

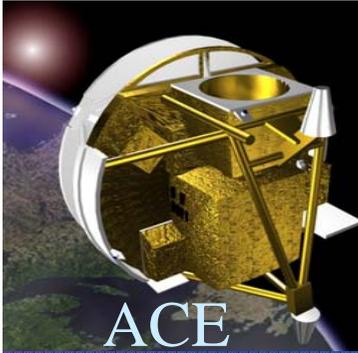
# Recent Results from the Atmospheric Chemistry Experiment (ACE)



Chris Boone, Gaelle Dufour, Curtis  
Rinsland, Kaley Walker, Ray Nassar,  
Dejian Fu, and Peter Bernath

OPAC-3

September 2007

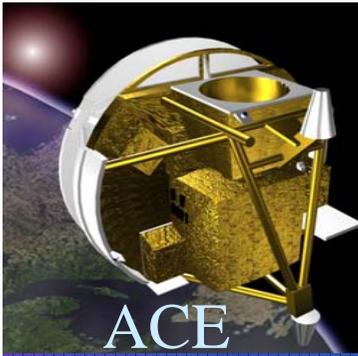


# Atmospheric Chemistry Experiment

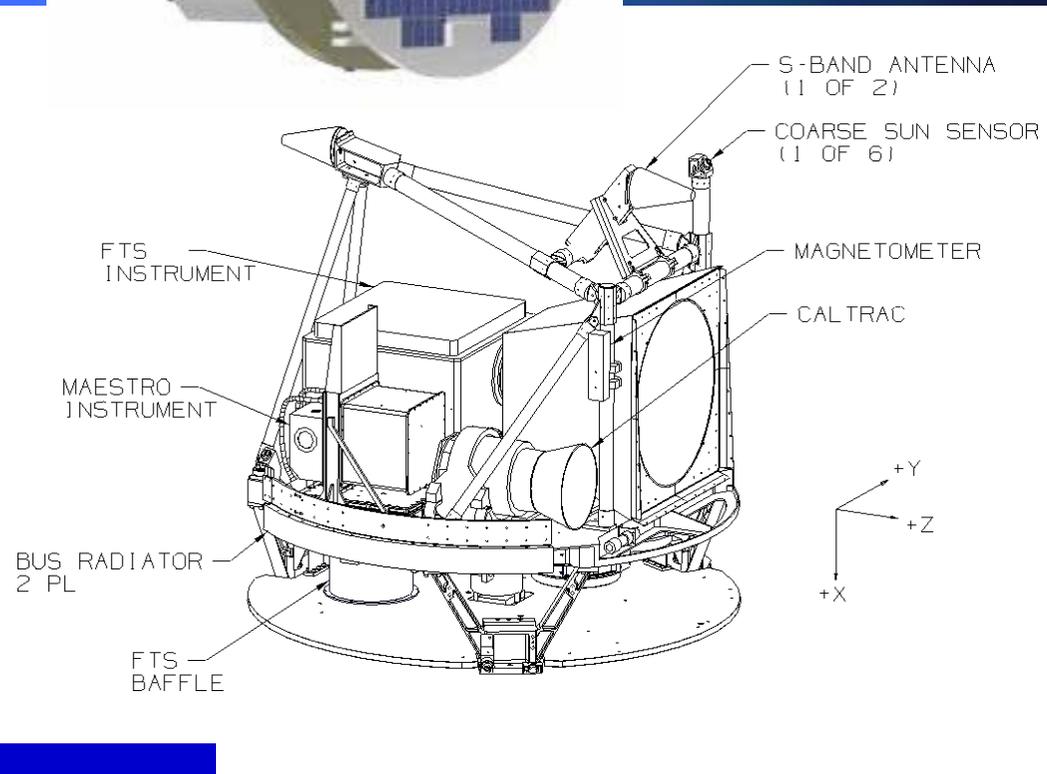


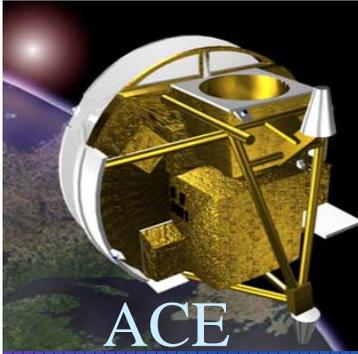
- Satellite mission for remote sensing of the Earth's atmosphere, with a primary focus on Arctic ozone
- Developed by the Canadian Space Agency
- Launched August 2003, science operations began February 2004
- Currently funded through April 2008.

# SCISAT-1 Spacecraft (Bristol)



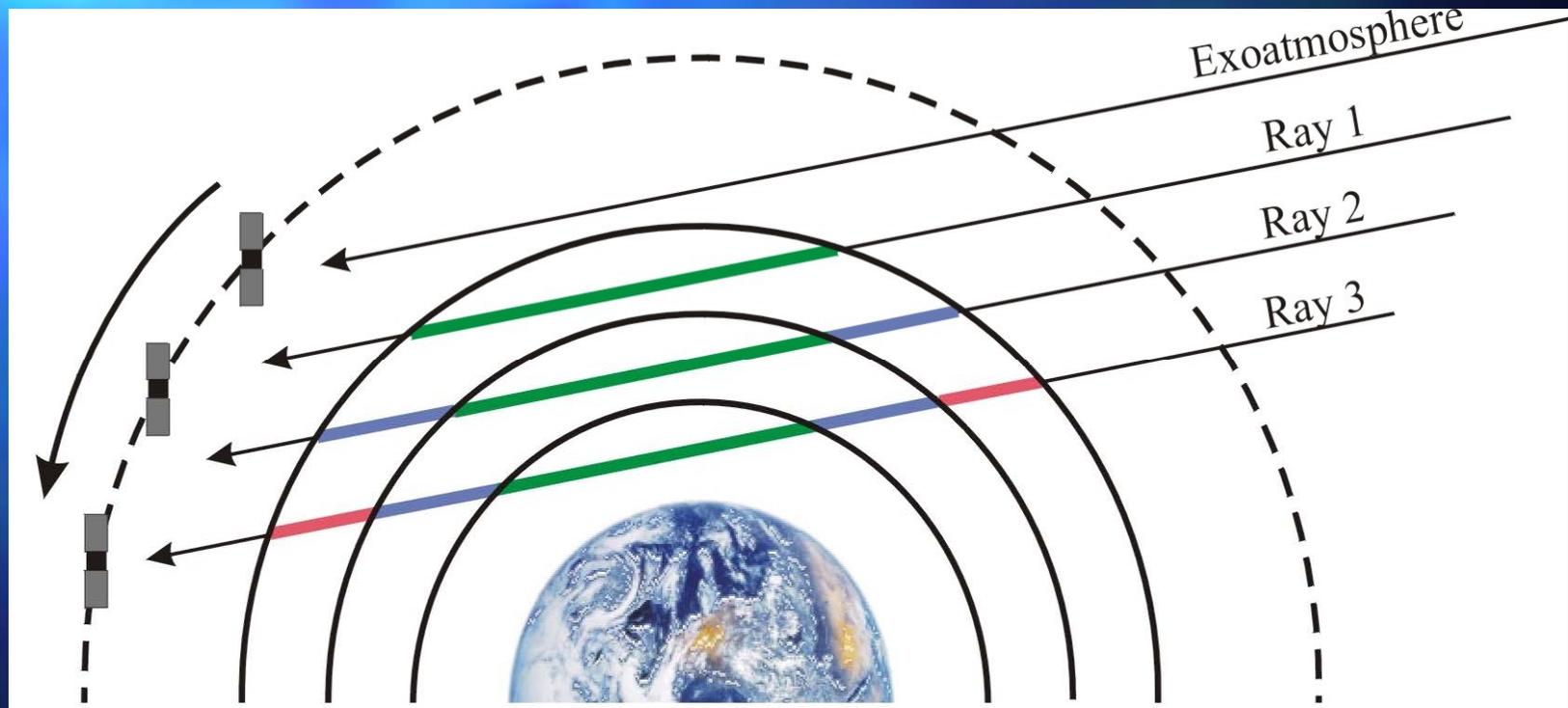
Key Specifications	
Spacecraft diameter	112 cm
Spacecraft mass	152 kg
Pointing control:	
Pitch/yaw ( $3\sigma$ )	$\pm 0.2^\circ$
Roll ( $3\sigma$ )	$\pm 0.7^\circ$
Pointing knowledge:	
Pitch/yaw	$\pm 0.1^\circ$
Roll	$\pm 0.6^\circ$
Solar array EOL power	175 W
Spacecraft OA power	75 W
Bus reliability (2-yrs)	80 %
Mass memory	1.5 Gb

