Mountain wave parametrization in a transient gravity wave model

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Orography induced gravity waves are investigated in a Multi Scale Gravity Wave Model (MS-GWaM) over idealized topography. MS-GWaM is a prognostic gravity-wave model, which parametrizes both the propagation and dissipation of subgrid-scale GWs. It is a Lagrangian ray-tracer model, which applies WKB-theory and calculates the propagation of ray volumes in spectral space. Its novelty is that not only the dissipative effect, but also the non-dissipative effects due to direct wave-mean flow interaction are captured. In our conceptual studies we investigate mountain wave generation, which is induced via a time-dependent large-scale wind encountering a prescribed topography. The framework used in our experiments is the PincFloit model, which integrates the pseudo-incompressible equations. We use it both in low resolution with MS-GWaM and in high resolution LES mode as a wave resolving reference. In the reference LES simulations the idealized topography, a mountain chain, is represented with an immersed boundary method. In the MS-GWaM experiments there is no resolved topography, but its effect is modelled as a lower boundary condition. The lower boundary condition is represented by initializing ray volumes with wave number and wave action density depending on the mountain characteristics and the large scale wind speed, based on the assumption that the flow follows the terrain. In the wave resolving reference experiments the flow does not strictly follow the terrain, but other instabilities (rotor formation, boundary layer separation) arise around the mountains. These processes decrease the available momentum transported by GWs, which was initially not accounted for in MS-GWaM. Thus an overestimation of wind deceleration was found in the MS-GWaM parametrization compared to the wave resolving simulation. To correct for this overestimation, an effective mountain height is introduced into Ms-GWaM, which is calculated by a scaling function between mountain height and flow properties using the Froude number.

Aim and Experiments

Aim

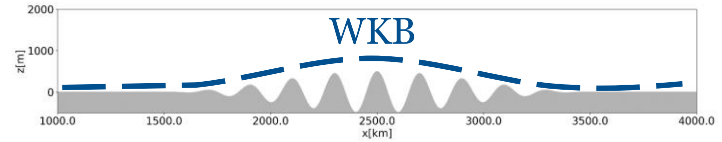
- Implementing orographic GW sources into transient GW model,
  MS-GWaM (Muraschko et al 2015, Bölöni et al 2016, Wilhelm et al 2018, Wei et al 2019)
  - GWs propagate in time and space (not instantaneous propagation)
  - GWs energy can change along the way, they interact with the mean flow even during the propagation not just via wave breaking
- There is no actual topography like in the wave resolving simulation, but ray volumes are initialized at lower boundary.
- WKB theory + assumptions (periodic orography, mountain waves are stationary, flow follows the terrain)

➢ Ray volumes energy depends on the mountain height.

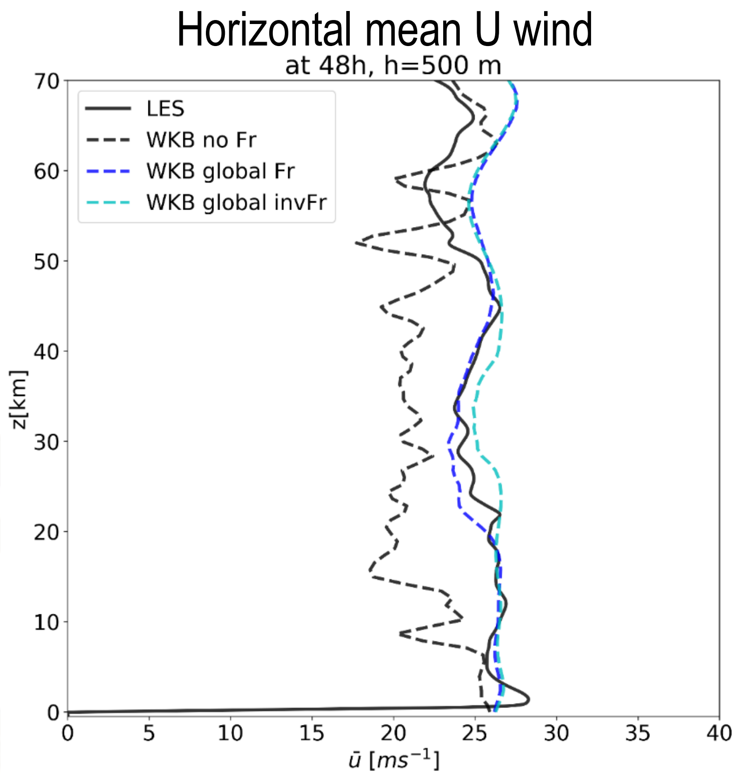
Experiments

- PincFloit (Rieper et al 2013, Wei et al 2019)
  (pseudo-incompressible flow solver using Dynamic Smagorinsky turbulence scheme) with idealized topography, 2D domain, 48 hours, wind forcing

- Mountain chain: Height=500m, HalfWidth=1000 km, Peaks=10
- High resolution wave resolving, **LES**
- Low resolution with GW parametrization, **WKB**



Results



- too strong wind deceleration (cf. LES and WKB no Fr)

⇩

- Momentum transport due to orography is too strong in MS-GWaM.
- In LES the flow does not strictly follow the terrain, and instabilities arise around the mountains, while in the low resolution simulation (WKB), there are no such instabilities, which results in to much available energy for GWs.

- Solution: scale back the energy of ray volumes. For the scaling function we use the Froude number and also the inverse Froude number.
- The scaling improves the horizontal mean wind profile, but at high altitudes there is now not enough wind deceleration.

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