

EVIDENCE-BASED EVOLUTION OF THE COPERNICUS MARINE SERVICE THROUGH OPEN SCIENCE PRACTICES







Julien Le Sommer

with the IMMERSE project consortium

This project is funded by the European Union







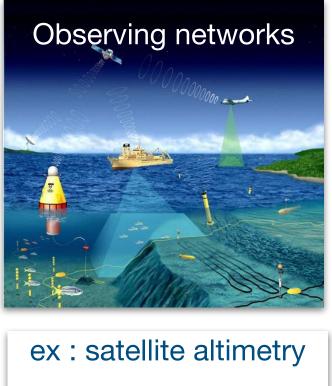






Continuous evolution of the Copernicus Marine Service



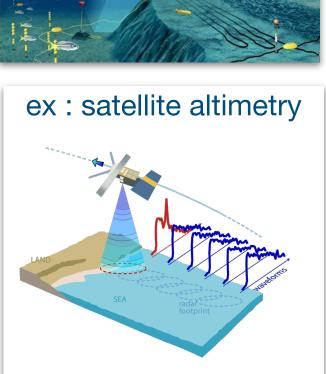


"Model-based" products

ex : (re-)analyses, forecast

"Data-based" products

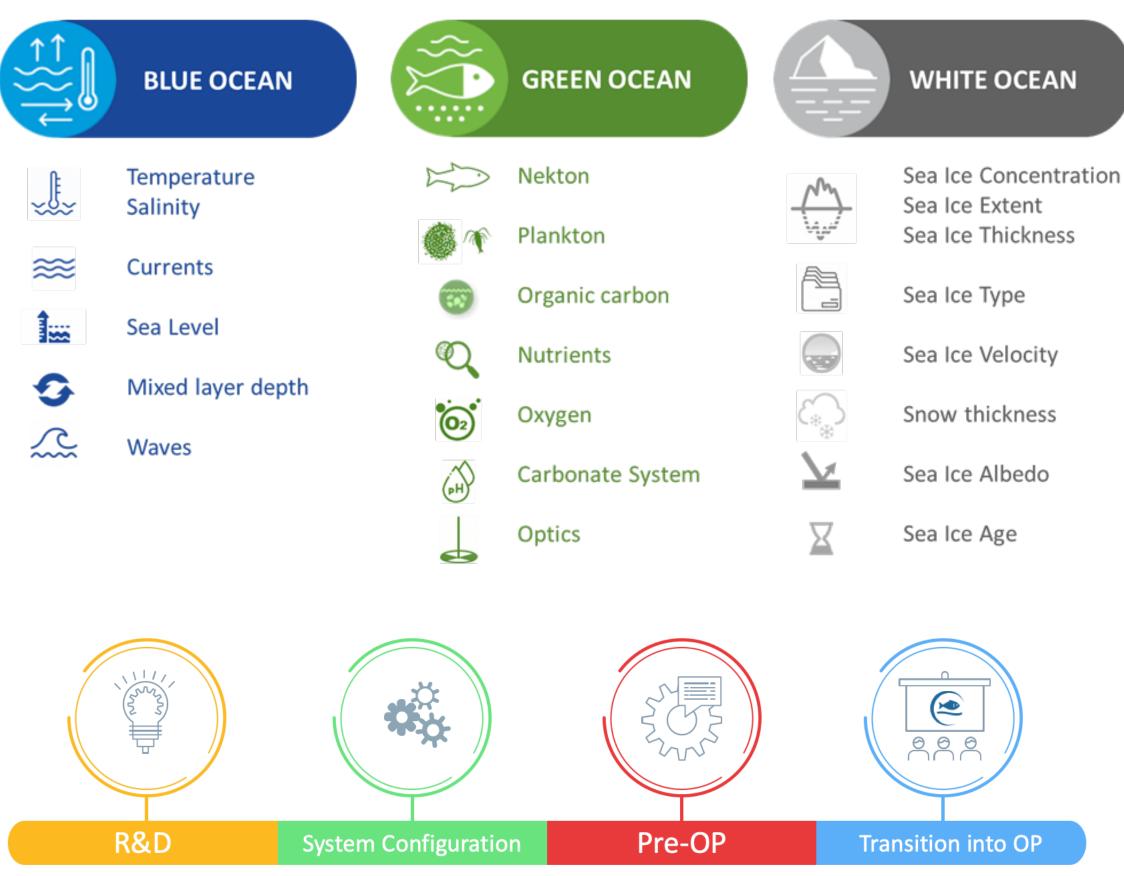
ex : SSH maps, GlobCurrent



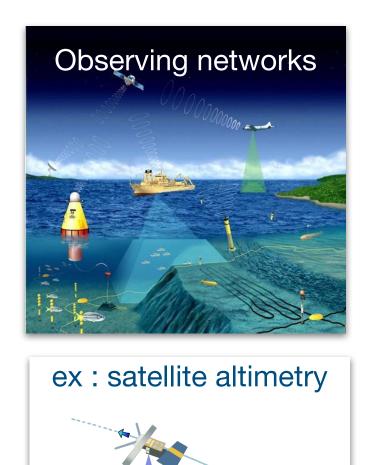




Continuous evolution of the Copernicus Marine Service



CMEMS products are continuously improved (users, science) Transition from research to operation is a key undertaking