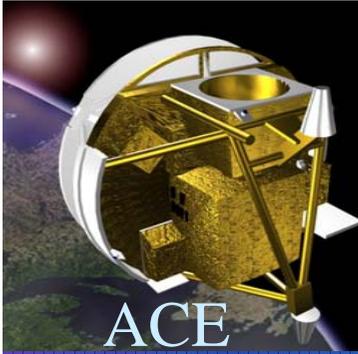




ACE

# Solar Occultation





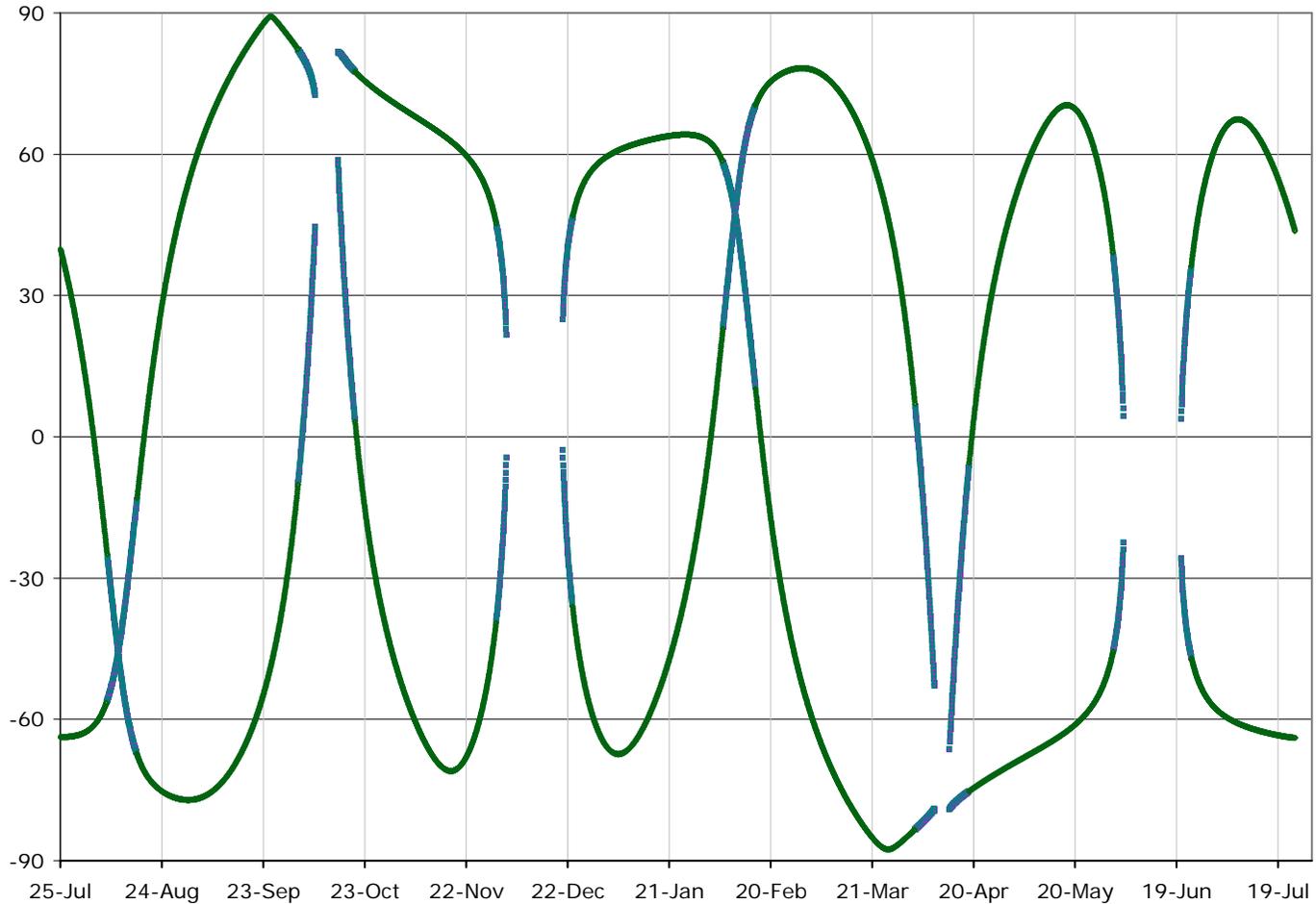
ACE

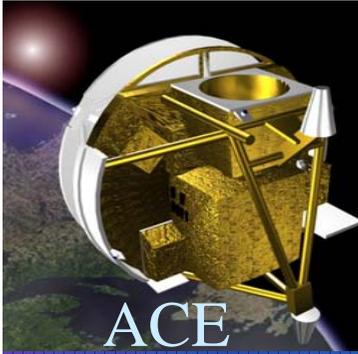
# ACE Geographic Coverage



Latitude  
/degrees

650 km,  
74°  
inclined  
circular  
orbit, RAAN  
55.7°



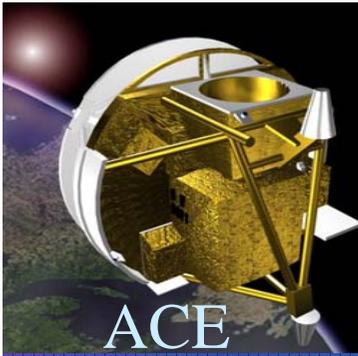


# Instruments



- Infrared Fourier Transform Spectrometer operating between 2 and 13 microns with a resolution of  $0.02 \text{ cm}^{-1}$  ( $\pm 25 \text{ cm MPD}$ )
- 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  $\sim 1\text{-}2 \text{ nm}$
- Suntracker
- Startracker

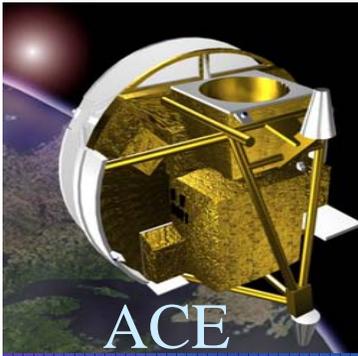
# ACE-FTS (ABB-Bomem)



Interferometer-side

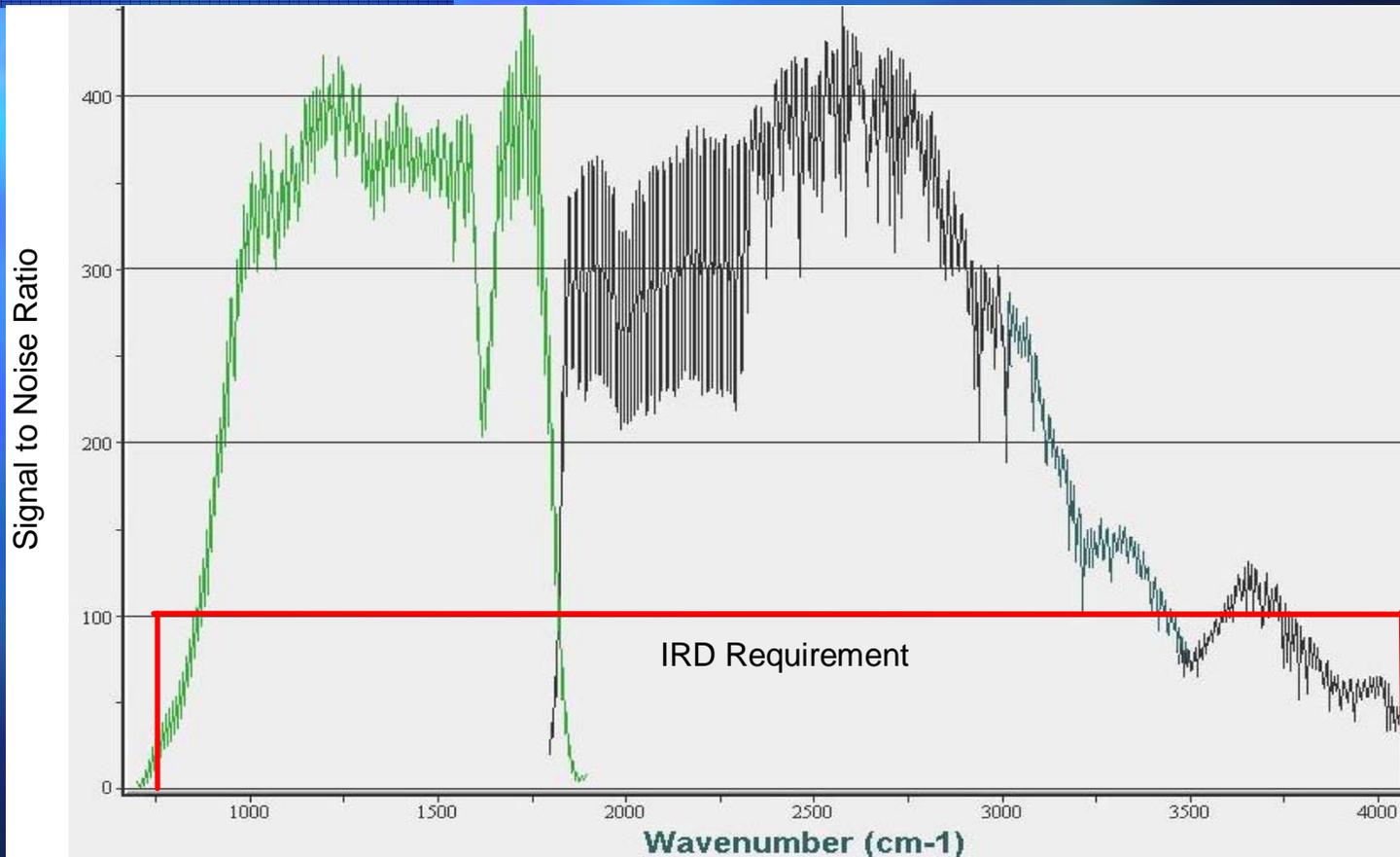


Input optics-side

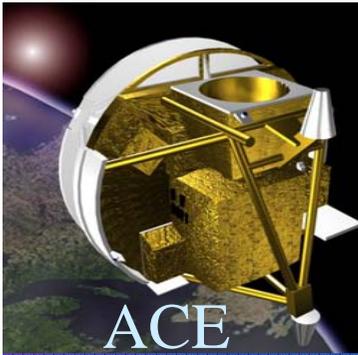


ACE

# Excellent SNR Performance



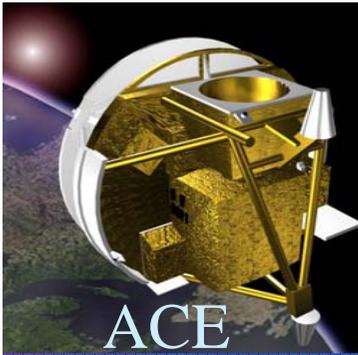
Note: after detector decontamination



# Molecules



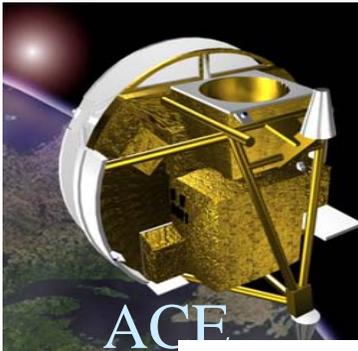
- Baseline:  $\text{CO}_2$ ,  $\text{H}_2\text{O}$ ,  $\text{O}_3$ ,  $\text{N}_2\text{O}$ ,  $\text{CO}$ ,  $\text{CH}_4$ ,  $\text{NO}$ ,  $\text{NO}_2$ ,  $\text{HNO}_3$ ,  $\text{HF}$ ,  $\text{HCl}$ ,  $\text{ClONO}_2$ ,  $\text{N}_2\text{O}_5$ ,  $\text{CFC-11}$ , and  $\text{CFC-12}$
- Others:  $\text{OCS}$ ,  $\text{HCN}$ ,  $\text{CH}_3\text{Cl}$ ,  $\text{CF}_4$ ,  $\text{CCl}_4$ ,  $\text{COF}_2$ ,  $\text{C}_2\text{H}_2$ ,  $\text{C}_2\text{H}_6$ ,  $\text{HCFC-22}$ ,  $\text{HCOOH}$ ,  $\text{CH}_3\text{OH}$ ,  $\text{SF}_6$ ,  $\text{ClO}$ ,  $\text{N}_2$ ,  $\text{O}_2$ ,  $\text{CFC-113}$ ,  $\text{HCFC-142b}$ ,  $\text{HFC-134a}$ ,  $\text{HNO}_4$ ,  $\text{H}_2\text{O}_2$ ,  $\text{HOCl}$ ,  $\text{H}_2\text{CO}$ ,  $\text{COCl}_2$ ,  $\text{COCIF}$ ,  $\text{PAN}$ , acetone, aerosols, etc.



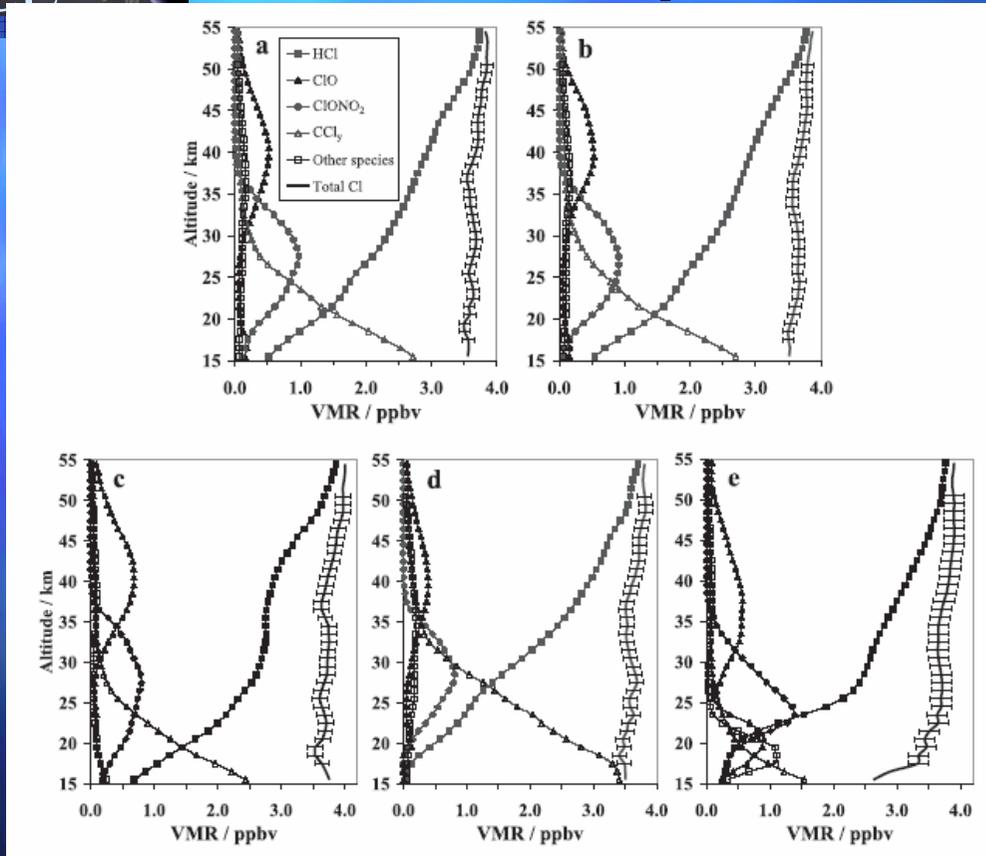
# Isotopologues



- $^{13}\text{C}\text{H}_4$ ,  $\text{C}\text{H}_3\text{D}$ ,  $^{14}\text{N}^{15}\text{N}^{16}\text{O}$ ,  $^{15}\text{N}^{14}\text{N}^{16}\text{O}$ ,  $\text{N}_2^{18}\text{O}$ ,  
 $\text{H}_2^{18}\text{O}$ ,  $\text{H}_2^{17}\text{O}$ ,  $\text{HDO}$ ,  $^{13}\text{C}\text{O}_2$ ,  $^{18}\text{O}^{12}\text{C}^{16}\text{O}$ ,  
 $^{17}\text{O}^{12}\text{C}^{16}\text{O}$ ,  $^{18}\text{O}^{13}\text{C}^{16}\text{O}$ ,  $^{18}\text{O}^{16}\text{O}^{16}\text{O}$ ,  
 $^{16}\text{O}^{18}\text{O}^{16}\text{O}$ ,  $^{17}\text{O}^{16}\text{O}^{16}\text{O}$ ,  $^{16}\text{O}^{17}\text{O}^{16}\text{O}$ ,  $^{13}\text{C}^{16}\text{O}$ ,  
 $^{12}\text{C}^{18}\text{O}$ ,  $^{12}\text{C}^{17}\text{O}$ , OCS isotopologues

