The Copernicus Marine Service Global Reanalysis Ensemble Product GREP:

deriving robustness estimates for ocean variability over the altimetry era

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[6]Environment Canada, Canada
[7]CMRE / NATO, Italy

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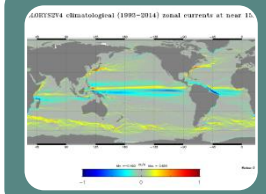
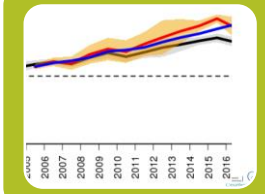
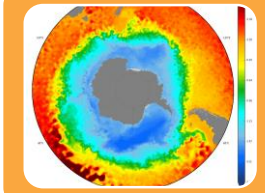
Overview



GREP : a global 1993-2017 multi-reanalysis ensemble product at ~25km and daily frequency



Ocean Monitoring Indicators and their robustness estimates



Other applications

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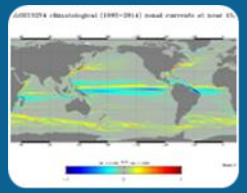
G R E P

Design and evaluation



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Four reanalysis products using NEMO ¼°

- ✓ Use of **NEMO ORCA025** (1/4°) **+ LIM & 75 vertical levels**
- ✓ Forced with **ERA-interim** reanalysis
- ✓ **Multivariate assimilation** of satellite SST, SLA, in situ T/S profiles + satellite Sea Ice concentrations
- ✓ oceanic initial conditions for coupled ocean-atmosphere seasonal (re)forecasts
- ✓ 1993-2017 ensemble mean, standard deviation and individual members for T, S, U, V, SSH, SIC available in July 2019 from **marine.copernicus.eu**
  - ✓ **¼°x ¼° daily frequency available in July 2019**
  - ✓ 1°x1° monthly 1993-2016 already online
  - ✓ CMEMS open and free data policy

Approach based on ORA-IP (Balmaseda et al , 2015) & multi ORA (Xue et al, 2017)

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Four reanalysis products using NEMO ¼°

Name / main reference	Production centre	Model version	Assimilation
GLORYS2V4 / Lellouche et al (2013) , Ocean Science	Mercator Océan	NEMO3.1 LIM2	SAM2 (SEEK) & 3Dvar bias correction 7-day assimilation window Hybrid MDT (obs+model)
GLOSEA5v13 / MacLachlan et al (2014) QJRMS	UK Met Office Hadley Center	NEMO3.4 CICE4.1	NEMOVAR (3Dvar) & bias correction 1-day assimilation window Hybrid MDT
C-GLORSv7 / Storto et al (2016) QJRMS	CMCC	NEMO3.6 LIM2	OceanVar (3Dvar) & bias correction 7-day assimilation window Model MDT
ORAS5 / Zuo et al (2017) ECMWF Tech Memo	ECMWF	NEMO3.4.1 LIM2	NEMOVAR (3Dvar) & bias correction 5-day assimilation window Model MDT

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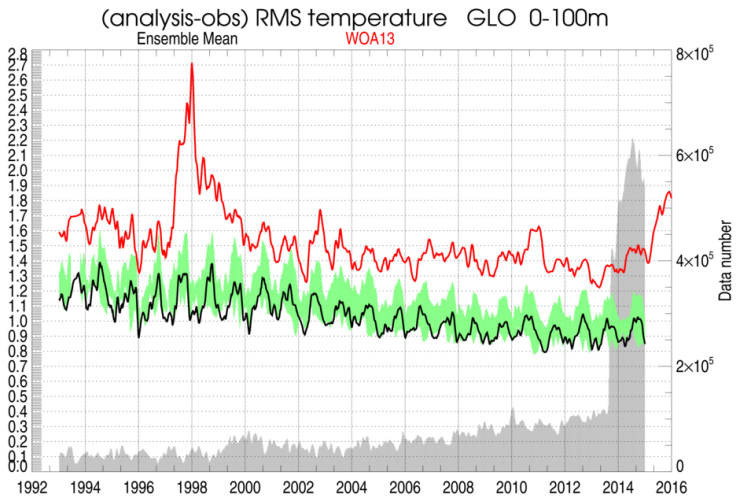
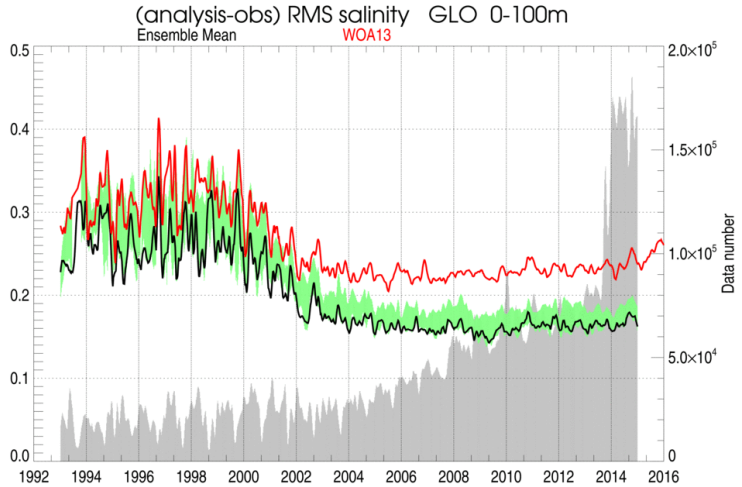
Evaluation with GODAE CLASS4 metrics

check of accuracy with respect to assimilated in situ T & S profiles





All individual members are evaluated with CLIVAR/GSOP/GODAE metrics

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Evaluation of individual members: GLORYS

