Project: **519**

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

Report period: **2016-01-01 to 2016-12-31**

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As announced in our computing time application for 2016, the work of the former Helmholtz-University Young Investigators Group NATHAN (funding finished end of 2015) has been continued within the national SOLIC project (Quantification of Uncertainties of SOLar Induced Climate variability; FKZ: 01 LG 1219A) throughout the report period. Funding for this project was provided by both, GEOMAR and the German Federal Ministry of Education and Research (BMBF) within the joint research initiative ROMIC (Role of the Middle Atmosphere for Climate).

1. Revision of simulation plans

Our simulation plan included four transient simulations (250 model years each) with the chemistry-climate model CESM1(WACCM, Marsh et al. 2013) constituting a set of sensitivity studies in order to assess solar induced decadal climate variability in the presence of anthropogenic climate change. These simulations are based on the solar forcing recommendation for CMIP6.

To avoid spurious side effects due to the abrupt change in solar forcing, initial conditions from an afore-conducted multi-centennial simulation under pre-industrial control conditions using time varying solar variability following a solar forcing recommendation of the WCRP[1]/SPARC[2] SOLARIS-HEPPA[3] initiative – referred to as VarSolPI (see section 2 for details) – are necessary to run the simulations we initially applied for in 2016. Due to a delay in the availability of the VarSolPI solar forcing dataset, we decided to use the computing resources at DKRZ to run this pre-industrial simulation. The simulations we initially applied for, are now performed at the Kiel University supercomputing facility once the VarSolPI simulation has been completed.

Besides the rather technical motivation of generating consistent initial conditions for the transient simulations, the VarSolPI experiment has shown to be beneficial to our overarching goal of understanding the impacts of solar variability on the coupled atmosphere-ocean system and the underlying mechanisms. Following a number of earlier studies (e.g., Matthes et al., 2013; Thiéblemont et al., 2015; Wang et al., 2015), the VarSolPI-simulation allows analyzing solar-induced climate variability based on model data representing several centuries without the anthropogenic influence on greenhouse gas concentrations or volcanic aerosol effects.

2. The VarPiSol-experiment: Setup and results

2.1 Experimental set up

As indicated in the previous section, the VarPiSol multi-centennial experiment uses the chemistry-climate model CESM1(WACCM, Marsh et al. 2013). In this simulation we apply pre-industrial external forcings except for the solar forcing where we use time varying solar variability following the VarSolPI solar forcing dataset described below. Additionally a nudging towards a cyclic 28-month Quasi-Biennial Oscillation (Matthes et al. 2010) is included.

The VarSolPI solar forcing dataset is based on the *variable pi control forcing* (v3.1) that is compiled and released by the SOLARIS-HEPPA-community and documented in Matthes et al. (2016). According to the SOLARIS-HEPPA-recommendations, the forcing for VarSolPI was created from this dataset by the following steps:

1. eliminating EUV-irradiance and 29 Feb of all leapyears

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[1] World Climate Research Programme

[2] Stratosphere-Troposphere Processes And their Role in Climate

[3] Solar Influence for SPARC

2. fill up first part of VarSolPI forcing by complete variable pi control forcing dataset (covering 253 years, 8 months, and 9 days until the end of solar cycle 27)
3. fill up remaining part of VarSolPI forcing by multiple repetition of solar cycles 12-27 (approx. 175.5 years)

Due to the excellent performance of the HLRE3 system and the generous CPU regulations we were able to complete 750 years of the VarPiSol in 2016. All (preliminary and not yet published) analyses presented here are based on the first 650 model years of the simulation. Given the preliminary character, no significance tests are implemented to any analyses, yet.

2.2 Preliminary result: Decadal NAO variability in VarSolPI

Setting up the VARPI experiment was strongly motivated by the findings of Thieblemont et al. (2015), who proposed a synchronization (or phase-locking) of the decadal part of the North-Atlantic Oscillation (NAO) with solar variability.

In a first step, we analyzed VarSolPI following the procedure of Thieblemont et al. (2015), though using a different type of bandpass. In the present analysis, the bandpass of Doblas-Reyes and Deque (1998) was employed with cut-off periodicities defined as 9 and 14 years, respectively. This 9-14 year corridor is approximately symmetric around a periodicity of 11 years in frequency space.

As indicated on Fig. 1, no permanent synchronization or phase-locking of the NAO-variability to solar forcing is evident, i.e. the findings of Thieblemont et al. (2015) cannot be confirmed based on these preliminary analyses of the VarSolPI-experiment.

