SPECIAL PROJECT PROGRESS REPORT

All the following mandatory information needs to be provided. The length should *reflect the complexity and duration* of the project.

Reporting year 2024

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

Computer Project Account: spdkdrew

Principal Investigator(s): Tian Tian

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Affiliation: Danish Meteorological Institute

Name of ECMWF scientist(s) collaborating to the project (if applicable) N/A

Start date of the project: Jan 1, 2024

Expected end date: Dec 31, 2025

Computer resources allocated/used for the current year and the previous one

(if applicable)
Please answer for all project resources

		Previous year		Current year	
		Allocated	Used	Allocated	Used
High Performance Computing Facility	(units)	0	0	16800000	7,954,218
Data storage capacity	(Gbytes)	0	0	25000	10,000

Summary of project objectives (10 lines max)

The project aims to develop an advanced decadal climate prediction system using the EC-Earth3 model under the framework of atmosphere-ocean coupled assimilation. By assimilating anomalies from ERA5 surface pressure and HadISST sea surface temperatures over 5-10 years, known as spin-up times, we aim to create realistic ocean states as initial conditions in subsequent free-running decadal climate hindcasts from 1990 to 2020. This approach will test different spin-up times, performing ensemble assimilations, and conduct hindcasts following the protocol of CMIP6 Decadal Climate Prediction Project (DCPP, Boer et al. 2016). The prediction skill will be evaluated and compared with the other prediction systems, in particular the previous system with the anomaly initialization (Tian et al, 2021). The approach seeks to achieve more realistic oceanic circulation and improve prediction skill by avoiding subsurface assimilation and enhancing the balance between model dynamics and observed climate states.

Summary of problems encountered (10 lines max)

We encountered a few problems, including

1) a need for a new historical simulation with version 3.3.4 as a reference to provide initial states for the assimilation spin-up and construct assimilation field (30-year modelled climatology + observation-based anomaly). To ensure a consistent comparison, the reference run and the assimilation run should be computed on the same platform. Additionally the version 3.3.4 has fixed a bug in surface restoring under sea ice for one NEMO subroutine sbcssr.F90, which was not used in the existing CMIP6 simulation (a free-run with version 3.3.1, Döscher et al., 2022), but it is crucial for the coupled assimilation experiments.
2) Issues with model compilations as well as adopting the qsub scripts to slurm scripts due to our new experiences with Atos HPC2020.
3) To manage data storage, we installed ece2cmor post-processing tools to cmorize a subset of model output and plan to clean up raw model outputs soon.

We received assistance from EC-Earth colleagues at KNMI and CNR, who has more experiences with Atos and sharing their scripts and materials to implement EC-Earth and cmorization.

Summary of plans for the continuation of the project (10 lines max)

Our final goal is to develop the next generation of decadal climate prediction and provide climate data from 1960 to 2035.

1) We are conducting a reference simulation using the CMIP6 historical forcing (1930-2014) and the ssp2-4.5 scenario (2015-2035) to establish a running 30-year climatology for generating initial states for the assimilation spin-up. This simulation and post-processing will be completed by June.

2) Next, we will perform spin-up tests with two different initial states but assimilating the same data to determine the optimal spin-up length for fully adjusted oceanic circulation. Different initial ocean states (cold vs. warm) will be investigated.

3) We will perform the initialized hindcasts from 1990-2020, with annual assimilation-initialization from the reference run. The planned simulation years will be (a few year of assimilation spin-up + 10 years of hindcast) x (5-10 members) x (30 start years).

List of publications/reports from the project with complete references

None so far.

Summary of results

Team and Documentation Efforts

At the beginning of this year, Shuting Yang, Rashed Mahmood, and Tian Tian began regular meetings to update and discuss the implementation plan for our project. An internal Confluence page was established (Figure 1) to step-by-step document the development of this coupled assimilation initialization approach. This includes the source code versions, model configuration files, compilation steps, and the procedures for pre- and post-processing necessary to run EC-Earth3. Additionally, we detailed the sources for reanalysis/observation data for coupled assimilation, methods for file transfers between Atos and DMI's data server, and the overall workflow organization.

Initial Conditions and Reference Runs

Utilizing this documentation, we systematically prepared the initial conditions generated from the reference run on Atos, starting from the year 1950. However, we identified the need for a 30-year climatology prior to 1960, prompting us to prepare new initial conditions for 1930 and rerun the reference simulation. This iterative process of learning-by-doing enabled us to refine our plan continually, documenting encountered problems and solutions to ensure reproducibility.

