ACE-FTS measurements of anthropogenic ozone depleting substances

Felicia Kolonjari[1], Kaley A. Walker[1, 2], Chris D. Boone[2], Susan Strahan[3], Chris McLinden[4], Gloria L. Manney[5*,6], William H. Daffer[5], and Peter F. Bernath[7,8]

[1]Department of Physics, University of Toronto, Toronto, Canada
[2]Department of Chemistry, University of Waterloo, Waterloo, Canada
[3]Universities Space Research Association & NASA Goddard Space Flight Center, Greenbelt, USA
[4]Environment Canada, Toronto, Canada
[5]Jet Propulsion Laboratory, Pasadena, USA
[6]Department of Physics, New Mexico Institute of Mining and Technology, Socorro, USA
[7]Department of Chemistry & Biochemistry, Old Dominion University, Norfolk, USA
[8]Department of Chemistry, University of York, York, UK
* Now at NorthWest Research Associates, Socorro, USA

SPARC-DA Workshop, Soccoro, NM, June 11-13, 2012

Outline

- How does ACE-FTS measure ODSs?
- Why should CFCs and HCFCs be examined?
- What do the ACE-FTS measurements look like?
- How do they compare to independent measurements?
- How does the GMI model represent these ODSs?

The Atmospheric Chemistry Experiment (ACE)

- On-board Canadian satellite SCISAT launched on August 12th 2003
- The primary goal of the mission is to study the chemical and dynamical processes controlling ozone distribution.

- The primary instrument is a Fourier transform spectrometer (ACE-FTS)
  - ➡ High spectral resolution (0.02 cm^{-1}) infrared FTS
  - ➡ Wide spectral range (750-4400 cm^{-1}) provides profiles of over 30 atmospheric species

Occultation Technique

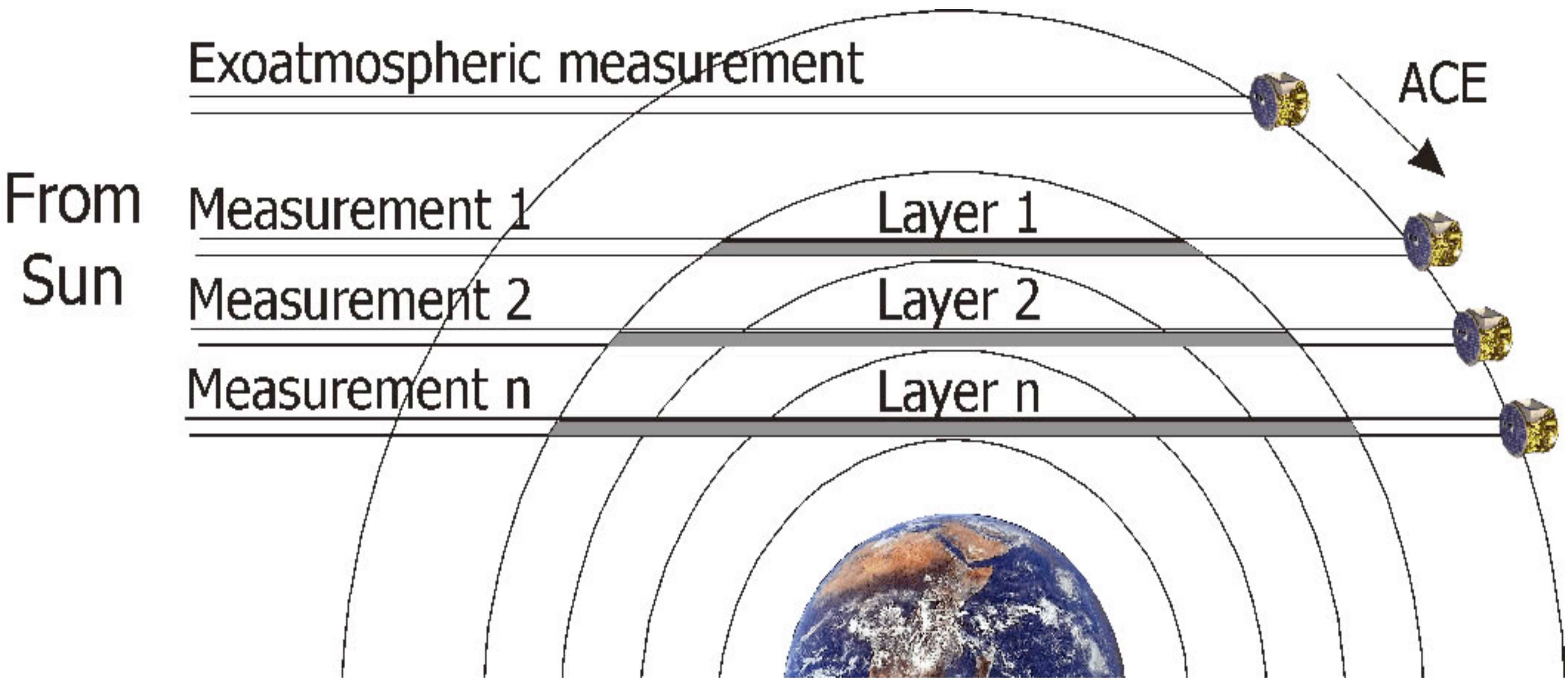
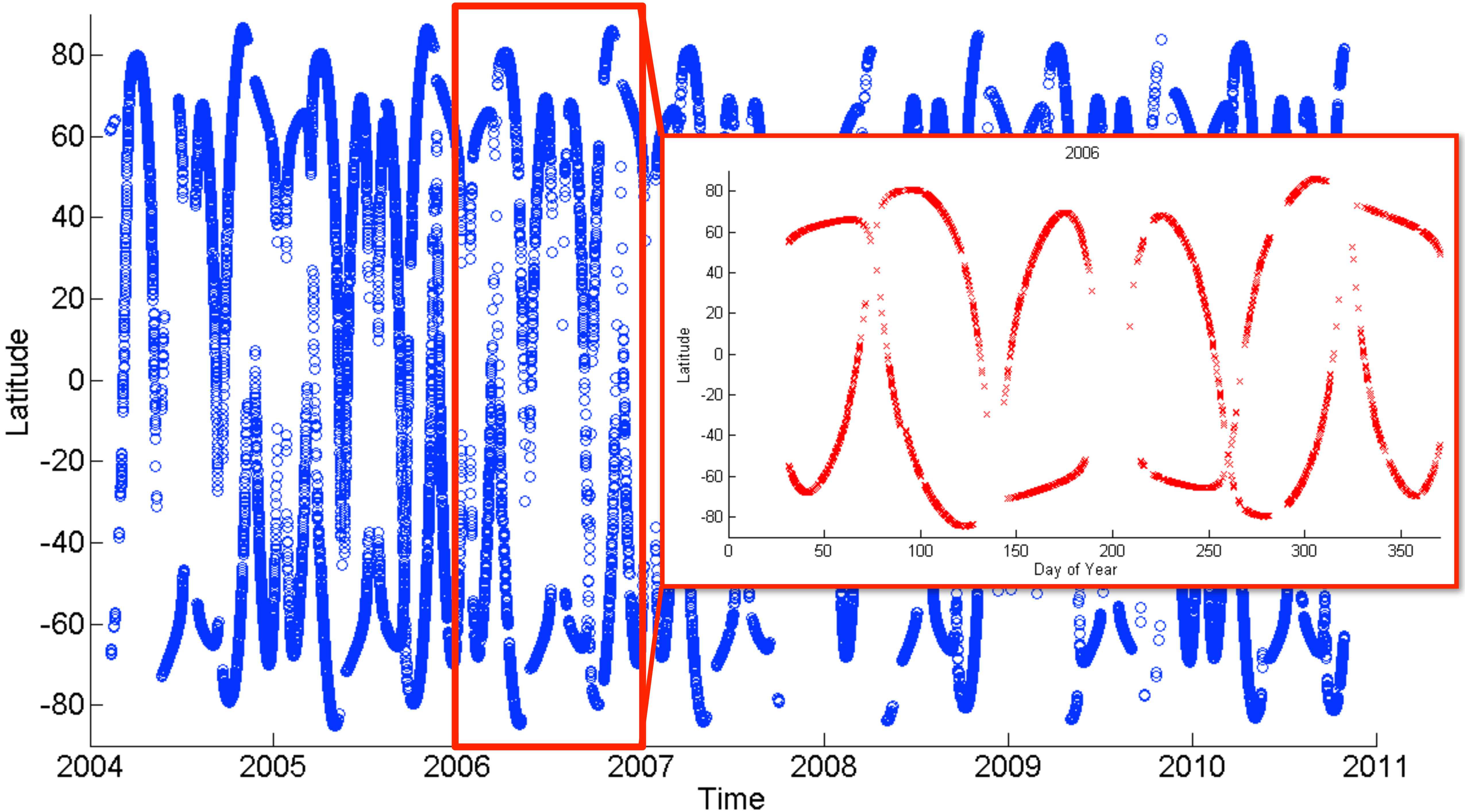
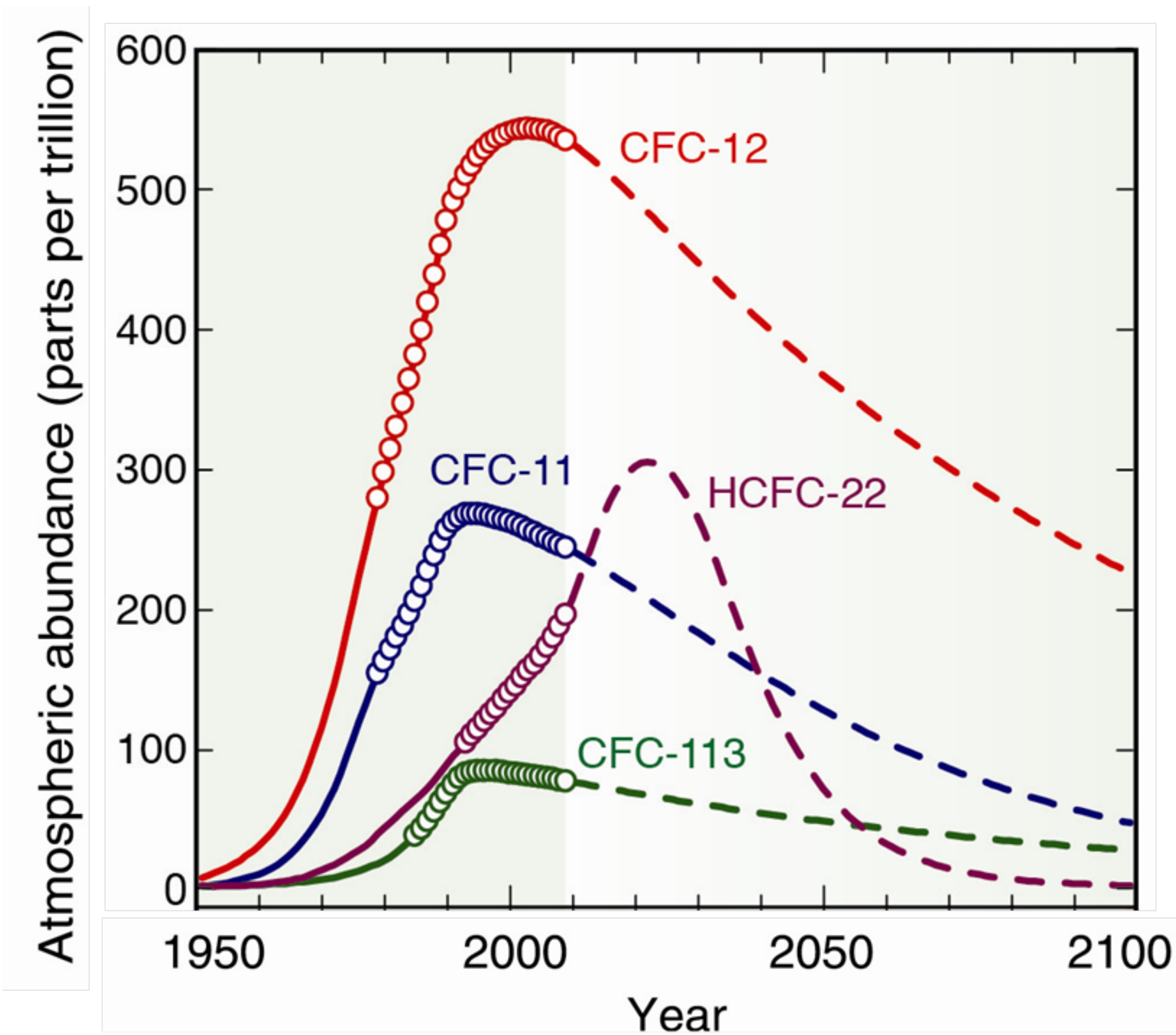


