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Atmospheric OH Response to the 11-year Solar Cycle

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

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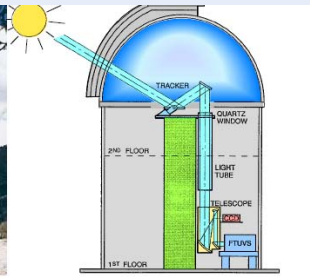
WACCM
Whole Atmosphere Community Climate Model



Background

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

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

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

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

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

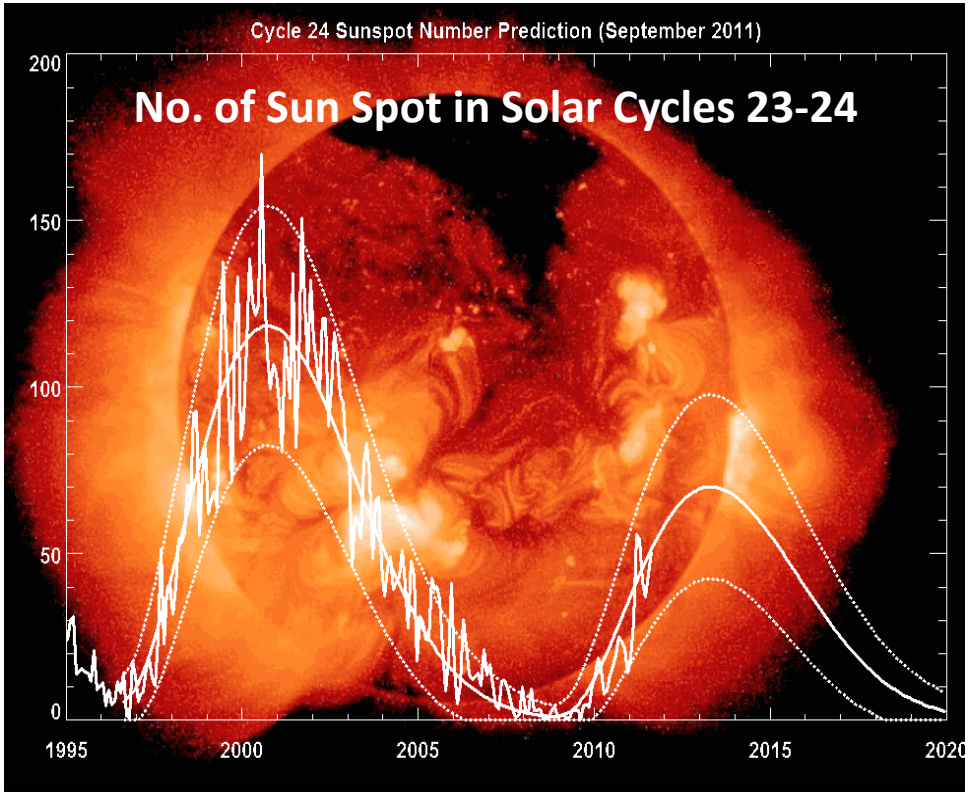
• The mechanisms appear to be straightforward but far from well understood.

UV change

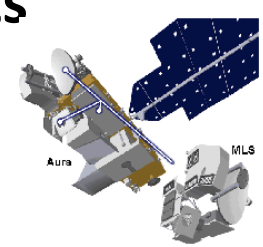
variability in source/sink species

change in the shield effect

• The variability in OH and the related odd hydrogen chemistry affects the variability in middle atmospheric O_3 (HO_x cycles destroy O_3).



AURA/MLS Measurements



— 2.5 THz module for OH measurement

Global coverage (82S – 82N) on 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

Ground-based Measurements

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

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

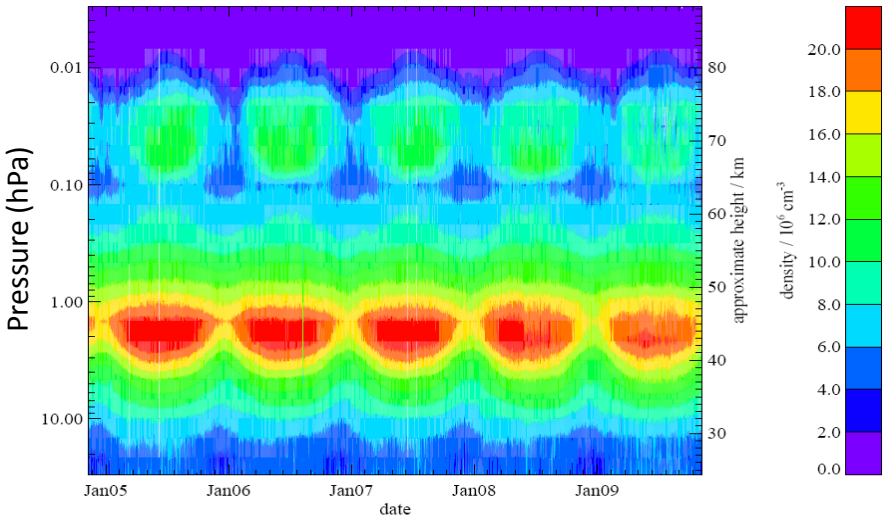
Altitude — ~2.3 km

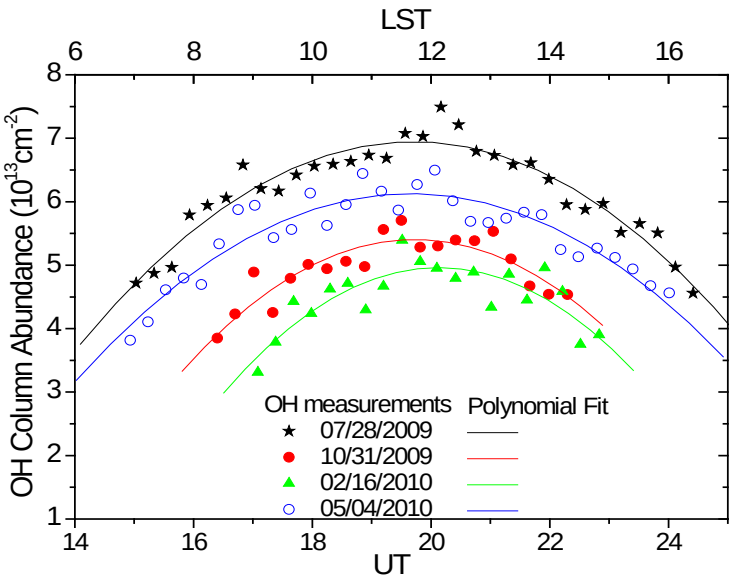
Setup — tracker (heliostat), telescope, and FTUVS interferometer