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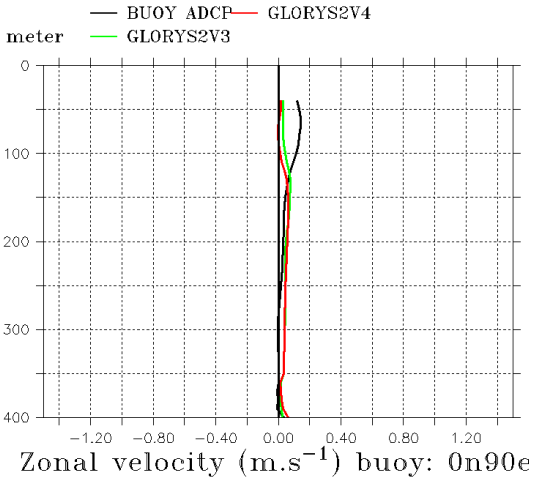
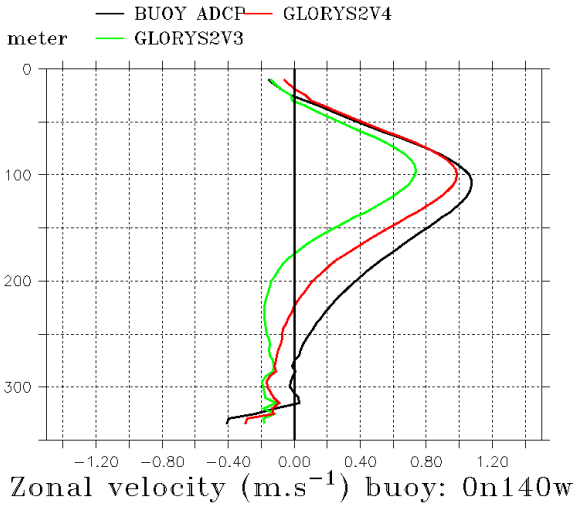
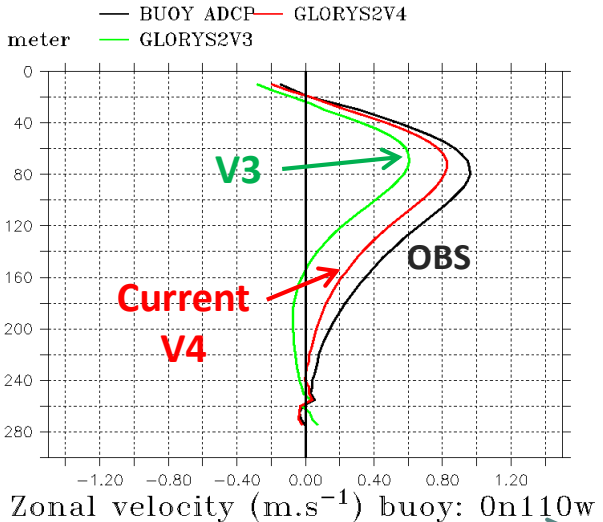
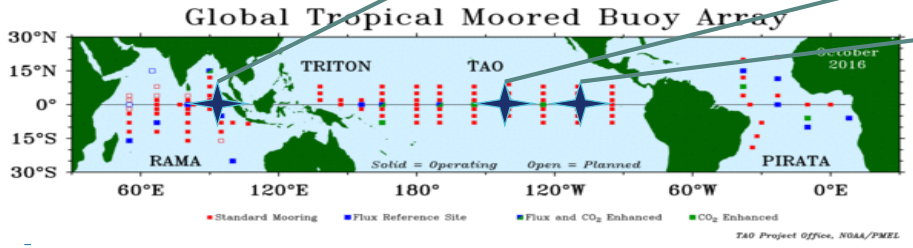
Independent current meters from TAO/TRITON (in situ TAC)









RMS < 0.3 m.s^{-1}

Underestimation of EUC (Equatorial Under Current)

Continuous improvement since the beginning of GLORYS

-> data assimilation & mean dynamic topography

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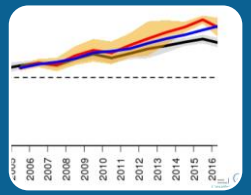
Ocean state reporting with GREP



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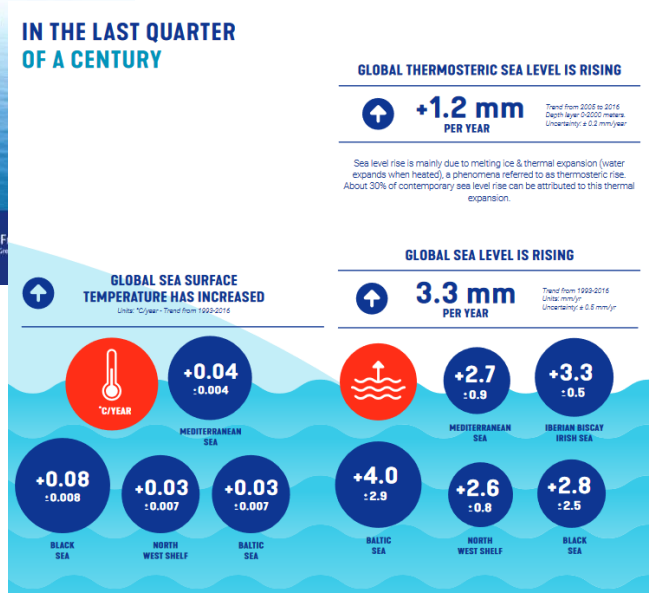
Ocean State Report

