Impact of Solar Spectral Irradiance Variability on Middle Atmospheric Ozone and Temperature

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Project goals

1-Comparison of temperature from two separate instruments (SABER & MSU/AMSU) and analysis for solar variability effects

2- Comparison of two independent ozone measurements (from SABER) in lower mesosphere and analysis for solar variability effects

Outline

- Solar cycle effects in the atmosphere
- SABER and MSU instruments
- Temperature Results
- Ozone Results
- Speculation/Further Research
- Extensions and Implications

Sunlight & Ozone

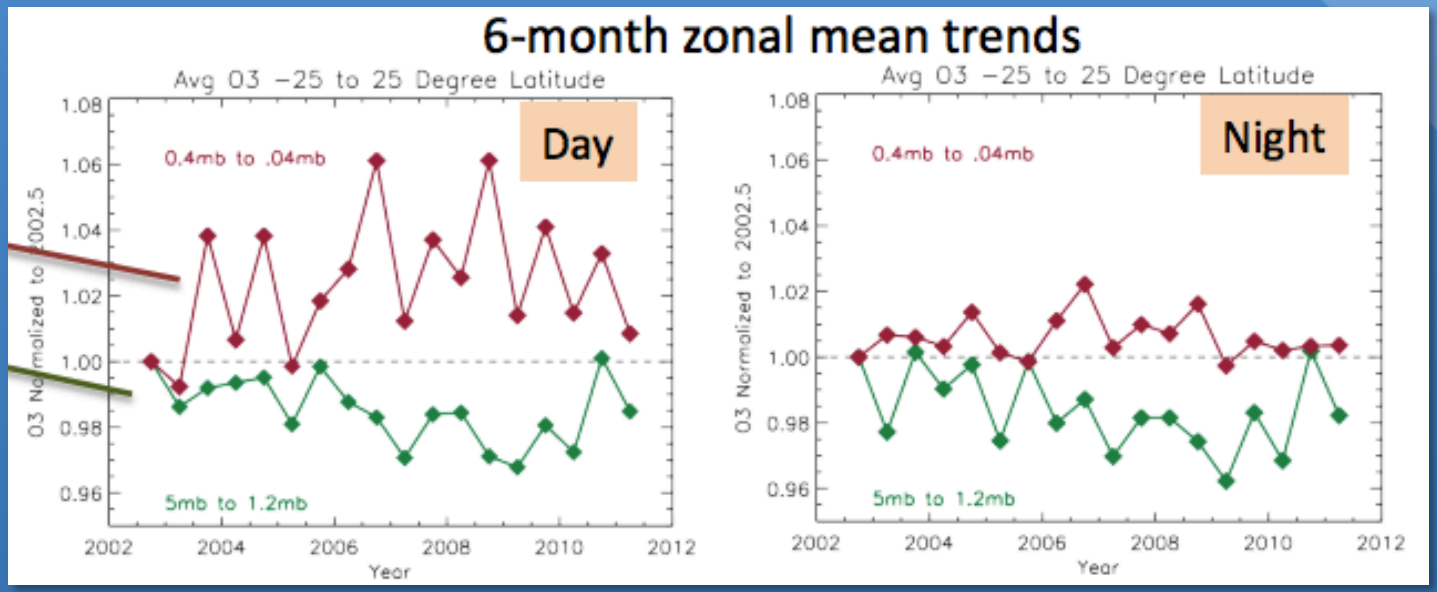
$O_2 + h\nu\ (< 242nm) \rightarrow 2O$

$O + O_3 \rightarrow 2O_2$

$O + O_2 + M \rightarrow O_3 + M$

$O_3 + h\nu\ (> 310nm) \rightarrow O_2\ (^3\Sigma_g^-) + O\ (^3P)$

$O_3 + h\nu\ (< 310nm) \rightarrow O_2\ (^1\Delta_g) + O\ (^1D)$



Lower Mesosphere

-Dependent on photochemistry

-Out of phase with solar cycle

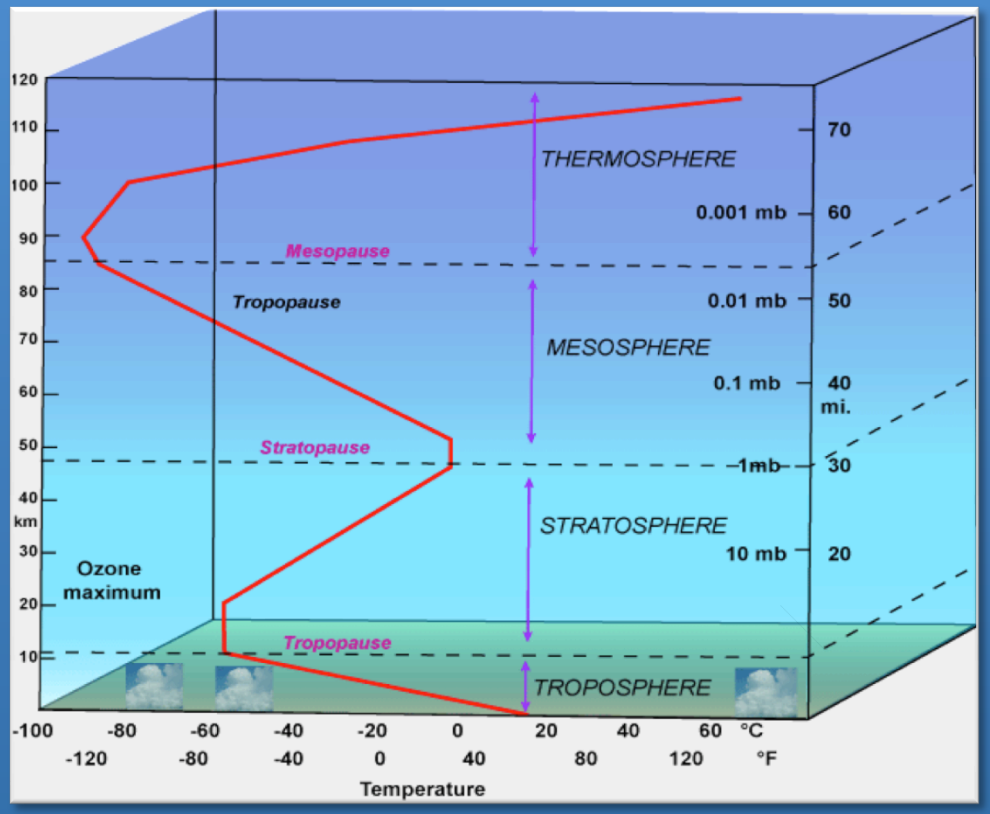
Stratosphere

-Dynamically dependent