Spectral region for OH measurements — ~308 nm

Diurnal observations of OH total column from 1997 to present

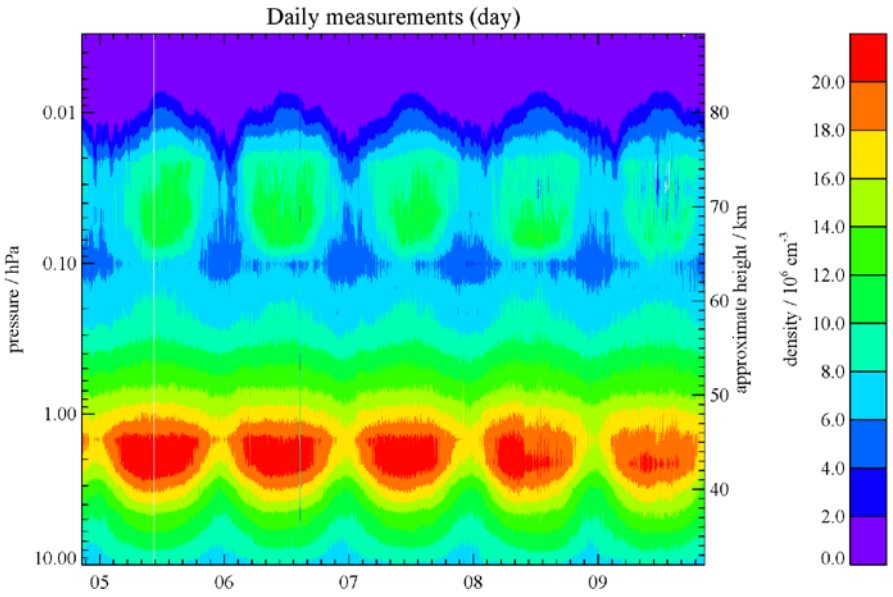
MLS OH Density at [29.5 °N, 39.5 °N]



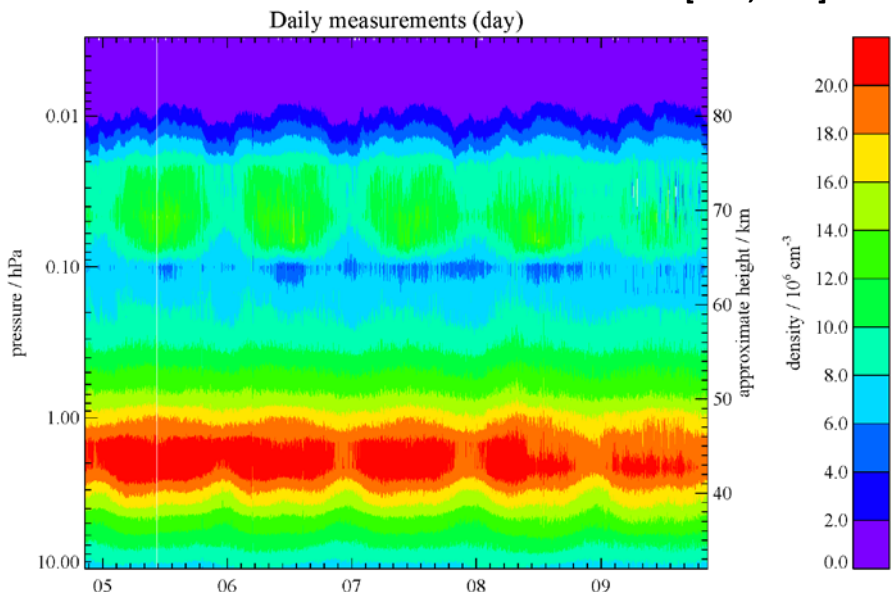


Hint of Solar Cycle Signal in MLS OH

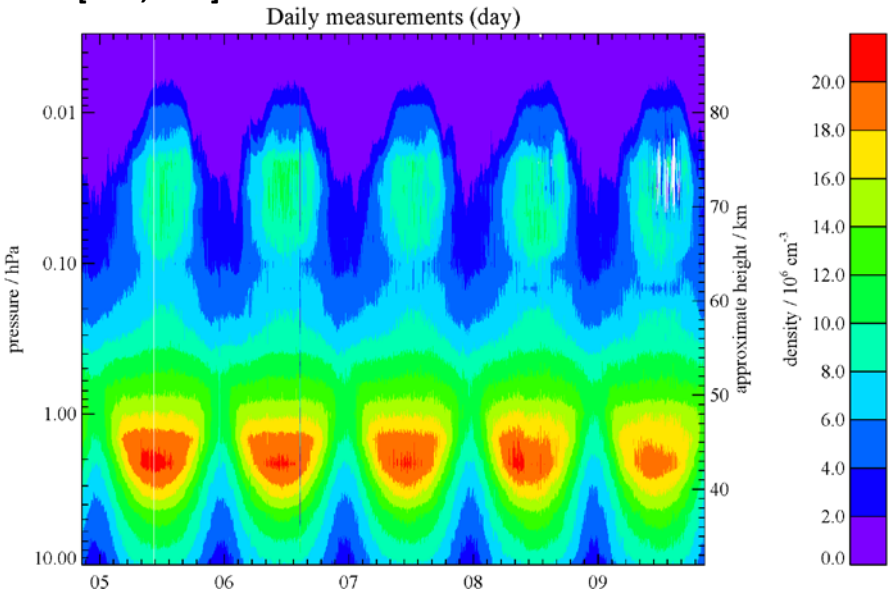
TMF [29.5N, 39.5N]



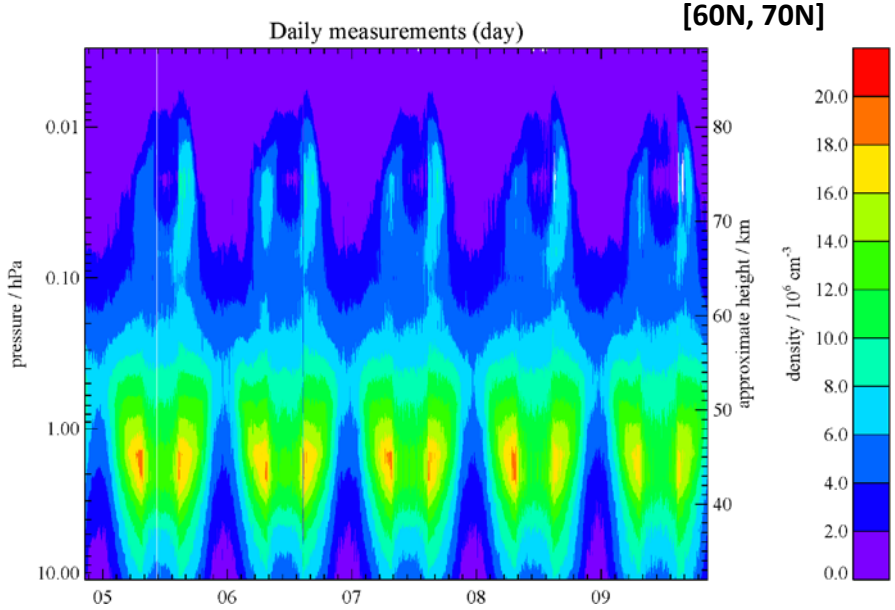
[10N, 20N]



