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Simulation and modeling of the turbulent katabatic flow along a hyperbolic tangent slope for stably stratified atmospheric boundary layer

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The behaviour of the Atmospheric Boundary layer (ABL) along alpine valleys is strongly dependent on the day-night thermodynamic cycle and might impact meteorology and air pollution prediction. At night, the ABL is stably stratified and the radiative cooling of the surface yields the development of a katabatic flow (Doran and Horst 1983, Monti et al. 2002). This flow consists of a downslope wall-jet which has the structure of both wall turbulence in the inner-layer zone and shear layer turbulence in the outer-layer zone and enhances a relative mixing eventhough stable stratification is considered (Baines 2005). A full 3D description of such flow by mean of Large Eddy Simulation of turbulence (LES) has not yet been achieved, except recently on relatively simple slopes (Skyllingstad 2003, Smith and Skyllingstad 2005) or including geostrophic wind forcing (Cuxart et al. 2006, Cuxart and Jimenez 2006). This is the purpose of the present study to accurately describe the ABL on a hyperbolic tangent slope with stable stratification. The numerical code used, Meso-NH, has been developed in CNRM/Meteo-France and Laboratoire d'Aérologie Toulouse, and consists of an anelastic non-hydrostatic model solving the pseudo-incompressible Navier-Stokes equations with a Boussinesq approximation. About 5 million grid points are necessary to afford a relatively precise description of the flow in the vicinity of the surface, with a special refinement in the vertical direction to capture the wall-jet developing along the slope. The setting of initial and boundary conditions is crucial for the simulation of stable ABL. Initial conditions consist of air at rest following a stable temperature profile with a constant Brunt-Väisälä frequency N=0.013. At the surface two sets of boundary conditions have been considered, first a rough surface condition, second an ideal case with slip conditions. A constant surface cooling q_w=-30 W/m2 is applied on the stably stratified fluid initially at rest, which generates a katabatic downslope flow along the bottom surface due to gravity effect. The surface temperature difference of the downslope-jet is about -2K to -4K with respect to the initial temperature. After a transient, a strong mean shear is observed in the external part of the ABL all along the slope which forms a shear layer with a thickness of about 10 to 20 m. Transition to turbulence occurs in the shear layer zone and turbulent structures develop along the slope, are stretched, advected further downstream, and increase local mixing, a property of direct interest for scalar mixing and which must be accurately described to allow for air quality prediction.