SPECIAL PROJECT FINAL REPORT

All the following mandatory information needs to be provided.

Project Title:	NUMERICAL INVESTIGSTION OF CIRCULATION CHANGES IN THE NORTH WESTERN MEDITERRENEAN THROUGHT DONWSCALING CMEMS REANALYSIS DATA
Computer Project Account:	SPITBRAN
Start Year - End Year:	2022 – 2024
Principal Investigator(s)	Carlo Brandini
Affiliation/Address:	ISMAR - Institute of Marine Sciences - National Research Council (CNR) ; Consorzio LaMMA (Environmental Monitoring and Modelling Laboratory)
Other Researchers (Name/Affiliation):	Fontana Clément - Istituto Nazionale di Oceanografia e di Geofisica Sperimentale – (OGS) / CONSORZIO LAMMA Maria Fattorini – ISMAR - CNR ; Consorzio LaMMA Sara Polselli - ISMAR - CNR ; Consorzio LaMMA

June 2024

The following should cover the entire project duration.

Summary of project objectives

The objective of this project is to perform a high-resolution downscaling of the circulation and biogeochemical reanalysis data (available through CMEMS) for the period 1987-2021 (physics) and 1999-2021 (biogeochemistry) over the North Western Mediterranean. Circulation and biogeochemistry is modelled with the non-hydrostatic MITgcm model (Adcroft et al. 2018) coupled with the BFM biogeochemistry model (Vichi et al. 2015) through the BFMcoupler (Cossarini et al 2017), while atmospheric forcing data were produced in a previous special project for the dynamical downscaling of the ERA5 reanalysis data (Vannucchi et al. 2021). The comparison of model results with multiple observations, such as HF radars, satellite data, temperature and salinity profiles, allows us to validate model performance. Downscaled dynamics is employed to characterize long-term circulation trends in the coastal areas, and their impact on biogeochemical fluxes, to better understand the effects of climate change on coastal circulation and biodiversity.

Summary of problems encountered

Initially, using the Atos infrastructure was not straightforward, although it becomes easier with experience. However, the ticketing system in place to address issues is efficient and fast, and the staff from ECMWF was very helpful during our experience using the Atos cluster.

The connection through Teleport and the double authentication procedure present a constraint, although we understand the high security requirements. In any case, it makes it impossible to connect without an X server to open a browser. On a virtual machine on a personal computer, one of our users had to regenerate an RSA key for every terminal device; this is a rigid constraint, and we have not yet fully understood why this is necessary.

The transfer speed is also rather slow, and we were never able to transfer at a speed higher than 8 MB/s, which does not really meet current standards. Furthermore, data synchronization is sometimes hard to handle. Indeed, if we plan a data transfer during the night, it generally fails as the system requires double authentication. The problem is that our laboratory network is not open 24/7, making it difficult to transfer data directly from Atos to our system. So far, we have always been able to find solutions and manage the situation, but for a team with no prior experience on Atos, it is not easy to set up an optimal procedure.

The project experienced some delays because our colleague who was in charge of leading the work left our team for another position, so we had to find new people to accomplish the task. This was not easy, as the project requires very specific skills and experience. Nevertheless, new people have been assigned to the project, and the situation is now resolved. Our modeling system is now up, and we will be able to meet every deadline by the end of the year. We will also be able to achieve results before the deadline, although the quantity of data produced compared to the SBUs required was initially overestimated (and therefore the SBUs underestimated). As a result, it is necessary to review the number of years to analyze with the available SBUs. At the same time, we will propose a new Special Project (SP), which, with the greater experience acquired, can be better focused and defined.

Experience with the Special Project framework

This was my second experience as a Principal Investigator for a Special Project, and I found the administrative aspects to be well-defined easy-to-handle. The presentation of the proposal requires an absolutely manageable effort. As such, I am very satisfied with the Special Project framework overall. The administrative management, requiring just one report per year, is sufficiently light, allowing us to focus more on technical-scientific work and results rather than on administrative tasks.
Any management issues we encountered were due to our internal organization during a difficult transition period, which unfortunately coincided with the shift to the Atos system. However, these were certainly not problems caused by the Special Project framework.

