Medium and Extended Range Prediction of Cyclogenesis over North Indian Ocean

D. R. Pattanaik

RSMC Training Workshop, 06 April 2022

India Meteorological Department
Mausam Bhavan, Lodi Road, New Delhi-110 003
E-mail : drpattanaik@gmail.com

Temporal Scales of weather prediction

- Nowcasting (up to 3 to 6 hrs)
- Very short range forecasting (Up to 12 hrs)
- Short range forecasting (Uo to 3 days)

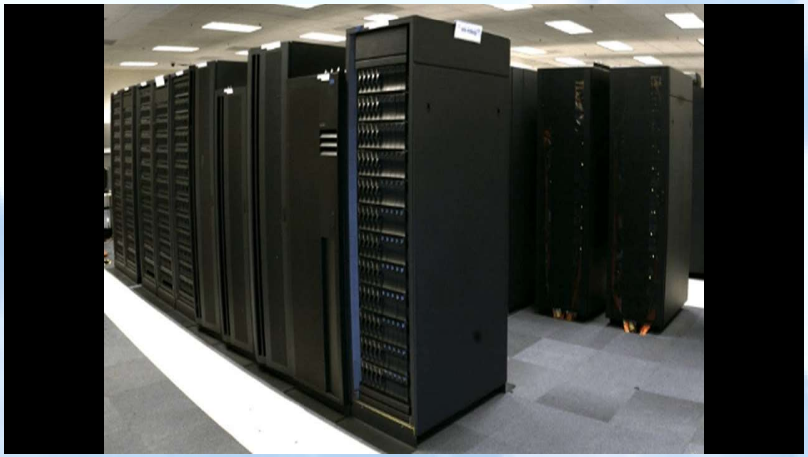
- Medium range forecast (Up to 10 days)

- Extended range forecast (up to 3 to 4 weeks to a month)

- Seasonal forecast (3 months to 4 months average)

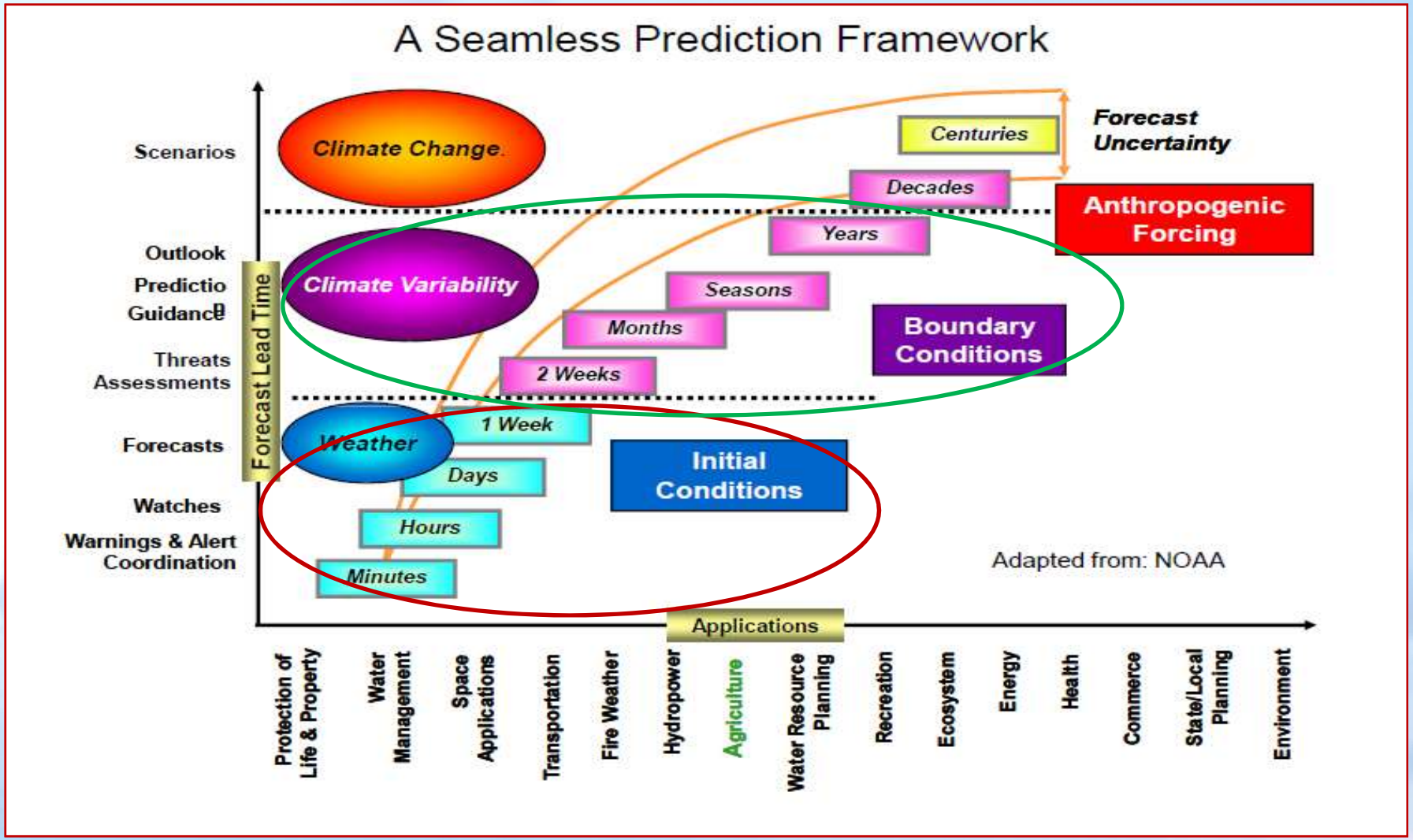
INFRASTRUCTURE FOR NWP

- ✓ MoES recently installed two HPC (2018); One each at NCMRWF, Noida and IITM Pune with computing capacity of 6.8 Peta Flops.
- ✓ The MoES combined HPC capacity now is 8.0 Peta Flops and India is placed at 4th Position after Japan, UK, USA for dedicated HPC resources for Weather/Climate services.
- ✓ The NWP division IMD uses these HPC capacities for its operational needs.



MIHIR HPC @NCMRWF,Noida PRATYUSH HPC @IITM, Pune

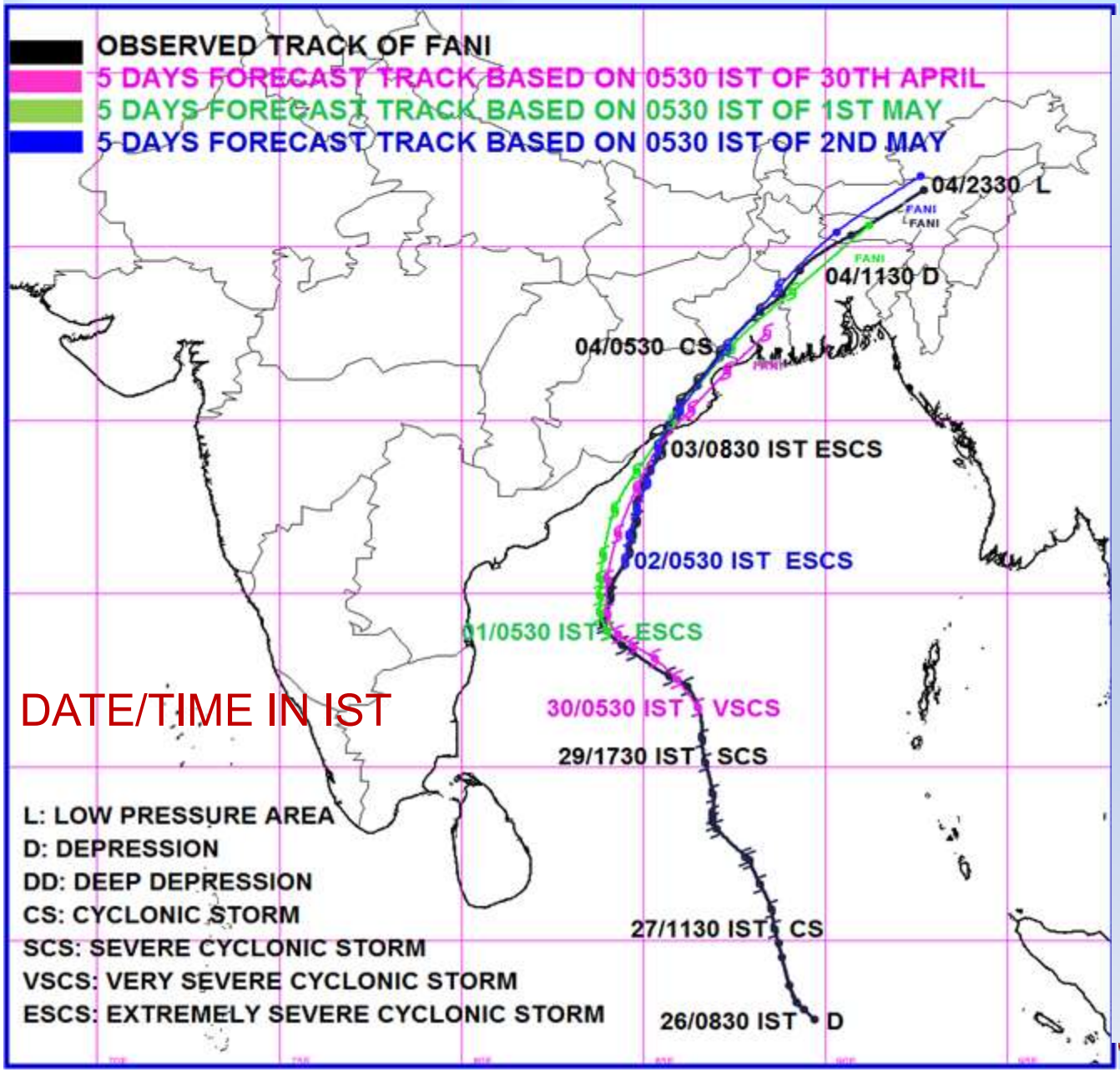
Weather and Climate Prediction in different temporal scales



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 - (Coupled) 5 days forecast**	• 09 km and 03 km run for 3 days (Run twice a day)
Medium range forecast	• **Global Forecast System (GFS) atmospheric model** • **Global Ensemble Forecast System (GEFS) atmospheric model (20 members)**	• **12 km (Run twice a day) 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**
Seasonal forecast	• Climate Forecast System (CFS) coupled models (20 members)	• 38 km (Run once in a month) for 4 to 7 months

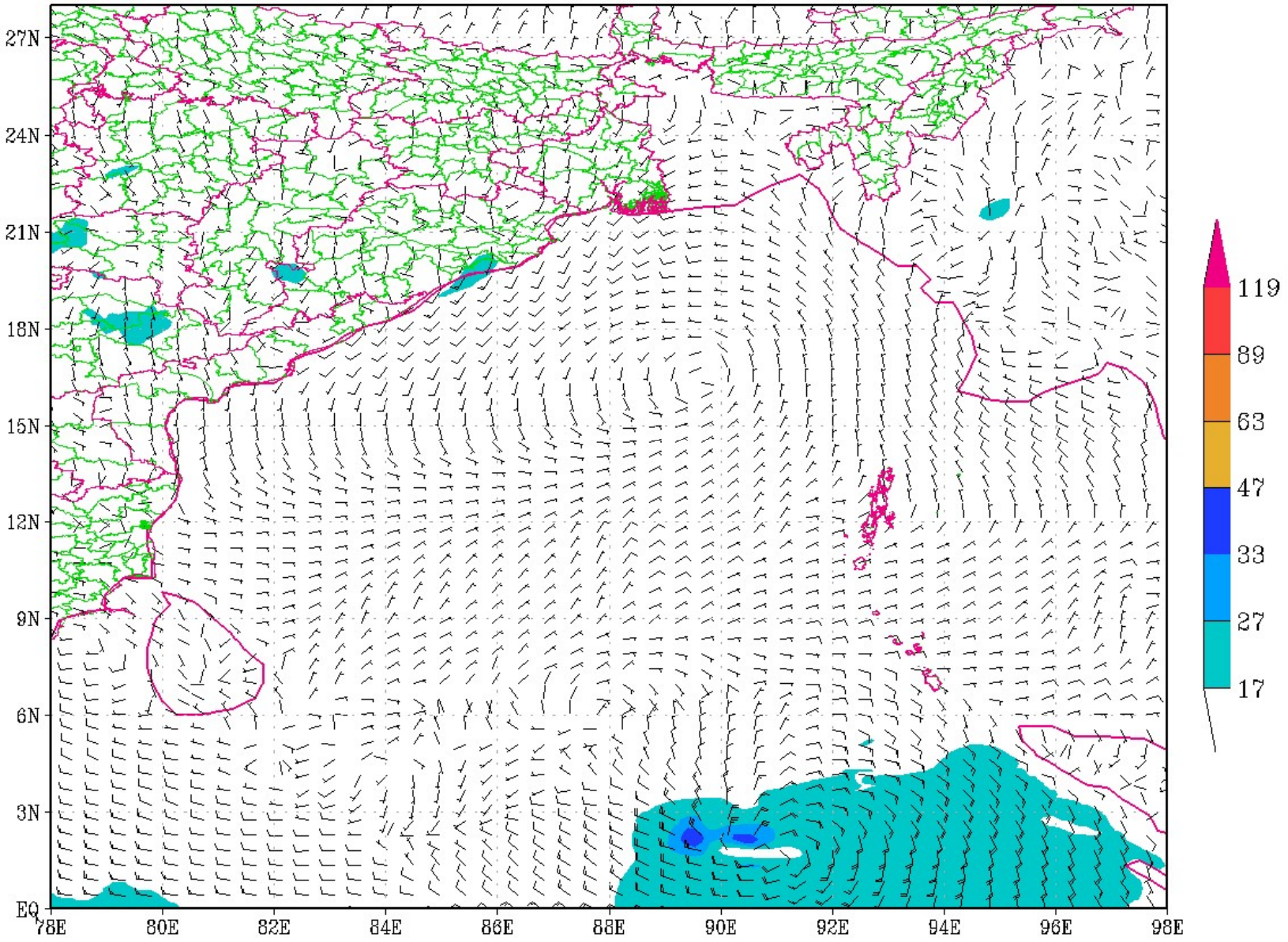
Typical observed and forecast tracks based on 0530 hrs IST of 30th April, 1st & 2nd May, 72 hrs, 48hrs & 24 hrs prior to landfall (FANI, 2019)



- IMD continuously predicted on 30th April, 1st & 2nd May that it will cross around Puri as an extremely severe cyclonic storm (ESCS) with wind speed of 175-185 kmph gusting to 205 kmph on 3rd May.
- The forecast issued on 30th April, 1st & 2nd May were almost same as actual track as shown in Fig.

IMD: GFS(12Km) 10m WIND (barb)& GUST (shaded:kt) FORECAST (00 HR)

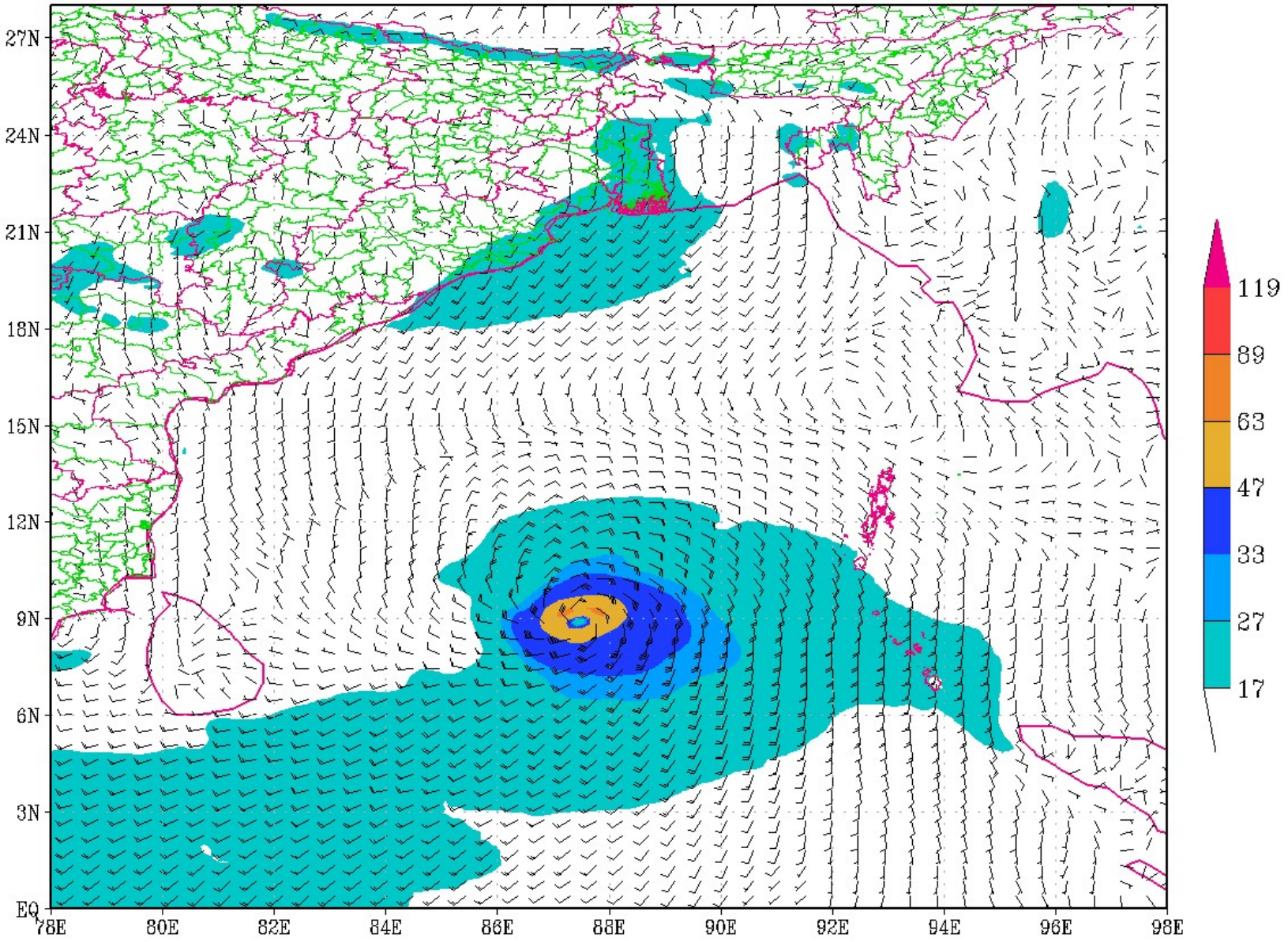
based on 00 UTC of 25-04-2019 valid for 00 UTC of 25-04-2019



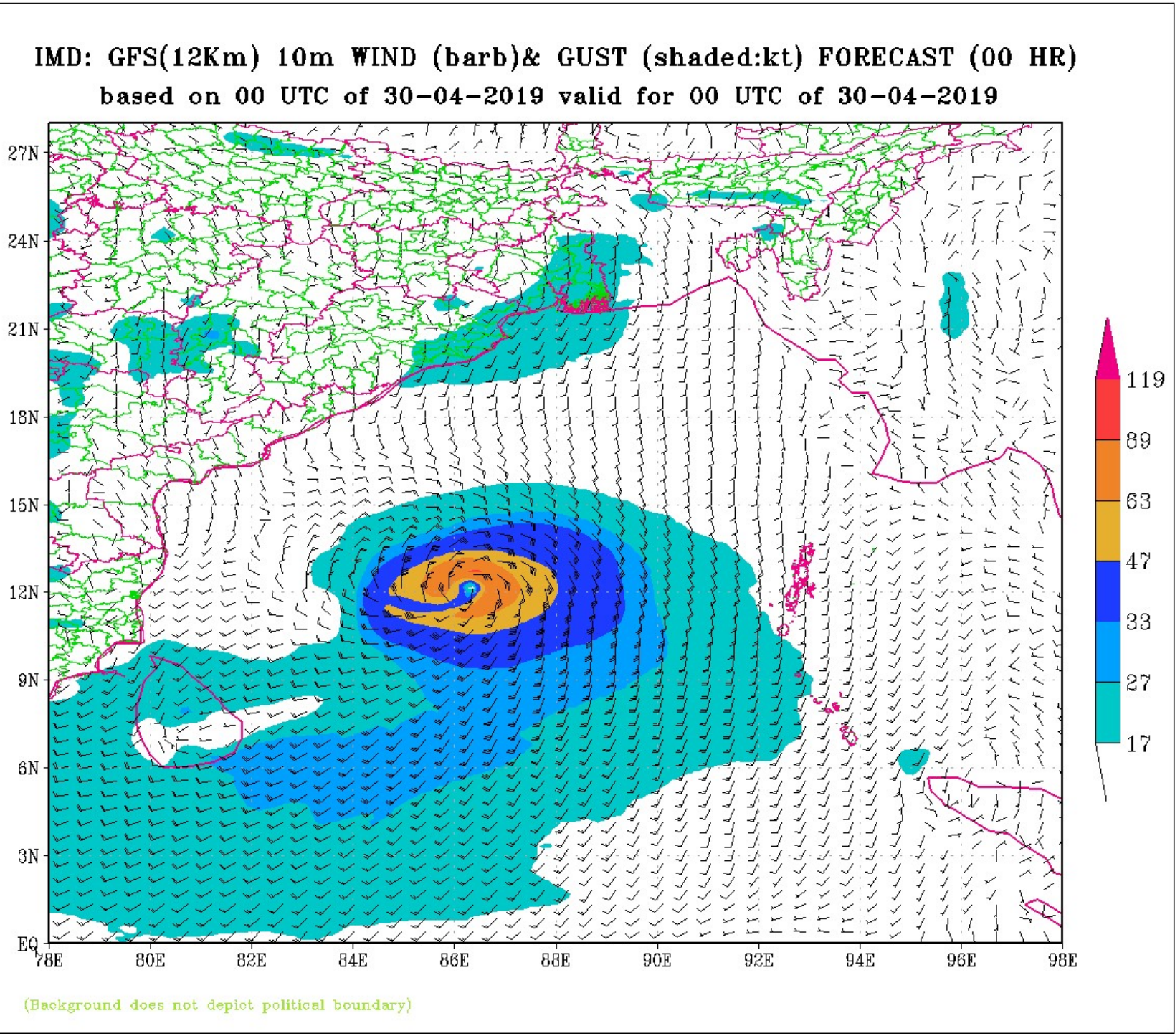
(Background does not depict political boundary)

