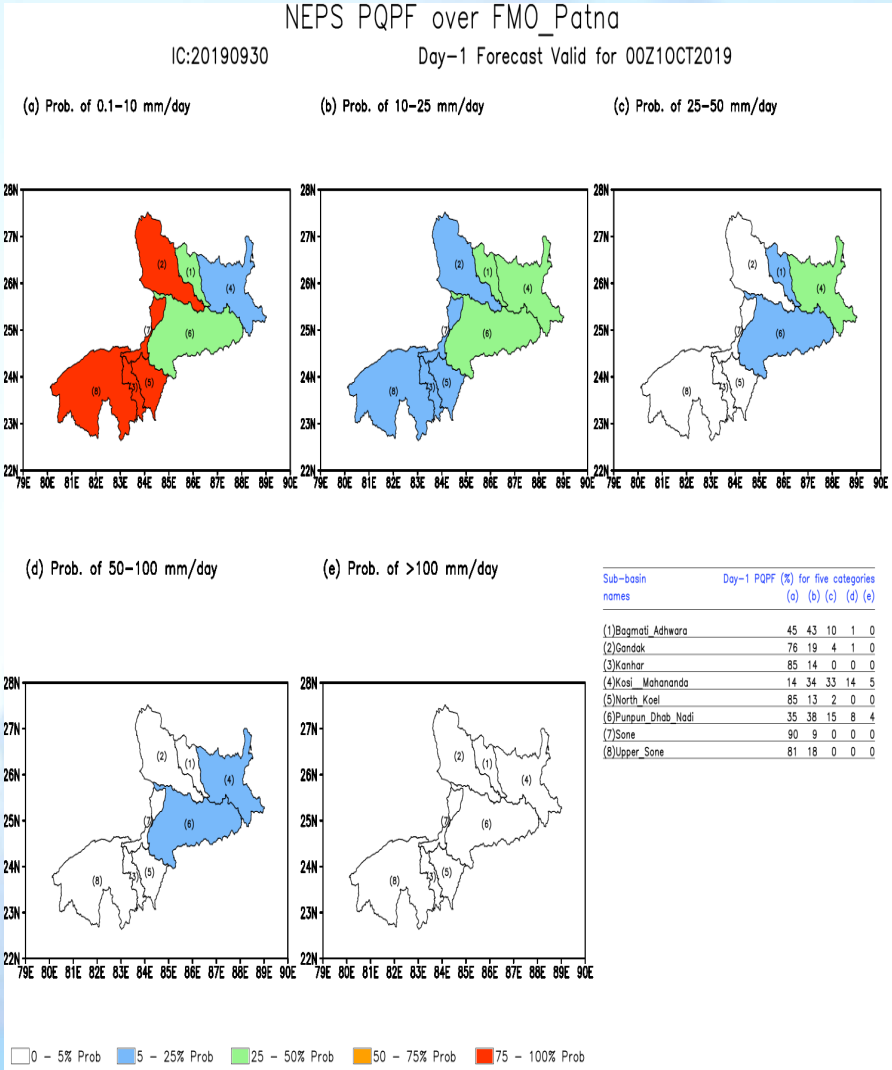
Baitarni =	12 mm
Brahmani =	14 mm
Burhabalang =	10 mm
Lower Mahanadi =	7 mm
Nagavali =	38 mm
Rushikulya =	5 mm
Subarnarekha =	26 mm
Upper Mahanadi =	16 mm
Vamsdhara =	15 mm

