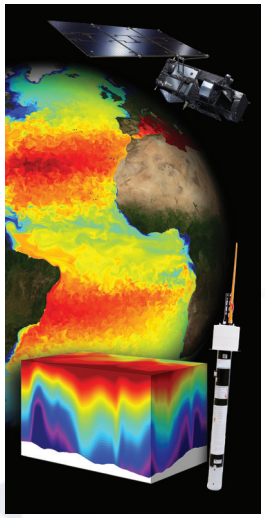
Role of Argo for the Copernicus Marine Environment and Monitoring Service

P.Y. Le Traon*, E. Remy, V. Turpin**, E. Gutknecht****

*Ifremer and Mercator Ocean,**Mercator Ocean

Euro-Argo Scientific Workshop, April 2016

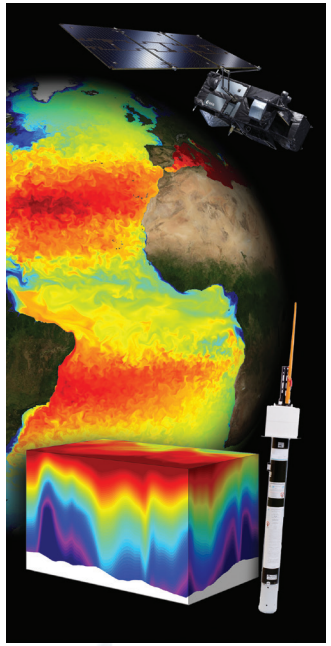


Outline

- The Copernicus Marine Environment Monitoring Service
  - Overview, objectives and organization
  - Products/services, users and applications

- Role of Argo for the Copernicus Marine Environment Monitoring Service
  - Impact of Argo data assimilation in Mercator Ocean global system (OSEs – Observing System Evaluations)
  - Simulating the impact of Deep Argo in Mercator Ocean global system (OSSEs – Observing System Simulation Experiments)

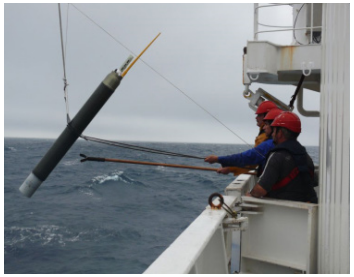
- Conclusions and recommendations



CMEMS : The Copernicus Marine Environment Monitoring Service

SATELLITES
(S1, S3, S6/Jason-CS)

(IN SITU)

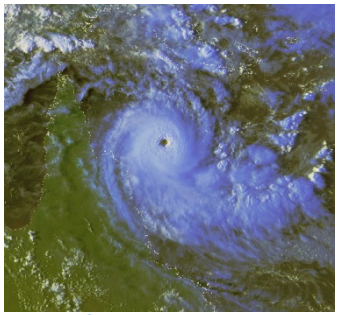
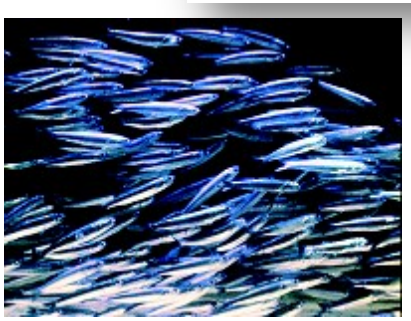


SERVICES

- **MARINE**
- **ATMOSPHERE**
- **LAND**
- **SECURITY**
- **EMERGENCY**
- **CLIMATE**

COPERNICUS MARINE SERVICE DRIVERS : CLIMATE + OCEAN HEALTH + OCEAN SERVICES



Climate (incl. climate extremes), decadal and seasonal forecasting
Weather and extreme events

Fisheries and fishery management




Renewable marine energy

Offshore Industry

Maritime Security,
Marine Safety

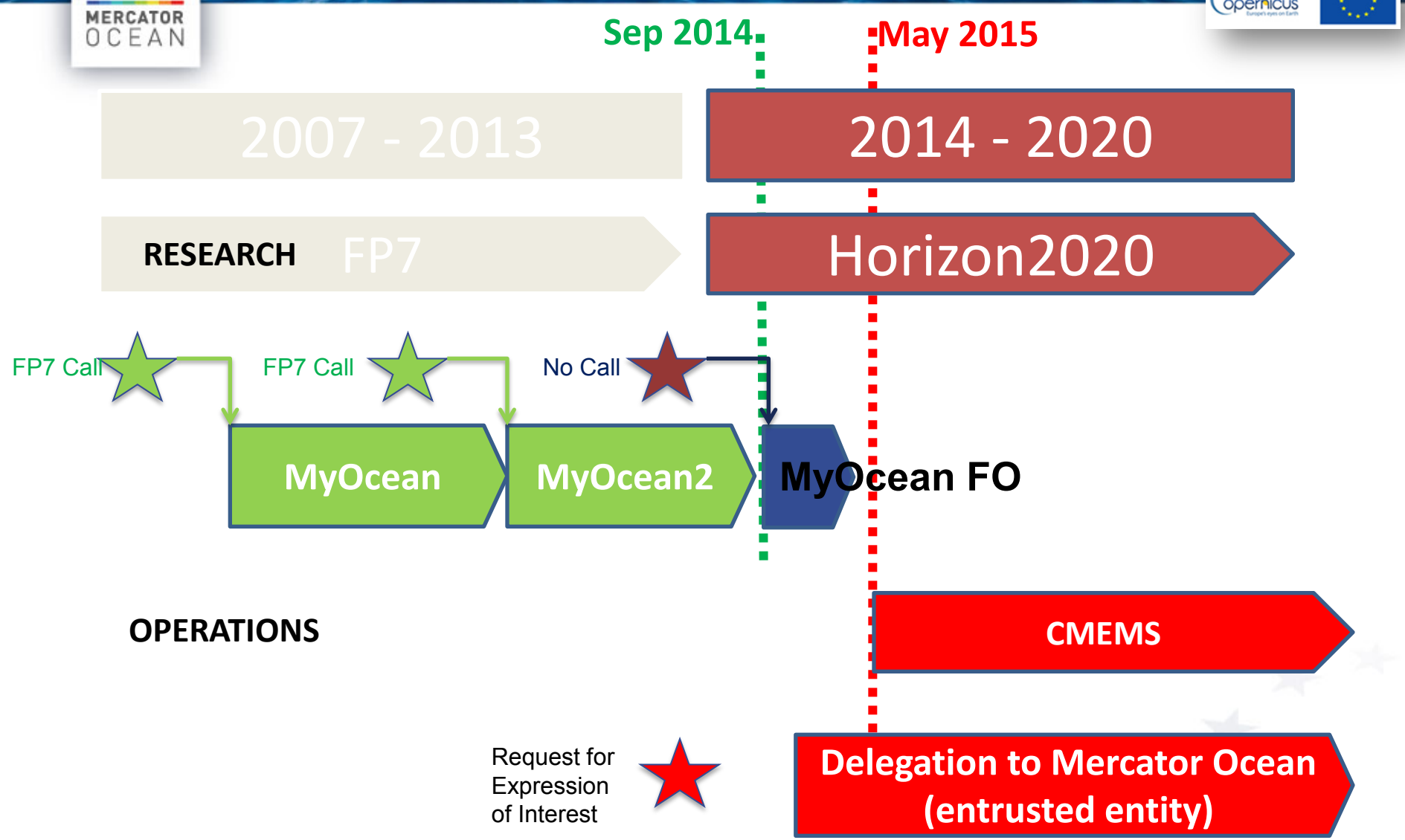
Navies


Coastal applications, water quality, environmental monitoring and reporting/regulation, coastal hazards

Ocean, climate and ecosystem research

others…

Implementation milestones



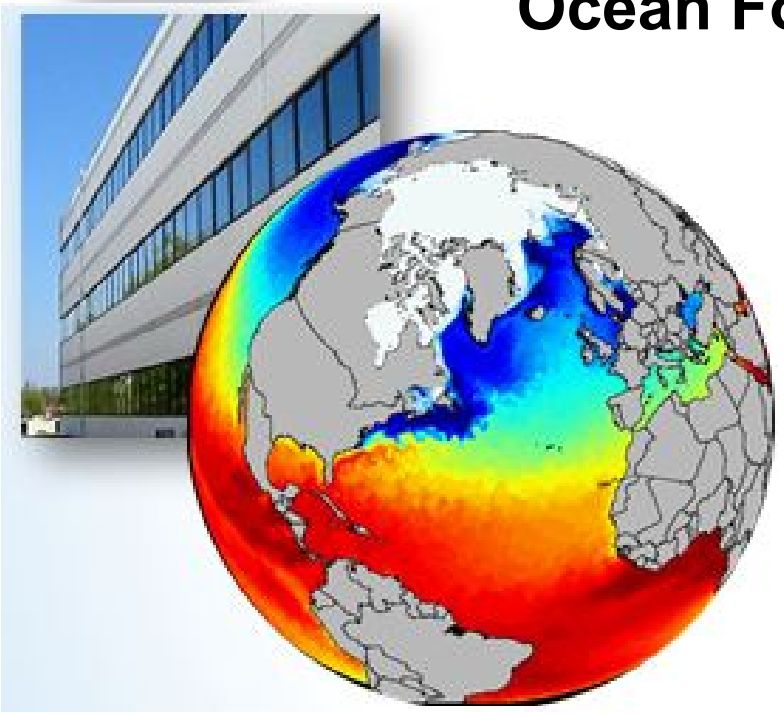
Mercator Ocean

Ocean Forecasting Centre, Toulouse, France

Société civile, non-for-profit, « core service »

Public shareholders

(CNRS, Ifremer, IRD, Météo-France, SHOM)



