Development of a Climatological Data Set from the Atmospheric Chemistry Experiment for Validating Atmospheric Model Simulations

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Introduction

A new climatological data set is being developed using recent satellite-based trace gas measurements. Building on the climatologies that have been developed from data from the Upper Atmosphere Research Satellite (e.g. Grooß and Russell, 2005), the goal for this project is to provide a new comparison data set that will extend the range of species available for model evaluation and assessment. Atmospheric profiles from the first five years (2004-2008) of the Atmospheric Chemistry Experiment (ACE) satellite mission will be the basis of this data set. The new climatological data set will be made available for use in assessing, validating, and refining atmospheric models such as coupled chemistry-climate models.

ACE Satellite and ACE-FTS Instrument

The Atmospheric Chemistry Experiment (ACE), also known as SCISAT-1, is a Canadian scientific satellite mission to perform remote sensing measurements of the Earth's atmosphere (Bernath et al., 2005). The satellite was successfully launched into low Earth orbit on 12 August 2003. The 650 km altitude, 74 degree circular orbit provides the mission with global coverage though the focus is on the Arctic and Antarctic regions. Routine satellite operations began in February 2004. Over the past 55 months, ACE has made more than 15,000 occultation measurements.

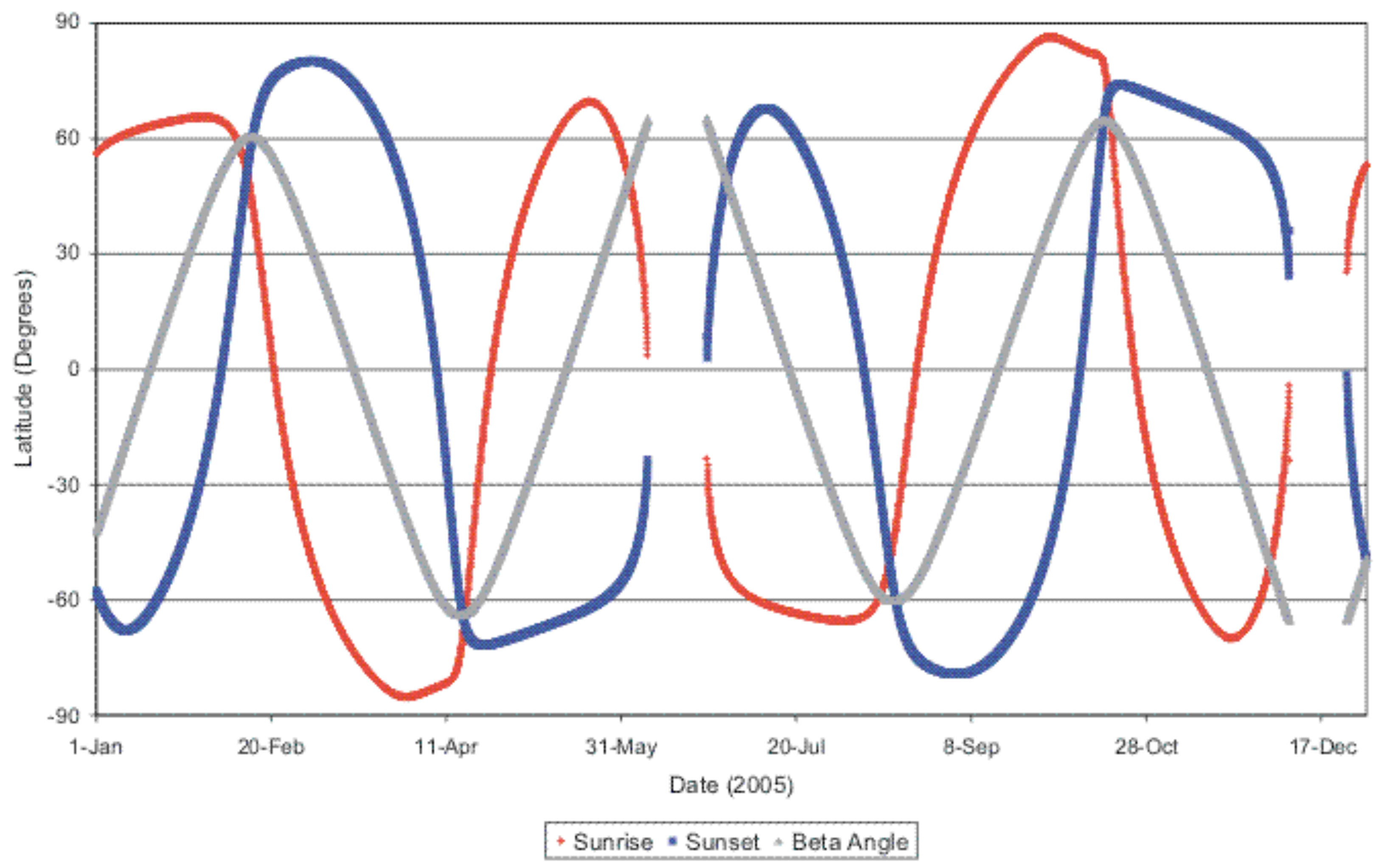

Figure 1. Diagram showing latitudes of ACE occultation measurements throughout one year. Beta is the angle between the orbit track of the satellite and the Earth-Sun vector. The greater the absolute value of this angle, the longer the measurement. ACE measurements are labeled using the latitude and longitude of the 30 km tangent point in the occultation (calculated geometrically).

The primary instrument on-board SCISAT-1 is a high-resolution (0.02 cm^{-1}) Fourier Transform Spectrometer (FTS) operating between 750 and 4400 cm^{-1}. A passive cooler, radiating to deep space, is used to cool the ACE-FTS detectors. Typical operating temperatures are lower than 90 K. Two filtered imagers measure atmospheric extinction at 0.525 and 1.02 microns. The ACE-FTS was built by ABB-Bomem of Quebec City and the imagers were provided by the Belgian government. A feedback controlled sun tracking mirror is used to keep the instrument pointed at the Sun centre during each measurement. The primary measurement method for the ACE-FTS is solar occultation. During each sunrise or sunset seen by the satellite, the instrument measures a series of spectra at different ray paths through the atmosphere. These measurements are "self calibrating". Atmospheric transmittance spectra are calculated using exo-atmospheric solar spectra as the reference thereby removing solar and instrumental features present in the single beam spectra.

