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*Tropospheric Emission Spectrometer*

**EOS Aura Science Team Meeting**

# **Aura TES Validation Update: V05**

**Robert Herman, Karen-Cady-Pereira, Dejian Fu, Susan Kulawik, Ming Luo, Vivienne Payne, Doug Shepard, Kevin Wecht, Helen Worden, John Worden, Kevin Bowman**

**Jet Propulsion Laboratory  
1 October 2012**

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## Outline

- V05 Improvements
- V05 New Products
- V05 Latest Validation Comparisons:
  - Radiance
  - H<sub>2</sub>O
  - H<sub>2</sub>O/HDO
  - CH<sub>4</sub>
  - NH<sub>3</sub>
  - O<sub>3</sub>
  - TATM
  - CO
  - CO<sub>2</sub>



# *Tropospheric Emission Spectrometer*

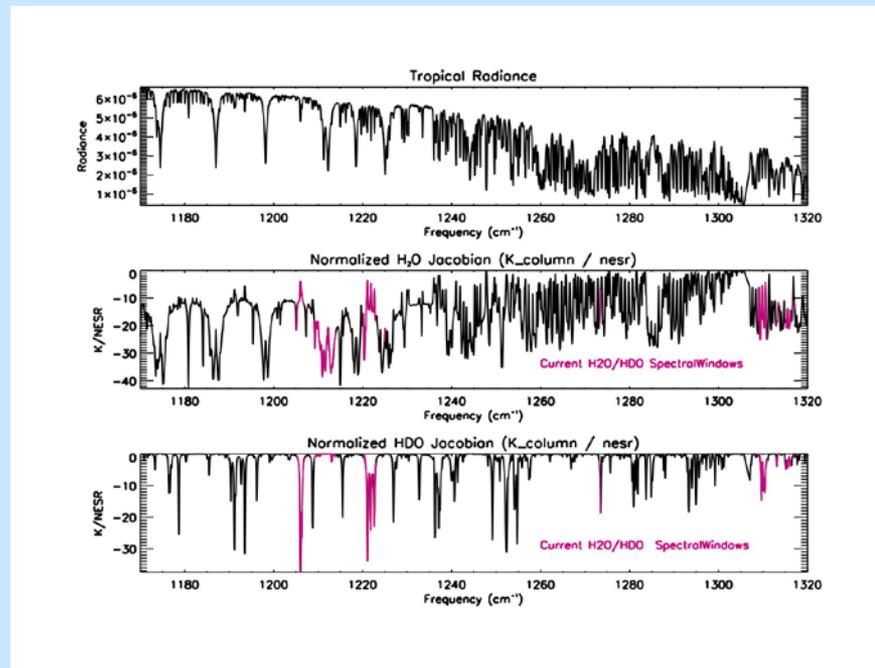
## **Validation Presentations this week**

- O<sub>3</sub> from combined TES-OMI retrieval (Dejian Fu)
- CO from combined TES-MLS retrieval (Ming Luo)
- Minor trace-gases HCOOH, CH<sub>3</sub>OH and NH<sub>3</sub> (Karen Cady-Pereira)
- CH<sub>4</sub> (talks by John Worden and Kevin Wecht)
- CH<sub>3</sub>OH (talk by Kelley Wells and Dylan Millet, UMN)
- CO<sub>2</sub> (Susan Kulawik)



## V05 Improvements

- Joint retrieval of  $\text{CH}_4$ , HDO,  $\text{H}_2\text{O}$ , and  $\text{N}_2\text{O}$  in the  $1170\text{-}1330\text{ cm}^{-1}$  spectral band.
  - Significant improvements to retrieval of these species.
  - Better sensitivity to resolve boundary layer and free troposphere.
- CO new climatology (MOZART4) and constraint matrices, same as MOPITT.
- Species dependent quality control information (e.g.  $\text{O}_3$  C-curve flag).
- Better handling of surface temperature (TSUR):
  - TSUR initial guess dependent on surface type (land/water)
  - Freshwater emissivity added
  - Ice emissivity if  $\text{TSUR} < 265\text{ K}$  over water



From Worden et al., 2011



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## *Tropospheric Emission Spectrometer*

### **V05 new products**

#### **TES V05 new standard products:**

- Carbon Dioxide
- Ammonia
- Ozone infrared forcing kernel and tropospheric ozone column added to the Ozone Level 2 file.

#### **TES new version in NetCDF format indexed by date rather than run id:**

- Lite Products
- Daily Ozone Products
- Monthly Mean Ozone Products
- TES Subsetter



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## DATA

Within these pages are descriptions of how TES data are processed, what are the standard TES data products and where to obtain them, and what are the data formats and the tools to manipulate them.

- [Products](#): lists TES standard products.
- [Lite Products](#): provides access to TES reduced size products in netCDF format providing L2 daily data organized by month.

Read more: [Release Description](#)

- [Daily ozone](#): provides access to TES Global Survey and Special Observations of daily ozone in netCDF format.
- [Daily ozone & IRK](#): provides access to TES Global Survey daily ozone and instantaneous radiative kernels in netCDF format.
- [Tools](#): describes tools useful for accessing TES L1B, L2, and L3 data.
- [Files](#): detailed description of data file specifications for L1B, L2, and L3.
- [Algorithms](#): description of TES data processing
- [Data Calendar](#): updated information on TES data availability in time and space.
- [Validation](#): current validation status and information regarding ongoing TES validation requirements.

The primary location for obtaining TES data is NASA's Reverb Tool ([Reverb](#)). The [TES subsetter](#) provides access to the TES L2 subsetter hosted at the ASDC website. The [TES Data Sets](#) page at NASA Langley Research Center ([LaRC ASDC](#)) provides access to software read tools, a Data Pool, and supporting documentation. Users of TES data are encouraged to contact the TES science team for further guidance on successfully applying and interpreting the data products.

The Aura Validation Data Center ([AVDC](#)) hosts an data archive site for preliminary TES data for validation and other science activities. Aura data including that from TES may be accessed from [Aura](#).

### Ozone profiles reprocessing (v004)

Ozone profiles with surface pressure larger than 1030 hPa should not be used in current v004 TES data set. This condition of surface pressure occurs in approximately 1.5% of target scenes processed thus far. These target scenes have been identified in the TES O3 HDF product files through the data field Pressure; those target scenes indicating a non-fill Pressure of greater than 1030 hPa should be ignored. The targets with this error can also be identified by the presence of negative AveragingKernelDiagonal values ( $< -0.01$ ). An update to the v004 software will fix the problem with these targets, and all targets listed in these [tables](#) will be reprocessed before v004 processing is completed.

