Impact of Argo floats on ocean analysis and forecast at Mercator Ocean

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Outline

- **Motivations for OSEs and OSSEs**

- **Dedicated experiments**

  - Impact of the number of altimeter on Mercator Ocean systems (OSEs)

  - Impact of the SLA post treatment and model equivalent computation

  - Impact of the future altimeter constellation in Mercator Ocean systems: LRM/SAR and SWOT OSSE *(Mounir Benkiran's talk and Simon Verrier's poster)*

  - Impact of the current and future Argo in situ array in the global $\frac{1}{4}°$ Mercator Ocean system: OSE, OSSE

- **Conclusion**

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Experimental setup for OSEs (*OSSEs*)

One year experiments in 2012 *(2009)* with the global $\frac{1}{4}°$ ocean system (PSY3V3):

Model and data assimilation system components:

- ocean and ice coupled model NEMO 3.1,
- SAM2 (local weekly analysis, use of a reduced order model space),
- Incremental Analysis Update,
- 3DVar large scale bias correction on temperature and salinity below the thermocline.

Assimilated data sets:

- Coriolis in situ T and S profiles and point observations,
- AVHRR Reynolds SST (1 daily field per week),
- SSALTO/DUACS along track (xvfec) sea level anomaly,
- CNES-CLS09 MDT + correction using Glorys innovations.

Boundary conditions:

- Initial ocean and ice conditions from the real time production at the beginning of 2012, boundary conditions from PSY3 for PSY2,
- Forcing fields: ECMWF atmospheric *analysis*.

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Argo OSEs

Global $\frac{1}{4}°$ system (PSY3)

Run name	Assimilated data sets			
	SST	SLA	INSITU No-argo	INSITU argo
Free Run				
Run Ref	X	X	X	X
Run argo/2	X	X	X	50% only
Run no argo	X	X	X	
Run no insitu	X	X		
RUN argo	X	X		X

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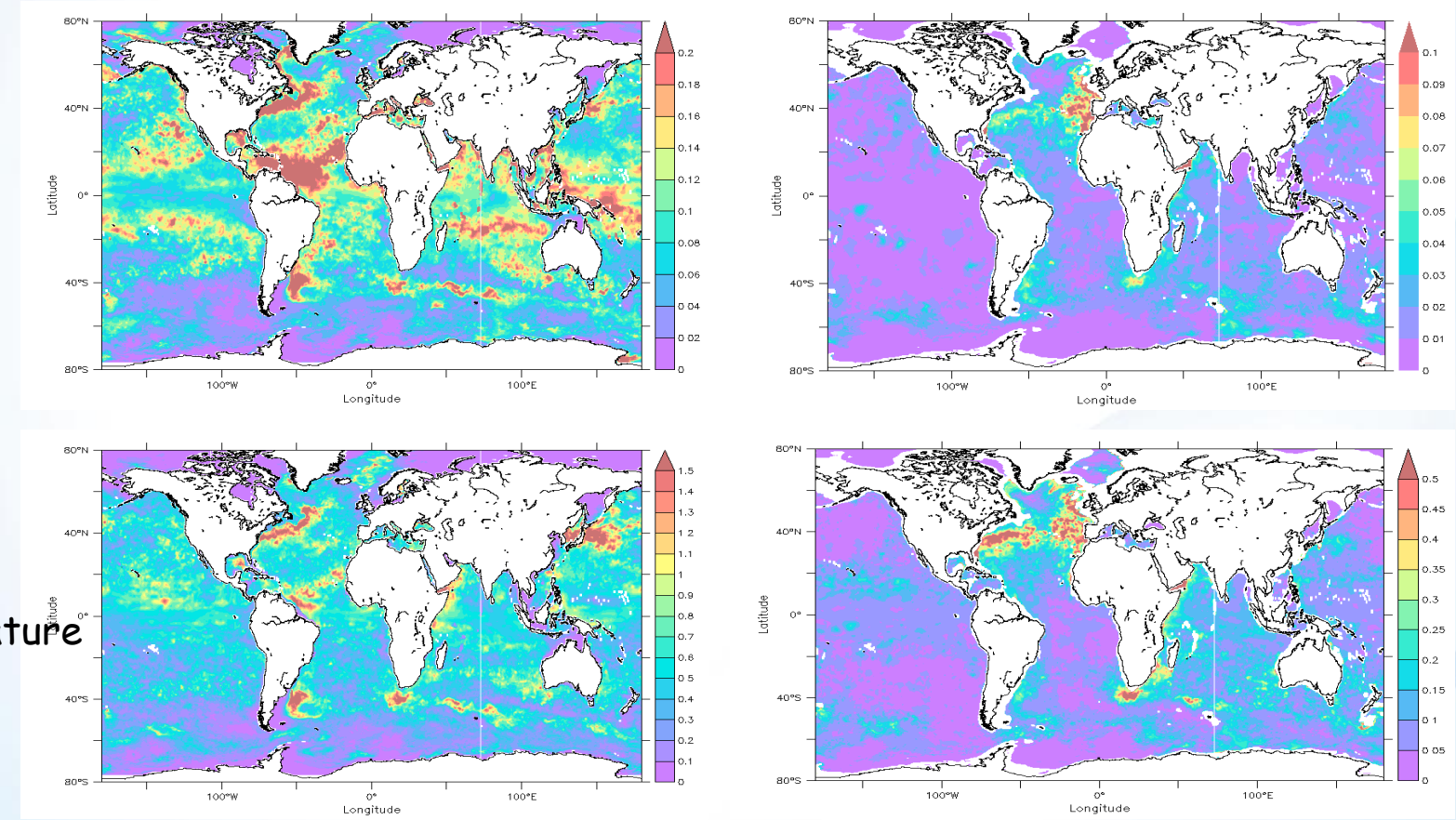
Analyzed temperature differences between OSEs

Statistics on analysed temperature between different OSEs with Argo or not assimilated (last 6 month of the experiments).

Salinity

Temperature



0-300m

700-2000m

RMS of salinity and temperature differences between Run-Ref and Run-NoArgo in the 0-300m layer and in the 700-2000m layer.

