Project title: Multiscale Dynamics of Atmospheric Gravity Waves
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Gravity waves (GWs) play an important role in the dynamics of the atmosphere. Excited mostly in the troposphere through processes such as flow over topography, convection, and jet imbalance, they transport momentum and energy to the stratosphere and mesosphere, where they break, deposit their momentum, and affect the thermodynamic energy balance, e.g. via turbulent frictional heating. This impact is crucial for the large-scale circulation in the middle atmosphere and – via downward control (Haynes et al. 1991) – potentially also has significant impacts on tropospheric weather and climate (e.g. Scaife et al. 2012; Scaife et al. 2005). In climate and weather–forecasting codes effects of GWs must be parameterized, since these models cannot resolve the entire range of GW scales. Wentzel-Kramer-Brillouin (WKB) theory (Bretherton 1966; Grimshaw 1975; Achatz et al. 2017) is the basis of most GW parameterizations in climate simulations and weather predictions (e.g. Lindzen 1981; Alexander and Dunkerton 1999; Warner and McIntyre 2001; Scinocca 2003; Song and Chun 2008). There is, however, an increasing appreciation that the present handling of this technique needs improvements: a simplification typically used is the neglect of (1) horizontal GW propagation (single-column approximation) and (2) transient effects such as direct GW-mean-flow interactions (steady-state approximation). The former has been shown to be an important weakness of state-of-the-art parameterizations by e.g. Senf and Achatz (2011) and Ribstein and Achatz (2016), while Bölöni et al. (2016) and Wilhelm et al. (2018) propose improvements with regard to the latter aspect. Another drawback of GW parameterizations in current climate and weather codes is that they assume balanced (hydrostatic, geostrophic) resolved flows, which might not be valid with the increasing spatial resolutions applied nowadays. If however the resolved flow is not balanced additional forcing terms due to the GW dynamics appear both in the momentum and the entropy equation representing e.g. elastic effects (Achatz et al. 2017). Potential wave-wave interactions in the atmosphere are also not taken into account in current GW parameterizations, although their neglect has never been justified explicitly. Besides the propagation issues listed above, faithful representation of GW sources is a key to success, and is another area where one finds room for improvement: theory and applications for orographic (e.g. Palmer et al. 1986; Bacmeister et al. 1994) and convective GW sources (e.g. Beres et al. 2005; Song and Chun 2008) are relatively well-developed, but a satisfactory parameterization for the emission of GWs by jets and fronts (spontaneous imbalance) does not exist yet. The aspects discussed above are going to be further tackled within the DFG research unit MS-GWawes (https://ms-gwaves.iau.uni-frankfurt.de/index.php) in projects 3DMSD, SI, and SV. Wave emission, propagation and dissipation, together with the ensuing wave-mean flow interaction will be investigated in wave resolving idealized simulations with the Large-Eddy-Simulation (LES) code PincFloit. The thereby improved and newly developed GW parameterization (or rather the Multiscale Gravity-Wave Model MS-GWaM) will be implemented into and applied in ICON with its upper-atmosphere extension (UA-ICON). Here we will investigate the resulting mean circulation as well as variability aspects (intermittency, interactions with planetary waves).

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