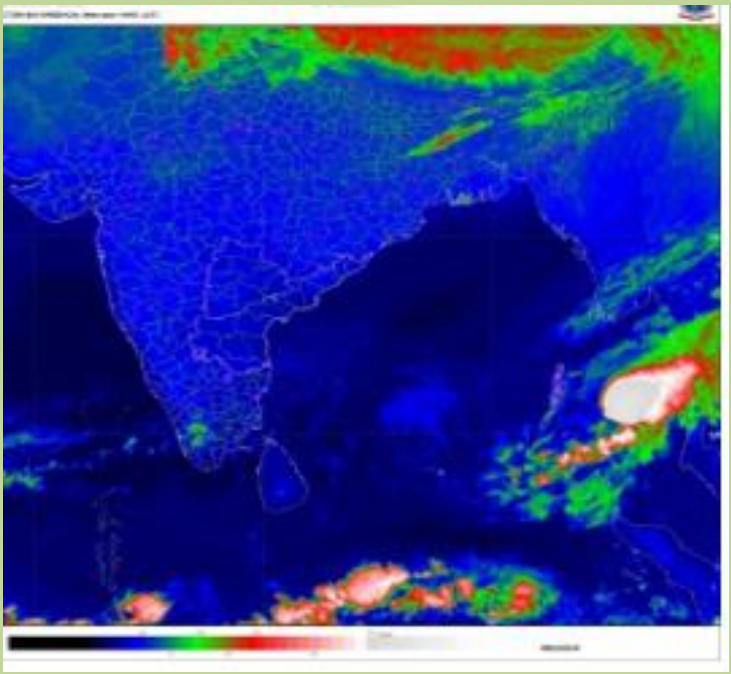
GOVERNMENT OF INDIA
MINISTRY OF EARTH SCIENCES
INDIA METEOROLOGICAL DEPARTMENT

Cyclonic Storm "Pabuk" over Andaman Sea (04-08 January2019): A Report



INSAT-3D typical satellite imagery 0000 UTC of 6th January

Cyclone Warning Division

India Meteorological Department

New Delhi

January 2019

Cyclonic Storm "Pabuk" over Andaman Sea (04-08 January)

1. Introduction:

Cyclonic Storm (CS) Pabuk originated from a low pressure area (LPA) which formed over south China Sea on 28th December, 2018**.** Under favourable environmental conditions, it concentrated into a tropical depression on 31st December, 2018. At around 0600 UTC of 1st January, 2019 it further intensified into a tropical storm "Pabuk" (Name given by JMA). It moved west-northwestwards and entered the Gulf of Thailand on 3rd January. It made landfall over Pak Phanang, Nakhon Si Thammarat, Thailand at 0545 UTC of 4th January. At 1200 UTC, the JMA issued the last advisory for Pabuk as it exited from their basin. Moving west-northwestwards, it emerged into the north Indian Ocean region over Andaman Sea in the morning (0300 UTC) of 5th January, 2019. Continuing to move west-northwestwards, it gradually weakened into a deep depression around noon (0600 UTC) and crossed Andaman Islands near 11.6°N/92.7°E, close to south of Port Blair during night (between 1300 and 1500 UTC) of 6th January 2018 with maximum sustained wind speed of 55-65 kmph gusting to 75 kmph. Thereafter, the northern component of it's movement gradually increased and the system weakened into a depression in the early morning (0000 UTC) of 7th and into a well marked low pressure area in the early morning (0000 UTC) of 8th January over eastcentral Bay of Bengal (BoB) and adjoining areas.

The observed track of the system during 4th-8th January is presented in **Fig.1**. The best track parameters of the system are presented in **Table 1**.

The salient features of the system were as follows:

- CS Pabuk is the first cyclonic disturbance over north Indian Ocean during 2019.
- It had many firsts to it's credit. It became the earliest forming storm over northwest Pacific after Alice in 1979. It became the first tropical storm over the Gulf of Thailand since Muifa in 2004. It became the first tropical storm to make landfall over southern Thailand since Linda in 1997. It became the first cyclonic storm over Andaman Sea in the month of January in the satellite era (1961 onwards). It also became the earliest cyclonic storm over north Indian Ocean in the satellite era.
- The system had the track length equal to 1058 km.
- Over the Andaman Sea, the peak intensity of the system was 70-80 kmph gusting to 90 kmph (about 12 hrs during 0300 -1500 UTC of 5th). The lowest estimated central pressure was 1000 hPa with pressure drop of about 8 hPa.
- The life period (CS to D) of the system over the north Indian Ocean was 69 hours (2 days and 21 hours) against the long period average (LPA) (1990-2013) of 98 hours for CS category over Bay of Bengal during winter season.
- It moved with normal speed, as the 12 hour average translational speed of the cyclone was 14.1 kmph against LPA (1990-2013) of 14.7 kmph for CS category over north Bay of Bengal.

- The Velocity Flux, Accumulated Cyclone Energy (ACE) and Power Dissipation Index (PDI) were 2.8 $X10^2$ knots, 1.13 X 10^4 $knots^2$ and $0.46X10^6$ $knots^3$ respectively

2. Brief life history

2.1. Genesis

Cyclonic Storm (CS) Pabuk originated from a low pressure area (LPA) which formed over south China Sea on 28th December. Under favourable environmental conditions, it concentrated into a tropical depression on 31st December, 2019. At around 0600 UTC of 1st January, it further intensified into a tropical storm "Pabuk" (Name given by JMA). Under marginal favourable conditions, including warm sea surface temperatures, poleward outflow but strong vertical wind shear, it maintained it's intensity of cyclonic storm for next two days over south China Sea. It moved west-northwestwards and entered into the Gulf of Thailand on 3rd January. It made landfall over Pak Phanang, Nakhon Si Thammarat, Thailand at 0545 UTC of 4th January. At 1200 UTC, the JMA issued the last advisory for Pabuk as it exited from their basin.

2.2 Intensification

However, RSMC New Delhi monitored the system since 31st December, about 5 days prior to it's emergence into the Andaman Sea) at 0300 UTC of 5th January.

At 0300 UTC of 31st December, 2018 the sea surface temperature was around 29-30 °C over Andaman sea and 27-28 °C over adjoining eastcentral BoB. The tropical cyclone heat potential was around 80-90 KJ/cm^2 over Andaman sea with decreasing trend towards north. The vertical wind shear was 20-25 knots over Gulf of Thailand and adjoining Andaman Sea. The low level vorticity was not favourable over Gulf of Thailand and adjoining Andaman Sea. However, a positive vorticity zone of $50x10^{-6}$ S^{-1} was seen over north Andaman Sea and adjoining eastcentral BoB. No favourable zones of lower level convergence and upper level divergence were seen over Andaman Sea at that time. Similar features continued for next 2-3 days indicating that Pabuk may weaken on entering into the Andaman Sea.

At 1200 UTC of 4th January, CS Pabuk lay over Thailand. Similar sea conditions prevailed over Andaman Sea. The lower level convergence was $50x10^{-5}$ s^{-1} towards the southeast of the system center. Lower level vorticity was $250x10^{-6}$ s^{-1} around the system center over Thailand. It indicated negative vorticity area over north Andaman Sea with slightly higher positive vorticity over Andaman Islands. Upper level divergence was $50x10^{-5}$ s^{-1} around the system center and vertical wind shear was 20-25 knots over the system area with increasing trend over north Andaman Sea and adjoining eastcentral BoB. The upper air ridge ran along 14°N over the system area. The Madden Julian Oscillation (MJO) index lay in phase 7 with amplitude more than 1. All these conditions indicated that the system would weaken on entering into the Andaman Sea.

On 05th January, 2019, the system lay over Andaman Sea & neighbourhood near latitude 9.1°N and longitude 98.1°E, about 650 km east-southeast of Port Blair.

Similar sea conditions prevailed over Andaman Sea and adjoining southeast & eastcentral BoB. The lower level convergence was $20x10^{-5}$ s^{-1} towards southeast and southwest of the system center. Lower level vorticity was $250x10^{-6}$ s^{-1} to the southwest of the system center. Upper level divergence was $10x10^{-5}$ s^{-1} around the system center and vertical wind shear was 20-25 knots over the system area. It was increasing along the forecast track. The upper air ridge ran along 15°N over the system region. The MJO index lay over phase 8 with amplitude more than 1. The system maintained it's intensity under these conditions.

At 0600 UTC of 6th January 2019, the system lay over Andaman Sea near latitude 11.2°N and longitude 94.0°E, about 150 km east-southeast of Port Blair. Similar sea conditions prevailed. The lower level convergence decreased and was around $15x10^{-5}$ s^{-1} to the southwest of the system centre. Lower level vorticity also decreased and was around $100\text{-}150x10^{-6}$ s^{-1} around the system centre. Upper level divergence was around $20x10^{-5}$ s^{-1} to the northeast of the system centre. Vertical wind shear was around 25-30 knots over the system area and indicated increasing trend along the forecast track. The upper tropospheric ridge ran along 15°N over the system region. The MJO index lay over phase 8 with amplitude more than 1. Due to the unfavourable vertical wind shear and other environmental factors over the system area, the system weakened into a DD at 0600 UTC of 6th January.

At 0000 UTC of 7th January 2019, similar sea conditions prevailed. The lower level convergence was $20x10^{-5}$ s^{-1} to the north of the system centre. Lower level vorticity decreased and was around $80x10^{-6}$ s^{-1} to the south-southwest of system centre. Upper level divergence decreased and was around $10x10^{-5}$ s^{-1} around the system centre. Vertical wind shear increased and was around 30-40 knots over the system area. The upper tropospheric ridge ran along 11°N over the system region. The MJO index lay over phase 8 with amplitude more than 1. Due to the unfavourable vertical wind shear, MJO phase and other environmental factors over the system area, the system weakened into a D over southeast BoB adjoining eastcentral BoB close to Andaman Islands near latitude 12.6°N and longitude 92.0°E.

Further moving northeastwards, the system weakened into a well marked low pressure area over eastcentral BoB and adjoining north Andaman Sea off Myanmar coast at 0000 UTC of 08th January, 2019.

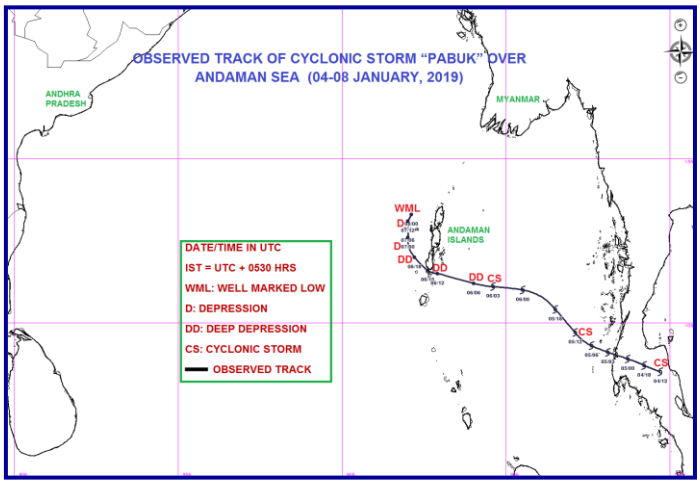


Fig.1: Observed track of CS "Pabuk" over Andaman Sea (04-08 January, 2019)

Table 1: Best track positions and other parameters of the Cyclonic Storm "Pabuk" over Andaman Sea during 4th – 8th January, 2019

Date	Time (UTC)	Centre lat.^{0} N/ long.^{0} E		C.I. NO.	Estimated Central Pressure (hPa)	Estimated Maximum Sustained Surface Wind (kt)	Estimated Pressure drop at the Centre (hPa)	Grade
04/01/2019	1200	8.5	99.7	2.5	998	45	10	**CS**
	1500	8.6	99.5	2.5	998	45	10	CS
	1800	8.7	99.2	2.5	998	45	10	CS
	2100	8.8	99.0	2.5	998	45	10	CS
05/01/2019	0000	8.9	98.7	2.5	1000	40	08	CS
	0300	9.1	98.1	2.5	1000	40	08	**CS**
	0600	9.3	97.6	2.5	1000	40	08	CS
	0900	9.5	97.3	2.5	1000	40	08	CS
	1200	9.8	97.1	2.5	1000	40	08	CS
	1500	10.1	96.8	2.5	1000	40	08	CS
	1800	10.4	96.5	2.5	1001	35	07	CS
	2100	10.7	96.0	2.5	1001	35	07	CS
06/01/2019	0000	11.0	95.5	2.5	1001	35	07	CS
	0300	11.1	94.6	2.5	1001	35	07	CS
	0600	11.2	94.0	2.0	1002	30	06	**DD**
	1200	11.5	92.9	2.0	1003	30	05	DD
	Crossed Andaman Islands near 11.6°N/92.7°E, close to south of Port Blair between 1300 and 1500 UTC of 6th January 2019							
	1800	12.0	92.2	2.0	1003	30	05	DD
07/01/2019	0000	12.6	92.0	1.5	1004	25	04	**D**
	0300	12.8	92.0	1.5	1004	25	04	D
	0600	12.8	92.0	1.5	1004	25	04	D
	1200	13.1	92.0	1.5	1004	25	04	D
	1800	13.1	92.0	1.5	1005	20	03	D
08/01/2019	0000	Weakened into a well marked low pressure area over eastcentral Bay of Bengal and adjoining north Andaman Sea off Myanmar coast						

The lowest estimated central pressure and the maximum sustained wind speed are presented in Fig.2. The lowest estimated central pressure had been 998 hPa and the estimated maximum sustained surface wind speed (MSW) was 45 knots during 1200 to 1800 UTC of 4th January. At the time of moving across Andaman Islands, the ECP was 1003 hPa and MSW was 30 knots (deep depression). The ECP and Vmax graph also indicates that the system weakened gradually during it's life period.

