

# Synoptic and Dynamical Characteristics of Severe Cyclonic Storm ASANI May 2022

## ABSTRACT:

The synoptic and dynamical conditions for genesis and intensification of tropical cyclone Asani clearly highlighted in the present paper. The observational favourable conditions for the genesis of Asani are high SST, 200hpa STWJ and weak vertical shear of horizontal wind, enhanced the convection and intensified the system. The SCS Asani entered a region with lower SST and lower ocean heat content led to weakening into a deep depression in the Bay of Bengal before touching the coast. Asani remained within 50 km from the coastline whole day due to anticyclone over Indian landmass, Thus, the system moved slowly and stayed nearly stationary. The slow movement lead to upwelling of sea water and rainfall over the Sea leading to further cooling of the sea surface, there was also land interaction, thereby increased friction for longer period. There was cold and dry air incursion from Indian land region in the middle and upper troposphere leading to weakening.

**Keywords** – SST, warm dry winds, Ridge, Ocean Heat Content, Surface latent heat flux.

## 1. INTRODUCTION

Tropical cyclones are the most notorious weather occurrence in the world; belong to the type of extremely precarious weather events. Their landfalls can result in human casualties building damage, and economic losses across the world (Simpson et al., 2002, Pielke and Pielke, 1997). They are large-scale rotating storms that arise over warm tropical ocean waters (Montgomery and Ferrel, 1993). Cyclones that appear in the Bay of Bengal (BoB) and the Arabian Sea and recurved in the premonsoon and postmonsoon seasons mostly impact India. These cyclones essentially migrate from west to North West (Chinchole and Mohapatra, 2017). These cyclones have a typical life cycle of 4-6 days. The average frequency of these cyclones over BoB and the Arabian Sea are 4 and 1, respectively (Mohapatra et al., 2014b). An early prediction regarding the genesis, development, and tracking of these systems can save many lives.

According to the earlier studies, tropical cyclones mainly develop over the warm ocean with Sea Surface Temperatures (SST) above 26 °C (Palmen, 1948), decreased vertical shear of horizontal wind (Gray, 1968), increased low-level moisture content and enhanced latent and sensible heat fluxes from the sea surface to the marine boundary layer. Many scientists have also argued that genesis and development of tropical cyclones depend on nearly classic baroclinicity (Bosart and Bartlo, 1991), the interaction of easterly waves or other low-level disturbances with tropical upper tropospheric disturbances (Ramage, 1959; Sadler, 1976; Montgomery and Ferrel, 1993), Rossby wave energy dispersion of a preexisting typhoon (Li and Fu, 2006), the pre-existing mid-tropospheric vortex that forms in radiative-convective equilibrium (Wang et al., 2019), easterly wave and Madden-Julian Oscillation (Sanap et al., 2020). This shows, the genesis and development process of tropical cyclone is very complex and depends on many factors.

Recently Severe Cyclonic Storm Asani which originated in the BoB caused serious destruction in the coastal districts of Andhra Pradesh state and Tamilnadu state. According to India Meteorological Department (IMD) it was marginal cyclone to occur in the BoB. The landfall of this cyclone occurred over Andhra Pradesh as Deep depression, causing major damage to agriculture. This is the rarest cyclone formed in the month of May, its track and movement changes from time to time and weaken within one day. In this study, the synoptic and dynamical characteristics that helped to the formation, intensification and weakening in the sea of SCS Asani are investigated. In particular, the impact of synoptic-scale factors such as upper-level dynamic factors like 850, 700, 500 and 200hpa Wind analysis, sub-tropical Westerly Jet (STWJ), Thermo dynamical factors such as K index, Precipitable water, surface energy fluxes, CAPE, Total column liquid water content, SST, wind shear, divergence are analysed.

## 2. STUDY AREA AND DATA

The study area under consideration is basically India and North Indian Ocean (NIO) region spanning between (0° N -30°N and 50°E TO 110°E) with particular focus on BoB region (0°N-30°N and 80°E - 110°E). IITM, GFS, Wyoming university data, Hourly 0.250X 0.250 resolution European center for Medium range Forecasts (ECMWF) ERA5 reanalysis data (Hersbach and Dee, 2016), for different parameters including wind speed direction, temperature, vertical velocity, divergence, specific

humidity, geopotential at different pressure levels, Mean sea level pressure (MSLP), Sea surface temperature (SST), surface latent heat flux, surface sensible heat flux, CAPE, column liquid water content, 850 hpa relative vorticity, 24 hours rainfall, 10m wind and 1000hpa specific humidity, surface observational data of coastal observatories, Radar data, Satellite data are utilized in this study for SCS Asani (May 7-12, 2022). Observed track data of SCS Asani have been collected from RSMC New Delhi.

### 3. DESCRIPTION OF LIFE PERIOD

A low-pressure area formed over South Andaman Sea and adjoining Southeast Bay of Bengal 0830 hrs IST of 6th May, 2022. It lay as a well-marked low pressure area over Southeast Bay of Bengal and adjoining south Andaman Sea in the early morning 0530 hours IST of 7th May. Under favourable environmental conditions, it intensified into a depression over the same region around noon 1130 hrs IST of same day, It moved north-west wards and intensified into a deep depression over same area in the evening 1730 hrs IST of 7th May. Continuing to move north-westwards, it intensified into the cyclonic storm "ASANI" in the early morning 0530 hrs IST of 8th May and into a severe cyclonic storm in the same evening (1730 hrs IST over southeast Bay of Bengal. Continuing to move north-westwards, it reached peak intensity of 55 knots (100-110 kmph gusting to 120 kmph) on 9th early morning 0530 hrs IST. It maintained its peak intensity till 10th noon around 1130 hrs IST, thus for 30 hrs. From 10th evening, it started gradually moving north-northwestwards and weakened into a cyclonic storm over westcentral Bay of Bengal about 60 km south-southeast of Machilipatnam in the early hours (0230 hrs IST) of 11th May. Thereafter, it started moving nearly northwards with a very slow speed and weakened into a deep depression over westcentral Bay of Bengal close to Andhra Pradesh coast in the evening 1730 hrs IST of 11th May. It crossed Andhra Pradesh coast near Machilipatnam during 1730-1930 hours IST of 11th May, 2022 as a deep depression with maximum sustained wind speed of 55-65 kmph gusting to 75 kmph. (IMD bulletins). It then moved slowly west-southwestwards and weakened into a depression in the early morning 0530 hrs IST and further into a well- marked low- pressure area in the morning 0830 hrs IST of 12th May over coastal Andhra Pradesh.

### 4. BRIEF DESCRIPTION OF IMPORTANT PARAMETERS

#### 4.1 Sub-Tropical Westerly Jet (STWJ)

According to WMO, a jet stream is a strong narrow current concentrated along a quasi-horizontal axis in the upper level troposphere or in the stratosphere characterized by strong vertical and lateral wind shears featuring one or more velocity maxima. STWJ is one of the most important jet stream and the mean position of this jet stream over Indian sub-continent is at 27°N at height of about 12 kms (200 hpa). This jet is caused by the concentration of the horizontal temperature gradient below the jet level and the reversal of the gradient above the jet level. This is a large scale feature of the upper air circulation in with a high-speed core which can be distinguished from the general wind current. This jet is located near poleward boundary of the Hadley cell. There is a downstream strengthening of the wind speed in this jet stream. It is seen that in association with the high -speed centres along the jet axis there is upper air divergence in the left entrance and right exit sectors.

To find the Jet 200 hpa wind has been plotted.

