Recent Advances and Challenges in Understanding and Predicting High-impact Weather and Climate Extremes over Indian Subcontinent in the Climate Change Context

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Impact of Ocean Stratification and Warming on the Intensification of Pre-Monsoon Tropical Cyclones over Northern Bay of Bengal

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Arkaprava Ray[a], Sudeep Das[a], and Sourav Sil[a],

[a] School of Earth, Ocean and Climate Sciences, Indian Institute of Technology Bhubaneswar

E-Mail:ar31@iitbbs.ac.in

Introduction

- Basin wise study of last three decades (1989–2019) confronts that only the Bay of Bengal itself contributes 4% of worldwide cyclones.
- The conversion rate of cyclonic storms to more intense stages is higher during the pre-monsoon season (0.88) than during the post-monsoon season (0.63).
- Warm oceanic conditions over the Bay of Bengal (BoB) restrict cyclone-induced cooling and eventually cause rapid intensification.
- In case of cyclone Amphan, the anomaly of Sea Surface Temperature (SST) was more than 2.5°C that lead to a Marine Heat Wave event and caused a rapid intensification of the tropical cyclone.
- The western Boundary Current and associated warm core eddy play an influential role on the intensification of tropical cyclones over the BoB.

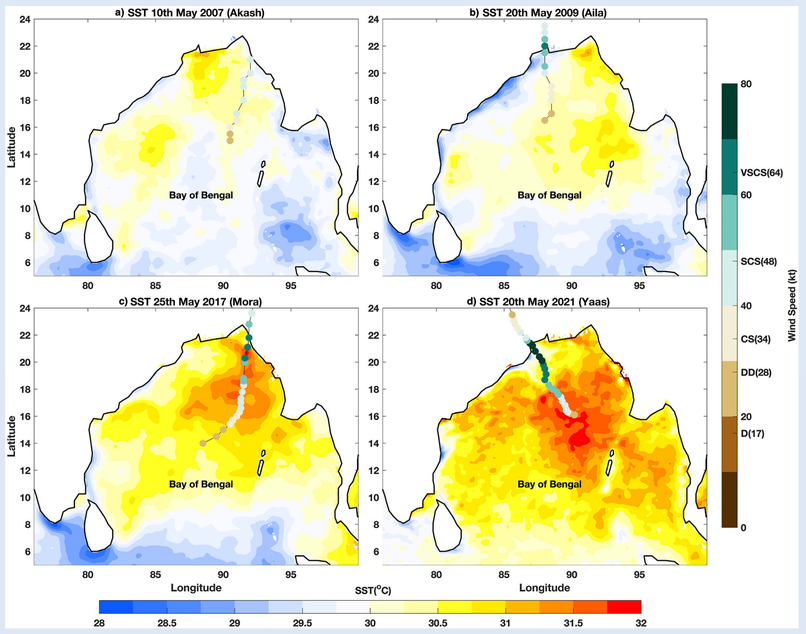
Methodology

Detection of MHW: MHW events are identified when the SST surpasses the threshold of the 90th percentile value of for five consecutive days, and if there is a gap of 2 days or less between successive events, they are treated as a single event.

