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Ocean Thermal Extremes in the Philippines during the Warmest Recorded Years

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Introduction

Marine Heatwaves (MHWs) are prolonged, discrete, and anomalously warm events [1]. Its cooling counterpart is called Marine cold spells (MCSs) [2]. Both events have recently gained global attention due to their far-reaching effects and reported impacts.

Knowledge gaps:

- Recent extremes from 2022 to 2025 → Updated knowledge
- High-resolution dataset → Better detection at coastal areas
- More recent climatological baseline → Extreme detection relative to a more contemporary state

Data and Methods

SST

Dataset	Resolution	Period	Climatology
CMEMS GLORYS	daily 0.083º x 0.083º	01 Jan 1993 to 31 Dec 2025	01 Jan 1993 to 31 Dec 2022

Analysis

- MHW detection (Hobday et al., 2016)
- MCS detection (Schlegel et al., 2021)
- → Metrics (frequency, duration, mean intensity, cumulative intensity) → Linear Trends (GLM); Interannual variability (metrics, spatial fraction)
- → 2022-2025 Events → Ocean-atmosphere anomalies (geopotential height, shortwave radiation, latent heat flux, currents)

Thermal Extremes Hotspots

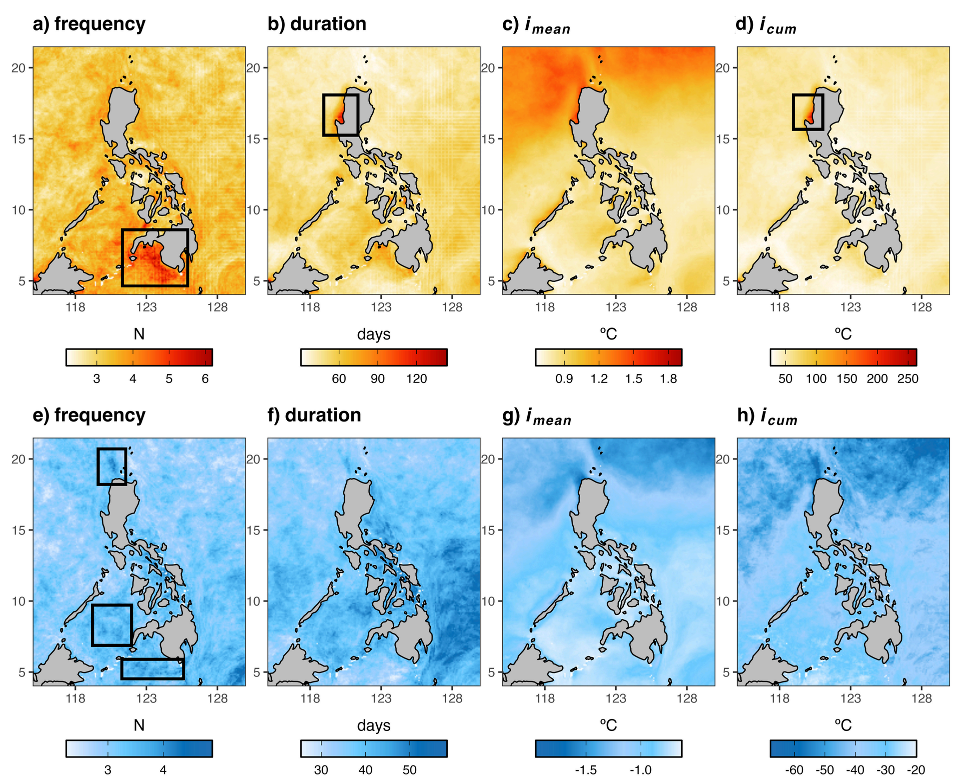


Figure 1. *Annual mean metrics of MHWs and MCS in the Philippines from 1993-2025 (33 full years).*

