# Observing System Evaluation Task Team

*Peter Oke (CSIRO) and Gilles Larnicol (CLS)*
*and the TT members*

*November 2016*

GODAE OceanView

# Overview

- OSEval-TT overview
- Progress and achievement since last meeting
- Future plans - Issues

# OSEval-TT Overview

To provide consistent and scientifically justified requirements and feedbacks to agencies in charge of Global and Regional Ocean Observing Systems

Provision and dissemination of Observation Impact Statements (OIS) based on OSEval evidence

Evaluation studies

- Perform impact studies of GOOS and ROOS on forecast and reanalysis GODAE systems
- Methodologies: OSE, OSSE and alternative methods

# Summary of OSEs & OSSEs

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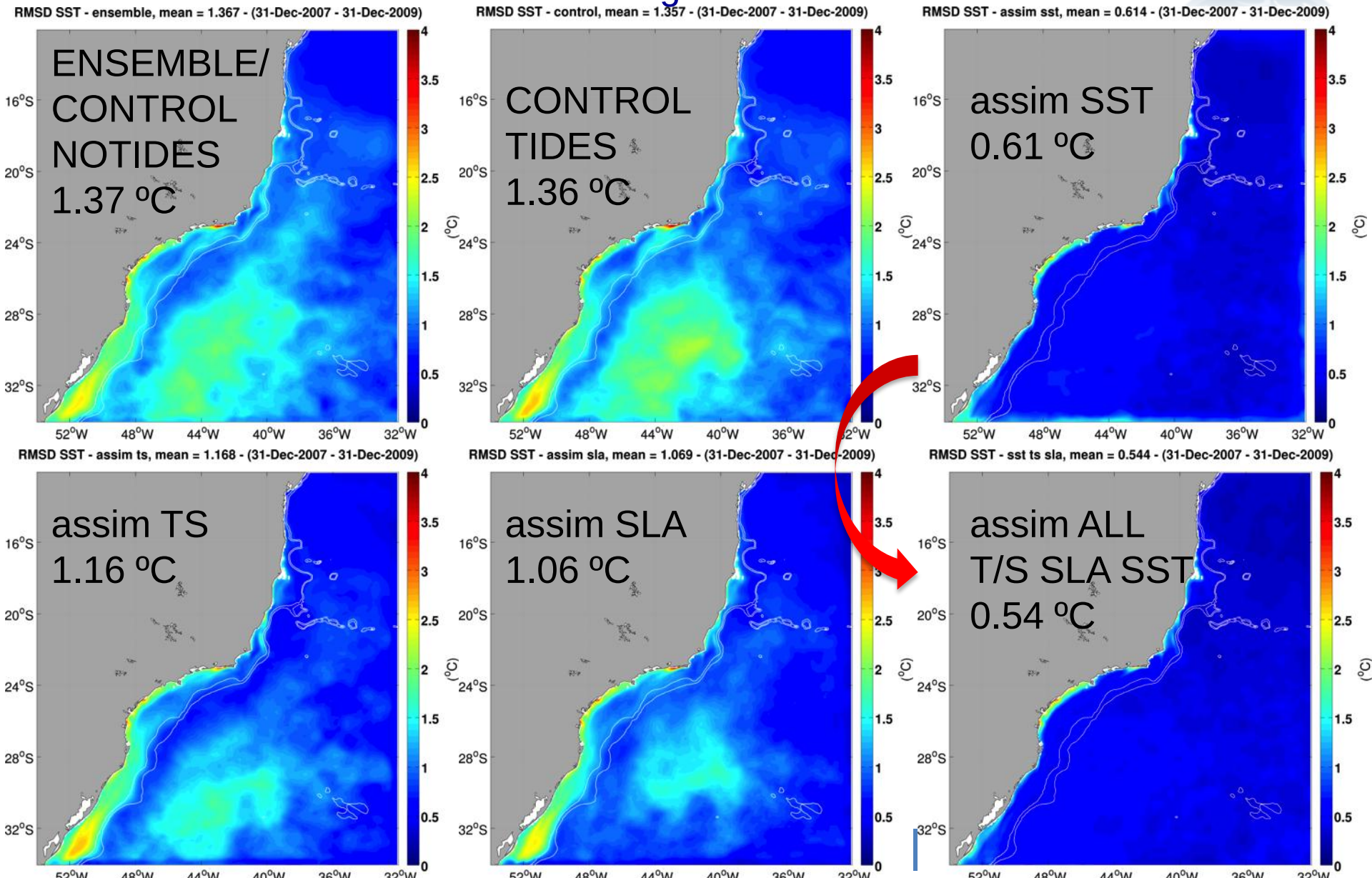
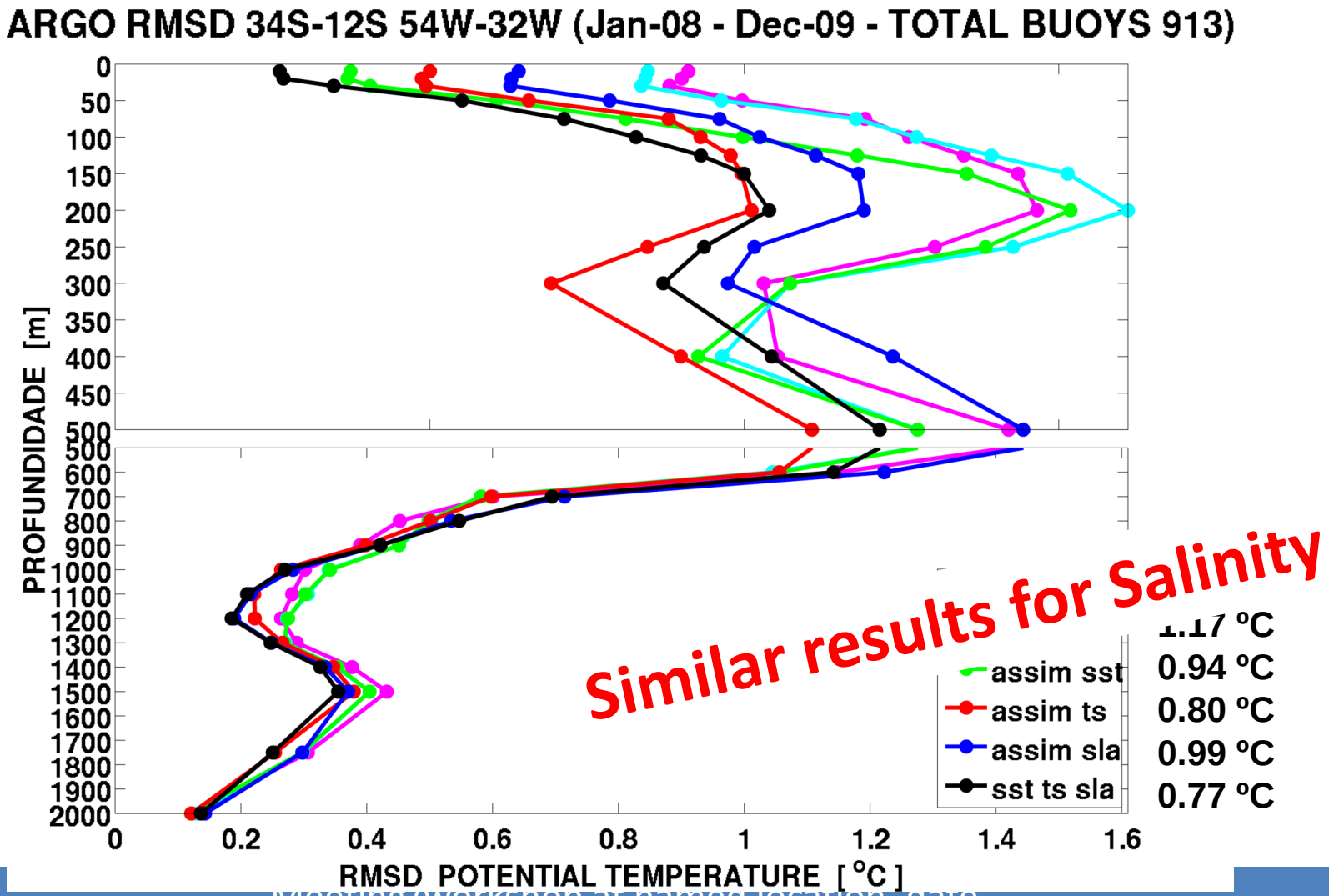
# RODAS – HYCOM 1/24º with tides (2009-2010) (C. Tanajura, REMO)

## 24-h forecasts evaluation against OSTIA SST



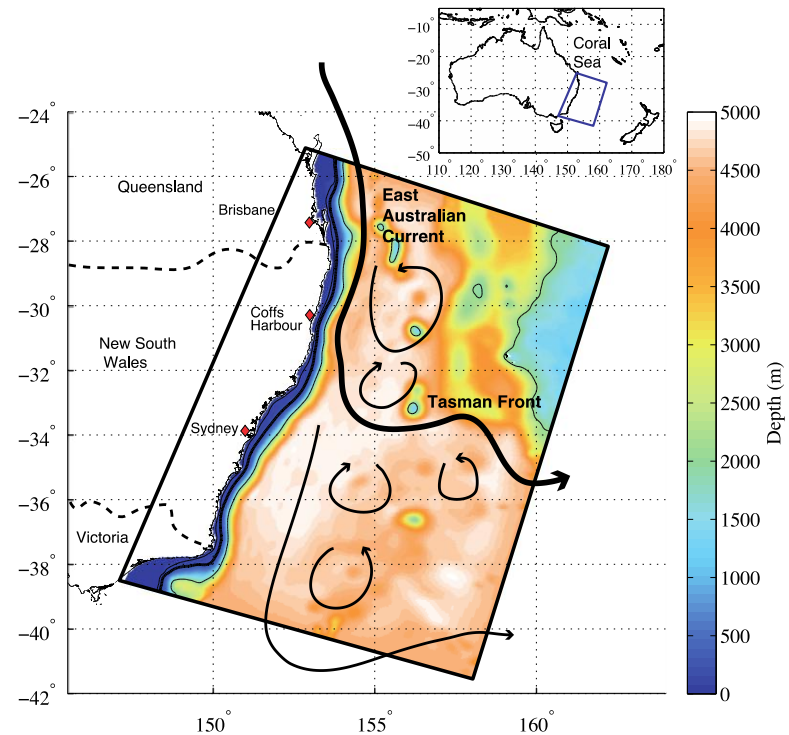
# RODAS – HYCOM 1/24º with tides (2009-2010)

