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Cloud-Aerosol-Radiation Ensemble Modeling System: Powerful application in future Earth System Modeling

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The cloud-aerosol-radiation interactions have been identified as the most uncertain part of all climate models, causing large spread of model climate sensitivities. The Cloud-Aerosol-Radiation (CAR) ensemble modeling system is aim to deal with cloud-aerosol-radiation issues, the core part of every general circulation model. This inner consistent system is comprised of enormous free choices of alternative parameterizations for cloud properties (cover, water, radius, optics, geometry), aerosol properties (type, profile, optics), and radiation transfers (solar, infrared) and their interactions. These schemes form the comprehensive collection currently available in the literature, including those used by the world leading general circulation models (GCMs). Hence the CAR system can be used to determine (via intercomparison across all schemes) or reduce (via the optimized ensemble integration) the range of the uncertainties caused by the likely cloud-aerosol-radiation interactions. More strikingly, the calculations for cloud structures are totally decoupled from those for radiation transfer due to the successful realization of the consistent applications of MOSAIC or McICA cloud treatments across all major radiation transfer codes in the CAR. This special design makes it more easily for us to investigate how much of the disparity in estimates of climate sensitivity is due to different treatment of radiative transfer, or due to different treatment of clouds, or due to different treatments of aerosol, or due to their interactions. Furthermore, the CAR also has powerful applications in other areas of climate researches, such as the radiative forcings of anthropogenic climate change agents, e.g., increase of greenhouse gases, land use and land cover changes, and direct and indirect effects of aerosol.

Both the online and offline experiments disclose quite large calculation uncertainties among different CAR cloud-radiation components, showing the strong model dependence on cloud-radiation interactions. It is also noted that the consistent uses of the MOSAIC or McICA schemes, i.e., the same cloud structure used, largely reduce the CRF uncertainties among different radiation transfer codes, e.g., for domain means over [60ºS, 60ºN], the CRF range about 20∼25Wm^{-2} reduced to $<$ 5 Wm^{-2} for MOSAIC, and to about 5∼10 Wm^{-2} for McICAs for SW, and from 5∼10 Wm^{-2} to 1∼3 Wm^{-2} for LW, rendering the smaller sensitivity to radiation schemes under almost the same cloud conditions. In this study, firstly we will introduce our CAR system, and then to show some interesting results from our CAR to indicate it's powerful application in future Earth System modeling.