A modeling study on the roles of cloud distribution in global tropospheric chemistry: detailed evaluation of clouds in a chemistry climate model (MIROC-CHASER)

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Chemical reactions in the atmosphere directly affect the formation and loss of ozone, methane, nitrogen oxides, sulfur oxides, and aerosols, and have a great influence on the atmospheric environment and climate change. Since these reactions are driven by photodissociation of ozone and related species caused by ultraviolet radiation, they can be largely modulated by the distribution of clouds. This study quantitatively investigates the photolytic impacts of clouds on atmospheric chemistry by using a global chemical transport model (chemical climate model, CHASER), observational (satellite and aircraft) data, and reanalysis data.

For cloud fields, CHASER reproduced generally well the global distribution of total cloud amount as observed in the satellite (ISCCP D2) and reanalysis data (JRA-55). This model, however, tends to underestimate low-level clouds in the tropics with an overestimate in the high latitudes. Further verification for the other cloud parameters like optical thickness and radiative forcing is now in progress and will be discussed in the presentation.

Our sensitivity experiments with respect to the impacts of clouds on photolytic processes show that clouds reduce OH radical concentrations by 10-20% near the surface and increase by 10-20% in the upper troposphere, basically as a result of scattering and reflection of UV radiation by low-middle level clouds. Our simulations also suggest that the global mean OH concentration, proxy of the oxidizing capacity of the atmosphere, increases by about 14% due to clouds. Also, tropospheric ozone (O_3) concentrations decreaced by about 3% near the surface and increased by about 4% in the upper troposphere reflecting changes in NO_x concentration. These clouds' impacts on the atmospheric chemistry were verified by using aircraft observation data (NASA ATom-1, 2, 3). The result shows that the observed OH and O_3 concentrations are reproduced more accurately when clouds are properly considered in the model.

These results indicate that clouds have significant influences on the global atmospheric chemistry (especially on the OH concentration field). Since OH determines the concentrations of chemical species such as methane, carbon monoxide (CO), fluorocarbons (CFCs), etc. which are important for climate and stratospheric ozone, this study suggests that the variation and trends in the clouds can largely affect the chemical species, which may give an additional influence on climate and atmospheric environment.

Keywords: Cloud, Chemistry-transport model, Ozone, OH radical

