European Geosciences Union General Assembly 2023
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EGU2023 - Session OS4.11

Copernicus Marine Service

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

Julien Le Sommer

with the IMMERSE project consortium

immerse
IMPROVING OCEAN MODELS FOR THE COPERNICUS PROGRAMME

https://immerse-ocean.eu/

This project is funded by the European Union

cnrs

IGE
Institut des géosciences de l'environnement

Continuous evolution of the Copernicus Marine Service

BLUE OCEAN

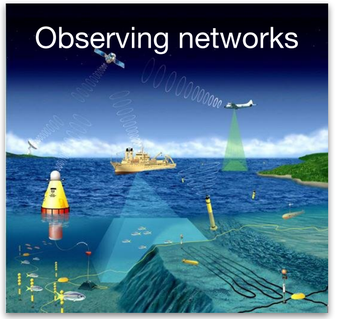
- Temperature
  Salinity
- Currents
- Sea Level
- Mixed layer depth
- Waves

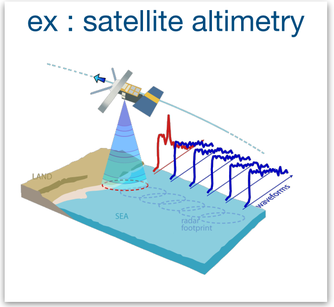
GREEN OCEAN

- Nekton
- Plankton
- Organic carbon
- Nutrients
- Oxygen
- Carbonate System
- Optics

WHITE OCEAN

- Sea Ice Concentration
  Sea Ice Extent
  Sea Ice Thickness
- Sea Ice Type
- Sea Ice Velocity
- Snow thickness
- Sea Ice Albedo
- Sea Ice Age





“*Model-based*” products

ex : (re-)analyses, forecast

“*Data-based*” products

ex : SSH maps, GlobCurrent

Copernicus Marine Service

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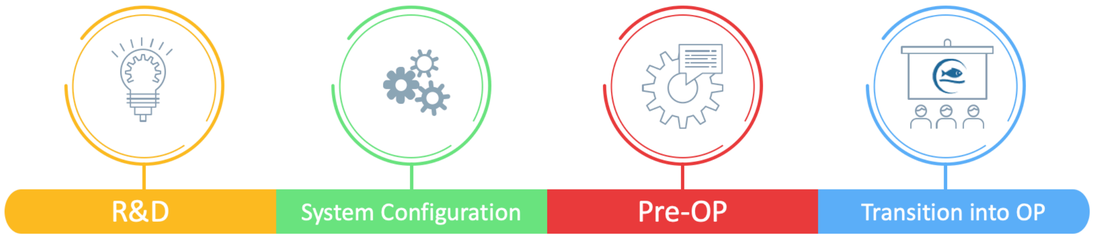
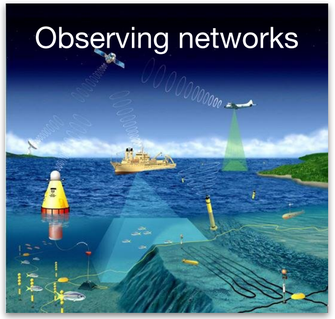
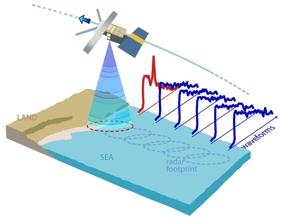




ex : satellite altimetry



"Model-based" products

ex : (re-)analyses, forecast

"Data-based" products

ex : SSH maps, GlobCurrent

Copernicus Marine Service

evidence-based

open science

CMEMS products are continuously improved (users, science)

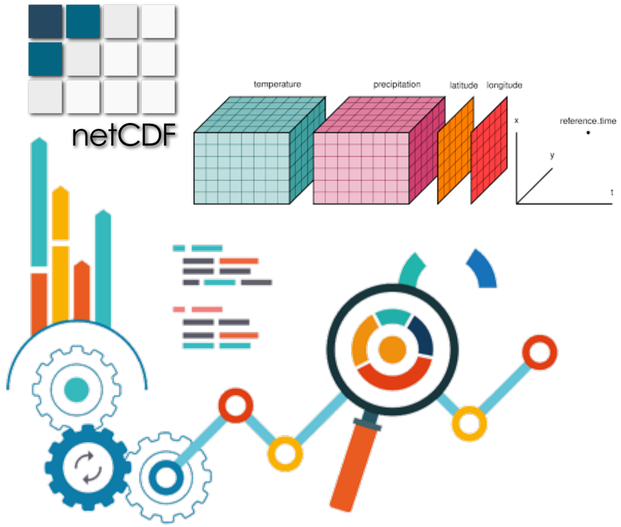
Transition from research to operation is a key undertaking

