NWP MODEL (GFS T-1534) PRODUCTS FOR OPERATIONAL WEATHER FORECASTERS

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GFS MODEL PRODUCTS FOR SOME SELECTED WEATHER SYSTEMS

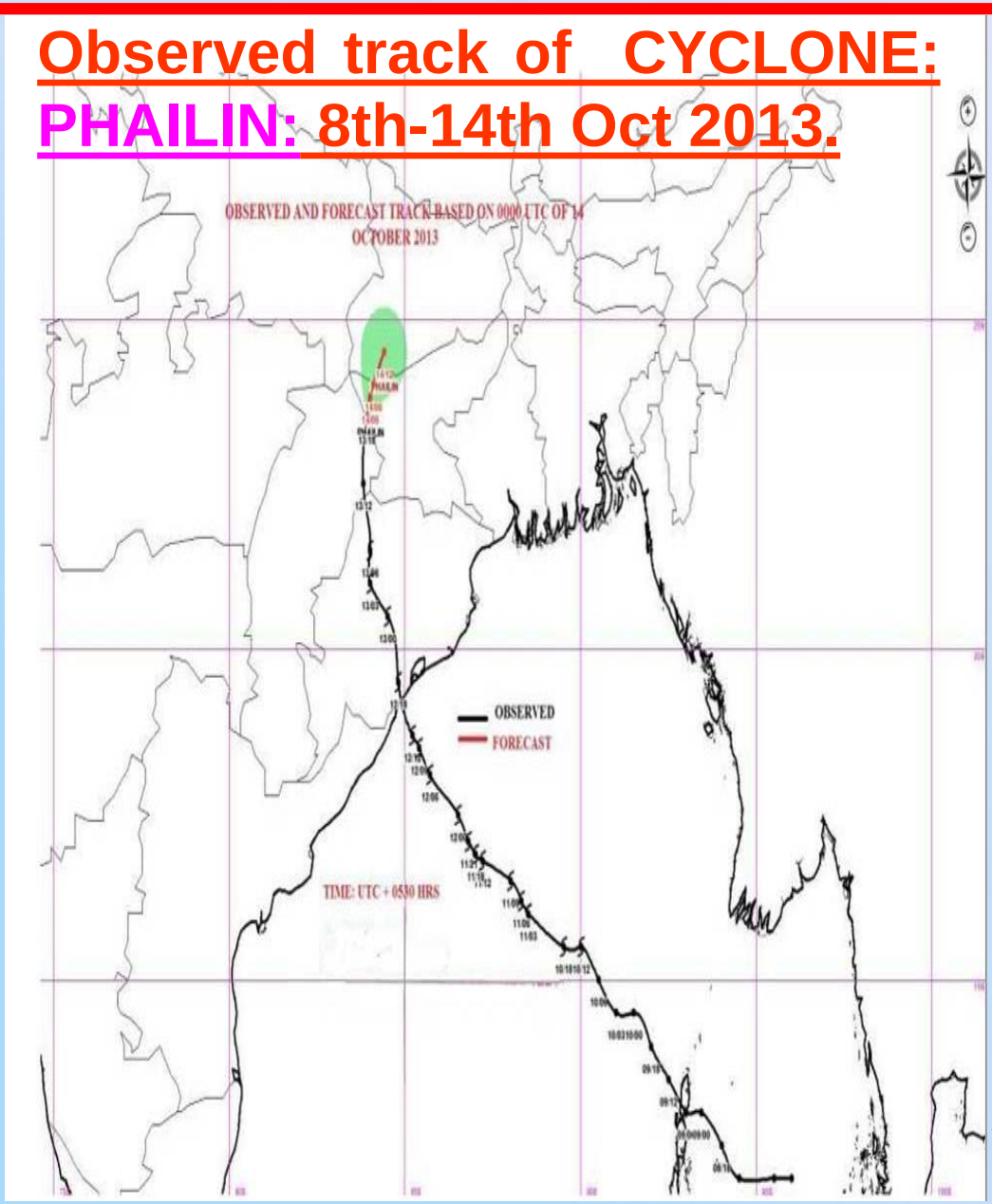
WEATHER SYSTEMS

GFS model products for

1. **Cyclone**
2. **Thunderstorm**
3. **Rainfall**
4. **Western disturbance (wd)**
5. **Monsoon trough**

GFS PRODUCTS FOR CYCLONE

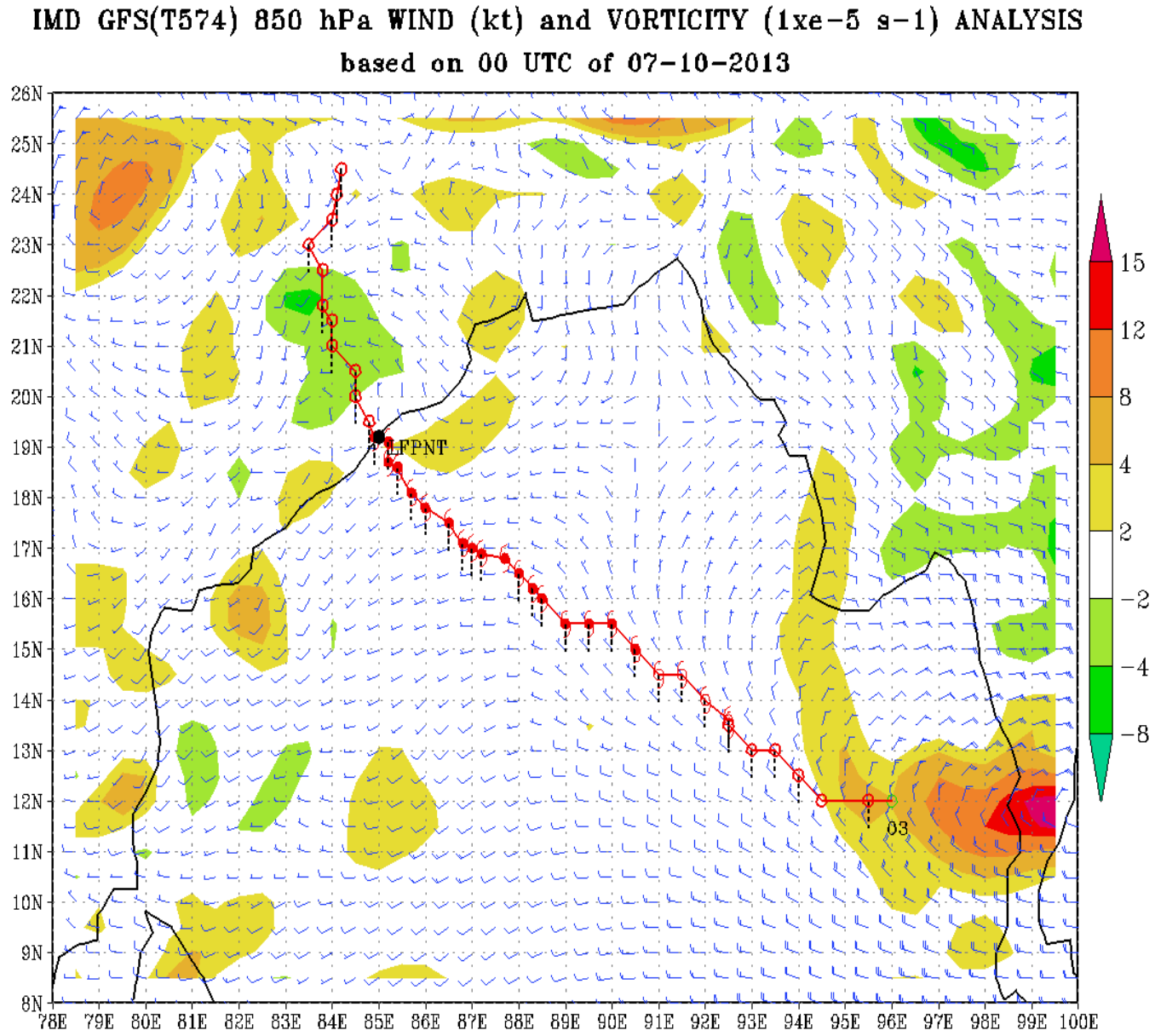
Observed track of CYCLONE: PHAILIN: 8th-14th Oct 2013.



- The cyclone PHAILIN started as a depression in the Bay of Bengal on 08th OCT 2013 near north Andaman sea.
- Intensified in to a tropical cyclone at 12 UTC of 09th Oct2013.
- It made landfall near Gopalpur at 17UTC of 12 OCT 2013

Low-pressure -7th Oct 2013
Depression -03UTC of 8th
DD- 00 UTC of 9th
Cyclone- 12UTC of 9th
Severe CS -03UTC of 10th
Very SCS –O6UTC of 11th
Landfall -17 UTC of 12th Oct 2013

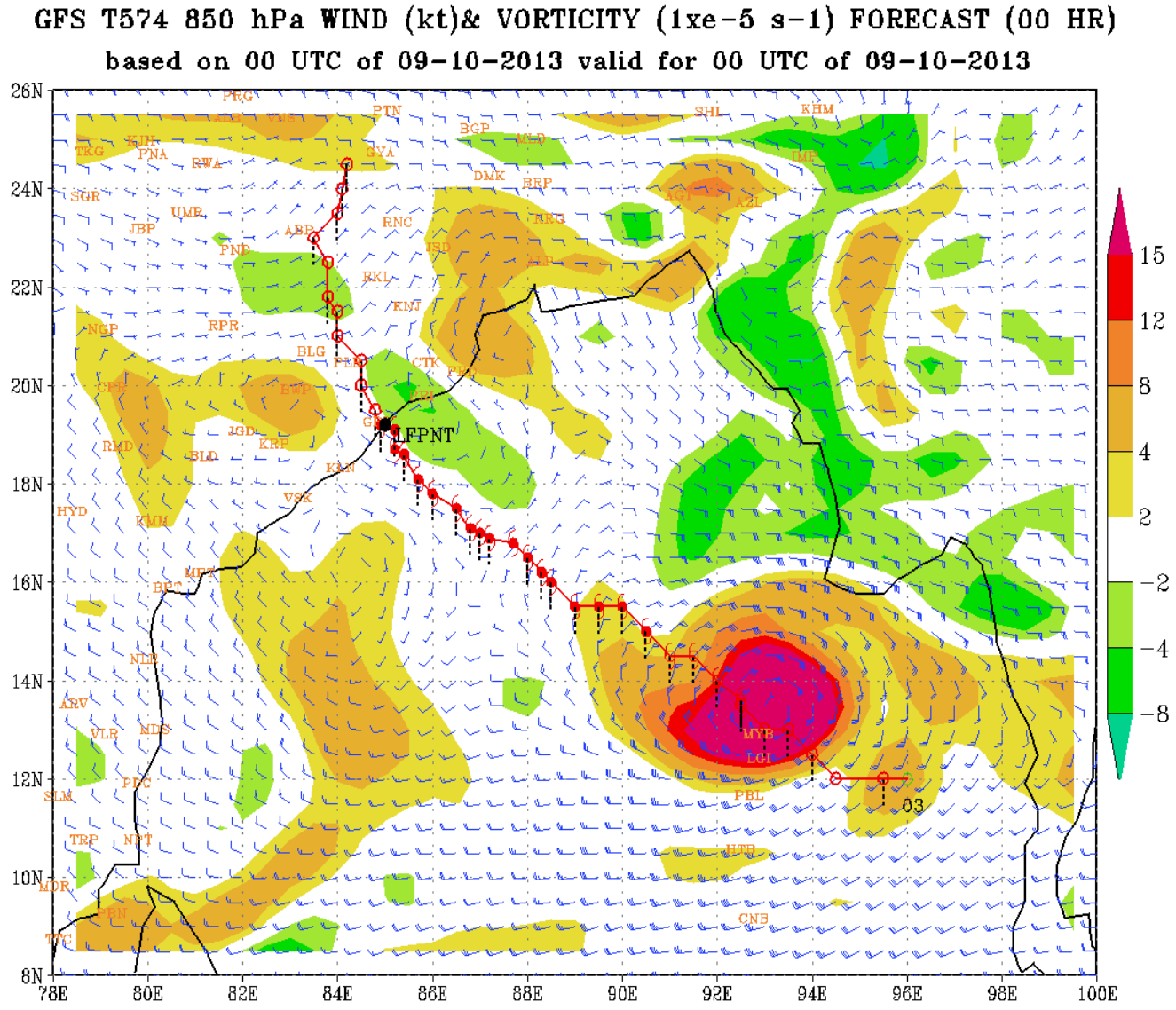
Movement of PHAILIN : 7th -13th Oct by GFS Analysis



GDAS analysis :

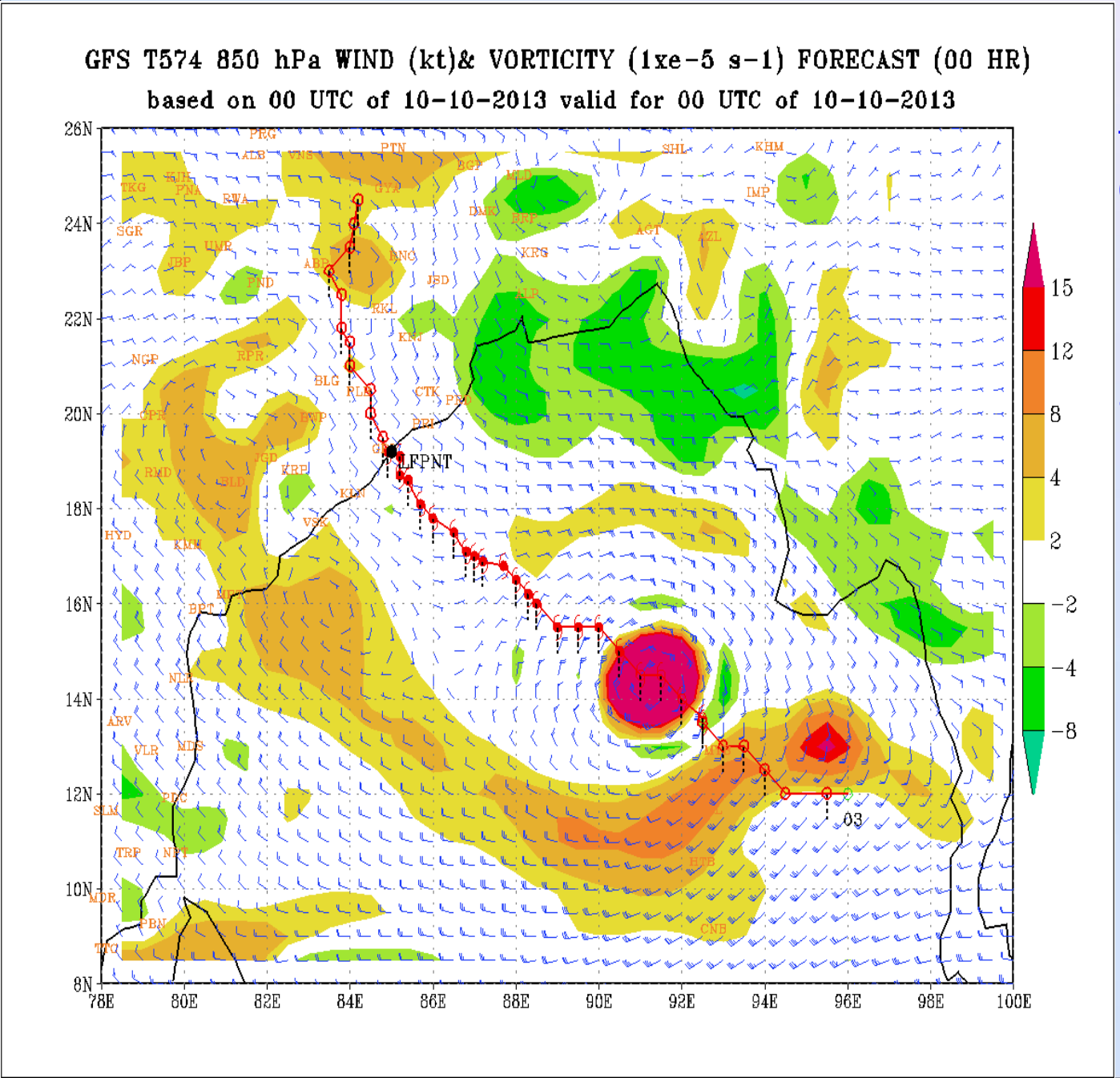
- The wind and vorticity at 850 hPa associated with the system from 7 – 13th Oct
- GDAS analyzed cyclonic center along with circulation pattern moves along the observed track
- The 850 hPa vorticity maximum of the order of 15 × 10−5/sec on 9 Oct was situated around 13.5◦N/93.5◦E

Cyclone Track Forecast by GFS : 0000 UTC of 09 Oct 2013.



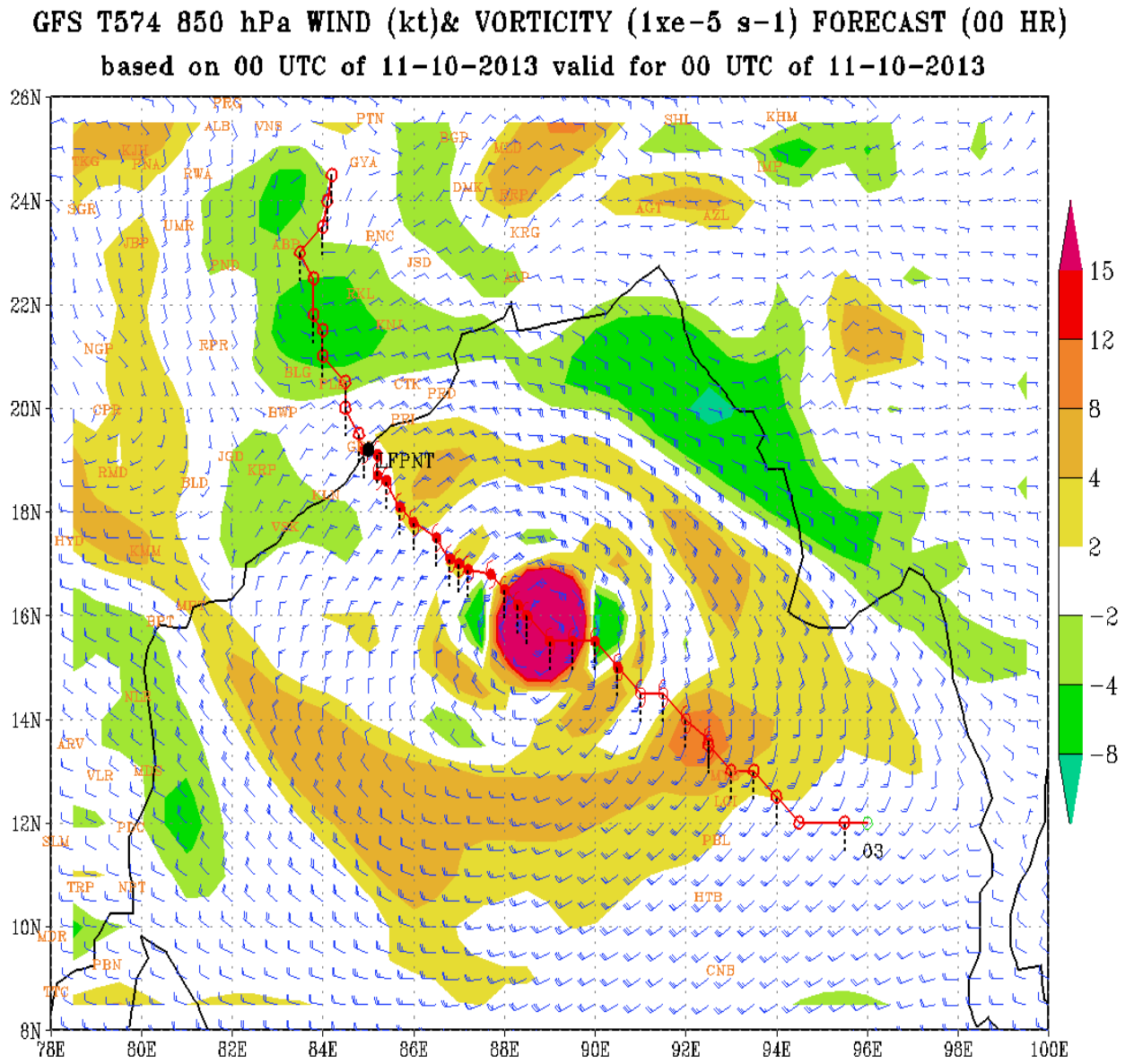
- **GFS track forecast based on 0000 UTC of 09 Oct 2013.**
- **Landfall near Gopalpur, at about 18 UTC of 12 October 2013.**

Cyclone Track Forecast by GFS : 0000 UTC of 10 Oct 2013.



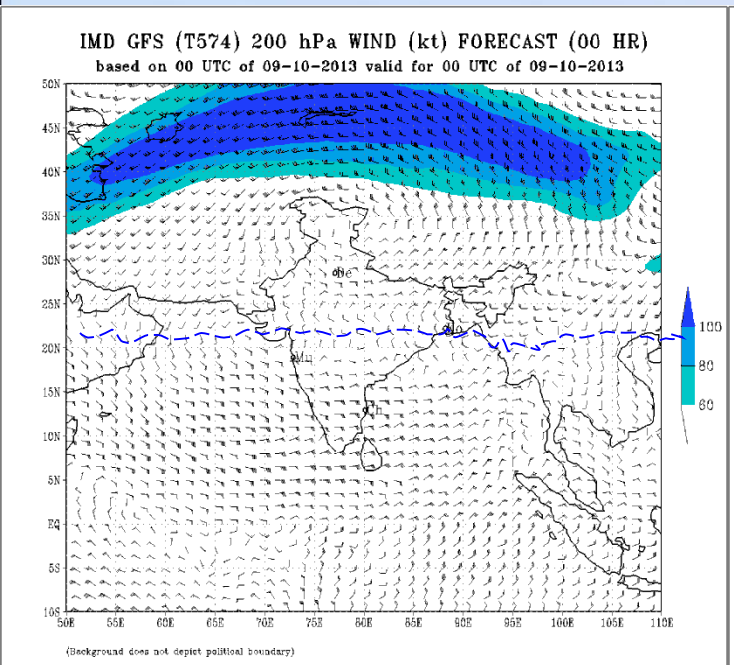
- GFS track forecast based on 00 UTC of 10th October 2013
- shows landfall near Gopalpur, at around 18 UTC of 12 October 2013.

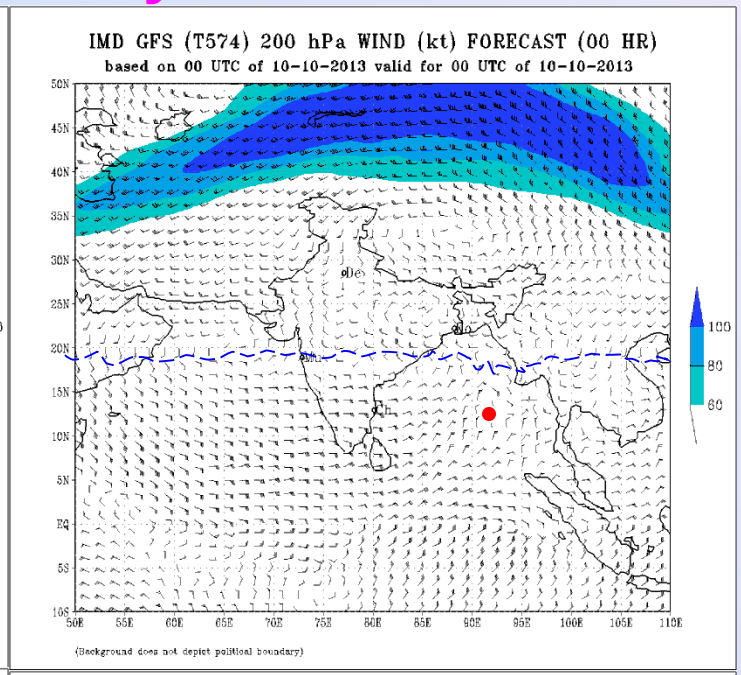
Cyclone Track Forecast by GFS : 0000 UTC of 11 Oct 2013.

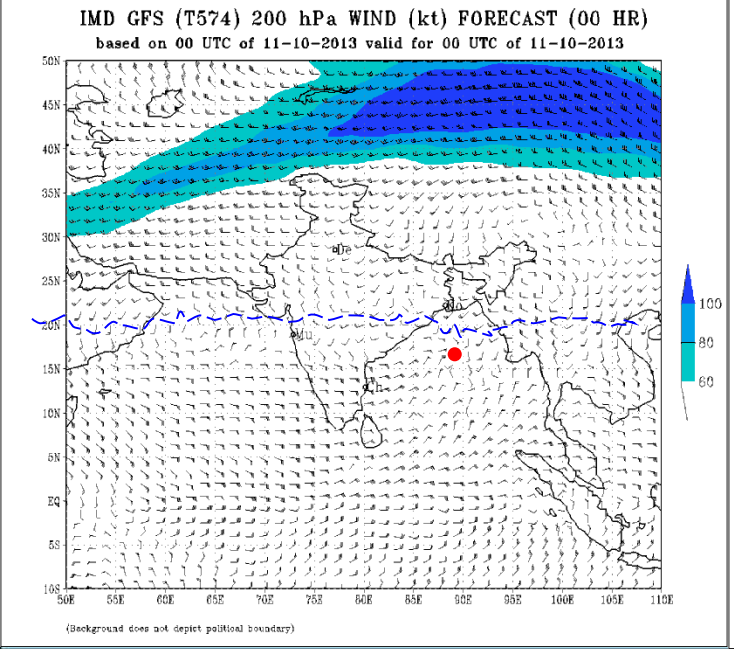


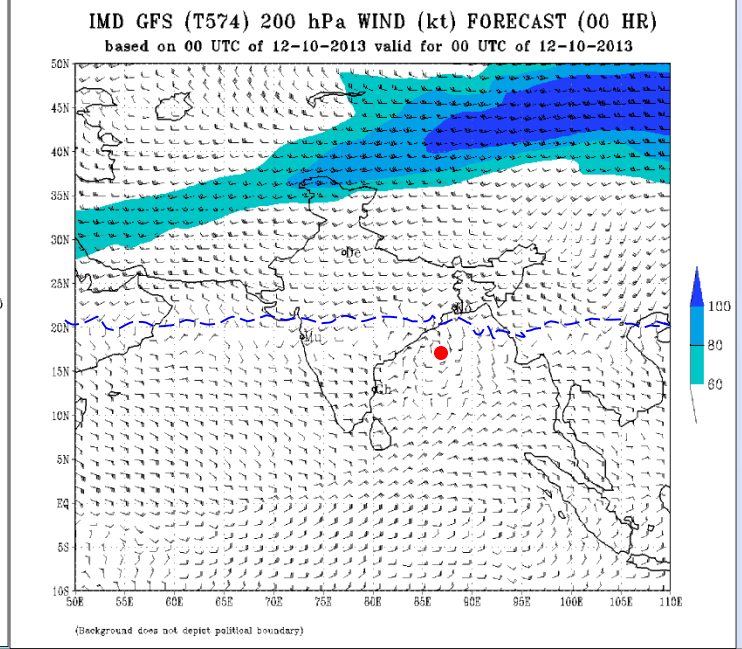
- **GFS track forecast based on 0000 UTC of 11 October 2013**
- **shows landfall near Gopalpur, at about 18 UTC of 12 October 2013.**

Wind at 200 hPa Analysis : 9-12 Oct 2013



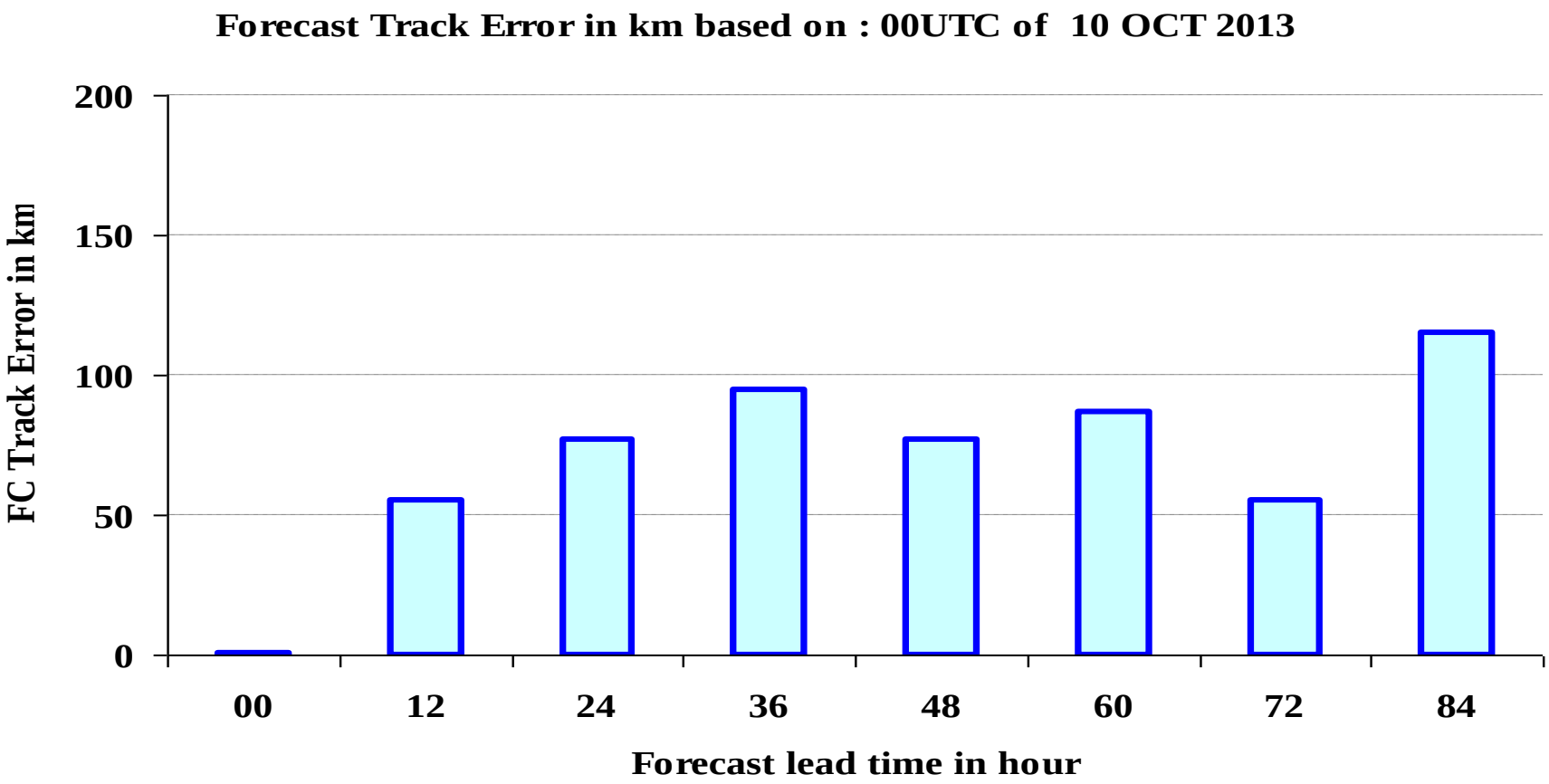






- The ridge line was (20N) quite north of the system center.
- This feature was helpful in moving the system as its normal NWly direction.

GFS Forecast Track Error: based on **00 UTC run of 10 Oct 2013**



Along Track Forecast Errors of GFS are in the range of 50-100 km

Cyclone Intensity Forecast

CLASSIFICATION OF CYCLONIC STORM INTENSITY

T. Number/ C.I. Number	Classification of Cyclonic Disturbance	Wind speed in Knots (Mean)	Wind criteria in Knots	DP
T1.0	Low		<17	
T1.5	D	25	17-27	
T2.0	DD	30	28-33	4.5
T2.5	CS	35	34-47	6.1
T3.0		45		10.0
T3.5	SCS	55	48-63	15.0
T4.0	VSCS	65	64-119	20.9
T6.5	SuCS	127	>120	80.0

PHAILIN

Low-pressure -7th Oct 2013

Depression -03UTC of 8th

DD- 00 UTC of 9th

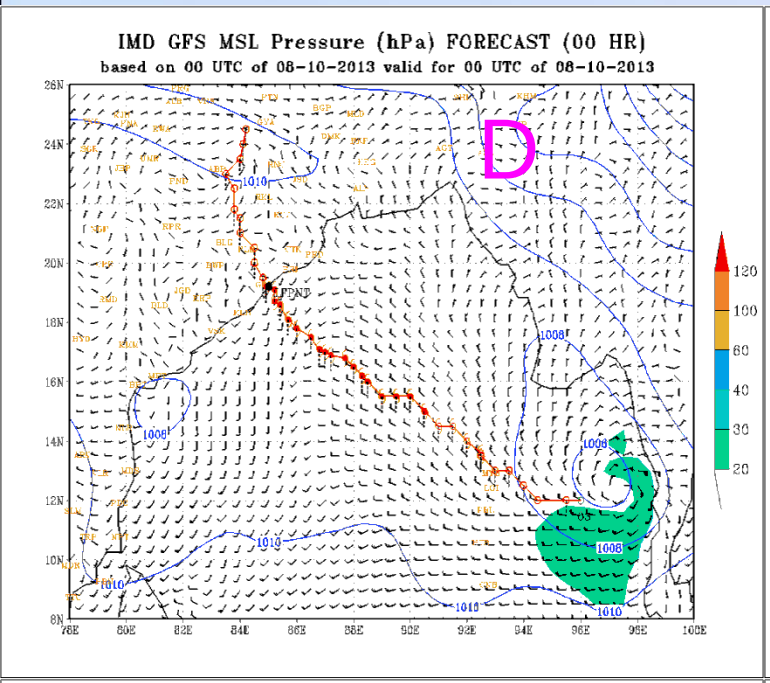
Cyclone- 12UTC of 9th

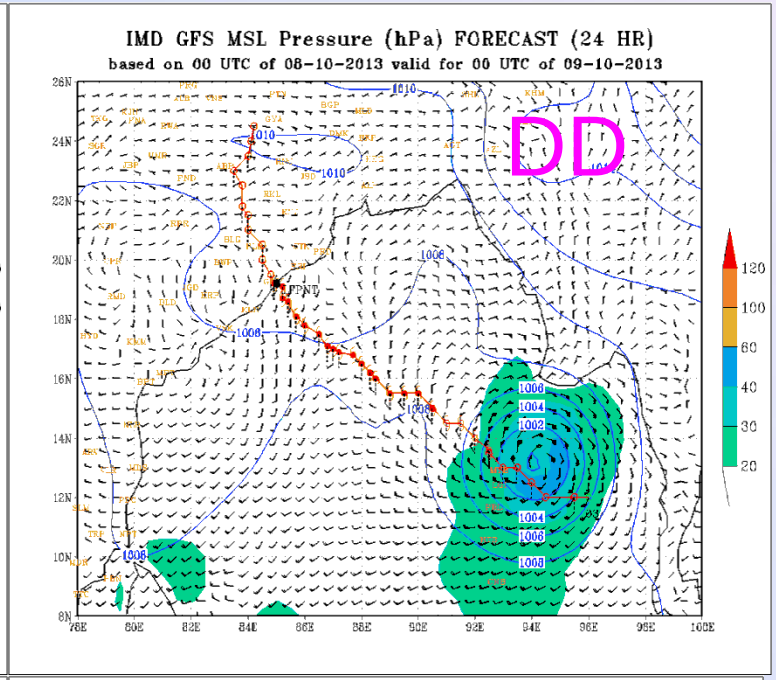
Severe CS -03UTC of 10th

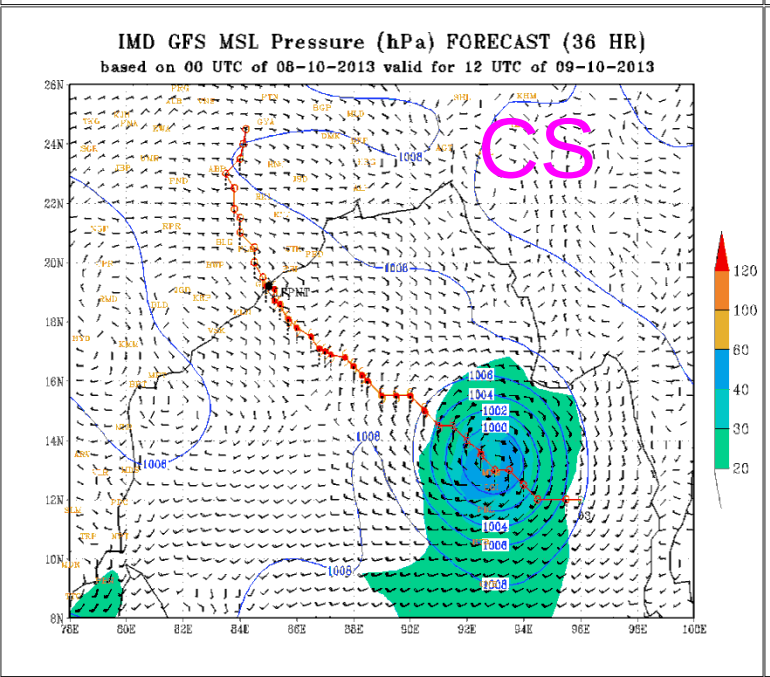
Very SCS –O6UTC of 11th

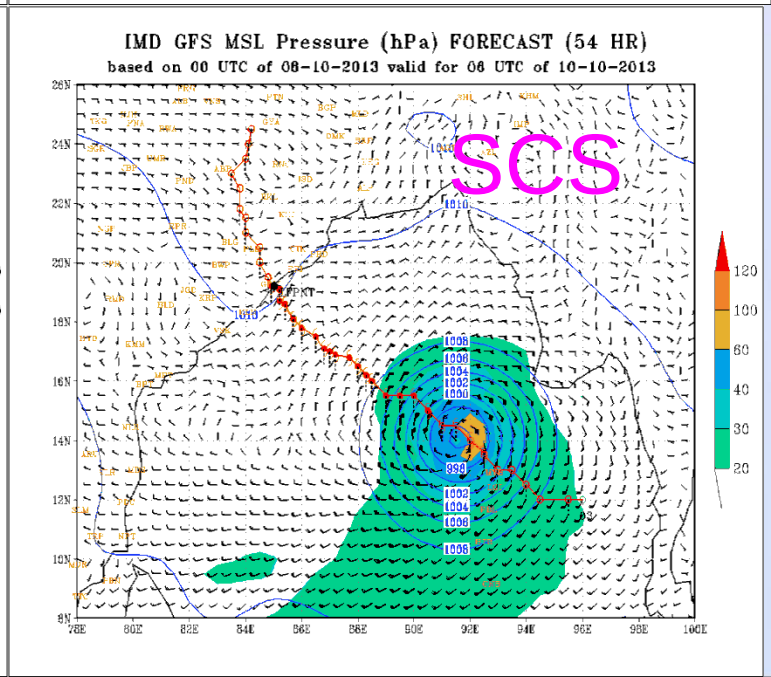
Landfall -17 UTC of 12Oct

Cyclone Intensity Forecast: based on : GFS 00UTC of 08-10-2013









GFS 10m wind and MSLP

•Depression near Andaman Sea would intensify into a

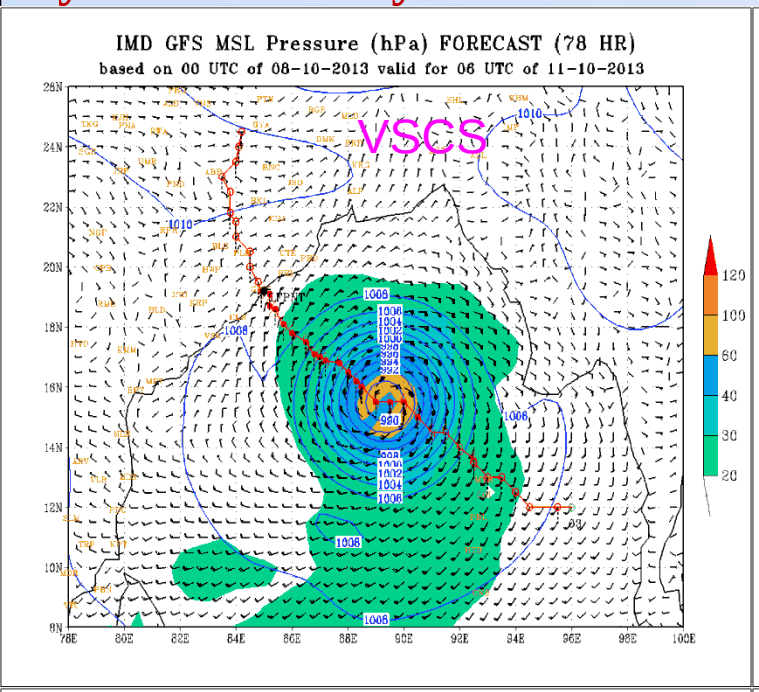
(i) DD at 00 UTC of 09 October 2013.

