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Atmospheric
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Discussions

Interactive comment on "Simultaneous atmospheric measurements using two Fourier transforminfrared spectrometers at the Polar Environment Atmospheric ResearchLaboratory during spring 2006, and comparisons with the AtmosphericChemistry Experiment-Fourier Transform Spectrometer" *by* D. Fu et al.

D. Fu et al.

kwalker@atmosp.physics.utoronto.ca

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Thank you to Dr. Hase for the thorough and detailed list of comments for improvements to our paper. We were able to address all points made by Dr. Hase in his referee's report and believe that we were able to improve the paper. In the following response, we present the original comments in italics and our responses below.

General comments:

The paper deals with partial column measurements of stratospheric trace species. It is very readable and well structured. The applied methodologies are properly described and the results are generated in a competent manner from the available observational material. I support to publish the paper in ACP. However, I suggest to clarify and strengthen the focus of the work.

Specific comments:

The paper presents a collection of several subtopics:

∗ *A side-by-side intercomparison of two ground-based FTIR spectrometers within the 2006 Canadian Arctic ACE validation campaign held in Eureka is presented, addressing several stratospheric trace species.*

∗ *Next, the measurements are exploited for the validation of ACE-FTS ver. 2.2 data.*

∗ *Finally, the trace-gas evolution during the campaign is discussed.*

A somewhat weak point of the paper is that a clearly defined focus is not apparent: In the introduction it is said "..., it is nessessary to understand the difference between ground-based instruments that are used in satellite validation studies and this is the focus of this paper." According to the title, the validation of the ACE-FTS seems to be of equal importance. Judging from the length of Sections 5.1 and 5.2 the first two topics listed above seem to be of about equal importance, the third topic (Section 5.3) proves to be a supplement of lower importance.

In my feeling, the intercomparison of the two ground-based instruments is not the main focus of the paper, it is more an - however important and valuable - prerequisite for the ACE-FTS validation. The excellent level of agreement as documented in Table 3 strengthens our confidence that both instruments are well maintained and that the applied analysis procedures work properly (giving compatible answers for instruments which differ considerably in spectral resolution). However, if the understanding of the difference between ground-based instruments is intended to be the main focus of the paper, then the reader should expect an even deeper investigation of the remaining discrepancies, beyond their quantification and a plot of the total column sensitivities.

Such an investigation should quantify the effects of expected atmospheric variability, individual instrumental error budgets, statistical confidence limits of the ensemble, etc. With respect to Section 5.3: I'm not sure whether the paper gains much out of this discussion (if we regard it as an instrument intercomarison and / or ACE-FTS validation paper). Concerning the arctic chemical vortex evolution in 2006, the authors refer to MLS and ACE-FTS observations as well as SLIMCAT-model studies. Do the ground-based observations presented here add new aspects to these probably more comprehensive investigations? Although a description of the dynamical and chemical vortex evolution during the campaign period is fully appropriate in the context of validation, it might be sufficient to present this in a more concise manner before the results of the validation are discussed. If the authors wish to treat the topic of chemical evolution in its own right, Section 5.3 should be extended and model results should be included.

The introduction to the paper has been rewritten to provide a better focus on the purpose of the paper and its relation to the other validation papers in this special issue. We have chosen to keep the discussion of the chemical evolution during spring

2006 as a comparison of the consistency of results between the three FTSs. The new version of the introduction is given below.

"As part of the validation program for the Atmospheric Chemistry Experiment (ACE), a series of springtime measurement campaigns have been held in Eureka in northern Nunavut (Kerzenmacher et al., 2005; Walker et al., 2005; Manney et al., 2008; Sung et al., 2007; Fraser et al., 2007). The primary objective of these campaigns is to provide a multi-year, high-latitude data set for validating satellite data obtained under the perturbed conditions present in the springtime Arctic stratosphere.

ACE, also known as SCISAT, is a Canadian-led satellite mission for remote sensing of the Earth's atmosphere from a circular, low Earth orbit (altitude 650 km, inclination 74°). This high inclination orbit provides global measurements over each season with a primary focus on the Arctic and Antarctic regions. An infrared Fourier transform spectrometer (ACE-FTS; Bernath et al., 2005) together with a dual, ultraviolet(UV)-visible-near-infrared spectrophotometer (Measurement of Aerosol Extinction in the Stratosphere and Troposphere Retrieved by Occultation (ACE-MAESTRO); McElroy et al., 2007) are the scientific instruments onboard the satellite. The primary goal of the ACE mission is understanding the chemistry and dynamics of ozone in the upper troposphere and stratosphere. Thus SCISAT measures the concentrations of more than 30 chemical constituents, including many that influence the distribution of stratospheric ozone (Bernath et al., 2005; Bernath, 2006).

Validating data products from satellite-borne infrared FTSs, such as ACE-FTS, can be challenging because of the wide range of atmospheric species that are measured. Ground-based FTSs, such as those that are part of the Network for the Detection of Atmospheric Composition Change (NDACC, http://www.ndsc.ncep.noaa.gov/), can contribute significantly to these efforts because they cover a similar spectral range with high spectral resolution (e.g., Vigouroux et al., 2007; Cortesi et al., 2007; Wetzel et al., 2007). Some information on the altitude distribution of the atmospheric trace gases can be retrieved from the shapes of the spectral lines obtained from these ground-based FTSs (e.g., Pougatchev et al., 1995; Rinsland et al., 1998). This allows partial column[1] densities to be calculated from the ground-based measurements and it is these quantities that are compared with partial columns derived from the satellite observations.

