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Climate-dependence in SGS parameterizations of low-order climate models derived by the Fluctuation-Dissipation Theorem

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The atmosphere is a complex system involving many interacting scales. Therefore, subgrid-scale (SGS) parameterizations are essential for climate simulations and numerical weather prediction. Many of those parameterizations contain tuning parameters obtained by fitting model behavior to reference data statistics. Consequently, if the atmosphere is perturbed, and hence also the statistics, these parameters might become erroneous and the SGS parameterization may no longer be able to help simulating the dynamics of the perturbed atmosphere.
Therefore, we propose a climate dependence of the tuning parameters using the Fluctuation-Dissipation Theorem (FDT). The FDT is able to predict the changes in the statistics of a system, caused by small external forcings. Those changes are then used to update the empirical components of the tuning parameters.
This procedure is tested in a toy atmosphere provided by a three-layer quasi-geostrophic model (QG3LM). The corresponding climate model is given by a low-order model, based on a reduced number of QG3LM variance patterns, with an empirical linear closure as SGS parameterization. The external perturbation is given by some local anomalous heating in the extratropics.
It is shown that the FDT is able to predict the required change in the closure parameters. The climate model with the FDT-corrected closure improves the agreement with the perturbed toy atmosphere, compared to the climate model without a corrected closure. In addition, we show that the climate model with FDT-corrected closure outperforms the direct FDT estimation of the response of the toy atmosphere, provided sufficiently many basis patterns are used.