However, considerable variations in decadal NAO-variability are visible which need further analysis. Future work will try to answer the question if this is related to phase-coherency of both oscillations, that means if the solar signal additively projects onto the NAO-variability during these periods. A further question is, whether the comparably small solar amplitude in VarSolPI is sufficient to significantly affect extra-tropical circulation patterns such as the NAO and if solar cycle induced climate signals scale linearly with the solar cycle amplitude. To answer this question, we plan an additional VarSolPI-simulation with enhanced solar cycle variability following the SOLARIS-HEPPA *variable picontrol forcing v3.2.* This new simulation is subject of our DKRZ computing time application for 2017.

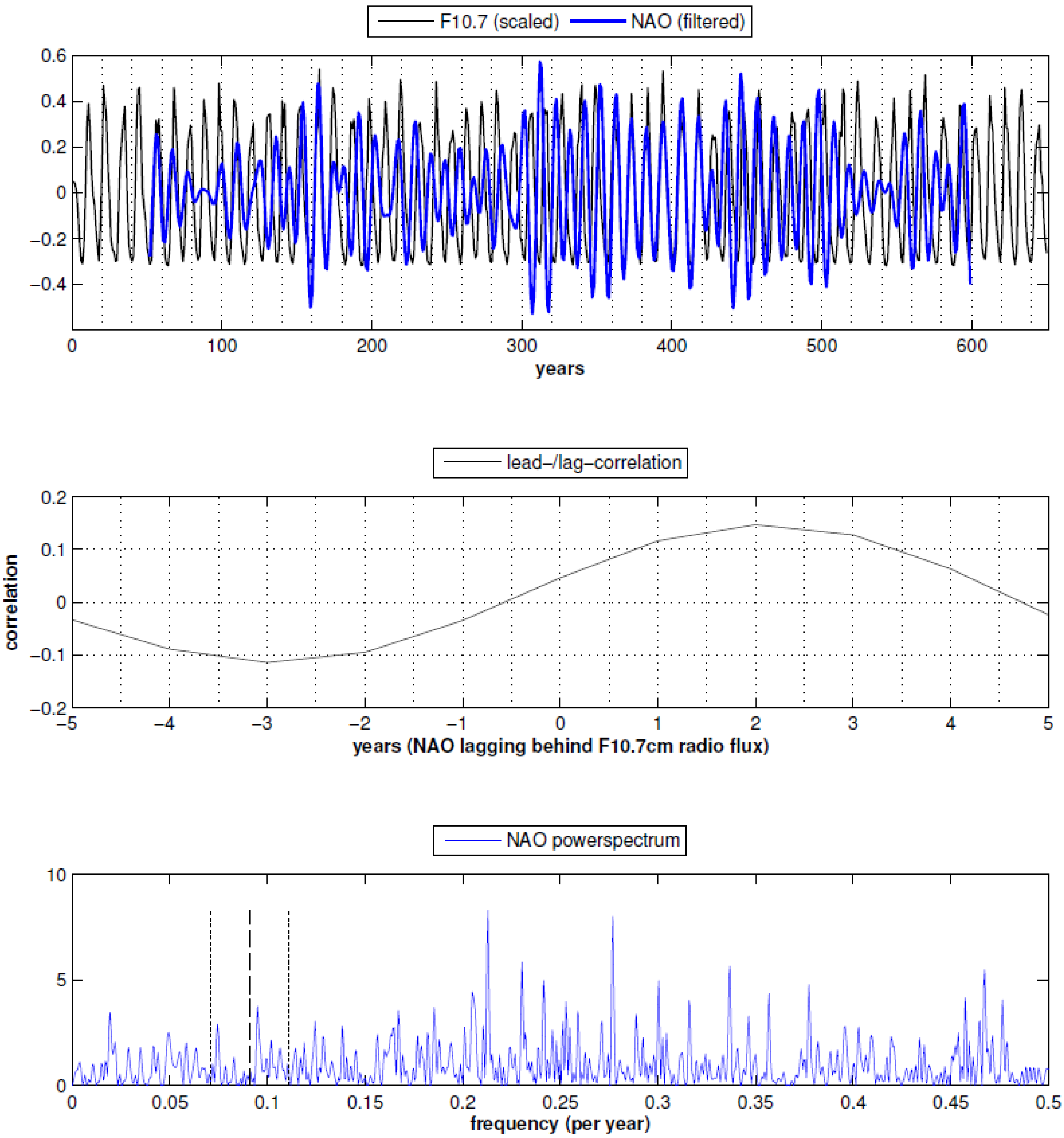

Fig. 1: Statistical relationship between the NAO and solar forcing; top: scaled F10.7 cm solar radio flux (black; proxy for solar UV-variability) and bandpass-filtered (9-14 years) NAO-index (blue); middle: lead-lag-correlation of the two timeseries shown above; bottom: NAO powerspectrum (blue) with dashed black line indicating a periodicity of 11 years and black dotted lines indicating the 9-14 year corridor used for bandpass-filtering

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