High resolution forecasting on all oceans

Modelling, data assimilation, use of satellite and in situ data, service operations, reanalyses

Real time operations since 2001, global since 2005

Coordinator of MyOcean, MyOcean2 & FO

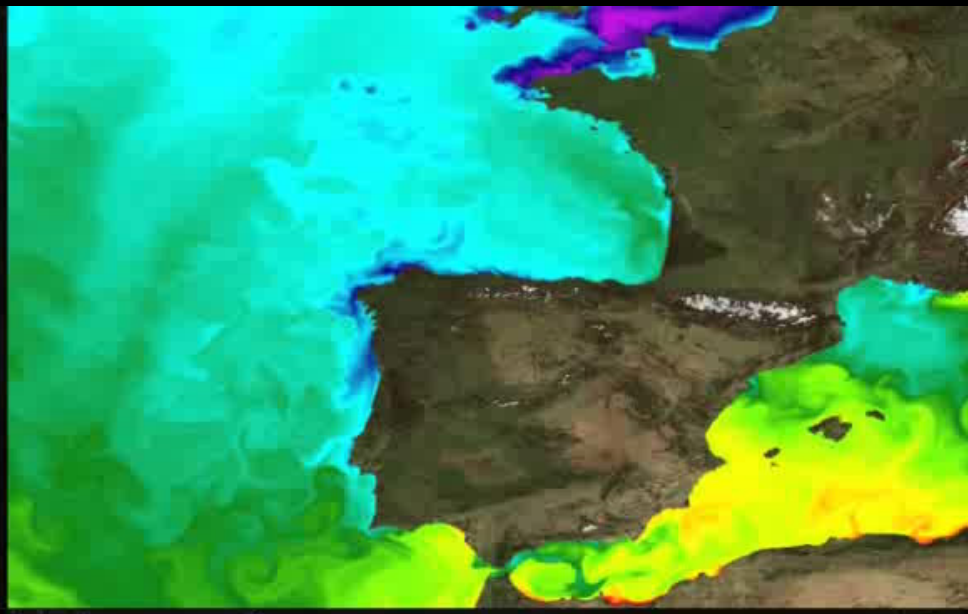
FP7, 2009-2012 and 2012-2015, 60 partners

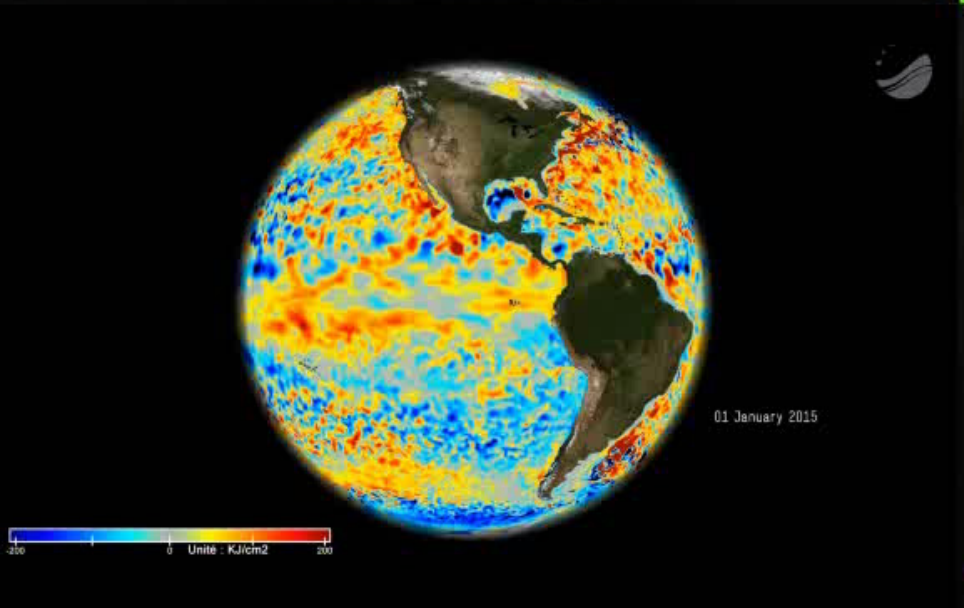
Admin and Technical coordination, Service desk to users

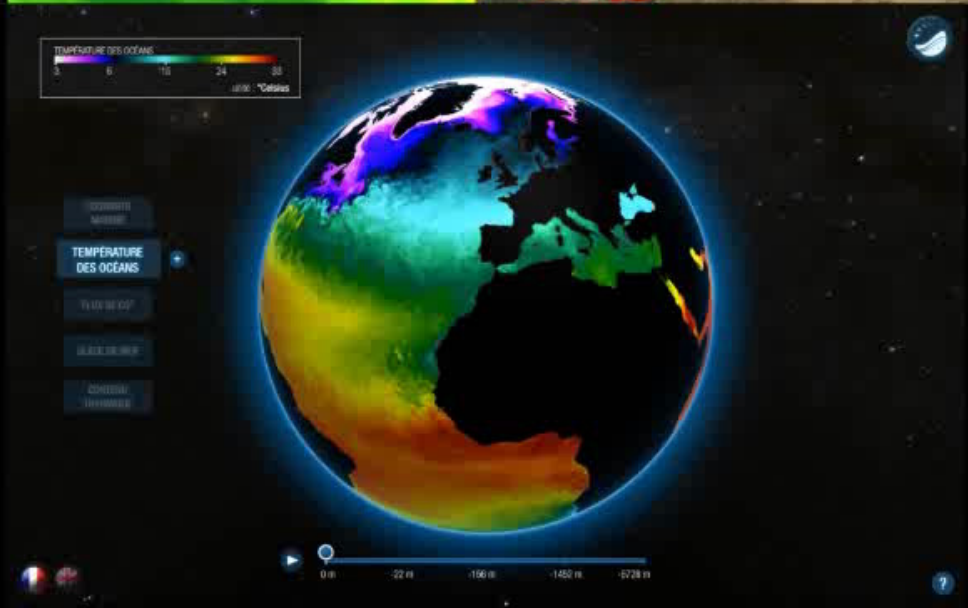
Global Ocean and Atlantic regional forecasting

Entrusted Entity to implement the Copernicus Marine Environment Monitoring Service (CMEMS)

CMEMS : Real time (analyses/forecasts) and delayed mode (reanalyses) global and regional ocean monitoring

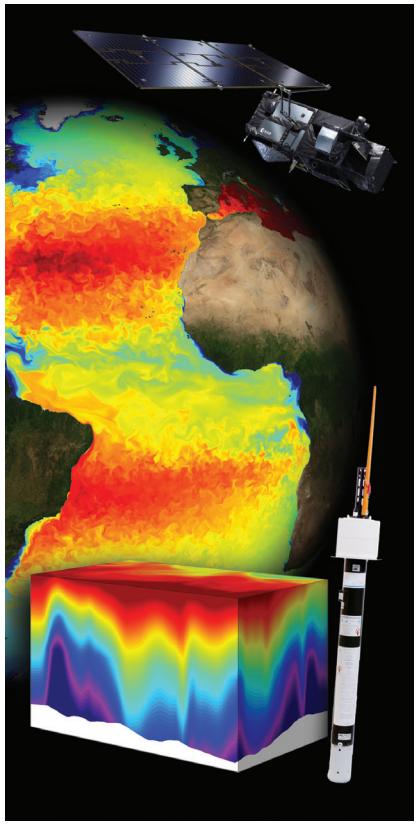






Copernicus Marine Service

1) A European «core» and integrated service



Observations and models

Global and European Seas

Physics and Biogeochemistry

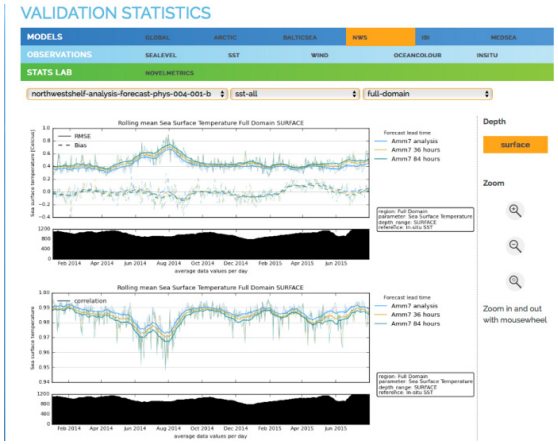
Reanalyses, analyses and forecasts

Copernicus Marine Service

2) a single interface to access the products

marine.copernicus.eu

Copernicus Marine Service
3) Product quality assessment



State-of-the art scientific assessment of product quality

Quality of all product documented

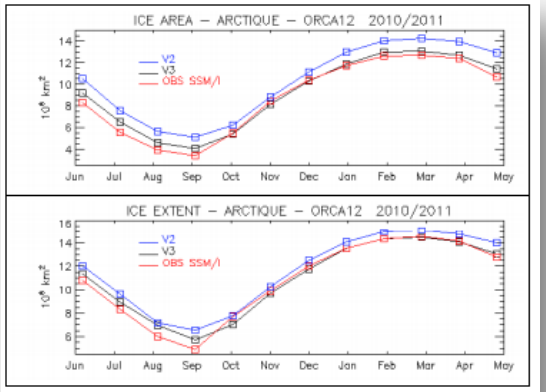
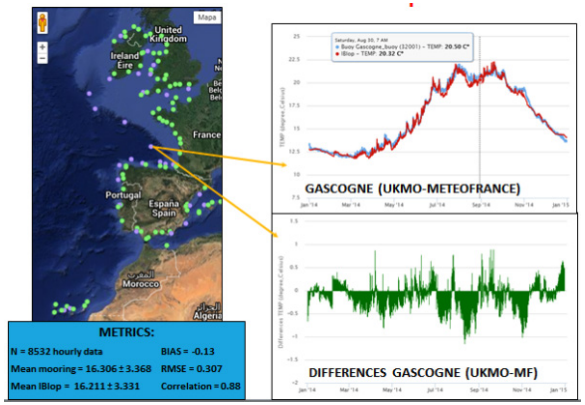