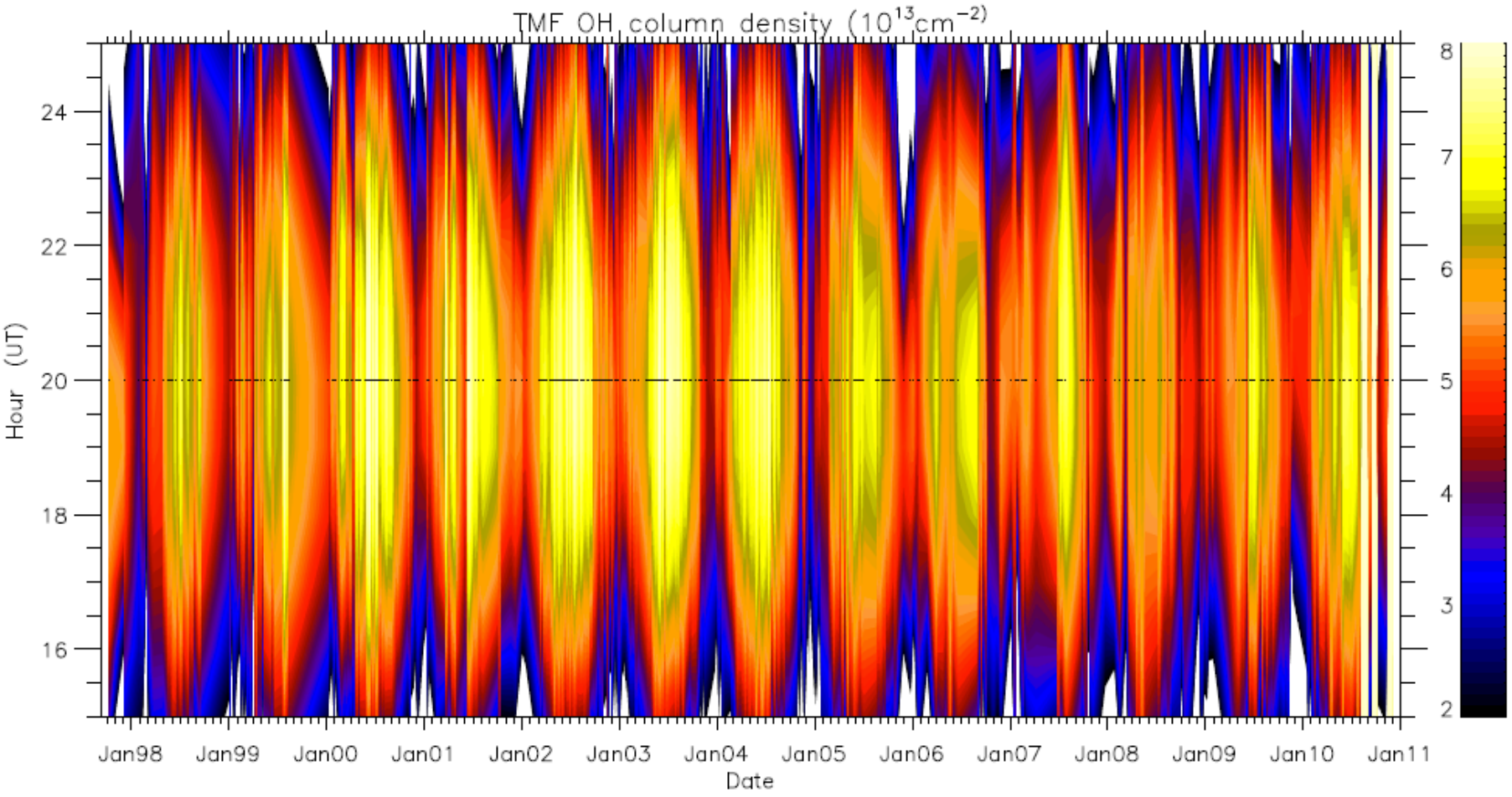
[50N, 60N]



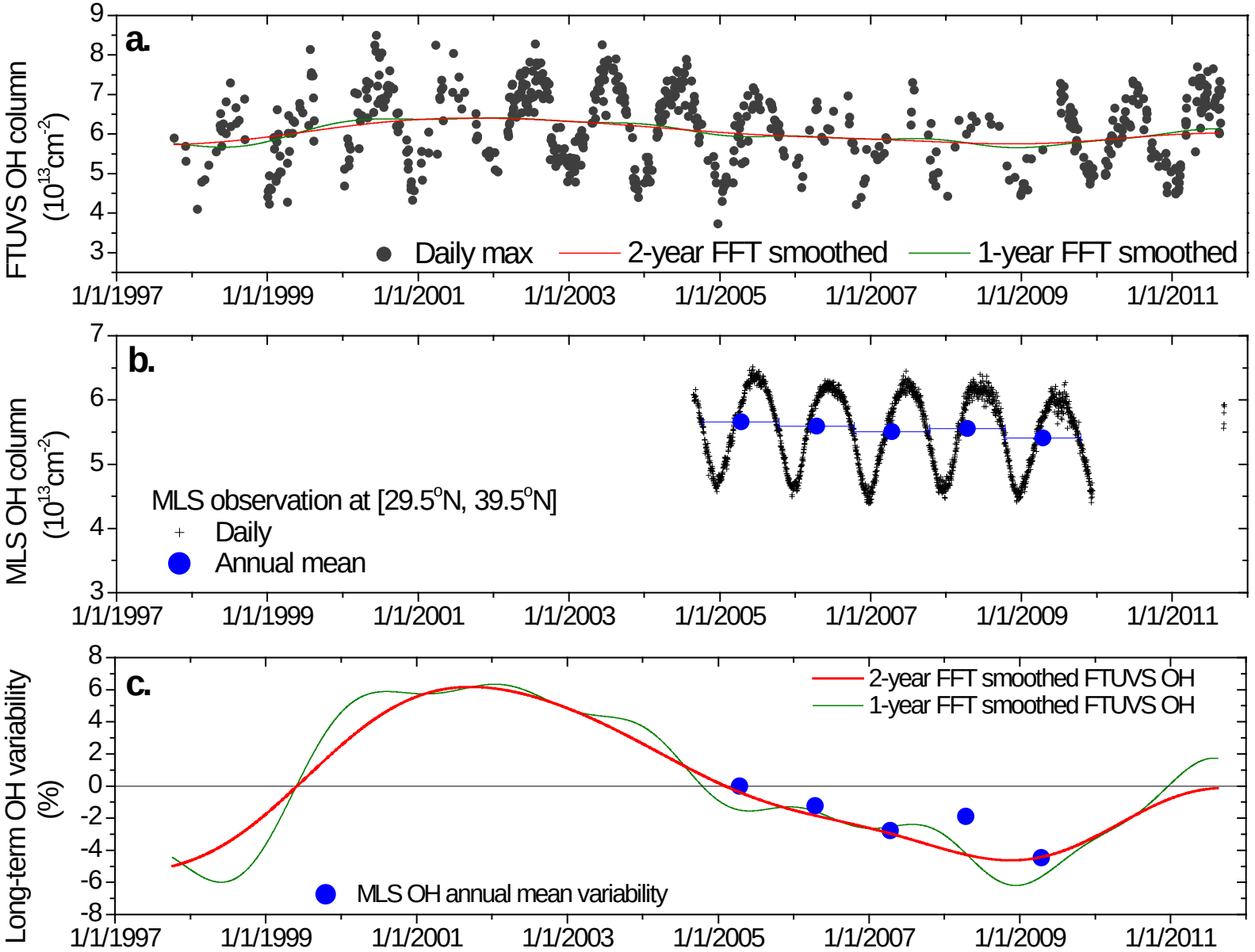
[60N, 70N]



