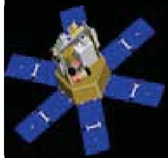

Atmospheric OH Response to the 11-year Solar Cycle

— Could the gap between model and observations be filled by SORCE data?

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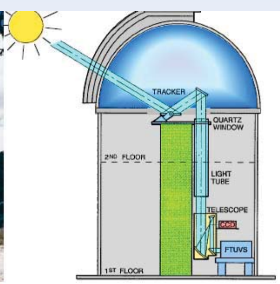
Whole Atmosphere Community Climate Model



Background

• During the 11-year solar cycle, the total solar irradiance (TSI) varies by only ~0.1%. However, the relative changes in UV flux is much larger.

• OH, produced through photolysis in the UV, is expected to be affected by the solar cycle.

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

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

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

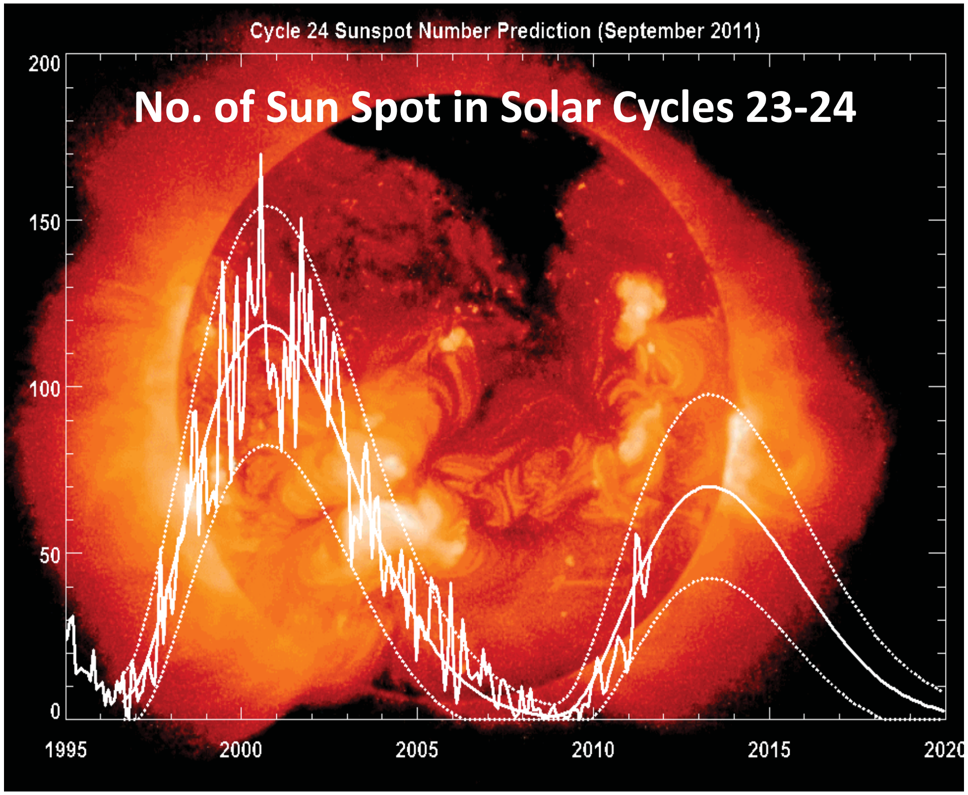
• The mechanisms appear to be straightforward but far from well understood.

UV change

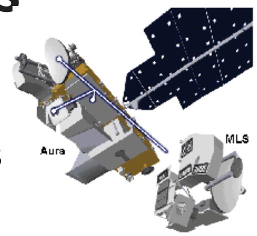
variability in source/sink species

change in the shield effect

• The variability in OH and the related odd hydrogen chemistry affects the variability in middle atmospheric O_3.



AURA/MLS Measurements



— 2.5 THz module for OH measurement

Global coverage (82S – 82N) on a daily basis

~32 – 0.0032 hPa (~90% of total OH)

[Pickett, 2006]

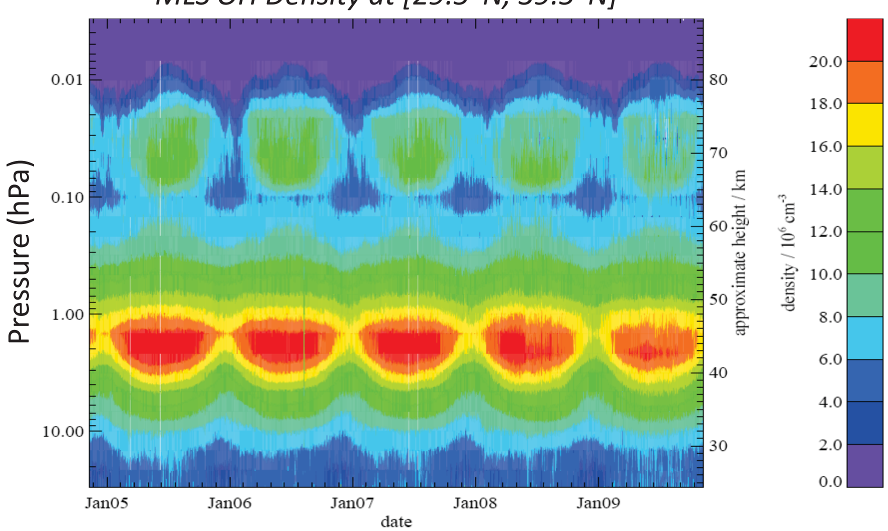
— Extensive Validation

Air-borne and ground-based measurements, models

[Canty et al., 2006, Pickett et al., 2008, Wang et al, 2008]

— Available data: Aug 2004 to Dec 2009, Aug to Sep 2011

MLS OH Density at [29.5 °N, 39.5 °N]



Ground-based Measurements

<u>Fourier Transform Ultra-Violet Spectrometer</u>

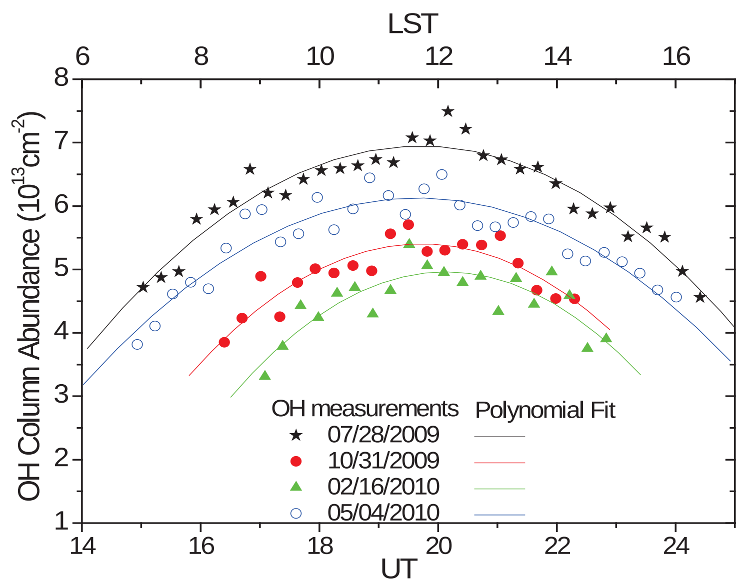
Location — TMF, Wrightwood, CA (34.4°N, 117.7°W)