Argo OSE: innovation statistics

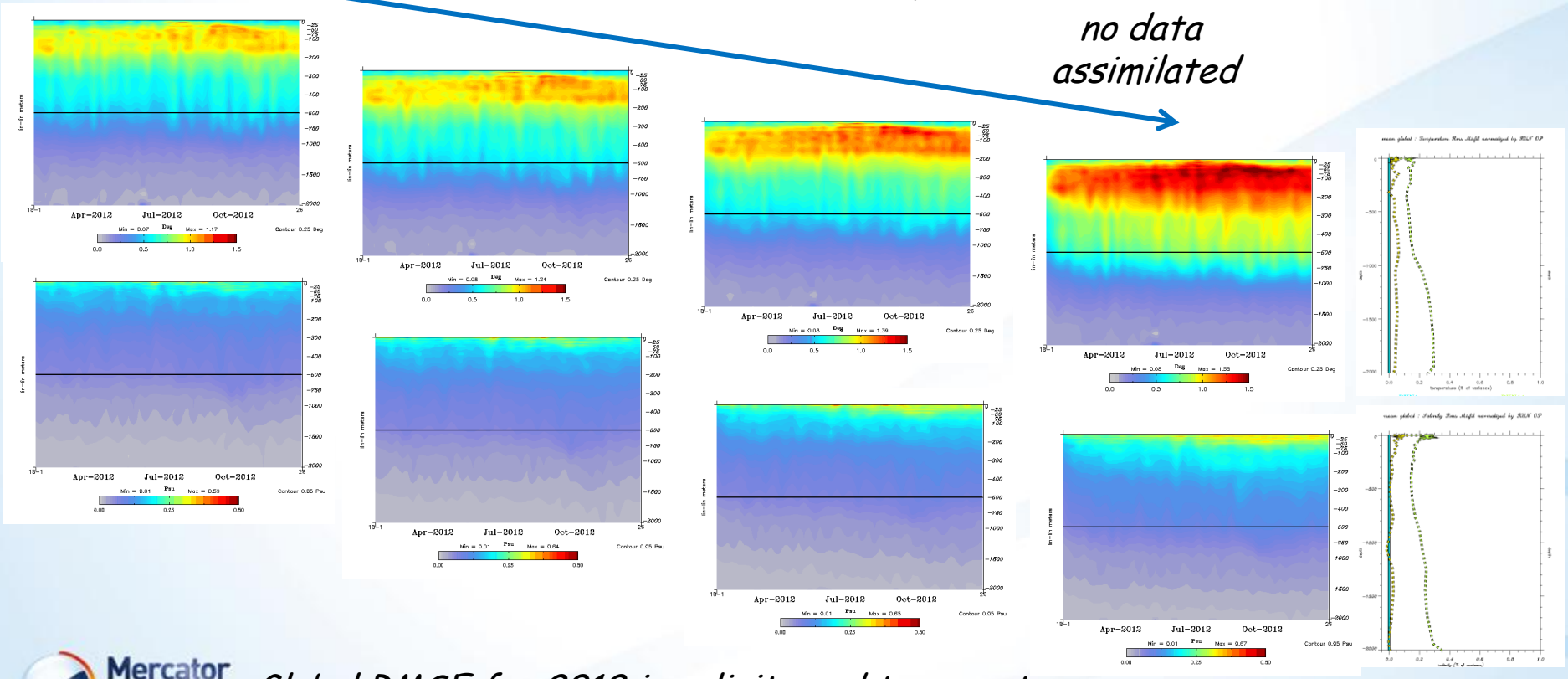
Impact of the current ARGO network on the global $\frac{1}{4}°$ analysis system: simulation comparisons in terms of observation minus model **forecast** misfits for all in situ T,S data in 2012.

