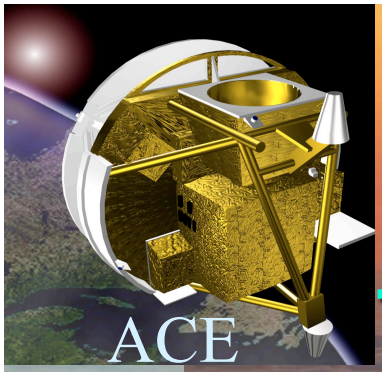

The Atmospheric Chemistry Experiment (ACE): Status and Latest Results

Chris Boone and Peter Bernath

5th Limb Conference and Workshop

November 16, 2009

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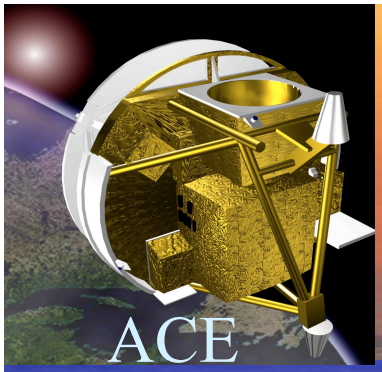

ACE Soldiering On

- ACE launched August 2003
- Science operations began February 2004
- Satellite and all instruments continue nominal operation.
- Version 3.0 of the data processing began in October 2009.
- Version 2.2 planned for public release.

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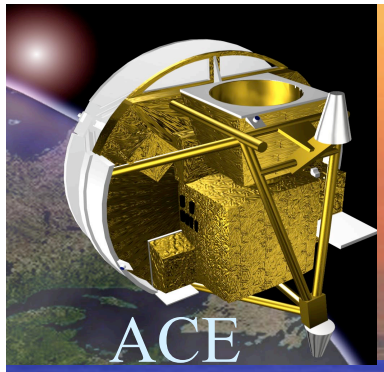

Instruments

- Infrared Fourier Transform Spectrometer operating between 2 and 13 microns with a resolution of 0.02 cm^{-1} (± 25 cm MPD)
- 2-channel visible/near infrared Imagers, operating at 0.525 and 1.02 microns
- UV / Visible spectrometer (MAESTRO) 0.285 to 1.03 microns, resolution ~1-2 nm
- Suntracker
- Startracker

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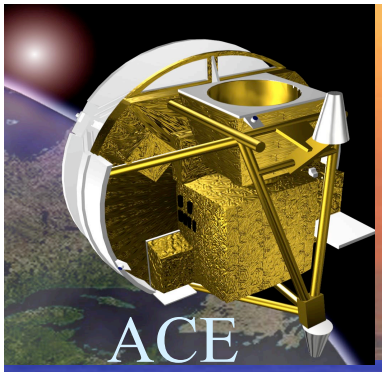

ACE-FTS (ABB-Bomem)

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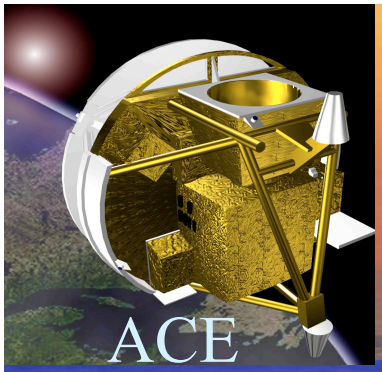
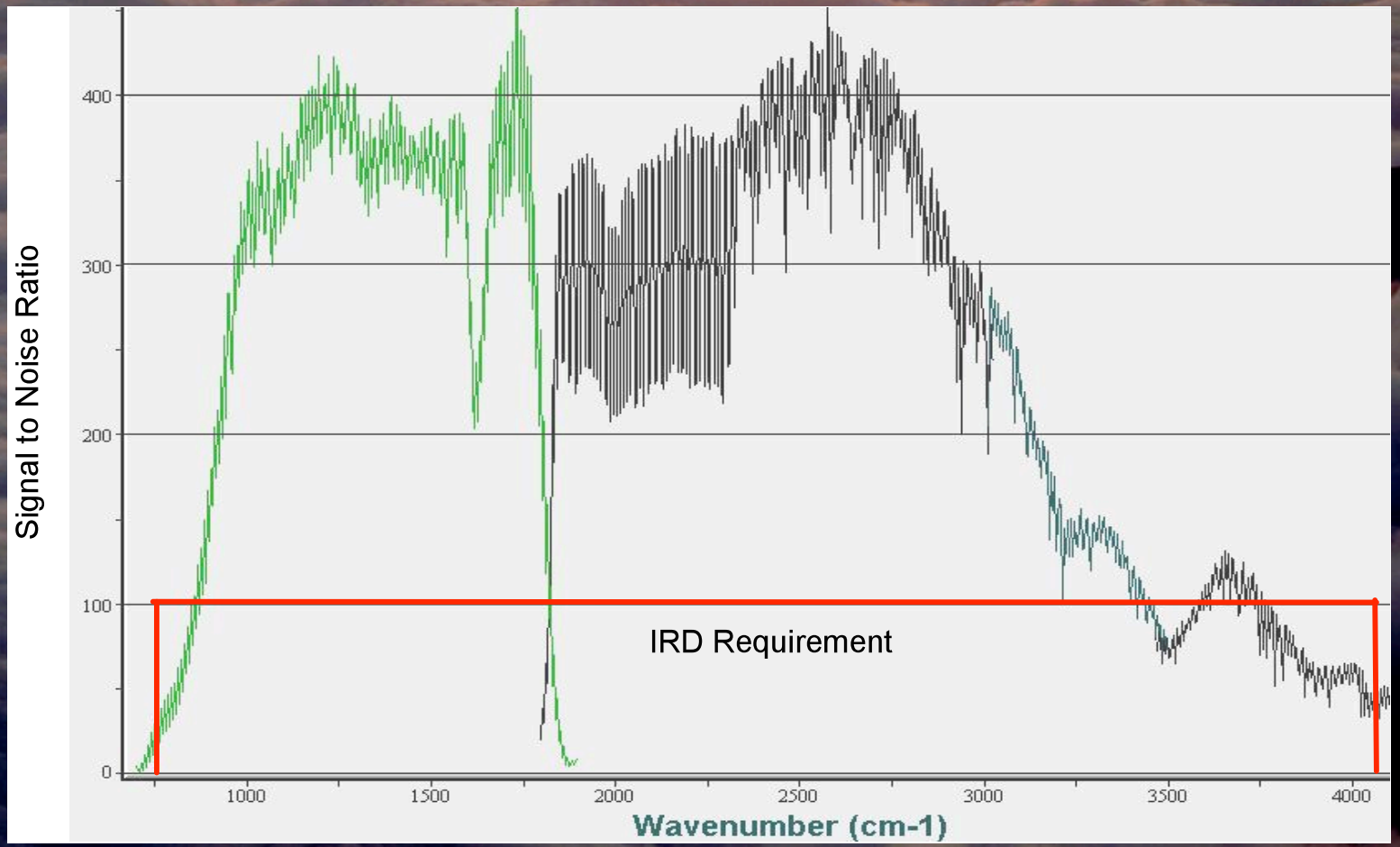


SNR



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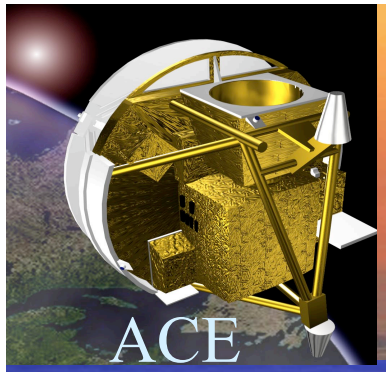

Molecules

- In ACE-FTS version 3.0 (37 molecules): CO_2, H_2O, O_3, N_2O, CO, CH_4, NO, NO_2, HNO_3, HF, HCl, $ClONO_2$, N_2O_5, CFC-11, CFC-12, OCS, HCN, CH_3Cl, CF_4, CCl_4, COF_2, C_2H_2, C_2H_6, CH_3OH, SF_6, HCOOH, HCFC-22, N_2, O_2, CFC-113, HCFC-141b, HCFC-142b, HNO_4, H_2O_2, H_2CO, $COCl_2$, COClF
- Future products?: HFC-134a, HFC-23, C_2H_4, SO_2, NH_3, PAN, acetone, propane, $BrONO_2$, …

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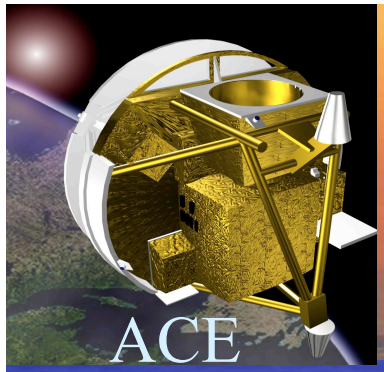

Isotopologues

- In ACE-FTS version 3.0 (23 subsidiary isotopologues): $H_2{}^{18}O$, $H_2{}^{17}O$, HDO, $^{13}CO_2$, $^{18}O^{12}C^{16}O$, $^{17}O^{12}C^{16}O$, $^{18}O^{13}C^{16}O$, $^{18}O^{16}O^{16}O$, $^{16}O^{18}O^{16}O$, $^{17}O^{16}O^{16}O$, $^{16}O^{17}O^{16}O$, $^{14}N^{15}N^{16}O$, $^{15}N^{14}N^{16}O$, $N_2{}^{18}O$, $N_2{}^{17}O$, $^{13}C^{16}O$, $^{12}C^{18}O$, $^{12}C^{17}O$, $^{13}CH_4$, CH_3D, $OC^{34}S$, $O^{13}CS$, $OC^{33}S$