#### 4.2 Wind shear

The speed and direction of the wind are different in different heights (pressure level). Generally, wind speed increases with height. Vertical shear of horizontal wind is calculated by using shear =velocity of wind at upper level- velocity of wind at lower level. Here wind shear between 200 to 1000 hpa has been taken into consideration.

#### 4.3. Divergence

This parameter is the horizontal divergence of velocity. It is the rate at which air is spreading out horizontally from a point, per square meter. This parameter is positive for air that is spreading out, or diverging and negative for the opposite, for air that is concentrating or converging (convergence). 200 hpa mean divergence of all synoptic hours for each day has been shown here,

#### 4.4 Vertical velocity ( $\omega$ )

This parameter is the speed of air motion in the upward or downward direction. Negative values of vertical velocity indicate upward motion. It can be expressed as:

$$\omega = - dp/dt$$

where, dp/dt is the rate of change of pressure.

#### 4.5 CAPE

This is an indication of the instability of the atmosphere and can be used to assess the potential for the development of convection, which can lead to heavy rainfall, thunderstorms and other severe weather. This is the potential energy represented by the total excess buoyancy. The larger positive CAPE value indicates larger instability.

#### 4.6. Surface heat fluxes

Surface latent heat flux is the transfer of latent heat (resulting from water phase changes, such as evaporation and condensation) between the Earth's surface and the atmosphere through the effects of turbulent air motion. The magnitude of sensible heat flux is governed by the difference in temperature between the surface and overlying atmosphere, wind speed and surface roughness. Surface heat fluxes are positive downwards and negative upwards.

#### 4.7. Column rainwater and liquid water content

Total column rainwater is the total amount of water in droplets of raindrop size (which can fall to the surface as precipitation) in a column extending from the surface of the earth to the top of the atmosphere. Total column liquid water content is the amount of liquid water contained within cloud droplets in a column extending from the surface of the Earth to the top of the atmosphere. Rain droplets which are much larger in size (and mass) are not included in this parameter.

#### 4.8. Vertical integral of total energy

This is the vertical integral of total energy for a column of air extending from the surface of the Earth to the atmosphere. Total atmospheric energy is made up of internal, potential, kinetic and latent energy. This is measured in joule/m<sup>2</sup>.

#### 4.9. Upper-level trough

The trough is an elongated region of relatively low atmospheric pressure without a closed isobaric contour that would define it as a low-pressure area. The trough may be near the surface or aloft. Upper-level troughs reflect cyclonic filaments of vorticity. Their motion induces upper-level wind divergence. The interaction with a cyclonic system can influence and guide the system. The trough at a particular level can be found out by plotting the geopotential at that particular level.

#### 4.10 Lifted index

It is a measure of thermal stability of the atmosphere at 500 hpa and is expressed in terms of parcel temperature and environmental temperature (Means 1952)

$$LI(K) = T_{500} - T_{\text{parcel}}$$

Where  $T_{500}$  is the environmental temperature at 500 hpa, and  $T_{\text{parcel}}$  is the temperature, it is lifted with the average temperature, pressure and dew point temperature from 500 m above the surface.

#### 4.11 TTI

This index is useful to assess the storm strength but fails to consider the latent instability below 850 hpa (Miller 1972)

$$TTI(K) = (T_{850} - T_{500}) + (T_{d850} - T_{500})$$

#### 4.12 SWEAT

This index was proposed by Miller in 1972 for determining severe weather.

$$SWEAT = 12 T_{d850} + 20(TTI - 49) + 2f_{850} + f_{500} + 125[\sin(d_{500} - d_{850})] + 0.2$$

Where  $f_{850}$ ,  $f_{500}$  are the wind speed in knots at 850 and 500 hpa, respectively, and  $d_{500}$ ,  $d_{850}$  are the wind direction in 0-360° at 500 and 850 hpa, respectively.

#### 4.13 KI

This index is used for determining the air mass thunderstorms. It is a combination of moisture at 850 and 700 hpa and temperature difference between 850 and 500 hpa (George 1960)

$$KI(K) = (T_{850} - T_{500}) + T_{d850} - T_{700} - T_{d700}$$

#### 4.14 CAPE

It represents vertically integrated positive buoyancy of an adiabatically rising parcel (Moncrieff and Miller 1976). Williams and Renno (1993) employed CAPE to study the conditional instability in the tropical atmosphere

$$CAPE(Jkg^{-1}) = g \int_{Z_{LFC}}^{Z_{LNB}} \frac{T_{ve} - T_{vp}}{T_{vp}}$$

Where  $g$  is the acceleration due to gravity,  $T_{ve}$  and  $T_{vp}$  are the virtual temperature of environment and parcel, respectively.  $Z_{LNB}$  and  $Z_{LFC}$  are the heights of the level of neutral buoyancy and the level of free convection respectively.

#### 4.15 BRN

indicates the type of the thunderstorm single, multi-cell, and super cell. (Weisman and Klemp 1982, 1984).

$$BRN = CAPE / (0.5 \times U^2)$$

Where U is the magnitude of shear

## 5. DYNAMIC AND THERMO DYNAMIC CHARACTERISTICS

Thermo dynamic indices calculated for Machilipatnam from 7<sup>th</sup> May 12z to 12<sup>th</sup> May 00z the results Table 1, table 1a, we got lifted index is more than threshold values -0.22 according to Kunz 2007) except 8<sup>th</sup> May 12 z. SWEAT index is more than threshold values >300 during 10<sup>th</sup> to 11<sup>th</sup> and 7<sup>th</sup>, 8<sup>th</sup> May according to Schulz 1989 indicating development of severe weather over Machilipatnam. K index is more than threshold value > 30 (According to Ackerman and Knox) 7<sup>th</sup> to 12<sup>th</sup> May was observed. Total totals index is more than threshold value > 46.7 according to Haklander and Delden 2003 from 7<sup>th</sup> May to 9<sup>th</sup> May it is more and in this period increasing in the SST was observed. CAPE is an indication of the instability of the atmosphere and can be used to assess the potential development of convection, which can lead to heavy rainfall, thunderstorms and other severe weather. CAPE values more than the threshold value >897 (Mukhopadhyay et al.2003) in all days was observed. Bulk richardson number is more than threshold value i.e >40 was observed in all the days except 9<sup>th</sup> May 12z to 11 00z remaining days more was observed, Precipitable water is more in all the days and it is maximum on 11<sup>th</sup> May and system is crossed the coast happened on the same day. All the days Perceptible water parameter indicating development of severe weather. Also all the days indicating conditions are favorable for the development of instability in the atmosphere.

	07/12	08/00	08/12	09/00	09/12	10/12	11/00	11/12	12/00
Lifted index	-7.0	-8.2	0.33	-5.31	-3.71	-2.29	-1.35	-1.75	-1.27
SWEAT index	333.8	376.1	217	261	282.6	386.6	356	311.6	290.42
K index	41.5	47.2	35.1	38.9	40.2	40.1	42.5	41	39.7
Total totals index	53.2	55.4	45.4	49.8	48.2	44.4	43.5	44.30	41.2
CAPE	2617.	2498.2	165.4	1367	1194.8	866.3	714.2	1970.9	880.3
CI	-251.7	-4.02	-296	-181.3	-119	-36.2	-92	-321	-1.73
EL	108	110.48	347.7	135.6	164.5	143.2	106	106	161.1
LFC	729.04	918.5	659	730.6	767.67	810.7	625	569	925.0
LCL	886.4	922.7	771	925	831	908.5	934	932	952.1
Bulk Richardson number	173	79.95	8.16	40.6	21.42	19.9	21.04	42.7	298
Precipitable Water(mm)	58.4	67.19	51.1	57.41	61.8	79.9	82.5	80.1	71.7

Table:1 Thermo Dynamic indices are calculated for the period from 7<sup>th</sup> May 12z to 12<sup>th</sup> May 00z of Machilipatnam station.

