REQUEST FOR AN EMI R&D PROJECT 2027–2029

Country/Organisation:	Austria……
Principal Investigator[1]:	Prof. Leopold Haimberger……
Affiliation:	Department of Meteorology and Geophysics, University of Vienna
Address:	Josef Holaubeck Platz 2, 1090 Vienna, Austria ……
Other researchers:	Prof. Alexander Bihlo, Dr. Susanna Winkelbauer, Mag. Ulrich Voggenberger, Dr. Michael Mayer
Project Title:	Applying hydrodynamic constraints to coupled energy budget analysis and to physics-informed machine learning based forecasting II

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** ATLH00.	
Starting year: (A project can have a duration of up to 3 years, agreed at the beginning of the project.)	2027	
Would you accept support for 1 year only, if necessary?	YES ☐	NO X

Computer resources required for project year:		**2027**	**2028**	**2029**
High Performance Computing Facility	[SBU]	20000	20000	20000
Graphics Processing Unit Cluster-A	[GBU]	100000	100000	100000
Graphics Processing Unit Cluster-B	[GBU]			
Accumulated data storage (total archive volume)[2]	[GB]	2000	3000	5000

[1] The Principal Investigator will act as contact person for this EMI R&D 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.

EWC resources required for project year:		**2027**	**2028**	**2029**
Number of vCPUs	[#]	20	20	20
Total memory	[GB]	200	200	200
Storage	[GB]	5000	5000	10000
Number of vGPUs[3]	[#]	2	2	2

Continue overleaf.

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Extended abstract

This special project is intended as a continuation of our efforts to use advanced energy and water budget diagnostics to better constrain climate and weather forecasting. The project has two components: (i) improving the precision of diagnostic budget estimates, particularly of the net surface energy budget and lateral energy transports in the atmosphere and ocean, globally and with a special focus on the polar regions. (ii) physical diagnostics built into ML based atmospheric forecast models. Both approaches made significant progress in the current special project but have a lot of potential to be realized.

In the context of diagnostic budgets based on utilizing atmospheric, oceanic and cryospheric reanalyses, we plan to make use of the latest generation of reanalyses, e.g. ERA6, JRA3Q and MERRA21C as well as of a large variety of oceanic reanalyses such as ORAS6, the GREP ensemble and many others. Several essential terms for atmospheric energy budgets, particularly the vertically integrated horizontal energy flux divergence, are archived in ERA6 as accumulated fields. This allows for less noisy estimates of the net surface energy flux which we compute indirectly from the sum of satellite-based net TOA radiation, the energy flux divergence and atmospheric energy tendency. We expect much more reliable estimates especially near steep orography. Most of the remaining noise can be further reduced by applying mass balance constraints and by using efficient spectral digital filters. The evaluation code takes advantage of GPU based spherical harmonics transforms, which helps a lot in processing long time series of ERA6 data. We plan to update or newly publish the products on the Copernicus Data Store (see Mayer et al., 2021). The research also feeds into assessments of the Earth's energy imbalance. Mayer et al. (2026)

Substantial progress has been made in evaluating ocean reanalyses, using a novel tool (Straitflux) for estimating the fluxes across almost arbitrary ocean sections (Winkelbauer et al. 2024). This research is well embedded in CMEMS activities and is well visible in the ocean science community (e.g. Winkelbauer et al. (2026 a,b). Such evaluations need multilevel ocean reanalysis data and would also profit from access to a GPU cluster with local access to the ocean reanalysis and forecast data.

While many of the input data needed for this activity can be downloaded from public resources, there has always been the need to extract experimental assimilation runs available only in the MARS archive. In addition, we expect that many of the budget evaluations will be run directly at ECMWF either on the HPC or on the GPU cluster that we have not used so far. This requires code adaptations avoid a transfer of the multi model level ERA6 input data for budget calculations over longer periods to Univ. Vienna premises. The GPU cluster is expected enable also budgets on much higher spectral resolutions than available in ERA6.

It is intended to continue also the work on ML based regional atmospheric forecast models using neural network based parameterisations (Kiven et al. 2026). The planning is still ongoing and we intend to do tests on the GPU clusters at ECMWF with that system which should require only moderate computing costs in 2027. It may be necessary to request more in 2028 and 2029 as the project progresses.

Kiven, M., Mouassom, F. L., Whittaker, T., Cardoso-Bihlo, E., and Bihlo, A.: Evaluating Regionally Diverse Pathways to Unprecedented Heat Extremes Across Africa in NeuralGCM. To be submitted to npj Climate and Atmospheric Science, 2026.

Mayer, J., Mayer, M., Haimberger, L., (2021): Mass-consistent atmospheric energy and moisture budget monthly data from 1979 to present derived from ERA5 reanalysis. Copernicus Climate Change Service (C3S) Climate Data Store (CDS). DOI: 10.24381/cds.c2451f6b (Accessed on 05-AUG-2026)

Mayer, M., Loeb, N. G., Lyman, J. M.,Johnson, G. C., & Winkelbauer, S. (2026). The atmosphere's substantial role in interannual variability of Earth's Energy Imbalance. Geophysical Research Letters,53, e2025GL119833. https://doi.org/10.1029/2025GL119833

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.

Winkelbauer, S., Winterer, I., Mayer, M., Fu, Y., and Haimberger, L.: Subpolar Atlantic meridional heat transports from OSNAP and ocean reanalyses – a comparison, Ocean Sci., 22, 629–651, https://doi.org/10.5194/os-22-629-2026, 2026a

Winkelbauer, S., Mayer, M., Forget, G., Song, Y., and Haimberger, L.: Atlantic Meridional Heat Transports from Ocean Reanalyses, Monitored Sections and Budget Constraints. To be submitted to Ocean Science, 2026b