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Characterizing Nonlinearities in ENSO Dynamics Using Hybrid Machine Learning Models

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Event-to-event differences of the El Niño Southern Oscillation (ENSO) result in different patterns of extreme climate conditions globally, which requires ENSO forecasts that accurately predict both the likelihood and the type of an event. One question regarding predictable ENSO dynamics is the extent to which they may be captured by multivariate linear dynamics and, relatedly, whether predictable nonlinearities must be accounted for or may be treated stochastically.

In this study, we combine Recurrent Neural Networks with the Linear Inverse Model (LIM) to assess the role of predictable nonlinearities and non-Markovianity in the evolution of tropical Pacific sea surface temperature anomalies. We observe that modeling nonlinearities significantly enhances the forecast accuracy, particularly in the western tropical Pacific within a 9 to 18-month lag time. Our results indicate that the asymmetry of warm and cold events is the main source of the nonlinearity. Moreover, we demonstrate that the predictability of the Hybrid-model can be reliably inferred from the theoretical skill of the LIM whereas a similar assessment is not possible in pure deep learning models.