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Performance and quality assessment of the new CMEMS global ocean monitoring and forecasting real-time system

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Outline

- Main ingredients of an analysis and forecasting system
- Main recent system updates and illustration of some of them
- Performance and quality of the new system
- Conclusions and Perspectives

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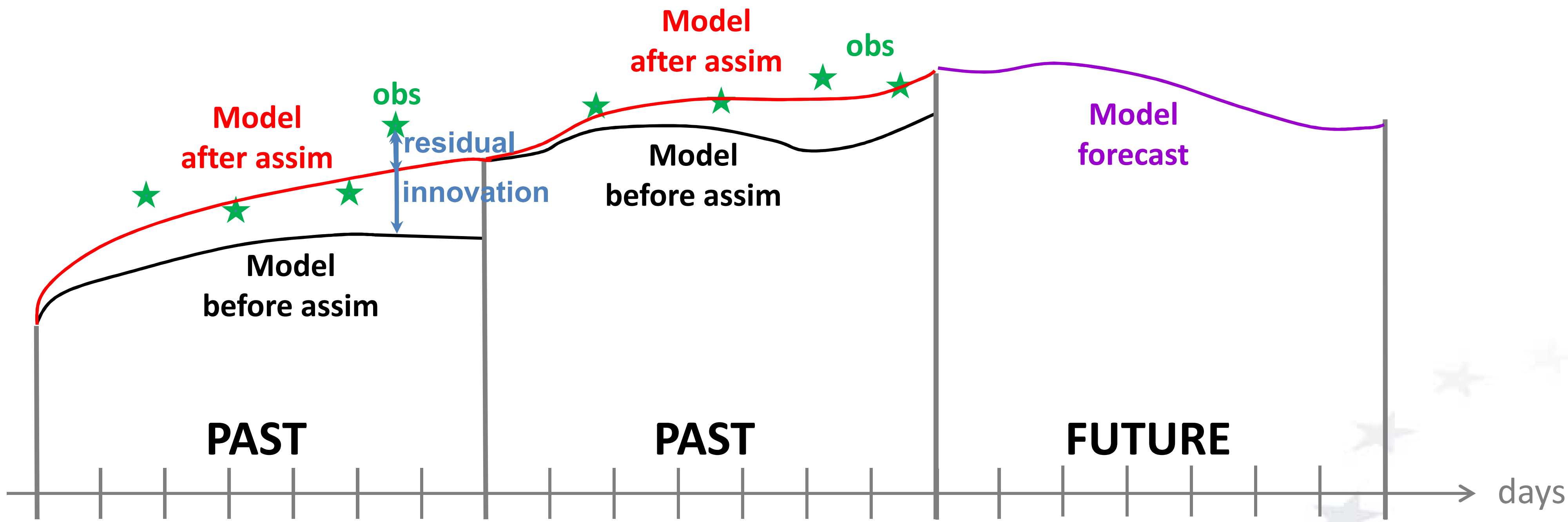
General principle

MERCATOR OCEAN

Ocean numerical model + observations + data assimilation (mathematical methods)

The aim of a data assimilation method is to force the ocean model to be **as close as possible of the observations** available in the past to obtain the **best forecast** in the future, **taking into account observations and model errors.**



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Main updates of the system

R&D activities have been conducted these last years to improve this system

Previous system

Service
Weekly 7-day analyses and daily 7-~~day fo~~recasts

Model (ocean and sea-ice)
- **NEMO 3.1, horizontal 1/12° et 50 vertical levels**
- **LIM2_EVP (sea-ice model)**
- **3h ECMWF atmospheric forcing**

Data assimilated
- **SLA (CMEMS) +** MDT CN~~ES CLS09~~
- SST ~~AVHRP~~
- **T/S vertical profiles (CMEMS)**

Assimilation
- **SEEK (Kalman filter)**
- **3D-Var large scales bias correction**

Available Period: 201~~3 → now~~

New system

(operational since Wednesday, October 19, 2016)

Service
Daily 10-day forecasts

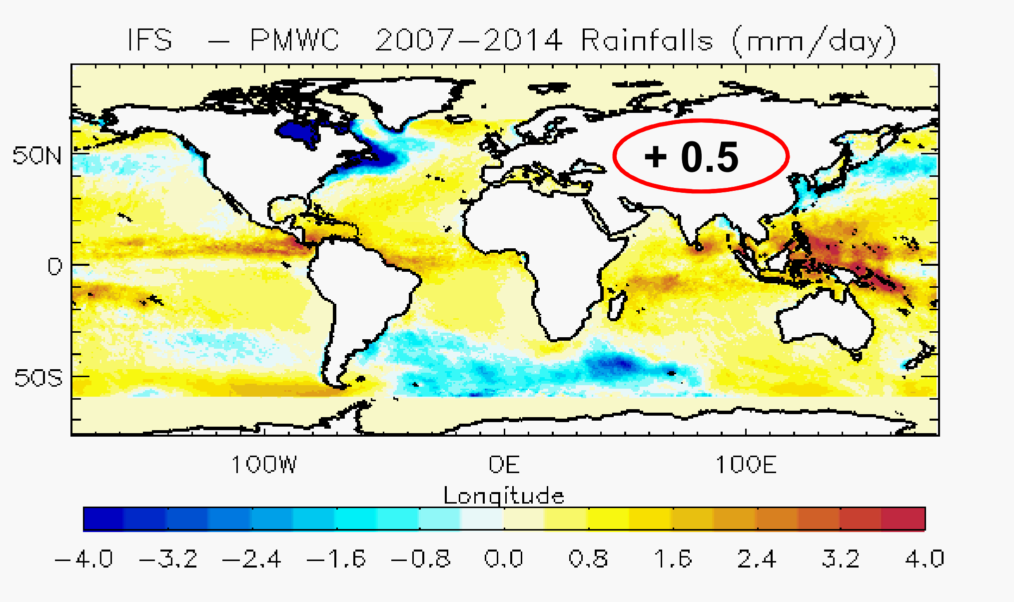
Model
- Ice-sheets and glaciers melting added to the runoffs
- Large scale correction of precipitations
- Global steric effect added to SSH

Data assimilated & Assimilation
- MDT CNES-CLS13
- Assimilation SST (OSTIA CMEMS)
- Assimilation sea-ice concentration (OSI-SAF CMEMS)
- WOA 2013 “weak assimilation” below 2000m
- Adaptive tuning of SLA and SST observation errors