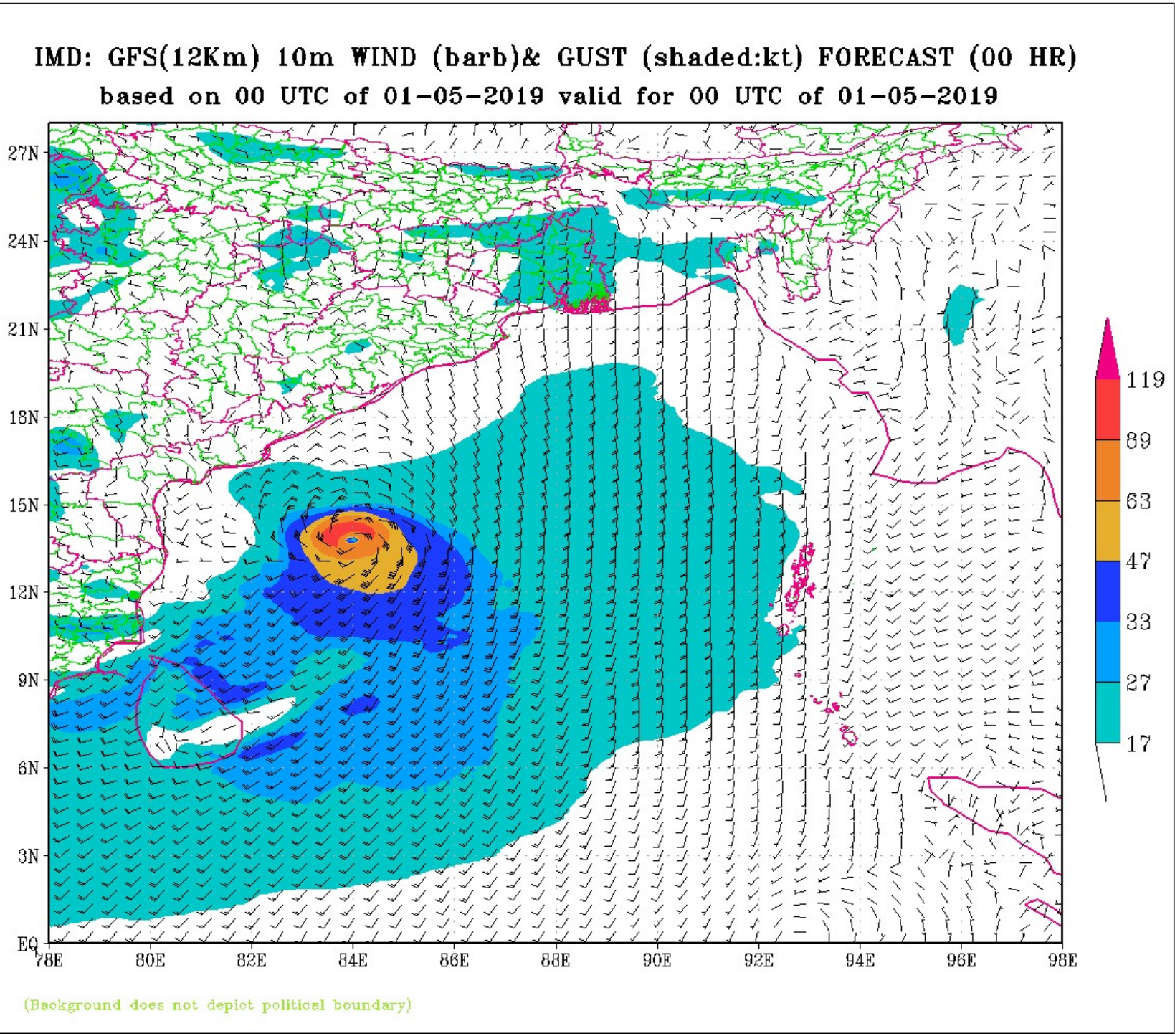
IMD: GFS(12Km) 10m WIND (barb)& GUST (shaded:kt) FORECAST (00 HR)

based on 00 UTC of 29-04-2019 valid for 00 UTC of 29-04-2019



(Background does not depict political boundary)


IMD: GFS(12Km) 10m WIND (barb)& GUST (shaded:kt) FORECAST (00 HR)
based on 00 UTC of 30-04-2019 valid for 00 UTC of 30-04-2019
27N
24N
21N
18N
15N
12N
9N
6N
3N
EQ
78E
80E
82E
84E
86E
88E
90E
92E
94E
96E
98E
119
89
63
47
33
27
17
(Background does not depict political boundary)


IMD: GFS(12Km) 10m WIND (barb)& GUST (shaded:kt) FORECAST (00 HR)
based on 00 UTC of 01-05-2019 valid for 00 UTC of 01-05-2019
27N
24N
21N
18N
15N
12N
9N
6N
3N
EQ
78E
80E
82E
84E
86E
88E
90E
92E
94E
96E
98E
119
89
63
47
33
27
17
(Background does not depict political boundary)

GFS T1534:

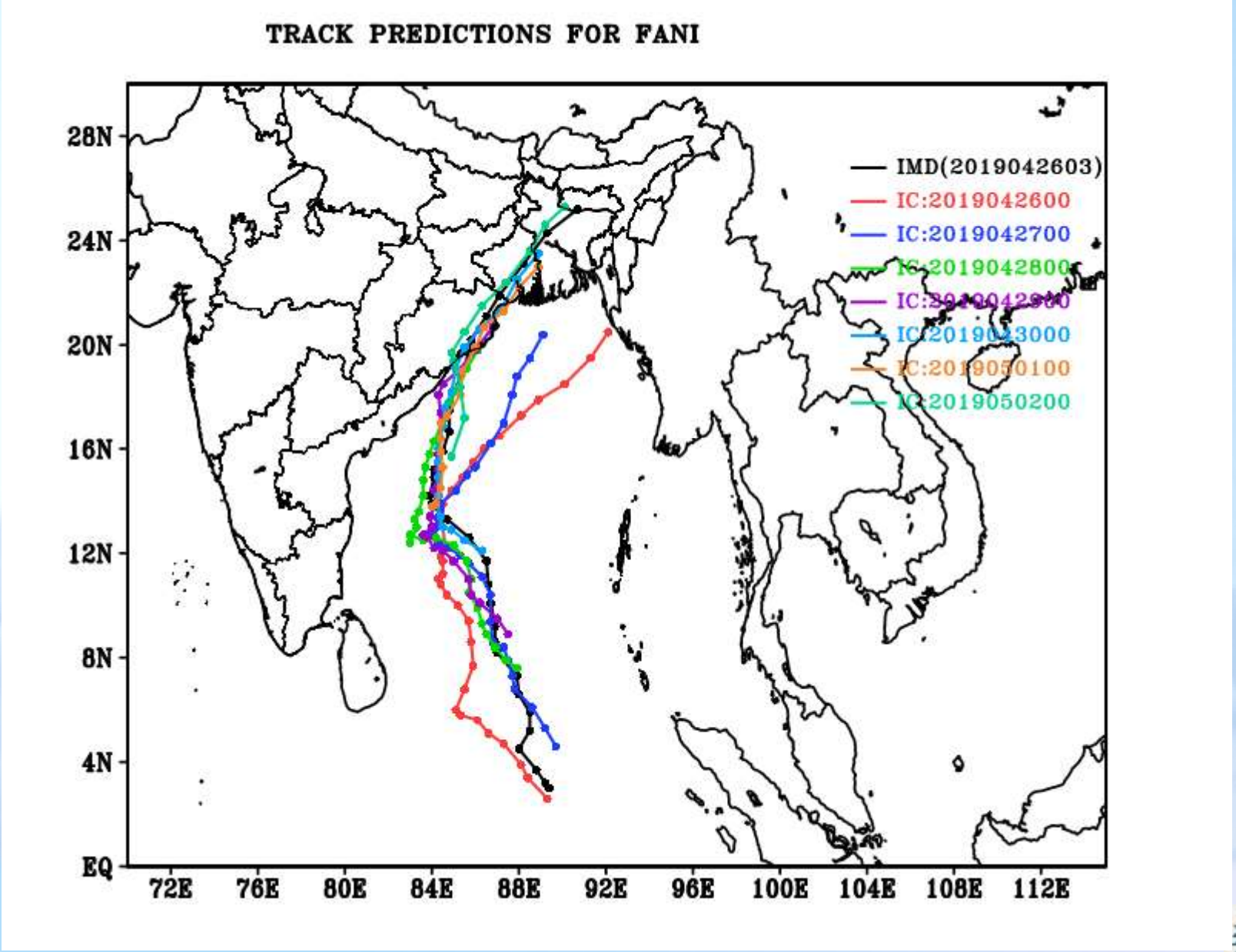
- **The Forecast with 5 days lead time are reliable and consistent in every cycle.**

- **The forecast base on the initial condition on 00UTC OF 20 April 2019 shows the formation of a cyclonic storm over south East Bay of Bengal on 28 April 2019, But it shows landfall over Tamilnadu coast.**

- **Forecast based on 22nd April 00 UTC shows the re-curvature of the cyclone track off Indian coast towards NE direction.**

- **The forecast with lead time more than 5 days before land fall has an inconsistency between consecutive cycles.(00,12 UTC of any day)**

GEFS


TRACK PREDICTIONS FOR FANI
28N
24N
20N
16N
12N
8N
4N
EQ
72E
76E
80E
84E
88E
92E
96E
100E
104E
108E
112E
IMD(2019042603)
IC:2019042600
IC:2019042700
IC:2019042800
IC:2019042900
IC:2019043000
IC:2019050100
IC:2019050200

ESCS ‘TAUKTAE’ & VSCS ‘YASS’

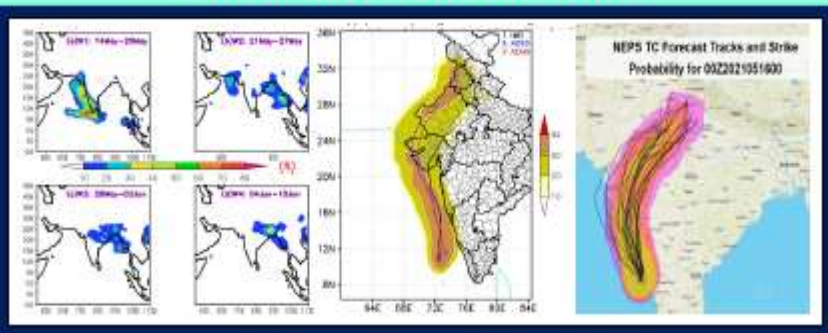
Government of India
Ministry of Earth Sciences
India Meteorological Department

A Report on

Operational NWP Models Forecast Performance for Extremely Severe Cyclonic Storm 'TAUKTAE' over the Arabian Sea

(14 – 19 May 2021)

Numerical Weather Prediction Division
India Meteorological Department



Numerical Weather Prediction Division
India Meteorological Department
New Delhi
June, 2021

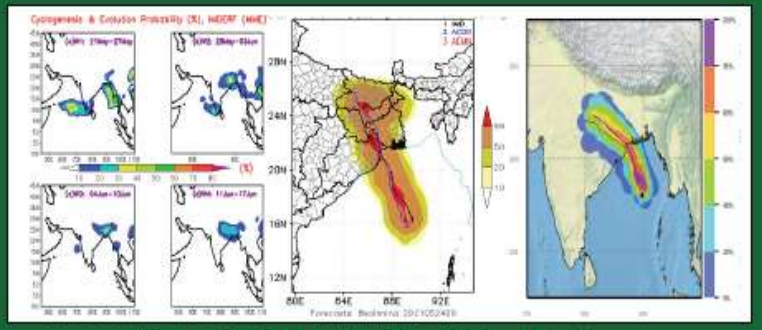
Government of India
Ministry of Earth Sciences
India Meteorological Department

A Report on

Operational NWP Models Forecast Performance for Very Severe Cyclonic Storm 'YASS' over the Bay of Bengal

(23-28 May 2021)

Numerical Weather Prediction Division
India Meteorological Department



Numerical Weather Prediction Division
India Meteorological Department
New Delhi
June, 2021

Tentative observed track of ESCS "TAUKTAE"

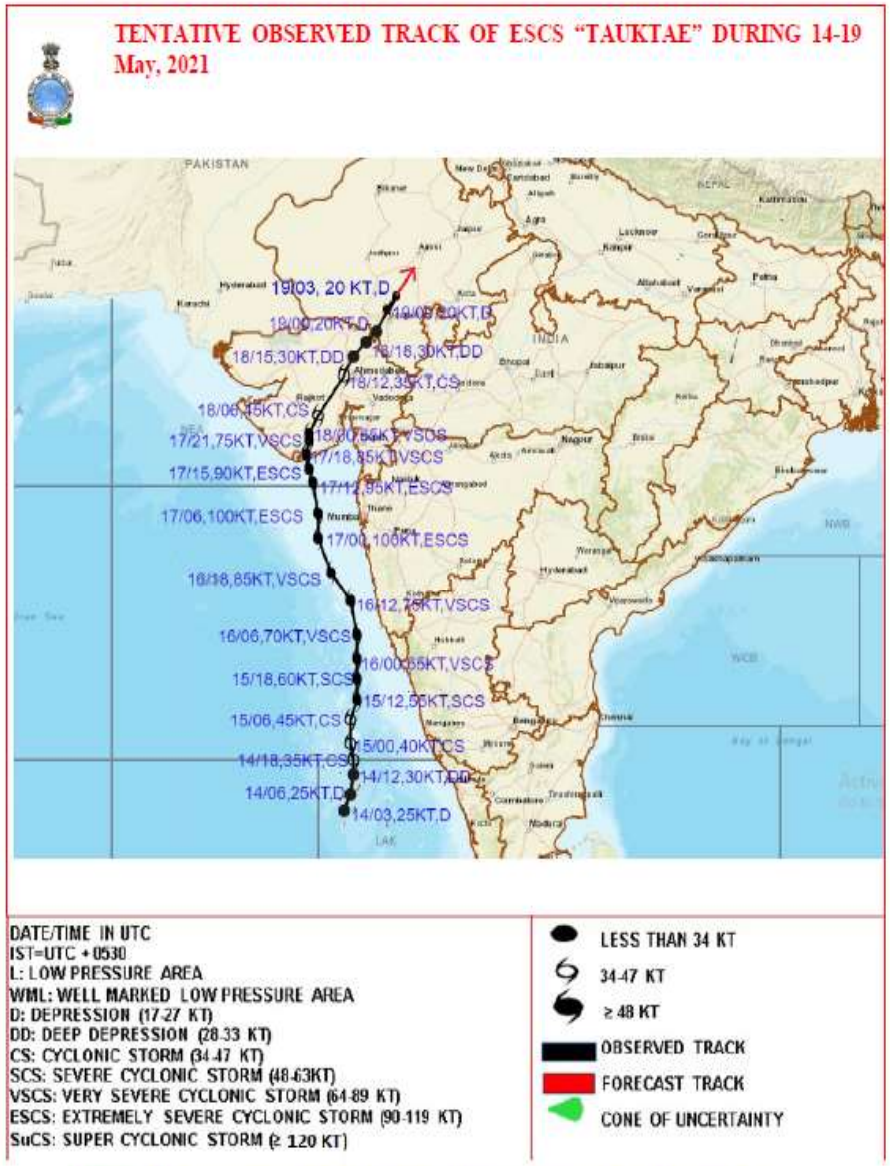


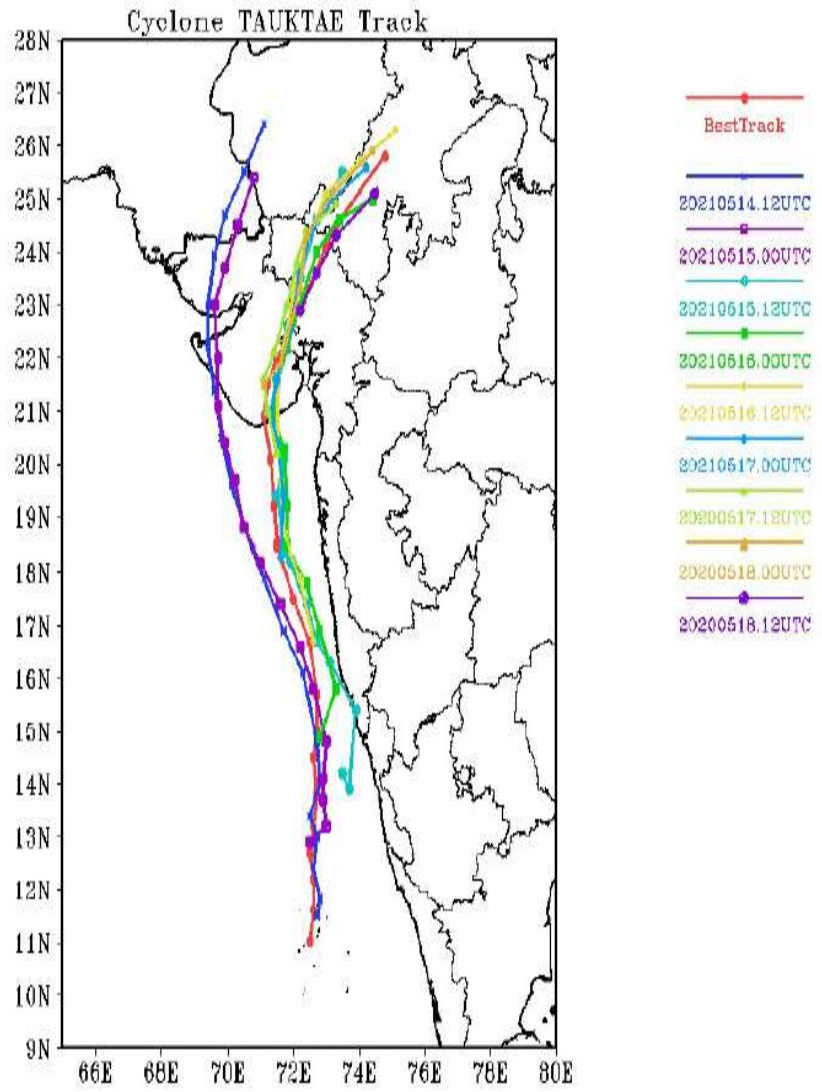
Fig. 1 : Observed track of ESCS "TAUKTAE" during 14-19 May, 2021.

Tentative observed track of VSCS "YASS"

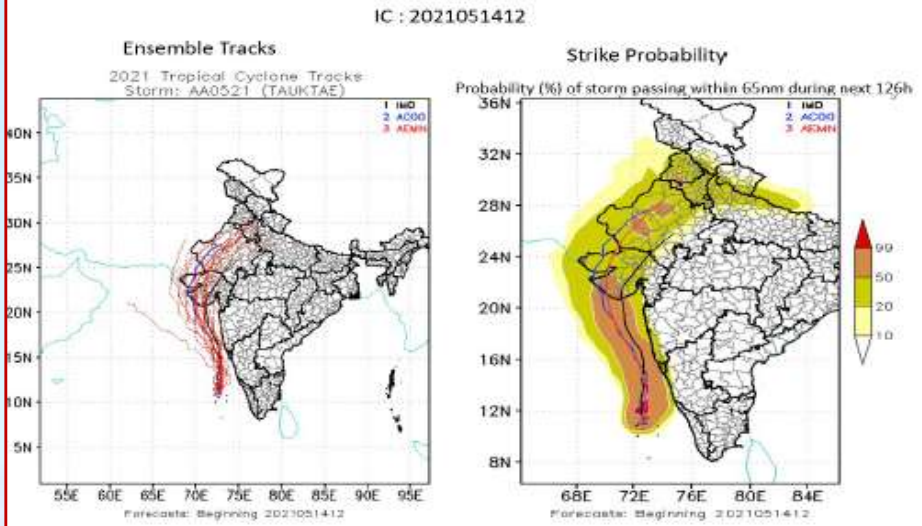
Fig. 1 : Observed track of VSCS "YASS" during 23-28 May, 2021.

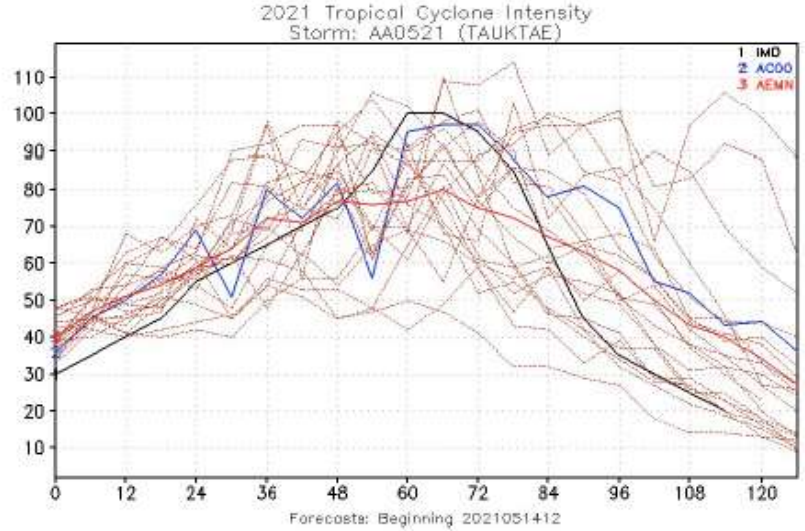
GFS T1534

3.1 Track & Intensity Errors of TAUKTAE Cyclone formed over Arabian



GEFS T1534





Intensity (Max. Sustained Wind Speed (kts))

GFDL Vortex tracker installation and cyclone track prediction

➢The performance of the Global forecast system (GFS) model in prediction of Tropical Cyclone tracks, formed over the North Indian Ocean is evaluated using a vortex tracker developed by Geophysical Fluid Dynamics Laboratory (GFDL).

➢The GFDL tracker program analyzes the forecast data and provides an estimation of the vortex center position i.e., Latitude & Longitude and track the storm for the duration of the forecast. It also provides the metrics of the forecast storm, such as intensity (10m maximum sustained wind speed (WS) and minimum mean sea level pressure (MSLP)), wind structure (wind radii for 34, 50 and 64 knot thresholds in each quadrant).

➢The 'tcvital' provided by Regional Specialised Meteorological Centre (RSMC), India Meteorological Department (IMD), New Delhi are used to relocate the Tropical Cyclone from the GFS model output.

