

Characteristics and Drivers of Marine Heatwaves in the Western Equatorial Indian Ocean

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Key points

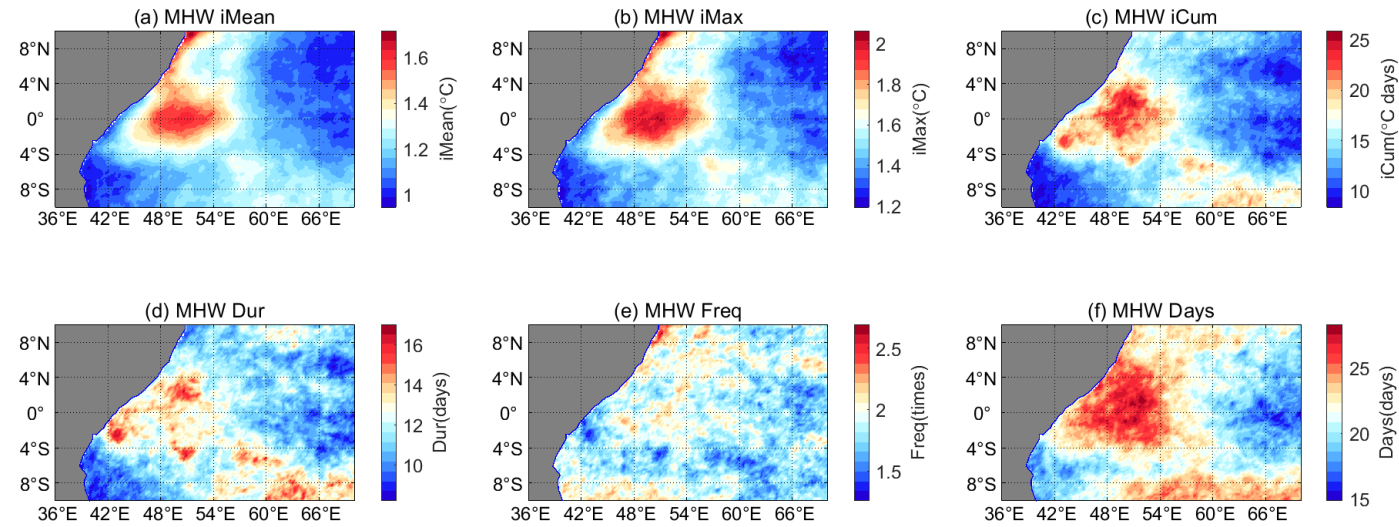
- Marine heatwaves (MHWs) in the western equatorial Indian Ocean (WEIO) have significant interannual variability related to the Indo-Pacific climate modes.
- MHWs in the WEIO are mainly driven by westward-propagating downwelling equatorial Rossby waves and off-equatorial Rossby waves.
- The frequency and duration of MHWs exhibited significant increasing trends in the WEIO from 1982 to 2020.

