REQUEST FOR A SPECIAL PROJECT 2026–2028

MEMBER STATE:	Denmark
Principal Investigator[1]:	Tian TIAN
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Project Title:	A new decadal climate prediction system: multi-ensemble production with EC-Earth3 and upgrade to EC-Earth4

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.)	2026	
Would you accept support for 1 year only, if necessary?	YES ☒	NO ☐

Computer resources required for project year:		**2026**	**2027**	**2028**
High Performance Computing Facility	[SBU]	37,44M	37,44M	31,8M
Accumulated data storage (total archive volume)[2]	[GB]	15,600	31,200	44,400

EWC resources required for project year:		**2026**	**2027**	**2028**
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.

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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 growing area of scientific and societal relevance. Unlike traditional climate projections, which primarily respond to external forcings (e.g., greenhouse gases and aerosols), decadal predictions also account for the initial state of internal climate variability, offering a more comprehensive outlook for the climate system over the next one to ten years (Smith et al., 2019; Meehl et al., 2021). These predictions are central to international efforts such as the Decadal Climate Prediction Project (DCPP) under the World Climate Research Programme (WCRP), which coordinates model evaluations and intercomparisons (Boer et al., 2016; Yeager et al., 2022).

Operational frameworks like the WMO's Global Annual to Decadal Climate Update (Hermanson et al., 2022) demonstrate that skillful predictions are achievable at the 1–5 year timescale, particularly for surface temperature and large-scale circulation patterns. However, their skill depends heavily on accurate initialization and representation of key processes (e.g., ocean heat uptake, AMOC variability), which remain challenging in current systems. For instance, the Atlantic Meridional Overturning Circulation (AMOC), a crucial driver of decadal climate variability, is highly sensitive to ocean initialization techniques (Balmaseda et al., 2013; Karspeck, et al., 2017). Many systems, including EC-Earth3, rely on simplified approaches (e.g., anomaly correction), which may inadequately capture observed subsurface states (Tian et al., 2021; Polkova et al., 2023).

To address these gaps, we have developed a new decadal prediction system based on EC-Earth3 in the previous Special Project (SPDKDREW, 2024-2025). Here we propose to produce a multi-ensemble set of forecasts with this system, specifically targeting improved prediction skill for the 1-5 year range - a critical timescale for adaptation planning. By initializing with a dynamically "spun-up" ocean (avoiding ad hoc subsurface assimilation), our system aims to better synchronize the model with observed climate states, particularly for AMOC and ocean heat content. This approach builds on the WMO's demonstrated success in shorter-term decadal forecasts (Hermanson et al., 2022) while addressing known initialization deficits (Polkova et al., 2023).

New decadal prediction system based on EC-Earth3

In the previous SPDKDREW (2024–2025), we developed and tested the new decadal prediction system using the EC-Earth3 model (Döscher et al., 2022), implementing a novel surface-only assimilation approach under the framework of atmosphere-ocean coupled initialization. Unlike traditional methods that directly assimilate subsurface ocean variables—potentially introducing imbalances—the system nudges the ocean toward observed states using 6-hourly ERA5 surface pressure and daily HadISST sea surface temperatures during a multi-year spin-up period (typically 5–10 years). This method allows the ocean circulation to dynamically adjust to surface forcing, generating physically consistent initial conditions for decadal forecasts.

For each prediction year, ocean fields from the end of the spin-up phase serve as the initial conditions, after which the forecasts proceed as free-running simulations without additional data assimilation. This approach avoids direct interference with the model's interior ocean dynamics, which may help preserve physical consistency and improve multi-year predictive skill.

During the development phase, the system was tested using hindcasts for selected years between 1990 and 2020—chosen to represent different climate states (e.g., warm or cold years)—to evaluate its feasibility and initialization performance. Preliminary comparisons with existing systems (e.g., Tian et al., 2021) focused on prediction skill metrics, particularly for ocean circulation patterns like the AMOC, which are sensitive to initialization methods. By the end of SPDKDREW (i.e. December 2025), the optimal spin-up duration will be selected based on its computational feasibility, its effectiveness in avoiding drifts from subsurface assimilation, and its ability to generate balanced initial conditions.

