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Boundary layer effects on lee wave resonance in the semi-T-REX environment

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At main focus of the Terrain-induced Rotor Experiment (T-REX) is a tight coupling of mountain-waves and boundary layer displayed in the formation of atmospheric rotors. In our earlier study of lee wave resonances over double bell-shaped obstacles, in which the profiles of wind speed and stability as well as terrain were derived from the T-REX observations of lee wave events over the Sierra Nevada and Inyo Mountains, we focused on the mountain-wave part of the problem, examining the interaction of trapped lee waves with downstream orography in absence of friction. It was shown that the displayed variation of wave amplitude and drag with the ridge separation distance can be attributed to nonlinear wave resonance.

In this study, effects of the frictional boundary layer on lee wave resonance are investigated by means of high-resolution 2D numerical simulations with the NRL COAMPS model, using the same idealized representation of the T-REX environment from our earlier study. Due to complex nonlinear interactions between the lee waves and boundary layer, new results show a different resonance pattern, which no longer displays itself in wave amplitudes or drag but rather in the amplitude ratio and steady-state averaged reversed flow strength underneath the primary lee-wave crest. The total destructive interference, in which waves completely cancel out in the lee of the downstream peak, is also observed for certain ridge separation distances when the height of the downstream obstacle is 2/3 the height of the upstream one. The flow within the valley exhibits a highly complex structure. Regions of reversed flow form at the surface underneath the lee wave crests and are lifted above the ground, extending up to 2 km AGL for 3 km high obstacles. The flow within a rotor is unsteady with multiple sub-vortices. The location of the inversion relative to the mountaintop is shown to significantly affect the resonance pattern, reversed flow strength, and the wave steadiness.