Background

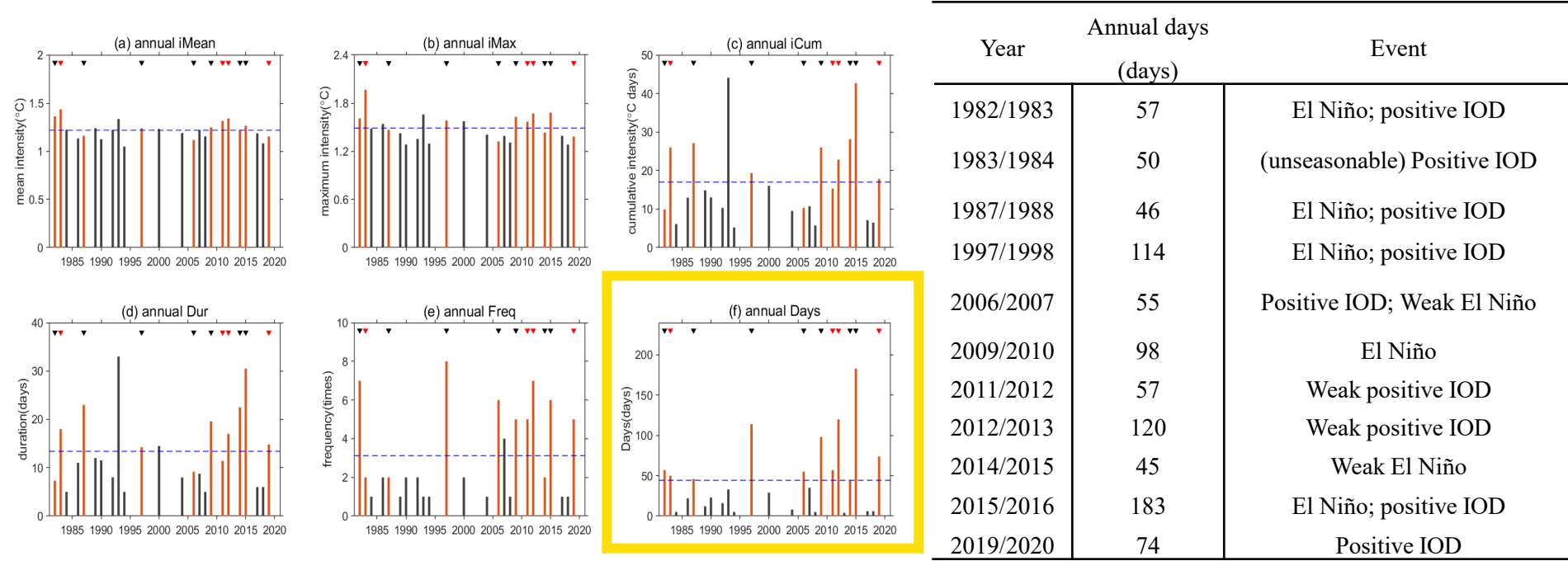
- MHWs are occurring widely around the world, with severe impacts on ecosystems and human activities.
- WEIO is unique due to its complex dynamical system forced by monsoon winds. It is the dynamic-thermal center of the eastern and western basins of the Indian Ocean and across the Northern and Southern Hemispheres.
- A better understanding of the ocean dynamic processes and air-sea interactions in the WEIO associated with climate modes contributes to predicting extreme events.

Results

Hot spot in the WEIO (48°E–54°E, 2°S–2°N)



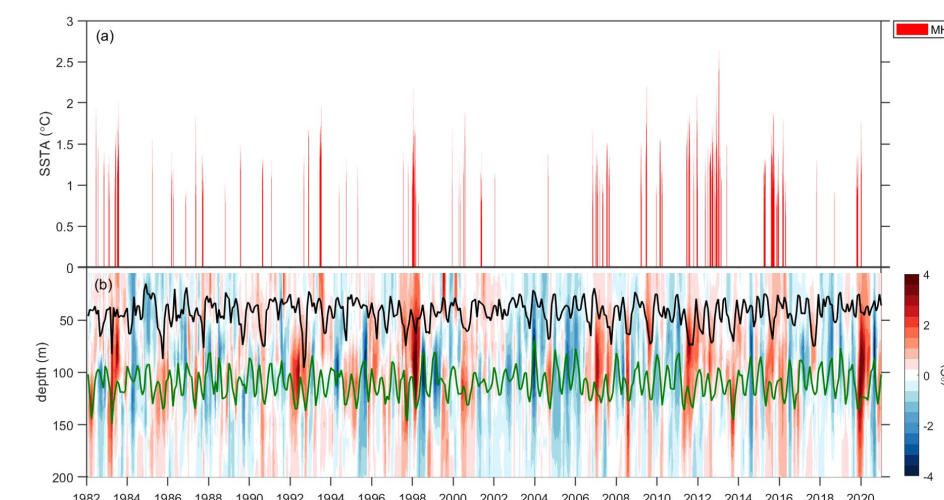
Annual variability associated with IOD and ENSO



- There are 11 years in which MHW Days exceed its one-time average -- years with a large number of annual MHW days.