– In phase with solar cycle

(Merkel 2011)

Ozone and Temperature



Higher ozone concentration→ higher temperatures

(Prentice Hall)

Sounding of the Atmosphere using Broadband Emission Radiometry (SABER) on NASA's TIMED satellite

-Polar orbiting satellite located ~ 625 km above Earth

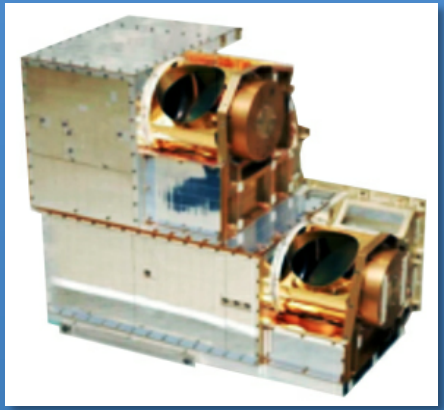
-Temperature and ozone measurements reported at 44 different pressures/altitude since 2002

-Measures ozone using two independent techniques at different wavelengths

9.6µm	1.27µm
O_3 concentration directly measured from emission of ozone molecule	O_3 concentration inferred from emission of molecular oxygen day glow
Measures from 15-100km	Measures from 50-105km
Day & night measurements	Day measurements

(NASA)

Microwave Sounding Unit (MSU) and Advanced Microwave Sounding Unit (AMSU) on NOAA satellites



-Polar orbiting satellites

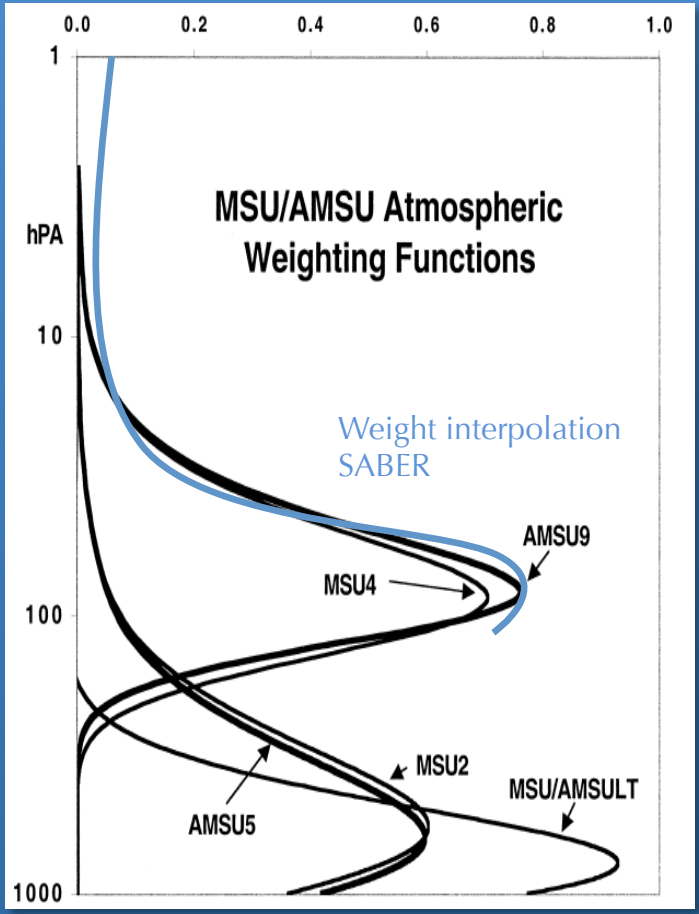
-Measures intensity of upwelling microwave radiation from atmospheric oxygen proportional to the temperature of broad vertical layers of the atmosphere

