

# Inferring Phase Dynamics of El Niño-Southern Oscillation under Annual Forcing

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The El Niño–Southern Oscillation (ENSO) accounts for a significant fraction of global climate variability on interannual time scales. While the period of ENSO events varies irregularly within the range of 2–7 years, El Niño events often peak in boreal winter. One approach to predicting ENSO events is to examine their synchronization with the annual cycle. Understanding this synchronization is also important for clarifying the underlying climate dynamics. Previous studies report a statistically significant 2:1 phase relationship between ENSO and the annual cycle [1,2].

In this study, we present a preliminary analysis of the synchronization properties between ENSO and the annual cycle by inferring the phase dynamics of ENSO. Recent studies have proposed data-driven methods based on Koopman operator analysis that enable the time evolution of ENSO to be represented using a rectified phase [3]. This phase evolves approximately as a harmonic oscillator. Using the rectified phase, we infer the phase dynamics of ENSO in the form of phase oscillators forced by the annual cycle [4,5]. The resulting equations describe the synchronization between ENSO and the annual cycle, enabling us to assess the strength of the annual forcing and determine whether it gives rise to phase locking at 2:1 or other rational ratios.

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