Re-processing for v004 was completed on March 11, 2010.



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### [DATA/ AURA/ TES V05](#)

Name	Size	Date
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<a href="#">CO2/</a>	<dir>	Sep 26 2012 10:03
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<a href="#">TATM/</a>	<dir>	Sep 26 2012 10:03
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<input type="checkbox"/> <a href="#">cdf_read.pro</a>	4 Kb	Aug 23 2012 16:46

2 file(s) found

select/unselect all

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AVDC Contact: [Ghassan Taha](#)  
[Michael M. Yan](#)  
 NASA Official: [Richard D. McPeters](#)  
 Last Updated: April 12, 2010





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[DATA/ AURA/ TES V05/ CO2](#)

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## **V05 Documentation**

- TES “Quick Start” guide is now available at TES web site:  
<http://tes.jpl.nasa.gov/uploadedfiles/TESQuickStartGuide.htm>
- Example of using TES data:  
<http://tes.jpl.nasa.gov/uploadedfiles/KulawikExampleUseTESdata.pdf>
- Updated TES Data User’s Guide v05 available soon at both the TES web site and Langley Atmospheric Science Data Center:
- TES Validation Report v05 – available online at the Langley Atmospheric Science Data Center:  
[http://eosweb.larc.nasa.gov/PRODOCS/tes/validation/TES\\_Validation\\_Reportv50.pdf](http://eosweb.larc.nasa.gov/PRODOCS/tes/validation/TES_Validation_Reportv50.pdf)
- TES L2 Data Quality Statement - Current validation status by species (Also included in the updated TES Data User’s Guide):  
<http://tes.jpl.nasa.gov/uploadedfiles/L2QualityStatementV04Data.htm>



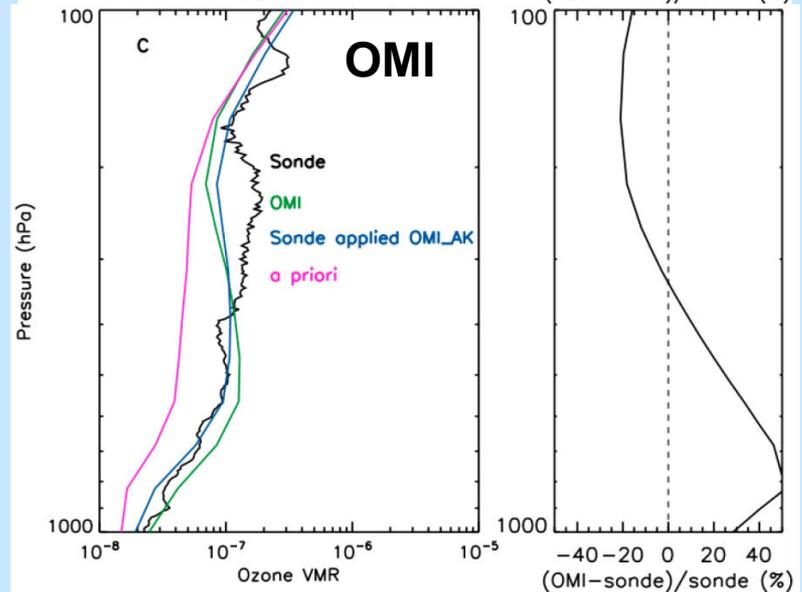
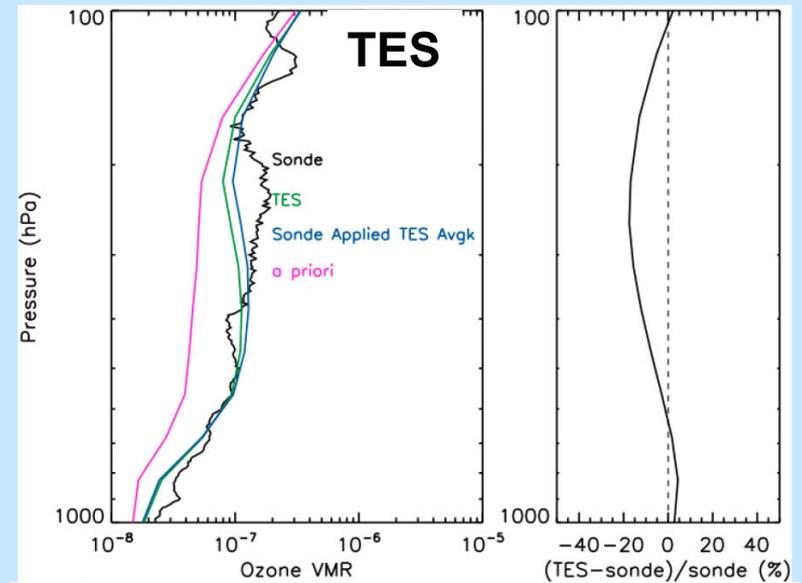
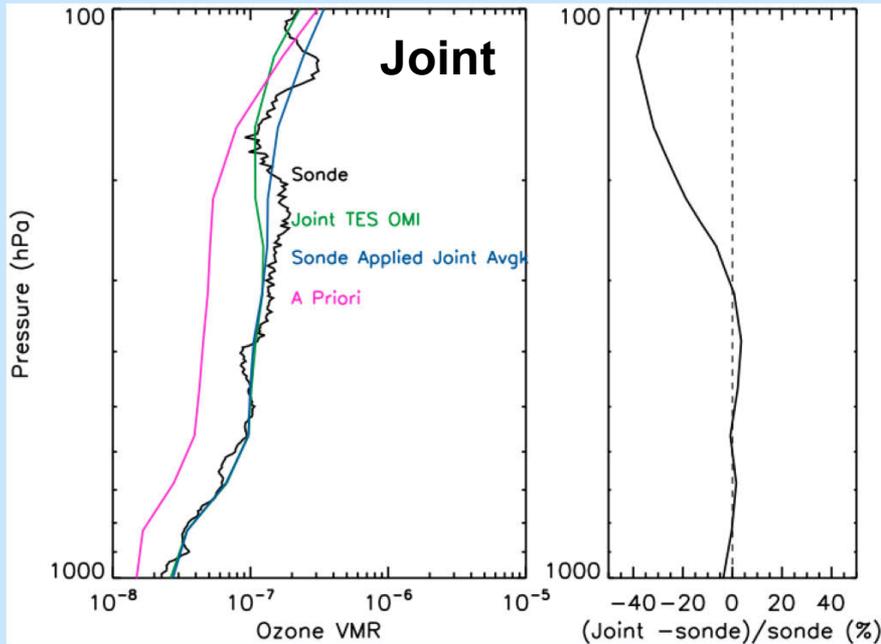
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## *Tropospheric Emission Spectrometer*

# Validation of combined Aura retrievals



## Combined TES/OMI Retrieval



See talk by Dejian Fu.