➢The forecast fields used by the tracker are

1. Relative Vorticity at 10m, 850 hPa and 700 hPa levels
2. Mean Sea Level Pressure (MSLP)
3. Geopotential height at 850 and 700 hPa levels
4. Wind speed at 10m, 850 and 700 hPa levels
5. 200-500 hPa and 500-850 hPa thickness

➢**8 Tropical cyclones (TC's) formed during 2019**

➢ **5 TC's during 2020**

➢**5 TC's during 2021**

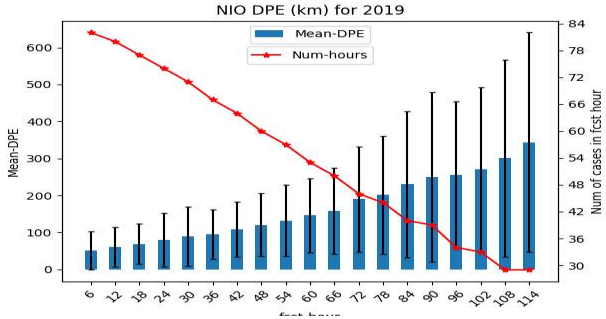
➢ The predicted tracks are evaluated against the Best track data developed by RSMC, IMD, New Delhi. The average track forecast error i.e. Direct position error (DPE) in km at different forecast lead periods (hours) are calculated for each cyclone. Along with the DPE, the Cross Track Error (CTE) and Along Track Error (ATE) (Heming, 2017) also calculated.

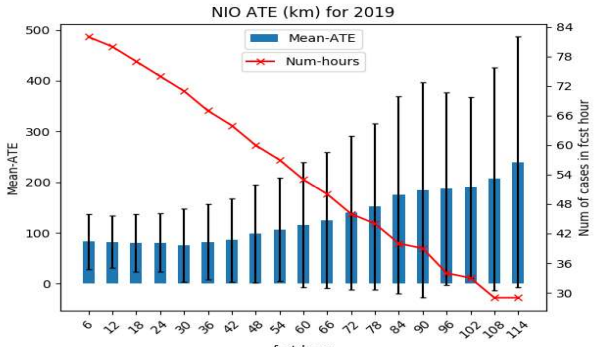
➢ The DPE is the great circle distance between the GFS forecasted track position and the RSMC best track position at the corresponding forecast verification time (Mohapatra et. al., 2013). **The Positive/negative values of ATE indicate that the movement of the cyclone in the forecasts is faster/slower compared to the observed best track** and **the positive/negative values of CTE indicate that forecast track is right/left of the observed track**.

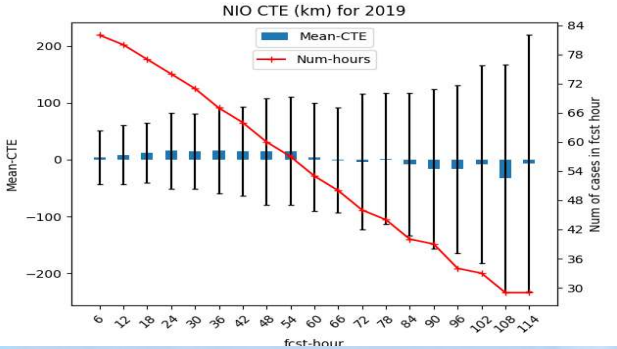
➢ The predicted cyclone intensity verified in terms of mean error (ME) and root mean square error (RMSE) for maximum wind speed (WS) and central mean seal level pressure (MSLP) (Mohapatra et.al., 2013).

Annual Mean Track Errors over NIO

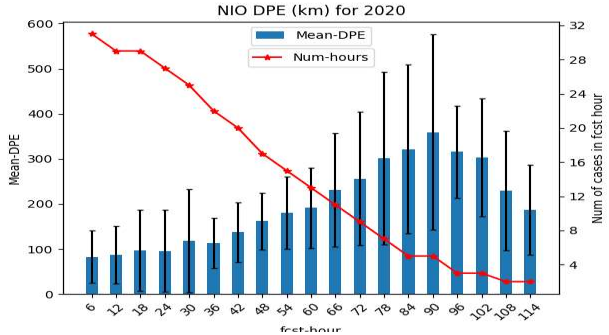
2019

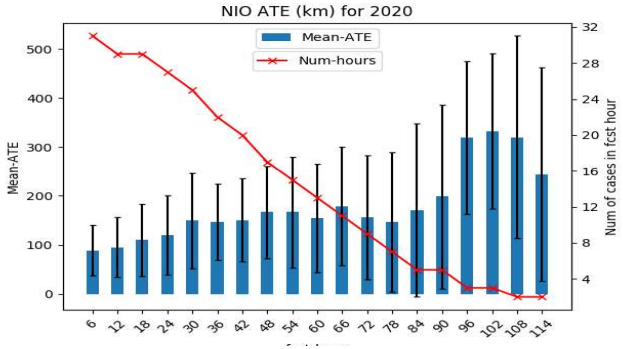


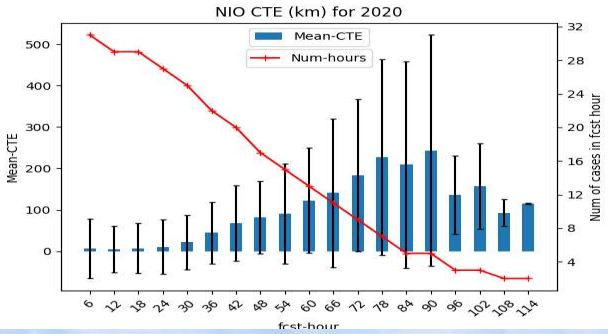




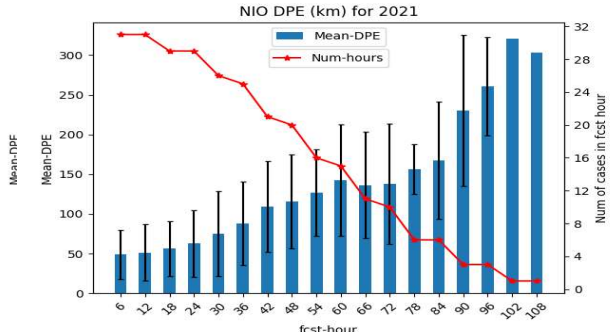
2020

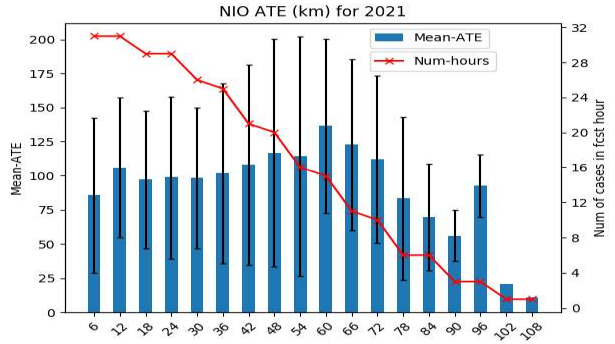


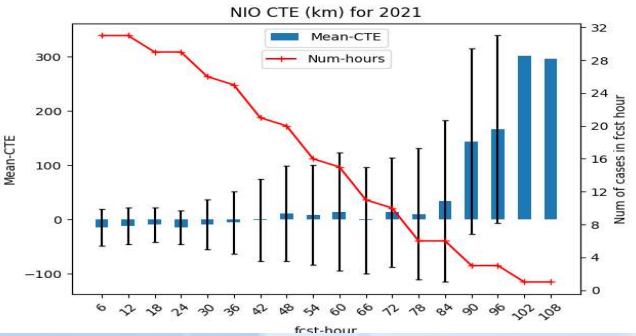




2021

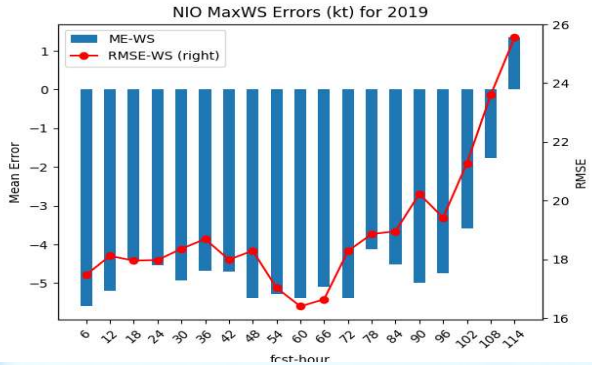




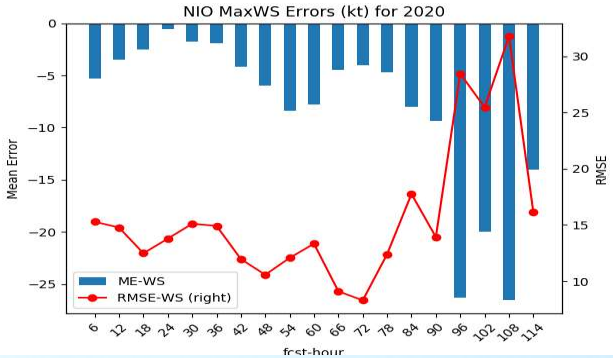


Annual Mean Intensity Errors over NIO

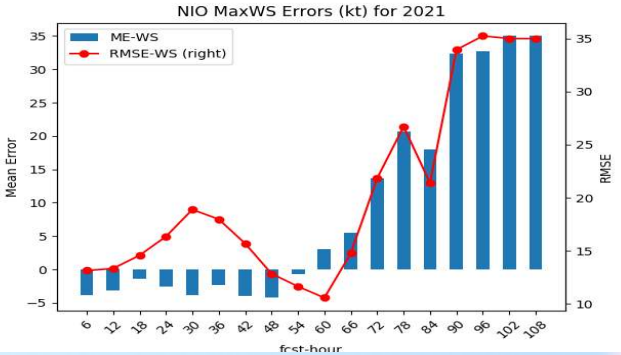
2019

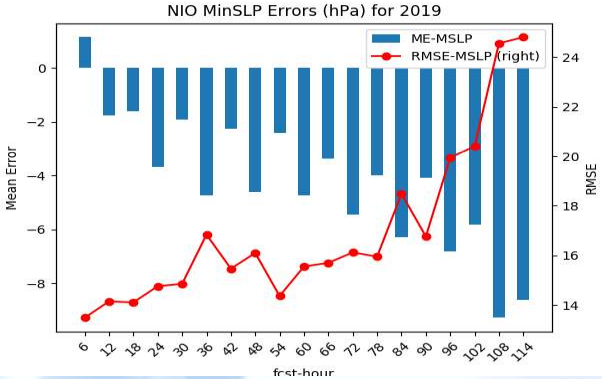


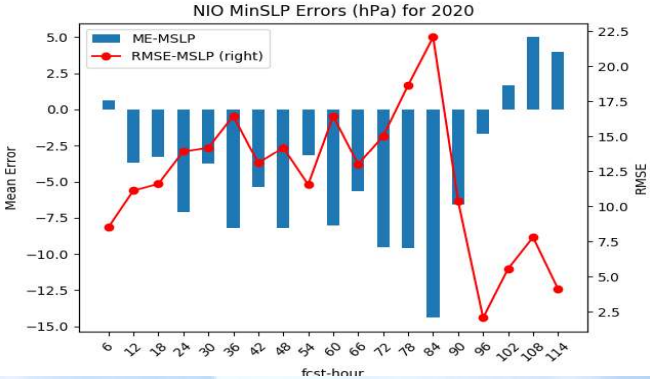
2020

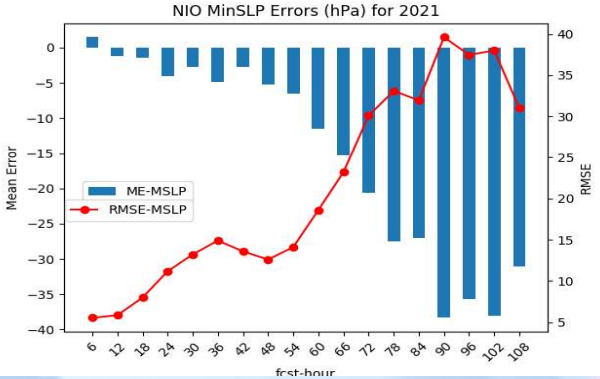


2021









The model under predicted the intensity of maximum sustained wind speed (MaxWS) during 2019 & 2020 and under/over predicted during 2021. The minimum mean sea level pressure (MinMSLP) also under predicted all the three years. The under estimation is high for the year 2021.

Forecast Tracks and Strike Probability

Fig. 21 show the observed and predicted tracks based on 00UTC of 16May 2021. The model predicted tracks indicate that the system would cross the coast very close to the observed position (over Gujarat). The forecast track errors are discussed in the next section. The strike probability and member tracks (Fig. 22) based on the 23 member NEPS-G ensemble indicate that the cyclone would cross the coast of Gujarat near Saurashtra region. These plots are available in real time and can be accessed through https://www.ncmrwf.gov.in/index.php ("NIO Tropical Cyclone").

Figure 21. Observed and forecast tracks of Taukte based on 00UTC on 16th May 2021

Figure 22 : NEPS-G strike probability and ensemble members tracks

NCUM
&
NEPS

ECMWF – Genesis & Track forecasts

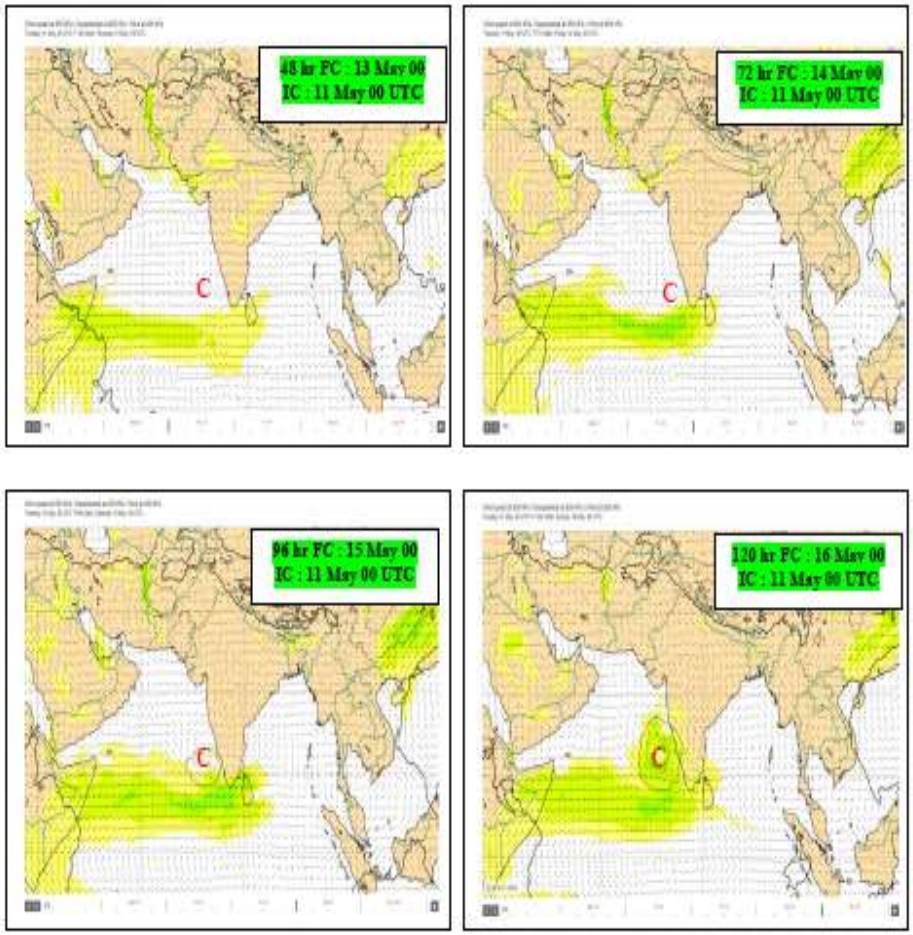


Figure 25 : ECMWF forecasts 850 hPa wind and geopotential height based on 11 May. Indicating the genesis of the system on 13 May and further intensification.

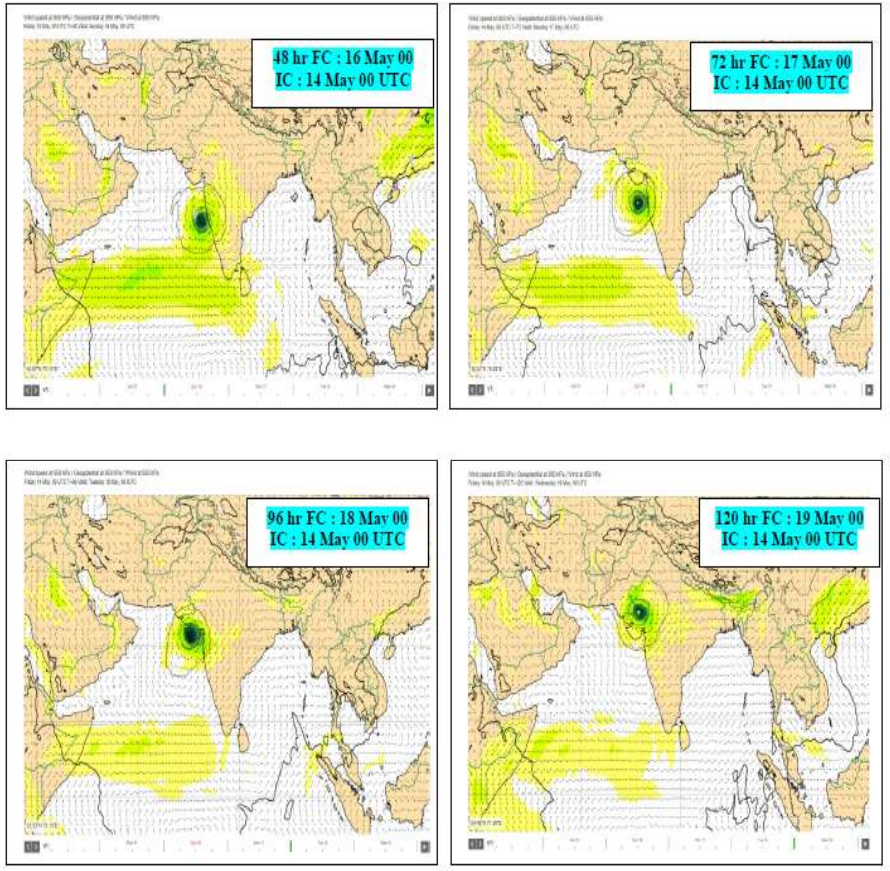


Figure 28: ECMWF forecasts 850 hPa wind and geopotential height based on 14 May. Indicating the gradual intensification and movement in north-northwest direction crossing Gujarat coast and recurving to east Rajasthan.

MME (Track & Intensity)

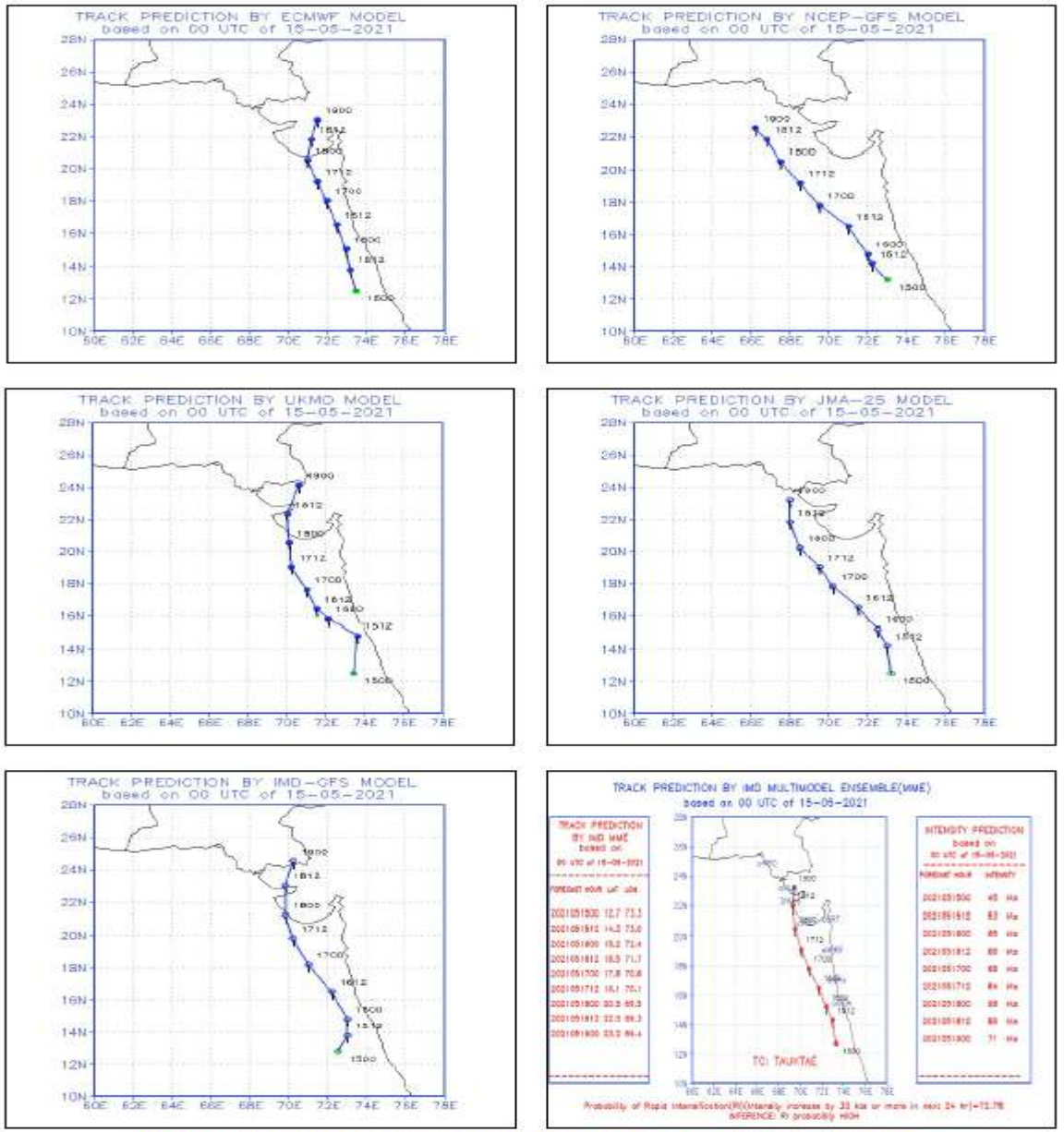


Fig. 33 : MME and individual model tracks based on 15th May 00 UTC.

