Centro Euro-Mediterraneo sui Cambiamenti Climatici

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CMCC reanalysis systems: in-situ data use and needs

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GTSPP/IQUOD/SOOIP/XBT science meeting

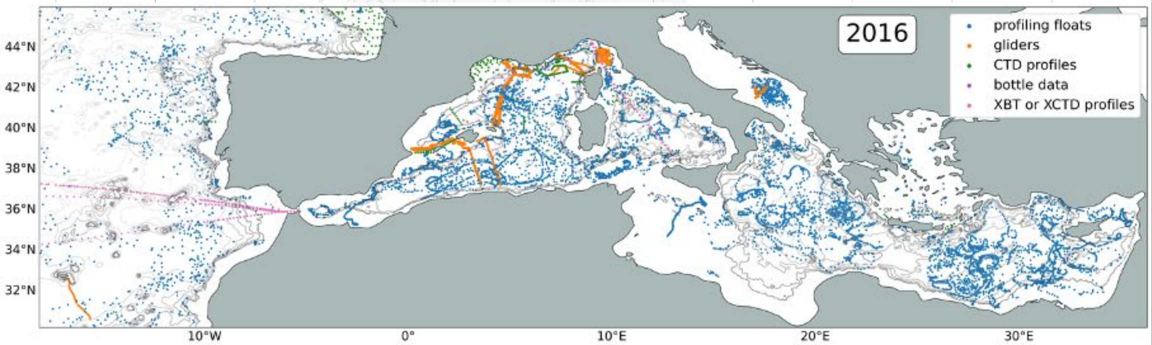
11-14 November 2024
Bologna

CMCC Multiyear Systems

- 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°) 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 Service | MERCATOR OCEAN INTERNATIONAL

COPERNICUS MARINE ENVIRONMENT MONITORING SERVICE

Copernicus Marine Service
CMEMS-MFC MED

COPERNICUS MARINE SERVICE
MEDITERRANEAN SEA MFC
Until 31 Dec. 2024
Contract 21002L5-COP-MFC MED-5300

Med-MFC In-situ observations requirements

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

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

BLK-MFC

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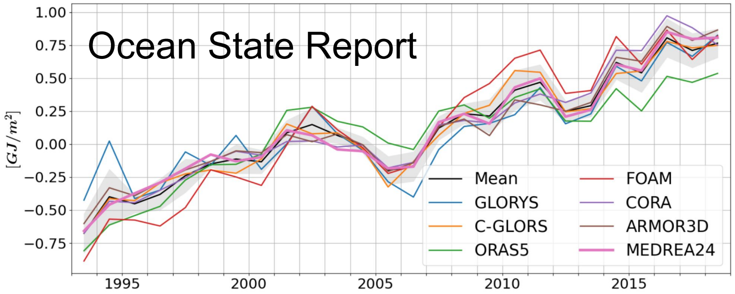
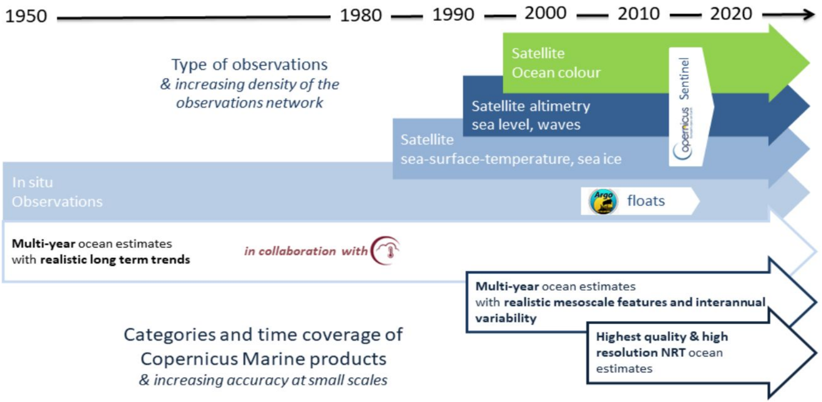
(1) CMCC, (2) Hereon, (3) University of Liege, (4) IO-BAS

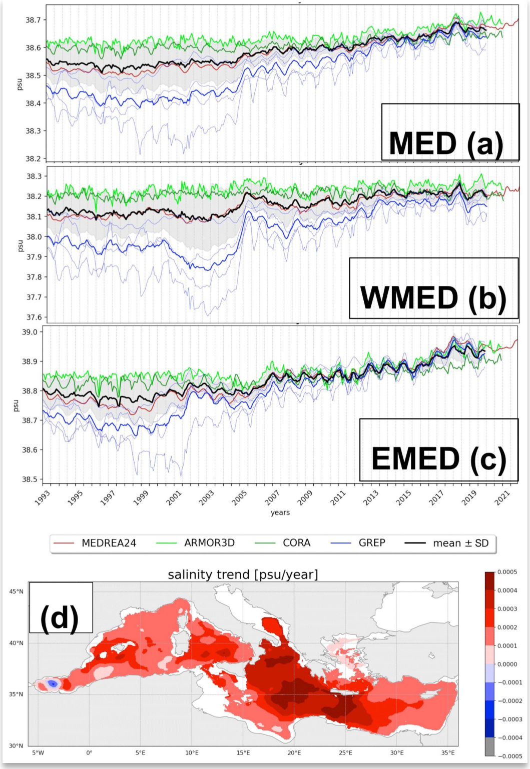
CMCC Multiyear Regional systems

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.)



