Project: **519**

Project title: **NATHAN - Quantification of Natural Climate Variability in the Atmosphere-Hydrosphere System with Data Constrained Simulations**

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Report period: **2018-01-01 to 2018-12-31**

Preface

As announced in our computing time application for 2018, the work of the former Helmholtz-University Young Investigators Group NATHAN (funding finished end of 2015) has been continued within the national BMBF-ROMIC SOLIC project (Quantification of Uncertainties of SOLar Induced Climate variability; FKZ: 01 LG 1219A) until 2017. In 2018 we continued to address questions related to the overall topic of solar induced natural climate variability financed through GEOMAR base funding. We are still waiting for the approval of the follow-on joint research project ROMIC-II, where we submitted two initial proposals at the end of January 2018, one related to "Solar contribution to climate change on decadal to centennial timescales (SOLCHECK)". Unfortunately, funding approval by the BMBF has been delayed and we expect an answer in the next 1-2 weeks. The model simulations performed in 2018 will be used as a first step for the potential new project SOLCHECK.

Model simulations in 2018

In 2018, we performed 3 sets of experiments (with 10 ensemble members each) using the chemistry-climate model CESM1(WACCM). All experiments cover the historical period from 1850 to 2014 using CMIP6 historical forcing, and differ by the prescribed solar forcing. The experiments are summarized in Table 1:

Experiment ID	Configuration
SOLAR-FULL	full solar variability (all timescales) and all other external forcings as in standard CMIP6 historical experiments
SOLAR-LOWFRQ	only low-frequency solar variability (timescales > 11y); all other external forcings as in standard CMIP6 historical experiments
SOLAR-FIX	fixed solar forcing, no solar variability; all other external forcings transient as in standard CMIP6 historical experiments

Table 1: Summary of model simulations performed at DKRZ in 2018. All model experiments used CESM1(WACCM) version 1.0.6

Until October 22, 2018 we were able to complete all simulations. Analysis of the experiments has started, and will continue into 2019. First results look promising and are briefly shown in the following section.

Results

The configuration of the experiments performed at DKRZ in 2018 allows us to separate the climate effect of low-frequency solar variability from the overall impact of solar variability on climate, as well as a further understanding of the impact of the 11-year solar cycle onto decadal variability of internal climate modes such as the Interdecadal Pacific Oscillation (IPO) or the North Atlantic Oscillation (NAO). Previously, Thiéblemont et al. (2015) showed a synchronization between the 11-year solar cycle forcing and a quasi-decadal NAO variability by comparing two model experiments with and without solar forcing variability based on an earlier CESM1-WACCM version 1.0.2. The output from the large ensemble simulations performed in 2018 allows us to revisit the previously proposed mechanisms with more solid statistics (10 ensemble members), and explore new mechanisms that may better explain the influence of solar variability on climate.

Using reanalysis data, Huo and Xiao (2017) showed that the 11-year solar cycle signal has a significant connection with the decadal variability of tropical Pacific SSTs and convection. However, the 11-year solar cycle signal is too week and its impact is veiled by strong internal variability in the

Pacific. The two ensemble experiments SOLAR-FULL and SOLAR-FIX are powerful tools for further investigations of the role of solar cycle forcing for the Pacific decadal variability as they allow to separate low and high frequency solar variability. A first ensemble composite analysis of solar maximum versus solar minimum conditions of the SOLAR-FULL set of simulations indicates