Threshold values for different parameters are given below

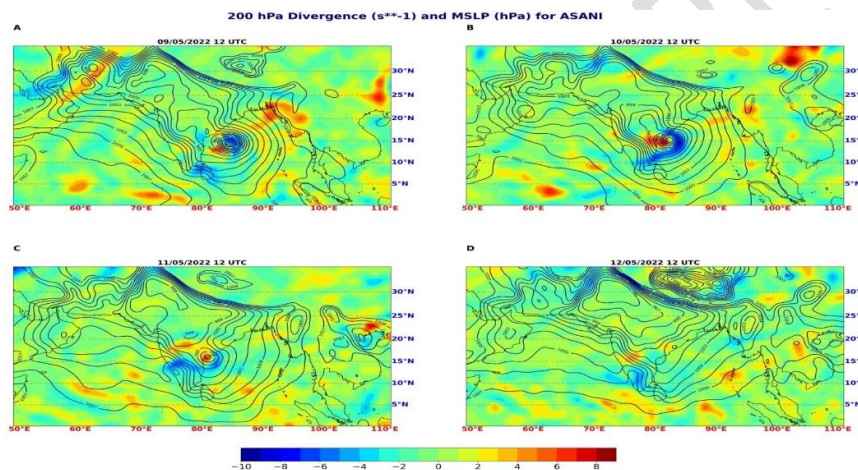
Lifted index (K)	≤-0.22 (Kunz 2007)
SWEAT	<-3 (Ackerman and Knox, online documentation) >300 (Schulz 1989)
K index	≥134 (Haklander and Delden 2003) ≥21 (Peppler and Lamb 1989, Andersson) ≥26.1 (Kunz 2007)
Total totals index	>30 (Ackerman and Knox) ≥46.7 (Haklander and Delden 2003) ≥48.1 (Kunz 2007)
CAPE	48 (Ackerman and Knox)
Bulk Richardson number (BRN)	>896.8 (Mukhopadhyay et al. 2003) >40 (online documentation)

Table 1a Threshold values for different Thermodynamic parameters

During Cyclogenesis tropical cyclones mainly depend on the sea surface heat fluxes and vertical shear of the horizontal wind (De maria,1996,). High SST plays a crucial role in enhancing deep convection by supplying necessary heat and moisture in the upward direction. At a given latitude the rate of intensification increases with increase in SST fig2 A, on account of the significant increase of the surface moisture fluxes from the warmer ocean (Crnivec et al., 2016). The low wind shear in an unstable stratified atmospheric environment allows the uniform upward and undisturbed release of the latent heat from the sea surface supporting the upper air supply is continued up to 9<sup>th</sup> May but later SST gradually decreased there by heat fluxes also reduced Fig.2 B,C,D in D SST is less than 26<sup>o</sup>C. Upper level jet also plays a crucial role in the genesis and development of tropical cyclones. According to the Dines compensation principle this divergence creates lower level convergence aloft the sea surface helps vertical development above the sea surface. With the strengthening of the jet, this vertical development strengthens and pressure falls on the sea surface. Thus upper – level jet helps in the genesis of tropical cyclones. But in this study jet supported intensification upto 9<sup>th</sup> May later as the storm weakened due to left exit came and result into upward convergence and while proceed towards coast, the height of the storm reduced being limited to middle tropospheric levels. As a result, steering wind of the system changed.

The area of low pressure was situated in a more favourable region comprising of low vertical shear of horizontal wind, high SST(>31<sup>o</sup>C) fig 3 A acts as initial inducement environment for the cyclone movement.

Divergence in the beginning it start increasing reaches peak shown more concentric lines fig3 A, B with more negative values on 9<sup>th</sup> to 10<sup>th</sup> May, later on divergence decrease C,D with less negative values was observed from fig 1(A-D).Sub tropical westerly jet (STWJ) generally is located at 27-30° N of Indian region.



• Fig1 200 Hpa Divergence and MSLP for Asani

Jet stream Right entrance was observed 9<sup>th</sup> may Divergence in upper level winds and continued for 10<sup>th</sup> May leads to surface convergence leads to intensification up to 10<sup>th</sup> May (Fig 3A-D) later jet left exit came upper level convergence leads to surface level pressure to rise leads to weakening of the system by 12<sup>th</sup> May.

Total column water vapour and total column Rain water content is more during 9<sup>th</sup> May and there onwards with intensity and water vapour content decreased (Fig4 A-D).all the water vapour content is available at west side of Machilipatnam. Total rain water content upto 10<sup>th</sup> May it is increasing and then water content gradually reduced finally on 12<sup>th</sup> May 12 UTC there is negligible vapour content.(Fig 4 (A-D).

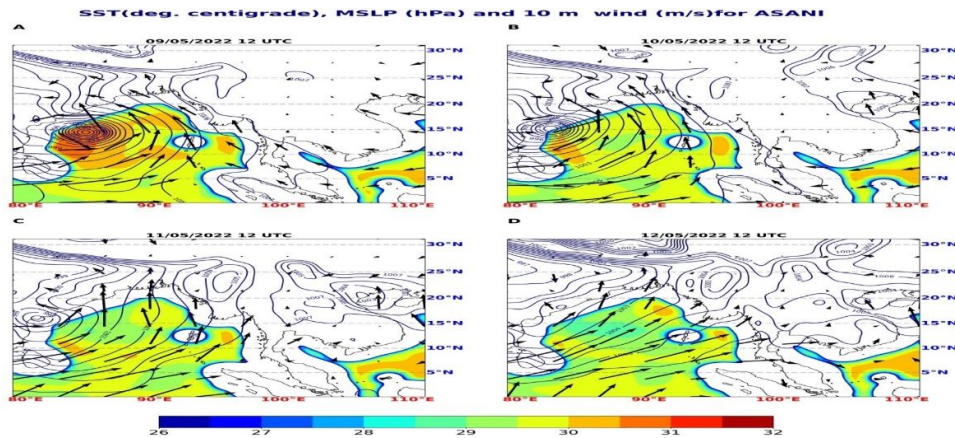


Fig2 SST(<sup>o</sup>.C), MSLP (Hpa) and 10m wind (m/s) for ASANI

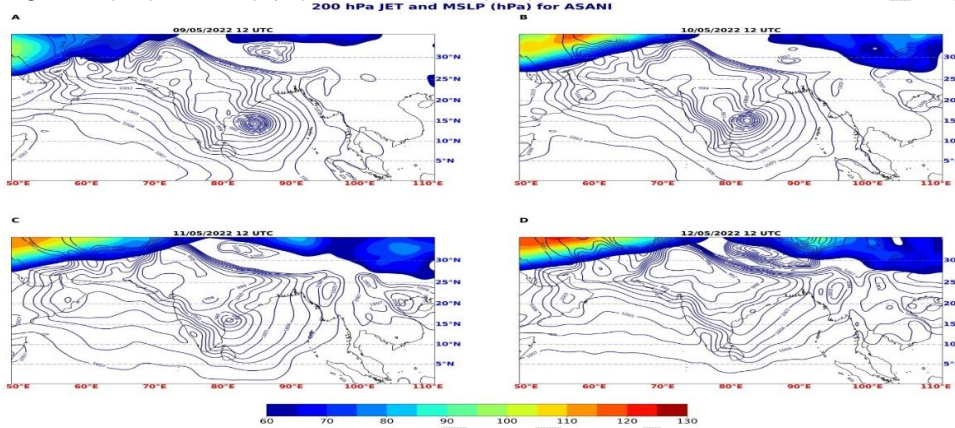


Fig:3 200hpa jet and MSLP hpa for Asani

Specific humidity during its intensification its content is more Fig 5(A-D) and once it met with cold waters the humidity levels also reduced leads to weakening of the system and moved west wards. The upper level jet, steering flow (averaged wind fields between 850-300hpa to incorporate upper level trough ridge) guides Asani in its trajectory till landfall on the Machilipatnam coast Fig:6 (A-D). (Hanley et al., 2001) examined that tropical cyclones over warm water and away from coast are more likely to

