Modelling the El Niño Southern Oscillations through the work of Zebiak-Cane

The El Niño Southern Oscillations (ENSOs) are generally known as a composite weather phenomena originating in the Pacific Ocean which produces lasting teleconnections on the global climate system. El Niño can be approximately considered to be an oceanic warming event which disrupts the normal Pacific circulation at irregular intervals of 2–7 years, whilst the Southern Oscillations are an inter-annual flip between the tropical sea level pressure between the western and eastern Pacific leading to the weakening and strengthening of the easterly trade winds across the ocean. Whilst the effects of ENSOs are mostly well understood, there is yet to be one conclusive theory which can describes the underlying mechanisms.

Bjerknes (1969) first theorised that a positive ocean-atmosphere feedback system results in an El Niño event. An initial positive sea surface temperature (SST) anomaly in the eastern Pacific would reduce the east-west SST gradient which leads to the strengthening of the Walker circulation and the production of weaker trade winds across the equatorial Pacific. In a complete ENSO theory this positive system should be counterbalanced by a negative loop which returns the Pacific to its "normal" (pre-ENSO) state. Whilst Bjerknes' hypothesis fails to provide a negative feedback mechanism, Zebiak and Cane (1987) presents a singular model which demonstrates and outlines the coupling between the atmosphere and the ocean to produce an ENSO event. The atmospheric component is a linear Gill-type model (Gill 1980) which describes the atmospheric response to SST anomalies, and the ocean is represented by a low-gravity model which is forced by the wind stress from the atmospheric component. The Zebiak-Cane (ZC) model is commonly used as the basic foundation for several modern ENSO oscillator theories: the delayed oscillator (Battisti and Hirst 1988, Suarez and Schopf 1988), the recharge oscillator (Jin 1997), the western Pacific oscillator (Wang et al. 1999, Weisberg and Wang 1997), and the advective-reflective oscillator (Picaut et al. 1997).

These variants of Zebiak and Cane's work provides adjustments to the atmospheric and oceanic components of the ZC model, allowing for improvements in the accuracy and precision in the prediction of ENSO events. Variations such as Neelin (1991) or Neelin et al. (1998)

This idea forms the basis of two approximate schools of thought on the theoretical origins of ENSOs (Wang et al. 2017). The first suggests El Niño to be a phase of a self-sustained, unstable, and natural oscillatory mode of the coupled ocean-atmosphere system. The second, describes El Niño to be a stable (or damped) mode which is triggered by or interacted with random forcing or noise such as westerly wind bursts, tropical instability waves in the eastern Pacific (An 2008), and Madden-Julian oscillation events (Gebbie et al. 2007).

The prevalent mechanism amongst both groupings of ideas is the effect of an oscillator on the Pacific climate system. There are several conceptual models which aim to describe ENSO including those based on the coupled system, for example the delayed oscillator (Battisti and Hirst 1988, Suarez and Schopf 1988) and the recharge-discharge oscillator (Jin 1997). These are generally there exists a "unified oscillator" (Wang 2001) which suggests that all alternative oscillator models are a special case of itself.

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