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A hierarchy of data-based paleoclimate models

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We apply the empirical mode reduction (EMR) methodology (Kravtsov et al., 2005) to construct a hierarchy of dynamic, stochastically forced models for the analysis and simulation of paleoclimate data. This methodology encompasses both linear and non-linear time-dependent models that aim to best describe the dataset's statistics. In EMR, multiple polynomial regression is used to estimate the deterministic propagator of the dynamics, as well as multi-level additive stochastic forcing, directly from the observations. In this multi-level approach, the residual stochastic forcing at a given level is subsequently modeled as a function of variables at this, and all preceding levels. The optimal number L of levels is determined from the data so that the lag-0 covariance of the residual forcing converges to a constant matrix, while its lag-1 covariance vanishes. When L is larger than unity, the forcing at the first level will be ‘‘warm-colored’’ (i.e., not white). Previous applications have included sea-surface temperature fields on seasonal-to-interannual time scales (Kondrashov et al., 2005) and geopotential height fields on intraseasonal time scales (Kondrashov et al., 2006).

We apply this methodology to a multivariate dataset consisting of Vostok ice-core and marine (SPECMAP) time series, representing proxy records for temperature and global ice-volume, respectively. In addition to residual stochastic forcing, the model is externally forced by orbital periodic forcing. The model's fit to the proxy records is verified by checking the probability density functions (PDFs) and autocorrelations, as well as the singular spectra of the paleo-data and of the reduced model's simulations. An analytical study of the reduced models suggests a role for stochastically forced internal variability, in addition to the periodic orbital forcing, and identifies the connections between the types of variability.