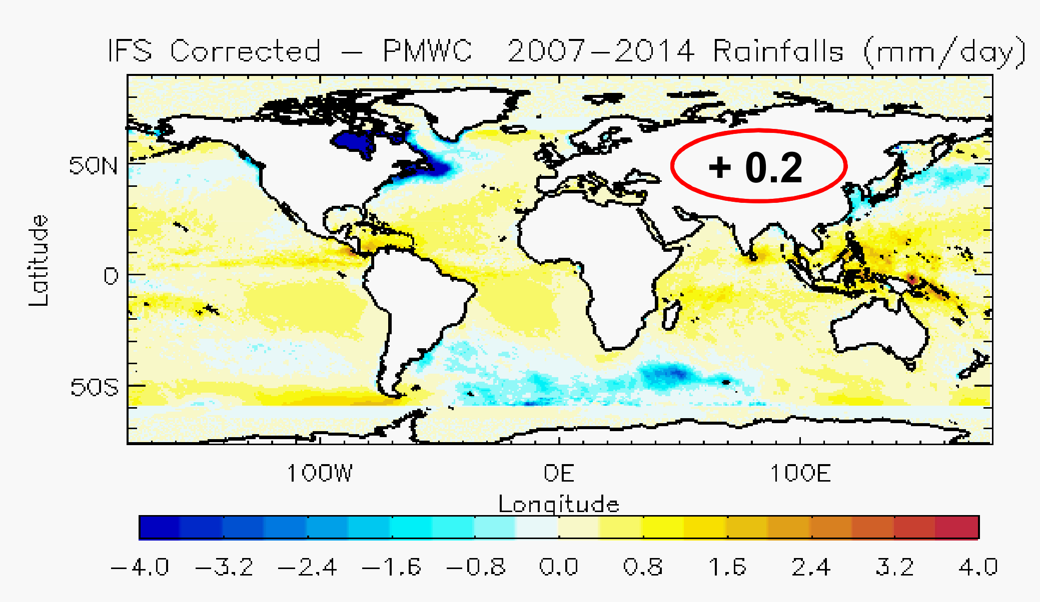
Available Period: 2007 → now

Large-scale correction of precipitations IFS

Without correction



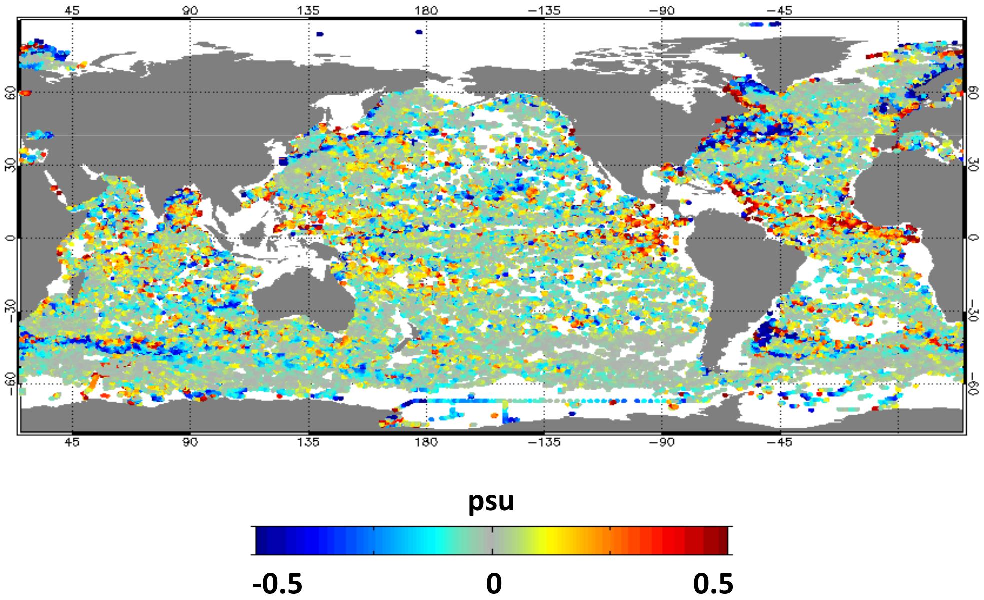
With correction

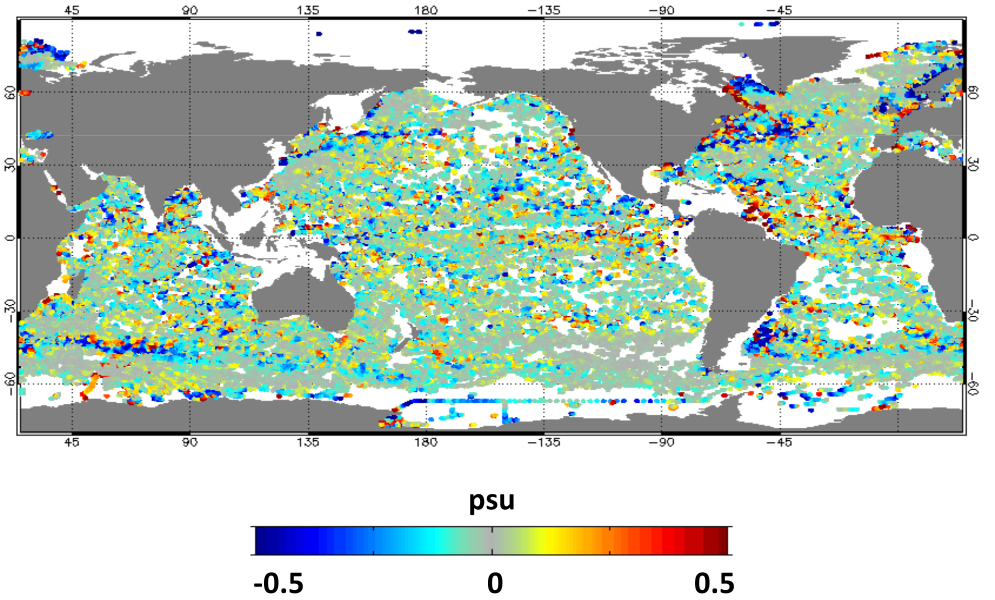


Impact of precipitations correction

Correction of precipitations …

Mean surface salinity innovation (2011)





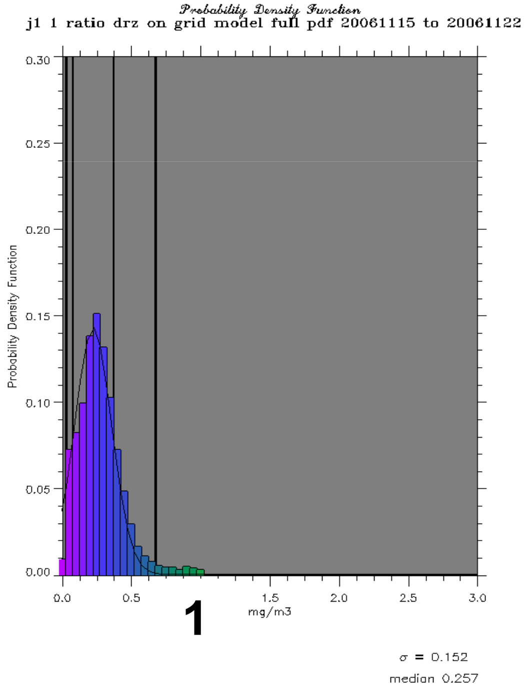
Adaptive tuning of observation errors

The prescription of observation errors in the assimilation systems is often too approximate...

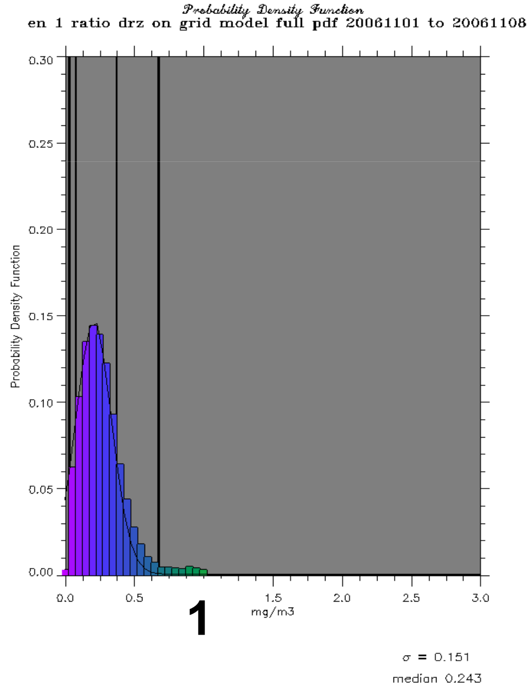
$$\text{Ratio} = \frac{\textbf{residual (innovation)}^{T}}{\alpha \ \textbf{obs error}}$$

- Ideally, ratio=1
- ratio < 1 => obs error overestimated
- ratio > 1 => obs error underestimated

Jason1



Envisat



The objective of this diagnostic is to improve the error specification by tuning **an adaptive weight coefficient α** acting on the error of each assimilated observation

Adaptive tuning of observation errors

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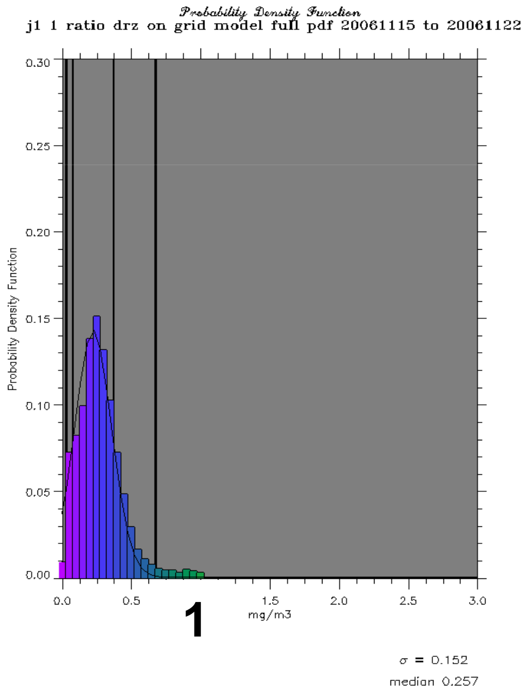
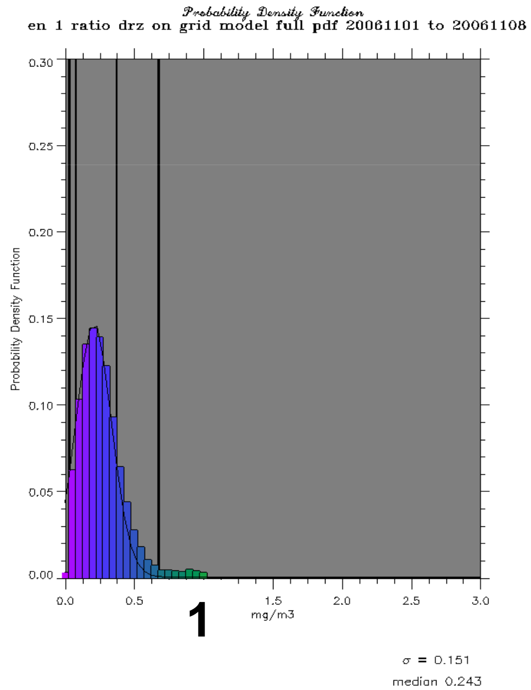


