Project: **519**

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

Principal investigator: **Katja Matthes (PI), Sebastian Wahl, Wenjuan Huo**

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Preface

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. 2019 brought an unfortunate situation as the payout of already approved funding (approved on Oct 30th, 2018) for the BMBF project "Solar contribution to climate change on decadal to centennial timescales (SOLCHECK)" was delayed by BMBF to after March 2020. With limited (human) resources we were not able to setup and perform the experiments planned on MISTRAL in 2019. Nevertheless, we were able to use some of the CPU hours to push forward our new modelling system based on the Flexible Ocean and Climate Infrastructure (FOCI, Matthes et al., 2019), and to run some of the model experiments to be performed as part of the CASISAC project[1] ahead of time.

Model simulations in 2019

The CPU time granted in 2019 was used for the experiments listed in table 1. As FOCI has been implemented for the first time on MISTRAL in 2019, we repeated our historical and historical chemistry experiments described in Matthes et al., 2019 to validate our model setup, and to produce additional ensemble members for our existing set of experiments. The experiments labelled *inalt10x* have been run with a 1/10° ocean nest covering the South Atlantic and western Indian Ocean including sea ice, and are part of the INALT-family (Schwarzkopf et al., 2019, Matthes et al., 2019).

Experiment ID	Years	Configuration
hist1-p2	1850 - 2013	Historical simulations restarted from spun-up piControl simulation
ssp370-1	2014 - 2099	Future simulation following the **SSP370** scenario, restarted from hist1-p2
hist2-ssp370-2	1850 - 2099	Historical simulation following the **SSP370** scenario after 2013, initialized from spun-up piControl simulation.
chem1-p2	1954 - 2013	Historical simulation with interactive chemistry, restarted from historical simulation similar to hist1-p2
chem2-ssp370	1954 - 2099	Historical simulation with interactive chemistry following the **SSP370** scenario after 2013, restarted from historical simulation.
chem3-inalt10x	1954 - 2013	Historical simulation with interactive chemistry and INALT10x nest refinement
chem4-inalt10x-ssp585	2014 - 2099	Future simulation following the **SSP585** scenario with INALT10x nest refinement, restart from nested simulation with chemistry not listed here.

Results

We present here two important characteristics of coupled models: Global surface air temperature (SAT) and northern hemisphere (NH) sea ice cover. Figure 1 shows that all model configurations (with/without ocean nest, with/without chemistry) are able to reproduce global mean climate under historical and assumed future climate conditions.

The decline in sea ice due to global warming is captured, however we do not find a significant difference in sea ice decline between the simulation following the SSP370 and SSP585 (stronger

[1] http://www.crslr.uni-kiel.de/de/projekte/casisac.html

global warming compared to SSP370). We also note that the *chem2-ssp370* simulation has an offset in NH sea ice cover of roughly 1 Mio km^2 whose reasons remain currently unclear. Detailed analysis of this specific simulations (which includes an ocean nest) is currently ongoing as part of the CASISAC project.

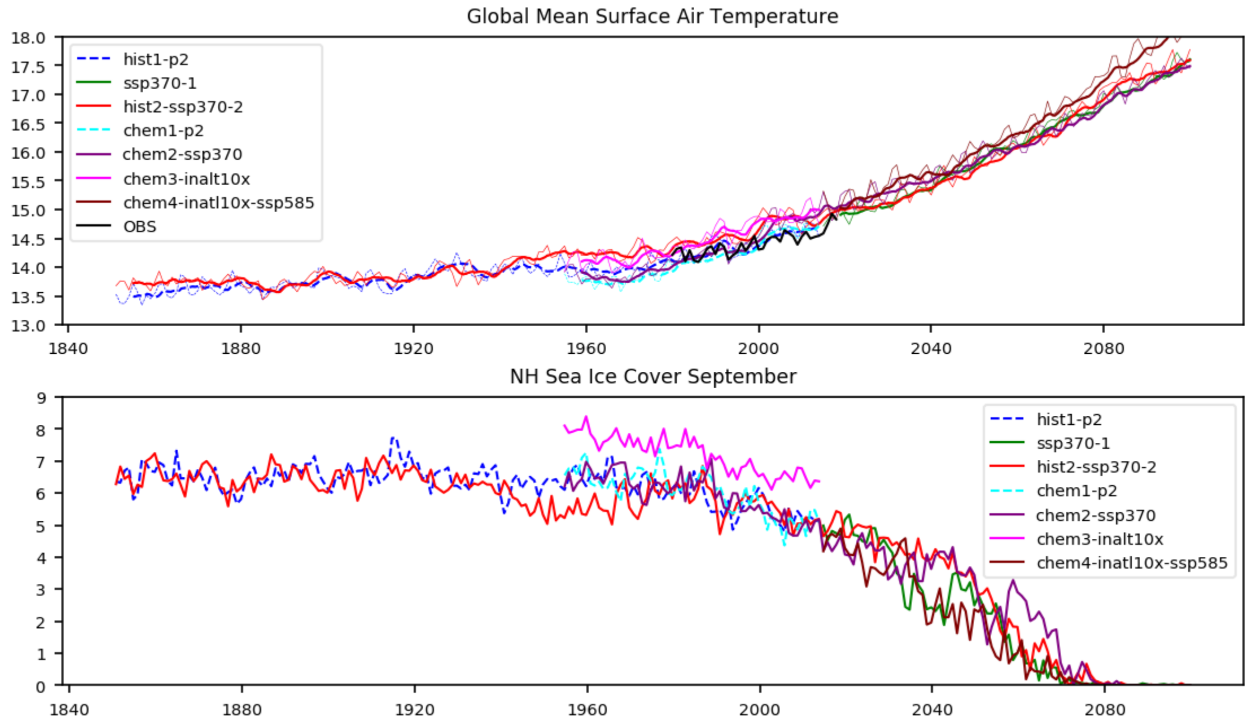

Figure 1: Global SAT (top) and NH sea ice cover at the end of NH summer (bottom) for all experiments listed in Table 1.

Global bias patterns, as well as major variability patterns (e.g,. ENSO, NAO) are reasonably simulated (Matthes et al., 2019). The model configurations with interactive chemistry simulate a reasonable strength of the ozone hole starting in the 1980s as well as the full recovery of the ozone hole in the 2050s (not shown).
Analysis of the 2019 experiments has just started, and current topics are:

- How does an increased resolution in the South Atlantic affect the transport of warm and saline Indian Ocean waters into the Atlantic via the so-called Agulhas leakage (e.g., De Ruijter et al. 1999), and how does it evolve under future climate conditions?
- How does the strength of the SH westerlies change under future climate conditions, and what role plays a better representation of the Agulhas system in our coupled and nested simulations?

The remaining CPU time in 2019 will be fully dedicated to additional nested simulations under both historical and future climate scenarios (SSP585) to build a small ensemble that allows us to draw more robust conclusions as part of CASISAC, and to better address the questions mentioned above.

References

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Schwarzkopf, F. U., Biastoch, A., Böning, C. W., Chanut, J., Durgadoo, J. V., Getzlaff, K., Harlaß, J., Rieck, J. K., Roth, C., Scheinert, M. M. and Schubert, R.: The INALT family – a set of high-resolution nests for the Agulhas Current system within global NEMO ocean/sea-ice configurations, Geoscientific Model Development, 12, 3329–3355, https://doi.org/10.5194/gmd-12-3329-2019, 2019.