Aerosol effects on ice clouds: can the traditional concept of aerosol indirect effects be applied to aerosol-cloud interactions in cirrus clouds?

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Cirrus clouds cover approximately 20–25% of the globe and thus play an important role in the Earth's radiation budget. Therefore the effect of aerosols on cirrus clouds can have a substantial impact on global radiative forcing if either the ice-water path (IWP) and/or the cloud ice number concentration (CINC) changes. This study examines the aerosol indirect effect (AIE) through changes in the CINC and IWP for a cirrus cloud case. We use a cloud-system resolving model (CSRM) coupled with a double-moment representation of cloud microphysics. Intensified interactions among CINC, deposition and dynamics play a critical role in increasing the IWP as aerosols increase. Increased IWP leads to a smaller change in the outgoing LW radiation relative to that for the SW radiation for increasing aerosols. Increased aerosols lead to increased CINC, providing increased surface area for water vapor deposition. The increased deposition causes depositional heating which produces stronger updrafts, and leads to the increased IWP. The conversion of ice crystals to aggregates through autoconversion and accretion plays a negligible role in the IWP response to aerosols, and the sedimentation of aggregates is negligible. The sedimentation of ice crystals plays a more important role in the IWP response to aerosol increases than the sedimentation of aggregates, but not more than the interactions among the CINC, deposition and dynamics.

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