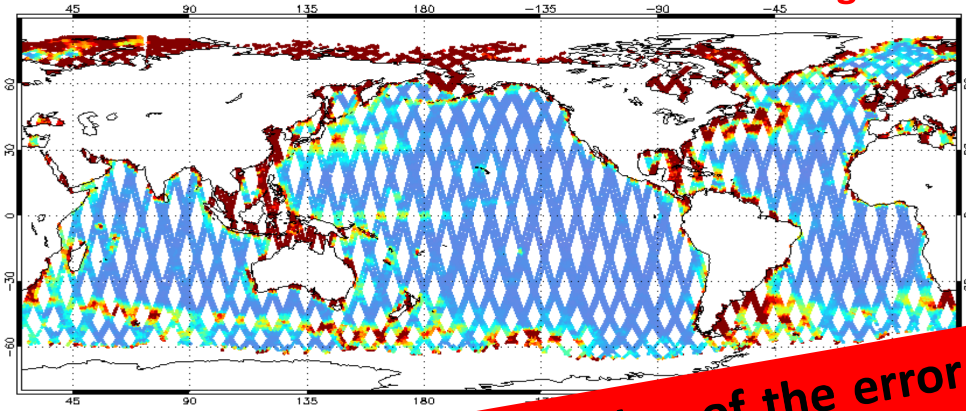
Envisat



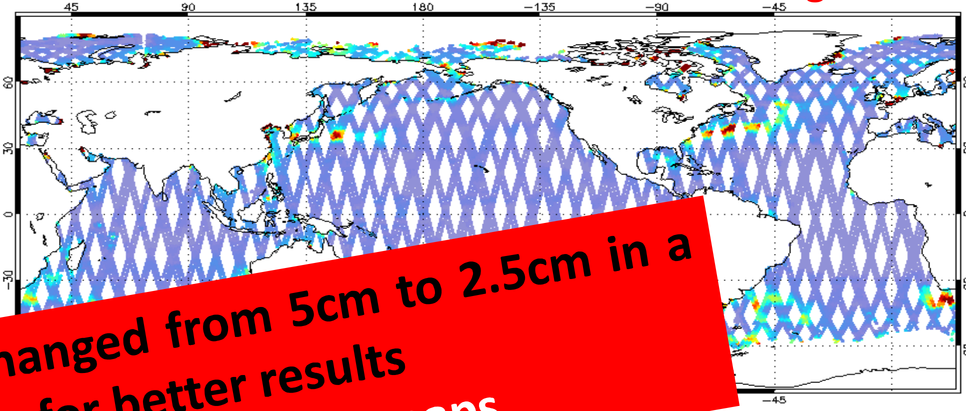
Either for SLA or SST, we improve the performances of the system using this adaptive tuning

Adaptive tuning of observation errors (SLA)

Envisat error on 20090923 without tuning

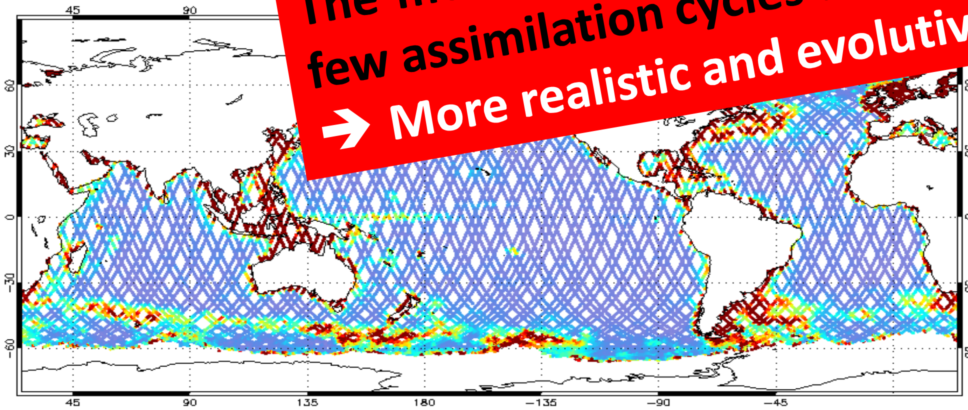


Envisat error on 20090923 with tuning

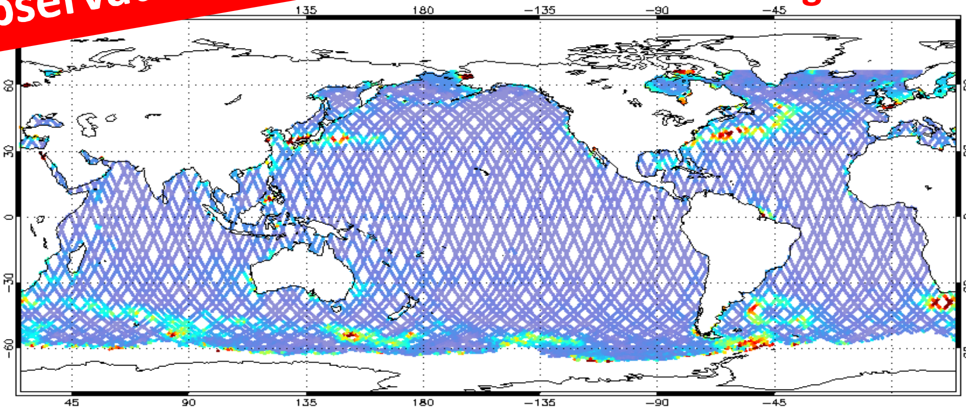


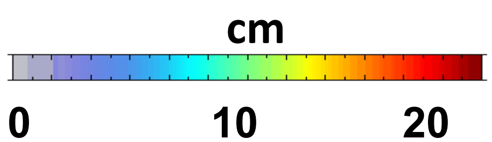
The median value of the error changed from 5cm to 2.5cm in a few assimilation cycles and allows for better results
➔ More realistic and evolutive observation error maps

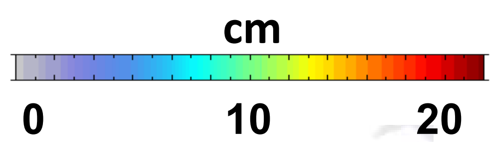
Jason2 e



or on 20090923 with tuning

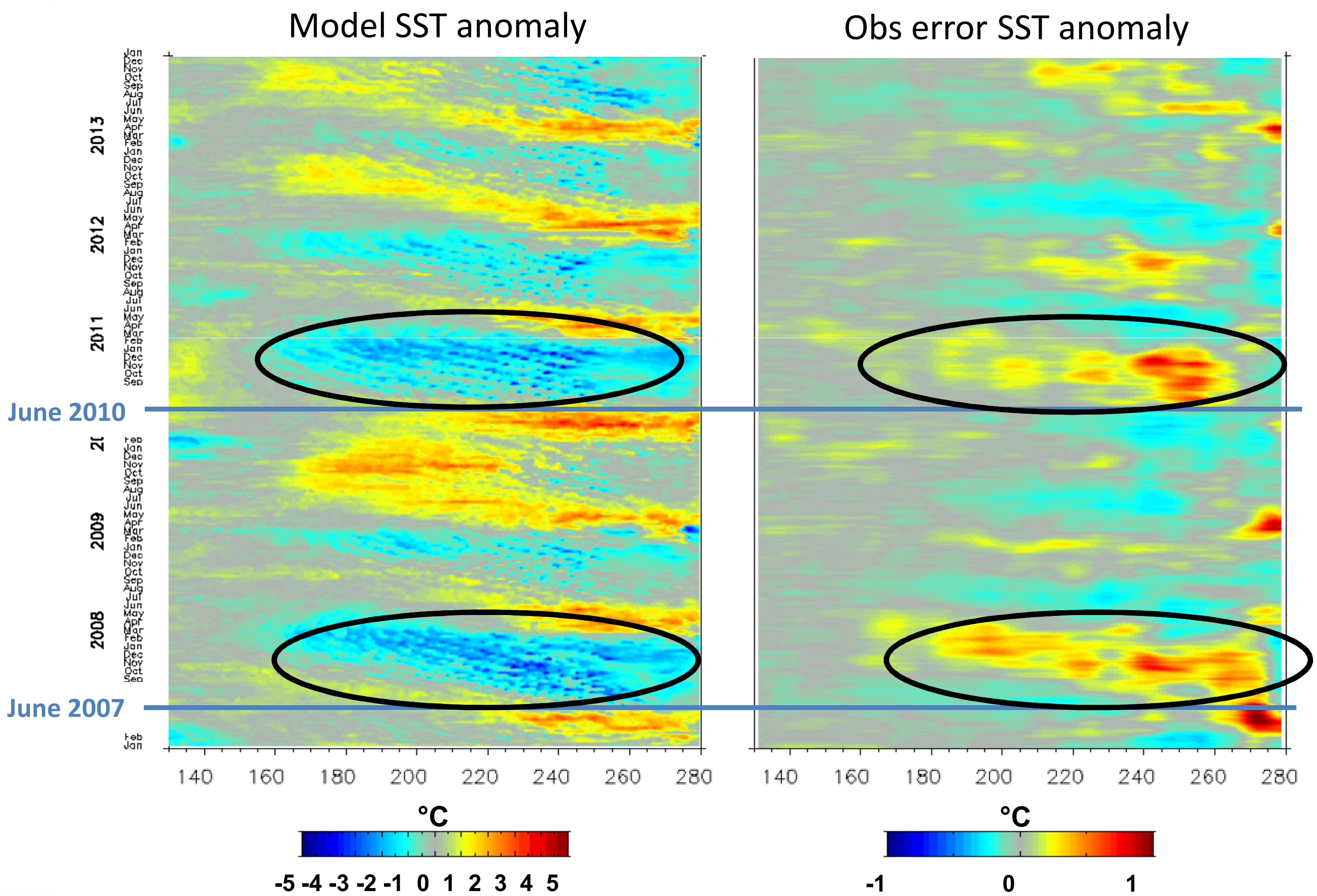






Adaptive tuning of observation errors (SST)

Section at latitude 3°N (seasonal cycle removed)



The SST anomalies in the equatorial Pacific clearly show the propagation westwards of TIW in the second half of the year. This is more pronounced during episodes of La Nina (mid- 2007 and mid-2010).