Reference eu peer reviewed **annual report (now #4 in preparation)** based on CMEMS products



Online **summary and indicators** for

- EU and Member States policy makers
- Environmental agencies
- Regional Sea Conventions
- International organizations (IPCC, UN SDG14, OECD…)

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Assessing robustness of OMIs with GREP

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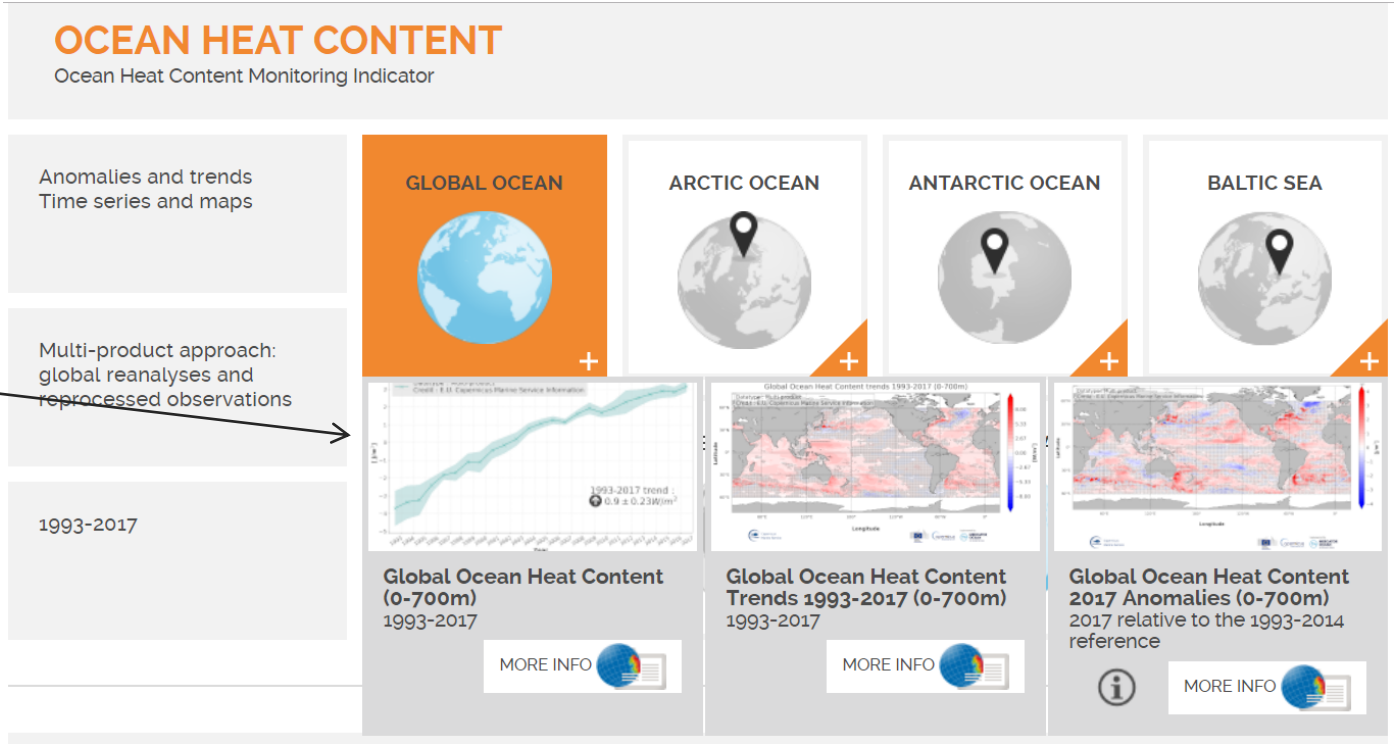
Heat content using GREP ensemble mean + CORA + ARMOR3D
shading = where signal < spread