Why : product quality, trust, community,

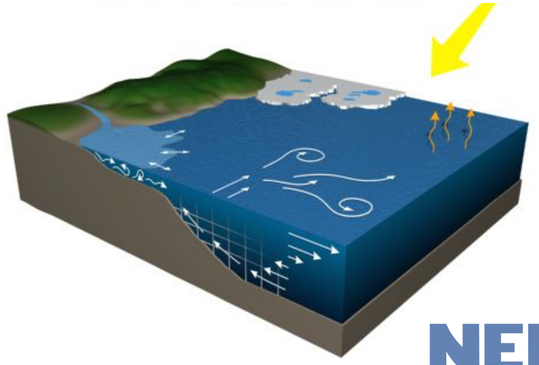
Key : time-to-transition

Software as the service underlying basis

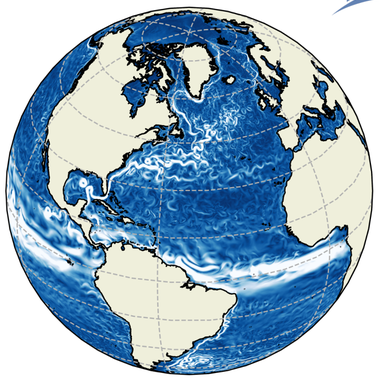
Data analytics



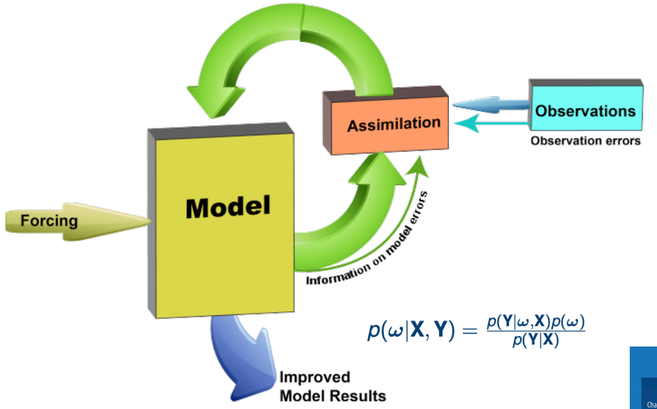
Physical models



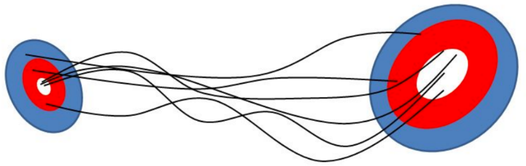
NEMO

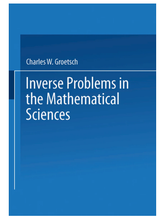


Inverse methods



$$p(\omega|\mathbf{X},\mathbf{Y}) = \frac{p(\mathbf{Y}|\omega,\mathbf{X})p(\omega)}{p(\mathbf{Y}|\mathbf{X})}$$





Software as the service underlying basis

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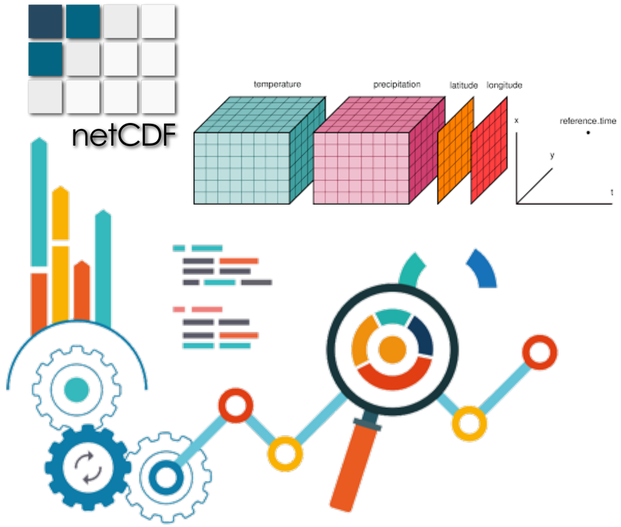
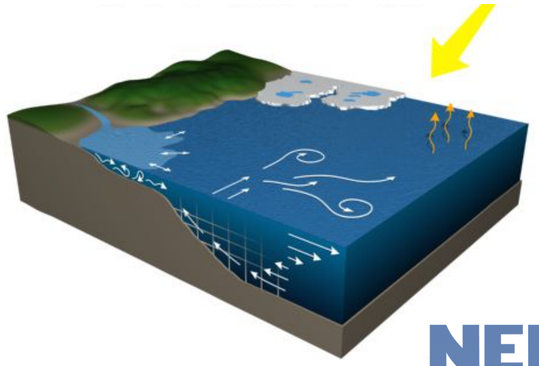


