Analysis of Marine Heatwaves in the Bay of Bengal region

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Abstract

In the ocean, temperature extremes have adverse effects on precipitation patterns, sea level change, and migration/damage of ecosystems. It has been found that most species are more sensitive to extreme events like marine heatwaves (MHWs), implying the severe impacts of MHWs on ecology. These events are driven by various atmospheric and oceanic processes. In recent years, these extreme events are more frequent and intense globally and their increasing trend is expected to continue in the upcoming decades. They have the potential to devastate marine habitats, and ecosystems together with ensuing socioeconomic consequences. It recently attracted public interest and scientific researchers, which motivates us to analyze the recent MHW events in the Bay of Bengal region. we have isolated 107 MHW events (above the 90th percentile threshold) in this region of the Indian Ocean and investigated the variation in duration, intensity, and frequency of MHW events during our test period (1982-2021). Our study reveals that the average of three MHW events per year in the study region with an increasing linear trend of 1.11 MHW events per decade. In the analysis, we found the most intense event has a maximum intensity was 5.29°C (above the climatology mean), while the mean intensity was 2.03°C. In addition, we observed net heat flux accompanied by anticyclonic eddies to be the primary cause of these events. Also, an effort has been made to understand the relationship between climate modes, sea surface height, and the difference between evaporation and precipitation with the occurrence of MHW events.

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Abstract

In the ocean, temperature extremes have adverse effects on precipitation patterns, sea level change, and migration/damage of ecosystems. It has been found that most species are more sensitive to extreme events like marine heatwaves (MHWs), implying the severe impacts of MHWs on ecology. These events are driven by various atmospheric and oceanic processes. In recent years, these extreme events are more frequent and intense globally and their increasing trend is expected to continue in the upcoming decades. They have the potential to devastate marine habitats, and ecosystems together with ensuing socioeconomic consequences. It recently attracted public interest and scientific researchers, which motivates us to analyze the recent MHW events in the Bay of Bengal region. we have isolated 107 MHW events (above the 90th percentile threshold) in this region of the Indian Ocean and investigated the variation in duration, intensity, and frequency of MHW events during our test period (1982-2021). Our study reveals that the average of three MHW events per year in the study region with an increasing linear trend of 1.11 MHW events per decade. In the analysis, we found the most intense event has a maximum intensity was 5.29°C (above the climatology mean), while the mean intensity was 2.03°C. In addition, we observed net heat flux accompanied by anticyclonic eddies to be the primary cause of these events. Also, an effort has been made to understand the relationship between climate modes, sea surface height, and the difference between evaporation and precipitation with the occurrence of MHW events.

Introduction

- Marine heatwaves (MHWs)—are anomalous warm seawater events - ocean temperatures exceeding a fixed, seasonally varying, or cumulative threshold (usually the 90th percentile).
- Caused by a combination of local oceanic and atmospheric processes, including air-sea heat flux and horizontal temperature advection.
- MHWs have the potential to result in economic losses due to impacts on fisheries and aquaculture[1]
- Between 1982 and 2016, the frequency of MHWs doubled, according to remote sensing data based on satellite observations.[2]

