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The Influence of Wave-Like Disturbances on Turbulence in the Very Stable Planetary Boundary Layer

Carmen J. Nappo
Knoxville, Tennessee, U.S.A. (cjn.gwaves@gmail.com)

The very stable planetary boundary layer (SPBL) can be characterized by sporadic episodes of turbulence. In many instances, these turbulence outbreaks seem to occur in conjunction with propagating wave-like disturbances observed by a stationary observer. However, gravity waves generated by terrain are stationary and cannot be detected using time series analyses. Lee waves generated by mountains often extend downwind for large distances; however, it has been observed in photographs that when conditions exist for lee waves sometimes the waves either fail to develop or decay rapidly with downwind distance. Theoretical studies suggest that a viscous and stably stratified boundary layer can extract wave energy thus reducing wave amplitudes. The rate of decay of wave amplitude is due more to stratification than viscosity.

In this presentation, it is proposed that lee wave energy can be transformed into turbulence energy through Kelvin-Helmholtz instability. To scale the mechanism, the SPBL is represented by a calm pool of cold air of fixed density beneath a layer of air with constant speed and constant density less than that in the lower layer. For a wind speed on the order of 1 m/s, it is shown that a wave perturbation speed of 1 to 2 m/s can result in rapid growth of billow clouds with horizontal wavelengths of 2 to 3 m. Disturbances such as these have been observed in SPBL near the ground surface.