Warming Impact On Air-Sea Heat Flux And Cyclone Heat Potential Over Bay Of Bengal

Mohammedali Nellayaputhenpeedika, V. Radhakrishnan

Abstract: Cyclones in Bay of Bengal (BoB) are distressing natural catastrophes that affect people, coastal ecosystem and property. Warming of BoB modifies heat flux variables and raises cyclone potential to higher extent. Analyses of Optimum Interpolation Sea Surface Temperature (OISST) data from 1981 till 2014 and Objectively Analyzed air-sea Fluxes (OAFlux) data were carried out in pursuant of air-sea heat flux and cyclone heat potential. Long term trend analysis between warming of BoB and cyclone heat potential was carried out. It is found out that the temperature of BoB and cyclone heat potential are increasing. Warmer atmosphere hold more moisture than that it could convey latent heat to atmosphere. Higher sea surface temperature (SST) increases heat flux, as a result, ocean stores more heat energy. Spatial analysis shows higher cyclone heat potential in North-Western side during April and North-Eastern side during October.

Index Terms: Warming, Bay of Bengal, Sea Surface Temperature, air-sea Heat Flux, Latent heat flux, Tropical Cyclone Heat Potential, Cyclone.

1. INTRODCUTION

Tropical Cyclones (TC) are the low-pressure wind systems, which form over tropical oceans. In BoB, predominantly cyclone occurs during pre-monsoon and post-monsoon periods which have strong changes in air-sea interaction and surface temperature variability [15]. BoB is one among the warm oceans and account for large number of cyclones globally, which encompasses more destructive and devastation character, deadly storm and heavy rain fall creating massive destruction [5]. Warming renders cyclone unpredictable. BoB regime countries face significant challenges due to increase in intensity of recent cyclones; in recent times unexpected changes in intensity level create mass destruction. BoB cycloneic impacts and huge damages are due to interlocked geographical location, bathymetry features, low-laying coastal terrain and dense population. SST of about 26.5°C or more required to form a cyclone; also warm ocean acts as an energy source producing more latent heat than that required to create low pressure gradient system inside cyclone core area [11], [5], [9]. SST is very important for the formation of cyclone; studies have shown that TC intensity strongly depends on SST [13], [10], [18]. The spatial variability of the SST in the TC has a direct impact on latent heat flux (LHF) and sensible heat flux (SHF) [13]. The tropical cyclone heat potential or the abundance of upper ocean heat energy is one of the important factors that enhance the intensity of cyclones [1]. Extensive studies in the BoB cyclone activities and warming use different approaches. An increasing trend in the frequency of intense TCs observed over the North Indian Ocean [17]. Previous studies show a decreasing trend in frequency of North Indian Ocean cyclones [12], [14]. Ocean upper layer heat content is very important for cyclone formation and intensification. The process of physical system that related to cyclone propagation and dissipation is very complex in nature. It is a hard task to predict cyclone intensity. However the thermal structure of the upper ocean is more critical and sensitive predictor for cyclones compared to SST [16].

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Intensification of cyclone is mostly related to upper ocean heat storage known as Ocean heat content (OHC) or tropical cyclone heat potential [4]. The aim of this research work is to inspect the alteration in cyclone heat potential due to warming of BoB and how ocean heat flux associated with cyclone heat potentialThis study conducted a comprehensive analysis over BoB sea surface temperature changes due to warming and its associated changes in heat flux and cyclone heat potential. Outcome of present study listed as follows.

1) Detection of warming using SST time series and spatial trend analysis during 1984-2014.
2) Changes in BoB heat flux due to warming through OAFlux air-sea data analysis.
3) Role of heat potential on cyclone and impact of warming.

