Significance of cloud and precipitation in aerosol effect on climate

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Aerosol impacts on Earth's climate are still subject to large uncertainty. A major part of this uncertainty arises from atmospheric processes relevant to cloud and precipitation. This is fundamentally due to a dominant role of moist processes in Earth's atmosphere. This study explores how aerosol's impacts on climate are significantly modulated by the presence of cloud and precipitation. For this purpose, numerical experiments are performed with two global models, i.e. (i) MIROC and (ii) NICAM-Chem. The former is a traditional type of global climate model and the latter is a global non-hydrostatic atmospheric model, both of which are coupled to the SPRINTARS aerosol transport module. In the simulations, emissions of scattering (i.e. sulfate) and absorbing (i.e. black carbon) aerosols are separately perturbed with uniform factors multiplied to investigate the climate responses to perturbations of each aerosol type. The results are analyzed in the context of global energy budget to find that energy budget components respond differently to perturbations of scattering and absorbing aerosols due to different responses of cloud and precipitation. The cloud response to perturbations of absorbing aerosols is found to produce a negative radiative effect that significantly reduces the original positive radiative forcing of the aerosols whereas the cloud response to scattering aerosols tends to enhance the original cooling effect of the aerosols via aerosol-cloud interactions. The two types of aerosols also cause distinctly different responses of precipitation through different pathways of energy budget modulations occurring over different time scales. These results underscore a significance of cloud and precipitation processes in quantification of aerosol impacts on global climate and may help reduce a large inter-model spread in estimates of the hydrologic sensitivity in climate predictions.

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