International Journal of Electronics and Applied Research
Vol. 13 issue 1, July 2026
Special issue: Proceedings (Part II) of National Symposium on
Advances in Electronics and Allied Science & Technology, NaSAEAST-25, December 26-27, 2025
Venue : Gauhati University, Guwahati, India-

Cyclones/ typhoons- attribute to Sub-Himalayan Environment: Observations and model approaches in search of Ocean-Atmosphere coupling dynamics

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Abstract

The exercise here is to adopt satellite and ground based observations on multidimensional atmospheric parameters, supported by wind flow and meso-scale climate models, in formulating and understanding ocean-atmospheric coupling dynamics leading to weather modifications in to Sub Himalayan range of India (in special reference to the NE zone), by Cyclones of categories 1 to 5 generated over Bay of Bengal (BoB), which is supplemented with the South China Sea (SCS) Typhoons , a first such study over this region. The paper while highlights that intense precipitation exceeding 20mm/hr over this region is one of the main weather-related phenomena, induced by BoB cyclones, the SCS typhoon induces multiple dynamical modifications in the atmosphere by modulating the vertical wind profiles at the study location with FFT components similar to those of the wave structures induced by typhoon in the wind flow track. The wind vortices being prominent at altitude > 1000m, they provide evidence of the effect of horizontal pressure variation along its path that plays the crucial role (Geostrophic wind) in wind modulation where the effect of the surface can be neglected, and when Coriolis forces work, as a consequence of the air parcel moving. Significantly, the wave-induced perturbations in the meteorological parameters, the prime contributions of typhoon Bualoi, (case study) provide features for the ocean-atmosphere coupling model essential for the worst weather environment, along with those contributed by the BoB cyclones.

Keywords: Cyclone; Typhoon ; Mesoscale Climate and Wind Flow Model ; FFT ; System Dynamics ; Weather Modulation; Ocean-Atmosphere Coupling

*Part of the contemns of MS was a topic in the discussion forum of the NaSAEAST-25

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1. Introduction

A Tropical Cyclone (TC) is a special state of weather situation of a zone encompassing the Tropic of Cancer and the Tropic of Capricorn (lat. ±23° to ± 2°), with an average annual temperature at a higher level compared to latitude above this zone and that in this tropical area, the Carioles force, an instrument of growth of a cyclone cannot be neglected. This situation results to an organized circulation of cloud, the movement of which is accompanied by winds, the magnitude of which determines the state of the TC strength. If the wind speed is less than 63km/h, a 'depression or low-pressure zone' is developed over the sea surface, a state for formation of a cyclone or the seed of the growth of its speed favored by the warm water surface and an atmosphere with no wind shear. If the speed of the depression zone reaches 63km/hr, a convenient situation is created for formation of Tropical Storm (TS) and when wind speed increases to 120km/h or beyond, this environment goes to a TC , in the Indian Ocean, and defined as a typhoon in the western Pacific and a hurricane in the eastern Pacific or Atlantic; a brief description of the growth of TC is well available in the literature (Devi et al ., 2014). .Table I shows the index of severity of storm (in terms of Category) identified with wind speed.

Table I

Saffir-Simpson Hurricane Scale

.

Category	Wind speed
1	74-95 mph, 119-153 km/h
2	96-110 mph, 154-177 km/h
3	111-129mph,178-208 km/h
4	130-156mph, 209-251 km/h
5	157mph or higher, 252 km/h or higher

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We will initiate this study by examining the cyclone-induced features in weather & atmosphere modification in NE, and adopt these observed characteristics as inputs, in understanding the Ocean-atmosphere coupling dynamics, along with those from SCS Typhoon The NE zone, being situated in the Sub-Himalayan territory (Figure 1a) and in seismic zone V, is a hazard-prone area with frequent earthquakes and is affected by severe weather such as thunderstorms, monsoon, and drought, compounded by cyclonic-induced artificial weather modulation. A star in Figure 1a marks the focal study location along with the Sub-Himalayan zones marked as 1, 2, and 3. Figure 1b shows the cyclone track path to the NE from the Bay of Bengal and the Arabian Sea, and Figure 1c displays a possible wind flow path from the South China Sea (SCS) typhoons, which is now included as a first case with a recent Typhoon Bualoy.

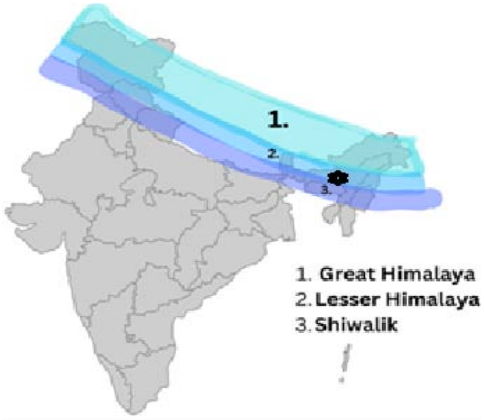
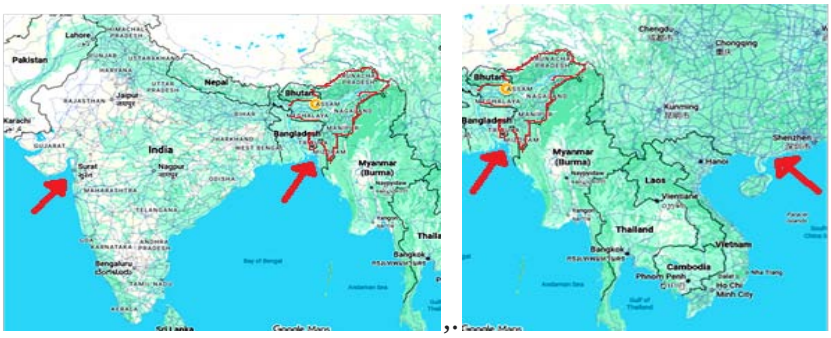


Figure 1a : The geographical position of study location Guwahati (given by a star) . The Sub-Himalayan ranges are marked as 1, 2 and 3.

. The past observations (Devi et al., 2013) show as to how the BoB cyclones induce heavy precipitation over the NE, modifying weather and system dynamics, a few more cases will be included here towards the support of the earlier work The contributions to such changes in atmosphere from the Arabian Sea are also present, though weak but their influence will likely be intensified (Singh 2025) because of an increase in relative sea temperature. Along with the track entry paths of these cyclones, as displayed in Figure 1b, a third possible wind flow track from the South China Sea (SCS) typhoons is now included here, to focus on cyclone- as well as of typhoon-induced weather-related issues and to understand ocean-atmospheric

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coupling dynamics controlled by these phenomena .



(b) (c)

Figures 1b,c : Track entry paths of b) Cyclones generated in Arabian Sea and BoB (identified by left and right arrow respectively) ; (c) the SCS Typhoon (right hand arrow)

Further, land–ocean interactive status dictated by (a) the Sea Surface Temperature (SST) (Demaria and Keplan 1994; Katsube and Inatsu 2016; Lin et al., 2015; Xu et al., 2016) , (b) anthropogenic components as well as by global warming (Dunion and Velden 2004: Emanuel 1987; Gray 1988; Shen et al., 2000; Emanuel et al., 2004 ; He and Soden 2015; Hill and lackmann 2009; Zeng et al., 2007; Hubert et al., 2003; Landsea 2005; Pielke et al., 2005; Rosenfield et al., 2012) and (c) finally the terrain environment are important issues in resultant contribution to growth of cyclone strength (Chen 2006) and subsequently to its after landfall activates (Devi et al., 2013; Chouhan et al., 2014; Risser and Wehner 2017; Sarkar et al., 2018). A few such issues will be brought in to ambit of discussion.

2. Observation and Analysis

2.1 A few case studies: BoB induced Cyclone effects at the NE zone

The comfortable environments of BoB with warm SST, low wind shear and sea lines prohibiting circulation of cold water, produce frequent cyclones compared to Arabian sea, (Table II) and we will introduce the consequent effects mainly of BoB cyclones, in atmospheric system dynamics and weather issues over the NE , for selected cases, based on their track path , intensities , and in growth environment.

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Table II
Specifications of a few cyclones generated in the BoB

Nargis BoB April-May 2008	962 hPa (3-min) 937 hPa (1 min) .	Formed : 27 April 2008 and dissipated : May 3,2008 **Extremely severe cyclonic storm Category 4-equivalent**	1minute sustained speed 215 km/h	3-minute sustained speed 165 km/h (105 mph)
Allia BoB May 2009	Lowest pressure: 968hpa.	Formed : May 25, 2009 Dissipated : May 27, 2009 **Severe cyclonic storm**	1-minute sustained Highest winds 120 km/h, •	3-minute sustained wind speed 110 km/h
Mora BoB May 2017	Lowest pressure 963 hPa	Formed: May 28, 2017 Dissipated: May 31, 2017 **Severe cyclonic storm**	1-minute sustained Highest wind speed 150 km/h	3-minute sustained wind speed 110 km/h
Fani BoB April 2019	Lowest pressure 932 hPa (3 min) 900 hPa (1 min),	formed on 26 April 2019 and dissipated on 5 May 2019 **Extremely severe Category 5-equivalent**	1-minute sustained Highest wind speed. 280 km/h	3-minute sustained wind speed 215 km/h
Amphan BoB May 2020	Lowest pressure 901 hPa . ,	Formed 16 May 2020 Dissipated 21 May 2020 **Category.5-equivalent**	1-minute sustained wind speed 270 km/h	3-minute sustained wind speed 240 km/h
Ramal BoB May 24-26 2024	Lowest pressure 978 hPa	Formed in to severe storm : May 26 ,2024 Dissipated : May 28 2024 **Severe cyclonic storm**	1 minute sustained wind speed 100 km/h	3-minute sustained wind speed 95 km/h

Our work tools consist of weather forecast & prediction models, observed atmospheric parameters from available websites, & satellites, radiosonde and ground based weather stations.

Adopted Models:

A spectral hydrostatic general circulation model for the prediction of the atmospheric varibilities, was run in an eight-processor Flosolver machine at Gauhati University (26º 10' N, 91º 45' E). The predictions were made to track cyclones generated in the Bay of Bengal and to forecast temperature, precipitation, humidity, surface pressure , over the north-eastern part (NE) of India, induced by such events. The initial conditions of the model are prepared from the FNL dataset of the National Centre for Environmental Prediction (NCEP), available at 1° X 1° resolutions.

