How well can we derive climate indices from Argo data?

Karina von Schuckmann[1] and Pierre-Yves le Traon[2]

[1] CNRS/LOCEAN Paris, hosted by Ifremer – LOS, Brest France
[2] Ifremer – LOS, Brest France

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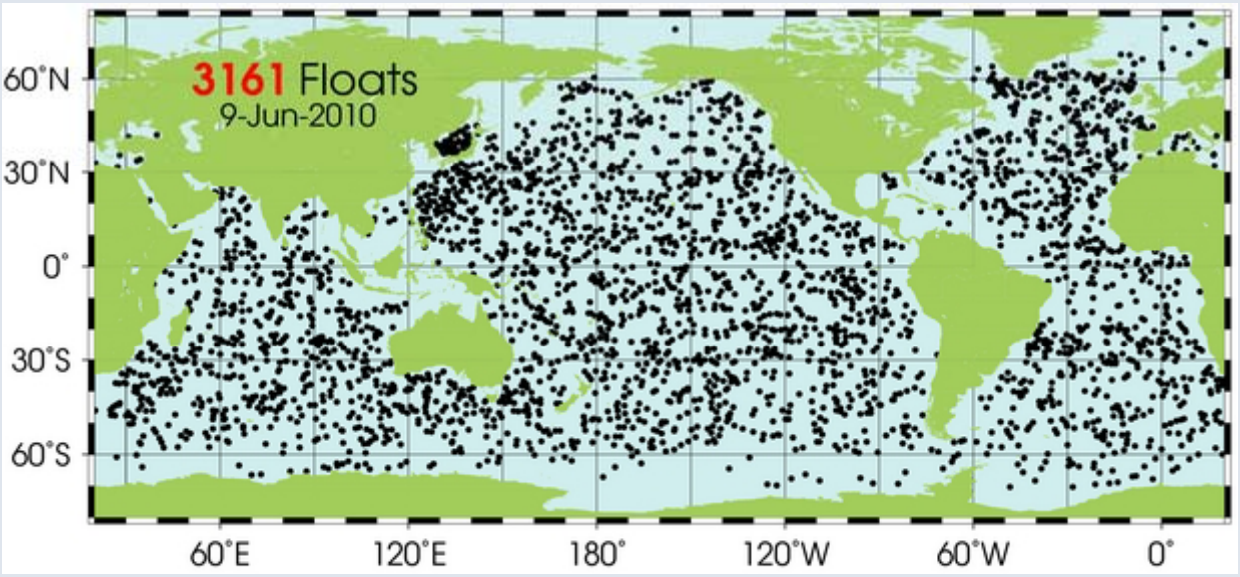
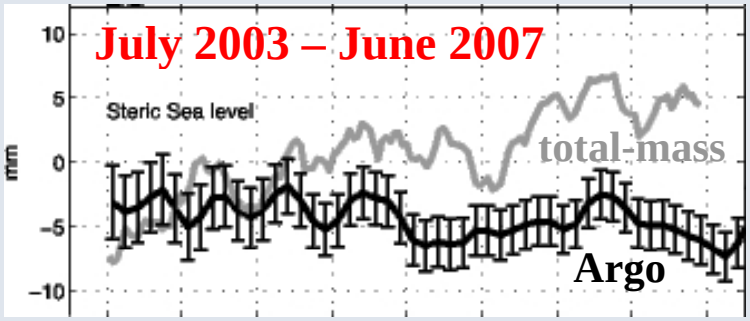
At the beginning of the year 2004, Argo sampling covers about 80% of the global ocean.

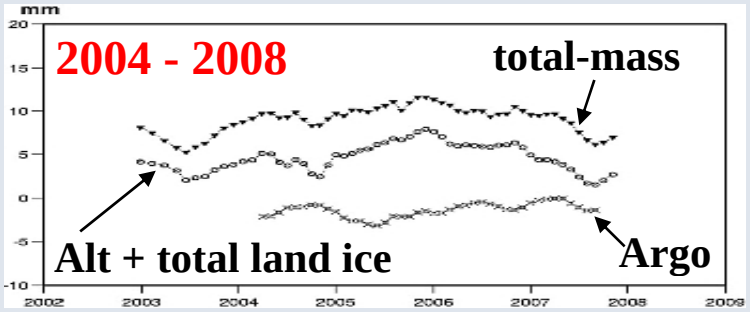


The Argo temperature and salinity measurements can be ideally used to assess global ocean indicators such as heat content variability, freshwater content and steric height based on hydrographic changes of the upper 2000m depth of the world ocean.

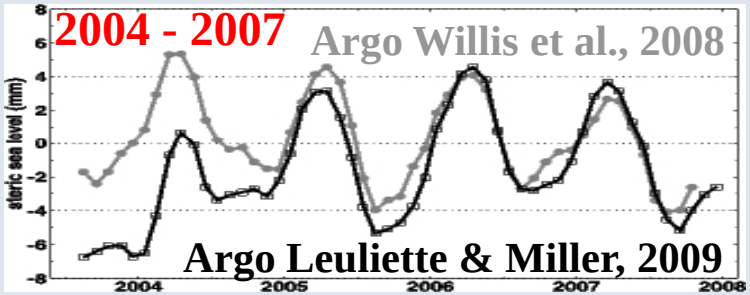
Global steric sea level variations from Argo have been derived over the past couple of years:



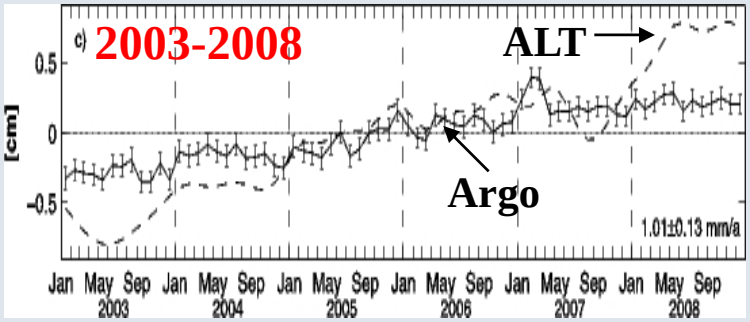
Willis et al., 2008: -0.5±0.5mm/a
rel. to 900 m depth; derived from gridded anomalies rel. to WOCE hydrographic climatology (WGHC).



