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The nonlinear recharge El-Niño oscillator : stochastic and seasonal forcing effects

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The substantial interest in the understanding of El-Niño/Southern-Oscillation (ENSO) phenomena and seasonal-to-interannual climate prediction based on these phenomena has produced a large number of conceptual, "toy" models and intermediate coupled models (ICMs) of ENSO variability. The nonlinear recharge-discharge model of Timmermann and Jin (*GRL*, 2002; hereafter T&J model) captures several essential physical ENSO mechanisms. This model has only three degrees of freedom (i.e., 3 prognostic variables) but still exhibits rich and pertinent dynamical behavior, arrived at through Hopf or homoclinic bifurcations, although it does not include seasonal forcing.

In this talk, we will present preliminary results for inclusion of the seasonal cycle, as well as of weather noise in this model. Our main objective is to consider the effects of such forcing by using novel mathematical concepts and theoretical results that have not been widely exploited so far in climate research. More specifically, we will use the concepts and tools of random dynamical systems (RDS) theory to analyze the stochastic dynamics of the T&J model.

Based on earlier results with a periodically forced quasi-geostrophic model of the double-gyre, wind-driven ocean circulation (see EGU 2007), we expect the deterministically robust Hopf bifurcation to give rise to its stochastic counterpart. The homoclinic orbit is structurally unstable and will be destroyed by either the seasonal or the stochastic forcing. But the concept of a *random attractor* allows us to provide a fairly detailed description of the residual structures in phase-parameter space.

We hope to be able to connect this description of the random attractor in the T&J model with the purely numerical results of Fedorov et al. (*BAMS*, 2003), who used a realistic ocean general circulation model (GCM) and wind forcing based on the Comprehensive Ocean-Atmosphere Data Set (COADS) (before 1993) and the National Centers for Environmental Prediction (NCEP) reanalyses (since 1993). The latter GCM results suggest the presence of a random attractor and would thus help integrate ENSO results across the full hierarchy of ENSO models, from toy through ICMs and all the way to coupled GCMs, as originally suggested by Ghil and Robertson (2000).