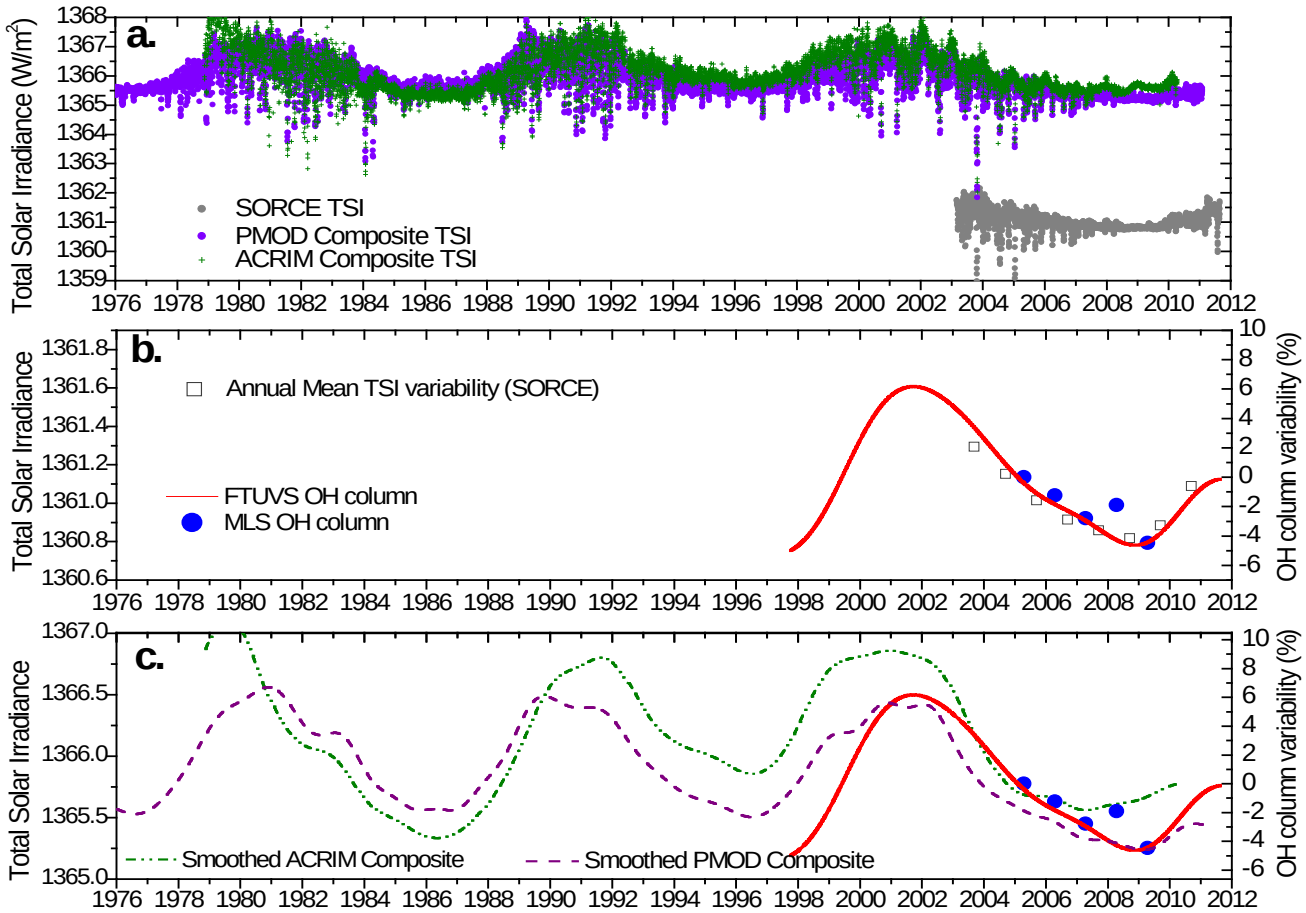
Solar Cycle Signal in FTUVS OH



Extract the Solar Cycle Signal from OH Observations

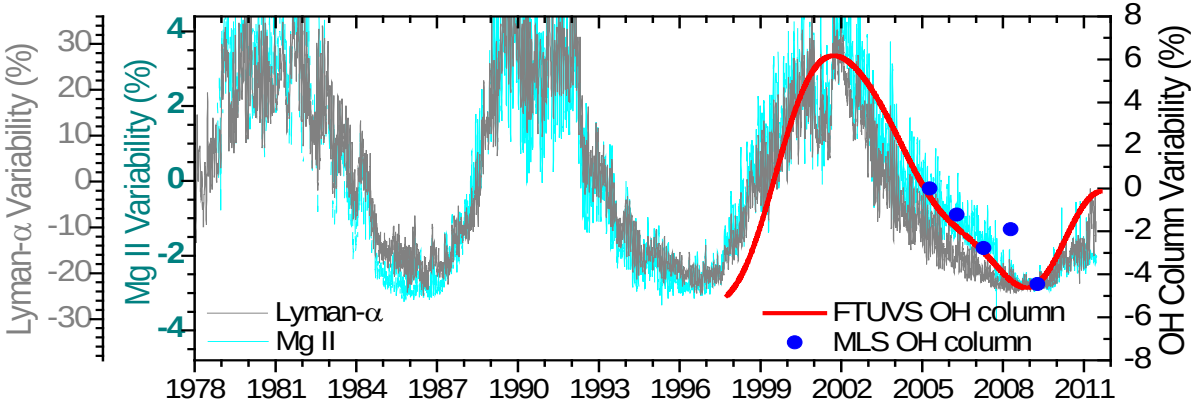


OH Response to 11yr Solar Cycle



- Observed OH long-term variability is correlated with TSI records from multiple satellites.
- The trends generally agree.

