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Annual Cycle/ENSO interactions - frequency entrainment or combination tones?

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One of the key characteristics of the El Niño-Southern Oscillation (ENSO) is its synchronization to the annual cycle, which manifests in the tendency of ENSO events to peak during boreal winter. Current theory offers two possible mechanisms to account the for ENSO synchronization: frequency locking of ENSO to periodic forcing by the annual cycle, or the effect of the seasonally varying background state of the equatorial Paciic on ENSO's coupled stability.

Using a parametric recharge oscillator (PRO) model of ENSO, we test which of these scenarios provides a better explanation of the observed ENSO synchronization. Analytical solutions of the PRO model show that the annual modulation of the growth rate parameter results directly in ENSO's seasonal variance, amplitude modulation, and 2:1 phase synchronization to the annual cycle. The solutions are shown to be applicable to the long-term behavior of the damped model excited by stochastic noise, which produces synchronization characteristics that agree with the observations and can account for the variety of ENSO synchronization behavior in state of the art coupled general circulation models. The model also predicts spectral peaks at Combination tones" between ENSO and the annual cycle that exist in the observations and many coupled models. In contrast, the nonlinear frequency entrainment scenario predicts the existence of a spectral peak at the biennial frequency corresponding to the observed 2:1 phase synchronization. Such a peak does not exist in the observed ENSO spectrum. Hence, we conclude that the seasonal modulation of the coupled stability is responsible for the synchronization of ENSO events to the annual cycle.

The talk will further demonstrate that the seasonal modulation of ENSO instability and the resulting combination tone dynamics are driven primarily by the seasonal cycle of winds in the western tropical Pacific and the seasonal development and march of the South Pacific Convergence Zone.

The insights gained from the analytical PRO model are also being tested against the current generation of CMIP5 coupled general circulation models. Only a small fraction of CGCMs captures ENSO combination tone dynamics realistically.