Forecast Summary

7.1 Direct Position Error For Tropical Cyclone "Tauktae"

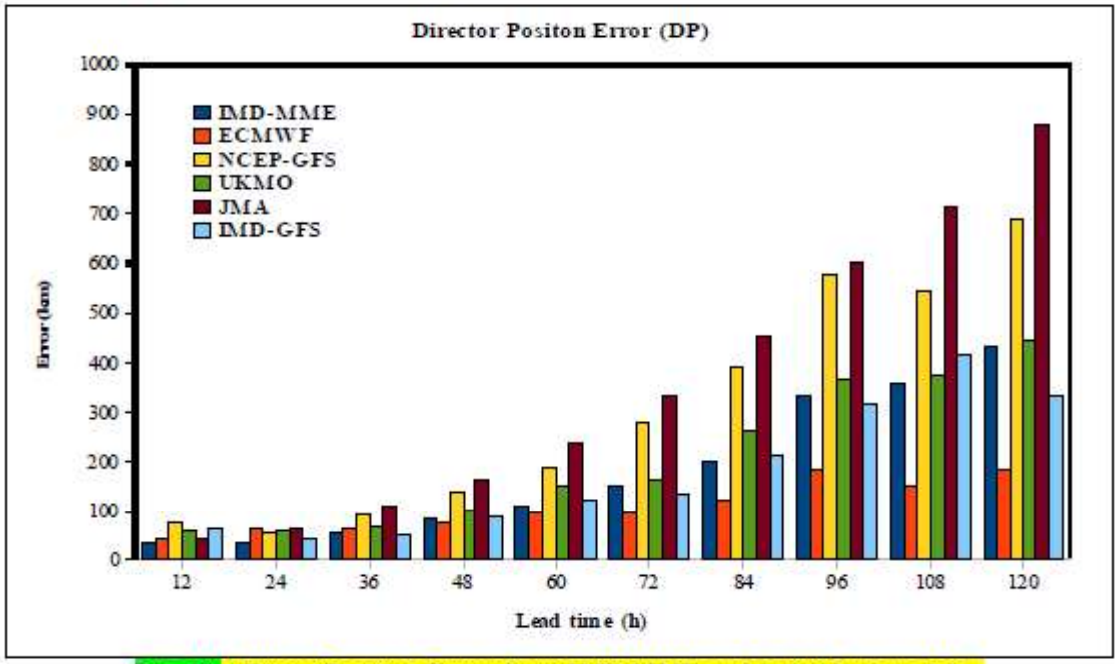


Fig. 38 : Direct Position Error from IMD MME and individual models .

Table 7.1 : Direct Position Error For Tropical Cyclone

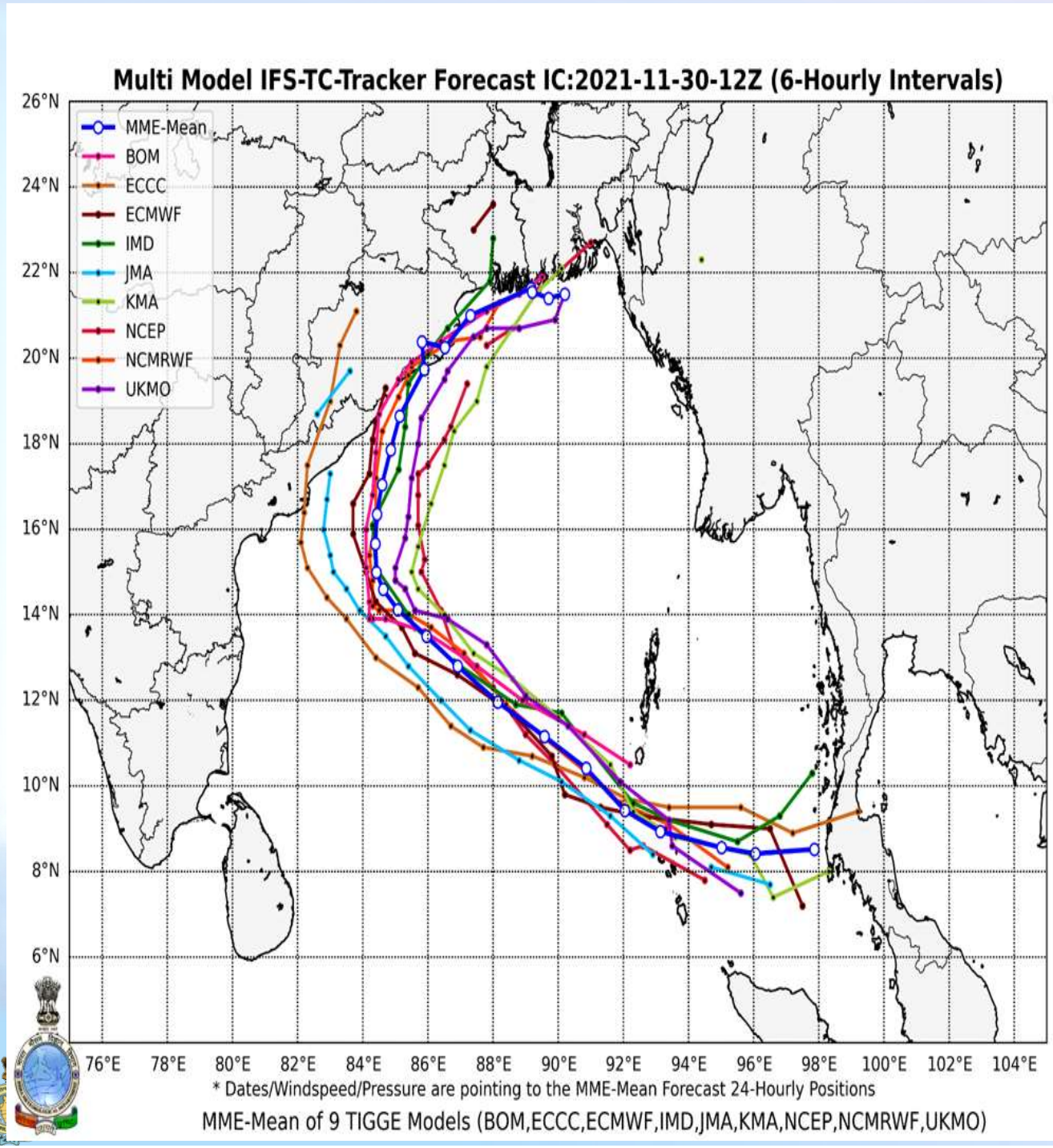
LEAD-TIME	12h	24h	36h	48h	60h	72h	84h	96h	108h	120h
IMD-MME	36(7)	36(7)	54(7)	83(7)	112(6)	151(5)	202(4)	333(3)	360(1)	435(1)
ECMWF	47	66	66	78	95	95	123	184	154	182
NCEP-GFS	77	54	93	138	190	278	388	576	543	688
UKMO	62	61	70	101	151	163	262	367	373	443
JMA-25	43	62	108	165	239	335	454	601	711	880
IMD-GFS	67	42	53	87	124	136	212	317	415	335

** The numbers within the parentheses against DP Errors for IMD-MME indicate the number of forecasts issued corresponding to the lead-time. The number of forecasts, corresponding to a particular lead-time, is the same for all the models.*

JAWAD-2021

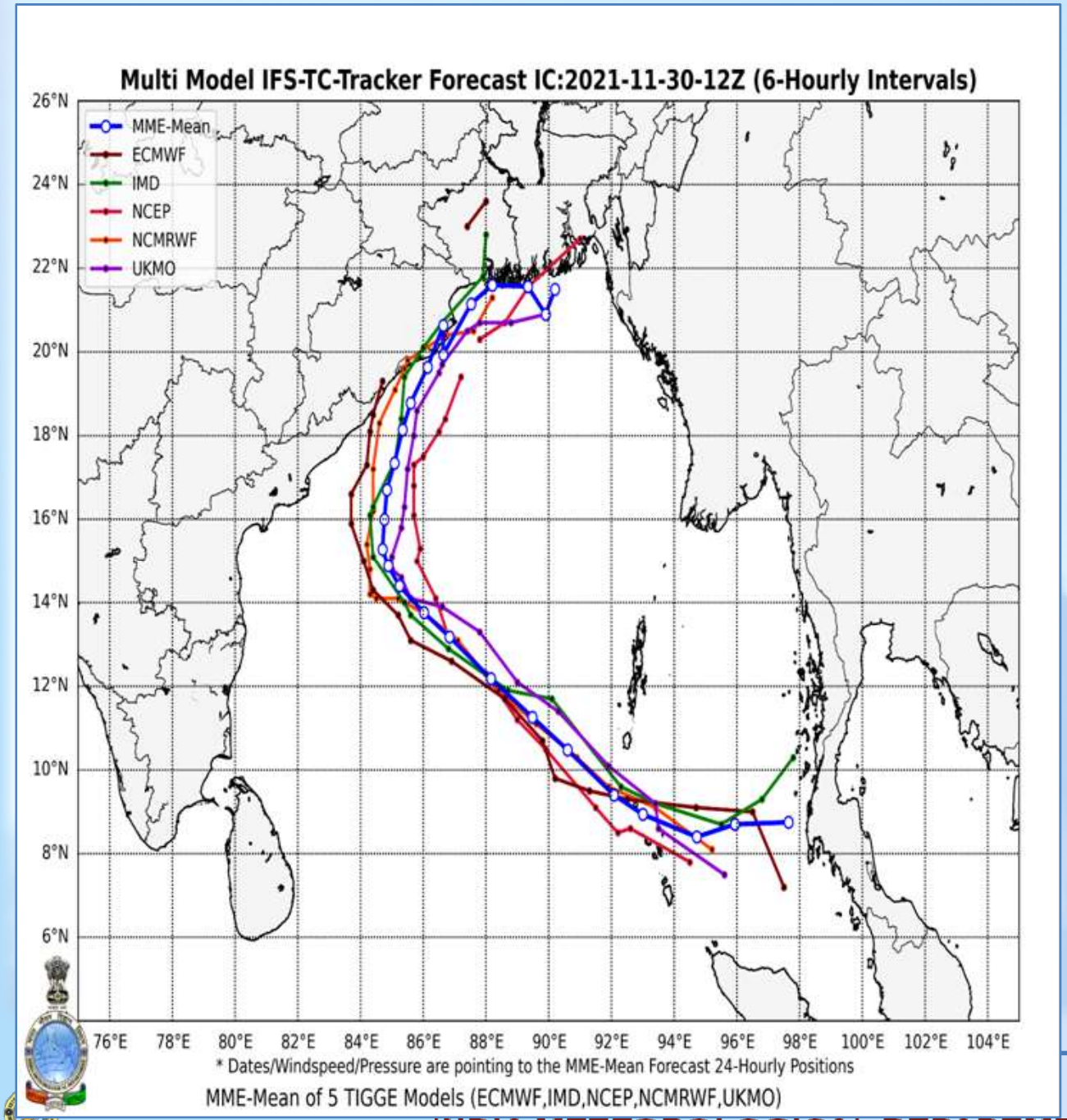
ECMWF-IFS-TC-TRACKER

USING TIGGE MULTI MODEL



At 2.5 days lag time,
we can make use of IFS-TC-Tracker by feeding in 9 models outputs (as grib file) from TIGGE and followed by Multi Model Mean.

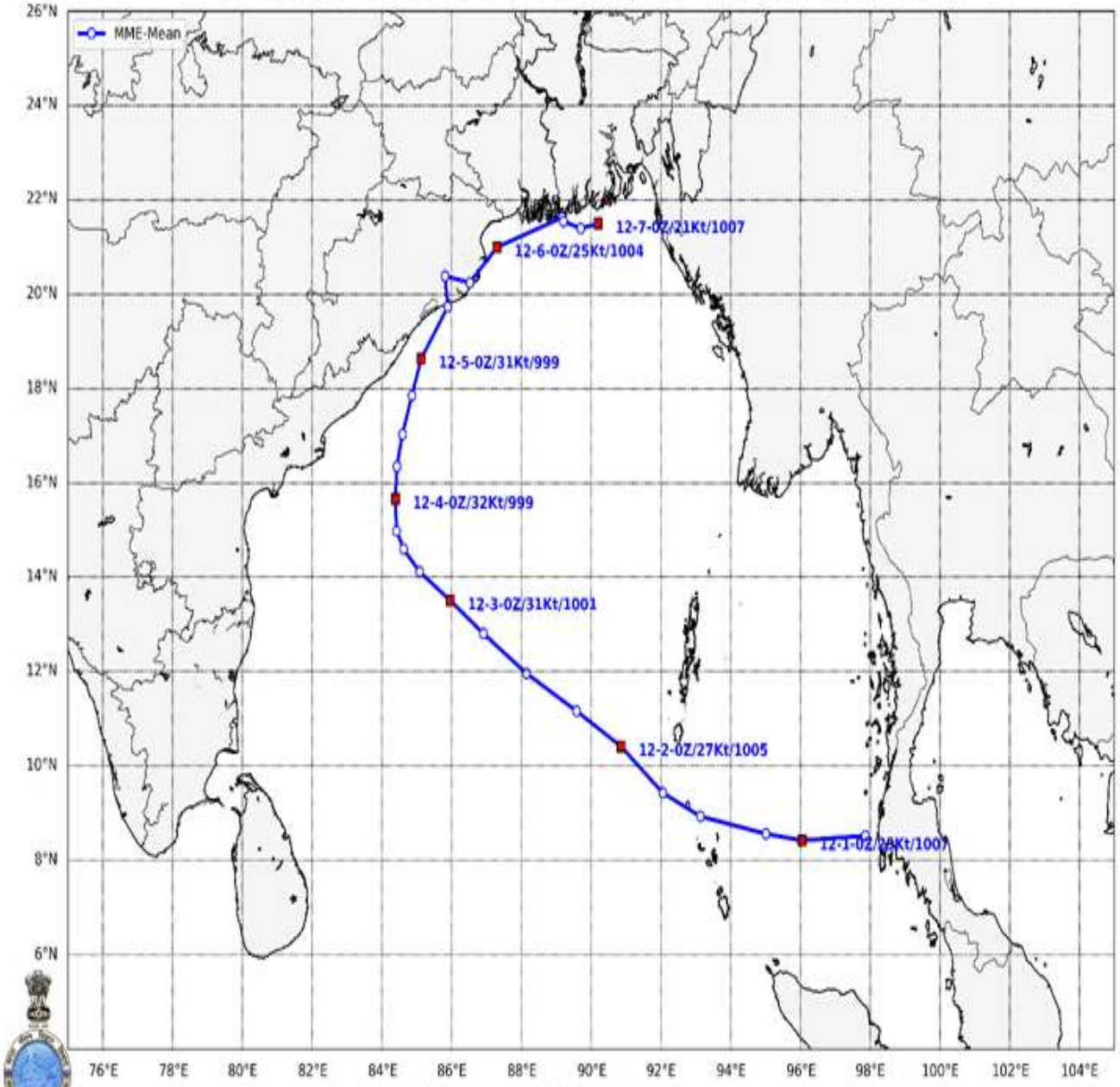
Yet to configure for feeding all the model's ensemble members individually.



On real-time, we can make use of IFS-TC-Tracker by feeding in 5 models outputs (as grib file) from TIGGE and followed by Multi Model Mean.

Yet to configure for feeding the real-time IMDGEFS and NEPS model outputs.

MultiModel-Mean IFS-TC-Tracker Forecast IC:2021-11-30-12Z



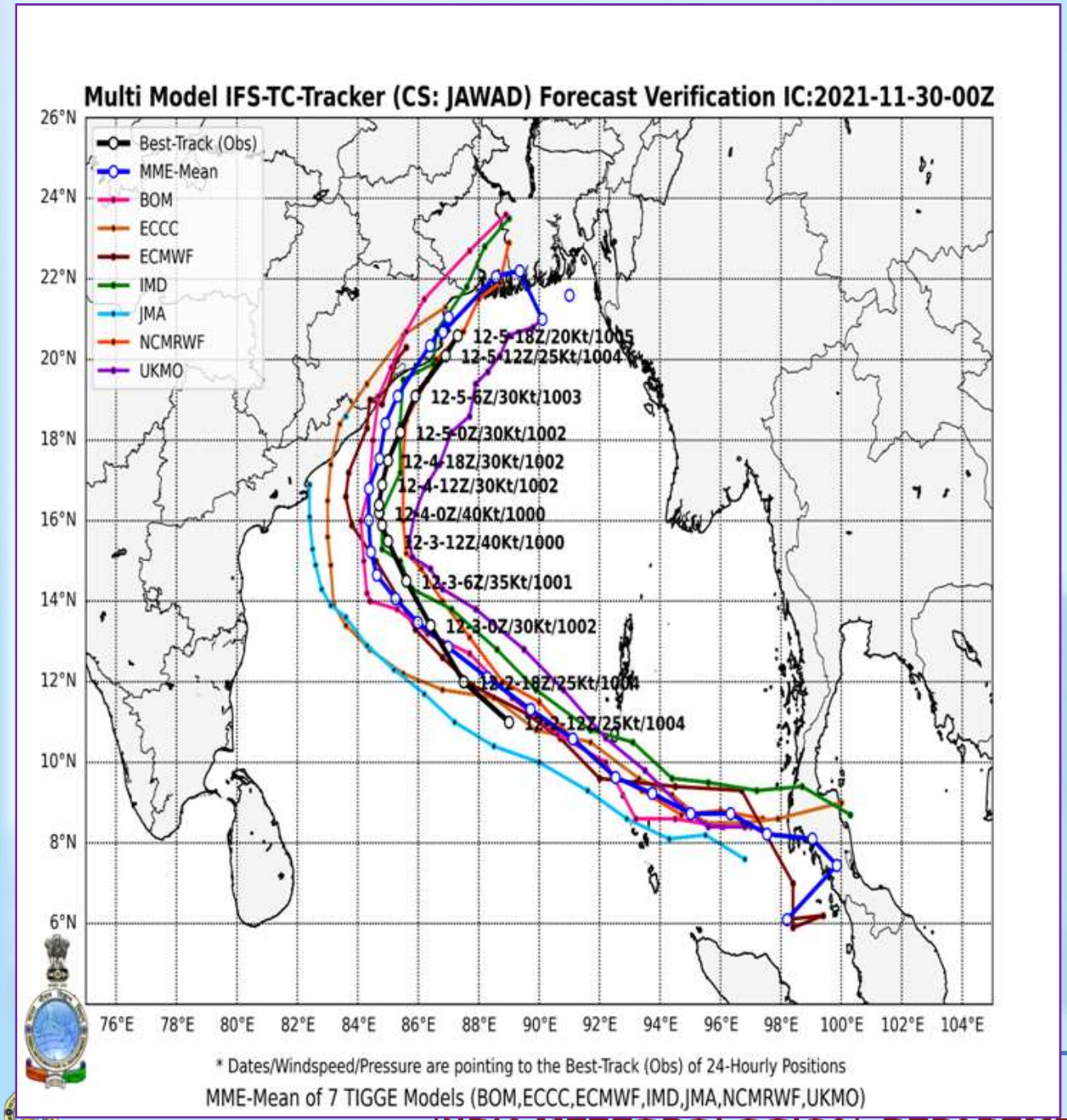
* Dates/Windspeed/Pressure are pointing to the MME-Mean Forecast 24-Hourly Positions

MME-Mean of 9 TIGGE Models (BOM,ECCC,ECMWF,IMD,JMA,KMA,NCEP,NCMRWF,UKMO)

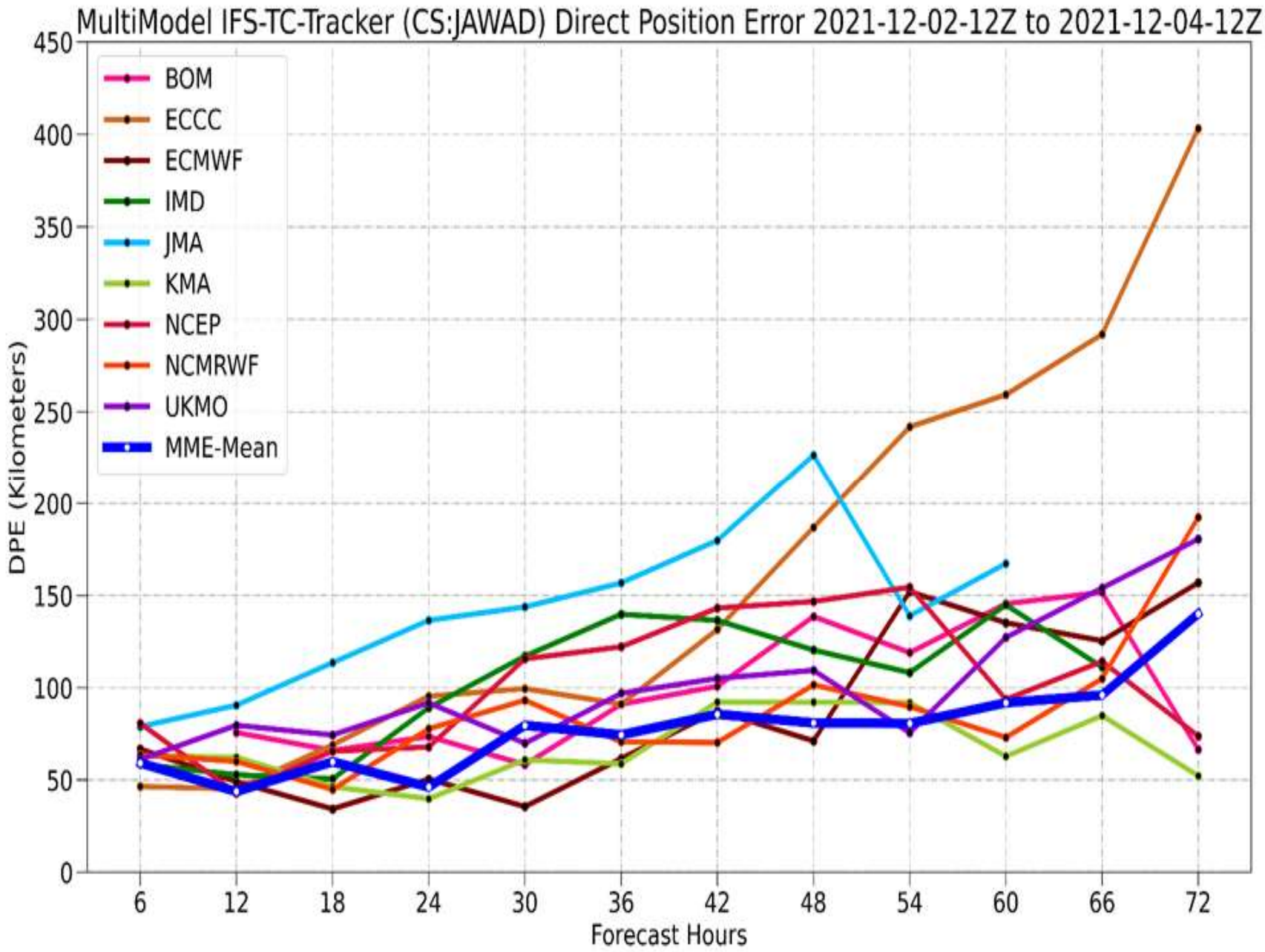
MME-MEAN

DATE	LAT	LON	WS (Kt)	MSLP (hPa)
2021-11-30-18Z	8.52	97.86	22.0	1007.6
2021-12-01-00Z	8.42	96.05	24.67	1006.67
2021-12-01-06Z	8.56	95.01	26.29	1005.86
2021-12-01-12Z	8.93	93.13	25.56	1005.33
2021-12-01-18Z	9.43	92.05	25.88	1006.0
2021-12-02-00Z	10.41	90.86	26.89	1005.0
2021-12-02-06Z	11.16	89.58	27.44	1005.11
2021-12-02-12Z	11.96	88.14	27.44	1003.22
2021-12-02-18Z	12.8	86.91	29.33	1003.44
2021-12-03-00Z	13.5	85.96	31.44	1000.89
2021-12-03-06Z	14.11	85.08	31.33	1000.56
2021-12-03-12Z	14.59	84.62	31.78	999.33
2021-12-03-18Z	14.99	84.42	31.56	1000.33
2021-12-04-00Z	15.67	84.39	32.22	998.67
2021-12-04-06Z	16.36	84.43	34.22	998.78
2021-12-04-12Z	17.04	84.59	33.56	997.56
2021-12-04-18Z	17.86	84.86	33.56	999.44
2021-12-05-00Z	18.64	85.13	30.78	999.33
2021-12-05-06Z	19.74	85.89	30.88	1001.12
2021-12-05-12Z	20.39	85.81	25.71	1002.43
2021-12-05-18Z	20.25	86.52	25.17	1003.83
2021-12-06-00Z	21.0	87.3	25.2	1004.0
2021-12-06-06Z	21.63	89.17	23.33	1006.0
2021-12-06-12Z	21.55	89.2	25.5	1005.0
2021-12-06-18Z	21.4	89.7	23.5	1006.0
2021-12-07-00Z	21.5	90.2	21.0	1007.0