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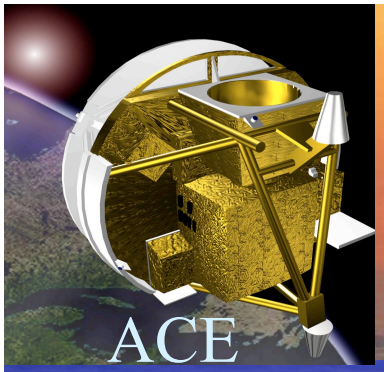
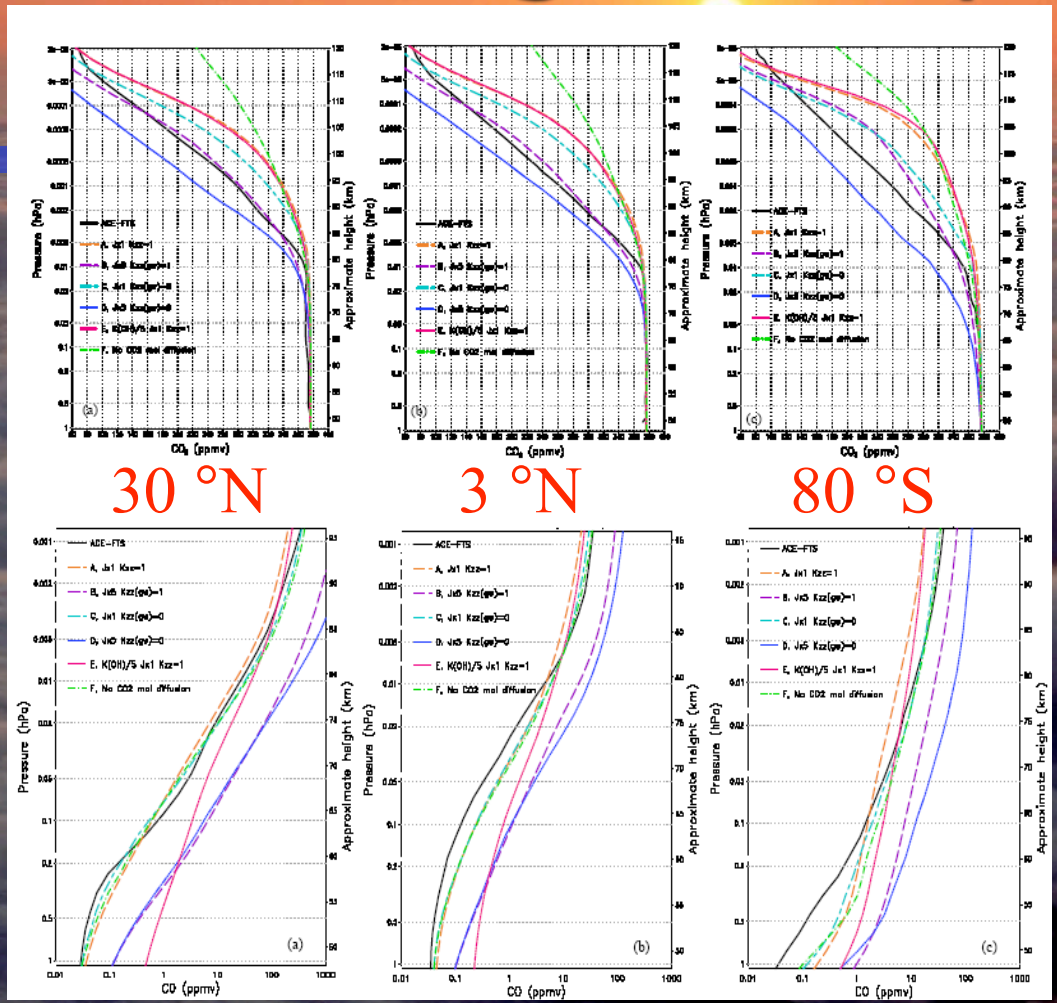


Modeling mesospheric CO_2



In the CMAM model, cannot reconcile CO_2 and CO.

Similar study underway using the WACCAM model.

First multi-year occultation observations of CO_2 in the MLT by ACE satellite: observations and analysis using the extended CMAM, S. R. Beagley, C. D. Boone, V. I. Fomichev, J. J. Jin, K. Semeniuk, J. C. McConnell, and P. F. Bernath, Atmos, Chem. Phys. Discussions, 9, 11551-11587 (2009).

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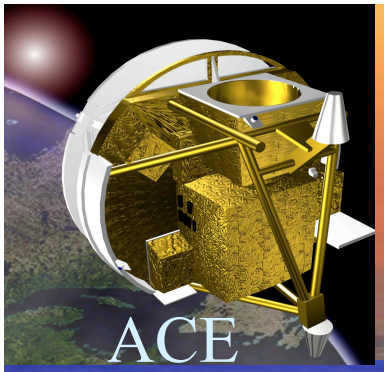
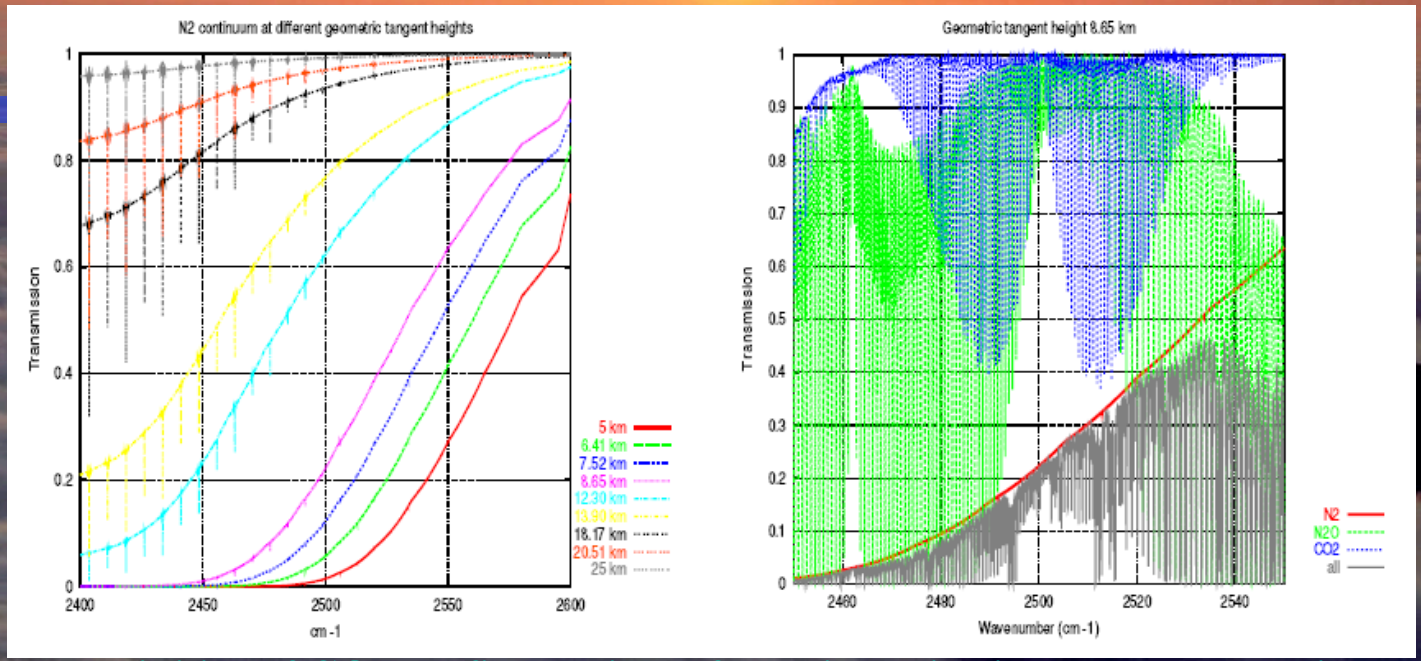


Retrieving UT/LS CO_2



Technical Note: Feasibility of CO_2 profile retrieval from limb viewing solar occultation made by the ACE-FTS instrument, P. Y. Foucher, A. Chedin, G. Dufour, V. Capelle, C. D. Boone, and P. Bernath, Atmos. Chem. Phys., 9, 2873-2890 (2009).

- Analysis of CO_2 spectral features used to determine ACE-FTS pressure, temperature, and tangent heights, with CO_2 VMR fixed to an assumed value.
- Retrieving CO_2 would be a circular problem
- Generate independent tangent heights using the N_2 continuum.