"Model-based" products

ex : (re-)analyses, forecast

"Data-based" products

ex : SSH maps, GlobCurrent





evidence-based



open science

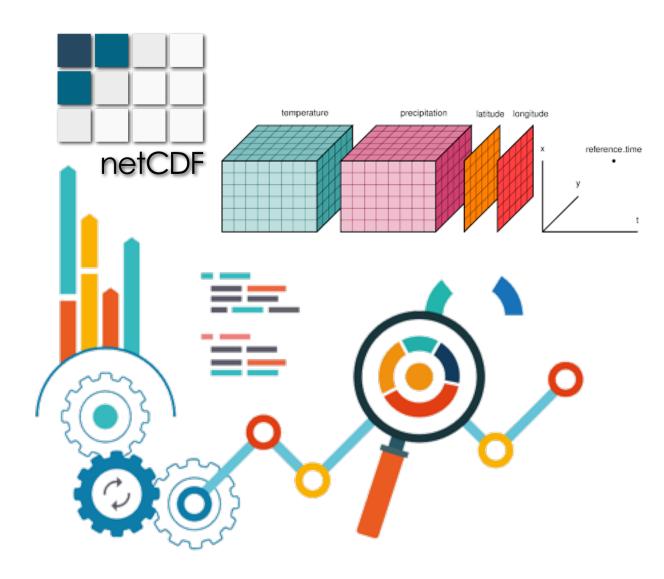
Why : product quality, trust, community, Key : time-to-transition