Figure 23: Sea ice area (upper panel, 10^3 km2) and extent (lower panel, 10^3 km2) in the Arctic in HR global products V2 (blue line), HR global products V3 (black line) and SSM/I observations (red line) for a one year period ending in June 2011



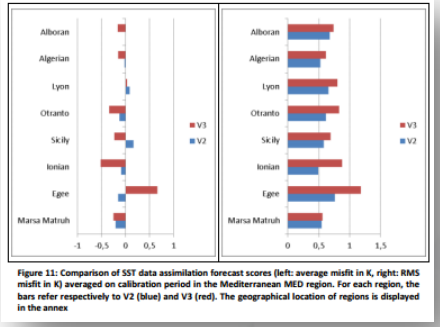
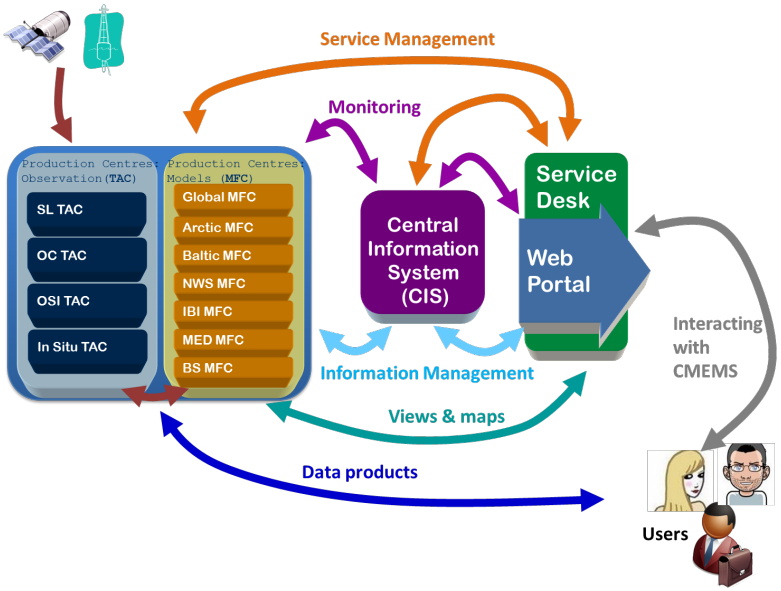
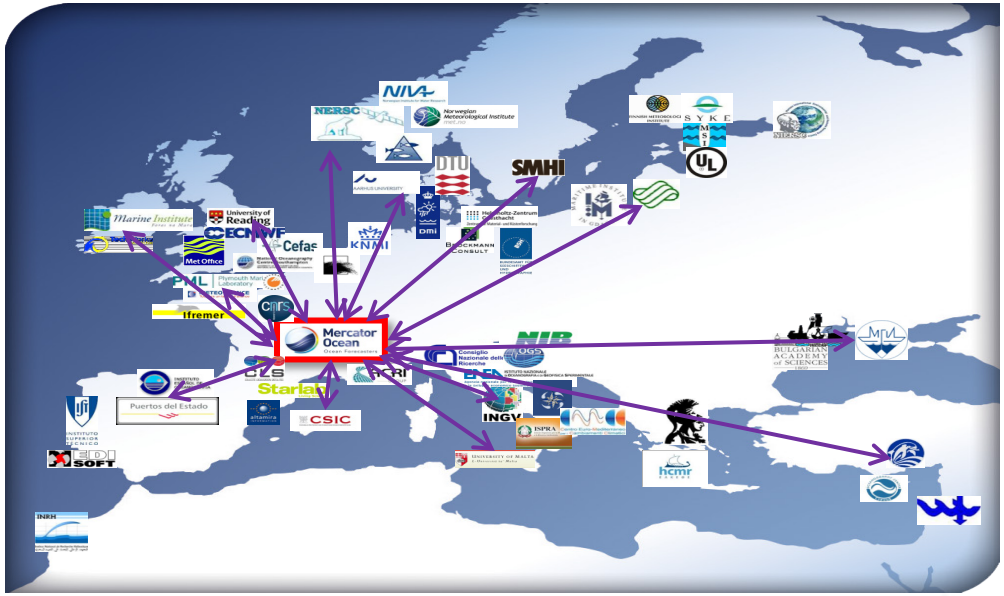


Figure 11: Comparison of SST data assimilation forecast scores (left: average misfit in K, right: RMS misfit in K) averaged on calibration period in the Mediterranean MED region. For each region, the bars refer respectively to V2 (blue) and V3 (red). The geographical location of regions is displayed in the annex

