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Nonlinear Stochastic Low-Order Models of Atmospheric Low-Frequency Variability

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Nonlinear stochastic low-order models are derived which are capable of simulating realistic atmospheric low-frequency variability. The reduced models deal explicitly only with a very limited number of essential low-frequency patterns; the influence of unresolved fast-evolving modes onto the resolved slowly-evolving large-scale modes is modelled by stochastic terms. A strategy of keeping the number of fitting parameters in the dynamical equations to a minimum is applied. The study focuses on two issues: (i) finding appropriate basis functions for spanning the resolved dynamics and a comparison between different choices of basis functions; (ii) the necessary characteristics of the noise processes, that is, white vs. red noise, Gaussian vs. non-Gaussian noise, and additive vs. multiplicative noise. A quasi-geostrophic three-level spectral model with realistic variability is used as dynamical framework.

Long-term integrations of the stochastic models are performed at various truncation levels and their long-term behaviour is compared to that of the full model. Monitored quantities include the mean state, the variance pattern, momentum fluxes, probability distributions and autocorrelation functions. Stochastic low-order models (already with white noise) greatly outperform purely deterministic low-order models. A Langevin equation with only 10 retained low-frequency patterns is able to self-consistently simulate the dynamics of these patterns whereas a deterministic model with this few modes is completely off. The extension from white to red noise offers a considerable further improvement. With both kinds of noise processes, models based on the dynamically motivated principal interaction patterns clearly outperform models based on empirical orthogonal functions.