

# Argo based statistics for climate monitoring

Fabienne Gaillard<sup>1</sup>, Thierry Reynaud<sup>1</sup>, Karina Von Shuckmann<sup>2</sup>, Fabien Roquet<sup>3</sup>, Annaig Prigent<sup>1</sup> and Catherine Lagadec<sup>1</sup>

1- Laboratoire de Physique des Océans (LPO), UMR 6523, Ifremer, CNRS, IRD, UBO, BP. 70, 29280 Plouzané France

2- Laboratoire d'océanographie et du climat: Expérimentations et Approches Numériques (LOCEAN), UMR 7159 Paris France

3- Stockholm University



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## Abstract

The Argo array, by offering simultaneously global coverage and high vertical resolution, made the monitoring of inter-annual and decadal variability of the ocean interior possible. In the ARIVO project, we have initiated the production of gridded monthly fields of temperature and salinity using an optimal analysis tool and designed an iterative approach to combine near-real time and delayed mode data.

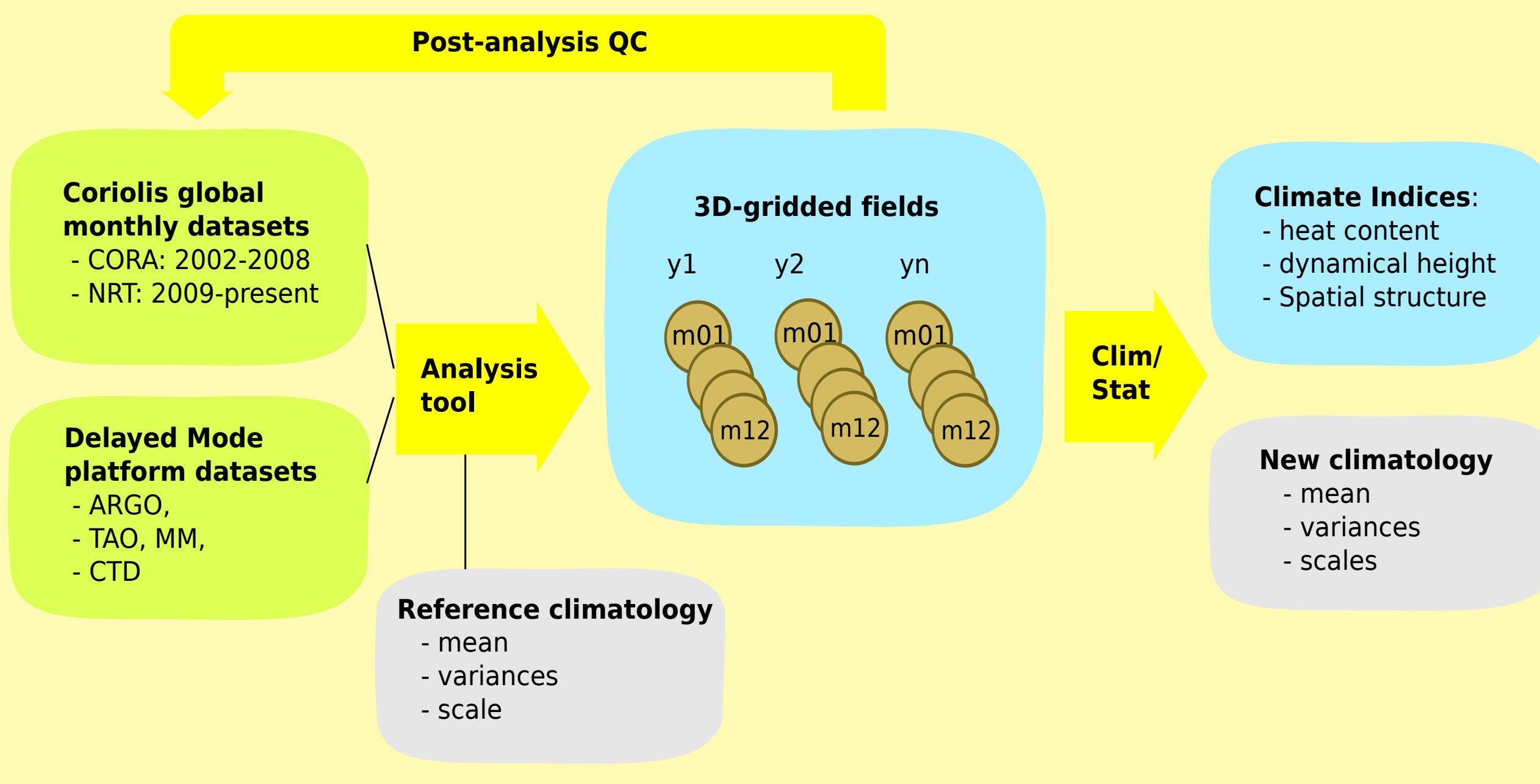
The monthly gridded fields are averaged over time to produce the reference state needed by climatological studies, dynamical modeling and reconstruction methods themselves. Higher degree statistics such as variances and extreme values are later derived. Global indices (heat content, dynamical height) and corresponding error bars are also computed.