Altitude — ~2.3 km

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

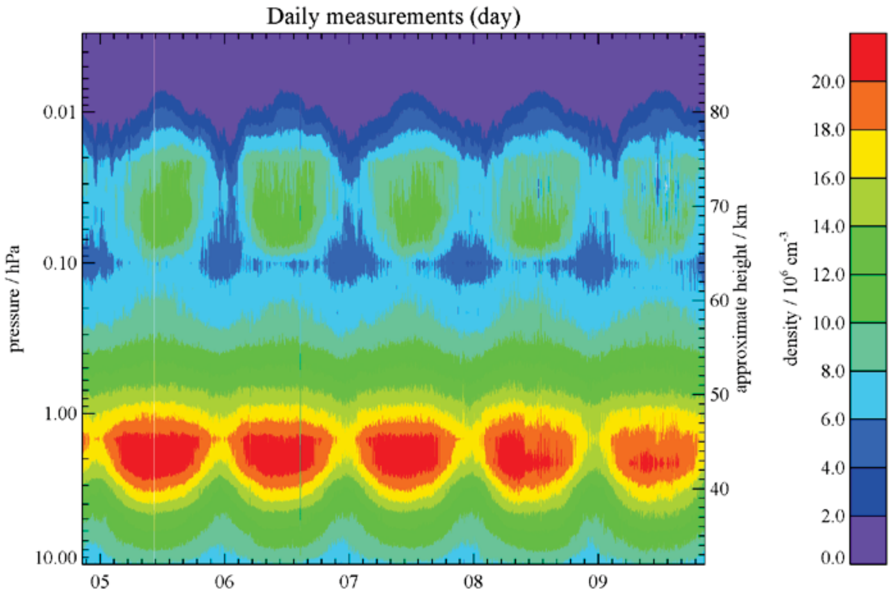
Spectral region for OH measurements — ~308 nm

Measurement duration — diurnal observations from 1997 to present

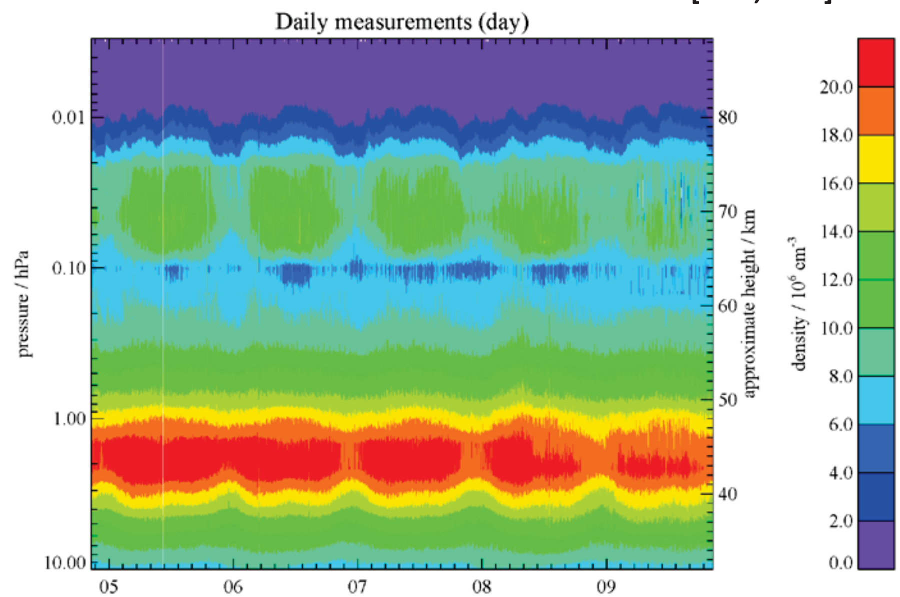


Hint of Solar Cycle Signal in MLS OH

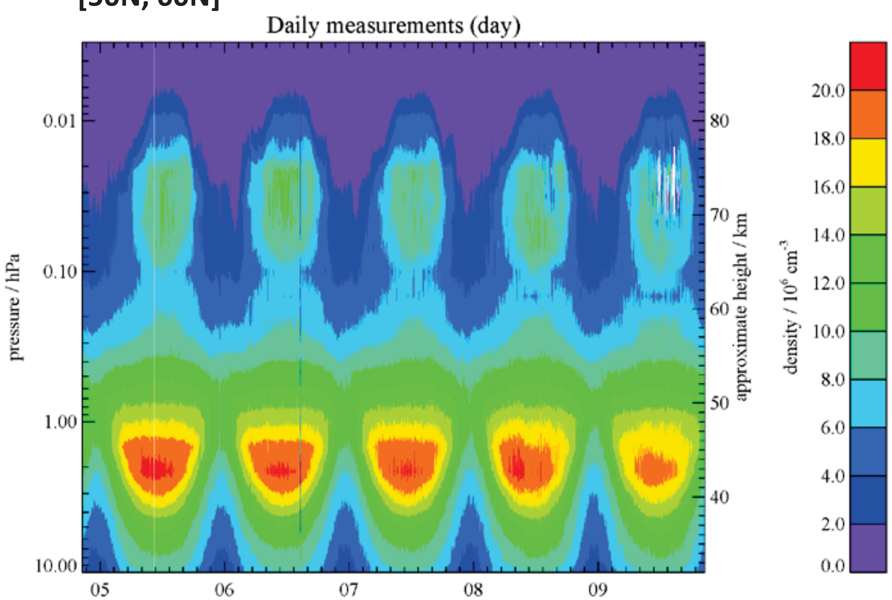
TMF [29.5N, 39.5N]



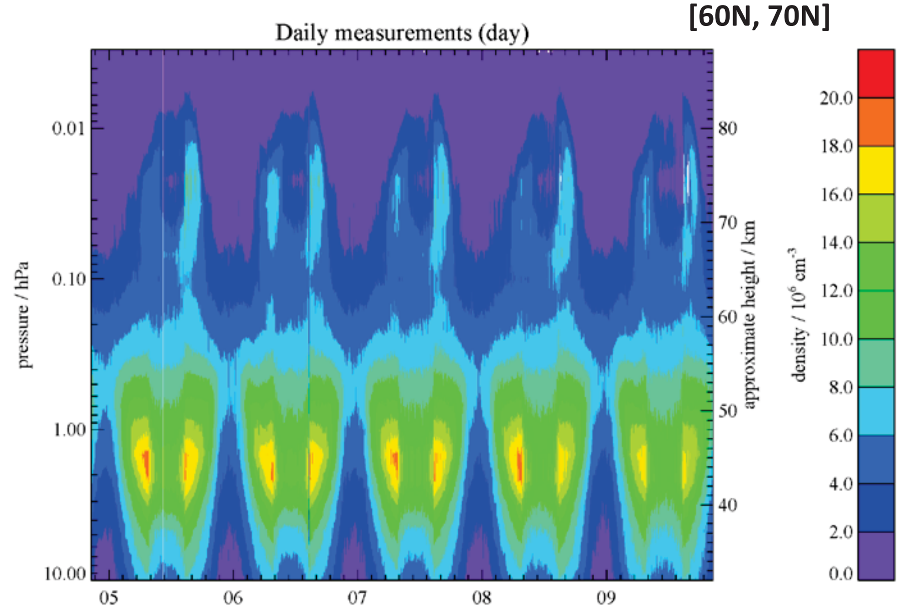
[10N, 20N]