Time series can be downloaded



Online Ocean Monitoring Indicator ***OMI***

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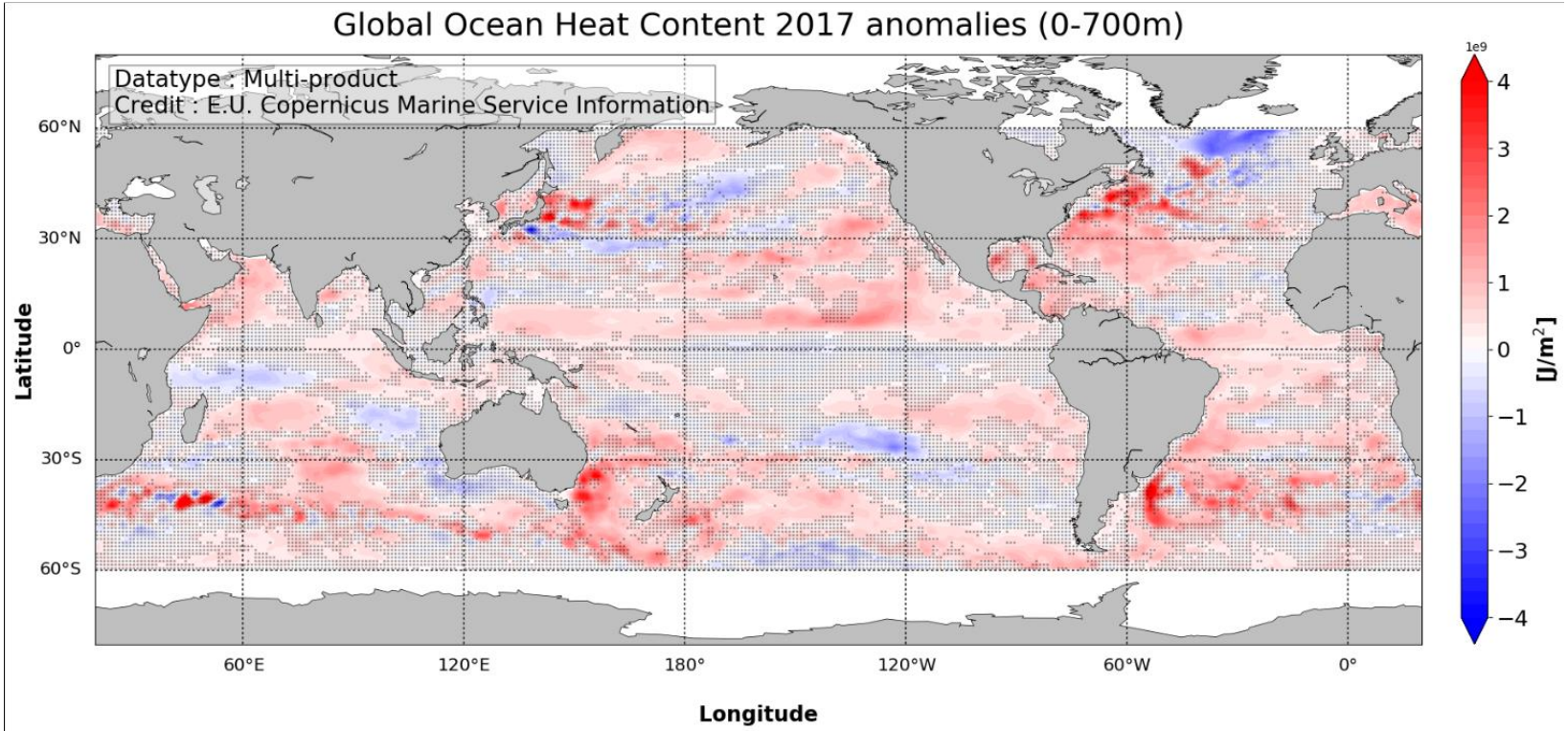
Assessing robustness of OMIs with GREP



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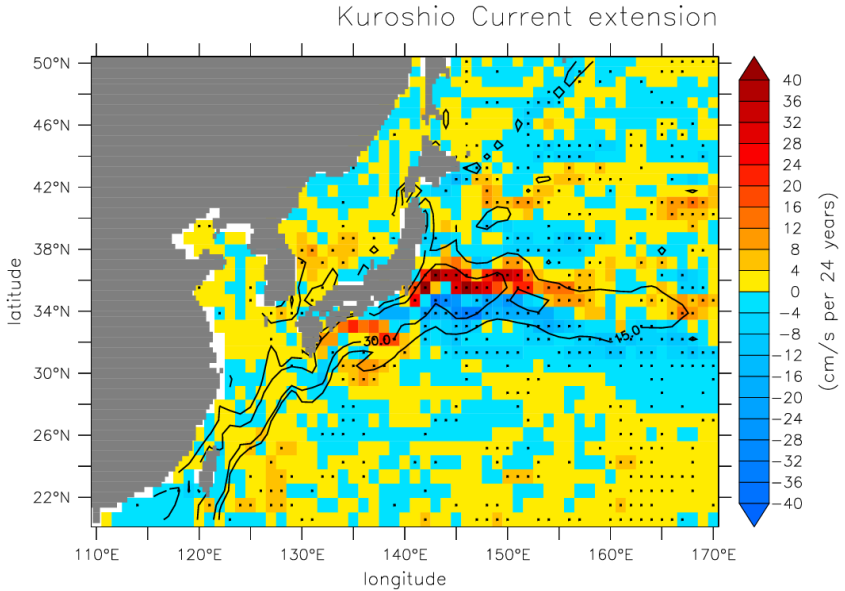
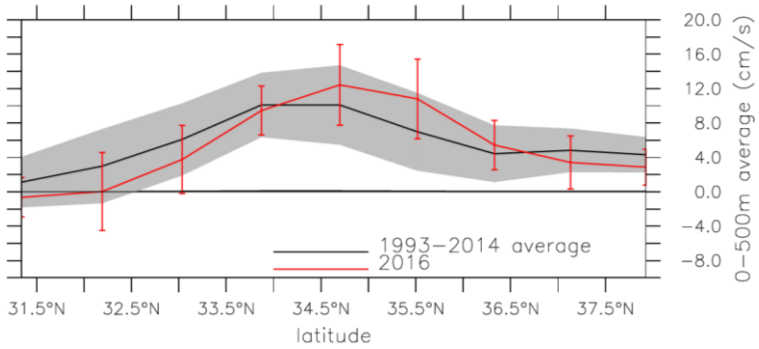
Assessing robustness of OMIs with GREP

Velocity @15m using GREP + Globcurrent (SLA + Ekman ERA interim)



