Understanding and Predicting El Niño

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Background

Our research is concerned with the variability of climate on time scales of a few months to a few decades. On these time scales, the atmosphere has little or no internal "memory"; that is, the processes acting within the atmosphere alone have time scales that are comparatively short - of order days to weeks. This is not to say that there is no predictability on longer time scales. In fact there is, but it derives from the interaction of the atmosphere with the oceans and land surface. Intrinsic to the land surface and especially the ocean are much longer internal timescales, and through the processes that couple these media to the atmosphere, the climate attains a degree of determinism and predictability.

In the ocean, time scales divide roughly according to depth. Processes operating within the so-called mixed layer (roughly the uppermost 50 m) give rise to variability of sea surface temperature (SST) on the time scales of a few months. The dynamics of the upper ocean above the so-called thermocline (the generally sharp transition between warmer near-surface waters and the colder abyssal waters at 200m-500m depth) result in waves with time scales of seasons to years. Finally the slow overturning of the deep ocean evolves on time scales of centuries.

Our great advancement in the understanding of ENSO (El Niño/Southern Oscillation) and its predictability came with the recognition that it is a fundamentally coupled interaction between the atmosphere and the tropical Pacific ocean. The important interactions involve the upper ocean, down to the thermocline, and thus the relevant oceanic internal time scales are in the range of seasons to years - not surprisingly, the dominant time scales of ENSO itself.

Our own group's work on ENSO began about a decade ago with the development of a numerical model embodying our ideas of the essential physical processes underlying the phenomenon. The model was to be the tool we would use to test the prevailing theories, and to form a more complete understanding of ENSO as a quasi-cyclic process. The primary goal in the initial modeling work was to simulate the major tropical Pacific manifestations of an El Niño event. These include the development of anomalously warm SST in the eastern tropical Pacific, and the associated slackening of the easterly trade winds across the central tropical Pacific, and then the subsequent return to more normal conditions. In idealized, but recognizable form, the model was able to simulate these features. Moreover, when run for a longer period, the model simulation produced a continuous succession of El Niño and La Nina (approximately opposite, anomalously cool Pacific SST) episodes, occurring irregularly,