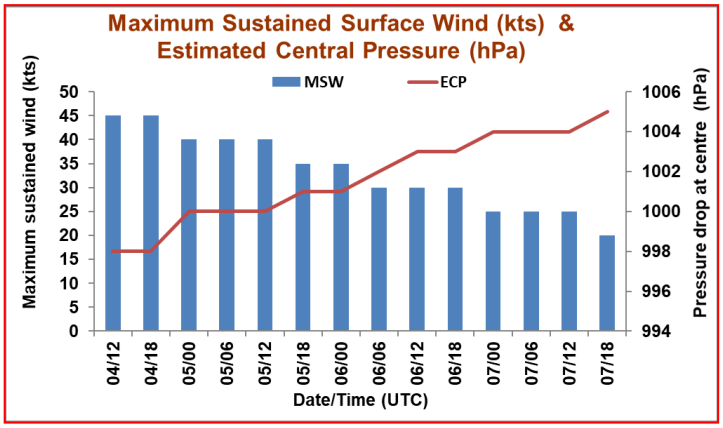


Fig.2: Lowest estimated central pressure and the maximum sustained wind speed

3.3. Movement

The six hourly average translational speed and direction of movement of CS Pabuk is presented in Fig.3. CS Pabuk moved nearly west-northwestwards till 1200 UTC of 6th January, as the system lay to the south of the upper tropospheric ridge. During this period, the ridge lay near 15°N. Thereafter, the northward component gradually increased and the system moved along the periphery of anticyclone to it's north over Gulf of Thailand. It moved nearly northwards from 0600 UTC of 7th till it's weakening. During this period, the system lay close to the north of the ridge. It is also seen that the translational speed increased gradually and reached maximum of 27.7 kmph at 0600 UTC of 6th January, thereafter it decreased gradually to 3.7 kmph at 0600 UTC of 7th.

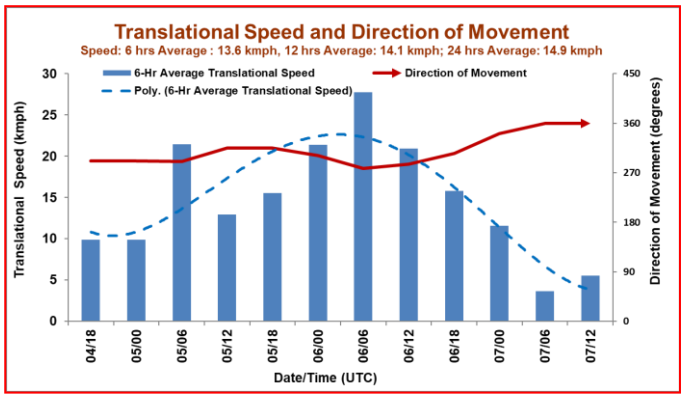


Fig.3: Six hourly average translational speed (kmph) and direction of movement in association with CS Pabuk

4. Monitoring and Prediction

The system was monitored & predicted continuously by India Meteorological Department (IMD) prior to it's emergence into Andaman Seas since 4th January. The system was monitored mainly with the help of satellite observations from INSAT 3D and 3DR, alongwith available ships & buoys observations in the region. Various national and international numerical weather prediction models and dynamical-statistical models were utilized to predict the genesis, track and intensity of the

cyclone. Tropical Cyclone Module, the digitized forecasting system of IMD was utilized for analysis and comparison of various models' guidance, decision making process and warning product generation. IMD issued regular bulletins to WMO/ESCAP Panel member countries including Bangladesh & Myanmar, National & State Disaster Management Agencies, general public and media since emergence of the system over Andaman Seas. The typical satellite imageries are presented in Fig.4 (a) – (c).

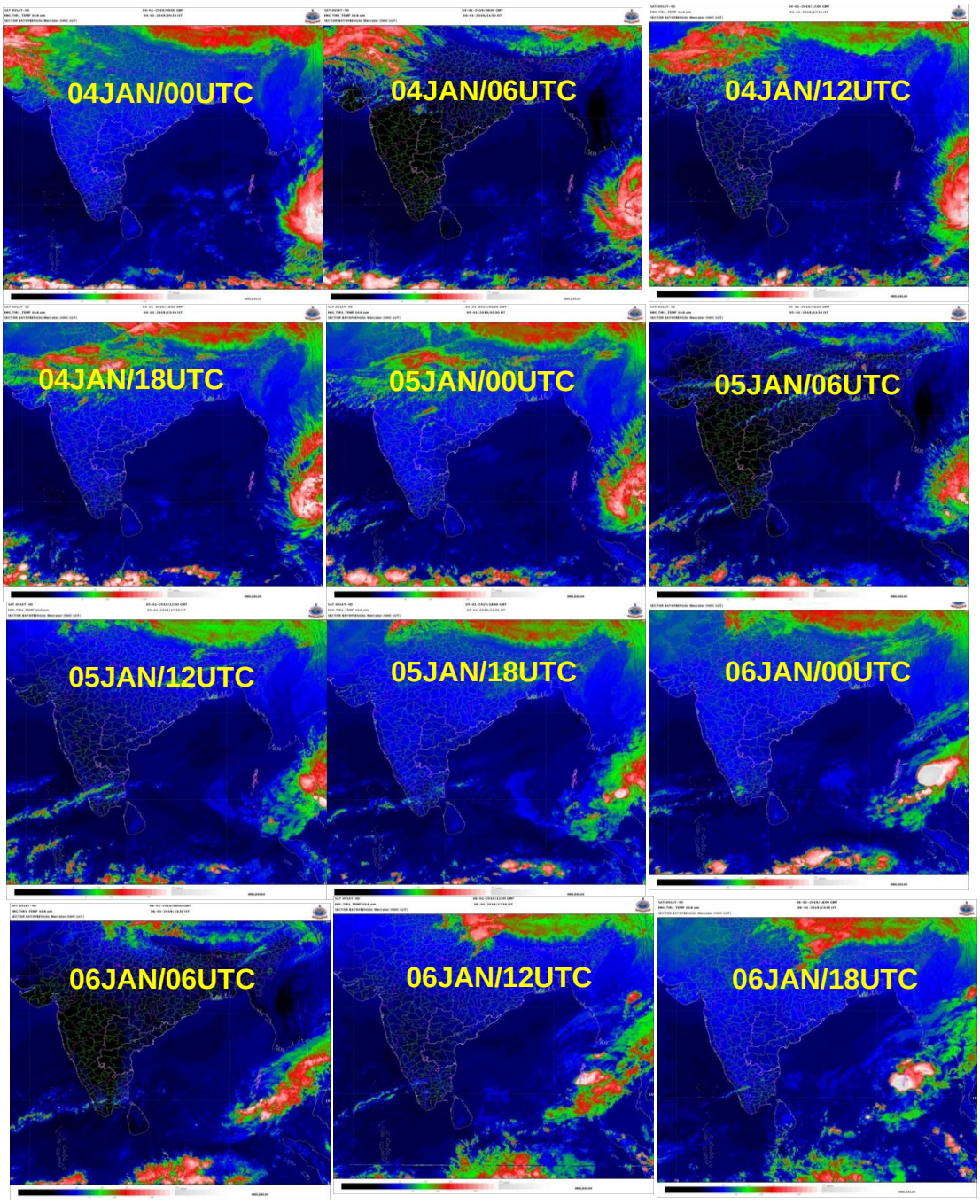


Fig.4(a) INSAT-3D enhanced colored imageries during 04-06 January 2019

At 1200 UTC of 04th January, the system lay as a CS over Thailand. Broken low to medium clouds with embedded intense to very intense convection were observed over east Andaman Sea, Tenasserim coast, Thailand, west Cambodia and Gulf of Thailand. Minimum cloud top temperature was - 93°C. Clouds were organized in shear pattern. At 0300 UTC of 05th January, the system lay over Andaman Sea and neighbourhood. Broken low to medium clouds with embedded moderate to intense convection were observed over east Andaman sea, Tenasserim coast, Thailand, and Gulf of Thailand. The minimum cloud top temperature was -60°C.

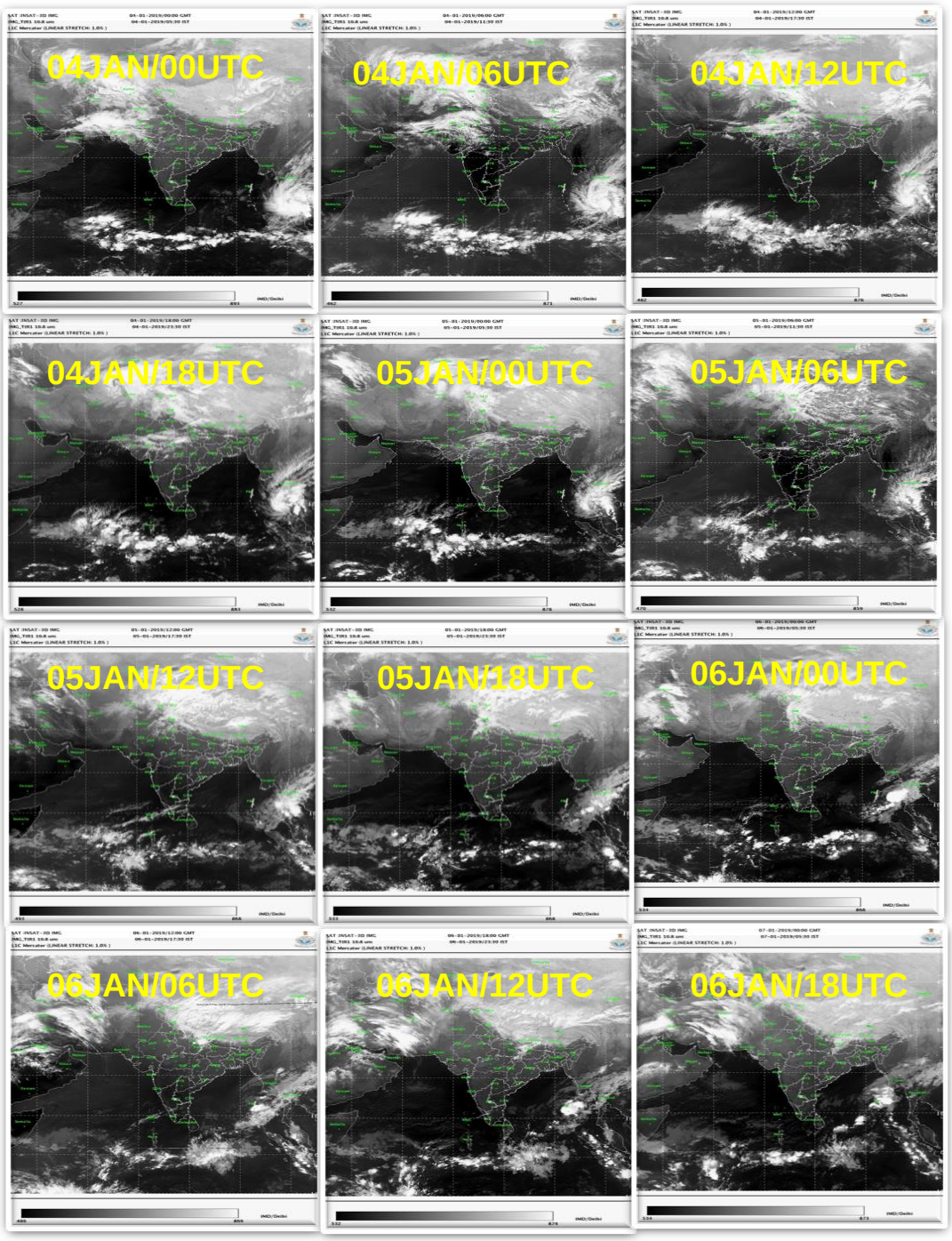


Fig. 4(b): INSAT-3D IR imageries during 04-06 January, 2019

At 0300 UTC of 06th January, the intensity of the system was C.I. 2.5 with shear pattern. Broken low to medium clouds with embedded intense to very intense convection lay over area Andaman Sea & adjoining eastcentral & southeast BoB and Tenasserim coast. Minimum cloud top temperature was minus -63°C. At 1200 UTC of 6th January, the system lay over Andaman Sea as a deep depression. The intensity of the system was T 2.0. Broken low to medium clouds with embedded intense to very intense convection lay over Andaman sea & adjoining southeast BoB and Tenasserim coast. Minimum cloud top temperature was -70°C. At 0300 UTC of 7th January, the system lay over southeast BoB and adjoining eastcentral BoB near Andaman Islands as a depression (T.No.1.5). Broken low and medium clouds with embedded moderate to intense convection lay over the region between latitude 11.5°N & 16.0°N and longitude 90.5°E & 95.3°E. Minimum cloud top temperature was -74°C.