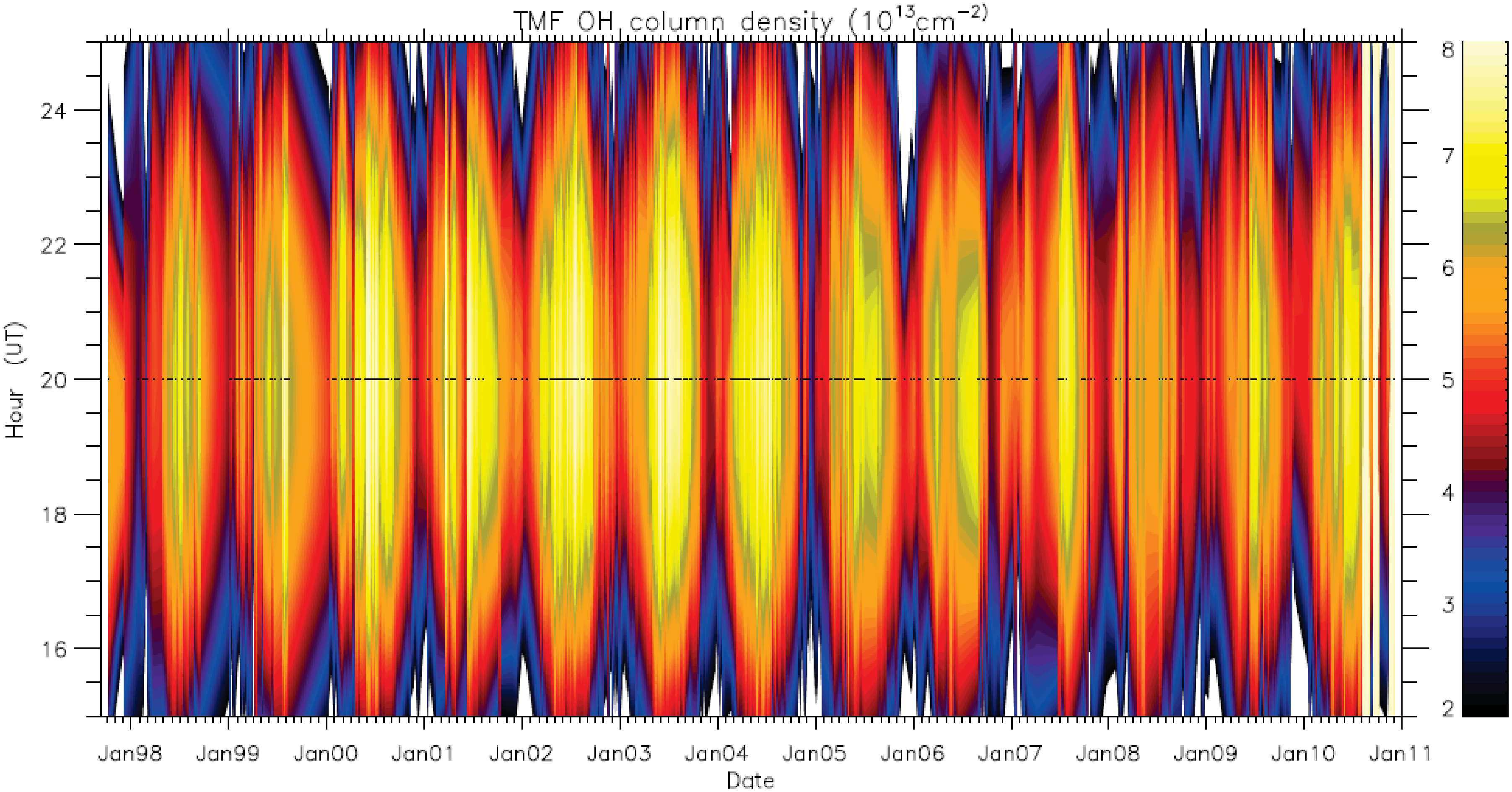
[50N, 60N]



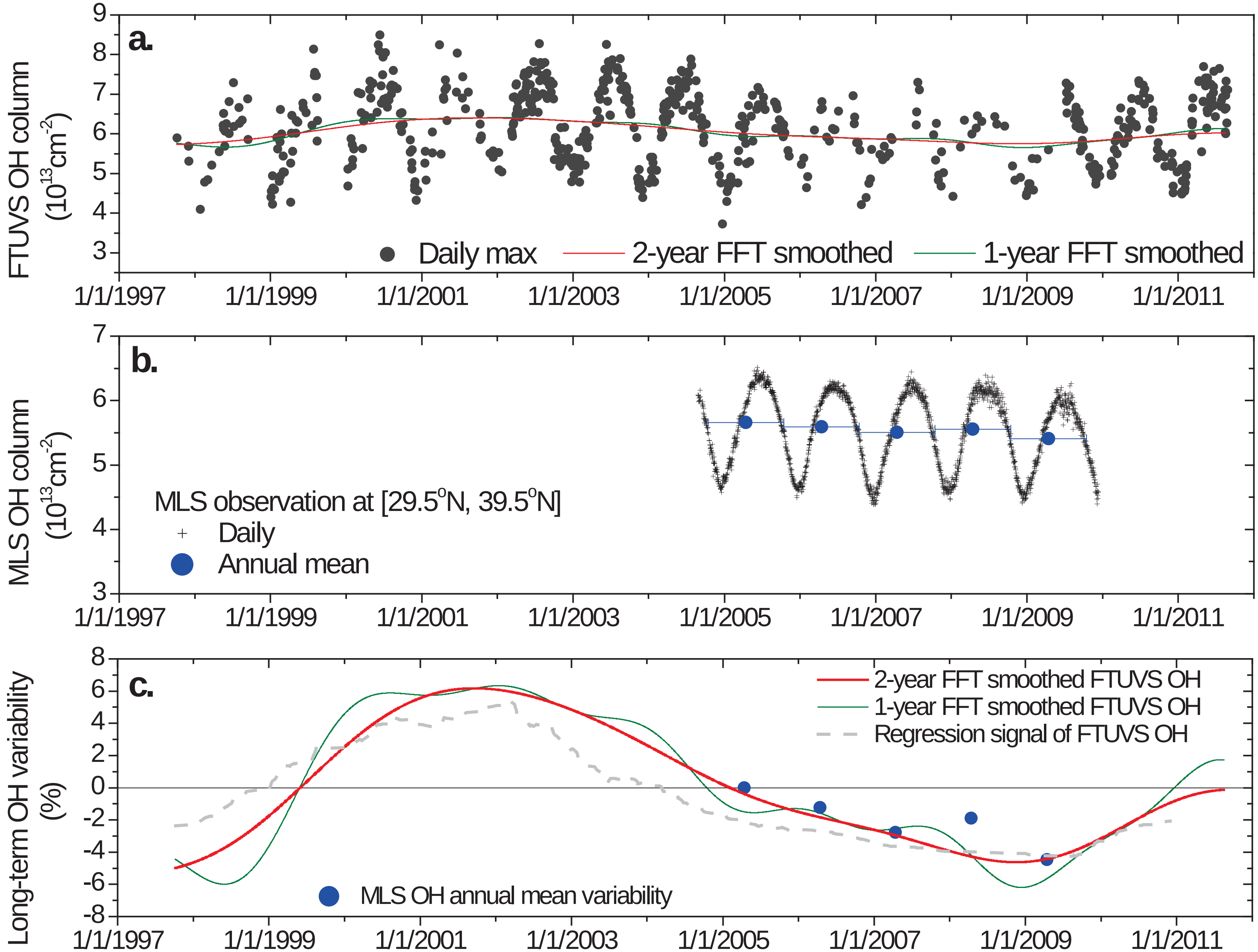
[60N, 70N]