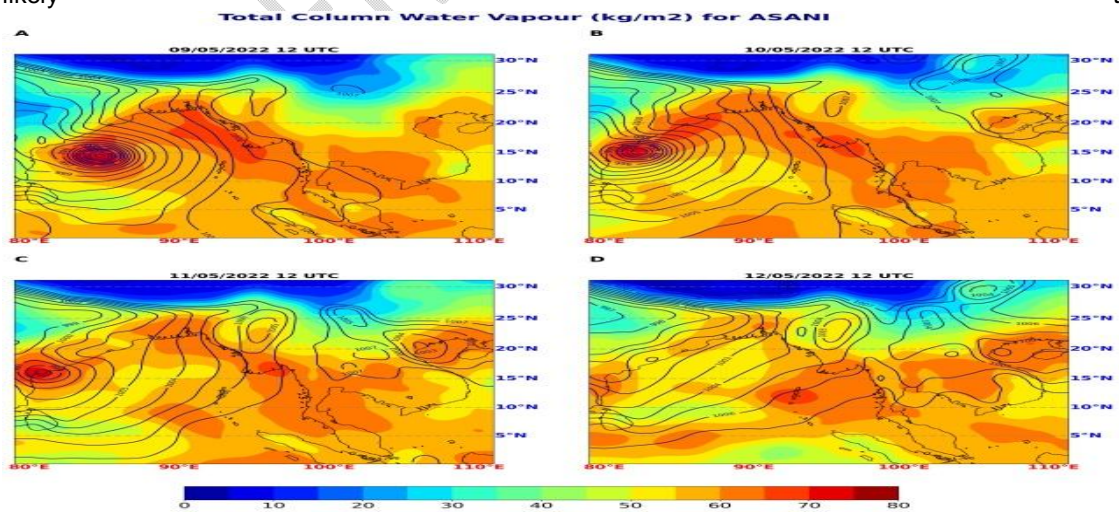


Fig 4 Total column water vapour (Kg/m<sup>2</sup>)

intensify than weaken after interaction with an upper-level trough. Here in this study Tropical cyclone over less warm water and near to the coast for a day led to the weakened the system due to interaction with an upper level trough. Fig7

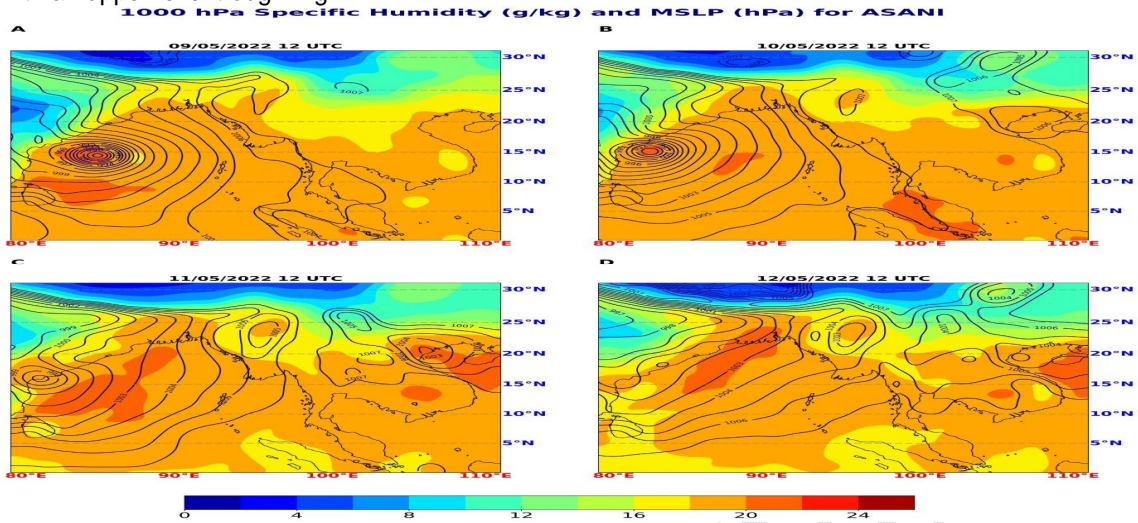


Fig:5 1000hpa specific humidity (g/Kg) and MSLP in hpa.

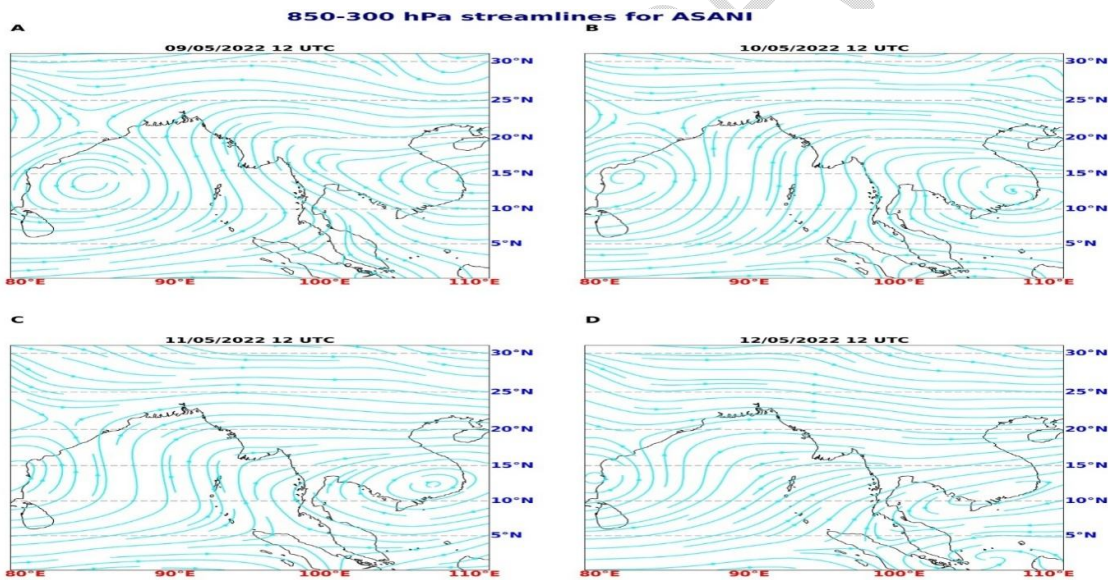


Fig :6 Stream line for Asani from 850-300hpa

The fig 2 200 hpa wind and MSLP show the time evolution of STWJ and the system. It is seen from this fig 2 that with time STWJ strengthen and isobars become closely spaced. This STWJ is associated with upper level divergence fig1 & lower level convergence indicated by SST fig 10 relative vorticity. This is also evident from the vertical profile of divergence shown in fig 1. This existence of the upper level divergence enhances the lower level convergence, which enhances the instability and favours intensification upto 10<sup>th</sup> May there by Asani becomes a severe cyclonic storm but its direction changed due to upper level ridge position, Fig 13a and Fig 14 it moved slowly northward/north-westwards on 11th May up to evening and slowly west-south-westwards thereafter. It was mainly due to the cyclonic storm was supposed to move north-eastwards near the coast under the influence of a short amplitude westerly trough in middle and upper tropospheric levels that proceed from the west. However, as the storm weakened while proceed towards coast, the height of the storm reduced being limited to middle tropospheric levels fig 14. As a result, the steering wind of the storm changed being dominated by south-easterly winds and led to north-west ward movement. However, the north-westward movement was restricted/ blocked due to an anticyclone lying over the peninsular India fig 13b and 14. Thus, the system moved slowly & remained practically stationary near to the coast

