REQUEST FOR A SPECIAL PROJECT 2015–2017

MEMBER STATE: United Kingdom

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Project Title:

Seasonal forecasts of the 20th Century: Reliability, attribution and the impact of stochastic perturbations

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.)		
Would you accept support for 1 year only, if necessary?	YES ☒	NO ☐

Computer resources required for 2015-2017: (The maximum project duration is 3 years, therefore a continuation project cannot request resources for 2017.)	**2015**	**2016**	**2017**
High Performance Computing Facility (units)	25 000 000	25 000 000	
Data storage capacity (total archive volume) (gigabytes)	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):

25 June 2014

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.

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Extended abstract

It is expected that Special Projects requesting large amounts of computing resources (500,000 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.

Project description

Our proposal consists of performing an extended seasonal re-forecast set and sensitivity experiments covering the entire 20th Century to address questions about i) the reliability of seasonal forecasts relevant for extreme weather and climate event attribution, and about ii) the impact of stochastic perturbations on the model performance.

Climate change is expected to impact extreme weather in Europe. While there have always been extreme weather events such as heat waves, floods and droughts without any human-induced changes of the atmospheric greenhouse gas concentration, climate model results indicate that a warming atmosphere will bring an increased frequency and magnitude of high temperature extremes and heavy precipitation (*Seneviratne et al., 2012*).

Extreme weather events are associated with both natural and anthropogenic effects. It is hard to imagine many cases in which it would be possible to state definitely that any particular extreme event could not have happened without human-induced climate change (*Stott et al., 2004*). Over the last decade attribution science has progressed to the point that it is now possible to make attribution statements about individual events. The approach taken is to quantify the changed probability of a particular event attributable to human or natural factors by making two ensemble of simulations of atmosphere-only climate models: one ensemble is run with observed SSTs and current atmospheric gas concentrations while the second ensemble is run with pre-industrial atmospheric concentration and observed SSTs from which greenhouse gas induced warming has been removed (*Pall et al., 2011; Stott and Walton, 2013*). In a non-stationary climate the calculation of these probability distributions requires climate models with an adequate representation of climate variability to estimate the systematic change in climate attributable to natural and anthropogenic factors (*Christidis et al., 2012*).

However, scientifically robust information about the extent to which recent extreme weather can be linked to climate variability and change is often lacking. The EU FP7-funded project EUCLEIA (EUropean CLimate and weather Events: Interpretation and Attribution), led by Peter Stott at the UK Met Office, aims at providing well verified assessments of the extent to which such weather-related risks have changed due to human influences on climate, and at identifying those types of weather events where the science is still too uncertain to make a robust assessment of attributable risk. Our group at the University of Oxford is part of the EUCLEIA consortium and contributes to the development and evaluation/diagnostics of attribution methodologies.

Event attribution relies on the model's ability to reliably simulate the climate conditions generating the extreme weather event. A key aspect is the ability of the models to represent the processes involved and thereby correctly quantify the risk. Here we plan to use measures developed in seasonal forecasting for assessing the reliability of certain weather and climate events (e.g. *Weisheimer and Palmer, 2014*). Reliability describes how well, in a statistical sense, a probabilistic forecasting system is in agreement with the observed frequency of an event given certain forecast probabilities. Reliability is an essential criterion for the usefulness of the forecasts in real-life decision making: forecasts need to be reliable as otherwise they will mislead users which can result in bad decisions to be taken. The statistical assessment of reliability is limited by the amount of past seasonal forecast data, which is usually not more than 30 years of data.

The re-forecast (hindcasts) of ECMWF's operational fully coupled seasonal forecasting System 4 cover the 30-year period 1981-2010 over which a full verification in terms of reliability diagrams for warm/cold and wet/dry seasonal forecast anomalies has been performed (*Weisheimer and Palmer, 2014*). The simulations we would like to carry out in the proposed special project involve, on the one hand, a much longer period of seasonal hindcasts than the 30-year period mentioned above but, on the other hand, performed not with the fully coupled ocean-atmosphere system as in System 4 but with the uncoupled atmosphere-only system of the IFS prescribing observed SSTs as a lower boundary condition for the atmosphere. Such a set-up is currently being run by Tim Stockdale in the Ensemble Prediction Section at ECMWF in conjunction to the operational coupled seasonal forecasts. A hindcast data set for the uncoupled seasonal forecasts already exists for the 1981-2010 period and the real-time coupled forecasts are complemented by these retrospect observed SST runs to inform us about the impact of the ocean on atmospheric predictability.

We plan to carry out seasonal re-forecasts for the period from 1900 to 2012 which is the period for which atmospheric and SST data are available through the ERA-20C reanalysis. ERA-20C is ECMWF's first atmospheric reanalysis of the 20th Century by assimilating observations of surface pressure and surface marine winds only. The atmospheric data of ERA-20C will be used to initialize the seasonal re-forecasts over the 20th Century and also to verify and evaluate the re-forecasts. This will provide us with the unique situation of having a seasonal hindcast data set covering 110 years which brings us well beyond the commonly used hindcast period length.

