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Acta Geophysica
vol. 57, no. 4, pp. 981-1010
DOI: 10.2478/s11600-009-0027-4

Structure of Numerically Simulated Katabatic and Anabatic Flows along Steep Slopes

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Abstract

Direct numerical simulation (DNS) is applied to investigate properties of katabatic and anabatic flows along thermally perturbed (in terms of surface buoyancy flux) sloping surfaces in the absence of rotation. Numerical experiments are conducted for homogeneous surface forcings over infinite planar slopes. The simulated flows are the turbulent analogs of the Prandtl (1942) one-dimensional laminar slope flow. The simulated flows achieve quasi-steady periodic regimes at large times, with turbulent fluctuations being modified by persistent low-frequency oscillatory motions with frequency equal to the product of the ambient buoyancy frequency and the sine of the slope angle. These oscillatory wave-type motions result from interactions between turbulence and ambient stable stratification despite the temporal constancy of the surface buoyant forcing. The structure of the mean-flow fields and turbulence statistics in simulated slope flows is analyzed. An integral dynamic similarity constraint for steady slope/wall flows forced by surface buoyancy flux is derived and quantitatively verified against the DNS data.

Key words: katabatic flow, anabatic flow, numerical simulation, boundary layer, turbulence.