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Spectral budget of energy and potential enstrophy in high resolution General Circulation Models

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Nastrom and Gage (1985) showed that the atmospheric kinetic energy and potential temperature spectra measured in the upper troposphere and lower stratosphere present two inertial ranges. At the mesoscales, the spectra have a $k_h^{-5/3}$ power law dependence and at larger scales there is a narrow range where the spectra show a k_h^{-3} dependence. Recently, there has been considerable progress in simulating the observed spectra with some high resolution General Circulation Models (GCMs) (see e.g. Hamilton et al., 2008).

Our aim is to understand fundamental mechanisms of energy and enstrophy (half the square of vorticity) transfer between different scales and how well these mechanisms are described by different GCMs. In particular, we wish to test the hypothesis recently proposed by Vallgren, Deusebio & Lindborg (2011), that the atmospheric kinetic and potential energy spectra can be explained by assuming that there are two cascade processes emanating from the same large scale energy source at scales of thousands of kilometres.

In order to do this, we calculate the spectral budgets of energy and enstrophy using data from different GCMs, including data from the AFES-model and the model developed at ECMWF (European Centre for Medium Range Weather Forecasting). The concept of available potential energy (APE, Lorenz, 1955) and the theory of quasi-geostrophic turbulence (Charney, 1971) have been used to formulate the spectral budgets of the so called "primitive equations" in pressure coordinates with spherical harmonics as the base functions.

Preliminary results show that if some GCMs simulate the $k_h^{-5/3}$ spectra at the mesoscales, other high resolution GCMs obtain unrealistic very steep spectra at all scales and, consequently, very low energy levels at the smaller resolved scales. We have shown that for the AFES model, the ratio of the total APE over the total kinetic energy is large, of the order of 4, and that this is due to a larger magnitude of the APE spectrum at the very large scales of the atmosphere. At the synoptic scales and mesoscales, APE and kinetic energy spectra are of the same order of magnitude. During the conference, we will present results on non-linear transfer of energy between different scales and conversion from APE to kinetic energy.

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