Tropical Cyclones Wind Radii Monitoring and Prediction over North Indian ocean

MONICA SHARMA
moniimd@gmail.com
Cyclone Warning Division
India Meteorological Department
Mausam Bhavan, Lodi Road, New Delhi-110003

भारत मौसम विज्ञान विभाग
INDIA METEOROLOGICAL DEPARTMENT

Presentation layout

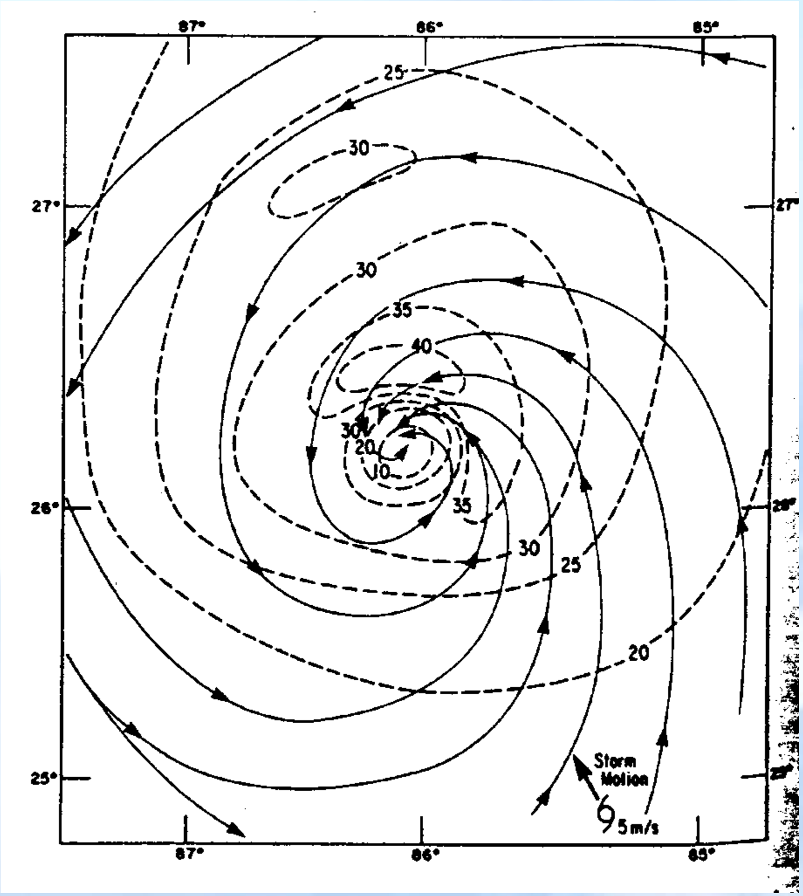
- Introduction
- Utility
- Characteristic features of TC wind radii
- Methodology adopted for TC wind radii monitoring and prediction
- Products generated by RSMC
- Limitations and future Scope

Introduction

- India Meteorological Department (IMD) is the nodal agency for Tropical Cyclones (TC) monitoring and prediction over the North Indian Ocean.
- TC forecast issued by IMD contains forecasts of TC wind field for 5 days. This forecast is given six hourly for first 24 hrs and 12hrly for subsequent hrs.
- This forecast is issued four times a day based on 00, 06, 12, 18 UTC observations.
- The monitoring and forecasting of TC wind radii was introduced during TC, Giri over the Bay of Bengal in October, 2010. Coded bulletin was introduced from Cyclone Viyaru, 2013.
- Objective of the study is to bring out a road map for wind field analysis and find out limitations and future scope in monitoring and forecasting of Quadrant wind radii of TCs.

Introduction

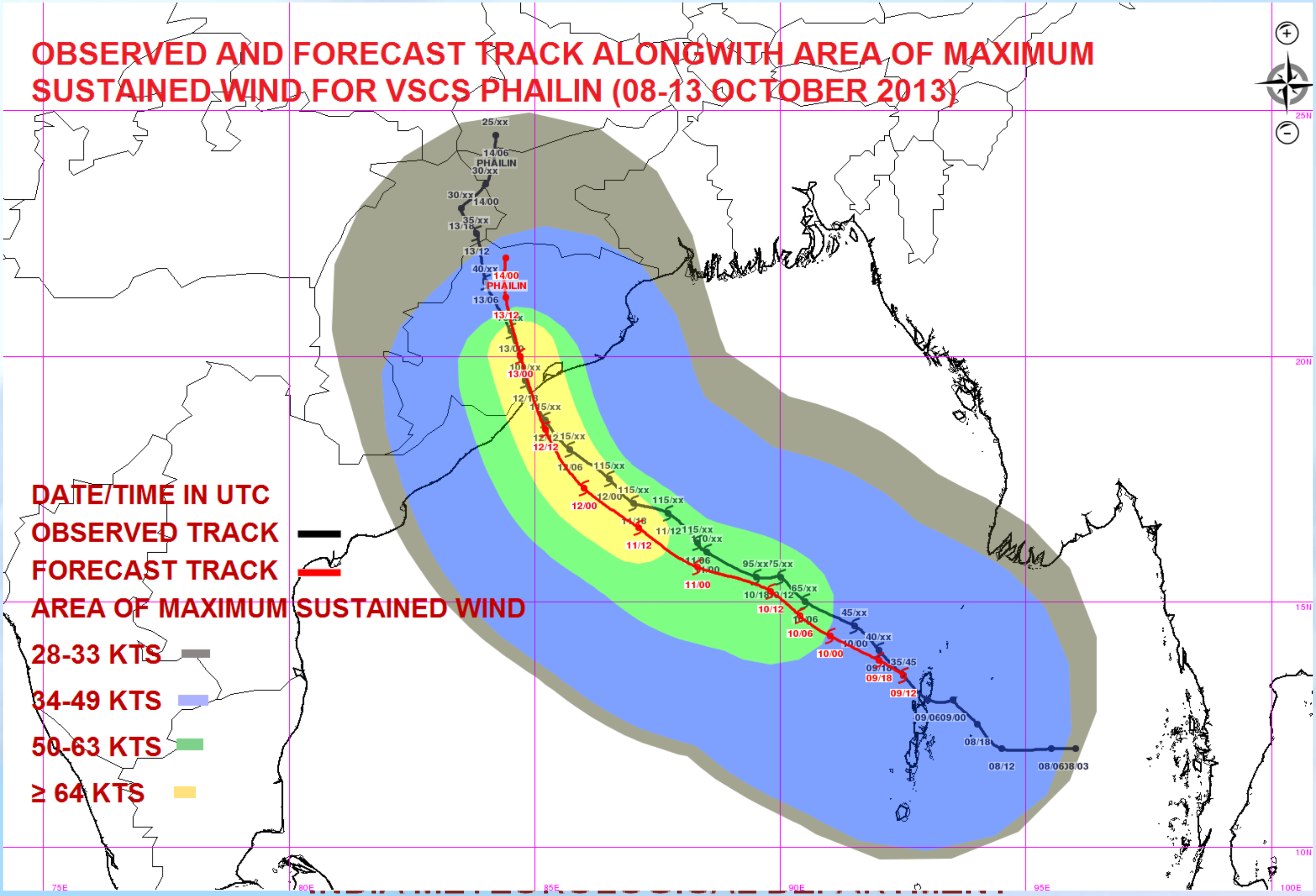
TC Wind Field



- **Series of concentric circles of wind**
- **Size of a cyclone**
- **Intensity of a cyclone**
- **Monitoring is dependent on indirect observations**

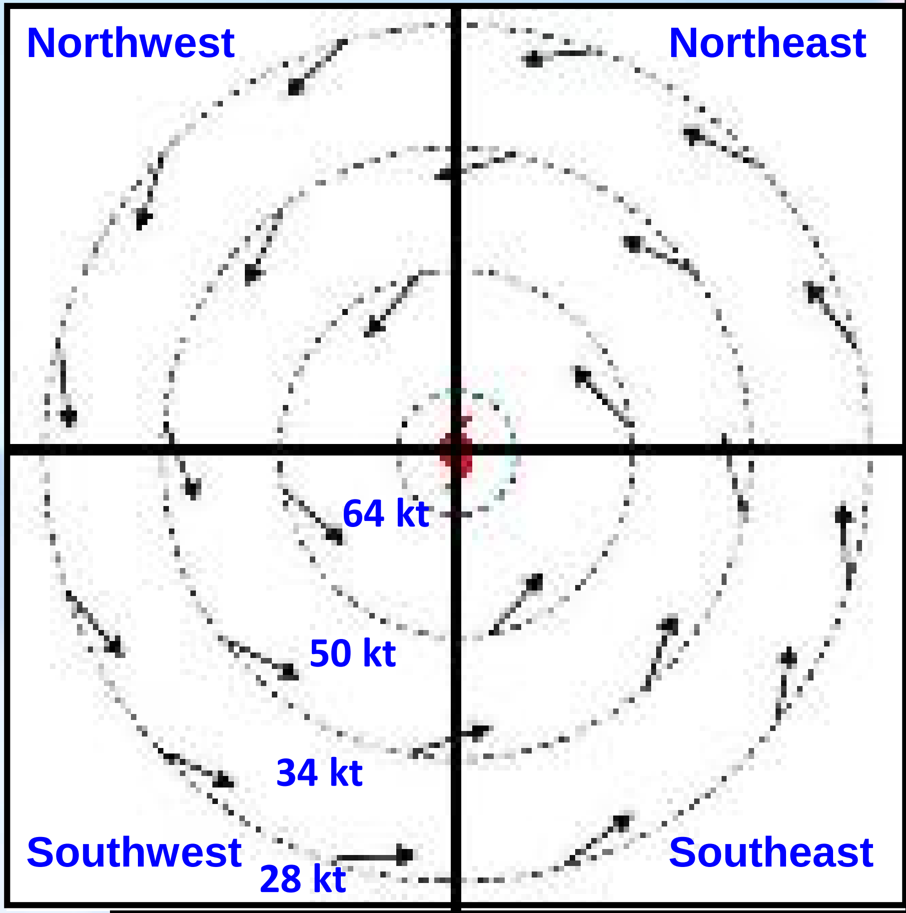
Utility of wind radii forecast

- ❖Mariners
- ❖Modeling Group
- ❖Storm surge forecast
- ❖Insurance agencies
- ❖Disaster Managers
- ❖Planners



Characteristic features of wind radii forecast

- Wind radii represents the maximum radial extent of winds reaching a threshold value in each quadrant.
- It is represented in nautical miles (1nm=1.85 km).
- The wind radii forecasts are issued over the sea area only as per the requirement of the users.
- The TC wind radii forecasts are generated in terms of the radii of winds reaching 34kts, 50kts and 64kts value in four geographical quadrants around the tropical cyclone. In addition, radii of 28 kts is also added.



Radii of surface wind thresholds used by IMD for TC forecasting

- These are referred as R28, R34, R50 and R64 respectively.

Threshold Criteria

- The thresholds of 28 kts, 34kts, 50kts and 64kts are chosen according to users requirement.
  - the wind of 28kts corresponds to squally wind threshold
  - the wind of 34kts corresponds to gale wind threshold
  - the wind of 50kts is the requirement of mariners
  - the wind of 64kts is the wind with hurricane force.

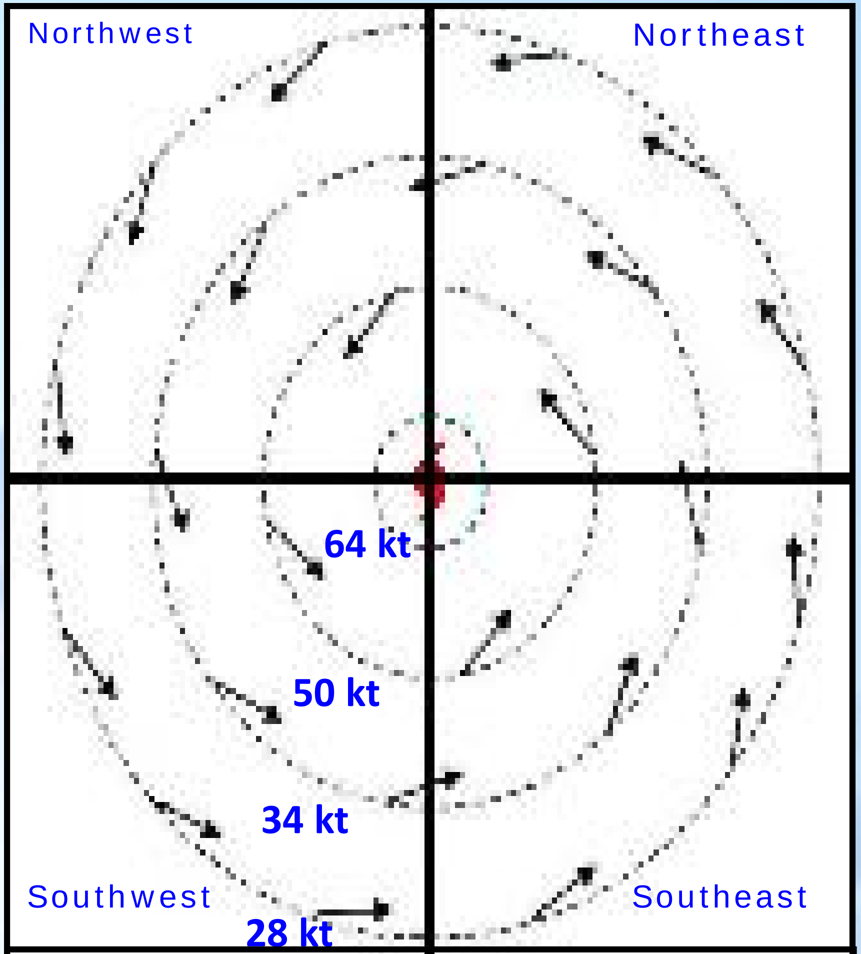


Fig.1. Radii of surface wind thresholds used by IMD for TC forecasting

Methodology for TC wind radii monitoring

The inputs for monitoring are obtained from following observations

❖Surface observations (ships, buoys, GTS data, AWS, HWSR)

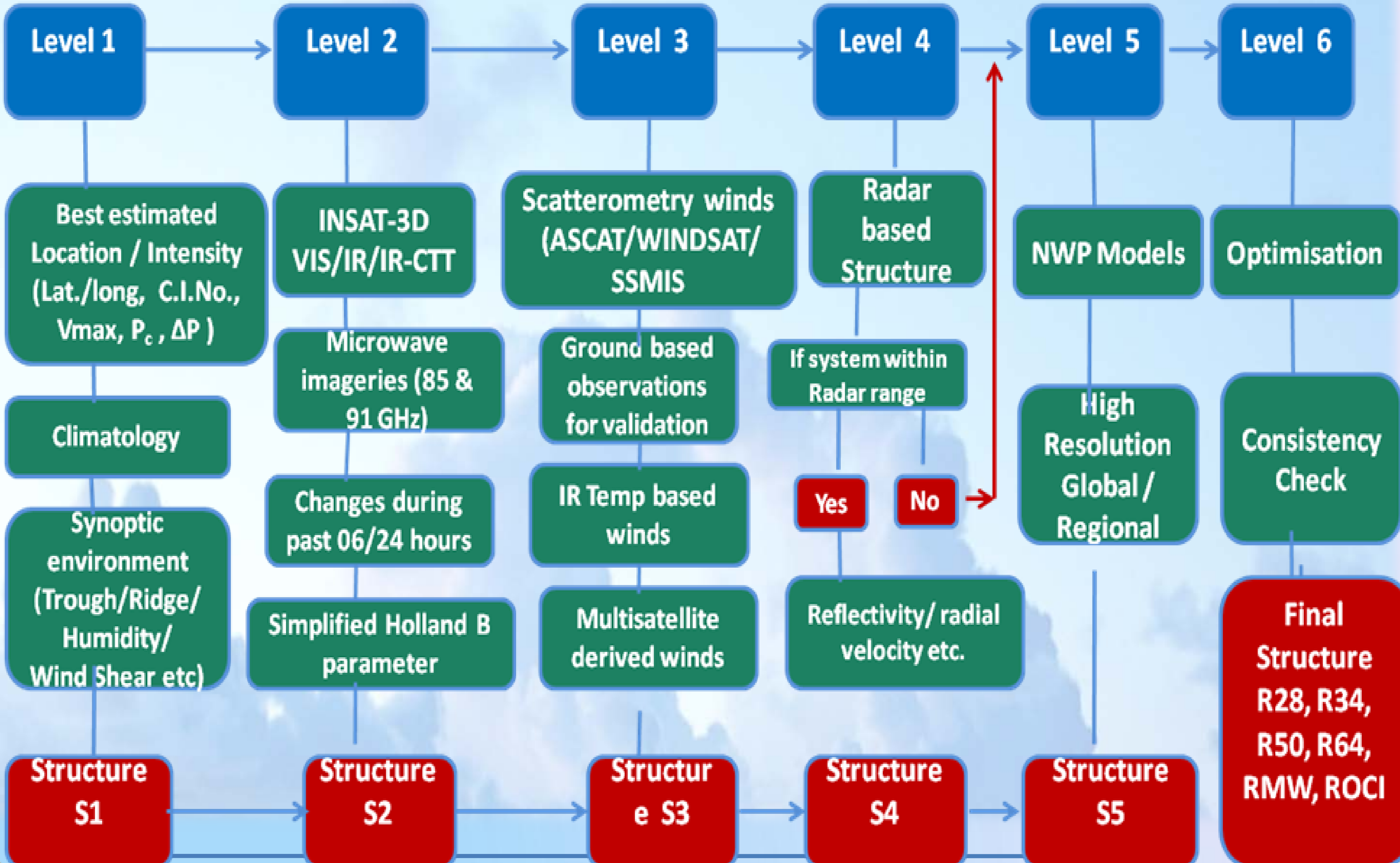
❖Satellite observations (Scatterometer, Microwave, CIMSS, Geostationary satellites)

❖Dvorak T. No. estimates (IMD Sat., JTWC, NOAA, ADT estimates from CIRA)

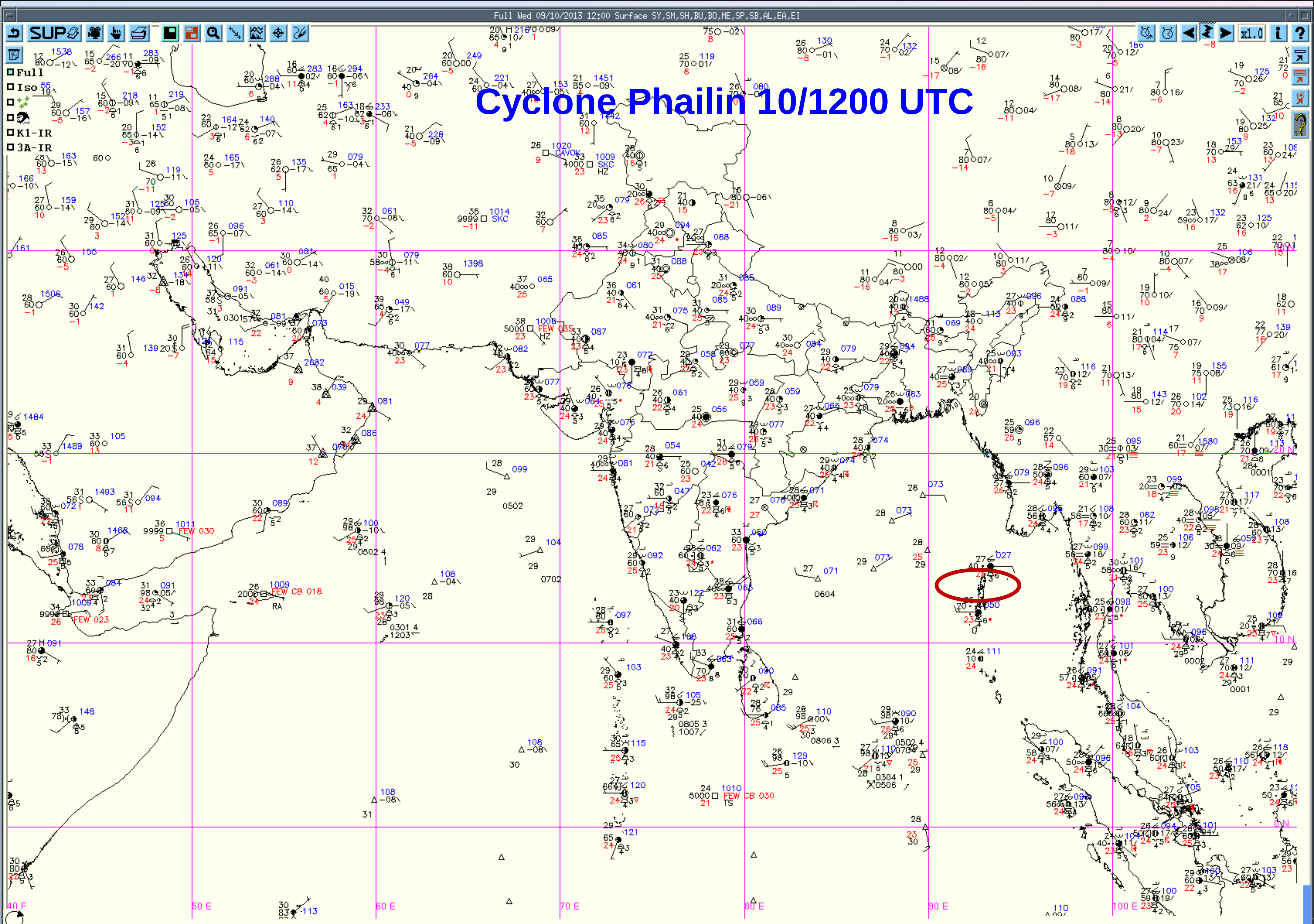
❖DWR (when system is within the radar range)