Figure courtesy of Dr. Ray Nassar

ACE Latitude Sampling



Motivation



Taken from: Figure Q16-1 (WMO, 2011)

HCFC-22 has replaced CFC-11 and CFC-12

Increase in atmospheric abundance is of concern because of its ozone depletion potential (0.055) and its global warming potential (1810)

The phase out of HCFC-22 began on January 1, 2010

Observations included are based upon atmospheric samples at the surface

CFC Chemistry

CFC-11 stratospheric loss process

$CFCl_3 + O(^1D) \rightarrow 3Cl + products$

$CFCl_3 + hv \rightarrow 3Cl + products$

CFC-12 stratospheric loss processes

$CF_2Cl_2 + O(^1D) \rightarrow 2Cl + products$

$CF_2Cl_2 + hv \rightarrow 2Cl + products$

HCFC-22 Chemistry

Four reactions govern the loss of HCFC-22 (CHF_2Cl) in the troposphere and stratosphere.

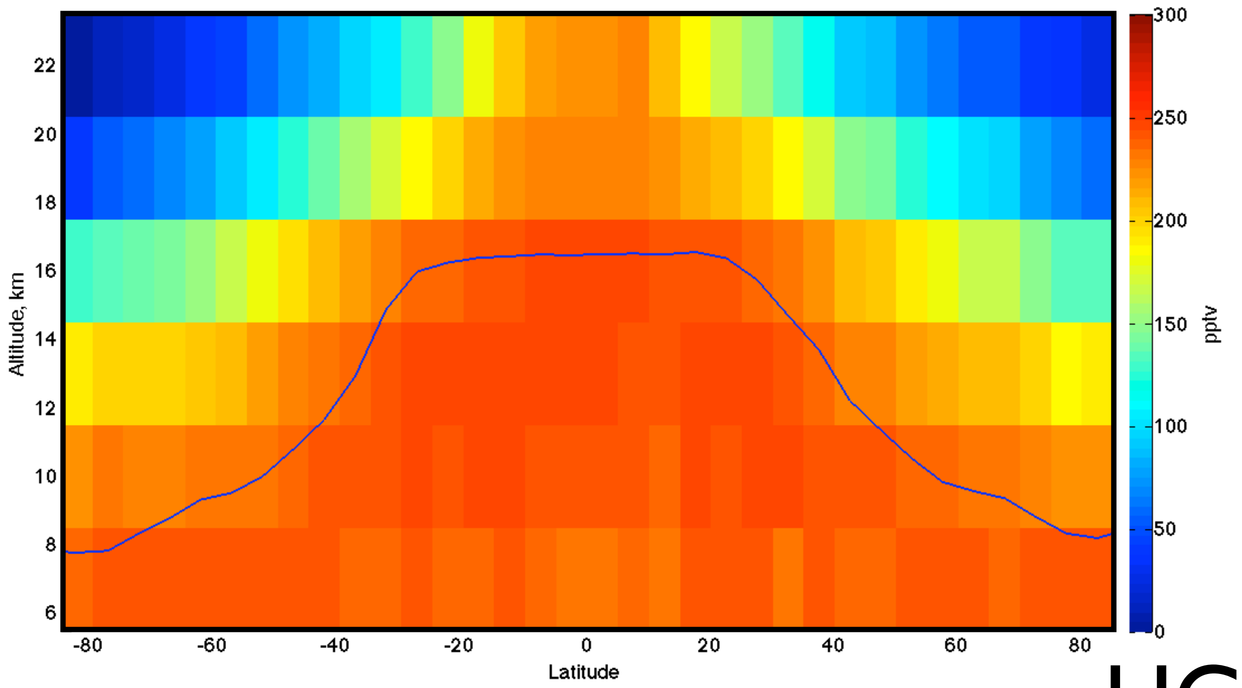
$$CHF_2Cl + OH \rightarrow Cl + H_2O + \text{products}$$

