A Conceptual Model for Two Modes of El Niño: The Role of Westerly Wind Bursts

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A new classification of El Niño is recently proposed, which divides the dominant short-term climate variability in the tropical Pacific into two modes, the so-called warm-pool (WP) El Niño and cold-tongue (CT) El Niño. The latter can be regarded as the traditional El Niño which has maximum variance in the eastern Pacific cold tongue, while the former has its center of action in the western-central equatorial Pacific, close to the eastern edge of the warm pool. Although the strength of the WP El Niño is much less than that of the conventional CT El Niño, it appears to be an independent mode of variability with distinct characteristics that can be identified from both oceanic and atmospheric fields. This phenomenon, sometimes also called by other names, has drawn much attention in recent years, but its physical basis and excitation mechanism are still far from clear.

Using observations from 1971-2007, we found that all of the WP El Niño events are accompanied by frequent westerly wind bursts (WWBs). Based on this relationship and previous studies on the interaction between the traditional CT El Niño and WWBs, we present a conceptual multi-box model for both WP and CT El Niño, in attempt to provide a unified theoretical framework for the tropical Pacific climate variability. With realistic parameters derived from observations, the model exhibits a self-sustaining variability that is dynamically consistent with classic ENSO theories. When external WWBs are introduced, the model behaves in different ways, depending on the phase of model ENSO. If WWBs occur right before an El Niño takes place, they enhance the event and lead a strong CT El Niño. But if WWBs appear at a time that is not favorable for the development of El Niño, the model generates a mode of variability that resembles the WP El Niño. In essence, this mode is a result of the advective warming related to the zonal migration of the warm pool forced by the surface wind-driven currents. For the CT El Niño, both wave dynamics and advection are important, with the former playing a more vital role. For the WP El Niño, however, advection is the dominant process at work.