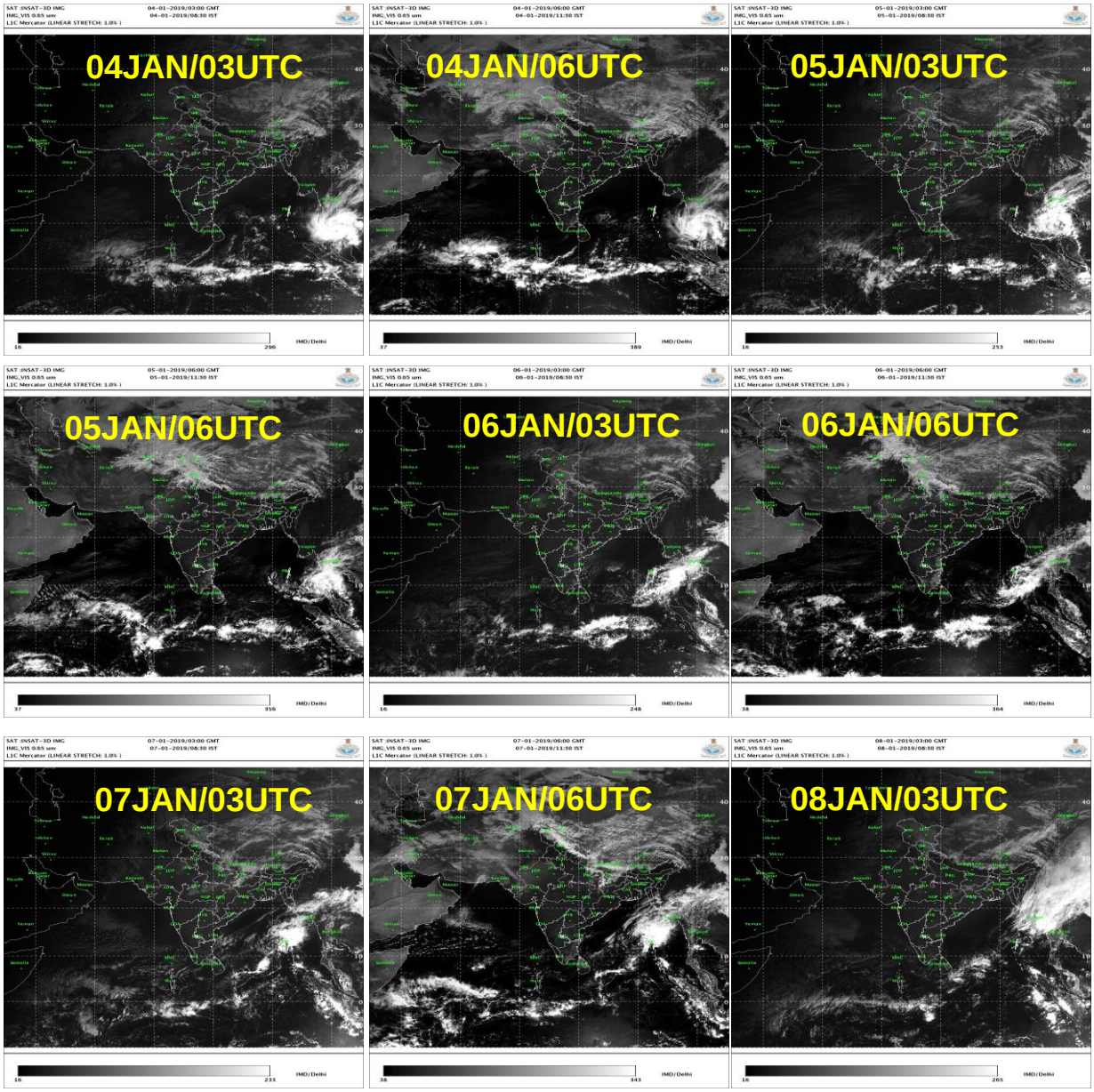


Fig. 4(c): INSAT-3D Visible imageries during 04-08 January 2019

5. Dynamical features

IMD GFS (T1534) mean sea level pressure (MSLP), winds at 10m, 850, 500 and 200 hPa levels are presented in Fig.5. GFS (T1534) could not capture the CS Pabuk in the Gulf of Thailand. At 0000 UTC of 4th January, it lay over Gulf of Thailand around 8.5°N/101.5°E.

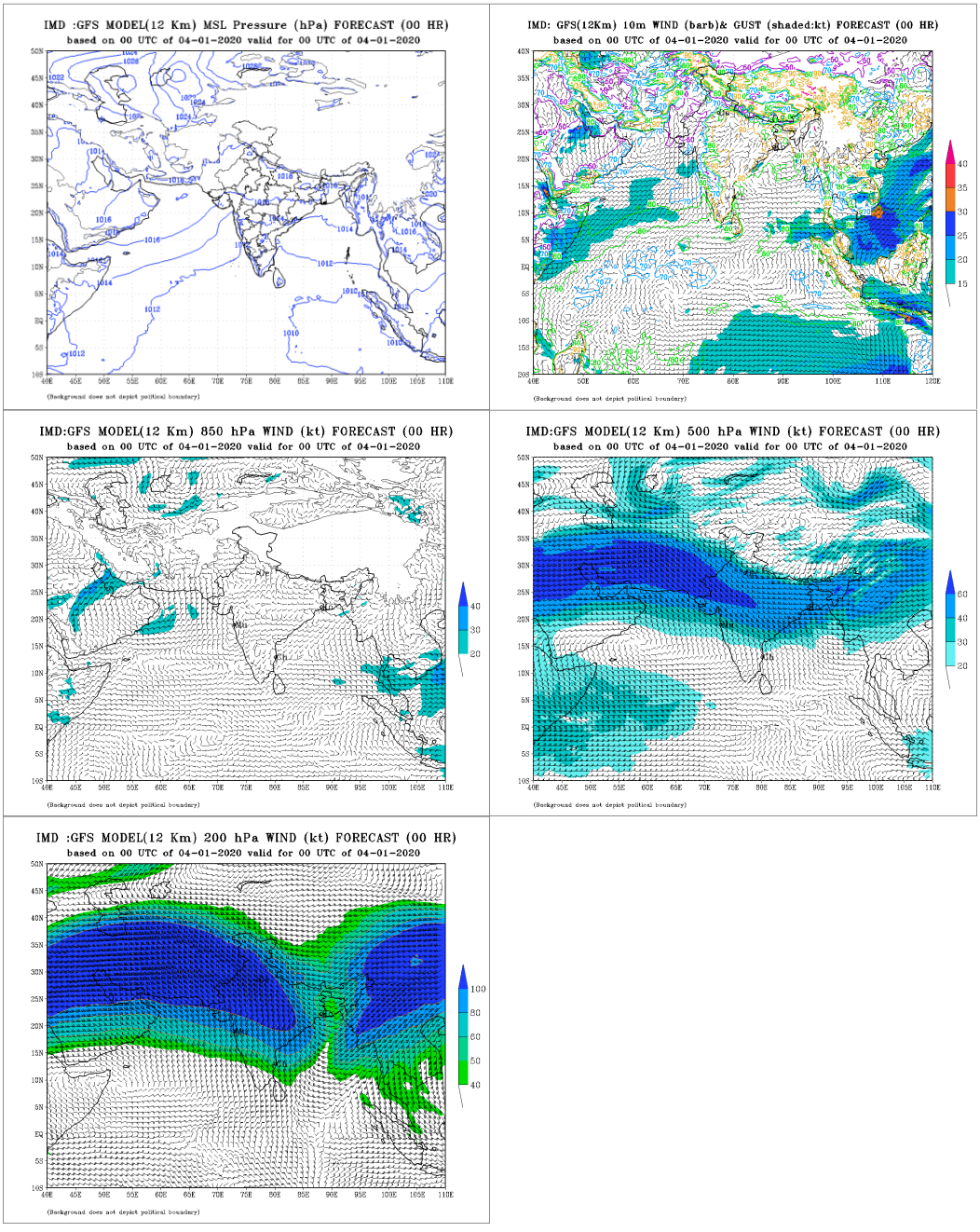


Fig. 5 (a): IMD GFS (T1534) mean sea level pressure (MSLP) and winds at 10m, 850, 500 and 200 hPa levels based on 0000 UTC of 4th January 2019.

At 0000 UTC of 5th January, 2019, the system lay over Thailand and neighbourhood near 8.9°N/98.7°E as a CS with MSW of 40 kts. GFS (T574) pressure and wind field could not capture the CS Pabuk in the Gulf of Thailand. The system was being steered by anticyclone to the east of Malay Peninsula. However, the same was not captured by IMD GFS.

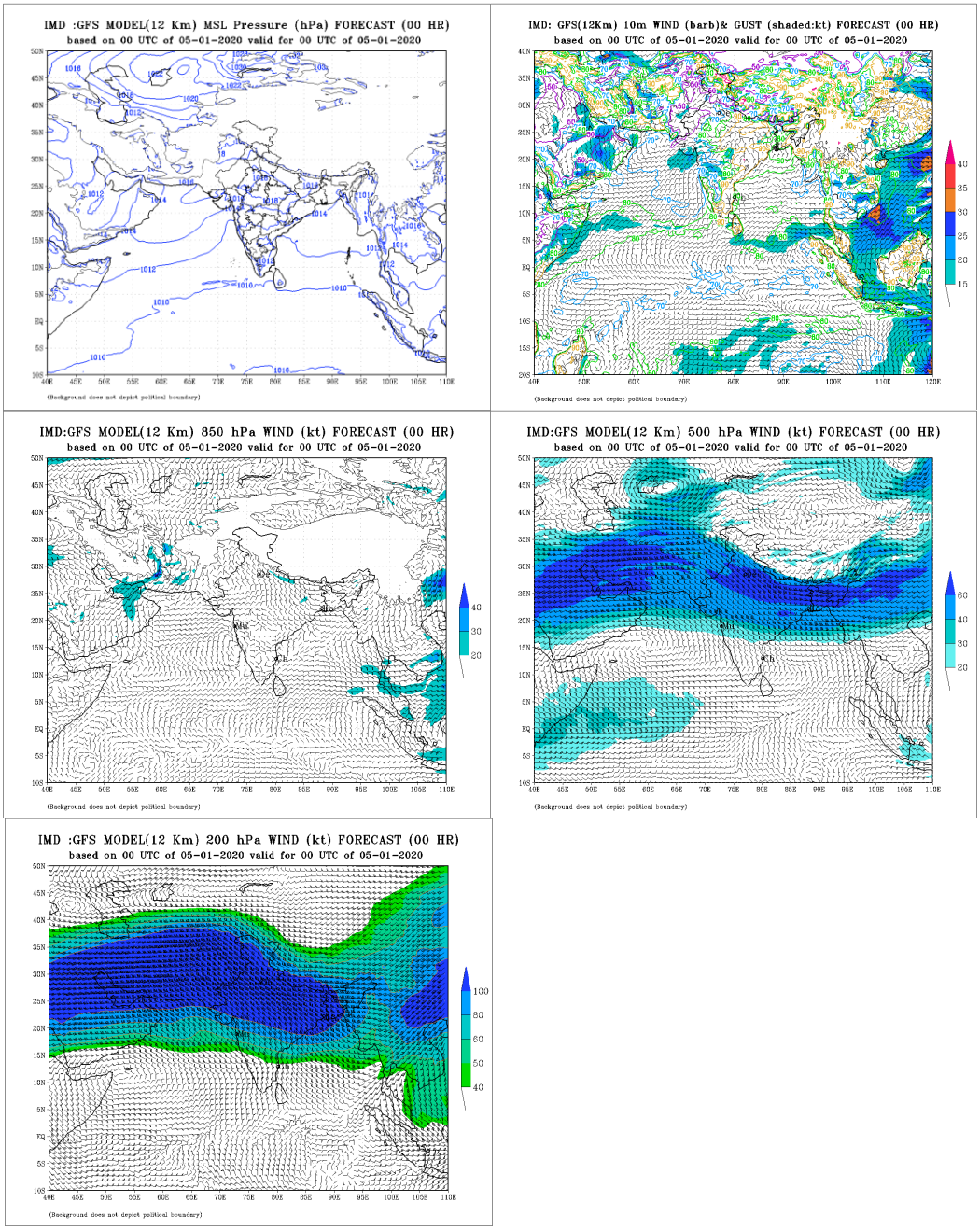


Fig. 5 (b): IMD GFS (T1534) mean sea level pressure (MSLP) and winds at 10m, 850, 500 and 200 hPa levels based on 0000 UTC of 5th January 2019.

At 0000 UTC of 6th January, 2019, the system lay over Andaman Sea and neighbourhood near 11.0°N/95.5°E as a CS with MSW of 35 kts. GFS (T1534) pressure and wind field could not capture the CS Pabuk over Andaman Sea. Ridge was near 15°N. However, the same was not captured by IMD GFS.

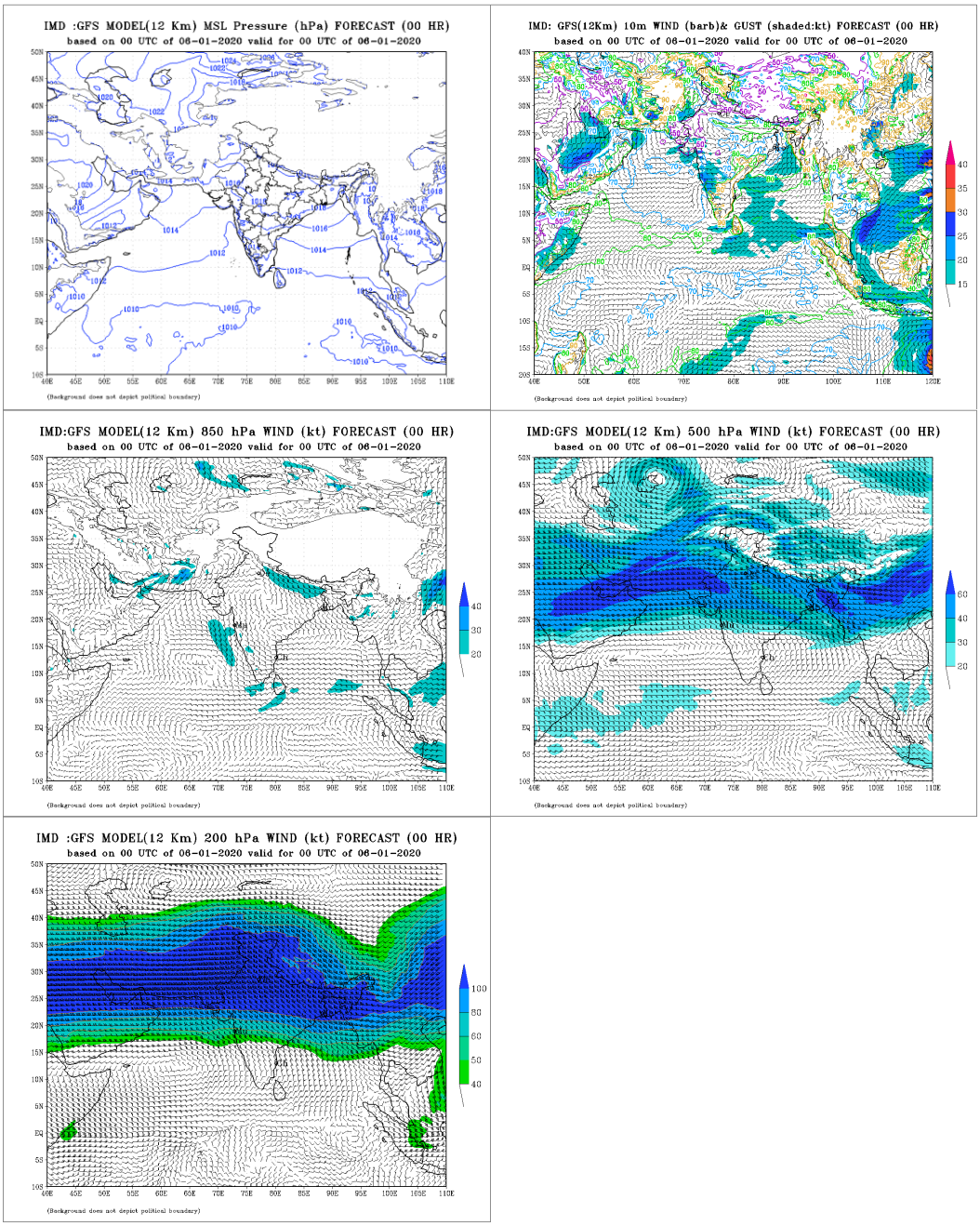


Fig. 5 (c): IMD GFS (T1534) mean sea level pressure (MSLP) and winds at 10m, 850, 500 and 200 hPa levels based on 0000 UTC of 6th January 2019.

