SPECIAL PROJECT PROGRESS REPORT

Reporting year	2023/24
Project Title:	Applying hydrodynamic constraints to coupled energy budget analysis and to physics-informed machine learning based forecasting
Computer Project Account:	spatlh00
Principal Investigator(s):	Leopold Haimberger, Alexander Bihlo
Affiliation:	University of Vienna
Name of ECMWF scientist(s) collaborating to the project (if applicable)	Michael Mayer
Start date of the project:	1.1.2024
Expected end date:	31.12.2026

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

		Previous year		Current year	
		Allocated	Used	Allocated	Used
High Performance Computing Facility	(units)			10000	0.0
Data storage capacity	(Gbytes)			500	32

Summary of project objectives

The special project focuses on optimally extracting energy budget terms from the IFS in the version to be adopted for the forthcoming Copernicus reanalysis ERA6. Its second focus is to investigate the use of machine learning for meteorological applications, in particular for replacing the ensemble prediction system and for physics-informed machine learning based weather forecasting.

Summary of problems encountered (if any)

Use of European Weather Cloud not yet extensive. Setting up a VM and login worked, but no time yet to explore more.

Summary of results of the current year (from July of previous year to June of current year)

Since the project has just started, there are not yet many results to report. We created accounts on the European Weather Cloud but have not yet started to use it seriously. Also new personnel had to be hired.

This special project is a continuation of the special project *"Mining 5th generation reanalysis data for changes in the global energy cycle and for estimation of forecast uncertainty growth with generative adversarial networks"* that finished in 2023. We used the resources in 2024 mainly to finalize writing papers resulting from this preceding project; its final report has been submitted together with the current progress report.

We can report about the publication of a novel tool for evaluating horizontal transports across waterstraits (StraitFlux, Winkelbauer et al. 2024b), which was also extensively used for a comparison of almost 40 CMIP6 historical model runs against transports from GREP ocean reanalyses (Winkelbauer et al. 2024 a).

Besides this we have also updated energy budget fields for Copernicus
https://cds.climate.copernicus.eu/cdsapp#!/dataset/derived-reanalysis-energy-moisture-budget?tab=overview
up to March 2024 so that the 2023/24 ENSO event can be analysed from a budget perspective. The fields for 2023 have yet to be made available also on the CDS.

With regard to ensemble prediction with Deep Learning, we refer to the above mentioned final report and to the most recent papers (Brecht and Bihlo, 2024a,b).

List of publications/reports from the project with complete references

R. Brecht and A. Bihlo, 2024a. Towards replacing precipitation ensemble predictions systems using machine learning. Atmospheric Science Letters (accepted), arXiv:2304.10251.

R. Brecht and A. Bihlo, 2024b. M-ENIAC: A machine learning recreation of the first successful numerical weather forecasts Geophys. Res. Lett. 51, e2023GL107718, arXiv:2304.09070 .

Winkelbauer, S., Mayer, M. & Haimberger, L. Validation of key Arctic energy and water budget components in CMIP6. Clim Dyn 62, 3891–3926 (2024). https://doi.org/10.1007/s00382-024-07105-5

Winkelbauer, S., Mayer, M., and Haimberger, L.: StraitFlux – precise computations of water strait fluxes on various modeling grids, Geosci. Model Dev., 17, 4603–4620, https://doi.org/10.5194/gmd-17-4603-2024, 2024.

Summary of plans for the continuation of the project

As stated in the project proposal, we found a way to reduce the noise that is still visible in state of the art energy budget evaluations. We expect to use resources allocated for the new special project to deliver an even more accurate version of the current mass consistent energy budget data set in Copernicus mentioned above. For that purpose, we will try to use OpenIFS v48.1 or at least some of the filtering routines of it to be able to do these calculations offline.

We will start using the EWC for doing the budget calculations so that we can avoid copying all the input data to University premises. One idea would be to establish Straitflux (Winkelbauer et al. 2024) as a calculation tool for horizontal oceanic transports within a VM of the EWC.

We will also try to port the recently developed multi-parameter ensemble machine learning systems to the HPC or EWC, depending on computational demand. This system can forecast not only single

meteorological parameters as in our previous work, but the entire catalogue of meteorological parameters of interest.