Long-term Validation of Satellite OH Measurements with Ground-based Observations and GMI simulations

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Introduction

- OH (together with HO_2) plays a key role in the HO_x catalytic reaction cycle, leading to O_3 destruction in the middle atmosphere

- Primary sources of OH:

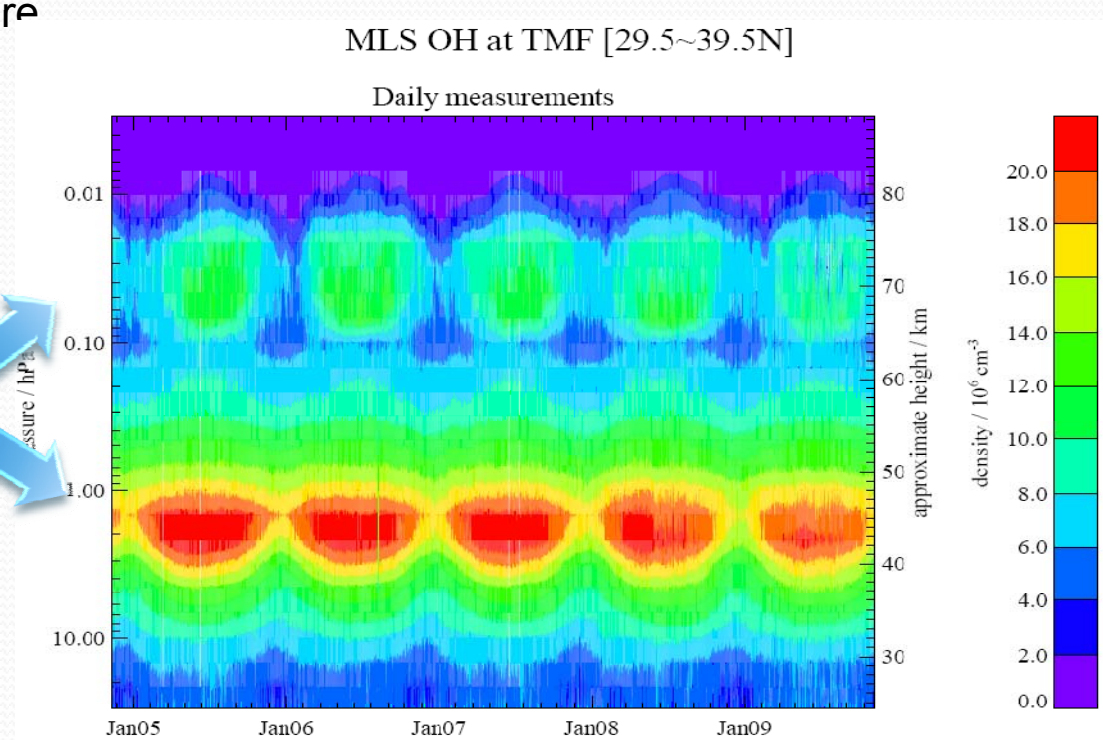
Stratosphere

$O_3 + h\nu \rightarrow O(^1D) + O_2$

$O(^1D) + H_2O \rightarrow 2\ OH$

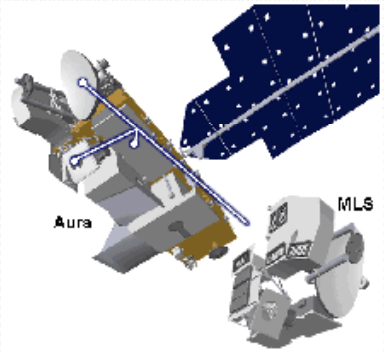
Mesosphere

$H_2O + h\nu \rightarrow OH + H$



- Aura MLS (Microwave Limb Sounder) provides the first global measurement of OH on a daily basis during 2004-2009. Such a unique data record is extremely useful in studying middle atmospheric hydrogen chemistry.
- Long-term validation is important (Ground-based measurements and GMI).

Measurements – MLS on Aura



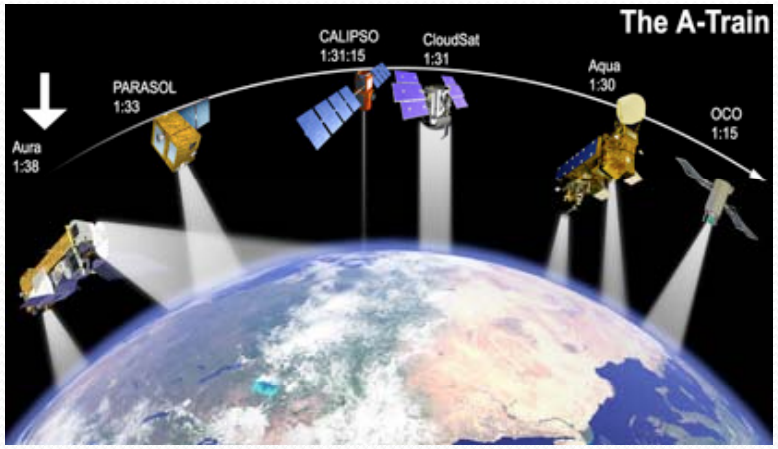
MLS (Microwave Limb Sounder)

— One of four instruments on Aura (part of A-train), launched on July 15th 2004

— Measures over 20 parameters (chemical composition, temperature, and humidity)

— Provides global coverage (82ºS – 82ºN) on a daily basis (ascending / descending)

[Waters et al., 2006]



— 2.5 THz module for OH measurement

Currently available data: Aug 2004 to Dec 2009

[Pickett, 2006]