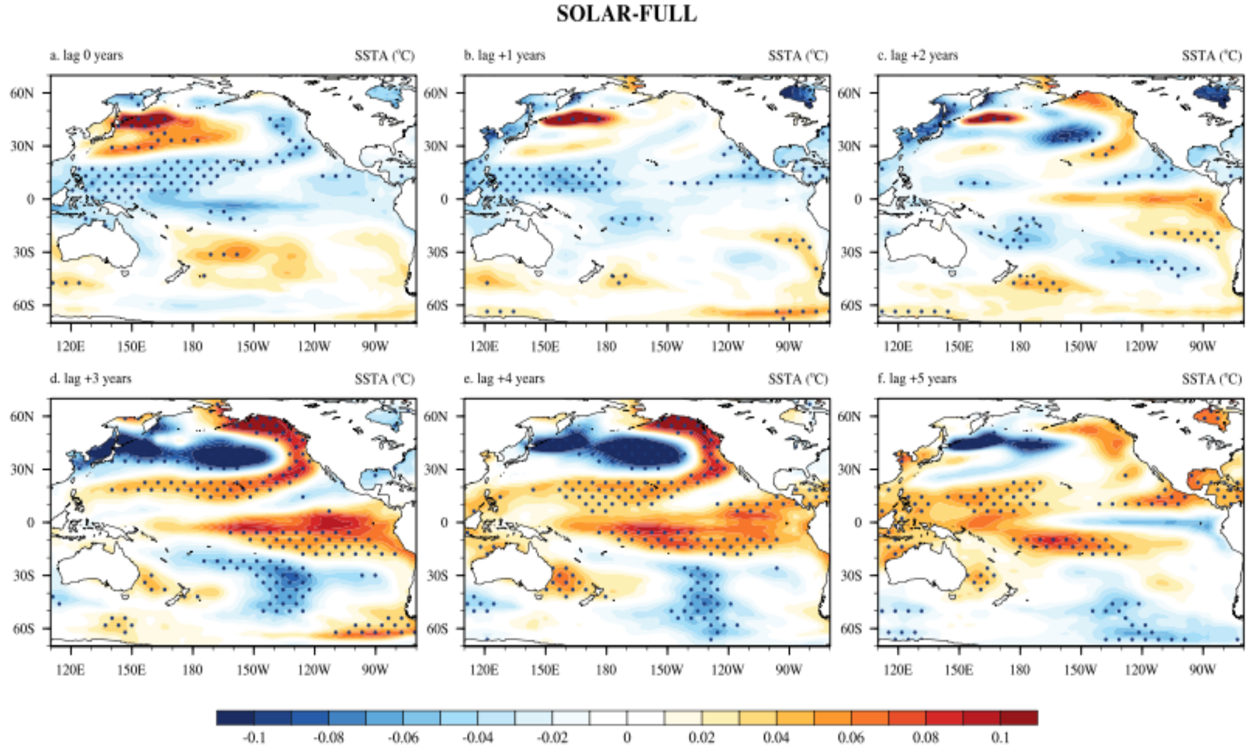

Figure 1: Consecutive lagged composite solar maximum minus minimum differences for sea surface temperature in the10-members ensemble results from SOLAR-FULL experiments. 90% significance level is indicated by stippled regions.

negative SST anomalies in the tropical Pacific and positive anomalies in the extratropical Pacific at lag time between year 0 and 1. As the lag increases, the SST anomalies decay. At lag times of 3 to 4 years, the pattern resembles the positive phase of the IPO (Figures 1d and 1e). These features are absent in the SOLAR-FIX ensemble composite results (not shown). Our results are consistent with previous work by Meehl and Arblaster (2009), who find La Nina-like patterns during solar maximum years, followed by an El Nino-like pattern. The ENSO events can act as a trigger for a decadal transition of tropical Pacific SSTs to the opposite IPO phase (Meehl et al., 2016).

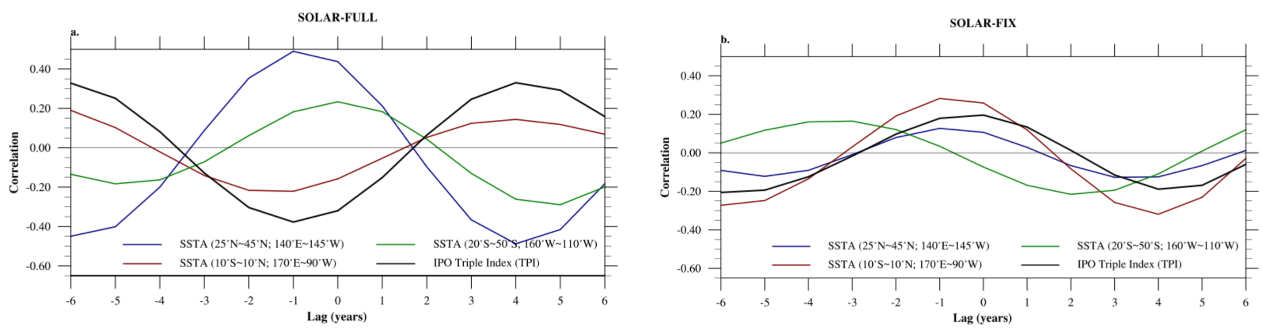

Figure 2: Correlation coefficients between the f10.7 cm solar radio flux and filtered IPO index (black line) of the SOLAR-FULL (left) and SOLAR-FIX (right) experiments.

We defined an IPO index based on the difference between the SSTA averaged over the central equatorial Pacific and the average of the SSTA in the North and South Pacific (details in Figure 2). In the SOLAR-FULL experiment (Figure 2a), a quasi-decadal correlation is found between the F10.7 solar index and SST anomalies averaged in the IPO index regions. A positive correlation between the filtered IPO index and the F10.7 index can be found at lag times between 3 and 5 years, and is consistent with the positive IPO phase shown in Figures 1d to 1f. This phase-locked quasi-decadal correlation between the solar cycle and the IPO indices disappears in the SOLAR-FIX experiments (Figure 2b).

Does intensified solar radiation during solar maximum conditions help to prepare a pre-condition for the IPO phase transition from negative to positive during years with high solar activity? Does the 11-year solar cycle synchronize the internal decadal variability in the Pacific just as in the North Atlantic, or does it work more as a “pacemaker” to adjust the internal variability to the solar cycle? Further analysis of our three sets of experiments during the remainder of 2018 and in 2019 in conjunction with the experiments planned for 2019, will hopefully help to find answers to these questions.

References

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