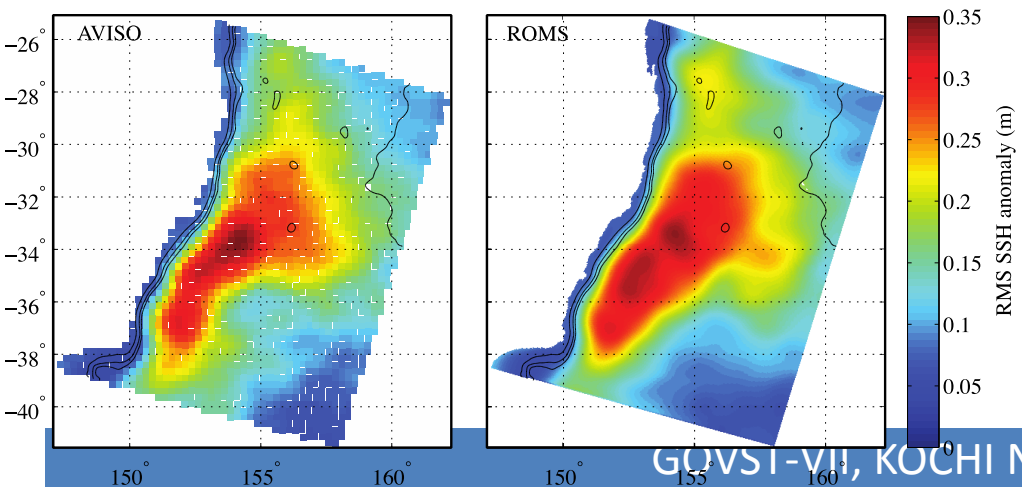
24-h forecasts evaluation against Argo T



# A high resolution reanalysis for the East Australian Current: ROMS model (Kelly et al. UNSW)

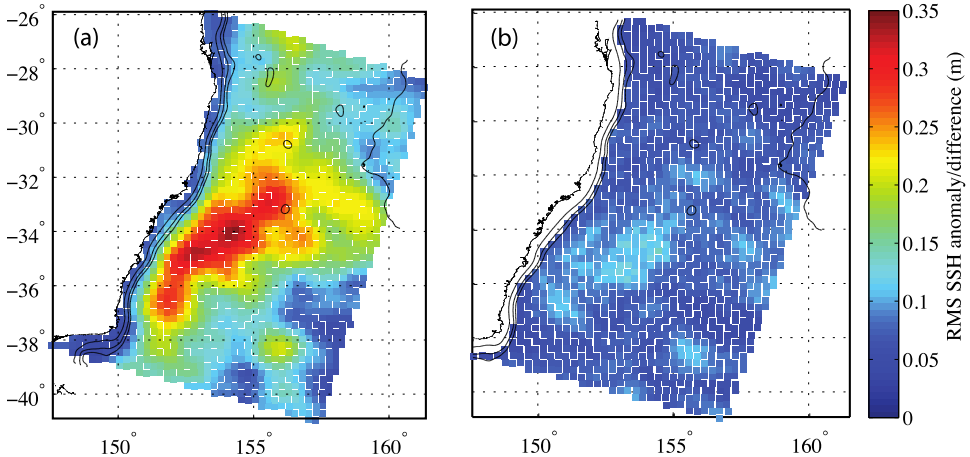
- Variable horizontal resolution
  - 2.5-6km cross shore
  - 5km alongshore
  - 30 s-levels
- Smoothing with emphasis on maintaining shelf width, key to EAC separation
- BRAN 3p5 initial and boundary conditions
- ACCESS-R 12km for atmospheric forcing

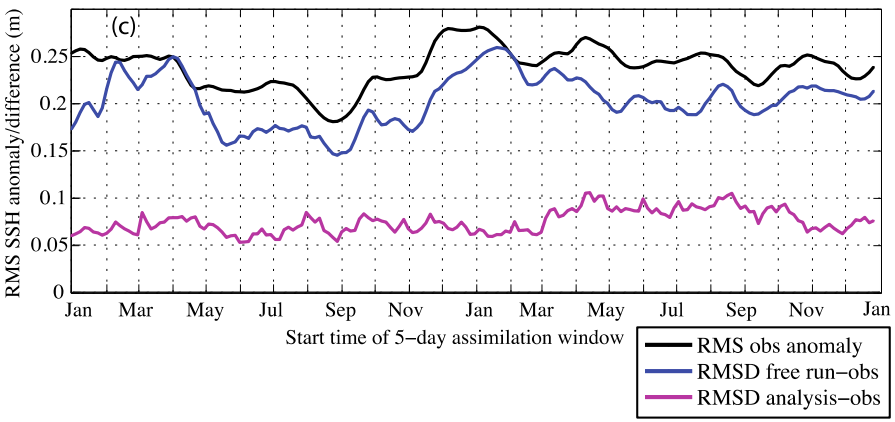


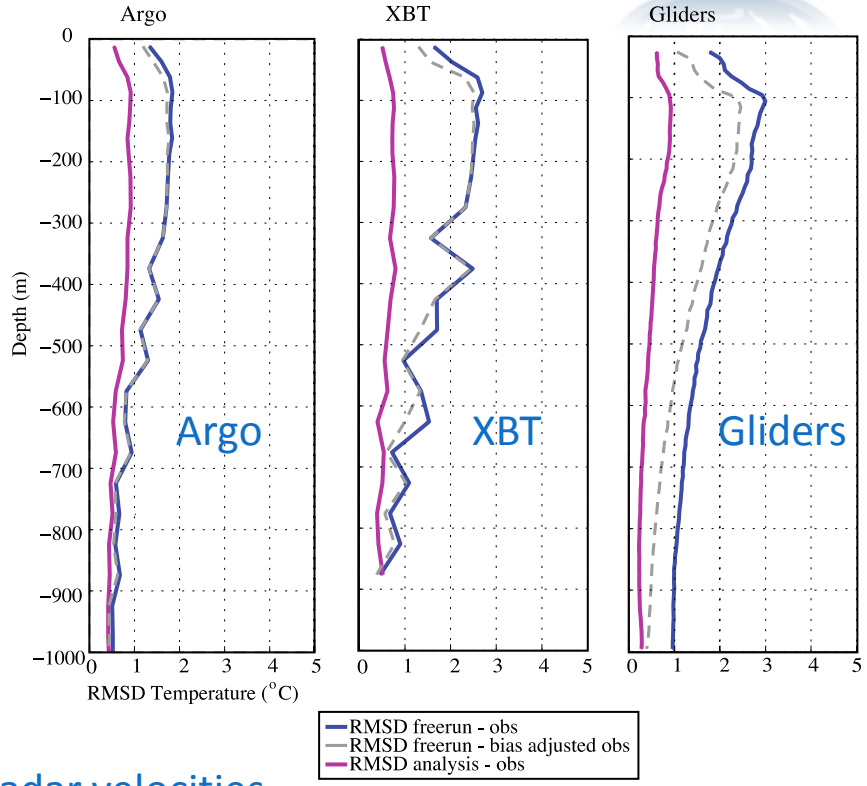



# A high resolution reanalysis for the East Australian Current: Reanalysis performance

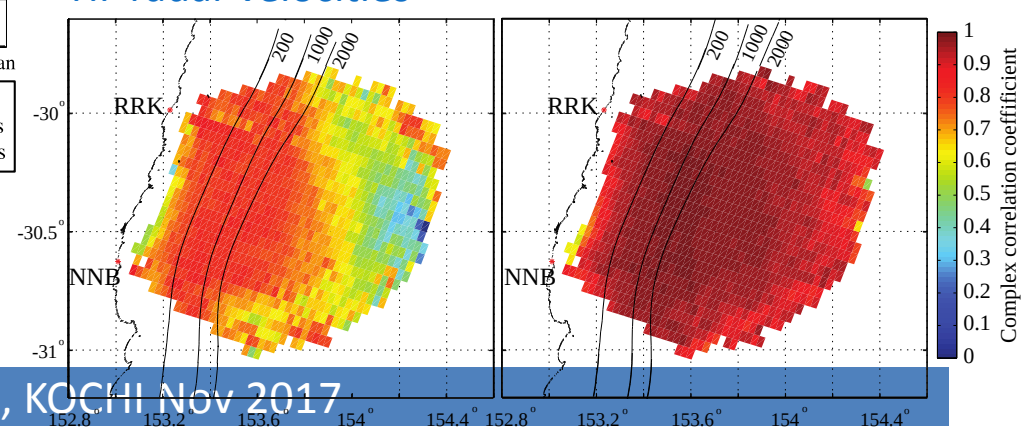
## AVISO SSH




## HF radar velocities



# Which observations best capture the dynamics ?

## Analysis sensivity diagnostics

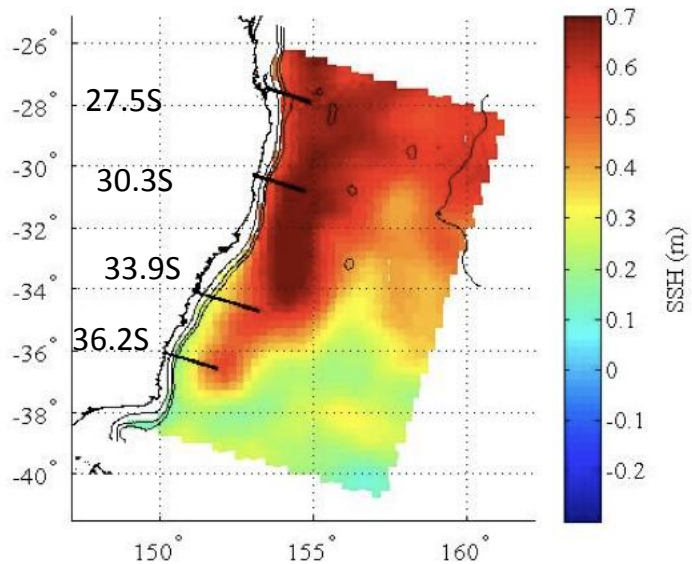
| | Mean % of all observations | Mean % impact Brisbane | Mean % impact Coffs Harbour | Mean % impact Sydney | Mean % impact Narooma |
|---|---|---|---|---|---|
| AVISO SSH | 10.1 | -2.7 | 19.2 | 17.6 | 15.1 |
| NAVO SST | 40.6 | 49.7 | 32.9 | 27.3 | 35.5 |
| HF radar | 19.3 | 26.0 | 33.2 | 32.8 | 30.6 |
| EAC array | 12.1 | 15.9 | 2.5 | 8.7 | 9.9 |
| Gliders | 6.9 | 6.6 | 4.9 | 9.1 | 3.4 |

