Assessing an improved treatment of the surface-atmosphere longwave radiative coupling in the E3SM v2

Xianglei Huang[1], Xianwen Jing[1], Wuyin Lin[2], Ping Yang[3], Mark Flanner[1]

1. The University of Michigan
2. Brookhaven National Laboratory, DoE
3. Texas A&M University

In current E3SM or any other earth system models, two issues stand out in the longwave radiation treatment. First, all atmospheric modules assume the blackbody surface in their radiation scheme, while the actual surface emissivity can vary significantly from one spectral band to another. Second, the longwave scattering by clouds has been only considered by a couple of modeling centers. These issues are further compounded by another fact: the surface's spectral radiative properties are assumed differently in the surface and atmosphere modules. This inconsistency can be found in both the longwave and shortwave radiation schemes. Even the coupler ensures conservation of the broadband fluxes across the modules, the spectral decomposition of such broadband flux is not consistent across the modules. Given that atmospheric absorption is highly spectrally dependent, any unrealistic spectral decomposition of upward radiant flux at the surface essentially provides an incorrect lower boundary condition to the atmospheric radiative transfer scheme.

In the awareness of the above issues, over the recent years, we have developed more realistic treatments for surface spectral emissivity, ice cloud optics, and ice cloud longwave scattering for the E3SM. Since the last-year ESMD PI meeting, we have implemented such treatments into the E3SM v2 alpha. Multiple-year fully coupled simulations were carried out to assess the treatments. In terms of the global energy budget, the largest differences from the E3SM v2 are seen in both the TOA and surface longwave fluxes: our treatment reduces discrepancies from the CERES-EBAF observations by ~1 Wm-2 for both the OLR and surface net longwave flux. In terms of surface climate, the most noticeable change is the high-latitude surface temperature difference with a distinct seasonal dependence, which can be explained in terms of both ice cloud scattering effect and the surface energy process. Such impact, in turn, affects the simulation of sea ice fraction in the E3SM v2. The impact on precipitation is negligible.

Both the direct response to the ice cloud longwave scattering and climate feedback mechanisms can cause the mean climate differences described above. We have further carried out short-term double-call runs to estimate the direct response to the changes made to the longwave scheme. As expected, the zonal-mean direct response is well correlated with the zonal-mean cloud amount. The long-term mean difference exhibits a spatial pattern different from that of direct response, indicating the vital role played by the feedback mechanisms.