Prolonged Westerlies in the Equatorial Indian Ocean: Atmospheric Drivers and Upper-Ocean Responses

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Abstract
Anomalous prolonged westerly (PW) winds over the equatorial Indian Ocean during December–January significantly modulate upper-ocean dynamics, altering currents, thermocline structure, and sea surface temperature (SST). Atmospheric analyses indicate PW events preferentially occur during La Niña conditions when convection shifts toward the Maritime Continent. While the Madden–Julian Oscillation typically modulates westerly wind bursts, PW events extend beyond active MJO phases, highlighting the critical role of successive tropical cyclones. Using observations and a data-assimilative model, we contrast the upper-ocean response during the two strongest PW periods (2020–2021, 2024–2025) against a non-PW year (2018–2019). We show that sustained westerlies intensify and prolong the eastward Wyrtki Jet through January. Further south, anomalous wind-stress curl intensifies the South Equatorial Countercurrent (SECC) to ~1 m s^{-1} during January–February. In the eastern equatorial basin, persistent westerlies maintain an anomalously deep thermocline into late January. Conversely, in the Seychelles–Chagos Thermocline Ridge (SCTR), enhanced cyclonic wind-stress curl drives Ekman divergence, initially shoaling the thermocline to ~60 m by mid-January. Subsequent wind relaxation and the arrival of a reflected downwelling Rossby wave rapidly deepen the SCTR thermocline to ~120 m in late February. Despite enhanced shear-driven mixing during PW events, SST cooling remains modest (~0.5°C), as surface heat fluxes partially offset dynamical cooling. This yields a relatively stable SST (~29°C) compared to episodic intraseasonal fluctuations during non-PW years. Ultimately, these results demonstrate how sustained atmospheric forcing and equatorial wave dynamics jointly dictate upper-ocean variability during the boreal winter.