Further Hypersplit trajectory model is run regularly at different altitudes to track the wind flow directions to this zone along with CPC, GFS and GTS forecast models of NOAA. .

Case Presentations:

Case 1 :Mora Cyclone :

Mora is a powerful Cyclone (see Table II) developed over Bay of Bengal. on 27th May, 2017 with its peak 1 minute wind speed of 150 km/hr and it landed in Bangladesh on 30th May, 2017 and totally dissipated after hitting the North East India (see the track in Figure 2) on 31th May. The precipitation brought in by the track that entered the NE are mapped by the model (Figure 3a) which displays that very weak precipitator status of May-27 , was gradually flooded with rain (Figures 3b,c.d) and strong intense precipitation of 100mm-200mm on May 30 (Figure 3c) in extreme north east part of this zone is contribution of Mora cyclone . The model predicted output is supported by satellite and radar precipitation results with 20mm /hr at times (Figure 3e), on May 30. It is reported that the Mora triggered rain led to devastating floods in Assam that caused 59,000 families to abandon the flooded districts of Lakhimpur, Karimganj and Darrang and also in extreme north east part of this zone.

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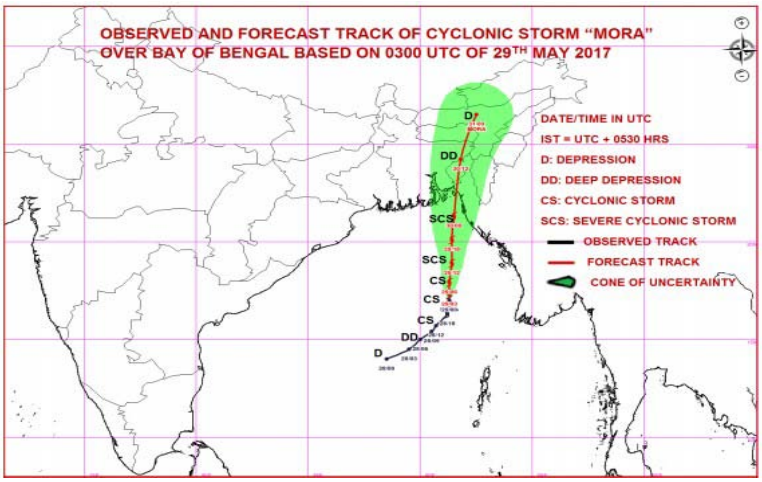
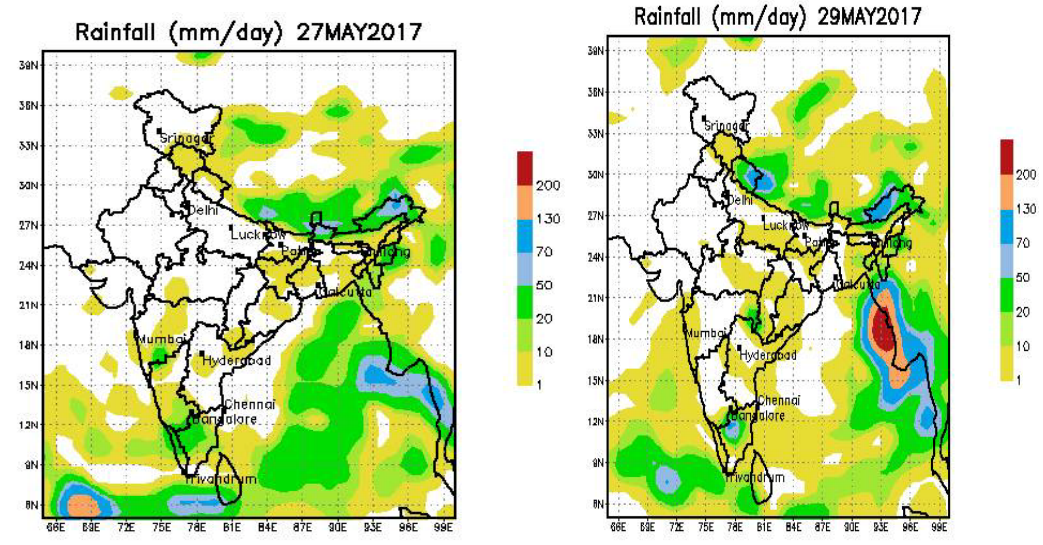
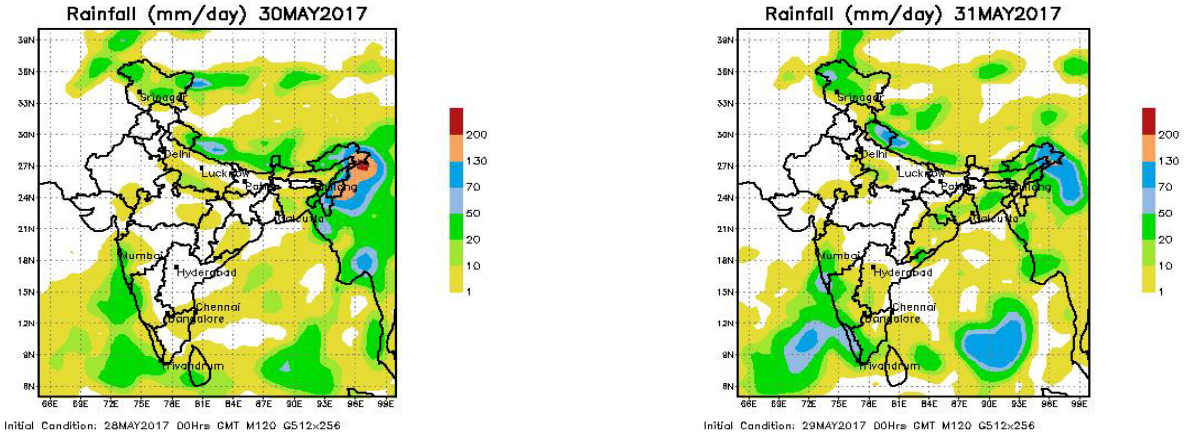


Figure 2 : Track of Mora Cyclone and its entry to the NE



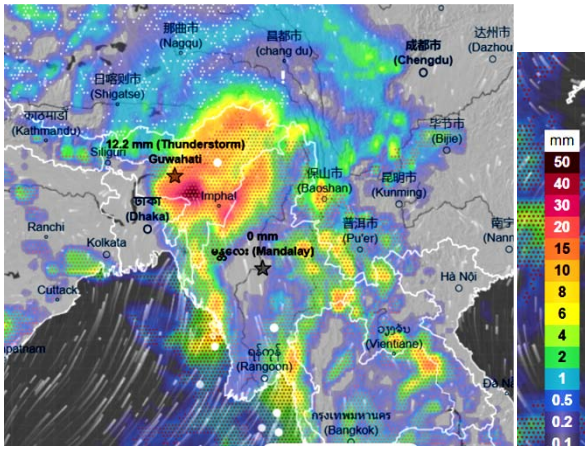
(a) (b)

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(c) (d)

Figure 3a,b c.d : Precipitaion induced by Mora : Mesoscale climatic model output May 27, May 29, May 30 and May 31, 2017. Note 60/70mm of rain on May 31 over studied zone and more than 100mm in extreme NE



(e)

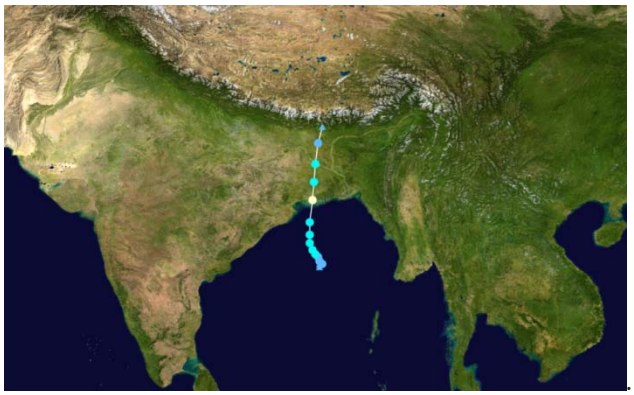
Figure 3e :Precipitaion (mm/hr) over NE induced by by Mora cyclone on May 30, 2017 (Radar ,Wind map , overall forcast)

Case 2 :Cyclone Aila

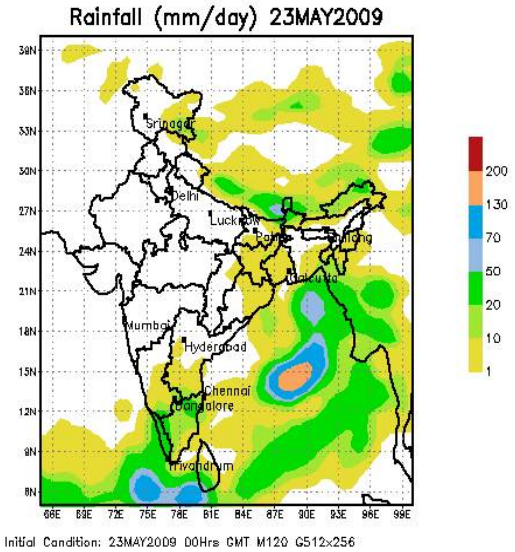
Aila cyclone, which formed on May 25, 2009, dissipated on May 27, 2009, was a severe but short-lived cyclone that originated at BoB (Figure 4a) with a 1-minute sustained speed of 120

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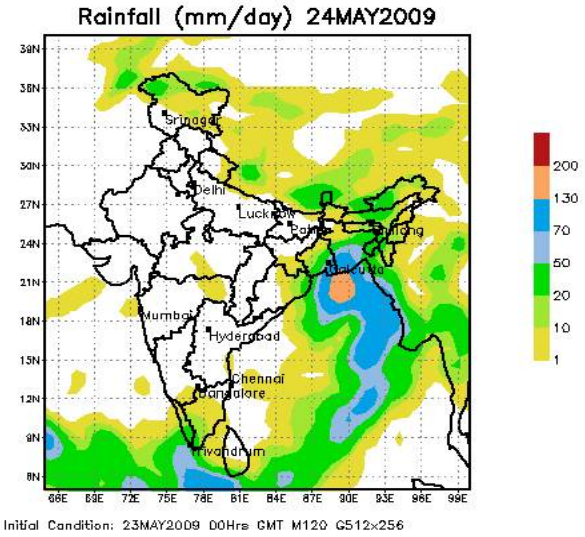
km/hr. The resultant precipitation was model-evaluated before and during the cyclone track entered the zone, as displayed in Figures 4. One can see that the weak/no rain status in the NE on May 23 and May 24 (Figures 4b to 4c) was suddenly flooded with 100mm/day precipitation on May 25 & 26 after the Aila track entered the zone (Figures 4d,e), and precipitation with an intensity of 16mm/hr was recorded through radar/satellite wind map forecast (Figure 4f). as a support to model prediction .