MHWs Hotspots

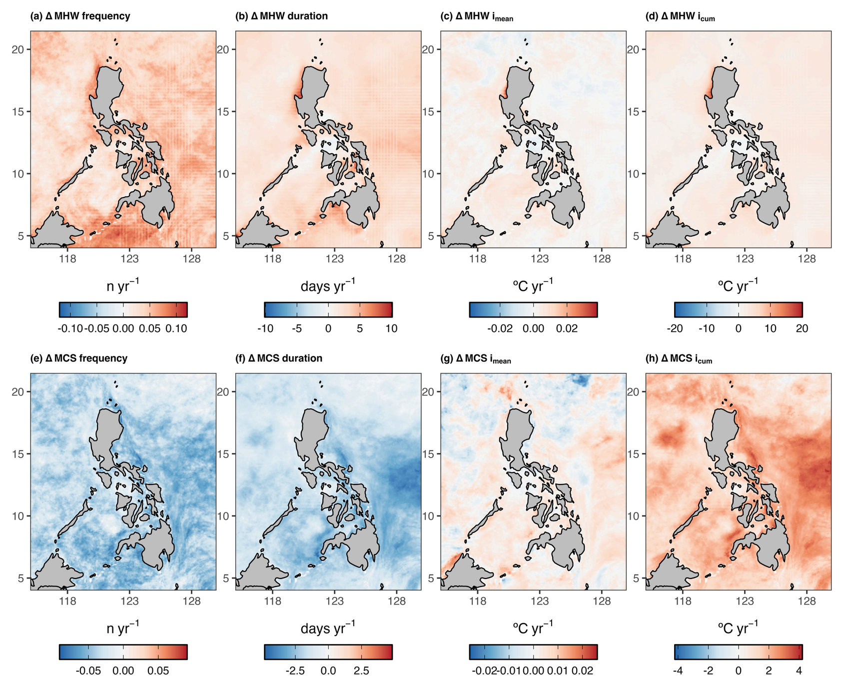
- generally more organized and isolated
- more frequent in the southern region
- more intense and prolonged in the northern region

MCSs Hotspots

- more scattered and widespread in terms of frequency and duration
- concentrated in the northern region in terms of intensities

MHWs are relatively more frequent, prolonged, and intense than MCSs

Asymmetry in marine heatwaves and cold spells



Increasing MHWs across all metrics

Decreasing frequency and duration and weakening MCS intensities

Figure 2. *Annual linear trends of MHW (upper row) and MCS (lower row) primary metrics from 1993-2025.*

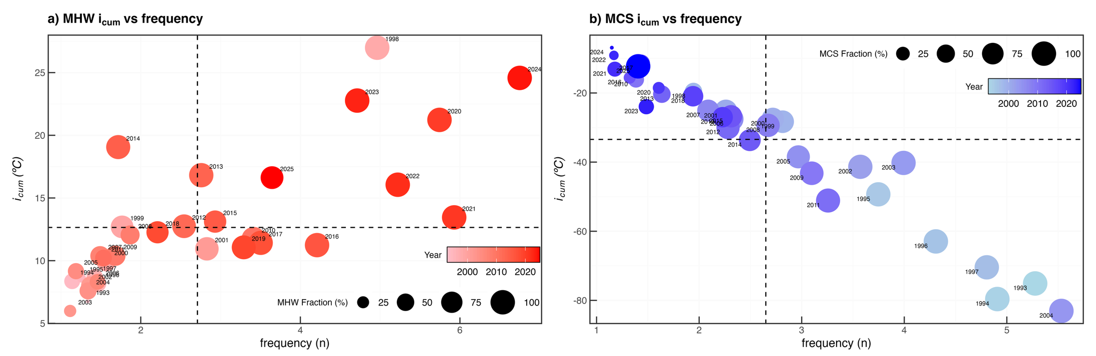
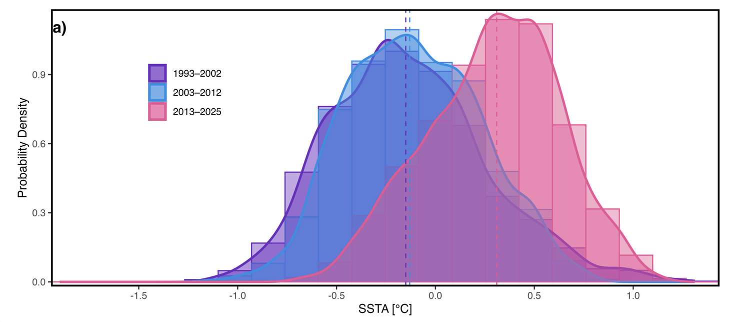


Figure 3. *Interannual variability of primary metrics of (a) MHWs and (b) MCSs. The MHW (MCS) fraction is defined as the number of pixels with MHW (MCS) over the total number of pixels in the study area multiplied by 100.*

MHWs have been increasing in frequency, cumulative intensity, and spatial fraction (up to 100%), especially in the recent six years

MCSs have been decreasing in frequency, cumulative intensity, and spatial fraction (up to ~2%), especially in the recent decade



b)

Period	Mean (°C)	Variance (°C²)	Skewness	N
1993–2002	-0.14	0.16	0.44	3652
2003–2012	-0.11	0.11	0.11	3653
2013–2025	0.29	0.11	-0.22	4748

Figure 4. *(a) Normalized histograms (bars) and probability density functions (solid lines) of SSTA for three periods (1993–2002, 2003–2012, and 2013–2025), (b) summary statistics.*

