REQUEST FOR A SPECIAL PROJECT 2017–2019

MEMBER STATE: United Kindgdom

Principal Investigator[1]: Dr. Antje Weisheimer

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Other researchers:

Dr. Patrick Laloyaux (ECMWF)

Project Title:

Coupled seasonal forecasts of the 20th Century (CSF-20C)

If this is a continuation of an existing project, please state the computer project account assigned previously.	**SP** __________________	
Starting year: (Each project will have a well-defined duration, up to a maximum of 3 years, agreed at the beginning of the project.)	2017	
Would you accept support for 1 year only, if necessary?	YES ☐x	NO ☐

Computer resources required for 2017-2019: (To make changes to an existing project please submit an amended version of the original form.)		**2017**	**2018**	**2019**
High Performance Computing Facility	(SBU)	26 200 000	26 200 000	
Accumulated data storage (total archive volume)[2]	(GB)	24 000	24 000	

***An electronic copy of this form must be sent via e-mail to**:* *special_projects@ecmwf.int*

Electronic copy of the form sent on (please specify date):

23 June 2016

Continue overleaf

[1] The Principal Investigator will act as contact person for this Special Project and, in particular, will be asked to register the project, provide an annual progress report of the project's activities, etc.

[2] If e.g. you archive x GB in year one and y GB in year two and don't delete anything you need to request x + y GB for the second project year.

Principal Investigator: Dr. Antje Weisheimer

Project Title: Coupled seasonal hindcasts of the 20th Century

Extended abstract

It is expected that Special Projects requesting large amounts of computing resources (1,000,000 SBU or more) should provide a more detailed abstract/project description (3-5 pages) including a scientific plan, a justification of the computer resources requested and the technical characteristics of the code to be used. The Scientific Advisory Committee and the Technical Advisory Committee review the scientific and technical aspects of each Special Project application. The review process takes into account the resources available, the quality of the scientific and technical proposals, the use of ECMWF software and data infrastructure, and their relevance to ECMWF's objectives. - Descriptions of all accepted projects will be published on the ECMWF website.

Motivation

Forecasts of seasonal-mean anomalies of the climate using physically based circulation models are now routinely made at many operational meteorological forecast centres around the world. Such seasonal predictions provide estimates of seasonal-mean statistics of weather, typically up to four months ahead. The physical basis for extended-range predictions originates from slow variations in the lower boundary forcing of the atmosphere due to the dynamics of the oceans and the hydrology of the land masses, and from large-scale components of the atmospheric general circulation with an intrinsic predictability time beyond that of individual synoptic weather systems, including the stratosphere.

The dominant mode of interannual variability of the coupled atmosphere-ocean system, the El Niño Southern Oscillation (ENSO), is a source of considerable seasonal predictability of the large-scale atmosphere in the tropics and, through global teleconnection patterns to a lesser degree also elsewhere in the world. Predicting the extra-tropical weather and climate is more difficult because atmospheric and oceanic instabilities and nonlinearities result in increased levels of variability compared to the tropics. On the other hand, a large component of extra-tropical predictability is of tropical origin with circulation patterns in the tropics influencing the extra-tropical circulation through teleconnections induced by Rossby wave dynamics.

The exact extent to which these links between the tropics and the extra-tropics translate into useful forecast information in seasonal predictions, however, remains an active area of research. In particular, the question of whether the North Atlantic Oscillation (NAO) and associated climate anomalies over the North Atlantic-European area during winter can be predicted with any confidence is still a matter of on-going scientific debate. *Shi et al. (2015)* reported that the skill of predicting the NAO in retrospective forecast experiments of past years (also referred to as re-forecasts or hindcasts) with 8 seasonal forecast models varies considerably within the last four decades. They found significant skill in predicting the interannual fluctuations in the atmospheric flow for some 20-year sub-periods but in general not for the longer hindcast periods of 42 years from 1960 onwards. A recent study by *Scaife et al. (2014)* reports high predictability of the NAO in the latest UK Met Office seasonal forecasting system over a recent 20-year period. However, the relatively short length of this hindcast set raised concerns over the robustness of the skill estimates for longer forecast periods. An important open question with implication for future skill estimates is whether this model would also be able to skilfully predict the NAO in earlier decades where the models analysed by *Shi et al. (2015)* struggled the most.