Summary of results

In this special project, we use the physical oceanographic model MIT Global Circulation Model coupled by the Biogeochemical Flux Model to perform simulations of the ocean state in the Pelagos Sanctuary (North Western Mediterranean Sea). The model resolution is of 1/128° (784 x 336 grid cells) for 61 vertical levels. Initially, the model was set up to run in operational mode in the framework of the SHAREMED project.
https://sharemed.interreg-med.eu
For what concerns the SHAREMED project, the project context and the adopted modelling framework can be found in project deliverables like these:
https://sharemed.interreg-med.eu/what-we-achieve/deliverables-database/detail/?tx_elibrary_pi1%5Blivrable%5D=16407&tx_elibrary_pi1%5Baction%5D=show&tx_elibrary_pi1%5Bcontroller%5D=Frontend%5CLivrable&cHash=8acfe83cab0a4015906d427fce4b7255
https://sharemed.interreg-med.eu/what-we-achieve/deliverables-database/detail/?tx_elibrary_pi1%5Blivrable%5D=16425&tx_elibrary_pi1%5Baction%5D=show&tx_elibrary_pi1%5Bcontroller%5D=Frontend%5CLivrable&cHash=4b424c3125486090b1eb24487fa8f585

To adopt this modelling framework, we had to change several things in order to run the model for the specific purpose of the special project. In particular, some forcing parameters needed to run the coupled physical-biogeochemical models were missed for the previous downscaled dataset (i.e. SPITBRAN SP 2018-2021, using MOLOCH-ERA5).
Hence, the atmospheric forcings were changed to use the CERRA dataset (https://climate.copernicus.eu/copernicus-regional-reanalysis-europe-cerra) available from 1984 to 2021. In addition to the difficulty to process data to the needs of our model (variable

equivalence), we had to perform several tests to ensure that results were consistent with the previous ones. Some fine tuning was needed to obtain results fitting the data: for example, the model was initially overestimating the sea surface temperature when compared to satellite data. This issue was correctly addressed and results are now really close to the ground truth.

In addition, we had to change the dataset used for boundary conditions moving from using a forecast frame to using a reanalysis frame. The problem here was that the CMEMS API, in the meantime, had been completely rewritten with regards to the initial set up, so all the scripts had to be changed accordingly.

We were also forced to collect data from several sources to provide the model with realistic river runoff data, which is a very tedious task as data portals are not homogenous even with respect to language, being information given in both French and Italian.

A first run was conducted for the period March-April 2015. This period was chosen as it is related to some previous work we performed on the topic of whale behaviour. The model was spun up for 3 weeks and results presented hereafter are considered stable conditions for April 2015.

Figure 1 shows the bathymetry and the boundaries of the model used in this project.

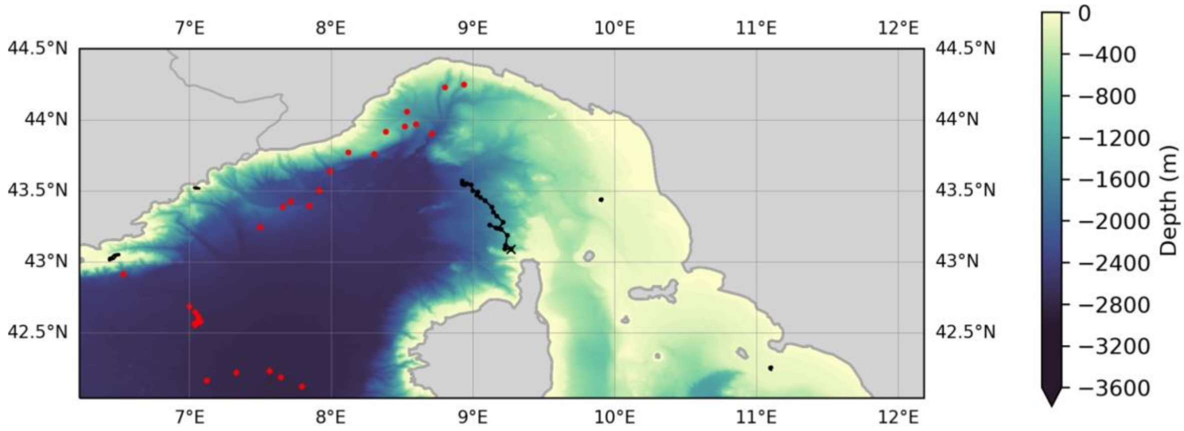

Figure 1: Bathymetry and boundaries used. Red dots show the position of Argo profiles used for validation. Black points show the trajectory of an eddy during the modelled period.

Figure 2 shows an example of model sea surface temperature (SST, to the left) compared to satellite data (CMEMS product, to the right). We can see that most of the global dynamics is well reproduced, and the modelled SST range is close to the satellite one.