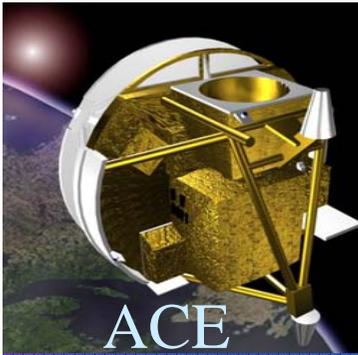


# Stratospheric Cl inventory

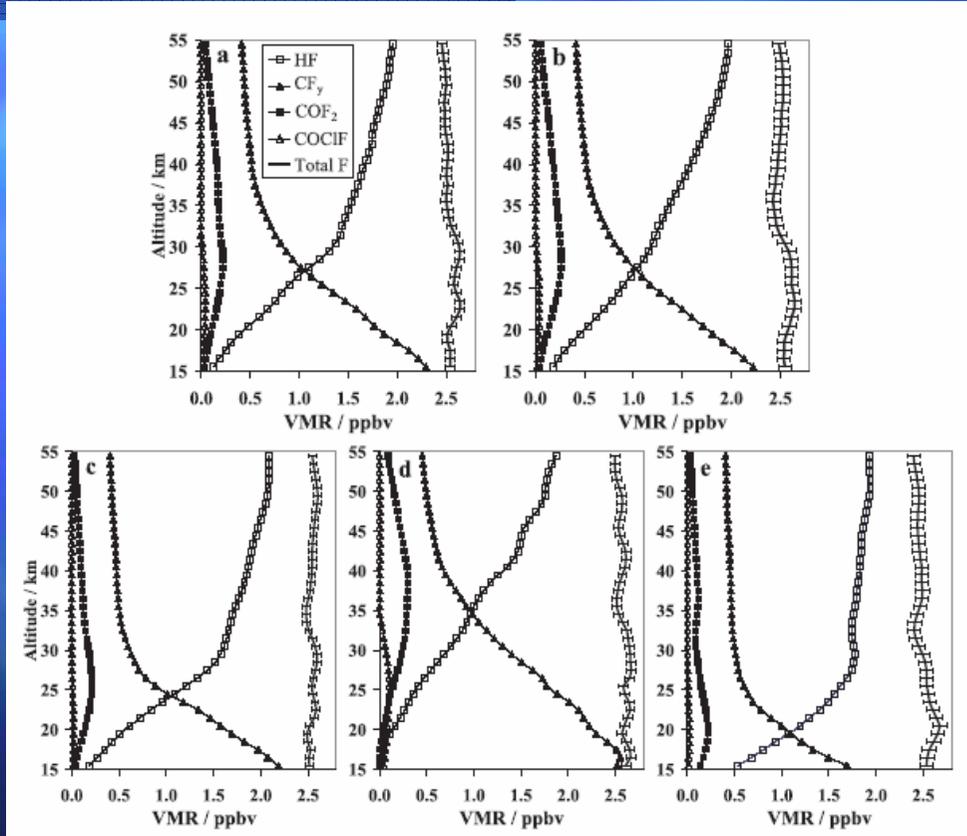


- a) Northern midlatitudes
- b) Southern midlatitudes
- c) Northern high latitudes
- d) Tropics
- e) Southern high latitudes

Nassar, R., P.F. Bernath, C.D. Boone, C. Clerbaux, P.F. Coheur, G. Dufour, L. Froidevaux, E. Mahieu, J.C. McConnell, S.D. McLeod, D.P. Murtagh, C.P. Rinsland, K. Semeniuk, R. Skelton, K.A. Walker, and R. Zander (2006), A global inventory of stratospheric chlorine in 2004, *J. of Geophys. Res.*, Vol. 111, D22312, doi:10.1029/2006JD007073, also in the next WMO report

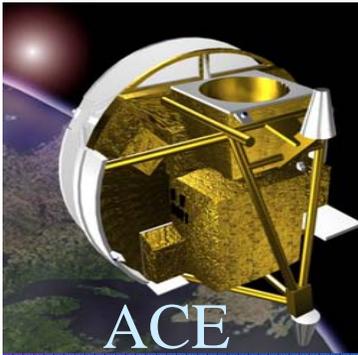


# Stratospheric F inventory



- a) Northern midlatitudes
- b) Southern midlatitudes
- c) Northern high latitudes
- d) Tropics
- e) Southern high latitudes

Nassar, R., P.F. Bernath, C.D. Boone, S.D. McLeod, R. Skelton, K.A. Walker, C.P. Rinsland and P. Duchatelet (2006), A global inventory of stratospheric fluorine in 2004 based on Atmospheric Chemistry Experiment Fourier transform spectrometer (ACE-FTS) measurements, *J. of Geophys. Res.*, Vol. 111, D22313, doi:10.1029/2006JD007395, also in the next WMO report

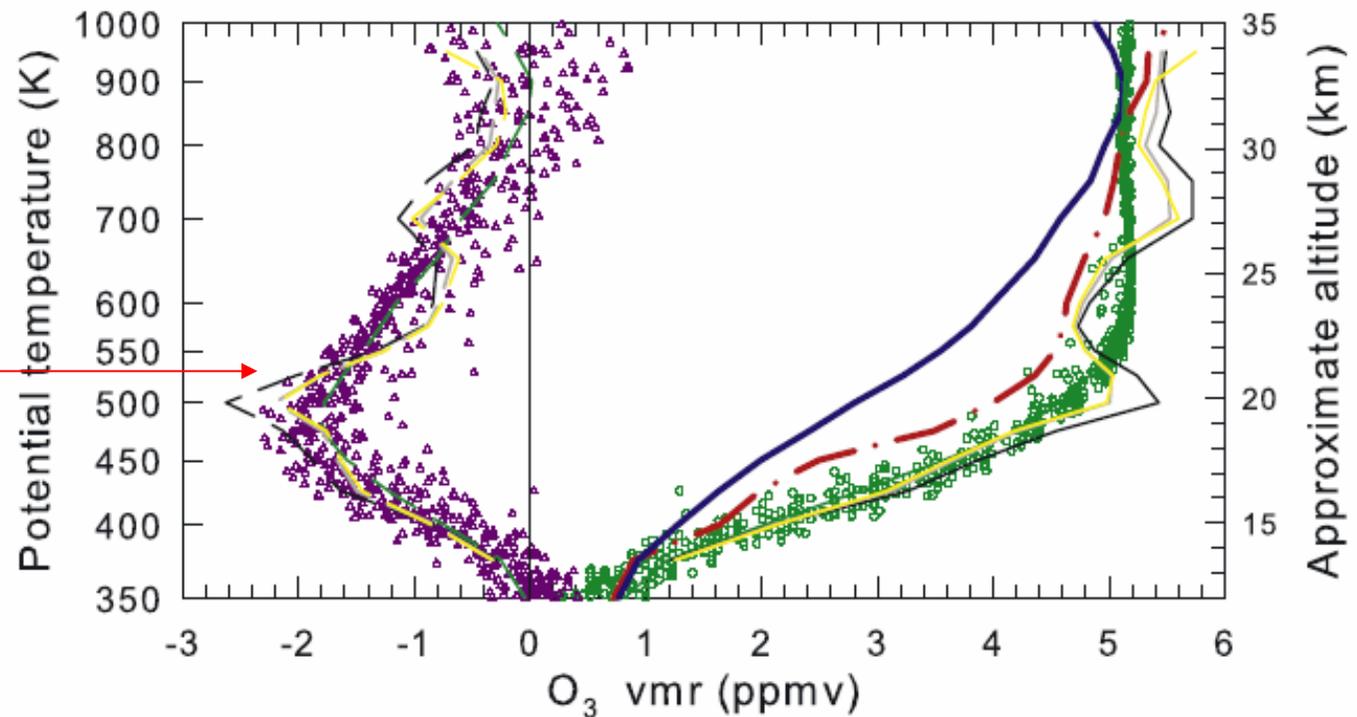


ACE

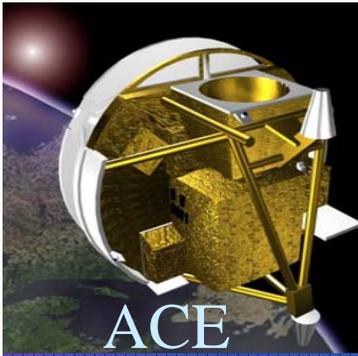
# Measuring O<sub>3</sub> losses



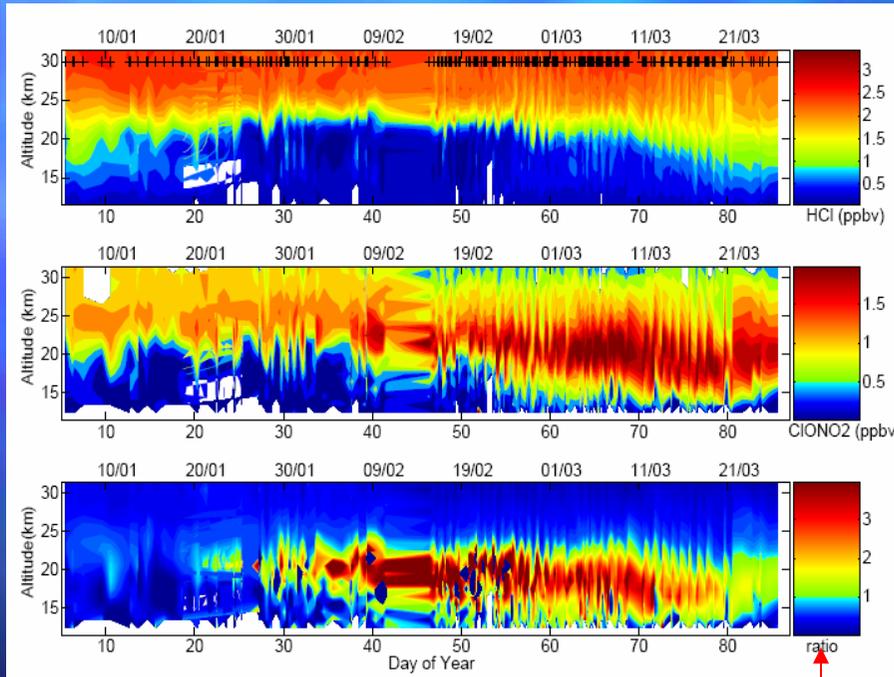
Losses inferred from correlations between O<sub>3</sub> and long-lived tracers



