Cyclogenesis Monitoring & Forecast by RSMC New Delhi

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भारत मौसम विज्ञान विभाग
INDIA METEOROLOGICAL DEPARTMENT

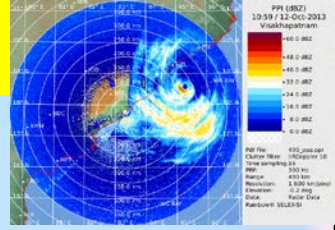
Evolution of Cyclonic disturbances Over the Indian Seas

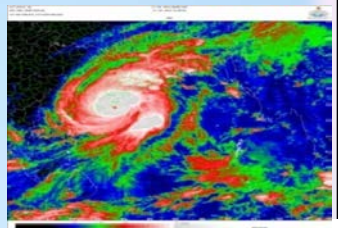
Low pressure system	Maximum sustained winds	
Low	< 17 knots	< 31 kmph
Depression	17 – 27 kts	31 – 51 kmph
Deep Depression	28 – 33 kts	52 – 62 kmph
Cyclone	34 – 47 kts	63 – 87 kmph
Severe Cyclone	48 – 63 kts	88 – 117 kmph
Very Severe Cyclone	64 – 89 kts	118 – 164 kmph
Extremely Severe Cyclonic Storm	90-119 kts	165 – 221 kmph
Super Cyclone	120 kts & above	222 kmph & above

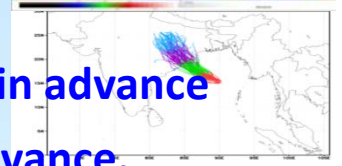
System	Pressure deficit (hPa) at the centre
Low	1.0
Depression	1.0 - 3.0
Deep Depression	3.0 - 4.5
Cyclone	4.5-8.5
Severe Cyclone	8.5-15.5
Very Severe Cyclone	15.5-65.6
Super Cyclone	>65.6

Cyclone Forecasting and Warning Process

- 15 days Extended Range Outlook for cyclogenesis issued every Thursday
- 5 days Probabilistic Cyclogenesis Forecast issued daily
- Track, intensity and structure forecast upto 5 days issued every six hours from depression stage and every three hrs during cyclone stage
- Impact based heavy rainfall, wind, wave & storm surge warning for 5 days with advice for action issued every 6 or 3 hrs
- Hourly update 12 hrs prior to landfall



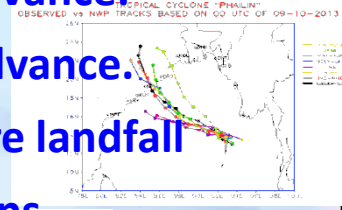


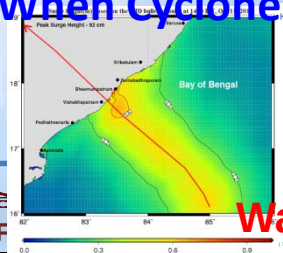


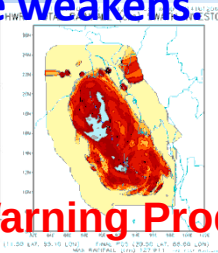
- Four stage cyclone warning
- Sea area bulletin
- Coastal weather bulletin
- Bulletins for Indian navy
- Fisheries warnings
- Port warnings
- Aviation warning
- Bulletin-for AIR/TV/ press
- Warnings for registered users.

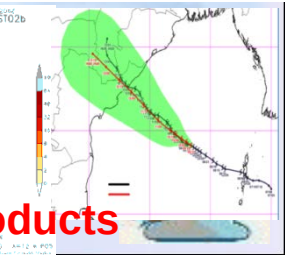
Four Stages of Warning System

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









Warning Products

Genesis Forecast

Seasonal

Not Issued

- Insufficient data
- Large interannual and intra-seasonal variability
- Low skill

Extended Range

22nd April, 2018, Every Thursday

Valid for next 15 days with quantitative forecast of cyclogenesis as LOW (0-33%), MOD (34-67%), HIGH (68-100%)

Short to medium Range

June, 2014 for 72 hours
April, 2018 for 120 hours
Issued Daily based on 03Z observations

Valid for next 5 days with cyclogenesis forecast as LOW NIL (0%), LOW(1-33%),, MODERATE (34-67%), HIGH (68-100%)

Utility: Suitable for forecasters to improve monitoring & forecasting in medium range based on extended range prediction. Help in planning & preparedness with longer lead period.

Extended Range Forecast (Consensus approach)

Large scale Processes

- MJO
- MISO
- Monsoon gyre
- Cyclogenesis over NW Pacific

Synoptic scale processes

- Genesis Prameters (low level vorticity & convergence ,upper level divergence
- Ocean State (SST,OTE)
- 10 m winds
- MSLP

Deterministic Global models (10 days forecast)

- IMD GFS
- NCUM
- NCEP-GFS
- ECMWF (MSLP, 10m wind, Genesis parameters)

Ensemble Models 10-15 days

- NEPS
- GEFS
- ECMWF Ensemble

ERF Models 4 weeks

- MME CFS V-2
- CFS NCMR WF

Genesi Potential parameter

- Global Cyclogenesis from CIRA (48 hours)
- IMD GPP (7 days)
- Global Tropics Hazards Outlook by NOAA (2 weeks)

Extended Range Forecast (Consensus approach)

(*i*) Madden Jullian Oscillation (MJO) phase and amplitude following Mohapatra and Adhikary (2011)

(*ii*) The mean sea level pressure (MSLP) and 10 m wind fields from various global models including IMD-GFS, NCEP-GFS, NCUM, ECMWF, IMD-GEFS, NEPS following the criteria for genesis (IMD, 2013)

(*iii*) IITM/IMD CFSv-2 cyclogenesis probability, MSLP & 850 hpa winds forecast for 4 weeks (Pattanaik and Mohapatra, 2016)

(*iv*) IMD's Genesis Potential Parameter (Kotal and Bhattacharya, 2011)

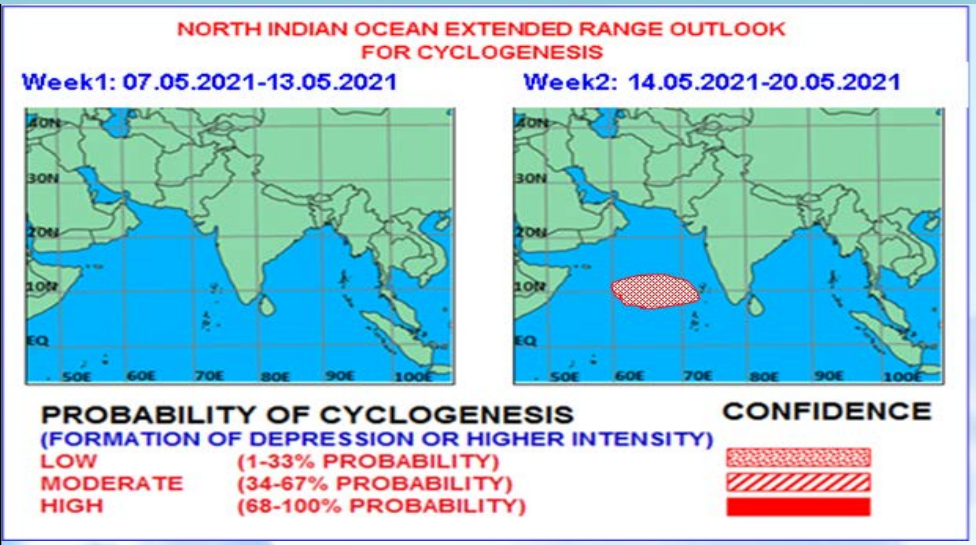
(*v*) 30 days cyclogenesis forecast from (http://www.atmos.albany.edu/facstaff/roundy/tcforecast/tcforecast.html)

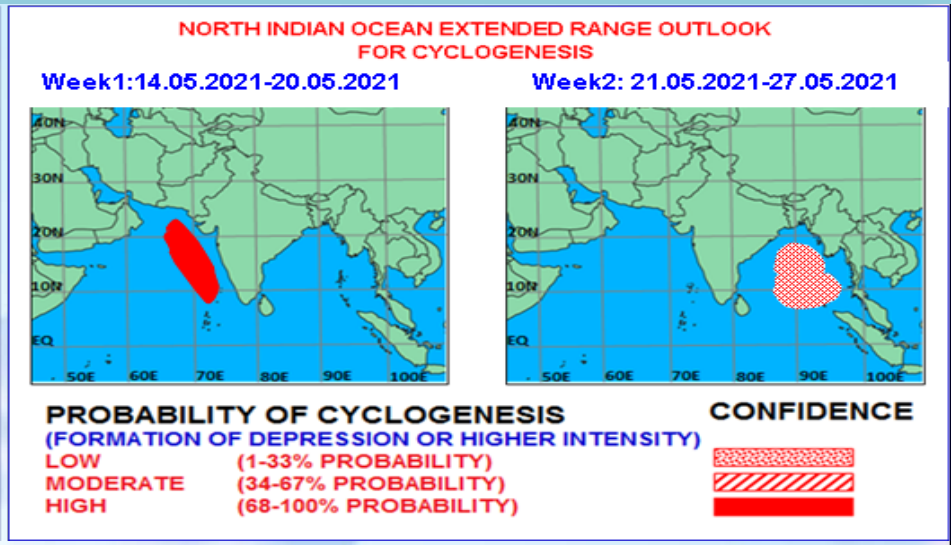
(*vi*) Tropical cyclone formation product probability by RAMMB, CIRA for next 48 hours (http://rammb.cira.colostate.edu/projects/gparm/)

(vii) Global Tropics Hazards and Benefits Outlook by NOAA for next two weeks (http://www.cpc.ncep.noaa. gov/products/precip/CWlink/ghazards/)

(viii) NINO 3.4 values for El-Nino or La-Nina conditions and dipole index for Indian Ocean Dipole (IOD) from Bureau of Meteorology (www.bom.gov.au)