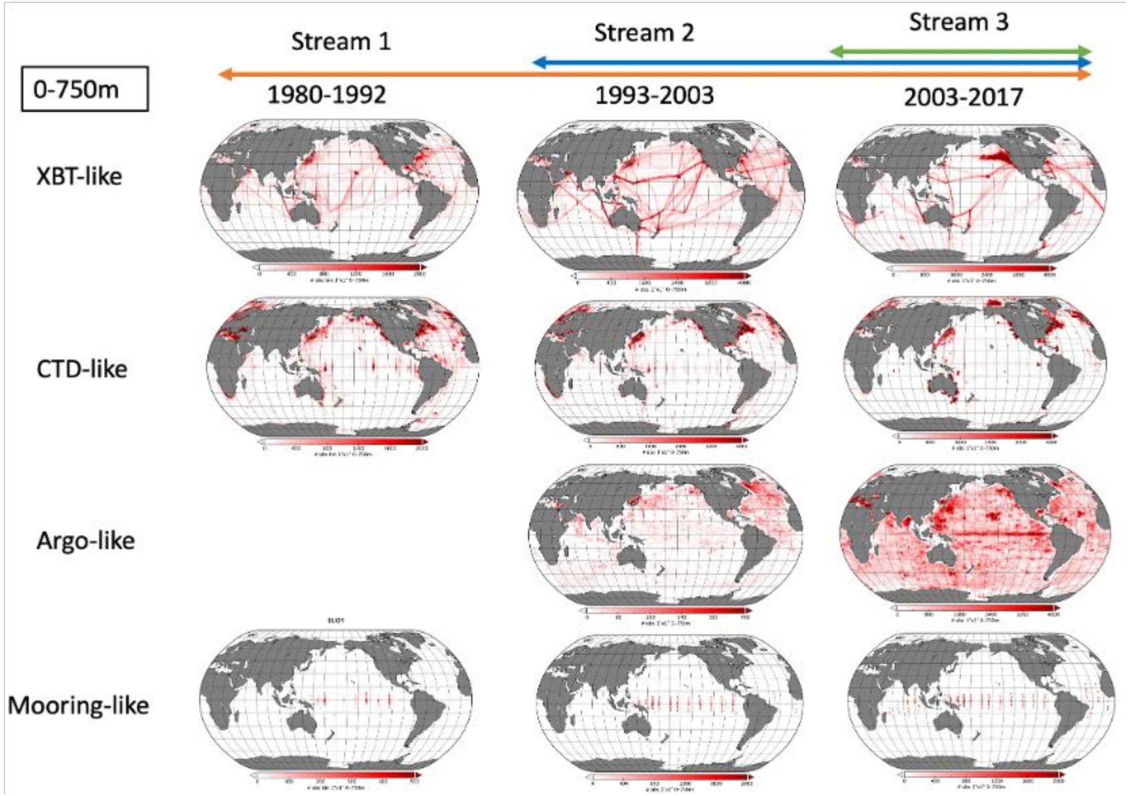




Mean **salinity** in the upper 300 m (a) MED (b) WMED (c) EMED from MEDREA24, ARMOR3D, CORA, GREP and their ensemble mean. (d) **trend**.
Aydogdu et al. (2023)

C-Glors Global Reanalysis

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

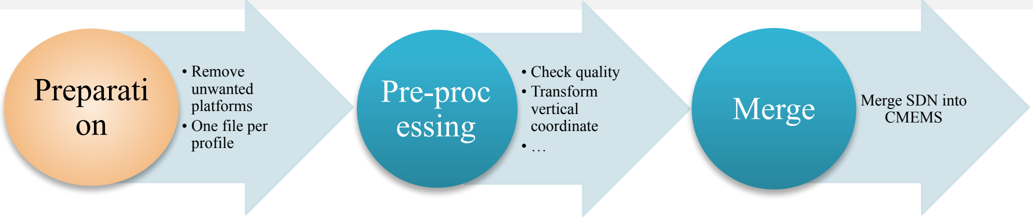


The model state can be far from the initial observations that are automatically treated as “outliers”, being too far from the model, and excluded

OBSERVATION DISTRIBUTION 0-750m (1°bin)

