

# Ocean state estimates from the observations

Contributions and complementarities of Argo,  
SST and Altimeter data

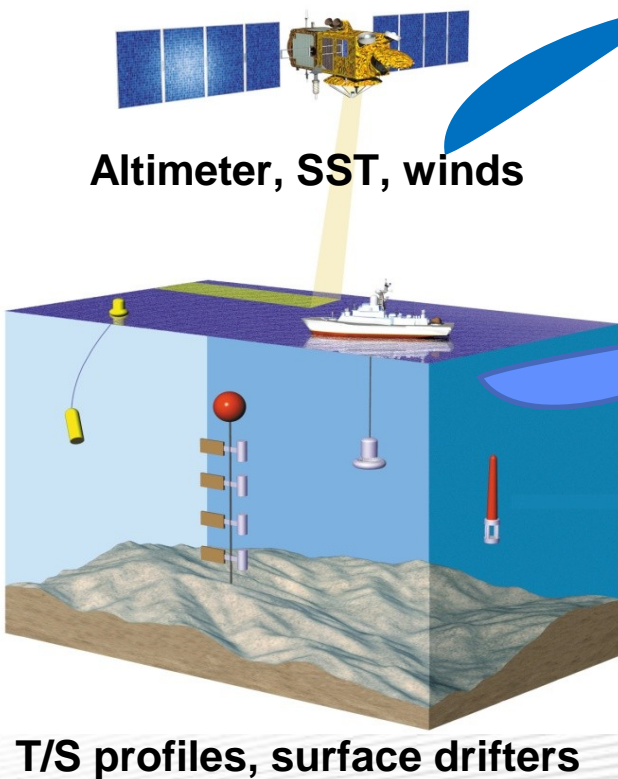
S. Guinehut  
G. Larnicol  
A.-L. Dhomps  
P.-Y. Le Traon

# Introduction

- Producing comprehensive and regular information about the ocean → the priority of operational oceanography and climate studies
- Our approach :
  - Consists of estimating 3D-thermohaline fields using ONLY observations
  - Represents an alternative to the one developed by forecasting centers – based on model/assimilation techniques
  - Observed component of the Global MyOcean Monitoring and Forecasting Center lead by Mercator
  - Rely on the combined use of observations and statistical methods (linear regression + mapping)
- Previous studies have shown the capability of such approaches :
  - In producing reliable ocean state estimates (Guinehut et al., 2004; Larnicol et al., 2006)
  - In analyzing the contribution and complementarities of the different observing systems (in-situ vs. remote-sensing) (1<sup>st</sup> GODAE OSE Workshop, 2007)
- Method revisited here :
  - How Argo observations help us to improve the accuracy of our ocean state estimates
  - Contribution/complementarities of the different observing systems

# The principle

## The observations

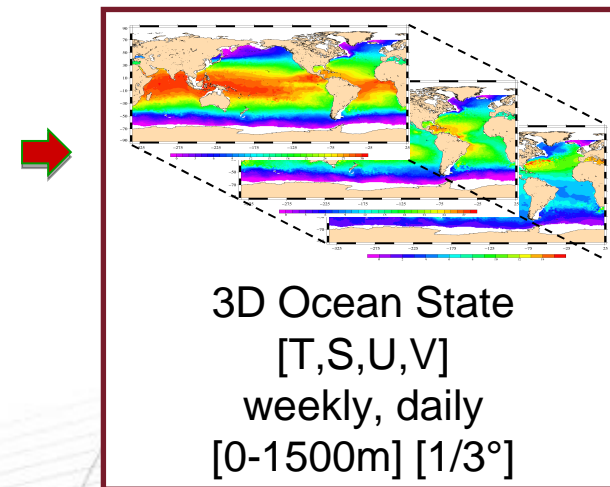


## The method



Guinehut et al., 2004  
Guinehut et al., 2006  
Larnicol et al., 2006  
Rio et al., 2009

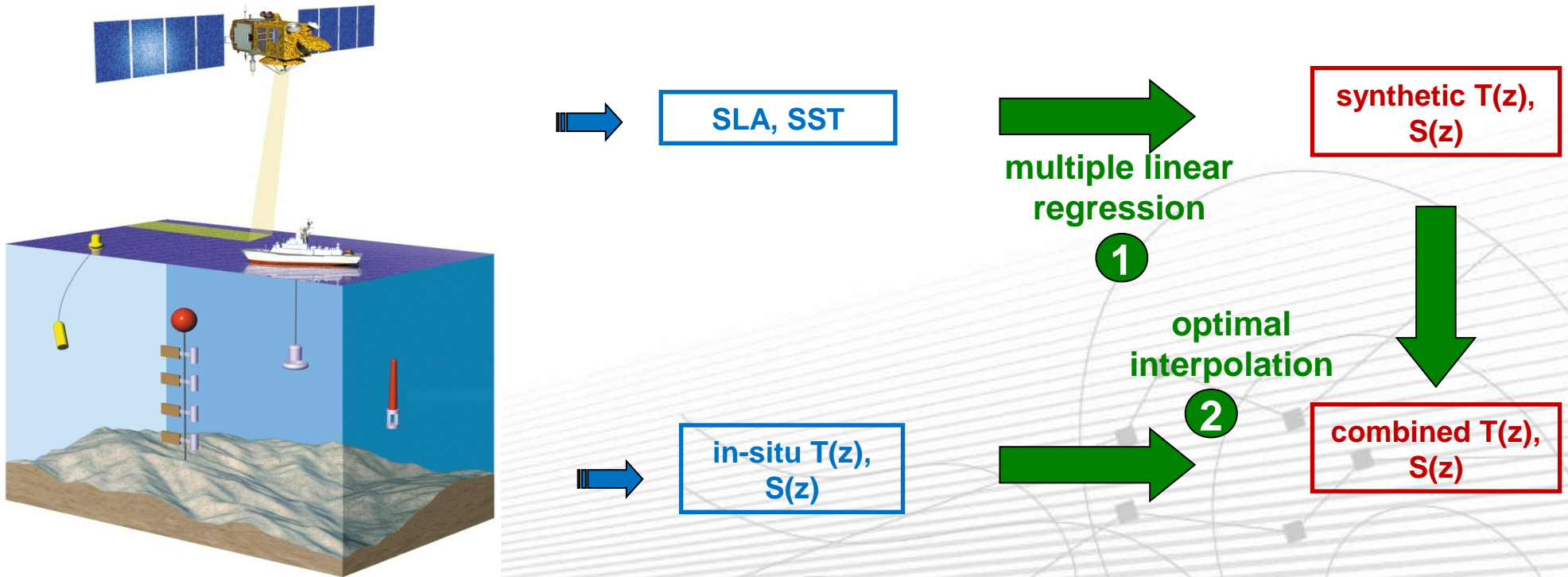
## The products



Validation of model simulations  
Analysis of the ocean variability  
OSE / OSSE

# 3D - T/S products

- 1 vertical projection of satellite data (SLA, SST)
- 2 combination of synthetic and in-situ profiles



# The method – step 1

- 1 vertical projection of satellite data (SLA, SST) → linear regression method

$$T(z) = \alpha(z).SLA_{steric} + \beta(z).SST' + T_{clim}(z)$$

$$S(z) = \alpha'(z).SLA_{steric} + S_{clim}(z)$$

How Argo improves the accuracy of the synthetic estimates → Old vs. New ?

1. Choice of [T,S] climatology : Levitus 05 to ARIVO (Ifremer)
1. Altimeter pre-processing: sea level # dynamic height anomalies
  - Barotropic/baroclinic partition: extraction of the steric part
1.  $\alpha(z)$ ,  $\beta(z)$  → local covariances computed from historical observations

# 3D - T/S products

Old (V1)

DUACS  
Guinehut et al. (2006)

Reynolds OI-SST 1°-weekly

Levitus 05  
WOD 01 - annual  
700 m (1500 m)

New (V2)

**Altimetry**  
Products  
Barotropic/baroclinic partition

**SST**  
Products

**Method**  
Reference climatology  
Covariances  
Max depth

DUACS  
Dhoms et al. (2009)

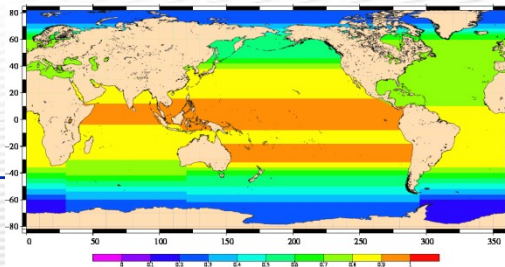
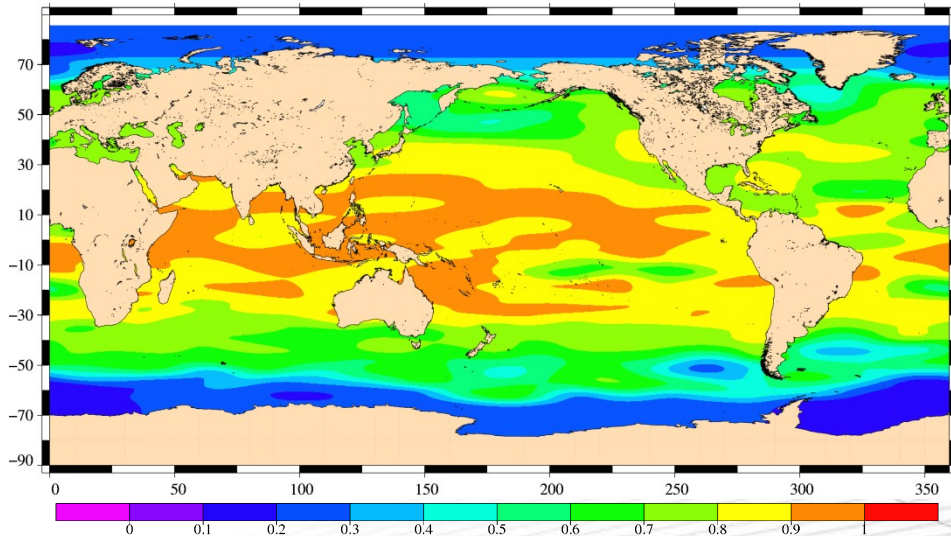
Reynolds OI-SST ¼°-daily

ARIVO  
WOD 05 + Argo - seasonal  
1500 m

# Barotropic / Baroclinic partition

- $SLA_{steric} = SLA \cdot \text{Reg-coef}$ 
  - Old - V1 → Guinehut et al., 2006 : use 1993-2003 observations
  - New - V2 → Dhomps et al., 2009 (to be sub) : use 2001-2007 Argo data (Coriolis)

Regression coefficient between SLA and  
DHA (0-1500m)

