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# The importance of Asian dust aerosols as CCN estimated from satellite data analysis

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Atmospheric aerosols play an important role in the Earth's climate system. Asian dust aerosol particles so-called "Yellow Sand" emitted from desert area in China are known to act as ice nuclei. Recently it is pointed out that the Asian dust aerosols are also important for cloud condensation nuclei (CCN). In the present study the effects of dust aerosols on water clouds in East Asian were analyzed by using satellite observation data.

We used the product data of MODIS on board Terra and Aqua satellites. RGB image, split window brightness temperature difference, cloud optical thickness, cloud effective particle radius, and cloud liquid water path were selected, referring to the dust storm events reported by Japan Meteorological Agency. Since the heavy dust event in East Asia is generally observed in spring season, the periods analyzed in this study were March, April, and May of 2006, 2007, and 2008. The brightness temperature difference (BTD) of infrared split window channels was used to detect the cloud region affected by dust aerosols. The BTD observed from space is generally positive in optically thin cloud and clear sky regions according to the wavelength dependency of absorption properties of ice, water, and water vapor, while it becomes negative for dust aerosols.

It is found from the analysis that the effective particle radius of dust mixed cloud is smaller than that of non-mixed cloud. This may suggest the indirect effect of dust aerosols. On the other hand, remarkable differences were not found for optical depth, and thus liquid water path of aerosol mixed cloud was smaller than that of non-mixed cloud. It is also suggested that the number concentration of CCN saturates where the dust aerosol number concentration is sufficiently large and the size of individual particles increases. The growth of cloud particle corresponds to increases in liquid water path and optical depth. Dust aerosols are mixed with air pollution such as sulfate over East Asia from Chinese coastline to Japan. Sulfate aerosol concentration was estimated by CFORS (Chemical weather FOrecasting System) as well as dust aerosols. It is found that dust aerosols mixed with sulfate aerosols gave rise to the indirect effect while sulfate aerosols without dust did not. It suggests a function as CCN where dust aerosols are mixed with sulfate. The similar analysis was carried out for the Atlantic Ocean region off the coast of Saharan desert, and the result shows that the Saharan dust aerosols did not act as CCN. It may be ascribed to a fact that the Saharan dust is not mixed with air pollution. The semi-direct effect due to dust aerosols was also observed where cloud optical depth is small. Dust aerosols absorb the solar radiation and heat the atmosphere although the absorptance is not so strong. Absorption of shortwave radiation by the clouds and aerosols and the heating rate were calculated with radiative transfer code for cloud layer mixed with dust aerosols, and it is shown that the heating of the cloud layer may be consistent with the semi-direct effect.