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Report on the first SOLARIS workshop

4-6 October 2006, Boulder, Colorado, USA

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The new SPARC working group on solar variability is an extension of the GRIPS solar influence intercomparison project (Matthes *et al*., 2003; Kodera *et al*., 2003). The objective of this group is "Modelling and understanding the solar influence on climate through stratospheric chemical and dynamical processes" in collaboration with working group 1 of the SCOSTEP CAWSES (Climate and Weather of the Sun-Earth System) programme.

The first SOLARIS (SOLAR Influence for SPARC) workshop was held in October 2006 and hosted by NCAR's Earth and Sun Systems Laboratory in Boulder, Colorado. This workshop was the latest in a series of meetings, beginning with the December 2004 AGU conference in San Francisco and continuing with the July 2005 IAGA conference in Toulouse that provide the middle atmospheric research community with a forum to review the latest results in the field of modelling the solar influence on climate.

Approximately 40 participants from Canada, Europe, Japan, Russia and the United States, plus local participants from Boulder (LASP/University of Colorado, NCAR) attended the workshop. The programme of the workshop and a list of participants can be found on the SOLARIS website (http://strat-www.met.fu-berlin.de/~matthes/sparc/meetingdetails.html).

The first day of the meeting included a series of overview talks from invited speakers that were open to the general public. These overviews covered topics ranging from solar variability (**T. Woods**) to new insights into dynamo theory (**M. Dikpati**), and observed solar signals in the middle atmosphere and possible transfer mechanisms. **L. Hood** and **W. Randel** presented the most up to date observational analyses of solar signals in ozone and temperature, which seem to agree better with each other than previous analyses. **K. Kodera** described some of the dynamical mechanisms through which small direct stratospheric effects can indirectly affect the lower parts of the atmosphere down to the Earth's surface. **A. Smith** talked about aliasing of the solar signal through the QBO and the problem of having data sets that are too short. **C. Randall** gave an overview about precipitating particles and their effect on stratospheric chemistry and dynamics. In the afternoon each modelling group participating in the SOLARIS project gave a summary of their current activities.

The following two days focused on the specific research activities of each group in order to determine which questions are still open and how they can be studied in more detail through the combined SOLARIS effort. These results were discussed within the context of the five coordinated research themes that comprise the SOLARIS effort (http://strat-www.met.fu-berlin.de/~matthes/sparc/goals.html):

I) Thermospheric and Mesospheric Response
II) Ozone and Temperature Response
III) Dynamical Response Including the Role of the QBO
IV) Stratosphere-Troposphere Coupling
V) Ocean Response and Paleo-Climate

