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: Eddy Predictability and Detection-Tracking processes in North Atlantic……

……

Computer Project Account: spitmaur……

Principal Investigator(s): Paolo Mauriello

……

……

Affiliation: Institute of Marine Sciences, National Research Council of Italy, Rome, Italy

……

Name of ECMWF scientist(s) collaborating to the project (if applicable)
Michela Gambale
Chunxue Yang
Andrea Storto

……

……

Start date of the project: 2026-01-01

……

Expected end date: 2028-12-31

……

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	(units)	N/A	N/A	12,000,000 SBU	5,227 SBU
Data storage capacity	(Gbytes)	N/A	N/A	15,000 Gb	0 GB archived in ECFS; working filesystem usage: 24,73

					TB on SCRATCH and 840,9 GB on HPCPERM.

Summary of project objectives (10 lines max)

The project investigates the predictability and representation of mesoscale eddies in the North Atlantic. It develops an object-based eddy detection, tracking and matching framework to evaluate ocean analyses and reanalyses, and in the next phase, ensemble forecasts, with the ultimate goal of extending the system to a global scale. The main objective is to quantify how model resolution, data assimilation and ensemble approaches affect eddy population, lifetime, amplitude, radius, trajectory and forecast skill. The project aims to provide not only an effective set of model forecasts, reanalyses, and ensemble outputs but also a comprehensive atlas of eddy physical characteristics. Satellite altimetry products, including AVISO DUACS and SWOT MIOST, are used as complementary reference dataset. The development of the validate framework will support NEMO-based experiments and probabilistic eddy-predictability diagnostics.

Summary of problems encountered (10 lines max)

The main difficulties during the first reporting period were linked to the large amount of daily multi-decadal data, the remapping of products on common grids, and the quality control of detection, tracking, matching-validation outputs. The verification metrics are sensitive to small and weak eddies close to the detection threshold, so several sensitivity tests on lifetime, amplitude and matching distance were required. The SWOT MIOST period is still short, and SWOT gridded products are not fully independent from conventional nadir altimetry. Therefore, the results must be interpreted as complementary rather than fully independent verification. For this reason, the first semester focused mainly on building a robust validation framework before starting the most expensive NEMO ensemble experiments.

……
……
……
……
……...

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

The next steps are to finalise the 30-year North-West Atlantic evaluation, complete the quality checks, and include GREP, SODA, GLORYS12V1, GIOPS and CIGAR in the same object-based framework. The aim is to extend the methodology over a climatological timescale to assess the temporal stability of ocean analyses and models, product improvements, the impact of new satellite observations, and the variability of key physical eddy parameters. A central objective will be to compare systems with different data assimilation schemes, including 3DVAR, Optimal Interpolation and ensemble-based methods. The analysis will also assess how eddy detection, tracking and matching skills change with different assimilation-window lengths and configuration parameters within similar DA schemes. This will help separate the effects of model resolution, DA methodology and specific DA settings on mesoscale eddy representation. The work will then be extended to global comparisons for 2020–2022 and to diagnostics such as POD/FAR maps, radius/amplitude statistics and hit-cost decomposition. These results will support a second manuscript on eddy representation in eddy-permitting and eddy-resolving reanalyses.

After this validation phase, the project will move towards NEMO ensemble and forecast experiments, using probabilistic and object-based metrics such as RMSE, POD and FAR to estimate mesoscale eddy predictability horizon.

……
……
……
……
……..……

List of publications/reports from the project with complete references

Mauriello, P., Smith, G. C., Storto, A., and Yang, C. (2026). *Quantitative Evaluation of Mesoscale Eddies in the North Atlantic Using Satellite Altimetry and Ocean Reanalyses*. Manuscript submitted/in revision.

Mauriello, P., Yang, C., Storto, A., Smith, G. C., Cipollone A., and collaborators (in preparation). *Evaluation of mesoscale eddies in an ensemble of ocean eddy-permitting and eddy-resolving reanalyses*.

……
……
……
……

Summary of results

During the first reporting period, the work focused on building and validating the eddy detection, tracking and verification framework that will be used for the predictability phase of the EMI R&D Project. The workflow processes daily sea-surface-height or absolute-dynamic-topography fields, remaps the products onto common grids, applies a 500 km high-pass Bessel filter to isolate mesoscale variability, detects cyclonic and anticyclonic eddies with py-eddy-tracker, and matches satellite and reanalysis eddies through a cost function based on amplitude, effective radius and centroid separation. This framework is essential before moving to forecast and ensemble experiments, in order to define the object-based diagnostics that are used to quantify eddy skill.