Sensitivity tests and careful examination of the analysis results have been performed to detect biases and inconsistencies. A strategy is proposed to reduce these errors and produce a coherent statistical representation of the first decade of the third millennium.

## Method and dataset

### ARIVO Analysis

A methodology has been defined to process the global in-situ datasets in order to produce monthly gridded fields. The methodology applies both to the Near-Real Time (hereafter NRT) processing (monthly) and to the processing of long time series for the purpose of climatic studies.



Simplified flow chart of the ARIVO processing.

### Datasets

The main dataset is ARGO that we complement with data from fixed platforms (mainly the TAO/Pirata array), marine mammals profiles and CTDs.

### Coriolis global monthly datasets

These global datasets are assembled by date and quality controled by Coriolis, they are the basic – or starting point data set of our analysis.

i) CORA : has been prepared for the MERCATOR re-analysis. We use CORA2 version for the period 2002-2008

ii) NRT : This Near-Real Time dataset is made available one week after the end of each month. We use this dataset since 2009. It allows the production of Near-Real Time monthly analysis.

### Delayed mode platform datasets

Delayed mode data have been validated and calibrated by PIs. We progressively build up a list of validated DM-platforms.

### Analysis method

The analyzed field  $x^a$  is the linear least square estimator deduced from the set of observations  $y^o$ .  $x^f$  is a reference field or first guess. The statistical information on variance and horizontal scales are expressed in the covariance matrices  $C$  and  $P$ , the noise in  $R$ .  $P$  is the covariance matrix of the estimated field.

$$x^a = x^f + K^{oi}d \quad K^{oi} = C_{ao}(C_{oo}+R)^{-1}$$
$$P^a = P - K^{oi}C_{ao}^T \quad d = y^o - x^f$$

More information on the method can be found in Gaillard et al (2009).

## References

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Corresponding author address: fabienne.gaillard@ifremer.fr

## Sensitivity to a priori information

### Reference climatologies

A Sensitivity test was performed on a dataset (D2) combining Cora-2 (until 2008) and NRT (starting in 2009) data. A simple pre-analysis climatological test was performed.

The reference climatology is the starting point of the analysis. As the dataset extended in time and space, this reference has been regularly updated. Three reference climatologies have been used:

+ **WOA05 [W5]:** To initiate the processing, the NODC climatology WOA05 has been interpolated on the ARIVO grid. This climatology serves as a reference for the global indices presented below (the zero of the ordinate).

+ **ARV9 [A1]:** Average of the fields from a preliminary analysis (D1CW5S1, not shown) covering 2002-2008.

+ **ARV11 [A2]:** Average of the field from run D2CA1S2 covering 2004-2010.

The influence of the a priori information has been tested by changing the reference climatology (mean/variance for CW5, CA1 and CA2) and the horizontal scales (S1,S2,S3).

The global heat content (60°S-60°N) and mean dynamical height are used as a measure of the ocean variability (von Schuckmann et al 2009).

Horizontal scales/amplitude of a priori variance have little influence (S1, S2, S3 curves). The reference climatology (mean state/variance) has a strong influence when the dataset is insufficient (before 2006).

