

# **CMCC reanalysis systems: in-situ data use and needs**

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GTSP/QUOD/SOIP/XBT science meeting

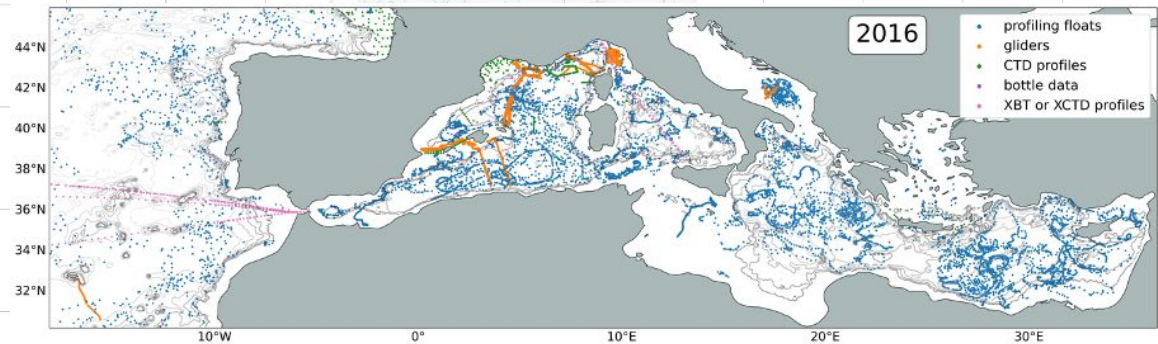
11-14 November 2024  
Bologna



- Ocean reanalyses combine ocean models, atmospheric forcing fluxes, and observations using data assimilation in a consistent way to give a four-dimensional description of the ocean (Storto et al. 2019).
- CMCC develops, produces and maintains
  - Copernicus Marine Service Mediterranean Sea and Black Sea NRT and Multiyear (Reanalysis and Interim) Systems (Lima et al. 2021; Escudier et al. 2021)
  - C-GLORS - a member of Copernicus Global Reanalysis Ensemble Product (GREP)

## CMCC Multiyear Regional Systems

- Regional Multiyear systems ingest observations from CMEMS and SDN
  - XBT, MBT, ARGO (and glider profiles in the next version)
  - SST, SLA from space-born instruments



# C-Glors Global Reanalysis

C-GLORS provides a 4D time-consistent view of the ocean at eddy-permitting resolution ( $1/4^\circ$ ) assimilating different near-real-time/reprocessed insitu products for different applications:

## Near-real-time CMEMS insitu for ICs

- Ocean-Sea Ice initial conditions for Seasonal prediction (ensemble-based, 9 members)

## EN4 reprocessed product for monitoring service

- Stream 2 consolidate reanalysis, part of Global Reanalysis Ensemble Product (GREP) from CMEMS

## EN4 reprocessed product for scientific-based studies

- Long-term reanalysis covering stream 1 (from 1980s, Storto & Masina 2016).
- Half-century reanalysis for decadal prediction (from 1960, ensemble-based, 4 members)

# CMCC Multiyear Regional Systems



COPERNICUS MARINE ENVIRONMENT MONITORING SERVICE

Copernicus Marine Service  
CMEMS-MFC MED



Regional systems in Marine Forecasting Centers (MFC) regularly gives feedback to Copernicus Marine Service Thematic Assembly Center (TAC) on the status and needs.

## Med-MFC In-situ observations requirements

## Update of the Copernicus Marine requirements for in-Situ Observing System

### BLK-MFC

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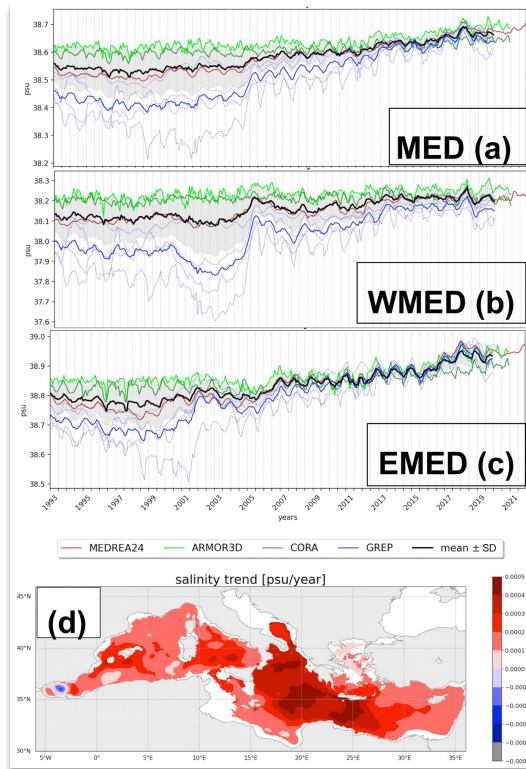
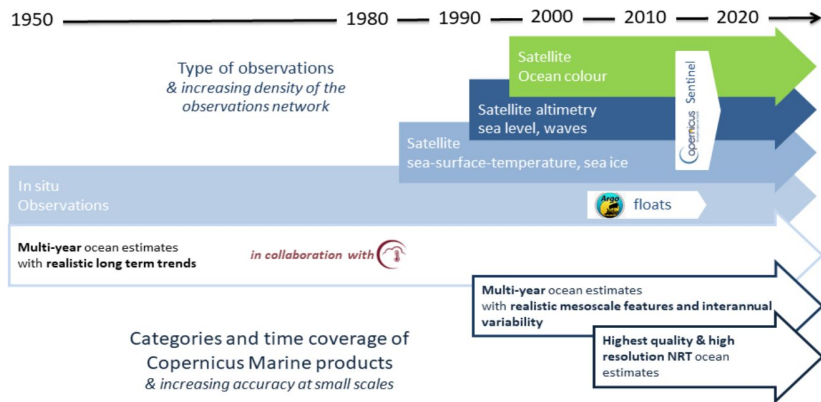
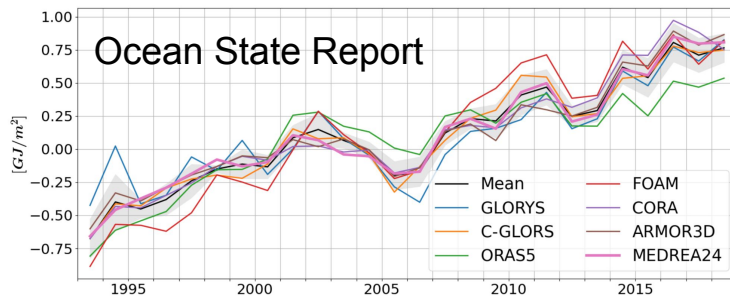