$$CHF_2Cl + O(^1D) \rightarrow Cl + \text{products}$$

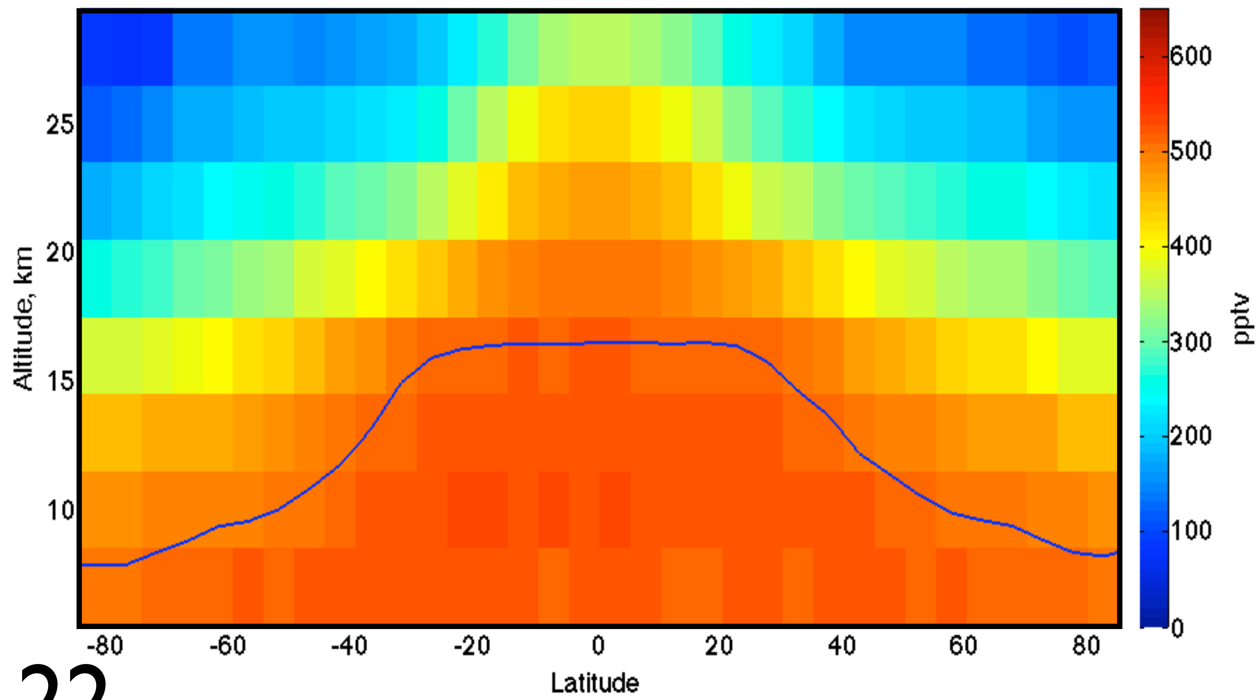
$$CHF_2Cl + h\nu \rightarrow Cl + \text{products}$$