— Long-term validation method

Compare with ground-based OH column measurements

MLS OH partial column: 21.5 – 0.0032 hPa (near 90% of total OH)

Location: 10º by 25º box ([29.5ºN, 39.5ºN]; [130ºW, 105ºW])

Use model to estimate the lower atmospheric OH not measured by MLS

Measurements –FTUVS at TMF

FTUVS (Fourier Transform Ultra-Violet Spectrometer)

Location — TMF at Wrightwood, CA (34.4°N, 117.7°W)

Altitude — ~2.3 km

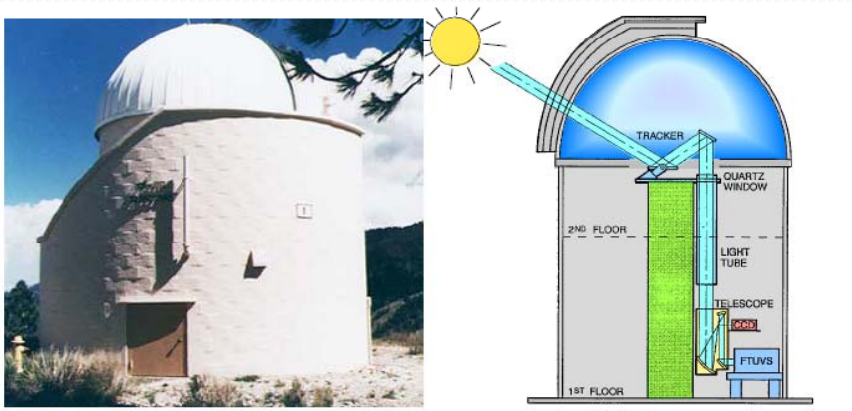
Setup — tracker (heliostat), telescope, and FTUVS interferometer

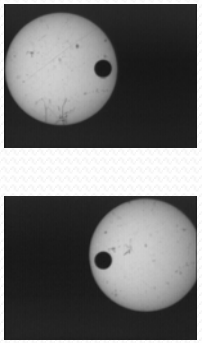
Spectral resolution — 0.06 cm^{-1}

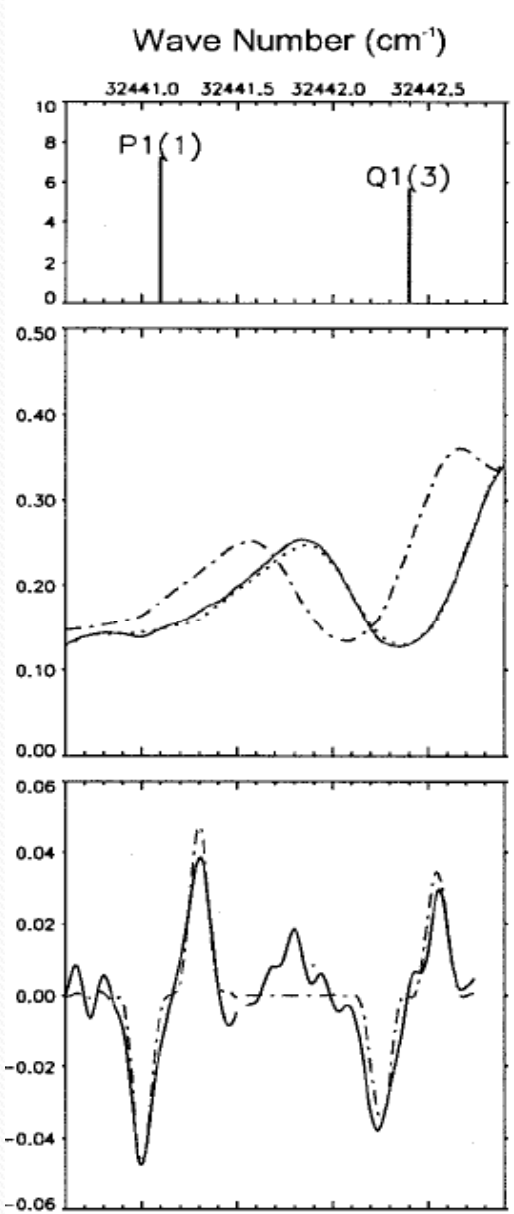
Spectral region of operation (290 - 675 nm) — ~308 nm for OH

Duration – diurnal measurements since 1997

A east and west limb measurement technique is used to remove the strong solar lines for the retrieval of the weak OH signal. Each limb measurement takes ~15 min. *[Cageao et al., 2001]*

