Measuring ozone and related species from space with The Atmospheric Chemistry Experiment (ACE)

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Atmospheric Chemistry Experiment (ACE) Satellite Mission:
Mission to measure atmospheric composition: profiles of trace gas species, cloud and aerosol extinction and temperature/pressure

Launch date: 12 August 2003
Orbit: 74° inclination at 650 km
Measurement mode: solar occultation

ACE-FTS:
- FTIR spectrometer, 2-13 microns at 0.02 cm⁻¹ resolution
- 2-channel visible/NIR imager, 0.525 and 1.02 microns

MAESTRO:
- dual UV / visible / NIR grating spectrophotometer, 285 to 1030 nm at ~1-2 nm resolution

Pointing: suntracker in ACE-FTS
ACE Mission Status

- Now starting 14th year in orbit – designed for 2 year lifetime
  - Starting to see some degradation in ACE-FTS performance and MAESTRO continues to “age gracefully”

- Since launch, satellite and instrument operations nominal
  - Routine operations began on 21 February 2004
  - As of today, SCISAT has completed more than 70,400 orbits!
  - ~50% of occultations occur in polar regions (> 60 degrees)

- Operation of SCISAT has been approved until end of March 2018

- Catching up on data processing for ACE-FTS v3.5 with transition to shared high performance system (also MAESTRO v3.12.1)
  - Next release of data expected by late 2016
ACE Data Products

• ACE-FTS profiles (current version 3.5; previous v2.2+updates):
  – Tracers: H$_2$O, O$_3$, N$_2$O, NO, NO$_2$, HNO$_3$, N$_2$O$_5$, H$_2$O$_2$, HO$_2$NO$_2$, N$_2$
  – Halogen-containing gases: HCl, HF, ClONO$_2$, CFC-11, CFC-12, CFC-113, COF$_2$, COCl$_2$, COFCl, CF$_4$, SF$_6$, CH$_3$Cl, CCl$_4$, HCFC-22, HCFC-141b, HCFC-142b
  – Carbon-containing gases: CO, CH$_4$, CH$_3$OH, H$_2$CO, HCOOH, C$_2$H$_2$, C$_2$H$_6$, OCS, HCN and pressure / temperature from CO$_2$ lines
  – Isotopologues: Minor species of H$_2$O, CO$_2$, O$_3$, N$_2$O, CO, CH$_4$, OCS
  – Research species: CH$_3$CN, acetone, SO$_2$, peroxyacetyl nitrate (PAN)…

• MAESTRO profiles (current version 3.12.1; validated version 1.2):
  – O$_3$, NO$_2$, optical depth, aerosol and water vapor (research version)

• IMAGERS profiles (current version 3.5; validated version 2.2):
  – Atmospheric extinction & aerosol extinction at 0.5 and 1.02 microns
Perturb different variables by their expected uncertainty and propagating through retrieval

**Measurement error**
Inverse instrument signal-to-noise ratio at each wavenumber
- Typically on the order of 1-5%, greater at upper altitude limits where lower signal.
  Typically less than v3.5 stat. fitting error

**Spectroscopic error**
Line strength and position uncertainty from HITRAN 2004
- Typically on the order of 1-5% in stratosphere, 5-20% in upper troposphere.
  Typically less than v3.5 fitting error

**Tangent height error**
Assumed max of ±0.5 km (extreme value!)
- Typically results in VMR variation ~10-20%

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**FTS Error Budget Development**

**2σ propagated error (in %) for v3.5 for O₃**

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N₂O surface sources are ocean and soil emissions, agriculture, biomass burning / fossil fuel combustion.

Sinks are photolysis and reaction with O(^1D).

Clear lower thermospheric N₂O source first shown by ACE-FTS.
- Previous highest observations from MIPAS only went up to ~70 km.
- This is present throughout the year – produced via energetic particle precipitation generating excited state N₂ (A³Σ_u⁺).

P. E. Sheese et al., GRL, 43, 2866–2872 (2016).
ACE-FTS upper atmosphere N₂O

Arctic (60-90 N) January to March time series – using 7-day running mean (in ppbv)
- **Top/middle** – N₂O VMRs / standard error of mean
- Shows descent of N₂O during/ following SSWs – destroys ozone through NOx cycle
- **Lower** – correlation coefficients for N₂O-CH₄ measured simultaneously
- Need to exercise caution when using N₂O as dynamical tracer in polar winter stratosphere

Ozone Loss Derived from ACE-FTS

- Comparison of calculation methods using tracer-tracer correlation, artificial tracer correlation, average vortex profile descent, and passive subtraction with model output (ATLAS & SLIMCAT)

Artificial tracers shown:
- Tracer 1: \( \text{N}_2\text{O}, \text{CH}_4, \text{CFC-11}, \) and \( \text{CFC-12} \) (from Esler & Waugh 2002)
- Tracer 4: \( \text{N}_2\text{O}, \text{CH}_4, \text{OCS}, \) and \( \text{CFC-11} \) (from Jin et al., 2006)

Integrated loss between 380-550K

D. Griffin et al., in preparation.
Ozone Loss Derived from ACE-FTS

- Generally good agreement between methods
  - Average profile descent shows smaller losses and passive subtraction showing slightly larger losses

D. Griffin et al., in preparation.
ACE-FTS v3.5 Climatology

• Building on Jones et al., ACP (2011) and recent work done for SPARC Data Initiative
• Using quality filtered ACE-FTS v3.5 profiles from Feb. 2004 – Feb. 2013 (was 2004-2009)
• \(\text{O}_3, \text{H}_2\text{O}, \text{CH}_4, \text{N}_2\text{O}, \text{CO}, \text{NO}, \text{NO}_2, \text{N}_2\text{O}_5, \text{HNO}_3, \text{HCl}, \text{HF}, \text{ClO}_2, \text{O}_3\), and CFC-11 and CFC-12
  – Added \(\text{C}_2\text{H}_6, \text{C}_2\text{H}_2, \text{HCN}, \text{OCS, HCOOH, CH}_3\text{OH, H}_2\text{CO}\)
  – 45 levels up to 0.0001 hPa as data available (was 0.1 hPa)

J.-H. Koo et al., JQSRT (accepted July 2016).
Summary

- ACE Instruments and satellite are continuing to function nominally and produce excellent results
- Data being used for scientific and validation studies
  - Reprints available from [http://www.ace.uwaterloo.ca](http://www.ace.uwaterloo.ca)
  - Climatological datasets and atlases available from website
  - Contact kaley.walker@utoronto.ca for data access!

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