

Final Report

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Project Title: Quantifying the Uncertainties of Aerosol Indirect Effects and Impacts on Decadal-Scale Climate Variability in NCAR CAM5 and CESM1.

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Summary

The main goal of this project is to systematically quantify the major uncertainties of aerosol indirect effects due to the treatment of moist turbulent processes that drive aerosol activation, cloud macrophysics and microphysics in response to anthropogenic aerosol perturbations using the CAM5/CESM1. To achieve this goal, the P.I. hired a postdoctoral research scientist (Dr. Anna Fitch) who started her work from the Nov.1st.2012.

In order to achieve the project goal, the first task that the Postdoc. and the P.I. did was to quantify the role of subgrid vertical velocity variance on the activation and nucleation of cloud liquid droplets and ice crystals and its impact on the aerosol indirect effect in CAM5. First, we analyzed various LES cases (from dry stable to cloud-topped PBL) to check whether this isotropic turbulence assumption used in CAM5 is really valid. It turned out that this isotropic turbulence assumption is not universally valid. Consequently, from the analysis of LES, we derived an empirical formulation relaxing the isotropic turbulence assumption used for the CAM5 aerosol activation and ice nucleation, and implemented the empirical formulation into CAM5/CESM1, and tested in the single-column and global simulation modes, and examined how it changed aerosol indirect effects in the CAM5/CESM1. These results were reported in the poster section in the 18th Annual CESM workshop held in Breckenridge, CO during Jun.17-20.2013.

While we derived an empirical formulation from the analysis of couple of LES from the first task, the general applicability of that empirical formulation was questionable, because it was obtained from the limited number of LES simulations. The second task we did was to derive a more fundamental analytical formulation relating vertical velocity variance to TKE using other information starting from basic physical principles. This was a somewhat challenging subject, but if this could be done in a successful way, it could be directly implemented into the CAM5 as a practical parameterization, and substantially contributes to achieving the project goal. Through an intensive research for about one year, we found appropriate mathematical formulation and tried to implement it into the CAM5 PBL and activation routine as a practical parameterized numerical code. During these processes, however, the Postdoc applied for another position in Sweden, Europe, and accepted a job offer there, and left NCAR in August 2014. In Sweden, Dr. Anna

Fitch is still working on this subject in a part time, planning to finalize the research and to write the paper in a near future.