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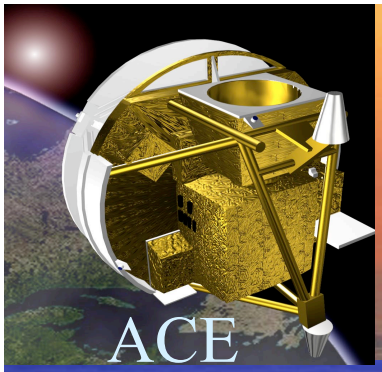
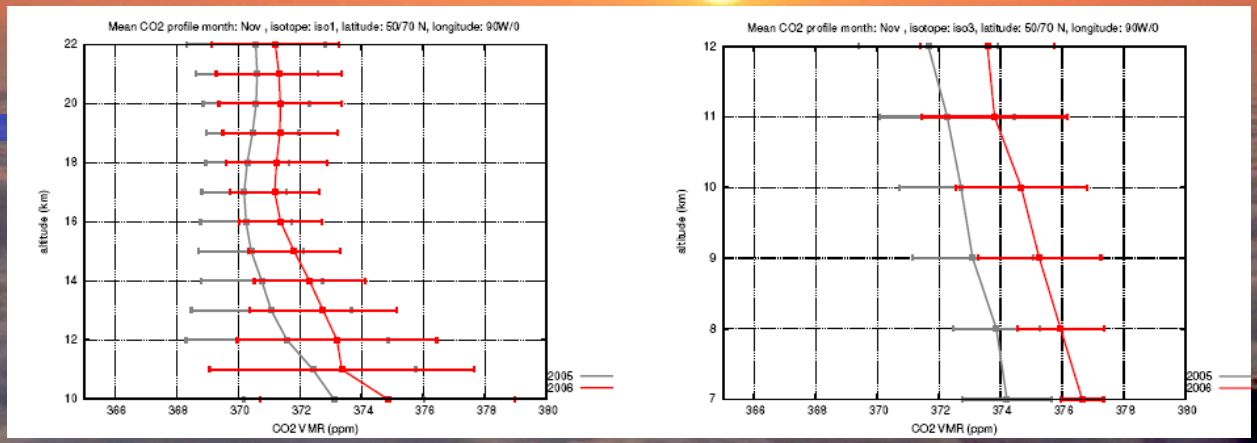
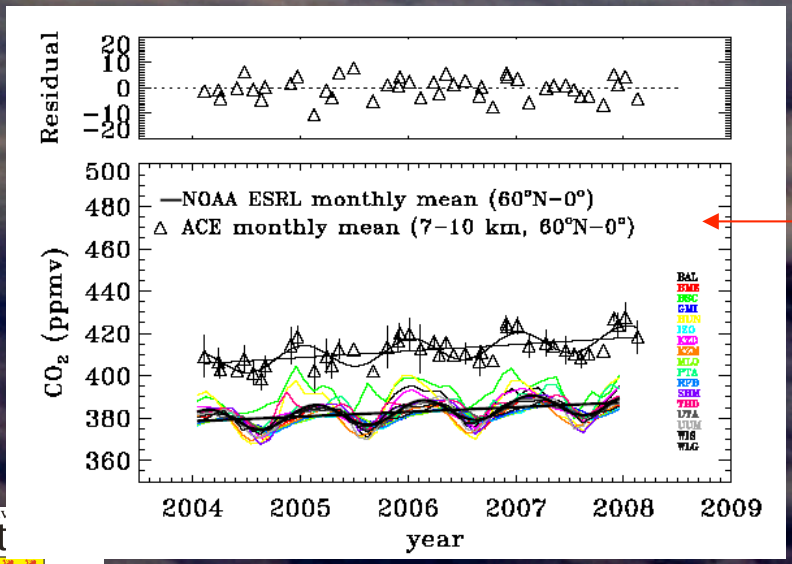


Two independent studies



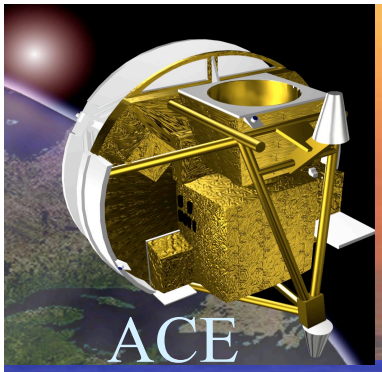
Technical Note: Feasibility of CO_2 profile retrieval from limb viewing solar occultation made by the ACE-FTS instrument, P. Y. Foucher, A. Chedin, G. Dufour, V. Capelle, C. D. Boone, and P. Bernath, Atmos. Chem. Phys., 9, 2873-2890 (2009).



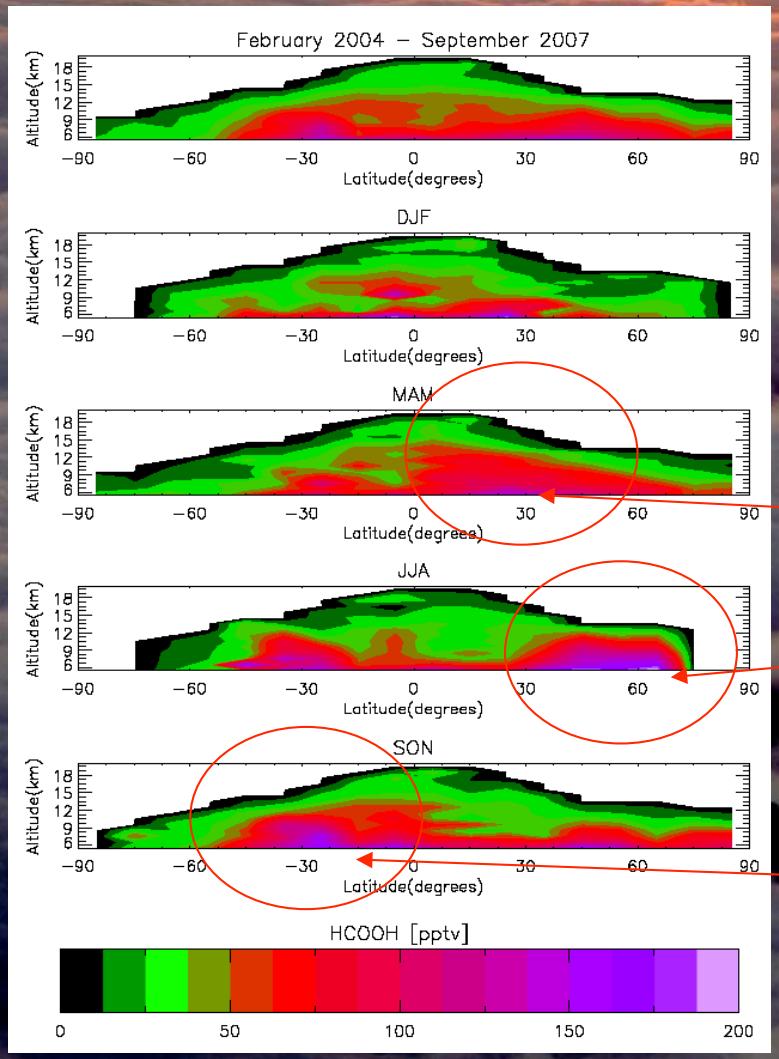
One study: CO2 isotopologue 1 above 10 km, $OC^{18}O$ below 12 km, scale latter results. Generate profiles.

Other study: only use $OC^{18}O$ lines and acknowledge expected offset. Generate average value for 7-10 km.

Carbon dioxide (CO_2) retrievals from Atmospheric Chemistry Experiment (ACE) solar occultation measurements, Curtis P. Rinsland, Linda Chiou, Chris Boone, and Peter Bernath, J. Geophys. Res., in press



HCOOH

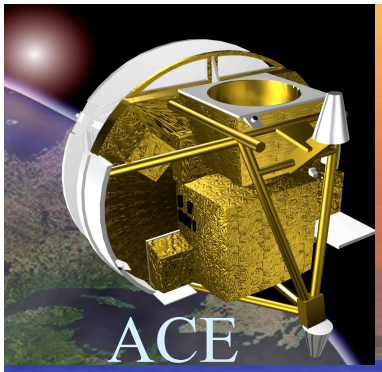


Global distribution of upper tropospheric formic acid from the ACE-FTS, G. Gonzalez Abad, P. F. Bernath, C. D. Boone, S. D. McLeod, G. L. Manney, and G. C. Toon, Atmos. Chem. Phys., 9, 8039-8047 (2009)

Growing season

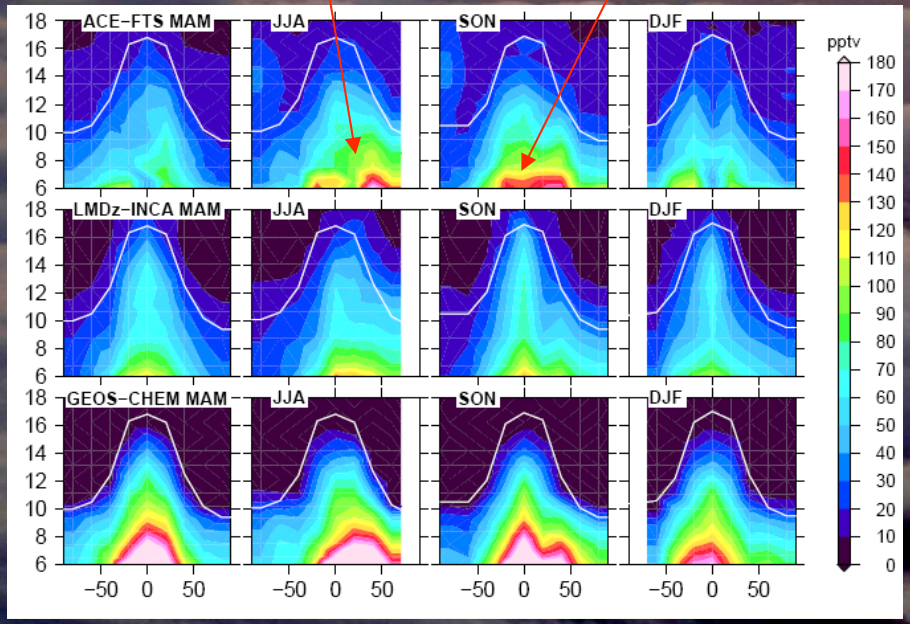
Boreal fires + plant growth?
Challenge for models.