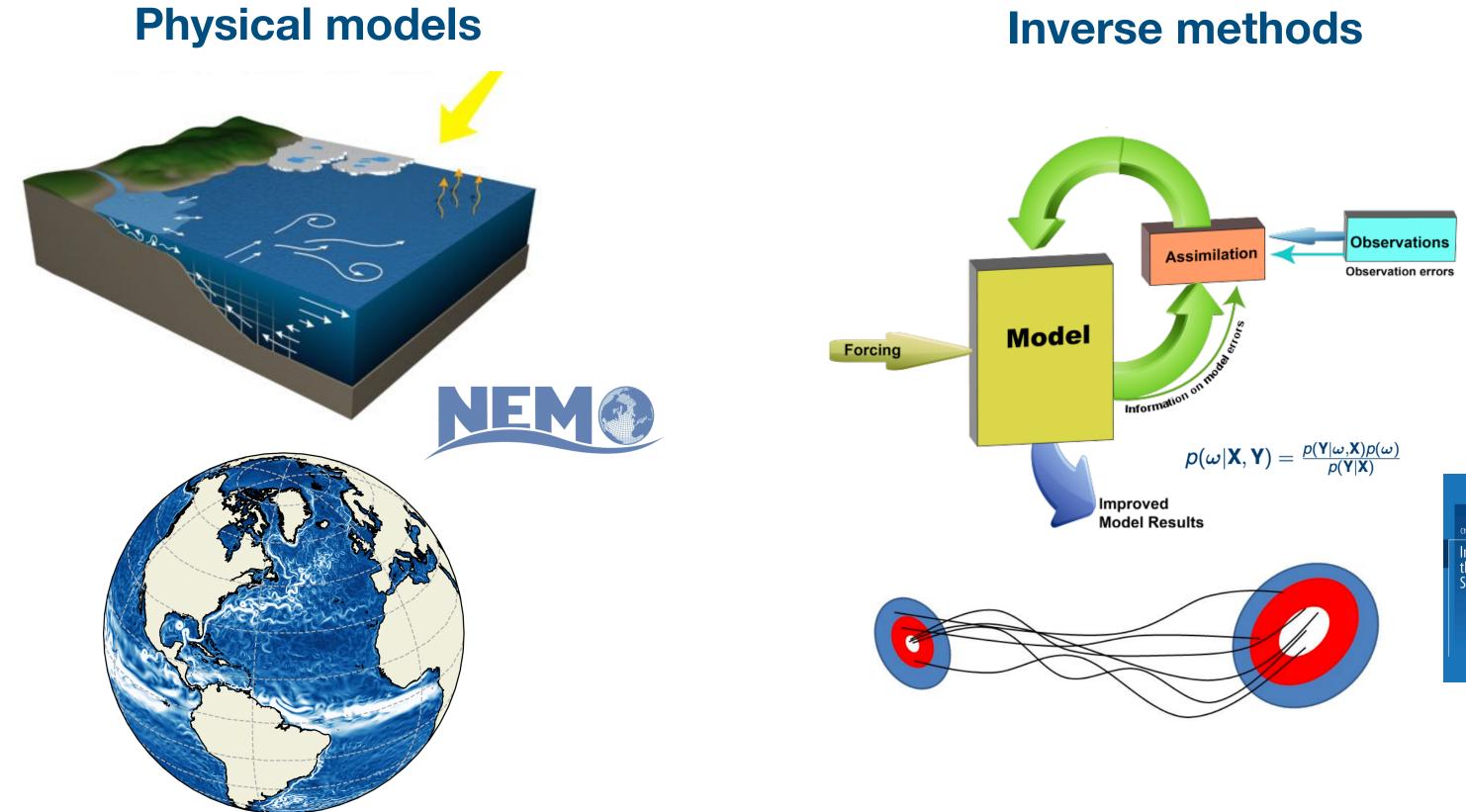


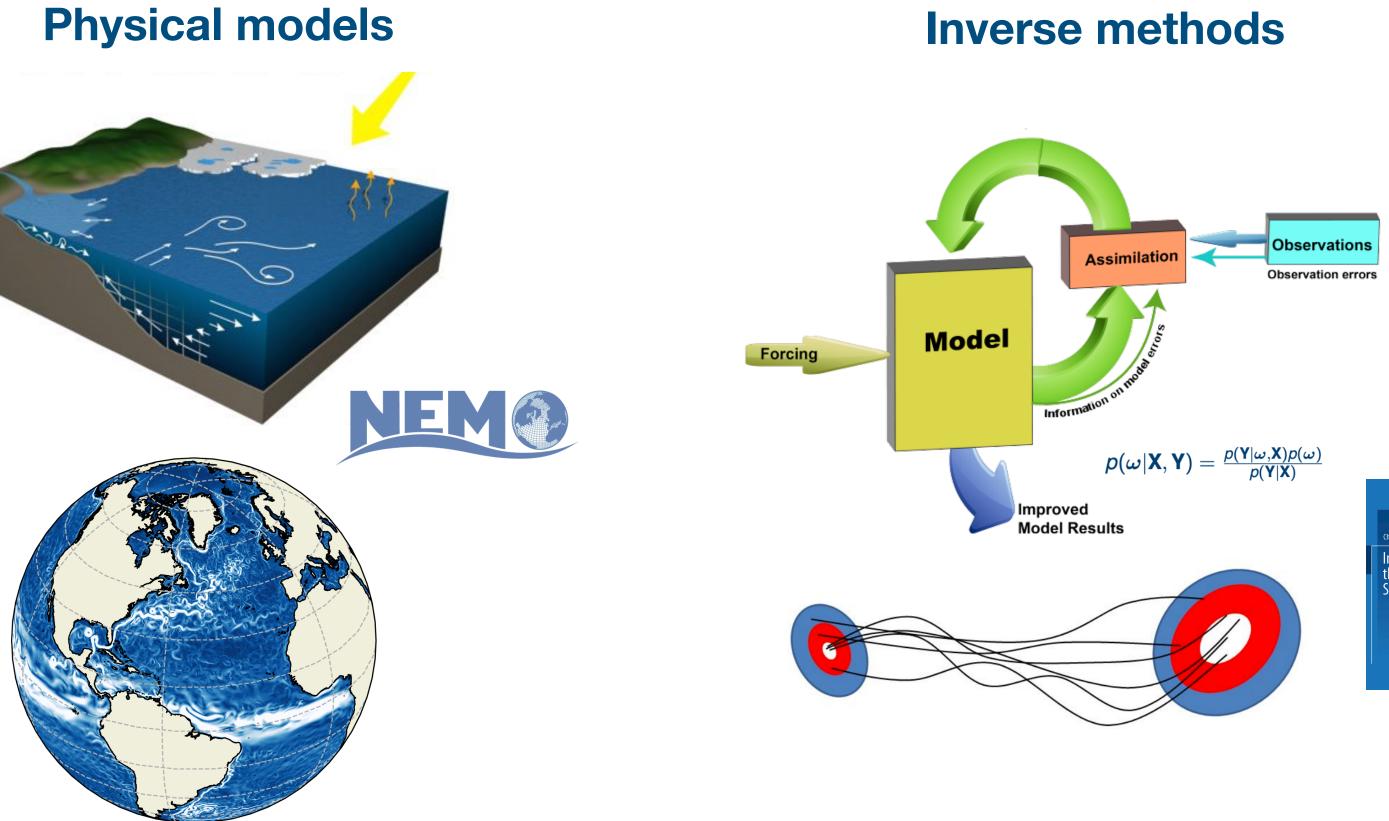


Software as the service underlying basis

Data analytics



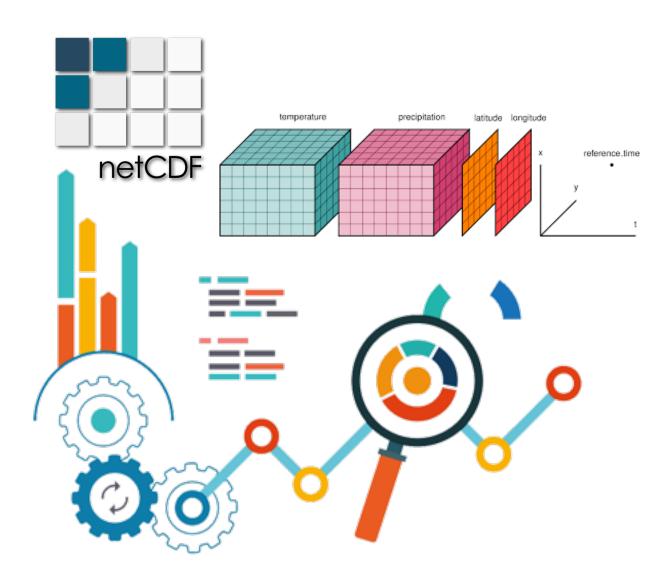


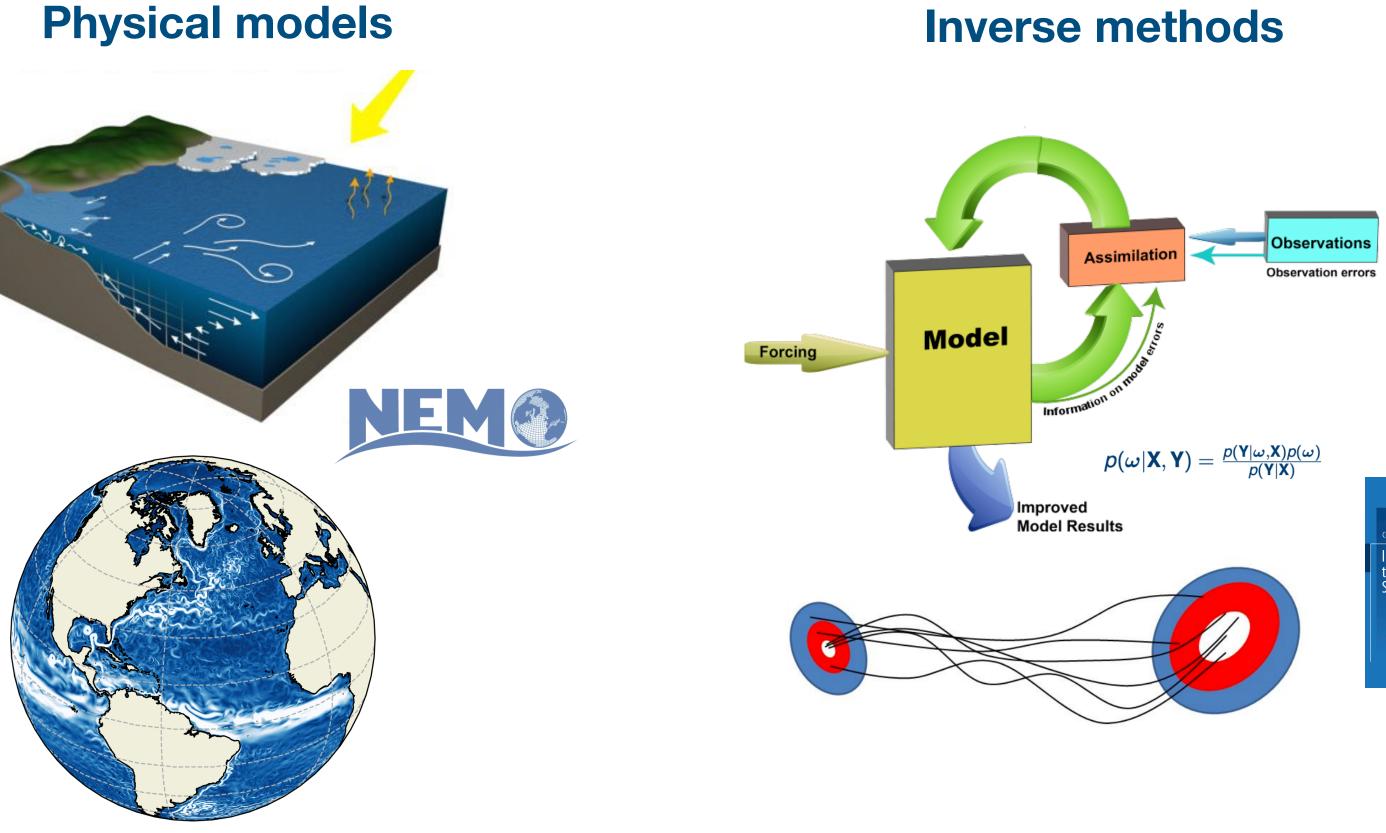




Software as the service underlying basis

Data analytics

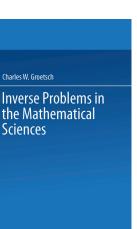




The service heavily relies on software developed by the community Codes and algorithms summarise/encode our collective knowledge







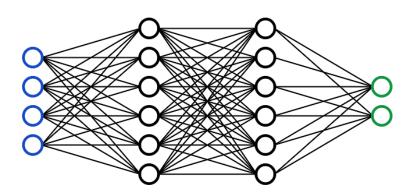
Improving further how we develop codes and algorithms





A strong legacy of software / data protocols and standards ex : netcdf, version control, evaluation chains, science papers...

