The impact of volcanic events and ENSO on the detection of the solar cycle signal in the tropical lower stratosphere

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1. Introduction

- Re-analysis and satellite data show increase in tropical-lower stratospheric (50-100hPa, 25N-25S) ozone and temperature during peaks of solar activity (SH 2006; FG 2010).
- Unambiguous attribution of decadal changes in ozone and temperature is hampered by spurious alignment of the 11-yr solar cycle with ENSO (MG 2007). Moreover, two major volcanic events coincide with peaks of solar activity (El-Chichón in 1982 and Pinatubo in 1991).
- Regression models need predictors (forcings) to be independent. This condition is not satisfied in real world!
- The impact of other sources of variability (e.g. QBO and volcanoes) on the solar signal needs to be investigated.
- A model study where the effect of single forcings can be isolated can improve the current knowledge on attribution of decadal changes in the lower stratosphere.

2. Model set-up

- We use the Whole Atmosphere Community Climate Model – version 3.5 for a set of **"refB.1"** transient simulations

→ Full interactive chemistry
→ 1.9x2.5 horizontal x 66L vertical resolution.
→ Nudged QBO in tropical stratospheric winds
→ Simulated period: 1960-2005

Ensemble a)

"Refb1. ENSEMBLE" (4x):

RefB1.1 -. RefB1.2 – RefB1.3 – RefB1.4

Set—up: all observed forcings, including a nudged QBO

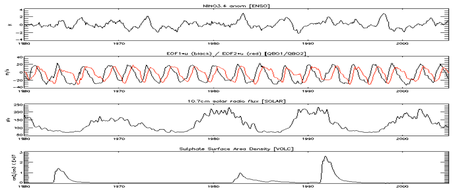

Figure 1. *Predictors used in the regression model in eq.1*

$$\mathrm{Var} = b_0 + b_1 t + b_2 \mathrm{AOD} + b_3 F_{10.7a} + b_4 \mathrm{QBO}_1(\mathrm{EOF1}) + b_5 \mathrm{QBO}_2(\mathrm{EOF2}) + b_6 N3.4(t - \mathrm{lag}_{\mathrm{ENSO}}) \quad (1)$$

Equation 1. Regression equation

Ensemble b)

"noQBO run" (1x)

Set-up : As refB1., no assimilated QBO

PURPOSE:
See the impact of the QBO on the solar signal

"fixedSSTs run" (1x)

Set-up : As refB1., climatological SSTs

PURPOSE:
See the impact of ENSO on the solar signal

"noVOLC run" (1x)

Set-up : As refB1., no volcanic eruptions

PURPOSE:
See the impact of volcanoes on the solar signal

3. Results

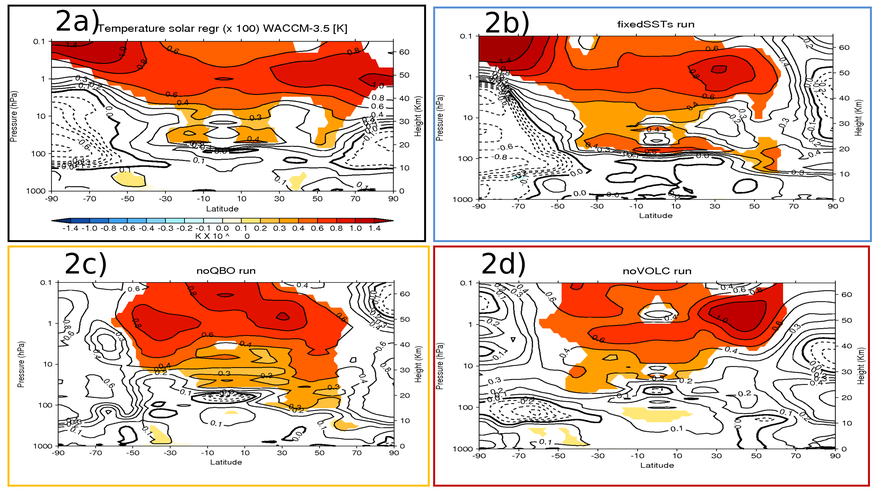

Figure 2. *Annual mean solar regression coefficient in zonal mean temperature In the (a) refb.ensmean, (b) fixedSSTs run, (c) noQBO run and (d) noVOLC run. Shaded areas are greater than 2*sigma. Units K.*