Cazenave et al., 2009: 0.37±0.1mm/a
rel. to 900 m depth; derived from gridded anomalies rel. to Argo climatology

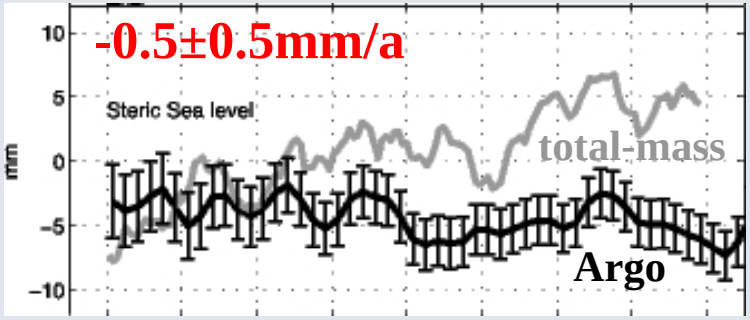


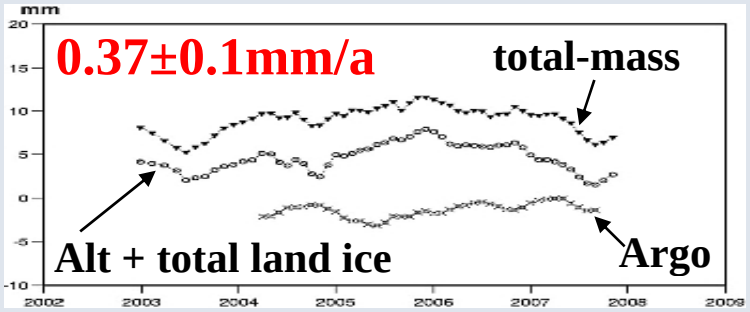
Leuliette and Miller, 2009: 0.8±0.8 mm/a
rel. to 900 m depth; derived from gridded anomalies rel. to WGHC

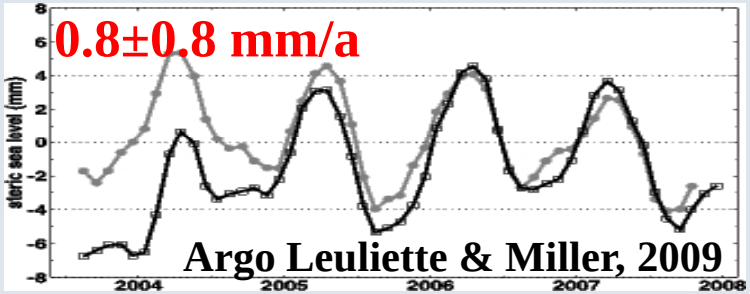


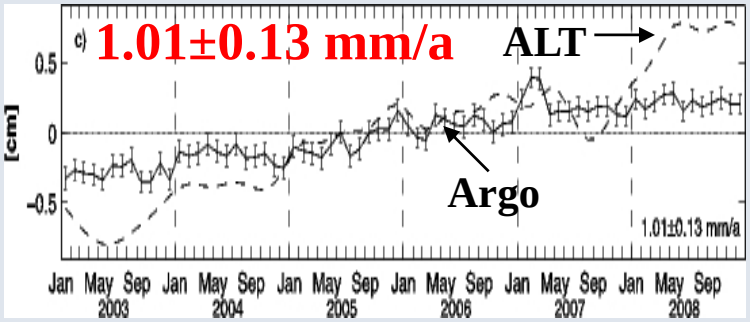
von Schuckmann et al., 2009: 1.01±0.13 mm/a
rel. to 1500m depth; derived from gridded anomalies rel. to Argo climatology

Global steric sea level variations from Argo have been derived over the past couple of years:









There are substantial differences in these global statistical analyses. They have been related to:

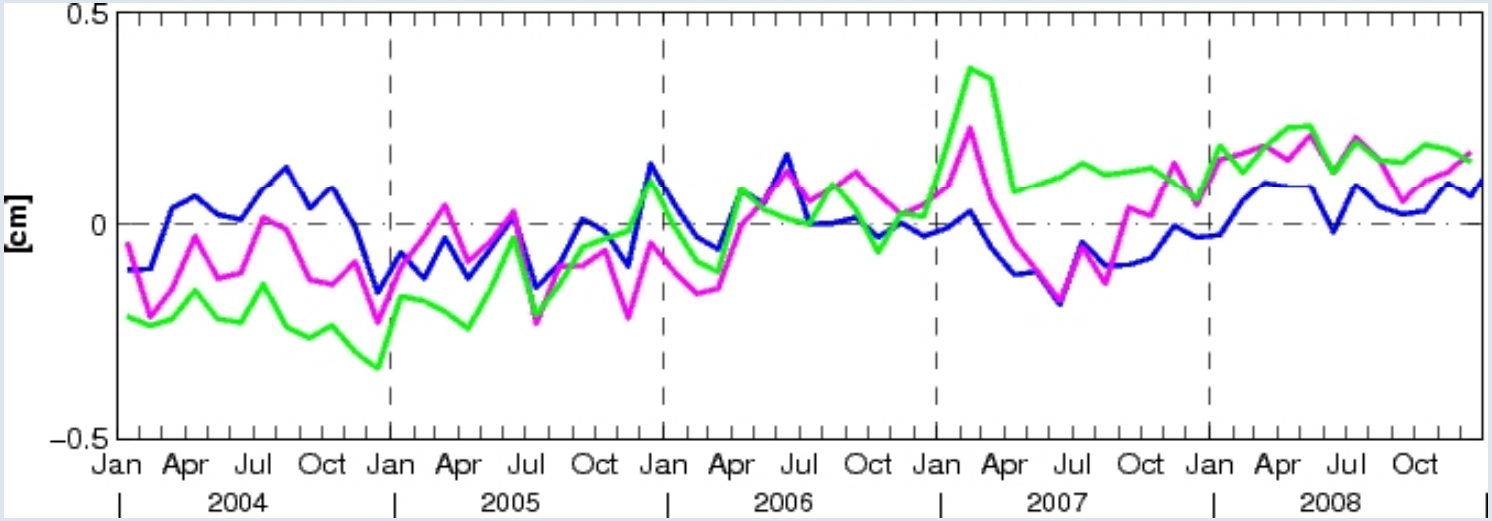
° instrumental biases, quality control and processing issues

° role of salinity and influence of reference depth for steric sea level calculation.

° sparse global sampling before 2005 also limits the statistical significance of some of the observed differences.

° choice of reference climatology may bias steric trend estimations

Gridded fields based on Argo data from the Argo home page:
Global steric height



Ifremer: 1.02±0.2 mm/a

Argo + other data; ½ ° resolution; reference climatology: WOA05

Scripps Institution of Oceanography: 0.08±0.2 mm/a

Argo only, 1° resolution; reference climatology: Argo

JAMSTEC: 0.57±0.2 mm/a

Argo + other data; 1° resolution; reference climatology: WOA01

How well can we derive climate indices from Argo data?

Outline:

1) description of the methods

2) Sensitivity test: comparison of the methods

3) Sensitivity test: influence of first guess estimation

4) Estimation of sampling error on global indicators

A revised estimation of global steric sea level variations is proposed here for the years 2005 to 2009.

This work is part of the MyOcean In-situ TAC: Research and Development activities

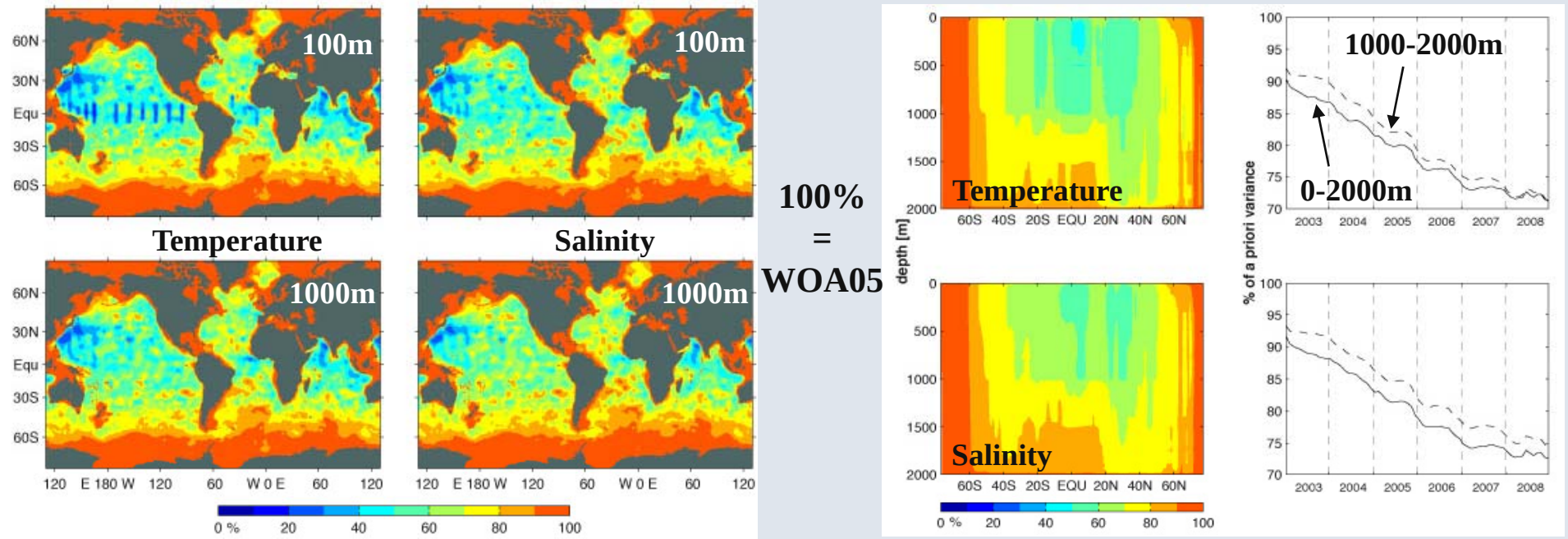
Description of the method: objective analysis (ARIVO)

The French project ARIVO (http://www.ifremer.fr/lpo/arivo/):

Monthly gridded fields of temperature and salinity are obtained by optimal analysis of in-situ data sets as Argo (95%), shipboard and mooring measurements (XBTs, XCTDs and SOLO floats are excluded)

Period: 2002-2008, ½° Mercator grid, 152 levels between the surface and 2000m

Reference: ARIVO climatology 2002-2008



Data coverage information: Percentage of 'A Priori Variance'