QPF PRODUCTS

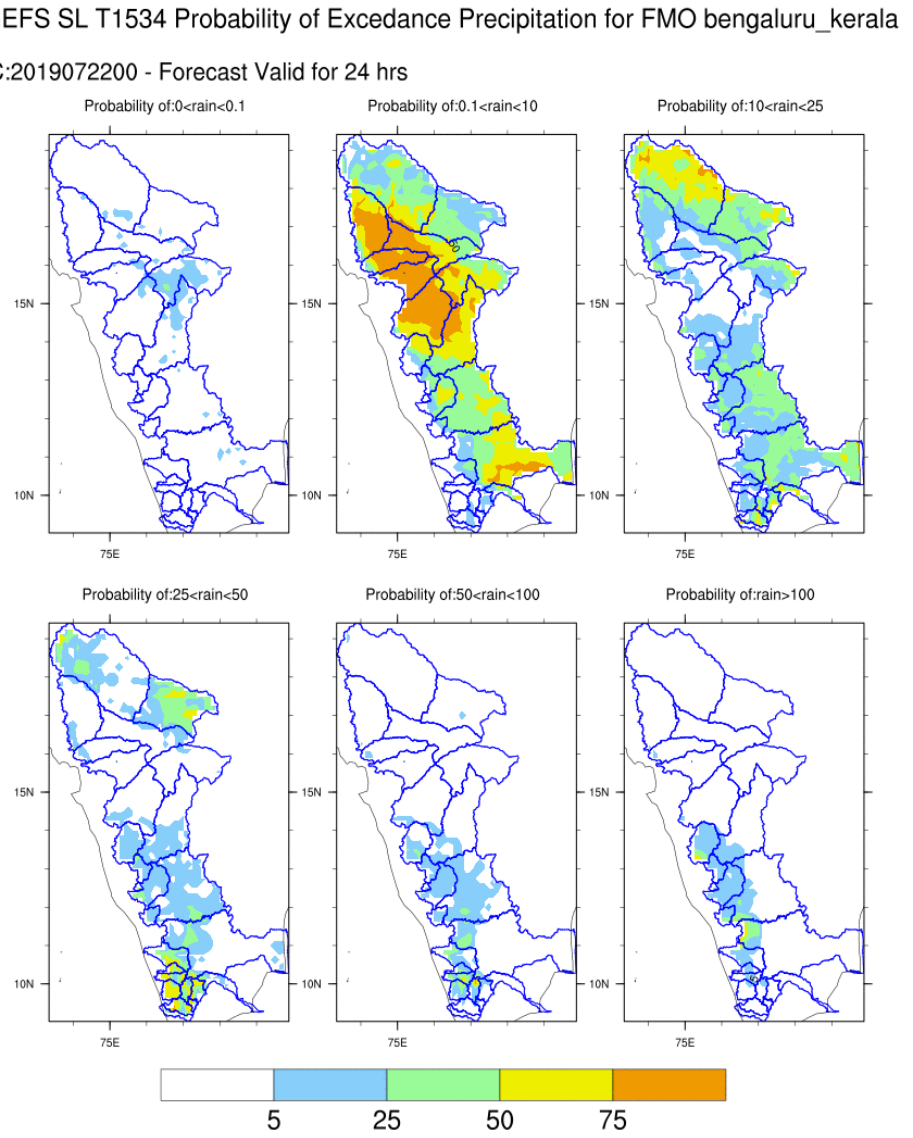




PROBABILISTIC QPF



Sub-basin names	Day-1 PQPF (%) for five categories (a)	(b)	(c)	(d)	(e)
(1)Bagmati_Adhwara	45	43	10	1	0
(2)Gandak	76	19	4	1	0
(3)Kanhar	85	14	0	0	0
(4)Kosi_Mahananda	14	34	33	14	5
(5)North_Koel	85	13	2	0	0
(6)Punpun_Dhab_Nadi	35	38	15	8	4
(7)Sone	90	9	0	0	0
(8)Upper_Sone	81	18	0	0	0