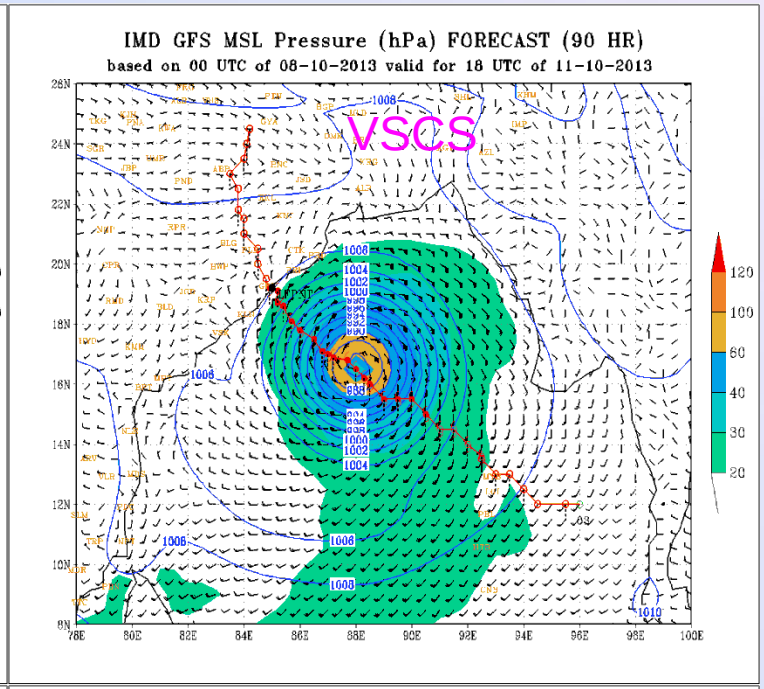
(ii) Cyclonic storm at 12 UTC of 09 October 2013

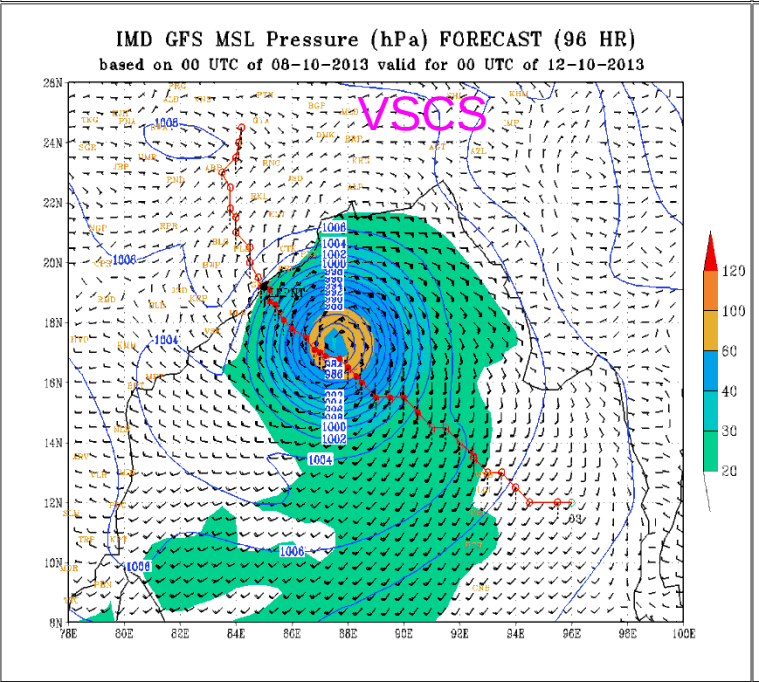
(iii) Severe CS at 06 UTC of 10 October 2013,

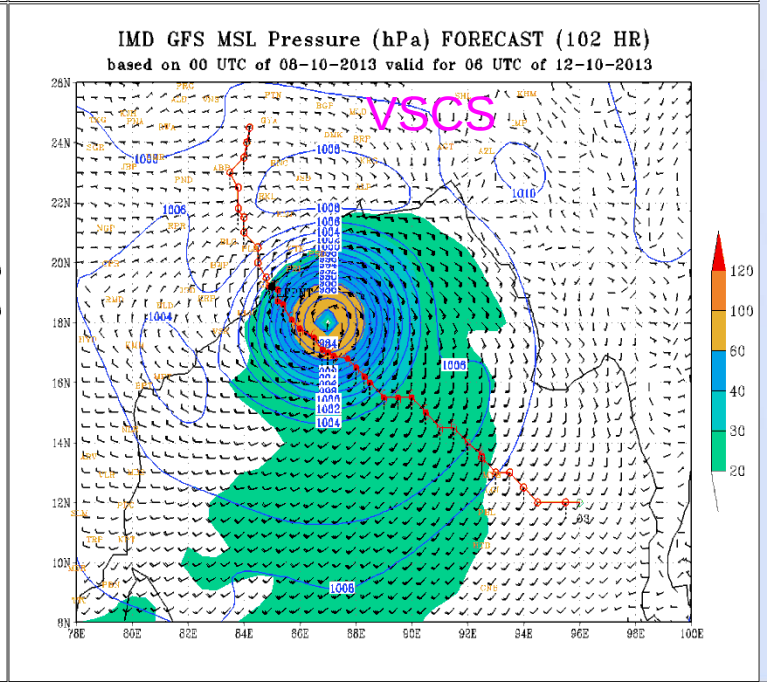
(iv) **Very Severe Cyclonic storm at 06 UTC of 11 October 2013.**

Cyclone Intensity Forecast: based on : GFS 00UTC of 08-10-2013



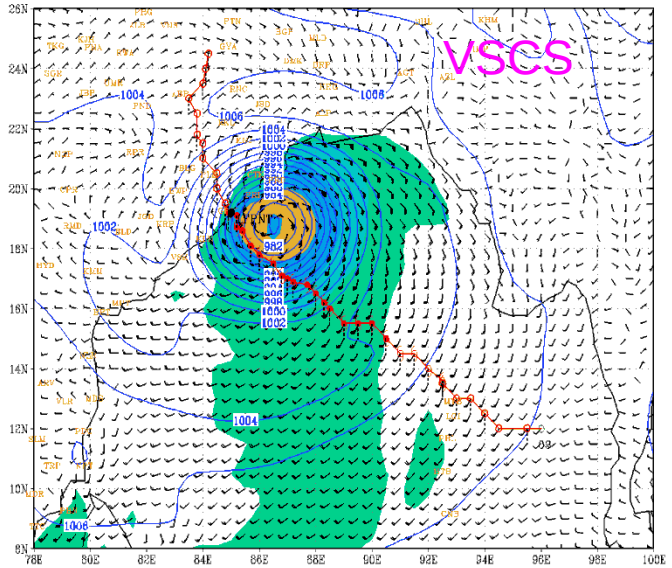


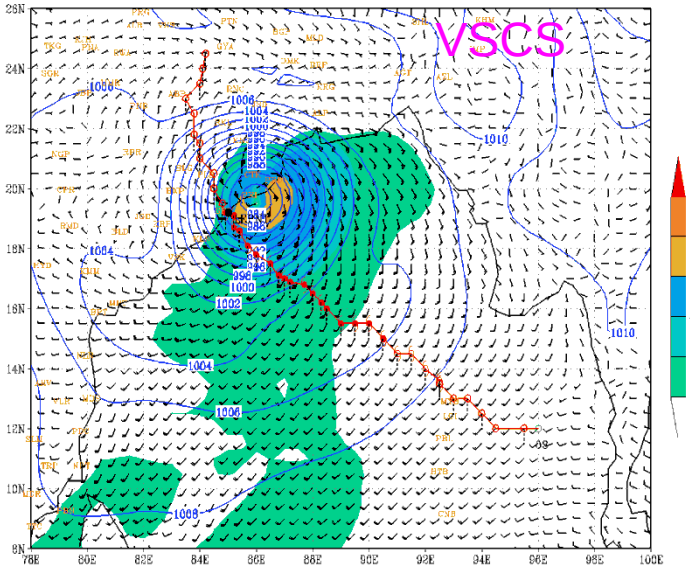


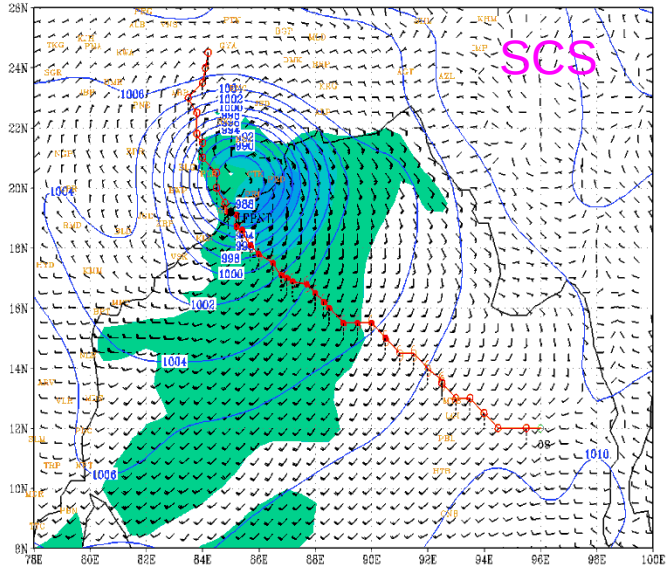


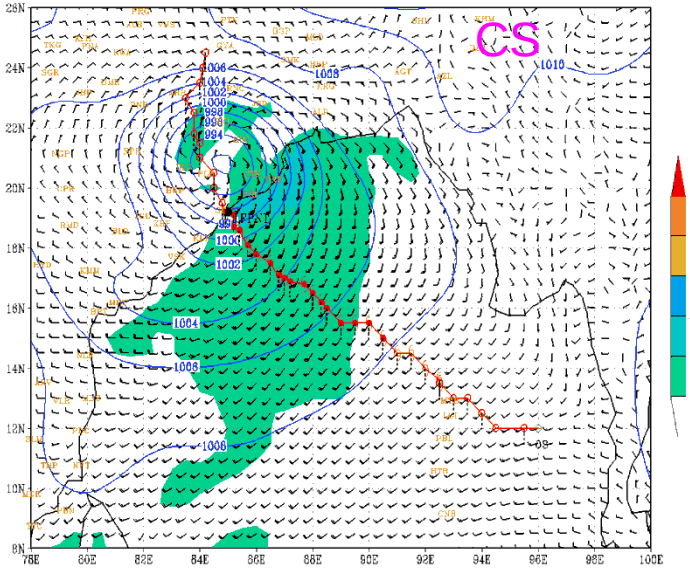
GFS 10m wind and MSLP

Cyclone Intensity Forecast: based on : GFS 00UTC of 08-10-2013









- system was VSCS at the time crossing the coast ,then it become SCS at 00 UTC of 13 Oct and then became CS at 06 UTC of 13 Oct 2013.

Convective weather System
Thunderstorm

Thunderstorm Formation

Four basic ingredients are required for a thunderstorm to form:

1) LIFTING
2) MOISTURE
3) CONVECTIVE INSTABILITY
4) WIND SHEAR

LIFTING

- Air in the lower troposphere is lifted until it becomes less dense than surrounding air. Once it is less dense, it rises on its own.
- Without enough lifting, parcels of air can not be lifted to a point in the troposphere where they can rise on their own

LIFTING

LIFTING MECHANISMS

Lifting is assessed on the NWP model forecast by examining

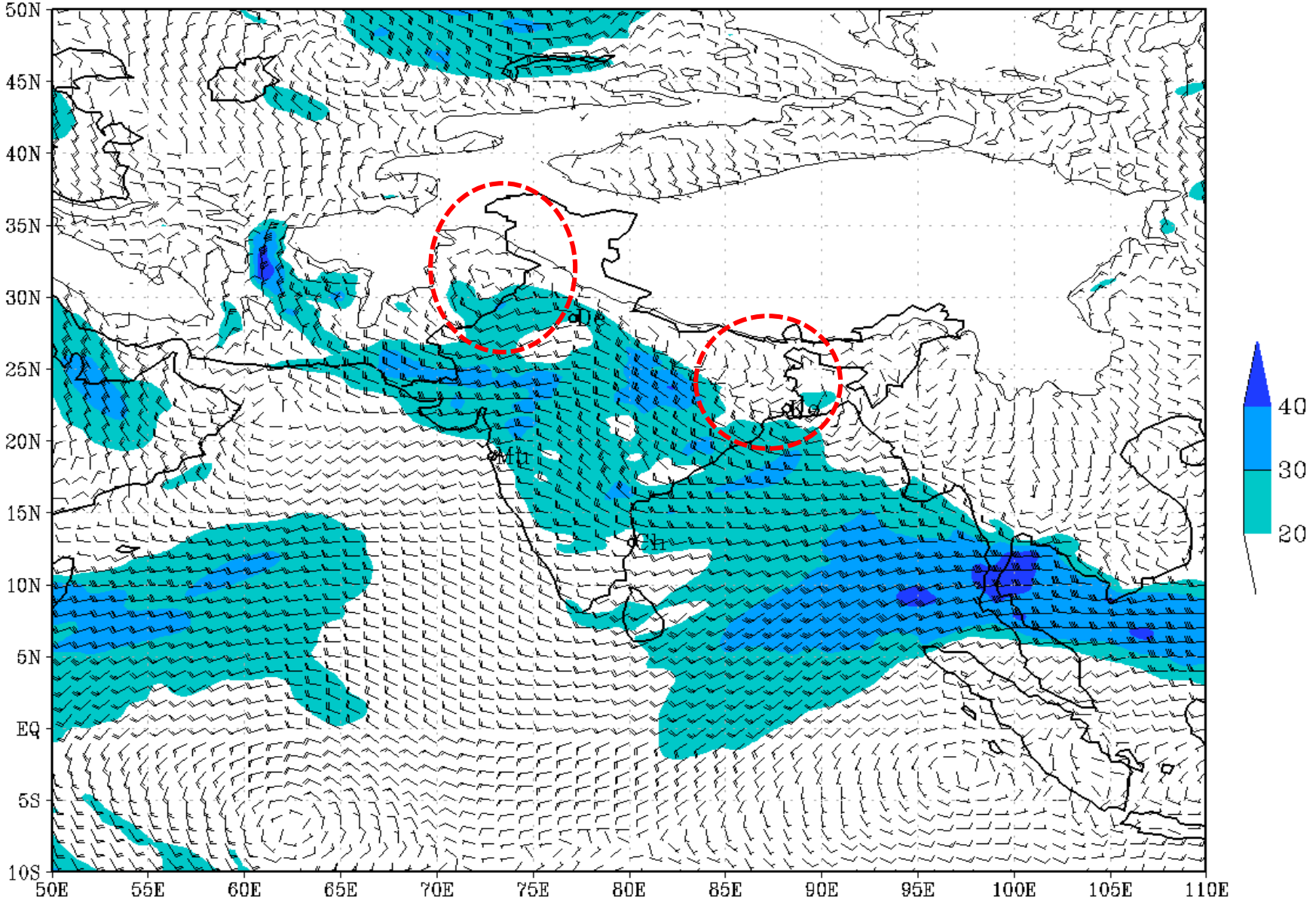
- Low level convergence.
- Vorticity /Advection
- 850/700 hPa upward vertical velocity.

Note

It is also important to examine the synoptic chart/satellite/radar images for lifting mechanisms that occur on a time and space domain that the models have a difficult time resolving (especially in thunderstorm situations).

IMD GFS (T574) 850 hPa WIND (kt) FORECAST (00 HR)

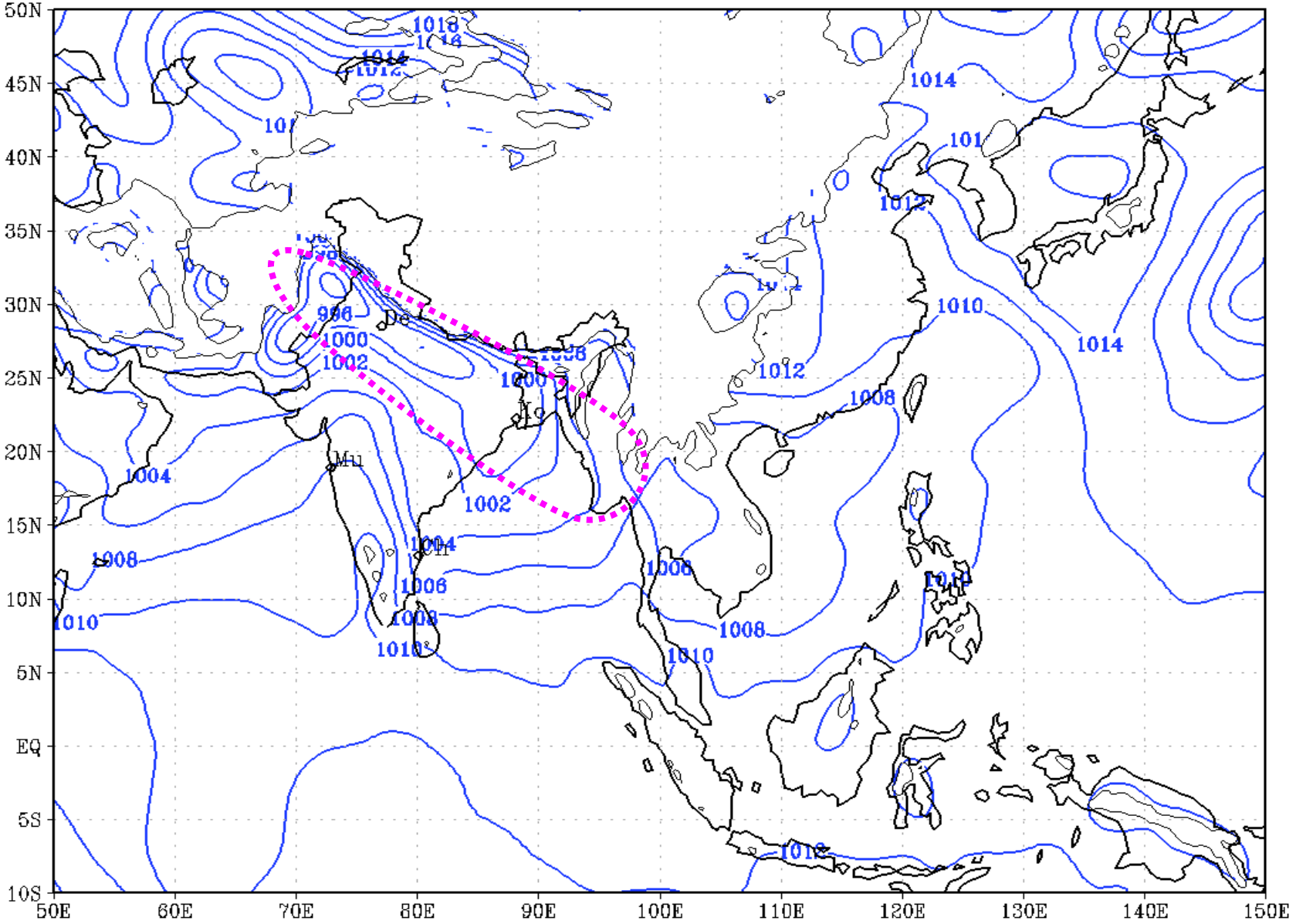
based on 00 UTC of 23-05-2016 valid for 00 UTC of 23-05-2016



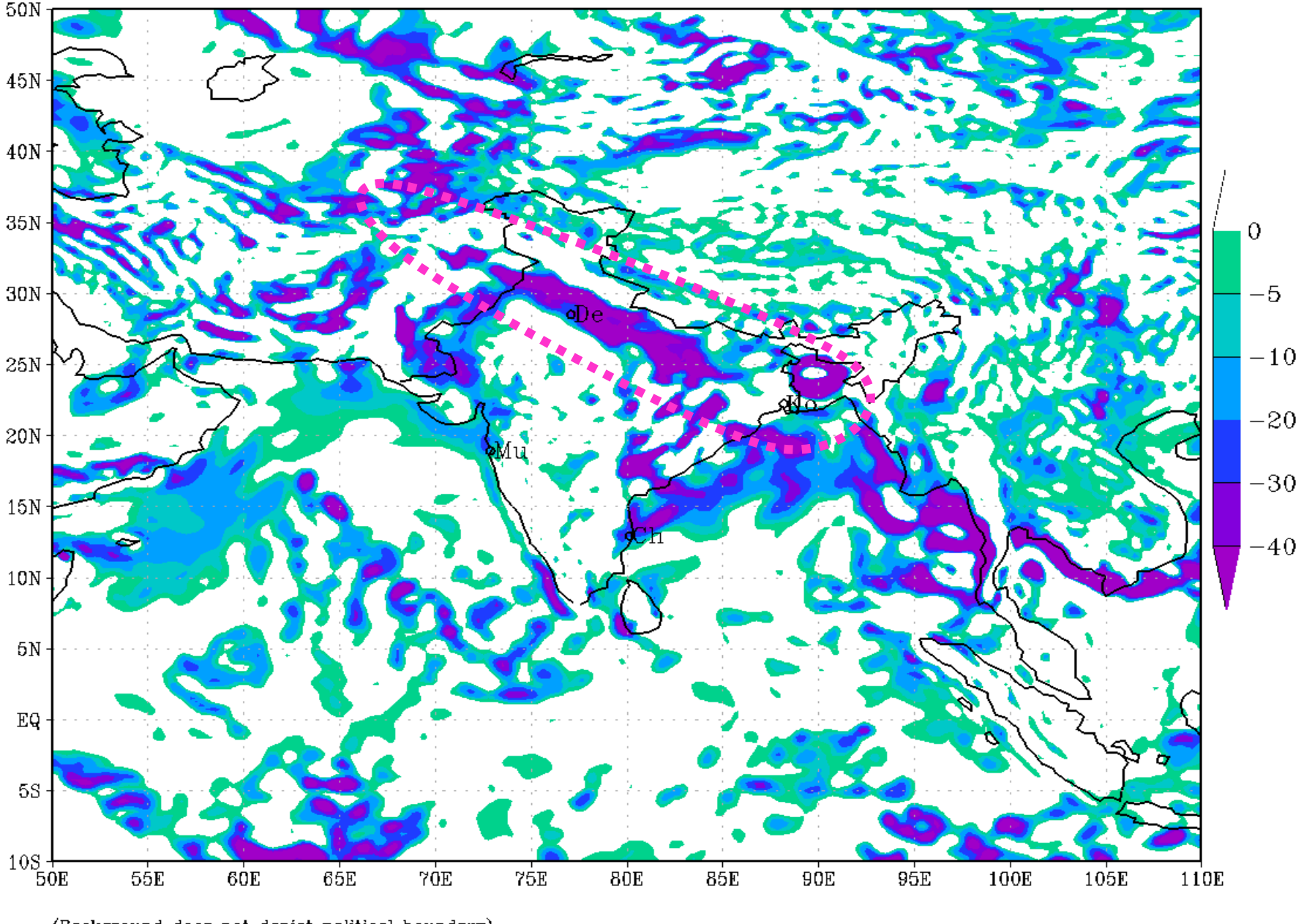
(Background does not depict political boundary)

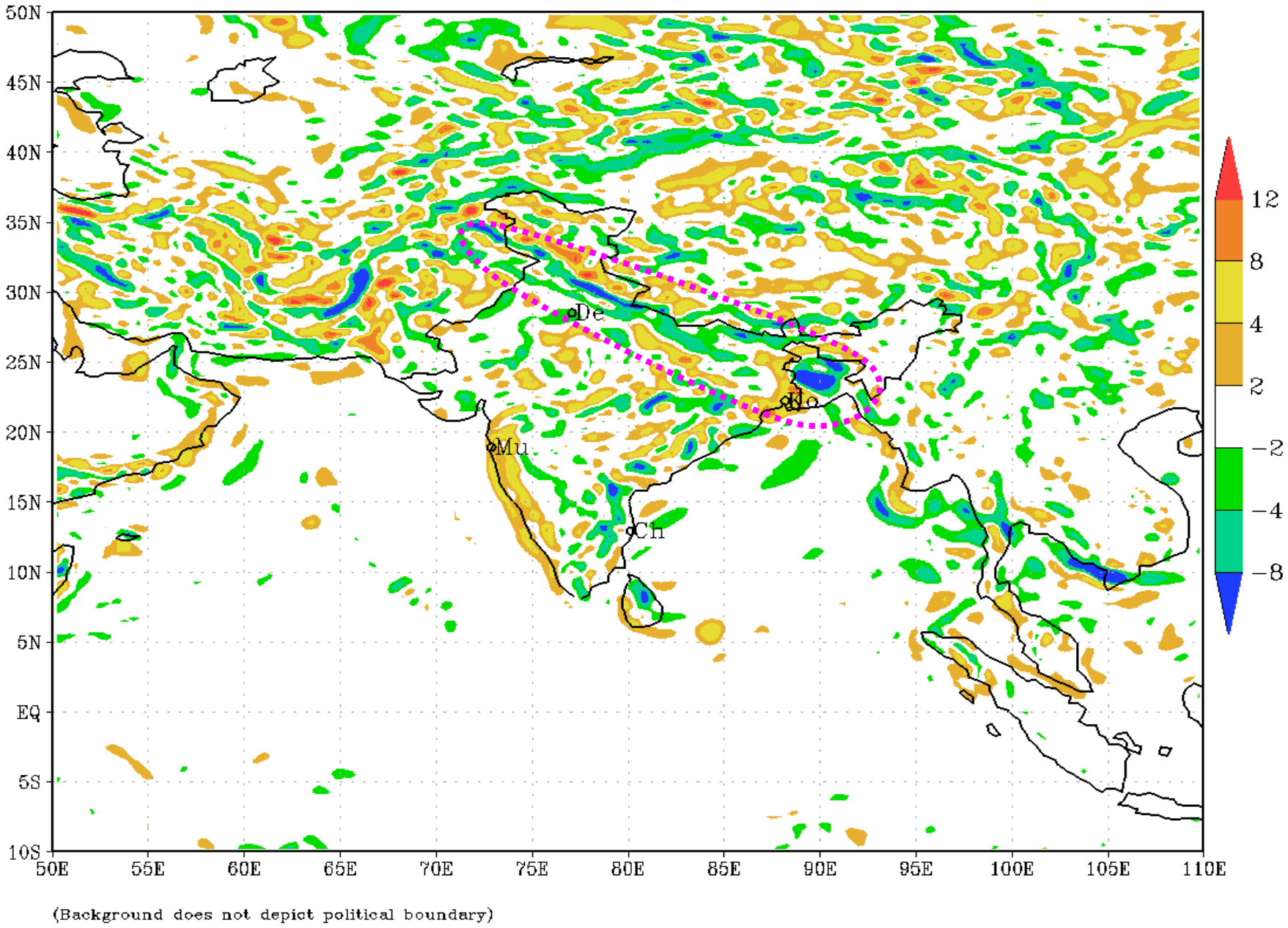
IMD GFS (T574) MSL Pressure (hPa) FORECAST (00 HR)

based on 00 UTC of 23-05-2016 valid for 00 UTC of 23-05-2016



(Background does not depict political boundary)


IMD GFS(T574) 850 hPa Pressure Vertical Velocity(1xe-4 hPa/sec) FORECAST (00 HR)
based on 00 UTC of 23-05-2016 valid for 00 UTC of 23-05-2016
50N
45N
40N
35N
30N
25N
20N
15N
10N
5N
EQ
5S
10S
50E
55E
60E
65E
70E
75E
80E
85E
90E
95E
100E
105E
110E
De
Mo
Mu
Ch
0
-5
-10
-20
-30
-40


IMD GFS(T574) 850 hPa DIVERGENCE (1xe-5 s-1) FORECAST (00 HR)
based on 00 UTC of 23-05-2016 valid for 00 UTC of 23-05-2016
50N
45N
40N
35N
30N
25N
20N
15N
10N
5N
EQ
5S
10S
50E
55E
60E
65E
70E
75E
80E
85E
90E
95E
100E
105E
110E
De
Mu
Ch
12
8
4
2
-2
-4
-8
(Background does not depict political boundary)

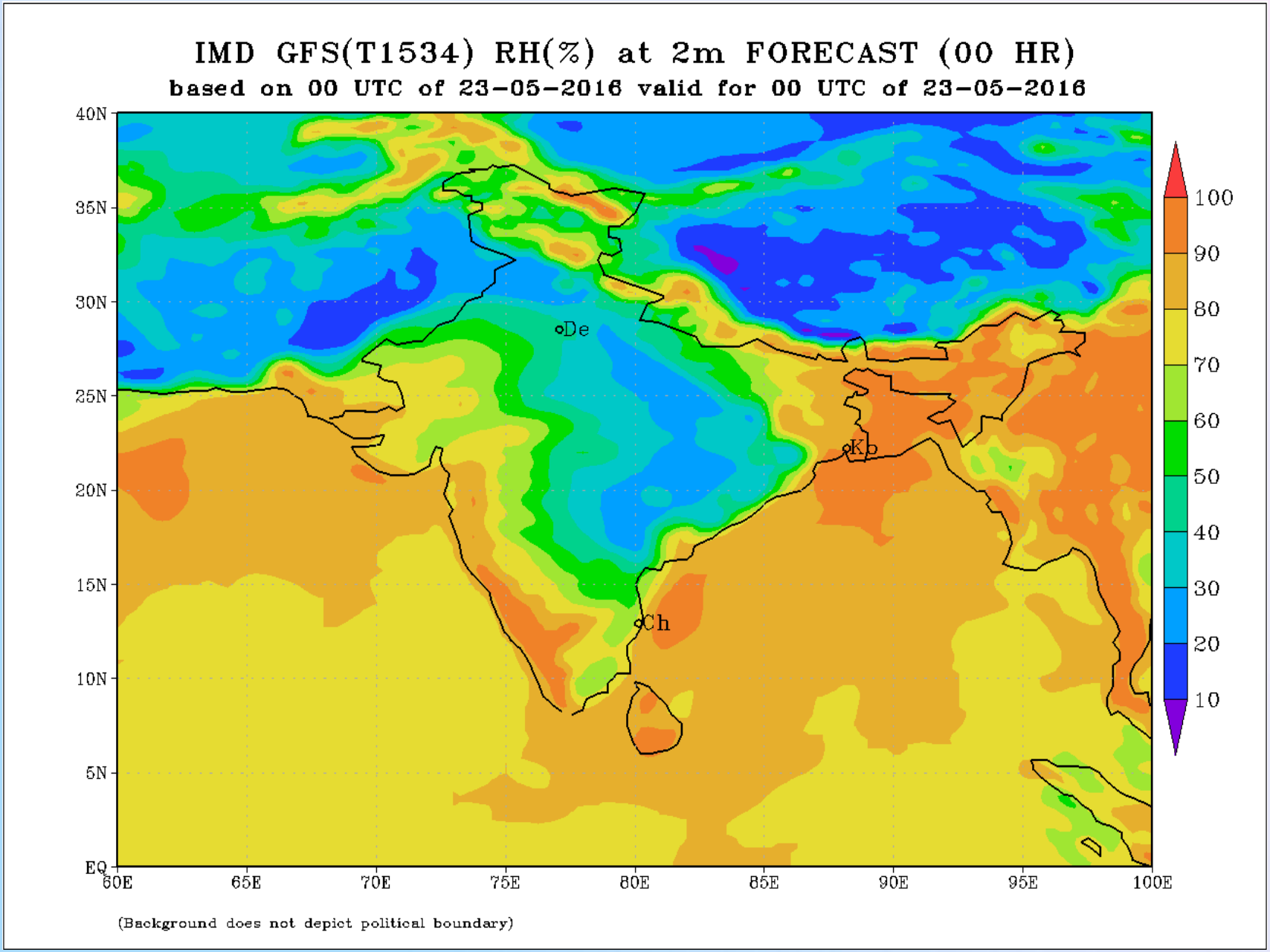
2. MOISTURE

Low level moisture is assessed by

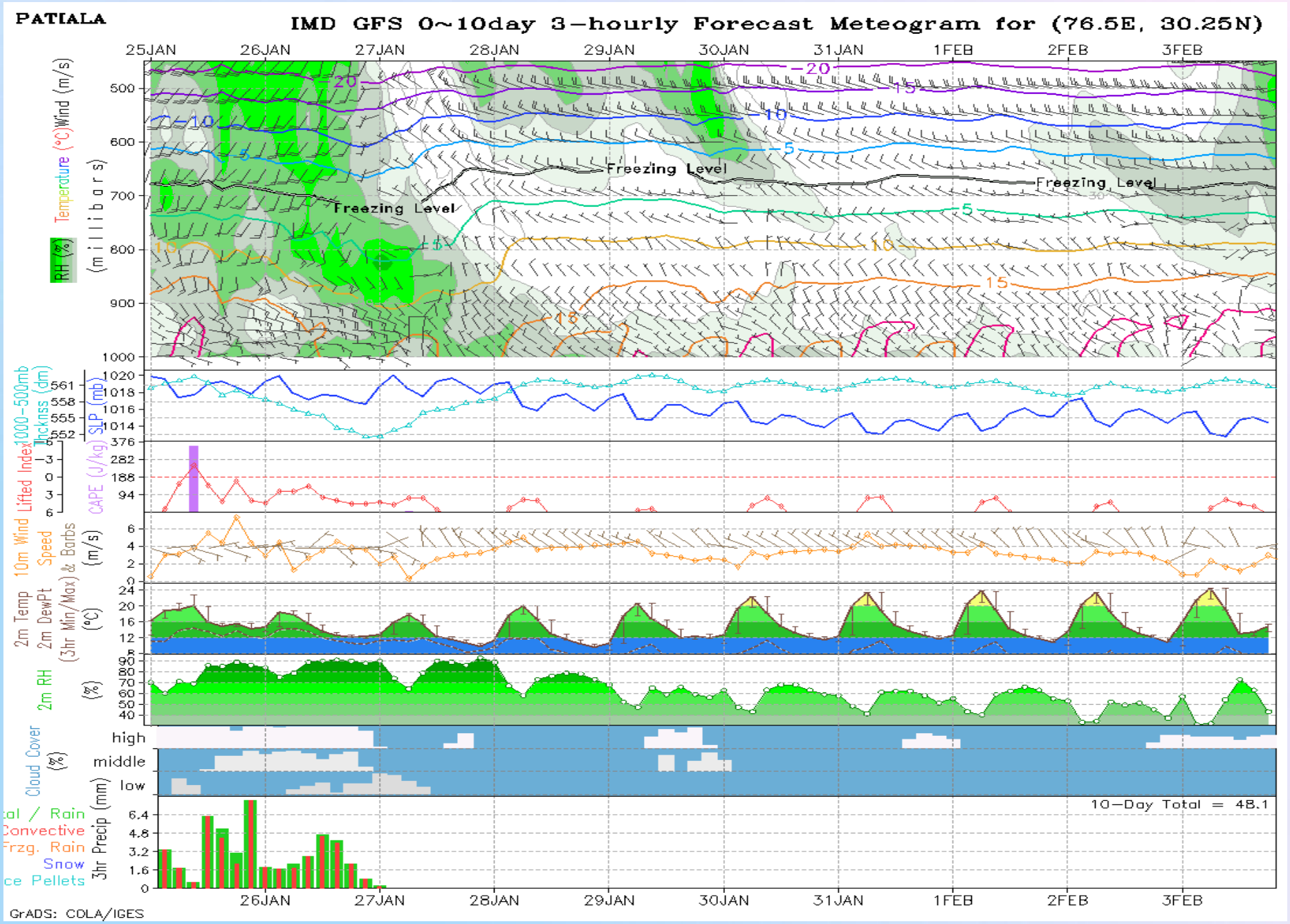
- Examining boundary layer dew points / moisture.
- The depth of moisture in the lower troposphere and the rate of moisture advection are also important to examine.
- Only look at 850-500 hPa relative humidity values in the warm sector of convective systems because this is where severe thunderstorms will develop.