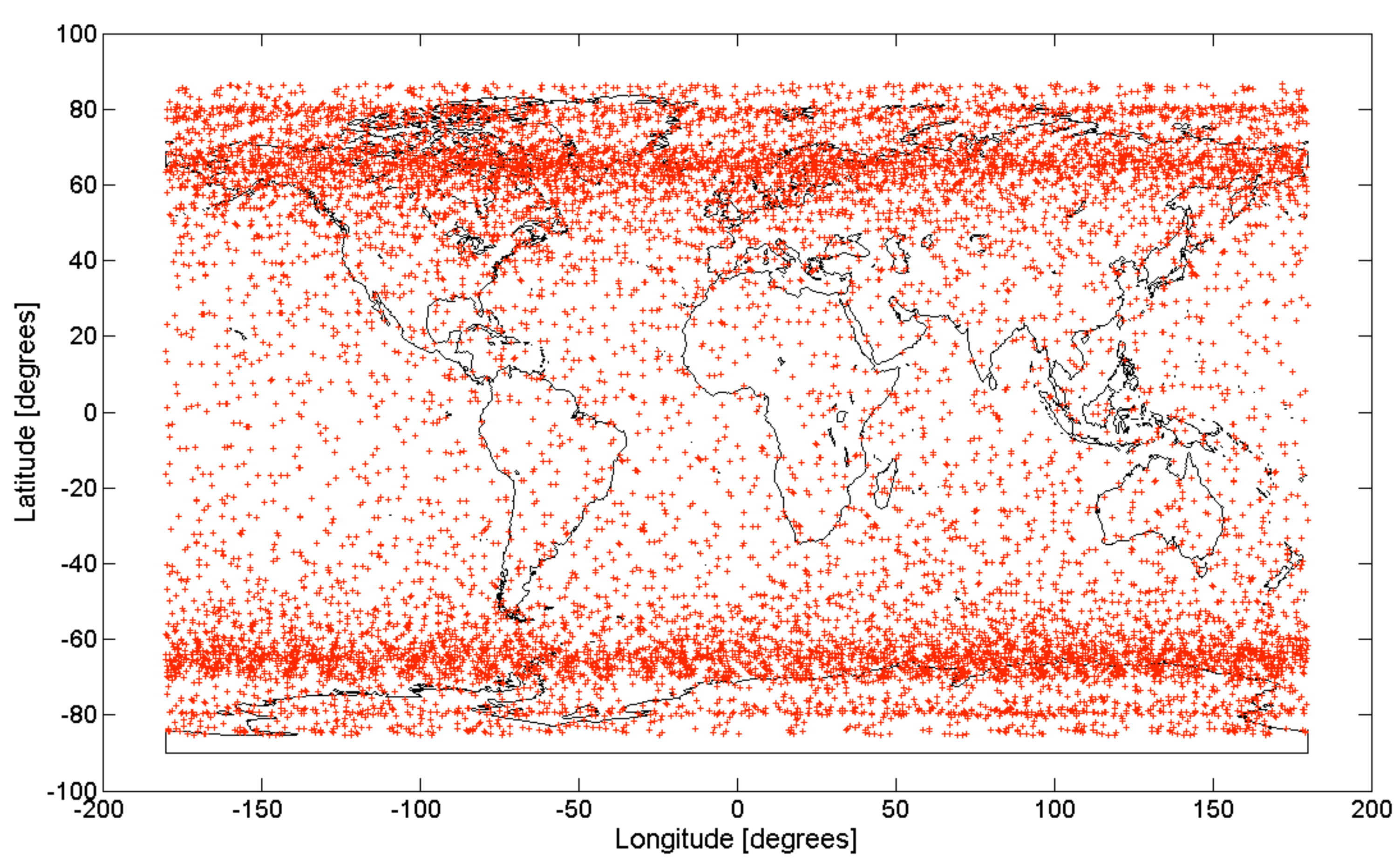

Figure 2. Map showing distribution of all ACE occultations that will be used for this data set (taken between February 2004 and December 2007). The high inclination of the SCISAT-1 orbit (74 degrees) provides the highest number of ACE measurements over the Arctic and Antarctic regions

ACE-FTS Data Products

The transmittance spectra from the sunrise and sunset measurements are used to determine atmospheric profiles of trace gases, temperature, pressure and atmospheric extinction. Atmospheric information is retrieved from the spectra using a two step process (Boone et al., 2005). First, the CO_2 features are used to retrieve the pressure and temperature profile for each occultation. Then the temperature profile is held fixed and volume mixing ratio profiles for the trace gas species are retrieved. The line parameters and cross sections from the HITRAN 2004 spectroscopic database are used for the processing of the ACE-FTS data. The current version of the ACE-FTS retrievals is version 2.2 with updates for O_3, N_2O_5, and HDO. ACE-FTS measures down to 5 km (in the absence of significant clouds). Profiles of almost 30 different species are available (including the baseline species: O_3, H_2O, CH_4, N_2O, NO, NO_2, HNO_3, $ClONO_2$, N_2O_5, HCl, HF, CFC-11, CFC-12, CO as well as COF_2, CHF_2Cl, HDO, SF_6, HCN, CH_3Cl, CF_4, C_2H_2, C_2H_6, ClO, HO_2NO_2, H_2O_2, HOCl). Validation results for the ACE-FTS baseline species have been published recently in a special issue of *Atmos. Chem. Phys.*, "Validation Results for the Atmospheric Chemistry Experiment (ACE)".

Preparation of Climatological Data Set

Multi-year averages of zonal mean volume mixing ratio (VMR) profiles for individual trace gas species will be created from the ACE data set (2004-2008). To facilitate use in model comparisons, the ACE-FTS profiles, which are retrieved on an altitude grid, will be mapped on to a standard pressure grid using the pressures retrieved from the ACE measurements. Since ACE obtains a significant portion of its measurements at high latitudes, averages will be made over ranges of equivalent latitude (of the order of 5-10°) in order to take account of the location of the polar vortex appropriately.

To obtain global coverage from 85 °N to 85 °S for the ACE climatology, a seasonal average will be required. This is because the SCISAT-1 satellite orbit repeats and, therefore, the latitudes sampled by ACE do not change from year-to-year. Since this may not be appropriate for all comparisons, investigations are being conducted to determine the best period over which to average the ACE results.

For this new climatological data set, the focus will be on expanding the range of species available for model comparisons and other studies. It will include additional chlorine-containing species (reservoir species: $ClONO_2$, source gases CFC-11 and CFC-12 and active species, ClO) and increasing the number of nitrogen-containing species to include HNO_3 and N_2O_5. This can provide further information about how species are partitioned within families.

