EMI R&D 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	2026
Project Title:	Mediterranean Sea Climate Response (MEDCLIM-R)
Computer Project Account:	SPGRVER2
Principal Investigator(s):	Vassilios D. Vervatis
Affiliation:	Department of Physics, National and Kapodistrian University of Athens
Name of ECMWF scientist(s) collaborating to the project (if applicable)	Sarantis Sofianos, John Karagiorgos, Rushit Dallenga, Stefanos Ziovas
Start date of the project:	01/01/2026
Expected end date:	31/12/2028

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	(MSBU)	n/a	n/a	23	~7,5
Data storage capacity	(TB)	n/a	n/a	40	~15

Summary of project objectives (10 lines max)

The resources allocated to the EMI R&D project support the research activities of the University of Athens and IASA within EU-INTERCHANGE, an EU-funded project awarded under the HORIZON-CL6-2024-CLIMATE-01-6 call.

EU-INTERCHANGE aims to enhance high-resolution regional ocean models and datasets by integrating methodologies from both current climate projections and Copernicus Marine forecasting models. The project's core objectives are twofold:

- Develop regionally optimized ocean physics, wave and biogeochemical models for the Med. Sea.
- Generate high-resolution model datasets by executing hindcast, historical and climate projections.

Summary of problems encountered (10 lines max)

During the configuration's development phase, we identified scalability limitations inherent in the initial MPI-only parallelization strategy. Specifically, simulations executed on more than six compute nodes experienced increased execution times and memory-related failures. To overcome these issues, we implemented a hybrid MPI–OpenMP parallelization strategy, which significantly improved scalability and computational performance by exploiting the spectral structure of WW3.

We estimate that troubleshooting these limitations and recovering from the associated simulation failures consumed approximately 4 MSBU, an overhead that was unaccounted for in our initial allocation. In addition, the overall resources required for the project were underestimated. Below, we provide a revised assessment of our computational resource and data storage requirements for the scientific committee's consideration and approval.

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

The EMI R&D project is scheduled to continue through the end of 2028, adhering to the original project timeline.

List of publications/reports from the project with complete references

Karagiorgos, J., Vervatis, V., Sofianos, S. Wave-Coupled Modulation of Air-Sea Fluxes in the Mediterranean. AGU Ocean Sciences Meeting 2026, 22-27 February 2026, Glasgow, Scotland.

Ziovas, S., Karagiorgos, J., Sofianos, S., Vervatis, V. High-resolution wave modelling in the Mediterranean Sea: Sensitivity to surface current forcing. AGU Ocean Sciences Meeting 2026, 22-27 February 2026, Glasgow, Scotland.

Karagiorgos, J., Vervatis, V., Sofianos, S. Representing Bio-Optical Interactions in a Coupled Modelling Framework for the Southern European Seas. EGU General Assembly 2026, 3-8 May 2026, Vienna, Austria.

Summary of results

If submitted **during the first project year**, please summarise the results achieved during the period from the project start to June of the current year. A few paragraphs might be sufficient. If submitted **during the second project year**, this summary should be more detailed and cover the period from the project start. The length, at most 8 pages, should reflect the complexity of the project. Alternatively, it could be replaced by a short summary plus an existing scientific report on the project attached to this document. If submitted **during the third project year**, please summarise the results achieved during the period from July of the previous year to June of the current year. A few paragraphs might be sufficient.

Model Configuration and Current Status

In brief, we have established a high-resolution 1/36° (~2.5 km) model configuration for the Mediterranean Sea. The ocean circulation model is based on NEMOv5 (Madec, 2022) and is coupled with the PISCESv2 biogeochemical model (Aumont et al., 2015) and the WW3 wave model (WAVEWATCH III® Development Group, 2019) via the OASIS3-MCT coupler (Craig et al., 2017), utilizing a common grid across all model domains.

As this is the first year of the project, the majority of our resources have been spent on porting model files and data from external HPC facilities, optimizing model scalability, and executing spin-up simulations for ocean physics and biogeochemistry. **Figure 1** illustrates sample fields from the MED36 coupled modeling system – specifically, Sea Surface Height (SSH) from the ocean model, Significant Wave Height (SWH) from the wave model, and Chlorophyll-a (Chl-a) concentration from the biogeochemical model – following a few years of spin-up, valid for April 1, 1994.

