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Linear stability of katabatic Prandtl slope flows with ambient wind forcing. (English)

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Summary: We investigate the stability of katabatic slope flows over an infinitely wide and uniformly cooled planar surface subject to a downslope uniform ambient wind aloft. We adopt an extension of Prandtl's original model for slope flows [*V. N. Lykosov* and *L. N. Gutman*, "Turbulent boundary-layer over a sloping underlying surface", Atmos. Ocean. Phys. 8, No. 8, 799–809 (1972)] to derive the base flow, which constitutes an interesting basic state in stability analysis because it cannot be reduced to a single universal form independent of external parameters. We apply a linear modal analysis to this basic state to demonstrate that for a fixed Prandtl number and slope angle, two independent dimensionless parameters are sufficient to describe the flow stability. One of these parameters is the stratification perturbation number that we have introduced in [the authors, "Stability of the Prandtl model for katabatic slope flows", J. Fluid Mech. 865, R2, 14 p. (2019; doi:10.1017/jfm.2019.132)]. The second parameter, which we will henceforth designate the wind forcing number, is hitherto uncharted and can be interpreted as the ratio of the kinetic energy of the ambient wind aloft to the damping due to viscosity and the stabilising effect of the background stratification. For a fixed Prandtl number, stationary transverse and travelling longitudinal modes of instabilities can emerge, depending on the value of the slope angle and the aforementioned dimensionless numbers. The influence of ambient wind forcing on the base flow's stability is complicated, as the ambient wind can be both stabilising as well as destabilising for a certain range of the parameters. Our results constitute a strong counterevidence against the current practice of relying solely on the gradient Richardson number to describe the dynamic stability of stratified atmospheric slope flows.

MSC:

86A10 Meteorology and atmospheric physics
76R10 Free convection
76E20 Stability and instability of geophysical and astrophysical flows

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