Copernicus Marine Service
(4) Pan-European integration





Copernicus Marine Service
5) a service focused on users

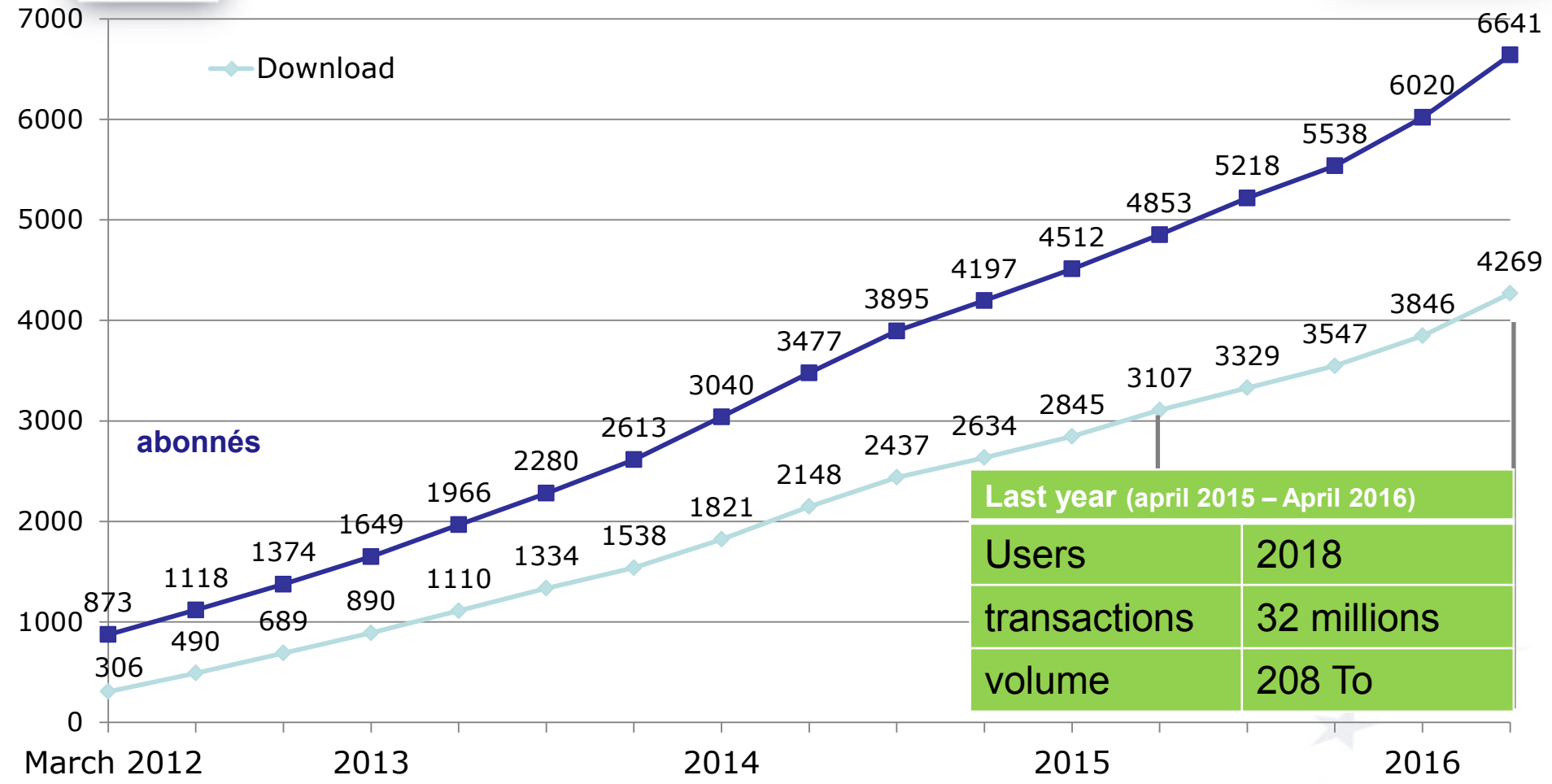
2016
6000+ SUBSCRIBERS

CENTRAL SERVICE DESK

6600+ SUBSCRIBERS IN APRIL 2016

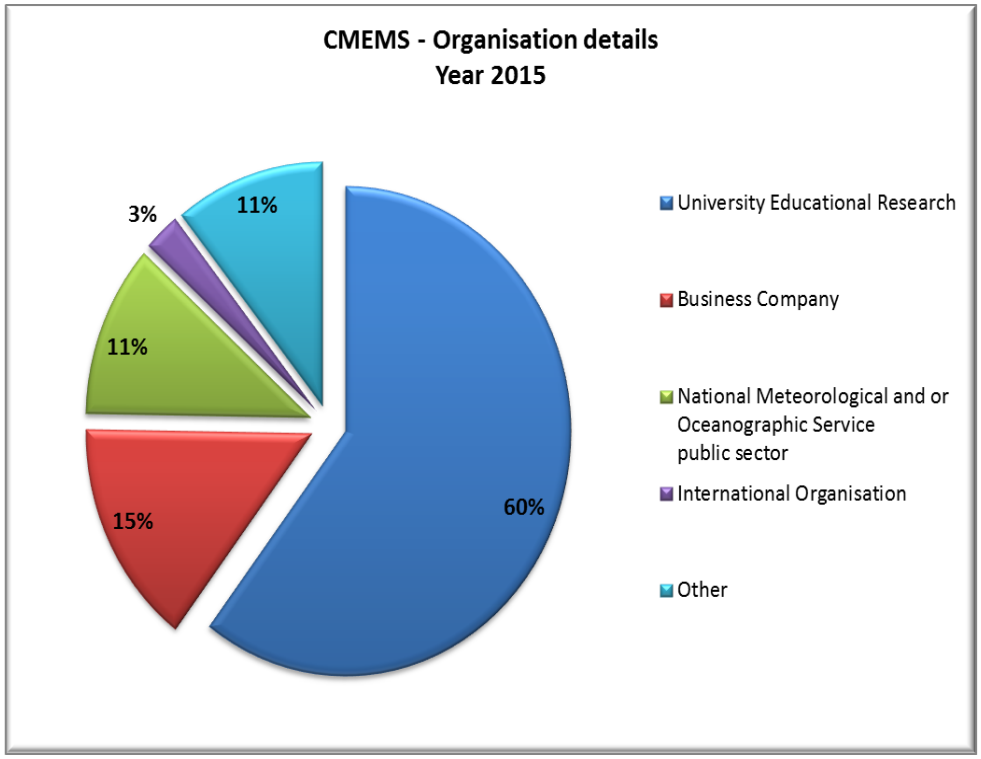
ALL CONTINENTS

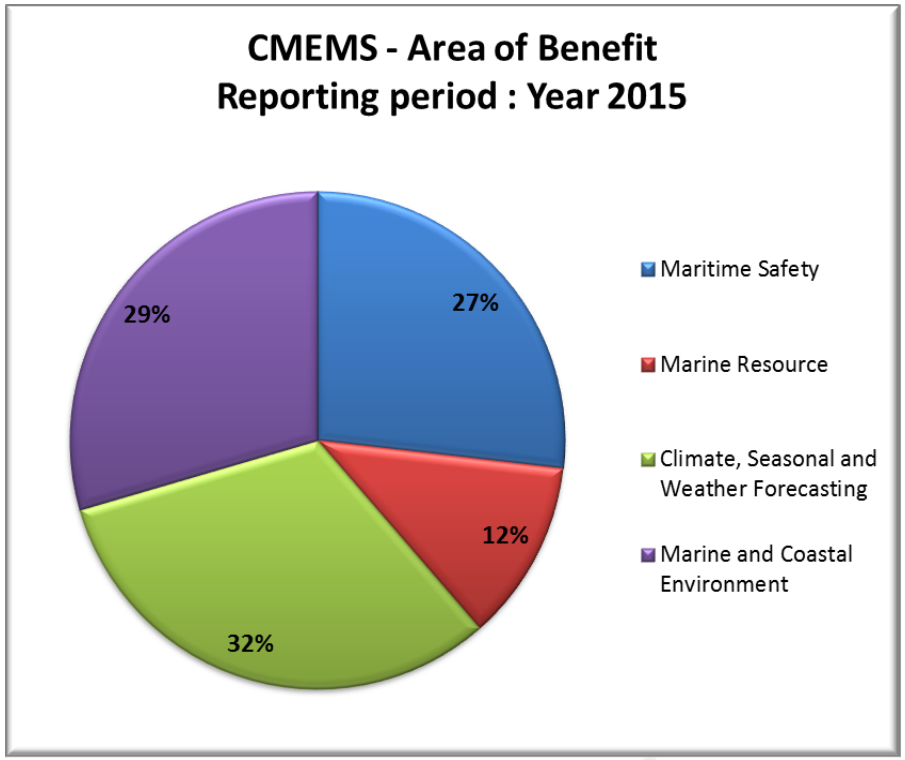
Copernicus Marine Service – Users



Last year (april 2015 – April 2016)	
Users	2018
transactions	32 millions
volume	208 To

Users in 2015





The Copernicus Marine Service

REANALYSES
10 to 45 years

REAL-TIME
Daily, hourly

FORECAST
2 to 10 days

1 Global
2 Arctic
3 Baltic
4 NWS
5 IBI
6 Med Sea
7 Black Sea

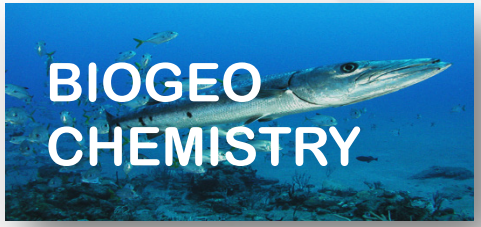
DISCOVER

VIEW

DOWNLOAD

Open & Free

ESSENTIAL MARINE VARIABLES



Euro-Argo is an essential component of the Copernicus Marine Service

Argo is the single most important in-situ observing system for the Copernicus Marine Service.

It delivers global data sets in a few hours that are critical/mandatory data for assimilation in ocean forecasting models.

Every 10 days, all Argo T & S profiles are assimilated in the CMEMS global and regional monitoring and forecasting centers. Strong impact.

Float technology is evolving to include new capabilities (e.g. biogeochemistry, deep ocean, marginal seas, polar seas) that are essential to the Copernicus Marine Service.

FP7 EU Project

Coordination Ifremer
January 2013 - December 2015

16 Partners (Euro-Argo, Copernicus Marine Service)

Links with the Euro-Argo ERIC
Links with Copernicus Marine Service

Overall objective: design and test of new float technology and impact for the Copernicus Marine Service

Prepare the evolution of Argo in Europe

One WP on impact (OSEs) and design studies (OSSEs) for Copernicus Marine Service led by Mercator Ocean (with Met Office, INGV, OGS, KNMI, USOF)

Focus here on Mercator Ocean results
(see Euro-Argo/E-AIMS WWW site for a more complete overview)

Experimental setup for OSEs

One year experiments in 2012 with the global ¼° ocean system (PSY3V3):

Model and data assimilation system components:

- ocean and ice coupled model NEMO 3.1,
- SAM2 (local weekly analysis, use of a reduced order model space),
- Incremental Analysis Update,
- 3DVar large scale bias correction on temperature and salinity below the thermocline.

Assimilated data sets:

- Coriolis in situ T and S profiles,
- Reynolds SST,
- SSALTO/DUACS along track sea level anomaly,
- CNES-CLS09 MDT + correction using Glorys innovations.

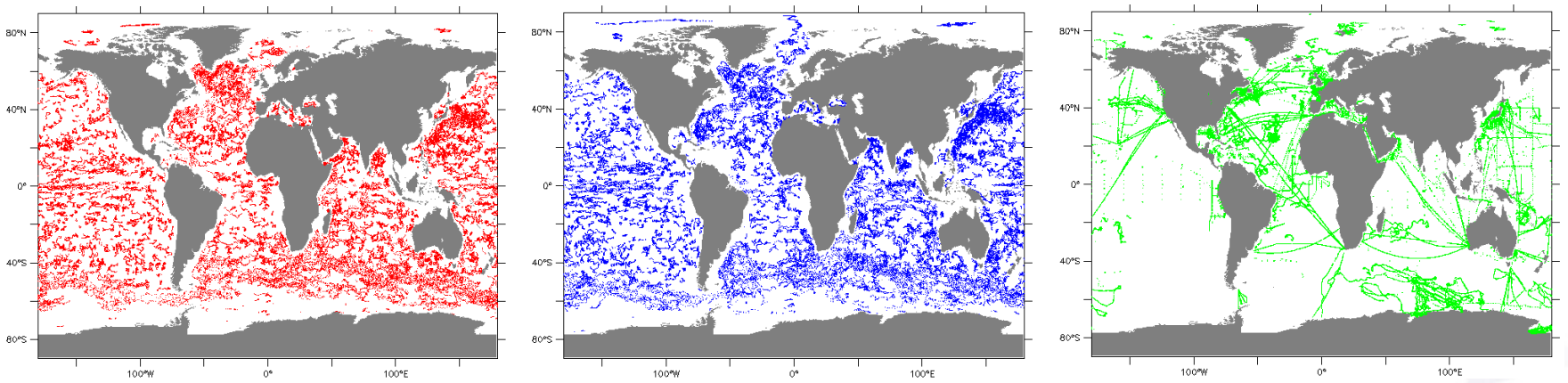
Boundary conditions:

- Initial ocean and ice conditions from the real time production at the beginning of 2012.
- Forcing fields: ECMWF atmospheric analysis.