At 0000 UTC of 7th January, 2019, the system lay over southeast BoB and adjoining eastcentral BoB near 12.6°N/92.0°E as a D with MSW of 25 kts. GFS (T1534) pressure and wind field could not capture the system at this stage.

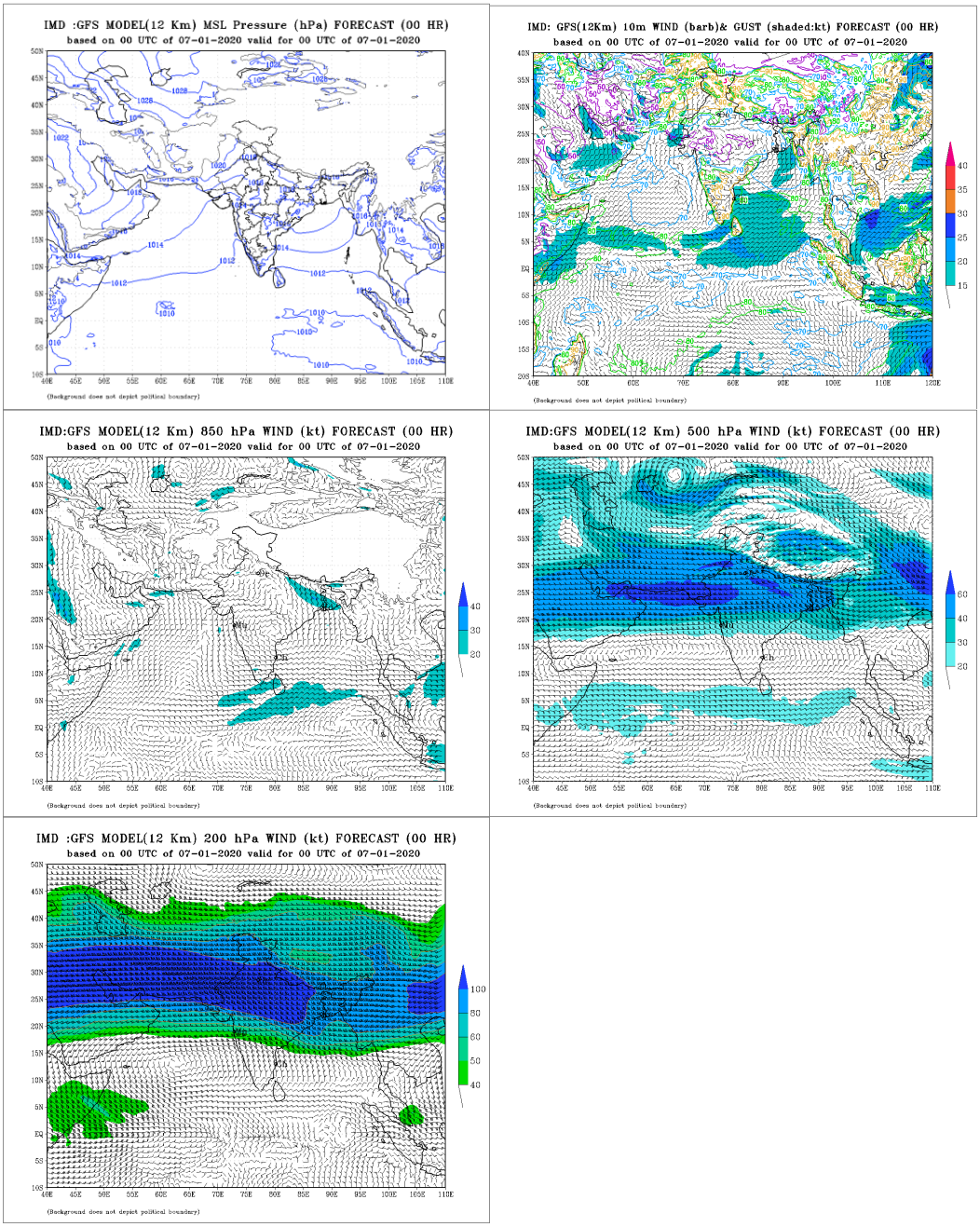


Fig. 5 (d): IMD GFS (T1534) mean sea level pressure (MSLP) and winds at 10m, 850, 500 and 200 hPa levels based on 0000 UTC of 7th January 2019.

At 0000 UTC of 8th January, 2019, the system lay as a well marked low pressure area over eastcentral BoB and adjoining north Andaman Sea off Myanmar coast. The GFS (T1534) pressure and wind field could not capture the system at this stage.

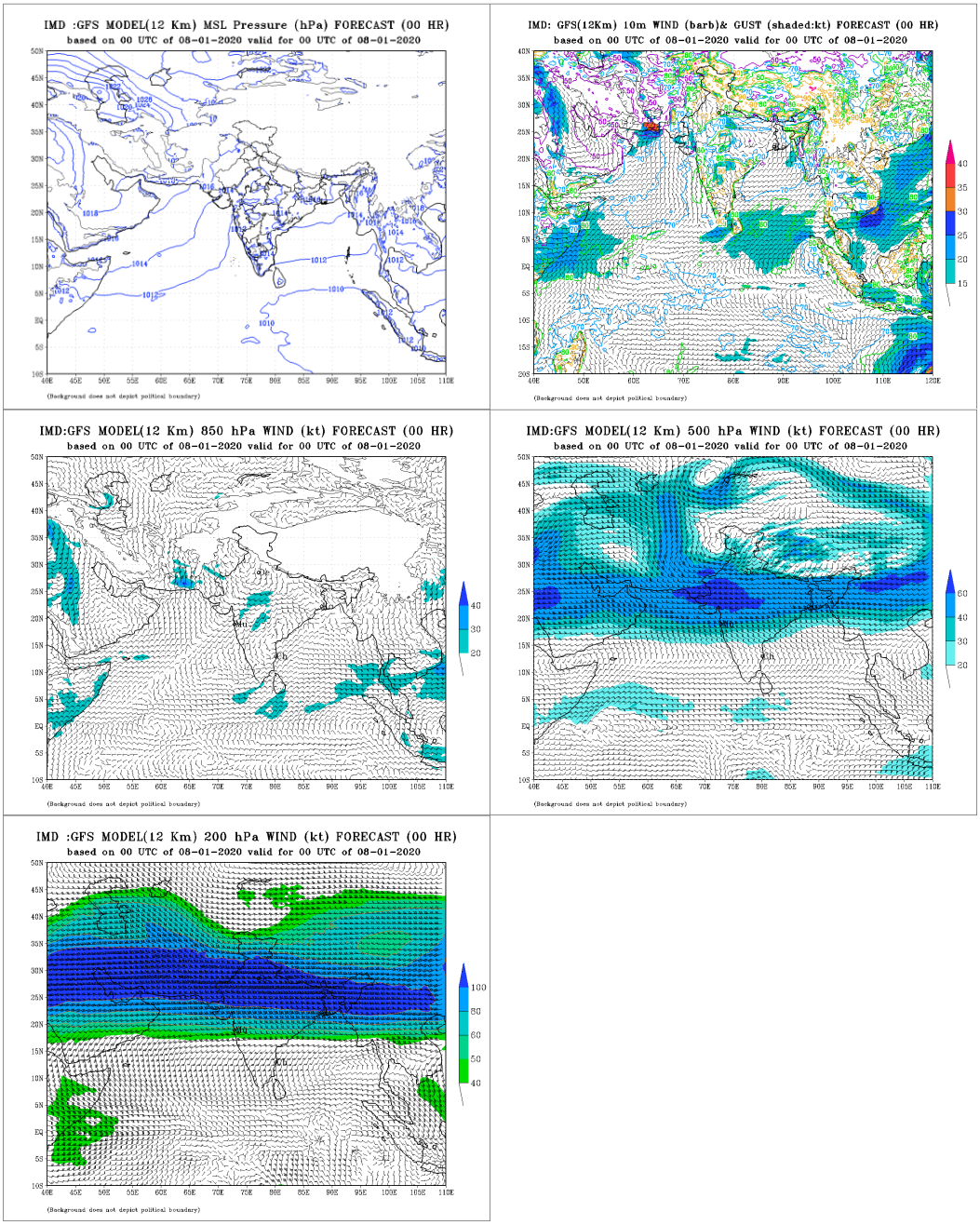


Fig. 5 (e): IMD GFS (T1534) mean sea level pressure (MSLP) and winds at 10m, 850, 500 and 200 hPa levels based on 0000 UTC of 8th January 2019.

Hence to conclude CS Pabuk was not captured by IMD GFS throughout it's life period.

6. Realized Weather:

6.1. Realised Rainfall:

According to IMD-NCMRWF merged satellite and rain gauge observation (Fig.6), on 6th January, heavy rainfall occurred at isolated places over north Andaman Sea and Andaman Islands. Moderate rainfall occurred over Andaman and Nicobar Islands on 7th. On 8th, the cloud mass was sheared northeastwards and light to moderate rainfall occurred at a few places over eastcentral BoB and adjoining Myanmar.

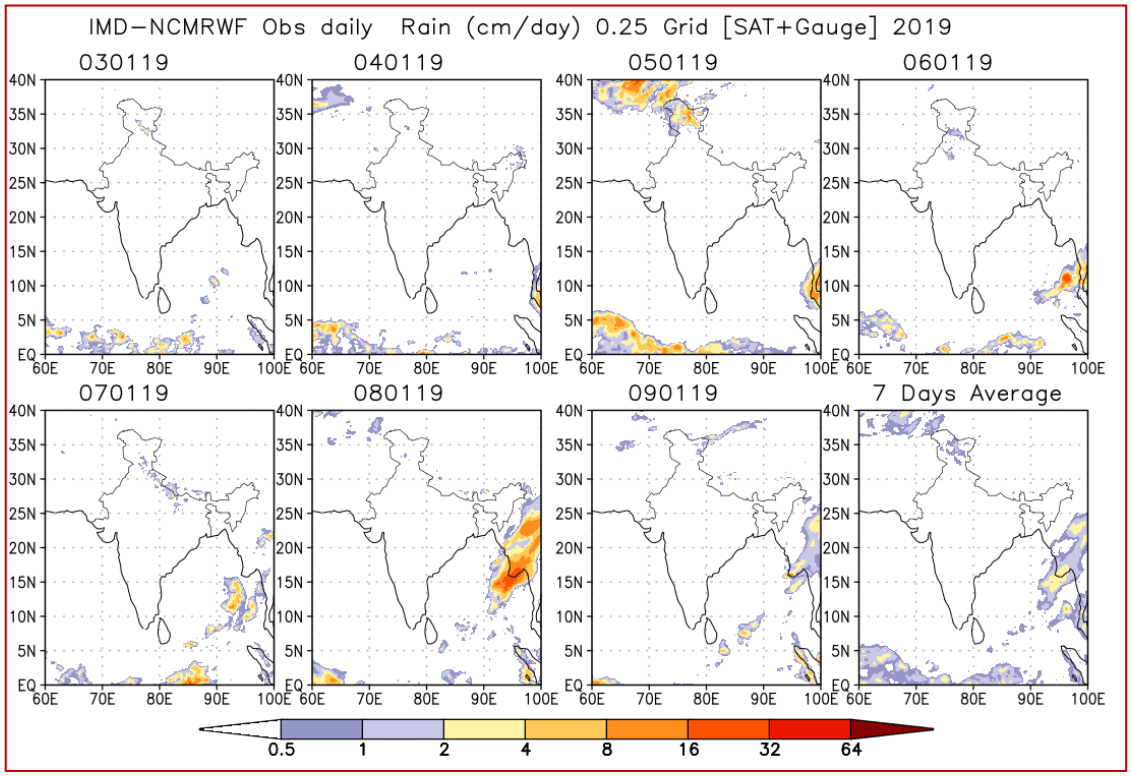


Fig.6: IMD-NCMRWF merged satellite and rain gauge observed rainfall (cm/day) during 05-08 January in association with CS Pabuk

Realized 24 hrs accumulated rainfall (≥7cm) ending at 0300 UTC of date during the life cycle of the system is presented below:
7th January: Hut Bay-10 and Maya Bandar & Port Blair-7 each.