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

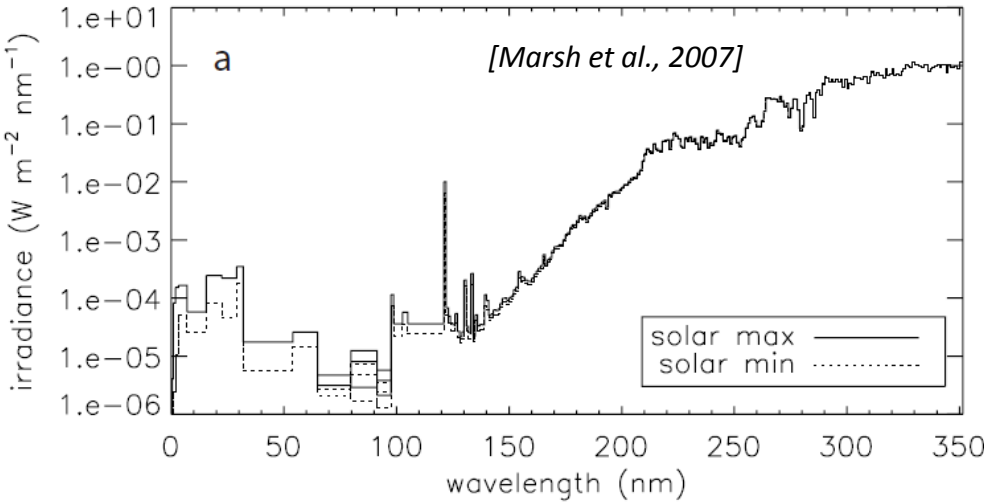


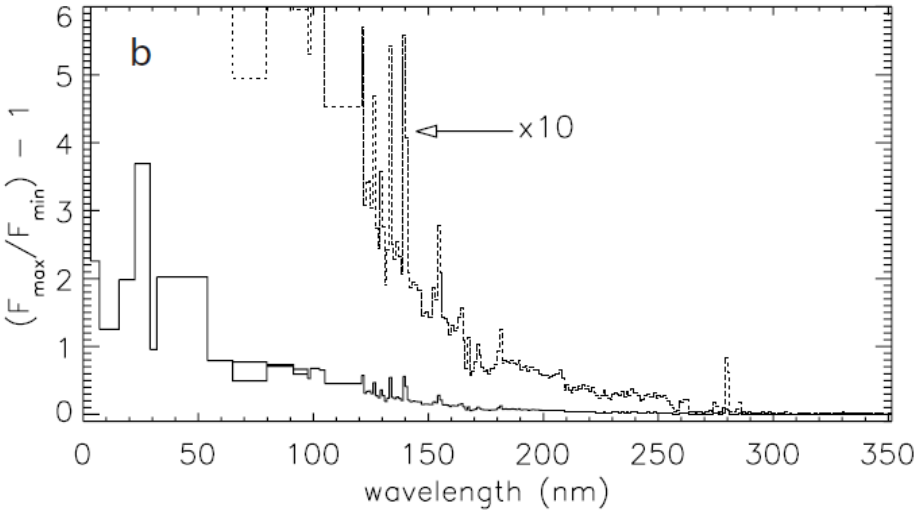
WACCM Simulations

- WACCM (Whole Atmosphere Community Climate Model)
  - Community Atmosphere Model (CAM3)
  - 66 levels (surface to mesosphere)
  - 5° longitude by 4° latitude
  - MOZART3 (the Model for Ozone and Related Chemical Tracers)

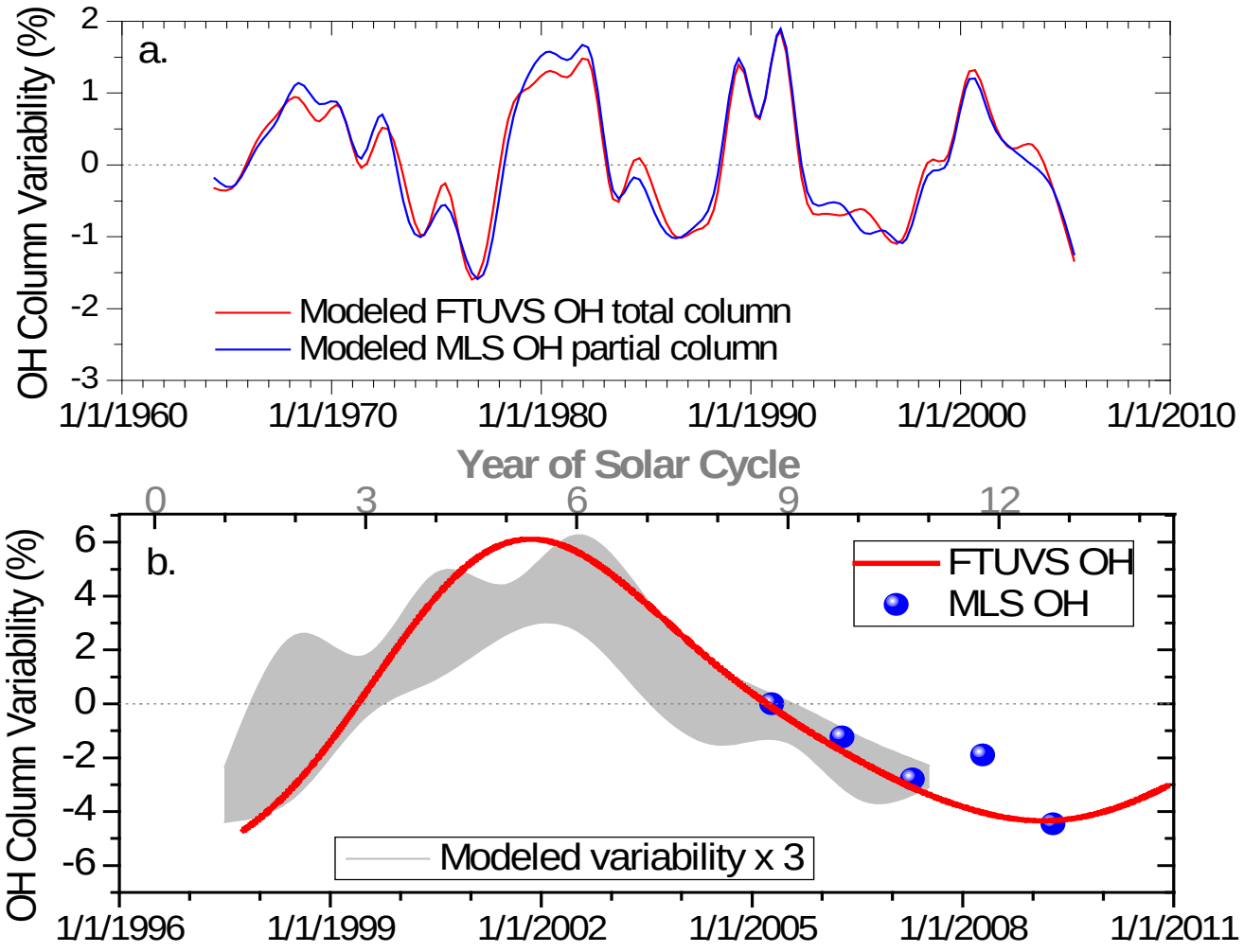
- For solar variability, many current models adopt Lean's parameterization [*Lean, 2000].*

- Standard WACCM3 uses modeled solar flux based on UARS/SOLSTICE UV measurements *[Woods and Rottman, 2002; Marsh et al., 2007; Austin et al., 2008]*, which is 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 Satellite observations of this solar forcing may change our view

Solar Radiation and Climate Experiment (SORCE)

— 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.

