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Smagorinsky-type diffusion in a high-resolution GCM

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The parametrization of the (horizontal) momentum diffusion is a paramount component of a Global Circulation Model (GCM). Aside from friction in the boundary layer, a relevant fraction of kinetic energy is dissipated in the free atmosphere, and it is known that a linear harmonic turbulence model is not sufficient to obtain a reasonable simulation of the kinetic energy spectrum. Therefore, often empirical hyper-diffusion schemes are employed, regardless of disadvantages like the violation of energy conservation and the second law of thermodynamics.

At IAP we have developed an improved parametrization of the horizontal diffusion that is based on Smagorinsky's nonlinear and energy conservation formulation. This approach is extended by the dynamic Smagorinsky model (DSM) of M. Germano. In this new scheme, the mixing length is no longer a prescribed parameter but calculated dynamically from the resolved flow such as to preserve scale invariance for the horizontal energy cascade. The so-called Germano identity is solved by a tensor norm ansatz which yields a positive definite frictional heating.

We present results from an investigation using the DSM as a parametrization of horizontal diffusion in a high-resolution version of the *Kühlungborn Mechanistic general Circulation Model* (KMCM) with spectral truncation at horizontal wavenumber 330. The DSM calculates the Smagorinsky parameter c_S independent from the resolution scale. We find that this method yields an energy spectrum that exhibits a pronounced transition from a synoptic -3 to a mesoscale $-5/3$ slope at wavenumbers around 50. At the highest wavenumber end, a behaviour similar to that often obtained by tuning the hyper-diffusion is achieved self-consistently. This result is very sensitive to the explicit choice of the test filter in the DSM.