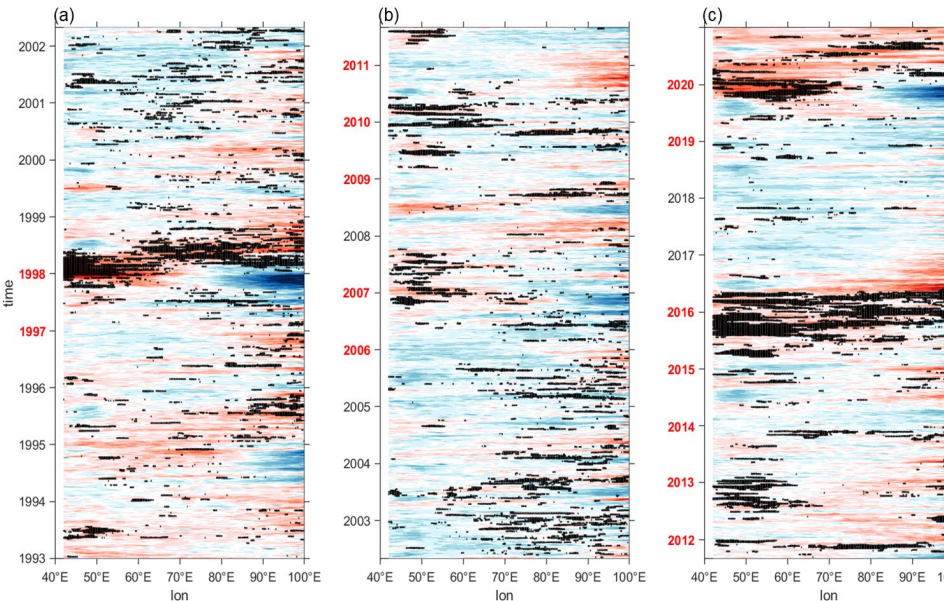
Oceanic Wave Processes

Vertical structure & MHWs in the hot spot region

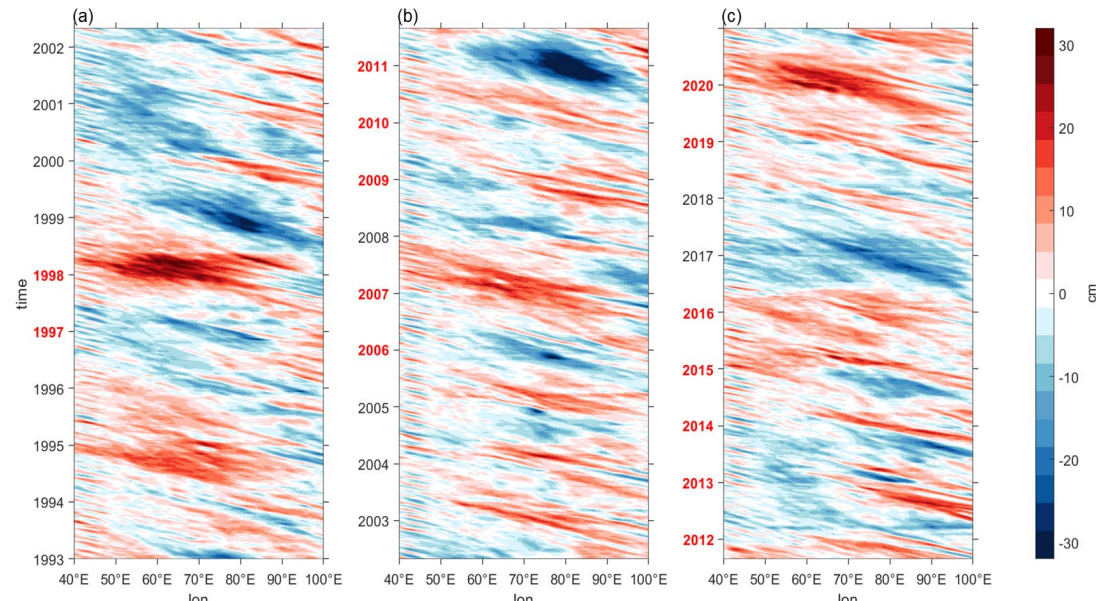


- Thermocline deepening and subsurface warming suggest the MHWs in the WEIO are associated with thermocline variations influenced by oceanic planetary waves.

