Modeling of subgrid-scale mixing in large-eddy simulation of shallow convection

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This paper will discuss representation of subgrid-scale turbulent mixing in models of warm (ice-free) clouds. For models with bulk representation of cloud microphysics, instantaneous adjustment to grid-scale saturation is assumed. This is a reasonable assumption for condensation of water vapor because supersaturations inside clouds are typically small (except near cloud bases where about order of magnitude larger supersaturations are anticipated). For the cloud evaporation, however, instantaneous adjustment to grid-scale saturation is questionable, especially when evaporation occurs as a result of turbulent mixing between a cloud and its unsaturated environment. This is because turbulent mixing between initially separated volumes of cloudy and cloud-free environmental air proceeds through a gradual filamentation of these volumes, with progressively increasing evaporation of cloud water during the approach to final homogenization. A relatively simple model of this chain of events is included in a bulk model of moist non-precipitating thermodynamics. The model delays adjustment to saturation for cloud evaporation following the turbulent mixing until the volume can be assumed homogeneous. Two additional prognostic variables, the mean width of a cloudy filament and the fraction of the grid-volume occupied by the cloudy air, are added to represent the progress of turbulent mixing and approach to homogenization. An extension of this approach to a two-moment cloud microphysics scheme predicting the supersaturation field is also being developed. Numerical tests presented at the conference will illustrate the impact of these developments on large-eddy simulations of shallow convection.