Assessing Argo contribution on the Mercator-Ocean system for an Integrated and More Sustainable Atlantic Ocean Observing System (AtlantOS)

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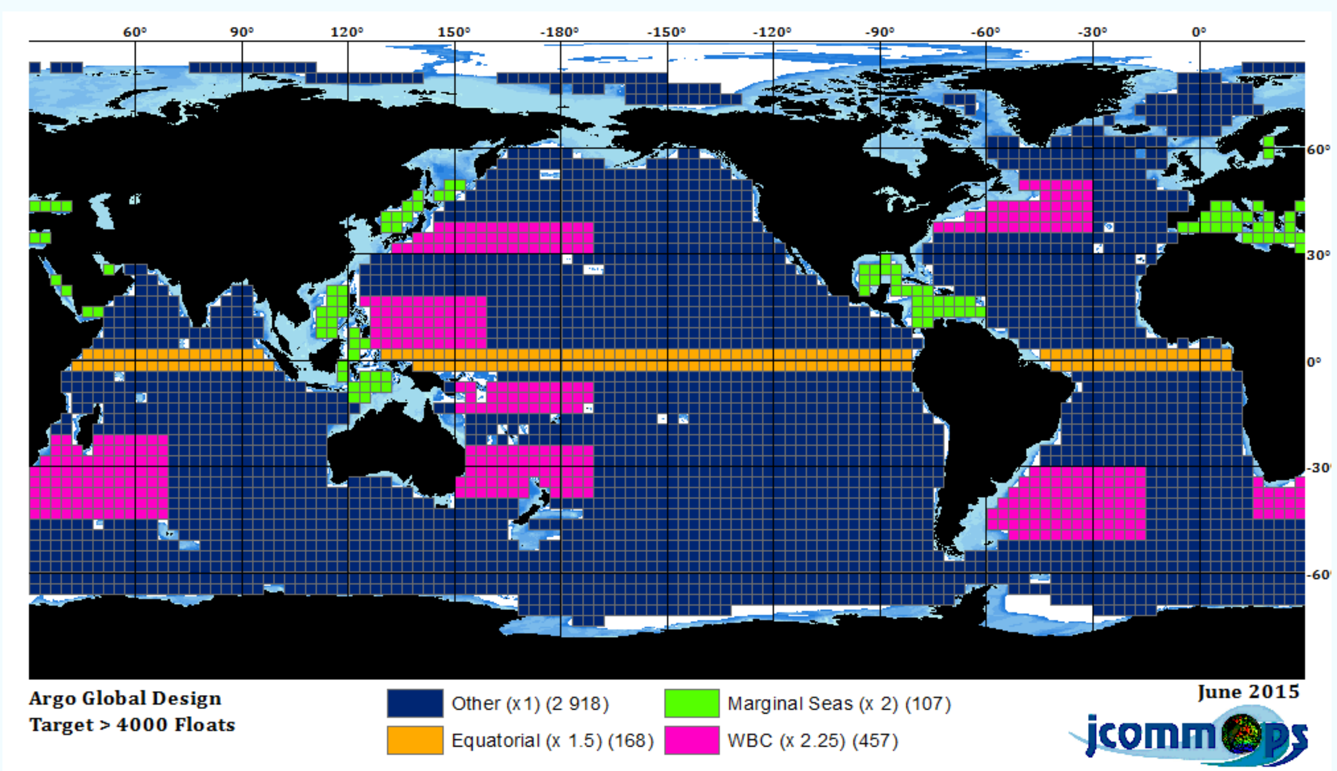
6th Euro-Argo Users Meeting

OUTLINE

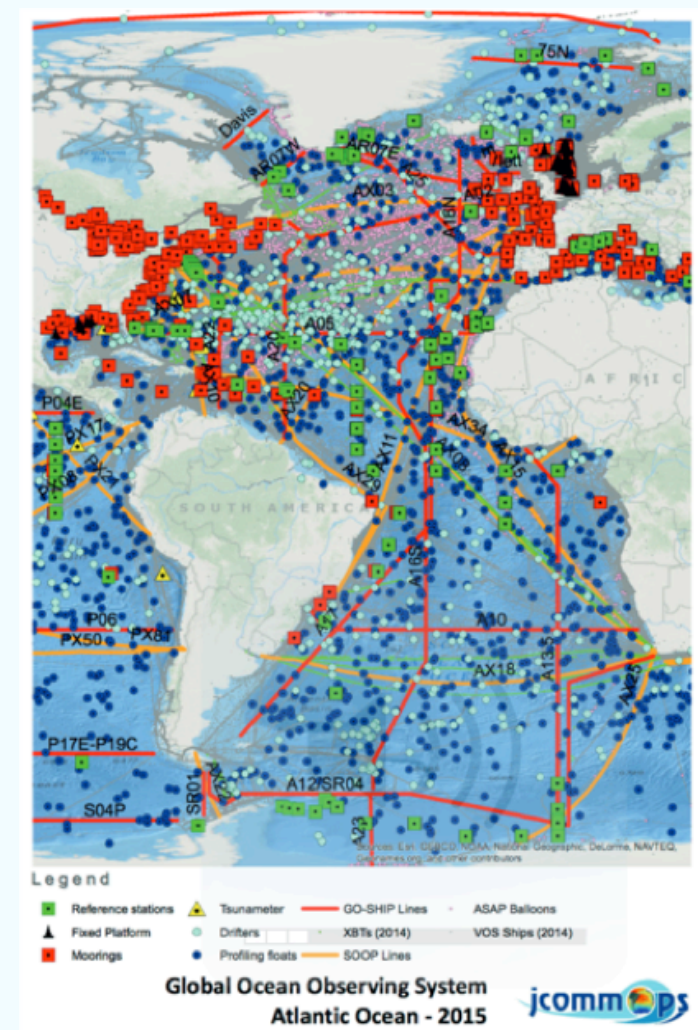
1. Why impact studies are needed ?
2. Observing System Simulation Experiment
3. The doubling of Argo in WBC and along the equator
4. The Deep Argo network
5. Conclusion/Discussion

1. Why observations impact studies are needed ?

- Obs. impact studies were limited by the development of models and data assimilation systems
- For supporting the evolution of an integrative global ocean observing system
- For improving data assimilation schemes in ocean reanalyses and monitoring systems
- For combining expertises of research labs and operational centres to define new metrics related to new scientific questions



Targeted Global core-Argo Design



Atlantic Ocean Observing System (2015)

The number of observations impact studies is limited

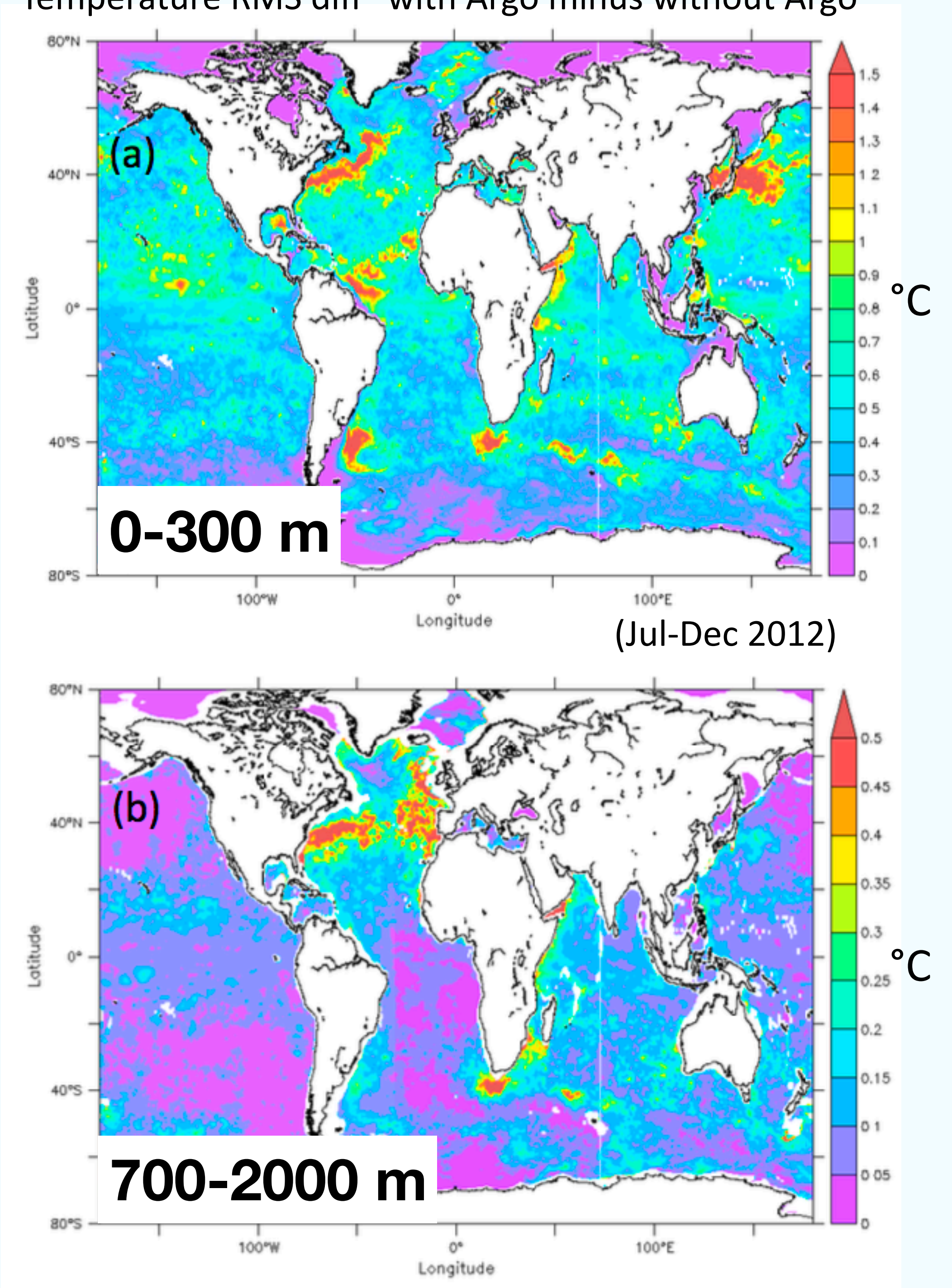
Observing System Experiment (OSE) = Impact of existing observations, with/without data assimilation.