❖ Coastal wind observations (when the system is close to coast or over land)

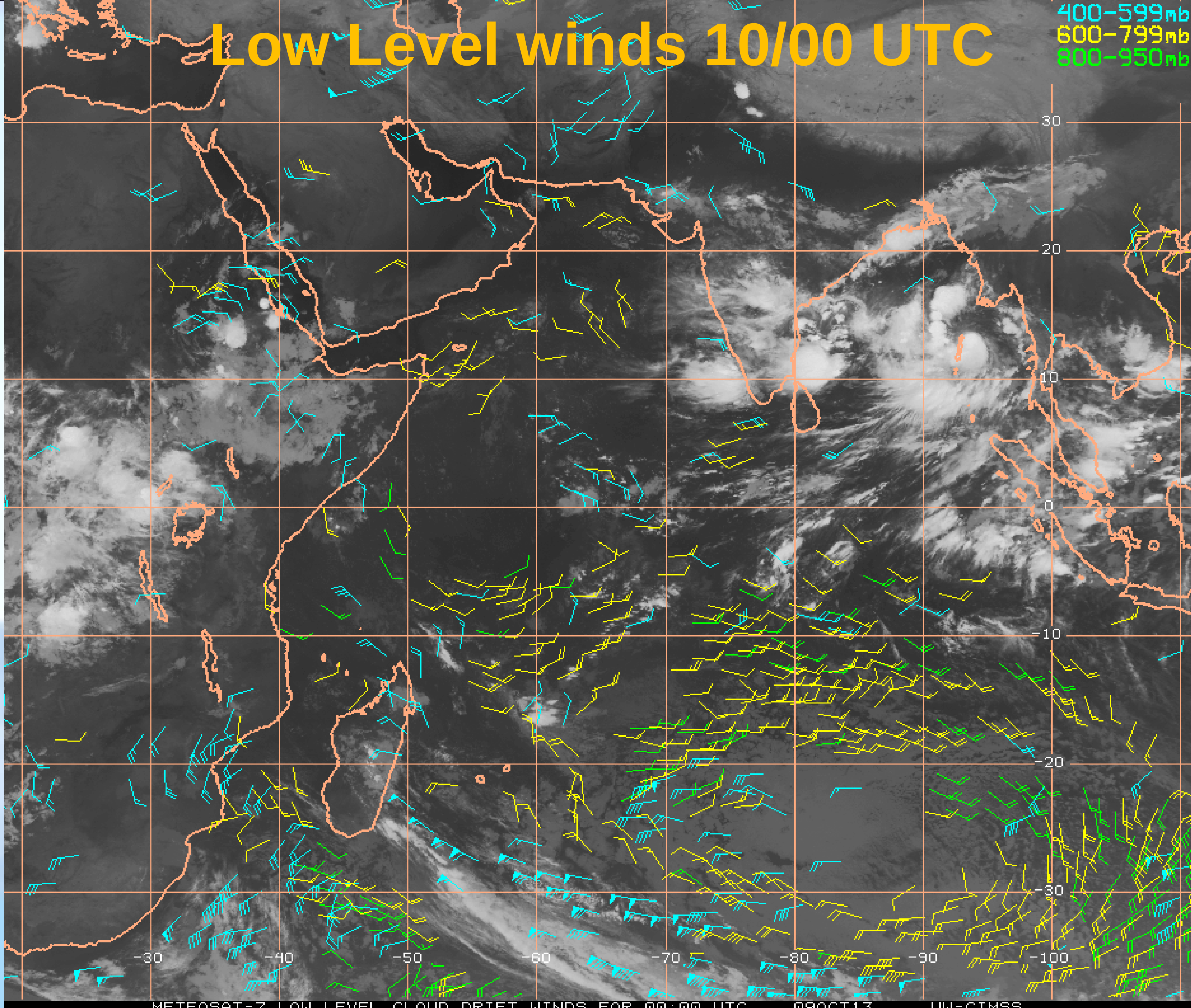
Methodology for TC wind radii monitoring



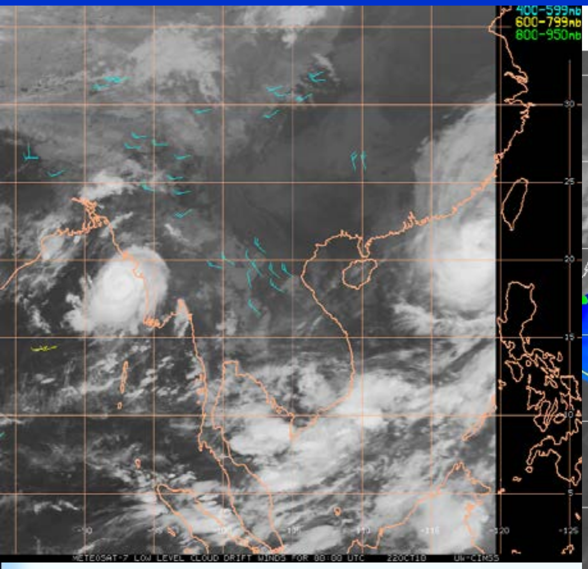
Cyclone Phailin 10/1200 UTC

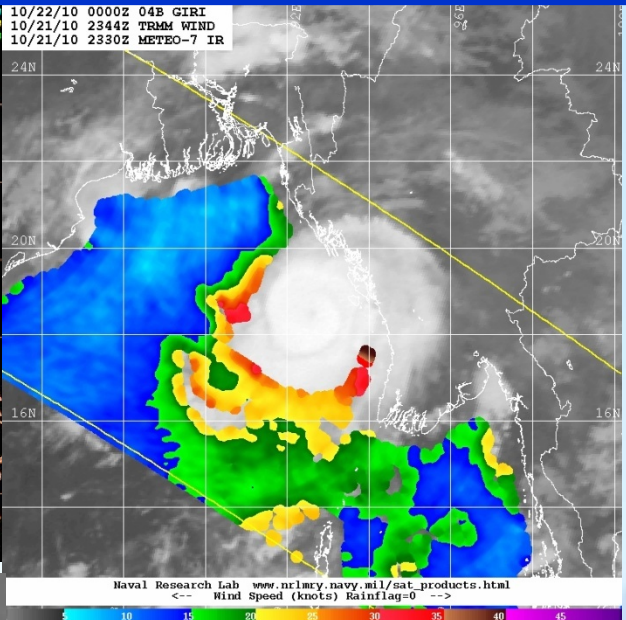


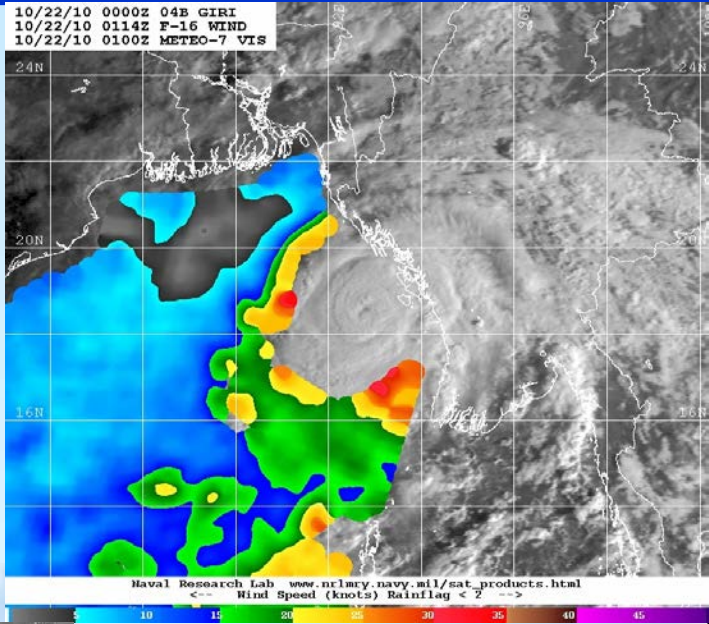
Low Level winds 10/00 UTC

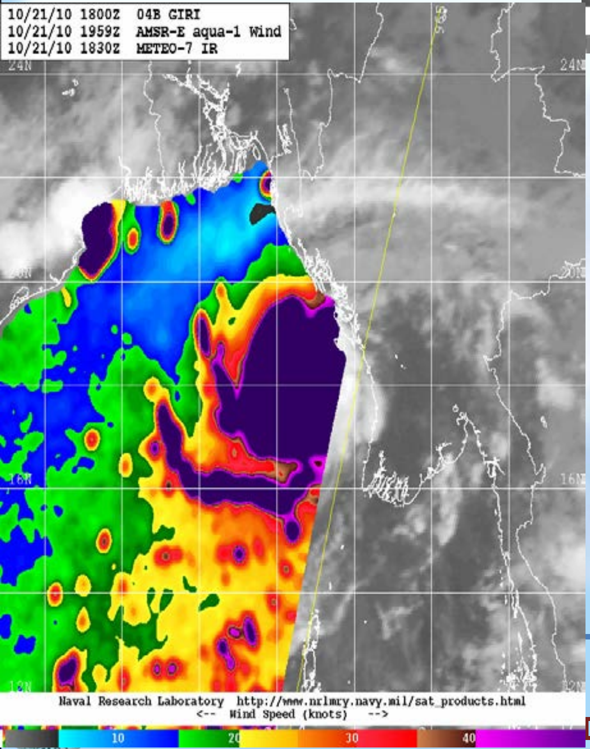


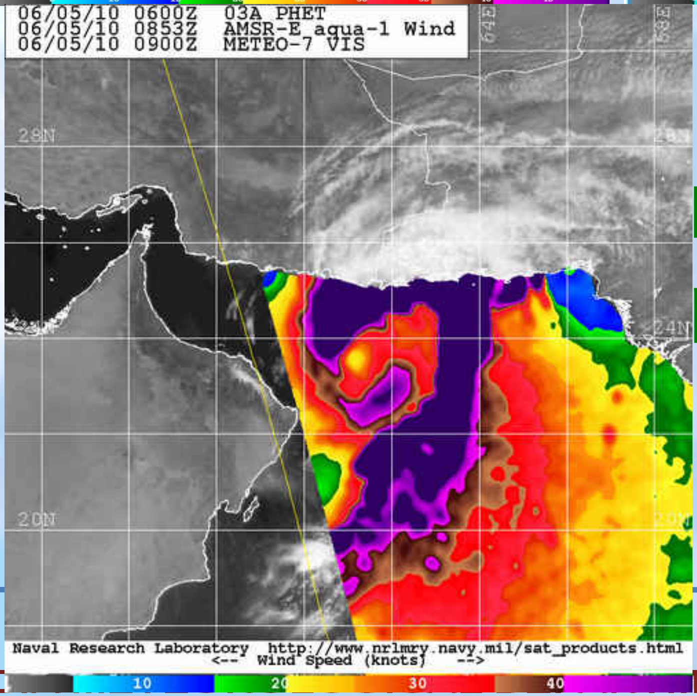
Example of TC wind radii monitoring products







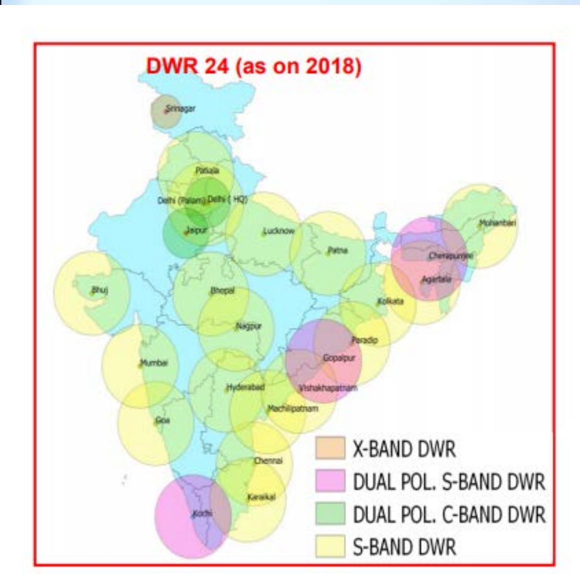


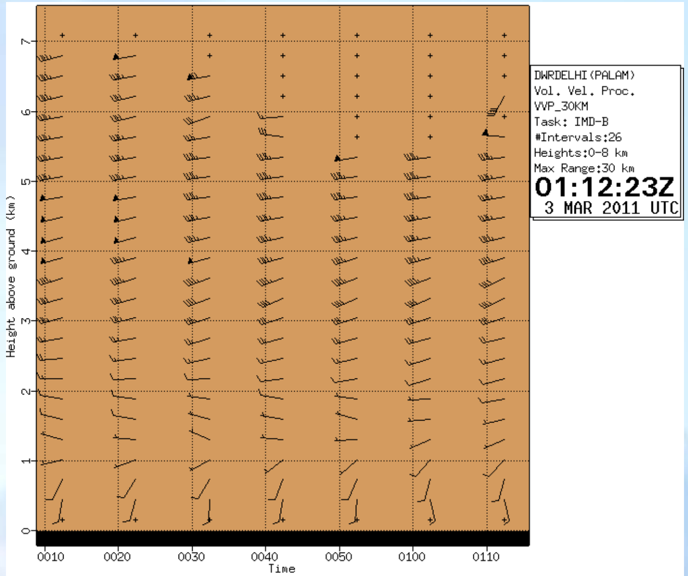


Remotely sensed products

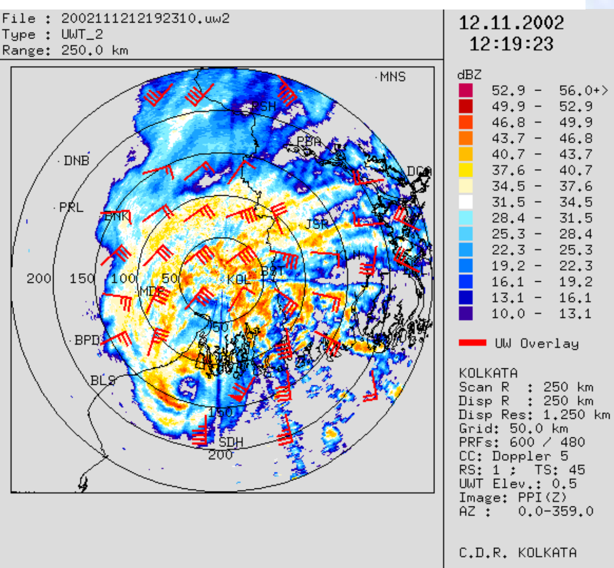
RADAR PRODUCTS

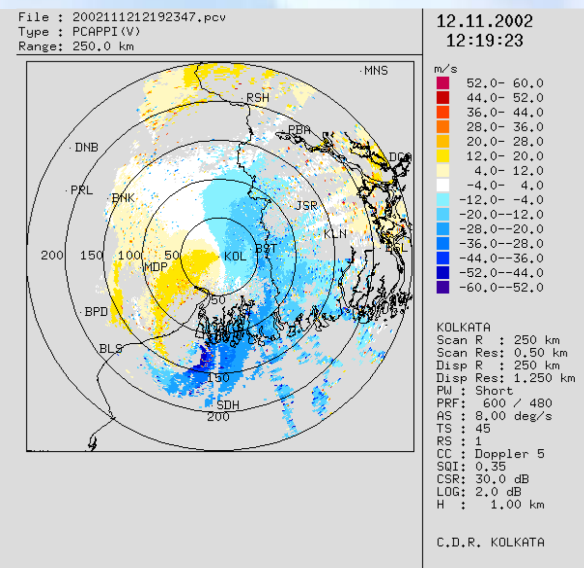
33 DWRs operational countrywide





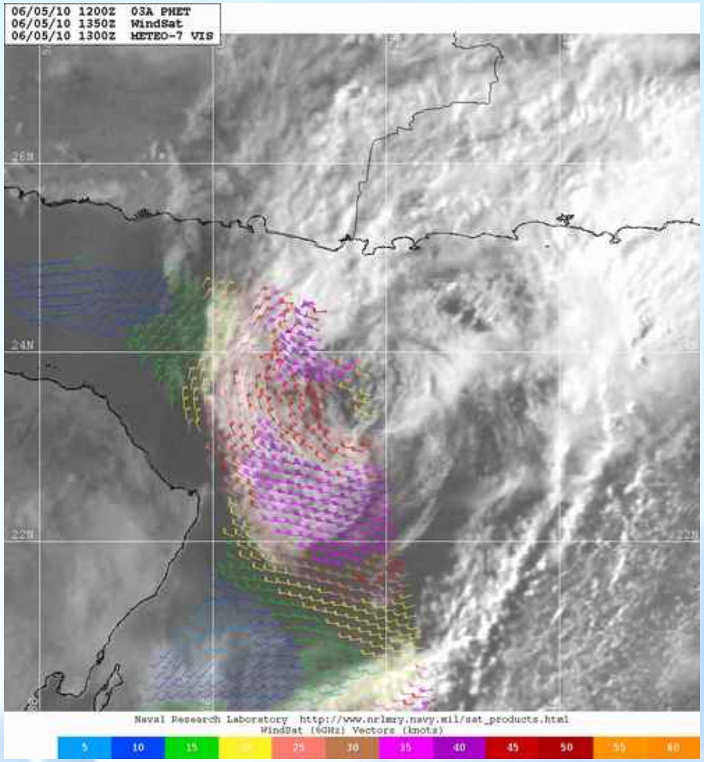
- ❖ Vertical profile of horizontal wind over station(VVP)
- ❖ Surface wind by uniform wind technique (UWT)
- ❖ PCAPPI (V)