Color : velocity @15m trend 1993-2016

Contour : velocity @15m mean value 1994-2014



shading : U 0-500m mean 1993-2014

Red : U 0-500m mean 2016

In OSR #2

Refs : Yang et al (2016) JGR Oceans

Wu et al (2012) Nature CC

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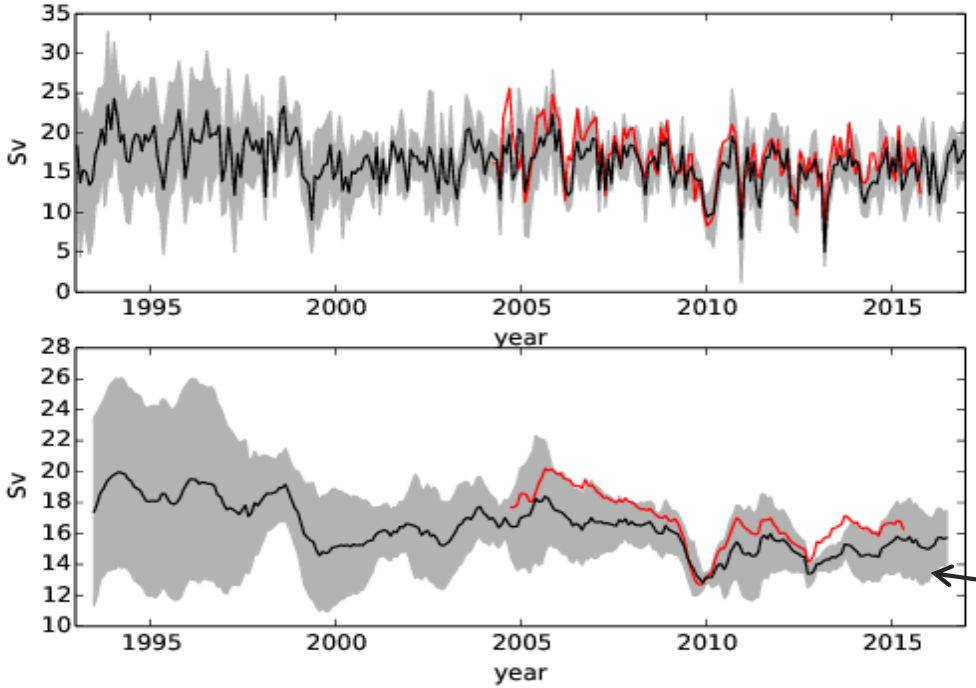
Assessing robustness of OMIs with GREP



AMOC using GREP ensemble mean (black line)
and RAPID array Smeed et al (2016) measurements (red line)
shading = spread = standard dev. between GREP members

Spread is reduced thanks to obs. from RAPID and ARGO

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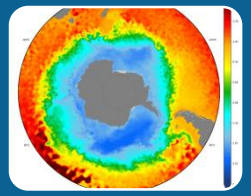
Other applications of GREP



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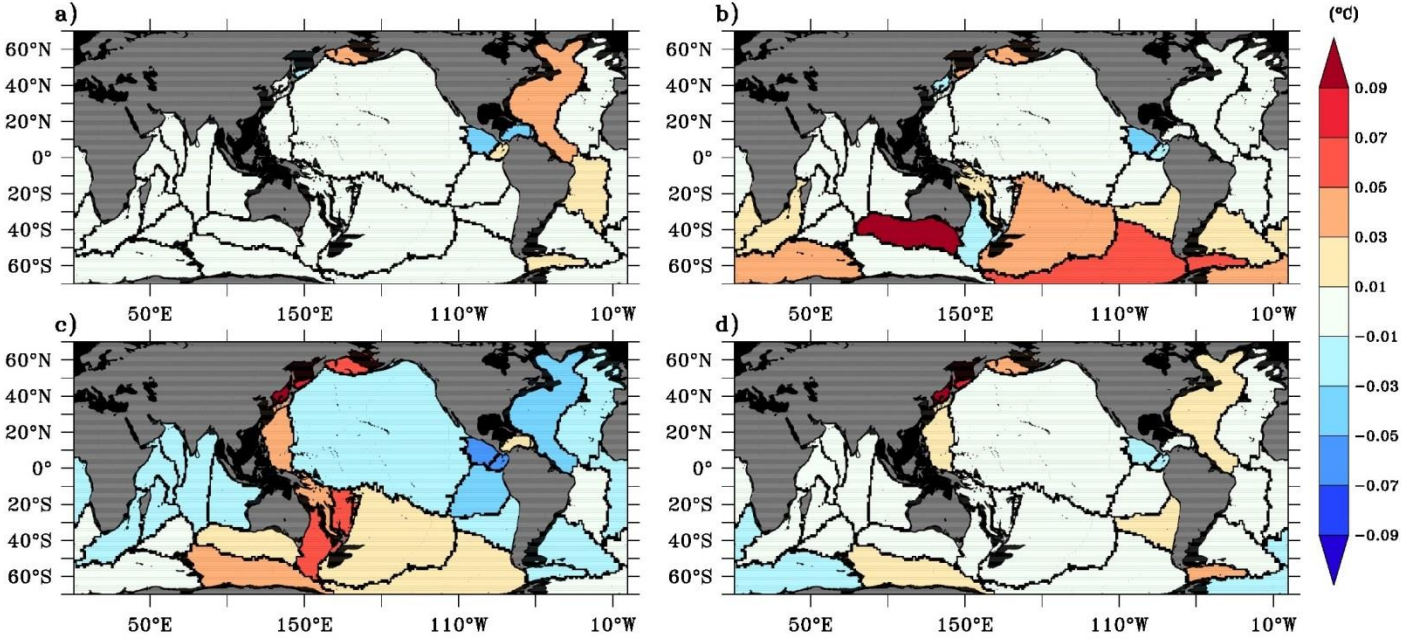
Need for deep ocean observations

Differences of the 2006-2015 minus 1996-2005 temperature at 3,000 m from the GREP ocean reanalyses; (a) C-GLORS, (b) FOAM, (c) GLORYS2V4 and (d) ORAS5. Unit is C.