ESCS TAUKTAE





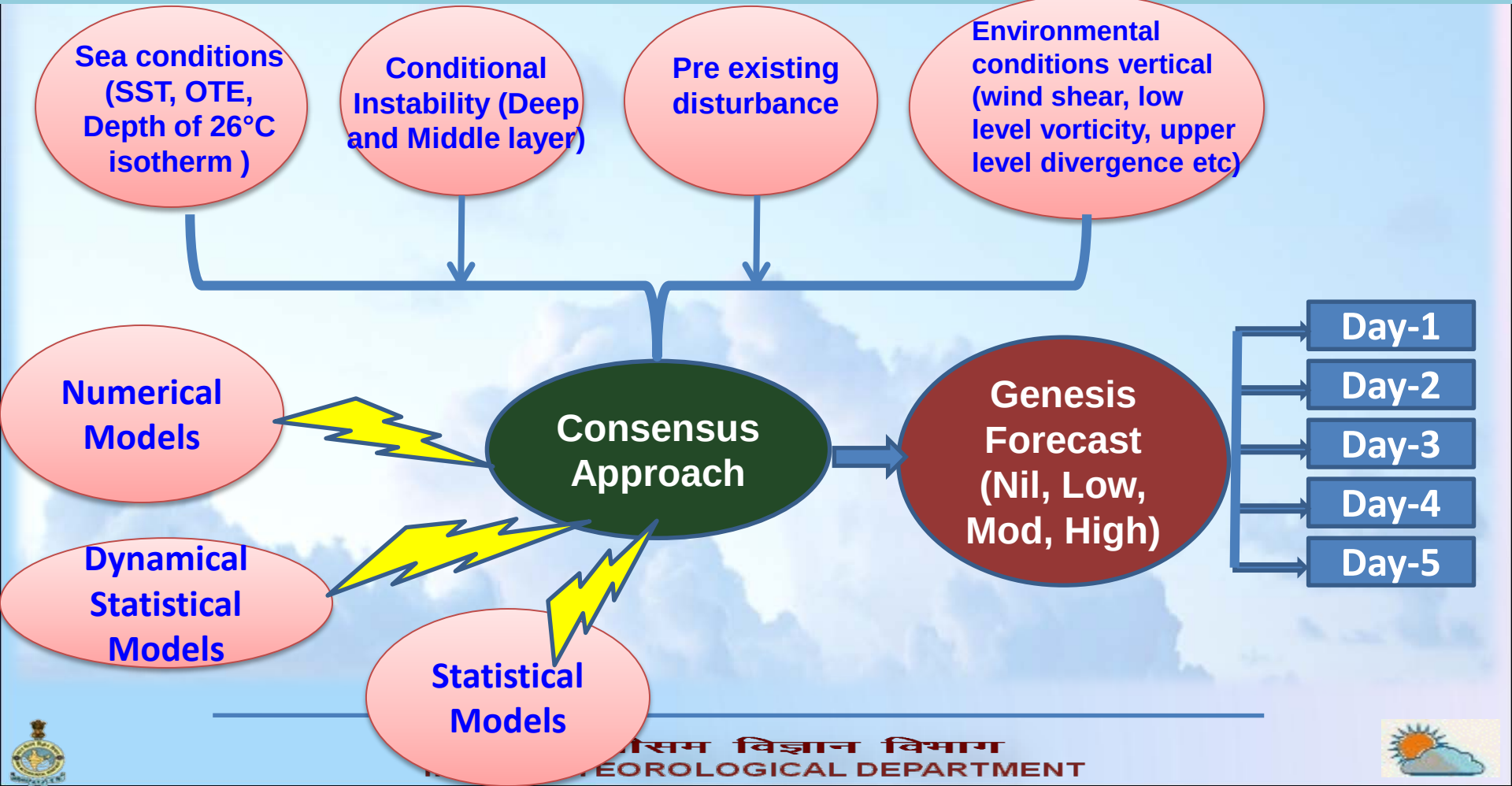
Extended range outlook dated 6th May indicated development of depression over southeast Arabian Sea and adjoining Lakshdweep during 14th-16th May

Depression formed over Lakshdweep on 14th May

Extended range outlook dated 13th May indicated HIGH probability of cyclogenesis and movement of system towards Gujarat coast parallel to West coast of India during 14-20 May.

Tauktae moved parallel to West coast of India and crossed south Gujarat coast on 18th May

GENESIS PROBABILITY: SHORT TO MEDIUM RANGE FORECAST



TYPICAL EXAMPLE OF MEDIUM RANGE FORECAST

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

DEMS-RSMC TROPICAL CYCLONES NEW DELHI DATED 10.05.2021

TROPICAL WEATHER OUTLOOK FOR NORTH INDIAN OCEAN (THE BAY OF BENGAL AND ARABIAN SEA) VALID FOR NEXT 120 HOURS ISSUED AT 0600 UTC OF 10.05.2021 BASED ON 0300 UTC OF 10.05.2021.

BAY OF BENGAL:

SCATTERED LOW AND MEDIUM CLOUDS WITH EMBEDDED MODERATE TO INTENSE CONVECTION LAY OVER SOUTHWEST BAY OF BENGAL OFF SRILANKA COAST,ALSO OVER SOUTHEAST BAY OF BENGAL & NORTH BAY OF BENGAL

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

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

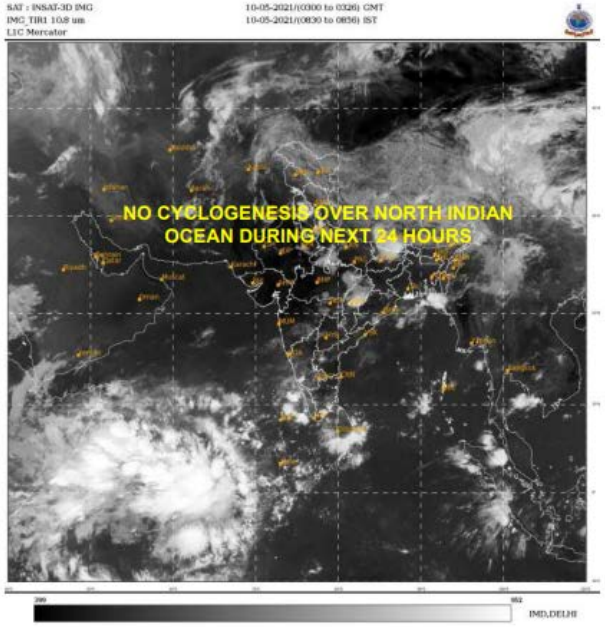
ARABIAN SEA:

BROKEN LOW AND MEDIUM CLOUDS WITH EMBEDDED INTENSE TO VERY INTENSE CONVECTION LAY OVER SOUTHWEST ARABIAN SEA ADJOINING INDIAN OCEAN BETWEEN LATITUDE 8.0^{0}N TO 2.0^{0}S LONGITUDE 50.0^{0}E TO 70.0^{0}E.SCATTERED LOW AND MEDIUM CLOUDS WITH EMBEDDED MODERATE TO INTENSE CONVECTION LAY OVER REST OF SOUTH ARABIAN SEA & MALDIEVES.
A CYCLONIC CIRCULATION EXTENDING UPTO 3.1 KM A.S.L. LIES OVER THE EQUATORIAL INDIAN OCEAN AND ADJOINING CENTRAL PARTS OF THE SOUTH ARABIAN SEA. IT IS LIKELY TO SHIFT EASTWARDS GRADUALLY AND UNDER ITS INFLUENCE A LOW PRESSURE AREA IS LIKELY TO FORM OVER SOUTHEAST ARABIAN SEA AND ADJOINING EQUATORIAL INDIAN OCEAN AROUND 14TH MAY. IT IS LIKELY TO BECOME MORE MARKED OVER THE SOUTHEAST ARABIAN SEA DURING THE SUBSEQUENT 48 HOURS.

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

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

REMARKS:
THE MADDEN JULIAN INDEX (MJO) CURRENTLY LIES IN PHASE 4 WITH AMPLITUDE CLOSE TO ONE. IT IS LIKELY TO CONTINUE IN THE SAME PHASE FOR THE NEXT 4-5 DAYS WITH GRADUAL REDUCTION IN AMPLITUDE. THE PHASE OF MJO IS CONDUCIVE FOR ENHANCED CONVECTION OVER THE ARABIAN SEA & BAY OF BENGAL DURING THE FORECAST PERIOD.
THE AREA OF CONVECTION DEVELOPED OVER SOUTHWEST ARBIAN SEA & ADJOINING EQUATORIAL INDIAN OCEAN AND ALONG & OFF SOMALIA COAST AROUND 8TH MAY IS PERSISTING CURRENTLY OVER SOUTHWEST & ADJOINING SOUTHEAST ARABIAN SEA AND EQUATORIAL INDIAN OCEAN. THE CROSS EQUATORIAL FLOW IN THE NEAR EQUATORIAL BELT IS LIKELY TO GET ENHANCED DURING THE NEXT 5 DAYS.LOW LEVEL CONVERGENCE OF 20-30 X10 (-5) / S AND AN UPPER LEVEL DIVERGENCE OF THE ORDER OF 30 X 10 (-5) /S IS PREVAILING CURRENTLY OVER THE REGION OF CONVECTION. WIND SHEAR IS FAVOURING CONVECTION TO PERSIST AND IT IS LIKELY TO CONTINUE SO OVER THE REGION. NUMERICAL MODELS ARE INDICATING PROBABLE CYCLOGENESIS OVER BOTH HEMISPHERES IN THE EQUATORIAL BELT TOWARDS THE END OF THE FORECAST PERIOD. HENCE WE ARE ASSIGNING A 'LOW' PROBABILITY FOR CYCLOGENESIS OVER SOUTHEAST ARABIAN SEA AND ADJOINING EQUATORIAL INDIAN OCEAN TOWARDS THE END OF THE FORECAST PERIOD.



PROBABILITY OF CYCLOGENESIS (FORMATION OF DEPRESSION):NIL: 0%, LOW: 1-25%, FAIR: 26-50%, MODERATE: 51-75% AND HIGH: 76-100%

This is a guidance Bulletin for the WMO/ESCAP Panel Member countries,. Please visit respective National websites for Country specific Bulletins

TWO issued on 10th indicated formation of LPA southeast Arabian Sea around 14th May likely intensification into a cyclone. (about 4 days prior to formation of cyclonic storm on 14th May). Even before formation of LPA on 13th May.

Genesis : Monitoring and prediction

- Analysis of all synoptic, satellite and NWP model products for genesis, intensity and track monitoring and prediction
- Development of an objective conceptual model

  - Daily Watch is essential for issue of tropical weather outlook for genesis
  - Check list
  - Road Map /Methodology

Factors Affecting Genesis and intensification of Cyclone (Gray's Parameter)

Formative Stage covers the period from the genesis of a cyclonic circulation to the cyclonic storm stage through low pressure, depression and deep depression stages.