$$CHF_2Cl + Cl \rightarrow HCl + \text{products}$$

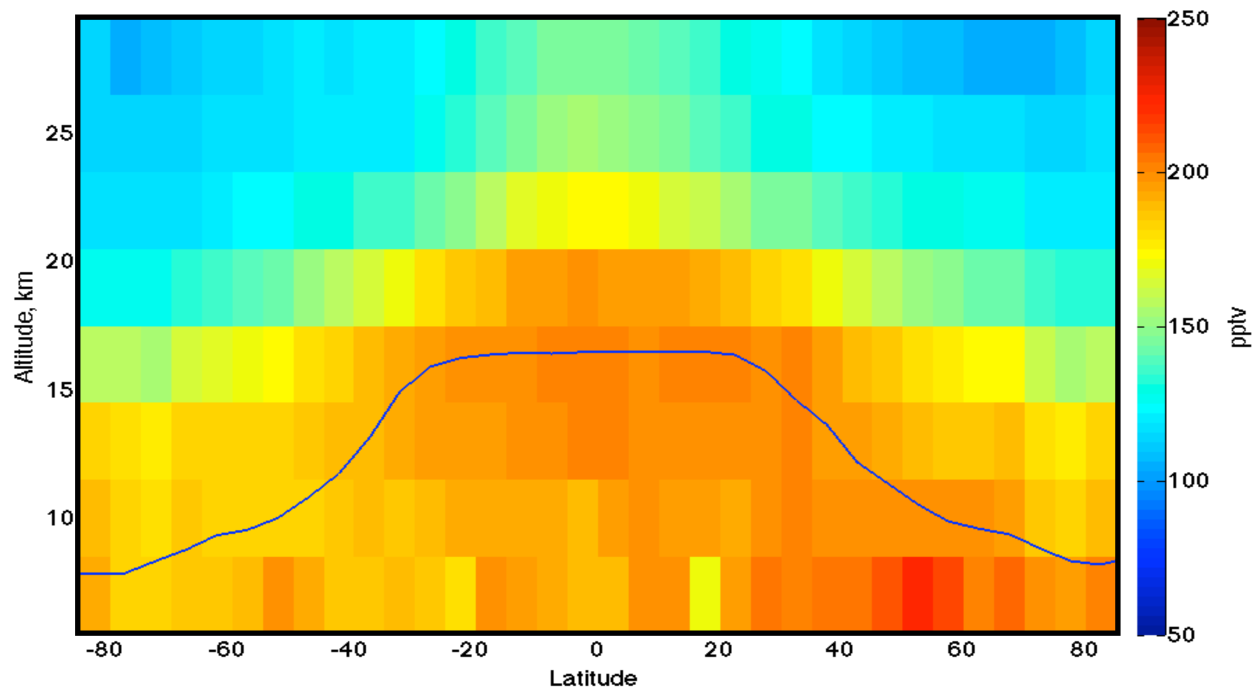
CFC-11
Validated V2.2



CFC-12
Research Product



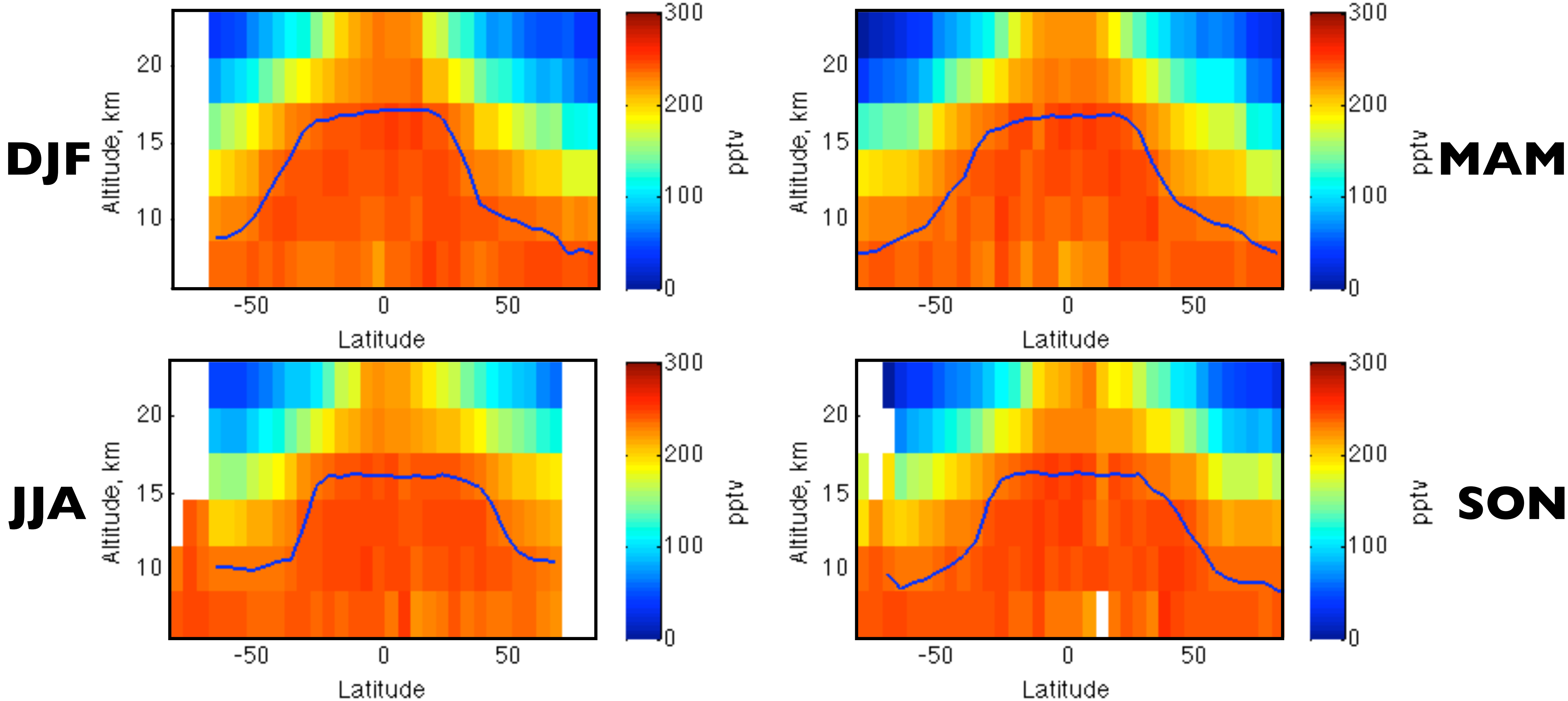
HCFC-22
Research Product



ACE-FTS data 2004-2010 with extra-vortex occultations only

Blue line indicates tropopause calculated by the WMO temperature definition

CFC-11 Seasonal Zonal Means

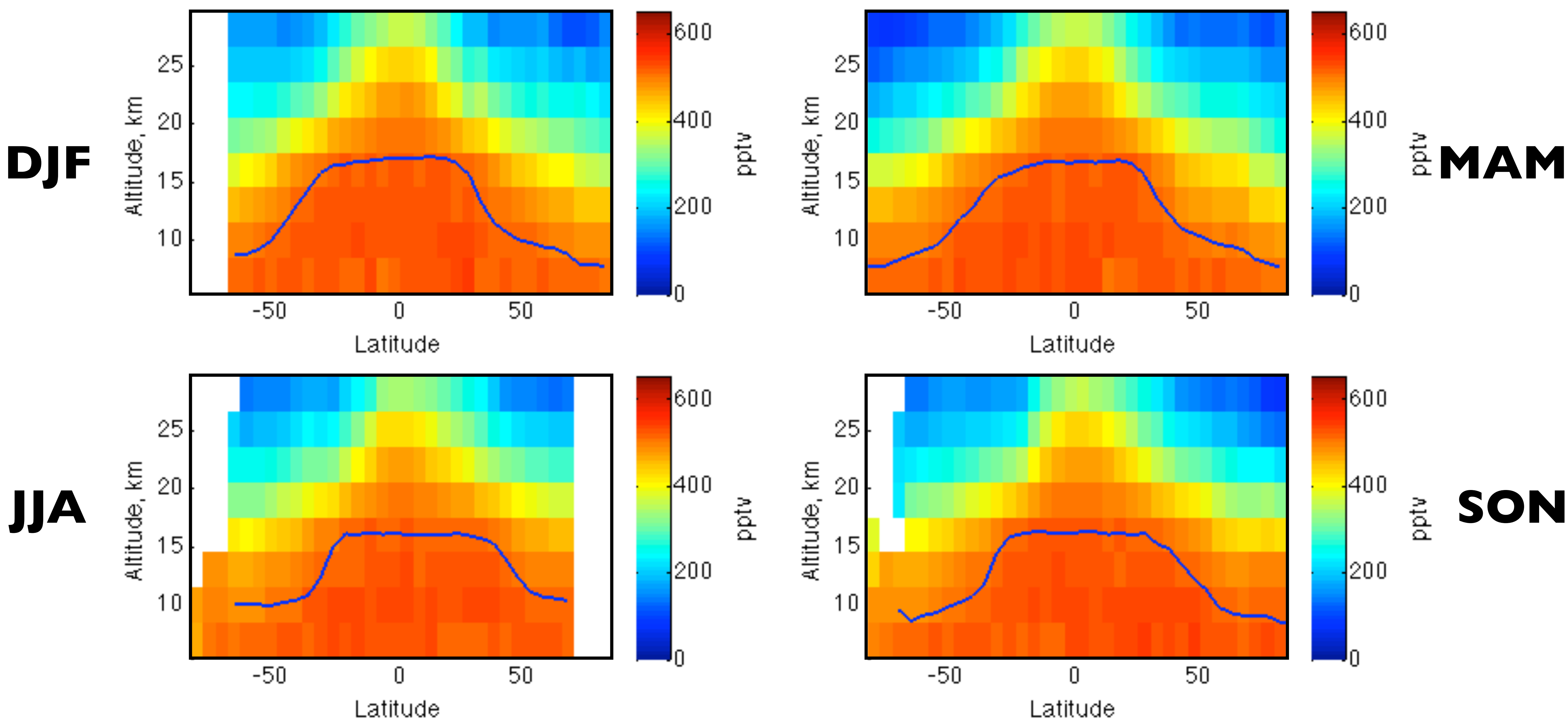


ACE-FTS data 2004-2010 with extra-vortex occultations only

Blue line indicates tropopause calculated by the WMO temperature definition

DMPs provided by Gloria Manney and William Daffer (JPL)

