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Entrainment and mixing at the top of stratocumulus in LES simulations

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Entrainment and mixing near the top of stratocumulus-topped boundary layer (STBL) is critical for the STBL structure and optical properties of the stratocumulus. In this paper, we will discuss results of large-eddy simulation of entrainment and mixing processes near the STBL top. Setup of the numerical experiment is based on the research flight RF-01 in DYCOMS-II field campaign. The focal point is the Entrainment Interface Layer (EIL), a few- to a few-tens of meters deep mixing zone that separates the cloudy and cold (in the potential temperature sense) boundary layer air from the dry and warm free-tropospheric air aloft. We focus on the stability of the flow in the cloud-top region using the local gradient Richardson number calculated at the surface of maximum static stability near the STBL top and at the material top of STBL, the latter defined using a threshold value of the total water content. Boundary-layer updrafts, spanning entire depth of the STBL, impinge upon the inversion and produce diverging horizontal flows just below the layer of maximum stability. Ensuing strong vertical shear results in the local gradient Richardson number smaller than the one typically associated with onset of flow instabilities. Turbulence, characterized by large local values of enstrophy, causes mixing responsible for the formation of the EIL and for the entrainment of free-tropospheric air into the STBL. Mixed parcels of cloudy and dry free-tropospheric air with mixing proportions corresponding to a negative buoyancy and typically void of cloud water form "cloud holes" - trenches of descending cloud-free air surrounding areas of the updraft. Entrainment processes are further analyzed using a passive scalar introduced after three hours of the simulation above the layer of maximum stability. Mixing fraction of this scalar within the STBL, an indicator of

the fraction of entrained free-tropospheric air, falls within the range corresponding to the buoyancy reversal at the cloud top. Some of negatively buoyant mixtures sinking through the cloud holes are wrapped around the edge of cloudy regions and recirculated into the cloud, resulting in a local increase of the cloud base height. The remnant sinks into the STBL and results in a gradual dilution of the boundary layer.