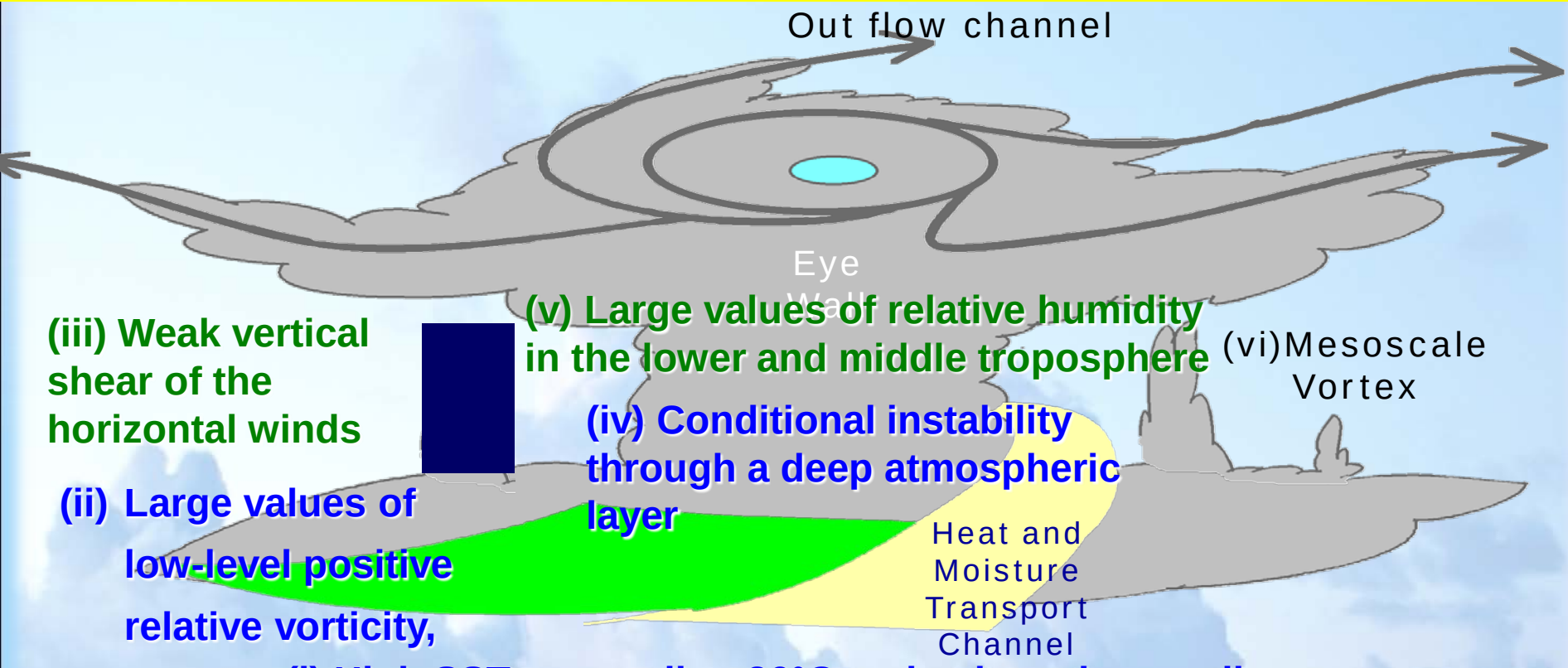
Following factors are considered favourable for cyclogenesis.

i. Coriolis Parameter
ii. Low level positive vorticity
iii. Weak vertical wind shear of horizontal winds
iv. Warm Sea surface temperature (> 26.5° Celsius)
v. Large convective instability
vi. Large relative humidity at lower and middle troposphere (CISK)
vii. Pre-existing disturbance

Broad scale features:

1. Madden Julian Oscillation
2. Equatorial Rosby waves
3. Kelvin waves
4. Inter Tropical Convergence Zone
5. LaNina conditions
6. Indian Ocean Dipole

Factors Affecting Genesis and intensification of Cyclone (Gray's Parameter)



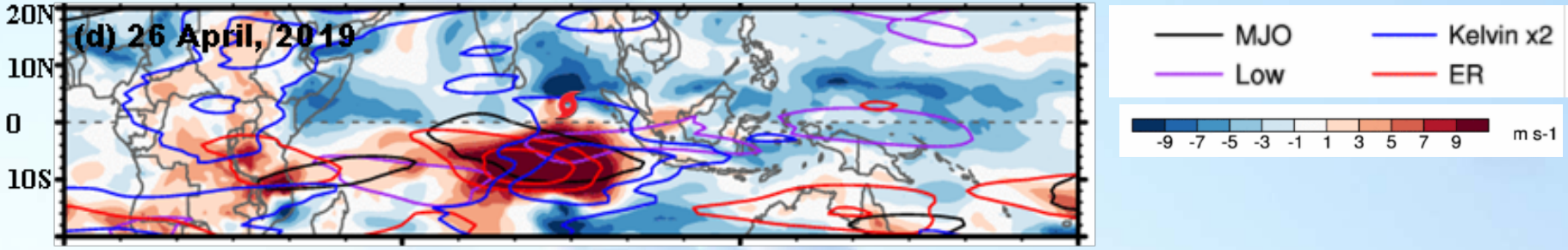
(Heavily dependent on Ocean observations)

Factors Affecting Genesis and intensification of Cyclone (Broad Scale features)

Parameters	Bay of Bengal	Arabian Sea
El-Nino Year (East Pacific warmer)	Less cyclones over BoB	No impact
La Nina Year (West Pacific warmer)	More cyclones over BoB (BoB warmer, more remnants from west Pacific)	No impact
Indian Ocean Dipole (SST West Indian Ocean – SST East Indian Ocean)	-ve IOD conditions favourable	+ve IOD conditions favourable
Madden Julian Oscillation (West to east propagating waves of enhanced & suppressed phase of convection). 30-40 days cycle. Movement : (5 0 /day towards east and 1 0 /day towards north) Impact: Increase RH	Phase 3,4,5	Phase 2,3
Rossby waves (east to west propagating waves). Develop due to rotation of earth and meander due to variation in coriolis effect with latitude. Impact: Increase vorticity	Presence support vorticity and hence convective activity. Most favourable for cyclogenesis after MJO	
Kelvin waves (west to east propagating waves). These waves are trapped to coastlines and at equator. Their amplitude is highest at coast and decays exponentially with off shore distance (polewards).	Support MJO activity. Not much impact is seen directly over cyclogenesis.	

Factors Affecting Genesis and intensification of Cyclone (Equatorial Waves)

Tropical Monitoring :: North Carolina Institute for Climate Studies (ncics.org)

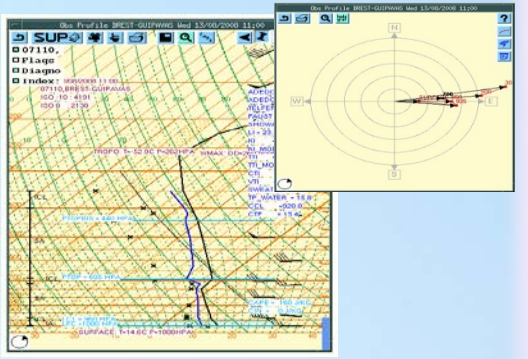


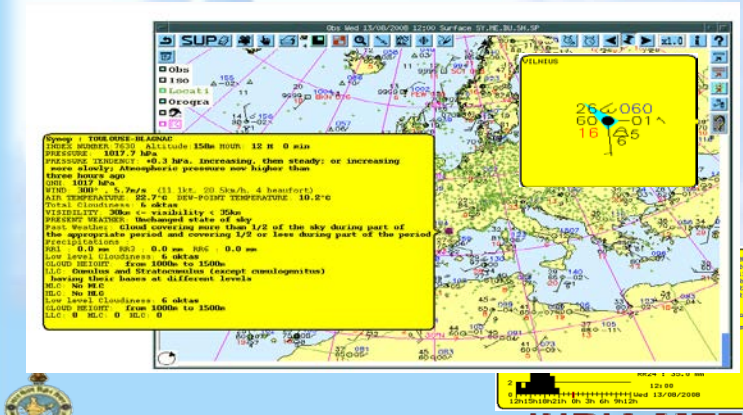
- Simultaneously propagating multiple waves are favourable for genesis of TC category storms over the BoB & AS in different seasons instead of single waves passing over the region.
- Simultaneous occurrence of MJO, ER & KW being most effective and that of LW+KW being least effective for genesis of TC category of storms.
- There is no preferred association of any convectively coupled equatorial waves for genesis of depression over the BoB and AS.

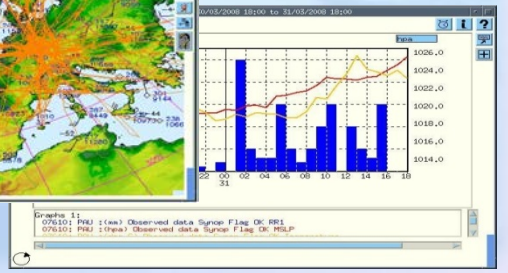
Tools to use for tropical activity daily watch

- Vis and IR geostationnary animation over the last 24 hours
  - Superimposed with EIR in Dvorak colors
  - Observations data
- Analysis of avalaible numerical models guidance
  - SLP (sea level pressure)
  - Relative Vorticity at 850 hPa : measures the rotation of air over itself. A maximum of 850 hPa vorticity shows deep convection organizing with circulation.
  - Low level winds (Favorable low level surges, or inflows, with trade wind or monsoon wind)
  - Upper level winds (200 hPa), threshold at 20 kt : upper level outflows, high or ridges favorable for good divergence, vertical wind sheared areas

Digital Forecasting System is very helpful for tropical daily weather watch :