Turpin, Remy and Le Traon, Ocean Science, 2016

Argo OSEs with the global ¼° ocean system

Run name	Assimilated data sets			
	SST	SLA	INSITU No-Argo	INSITU Argo
Run Ref	X	X	X	X
Run no argo	X	X	X	
Run argo/2	X	X	X	50% only

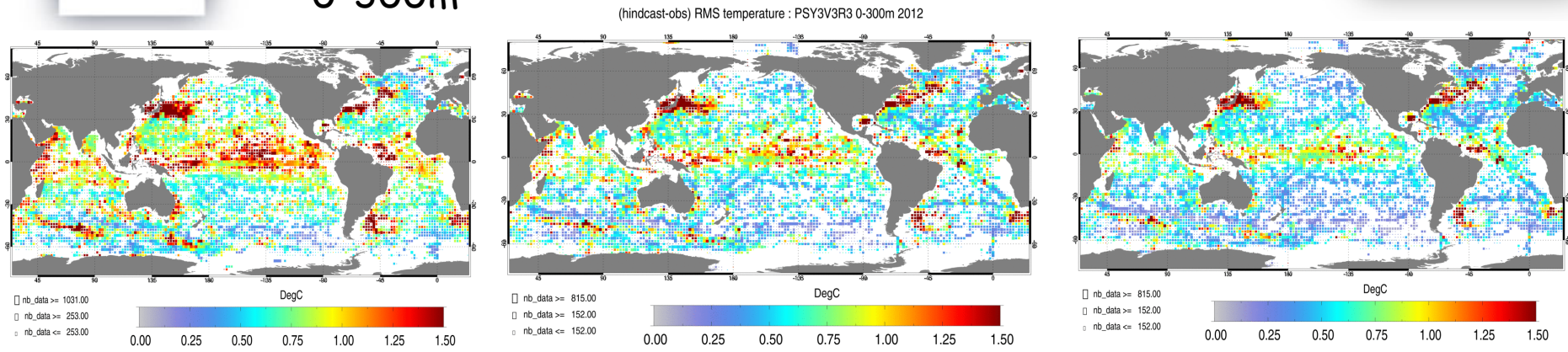


Spatial distribution of 2012 *in-situ* dataset divided is 3 sub datasets. Red dots are the odd Argo profiles, blue dots are even Argo profiles, green dots are the other *in-situ* observations.

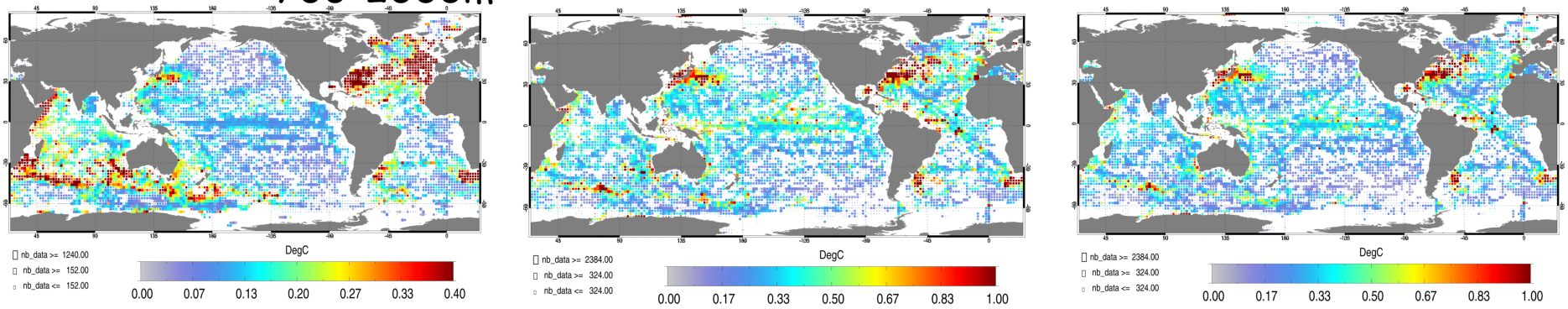
Argo OSEs: residual statistics in temperature

Global RMS misfit between the in situ observations and OSEs analysis (last 6 months)

0-300m



700-2000m



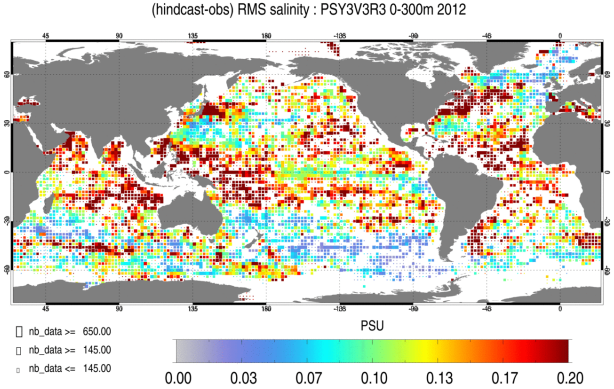
Run-NoArgo Run-Argo/2 Run-Ref

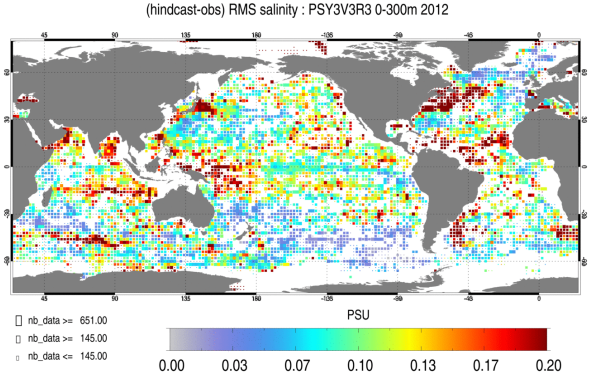
Spatial distribution of the RMS temperature differences between Run-NoArgo / Run Argo/2, Run-Ref and Argo observations in the 0-300m and 700-2000m layers

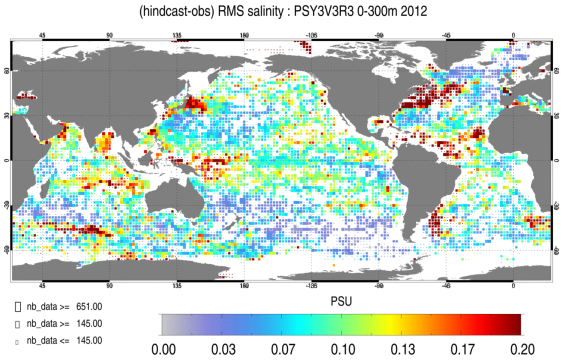
Argo OSEs: residual statistics in salinity

Global RMS misfit between the in situ observations and OSEs analysis (last 6 months)