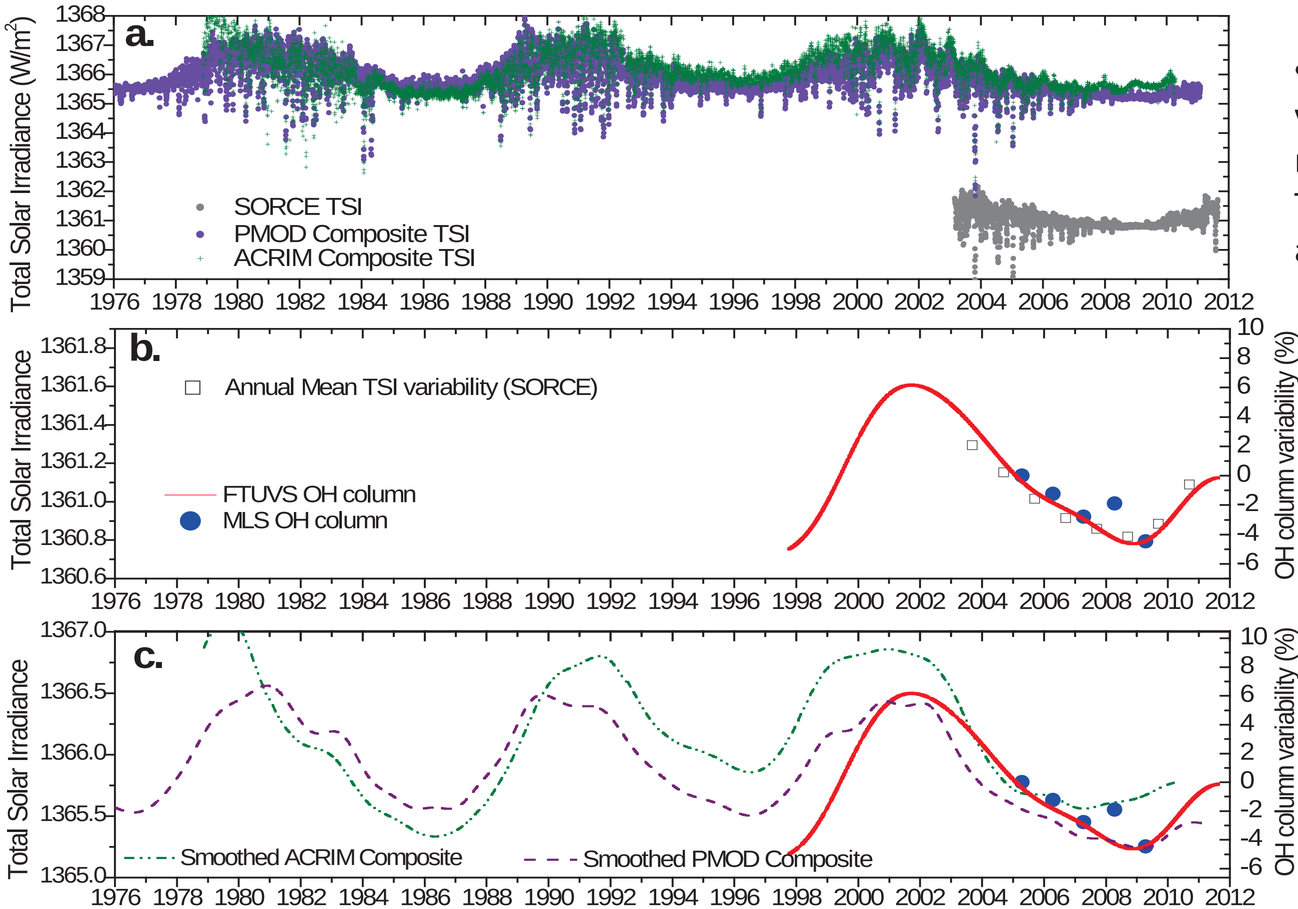
Solar Cycle Signal in FTUVS OH



Extract the Solar Cycle Signal from OH Observations

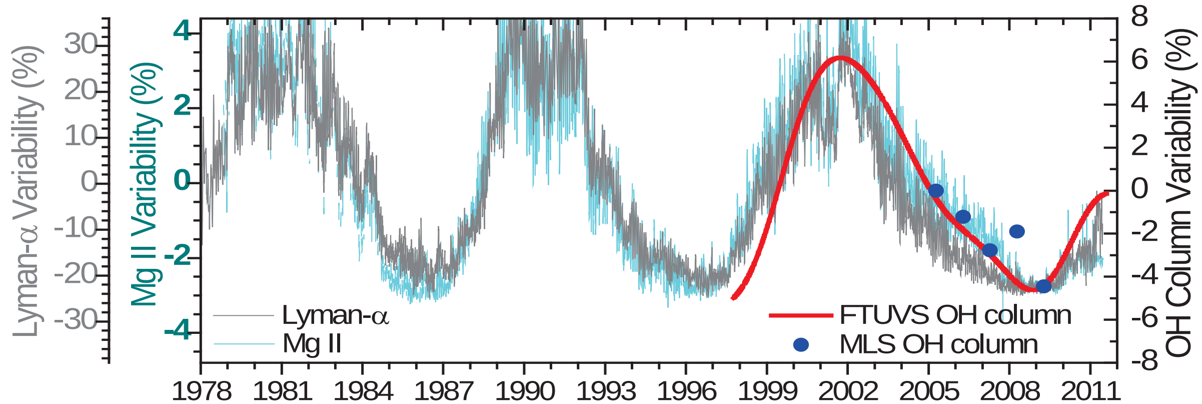


OH Response to 11yr Solar Cycle



• Observed OH long-term variability is correlated with TSI records from multiple satellites. The trends are generally in good agreement.

• Observed OH long-term variability is highly correlated with the solar UV parameters — Lyman-α (121.5 nm) and Mg II index (core-to-wing at 280 nm).

