Project: **873**
Project title: **Working group on seasonal prediction (formerly: SPECS/EUROSIP)**
Project lead: **Johanna Baehr (IfM), Wolfgang Müller (MPI-M)**
Project participants: Mikhail Dobrynin (IfM), André Düsterhus (IfM), Kristina Froehlich (DWD), Holger Pohlmann (MPI-M) and further members of the joint working group
Allocation period: **1.1.2016 - 31.10.2016**

Project-Overview: The central aim of the project is the continuation of the development of a seasonal prediction system based on the initialized coupled climate model MPI-ESM. In the reporting period, the simulations contributed to the SPECS project (UHH and MPI-M contributions), the RACE project (TP 2.3), and the continuing development of the German Climate Forecast System (GCFS).

Report-Summary: We conducted (or are right now in the process of conducting) all simulations required for the collaborative efforts in SPECS and FourS2O, and started all simulations needed for our contribution to the RACE II project. We also performed and analysed the simulations to enable our partner DWD to start the now operational version of the seasonal forecast system (GCFS1.0). The performed simulations were the basis for several joint publications (Bunzel et al., 2016, Domeisen et al., 2015), a contribution to the CHFP forecasts archive and a joint publication (Butler et al., 2016). Several further publications are submitted or in preparation for submission until the end of the year (Bunzel et al., Dobrynin et al., Düsterhus et al.). With the SPECS project finishing in early 2017, we also successfully participated in another H2020 proposal, so that for 2017 the development of the seasonal prediction system is again supported by three projects, in addition to CliSAP as well as our respective groups' resources.

Comparison to 2016 request: While we needed some time to get the MPI-ESM-HR prediction system up and running, we can now realistically estimate that we will be able to use our entire allocation (including the additionally granted CPUtime) by the end of the year. In the first quarter, we could not use as much CPU-time as planned, since there were both delays in the hiring process for the RACE project and the availability of the HR historical simulations. In the third quarter, due to an update of mpi libraries/environment and installation of a new version of Intel compiler in September, we could not optimally use our allocated time. However, these problems are successfully solved, the first ensemble member is complete, and the further members started.

Example results: 1. Seasonal prediction of the Winter-NAO index
When awaiting the completion of the MPI-ESM-HR historical simulation, we completed further MR ensemble members. The winter (DJF) hindcast correlation skill for the NAO improves from about 0.4 for 10 ensemble members (Fig. 1) to about 0.5 for 30 ensemble members (Dobrynin et al., submitted). Hence, MPI-ESM-MR is currently one of only two seasonal prediction systems that show reasonable DJF hindcast skill for the NAO (Butler et al., 2016).

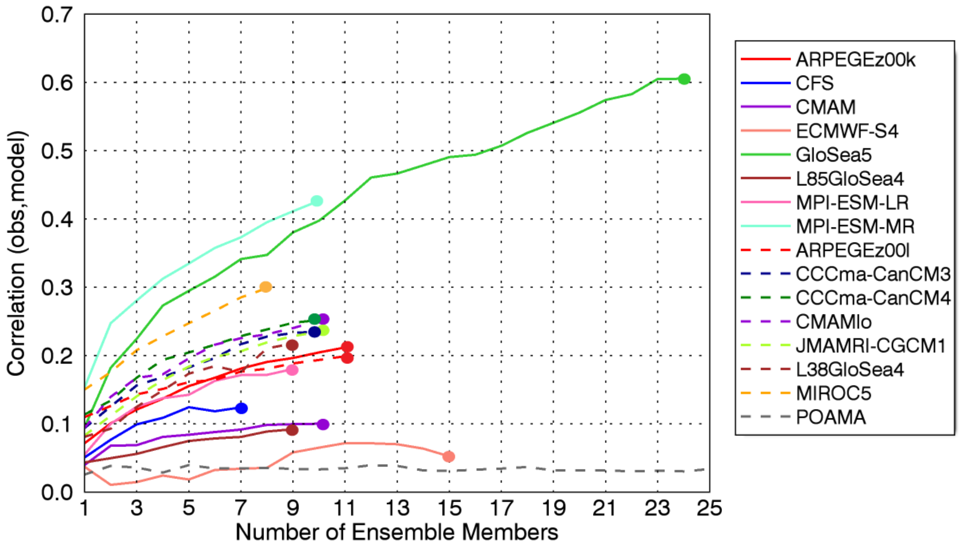

Figure 1: Skill of model forecasts of the DJF NAO index (from November start and against ERAinterim) versus the number of ensemble members.