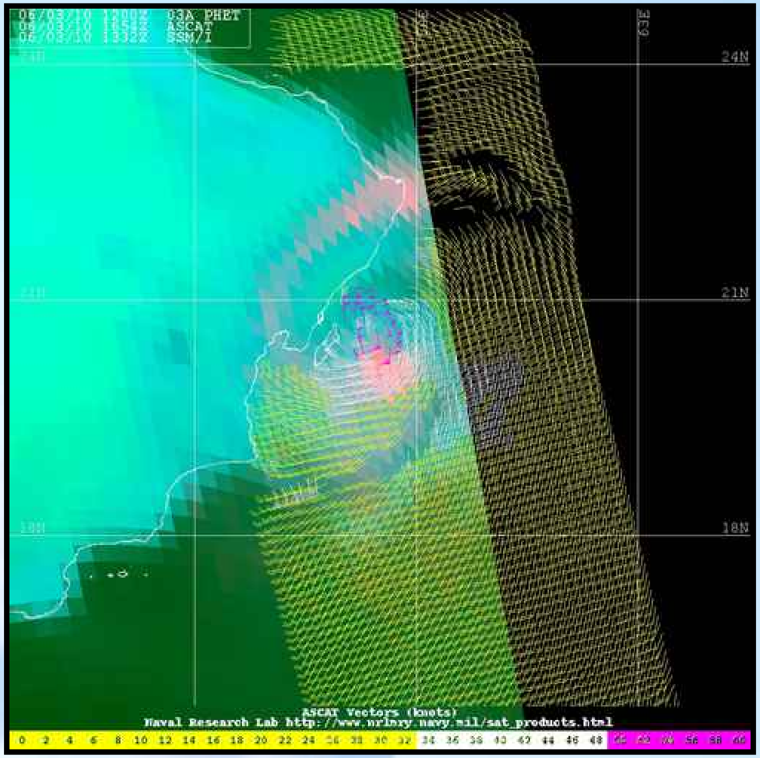


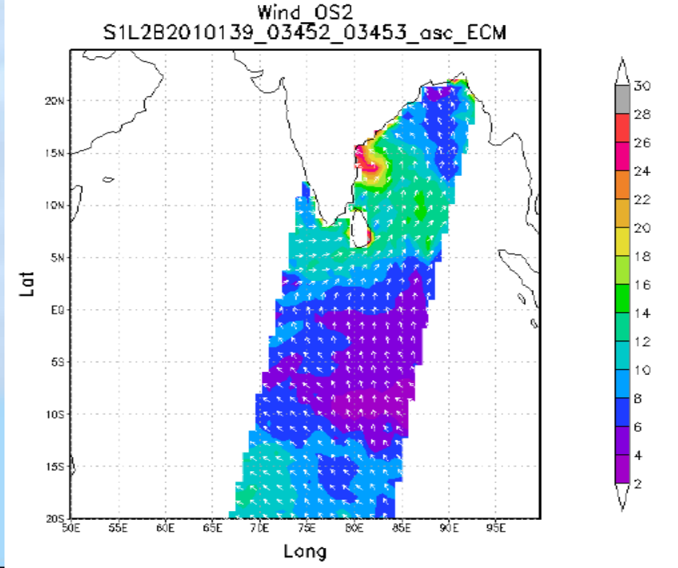


RTMENT

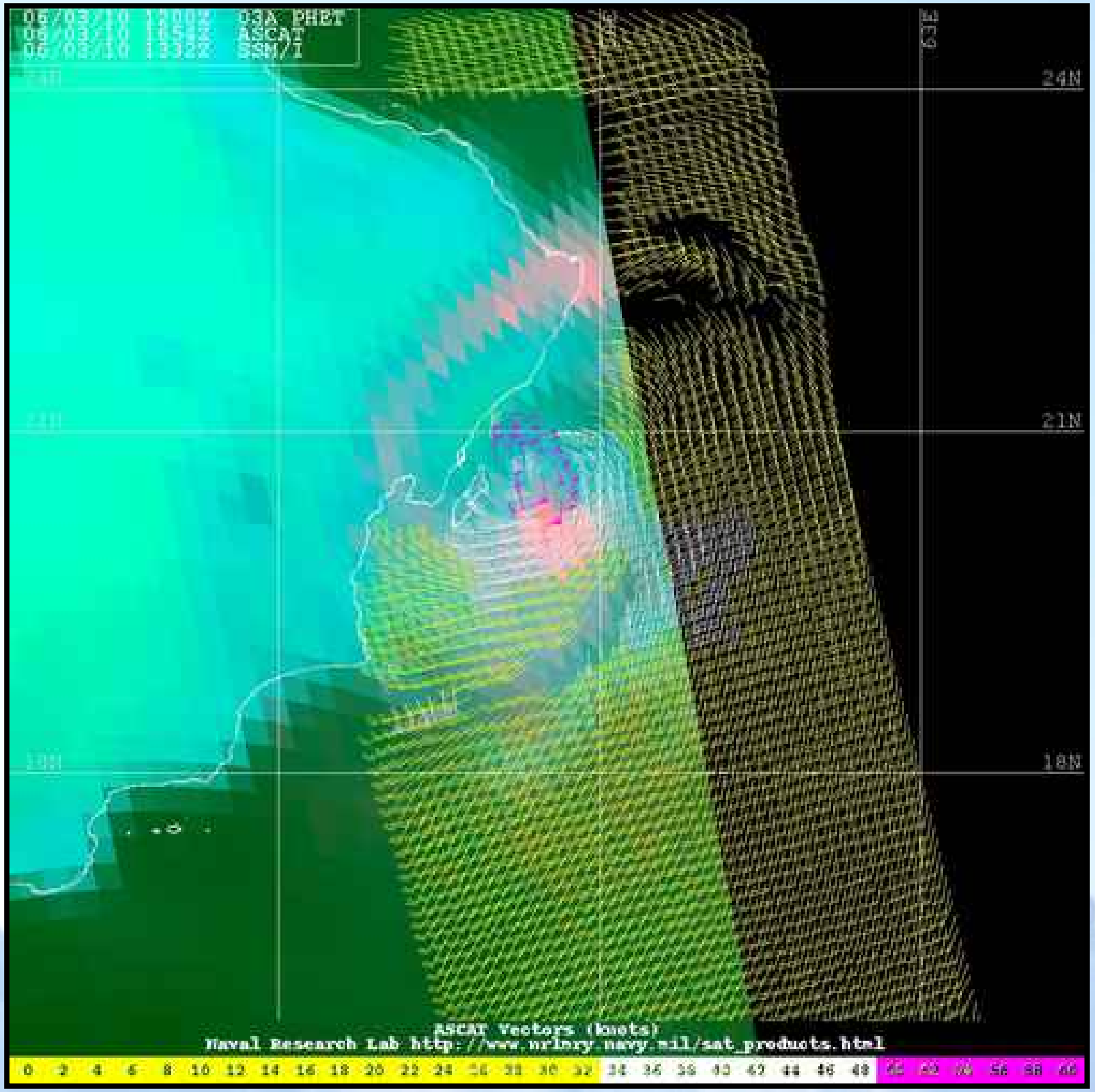
Example of TC wind radii monitoring products



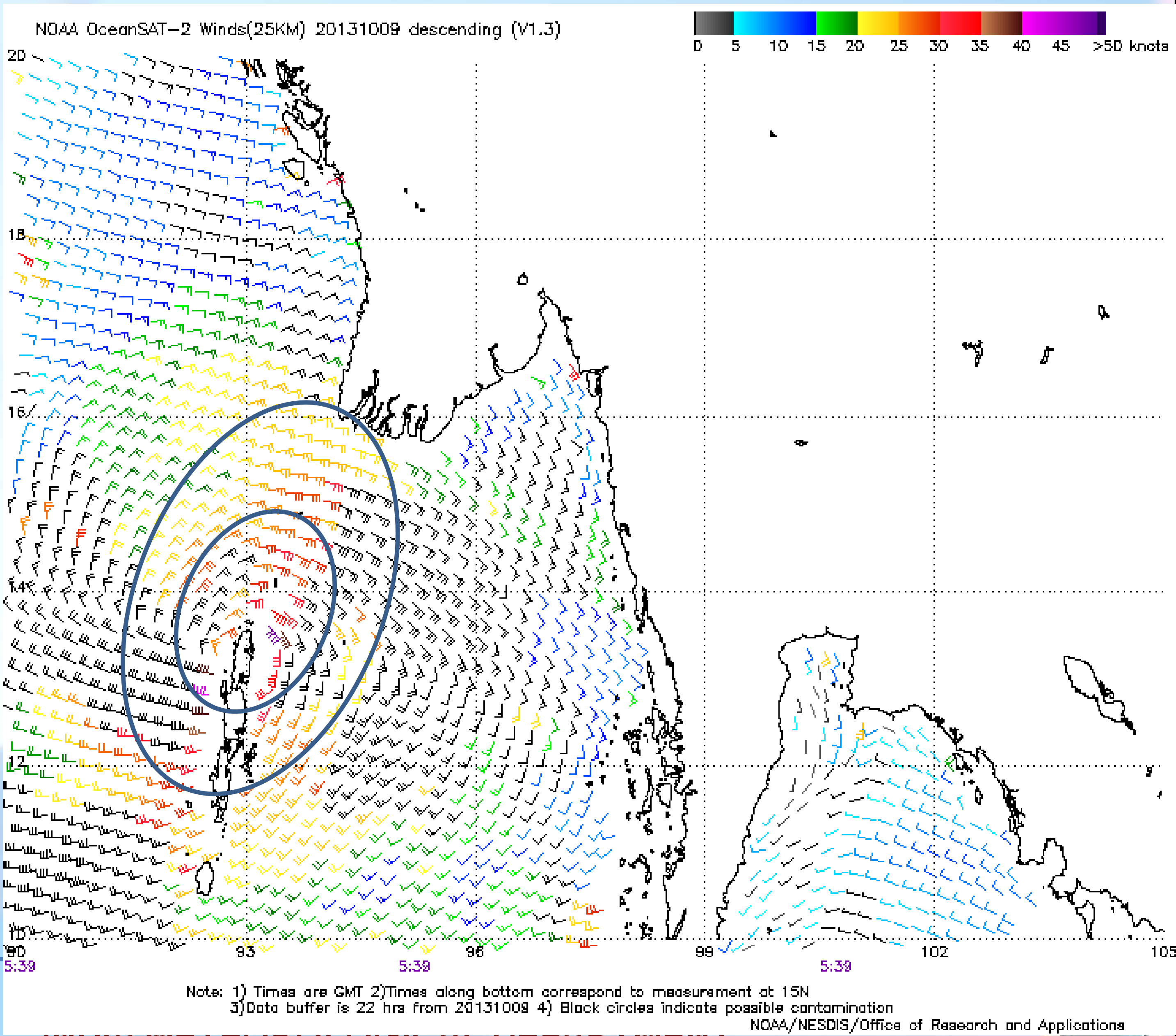


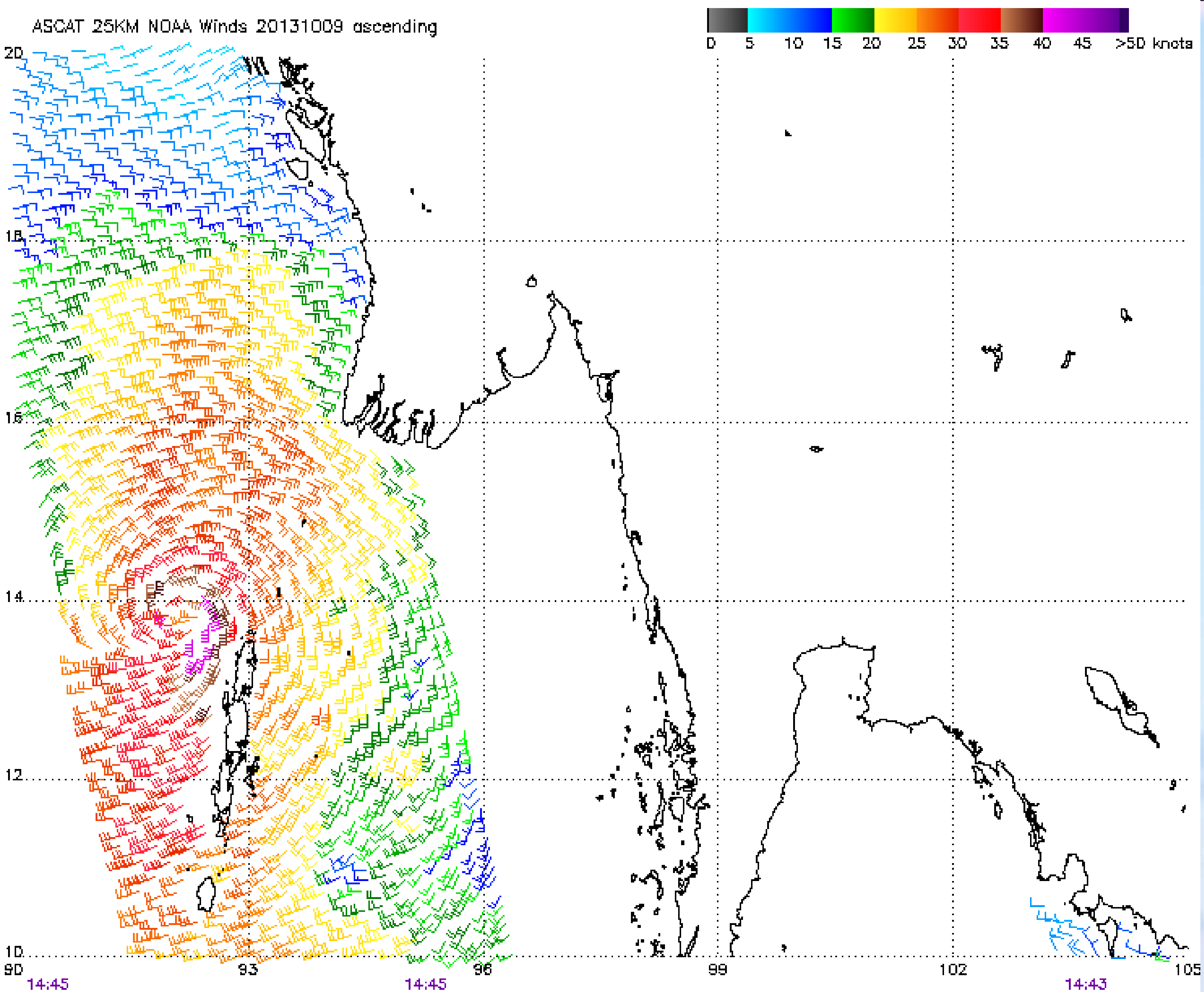


Scatterometry products


03A PHET
ASCAT
SSM/I
24N
21N
18N
ASCAT Vectors (knots)
Naval Research Lab http://www.nrlmry.navy.mil/sat_products.html
0 2 4 6 8 10 12 14 16 18 20 22 24
34 36 38 40 42 44 46 48

http://manati.star.nesdis.noaa.gov/datasets/ASCATData.php



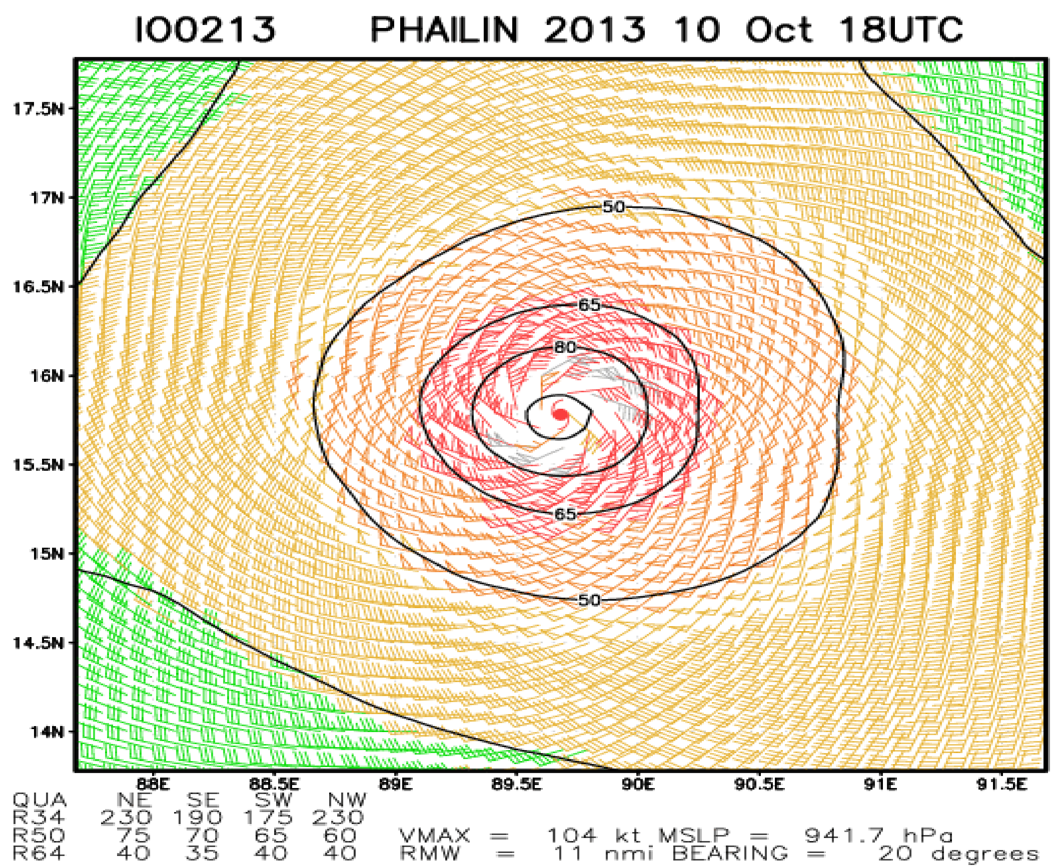


Note: 1) Times are GMT 2)Times along bottom correspond to measurement at 15N
3)Data buffer is 22 hrs from 20131009 4) Black circles indicate possible contamination

NOAA/NESDIS/Office of Research and Applications

CIRA Operational Page

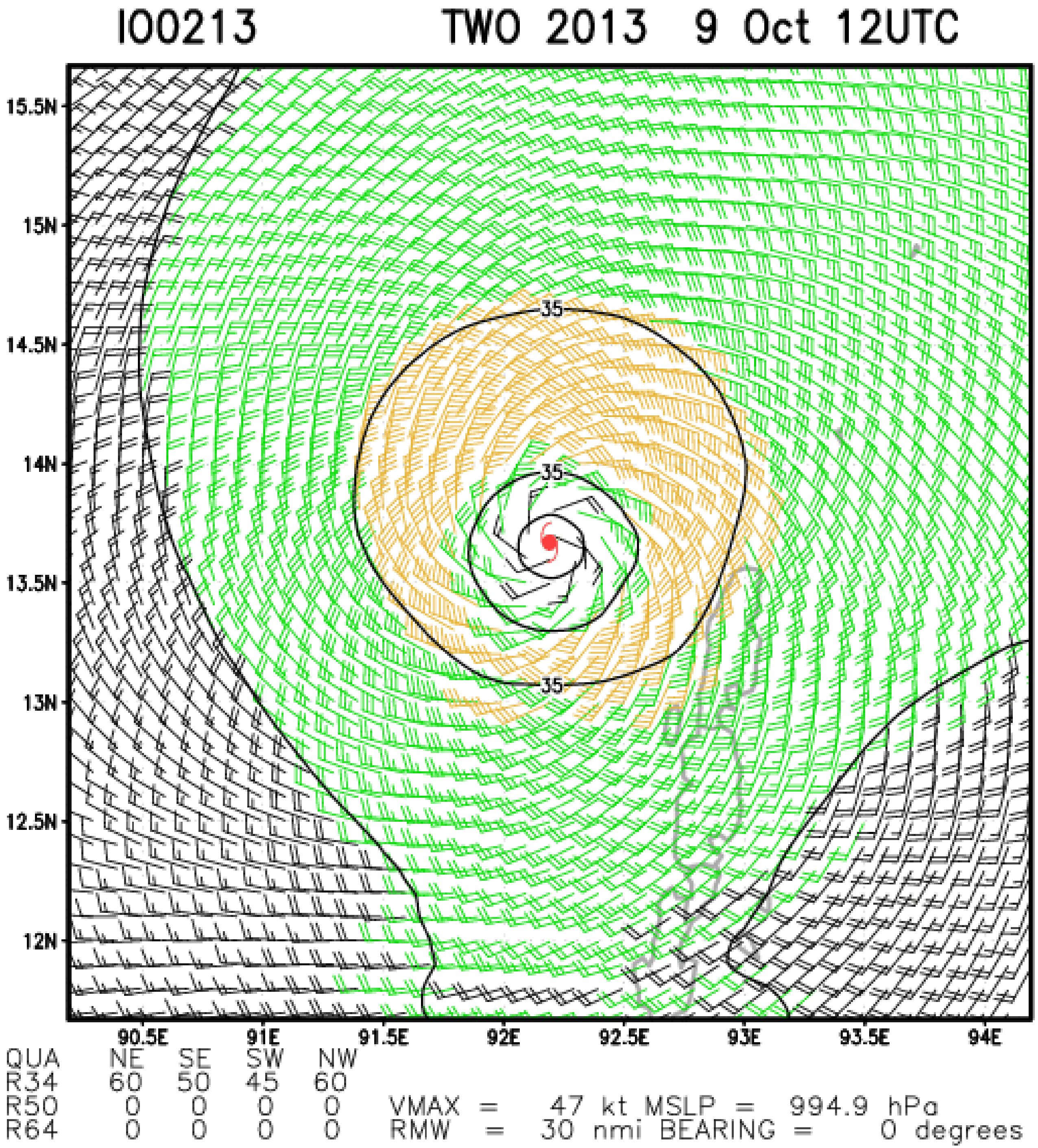
Real-time satellite products developed by OAA/NESDIS/STAR/RAMMB and the Cooperative Institute of Research in the Atmosphere (CIRA)--- http://severe.worldweather.wmo.int/TCFW/



