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Scale-invariant Horizontal Diffusion in a Global Circulation Model

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General Circulation Models (GCMs) are powerful tools to understand the dynamics of the general circulation of the atmosphere. A large amount of the kinetic energy (KE) produced by baroclinic waves is dissipated in the boundary layer. However, about one quarter of the KE is dissipated in the free atmosphere mainly by horizontal momentum diffusion. In GCMs this diffusion is often represented by an empirical hyper-diffusion scheme or by a numerical filter. It is well known that a reasonable simulation of the global circulation is not possible without such a scale-sensitive damping.

In this presentation we propose an improved parametrization of the horizontal diffusion. Until now, we have used the Smagorinsky scheme in the *Kühlungborn Mechanistic general Circulation Model* (KMCM), i.e. a harmonic diffusion based on the mixing length concept. The disadvantage of this approach is that it is not scale-invariant, neither in the synoptic nor in the mesoscale inertial range. The reason is the assumption of a constant mixing length. We replace this scheme by the Dynamic Smagorinsky Model (DSM), which is usually used in boundary layer theory. To the best of our knowledge, the DSM approach has never been used in a GCM as a parametrization of horizontal momentum diffusion.

The DSM provides a calculation of the local mixing length in dependence on the resolved flow. The method is based on evaluating the difference of the turbulent stress from two different resolutions by means of a test filter. This difference yields the turbulent stress due to the smallest resolved scales of the flow and should also be parameterized with the Smagorinsky approach. This constraint yields a local mixing length for the unresolved scales that ensures scale invariance. To ensure a positive dissipation rate, we use, unlike most other simulations, a tensor norm approximation to solve the basic tensor equation of the DSM.

Strong motivation for the use of the DSM is given by the fact that, in contrast to the often used hyper-diffusion schemes, it is like the classical Smagorinsky approach fully compatible with the hydrodynamic conservation laws. Surprisingly, the DSM has the counter-intuitive effect that the mixing length scales with the inverse wave number of the currently largest spectral component of the velocity field. Some preliminary results from a mechanistic climate simulation with the KMCM will be presented.