-Data reports temperatures over a single large layer

MSU	AMSU
-9 different MSUs launched; On NOAA satellites: TIROS-N, NOAA-6, -7, -8, -9,- 10,-11, -12, -14	NOAA-15, -16, -17, -18, -A, Aqua, -19
Operating since 1979-1998	Operating 1998-2012
4 channels of observation	15 channels of observation

(NASA, NOAA)

SABER and MSU/AMSU Temperature Comparisons



-MSU Channel 4, AMSU Channel 9: peak weighting at 87.1mbar

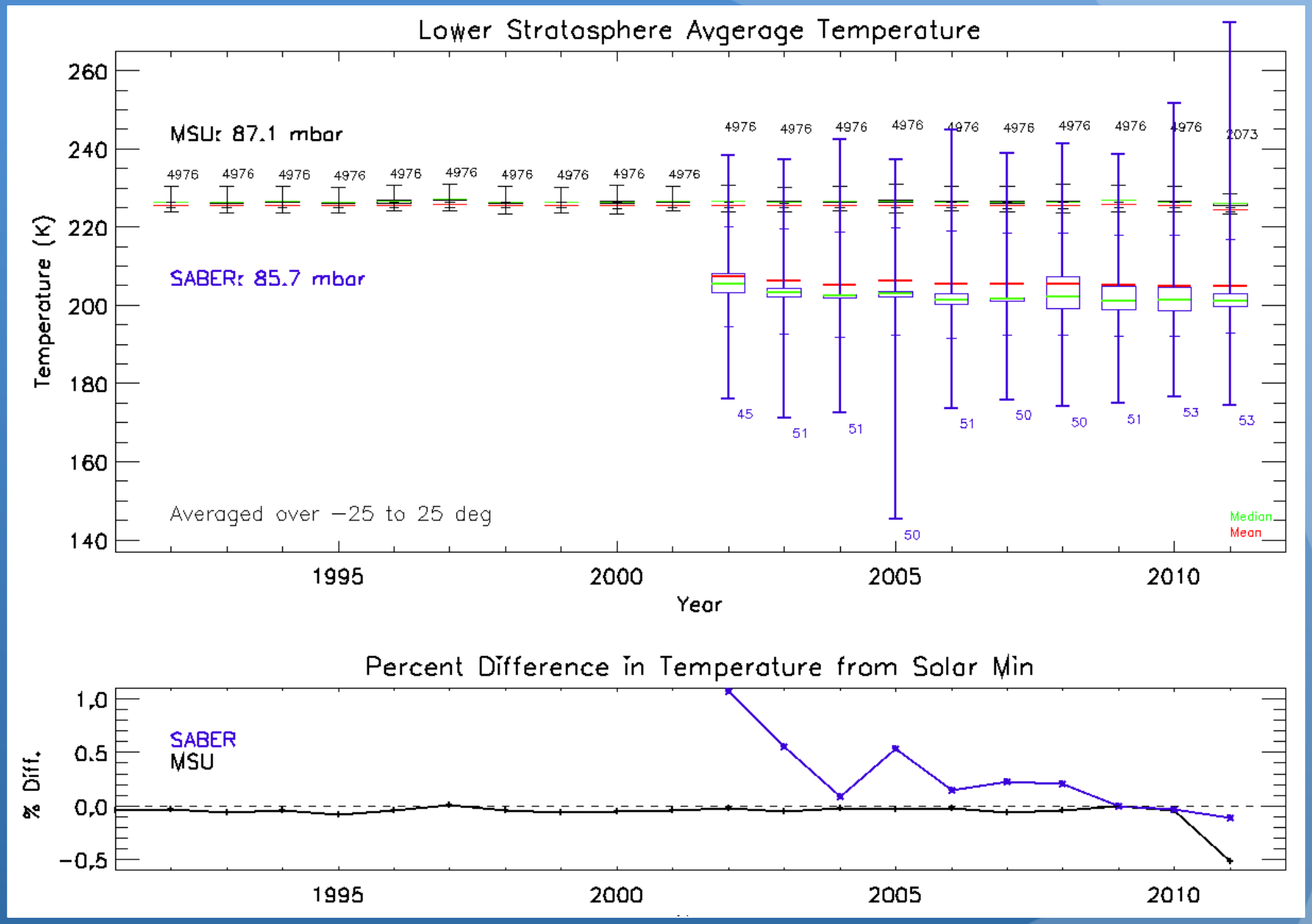
-Lowest SABER measurement made at ~100mbar

-3 overlapping SABER pressure levels with MSU/AMSU data set

-SABER data for all overlapping measurements could not be interpolated to match weighting function of MSU/ AMSU data

-Comparisons could only be made using 1 of the 44 levels of measurement from SABER at 85.7mbar

