Cloud Susceptibility Measures Potential Cloud Sensitivity to First Aerosol Indirect Effect

Contributors

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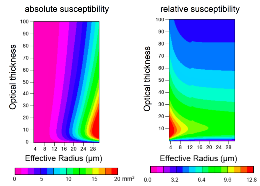
Research Highlight

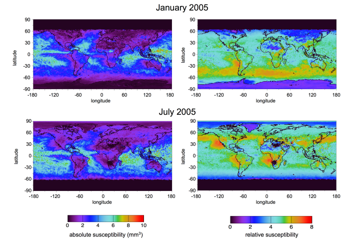
The global amount of atmospheric aerosol has increased substantially since the beginning of the industrialized era. Aerosol particles directly affect solar radiation by both reflecting and absorbing light. However, aerosol also can affect sunlight in an indirect manner by causing changes in cloud properties through the subset of particles that act as cloud condensation nuclei (CCN). The greater availability of CCN can yield clouds with more numerous but smaller cloud particles that are brighter, a process that is known widely as the first indirect effect. To the extent that clouds have a much greater global impact on sunlight than aerosols, understanding this indirect effect of aerosols on sunlight is a very important issue in climate studies.

Satellite studies of the first indirect effect remain challenging because of the difficulties involved in trying to quantify a change in cloud properties due only to changes in aerosol amount and type, while all other factors that affect cloud properties remain fixed. Furthermore, the response of the cloud depends on the cloud properties that existed before being modified by the presence of aerosol. Rather than confronting the formidable task of assessing the indirect effect on cloud properties at a particular place and time, we adopted an alternative approach where we estimate the cloud radiative sensitivity (or susceptibility) to a specified change in cloud particle numbers. An understanding of the cloud albedo sensitivity then can be used to specify the regions of the globe where the radiative indirect effect might be more significant and assist in climate model validation and interpretation. In two studies recently accepted by the Journal of Geophysical Research (JGR), we quantify the potential indirect radiative effect of aerosols on solar radiation both theoretically and using liquid water cloud properties provided by the moderate-resolution imaging spectroradiometer (MODIS) instrument onboard the Terra and Aqua satellites. Individual high spatial resolution data are analyzed as well as global data for four months. The analysis includes the effect of land surface albedo (reflectivity) and atmospheric absorption of sunlight by atmospheric gases.

Cloud susceptibility depends on the type of droplet number perturbation imposed, i.e., absolute or relative perturbations. Clouds with moderate optical thicknesses (~ 6-10) are the most sensitive to both types of perturbations, but absolute perturbations yield larger albedo changes the larger the unperturbed cloud effective radius. The study also demonstrates that, in addition to the cloud's properties, the location and environment in which the cloud forms also are critically important. Our realistic, but moderate, uniform droplet number perturbations yield global forcings on the order of 1-2 Wm-2 for current clouds.



Theoretical calculations with a shortwave broadband radiative transfer model of the spherical cloud albedo susceptibility due to a perturbation of 1 cm-3 in the droplet number concentration of clouds with liquid water content (LWC) of 0.3 gm-3 (left) and due to a perturbation of droplet number by 10% (right, multiplied by 1000, no LWC dependence). Note that the susceptibilities for the two types of perturbations behave completely differently, but both peak at moderate cloud optical thicknesses.



Geographical distribution of the January and July 2005 monthly mean susceptibility for 1 cm-3 (left, LWC = 0.3 gm-3) and 10% (right, no LWC assumed) droplet number perturbations, as inferred from the daily joint optical thickness-effective radius histograms for liquid clouds of the MODIS Terra Level-3 gridded product, ancillary surface and atmospheric data, and a shortwave broadband radiative transfer code.

Reference(s)

Platnick, S., and L. Oreopoulos. 2008. Radiative susceptibility of cloudy atmospheres to droplet number perturbations: 1. Theoretical analysis and

examples from MODIS, J. Geophys. Res., doi:10.1029/2007JD009654, in press.
Oreopoulos, L., and S. Platnick. 2008. Radiative susceptibility of cloudy atmospheres to droplet number perturbations: 2. Global analysis from MODIS, J. Geophys. Res., doi:10.1029/2007JD009655, in press.

Working Group(s)
Radiative Processes