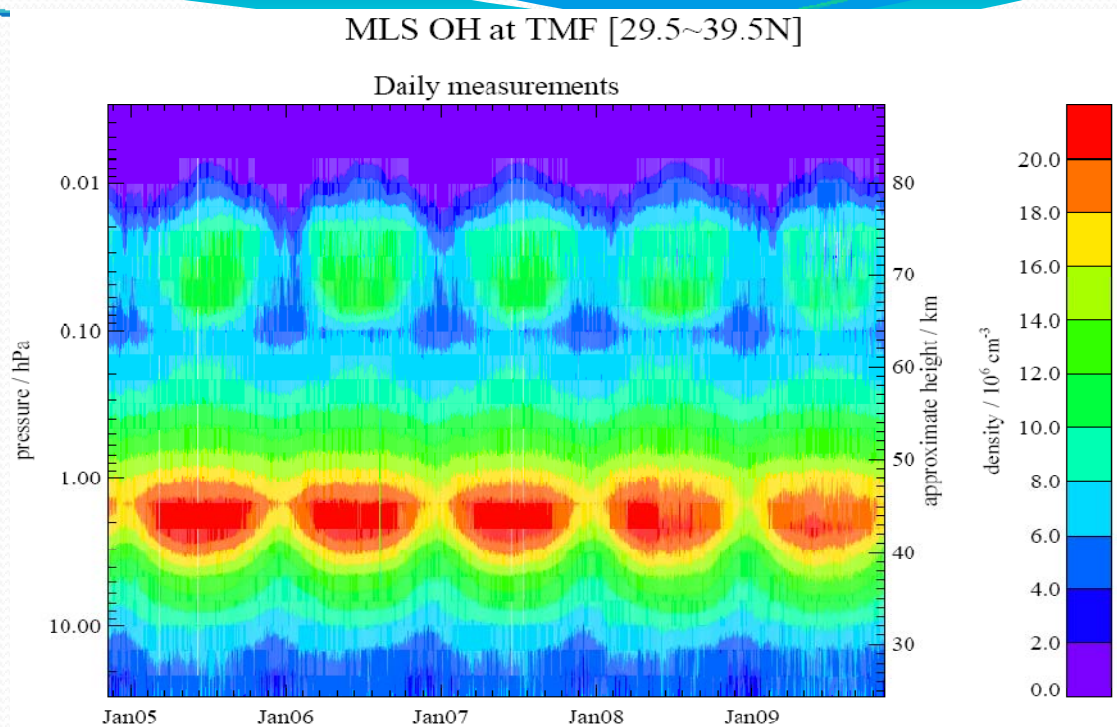


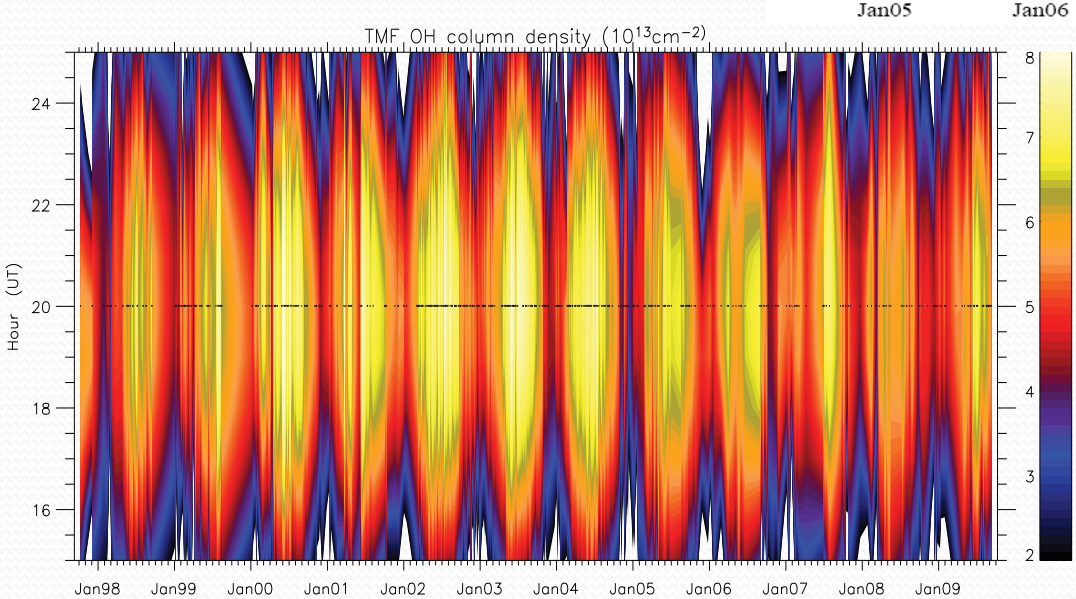


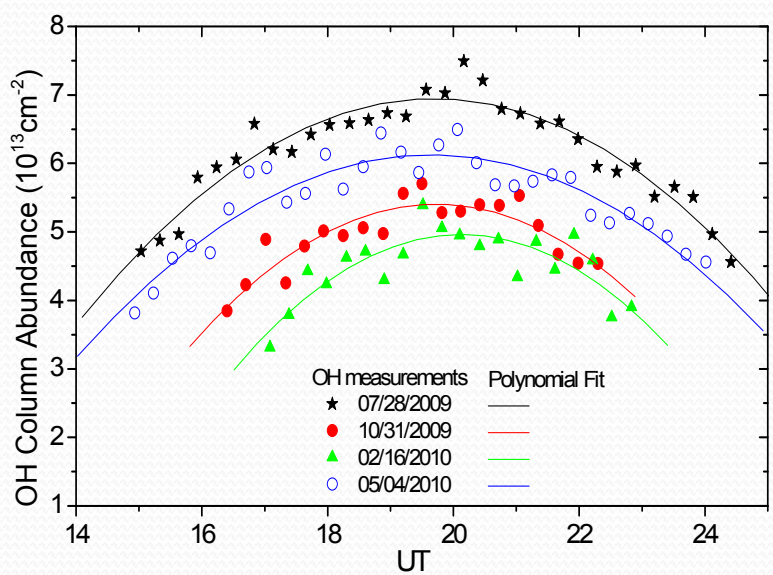


Measurements Overview

- MLS data at TMF location were extracted and integrated from 21.5 hPa to 0.0032 hPa.
- FTUVS OH column data at Aura overpass time were picked based on polynomial fit of the diurnal variation.