2 Data and Methodology

Cyclone climatology has been derived from IBTrACS (International Best Track Archive for Climate Stewardship) data, which is known to be incredibly precise. Monthly climatology of cyclone number (Fig. 2) is derived using adding cyclone for each month from 1984-2016. Spatial and time series trend computed from Monthly mean of 1/4 Degree monthly Optimum Interpolation Sea Surface Temperature (OISST) using AVHRR. Heat flux calculateon derived using Objectively Analyzed air-sea Fluxes (OAFlux) data, which subject to multi-decade, global analysis of air-sea heat and momentum fluxes for use in studies of global energy budget with resolution of 1°×1° latitude/ longitude. The objective analysis denotes the process of synthesizing measurements from various sources [19]. Such process reduces error in each input data source and produces an estimate that has the minimum error variance. The OAFlux products are created from an optimal blending of satellite retrievals and three atmospheric analyses.Cyclone heat potential downloaded from the link https://bhuvan-app3.nrsc.gov.in/data. Tropical cyclone heat potential is estimated using (i) sea surface height anomaly from the available altimeters, (ii) SST from Tropical Rainfall Measuring Mission (TRMM) Microwave Imager (TMI), and (iii) the climatological values of the depth of the 26°C isotherm (D26) using Artificial Neural Networks approach.

3 RESULT AND DISCUSSION

3.1 Cyclone Track

BoB is the place that source many deadly cyclones in the past. Fig.1 shows track of cyclone that between 1984-2016 over BoB. Bathymetry map (Fig.1) shows that most cyclones hit in Indian Coastal states where steepness of coastal structures make higher damage. Many Tropical cyclone formed between 5° N to 16° N latitudes and it made landfall over coasts of India, Bangladesh, Myanmar, and Sri Lanka[3]. In recent times cyclone movement is in unpredictable way due to warming of BoB. Warming trend in Fig.3 (b) shows Northern BoB is warming in alarming rate, and its influence on cyclone intensity. There is an escalating trend in accumulated cyclone energy (ACE) in north Indian Ocean (NIO), cyclone intensity with wind speed > 64 knots have notable increase [2].

3.2 Warming of BoB

BoB is warming more rapidly; SST of BoB show significant positive trend since 1960 [7]. Warming of BoB calculated using OISST which contain extended data from 1981-2014. Trend derived from the analysis of OISST show BoB warming at the rate of 0.001 ^{0}C/yr, which show BoB is warming at the distressing rates. BoB have many river input in Northern side, SST show low in that region due to excess fresh water from river. Spatial trend analysis demonstrates northern BoB is undergoing warming at the high time, also southern region also positive warming trend. Warming of BoB has an effect on air-sea interaction pattern, in addition to which affect climate variability. In general Northern BoB have coolest water due to inflow of many rivers, but result shows higher rate of warm occurring in Northern side and South-western side.

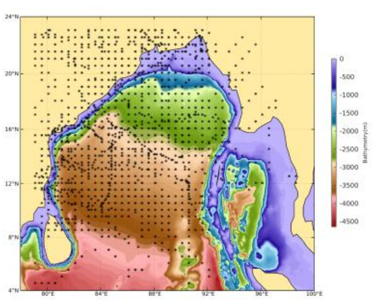

Fig .1. *Cyclone track in BoB during 1984-2016.*

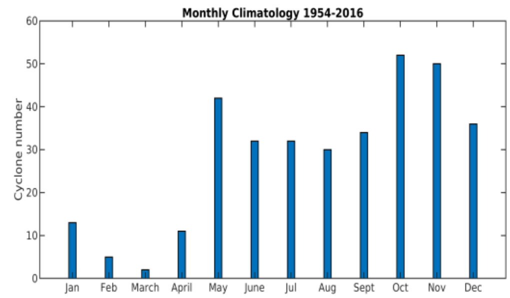

Fig .2. *Monthly climatology over BoB based on Cyclone number during 1954-2016.*

3.3 Air-sea heat flux

Warming directly alter air-sea latent and net heat flux; create higher air-sea difference leads to loss of heat to atmosphere at the higher rate. Latent heat is the amount of heat that release after condensation. Latent heat flux plays an important role in understanding and modeling the exchange of heat and moisture between air-sea. Surface latent heat changes is associated with SST and surface wind, both of them have equal important, observed an increasing trend in the Latent heat flux over the tropical and subtropical oceans [8]. Warm water evaporates more, further evaporation increase condensation rate and latent heat release.