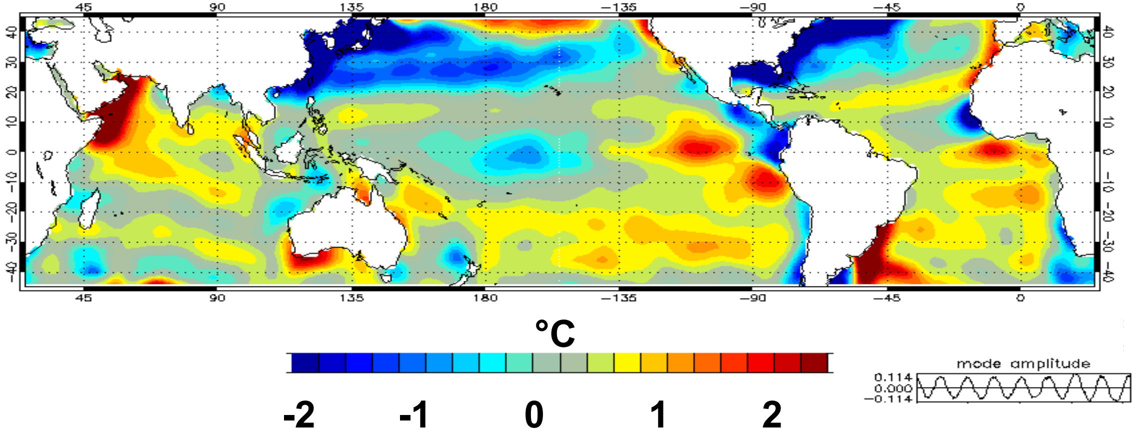
The error anomalies estimated by "Desroziers method" show that the error increases when these TIWs are more marked.

When model SST and OSTIA SST are smoother, the error decreases.

Adaptive tuning of observations errors (SST)

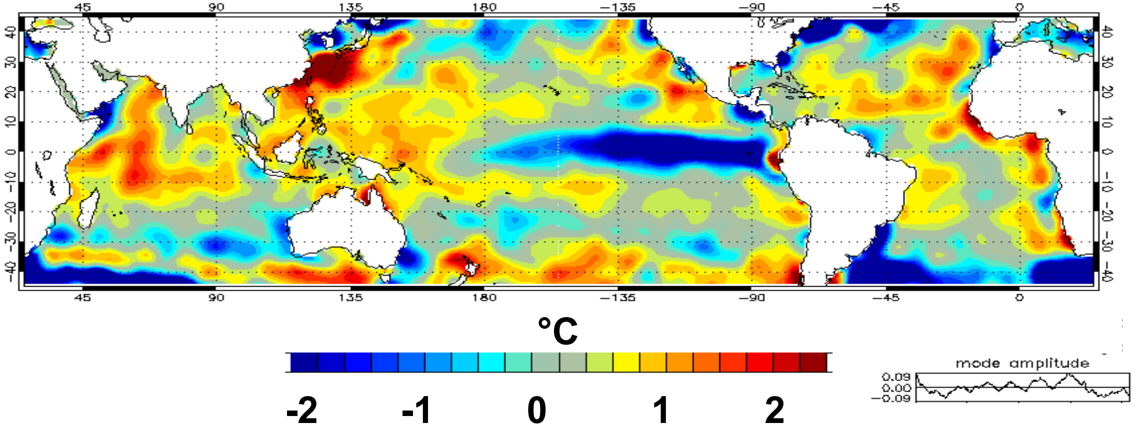
Mode 1 is associated to the seasonal cycle.

EOF SST error mode #1 with 30% variance



Mode 3 is associated to the interannual signal (La Nina → El Nino).

EOF SST error mode #3 with 8% variance



The SST error adapts both to the seasonal and interannual fluctuations

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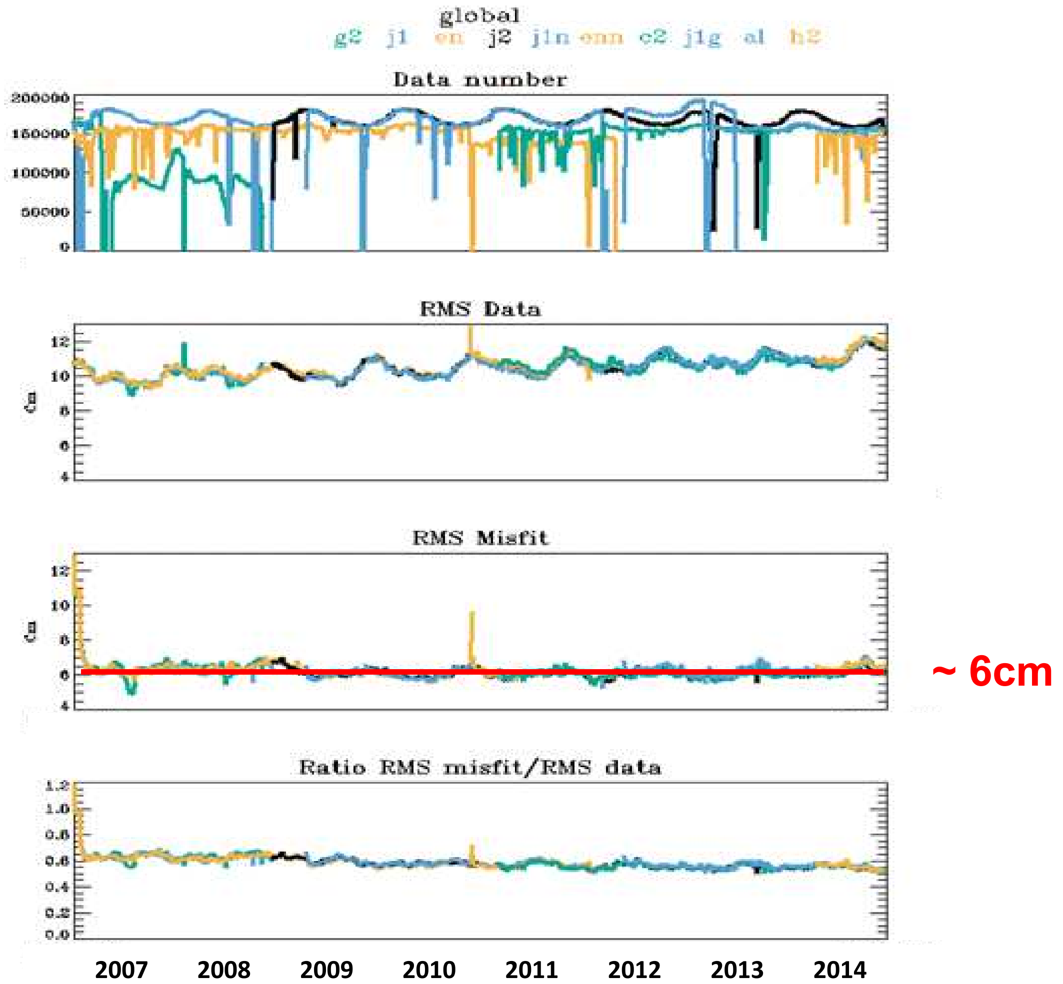
SLA