In situ data curation

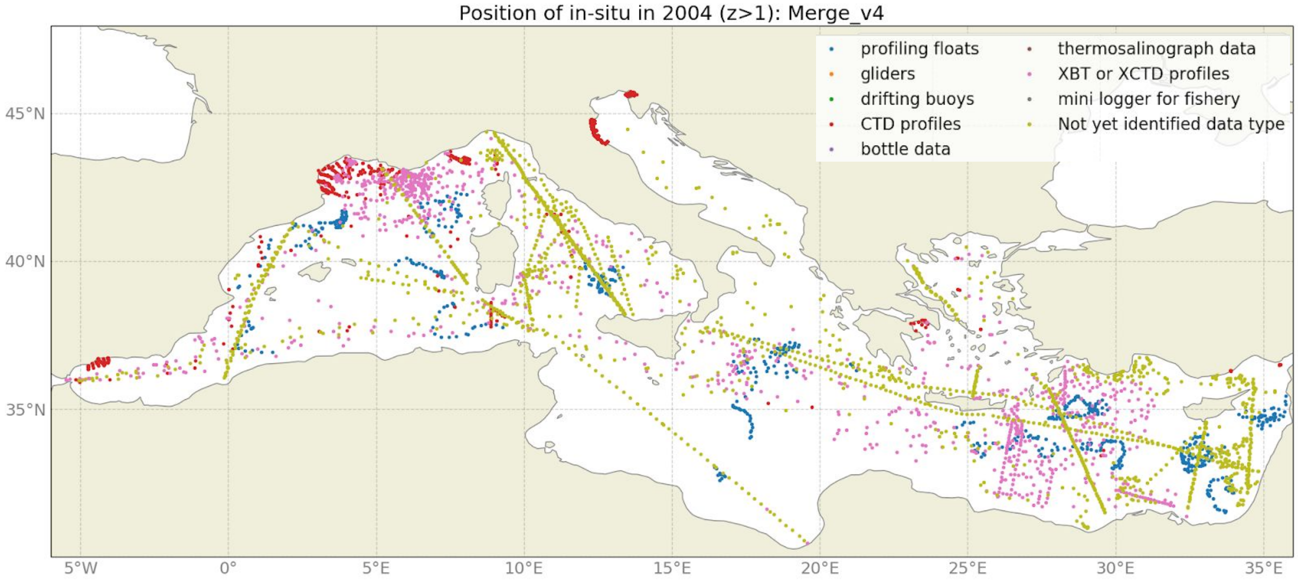
Temperature and salinity



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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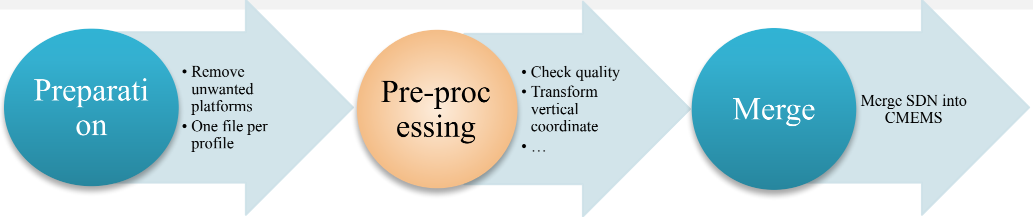

