Project: **1148**

Project title: **SOLCHECK**

Principal investigator: **Holger Pohlmann**

Report period: **2020-11-01 to 2021-08-31**

1. Project overview

Observational and modeling studies indicate a significant influence of solar variability on climate and in particular on internal climate variability modes in the coupled atmosphere-ocean system. However, the understanding of the relevant processes as well as the quantification of solar contributions to global and regional climate change remains a difficult task due to the limited availability of observations and the non-linearity of the involved processes. SOLCHECK aims at significantly advancing the understanding and quantification of the solar contribution to past, present, and future climate evolution in the Northern Hemisphere from decadal to centennial timescales. The research questions of SOLCHECK are addressed using German community models. In addition to the German decadal climate prediction system MiKlip (Marotzke et al., 2016), chemistry-climate models are applied that account for atmosphere-ocean feedback processes and include advanced schemes for the ozone response to solar variability, partially developed in ROMIC I. Our approach is unique in several aspects: 1) the realization of ensemble simulations with advanced chemistry climate models for different combinations of fixed or transient anthropogenic and solar forcing conditions provides an unprecedented statistical basis for the assessment of solar forcing contributions to decadal climate variability and climate change, 2) performing ensemble simulations with the MiKlip system with and without solar forcing provides for the first time a robust estimate of solar contributions to decadal climate prediction skill, and 3) a range of the potential impact of a future Grand Solar Minimum and other extreme solar events under different greenhouse gas scenarios is provided. The outcome of SOLCHECK is highly relevant to the WCRP Near-term Climate Prediction Grand Challenge and the IPCC report, and will provide the German contribution to the international WCRP/SPARC-SOLARIS/HEPPA initiative.

2. Achievements

SOLCHECK aims at identifying and better understanding the processes of solar signals from the middle atmosphere to the surface, with a special focus on solar cycle effects to internal climate variability modes. We have completed the planned suit of CMIP6 historical-like sensitivity experiments based on MPI-ESM-HR (Müller et al., 2018) over the period 1850-2013, which have been subject to a step-by-step reduction in variability of the solar forcing.

In our last report we had presented results from a set of 8-ensemble members of historical like experiments with solar and ozone forcing fixed to 1850 preindustrial conditions (NOSOL). We had analysed the results in terms of composite sections of zonal mean temperature (T) and zonal wind (u) for the years with maximum solar activity and minimum solar activity. With these composites, we could show a warming signal associated with the solar variability in the upper stratosphere and an influence on the quasi-biennial oscillation (QBO).

Since then, we have integrated a set of 8-ensemble members with low-pass filtered solar and ozone forcing in order to exclude the 11-year solar cycle and higher variability (LOWFREQ). The internal variability and the solar forcing is analysed by contrasting the scenarios to the CMIP6 historical simulations including the long-term solar variability and the 11-year solar cycle (FULL). The simulations are analysed by displaying the potential predictability variance fraction (ppvf; Boer, 2004) of 8-year running winter (DJF) mean surface air temperature for the FULL and LOWFREQ simulations and their differences (Fig. 1). The analysis is performed over the period 1932-2013, which is considered as an epoch of strong solar activity (Drews et al., 2021). The northwest North Atlantic as well as the North American continent and the eastern Pacific are regions where we find a large influence of the solar cycle on the decadal climate predictability (Fig. 1c), with up to 25% of the decadal variability of winter surface air temperature explained by the solar cycle. Our findings confirm the potential predictability results in an equivalent study with the WACCM model (Drews et a. 2021).

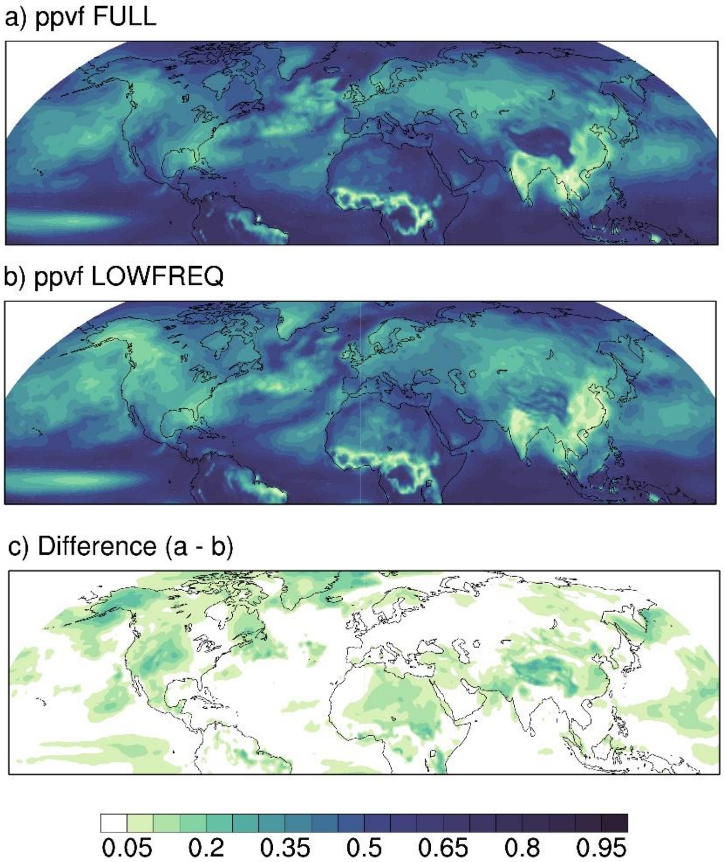

Figure 1: Potential predictability variance fraction (ppvf) with respect to the DJF 8-year averaged surface air temperature in the historical ensemble with a) the full external forcings (FULL), b) the low-pass filtered solar forcing in order to exclude the 11-year solar cycle (LOWFREQ) and c) their differences (a-b).

Our next task in SOLCHECK is to analyze further the simulations in terms of the effect of increasing anthropogenic forcing on the interaction of internal and solar variability by comparing periods with and without anthropogenic forcing (earlier and later part of the historical simulations as well as the existing preindustrial control simulations). Additionally, it is planned to perform a set of hindcasts with the MiKlip climate prediction system subject to suppressed solar forcing.

3. Data Lifecycle

Central aim of SOLCHECK is the long-term storage of the experiments. We had converted the 8-ensemble members historical like simulations with MPI-ESM-HR with solar forcing fixed to 1850 preindustrial conditions (NOSOL) into the CMOR-data format and stored in the CERA data archive at DKRZ (Pohlmann, 2021). A similar approach is planned for the historical like ensemble with low-pass filtered solar forcing in order to exclude the 11-year solar cycle and higher variability (LOWFREQ).

References

- Boer, G. J., 2004: Long time-scale potential predictability in an ensemble of coupled climate models. Climate Dynamics, 23, 29-44, doi:10.1007/s00382-004-0419-8
- Drews, A., et al., 2021: The Sun's Role for Decadal Climate Predictability in the North Atlantic, doi:10.5194/acp-2021-241
- Marotzke, J., et al., 2016: MiKlip - a National Research Project on Decadal Climate Prediction. Bull. Amer. Meteor. Soc., doi:10.1175/BAMS-D-15-00184.1
- Müller, W. A., et al., 2018: A high-resolution version of the Max Planck Institute Earth System Model (MPI-ESM1.2-HR). JAMES, 10, 1383-1413, doi:10.1029/2017MS001217
- Pohlmann, H., 2021: Metadata for 'SOLCHECK MPI-M MPI-ESM1-2-HR CMIP6 historical simulation without solar and ozone variability'. doi:10.26050/WDCC/SOLCHECK_MPI-ESM-HR_C6_hist