Windspeed >= 34 Knots are marked in red color



Verification with Best Track


MultiModel IFS-TC-Tracker (CS:JAWAD) Direct Position Error 2021-12-02-12Z to 2021-12-04-12Z
BOM
ECCC
ECMWF
IMD
JMA
KMA
NCEP
NCMRWF
UKMO
MME-Mean
DPE (Kilometers)
Forecast Hours
0
50
100
150
200
250
300
350
400
450
6
12
18
24
30
36
42
48
54
60
66
72

Extended Range Forecast

https://mausamjournal.imd.gov.in/index.php/MAUSAM/issue/view/14

Vol. 72 No. 1 (2021): MAUSAM

Published: 01-01-2021

Editors

M. Mohapatra
D.R.Pattanaik
P. Mukhopadhyay

https://mausamjournal.imd.gov.in/index.php/MAUSAM/article/view/124

Evolution of IMD's operational extended range forecast system of tropical cyclogenesis over North Indian Ocean during 2010-2020

D. R. PATTANAIK

M. MOHAPATRA

Keywords: Tropical cyclone, Extended range forecast, Bay of Bengal, North Indian Ocean, Coupled

Accurate tropical cyclone genesis forecasting is important because of

- The need to provide extended community response planning, especially in remote or large communities
- The need to provide advisories at extended forecast ranges for offshore and onshore commercial activities
- The requirement for National Meteorological Services to manage forecasting and reconnaissance resources
- The potential to reduce future track, intensity, and size errors by more accurately defining the likely genesis location

Background

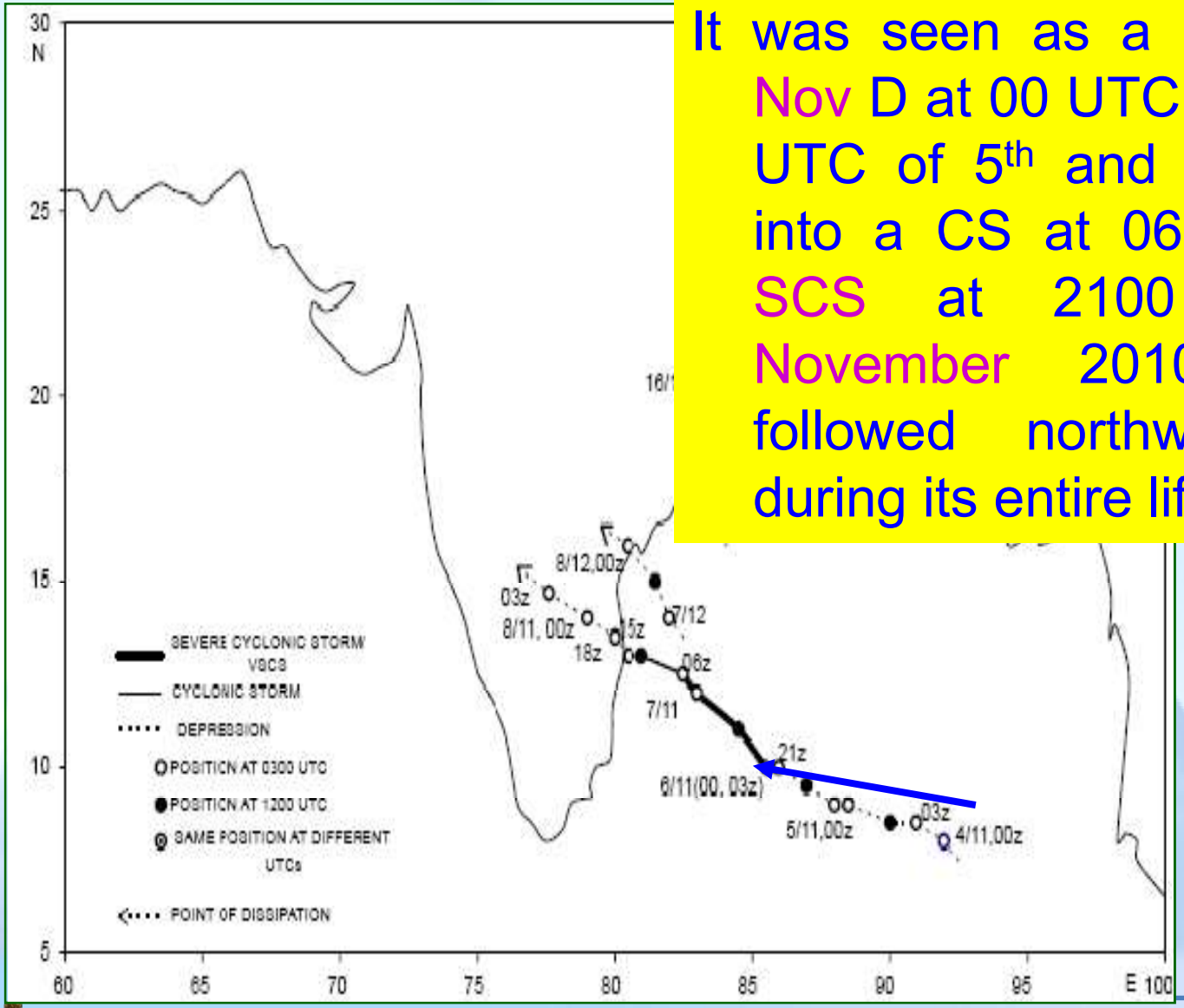
- With the improvement in numerical model and use of wide ranges of non conventional data in the assimilation system of the model there has been considerable improvement in the forecast skill of tropical cyclones particularly in the short range up to 72 hr.
- Significant amount of work have been done over the Atlantic and other Basins in forecasting in the extended range. (Monthly to Seasonal)
- There is large gap areas in prediction of tropical cyclone genesis with longer lead time.
- For North Indian Ocean, prediction of tropical cyclone genesis up to about two weeks time can be very useful.

Earlier Attempt of Extended Range Forecast of Cyclogenesis in IMD

i) Case-1 ; SCS JAL (01-07 Nov 2010)

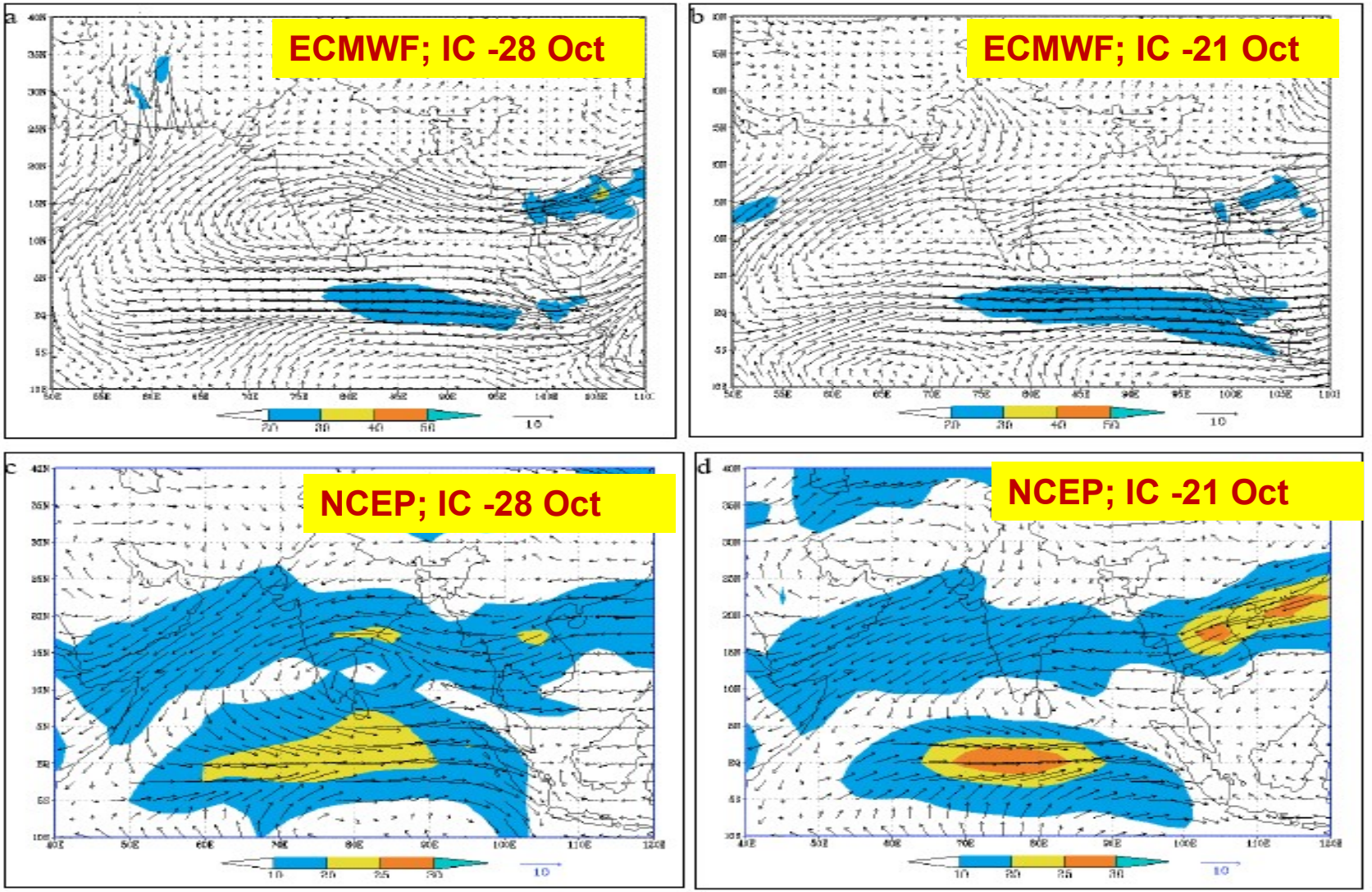
ii) Case -2 ; Active Arabian Sea (Oct-Nov, 2015)

Cyclonic Disturbance "JAL" during 2010



It was seen as a LOPAR on 2nd, Nov D at 00 UTC of 4th, DD at 00 UTC of 5th and then intensified into a CS at 0600 UTC of 5th, SCS at 2100 UTC of 5 November 2010. **SCS 'Jal'** followed northwestward track during its entire life span.

Forecast winds for 2 weeks from ECMWF and NCEP Coupled models (Valid for 01-07 Nov, 2010)



Figs. 8(a-d). Forecast 850 weekly mean wind for SCS "Jal" during the period 01-07 November, 2010. (a) ECMWF, days -11 forecast (IC=28 Oct.) (b) ECMWF, days 12-18 forecast (IC=21 Oct) (c) NCEP CFS, days 5-11 forecast (IC=28 Oct) and (d) NCEP CFS, days 12-18 forecast (IC=21 Oct)

Quantification of dynamical parameters

Dynamical parameters like vorticity and divergence from the forecast fields in case of SCS "Jal"

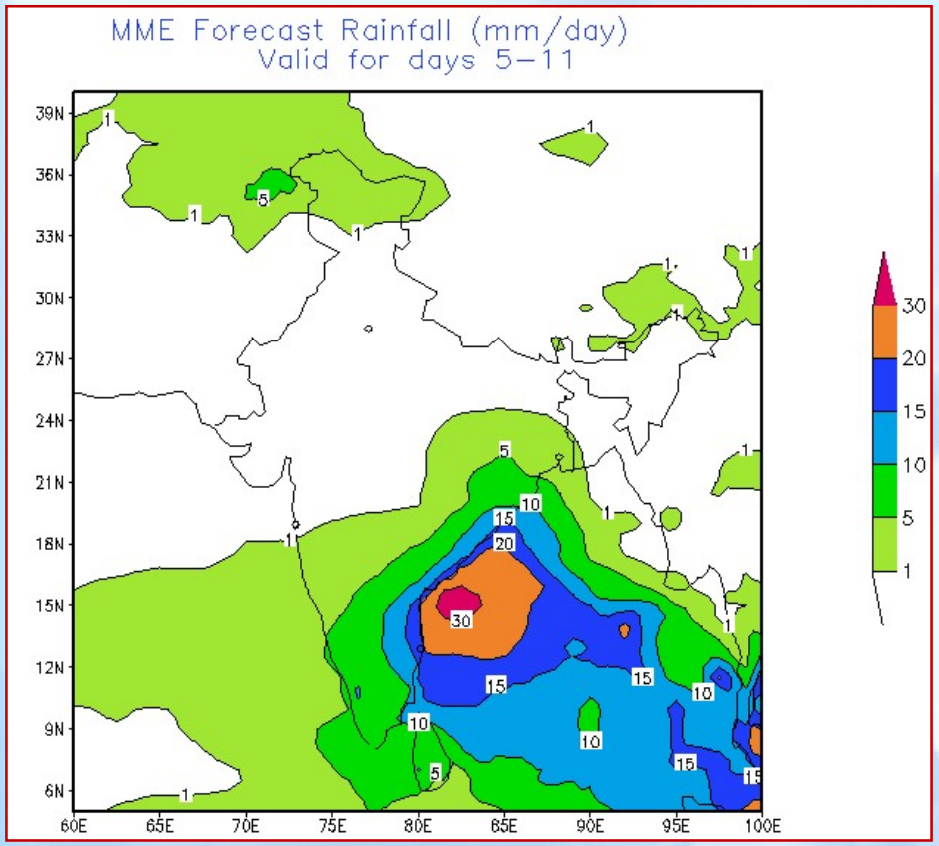
Dynamical Parameters	Mean and Anomaly	Week 1 (days 5-11) forecast Based on 28 Oct and valid for 01-07 November, 2010 (Area : 80°E-90°E, 05-15°N)			Week 2 forecast (days 12-18) Based on 21 Oct and valid for 01-07 November, 2010 (Area : 80°E-90°E, 05-15°N)		
		ECMWF	NCEP	2MAVE	ECMWF	NCEP	2MAVE
850 hPa max_vor (1×10^{-5} sec^{-1})	Mean	5.52	4.36	4.94	3.42	3.47	3.36
	Anomaly	4.33	3.81	4.05	2.00	2.81	2.32
850 hPa min_div (1×10^{-5} sec^{-1})	Mean	-3.02	-0.72	-1.65	-1.57	-0.60	-0.88
	Anomaly	-3.03	-0.58	-1.57	-1.42	-0.48	-0.80

D. R. Pattanaik, M. Mohapatra, B. Muhopadhyay and Ajit Tyagi

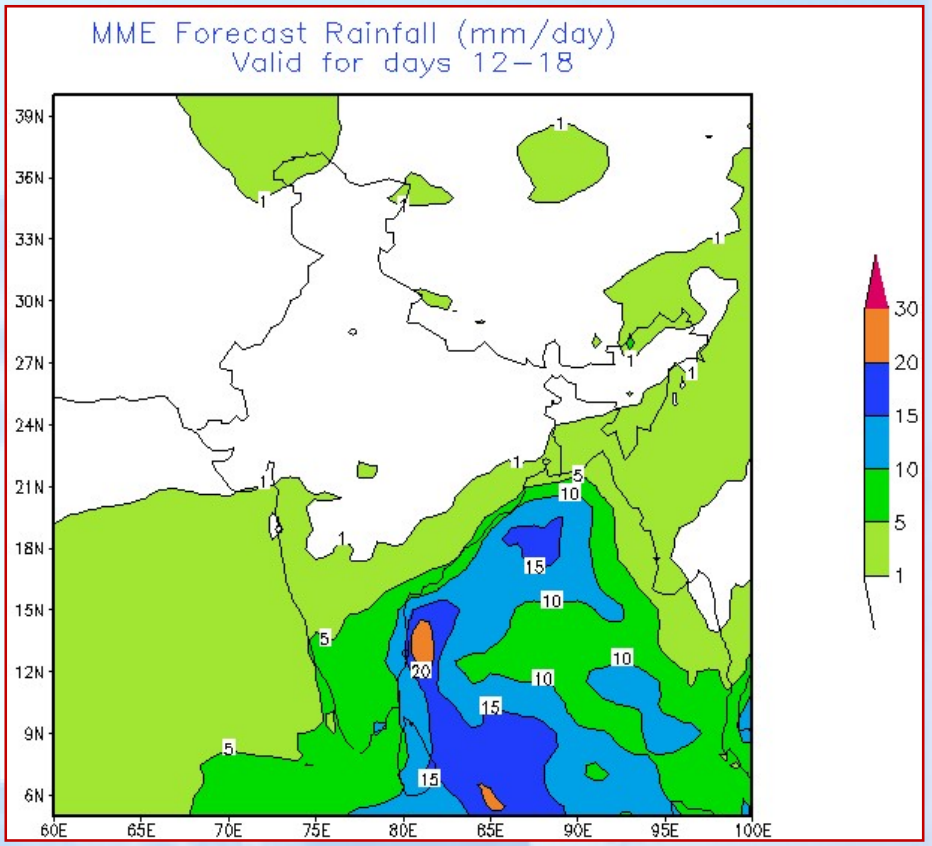
MAUSAM, 64, 1 (January 2013), 171-188

MME Rainfall for the period 01-07 Nov 2010

Days 5-11 (01-07 Nov, 2010)



Days 12-18 (01-07 Nov, 2010)



1. Cyclogenesis potential for 3 weeks

i) Low level vorticity

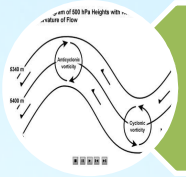
ii) Low level convergence

iii) Wind shear

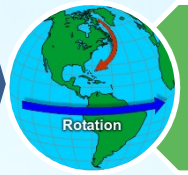
iv) MJO Phase

Necessary Conditions for Cyclogenesis in Tropics

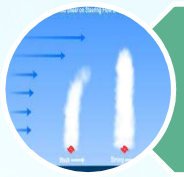
DYNAMIC



large values of low-level relative vorticity



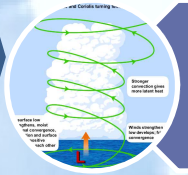
Coriolis parameter (at least a few degrees poleward of the equator)



weak vertical shear of the horizontal winds

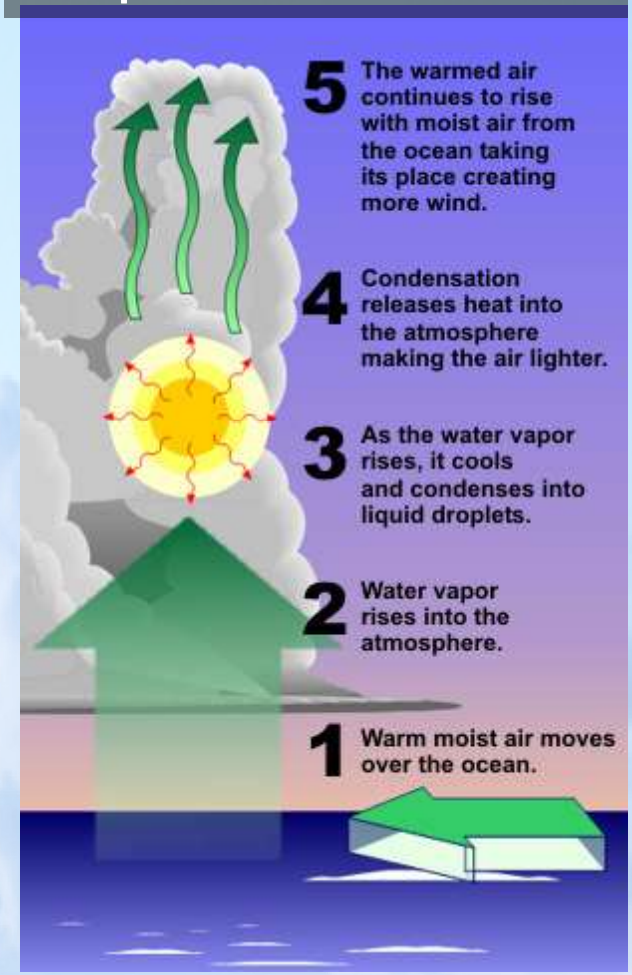
THERMODYNAMIC

high SSTs exceeding 26°C and a deep thermocline



conditional instability through a deep atmospheric layer

large values of relative humidity in the lower and middle troposphere.



