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Indications of upper tropospheric stratified turbulence in a high-resolution mechanistic GCM

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The horizontal kinetic energy spectrum and its budget are analyzed on the basis of a mechanistic general circulation model run at very high spatial resolution (spectral truncation at total wavenumber 330 and a level spacing of ∼250 m from the lower troposphere to the lower stratosphere). The mechanistic character of the model is due to simplistic parameterizations of radiative and latent heating. On the other hand we employ advanced parameterizations for the subgrid-scale turbulent diffusion such as a new Smagorinsky-type horizontal diffusion scheme which is scaled by a Richardson criterion for dynamic instability and combined with a stress-tensor based hyperdiffusion that acts only on the very smallest resolved scales. This setup allows to simulate the transition from the synoptic -3 to the mesoscale -5/3 slope of the upper tropospheric kinetic energy spectrum. We find indications that the -5/3 range should be explained as stratified macroturbulence, as has been proposed in recent works of E. Lindborg and others. In particular, the model shows a forward horizontal energy cascade in the mesoscales around 300-150 hPa that is 1) mainly due to the non-rotational flow and 2) strongly maintained by adiabatic conversion at the mesoscales themselves where the model includes no mechanism to generate available potential energy. The mesoscale adiabatic conversion is rather analogous to the well-known energy deposition by gravity waves in the middle atmosphere. Within the troposphere, the source of the corresponding vertical pressure flux is located in the mid troposphere, where the enstrophy and energy cascades maintained by baroclinic Rossby waves are strongest. The vertical energy exchange within the troposphere is therefore presumably due to nonlinear inertia gravity waves. A second region of stratified turbulence is identified for the lower troposphere around 850 hPa where mesoscale energy from the mid troposphere is deposited too.

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