CFC-12 Seasonal Zonal Means

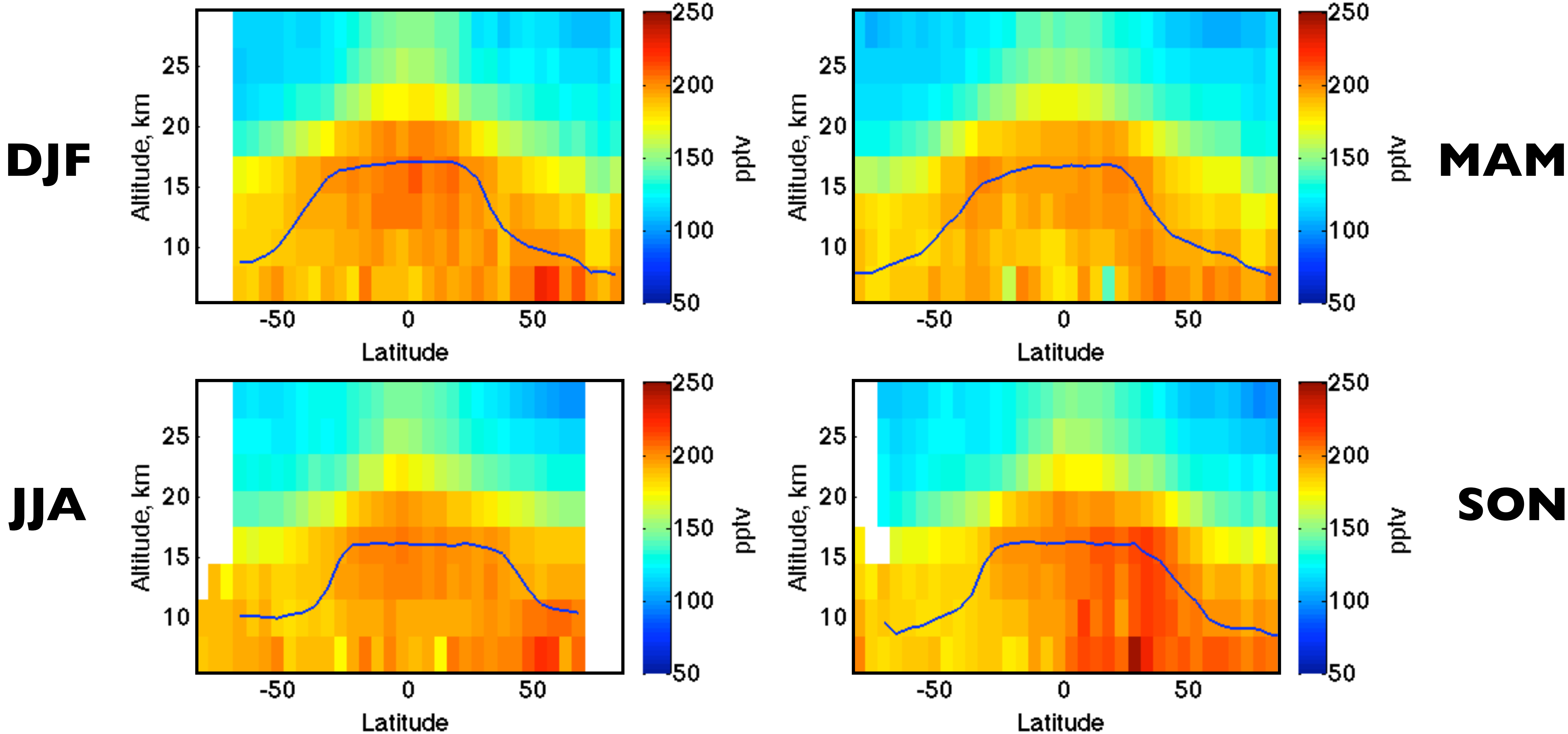


ACE-FTS data 2004-2010 with extra-vortex occultations only

Blue line indicates tropopause calculated by the WMO temperature definition

DMPs provided by Gloria Manney and William Daffer (JPL)

