Challenges in large-eddy simulation of stratocumulus clouds

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The representation of low clouds in global circulation models is one of the largest sources of uncertainty in climate projections. The projection sensitivity stems from the large contribution of low-cloud shortwave reflectivity in the planetary energy balance, particularly of stratocumulus (Sc) cloud decks that form over the ocean. The lack of physical understanding of the factors controlling Sc cloudiness leads to poor prediction skill. Typically, large-eddy simulations (LES) are used to gain insight into boundary layer physics and to inform the development and evaluation of coarse-grained parameterizations used in weather and climate models. However, LES of Sc clouds has been challenging. The discussion focuses on physics-based modeling of the DYCOMS II RF01 observations. An LES model with an explicit turbulence parameterization, the buoyancy adjusted stretched vortex model, and a low numerical dissipation advection scheme is used. To investigate the effect of model error, simulations are carried out with variable grid resolution and physical processes, e.g., with and without radiation. Two main sources of model error are identified: (a) under-prediction of the amount of cloud liquid because of small (< 5%) errors in temperature and humidity in the cloud layer, and (b) a feedback between cloud-top radiative cooling and vertical turbulent fluxes. The sharp inversion does not lead to the degradation of model performance, with the exception of cloud liquid. Even though cloud-top radiative cooling is not significant in driving the turbulence in the boundary layer in the present case, it creates difficulties in the accurate prediction of the turbulent fluxes, which show significant sensitivity to grid resolution. Turbulence spectra are also discussed.

Keywords: Stratocumulus clouds, Large-eddy simulation, Model error, Grid convergence