27.5S

30.3S

33.9S

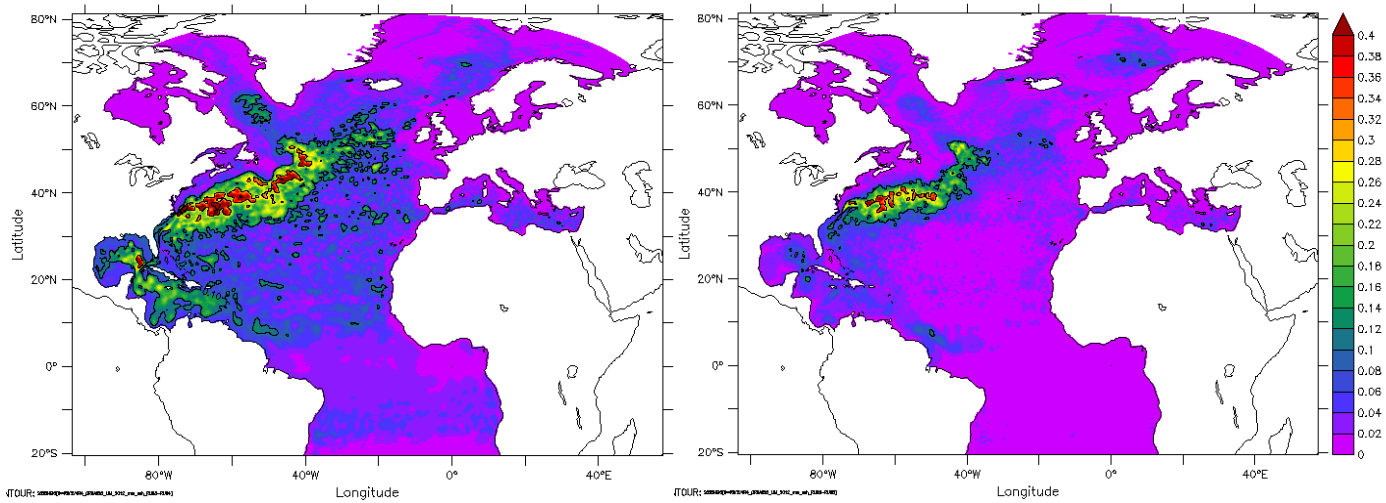
36.2S



# OSE: Impact of the altimeter constellation on the 1/12° Atlantic system (Remy et al. Mercator)

- 1-year OSEs (2012)
- - SLA observation error:
- Jason2: 2 cm, Jason1g: 3cm,
- CryoSat2: 4cm + 2D SSH
- representativity error.

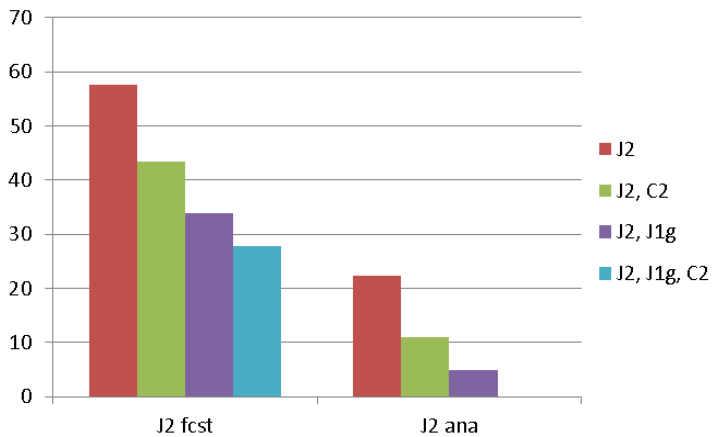
| | SST | In situ | J2 | C2 | J1n-J1g |
|---|---|---|---|---|---|
| No altimeter | x | x | | | |
| Exp 3 altimeters | x | x | x | x | x |
| Exp 2 bis altimeters | x | x | x | x | |
| Exp 2 altimeters | x | x | x | | x |
| Exp 1 altimeter | x | x | x | | |



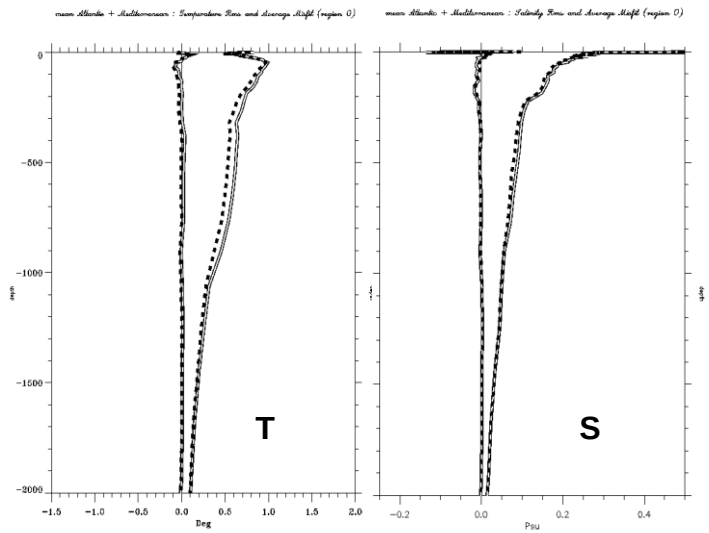

*RMS ($SSH_{NoAlt} - SSH_{J2}$);* *RMS ( $SSH_{J1g, J2, C2} - SSH_{J1g, J2}$ )*

*Differences between the analysed fields of different OSE experiments*

# Impact of the altimeter constellation




*$(Var(err_x) - var(err_{ana3sat}))/var(err_{ana3sat})$ en %*
*Error increase on the SSH estimation*



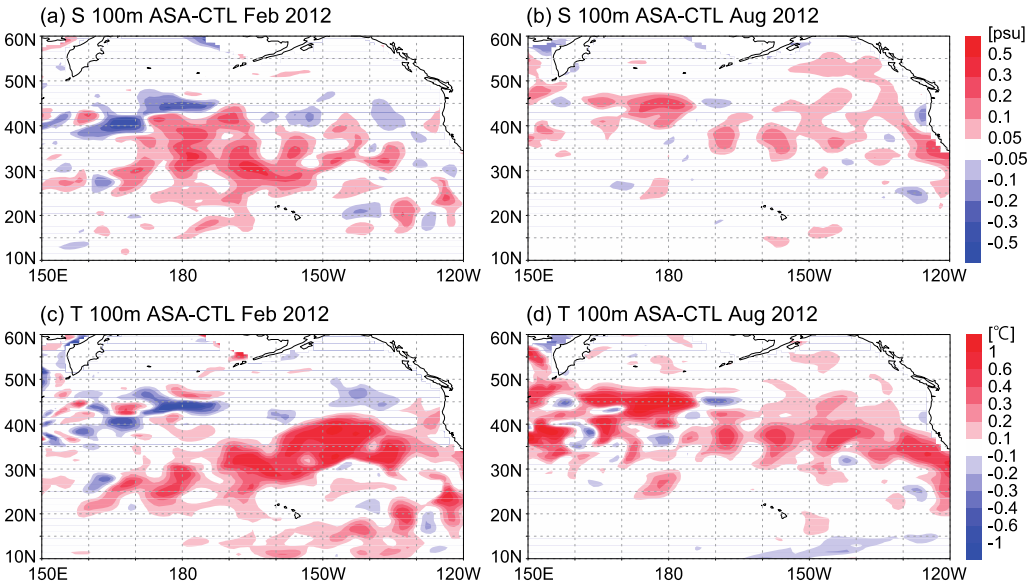

*Mean and RMS T and S forecast error: $OSE_{3Alti}$ in dashed line and $OSE_{NoAlti}$*

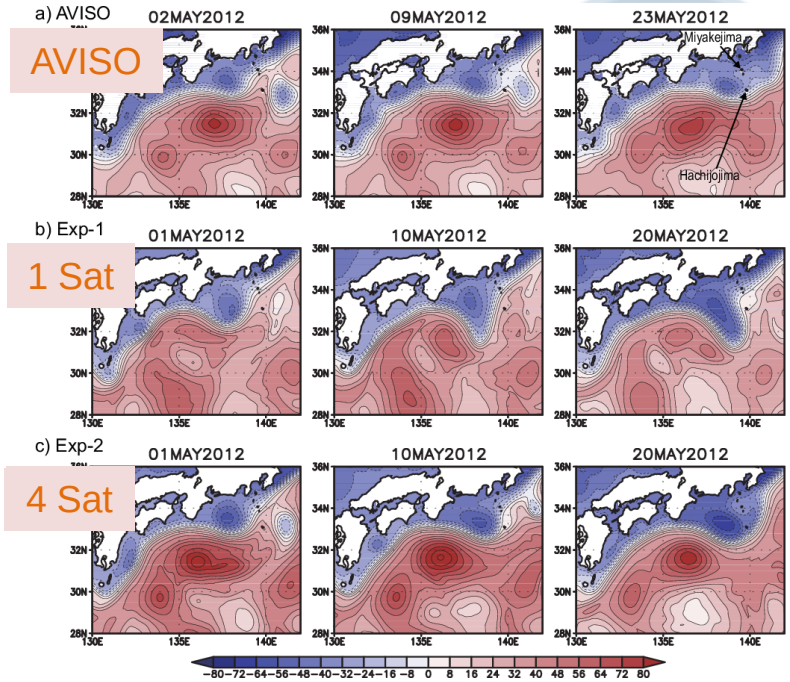
- An increased number of altimeters allows a global reduction of the SSH analysis and error forecast,
- **The impact highly depend on the region considered and the altimeter specifities (error, sampling orbit),**
- The misfit to temperature and salinity profiles is slightly reduced.

(Study supported by CNES fundings)

# Evaluation of Satellite Data at JMA (Y. Fujii)

- ✓ Evaluating values of satellite data in ocean/ climate monitoring and forecasting is essential to establish successive satellite missions.
- ✓ Evaluation of satellite altimetry is performed continuously in several studies.
- ✓ Evaluation of other data (SST, SSS, wind stress, etc.) is also required.




Impact of the number of altimetry satellite on the representation of the Kuroshio meander by JMA's eddy-resolving 4DVAR system

Assimilation of Aquarius SSS affects on 100-m TS due to the deep mixed layer in winter, and the influence remains even in summer. Results of OSE using JMA's global 3DVAR system.

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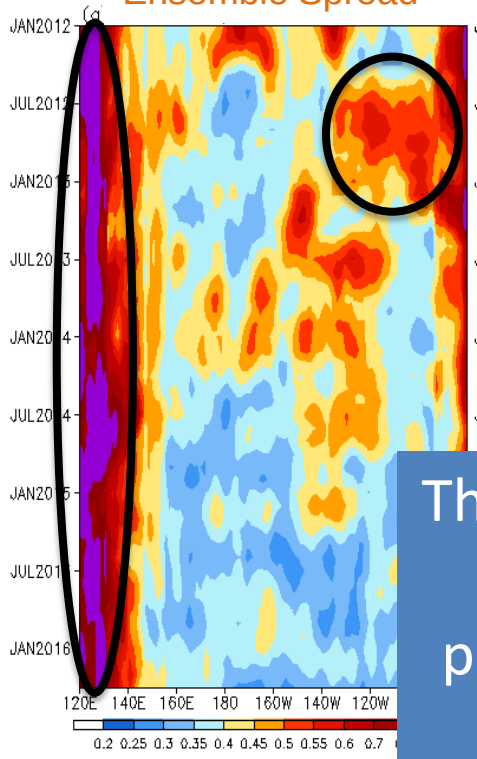
# Real-Time MultiORA Intercomparison for TPOS
## (led by Y. Xue, NCEP)

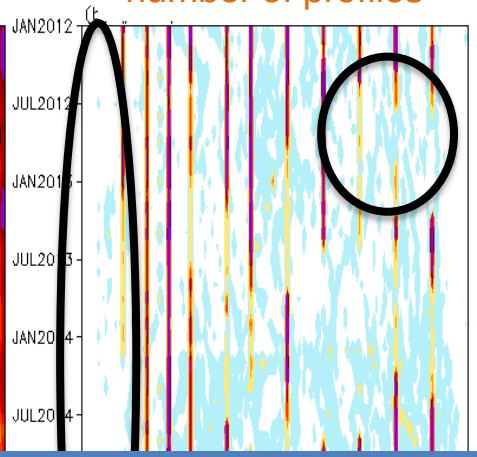
- Proposed in La Jolla for real-time monitoring of impacts of TPOS
- Members: NCEP (GODAS, CFSR), GFDL, ABoM, ECMWF, JMA, NASA, UKMO, MERCATOR
- Results of comparison are opened in near-real time via internet and NCEP Ocean Briefing. (Updated every month.)