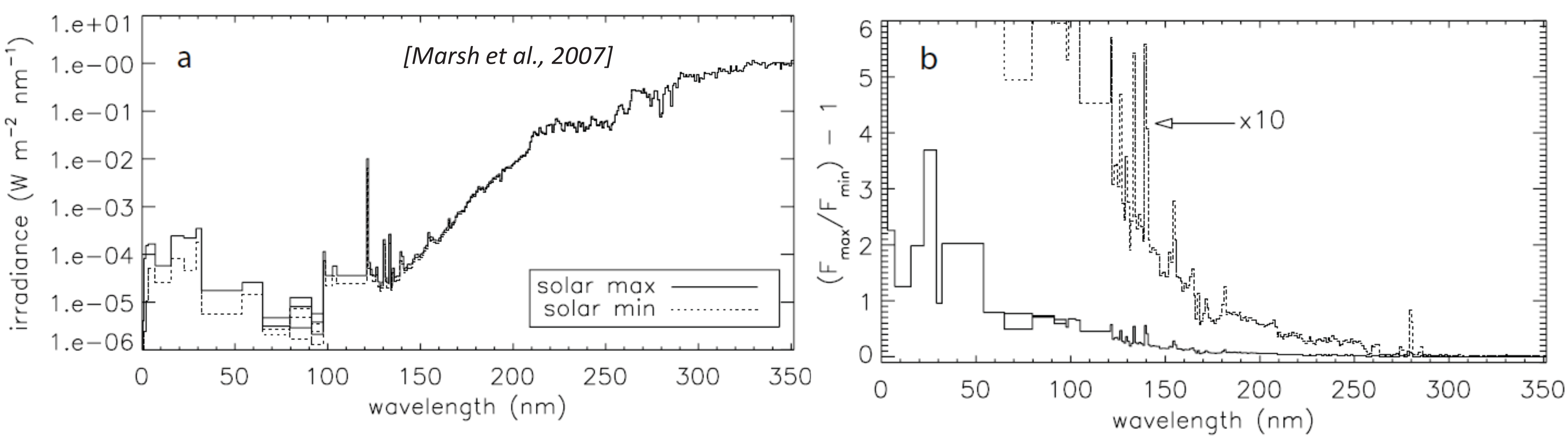


WACCM Simulations

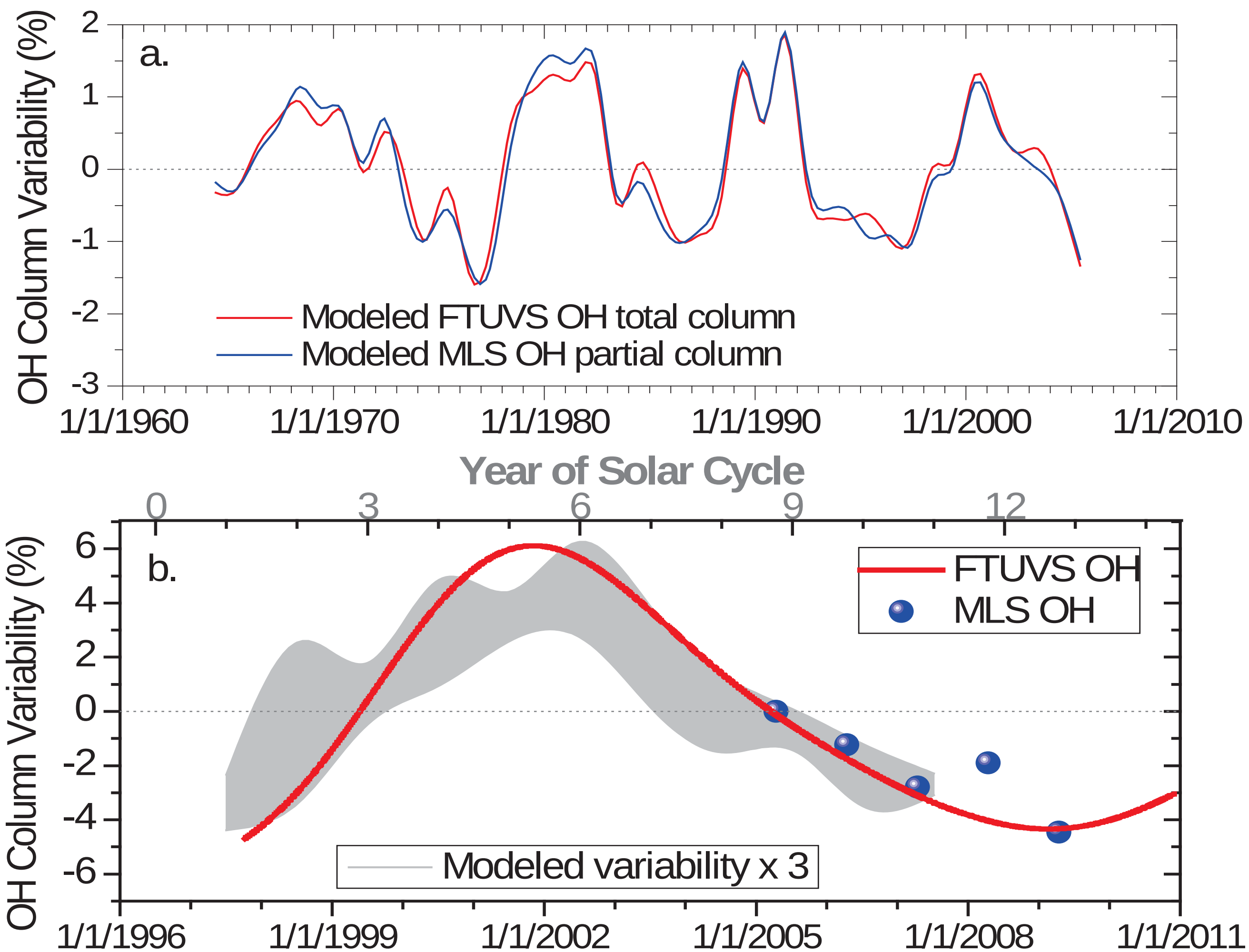
• WACCM (Whole Atmosphere Community Climate Model)
Community Atmosphere Model (CAM3)
66 levels from the surface to the mesosphere
5° longitude by 4° latitude
MOZART3 (the Model for Ozone and Related Chemical Tracers)
57 species; 211 photochemical reactions

• For solar flux variability, many current models adopt Lean's model/parameterization based on f10.7 measurements [Lean, 2000].

• The standard WACCM3 uses modeled solar flux based on UARS/SOLSTICE measurements in the UV *[Woods and Rottman, 2002; Marsh et al., 2007; Austin et al., 2008].* The solar spectral variability is very close to Lean's model.



Gap between modeled and observed OH variability



The discrepancy between modeled (using Lean's model, as shown, or UARS) and observed OH column variability due to the solar cycle is roughly a factor of 3.

Recent SORCE observations of this solar forcing may change our view

Solar Radiation and Climate Experiment (SORCE)

— NASA mission launched on Jan 25, 2003 (645 km, 40° orbit)

— Measurements of incoming x-ray, UV, visible, near-infrared, and total solar radiation (TSI).

The measured solar spectral irradiance (SSI) covers 95% of the spectral contribution to TSI.