GEFS and NEPS based Sub basin wise probabilistic QPF

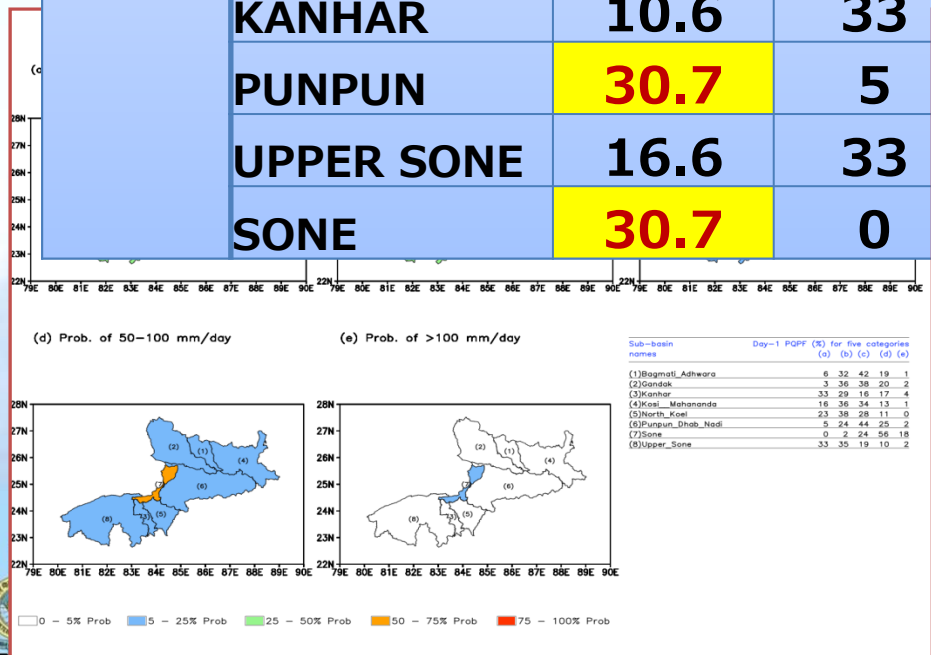
INDIA METEOROLOGICAL DEPARTMENT

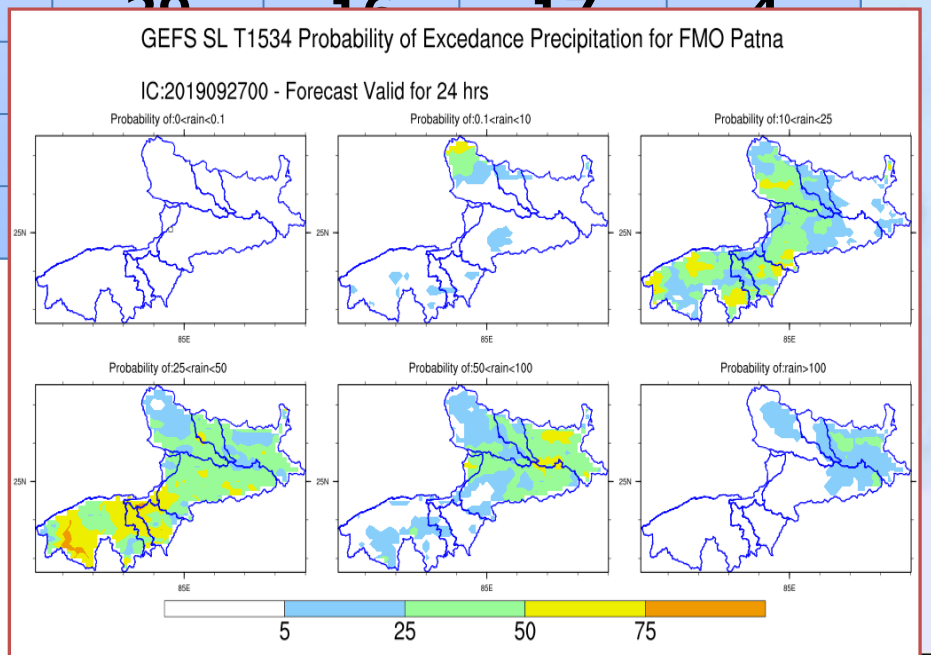
PROBABILISTIC QPF

S. No.	BASIN NAME	SUB BASIN CODE/ NAME	Day-1					Day-2					Day-3				
			0.1-10 mm	11-25 mm	26-50 mm	51-100 mm	>100 mm	0.1-10 mm	11-25 mm	26-50 mm	51-100 mm	>100 mm	0.1-10 mm	11-25 mm	26-50 mm	51-100 mm	>100 mm
1	B	B1	5-25	25-50	25-50	5-25	0-5	25-50	50-75	75-100	0-5	5-25	50-75	25-50	5-25	0-5	0-5
		B2	50-75	5-25	5-25	5-25	0-5	50-75	5-25	5-25	5-25	0-5	5-25	25-50	25-50	5-25	0-5
2	G	G1	5-25	5-25	25-50	25-50	5-25	25-50	25-50	5-25	0-5	0-5	25-50	25-50	5-25	5-25	0-5
		G2	75-100	5-25	0-5	0-5	0-5	5-25	5-25	25-50	5-25	5-25	5-25	5-25	5-25	5-25	5-25