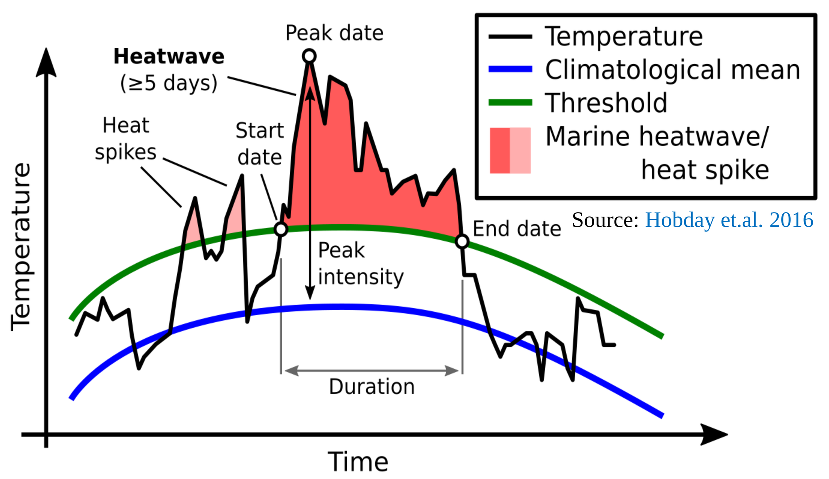


Fig 1: Defining MHW event

Data and Methodology

Name of the parameter	Source	Resolution	Duration
Sea Surface Temperature (SST)	OISST v2 (by NOAA)	0.25°x0.25°	Jan 1982 – Dec 2021
Sea Surface Height (SSH) Anomaly	Copernicus Website	0.25°x0.25°	Jan 1982 – Dec 2021
Surface Ocean Current (SOC)	Copernicus Website	0.25°x0.25°	Jan 1982 – Dec 2021
Air-sea heat flux	ERA5	1°x1°	Jan 1982 – Dec 2021
Evaporation	ERA5 (3 Hr.)	0.25°x0.25°	Jan 1982 – Dec 2021
Total Precipitation	ERA5 (3 Hr.)	0.25°x0.25°	Jan 1982 – Dec 2021
Oceanic Niño Index	NOAA Website	0.25°x0.25°	Jan 1982 – Dec 2021
Indian Ocean Dipole	NOAA Website	0.25°x0.25°	Jan 1982 – Dec 2021

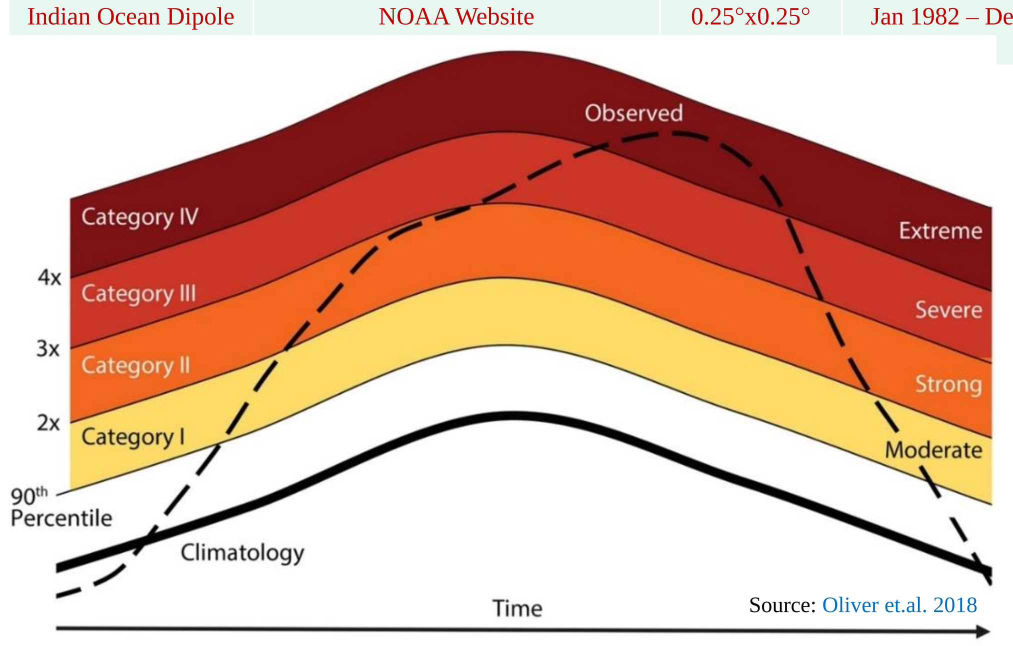


Fig 2: Categorizing MHW event

- The percentile calculation used a moving 11-day window to provide sufficient daily SST values for robust 90%ile estimate and a 31-day smoothing filter was applied to remove high-frequency noise.
- Characterizes MHW as an anomalous, warm, discrete event prolonged for more than 5 continuous days with SST more than a particular threshold.
- Two consecutive events within 3 days are considered as a single event.
- MHW duration defined as the days (between the start and end dates of an event), MHW intensity (which refers to maximum SST anomaly during an event) and MHW frequency (calculated based on the number of events occur during a season or year).
- Categorization of MHW events based on the intensity at each point in space and time.

Category	Type	Magnitude
I	Moderate	1-2 × D
II	Strong	2-3 × D
III	Severe	3-4 × D
IV	Extreme	>4 × D

D is the difference between the climatological mean and the 90th percentile threshold.Winter bloom mainly occurs due to cooling driven by convective mixing.