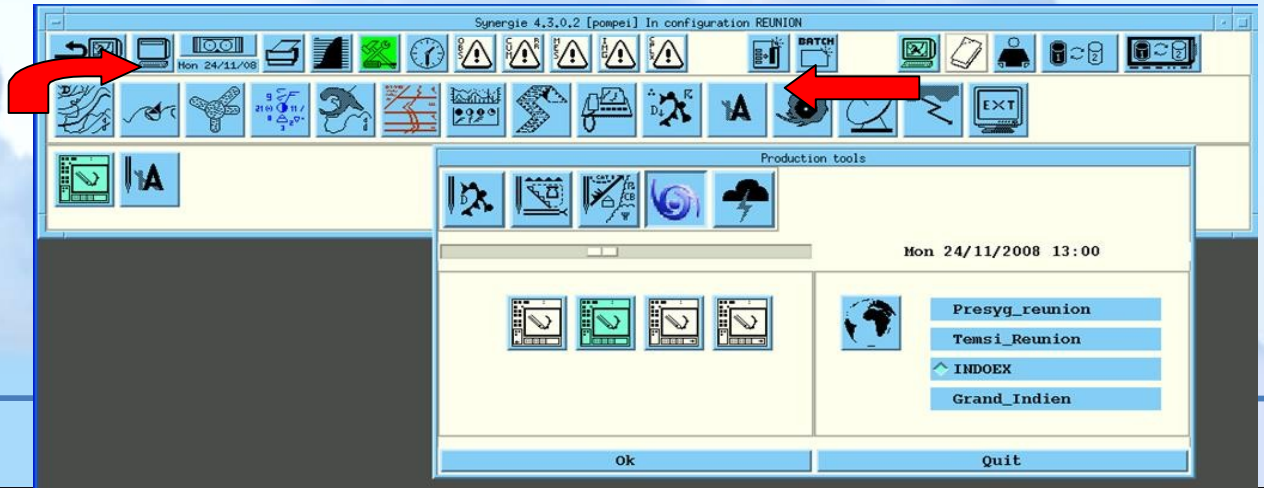






Digital Forecasting System is not sufficient

- In addition, forecaster should consult data from internet sources
- Internet data :
  - Scatterometry data
  - Micro-wave imagery for developing lows
  - CIMSS maps (vertical wind shear, upper level divergence)
  - MJO/OLR dry or enhanced convection phases.



Tropical Cyclone Module is not sufficient

Data and products from various national and international agencies need to be tapped through website. A few are given below

Track and intensity forecast Products

MONTEREY Tropical Cyclones

CIMSS Tropical Cyclones

ECMWF-LatestTropicalCycones

TIGGI,

Tropical cyclone prediction centres

WMO site

- Satellite derived winds
- Oceansat-II
- WindSat
- ASCAT

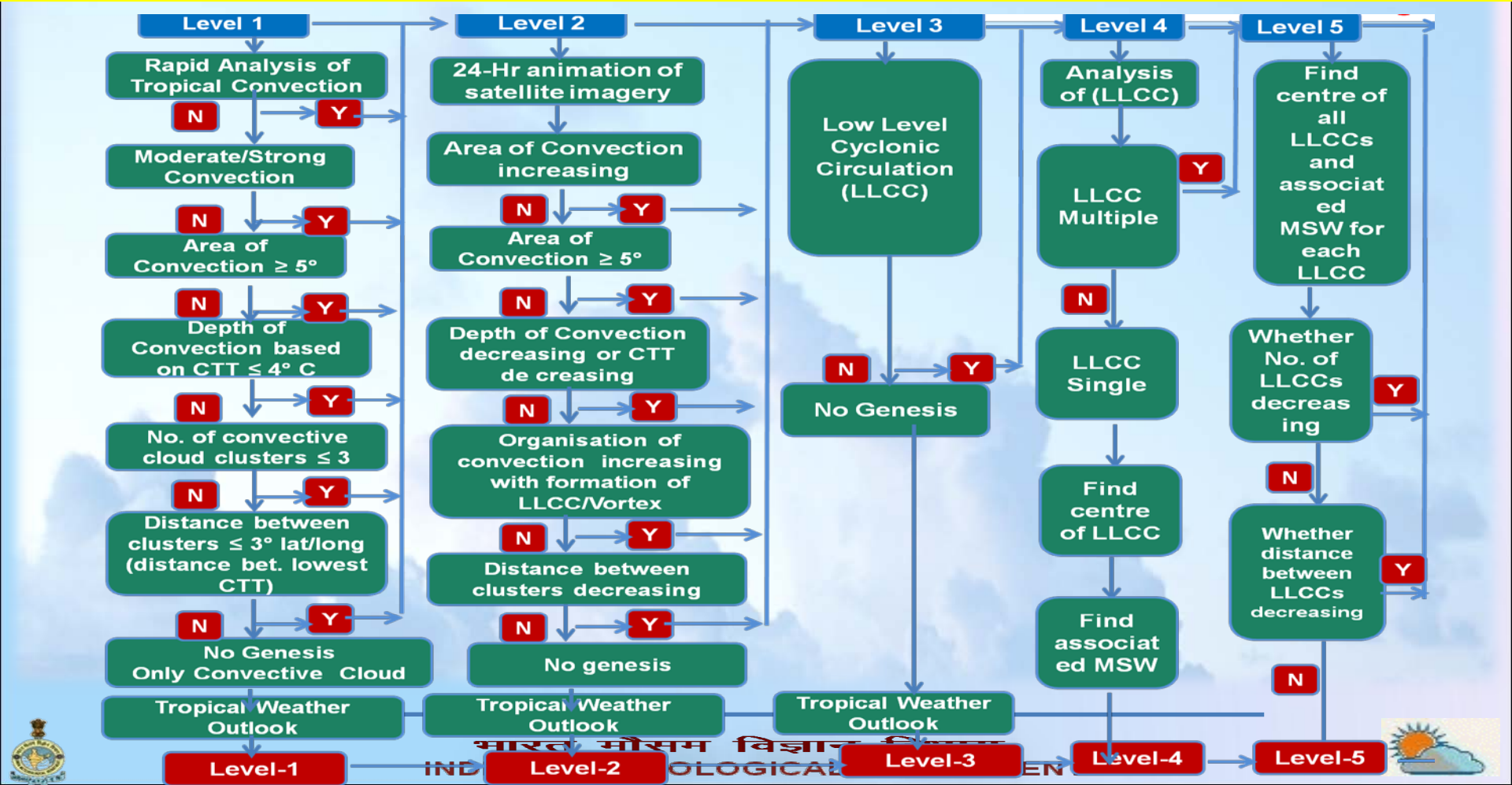
- SST and Heat Content
- NOAA SST & Tropical Cyclone Heat Potential
- Anomalies in SST (Nesdis_Noaa)
- Anomalies in SST (FNMOC)

- Satellite imageries and products
- Monterey
- CIMSS Tropical Cyclones
- TPC POLAR ORBITING SATELLITE DATA LINKS
- TRMM
- Interactive Weather Satellite Imagery Viewers from NASA GHCC
- Satellite INSAT
- Geostationaries from DUNDEE
- FNMOC Satellite Data Tropical Cyclone Homepage
- RSS / Tropical Cyclone Microwave Data Archive
- AMSU-A_NASAAMSU-A_NASA , AMSU_
- UW-CIMSS

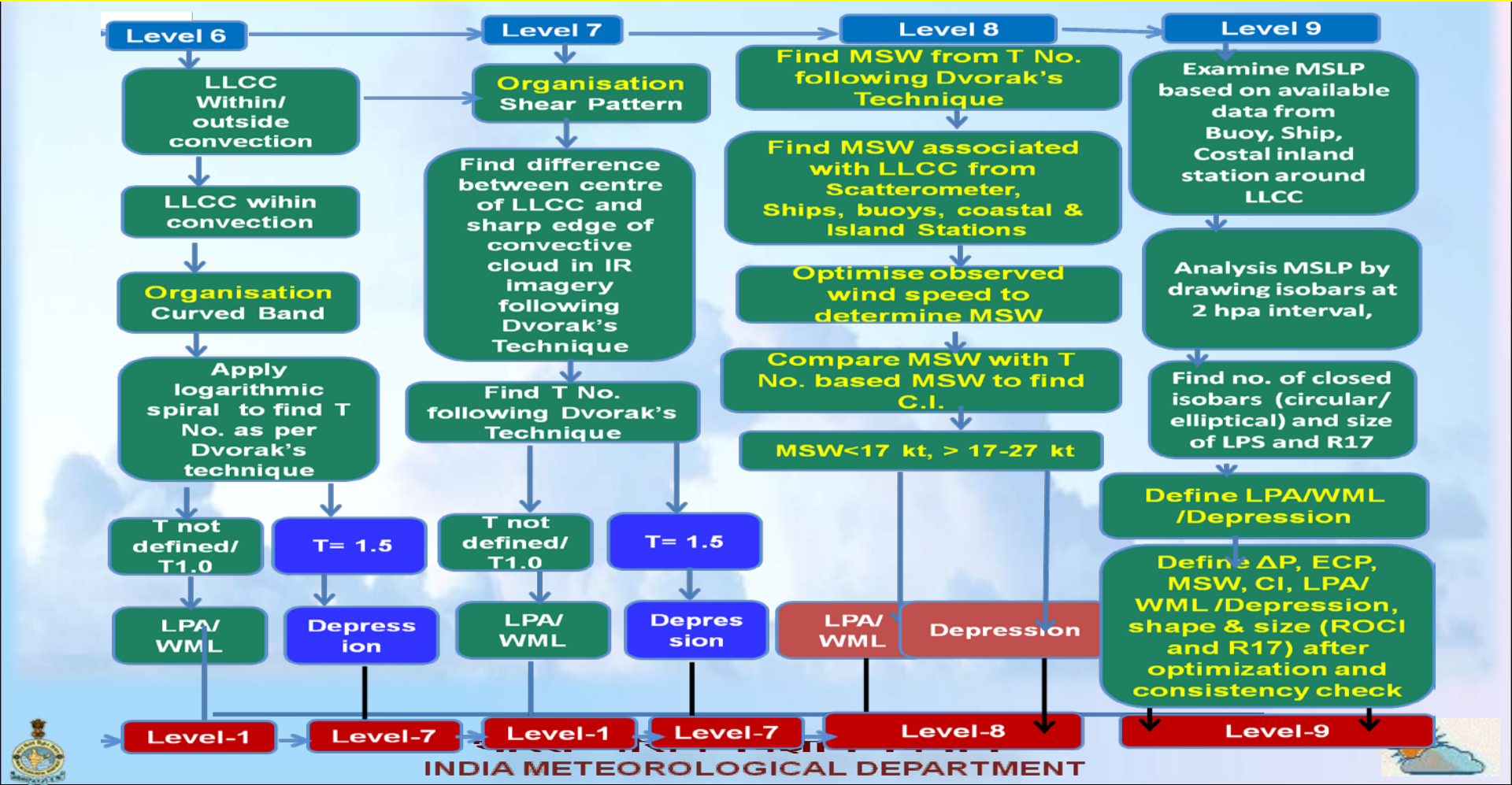
Large scale features

- OLR, MJO map- BOM
- CPC - Climate Weather Linkage: MJO
- OLR animations NOAA
- CDC Map Room Climate Products
- Probability of a Tropical Cyclone