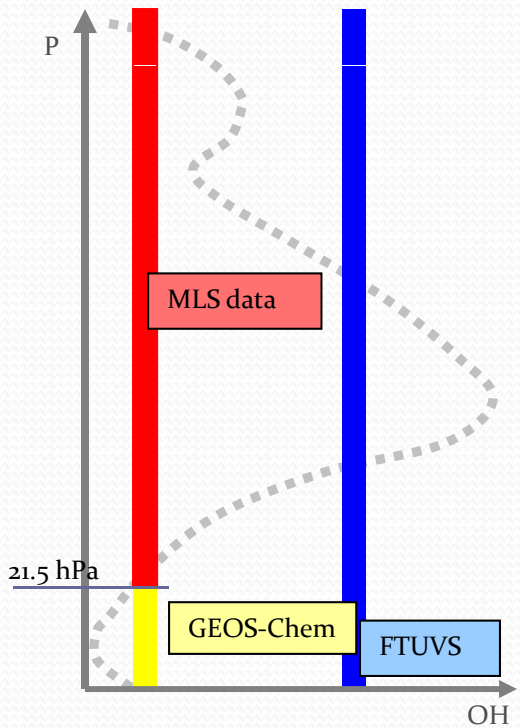


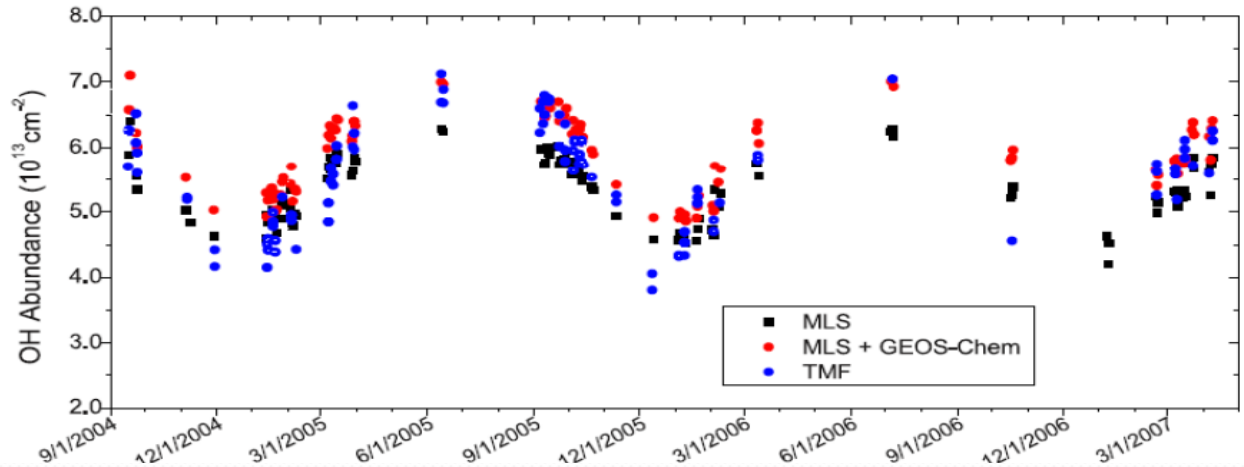


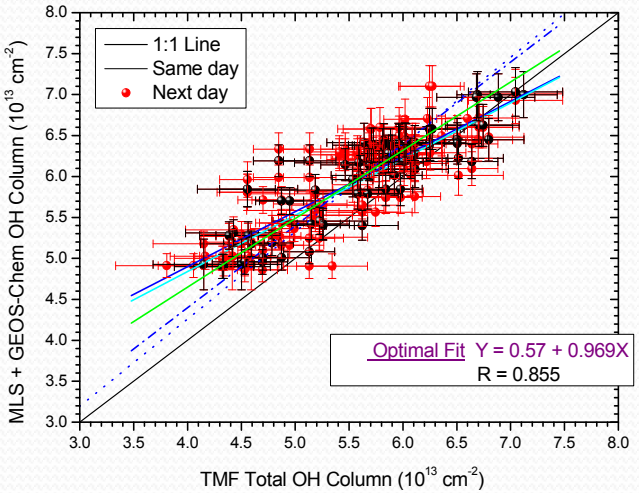


Previous Validation

- The previous "long-term" validation effort compareing MLS OH with FTUVS OH column used GEOS-Chem to estimate the lower atmospheric OH.