Physical models



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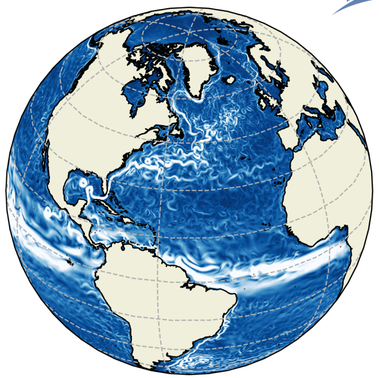
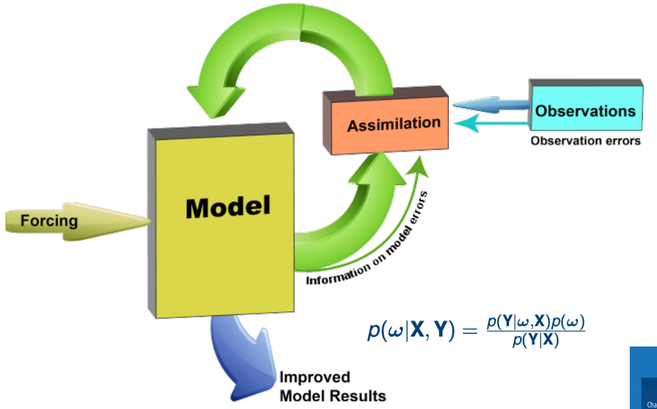
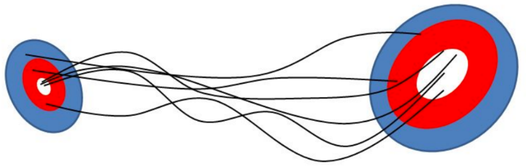
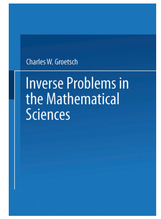


Inverse methods







The service heavily relies on software developed by the community

Codes and algorithms summarise/encode our collective knowledge

open source

Improving further how we develop codes and algorithms

Copernicus Marine Service

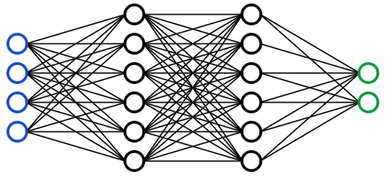
inter-comparison

protocols & standards

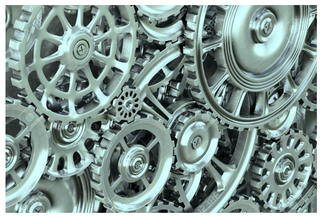
A strong legacy of software / data protocols and standards

ex : netcdf, version control, evaluation chains, science papers…

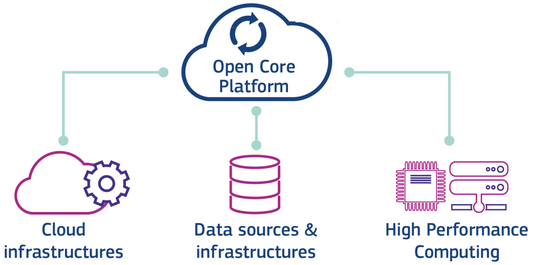
Here : describe recent attempts to open further our protocols



Trainable algorithms



Increasing complexity



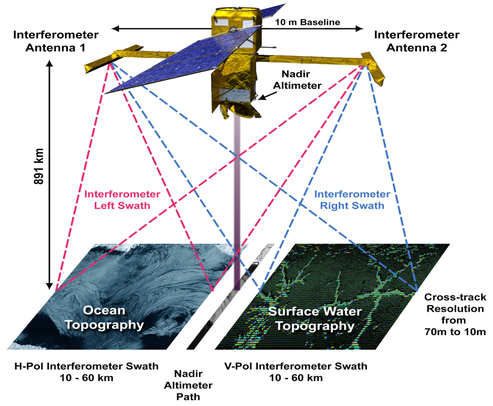
Digital twins of the Earth

Improving further how we develop codes and algorithms

Copernicus Marine Service

inter-comparison

protocols & standards



Algorithms for wide-swath altimetry

SWOT

A strong legacy of software / data protocols and standards

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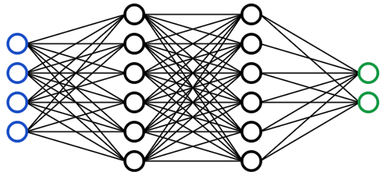