Biomass burning



H_2CO

Growing season Biomass burning



A good test for chemistry transport models. H_2CO in the upper troposphere is mostly from secondary production. Need to properly model precursors, transport, and chemistry. Current models are not yet up to the task.

Global upper-tropospheric formaldehyde: seasonal cycles observed by the ACE-FTS satellite instrument, G. Dufour, S. Szopa, M. P. Barkley, C. D. Boone, A. Perrin, P. I. Palmer, and P. F. Bernath, Atmos. Chem. Phys., 9, 3893-3910 (2009).

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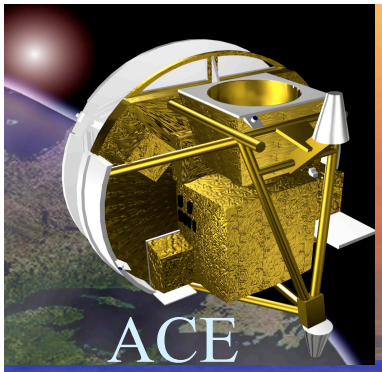
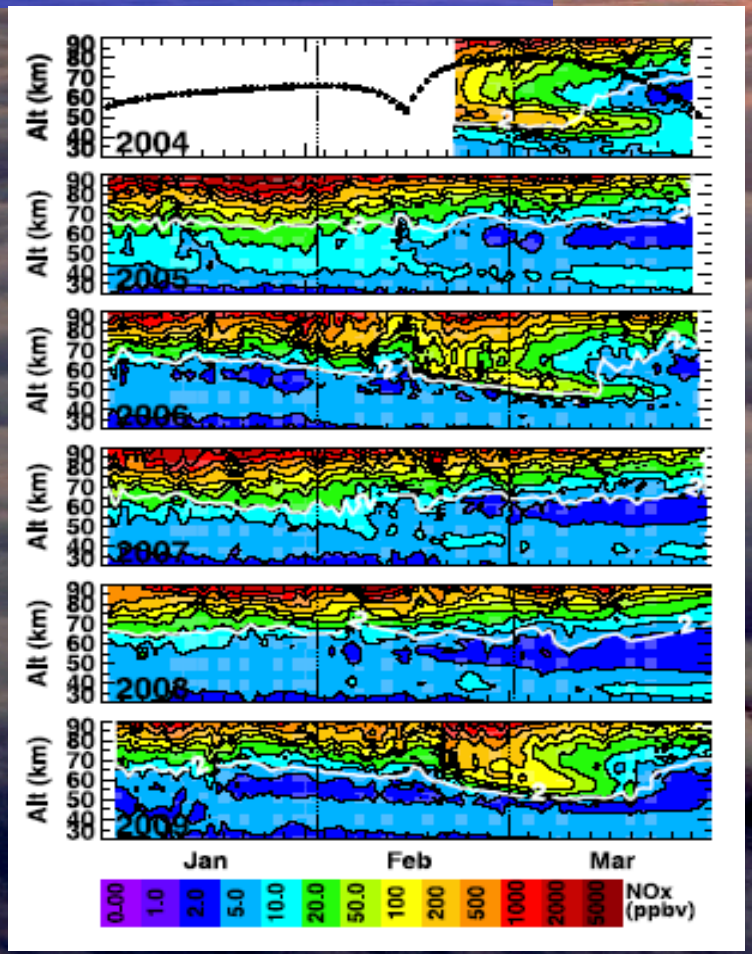
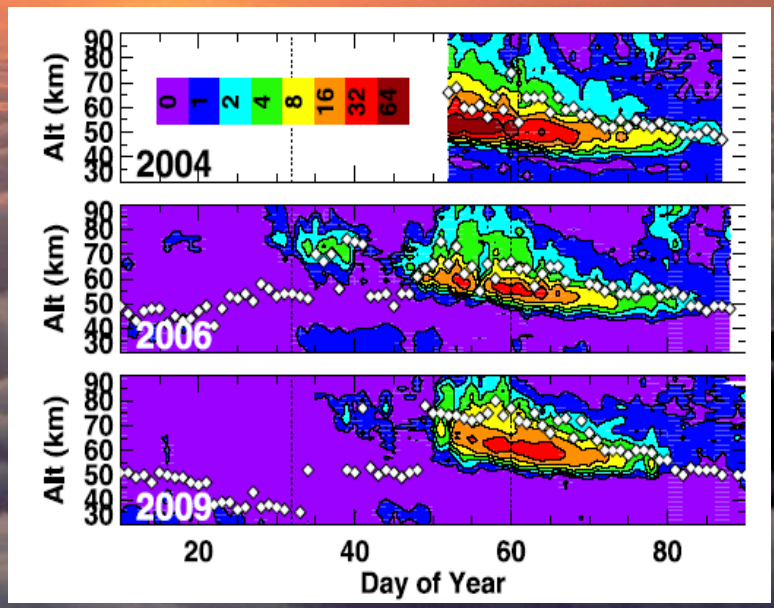


NO_x Descent



$NO + NO_2$ from ACE-FTS



Ratio of NO_x relative to the average of years without enhancement (2005, 2007, and 2008)

NO_x descent in the Arctic middle atmosphere in early 2009, C. E. Randall, V. L. Harvey, D. E. Siskind, J. France, P. F. Bernath, C. D. Boone, and K. A. Walker, Geophys. Res. Lett., 36, L18811, doi:10.1029/2009GL039706 (2009)

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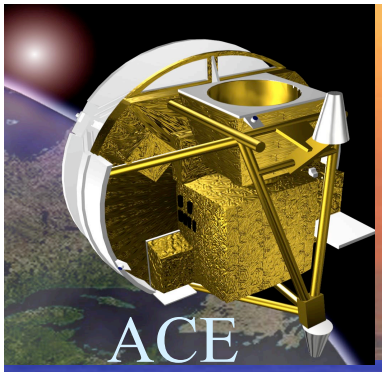
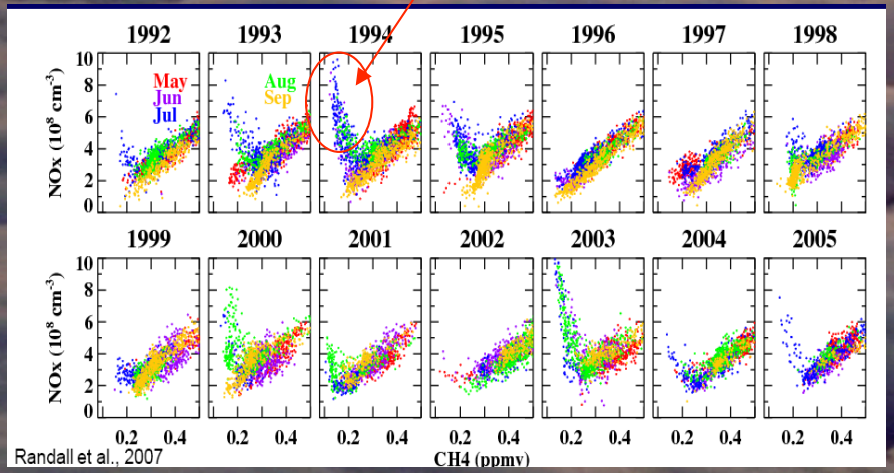
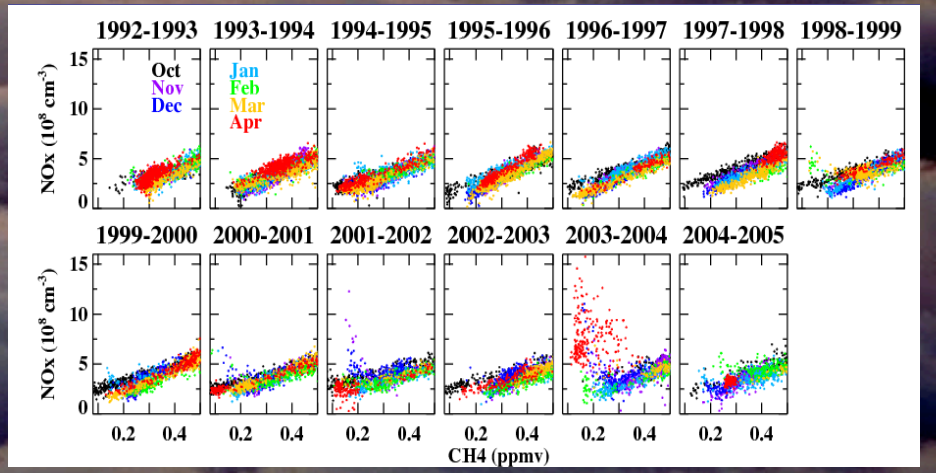


All is quiet in the north, until…

Enhanced NO_x created in the mesosphere descends into the stratosphere within the polar vortex





HALOE Southern Hemisphere HALOE Northern Hemisphere

Energetic Particle Precipitation Effects on the Southern Hemisphere Stratosphere in 1992-2005, C.E. Randall, V.L. Harvey, C.S. Singleton, S.M. Bailey, P.F. Bernath, M. Codrescu, H. Nakajima and J.M. Russel III, J. Geophys. Res, 112, D08308, doi:10.1029/2006JD007696 (2007)

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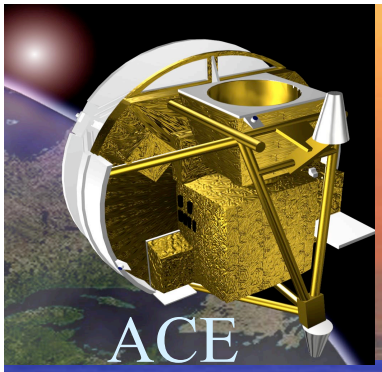

New(?) threat to Arctic ozone

- How new is it? HALOE coverage extended into high latitudes in April. Would not see enhancements in February and March.
- In 2004, 2006, and 2009, observed descent of enhanced NO_x in the NH polar vortex.
- Originally attributed to strong energetic particle precipitation (EPP) from the solar storm of Halloween 2003, until ACE saw enhancements in 2006 and 2009 when there was weak EPP.