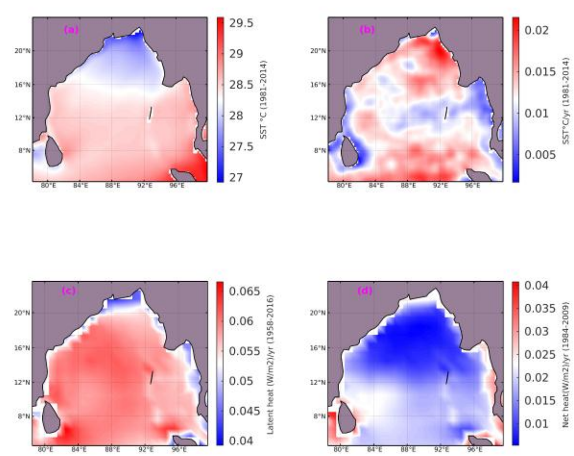

Fig .3. *Long term spatial trend derived using OISST 1981-2014 and OAFlux data.*

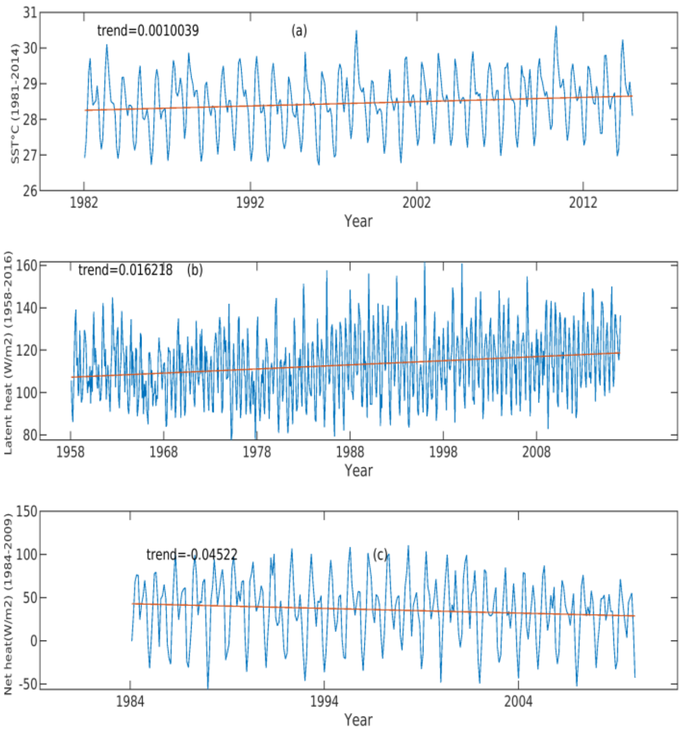

Fig .4. *Long term time series trend derived using OISST and OAFlux data.*

Net heat flux loss in BoB is rising due to higher sea surface temperature. In Fig.3 (a-c) shows an increasing trend for SST and latent heat, also Fig.3d shows net heat loss is increasing at the rate of 0.045 w/m^2 per year, which is a higher rate. Net heat loss is achieved through latent heat, sensible heat and long wave radiation, all of them undergoing considerable changes during warming climate. Spatial image shows Fig.3(c) more latent heat trend is observed in North-western side and South-western side. Also observed higher latent heat trend in central part of BoB, which indicate storage of higher heat content and rise in air-sea difference due to warming of BoB.