Description of the method: Simple box averaging

1) Incomplete vertical T&S profiles are filled with a climatology

2) Steric height is calculated at every profile position

3) Steric height anomalies: relative to ARIVO steric climatology (2004-2009)

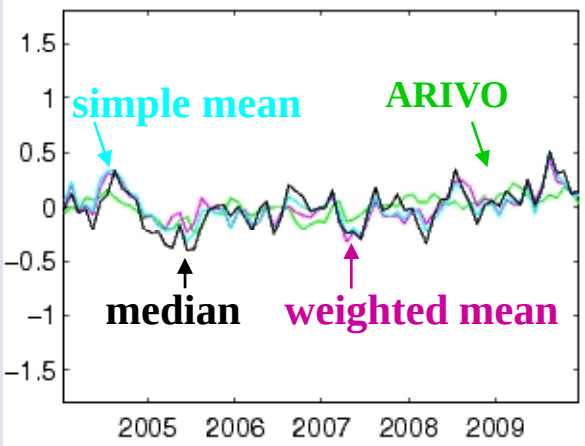
4) For each 5° latitude x 10° longitude x 3 month box, the mean is calculated through a **simple space/time averaging**, **a median filter** or using a **weighted mean** that takes into account the space and time correlation of observations within a given box (Bretherton et al., 1976): space and time correlation scales of 150 km and 15 d.

5) Boxes with less than 10 observations are not kept and the box value is set to the mean of all observations.

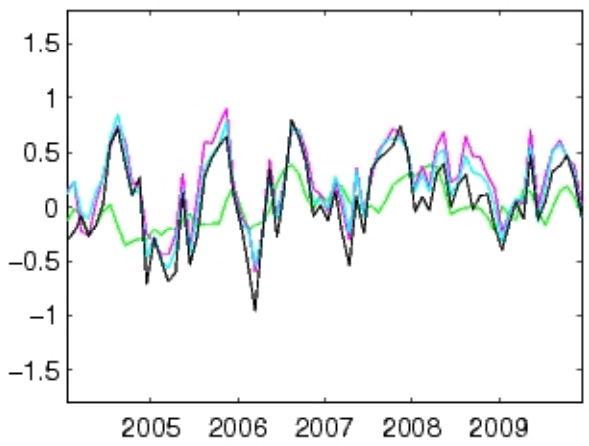
6) The global (and regional) steric mean sea level and its error are then computed as an average of all boxes weighted by their surface area.

