Bernoulli Equation and Flow over a Mountain

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Abstract

The traditional energy conversion between potential and kinetic energies failed to explain the flow moving over mountain. Hence, we apply Bernoulli equation to simulate the air parcel which originates at low level at the inflow region, climbs adiabatically over a mountain with an increase in velocity, then descends on the lee and forms a strong downslope wind. The parcel departs from hydrostatic equilibrium during its vertical motion. It can be noticeably cooler than the temperature calculated from adiabatic lapse rate, which allows part of enthalpy to be converted to kinetic energy and produces a stronger wind at mountain peak, and/or a severe downslope wind on the lee side. It was found that the hydrostatic assumption tends to suppress the conversion from enthalpy to kinetic energy. It is also shown that the popular Froude number defined in the atmosphere is equal to the ratio of kinetic energy to the potential energy, same as in Boussinesq fluid. But the Froude number cannot be used to determine whether a parcel can move over a mountain or not, unless the vertical motion is weak and the system is near hydrostatic equilibrium. Numerical simulations confirm that the potential temperature and Bernoulli function are almost conserved along the streamline, as well as the change of kinetic energy comes from the change of enthalpy instead of potential energy. Hence, parcel can move upward and wind speed increases at the same time, when it is cooler than adiabatic lapse rate, i.e,, the increase of potential and kinetic energies comes from the decrease of enthalpy.