2ºS-2ºN

Ensemble Spread

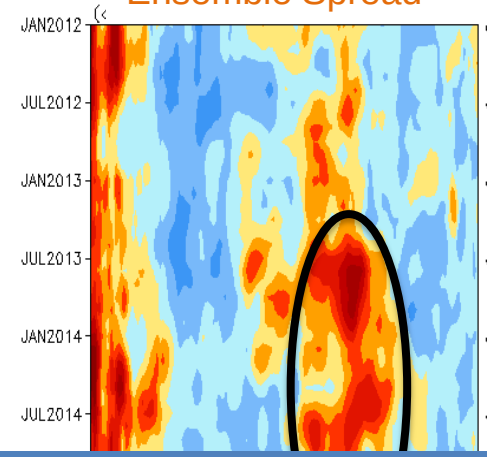



number of profiles




3ºN-8ºN

Ensemble Spread

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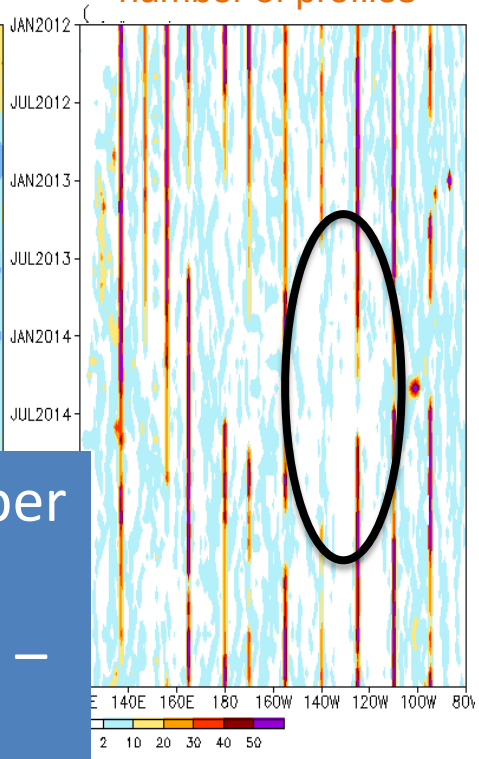


The ensemble spread of a multi-member ensemble (for seasonal prediction) provides an indication of forecast skill – and "gaps" in the observing system

The multi-system ensemble spread becomes larger where the number of profiles is small.

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# Evaluation of Atlantic Ocean OSSEs- Impact of gliders

*V. Kourafalou, Univ. of Miami-RSMAS/NOAA-AOML Joint Ocean Modeling and OSSE Center (OMOC)*

GODAE OceanView

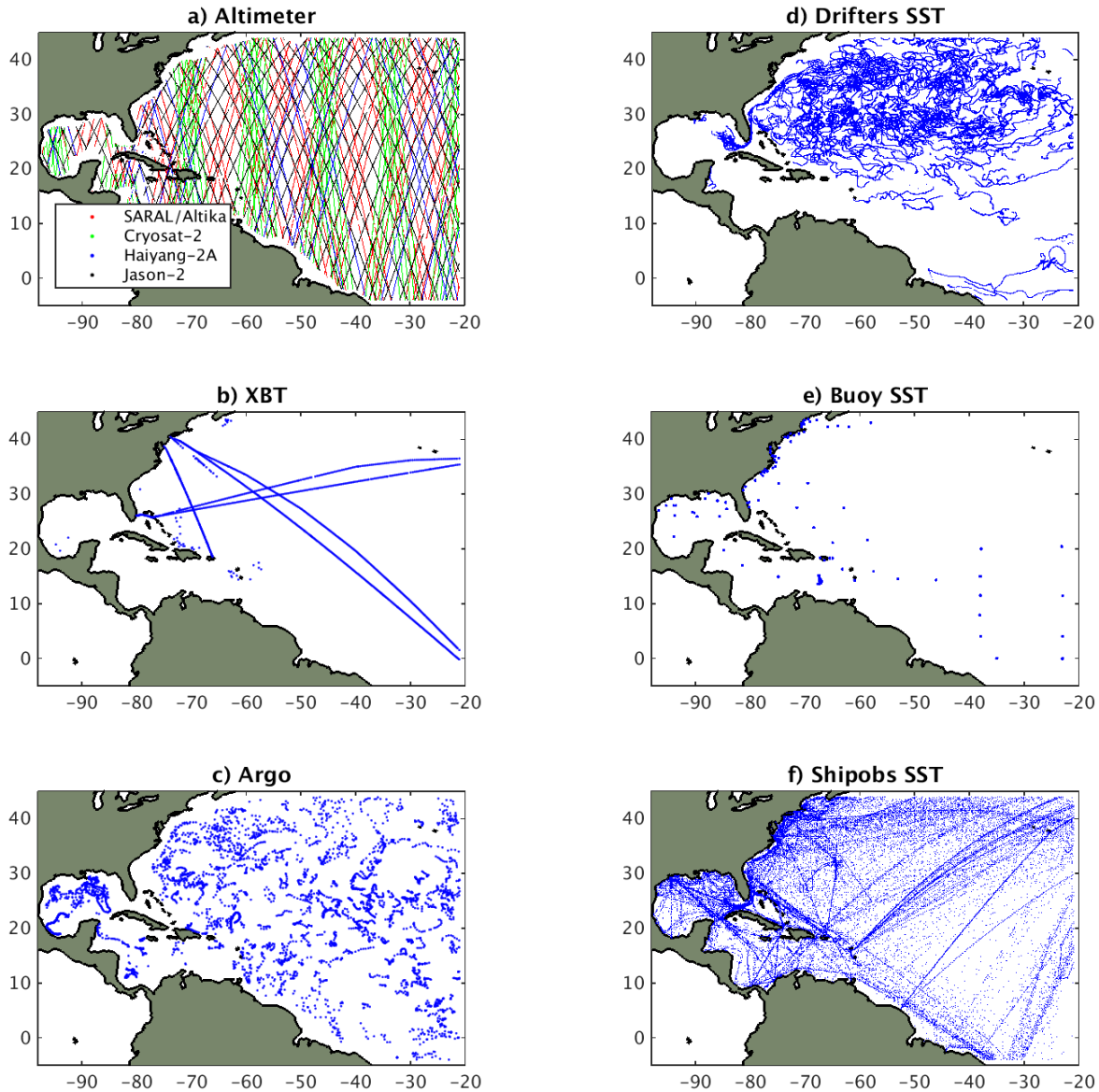
## Assimilation of Existing Ocean Observing System Components

Panels show existing altimetry and in-situ observing systems assimilated from 1 March through 31 October 2014.

Satellite SST data that were assimilated (MCSST) are not shown.

This experiment is referred to as the Control experiment.

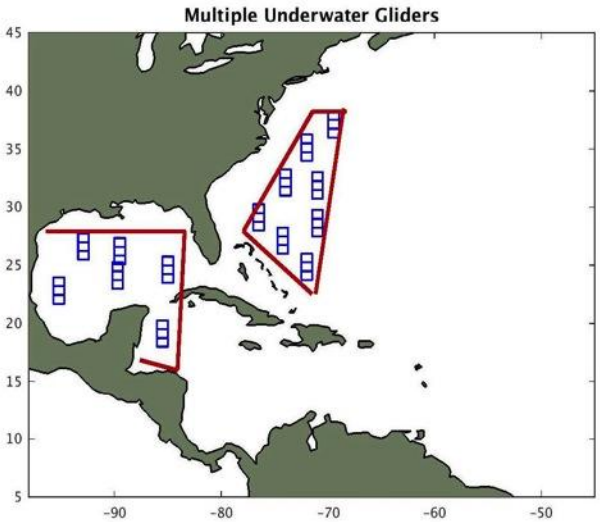
An unconstrained FM simulation is used as a reference to represent no assimilation.

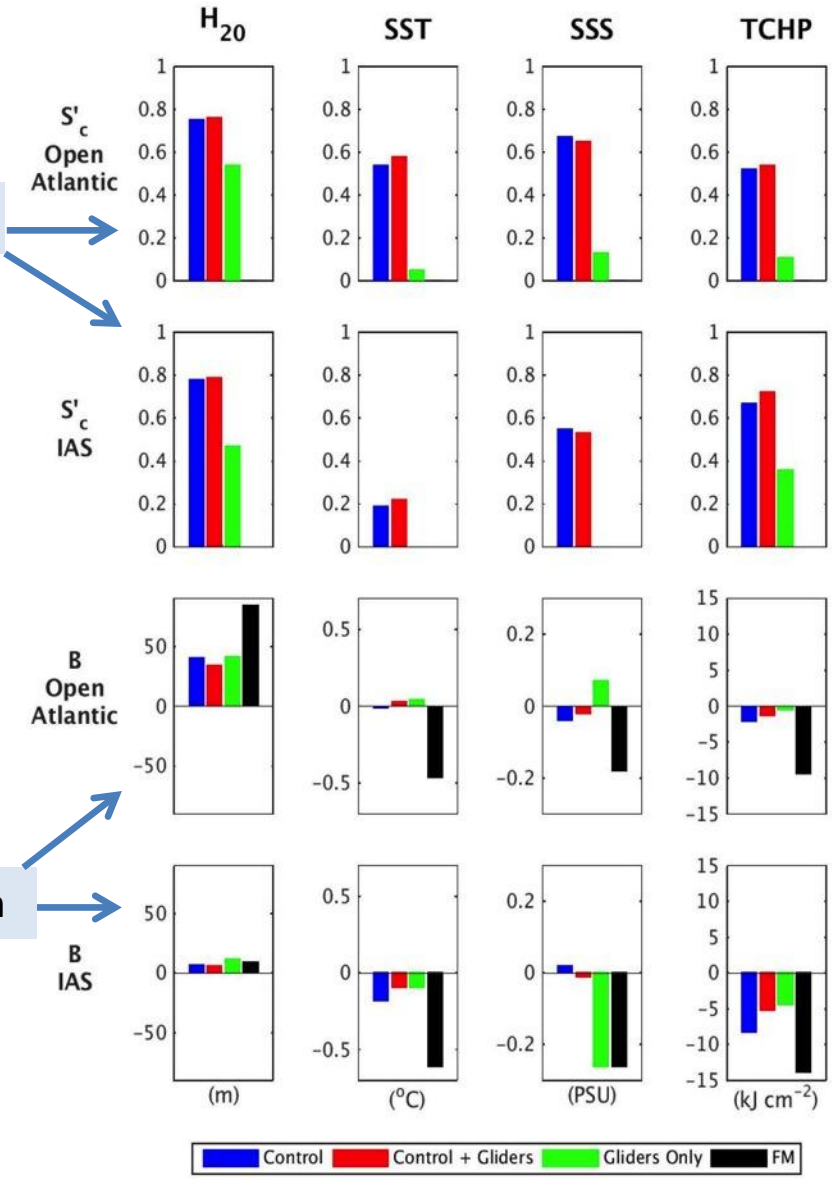


# Assimilate profiles from 14 underwater gliders (both alone and added to the existing ocean observing system) from June-October 2014

Statistics calculated from 15 July through 31 October.