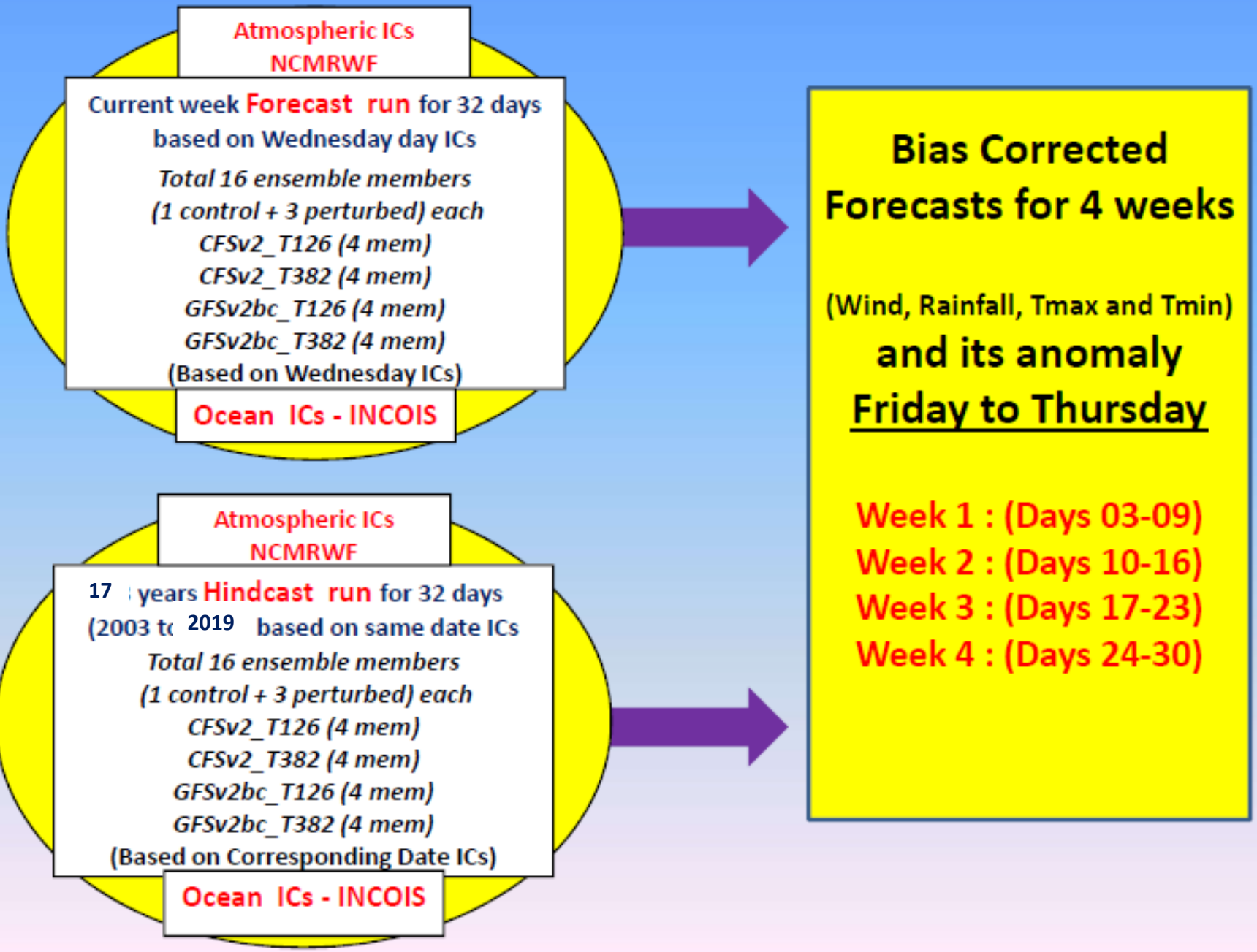
MODEL PROBABILISTIC QPF: 27-30 SEPT, 2019 UNDER FMO PATNA

Date	SUB-BASIN	Observed AAP	NEPS PQPF(%) 27.09.19(Day 1)				
		(mm)	0.1-10 mm	10-25 mm	25-50 mm	50-100 mm	>100 mm
28-09-2019	KOSI/MAHANANDA	23.5	16	36	34	13	1
	BAGMATI/ADHWARA	41.8	6	32	42	19	1
	GANDAK	25.8	3	36	38	20	2
	NORTH KOEL	14.6	23	38	28	11	0
	KANHAR	10.6	33				
	PUNPUN	30.7	5				
	UPPER SONE	16.6	33				
	SONE	30.7	0				