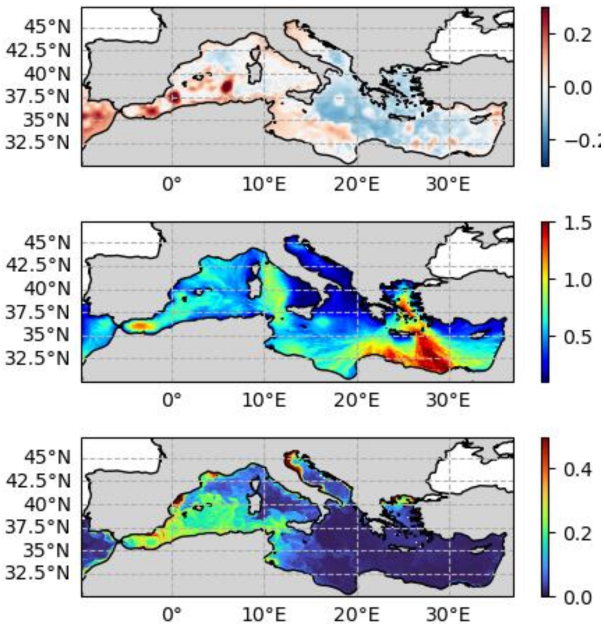

Figure 1. *SSH (m), SWH (m) and Chl-a concentration (g/m³) (from top to bottom), in the MED36 coupled modelling system on 1st of April 1994.*

Revised Assessment of Computational Resources and Data Storage

To improve the computational efficiency of our coupled modeling system, several targeted developments and optimizations have been implemented. These modifications aim to reduce the computational cost of the high-resolution configuration while maintaining numerical stability and solution accuracy.

The optimal MPI model domain decomposition for ocean physics and biogeochemistry is approximately 1,000 CPUs, which includes the use of XIOS for model I/O. The wave model's domain decomposition varies from 900 to 1,200 CPUs, depending on the coupling mode.

The baseline computational costs per simulation year are broken down as follows:

- **Stand-alone ocean model:** ~0.1 MSBU per simulation year.
- **Online-coupled ocean and biogeochemistry (NEMO-PISCES):** ~0.4 MSBU per simulation year (representing a 4x increase in computational cost over the stand-alone ocean model).
- **Stand-alone wave model (WW3):** ~0.3 MSBU per simulation year.
- **Fully coupled system (NEMO-PISCES-WW3):** ~0.9 MSBU per simulation year.
- **OASIS Coupling Overhead:** ~0.2 MSBU per simulation year (incurred by the 3-way online coupling via OASIS).

In addition to the primary 3-way online-coupled configuration (OC-BGC-WW3), we intend to execute a series of supplementary experimental runs with selective deactivation of specific coupling components (i.e., OC-BGC, OC-WW3, stand-alone WW3, and stand-alone ocean), as well as runs utilizing CERRA forcing (Ridal et al., 2024). Finally, we have factored in an approximate 5% contingency buffer to account for potential system failures, queue interruptions, or unexpected job overheads. **Table 1** presents the complete, revised assessment of the computational resources required for this EMI R&D project, encompassing both the primary EU-INTERCHANGE simulations and these supplementary experiments.

Table 1. *Revised computational resources, per sim. year, for the hindcast, historical & climate projections, using 3-way online coupling (OC-BGC-WW3) & supplementary experiments.*

Simulation	Experiment		Period (sim. years)	Models	Resources (MSBUS)
Project experiments					
Hindcast	Evaluation	ERA5	1995-2025 (30)	NEMO PISCES WW3	~ 27
	Historical CMIP6	SSP1-2.6 and/or SSP2-4.5	2015-2025 (10)		~ 9
Climate	Projection CMIP6	SSP1-2.6 and/or SSP2-4.5	2025-2050 (25)		~ 23
	Projection CMIP6	SSP1-2.6 and/or SSP2-4.5	2080-2100 (20)		~ 18
Total resources for project: $\sim$ 77 MSBUS					
Supplementary experiments					
Sensitivity	Evaluation	CERRA	2015-2025 (10)	NEMO PISCES WW3	~ 9
	Ocean-Wave coupling		2020-2025 (5)	NEMO WW3	~ 3
	Ocean-Biogeochemical coupling		2020-2025 (5)	NEMO PISCES	~ 2
	Wave stand-alone		2020-2025 (5)	WW3	~ 1.5
	Ocean stand-alone		2020-2025 (5)	NEMO	~ 0.5
Total resources for supplementary experiments: $\sim$ 16 MSBUS					
Overall					
Total resources + 5 % increase misc. job failures: $\sim$ 98 MSBUS					