Reference run

without $\frac{1}{2}$ ARGO floats

without ARGO floats

no data assimilated

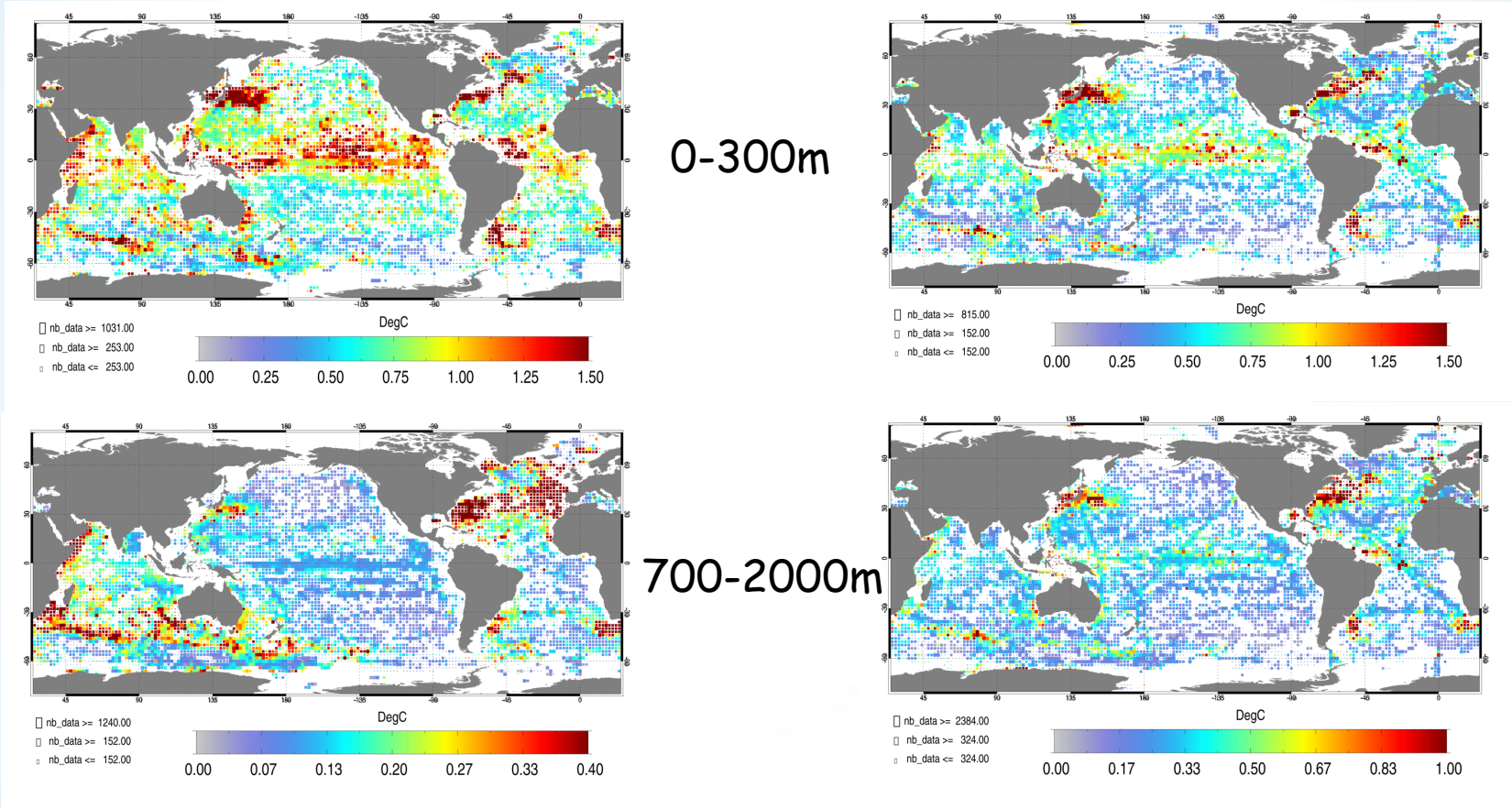


Global RMSE for 2012 in salinity and temperature

1-rmse/rmse$_{ref}$

Argo OSE: residual (O-A) statistics

Global RMS misfit between the in situ observations and OSEs analysis (last 6 months)



Run-NoArgo

Run-Ref

Spatial distribution of the RMS temperature differences between Run-NoArgo / Run-Ref and Argo observations in the 0-300m and 700-2000m layers

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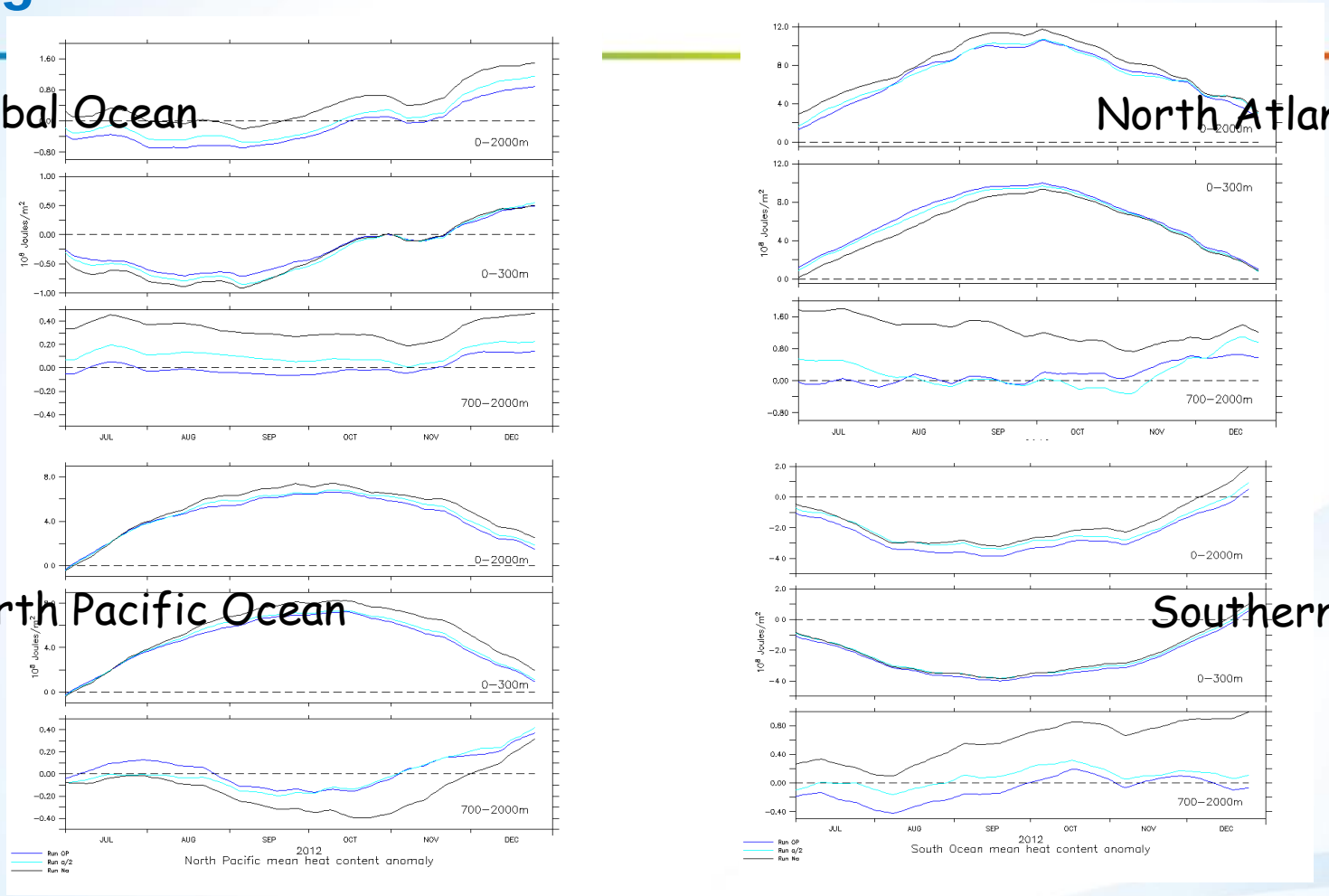
Argo OSE: heat content estimation



Heat content anomaly time series for 0-2000m layer, 0-300m layer and 700-2000m layer for the Run-Ref (blue), Run-Argo2 (light blue) and Run-NoArgo (black)

-> would be very interesting to run in a reanalysis context to explore error estimation from the observation array variations (here too short period with memory of the IC).

Conclusion of Argo OSE

The system reacts as we expected to the ARGO float assimilation in terms of observation errors.

Regions of higher impact were highlighted:

- at depth, water masses from outflow or deep convection are better represented,
- in the surface layers, the largest impact is found in the tropical band and energetic ocean regions (WBC,…)

Keeping only half of the ARGO floats degrades the analysis at all depth.

The heat and salt content estimations are sensitive to the Argo array sampling.

Argo OSSE

Motivation

Estimate the impact of some Argo network evolution on the global $\frac{1}{4}°$ ocean analysis and forecasts.
Draw some recommandations.

Observation simulation

Collocation of 2009 CORA in situ profiles with a forced **1/12°** simulation.
The simulation was initialized in October 2006 with the Levitus 2005 climatology. It is forced by real time ECMWF forcing with bulk formulae.

Assimilation in 2009 in the global $\frac{1}{4}°$ system

Initialisation with a forced model restart at the beginning of 2009.
The $\frac{1}{4}°$ simulation (T323) was initialized in january 1989 from the Levitus 98 climatology. It is forced by ERA interim atmospheric fluxes forcing with bulk formulae.

