On the relationship between aerosols and shallow cloud fraction as a function of region, season and aerosol type

Jennifer D. Small Griswold*, Jonathan H. Jiang§, Hui Su§ and Chengxing Zhai§

*Atmospheric Sciences Department, University of Hawaii at Manoa, Honolulu, HI 96822-2219
Phone: (808) 965-3636, Fax: (808) 956-2877, Email: smalljen@hawaii.edu

§California Institute of Technology, Jet Propulsion Laboratory, 4800 Oak Grove Drive, Pasadena, CA 91109

Aerosols, including biomass burning smoke, dust, and anthropogenic and industrial pollutants affect large regions of the globe with the potential to influence and modify clouds. As climate models are improved for the 6th phase of the World Climate Research Programme Coupled Model Intercomparison Project (WCRF CMIP6), modelers need guidance for how to parameterize cloud-aerosol interactions. In this work we study the regional and seasonal relationships between aerosols, clouds, and large scale dynamics during the period 2002-2014 to evaluate the applicability of the aerosol microphysics-radiation-effect (MRE) theory proposed by Koren et al. [2008] in regions characterized by different aerosol types including absorbing and non-absorbing. This analysis provides empirical relationships between aerosol amount and cloud fraction dependent on region and season which can be incorporated into a climate modeling framework. We identify regions of interest with varying aerosol types and loads based on previous studies of global aerosol amounts.

We use aerosol optical depth, fire counts, and cloud fraction from Aqua-MODIS, and NCEP Reanalysis vertical velocities at 500 mb as a proxy for dynamic regime. We use daily Level-3 MODIS cloud fraction, obtained by calculating global cloud amounts from instantaneous cloud masks. We use Level-3 MODIS cloud top pressures as a measure of cloud vertical development. Since aerosols and clouds are influenced by local and regional meteorology we use daily re-gridded NCEP Reanalysis data to set the meteorological and dynamical context. Specifically, we use vertical velocities at 500 mb to account for differences in large scale dynamics and evaluate precipitable water and relative humidity as a function of aerosol to account for differences in available water vapor. In addition to MODIS we also include parallel and additional analyses with ISCCP cloud fractions (various cloud types and heights), CloudSat liquid water content, GPCP Precipitation amounts, OMI aerosol optical depth and CALIPSO aerosol types. Additional satellite data sets and ground based data such as AERONET are also used to corroborate the CALIPSO aerosol types in each region and season.

Preliminary results, focusing on the South American and South African biomass burning regions, indicates strong seasonal shifts the aerosol-cloud fraction relationship that varies with biomass burning activity, precipitation and region. The MRE relationship clusters with the characteristic “boomerang” shape during the dry season during which absorbing aerosols are present in sufficient quantities to affect cloud fraction and a distinctly different relationship during the wet season. This suggests a method for parameterizing the MRE for cloud-aerosol interactions based on seasonal shifts in precipitation and aerosol that can be incorporated into CMIP6 modeling efforts.