Results

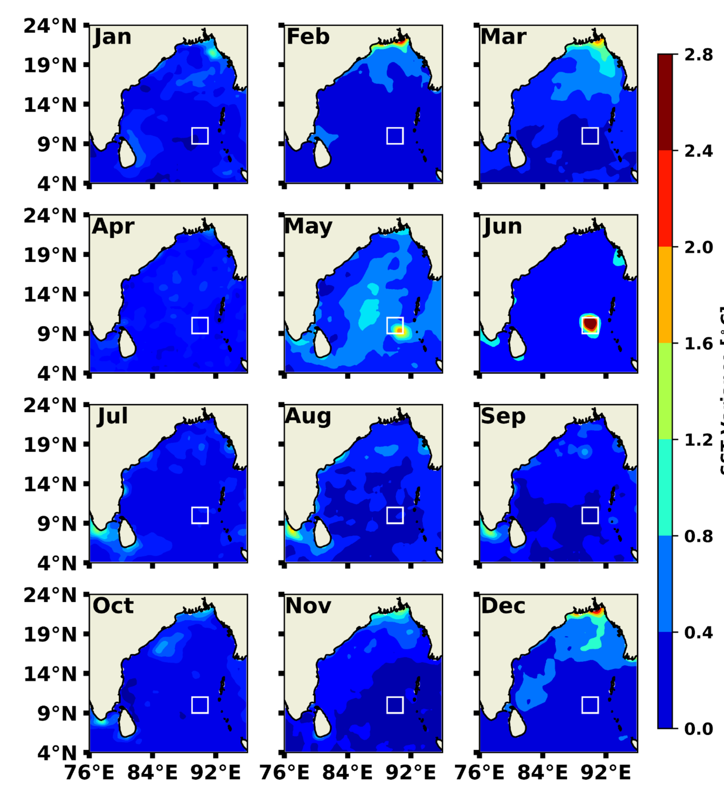


Fig 3: Monthly averaged SST variance (° C) of the last 10 years (Jan 2012- Dec 2021) for the Bay of Bengal region (4 °N -24°N; 76 °E -96 °E)

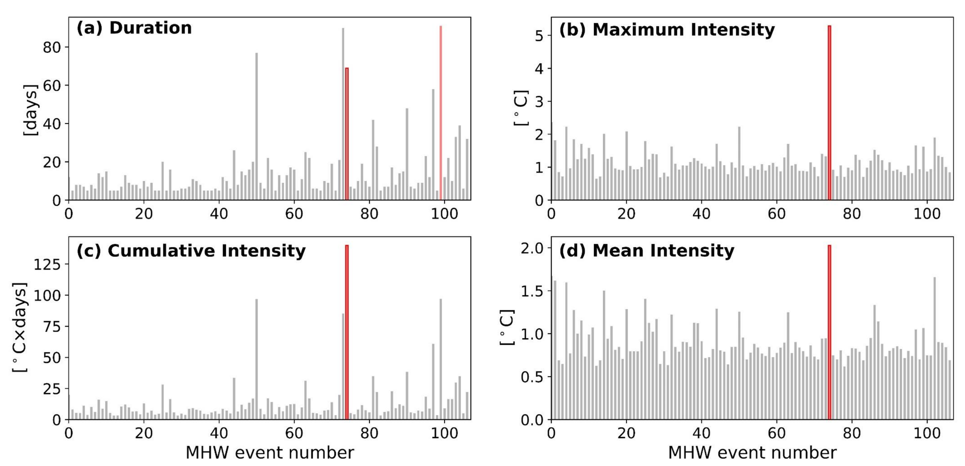


Fig 4: Shows all MHW events between Jan 1982- Dec 2021.(a) Duration, (b) Maximum intensity, (c) Cumulative intensity, and (d) Mean intensity of all events occurred

