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Nocturnal Low-Level Jet over a Shallow Slope

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Abstract

A simple theory is presented for a nocturnal low-level jet (LLJ) over a planar slope. The theory extends the classical inviscid inertial-oscillation model of LLJs to include up- and downslope motion in the boundary layer within a stably stratified environment. The particular scenario considered is typical of LLJs over the Great Plains of the United States: southerly geostrophic wind over terrain that gently slopes down toward the east. First, an initial value problem for the coupled equations of motion and thermodynamic energy is solved for air parcels suddenly freed of a frictional constraint near sunset. The solution is an oscillation that takes, on the hodograph plane, the form of an ellipse having an eastward-oriented major axis and an eccentricity that increases with increasing stratification and slope angle. Next, the notion of a tilted residual layer (TRL) is introduced and used to relate initial (sunset) air parcel buoyancy to free-atmosphere stratification and thermal structure of the boundary layer. Application of the TRL-estimated initial buoyancy in the solution of the initial value problem leads to expressions for peak jet strength and the slope angle that maximizes the jet strength. Analytical results are in reasonable qualitative agreement with observational data.

Key words: low-level jet, inertial oscillation, planar slope, stable stratification, residual layer.