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Intercomparison of cloud model simulations of Arctic mixed-phase boundary layer clouds observed during SHEBA/FIRE-ACE

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A long-lived precipitating mixed-phase boundary layer cloud observed during the Surface Heat Budget of the Arctic Ocean (SHEBA) experiment is used as a case study for intercomparison of six cloud and large-eddy simulation models. In general, there are large differences among the models in terms of cloud phase, condensed water path, surface radiative fluxes, and other quantities. Overall, the simulations tend to group into two quasi-steady states within the first few hours of integration: (1) long-lived mixed-phase cloud, or (2) all-ice cloud after rapid glaciation of the mixed-phase cloud. Due to close coupling between the microphysics, radiation, and cloud dynamics, these two states have distinctly different characteristics. In particular, simulations with mixed-phase clouds tend to have greater rates of cloud-top radiative cooling, a more well-mixed boundary layer, greater kinetic energy, and larger water vapor flux convergence in the cloud layer, relative to the simulations with all-ice clouds. These results suggest that the simulated mixed-phase clouds are in part self-maintaining. All models exhibit significant sensitivity to the specified ice crystal concentration. In most models, an increase in crystal concentration results in rapid glaciation and transition from the mixed-phase to all-ice state. Various processes are analyzed and compared among the simulations to elucidate specific causes of the differences.