Influence of Indian Ocean Dipole on Westerly Wind Bursts in the Indian Ocean during South West Monsoon

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Introduction

Westerly Wind Bursts (WWBs) in the Indian Ocean significantly influence oceanic and atmospheric parameters. This study used 40 years of ERA5 reanalysis 10 m zonal wind data, from January 1984 to December 2023, to identify WWBs influence on Indian Ocean. The area between 2.5 °S to 2.5 °N and from 50 °E to 100 °E was used to detect the WWB events happening on the equator in this study. Composite analysis was performed to examine the influence of WWBs on precipitation, Sea Surface Temperature (SST), and Significant Wave Height (SWH) anomalies.

The anomalous temperature difference between the western and eastern equatorial Indian Ocean at different time scales is known as the Indian Ocean Dipole (IOD). The IOD occurrs due to the Bjerknes feedback of wind, evaporation and SST.

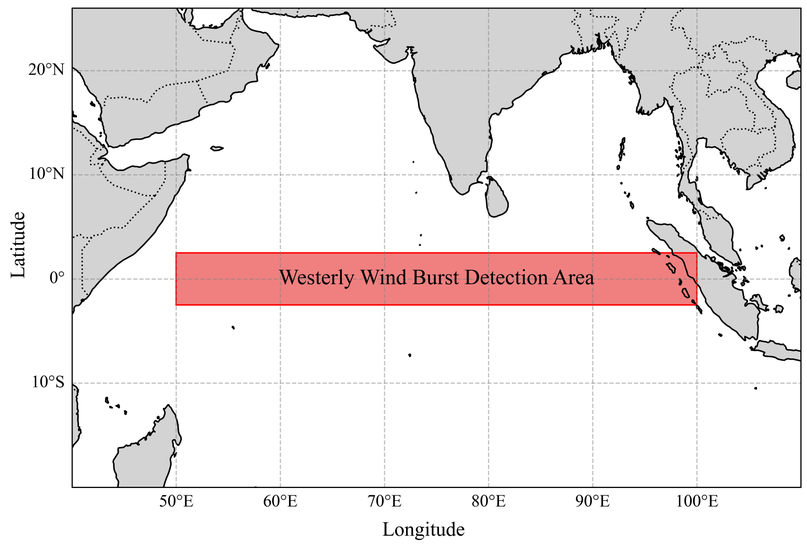

Figure 1. Study Area

Methodology

Westerly wind bursts are identified if;

- Westerly wind speed exists at least 5 ms^{-1},
- Westerly wind anomaly should be greater than 2 standard deviations,
- Zonal extent more than 5° longitudes and
- Above conditions exist for minimum of 2 days.

The climatological daily annual cycle is removed to obtain zonal wind anomalies.

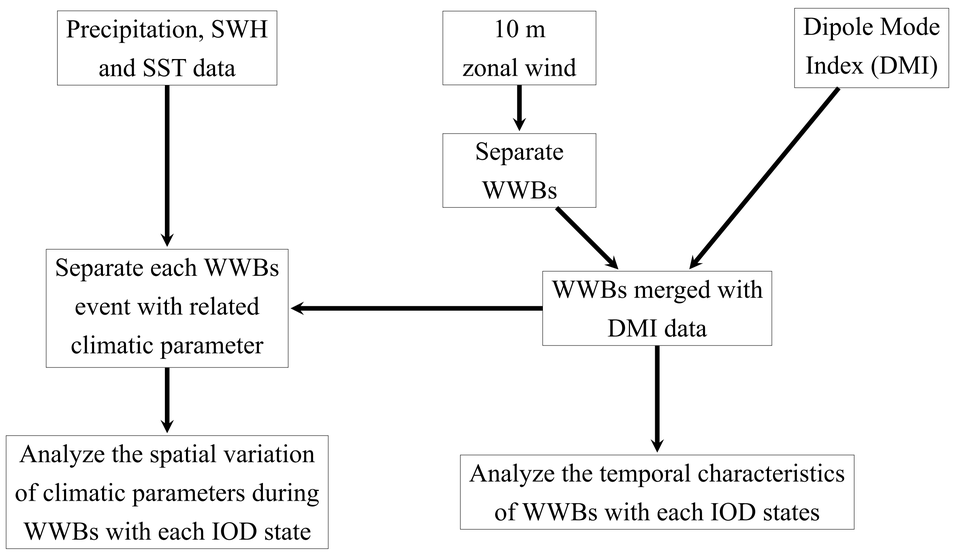

Figure 2. Flow chart of the study

Temporal Characteristics of WWBs

The study found that WWBs were most likely to occur during the neutral IOD, with a particularly high occurrence in June and July during the SWM, exceeding frequency of 4 WWBs per month. May and August observed for more than 1 WWBs frequency per month with neutral IOD condition. Negative IOD conditions had the second highest occurrence of WWBs, while positive IOD conditions had the least occurrence. Frequency of WWBs during the negative IOD state highest at September, comparing with other negative IOD observed months.