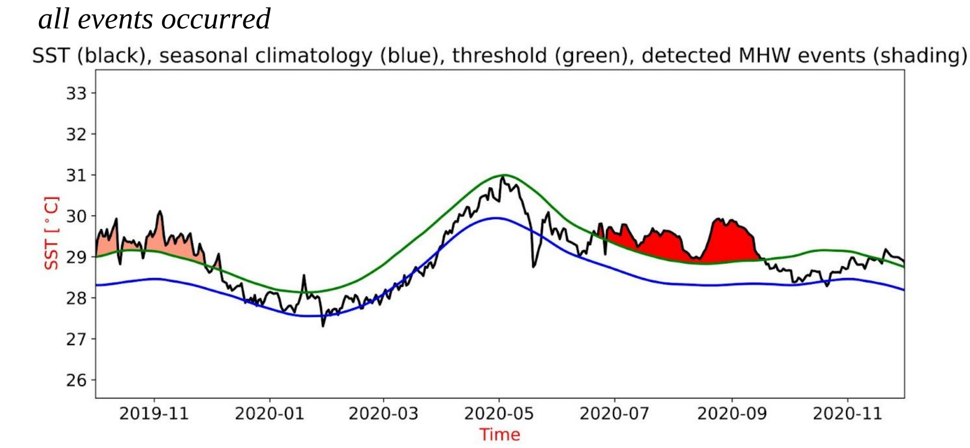


Fig 5: Figure 4: Temporal variation for longest duration MHW event

Lasted for 91 days (20 June - 18 September) with 1.62 °C, 1.06 °C, and 96.98 °C-days as maximum (i_{max}), mean (i_{mean}), and cumulative (i_{cum}) intensity respectively above the climatological mean

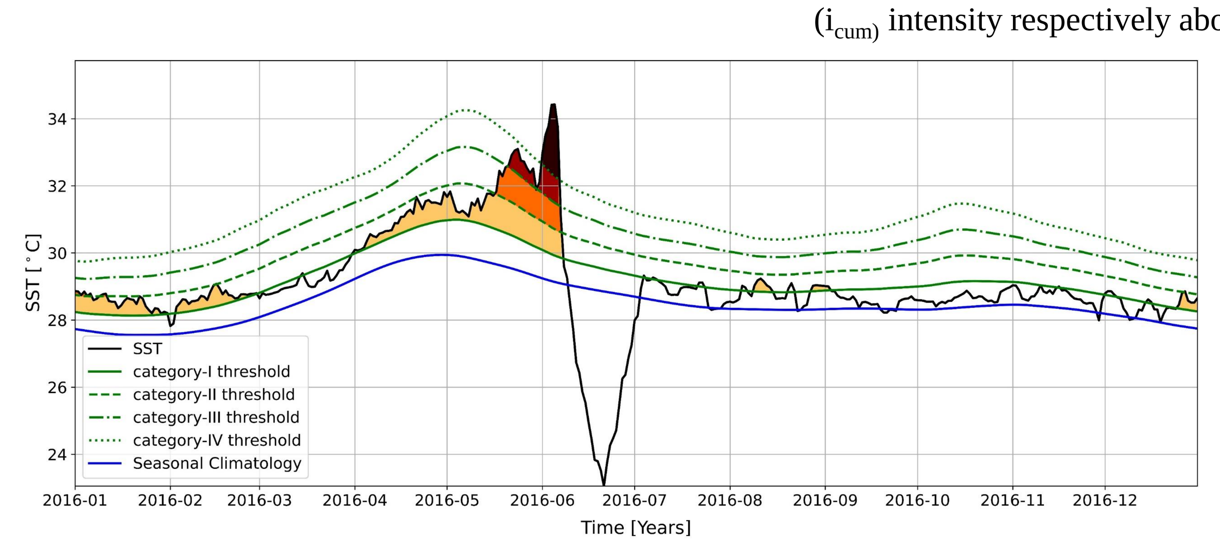


Fig 6: Temporal variation of MHW events with maximum intensity (color shades), category I-IV by dashed and dotted lines.

- Event had an i_{max} of **5.29 °C** and lasted for **69 days** (31 March - 07 June) with an i_{mean} of 2.03 °C and i_{cum} of 139.93 °C-days
- This event has 7% of days in the extreme category, and 16%, 9%, and 68% as severe, strong, and moderate categories, respectively

