SPECIAL PROJECT PROGRESS REPORT

Reporting year	2022/23
Project Title:	Mining 5th generation reanalysis data for changes in the global energy cycle and for estimation of forecast uncertainty growth with generative adversarial networks
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)	Hans Hersbach, M. Balmaseda
Start date of the project:	1.1.2021
Expected end date:	31.12.2023

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	10000	0.0
Data storage capacity	(Gbytes)	1000	32	1000	32

Summary of project objectives

The special project focuses on detecting and estimating changes in the coupled oceanic/atmospheric water and energy cycles. Its second focus, also employing reanalysis data, are novel methods for describing forecast uncertainty growth.

Summary of problems encountered (if any)

Less HPC resources than requested have been used, simply because we did not need them. Transition to ATOS and new login services was smooth.

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

This year we continued our work on evaluating coupled energy and water budgets from ERA5 and ocean reanalyses. In addition we analysed budgets from the GREP ocean reanalysis ensemble with CMIP6 output. Results are published or at least available in manuscript form in Mayer et al. 2023, Fritz et al. 2023, Winkelbauer et al. 2023.

This year we have also worked on the problem of replacing the ensemble prediction system for precipitation with machine learning. Precipitation forecasts are less accurate compared to other meteorological fields because several key processes affecting precipitation distribution and intensity occur below the resolved scale of global weather prediction models. This requires to use higher resolution simulations. To generate an uncertainty prediction associated with the forecast, ensembles of simulations are run simultaneously. However, the computational cost is a limiting factor here. Thus, instead of generating an ensemble system from simulations there is a trend of using neural networks. Unfortunately, the data for high resolution ensemble runs is not available.