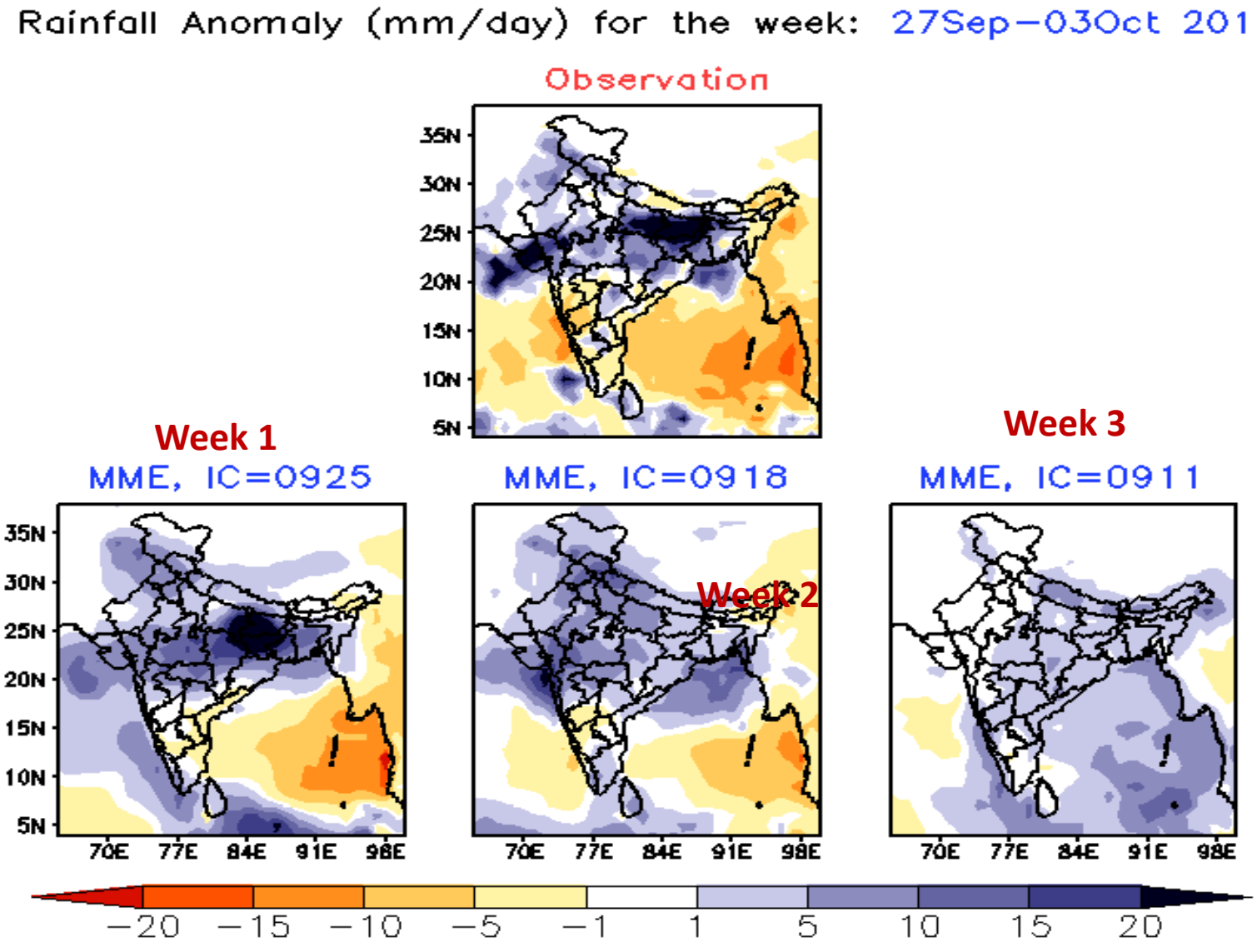




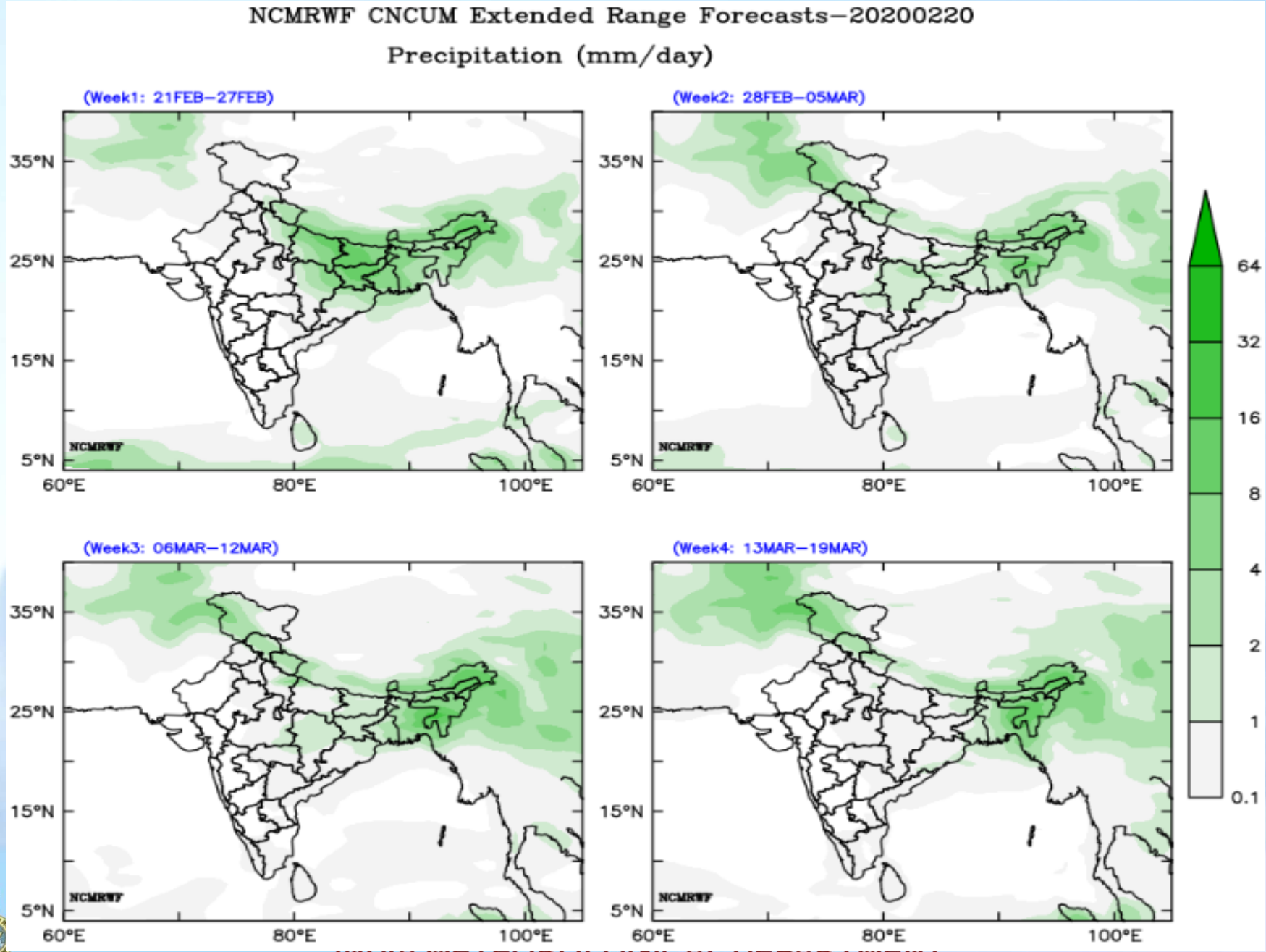
IMD's Operational Extended Range Forecast (ERF) System