(a).

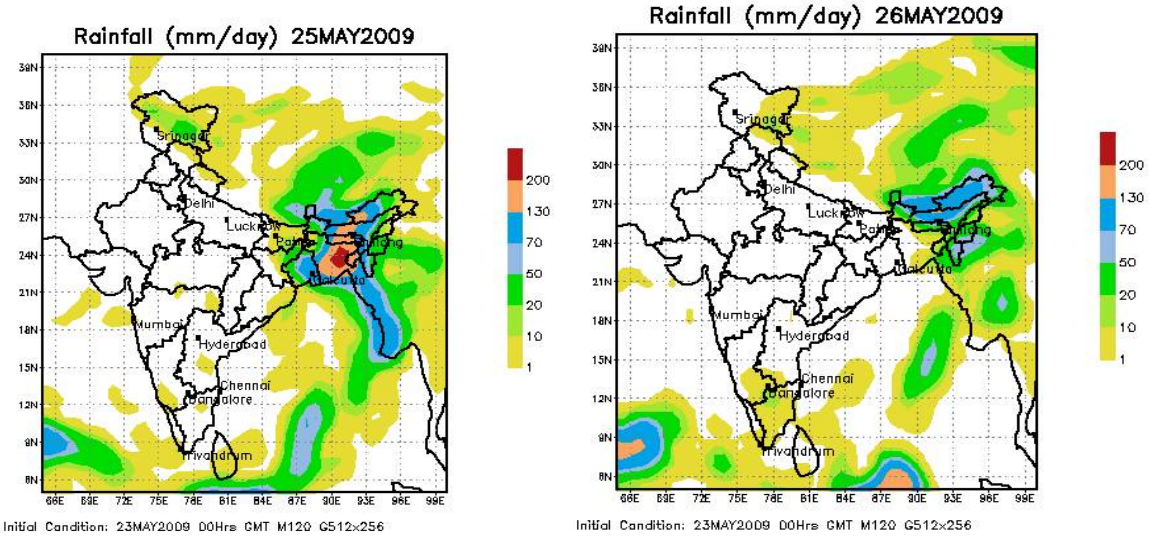


(b)

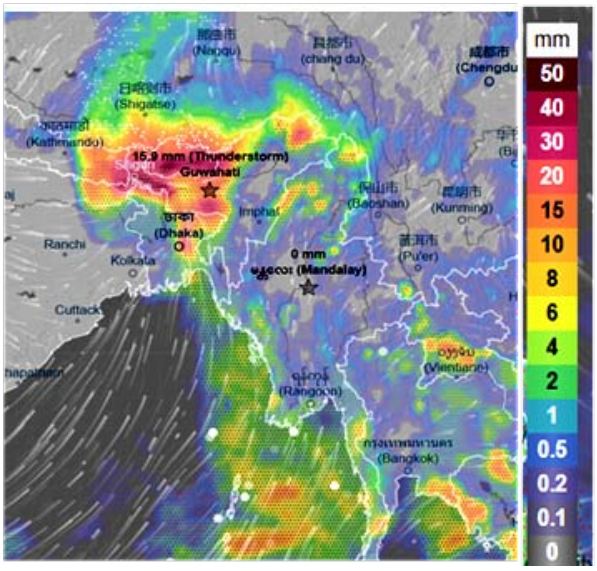


(c)

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(d) (e)



(f)

Figure 4: Mesoscale climate model output : (a) Aila track; b) before Aila track entered the NE , no rain ; (c) weak precipitation induced by sources not related to the cyclone; (d ,e) cyclone induced strong precipitation >100mm/day on 25th and 26 May ; 4(f) Radar Satellite wind model forecast result : strong rain 16mm/hr on May 26 over NE.

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Case 3 :Ramal cyclone

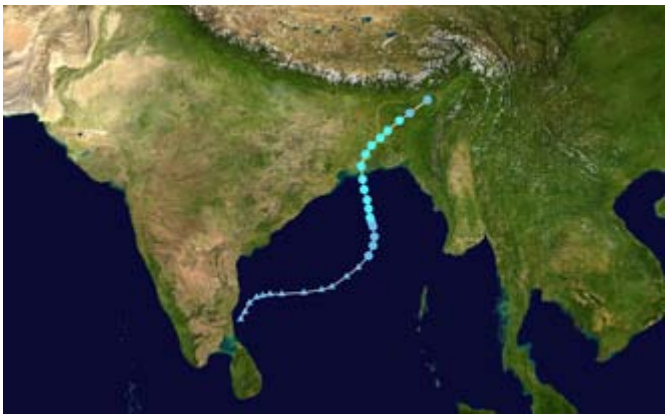


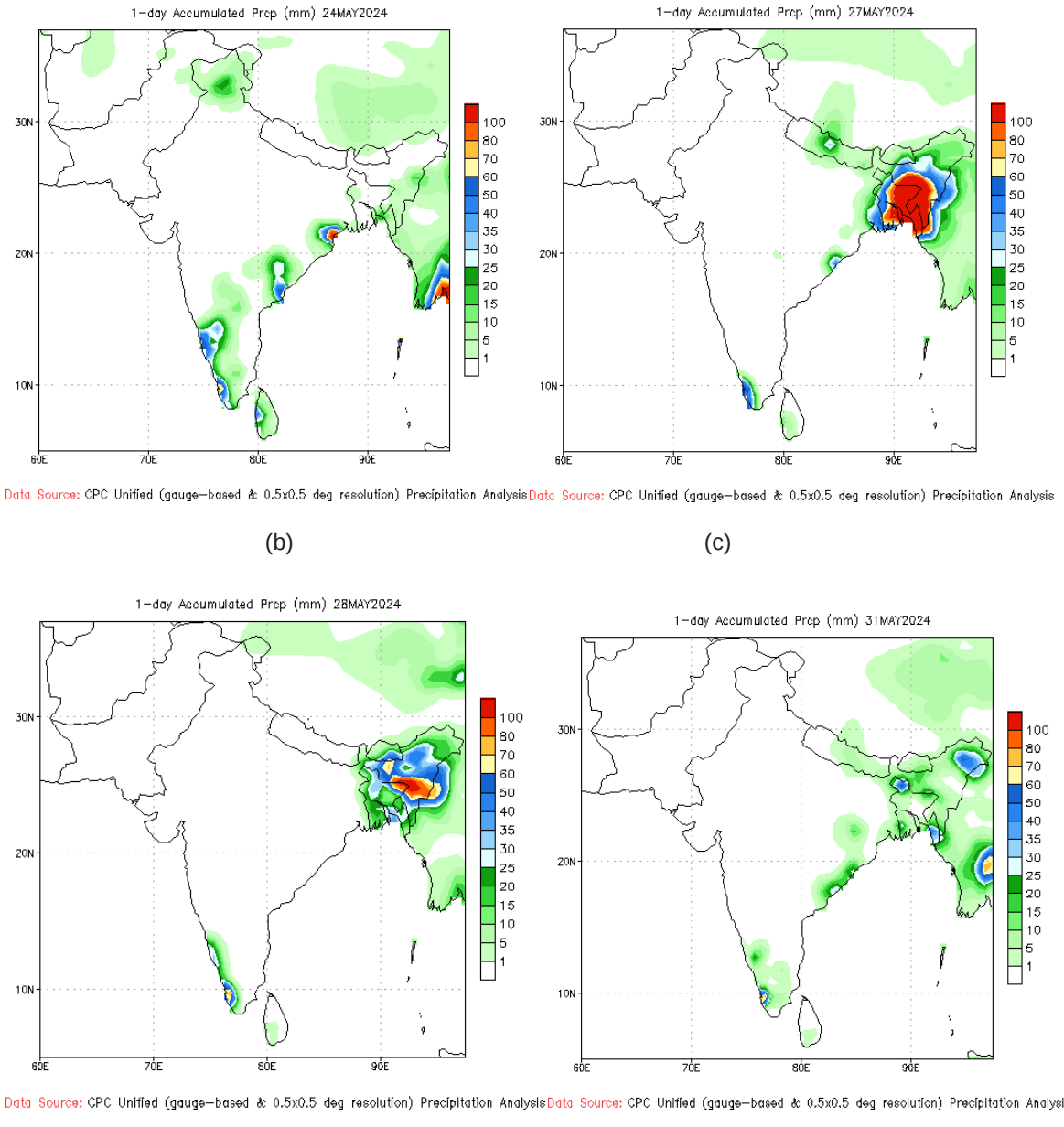
Figure 5(a): Track of Ramal Cyclone

A low-pressure depression formed in the BoB on 22 May 2024 and started moving towards NE and strengthened on May 24 to a tropical depression, which further intensified to a cyclonic storm, Ramal, on May 25. The storm moved further north, strengthened its intensity to a severe cyclone storm on May 26, and then began its landfall in Bangladesh on the same day. On 27 May, it continued to move north, weakened into a cyclonic storm, and finally became a depression on May 28.

The cyclone track while entering the NE region (Figure 5a) brought with it sufficient humid air that resulted in precipitation (Devi et al ., 2025), as displayed in one day's accumulated rain intensity (through CPC analysis) in Figure 5(b) from May 24 to May 31, 2024. The no-rain status of the NE on May 24 (Figure 5b), i.e., before the cyclone track entered the region, suddenly flooded with 60-70 mm of rain on May 27 -28 (Figures 5c, d), and then finally returned to its almost no precipitation status on May 30 (Figure 5e) after total dissipation of the cyclone.

Figure 6 displays 19.2mm/hr precipitation over Guwahati on May 28, the satellite. Radar and wind model results , a clean Ramal Cyclone effect .

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Figures 5 b,c,d,e: One day accumulated rain (CPC analysis) (b) May 24 ; (c) May 27; (d) May 28 and (e) on May 31. Note the effect of cyclone induced precipitation during May 27 and 28 (Devi et al., 2025).

