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:	CASCADE (Coupled regional coAStal oCeAn moDel Ensembles)
Computer Project Account:	**SPGRVER2**
Principal Investigator(s):	Vassilios D. Vervatis (1), Pierre De Mey-Frémaux (2)
Affiliation:	(1) National Kapodistrian University of Athens (UoA). (2) Laboratoire d'Etudes en Géophysique et Océanographie Spatiales (LEGOS).
Name of ECMWF scientist(s) collaborating to the project (if applicable)	Sarantis Sofianos (1), Nadia Ayoub (2).
Start date of the project:	05/04/2022
Expected end date:	31/12/2024

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)	2,5	~2,1	2,5	~0,1
Data storage capacity	(TB)	2,5	~2	2,5	-

Summary of project objectives (10 lines max)

The requested resources in this ECMWF Special Project are used to support the R&D activities of the University of Athens (Greece) and LEGOS/CNRS (France) teams, in a joint research Copernicus Marine project named MULTICAST (https://marine.copernicus.eu/about/research-development-projects/2022-2024/MULTICAST), within the CMEMS Service Evolution framework. This ECMWF SP and the MULTICAST project aim at strengthening CMEMS in the areas of ocean uncertainty modelling, consistency verification and multigrid ensemble data assimilation. Our work is based on the development of an ensemble ocean data assimilation system, using two-way coupled high-resolution parent-child nested domains for the Bay of Biscay, as a case study for the CMEMS SE and the future capabilities of CMEMS Modelling and Forecasting Centers (MFCs).

Summary of problems encountered (10 lines max)

n/a

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

We expect to continue the project till the end of this year.

List of publications/reports from the project with complete references

Journals

Vervatis, V., P. De Mey-Frémaux, et al., Regional ocean model uncertainties using stochastic parameterizations and a global atmospheric ensemble, Ocean Modelling, under review.

Edwards, C.A., P. De Mey-Frémaux, et al., Assessing the impacts of observations on ocean models in coastal and shelf sea environments, Frontiers in Marine Science, submitted.

Conferences

Vervatis, V., P. De Mey-Frémaux, N. Ayoub, M. Ghantous and S. Sofianos, Multigrid nested ocean ensembles using stochastic modelling, 9th COSS-TT meeting, Montréal, Canada, 2-4 May 2023.

De Mey-Frémaux, P., Predictability of the Coastal Ocean. 2023 Coastal Ocean Dynamics Gordon Research Conference "Coastal Ocean Physics and its Connections to Marine Ecosystems", Bryant University, Smithfield, RI, USA, June 18-23, 2023. (included MULTICAST examples)

Vervatis, V. and P. De Mey-Frémaux, MULTICAST, CMEMS General Assembly & Service Evolution mid-term meeting, Brussels, Belgium, June 5-7, 2023.

Vervatis, V., Generation of coupled biogeochemical-physical ensembles, Mercator Ocean International, online Workshop, October 16, 2023.

Vervatis, V., Ongoing MFCs activities about Ensemble Approaches, hybrid joint METOF Workshop with COP2-EAWG, Bologna, March 12-14, 2024.

De Mey-Frémaux, P., 2024: Towards nested data assimilation. Kick-off meeting of the SCOEPUS project ("SWOT Coastal Ocean and Estuarine Products Usability Study"), Toulouse, April 30, 2024.

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.

In brief, we set up a dual-grid configuration for the Bay of Biscay to generate Ensembles, using appropriate hypotheses for sources of error in the wind forcing and the Open Boundary Conditions (OBCs). The Ensemble simulations are performed following Target Operation Protocols (TOPs) relevant to the CMEMS MFCs (cf. previous year SP progress report). The prediction skills of the TOPs are compared with one another in assimilated vs. non-assimilated modes.

In the third year of this SP, we mainly focused on the following R&D activities: (a) development of a fully multigrid version of our Ensemble-based data assimilation platform (SDAP 1.7), including multigrid versions of Ensemble Empirical Consistency Analysis (EECA) tools, and (b) development of specific multigrid skill assessment metrics, with a particular forecast state estimator and compare it with a reference estimate, either in state space or data space.

