Impact of a multidecadal climate mode from the Southern Hemisphere on El Niño Southern Oscillation seasonal transitions

El Niño Southern Oscillation (ENSO) is the dominant interannual mode of quasi-periodic climate variability in the tropical Pacific Ocean. It oscillates between a warm state (El Niño) and a cold state (La Niña) with a period of two to seven years. In addition to this cycle, ENSO exhibits a seasonal pattern, typically peaking in intensity during the boreal winter and transitioning through spring. However, in recent decades, such winter-to-summer ENSO transitions have become eclectic, primarily due to the tropical-extratropical interactions at interannual timescales. These interactions influence the prevailing trade winds, which normally blow east to west across the equatorial Pacific Ocean, thus impacting the lifecycle of ENSO. For example, El Niño (the warm phase of ENSO) occurs when these trade winds weaken (anomalous westerly winds) in the equatorial Pacific Ocean.

In our study, we report the existence of a climatic mode (EOF2) that drives multidecadal sea-level pressure (SLP) variations in the extratropical South Pacific Ocean during boreal spring (see Figure 1a). This pattern, characterized by a zonal SLP dipole, impacts the seasonal transitions of ENSO from boreal winter to summer by influencing equatorial zonal winds in the Pacific Ocean. Therefore, we refer to this pattern as the ENSO transition mode (ETM). In its positive phase, ETM features anomalous westerly winds in the central-eastern equatorial Pacific Ocean that amplify boreal winter-to-summer Nino3.4 sea-surface temperature anomalies (N34SST), a metric used to quantify ENSO variability.

ETM's impact on the decadal variability of ENSO

Understanding climate variability, particularly over decadal to multidecadal periods (e.g., 10 to 20 years ahead), is crucial for long-term planning related to food security, water resources, and the economy. Using ETM, we constructed a multivariate linear regression model that effectively reconstructed the multidecadal fluctuations in boreal summer N34SST (N34JJA), as illustrated in Figure 1c. During decades with frequent positive ETM, anomalous westerlies lead to more frequent seasonal warming of N34SST, leading to a warmer decadal phase of N34JJA. The converse is true for decades with frequent negative ETM. Therefore, ETM's impact on ENSO's seasonal transition shapes the multidecadal variations of ENSO.

Finally, we believe that ETM-driven multidecadal warming of the equatorial Pacific Ocean can elucidate the multidecadal variations of the Indian Monsoon, which already exhibit significant associations with ENSO at interannual timescales.

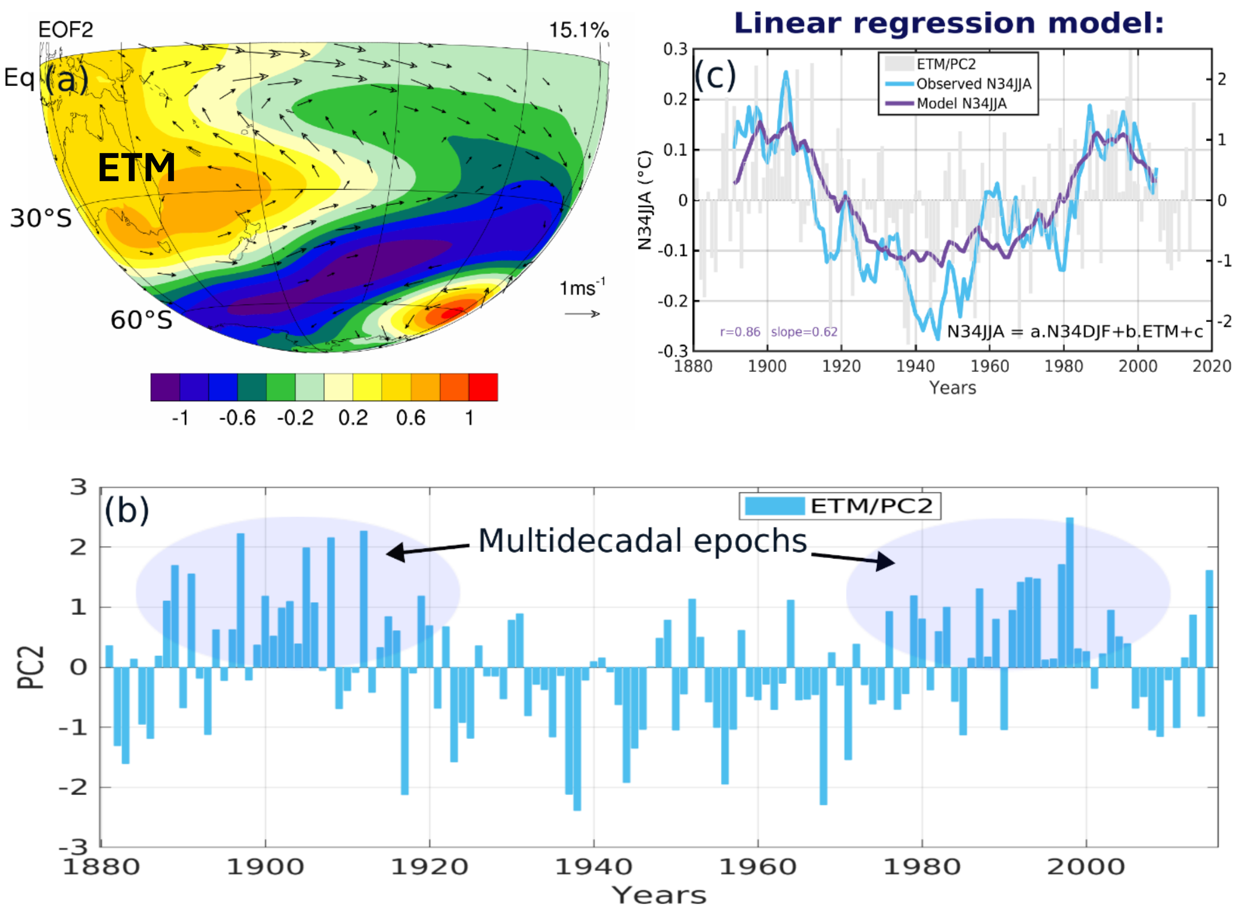

Figure 1 (a) Spatial loading of EOF2 of the sea-level pressure (SLP) pattern over the equatorial and Southern Indo-Pacific region (10° N–90° S, 45° E–290° E) for March–April–May. The variance explained by EOF2 is 15.1%. The vectors represent the linear regression of normalized PC2 (ETM) against 10 m surface winds for March–April–May. (b) The PC2 time series corresponds to the EOF2 spatial plot, clearly depicting the multidecadal cycle. (c) The 21-year running mean of the observed N34JJA (light blue) and model reconstructed N34JJA (purple). The PC2/ETM time series is shown on the secondary *y*-axis (grey bars). The model successfully captures the multidecadal variations of summer N34SST. N34DJF represents boreal winter (December-January-February) N34SST and N34JJA represents summer (June-July-August) N34SST. N34SST is sea-surface temperature anomalies in the central-eastern equatorial Pacific Ocean and is widely used as a metric to quantify ENSO variations.

Reference

Srivastava, S., Chakraborty, A., & Murtugudde, R. (2024). Decadal preference of seasonal ENSO transition through a southern hemisphere climate mode. *Environmental Research Letters*, *19*(6), 064040.