Jin, J.J., K. Semeniuk, G.L. Manney, A.I. Jonsson, S.R. Beagley, J.C. McConnell, G. Dufour, R. Nassar, C.D. Boone, K.A. Walker, P.F. Bernath, and C.P. Rinsland (2006), Severe Arctic Ozone Loss in the Winter 2004/2005: Observations from ACE-FTS, *Geophys. Res. Lett.*, 33, L15801, doi:10.1029/2005GL026752

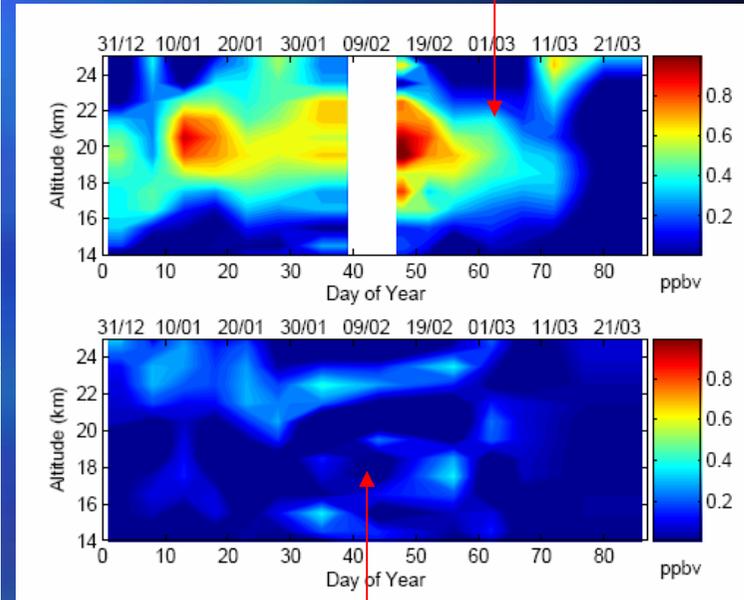


# Chlorine Partitioning



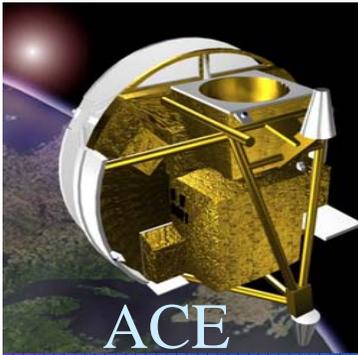
ClONO<sub>2</sub> / HCl

ClO inside vortex



ClO outside vortex

Dufour, G., R. Nassar, C.D. Boone, R. Skelton, K.A. Walker, P.F. Bernath, C.P. Rinsland, K. Semeniuk, J.J. Jin, J.C. McConnell, and G.L. Manney (2006), Partitioning between the inorganic chlorine reservoirs HCl and ClONO<sub>2</sub> during the Arctic winter 2005 from the ACE-FTS, *Atmos. Chem. Phys.*, 6, 2355-2366

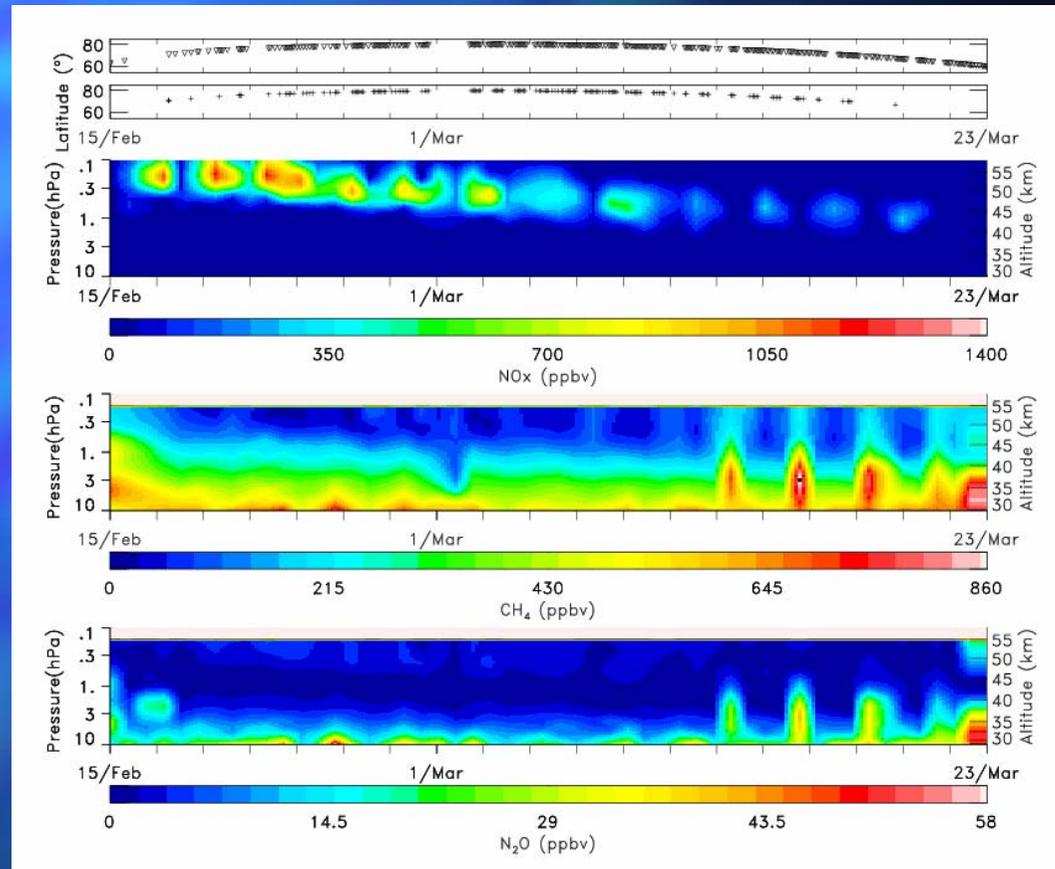


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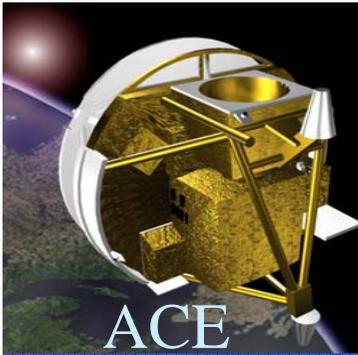


# Enhanced NO<sub>x</sub>

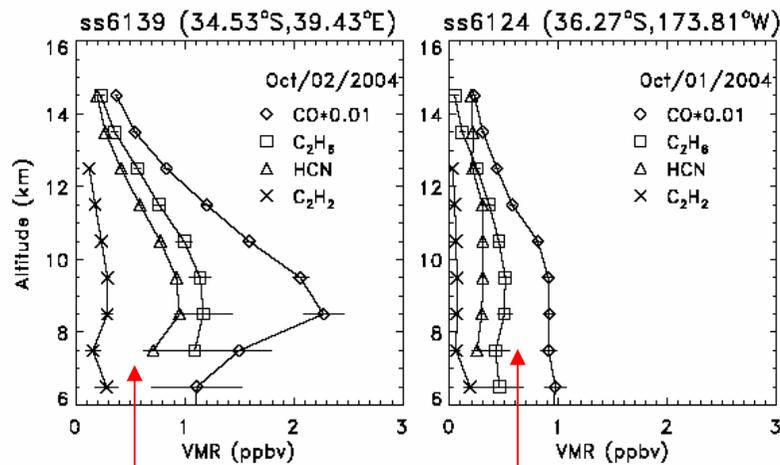
Enhanced NO + NO<sub>2</sub> created at high altitudes descends slowly to lower altitude within the polar vortex.



Rinsland, C. P., C. Boone, R. Nassar, K. Walker, P. Bernath, J. C. McConnell, and L. Chiou (2005), Atmospheric Chemistry Experiment (ACE) Arctic stratospheric measurements of NO<sub>x</sub> during February and March 2004: Impact of intense solar flares, *Geophys. Res. Lett.*, 32, L16S05, doi:10.1029/2005GL022425.

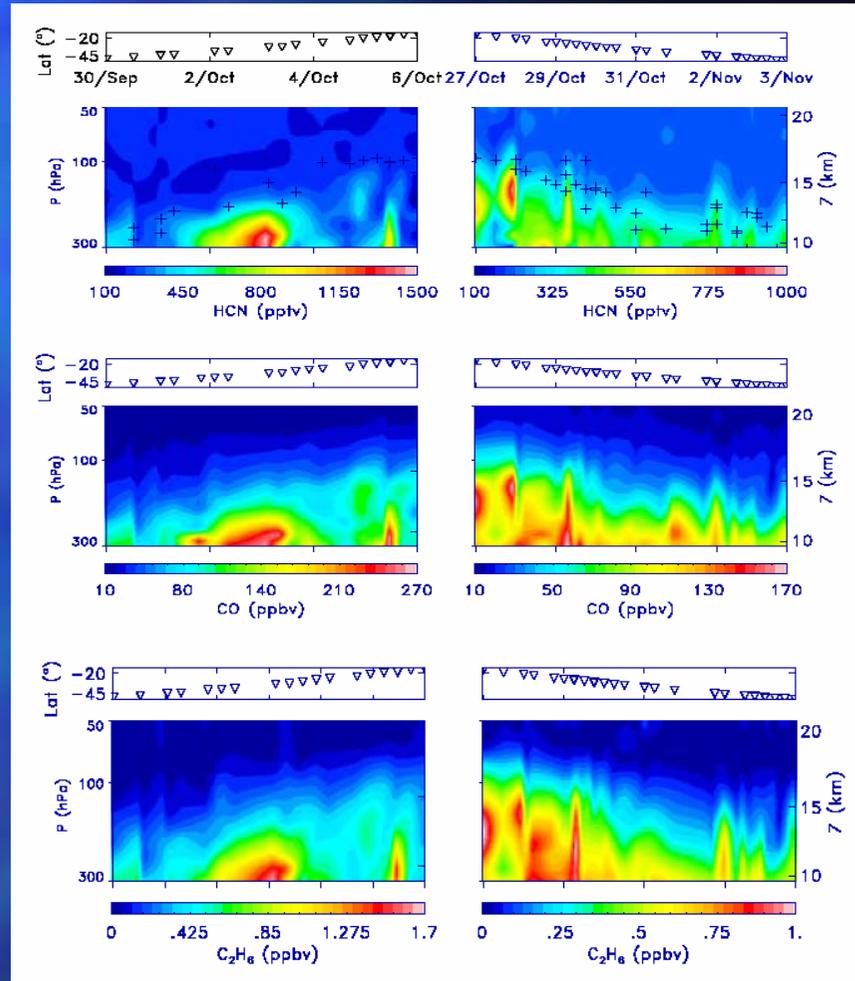


# Biomass Burning

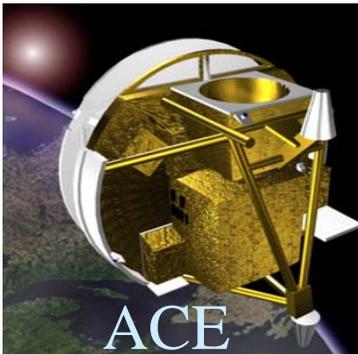


Contains biomass burning signature

“Background”