Differences in the deep ocean illustrate the critical need for more frequent and global **deep ocean observations**

Gasparin et al, 2019

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Impact of changes in the observing network

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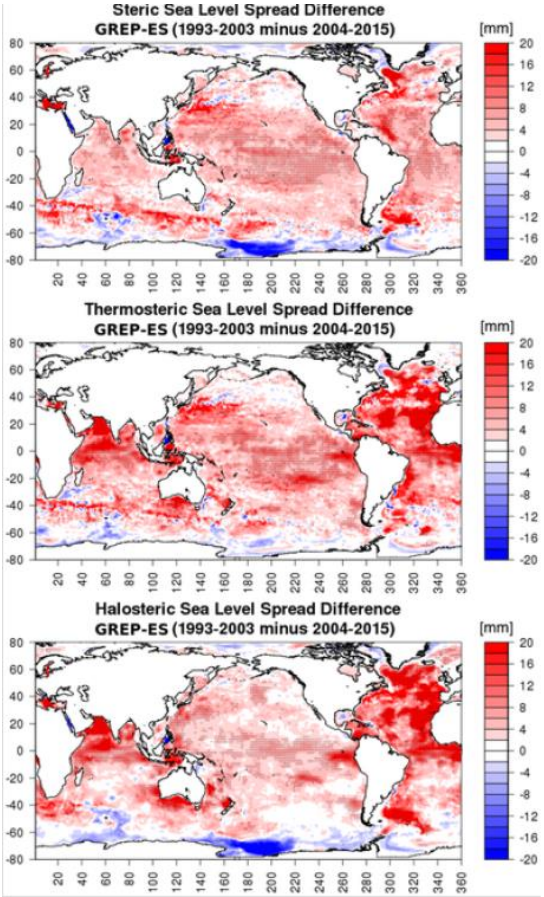

Global reduction of steric sea level spread in GREP thanks to ARGO

Storto et al, 2018, Clim. Dyn.

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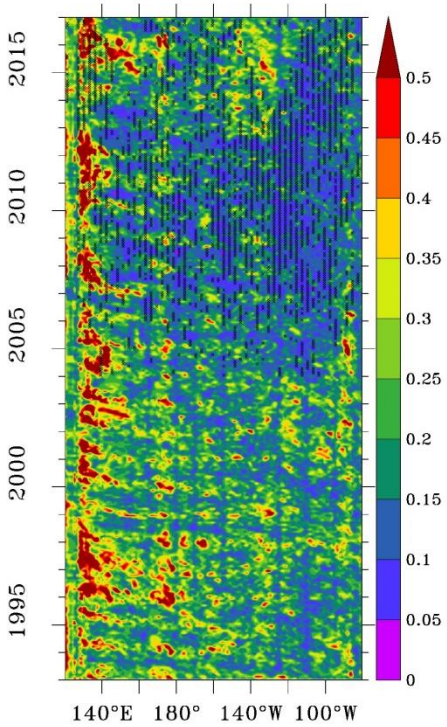
Tropical Pacific observing network

GREP standard deviation 0-300m Ocean Heat Content @[5°N-8°N]

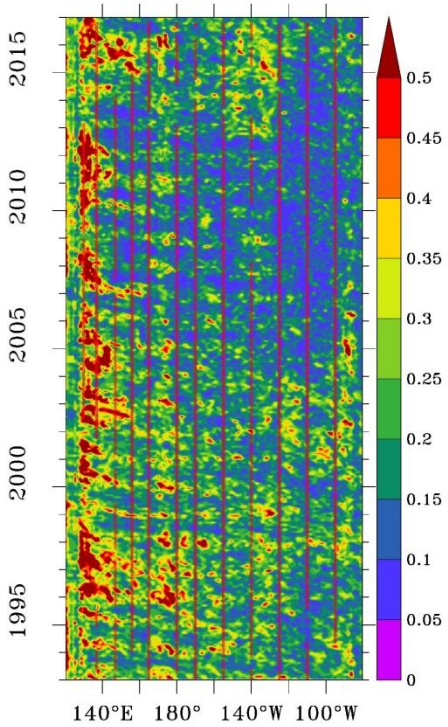
Argo float

(x)



TAO/TRITON

(x)



Both ARGO and moorings contribute in reducing GREP's spread

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Multi model error statistics for data assimilation

