How well is Solar induced Climate Variability represented in Chemistry-Climate models?

Investigation of Solar induced climate Variability in Chemistry-Climate Model simulations (SolVarCCM)

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In Short

- Investigations are related to solar variability effects on climate, to be analysed in CCMs:
- 11-year solar cycle effects
- effects of energetic particle effects
- downward propagation of solar signals to the troposphere

Solar induced climate variability is an important part of natural climate variability, detectable in atmospheric chemical and dynamical quantities. The physical processes driving this atmospheric solar signal involve variability in the spectral solar irradiances (SSI), the total solar irradiance (TSI) and also energetic particles precipitating (EPP) at high geomagnetic latitudes into the thermosphere and mesosphere. While the magnitude of the solar signal is large in the upper part of the atmosphere, where a direct impact of SSI variations on ozone chemistry and temperature is observed, the direct impact of TSI variations at the Earth's surface is rather small. Due to dynamical processes, which transfer the solar signal downward, an indirect amplification of the solar signal occurs in the troposphere. However, there still exist large uncertainties in quantifying the solar signal and in attributing physical processes to detected solar signals at the surface [1].

The aim of the project is to further improve our understanding of solar induced climate variability by exploring the most recent model simulations. The Chemistry Climate Model Initiative (CCMI) provides an excellent database for the analysis of the solar signal in atmospheric chemistry and dynamics extending from the troposphere to the upper mesosphere. As the Chemistry Climate Model (CCM) database has some limitations concerning solar forcing alternatives, SolVarCCM will produce additional CCM simulations to enlarge the database with respect to solar forcing. In the HLRN-project bek00021 a CCM coupled to an interactive ocean will be used to address the influence of the alternative CMIP6-SSI/TSI dataset and EPP on the solar signal under two different future prediction scenarios. These datasets together with the CCMI database will allow for the analysis of the solar signal in a number of model subsets to identify processes responsible for the transfer of the solar signal from the middle atmosphere to the troposphere.

The model simulations will be performed with the CCM EMAC (ECHAM/MESSy Atmospheric Chemistry). EMAC was developed at the MPI for Chemistry [2] and has, with some modifications, been locally implemented at FUB and successfully applied in a number of scientific studies. EMAC is based on the ECHAM5 general circulation model developed at the Max-Planck-Institute (MPI) for Meteorology, originally derived from the weather forecast model of the European Centre for Medium-range Weather Forecasts (ECMWF), and has been extended to a modular CCM at the MPI for Chemistry allowing the implementation of multi institutional codes via the Modular Earth Submodel System (MESSy) interface. EMAC is specifically qualified for the goals of SolVarCCM, because it includes a complex module for stratospheric/lower mesospheric (and tropospheric) chemistry enabling it to consider feedback mechanisms between atmospheric composition and changes in solar variability. The submodel UBCNOX is available, a parametrization to simulate enhaced NO_y production by energetic particles in polar latitudes of the upper mesosphere. In addition, EMAC includes an updated version of the high resolution SW radiation scheme FUBRad [3] which will allow us to investigate systematically the relevance of spectral resolution on the simulated solar radiative signal in CCMs. In this project EMAC will be used as an atmosphere-ocean CCM (coupled to the MPI-OM ocean module, i.e. EMAC-MPIOM), hence allowing the study of the response of the coupled atmosphere-ocean system to stratospheric-mesospheric internal or external forcing.

Within this project simulations with EMAC-MPIOM using the CMIP6-SSI, -TSI and -EPP forcing will be performed. The solar forcing for the CMIP6 simulations [4] consists of a new dataset for SSI and TSI. It also includes updated recommendations for particle forcing to account for the effects of solar protons, electrons and galactic cosmic rays. Using the CMIP6 recommendation for the upper boundary condition (UBC) of EPP induced NO_y allows us to create additional CCM simulations (REF-C2 transient simulations; 1960-2100) with EPP-forcing and alternative CMIP6-SSI and TSI forcing, which are complementary to the existing CCMI database.

WWW

http://www.geo.fu-berlin.de/en/met/ag/strat/

More Information

[1] Gray, L. J., et al. *Rev. Geophys.* **132**, 154104 (2010). doi:10.1029/2009RG000282

[2] Jöckel, P., et al. *Geosci. Model Dev.* **9**, 1153-1200 (2016). doi:10.5194/gmd-9-1153-2016

[3] Kunze, M., et al. *Planetary and Space Science* **98**, 77-92 (2014). doi:10.1016/j.pss.2013.09.011

[4] Matthes, K., et al. *Geosci. Model Dev.* **10**, 2247-2302 (2017). doi:10.5194/gmd-10-2247-2017

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