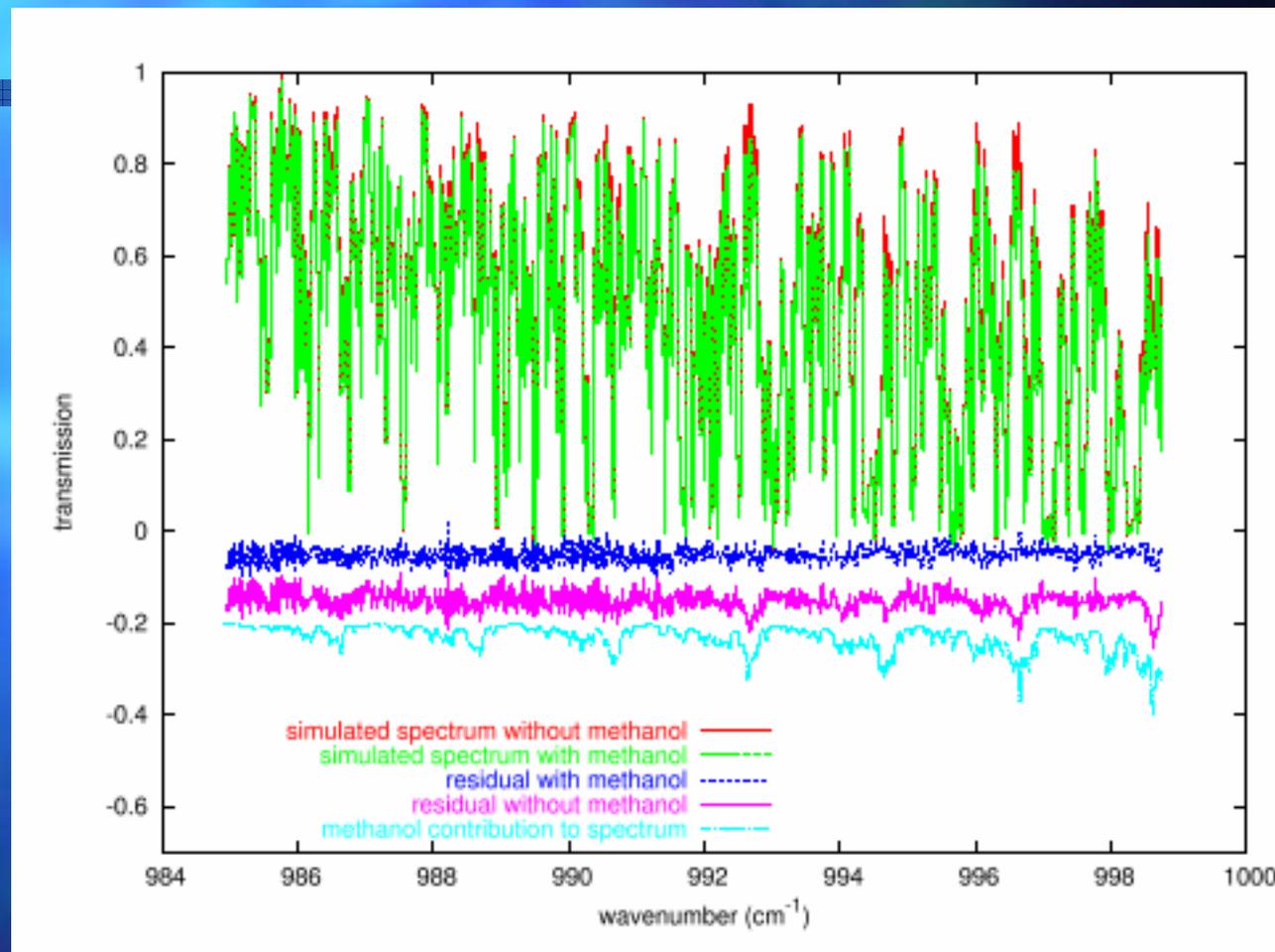
Rinsland, C.P., Dufour, G., Boone, C.D., Bernath, P.F., Chiou, L (2005) Atmospheric Chemistry Experiment (ACE) measurements of elevated Southern Hemisphere upper tropospheric CO, C<sub>2</sub>H<sub>6</sub>, HCN, and C<sub>2</sub>H<sub>2</sub> mixing ratios from biomass burning emissions and long-range transport, Geophys. Res. Lett., 32, L20803, doi:10.1029/2005GL024214



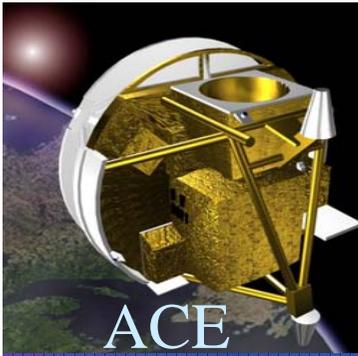
ACE



# First $\text{CH}_3\text{OH}$ detection from space



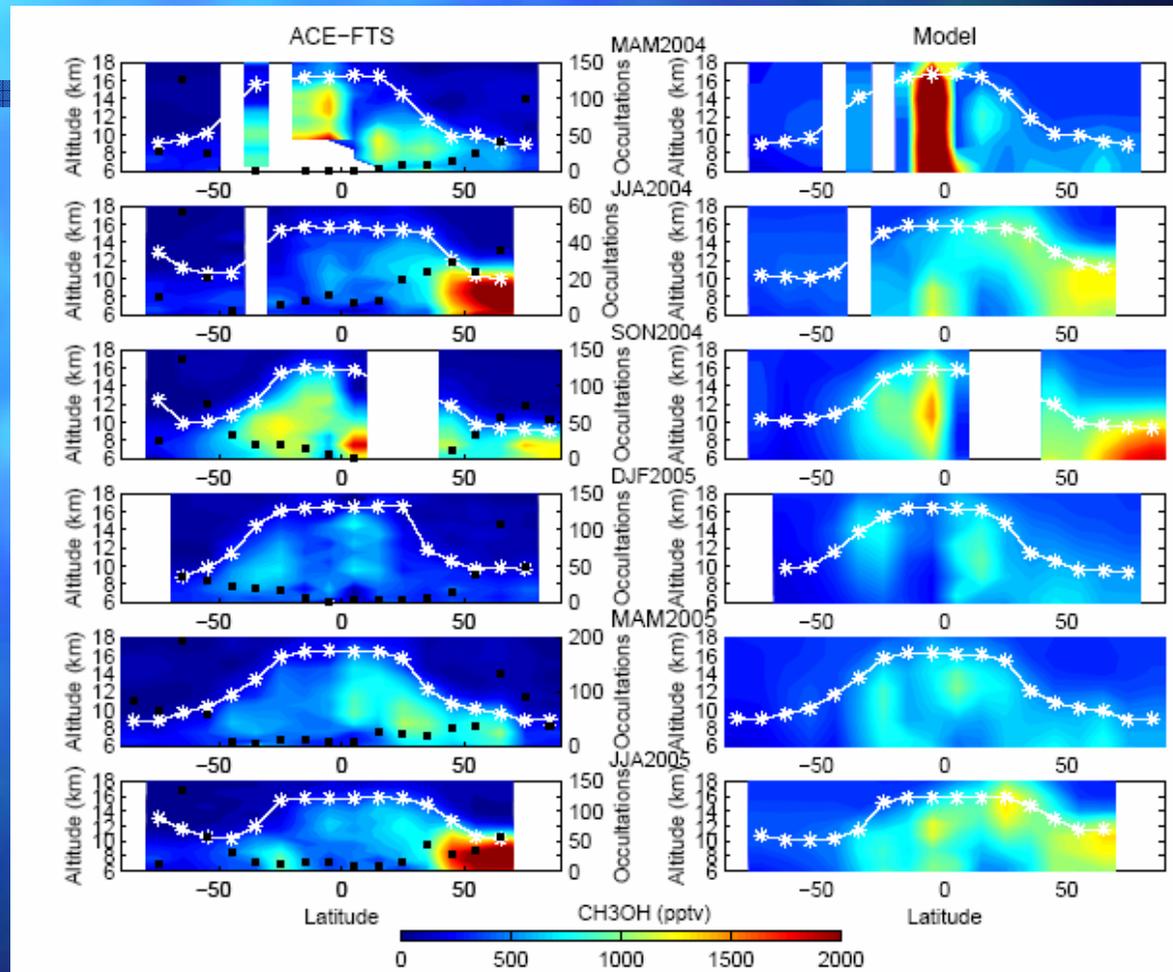
Dufour, G., C.D. Boone, C.P. Rinsland, P.F. Bernath (2006), First space-borne measurements of methanol inside aged southern tropical to mid-latitude biomass burning plumes using the ACE-FTS instrument, *Atmos. Chem. Phys.*, 6, 3463-3470



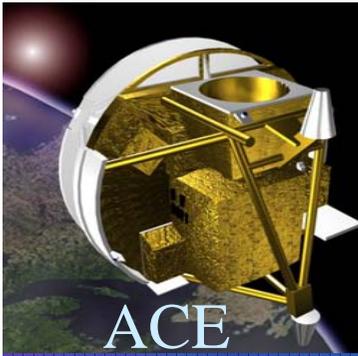
ACE



# CH<sub>3</sub>OH distributions

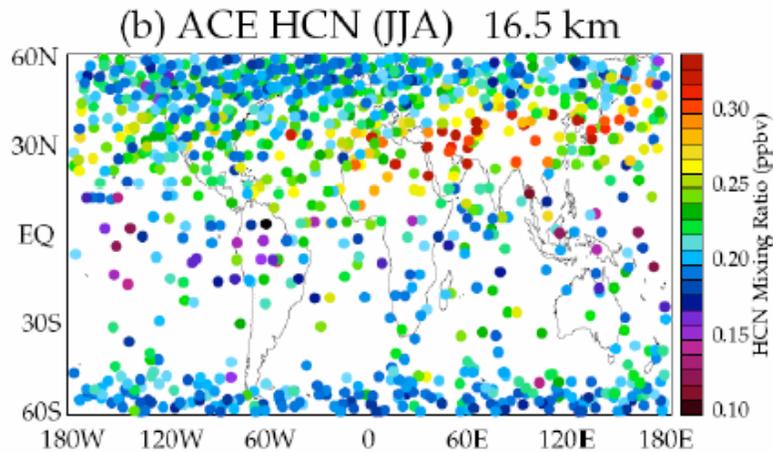
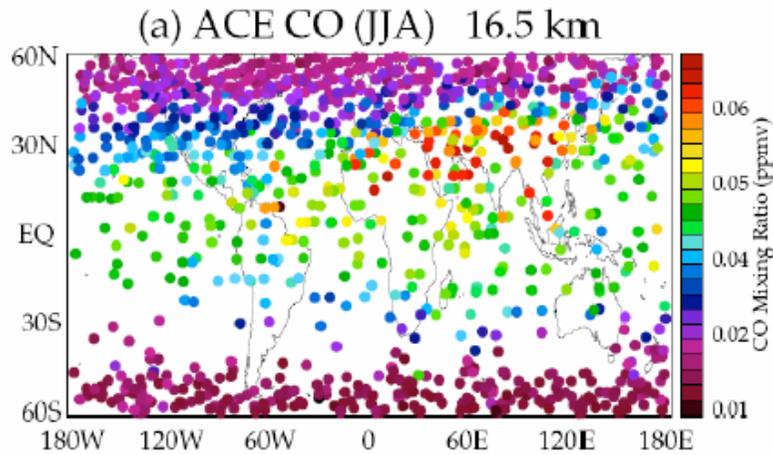


Dufour, G., S. Szopa, D.A. Hauglustaine, C.D. Boone, C.P. Rinsland, and P.F. Bernath (2007), The influence of biogenic emissions on upper-tropospheric methanol as revealed from space, *Atmos. Chem. Phys. Discuss.*, 7, 9183-9202, (2007).