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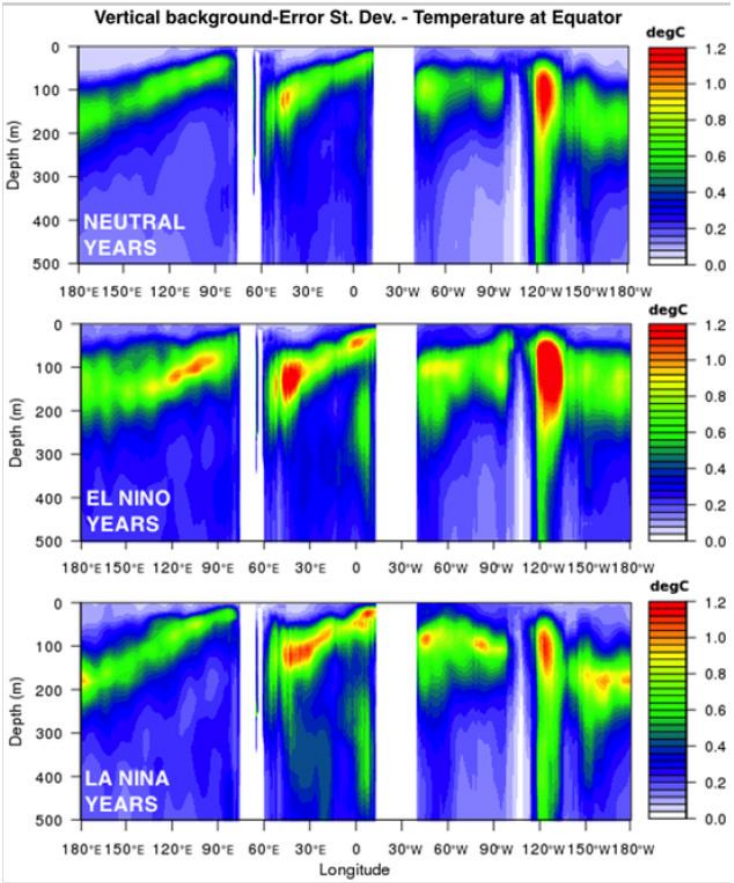
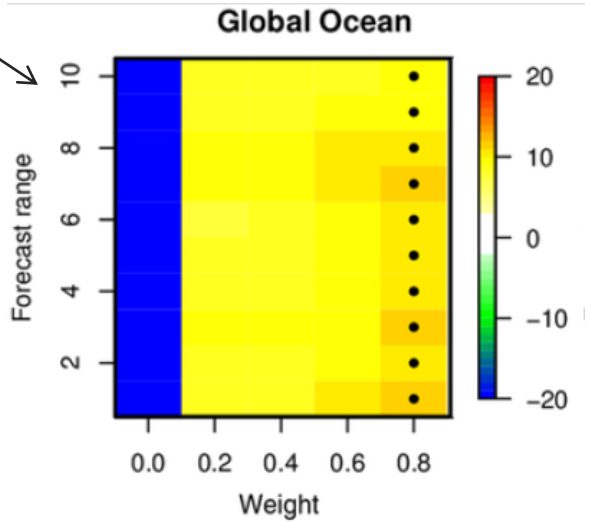


The use of a hybrid ensemble-variational scheme allows a reduction of errors o(10%)



Storto et al, 2018, Climate Dynamics

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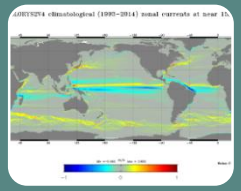
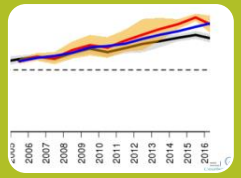
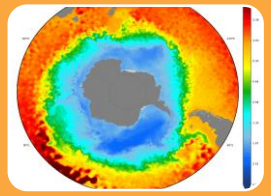
Summary



GREP : ensemble of global reanalyses, and derived ocean monitoring indicators and uncertainty estimates are available from CMEMS -> powerful tool for ocean reporting *(see poster P-100)*



GREP is complementary with reanalyses at higher resolution available from CMEMS (global, regional); intercomparison and ensemble approaches are favored to provide reliability/robustness estimates for CMEMS indicators



Spread from GREP shows where observations are needed

spread/uncertainty is large before ARGO period -> central role of sustainable observing system