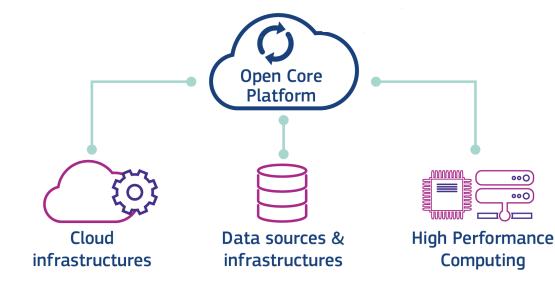
Here : describe recent attempts to open further our protocols



Trainable algorithms



Increasing complexity



Digital twins of the Earth



protocols & standards

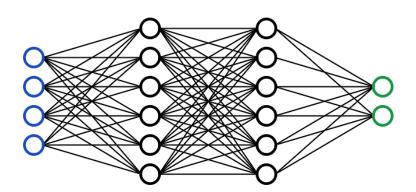
Improving further how we develop codes and algorithms





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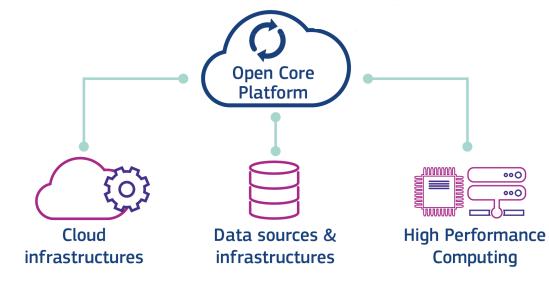
Here : describe recent attempts to open further our protocols



Trainable algorithms



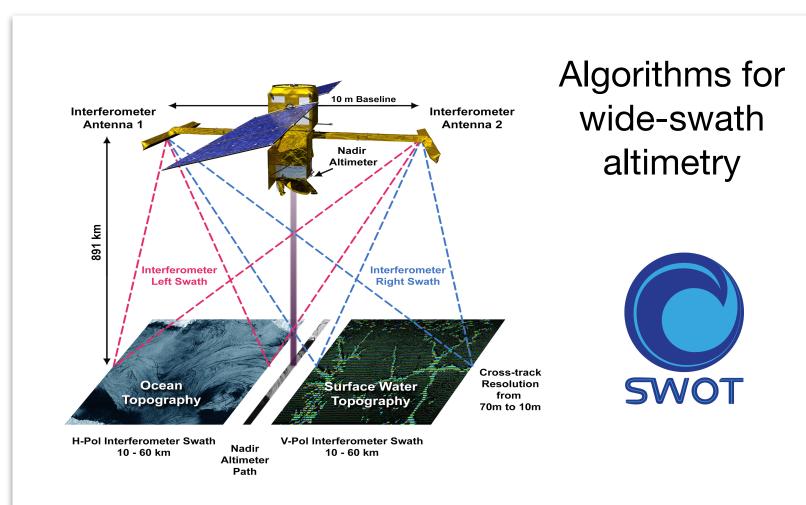
Increasing complexity

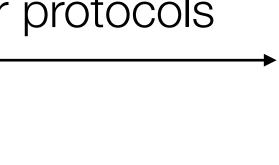


Digital twins of the Earth



protocols & standards







Development of the NEMO model (cf v4.2)