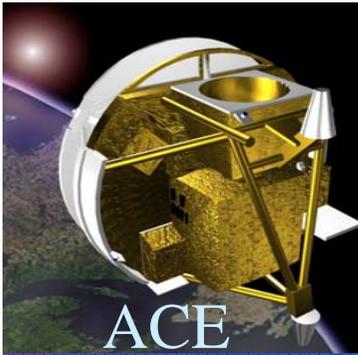


ACE

# Asian Monsoon Region



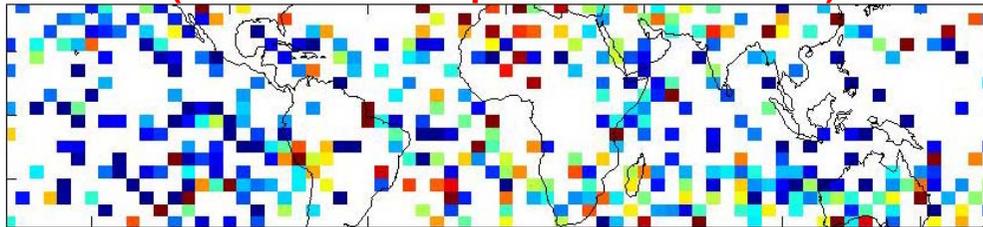
M. Park et al,  
submitted July 2007



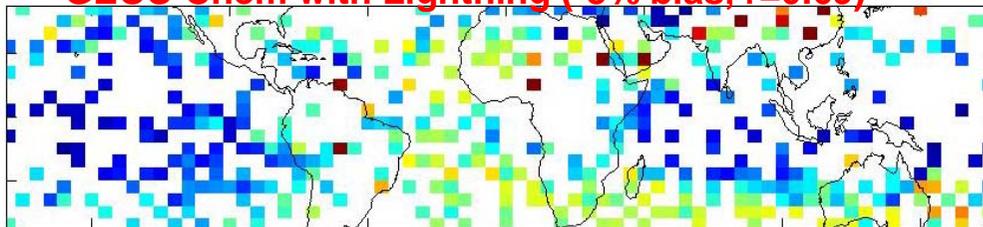
# HNO<sub>3</sub> from Lightning



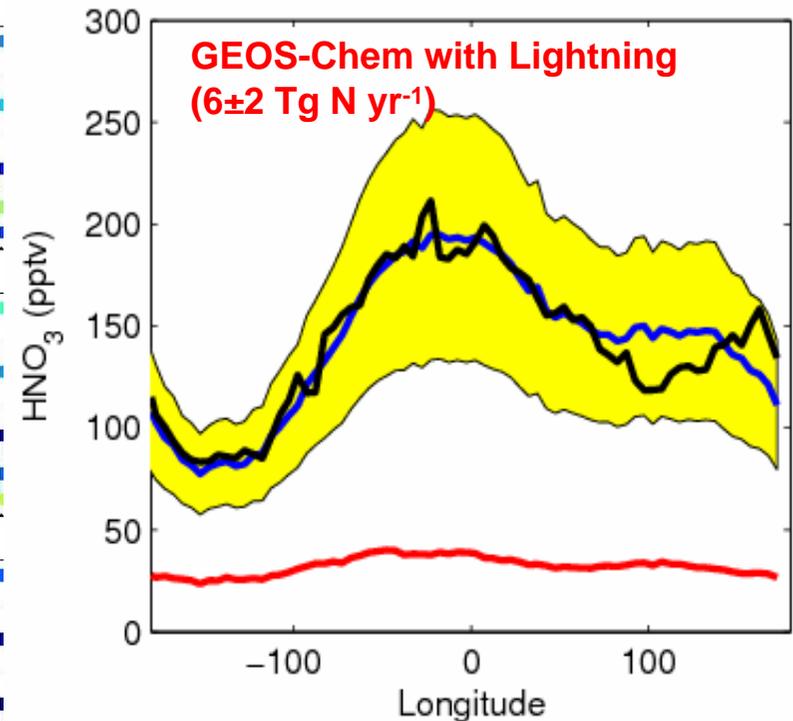
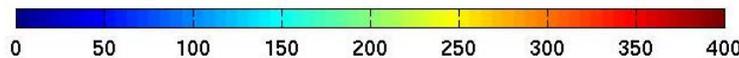
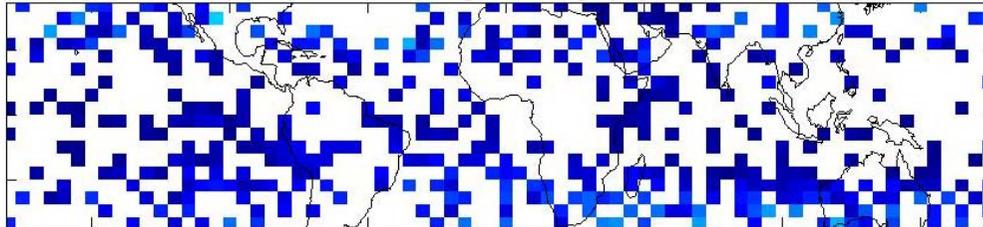
ACE (Uses 80% of Tropical Measurements)



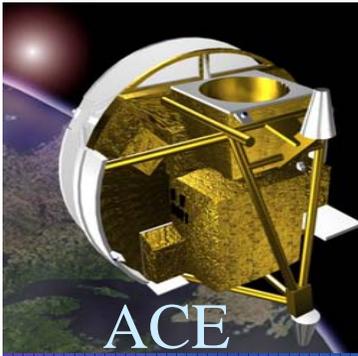
GEOS-Chem with Lightning (-8% bias, r=0.69)



GEOS-Chem without Lightning (-76% bias, r=0.17)



Martin, Randall V., Bastien Sauvage, Ian Folkins, Christopher E. Sioris, Christopher Boone, Peter Bernath and Jerry Ziemke (2007), Space-based constraints on the production of nitric oxide by lightning, *J. Geophys. Res.*, Vol. 112, D09309, doi:10.1029/2006JD007831

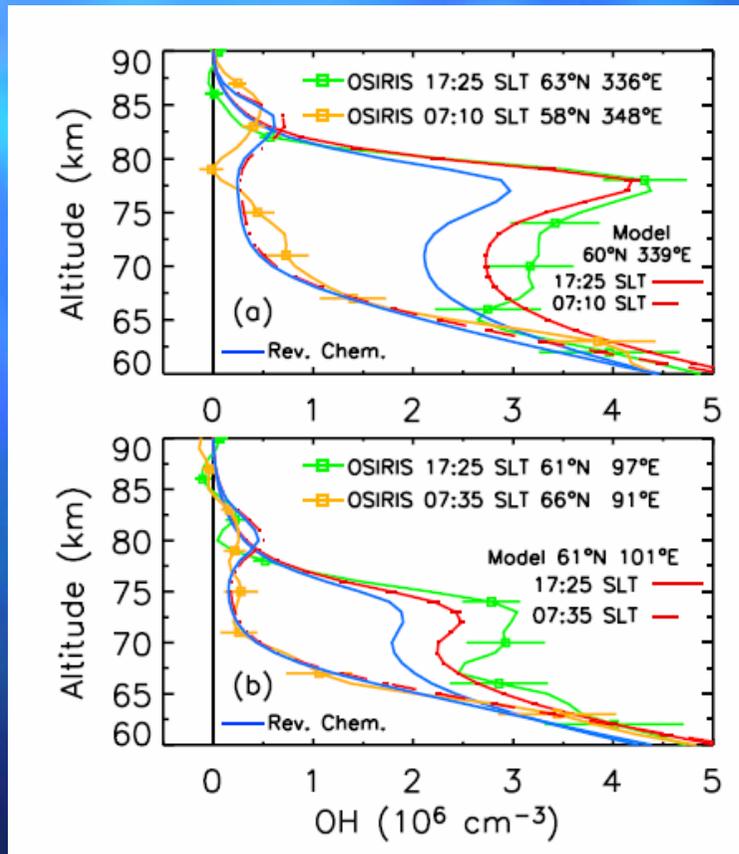


ACE

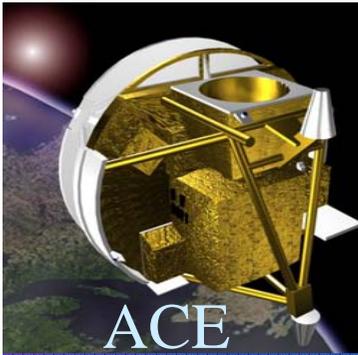


# OH

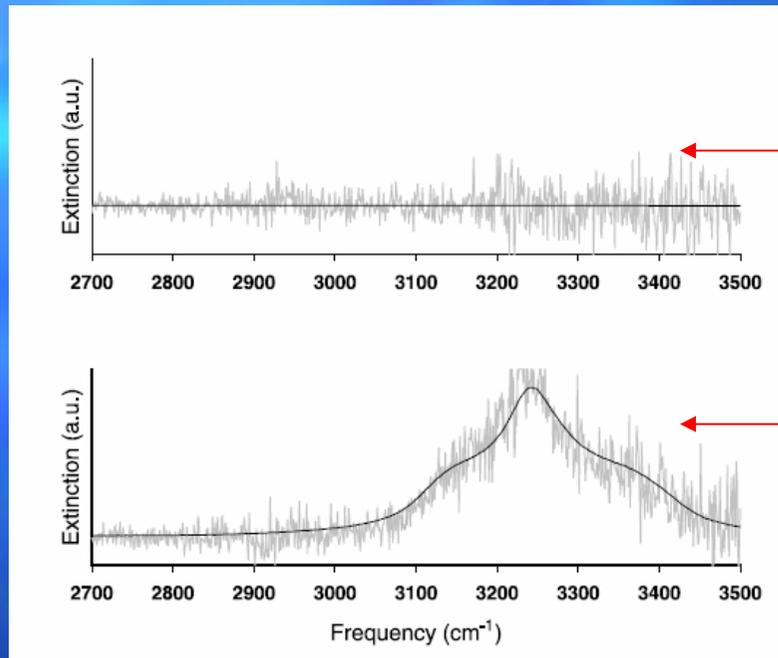
Using ACE-FTS  $\text{H}_2\text{O}$ , temperature, and density, calculate OH from a model and compare with OSIRIS measurements.



Gattinger, R. L., C. D. Boone, K. A. Walker, D. A. Degenstein, P. F. Bernath, and E. J. Llewellyn (2006), Comparison of Odin-OSIRIS OH A-X 0-0 mesospheric observations and ACE-FTS water vapor observations, *Geophys. Res. Lett.*, 33, L15808, doi:10.1029/2006GL026425



# Polar Mesospheric Clouds

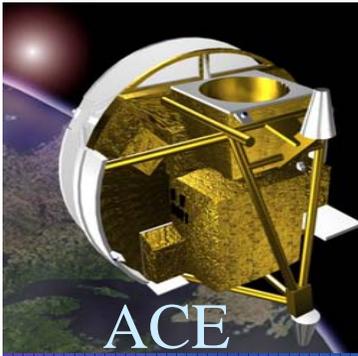


Near 3200 cm<sup>-1</sup>, measurements at high altitude (~80 km) are clear in the absence of PMCs

PMC present, the OH vibrational band for ice particles clearly visible

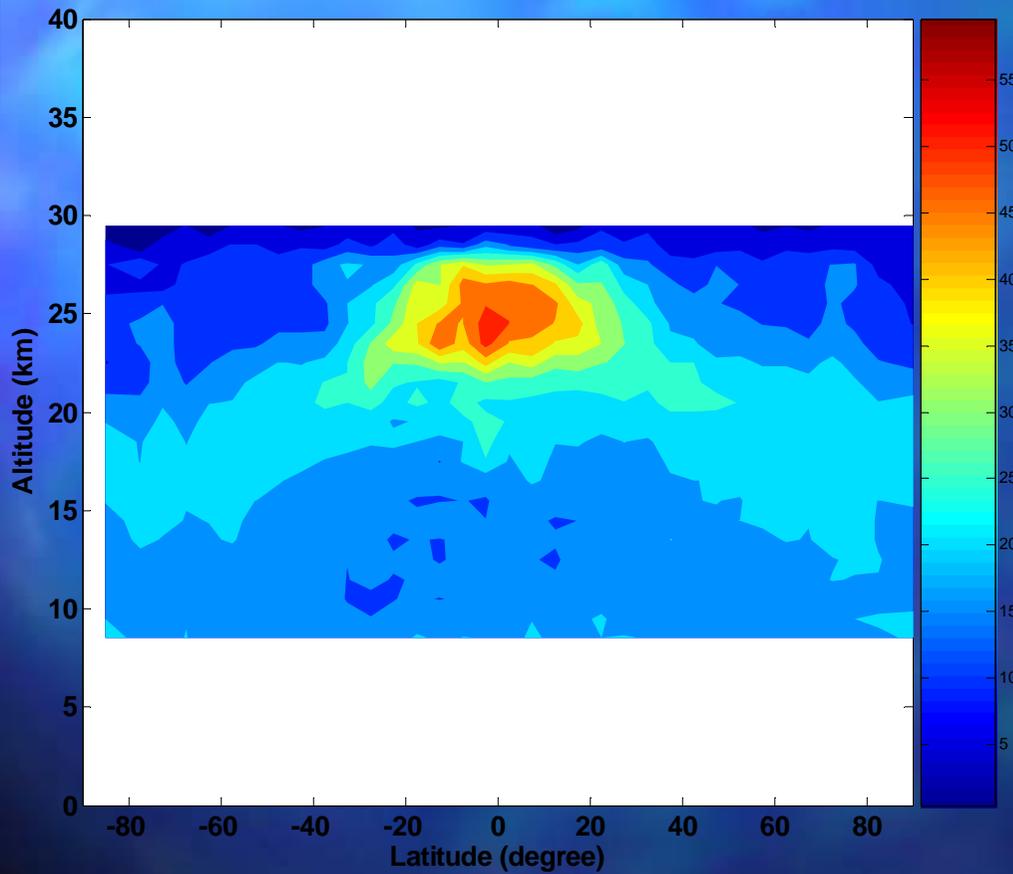
The shape of the spectral feature provides information on the composition of the PMC particles.

