

Performance and quality assessment of the global ocean eddy-permitting physical reanalysis GLORYS2V4.

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Mercator Ocean, ¹CLS (Toulouse)

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The Mercator Ocean Global Reanalysis GLORYS2V4

Outlines

1. Objectives
2. The New GLORYS system
3. Validation Protocol/Results
4. Summary/Prospectives



Mercator Ocean Reanalysis at $\frac{1}{4}^\circ$ GLORYS (1993-2015)

Objectives

- Reproduction of climatic signals on altimeter periods (from 1993 until present), with interannual variability and trend (essential variables, heat content, mass, sea ice, biogeochemistry...).
- A reference database for the description of the global ocean (Ocean State Report/CMEMS).
- As close as possible to Near Real Time in order to be a reference for real time application (Copernicus Marine Environment Monitoring service/CMEMS).
- Deliver boundaries conditions for coastal and regional applications (CMEMS).
- Deliver initial conditions to coupled predictions (seasonal, climatic scenario).
- All available observations are assimilated.



Mercator Ocean Reanalysis at $1/4^\circ$ GLORYS (1993-2015)

The core of the actual GLORYS System

Model/Configuration

- **NEMO3.1** (TKE, ...) at $1/4^\circ$, 75 z-levels.
- LIM2 : thermodynamic-Dynamic (2+1 Semtner-like) sea ice model
- Atmospheric forcing : **ERA-Interim** (3H) – Bulk Formulation.
- Bathymetry: ETOPO+GEBCO
- Runoffs: seasonal climatology (120 rivers).

Assimilation

- SAM2 (Singular Evolutive Extended **Kalman filter**) / 3D-FGAT innovation (First Guess at Appropriate Time) / IAU (Incremental Analysis Update)/ Local 2D Technic.
- **3D-VAR** Large Scale Biases Correction
- Assimilation of sea ice concentration

Observations

- **SST** ($1/4^\circ$) from AVHRR+AMSRE
- **Altimetry** (T/P, Jason, Cryosat2, ...)
- **In situ** (T,S) (Argo) from CORA (CMEMS*) data base
- Hybrid Mean Dynamical Topography (**MDT**)

CMEMS* = Copernicus Marine Environment Monitoring Service



Changes since last release

GLORYS2V3

Runoff (rivers): Dai & Trenberth (2002)

EmP=0 (Mass surface budget)

Initial conditions (T,S) from Levitus (1998)

3D (T,S) damping south. 60°S and below 2000m depth. **No SSS restoring.**

Large scale correction of rainfalls and radiative fluxes towards resp. GPCPV2.2 & GEWEX SRB3.0.

Hybrid MDT CNES-CLS 09

CORA3.3 in situ data base

Assimilation of sea ice CERSAT



GLORYS2V4

Idem but Dai & Trenberth (2009) + Greenland and Antarctica's freshwater fluxes

Idem +
Mass surface budget =+1.74mm/yr

Global mean of steric* increment=0

Initial conditions (T,S) from **EN4** (90's)

Idem + damping in Gibraltar and Bab-EI-Mandeb straits.

Idem but Large scale correction of rainfalls towards PMWC

Hybrid MDT CNES-CLS **13**

CORA4.1 in situ data base

Idem.

steric* = volume changes due to density changes



Validation Protocol

QUID (Quality Information Document/CMEMS)

GLORYS quality control

Current quality control : Assessment of the reliability of the reanalysis on average, and at basin scale

- **Model physics**
 - **Water masses, Currents and transports, Variability, Mesoscale, Waves, high frequencies, tides**
- **Data assimilation performance, error tunings**
- **Stability over time (need for long hindcast)**
- **Intercomparisons between reanalysis products (GOV/CLIVAR/GSOP ORA IP)**
- **QC on assimilated data → feedback to observation data centers**
- **Non regression with respect to previous versions**
- **Summary of results.**