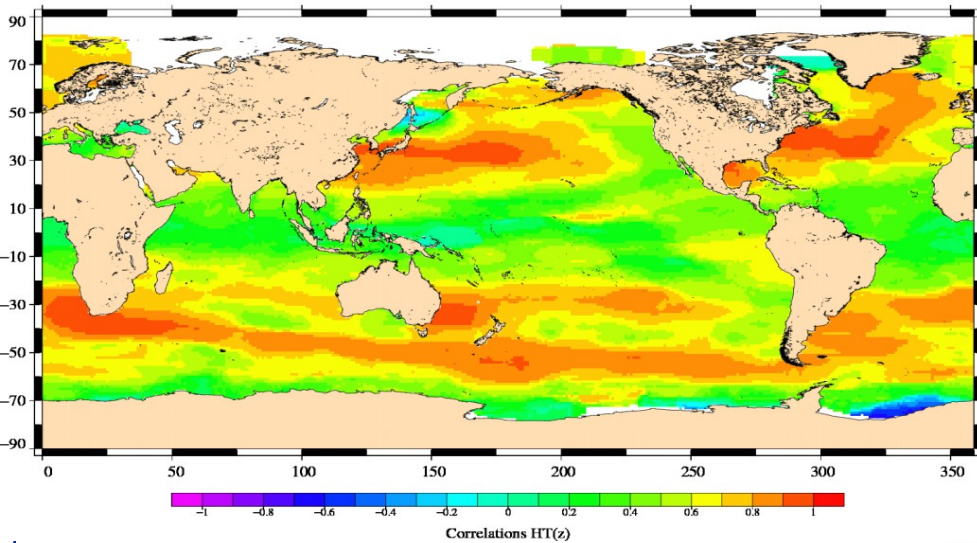


- Much better global coverage
- More accurate estimates thanks to salinity data
- Deeper estimate (1500 m vs. 700 m)

# New covariances

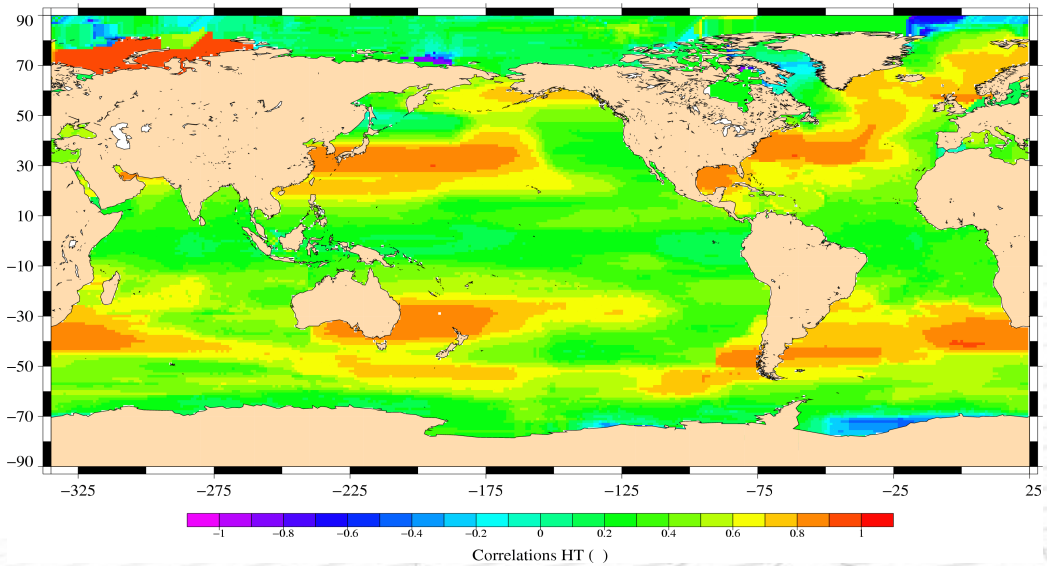
New : WOD 05 + ARGO

Corrélation H-T(500m)



Old: WOD01

Correlation H-T(500m)



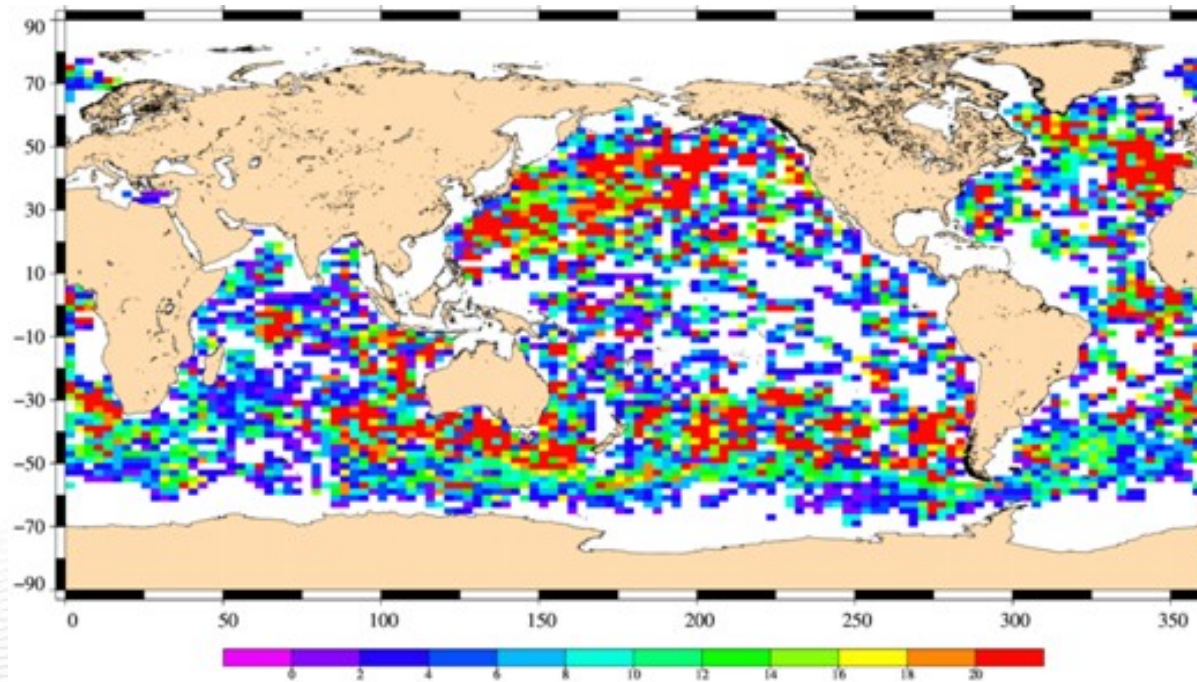
- Better coverage and continuity in the Southern Ocean
- With increased values
- More accurate estimates thanks to salinity data
- Deeper estimate (1500 m vs. 700 m)



# Validation of step-1

- Results over the year 2007
  - 3D – T/S synthetic fields : weekly, [0-1500m], 1/3° grid
  - Validation by comparison with in-situ profiles

Repartition of the in-situ T/S profiles valid up to 1500 m



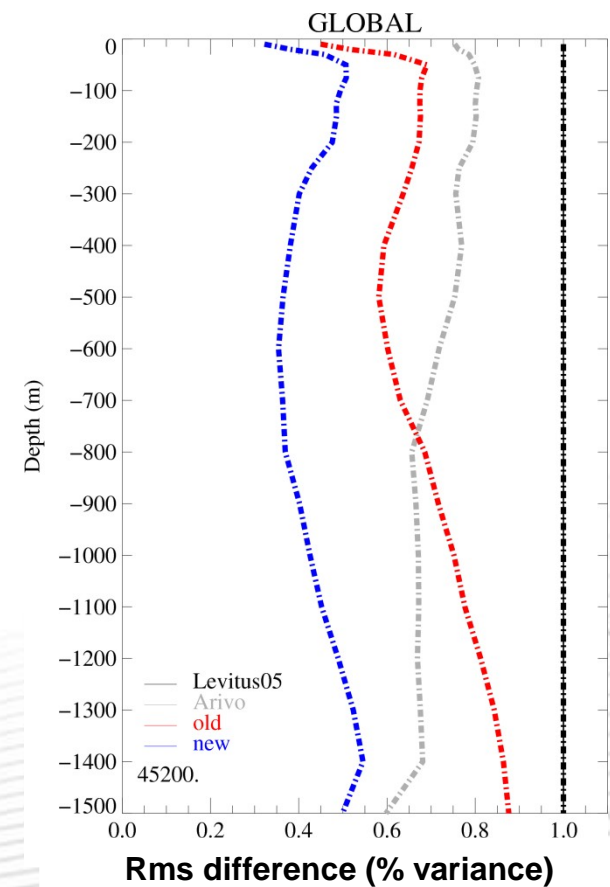
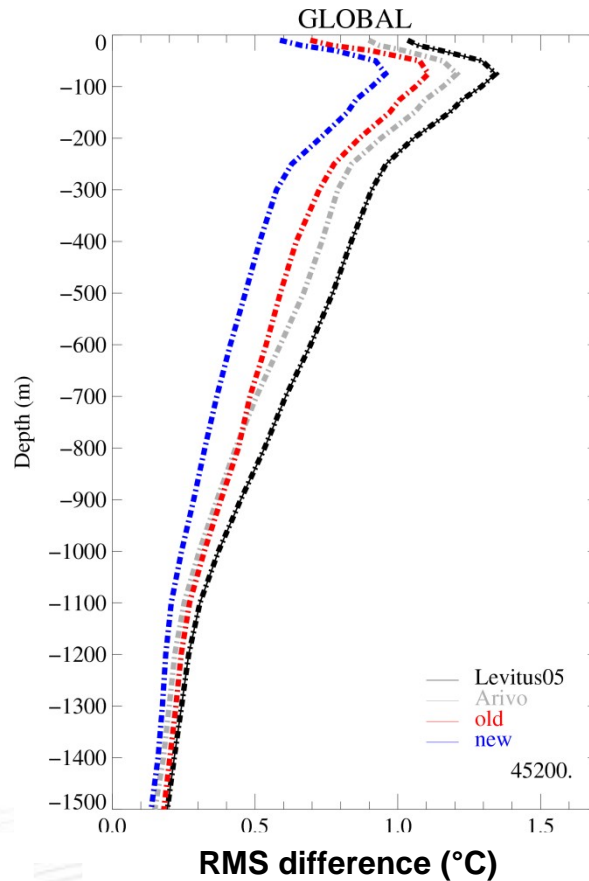
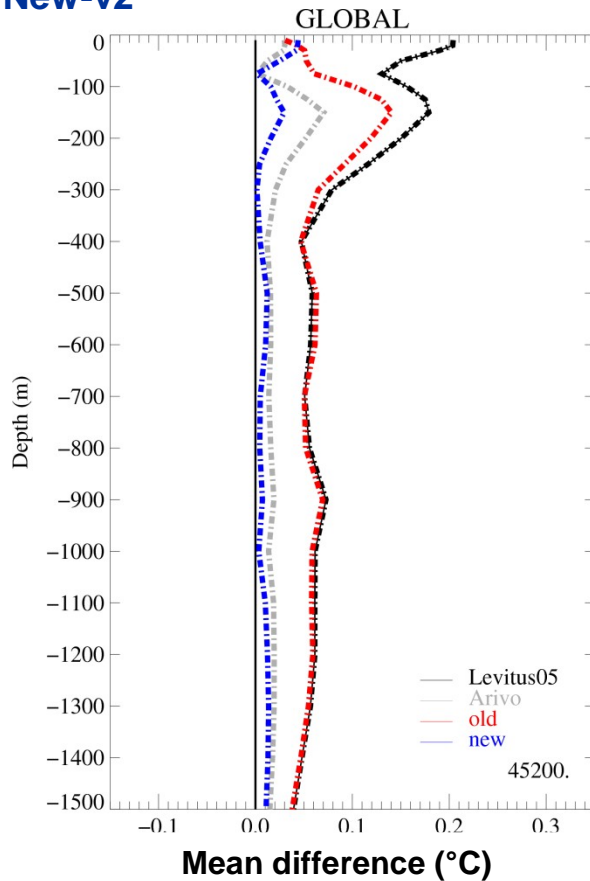
Levitus 05