As reported in other papers in this Special Issue, measurements from ground-based FTSs at 12 NDACC stations around the world have been employed in the ACE validation program (e.g. Clerbaux et al., 2008; De Mazière et al., 2008; Dupuy et al., 2009; Kerzenmacher et al., 2008; Mahieu et al., 2008; Strong et al., 2008; Wolff et al., 2008). This paper presents complementary work focusing on comparisons of ground- and satellite-based FTSs during Arctic springtime and on results for trace gas species that play an important role in ozone depletion processes that occur each spring in the polar vortex, including O_3, the chlorine and nitrogen reservoir species (HCl, $ClONO_2$ and HNO_3), NO_x (NO and NO_2), and a stratospheric tracer (HF) (e.g. Solomon, 1999).

The 2006 Canadian Arctic ACE Validation campaign was the third in this series of campaigns. It took place at the Polar Environment Atmospheric Research Laboratory (PEARL, 80.05° N, 86.42° W, 610 m above sea level) in Eureka, Nunavut, Canada, from 17 February to 31 March 2006. PEARL is located in a region of large stratospheric variability in the Arctic (Harvey and Hitchman, 1996), where there is a higher probability of making measurements both inside and outside the polar vortex. Ten scientific instruments were used during the campaign. These included PARIS-IR (Portable Atmospheric Research Interferometric Spectrometer for the Infrared, a terrestrial version of the ACE-FTS) (Fu et al., 2007), a high-resolution Bomem DA8 FTS that is part of NDACC (Donovan et al., 1997; Wiacek et al, 2006; Farahani et al., 2007), and balloon-borne ozonesondes (Davies et al., 2000; Tarasick et al., 2005). These instruments were used to derive total columns, partial columns, and vertical profiles for most of the ACE target species, as well as temperature and pressure.

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[1] Throughout this paper, the term “total column” is used to indicate that the column amount was calculated from the full altitude range of the ground-based measurement (typically from the ground to 100 km) whereas the term “partial column” is used for results obtained over a narrower altitude range. Depending on the type of ground-based measurement, the total column retrieved may be more sensitive to one region of the atmosphere than another (for example, NO_2 retrievals from FTSs are only sensitive to the stratospheric part of the total column; Sussmann et al., 2005).

Herein, we describe the 2006 campaign observations made by PARIS-IR and the Environment Canada (EC) DA8 FTS and discuss comparisons both between the ground-based instruments and with the ACE-FTS results. To compare the ground-based and satellite results, this work first investigates the differences between the retrieved columns obtained by PARIS-IR, which is a relatively “new” campaign instrument, and the DA8 FTS, which is a permanently installed instrument and has been making long term observations at PEARL since 1993. To focus on the differences in the vertical columns that arise from the instrument performance, PARIS-IR and the DA8 FTS were configured to measure atmospheric absorption spectra simultaneously. Details on the two ground-based FTSs and their observation strategies are illustrated in Sect. 2. The ground-based FTS retrieval method and measurement characterization are described in Sect. 3. The ACE-FTS measurements and retrievals are described in Sect. 4. In Sect. 5, total columns, partial columns and column ratios obtained from simultaneous atmospheric remote sensing measurements using PARIS-IR and the DA8 FTS at Eureka are reported. The results are used to compare measurements from PARIS-IR and the DA8 FTS, to investigate the quality of ACE occultation measurements, and to examine the consistency of the time evolution of the chemical constituents in the atmosphere over the Canadian high Arctic during spring 2006 obtained from these different data sets. ”

Technical corrections:

Given the limited number of measurements, it is probably generally sufficient to specify percentage differences to one decimal place in the text.

This has been changed in Tables 3 and 5 in the revised manuscript.

Page 5314: Are you sure about the cell pressure? 14.7 hPa is quite high. I expect that the resulting linewidth will compromise the ILS inversion at least in case of the DA8.

Indeed, 14.7 hPa is a typo. The data log for PARIS-IR shows that the cell pressure was 5.6 Torr, that is, 7.5 hPa when the cell was filled with N_2O gas. This line has been corrected in the text.

“These spectra were measured using a blackbody source and a 10-cm-long, 5.0-cm-diameter cell that was filled with 7.5 hPa of N_2O.”

Page 5318: In ground-based solar absorption geometry, there is no tangent point.

The tangent point was referred to the observations made by ACE-FTS. The following is the revised version of this sentence in the text.

“The point at which the observation slant path intersects with the atmospheric layer where the measurement is most sensitive can be located up to several hundred km away from the observatory.”

Page 5328: When ground-based and ACE-FTS NO2 and NO measurements are discussed, is a box model correction included as has been exercised in Kerzenmacher et al?

For consistency with the study of Kerzenmacher et al. [2008], the box model correction has been added for the NO and NO_2 comparisons. The discussion has

been updated and the table results emended.

Interactive comment on Atmos. Chem. Phys. Discuss., 8, 5305, 2008.