<http://marine.copernicus.eu/documents/QUID/CMEMS-GLO-QUID-001-025-011-017.pdf>

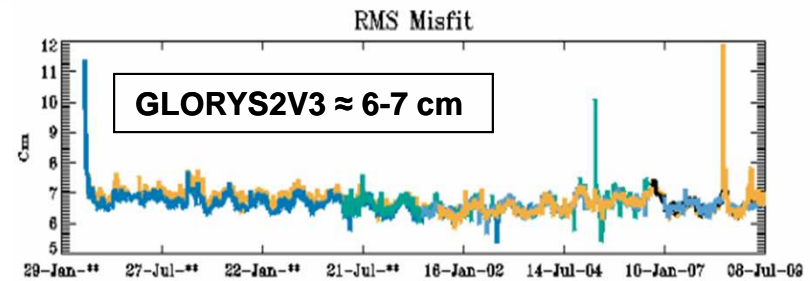
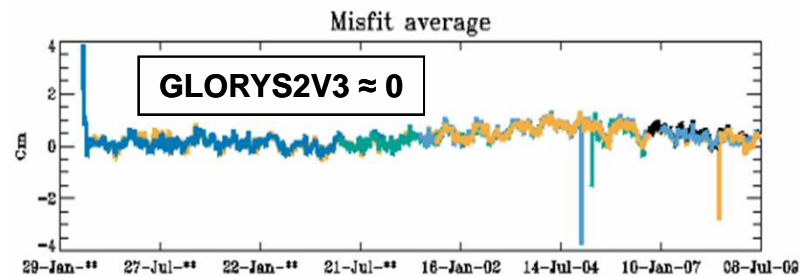
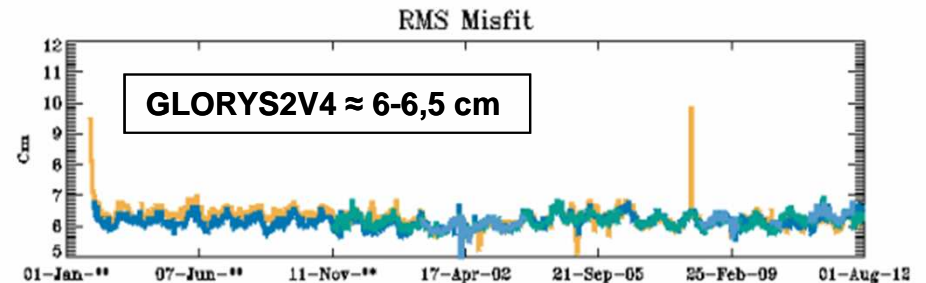
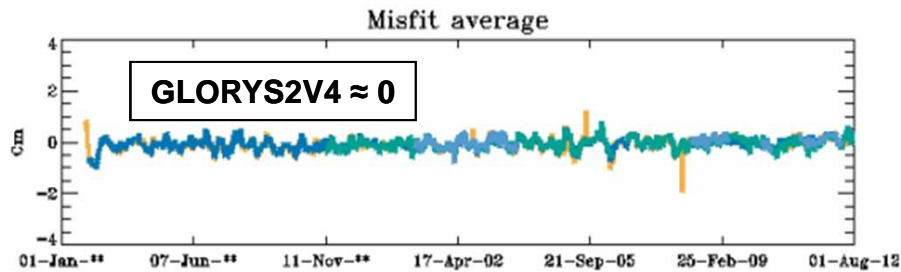


Validation Protocol QUID (Quality Information Document/CMEMS) GLORYS quality control

Sea Surface Height

Bias with satellite data

Root Mean Square Error with satellites



Satellite Data include : ERS, T/P, Jason 1 & 2, Envisat, GFO, Saral/AltiKa, Cryosat2, HY2A.

Validation Protocol

QUID (Quality Information Document/CMEMS)

GLORYS quality control

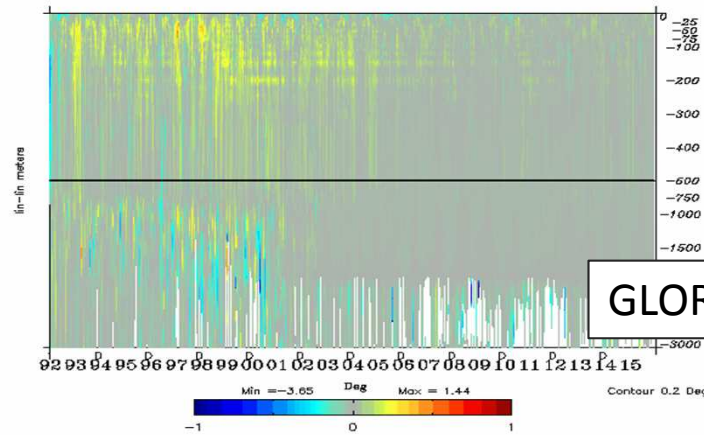


In Situ Data

(Blue is warmer or saltier.)

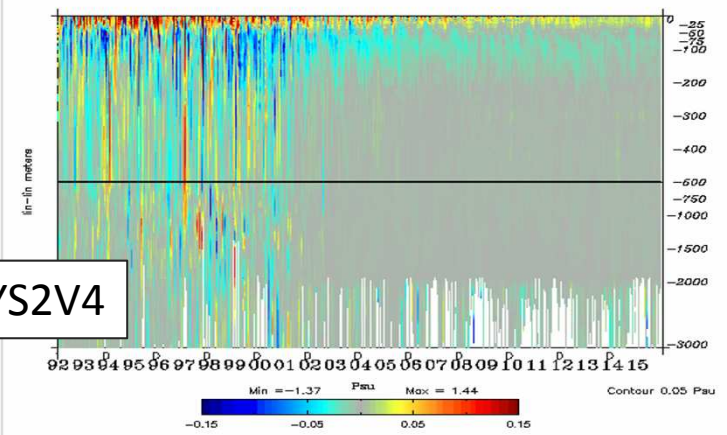
- Less biases with ARGO network.
- Less biases in G2V4 in Temperature and surface salinity.
- Salty bias at 100m depth (< 0.05Psu).