In order to address these questions, we propose for this project to perform long retrospective seasonal forecast experiments for all boreal winter and summer seasons during the period 1901 to 2009. We will be using CERA-20C, ECMWF's new coupled reanalysis of the 20th Century, for the initialisation of the coupled model and verification. Such reanalysis dataset is crucial to compute long hindcast periods and sample the different NAO phases.

Earlier results

In a previous Special Project (Seasonal forecasts of the 20th Century: Reliability, attribution and the impact of stochastic perturbations) the PI has already performed seasonal hindcasts of the 20th Century using ECMWF's atmosphere-only model in seasonal hindcast mode with prescribed SSTs for the lower boundary conditions, called ASF-20C (Atmospheric Seasonal Forecasts of the 20th Century). At that time ERA-20C, ECMWF's atmospheric reanalysis of the 20th Century had been used to initialise and verify the hindcasts. The simulations run smoothly and all data were archived in MARS. The data set offers a wide range of opportunities to study seasonal predictability including forecasts of the European climate, global teleconnections and hydrological applications. The large ensemble size of 51 ensemble members enabled the probabilistic analysis of the forecasts for extreme events that have a relatively small probability to occur. First results of these atmospheric seasonal hindcasts were recently written up and submitted for publication (Weisheimer et al., 2016).

In *Weisheimer et al. (2016)* it was found that the seasonal forecasts show significant positive seasonal correlation skill of the winter NAO over the entire forecast period. However, the predictive skill exhibits distinct multi-decadal variability: periods of significant skill occur in the earlier parts of the 20th Century and during recent decades, while the mid-century period is characterised by intrinsically lower levels of forecast skill and weakly negative values of the NAO (see Fig 1). These mid-century decades stand out as an important period on which to test the performance of future seasonal forecast systems. The analysis showed that probabilistic forecast for winters with a NAO in a strongly negative phase or in positive phases are highly skilful. However, the model does not perform as well for weakly negative phases, for reasons not yet fully understood. It was further proposed and demonstrated how seasonal forecast reliability can be of importance for increasing confidence in statements of extreme weather and climate event attribution to anthropogenic climate change.

In the proposed project here we plan to build on the success of these previous simulations and extend them with a fully coupled ocean-atmosphere forecast model. CERA-20C provides the initial conditions for both the atmosphere and the ocean and will thus be a central part of the project.

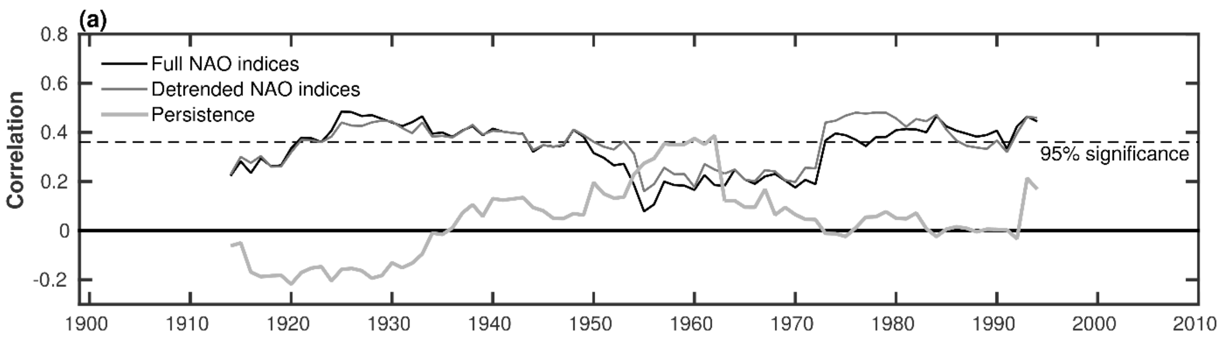

Figure 1: Anomaly correlation coefficient of the DJF NAO index between the ensemble mean seasonal hindcasts and ERA-20C (black) over the period 1900 to 2009 computed for moving 30-year windows by one year. Values are plotted at the 15th year of each window. The dashed horizontal line indicates the *t*-test 95% significance level of the correlation. From *Weisheimer et al. (2016).*

CERA

ECMWF has completed the production of a new global 20th-century reanalysis, reconstructing the Earth's past weather from historical observations (*Laloyaux, 2016*). This reanalysis, called CERA-20C, is based on a coupled atmosphere–ocean data assimilation system developed over the last few years in the Research Department (*Laloyaux et al., 2016*). Twentieth-century reanalyses provide a long record of low-frequency climate variability and change using a consistent set of observations. In the CERA-20C reanalysis, different datasets are used to constrain the atmospheric and ocean components of the Earth system (mean sea-level pressure and surface marine wind from ISPDv3.2.6 and ICOADSv2.5, as well as subsurface temperature and salinity profiles from the EN4 dataset). The air–sea interface is constrained by the HADISST2 sea surface temperature monthly product.