Observing System Simulation Experiment (OSSE) = Impact of new observations prior to development, with/without synthetic data assimilation sampled in a realistic simulation

OSE/OSSE are expensive and often hardly conclusive, due to:
- the systematic errors in models and
- the dependence on the details of the model and assimilation system.

(i) Rigorous OSSE methodology, with specific steps
(ii) Standard metrics but also focusing on specific phenomena, time and spatial scales
(iii) Joint experiments for robustness of results

Temperature RMS diff "with Argo minus without Argo"



(Jul-Dec 2012)

(Turpin et al., 2016)

Toward an integrative Atlantic Ocean Observing System (AtlantOS)

In the context of an integrated ocean observing system …

- *What is the added-value of XBT lines for AMOC transport ?*
- *What is the impact of doubling Argo in WBC and along equatorial regions ?*
- *How deep Argo (down to 6000m) will improve ocean state estimate ?*
- *How sparse high-frequency moorings impact on ocean analysis and forecasting systems ?*
- *What is the potential impact of an extension to 150m of drifters thermistor chain ? etc …*

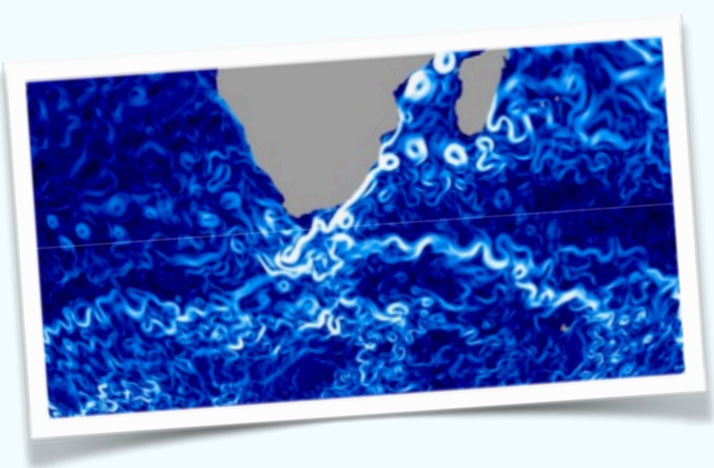
Task 1.3 - H2020 AtlantOS : Observing System Design Studies

including Core-Argo + BGC-Argo (Poster Germinaud *et al.*)

➔ Multi-models / multi-approaches exercice on the mid-2008/mid-2010 period

➔ Same synthetic observations assimilated in different systems

Common Synthetic observations from the Mercator-Ocean system

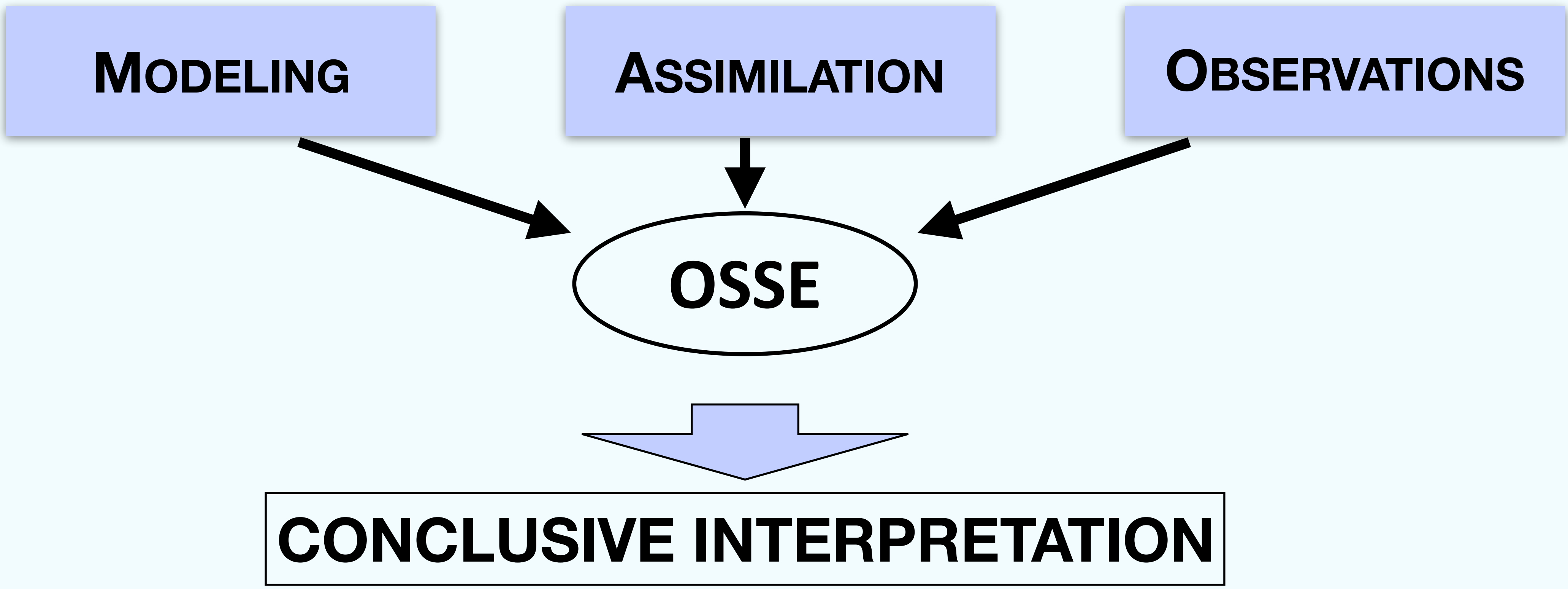


Assimilation in different systems

- ARMOR3D (CLS)
- PSY3, NEMO+SAM2 (Mercator)
- Ensemble NEMO simulations (CMCC)
- NEMO+NEMOVAR (MetOffice)

Combining expertise of research labs and operational centres

- OSSE have been in longer use and are more advanced for the atmosphere
- OSSE need to follow the complete set of design strategies and rigorous validation techniques (GODAE - OSEvalTT, Halliwell *et al.*, 2014, Oke *et al.*, 2015)
- OSSE system includes several domains of oceanography



- Explaining the strengths and limitations
- Demonstrating that credible results can be obtained
- Providing quantitative impacts understandable for the entire oceanography community

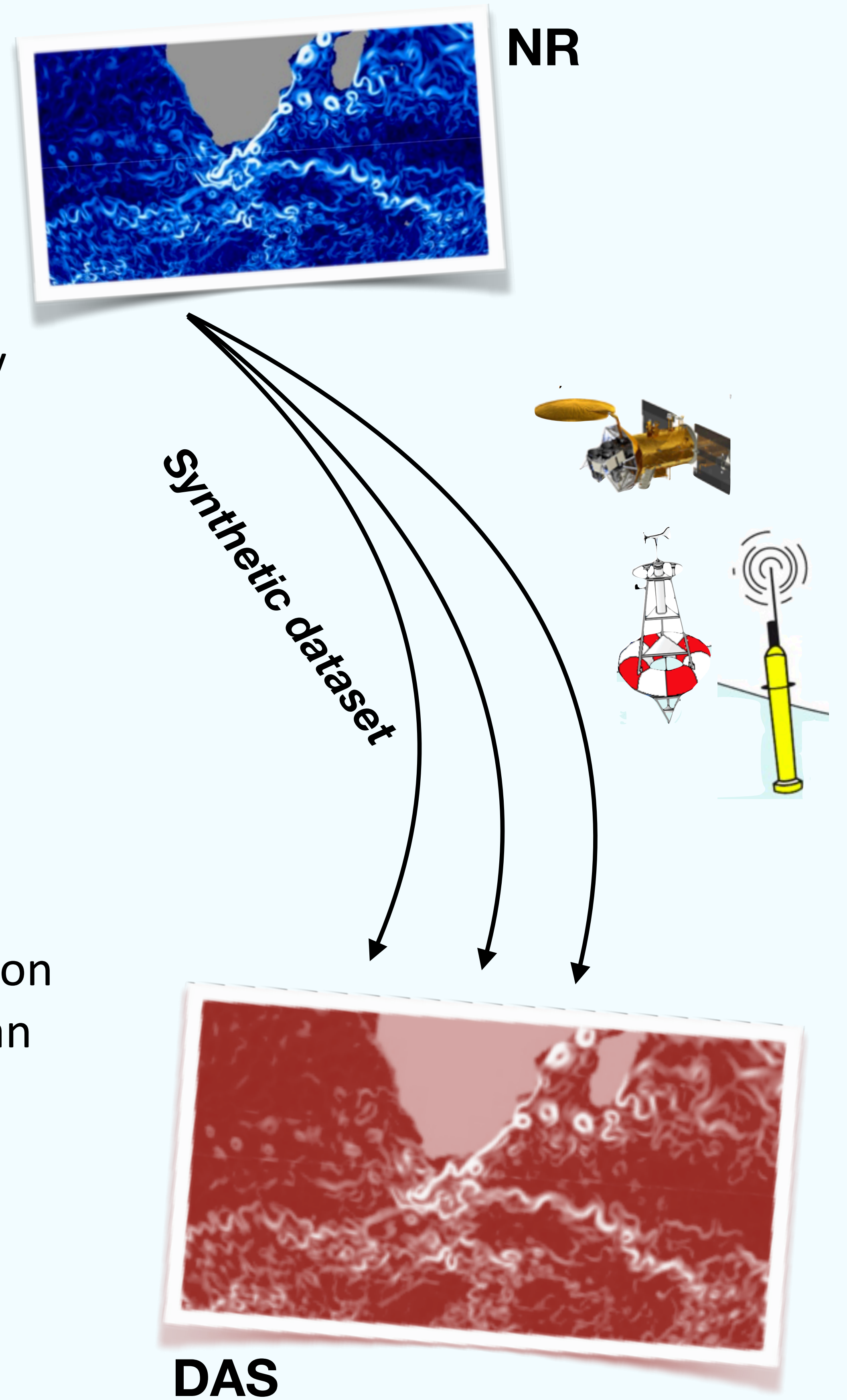
2. Observing System Simulation Experiment

