

Measurements of atmospheric trace gases in the Arctic: First light measurements from the new FTIR spectrometer at PEARL

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Introduction

The Arctic has been identified as one of the places on Earth most likely to be affected by climate change. Global circulation ensures that pollutants and chemicals released anywhere in the atmosphere also affect the fragile ecosystems in the polar regions. Cold conditions inside the winter polar vortex combined with anthropogenic chlorine and bromine species in the stratosphere result in spring-time ozone depletion in the polar regions. In order to see and understand the changes occurring in the Arctic, high quality atmospheric ground-based measurements recorded over a long time period are essential. In addition to standing on their own as a snapshot of the Arctic atmosphere, these measurements serve to validate the models and satellite measurements that give us a more global view of our atmosphere.

In July 2006, a new Bruker-IFS 125 HR Fourier transform infrared spectrometer (FTIR) was installed at Eureka, Nunavut (80°N, 86°W, see map above) as part of the Canadian Network for the Detection of Atmospheric Change (CANDAC) suite of instruments at PEARL (the Polar Environment Atmospheric Research Laboratory). This state-of-the-art instrument has an extremely high resolution of 0.0024 cm^{-1} and is capable of measuring at least 14 different atmospheric trace gases nearly simultaneously, using the Sun (or Moon) as a light source. This poster will present some preliminary results obtained using this instrument.

The Bruker was delivered to Eureka in July 2006, on a chartered 737, and installed at PEARL.



Measurement and Retrieval Details

Bruker FTIR measurements were made using the Sun as a light source for several weeks prior to sunset in 2006, and then as part of the 2007 Canadian Arctic ACE Validation Campaign (see below). This work presents measurements made during the spring period. Measurements were made with one of 5 filters, each covering different wavelength regions, on either the InSb ($1850\text{-}11000 \text{ cm}^{-1}$) or the HgCdTe ($600\text{-}6000 \text{ cm}^{-1}$) detector. Measurements were typically 4 scans each, with the field of view and preamplification selected to maximize the signal. Signal-to-noise ratios were high (500+) for those spectra recorded with the InSb detector, and lower (~100) for those on the HgCdTe detector. Profile retrievals of the trace gases from the spectra were made using the SFIT2 retrieval package, whereby a synthetic spectrum is fitted to the measured spectrum using an optimal estimation technique [1]. Total column amounts were determined from the retrieved profiles. Examples of the fits for HCl, HF and O_3 are shown below. While there is ample information in the spectra to retrieve total (and some partial column) trace gas amounts, there is not sufficient independent information in the measurement to retrieve a full profile.

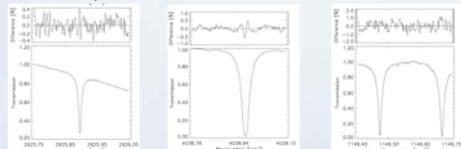


Figure 1: Example fits for spectra obtained on 4 March 2007. From left: HCl, HF and O_3 . The dotted line is the calculated spectrum, solid line is the measurement. The residual difference between the two is plotted above.

2007 Canadian Arctic ACE Validation Campaign



Spring campaigns have been carried out at Eureka to validate the Atmospheric Chemistry Experiment (ACE) satellite instruments [2] since 2004. The 2007 spring campaign ran from February 21st until April 1st. At this time of year, the polar vortex is strong and the return of the Sun is causing chemical changes to occur in the stratosphere. The campaign is comprised of simultaneous measurements with multiple instruments, including ground-based versions of the ACE-FTS and MAESTRO, as well as frequent ozonesonde launches. The Bruker was one of three FTIR instruments participating in this campaign. The solar beam was shared, with 1/3 of the beam continuously going to PARIS-IR (the ground-based version of the ACE-FTS), and the remaining 2/3 of the beam being alternated between the Environment Canada Bomem DA8 and the Bruker. While the comparison between these instruments is of interest, it will not be presented here.

During the course of the campaign, the polar vortex moved so that Eureka was both inside and outside it at various times (Figure 2). The first part of the campaign was characterized by frequent movement in and out of the vortex. An ozone "mountain" just outside the vortex was sampled on several occasions. After day 67 (Mar 8), Eureka remained consistently within the vortex for approximately 17 days, then was mostly outside for the last few days of the campaign.