Description of the method: First results

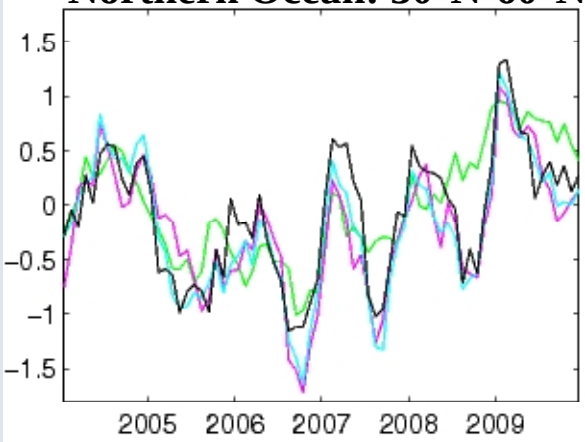
Global Ocean: 60°S-60°N



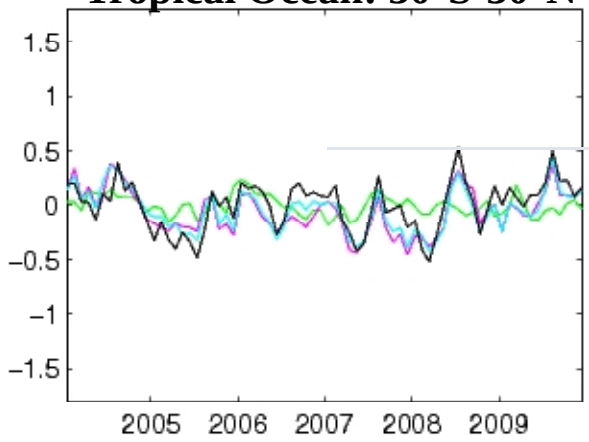
Southern Ocean: 30°S-60°S



Northern Ocean: 30°N-60°N



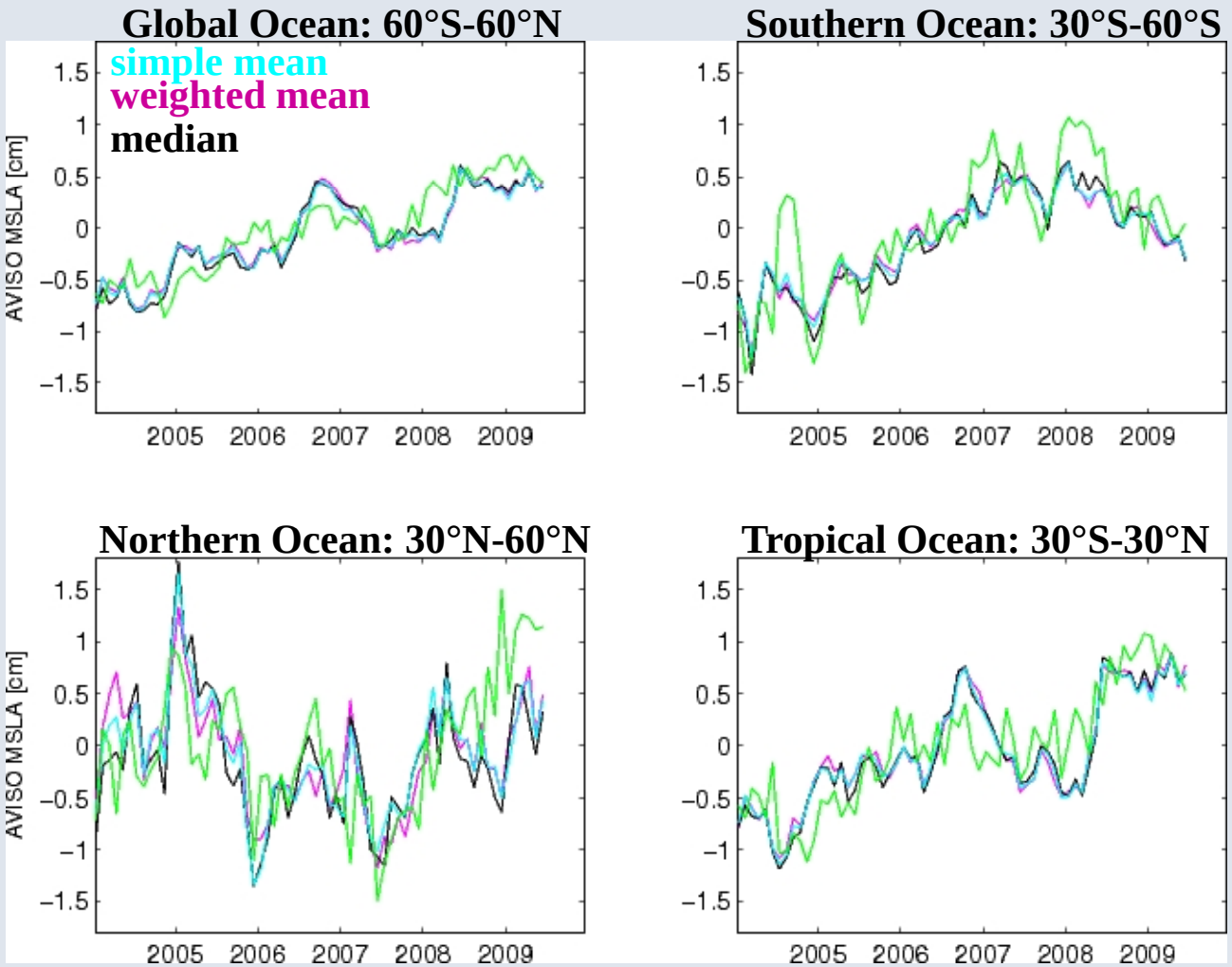
Tropical Ocean: 30°S-30°N



➔ **General good agreement between the different methods.**

Sensitivity test: comparison of the methods

data from www.aviso.oceanobs.org: SSALTO DM MSLA



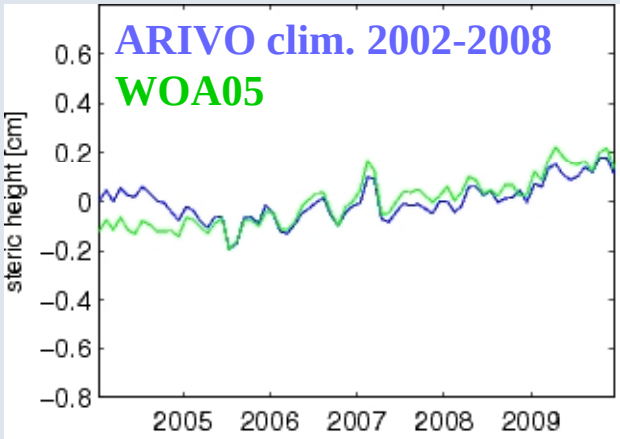
Gridded MSLA is subsampled to Argo sampling
➔ good agreement

View of the error caused by the array's sampling using satellite altimetry: e.g. see also Roemmich and Gilson, 2009.

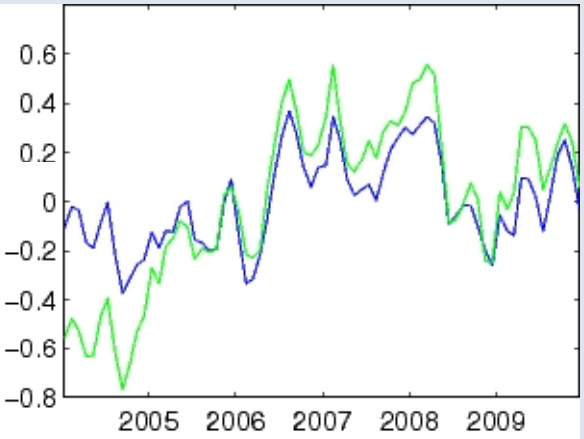
Sensitivity test: choice of climatology

ARIVO gridded field: sensitivity to choice of first guess: Collaboration with Fabienne Gaillard