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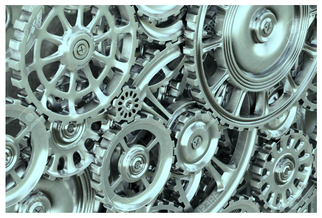

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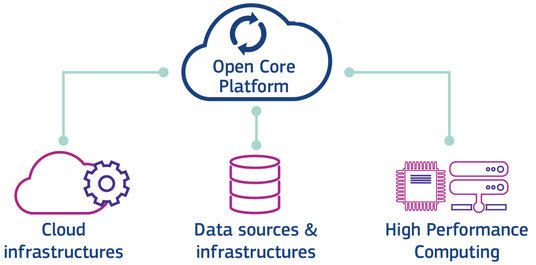


Digital twins of the Earth

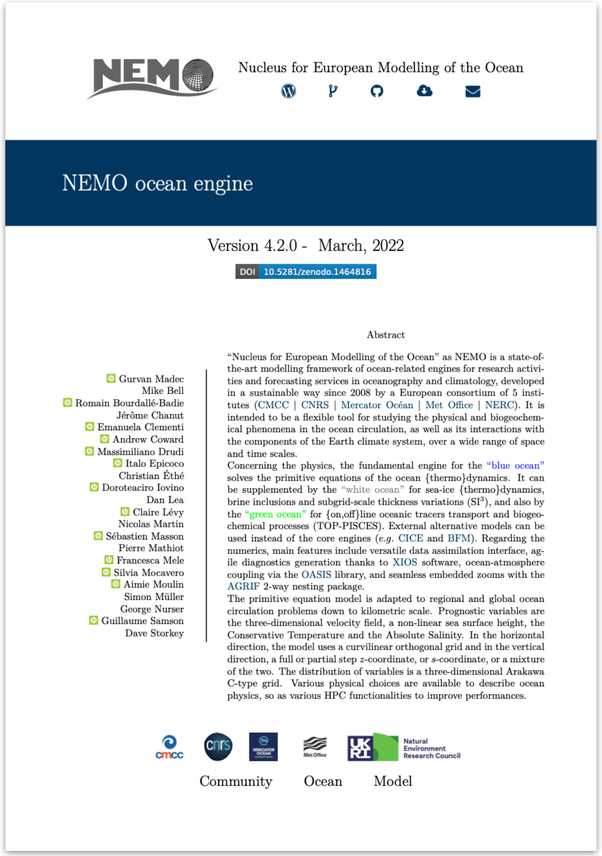
NEMO

Development of the NEMO model (cf v4.2)

immerse

IMPROVING OCEAN MODELS FOR THE COPERNICUS PROGRAMME

Improving NEMO ocean/sea-ice model development workflow



Nucleus for European Modelling of the Ocean

NEMO ocean engine

Version 4.2.0 - March, 2022

DOI 10.5281/zenodo.1464816

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Francesca Mele
Silvia Mocavero
Aimie Moulin
Simon Müller
George Nurser
Guillaume Samson
Dave Storkey

Abstract

"Nucleus for European Modelling of the Ocean" as NEMO is a state-of-the-art modelling framework of ocean-related engines for research activities and forecasting services in oceanography and climatology, developed in a sustainable way since 2008 by a European consortium of 5 institutes (CMCC | CNRS | Mercator Océan | Met Office | NERC). It is intended to be a flexible tool for studying the physical and biogeochemical phenomena in the ocean circulation, as well as its interactions with the components of the Earth climate system, over a wide range of space and time scales.

Concerning the physics, the fundamental engine for the "blue ocean" solves the primitive equations of the ocean {thermo}dynamics. It can be supplemented by the "white ocean" for sea-ice {thermo}dynamics, brine inclusions and subgrid-scale thickness variations (SI^3), and also by the "green ocean" for {on,off}line oceanic tracers transport and biogeochemical processes (TOP-PISCES). External alternative models can be used instead of the core engines (*e.g.* CICE and BFM). Regarding the numerics, main features include versatile data assimilation interface, agile diagnostics generation thanks to XIOS software, ocean-atmosphere coupling via the OASIS library, and seamless embedded zooms with the AGRIF 2-way nesting package.

The primitive equation model is adapted to regional and global ocean circulation problems down to kilometric scale. Prognostic variables are the three-dimensional velocity field, a non-linear sea surface height, the Conservative Temperature and the Absolute Salinity. In the horizontal direction, the model uses a curvilinear orthogonal grid and in the vertical direction, a full or partial step z-coordinate, or s-coordinate, or a mixture of the two. The distribution of variables is a three-dimensional Arakawa C-type grid. Various physical choices are available to describe ocean physics, so as various HPC functionalities to improve performances.