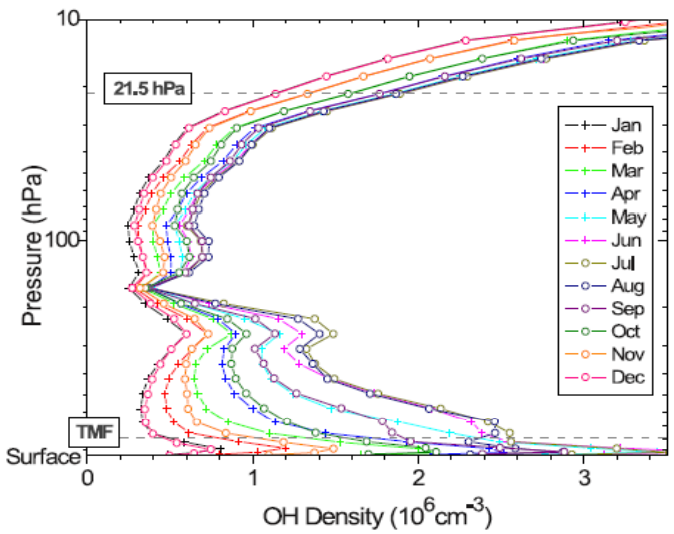


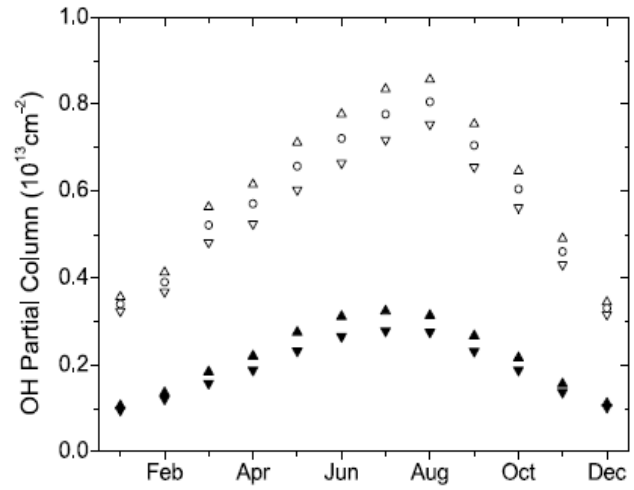
Good agreement is found between the total OH columns from MLS+Model and FTUVS.

[Wang et al., 2008]

Things Could be Improved

- The previous work uses GEOS-Chem 2003 monthly mean simulation results of OH in the troposphere. The lower stratospheric part (tropopause to 21.5 hPa) is from the Harvard 2-D model implemented in GEOS-Chem.
- A number of assumptions had to be made to interpolate the monthly results into the daily reasults at the satellite overpass time.

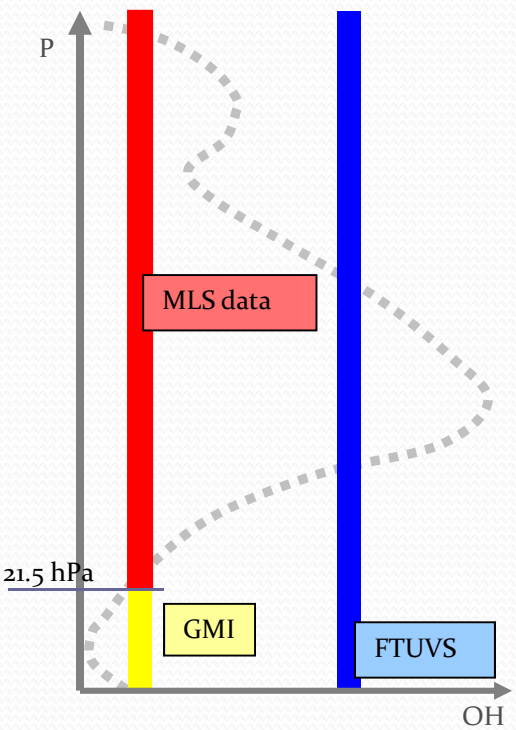




- We could use better model results to avoid the questions raised due to
  - the combination of models
  - the interpolations based on assumptions