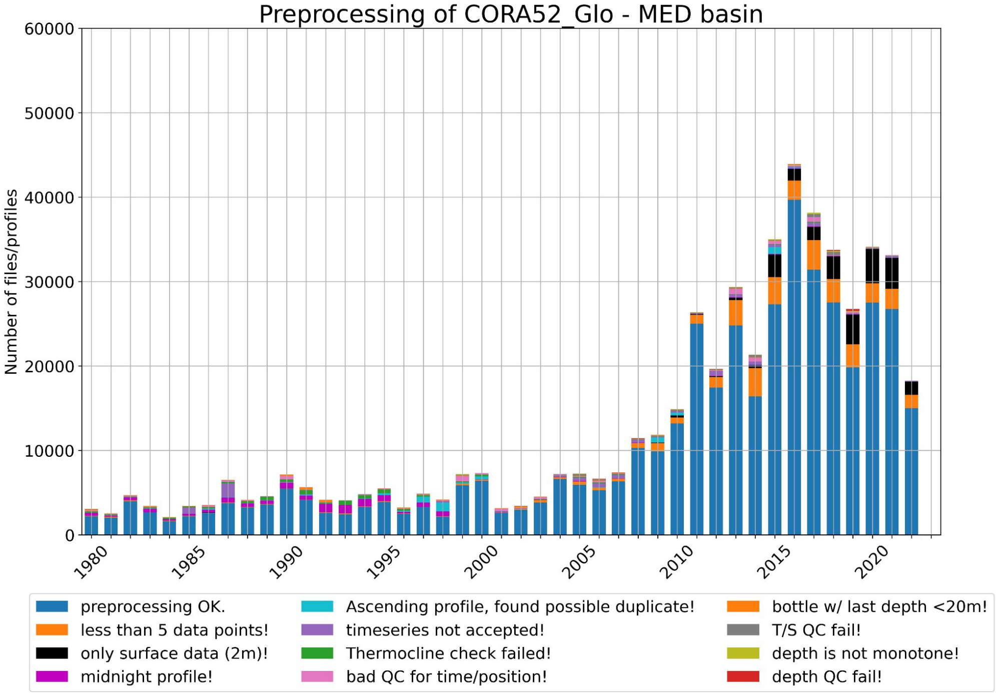

Quality check before merging

In situ data curation

Temperature and salinity

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- INSITU CMEMS REP Global
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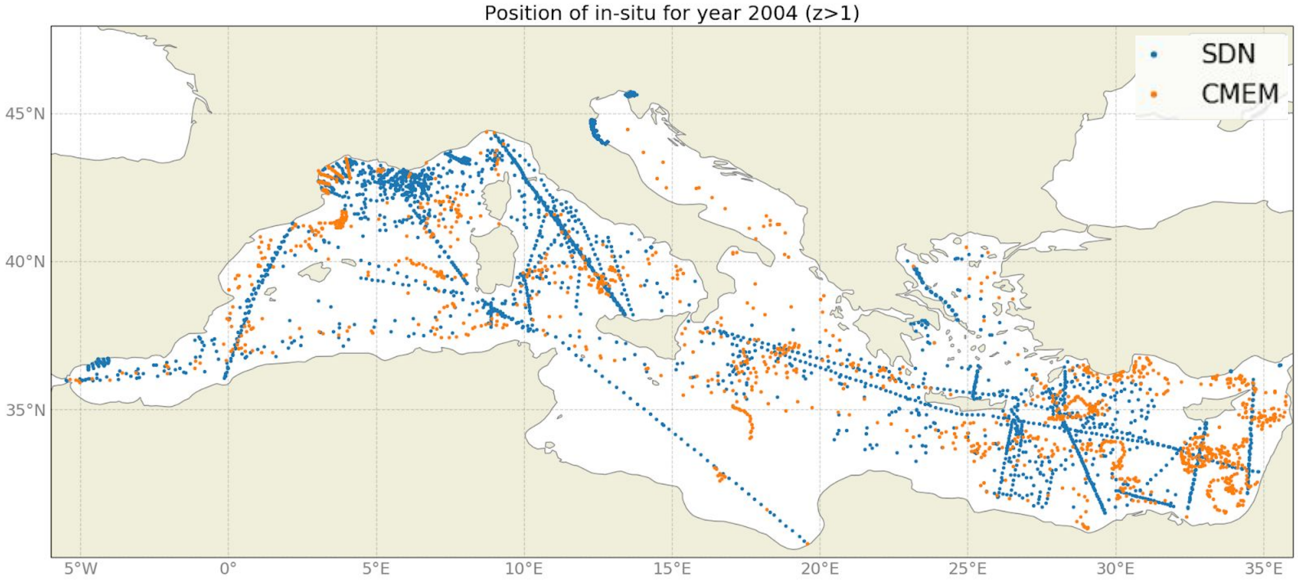
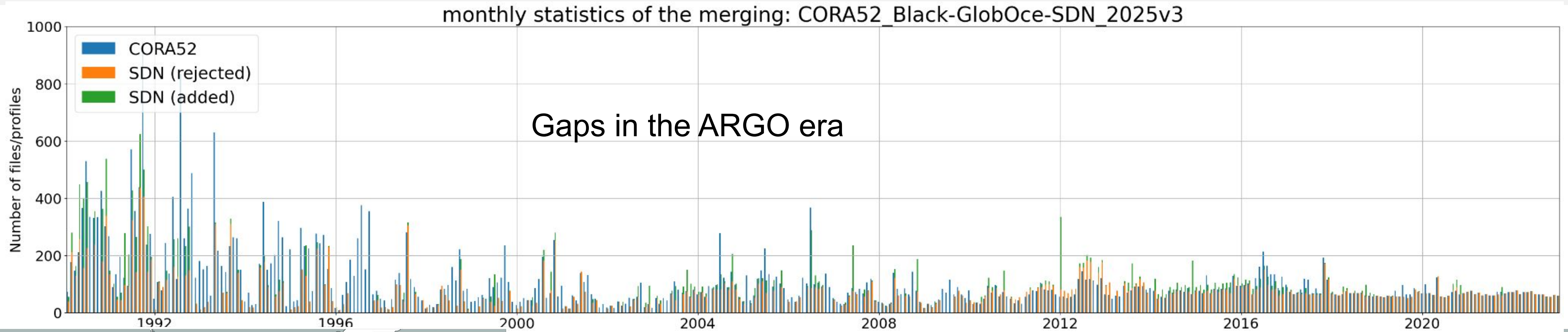
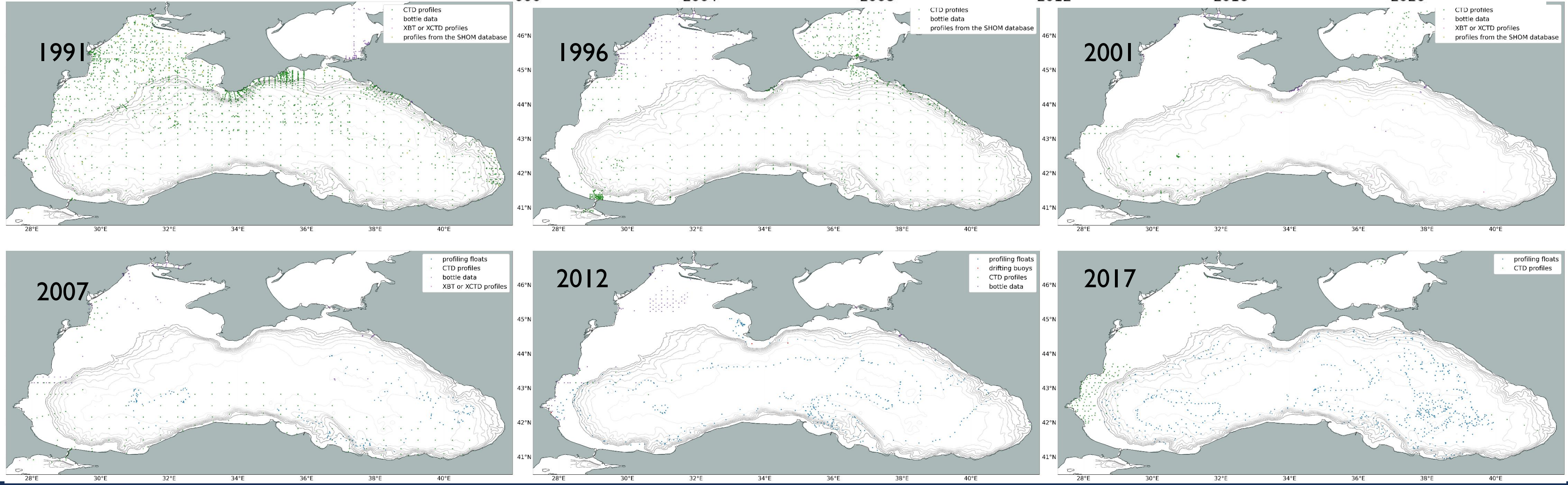
for profiles of Temperature and Salinity from ARGO, CTD and XBT.