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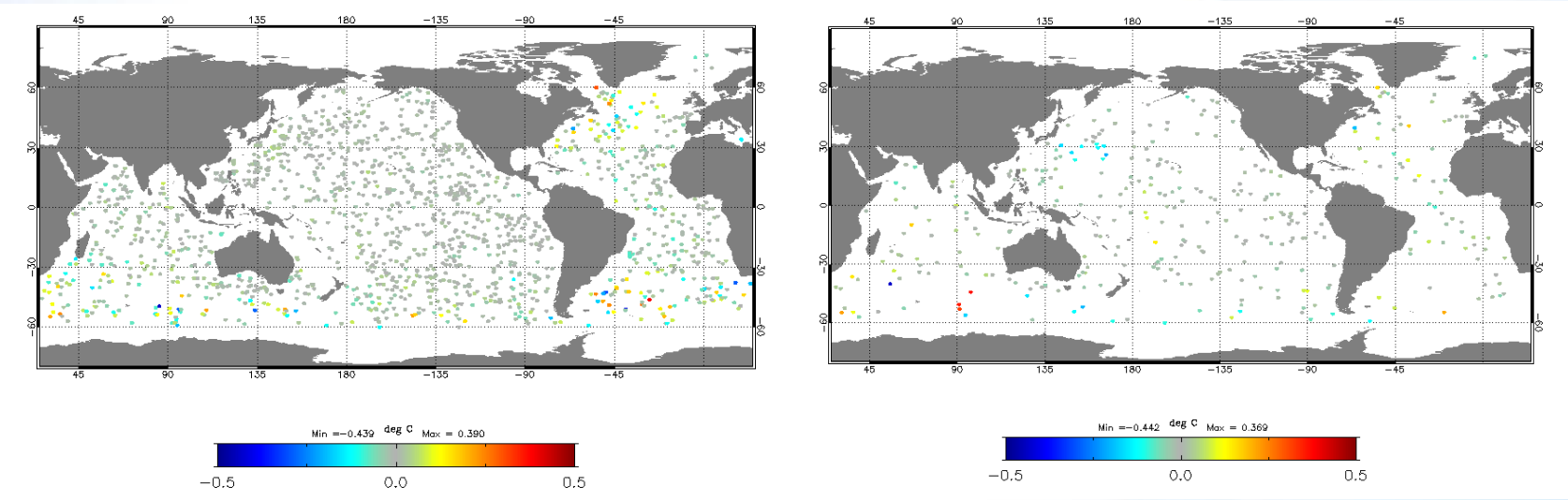
Argo OSSE

List of OSSEs experiments

	Argo up to 2000m	Argo up to 4000m	Argo up to ocean bottom
Run1 – Reference	100%	0%	0%
Run2 – all 4000m	100%	100%	0%
Run4 – 1/9 4000m	100%	11%	0%
Run3 - 1/9 bottom	100%	11%	11%

Observation locations for one week in october 2009 at 3200 m depth



All Argo floats are diving below 2000 m depth

1/3 of the floats are diving below 2000 m depth each 3 profiles.

