THE INFLUENCE OF THE EL NIÑO-SOUTHERN OSCILLATION ON SHEAR LINE OCCURRENCE IN THE PHILIPPINES DURING THE WINTER MONSOON

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Abstract

Shear lines (SLs) are a major driver of heavy rainfall over the Philippines during the boreal winter monsoon, yet their climatology and link to large-scale climate variability remain understudied. This study presents a 35-year climatology (1990–2024) of Philippine winter monsoon shear lines and examines how the El Niño–Southern Oscillation (ENSO) modulates their behavior. The analysis covers three components: (1) objective detection and validation of shear lines from ERA5 reanalysis, (2) assessment of ENSO-related changes in shear line frequency, duration, spatial position, and rainfall, and (3) composite characterization of atmospheric conditions during events.

In this study, shear lines were objectively identified using the ERA5 data for the NDJFM season from 1990–2024 by three simultaneous criteria 925 hPa meridional wind shear ($\partial V/\partial y \leq -1\times10^{-5}$ s^{-1}), positive vertically integrated moisture flux convergence (VIMFC > 0), and positive relative vorticity ($RV_{925} > 0$), combined with pre-gradient Gaussian smoothing ($\sigma = 3$), DBSCAN spatial clustering, and a minimum longitude extent of 7°, calibrated for ERA5 resolution in line with Olaguera et al. (2025) shear line detection methodology. The algorithm detected 3,306 shear line days (62.4% of 5,294 calendar days) and 2,094 events across 35 NDJFM winter seasons, yielding an average of 94.5 SL days and 59.8 events per NDJFM season.

ENSO exerts a strong and statistically significant control on shear line activity. La Niña seasons show the highest frequency (109.1 days/season), followed by Neutral (91.1) and El Niño (78.4). Events during La Niña also persist longer (1.19 days) than during El Niño (0.81 days; $p < 0.0001$). Spatially, shear lines shift southward during La Niña (~14.4°N) and northward during El Niño (~16.0°N; $p < 0.001$), expanding rainfall exposure toward the Visayas and Mindanao during La Niña. Rainfall linked to shear lines follows the same pattern, with higher daily totals (20.64 mm day^{-1}) and more frequent heavy rainfall events (12.17%) during La Niña compared to El Niño (12.20 mm day^{-1}; 6.18%).

Composite analysis shows that ENSO modulates shear lines by altering low-level wind convergence over the Philippines. During La Niña, strengthened northeasterly monsoon flow and enhanced easterly winds from the Pacific converge more frequently and persistently, favoring shear line formation. During El Niño, these flows weaken and shift, reducing convergence and displacing shear lines northward. This simplified mechanism links ENSO-driven circulation changes directly to observed variations in shear line frequency, duration, and location.

Overall, the results demonstrate that ENSO systematically controls Philippine shear line activity, with direct implications for seasonal rainfall variability, early warning, and disaster risk reduction across the country.

Keywords: shear lines; ENSO; Philippines; winter monsoon; heavy rainfall; ERA5; moisture convergence; climate variability