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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 less than 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. The only subgrid-scale parameterization is a Smagorinsky-type anisotropic 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 present indications that the -5/3 range should be explained as stratified macro-turbulence, 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. The mesoscale adiabatic conversion in the upper troposphere 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. 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. When the same model setup is run with a conventional coarse vertical resolution (1 km level spacing from the lower troposphere to the stratosphere), a -5/3 law in the mesoscales of the upper troposphere is obtained even more clearly than for high vertical resolution. However, the necessary conditions for stratified turbulence are no longer fulfilled. We argue that this behavior reflects the simple scaling argument that the horizontal energy cascade must dominate over the enstrophy cascade from some wavenumber on. We argue that for coarse vertical resolution the -5/3 law is simulated for the wrong reason.