Mean state shift in SSTA in the recent decade rather than isolated episodes

Mechanism of recent extremes

2022 MHW (La Niña Decay Phase)

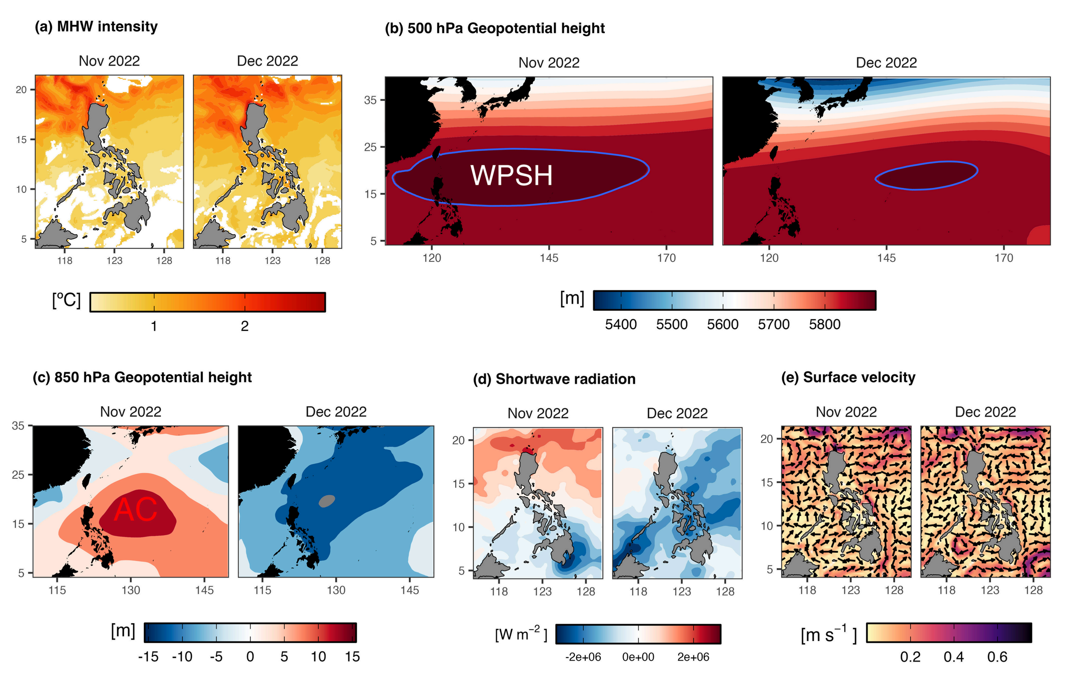


Figure 5. *Mechanism of the (a) 2022 MHW occurring from November to December. Corresponding anomaly fields of (b) geopotential height at 500 hPa, (c) geopotential height at 850 hPa, (d) shortwave radiation, and (e) surface current velocity are also shown. The blue contour line denotes the 5880 geopotential meter (gpm) of the WPSH.*

