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Large Eddy Simulations of Flow over Double-Ridge Orography

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Lee waves excited by a single mountain range have been studied extensively in the past. Flow over a single mountain range is often associated with downslope windstorms and turbulence, both of which may pose a hazard for aviation. A particularly turbulent phenomenon associated with large-amplitude lee waves or hydraulic jumps is an atmospheric rotor, characterized by a reversal of surface flow on the lee of the mountain range and turbulent internal structure. In reality, mountain ridges are rarely isolated. Flow over double or multiple ridges can lead to lee wave interference, either enhancing or diminishing the amplitude of lee waves downstream of the ridges. A similar effect can be expected on the flow field in between the individual ridges.
To test the influence of secondary topography on lee wave amplitudes, wavelengths, steadiness, and the boundary layer separation point, water-flume experiments are planned with a double ridge setup. In preparation for these experiments, several possible laboratory setups have been simulated numerically with the CM1 model (Bryan Cloud Model 1, version 16) with two- and three-dimensional (2D and 3D) large-eddy simulations (LES). Non-dimensional parameters such as the Froude number (Fr) and the mountain/inversion height ratio (H/zi) are used for classifications of the simulation results. For the 2D simulations, both with a single and double-ridge topography, a series of sensitivity tests were conducted to examine the dependence of the flow field on a number of physical parameters, including the inversion height and strength, horizontal wind speed, and mountain shape. In the double-ridge simulations, a lee wave interference pattern is observed for setups including inversions, and the results mostly agree with previous findings by Stiperski and Grubišić (2011) for nonlinear flow regimes.
From the 2D sensitivity tests, special cases were selected for the 3D LES simulations. In the analysis, a special focus was laid on the difference between the 2D and 3D simulations in terms of rotor dynamics and turbulence. In the 3D LES, the horizontal vorticity field shows that the rotor consists of several smaller-scale subrotors, which are more intense than in the corresponding 2D simulations. The distribution of the TKE field also gives insight into the dynamics of highly turbulent regions, such as rotors, hydraulic jumps, and breaking mountain waves.