4.2. Realised Wind:

Port Blair reported maximum wind speed of 55-65 kmph gusting to 75 kmph between 1300 and 1500 UTC of 6th January 2019.

4.3. Realised Storm Surge:

No significant Storm Surge was reported from Andaman Islands.

5. Bulletins issued by IMD

5.1. Bulletins issued by Cyclone Warning Division, New Delhi

- **Track, intensity and landfall forecast:** IMD continuously monitored, predicted and issued bulletins containing track, intensity and landfall forecast for +06, +12, +18, +24, +36 and +48… +120 hrs lead period till the system weakened into a low pressure area. The above forecasts were issued from the stage of its emergence into Andaman Sea onwards along with the cone of uncertainty in the track forecast every three hourly during the cyclone period and five times a day during deep depression/depression stage.
- **Cyclone structure forecast for shipping and coastal hazard management:** The radius of maximum wind and radii of MSW ≥28 knots and ≥34 knots wind in four quadrants of cyclone was issued every six hourly giving forecast for +06, +12, +18, +24, +36 ….. +120 hrs lead period.
- **Four stage Warning:** The pre-cyclone watch for Andaman Islands was issued on 3rd January itself, when the system was over south China Sea in the first bulletin issued by IMD at 1230 hrs IST (0700 UTC) of 3rd January. It was upgraded to cyclone alert in the bulletin issued at 2000 hrs IST (1430 UTC) of 4th January when the system was over Thailand. It was further upgraded to cyclone warning in the bulletin issued at 1230 hrs IST(0700 UTC) of 5th Dec (about 12 hours prior to landfall).
- **Adverse weather warning bulletins:** The tropical cyclone forecasts alongwith expected adverse weather like heavy rain, gale wind and storm surge was issued with every three hourly update during cyclone period to the central, state and district level disaster management agencies including MHA NDRF, NDMA for all concerned states along the east coast of India including Tamil Nadu, Andhra Pradesh, Puducherry, Odisha, West Bengal and Andaman & Nicobar Islands. The bulletin also contained the suggested action for disaster managers and general public in particular for fishermen. These bulletins were also issued to Defense including Indian Navy & Indian Air Force.
- **Warning graphics:** The graphical display of the observed and forecast track with cone of uncertainty and the wind forecast for different quadrants were disseminated by email and uploaded in the RSMC, New Delhi website (http://rsmcnewdelhi.imd.gov.in/) regularly. The adverse weather warnings related to heavy rain, gale/squally wind & storm surge were also presented in graphics alongwith colour codes in the website.
- **Warning and advisory through social media:** Daily updates were uploaded on Face book and Twitter regularly during the life period of the system.
- **Press release and press briefing:** Press and electronic media were given daily updates since inception of system through press release, e-mail, website and SMS.
- **Warning and advisory for marine community:** The three/six hourly Global Maritime Distress Safety System (GMDSS) bulletins were issued by the Marine Weather Services division at New Delhi and bulletins for maritime interest were

issued by Area cyclone warning centres of IMD at Chennai, Kolkata and Cyclone warning centres at Bhubaneswar and Visakhapatnam to ports, fishermen, coastal and high sea shipping community.

- **Fishermen Warning:** First warning for fishermen of the states of West Bengal, Odisha, Andhra Pradesh, Tamil Nadu and Andaman & Nicobar Islands was issued at 1230 hrs IST (0700 UTC) of 3rd January for the Andaman Seas and southeast & eastcentral BoB.
- **Advisory for international Civil Aviation:** The Tropical Cyclone Advisory Centre (TCAC) bulletin for International Civil Aviation were issued every six hourly to all meteorological watch offices in Asia Pacific region for issue of significant meteorological information (SIGMET). It was also sent to Aviation Disaster Risk Reduction (ADRR) centre of WMO at Hong Kong.
- **Diagnostic and prognostic features of cyclone:** The prognostics and diagnostics of the systems were described in the RSMC bulletins and tropical cyclone advisory bulletins.
- Statistics of bulletins issued by RSMC New Delhi and Area Cyclone Warning Centres & Cyclone Warning Centres of IMD in association with the CS Pabuk are given in **Table 2 (a) and Table 2 (b)** respectively.

Table-2a: Bulletins issued by Cyclone Warning Division, New Delhi

S.N	Bulletin	No. of Bulletins	Issued to
1	National Bulletin	27	1. IMD's website, RSMC New Delhi website 2. FAX and e-mail to Control Room Ministry of Home Affairs & National Disaster Management Authority, Cabinet Secretariat, Minister of Science & Technology, Headquarter Integrated Defense Staff, Director General Doordarshan, All India Radio, National Disaster Response Force, Chief Secretary- Tamil Nadu, Andhra Pradesh, Puducherry, Odisha, West Bengal, and Andaman & Nicobar Islands.
2	Bulletin from DGM	6	FAX and email to Cabinet Secretary, Principal Secretary to Prime Minister, Secretary, Ministry of Home Affairs, Defense, Agriculture, Information & Broadcasting, Department of Sc. & Technology, NDMA, and Shipping & Surface Transport, Control Room Home Affairs, Director Indian Railways, Director General Doordarshan & All India Radio, Director General National Disaster Response Force and Chief Secretary- Tamil Nadu, Andhra Pradesh, Puducherry, Odisha, West Bengal, and Andaman & Nicobar Islands.
3	RSMC Bulletin	27	1. IMD's website 2. WMO/ESCAP member countries and WMO through GTS and E-mail.
4	GMDSS Bulletins		1. IMD website, RSMC New Delhi website 2. Transmitted through WMO Information System (WIS) to Joint WMO/IOC Technical Commission for Ocean and Marine Meteorology (JCOMM)
5	Tropical Cyclone	08	1. Met Watch offices in Asia Pacific regions and middle east through GTS to issue Significant Meteorological

	Advisory Centre Bulletin (Text & Graphics)		information for International Civil Aviation 2. WMO's Aviation Disaster Risk Reduction (ADRR), Hong Kong through ftp 3. RSMC website
6	Warnings through SMS	Daily	SMS to disaster managers at national level and concerned states (every time when there was change in intensity) (1067 messages) To general public and users registered with RSMC website from the states of Odisha, Andhra Pradesh, West Bengal, Tamil Nadu, Andaman & Nicobar Islands and National level disaster managers. To fishermen through INCOIS on Ocean State Forecast-10,320.
7	Warnings through Social Media	Daily (4 times)	Cyclone Warnings were uploaded on Social networking sites (Facebook and Twitter) since inception to weakening of system (every time when there was change in intensity).
8	Message through Whatsapp	Daily	Everyday based on observation of 00, 03, 06, 12, 18 UTC observations to central level disaster managers
9	Press Release	6	Disaster Managers, Media persons by email and uploaded on website
0	Press Briefings	Daily	Regular briefing daily

Table-2b: Bulletins issued by Area Cyclone Warning Centre (ACWC) Kolkata and Cyclone Warning Centre (CWC) Bhubaneswar and Meteorological Office (MO) Port Blair

S.No.	Type of Bulletin	No of Bulletins issued by	
		ACWC Kolkata	MO Port Blair
1.	Sea Area Bulletins	19	NIL
2.	Coastal Weather Bulletins	WB Coast- 12 A & N Coasts-12	NIL
3.	Fishermen Warnings issued	WB Coast -Nil A & N Coasts-28 (Issued from 01.01.19 for not to venture into the sea from 05.01.19 to 07.01.19)	NIL
4.	Port Warnings	WB - 06 A & N Ids -11	NIL
5.	Heavy Rainfall Warning	GWB- 0 SHWB & Sikkim- 0 A N Ids- 03	NIL
6.	Gale Wind warning	WB- NIL A & N Ids-02	NIL

7.	Storm Surge Warning	WB- NIL A & N Ids-NIL	NIL
8.	Information & Warning issued to State Government and other Agencies	WB- 03 A & N- 11	21
9	SMS/ (Whatsapp message in group)	930 (Appx)	
10	Press Release		

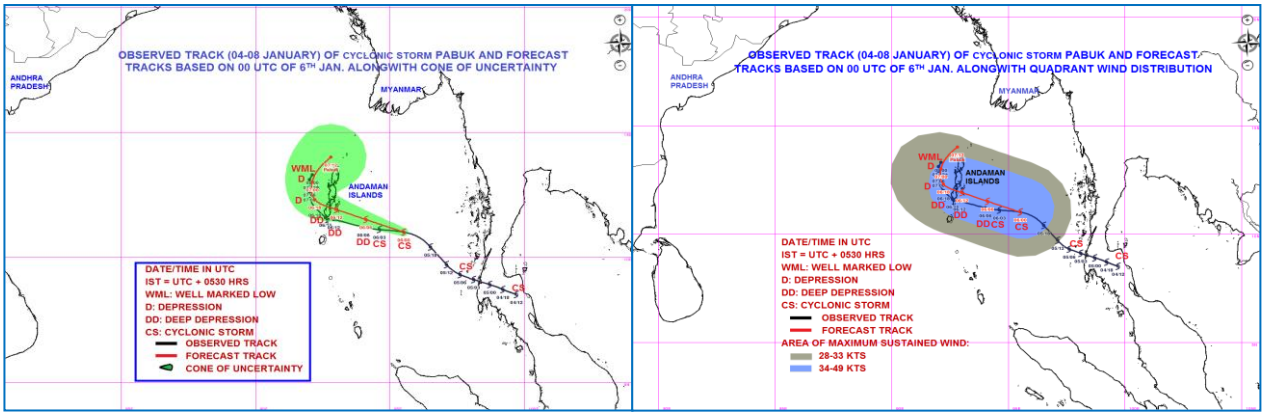


Fig.7: (a)Typical forecast and observed tracks of CS, Pabuk demonstrating accuracy in track and landfall point forecast and (b) typical wind forecast graphics.

9. Damage due to CS Pabuk

(a) Thailand:

Pabuk killed 8 people in Thailand. It also caused an estimated damage of US$156 million in Thailand (Source: https://en.wikipedia.org/wiki/Tropical_Storm_Pabuk_(2019). Some damage photographs from Thailand are presented in Fig. 8.

Fig. 8 (a) Fallen electricity lines in southern Thai Province (Source: The Associated Press) and (b) Rains lashed southern Thailand (Source: BBC.com)

(b) Andaman Islands:

No death as well as damage was reported from Andaman Islands.

10. Performance of operational NWP models

IMD operationally runs a regional model, WRF-Var for short-range prediction and one Global model T1534 for medium range prediction (7 days). The WRF-Var model is run at the horizontal resolution of 27 km, 9 km and 3 km with 38 Eta levels in the vertical and the integration is carried up to 72 hours over three domains covering the area between lat. 25^o S to 45^o N long 40^o E to 120^o E. Initial and boundary conditions are obtained from the IMD Global Forecast System (IMD-GFS) at the resolution of 12 km. The boundary conditions are updated at every six hours interval.

Global models are also run at NCMRWF. These include unified model adapted from UK Meteorological Office. Apart from the observations that are used in the earlier system, the new observations assimilated at NCMRWF include (i) Precipitation rates from SSM/I and TRMM (ii) GPSRO occultation (iii) AIRS and AMSRE radiances (iv) MODIS winds. Additionally, ASCAT ocean surface winds and INSAT-3D AMVs are also assimilated. NCUM (N768/L70) model features a horizontal resolution of 17km and 70 vertical levels. It uses 4D-Var assimilation and features no cyclone initialization/relocation. NCUM is a grid point model which has a Non-hydrostatic dynamics with a deep atmosphere suitable for all scales. It has semi-implicit time integration with 3D semi-Lagrangian advection, terrain following height coordinates and high order advection. It features mass-flux for shallow convection with convective momentum transport, non-local mixing and entrainment for boundary layer. NCMRWF Ensemble Prediction System (NEPS) is a global medium range probabilistic forecasting system adapted from UK MET Office. The configuration consists of four cycles of assimilation corresponding to 00Z, 06Z, 12Z 18Z and 10-day forecasts are made using the 00Z initial condition. The N400L70 forecast model consists of 800x600 grid points on the horizontal surface and has 70 vertical levels. Horizontal resolution of the model is approximately 33 km in the mid-latitudes. The 10 day control forecast run starts with N768L70 analysis of the deterministic assimilation forecast system and 44 ensemble members start from different perturbed initial conditions consistent with the uncertainty in initial conditions. The initial perturbations are generated using Ensemble Transform Kalman Filter (ETKF) method. An important component common to both the deterministic and ensemble model is that they do not use any TC relocation in the analysis.

IMD also makes use of NWP products prepared by some other operational NWP centres like, ECMWF (European Centre for Medium Range Weather Forecasting), GFS (NCEP), JMA (Japan Meteorological Agency). Hurricane WRF (HWRF) model and Ensemble prediction system (EPS) has been implemented at the NWP Division of the IMD HQ for operational forecasting of cyclones.

In addition to the above NWP models, IMD also run operationally dynamical statistical models. The dynamical statistical models have been developed for (a) Cyclone Genesis Potential Parameter (GPP), (b) Multi-Model Ensemble (MME) technique for cyclone track prediction, (c) Cyclone intensity prediction, (d) Rapid

intensification and Predicting decay in intensity after the landfall. Genesis potential parameter (GPP) is used for predicting potential of cyclogenesis (T3.0) and forecast for potential cyclogenesis zone. The multi-model ensemble (MME) for predicting the track (at 12h interval up to 120h) of tropical cyclones for the Indian Seas is developed applying multiple linear regression technique using the member models IMD-GFS, IMD-WRF, GFS (NCEP), ECMWF and JMA. The SCIP model is used for 12 hourly intensity predictions up to 120-h and a rapid intensification index (RII) is developed and implemented for the probability forecast of rapid intensification (RI). Decay model is used for prediction of intensity after landfall. In this report performance of the individual models, MME forecasts, SCIP, GPP, RII and Decay model for CS Pabuk are presented and discussed in following sections:

10.1 Prediction of cyclogenesis (Genesis Potential Parameter (GPP)) for Pabuk

Figure 9 shows the Grid point analysis and forecasts of GPP based on 0000 UTC of 4th. Figure 10 shows the predicted zone of cyclogenesis on 5th January based on initial conditions of 0000 UTC of 1st-5th January.