Arivo

Old-V1

New-v2

# Validation of step-1 / temperature

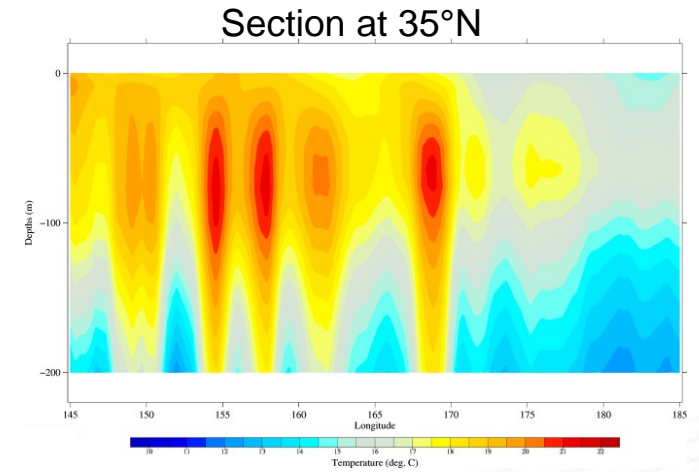
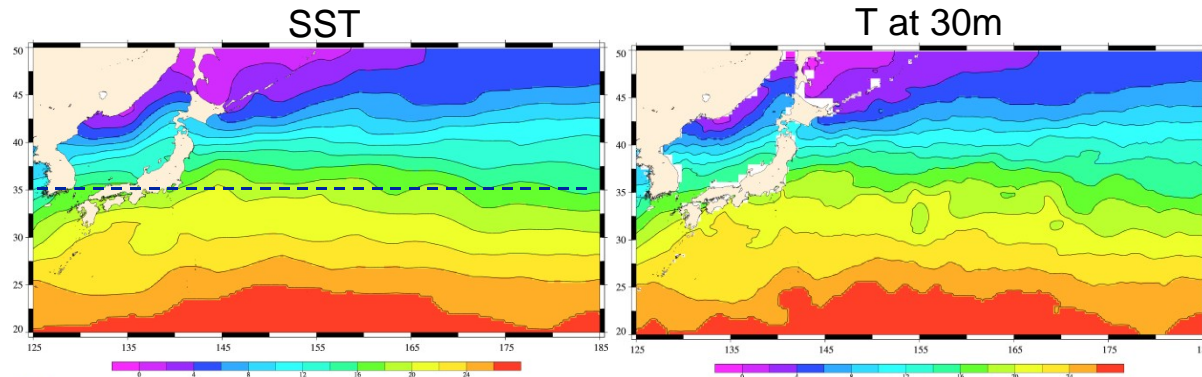


- Big impact of the climatology – reduction of the bias at all depths
- Improvement at the surface → higher resolution SST
- Improvement in the mixed layer → seasonal covariances
- Improvement at depth → more precise covariances (Argo T/S)

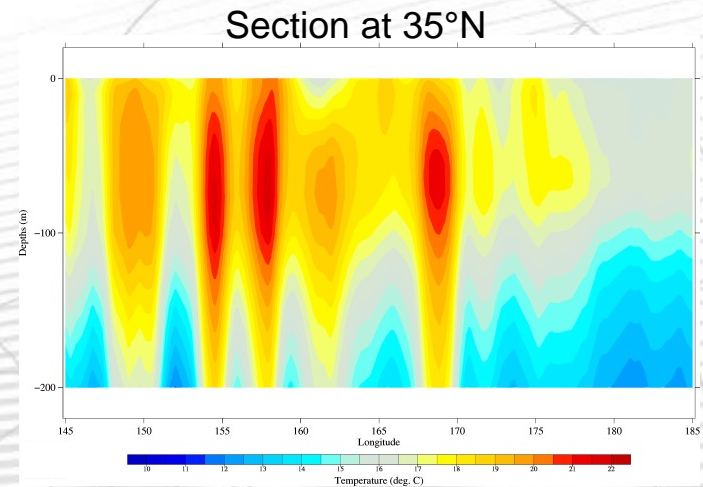
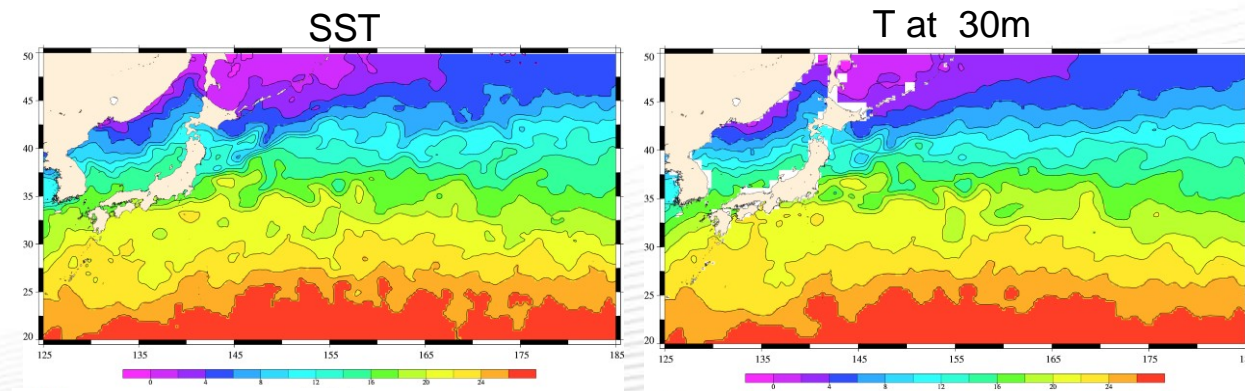
- ✓ **Improvements :**
  - **20 % in the surf layers**
  - **Up to 35 % at depth**

# Validation of step-1 / temperature / impact of SST

Old - OI-SST 1°



New - OI-SST 1/4°



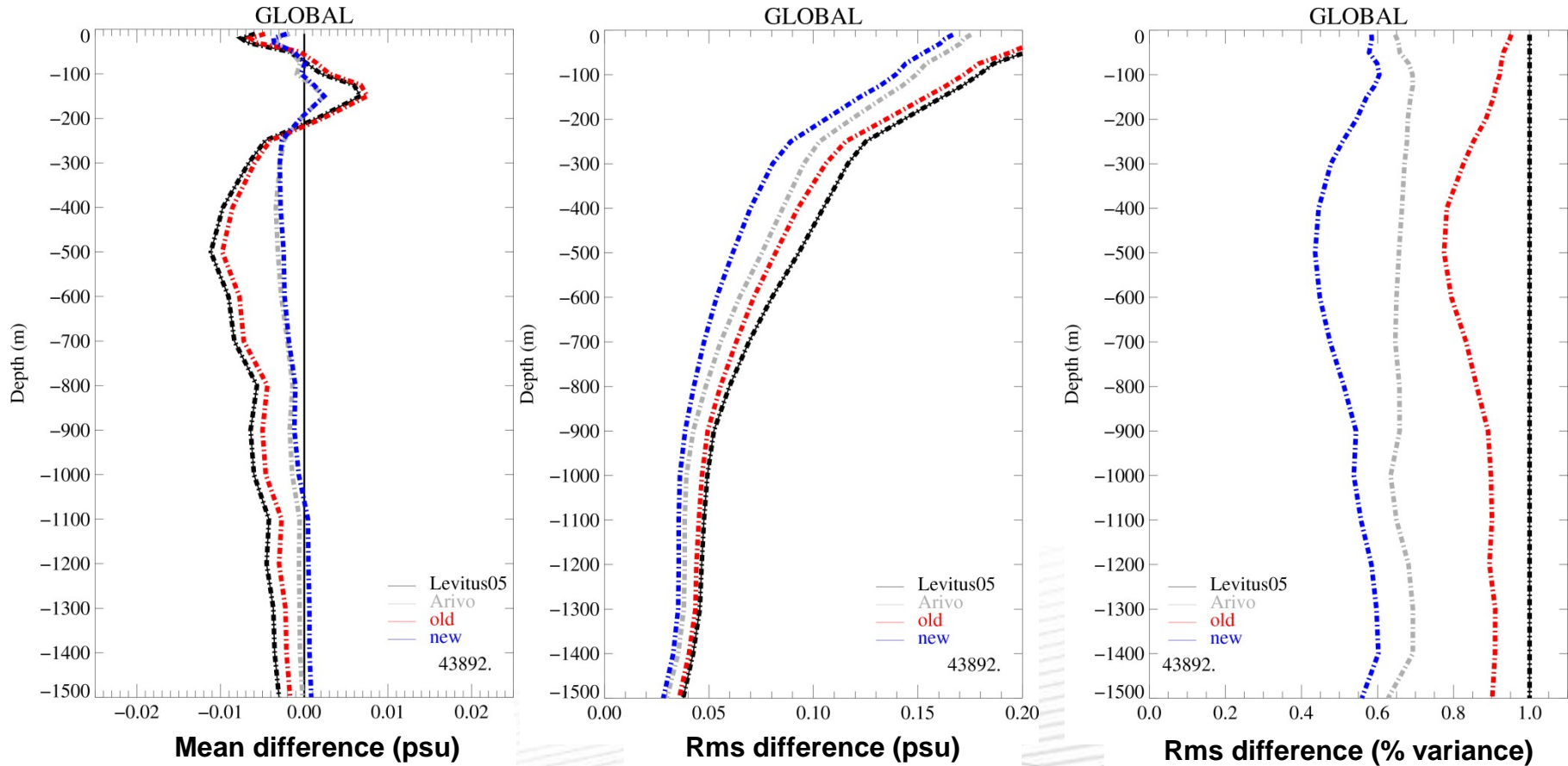
Levitus 05

Arivo

Old-V1

New-v2

# Validation of step-1 / salinity



- Improvement similar than for temperature
- Much more difficult to infer salinity at depth from surface measurements

