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The Impact of the Horizontal Turbulent Length Scale on the Representation of Simulated TKE in Complex Terrain

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The right representation of both terrain and boundary-layer structure in mesoscale NWP models is of great importance for the correct simulation of atmospheric processes in complex terrain. Unfortunately, there are shortcomings, especially in common 1D turbulence parameterizations, which do only consider the vertical turbulent exchange. We evaluated the turbulence parameterizations of the mesoscale NWP model COSMO-1 (setup by Meteo Swiss) in the Inn Valley, Austria. A measurement data pool is provided by the so-called i-Box stations. We focus on six turbulence flux-towers at representative sites in mountainous terrain, such as the valley floor, various slopes, and the mountaintop.

After the evaluation of the model with observations of TKE and its budget terms for days when boundary-layer processes dominate, we found that the default 1D turbulence parameterization underestimates the modeled TKE both during night-time and during daytime, when a strong up-valley wind is present associated with strong vertical shear production. TKE simulation can be improved significantly when a hybrid turbulence parameterization including horizontal shear production processes is invoked.

However, the horizontal length scale in the shear production term of the hybrid turbulence parameterization depends entirely on the horizontal grid spacing, which is 1 km in our model setup. This is clearly unphysical, therefore we present a novel approach for estimating the horizontal length scale of TKE production in complex terrain. The horizontal length scale includes the Lagrangian integral timescale – dependent on the boundary layer height and on the horizontal wind variance – multiplied with a velocity scale, e.g. the mean valley wind speed. The new length scale is dependent on the location and on the present boundary layer structure and is based on physical processes. It is shown that the new length scale is a more realistic way to simulate horizontal shear contributions to TKE production compared to the hybrid turbulence parameterization.