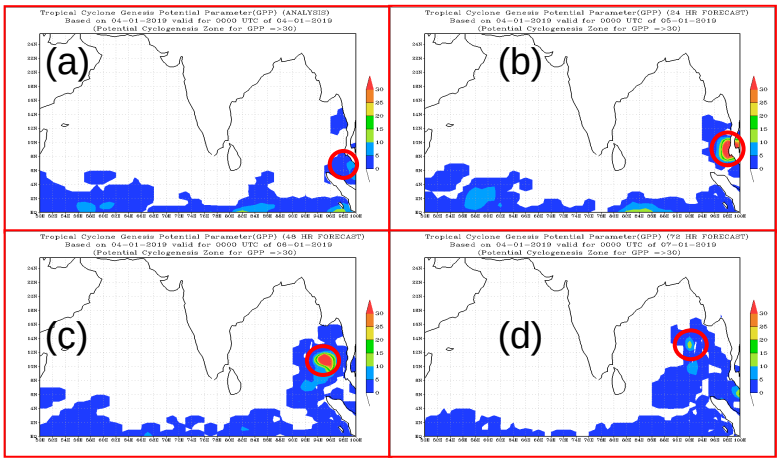


Fig.9: Predicted zone of cyclogenesis based on 0000 UTC of 4th January for next 72 hours.

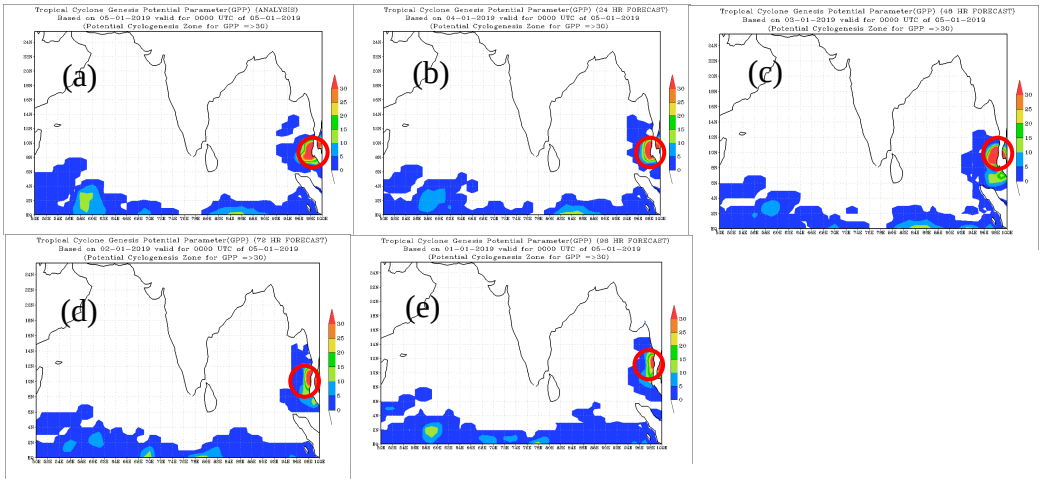


Fig.10: Predicted zone of cyclogenesis based for 5th January based on 0000 UTC of 1st-5th January.

The forecast field of GPP based on 0000 UTC of 4th (Fig.9) predicted potential zone of cyclogenesis zone over southern Thailand and neighbourhood on 5th, over Andaman Sea on 6th and a potential zone with GPP around 20 over eastcentral BoB on 7th. Thus, on 4th itself when the system was over Thailand, GPP forecast fields predicted it's emergence into Andaman Sea on 5th and it's gradual movement & weakening over eastcentral BoB on 7th correctly. The forecasts based on 0000 UTC of 1st-5th for 0000 UTC of 5th January, consistently predicted potential zone of cyclogenesis over Andaman Sea and adjoining Thailand on 5th (96 hours prior to actual emergence into Andaman Sea) (Fig.10).

10.2 Track prediction by NWP models

Based on initial conditions of 0000 UTC of 4th, models like ECMWF, JMA, UKMO, MME and HWRF predicted near northwest movement and landfall near 11.5°N/92.5°E around 1800 UTC of 6th. All these except HWRF were also predicting northwards movement after landfall. Only WRF-Var was not predicting landfall. Both statistical cyclone intensity prediction (SCIP) model and HWRF overestimated the intensity of the system throughout it's life period. Also both were predicting that the system would cross Andaman Islands as a CS. The track forecast by different models based on 0000 UTC of 4th January is presented in Fig. 11 (a).

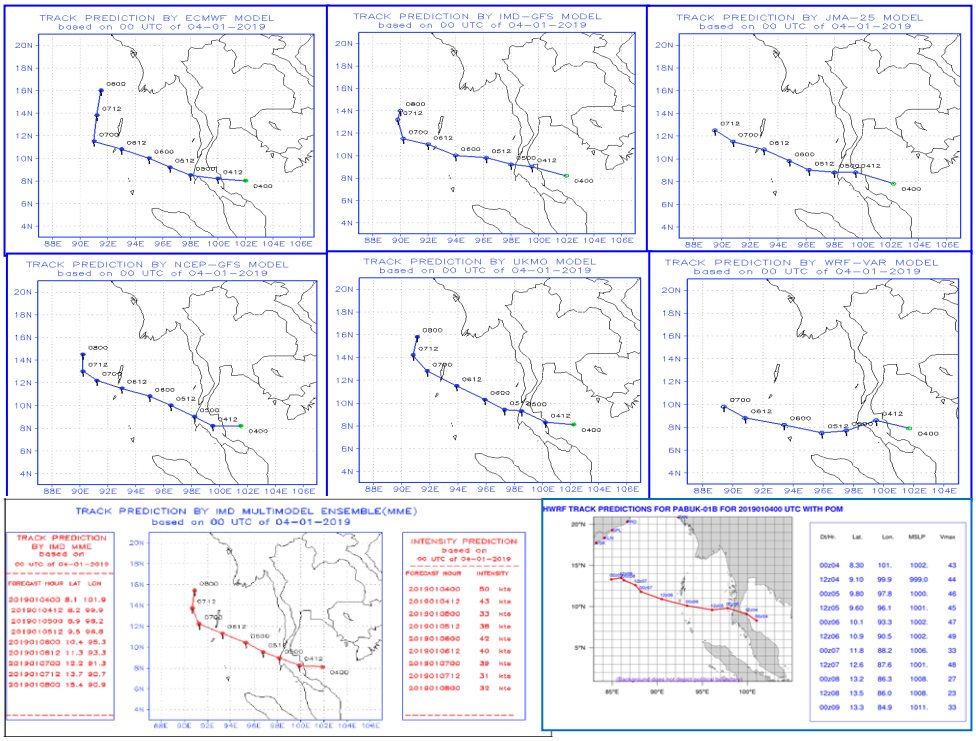


Fig.11 (a): Track prediction by NWP models based on 0000 UTC of 4th January, 2019

Based on initial conditions of 0000 UTC of 5th, models like ECMWF, IMD-GFS, JMA-25, UKMO, MME and HWRF predicted near northwest movement and landfall near 11.5°N/92.5°E around 1200 UTC of 6th. All these except HWRF were also predicting northwards movement after landfall. Only WRF-Var was not predicting landfall. Both SCIP and HWRF models overestimated the intensity of the system throughout it's life period. However, MME predicted that the system would cross Andaman Islands as a marginal CS/DD. HWRF predicted that the system would cross as CS/SCS. The track forecast by different models based on 0000 UTC of 5th January is presented in Fig. 11 (b).

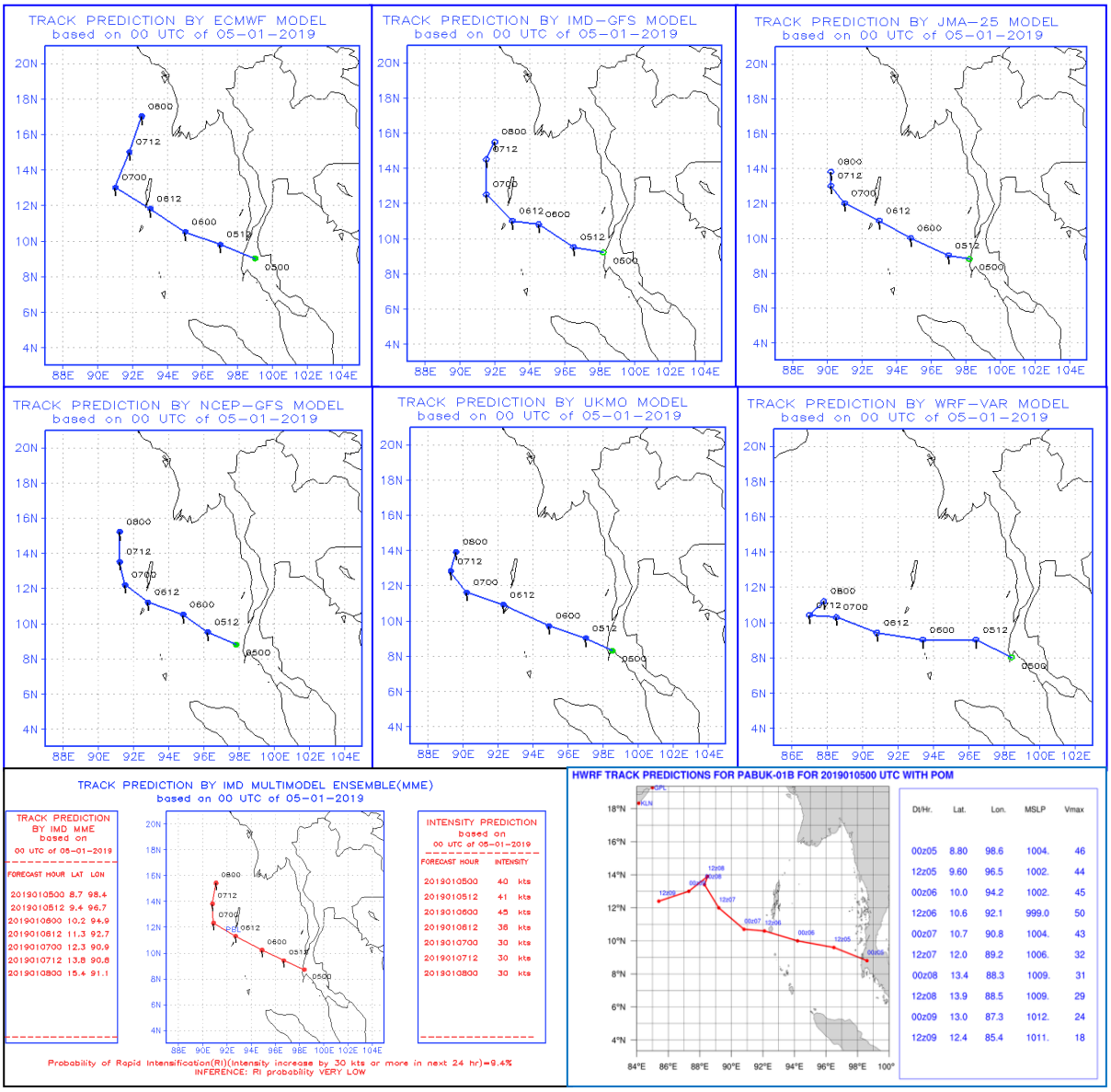


Fig.11 (b): Track prediction by NWP models based on 0000 UTC of 5th January, 2019

Based on initial conditions of 0000 UTC of 6th, models like ECMWF, IMD-GFS, JMA-25, WRF-VAR, UKMO, MME and HWRF were predicting landfall over Andaman Islands, however there was large variation with respect to point of landfall.

These models were predicting landfall near 1200 UTC of 6th. All these except IMD-GFS and WRF-VAR were predicting northwards/northeastwards re-curvature after landfall. Both SCIP and HWRF models indicated that the system would cross as a marginal CS/DD. The track forecast by different models based on 0000 UTC of 6th January is presented in Fig. 11 (c).