- ✓ **Improvements :**
  - **35 % at all depths**

# Summary – step 1 results

- ✘ Indirectly, Argo observations have helped a lot to improve the accuracy of the method
  - Deeper estimates (1500 m vs. 700 m)
  - More precise globally (Southern Oceans)
  - 20 to 35 % at depth for the T field
  - 35 % for the S field
  - Indirectly, Argo observations have helped a lot to improve the accuracy of the method
  
- ✘ Large-part of T/S fields reconstructed using only remote-sensing observations and a statistical method

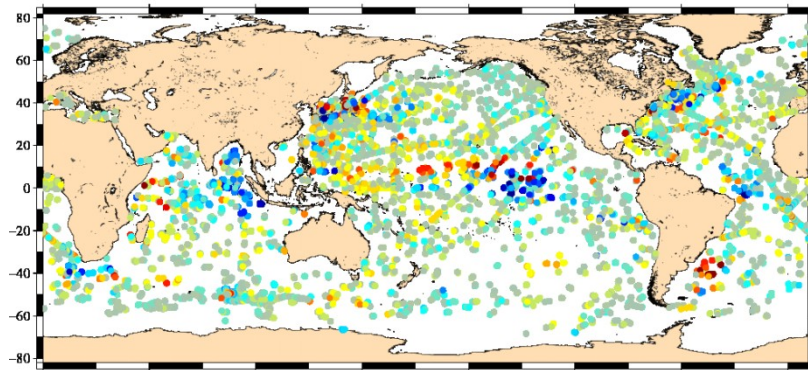
# The method – step 2

**2** combination of synthetic and in-situ profiles → optimal interpolation method

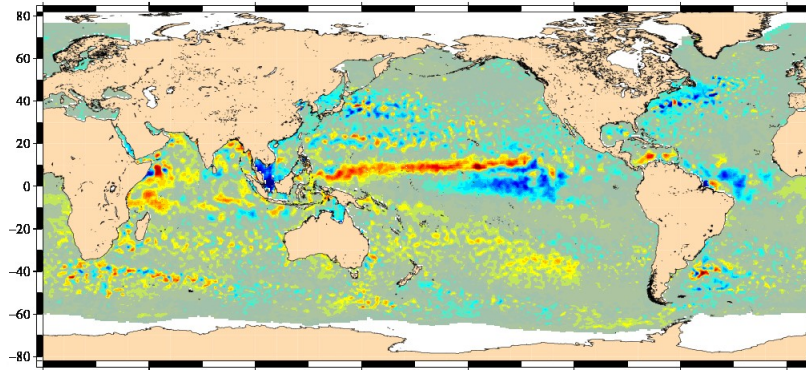
Not much change yet (perspectives: correlation scales, error ...)

How it works : ex. T anomaly field at 100 m →

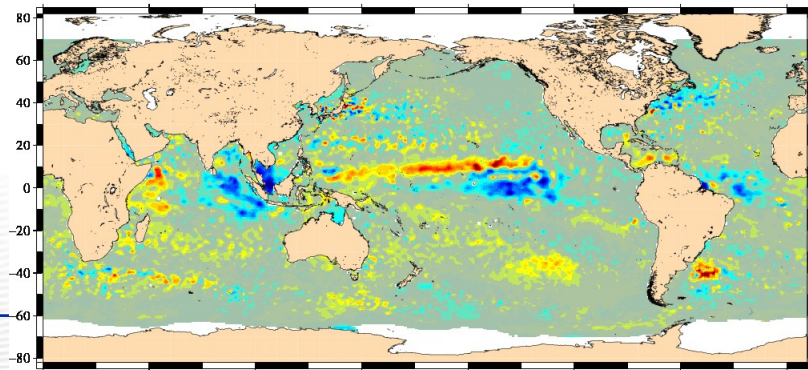
In-situ observations



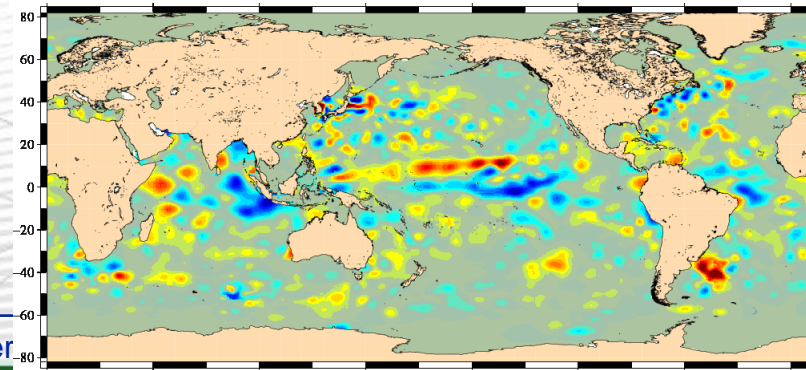
Synthetic T



Combined T



Argo T



# Observing System Evaluation

- 4 “products” :
  - Climatology (=Arivo) - monthly fields
  - Synthetic fields - weekly fields
  - Combined fields
  - Argo fields
- Observing system evaluation :
  - Combined fields / Argo fields → SLA+SST / SLA impact
  - Combined fields / Synthetic fields → Argo impact
  - Argo fields / Arivo → Argo impact (when no remote-sensing)
  - Synthetic fields / Arivo → SLA+SST / SLA impact (when no Argo)

Levitus 05

Arivo

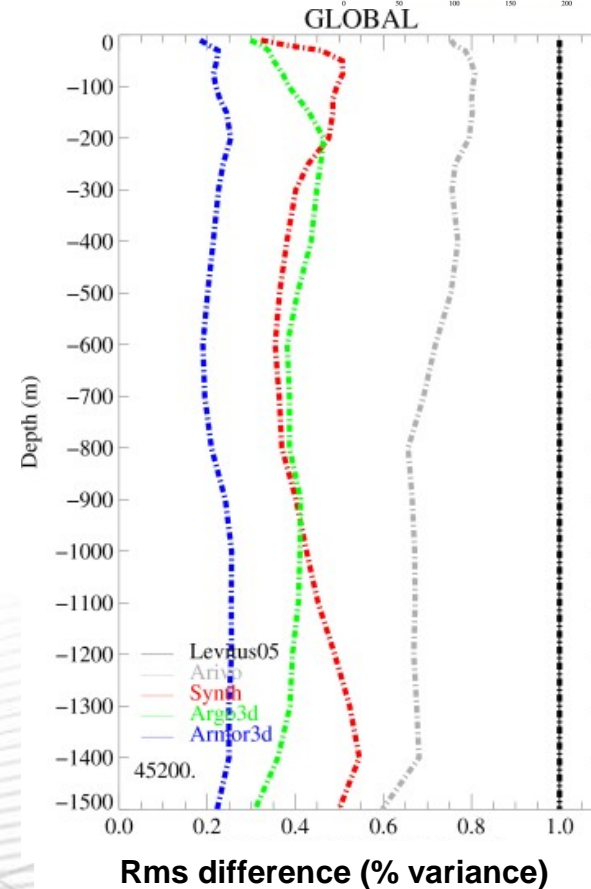
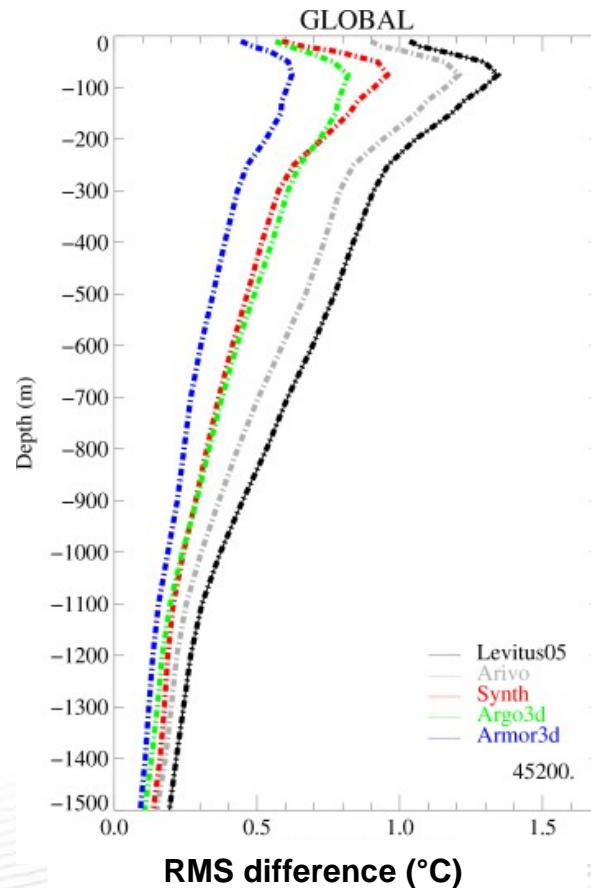
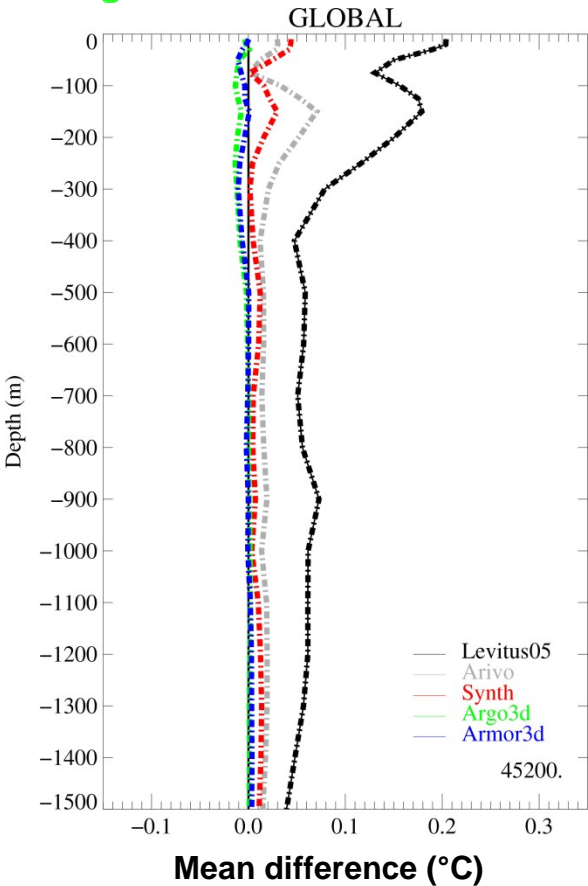
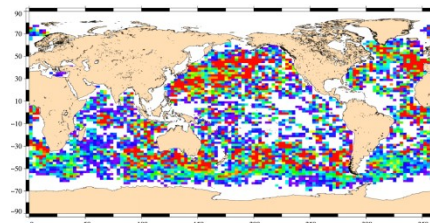
Synth