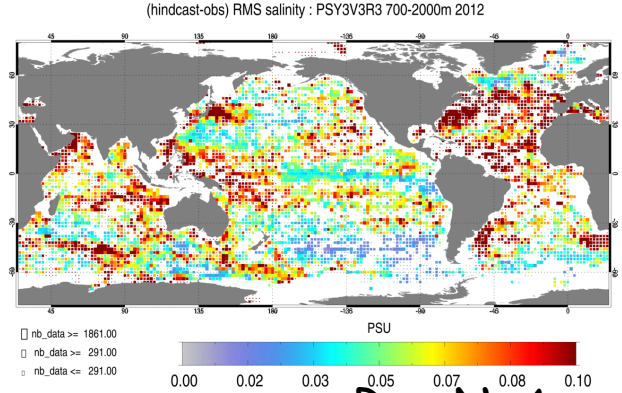
0-300m



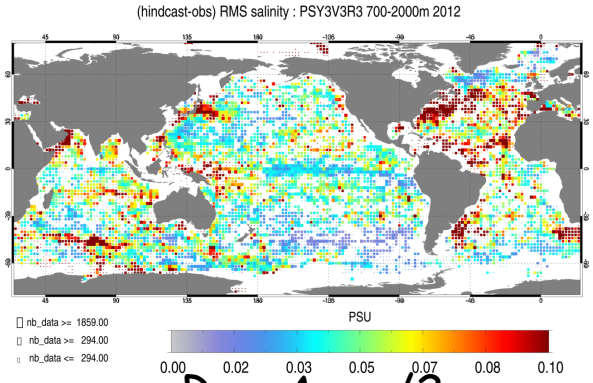




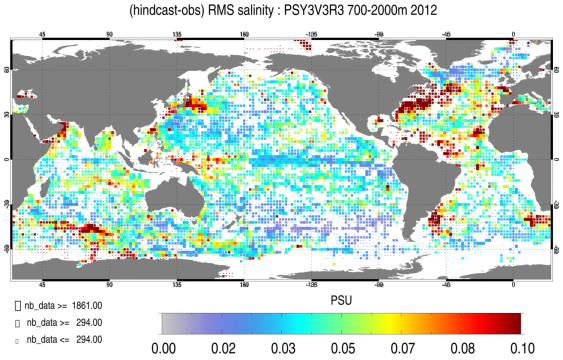
700-2000m



Run-NoArgo



Run-Argo/2



Run-Ref

Argo OSEs: innovation statistics

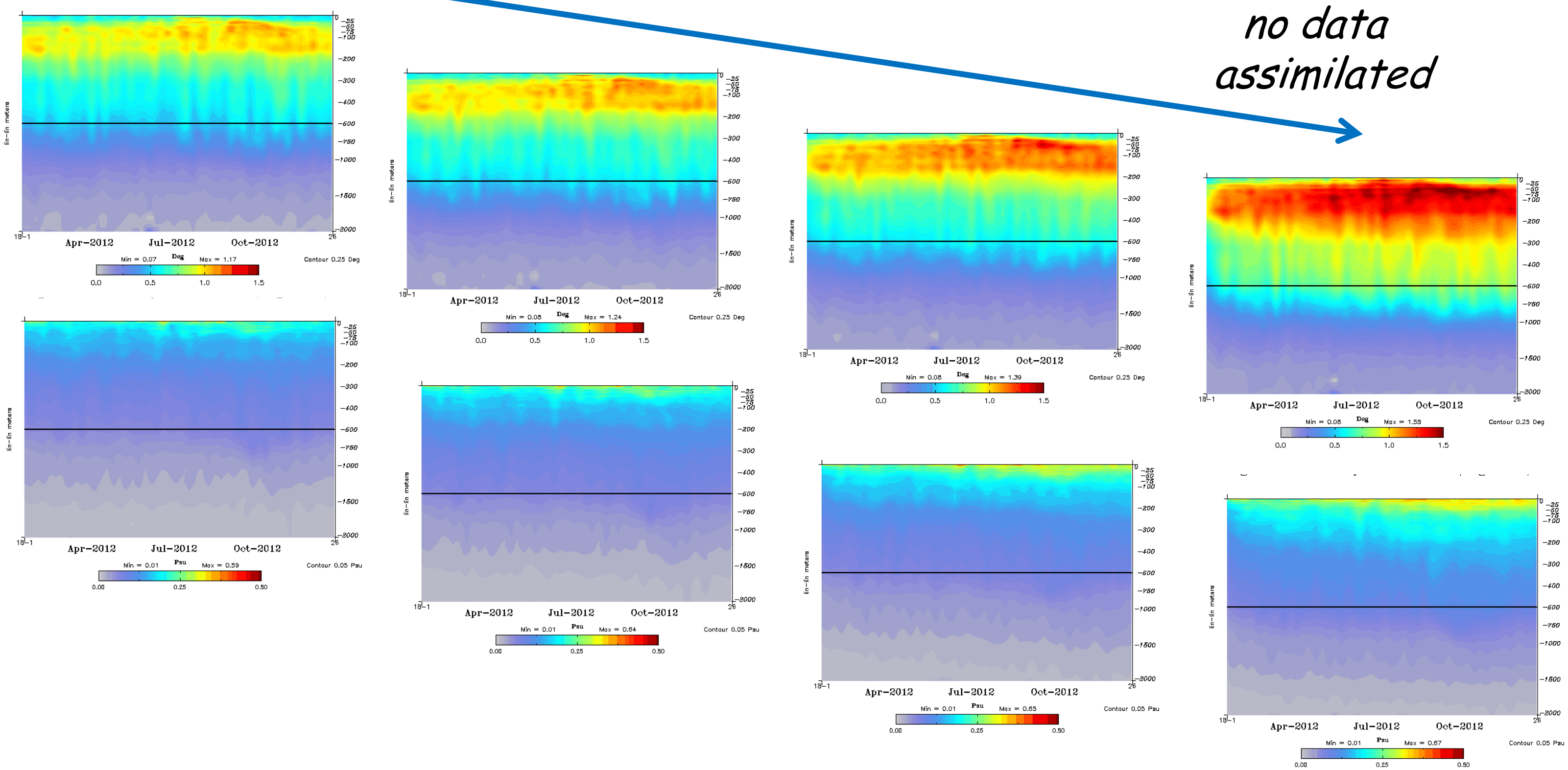
Impact of the Argo array on the global $\frac{1}{4}°$ analysis system: observation minus model **forecast** misfits for all in situ T,S data in 2012.

Reference run

without $\frac{1}{2}$ ARGO floats

without ARGO floats

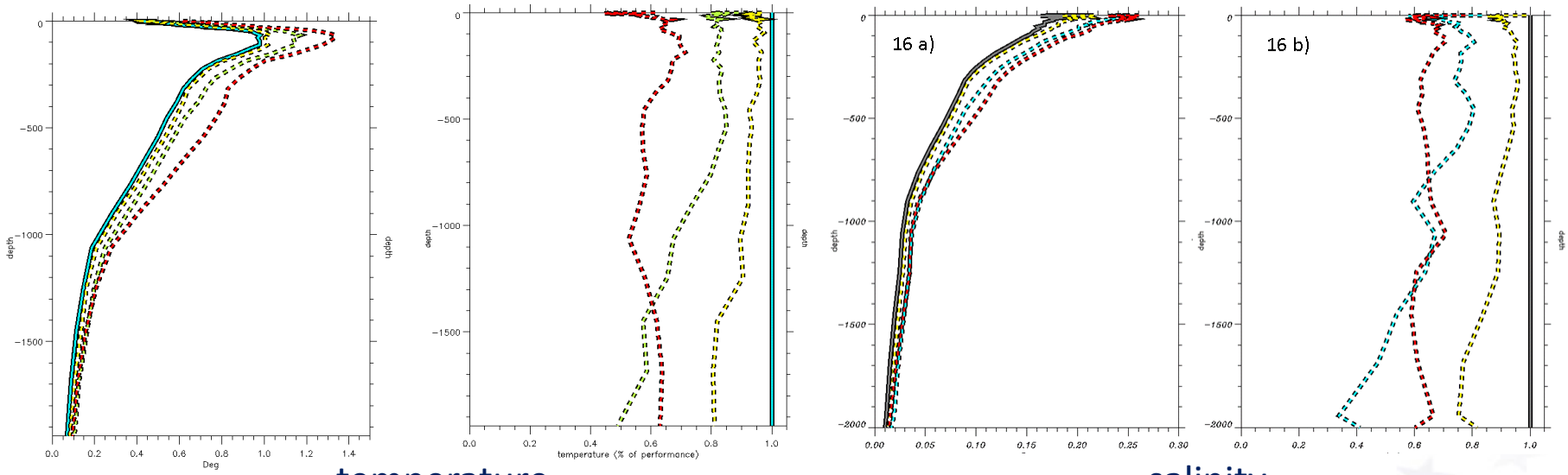
no data assimilated



Global RMSE for 2012 in salinity and temperature

Conclusion of Argo OSEs

Argo has a large impact and is mandatory to constrain T&S fields. Temperature and Salinity forecast errors (rms of innovations) are reduced by 20% to 60% when Argo float are assimilated. Keeping only half of the Argo floats degrades significantly the analysis.



temperature salinity

Vertical structure of RMS of temperature and salinity innovations and normalized RMS temperature and salinity innovations for Run-Ref (blue), Run-Argo2(yellow), Run-NoArgo (green) and Free Run (red)

Deep Argo OSSEs

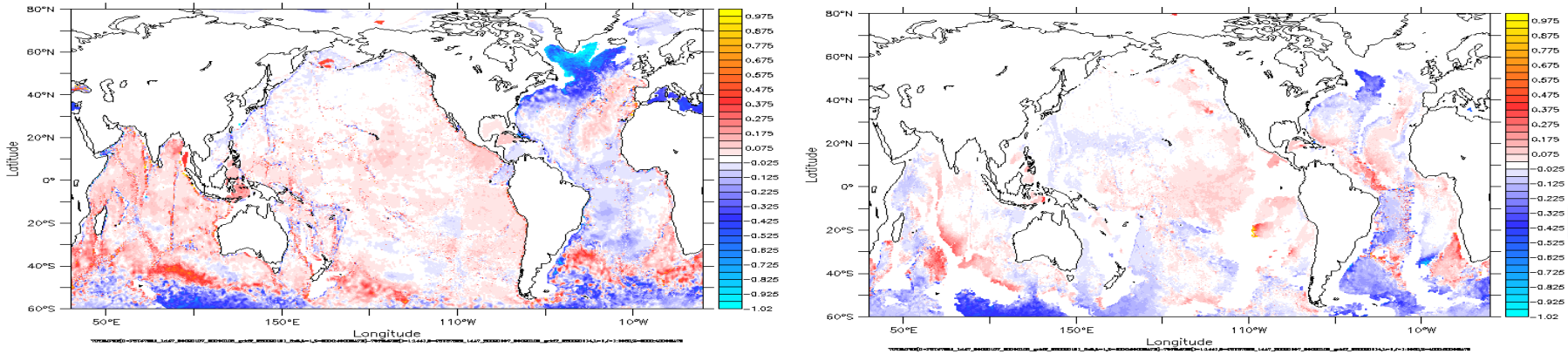
Estimate the impact of Argo evolution on the global ¼° ocean analysis and forecasting system

Observation simulation

- Collocation of 2009 CORA in situ profiles with a forced 1/12° simulation.
- Simulation initialized in October 2006 with the Levitus 2005 climatology. It is forced by real time ECMWF forcing with bulk formulae.

Assimilation in 2009 in the global ¼° system

- Initialisation with a forced model restart at the beginning of 2009.
- The ¼° simulation (T323) was initialized in January 1989 from the Levitus 98 climatology. Forced by ERA interim atmospheric fluxes forcing with bulk formulae.

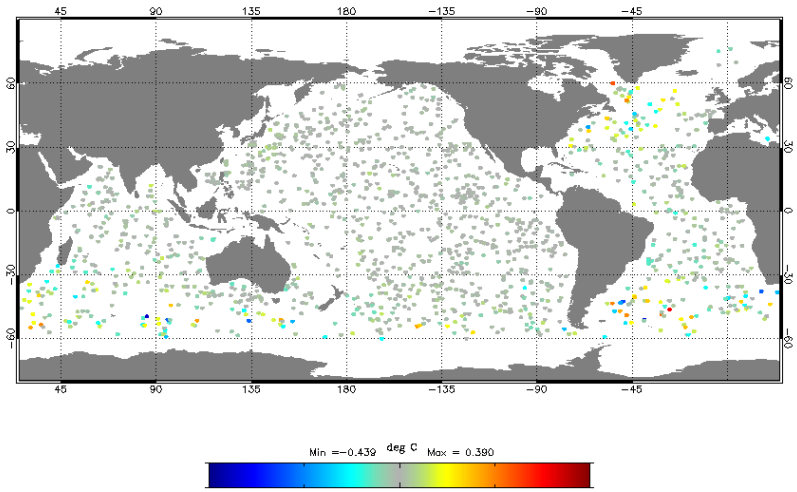


Initial temperature difference simulated between the “true” ocean and the OSEs for the depth 2000-4000m and 4000-6000m.

