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Studying the impact of small-scale atmospheric fluctuations on the temperature response to CO_2 forcing within a stochastic framework

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It is known that the parameterizations of nonlinear thermodynamical feedback processes involving water vapor, clouds and surface albedo are the main sources of uncertainty of the modeled climate sensitivity to CO_2 forcing. However, the climate system is not only characterized by the interactions of complex thermodynamical processes but also by nonlinear dynamical coupling of various scales of motion. As a consequence of the limited model resolution the governing equations are truncated at a certain scale. This approximation of the governing equations can also have an effect on the modeled climate sensitivity.
Using a coupled atmosphere-ocean-sea ice general circulation model (ECHAM5/MPI-OM) we carried out several experiments with different representations of small-scale fluctuations. To enhance the small-scale variability we reduced the horizontal diffusion or added white noise to spectral coefficients with high total wavenumbers. The experiments showed that the strength of the global warming caused by doubling the CO_2 concentration depends on the representation of small-scale fluctuations. For example, a reduction of the horizontal diffusion by a factor of 3 led to an increase of the temperature response by up to 16%.
The aim of this study is to explain the effect of small-scale atmospheric fluctuations on the climate sensitivity within a stochastic framework. A stochastic model based on a Langevin equation is fitted to the global mean temperature time series obtained from the different model experiments. Besides a stochastic forcing the model includes a linear damping and a constant forcing term. We find that enhanced small-scale variability

has no significant effect on the statistical damping. However, the representation of the small-scale components changes the large-scale forcing.