Observations of the ice water content–extinction relationship in TTL cirrus during ATTREX 2014

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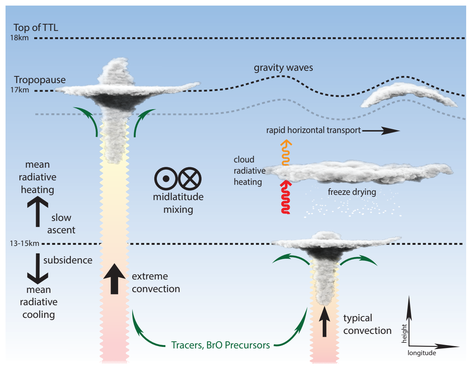
The Airborne Tropical Tropopause Experiment

The NASA Airborne Tropical Tropopause Experiment (ATTREX) is a five-year project using the NASA Global Hawk UAS to study transport and chemical processes in the Tropical Tropopause Layer (TTL) over the Pacific Ocean. The TTL, particularly over the western Pacific, is the principal gateway for air that is transported from the troposphere into the stratosphere.

The goals of the ATTREX mission include investigating:

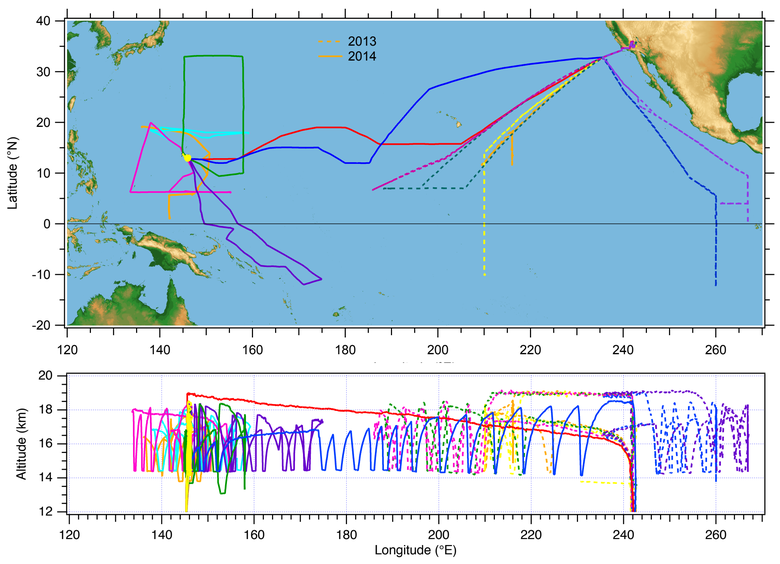
- The role of stratospheric water vapor in Earth's energy budget and climate
- Dehydration of tropospheric air entering the stratosphere
- The formation processes, microphysical properties, and climate impact of TTL cirrus



Primary deployments were:

- January - March 2013: Dryden Flight Research Center, California (Central and Eastern Pacific)
- Jan - Mar 2014: Andersen AFB, Guam (western Pacific)

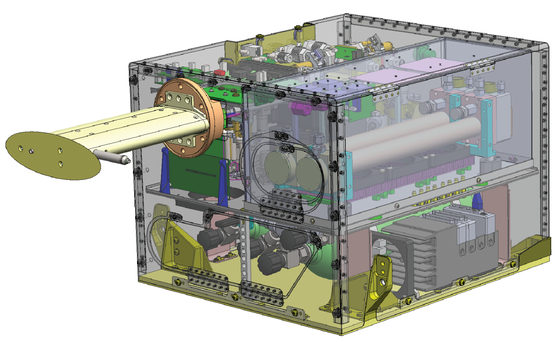
ATTREX achieved 184 hours sampling in the TTL, more than 34 hours in TTL cirrus



The NOAA Water Instrument

A two channel, TDL-based hygrometer for measuring water vapor and total (vapor + condensed) water in the TTL.