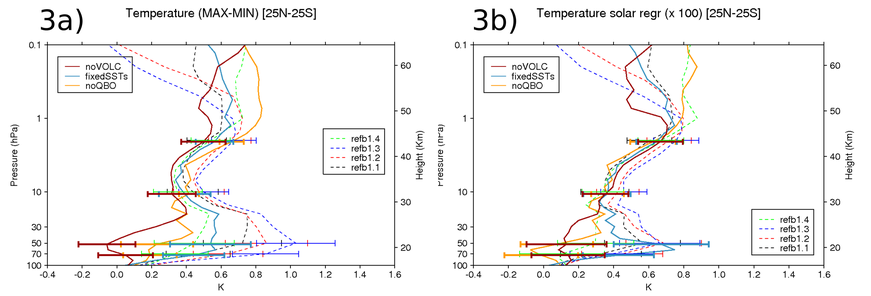

Figure 3. *Tropical mean (25N-25S) profile of the annual mean zonal mean temperature in (a) composite differences (solar MAX- solar MIN), and (b) solar regression coefficient. The error bars in (b) span over the 2*sigma uncertainty*

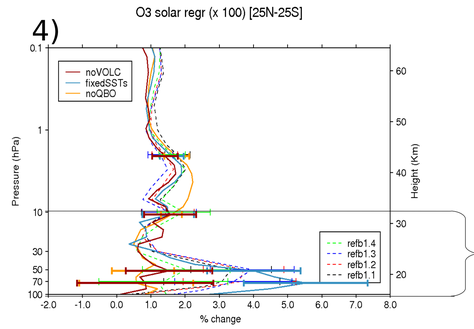

Figure 4. *Tropical mean (25N-25S) profile of the solar regression coefficient in ozone. The error bars span over the 2*sigma uncertainty. Units are % -change*

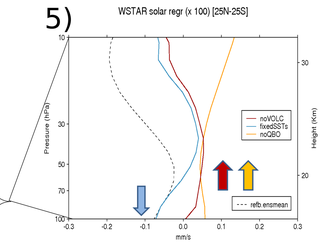

Figure 5. *As in Fig.4, for the TEM-w* velocity. Negative anomalies indicate relative downwelling. Units are mm/s*

4. Discussion

→ The simulated solar-induced warming in the upper stratosphere (1-10 hPa) is robust and not affected by the other forcings (Figs. 2 a-d).

→ A significant warming of 0.4-0.8 K in the lower-tropical stratosphere is simulated if all forcings are used (Fig. 2a), and also if SSTs are kept constant (Fig.2 b). This response agrees with re-analysis (FG 2010).

→ When volcanoes and QBO are not included, no response is found in this region (Fig.2c-d)

→ The difference in the simulated lower-tropical stratospheric response between the "fixedSSTs" / "refb1.1-1.2-1.3" runs, and the "noQBO" / "noVOLC" runs is significant in the regression (Fig.3b).

→ A similar increase is simulated in stratospheric ozone (Fig.4)

→ The ozone and temperature response is due to relative downwelling at 70 hPa (Fig.5). No response, or weak upwelling is found in the runs without QBO and volcanic forcing.

5. Conclusions

- A decadal change in lower-tropical stratospheric temperature and ozone is simulated only if all forcings are included in the model simulations.
- In WACCM, part of the decadal change attributed to the solar cycle seen in the transient simulations with all forcings could be due to the QBO and volcanic events.

Acknowledgments

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