Impact of surface-cloud coupling for aerosol-cloud-interactions over the Southern Great Plains

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Aerosol-cloud interactions (ACI) have emerged as one of the primary sources of uncertainty in climate change, as acknowledged in the latest IPCC report. The uncertainties arise from the many variables involved, such as meteorological settings, cloud regimes, and aerosol types. The coupling between clouds and the Earth's surface is particularly important, as it plays a crucial role in determining whether aerosols can affect cloud properties. Despite its significance, previous studies on ACI over land have paid no or little attention to cloud-surface coupling, due to a lack of such knowledge.

In this study, we aim to address this critical gap by examining the effects of aerosols on clouds under coupled and decoupled conditions. We consider the planetary boundary layer height (PBLH) as the maximum height directly influenced by surface fluxes, and thus, coupling with the PBL is equivalent to coupling with the surface. Our results indicate that coupled clouds respond more significantly to increased surface aerosol concentration. For non-precipitating low-level clouds, an increase in aerosols results in a decrease in cloud droplets size under coupled conditions, especially for low Liquid Water Path. The decrease in cloud droplet size is accompanied by an increase in Cloud Optical Thickness, resulting from the higher number of small cloud droplets and increased scattering. In contrast, during decoupled conditions, non-precipitating low-level clouds show no trend with respect to changes in aerosol loading.

We also found that considering coupled and decoupled conditions is critical when studying the development of convective clouds. Under coupled conditions, an increase in surface aerosol concentration leads to an increase in cloud thickness, likely due to the longer cloud lifetime and increased number of droplets, yielding more latent heat release. Furthermore, as the concentration of surface aerosols increases, the ratio of deep clouds to low-level clouds also increases. These findings suggest that surface aerosols can significantly modulate cloud properties and form different cloud types. Our study highlights the importance of considering cloud-surface coupling in addressing ACI, as they play a crucial role in determining the response of clouds to aerosols and providing a more comprehensive understanding of the complex interplay between them.

Keywords: observational study, aerosol, clouds, planetary boundary layer, cloud-surface coupling