While a lack of moisture in the lower troposphere reduces the severe storm threat, a lack of moisture in the middle troposphere is helpful to the severe storm threat if there is abundant moisture in the lower troposphere.

MOISTURE


IMD GFS(T1534) RH(%) at 2m FORECAST (00 HR)
based on 00 UTC of 23-05-2016 valid for 00 UTC of 23-05-2016
40N
35N
30N
25N
20N
15N
10N
5N
EQ
60E
65E
70E
75E
80E
85E
90E
95E
100E
De
Kb
Ch
100
90
80
70
60
50
40
30
20
10
(Background does not depict political boundary)

Vertical cross section of moisture



3. INSTABILITY

❖The combination of moisture and temperature determine the stability of the air and the resulting weather.

a) Cool, dry air is very stable and resists vertical movement, which leads to generally clear weather.

b) The greatest instability occurs when the air is warm and moist, which leads to disturbed weather (it is more in the tropical regions)

CONVECTIVE INSTABILITY

Convective Instability is assessed by examining

1. CAPE.
2. Lifted Index
3. Total Totals (TT) Index
4. K- Index, etc ..

Instability is a condition in which air will rise freely on its own due to positive buoyancy.

Convective available potential energy (CAPE)

- CAPE is the area between the parcel's temperature line and the environmental temperature line, where the ascending parcel is warmer than the environment
- It is an indicator of atmospheric instability, valuable in predicting severe weather.

Convective Available Potential Energy (CAPE)

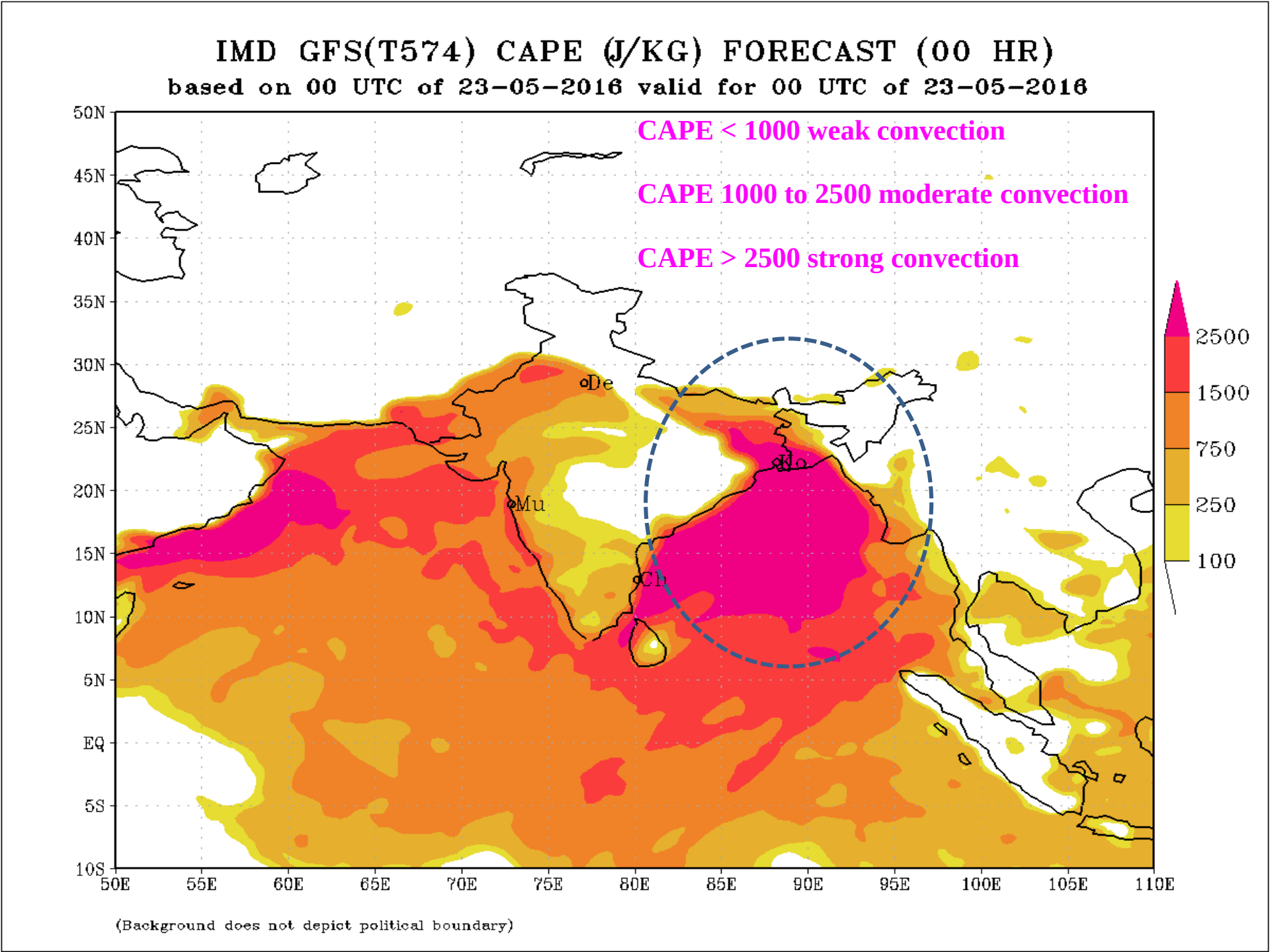
$$CAPE = -\int_{p_f}^{p_n} R_d \left(T_{vp} - T_{ve}\right) d \ln p$$

an indicator of atmospheric instability

Convective inhibition (CINE)

$$CIN = -\int_{p_i}^{p_f} R_d \left(T_{vp} - T_{ve}\right) d \ln p$$

- ✓Expect isolated regions of very heavy rain when thunderstorms form in a large CAPE and small CINE environment.
- ✓Large CAPE will produce thunderstorms with abundant lightning


IMD GFS(T574) CAPE (J/KG) FORECAST (00 HR)
based on 00 UTC of 23-05-2016 valid for 00 UTC of 23-05-2016
CAPE < 1000 weak convection
CAPE 1000 to 2500 moderate convection
CAPE > 2500 strong convection
2500
1500
750
250
100
De
Mu
Ch
Ko
50N
45N
40N
35N
30N
25N
20N
15N
10N
5N
EQ
5S
10S
50E
55E
60E
65E
70E
75E
80E
85E
90E
95E
100E
105E
110E
(Background does not depict political boundary)

K - Index

K-INDEX K = $(T_{850} - T_{500}) + Td_{850} - (T_{700} - Td_{700})$

❖The temperature difference between 850 hPa and 500 hPa is used to assess the vertical temperature lapse rate.

❖The 850 hPa dew point provides information on the moisture content of the lower atmosphere.

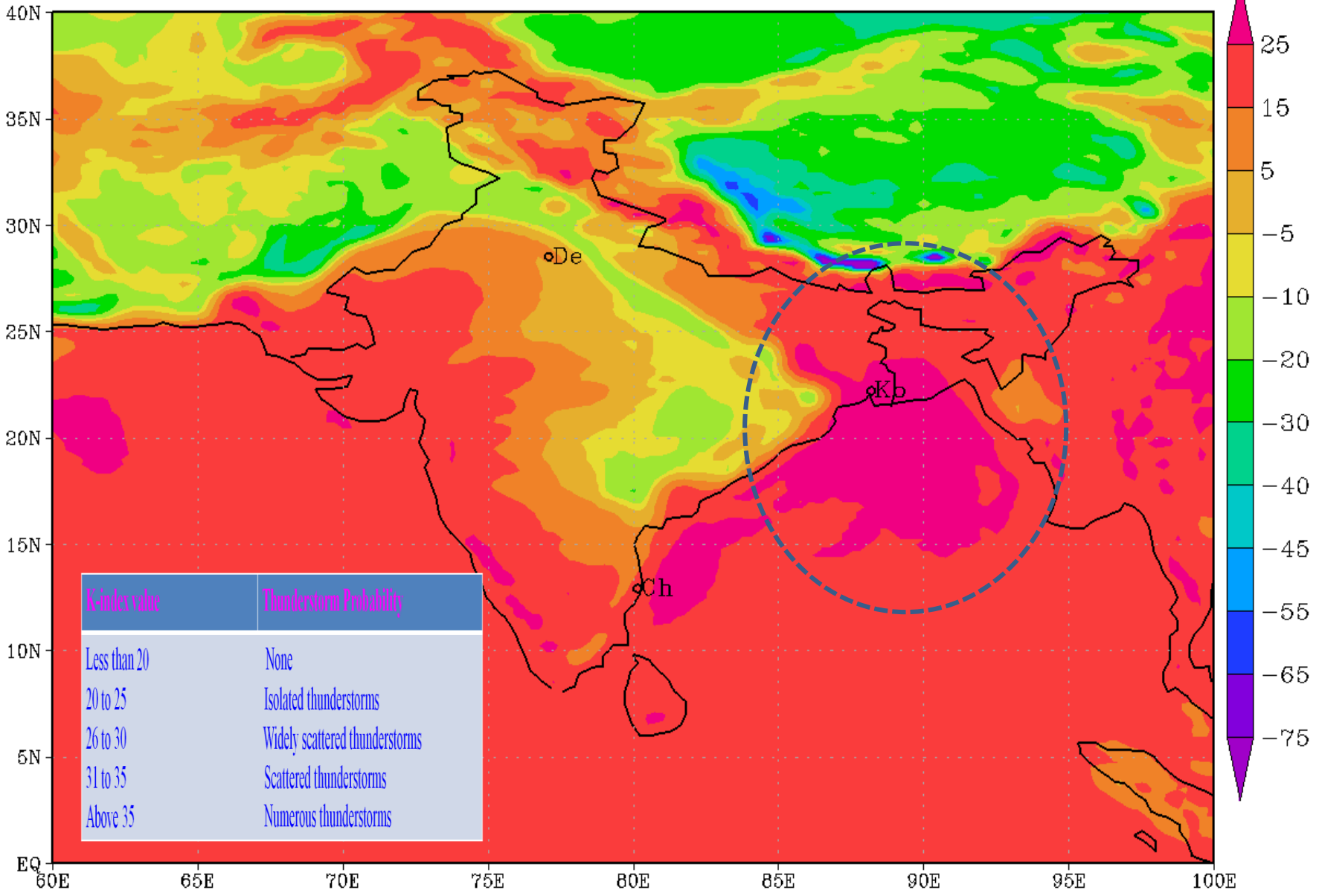
❖• The vertical extent of the moist layer is represented by the difference of the 700 hPa Temp and 700 hPa dew point temperature.

K-index value	Thunderstorm Probability
Less than 20	None
20 to 25	Isolated thunderstorms
26 to 30	Widely scattered thunderstorms
31 to 35	Scattered thunderstorms
Above 35	Numerous thunderstorms

The K index is a poor indicator of severe thunderstorms since dry air at 700 hPa may indicate convective instability. Dry air at 700 hPa will give a low value to the K-Index.

IMD GFS(T1534) K-INDEX (DEG. C) FORECAST (00 HR)

based on 00 UTC of 23-05-2016 valid for 00 UTC of 23-05-2016



K-index value	Thunderstorm Probability
Less than 20	None
20 to 25	Isolated thunderstorms
26 to 30	Widely scattered thunderstorms
31 to 35	Scattered thunderstorms
Above 35	Numerous thunderstorms

(Background does not depict political boundary)

LIFTED INDEX

$$LI = T_{500} - Tp_{500}$$

- The lower the value, the better the chance for thunderstorms (severe weather).

Operational Guide:

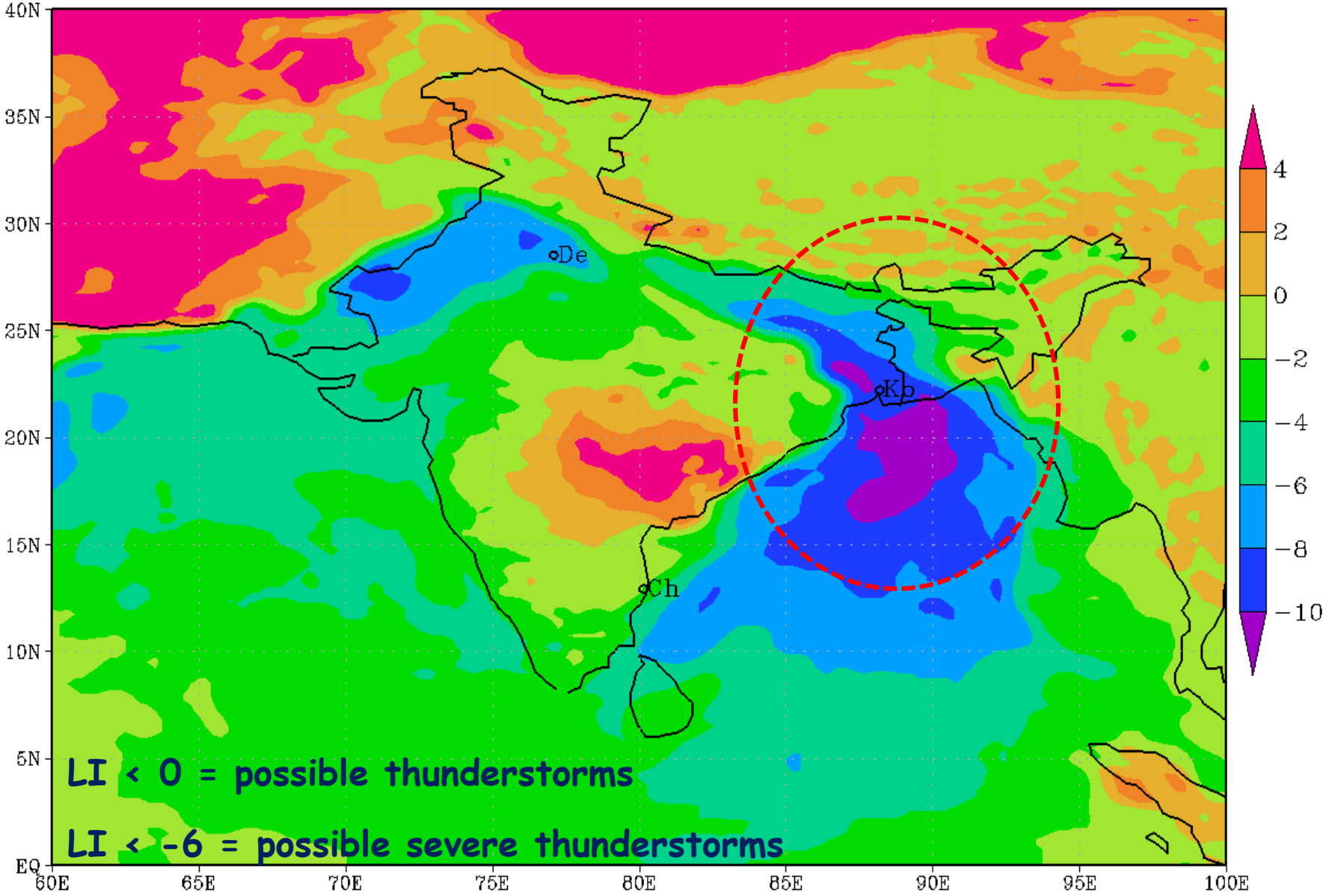
LI < 0 = possible thunderstorms

LI < -6 = possible severe thunderstorms

The LIFTED INDEX can be used in thunderstorm forecasting, however, CAPE is considered as a superior measurement of instability and is preferred by many meteorologists for convection forecasting.

IMD GFS(T1534) LIFTED INDEX FORECAST (06 HR)

based on 00 UTC of 23-05-2016 valid for 06 UTC of 23-05-2016



(Background does not depict political boundary)

4. WIND SHEAR

❖Strong vertical wind shear **(200-850 hPa)** is important to severe thunderstorm development.

❖Wind shear influences a storm in several ways:

1. VERTICAL SPEED SHEAR: Significant increase of wind speed with height.
2. VERTICAL DIRECTIONAL SHEAR: Significant change of wind direction with height.

VERTICAL SPEED SHEAR

A significant increase of wind speed with height

- Allows the updraft and downdraft to occur in separate regions of the storm
- Reduces water loading in the updraft.
- The downdraft will not cut-off the updraft
- Allows the updraft to sustain itself.

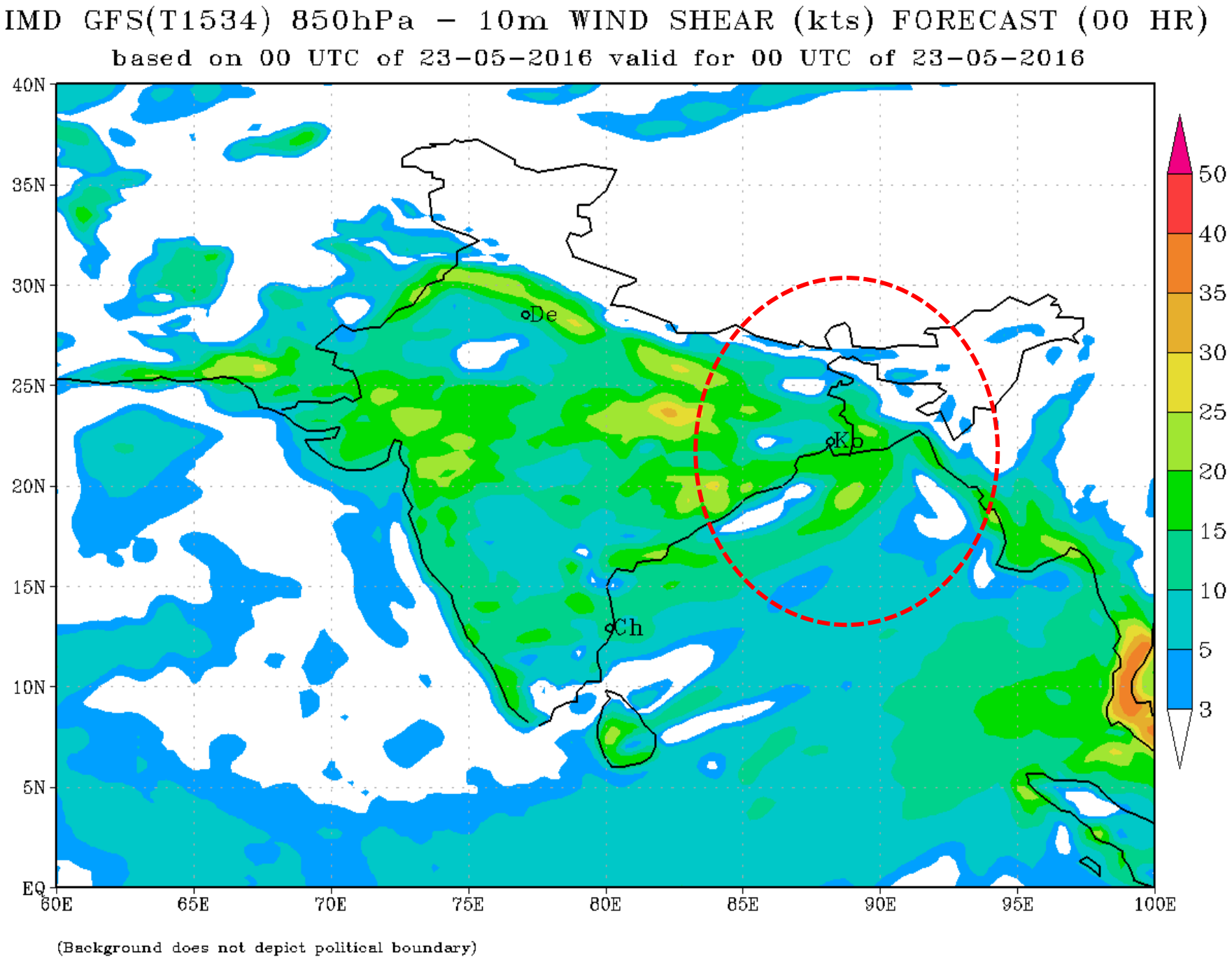
VERTICAL DIRECTIONAL SHEAR

- Directional shear in the lower troposphere initiate the development of a rotating updraft.
- This is one component that is important to the development of any convective systems genesis.

Low Level wind shear

Low Level Wind Shear: 850 hPa - 10m

❖This **Low Level wind shear** between 900 hPa and 10m is computed from the magnitude of **wind** vector i.e. the zonal (*U*) and meridional (*V*) wind components at 2 different vertical levels.


IMD GFS(T1534) 850hPa – 10m WIND SHEAR (kts) FORECAST (00 HR)
based on 00 UTC of 23-05-2016 valid for 00 UTC of 23-05-2016
40N
35N
30N
25N
20N
15N
10N
5N
EQ
60E
65E
70E
75E
80E
85E
90E
95E
100E
De
Kb
Ch
50
40
35
30
25
20
15
10
5
3
(Background does not depict political boundary)

HAILSTORM

HAILSTORM

❖Any thunderstorm that produces hail that reaches the ground is known as a Hailstorm.

❖Hail is classified as severe if it is equal to or greater than 1" in diameter.

❖Below are factors to consider when trying to forecast for the likeliness of Hail.

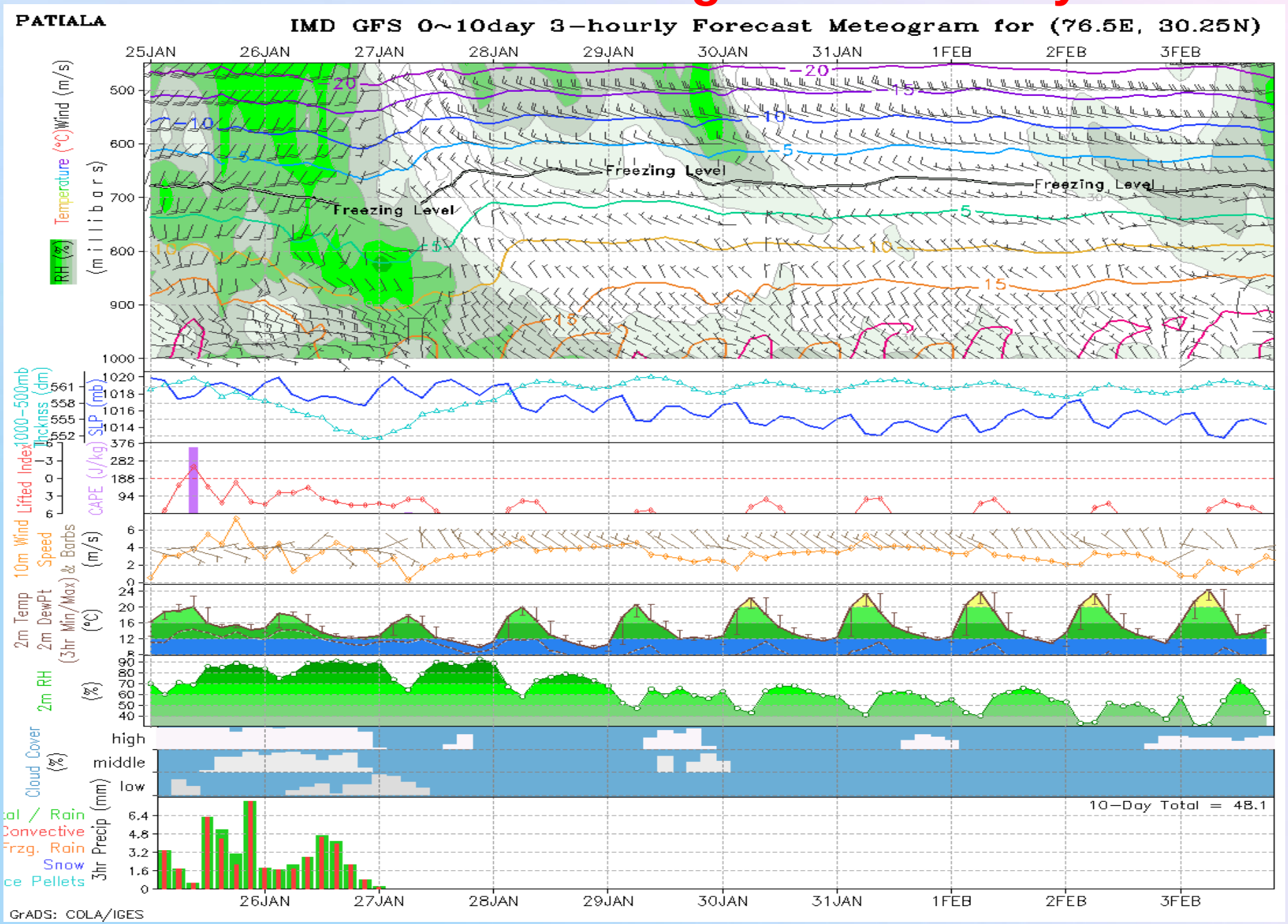
- LOW FREEZING LEVELS,
- HIGH ELEVATION,
- LOW PRECIPTABLE WATER,
- DRY AIR IN MID-LEVEL ,
- HIGH CAPE,
- LARGE WIND SHEAR.

FREEZING LEVEL:

- The **freezing level** determines the depth of the atmosphere that is above freezing.
- If the freezing level is high in the atmosphere, hailstones will have more time to melt than if the freezing level is close to the surface.
- The freezing level depends on elevation, the season, and the temperature profile of the atmosphere.
- High elevation areas will have relatively low freezing levels in all seasons.
- For low elevation areas, a general rule to follow is:
  - ✓ If the freezing level is closer to the surface than 700 hPa, strong thunderstorms have a good probability of producing hail that will reach the surface.

(The freezing level can be found readily by examining the T-Phigram /meteogram/model temperature plots.)

Hailstorm over Patiala during 25-26 January 2017



Rainfall

Study of Atmospheric Moisture Flux and Its Effect on Precipitation over India during summer monsoon season using Global Forecasting System (GFS)

Data and Methodology

- In this study, the daily rainfall analysis from the use of rain gauge observations (IMD Pune) over land and satellite (TRMM) derived quantitative precipitation estimates (3B42V6) over sea areas are used.

1. The vertically integrated water moisture flux (**Q)** is computed by

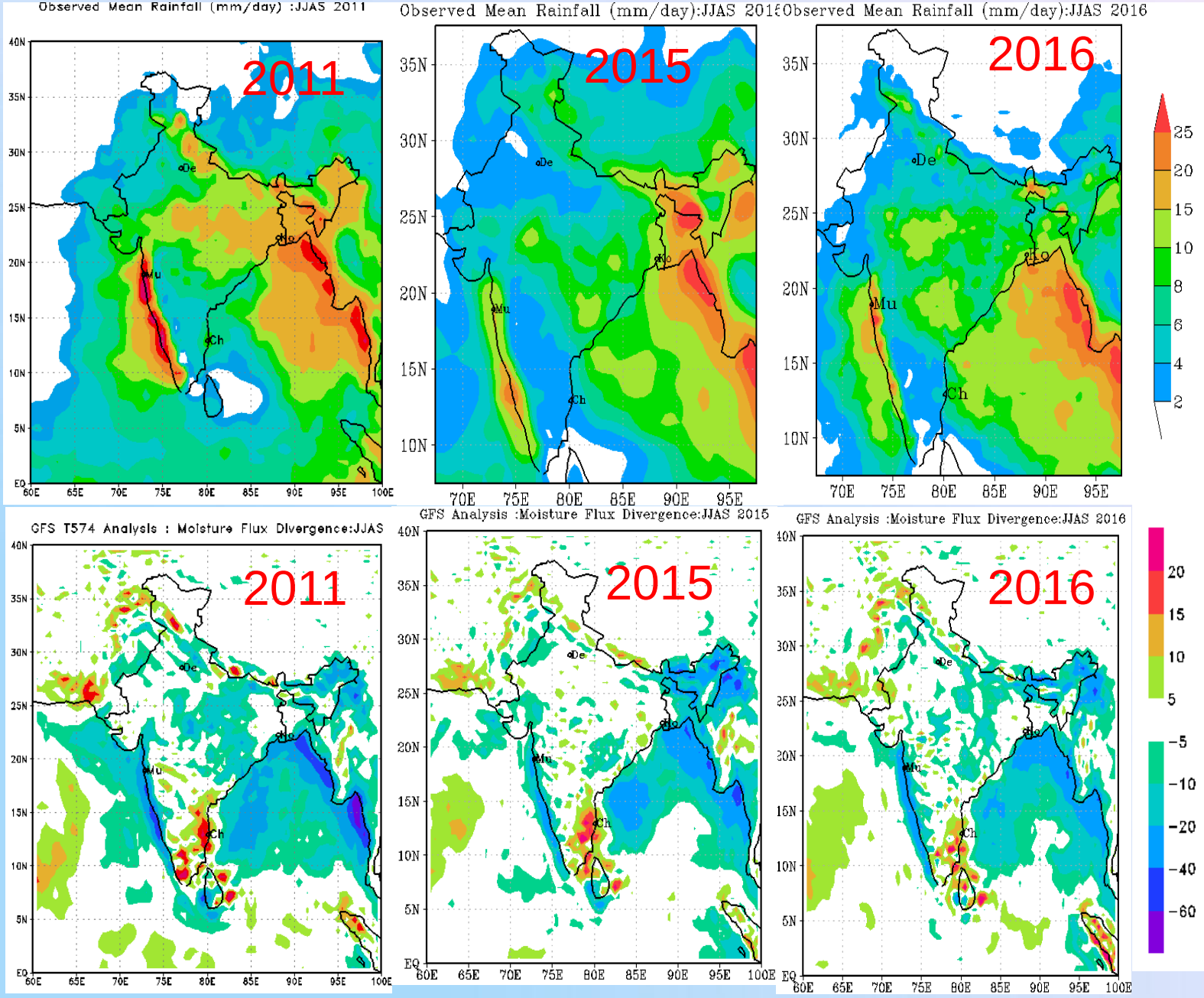
$$Q = \frac{1}{g}\int_{P_{sfc}}^{P_{top}} qV\,dp$$

where the limit of the integration is from the surface to the top of the atmosphere and g is the acceleration due to gravity. V is the vector wind velocity

2. The vertically integrated moisture flux convergence **(MFC)** is computed by

$$MFC = -\nabla.Q$$

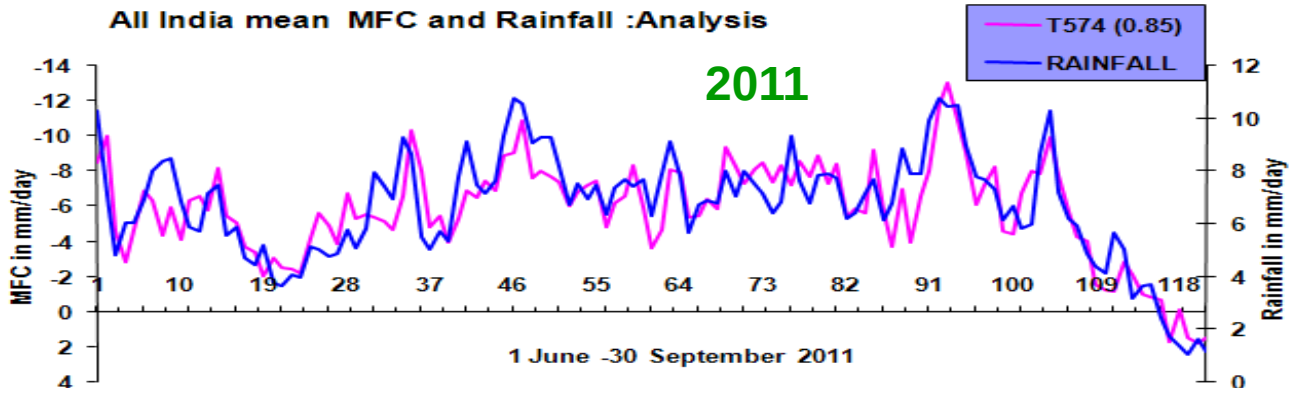
Seasonal Mean (JJAS): Vertically Integrated Moisture Flux Convergence *(1.e-5 *Kg /m2/sec)*

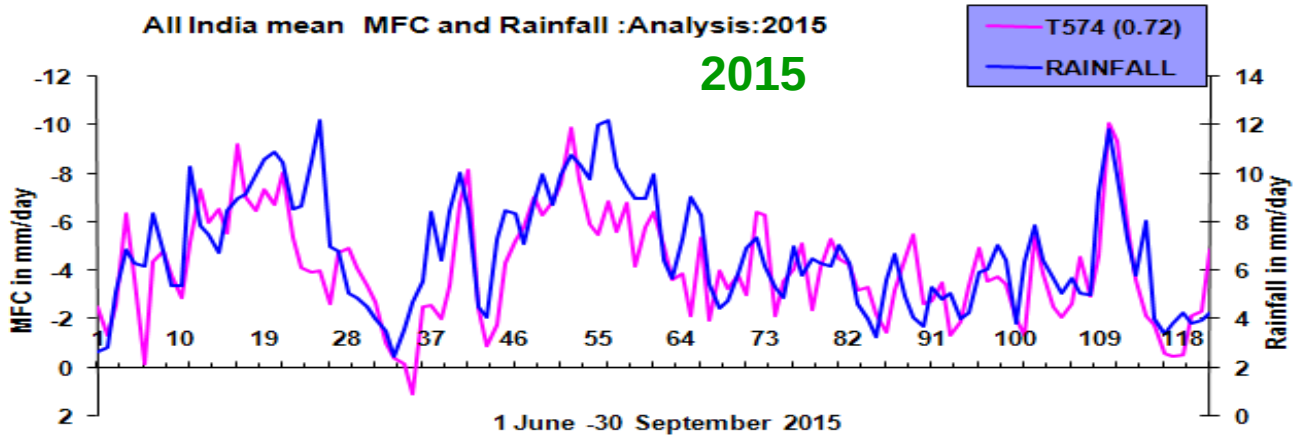


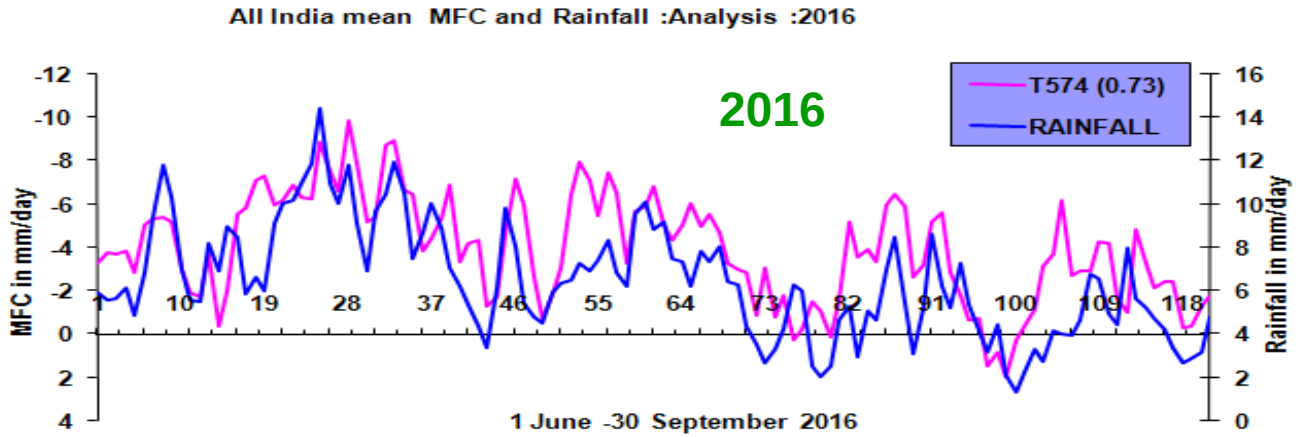
- GFS T574 VMFC shows that the monsoon region is dominated by moisture flux convergence with maximum along the west coast of India and another along the Myanmar – Thailand coast.