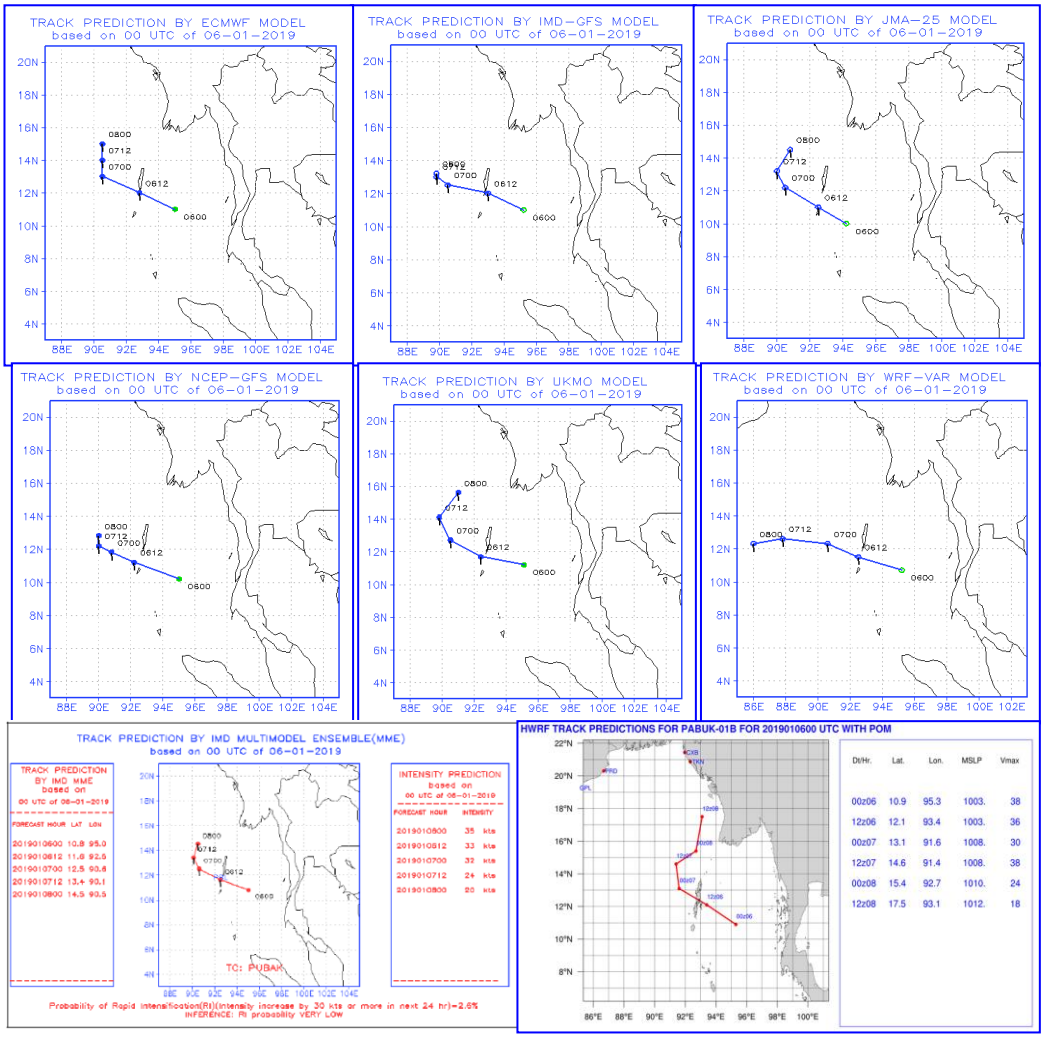


Fig.11 (c): Track prediction by NWP models based on 0000 UTC of 6th January, 2019

Hence to conclude, most of the models like ECMWF, JMA-25, UKMO, MME and HWRF could capture the movement and landfall correctly. However, intensity was overestimated till 6th January by SCIP and HWRF models.

10.3: Track and intensity forecast errors by various Models

The average track forecast errors (Direct Position Error) in km at different lead period (hrs) of various models are presented in Table 3. From the verification of the forecast guidance available from various NWP models, it is found that the average track forecast errors of MME. Considering the individual NWP models, the error was minimum with NCEP-GFS for 24-60 hrs forecasts and UKMO followed by

NCEP_GFS for 72 hrs forecast periods. The average errors of IMD WRF were the maximum.

Table-3: Average track forecast errors (Direct Position Error (DPE)) in km (Number of forecasts verified is given in the parentheses)

Lead time →	12H	24H	36H	48H	60H	72H	84H
IMD-GFS	83(4)	98(4)	113(4)	139(3)	139(2)	231(1)	238(1)
IMD-WRF	93(4)	223(4)	366(4)	449(3)	499(2)	421(1)	-
JMA	89(4)	115(4)	138(4)	166(3)	137(2)	179(1)	279(1)
NCEP-GFS	87(4)	91(4)	113(4)	108(3)	54(2)	98(1)	195(1)
UKMO	76(4)	110(4)	139(4)	171(3)	202(2)	31(1)	178(1)
ECMWF	42 (4)	98 (4)	105 (4)	159 (4)	145 (4)	164 (4)	116 (4)
IMD-HWRF	117(6)	123(5)	126(4)	188(3)	357(2)	511(1)	-
IMD-MME	60(4)	88(4)	91(4)	125(3)	100(2)	88(1)	156(1)

The average errors in intensity forecast (kts) at different lead period (hrs) of IMD-SCIP and IMD HWRF are presented in Table 4. For all lead periods, the intensity forecast errors of IMD SCIP were less than that due to IMD HWRF upto 60 hrs forecast period.

Table-4: Average absolute errors (AAE) and Root Mean Square (RMSE) errors in kts of IMD SCIP and HWRF model

(Number of forecasts verified is given in the parentheses)

Lead time →	12H	24H	36H	48H	60H	72H	84H
IMD-SCIP (AAE)	0.5 (4)	3.8(4)	8.3(4)	7.0(4)	7.3(3)	9.5(2)	6.0(1)
IMD-HWRF (AAE)	7.7 (6)	10.6 (5)	17.0 (4)	14.3 (3)	10.5 (2)	9.0 (1)	
IMD-SCIP (RMSE)	1.0 (4)	4.3 (4)	8.8 (4)	8.4 (4)	7.6 (3)	10.5 (2)	6.0 (1)
IMD-HWRF (RMSE)	9.1 (6)	11.7 (5)	17.5 (4)	14.8 (3)	11.1 (2)	9.0 (1)	

Intensity forecast by IMD SCIP based on various lead periods during 4th-6th is presented in Fig.12. For all lead periods, IMD SCIP over estimated the intensity of the system, except based on 0000 UTC of 4th, which underestimated the intensity of CS Pabuk till 1200 UTC of 5th January.

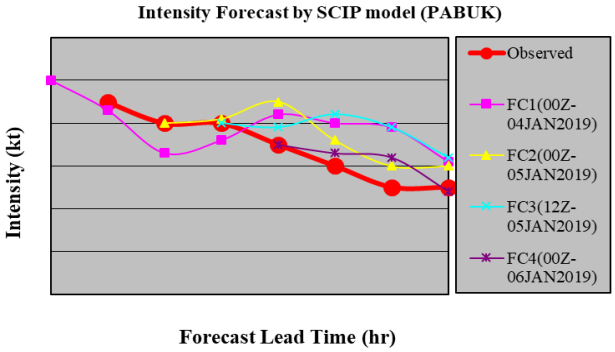


Fig.12: Intensity prediction by SCIP Model

10.4. Heavy rainfall forecast by HWRF model

The forecast rainfall swaths by HWRF model is presented in Fig.13. Rainfall associated with the system decreased near landfall. The system caused more rainfall during initial stages.

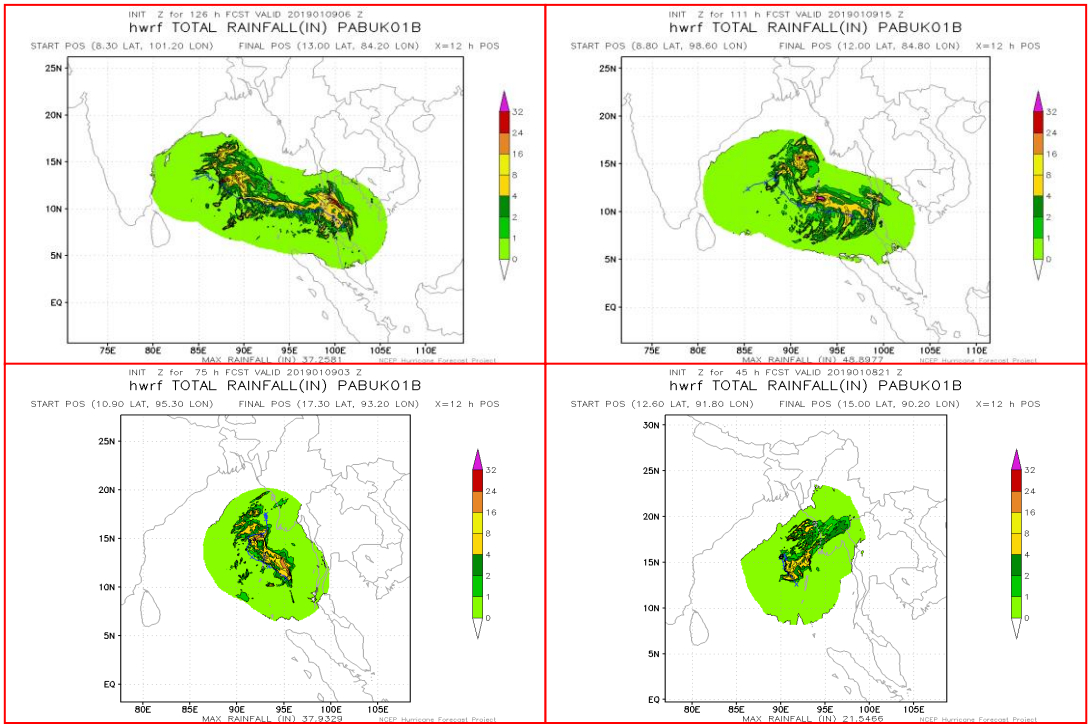


Fig.13: HWRF rain swath (inch) based on 0000 UTC of 4th -7th January, 2019

11. Operational Forecast Performance

11.1. Genesis Forecast:

First information about the probable emergence of a cyclonic disturbance into Andaman Sea around 5th January was given in the Tropical Weather Outlook (TWO) issued at 0700 UTC of 31st December (about 5 days in advance). CS Pabuk emerged into Andaman Sea at 0300 UTC of 5th January.

11.2. Operational landfall forecast error and skill

- In the first bulletin issued on 3rd January (issued at 0700 UTC), it was mentioned that, the system would emerge into Andaman Sea around 5th forenoon and cross Andaman Islands around evening/ night of 06th January (about 56 hours in advance of actual landfall). Thereafter, it would move north-northwestwards and then recurve northeastwards towards Myanmar coast during 7th-8th January, 2019. The system emerged into Andaman Sea at 0300 UTC (0830 hrs IST) of 5th, crossed Andaman Islands around 1400 UTC (1930 hrs IST, late evening/night) of 6th January and moved northwards during 7th-8th

early morning. It lay as a low pressure area over Myanmar and neighbourhood at 0300 UTC of 8th. Typical observed and forecast track is presented in **Fig. 7**.

- The landfall point forecast errors were about 44, 11 and 11 km for 12, 24 & 48 hrs lead period respectively against past five year (2014-18) average errors of 27, 47 and 70 km respectively. The landfall time forecast errors were about 0, 0 and 2 hours for 12, 24 & 48 hrs lead period against past five year (2014-18) average errors of 2, 3 and 5 hours respectively (**Fig.14 and Table 5**).

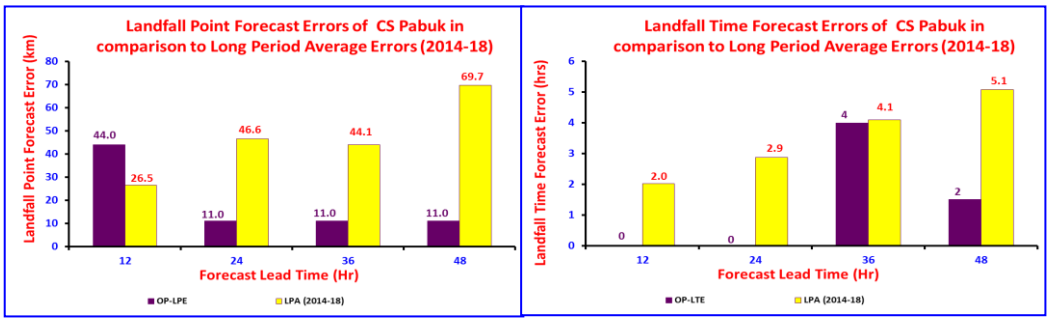


Fig 14: Landfall Point and Time Error in association with CS Pabuk

Table 5: Operational and long period average landfall point (km) and time (hrs) errors in association with CS Pabuk

Lead Period (hrs)	Base Time	Landfall Point (^{0}N/^{0}E)		Landfall Time (hours)		Operational Error		LPA error (2014-18)	
		Forecast	Actual	Forecast	Actual	LPE (km)	LTE (hours)	LPE (km)	LTE (hours)
12	06/00	12.0/92.7	11.6/92.7	06/1400	06/1400	44	0	26.5	2.0
24	05/12	11.7/92.7	11.6/92.7	06/1400	06/1400	11	0	46.6	2.9
36	05/00	11.5/92.7	11.6/92.7	06/1800	06/1400	11	4.0	44.1	4.1
48	04/12	11.5/92.7	11.6/92.7	16/1530	06/1400	11	1.5	69.7	5.1

LPE: Landfall Point Error, LTE: Landfall Time Error, LPA: Long Period Average, LPE=Forecast landfall point-Actual landfall point, LTE=Forecast Landfall Time-Actual landfall time

11.3 Operational track forecast error and skill

- In the first bulletin issued on 3rd January (0700 UTC), it was mentioned that, the system would move west-northwestwards till landfall. Thereafter, it would move north-northwestwards and then recurve northeastwards towards Myanmar coast during 7th-8th January, 2019. Typical forecast tracks and observed track is presented in **Fig.15.**
- The track forecast errors were about 57, 96 and 156 km for 24, 48 and 72 hrs lead period against past five year (2014-18) average errors of 86, 132 and 178 km respectively. The track forecast skills were about 74, 76 and 44 % for 24, 48 and 72 hrs lead period against past five year (2014-18) average skills of 58, 70 and 74% respectively. The track forecast errors were less than long period average for all lead periods. (**Fig.16 and Table 6**).

