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Normal Forms for Reduced Stochastic Climate Models

C. Franzke (1), A. Majda (2), and D. Crommelin (3)

(1) British Antarctic Survey, Cambridge, United Kingdom (chan1@bas.ac.uk, +44 1223 221226), (2) Courant Institute of Mathematical Sciences, New York University, New York, USA, (3) CWI, Amsterdam, The Netherlands

The systematic development of reduced low-dimensional stochastic climate models from observations or comprehensive high-dimensional climate models is an important topic for low-frequency variability, climate sensitivity, and improved extended range forecasting. Here techniques from applied mathematics are utilized to systematically derive normal forms for reduced stochastic climate models for low-frequency variables. The use of a few Empirical Orthogonal Functions (EOF) depending on observational data to span the low-frequency subspace requires the assessment of dyad interactions besides the more familiar triads in the interaction between the low- and high-frequency subspaces of the dynamics. It will be shown that the dyad and multiplicative triad interactions combine with the climatological linear operator interactions to simultaneously produce both strong nonlinear dissipation and Correlated Additive and Multiplicative (CAM) stochastic noise. For a single low-frequency variable the dyad interactions and climatological linear operator alone produce a normal form with CAM noise from advection of the large-scales by the small scales and simultaneously strong cubic damping. This normal form should prove useful for developing systematic regression fitting strategies for stochastic models of climate data. The validity of the one and two dimensional normal forms will be presented. Also the analytical PDF form for one-dimensional reduced models will be derived. This PDF can exhibit power-law decay only over a limited range and its ultimate decay is determined by the cubic damping. This cubic damping produces a Gaussian tail.