global : Temperature Mean Misfit (region 0)

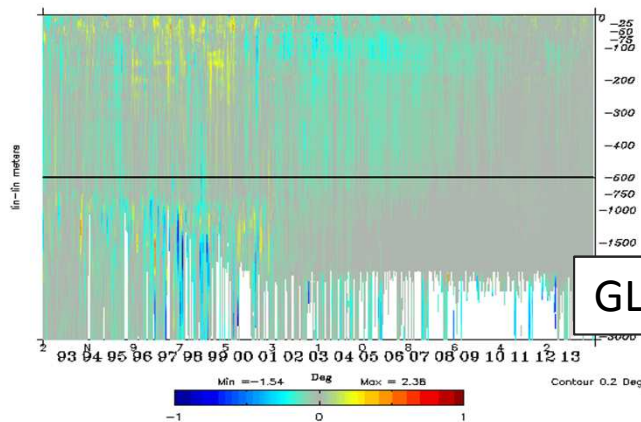


GLORYS2V4

global : Salinity Mean Misfit (region 0)

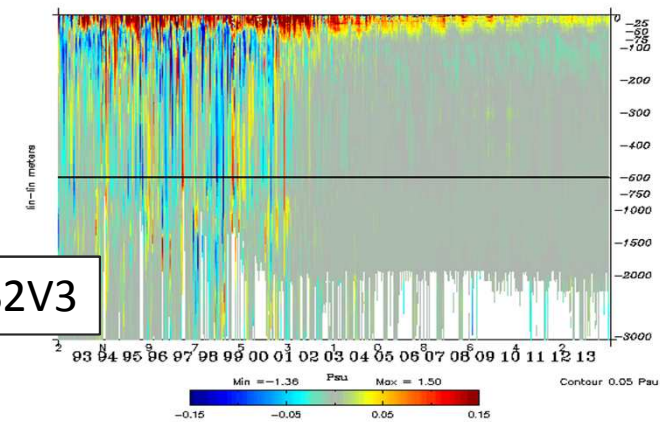


global : Temperature Mean Misfit (region 0)



GLORYS2V3

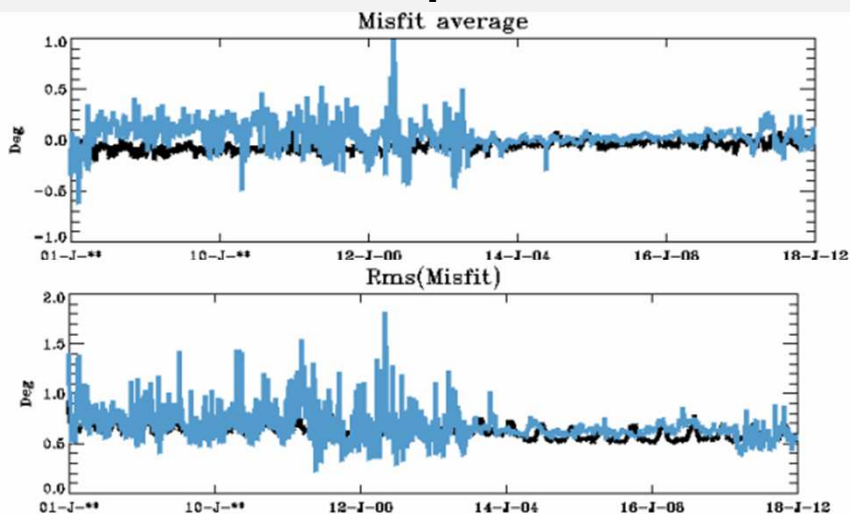
global : Salinity Mean Misfit (region 0)





Validation Protocol QUID (Quality Information Document/CMEMS) GLORYS quality control

Sea Surface Temperature



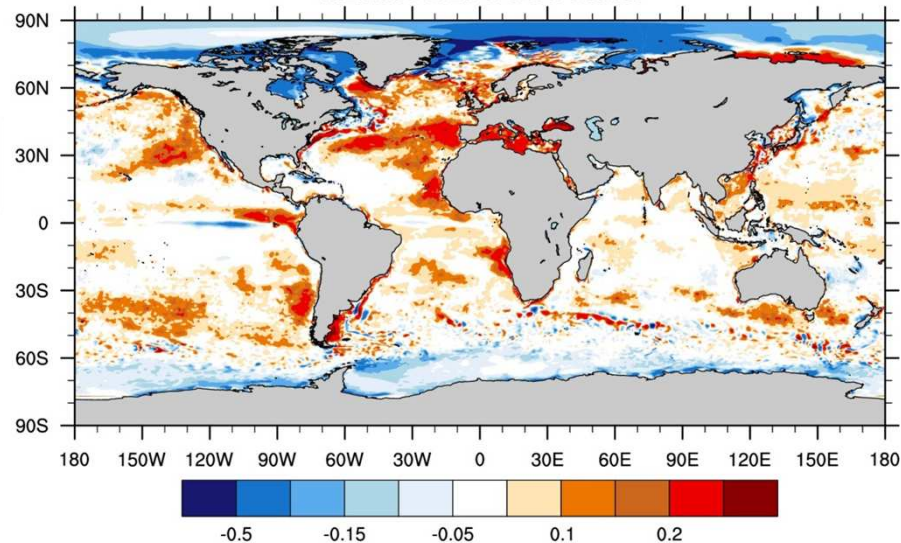
Differences relative to SST AVHRR $\frac{1}{4}^\circ$

