Examining ACE-FTS and PEARL-FTIR Data in the Arctic

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Motivation
During the winter, conditions in the Arctic atmosphere become extremely cold due to the formation of the polar vortex, a stable circulation cell that isolates the Arctic from the rest of the atmosphere. This in turn allows reactions that impact the ozone layer to favorably occur. Much can be learned by observing, analyzing and comparing data from occlusions of the trace gases that react due to the conditions brought on by the polar vortex. As a result, this research seeks to demonstrate these observations to compare measurements from different instruments to see how they agree during the Arctic springtime.

Background
Hydrogen chloride or HCl, can be found throughout the stratosphere and the upper troposphere, but the gas is most important in the middle stratosphere due to the ozone layer and the polar stratospheric clouds (PSCs) that form in the region. PSCs are ice-like clouds that form at very low temperatures in the polar vortex during winter

ACE-FTS
Name: Atmospheric Chemistry Experiment Fourier-Transform Spectrometer (ACE-FTS).
Launch: Launched onboard the CESAT satellite on 15 August 2003.
Objective: To help scientists understand the depleting of the ozone layer better, especially in the Arctic region. This was done by measuring the atmospheric focus on high latitudes.
Measurements: The ACE-FTS instrument is a Fourier-transform infrared spectrometer that measures the atmosphere by solar occultation. These occultations occur during the sunrise or sunset as the satellite travelling in the orbit. Figure 1 shows the limb-viewing (occultation) method used by the instrument so that it can measure different layers of the atmosphere. The measurements retrieved from the spectra include profiles of temperature, pressure, and volume mixing ratio from 70 different trace gases.
Coverage: The region of coverage can be seen in figure 1. This region varies throughout the year as the sunrises and sunsets change. This coverage goes from 85° N to 85° S.

PEARL-FTIR
Name: Polar Environment Atmospheric Research Laboratory Fourier-Transform Infra-Red Spectrometer. Also called the Bruker 125HR.
Installed: Installed at the Polar Environment Atmospheric Research Laboratory (PEARL) in Eureka, Nunavut, Canada in July 2008.
Objective: Installed in northern Canada, the instrument is used to take profile and column measurements of the atmosphere of the high Arctic. Its positioning also allows it to take measurements inside and outside of the polar vortex depending on the year.
Measurements: The PEARL-FTIR is a ground-based high-resolution Michelson interferometer. The PEARL-FTIR records solar absorption spectra (as does the ACE-FTS), which are used with the SFIT4 retrieval algorithm to obtain estimates of trace gas profiles and total column quantities.
Coverage: The covered region is around the PEARL Ridge Lab located in Eureka, Nunavut (80.88N, 95.42W), depending on where the solar occultation is occurring and the weather at the time.

PEARL-FTIR Retrieval Properties
The information content of the retrievals performed using the PEARL-FTIR observations is contained within the averaging kernel (AK) of the retrievals. This AK is a matrix used to characterize the data and is the result of the retrieval algorithm. x = A(x−A)(x−A) is the best estimate profile estimated by the SFIT4 algorithm, x is a priori profile measured by the instrument, x is the true unknown profile representing the real gas concentrations of the atmosphere, i is the identity matrix and A is the averaging kernel.

The a priori is the initial guess taken by the instrument using other sources, this is then used by the retrieval algorithm to better treat the measured data. The AK contains information about the sensitivity of the retrieval to the measurement, and the amount of information contained in the retrieved trace gas profiles and columns.

These plots are split into 4 different sections depending on measurement location with respect to the polar vortex (e.g., inside the vortex, outside the vortex, on the edge, all measurements). The degrees of freedom for signal on the left represent the amount of information available at different latitudes. This sensitivity in the middle represents the fraction of the data that is derived from the measurement versus the a priori information (value of 1 is best). On the bottom is the volume mixing ratio (VMR) plots that these first two plots apply to. The VMR plots are more uniform as the sensitivity decreases because the retrieval profiles converge to the a priori estimate used.

This instrument does not use this retrieval method which means that its dataset does not routinely produce averaging kernels and related metrics.

Discussion
Looking at these 15 years of data from the ACE-FTS instrument dataset as well as the PEARL-FTIR instrument dataset, we can observe that the two do not seem to be too far off. The mean percentage difference for the partial column and the total column measurement shows that the difference between these two datasets is ~15%. This demonstrates that there is a difference between the datasets measured by each instrument, but when looking at the orders of magnitude, that being of 10^6 to 10^16 molecules/cm^2, this difference ends up not being that great. Juxtaposing this comparison technique and percentage difference to the ones found in the Griffin et al. 2017 paper, we can get an idea of what could be done in the future to compare these two datasets better. Future work in this research could be done to account for the difference in measurement sensitivity between the two instruments and smooth the ACE-FTS measurements by the AK from the PEARL-FTIR.

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References