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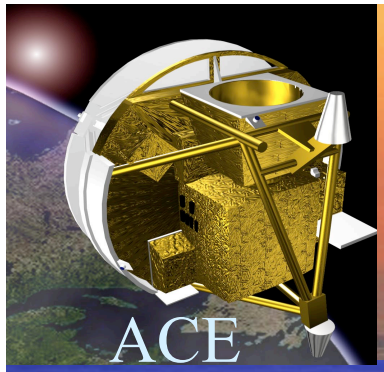

The new world order?

- Associated with a "remarkable" vortex recovery following a sudden stratospheric warming. A strong vortex led to enhanced adiabatic descent in the mesosphere.
- What was an unexpected occurrence in 2004 has now occurred 3 times in 6 years.
- Implications for Arctic ozone.
- Will the unusual meteorology linked to the effect persist? If so, what caused the change in atmospheric behavior?

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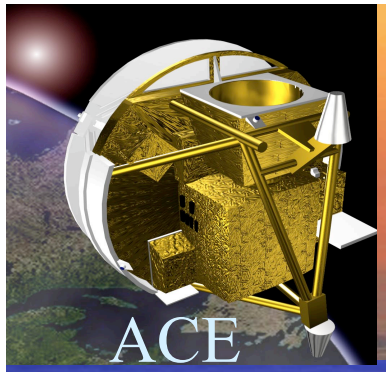

It all seemed too easy…

- Searching for weak spectral signatures in the troposphere (organics, CFCs, HCFCs).
- Bad residuals from stronger absorbers (e.g., CH_4 and H_2O) impeding the search.
- Limitations of using a simple Voigt.
- Implementing line mixing and alternative lineshapes (e.g., speed-dependent Voigt).
- Developed fast analytical approaches appropriate for "operational" retrievals.

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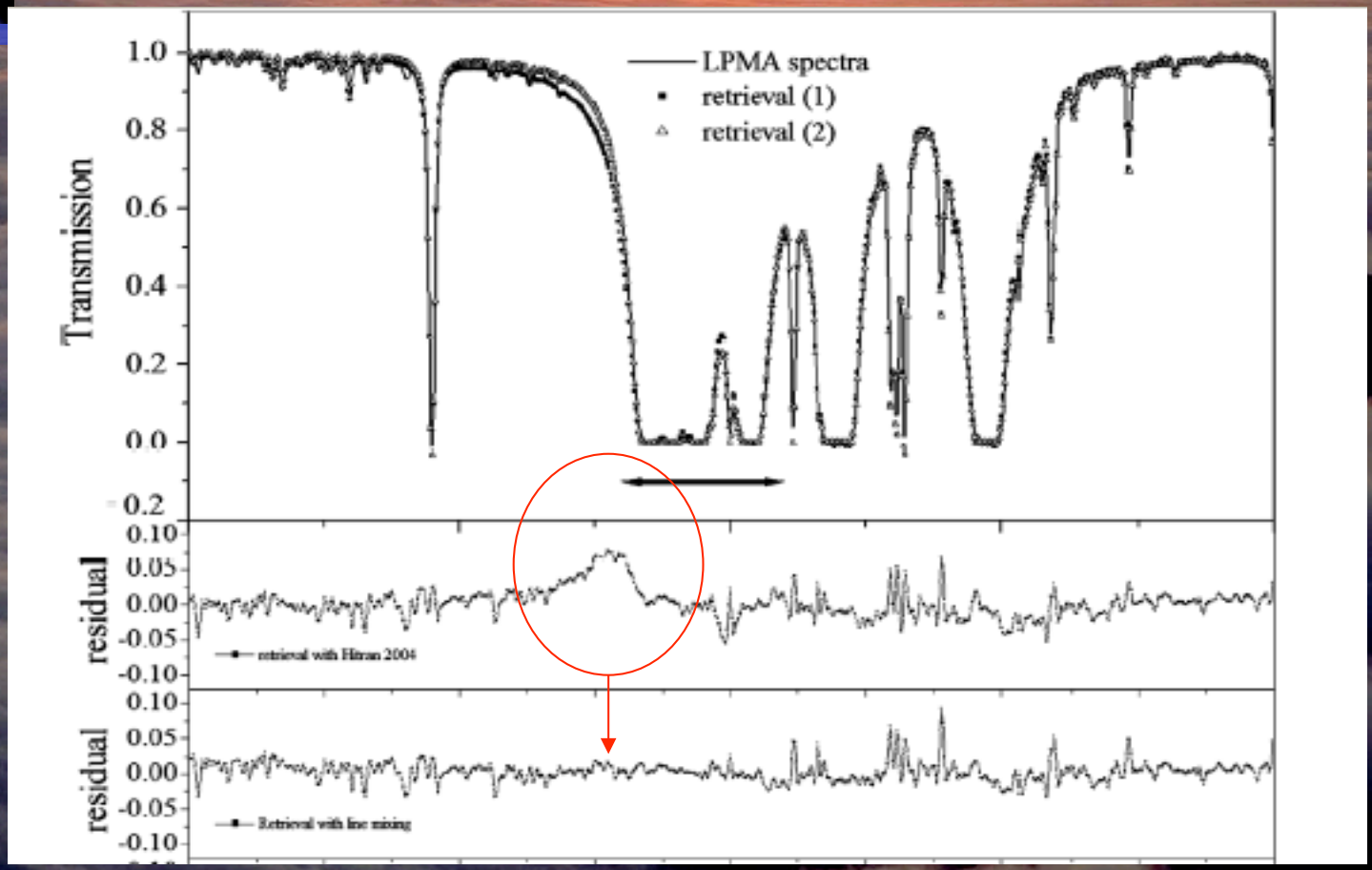
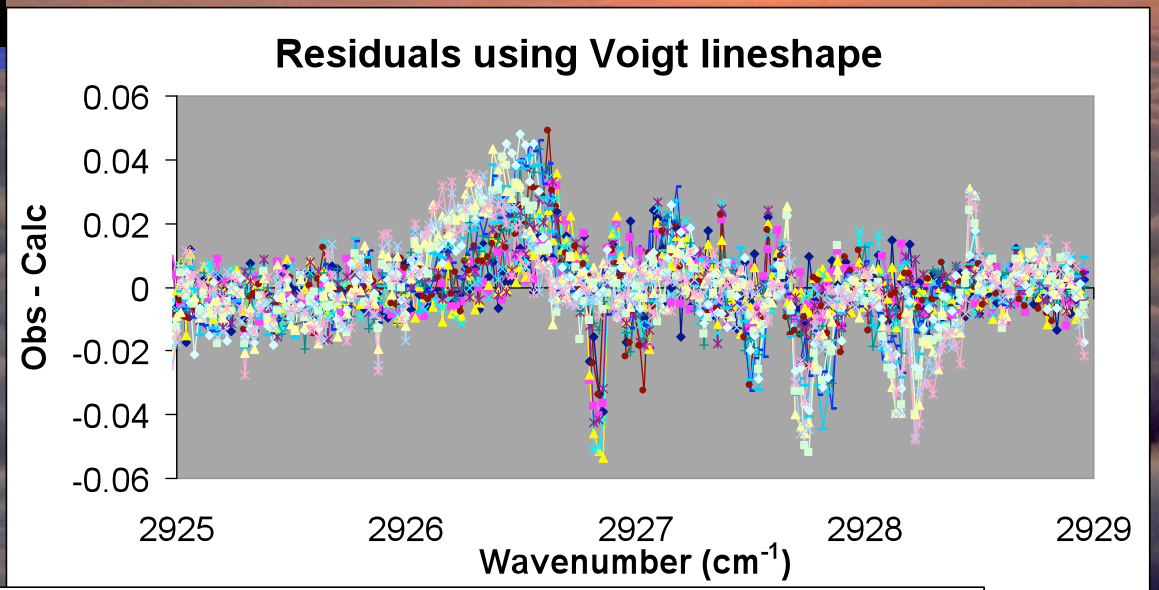
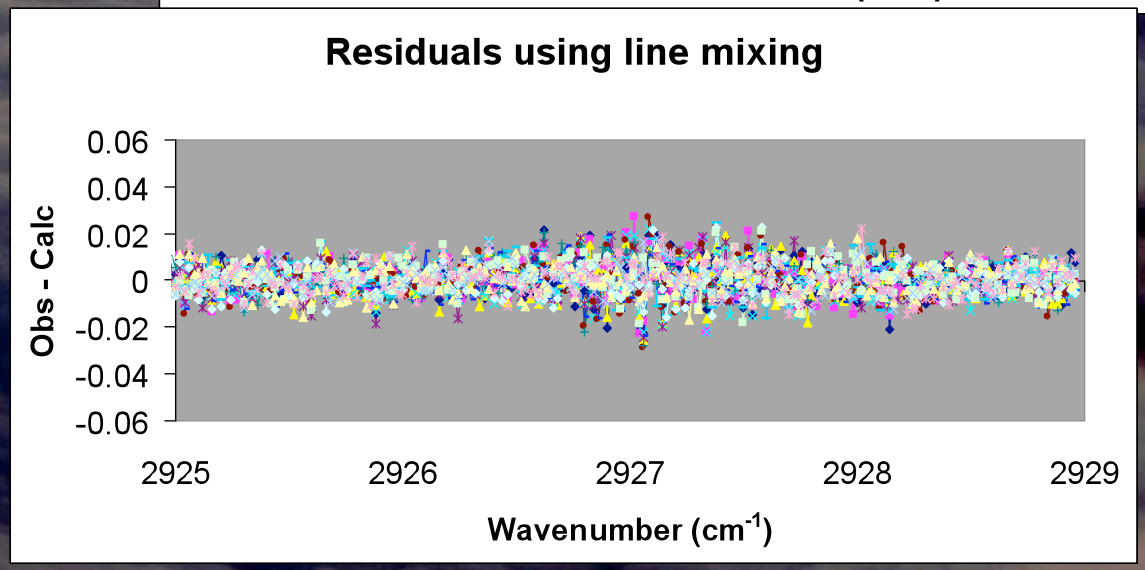
P9 manifold in the ν_3 band of CH_4