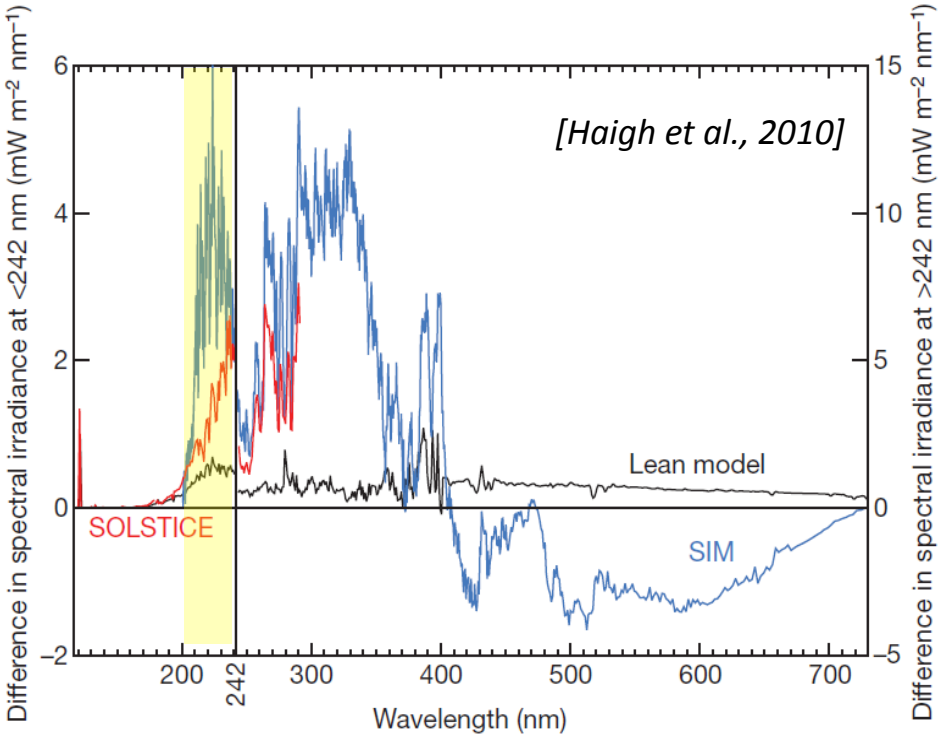
Solar Stellar Irradiance Comparison Experiment (SOLSTICE)

— 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)

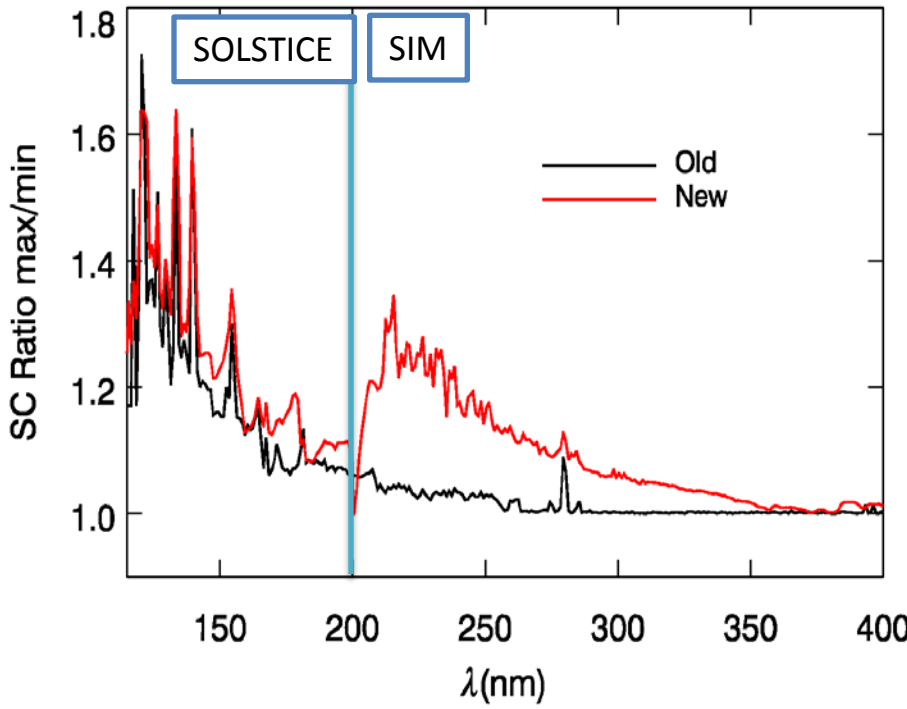
— covers 200 – 2700 nm
— absolute accuracy, better than 2%
— data at 310-2400 nm are available from LASP/LISIRD
— data at 200-310 nm are available upon request

Recent Satellite observations of this solar forcing may change our view

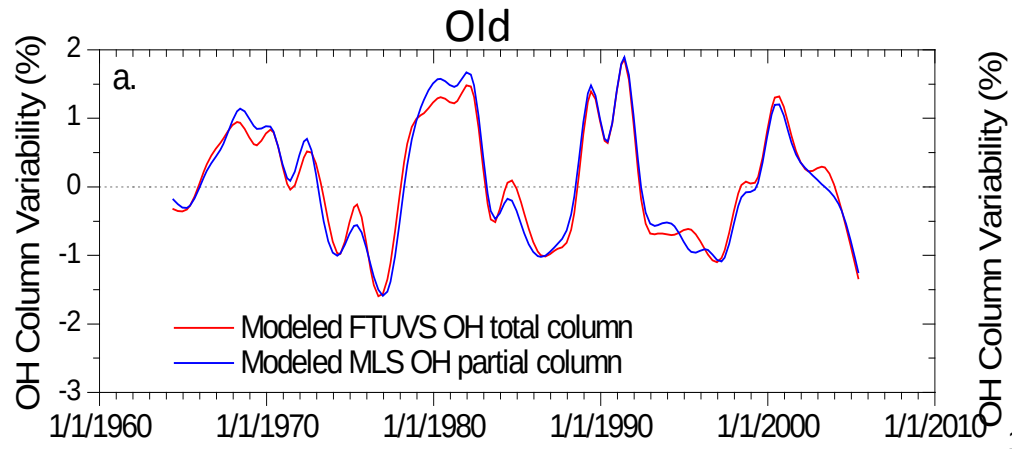


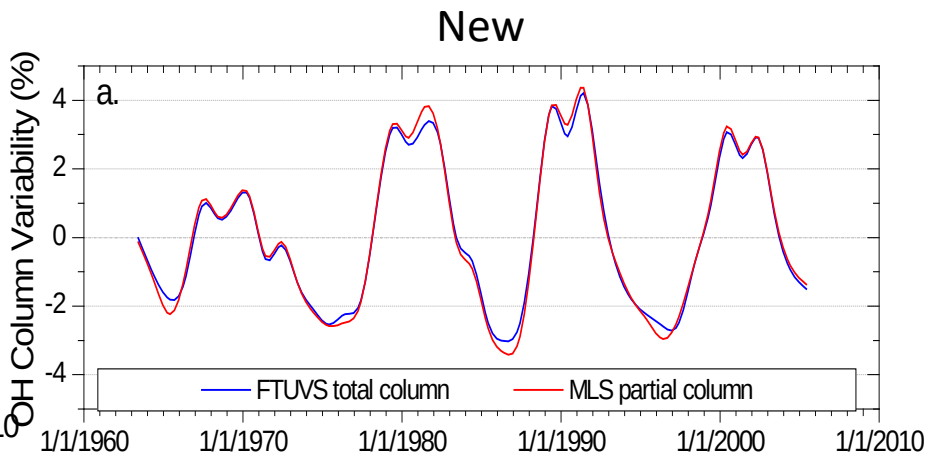
- We made WACCM runs using SORCE solar data.
- Solar UV spectral variation is based on the combination of SOLSTICE and SIM.
- To extrapolate the published solar flux variability to the full solar cycle, we use Mg II (LASP long-term composite) as proxy to estimate scaling factors.