- Closed-path, single-reflection (optical path length = 78.6 cm); optical cells operated at constant T, P, and flow
- 2f detection in the wavelength range near 2.694 μm used to achieve high precision at low mixing ratios
- S/N (2σ, 1 s) @ 1 ppm = 4
- Scan across two H_2O lines with different strengths to achieve large dynamic range (1 – 2500 ppm)
- Total instrument weight: 40 kg
- On-board calibration using catalytic oxidation of H_2/air to H_2O (*Rollins et al., 2011*)
- Overall H_2O vapor measurement uncertainty (accuracy + precision) = 6% + 0.23 ppm
- Side-facing inlet for water vapor sampling (even in clouds)



- Forward-facing inlet for sampling of vapor + condensed-phase H_2O
- Subisokinetic flow results in inertial sampling enhancement factor of 33 – 48 at Global Hawk flight conditions for particles larger than ~7 μm, which yields an IWC detection limit of < 3 μg/m^3
- Size-dependent enhancement factor calculated using CFD-based parameterization described in *Eddy et al., Aerosol Sci., 2006*

TTL cirrus ice water content (IWC) vs extinction (σ)

The IWC – σ relationship is used to relate satellite observations of clouds to the cloud IWC, an important parameter in global climate models which directly affects the cirrus net radiative forcing

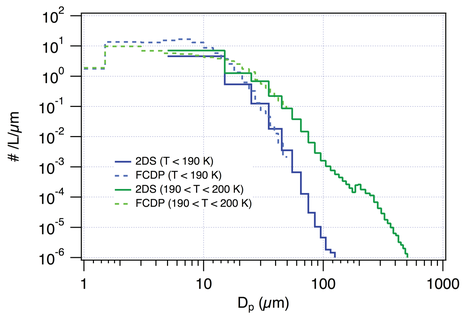
ATTREX cirrus cloud observations

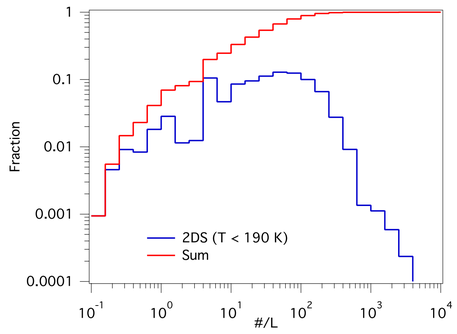
In the temperature ranges < 190 K and 190 – 200 K, the dominant fraction of the size distribution resides in D_p < 15 μm, although a shift toward larger sizes with increasing temperature is observed

Ice crystal mass is also concentrated in small sizes (D_p < 35 μm) at low temperatures, which has implications for dehydration

90% of cirrus observations have N < 100/L, less than 0.05% have N > 1000/L
— will shift to slightly higher number with inclusion of FCDP small particle data

Are the low values of N relative to what would be expected from homogeneous nucleation evidence for importance of wave-moderated homogeneous nucleation (e.g. *Spichtinger and Krämer, 2013*) or heterogeneous nucleation in TTL cirrus?