followed with slow west-south-westward movement till its weakening into a well-marked and a low-pressure area in the morning of 12th May over the region.

The magnitude of sensible Latent heat flux is governed by the difference in temperature between the surface and overlying atmosphere, wind speed and surface roughness. Surface latent heat flux is the transfer of latent heat between Earth's surface (land/ocean) and the atmosphere through the effects of turbulent air motion. Evaporation from the Earth's surface represents a transfer of energy from surface to the atmosphere. (Emanuel, 1986) proposed that "interaction and maintenance of tropical cyclones depend exclusively on self - induced heat transfer from the ocean" via surface heat fluxes. (Wing *et al.*, 2019) also argued that strong feedback of surface heat fluxes such as surface latent heat flux and surface sensible heat flux can intensify tropical cyclones.

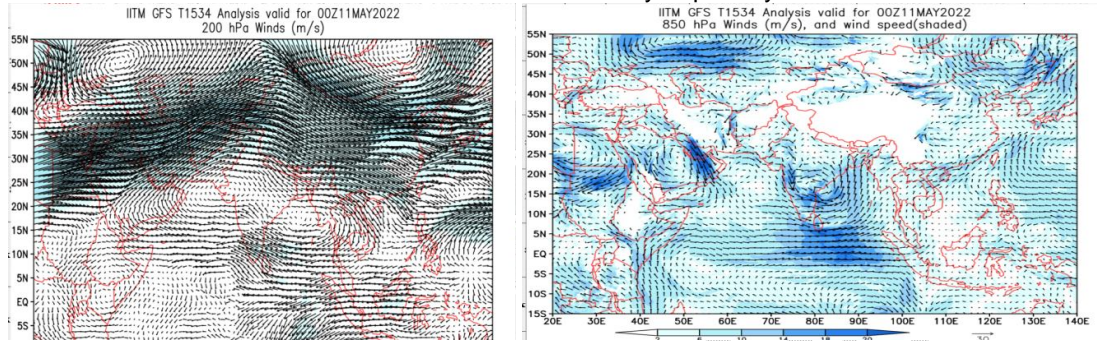


Fig:7 IITM GFS T1534 wind analysis for 11<sup>th</sup> May at 200hpa(a) and 850 hpa(b) level

Latent heat flux exchanges at the air –sea interface play important roles in the formation and development of tropical cyclones. It is a fundamental source of energy of tropical cyclones (Ma *et al.*, 2015). Fig8 (A-D) latent heat fluxes are more negative in intensification process once the SST decreases in the sea and system met with cold waters latent heat decreases led to system weakening.

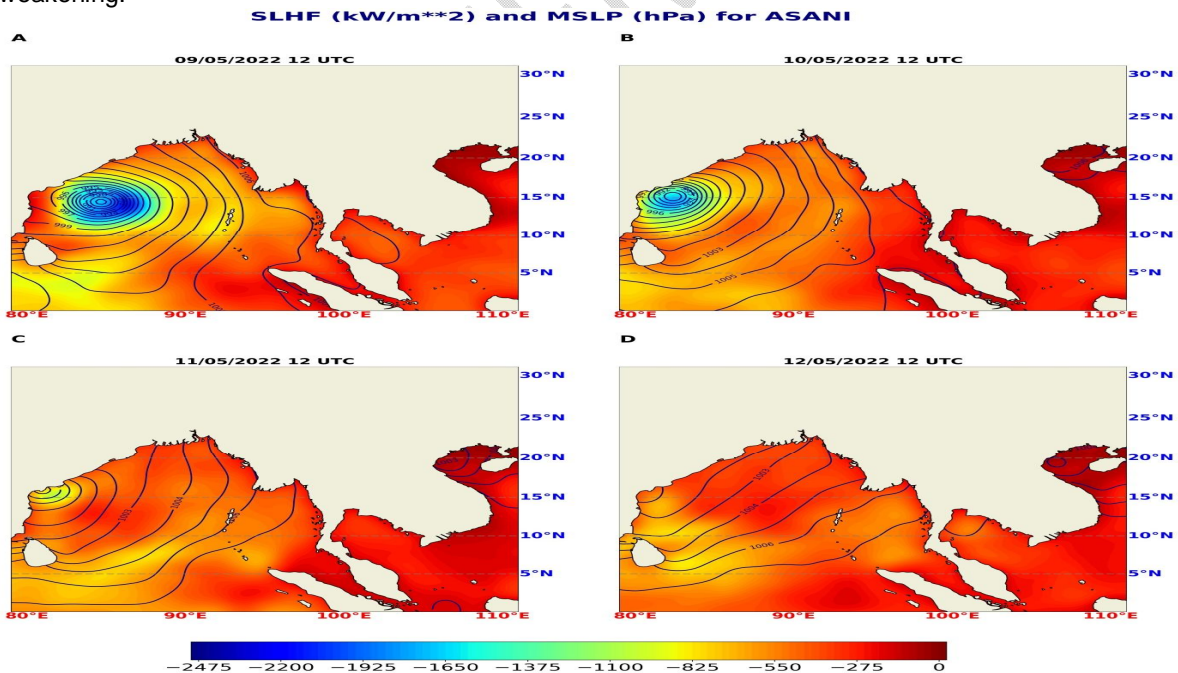


Fig 8 Sensible latent heat flux

The magnitude of sensible heat flux is governed by the difference in temperature between the surface and overlying atmosphere, wind speed and surface roughness. Surface heat fluxes are positive downwards and negative upwards. From Fig 9 for Surface sensible heat flux if more during 9<sup>th</sup> May and for any system during intensification surface heat flux are negative upwards A,B and later days positive values indicating weakening of the system, clearly can see from Fig 9 C,D.