2023 MHW (El Niño Mature Phase)

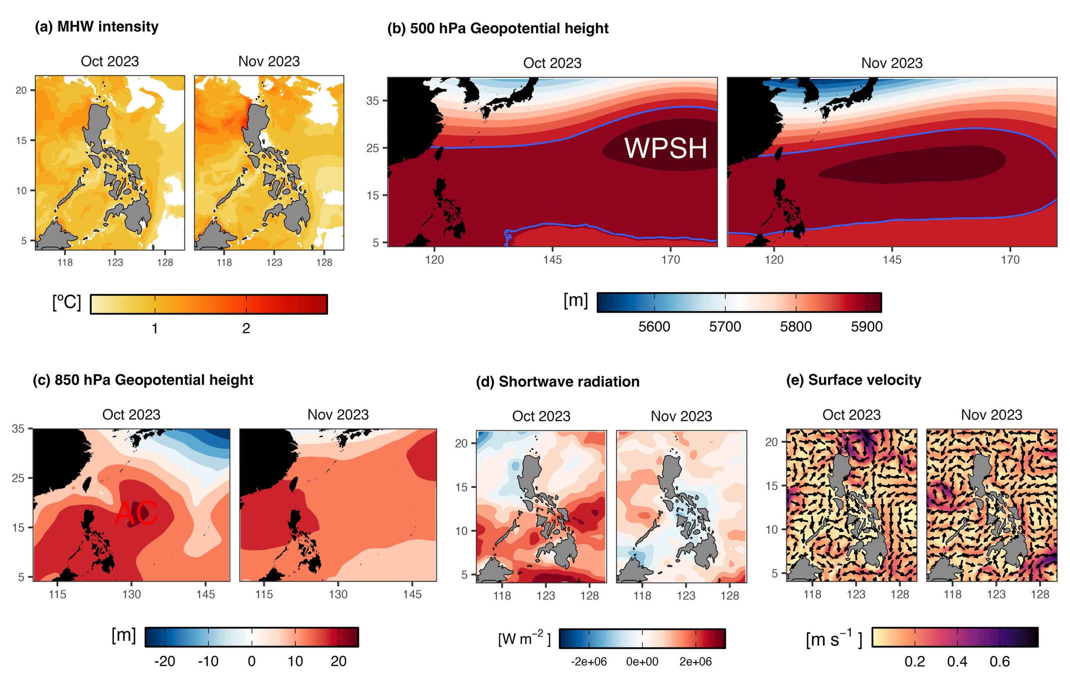


Figure 6. *Mechanism of the (a) 2023 MHW occurring from October to November. Corresponding anomaly fields of (b) geopotential height at 500 hPa, (c) geopotential height at 850 hPa, (d) shortwave radiation, and (e) surface current velocity are also shown. The blue contour line denotes the 5880 geopotential meter (gpm) of the WPSH.*

2024 MHW (El Niño Decay Phase)

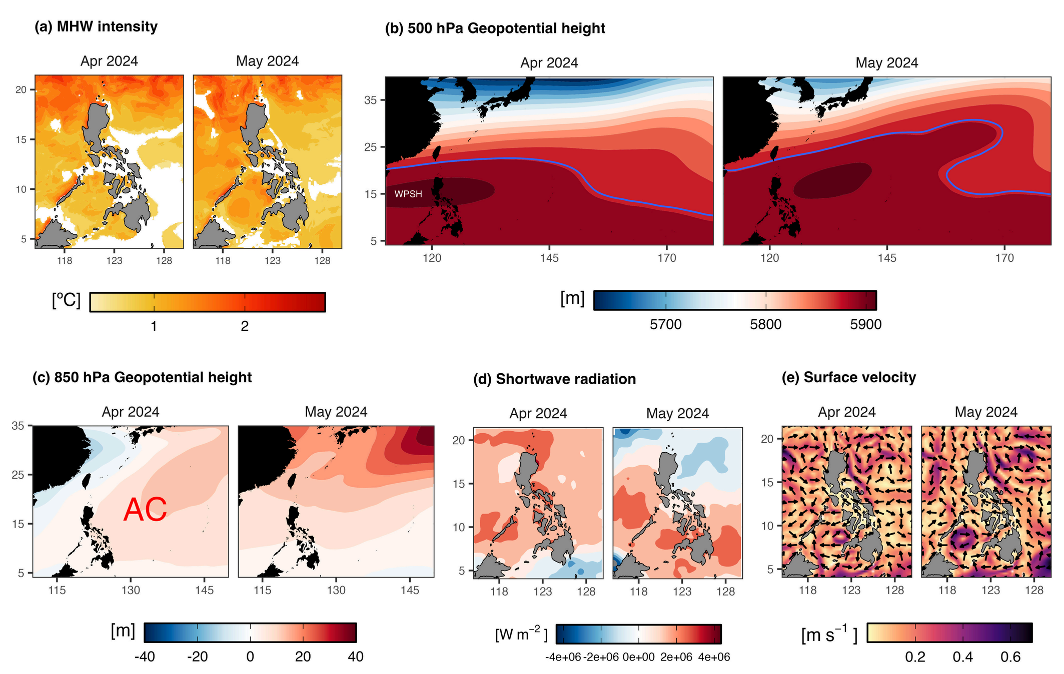


Figure 7. *Mechanism of the (a) 2024 MHW occurring from April to May. Corresponding anomaly fields of (b) geopotential height at 500 hPa, (c) geopotential height at 850 hPa, (d) shortwave radiation, and (e) surface current velocity are also shown. The blue contour line denotes the 5880 geopotential meter (gpm) of the WPSH.*

ENSO → Rossby response → WPSH shift → anticyclone → flux changes → MHW

- No MCS was detected since 2020
- Single warming during La Niña and double warming peaks during El Niño [4]
- Higher MHW intensities relative to the mean in Figure 2
- Persistence of anticyclonic circulation (AC) in the lower-level atmosphere during El Niño Southern Oscillation (ENSO) [4]
- AC is modulated by shifts in the western Pacific subtropical high (WPSH) during ENSO episodes [6].
- It is important to note, however, that formation of AC over the Philippines is due to the combined effects of remote ENSO forcing, tropical-extra tropical interaction, and monsoon-ocean interaction [5].
- Warm-core anticyclonic eddy in Sulu Sea, although there is no strong evidence of correlation with ENSO [3]

Conclusion

- MHWs are continuously increasing across all metrics, especially after 2020
- MCSs are declining in frequency and duration, but increasing in intensities
- The present study captured the intense warming in the western coast of the Luzon Island
- Apart from the long-term warming trend, drivers of the recent MHWs are primarily associated with ENSO-induced changes in the atmosphere and anomalous local ocean dynamics

References

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Sharing is encouraged

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