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Nonlinear and stochastic effects in ENSO variability: From observations to intermediate models

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The El-Nino/Southern-Oscillation (ENSO) phenomenon dominates interannual climate signals in and around the Tropical Pacific and affects the atmospheric circulation and air-sea interaction over many parts of the globe. Observational campaigns over the last decades have helped infer the most relevant processes, time scales and spatial patterns. A hierarchy of models has been developed to understand these processes and their interaction. These models have been, by-and-large, either deterministic and nonlinear or stochastic and linear, and have been applied to the prediction of future variability as well.

The purpose of our work is to combine these two complementary points of view, and thus account for (i) the most robust and relevant aspects of the observations; (ii) the advances in understanding the nonlinear, deterministic interactions between the largest and most energetic scales; and (iii) the impact of small-scale (“noise”) and remote (“external”) processes. The main thrust of our approach is based on the concepts and tools of the theory of random dynamical systems (RDS).

So far, two of the co-authors (MC & MG), in collaboration with E. Simonnet, have successfully applied RDS theory to, and described in detail the random attractors of several idealized climate models, such as the Lorenz (JAS, 1963) model of convection and the ENSO model of Timmermann and Jin (GRL, 2002). In the present work, we are extending these results to more detailed and realistic models, on the way to their eventual application to IPCC-class general circulation models (GCMs). Specifically, we address here two classes of such intermediate models.

The first class is that of nonlinear inverse models derived by empirical mode reduction (EMR), as developed by two of the co-authors (MG and DK), in collaboration with S. Kravtsov, A. W. Robertson and others. In particular, we are studying the random attractor of the ENSO model derived in 2005 from sea surface temperature data over the past century, and being routinely applied to ENSO prediction since.

The second class is that of intermediate models developed by one of the coauthors (JDN) in the early 1990s. These models are based on thermodynamical and fluid mechanical principles classically used in ENSO theory. This particular model has also been used over several years in routine ENSO prediction, as summarized over two decades by NOAA’s Experimental Long-Lead Forecast Bulletin (ELLFB) and, more recently, by the ”ENSO prediction plume” of the International Research Institute for Climate and Society (IRI).

In both types of intermediate models, we study the effects of stochastic forcing that exhibits spatial correlations with the twofold purpose of (i) helping parameterize the unresolved processes, and (ii) improving prediction capabilities.