- The MFC provides the necessary net moisture availability over the monsoon region to sustain the high levels of condensation.

Daily mean: Observed Rainfall and GFS MFC Analysis

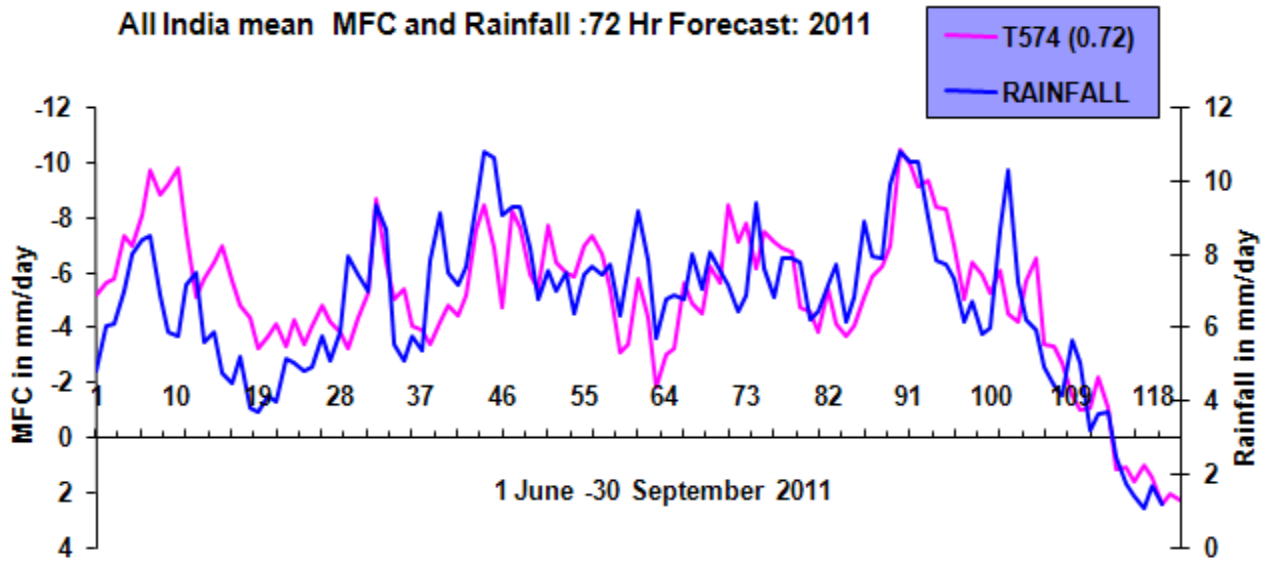


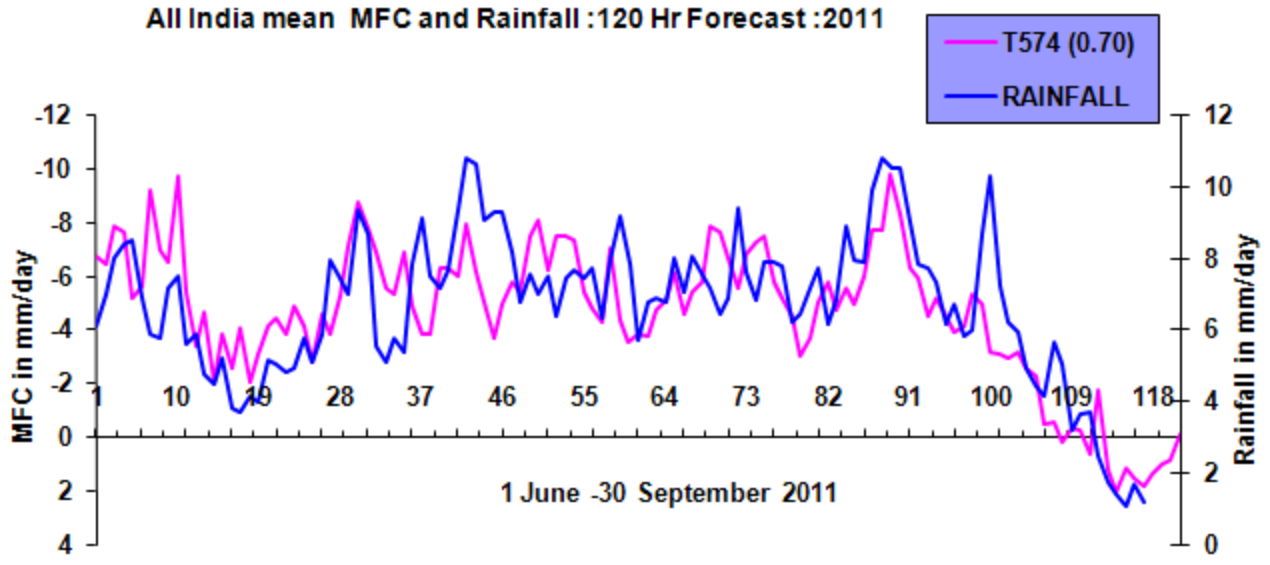




Daily mean all India vertically integrated moisture flux convergence of GFS Analysis is matching with mean observed rainfall with high CC during monsoon 2011,2015 & 2018 seasons.

Daily mean: Observed Rainfall and MFC *72 & 120 hr. Forecast:* ***2011***





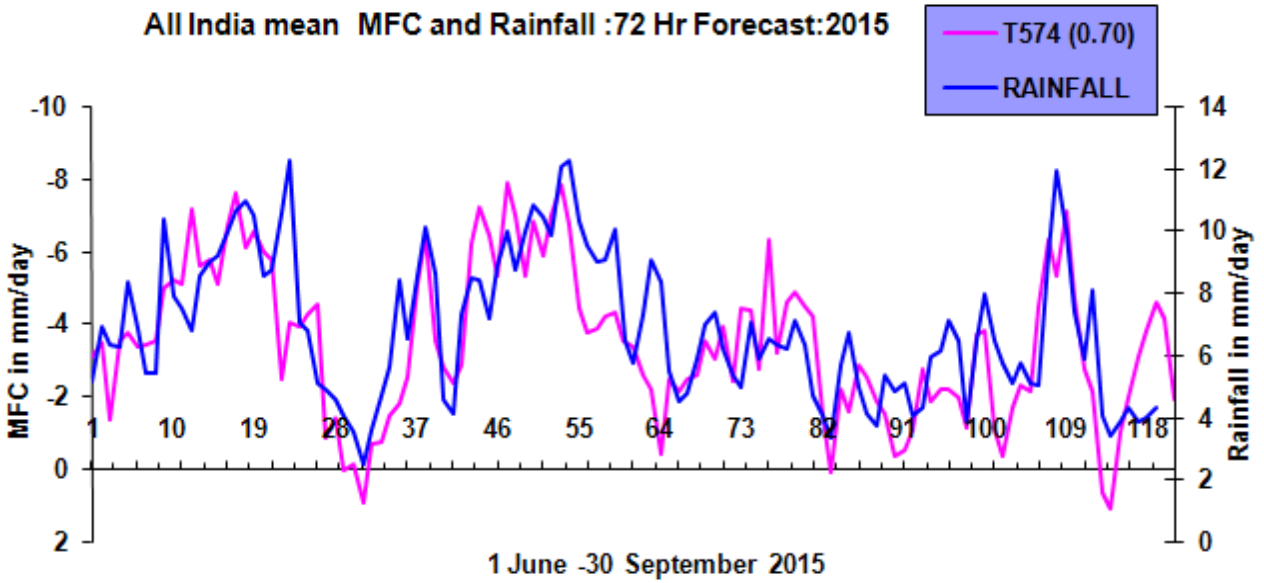
Daily mean all India observed rainfall ; and vertically integrated moisture flux convergence in the 72 & 120 hr forecast of GFS T574 during monsoon 2011

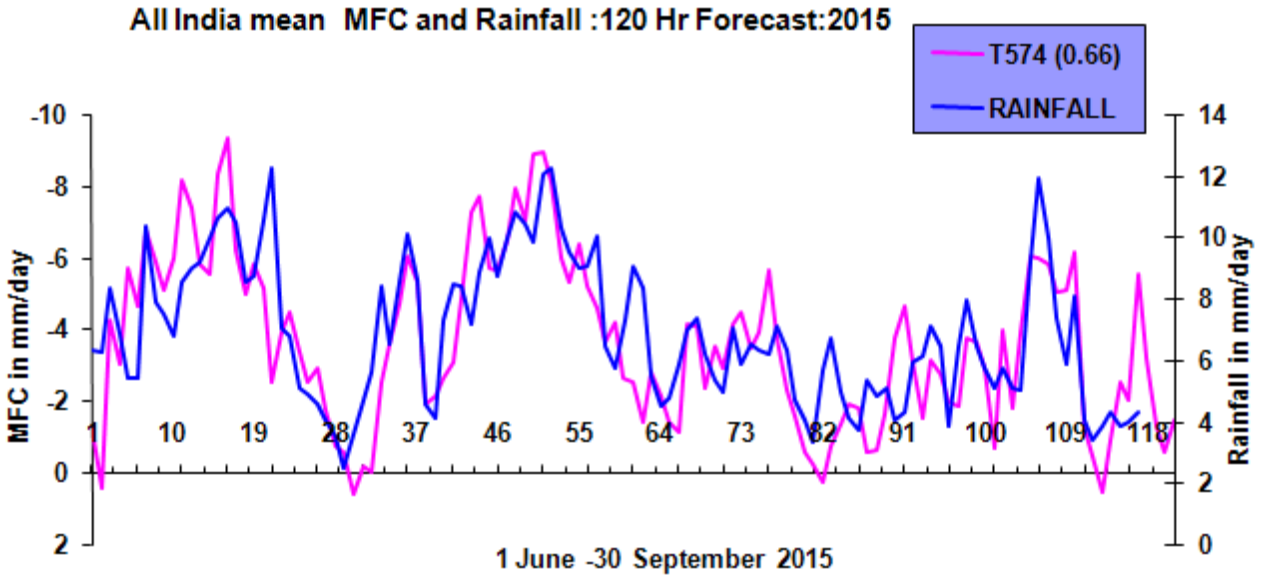
CC :

DAY-3: 0.72

DAY-5 :0.70

Daily mean: Rainfall and MFC*(mm/day)* *72 & 120 hr. Forecast:* ***2015***





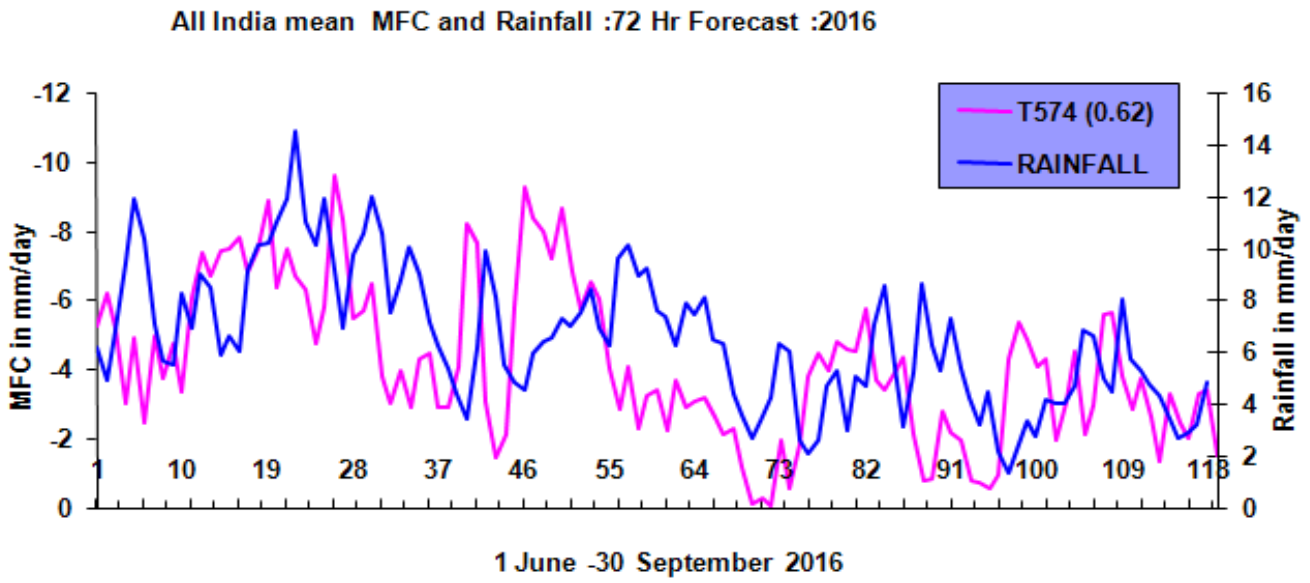
Daily mean all India observed rainfall ; and vertically integrated moisture flux convergence in the 72 & 120 hr forecast of GFS T574 during monsoon 2015

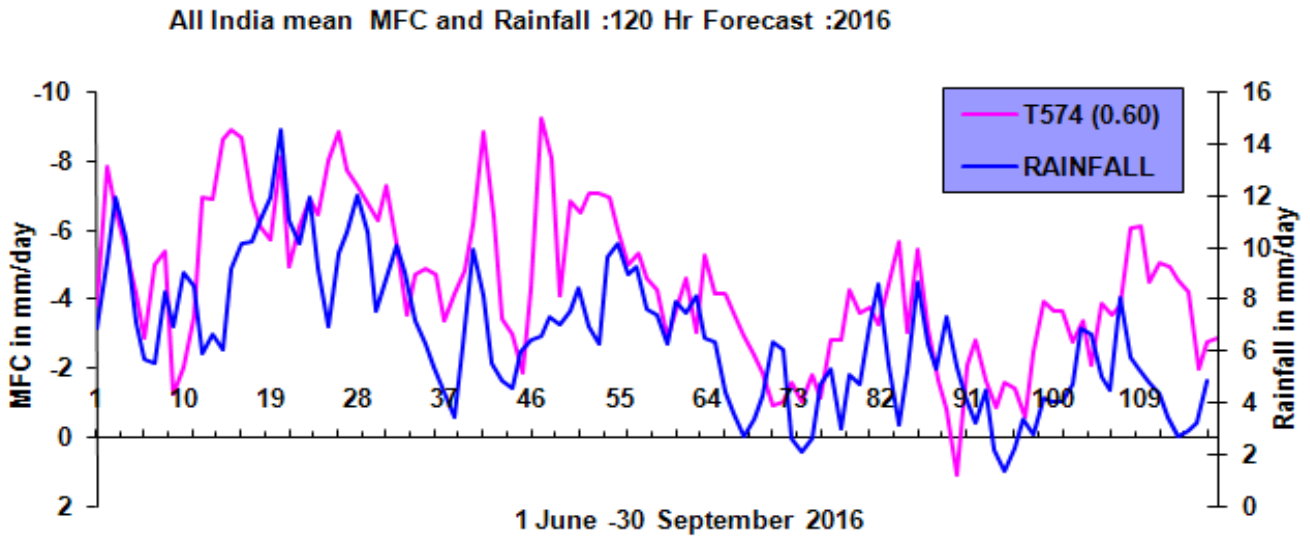
CC : 2015

DAY-3: 0.70

DAY-5 :0.66

Daily mean: Rainfall and MFC*(mm/day)* *72 & 120 hr. Forecast:* ***2016***





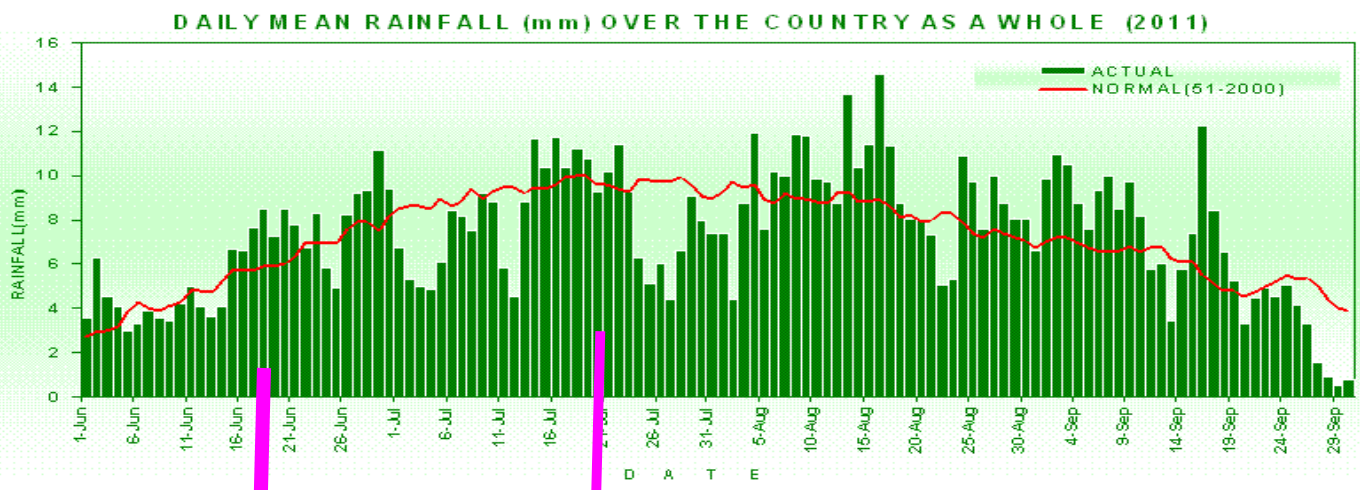
Daily mean all India observed rainfall ; and vertically integrated moisture flux convergence over India in the 72 & 120 hr forecast of GFS during monsoon 2016

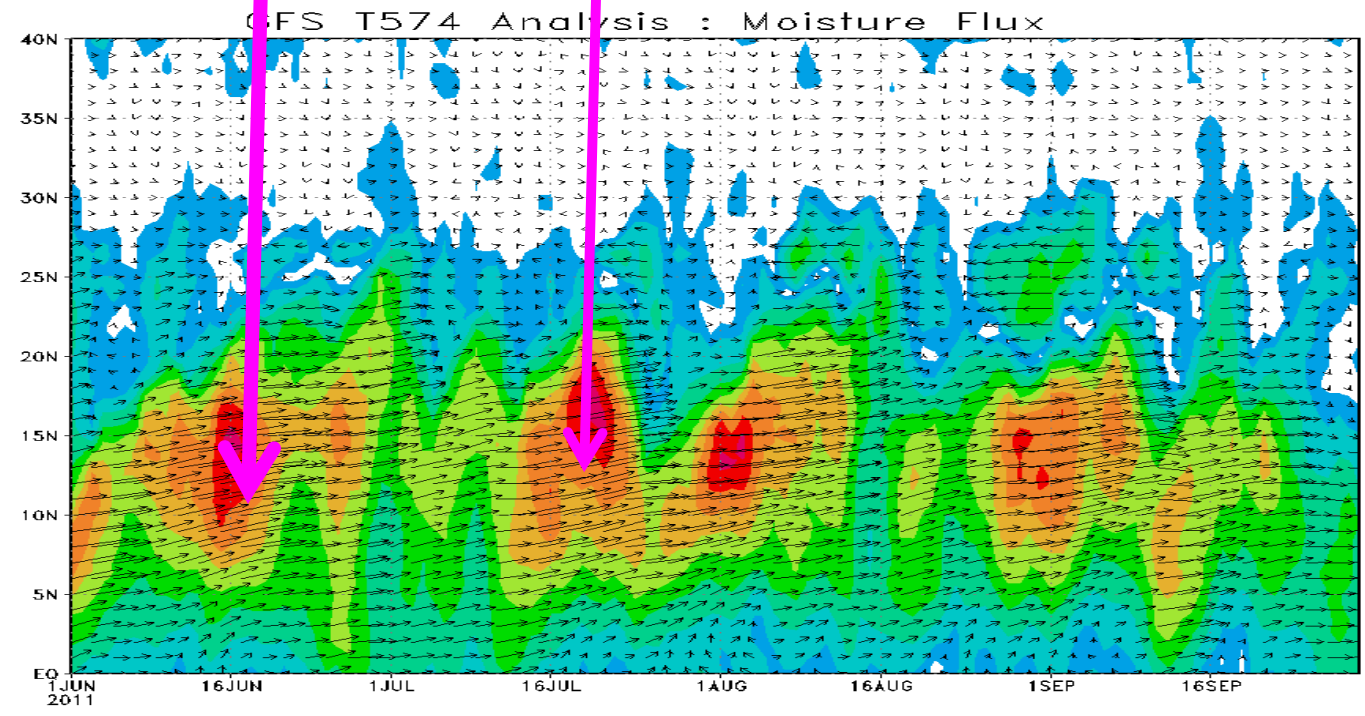
CC : 2016

DAY-3: 0.62

DAY-5 :0.60

Active and weak phase : monsoon 2011

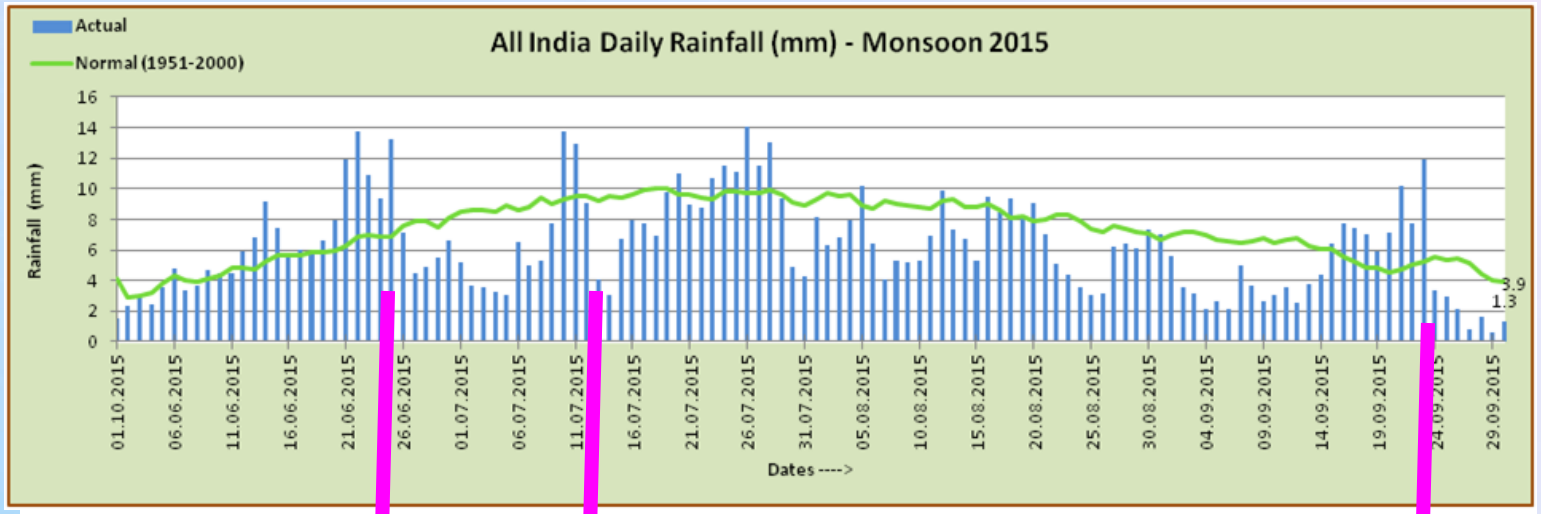


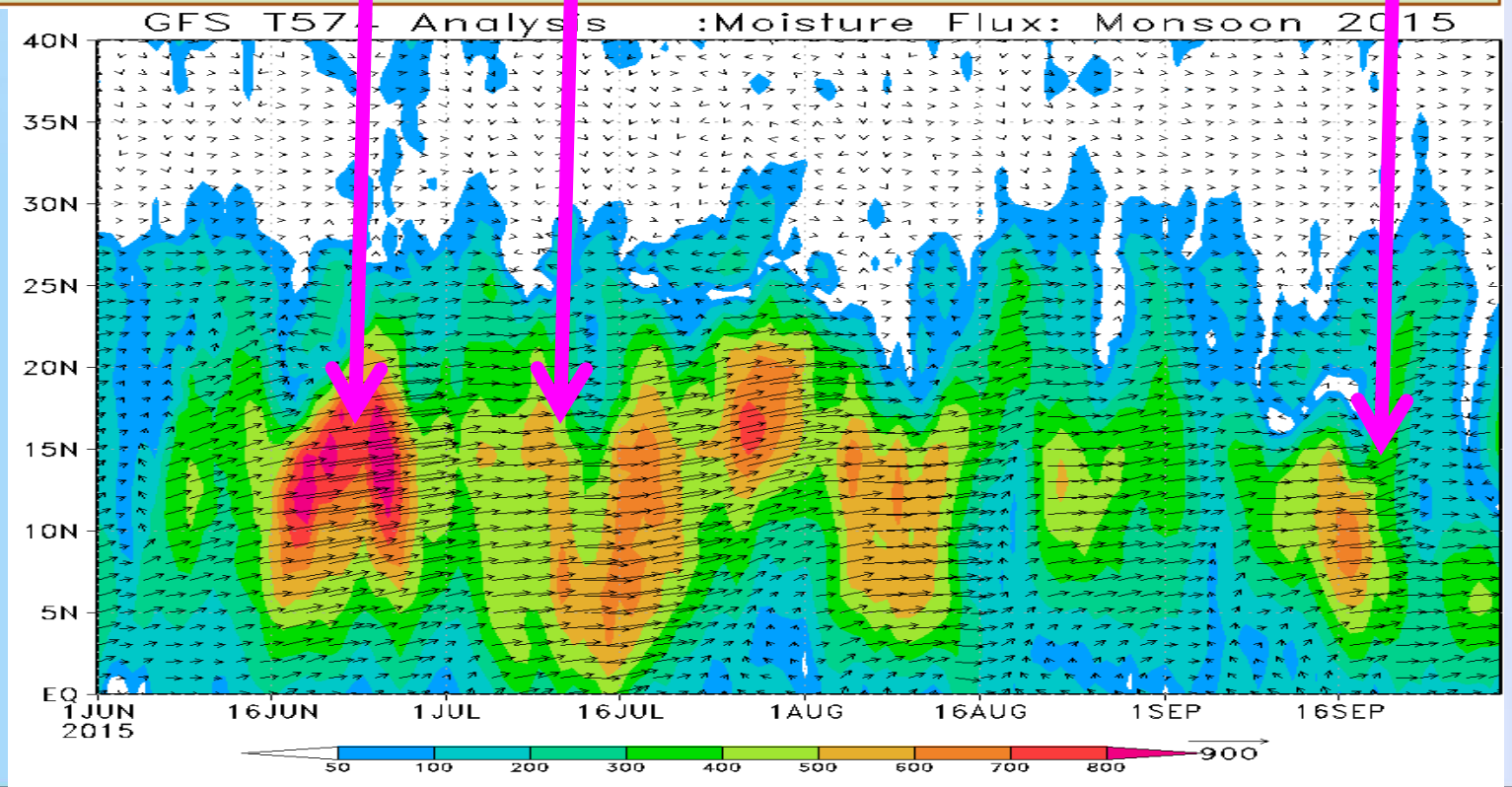


Availability of Moisture flux during Active and weak phases of monsoon :2011

Zonally averaged Vertically integrated moisture flux of GFS model could capture the Active and weak phases monsoon

Active and weak phase : monsoon 2015

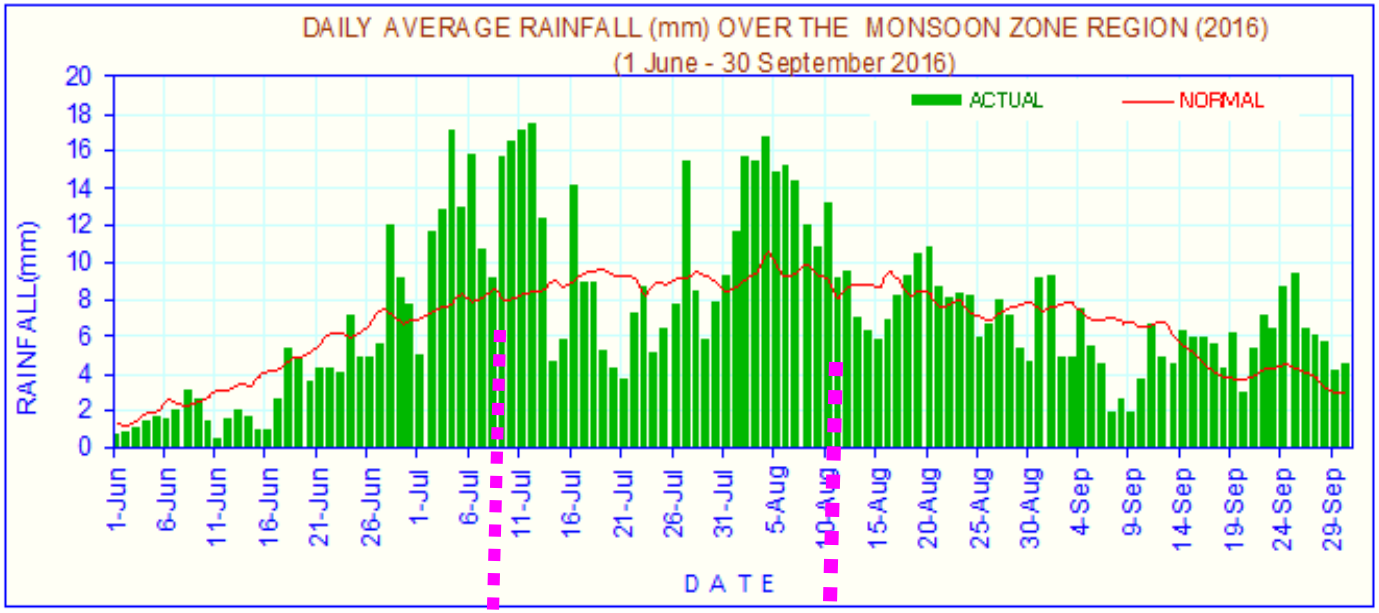


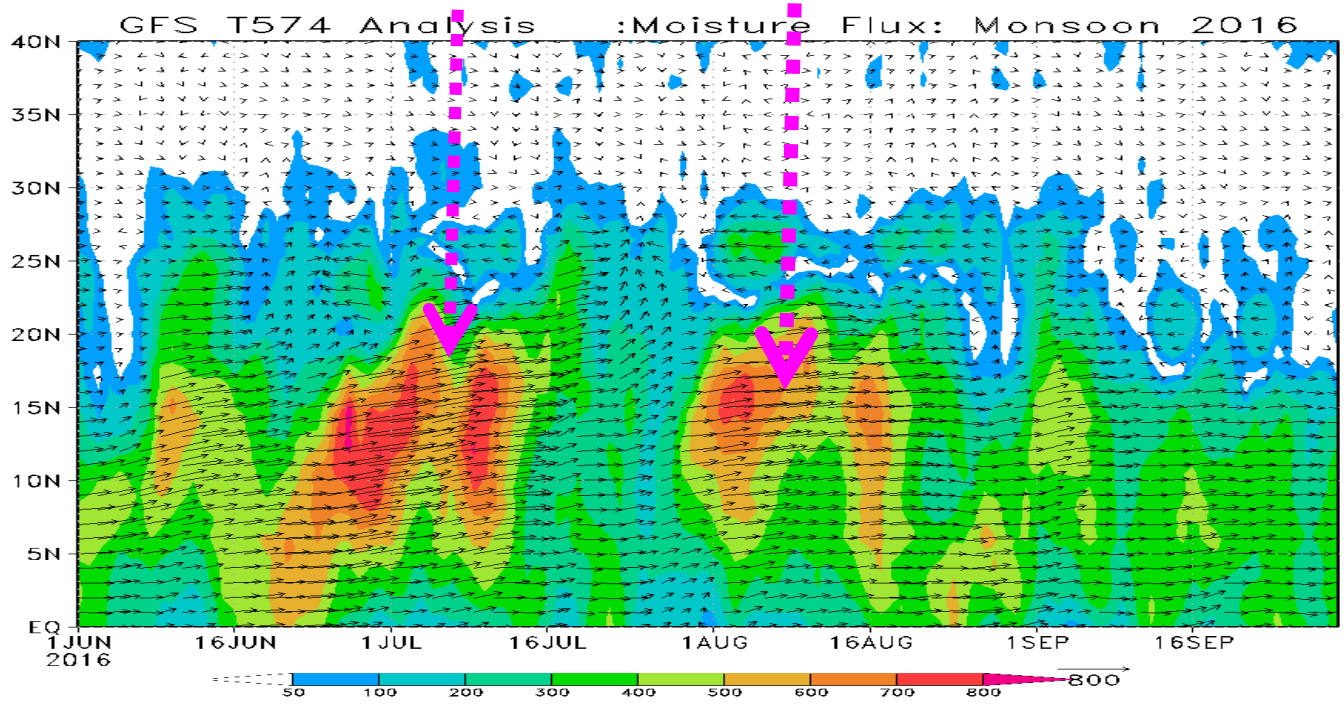


Availability of Moisture flux during Active and weak phases of monsoon :2015

model could capture the Active and weak phases monsoon

Active and weak phase : monsoon 2016





Availability of Moisture flux during Active and weak phases of monsoon :2016

Zonally averaged Vertically integrated moisture flux of GFS model could capture the Active and weak phases monsoon

Conclusion

- Results shows that Daily mean all India vertically integrated moisture flux convergence of GFS model is matching with mean observed rainfall with high CC during monsoon seasons.