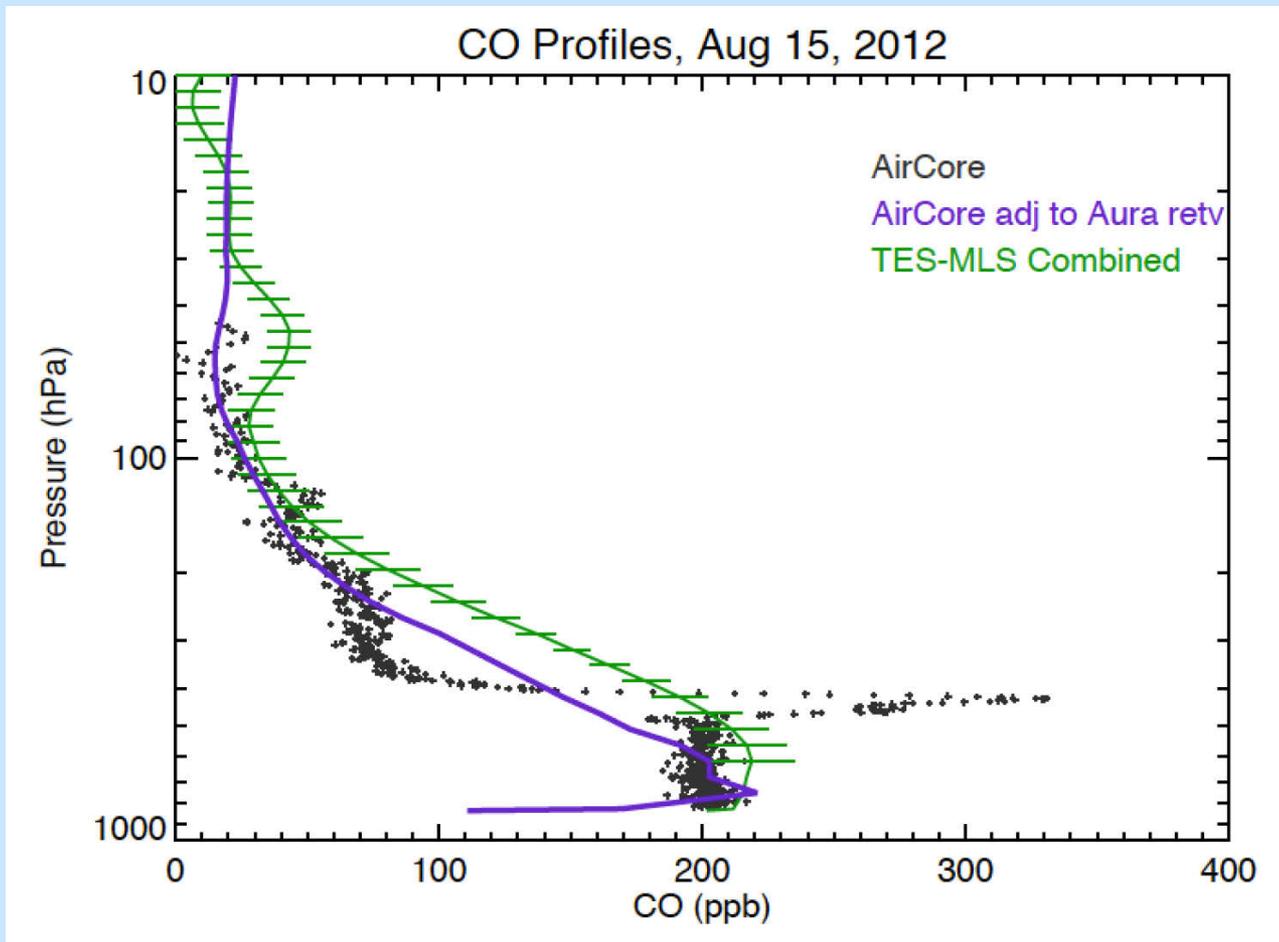
The combined TES/OMI retrieval:

- closely matches the original ozonesonde measurements
- differs from the *a priori* profiles
- has the smallest differences to the *in situ* measurements among the three sets of satellite measurements

## Combined TES/MLS retrieval

See poster by Ming Luo, "CO profile retrieved from combined TES and MLS measurements on Aura satellite"

- Combined retrieval of carbon monoxide by TES and MLS.
- New validation technique: balloon-borne AirCore measurement of CO and other gases (C. Sweeney, NOAA).
- More launches are planned for Oct 2012.





