Geophysical Research Abstracts
Vol. 18, EGU2016-11803, 2016
EGU General Assembly 2016

The role of updraft velocity in temporal variability of cloud hydrometeor number

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Significant effort has been dedicated to incorporating direct aerosol-cloud links, through parameterization of liquid droplet activation and ice crystal nucleation, within climate models. This significant accomplishment has generated the need for understanding which parameters affecting hydrometer formation drives its variability in coupled climate simulations, as it provides the basis for optimal parameter estimation as well as robust comparison with data, and other models. Sensitivity analysis alone does not address this issue, given that the importance of each parameter for hydrometer formation depends on its variance and sensitivity.

To address the above issue, we develop and use a series of attribution metrics defined with adjoint sensitivities to attribute the temporal variability in droplet and crystal number to important aerosol and dynamical parameters. This attribution analysis is done both for the NASA Global Modeling and Assimilation Office Goddard Earth Observing System Model, Version 5 and the National Center for Atmospheric Research Community Atmosphere Model Version 5.1. Within the GEOS simulation, up to 48% of temporal variability in output ice crystal number and 61% in droplet number can be attributed to input updraft velocity fluctuations, while for the CAM simulation, they explain as much as 89% of the ice crystal number variability.

This above results suggest that vertical velocity in both model frameworks is seen to be a very important (or dominant) driver of hydrometer variability. Yet, observations of vertical velocity are seldomly available (or used) to evaluate the vertical velocities in simulations; this strikingly contrasts the amount and quality of data available for aerosol-related parameters. Consequentially, there is a strong need for retrievals or measurements of vertical velocity for addressing this important knowledge gap that requires a significant investment and effort by the atmospheric community. The attribution metrics as a tool of understanding for hydrometer variability can be instrumental for understanding the source of differences between models used for aerosol-cloud-climate interaction studies.