Corrected skill scores




Mean bias correction

T-S profiles to 1000 m are assimilated. Glider assimilation is more effective at correcting mean bias than at correcting mesoscale structure.

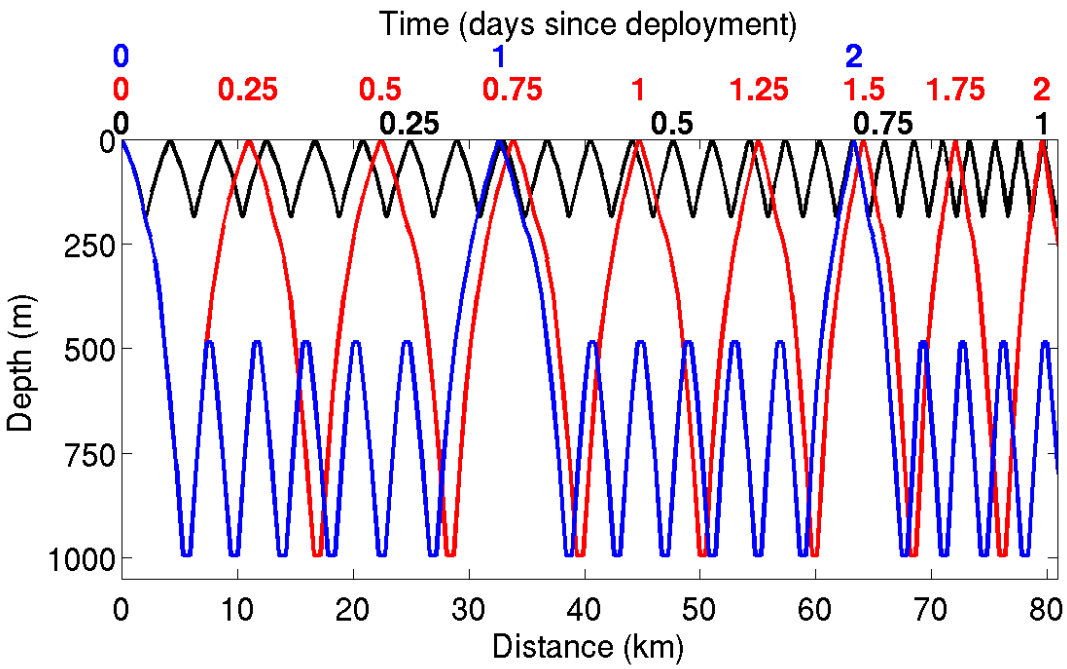
# Can gliders be kept on station in the presence of a strong western boundary current? What strategies are best?

CSIRO (P. Oke)

**Three cases considered:**

1. Deep glider (0-1000 m sampling)
2. Deep glider with daily surfacing
3. Shallow glider (0-200 m sampling)

Four 6-month deployments with different starting points




**Assumptions**:

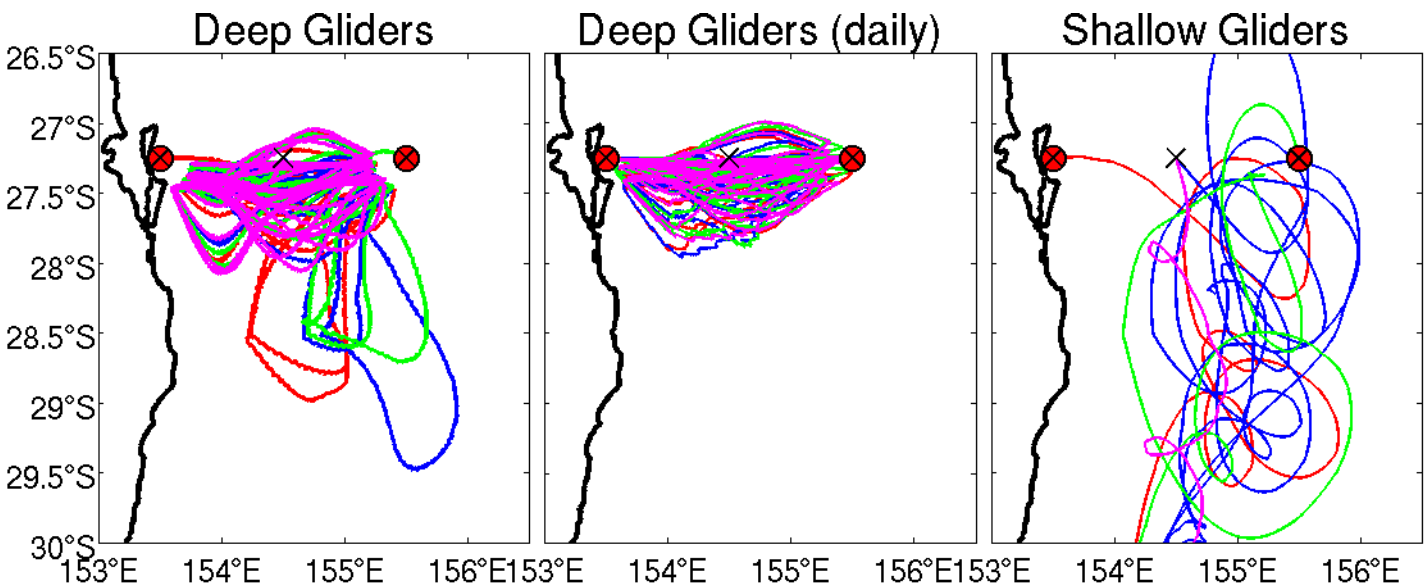
- Horizontal glider speed is 25 cm/s;
- Vertical glider speed is ~11 cm/s … 22 degree glider angle
- Glider heading adjusted every time it surfaces

- Deep gliders dive 0-1000 m over 6 hours
- Shallow gliders dive 0-200 m every hour

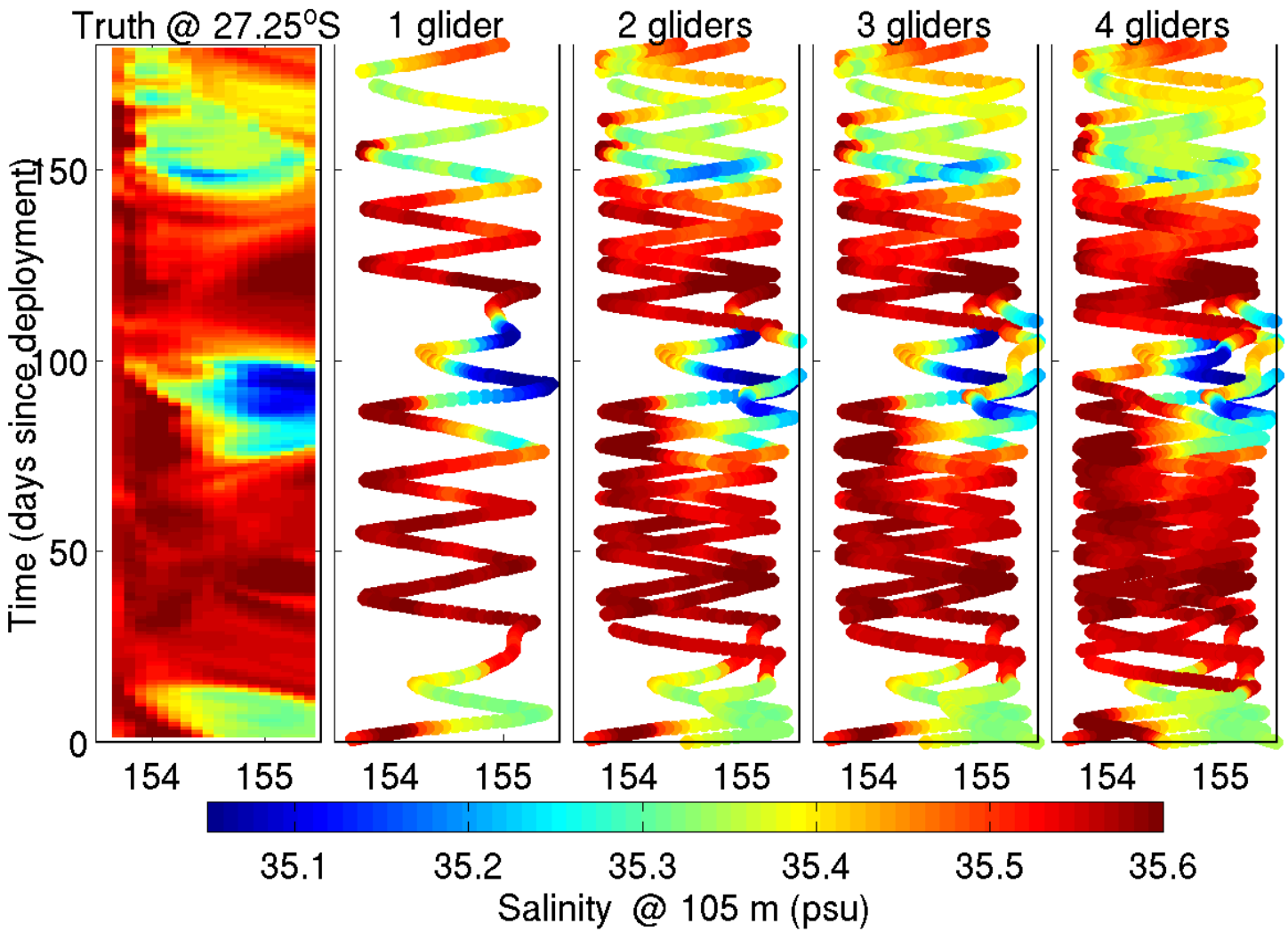
# Simulated glider paths f(x,y)

**Results:**

- Deep glider take ~9.2d per section;
- Deep daily gliders take ~8.3d per section;
- Shallow gliders are hopeless;
- Deep gliders sometimes escape (6 escapees in 6 months … monthly rescue missions
- Deep gliders with daily surfacing looks pretty good!