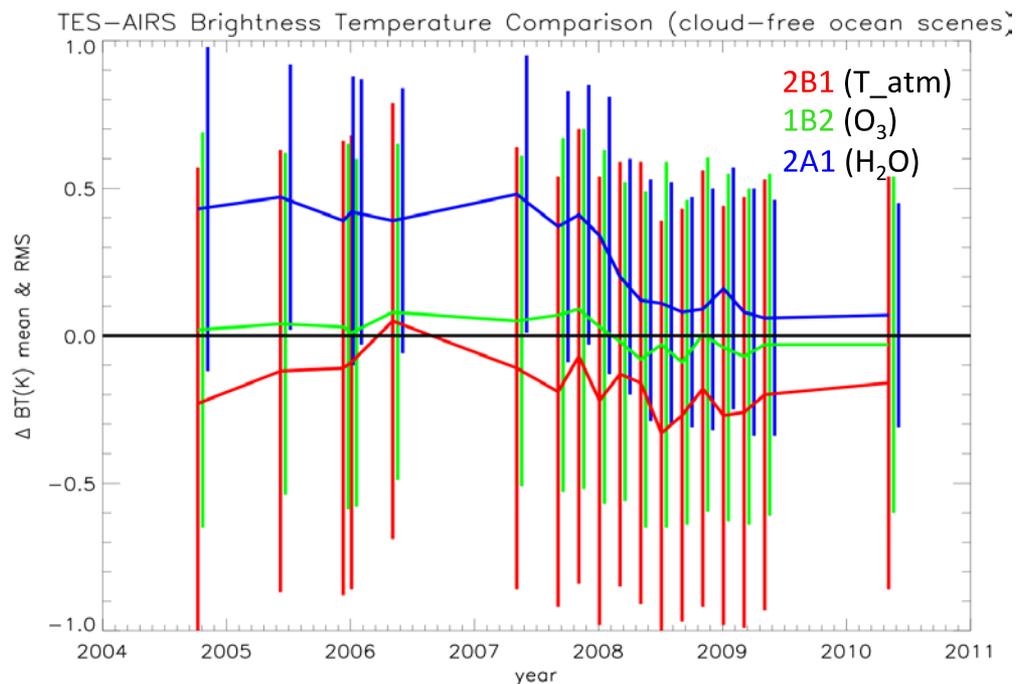
## Validation

- Latest Validation Comparisons:
  - Radiance
  - H<sub>2</sub>O
  - H<sub>2</sub>O/HDO
  - CH<sub>4</sub>
  - NH<sub>3</sub>
  - O<sub>3</sub>
  - TATM
  - CO
  - CO<sub>2</sub>



## TES V05 Radiance

### TES Radiance Validation – evaluation of new calibration approach



**No changes from 2009 to 2010 due to new calibration approach**

S.



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## *Tropospheric Emission Spectrometer*

# Jointly retrieved species

- H<sub>2</sub>O
- HDO
- CH<sub>4</sub>

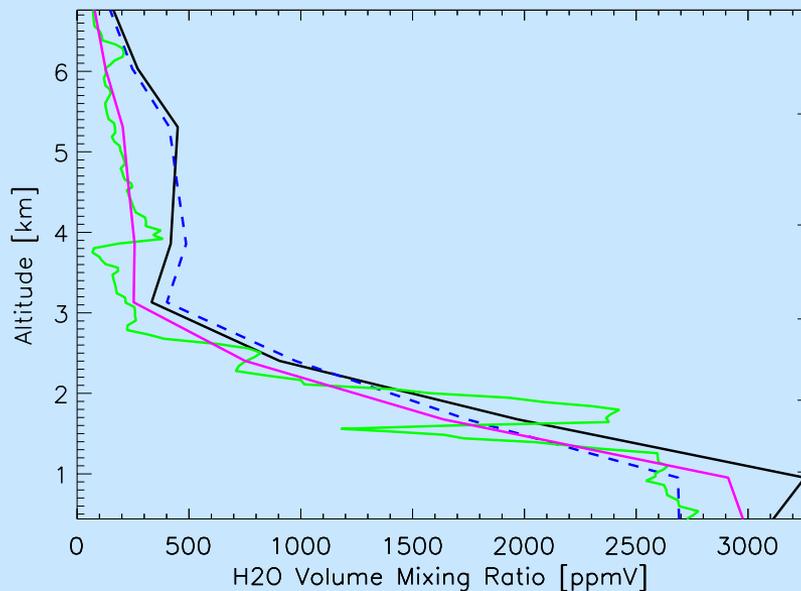
(N<sub>2</sub>O used to correct  
errors in CH<sub>4</sub>)