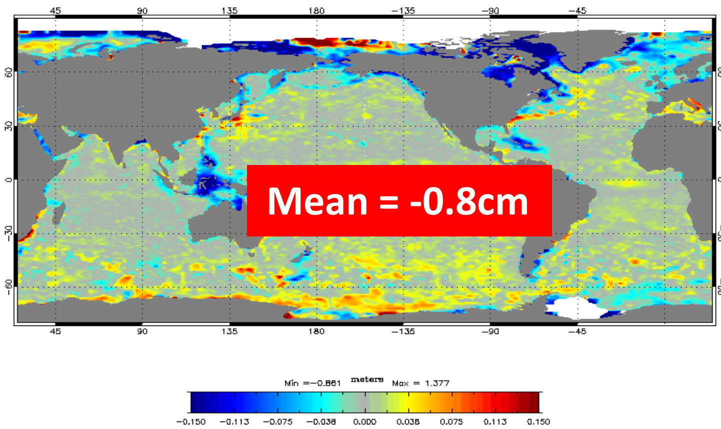
New system



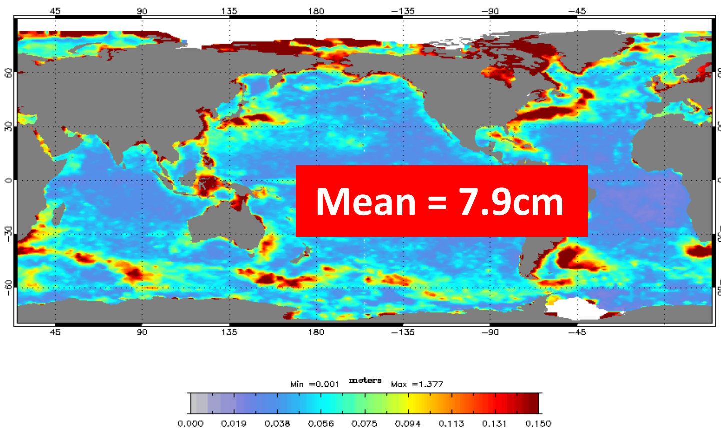
SLA (year 2015)