(Christy 2003)


Lower Stratosphere Avgerage Temperature
MSU: 87.1 mbar
SABER: 85.7 mbar
Averaged over −25 to 25 deg
Median
Mean
Temperature (K)
Year
260
240
220
200
180
160
140
1995
2000
2005
2010
4976
2073
45
51
50
53
Percent Difference in Temperature from Solar Min
SABER
MSU
% Diff.
1.0
0.5
0.0
−0.5

Temperature Comparison Conclusions

- No QBO/solar cycle effects observed in MSU/AMSU data

- .06% average annual variation from solar min value

- MSU/AMSU not as useful for stratospheric measurements

- Too many complications for further comparisons with SABER data

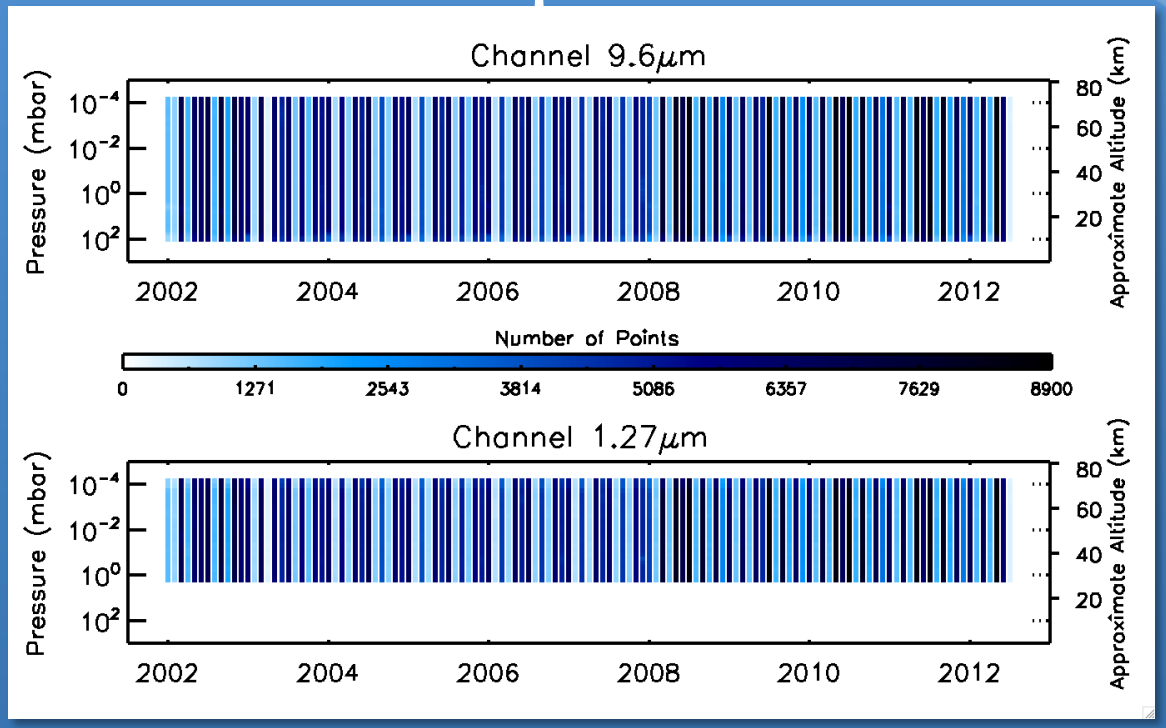
- Plausible that future comparisons with SABER data could be done with Stratospheric Sounding Unit (SSU)

SABER Ozone Channels

- Direct measurements at 9.6µm and relied on more than 1.27µm inferred measurements in past scientific studies.
- Comparisons of 9.6µm data with multiple other instruments, but not with 1.27µm
- 9.6µm channel positively biased in the middle to upper stratosphere and throughout the lower mesosphere in all comparisons
- 5-7% bias in lower mesosphere, 10-17% in stratosphere around equator

(Rong, 2009)

Ozone Comparisons



(Direct)