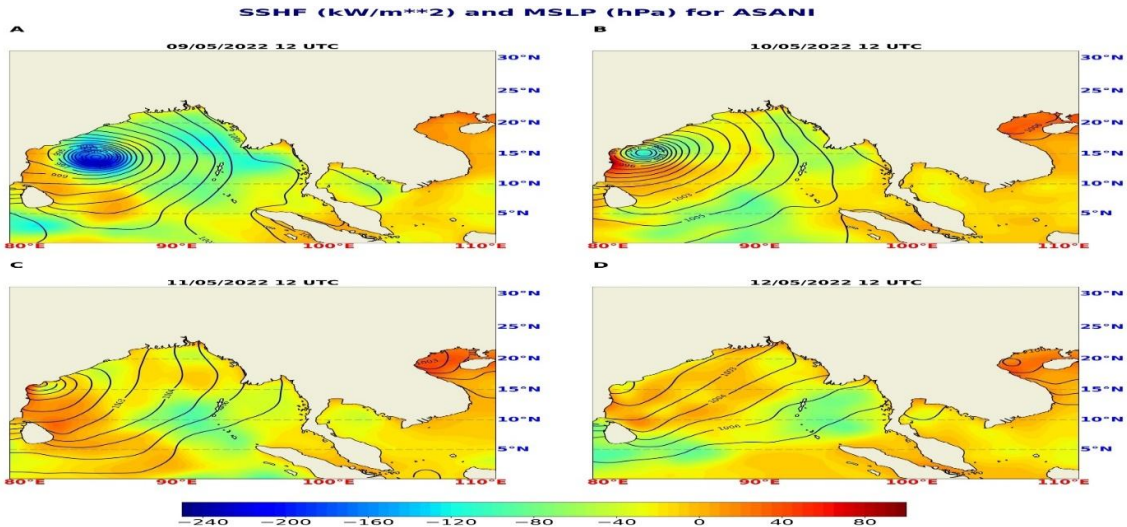
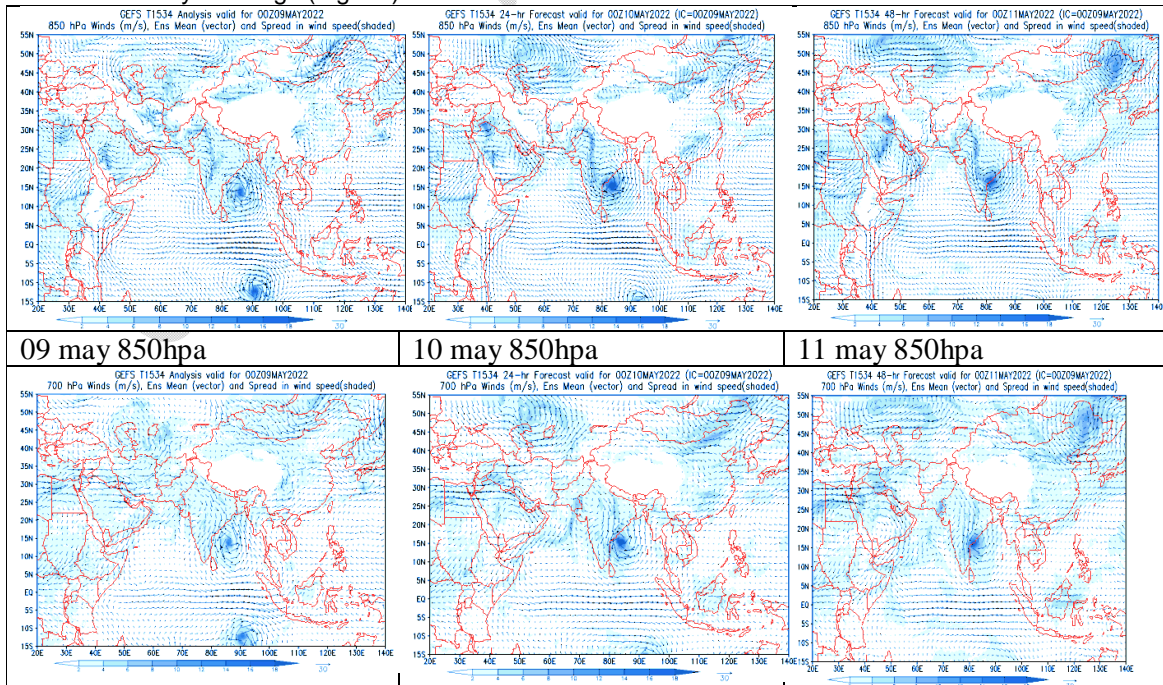


Fig:9 Surface sensible heatflux and MSLP hpa

Sea surface temperature (SST) was around 30-31<sup>o</sup> Cover entire bob. It decreases gradually towards the andhra pradesh & odisha coasts becoming 28<sup>o</sup>c. the ocean heat content (ohc) is >100 kJ/cm2 over westcentral & south bay of bengal (bob) becoming 50-70 kJ/cm2 over northwest bob & along & off Andhra pradesh & Odisha coasts and adjoining westcentral bob.

As IMD predict that low level vorticity is about  $250 \times 10^{-6} \text{ s}^{-1}$  to the south of system centre. vertically it is extending upto 200 hpa level. vorticity field is east-west oriented indicating gradual westwards vorticity advection. low level convergence is around  $10 \times 10^{-5} \text{ s}^{-1}$  to the southwest of system centre. upper level divergence is  $05-10 \times 10^{-5} \text{ s}^{-1}$  to the northeast of the system centre. wind shear is low (10-15 knots) (IMD RSMC website) around the system area and also along the forecast track. As the system moves further northwards, it will encounter lower SST & OHC and hence will show gradual weakening. There will be dry air incursion reaching into the core area from indian landmass as the system moves further northwards. It will help in weakening of the system. Instead of recurve northeastwards the system moved north west wards and after crossing the coast south west direction while moving along the periphery of sub-tropical ridge associated with anticyclonic circulation over the eastcentral Bay of Bengal(Fig 14).