# How many gliders are needed?



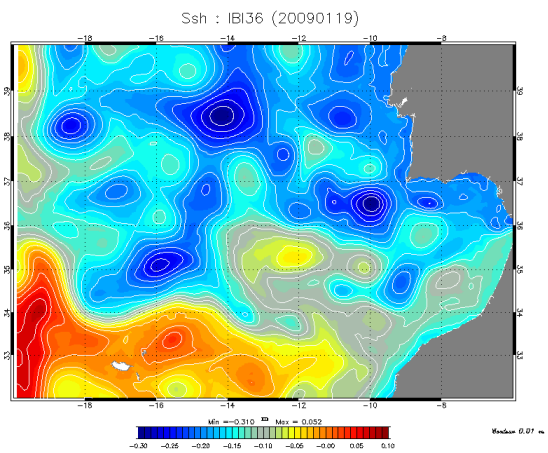
# OSSE for the future SWOT mission

(E. Remy, Mercator)

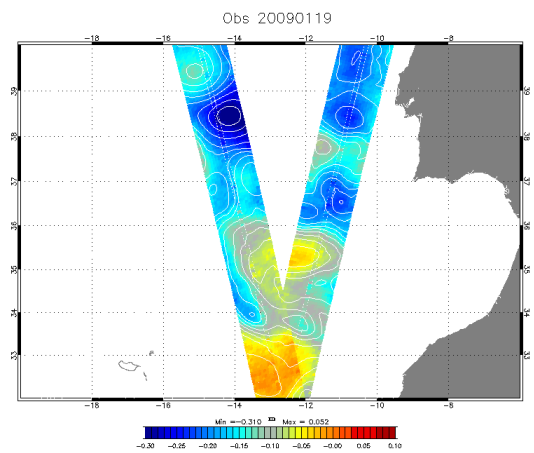
**Observations** from different type of altimeter **are simulated**:

- a large swath altimeter,
- three nadir altimeters.

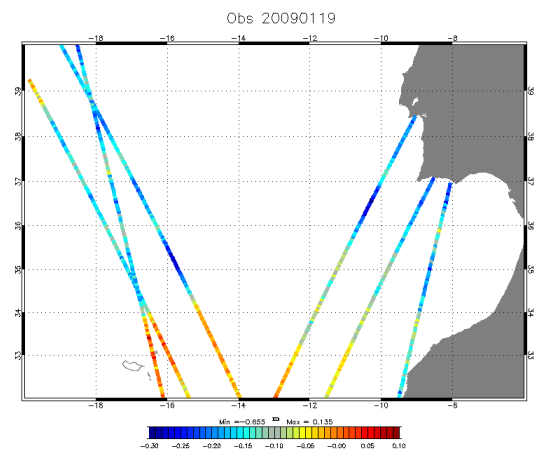
-> the efficiency of those two scenarios to constrain the ocean high resolution circulation is compared (zoom on the Mediterranean outflow region).




*Snapshot of the model SSH(m) of the Nature Run*



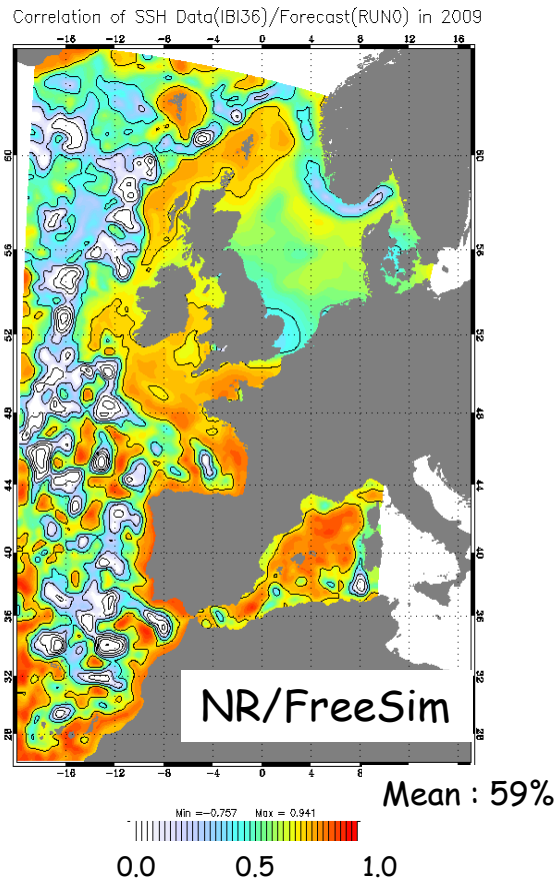

*Simulated SSH sampling by SWOT in 1 day*

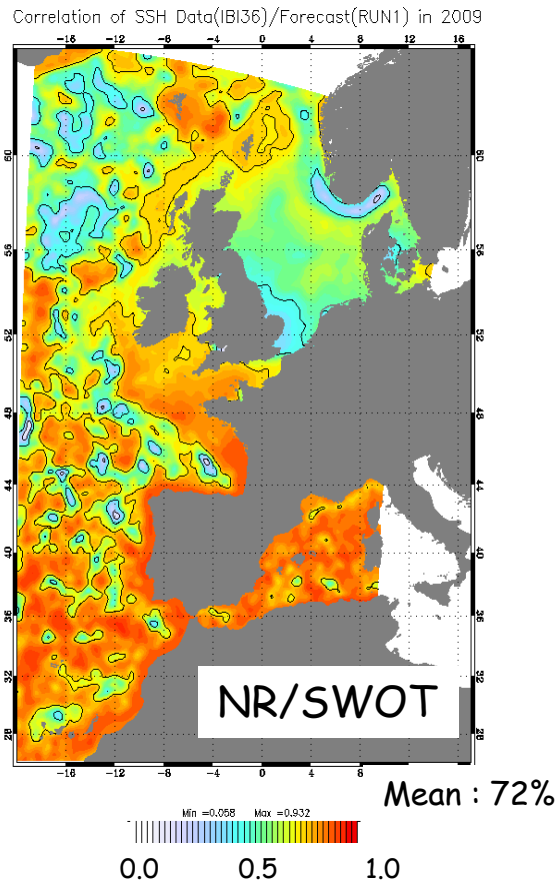


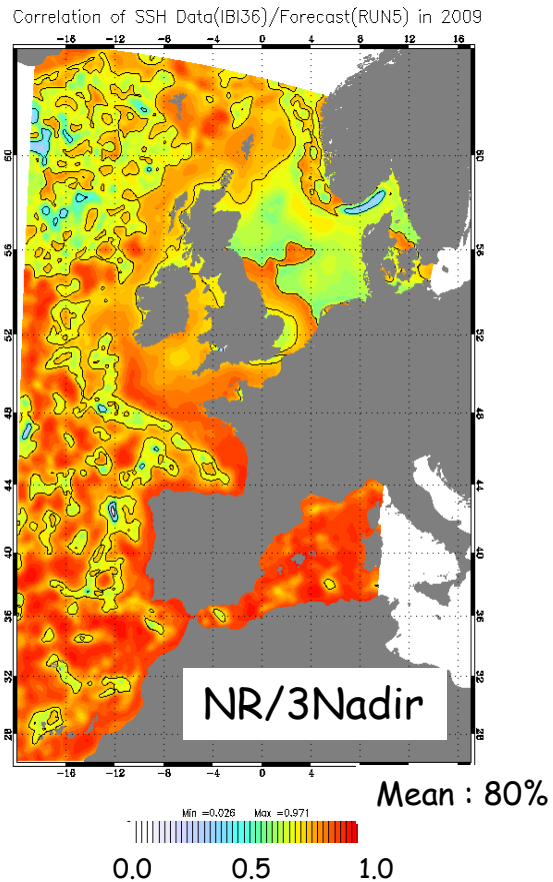

*Simulated SSH sampling by Jason2, Jason1g, Envisat in 1 day*

# OSSE for the future SWOT mission

Correlation of the estimated SSH in the different OSSE experiments compared to the « True » Ocean (Nature ) over one year (2009)



# TOPAZ contribution

*L. Bertino, J. Xie, NERSC*

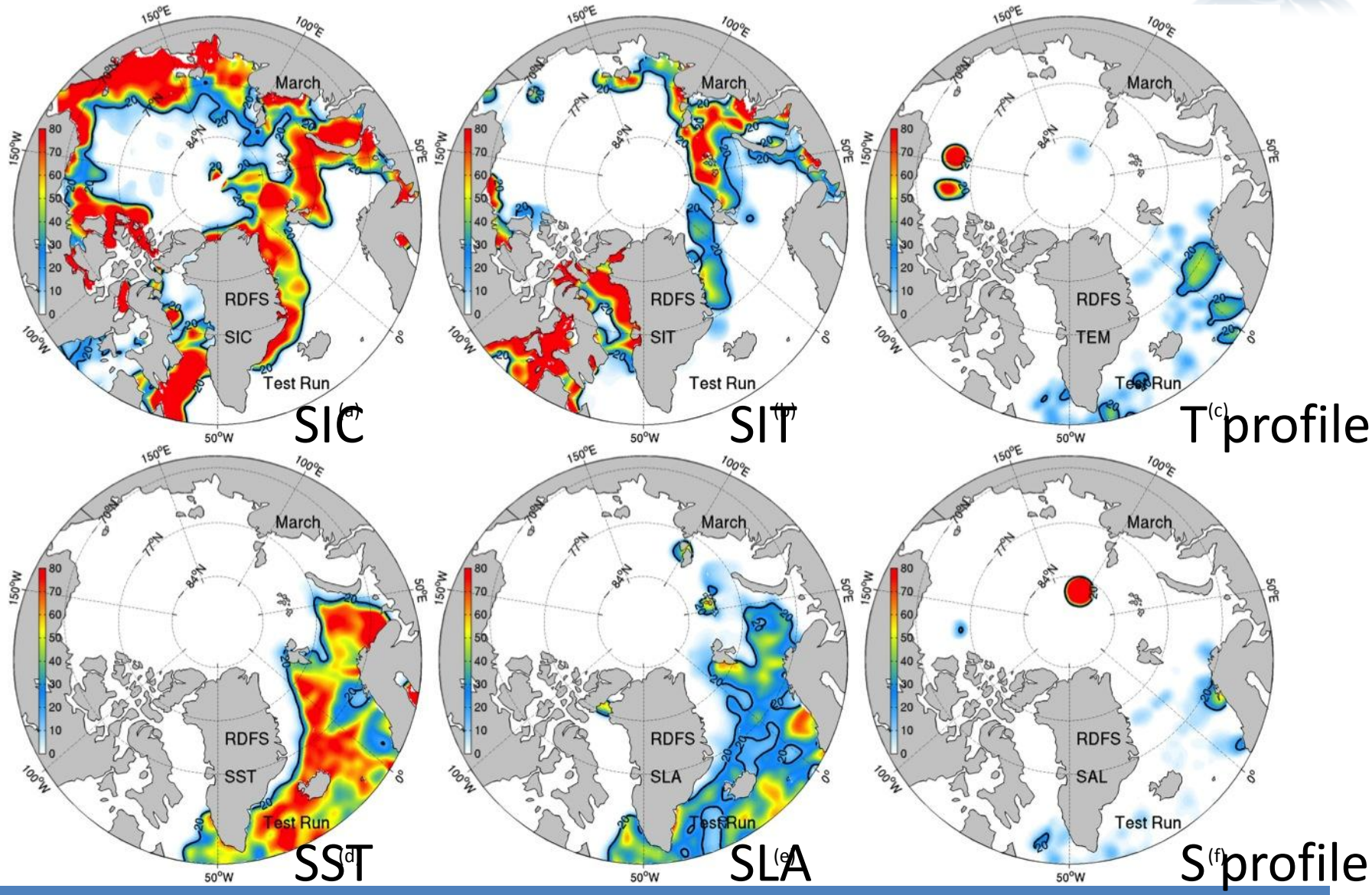
**Key message:**

SMOS Sea Ice Thickness observations compliment conventional observations for initialising sea-ice in TOPAZ forecasts