(Warm) Bias in GLORYS2V4 $< 0.5^\circ\text{C}$

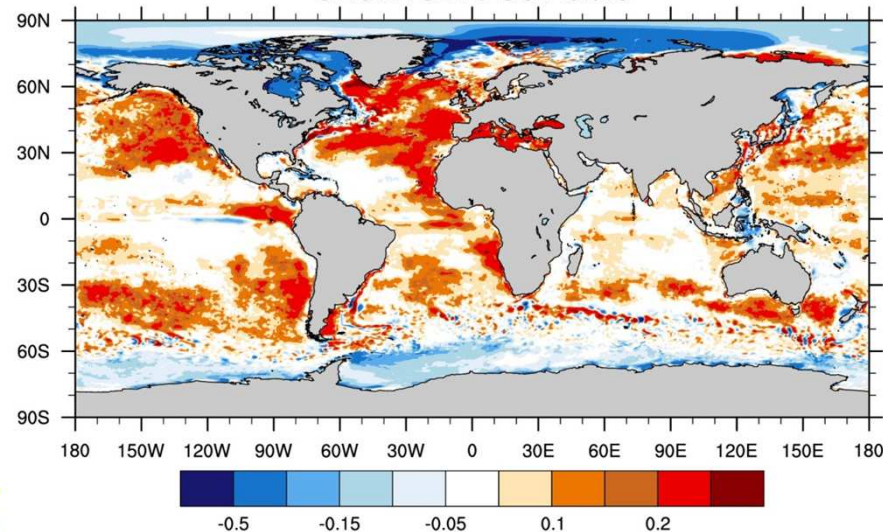
(Warm) Bias in GLORYS2V3 $< 0.7^\circ\text{C}$

Diagnostics of interest for seasonal forecast.

GLORYS2V4 SST biases



GLORYS2V3 SST biases

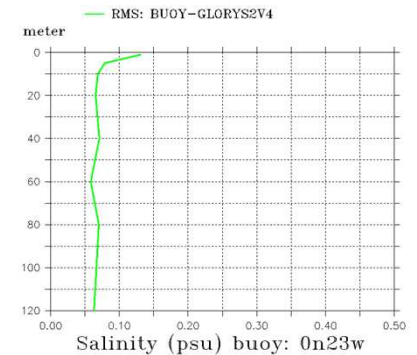
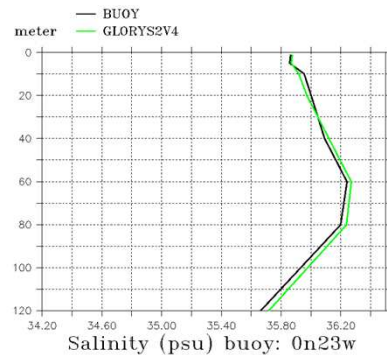
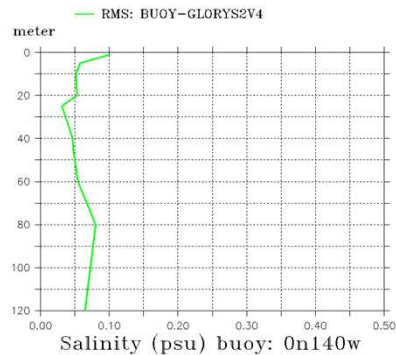
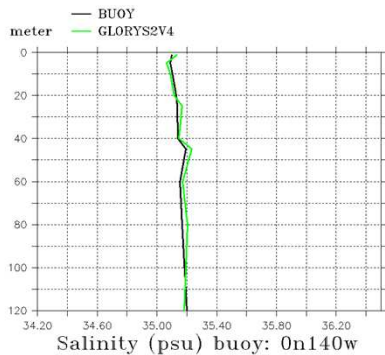