Table 6: Operational & long period average track forecast errors(km) & Skill(%)

Lead Period (hrs)	No. of obs. verified	Operational Track Forecast		Long Period Average (2014-18) Track Forecast	
		Error (km)	Skill (%)*	Error (km)	Skill (%)*
12	10	52.7	52.2	54.7	54.8
24	8	57.4	74.1	86.1	58.2
36	6	54.9	82.7	102.7	67.9
48	6	95.8	76.1	132.3	70.3
60	4	129.7	59.9	156.8	72.6
72	2	157.5	44.0	177.7	74.1

* Skill is calculated by comparing the operational track forecast error with the forecast error based on climatology and persistence (CLIPER) model.

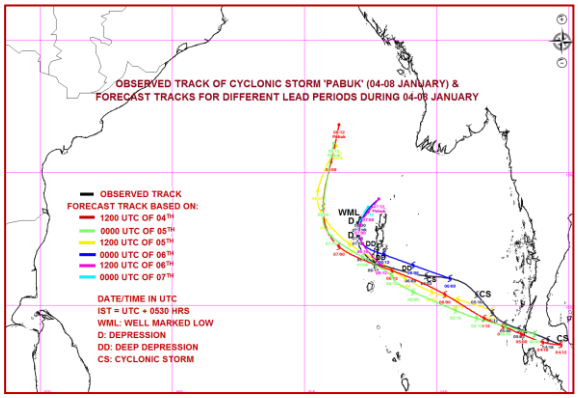


Fig.15: Forecasts tracks based on 0000 and 1200 UTC during 4th-7th January and observed track of CS Pabuk during 4th-8th January

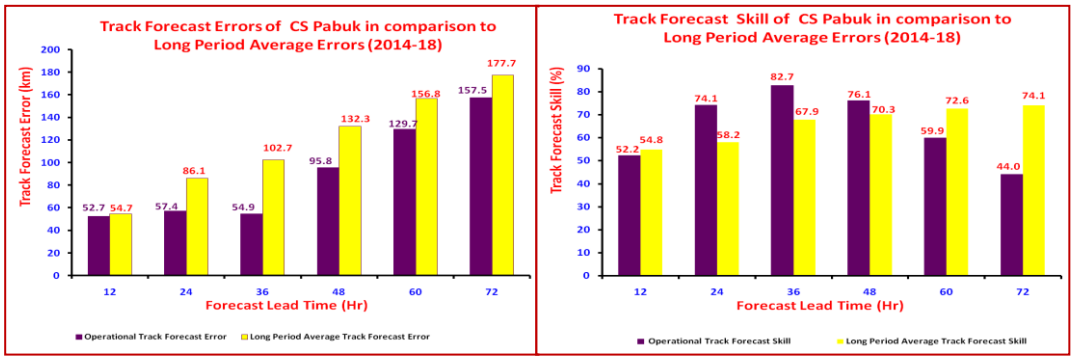


Fig.16: Track Forecast Errors and Skill for CS Pabuk

11.4 Operational Intensity forecast error and skill

- In the first bulletin issued by IMD at 0700 UTC (1230 hrs IST) of 3rd January, when the system was over south China Sea, it was indicated that the system would weaken during 7th-8th January.
- In the third bulletin issued by IMD at 1430 UTC (2000 hrs IST) of 4th January, it was predicted that the system would cross Andaman Islands around evening/night of 06th January as a cyclonic storm with a wind speed of 70-80 kmph gusting to 90 kmph.

- The warning was further updated in the bulletin issued at 0600 UTC (1130 hrs IST) of 6th that the system would cross Andaman Islands as a deep depression with a wind speed of 55-65 kmph gusting to 75 kmph.
- The system crossed Andaman Islands as a deep depression with a wind speed of 55-65 kmph gusting to 75 kmph.
- The absolute errors (AE) of intensity (wind) forecast for 24, 48 and 72 hrs lead period were 6.6, 9.8 and 15.3 knots against the LPA of 9.6, 14.1 and 14.3 knots respectively. The skill in intensity forecast based on AE for 24, 48 and 72 hrs lead period was 41.4, 35.0 and 31.8% respectively (**Fig.17 and Table 7**).
- The root mean square error (RMSE) of intensity (wind) forecast for 24, 48 and 72 hrs lead period were 7.4, 10.2 and 15.5 knots against the LPA of 12.5, 19.0 and 18.9 knots respectively. The skill in intensity (wind) forecast based on RMSE for 24, 48 and 72 hrs lead period was 36.6, 31.9 and 31.6% respectively (**Fig.18 and Table 7**). For all lead periods, the errors in intensity forecast were less than long period average.

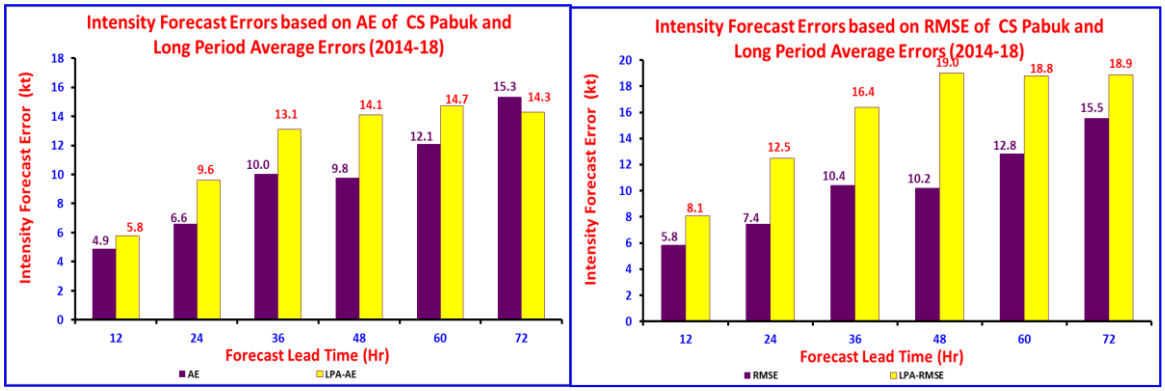


Fig 17: Average Intensity forecast error in association with CS Pabuk

Table 7: Mean Intensity forecast errors(kt) and Skill (%) in association with CS Pabuk

Lead Period (hrs)	N	Average error in Intensity forecast (kts)		LPA (2014-18) Intensity forecast error (kts)		Operational Skill* (%) in intensity forecast		LPA (2014-18) Skill* (%) in intensity forecast	
		AE	RMSE	AE	RMSE	AE	RMSE	AE	RMSE
12	10	4.9	5.8	5.8	8.1	18.5	7.6	28.5	35.7
24	8	6.6	7.4	9.6	12.5	41.4	36.6	42.6	49.2
36	6	10.0	10.4	13.1	16.4	24.8	23.0	65.1	53.3
48	6	9.8	10.2	14.1	19.0	35.0	31.9	68.1	59.4
60	4	12.1	12.8	14.7	18.8	39.7	35.8	69.8	66.3
72	2	15.3	15.5	14.3	18.9	31.8	31.4	72.3	69.2

N: No. of observations verified; AE: Absolute Error; RMSE: Root Mean Square Error, LPA: Long Period Average (2014-18).
* Skill of forecast is calculated by comparing the operational forecast error with the forecast error based on persistence method

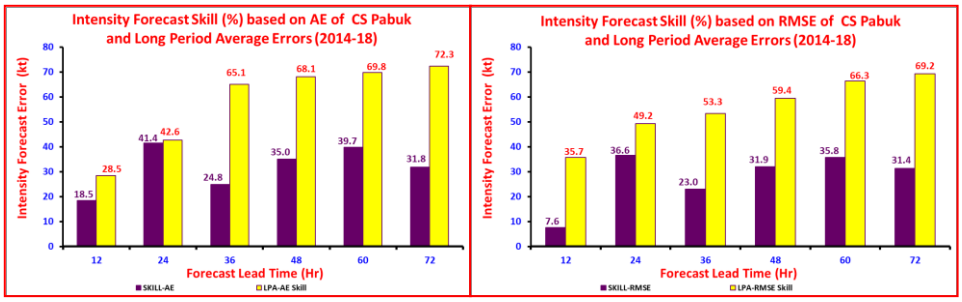


Fig 18: Average Intensity forecast skill in association with CS Pabuk

11.5. Adverse weather forecast verification

The verification of adverse weather like heavy rainfall, gale wind and storm surge forecast issued by IMD are presented in Table 8-10. It is found that all the three types of adverse weather were predicted accurately and well in advance.

Table 8: Verification of Heavy Rainfall Forecast

Date/Base Time of observation (0300 UTC)	24 hr Heavy rainfall warning ending at 0300 UTC of next day	Realised 24-hour heavy rainfall ending at 0300 UTC of date
03/01/2019	Heavy falls at isolated places likely to commence over Andaman Islands from 5th January evening. Intensity is very likely to increase and heavy to very heavy rainfall at a few places on 6th and at isolated places on 7th over Andaman Islands	**7th January** Hut Bay-10 and Maya Bandar& Port Blair-7 each.
04/01/2019	-do-	
05/01/2019	-do-	
06/01/2019	Heavy to very heavy rainfall at a few places on today, the 6th January, 2019 and at heavy rainfall isolated places on 7th over Andaman Islands.	
07/01/2019 0300 UTC	Heavy rainfall at isolated places over Andaman Islands during next 24 hours.	

Table 9: Verification of Gale/Squally Wind Forecast issued by IMD

Date/ Time of observation (0300 UTC)	Gale/ Squally wind Forecast for north Andhra Pradesh, Odisha and West Bengal	Realised wind speed
03/01/2019	Squally wind speed reaching 40-50 kmph gusting to 60 kmph is likely to commence over Andaman Sea along and off south Myanmar and Thailand coast from 4th January evening. It is very likely to increase gradually becoming 55-65 kmph gusting to 75 over Andaman Sea on 5th and over Andaman Islands, Andaman Sea and adjoining areas of eastcentral and southeast Bay of Bengal on 6th and 7th.	The system crossed Andaman Islands as a deep depression with a wind speed of 55-65
04/01/2019	-do-	
05/01/2019 0300 UTC	● Gale wind speed reaching 70-80 kmph gusting to 90 kmph is likely to prevail over Andaman Sea and along & off south Myanmar &	

	Thailand coasts till today, the 5th evening. ● Gale wind speed reaching 70-80 kmph gusting to 90 kmph is likely to prevail over Andaman Islands, Andaman Sea and adjoining areas of eastcentral and southeast Bay of Bengal from the 5th evening to 7th morning. It is very likely to gradually decrease thereafter becoming 50-60 kmph gusting to 70 kmph over southeast Bay of Bengal, Andaman Islands and adjoining Andaman Sea & eastcentral Bay of Bengal by 8th morning and 40-50 kmph gusting to 60 kmph over eastcentral and adjoining southeast Bay of Bengal by 8th evening. ● Squally wind speed reaching 40-50 kmph gusting to 60 kmph is likely over Nicobar Islands till 6th.	kmph gusting to 75 kmph.
06/01/2019 0300 UTC	● Gale wind speed reaching 60-70 kmph gusting to 80 kmph is likely to prevail over Andaman Sea during next three hours. ● It is very likely to gradually decrease thereafter becoming 55-65 kmph gusting to 75 kmph over southeast Bay of Bengal, Andaman Islands and adjoining Andaman Sea & eastcentral Bay of Bengal till today, the 6th January 2019 night and 40-50 kmph gusting to 60 kmph over eastcentral and adjoining southeast Bay of Bengal by 7th morning. ● Squally wind speed reaching 40-50 kmph gusting to 60 kmph is likely to prevail over Nicobar Islands till today, the 6th January 2019 night.	
07/01/2019 0300 UTC	● Squally wind speed reaching 45-55 kmph gusting to 65 kmph is very likely to prevail over southeast Bay of Bengal, Andaman Islands and adjoining Andaman Sea & eastcentral Bay of Bengal during next 06 hours and 40-50 kmph gusting to 60 kmph over eastcentral Bay of Bengal and adjoining Andaman Sea during subsequent 06 hours.	

Table 10: Verification of Storm Surge Forecast issued by IMD

Date/ Time(UTC)	Storm Surge Forecast	Recorded storm surge
05/01/2019 0300 UTC	Storm surge of height of about 0.5 m above the astronomical tides likely to inundate the low lying areas of Andaman Islands at the time of landfall.	No significant surge was reported from Andaman Islands.

12. Summary and Conclusion:

Cyclonic Storm (CS) Pabuk emerged into the north Indian Ocean region over Andaman Sea in the morning (0300 UTC) of 5th January, 2019. Moving west-northwestwards, it gradually weakened into a deep depression around noon (0600 UTC) and crossed Andaman Islands near 11.6°N/92.7°E, close to south of Port Blair during night (between 1300 and 1500 UTC) of 6th January 2019 with maximum sustained wind speed of 55-65 kmph gusting to 75 kmph. It weakened into a depression in the early morning (0000 UTC) of 7th and into a well marked low pressure area in the early morning (0000 UTC) of 8th January over eastcentral BoB and adjoining areas.

The system was monitored & predicted continuously by IMD prior to it's emergence into Andaman Sea on 5th January till it's weakening on 8th January. The landfall point forecast errors were about 44, 11 and 11 km for 12, 24 & 48 hrs lead period respectively against past five year (2014-18) average errors of 27, 47 and 70

km respectively. The landfall time forecast errors were about 0, 0 and 2 hours for 12, 24 & 48 hrs lead period against past five year (2014-18) average errors of 2, 3 and 5 hours respectively. The track forecast errors were about 57, 96 and 156 km for 24, 48 and 72 hrs lead period against past five year (2014-18) average errors of 86, 132 and 178 km respectively. The track forecast skills were about 74, 76 and 44 % for 24, 48 and 72 hrs lead period against past five year (2014-18) average skills of 58, 70 and 74% respectively. The absolute errors (AE) of intensity (wind) forecast for 24, 48 and 72 hrs lead period were 6.6, 9.8 and 15.3 knots against the LPA of 9.6, 14.1 and 14.3 knots respectively.

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