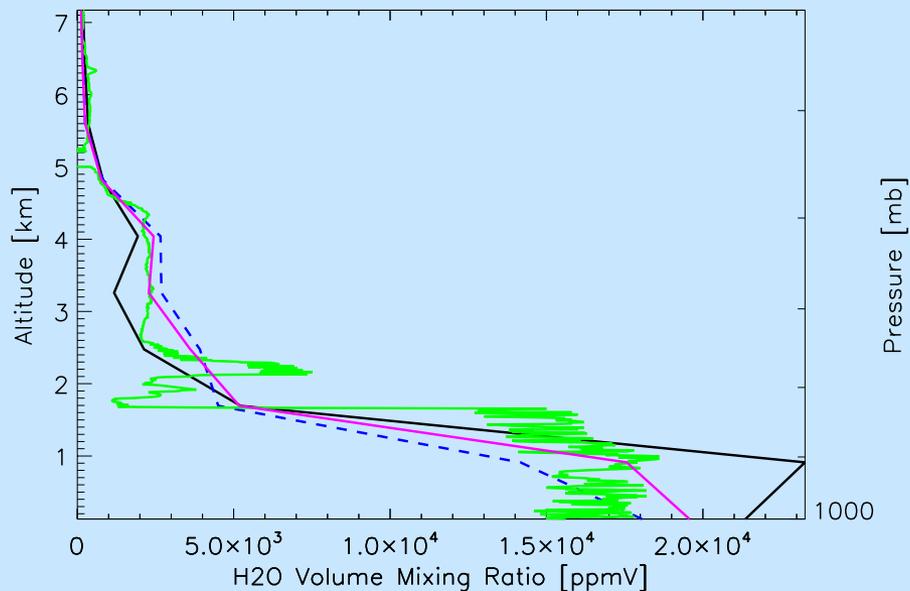
# Tropospheric Emission Spectrometer

## H<sub>2</sub>O V05

ARM SGP radiosonde, 2/12/2006



Houston (MACPEX) radiosonde, 4/13/2011



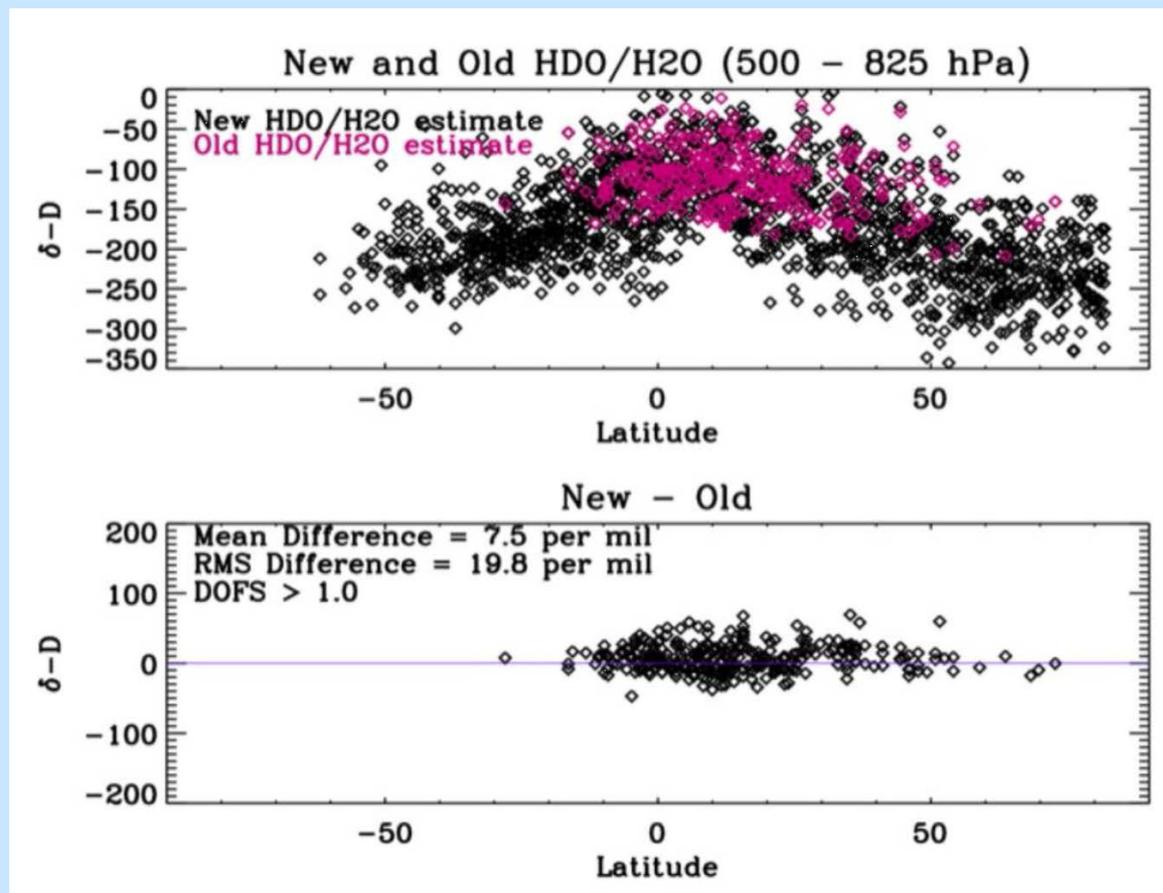


# Tropospheric Emission Spectrometer

## H<sub>2</sub>O/HDO (J. Worden)

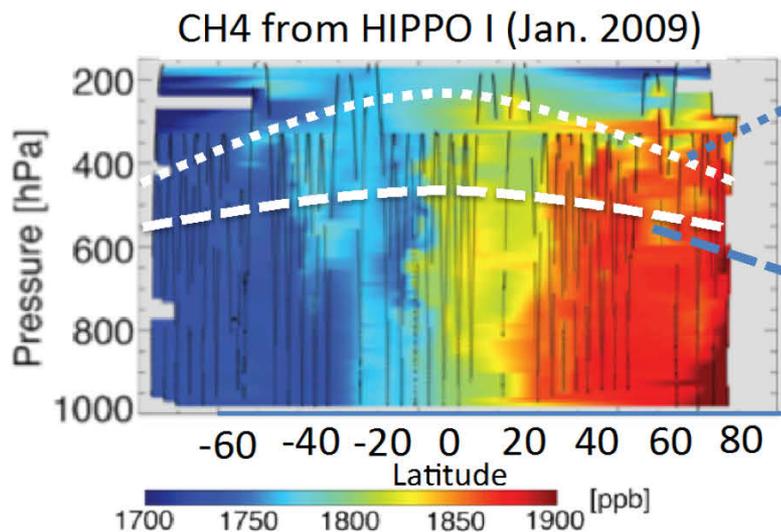
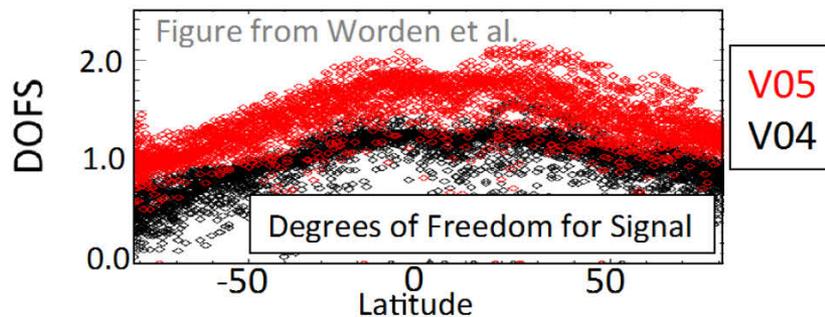
V05-V04 (Worden et al., 2011)

- Greater sensitivity to the boundary layer and the free troposphere.
- Greater latitudinal coverage.



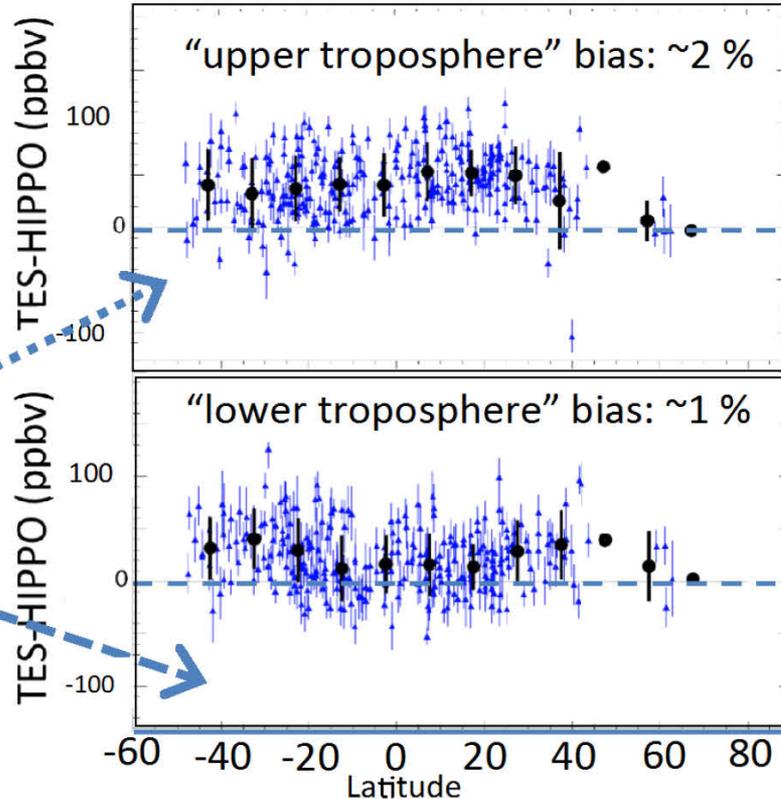


- Retrieval approach: Worden et al., AMT [2012]
- Validation against HIPPO data: Wecht et al., ACP [2012]



Dotted/dashed lines show approximate pressure values for “upper/lower troposphere” values

Figure from Wecht et al.