Combined

Argo

# Observing System Evaluation Temperature

Year 2007



- Combined fields / Argo fields → SLA+SST impact ~ 10 to 20 %
- Combined fields / Synthetic fields → Argo impact ~ 20 % to 30 % at depth
- Argo fields / Arivo → Argo impact (when no remote-sensing) ~ 30 to 40 %
- Synthetic fields / Arivo → SLA+SST impact (when no Argo) ~ 40 to 10 % at depth

→ Argo  
important at  
depth



Levitus 05

Arivo

Synth

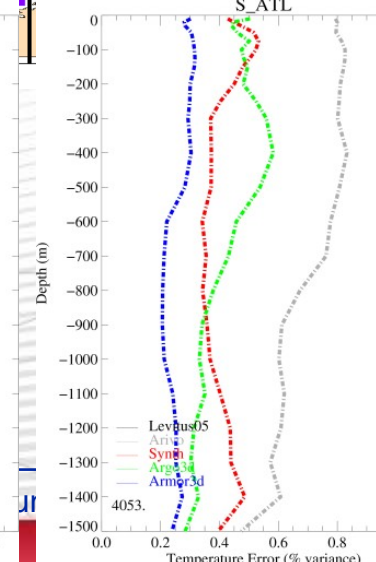
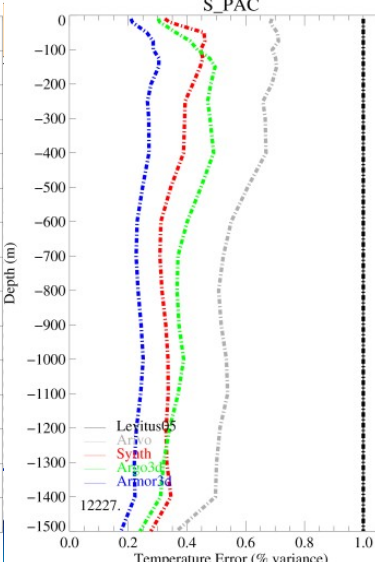
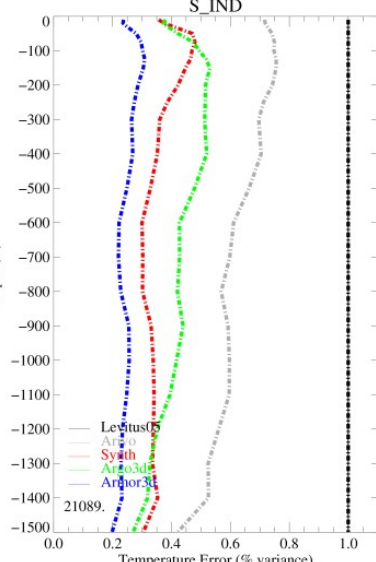
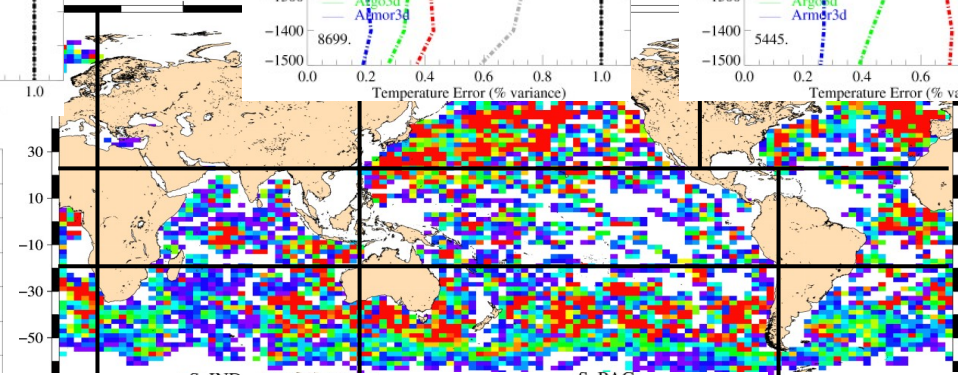
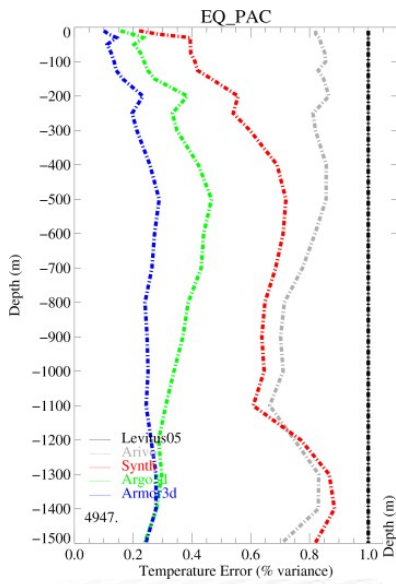
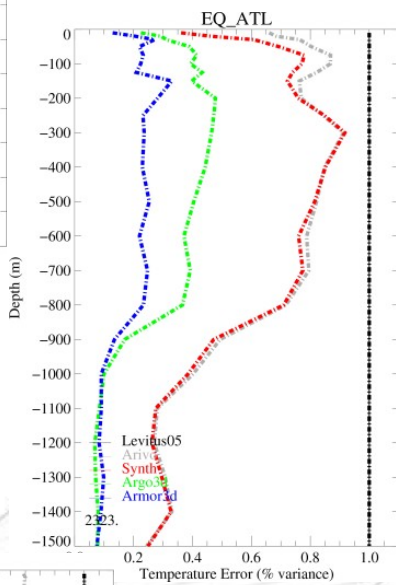
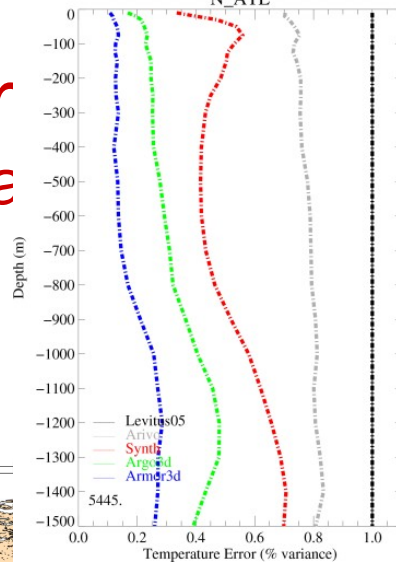
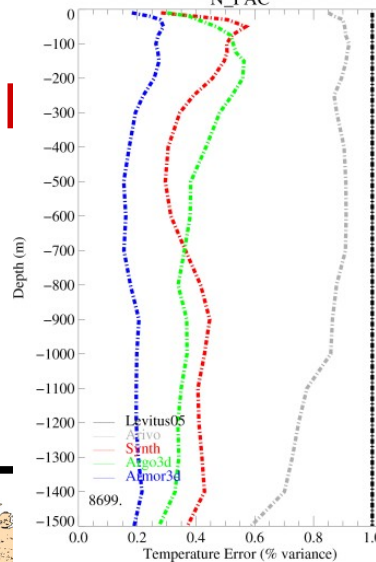
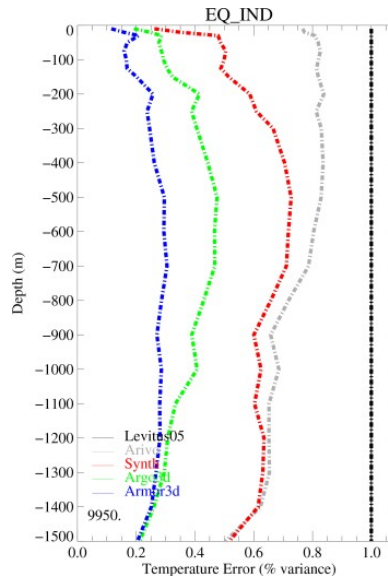
Combined

Argo

Observed

Temperature

Error



→ Argo mandatory at depth – in the eq. zones

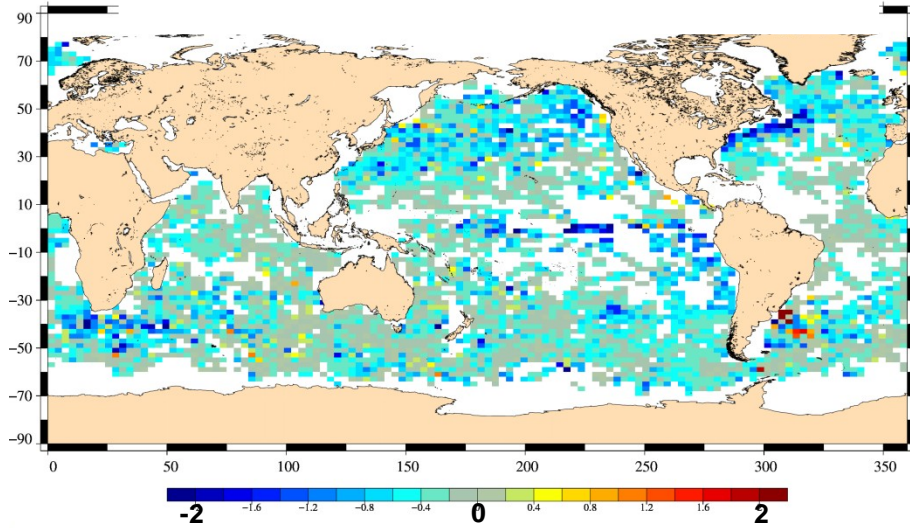
→ SLA+SST important in the Southern Oceans

