Abstract
Solar spectral fluxes (or irradiance) measured by the Solar Radiation and Climate Experiment (SORCE) show different variability at ultraviolet (UV) wavelengths compared to other irradiance measurements and models (e.g. NRL, SATIRE-S). Some modelling studies have suggested that stratospheric/ lower mesospheric O3 changes during solar cycle 23 (1992-2008) can only be reproduced if SORCE solar fluxes are used. We have used a 3-D chemical transport model (CTM), forced by meteorology from the European Centre for Medium-Range Weather Forecasts (ECMWF), to simulate middle atmospheric O3 using three different solar flux datasets (SORCE, NRL-SSI and SATIRE-S). Simulated O3 changes are compared with Microwave Limb Sounder (MLS) and Soundings of the Atmosphere using Broadband Emission Radiometry (SABER) satellite data. Modelled O3 anomalies using all solar flux datasets show good agreement with the observations, despite the different flux variations. The off-line CTM reproduces these changes through dynamical information contained in the analyses. A notable feature during this period is a robust positive solar signal in the tropical middle stratosphere due to changes in stratospheric dynamics. Detailed analysis of long-term simulations suggests significant differences in solar signal on stratospheric ozone. SLIMCAT simulates negative solar signal in the upper stratospheric/lower ozone over HALOE time period (1992-2005), even with NRL solar fluxes. We also show that robust positive solar signal observed in SAGE/SBUV data could be simulated only if unrealistic meteorological fields are used.

1. Model Set-up

<table>
<thead>
<tr>
<th>Run</th>
<th>Solar fluxes</th>
<th>Dynamics</th>
</tr>
</thead>
<tbody>
<tr>
<td>A_NRL</td>
<td>NRL</td>
<td>ERA-interim</td>
</tr>
<tr>
<td>B_SAT</td>
<td>SATIRE</td>
<td>Same as A_NRL</td>
</tr>
<tr>
<td>C_FIX</td>
<td>Fixed (mean NRL)</td>
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<tr>
<td>D_SORCE04_1</td>
<td>SORCE_1 (2004)</td>
<td>Same as A_NRL</td>
</tr>
<tr>
<td>E_SORCE07_1</td>
<td>SORCE_2 (2007)</td>
<td>Same as A_NRL</td>
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<tr>
<td>F_SORCE04_2</td>
<td>SORCE_2 (2004)</td>
<td>Same as A_NRL</td>
</tr>
<tr>
<td>G_SORCE07_2</td>
<td>SORCE_2 (2007)</td>
<td>Same as A-NRL</td>
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Table 1. Solar fluxes and dynamical conditions for model simulations.

2. Solar Flux Variations

Figure 1: - Relative differences in solar fluxes (100 X (2004-2007)/2004) from NRL-SSI, SATIRE-S and SORCE_1 (as used by Haigh et al., 2010) and updated SORCE (SORCE_2, Ball et al., 2013) data. Black dotted lines indicate threshold wavelength (240nm) controlling ozone production and destruction as well as Lyman-alpha line (121 nm).

3. Comparison with Satellite Data in Tropics

Figure 2: – Tropical (25S-25N) monthly mean ozone anomalies at 30hPa, 3hPa and 0.3hPa from SLIMCAT (runs A_NRL and B_SATIRE). Ozone anomalies from two satellite instrument datasets (SABER - 2002-2010 and MLS - 2004-2010) are also shown with black coloured symbols. Rank-correlation between model and observation data are also shown.


Figure 3: (a) Solar max minus solar min solar signal in tropical ozone (25S-25N) from earlier SLIMCAT simulations presented in Dhomse et al., (2011) as well as SAGE-based (Randel and Wu, 2007) and SBUV (McLinden et al, 2008) data for 1979-2005 time period. (b) Estimated solar signal using in tropical ozone using regression model from Run A_NRL-B_SATIRE, C_FIX (2001-2010), SABER (2002-2010) and MLS (2004-2010). Sign of lower mesospheric solar signal can not be confirmed due to larger uncertainties (See Dhomse et al., 2013).

5. Solar Signal During Different Time Periods

Figure 4: Estimated solar signal using multi-variate regression analysis for (a) 1979-2012, (b) 1984-2005, and (c) 1992-2005 from run A_NRL. Regression model uses seasonal cycle, QBO (30 & 50 hPa), EESC and stratospheric aerosol term (for details of regression analysis see Dhomse et al., 2006).

6. O3 vs T relationship in the upper stratosphere (50 km) is different in SAGE data compared to ACE and HALOE

Figure 5: – Ozone anomalies at 30hPa, 3hPa and 0.3hPa from SLIMCAT (runs A_NRL and B_SATIRE). Ozone anomalies from two satellite instrument datasets (SABER - 2002-2010 and MLS - 2004-2010) are also shown with black coloured symbols. Rank-correlation between model and observation data are also shown.

7. Summary
- Good agreement between modelled and observed ozone in the stratosphere
- Differences in SABER and MLS ozone in the lower stratosphere indicate observational uncertainties in lower mesospheric ozone.
- SLIMCAT simulations suggest significant differences in estimated solar signal over different time period. SLIMCAT simulates negative solar signal in the upper stratospheric/lower mesospheric region over HALOE period.
- Positive signal in upper stratospheric ozone in SAGE data could be simulated only if unrealistic dynamics is used. Also, inverse relationship between ozone & temperature is not visible in SAGE II data.

References
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