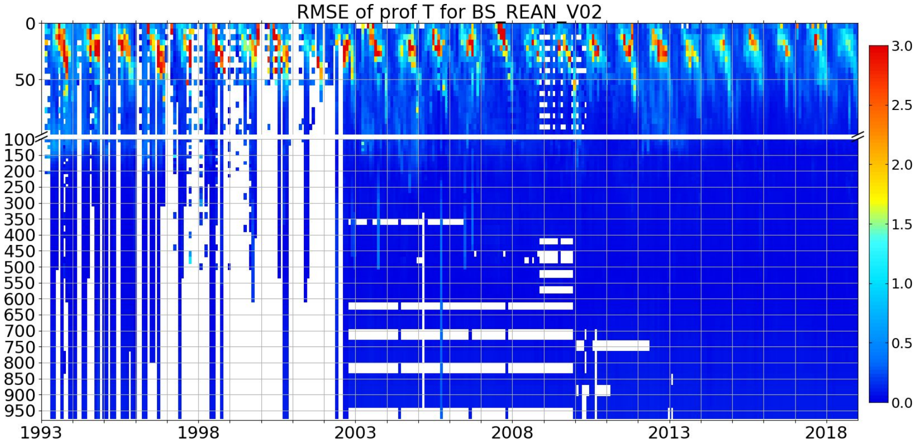
Gaps in the African coast, Adriatic Sea and Aegean Seas