Wind distribution at 700 hPa level is derived based on

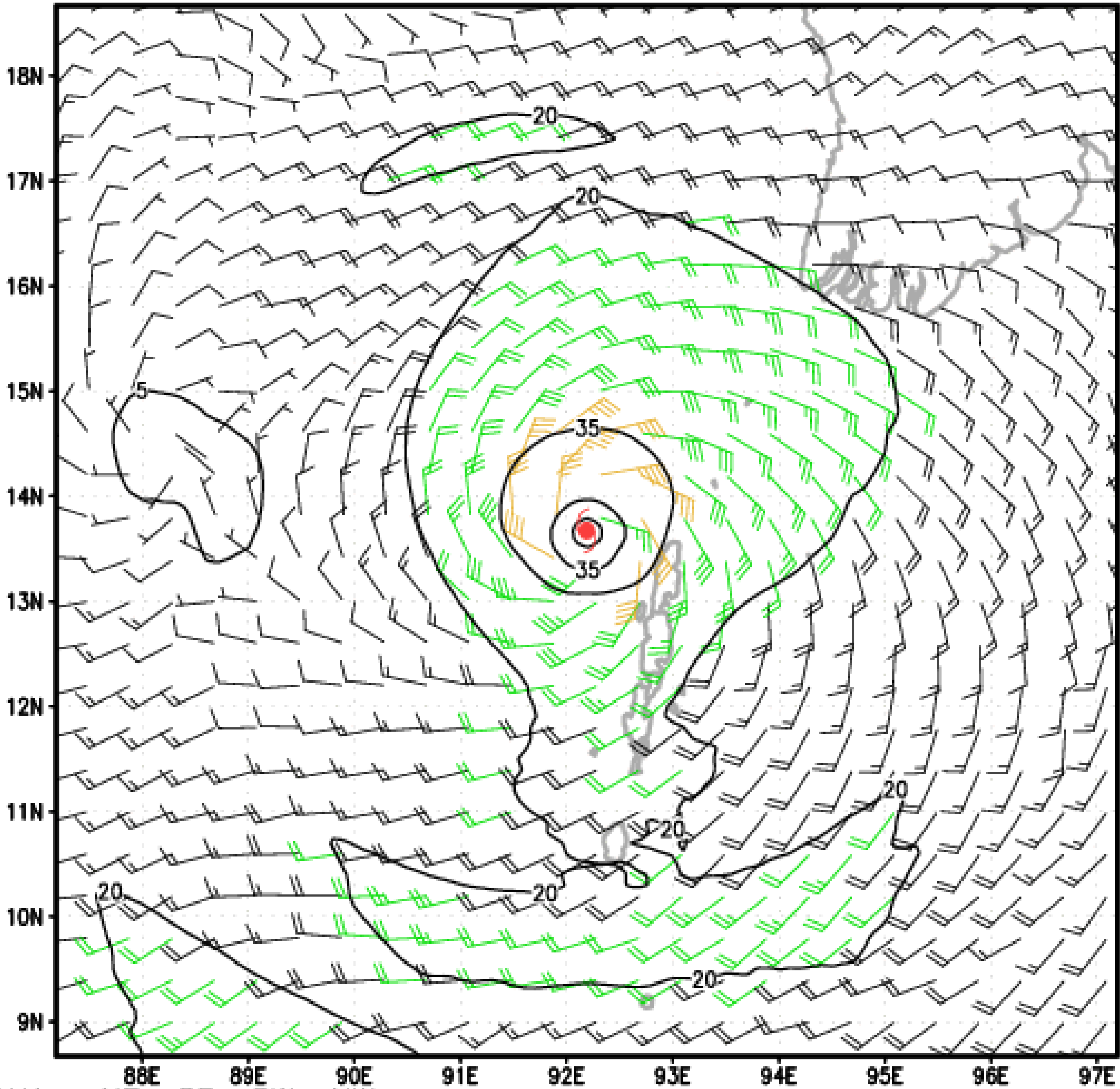
- ❖ **AMSU**
- ❖ **Cloud drift winds (IR/WV)**
- ❖ **Scatterometer winds**

Resulting mid level winds are adjusted to surface level applying certain algorithms

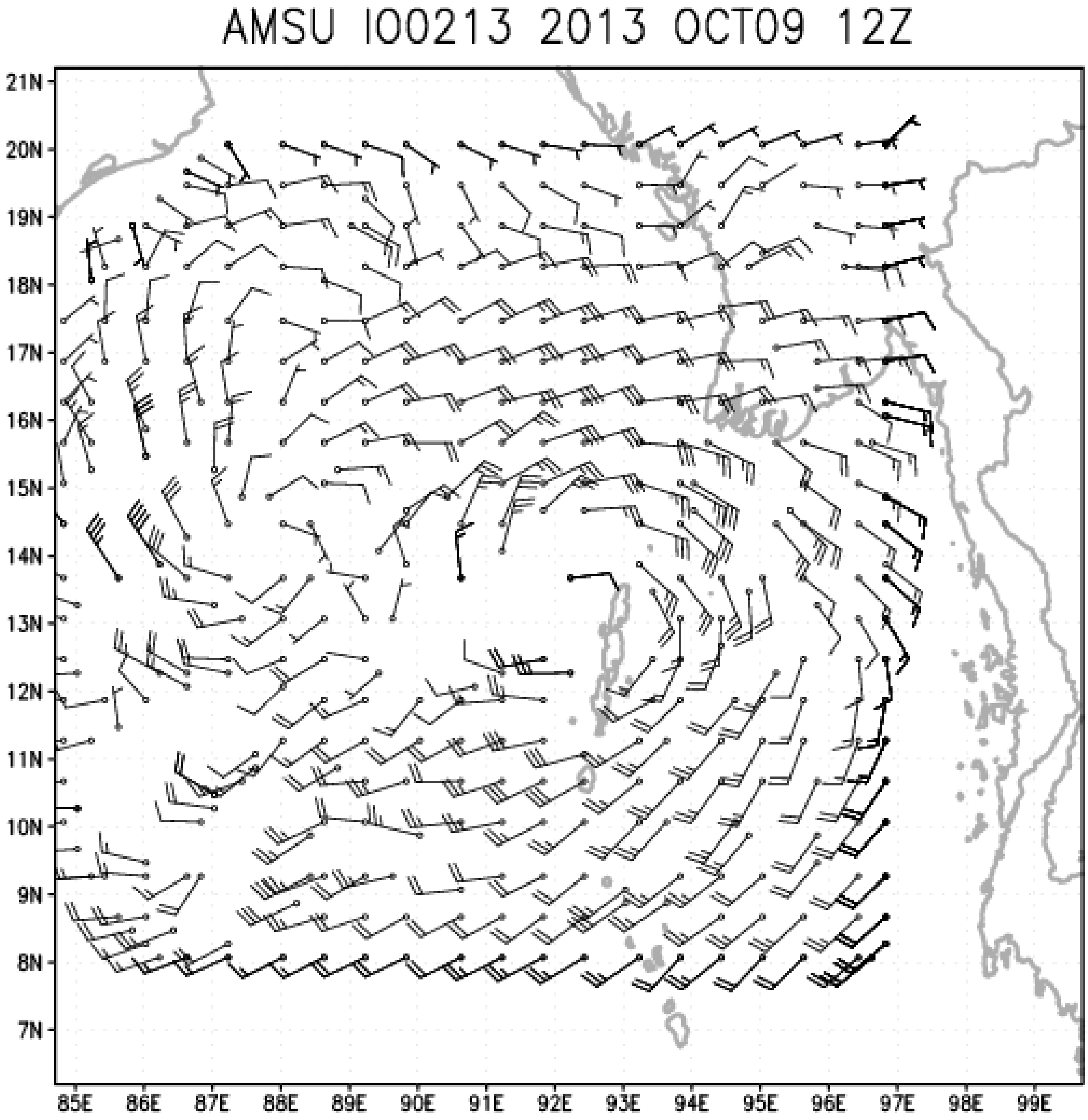


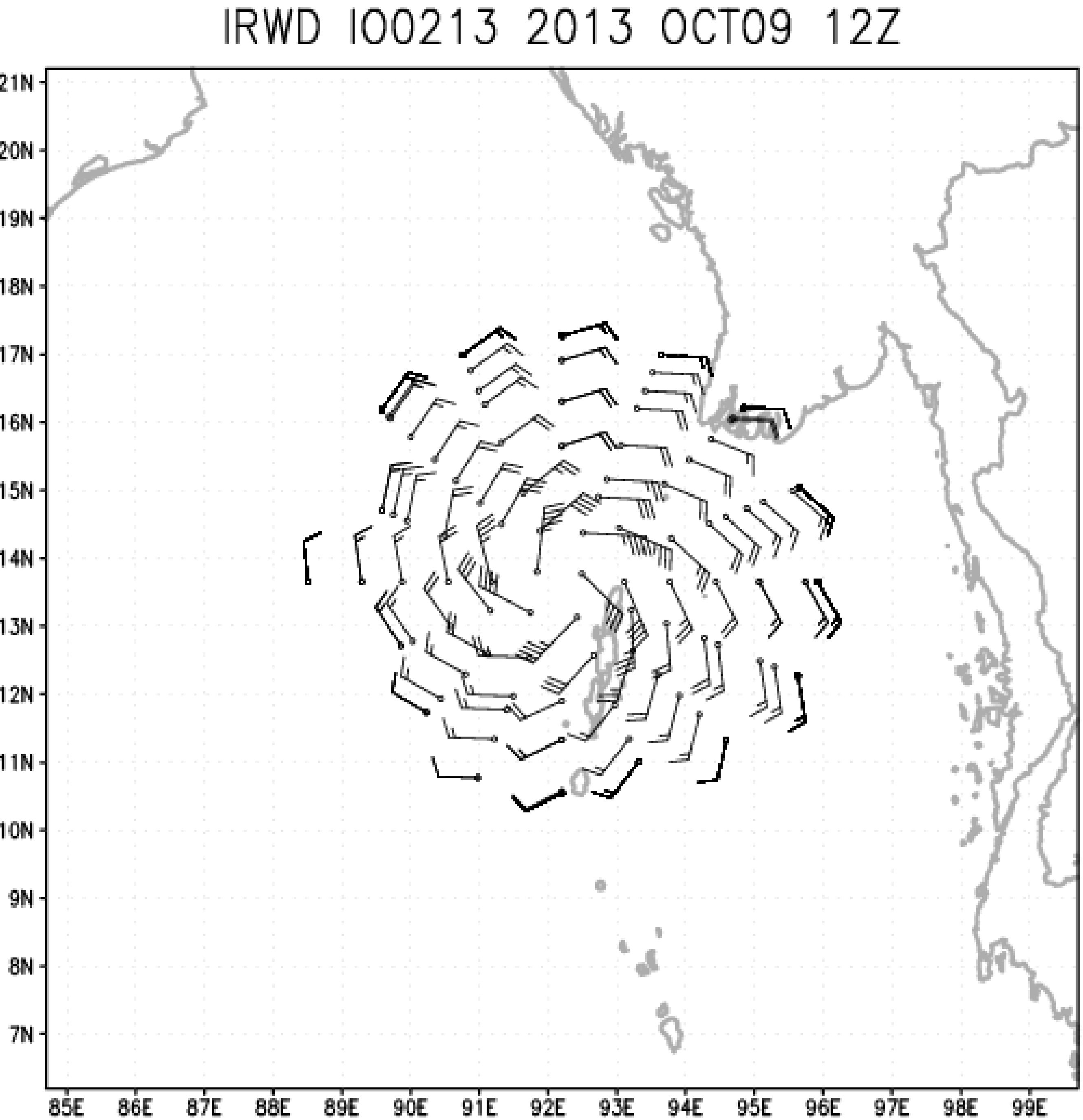
IO0213
TWO 2013 9 Oct 12UTC
15.5N
15N
14.5N
14N
13.5N
13N
12.5N
12N
35
35
35
90.5E
91E
91.5E
92E
92.5E
93E
93.5E
94E
QUA NE SE SW NW
R34 60 50 45 60
R50 0 0 0 0
R64 0 0 0 0
VMAX = 47 kt MSLP = 994.9 hPa
RMW = 30 nmi BEARING = 0 degrees

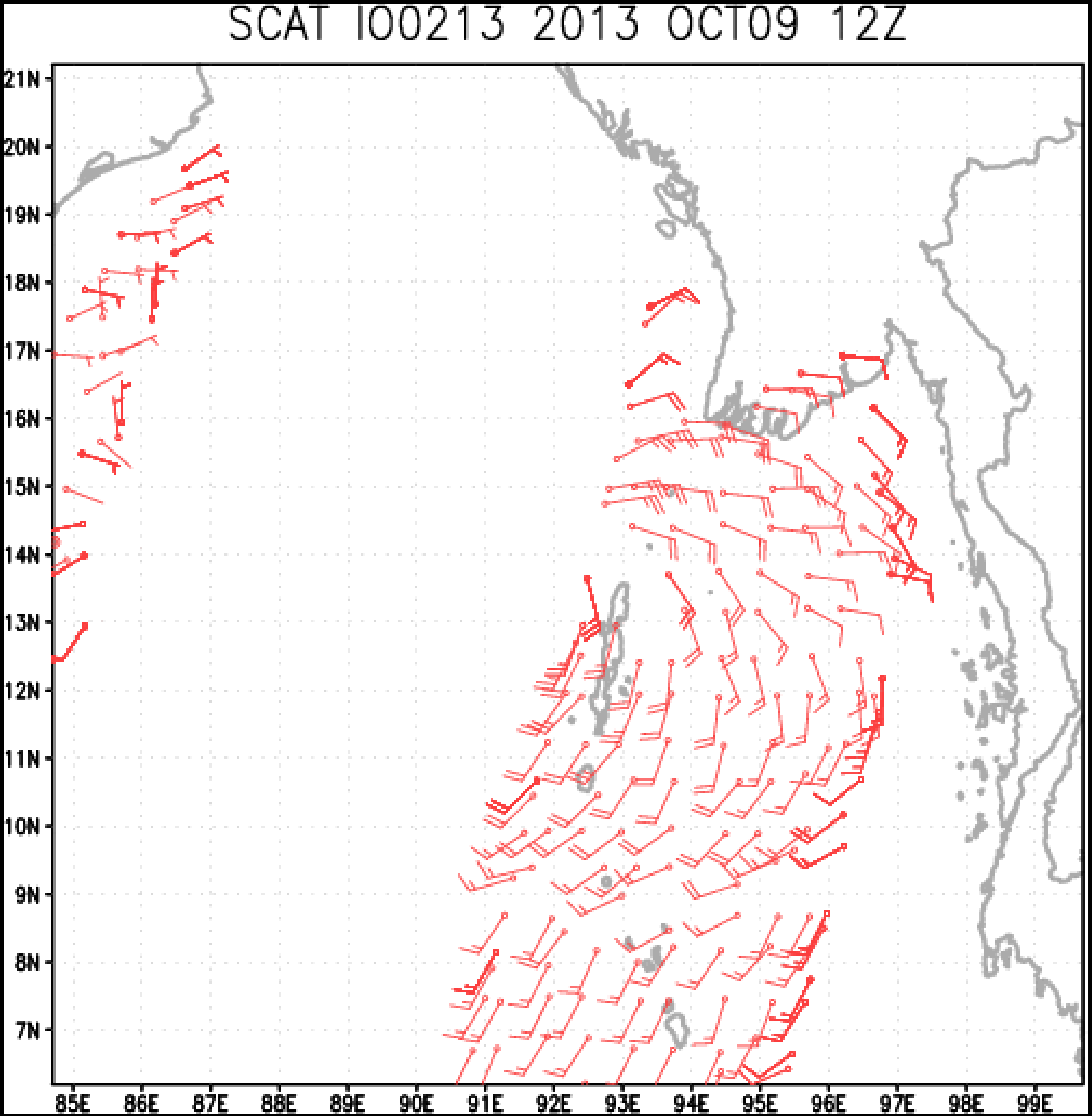
IO0213 TWO 2013 9 Oct 12UTC



QUA	NE	SE	SW	NW		
R34	60	50	45	60		
R50	0	0	0	0	VMAX = 47 kt	MSLP = 994.9 hPa
R64	0	0	0	0	RMW = 30 nmi	BEARING = 0 degrees

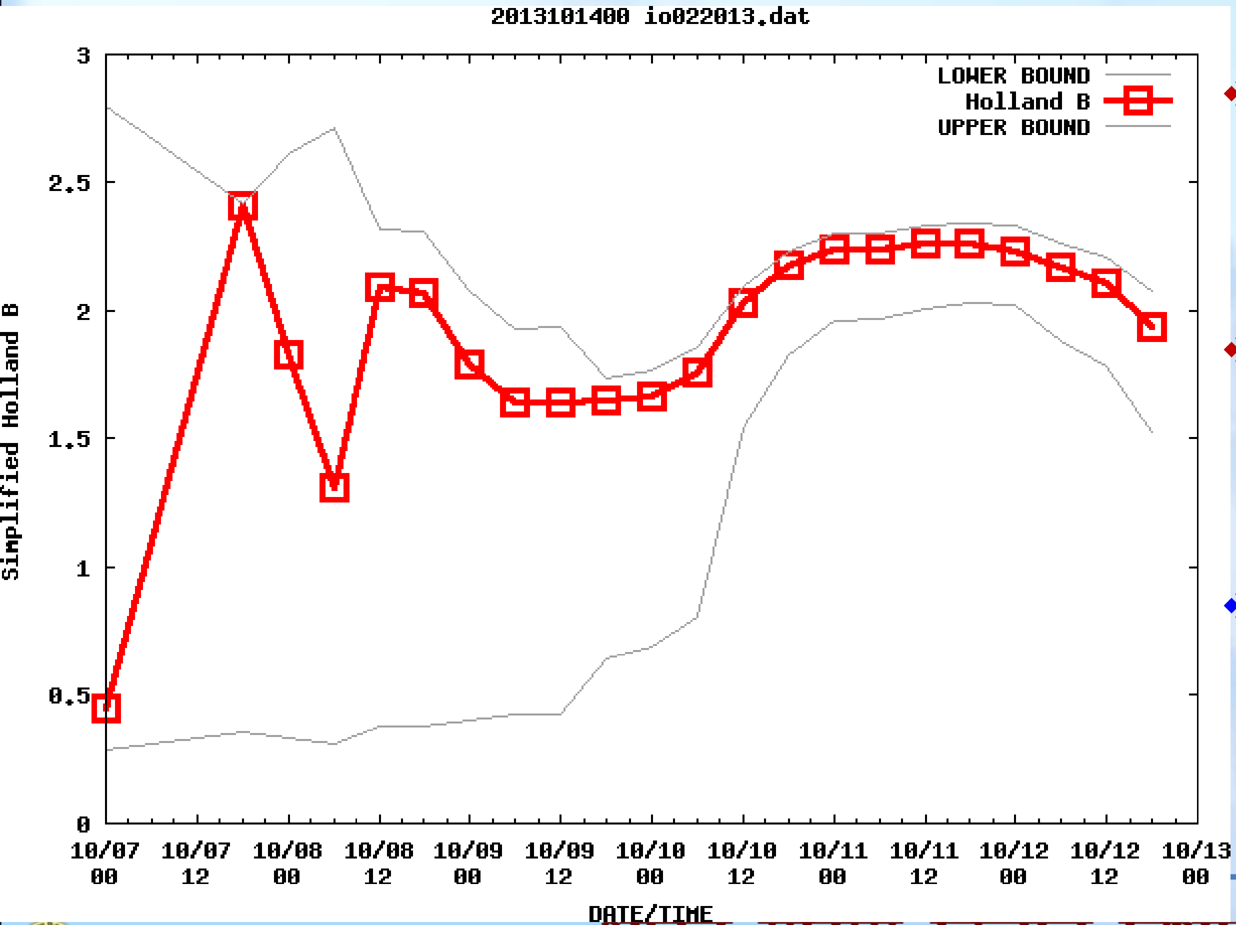

AMSU IO0213 2013 OCT09 12Z
21N
20N
19N
18N
17N
16N
15N
14N
13N
12N
11N
10N
9N
8N
7N
85E
86E
87E
88E
89E
90E
91E
92E
93E
94E
95E
96E
97E
98E
99E


IRWD IO0213 2013 OCT09 12Z
21N
20N
19N
18N
17N
16N
15N
14N
13N
12N
11N
10N
9N
8N
7N
85E
86E
87E
88E
89E
90E
91E
92E
93E
94E
95E
96E
97E
98E
99E


SCAT IO0213 2013 OCT09 12Z
21N
20N
19N
18N
17N
16N
15N
14N
13N
12N
11N
10N
9N
8N
7N
85E
86E
87E
88E
89E
90E
91E
92E
93E
94E
95E
96E
97E
98E
99E