# CMCC Multiyear Regional systems

Regional MY systems  
(MEDRAN24 & BSRAN):

Preparation of the new high resolution physical reanalysis to address Ocean State Monitoring and Climate Reporting

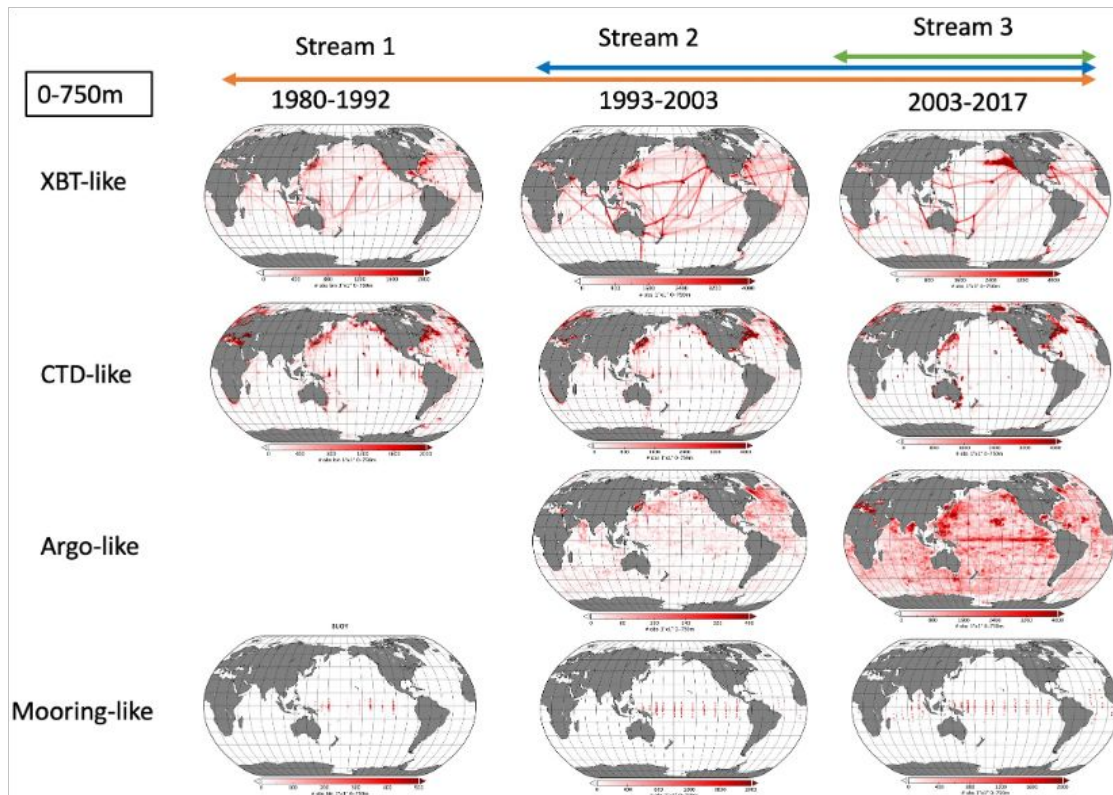
Ocean Heat Content in the Mediterranean Sea  
(upper 700 m.)



Mean **salinity** in the upper 300 m (a) MED (b) WMED (c) EMED from MEDREA24, ARMOR3D, CORA, GREP and their ensemble mean. (d) **trend**. Aydogdu et al. (2023)

# C-Glors Global Reanalysis

Assimilation of all the reprocessed observations is instead crucial before the Argo era (before 2003)



The model state can be far from the initial observations that are automatically treated as “outliers”, being too far from the model, and excluded

OBSERVATION DISTRIBUTION 0-750m (1°bin)

# In situ data curation

## Temperature and salinity

### Preparation

- Remove unwanted platforms
- One file per profile

### Pre-processing

- Check quality
- Transform vertical coordinate
- ...

