Theoretical predictions of the El Niño Southern Oscillations with the Zebiak-Cane model

1. INTRODUCTION

The El Niño Southern Oscillations (ENSOs) are generally known as a composite weather phenomena originating in the Pacific Ocean producing lasting teleconnections on the global climate system. The El Niño component of ENSO 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 of 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. To produce a conclusive theory for ENSOs one must be able to describe and understand the complete underlying mechanisms. One such hypothesis has yet to arise, however various attempts have been made to comprehend individual components and effects.

Bjerknes (1969) first theorised that a positive ocean-atmosphere feedback system would result 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 thus the production of weaker trade winds across the equatorial Pacific. In a complete ENSO theory this positive system would 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) presented a model which demonstrated and outlined the coupling between the atmosphere and the ocean to produce an ENSO event. The atmospheric component used was a linear Gill-type model (Gill 1980) which describes the atmosphere's response to SST anomalies, and the ocean represented by a low-gravity system which is forced by the wind stress from the atmospheric constituent.

With their model they were able to replicate features observed during ENSO events such as equatorial westerly wind anomalies in the central Pacific and large SST anomalies in the eastern Pacific, on top of that they were able to predict the onset of the 1986–1987 and 1991–1992 ENSO events. Despite this success, they recognised their limited ability in simulating the real complete system as detailed comparisons with observational data would reveal discrepancies in their atmospheric and oceanic simulations. Furthermore, the short warm episodes in 1993 and 1994 would not be predicted by the Zebiak-Cane (ZC) model.

2. LIMITATIONS OF THE ZEBIAK-CANE MODEL

The prediction of ENSO events is particularly difficult as there are generally two types of El Niño events to account for. The first are canonical events which normally develop along the South American coast and then propagates westwards across the Pacific (Rasmusson and Carpenter 1982). The second type of events have warm SST mostly centred in the central Pacific which do not propagate (Ashok et al. 2007).

They suggest that more sophisticated models would have to be produced to correctly simulate the real ENSO cycle.

3. IMPROVING THE ZEBIAK-CANE MODEL

For several modern ENSO oscillator theories, the Zebiak-Cane (ZC) model is used as a basic foundation: 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 provide adjustments to the atmospheric and oceanic components of the ZC model which allows for improvements in the accuracy and precision in the prediction of ENSO events.

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