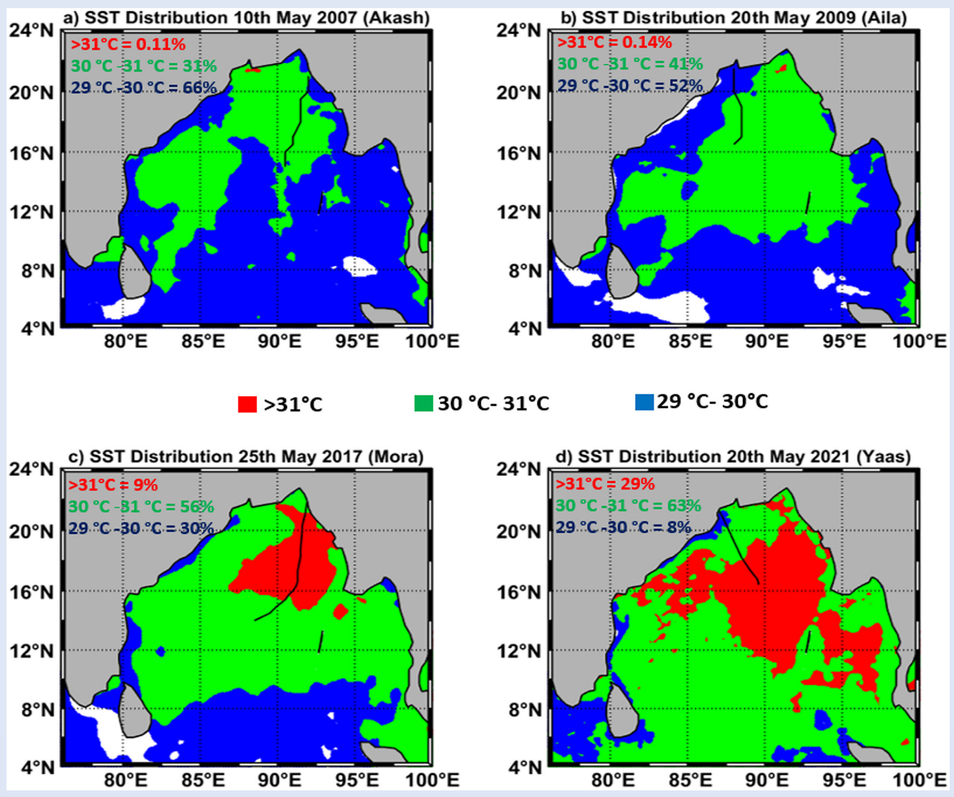
Ocean Heat Content: $OHC = C_p \int_0^d \rho(z)T(z)dz$

where, C_p is the specific heat capacity of sea water taken as 4200 J/Kg. K. ρ and T are the density and temperature of seawater respectively, which are function of ocean depth.

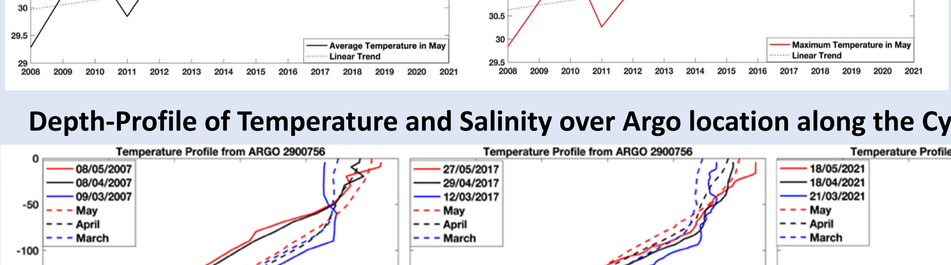
Distribution of SST before (-3days) Cyclogenesis and Cyclone Tracks



Spread of Area for Different SST Ranges before the Cyclogenesis



Timeseries and Linear Trend of Average and Maximum SST over North BoB



Results

1) The area with temperature of more than 31°C has increased from 0.1% to29% in the BoB. The warming in May has a gradually increasing trend (0.09°C/year and 0.1°C/year for average and maximum SST respectively).