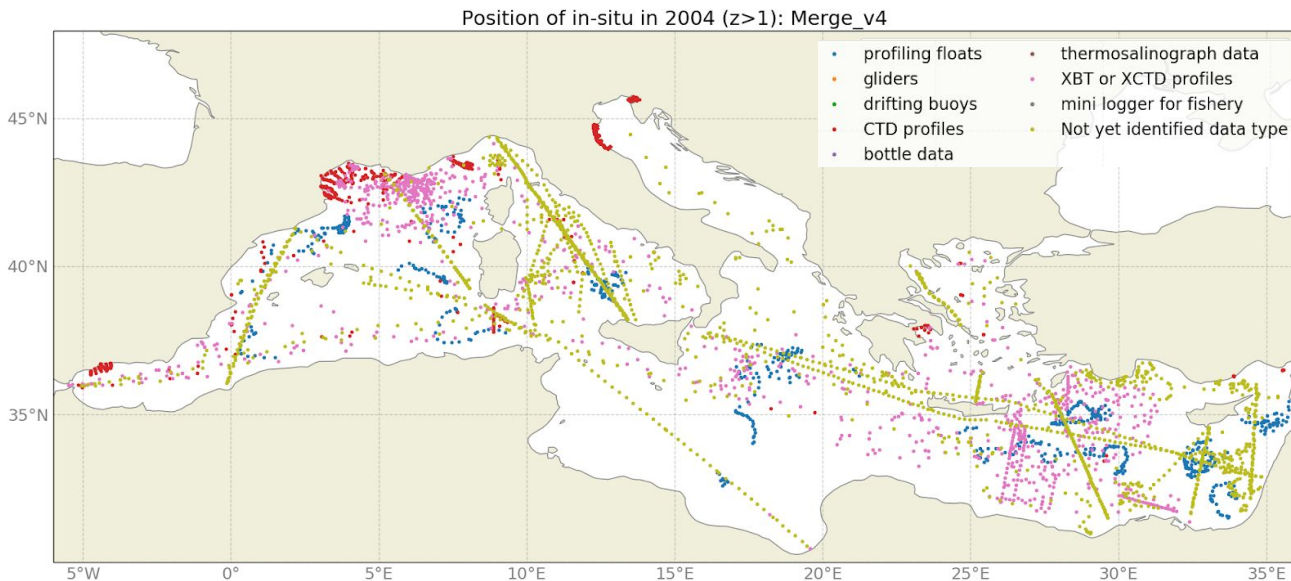
### Merge

Merge SDN into CMEMS

### Databases:

- INSITU CMEMS REP Global
- INSITU CMEMS MED HISTORY Global
- SeaDataNet

for profiles of Temperature and Salinity from ARGO, CTD and XBT.



In-situ observations in 2004



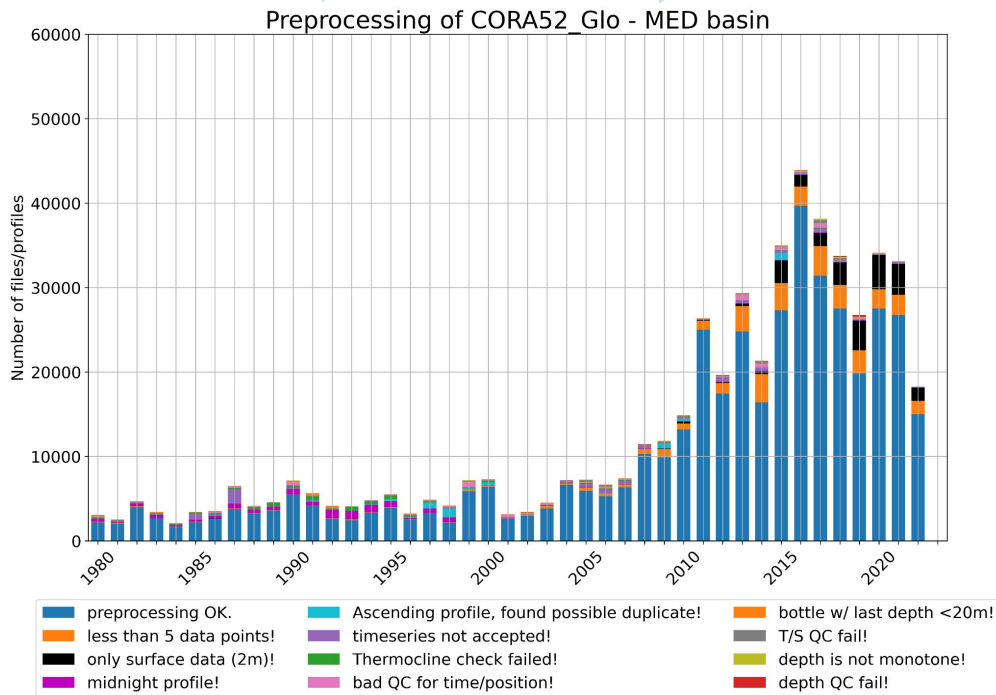
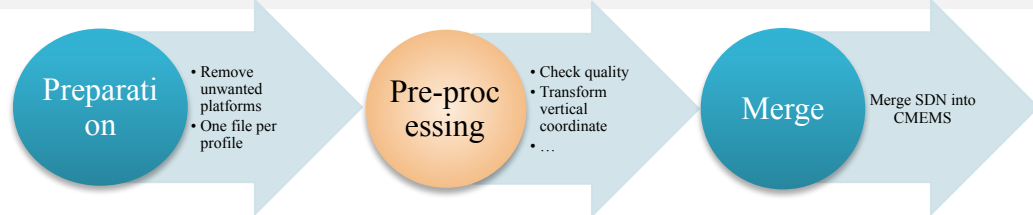
# In situ data curation

## Temperature and salinity

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- INSITU CMEMS REP Global
- INSITU CMEMS MED HISTORY Global
- SeaDataNet

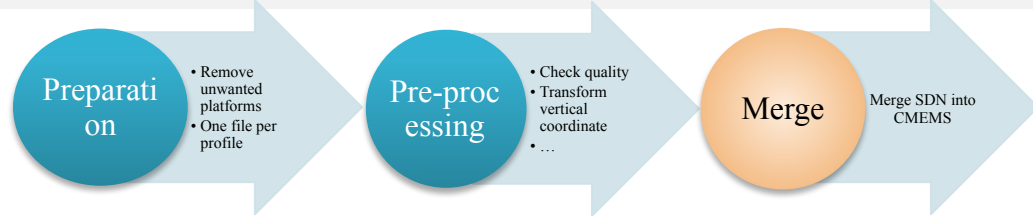
for profiles of Temperature and Salinity from ARGO, CTD and XBT.