OSSE is a **complex system**

- A model **(Nature Run, NR)**, closely reflecting the reality
  = CMEMS operational system (1/12°, no assimilation)

- Construction of **synthetic dataset from the NR**
  + Physical parameters (T/S, SSH)
  + Introduction of realistic errors

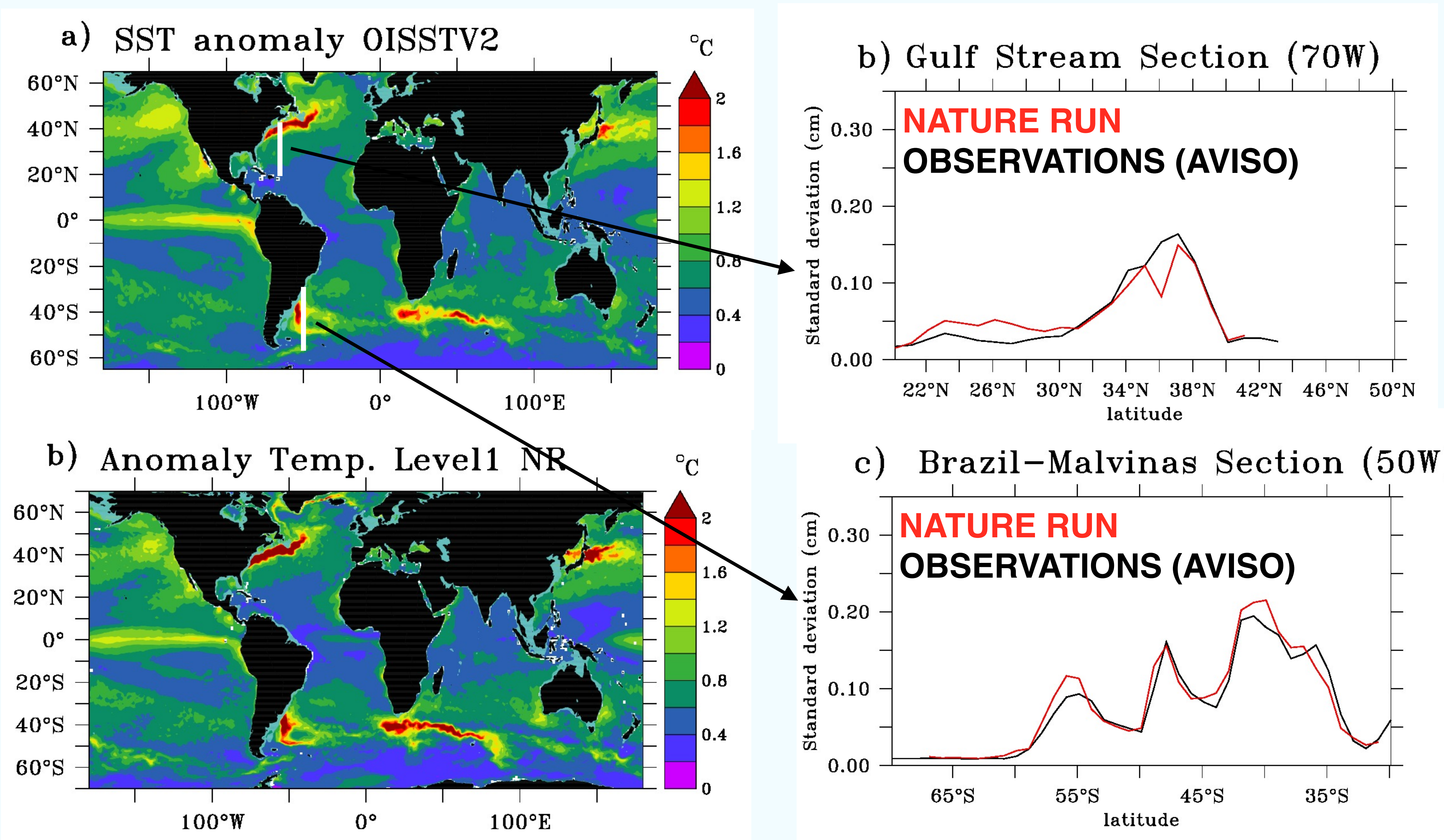
- An ocean data assimilation system **(DAS)**, with calibration so that existing observation impact and simulated ocean is similar
  = Mercator-Ocean system 1/4°, with substantial differences with NR (initialisation, forcings, resolution)



Nature Run, closely reflecting the reality (phenomena of interest)

- Realistic mean climatology and variability
- Can be used for process studies
- Available to the community

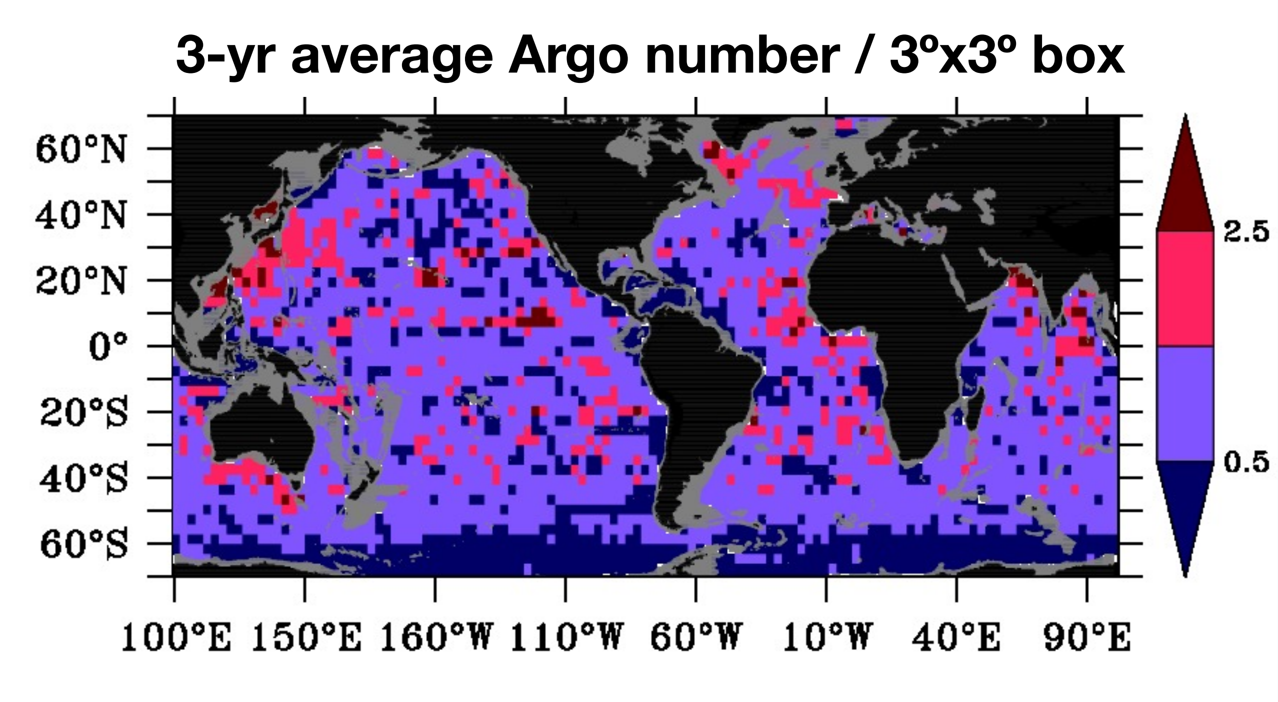
SST variability (stand. dev.) **SSH intraseasonal variability (stand. dev.)**

