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Climate-Dependence in empirically tuned Subgrid-Scale Parameterizations using the Fluctuation-Dissipation Theorem

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In climate models many subgrid-scale (SGS) parameterizations contain tuning parameters and are thus data dependent. In particular, if the atmosphere is perturbed (and hence also its statistics), these parameters might become erroneous and the SGS parameterization may no longer be able to help simulating the dynamics of the perturbed atmosphere. We propose a climate dependence of the tuning parameters using the Fluctuation-Dissipation Theorem (FDT). The FDT provides estimations of the changes in the statistics of a system, caused by a small external forcing. This procedure is tested in a toy atmosphere provided by a three-layer quasi-geostrophic model (QG3LM). A low-order climate model is constructed based on a reduced number of QG3LM variance patterns and with an empirical linear closure as SGS parameterization. The external perturbation is given by a local anomalous heat source in the extratropics. We found that the FDT is able to predict the estimate 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.