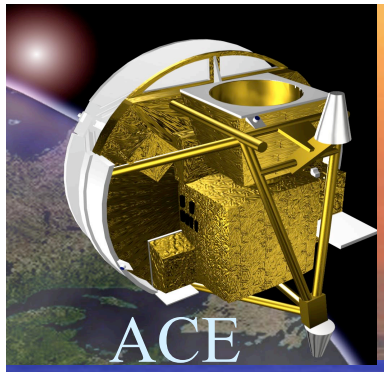
Measurement of the temperature dependence of line mixing and pressure broadening parameters between 296 and 90 K in the ν3 band of 12CH4 and their influence on atmospheric methane retrievals, Didier Mondelain, Sebastien Payan, Wenping Deng, Claude Camy-Peyret, Daniel Hurtmans, and Arlan Mantz, J. Mol. Spec., 244, pp 130-137 (2007)

ACE results for P9





Along with line mixing parameters, also fitted intensities and the position for one of the lines.



Non-Voigt lineshape?

- Minor features remaining in the residuals.
- Could be a need for tweaked spectroscopic constants (width, T-dependence, position) for CH_4 lines or interferences.
- Could be deviations from Voigt lineshapes for the CH_4 lines. Residuals further reduced using speed-dependent Voigt lineshapes.
- Too much going on in atmospheric spectra. Need simpler CH_4 lab spectra to analyze. Plans to measure these spectra underway at York (U.K.).

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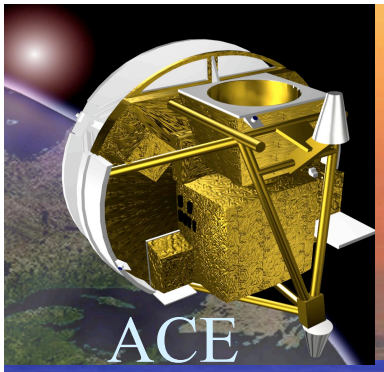
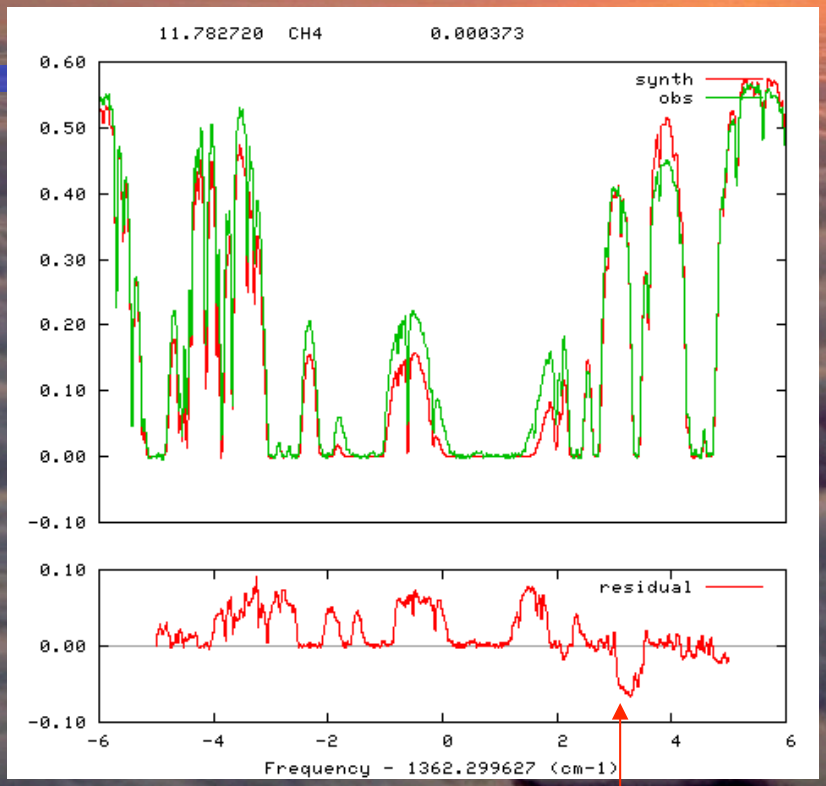


Acetone



Spectral signature for acetone visible in the residuals, but the region is polluted with bad residuals from both CH_4 (from line mixing) and H_2O.

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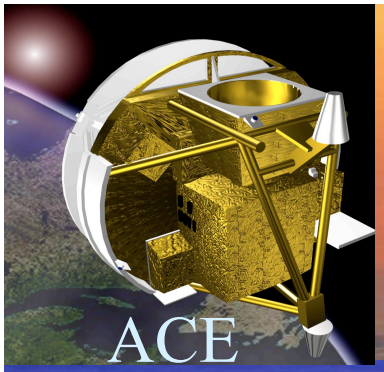
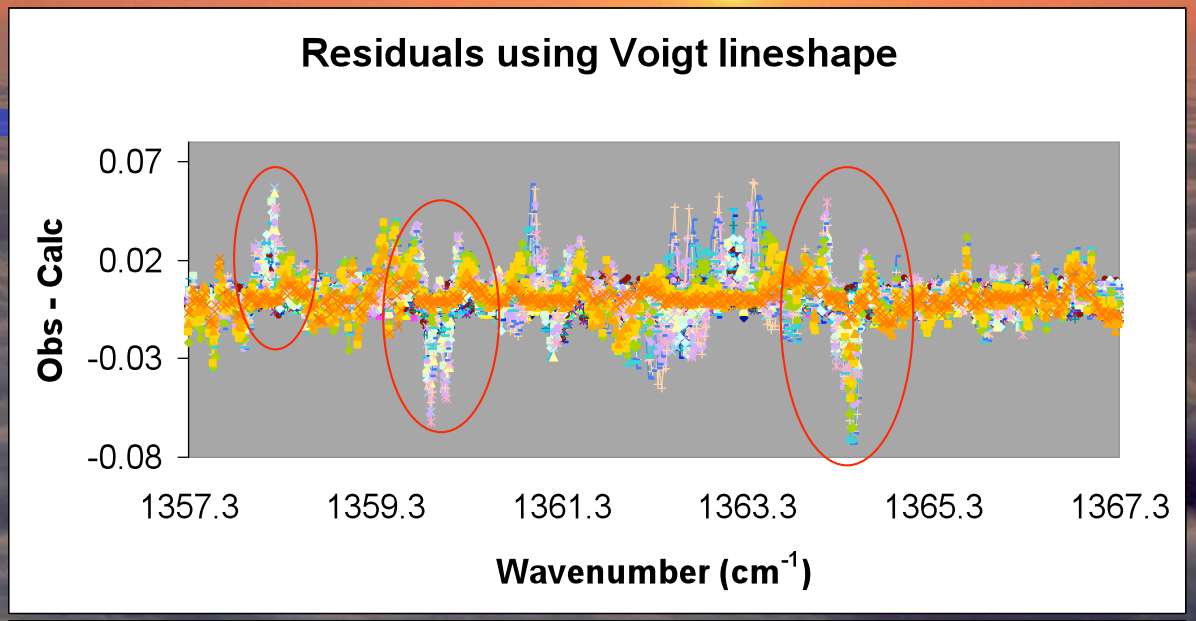
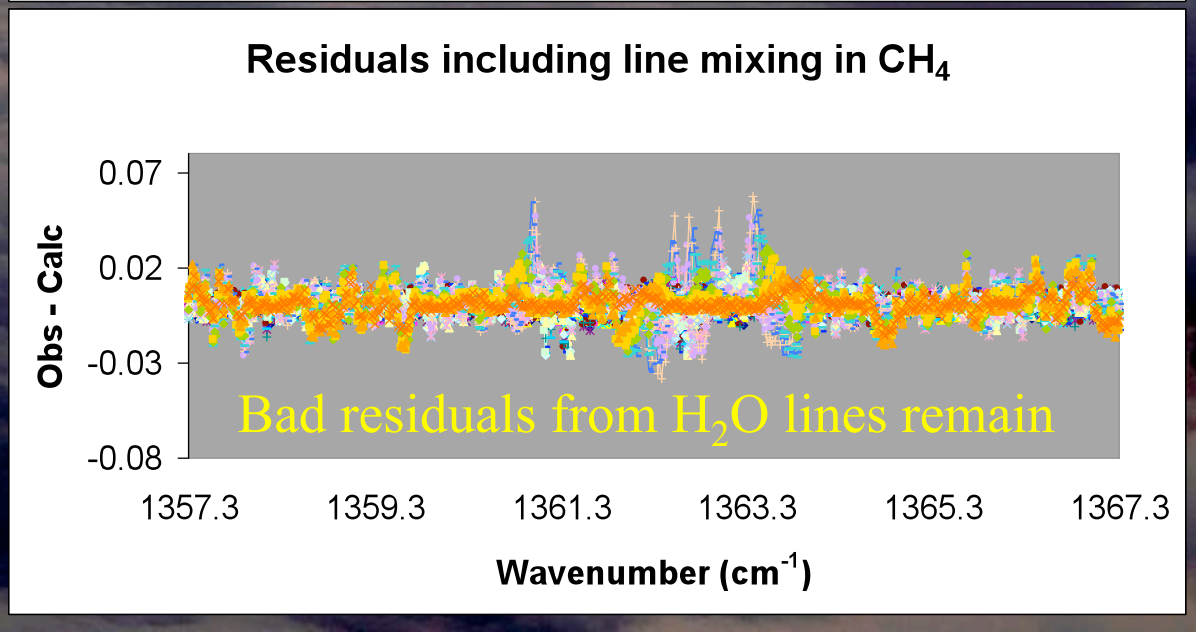