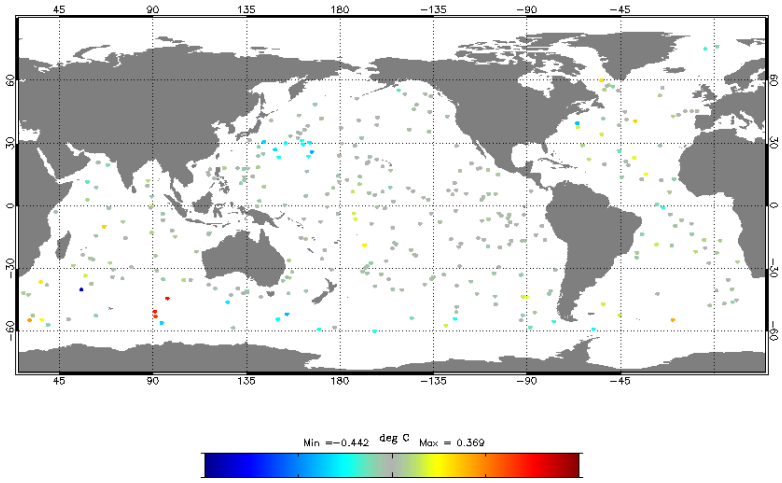
Deep Argo OSSEs

	Argo up to 2000m	Argo up to 4000m	Argo up to ocean bottom
Run1 – Reference	100%	0%	0%
Run2 – all 4000m	100%	100%	0%
Run4 – 1/9 4000m	100%	11%	0%
Run3 - 1/9 bottom	100%	11%	11%

Observation location for one week in October 2009 at 3200 m depth



All Argo floats are diving below 2000 m depth



1/3 of the floats are diving below 2000 m depth each 3 profiles.

Deep Argo OSSEs: impact on analysed temperature

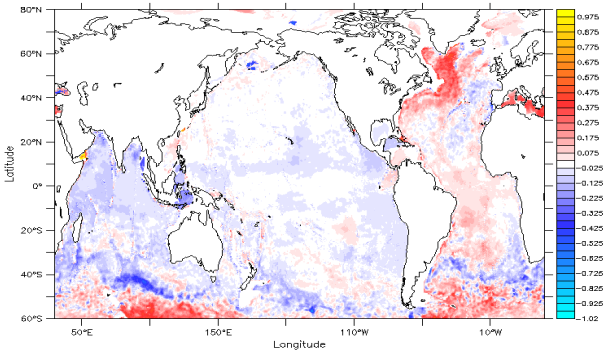
Mean temp. diff. 2000m-4000 m

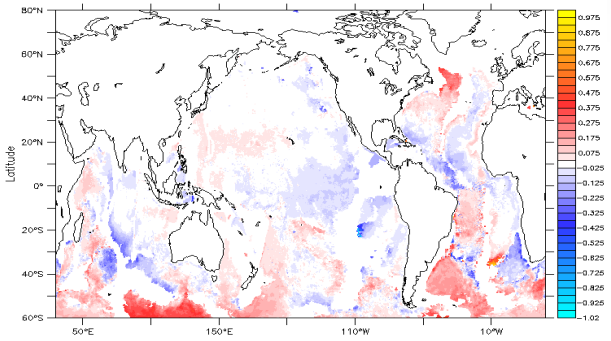
Mean temp. diff. 4000m-6000 m

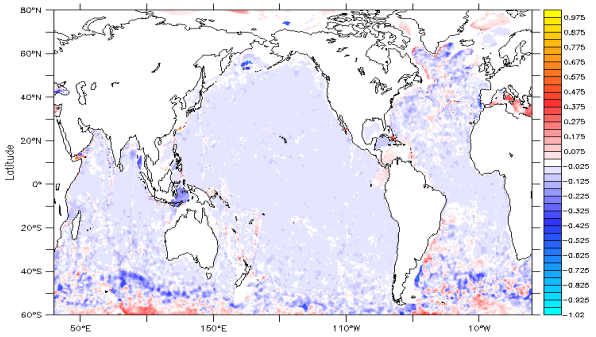
Run with Argo up to 2000 m

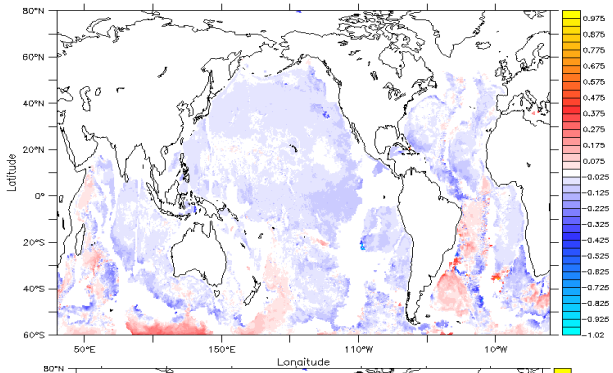
Run with 1/9 Argo up to 4000 m

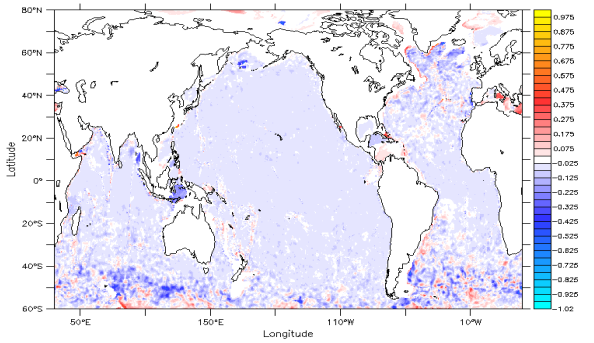
Run with all Argo up to 4000 m

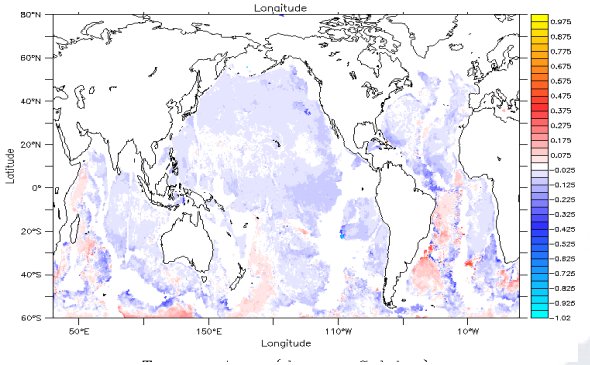












Mean deep ocean temperature misfits in °C between the "truth" and different OSEs for different depth ranges.

Deep Argo OSSEs: main results

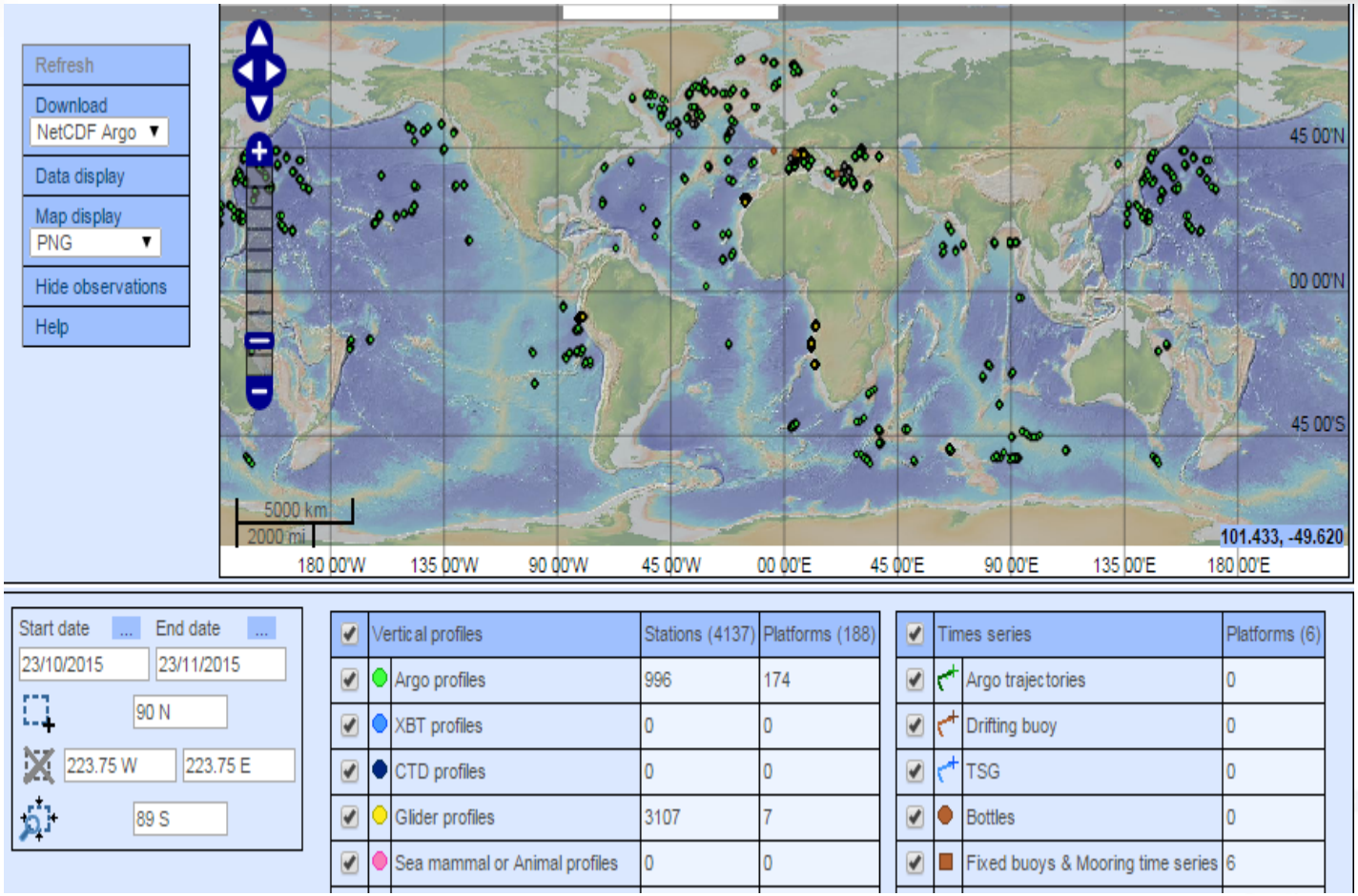
- Increasing the depth of Argo floats **profiles up to 4000 m depth** instead of 2000m reduce the biais between 2000 up to the bottom where it was large,

- Increasing the depth of Argo floats **profiles up to 4000 m depth** instead of 2000m **for only 1/9 of them** gives comparable results than if all are going up to 4000m. This is coherent with the fact we found a low temporal variability but significant bias in some regions.