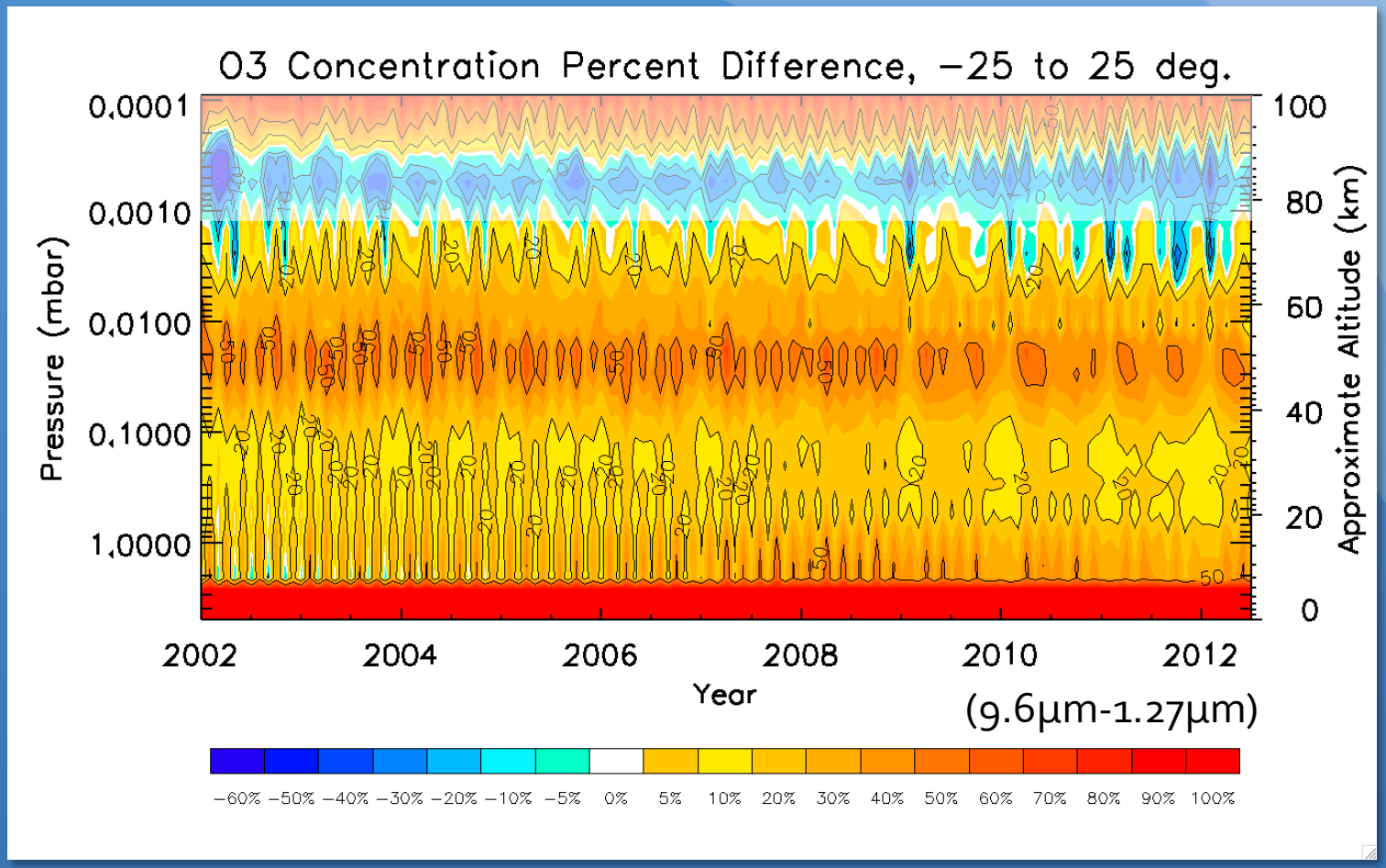
(Inferred)

-Even coverage through all 44 levels

-Both channels show equal population through time (9.6μm ~2% more)