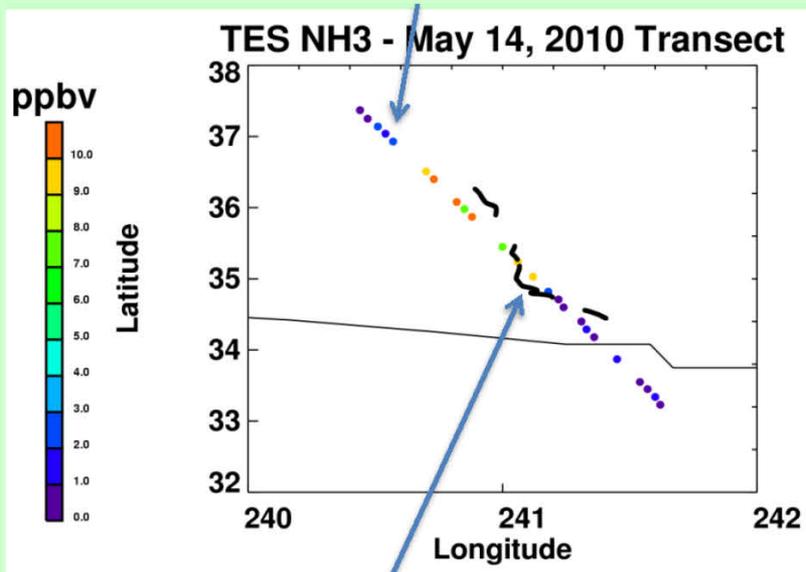
Biases shown here are *after* N<sub>2</sub>O correction – see Worden et al. [2012] for more details



Atmospheric and Environmental Research, Inc.

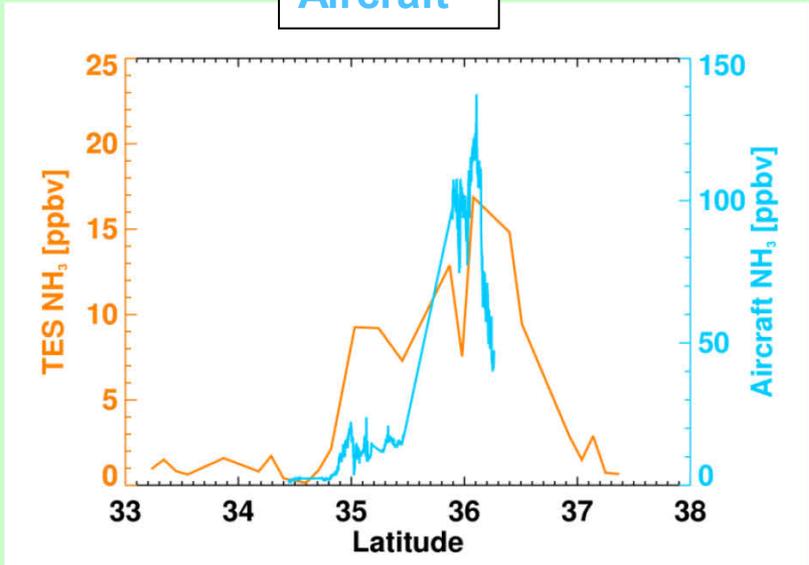
# CALNEX: TES vs Aircraft

TES May 14 transect @13:15 local



Partial P3 May 12 track  
 (flying at ~ 300 AGL @ 17:30 local)