! Negative values means that the errors are decreased

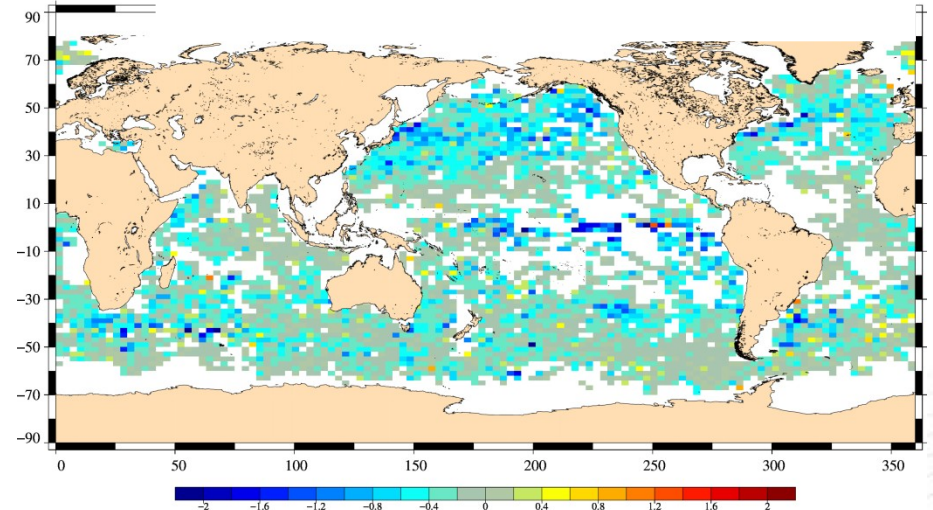
# Observing System Evaluation

## Temperature at 10 m

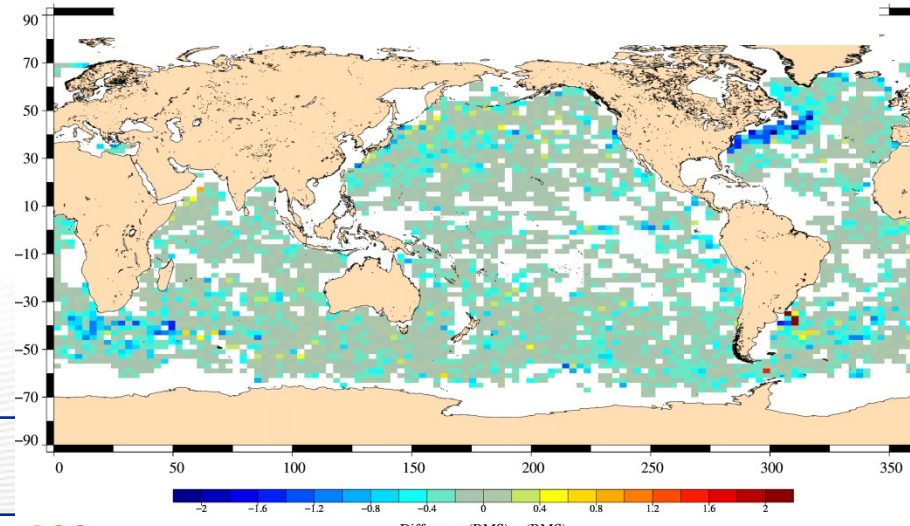
Argo impact (when no remote-sensing)



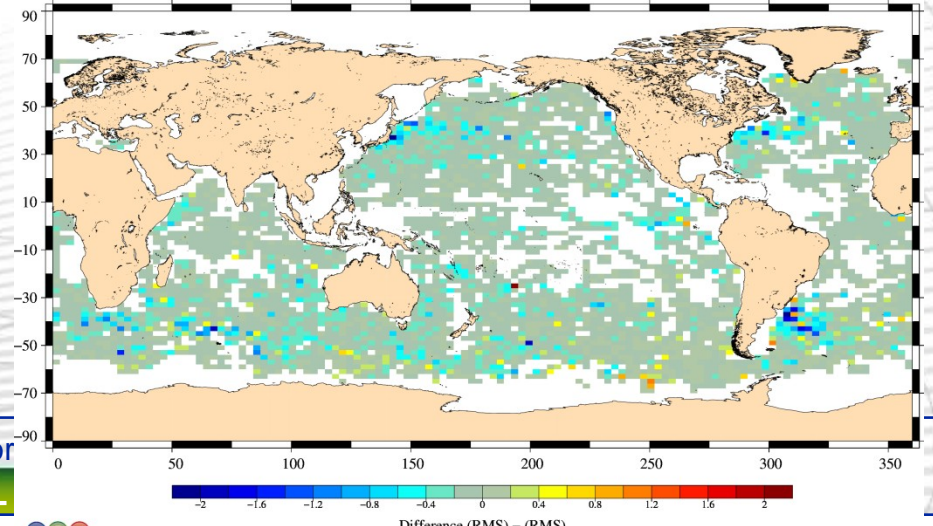
SLA+SST impact (when no Argo)



Argo impact (when remote-sensing)



SLA+SST impact (when Argo)



Levitus 05

Arivo

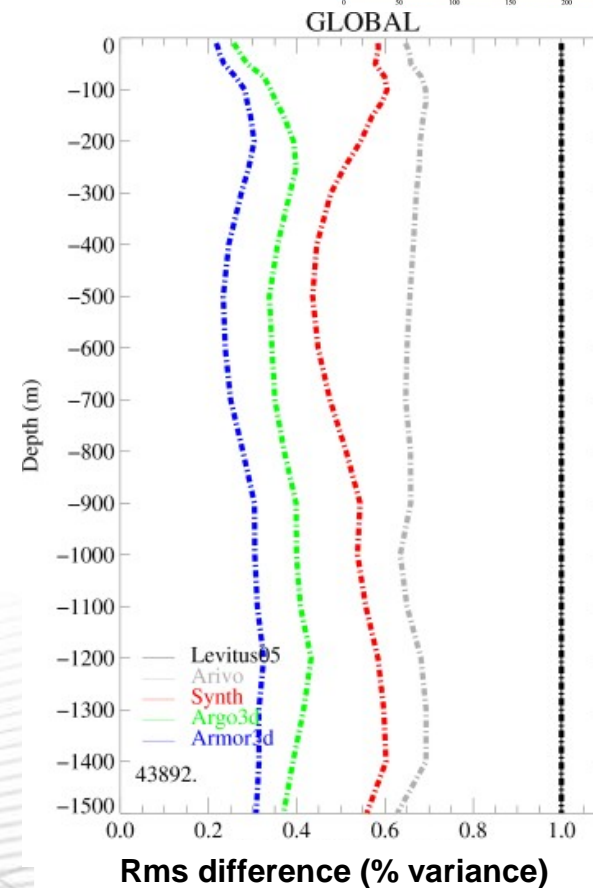
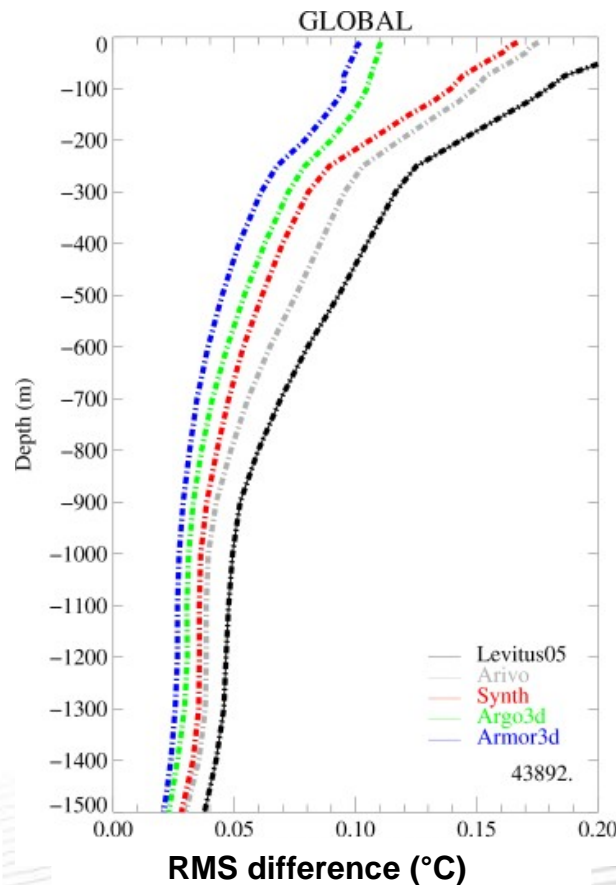
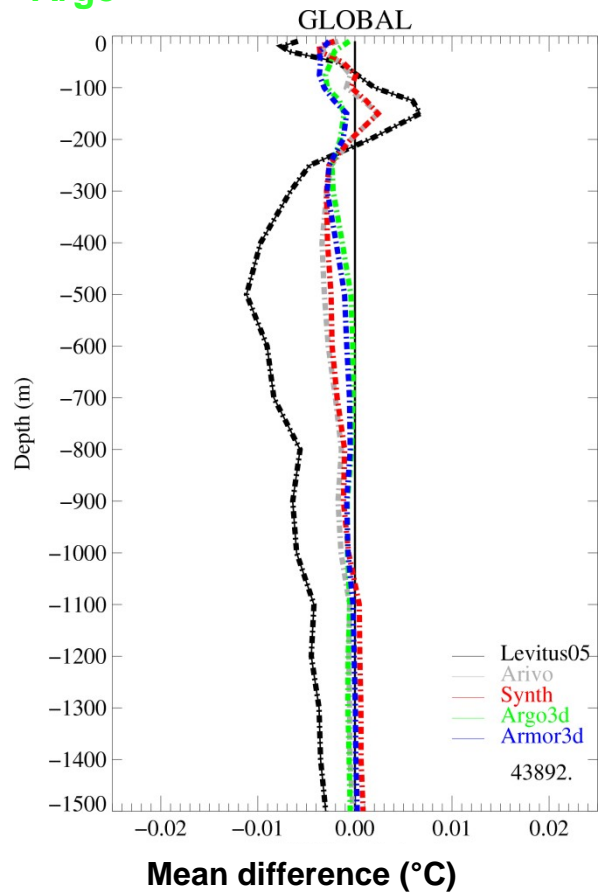
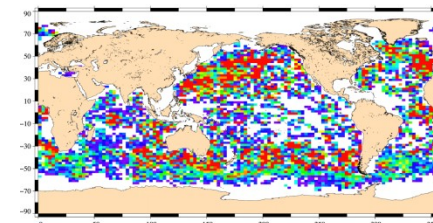
Synth

Combined

Argo

# Observing System Evaluation Salinity

Year 2007



- Combined fields / Argo fields → SLA impact ~ 10 %
- Combined fields / Synthetic fields → Argo impact ~ 30 %
- Argo fields / Arivo → Argo impact (when no remote-sensing) ~ 30 to 40 %
- Synthetic fields / Arivo → SLA impact (when no Argo) ~ 10 to 20 % at depth