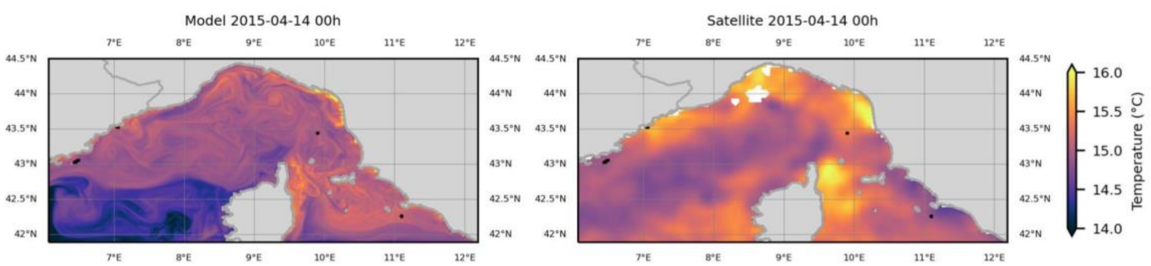

Figure 2: Modelled sea surface temperature (to the left), satellite-estimated sea surface temperature (to the

right) on April 14th 2015.

Figure 3 shows the evolution of the global mean averaged SST comparing the model evolution to the satellite one (to the left; model as thick line and data as dashed line). The global evolution is well reproduced and the model is able to adapt to the warming normally occurring from March to April. Some discrepancies can appear, but they seem to be related to bias in the data. Indeed, the data product used is a multi-sensors combination so the global picture can be influenced by the daily availability of data from different sensors. As an example, it is really intriguing to see a shift of 1°C in satellite data on April 8th, while the signal is supposed to be more stable in such a short period.
Figure 3 (to the right) presents the same comparison but for satellite-estimated sea chlorophyll concentration. Once again here, some divergences can appear on a daily basis between model and data, but globally the general dynamics of the period is well described.

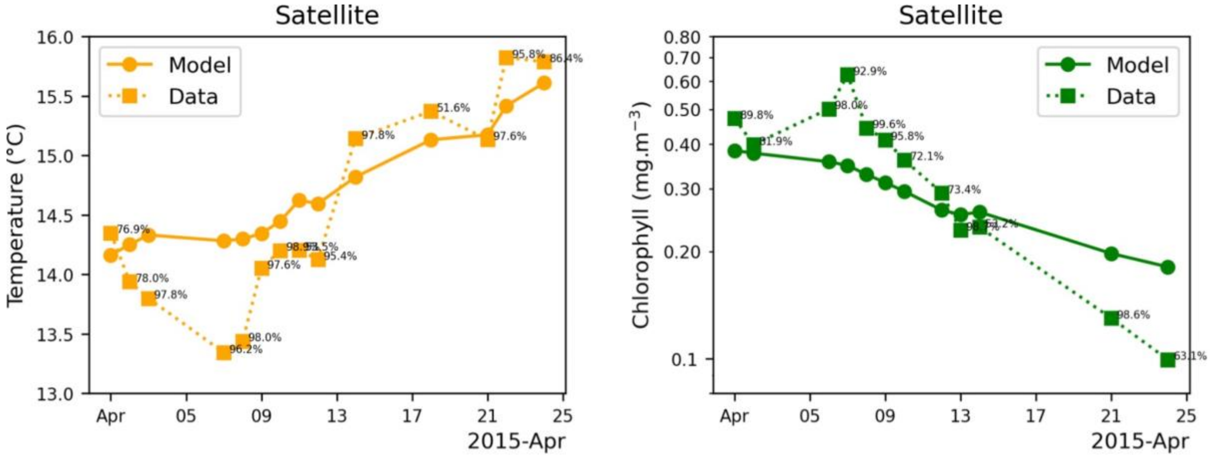

Figure 3: Comparison between mean spatially averaged satellite-estimated sea surface temperature and modelled one (left). Comparison between mean spatially averaged satellite-estimated surface chlorophyll concentration and modelled one (right).

Figure 4 shows an example of comparison between modelled and satellite estimated chlorophyll concentration, showing once again that results are quite satisfying and many spatial structures well described.