SSHA & MHWs 1°N - 1°S



SSHA 8°S - 12°S

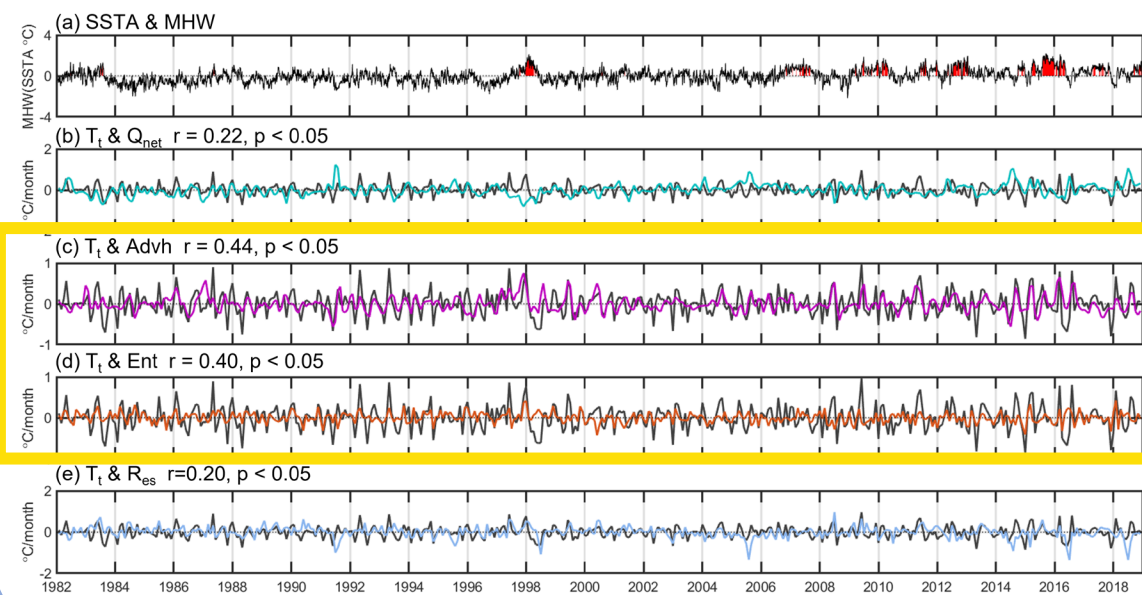


Equatorial Rossby waves & Off-equatorial Rossby waves

- Westward-propagating downwelling oceanic planetary waves in the **equatorial Indian Ocean**
- Downwelling Rossby waves propagate westward in the **southern tropical Indian ocean**
- After reaching the western boundary, Rossby waves → coastal Kelvin waves propagate northward to the equator → equatorial Kelvin waves → SST
- Upper warm water converges & Upwelling processes are suppressed → SST

