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Prediction of Large-Scale Atmospheric Flow by a Mixture of Empirical Linear Models

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The approach of modelling large-scale atmospheric dynamics with empirical linear models is extended to a nonlinear framework by using a mixture of local linear models instead of one global linear model. The study is performed within a three-level quasigeostrophic (QG) model with realistic climatological mean state and variance pattern as well as Pacific/North America and North Atlantic Oscillation teleconnection patterns. The empirical model is constructed in the space of the leading empirical orthogonal functions (EOFs) of the QG model. The methodology of cluster-weighted modelling is used to design an optimized mixture of local discrete linear Markov models. Each of the local models has a Gaussian cluster in the space of EOFs defining a regime in the large-scale circulation and an associated predictive linear regression model with Gaussian uncertainty into the space of EOFs some time lag ahead. The whole model is a weighted mixture of the local models, resulting in a locally linear but globally nonlinear system driven by multiplicative noise. The approach identifies and harnesses nonlinear correlations in the system by dealing with state-dependent means and covariances. The parameters of the model are determined consistently from a large data set of the QG model according to maximum likelihood; only the number of clusters has to be given beforehand. For only one cluster, the method degenerates to a single globally linear Markov model with purely additive noise.

The predictive skill of the cluster-weighted model is investigated. The method provides probabilistic predictions which can be cast into deterministic ones by restricting attention to the mean of the predictive distribution. While in deterministic mode a mixture of two and three local models only marginally outperformes a single linear

model, the former is clearly superior to the latter in probabilistic prediction.

The results indicate that the nonlinear propagator in the space of the leading EOFs in the QG model can be efficiently approximated by a mixture of linear models; locally linear dynamics driven by multiplicative noise may serve as a paradigm model for large-scale atmospheric dynamics.