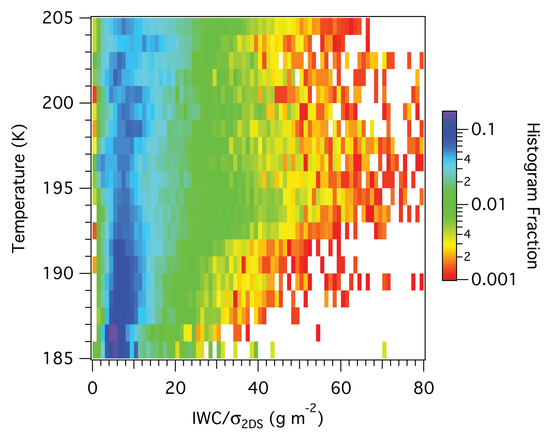


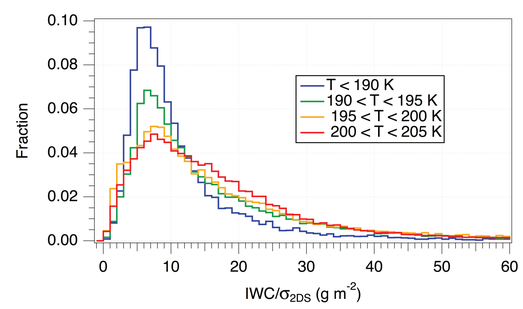
The IWC – σ relationship in TTL cirrus

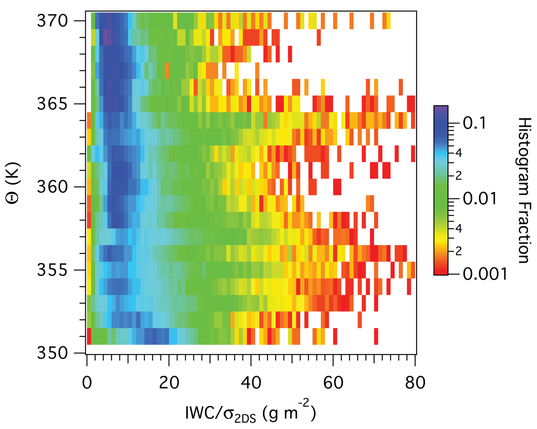
The IWC/σ ratio in TTL cirrus during ATTREX 2014 is observed to not vary significantly with temperature between 185 and 205 K

The IWC/σ distribution peak values near 8 is similar to that reported by Heymsfield et al. (2005) for the lowest temperature data (~205 K) from several previous measurement campaigns

A slight increase in the ratio is observed at the lowest potential temperatures and a slight decrease at the highest potential temperatures at which cirrus were sampled in the TTL







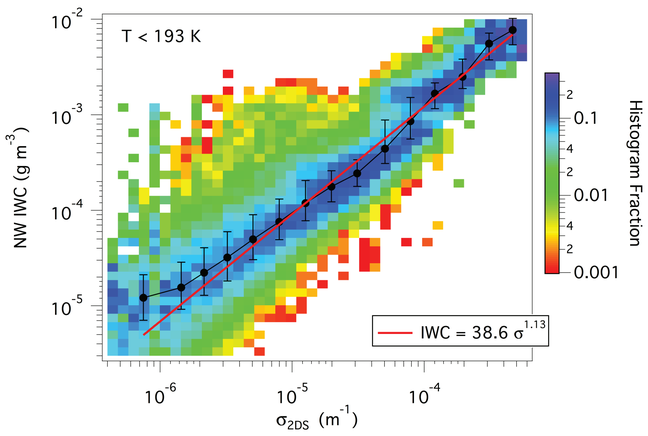
A power law fit to median values yields reasonably consistent relationship

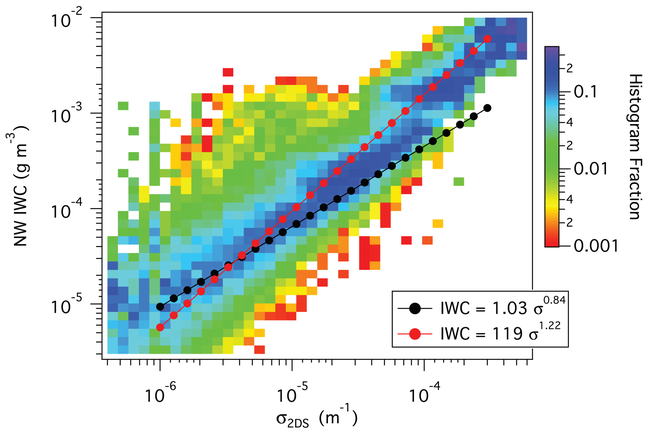
Best fit parameterization ot the ATTREX observations for T < 193 K is

IWC = 38.6 $\sigma^{1.13}$

which falls between previous estimates reported in *Heymsfield et al., 2005* for all data (red), and *Heymsfield et al., 2014* for low temperature data (black)

Deviation at small values possibly due to a larger contribution from small particles





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