**Experiments:**

- Series of OSEs with and without SMOS
  - Assimilated SMOS Sea-Ice by every week, QC checks
  - SMOS Sea-ice thickness less than 0.4 m in the day prior to assimilation
  - Observations further than 30 km from the coast
  - excluded if uncertainty larger than 5 m

# Relative impact (DFS) of observations in March 2014



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| OSSE | Glider | Central EasternAustralia | CSIRO | Best Glider design: deep with daily surfacing |
| OSE | Sea Ice from SMOS | Arctic | TOPAZ | kind of data usefull to improve initialisation of forecast model |
| OSSE | In-Situ Obs Syst (physic & biogeo) | Atlantic (north) | H2020 AtlantOS project (all european centers )<br>Collaboration with US & Canada | on going work : nature run and design of the OSSE |
| OSE | SSS from satellite (SMOS, Aquarius, SMAP) | Tropical Pacific | ESA SMOS-Nino15 project (CLS, Mercator, MetOffice) | just started: design of the OSE |

# SMOS Nino15 project

## The objective of the SMOS-Niño15 project is:

- The design, the implementation and the reporting of an Observing system Evaluation of satellite SSS during the strong El Niño 2015/16 event in the Tropical Pacific Ocean.
- The ESA's SMOS products will be primary used jointly with other SSS products (NASA's Aquarius/SMAP) and ocean remote-sensing and in-situ observations.
- **ESA support to GODAE Ocean View**

## Means:

- Design, implement and perform an Observing System Experiment of the Sea Surface Salinity (SSS) with two different operational ocean forecasting systems.
- Provide feedbacks to the operational forecasting community (GODAE Ocean View) and ocean and climate science community
  - Through a dedicated web site
  - Observation Impact Statement Report
  - Organization of workshop to promote and enhance the use the SSS SMOS products.

## KO: October 2th 2016 ; 2 years project

## Partners:

**Associated partners:**

# The Experiments

- Design of the OSEs to be consolidated by the end of the year

  - Period: January 2014 – march 2016

  - Simulations perfomed by

| Planned experiment | Main Characteristics |
|---|---|
| 1 | Assimilate current network of observations without satellite SSS. |
| 2 | Assimilate current network plus SMOS satellite SSS observations. |
| 3 | Assimilate current network plus SMAP/Aquarius satellite SSS observations. |
| 4 | Assimilate current network plus all SSS satellite observations (using datasets giving the best improvement, if any). |

  - Adaptation to the Model/Assimilation component:

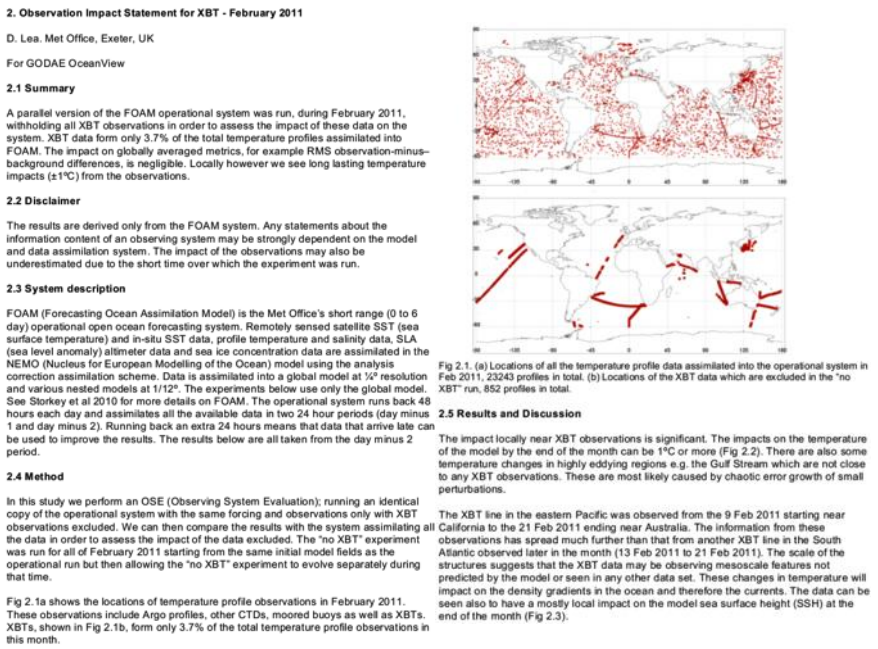
    Observation error, SSS bias correction,

# Expected outcomes

- Provide recommendations to OSEVal-TT community on:
  - the use of SSS data assimilation (error and observation operator)
  - the implementation complete set of metrics (based on GOVST OSEVal-TT community best practice) to evaluate the impact of satellite SSS

- Demonstration of usefulness of SSS data through scientific articles

- Provide Observation Impact Statement (GOV-OSEval-TT contribution)



**2. Observation Impact Statement for XBT - February 2011**

D. Lea. Met Office, Exeter, UK

For GODAE OceanView

**2.1 Summary**

A parallel version of the FOAM operational system was run, during February 2011, withholding all XBT observations in order to assess the impact of these data on the system. XBT data form only 3.7% of the total temperature profiles assimilated into FOAM. The impact on globally averaged metrics, for example RMS observation-minus–background differences, is negligible. Locally however we see long lasting temperature impacts (±1ºC) from the observations.

**2.2 Disclaimer**

The results are derived only from the FOAM system. Any statements about the information content of an observing system may be strongly dependent on the model and data assimilation system. The impact of the observations may also be underestimated due to the short time over which the experiment was run.

**2.3 System description**

FOAM (Forecasting Ocean Assimilation Model) is the Met Office's short range (0 to 6 day) operational open ocean forecasting system. Remotely sensed satellite SST (sea surface temperature) and in-situ SST data, profile temperature and salinity data, SLA (sea level anomaly) altimeter data and sea ice concentration data are assimilated in the NEMO (Nucleus for European Modelling of the Ocean) model using the analysis correction assimilation scheme. Data is assimilated into a global model at ¼º resolution and various nested models at 1/12º. The experiments below use only the global model. See Storkey et al 2010 for more details on FOAM. The operational system runs back 48 hours each day and assimilates all the available data in two 24 hour periods (day minus 1 and day minus 2). Running back an extra 24 hours means that data that arrive late can be used to improve the results. The results below are all taken from the day minus 2 period.

**2.4 Method**

In this study we perform an OSE (Observing System Evaluation); running an identical copy of the operational system with the same forcing and observations only with XBT observations excluded. We can then compare the results with the system assimilating all the data in order to assess the impact of the data excluded. The "no XBT" experiment was run for all of February 2011 starting from the same initial model fields as the operational run but then allowing the "no XBT" experiment to evolve separately during that time.

Fig 2.1a shows the locations of temperature profile observations in February 2011. These observations include Argo profiles, other CTDs, moored buoys as well as XBTs. XBTs, shown in Fig 2.1b, form only 3.7% of the total temperature profile observations in this month.

Fig 2.1. (a) Locations of all the temperature profile data assimilated into the operational system in Feb 2011, 23243 profiles in total. (b) Locations of the XBT data which are excluded in the "no XBT" run, 852 profiles in total.

**2.5 Results and Discussion**

The impact locally near XBT observations is significant. The impacts on the temperature of the model by the end of the month can be 1ºC or more (Fig 2.2). There are also some temperature changes in highly eddying regions e.g. the Gulf Stream which are not close to any XBT observations. These are most likely caused by chaotic error growth of small perturbations.

The XBT line in the eastern Pacific was observed from the 9 Feb 2011 starting near California to the 21 Feb 2011 ending near Australia. The information from these observations has spread much further than that from another XBT line in the South Atlantic observed later in the month (13 Feb 2011 to 21 Feb 2011). The scale of the structures suggests that the XBT data may be observing mesoscale features not predicted by the model or seen in any other data set. These changes in temperature will impact on the density gradients in the ocean and therefore the currents. The data can be seen also to have a mostly local impact on the model sea surface height (SSH) at the end of the month (Fig 2.3).

