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Resonant interaction between a mountain wave and an environment with a vertically oscillating Scorer parameter

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Among the mechanisms that lead to an increase of the drag produced by atmospheric mountain waves, the resonance that occurs when the environment has a Scorer parameter profile that oscillates with height has been the object of recent interest. This resonance, which has been re-discovered only very recently, was studied by previous authors in rather limited conditions, and was claimed to be intrinsically nonlinear by comparison with results of a linear model which did not detect it.

In the present study, this drag enhancement mechanism is investigated further using a linear model and numerical simulations of a mesoscale non-hydrostatic numerical model. The linear model uses a perturbation approach, where the Scorer parameter is assumed to be the sum of a constant and a term proportional to a small parameter, which varies sinusoidally in the vertical. The solution to the Taylor-Goldstein equation, which commands the behaviour of the waves, is expanded in powers of this small parameter, and the resonance that is the focus of this study is found at first order.

The drag normalized by its non-hydrostatic value is calculated as a function of the wavelength and phase of the Scorer parameter oscillation. It is found, in agreement with previous results, that departures of the drag from 1 occur primarily near the parameter range where the vertical wavelength of the primary gravity waves generated is twice that of the Scorer parameter oscillation. Additionally, the drag behaves differently depending on the phase of this oscillation, displaying either a considerable increase or a decrease.

For the conditions considered by previous authors, the drag is enhanced by more than 50% for a specific value of the phase. In order to reproduce this enhancement in our linear model, it is essential that friction be accounted for. In the present study, this is done in the simplest possible way, by representing friction as a Rayleigh damping. The value of the Rayleigh friction coefficient may be estimated from the numerical simulations. We speculate that the reason why this drag enhancement was not captured in previous linear calculations is because they neglected friction.

From these results, it is expectable that the characteristics of the resonant waves produced in this setup, and thus of the ensuing drag enhancement, are sensitive to frictional processes in numerical models. These processes may either be associated with the closure employed to parameterize the turbulence, or with the numerical damping inherent to the discretization scheme.