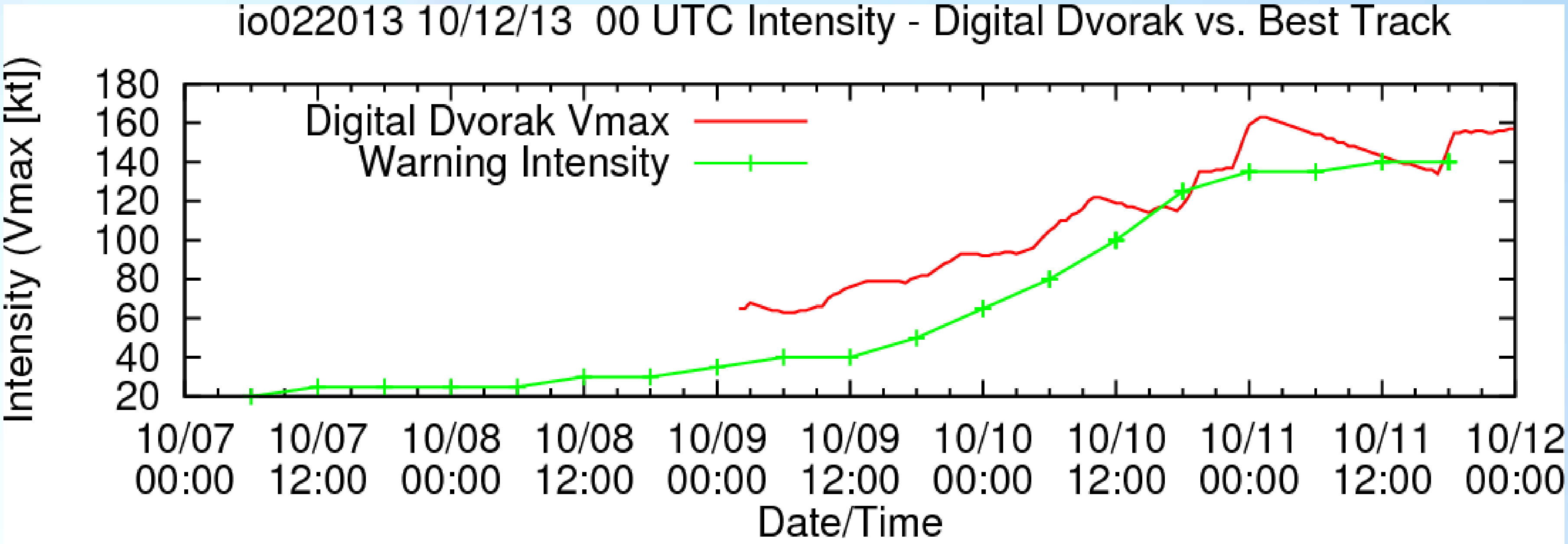
Simplified Holland B Parameter

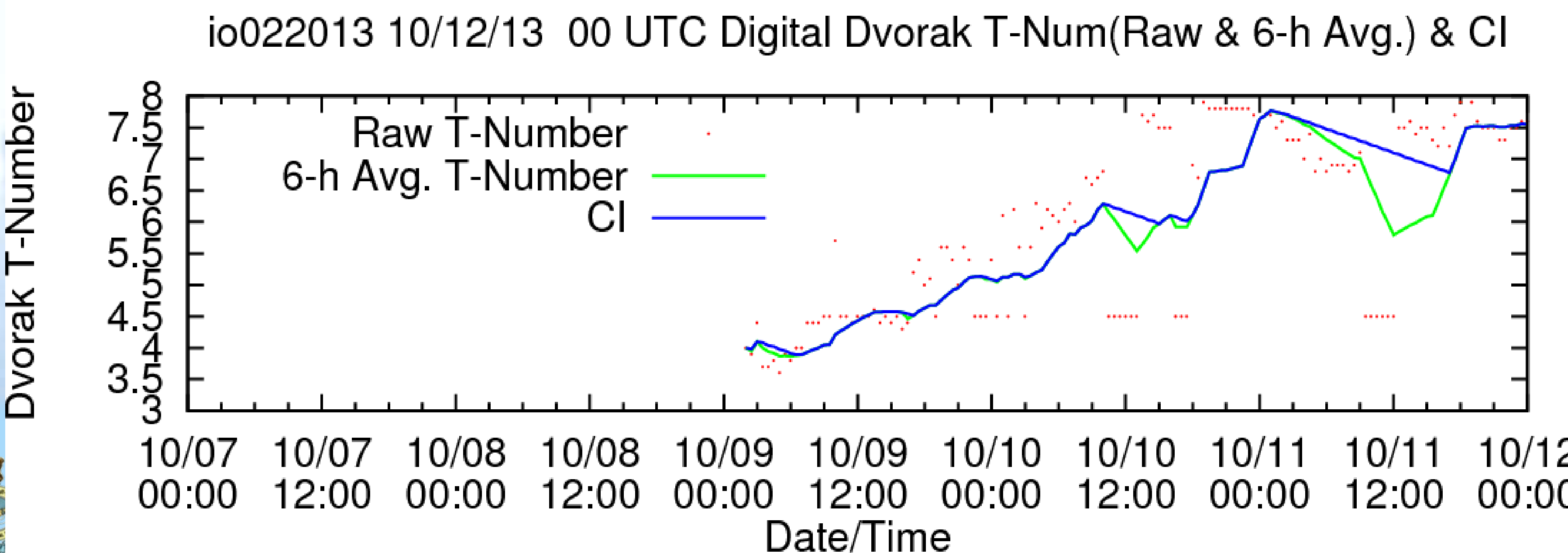
- SHB is related to shape of tangential wind profile beyond RMW. Insensitive to variations of RMW.
- Weak TCs have large range of SHB, between 0.5 and 2.25
- Intense TCs have SHB values in a narrow range between 1.75 and 2.3.



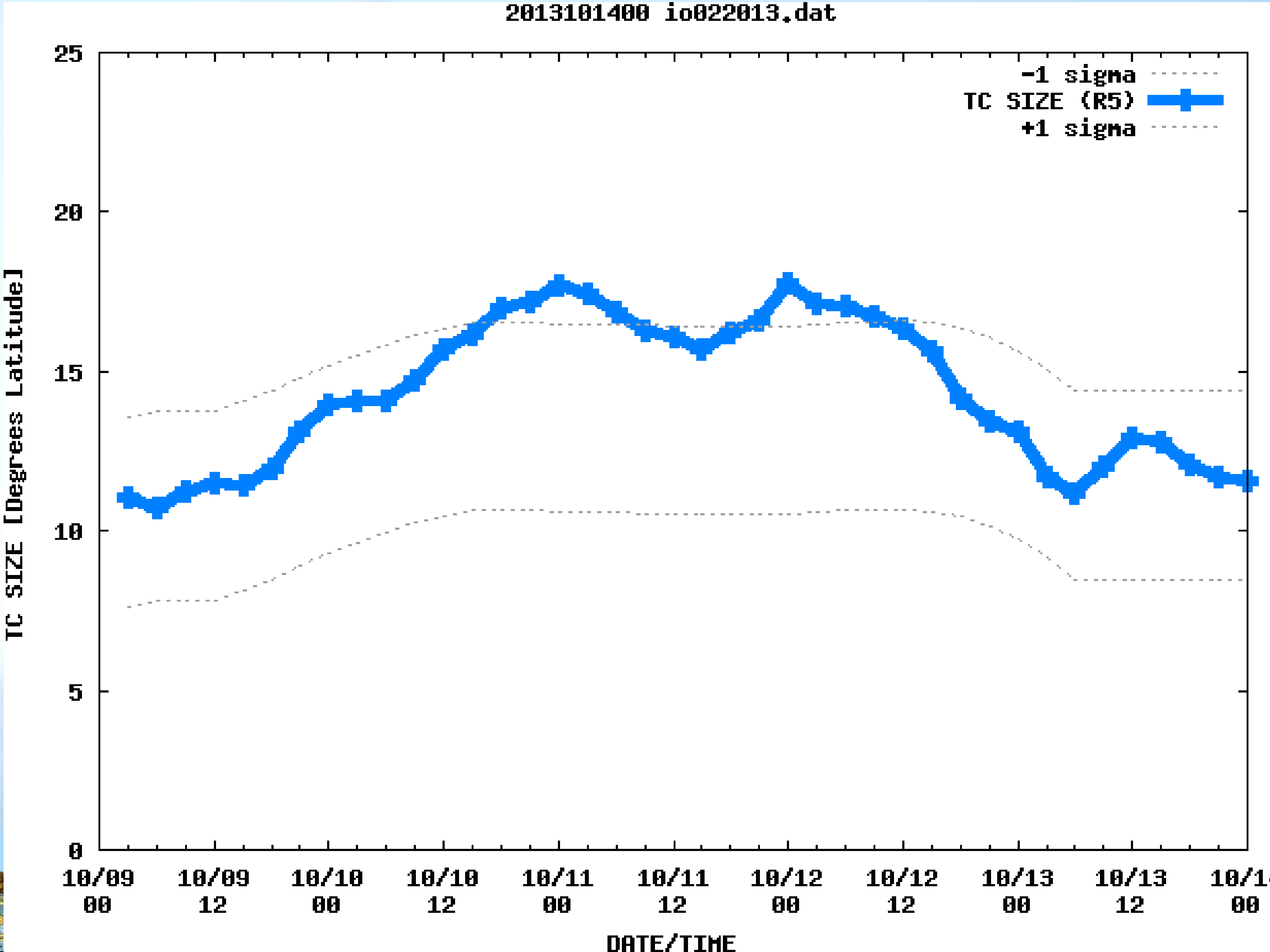
- Large values of SHB (order 2.25) imply compact tangential wind profiles.
- Small values (<1.0) are related to broad tangential wind profiles.
- SHB increases with both the intensity and radial extent of the wind field.

CIRA based Dvorak T. No. estimates estimates

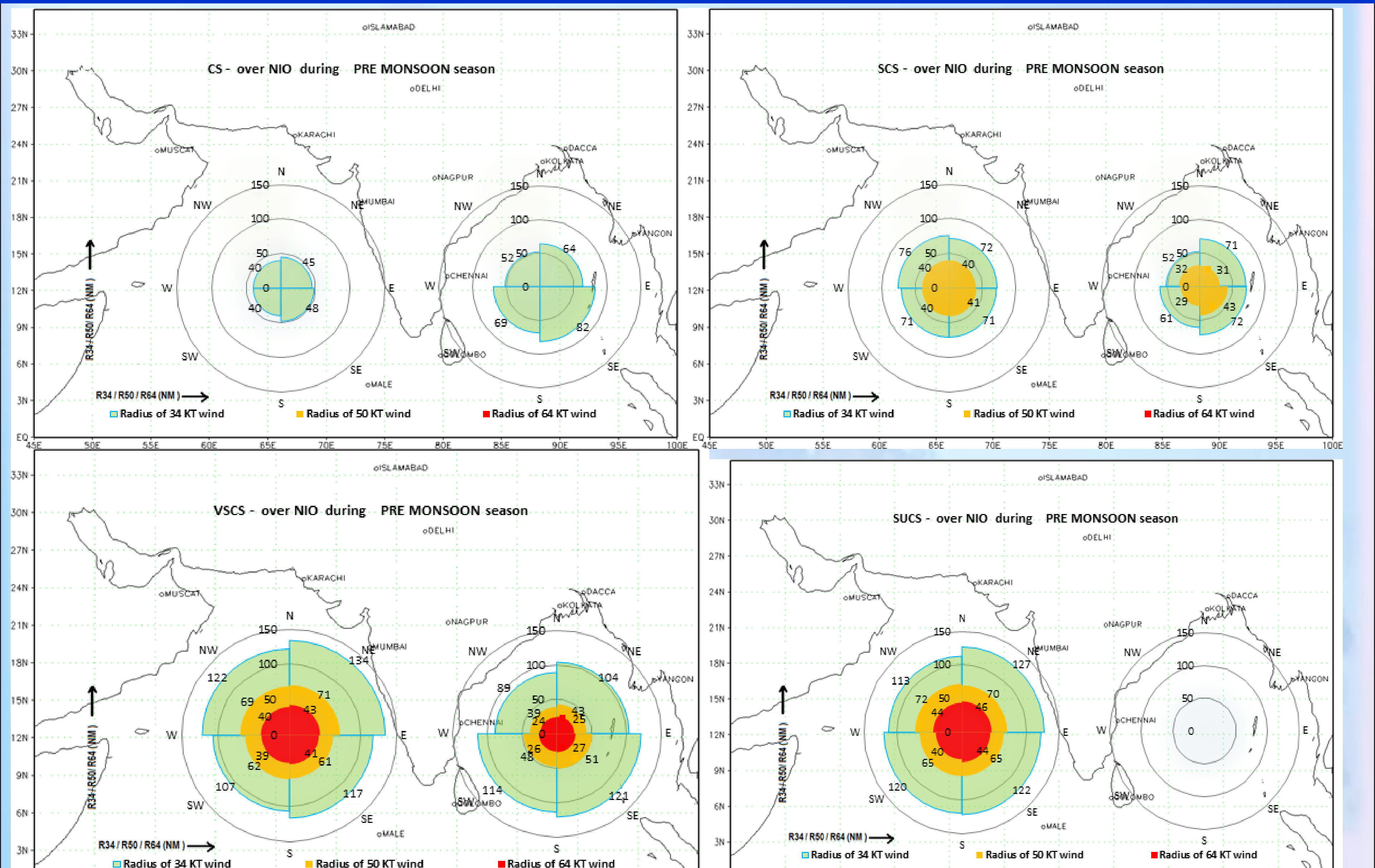




IR based TC size

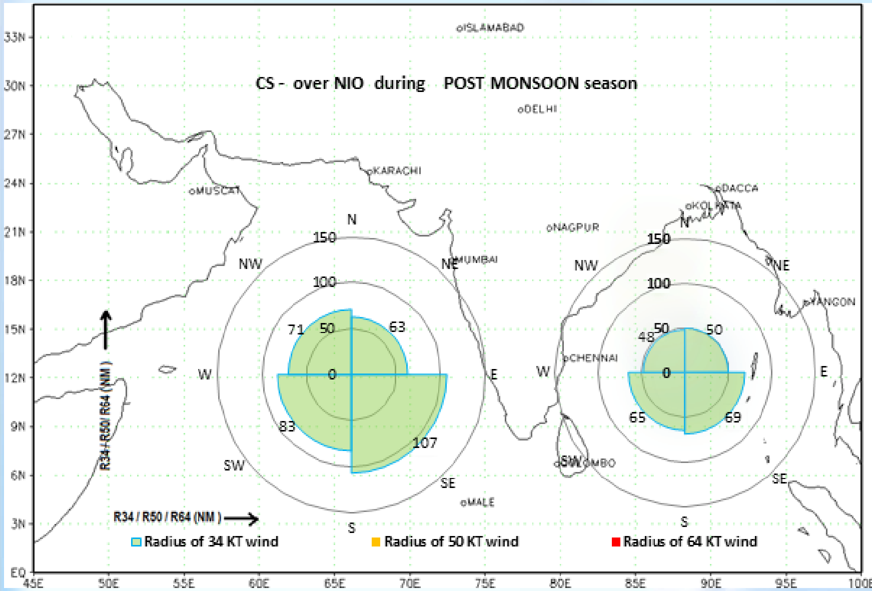


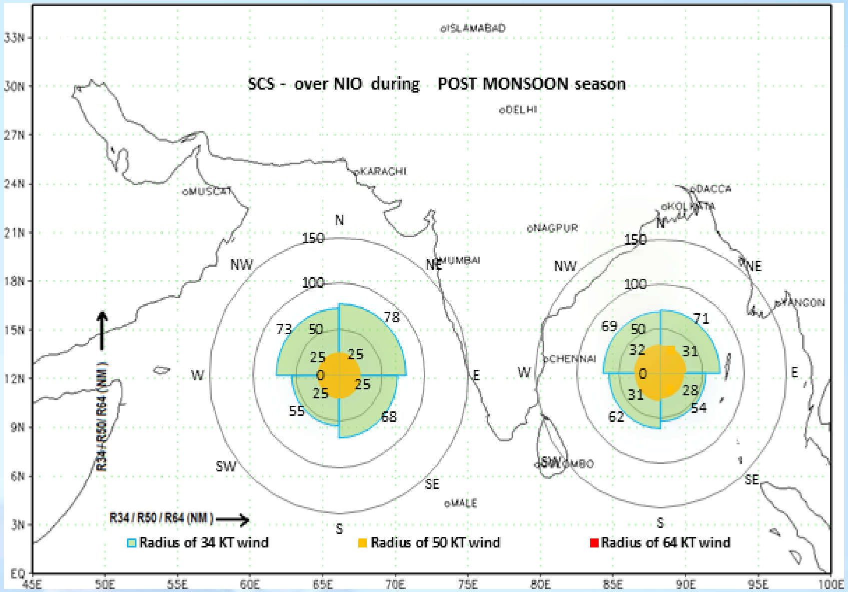
Climatology-Pre Monsoon season

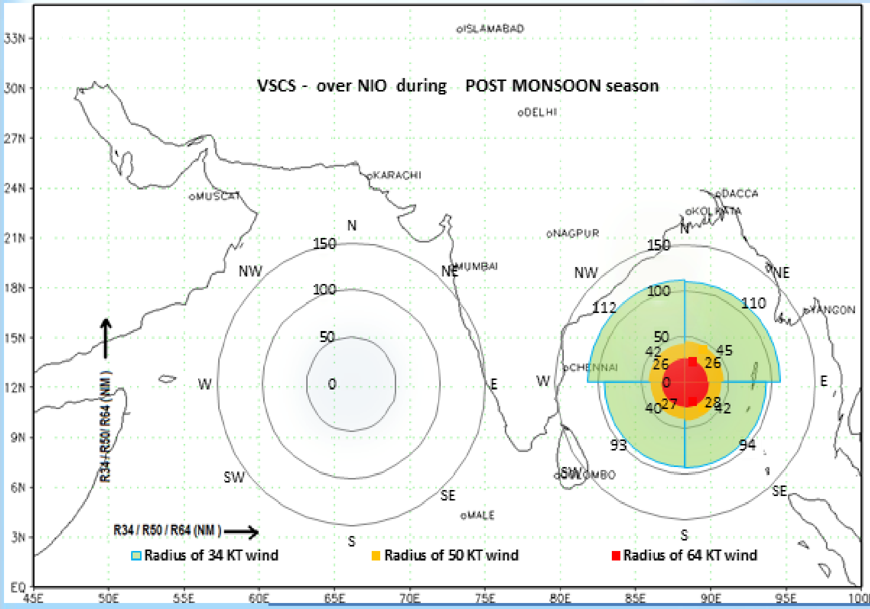


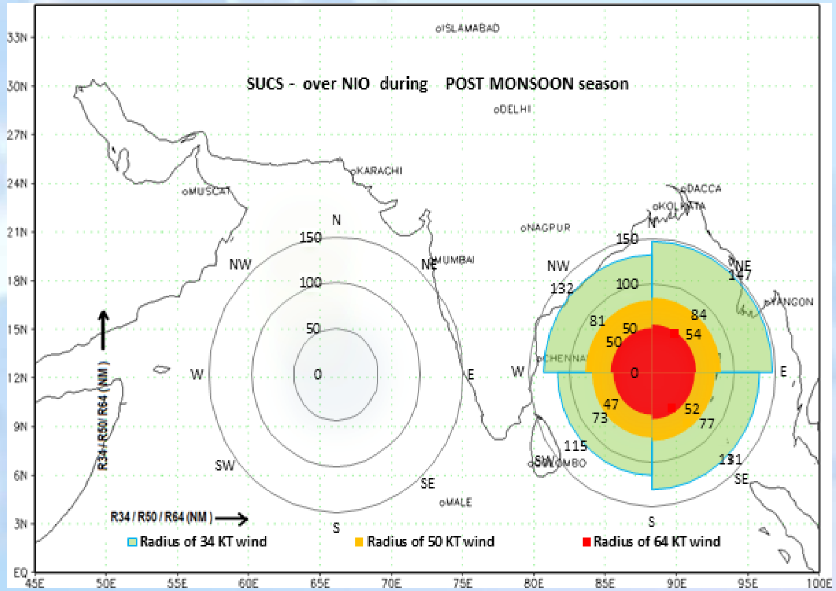
Mohapatra and Sharma, 2016, JESS (1997-2013)

Climatology- Post Monsoon Season









Mohapatra and Sharma, 2016, JESS

Wind distribution in case of cyclone Phyan over Arabian Sea (November)

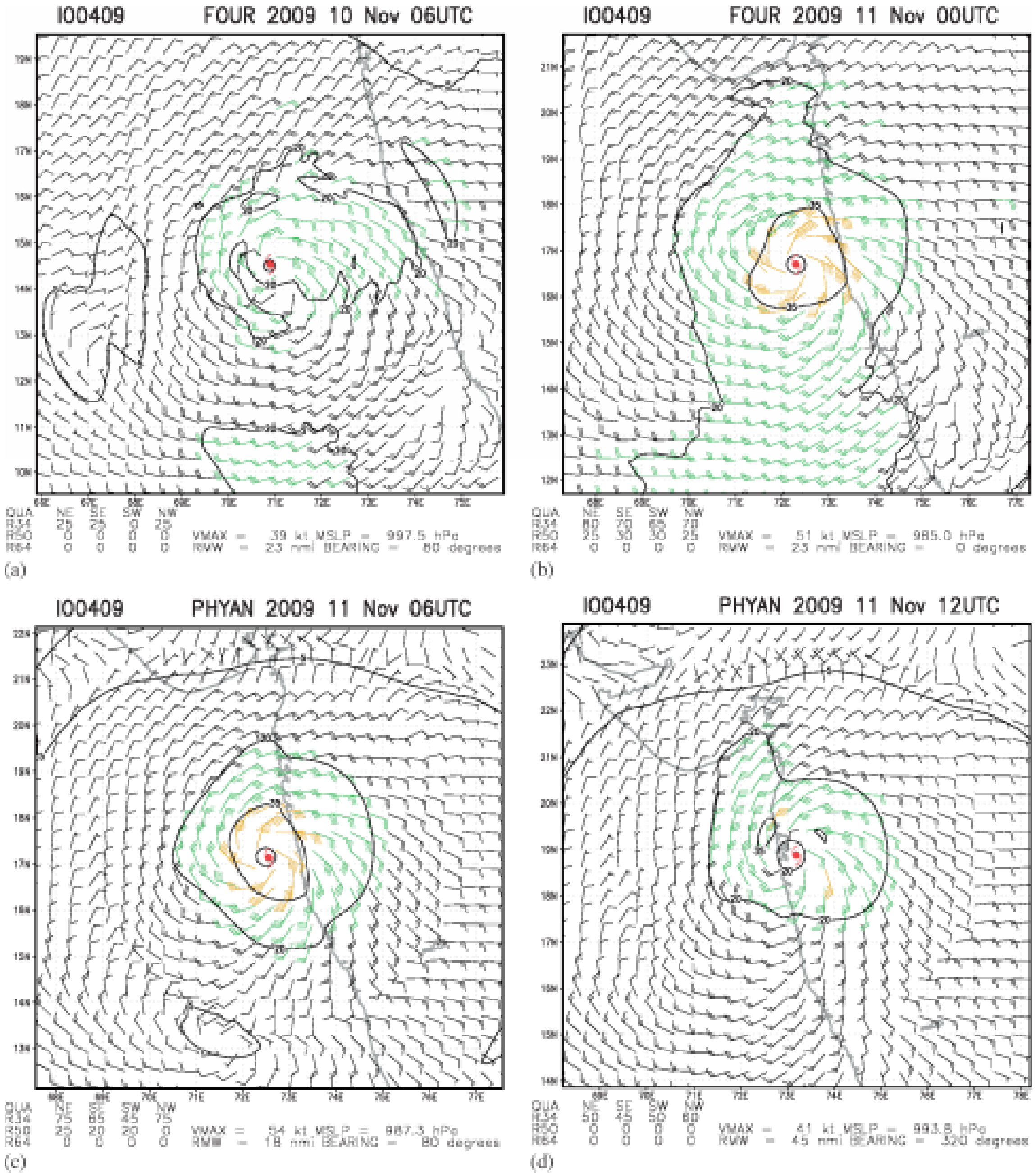


Figure 7. Surface wind distribution at (**a**) 0600 UTC of 10 November, (**b**) 0000, (**c**) 0600, and (**d**) 1200 UTC of 11 November, in association with cyclonic storm, Phyan over the Arabian Sea (9–12 November 2009).

