Correlations between sea-salt aerosol and cloud droplet effective radius of water clouds in a general circulation model

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(Introduction)

Aerosols can absorb or scatter the solar and thermal radiation and can also change cloud properties to act as cloud condensation nuclei (CCN). The former is the aerosol direct effect and the latter is the aerosol indirect effect. The estimation of aerosol radiative forcing of both direct and indirect effects is highly uncertain and different among atmospheric general circulation models (AGCM) [Houghton et al., IPCC2001; Lohmann and Feither, 2005]. The uncertainty is mainly caused by a complex relationship between aerosols and clouds, including aerosol activation process, which means that hygroscopic aerosols grow into CCN. In most AGCMs aerosol activation processes are simplified by empirical relationships between aerosol and cloud number concentrations [e.g. Menon and Rotstayn, 2006]. Measurements and theoretical analysis show that, however, the aerosol activation is determined by four parameters: aerosol number concentration, aerosol size distribution, aerosol chemical component and updraft velocity in a cloud [e.g. Pruppacher and Klett, 1997]. Additionally when aerosols activate in a circumstance, each aerosol compete to get water vapor. For example, if there are both sulfate and sea-salt aerosols and the size of sulfate particles is smaller than that of sea-salt particles, sea-salt aerosols can activate more easily rather than sulfate aerosols. O'Dowd et al. (1999) showed such phenomena, yet so far there are no results of capturing them globally. Therefore we used global three dimensional aerosol transport model (SPRINTARS), which represents aerosol properties and competition effects in activation processes [Takemura et al., 2005]. Using this, we investigated an influence by aerosol activation, especially by sea-salt, to cloud droplet effective radius (Reff) of water clouds and then global cloud fields.

(Model Description and Experimental Settings)

We used a global aerosol transport model, SPRINTARS, coupled with Center for Climate System Research (CCSR)/National Institute for Environmental Studies (NIES)/ Frontier Research Center for Global Change (FRCGC) AGCM [Takemura et al., 2005]. In this study we assumed scavenged fractions of aerosol in clouds are the same as calculated ratios of activated aerosol to total aerosol. We calculated aerosol activation ratio using Abdul-Razzak and Ghan (2000)'s parameterization. This parameterization can calculate supersaturation ratio including the competition effects by sea-salt aerosols. Besides we also calculated Reff by combinations of both cloud liquid water calculated in physical frame and CCN number concentrations calculated through the parameterization. In order to investigate an impact of sea-salt aerosol to CCN spectra, we executed several numerical experiments with several sea-salt emission fluxes and compared simulated activation ratio of aerosols and simulated Reff.

(Results)

In general, when hygroscopic aerosol number concentrations increase, CCN number concentrations increase [Twomey, 1974]. However this statement could not be applied when aerosol size distributions in clouds are wider. The situations are often occurred near coastal areas where two major type aerosols coexist: smaller-hygroscopic particles such as sulfate and organic aerosols and larger-hygroscopic particles such as sea-salt aerosols. Figure shows the Reff difference between two different flux intensities. In coastal and continent areas, as sea-salt number concentrations increased, supersaturation decreased. Thus activation ratio of smaller-hygroscopic aerosols reduced dramatically. As a result, CCN concentrations decreased and the Reff increased. In contrast, in oceans far from continents, as sea-salt number concentrations increased, CCN concentrations increased and thus the Reff increased, because smaller-hygroscopic aerosols were not distributed around there.

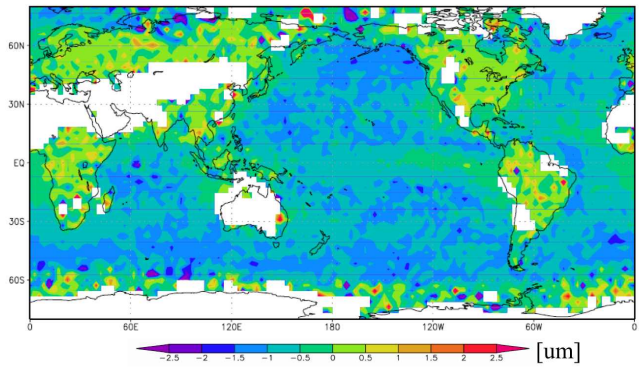

Fig. Monthly mean simulated R_{eff} difference near the top of water clouds between sea-salt emission fluxes set at 133% and at 100% .