Larcform1: A process-based evaluation of model biases in the Arctic boundary layer

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Weather and climate models struggle to represent lower tropospheric temperature and moisture profiles and surface fluxes in Arctic winter, partly because they lack or misrepresent physical processes that are specific to high latitudes. Observations have revealed two preferred states of the Arctic winter boundary layer. In the cloudy state, cloud liquid water limits surface radiative cooling, and temperature inversions are weak and elevated. In the radiatively clear state, strong surface radiative cooling leads to the build-up of surface-based temperature inversions. Many large-scale models lack the cloudy state, and some substantially underestimate inversion strength in the clear state. Here, the transformation from a moist to a cold dry air mass is modeled using an idealized Lagrangian perspective. The trajectory includes both boundary layer states, and the single-column experiment is the first *L*agrangian *Arc*tic air *form*ation experiment (Larcform 1) organized within GEWEX GASS (Global atmospheric system studies). The intercomparison reproduces the typical biases of large-scale models: some models lack the cloudy state of the boundary layer due to the representation of mixed-phase microphysics or to the interaction between micro- and macrophysics. In some models, high emissivities of ice clouds or the lack of an insulating snow layer prevent the build-up of surface-based inversions in the radiatively clear state. Models substantially disagree on the amount of cloud liquid water in the cloudy state and on turbulent heat fluxes under clear skies. Observations of air mass transformations including both boundary layer states would allow for a tighter constraint of model behavior.

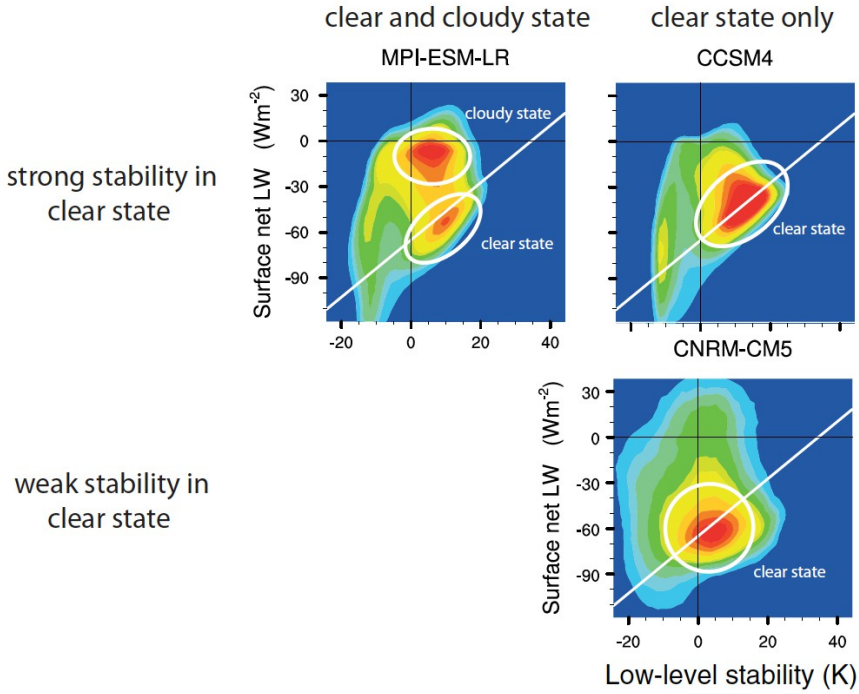

Figure 3. Bivariate PDFs as in Figure 1 using CMIP5 model output from the ocean domain north of 64°N. The models shown serve as examples for the three groups of models determined in *Pithan et al.* [2014]. White lines are included as visual reference indicating the observed relationship between stronger inversions and weaker surface cooling within the clear state.