ENT

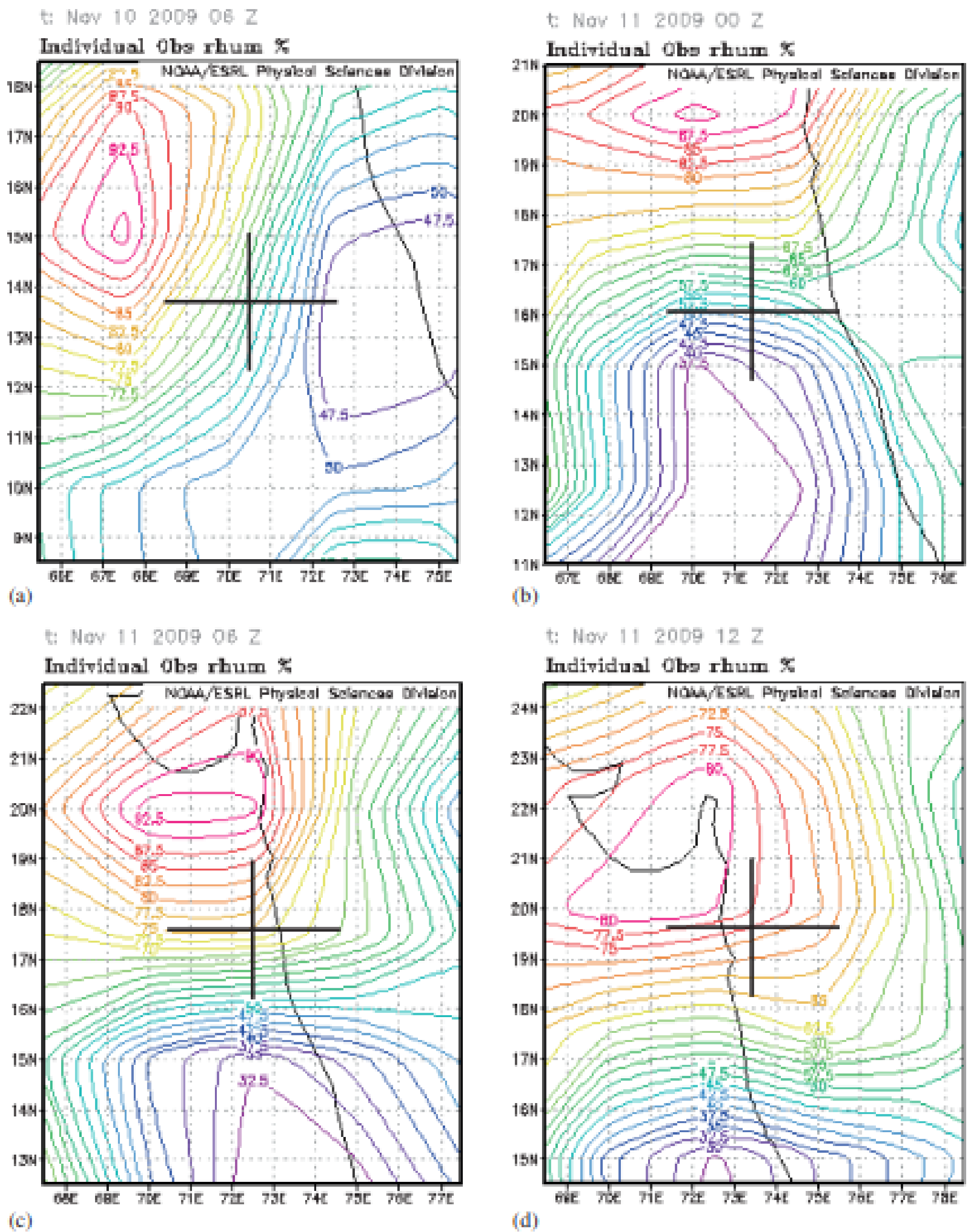


Figure 8. Relative humidity at 500 hPa level at (a) 0600 UTC of 10 November and (b) 0000, (c) 0600 and (d) 1200 UTC of 11 November 2009 in association with the cyclonic storm, Phyan over the Arabian Sea (9–12 November 2009). +: Centre of TC as per IMD best track.

Relative humidity profile at 500 hPa level around the system centre in case of cyclone PHYAN, over Arabian Sea

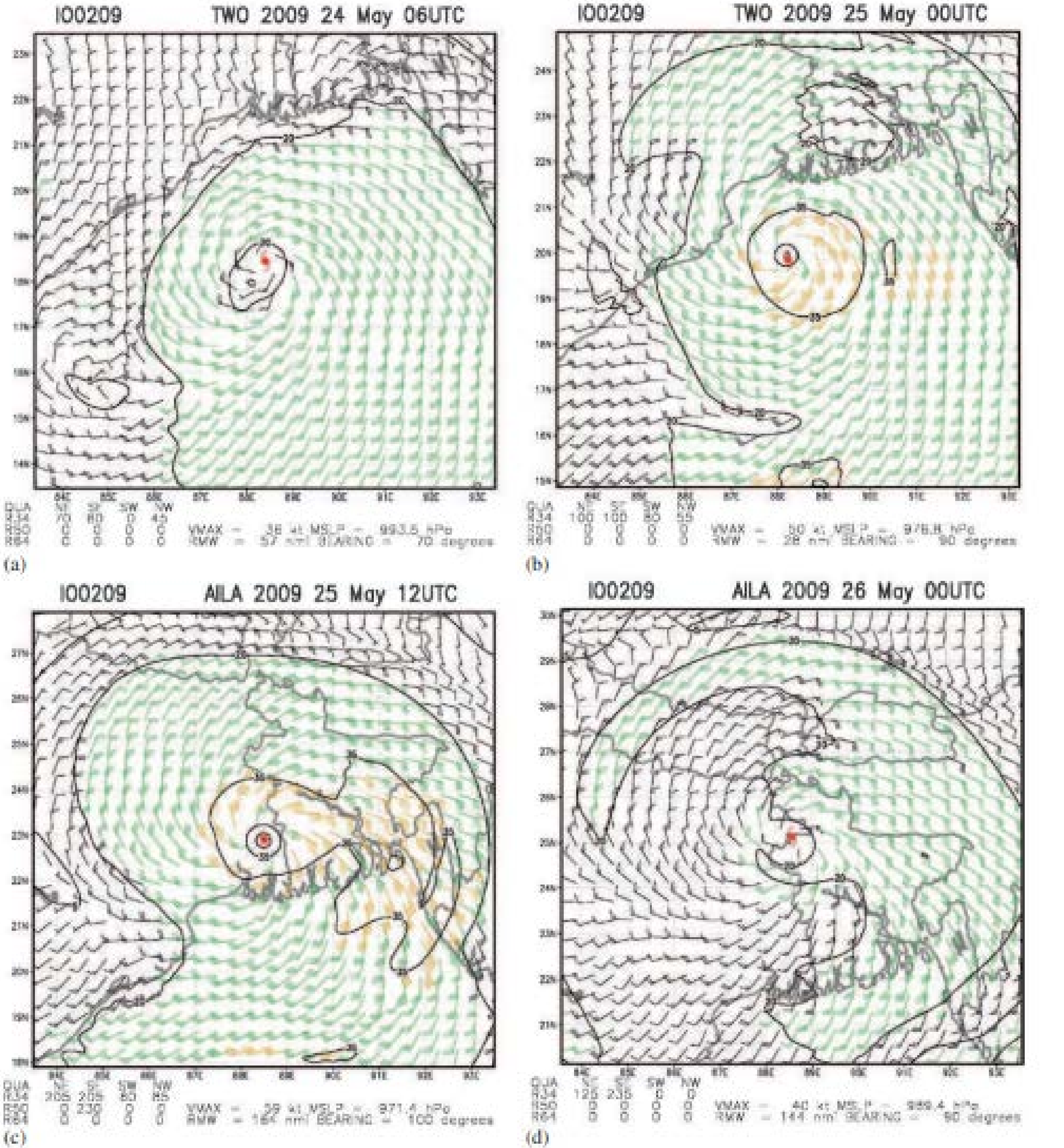


Figure 9. Surface wind distribution at (a) 0600 UTC of 24 May and (b) 0000 and (c) 1200 UTC of 25 May and (d) 0000 UTC of 26 May in association with severe cyclonic storm, Aila over the Bay of Bengal (23–26 May 2009).

Wind distribution in case of cyclone Aila over BoB (May)
(More winds in NE & SE sector)

T

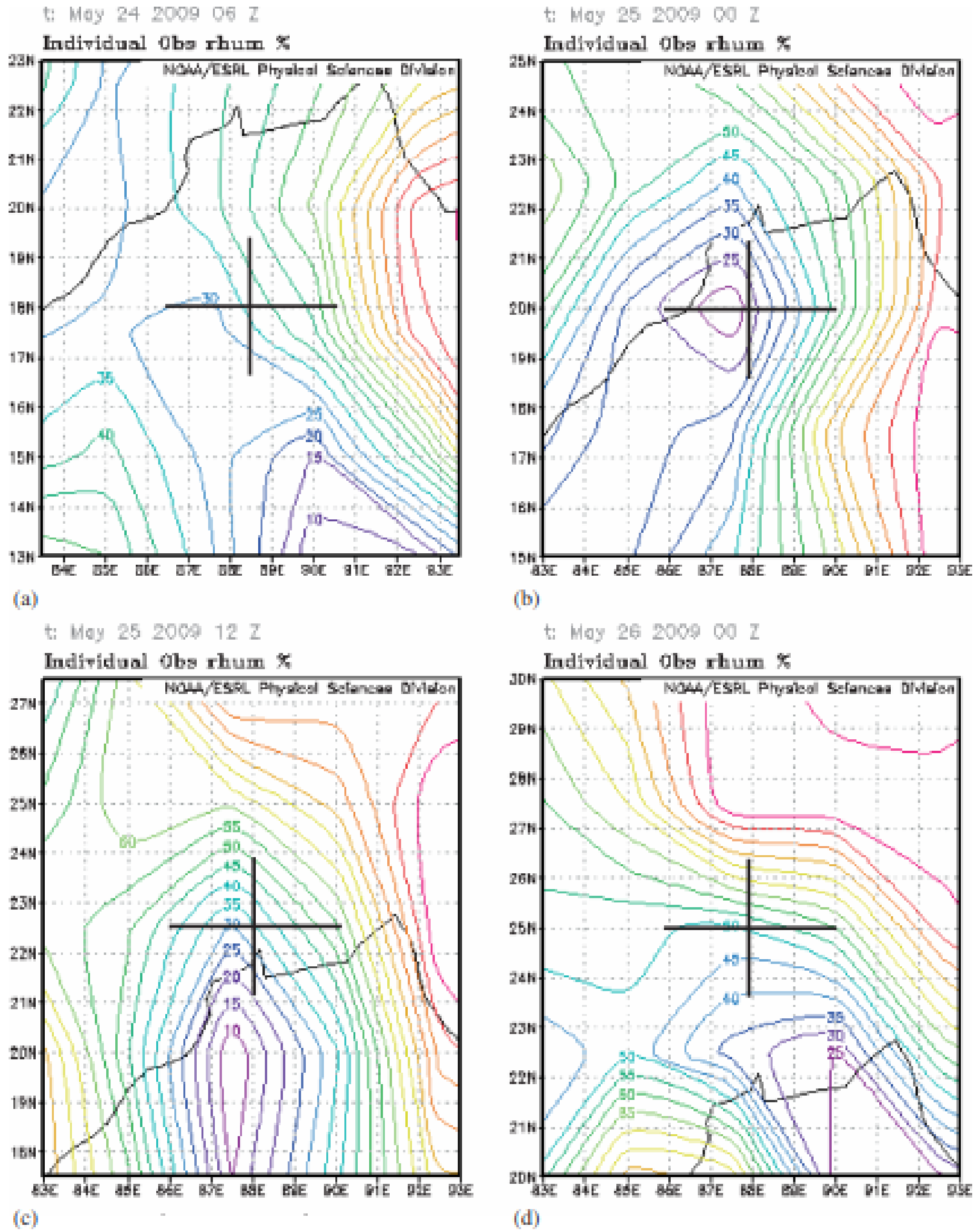
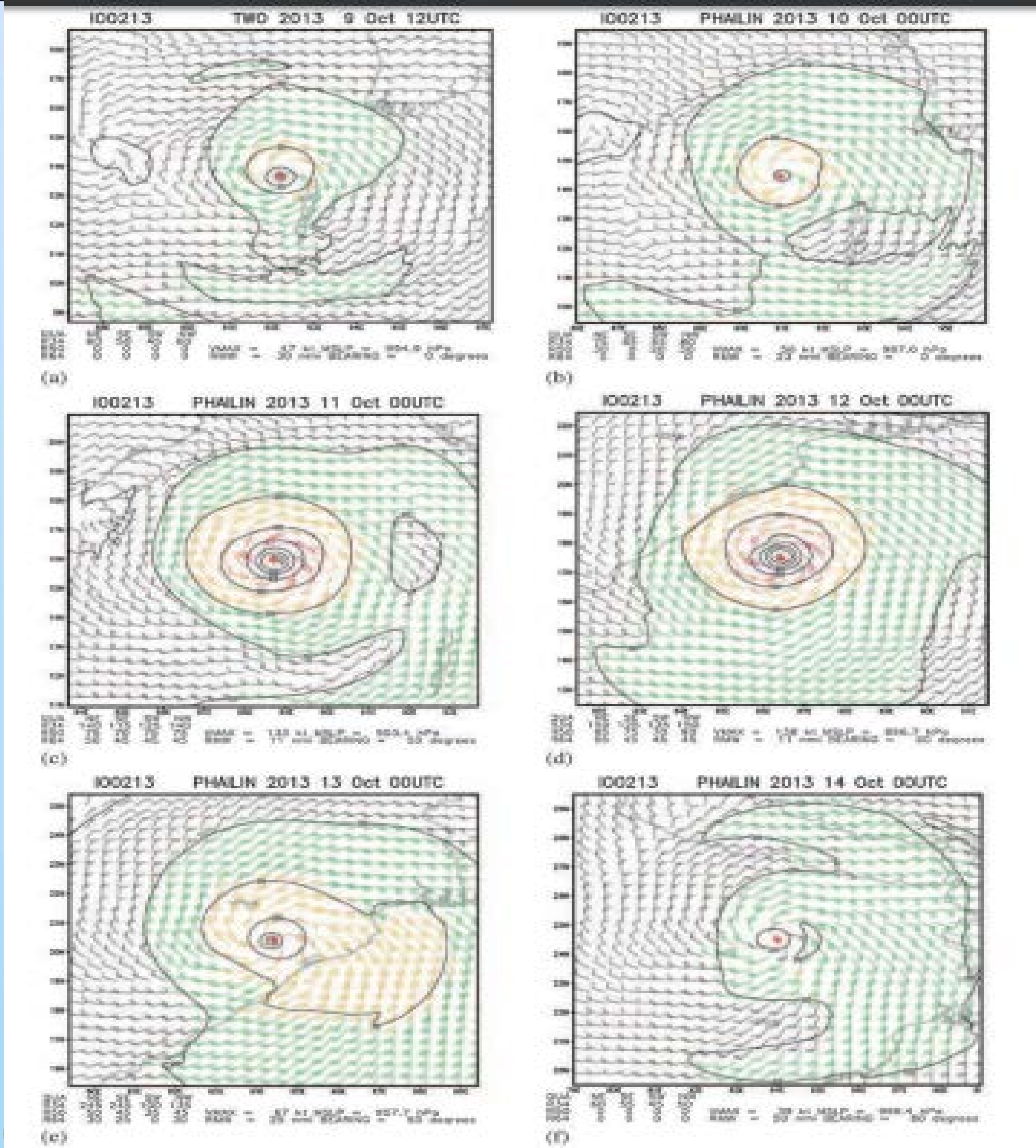


Figure 10. Relative humidity at 500 hPa level at (**a**) 0600 UTC of 24 May and (**b**) 0000 and (**c**) 1200 UTC of 25 May and (**d**) 0000 UTC of 26 May 2009 in association with the severe cyclonic storm, AILA over the Bay of Bengal (23–26 May 2009). +: Centre of TC as per IMD best track.