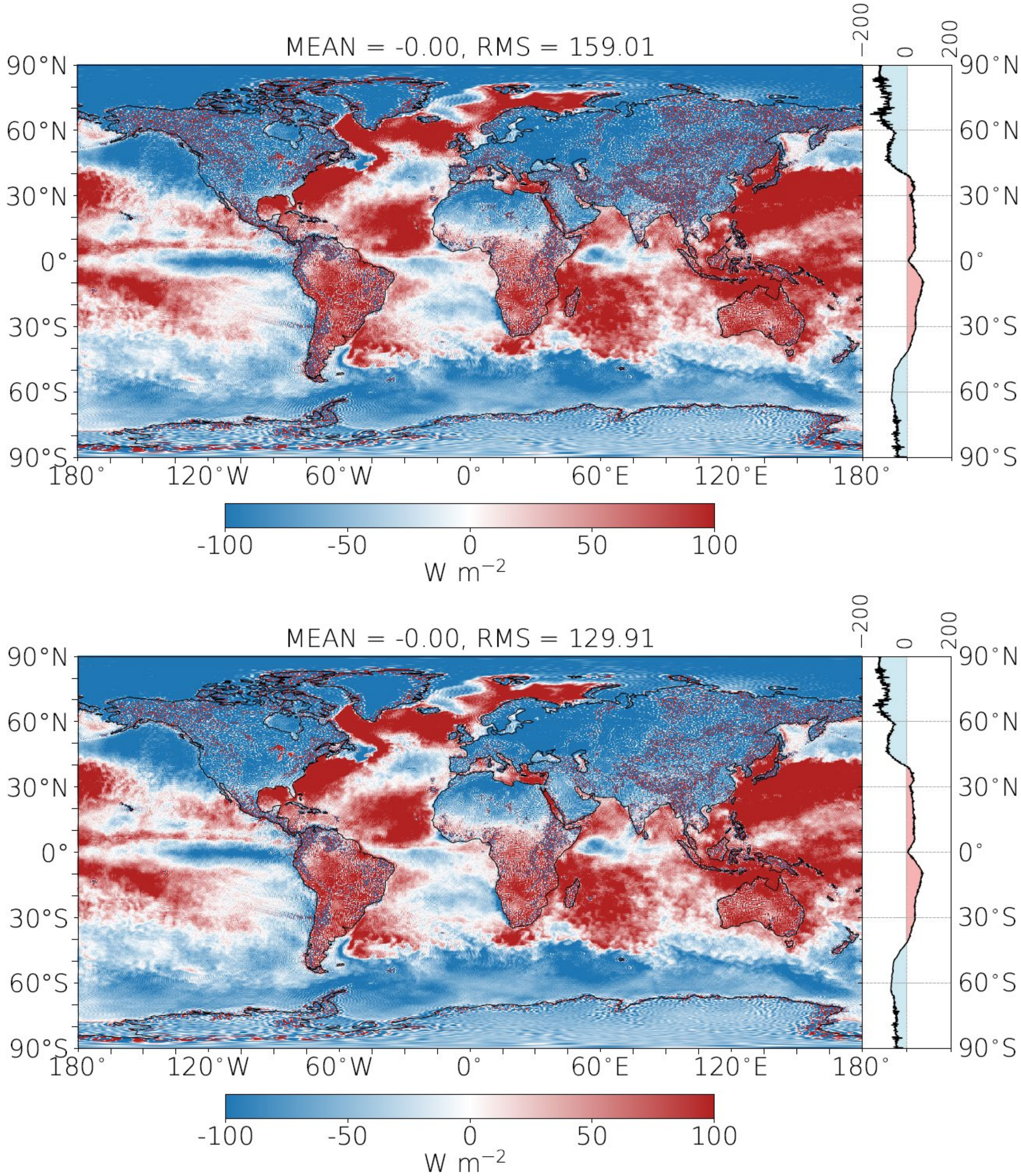

Fig. 1: Monthly mean total energy flux divergence for January 2015 calculated from ERA5 data as described in Mayer et al. (2021) applying uniform mass flux adjustment across all model levels (upper panel) and adjustment applied only to the lower 14 model levels. RMS is reduced by another 20% using the second method. Plot uses full resolution F480 Gaussian grid (quadratic grid for T639 native ERA5 resolution)

We propose a new approach to generating ensemble weather predictions for high-resolution precipitation without requiring high-resolution training data. The method uses generative adversarial networks to learn the complex patterns of precipitation and produce diverse and realistic precipitation fields, allowing to generate realistic precipitation ensemble members using only the available control forecast. We demonstrate the feasibility of generating realistic precipitation ensemble members on unseen higher resolutions. We use evaluation metrics such as RMSE, CRPS, rank histogram and ROC curves to demonstrate that our generated ensemble is almost identical to the ECMWF IFS ensemble (Brecht and Bihlo 2023 a,b).

List of publications/reports from the project with complete references

R. Brecht and A. Bihlo, 2023a. Computing the ensemble spread from deterministic weather predictions using conditional generative adversarial networks, Geophysical Research Letters, 50 (2), e2022GL101452

R. Brecht and A. Bihlo, 2023b. Towards replacing precipitation ensemble predictions systems using machine learning, submitted to Geophysical Research Letters.

Fritz, M., Mayer, M., Haimberger, L., and Winkelbauer, S.: Assessment of Indonesian Throughflow transports from ocean reanalyses with mooring-based observations, EGUsphere [preprint], https://doi.org/10.5194/egusphere-2023-435, 2023.

Mayer, J., Mayer, M., and Haimberger, L. (2021). Consistency and Homogeneity of Atmospheric Energy, Moisture, and Mass Budgets in ERA5. Journal of Climate 34, 10, 3955-3974, https://doi.org/10.1175/JCLI-D-20-0676.1

Mayer, J., Mayer, M., Haimberger, L. (2022): Mass-consistent atmospheric energy and moisture budget monthly data from 1979 to present derived from ERA5 reanalysis, v1.0, Copernicus Climate Change Service (C3S) Climate Data Store (CDS), https://doi.org/10.24381/cds.c2451f6b

Mayer, J., Haimberger, L., and Mayer, M.: A quantitative assessment of air-sea heat flux trends from ERA5 since 1950 in the North Atlantic basin, Earth Syst. Dynam. Discuss. [preprint], https://doi.org/10.5194/esd-2023-8, in review, 2023.

Winkelbauer, S., Mayer, M. and Haimberger, L., 2023: Validation of Arctic energy and water budget components in CMIP6. Submitted to Clim. Dyn.

Summary of plans for the continuation of the project

In the remaining time of the project we aim to update the Copernicus mass consistent energy budget data set that is now public (Mayer et al. 2022). We also plan to explore methods to get better noise reduction over land, where some preliminary progress could be recently made (see Fig. 1)

A proposal for another special project devoted to further refinement of the developed methods together with usage of forthcoming reanalysis data products has been submitted.

We plan to continue the development of differential equations-based machine learning models for global ensemble forecasting.