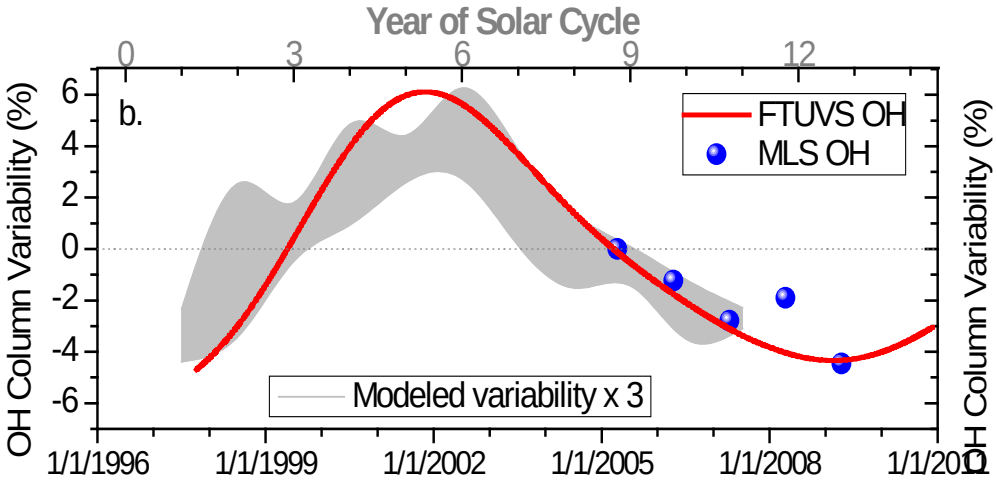
- Differences in solar spectrum between Apr 2004 and Nov 2007 derived from SIM and SOLSTICE data are much larger than Lean's model.
- In UV region, the difference is a factor of 2 - 6.
- In visible, they show opposite signs.

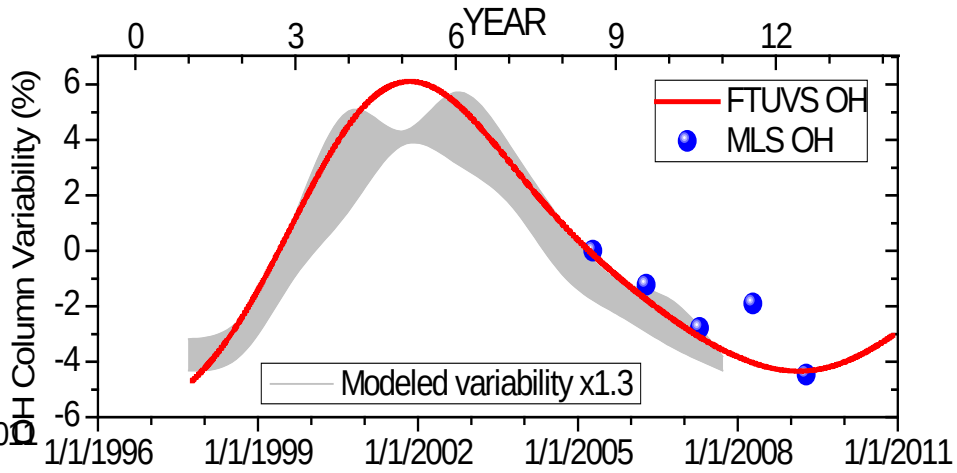


Gap between modeled and observed OH variability filled by SORCE data ?