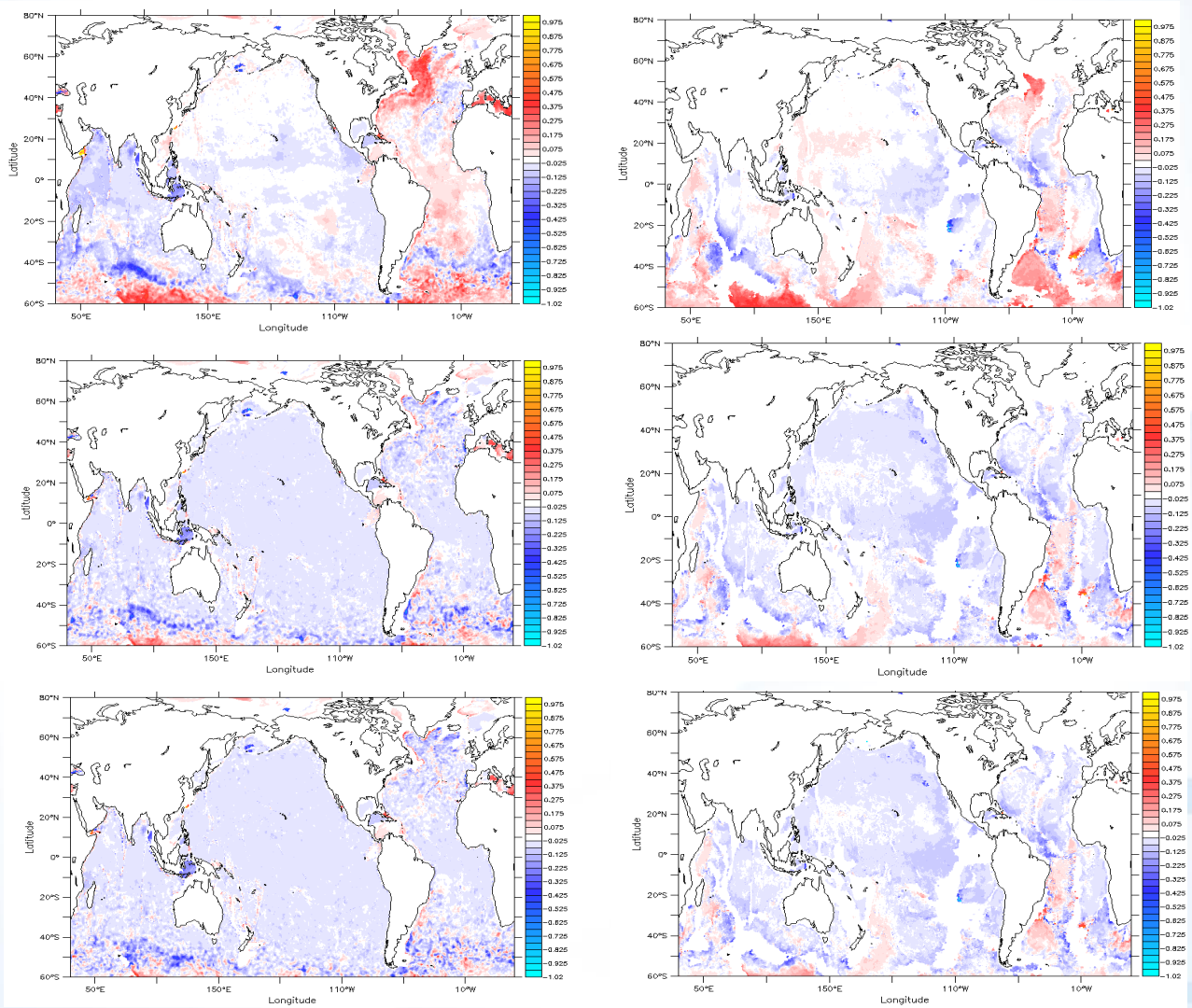
Argo OSSE: analyzed temperature error

Bias temp 2000m-4000 m — *Bias temp 4000m-6000 m*

Run with Argo up to 2000 m

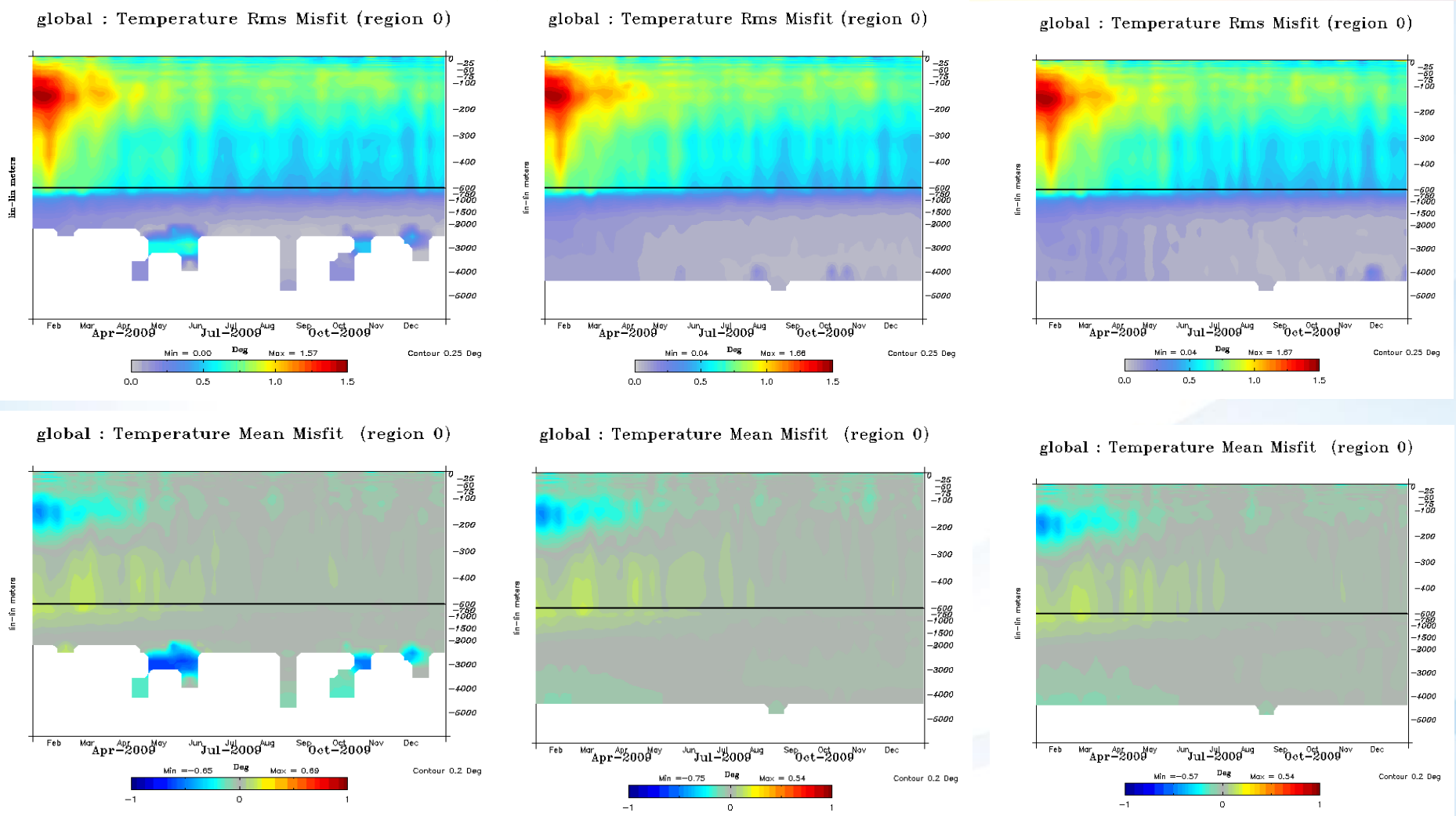
Run with 1/9 Argo up to 4000 m

Run with all Argo up to 4000 m



Mean deep ocean temperature misfits in °C between the "truth" and different OSEs for different depth ranges, over the last 5 months.

Argo OSSE: mean and RMS temperature innovations



Global RMS and mean assimilated observation – model differences in temperature when Argo floats dive at 2000 m depth maximum (left), all up to 4000m (middle) and when 1/9 dive up to 4000 meter depth (right).