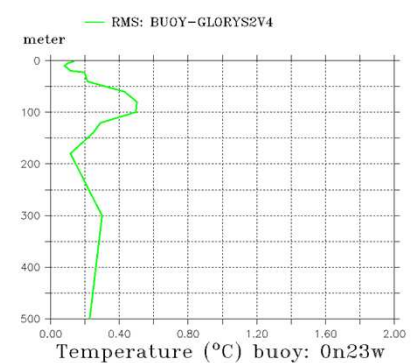
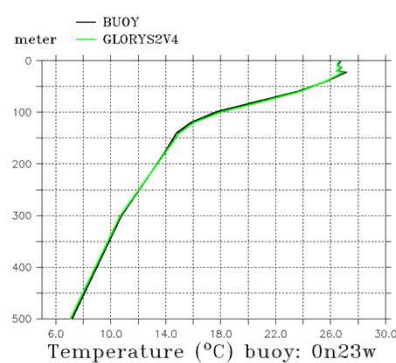
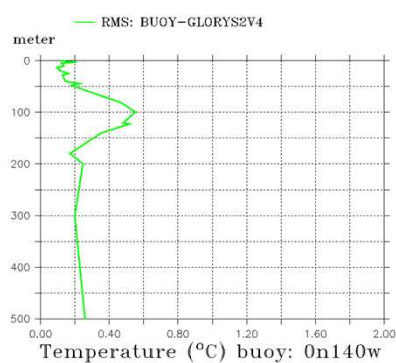
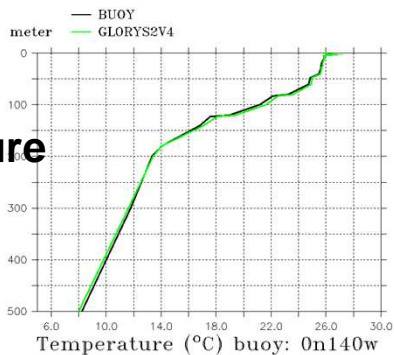
Validation Protocol QUID (Quality Information Document/CMEMS) GLORYS quality control

