Recent studies show that spectrally-resolving the surface emissivity greatly improves the simulated energy budget in desert and polar regions of current Earth System Models. However, these studies mostly assume cryospheric surface-types to be a single medium in terms of emissivity, with no difference among ice, snow, and liquid water. Here we use single column radiative transfer modeling to investigate the instantaneous longwave radiation biases due to assuming blackbody and neglecting spectrally-resolved emissivities for three cryospheric media: ice, snow, and liquid. We examine the surface and top-of-atmosphere (TOA) longwave radiation for a range of atmospheric profiles.

In the warmest profile the blackbody assumption increases the surface upwelling longwave fluxes by 3.97 W m-2, 1.66 W m-2, and 2.66 W m-2 for ice, snow, and liquid water media, respectively. These biases increase from the coldest to the warmest profile by ~10% (0.43W m-2) for ice and ~20% (0.36 W m-2) for snow. In comparison differences in the surface emission amongst the media are at least 1 W m-2 and as great as 2.37 W m-2. All instantaneous biases at the surface and most at TOA exceed 1 W m-2, comparable to greenhouse gas forcings. Interestingly, effective blackbody emissivities are better than effective greybody emissivities at reproducing the most accurate (spectrally resolved) integrated fluxes over liquid and ice surface types, thus motivating introduction of spectrally resolved longwave radiation

in all surface components of E3SM (v3).