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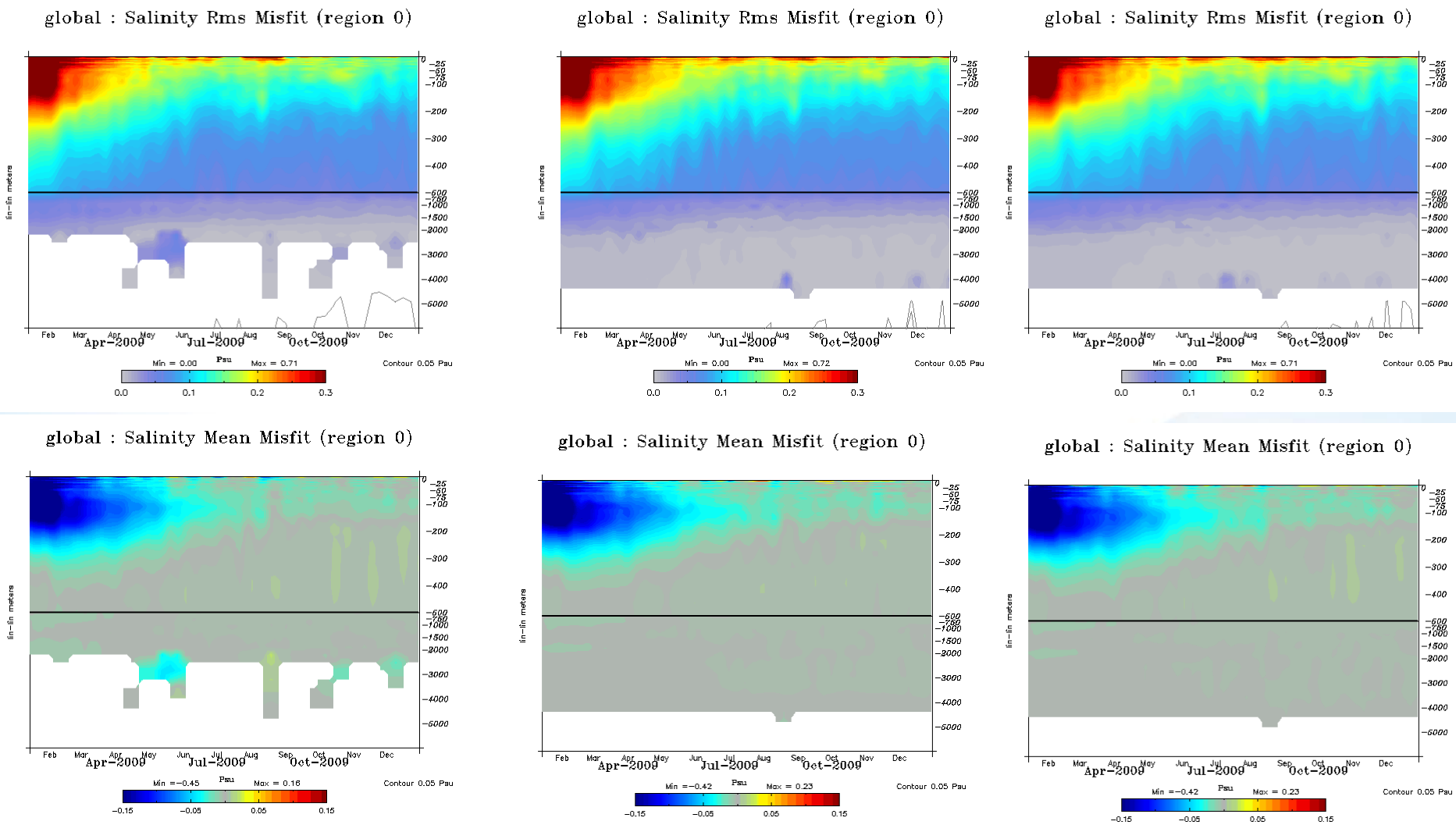
Argo OSSE: salinity innovation



Global RMS and mean assimilated observation – model differences in salinity when Argo floats dive at 2000 m depth maximum (left), all up to 4000m (middle) and when 1/9 dive up to 4000 meter depth (right).

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Argo OSSE conclusion

OSSE experiments show:

- Increasing the depth of Argo floats **profiles up to 4000 m depth** instead of 2000m reduce the biais between 2000 up to the bottom where it was large,

- Increasing the depth of Argo floats **profiles up to 4000 m depth** instead of 2000m **for only 1/9 of them** gives comparable results than if all are going up to 4000m. This is coherent with the fact we found a low temporal variability but significant large bias in some regions.

- Increasing the depth of Argo floats **profiles up to 6000 m depth** instead of 2000m **for only 1/9 of them** degrades the model solution. This shows that our present system is not tuned to handle observations up to the bottom. A deep biais slowly appears under 4000 m depth and reach 0.5°C after one year simulation.

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Conclusion on OSE/OSSE at Mercator Ocean

For Argo in situ observations:

- The $\frac{1}{4}°$ ocean forecast and analysis system is sensitive to the density change of the actual Argo array.
- Expending to depth the float profiles should allow the reduction of deep biases. A work has to be done to understand the small uniform bias appearing at depth.

Deep ocean measurements are crucial for model initialization (climatology) and validation of model estimates (forced and with data assimilation).

For along track SLA:

- Each additional altimeter has a strong impact on model fields (scale dependent).
- The analysis error reduction seems to « saturate » with the 3d altimeter.

OSE/OSSE are useful approaches for a better understanding of the impact of present and future observation array in the analysis and forecasts:

+ measure the assimilation scheme efficiency to reduce the misfit,
+ show the changes on the full 3D ocean state,
- need of independent data and relevant/sensitive criteria to evaluate the changes,
- can be far from the real situation (OSSE).

Results will depend on the model configuration, prescribed model and observation errors, the assimilation scheme itself,… -> caution when communicate on "usefulness" of a given data set for real time ocean analysis and forecasts.

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Thank you for your attention!