IMPROVING OCEAN MODELS FOR THE COPERNICUS PROGRAMME



Improving NEMO ocean/sea-ice model development workflow



NEMO 4.2 Official Release in March 2022 (reference release)

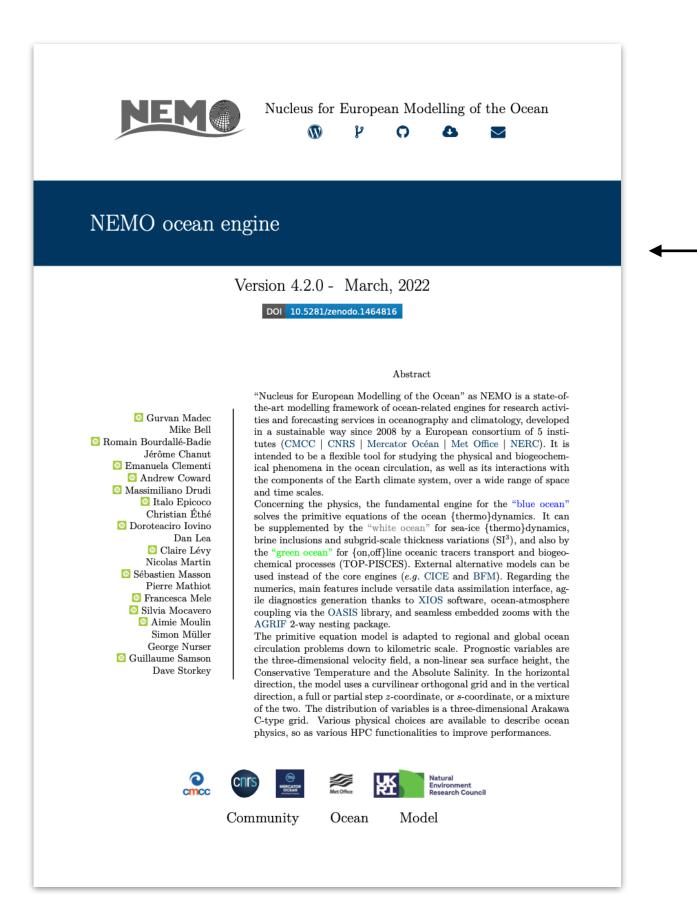
kernel (time-stepping), HPC, processes (k-scale)

https://doi.org/10.5281/zenodo.6334656



Will be used for NRT product in CMEMS forecasting centers by 2024

Improving NEMO ocean/sea-ice model development workflow



NEMO 4.2 Offic in March 2022 (refe

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Will be used for in CMEMS forecast

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https://forge.nemo-ocean.

https://doi.org/10.5281/zenodo.6334656



All the <u>communications</u>, including discussion threads, development branches are <u>now open</u> without registration

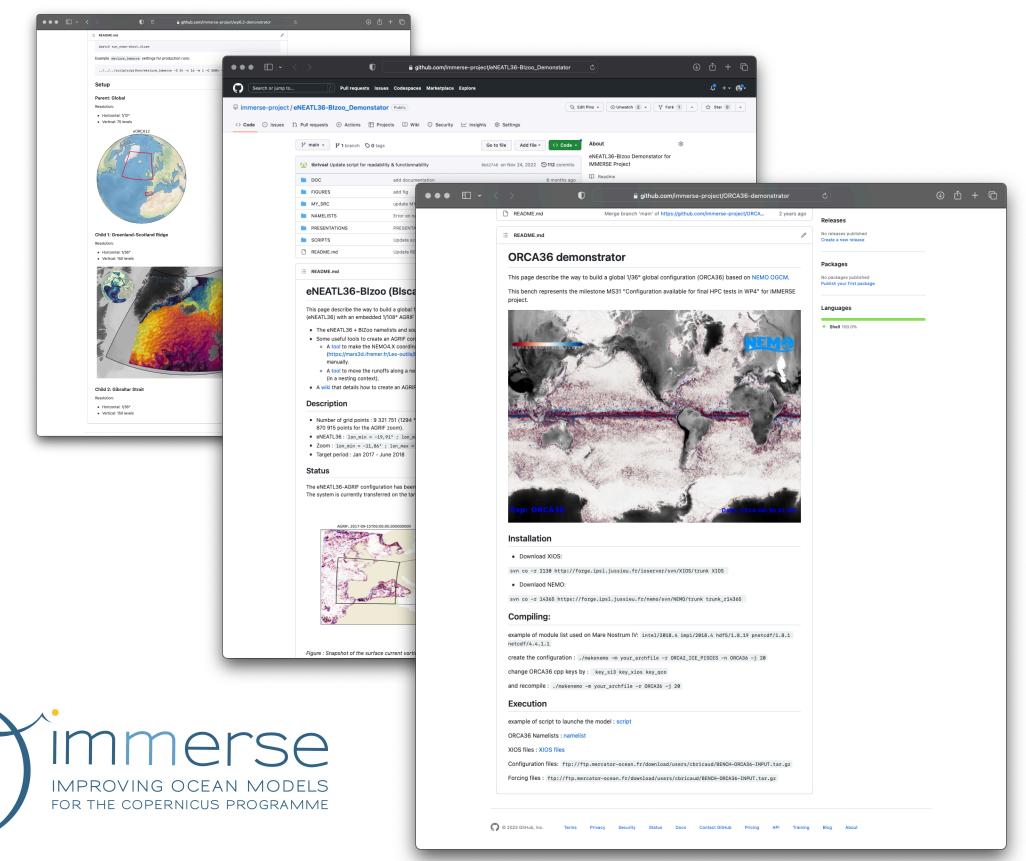
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https://forge.nemo-ocean.eu/nemo/nemo





