Solar Cycle Spectral Irradiance Variation and Stratospheric Ozone

Richard S. Stolarski, Johns Hopkins University, Baltimore, MD; William H. Swartz, Johns Hopkins University Applied Physics Laboratory
Charles H. Jackman, NASA Goddard Space Flight Center, Greenbelt, MD; Eric L. Fleming, SSAI, Lanham, MD

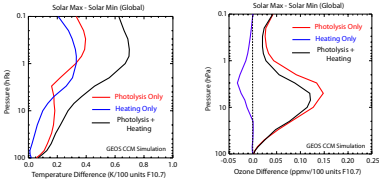
☐ Solar cycle temperature change has equal (approximately) contributions from direct heating and from ozone change due to photolysis.

☐ Solar cycle ozone change is dominated by contribution due to photolysis *(Chemistry Transport Models get it about right)*

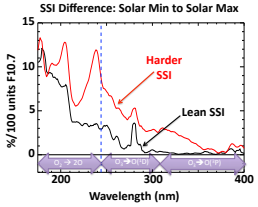
Photolysis vs Heating contributions

- Direct heating
  - hv + O_2, O_3 → T increase
  - speeds ozone loss reactions → O_3 decrease
- Photolysis
  - hv + O_2 produces O_3 → O_3 increase
  - More O_3, more heating → T increase

Same direction for temperature
Opposite direction for ozone



☐ The studies on wavelength dependence of ozone change over a solar cycle is motivated by the remarkably different reconstruction of the 11-year solar UV variation put forward by Harder et al. (2009) based on 6 years of SORCE data compared to the previous reconstruction by Lean (2000) based on 30+ years of data from multiple satellite instruments.



Harder, J. W., J. M. Fontenla, P. Pilewskie, E. C. Richard, and T. N. Woods (2009), Trends in solar spectral irradiance variability in the visible and infrared, *Geophys. Res. Lett., 36,* L07801, doi:10.1029/2008GL036797.

Lean, J. (2000), Evolution of the Sun's spectral irradiance since the Maunder Minimum, *Geophys. Res. Lett., 27,* 2425–2428.

SSI = Solar Spectral Irradiance

☐ Radiation shortward of 242 nm causes ozone to change in phase with solar cycle through ozone production by photolysis of O_2.

☐ Radiation longward of 242 nm causes ozone to change out of phase with solar cycle through the enhanced ozone loss from O atoms produced by photolysis of O_3.

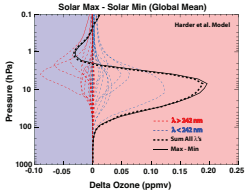
☐ Expected solar signal in upper stratosphere depends on SSI variation with wavelength

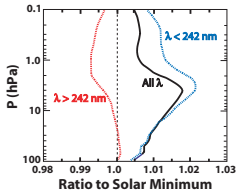
Wavelength Dependence of Ozone Response as a Function of Altitude

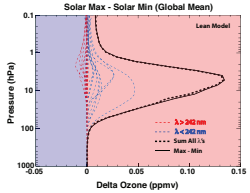
- Below 242 nm
  - hv + O_2, O_3 → J_{O2} and J_{O3} increase
  - J_{O2} produces odd oxygen and dominates
- Above 242 nm
  - hv + O_3 → J_{O3} increase
  - More O atoms → increased ozone loss
  - hv + O_3 → $O(^1D)$ increase → HOx increase → ozone loss

increase

End result depends on relative amount of solar cycle variation above and below 242 nm





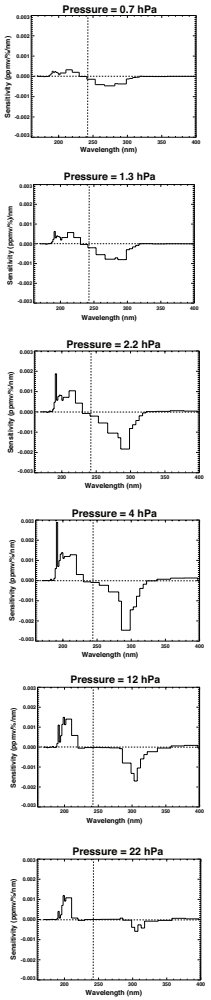


Calculations with GSFC 2D Interactive Model

☐ Wavelength-dependent sensitivities of ozone to UV change can be used to understand the altitude profile of ozone change expected over a solar cycle.

☐ The sensitivities can be used to construct ozone profile change due to arbitrary (small) changes in solar UV.

Ozone Sensitivity vs Wavelength



Acknowledgement: We thank J. W. Harder (University of Colorado/Laboratory for Atmospheric and Space Physics) for providing the SORCE/SIM SSI time series data. Resources supporting this work were provided by the NASA High-End Computing (HEC) Program through the NASA Advanced Supercomputing (NAS) Division at the NASA/Ames Research Center. This work was supported by NASA under grants NNX09AQ74G, issued through the NASA/Goddard Space Flight Center, and NNX11AR19G, through the Living With a Star Targeted Research and Technology program."