Gaps in the ARGO era

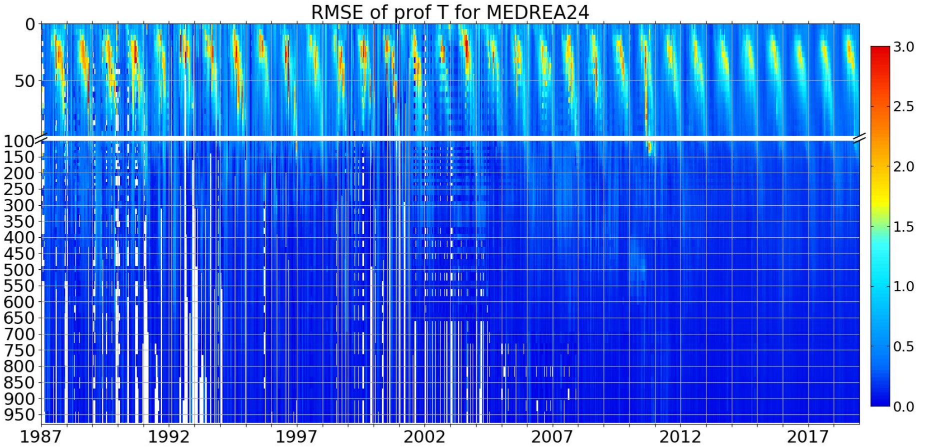


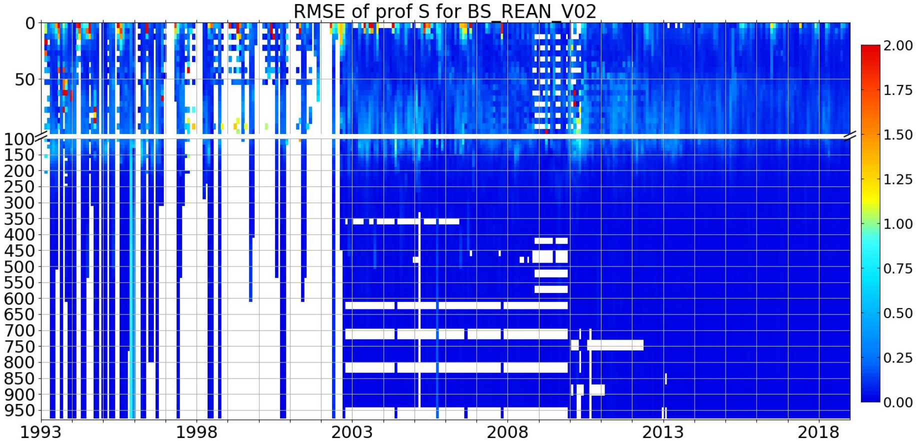


Black Sea temperature Hovmoeller of RMSD

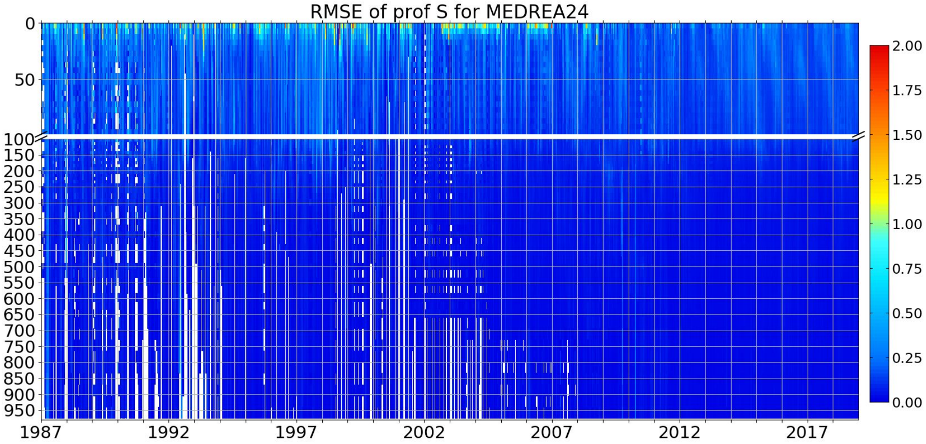


Med Sea temperature Hovmoeller of RMSD





Black Sea Salinity Hovmoeller of RMSD



Med Sea salinity Hovmoeller of RMSD

Vertical distribution of the observations

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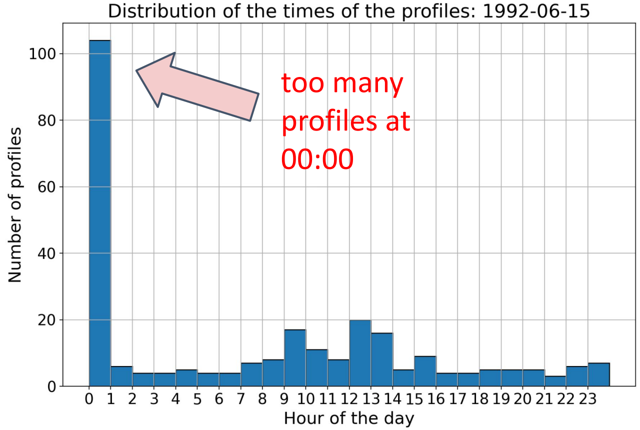
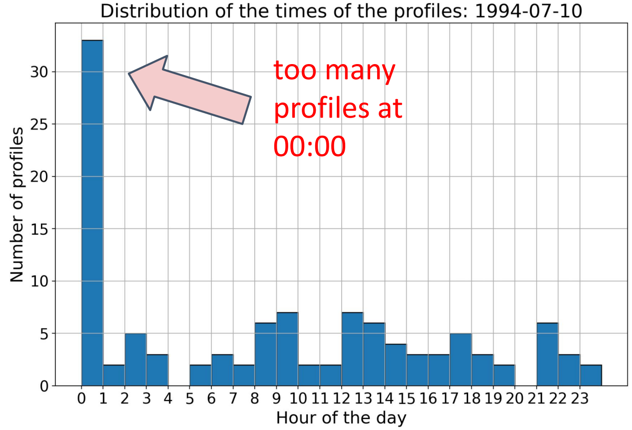
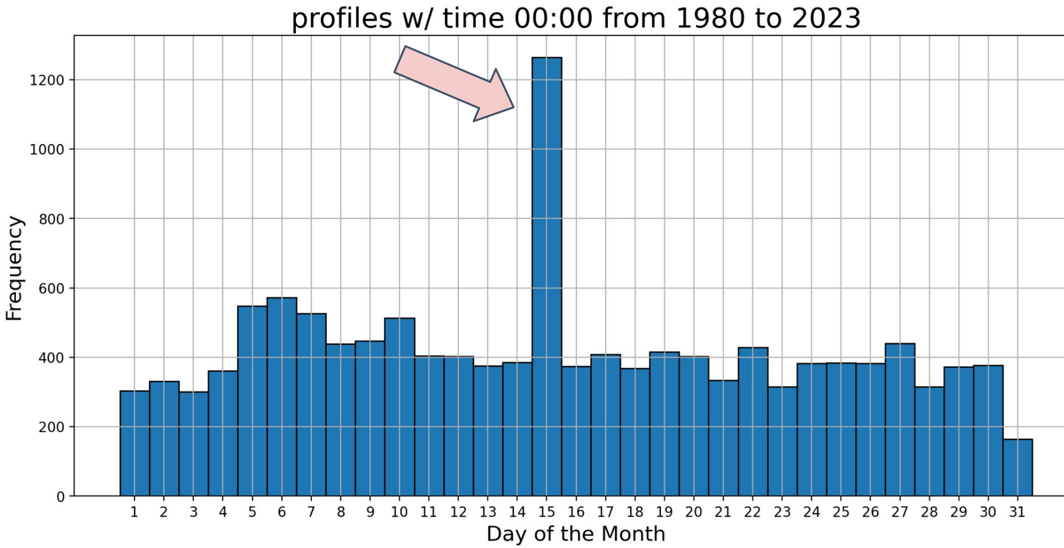
CTD profiles with time = 00:00:00 (Med Sea)

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.