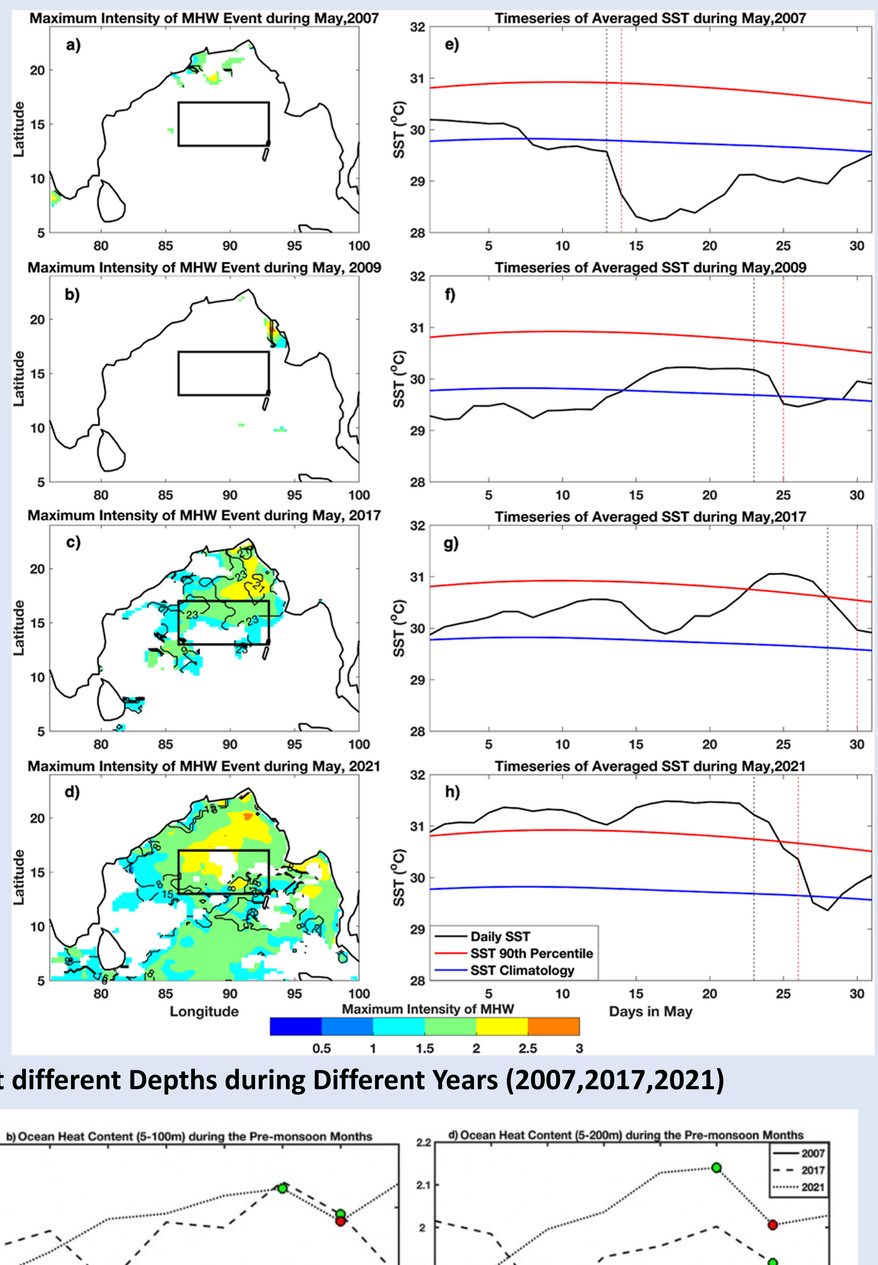
2) In 2021, the entire Bay of Bengal experienced a prolonged period of MHWs that lasted for over 20 days and may have played a key role in the rapid intensification of the cyclone, turning it into a very severe cyclonic storm within two days of formation.

3) In 2021, the temperature in the subsurface was much higher, and the upper surface salinity was unusually low, which may have aided in the intensification of the cyclone Yaas within two days. The presence of two distinct thermoclines at different depth ranges in 2017 and 2021 is also a typical finding of this study.