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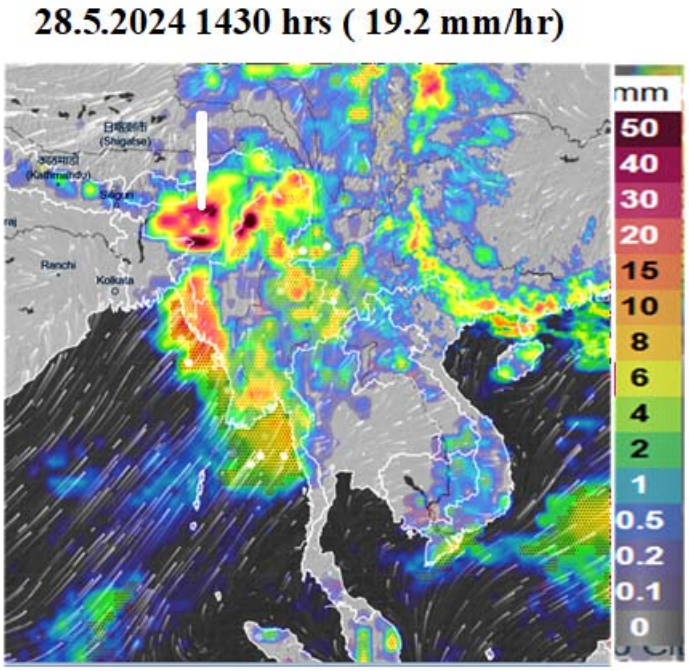


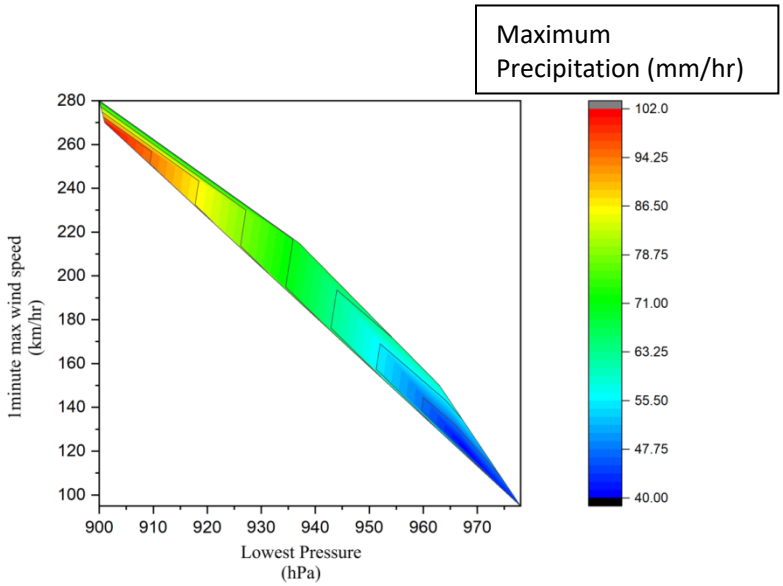
Figure 6 : Strong rain 19.2 mm/hr on May 28, over Guwahati , the study zone ; Ramal cyclone effect (Satellite. Radar , Wind model forecast results)

2.2. BoB cyclone effect to NE environment: Summary of observation: *Wind Speed. Pressure and Precipitation*:

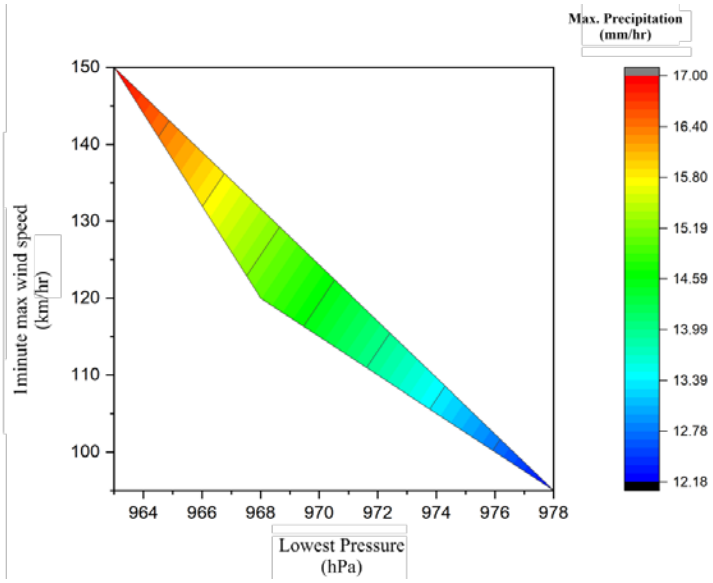
The presence of an inherent relation between the lowest pressure at the cyclone eye and the maximum wind speed caused by evaporation and condensation of moisture resulting in updrafts has been a study topic for decades. The updrafts finally led to an increase in the height of the storm, which causes more condensation and thereby precipitation. We present in Figure 7 the relation between cyclone-time wind speed, the eye pressure (minimum), and the precipitation both at the landfall and at the study zone caused by the BoB cyclones.

The relation is distinct, with the decrease in pressure, wind speed goes high and precipitation rate (average) increases and may go beyond 100mm/hr, based on the core pressure (Figure 7a), and in a landlocked place like Guwahati, it may go beyond 17mm/hr (subject to the eye pressure, Figure 7b).

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(a)



(b)

Figure 7: Relation between 1-minute maximum wind speed, lowest eye pressure, and maximum Precipitation (mm/hr) during BoB cyclone (see Table II) : (a) at landfall area , (b) at Guwahati

The figures, as expected, demonstrate an increase in precipitation magnitude with a decrease in core/eye pressure. However, the situation is rather complex;based on the cyclone track modulated by air pollutants, the aerographic status, and the physical environment of the landfall zone, a few such issues will be brought up in the following articles.

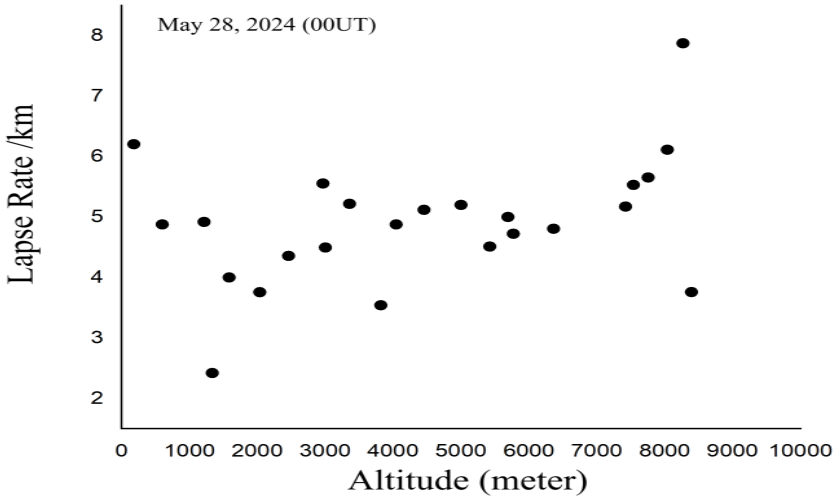
2.3 Cyclonic effect on understanding system dynamics :

2.3.1 Lapse Rate : determination of atmospheric stability

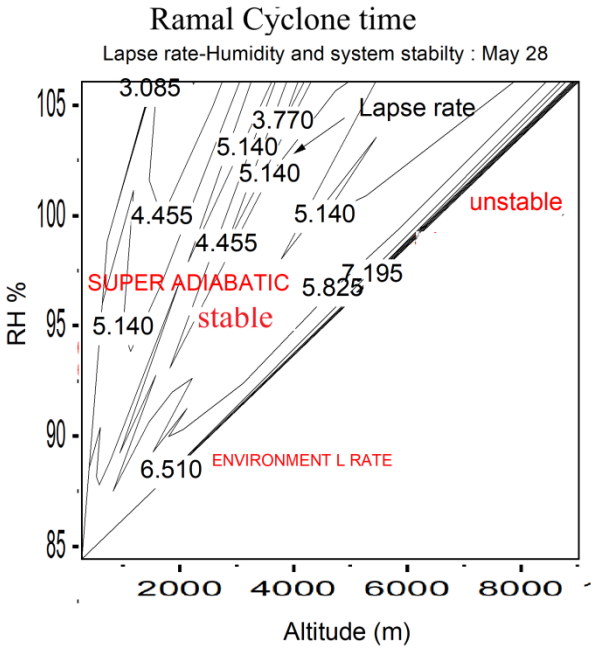
. The lapse rate (LR) provides the status of stability or instability of the atmosphere, a highly sensitive parameter affected by radiation, convection, and condensation, and thus an essential tool to understand the stability of the system caused by a cyclone environment. It is defined by changes in temperature with altitude, modulated by dry adiabatic and wet adiabatic situations, as well as environmental background; its value is dictated by orographic lifting, frontal lifting, and convergence lifting important issues relevant to cyclone-induced system dynamics.

In normal status, the LR value is 6.5 °C/km in the lower troposphere and may be termed the Environment Lapse Rate (δ). But with adiabatic changes of temperature with rising or sinking air parcels, lapse rate varies significantly, and depending on the state of water vapour content, these are termed dry or moist; the difference between the normal lapse rate in the atmosphere and the dry and moist adiabatic lapse rates determines the vertical stability of the atmosphere. In Figures 8 (a and b), we present an example of LR modification by Ramal cyclone (Devi et al., 2025) induced by RH and how, with increase of RH content (almost to saturation) LR drastically changes from normal environmental LR to super saturated moist adiabatic condition of 4.0/km. Around the TTL level, the moist adiabatic status changes because of cooling of the air parcel and release of latent heat as the parcel moves to higher altitudes , indicating generation of system instability. Thus, a cyclone-induced environment provides an artificial laboratory with hazard-time atmospheric variability, which acts as inputs for framing a model suitable for a system.

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(a)



(b)

Figure 8(a and b): Example of lapse rate status during the Ramal cyclone

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2.3.2 Air quality, Pollution, Environment and Cyclone

The contribution of cyclone-carrying wind to the environment is significant both in terms of polluting the invaded area and modulating the background temperature. Devi et al. (2021) have shown how, during Amphan, the temperature over the study zone suddenly decreased along with the clean air carried by the cyclone wind during the COVID-19 protocol lockdown in the Indian continent. Figure 9 shows the relation between pollution (anthropogenic) and temperature during this period. The significant issue is the drastic decrease in temperature from 22 May (Figure 9), with the Amphan wind carrying pure air to this region, when absorbing-type aerosols generated through human activities were virtually absent due to the lockdown.