Eremenko, M. N., S. V. Petelina, A. Y. Zasetsky, B. Karlsson, C. P. Rinsland, E. J. Llewellyn, and J. J. Sloan (2005), Shape and composition of PMC particles derived from satellite remote sensing measurements, *Geophys. Res. Lett.*, 32, L16S06, doi:10.1029/2005GL023013



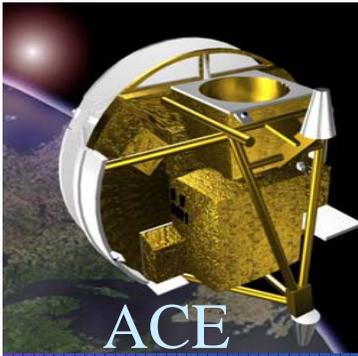
ACE

$\text{COCl}_2$

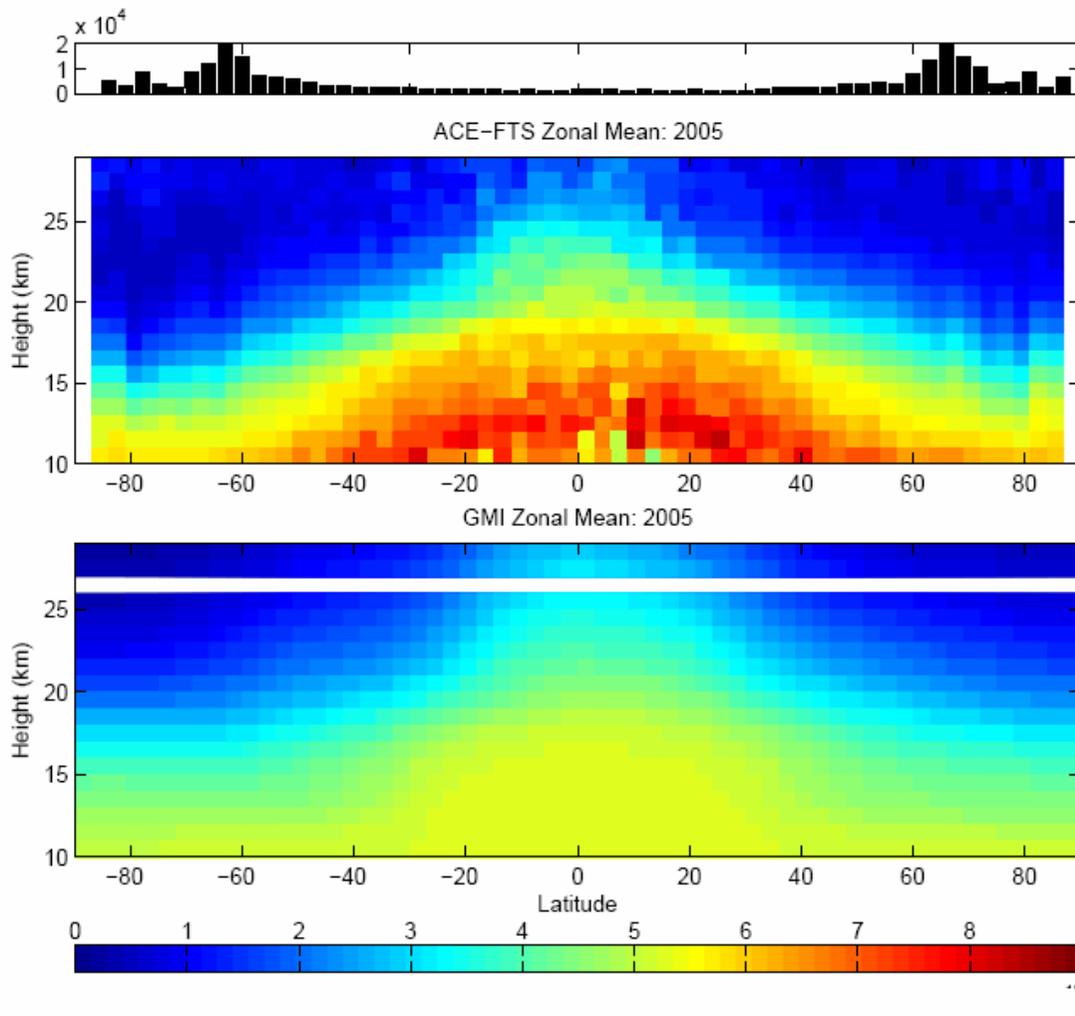


D. Fu et al, accepted  
to GRL August 2007

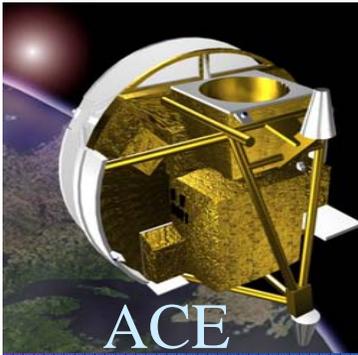
Similar studies are  
upcoming for  $\text{COF}_2$   
and  $\text{COClF}$ .



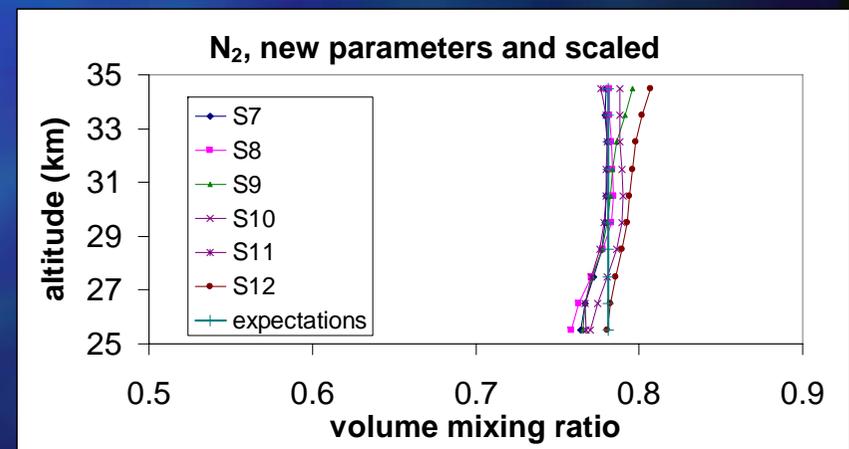
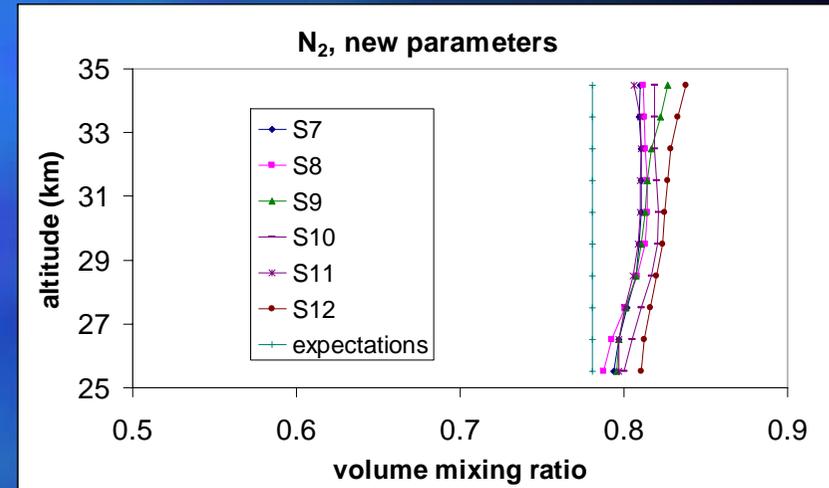
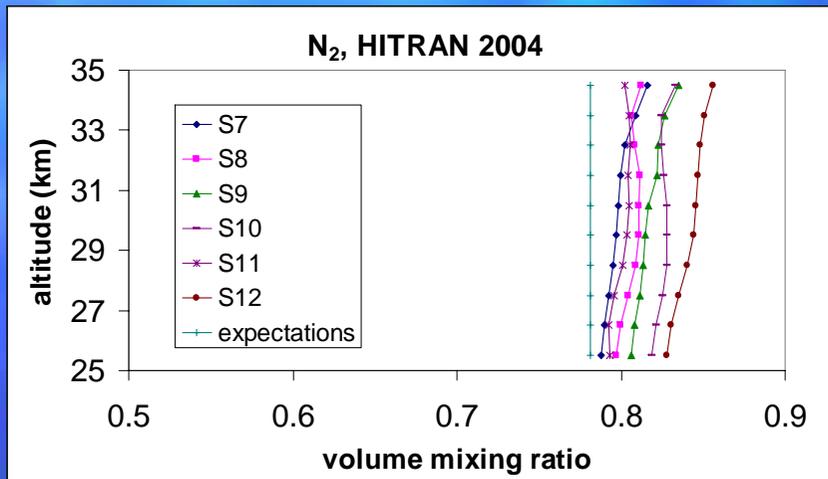
ACE



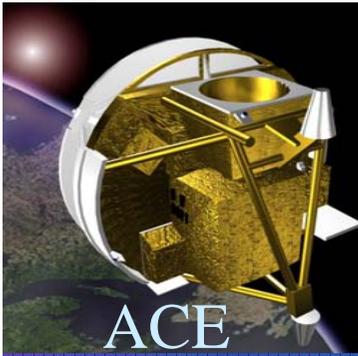
Model missing CH<sub>3</sub>Cl sources (e.g., tropical plants). Paper in preparation.



N<sub>2</sub>



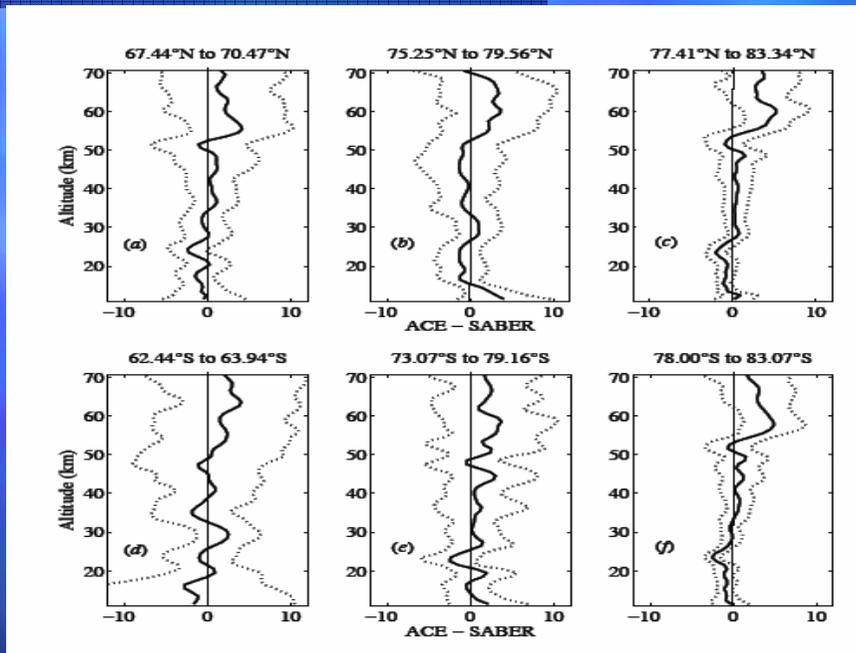
Goldman, A., R.H. Tipping, Q. Ma, C.D. Boone, P.F. Bernath, P. Demoulin, F. Hase, M. Schneider, J.W. Hannigan, M.T. Coffey and C.P. Rinsland (2006), On the Line Parameters for the (1-0) quadrupolar transitions of N<sub>2</sub>, Journal of Quantitative Spectroscopy and Radiative Transfer, 103 (2007) 168-174.