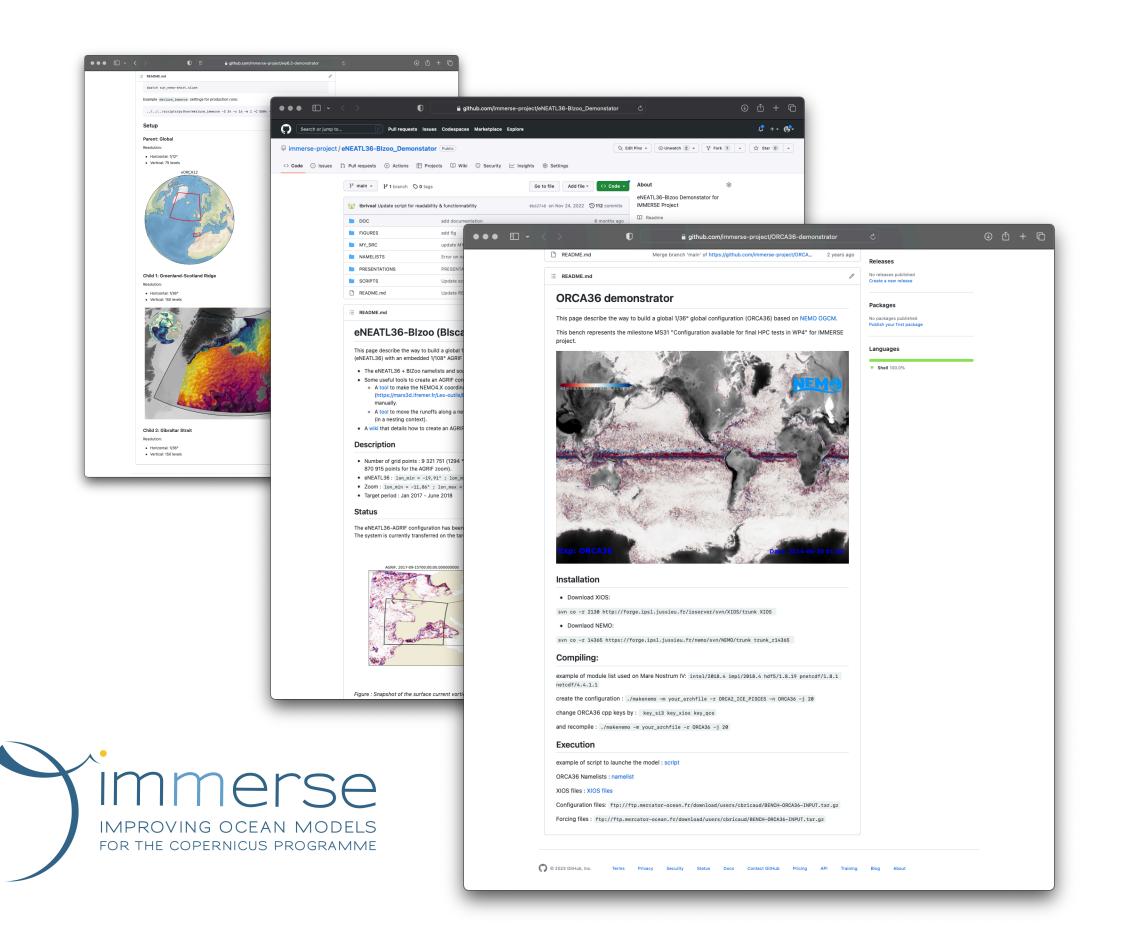
Better sharing model experiments and configurations



https://github.com/immerse-project/

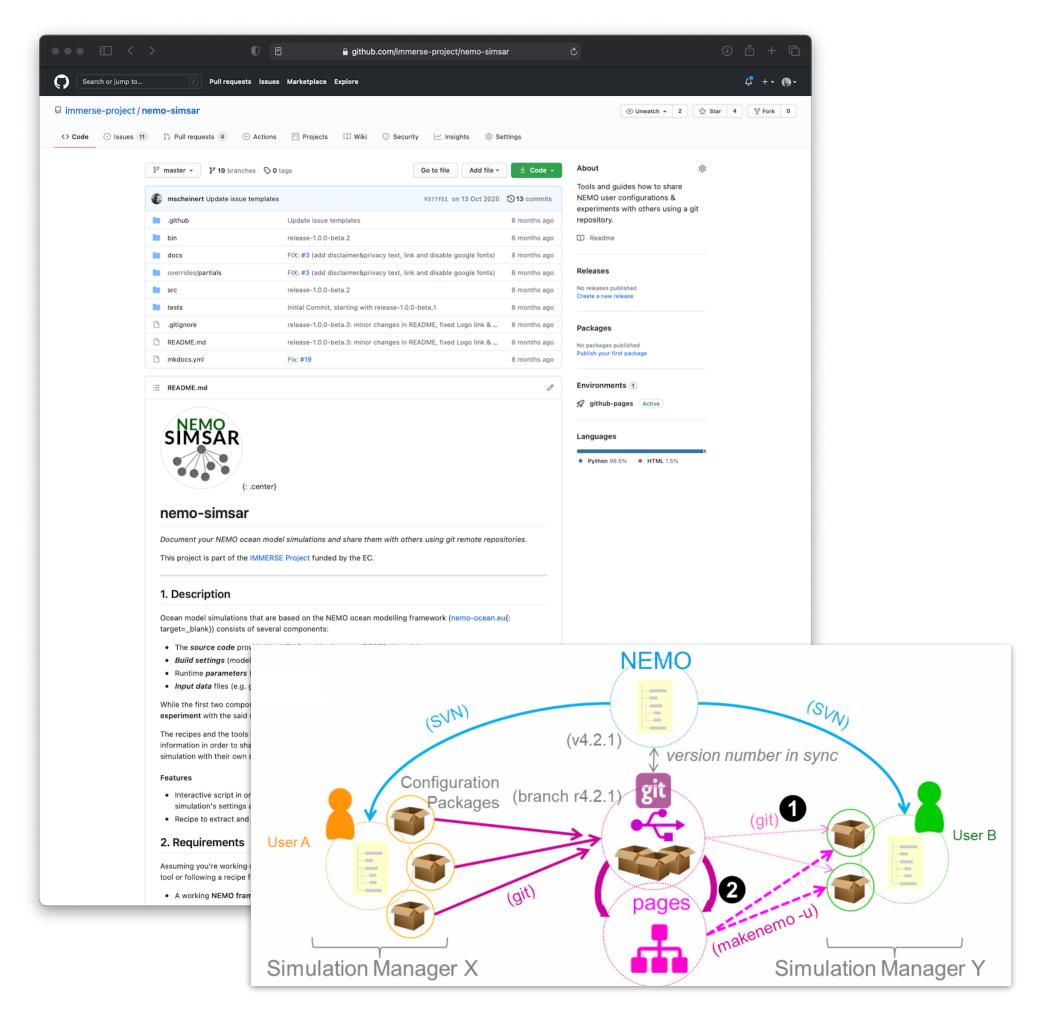
A series of model configurations prefiguring future k-scale CMEMS models