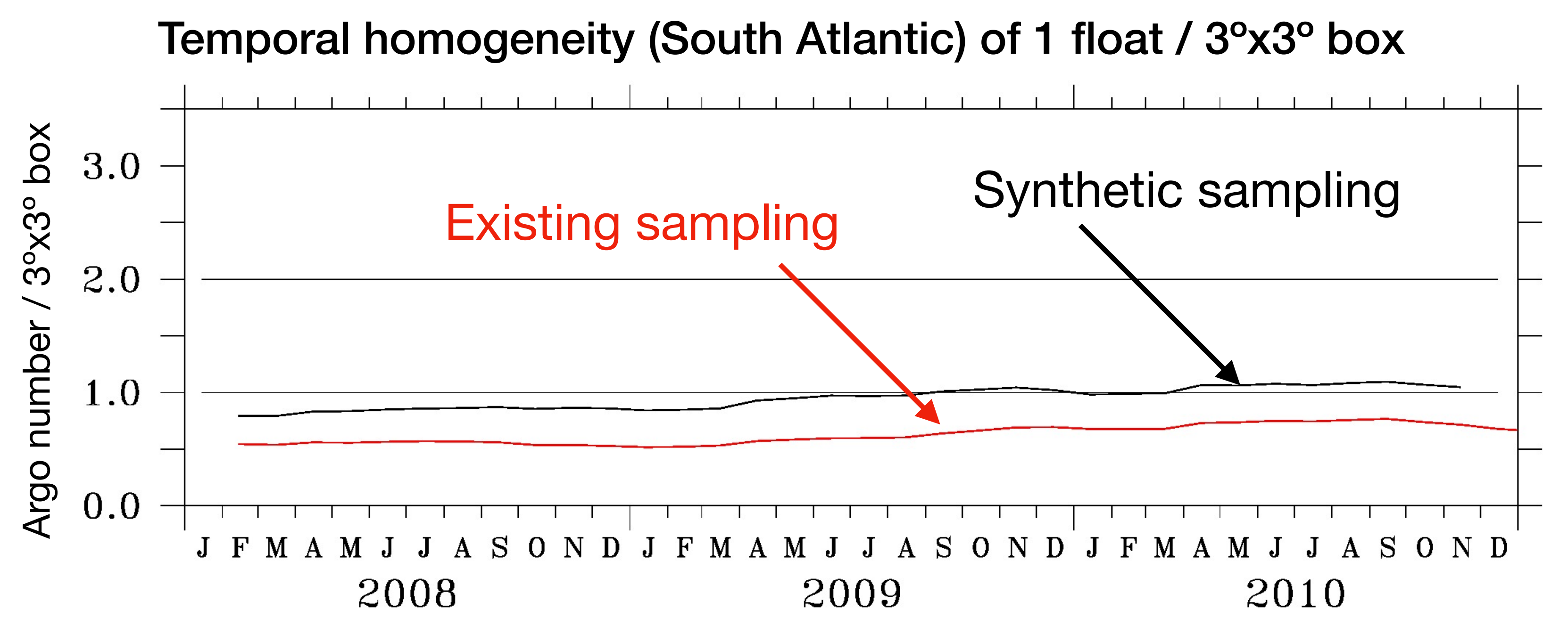


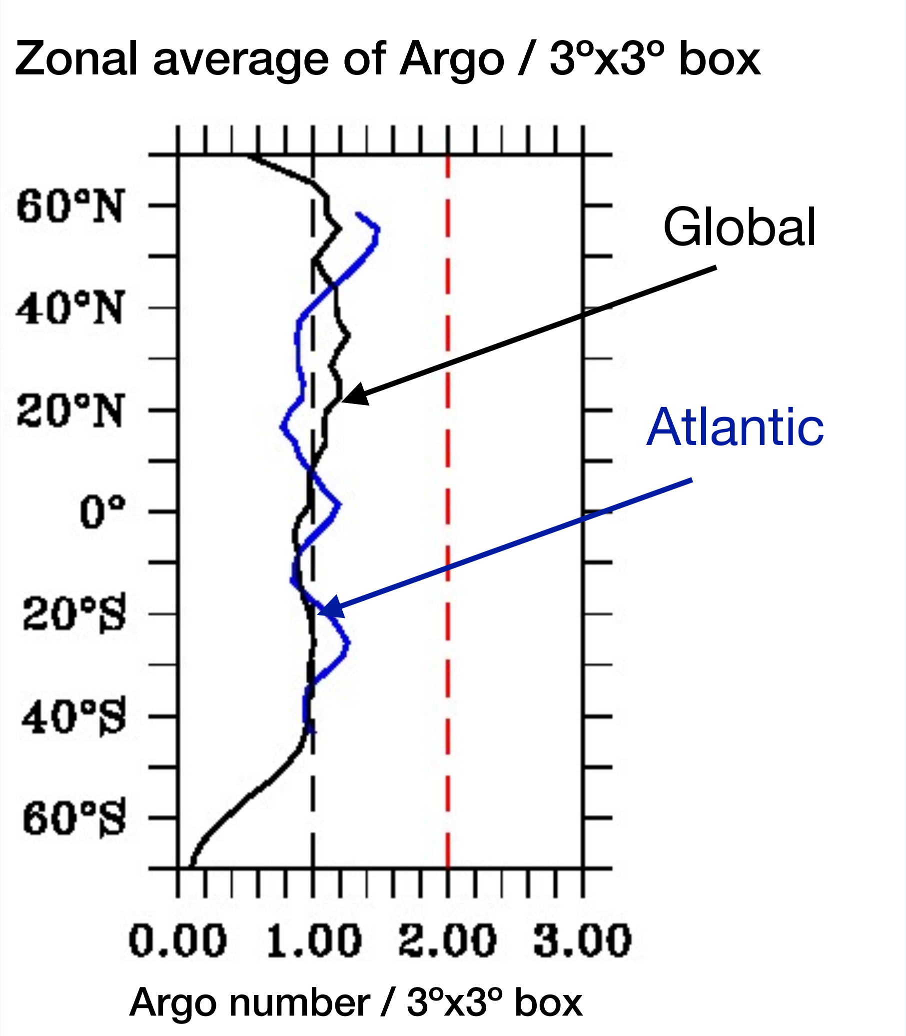
Construction of synthetic *original Argo design* (*Backbone network*)

- Not artificially gridded, existing Argo positions
- Period 2008-2012
- Low sampling South Atlantic, High sampling in Kuroshio region

➔ Subtraction of floats in the Kuroshio + Addition in the South Atlantic (following year) to get a <u>quite homogeneous</u> distribution with 1 float / 3°x3° box