HCFC-22 Seasonal Zonal Means

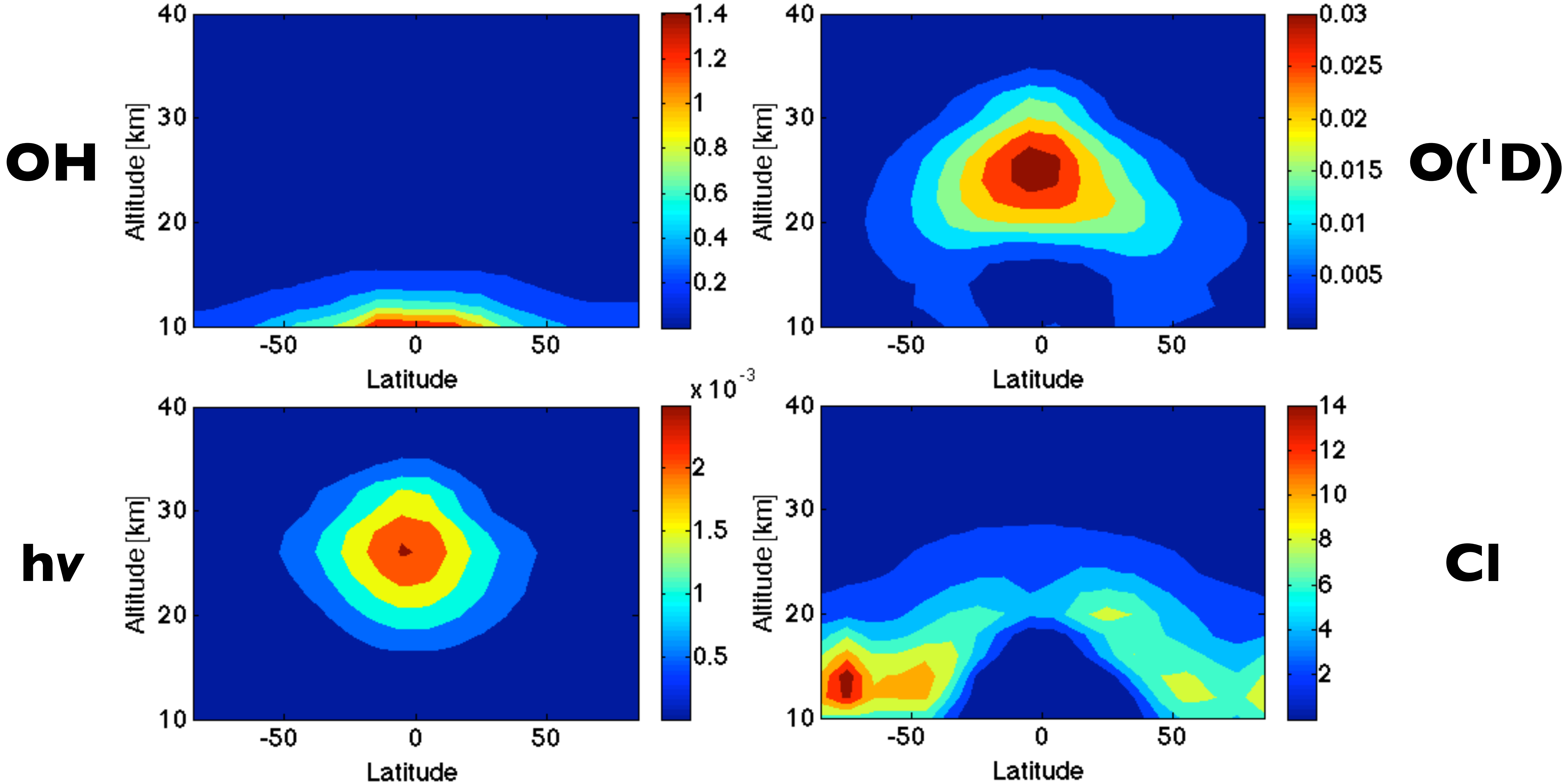


ACE-FTS data 2004-2010 with extra-vortex occultations only

Blue line indicates tropopause calculated by the WMO temperature definition

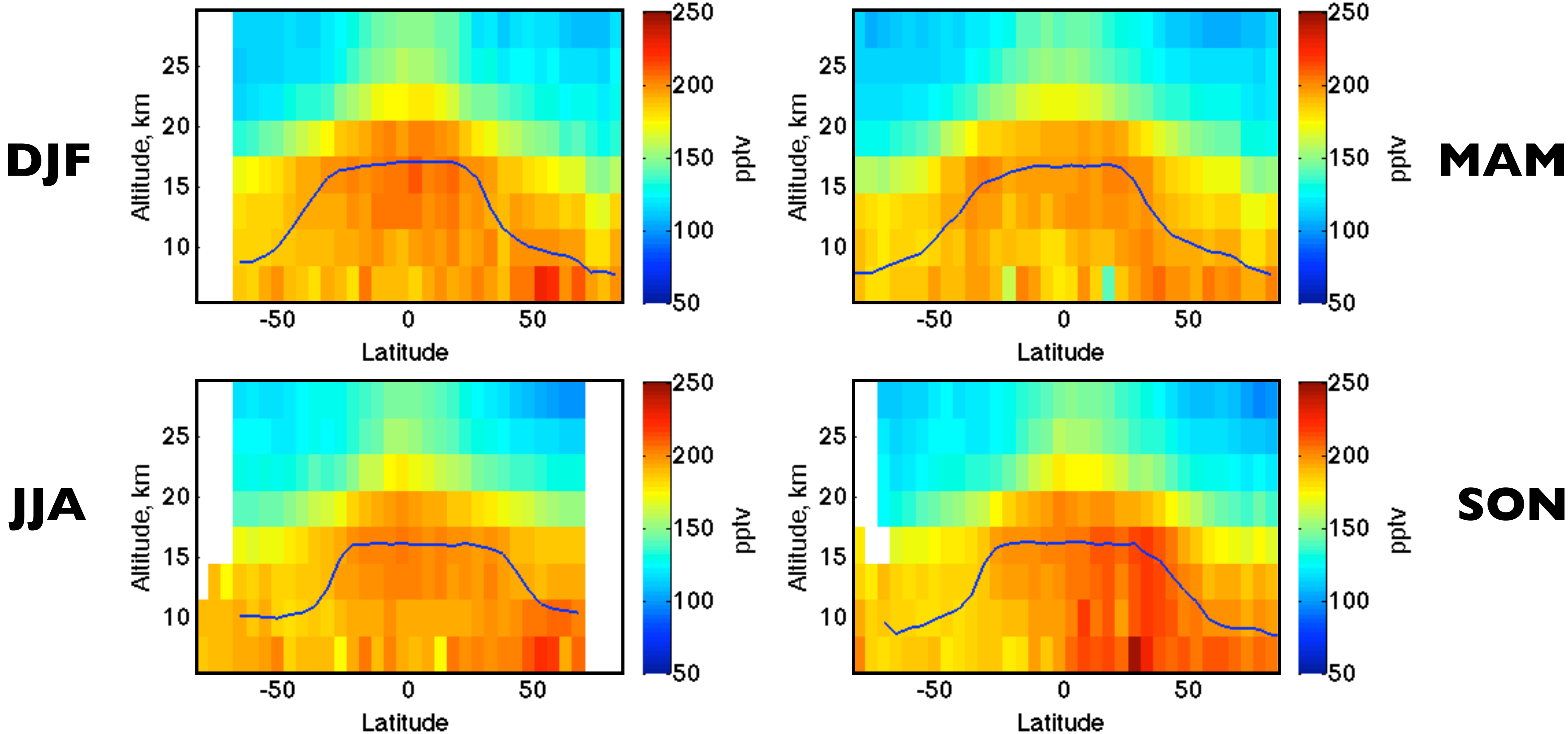
 DMPs provided by Gloria Manney and William Daffer (JPL)

HCFC-22
Chemical Loss Rates



Modelled annual loss rates (molec/cm^3/s) from a CTM (McLinden, 2003)

HCFC-22 Seasonal Zonal Means



ACE-FTS data 2004-2010 with extra-vortex occultations only

Blue line indicates tropopause calculated by the WMO temperature definition

DMPs provided by Gloria Manney and William Daffer (JPL)

Data Comparisons: In situ measurements at the surface

SPECIES	Site	Cape Grim, Australia (CGO)	Mace Head, Ireland (MHD)	Ragged Point, Barbados (RPB)	Cape Matatula, American Samoa (SMO)	Trinidad Head, USA (THD)
	Latitude	40.68° S	53.33° N	13.17° N	14.23° S	41.05° N
CFC-11	Average Difference (%)	-1.50	-3.20	-2.80	-4.04	-3.21
	Std Dev Difference(%)	4.72	2.43	2.63	11.21	3.12
CFC-12	Average Difference (%)	-3.84	-4.72	-4.11	-3.15	-4.09
	Std Dev Difference(%)	2.83	2.40	2.12	1.25	1.68
HCFC-22	Average Difference (%)	10.03	5.64	5.95	11.44	2.94
	Std Dev Difference(%)	3.40	6.96	3.76	3.25	4.59

Surface data courtesy of the AGAGE Network

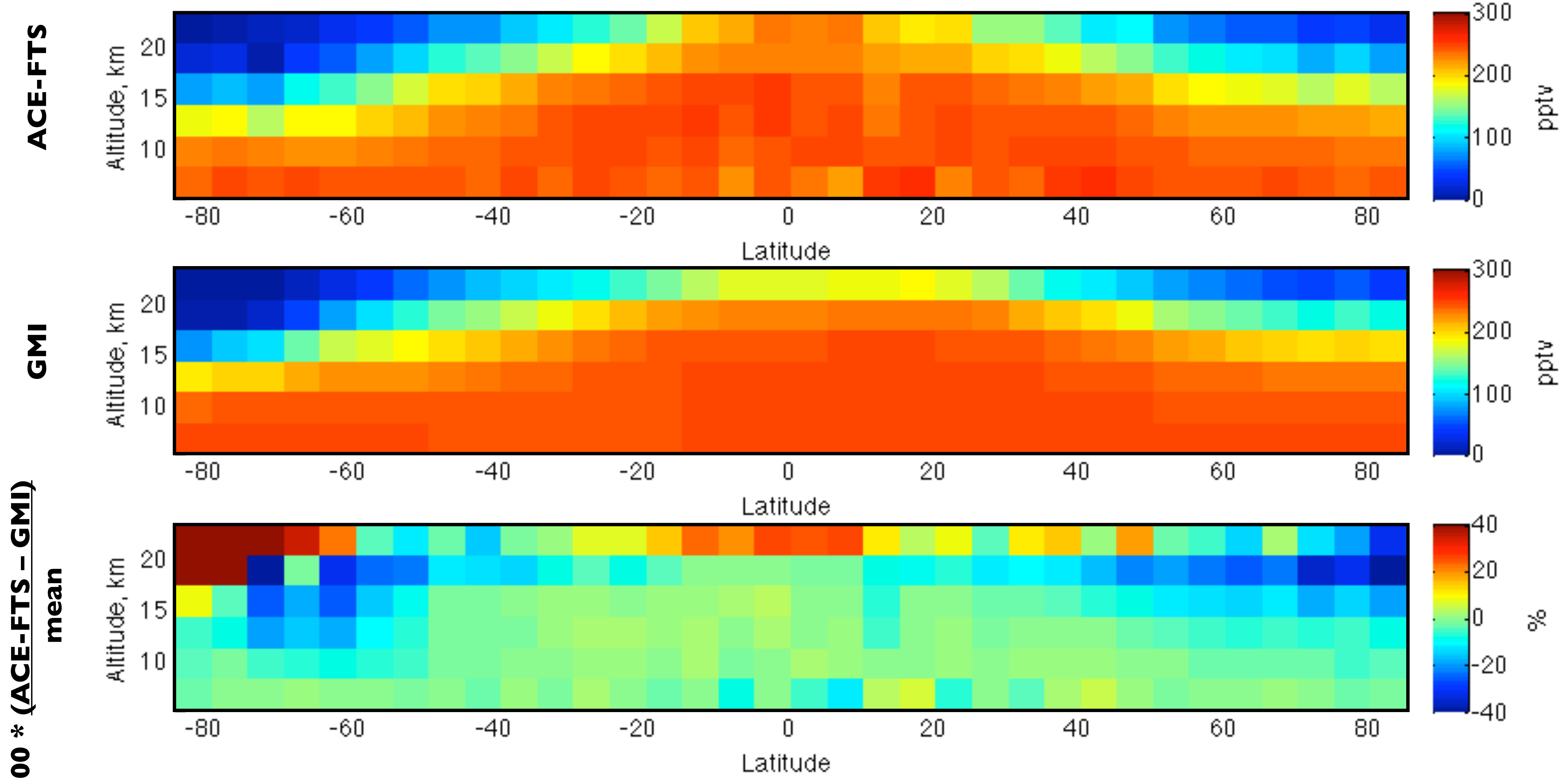
Global Modeling Initiative Combination Troposphere-Stratosphere Model

