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Linear instability of the Prandtl model for stratified slope flows[1]

INANC SENOCAK, CHENG-NIAN XIAO, University of Pittsburgh — Ludwig Prandtl dedicated the last three pages in the authorized translation of his famous book "Essentials of Fluid Dynamics" to describe mountain and valley winds in stratified air. The exact solution assumes the presence of a constant linear background stratification above a sloped surface of infinite extent in all directions with a constant heating or cooling applied to it. Over the years, the Prandtl model has been found to describe the flow profile of katabatic winds observed in nature. Despite the usefulness of the Prandtl model, its stability characteristics have gone unexplored for many decades since its publication. In the present work, we use linear modal analysis and direct numerical simulations to uncover two types of flow instabilities in the Prandtl model for anabatic and katabatic slope flows. These instabilities manifest themselves as a function of the slope angle, the Prandtl number and a newly introduced stratification perturbation parameter, which is a measure of the relative importance of the surface heat flux with respect to the background stratification. We investigate the characteristics of these instabilities as a function of the aforementioned dimensionless parameters and highlight their differences under katabatic and anabatic scenarios.

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