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Information flow in multi-scale dynamical systems using ordinal symbolic analysis

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In this work, information flow quantifiers between variables of multi-scale dynamical systems simulating atmospheric processes are evaluated in non-linear and non-gaussian statistical regimes. The atmosphere is a spatially extended, highly non-linear dynamical system with complex interactions between the different dynamical scales, as well as between the different physical processes involved in it. We evaluate whether conditional mutual information and transfer entropy are able to detect and quantify causal interactions between large-scale and small-scale dynamics. As simple prototype models of these atmospheric interactions, we use a two-scale Lorenz 96 model and a two dimensional barotropic model. In order to obtain the information quantifiers, temporal series from the experiments are examined with ordinal symbolic analysis using the Band-Pompe symbolic reduction in the data signal and using the Kraskov-Stogbauer-Grassberger method to estimate mutual information using k-nearest neighbors. Comparing different experiments, we show that the interactions between small-scale variables and large-scale variables may introduce spatial long-range information flows. We also found that conditional mutual information is able to detect energy and enstrophy cascades in the barotropic model. Ordinal symbolic analysis allows us to obtain robust measures and may be efficiently applied to long temporal series with correlations between several processes. We conclude that information measures are useful tools to establish observational information flows in the atmosphere. These tools may be helpful to quantify the role of small - scale processes and constraining stochastic parameterizations.