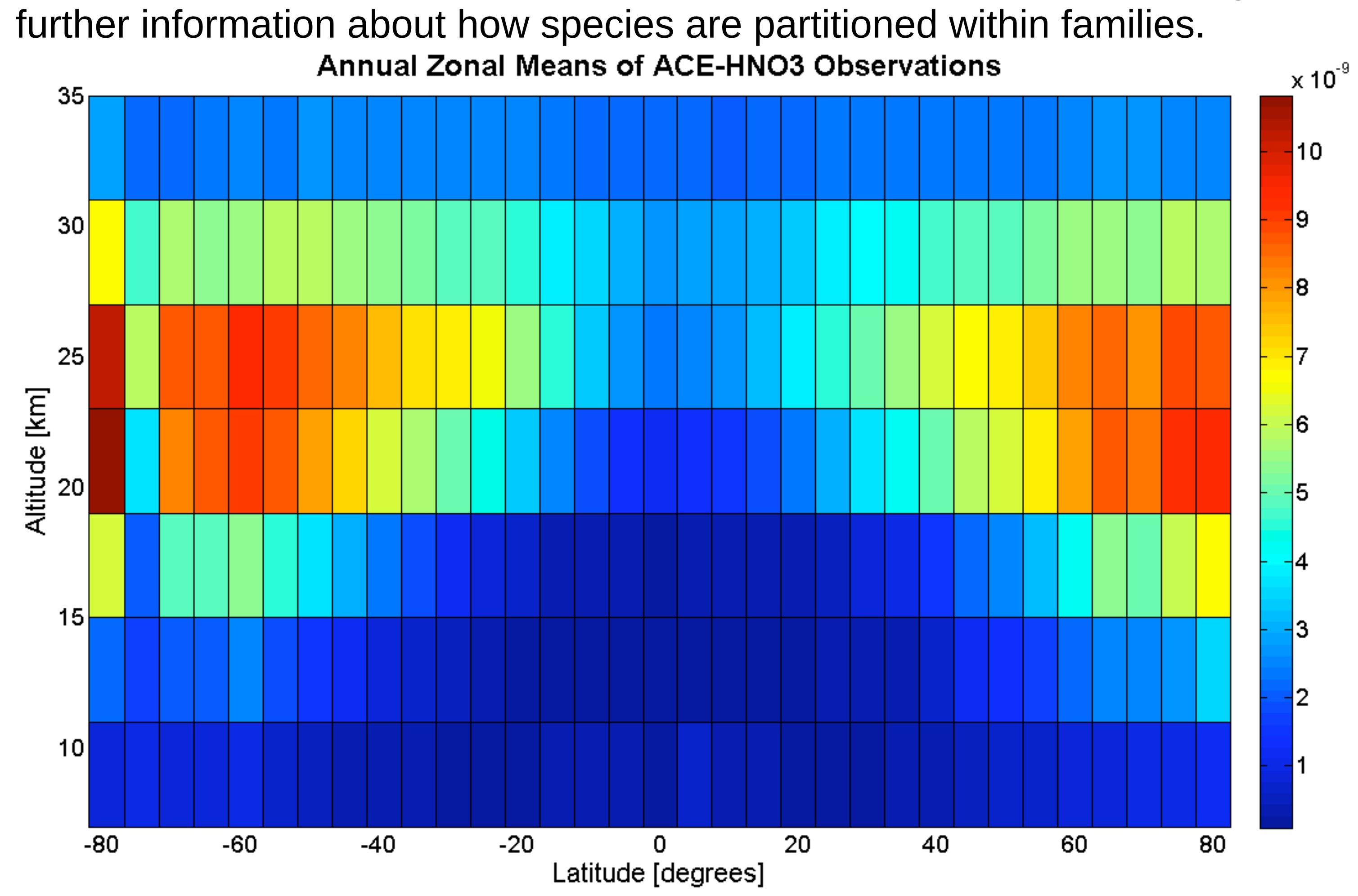

Figure 3. Preliminary zonal mean profiles of HNO_3 from February 2004 to December 2007. The zonal mean volume mixing ratio (VMR) values (in ppv) were calculated over the globe in 5° latitude bins on a 4 km altitude grid (vertical resolution based on field-of-view of the ACE-FTS). Variability of the zonal mean profiles will be investigated using the standard deviations of the mean VMR profiles.

Interested in the ACE Data Set?

Contact Kaley Walker (kwalker@atmosp.physics.utoronto.ca) if you are interested in using this data set or the ACE data products.

References

Bernath, P. F., *et al.*, Atmospheric Chemistry Experiment (ACE): Mission Overview, *Geophys. Res.Lett.* **32**, L15S01, doi:10.1029/2005GL022386, 2005.
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Grooß, J.-U. and James M. Russell III, Technical note: A stratospheric climatology for O3, H2O, CH4, NOx, HCl and HF derived from HALOE measurements, *Atmos. Chem. Phys.*, **5**, 2797–2807, 2005.

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