In CERA-20C, the evolution of the global weather for the period 1901–2010 is represented by a ten-member ensemble of 3-hourly estimates for ocean, surface and upper-air parameters. The ensemble technique takes into account inevitable uncertainties in the observational record and the forecast model to provide an indication of the analysis confidence. These ten different realisations will be used to initialise the 51 members of the ensemble seasonal hindcasts.

Some preliminary results showed that the analysis produce by the CERA system has a better balanced atmosphere-ocean state with more consistent fluxes at the air-sea interface. In the context of medium-range weather forecasting, preliminary results showed the potential of the CERA analysis to reduce initial shocks and to improve forecast skill score compared to the separate initialisation currently used in operations (*Mulholland et al., 2016*). This project achieves a considerable expansion of scope assessing the benefits of a coupled analysis on the seasonal predictability over the 20-th century.

Scientific plan

For this project we plan to carry out the following steps:

1. Hindcast experiments over the period 1981-2010 using CERA-20C for the atmosphere and ocean initialisation.
2. These simulations will be carefully compared with existing hindcasts that utilised ERA-Interim and ORA-S4 as initial conditions and with atmospheric seasonal hindcasts using ERA-20C from a previous project.
3. Once we are confident that the CERA-20C coupled initialisation gives satisfying results, hindcasts for CSF-20C over the entire period 1901 to 2010 will be performed.
4. Analysis of these runs and comparison with previous atmosphere-only simulations.

During the first project year, we plan to run the hindcast experiments for the period 1981-2010 for November start dates only (see point 1. above). If these simulations perform as expected, we will move on to run simulations for the entire 20th Century period 1901-2010 for 1st November start dates first and 1st May start dates thereafter. All hindcasts will be 4-month long so that they cover the standard meteorological boreal winter (December to February) and summer (June to August) seasons. In order to be able to perform a probabilistic evaluation of the seasonal hindcasts, and in particularly with the view on extreme and high impact events, it is proposed to run ensemble simulations with 30 perturbed ensemble members each. This means a reduction of the ensemble size compared to the uncoupled seasonal hindcasts of the 20th Century (ASF-20C) which had 50 ensemble members each.

During the second project year, it is planned to run all the hindcasts from 1901-2010 for start dates on 1st February and 1st August to cover the spring (March to May) and autumn (September to November) seasons as well.

Model version to be used

We propose to use the coupled ECMWF model for the seasonal hindcasts. The atmospheric part of IFS will be run in Cycle 41r1 and resolution T_L255L91 which is similar to the model version of the uncoupled long seasonal hindcasts generated before and thus allows a fair comparison. The NEMO version that will be used is the default version 3.4 be run with a 1° horizontal resolution and 42 vertical model levels. This coupled configuration has been well tested and control experiments for the DJF and JJA seasons over the period 1981-2010 already exist.

Estimated computer resources

For the proposed model configuration the anticipated costs in terms of SBUs are as following:

1 forecast month with 1 ensemble member and 1 start year: ca. 990 SBU

4 forecast months with 1 ensemble member and 1 start year: ca. 3960 SBU

4 forecast months with 1 ensemble member and 110 start dates (1901-2010): ca. 435 600 SBU

4 forecast months with 30 ensemble member2 and 110 start dates (1901-2010): ca. 13 068 000 SBU

The resulting costs for our proposed experiments summarise as following:

2017:

- November start dates 1901-2010: 13 068 000 SBU
- May start dates 1901-2010: 13 068 000 SBU
- Sum: 26 136 000 SBU

2018:

- February start dates 1901-2010: 13 068 000 SBU
- August start dates 1901-2010: 13 068 000 SBU
- Sum: 26 136 000 SBU

These numbers rely on initial testing on the Broadwell nodes on CCA.

References

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