- Zonally averaged Vertically integrated moisture flux of GFS model could capture the Active and weak phases monsoon.

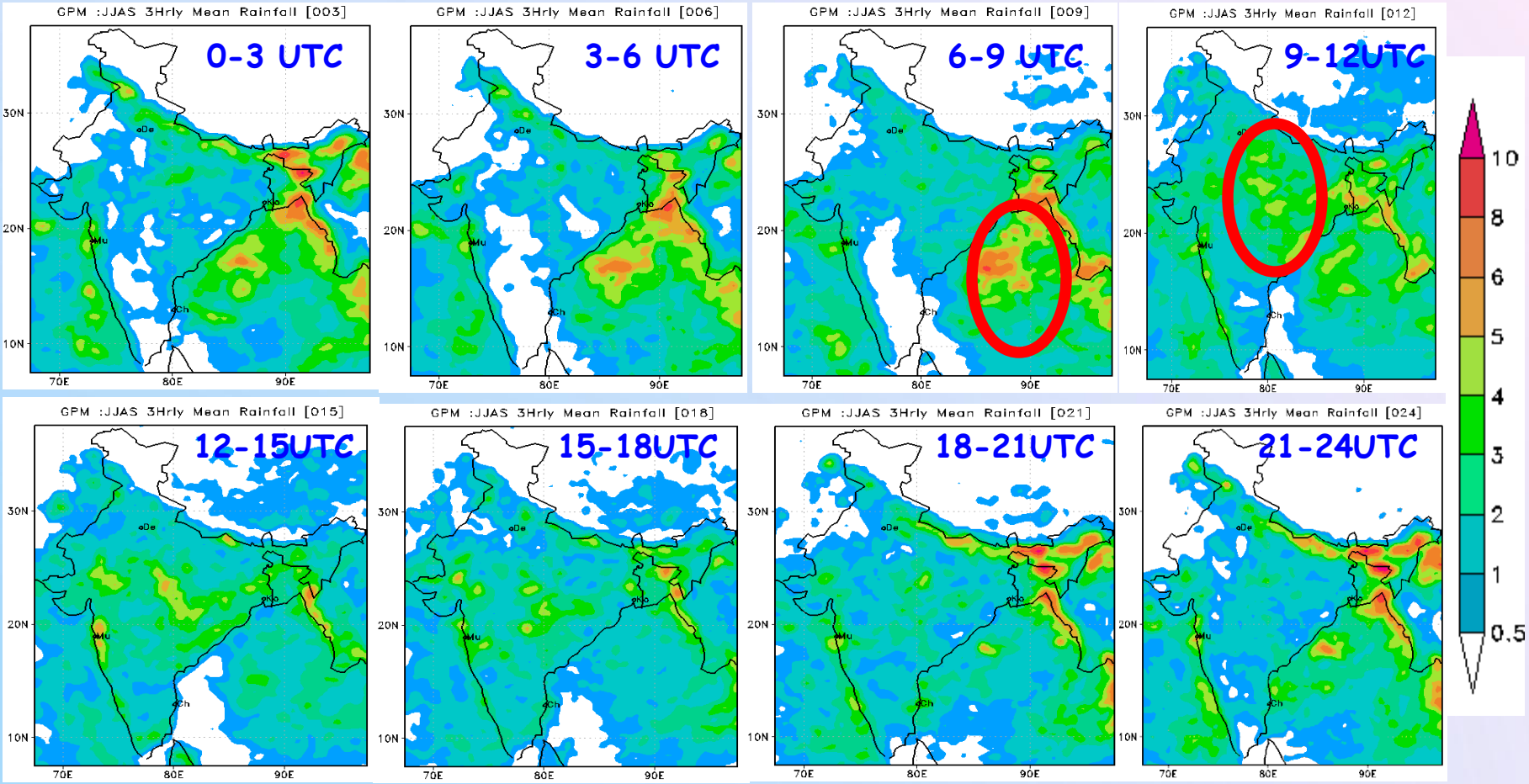
Diurnal cycle of Summer Monsoon Rainfall

Diurnal Variability of Summer Monsoon Rainfall

- The mechanisms/forces responsible for the diurnal variation of rainfall are,
  a) heating caused by solar radiation
  b) land/sea breezes (along the coast)
  c) Meso-scale circulations

- Results of the diurnal variability of the Observed and Model Predicted Precipitation over India during the Summer Monsoon Season 2017 is discussed.

GPM- 3 hourly JJAS mean rainfall (mm) of 2017

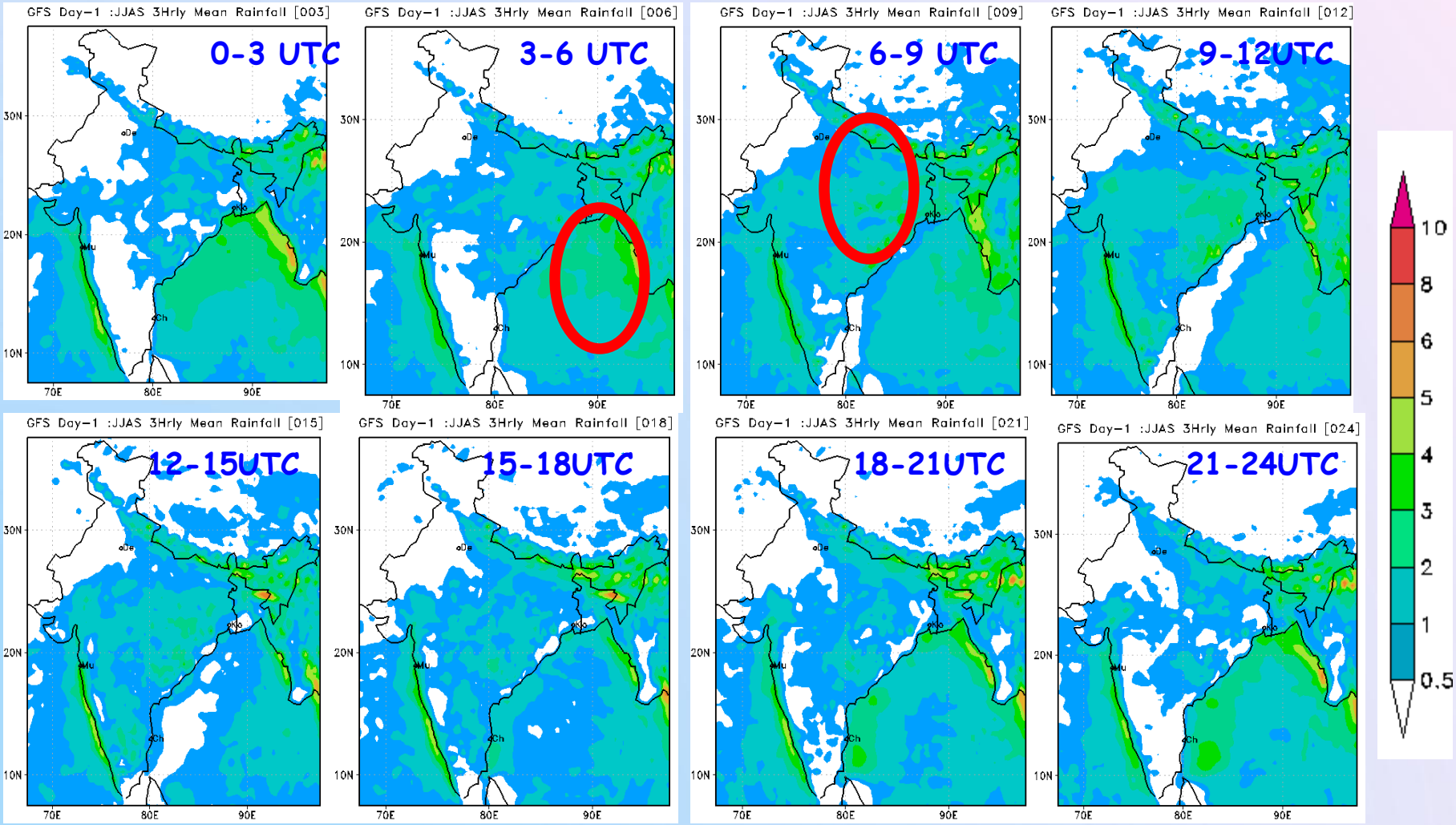


The satellite estimated rainfall (GPM) suggest that

a) the land region in the tropics tends to receive its highest rainfall during 9-12 UTC (the afternoon to late evening hours).

b) Over the sea areas, the maximum precipitation occurs bet 6 -9 UTC.

GFS DAY1- Forecast 3 hourly JJAS mean rainfall of 2017



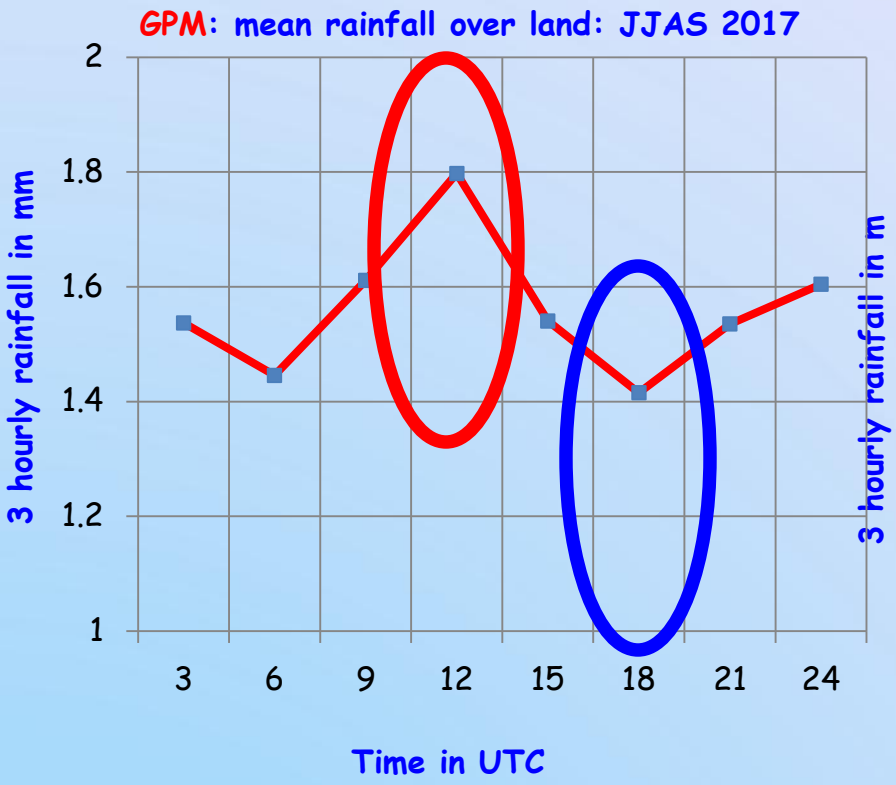
The GFS model simulated rainfall suggest that

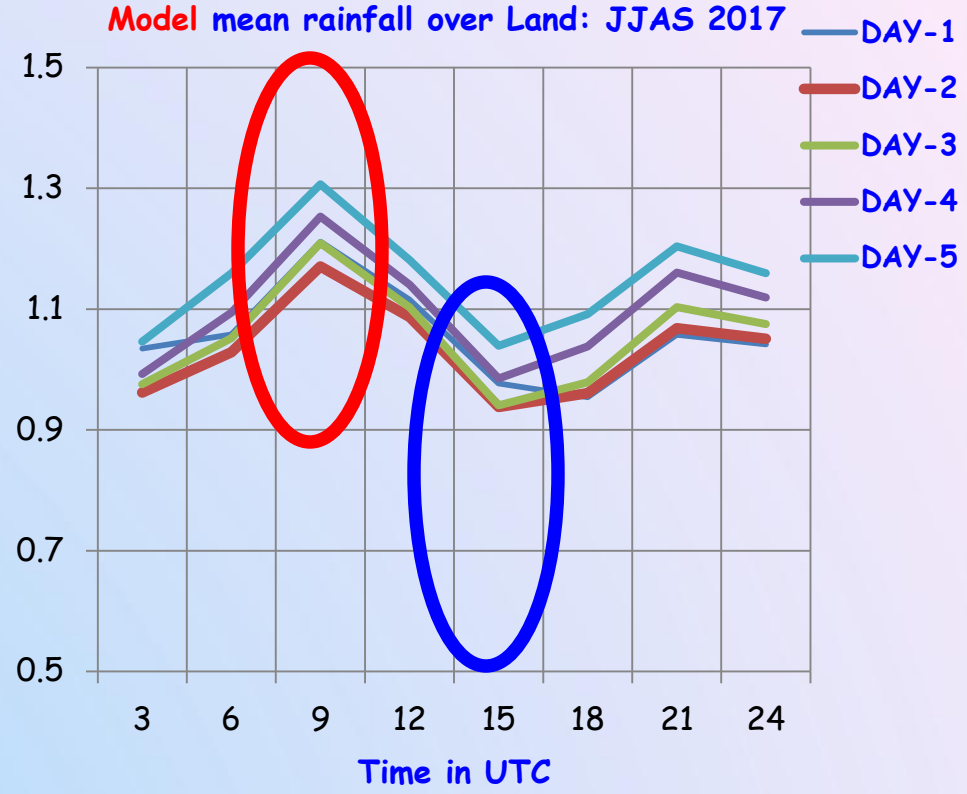
a) the land region in the tropics tends to receive its highest rainfall during 6-9 UTC.

b) Over the sea areas, the maximum precipitation occurs bet 3-6 UTC.

c) the peaks are shifted approximately 1-3 hour ahead.

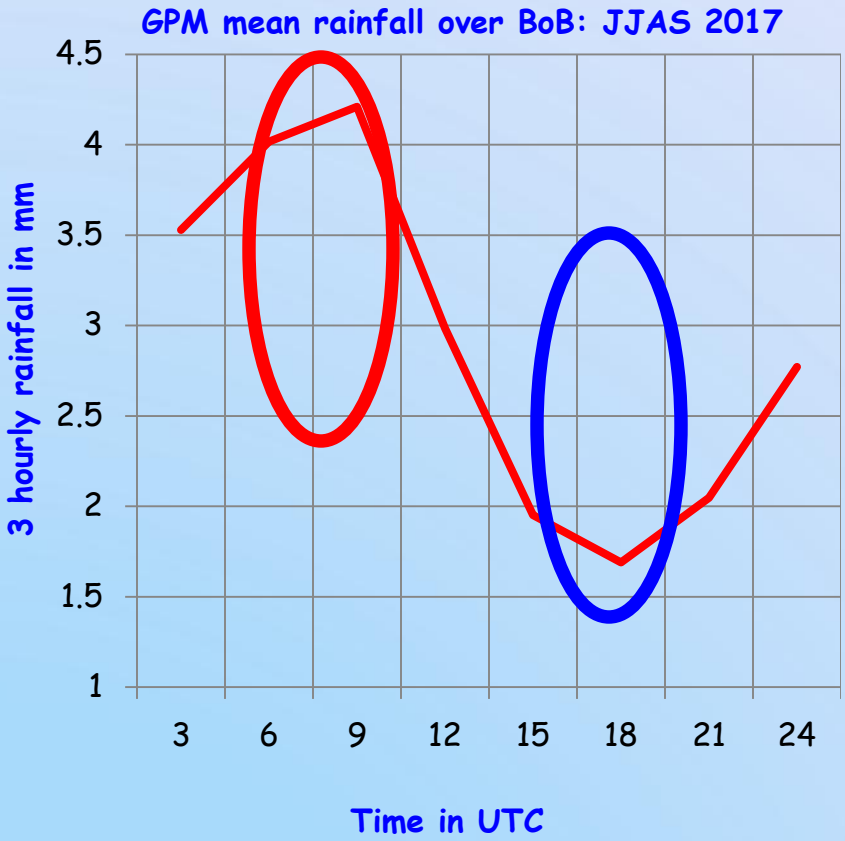
Diurnal variation of mean rainfall :Land areas (All India)

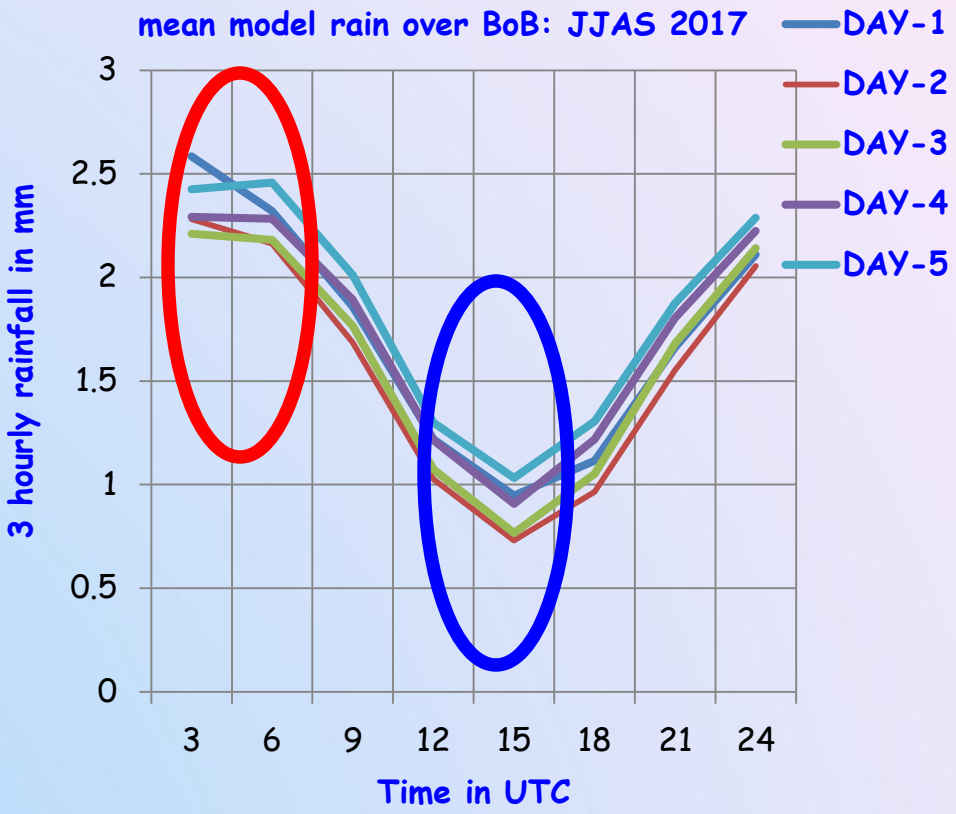




- The land region tends to receive its highest rainfall during the afternoon to late evening hours.
- Over the land areas, the maximum precipitation occurs bet 09 - 12 UTC, while the minimum is bet 15 -18UTC.
- The model simulated diurnal cycles of precipitation amount are also comparable to the corresponding observations (GPM).
- However, the peaks are shifted approximately 2 -3 h ahead.

Diurnal variation of mean rainfall :Ocean (Bay of Bengal)

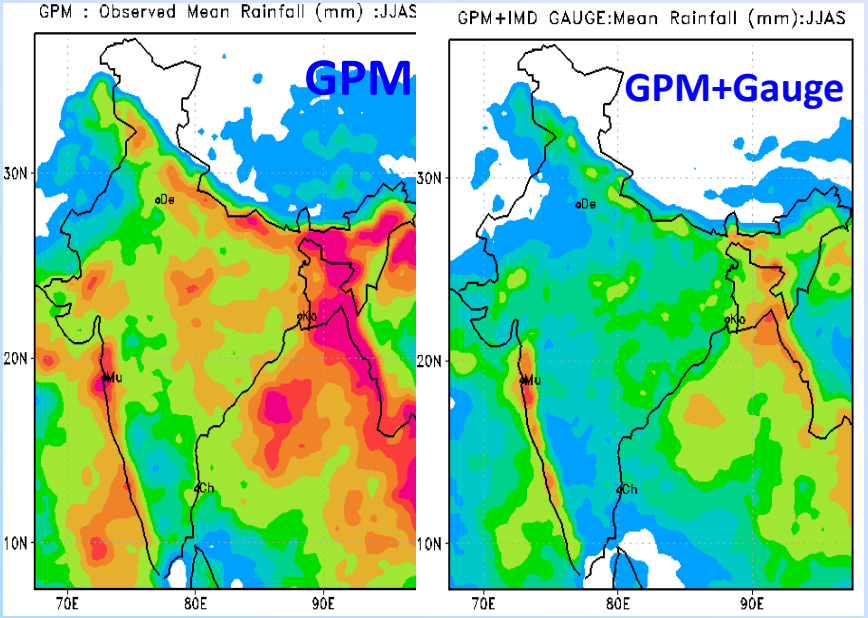


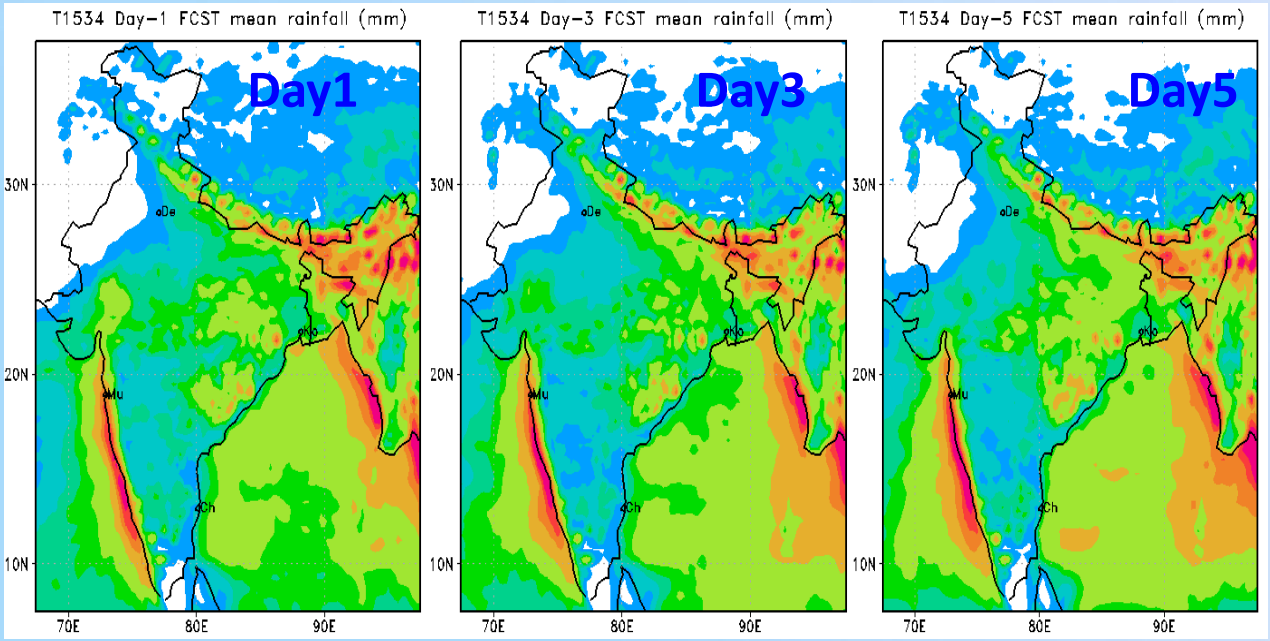


- Over the sea areas, the maximum precipitation occurs bet 06 - 09 UTC, while the minimum is close to 15 -18UTC (local evening).
- The model simulated peak is generally shifted approximately 2-3 h ahead.

Seasonal mean Observed and Model predicted rainfall (mm/day)

JJAS 2017



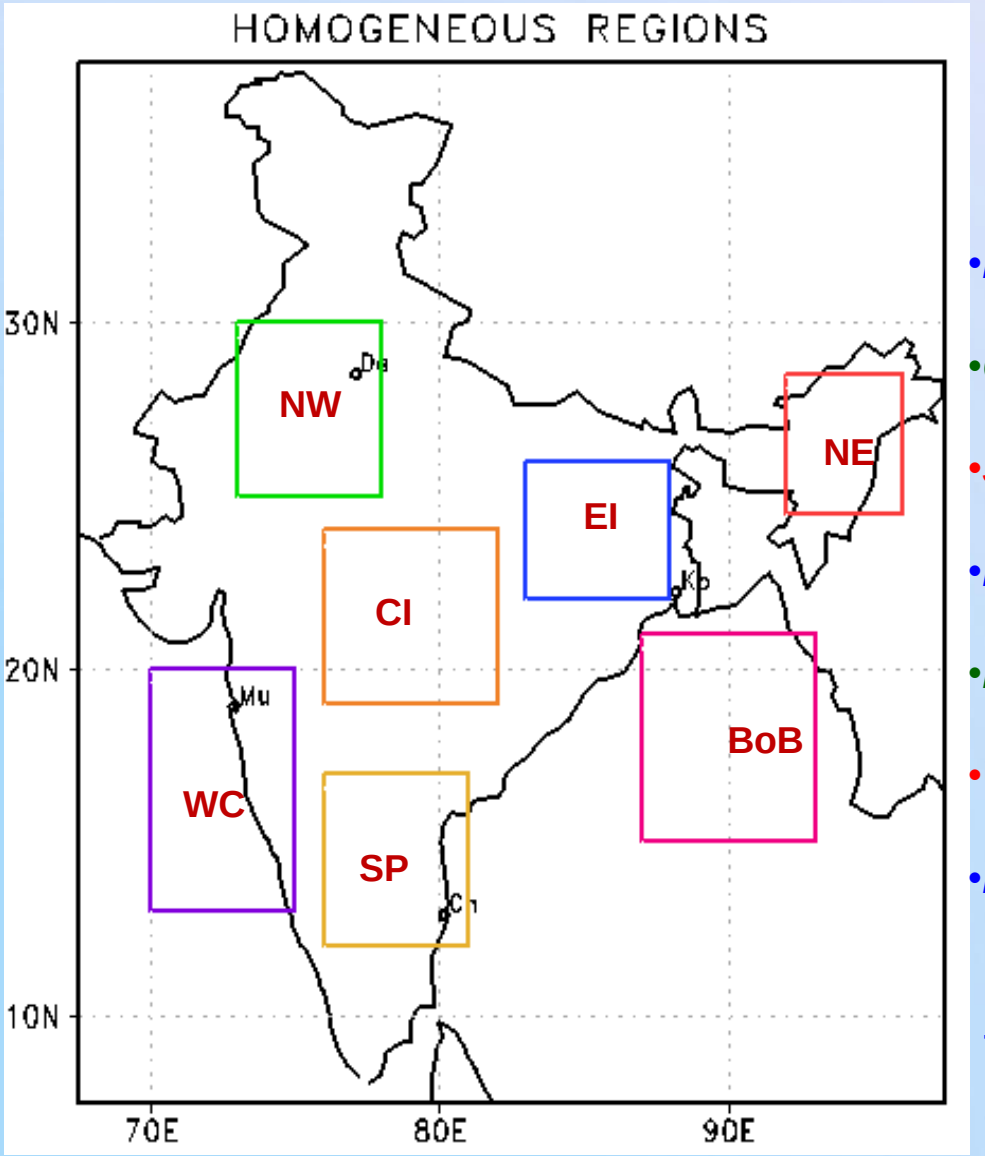


- The spatial distribution of the day-1,,day-3 and day-5 model forecasts of rainfall, accumulated over the whole season is similar to that obtained from the observations.

- Model reproduce the observed seasonal mean pattern of rainfall satisfactorily in all the time scale.

- The day-1 to day-5 forecasts shows that the model under predicts precipitation amounts in the northern and northwest India.

Diurnal variation of rainfall over Homogeneous regions

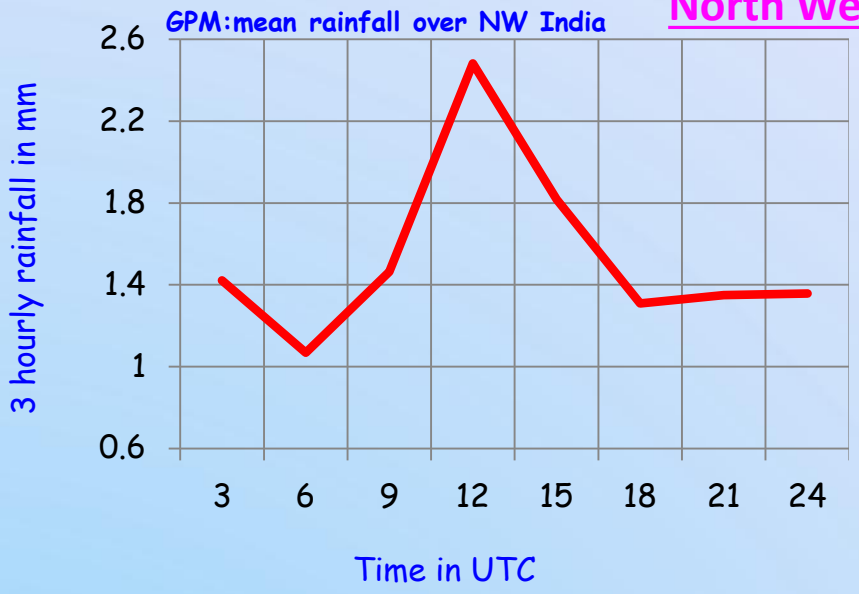


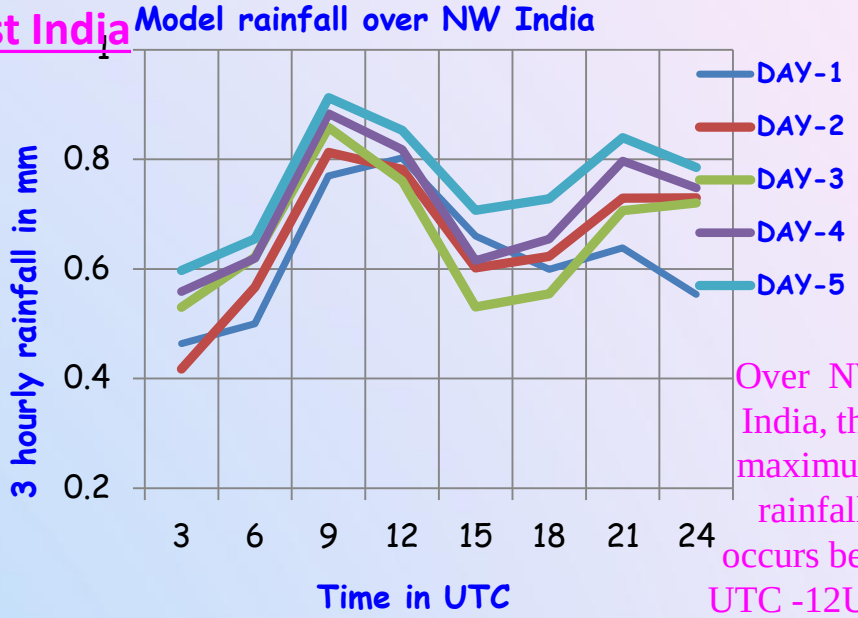
- ***NW-Norst West India:70-75E ;13-20N***
- ***CE- Central India: 76-82E;19-24N***
- ***SP-Southern Peninsula:76-81E;12-17N***
- ***EI-East India:83-88E;22-26N***
- ***NE-North East:92-96E;24.5-28.5N***
- ***WC-West Coast:70-75E;13-20N***
- ***BoB-Bay of Bengal:87-93E;5-21N***

The domains mean values of 3 hourly accumulated rainfall forecast from GFS and observation from GPM is compared