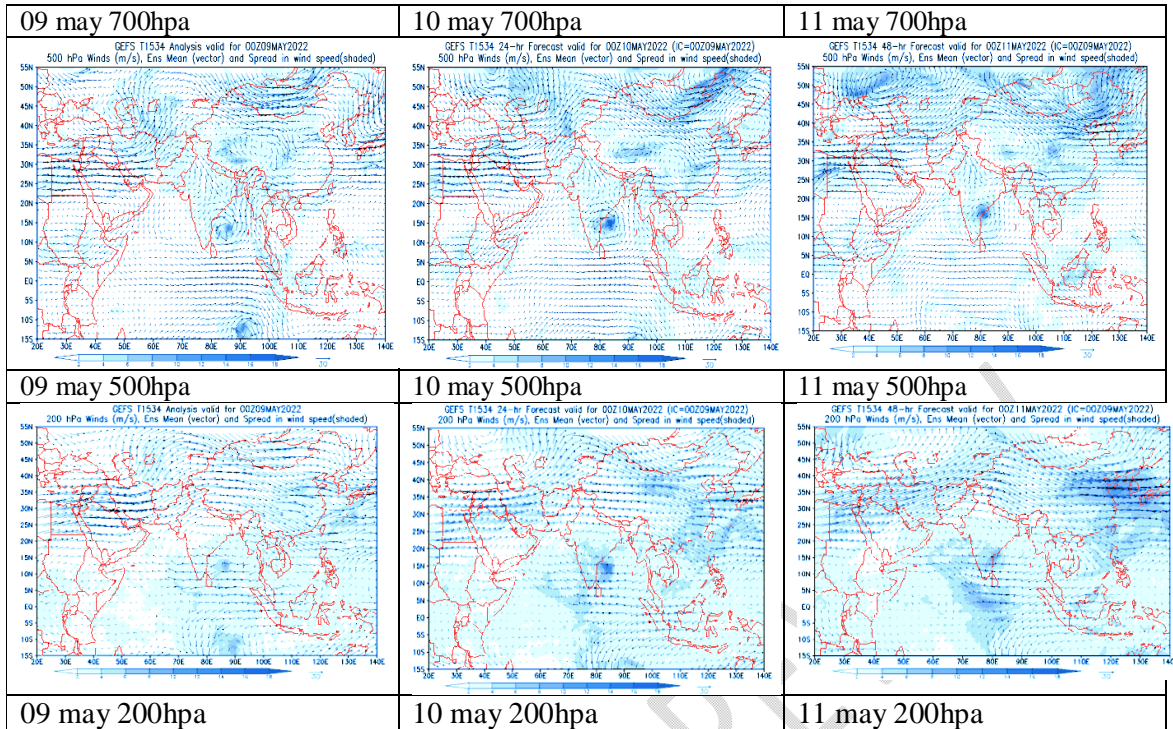


Fig 10 GEFS Wind Analysis At 850,700,500 And 200hpa

11<sup>th</sup> 1200 UTC sea surface temperature (SST) is around 29 °c over westcentral bob along & off Andhra Pradesh and along the forecast track. The ocean heat content (OHC) is 100 KJ/cm 2 over west-central & south bay of bengal (bob) becoming 50-70 kj/cm2 over northwest bob along & off Andhra Pradesh, Odisha coasts and adjoining west-central bob. lowlevel vorticity has decreased and is about 150 x10-6 s-1 to the south of system (bulletins issued by RSMC IMD) centre. Vertically it is extending upto 200 hpa level. low level convergence has slightly increased and is around to 20 x10 -5 s -1 to the southwest of system Centre. Upper level divergence is 05 x10-5 s-1 around and to the northeast of the system Centre. Wind shear is low (15-20 knots) around the system area and also along the forecast track. The system weakened due to land interactions and will weaken further gradually. also as the system moved further West-northwestwards, it encountered lower SST, lower OHC and hence weakened. the incursion of cold and dry wind from Indian peninsula at middle and upper troposphere also contributed to weakening of the system.

11<sup>th</sup> may 1800 (bulletins issued by RSMC IMD)

sea surface temperature (SST) is around 29 °c over westcentral bob along & off andhra pradesh. the ocean heat content (OHC) is >100 kj/cm 2 over westcentral & south bay of bengal (bob) becoming 50-70 kj/cm2 over northwest bob & along & off Andhra Pradesh & Odisha coasts and adjoining Westcentral bob. low level vorticity has decreased and is about 150 x10 -6 s -1 to the south of system centre. vertically it is extending up to 200 hpa level. low level convergence is around to 30 x10 -5 s -1 to the northwest of system centre. upper level divergence is 05 x10 -5 s-1 around to the southwest of system centre. wind shear is low (15-20 knots) around the system area.

The system weakened due to land interactions and will weaken further gradually.

#### 6. Relised weather observed :

1. Extremely Heavy and Highest rainfall of 256.4 mm was recorded at Kandukur (Prakasam District) in Andhra Pradesh in 24 hrs ending at 0830 hrs IST of 12th May, 2022.
2. Winds: Gale Winds of 75-85 kmph (40-45 kts) gusting to 95 kmph (50 kts) were experienced around the system centre over West-central Bay of Bengal on 11th morning and 65 to 75 kmph (35 to 40 over the land, maximum wind of moderate intensity of 39 kmph (21 kts) from South-easterly direction was experienced at Machilipatnam at 1600 UTC (2130) hrs IST and at Bapatla 37 kmph (20 kts) from North-westerly direction at 1700 UTC (2230 hrs IST) of 11th May 2022. Damages occurred due to winds in association with storm over land was less or very minimum.

3. The worst affected areas due to rains were southern coastal strip of Prakasam and northern coastal strip of Nellore districts where 20 to 30 cm of average rainfall was recorded in 3 days (11 to 13th May).

**6.1 Wind Direction Before and After passage of Low Pressure System at a station.**

When a Low Pressure System / Cyclone approaches a station along the coast from the sea, winds will blow from northeast or east, if the centre of the system is to the south of the station. After the center has passed inland winds will veer and blow from east or southeast. If the centre lies to north of the station, winds will blow from northwest or west before crossing and they will back and blow from southwest or south after crossing. If the center passed directly over the station, the wind will blow from north or northeast at first, become calm or very light during the passage of the center (or eye) and blow from southwest or south afterwards.

**6.2 FIXING OF LANDFALL POINT AND MOVEMENT OF SYSTEM IN SOUTHWESTERLY DIRECTION OVER LAND**

Hourly weather observations recorded at coastal observatories along Andhra Coast are considered in assessing landfall point and movement of system thereafter (Fig.11) At Machilipatnam northerly winds prevailed in the morning of 11th May, 2022 and they veered and became northeasterly by afternoon and it became easterly (10 kt) at 1400 UTC (1930 hrs IST). At that hour the station recorded lowest pressure of 994.9 mb along Andhra Coast. The wind became southeasterly by 1500 UTC (2030 hrs IST). It clearly indicates that the Deep Depression Crossed Coast to south of Machilipatnam and very close to it. It is further substantiated by the fact that at Bapatla on 11th northwesterly winds blowed since morning and it was west-northwesterly 5kt at 1500 UTC, Fig 11 which indicates backing of wind and the system is located to the north of the station. Based on the above synoptic features and fixing centre of the system by means of drawing lines at an angle of 1200 to the direction of wind observed at stations and centroid position of lines, at 1400 and 1500 UTC, it can be well assessed.

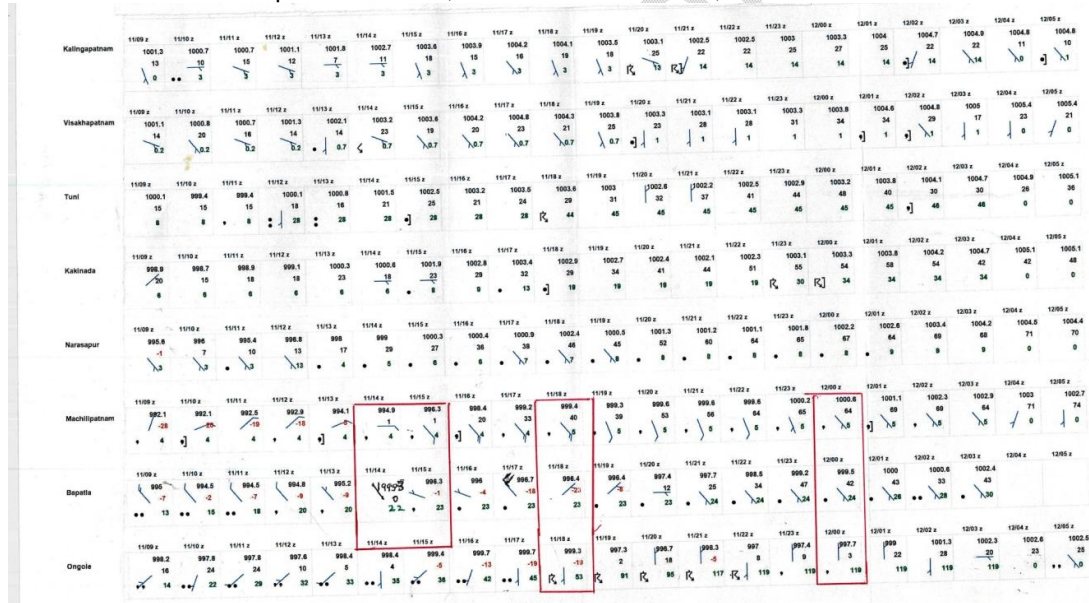


FIG:11 HOURLY OBSERVATIONS RECORDED OVER COASTAL OBSERVATORIES OF COASTAL ANDHRA PRADESH

It is a rare phenomenon that was observed, that a low pressure system moved in a south-westerly direction after its landfall. In the present case, the system after crossing the coast in its weakening stages of Depression and Low-Pressure stage moved near Machilipatnam in a south-westerly direction over coastal areas of Guntur, Prakasam and Nellore Districts on 11th & 12th May 2022 (Fig.12). A similar case of south-westerly movement after land fall, occurred in the year 1984. A severe cyclonic storm with a core of cyclonic winds crossed south Andhra Coast just north of Sriharikota in the afternoon of 14th November, 1984. After crossing coast, the system slowly moved in a south-westerly direction and rapidly weakened into a cyclonic storm by 14th evening and into a Depression by 15<sup>th</sup> morning and fizzled out thereafter.

