Update on ACE: Mission Status and Recent Validation Results

Kaley A. Walker¹, Patrick E. Sheese¹, Jiansheng Zou¹, Chris D. Boone²

¹Department of Physics, University of Toronto, Toronto, Canada
²Department of Chemistry, University of Waterloo, Waterloo, Canada

SAGE III/ISS Science Team Meeting – Online – 19 October 2020
SCISAT/ACE Mission Status

• Now into 18th year in orbit – designed for 2 year lifetime
  – Starting to see some degradation in ACE-FTS performance and ACE-MAESTRO continues to “age gracefully”

• Since launch, satellite and instrument operations nominal
  – Routine operations began on 21 February 2004
  – ~50% of occultations occur in polar regions (> 60 degrees)

• Operation of SCISAT has been approved until end of March 2021
  – Mission level review by CSA for 3-year extension is underway now
ACE Data Products

- **ACE-FTS profiles (new version 4.1; validated version 3.5/3.6; 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$_2$, SO$_2$
  - Halogen-containing gases: HCl, HF, ClONO$_2$, CFC-11, CFC-12, CFC-113, COF$_2$, COCl$_2$, COFCl, ClO, CF$_4$, SF$_6$, CH$_3$Cl, CCl$_4$, HCFC-22, HCFC-141b, HCFC-142b, HFC134a, HFC-23
  - Carbon-containing gases: CO, CH$_4$, CH$_3$OH, H$_2$CO, HCOOH, C$_2$H$_2$, C$_2$H$_4$, C$_2$H$_6$, OCS, HCN acetone, CH$_3$CN, peroxyacetyl nitrate (PAN), CO$_2$ (5-18 km and >60 km), pressure / temperature from CO$_2$ lines
  - Isotopologues: Minor species of H$_2$O, CO$_2$, O$_3$, N$_2$O CO, CH$_4$, OCS, NO$_2$, HNO$_3$

- **MAESTRO profiles (current version 3.13; validated version 1.2):**
  - O$_3$, NO$_2$, optical depth, aerosol and water vapor (v31)

- **IMAGERS profiles (current version 4.1; validated versions 3.5 and 2.2):**
  - Atmospheric extinction & aerosol extinction at 0.5 and 1.02 microns
Comparison of ACE-FTS v4.1 to other data sets

Methodology for difference calculations in satellite instrument comparison:

- ACE – INST for versions 3.6, 4.0, and 4.1 (used same occultations between versions)
- INST – One of suite of limb viewing remote sensing instruments used (UV, VIS, IR, MW)
  - Coincidence criteria used: ±5h, 500 km
  - All comparisons are global for plots shown
- Relative differences calculated with respect to mean of two measurements
- Mean and 1-σ of relative differences shown along with correlation coefficient

Selection of 74 species/isotopologues measured by ACE-FTS shown:

- O₃, NO₂, H₂O, T, HCl, and HNO₃ will be shown
- Looked at species measured by more than one other limb sounder
Note, these have not been scaled diurnally for comparison.
Version 4.1 data issues at high altitudes

- Issue in MLT polar summer, more so in NH (not seen for these in previous versions)
- CO has enhancements in lower thermosphere ~95-110 km
  - Similar issue also seen in H₂O and O₃ near 95 km
  - T has cold spikes around mesopause
- Related to using temperature sensitive CO₂ lines for this altitude region, become too weak at very low temperatures – will be fixed in v5.0
Validation comparisons for ACE-FTS v4.1

- Overall impression: biases have mostly improved over v4.0
  - The only region where v4.1 is significantly worse than both v3.6 and v4.0 is H$_2$O in upper stratosphere (but mesospheric H$_2$O greatly improved)
- Drifts seen in v3.5/3.6 are no longer present in v4
  - For trend analysis, ACE-FTS v4.1 should be used
Comparison of v4.1 ACE-FTS with ozonesondes

- Comparison of biases and linear trends in ozone
- Coincident pairs found for each station
- ±5 degree latitude range with wide longitude ranges
- Deseasonalized monthly means used for analysis
- Hilo example (19.7 N)
Comparison of v4.1 ACE-FTS with ozonesondes

- Comparison of biases and linear trends in ozone
- Coincident pairs found for each station
- ±5 degree latitude range with wide longitude ranges
- Deseasonalized monthly means used for analysis
- Hilo example (19.7 N)
Assessment of ACE-FTS uncertainty budget

• To support SPARC TUNER activity, uncertainty budget being done for ACE-FTS
  – Using v3.6 retrievals as development platform

• Selecting 100 random occultations from full ACE-FTS data set, re-retrieving profiles with perturbation of one of the uncertainty components
  – Uncertainty is the MAD of differences between standard and perturbed retrievals
  – The median of the differences would give estimate of bias
  – Sources considered include: FOV modelling, ILS modelling, altitude registration, measurement noise, temperature measurement noise, convergence tolerance, derivative recycling – spectroscopic uncertainty in progress
Total uncertainties (no spectroscopic uncertainty)

- Total uncertainty is calculated as the root sum square of the uncertainty components
- Total bias is sum of biases from the different bias components
- Dominated by FOV modelling uncertainty, then altitude registration uncertainty

NOTE: different scale for T
ClO improvements for v5.0

- It was originally anticipated that ClO results would only be good during enhanced polar spring conditions
- v4.1 results for background conditions seem viable (with sufficient averaging)
  - Here examples of pushing the retrievals higher to capture the secondary peak
- This new upper altitude limit to be used in v5.0 processing

Chris Boone
New molecule for v5.0 – HOCl

- HOCl a new molecule for ACE-FTS – very weak absorber
- Preliminary test results show a significant Hemispheric difference, with higher levels in the North.

Each profile is an average from 5-10 occultations (2019)
New HFC for v5.0 – HCF-32 - CH$_2$F$_2$

- Being used in refrigeration in some countries, will be controlled under Kigali Amendment
- Results are showing Hemispheric differences, as expected, and are varying strongly with time, which is expected for this molecule with a rapidly increasing concentration.
- New retrieval will be included in v5.0.
Summary

• New data version available for ACE-FTS (v4.1) since July 2020
  – Download from https://databace.scisat.ca/level2 (registration required)
  – Data quality flags are being produced separately doi:10.5683/SP2/BC4ATC
• Validation work continuing for ACE-FTS and ACE-MAESTRO
  – Version 4.1 shows improvement over v4.0 for ACE-FTS and drift has been improved in this version

Funding for ACE and this work provided by:
• Canadian Space Agency (CSA)
• Natural Sciences and Engineering Research Council of Canada

Thanks to:
• Peter Bernath and the SCISAT Science Operations Centre