Community Ocean Model

NEMO 4.2 Official Release
in March 2022 (reference release)

←

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

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

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

immerse
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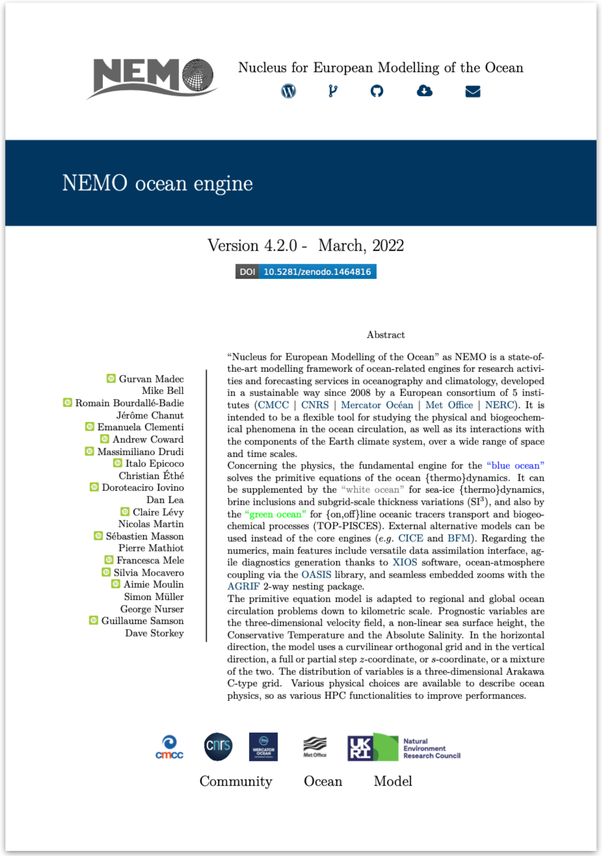

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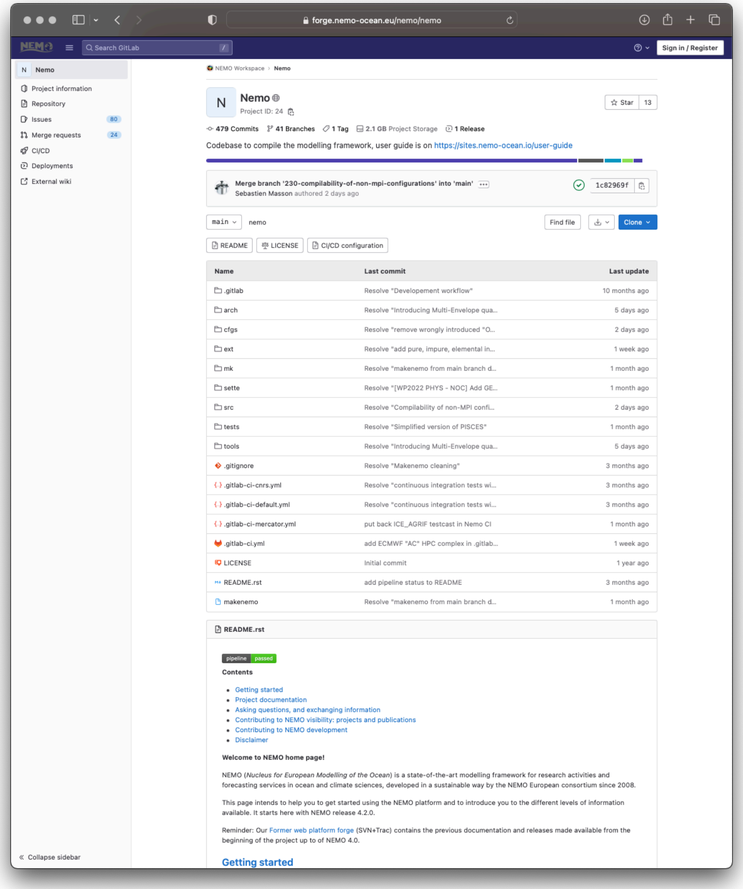
kernel (time-stepping), HPC, processes (k-scale)

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

Distributed on a new Gitlab platform
with automated testing service
(ci-service, on idealised configurations)

https://forge.nemo-ocean.eu/nemo/nemo/-/tree/main/tests



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

immerse
IMPROVING OCEAN MODELS
FOR THE COPERNICUS PROGRAMME

All the communications, including discussion threads,
development branches are now open without registration