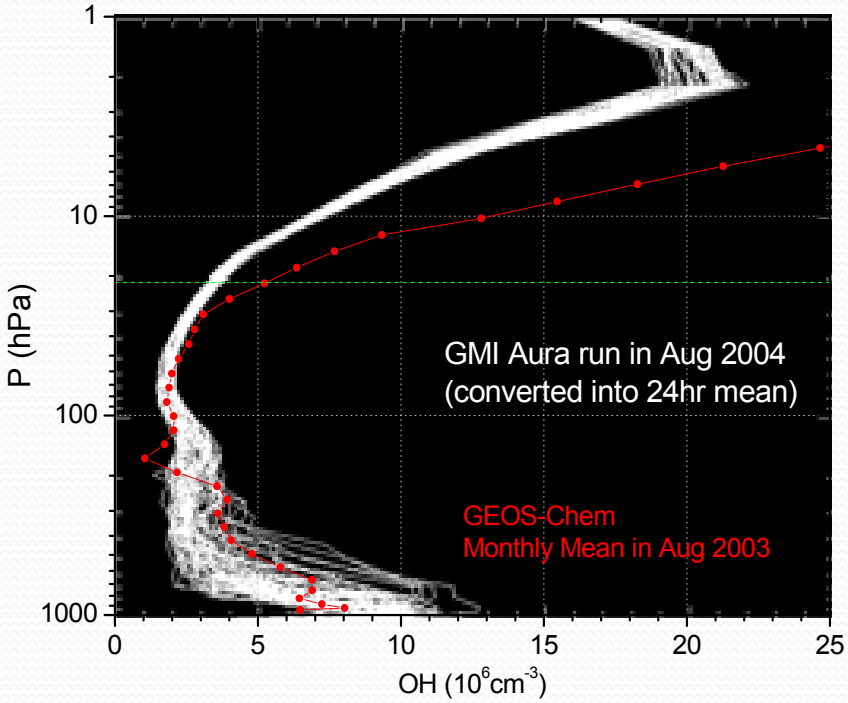
Current Work

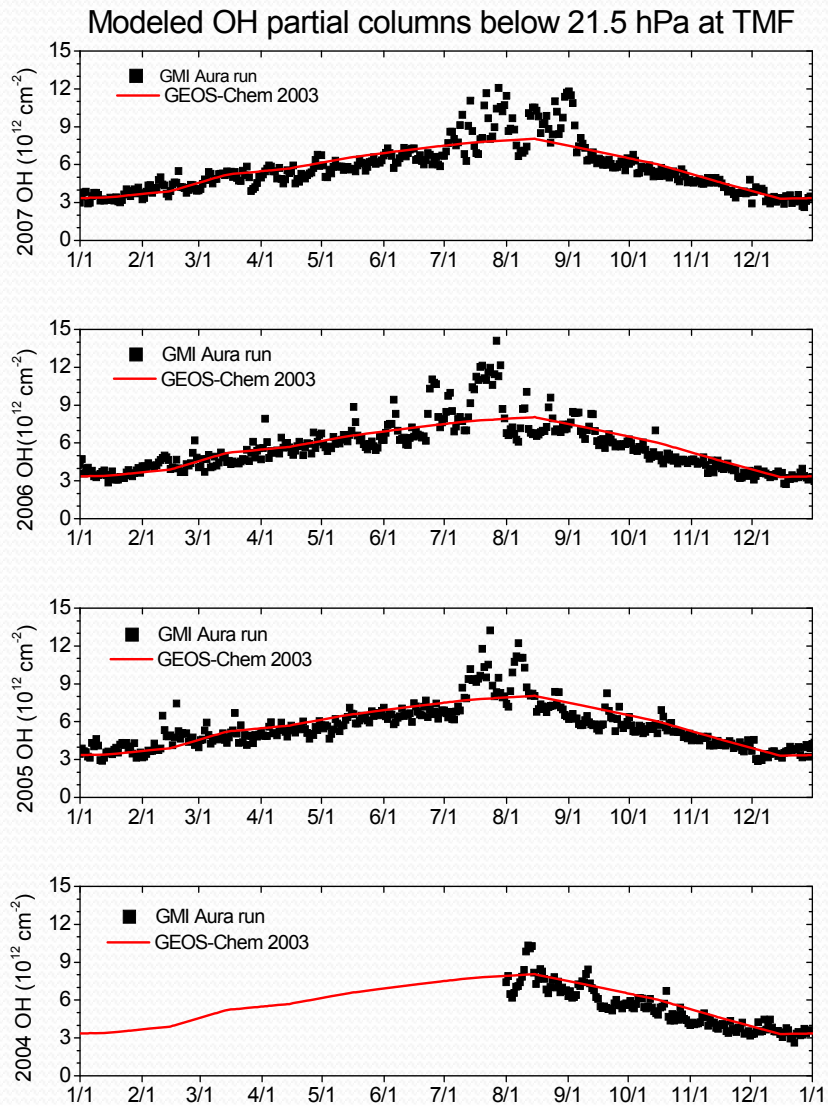
- The estimate of lower stratospheric OH is from GMI, which has realistic chemical mechanisms for both troposphere and stratosphere.
- The OH calculations from the GMI Aura run contains results at the satellite overpass time (1-2 pm). No additional interpolation is needed.



	GMI (Aura4)	GEOS-Chem
	GMI covers both trop and strat	GEOS-Chem for trop Harvard 2-D for strat
Spatial resolution	2 by 2.5 degree	2 by 2.5 degree
Vertical resolution	~22 levels from TMF to 21.5 hPa	~ 22 levels from TMF to 21.5 hPa
Time of output	Average of 1-2 pm	Monthly mean
Duration	Aug 2004 – Dec 2007	2003

Modeled Lower Atmospheric OH





The OH profiles from GEOS-Chem and GMI show some differences below 21.5 hPa.

The integrated partial column OH from two models generally agree (GMI shows the day-to-day variability which is larger in summer).

There is no significant change in this partial column from 2003 – 2007.