Flow chart for genesis monitoring



Flow chart for genesis monitoring



Methodology for tropical activity daily watch

First step: Rapid analysis of the tropical convective activity

- **Is it poor, moderate, strong ?**
- **What is its evolution during the last 24 hours ?**
  - ✓ **The deep convection has intensified or not (in geographical extension, in intensity – coldness of Cb's top –, in cyclonic organization)?**
  - ✓ **Comparison must be done with the days before at the same hours, to avoid to be influenced by the diurnal effect : over ocean, deep convection naturally intensifies (depth and extension) during the night, between 18 UTC and 02 UTC (maximum of deep convective activity at the end of the night, near 23 UTC-01UTC).**

MONITORING OF CYCLOGENESIS : CONVECTIVE CLOUD CLUSTER

Parameters	Criteria	Source	Product
(i) Area	(i)> 5x5°	INSAT 3D/3DR	Visible imagery
(ii) Depth	(ii)reflectivity > X		
(iii)Number of clusters with reflectivity> X	(iii)Number of clusters with reflectivity> X		
(iv)Clusters organisation	(iv)organized if associated with low level circulation centre		

MONITORING OF CONVECTIVE CLOUD CLUSTER THROUGH IR IMAGERY

Parameters	Criteria	Source	Product
(i) Area (ii) Depth (iii) No. of clusters with CTT < -40^{0}C	(i)> 5x5 ° (ii) CTT < -40^{0}C (iii) No. of clusters with CTT < -40^{0}C	INSAT 3D/3DR Meteosat	IR imagery

MONITORING OF CONVECTIVE CLOUD CLUSTER

Parameters	Criteria	Source	Product
Persistence of convective clusters during past 24 hrs	(i)Is it persisting for more than 24 hrs (ii)increase or decrease in area (iii)increase/decrease in depth (iv)increase in organisation/scattering (v)increase/decrease in number of clusters (vi)Clusters coming closer or going away from each other	INSAT 3D/3DR	IR imagery

MONITORING OF LLCC MICROWAVE PRODUCTS

Parameters	Criteria	Source	Product
(i)single or multiple LLCC ii) cyclonic circulation (iii)Outer wind field structure (iv)Storm size information	(i) Associated wind speed=17kt or more (ii)Centre location well defined (iii) storm size extends upto extent of circulation (iv)If multiple LLCC→They are coming together or away (v)Within deep convective cluster or exposed LLCC (outside deep convection	Multiplatform Satellite Surface Wind Analysis - CIRA, Colorado State Univ http://rammb.cira.colostate.edu/products/tc_realtime/image_mpsatwnd.asp	

3. ENVIRONMENTAL PARAMETERS

Parameters	Criteria	Source	Product
(a) SST	SST>26.5^{0}C	TMI, AMSRE, Windsat) http://www.aoml.noaa.gov/phod/dataphod1/work/HHP/	Data and analysis
		INSAT 3D imd.gov.in	Data and analysis
		GODAS INCOIS	Data and analysis
		ROMS INCOIS	Data and analysis

3. ENVIRONMENTAL PARAMETERS

Parameters	Criteria	Source	Product
(b) Tropical Cyclone Heat Potential (TCHP)/ Ocean heat content (OHC)	>50 KJ/cm^2	http://www.aoml.noaa.gov/phod/dataphod1/work/HHP/ http://rammb.cira.colostate.edu/products/tc_realtime/products/storms/ INCOIS	Data and Analysis Data and Analysis

3. ENVIRONMENTAL PARAMETERS

Parameters	Criteria	Source	Product
(c) Depth of 26 deg. Isotherm	Threshold : > 50 metre	http://www.aoml.noaa.gov/phod/dataphod1/work/HHP/NEW/	
(d) Sea height anomaly	Threshold: > 10 centi metre	http://www.aoml.noaa.gov/phod/dataphod1/work/H HP/ INCOIS	

3. ENVIRONMENTAL PARAMETERS

Parameters	Criteria	Source	Product
(e) Mid-tropospheric relative humidity	Threshold : > 50%	IMD (NWP) NCMRWF IMD (GTS) Microwave satellite http://manati.star.nesdis.noaa.gov/datasets/SSMIDat a.php	Model analyses Actual observation Moisture

3. ENVIRONMENTAL PARAMETERS

Parameters	Criteria	Source	Product
(f) Upper level wind	· Upper level outflow region · Location of trough · Location of ridge · Jet region and strength · Steering current	CIMSS http://tropic.ssec.wisc.edu/real-time/windmain.php?&basin=ndian&sat=wm5&prod=wvir&zoom=&time IMD/SAC-ISRO IMD IMD (Radar Lab), New Delhi, imd.gov.in	Satellite based wind (300-100 hPa) Satellite based wind (300-100 hPa) wind Observation Radar based upper wind

3. ENVIRONMENTAL PARAMETERS

Parameters	Criteria	Source	Product
(g) Lower level winds	· Lower level inflow · LLCC and intensity (outer layer) · Outer storm size	CIMSS http://tropic.ssec.wisc.edu/real-time/windmain.php	Satellite based wind (850-700 hPa)
		IMD/SAC-ISRO	Satellite based wind (850-700 hPa)
	Comparison with actual wind Determination of the model with best initial condition	IMD	Wind observations
		IMD (Radar Lab), New Delhi, imd.gov.in	Radar based wind over Radar station
		IMD (NWP)	Model Analysis

3. ENVIRONMENTAL PARAMETERS

Parameters	Criteria	Source	Product
(h) Vertical Wind shear	· <10 kt-low wind shear · 10-20 kt – Moderate wind shear · >20 kt- high wind shear Threshold : low to moderate wind shear Low to moderate wind Shear	CIMSS http://tropic.ssec.wisc.edu/real-time/windmain.php CIMSS AMSU http://rammb.cira.colostate.edu/products/tc_realtime/products/storms/	Wind shear (200-850 hPa level) Wind shear (500-850 hPa level) Area Averaged wind shears and Layer means

3. ENVIRONMENTAL PARAMETERS

Parameters	Criteria	Source	Product
(h) Vertical Wind shear tendency	Decrease/increase- intensification/ weakening	CIMSS http://tropic.ssec.wisc.edu/real-time/windmain.php	24 hr tendency in wind shear
(i)Upper level divergence	TC secondary circulation Convective updraft Outflow Storm development Threshold : >$10x10^{-5}$ sec^{-1}	CIMSS http://tropic.ssec.wisc.edu/real-time/windmain.php	Satellite based analysis 300-100 hPa level
(i)Lower level convergence	Entrainment of dry air Low level inflow Threshold : > $10x10^{-5}$ sec^{-1}	CIMSS http://tropic.ssec.wisc.edu/real-time/windmain.php	Satellite based 850 hPa analysis

3. ENVIRONMENTAL PARAMETERS

Parameters	Criteria	Source	Product
(k) Lower level vorticity	· Measure of rotation · Positive : Cyclonic · Negative : Anti-cyclonic · Increasing/decreasing – Strengthening/weakening of TC · Merging of vorticity centres leads to intensification and vice versa Threshold : > $10x10^{-5}$ sec^{-1}	http://tropic.ssec.wisc.edu/real-time/windmain.php	Satellite based 850 hPa vorticity Satellite based 700 hPa vorticity Satellite based 500 hPa vorticity

3. ENVIRONMENTAL PARAMETERS

Parameters	Criteria	Source	Product
(l) MJO	· MJO index in phase 2-5 are favourable for genesis. · Amplitude >1 favourable for intensification.	http://cawcr.gov.au/staff/mwheeler/maproom/RMM/fcsts/pd.MW05.Last.gif http://www.cpc.ncep.noaa.gov/products/precip/Cwlink/MJO/CLIVAR/clivar_wh.shtml	Phase and amplitude of MJO and its statistical forecast Phase and amplitude of MJO and its Dynamical forecast
(m) OLR	Convection monitoring through animation, Diurnal variation Location and intensity of convection Threshold:<200watt/m^2	IMD (TIR1, TIR2, WV)	

4. GENESIS PROBABILITY BY DYNAMICAL STATISTICAL MODEL

Parameters	Criteria	Source	Product
Genesis Probability by statistical models	Above normal probability	CIRA http://rammb.cira.colostate.edu/projects/gparm/	Daily probability for 2 days
		http://www.ssd.noaa.gov/PS/TROP/TCFP/ndian_oc_ean.html	Daily probability for 2 days
		NOAA http://www.ssd.noaa.gov/PS/TROP/TCFP/index.ht	Climatological probability

4. GENESIS PROBABILITY BY DYNAMICAL STATISTICAL MODEL

Parameters	Criteria	Source	Product
Genesis probability by statistical models	IMD-GPP (grid)>30	IMD(NWP)	Daily probability for 7 days
	IMD-Average GPP>08	IMD(NWP)	Daily probability for 3 days
	Above normal Probability	ISRO Sriharikota ISRO,	Daily probability for 7 days
	Probability : above normal (matching index>0.6)	Ahmedabad	Based on scatterometer pass

4. GENESIS PROBABILITY BY DYNAMICAL STATISTICAL MODEL

Parameters	Criteria	Source	Product
Genesis Probability by statistical models	Probability : above normal	JTWC http://www.cpc.ncep.noaa.gov/products/precip/CWlink/ghazards/index.php	Probability of genesis in the week
	Probability of genesis over a grid	Cyclone eAtlas-IMD www.rmcchennaieatlas.tn.nic.in	Climatology of genesis

5. GENESIS MONITORING AND PREDICTION BY NWP

Parameters	Criteria	Source	Product
Monitoring and prediction of genesis	· two closed isobars with interval of two hPa is considered as cyclogenesis (formation of depression) · In case of wind field, threshold cyclonic wind is 17 knots or more · Location of centre is the location of lowest pressure	IMD(NWP) IAF NCMRWF	WRF Model analysis and forecast WRF Model analysis and forecast NCUM-R Model analysis and forecast