TES  
 Aircraft

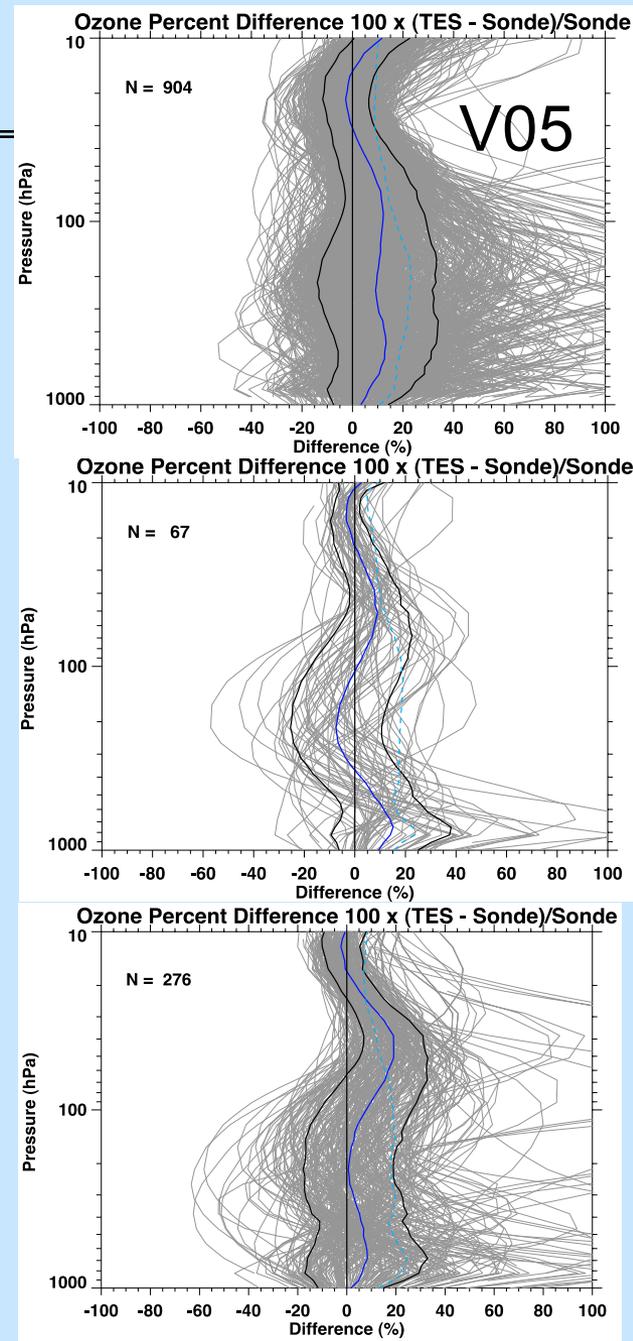
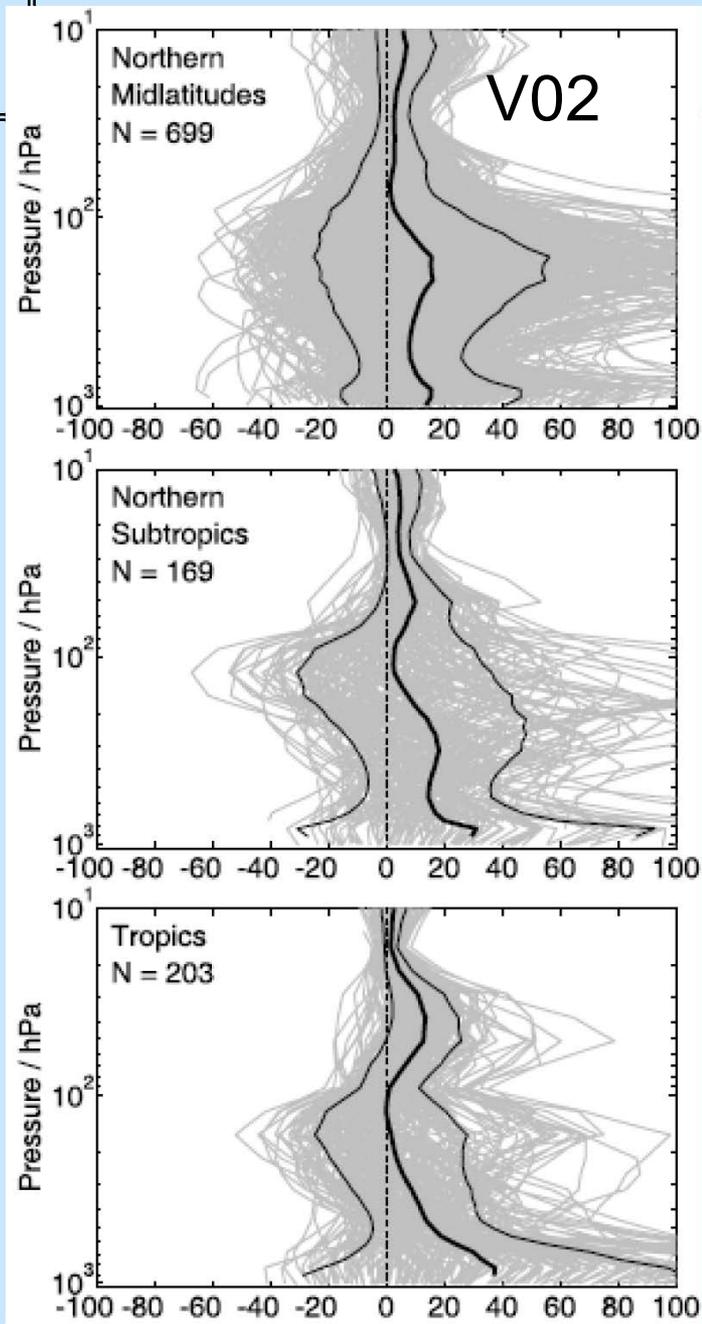


NH<sub>3</sub> measurements from TES and aircraft are well correlated

# Tropospheric Emission Spectrometer

## TES OZONE (D. Fu):

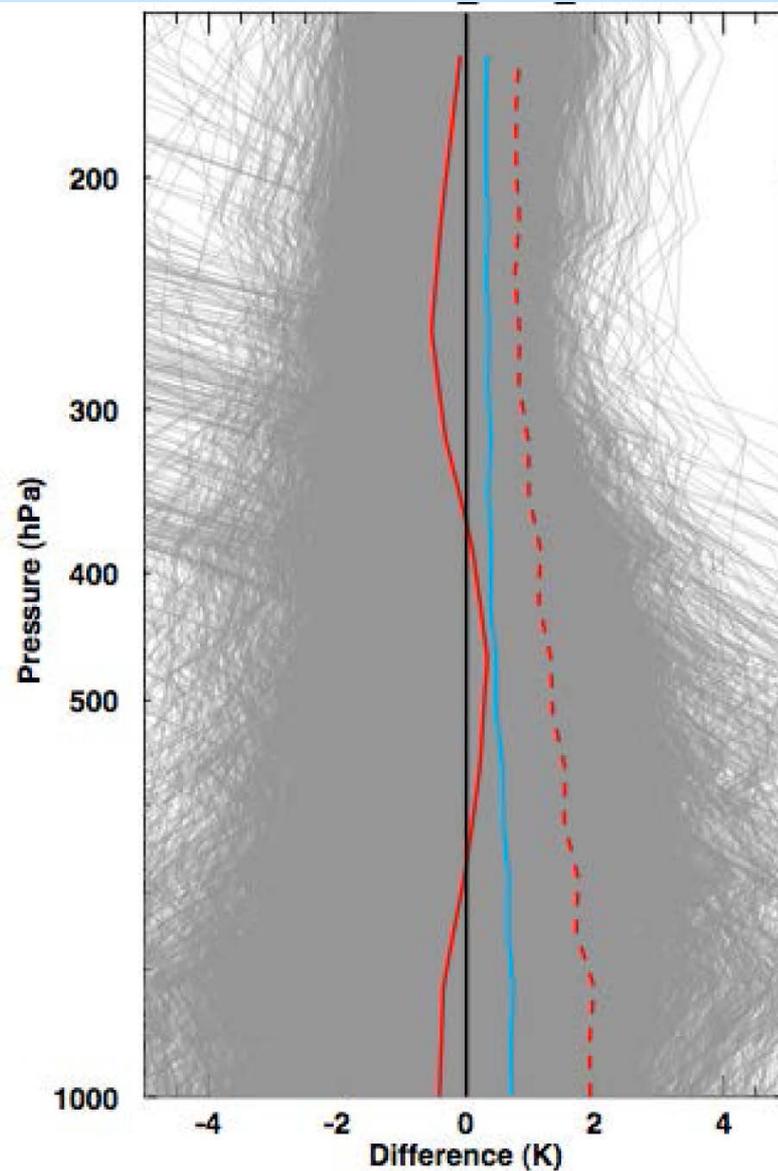
- Ozonesonde-TES matches (2004-2009)
- Matching criteria:  $\pm 9$  hr, 300 km, with a cloud filter [Nassar et al., 2008].
- V05 results (right) similar to V02 (left) from [Nassar et al., 2008].
- No change to  $O_3$  retrieval from V04 to V05 – except for Ccurve quality flag.