-Every other month more populated

-Comparison not limited by number of data points

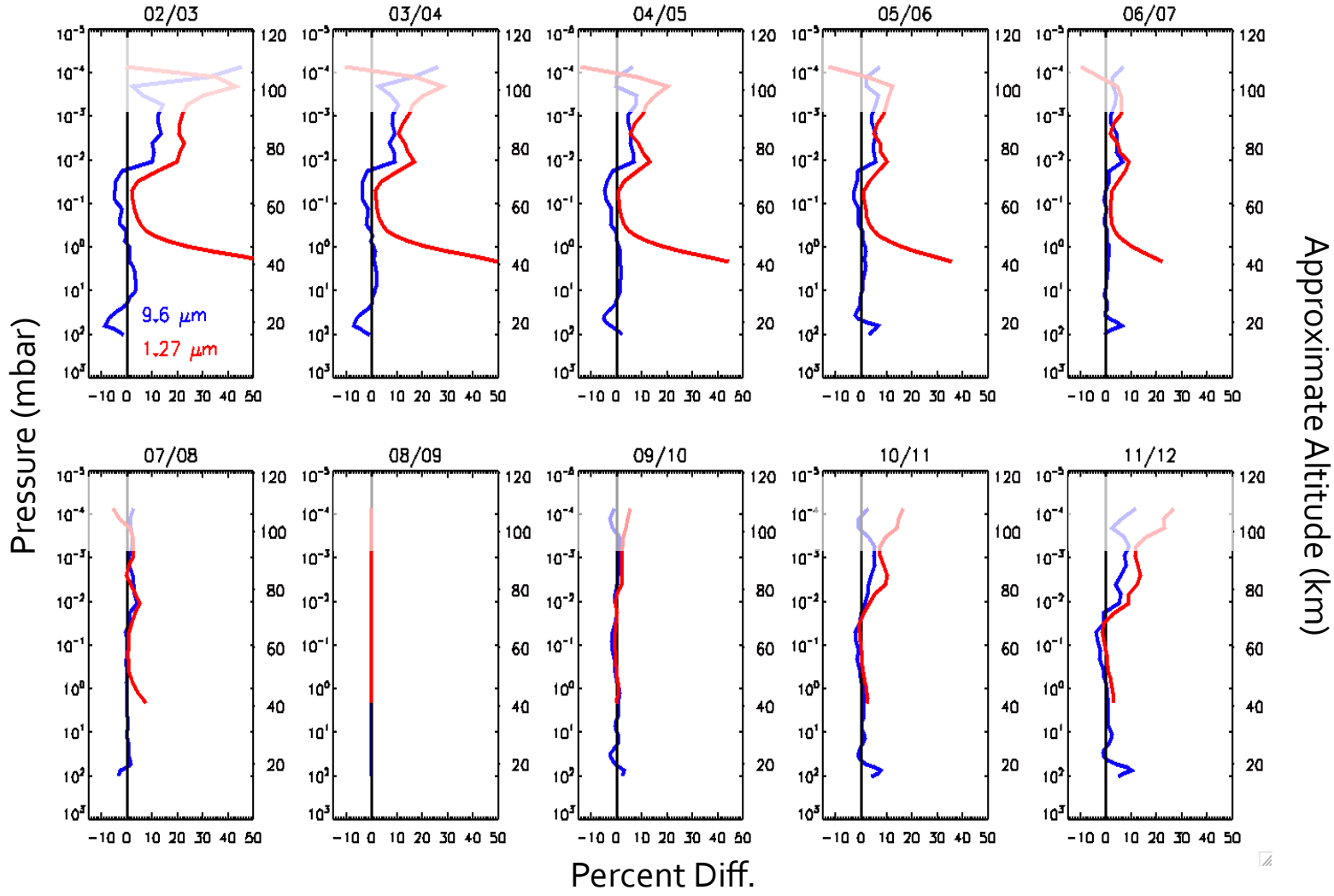


-Constant bias through time observed

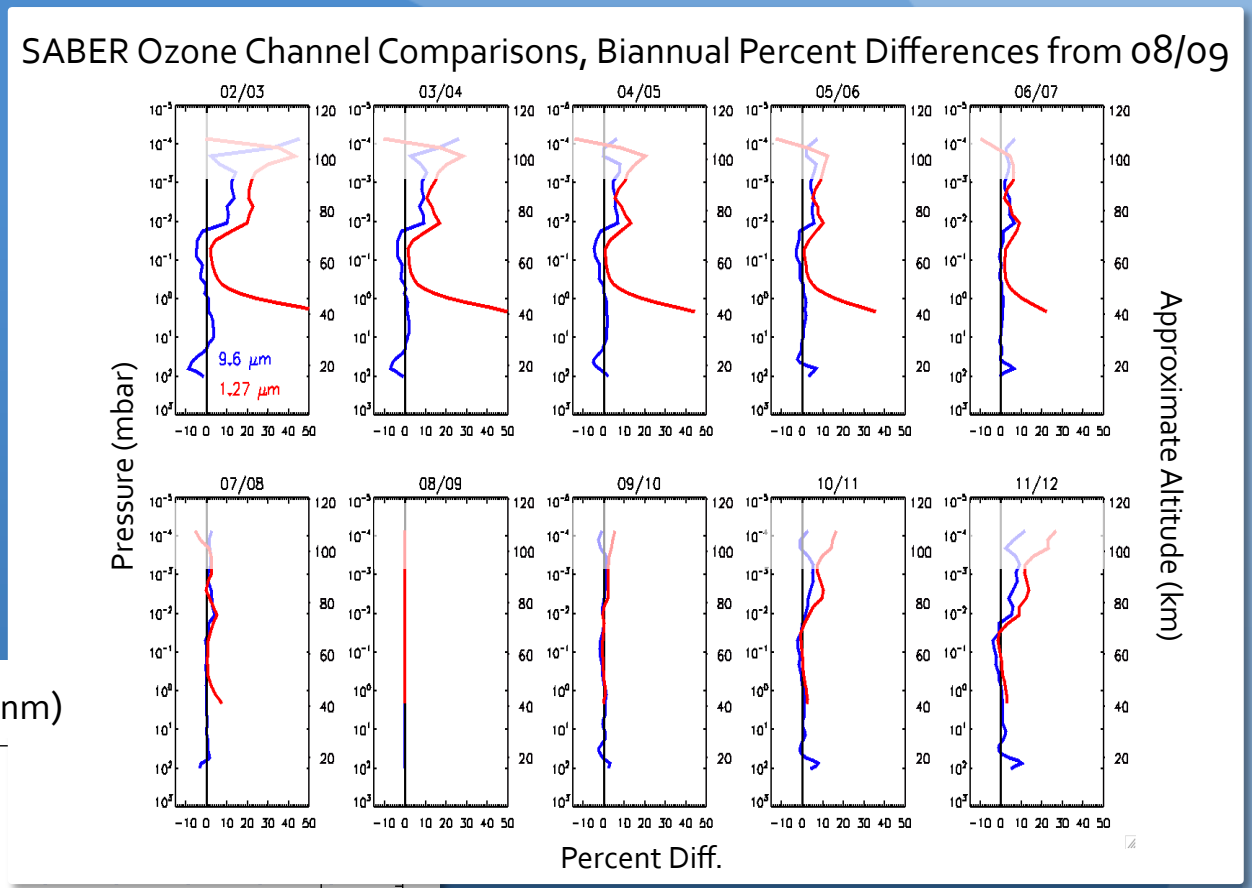
-9.6µm on average 23.1% higher in Lower Mesosphere (.4mbar to .04mbar)