Solar Stellar Irradiance Comparison Experiment (SOLSTICE)

— covers short UV 115 – 300 nm

— absolute accuracy, better than 5%

— data available at LASP (LISIRD; http://lasp.colorado.edu/lisird/)

Spectral Irradiance Monitor (SIM)

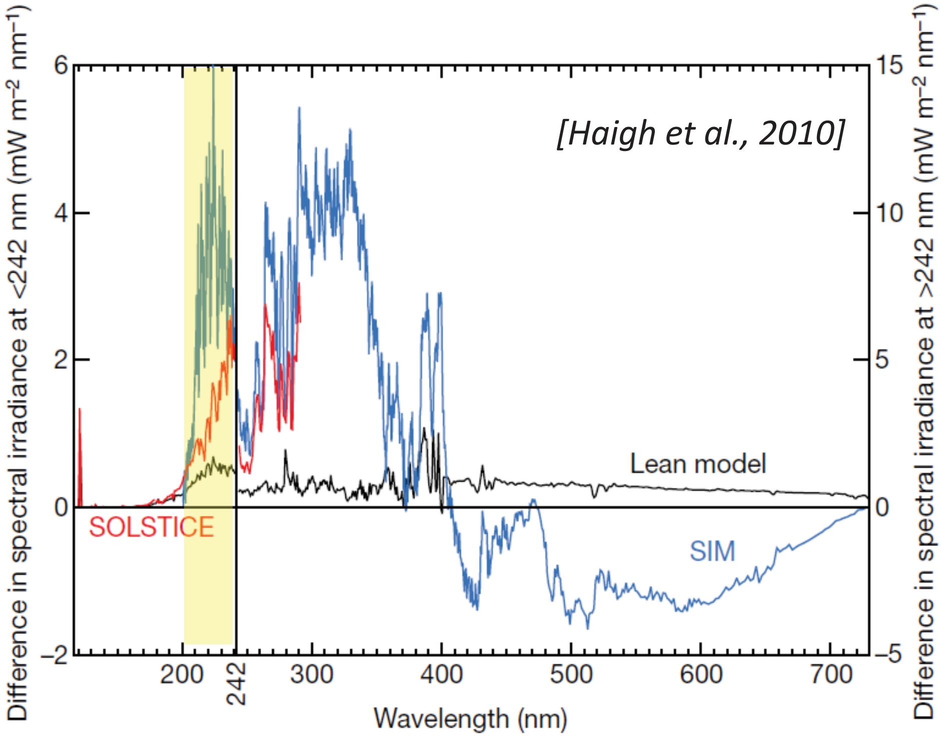
— covers 200 – 2700 nm

— absolute accuracy, better than 2%

— data at 310-2400 nm are available from LASP/LISIRD

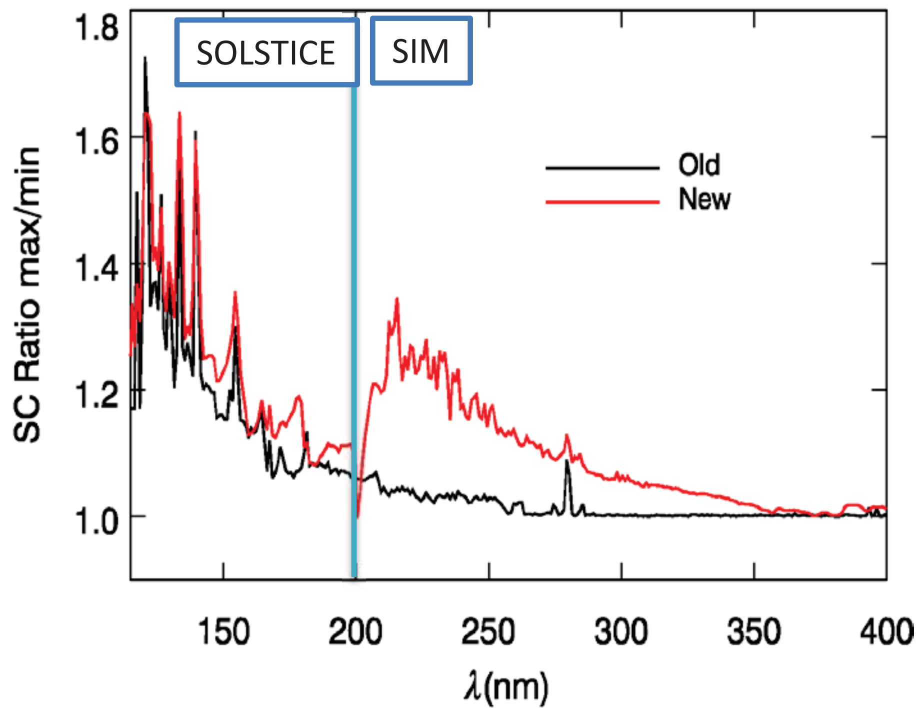
— data at 200-310 nm are available upon request