Add in line mixing





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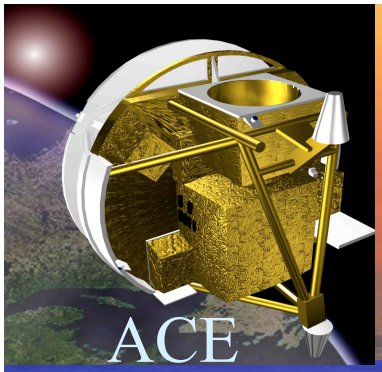

H_2O lineshape

- Bad H_2O residuals cause problems for other molecules (e.g., acetone, HFC-134a,…).
- Not as straightforward as CH_4. Still haven't determined a reliable solution.
- Rapid change of H_2O VMR in troposphere a challenge for working on a 1-km grid.
- H_2O lab spectra from Manfred Birk at DLR.

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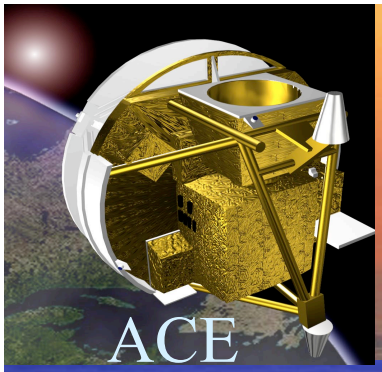
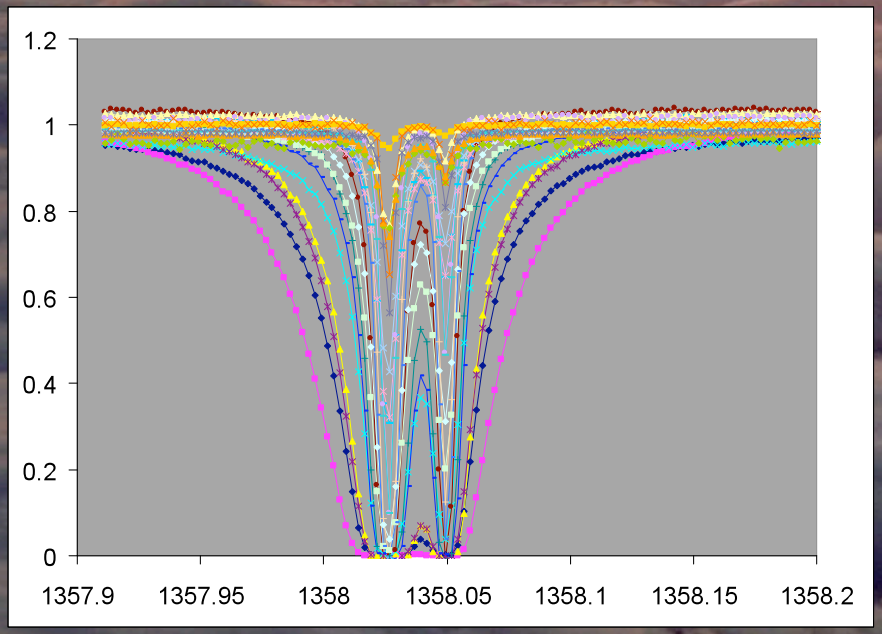
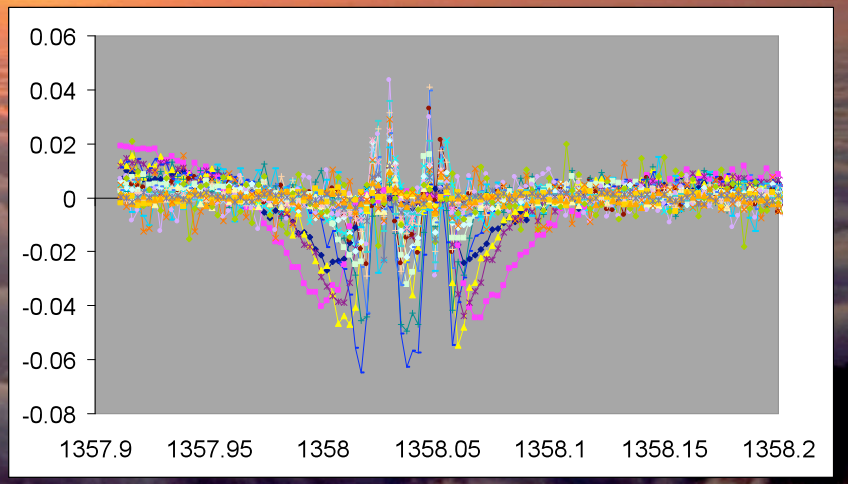


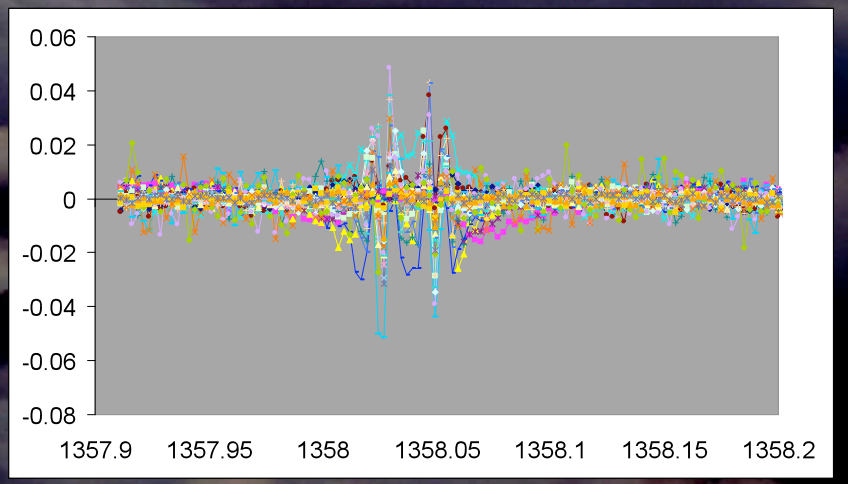
H_2O lab spectra



A set of 27 air broadened H_2O spectra, plus 4 self broadened



Residuals using Voigt function



Adjusting broadening parameters

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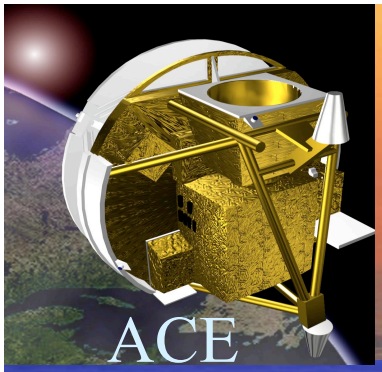
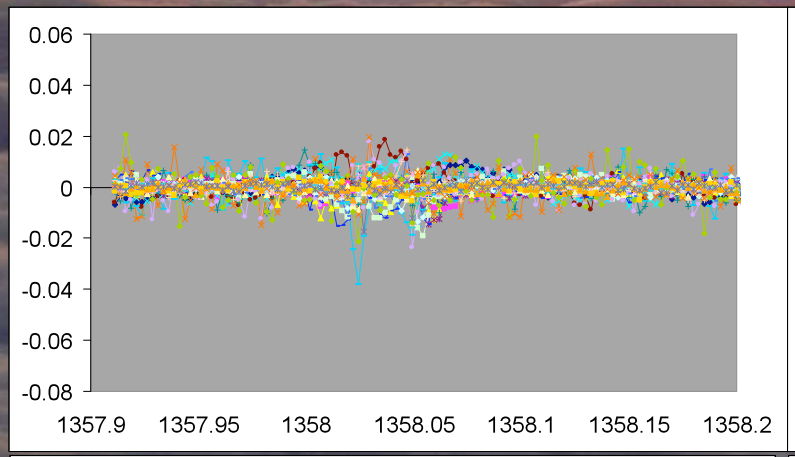