Quality check before merging

# In situ data curation

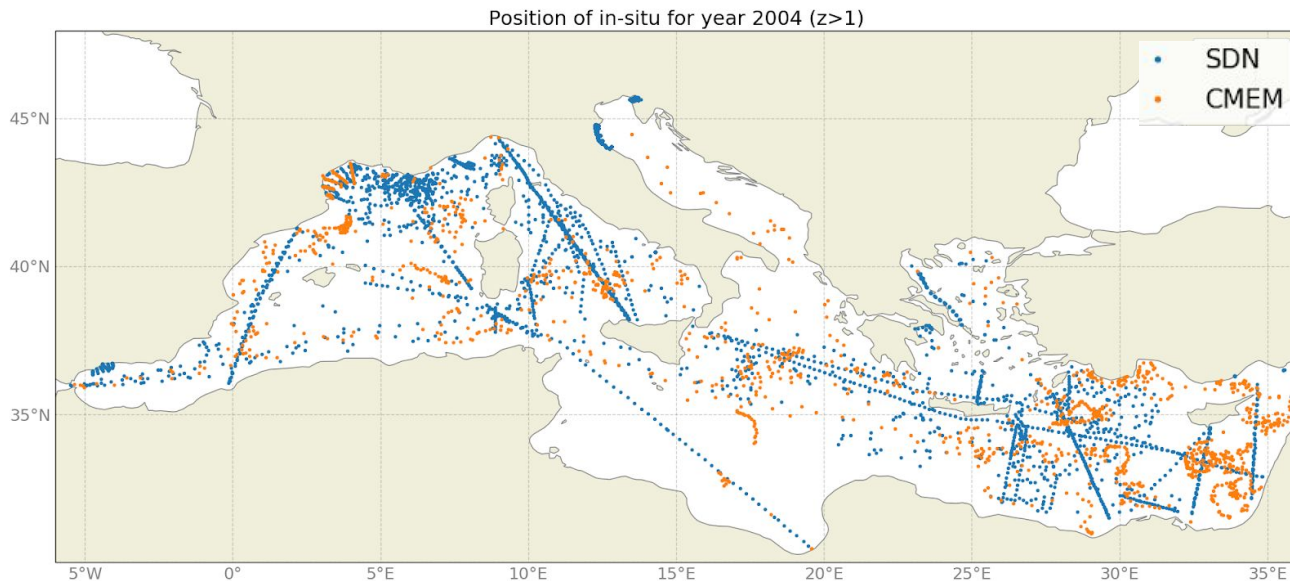
## Temperature and salinity



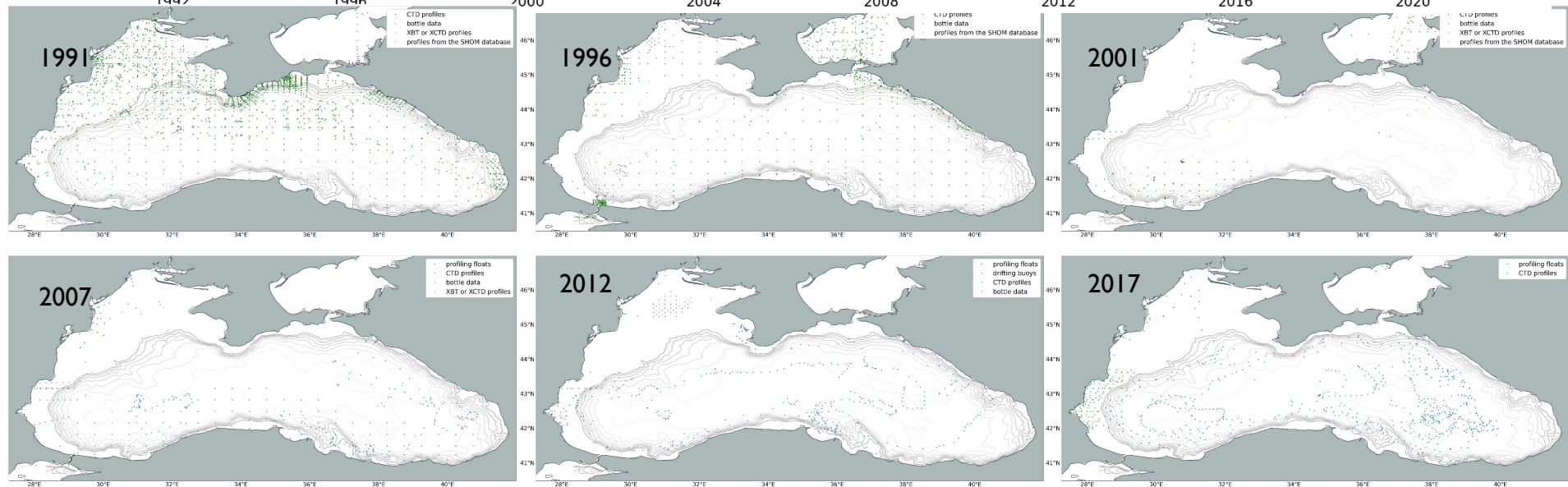
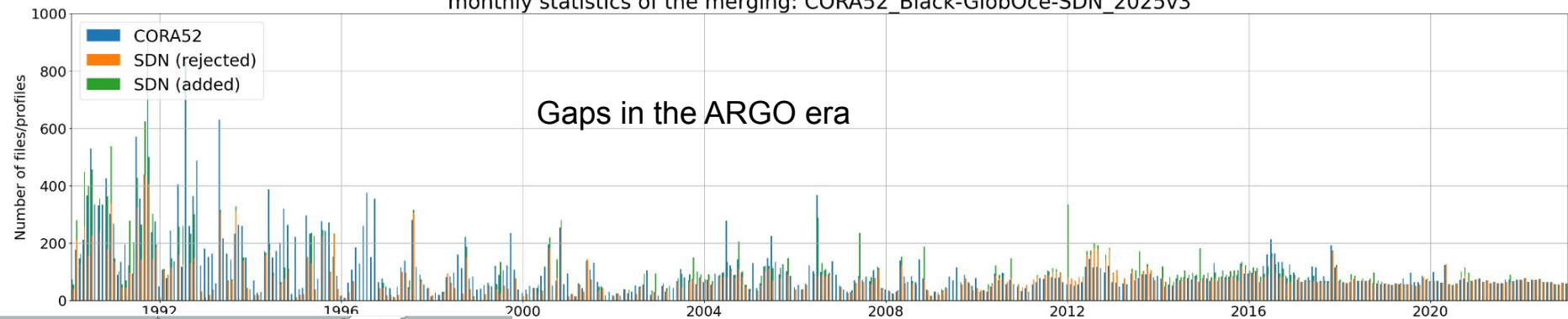
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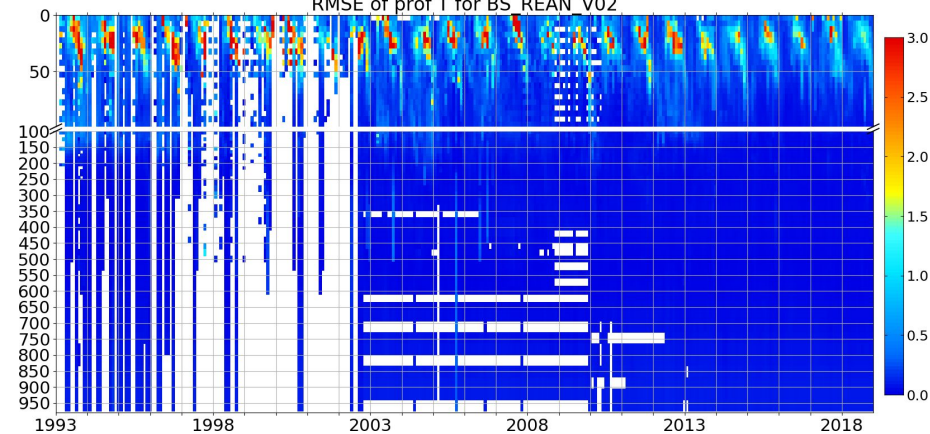
Gaps in the African coast, Adriatic Sea and Aegean Seas





