Collaborative Research: An Interactive Multi-Model for Consensus on Climate Change

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Project synopsis

This collaboration has several components but the main idea is that when imperfect copies of a given nonlinear dynamical system are coupled, they may synchronize for some set of coupling parameters. This idea is to be tested for several IPCC-like models each one with its own formulation and representing an "imperfect" copy of the true climate system. By computing the coupling parameters, which will lead the models to a synchronized state, a consensus on climate change simulations may be achieved.

Recent results

Another aspect of synchronization in climate (and my part of the project) is the synchronization of climate modes. These modes represent low-order subsystems in climate and it has been shown that they often synchronize. An important element in the theory of synchronization between coupled nonlinear oscillators is coupling strength. The theory of synchronized chaos (Pecora et al. 1997; Boccaletti et al. 2002) predicts that in many cases when such systems synchronize, an increase in coupling strength between the oscillators may destroy the synchronous state and alter the system's behavior. These ideas were initially explored in a network of four climate oscillators, namely El Nino-Southern Oscillation (ENSO), the North Atlantic Oscillation (NAO), the North Pacific Index (NPI), and the Pacific Decadal Oscillation (PDO; Tsonis et al. 2007; Swanson and Tsonis 2009; Wang et al. 2009). The results indicate that this network in the 20th century synchronized several times. It was then found that in those cases where the synchronous state was followed by a steady increase in the coupling strength between the indices, the synchronous state was destroyed, after which a new climate state emerged. These shifts are associated with significant changes in global temperature trend over decadal time scales. We also find the evidence for such type of behavior in three climate simulations (control and CO_2 forced) using simulation from state-of-the-art models.

Part of my work was to understand relationships between regime shifts and synchronization in a set of ordinary differential equations (ODE's) representing climate modes. To this end we further studied synchronizations by extending the previous analysis to include more indices. Some results are shown in figure 1. On the x-axis are the different modes and on the y-axis is time. This figure may be interpreted as follows. Horizontal orange or yellow lines indicate synchronization events and the modes involved in each synchronization event. The main conclusion here is that de-synchronization does not always mean a regime shift. For example, while in the early 1940s a climate shift took place, no shift occurred in the 1920s or early 1930s. In accordance with the previous results only in those times when increase in coupling is involved de-synchronization is associated with a climate regime. In relation to the goals of the complete proposal it is important to establish the mechanism via which synchronization and coupling increase occur. Our results also indicate that in the four mode network the direction of influences begins with North Atlantic coupling to North Pacific which then couples to tropical Pacific which in turn couples back to North Atlantic Wang et al. 2009; Ineson and Scaife 2009).