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Constraining ice nuclei freezing efficiency using cloud phase observations together with climate models.

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Aerosol-cloud interactions are an important source of uncertainty in current climate models. In particular, the role of mineral dust and soot particles in cloud glaciation is poorly understood. This lack of understanding leads to high uncertainty in climate predictions.

To estimate the global co-variability between mineral dust aerosol and cloud glaciation, we combined an aerosol model reanalysis with satellite retrievals of cloud thermodynamic phase. Our results confirmed that the cloud thermodynamic phase increases with higher mineral dust concentrations.

To better understand and quantify the impact of ice-nucleating particles on cloud glaciation, it is crucial to have a reliable estimation of the hemispheric and seasonal contrast in cloud top phase, which is believed to result from the higher dust aerosol loading in boreal spring. For this reason, we locate and quantify these contrasts by combining three different A-Train cloud-phase products for the period 2007-2010. These products rely on a spaceborne lidar, a lidar-radar synergy, and a radiometer-polarimeter synergy. We used these observations to constrain the droplet freezing in the ECHAM-HAM climate model. After tuning, the model leads to more realistic cloud-top-phase contrasts and a dust-driven glaciation effect of $0.14 \pm 0.13 \text{ Wm}^{-2}$ between $30\text{--}60^\circ\text{N}$. Our results show that using observations of cloud-top phase contrasts provide a strong constraint for ice formation in mixed-phase clouds and a weak constraint for the associated impact on radiation and precipitation.

Besides mineral dust, it has been under debate whether black carbon also contributes to cloud glaciation. Therefore, we studied the cloud top phase retrieved by CALIOP during the Australian wildfires in 2020. After repeating the tuning strategy for black carbon, we were able to replicate the increase in ice cloud frequency observed during the wildfires.