Diurnal variation of seasonal mean rainfall :JJAS 2017

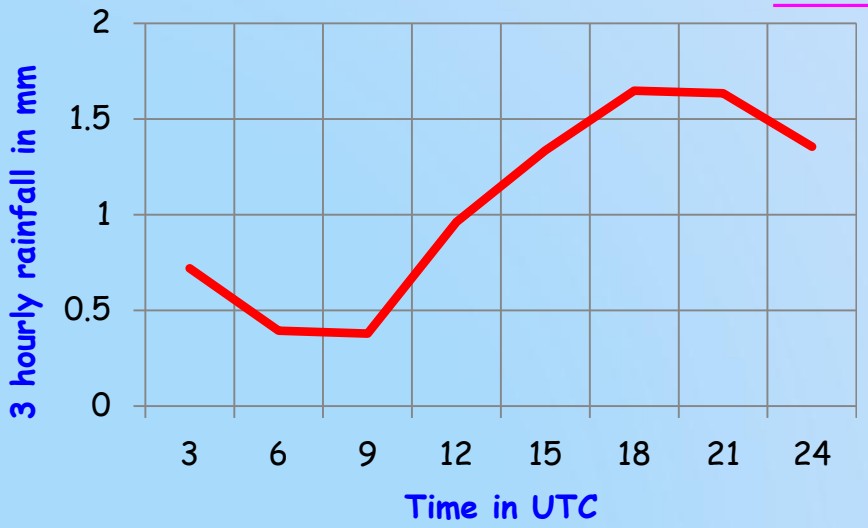
North West India

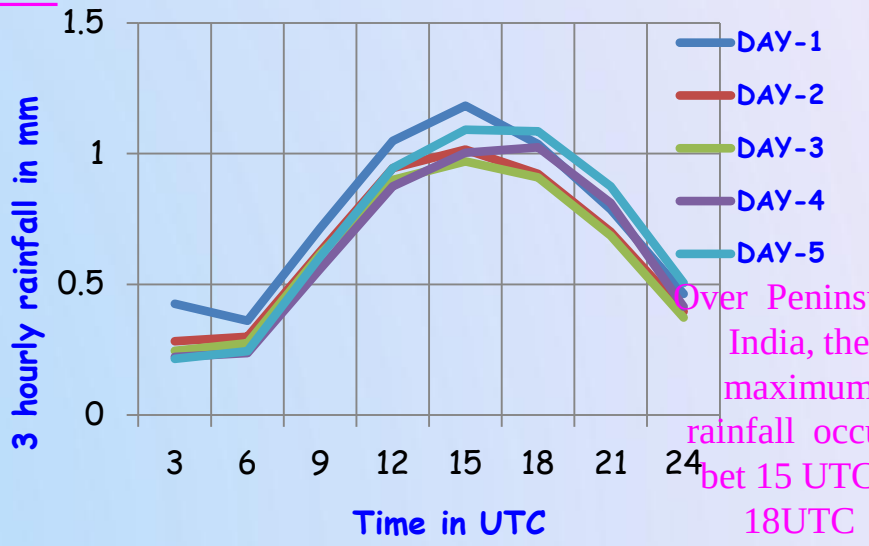




Over NW India, the maximum rainfall occurs bet 9 UTC -12UTC

SP India

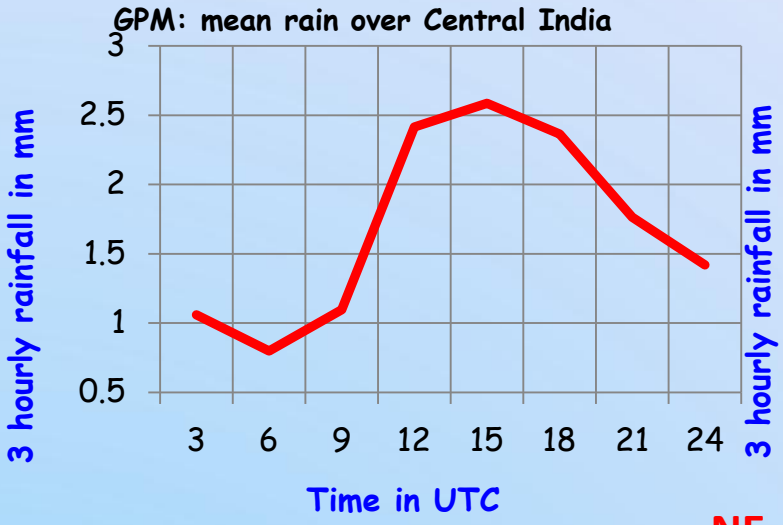


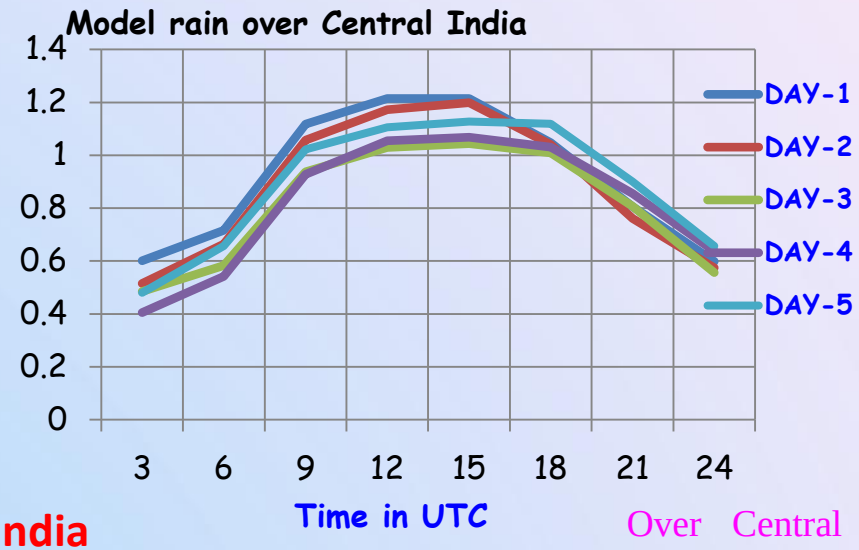


Over Peninsular India, the maximum rainfall occurs bet 15 UTC - 18UTC

Diurnal variation of seasonal mean rainfall :JJAS 2017

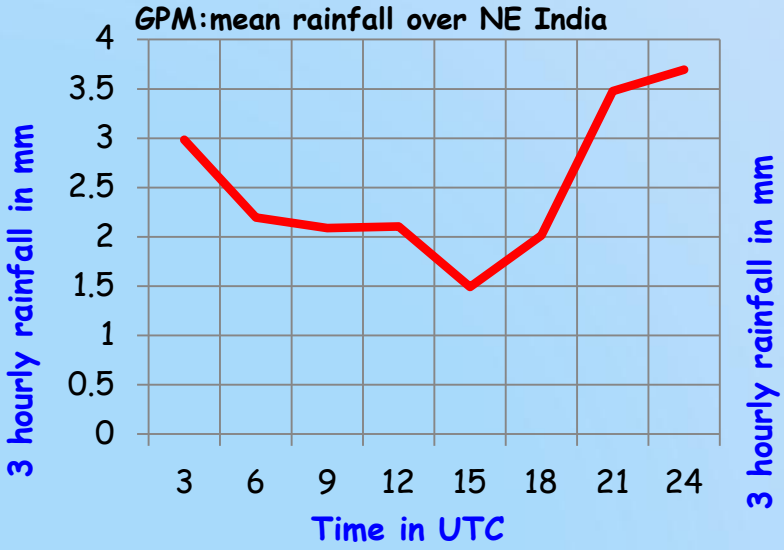
Central India

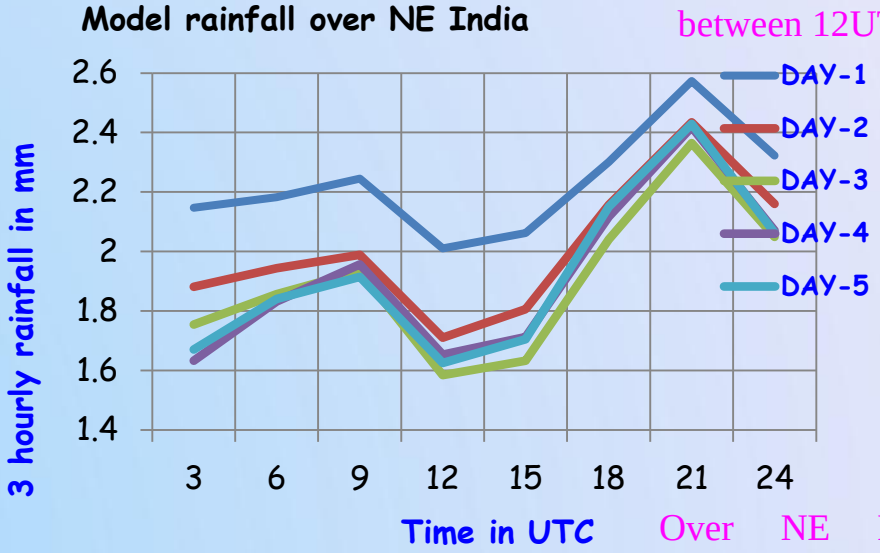




Over Central India, the maximum rainfall occurs between 12UTC -15UTC

NE India

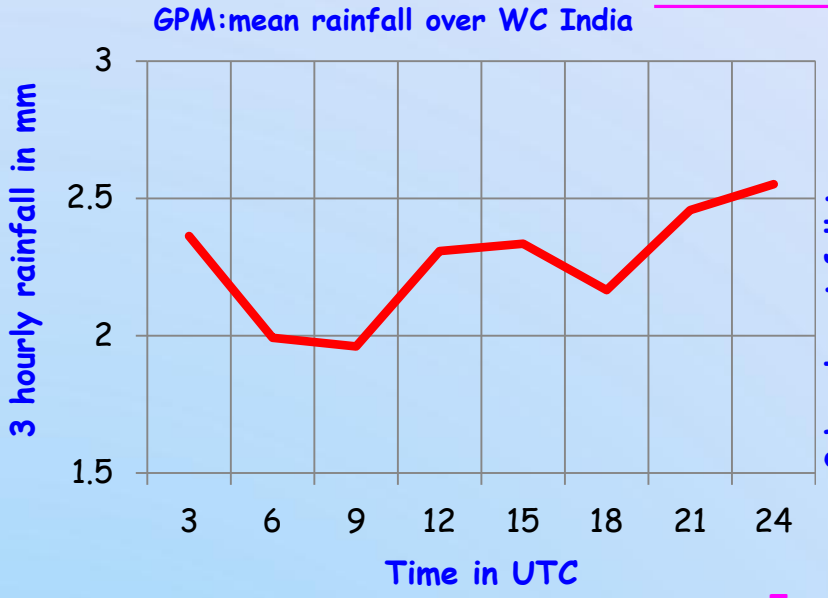


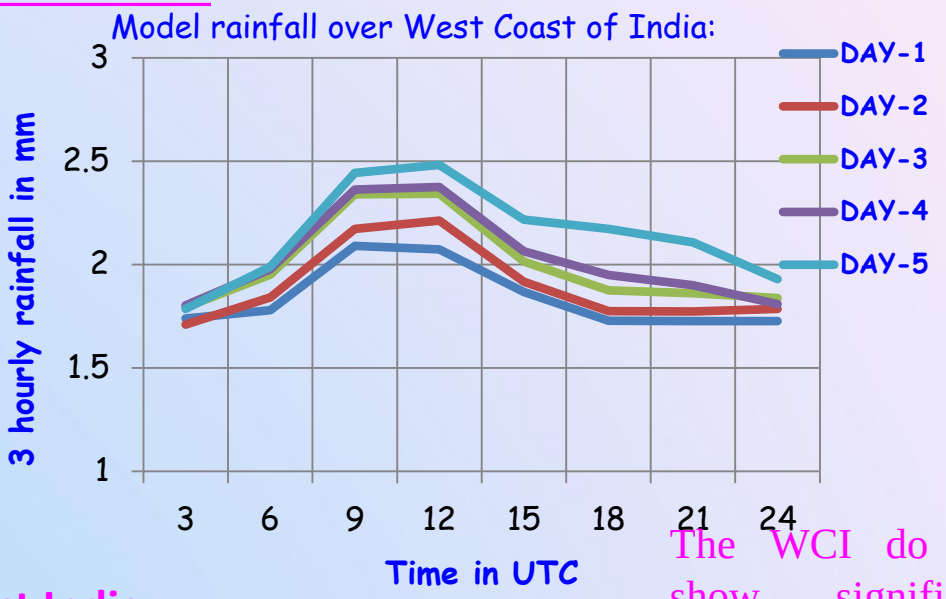


Over NE India, the maximum rainfall occurs bet 21UTC - 00 UTC ,

Diurnal variation of seasonal mean rainfall :JJAS 2017

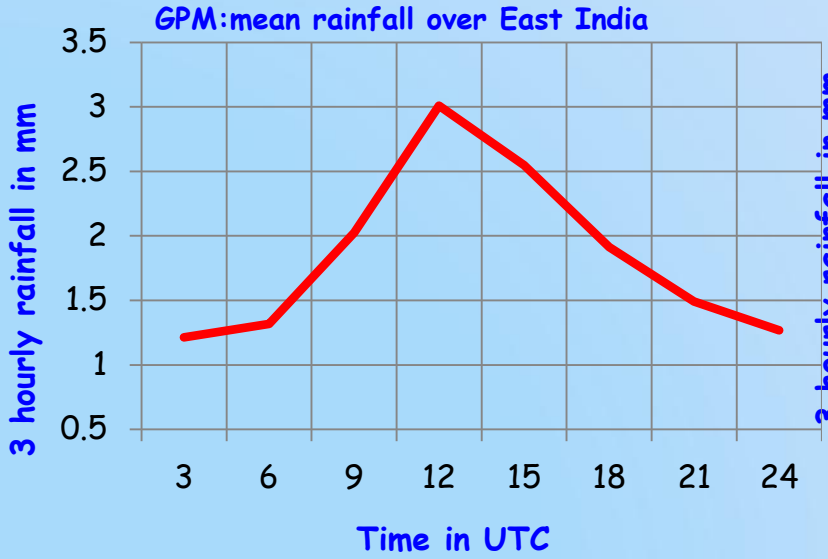
west coast of India

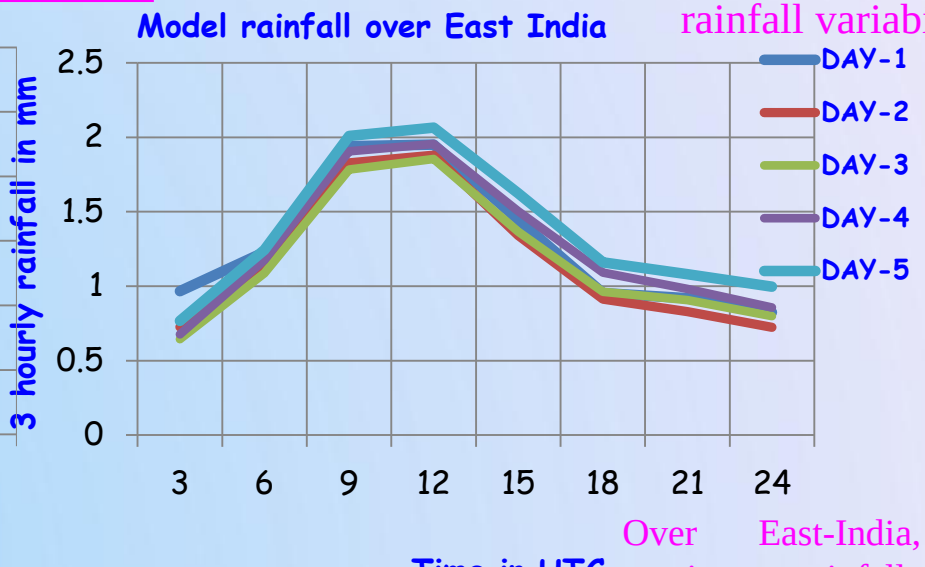




The WCI do not show significant rainfall variability

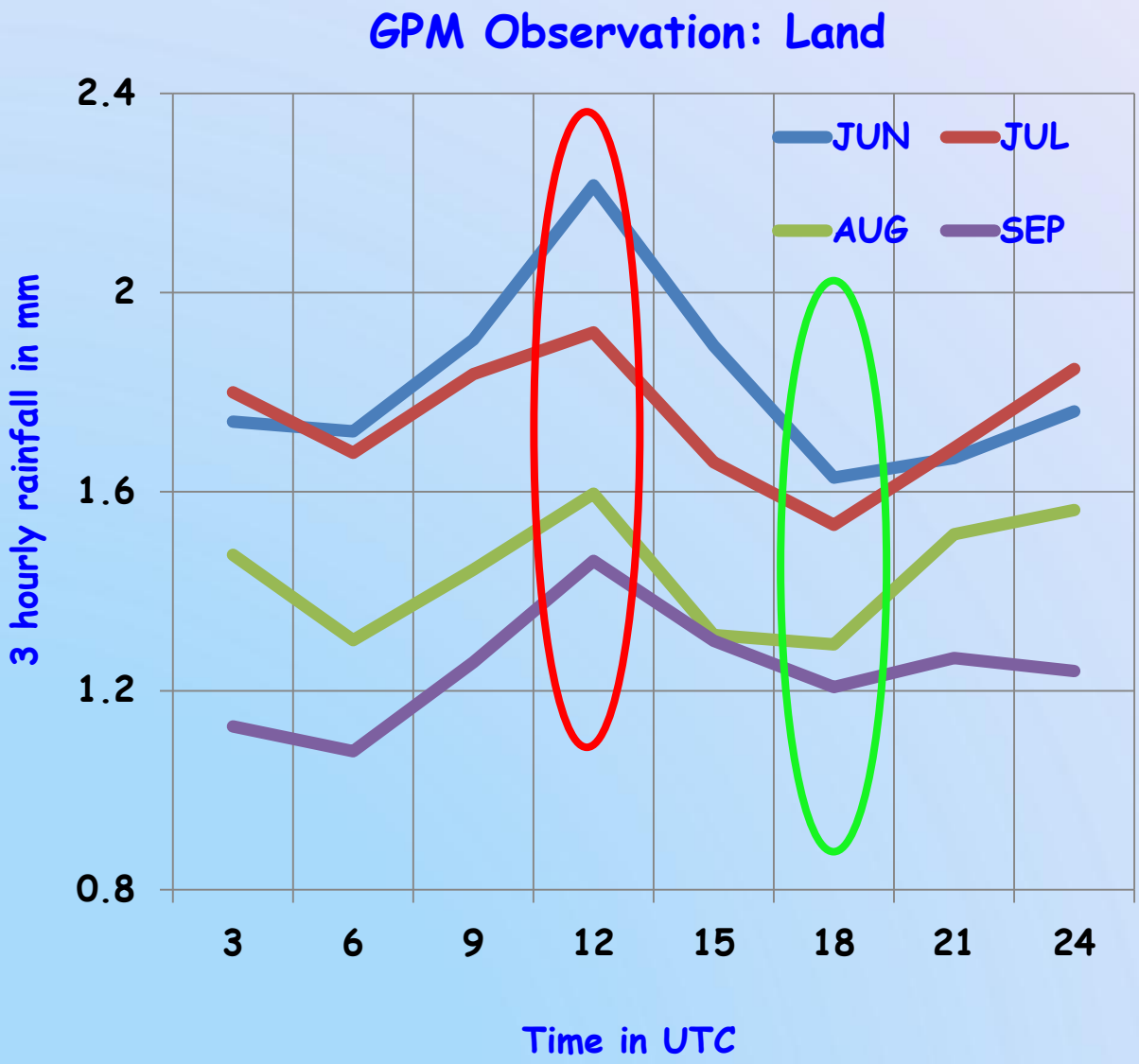
East India





Over East-India, the maximum rainfall occurs between 9UTC -12UTC

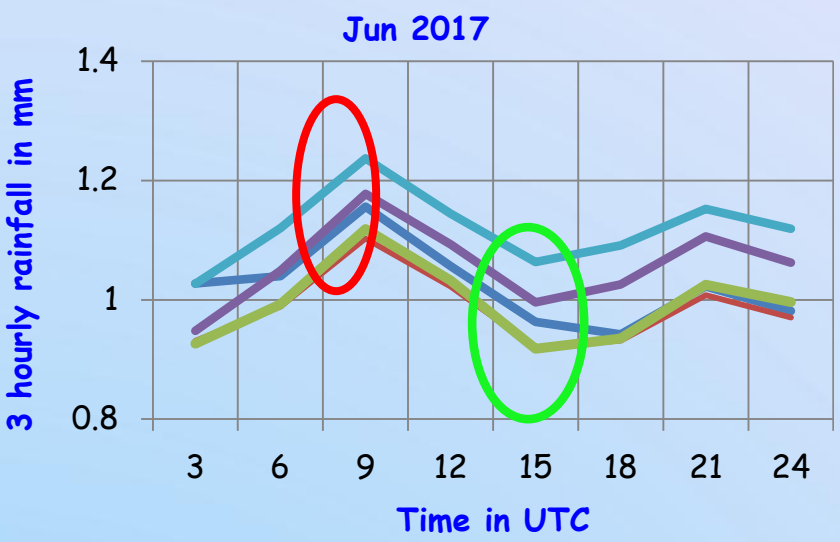
Diurnal variation of monthly mean rainfall :Land areas (All India)

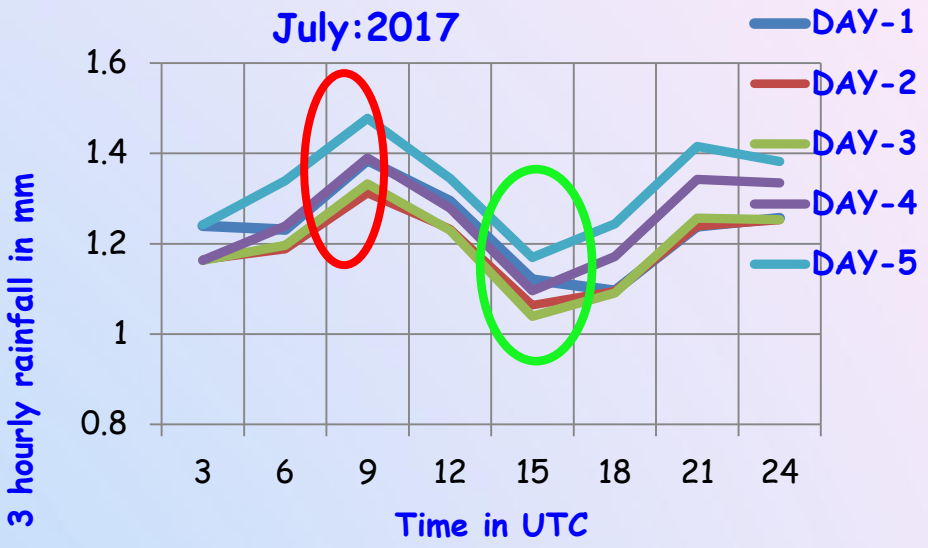


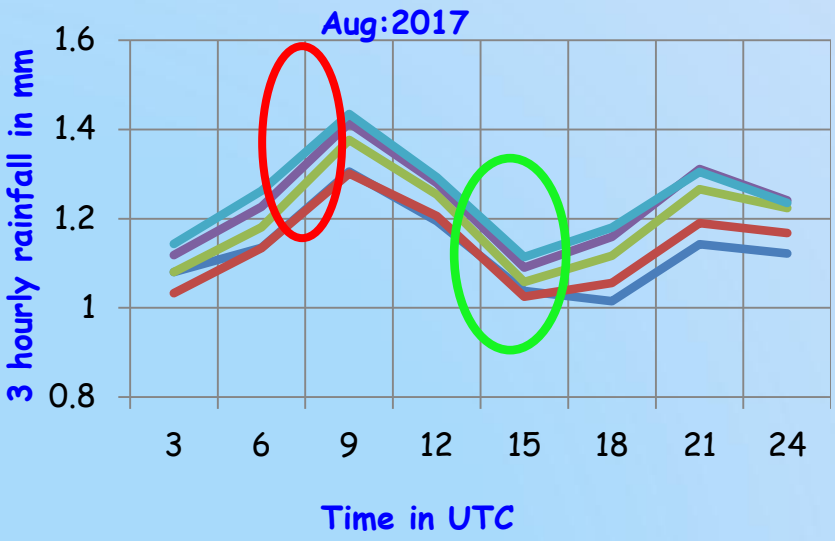
3Hourly precipitation averaged over the whole of India (Land point) and accumulated for each month during the monsoon season of 2017.

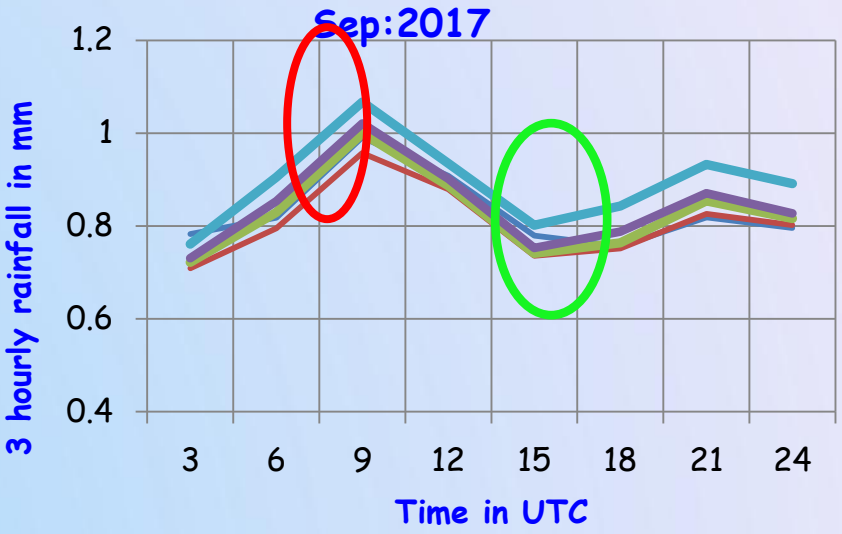
The peak precipitation occurs between 9 and 12 UTC in all the four months.

Diurnal variation of monthly mean model rainfall :Land areas (All India)



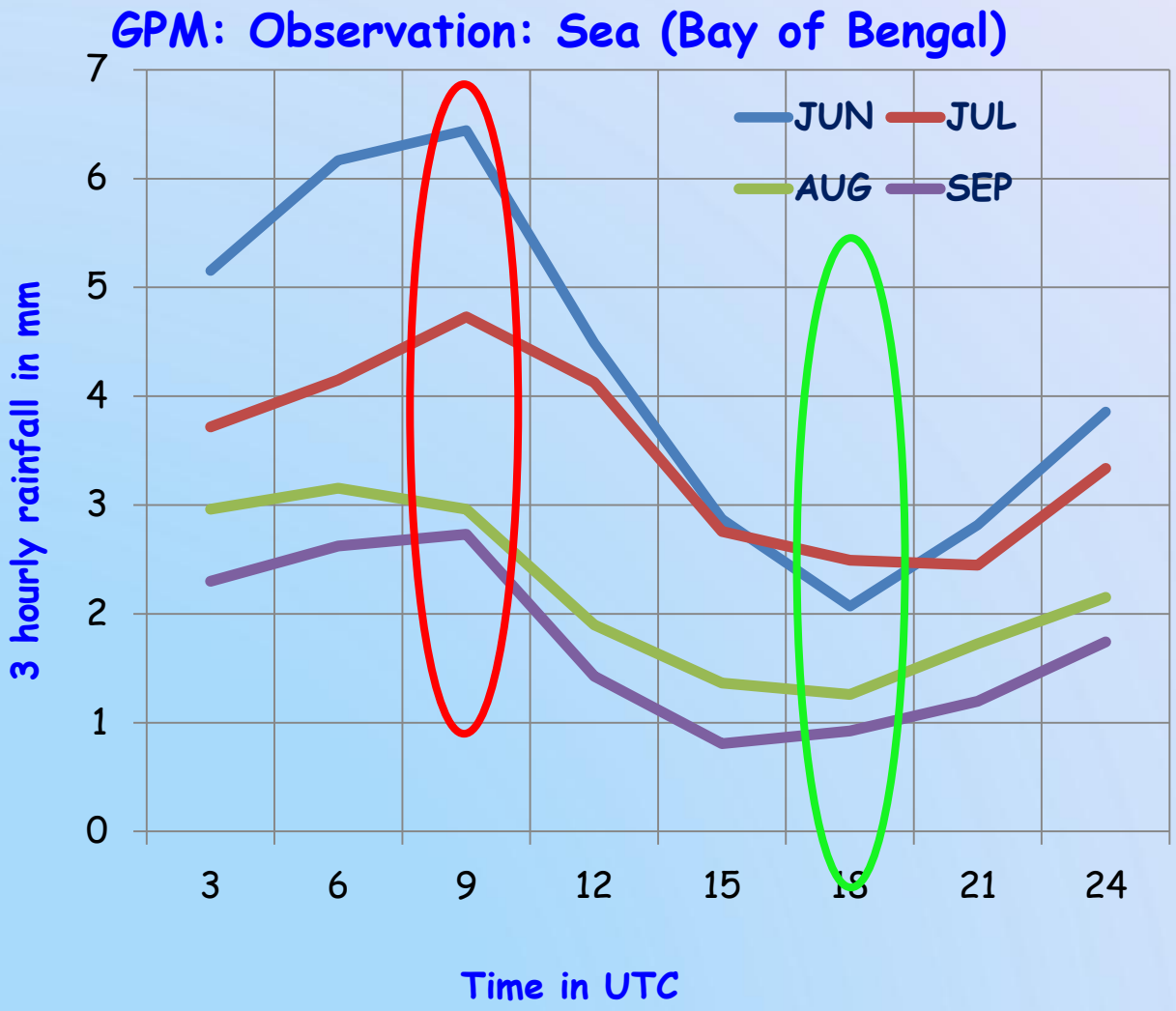






The model simulated rainfall peak is generally shifted approximately 2-3 h ahead regardless of domain in both over sea and land.

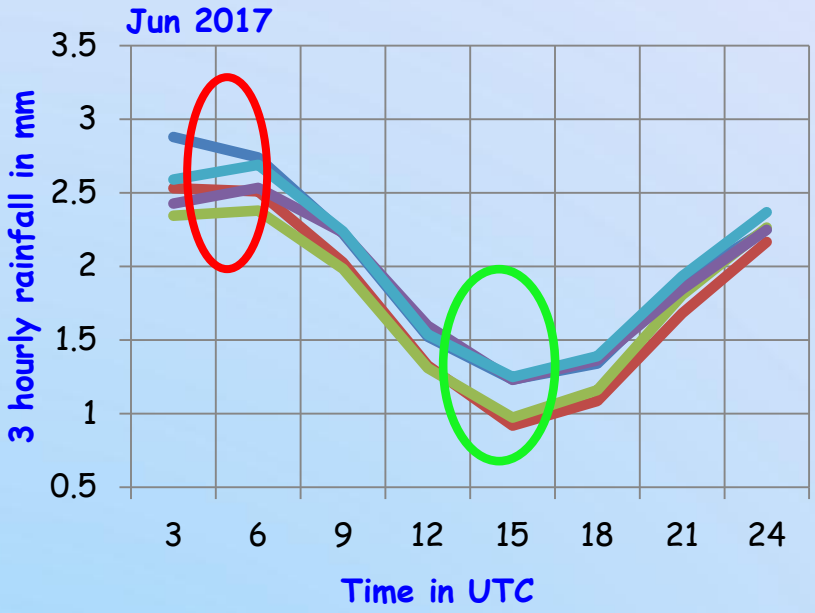
Diurnal variation of monthly mean GPM rainfall :Sea (Bay of Bengal)

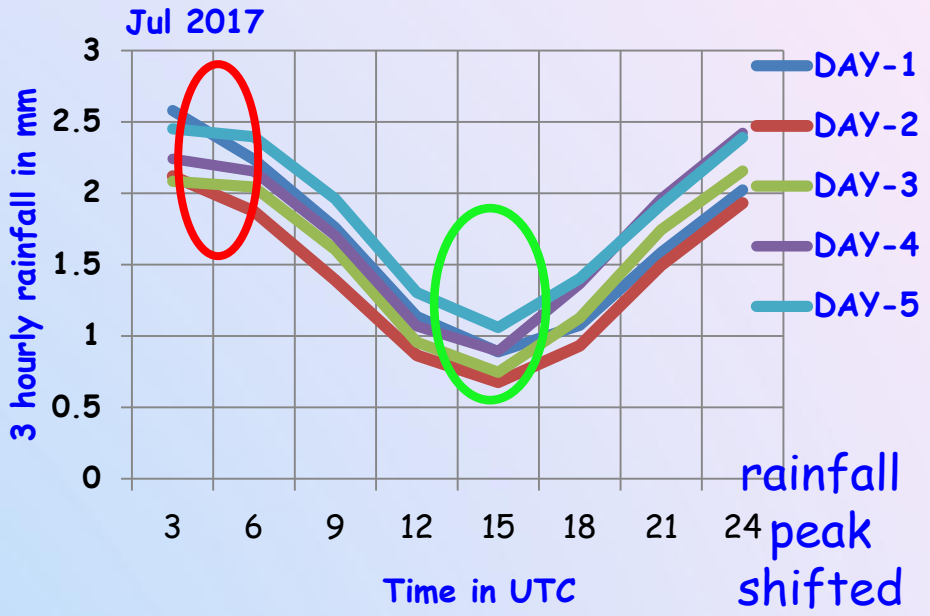


The 3 Hourly GPM estimated precipitation averaged over the north Bay of Bengal (over the sea) and accumulated for each month during the monsoon season of 2017.

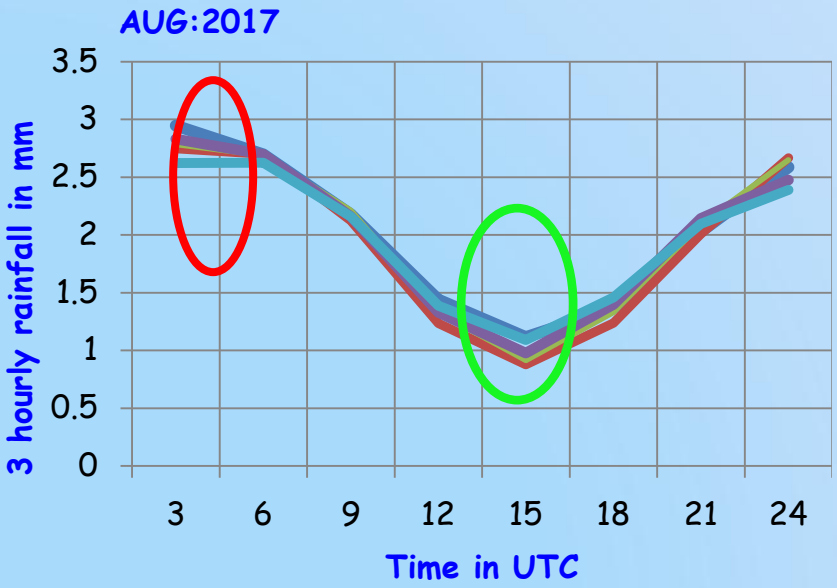
the peak rainfall occurs between 06 and 09 UTC in all the months

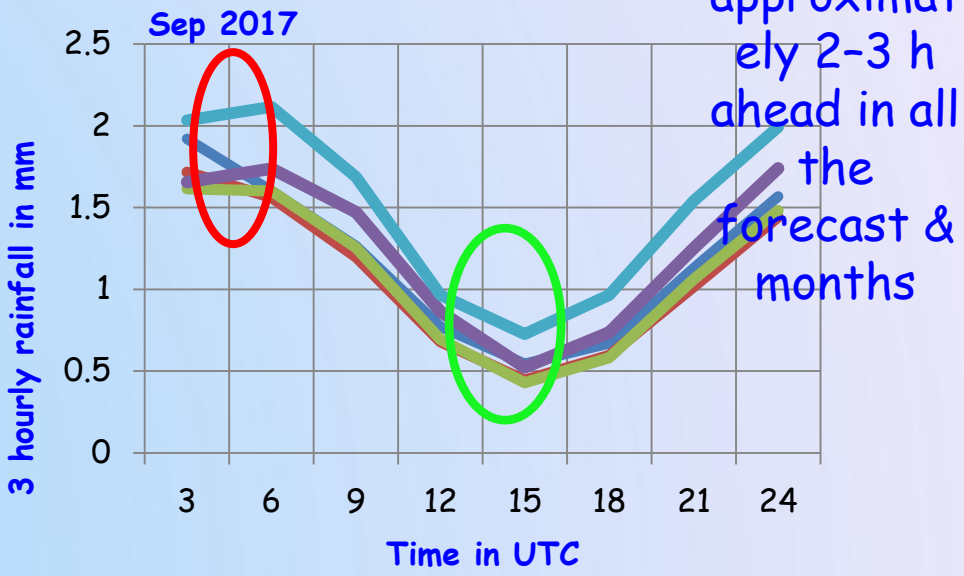
Diurnal variation of monthly mean model rainfall :Sea (Bay of Bengal)





rainfall peak shifted approximately 2-3 h ahead in all the forecast & months





Summary and Conclusion

- The model simulated rainfall peak is generally shifted approximately **2–3 h ahead** regardless of domain in both over the sea and the land areas.

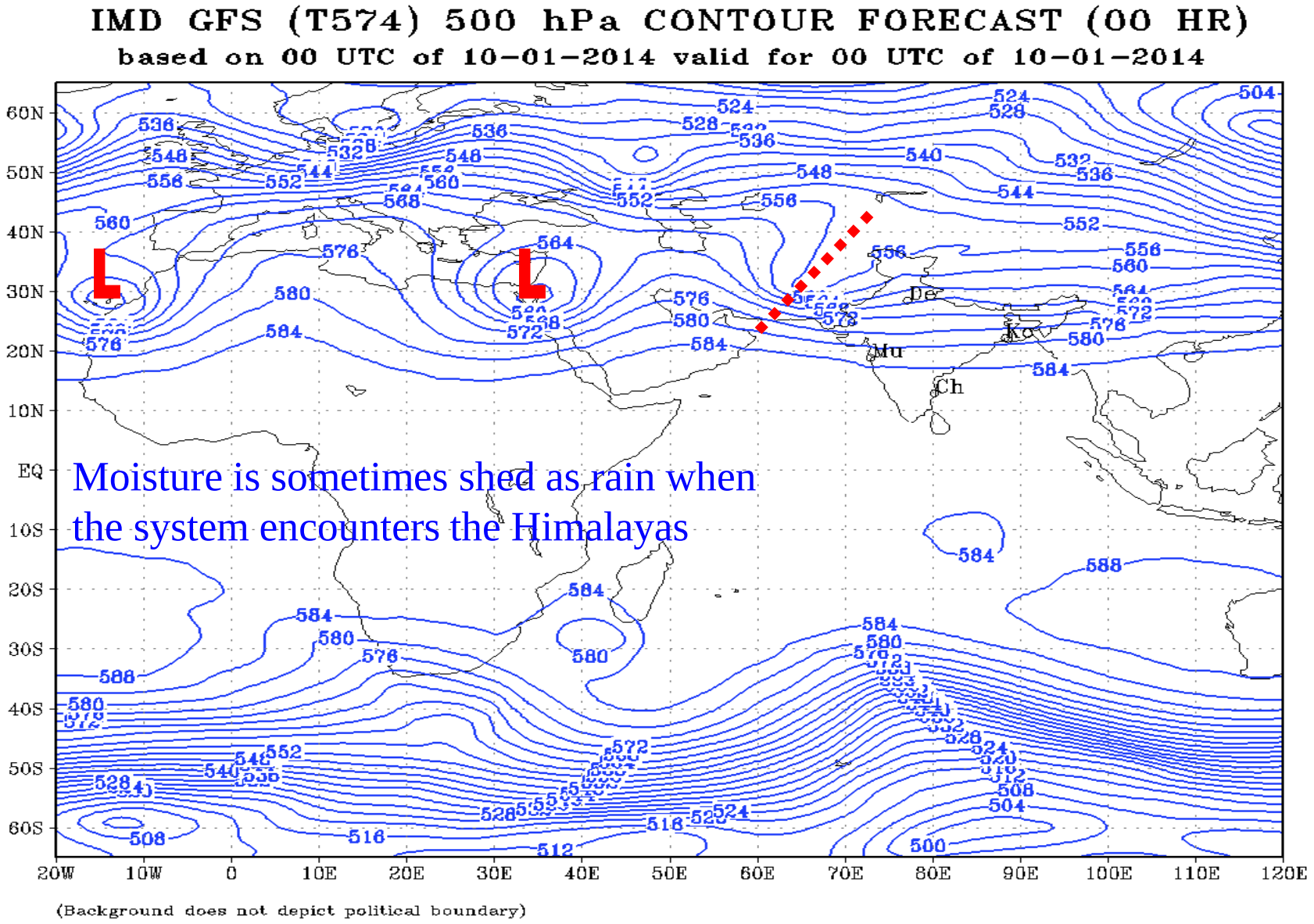
- A common feature noticed over all the homogeneous regions selected for comparison of diurnal variations is that the pattern of diurnal variation is similar for all four months of the monsoon season.