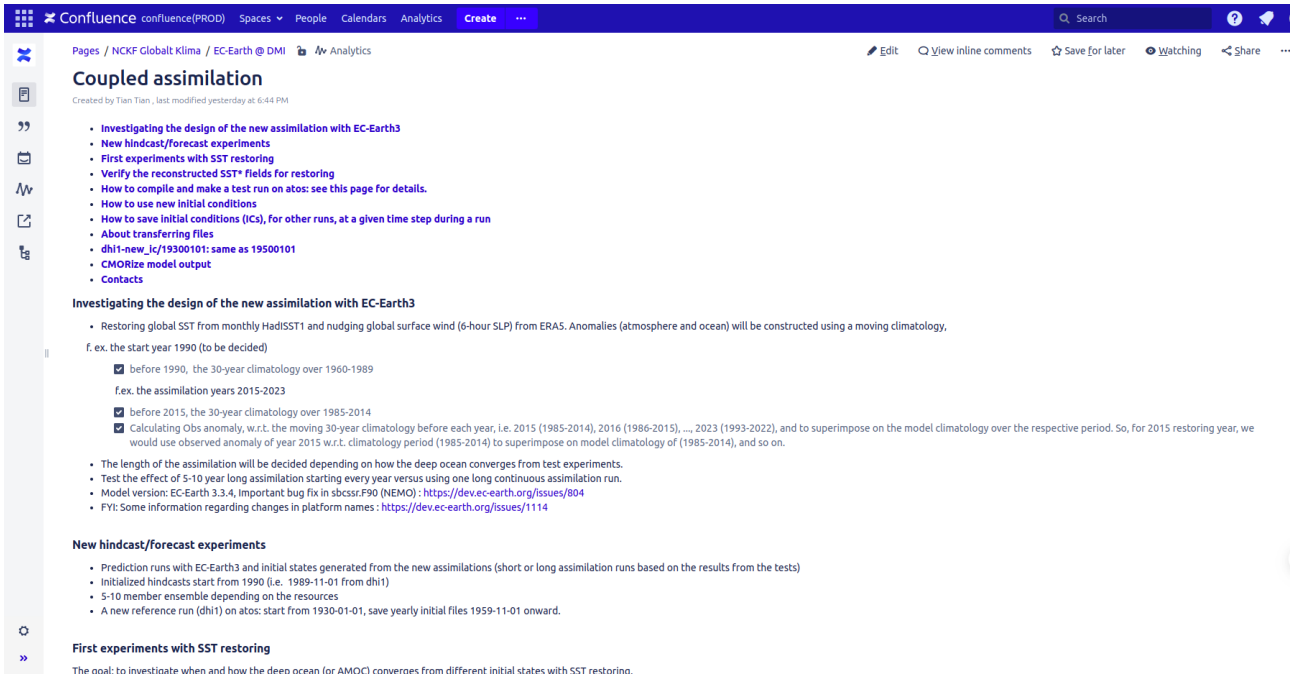

Figure 1. Screenshot of the technical documentation on DMI's Confluence page.

Currently, we have nearly completed the reference simulation. Figure 2 presents a comparison of the global annual mean surface air temperature from 1930-2005 (the last year available with post-processing) between the new reference run and an earlier version performed on another HPC platform, which was permanently shut down in June. The new reference run on Atos (in orange) shows a slightly smaller inter-annual variability with 0.20 K, compared to the one computed on DMI's computer (in blue) with 0.22K. Both versions capture the overall warming trend effectively, demonstrating the robustness of the EC-Earth model in simulating historical climate trends. The overall RMSE of the monthly mean is 0.22 K. The remarkable differences throughout years between the two versions also highlight the need to perform the new reference for the new decadal prediction for initialization and further skill assessments. Further detailed analysis and validation is ongoing to understand specific improvements and the implications for climate prediction and assimilation methods.