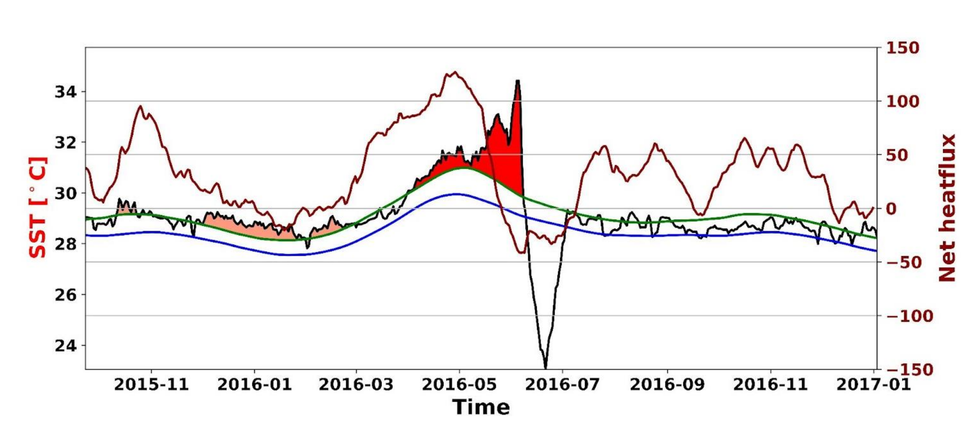


Fig7 : Temporal variation of SST (black), Seasonal climatology (blue), threshold (green), and MHW event shading in time series from October 2015 to December 2016 and net heat flux (dark red) for the same period.

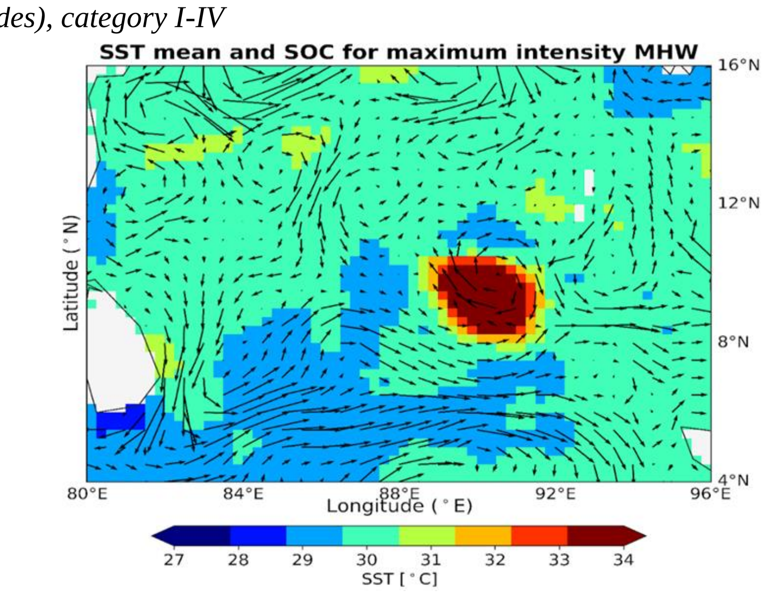


Fig 8 : SST (Color) and SOC (vector) for the most intense MHW event.

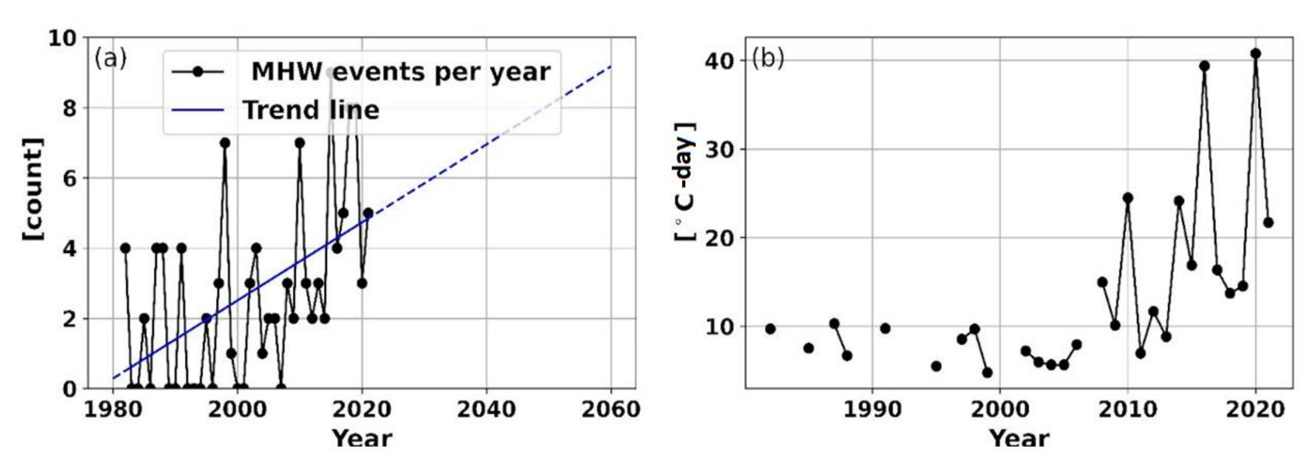
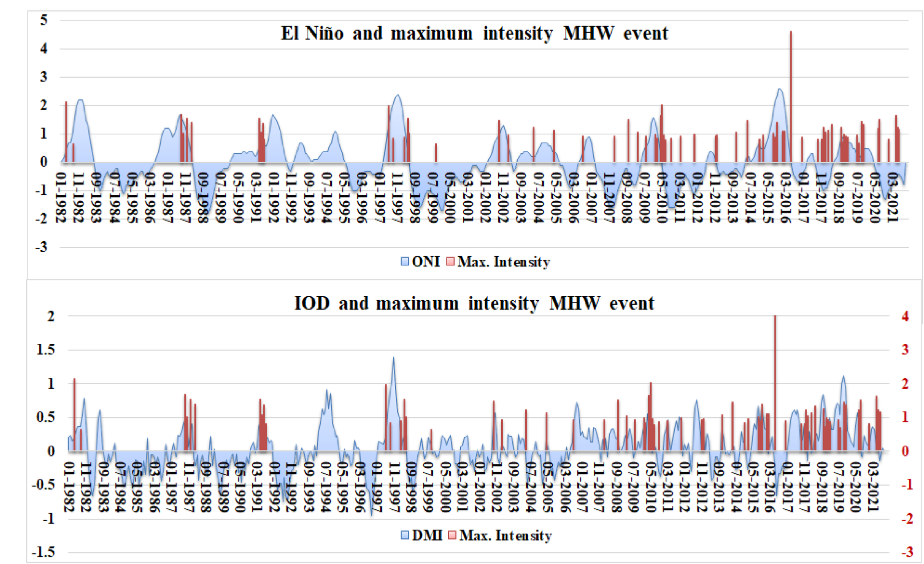