Figure 1 shows a schematic of our correction and restart strategy in assimilation mode, using the NEMO direct initialization approach, and the stochastic EnKF method provided by the SDAP kernel. This is done for one assimilation cycle generating multigrid "parent-child" analysis simultaneously, for both model configurations of our Bay of Biscay setup.

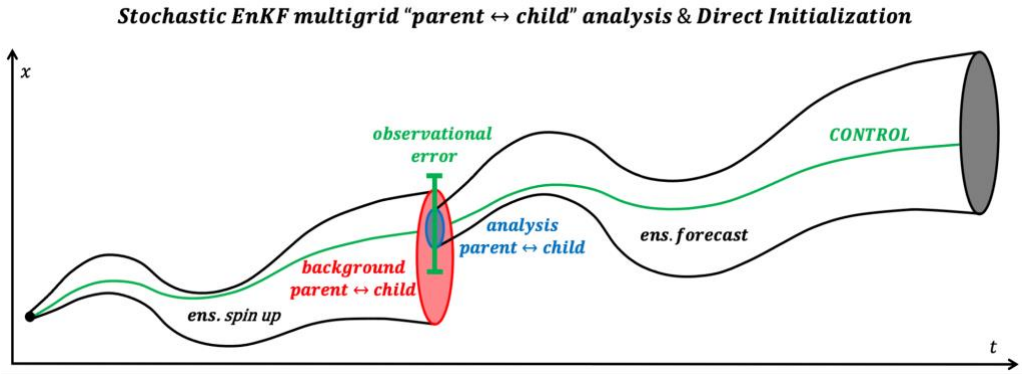

Figure 1: NEMO correction and restart strategy using a stochastic EnKF multigrid "parent-child" analysis and direct initialization.

Figure 2 shows the comparative assessment of an assimilated Ensemble vs. a free (non-assimilated) Ensemble, using 2-way "parent-child" nesting and multigrid covariances. Details for the assimilation approach will be given in the SP Final Report to be submitted next year. The metric shown in Fig. 2 is the CRPS. In this context, we can verify that the assimilated Ensemble (solid line) shows a small but measurable improvement in performance wrt. the free Ensemble (dashed line), the former having smaller CRPS values (for several days in the forecast). The somewhat small impact of DA is perhaps due to the small Ensemble spread we have for this particular case demonstrated for the winter season.

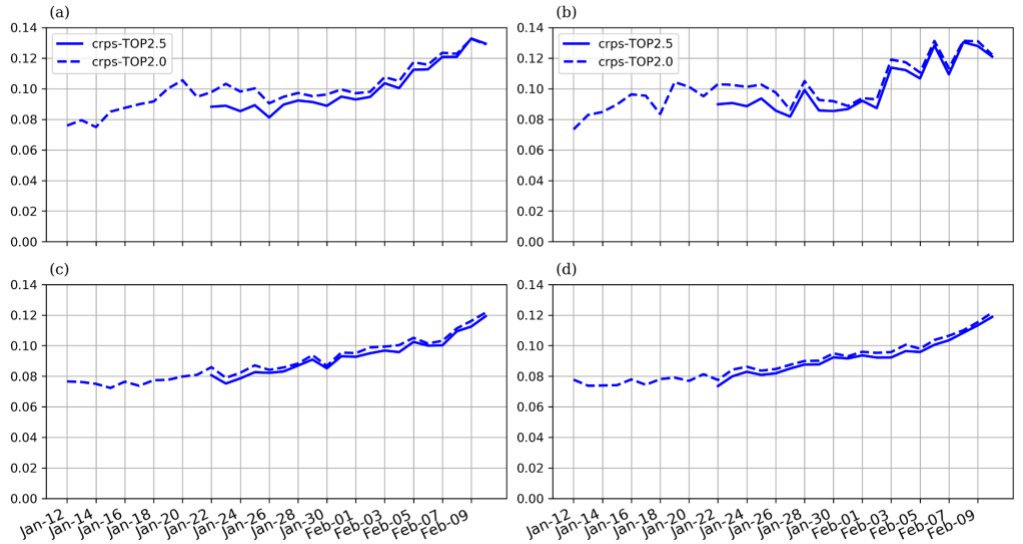

Figure 2: CRPS comparative assessment for winter Ensembles: assimilated (TOP2.5) vs. non-assimilated (TOP2.0). (a/b) parent/child models in open-ocean, (c/d) same as (a/b) in coastal area.