The duration of WWBs was categorized into five groups: 2–3 days, 3–5 days, 5–7 days, 7–10 days, and over 10 days. Over 25% of WWBs occurred in the 2–3 day category across all IOD states, while the fewest WWB events occurred in the over 10 day category. The highest number of WWB events in the positive and neutral IOD states was observed in the 2–3 day category, while in the negative IOD state, the highest occurred in the 3–5 day category. During neutral IOD conditions, the frequency of WWBs gradually decreased with increasing duration.

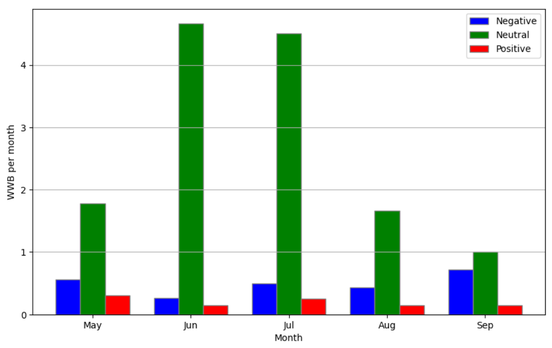

Figure 3. Monthly distribution of WWBs during SWM

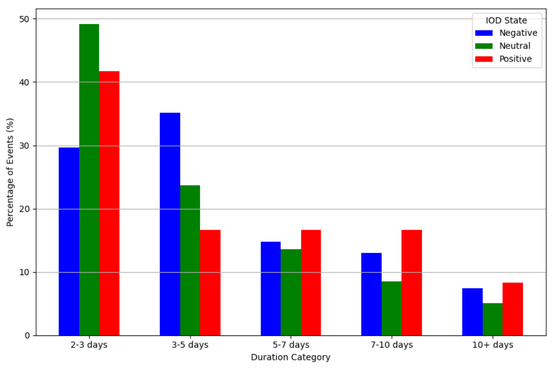

Figure 4. Percentages of WWBs duration at each IOD

Spatial variation of climatic parameters

Central Indian Ocean experienced more than 0.4 m SWH anomaly during positive IOD. During neutral IOD, SWH anomalies experienced over 0.1 m along the equator and East Madagascar waters exceeded the 0.2 m. Bay of Bengal (BOB) and Northern Arabian Sea (AS) had - 0.2 m SWH. During negative IOD, stronger positive SWH anomalies observed between 80 °E to 90 °E on equator and weakly positive SWH anomaly reported at Southern Indian Ocean, while BOB observed for negative SWH anomaly.

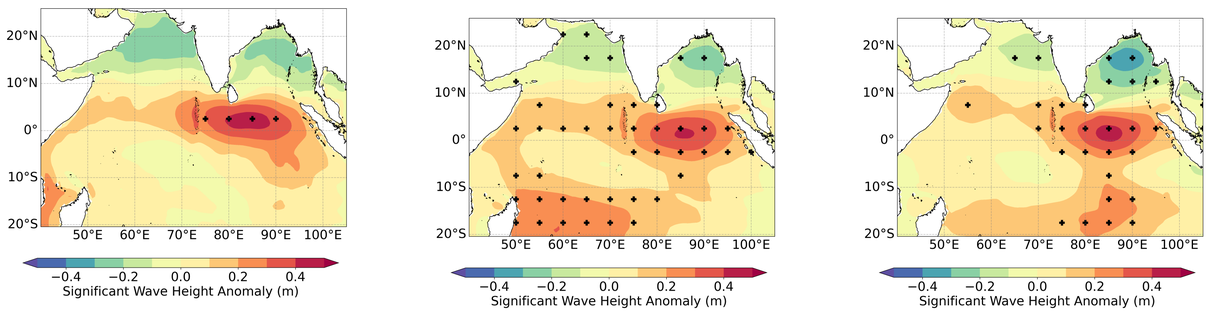

Figure 5. Composites of SWH during WWBs at (a) Positive, (b) Neutral and (c) Negative IOD ("+" indicate those exceed the 95% confidence)

South equatorial Indian Ocean, AS, and BOB displayed the higher SSTA, while Equatorial East Indian Ocean (EEIO) displayed the cooler SSTA during positive IOD. During neutral IOD, BOB experienced over 0.1 °C SSTA, and central Indian Ocean and sea around Madagascar experienced cooler SSTA. The EEIO experienced over 0.5 °C SSTA and Equatorial West Indian Ocean (EWIO) experienced SSTA cooler than - 0.2 °C during the negative IOD. Bay of Bengal experienced 0 to 0.4 °C SSTA variation.