2. Seasonal prediction of European summer temperatures: Improvements with the new 5-layer soil-hydrology scheme implemented in MPI-ESM

In this study we evaluate the seasonal prediction skill for European summer temperatures in two sets of seasonal hindcast experiments performed with the Max Planck Institute Earth System Model (MPI-ESM, Stevens et al. [2013]) using the same initialization setup and model configuration but different soil schemes. For one hindcast set the MPI-ESM bucket soil scheme [Raddatz et al., 2007] is used, for the other set the new 5-layer soil-hydrology scheme [Hagemann and Stacke, 2015] is used. Both hindcast sets are initialized from fully-coupled assimilation experiments where different atmospheric and oceanic variables are nudged, but no direct assimilation of soil-moisture data is performed. We find significant seasonal hindcast skill for European summer temperatures only if the 5-layer soil-hydrology scheme is switched on (Fig. 2), and investigate possible causes for this skill improvement. On the one hand, the indirect soil-moisture assimilation is more realistic causing a different behaviour of land-atmosphere coupling in the 5-layer scheme compared to the bucket scheme. On the other hand, the prediction of the atmospheric blocking frequency is improved, reflecting more realistic persistence of large-scale weather patterns over Europe (Bunzel et al., in preparation).

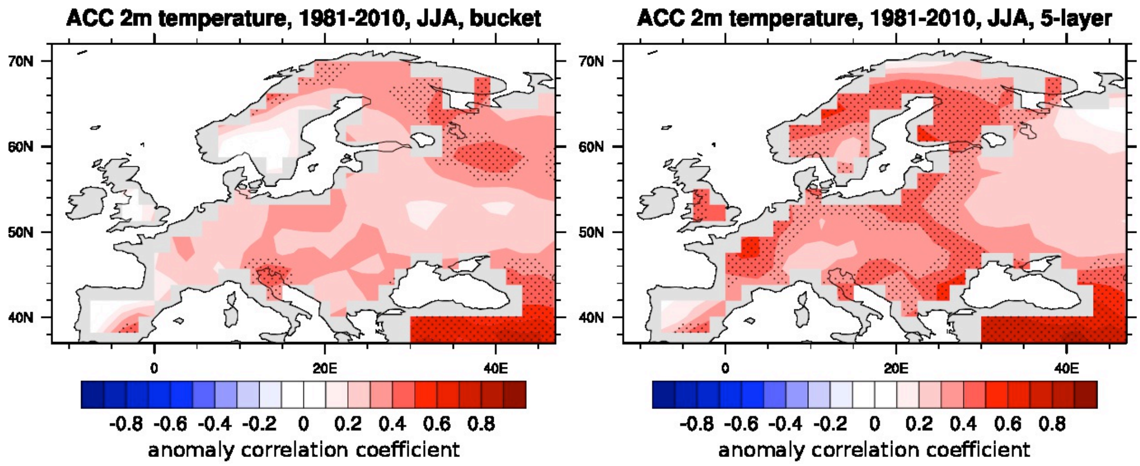

Figure 2: Anomaly correlation coefficients (ACCs) for JJA-mean 2-meter air temperature over Europe, computed from the ensemble mean of seasonal hindcasts started each year on 1 May within 1981-2010 with respect to ERA-Interim reanalysis data. Results are shown for both the bucket soil scheme (left), and the 5-layer soil-hydrology scheme (right). Dotted regions indicate significant ACCs at the 95%-level obtained from a distribution of 1000 re-sampled 10-member ensemble means [Goddard et al., 2013].

3. Seasonal prediction of the Summer-NAO index

We have used the MR-Hindcasts to predict the Summer North-Atlantic Oscillation (SNAO) in the months of July and August with a lead time of three to four months. The SNAO is less influential for European weather as its counterpart in winter, but still allows to describe an important part of its variability. A capability to predict the variation of the SNAO index by the dynamical model alone is not given. Applying a statistical dynamical approach by using a physics-based ensemble subsampling generates a significant correlation between a subsampled ensemble mean and the ERA interim reanalysis (Fig. 3; Düsterhus et al., in preparation).