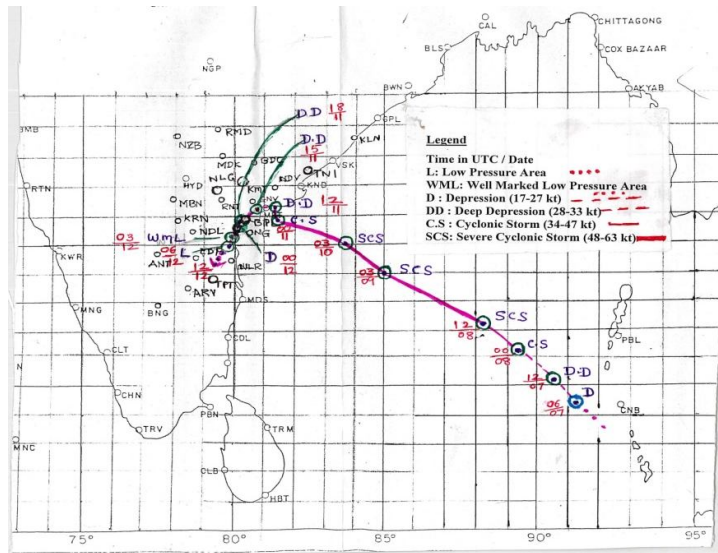


Fig :12 Observed track of SCS Asani Cyclone

#### Benefits:

Due to the passage of cyclonic storm people in Andhra Pradesh experienced relief from scorching hot weather from 10 to 13th May 2022, as thick cloud canopy protected them from hot sun rays. The maximum temperatures recorded were markedly below normal by 5 to 14<sup>0</sup>C over Andhra Pradesh during the above period. Due to Upwelling of seawater led to off south coastal Andhra Pradesh became a potential fishing zone with this system.

#### Conclusion:

1. The observations of the synoptic and dynamical parameters connected with SCS Asani clearly reveal that under favourable conditions of high SST, high energy, weak wind vertical shear of horizontal wind, and the 200hpa STWJ aided in the formation of SCS Asani. The violent cyclonic storm "Asani" deteriorated into a deep depression before reaching the shore, owing to a drop in sea surface temperature and heat content in the water. It travelled slowly towards the shore (5-6 kph compared to the average pace of 13 kph) and stayed within 50 km of the coast from the morning until the evening of May 11th. The sluggish movement caused upwelling of sea water and rainfall over the sea, which resulted in additional cooling of the sea surface. Because of the slow movement, there was more time for land interaction, which resulted in weakening owing to relatively high friction with the land surface. In the middle and upper tropospheres, there was cold and dry air intrusion from the Indian landmass, which is unfavourable for maintaining the tenacity of any cyclonic storm.

2. Because the cyclonic storm was expected to proceed north-eastwards along the coast under the influence of a short amplitude westerly trough in the middle and upper tropospheric levels arriving from the west, it moved west-southwest. However, when the storm weakened as it approached the shore, its height fell, limiting it to the middle tropospheric regions. As a result, the storm's steering wind shifted from being dominated by south-easterly winds to being dominated by north-westerly winds, causing it to proceed north-westward. However, the north-westward movement was restricted/blocked due to an anticyclone over peninsular India. Thus, the system moved slowly and stayed nearly stationary along the shore until weakening into a well-defined low pressure area in the morning of 12<sup>th</sup> May.

3. The coastal winds that are caught up in the cyclonic circulation of low-pressure systems determine the landfall site and migration of low-pressure systems across land (normally about 150 to 200 km away from the coast). It is well documented that micro-scale variations in wind and pressure are the primary ingredients or rather play a vital role in determining land fall position and continued movement of the low-pressure system over land. Satellite and radar cloud images serve an auxiliary role in system forecasting over land areas.

4. It is an infrequent occurrence when a low-pressure system moves in a south-westerly direction after its landfall.

## Abreviations

RSMC	:	Regional specialised Meteorological centre
ECMWF	:	European Centre for Medium Range Forecast
BoB	:	Bay of Bengal
MSLP	:	Mean Sea Level Pressure
CAPE	:	Convective available Potential Energy
SST	:	Sea Surface Temperature
STWJ	:	Sub Tropical Westerly Jet

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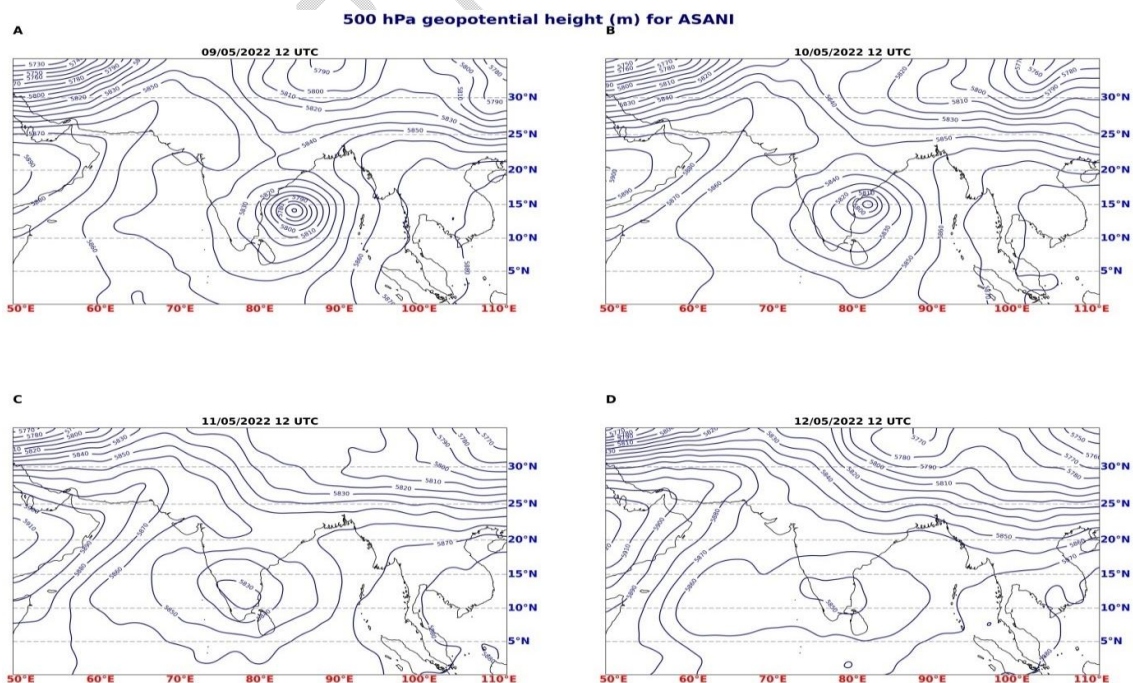


Fig: 13 500hpa geopotential height for Asani

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