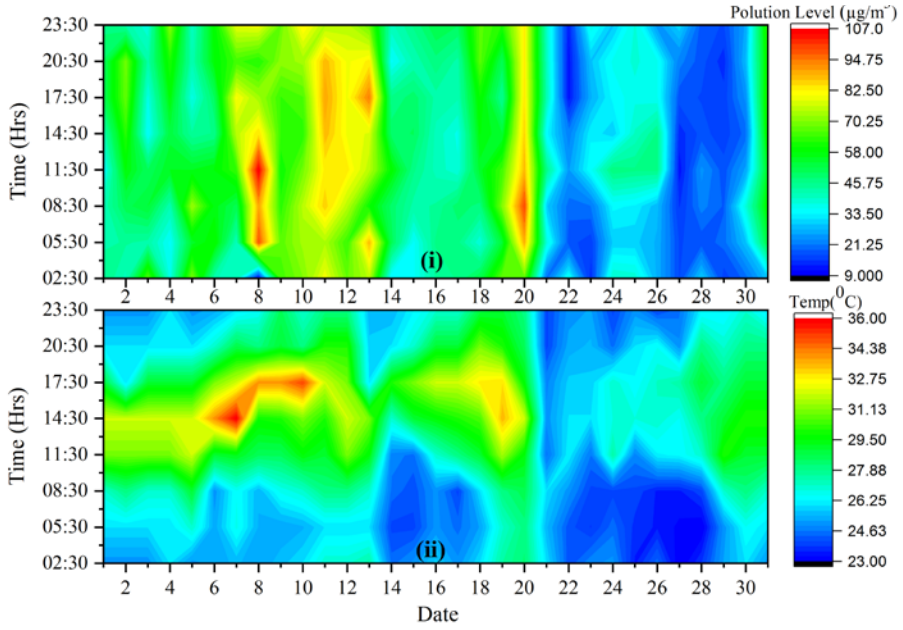
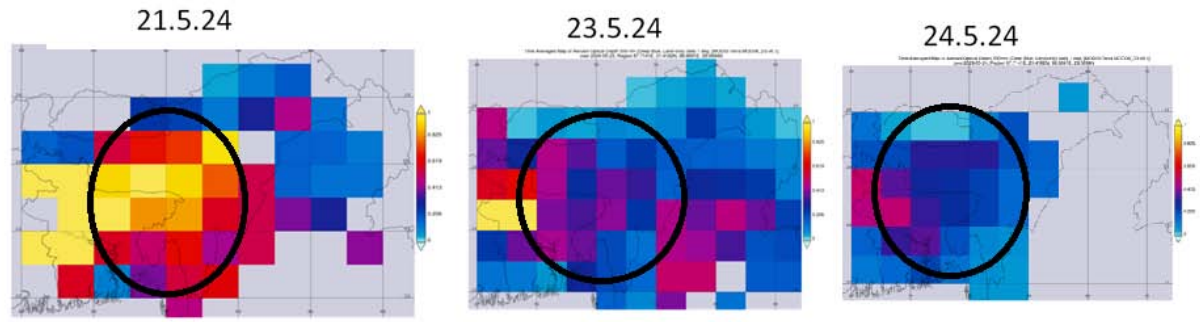


Figure 9: Pollution in µg/m^{3}and Temperature in ^{0}C for May 2021 over Guwahati. Note, the presence of strong correlation between pollution and temperature from May 21 to May 30.during Amphan cyclone (Devi et al., 2021)

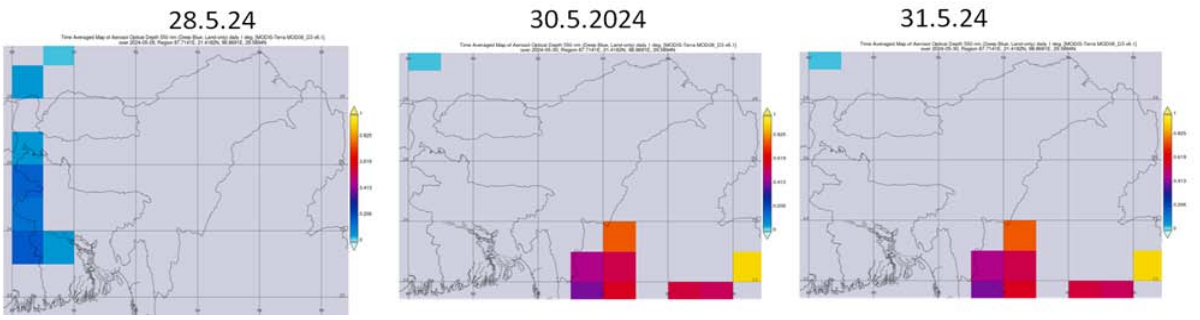
Devi et al., (2025) have also demonstrated that the cyclone-induced heavy precipitation could bring relief from the contaminated air, as the MODIS aerosol map (AOD) during Ramal Cyclone shows (Figure 10) how existing pollution over the study zone, which includes sources of fossil burning, a large contributor to WSOA (Figure 10a), is washed out, making the environment

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free of the contamination (Figure 10b) while the Ramal Cyclone track entered this zone.



(a)



(b)

Figure 10: MODIS AOD map (a) before Ramal cyclone track entered NE and (b) aerosol depletion level after the track reached the zone (Devi et al., 2025)

Under this background, we will bring the SCS Typhoon-induced resultant modifications to the atmospheric environment over this area , with special reference to a recent typhoon, Bualoi, a category 2 event.

4. South China Sea (SCS) Typhoon

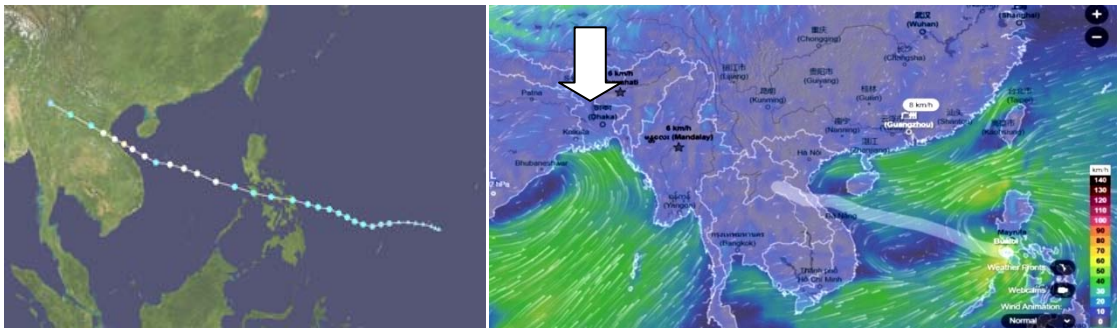
Unlike the emerging contributions of BoB cyclones to weather-related issues in this zone, as highlighted here, the weather or environmental modulations by SCS typhoons were yet to understand, and this is our first such case study with a recent typhoon, the Bualoi, that occurred in the SCS during September 2025 (see Table III)

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Table III
SCS typhoon : case study

Bualoi South China Sea	Lowest pressure :967 hPa Formed : 22September 2025 Dissipated: September 29.2025	Category 2 typhoon	1minute sustained speed 155km/hr

The Bualoi, the Category 2-equivalent typhoon with one minute highest speed of 155 km/h and lowest pressure of 967 hpa, (85 mph) , originated as disturbance north of Yap on September 22, made a final landfall over Hà Tĩnh on September 29 and started decapitating on September 30 (Figure 11).



(a) (b)

Figure 11: Typhoon Bualoi (a) track (b) Location of study area marked by an arrowhead

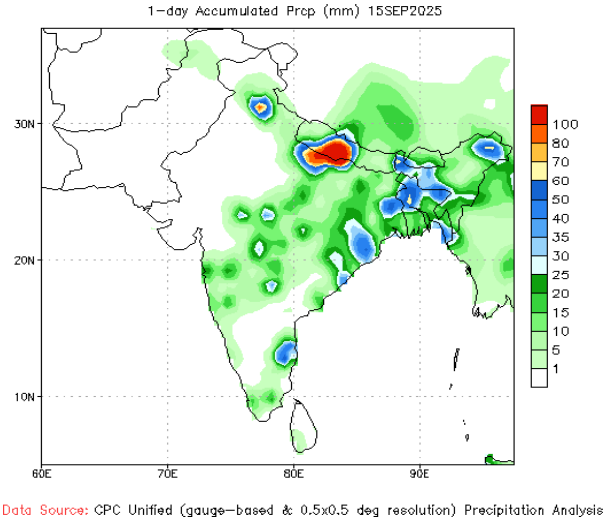
4.1 Bualoi Typhoon, atmospheric environment and dynamics in NE :

The fundamental parameters and components modulating atmospheric environment and dynamics, by cyclone carrying wind are sea aerosols and green house gases like water vapors , obviously polluting the background in general (based on type of aerosols), and bringing torrential precipitation, as presented here in BoB involved cases . Bualoi- time precipitation

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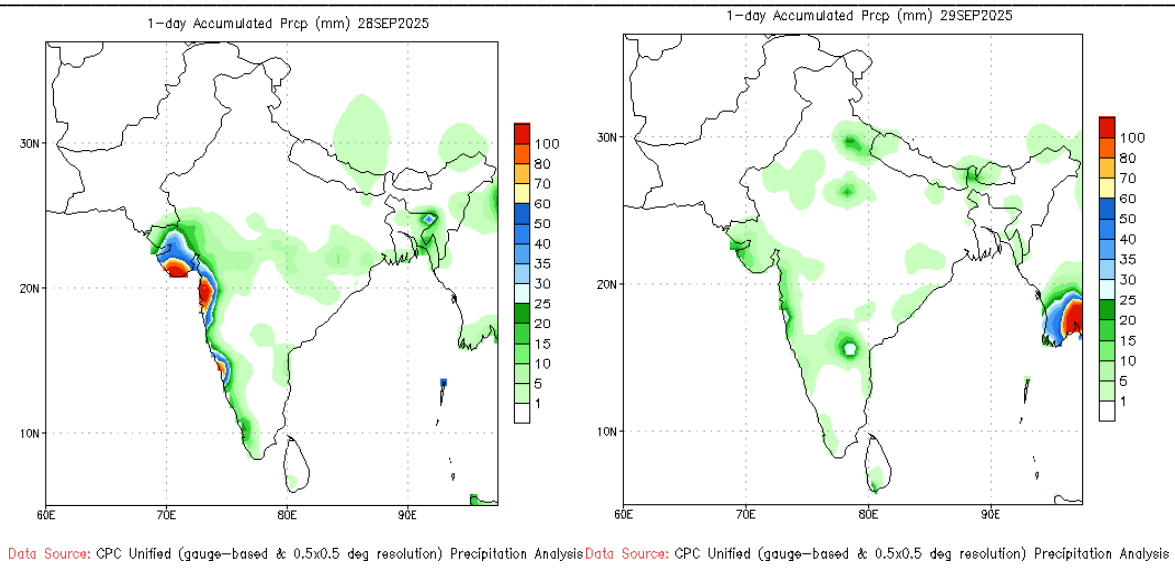
scenario at least in the study area with practically no rain or rather generating a dry spell with the entry of the Typhoon tack , is significant, as the daily accumulated rain (CPC analysis) map revealed (Figure 12) that the typical daily accumulated precipitation magnitude of 35/40 mm (Figure 12a) of this month , resulted to a draught like situation (Figures 12 b, c) during September 28 -29 after the landfall of the Bualoi and Typhoon wind entered the zone.