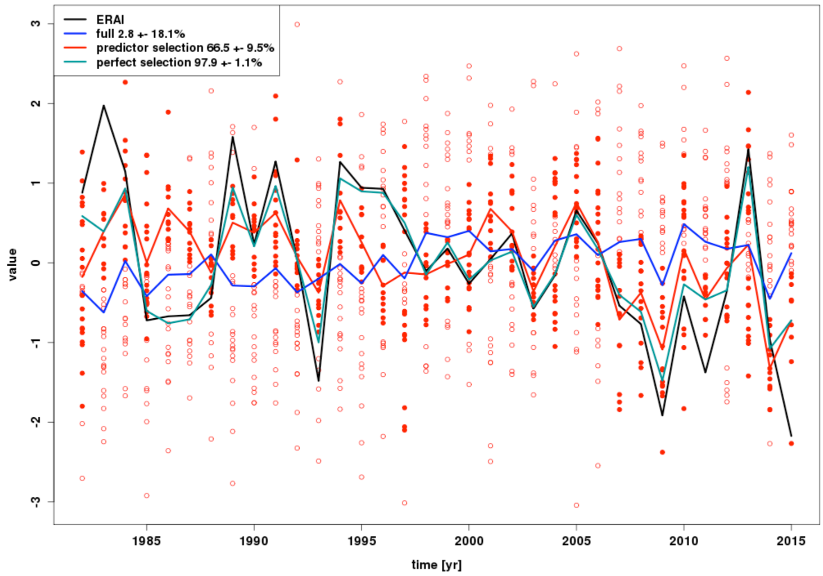

Figure 3: Seasonal prediction of the SNAO index. ERA interim value as a reference in black, the full ensemble mean in blue, our subsampled ensemble mean in red and a perfect selection mean basing on knowing the SNAO index in advance in cyan. Numbers in the legend give the correlation and its uncertainty by a bootstrapping with 10,000 iterations. Red circles give the values of each ensemble member, while the filled red circles show the selected ensemble members by our subsampling algorithm.

4. Long assimilation experiment (1900 – 2010) - status

A new experiment for decadal predictions using the MPI-ESM-LR (ECHAM6, MPIOM) at T63 resolution and 47 vertical levels in the atmosphere, and an average horizontal resolution of 1.5° with 40 vertical levels in the ocean is currently prepared. Two ensembles of assimilation experiments of 7 members each were conducted, using full field nudging of vorticity, divergence, pressure, and temperature in one ensemble (i1) and surface pressure nudging in the other (i2). The parameters for nudging are taken from ECMWF's ERA20C atmospheric reanalysis, covering the time from 1900 to 2010. Atmospheric and most ocean parameters seem reasonable for both i1 and i2, while particularly upper-ocean temperature and the AMOC seem to develop a drift in i2. A deeper analysis of both assimilation experiments is currently ongoing.

Recent articles based on previous use CPUtime allocated to the present project

Baehr, J.; Fröhlich, K.; Botzet, M.; Domeisen, D.I.V.; Kornblueh, L.; Notz, D.; Piontek, R.; Pohlmann, H.; Tietsche, S.; Müller, W.A.. "The prediction of surface temperature in the new seasonal prediction system based on the MPI-ESM coupled climate model". *Climate Dynamics* 44 (9-10). (2015): S. 2723-2735. doi: 10.1007/s00382-014-2399-7

Bunzel, F.; Notz, D.; Baehr, J.; Müller, W.A.; Fröhlich, K.. "Seasonal climate forecasts significantly affected by observational uncertainty of Arctic sea ice concentration". *Geophysical Research Letters* 43 (2). (2016): S. 852-859. doi: 10.1002/2015GL066928

Butler, A.H.; Arribas, A.; Athanassiadou, M.; Baehr, J.; Calvo, N.; Charlton-Perez, A.; Déqué, M.; Domeisen, D.I.V.; Fröhlich, K.; Hendon, H.; Imada, Y.; Ishii, M.; Iza, M.; Karpechko, A.Y.; Kumar, A.; MacLachlan, C.; Merryfield, W.J.; Müller, W.A.; O'Neill, A.; Scaife, A.A.; Scinocca, J.; Sigmond, M.; Stockdale, T.N.; Yasuda, T.. "The Climate-system Historical Forecast Project: do stratosphere-resolving models make better seasonal climate predictions in boreal winter?". *Quarterly Journal of the Royal Meteorological Society* 142 (696). (2016): S. 1413-1427. doi: 10.1002/qj.2743

Domeisen, D.I.V.; Butler, A.H.; Fröhlich, K.; Bittner, M.; Müller, W.A.; Baehr, J.. "Seasonal Predictability over Europe Arising from El Niño and Stratospheric Variability in the MPI-ESM Seasonal Prediction System ". *Journal of Climate* 28. (2015): S. 256-271. doi: 10.1175/JCLI-D-14-00207.1

References

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Hagemann, S., and T. Stacke (2015), Impact of the soil hydrology scheme on simulated soil moisture memory, Climate Dynamics, 44 (7-8), 1731–1750.

Raddatz, T., C. Reick, W. Knorr, J. Kattge, E. Roeckner, R. Schnur, K.-G. Schnitzler, P. Wetzel, and J. Jungclaus (2007), Will the tropical land biosphere dominate the climate–carbon cycle feedback during the twenty-first century?, Climate Dynamics, 29 (6), 565–574.

Stevens, B., M. Giorgetta, M. Esch, T. Mauritsen, T. Crueger, S. Rast, M. Salzmann, H. Schmidt, J. Bader, K. Block, et al. (2013), Atmospheric component of the MPI-M Earth System Model: ECHAM6, Journal of Advances in Modeling Earth Systems, 5 (2), 146–172.