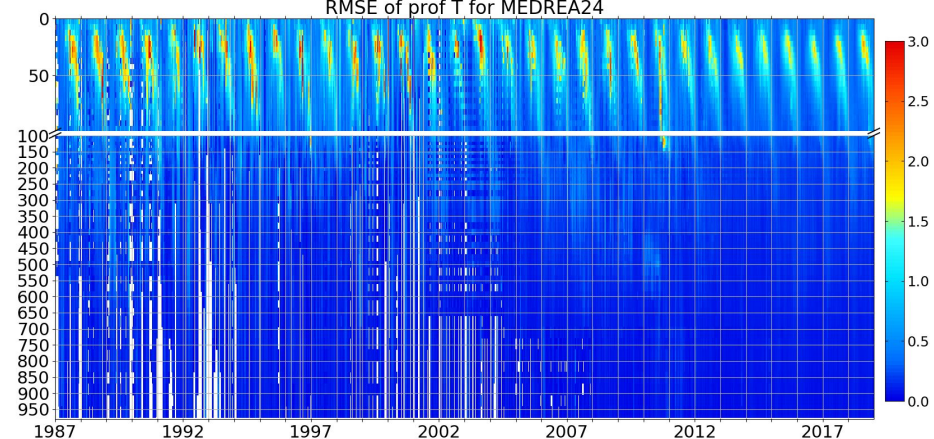
# Black Sea temperature Hovmoeller of RMSD