Spread from GREP can be used to derive flow-dependent errors

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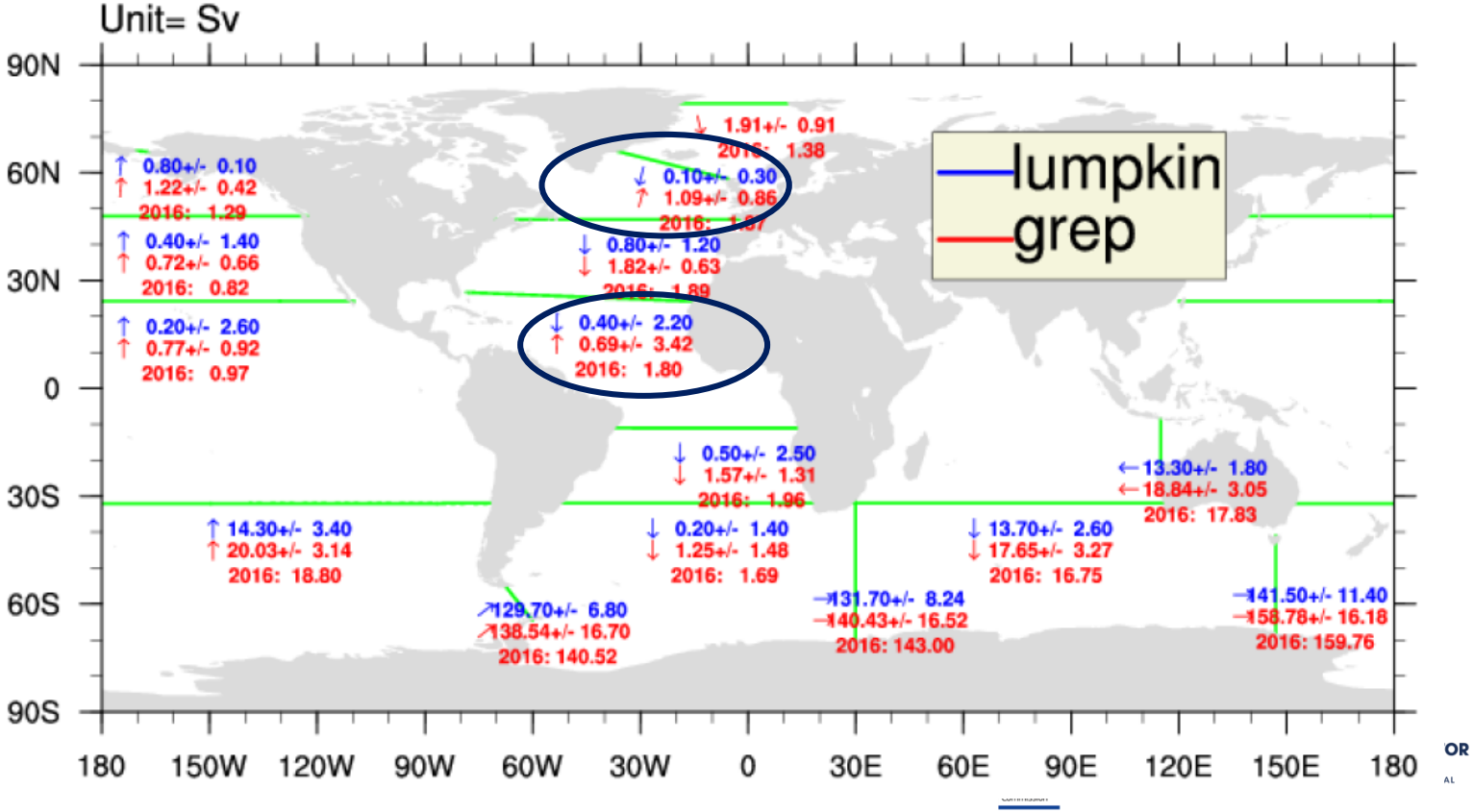
Volume transports using GREP



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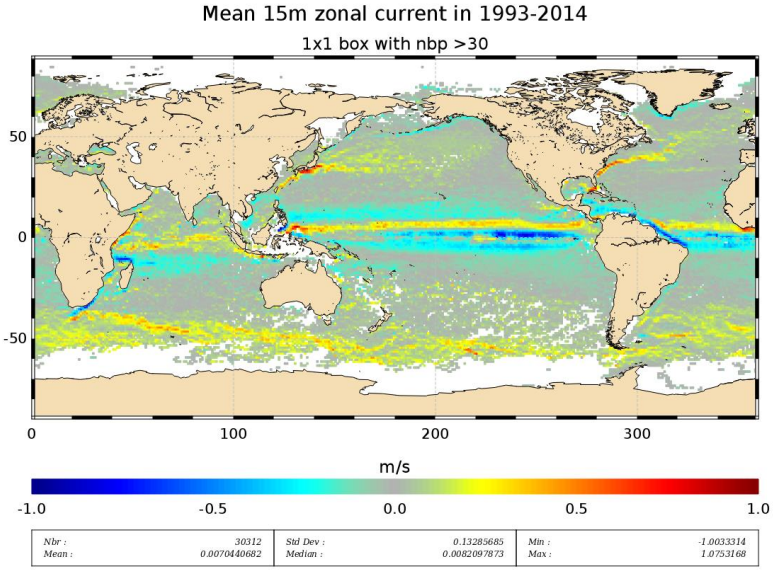
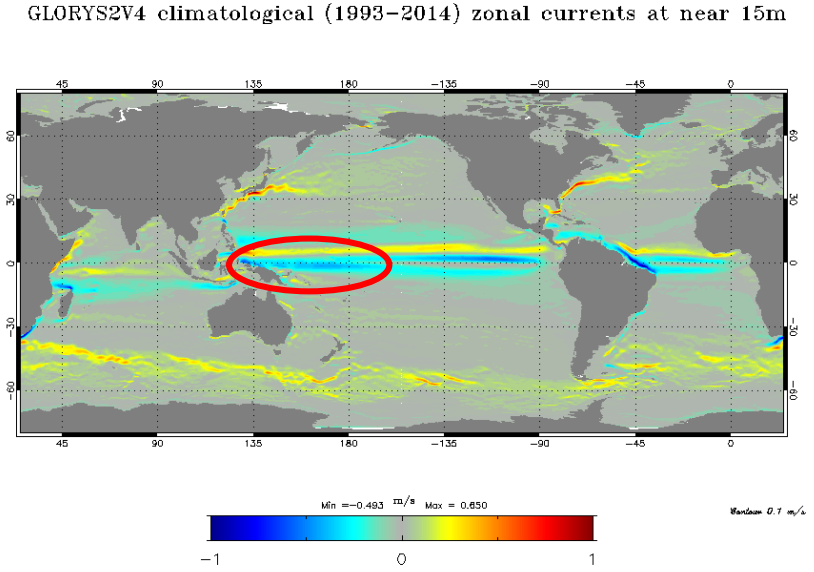
Evaluation of invidual members: GLORYS

Independent SVP drifters with drogue loss correction (in situ TAC)





Global agreement is good

Overestimation of westward branch in Western Tropical Pacific

Continuous improvement since the beginning of GLORYS

-> data assimilation & mean dynamic topography

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