Within theme I, model studies about

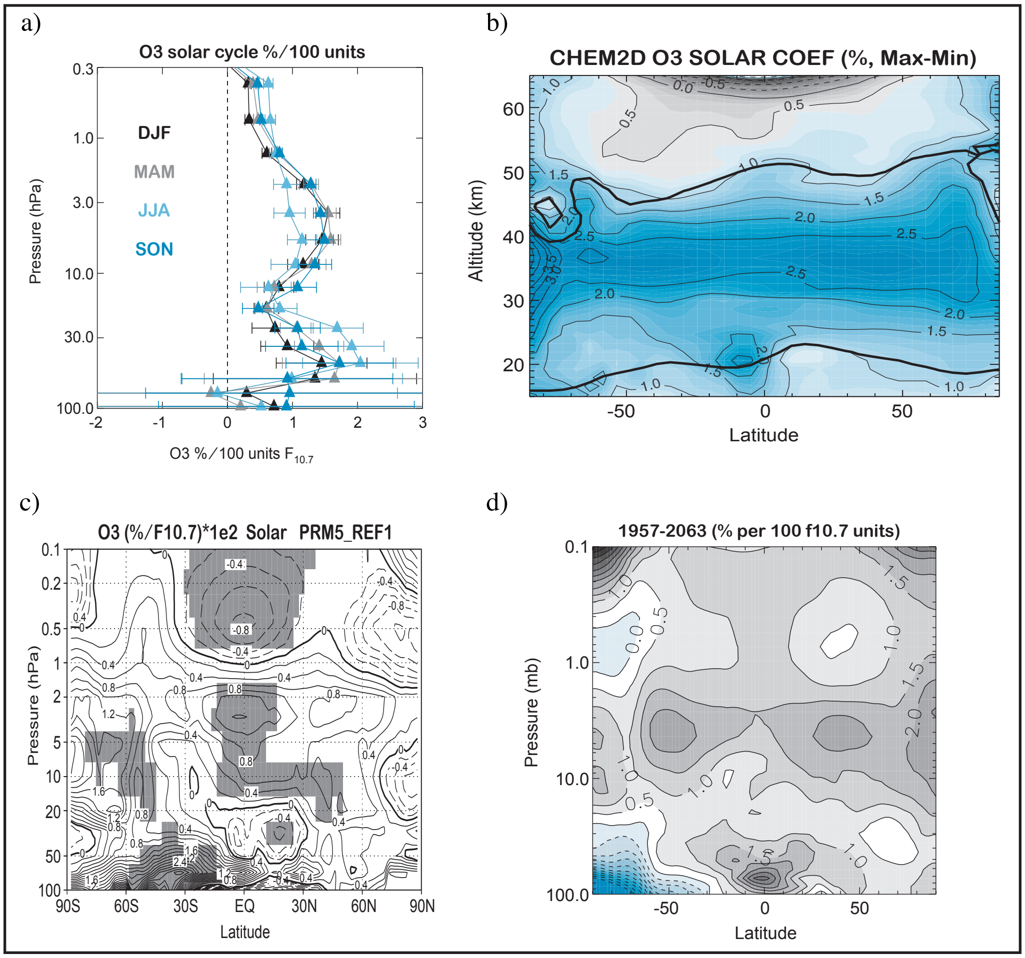

Figure 2: a) Simulated seasonal mean ozone solar response in % per 100 units of 10.7 cm flux with the CCMAMTRAC. The results have been averaged over the latitude range 25°S to 25°N and over all three ensemble members. The error bars indicate 95% confidence intervals from the linear regression analysis. (From Austin et al., 2006); b) Simulated annual mean ozone solar response in %/max-min from a 50 year simulation of the CHEM2D model. Thick black lines enclose regions where Cs is greater than 2-sigma (From McCormack and Siskind, 2006); c) Simulated annual mean ozone solar response in % per 100 units of 10.7 cm flux from the REF1 simulation of the MRI-CCM (Courtesty of K. Shibata); d) Simulated annual mean ozone solar response in % per 100 units of 10.7 cm flux from 106 years of simulations with the CCM WACCM from 90°S to 90°N and 100 to 0.1 hPa (16 km to 60 km). (Courtesy of K. Matthes.)

the influence of solar proton events on the atmosphere were shown. **Figure 1** (colour plate IV) shows one example of an experiment with NCAR's Whole Atmosphere Community Climate Model (WACCM) that incorporated solar protons during the 2003 "Halloween storm." Increased solar proton fluxes lead to increases in NO$_y$ (see **Figure 1b,** colour plate IV) that are comparable to observations (see **Figure 1a,** colour plate IV) (presentation by **D. Marsh**). The ionization rates computed from solar fluxes for the period of 1963-2005 used in WACCM were provided by Charles Jackman and are now available on the SOLARIS website. Other studies dealt with solar influence on tides (presentation by **T. Hirooka**).

A more coherent temperature and ozone response to the 11-year solar cycle from different models came out of the discussion from themes II and III. **Figure 2** shows examples of the resulting solar signal in ozone from three different coupled chemistry climate models (CCMs) and one 2D chemistry-transport model when the 11-year solar cycle in irradiance was included. In all of the models the solar cycle was time-varying, instead of the usual constant solar min/max experiments of the past. The GFDL AMTRAC (Atmospheric Model with TRansport And Chemistry) simulations were run for 135 years (3x45 years) with observed solar cycle, SSTs, GHG, and volcanoes (REF1 simulations of CCMVal) (presentation by **J. Austin**). Note that AMTRAC does not have an internally generated QBO or a specified one. The MRI-CCM simulations are similar to the AMTRAC simulations except that the model generates a self-consistent QBO (presentation by **K. Shibata**). The NRL CHEM2D model was run for 50 years with an interactive parameterization for the QBO (presentation by **J. McCormack**). The WACCM simulations had a prescribed QBO (the observed time series were repeated in order to reach 110 years of simulation), fixed SSTs, GHGs and no volcanic aerosols (presentation by **K. Matthes**).

