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ENSO Response to ITCZ Shift and Bjercknes Feedback under Climate Engineering

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Stratospheric aerosol injection (SAI) has been proposed as a cost-effective geoengineering strategy to mitigate global warming. This study examines changes in El Niño–Southern Oscillation (ENSO) variability under SAI scenarios using CESM2 simulations, including historical, SSP2-4.5, and SAI experiments. In the SAI simulations, sulfur dioxide (SO₂) aerosols were injected into the lower stratosphere (~22 km altitude) from 2035 to 2069 at 15° latitude intervals between 45°S and 45°N.

Under the SSP2-4.5 scenario, ENSO variability increased significantly relative to the historical period. The impact of SAI on ENSO, however, was strongly dependent on the hemisphere of aerosol injection. Southern Hemisphere injection substantially restored ENSO variability to historical levels. In contrast, Northern Hemisphere injection had little effect, with ENSO variability remaining similar to that under SSP2-4.5.

The enhanced variability in SSP2-4.5 was linked to an equatorward shift of the Intertropical Convergence Zone (ITCZ). This shift altered meridional and zonal sea surface temperature (SST) gradients in the tropical Pacific, weakened trade winds, and flattened the thermocline. These processes collectively intensified Bjercknes positive feedback, particularly the sensitivity of ocean surface currents to wind stress, as revealed by the Bjercknes Stability Index (BJ index) analysis. Southern Hemisphere SAI largely reverses these mechanisms by inducing a poleward shift of the ITCZ, which in turn strengthens trade winds and steepens the thermocline, thereby weakening Bjercknes positive feedback and restoring ENSO variability. In contrast, Northern Hemisphere injection exerts little influence, with ENSO variability remaining elevated and comparable to SSP2-4.5.

Keywords: Climate Engineering, Stratospheric Aerosol Injection (SAI), El Niño–Southern Oscillation (ENSO), Bjercknes feedback, ITCZ shift