Similar are the scenarios in anomaly in weekly precipitation on these days, when accumulated magnitude of excess precipitation (Figures 13 a ,b), suddenly displayed deficit with the entry of the typhoon wind track (Figures 13 c, d) to the NE zone.



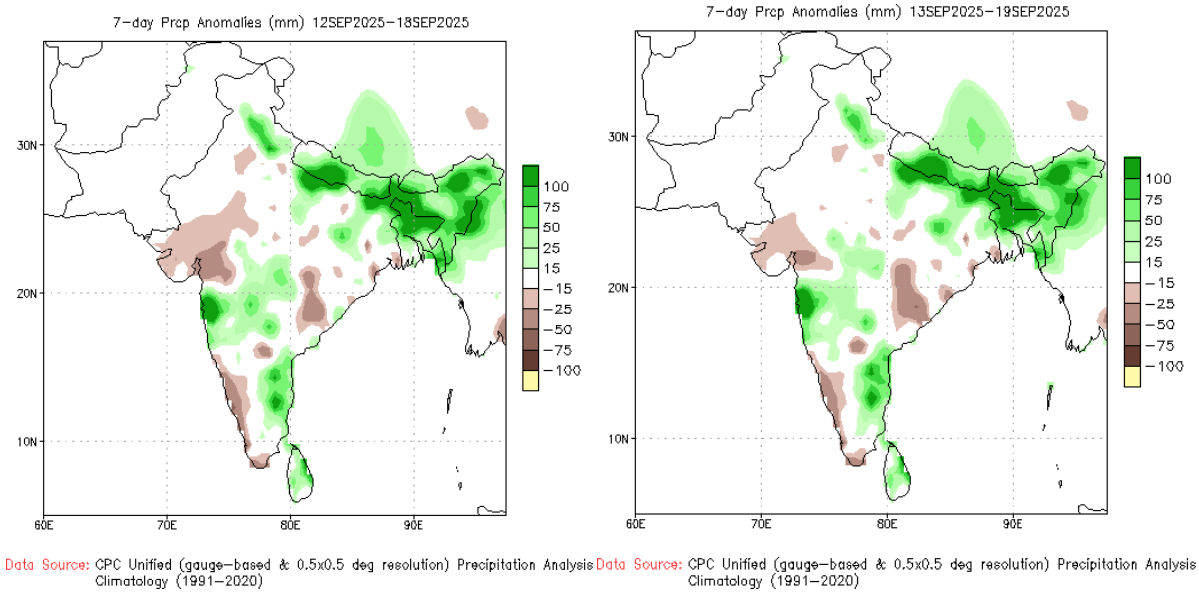
(a)

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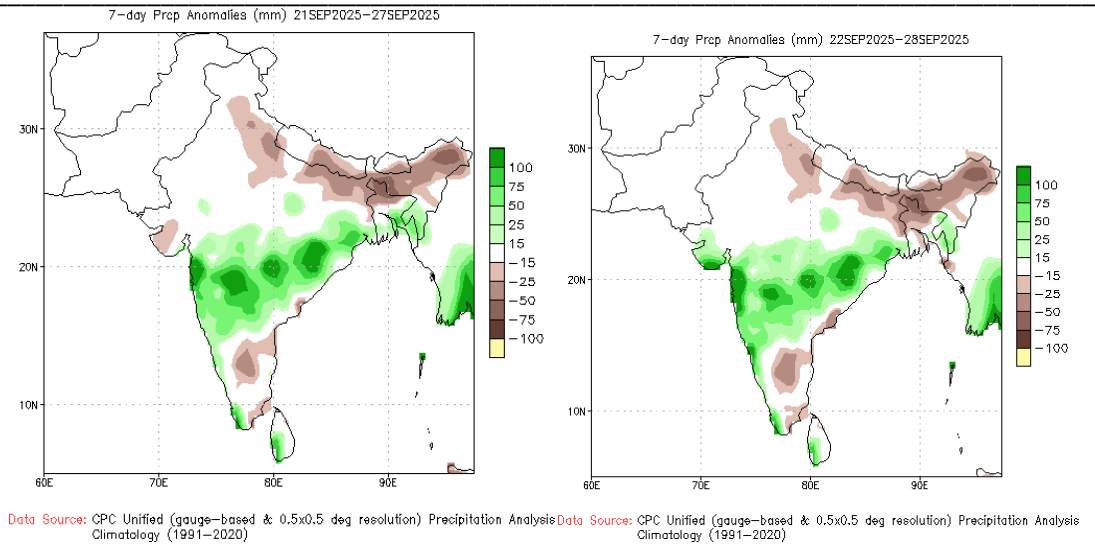
(b) (c)

Figure12 : Daily accumulated precipitation : (a) September 15 , note the normal precipitation over NE before Bualoi Typhoon track enters ; (b,c) September 28, 29 after the Bualoi landfall and wind flow induced effects at NE , with deficit in precipitation.

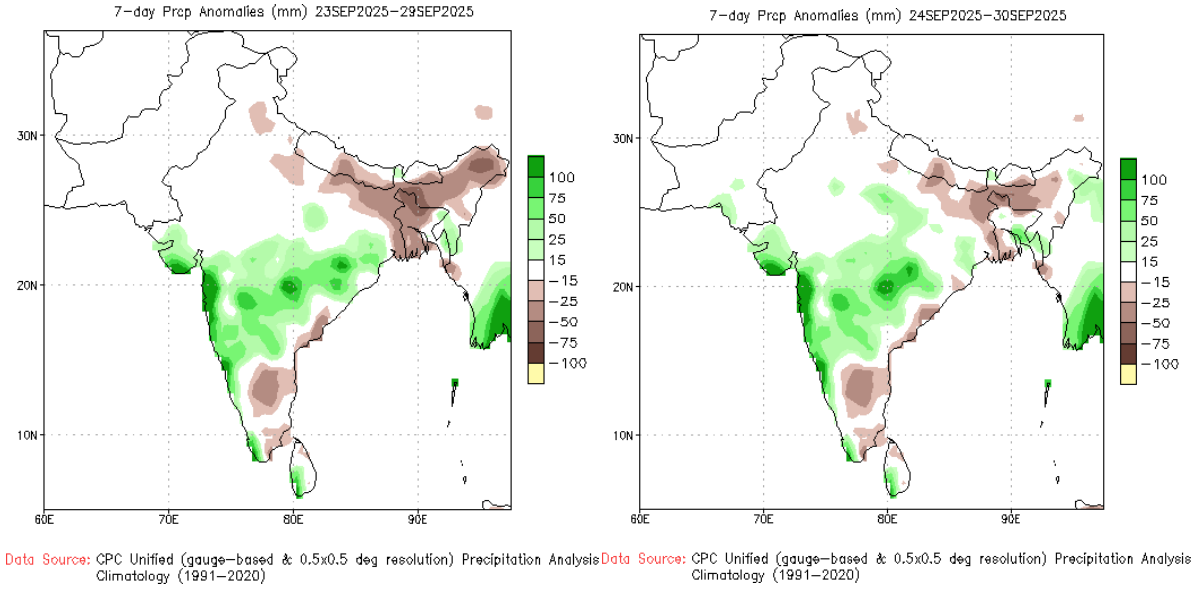


(a) (b)

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(c)



(d)

Figure :13 Anomaly in weekly precipitation over NE; (a .b) Excess precipitation before typhoon induced wind effect ; (c,d) deficit in precipitation in NE on entry of typhoon wind flow to the zone.

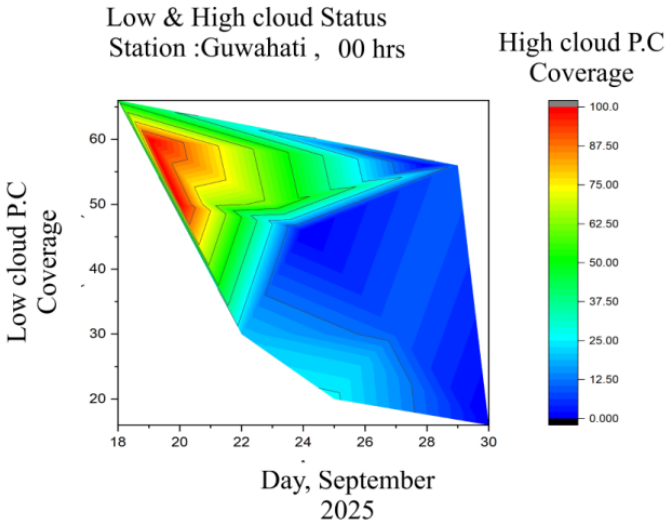
With the minimum core pressure strength of a cyclone, the precipitation severity increases as we have already demonstrated, and under this background , the Bualoi a category 2 typhoon with 966 mb minimum pressure and 150km /hr sustained wind speed should brought an average of 10 -12mm/hr rain to this region if it follows the BoB induced precipitation map between these indices (Figure 7) , which was not the case as we see. Thus there are other instrumental parameters to be considered and brought in to views like the topography of land fall area , background pollutant, track distance, and factors involving atmospheric and meteorological parameters possibly affected by a typhoon : a few of such factors and issues are now taken up .

