

## Smaller susceptibility of precipitation onset to aerosols in a global cloud-resolving model

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A growing body of evidence proposes that the aerosol indirect forcing, particularly due to the cloud lifetime effect or the second indirect effect, may be substantially smaller than what has been considered. This is largely influenced by uncertainty of the cloud water response to aerosol perturbations, which varies even in sign as reported by recent studies. Given that the cloud water response is largely dictated by the rain formation process and its modulation induced by aerosols, this study investigates how the precipitation onset responds to aerosol perturbations with a combined use of a global cloud-resolving model (NICAM), a global climate model (MIROC) and satellite observations (CloudSat and MODIS). Methodologies recently proposed to diagnose the rain formation process are applied to both the model output and satellite observations to quantify how the precipitation onset is susceptible to aerosol perturbations in the models and the real atmosphere. The methodologies construct the global statistics of the probability of precipitation (POP) as a function of liquid water path (LWP) to demonstrate how the POP tends to monotonically increase with increasing LWP in the manner that varies systematically with droplet number concentration. This variation is then used to quantify the susceptibility of precipitation onset to perturbed aerosols. The susceptibility thus obtained is compared between the two global models and satellite observations to show that NICAM reproduces the susceptibility well close to what is obtained from satellite observations, in contrast to MIROC that exerts significantly larger susceptibility. This proposes that NICAM represents the aerosol effect on rain formation more realistically than MIROC and other traditional climate models that have been reported to overestimate the susceptibility. Further analysis exploring the microphysical process representations in the two models reveals that the cloud-rain water composition is a key factor that controls the precipitation onset susceptibility and is qualitatively different between the two models. The cloud-rain composition varies in response to aerosol perturbations through auto-conversion and accretion processes, whose relative contributions are in turn largely influenced by the cloud-rain composition. This mutual interplay between the cloud-rain water composition and the process proportion plays a key role in determining the precipitation susceptibility and modulation of cloud water budget in response to aerosol perturbation. This presentation highlights a stark contrast between the two models in representations of these fundamental aspects of the aerosol indirect effect in comparison to satellite observations that provide key constraint on some of these aspects.

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