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Analytical Results of Mountain Wave Drag for Effects by Shear and Curvature in the Wind Profiles: the Rotating Model

YUAN WANG[1] and JINYUN TANG[1]

[1]*Department of Atmospheric Sciences, Nanjing University*

The linear surface drag by gravity waves induced by an isolated mountain for air currents with shear and curvature in profiles is investigated in the context of a new three-dimensional analytical model. The motion is assumed to be steady, adiabatic, inviscid and rotating; and the flow is dry and Boussinesq.

The Wentzel-Kramers-Brillouin (WKB) expansion is employed to solve the modified Taylor-Goldstein equation to the order of $O(Ri^{-1})$, where Ri is required to be high for the model's validity. Generic formulas for the zero-order, first- and second-order contributions to the drag and the associated perturbed pressure are put forward for arbitrary mountain shapes, which are then simplified under hydrostatic approximation. With three ideal tests, it reveals that, for the rotating flow,

(a) the drag is always misaligned with respect to the wind, as long as the linear shear exists;

(b) the first order correction to the drag is negatively correlated with the linear shear, with its relative magnitude being proportional to $Ri^{-1/2}$ for a fixed k_f, a parameter being proportional to the inverse of the Rossby number Ro^{-1} defined at the surface;

(c) for a wind rotates with height, while maintaining its magnitude, a high drag state is found for small Richardson number when $a < k_f < b$, where a and b are flow and mountain shape dependent values.