Active Monsoon : Target Week (27 September-03 Oct 2019)



UM Based NCMRWF ERF



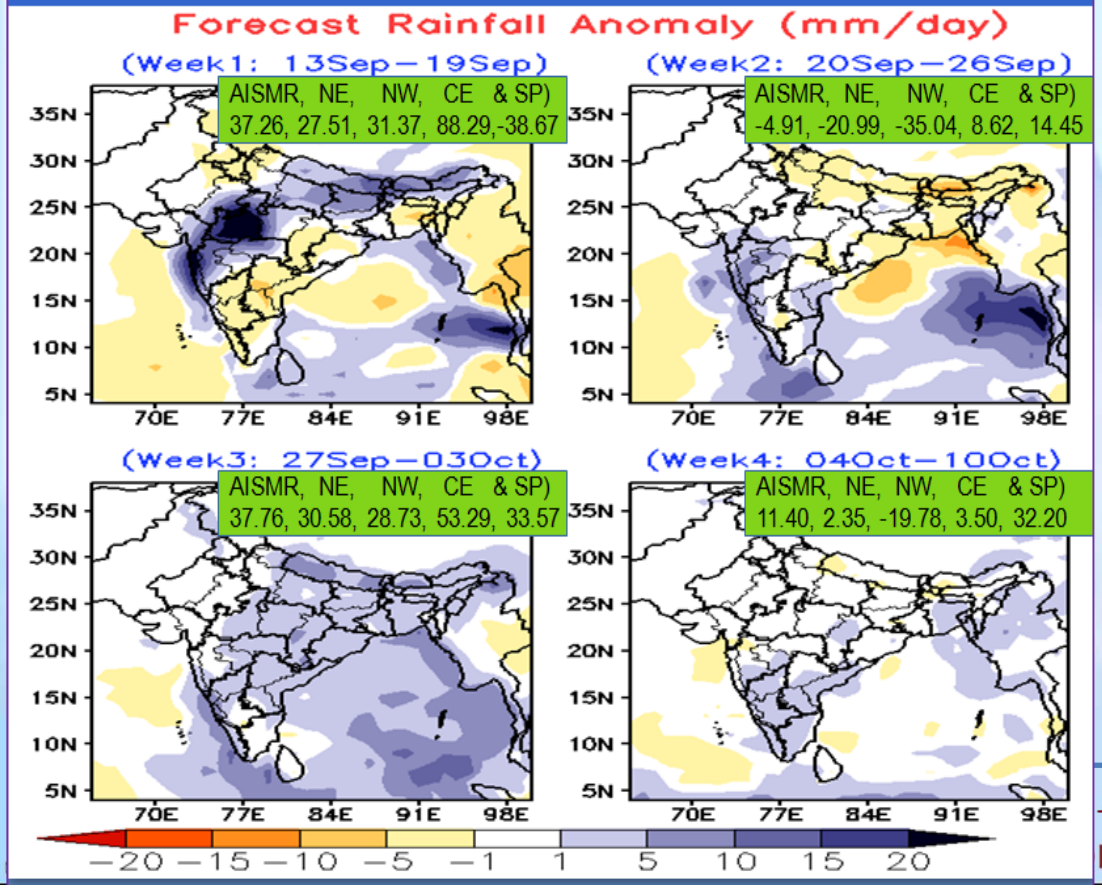
Category for verification of Met-Subdivision level forecast

Categories	% Departure	3 Categories
Large Excess (LE)	+60% or more	Above Normal (AN)
Excess (E)	+20% to +59%	
Normal (N)	+19% to -19%	Normal (N)
Deficient (D)	-20% to -59%	Below Normal (BN)
Large Deficient (LD)	-60% to -99%	
No Rain (NR)	-100%	

Above Normal : Normal : Below Normal :