- Increasing the depth of Argo floats **profiles up to 6000 m depth** instead of 2000m **for only 1/9 of them** : analysis in progress.

Those conclusions are based on model simulation only.

Copernicus Marine Service – In Situ TAC – Biogeochemical data/O2 available over one month

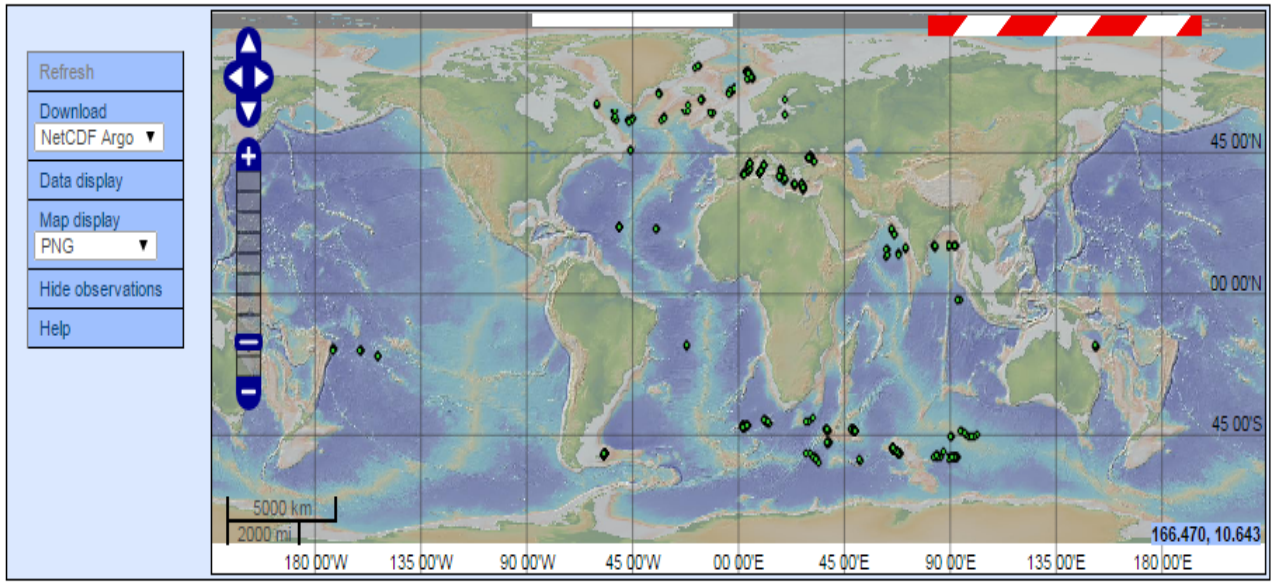


Vertical profiles	Stations (4137)	Platforms (188)
Argo profiles	996	174
XBT profiles	0	0
CTD profiles	0	0
Glider profiles	3107	7
Sea mammal or Animal profiles	0	0

Times series	Platforms (6)
Argo trajectories	0
Drifting buoy	0
TSG	0
Bottles	0
Fixed buoys & Mooring time series	6

One Month of Oxygen : 174 Argo Floats , 7 gliders, 6 moorings

Copernicus Marine Service – In Situ TAC – Biogeochemical data/Chl-a available over one month



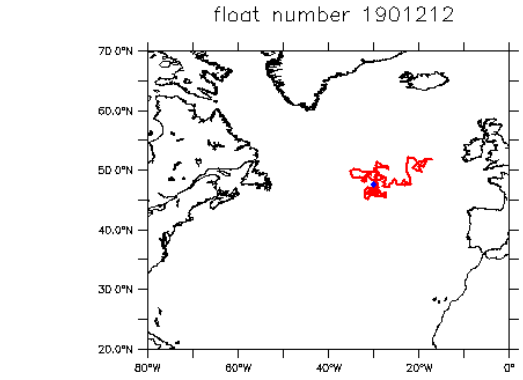
Start date ... End date ...
23/10/2015 23/11/2015
90 N
223.75 W 223.75 E
89 S

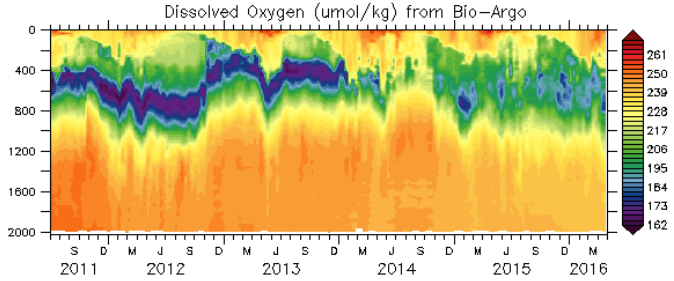
Vertical profiles	Stations (522)	Platforms (73)
Argo profiles	522	73
XBT profiles	0	0
CTD profiles	0	0
Glider profiles	0	0
Sea mammal or Animal profiles	0	0
Fixed buoys and mooring profiles	0	0
Other profiles	0	0

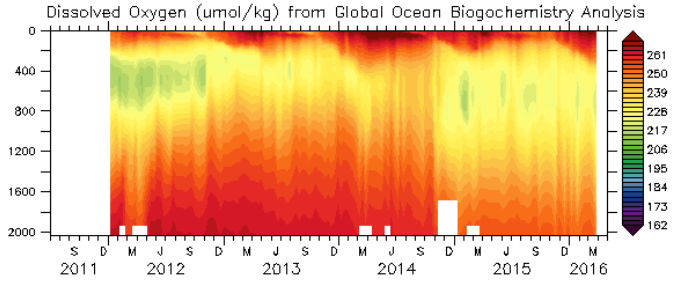
Times series	Platforms (4)
Argo trajectories	0
Drifting buoy	0
TSG	0
Bottles	0
Fixed buoys & Mooring time series	4
Other time series & trajectories	0

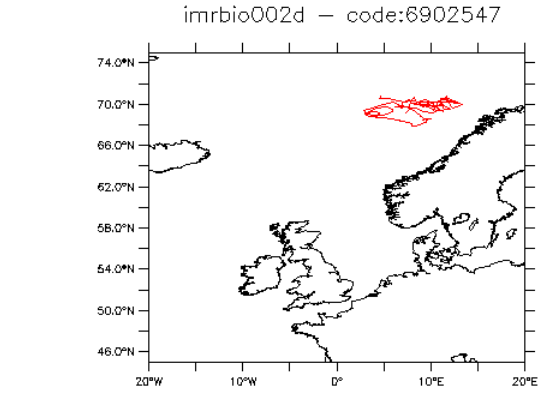
One month of Chlorophyll-a data : 73 Argo floats, 4 moorings (a few Ferryboxes – surface - not shown on the map)

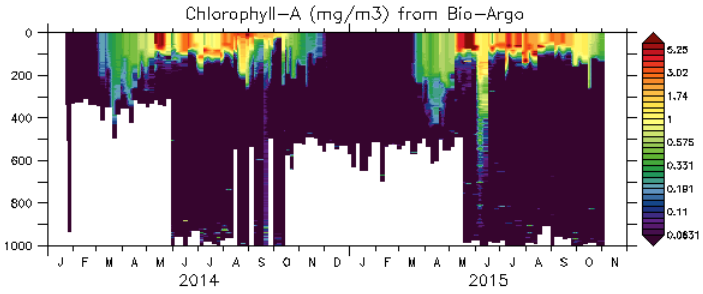
Bio-Argo floats versus Mercator Ocean (CMEMS) biogeochemical model (O2/left, Chl-a/right)

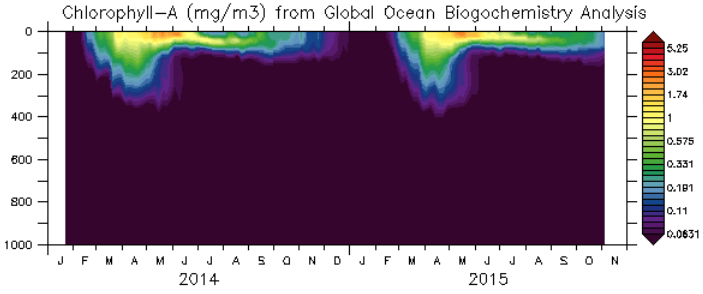












Conclusions

Impact of Argo on Mercator Ocean/CMEMS modelling and data assimilation system :

- Very large impact of Argo data assimilation. Temperature and salinity forecast errors (rms) reduced by 20 to 60%.
- Expending to depth the float profiles should allow reducing deep model biases.
- Essential role of Bio/BGC-Argo for model validation

Recommandations:

- The Argo array must be at least maintained at its present level of coverage and data quality.
- Deeper (at least 4000 m) ocean measurements are required to constrain deep T&S model fields. Measurement with a coarse resolution (1/9) seems to be enough to constrain deep T&S model fields.
- Development of Bio/BGC-Argo very much needed.

Perspectives:

- New experiments planned as part of the Atlantos EU project (Argo and Bio/BGC-Argo). Revisit deep Argo OSSEs + OSSEs to assess the impact of doubling Argo density in specific regions (tropics, WBCs).