## TATM V05 Validation (Herman)

- Radiosonde-TES comparisons (2004-2008):
- Lower Tropospheric bias is within  $\pm 0.5$  K.
- Upper Tropospheric bias is  $-0.5$  K.
- No change from V04 to V05, except for ice emissivity.





## TES V05 CO

### Major changes from TES V04:

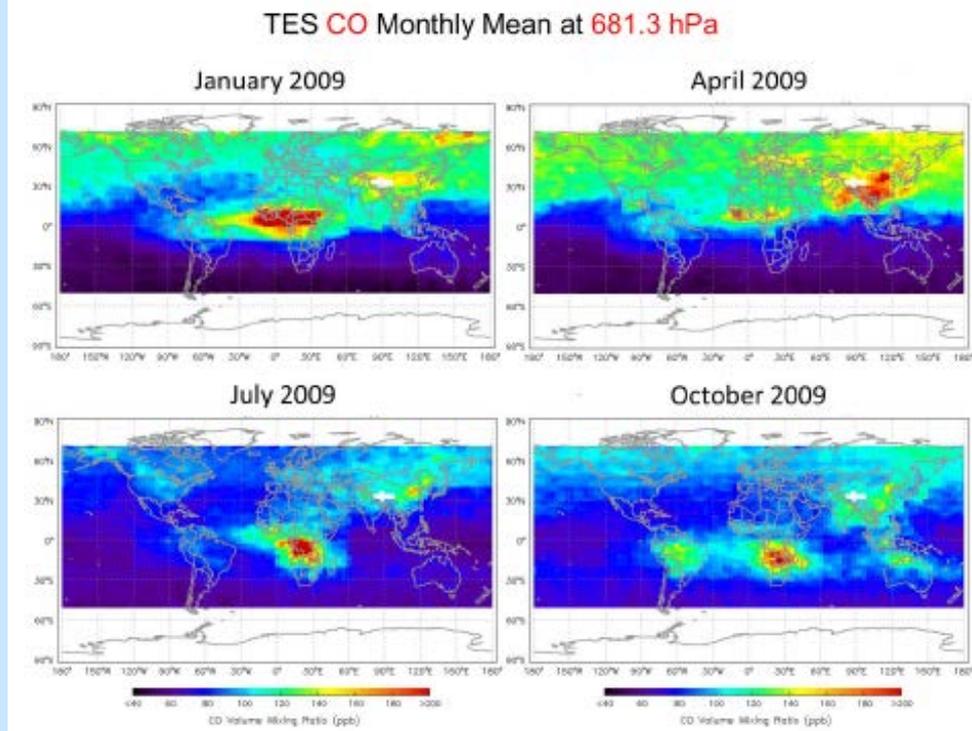
- ✓ Update the a priori profiles with MOZART V04 model monthly, lat/lon bin.
- ✓ Update the a priori constraint with the same algorithm as the MOPITT V04 retrievals.

### Instrument performances affecting CO data quality:

- ✓ Better CO data (e.g., larger DOFS) due to better optical alignment since Dec 2005.
- ✓ Worse CO data (e.g., drop-off in retrieval throughput) in 2011 due to poor ICS performance. 2012 data is normal.

### Repeated CO validations by comparing to MOPITT V04.

- ✓ Global patterns of CO distributions seen from TES are in good qualitative agreement with MOPITT.
- ✓ Direct comparisons are much improved over previous versions of TES and MOPITT data, due to similar a priori profiles and constraints.
- ✓ After properly adjusted for the a priori and averaging kernels, TES and MOPITT CO agrees better than the direct comparisons.
- ✓ In comparisons of selected measurements taken post Dec 2005, TES CO at upper troposphere is biased lower than that of MOPITT by a few percent.





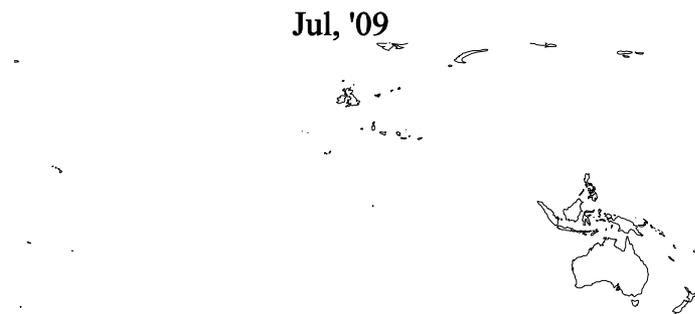
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## Carbon Dioxide V05 (S. Kulawik)

**v5 Aura-TES CO<sub>2</sub> - 2009**

Jul, '09





## Summary

We have shown the latest TES V05 Validation Comparisons:

- Radiance
- H<sub>2</sub>O
- H<sub>2</sub>O/HDO
- CH<sub>4</sub>
- NH<sub>3</sub>
- O<sub>3</sub>
- TATM
- CO
- CO<sub>2</sub>



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Extra

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## **Latest Validation Publications**

Work is being done on updating validation status for most species, specifically:

- TES nadir ozone/ozonesonde comparisons during ARC-IONS – Boxe et al., ACP, 2009
- TES nadir ozone/ozonesonde comparisons from Houston – Boxe, Morris, Herman, Osterman et al., 2010
- TES nadir ozone/ozonesonde global comparison for V04 data – Boxe, Saha, Herman, Osterman et al., 2010
- HDO – Worden, Lee et al., 2009
- Carbon Monoxide – Ho et al., 2009
- Carbon Dioxide – Kulawik et al., ACP, in press
- Ammonia – Pinder, Cady-Pereira et al., 2010