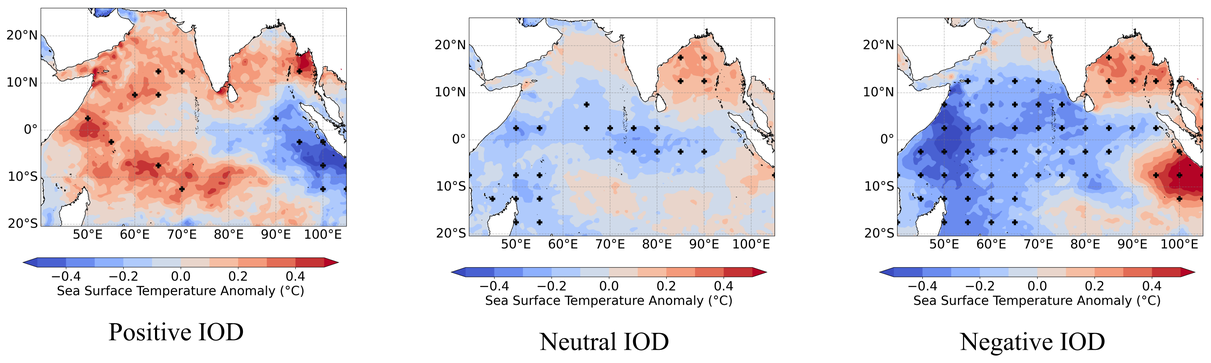

Figure 6. Composites of SST during WWBs at (a) Positive, (b) Neutral and (c) Negative IOD ("+" indicate those exceed the 95% confidence)

During the Positive IOD, Vertically Integrated Water Vapor Flux (IWVF) blew across Thailand easterly and then crossed the Indian Peninsula, and turned back to the EEIO and observed more than 8 mm day^{-1} precipitation anomaly. North Indian Peninsula and Burma coastal regions had less than - 4 mm day^{-1} precipitation anomaly. East Indonesian Sea and Sri Lanka experienced precipitation anomaly more than 2 mm day^{-1}. During neutral IOD, west sea of Sumatra experienced over 6 mm day^{-1} precipitation anomaly. During negative IOD, Northern BOB experienced precipitation anomaly below - 3 mm day^{-1}. Equatorial West Indian Ocean also experienced mixed precipitation anomaly, while EEIO experienced over 8 mm day^{-1}.

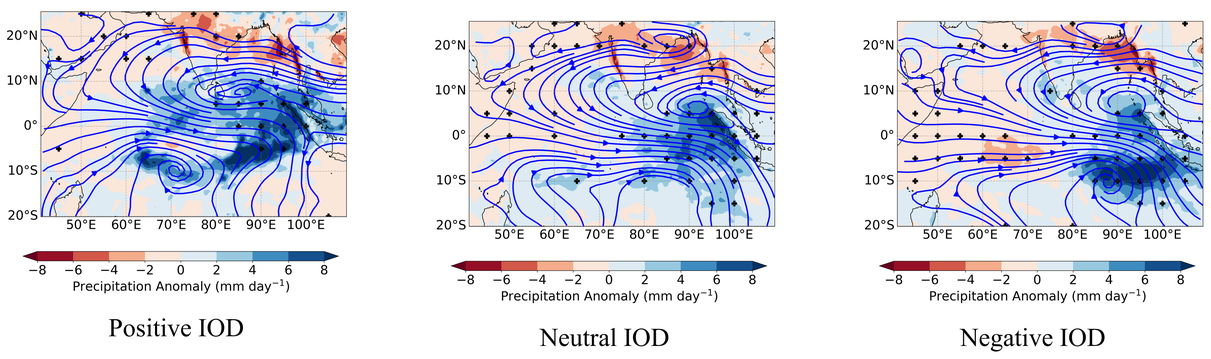

Figure 7. Composites of Precipitation during WWBs at (a) Positive, (b) Neutral and (c) Negative IOD ("+" indicate those exceed the 95% confidence)

Conclusions

- Neutral IOD condition observed for higher WWBs generation on the equator, while positive IOD the least during SWM period.
- During 2-3 days duration category over 25% of WWBs monitored at all IOD conditions, which was gradually lower with higher duration categories. Lowest duration reported over 10 days category at all IOD conditions.
- Significant wave height anomalies were mostly observed along the equator, corresponding to the regions where WWBs were observed.
- During the positive IOD with WWBs, warm SST observed at the central Indian Ocean, while negative IOD it was observed for colder SST, suggesting that WWBs modulates the surface layer of the ocean.
- Precipitation and IWVF circulation was moduled during WWBs resulting increased rainfall anomaly over EEIO. Circulations of IWVF varied with each IOD condition, resulting mixed precipitation over Indian Peninsula.

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