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Orographic wave drag as a possible explanation for intermittent behaviour in stable boundary layers over land

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In night-time stable boundary layers, undulating orography in the landscape may trigger gravity wave propagation. Until now the quantitative role of orographically induced gravity wave drag in the total momentum budget of the stable boundary layer is unclear, and limited from high resolution numerical studies over idealized terrain and for idealized forcing. At the same time it is realized that large-scale weather forecast models encounter problems with forecasting winds and temperatures in the stable boundary layer (SBL). Therefore it is interesting to further investigate the role of gravity wave drag.

We quantitatively investigate the role of gravity wave drag in the SBL over realistic (i.e. non idealized) terrain. We use a high resolution column model for the SBL that includes a first order turbulence closure, a broadband longwave radiation scheme, and has a full coupling with the land surface. The model has been validated for Cabauw and CASES99 observations before. This model is has been coupled with a module that analyzes the vertical profiles of wave drag from wind and temperature profiles. The innovative aspect of this module is that the contributions of the individual Fourier mode of the terrain to the wave drag are considered for each wind sector. Also it allows for analyzing critical levels, and wave stress divergence, which might trigger flow acceleration, and turbulence.

We run the model for 23 nights of the CASES99 experimental campaign, which was especially designed to improve our SBL knowledge. For weak wind nights, a substantial amount of wave drag is found, especially relative to the turbulent drag. In a number of nights the wave drag was continuously substantial for the whole night. More interesting, the wave drag seems of intermittent nature in certain nights, and particularly during nights in which intermittent turbulence was observed. Then wave drag was of similar magnitude as the turbulent drag. In addition, the time scale of the wave drag events appears to roughly correspond with the time scale of typical oscillations in the temperature and wind speed during global intermittency. As such, the findings suggest that wave drag can be important and need to be parameterized in large-scale models.

Ref:

Steeneveld, G.J., C.J. Nappo, and A.A.M. Holtslag, 2009: Estimation of Orographically Induced Wave Drag in the Stable Boundary Layer during CASES99, Acta Geophys., 57, 857-881.