Project: **1148**

Project title: **SOLCHECK**

Principal investigator: **Holger Pohlmann**

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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 upcoming 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 suite 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 low-pass filtered solar and ozone forcing which excludes the 11-year solar cycle in comparison to the respective CMIP6 ensemble of historical runs with full

forcing. An analysis of the potential predictability variance fraction (ppvf; Boer, 2004) of 8-year running winter (DJF) mean surface air temperature for the two ensemble suites and their differences pointed at the northwest North Atlantic as well as the North American continent and the eastern Pacific as regions where we find a large influence of the solar cycle on the decadal climate predictability with up to 25% of the decadal variability of winter surface air temperature explained by the solar cycle.

Currently we are integrating a suite of hindcasts with MiKlip which differs from the CMIP6 ensemble hindcasts (FULL) in the solar and ozone forcing that is fixed to values from year 1850 (NOSOL). Here we present a preliminary correlation skill score of lead-year 1 surface temperatures based on 5 ensemble members, which compares the new set of hindcasts to 5 members of the CMIP6 hindcasts with full forcing to elucidate the effect of solar and ozone variability on surface temperature predictions (Fig. 1), e.g., significant improvements in the Pacific ENSO region or in the northern North Atlantic. The integration and analyses of these hindcast experiments are still ongoing.

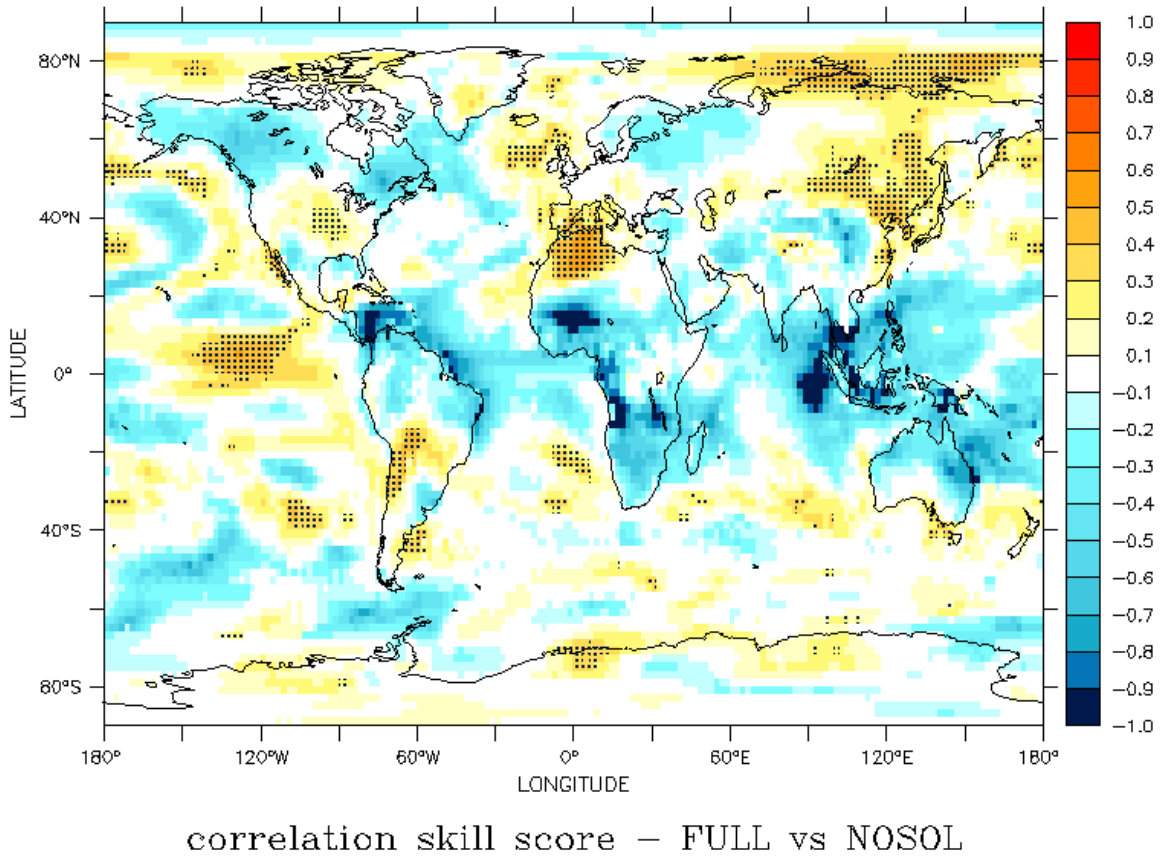

Figure 1: MiKlip: Correlation skill scores (CSS) of ensemble (1-5) hindcasts of annual mean surface temperatures for start years 1960-2013 and lead year 1. CMIP6 decadal predictions (FULL) versus reference forecast with suppressed variability in solar & ozone forcing (NOSOL). Correlations are computed with observations from GIStemp v4 (Lenssen et al., 2019). Dots indicate significance at 99% according to a bootstrap test.

Our next task in SOLCHECK is to perform a set of hindcasts with the MiKlip climate forecast system that is subject to a suppressed 11-year solar cycle but includes long-term solar and ozone forcing.

3. Data Lifecycle

Central aim of SOLCHECK is the long-term storage of the experiments. The historical-like sensitivity simulations performed in this project have been converted into the CMOR data format and stored in the CERA data archive at DKRZ. The hindcast runs will be subject to long-term archiving (LTA) at DKRZ as well.

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
- 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
- Mitchell, M. et al., 2015: Solar signals in CMIP5 simulations: the stratospheric pathway. G. J. R. Met. Soc 141, 2390-2403 doi:10.1002/gj.2530
- Lenssen, N., G. Schmidt, J. Hansen, M. Menne, A. Persin, R. Ruedy, and D. Zyss, 2019: Improvements in the GISTEMP uncertainty model. J. Geophys. Res. Atmos., 124, no. 12, 6307-6326, doi:10.1029/2018JD029522