- Chemical Transport Model that incorporates reactions that are important in both the troposphere and stratosphere (Rotman et al., 2001)
- CFC-11 loss processes $CFCl_3 + h\nu \rightarrow 3Cl + \text{products}$
- CFC-12 loss processes $CF_2Cl_2 + O(^1D) \rightarrow 2Cl + \text{products}$

  $CF_2Cl_2 + h\nu \rightarrow 2Cl + \text{products}$
- HCFC-22 loss processes $CHF_2Cl + OH \rightarrow Cl + H_2O + \text{products}$

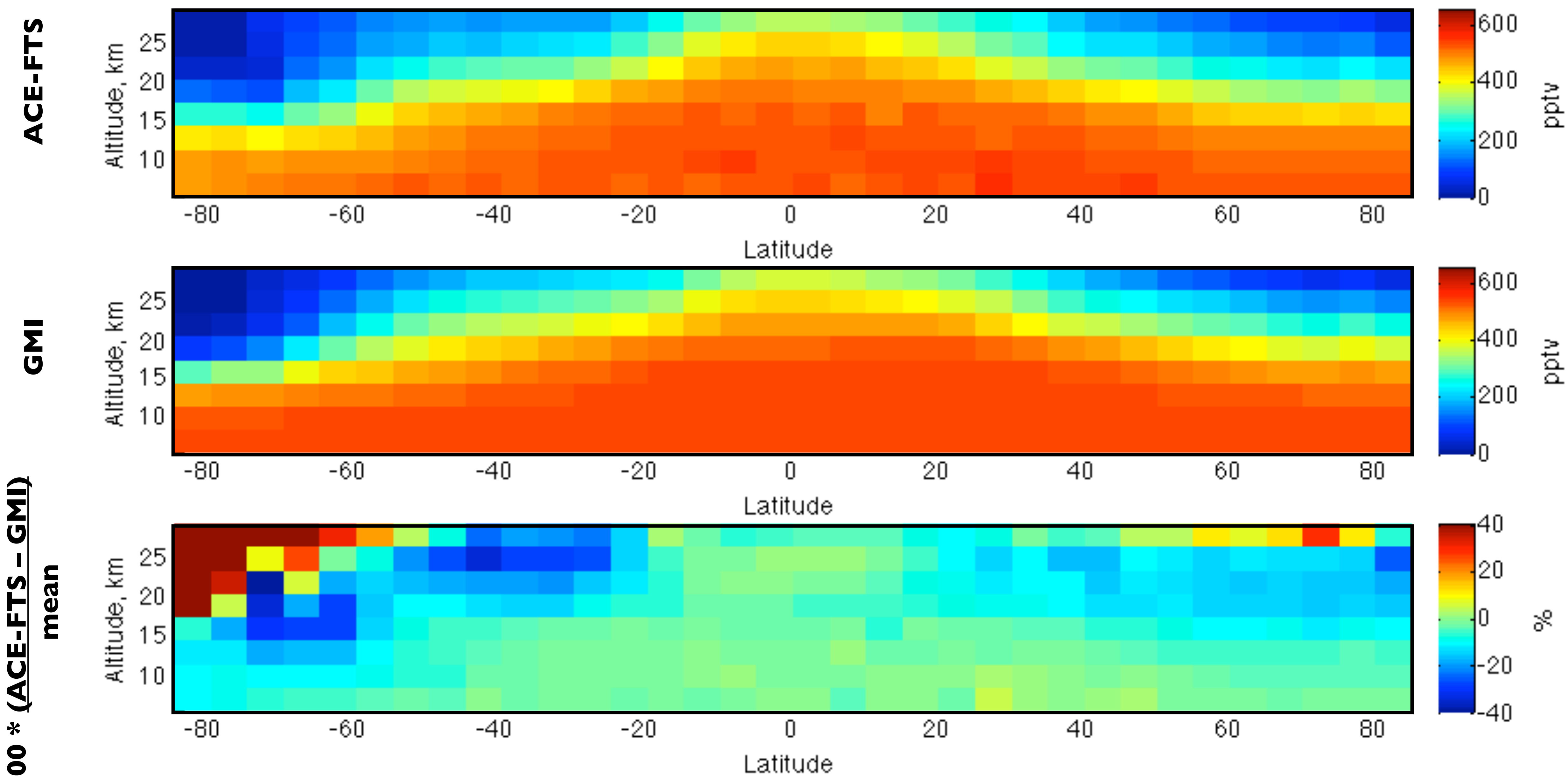
  $CHF_2Cl + O(^1D) \rightarrow Cl + \text{products}$
- Met fields: MERRA Reanalysis
- 2° lat x 2.5° lon x 72 levels (lid at 0.01 hPa)
- Time Period: 2004 - 2010; monthly mean output