Occurrence of MHWs in the WEIO

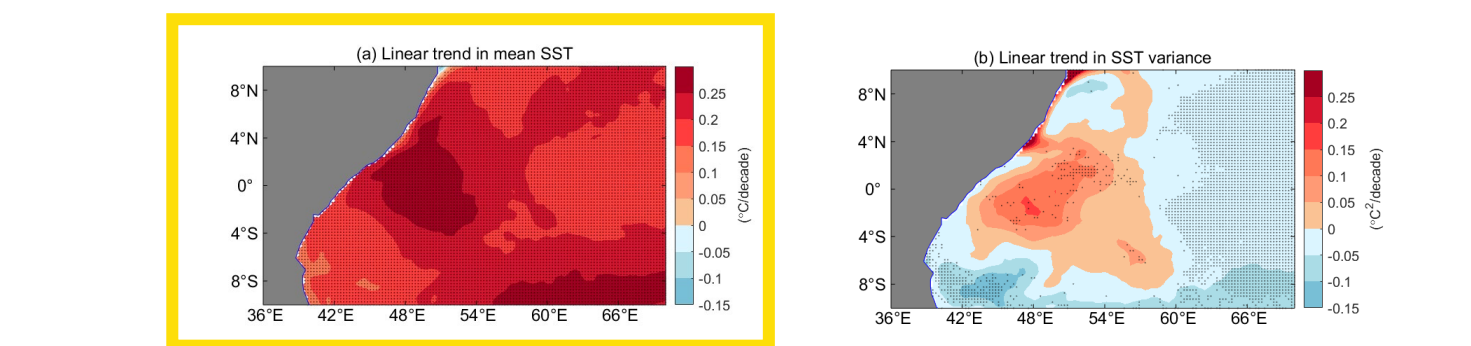
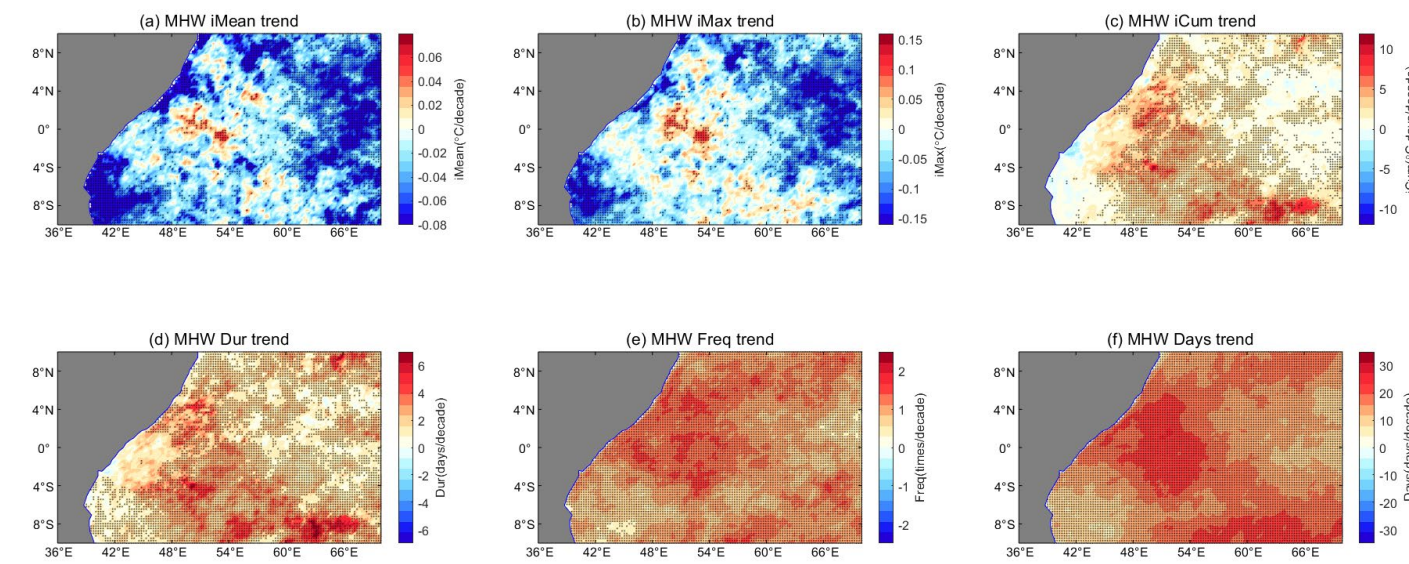
Heat Budget Assessment



$$\frac{dT}{dt} = \frac{Q_{net}}{\rho C_p h} - V \cdot \nabla T - \frac{w_e(T - T_d)}{h} + R_{es}$$

- MHWs are mainly affected by the **ocean horizontal** and **vertical processes**, while the air-sea heat flux works in some cases.

Long-Term Trend of MHWs in the WEIO



- Over the past 39 years, the MHW frequency, duration, total days, and cumulative intensity in the WEIO have shown an **increasing trend**.
- The increasing trend of **the mean SST** is important in determining the increasing trends of the frequency, duration, total days, and cumulative intensity of MHWs.

Summary & Discussion

- MHWs in the **hot spot** region (48°E-54°E, 2°S-2°N) of the WEIO are particularly strong. **Significant interannual variability** of MHWs has also been observed in the WEIO over the past few decades which is associated with a **positive IOD event**, or an **El Niño event**, or both.
- **The oceanic planetary wave processes** associated with the IOD and ENSO have an important impact on MHWs in the WEIO.
- The annual MHW frequency, duration, and total days in the hot spot region increase up to 1.56 times, 4.95 days, and 31.72 days per decade, respectively, related to the **significant increase in mean SST under global warming**.
- Climate modes and their atmospheric or oceanic teleconnections affect SST, which further influences both the occurrence and intensity of MHWs. **The complex relationship between MHWs and climate modes deserves further attention**.