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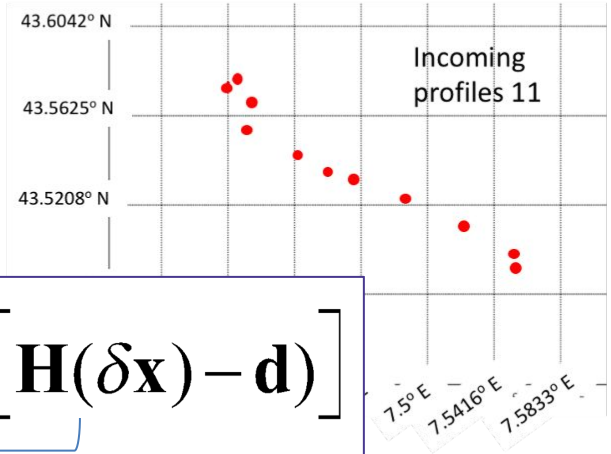
Data Assimilation problem

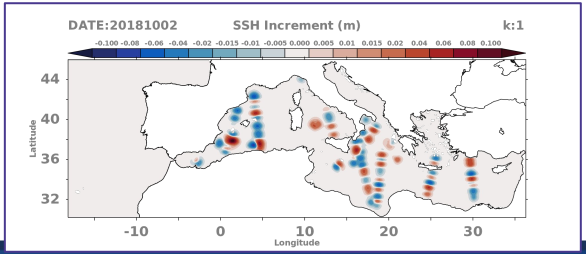
observation space



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

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

model space



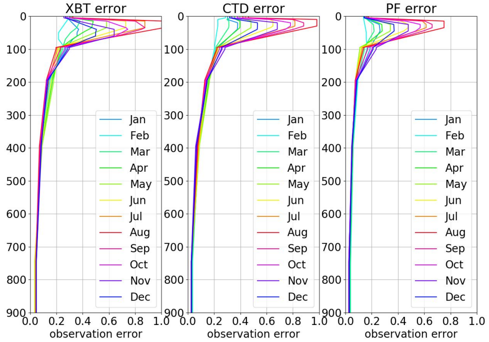
B	background error covariance matrix
R	observation error covariance matrix

Quality Check

The treatment of <u>outliers</u> 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