→ Argo  
mandatory  
for salinity

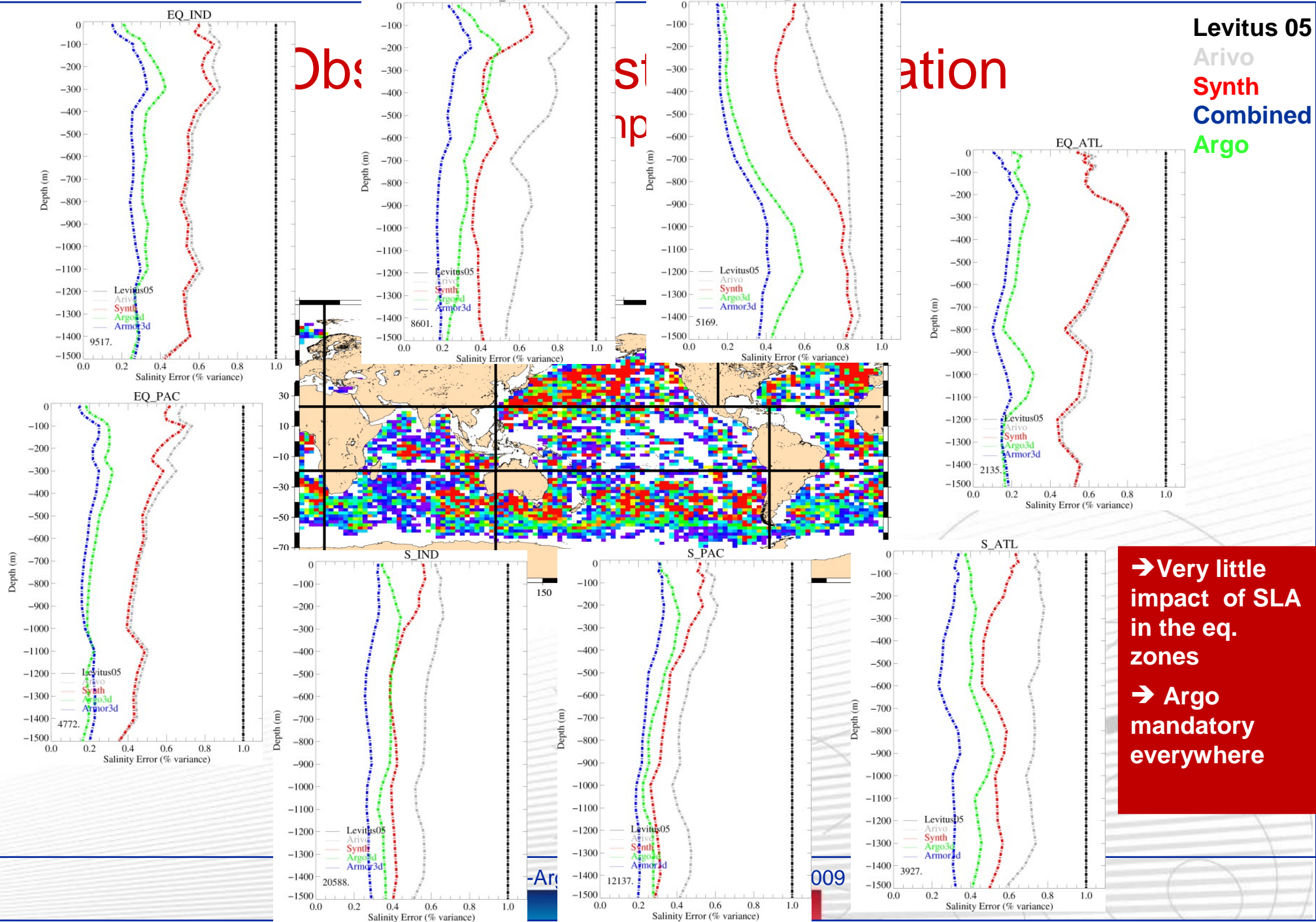
Levitus 05

Arivo

Synth

Combined

Argo

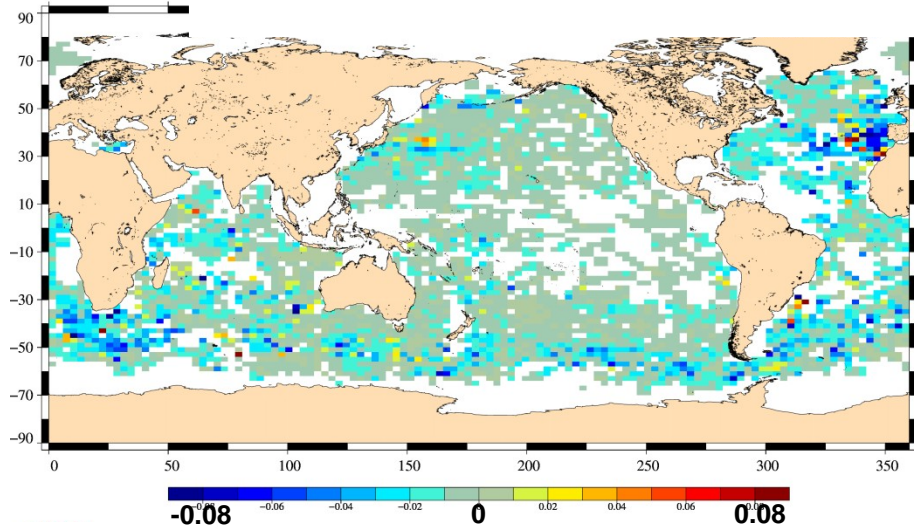


! Negative values means that the errors are decreased

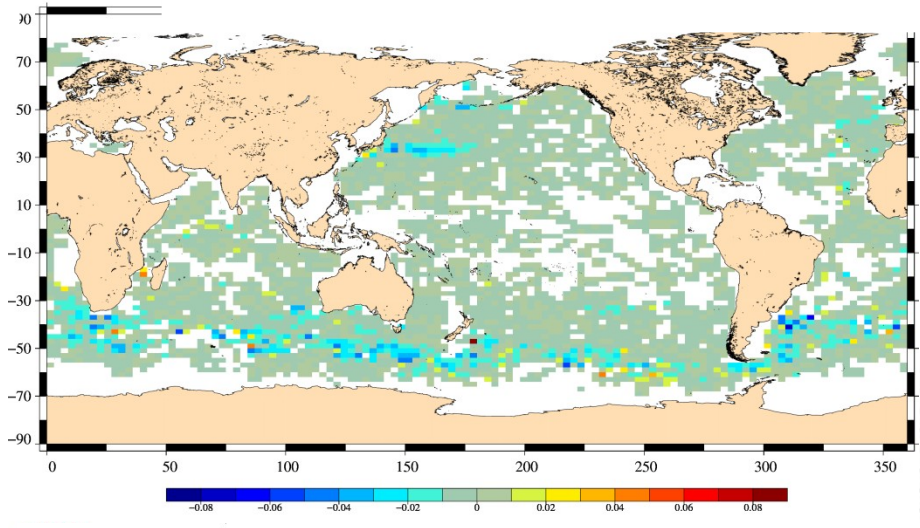
# Observing System Evaluation

## Salinity at 1200 m

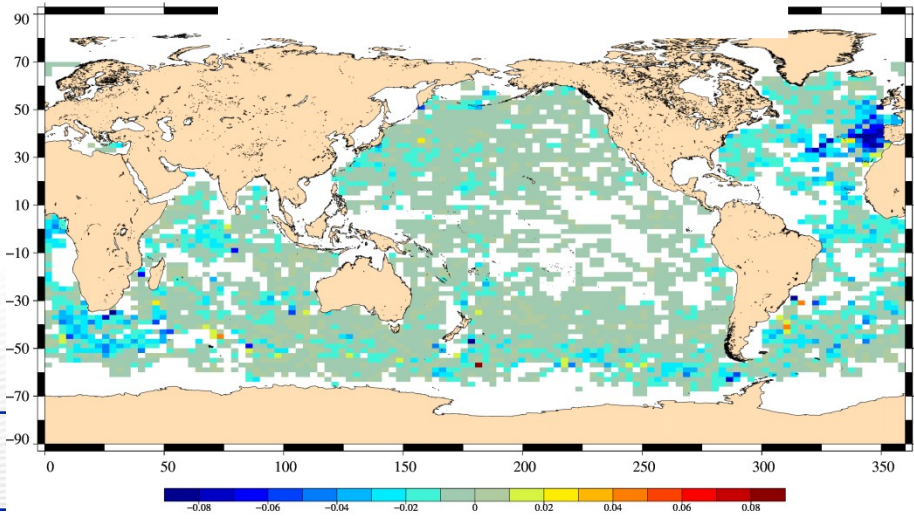
Argo impact (when no SLA)



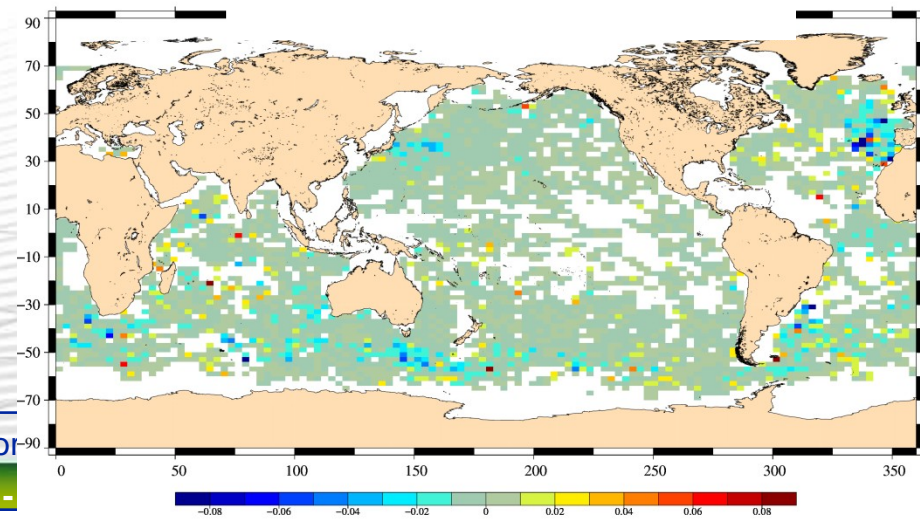
SLA impact (when no Argo)



Argo impact (when SLA)



SLA impact (when Argo)



# Conclusion / Perspectives

Using simple statistical techniques, about 50 to 60 % of the variance of the T field can be deduced from SLA+SST – the use of Argo improve the estimate by 20 to 30 %

- More difficult to reconstruct S at depth from SLA and statistics – 40 to 50 % of the variance of the S field nevertheless reconstructed – the use of Argo improve the estimate by 30 %

This Ocean state estimate tool is able to evaluate the impact and complementarities of the different observing systems :

- ✗ Implement metrics for routine monitoring of the observing system

Perspectives:

- ✗ Computation of a reanalysis of the 1993-2009 period
- ✗ To analyze the ocean variability
- ✗ To be compared to the Mercator reanalysis (Glorys project / MyOcean)

x ...

...