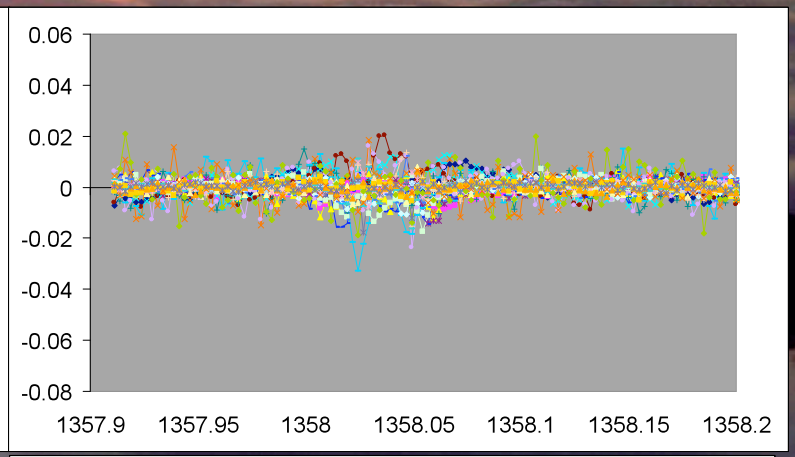
Speed-dependence

$\eta = 0$

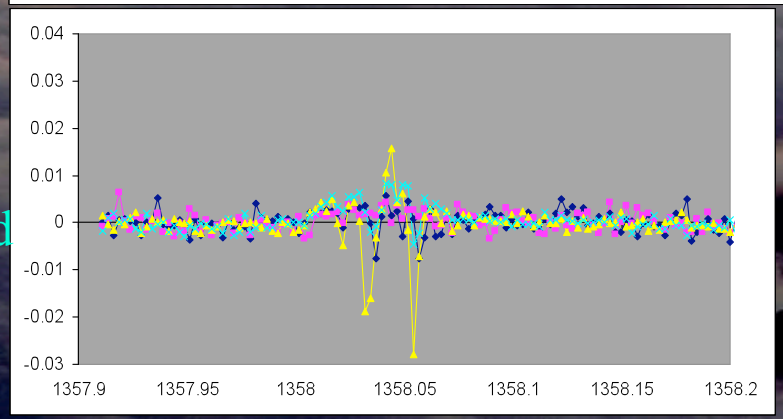
$\eta \neq 0$

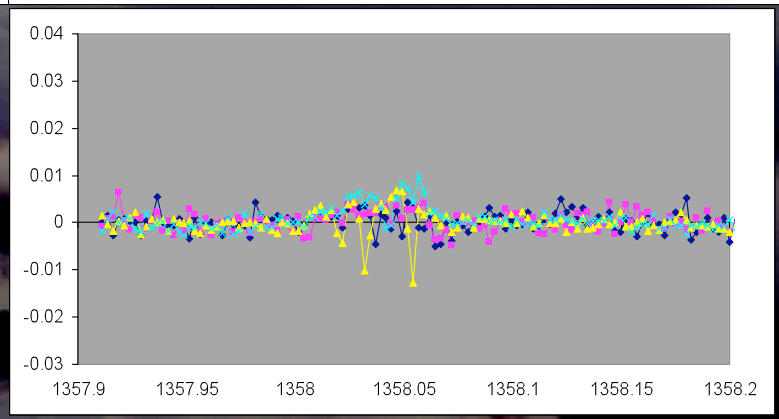
Air-broadened



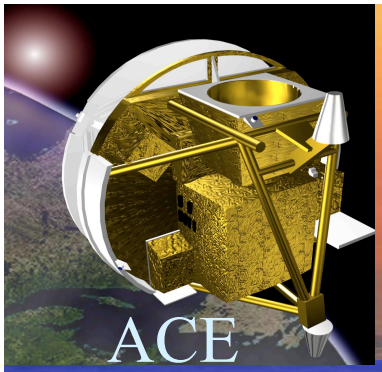


Self-broadened



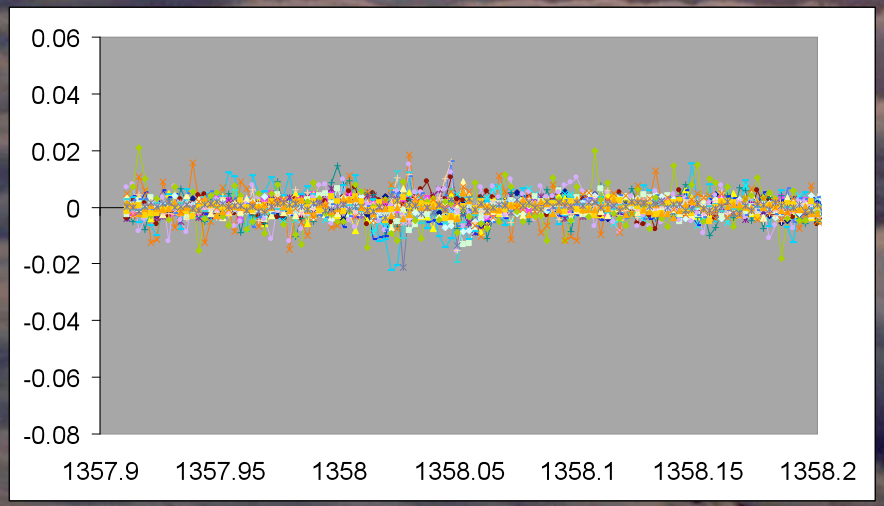


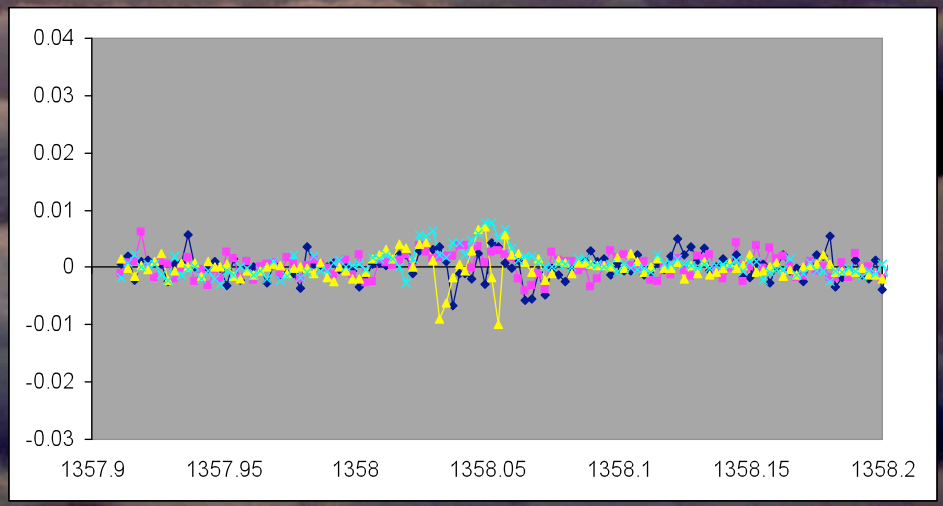
Speed-dependent Voigt profile for water vapor in infrared remote sensing applications, Chris D. Boone, Kaley A. Walker, and Peter F. Bernath, JQSRT, 105, 525-532 (2007).



A work in progress

Separate T-dependence for self-broadening





Note the different vertical scales. These residuals smaller than the air-broadened ones. Less noise.

Much work remains.

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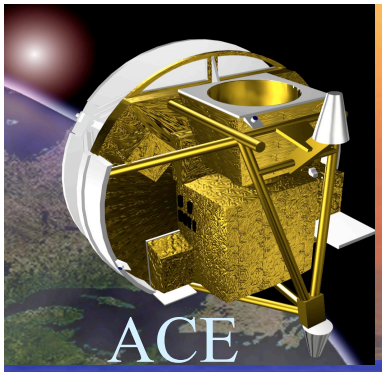

Summary

- ACE satellite continues to collect measurements.
- Start to look at trends.
- Further refining spectral calculations. Seeking weaker and weaker signatures.
- Generating spectroscopic parameters from lab spectra. Unavailable elsewhere.
- Version 2.2 data slated for public release.
- Version 3.0 underway. A few months to catch up.
- Follow-on mission? Some preliminary studies.

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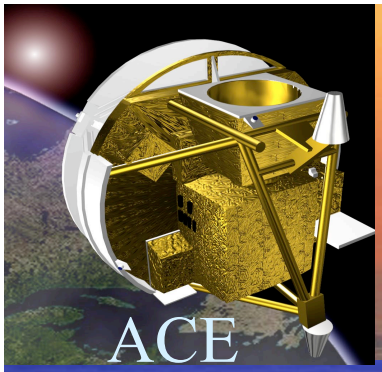

Acknowledgement

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