Convective Status :

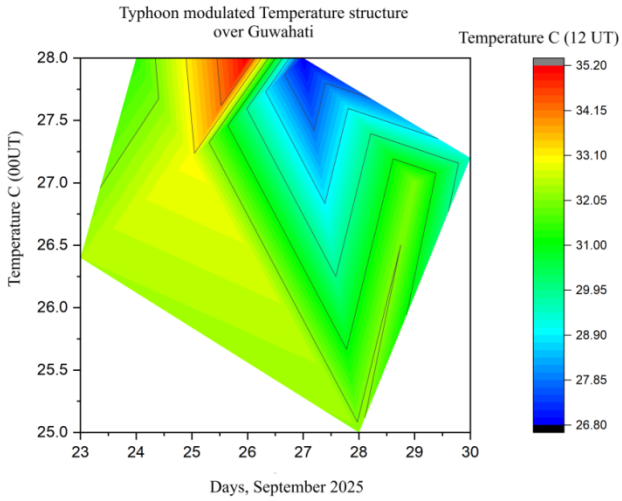
One of the approaches to understand the presence /absence of green house components carried by the typhoon track to the study area is to evaluates the convective situation, by mapping the P.C coverage of high and low clouds over our interested location . The analysis conducted during the relevant periods as presented for 00 hrs (UT) and 12 hrs (UT) in Figure 14, displays absence of high convective clouds from September 27, over our focused area, which goes in support towards the generation of draft like situation (Figure 13) at these locations which also support that less green house component was carried by the track (Figure 14a) . The temperature modulation of Figure 14b also a corroborator to this result

However other factors like wind trajectory path , topographic environment, and the path geometry of landfall to the study location, are equally important issues to be considered ; we present now model evaluated wind trajectory while traversing from the source to the study area in the next article .

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(a)



(b)

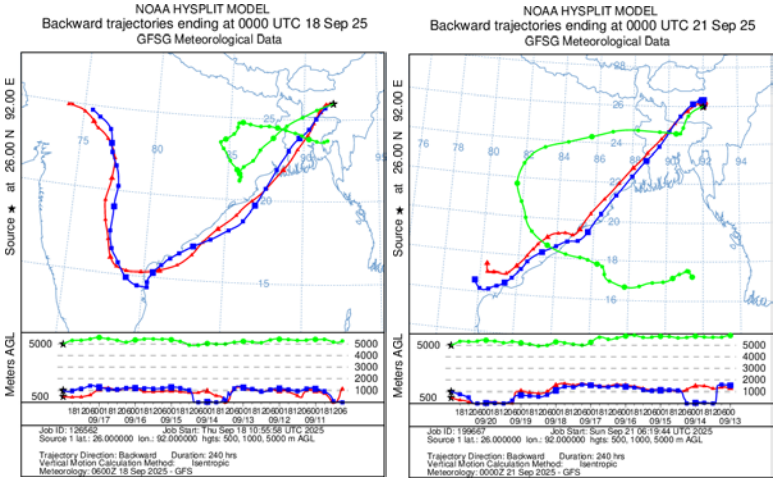
Figure 14. The convective status during Typhoon track entered the study zone (a) Cloud type availability (b) modulation in temperature (00 UT and 12 UT)

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4.2 Model computation of wind trajectory

To understand the mode of wind flow direction to this zone , we compute the wind trajectories (backward) to the study location, adopting the Hyper split wind flow model of NOAA which was regularly run at least three altitude levels, and an exclusive analysis on the wind flow path with embedded features on it for the Bualoi period, is presented below .

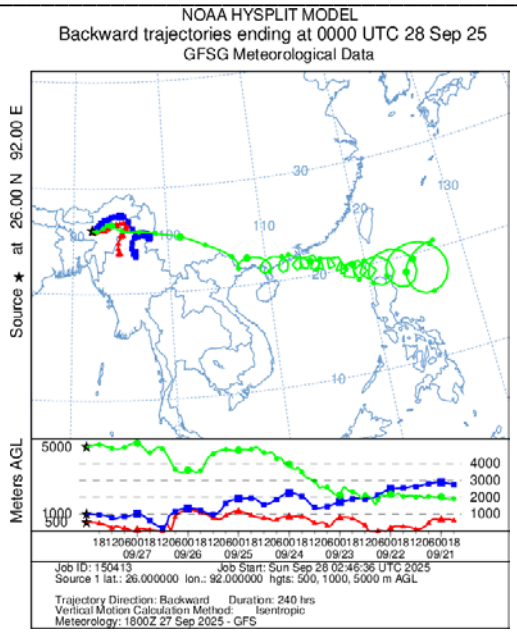
Before computing Bualoi- period wind circulations mode, we first display in Figures 15 (a and b) normal wind flow tracks to this area during September, which we see are significantly from the BoB resulting to precipitation (one of the wet air sources). But on entry of Bualoi track to this region, the wind trajectories to NE get modified and a strong wind component from the East a very rare flow with clear modulated structures in the wind profile did penetrate from around 100° E longitude and 20 °N, after the land fall of the Typhoon during September 28 to 30 (Figures 16 a, b, c). The structured modulations in the profiles displayed in Figure 17 are the result of pressure undulations varying from 20 Km to 200km in dimensions controlled by its gradient (Figure 18), strongest the gradient larger the pressure structure. Significant is the absence of wind flow from the BoB during this period.



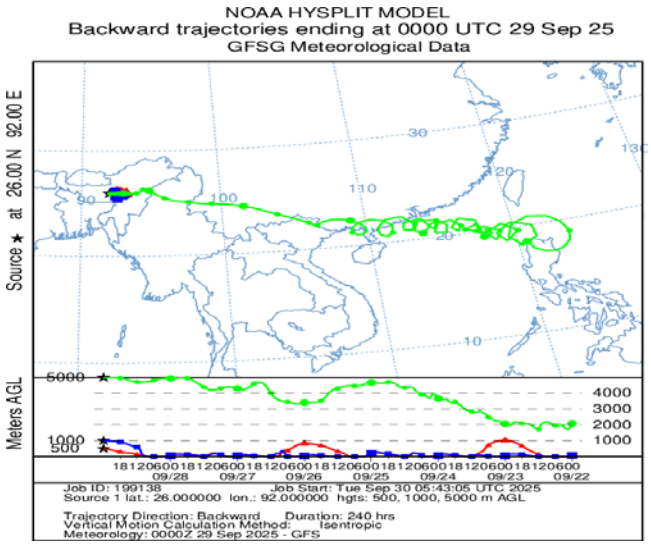
(a) (b)

Figure 15: NOAA Hyper split wind trajectories that display wind flow paths ; (a, b) Normal September environment : source mainly the BoB

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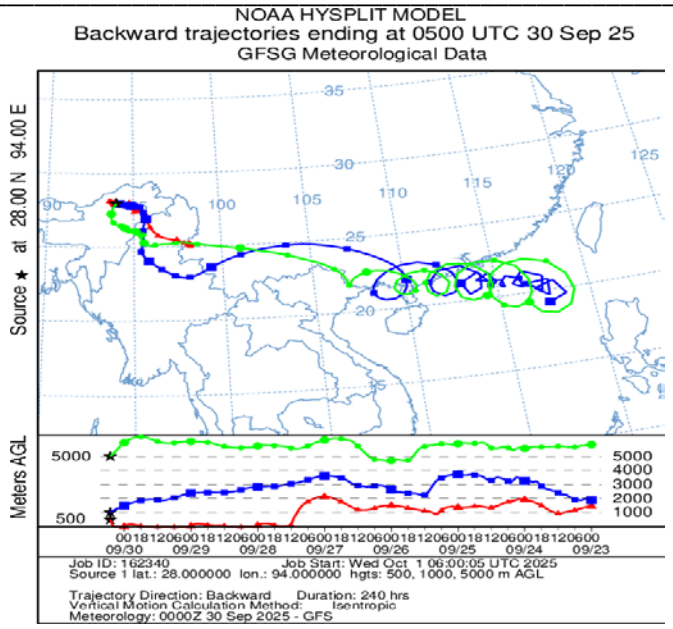


(a)



(b)

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(c)

Figure 16 (a.b.c) : NOAA Hyper split wind trajectories that display wind flow paths on entry of Bualoi trajectory to the NE zone after its land fall . Note that the wind trajectories from source to the study zone show periodic structure in the track , also rare cases of eastward wind to the study area .

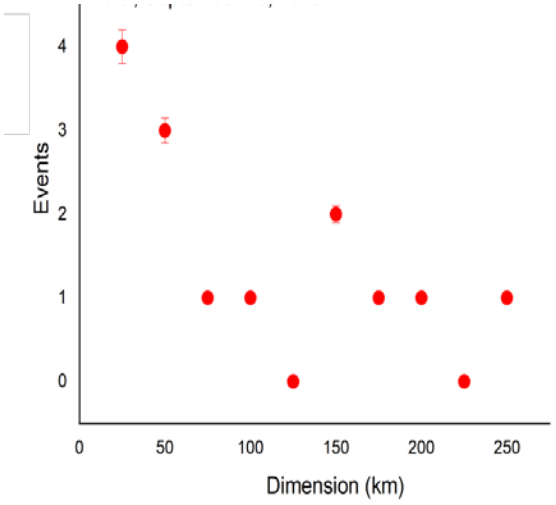
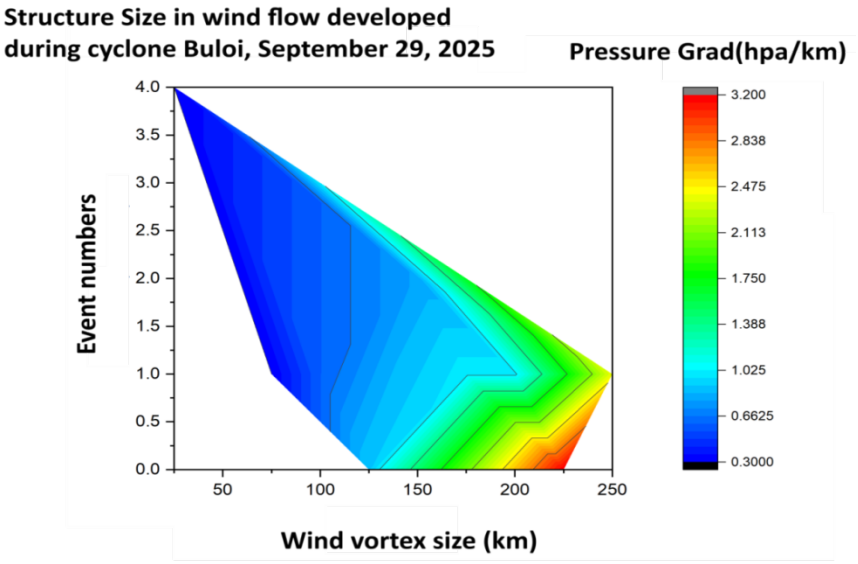