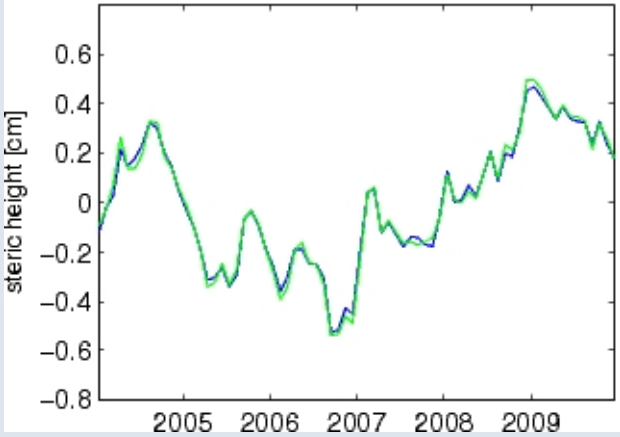
Global Ocean: 60°S-60°N



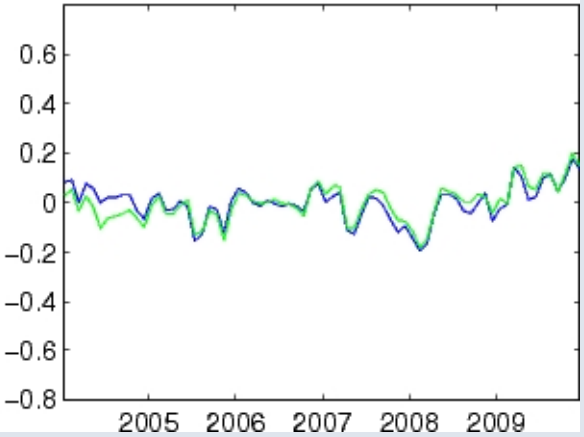
Southern Ocean: 30°S-60°S



Northern Ocean: 30°N-60°N



Tropical Ocean: 30°S-30°N



Bias in the Southern Ocean which also shows an impact on the global estimation

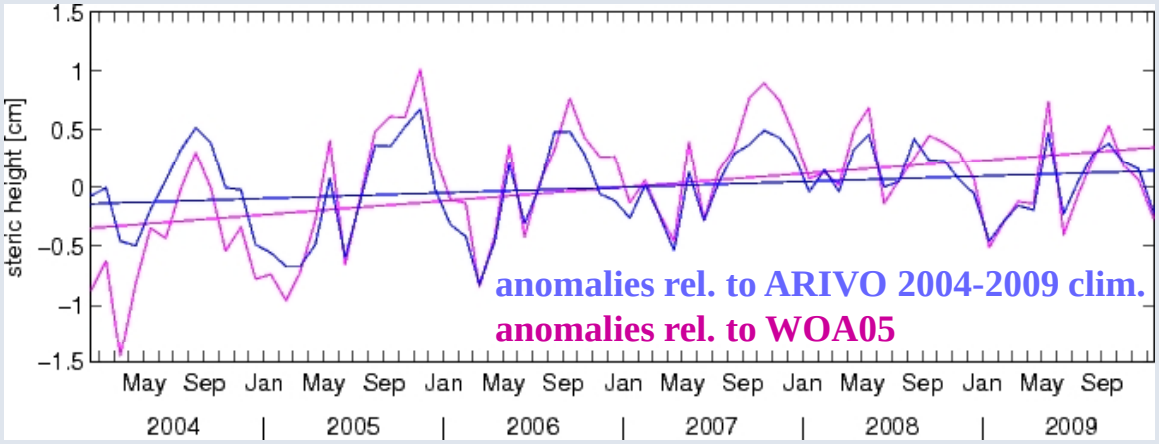
➔ large sensitivity of choice of baseline climatology on global rate estimation before the year 2005.

➔ For the definition of global ocean indicators and estimating its rates: start after 2005

Under-sampled Southern Ocean: Possibility of a yet unresolved bias in the long-term estimation of global ocean indicators…

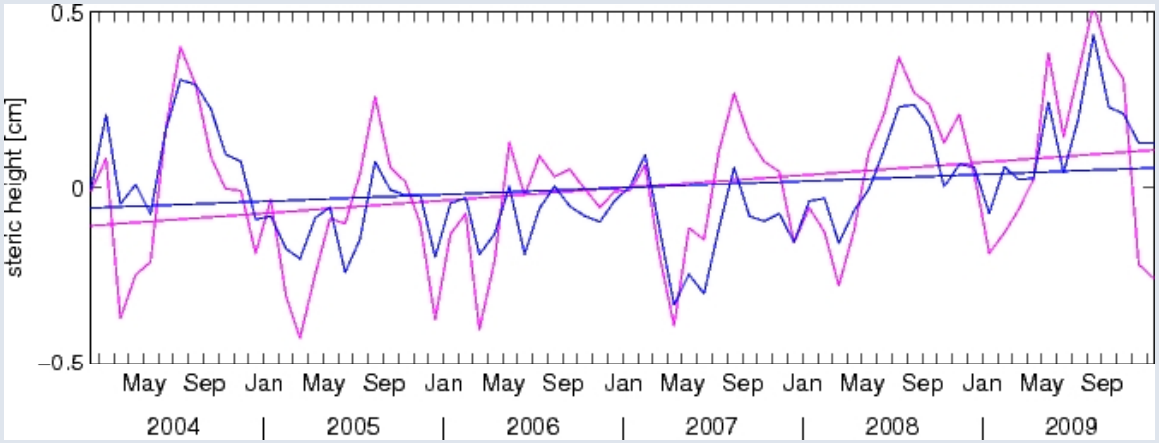
Sensitivity test: choice of reference climatology

Southern Ocean: 30°S-60°S



The choice of the reference climatology (mean seasonal cycle) mostly impacts regional mean steric height estimations, i.e. the Southern Ocean subdomain.

Global Ocean: 60°S-60°N



The impact on the global estimation appears to be low.

➔ To minimize biasing effects, a global estimation after the year 2004 is advantageous.