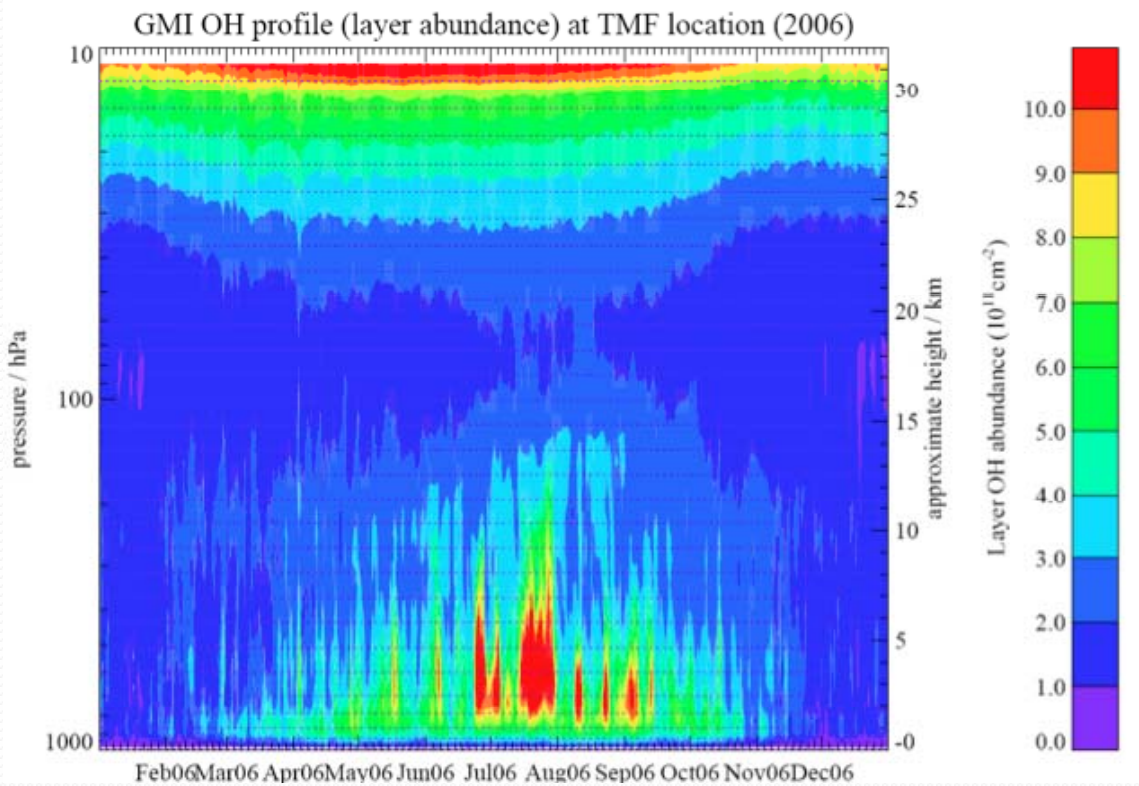
Modeled Lower Atmospheric OH

- The day-to-day variability in GMI OH partial column

  — the largest variability occurs when GMI OH is near its peak in summer.

  — the variability is mostly from the lower troposphere

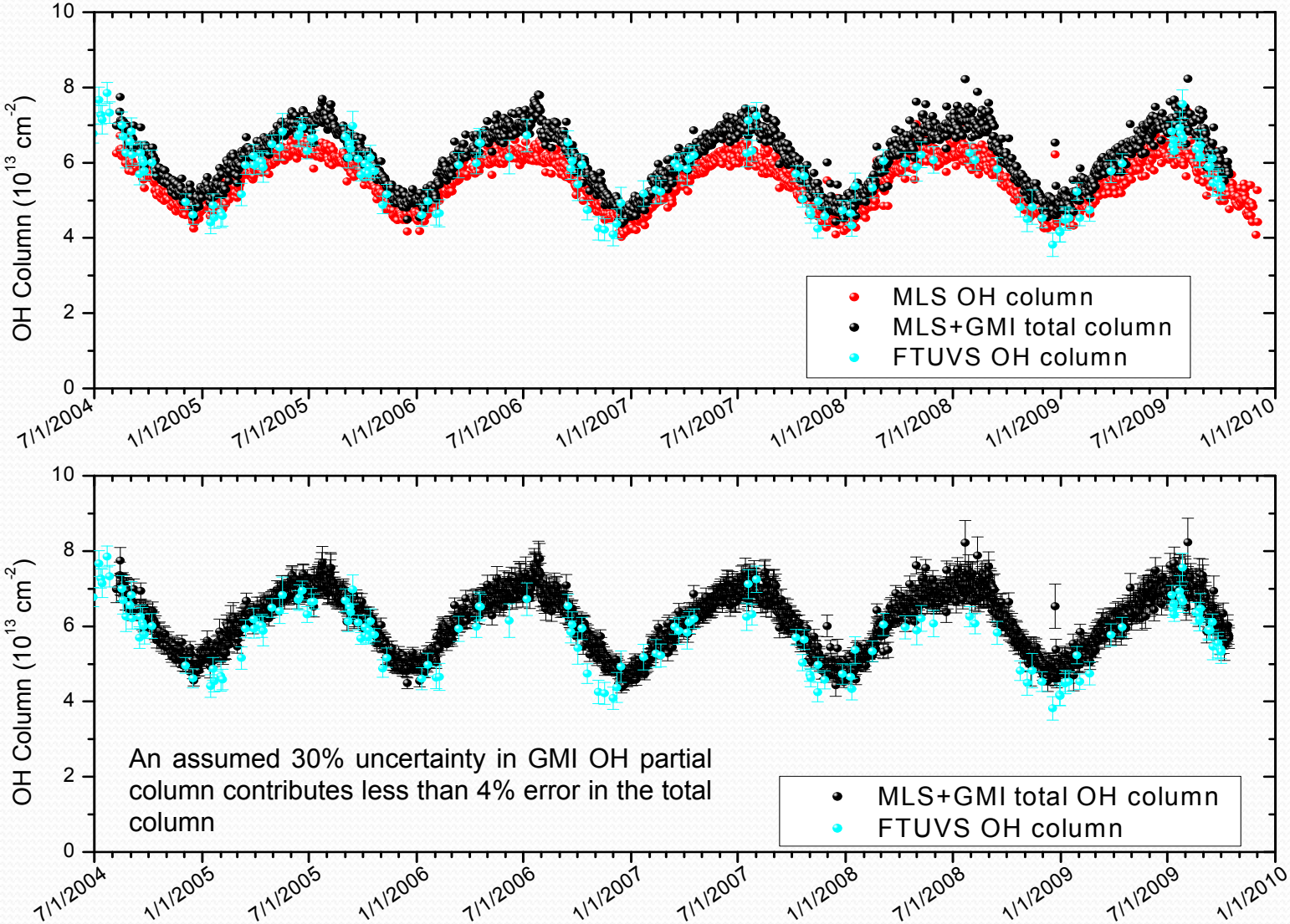
- This variability contributes less than 10% variability in the total OH column.



- The GMI OH partial column (below 21.5 hPa) peak time varies from year to year (Jul to Sep), while the MLS OH partial colum (above 21.5 hPa) peak time always occurs in late Jun to early Jul.