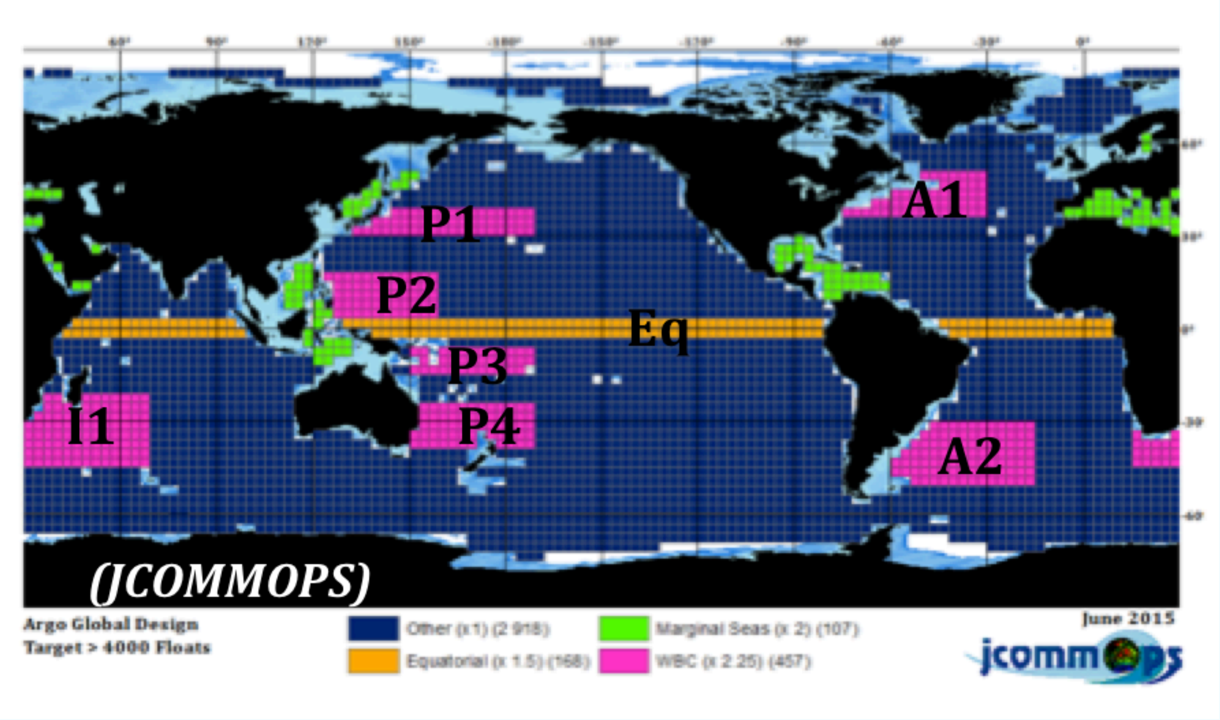




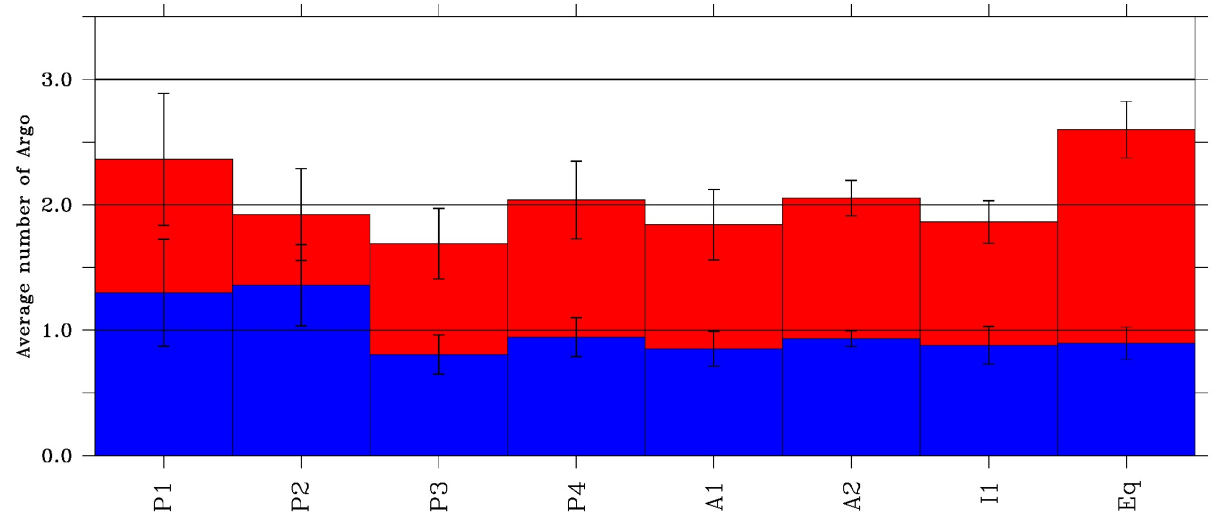


Construction of synthetic *Argo doubled design* and *Deep Argo design*

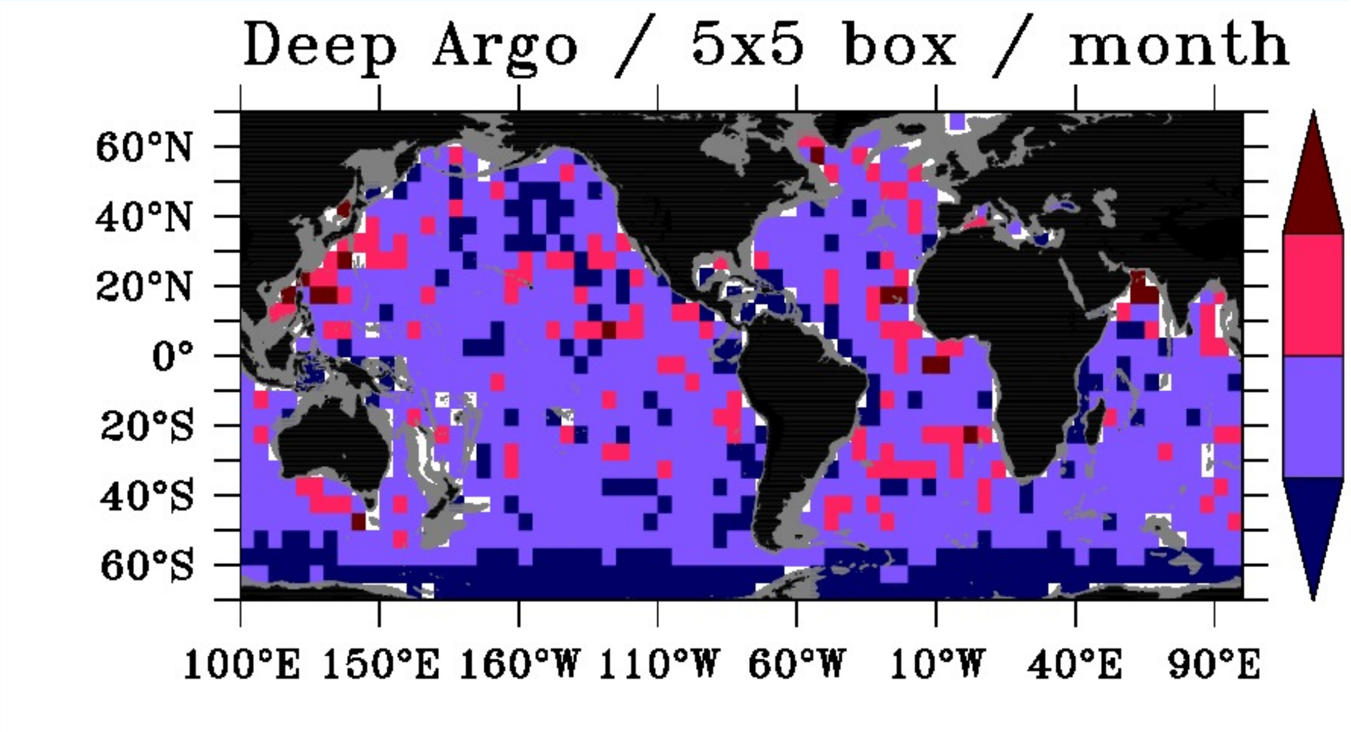
Argo doubled design = Addition of Argo profiles (following year) in magenta/orange regions

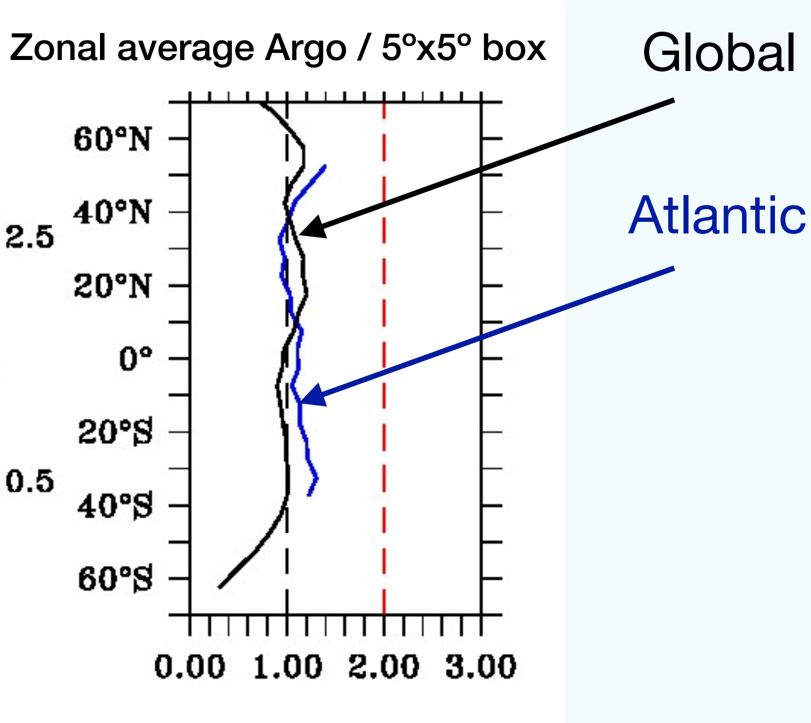


3-yr average profiles number in 3x3 box / 10 days for each area of the mask and its temporal standard deviation



Deep Argo design = Deep extension on model levels of 1/3 floats from the *Original Argo design*





Introduction of realistic errors on synthetic observations

All errors present in existing observations must be added to synthetic observations. Failure to realistically add all errors will lead to inaccurate impact assessments.

1. Random instrument errors are added as a Gaussian white noise with a standard deviation of 0.01°C for temperature, 0.01 psu for salinity (Cabanes *et al*., 2013)

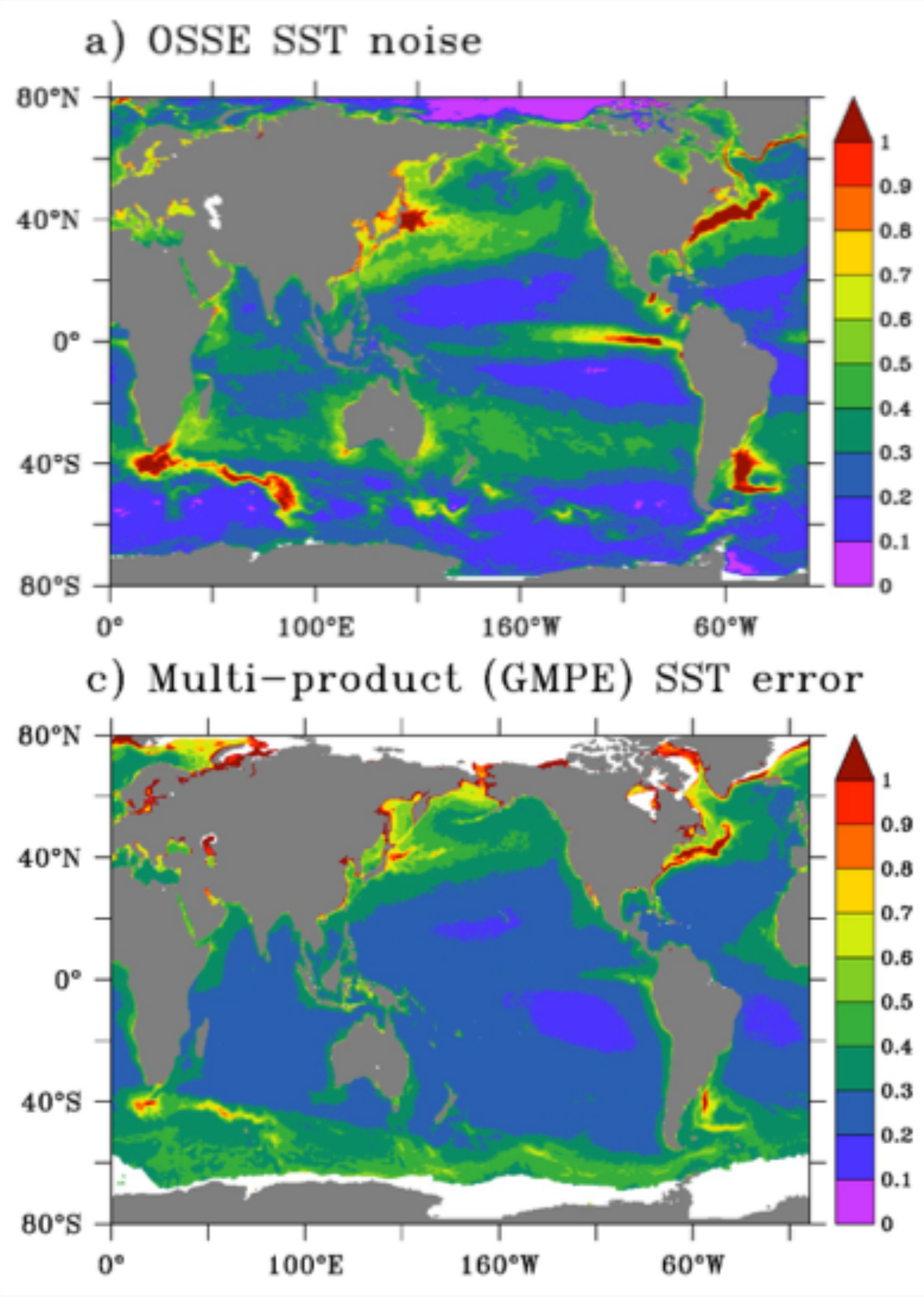
2. Representation errors are spatial and temporal scales as well as physical processes that are not represented by the data assimilation model (Oke and Sakov, 2008)

(i) Synthetic observations are extracted from a higher resolution model (1/12°) to that of the model included in the data assimilation system (1/4°).

However, this error is not sufficient to realistically represent errors.