- Extended forecast at different spatial domains are prepared once in a week.
- Two weeks met-subdivision level forecasts are used for Agro-advisory
- Four weeks guidance for health sector are prepared

Predicted week wise weekly mean rainfall (MME) with % departure of rainfall over India as a whole and 4 homogeneous regions (IC – 11 Sep, 2019)



RECAST >> | MEDIUM RANGE FORECAST >> | EXTENDED RANGE FORECAST >> | SE

VIEW SUB-DIVISION WISE PLOTS

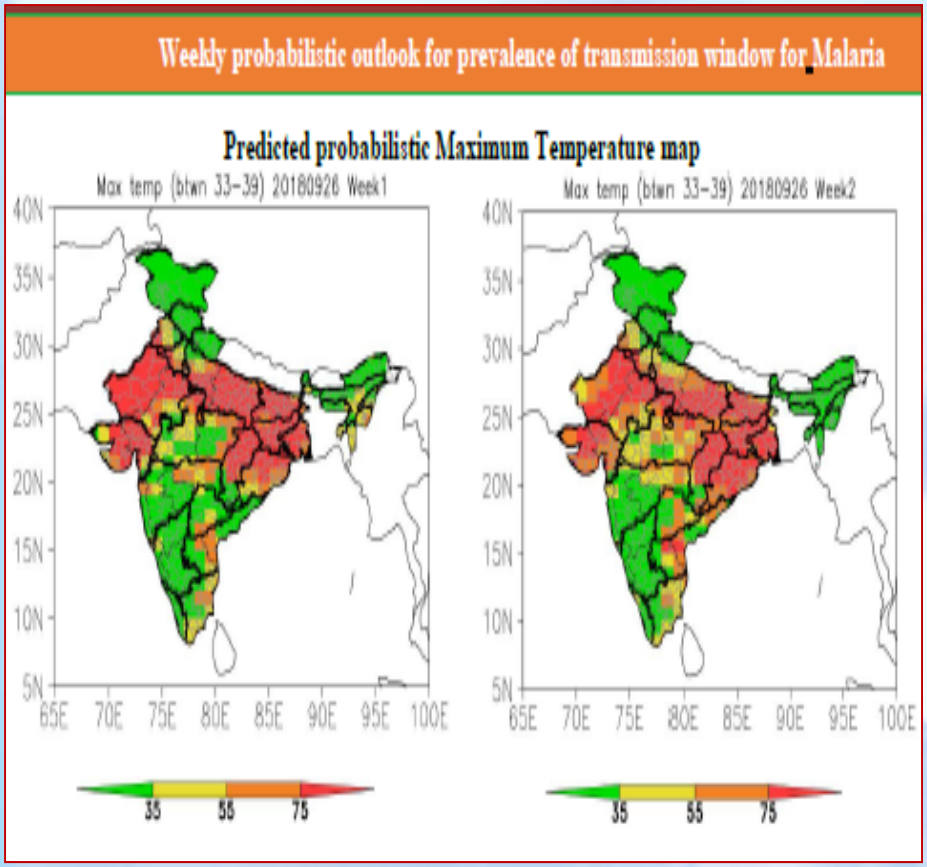
MME WEEKLY RAINFALL FORECAST

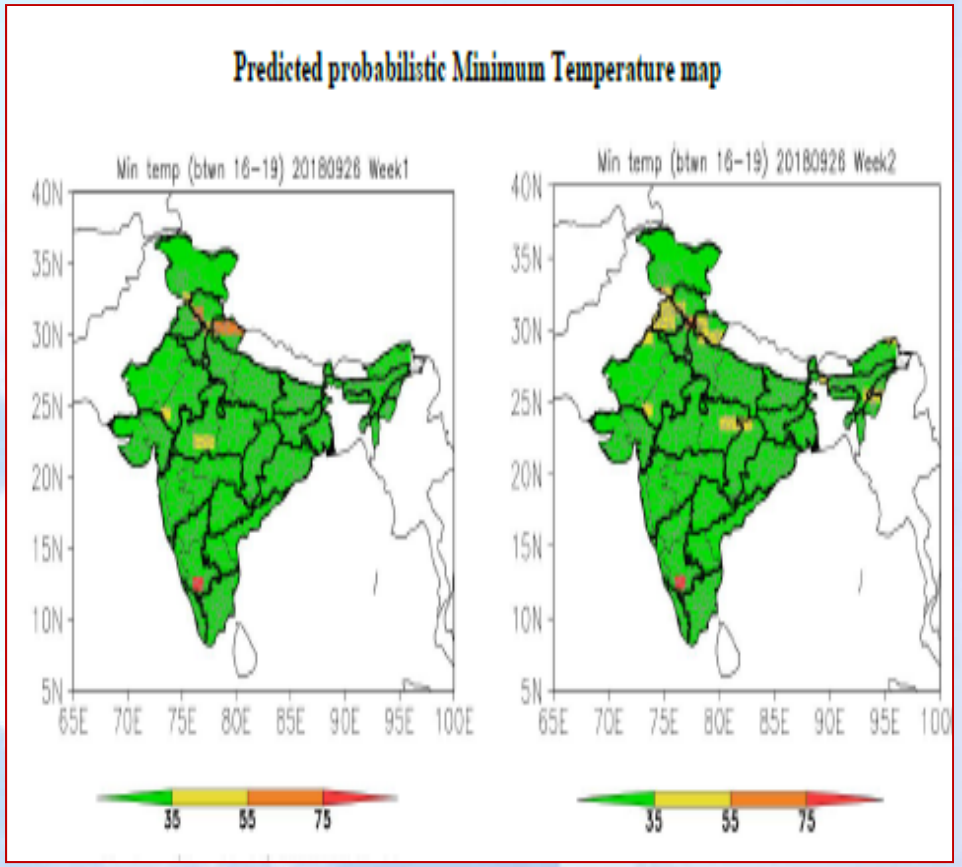
RAINFALL DEPARTURE (%) WITHIN SUB-DIVISION DURING NEXT 04 WEEKS

BASED ON 16-10-2019

S.NO.	SUB-DIVISION	WEEK-1	WEEK-2	WEEK-3	WEEK-4
1	A & N ISLAND	34.12	0.35	79.69	29.50
2	ARUNACHAL PRADESH	45.76	20.22	43.17	-14.76
3	ASSAM & MEGHALAYA	-1.69	15.51	-41.96	-9.69
4	N M M T	2.24	65.54	5.76	143.33
5	SHWB & SIKKIM	-33.63	52.02	-7.69	-77.87
6	GANGETIC WEST BENGAL	71.65	137.44	13.45	30.31
7	ORISSA	118.07	248.47	112.60	1.27
8	JHARKHAND	116.59	227.77	25.04	-54.93
9	BIHAR	30.43	377.51	56.71	-77.09
10	EAST UTTAR PRADESH	136.19	862.19	92.84	-47.33
11	WEST UTTAR PRADESH	-86.77	244.24	145.03	-21.65
12	UTTARAKHAND	-78.25	-76.21	105.36	-54.57
13	HAR.CHD & DELHI	-95.47	-90.23	284.92	-51.21
14	PUNJAB	-89.43	-85.47	213.64	-56.55
15	HIMACHAL PRADESH	-50.73	-41.71	83.43	-16.62
16	JAMMU & KASHMIR	1.41	6.82	19.14	9.06
17	WEST RAJASTHAN	-87.48	66.85	137.07	5.10
18	EAST RAJASTHAN	124.32	1,707.49	138.59	-23.30
19	WEST MADHYA PRADESH	1,731.76	910.18	144.11	-13.11
20	EAST MADHYA PRADESH	635.27	681.54	137.73	-43.51
21	GUJARAT REGION	6,867.56	2,352.89	22.78	-71.10