Previous system

SLA residual

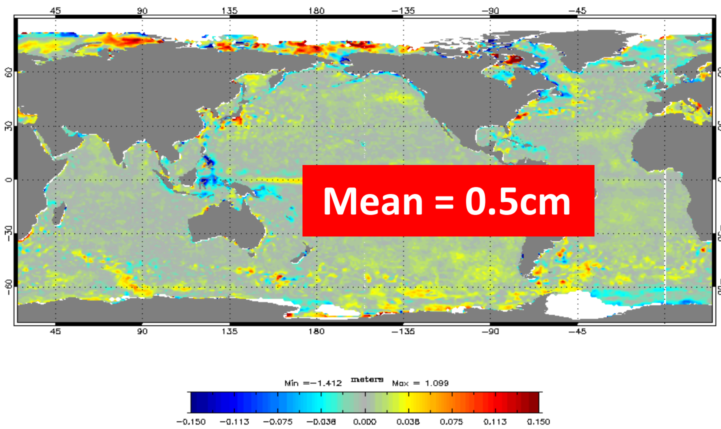


SLA RMS residual

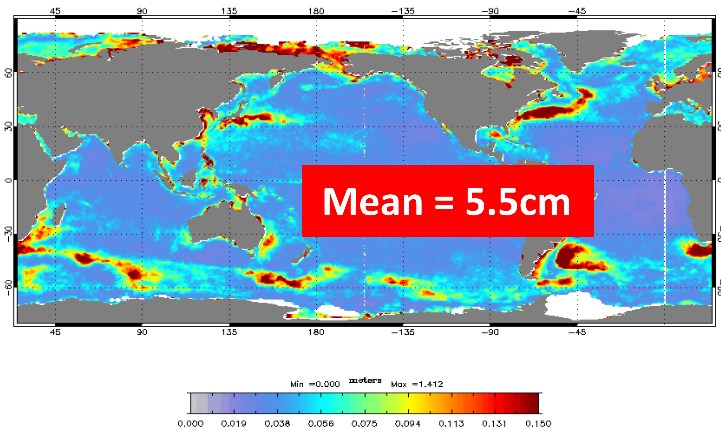


New system

SLA residual

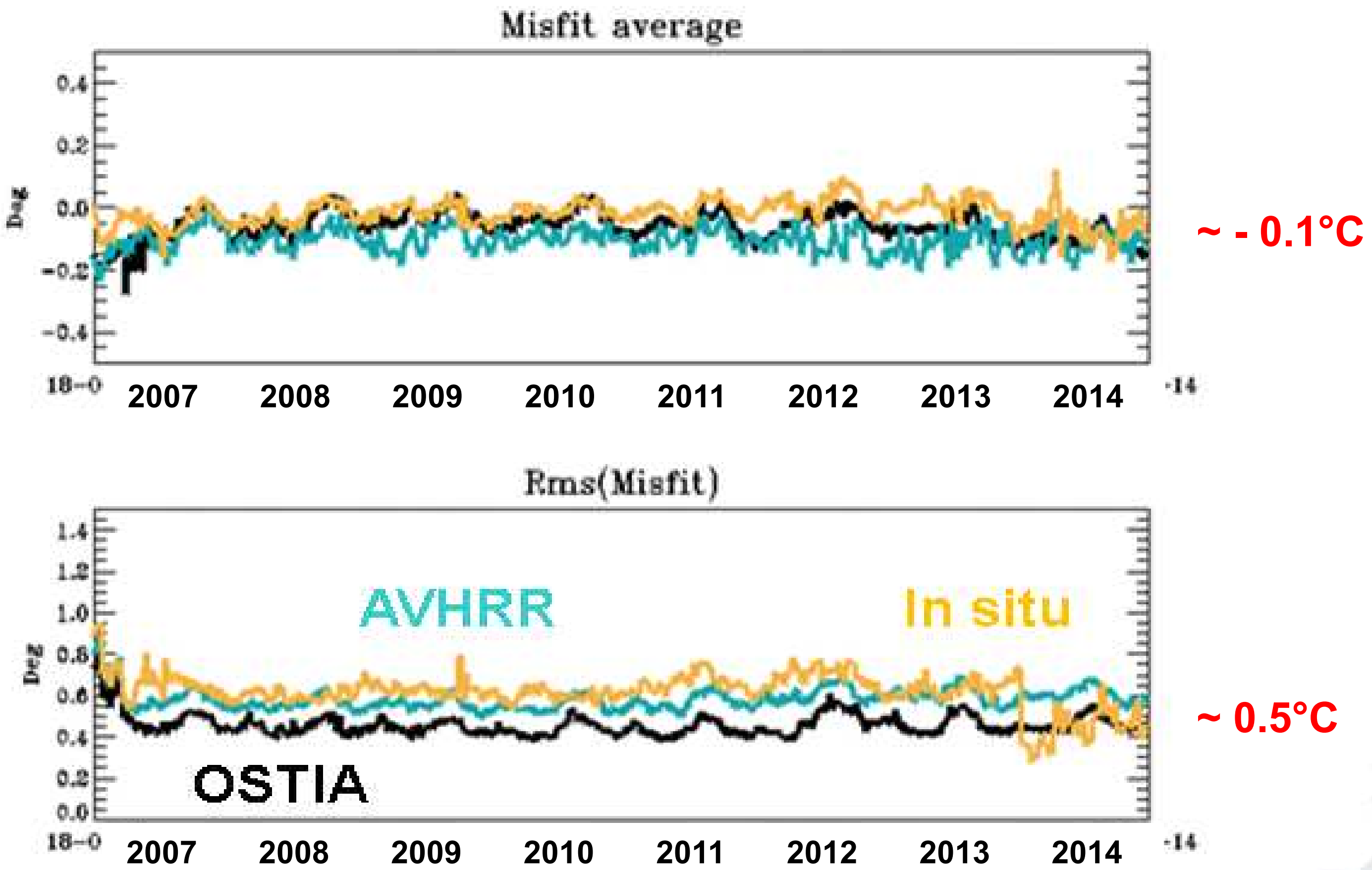


SLA RMS residual

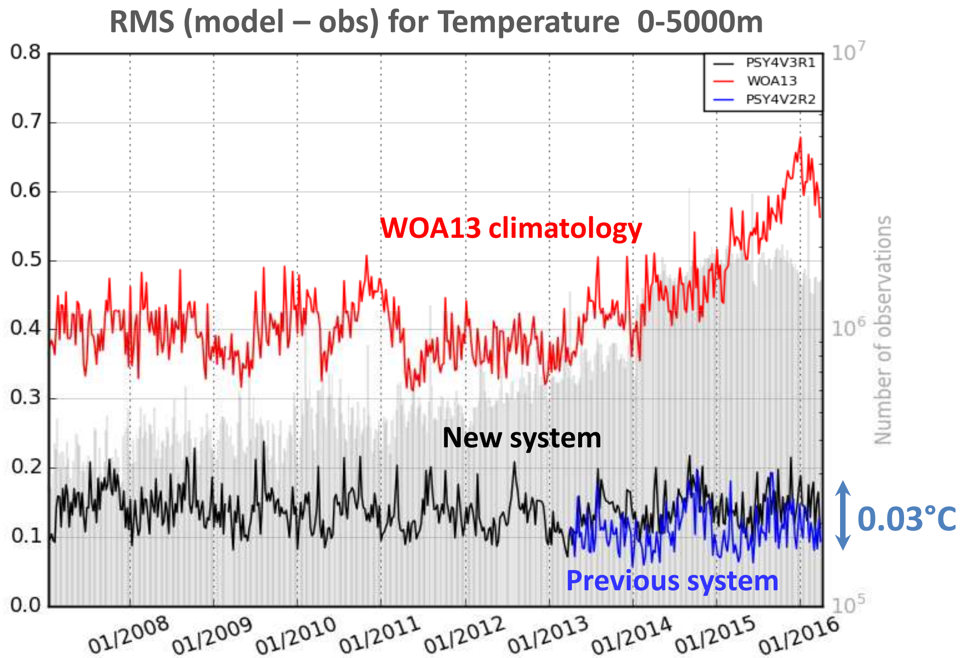


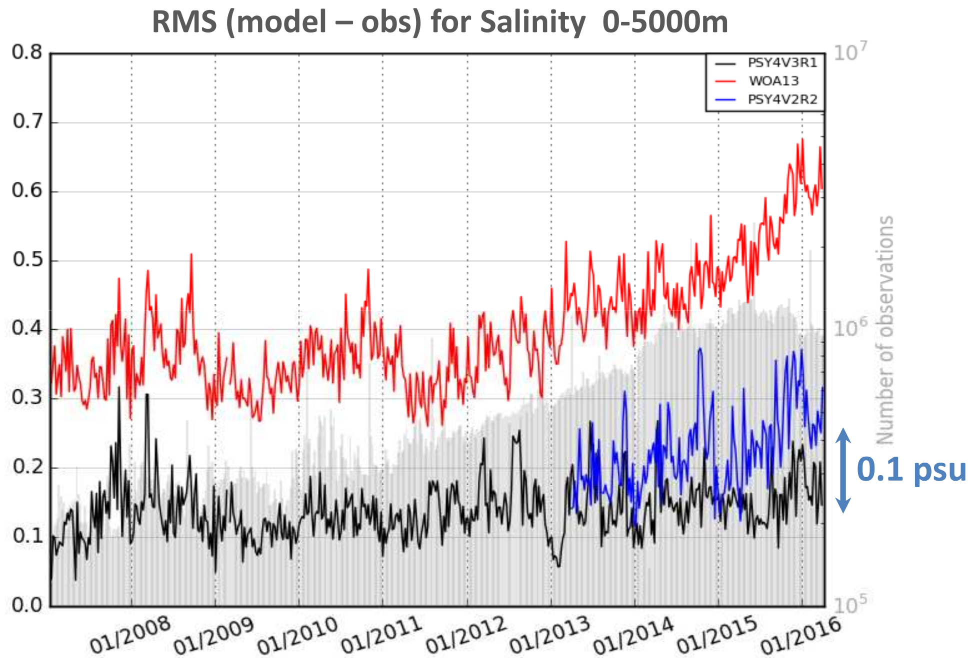
SST

New system



3D T/S : RMS (analysis-obs)

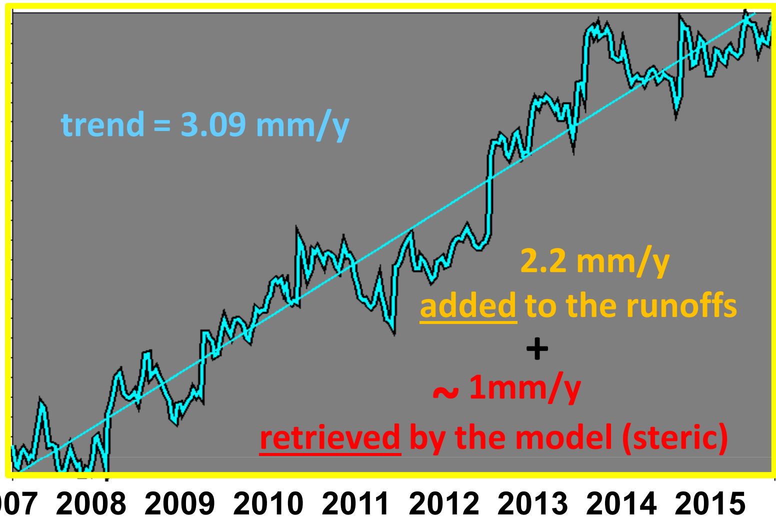


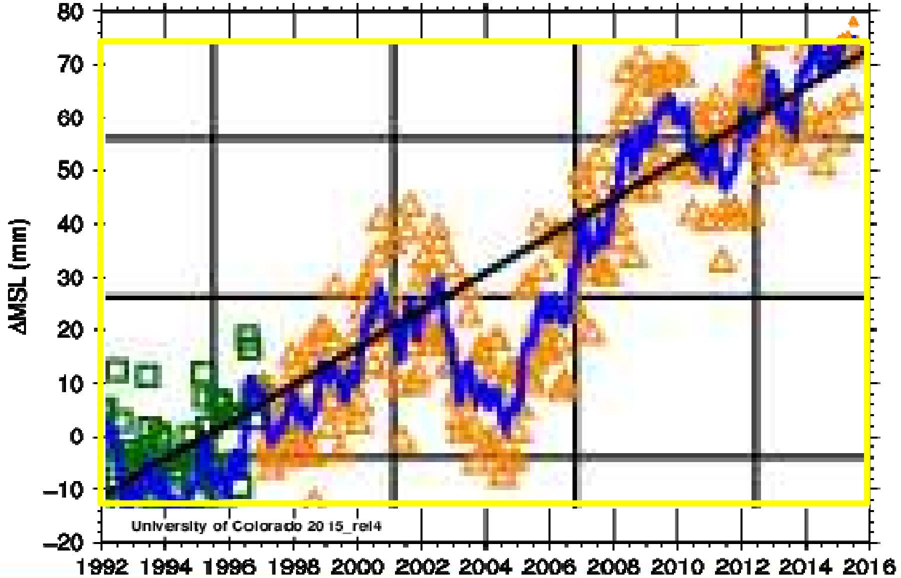


→ **This allows having more accurate description of the water masses**

Global mean SSH (2007-2015)

Better mass balance and GMSL trend





Recent estimated trends in GMSL and components (Chambers et al., 2016)

Quantity	Period	Trend (mm yr–1)
GMSL	2005.0-2015.0	3.17 ± 0.671
Thermosteric		
0-2000m	2005.0-2015.0	0.86 ± 0.11
Below 2000m	~1995-2005	0.11 ± 0.1
Total Thermosteric	~2005 - ~2015	0.97 ± 0.15
Mass	2005.0-2015.0	2.11 ± 0.362
Sum of Components		3.08 ± 0.39

Model = 3.09 mm/y

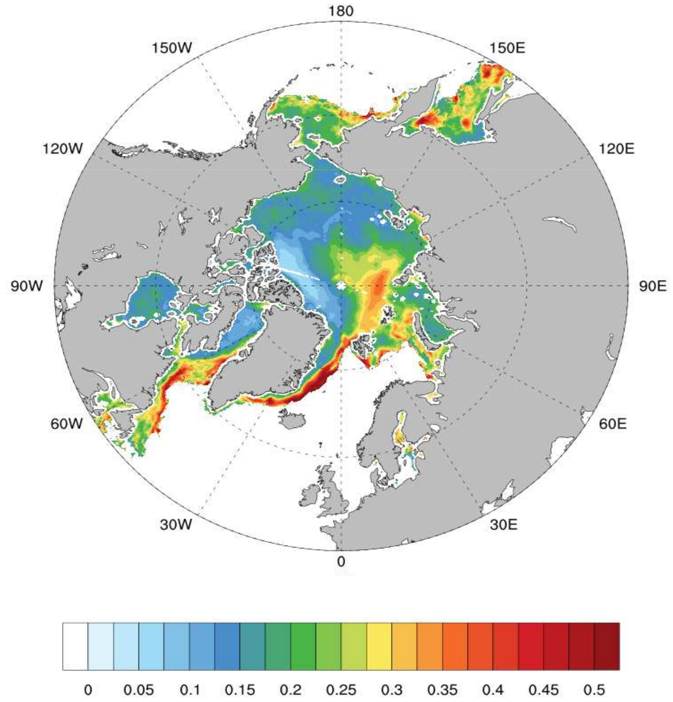
Model = 1 mm/y

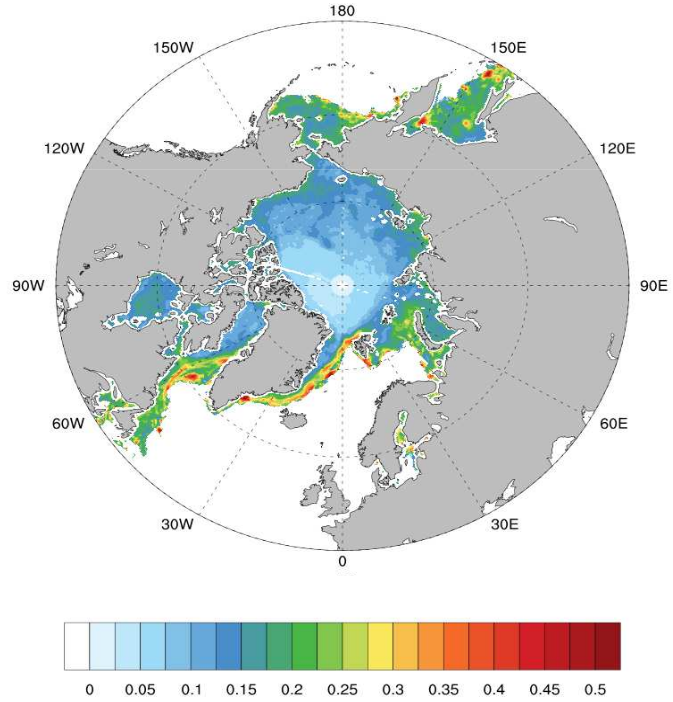
Model = 2.2 mm/y

Sea-ice concentration (Arctic)