RMSE of prof T for BS REAN V02

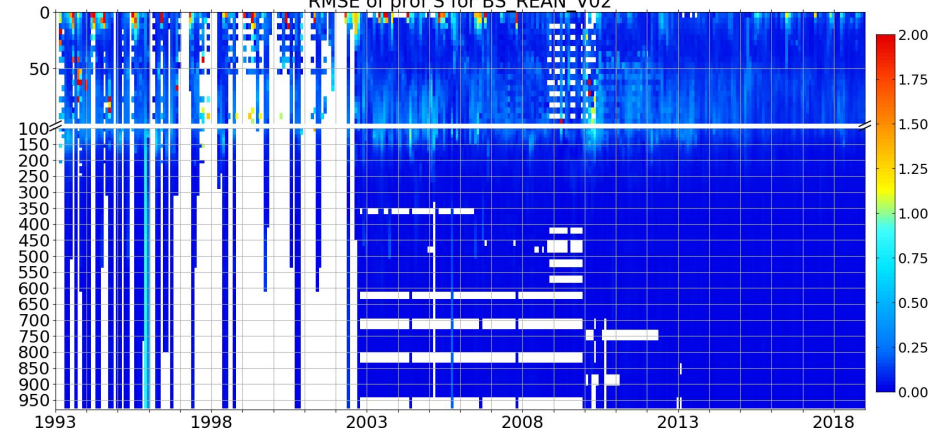


# Med Sea temperature Hovmoeller of RMSD

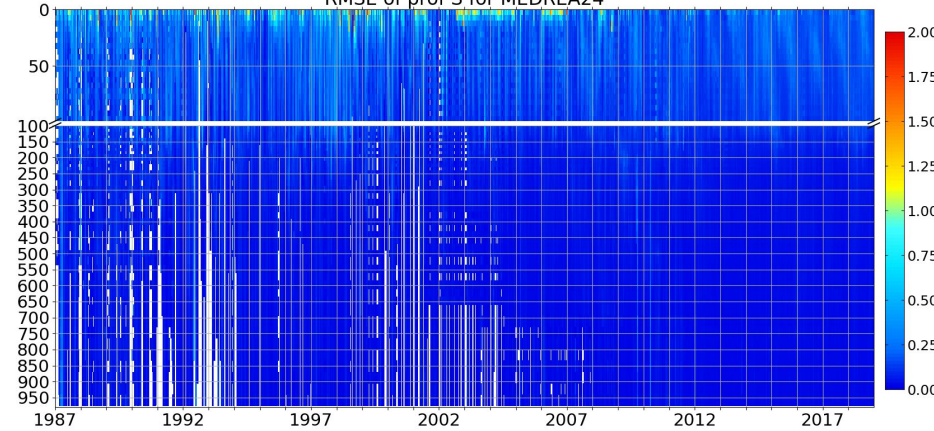
RMSE of prof T for MEDREA24



RMSE of prof S for BS REAN V02



RMSE of prof S for MEDREA24



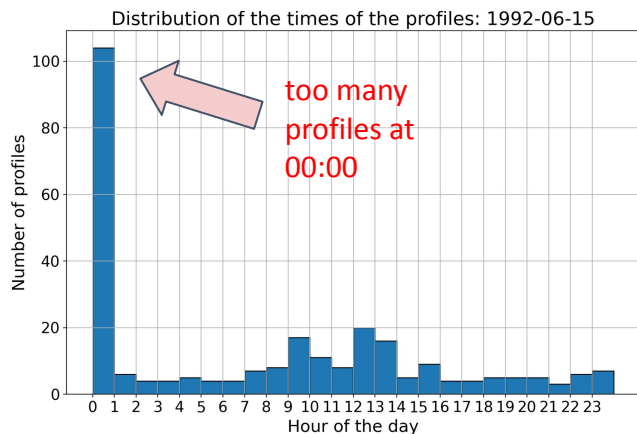
# Black Sea Salinity Hovmoeller of RMSD

# Med Sea salinity Hovmoeller of RMSD

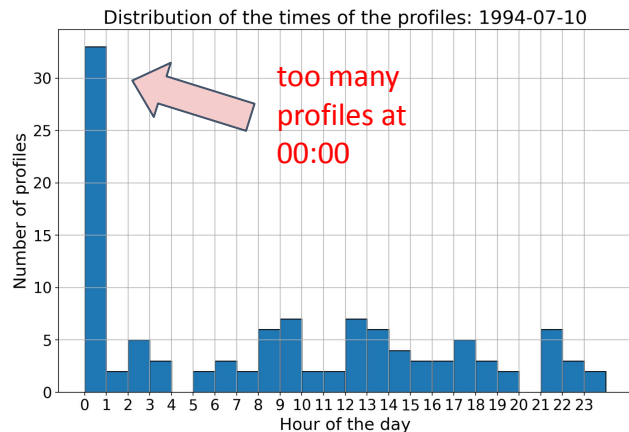
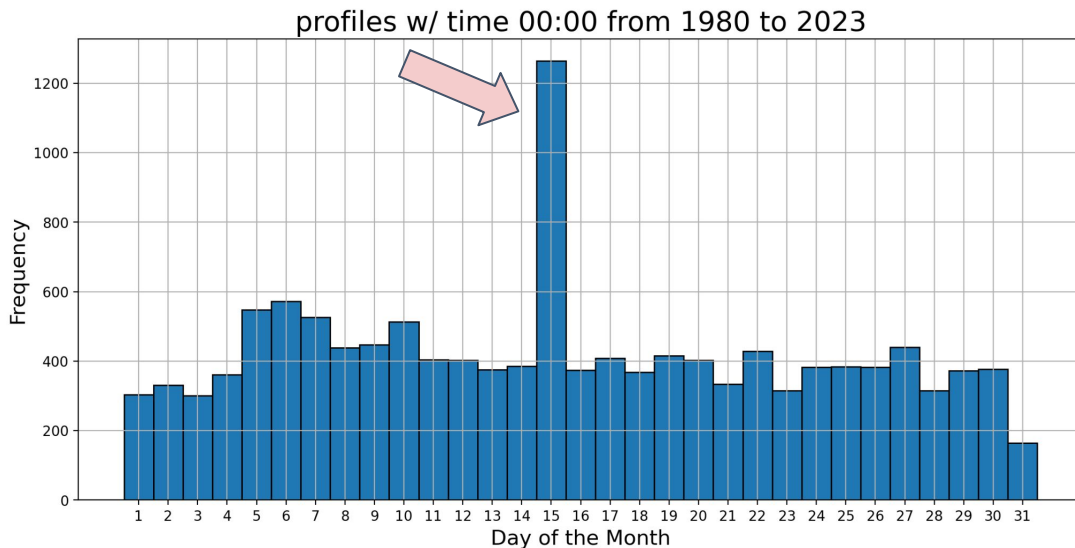
Vertical distribution of the observations

# CTD profiles with time = 00:00:00 (Med Sea)

CMEMS product: INSITU\_GLO\_PHY\_TS\_DISCRETE\_MY\_013\_001



The anomalous number of profiles at 00:00 is more frequent on (but not limited to) the 15th of the month.

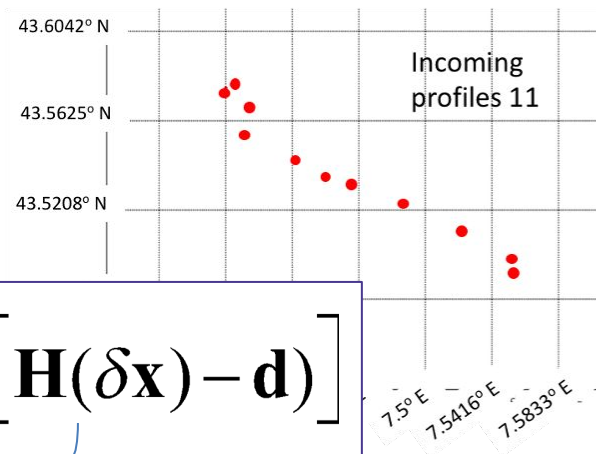




## Data Assimilation problem

blend a model and observations  
e.g. minimize 3DVar cost function

observation space

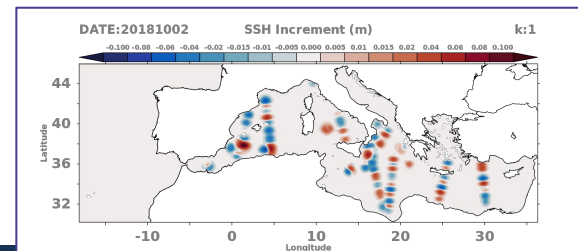


$$J(\delta x) = \underbrace{\frac{1}{2} \delta \mathbf{x}^T \mathbf{B}^{-1} \delta \mathbf{x}}_{\text{Error Background}} + \underbrace{\frac{1}{2} [\mathbf{H}(\delta \mathbf{x}) - \mathbf{d}]^T \mathbf{R}^{-1} [\mathbf{H}(\delta \mathbf{x}) - \mathbf{d}]}_{\text{Error Observations}}$$

model space

**B** background error covariance matrix

**R** observation error covariance matrix



# Quality Check

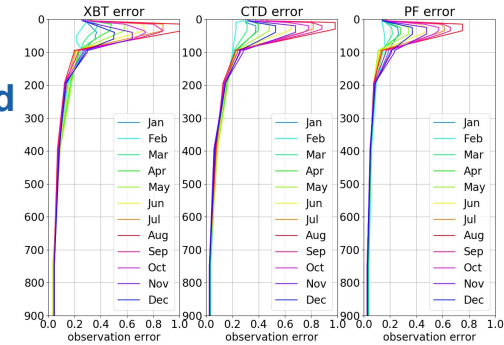
The treatment of outliers in C-GLORS can differ, according whether we assimilated near-real-time and reprocessed products, two different quality checks are present:

Standard gaussian background quality check

$$(y - \mathbf{H}(x^b))^2 < \alpha [\sigma_o^2 + \sigma_b^2]$$

Desroziers method

A non-gaussian variational quality check has been implemented (Storto, Ocean Modelling 2016) that allow the assimilation of values far from model states giving them less weight into the cost function



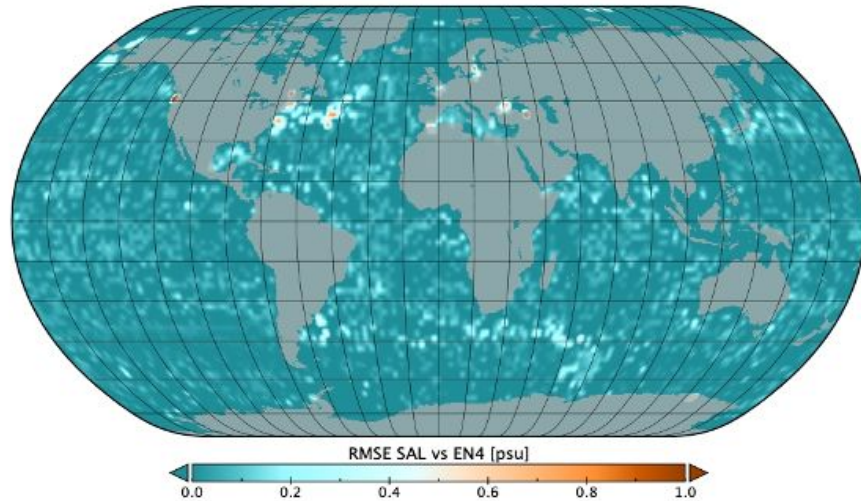
Huber-norm pdf

$$P(\mathbf{y} | \mathbf{x}) = \begin{cases} k \exp\left(-\frac{1}{2}\mathbf{w}^2\right) & \text{if } |\mathbf{w}| \leq a \\ k \exp\left(\frac{1}{2}a^2 - a|\mathbf{w}|\right) & \text{if } a < |\mathbf{w}| \leq b \\ k \exp\left(-c|\mathbf{w}|^{\frac{1}{2}} + e\right) & \text{if } |\mathbf{w}| > b \end{cases}$$

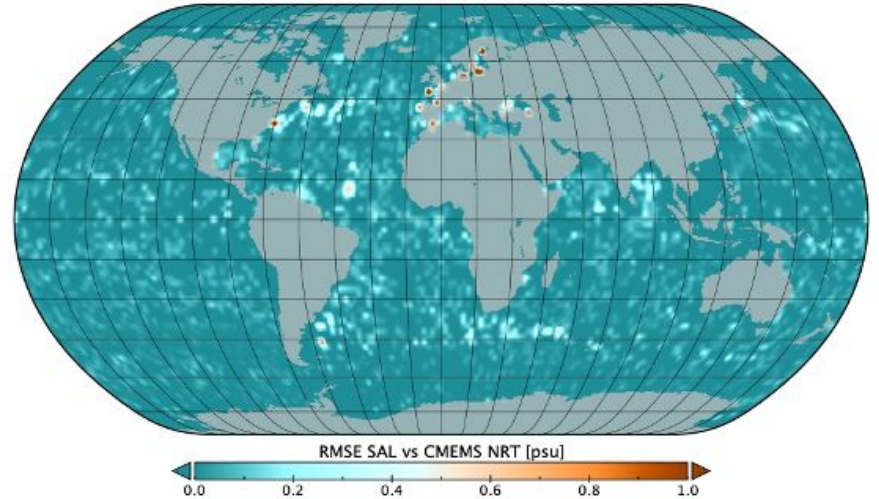
## C-Glors Global Reanalysis

The assimilation of “outliers” in near-real-time products can be problematic and produce inconsistencies. The two maps show the assimilation of EN4 and NRT product for Jan and Feb 2020 starting from the same initial conditions using variational QC. Errors > 1 psu can be seen close to the European coastlines

Salinity RMSE [0-1500]



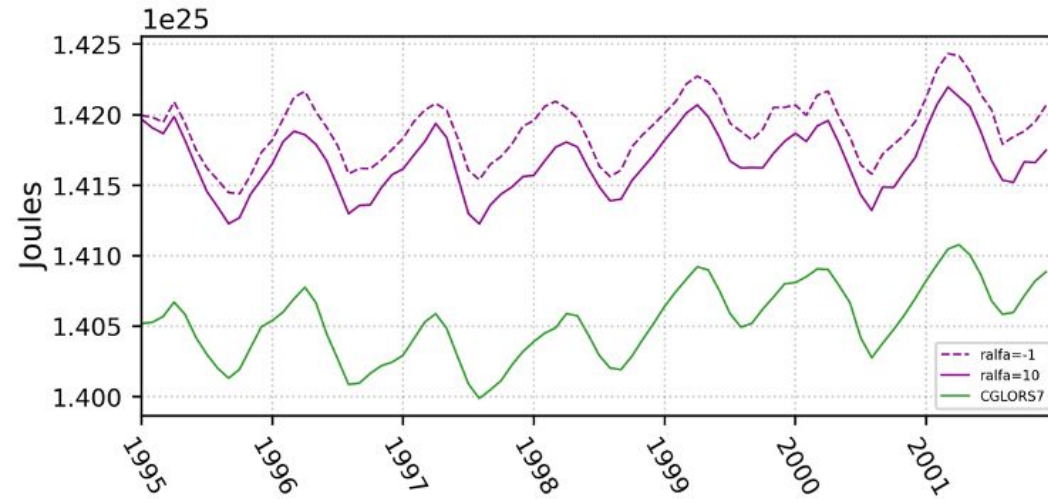
Salinity RMSE [0-1500]