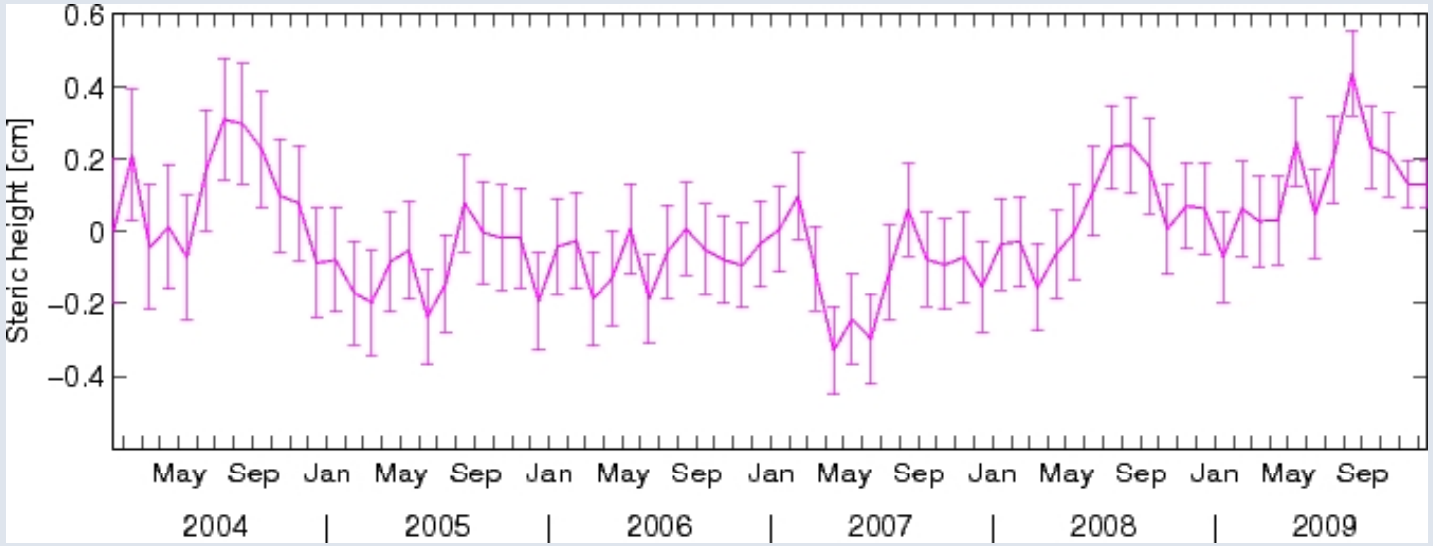
Description of the methods ➔ simple box averaging method can be applied: weighted box mean (Bretherton et al., 1976): 5°x10°x3month

Sensitivity test: influence of first guess estimation ➔ global estimation should start with the year 2005

Estimation of sampling error on global indicators

Revised estimation of global steric sea level variations - Estimation of sampling error

Global Ocean: 60°S-60°N



Weighted box mean: 5°x10°x3month:
Compared to error on simple box average (variance): reduced number of degrees of freedom as it takes into account the space and time correlation of observations within a given box.

Description of the methods ➔ simple box averaging method can be applied: weighted mean (Bretherton et al., 1976): 5°x10°x3month

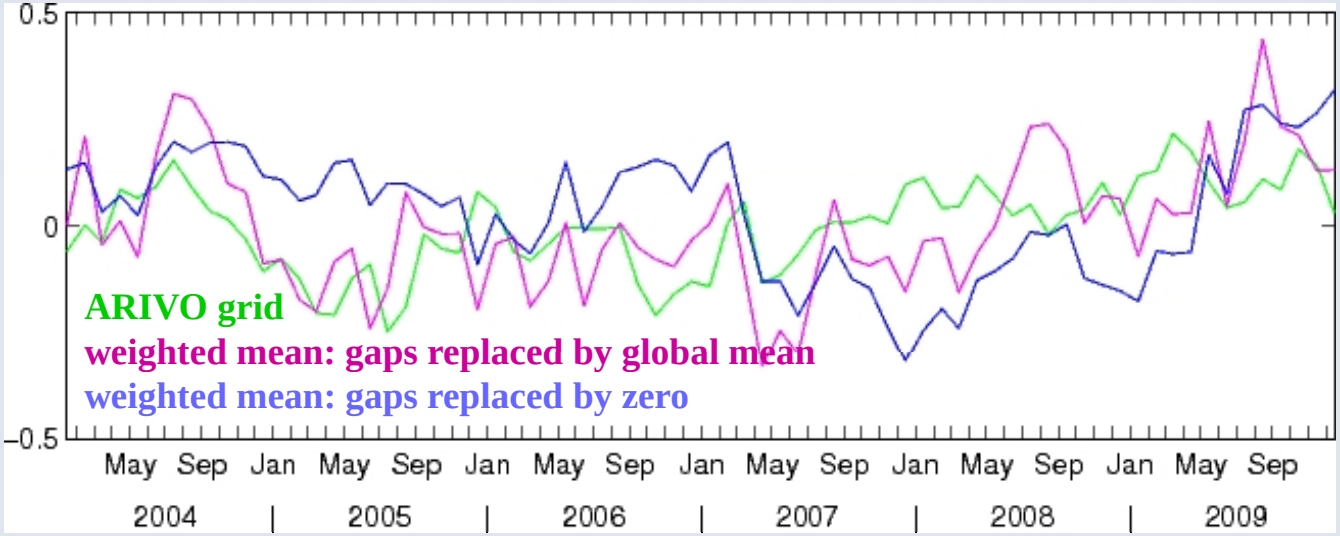
Sensitivity test: influence of first guess estimation ➔ global estimation should start with the year 2005

Estimation of sampling error on global indicators ➔ error takes into account the space and time correlation of observations within a given box

Replacing gaps while averaging globally

Revised estimation of global steric sea level variations – Impact of gaps

Global Ocean: 60°S-60°N



As already discussed in previous studies (e.g. Roemmich and Gilson, 2009), replacing gaps by the mean of the observations is to be preferred.