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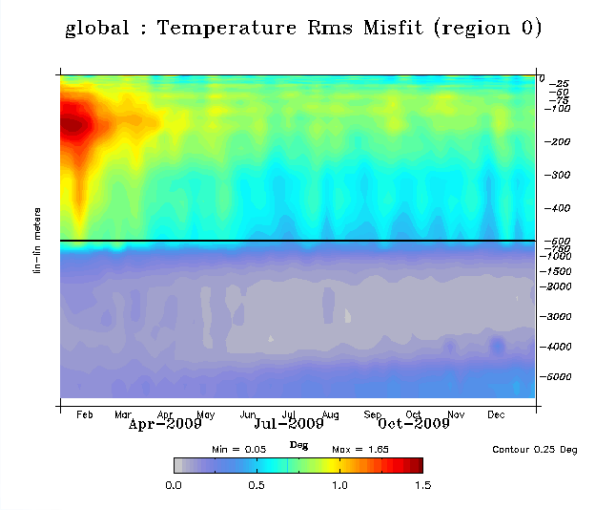
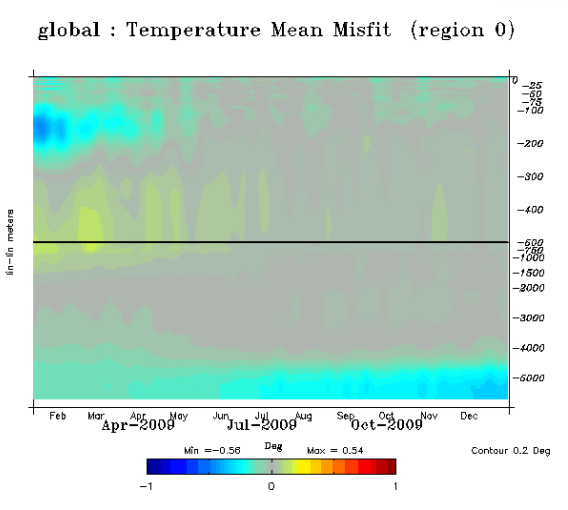
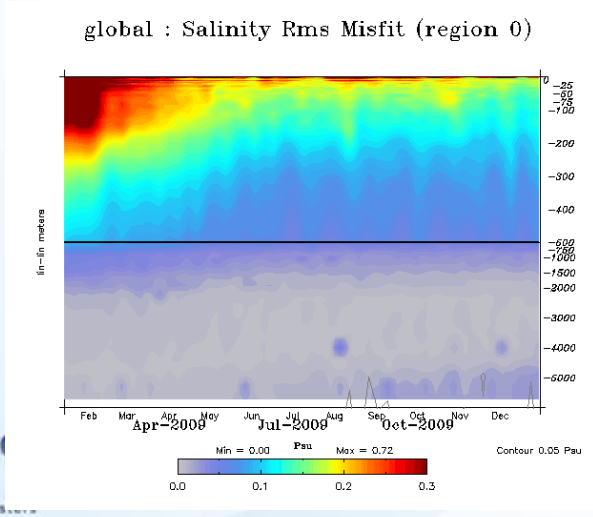
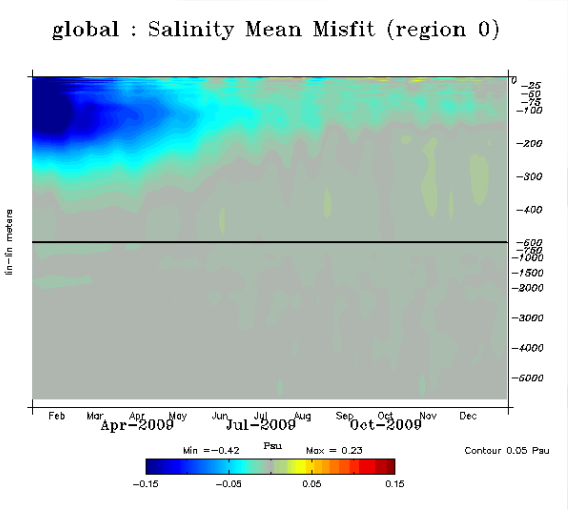
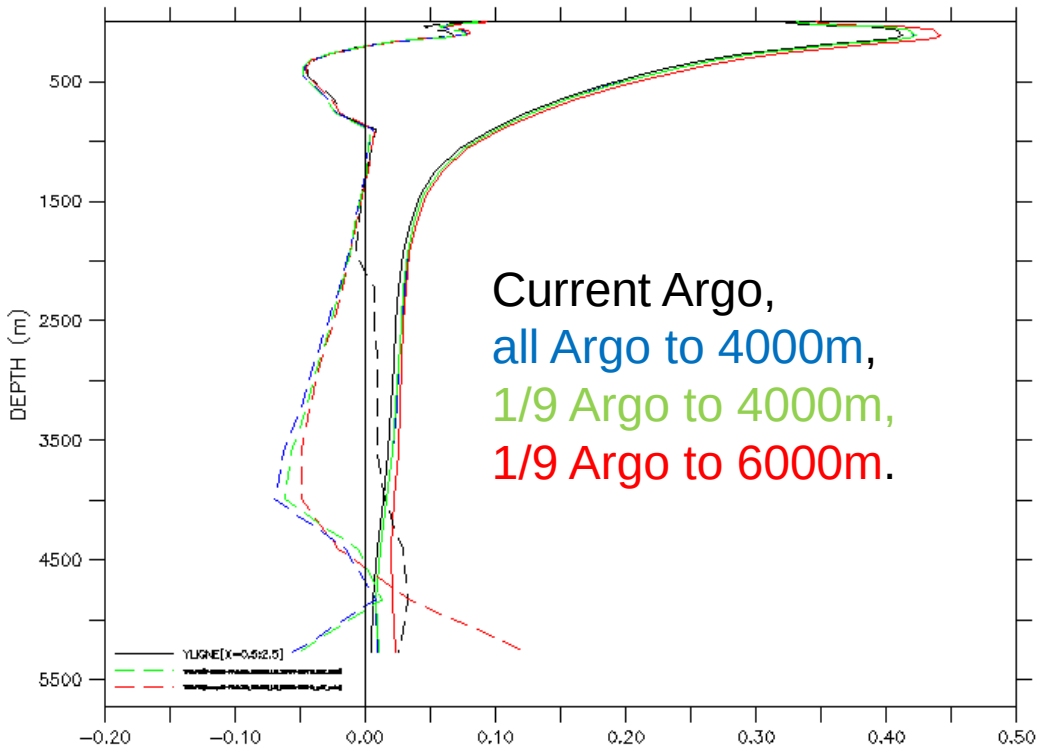
When 1/9 Argo floats are diving up to 6000 m