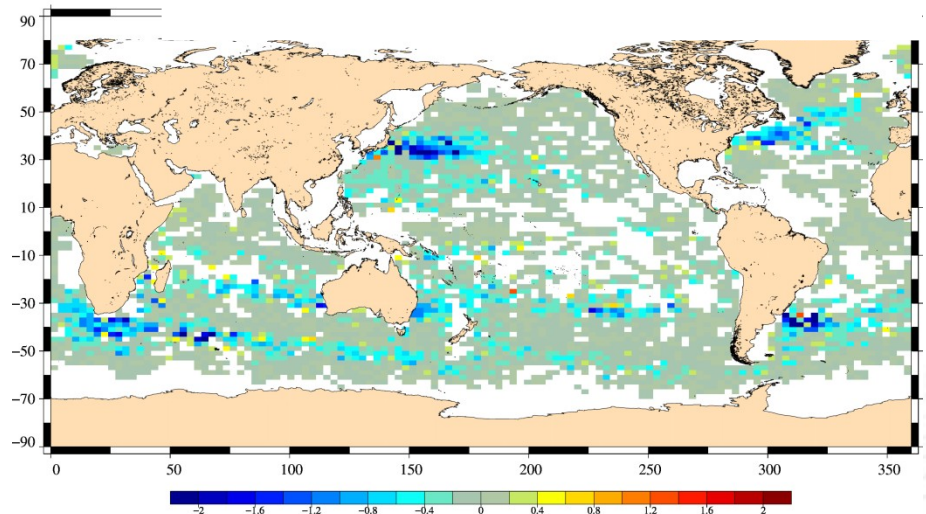
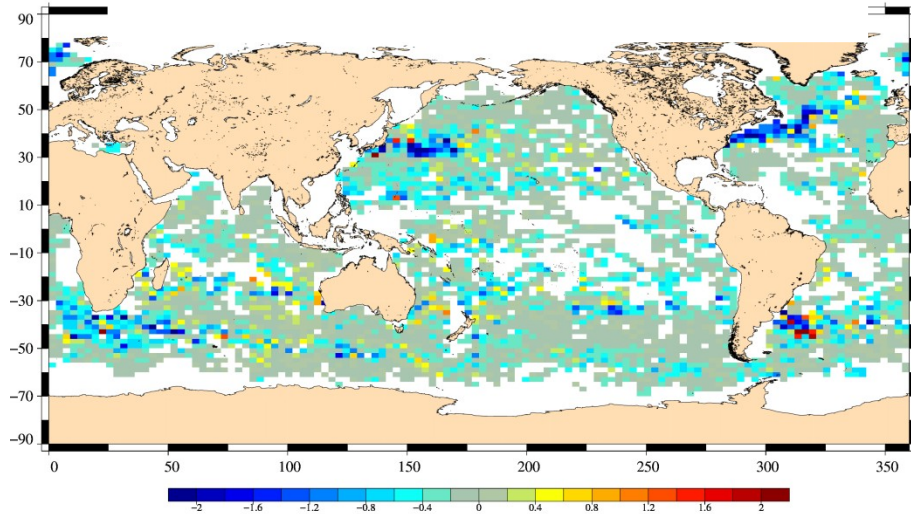
! Negative values means that the errors are decreased

# Observing System Evaluation

## Temperature at 300 m

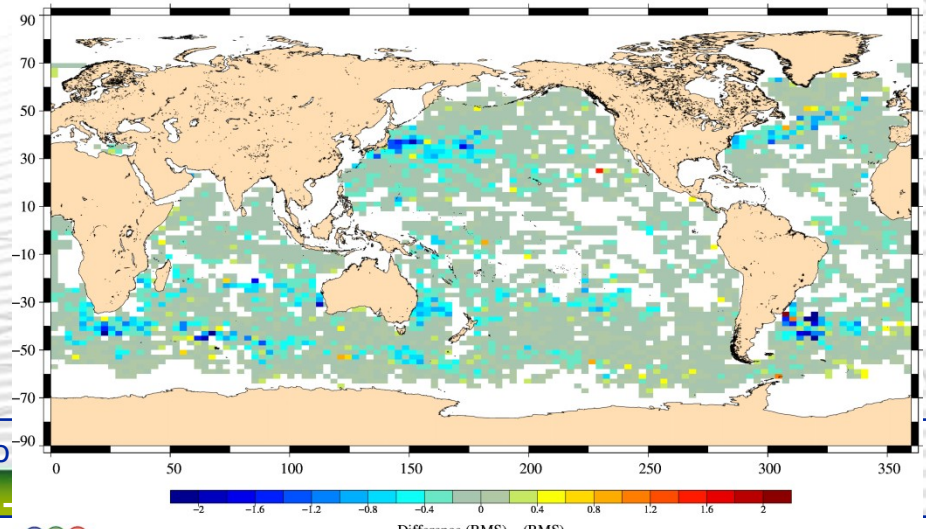
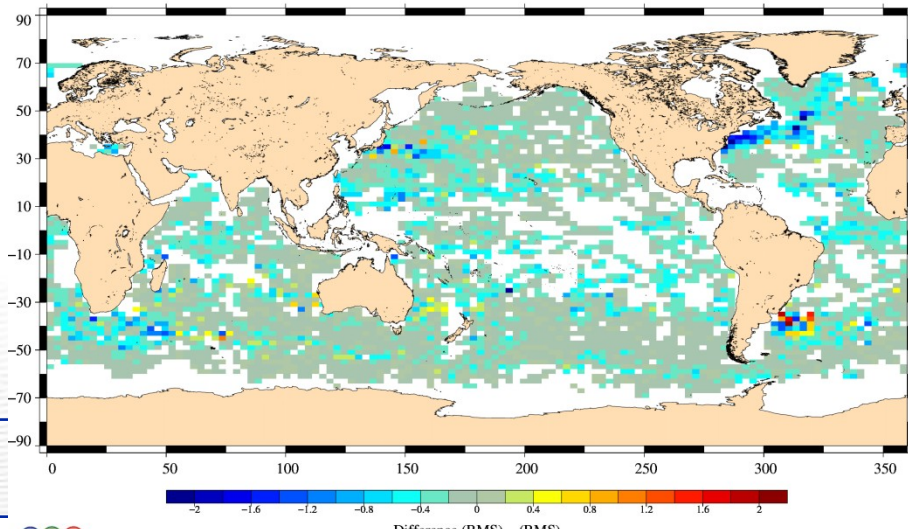
Argo impact (when no remote-sensing)

SLA+SST impact (when no Argo)



Argo impact

SLA+SST impact



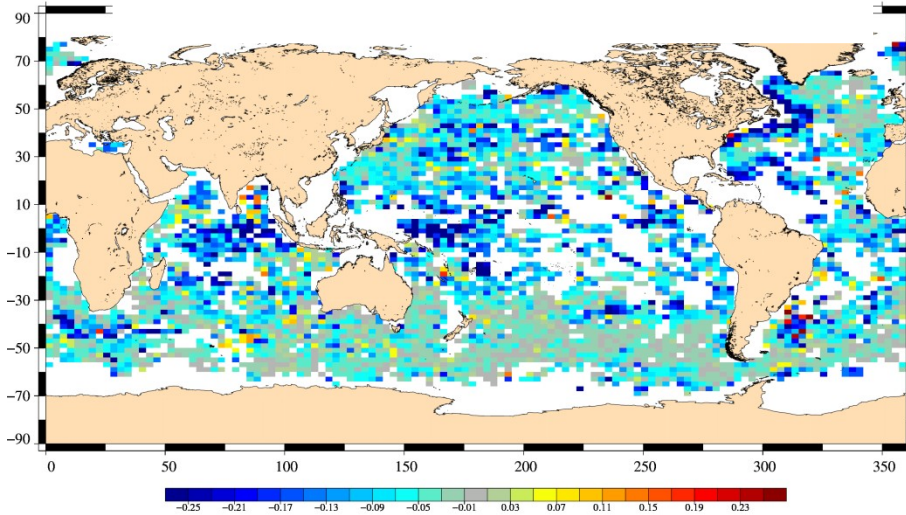


! Negative values means that the errors are decreased

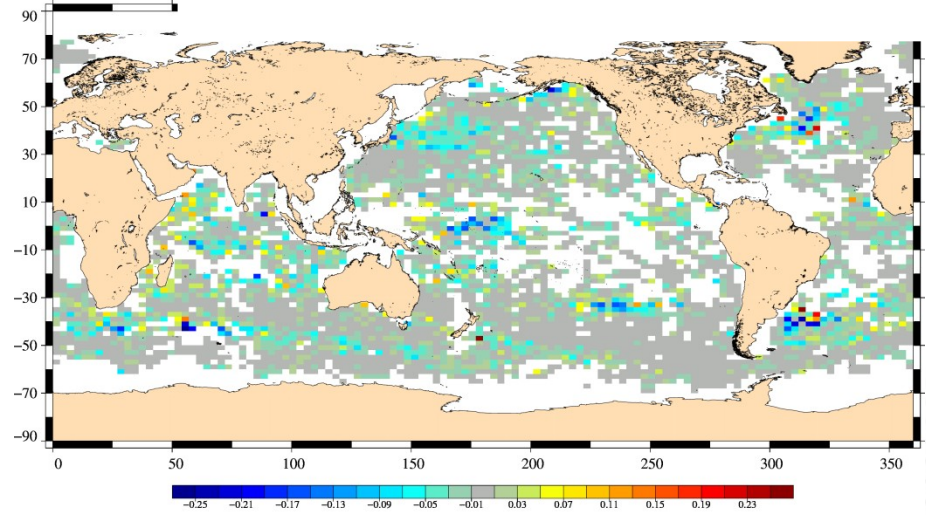
# Observing System Evaluation

## Salinity at 10 m

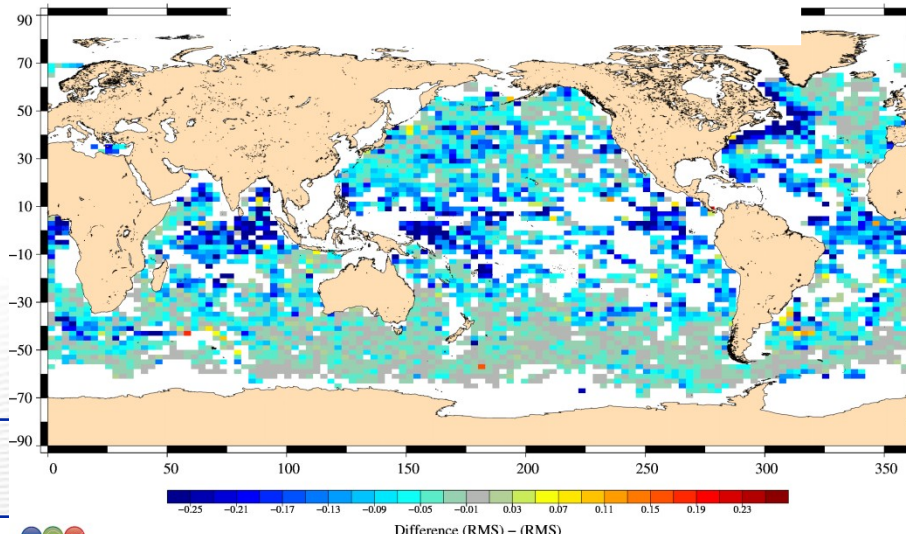
Argo impact (when no SLA)



SLA impact (when no Argo)



Argo impact (when SLA)



SLA impact (when Argo)