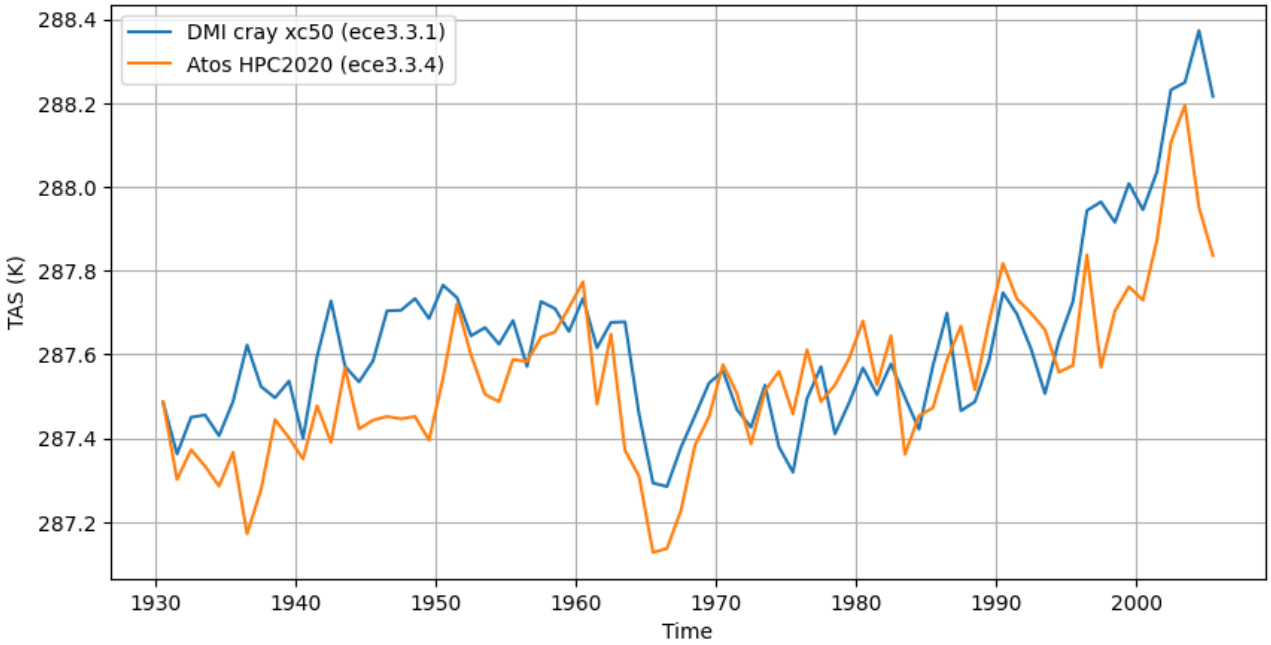

Figure 2. Comparison of global annual mean TAS time series performed on two different HPC platforms. The initial condition for ece3.3.4 was taken from the restart files from the existing simulation with ece3.3.1. There is no change in the model code for the physics or dynamics of the atmospheric and oceanic components between the two versions.

Participation in EC-Earth Annual Assembly

In March, we actively participated in the EC-Earth Annual Assembly 2024 in Utrecht. This event provided a valuable opportunity to engage with EC-Earth colleagues with experience in coupled assimilation methods, particularly within the climate prediction working group. We organized discussions to address technical issues in atmospheric nudging with EC-Earth3 and explored opportunities for joint analysis on the effects of coupled assimilation on seasonal to decadal timescales.

Collaborative Efforts and Simulation Progress

We have been collaborating with colleagues from SMHI, who recently completed decadal prediction hindcasts for 1990-2020 initialized from one continuous assimilation with SST-restoring and wind nudging. This collaboration has been instrumental in advancing our understanding and methodology.

References

Boer, G. J., and Coauthors, 2016: The Decadal Climate Prediction Project (DCPP) contribution to CMIP6. Geosci. Model Dev., 9, 3751–3777, https://doi.org/10.5194/gmd-9-3751-2016.

Döscher, R., and the EC-Earth consortium, 2022: The EC-Earth3 Earth system model for the Coupled Model Intercomparison Project 6, Geosci. Model Dev., 15, 2973–3020, https://doi.org/10.5194/gmd-15-2973-2022.

Tian, T., Yang, S., Karami, M. P., Massonnet, F., Kruschke, T., and Koenigk, T. 2021: Benefits of sea ice initialization for the interannual-to-decadal climate prediction skill in the Arctic in EC-Earth3, Geosci. Model Dev., 14, 4283–4305, https://doi.org/10.5194/gmd-14-4283-2021.