22	SAURASHTRA & KUTCH	8,995.72	3,761.61	-25.02	-72.18
23	KONKAN&GOA	1,045.81	546.34	156.11	59.32
24	MADHYA MAHARASHTRA	887.01	447.85	215.44	58.48

Tmax (33-39 C) and Tmin 16-19 C)
Probability for 2 weeks





भारत मौसम विज्ञान विभाग
INDIA METEOROLOGICAL DEPARTMENT

Scope for ERF Application Products

- Agriculture (Active/Break cycle, Temperature)
- Disaster risk reduction (Cyclogenesis)
- Water (Heavy rainfall/reservoir operation etc)
- Health (Vector borne diseases)
- Energy (Tmax, Tmin/ Heat wave/Cold wave)

Future Plans

- New Global Forecast System (GFS) for medium range weather forecasting up to 10 days for Forecasts of heavy rainfall, gusts and lightning due to thunderstorms, cyclones, Heat-wave and cold-wave forecasts.

12km of 6 hourly FCST up to 10 days

↓

6km of 6 hourly FCST up to 10 days

- Global Ensemble Forecast System (GEFS) for probabilistic medium range weather forecasting days for Probabilistic weather forecasts for extreme weather events for 10 days at 3 hours interval.

12km of up to 10 days updates twice daily

↓

12km of up to 10 days updates every 6 hours

- High-resolution regional mesoscale ensemble modelling system for very-short to short range weather forecasting for Location specific forecasts of precipitations, wind, lightning and temperature.

03 km resolution up to 3 days updating four times daily → 01 km resolution up to 3 days with 3 hourly updates

EPS based dynamical COU for cyclone forecast to be introduced

Thank You.

Dr. Mrutyunjay Mohapatra
Director General of Meteorology,
India Meteorological Department,
New-Delhi, India.
Email:- dgmmet@gmail.com
directorgeneral.imd@imd.gov.in