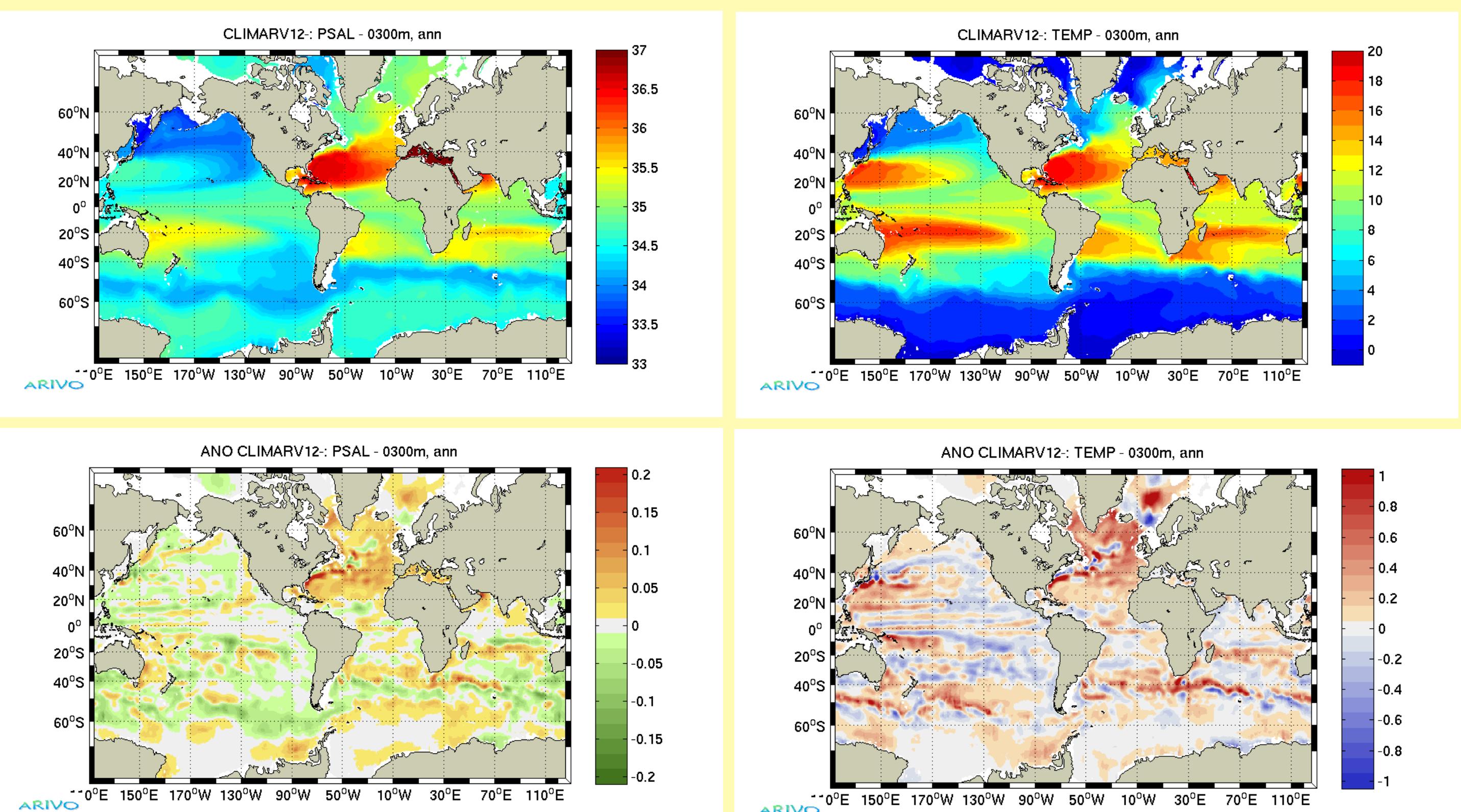
## Post-Analysis Quality Control

The process exposed in the flow chart includes a post-analysis quality control step in which data that produce strong field anomaly and high residuals are visually checked and discarded if the anomaly is confirmed. This process has been applied in the D2 dataset for the 2002-2011 period and led to the D3 dataset. Moreover, a list of uncalibrated platforms known to show strong biases have been removed. The final dataset D4 will be the starting point for the combination with the Delayed Mode data from selected platforms.

Switching from D2 to D4 produces little changes in the global indices.

### Error estimate

The optimal interpolation method produces the error field estimate. Integrating the error lead to put error bars on the global indices. In 2004, estimates of the global quantities are not compatible within error bars ! Errors on data and/or a priori variance in some areas have been under estimated.



## Perspectives

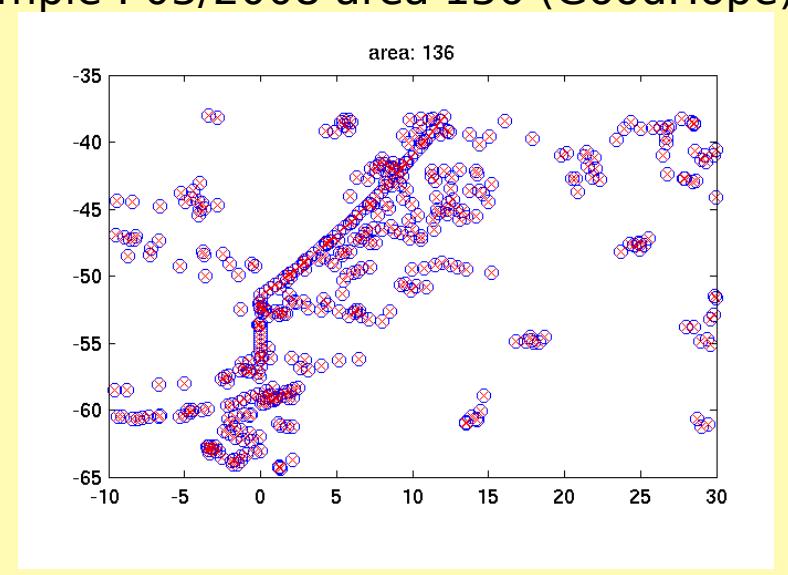
### 1) adding selected Delayed Mode datasets (D5 analysis)

Example : 03/2008 area 136 (GoodHope)

+ **OVIDE:** 44 ARGO floats in the North Atlantic (PI : V. Thierry)

+ **GoodHope:** 94 GoodHope ARGO floats in the southern Ocean (PI : S. Speich) plus selected floats found in the area that have been validated by the GH project

+ **Elephant-Seals:** 26 elephant seals in the southern ocean equiped with T-S sensors (PI : Roquet, F. Roquet et al. 2011).



### 2) Improve a-priori statistics

- D5 will be used as a basis for the new mean field.

- A priori variance on the field will be recomputed from the new dataset and a strategy has to be defined to improve the estimate in undersampled areas

- Measurement error : increase measurement error on NRT data to take into account biases and give priority to DM well qualified

### 3) Run the analysis on the 2002-2012 period