Multi-ensemble production plan with EC-Earth3 (2026-2027)

This Special Project proposal for 2026–2028 builds directly on SPDKDREW (2024–2025). In this continuation phase, we aim to transition from system development to full production of retrospective decadal hindcasts and near-real-time forecasts, in alignment with the updated CMIP7-DCPP protocol. Using an operationally ready system, we will generate multi-member ensemble decadal predictions.

As part of a coordinated effort involving four climate prediction centers—BSC, DMI, NERSC, and MPI—all of which are developing new initialized prediction systems, we will implement the newly agreed minimal DCPP multi-annual experiment. This experiment focuses on 28-month hindcasts using the new systems, in contrast to the conventional DCPP decadal setup, which involves forecasts initialized on 1 November and extends for 2 months plus 10 years.

However, we plan to extend the 28-month hindcasts to 1–5-year predictions, aligning with the timescale of the WMO's Global Annual to Decadal Climate Update. This extension could support upcoming WMO updates for the periods 2026–2030 and 2027–2031.

As SPDKDREW, the production run will use the 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.

Specifically, we will perform ensemble simulations in 2026 and 2027, covering the DCPP-A and DCPP-B components. These will include:

- A hindcast set spanning 1990–2025;
- Forecasts for 2026–2028 to support CMIP7 near-term prediction experiments;
- Initializations on 1 May and 1 November each year;
- Each simulation extending over 5 years;
- A total of 10 ensemble members per forecast

This production phase will generate key contributions to CMIP7 and WMO decadal outlooks, supporting both scientific assessments and the broader climate services community.

As a prerequisite, all prediction years from 1990 to 2025 must undergo spin-up for the same duration. For each year, the 1 May and 1 November initializations will share the same spin-up simulation to ensure consistency and computational efficiency. This will start from the on-going SPDKDREW (2024–2025) and will complete in early 2026. Potential additional resources for this transition will be required.

We request computing resources to support these production simulations, which will be carried out on ECMWF's Atos HPC. Each ensemble member requires approximately 19,200 SBU per simulated year. Based on the final configuration and ensemble design—2 start dates × 5 years × 10 members × 39 start years—we estimate a total need of 3,900 simulation years.

The model output will be CMORized and transferred to DMI's data server; however, **in case the DMI datanode for CMIP publication is not ready and the storage preparation is incomplete, we request to store the data on MARS or ECFS as a temporary solution.**

Upgrade to EC-Earth4 (2028)

EC-Earth4 is the next-generation Earth system model developed by the EC-Earth consortium to improve process understanding and support climate applications. It is based on OpenIFS and the latest NEMO4 ocean model. The first version includes OpenIFS cy43r3, NEMO 4.2, OASIS3-MCT 5.0, and XIOS 2.5. Preliminary tuning has been supported by the SPNLTUNE project. We are now upgrading to OpenIFS cy48r1 to align with ECMWF's operational model and benefit from recent developments. EC-Earth4 will be prepared for CMIP7 FastTrack and broader participation in CMIP7 MIPs and climate services.

The baseline resolution for EC-Earth4 in the FastTrack experiments is set to TL255L91 for the atmosphere and ORCA1 for the ocean. Since this aligns with the resolution adopted by EC-Earth3 under SPDKDREW, we intend to replicate the identical experiments using EC-Earth4. This endeavor will demand computing resources on a par with the previous setup, while requiring less storage—owing to our exclusive focus on CMORized data.

The specific numbers are summarized in Table 1 below.

Year	Experiment	SBU/year	Total years	Total SBU
2026	Hindcast (1990-2025)/forecast(2026-2027), 5 members	19200	1950	37,44M
2027	As in 2026, for an additional 5 members	19200	1950	37,44M
2028	Repeat SPDKDREW experiments with EC-Earth4	19200	1650	31,8M
Total SBU			5550	106,68M
Total storage 8 GB/year (with clean up underway)			5550	44,400GB

Table 1: Estimated resources needed for our experiments.

References

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