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Explicit global simulation of gravity-wave effects in the mesosphere

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The general circulation of the mesosphere/lower thermosphere (MLT) is driven by the breakdown of internal gravity waves (GWs). Up to date, any reasonable global modeling of the MLT has not been feasible without parameterizing the corresponding wave drag. Mainly because, due to the restriction of resolution, GWs cannot be resolved in a comprehensive general circulation model (GCM) that extends beyond the mesopause. GW parameterizations rely on strong assumptions, such as single-column dynamics and an instantaneous response of the GW column to changes of the resolved flow. Moreover, the dissipation mechanism and the specification of GW sources vary considerably among different schemes. Therefore it seems worthwhile to try to simulate GWs explicitly in a global model. In order to resolve at least mid-and low-frequency GWs up to the lower thermosphere, we employ a mechanistic GCM with moderate horizontal resolution (T85) and very high vertical resolution (L190). Both the horizontal and vertical diffusion schemes are mixing-length based formulations. Wave dissipation in the MLT is controlled by adjusting the mixing lengths as functions of height.

Under these conditions, the resolved GWs generate considerable wave drag and dissipative heating in the summer MLT, corresponding well to previous estimates known from GW parameterizations. The simulated GW spectrum is broad. Its evolution with height is reminiscent of spectral parameterizations. The dominant waves in the summer MLT have horizontal wavelengths and intrinsic periods of about 700 km and a few hours. Even though the turbulent diffusion is strongest in the region of the GW drag, the associated sponge-layer feedback is negligible. Furthermore, planetary-scale baroclinic waves, dominated by the quasi-2-day wave, develop in the summer MLT and offset the GW drag by about one third. As a result, the overall Eliassen-Palm-flux divergence in the summer MLT is too weak, even though leading to a reversal of the

mean zonal wind and to temperatures far below radiative equilibrium. Also the dissipative heating in the summer MLT is still too weak compared to rocket-borne in-situ-measurements. These shortcomings suggest that the GW drag in the real atmosphere is stronger than simulated, and that the counterbalancing effect of the quasi-2-day wave has previously been underestimated.