Example extract of an observation impact statement from a previous project

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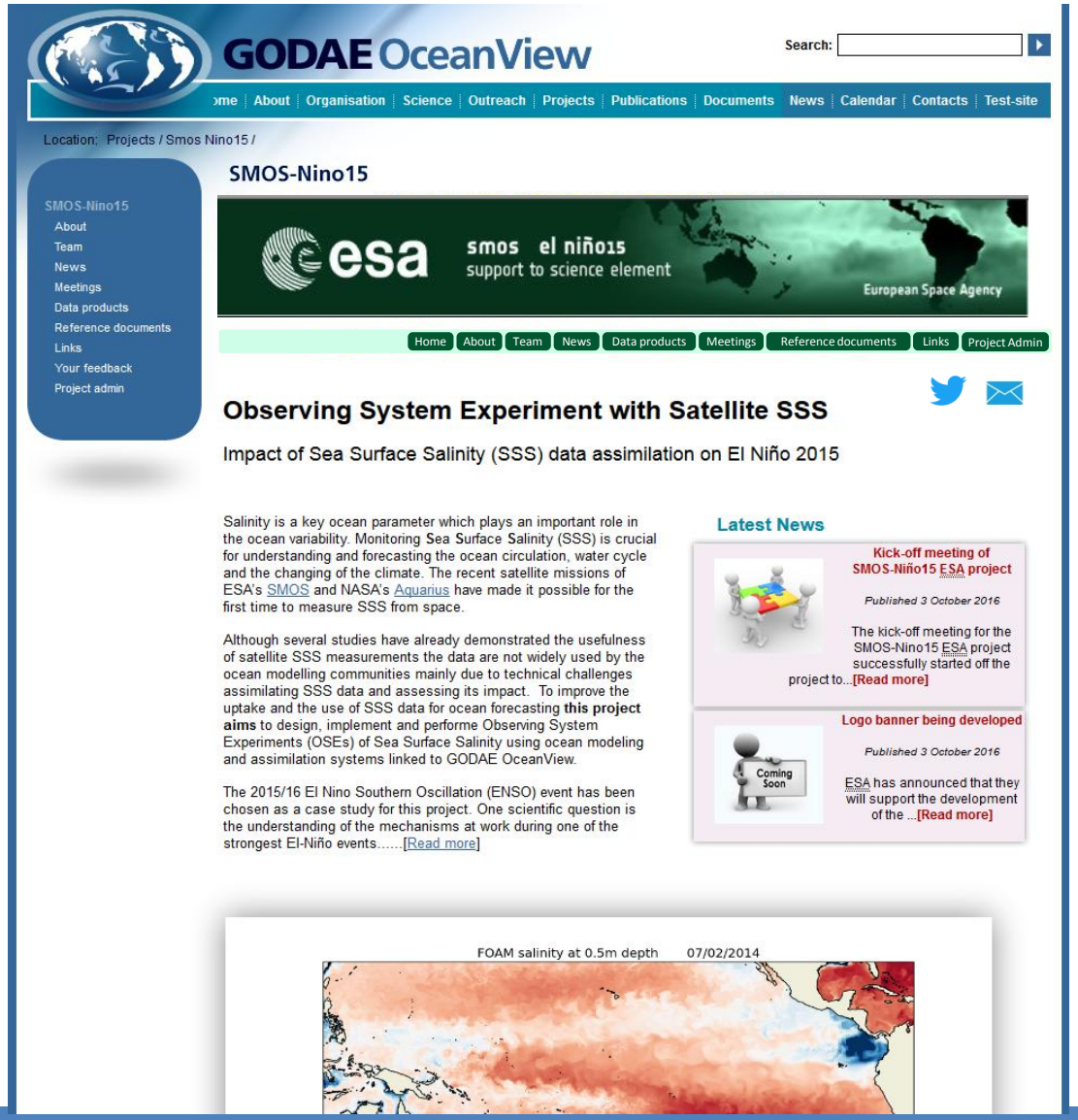
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Observing System Experiment with Satellite SSS
Impact of Sea Surface Salinity (SSS) data assimilation on El Niño 2015
Salinity is a key ocean parameter which plays an important role in the ocean variability. Monitoring Sea Surface Salinity (SSS) is crucial for understanding and forecasting the ocean circulation, water cycle and the changing of the climate. The recent satellite missions of ESA's SMOS and NASA's Aquarius have made it possible for the first time to measure SSS from space.
Although several studies have already demonstrated the usefulness of satellite SSS measurements the data are not widely used by the ocean modelling communities mainly due to technical challenges assimilating SSS data and assessing its impact. To improve the uptake and the use of SSS data for ocean forecasting this project aims to design, implement and performe Observing System Experiments (OSEs) of Sea Surface Salinity using ocean modeling and assimilation systems linked to GODAE OceanView.
The 2015/16 El Nino Southern Oscillation (ENSO) event has been chosen as a case study for this project. One scientific question is the understanding of the mechanisms at work during one of the strongest El-Niño events.....[Read more]
Latest News
Kick-off meeting of SMOS-Niño15 ESA project
Published 3 October 2016
The kick-off meeting for the SMOS-Nino15 ESA project successfully started off the project to...[Read more]
Logo banner being developed
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Coming Soon
ESA has announced that they will support the development of the ...[Read more]
FOAM salinity at 0.5m depth 07/02/2014

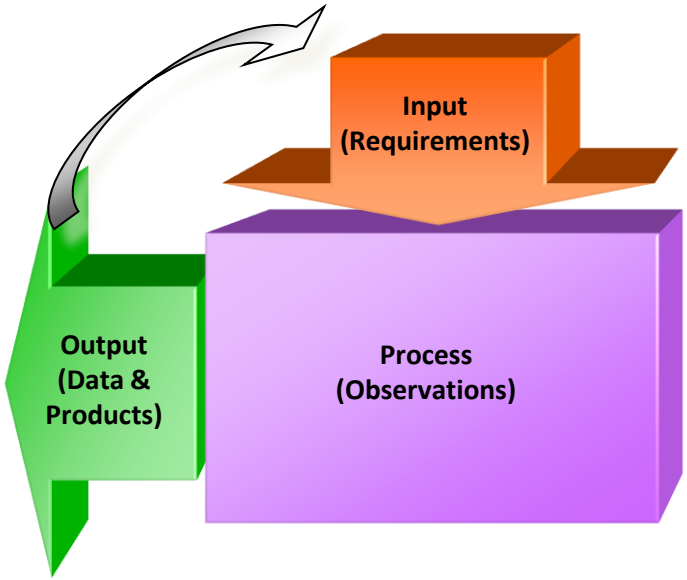
# H2020 AtlantOS project

Optimising and Enhancing the Integrated Atlantic Ocean Observing Systems

GODAE OceanView

European Commission H2020 project;  Budget ~ 20 M€ ; 57 partners
Started in april 2015 for 4 years;

→ To deliver an advanced framework for the development of an integrated Atlantic Ocean Observing System that goes beyond the state-of–the-art, and leaves a legacy of sustainability after the life of the project.

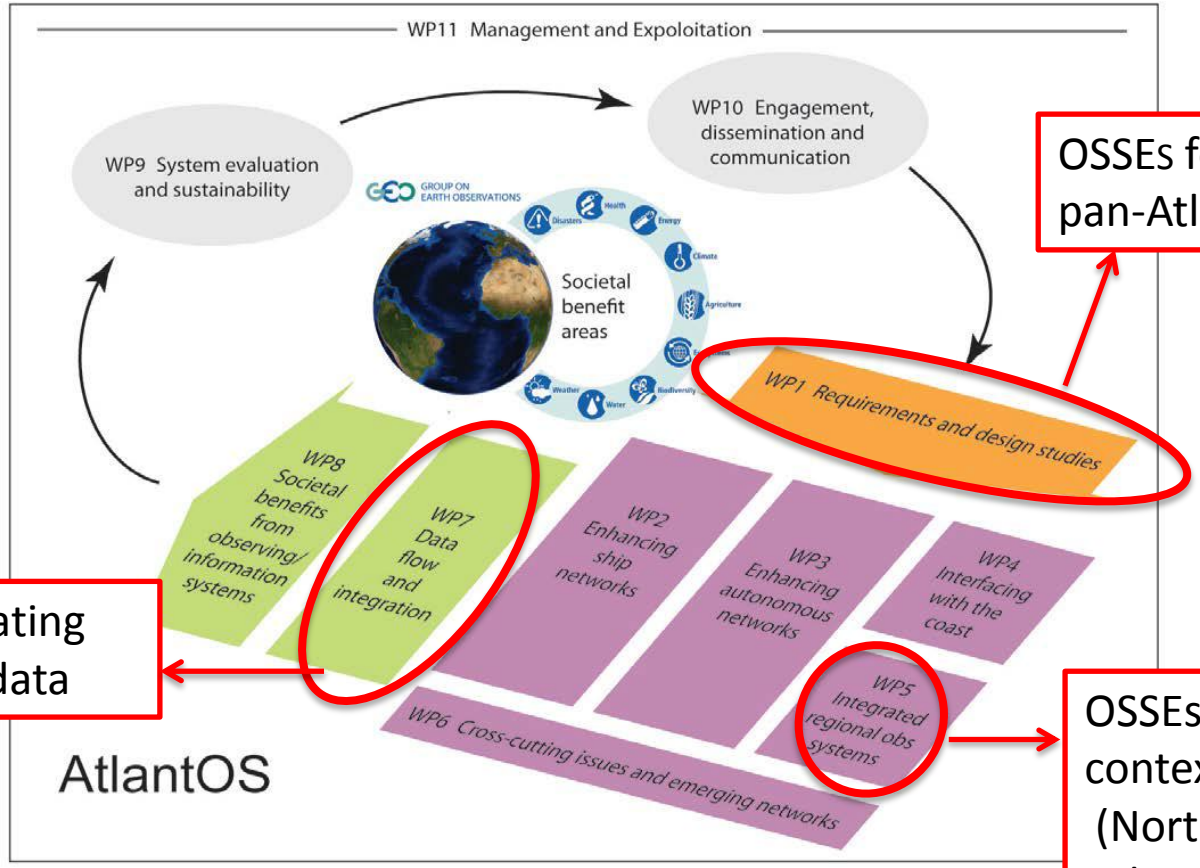



Framework for Ocean Observing

# H2020 AtlantOS project

Optimising and Enhancing the Integrated Atlantic Ocean Observing Systems

GODAE OceanView




OSSEs for global/ pan-Atlantic context

OSEs for demonstrating the impact of real data

OSSEs for regional context (North & South Atl subpolar gyre)

**→ Coordinated work involving different Copernicus systems to get more robust conclusions on in situ network evolution in the Atlantic**

# **WP 1 OSSEs** (lead Mercator)

GODAE OceanView

• Workshop organized in September 2016 to agree on the main OSSEs that will be carried out from October 2016 to early 2018.

**Experiment for Physical variables:**

- "Backbone" experiment: Satellite altimetry (3 sat), SST, Argo, moorings and XBT,
- Addition of Argo profiles in western boundary currents and tropics (doubling of sampling),
- Impact of deep Argo profiles (4000 and/or 6000 m depth),
- Impact of gliders and their possible extensions,
- Impact of drifters equipped with an additional thermistor chain from the surface down to 150 meter depth.

**Experiment for Biogeochemistry variables:**

Focus on nutrients, oxygen, Chl-a and pH observations

Testing value of Bio-Argo (BGC-ARGO) as well as the value of satellite ocean colour data. The following scenarios will be assessed:

- Backbone experiment: Ocean colour data
- Ocean colour data and BGC-Argo on ¼ of existing Argo array (1000 floats).
- Ocean colour data and BGC-Argo on full existing Argo array (4000 floats).

# Summary

- OSEval-TT members are active in performing OSE/OSSEs with relevant results

But

- Except for Multi ORA intercomparison and recent European funded projects, these studies are done by a single center → no community OSE/OSSEs as it was proposed during the OSEval-TT workshop (Toulouse)

- Despite good feedback during the 2013 review difficulties appear to maintain the momentum and really set up "Community OSE/OSSEs" , part of the activities are done in the frame of other TTs (IV, DA, …) or initiatives (GSOP)

- Funded projects (as AtlantOs, SMOS-Nino15) is a good way to perform "Community OSE/OSSEs"

# Summary

- OSEval-TT leadership: Peter & Gilles would like to step down

  →identification of new Co-Chairs and a transition to new leadership with new ideas and energy

Discussion planned during the TT co-chair breakout session

# OSEval next workshop ?

- 11/2007 (Paris) – OSEval TT established;
- 6/2009 (Toulouse) - Towards routine monitoring (promotion of routine DA-derived metrics for routine observing system assessment);
- 6/2011 (Santa Cruz) – joint mtg IV (promotion of class-4 inter-comparisons with an intention to be used for routine OSEval … but the final step hasn't been accomplished);
- 12/2014 (Toulouse) – joint mtg with CLIVAR/GSOP – provided a forum for exchange of ideas etc in OSEval area (as community OSE/OSSEs)

- **mid-2017 (Sanya, China, TBC) – Theme TBC.**

  to be coordinate with

  AtlantOS will organise a wks in Nov/Dec 2017

  DA-TT have proposed a joint workshop in 2018

# Thank You