Recent Satellite observations of this solar forcing may change our view

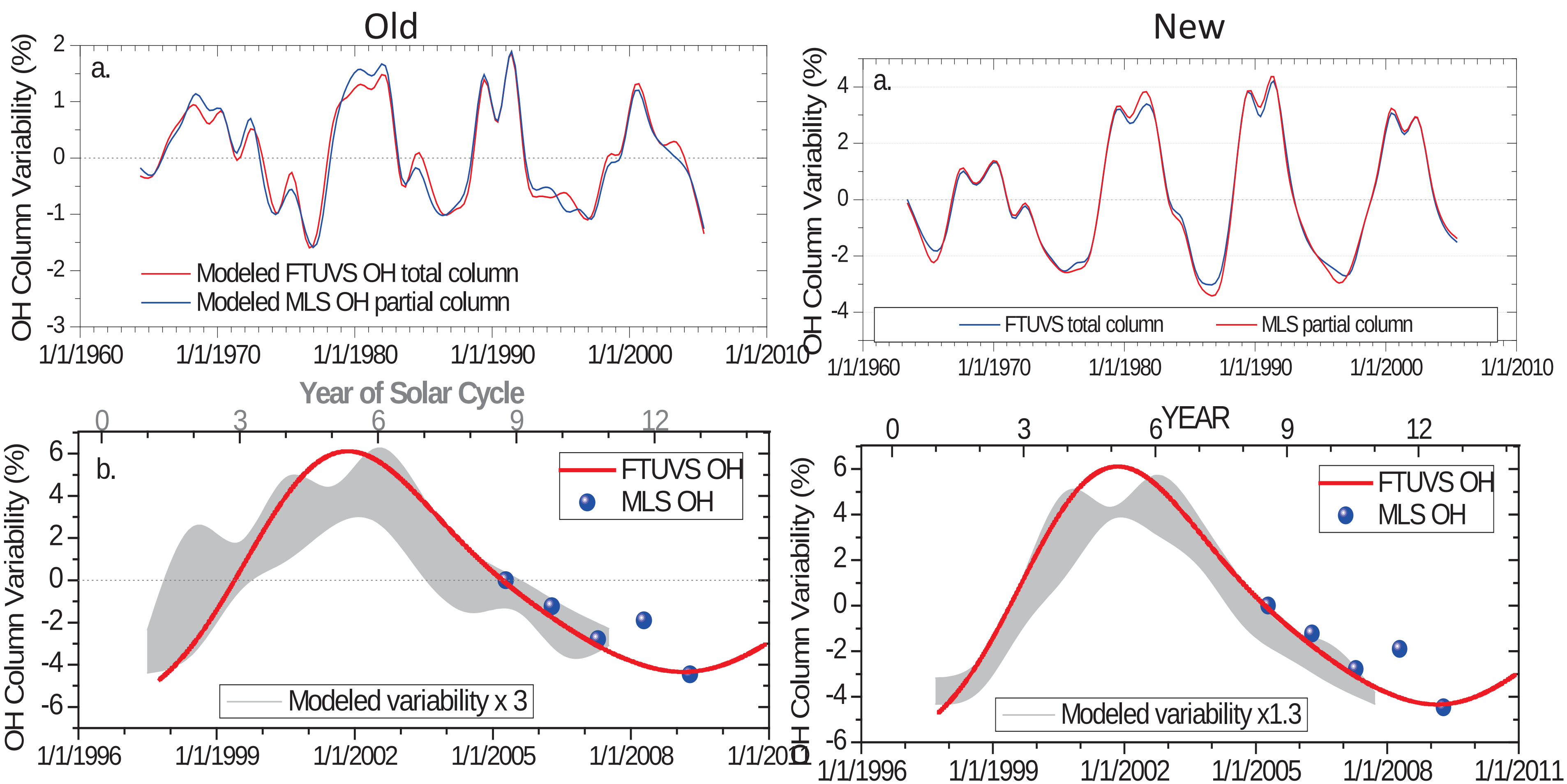


- We made WACCM runs using SORCE solar data.
- Solar UV spectral variation is based on the combination of SOLSTICE and SIM.
- To extrapolate the published solar flux variability to the full solar cycle, we use lyman-α (LASP long-term composite) as proxy to estimate scaling factors.

- Differences in solar spectrum between Apr 2004 and Nov 2007 derived from SIM and SOLSTICE data are much larger than Lean's model.
- In UV region, the difference is a factor of 2 - 6.
- In visible, they show opposite signs.



Gap between modeled and observed OH variability filled by SORCE data ?

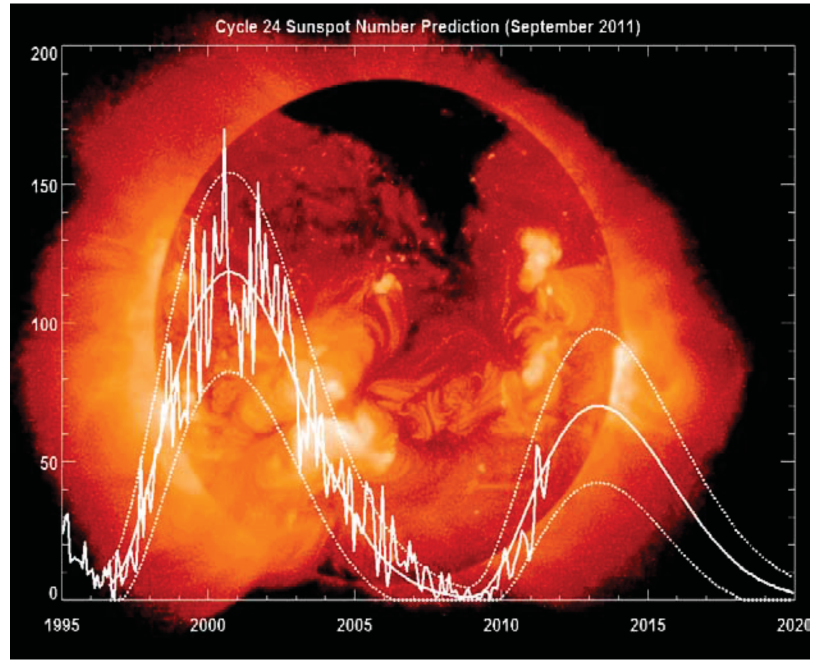


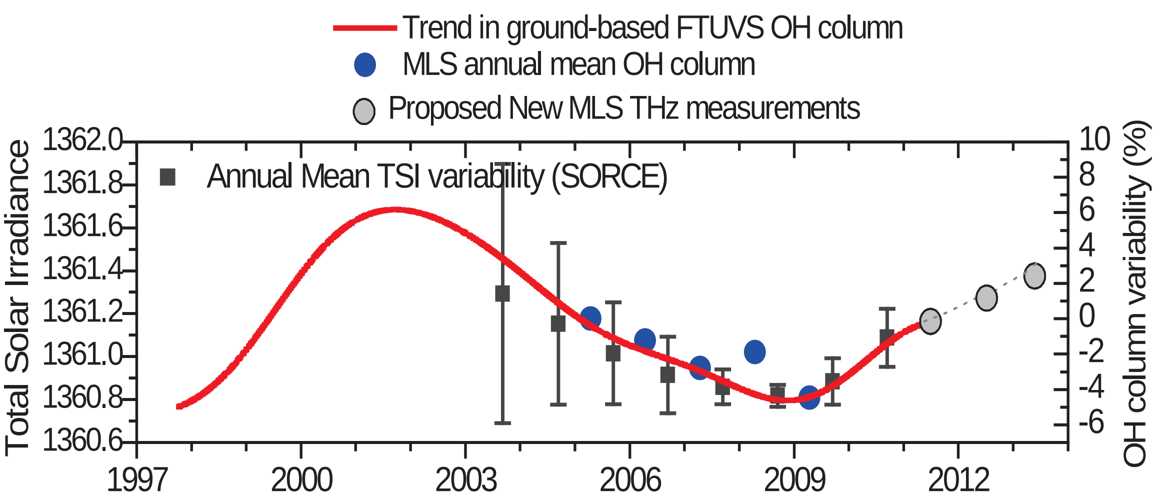
The model results using the SORCE solar flux variability as input give a OH variability that is much closer to observations.

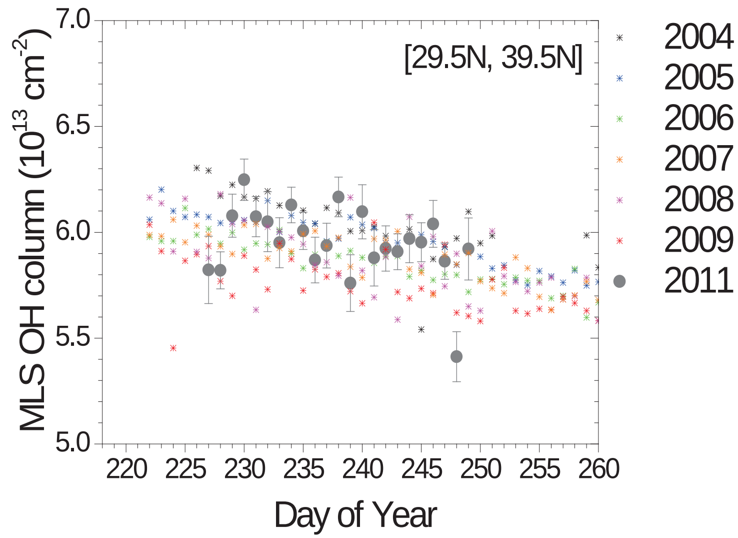
* Different combinations of SOLSTICE and SIM (at different cutoff wavelengths) give similar results (Scale factor ~1.3 ~ 1.5

Continuing OH measurements through the next solar max

- Ground-based OH measurements with FTUVS is continuing.
- MLS sub-instrument for OH is expected to perform measurements for one month in each of the coming years.
- These observations through the next solar max will provide extremely valuable evidence for solar cycle signal in OH.