The discrepancy in the ozone response between observations, and 2D and 3D model simulations carried out in the 1990's seems to be reduced in the latest simulations. More models show the observed vertical structure in the tropical stratosphere, with a maximum in the upper stratosphere, a relative minimum in the middle stratosphere, and a secondary maximum in the lower stratosphere. Possible factors that may be important in obtaining the correct vertical structures are a time-dependent solar cycle, a time-varying QBO (either self-consistent or synthetic), variable SSTs, and a long enough time series (at least 50 years). Other issues that were discussed and seem to be important for producing a more realistic solar signal include a high-resolution short wave heating scheme as well as a good model climatology (presentation by **U. Langematz**). Also the question was raised of how high the top of the model has to be to simulate a realistic solar signal in the middle atmosphere. The importance of the background ozone field to the resulting temperature response was pointed out as well (presentation by **L. Gray**).

We now have a good set of model experiments with different levels of complexity that will be used to understand the relative importance of these factors in producing the solar signal in ozone. As a starting point, J. Austin, E. Rozanov and K. Tourpali have started an intercomparison of the tropical solar signal in ozone by analysing the REF1 simulations of the CCMVal SPARC initiative (Eyring *et al.*, 2006).

The SOLARIS model experiments will also be used to investigate the dynamical response of QBO and solar signals. So far the observed modulation of the polar night jet and the Brewer Dobson circulation (Kodera and Kuroda, 2002), the modulation of the occurrence of Strato-

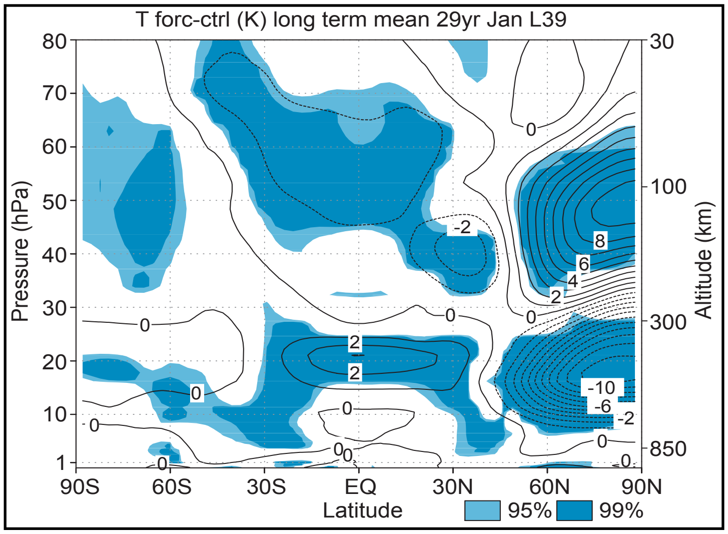

Figure 3: Zonal mean temperature differences in K between the forcing and the control run of the T42L39 perpetual January experiment with the ECHAM5-MESSY CCM. Contour interval is 2 K, light blue (blue) shading denotes statistical significance at the 95% (99%) level. (Courtesy of A. Kubin and U. Langematz.)

spheric Warmings (Labitzke and van Loon, 1988) including the importance of equatorial winds in the upper stratosphere (Gray *et al.*, 2001a, b; Gray, 2003, Gray *et al.*, 2004) have only been reproduced in a few model simulations (*e.g.*, Matthes *et al.*, 2004, 2006; Palmer and Gray, 2005). Further work is required to investigate the importance of this QBO interaction and whether it impacts the mechanism for transfer of the solar signal to the troposphere.

Within theme IV, different sensitivity studies of stratosphere-troposphere coupling were shown. A perpetual January sensitivity experiment with the ECHAM5-MESSY CCM, in which a momentum forcing was introduced in the mid-latitude stratosphere, shows a dynamically induced temperature increase in the tropical lower stratosphere (**Figure 3**) that leads to changes in vertical velocity and precipitation in the tropics, and changes in the extratropical regions with an AO-like pattern in the Northern Hemisphere troposphere (presentation by A. Kubin, U. Langematz). This idealised experiment shows that stratospheric changes can have significant effects on the tropospheric circulation and confirms earlier findings of Haigh (1996), Haigh *et al.* (2005), the presentation by **J. Haigh**, and Matthes *et al.* (2004, 2006).

Within theme V, the importance of an interactive ocean was discussed. A fully interactive ocean seems to better represent the reconstructed surface temperature signal during the Maunder Minimum (**Figure 4**, presentation by **D. Shindell**). **J. Meehl** showed results from NCAR's Community Climate System Model (CCSM) in which only total solar irradiance (TSI) changes at the top (~10hPa) were introduced, and which does not have a stratosphere; these results look very similar to the changes that were achieved with a CCM that included spectrally resolved solar irradiance changes and a proper stratosphere (Matthes *et al.*, 2007). The vertical structure of the response needs to be investigated further and it needs to be clarified how much of the tropospheric equatorial signal comes from TSI and how much from spectrally resolved UV changes.