Western Disturbance (WD)

3. Western Disturbance (WD)

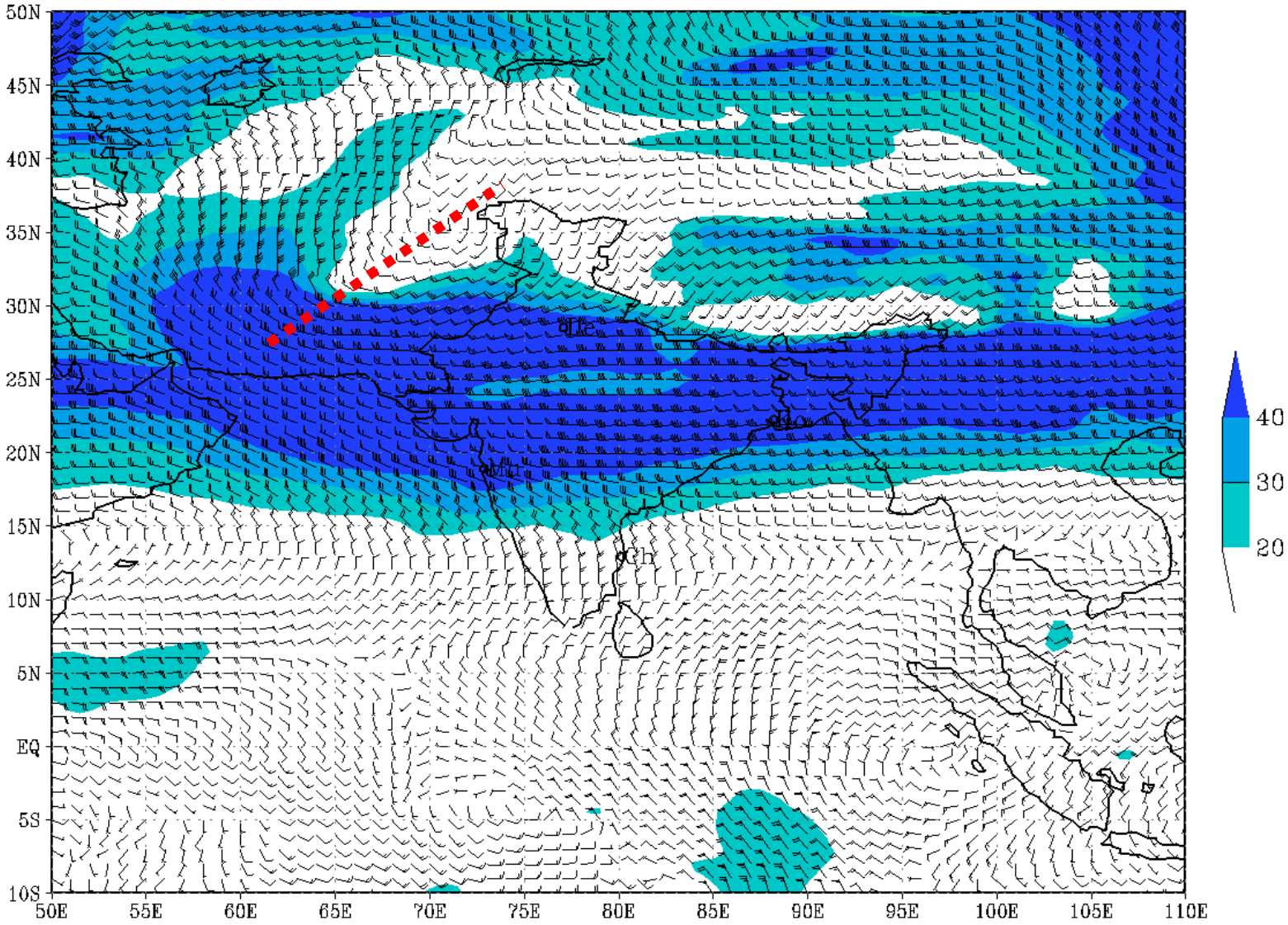
- Western Disturbance (WD) is an extra tropical storm that brings rain and snow to the northwestern parts of the India.
- The moisture in these storms usually originates over the Mediterranean Sea
- Extra tropical storms carries moisture usually in the upper atmosphere. [unlike tropical storms which carries moisture in the lower atmosphere].

Western Disturbance : on 10 Jan 2014 :Winter seasons

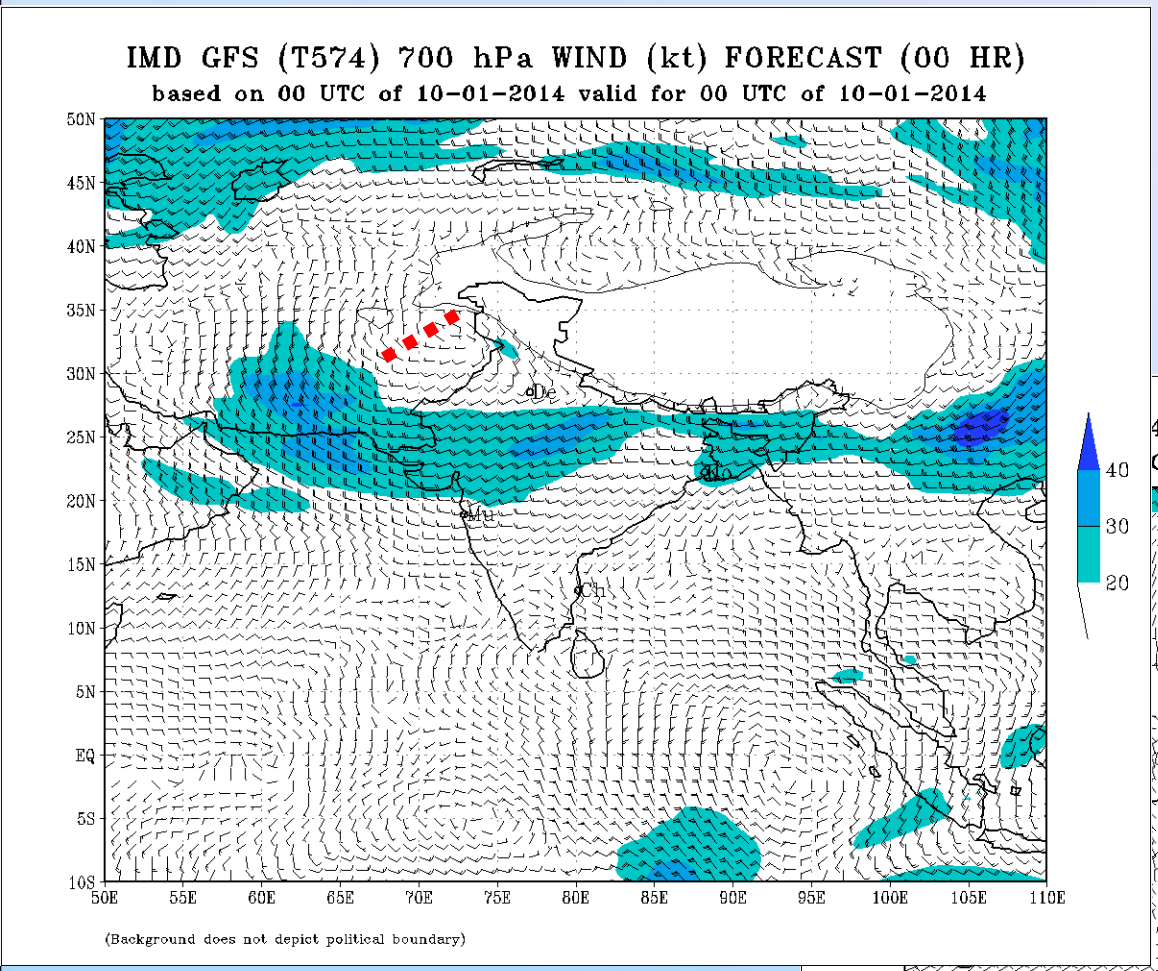


The 500 hPa contour chart is used to note the positions of troughs and ridges in the WD.

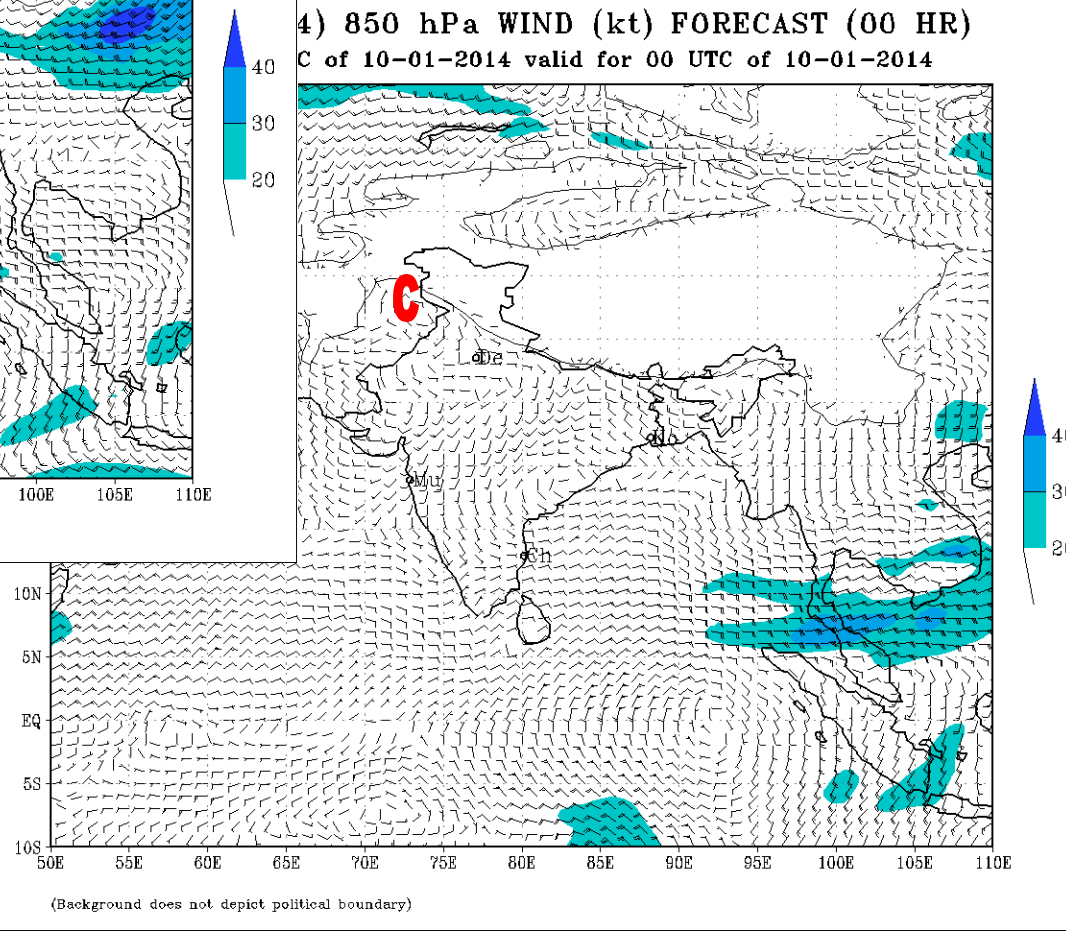
Western Disturbance : Winter seasons



Western Disturbance (WD) : Winter seasons



WD is seen as cyclonic circulation at low levels

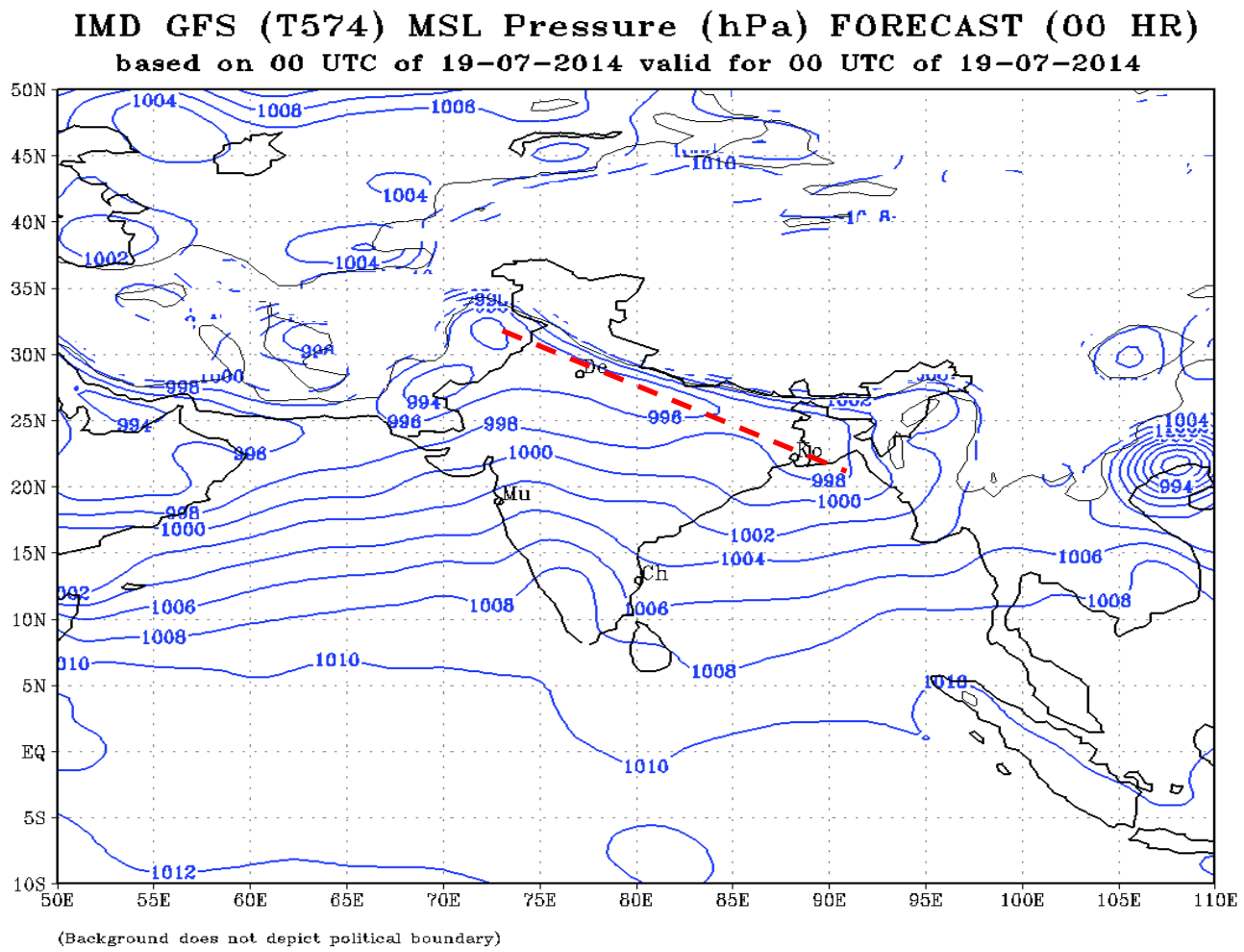


Thank You

1. Monsoon Trough

- Monsoon trough is an extended trough of low pressure which runs across Gangetic Plains of north India with its axis runs from Ganga Nagar in Rajasthan to Kolkata via Allahabad.
- The maxima of rainfall lie on the south of its axis.
- The northward and southward movements of monsoon trough axis are generally indicative of the large scale active and weak monsoon conditions.
- The position of monsoon trough axis is an important factor in the monsoon activity over the sub continent.

Monsoon Trough : on 19 July 2014 : Active Periods



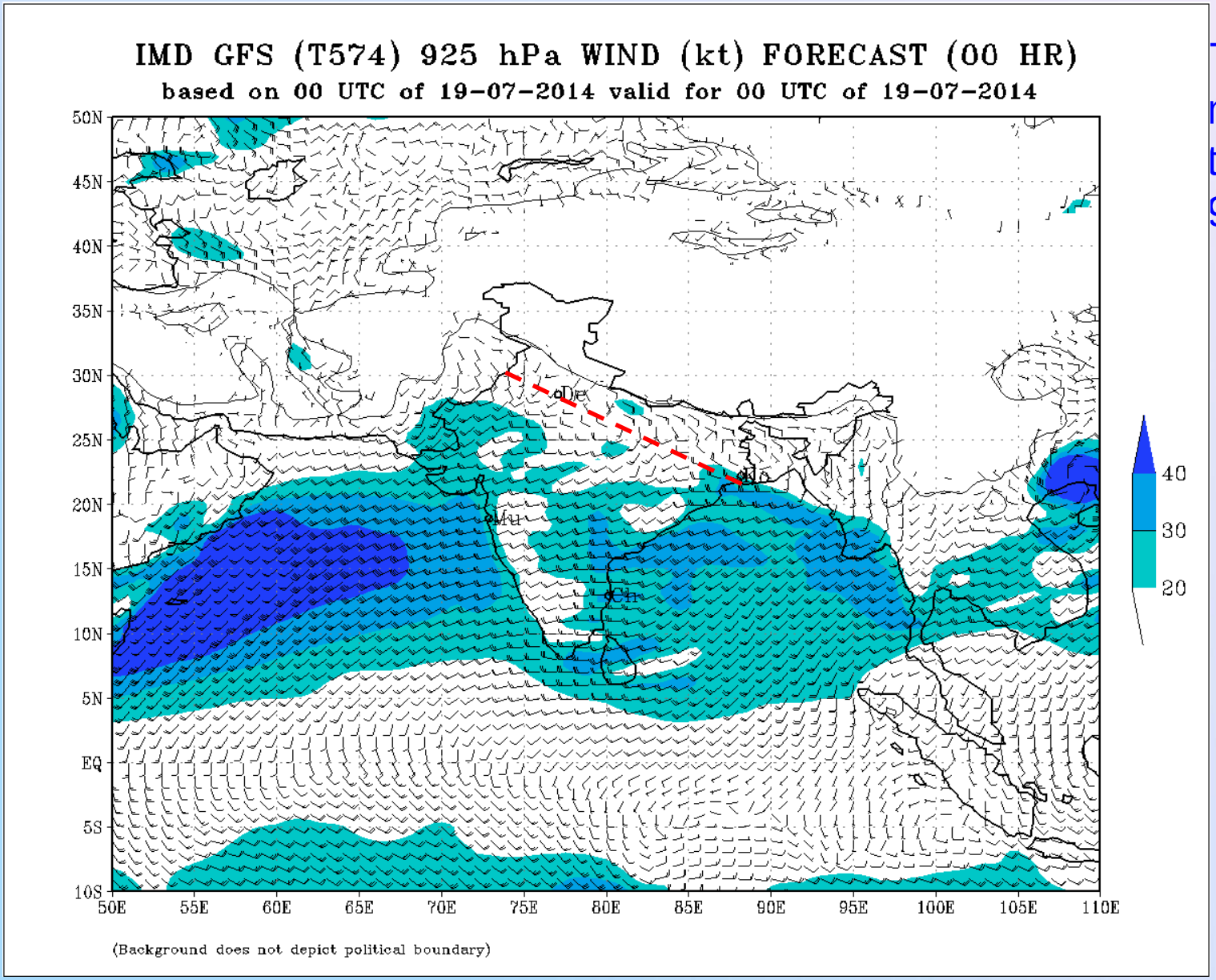
MSLP:

When the trough stays in the normal position, this is considered to be an active monsoon situation.

The rainfall is well distributed over the northern plains and central parts of the country

When the trough dips into the Bay, conditions becomes favorable for the formation of depression/low in the Bay of Bengal, which eventually moves northwest ward across the main land and produces good rainfall activity.

Monsoon Trough : on 19 July 2014 : Active Periods



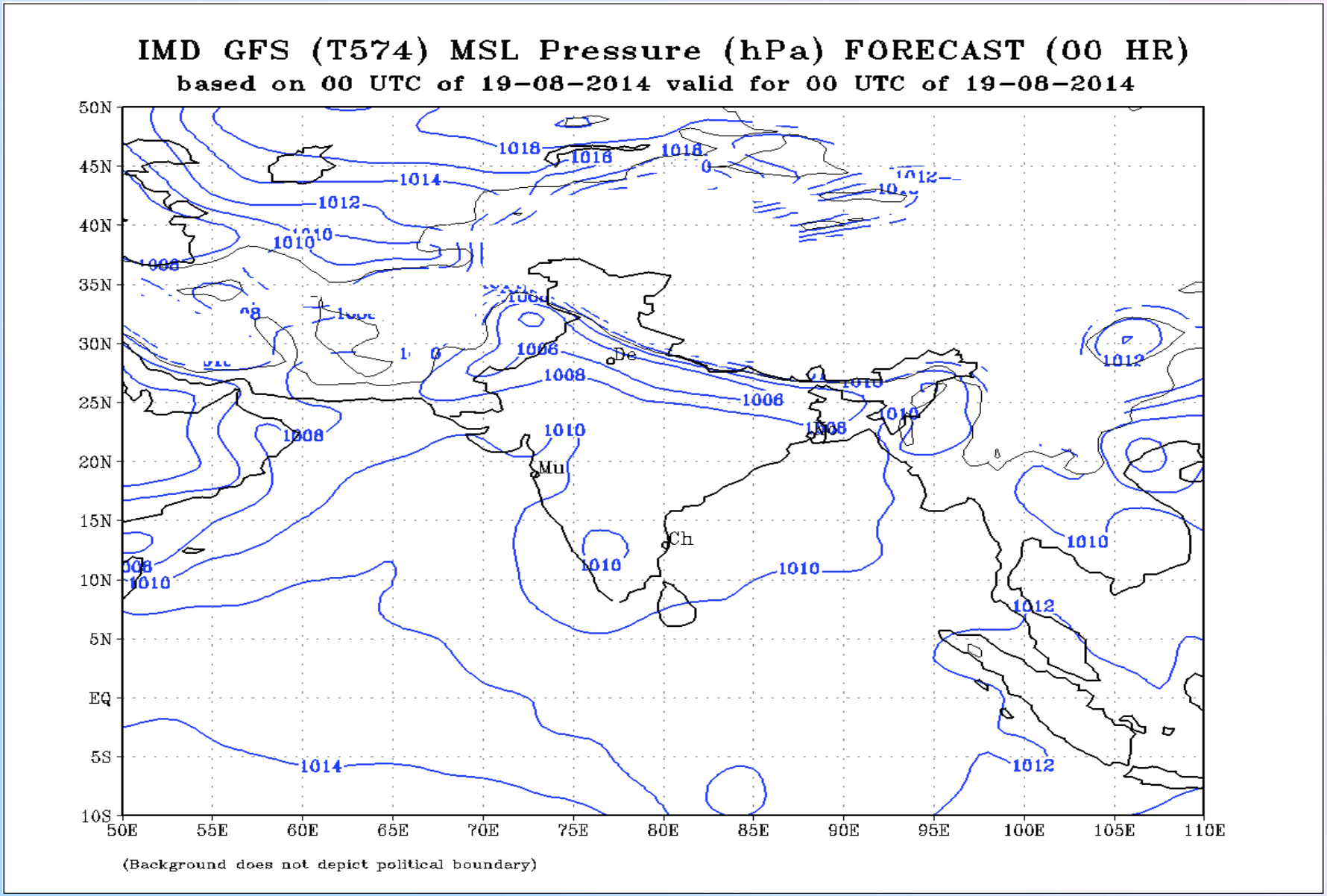
The axis of monsoon trough at 925 hPa

The axis of monsoon trough at 850 hPa shift southward with height

Monsoon Trough ---“Break” monsoon condition

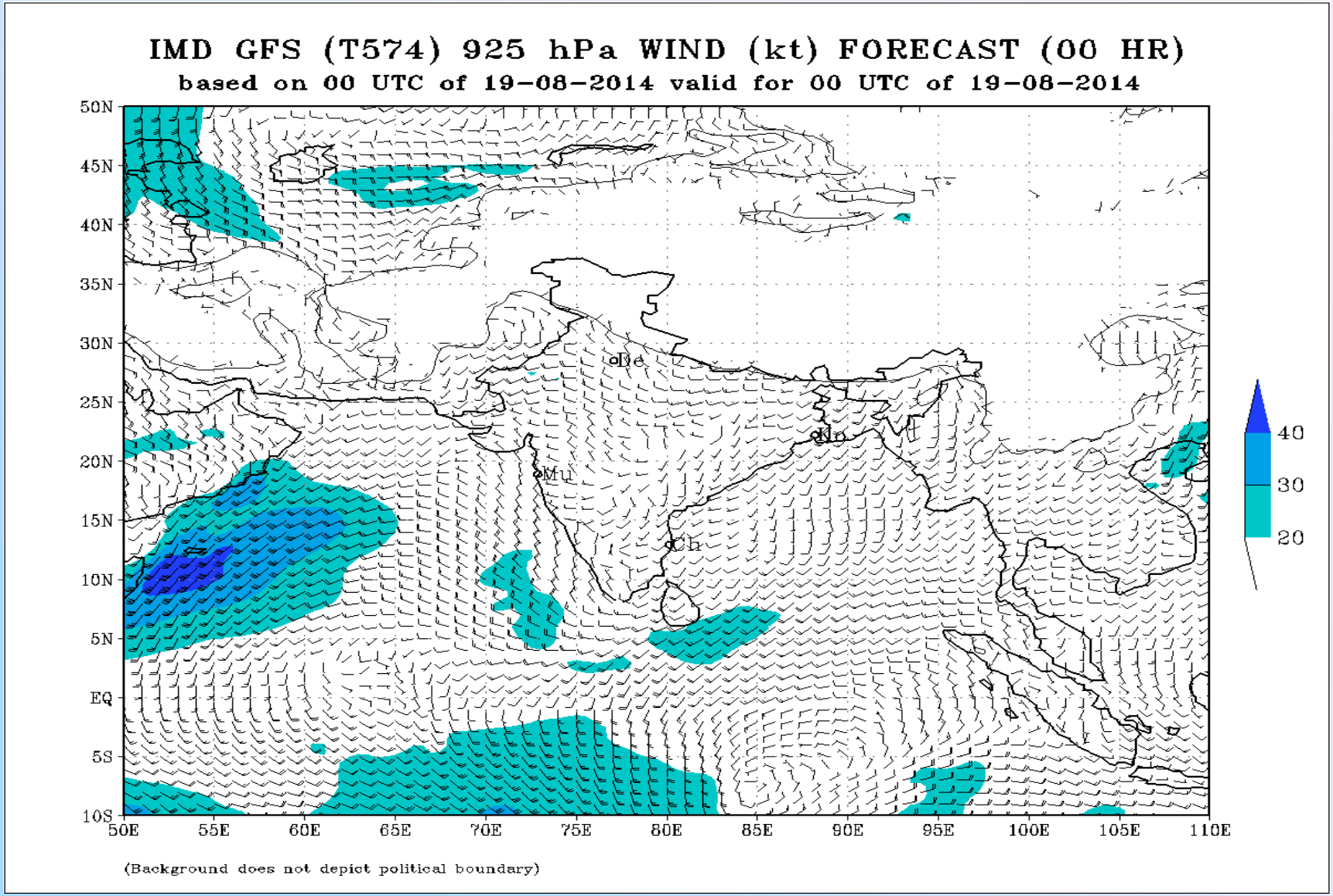
- The monsoon trough shifts northward to the foot hills of Himalayas,
- Rainfall activity decrease over the central and northern parts of the country
- Rainfall activity increases over southern peninsular India and along the foot hills of Himalayas..
- The break monsoon condition usually last for a few days.

Monsoon Trough : 0n 19 Aug 2014 : Weak/Break Periods



The monsoon trough gets completely wipe out in the MSLP and low level wind fields.

Monsoon Trough : Weak/Break Periods



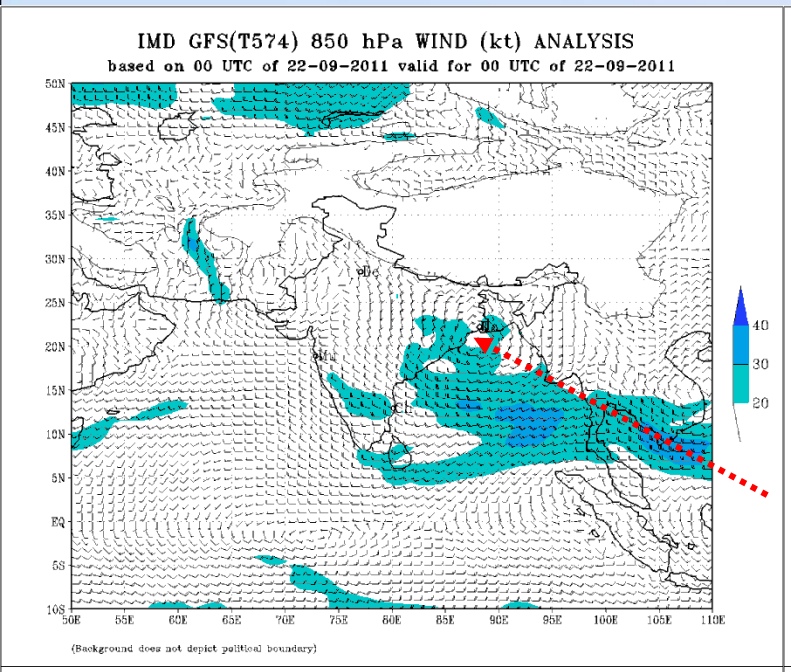
- The monsoon trough is missing in the low level 925 hPa wind chart
- NO Easterlies found over NW India

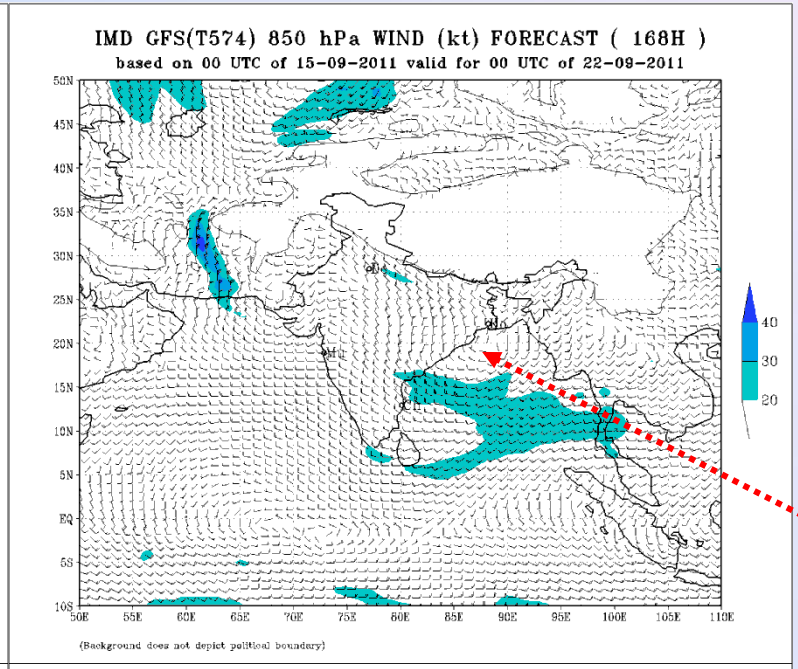
4. Low Pressure System

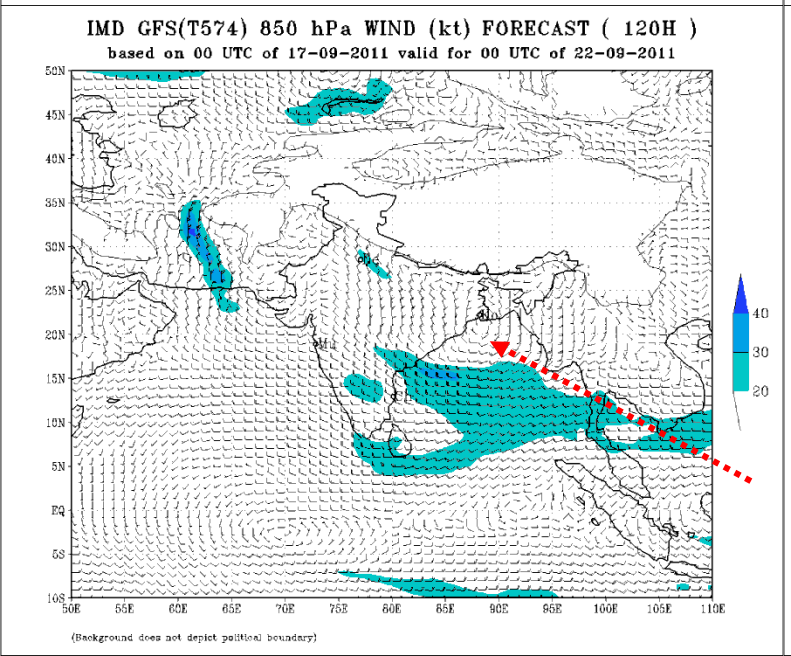
Monsoon Depression

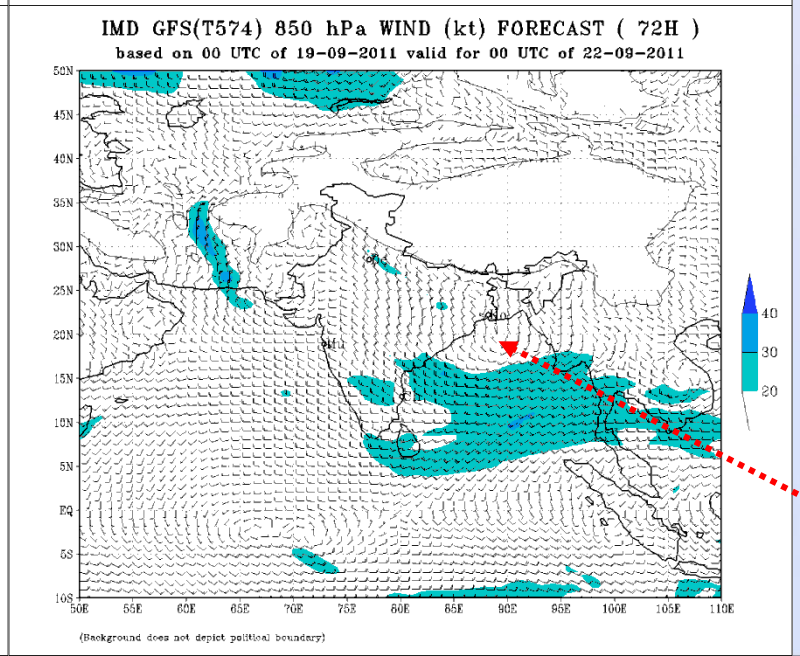
- Monsoon depression is the main rain producing system which usually forms in the North Bay of Bengal and subsequently moves northwestwards across the country giving heavy to very heavy rainfall during its passage.
- Currently most of the operational NWP models are capable to predict the initial formation of low pressure system as well as the intensification process 3 to 5 days in advance.