In Situ Data – Tropical Moorings

Salinity

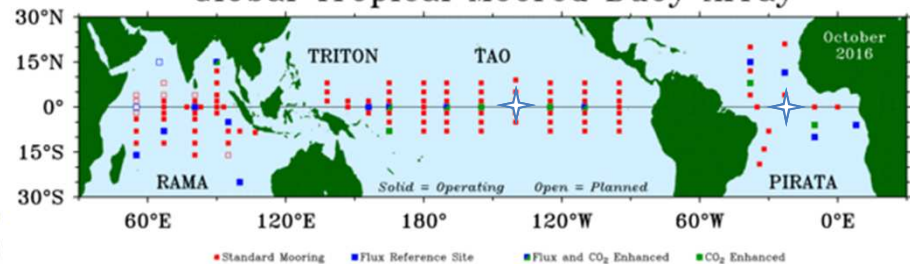


Temperature



RMS Temp. < 0.5 °C
RMS Salt < 0.2 PSU

Global Tropical Moored Buoy Array

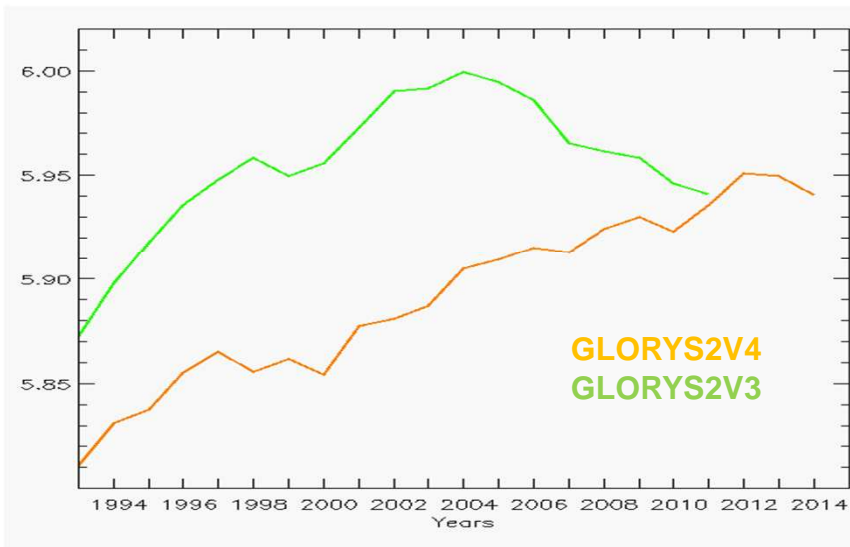




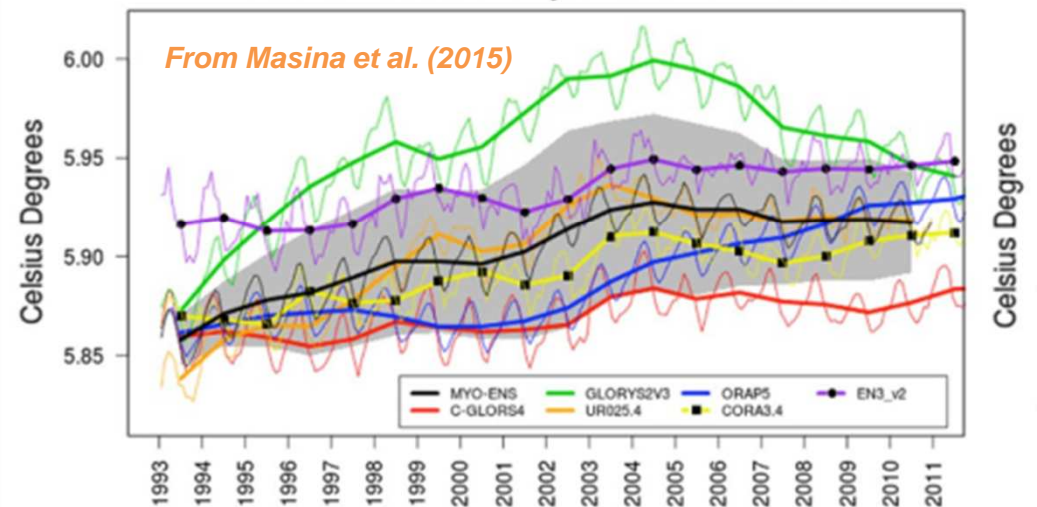
Validation Protocol QUID (Quality Information Document/CMEMS) GLORYS quality control

Mean 3D Temperature

Global Ocean Temperature 0-2000m

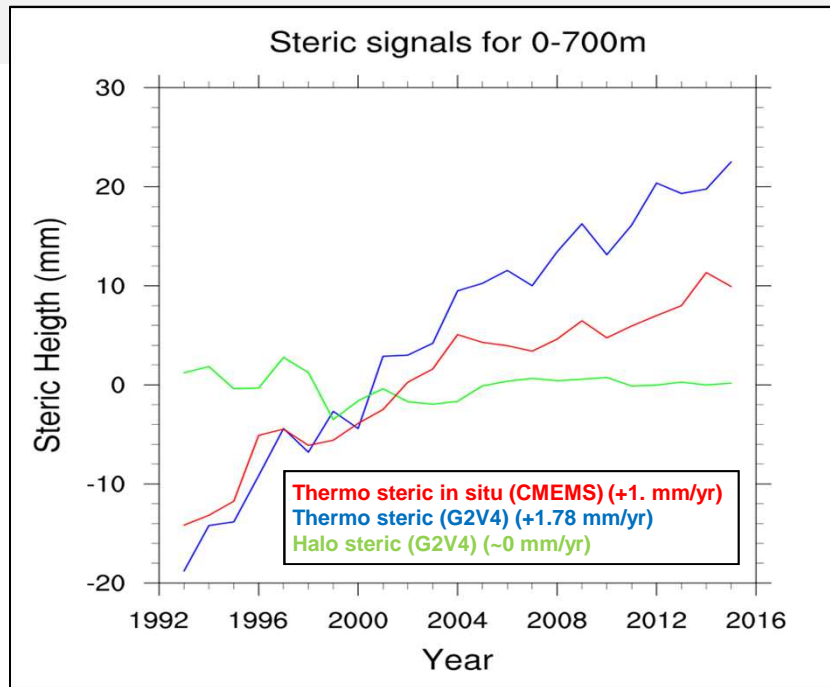


Global Ocean Temperature 0-2000 m





Steric height



Steric signal for 0m-Bottom

Trend (mm/yr)	GLORY2V4	Chambers et al. (2017)
Total steric	1.6	1.2 ± 0.23
Thermo-steric	1.8	1.2 ± 0.23
Halo-steric	-0.2	~ 0
Total mass	1.74	1.8 ± 0.46
Sum of components	3.34	3.0 ± 0.52
GMSL* (GIA* corrected)	3.56	3.19 ± 0.63

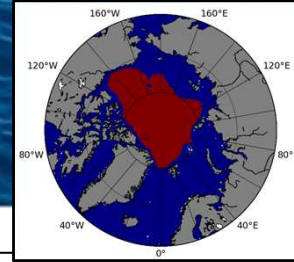
GMSL*=Global Mean Sea Level
 GIA* : Glacial Isostatic Adjustment

- Steric signal dominated by thermo-steric.
- GLORYS2V4 in good accordance with recent observed estimations.





Arctic Freshwater Content (FWC) Impact of assimilation in sparsely observed areas