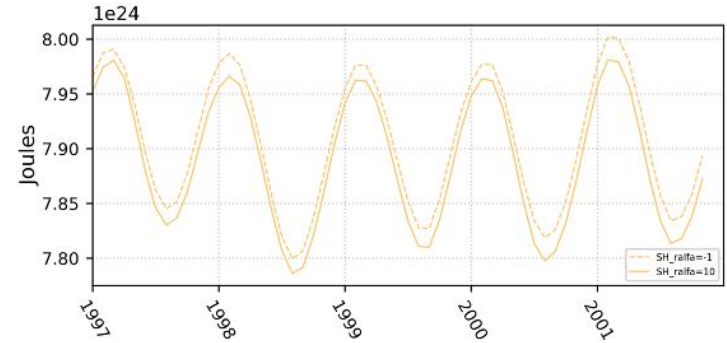
# C-Glors Global Reanalysis

A slightly warmer ocean state comes from the assimilation of data via variational QC (especially in the SH) without disrupting the time-series

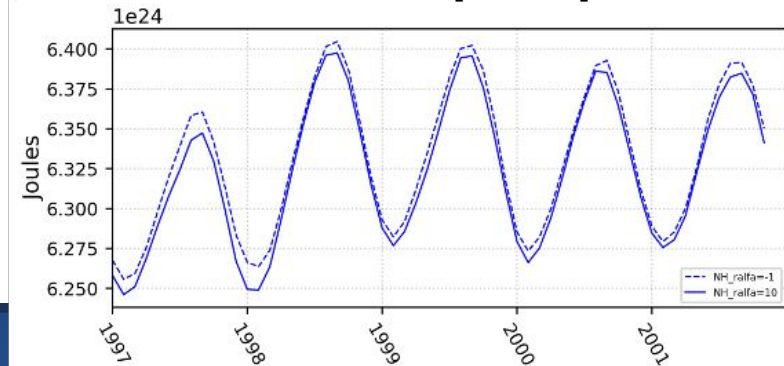
OHC [0-1500]



SH OHC



NH OHC [0-1500]



# Interaction with observation producers

Glider observations in the Western Mediterranean Sea: their assimilation and impact assessment using four analysis and forecasting systems

# EuroSea



Ali Aydogdu, Romain Escudier, Jaime Hernandez-Lasheras, Carolina Amadio, Jenny Pistoia, Nikolaos Zarokanellos, Baptiste Mourre, Gianpiero Cossarini, Elisabeth Remy

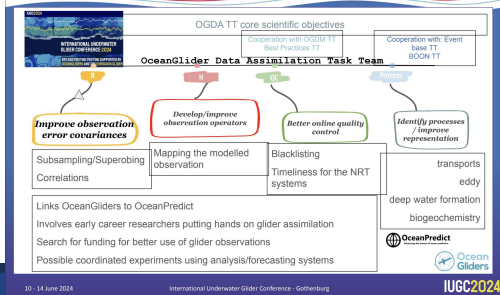
IUGC2024



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 862626.

## Engagement with OceanGliders community

EuroSea



10 - 14 June 2024

International Underwater Glider Conference - Gothenburg

IUGC2024

## Workshop with observation scientists/providers

EuroSea

- the best practices in use of glider and floats in
- On the accessibility to the glider / Argo floats data
- On the quality control (QC) in the assimilation

Leveraging the multi-system glider data assimilation experiments within EuroSea to the international level

29 JUNE - 1 JULY 2022  
EuroSea/OceanPredict

Victor Turpin, Elisabeth Remy, Ali Aydogdu, Baptiste Mourre, Romain Escudier, Pierre Tassin, Jaime Hernandez-Lasheras, Nikolaos Zarokanellos, and others

Co-funded by the European Union under Horizon 2020 research and innovation programme under grant agreement No 862626



# EuroSea

Internal Milestone #28

Joint workshop between CMCC SOCIB Task 4.2, Task 4.3, Task 4.4 partners and WP3 on sharing best practices on how to use novel sensors (glider, floats) data for assimilation and validation in the CMEMS (global and MED) and SOCIB operational systems (physical and biogeochemical)

Date: 24 June 2021 10:00-12:00 CET

Goal: EuroSea Task 4.2 aims at evaluating the impact of the glider and BGC Argo observations on marine forecasting systems in the Mediterranean Sea. The question of where and how to access the data in both near-real-time (NRT) and delayed-time (DT) is critical for this task. Several issues have been identified concerning the glider data availability, especially for NRT systems. The objective of this workshop is to bring together European experts on glider data collection, processing and management with the data assimilation experts to open a discussion on this issue and propose solutions to use glider and float observations in operational forecasting systems in the best possible way.

### AGENDA

- 10:00-10:15 Objectives and overview of the status (Ali Aydogdu)
- 10:15-10:25 Update on SOCIB experience (Jaime Hernandez)
- 10:25-10:35 NRT and delayed mode data exchange strategy and further opportunities (Victor Turpin / Daniel Heyes)
- 10:35-10:45 The status of glider observations in the CMEMS (Thierry Carnal)
- 10:45-12:00 Discussion

10 - 14 June 2024

International Underwater Glider Conference - Gothenburg

IUGC2024

## Best practices on how to use novel sensors (gliders and floats) for assimilation and validation

A need...

- for more time to assimilate the high-quality glider and BGC-Argo observations in the NRT systems however, DM observations are already high-quality and synchronized to the required repositories.
- to come up with a universal solution. CMEMS (European) and SOCIB (Balearic) systems involved in EuroSea can be taken as a base to detect the need for improvements and propose solutions for every step of the data flow and usage.
- for communication between the communities, e.g., Argo vs. Glider communities to converge on coherent procedure and avoid inconsistencies, Argo + Glider vs. modelling + assimilation communities for the best practices on the use of observations in forecasting and reanalysis systems, e.g., on QC standards.





## Take Home / Comments

There are challenges and opportunities for collaboration

- consistency in input observations leads temporal consistency
- mass and energy balances
- Reanalysis community can improve:
  - Re-estimate of covariances in case of change in observing system
  - Correct biases to minimize systematic errors
  - Flux optimization
  - Coupled reanalysis
  - Efficient use of non-assimilated data for validation
- Observation community can:
  - Homogenize dataset / data format tailored for data assimilation
  - Improve metadata / ease access
  - Data rescue initiatives (Hawkins et al.)
  - Interface with reanalysis / data assimilation community