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An analytical model for the amplitude of lee waves forming on the boundary layer inversion

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Lee waves are horizontally propagating gravity waves with a typical wavelength of 5-15 km that may be generated when stratified flow is lifted over a mountain. A frequently observed type of such waves is that of interfacial lee waves. Those develop, similar to surface waves on a free water surface, when the upstream flow features a density discontinuity. Such conditions are often present for example at the capping inversion in boundary layer flow. The dynamics of interfacial lee waves can be described concisely with linear interfacial gravity wave theory. However, while this theoretical framework accurately describes the wavelength, it fails to properly predict the amplitude of lee waves. It is well known that large amplitude lee waves may lead to low-level turbulence, which poses a potential hazard for aviation. Therefore, this property of interfacial lee waves deserves further attention.

In this study, we develop a simple analytical model for the amplitude of lee waves forming on the boundary layer inversion. This model is based on the energetics of two-layer flow. We obtain an expression for the wave amplitude by equating the energy loss across an internal jump with the energy radiation through lee waves. The verification of the result with water tank experiments of density-stratified two-layer flow over two-dimensional topography from the HYDRALAB campaign shows good agreement between theory and observations. This new analytical model may be useful in determining potential hazards of interfacial lee waves with negligible computational cost as compared to numerical weather prediction models.