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Seasonal Timing Controls ENSO Responses to Tropical Volcanic Eruptions

Francesco S.R. Pausata and Davide Zanchettin

University of Quebec in Montreal, Earth and Atmospheric Sciences, Montreal, Canada (pausata.francesco@uqam.ca)

Volcanic eruptions in the tropics inject aerosols into the stratosphere, altering radiative fluxes and perturbing climate patterns, including the El Niño–Southern Oscillation (ENSO). Using a set of 40-member ensemble simulations with the NorESM1-M model, we investigate how the season and hemisphere of tropical eruptions influence ENSO responses. Our results demonstrate that the eruption season significantly modulates aerosol distribution and radiative forcing, with summer eruptions producing up to 50% stronger forcing than fall or winter events. ENSO responses exhibit a pronounced phase-locking behavior: tropical Northern Hemisphere eruptions in spring or summer trigger El Niño-like anomalies in the first post-eruption winter, followed by La Niña-like conditions in the second year, whereas fall and winter eruptions produce weaker, delayed anomalies. Southern Hemisphere eruptions generally induce muted ENSO signals, emphasizing the role of hemispheric location in modulating response amplitude. These findings reveal a two-tiered control on volcanic impacts: eruption timing sets the ENSO “anomaly clock,” while injection hemisphere modulates its strength, highlighting the importance of seasonality in predicting climate responses to tropical volcanic events.