Seasonally dependent impact of cloud longwave scattering on the polar climate: why it is a necessity in polar climate modeling?

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The importance of cloud-radiation interactions is well known. Most climate models assume non-scattering clouds in the longwave (LW) because LW scattering is considered negligible compared to strong LW absorption by clouds and greenhouse gases. Here we show that neglecting LW scattering is reasonable for simulations forced by observed sea surface temperature (SST) and sea ice (prescribed SST) and for the simulated extra-polar climate, but is invalid for simulated polar climate when the SST and sea ice are also simulated by the model. The traditional wisdom to ignore LW scattering can be well justified in the tropics and mid-latitudes, but it breaks down in the high-latitudes due to much less water vapor in the atmosphere. As a result, cloud LW scattering is non-negligible anymore. Furthermore, the cloud LW scattering increases downward LW radiation, warming the surface and then further warming and moistening the atmosphere. A prescribed SST run does not allow such ocean-atmosphere LW coupling, another issue that has been overlooked in traditional radiation scheme development. We incorporated a hybrid 4-stream and 2-stream scheme into the NCAR CESM model to handle the ice cloud longwave scattering. Using coupled simulations, we show that warming from LW scattering, especially in the far IR, is largest over the polar winter and can increase winter surface air temperature by 0.8-1.8K in the Arctic and 1.3-1.9K in the Antarctic. Climate models need to include cloud LW scattering to properly simulate polar climate. It is a necessity to have cloud LW scattering for faithfully representing the radiative coupling between atmosphere and surface in the polar regions.

Keywords: Polar climate, cloud longwave scattering, surface-atmosphere radiative coupling