Desroziers method



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

- 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

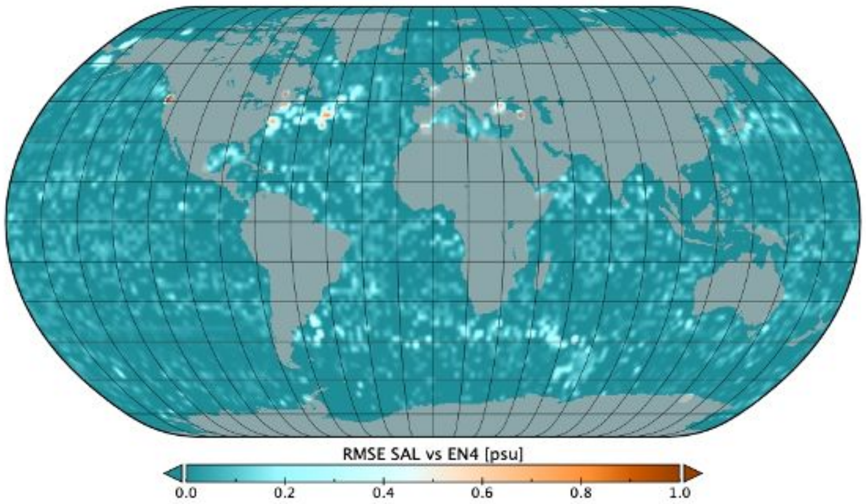
Huber-norm pdf

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

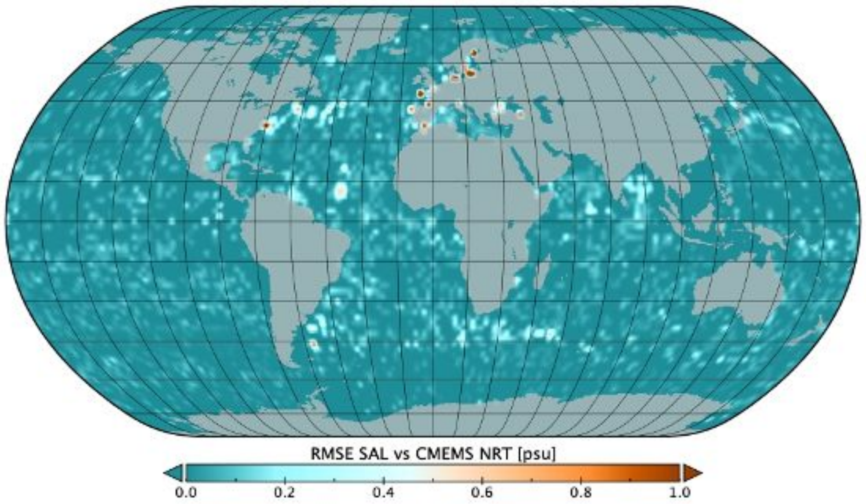
C-Glors Global Reanalysis

The assimilation of “outliers” in neal-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]



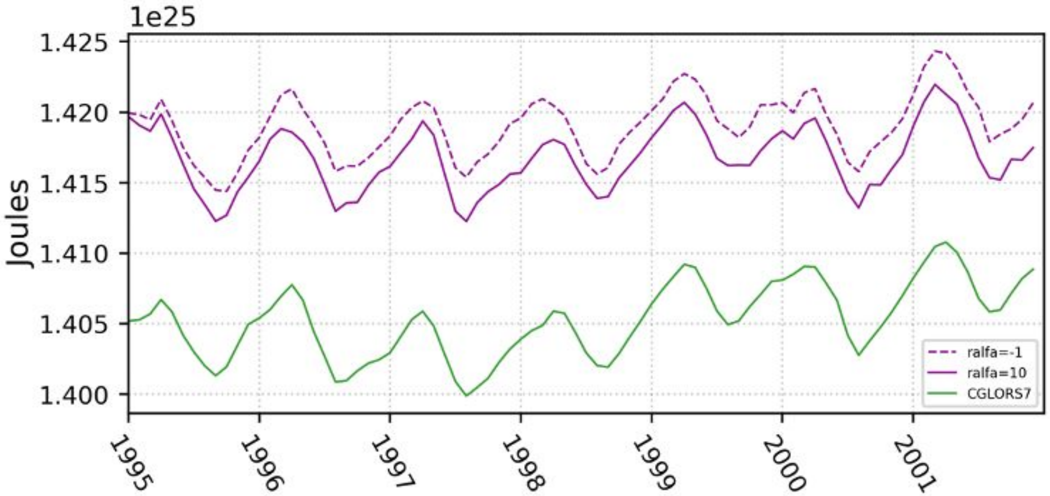
Salinity RMSE [0-1500]



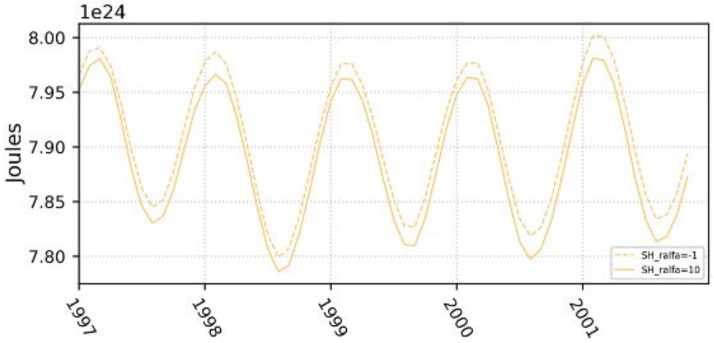
C-Glors Global Reanalysis

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

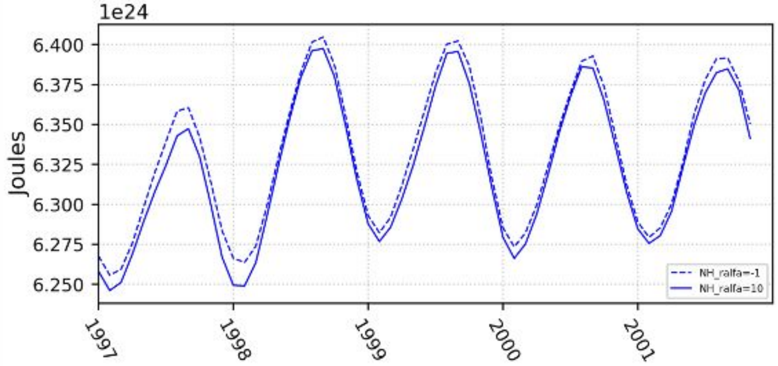
OHC [0-1500]



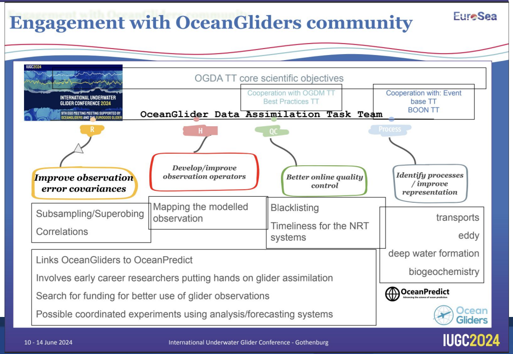
SH OHC



NH OHC [0-1500]



Interaction with observation producers



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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