Courtesy: http://oceanservice.noaa.gov/education/yos/resource/JetStream/tropics/images/waterpower.jpg

Mcbride and Zehr ,1981

- Showed that , out of Gray's 6 climatological parameters required for genesis, **thermodynamic parameters are seasonal** where as the three **dynamic parameters had a large day to day variation**.
- 1 parameter Daily Genesis Potential (DGP) defined as **vorticity difference between 900 and 200 hPa, DGP = ζ_{900mb}-ζ_{200mb}**

Zehr et. Al, 1992

- **Used vorticity at 850 hPa, divergence at 850 hPa, and vertical wind shear to derive a genesis parameter (GP)**.
- Showed that this **GP was useful in differentiating between non-developing and developing tropical disturbances** in the western North Pacific

DeMaria et al 2001

- Developed a genesis parameter to evaluate the potential of tropical cyclone formation in the North Atlantic between Africa and the Caribbean islands.
- used scaled 5-day running mean **vertical wind shear, instability, and moisture variables**
- genesis parameter **could explain intra- and interseasonal variability in tropical cyclone formation**.

Emmnuel and Nolan (2004)

- Genesis Potential index (GP) was developed motivated by the work of Gray (1979).
- The set of chosen predictors used includes **the potential intensity (Emanuel, 1986), relative humidity and absolute vorticity at various levels, and vertical wind shear.**

Murakami et al 2011

- Studied the possible future changes in TC activity associated with Global warming and **modified the GP of Emanuel and Nolan including vertical velocity term.**
- Modified GPI includes vertical velocity at 500hPa **which enables correct reproducibility of TC genesis over regions with strong ascending motions, such as ITCZ.**

The proposed GPP is defined as:

$$\text{GPP} = \frac{\xi_{850} \times M \times I}{S} \quad \text{if } \xi_{850} > 0, M > 0 \text{ and } I > 0$$

$$= 0 \quad \text{if } \xi_{850} \leq 0, M \leq 0 \text{ or } I \leq 0$$

where ξ_{850} = low-level relative vorticity (at 850 hPa) in 10^{-5} s^{-1}

S = vertical wind shear between 200 and 850 hPa (m s^{-1})

$$M = \frac{[\text{RH} - 40]}{30} = \text{Middle tropospherererelative humidity,}$$

$$\text{I} = (T_{850} - T_{500})\ ^{\circ}\text{C} = \text{Middle-tropospheric instability}$$

Each of the four variables are estimated by averaging of all grid point values within a circle of radius 2.5 around the centre of cyclonic system for the computation of GPP value.

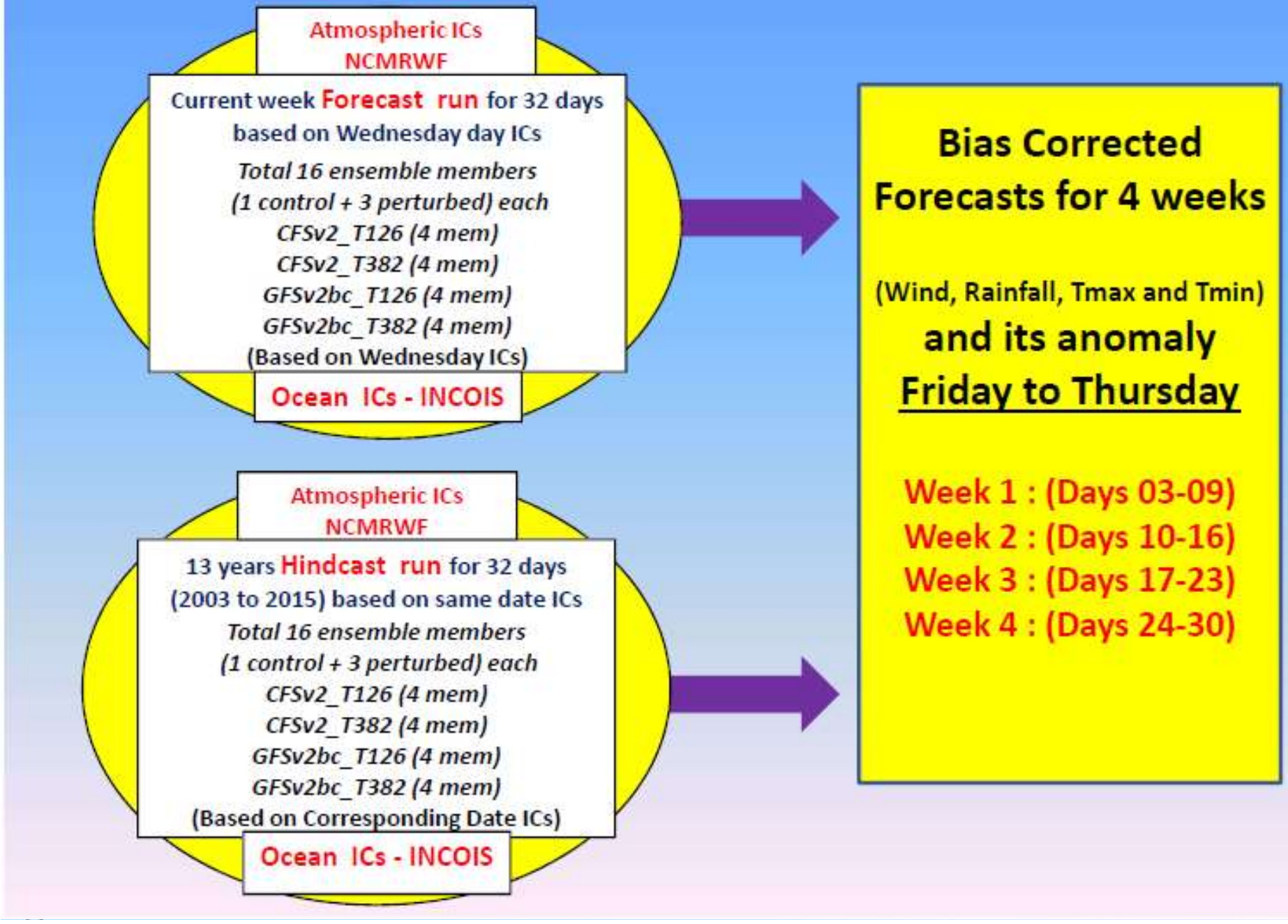
Results showed that most developing cases had a GPP value greater than 8 and non-developing cases had a GPP less than 8. So GPP=8 is set as the threshold value.

IMD's New Operational System

- Objective of MoES was to have a indigenously developed Coupled Modelling System for IMD to run operationally.
- IMD current ERF system is rendered through joint collaboration of IMD, IITM, NCMRWF and INCOIS.
- The system was developed at IITM and was transferred to IMD in Jan 2017.
- IMD is running this ERF system operationally every week with adopting following three changes

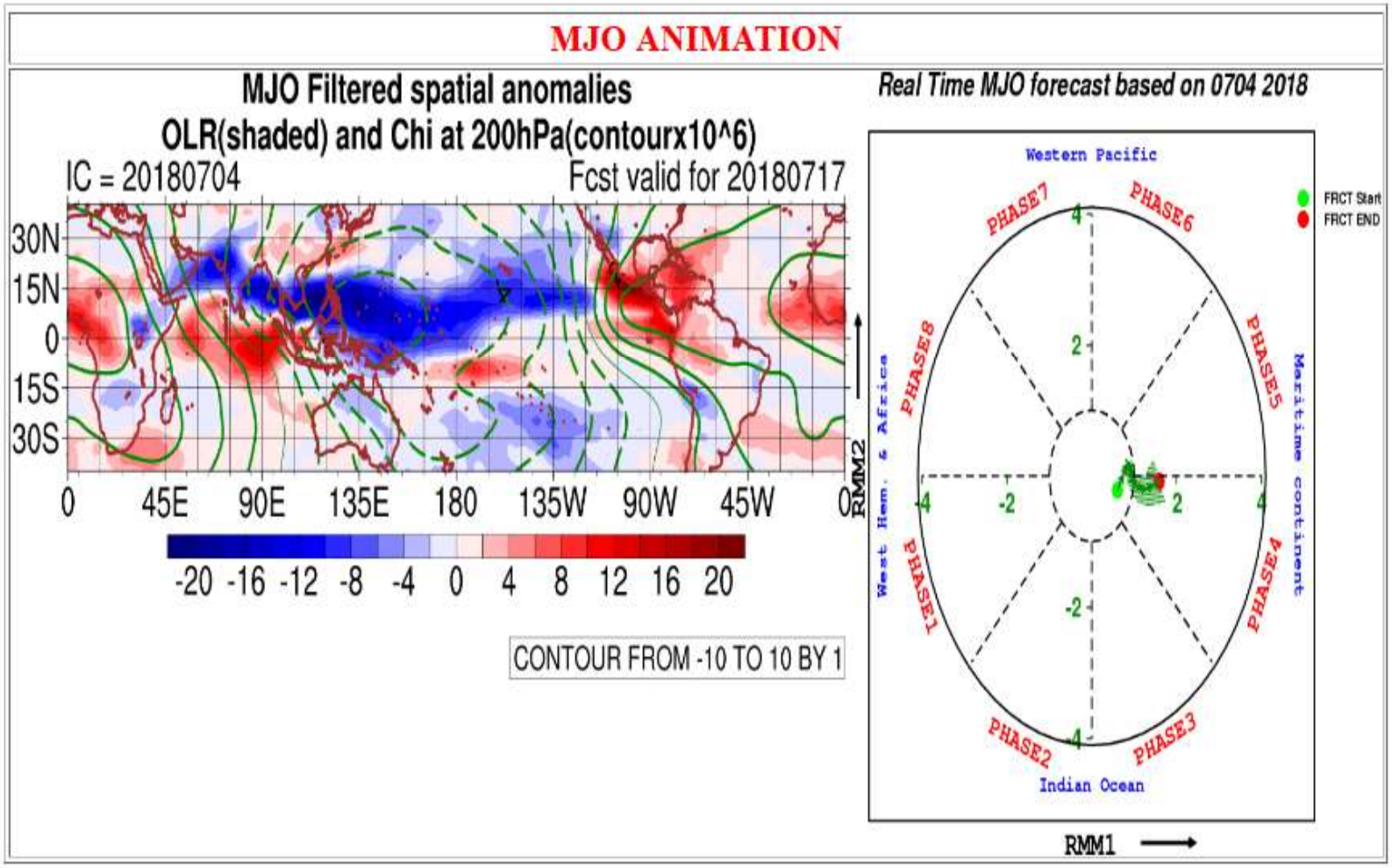
- *To migrate from the existing pentad system of IITM to weekly system*
- *Operational and hindcast runs to be carried out based on a fixed day of every week*
- *The atmospheric and oceanic initial conditions are to be used based on the analysis available from NCMRWF and INCOIS*

IMD's Operational Extended Range Forecast (ERF) System



MJO forecast

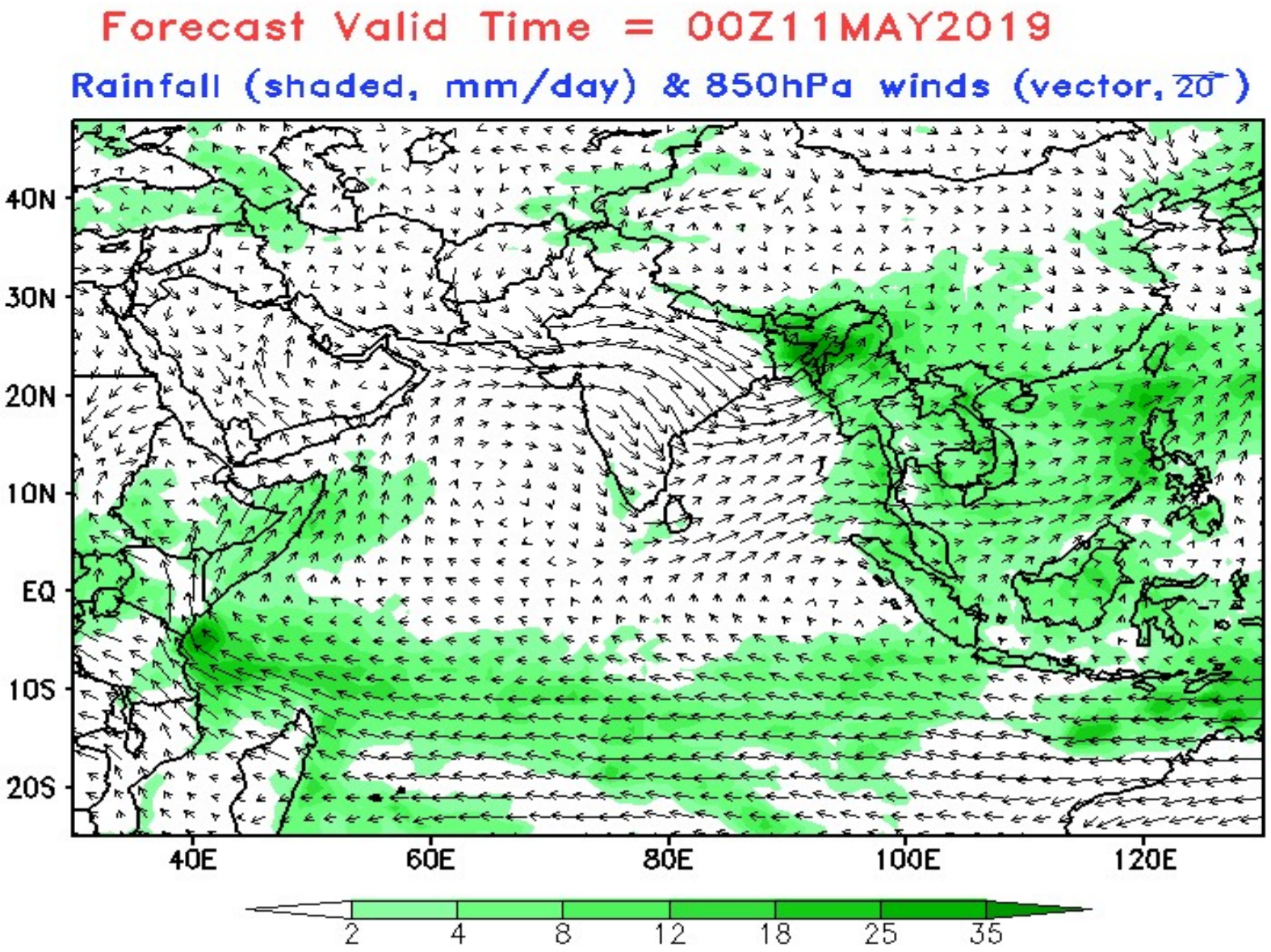
ATION | MISO SPATIAL PLOT | MISO PHASE PLOT | MJO ANIMATION | MJO SPATIAL PLOT | MJO PHASE PLOT



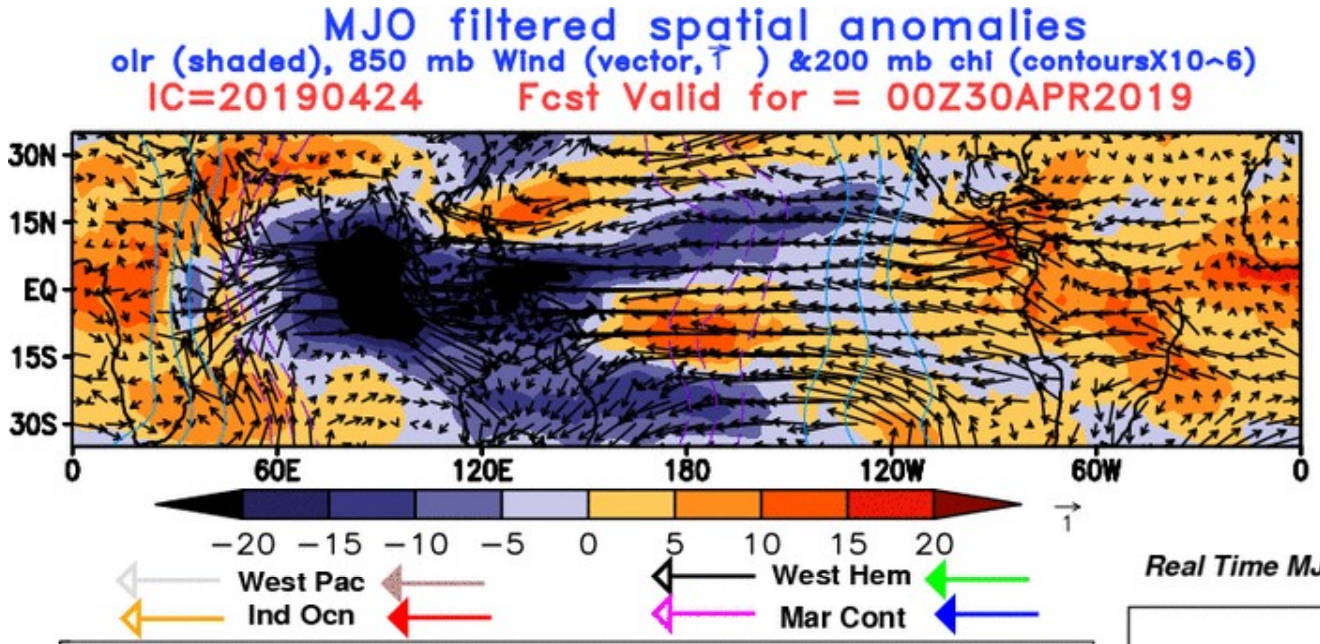
ID OPERATIONAL COUPLED MODEL FOR EXTENDED RANGE FORECAST (Rendered through joint efforts of IITM, NCMRWF & INCOIS)

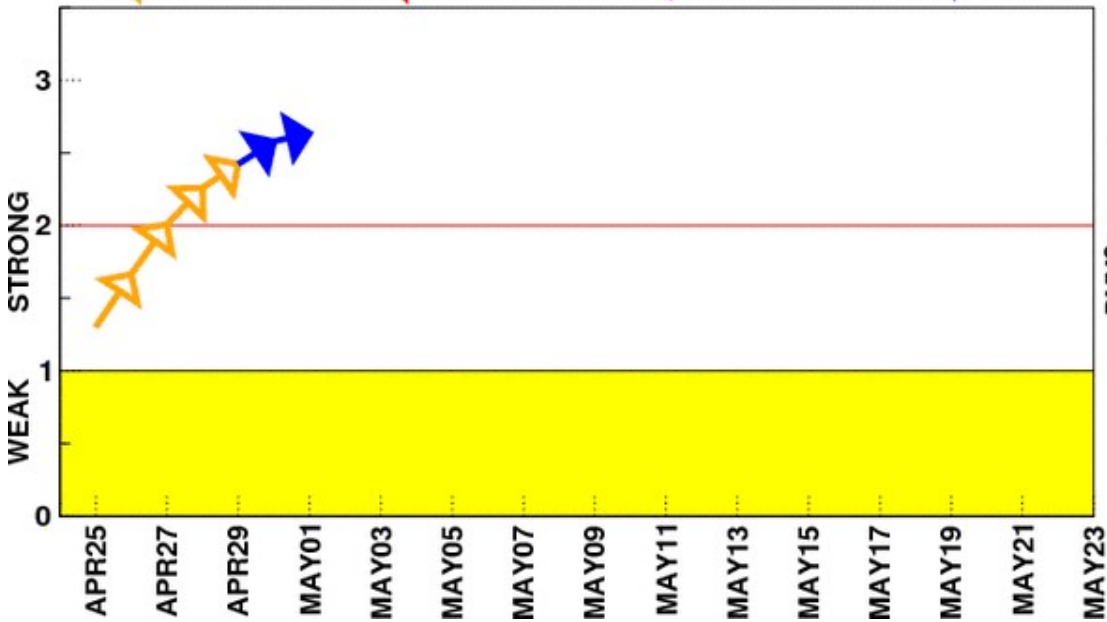
i) FANI Cyclone, 26 April- 05 May 2019

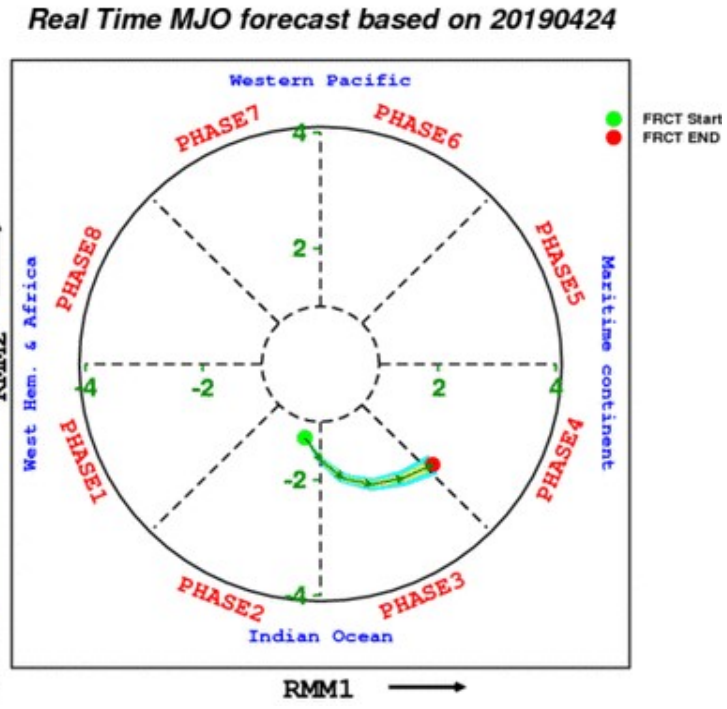
IMD ERF 850 hPa wind animation (IC – 24 Apr 2019)