3.4 Cyclone heat potential

Ocean heat content is an important aspect for cyclone energy source, tropical cyclone heat potential measure the heat content and calculates the possibility of cyclone. Ocean heat content gives an idea about indication of cyclone genesis and intensification. It is the measure of ocean heat content from the ocean surface to the 26^0 isotherm depth. Ocean have important role in tropical cyclone formation, it has been largely recognized and accepted, there is a strong association identified between high tropical cyclone heat potential values and intensification of TCs [10], [17]. Tropical cyclone heat potential, but not SST, plays an important role in TC intensity and its intensification of Western pacific [20]. Trend analysis between cyclone heat potential and SST disseminate the positive relation between due to BoB warming. Even though cyclone form over warm water body SST is not enough to predict the possibility of cyclone, further subsurface heat also have a potential role in cyclone prediction. Tropical cyclone heat potential is measure of its possible outcome through SST, sea level anomaly. Result of trend analysis from (Fig.5a) 1998-2019 shows a positive trend of 0.21376(kJ/cm^2) per year in April and 0.1685(kJ/cm^2) per year in October, high cyclone heat potential observed in April than October. April is summer and pre-monsoon periods, higher SST enhances the cyclone potential. Spatial analysis shows higher cyclone heat potential in North-Western side during April and North-Eastern side during October. North Eastern side is the place that many cyclones pass through, which due to high subsurface heat content in Eastern side. High value of heat content lead to sudden cyclone intensifications.

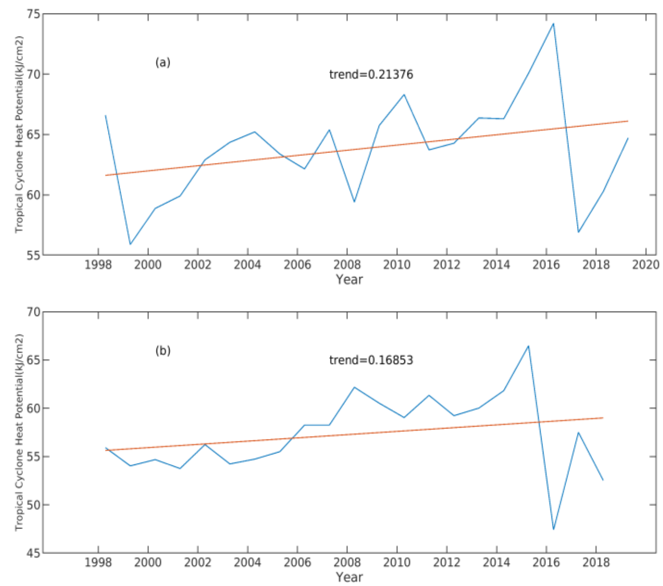

Fig . 5*. Tropical Cyclone heat potential during 1998-2019 over BoB.*

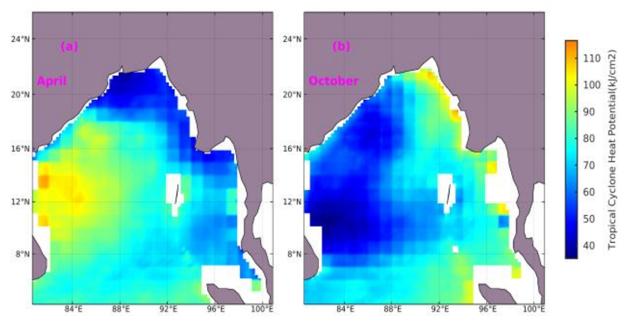

Fig .6. *Spatial average of Tropical cyclone heat potential during 1998-2019 for April and October.*

4 CONCLUSION

BoB is warming at distressing rate, long term sea surface trend indicate warming is faster than expected, which alter air-sea interaction parameters and climate. Based on analysis of air-sea surface flux parameters, which shows a positive trend during last year's, indicate warming have an effect on air-sea heat flux parameters and climate change. Latent heat and net heat flux is the important parameters that related to cyclone show a considerable positive trend, which point out possible changes in future cyclone characters. Cyclone form only in warm water bodies, present data analysis shows heat content of BoB is changing due to warming. Net heat flux loss is increasing in BoB at higher rates shows warmer water create more latent heat loss and evaporation occurring at higher rate. Positive trend acquired through the analysis of cyclone heat potential indicate, BoB cyclone heat potential is increasing at the rate of 0.21 kJ/cm2 and which is modifies character of cyclone.

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