Comparisons of cirrus cloud properties between polluted and pristine air based on in-situ observations from the NASA ATTREX, NSF HIPPO and EU INCA campaigns

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Cirrus clouds, covering about 30% of the Earth's surface area, play an important role in the climate and weather systems. Cirrus cloud radiative forcing (cooling or warming) is influenced by their microphysical (e.g., ice crystal number concentration and size distribution) and macroscopic (e.g., spatial extent) properties. Currently it is still unclear how the formation of cirrus clouds and their microphysical properties are influenced by anthropogenic emissions.

In this work, we use in-situ observations from three flight campaigns to compare the cirrus cloud properties between polluted and pristine regions. Our dataset includes: (1) the NASA Airborne Tropical Tropopause Experiment (ATTREX) campaign (2013), (2) the NSF HIAPER Pole-to-Pole Observations (HIPPO) Global campaign (2009-2011), and (3) the European Union (EU) Interhemispheric Differences In Cirrus Properties from Anthropogenic Emissions (INCA) campaign (2000). The combination of these three campaigns provides in-situ measurements of both extratropical and tropical cirrus clouds, over the Northern and Southern Hemispheres.

We use the in-situ measured carbon monoxide (CO) mixing ratio as a pollution indicator, and compare ice microphysical properties (i.e., ice number concentration (Nc) and mean diameter) between polluted and pristine air masses. All analyses are restricted to temperatures ≤ -40°C to exclude mixed-phased clouds. By analyzing the ice crystal measurements (Fast-2DC probe, 87.5-1600 μm) from the HIPPO data, we found that the mean diameter of ice crystals decreases with increasing CO concentration. In addition, analysis of INCA data shows that the number concentration of small ice particles (FSSP 3-20 μm) increases at higher CO concentrations. We filter out the particles smaller than 87.5 μm in Fast-2DC data to minimize the shattering effect, but the FSSP measurements are subject to possible shattering. The HIPPO and INCA datasets are mostly confined to cirrus clouds in the extratropical regions due to the flight ceiling. On the other hand, analysis of the ATTREX data (FCDP 1-100 μm), which mostly sampled cirrus in the tropical tropopause layer, shows that the correlation between Nc and CO is not significant. The results suggest that when extratropical cirrus clouds form in the more polluted background, they are likely to have more numerous small ice particles, yet no obvious adjustments have been observed for tropical cirrus clouds.

More work is required to investigate if the different responses of cirrus microphysical properties between the extratropical and tropical cirrus clouds sampled from these three campaigns are due to different dynamical conditions, or due to the different temperature ranges being used for the analysis (i.e., -40°C to -65°C for HIPPO and INCA versus -65°C to -75°C for ATTREX). Overall, these analyses will help to improve the estimation of the impacts from anthropogenic emissions on cirrus cloud formation.