Fig 8 : Time series of (a) Number of MHW events per year from January 1982 to December 2021 (black) and trend line (blue), (b) Year-wise average MHW cumulative intensity.

More Results



- Positive correlation with MHWs till 2000.
- warming due to anthropogenic climate change since the 2000s contributed to the generation of MHWs, and it further increased after 2010.

Fig 9: Temporal variation for ONI (top) and DMI (bottom) with the maximum intensity of MHW events for the period 1982 to 2021.

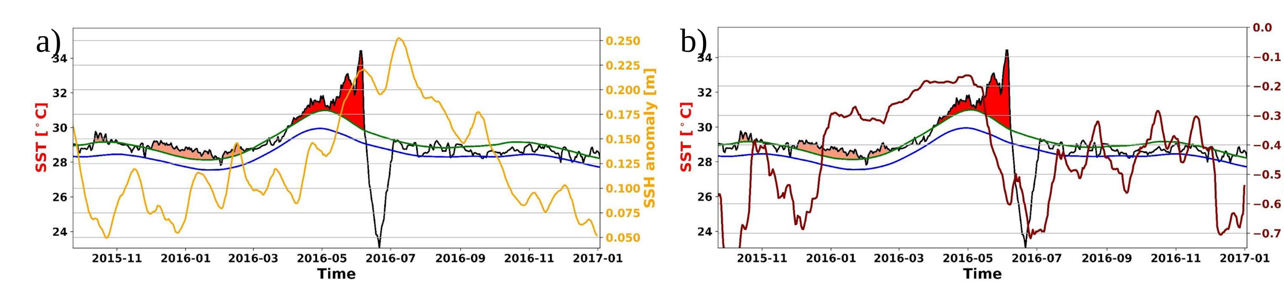


Fig 10: Temporal variation of SST (black), Seasonal climatology (blue), threshold (green), and MHW event shading in time series from October 2015 to December 2016 and (a) SSH anomaly (Yellow), (b) Total precipitation (dark red) for the same period..

Conclusions

- The longest MHW event out of 107 MHW events for the period 1982-2021 that were observed in the Bay of Bengal region lasted for 99 days.
- The most intense MHW event had a maximum intensity of 5.29 °C and lasted for 69 days with a mean intensity of 2.03 °C above the climatological mean.
- MHWs were observed to be influenced by net heat flux along with surface ocean currents, and affect sea surface height along with E-P.
- Climate modes like ENSO and IOD also influence MHWs along with anthropogenic climate change.
- Spatial variations shows that intense heatwaves in northern and longer heatwaves are observed in the eastern part of BoB region.
- MHWs will become long-lasting, more intense, and extensive in future.

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