How Robust is the Observed 11-year Solar Cycle Signal in the Tropical Stratospheric Ozone?

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Introduction

- Understanding the natural decadal variability of stratospheric ozone (O_3) is cruical for monitoring ozone recovery as well as anthropogenic-related changes.
- The currently accepted solar response of the tropical stratospheric O_3 has a double-peak structure: one peak of ~3% in the upper stratosphere near 1 hPa and another peak of 3% in the lower stratosphere near 100 hPa. In the broad region of the middle stratosphere (3–30 hPa), the observed response is statistically insignificant (Figure 1).
- The aforementioned solar response has been dervied from three long-term satellite intruments: TOMS/SBUV, SAGE I/II, and HALOE.

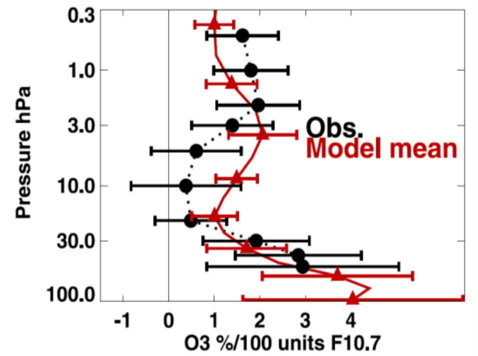

Figure 1. O_3 solar-cycle response averaged over the latitude range 25°S to 25°N. The red line shows simple mean of simulations of seven chemistry-climate models with solar forcing. The dotted black line is the mean of the observations from three independent satellite instruments presented by *Soukharev & Hood* [2006]. The uncertainty ranges are 95% confidence intervals. Extracted from *Austin et al.* [2008].

Unresolved Problems

- From the modeling perspective, the upper stratospheric peak is due to direct photochemical production of O_3 while the lower stratospheric peak is likely an aliasing of volcanic eruptions [*Austin et al.*, 2008; *Chiodo et al.*, 2014].
- However, the mid-stratospheric minimum has not been simulated satisfactorily (Figure 1).
- Proposed mechanisms including QBO and residual ciruclations and NO_x transport do not fully explain the existence of the minimum [*Callis et al.*, 2001; *Dhomse et al.*, 2011; *Kren et al.*, 2014].

Aim

- Re-examine the tropical stratospheric O_3 solar response using long-term O_3 data publicly available online.

Data

- SBUV MOD v8.0
  SBUV MOD v8.6
  SBUV Merged Cohesive (CDR)
  1979 onwards
- SAGE-II
  1984 – 2005
- HALOE
  1991 – 2005
- GOZCARDS
  Merged SAGE-I/II, HALOE, ACE-FTS, UARS-MLS, Aura-MLS
  1979 – 2012
- SWOOSH
  Similar to GOZCARDS except without ACE-FTS and different merging methods
  1984 – 2012

Linear Regression Model

The ozone time series are first deseasonalized to obtain the monthly anomalies. Subsequently, the solar-cycle modulation is retrieved using a regression model delineated in *Randel and Cobb* [1994] and *Li et al.* [2008]:

$$\begin{aligned} X_{O_3}(t) &= \alpha(t)\cdot t + \beta(t)\cdot F_{10.7}(t) \\ &+ \gamma_1(t)\cdot QBO_1(t) + \gamma_2(t)\cdot QBO_2(t) \\ &+ \varepsilon(t)\cdot ENSO(t) + residual \end{aligned}$$

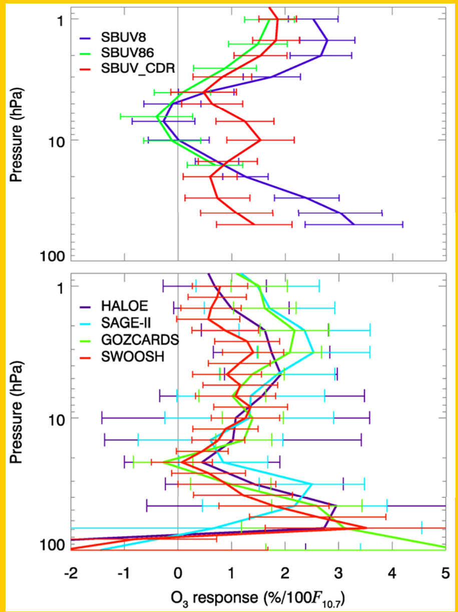

Figure 2. The vertical solar responses of tropical stratospheric O_3 derived from various satellite datasets.

Results and Discussions

- Only the upper stratospheric peak persists in all dataets. But the vertical location of this peak is higher (1 hPa) in the SBUV datasets. In the other datasets, the upper peak is at 3 hPa, which is more consistent with the model simulation.
- The mid-stratospheric minimum derived from the SBUV v8/v8.6 datasets has a broad vertical extent (3 – 30 hPa), consistent with *Soukharev and Hood* [2006]. However, in the merged SBUV data, not only the broad mid-stratospheric minimum disappears, but there is also a new third peak in the mid-stratosphere that cannot be explained by models.
- The O_3 solar responses derived from SAGE-II, HALOE, GOZCARDS and SWOOSH do not show a broad minimum in the mid-stratosphere; rather they show a narrower minimum at lower altitudes that better agrees with the model simulations.

Conclusions

- The mid-stratospheric minimum of the tropical stratospheric O_3 solar response only appears in SBUV v8/v8.6 datasets.
- Cross-instrument validation is required to evaluate the O_3 data quality on decadal time scales.

References

Austin *et al* (2008), JGR, **113**, D11306; Soukharev & Hood (2006), JGR, **111**, D20314; Li *et al* (2008), JGR, **113**, D14109; Randel & Cobb (1994), JGR, **99**, 5433; Dhomse *et al* (2011), **11**, 12773 ; Callis *et al* (2001), **106**, 7523**;** Chiodo *et al* (2014), ACP, **14**, 5251.