REQUEST FOR A SPECIAL PROJECT 2024–2026

MEMBER STATE: Denmark ……………………………………………………………………………………

Principal Investigator[1]: Annika DREWS ………………………………………………………………………………

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Project Title: A new decadal prediction system based on EC-Earth3

To make changes to an existing project please submit an amended version of the original form.)

If this is a continuation of an existing project, please state the computer project account assigned previously.	**SP** ………….	
Starting year: (A project can have a duration of up to 3 years, agreed at the beginning of the project.)	2024	
Would you accept support for 1 year only, if necessary?	YES ☒	NO ☐

Computer resources required for project year:		**2024**	**2025**	**2026**
High Performance Computing Facility	[SBU]	16 800 000	14 880 000	---
Accumulated data storage (total archive volume)[2]	[GB]	25 000	40 000	---

EWC resources required for project year:		**2024**	**2025**	**2026**
Number of vCPUs	[#]			
Total memory	[GB]			
Storage	[GB]			
Number of vGPUs[3]	[#]			

[1] The Principal Investigator will act as contact person for this Special Project and, in particular, will be asked to register the project, provide annual progress reports of the project's activities, etc.
[2] These figures refer to data archived in ECFS and MARS. 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 etc.
[3]The number of vGPU is referred to the equivalent number of virtualized vGPUs with 8GB memory.

Continue overleaf.

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Extended abstract

All Special Project requests should provide an abstract/project description including a scientific plan, a justification of the computer resources requested and the technical characteristics of the code to be used. The completed form should be submitted/uploaded at https://www.ecmwf.int/en/research/special-projects/special-project-application/special-project-request-submission.

Following submission by the relevant Member State the Special Project requests will be published on the ECMWF website and evaluated by ECMWF and its Scientific Advisory Committee. The requests are evaluated based on their scientific and technical quality, and the justification of the resources requested. Previous Special Project reports and the use of ECMWF software and data infrastructure will also be considered in the evaluation process.

Requests exceeding 5,000,000 SBU should be more detailed (3-5 pages).

Decadal climate prediction

Decadal climate prediction is a topic of growing interest and societal importance. By taking into account both the climate evolution due to external forcing such as greenhouse gases as well as the state of internal multi-annual variability, decadal prediction systems are modelling the climate up to a decade ahead with a more comprehensive approach than projection runs. Evaluating the skill of decadal climate prediction systems has also been the focus of the coordinated efforts of the Decadal Climate Prediction Project (DCPP) by the WCRP (Boer et al. 2016).

The newest predictions are also collected by the World Meteorological Organization (WMO) and published online: https://hadleyserver.metoffice.gov.uk/wmolc/

While current decadal prediction systems exhibit some skill, they also still suffer from deficits. For example, several recent studies show that the decadal prediction skill comes largely from the anthropogenic and natural forcings in the historical period (Bilbao et al., 2021, Borchert et al., 2021a, 2021b), and there is only limited improvement of predictions on annual to decadal time scales from initialization in comparison with uninitialized historical simulations (e.g., Borchert et al., 2021a). One key issue is the representation of the state of the AMOC, which has been shown to be difficult and very sensitive to subsurface assimilation procedures (Balmaseda et al. 2013; Karspeck et al. 2017).

Thus there is a need for advanced initialization methods that can better synchronize the model and the observed state of the climate (e.g., atmosphere, ocean and sea ice) than methods currently applied in climate predictions such as the simple anomaly initialization method in the EC-Earth3 climate prediction system (Tian et al., 2021). We are therefore proposing a new decadal prediction system based on EC-Earth3, which is initialized with a “spun-up” ocean, avoiding assimilation of subsurface quantities.

New approach

In this new approach the ocean is forced by observed variables at the surface only (planned here: surface pressure and sea surface temperatures) in order to “push” the ocean into a more realistic circulation regime. Surface pressure will be used from ERA5 with a time step of 6 hours, and daily sea surface temperatures will be taken from HadISST. These surface variables are assimilated with a proper spin-up time (e.g., 5 years). The exact length of the spin-up will be tested in the first phase of the project to allow the oceanic circulation has fully adjusted. The assimilation will start every year from existing historical simulation(s) to generate a set of initial states. The predictions can then be started from these initial states; hereafter the model runs freely. We hypothesize that this assimilation procedure may provide initial conditions that are in better balance between the model dynamics and observed state of climate, so that it has the potential to improve the prediction skill.

While this assimilation technique has been used previously (e.g., Reintges et al. 2020; Dai et al. 2020), many of the studies have been a proof of concept and only very few prediction system have yet been developed on this basis (Thoma et al. 2015; Yang et al. 2021). We therefore propose here to develop a new generation of a decadal prediction system based on the European Earth System Model EC-Earth3 (Döscher et al., 2022).

Experimental design

Our new decadal prediction system will be based on EC-Earth3 including IFS cy36r3 and NEMO 3.6 in their standard configurations: IFS with T255 and 91 vertical levels, NEMO on the ORCA1 grid (1° resolution) and 75 vertical levels.

As a prerequisite, we will run some simulations with assimilation to investigate the model’s behaviour when this additional constraint is included and how quickly and well the ocean adjusts.

Our predictions including the spin-up/assimilation period will be run in ensemble mode to be able to distinguish the predictable signal from internal variability. We plan to run five members on the Atos HPC with the possibility to enlarge the ensemble on DMI’s HPC in Iceland (UWC-W).

As a first step for the predictions, we will assimilate atmospheric variables (planned: surface pressure) and SSTs for five years to achieve an ocean state that is drawn close(r) to reality. This needs to be done for each of the five members separately.

Then, after the end of this spin-up period, the ocean fields will be used as initial states for the prediction runs that run freely after initialization. Again, this ensemble will contain five members.

To evaluate the performance or the new prediction system, we will run retrospective forecasts ("hindcasts") starting from 1990, initializing one ensemble once a year, to 2020 as the last start year, and each of the prediction ensembles will run for 5 years (with the potential to be extended at some point in the future).

From experience of other EC-Earth3 users on Atos, we estimate that we need 19 200 SBUs per model year. The specific numbers are given in Table 1 below.

Exp. name	Description	SBU/year	Total years	Total SBU	Year 1	Year 2
Testing	Testing the setup and model behaviour incl. buffer	19200	100	1 920 000	1 920 000	0
Assimilation	Coupled assimilation runs to synchronize ocean surface with proper spin up time to generate set of initial states for prediction runs	19200	5 mem. x 5 years x 31 start years = 775	14 880 000	7 440 000	7 440 000
Hindcast	Prediction runs starting from assimilation	19200	5x5x31 = 775	14 880 000	7 440 000	7 440 000
TOTAL			1650	31 680 000	16 800 000	14 880 000
TOTAL storage 45 GB / year (with clean-up underway)			40 000 GB		30 000 GB	40 000 GB

Table 1: Estimated resources needed for our experiments.

References

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