Better sharing model experiments and configurations

immerse
IMPROVING OCEAN MODELS
FOR THE COPERNICUS PROGRAMME

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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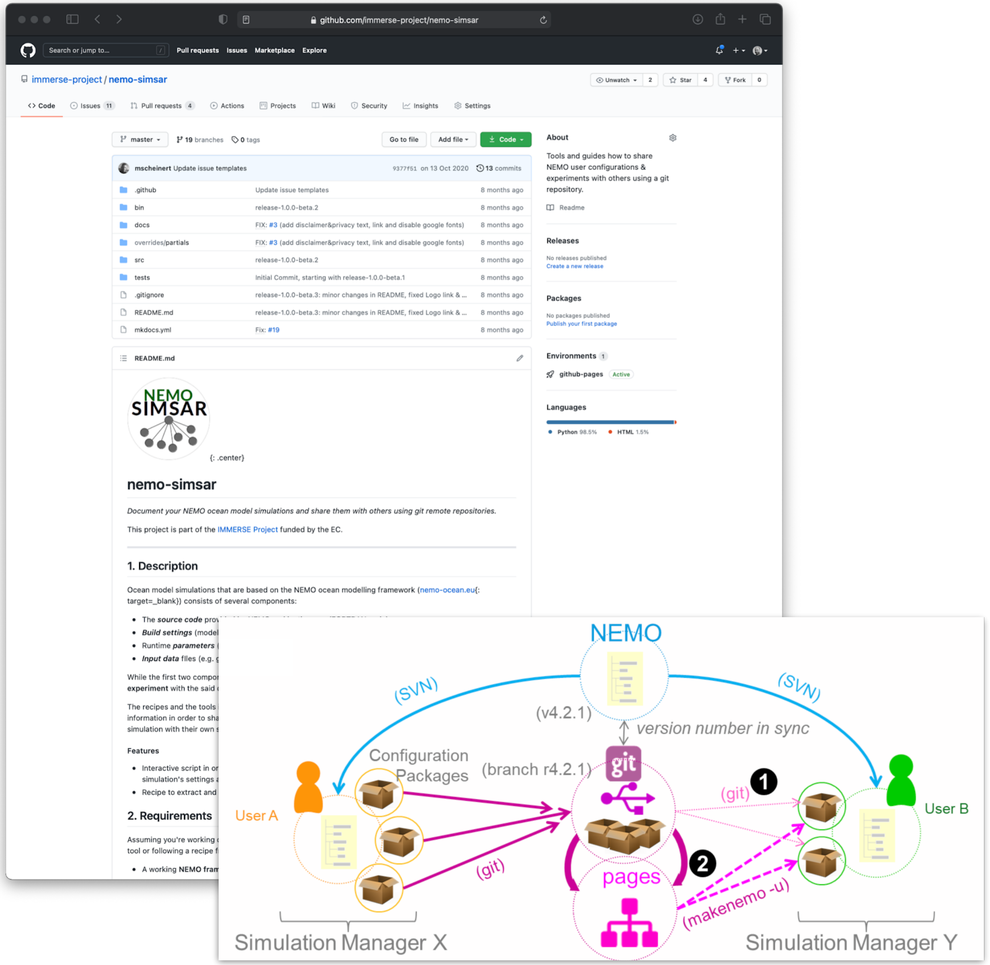
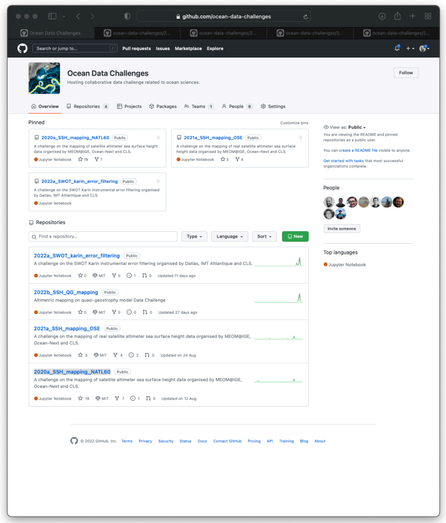