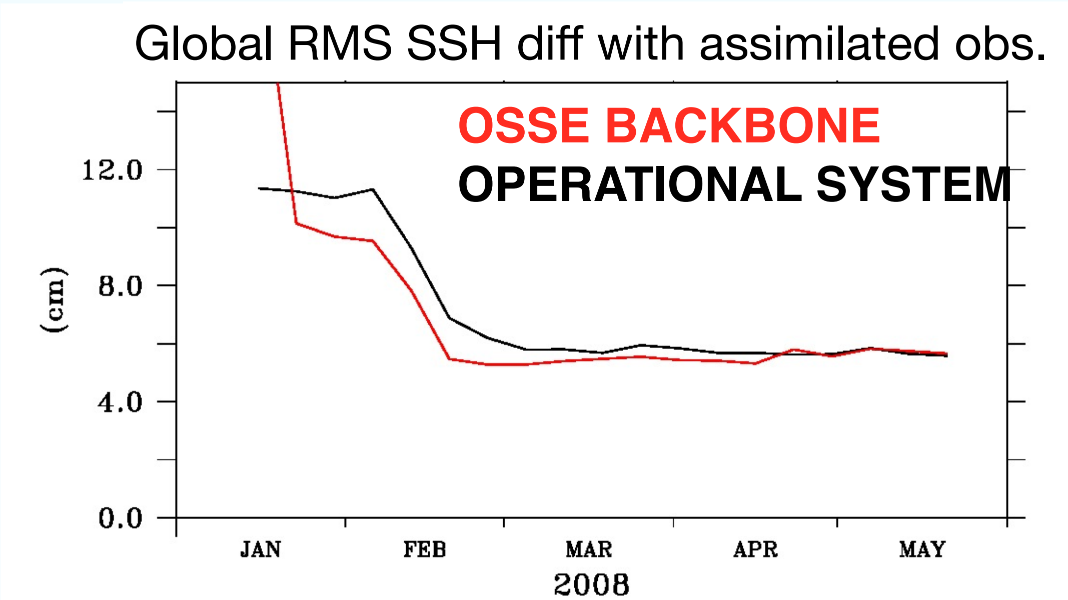
(ii) We add more representativity error by randomly shifting Nature Run model by ±3 days. This introduces horizontal and vertically correlated errors.

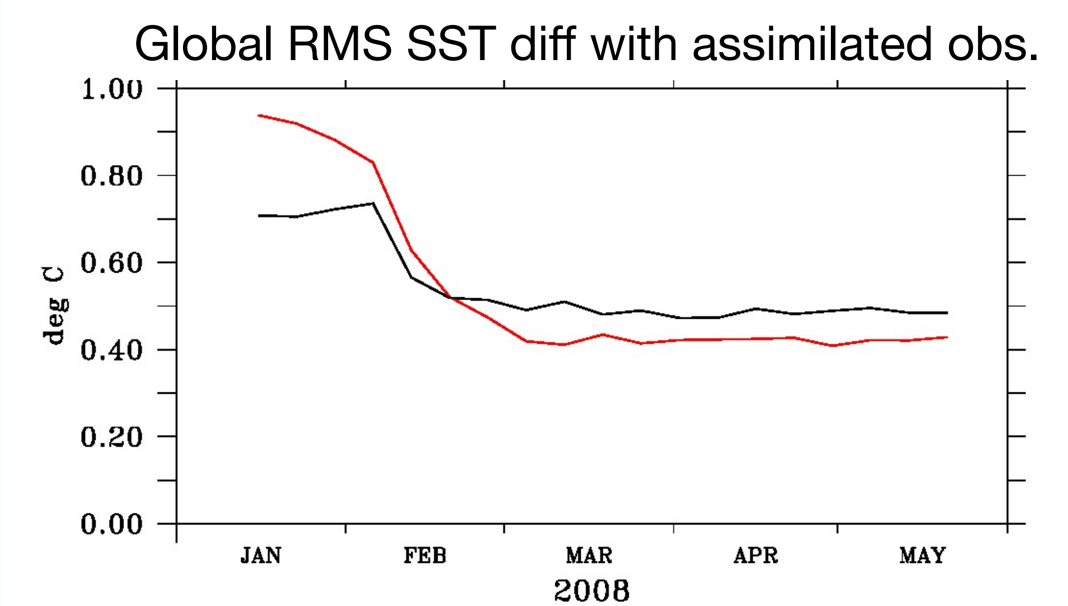
Stand. dev. of SST noise compared to stand. dev. of the CMEMS Global Multi-Product Ensemble.

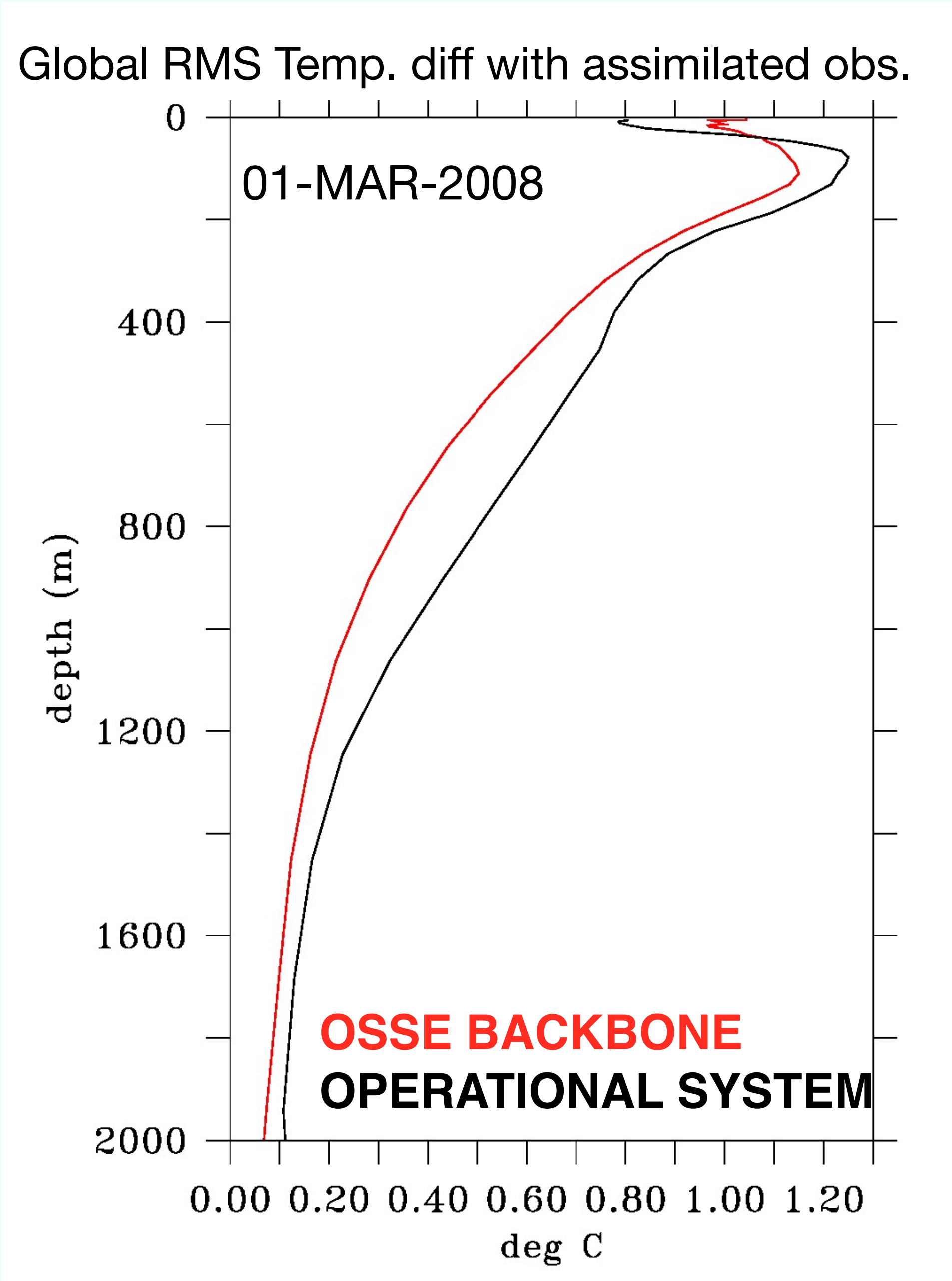


System calibration for realistic experiments

Introducing differences with the NR, considered as errors, which mimic the differences existing between the actual ocean and operational ocean model simulations, and which are to be corrected through the assimilation.