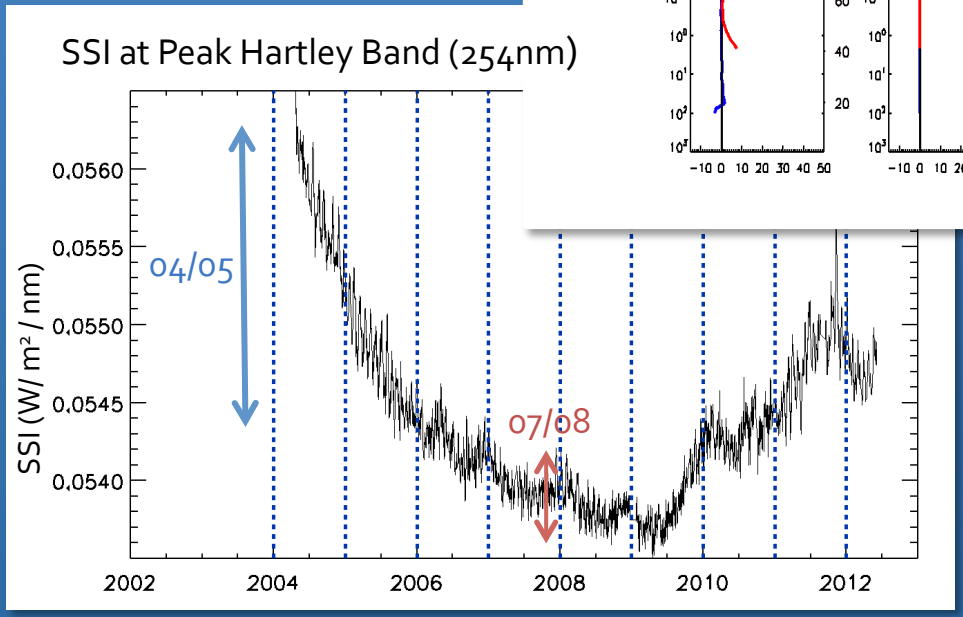
-Constant bias higher than expected from known deviation in 9.6µm

SABER Ozone Channel Comparisons, Biannual Percent Differences from 08/09 (Averaged over -25 to 25 deg. N)



-Greater difference in solar intensity, channels separated by a constant





-Low difference in solar intensity, channels agree.

Ozone Comparison Conclusions

- Channels equally populated and a meaningful comparison can be made between 9.6μm and 1.27μm measurements
- Constant bias found between channels - larger than would be expected from known instrumentation differences
- Channel agreement definitively effected by solar variability

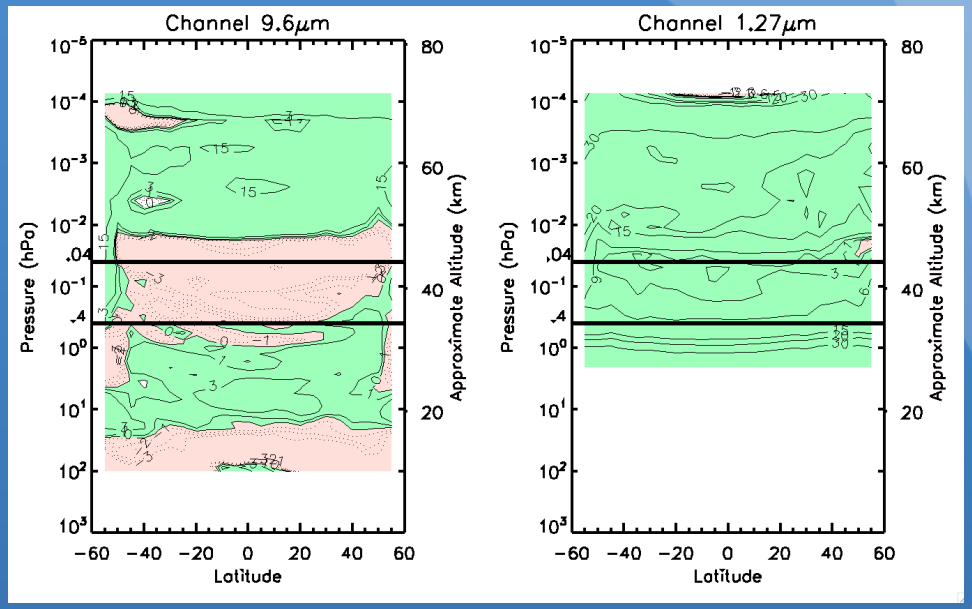
Speculation and Future Research

- Woods-Rottman model SSI variability input used to determine photolysis rates used in inferring 1.27µm measurements COULD be underestimating solar variability in Hartley and Schumann-Runge bands
- Plausible that SORCE data observing SSI could bring SABER channels into agreement
- Full reanalysis of the SABER 1.27µm data would be required to make this assessment.
- More offline studies on 1.2µm data need to be done to determine if a full reanalysis of the SABER 1.27µm data could bring channels into agreement

