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A Climate-Dependent Sub-Grid-Scale Parameterization in Reduced Climate Models

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Presently even, and perhaps especially, the most elaborate climate system models use a multitude of parameterization schemes for small-scale processes. These should respond to externally forced climate variability in an appropriate manner so as to reflect the response of the parameterized process to a changing climate. The most attractive route to achieve such a behavior would certainly be provided by theoretical understanding sufficiently deep to enable the à-priori design of climate-sensitive parameterization schemes. An alternative path might, however, be helpful when the parameter tuning involved in the development of a scheme is objective enough so that these parameters can be described as functions of the statistics of the climate system. Provided that the dynamics of the process in question is sufficiently stochastic, and that the external forcing is not too strong, the fluctuation-dissipation theorem (FDT, Risken 1984) might be a tool to predict from the statistics of a system (e.g. the atmosphere) how an objectively tuned parameterization should respond to external forcing (e.g. by anomalous sea-surface temperatures). This problem is addressed within the framework of low-order (reduced) models for barotropic flow on the sphere, based on a few optimal basis functions (Selten 1995) and using an empirical linear sub-grid-scale (SGS) closure (Achatz and Branstator 1999). The FDT is used to predict the response of the SGS closure to anomalous local vorticity forcing. At sufficiently weak forcing use of the FDT is found to systematically improve the agreement between the response of a reduced model and that of a classic spectral code for the solution of the barotropic vorticity equation.

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