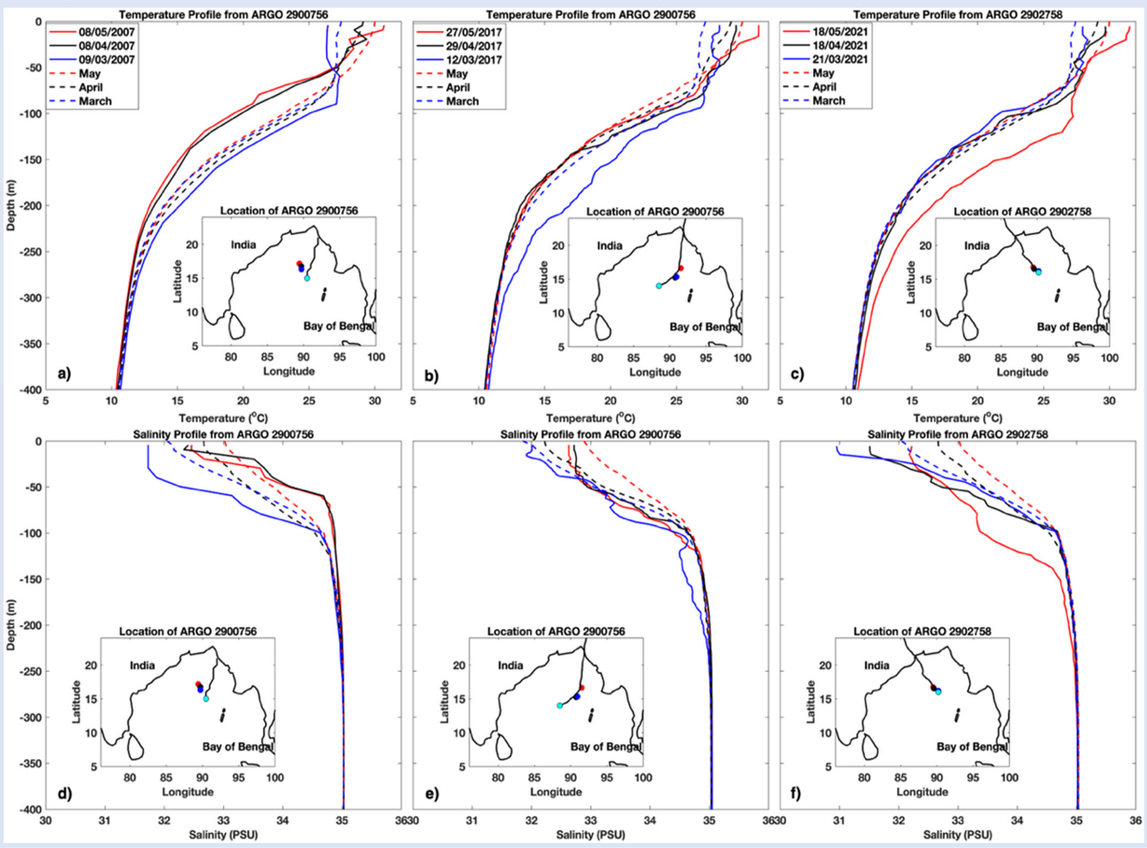
4) The OHC in all different depth ranges is comparatively higher during 2021 than in other years. The drop in OHC at those referred depths is also significant after the passage of cyclone Yaas, indicating the role of the ocean on its intensification.

5) In case of the cyclone Yaas, the higher freshwater plume in northern BoB and the absence of strong western boundary current caused a haline stratification over the region which played an essential role in intensification. [Ray et al., 2024]