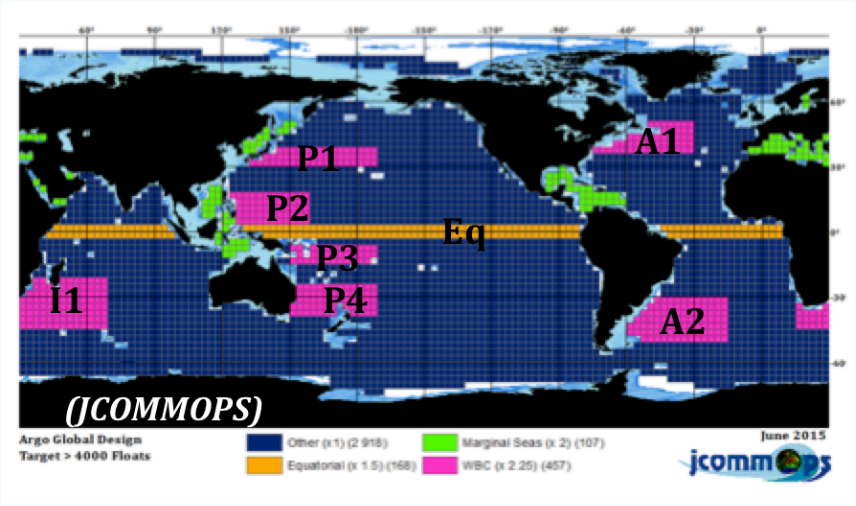




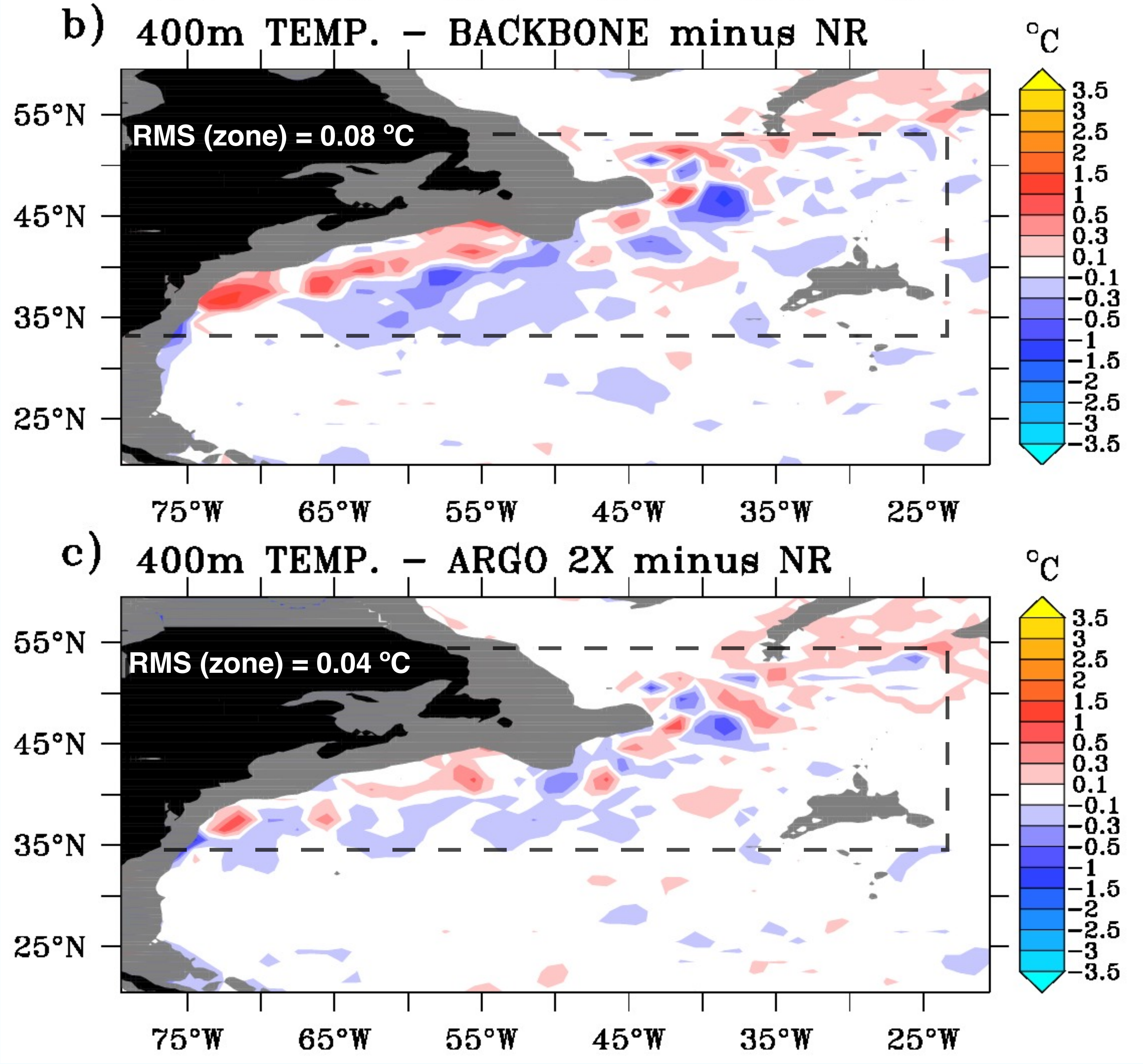


Similar RMS difference between **"Existing obs minus operational system"** with **"Synthetic obs. minus OSSE system"**

3. The doubling of Argo in WBC and along the equator



- Air-sea interaction
- WBC Vs basinwide variability
- Impact of WBC on mid-latitude climate variability and predictability



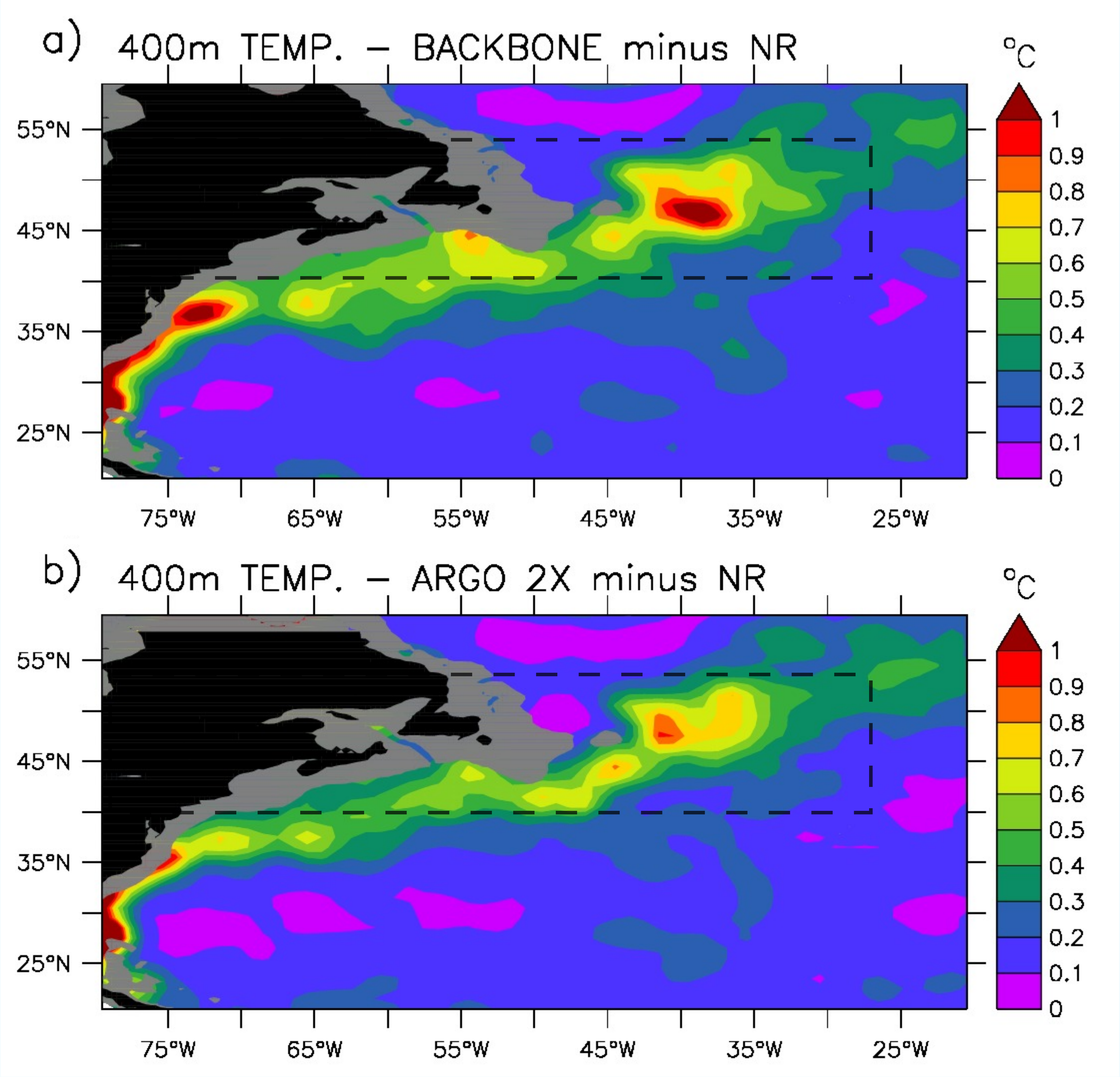
➔ Improving the 2-yr mean position of the Gulf Stream

3. The doubling of Argo in WBC and along the equator

➔ **Decreasing of the RMS diff. compared to NR when core-Argo is doubled**

RMS (zone) = 0.30 ºC

RMS (zone) = 0.25 ºC



4. The Deep Argo network

Regional disparity: Northern H. Vs Southern H.

Temporal disparity*:* > 75% of profiles after 2004

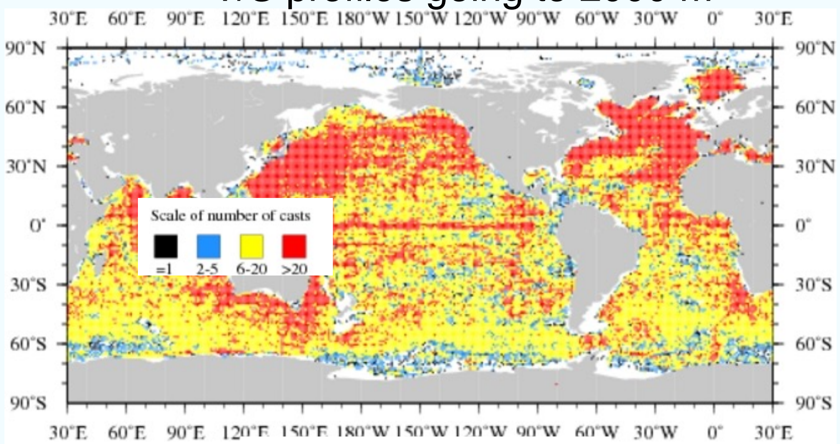
Vertical disparity*:* 0-3000 dbar profiles = 1/10 0-2000 profiles

- How much time for filtering variability (eddies, interannual)?