**Annual mean
Arctic FWC anomaly**

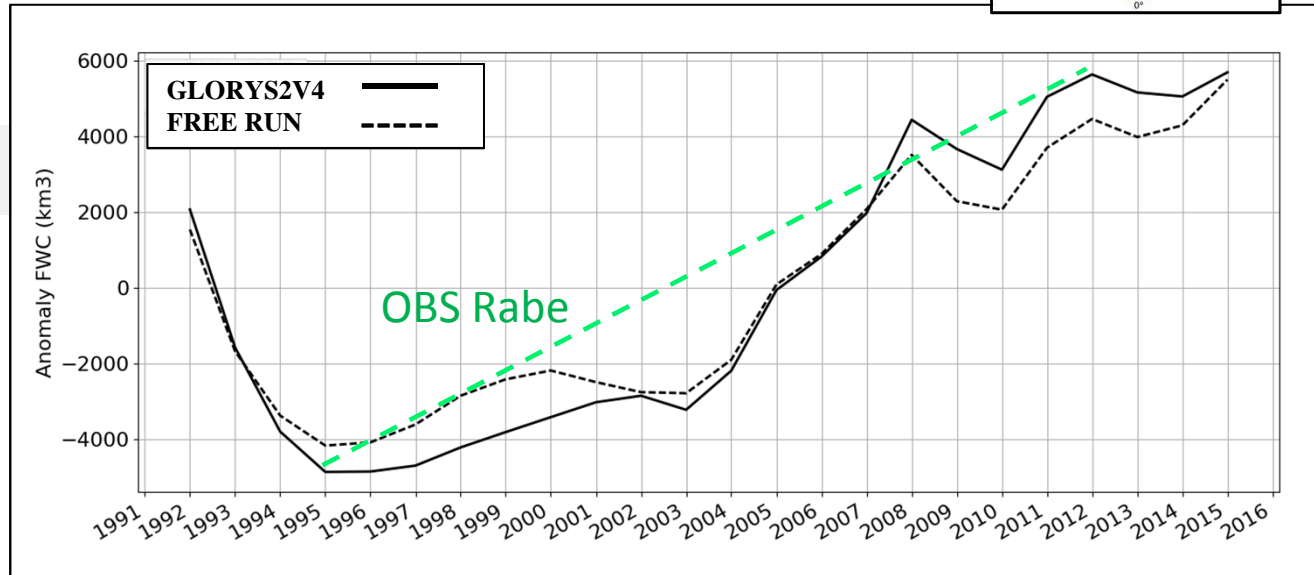
Trend 1995-2012

GLORYS2V4

677 +/- 50 km³/year⁻¹

FREE RUN

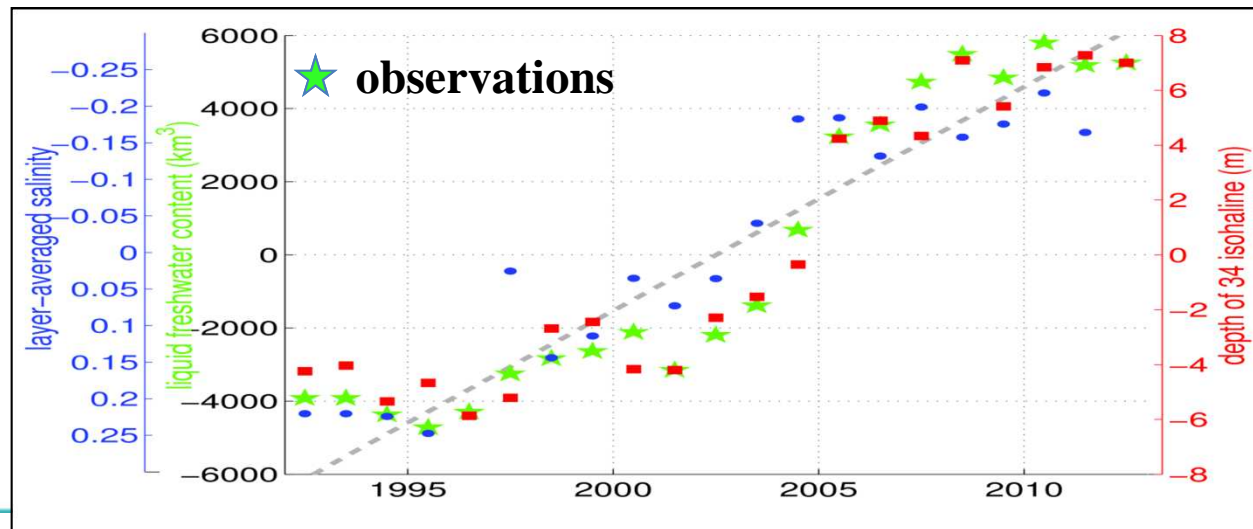
520 +/- 44 km³/year⁻¹

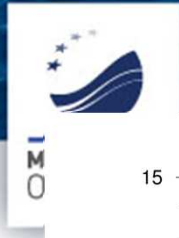


Trend 1992-2012

Rabe et al. (2014)