Better sharing model experiments and configurations



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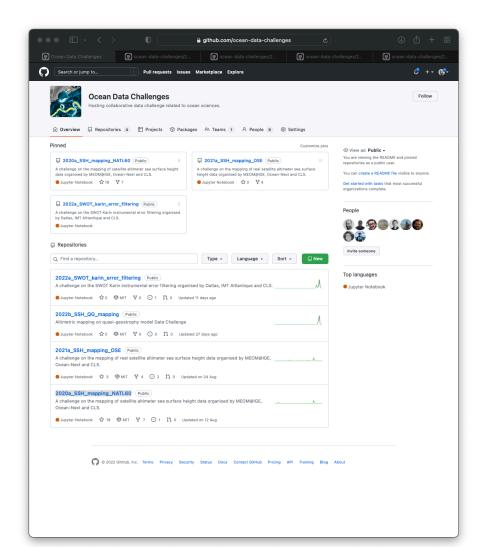
A series of model configurations prefiguring future k-scale CMEMS models



https://immerse-ocean.eu/nemo-simsar/

A prototype tool for documenting and sharing NEMO model experiments

Systematic assessment of altimeter data treatment algorithms



Collaborative data-challenges

- problem description + baseline

Image: Image:

- data, metrics (with codes)
- tools for collaboration and papers

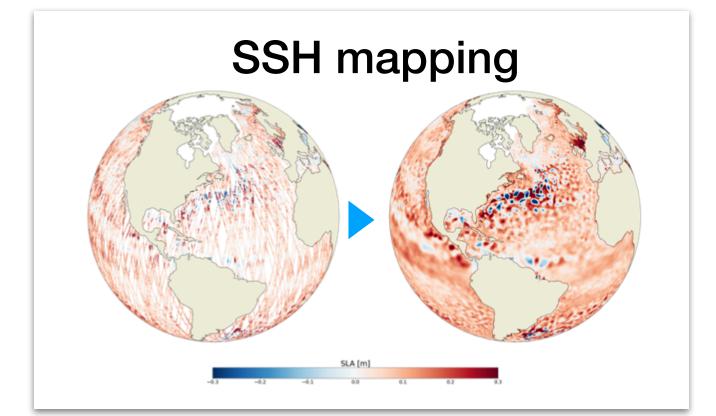
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see : <u>https://github.com/ocean-data-challenges/</u>

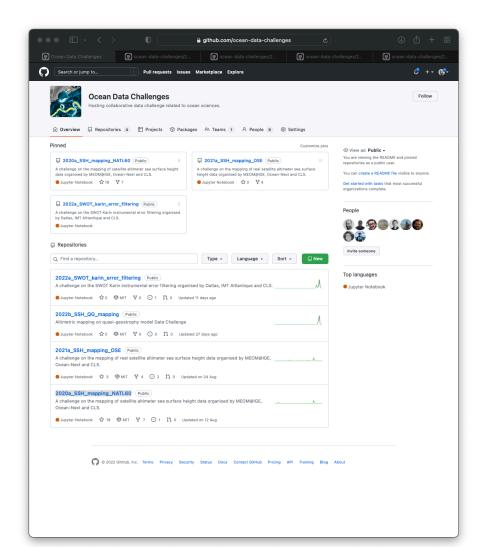




bs data



Systematic assessment of altimeter data treatment algorithms



Collaborative data-challenges

- problem description + baseline

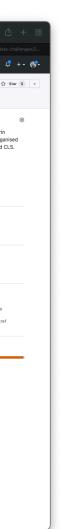
github.com/ocean-data-challenges/2022a_SWOT_kar