A first scientific outcome is the manuscript *Quantitative Evaluation of Mesoscale Eddies in the North Atlantic Using Satellite Altimetry and Ocean Reanalyses*. This study evaluates GLORYS12V1, at 1/12° resolution, and GLORYS2V4, at 1/4° resolution, both remapped onto AVISO DUACS grid (1/8°), against AVISO DUACS and SWOT MIOST Science over the North-West Atlantic during the period from 1 August 2023 to 1 May 2025. The comparison shows that GLORYS12V1 provides a better representation of mesoscale eddies than GLORYS2V4. In both the DUACS and SWOT comparisons, the Probability of Detection increases by more than 30% when moving from GLORYS2V4 to GLORYS12V1. The False Alarm Ratio also increases by about 10%, mainly because the higher-resolution reanalysis detects more small and weak eddies, some of which are close to the detection threshold. Overall, POD remains above 60% and reaches about 63% with SWOT, while FAR remains close to 20%. The comparison with SWOT MIOST Science provides useful additional information on the representation of fine-scale variability. SWOT-based diagnostics indicate a reduction in the total hit cost and in the amplitude error of matched eddies, suggesting better compatibility between high-resolution altimetry and eddy-resolving reanalyses. At the same time, these results must be interpreted with caution because the SWOT period is still short and gridded SWOT products are not fully independent from conventional nadir altimetry. Therefore, DUACS and SWOT are used here as complementary reference datasets rather than as fully independent validation products.

In parallel, the same methodology has been extended to a broader set of ocean reanalyses, including eddy-permitting and eddy-resolving systems. In addition to GLORYS12V1, GLORYS2V4, CGLOR and ORAS5, the analysis includes GIOPS, CIGAR and SODA. GIOPS is particularly useful because it has the same nominal spatial resolution as GLORYS2V4, namely 1/4°, and uses a data assimilation approach that is very similar to GLORYS2V4. This makes it possible to evaluate how relatively small differences in data assimilation configuration can affect the detection, tracking and matching of mesoscale eddies. CIGAR, a CNR global ocean reanalysis, is also included. Since it uses a 3DVAR data assimilation scheme, similarly to the CGLOR reanalysis from CMCC, it allows us to assess differences between two systems with comparable assimilation approaches but different model configurations and production frameworks. Finally, SODA is included because it uses a different data assimilation method, based on Optimal Interpolation. This provides an additional comparison point for evaluating how different assimilation strategies affect the representation of mesoscale eddies.

Preliminary results for the 1993–1995 pilot period show that the framework is able to discriminate between products with different resolutions and assimilation characteristics. GLORYS12V1 and GLORYS2V4 generally show better eddy matching skill than smoother eddy-permitting products such as ORAS5, CGLORV8, GIOPS, particularly in terms of detection capability, generation of false alarm eddies, and centroid-distance errors. The inclusion of GIOPS, CIGAR and SODA extends this comparison and allows the project to evaluate, across different spatial and temporal scales, how the capacity to detect, track and represent mesoscale eddies changes when the data assimilation scheme, model resolution and reanalysis configuration are modified.

The analysis has also started to move towards a climatological timescale, with preliminary multi-decadal diagnostics for the North-West Atlantic over 1993–2022. This extension is important because it allows the project to evaluate the temporal stability of reanalysis performance, the impact of product improvements and observing-system changes, including new satellite observations, and the long-term variability of physical eddy parameters such as radius, amplitude, lifetime and propagation. In addition, this climatological framework makes it possible to assess how the results change depending on the characteristics of the data assimilation system, including both different assimilation

schemes and variations in the parameters of the same scheme. This is particularly relevant for understanding whether changes in eddy detection, tracking and matching skill are mainly controlled by model resolution, by the type of assimilation method, or by specific choices within a given assimilation configuration. This climatological evaluation will provide the basis for a second manuscript on eddy representation in an ensemble of eddy-permitting and eddy-resolving reanalyses.

The SBU usage for the first semester of 2026 was relatively limited, with 5,227 SBU used between 1 January and 30 June 2026. This reflects the fact that the first phase of the project was mainly devoted to diagnostic development, quality control, remapping, and validation of the eddy-verification framework using existing reanalysis and altimetry datasets. The more computationally expensive NEMO ensemble and forecast experiments are planned for the next phase, after the object-based verification workflow has been fully consolidated.

Overall, the first six months of the project have produced a tested eddy-verification framework, one submitted/in-revision manuscript, and preliminary results for a second multi-system and multi-decadal evaluation study. The main scientific outcome of this phase is the identification of both the benefits and limitations of higher-resolution ocean reanalyses for mesoscale eddy representation. The extension to products with different data assimilation schemes, including GIOPS, CIGAR and SODA, further strengthens the project by allowing a more systematic assessment of how model resolution and assimilation strategy influence mesoscale eddy detection, tracking and future predictability estimates. A third study is also being developed, focused more directly on the predictability of mesoscale eddies. In this future work, the verification methodologies developed in the first two studies will be adapted to compare forecast products, such as GEPS (Global Ensemble Prediction System, from ECCC), with AI-based ocean prediction systems and satellite-altimetry observations. This will allow the project to assess how well different forecasting approaches can predict the position, intensity, lifetime and evolution of mesoscale eddies, following the broader benchmarking philosophy of initiatives such as OceanBench, which evaluates ocean forecasting systems against reference analyses and observations using a set of forecast-quality metrics.
……