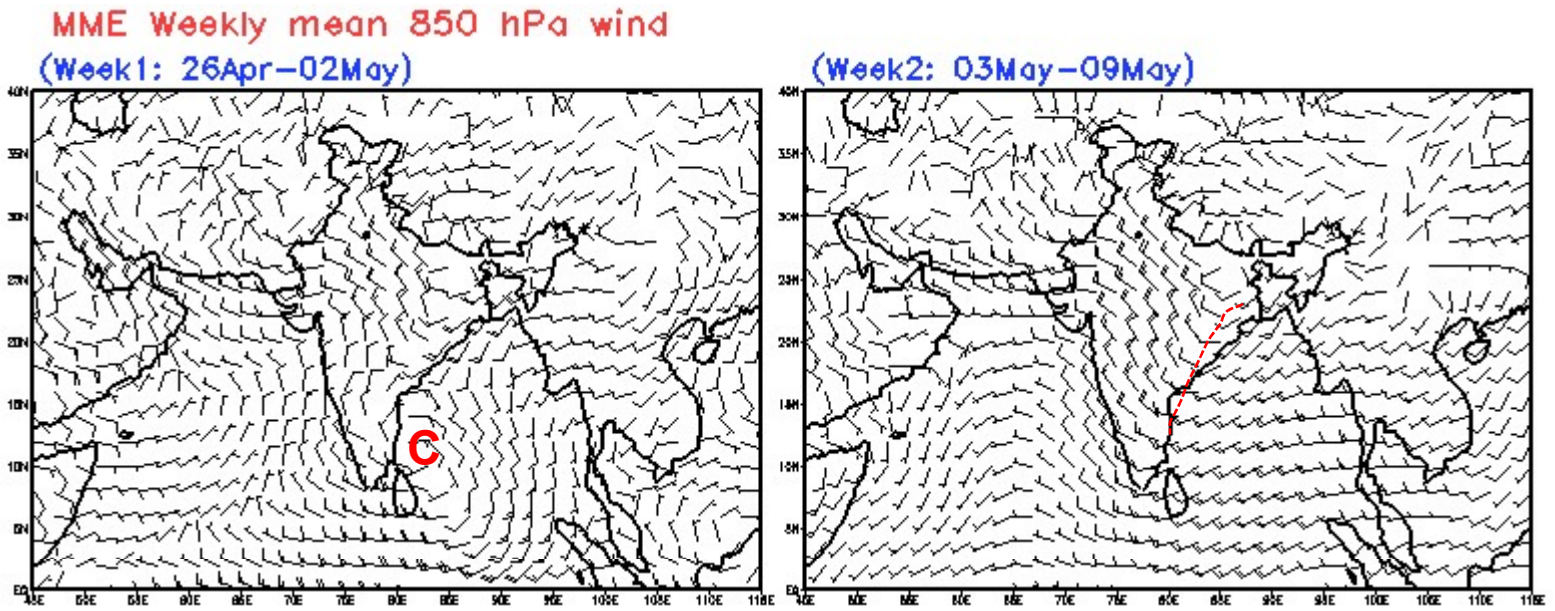
IMD ERF MJO (IC – 24 Apr 2019)

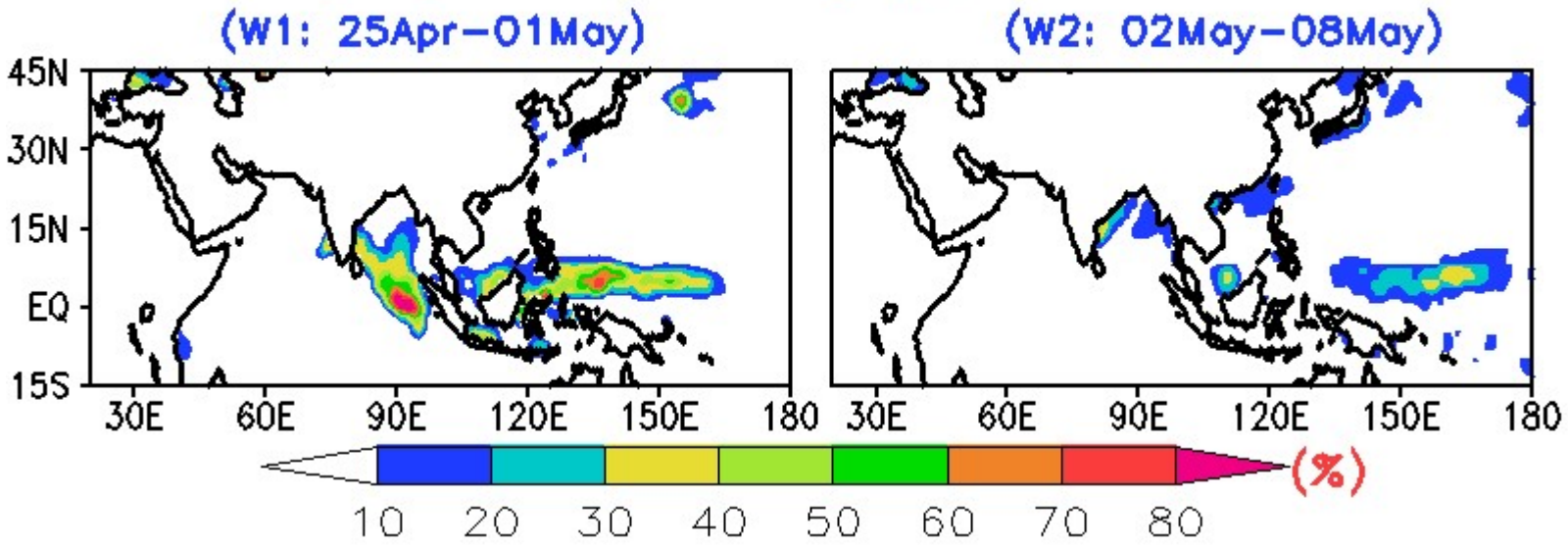






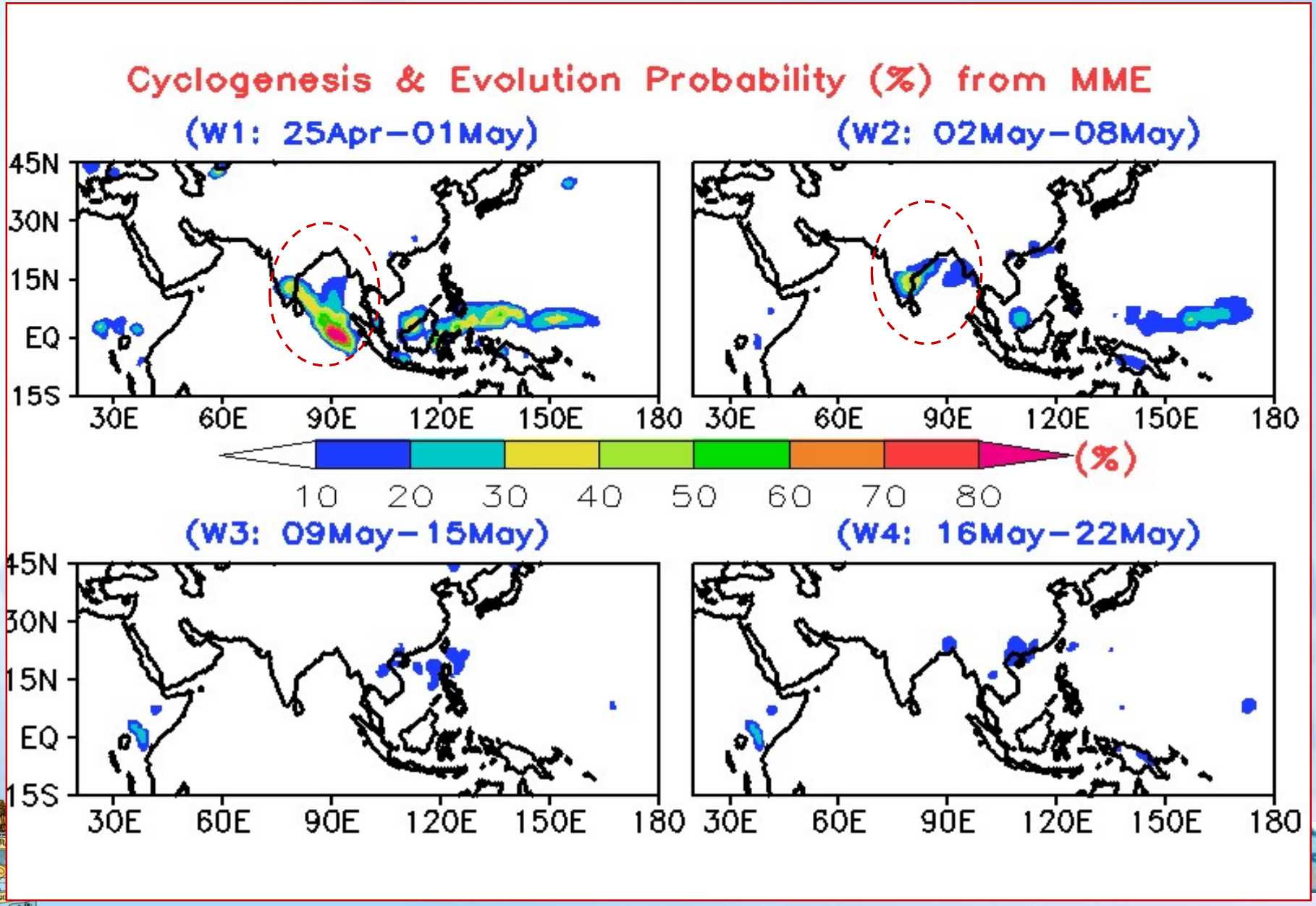
IMD ERF (IC – 24 Apr 2019)



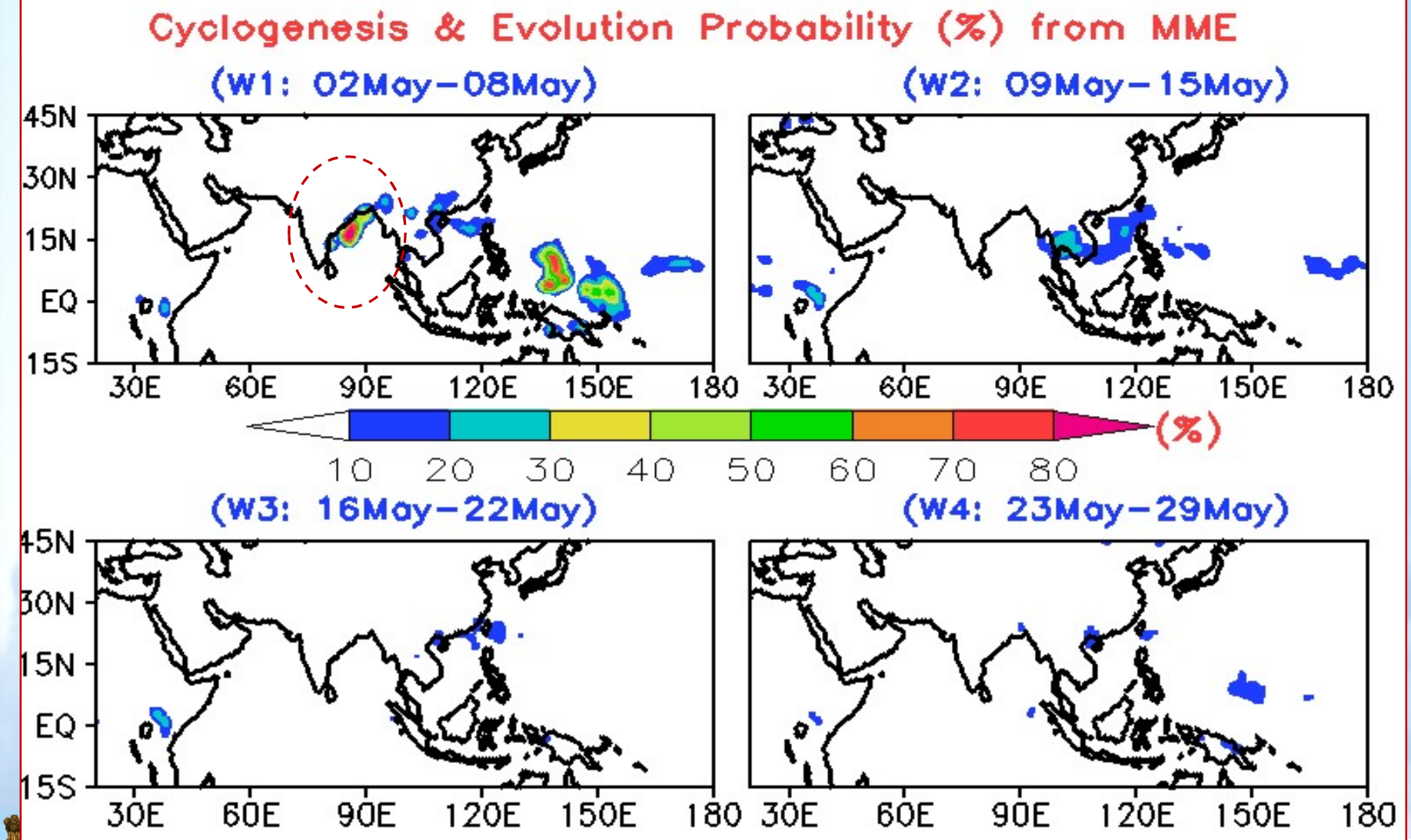


Modified GPP (Applicable over both land and Ocean)

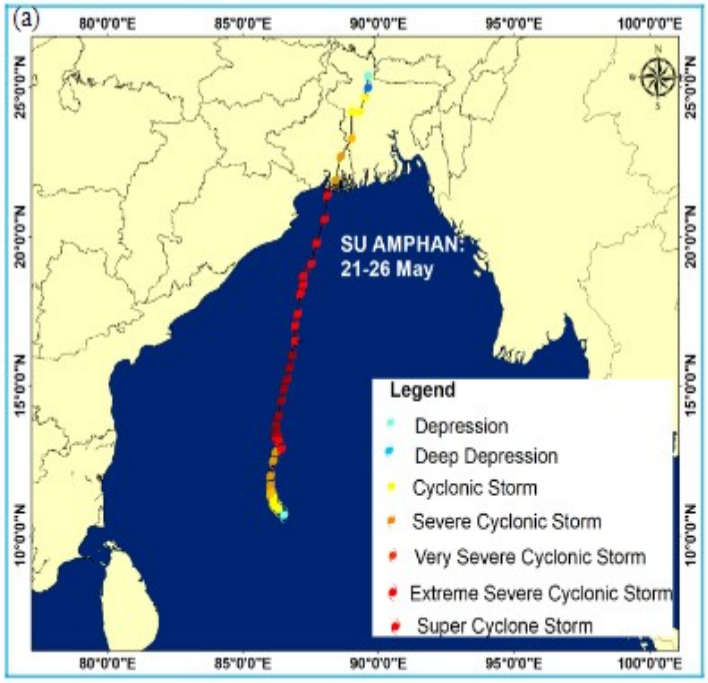
IC – 24 April, 2019

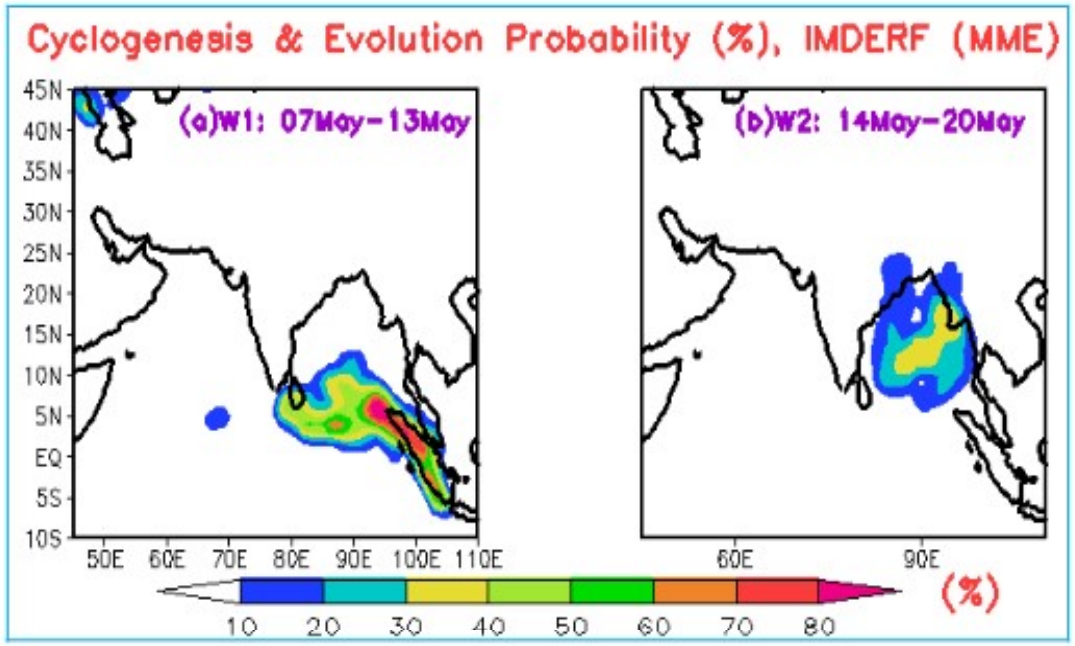


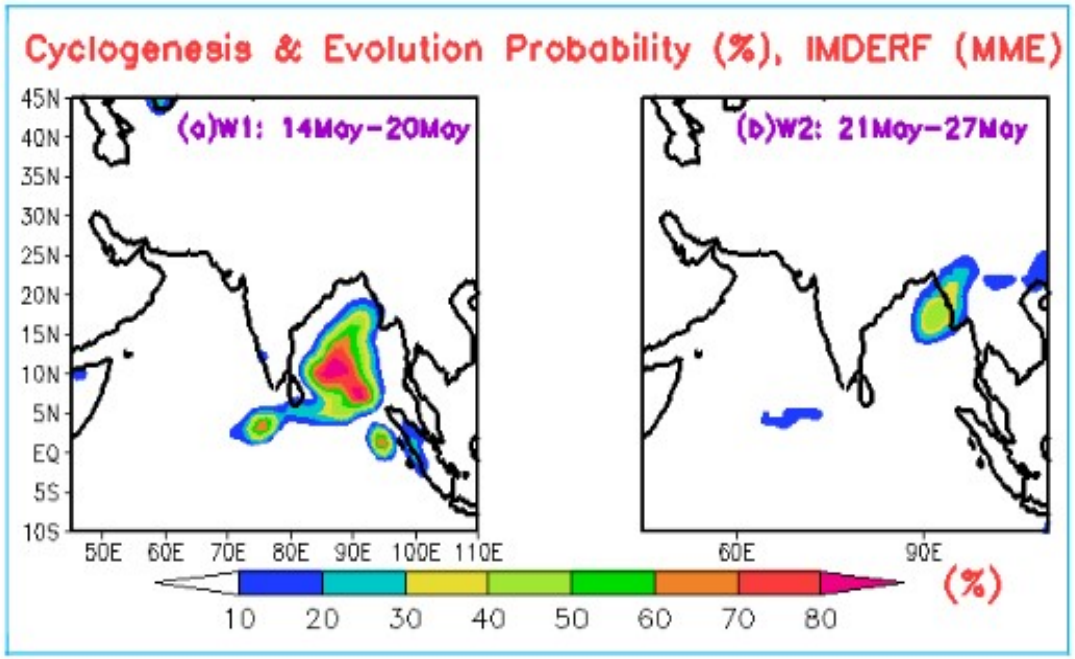
IC – 1st May, 2019



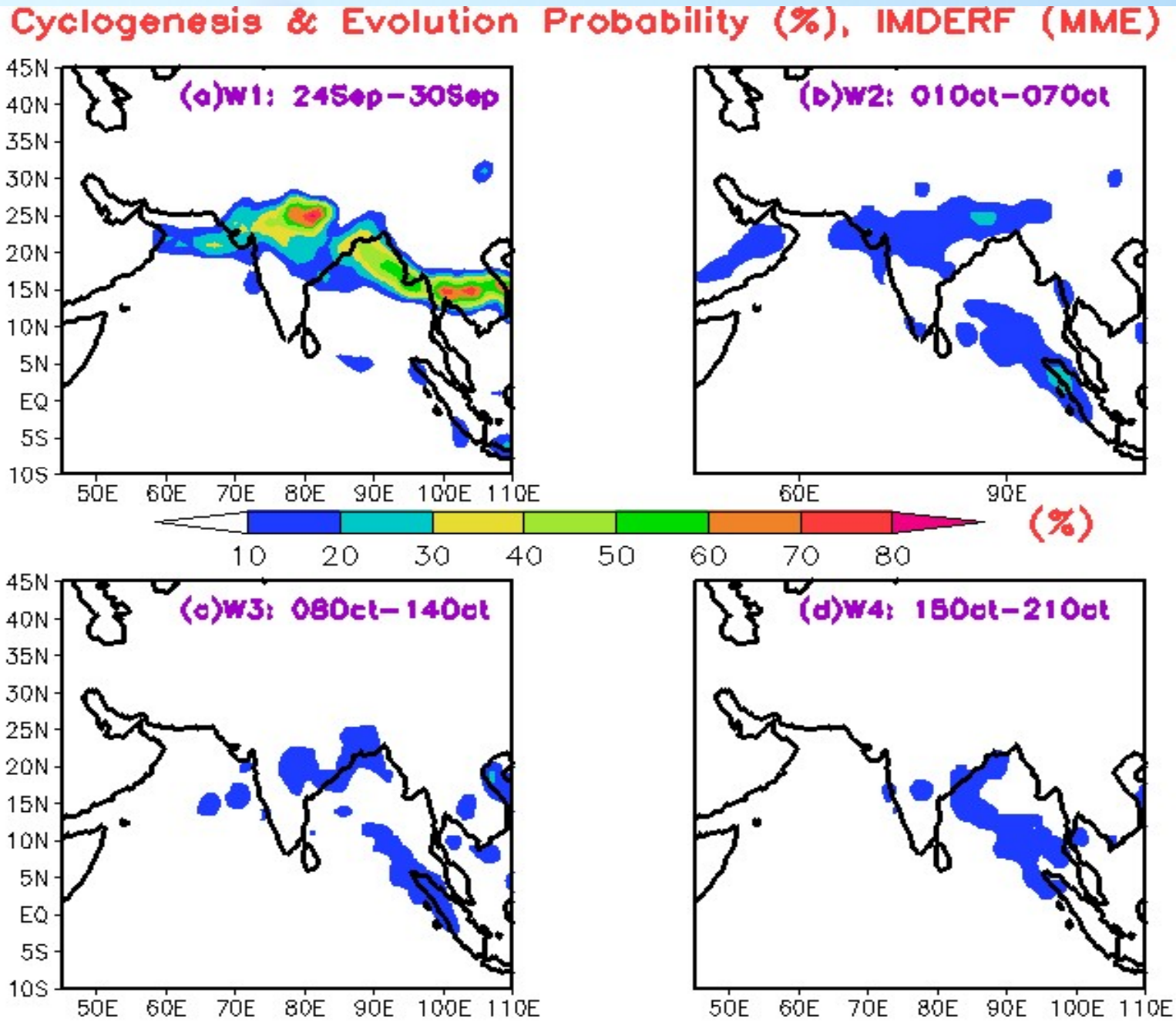
Amphan" during the period 16-21 May, 2020



