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Spatio-temporal Patterns of the Precipitation Response to Aerosol Perturbations from an Energetic Perspective

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Absorbing and non-absorbing aerosols have distinct effects on both global-mean and regional precipitation. Local changes of precipitation in response to aerosol perturbations are more complex than global-mean changes, which are strongly constrained by global energy budget. This work examines the changes of atmospheric energetic budget terms to study effects of large perturbations in black carbon (BC) and sulphate (SUL) on precipitation. Both cases show decrease of global-mean precipitation but with different geographical patterns. Decreased atmospheric radiative cooling contributes to the majority of decreased global-mean precipitation. It is caused by increased aerosols absorption in BC case but decreased cooling from clean-clear sky (without clouds and aerosols) in SUL case. Fast responses, which are independent of changes in sea surface temperature (SST), dominate the precipitation changes in the BC case, not only for global mean but also for regional patterns. Slow responses, which are mediated by changes in SST, dominate the precipitation responses in SUL case, both globally and regionally.

Relationships between temporal responses of local precipitation and diabatic cooling and precipitation are also examined for both BC and SUL perturbations. Both cases show remarkable similar pattern of correlations despite of essentially different patterns of changes in precipitation and diabatic cooling. Strong positive correlations are found over mid-latitude land and this is mainly due to the changes from surface sensible heat fluxes. Negative correlations are found over tropical oceans, mainly contributed by (longwave) radiative cooling from clouds and clean-clear sky. Further analysis shows this similarity is caused by the natural variability which is independent from external forcing. It indicates that the temporal relationship between changes in local precipitation and diabatic cooling is forcer-independent. This correlation is examined as a function of increasing spatial scales, which demonstrates the scale at which the dominating energetic term on regional precipitation shifts from energy transport to atmospheric diabatic cooling.