Previous system | **New system**

RMS (model – OSISAF)

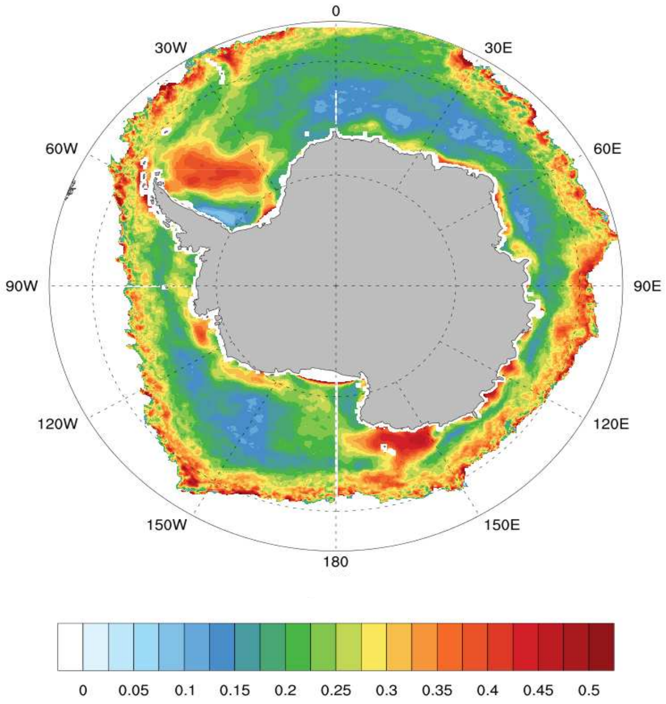


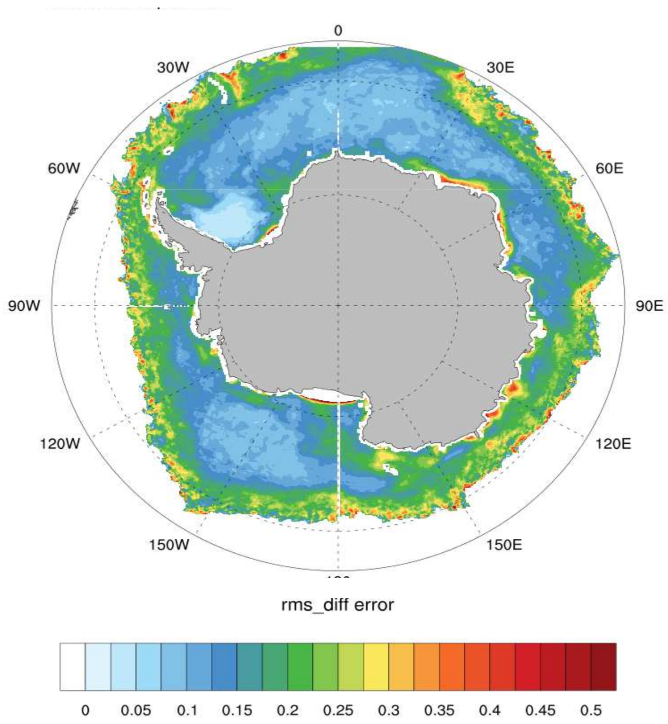


Sea-ice concentration (Antarctic)

Previous system | **New system**

RMS (model – OSISAF)





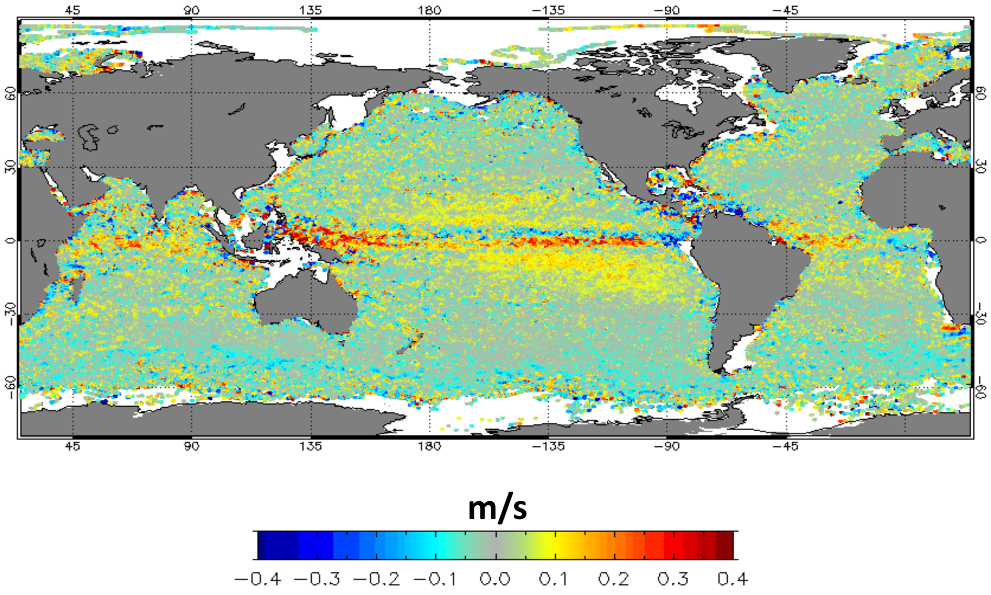
Mean surface currents (2008-2013)