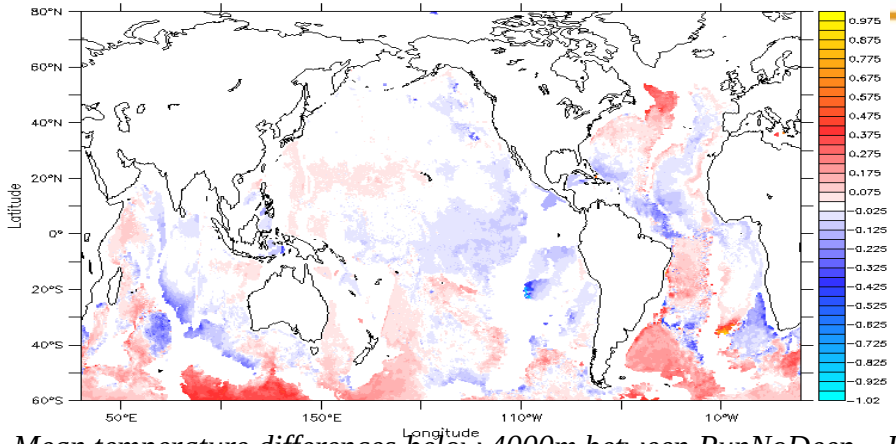




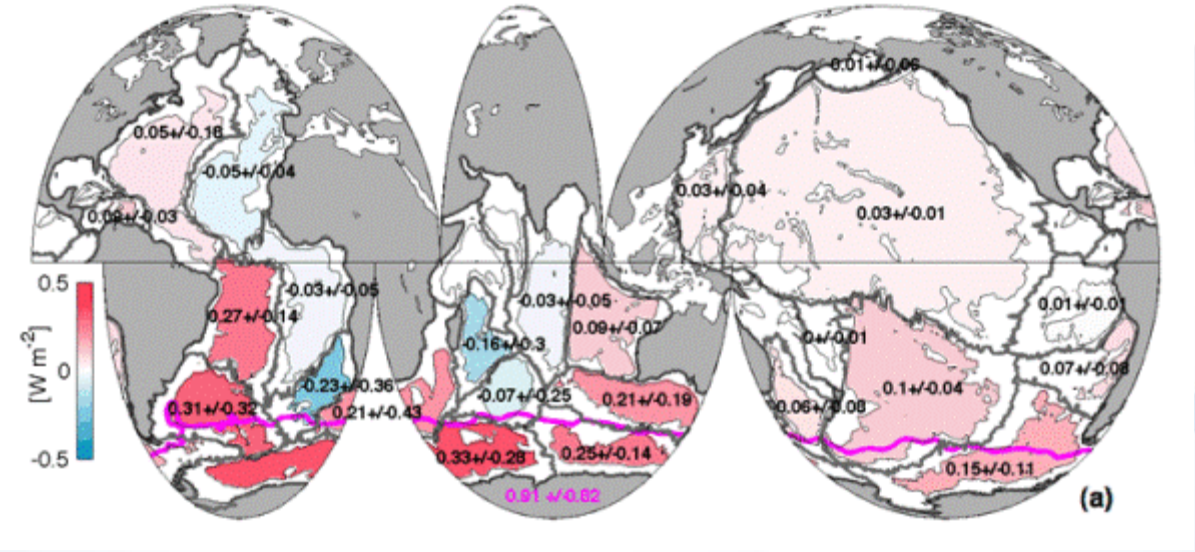


Mean (dashed lines) and Standard Deviation differences between the "true" ocean and the analysed temperature.

Deep ocean variability



Mean temperature differences below 4000m between RunNoDeep – RunTruth.

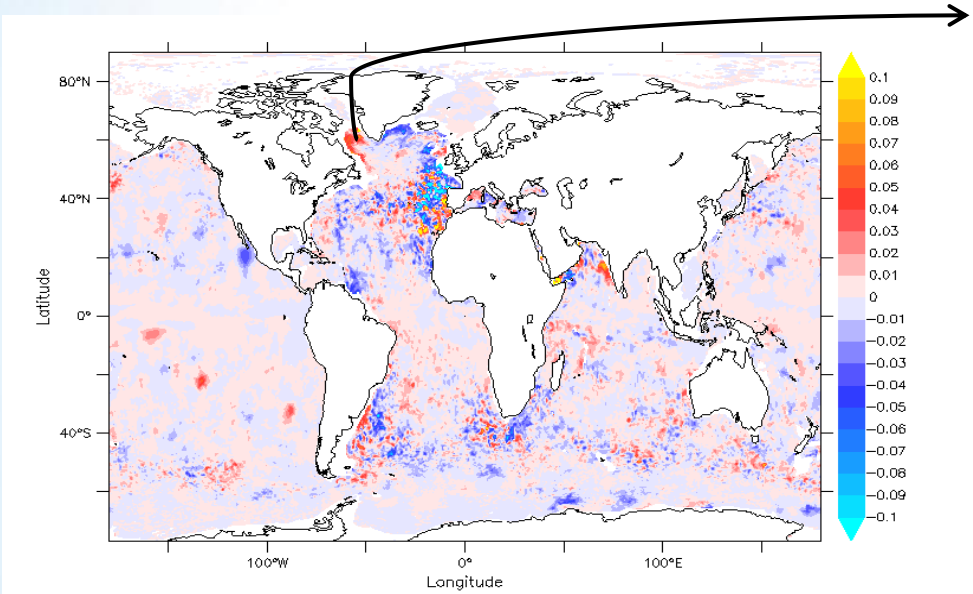


*(a) Mean local heat fluxes through 4000 m implied by abyssal warming below 4000 m from the 1990s to the 2000s within each of the 24 sampled basins (black numbers and color bar) with 95% confidence intervals. The local contribution to the heat flux through 1000 m south of the SAF (magenta line) implied by deep Southern Ocean warming from 1000 to 4000 m is also given (magenta number) with its 95% confidence interval. Basin boundaries (thick gray lines) and 4000-m isobath (thin black lines) are also shown (**from Purkey and Jonhson, 2010**).*

Analysed temperature in different OSEs

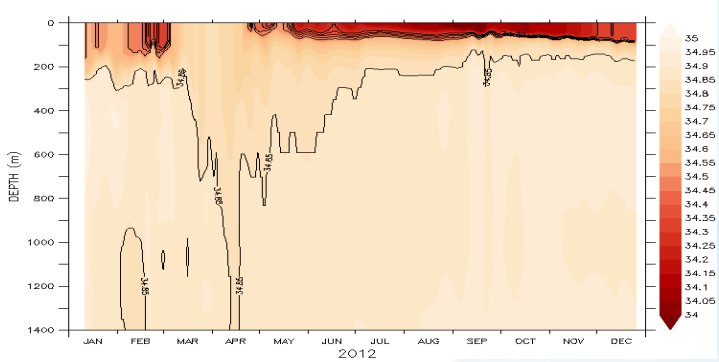
Impact of the current ARGO network on the global $\frac{1}{4}°$ analysis system:

Water mass representation

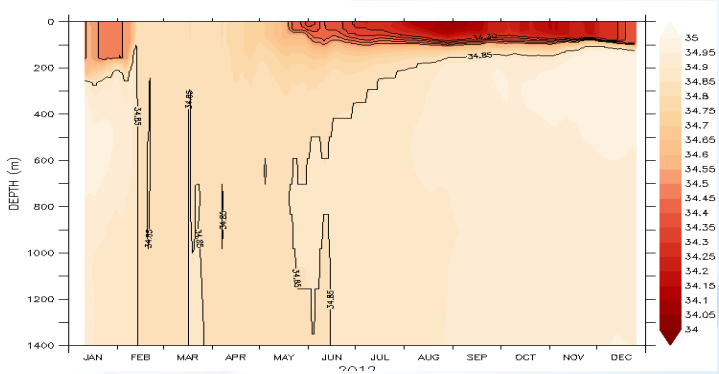


Differences in 1000-2000 m salt content for June 2012 between the simulation with all ARGO and no ARGO floats assimilated (in PSU).

All ARGO floats



No ARGO floats



Time evolution of the salinity profile in the Labrador Sea at 56°E-60°N