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The competing effect of aerosols on stratiform mixed-phase clouds

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Due to limited in-situ observations, spaceborne retrievals of cloud top phase are often used to study the behaviour of mixed-phase clouds and their sensitivity to aerosols. By stratifying 35 years of cloud observations by temperature and cloud thickness, we gained valuable insights into the interplay between aerosols and mixed-phase clouds.

First, there is evidence that the ice-to-liquid frequency (ILF) is dominated by two sources of cloud ice: For thin clouds, a cirrus-origin due to ice sedimentation from temperatures colder than -38 dgC, and for thick clouds, a glaciation-origin due to aerosol-driven droplet freezing. These different sources of ice may explain differences in the ILF from different retrieval methods. For example, active instruments, which are more sensitive to thin cirrus, may estimate a higher ILF compared to passive instruments, which are more sensitive to thick clouds.

Second, we find that in extratropical thick mixed-phase clouds, aerosols have two dominant effects on the ILF: For liquid clouds, aerosols increase cloudiness at warm temperatures, but they decrease cloudiness at cold temperatures. Our results suggest that precipitation inhibition (by increasing the number of droplets) and enhanced cloud glaciation (by increasing the rate of droplet freezing at cold temperatures) can explain this behaviour. As a result, we find that the indirect effect of aerosols through mixed-phase clouds is strongly temperature dependent.

Third, at cold temperatures, both dust aerosol and organic aerosols are temporally correlated with higher ILF on a monthly basis. Spatially, this correlation coincides with regions downwind of deserts and highly biologically productive regions in the ocean. We also find that the ILF increases logarithmically with increasing aerosol concentrations, at a rate consistent with the behaviour reported from laboratory studies. Thus, for the first time, we provide a link between laboratory studies of droplet freezing and space-based studies of cloud glaciation.