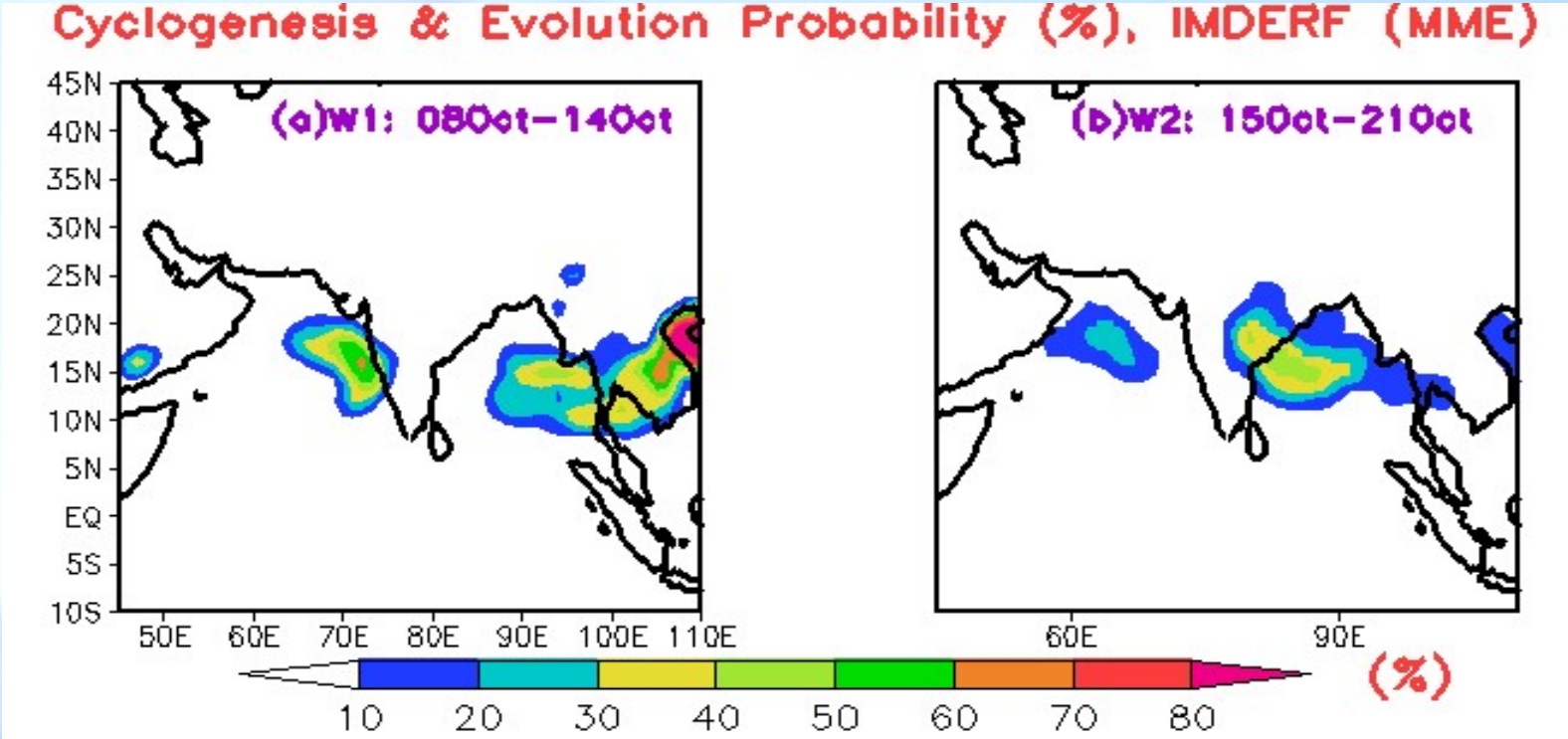




Cyclogenesis probability (Week wise plots) IC : 22 Sep 2021 (GULAB)



Cyclogenesis probability (Week wise plots) : IC : 06 October, 2021



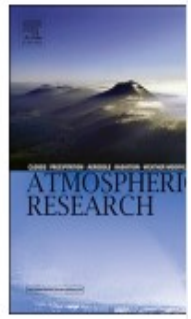
Tropical Cyclogenesis - MJO

Atmospheric Research 229 (2019) 23–38

Contents lists available at ScienceDirect

Atmospheric Research

journal homepage: www.elsevier.com/locate/atmosres



Modulation of bay of bengal tropical cyclone activity by the madden-julian oscillation

Pankaj Bhardwaj[a], Omvir Singh[a,*], D.R. Pattanaik[b], Philip J. Klotzbach[c]

[a] Department of Geography, Kurukshetra University, Kurukshetra 136119, India
[b] India Meteorological Department, Mausam Bhawan, Lodhi Road, New Delhi 110003, India
[c] Department of Atmospheric Science, Colorado State University, Fort Collins, CO, USA

ARTICLE INFO

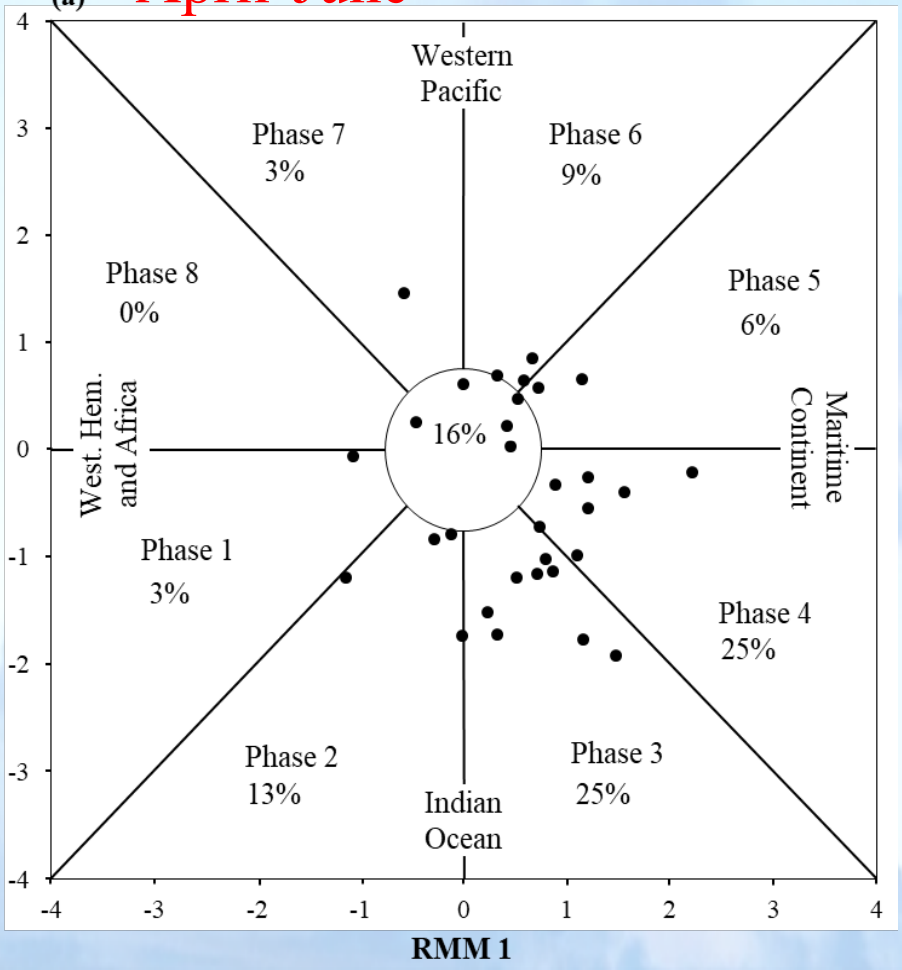
Keywords:
Madden-Julian oscillation
Tropical cyclones
Convective activity
Environmental conditions
Bay of Bengal

ABSTRACT

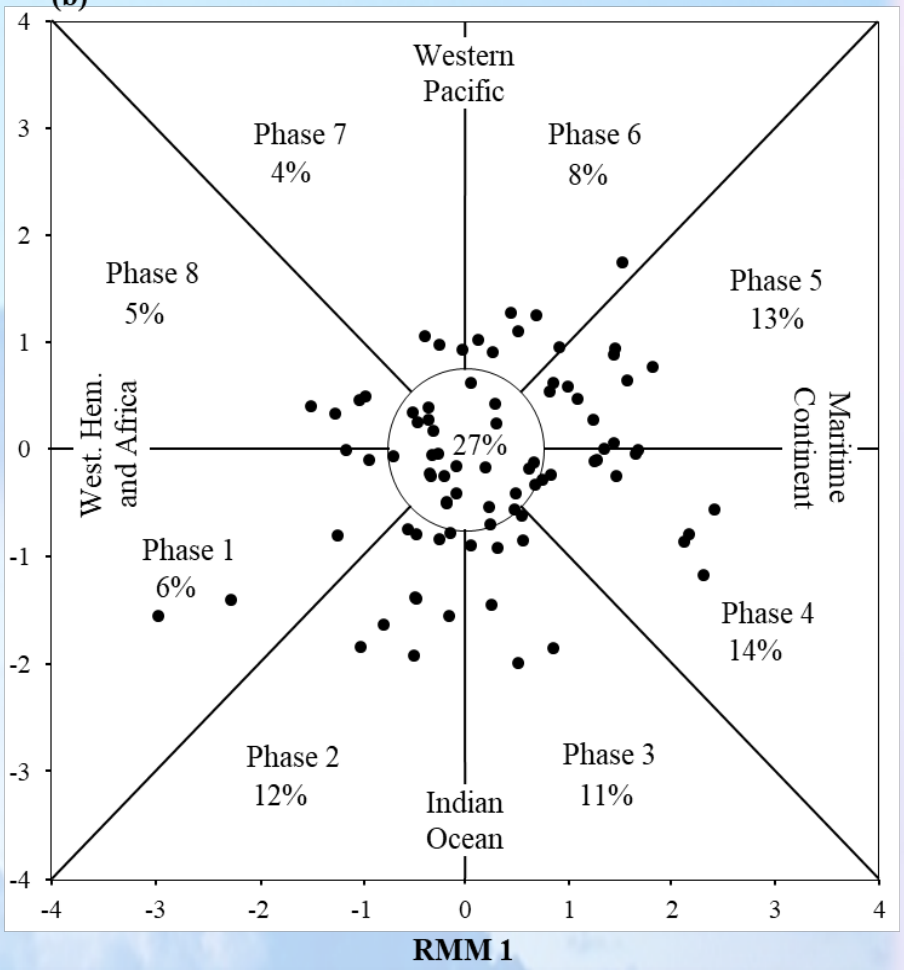
The influence of the Madden-Julian oscillation (MJO) on global tropical cyclone (TC) activity has been w
documented in many earlier studies. However, no prior studies have focused specifically on the MJO's impa
on TCs in the Bay of Bengal (BoB). Therefore, the present study examines the impact of the MJO on BoB
activity during the two peak TC periods i.e. April–June (AMJ) and October–December (OND) from 1974 to 20
The MJO considerably modulates various measures of TC activity in the BoB, including the number of TCs, t
number of TC days, accumulated cyclone energy, the power dissipation index, TC genesis location and TC trac

TC genesis and MJO phase

April-June



Oct-Dec



Genesis location (dots) and tracks (lines) of TCs in each MJO phase

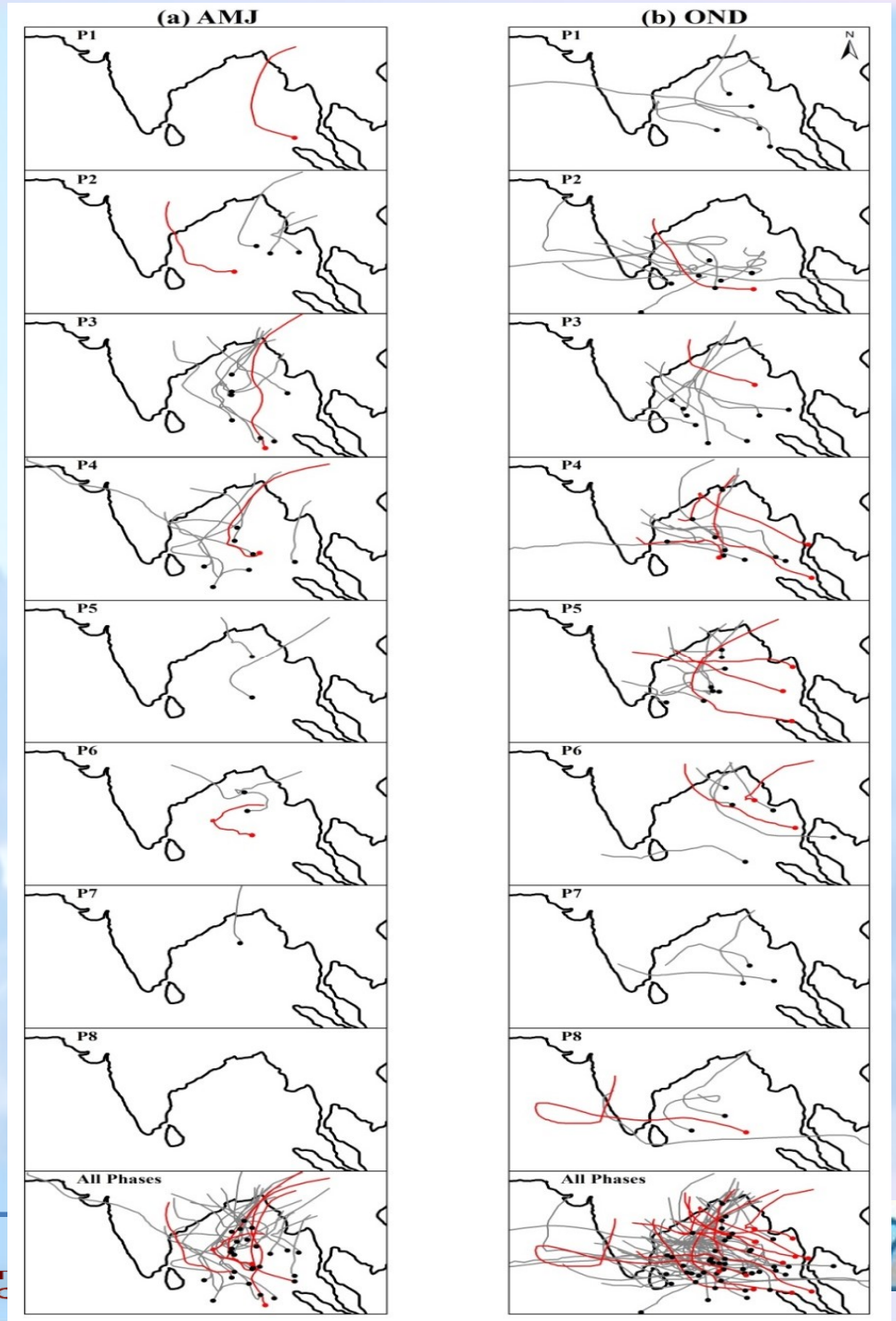
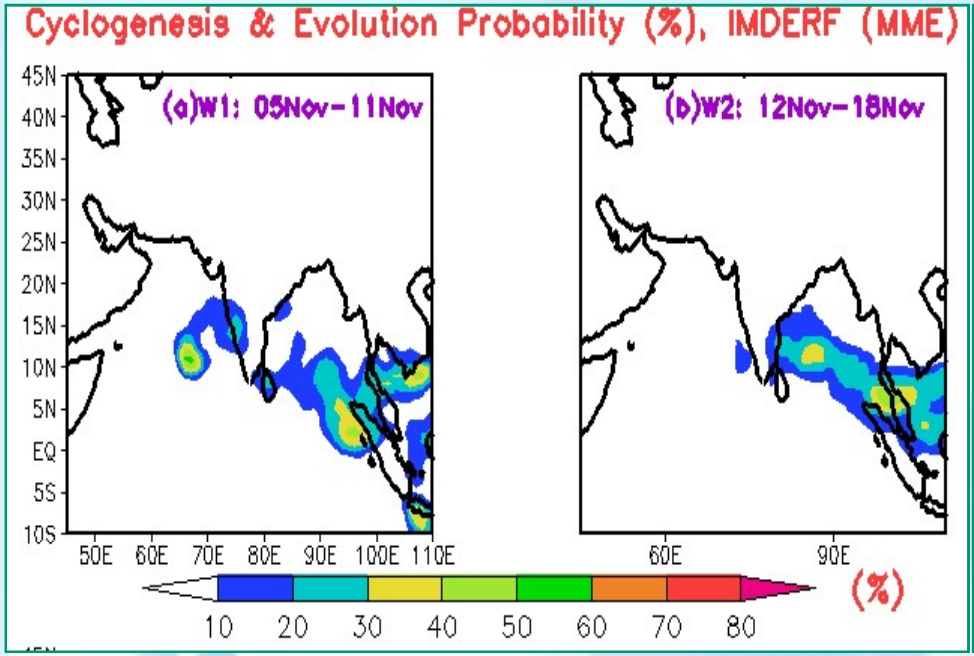


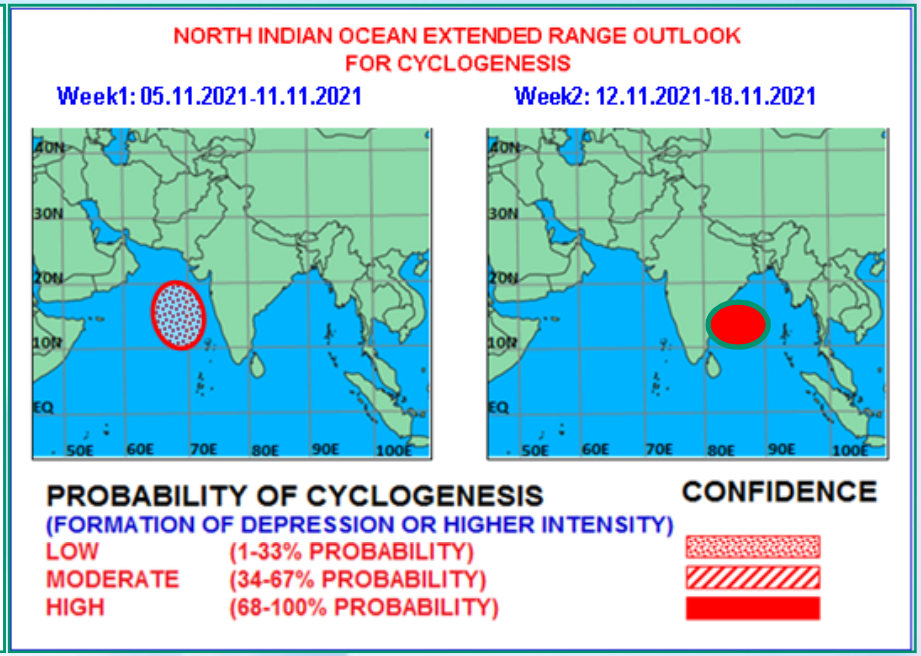
Table: The averaged anomalous values of OLR (Wm^{-2}), 500-hPa RH (%), SSTA (°C), SLP (hPa), 200-hPa U, 850-hPa U, and the difference of 200 and 850-hPa U (e.g., zonal wind shear) by MJO phase for all days during AMJ and OND for the period 1974-2015. Anomalies are calculated from the 1981-2010 average. Anomalies are calculated over the BoB region (5°-22.5°N, 80-100°E). The values that are 95% significant in a positive (negative) manner for TCs are bold faced (italicized).

MJO Phase	OLR (Wm^{-2})	RH_{500} (%)	SSTA (°C)	SLP (hPa)	U_{200} (ms^{-1})	U_{850} (ms^{-1})	$U_{200-850}$ (ms^{-1})
AMJ							
1	5.80	-2.28	0.01	0.05	*1.58*	*-0.92*	*2.51*
2	-1.12	**1.22**	0.04	-0.18	*1.68*	*-1.21*	*2.89*
3	**-6.69**	**2.49**	**0.13**	**-0.47**	*1.11*	*-0.84*	*1.96*
4	**-7.54**	**2.45**	**0.11**	**-0.89**	**-1.24**	-0.09	1.14
5	**-5.52**	**3.11**	-0.05	**-0.67**	**-2.40**	**1.09**	**-3.49**
6	2.93	-0.58	*-0.18*	0.01	**-1.57**	**1.69**	**-3.25**
7	*10.91*	*-4.22*	*-0.17*	*0.55*	*0.04*	0.89	-0.93
8	*10.81*	*-4.17*	-0.09	*0.56*	*0.80*	*-0.72*	*1.52*
OND							
1	*6.45*	*-3.10*	-0.02	*0.87*	*4.03*	*-1.63*	*5.66*
2	**-2.88**	0.50	0.03	-0.20	*2.99*	*-1.36*	*4.35*
3	**-9.77**	**2.28**	**0.10**	**-0.76**	**-0.96**	-0.26	-0.70
4	**-10.05**	**1.30**	**0.08**	**-0.90**	**-3.47**	**0.86**	**-4.33**
5	**-2.99**	**1.97**	0.00	**-0.68**	**-3.25**	**1.35**	**-4.60**
6	*6.58*	-0.62	-0.02	0.01	**-1.34**	**1.47**	**-2.81**
7	*11.78*	*-3.32*	*-0.17*	*0.84*	*1.65*	0.07	*1.58*
8	*9.42*	*-3.79*	*-0.18*	*0.90*	*2.60*	*-0.95*	*3.55*

Cyclongenesis Outlook for Next Two Weeks

Based on 3rd Nov 2021





A 'Low' probability for cyclogenesis is assigned over the east-central Arabian Sea during Week-1. The indication is that the present Low Pressure Area located over southeast Arabian Sea & adjoining Lakshadweep area is likely to move north-northwestwards and become more marked over east-central AS during next 48 hours. The chances of its further intensification into a Depression during the subsequent period is demarcated with 'Low' probability. Also another Low Pressure area is likely to form over southeast BoB and move west-northwestwards with marginal intensification during 9th – 12th November 2021.

Summary

- *NWP models (GFS, GEFS, MME, etc) forecast are providing very useful guidance in the medium range time scale.*
- *All global models and MME is giving skillful forecast both for the track and intensity.*
- *The ERF of cyclogenesis is useful for providing guidance to the forecasters for about two weeks.*
- *In case of "FANI", based on 17 April IC genesis of the system was not very clear with weak MJO*
- *24 April initial condition indicated strong MJO associated with formation as well as re-curvature of the system FANI to the northeast, which is found to be slightly better with modified GPP.*
- *ERF forecast for AMPHAN & GULAB also very encouraging.*
- *The Two weeks cyclogenesis forecasts is issued by RSMC based on model forecasts as well as others parameters like MJO.*