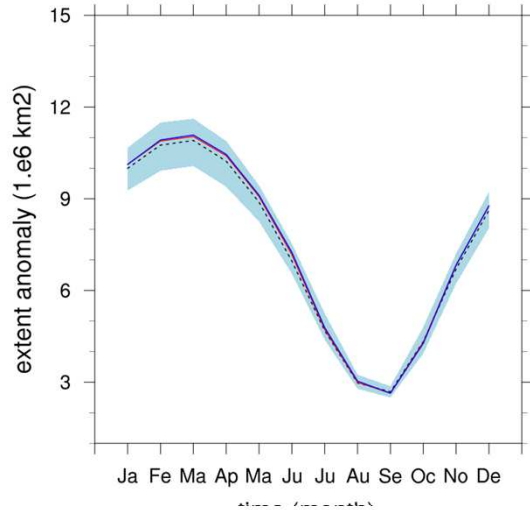
600 +/- 300 km³/year⁻¹





Sea Ice

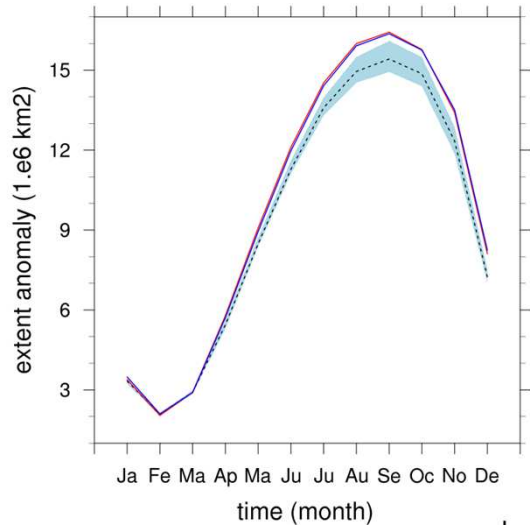
Sea ice extent mean seasonal



Arctic Ocean

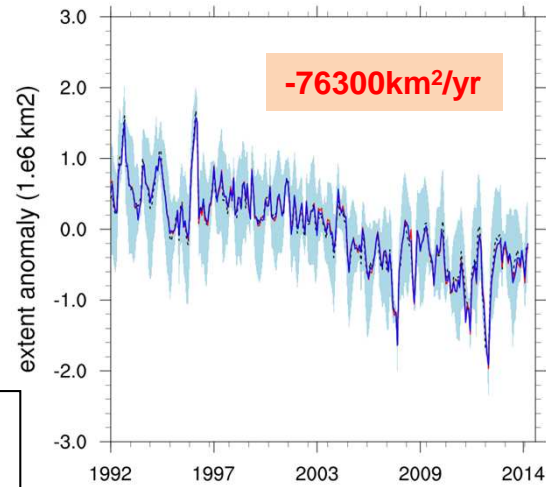
Use of different data :
CERSAT, NSIDC,
OSI SAF (CMEMS) to
assess uncertainties.

Sea ice extent mean seasonal

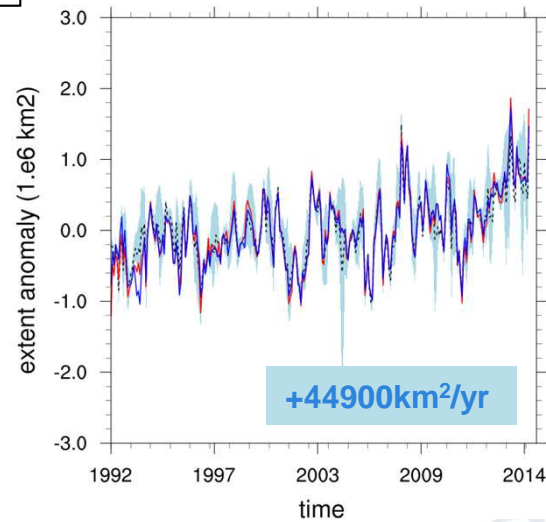


Antarctica

Sea ice extent interannual variability



Sea ice extent interannual variability





Summary/Prospectives

Summary

- ✓ Important improvement with the new release GLORYS2V4: bias & rms, SST, T, S, Heat & Salt content, Steric height (Surface Heat Flux = +0.5 W.M²).
- ✓ Validation still ongoing (biogeochemistry application, ...)
- ✓ Products (T, S, U, V, ...) available in CMEMS catalogue.
- ✓ Look forward to users' feedback!!

Prospectives

- ✓ Improvement of Surface mass budget
- ✓ Use last updates for assimilation and physics (available in NEMO3.6, time-splitting, Variable Volume, LIM3, ...).
- ✓ **Ensemble approach** (stochastic & analysis)
- ✓ Assimilation of CMEMS products (SST, sea ice, ...)
- ✓ **GLORYS12V1 (1/12°) (1993-2016) ongoing run.**



CMEMS Ensemble Products:

- ✓ Multi model (CMCC/ECMWF/Mercator/MetOffice) multi year global $\frac{1}{4}^\circ$ reanalysis product with uncertainty estimates for T, S, U and V and able to derive Ocean Monitoring Indices (Ocean State Report).

- *'GREP: Evaluation of the Copernicus Marine Service Global Reanalysis Ensemble Product: deriving uncertainty estimates for 3D T and S variability in the ocean'*, Desportes et al., Tue, 25 Apr, 17:30–19:00, Hall X4, X4.115.
- *'The Ocean State Report of the Copernicus Marine Environment Monitoring Service'*, von Schuckmann and the Ocean State Report Task Team, Tue, 25 Apr, 17:30–19:00, Hall X4, X4.103.