Short-term variability is expected to be much larger than longer-term

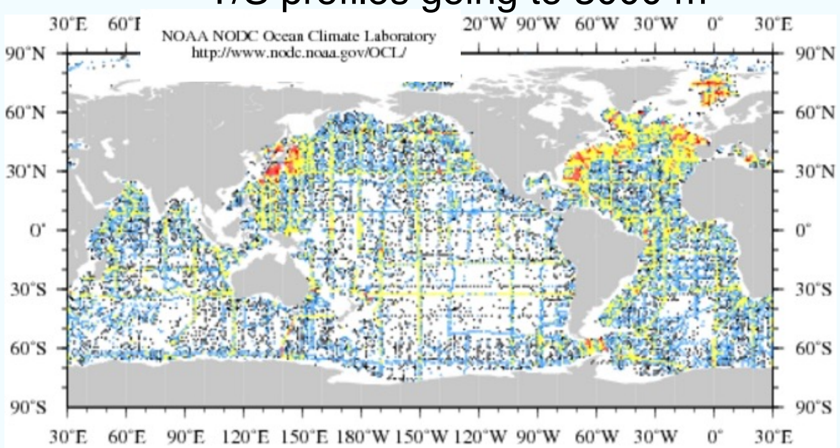
➔ Unbiasing the deep ocean

T/S profiles going to 2000 m



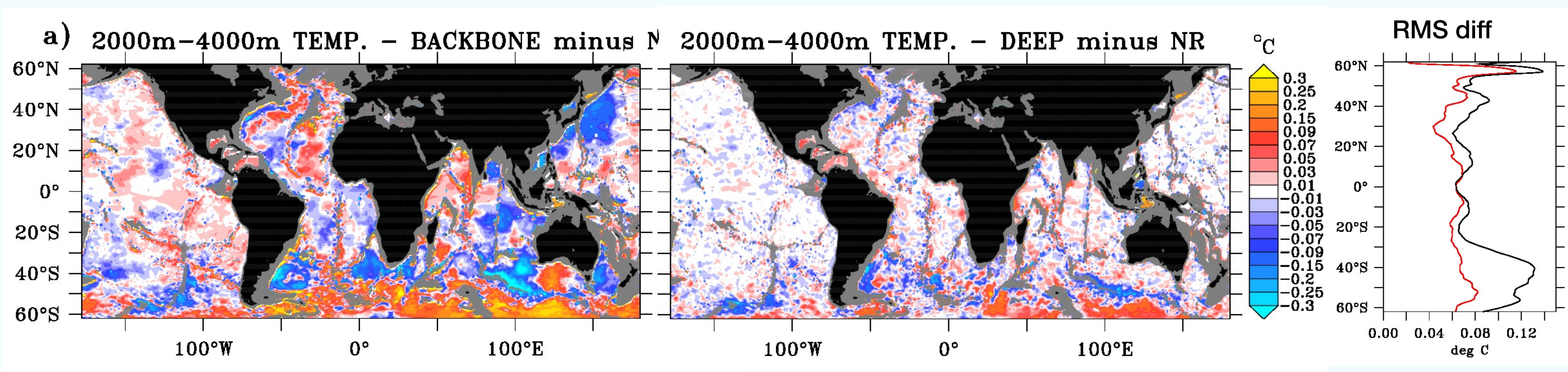
~ 1 000 000 profiles

T/S profiles going to 3000 m



~ 100 000 profiles

(World Ocean Database)

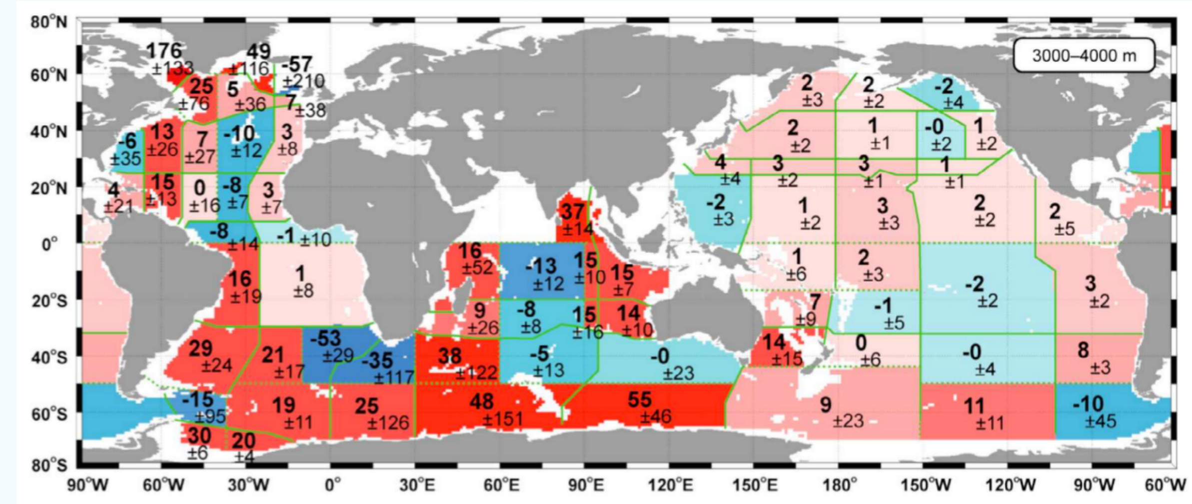


NO DEEP FLOATS

WITH DEEP FLOATS

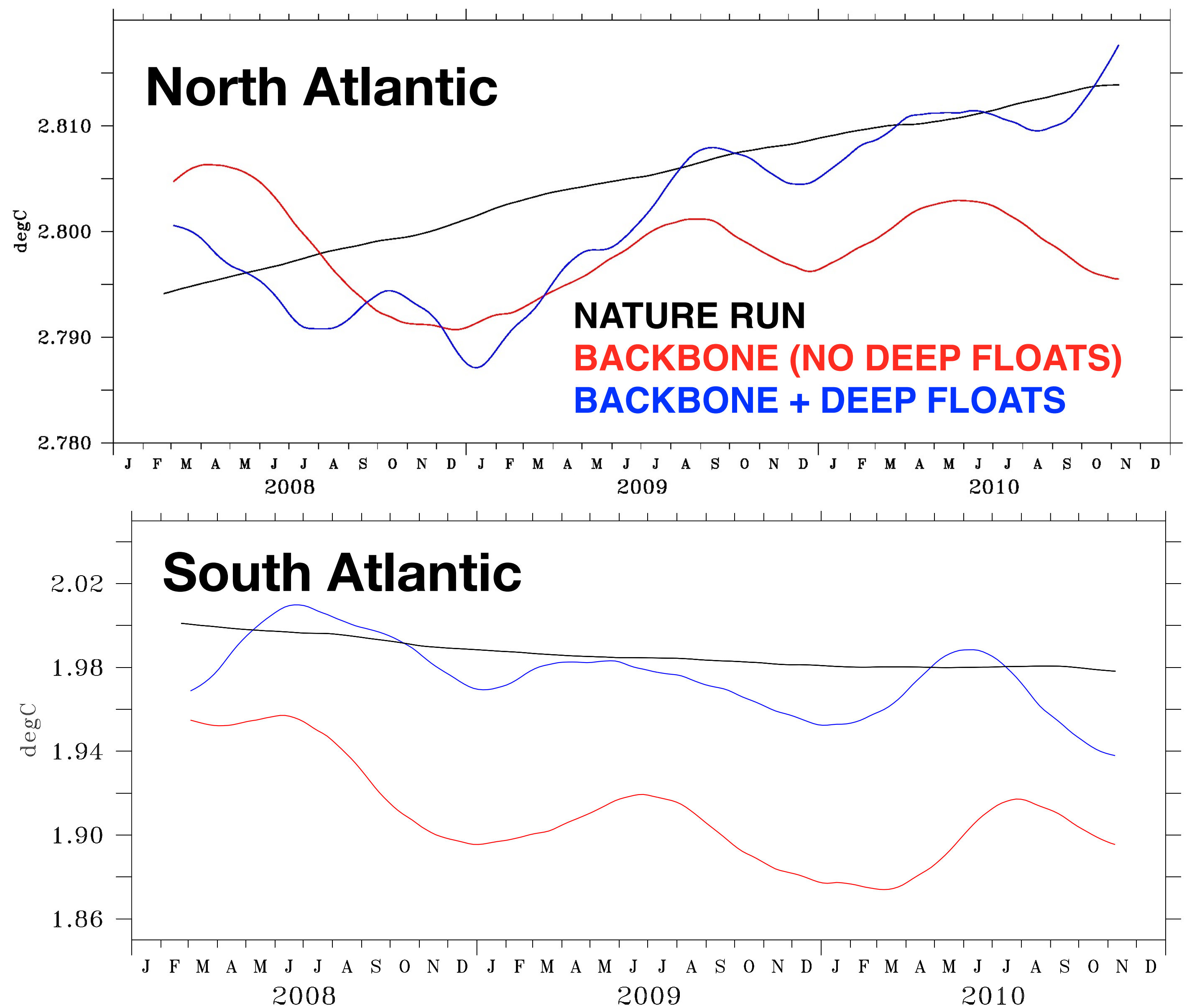
4. The Deep Argo network

➔ Recovering long-term signal of the NR in the Atlantic



(Kouketsu *et al.*, 2011))

3-month running mean of 2000-4000m layer temperature



- Long-term variability of the NR has similar amplitude than literature (around 1 x 10^{-3} / decade)
- 5°x5° deep Argo would capture long-term variability

(i) No short-term variability in the NR for the deep ocean (added by errors)

(ii) Need more observations for better calibration of deep ocean OSSE

SUMMARY

1. Observation impact studies are needed to support the evolution of global ocean observing system, but also refine data assimilation schemes in operational systems (e.g., Deep Argo).
2. Observing System Simulation Experiment (OSSE) dedicated to *in situ* observations are performed, and a rigorous framework has been recently undertaken by GODAE.
3. Multi-approach OSSE are underway for the Argo network in AtlantOS project and discussions are in progress for defining impact metrics. Community input is needed.
4. First OSSE results from Mercator-Ocean are encouraging and suggest that:
   - Doubling Argo in WBC and along the equator would improve the mean in WBC, but also improve representation of specific timescales (intraseasonal, interannual).
   - The implementation of a Deep Argo array would capture long-term variability in the deep ocean.
5. Next steps:
   (i) Discussions on impact metrics with other OSSE groups (CLS, MetOffice, CMCC)
   (ii) Robustness of results will be done by comparing similar experiments results using others systems (MetOffice/CLS/CMCC) - OSSE meeting (3^{rd} GA AtlantOS, Canary islands)
   (iii) Specific metrics have to be carefully defined depending on components (e.g., moorings, drifters, XBT).