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An analytic solution for periodic thermally-driven flows over an infinite slope

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The flow generated along an infinite slope in an unperturbed stably stratified atmosphere at rest by a time periodic surface temperature forcing is examined.

Following Defant (1949), a set of equations is derived which extends Prandtl's (1942) theory to allow for non-stationary conditions. Uniform boundary conditions are conducive to an along-slope parallel flow, governed by a periodically reversing local imbalance between along-slope advection and slope-normal fluxes of momentum and heat. Solutions include both a transient part and a subsequent periodic regime. The former can only be expressed in an integral form, whereas the latter is a combination of exponential and sine or cosine functions of time and height normal to the slope.

Key parameters are the quantity $N_\alpha = N \sin\alpha$ (where α is the slope angle, and N is the Brunt-Väisälä frequency of the unperturbed atmosphere) and the angular frequency of the driving surface temperature cycle, ω. Three different flow regimes may occur, namely subcritical $(N_\alpha < \omega)$, critical $(N_\alpha = \omega)$ and supercritical $(N_\alpha > \omega)$. The properties of the solutions in each regime are examined and discussed. The relationship between the present solutions and the earlier time-dependent slope flow model by Defant (1949) is also discussed.

References

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