Regarding data storage, the archived model outputs for the ocean state consist of five core variables alongside a few surface atmospheric fluxes. We retain 17 variables for the wave model and 21 variables for the biogeochemical model. The archiving frequencies are structured as follows:

- **Hindcast Simulations:** Archived at an hourly frequency for the wave model, a daily frequency for the ocean model, and a 5-day frequency for the biogeochemical model.
- **Historical & CMIP6 Regional Climate Projections:** Archived at daily intervals for ocean variables and monthly intervals for biogeochemical variables (with the wave model retaining a higher-frequency output archive).

Table 2 presents the detailed, revised data storage requirements for each model component across all planned simulations.

Table 2. *Revised data storage for the planned simulations in Table 1.*

Models	Hindcast sim. outputs (TB/years)	Climate sim. outputs (TB/years)	Sensitivity sim. outputs (TB/years)	Archives
NEMO (ocean)	0.9	0.7	0.9	2.4 TB/year hindcast × 40 years hindcast sim. ∼ 96 TB
PISCES (bgc)	1.1	0.1	1.1	1.2 TB/year climate × 45 years climate sim. ∼ 54 TB
WW3 (wave)	0.4	0.4	0.4	8 GB/year model restarts × 85 years ∼ 0.7 TB
Total storage for project: ∼ 150 TB				
Total storage for supplementary experiments: ∼ 50 TB				
Total storage: ∼ 200 TB				

Formal Request for Resource Reallocation

We respectfully request the scientific committee's consideration and approval for a revised budget and temporal redistribution of our computational and data storage resources.

Based on the technical challenges encountered during the initial setup phase and the expanded multi-model experimental matrix outlined above, our total required computational resources have been revised from 65 MSBU to 98 MSBU. Similarly, our total data storage requirements have been updated from 85 TB to 200 TB. The tables below provide a detailed comparison between our initial allocations and the proposed multi-year distributions for the years 2026, 2027 and 2028.

Table 1. *Revised Computational Resources (2026–2028).*

Year	Initial Allocation (MSBU)	Proposed Allocation (MSBU)	Net Change (MSBU)
2026 (Current)	23	28	+5
2027	22	36	+14
2028	20	34	+14
Total	65	98	+33

Table 2. *Revised Data Storage Requirements (2026–2028).*

Year	Initial Allocation (TB)	Proposed Allocation (TB)	Net Change (TB)
2026 (Current)	40	60	+20
2027	25	60	+35
2028	20	80	+60
Cumulative	85	200	+115

Justification of Temporal Shift

The proposed restructuring reflects a ramp-up in our computational intensity and storage footprint as the project progresses. While 2026 focuses heavily on baseline optimization, scalability fixes, and spin-ups, the subsequent years (2027 and 2028) will bear the high-frequency archival demands of the full 3-way NEMO-PISCES-WW3 coupled historical runs and CMIP6 regional climate projections.

We thank the scientific committee for their time, continuous support, and understanding as we optimize this high-resolution modeling framework.

References

Aumont, O., Ethé, C., Tagliabue, A., Bopp, L., and Gehlen, M. (2015). PISCES-v2: an ocean biogeochemical model for carbon and ecosystem studies, Geosci. Model Dev., 8, 2465–2513, https://doi.org/10.5194/gmd8-2465-2015.

Craig, A., Valcke, S., & Coquart, L. (2017). Development and performance of a new version of the oasis coupler, oasis3-mct_3.0. Geosci. Model Dev, 10, 3297–3308. https://doi.org/10.5194/gmd-10-3297-2017.

Madec, G., Bourdallé-Badie, R., Chanut, J., Clementi, E., Coward, A., Ethé, C., et al. (2022). NEMO ocean engine. https://doi.org/10.5281/zenodo.6334656.

Ridal, M., Bazile, E., Le Moigne, P., Randriamampianina, R., Schimanke, S., Andrae, U., et al. (2024). CERRA, the Copernicus European Regional Reanalysis system. Quarterly Journal of the Royal Meteorological Society, 150(763), 3385–3411. https://doi.org/10.1002/qj.4764.

The WAVEWATCH III® Development Group (2019). User manual and system documentation of WAVEWATCH III® version 6.07. Tech. Note 333, NOAA/NWS/NCEP/MMAB, College Park, MD, USA, 326 pp. + Appendices.