This very long hindcast set will enable us to estimate the statistical reliability of seasonal forecasts with greater confidence. It also offers the possibility to analyse the effect of internal decadal variability of forecast skill which is something that by definition cannot be done with much shorter forecast data sets. We will also study and compare the reliability of these SST-driven atmospheric predictions for different sub-periods where the early part of the 20th century will be used as a proxy for conditions where the anthropogenic influence on the climate was still small compared to later periods in the 20th Century.

In the second part of our proposed project, the 20th Century seasonal hindcasts will be used to study the impact of stochastic perturbations in the atmosphere on the climate of the model. The IFS contains two schemes to account for model error: the Stochastically Perturbed Physical Tendency (SPPT) and Stochastically Perturbed BackScatter (SPBS) schemes. Recent analysis by *Dawson and Palmer (2014)* and *Weisheimer et al. (2014)* suggest that stochastic perturbations in either AMIP-type long atmosphere only integrations or in the operational coupled seasonal forecasts modify not only the variability and spread of the system, but also lead to changes in the mean state of the system and noise-induced regime transitions.

Here we plan to further investigate the impact of stochastic parameterisation on the simulated climate by comparing climatological statistics of seasonal forecasts made with and without stochastic parameterisation, in order to better understand the effects of including it in seasonal forecast and climate models. The length of this dataset would allow important effects to be detected that are difficult to identify in hindcasts over a shorter period.

The aspects of climate that we will investigate include:

- Variability about the mean state and the frequency of extreme events in variables such as temperature and precipitation.
- Time scales of variability, such as of the annular modes, which are generally overestimated by models used in climate projections (e.g. *Gerber et al., 2008*).
- The frequency of meteorological events such as blocking. At resolutions typical of seasonal forecast and climate models, the climatological frequency of Euro-Atlantic blocking is underestimated (*Jung et al., 2012*), and it is of interest to determine whether stochastic parameterisation improves this.
- Further analysis of regime behaviour, for example to determine whether stochastic parameterisation improves simulations of "jet regimes" identified by *Woollings et al. (2010).*

While the simulation with stochastic physics will be the same one as described in the first part of the project (seasonal hindcasts for the 20th Century), the control simulation without stochastic physics will be run in a similar configuration but with only 2 ensemble members.

We propose several additional sensitivity experiments to test what might cause the effect of stochastic parameterisation, performed over the winter season:

A. Runs with random noise included in the model that is unrelated to the physics parameterisation output, to test if this produces similar effects to stochastic parameterisation. This would help to indicate whether the effects depend much on the way in which stochastic parameterisation is implemented.
B. Runs with SPPT only and a set with SPBS only included to test the impact of each scheme separately.
C. Runs at T159 resolution with both SPPT and SPBS, to see if the effect of stochastic parameterisation is more beneficial at lower resolutions, as found by *Dawson and Palmer (2014).*

Technical requirements

It is planned to perform these seasonal hindcasts in the same configuration as Tim Stockdale's current parallel suite to System 4. This will mean running the IFS atmospheric model in CY36R4 at a horizontal resolution T255 with 91 vertical levels. The proposed size of the ensemble is 51 members in accordance with both the operational forecast and System 4 hindcast ensemble size. Forecasts with a lead time of 4 months will be started every 1st of Feb/May/Aug/Nov so that they cover the main meteorological seasons.

The required resources for the proposed experimentation are estimated as follows:

Costs for one individual run over one month:

- approx. 405 SBU (courtesy Tim Stockdale)

Total costs for 4 forecast months * 4 start dates per year * 110 hindcast years * 51 ensemble members:

- approx. 36 353 000 SBUs

Total costs for stochastic physics control simulation of 4 forecast months * 4 start dates per year * 110 hindcast years * 2 ensemble members:

- approx. 1 500 000 SBUs

Costs of sensitivity experiments:

A. 4 forecast months * 4 start dates per year * 110 hindcast years * 2 ensemble members = approx. 1 500 000 SBUs
B. Two experiments each with 4 forecast months * 2 start dates per year * 110 hindcast years * 2 ensemble members = approx. 1 500 000 SBUs
C. Two T159 experiments each with 4 forecast months * 2 start dates per year * 110 hindcast years * 2 ensemble members = approx. 800 000 SBUs

All the above estimates are based on running simulations on the c2a IBM supercomputer. While the new CRAY is still in its testing phase, it is anticipated that the SBU costs for the experiments are higher by approx. 20%. Thus, an overall additional 20% have been taken into account for the total resources asked for.

We propose to run in the first year of the project two start dates (May and Nov) of the long seasonal hindcasts, control and sensitivity experiment A plus one start date for the experiments B and C. The remaining start dates for all experiments are planned to be carried out during the second year of the project.

We collaborate with Tim Stockdale from the Seasonal Forecasting team in the Ensemble Prediction Section of ECMWF for this project and will be working with him to modify the current model set up so that it can use ERA-20C as initalisation.

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