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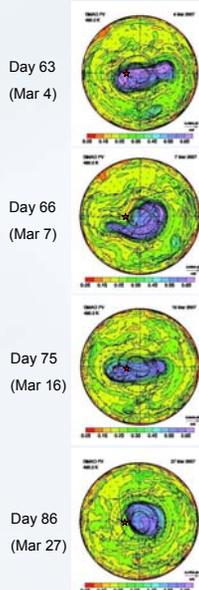


Figure 2: Potential vorticity on the 490K θ -surface, obtained from NASA's GMAO GEOS-4 analyses. Courtesy of Gloria Manney, JPL. The red star shows location of Eureka.

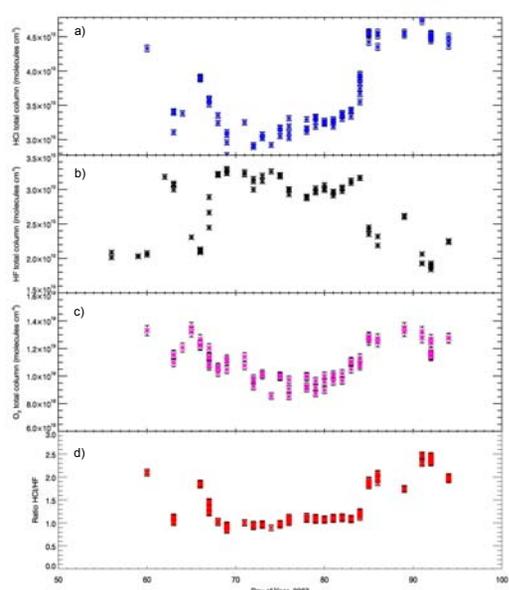


Figure 3: Total column amounts of (a) HCl, (b) HF, (c) O_3 and (d) the HCl/HF ratio over Eureka during spring 2007. Error bars are measurement + smoothing error only. For discussion, see text.

Discussion and Conclusions

Figure 3 shows the total column amounts of a) HCl, b) HF and c) O_3 over Eureka in spring 2007. In addition, the ratio of HCl/HF is shown in panel d). HCl is the primary reservoir species for chlorine in the stratosphere. While it is generally unreactive, HCl is able to react heterogeneously to release chlorine into more reactive forms (such as Cl_2 or ClO). Typically these reactions occur on a special type of cloud, called a polar stratospheric cloud, which only forms inside the polar vortex when temperatures are very cold. HF is a tracer species. It has a similar profile to HCl in the stratosphere, but does not react chemically. Thus changes in the HF total column amounts reflect dynamical changes. In Figure 3 b), we see low values of HF when Eureka is outside the vortex, and higher values (a result of descent) inside it. This is confirmed by looking at potential vorticity maps which show the location of the polar vortex (determined for the mid-stratosphere). Examples of these maps are shown in Figure 2 for days 63 (in), 66 (out), 75 (in) and 86 (out). Stars show the location of PEARL. The HCl total columns (a) also reflect the vortex movement; however the column amounts decrease inside the vortex, suggesting conversion to active forms has taken place. This is confirmed by looking at the HCl/HF ratio. If no conversion had taken place, this ratio would be roughly constant inside or outside the polar vortex. Plot c) shows the total column amounts of O_3 . Like HCl and HF, dynamical changes dominate the shape of the O_3 time series, but again we see evidence of depletion having occurred inside the polar vortex. This is consistent with our understanding of ozone depletion, whereby the reactive chlorine species are broken up by the returning sunlight into Cl- molecules which can catalytically destroy ozone. For all three gases, scatter in the dataset on a given day may be explained by the different air masses being sampled as the Sun moves through the sky.

In conclusion, the new Bruker-IFS 125HR at PEARL is providing high-quality atmospheric trace gas measurements that can be used for studying the Arctic atmosphere, both on their own or in conjunction with models and satellite measurements. Measurements from the 2007 Canadian Arctic ACE validation campaign show chlorine activation to have occurred within the polar vortex, leading to ozone depletion. Further work will expand the spring measurements to include other species, as well as building a long-term time series of this data throughout the year.

References:

- 1) Pougatchev, N. S., B. J. Connor, and C. P. Rinsland (1995), Infrared measurements of the ozone vertical distribution above Kitt Peak, *J. Geophys. Res.*, 100(D8), 16,689–16,698.
- 2) Bernath, P. F., et al. (2005), Atmospheric Chemistry Experiment (ACE): Mission overview, *Geophys. Res. Lett.*, 32, L15S01, doi:10.1029/2005GL022386.

