EGU22-4098
https://doi.org/10.5194/egusphere-egu22-4098
EGU General Assembly 2022

Observing vertical coupling near the surface in a shallow mid-range mountain valley using a suite of ground-based remote sensing and tower observations

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Mid-latitude atmospheric boundary layers (ABL) in complex, mountainous terrain are often complicated because the large-scale radiative and dynamic forcings are modulated by local-scale forcings which may dominate the near-surface transport. The large-scale forcings of interest in our study are geostrophic winds and cloudiness which are known to cause variations in ABL depth and vertical coupling. The local-scale forcings we investigate are the slope, aspect, and land cover of valley shoulders and bottom which can create high-density cold airflows and pools often associated with submeso-scale motions. These topography-related phenomena may lead to vertical decoupling between the surface, the surface layer and the ABL in absence of strong large-scale synoptic forcing. Understanding the mechanisms by which the large-scale synoptic and local-scale topographic forcings interact has remained poorly understood despite many observational and modeling studies, but is crucial to understanding and quantifying mass and heat exchange in locations to weak winds.

We present results from the Large eddy Observation Voitsumra Experiment (LOVE) in summer 2019 conducted in a mid-range mountain valley in the Fichtelgebirge mountains, Germany over a two-month period as part of the ERC DarkMix project. Observations consist of fine to medium-scale (1s to 10 min) measurements from ground-based remote sensing including a ceilometer (150 to 8000 m above ground), wind Lidar (80 to 800 m above ground), and Sodar-Rass (15 to 300 m above ground) in combination with sonic anemometry and fiber-optic distributed temperature and wind sensing. The objective is to identify the mechanisms by which the land surface gets coupled or decoupled from the near-surface air aloft eventually forming the ABL, stable boundary layer, or residual layer. Particular attention is given to the stable weak-wind flow regime often persisting from sunset to sunrise.

We test the following two hypotheses: (1) The observed meandering of the near-surface nocturnal flow in the lowest tens of meters is the result of three competing flow modes generated by cold-slope flows from a closely co-located valley slope by net-radiative cooling, an along-valley flow supported by a weak synoptic pressure gradient, and a colder-air pool collecting at the valley bottom. Differences in the relative temperature of the three modes cause quasi-oscillatory

variations in static stability and thus vertical coupling. (2) Erosion of the near-surface inversion starts well before arrival of the direct shortwave radiation at the valley bottom caused by radiative warming of the surrounding mountain slopes and enhanced mixing from aloft. As a result, coupling the land-surface to the evolving ABL may be achieved earlier than anticipated from the local surface energy balance in the valley bottom.