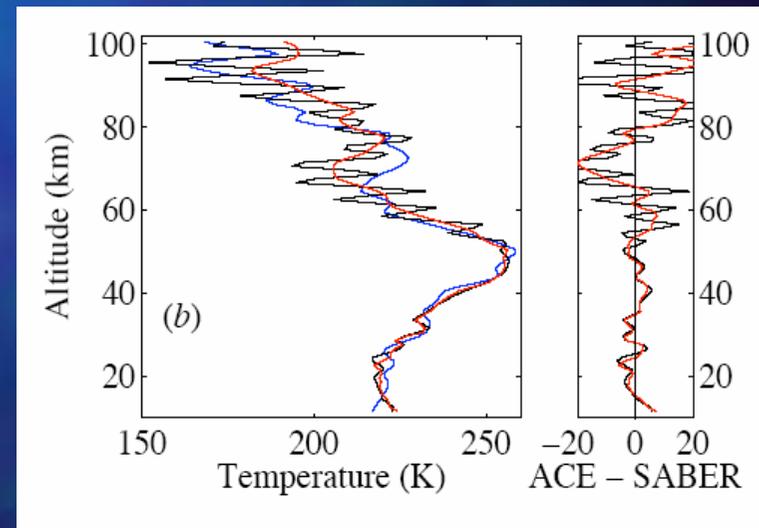
# T validation results

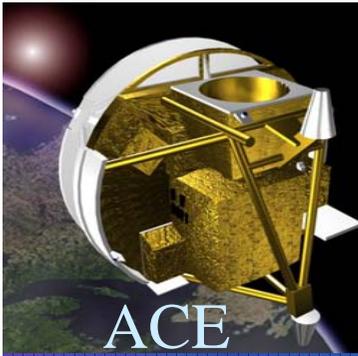
Upcoming ACE special validation issue in ACP

Blue curve: SABRE  
black curve: ACE-FTS v2.2  
red curve: ACE-FTS v3.0



Good agreement with other data sets, although some (~10 %) T profiles exhibit unphysical oscillation (fixed for the next processing version).



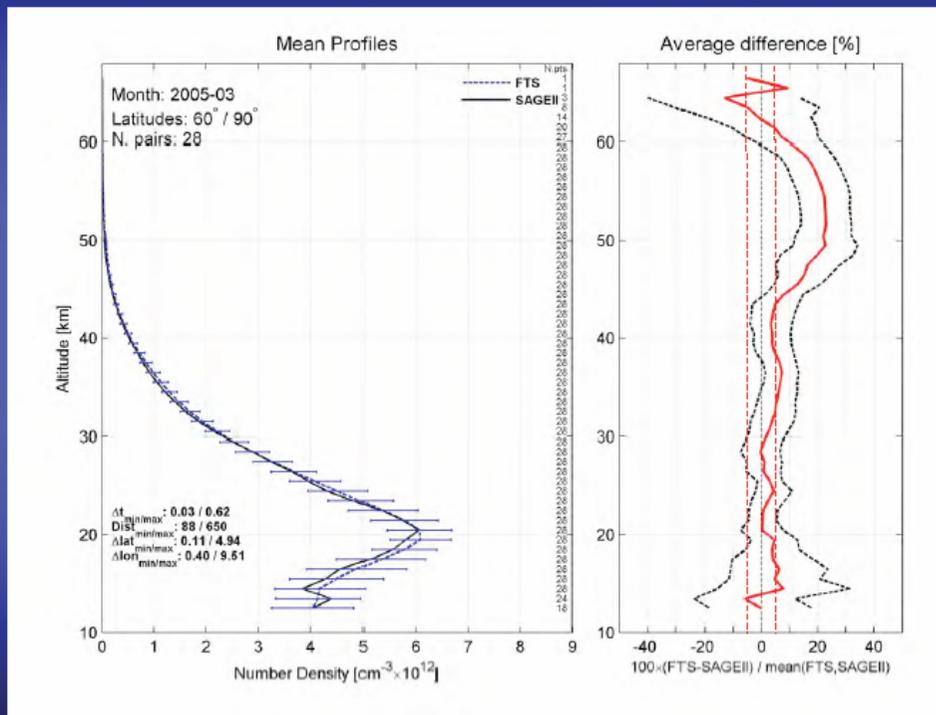


ACE

# O<sub>3</sub> validation results

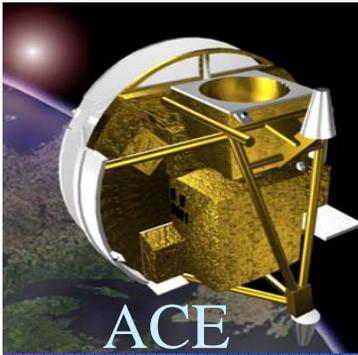


## FTS - SAGE II: Mean profiles 2005-03



Comparison compiled by Eric Dupuy. ACE-FTS results show a high bias between 40 and 60 km.

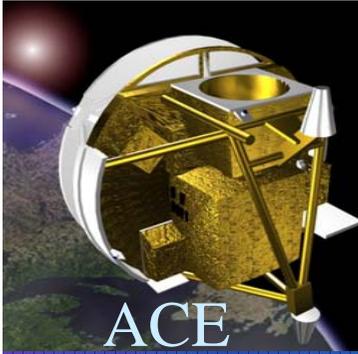
Upcoming ACE special validation issue in ACP



# H<sub>2</sub>O line shape



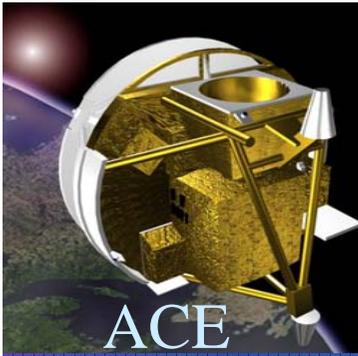
- The Voigt function is not sufficiently accurate to model the line shape of water for the ACE-FTS measurements.
- Collisional effects (changes of velocity during collisions and/or the dependence of collisional parameters on absorber velocities) yield deviations from the Voigt profile.



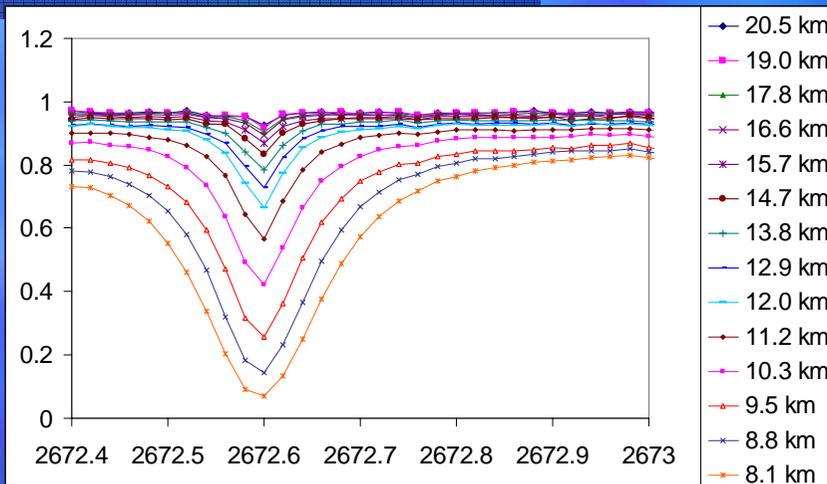
# Speed-dependent Voigt



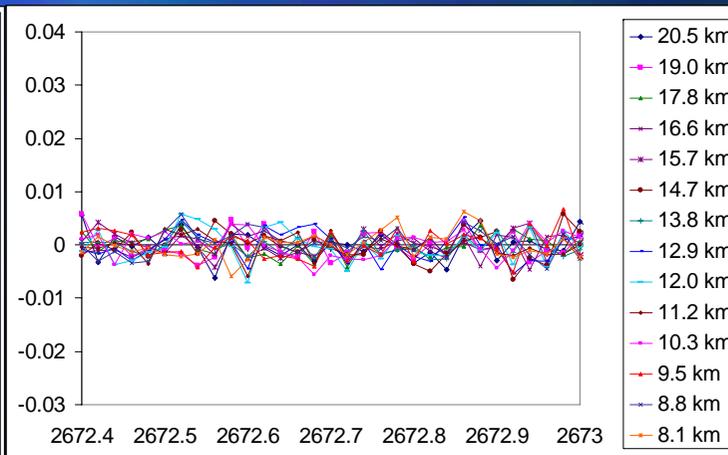
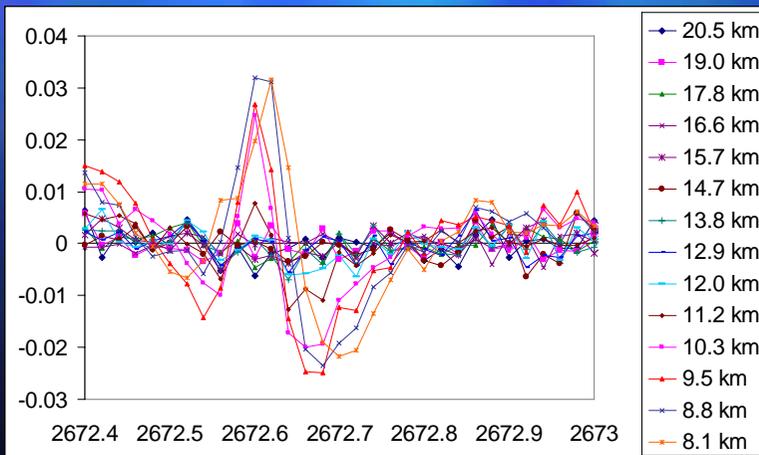
- Generated an analytical approach for calculation of the speed-dependent Voigt line shape, expressed as the difference between two Voigt functions
- Slower calculation than for the Voigt function, but the improved accuracy is needed for improving water retrievals.
- Does not include the effects of velocity changes during collision.



# Example HDO line (sr10909)

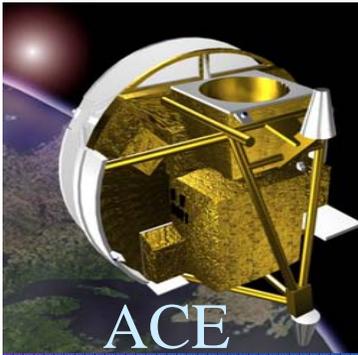


Boone, Chris D., Kaley A. Walker and Peter F. Bernath, Speed-dependent Voigt profile for water vapor in infrared remote sensing applications, *Journal of Quantitative Spectroscopy and Radiative Transfer*, 105 (2007) 525-532.



Voigt profile

Speed-dependent Voigt profile



# Summary



- Over four years in orbit, 3.5 years (and counting) worth of measurements.
- Starting to look at global distributions and year-to-year variations.
- A wealth of information still to be mined from the ACE data.
- A new processing version (v3.0) in development, to start later this year after feedback from validation partners.