- data, metrics (with codes)
- tools for collaboration and papers

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This repository contains codes and sample notebooks for downloading	and processing the SSH mapping data		Alt	imetric QG ma	pping			CODETTIONS OF MERCATOR COLLOS		
challenge.		Contributors 6							Mit Abertagen Mitte States Mitte	
The quickstart can be run online by clicking here: 🧐 launch binder		🚯 🗘 🥮 🕲 🚯		🖌 🔘 🖉			itext & Motiv	vation		
Motivation										
		Languages		des and sample notebooks for downloading	and processing the SSH QG mapping			ea level SWOT products are very much expected tions which will make them an unprecedented L3		
The goal is to investigate how to best reconstruct sequences of Sea Su satellite altimetry observations. This data challenge follows an Observa		Jupyter Notebook 100.0%	ita challenge.					r be contaminated by instrumental and geophysi z, 2018). In order to be able to observe front, me		
framework: "Real" full SSH are from a numerical simulation with a reali- model: the reference simulation. Satellite observations are simulated b			. Context and	motivation			WOT data will req	uire specific processing. Also, these errors are ex	pected to strongly pollute the first	
based on realistic orbits of past, existing or future altimetry satellites.	A baseline reconstruction method is							of the SSH data which are used for the computa able to remove the SWOT errors will be of signific		
provided (see below) and the practical goal of the challenge is to beat described below and in Jupyter notebooks.	this baseline according to scores also			ping challenges have been proposed to the of this simplified altimetric mapping data ch				ace currents and vertical mixing.		
				nunities to play and bring their outside knowl			WOT errors are e	xpected to generate noises that are both correlat	ed on the swath and spatially	
Reference simulation			eneral goal							
The reference simulation is the NATL60 simulation based on the NEMC doi:10.1029/2019JC015827). The simulation is run without tidal forcing			· ·	······ · · · · · · · · · · · · · · · ·	for height (COL) and (
			itellite altimetric observati	ow to best reconstruct sequences of sea sur ions. The end goal is to have efficient metho	ds that are able to extrapolate					
Observations				(in time and space) satellite data in order to this OSSE experimental context i.e. when						_ /
The SSH observations include simulations of Topex-Poseidon, Jason 1, altimeter data. This nadir altimeters constellation was operating during				he methods' performances are assessed by				mode	el data	ว /
considered as a historical optimal constellation in terms of spatio-temp simulates the addition of SWOT to this reference constellation. No obs	ooral coverage. The data challenge								JI UUU	u /
simulates the addition of SWOT to this reference constellation. No obs challenge.	ervation erfor is considered in this									
Data sequence and use										

see : <u>https://github.com/ocean-data-challenges/</u>



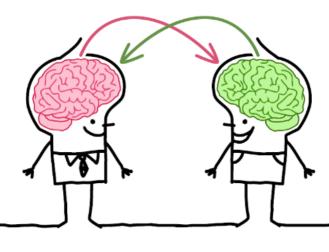


bs data

Leaderbo	ard					
Method	μ(RMSE)	σ(RMSE)	λx (degree)	λt (days)	Notes	Reference
baseline OI 1 nadir	0.69	0.03	3.31	33.32	Covariances not optimized	quickstart.ipynb
baseline OI 4 nadirs	0.83	0.04	2.25	15.67	Covariances not optimized	quickstart.ipynb
baseline Ol 1 swot	0.85	0.05	1.22	12.38	Covariances not optimized	quickstart.ipynb
duacs 4 nadirs	0.92	0.01	1.42	12.0	Covariances DUACS	eval_duacs.ipynb
bfn 4 nadirs	0.92	0.02	1.23	10.6	QG Nudging	eval_bfn.ipynb
dymost 4 nadirs	0.91	0.01	1.36	11.79	Dynamic mapping	eval_dymost.ipyn
miost 4 nadirs	0.93	0.01	1.35	10.19	Multiscale mapping	eval_miost.ipynb
4DVarNet 4 nadirs 🏆	0.94	0.01	1.18	10.34	4DVarNet mapping	eval_4dvarnet.ipy
duacs 1 swot + 4 nadirs	0.92	0.02	1.22	11.15	Covariances DUACS	eval_duacs.ipynb
bfn 1 swot + 4 nadirs	0.93	0.02	0.8	10.09	QG Nudging	eval_bfn.ipynb
dymost 1 swot + 4 nadirs	0.93	0.02	1.2	10.07	Dynamic mapping	eval_dymost.ipyn
miost 1 swot + 4 nadirs	0.94	0.01	1.18	10	14.14 ¹ 1-	SS
4DVarNet 1 swot + 4 nadirs Y	0.95	0.01	0.82	6.	and the second second	33

µ(RMSE): average RMSE score σ(RMSE): standard deviation of the RMSE score. λx: minimum spatial scale resolved. λt: minimum time scale resolved.

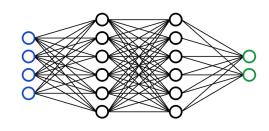
Le Guillou et al. 2021 Febvre et al. 2021 Beauchamp et al. 2022

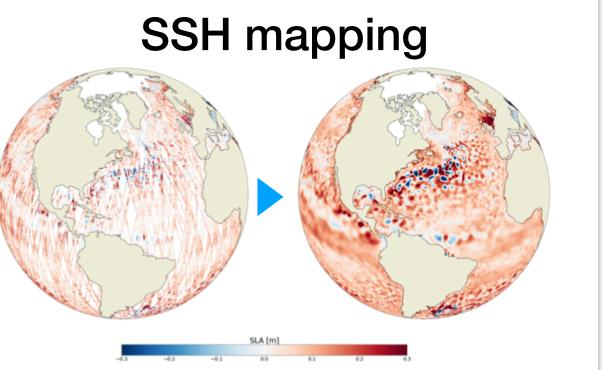


interdisciplinary

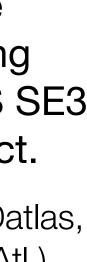
see Slicing CMEMS SE3 project.

> (CLS, Datlas, IMT-Atl.)









Lessons learned and future challenges

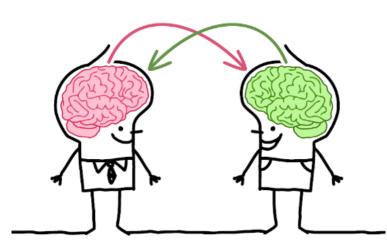




open science

protocols & standards

inter-comparison



interdisciplinary



data-challenges

- The Copernicus Marine Service is continuously evolving - A strong legacy of robust protocols for evidence-based decisions - But challenges ahead : AI, digital twins, complexification of systems - Need for accelerating the transition from research to operation (R2O)

- Open sciences practices are key to a fast R2O transition - Gradually transition to continuous integration of new features - Guarantees that the service is based on the best methodologies - Key to foster a vivid and active research community

- But this is not easy, it takes time, resources and efforts - Need to experiment to find what are the best practices - Some parts of our systems are still not fully open - Requires both technological and cultural evolutions

