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TTL cirrus ice water content–extinction relationships from ATTREX measurements

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Cirrus clouds cover a large fraction of the globe and play a significant role in the radiative balance of the Earth system, but remain a source of uncertainty since their net radiative effect varies depending on their microphysical properties. Cirrus are particularly prevalent in the tropical central and western Pacific, where they form at the extremely cold temperatures in the tropical tropopause layer (TTL) and result in dehydration of air as it rises into the stratosphere. TTL cirrus typically exhibit low ice number concentrations and small particles relative to mid-latitude cirrus, resulting in significantly lower ice water contents (IWC).

Lidar observations of TTL cirrus produce measurements of volume extinction (σ) and rely on empirically derived relationships to calculate cloud IWC. To date, TTL cirrus σ–IWC relationships have been extrapolated from measurements of mid-latitude, higher temperature clouds, or based on a limited number of observations within TTL cirrus. In this analysis we use measurements of cirrus extinction and IWC acquired during the Airborne Tropical Tropopause Experiment (ATTREX) mission in the TTL over the western Pacific to derive new relationships between these parameters for TTL cirrus that can be used to improve the determination of TTL IWC from satellite, airborne and ground-based lidar. ATTREX yielded more than 24 hours of sampling in TTL cirrus at temperatures below 203 K (-70° C). Cirrus clouds were encountered at altitudes between 14.5 km and 17.5 km with IWC down to the $\sim$2 μg m^{-3} detection limit of the NOAA Water instrument and water vapor mixing ratios as low as 1.5 ppm. Most TTL cirrus sampled had ice number concentrations (INC) less than 100 L^{-1}, and very few had INC of more than 1000 L^{-1}. σ values measured by the in situ cloud probes ranged from $< 10^{-6}$ m^{-1} to $\sim 10^{-3}$ m^{-1}.