Description of the methods ➔ simple box averaging method can be applied: weighted mean (Bretherton et al., 1976): 5°x10°x3month

↓

Sensitivity test: influence of first guess estimation ➔ global estimation should start with the year 2005

↓

Estimation of sampling error on global indicators ➔ error takes into account the space and time correlation of observations within a given box

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Replacing gaps while averaging globally ➔ gaps replaced by global mean

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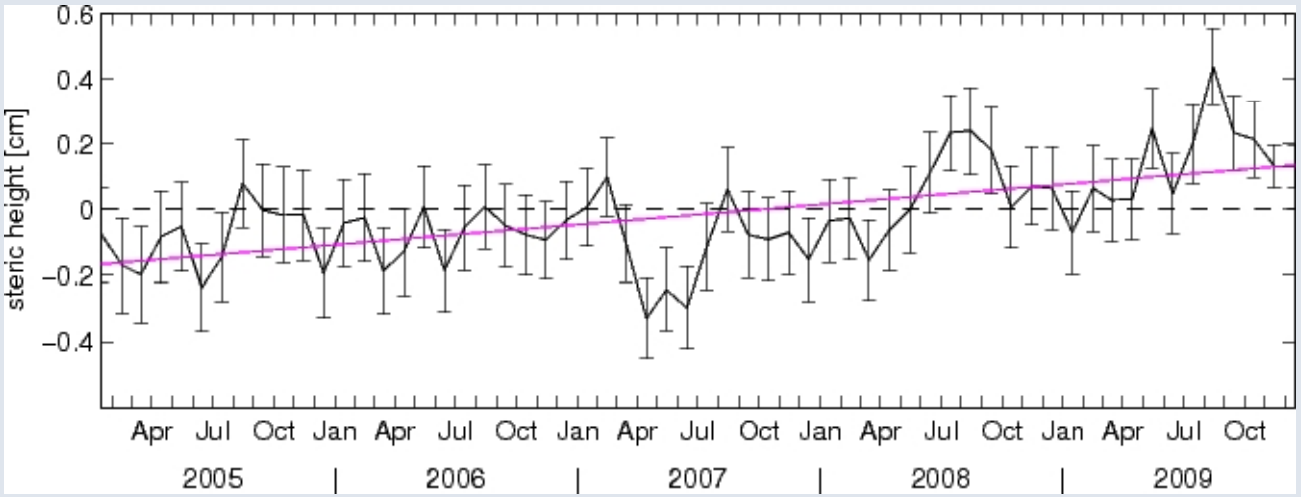
Revised estimation of global steric sea level variations

Revised estimation of global steric sea level variations

Global mean steric height



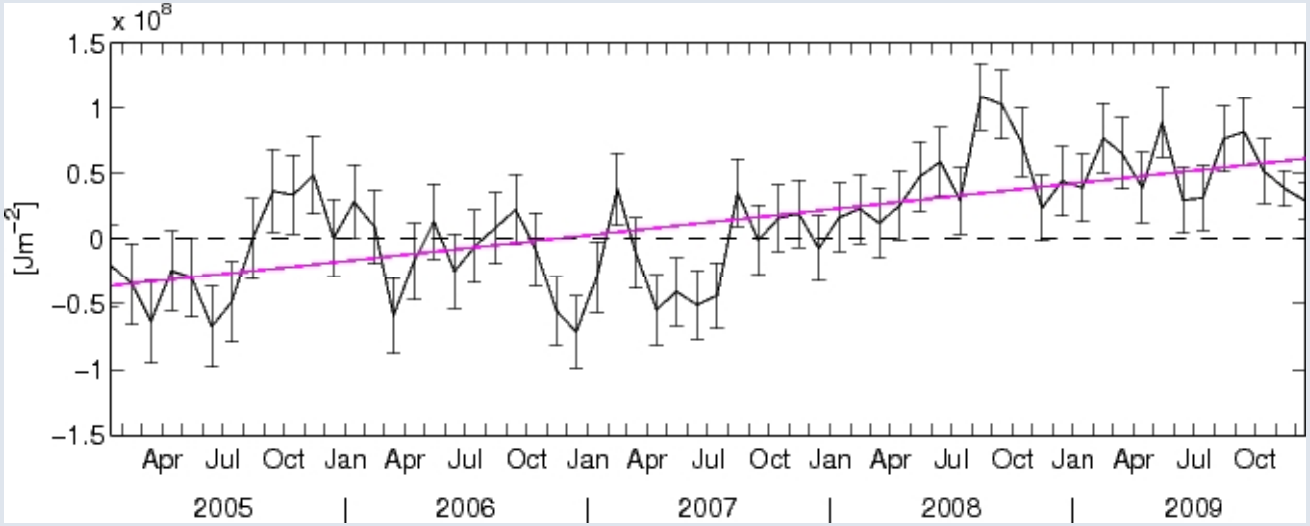
Rate of global mean steric sea level from Argo temperature and salinity measurements during 2005 to 2009:

0.6 ± 0.2 mm/year

Global steric height is calculated between 10-1500m depth and 60°S-60°N.

Revised estimation of global heat content variations

Global mean heat storage



Rate of global mean heat storage from Argo temperature measurements during 2005 to 2009:

0.62 ± 0.14 Wm^{-2}

Global heat storage is calculated between 10-1500m depth and 60°S-60°N.

Conclusions

Here we have presented a revised estimation of Argo global ocean indicators for the years 2005 to 2009 together with refined sampling error estimates. Further uncertainties need to be quantified in future studies.

➔ Since the sensitivity tests have revealed that further uncertainties are likely to exist, the main conclusion includes that the global Argo data set is not yet long enough to observe global change signals and currently, global indicators cannot be interpreted as long-term climate signals.

Indeed, the international Argo program provides data with unprecedented accuracy and coverage. But the estimation of climate signals requires very careful data quality control as well as a proper estimation of errors which is essential for a sound interpretation of results.