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Lagrangian Gravity Wave Spectra in the lower stratosphere of current (re)analyses

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The increasing resolution of numerical weather prediction (NWP) models and the associated analyses implies that a growing fraction of the gravity wave (GW) spectrum is resolved in those products. However, besides nominal resolution, numerical and parameterized dissipation, physical parameterizations and data assimilation also influence GWs in NWP models, and it is not entirely clear how well the "resolved" part of the GW spectrum actually corresponds to the actual atmospheric variability. In the past, most studies have compared the modelled horizontal-wavenumber or ground-relative frequency spectra with those obtained from measurements in the atmosphere (airplanes, ground-based Lidar and radar). However, a more genuine parameter for GWs is their intrinsic frequency (frequency following the flow), which provides a natural view of the GW spectrum and its boundaries at the Coriolis and buoyancy frequency.

In this presentation, we evaluate the representation of intrinsic-frequency spectra in recent (re)analyses by comparing long-duration, quasi-Lagrangian balloon observations in the equatorial and Antarctic lower stratosphere to synthetic balloon observations along trajectories calculated in different reanalyses (ERA-interim, ERA-5, the ECMWF operational analysis, MERRA2 and JRA-55). The reanalyses show realistic features, and notably exhibit a spectral gap between planetary and gravity waves and a peak in horizontal kinetic energy associated with inertial waves near the Coriolis frequency in the polar region. The spectrum slope at low frequency in the tropics is generally also well simulated. However, the analyses generally underestimate the variability even in the "resolved" part of the spectrum. We also compare the variability of temperature, momentum flux and vertical wind speed, which are respectively related to low, mid and high frequency waves. The distributions (PDFs) have similar shapes, but show increasing disagreement with intrinsic frequency. We quantify the fraction of resolved variability and its dependency on model resolution for the different variables. In all products a significant part of the "resolved" variability is missing and should still be parameterized.