Example Comparison CFC-11: Sept-Oct-Nov



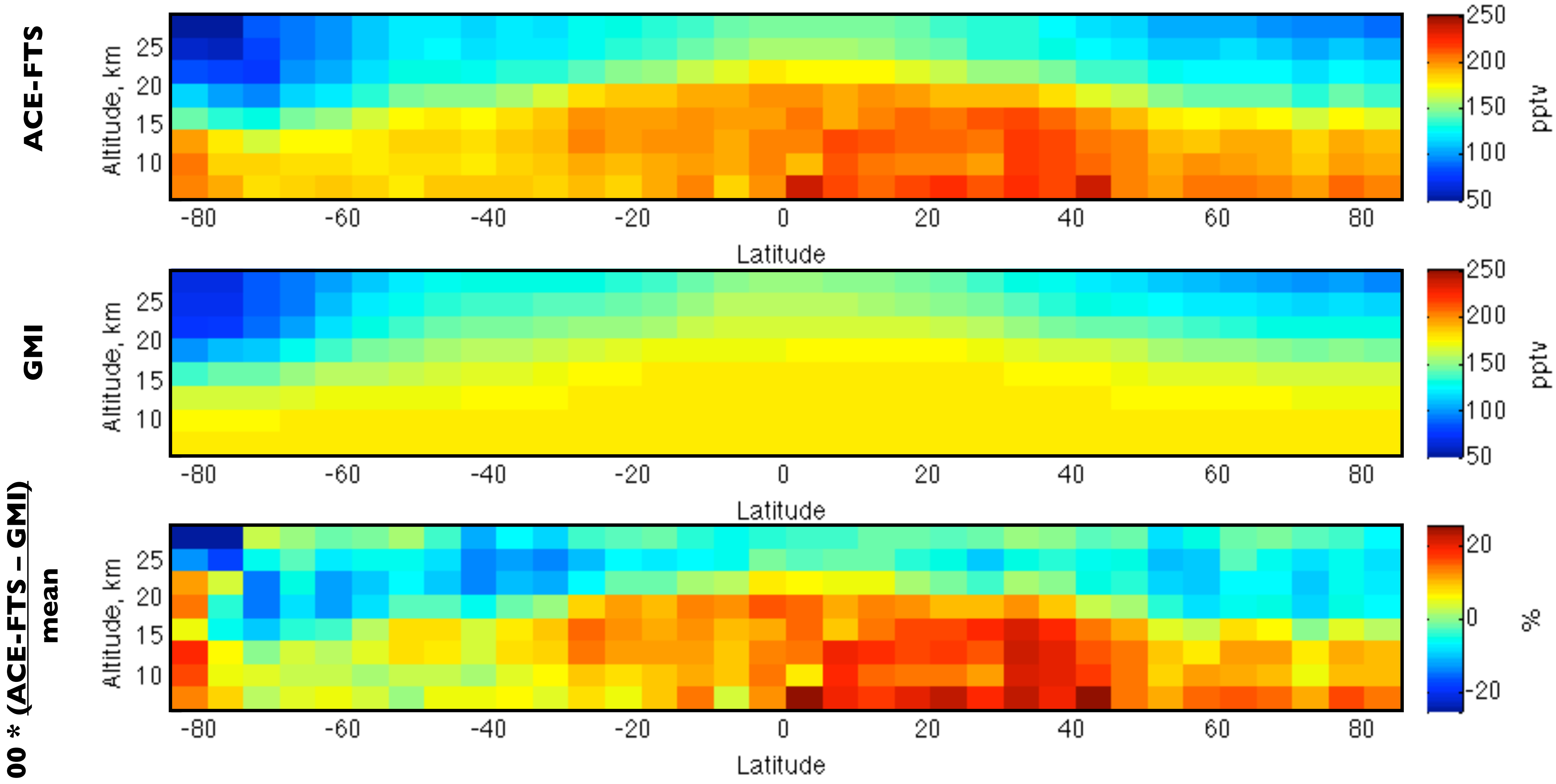
2004-2010 ACE-FTS occultations included; All zonally coincident GMI output included

Example Comparison
CFC-12: Sept-Oct-Nov



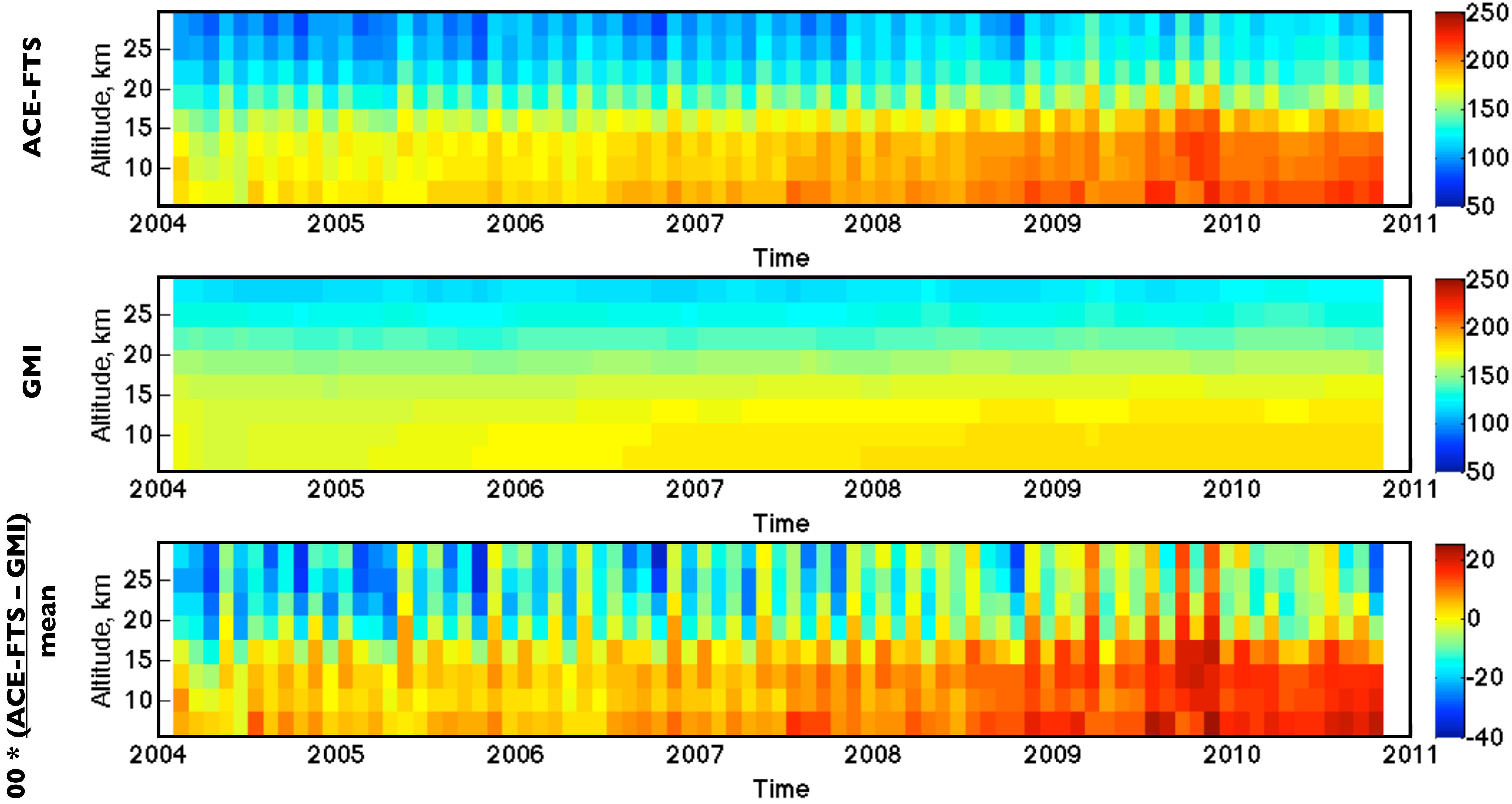
2004-2010 ACE-FTS occultations included; All zonally coincident GMI output included

Example Comparison HCFC-22: Sept-Oct-Nov



2004-2010 ACE-FTS occultations included; All zonally coincident GMI output included

HCFC-22 Monthly Global Mean



2004-2010 ACE-FTS occultations included; All zonally coincident GMI output included

Summary

- Measurements of the zonal mean distribution of CFC-11, CFC-12, and HCFC-22 have been computed.
- The ACE-FTS measurements of these species compare well with surface in situ measurements.
- Comparisons of CFC-11 and CFC-12 with the GMI model show these species are represented well in the troposphere. However, there are differences observed in the stratosphere.
- Large differences between the GMI model and ACE-FTS measurements of HCFC-22 reveal issues with the boundary value mixing ratios.
- ACE-FTS comparisons with models such as GMI can aid in assessment of the quality of winds from data assimilation systems in both the troposphere and the stratosphere.

Acknowledgements

- Funding for ACE is provided by the Canadian Space Agency (CSA) and the Natural Sciences and Engineering Research (NSERC) of Canada.
- This work is supported by a grant from the CSA.
- Thanks to the MkIV and AGAGE teams for making their data available for this analysis.
- Thanks to GMI for providing model output.
- GMI is supported by the NASA Modeling Analysis and Prediction program.