Abstract

"*A probabilistic plume model to represent dry, shallow and deep convection*"
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A probabilistic model for the convective boundary layer, the probabilistic plume model (PPM), is presented. Unlike prior bulk approaches that have relied on top of the mixed layer entrainment rates modeled as a constant fraction beta of the surface buoyancy flux, PPM implements a new closure based on the mass flux of updrafts overshooting the inversion and originating from the surface. This mass flux is related to the variability of the surface state (potential temperature theta and specific humidity q) of an ensemble of updraft plumes. Evaluating the model against observed clear-sky reference theta and q-profiles from the test cases of Sullivan (1998) and over the Southern Great Plains Atmospheric Radiation Measurement Climate Research Facility shows that PPM performs very well.

PPM is extended to unify the dry boundary layer and shallow convection regime. The cloud base mass flux is obtained explicitly by integrating the surface distribution over the uppermost buoyant updrafts. Significantly, the mass flux reduces the entrainment rate both directly, by reducing the number of updrafts contributing to the growth of the mixed layer, and indirectly, by inducing compensating subsidence on top of the mixed layer. Comparisons of PPM cloud base, cloud top heights, cloud cover and cloud base mass flux against large-eddy simulations from the Barbados Oceanographic and Meteorological Experiment (BOMEX) and from the Southern Great Plains Atmospheric Radiation Measurement (ARM) Climate Research Facility demonstrate favorable agreement. The main advantage of the model is that it unifies the definition of the mixed-layer growth, cloud fraction and Convective Inhibition to shallow convection based on the distribution of surface updraft characteristics. At steady-state a tight equilibrium is naturally ensured between the cloud base mass flux, radiation and mixed-layer state. The model is extended to unveil the trigger mechanism of deep convection over land as well as the surface-moist convection feedbacks. Comparison of deep convection triggering over the African Monsoon Multidisciplinary Analysis (AMMA) campaign and ARM datasets demonstrate that PPM is able to naturally characterize the diurnal cycle of deep convection triggering over continents. Extensions of the model toward a unified parameterization of dry and moist convection will be discussed.

Given the relative simplicity and transparency of PPM we suggest that the model can be a powerful tool for developing process-based understanding and intuition about the physical processes involved in surface-boundary layer-convection interactions.