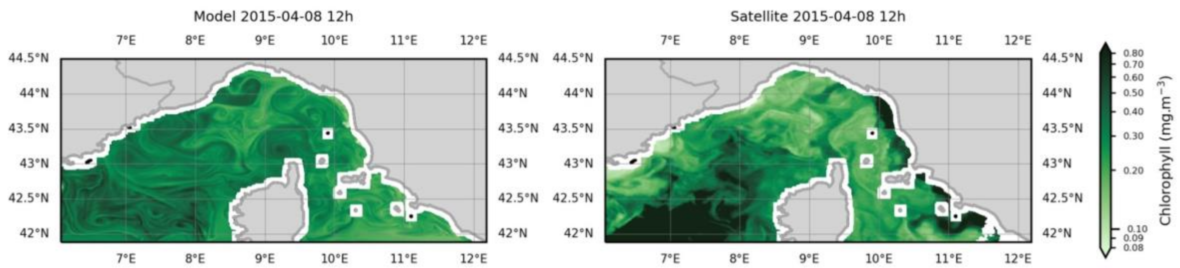

Figure 4: Modelled sea surface chlorophyll concentration (left), satellite-estimated sea surface temperature (right) on April 8th 2015.

Figure 5 shows the mean error in temperature (to the left) and salinity (to the right) when comparing in-depth modelled state variables with 30 Argo float profiles available for the period. Errors are not larger than 0.4°C in the surface mixed layer which is a really satisfying agreement considering the high resolution of the model and the noise induced by the mesoscale (i.e. fine scale structures) in this turbulent environment due to sharp topography. Under 50 meters depth, the mean error on the temperature does not overcome 0.2°C.

