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Data-driven deterministic and stochastic subgrid-scale parameterization for atmosphere and ocean models: a pattern-based approach

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Data-driven multivariate deterministic and stochastic subgrid modelling schemes for atmosphere and ocean models are discussed. A pattern-based approach is taken where pairs of patterns in the space of resolved variables (or functions of these) and in the space of the subgrid forcing are identified and linked in a predictive manner. On top of this deterministic part of the subgrid scheme the subgrid patterns may be forced stochastically with a fitted vector-autoregressive process. Both the deterministic and the stochastic scheme can be constrained by physically motivated conservation laws, such as momentum conservation or (kinetic) energy conservation but enstrophy dissipation. The method can also be extended by combining it with a clustering algorithm to arrive at a set of local subgrid models. The schemes are machine-learning-style but not based on deep learning. Unlike black-box approaches such as neural networks the present methodology still allows to understand and interpret the subgrid model.

The subgrid modelling schemes are explored in the multiscale Lorenz 1996 model and then implemented in a spectral quasi-geostrophic three-level atmospheric model with realistic mean state and variability. The atmospheric model at a horizontal resolution of T30 is regarded as the reference against which coarser-resolution versions at T21 and T15, equipped with the subgrid modelling schemes, are compared. In long-term simulations, the novel subgrid schemes greatly improve on a standard hyperviscosity scheme as evidenced by the mean state, the variability pattern as well as kinetic energy and potential energy spectra. They also show marked skill improvements in an ensemble prediction setting.

Primary author: KWASNIOK, Frank (University of Exeter, UK)

Presenter: KWASNIOK, Frank (University of Exeter, UK)

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