https://immerse-ocean.eu/nemo-simsar/

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

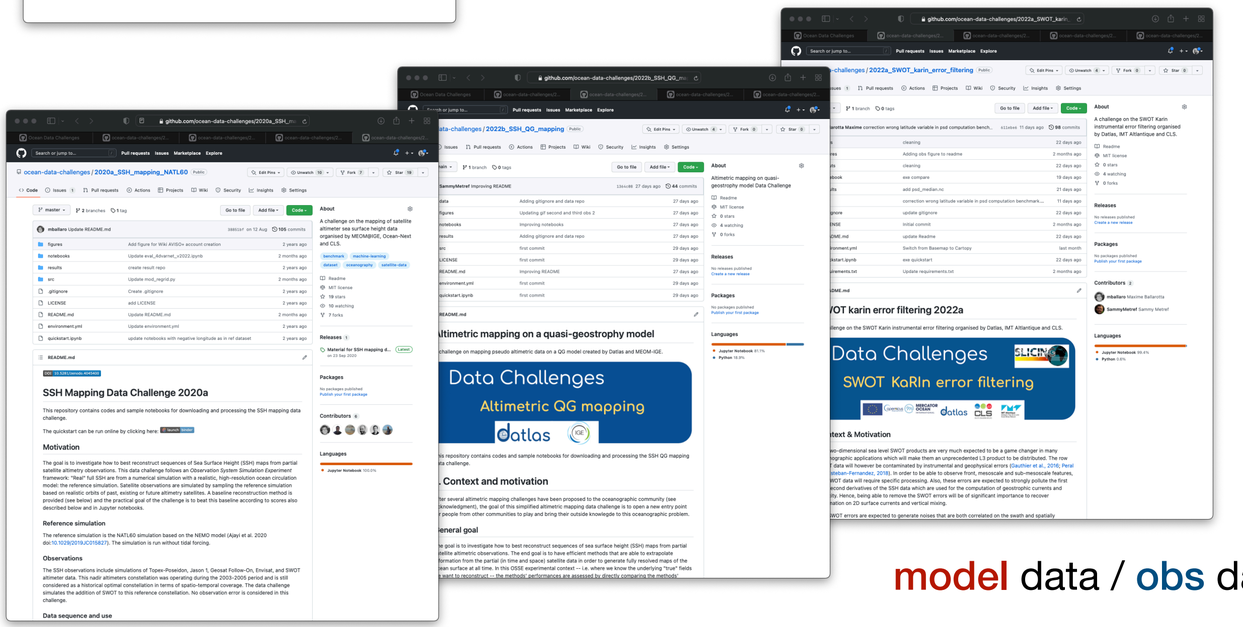
A prototype tool for documenting and sharing NEMO model experiments

Systematic assessment of altimeter data treatment algorithms

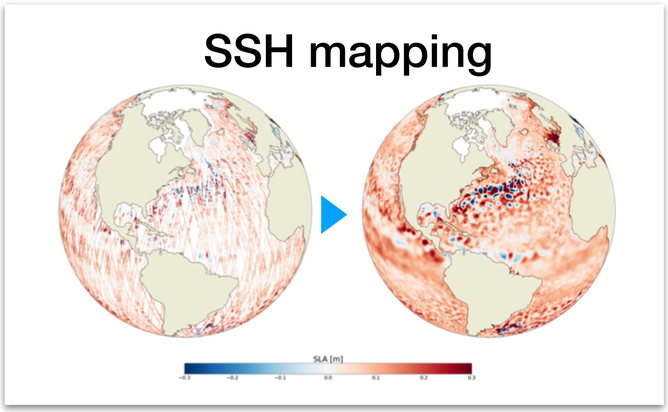


Collaborative data-challenges

- problem description + baseline
- data, metrics (with codes)
- tools for collaboration and papers



model data / **obs** data



see : https://github.com/ocean-data-challenges/

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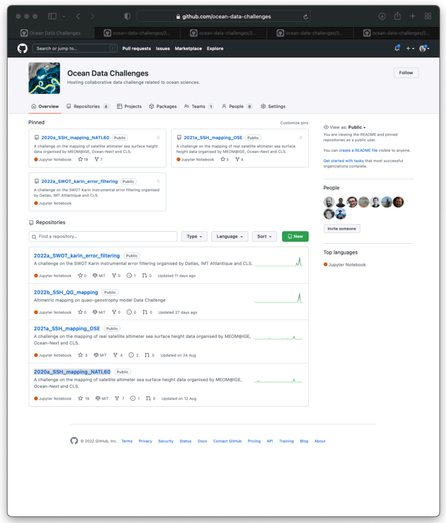