Figure 17: The structured modulations in wind trajectories , 29 September 2025

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..Figure 18 vortex structure in wind trajectory along with pressure gradient

A few more issues like land fall area topography and track path physical environmet their role in atmospheric dynamics will be brought in to ambit of discussiion

5.0 Discussion :

Cyclone intensity is controlled by air-sea interacting exchange process and there are innumerable reports specially on tropical cyclone –atmosphere-ocean interaction , thus the SST is an important factor in dictating growth environment of a TC. Study shows how the contributions of aerosols are significant components on SST modification and global warming and that the presence of pollutant can result to both positive and negative anthropogenic involvements to the strength of a TC (Schadel 2000; Ginnis 2002; Vecchi et al., 2006**;** Vecchi and Soden 2007; Cotton et al., 2007; Khain et al., 2008; Zhang et al., 2009; Xie et al ., 2010; Krall and Cotton 2012; Walsh et al., 2019). It is thus considered essential to examine the influence of suspended particles on cyclone induced effects , when Devi et al., (2021) have shown that Amphan had provided a unique artificially reduced pollutant state of environment through lockdown over Indian subcontinent, which brought cooling effect along its track (also see Figure 9).

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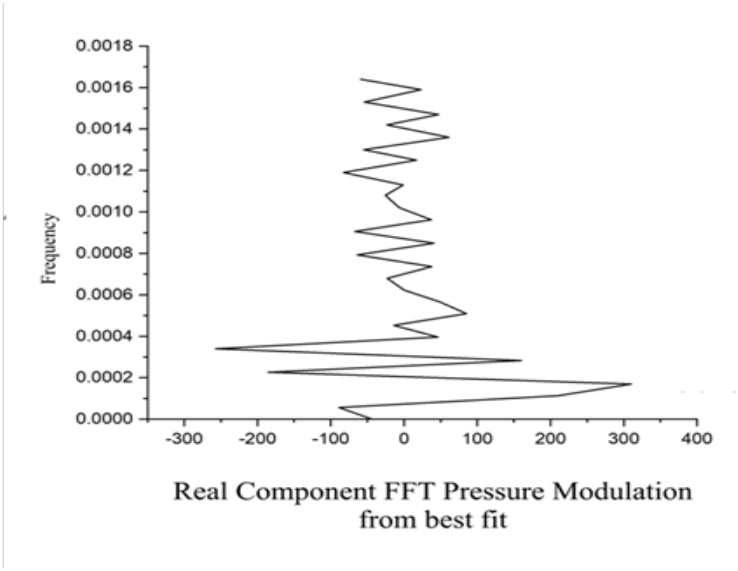
One of the most serious issues of today is green houses gas contributions to the drastics changes in global climate, where water vapour is one of the strong components. Because enhancemnt of greenhouse warming goes with increase in concentration of water vapour which provides positive feedback and less amount of water vapour results to ngative feedback and thereby inhibiting the wraming process. Therefore cloud has a signifucant role on it either through positive or negative feedback process,where water vapour is an in built component of formation of cloud. We refer here two types of clouds, low level (bright) one reflects sunlight , thereby prevnting the sumlight to reach the earth resulting a negative feedback, reducing green house warming (in global view) and high level convective clouds which absorbs heat from earth at higher temperature than they radiate to the space amounts to trapping of energy i.e., helping in greenhouse warming (global view). We observed here how Typhoon induced responses to the environment provide inputs for understanding dynamics of the system, when Bualot track brought less green house component lowering the presence of convectie cloudes and with negative feedback brought down the temprrature even in deficit to precipitation status .

Aother significant issue regading system modification by typhoon induced wind as presented here (through wind flow model), is the development of vortices in wind profiles while the wind traverses from its sources to the SE Asia and finally to the study zone. The structure size of the vortices may vary from 100 km and decreases as moves away from the source . The wind vortices being prominent at altitude > 1000m, provide an evidence of the effect of horizontal pressure variation along its path that plays the crucial role (Geostropic wind) where effect of surface can be neglected and when corriolies force $=\cap X \cup$ arises as a consequent of air parcel moving .The effects of the air parcel flow to the NE environment, result to modulations in vertical pressure gradient and consequently to the wind structure , as supported by good synchronizations of FFT components, between the two profiles (Figure 19) representing pressure modulation in track path and vertical wind modulation .

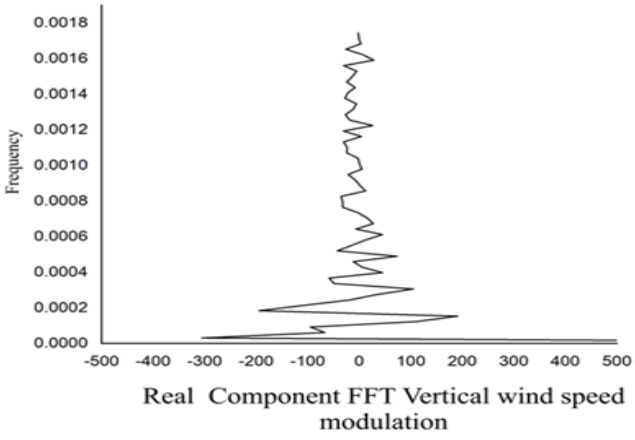
The relatively weak precipitation either in the one day accumulated result or in the weekly accumulated profiles and also the absence of strong convective processes reflected in the environment-cooling by the typhoon track over the NE region, is the result of relatively dry air

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parcel that wind track brought with it which was unlike the moist air track of the BoB generated super cyclones .



(a)

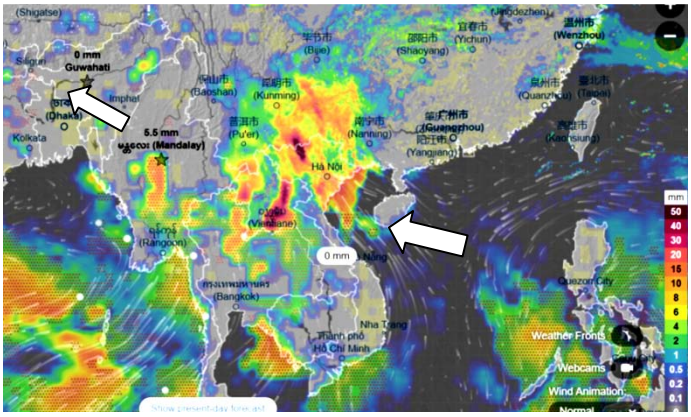


, (b)

Figure 19 : Synchronizations of FFT components, between those developed in pressure gradient and vertical wind structure profiles. (Frequency is in Hertz)

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The absence of precipitation in the studied location by Bualoi also has a strong topographical background of the land fall area (Figure 20) . The strong precipitation as we see around the land fall zone of Bualoi (Figure 20a) , is the typhoon effect carrying humid air, but its magnitude gradually recedes as the track moves towards North along the hilly terrain , resulting virtually less humid content as it reaches further north to the North East India. Equally important is the synchronization in the periodic component of the wind modulation to the study zone with pressure variation in the track path Thus the track direction and topographical aspects around tits path equally controls the ocean atmospheric dynamics . In this context we bring that a weak storm (depression) that develops in the ARB brings precipitation to NE (Figure 20b), traversing around 2000 km over a reasonably flat terrain. Singh (2024) in recent presentation on such issue pointed out significant warning on the effect of ARB cyclone to the NE environment .



(a)

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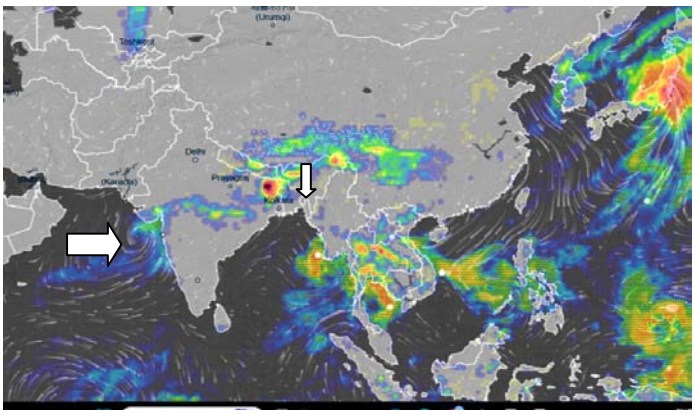


Figure 20 : (a) Terrain status of Bualoi Typoon track path and (b) that of ARB cyclone track (depression) to the NE zone of India

Finally the paper, as a first such case study on SCS typhoon , presents that even a category 2 events, originated in South China Sea has its effects beyond its land fall zone by modifying the pressure gradient , developing wind structure and modulates the temperature bringing less green house component Significant of the study is that we see how the Easterly wind to the NE zone plays a prominent role in understanding Ocean - atmosphere dynamics . It is also important that our exercise of wind modeling is based on isentropic process, thus ideal thermodynamic cycles conception is applicable and the observed growth of wave structures in the wind profiles may supplement added inputs for framing of reliable hazard time wind model specially for this zone As a future plan ,more cases will be taken up in association with observations from SE Asian station that falls along the wind trajectory ; important because our study area falls on South East Asia in physical environment rather than South Asia (Figure 21). Further, considering the strategically vulnerable position of the NE towards atmospheric and weather modulation by all the hazard sources be thunderstorm and cyclone (Devi et al., 20216; Devi et al., 2020 ; Devi et al ., 2023) it is planned for a comprehensive study through Nano satellite observations along with the platforms taken up here.

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Figure 21 : Physical/Topographical environment of Bualoi induced wind trajectory path to the NE zone of India .

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