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Trapped mountain waves and stratified shear flow stability

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The relation between the onset of trapped mountain waves and the stability properties of the incident flow are investigated with a theoretical model (Lott 2016) and compared to fully nonlinear simulations done with WRF. In all cases considered the incident wind near the surface is very small as expected in the presence of a boundary layer. For small mountains the theory and the simulations compare well, providing we specify an adequate boundary layer depth in the theory. When the incident flow near the surface is dynamically unstable, i.e. when the surface Richardson number $J = N^2/U_z^2$ is small the onset of trapped lee-waves is favored at least for small mountains. In this case the trapped lee waves resemble to the neutral modes of Kelvin-Helmholtz instabilities when $J < 0.25$. In general the onset of trapped lee waves is favored for small surface J, because J controls the surface absorption of the stationary gravity waves (Smith et al. 2006, Lott 2007). Although in the theory the boundary layer is highly simplified, these results are corroborated by numerical simulations with realistic boundary layer parameterizations.

For high mountains the theory fails, and trapped lee waves can exist even when the surface stability of the incident flow is large. In this case the onset of trapped lee waves follows that for large J the theory predicts strong downslope winds and foehn. In the fully nonlinear simulations these yield intense mixings downstream of the mountain that destabilize the large-scale flow at low level. Trapped lee waves then result from the absolute instability of the downstream flow.

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