Extensions

-Merkel et al 2011 uses 9.6μm data to assess the NRLSSI model underestimates solar variability in mesosphere

Ozone Concentration Percent Difference
(2002/2003 – 2008/2009)



Greater than o8/o9 average

In Phase with Solar cycle

Less than o8/o9 average

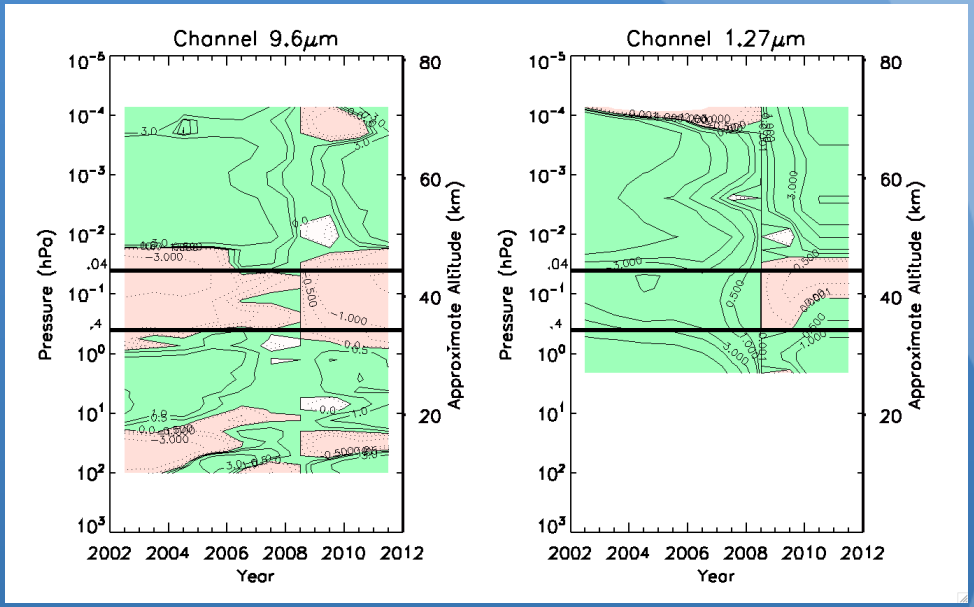
Out of Phase with Solar cycle

Extensions

-Adjusting 1.27µm to account for variability difference could corroborate Merkel 2011 among others

-Future research could be done comparing both ozone measurements to independent MLS data

Ozone Concentration
Percent Difference Time Series
(Biannual Avg. – 2008/2009)
-25 to 25 deg.



O_3 greater than 08/09 average

In Phase with Solar cycle

O_3 less than 08/09 average

Out of Phase with Solar cycle

Implications

-If 1.27µm data could be corrected and adjusted, it would provide another source of ozone concentration tracked at local time for use in scientific studies

-If corrected, it could lend credibility to measurement technique and extend technology in inferring measurements

References

- Christy, John R., Roy W. Spencer, William B. Norris, and William D. Braswell (2003), Error Estimates of Version 5.0 of MSU–AMSU Bulk Atmospheric Temperatures, Journal of Atmospheric and Oceanic Technology
- Merkel, A.W., J.W. Harder ,D.R. Marsh, A.K. Smith, J.M.Fontenla, and T.N. Woods (2011), The impact of solar spectral irradiance variability on middle atmospheric ozone, Geophys. Res., 38,L13802, doi: 10.1029/2011GL047561.
- "MSU (Microwave Sounding Unit) Daily Troposphere Temperatures and Precipitation. "*NOAA: Earth Systems Research Laboratory*. Web. <http://www.esrl.noaa.gov/psd/data/gridded/data.msu.html>.
- "POES Instruments: AMSU." *NASA*. Web. http://poes.gsfc.nasa.gov/amsu.html.
- Rong, P. P., J. M. Russell III, M. G. Mlynczak, E. E. Remsberg, B. T. Marshall, L. L. Gordley, and M. López-Puertas (2009), Validation of TIMED/SABER v1.07 ozone at 9.6 mm in the altitude range 15–70 km,J. Geophys. Res., 114, D04306, doi:10.1029/2008JD010073.
- "SABER Fact Sheet." *NASA*. N.p., Apr. 2008. Web. <http://www.nasa.gov/centers/langley/news/factsheets/SABER.html>.
- "Temperature Profile." *Prentice Hall*. Web. <http://dev.prenhall.com/divisions/esm/artworks/media_gallery/Aguado/CH01_Images/HTML_01_2of4.html>.

Questions?