  (The seasonal variation in the upper stratospheric and mesospheric OH is primarily controlled by the SZA, while more factors have to be considered in the troposphere)

Comparison of OH Columns

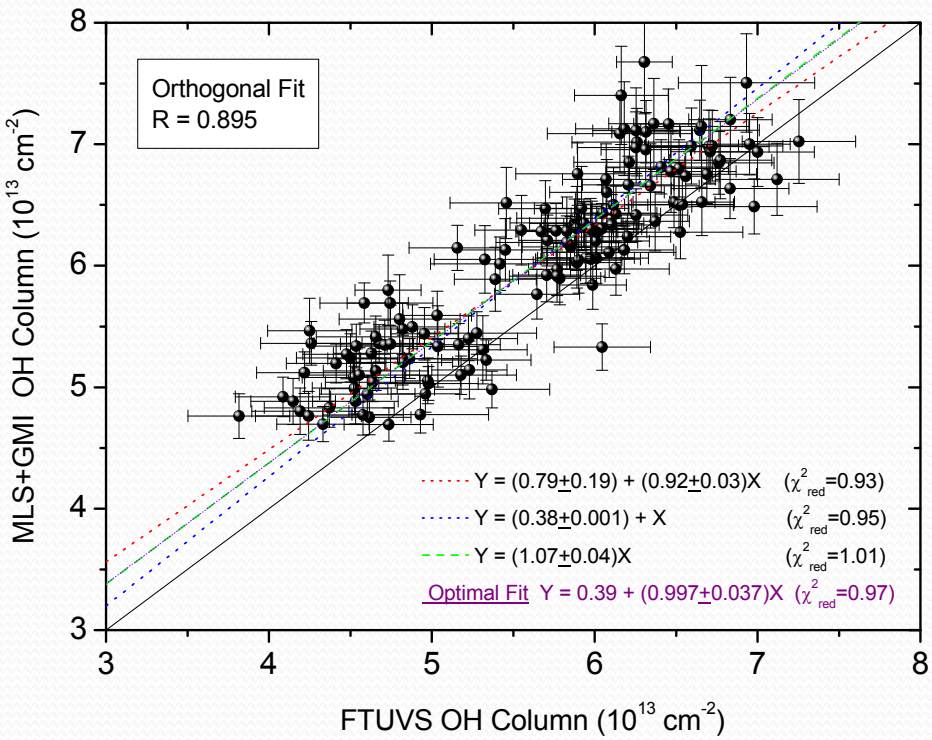


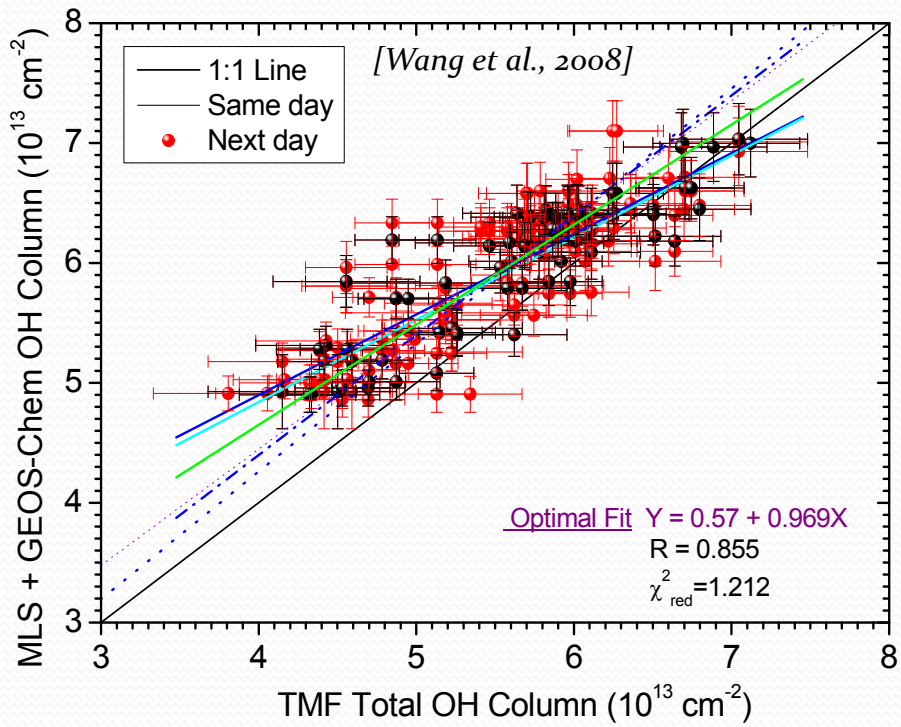
Comparison of OH Columns

- The overall agreement is improved compared to the previous validation using GEOS-Chem.

  — GMI daily Aura overpass time OH calculations during 2004-2007 are expected to be closer to the truth than the derived OH from GEOS-Chem 2003 monthly mean.

  — We have nearly doubled data points to compare → only same-day data are compared





Summary

• Aura MLS OH measurements have been compared with ground-based FTUVS OH column measurements for a period of ~5.5 years with the help of GMI simulations of the lower atmospheric OH.

OH total column comparison – MLS+GMI vs. FTUVS.

• Using GMI has advantages over the previous validation effort using GEOS-Chem.

GMI chemistry module includes both tropospheric and stratospheric chemistry.
GMI Aura4 runs provide satellite overpass time results.

• The long-term comparison of total OH columns from MLS+GMI and FTUVS shows excellent agreement.

This is a remarkable agreement, particularly considering the large discrepancies among previous OH measurements. .

GMI tropospheric OH shows large day-to-day variability in summer, which contributes to the variability in MLS+GMI total column OH.

The varying peak time of OH in the troposphere (GMI) and the constant peak time of OH in the upper stratosphere and mesosphere (MLS) suggest that the latter is primarily controlled by the SZA change throughout the year while the former is controlled by more factors.

Acknowledgement

- Herb Pickett, PI of the MLS OH measurements (retired).
- Susan Strahan and the GMI team.