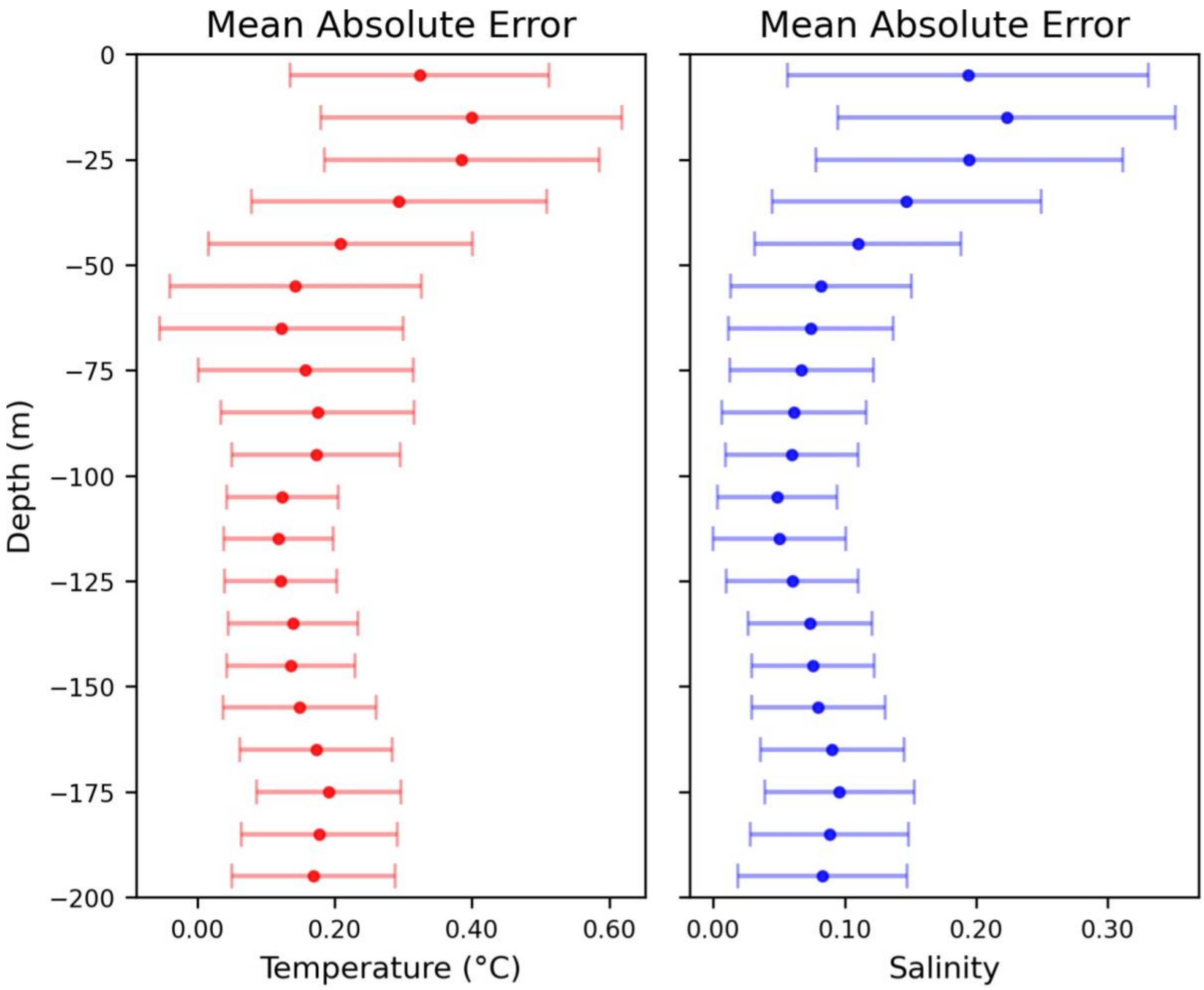

Figure 5: Mean difference between temperature (left) and salinity (right) between model and 30 Argo float profiles, binned at 10 meters from surface

Figure 6 shows a modelled map of zooplankton and the trajectory of a fin whale in the domain for the same date. It is really interesting to see that an eddy transporting zooplankton (i.e. the primary feeding sources of fin whales) coincides with the trajectory of the whale. This could indicate that our model is accurate enough to define the preferential feeding area of whales, even though these results will have to be refined with further data.

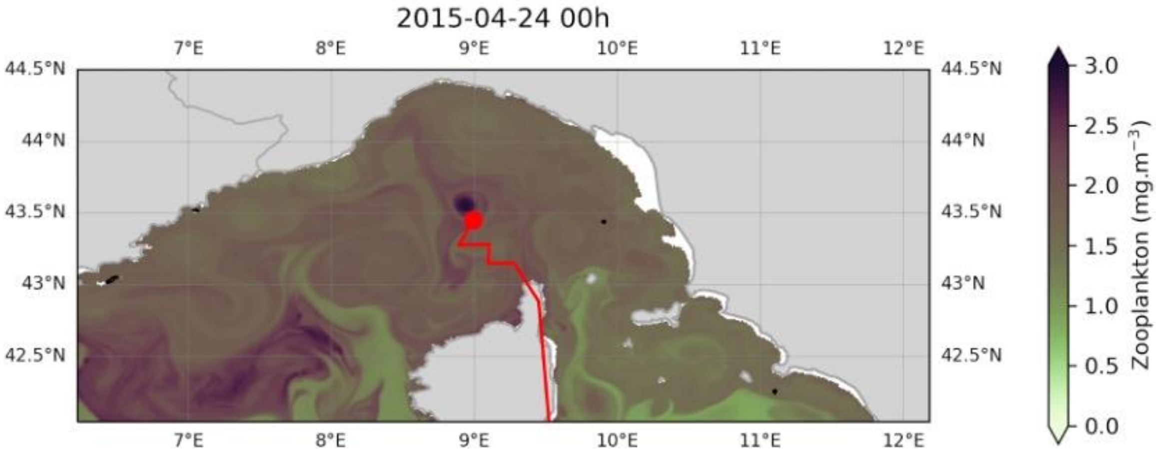

Figure 6: Modelled zooplankton concentration on April 24th 2015. Trajectory of a fin whale as red dot and line.

List of publications/reports from the project with complete references

A publication is currently under preparation regarding the results presented above.
These results will also be presented at the OceanPredict symposium, taking place from the 18th to the 22th of November 2024 in Paris (https://www.oceanpredict24.org/).

Future plans

(Please let us know of any imminent plans regarding a continuation of this research activity, in particular if they are linked to another/new Special Project.)

So far, about 10% of SBUs were used on a total of 10,000,000 allocated for this special project in 2024. In addition to the test case presented in the results section of this document, other experiments are on-going to simulate different test cases and validate the model results in different scenarios (i.e. different seasonality, extreme events, etc).
Once the model will be validated with enough confidence, we will be able to run longer simulations (8-10 years) and submit them to the research community for analysis.
In particular these results will be part of what is expected by the SeaSteMar project (PC IFM 21-27, project stated in March 2024 and lasting 3 years), in which it is expected the availability of 10 years data from high-resolution coupled physical-biogeochemical models, starting from the period 2015-2024 (the last 10 years).
Estimation on the use of available HPC resources, for the domain shown in Fig. 1, was done and it is 2500 SBUs/day simulated, meaning that the computational resources still available will be sufficient for run 6-7 years (including the spin-up periods) by the end of 2024, including the need for running some specific case studies for further cal-val of model parameters.
Considering this timeline for the special project, all SBUs will be used in due time by the end of the year 2024.
A possible request for additional resources will be evaluated in the next months, as a 'Late request for a Special Project (2024-2026)' , based on the ongoing achievements.