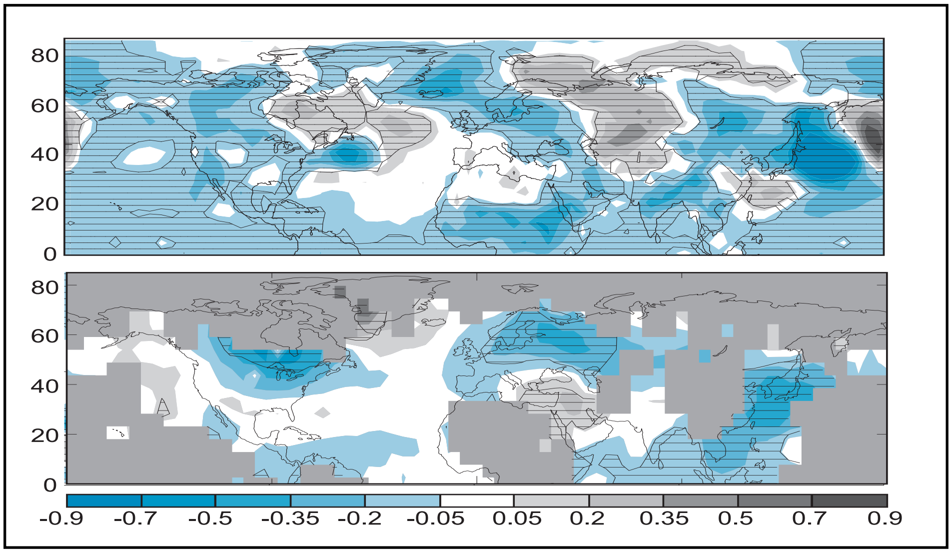

Figure 4: Annual average surface temperature change (˚C) due to solar irradiance change of ~1 W/m² (top of the atmosphere, equivalent to ~0.19 W/m² at the tropopause) in the GISS ModelE (top) and the regression during the period 1650-1850 between reconstructed solar irradiance (From Lean et al., 1995) and annual average surface temperatures (bottom) (From Mann et al., 1998) filtered to only include contributions from timescales longer than 40 years, with a 20 year lag. The correlation is given in ˚C per change from roughly the Maunder Minimum to a century later, which is roughly 0.2 W/m² in recent reconstructions (e.g. Wang et al., 2005). Grey areas indicate no data, while hatched areas indicate statistical significance at the 90% level. (Courtesy of D. Shindell.)

The short-term (27-day) response of the middle to upper atmosphere was discussed with the Hamburg Model of the Neutral and Ionized Atmosphere (HAMMONIA) (presentation by **H. Schmidt**), with the GFDL AMTRAC model (presentation by J. Austin) and with the SOCOL model (presentation by **E. Rozanov**). It was proposed to use 27-day cycle simulations to investigate the mechanisms for solar forcing in the stratosphere. For a decade or more 27-day processes have been simulated reasonably accurately whereas the response to the 11-year solar cycle is only now getting more coherent in the different model simulations. One of the main issues is whether different processes are operating on the 11-year and 27-day timescale.

Further progress and updates on our activities can be found on the SOLARIS website: http://strat-www.met.fu-berlin.de/~matthes/sparc/solaris.html.

Acknowledgments

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A note on an AGU spring meeting discussion of the role of atmospheric water vapour in climate and atmospheric composition

23-26 May 2006, Baltimore, Maryland, USA

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Introduction

Since the early 1970s the study of the middle atmosphere has focused on understanding the variability of its chemical and dynamical states as driven by both natural and anthropogenic processes. Concurrent with these efforts, studies have been carried out to understand both short- and long-term climatic variations that occur naturally, as well as those due to the emissions and/or alterations of optically active gases and aerosols by humanity. In these areas of study, stratospheric and tropospheric water vapour (H_2O) has been of particular interest. Water vapour is a greenhouse gas and is important for atmospheric chemistry, as it is the source of the hydroxyl radical, OH, which regulates among others the atmospheric methane lifetime and the production and destruction of ozone. Also, water vapour plays an important role in atmospheric heterogeneous chemistry, defining the aerosol effect on climate *via* formation of the stratospheric clouds. While some progress has been made in simulating the changing atmosphere, a number of observed phenomena remain unexplained, among them the reasons for the recently