Conclusions

• The total OH column response to the solar cycle, from Aura/MLS and TMF/FTUVS observations, is ~10%.

• The 3D WACCM model is used to study such OH variability and compared to observations.

• While WACCM model with "traditional" solar flux variability give a OH response only 1/3 of the observed variability (~3%), the model runs using the recent SORCE solar spectrum irradiance measurements show OH results close to observations (~7%).

• *We also used a 1D photochemical model to investigate this solar cycle signal in detail (presentation by Li et al.). The modeled vertical profile variability in OH show features similar to observations. The major peaks of the variability can be well explained by the related photochemistry (H_2O photolysis, O_3 photolysis, and the shielding effect from overhead O_3).*

• These findings are consistent with the conclusions from Haigh et al., [2010], preferring SORCE measurements of solar spectral variation over Lean's model.

• Questions remain on whether there are shortcomings in Lean's solar model or Solar Cycle 23 is substantially different from earlier solar cycles or both.

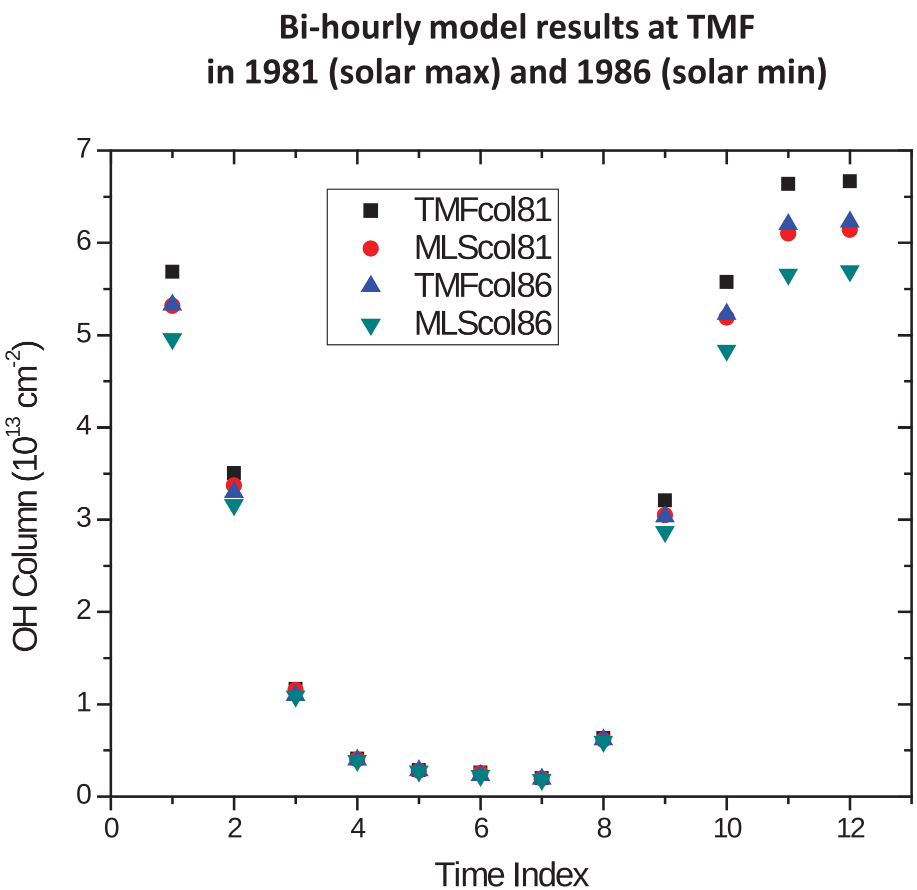
• The continuing OH measurements, in particular the Aura/MLS OH measurements through the next solar cycle, will be extremely valuable for this investigation.

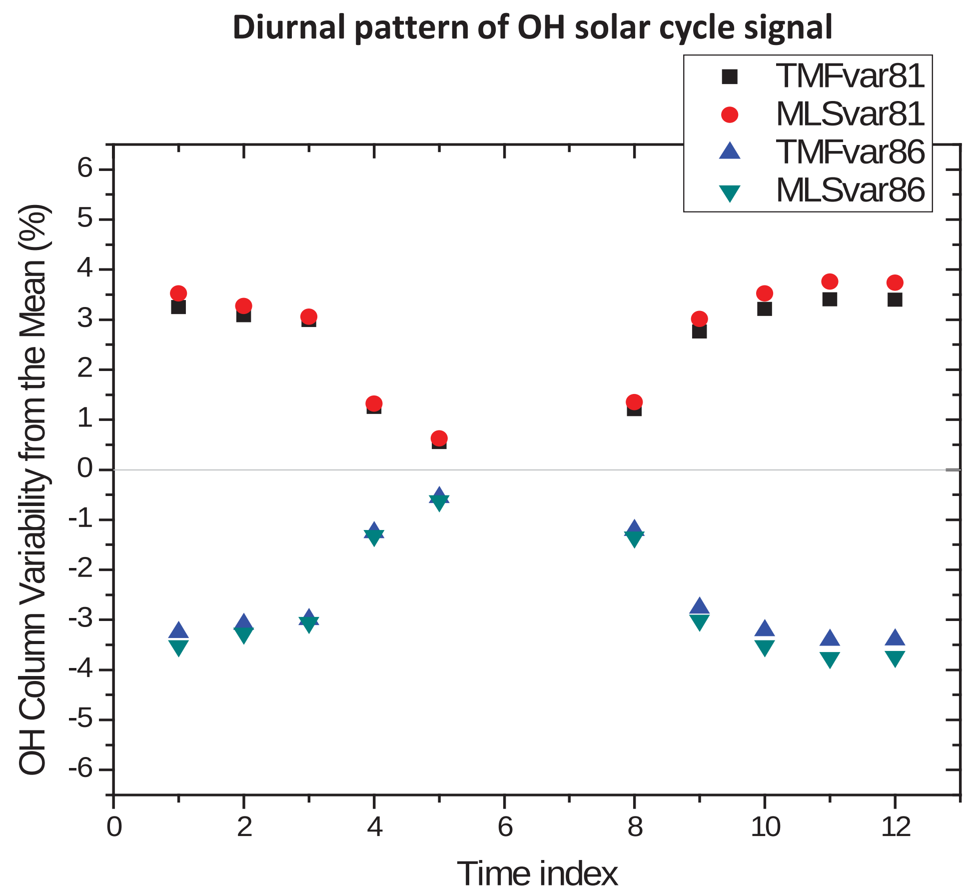
Acknowledgements

- MLS team and TMF facility
- SOLSTICE and SIM team
- Herb Pickett (retired, MLS OH PI)

Back Up

Diurnal Pattern of OH Column Variability





- The diurnal pattern of modeled OH columns (using SORCE solar data) are derived from the solar max year (1981) and the solar min year (1986) model outputs.
- The solar cycle signal in OH column (% variability) appears to be larger when OH abundance is larger (at smaller SZA). The daily max (near noon) shows a solar cycle very close to the diurnal-averaged signal.