Relative humidity profile at 500 hPa level around the system centre in case of cyclone AILA, over BoB

NT

Wind distribution in case of TC Phailin



Relative humidity profile at 500 hPa level around the system centre in case of cyclone Phailin, over BoB

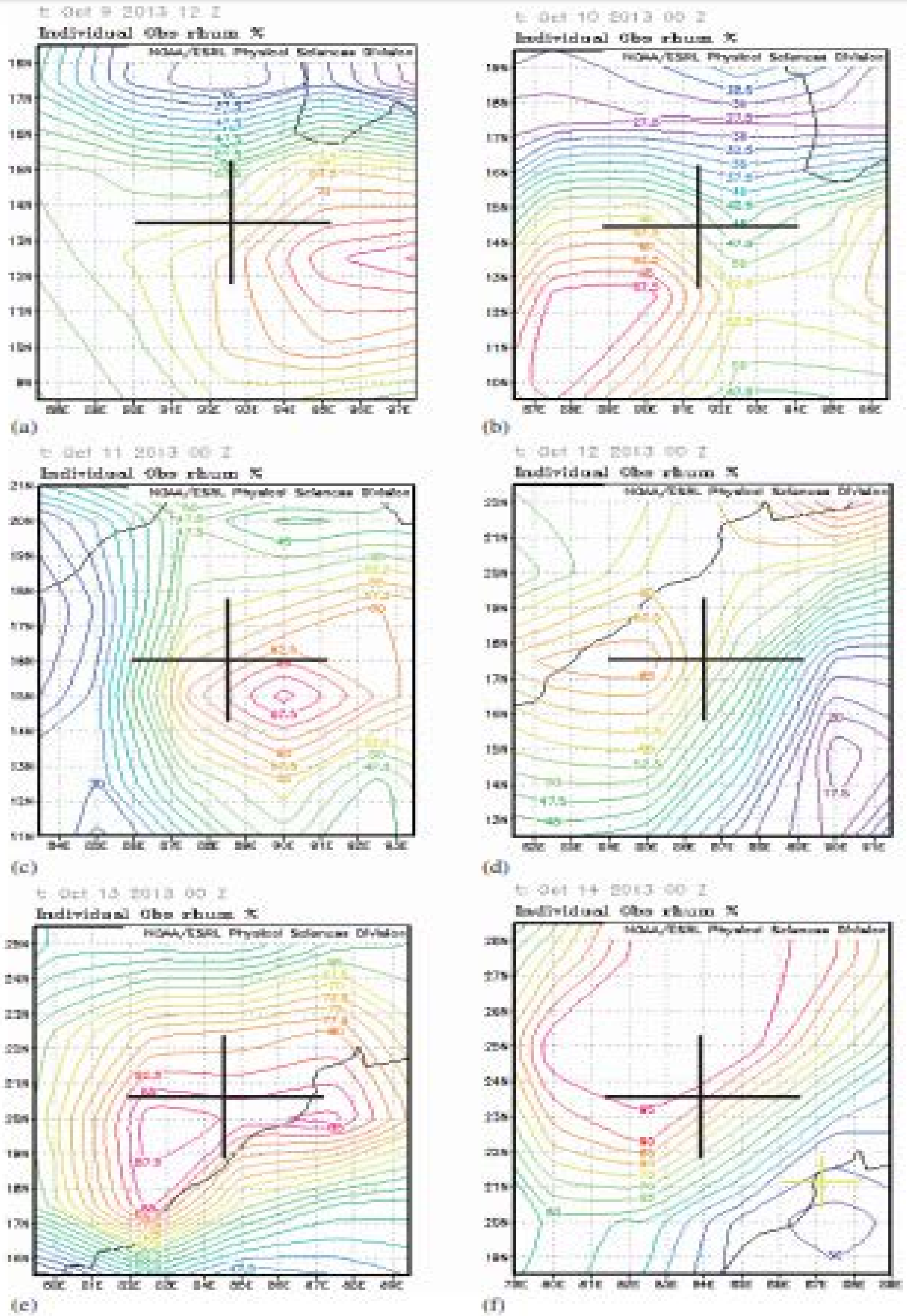


Figure 12. Relative humidity at 500 hPa level at (a) 1200 UTC of 9 October and (b–f) 0000 UTC of 10–14 October 2013 in association with the very severe cyclonic storm, Phailin over the Bay of Bengal (8–14 October 2013). +: Centre of TC as per IMD best track.

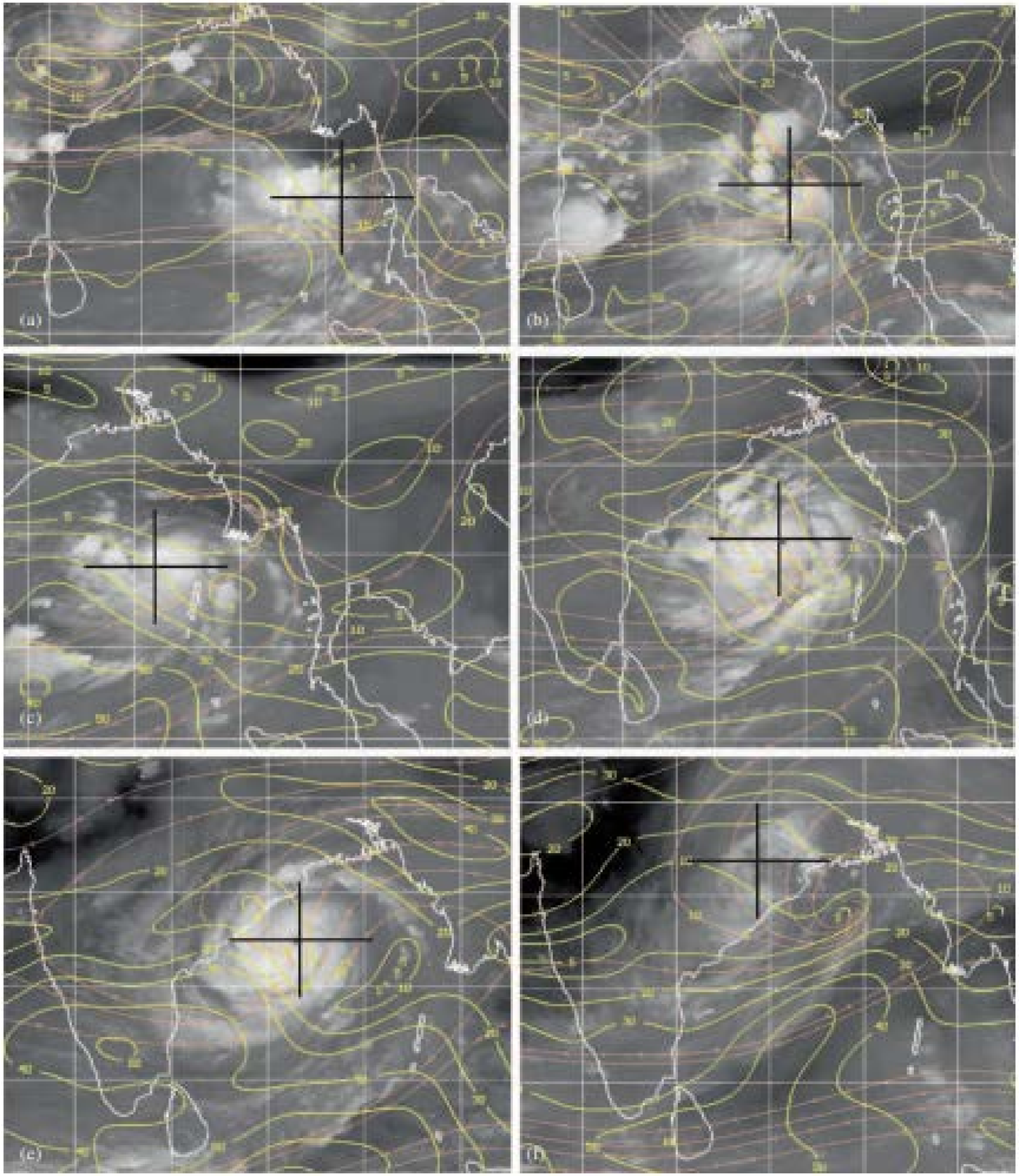


Figure 13. Vertical wind shear in a deep layer (200–850 hPa level) at (a–f) 0000 UTC of 8–13 October 2013 in association with the very severe cyclonic storm, Phailin (8–14 October 2013) over the Bay of Bengal.

Wind shear between 200-850 hPa levels around the system centre in case of cyclone Phailin, over BoB

T
TMENT

STRUCTURAL CHARACTERISTICS

- The average size of TC (radius of 34(17) knot (ms^{-1}) wind) category-wise over the AS and BoB

Intensity	Arabian Sea		Bay of Bengal	
	Pre -Mon	Post -Mon	Pre -Mon	Post -Mon
CS	43	70	73	57
SCS	72	70	64	64
VSCS	120	-	107	102
SuCS	-	-	-	130

- The size of outer core (34(17) knot (ms^{-1}) wind radial extension) as well as inner core winds (50(26) and 64(33) knot (ms^{-1}) wind radial extension) increases significantly with increase in intensification of TC over BOB during both pre- and post-monsoon seasons.
- Over the AS, the size of outer core of the TC increases with increase in intensity during pre-monsoon season and no significant change during post-monsoon season.

STRUCTURAL CHARACTERISTICS

- The average sizes of outer core wind of the TCs over the BOB and AS as well as during pre and post-monsoon seasons differ from each other only in case of CS stage.
- The average size of CS is higher in pre-monsoon than in post-monsoon season over the AS and opposite is the case over the BOB.
- The average size of the CS over BOB is higher than that over the AS during pre-monsoon season and there is no significant difference during post-monsoon season.
- Though overall size of the TC during premonsoon season is larger over BOB, as compared to that over the AS, the inner core is smaller.

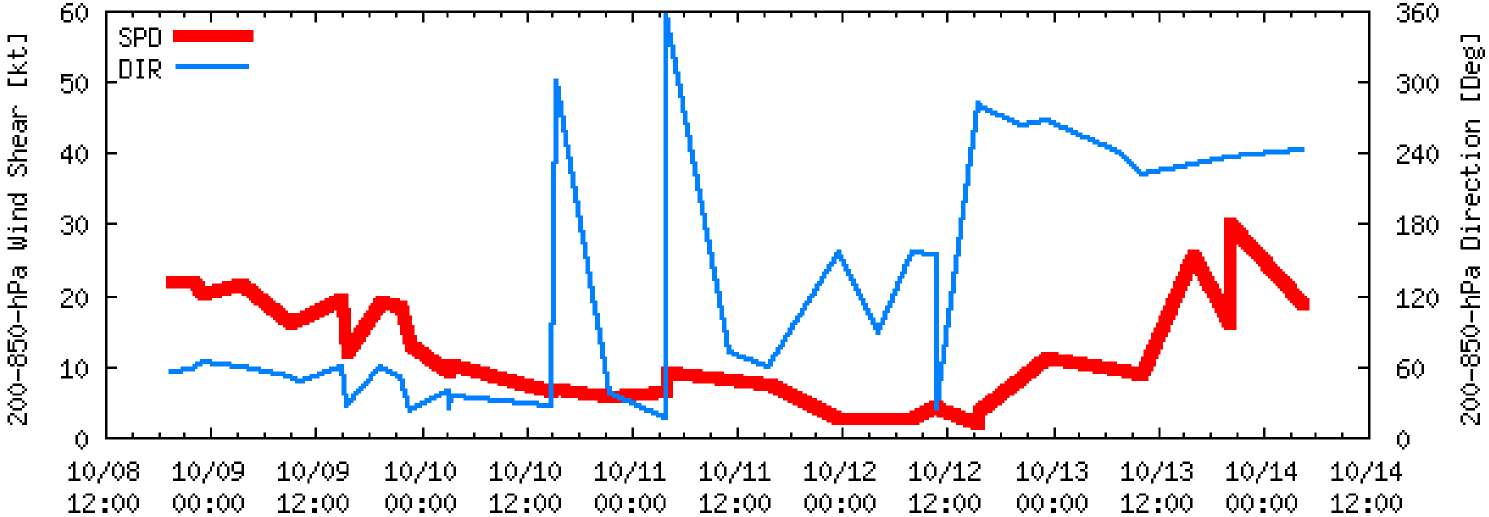
STRUCTURAL CHARACTERISTICS

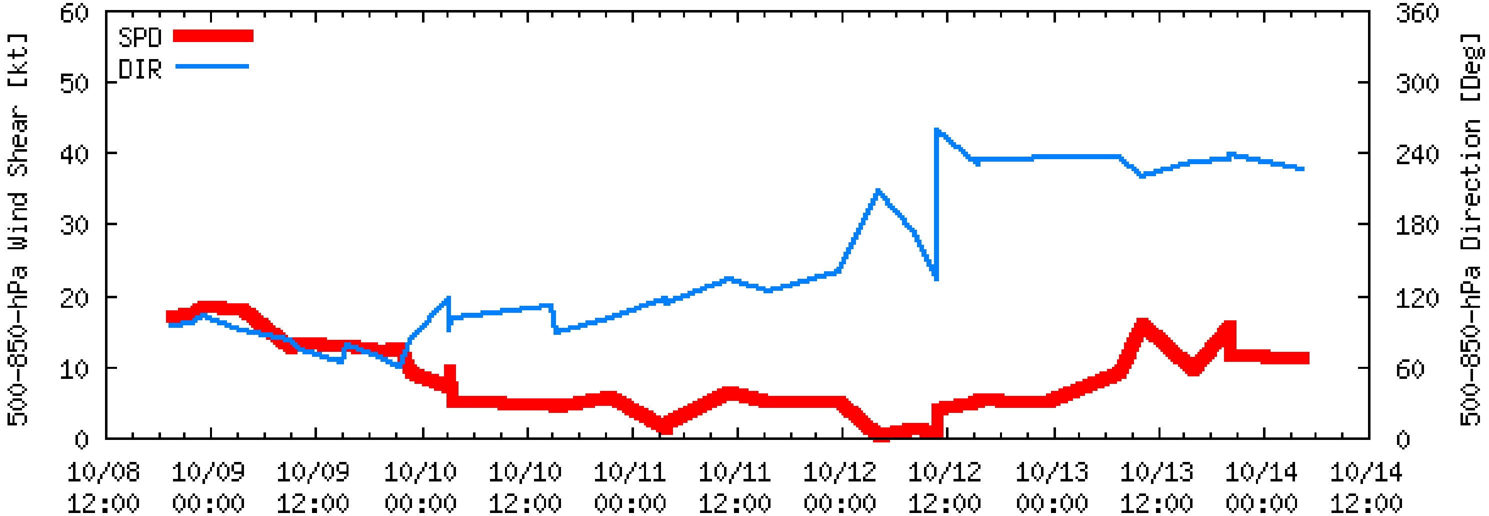
Determining factors for the size and asymmetry of TCs over the NIO.

- **enhanced cross equatorial flow,**
- **lower and middle level RH,**
- **vertical wind shear and**
- **proximity of TC to the land surface**

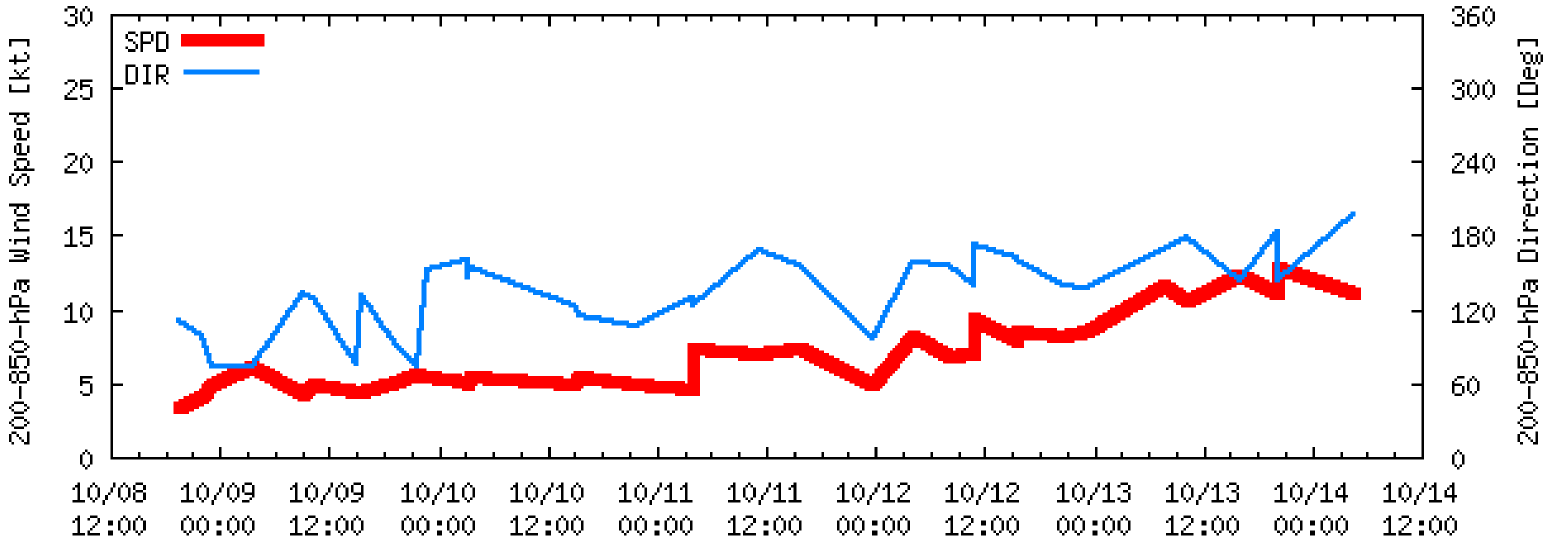
AMSU Area-Averaged Wind Shears and Layer Means

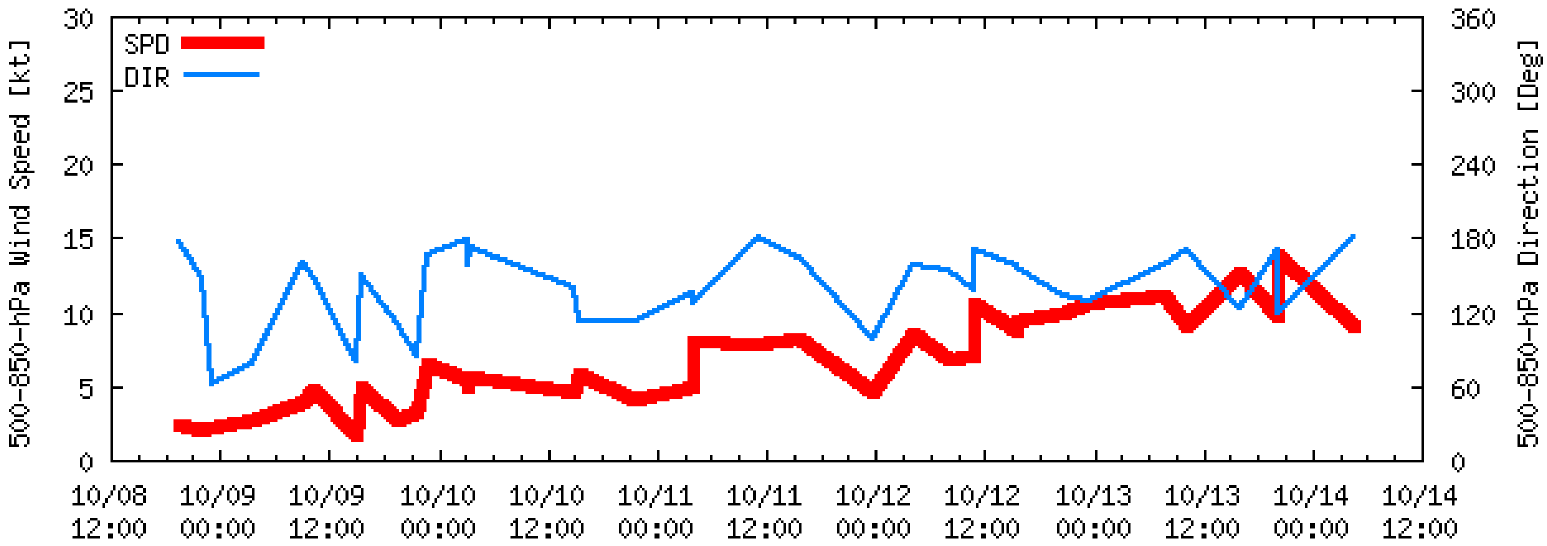
io022013



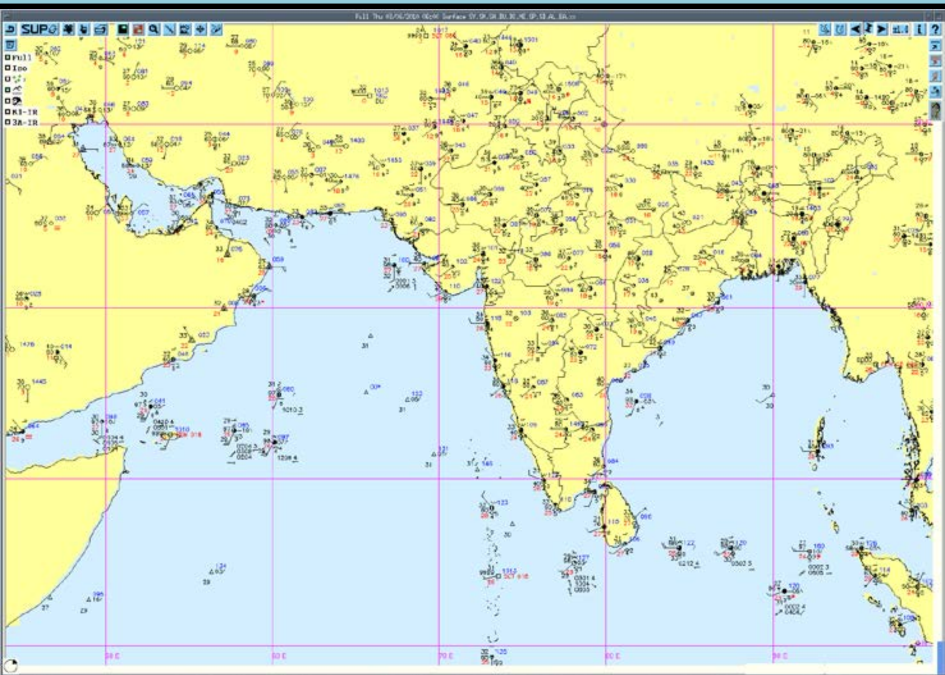


AMSU Area-Averaged Wind speed in upper and mid to lower level





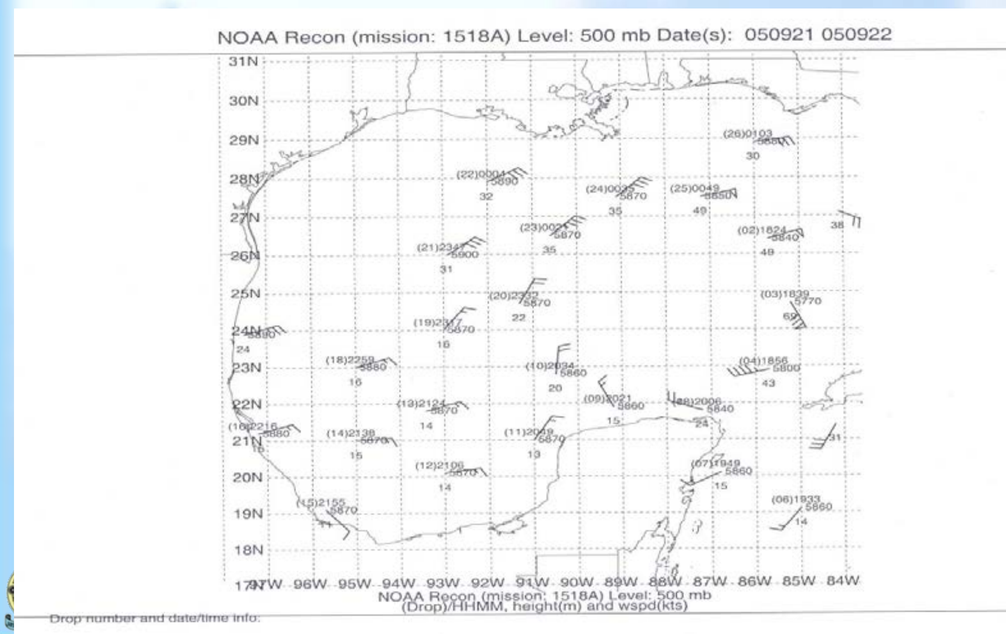
Limitations and Future Scope in Quadrant Wind Monitoring



