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Progress towards an improved parameterisation of small-scale orographic impacts on the atmospheric boundary layer

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An accurate representation of the momentum budget in numerical models is essential in the quest for reliable weather forecasting, from large scales (climate models) to small scales (numerical weather prediction models, NWP). It is well known that orographic waves play an important role in large-scale circulation. The vertical propagation of such waves is associated with a vertical flux of horizontal momentum, which may be transferred to the mean flow by wave-mean flow interaction and wave-breaking (Sandu et al., 2019). The orography scales inducing such phenomena are often smaller than the model resolution, even for NWP models, leading to the need for parameterisation schemes for orographic drag. Yet, such parameterization in current models is fairly limited (Vosper et al., 2020). The present work aims to contribute to an improved understanding and parameterization of the impact of small-scale orography on the lower atmosphere with a focus on the stable atmospheric boundary layer.

As a first step, an idealized set of experiments has been designed to explore the capabilities of the Icosahedral Nonhydrostatic model in its large eddy simulation mode (ICON-LES, Dipankar et al., 2015) to represent turbulence processes in the stably-stratified atmosphere. Initial experiments testing the model performance over flat terrain (GABLS experiment, Beare et al., 2006), orographic wave generation (shallow bell-shaped topography, Xue et al., 2000) and moderate complex terrain (U-shaped valley, Burns and Chemel 2014) have been conducted. The results demonstrate that ICON-LES adequately represents the boundary layer processes for the investigated cases in comparison to the literature.

In a second step, an idealized set of experiments of atmospheric flow over idealized sinusoidal and multiscale terrain has been designed to study the impact of the orographically-induced gravity waves on the total surface drag and the vertical flux of horizontal momentum. The influence of different atmospheric conditions is assessed by varying the background wind speed and the temperature stratification at the initial time.