5. GENESIS MONITORING AND PREDICTION BY NWP

Parameters	Criteria	Source	Product
Monitoring and prediction of genesis	· two closed isobars with intervalof two hPa is considered as cyclogenesis (formation of depression) · In case of wind field, threshold cyclonic wind is 17 knots or more · Location of centre is the location of lowest pressure	NCMRWF GTS GTS ECMWF	NCUM Model analysis and forecast JMA Model analysis and forecast ARP Model analysis and forecast ECMWF Model analysis and forecast

6. OFFICIAL MONITORING AND FORECAST

Parameters	Criteria	Source	Product
(a)NWP Models	· two closed isobars with interval of two hPa is considered as cyclogenesis (formation of depression) · In case of wind field, threshold cyclonic wind is 17 knots or more · Location of centre is the location of lowest pressure	Model products of IMD/NCMRWF /NCEP/JMA/ ECMWF/ARP etc.	Number of closed isobars and associated surface wind speed

6. OFFICIAL MONITORING AND FORECAST

Parameters	Criteria	Source	Product
(b)Statistical models	Location of centre is the location of lowest pressure	CIRA / NOAA / IMD-GPP / ISRO / JTWC	Probability of genesis
(c)Radar	Reflectivity /Radial Velocity	RADAR Lab, IMD	Wind speed / Vertical extension o convective clouds
(d)Satellite observations	Intensity estimation	INSAT-3D / 3DR	T number based on Dvorak technique

6. OFFICIAL MONITORING AND FORECAST

Parameters	Criteria	Source	Product
(e)Synoptic observations	· two closed isobars with interval of two hPa is considered as cyclogenesis (formation of depression) · In case of wind field, threshold cyclonic wind is 17 knots or more · Location of centre is the location of lowest pressure	GTS / INCOIS	Number of closed isobars and associated surface wind speed
(f)Environment al parameters		INCOIS / NRL / CIRA	Conditions for genesis, intensification and movement

Check list for the north Indian Ocean

Dated **Time**

1.Mean sea level pressure (MSLP) Central pressure:

Outer most closed isobar Pressure:

Radius of outermost closed isobar Pressure deficit :

No. of closed isobar (within 6 deg):

Shape of isobar (circular/elliptical) Size of the system (lat./long.)

2.Number of days the low pressure area is persisting :

3.Region of occurrence of low pressure area :

4. 24 hrs pressure change
    a. General description :
    b. Maximum fall and station/buoy :
5. Pressure departure from normal
    a. General description :
    b. Maximum negative departure and station :
6. Circulation:
    a. Vertical extension :
    b. Tilting
    c. Wind speed (sector):west/ east/ north/ south Surface
0.9 km
1.5 km
d. Maximum wind (Magnitude, Region of occurrence and Distance of maximum wind from centre of circulation at surface level

Check list for the north Indian Ocean

7. Lower level convergence :
   a. Maximum value and region of occurrence) :
   b. Convergence in forward sector
   c. Tendency during past 06/12/24 hrs
8. Upper level divergence :
   a. Maximum value and region of occurrence :
   b. Divergence in forward sector
   c. Tendency during past 06/12/24 hrs
9. Lower level vorticity
   a. Maximum value and region of occurrence) :
   b. Vorticity in forward sector
   c. Tendency during past 06/12/24 hrs
10. Vertical wind shear
   a. Minimum value and region of occurrence) :
   b. Wind shear in forward sector
11. Wind shear tendency
   a. Minimum value and region of occurrence :
   b. Wind shear tendency in forward sector :

Check list for the north Indian Ocean

12. QPE
    a. QPE during past 12 hrs (Maximum value and region of occurrence) :
    b. QPE during past 24 hrs (Maximum value and region of occurrence) :
    c. Tendency (Increasing/decreasing) :
12. OLR :
    a. Daily mean (Maximum value and region of occurrence) :
    b. 3 hourly mean (Maximum value and region of occurrence) :
    c. Tendency (Increasing/decreasing) :
13. SST
    a. Maximum SST and region of occurrence
    b. SST in forward sector
    c. Tendency in SST
14. Location and intensity from other sources
    a. NOAA SSD
    b. JTWC

Check list for the north Indian Ocean

Radar features :

1.Pattern : Line curve/Spiral band/Eye

2.line Curve (Number and tendency, associated maximum reflectivity and its place of occurrence

3.Characteristics of spiral bands (Number and tendency, Maximum reflectivity and its place of occurrence)

4.Eye characteristics :

(i) Visible/Invisible width Tendency

(ii) Open/ closed, If open howmuch and tendency

(iii) Circular/elliptical

5. Characteristics of eye wall

(i) maximum reflectivity and its place of occurrence and tendency

(ii)Single eye wall/ double eye wall

(iii)Size of eye and eye wall (Diameter/radius)

6. Pre-cyclone squall lines (Region of occurrence, time of occurrence

7. Precipitation characteristics (Place and time of occurrence of maximum precipitation)

8. Radius of maximum reflectivity (in different quadrants)

9. Radius of maximum wind (in different quadrants)

10. Vertical extension of convective clouds

11. Radar estimaded location of centre with confidence (Multiple centres in case of multiple radars) and intensity with confidence

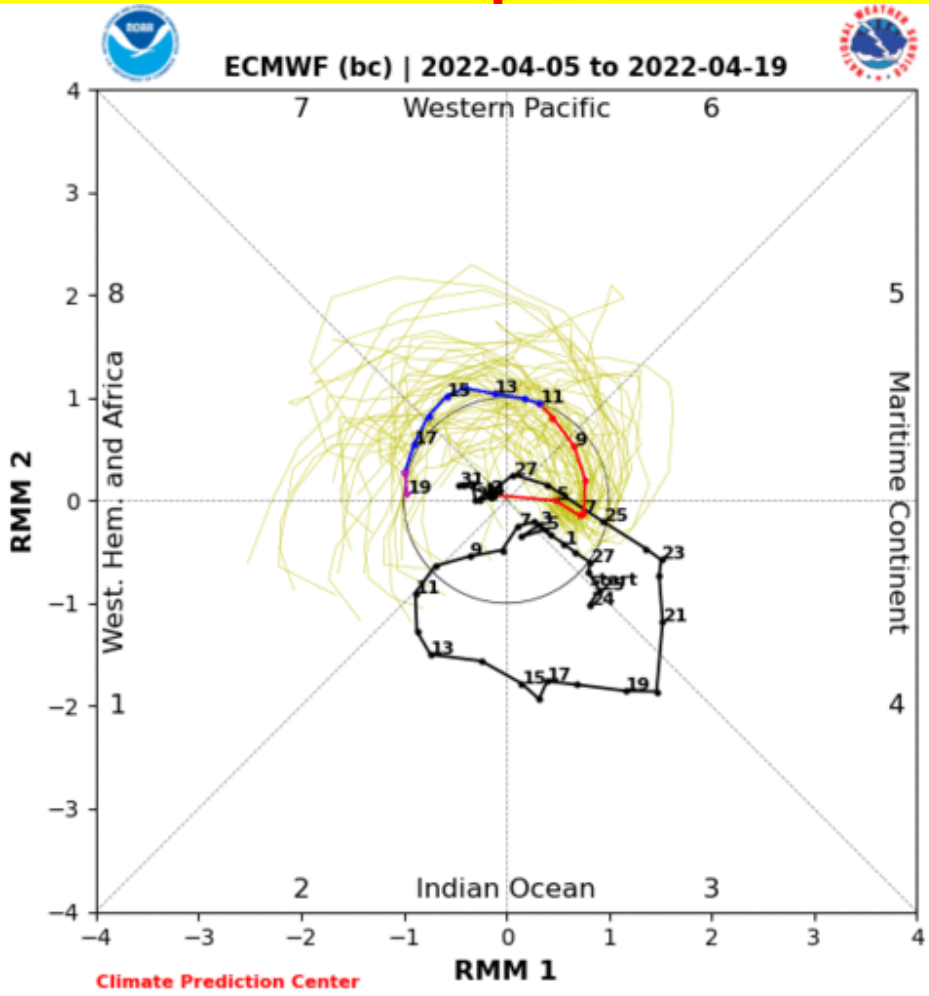
Decision on cyclogenesis and further intensification

- Based on all the inputs as discussed in check list derived by following the sequential steps as given in the road map, forecaster will be able to take a judicious decision in the probabilistic/deterministic term.

Case Study

(To prepare extended range & short to medium range forecast bulletin based on 0300 UTC of 7th April, 2022)

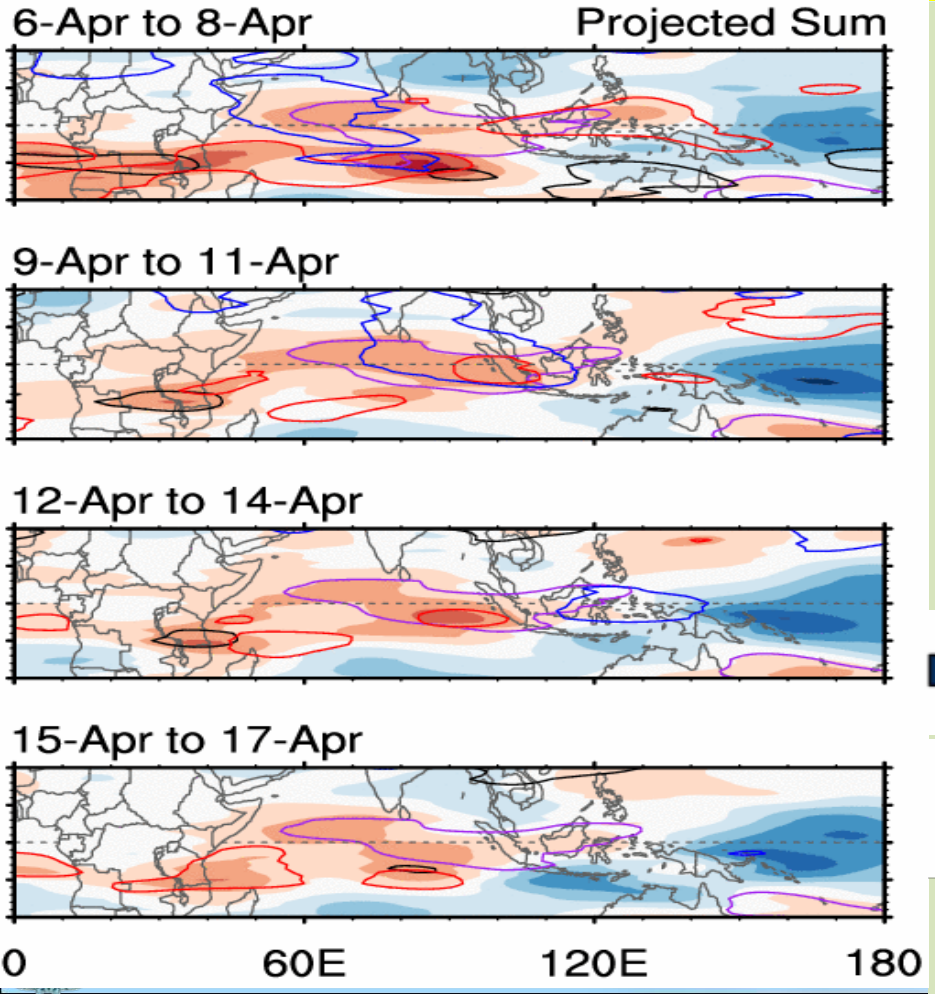
Step 1: Broad scale features (MJO)



Step 1: Broad scale features

MJO in phase 4 with amplitude less than1 on 7th April. To move eastwards into phase 5 during first half of week 1. Thereafter, will move across phases 6 & 7 during remaining part of the forecast period. Favourable for enhancement of convective activity over NIO during first half of week 1.