Example of Cyclone PHET over Arabian Sea

Limited observational data

No aircraft reconnaissance



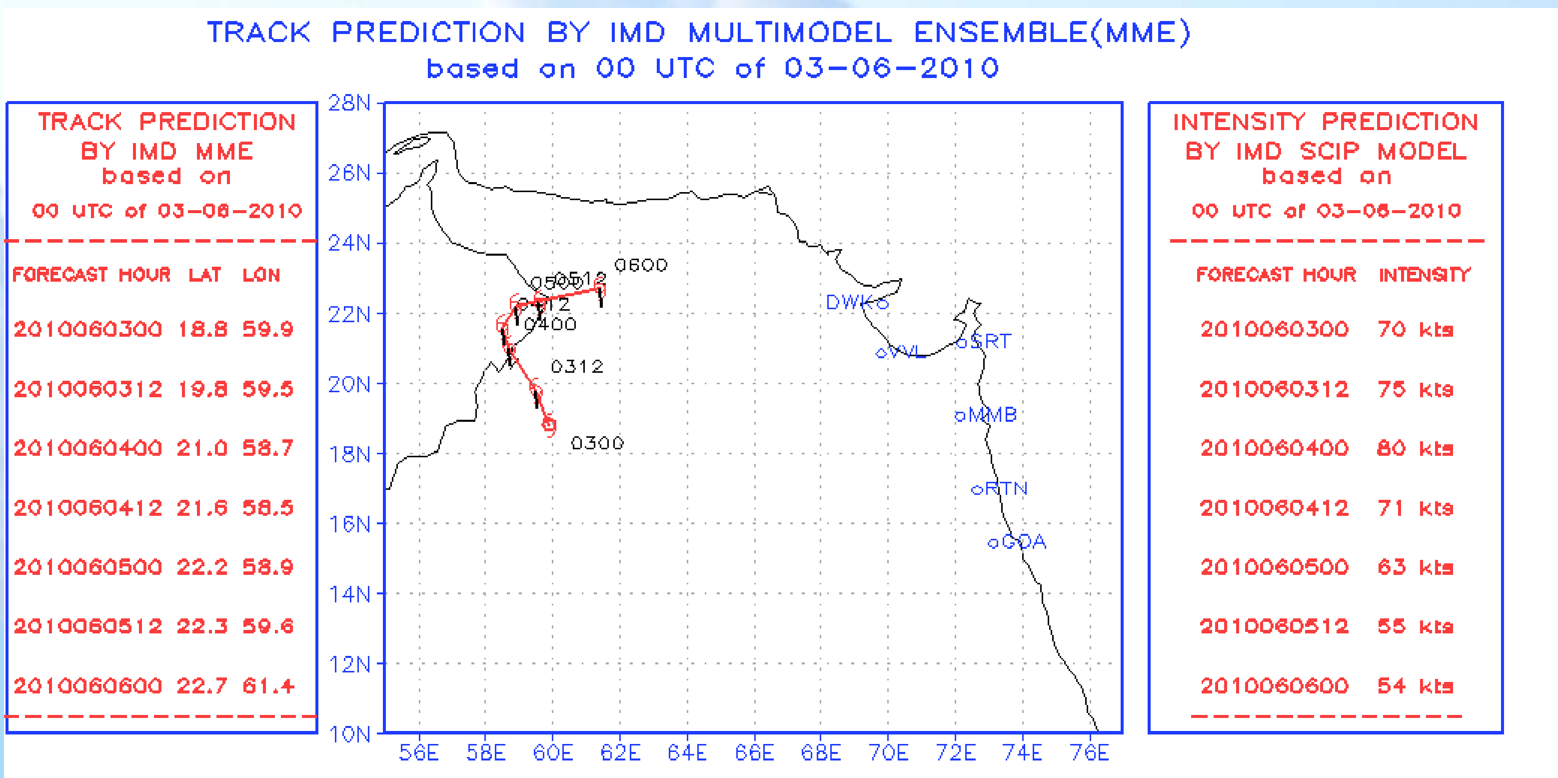
TC, RITA

over North Atlantic Ocean

Quadrant wind monitoring based on Dropsonde wind and SFMR data

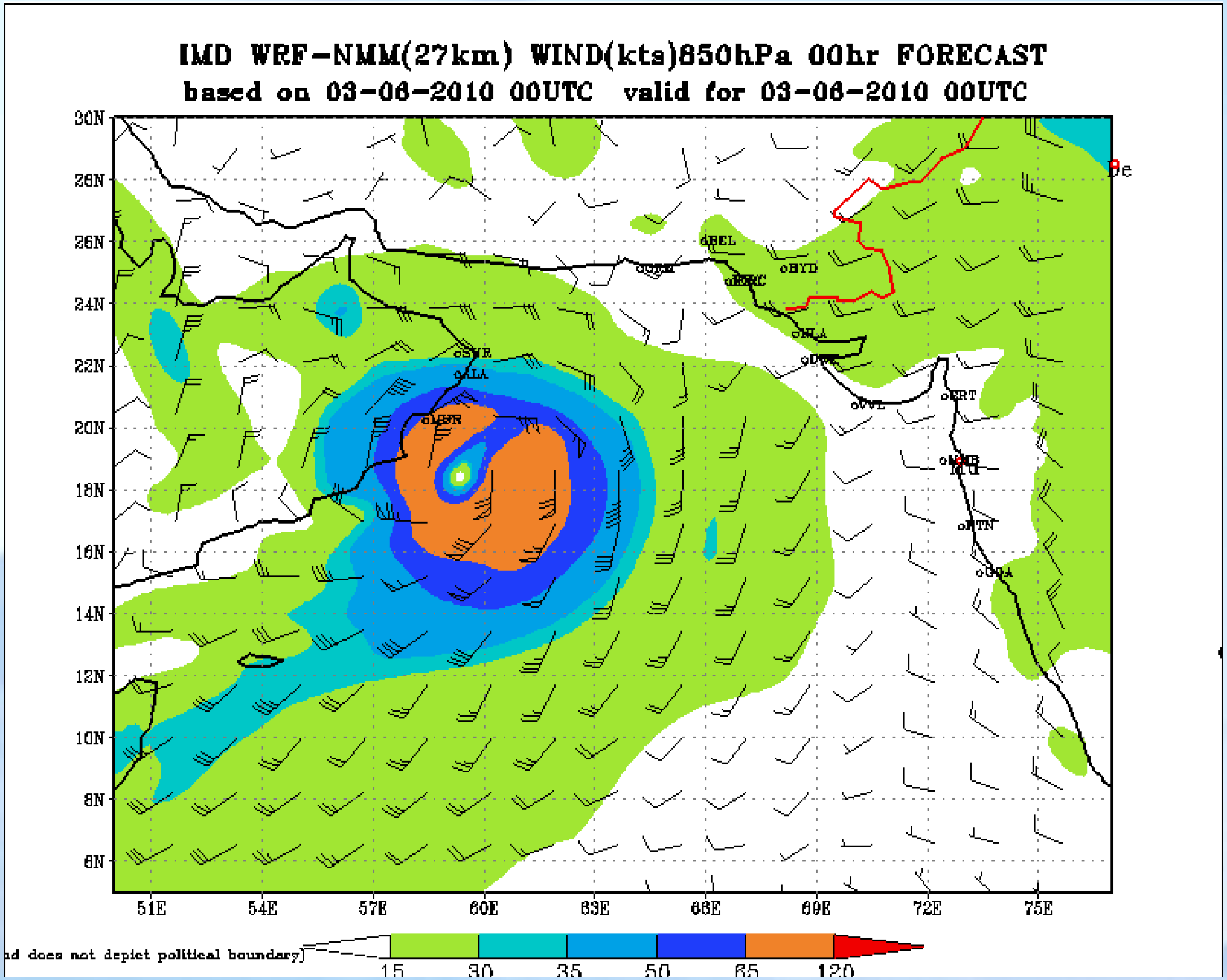
Difficulties and Limitations

- ❖ **Unavailability of objective wind radii forecast methods**
- ❖ **Numerical Weather Prediction (NWP) models fail to produce forecasts that are better than climatology**
- ❖ **Wind radii forecasts depend on track and intensity forecasts.**
- ❖ **It is very sensitive to vortex initialisation in NWP models and intensity forecasts.**



NWP Model analysis

Wind analysed from WRF model during cyclone, Phet



Difficulties and Limitations

- Over the past several years, there have been large improvements in track skill (RSMC, New Delhi, 2011) and modest improvements in the intensity skill like other Ocean basins.
- Intensity and track errors at 24 hrs (say) are still of the order of 15kts and 75 km.
- These errors, particularly the intensity errors negatively affect wind radii forecasts.
- The poor intensity forecast is particularly pronounced when intensity forecast fail to or falsely forecast winds that exceed the 34kts, 50kts and 64kts thresholds.

Products: Textual

(i) QUADRANT WIND DISTRIBUTION TEXT FORM

QUADRANT WIND DISTRIBUTION IN ASSOCIATION CYCLONIC STORM THANE OVER BAY OF BENGAL
DATE AND TIME BASED UPON WHICH FORECAST IS PREPARED:
PRESENT DATE AND TIME : 280600 UTC
PRESENT POSITION:12.5^{0}N/ 85.0^0 E
POSITION ACCURATE TO 50 KM
PRESENT MOVEMENT (DDD/FF) PAST SIX HOURS: 270/07KT

PRESENT WIND DISTRIBUTION:
MAX SUSTAINED WINDS: 55 KT, GUSTS 65 KT
RADIUS OF MAXIMUM WIND
WINDS VARY IN EACH QUADRANT
RADII ARE LARGEST RADII EXPECTED ANYWHERE IN THE QUADRANT
WIND RADII VALID OVER OPEN WATER ONLY

FORECASTS:
06 HRS, VALID AT:
281200Z 12.5^{0}N/ 84.3^0 E
MAX SUSTAINED WINDS: 60 KT, GUSTS 70 KT
RADIUS OF 050 KT WINDS:
30 NM NORTHEAST QUADRANT
25 NM SOUTHEAST QUADRANT
25 NM SOUTHWEST QUADRANT
30 NM NORTHWEST QUADRANT

RADIUS OF 034 KT WINDS:

80 NM NORTHEAST QUADRANT
60 NM SOUTHEAST QUADRANT
60 NM SOUTHWEST QUADRANT
80 NM NORTHWEST QUADRANT

RADIUS OF 028 KT WINDS:

150 NM NORTHEAST QUADRANT
130 NM SOUTHEAST QUADRANT
130 NM SOUTHWEST QUADRANT
150 NM NORTHWEST QUADRANT

12 HRS, VALID AT:

281800 12.7^{0}N/ 83.7^{0}E

MAX SUSTAINED WINDS : 65 KT, GUSTS 75 KT

RADIUS OF 050 KT WINDS:

30 NM NORTHEAST QUADRANT
25 NM SOUTHEAST QUADRANT
25 NM SOUTHWEST QUADRANT
30 NM NORTHWEST QUADRANT

RADIUS OF 034 KT WINDS:

80 NM NORTHEAST QUADRANT
60 NM SOUTHEAST QUADRANT
60 NM SOUTHWEST QUADRANT
80 NM NORTHWEST QUADRANT

RADIUS OF 034 KT WINDS:

80 NM NORTHEAST QUADRANT
60 NM SOUTHEAST QUADRANT
60 NM SOUTHWEST QUADRANT
80 NM NORTHWEST QUADRANT

RADIUS OF 028 KT WINDS:

150 NM NORTHEAST QUADRANT
130 NM SOUTHEAST QUADRANT
130 NM SOUTHWEST QUADRANT
150 NM NORTHWEST QUADRANT

48HRS, VALID AT:

300600 12.7^{0}N/ 79.9^0 E

MAX SUSTAINED WINDS :55 KT, GUSTS 65 KT

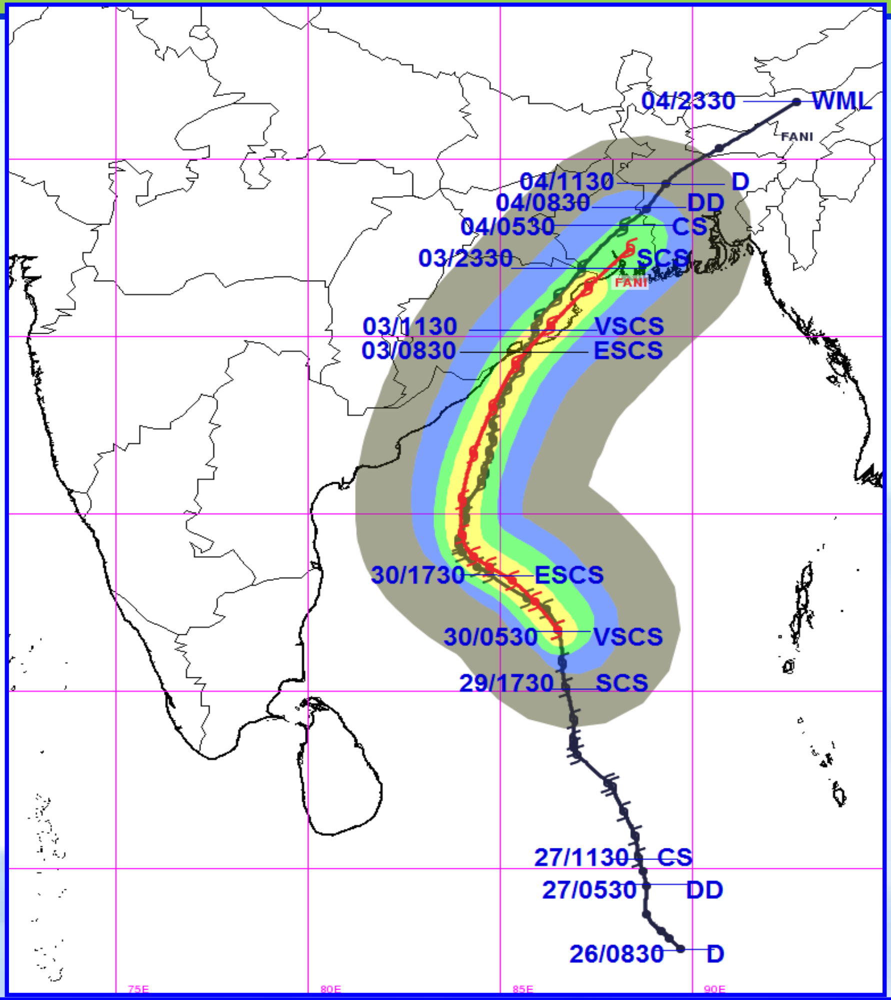
RADIUS OF 050 KT WINDS:

30 NM NORTHEAST QUADRANT
25 NM SOUTHEAST QUADRANT
25 NM SOUTHWEST QUADRANT
30 NM NORTHWEST QUADRANT

RADIUS OF 034 KT WINDS:

80 NM NORTHEAST QUADRANT
60 NM SOUTHEAST QUADRANT
60 NM SOUTHWEST QUADRANT
80 NM NORTHWEST QUADRANT

Products: GRAPHICAL



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

Description of characters:

character*4	tcv_center	! Hurricane Center Acronym	IMD(give one space)
character*3	tcv_storm_id	! Storm Identifier (02B, etc)	01B
character*9	tcv_storm_name	! Storm name	VIYARU(give2space)
integer	tcv_century	! 2-digit century id (19 or 20)	20
integer	tcv_yymmdd	! Date of observation	130515
integer	tcv_hhmm	! Time of observation (UTC)	1800
integer	tcv_lat	! Storm Lat (*10), always >0	190 (for $19.0^{0)}$
character*1	tcv_latNS	! 'N' or 'S'	N
integer	tcv_lon	! Storm Lon (*10), always >0	0885 (for $88.5^{0)}$
character*1	tcv_lonEW	! 'E' or 'W'	E
integer	tcv_stdir	! Storm motion vector (in degr)	030 (from Syn.in 3 digits)
integer	tcv_stspd	! Spd of storm movement (m/s*10)	reported in 3 digits)

IMD 04B PHAILIN 20131012 0000 175N 0865E 315 080 0932 1006 0400 060 020 0185 0185 0165 0150 D

Description of characters:

```
integer       tcv_pcen       ! Min central pressure (mb)
integer       tcv_penv       ! val outrmost closed isobar(mb)
integer       tcv_penvrad    ! rad outrmost closed isobar(km)
integer       tcv_vmax       ! max sfc wind speed (m/s)
integer       tcv_vmaxrad    ! rad of max sfc wind spd (km)
integer       tcv_r15ne      ! NE rad of 15 m/s winds (km)
integer       tcv_r15se      ! SE rad of 15 m/s winds (km)
integer       tcv_r15sw      ! SW rad of 15 m/s winds (km)
integer       tcv_r15nw      ! NW rad of 15 m/s winds (km)
character*1   tcv_depth      ! Storm depth (S,M,D) X=missing      M
```

S stands for shallow (for Dep), M stands for Medium (for DD), D stands for Deep (for CS and above) and X stands for missing

Thus the TC Vital message for the above example is given below.

IMD 01B VIYARU   20130515 1800 190N 0885E 030 050 0990 1000 0250 022 060 0170 0130 0120 0170 M

N.B.:

- Century and yymmdd are given in one column (column number 4)
- Latitude of centre of TC is given in three digits alongwith N/S (column 6)
- Longitude of the centre of TC is given in four digits alongwith E/W (column 7)

4. Starts from DD stage and in place of storm name give 13 blank spaces
5. Storm identifier is system No. in particular basin and reported as NNB or NNA (reported in 3 digits as 01B)

Products: Coded

(ii) TC VITALS—CODED FORM

IMD 04B PHAILIN 20131012 0000 175N 0865E 315 080 0932 1006 0400 060 020 0185 0185 0165 0150 D

Exercise: Preparation of TC Vital for modelling group

System No. 4
Deep Depression
Base time 10/0600 UTC
Centre 17.5N/80.5 E
Previous location based on 10/00 UTC: 17.0/90.0
POCI: 1006
P central: 932
ROCI: 200 nm
MSW: 30 kt
RMW: 90 km
R28: NE/SE/SW/NW: (nm): 90/90/80/75

Future Scope

- **In the absence of a reliable NWP model, a common approach is to develop Multi Model Ensemble.**
- **Development of a climatology and persistence (CLIPER) model for TC wind radii forecast over the North Indian Ocean is being attempted like that over North Atlantic Ocean.**
- **CLIPER model will also provide a reference forecast for verifying other techniques.**
- **Aircraft reconnaissance as in other basins will make study more objective.**

Thank you