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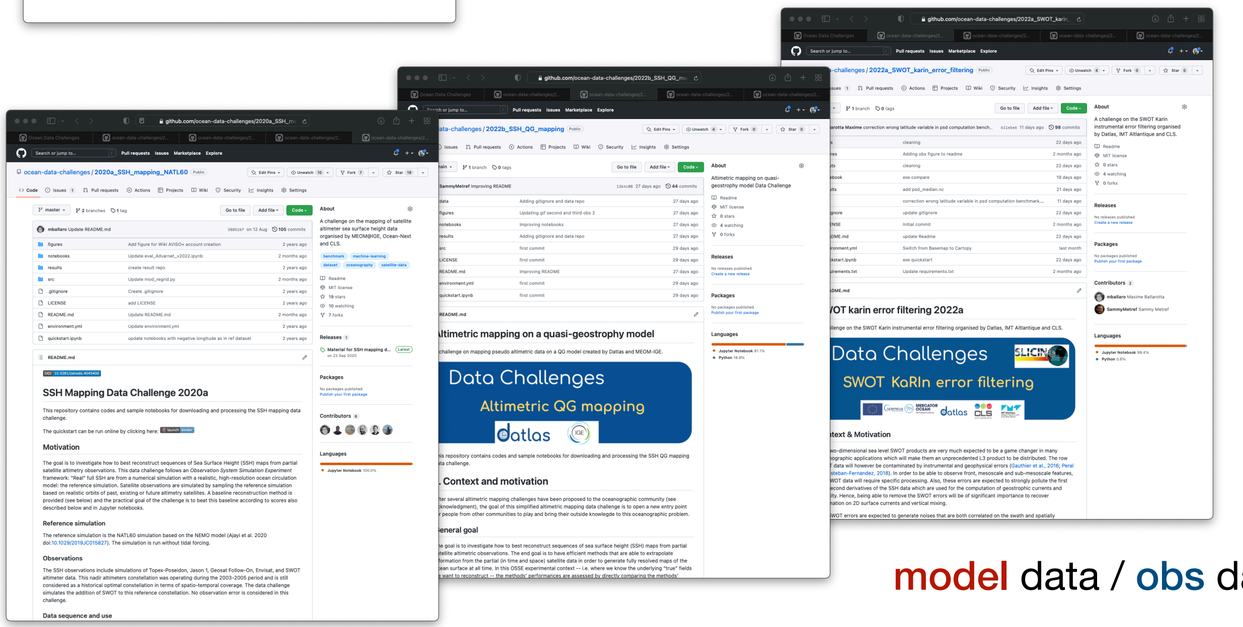


model data / obs data

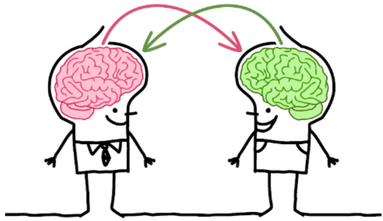
see : https://github.com/ocean-data-challenges/

Leaderboard

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 OI 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.ipynl
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.ipynl
miost 1 swot + 4 nadirs	0.94	**0.01**	1.18	10		
4DVarNet 1 swot + 4 nadirs 🏆	**0.95**	**0.01**	0.82	6		

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

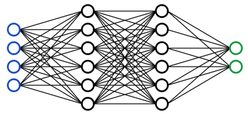
Le Guillou et al. 2021
Febvre et al. 2021
Beauchamp et al. 2022

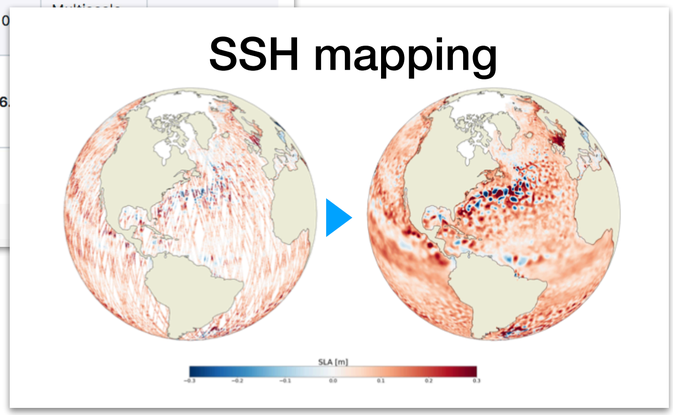


interdisciplinary

see Slicing CMEMS SE3 project.

(CLS, Datlas, IMT-Atl.)



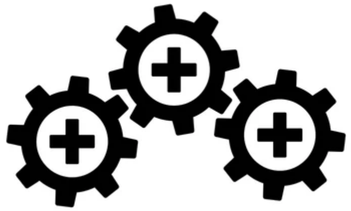


Lessons learned and future challenges

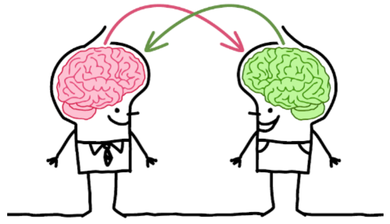
evidence-based

open science

- 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)



protocols & standards



interdisciplinary

- 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

inter-comparison

data-challenges

- 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