Step 1: Broad scale features (Equatorial waves)

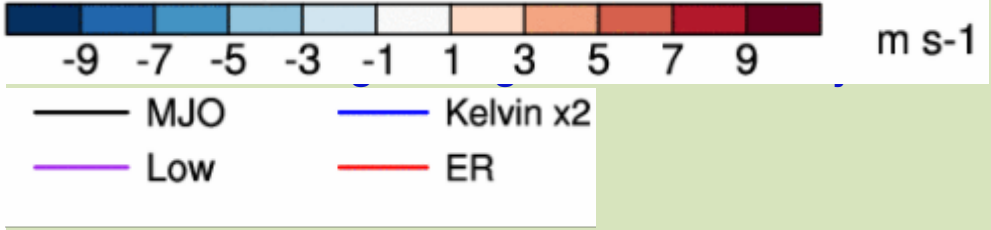


Week 1 (first half):

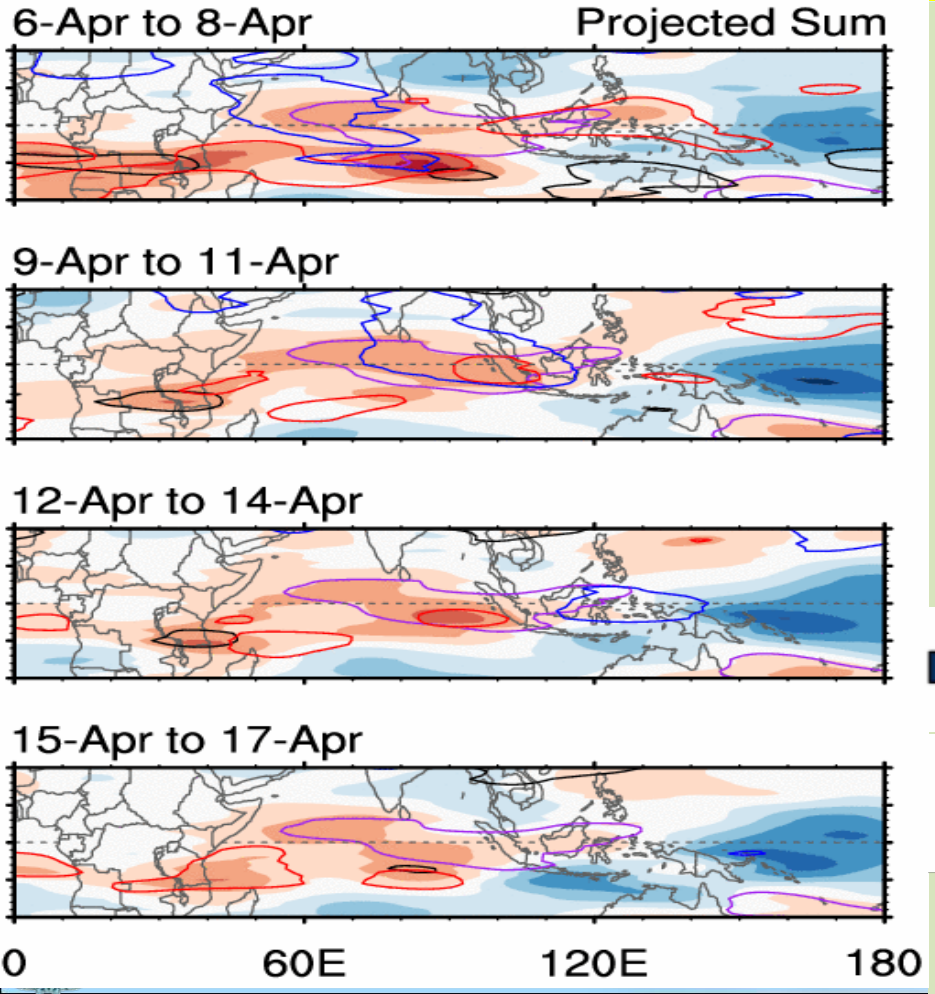
3-5 mps easterly waves over central BoB, 3-5 mps westerly waves over EIO & adj. south BoB, Kelvin waves over south AS, low frequency background waves over EIO & adj. south BoB and Rossby waves over southwest BoB

Week 1 (later half):

Easterlies disappeared. Westerly flow more towards SIO. Kelvin waves over BoB & adj. EIO. And Rosby waves over SIO & adjoining Malay peninsula



Step 1: Broad scale features (Equatorial waves)

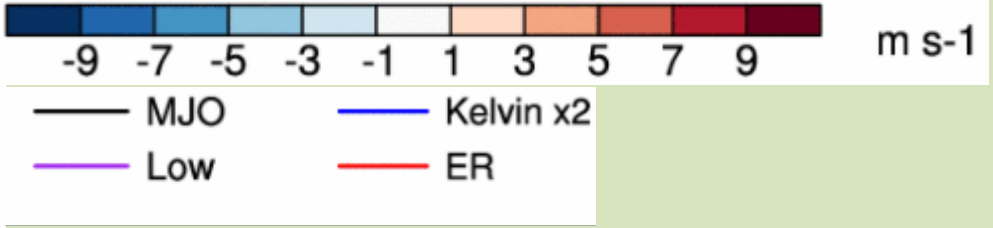


Week 2 (first half):

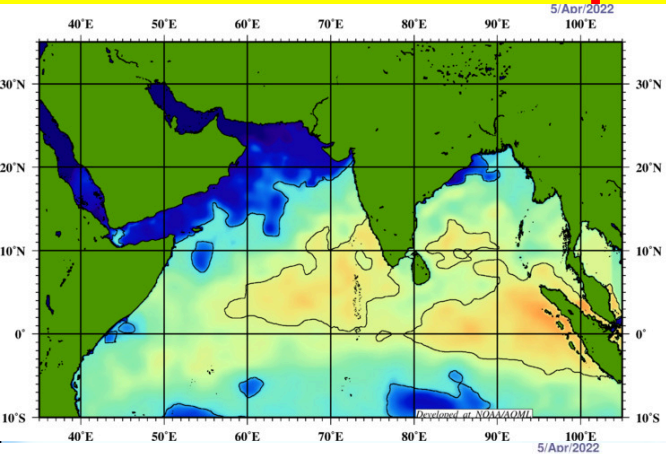
No easterly flow, westerly waves strong (3-5) over south AS and westerly flow over EIO & adj. south BoB, Kelvin waves over south AS and south BoB, low frequency background waves over EIO & adj. south BoBSIO & adj. south BoB.

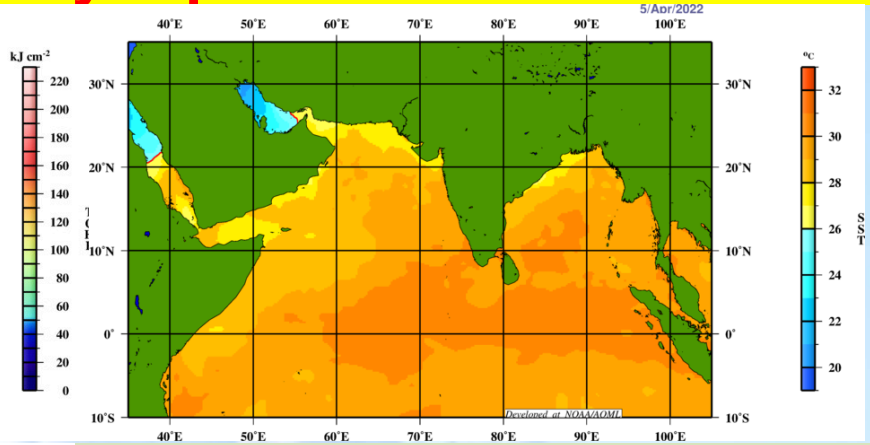
Week 2 (later half):

Easterlies 1-3 mps over central BoB.. Westerly flow over EIO & adj. south BoB. Kelvin waves over BoB & adj. EIO. And Rosby waves over SIO.