Monsoon depression :







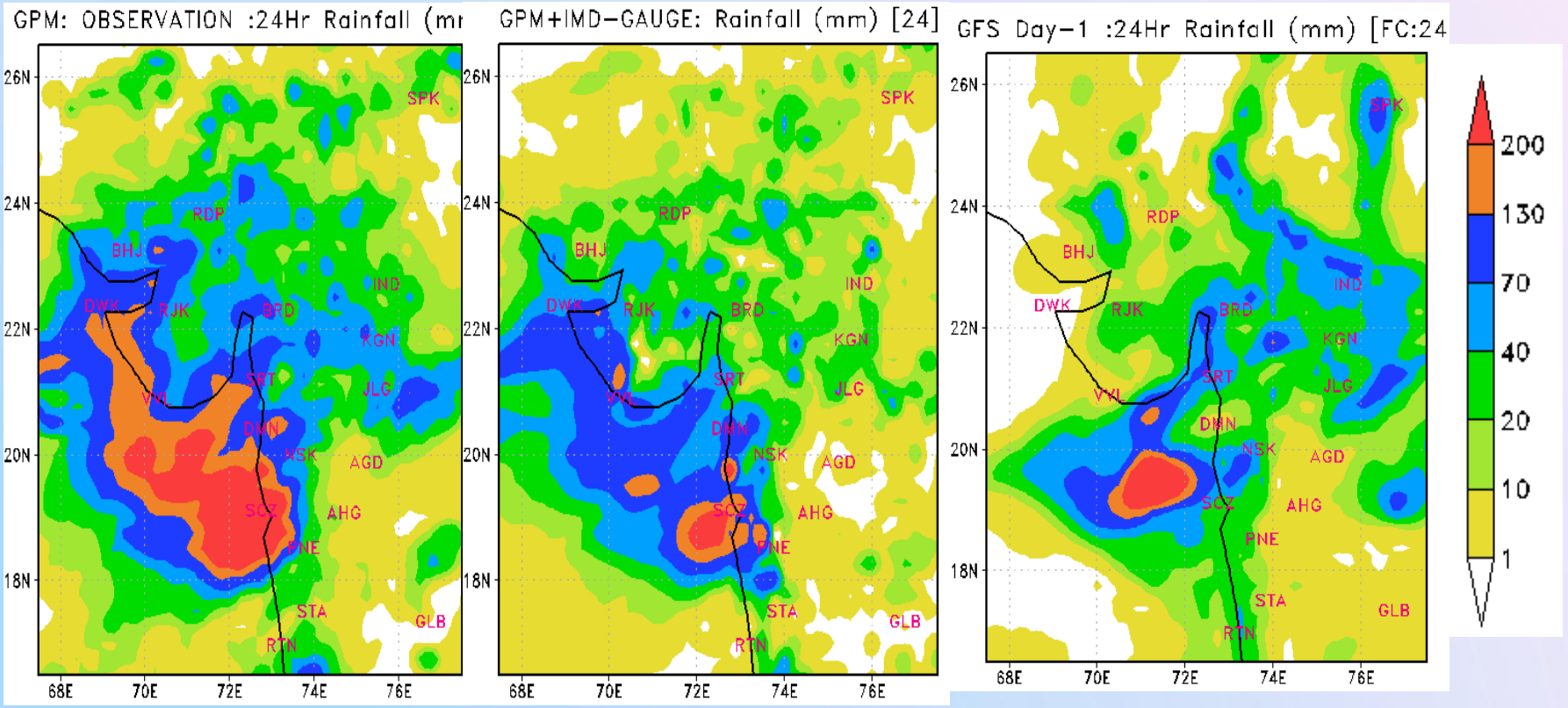


GFS model showed considerable skill in predicting the Tropical cyclogenesis Location over Bay of Bengal 7 days in advance

Observed and Model predicted rainfall (mm/day) for 29 AUG 2017

valid for 00 UTC of 29 AUG 2017 - 03 UTC of 30AUG 2017

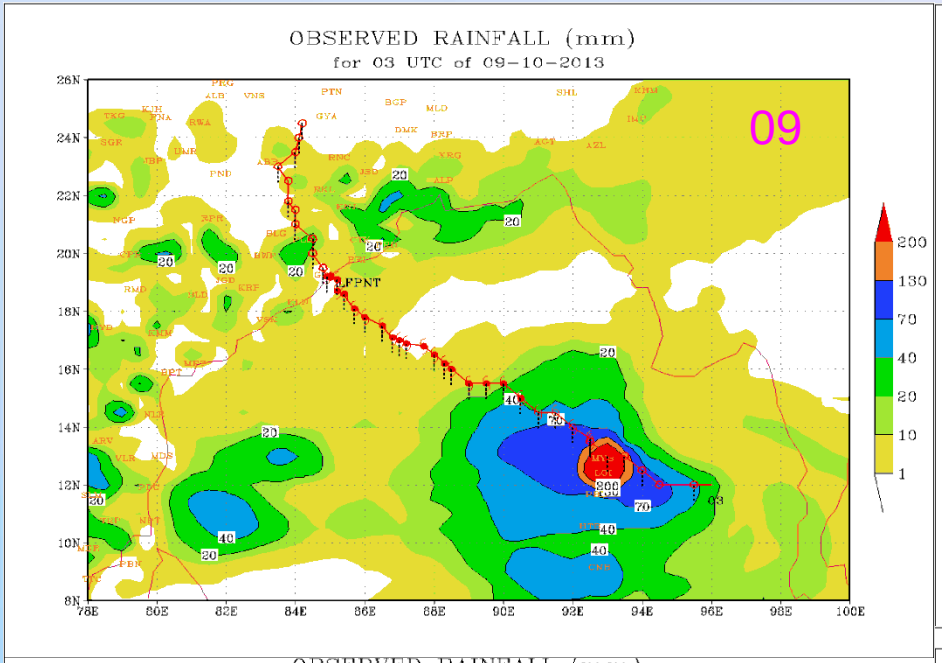
GPM | **GPM + RAINGAUGE** | **GFS**

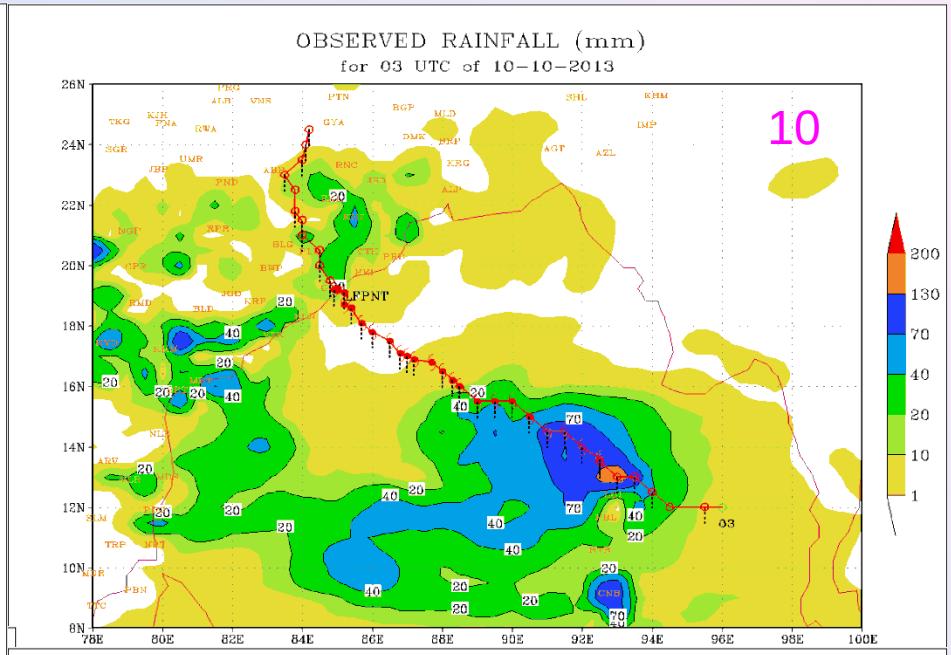


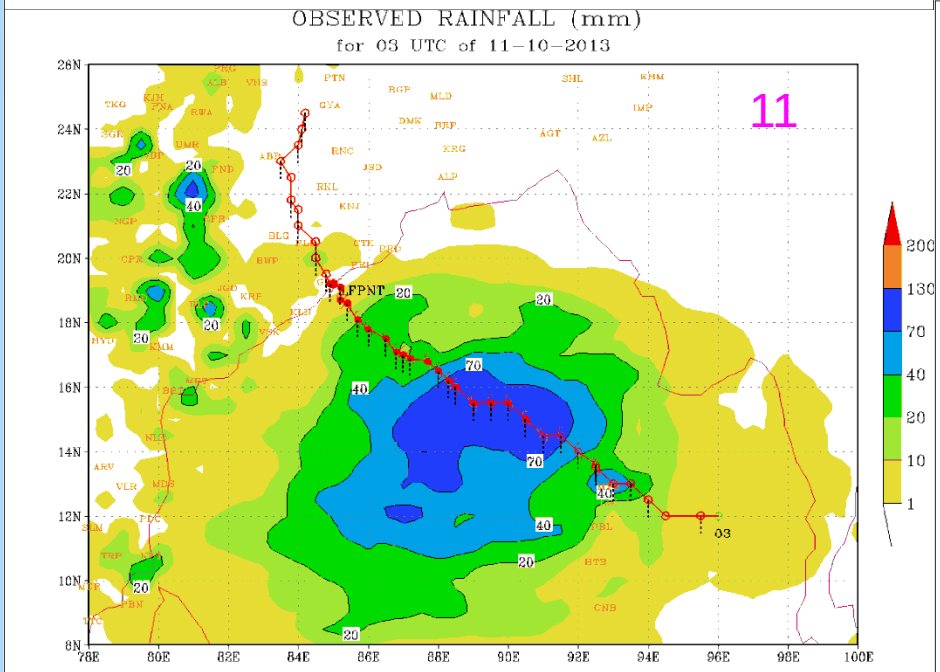
The spatial distribution of DAILY rainfall pattern shows that the magnitude of heavy rainfall of 29 August 2017 over Mumbai and adjoining coastal regions is better captured by GFS T1534.

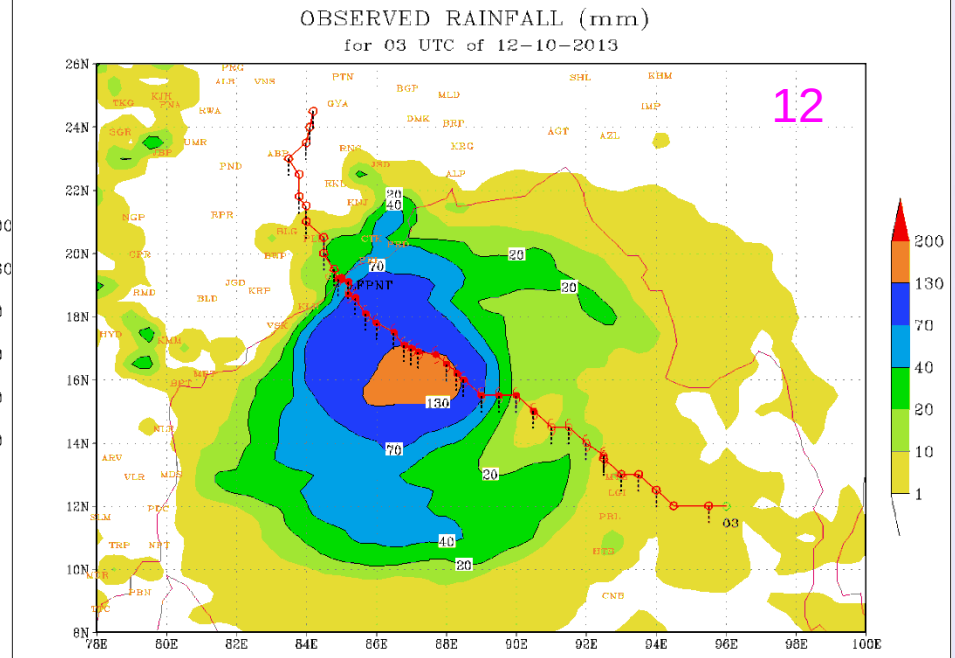
5. Heavy Rainfall

Heavy Rainfall (9-12 OCT) due to PHAILIN Cyclone over sea observed from TRMM

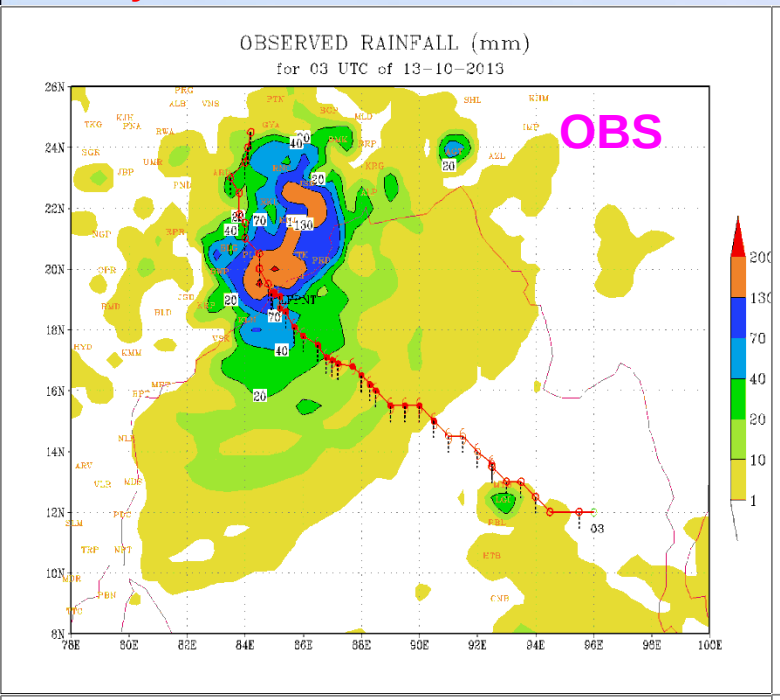


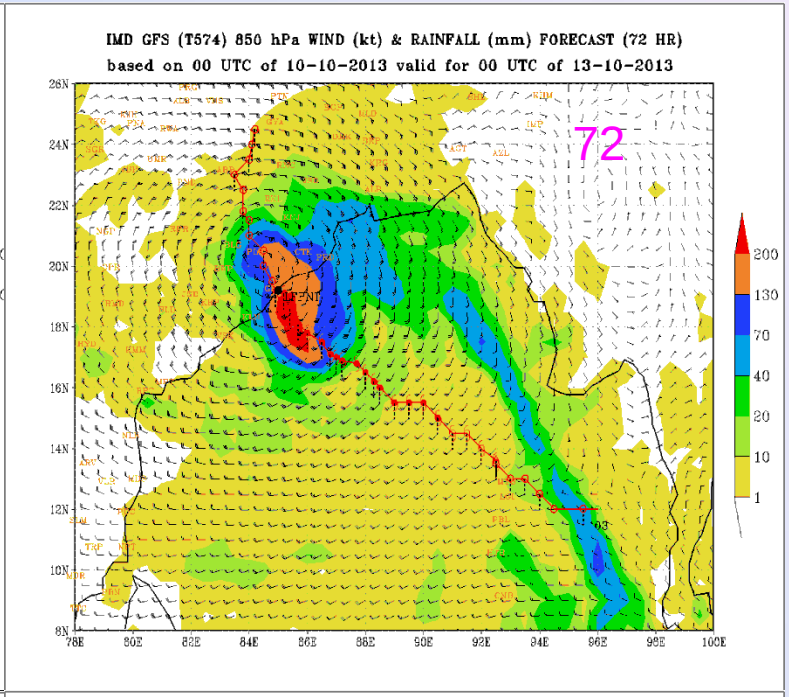


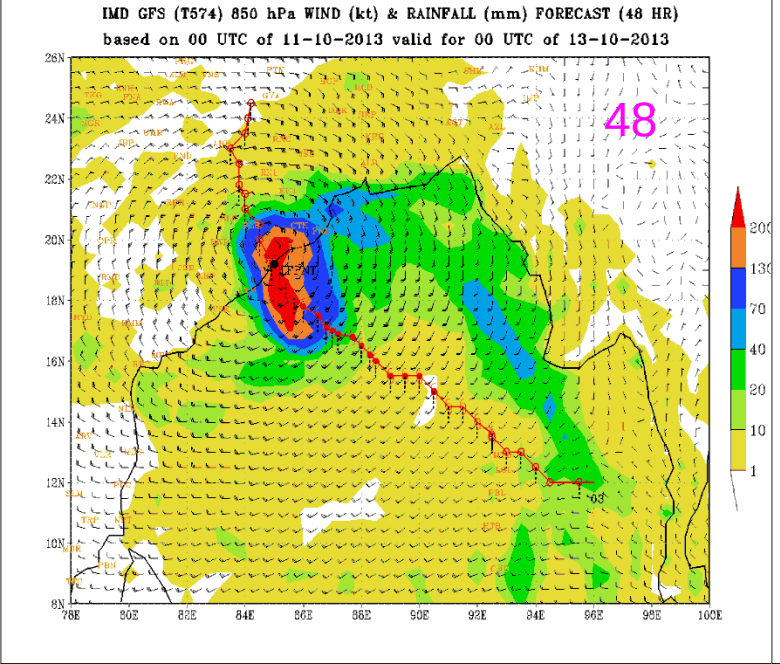


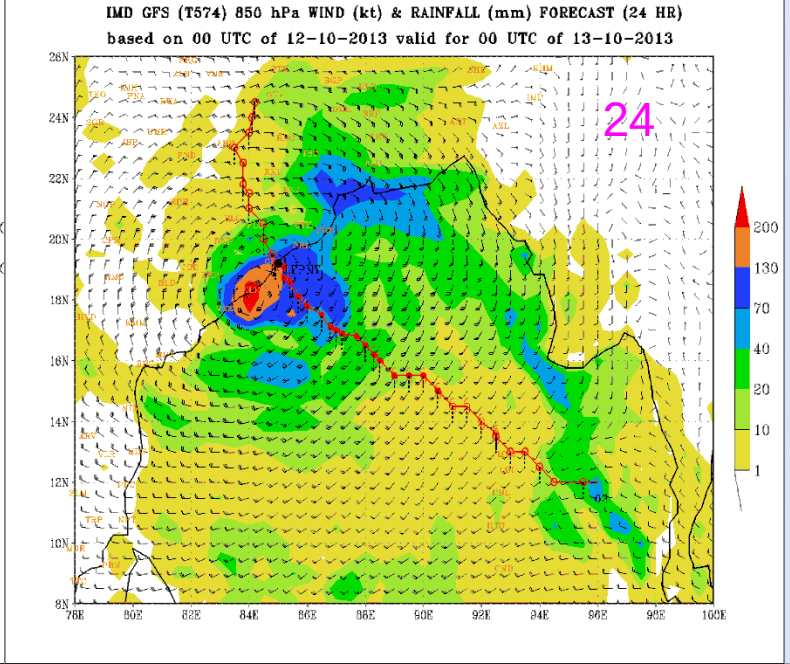


Heavy Rainfall on 13 Oct 2013 : observation from 03UTC 12 OCT to 03 UTC of 13 OCT 2013



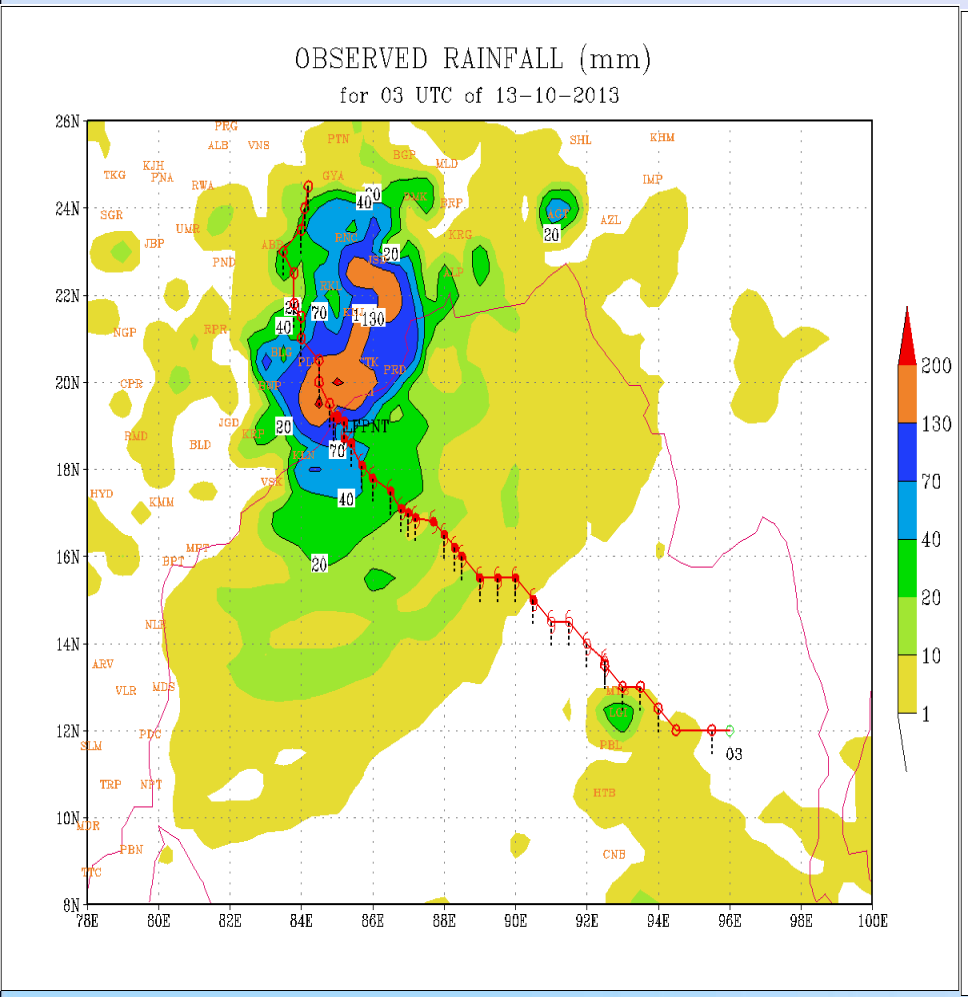


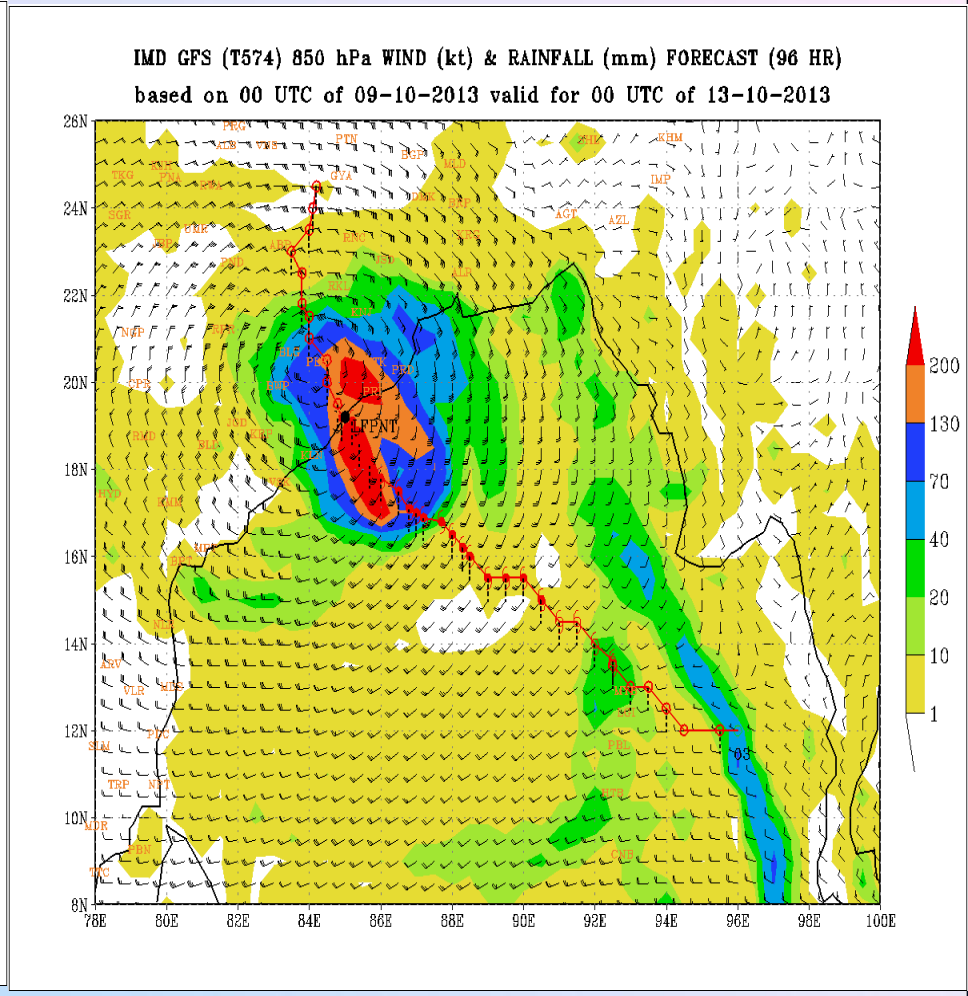




- Heavy Rainfall due to PHAILIN Cyclone over Orissa and adjoining areas ON 13th OCT 2013
- GFS could capture the area of heavy rainfall in the 24-72 hour forecast

Heavy Rainfall on: 13 OCT 2013 (observation from 03UTC 12 OCT to 03 UTC of 13OCT)

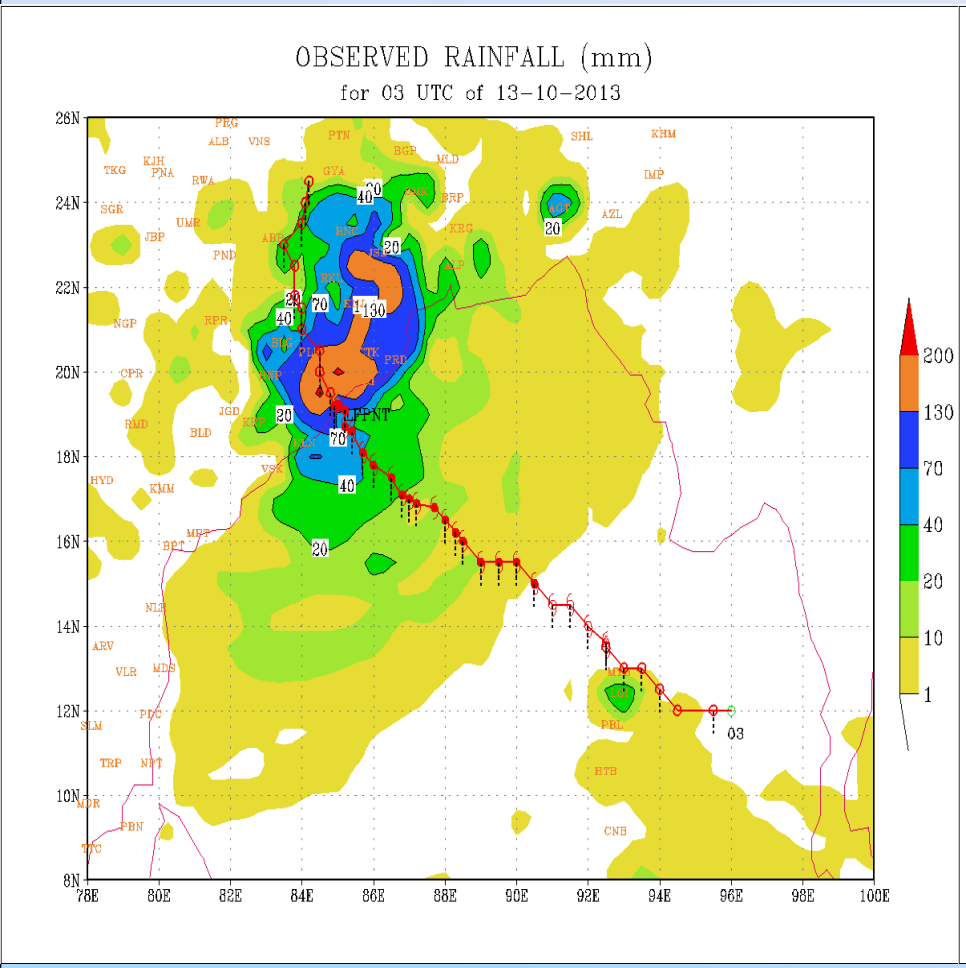


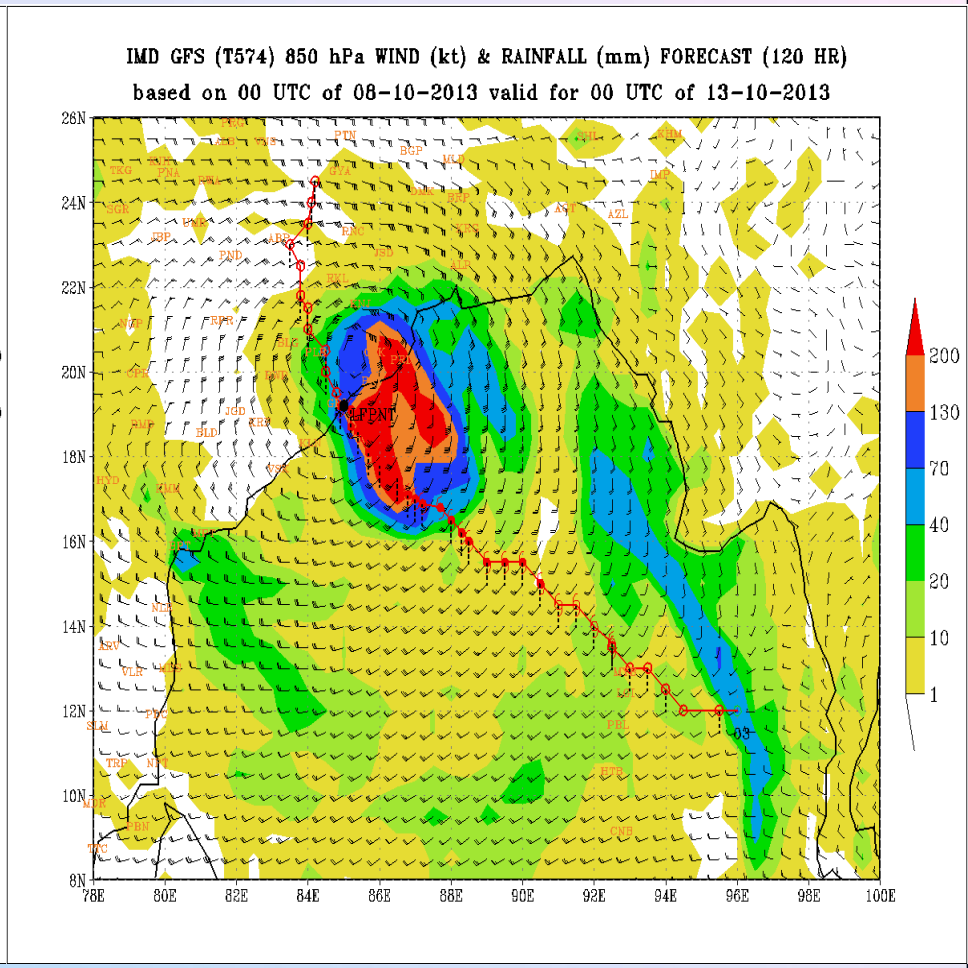


Heavy Rainfall due to PHAILIN Cyclone over Orissa on 13 OCT 2013

GFS 96 hour forecast could capture the broad rainfall distribution.

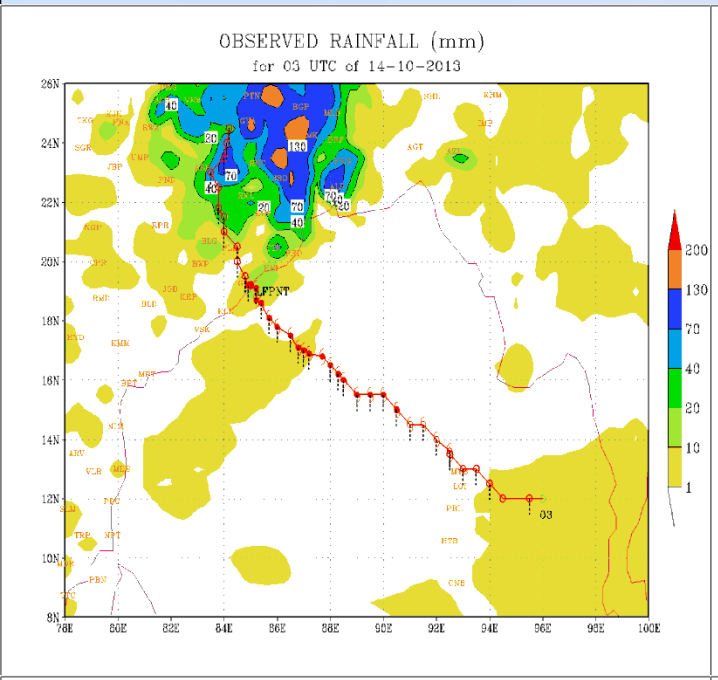
Heavy Rainfall on: 13 OCT 2013 (observation from 03UTC 12 OCT to 03 UTC of 13OCT)

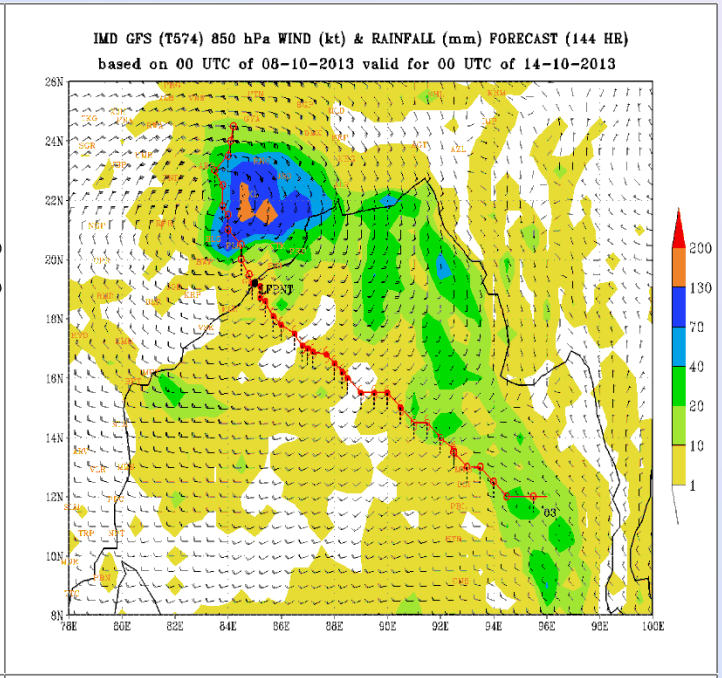


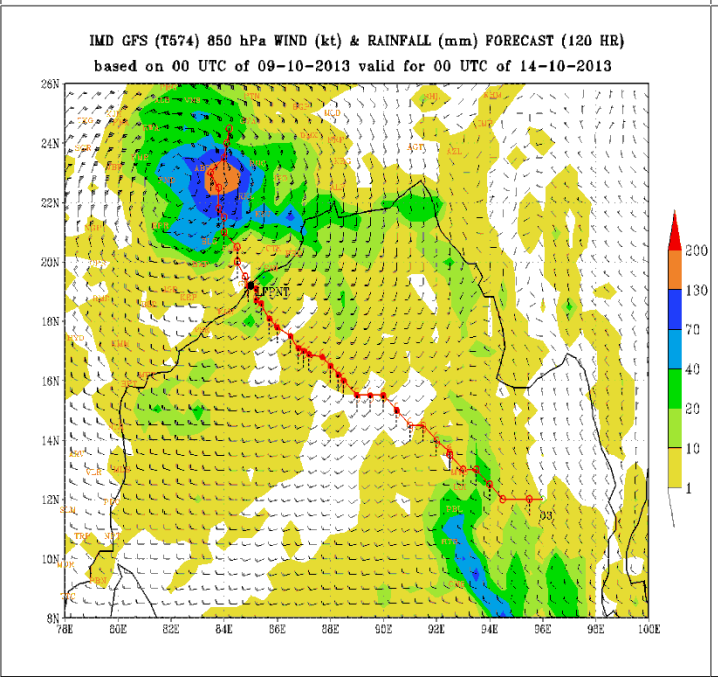


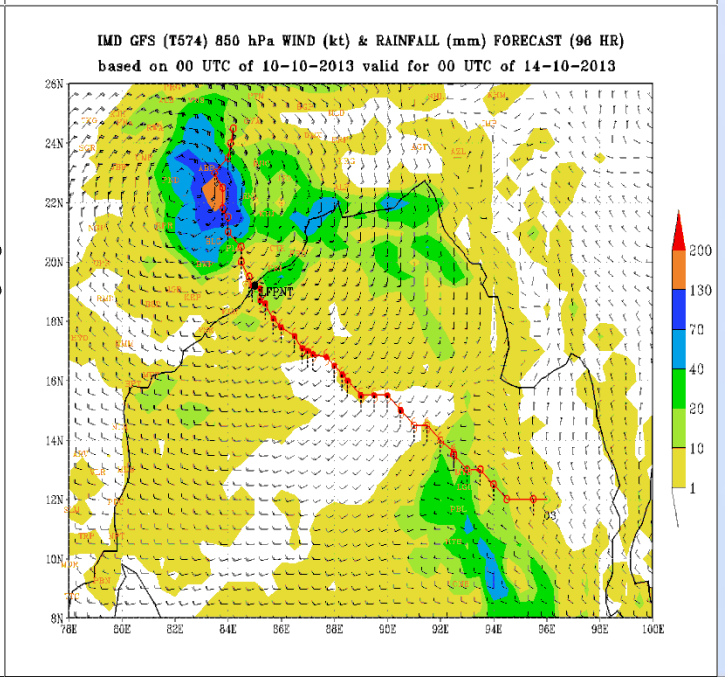
Heavy Rainfall due to PHAILIN Cyclone over Orissa on 13 OCT 2013
GFS 120 hour forecast could capture the broad rainfall distribution.

Heavy Rainfall ON 14 OCT 2013









Heavy Rainfall due to PHAILIN Cyclone over Orissa and adjoining areas ON 14 OCT 2013

•GFS could capture the area of heavy rainfall on 14 Oct 2013 in the 144h, 120h and 96 hour forecast.

Thank You