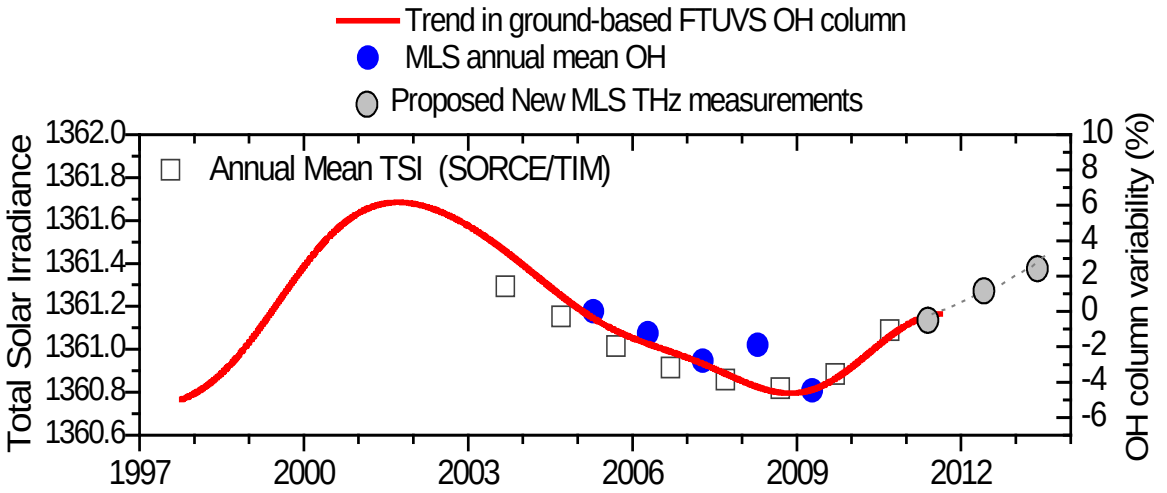


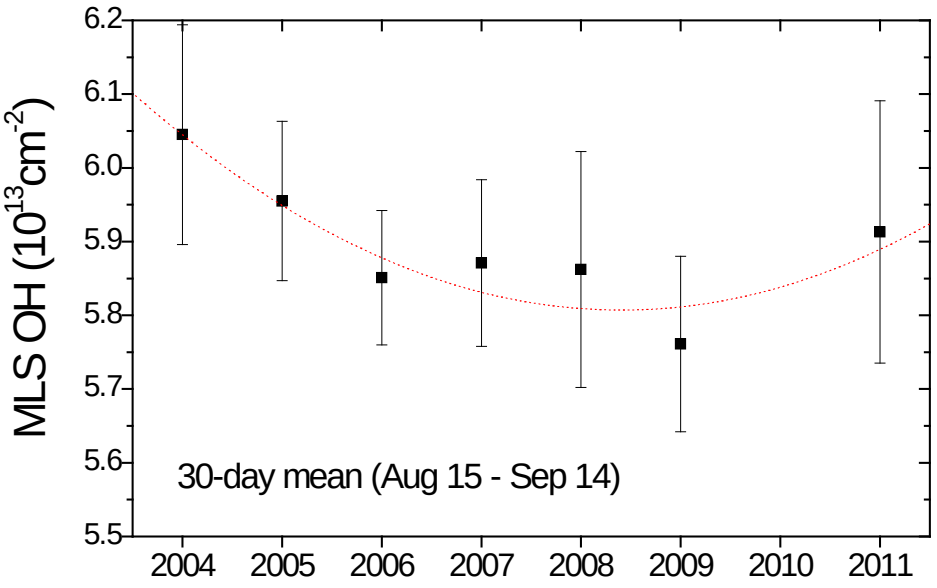


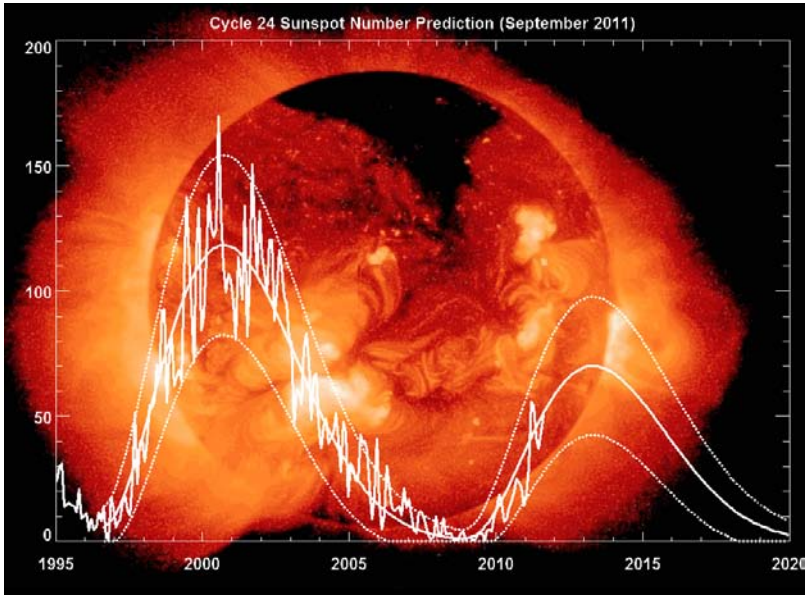
The model results using the SORCE solar flux variability as input give a OH variability that is much closer to observations.

Continuing OH measurements through the next solar max

- Ground-based OH measurements (FTUVS) will continue.
- 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.



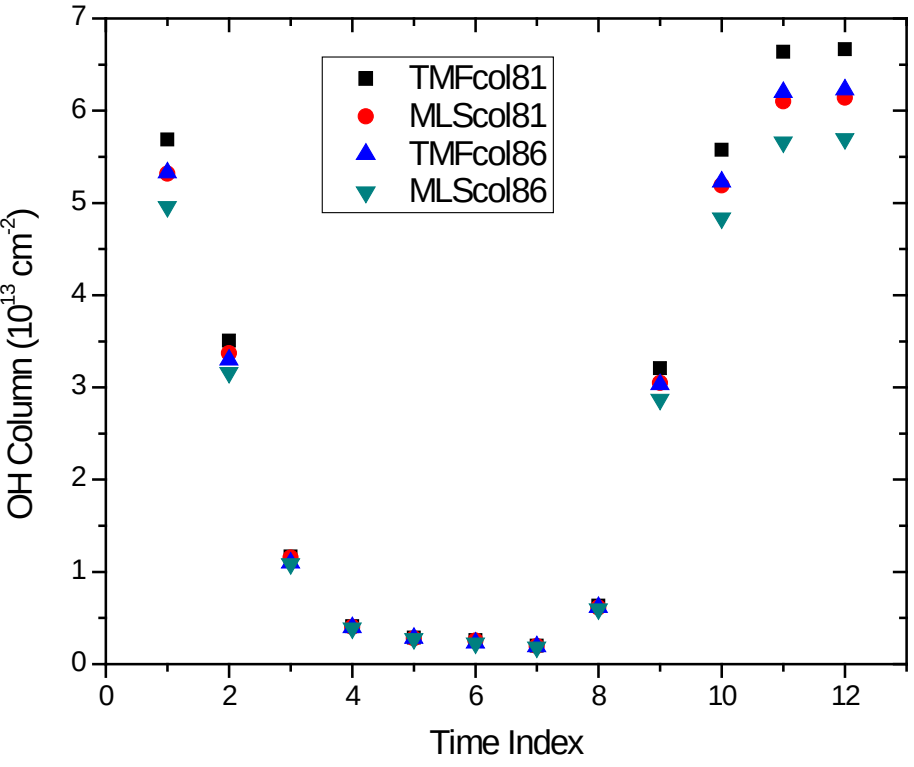




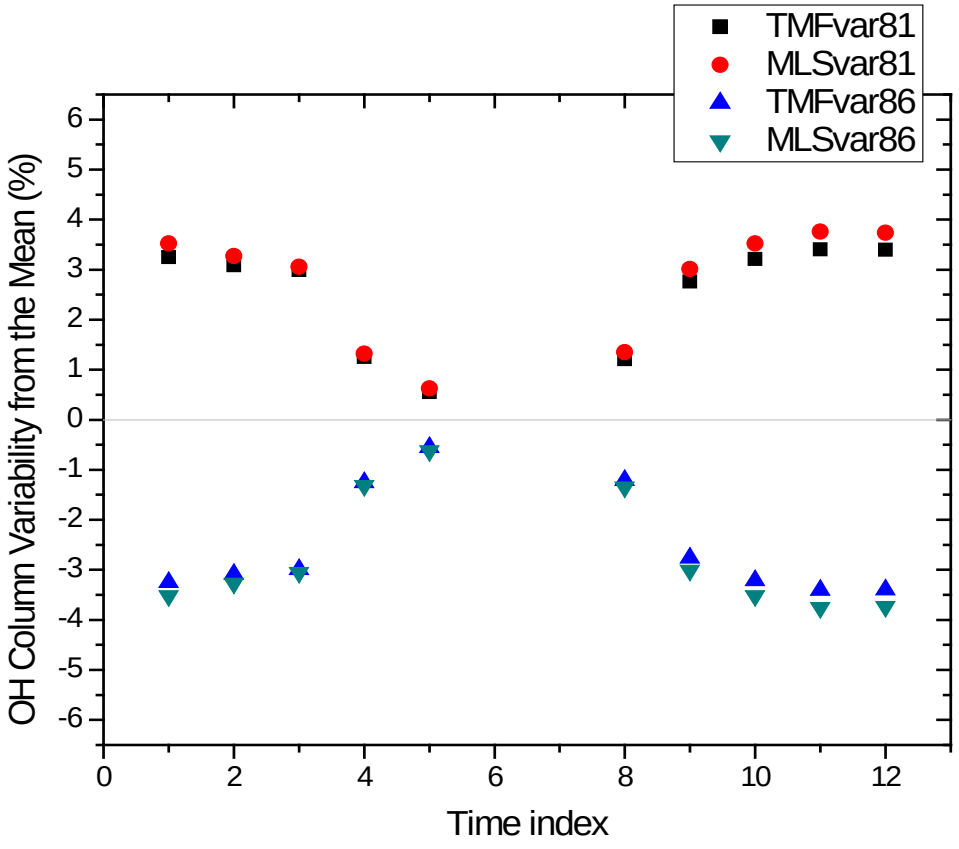
Back Up

Diurnal Pattern of OH Column Variability

Bi-hourly model results at TMF in 1981 (solar max) and 1986 (solar min)



Diurnal pattern of OH solar cycle signal



- 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.