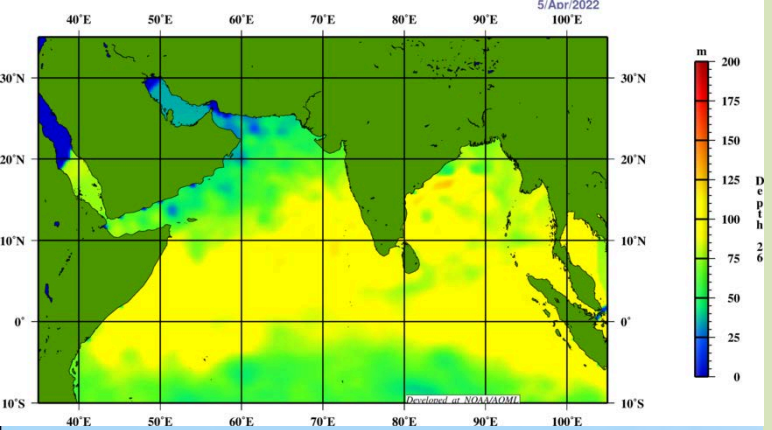


Step 2: Synoptic scale features



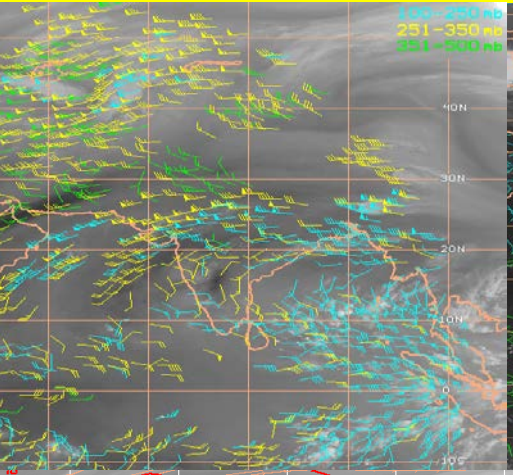


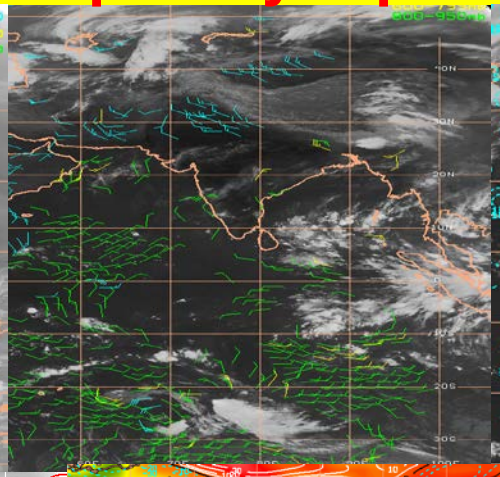
https://www.aoml.noaa.gov/phod/cyclone/data/ni.php

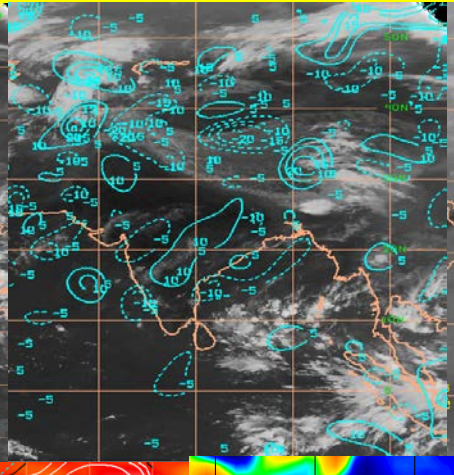


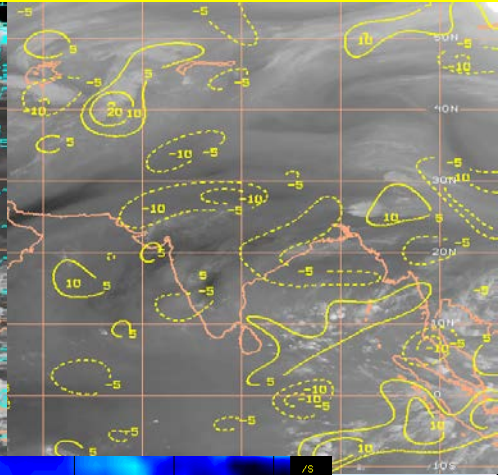
- SST is around 29-30degC over south & adj. westcentral BoB and adj. southeast AS.
- OHC is >100 KJ/cm2 over south Andaman Sea and adjoining SE BoB with gradually decreasing trend, becoming 60-80 KJ/cm2 over remaining parts of south & major parts of adjoining central BoB and Andaman Sea. Over the AS, OHC is >100 KJ/cm2 over southeast & adj. EC AS.
- Depth of 26 deg isotherm around 100 m over major parts of south BoB & AS.

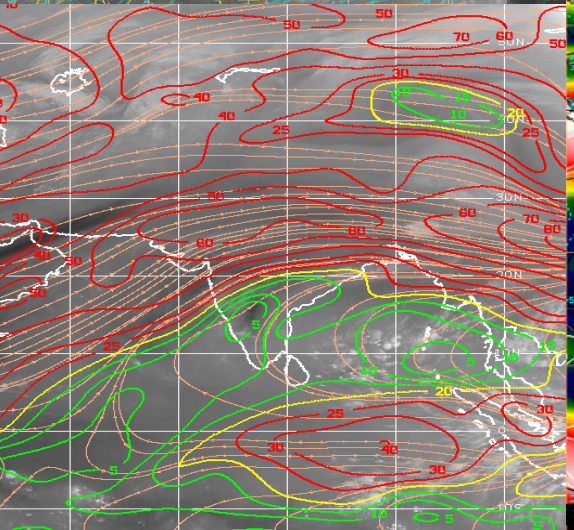
Step 2: Synoptic scale features

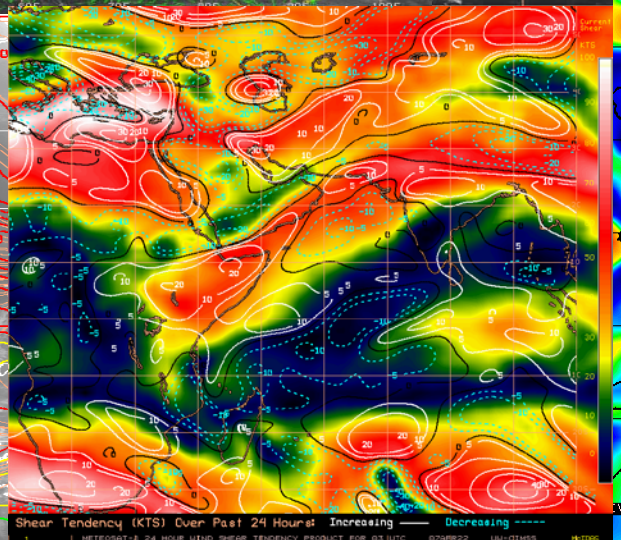


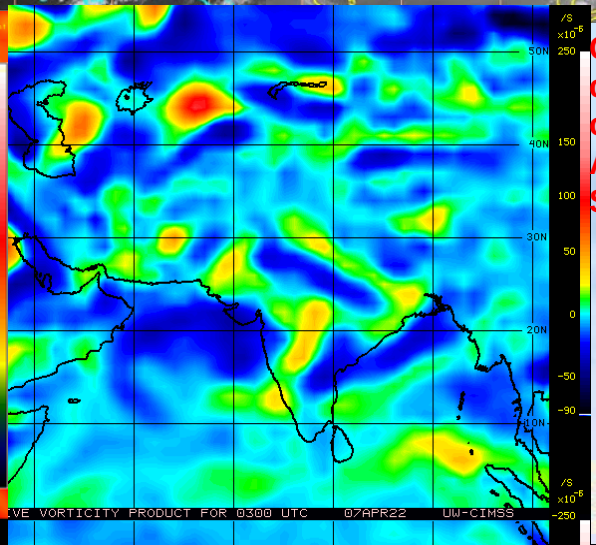












Cyclonic circulation over south Andaman Sea

Step 3: Climatological guidance

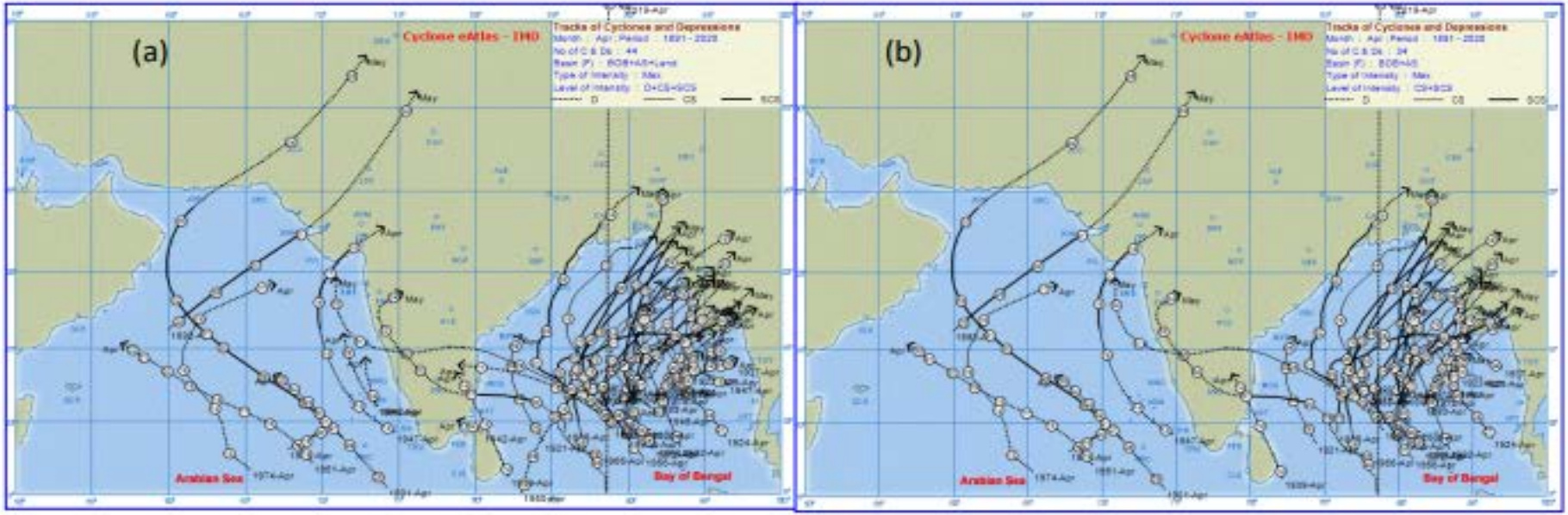


Fig. 1: Tracks of (a) cyclonic disturbances (MSW) ≥ 17 kt) and (b) cyclonic storms (MSW≥ 34 kt) in the month of April during the period 1891-2020

Step 3: Model guidance

Most of the models including IMD GFS, GEFS, NCUM, NEPS, ECMWF, ECMM, JMA etc. are indicating that there is no likelihood of formation of depression over NIO during next 2 weeks. IMD GPP is indicating a potential zone of cyclogenesis over southeast BoB on 8th with west-northwestwards movement. However, models like GFS, NCUM, ECMWF etc. are indicating that the existing cyclonic circulation over south Andaman Sea would move west-northwestwards towards TamilNadu coast.

Conclusion:

In view of all the above,

- **Probability of cyclogenesis for next 120 hours is taken as NIL.**
- **Probability of cyclogenesis during next 2 weeks is taken as NIL. However, the cyclonic circulation over south Andaman Sea would move west-northwestwards.**

Thank you