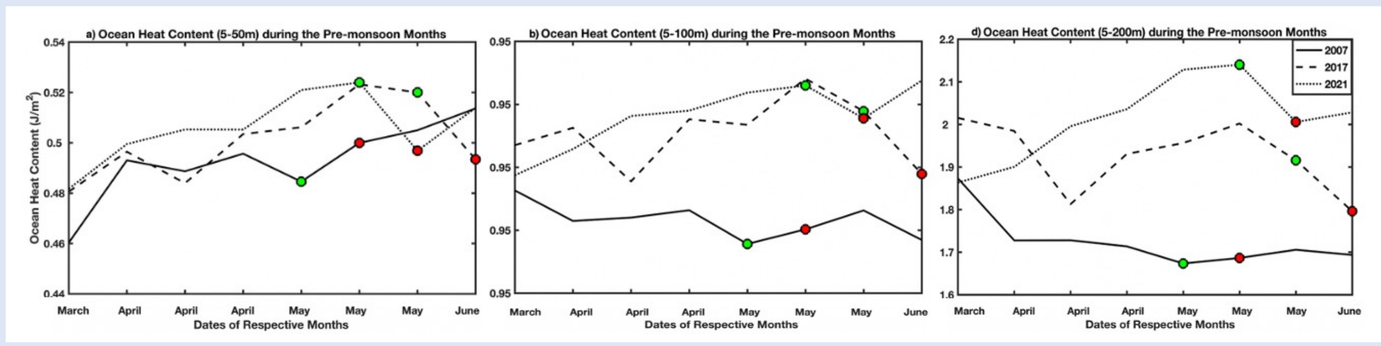
MHW events in May for the corresponding years



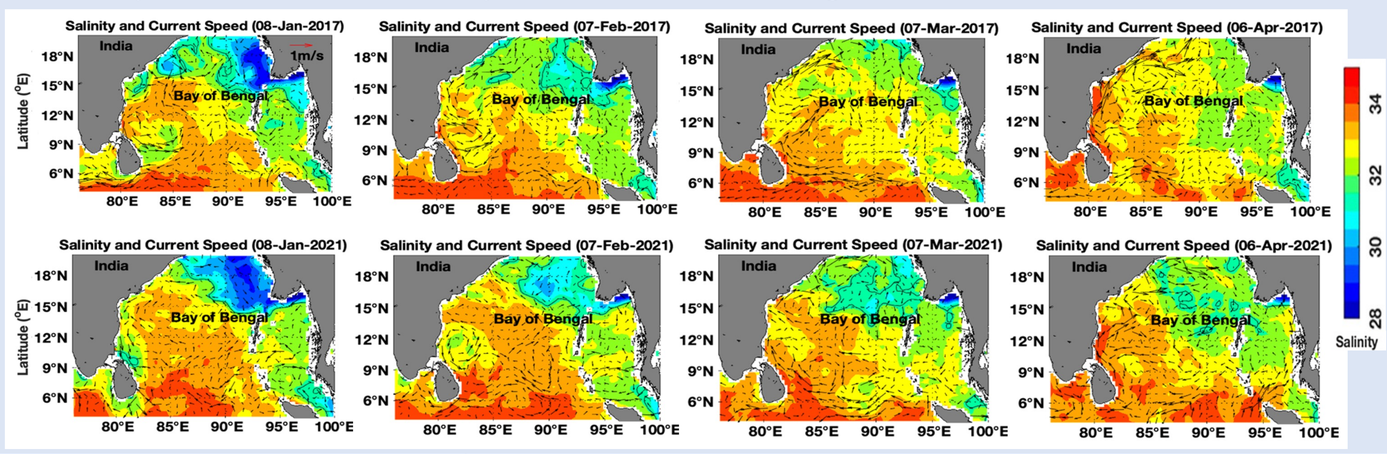
Depth-Profile of Temperature and Salinity over Argo location along the Cyclone Tracks



Integrated Ocean Heat Content at different Depths during Different Years (2007,2017,2021)



Spatial Distribution of Salinity and Surface Current during Different Months of 2017 and 2021



Summary

- Temperature greater than 31°C increased from 0.1 percent to 29 percent. The northern area experienced a gradual warming with a rate of 0.1°C per year.
- In 2021, the unusual warming corresponded to a widespread long lasting Marine Heat Wave event (more than 20 days) during the entire month of May, which became one of the leading factors for the rapid intensification of the cyclone Yaas.
- This typical phenomenon of ocean warming is extended deeper and confined longer because of the abnormal spread of freshwater over northern BoB along with an embedded clockwise ocean circulation on the track of the cyclone.
- The absence of strong and well developed western boundary current was another reason for the anomalous distribution of salinity

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