Available Observations: Argo surface floats and AOML surface drifters

Not yet assimilated in the system …

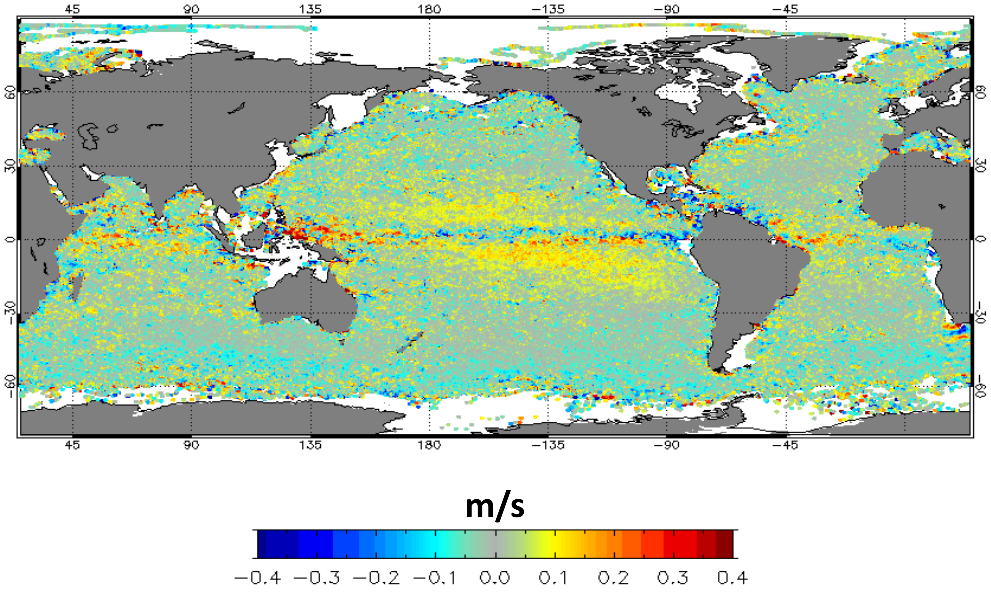
Previous system

U drift innovation in 2008-2013



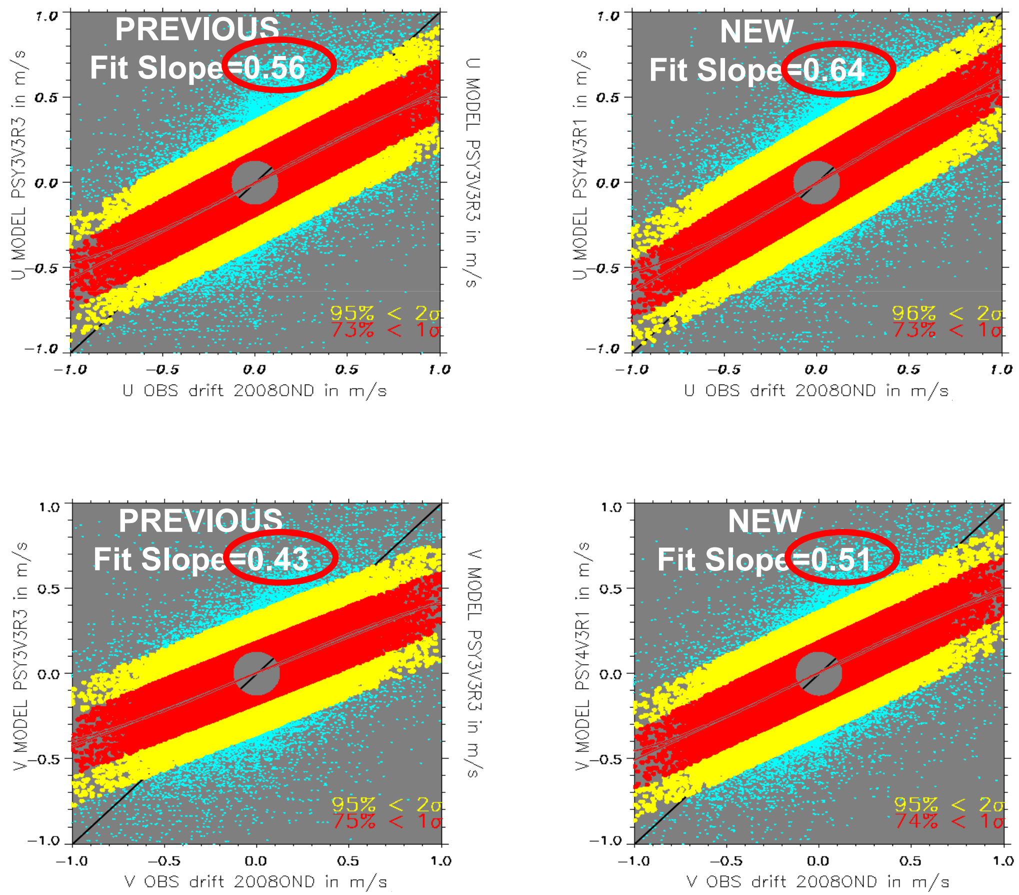
New system

U drift innovation in 2008-2013

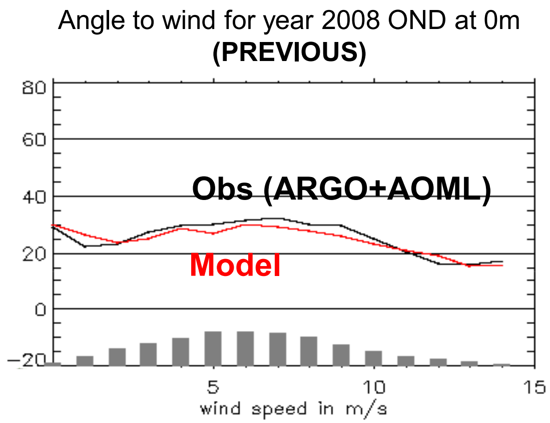


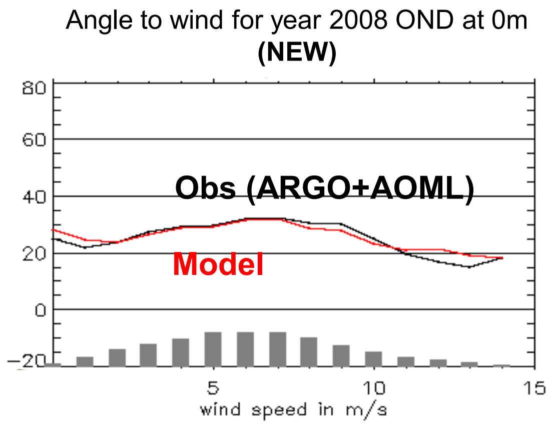
Mean surface currents (OND 2008)

The zonal and meridional slopes are improved



The Ekman spiral is improved (angle between the model or observed surface current and the wind for different wind intensities)

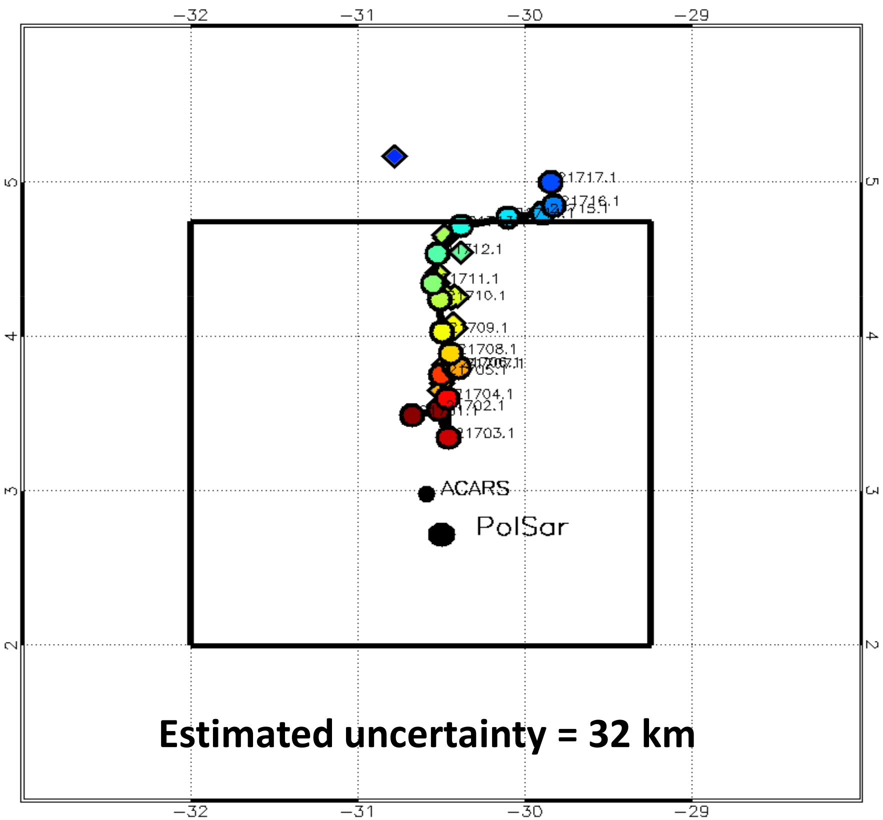




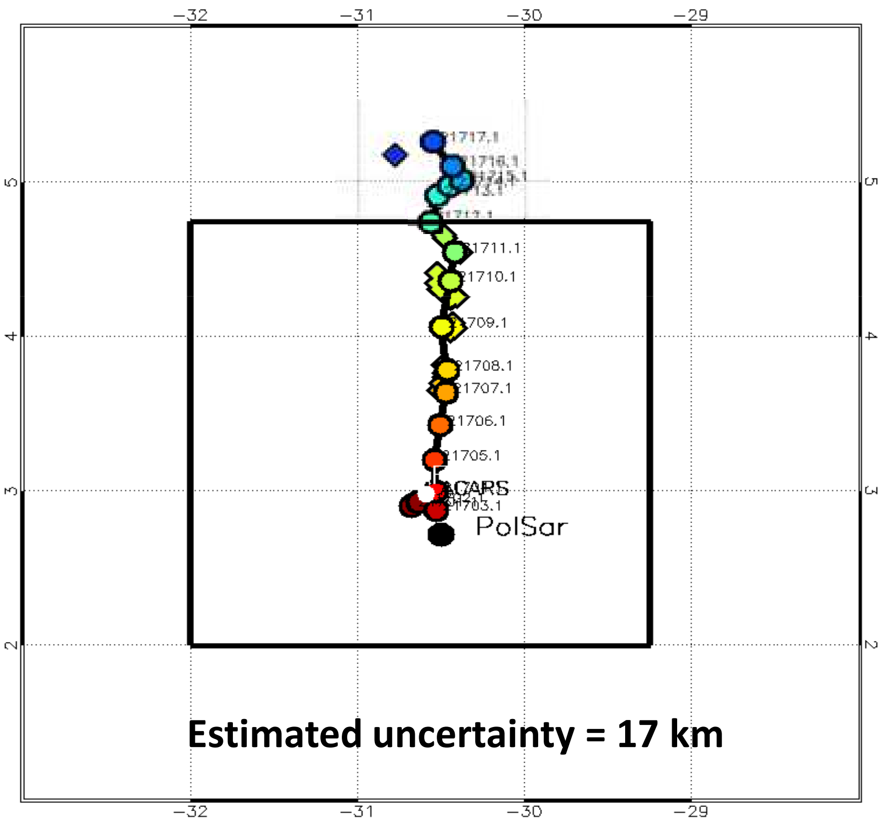
Crash AF447 flight on the night of 1st June 2009
We would have done better …

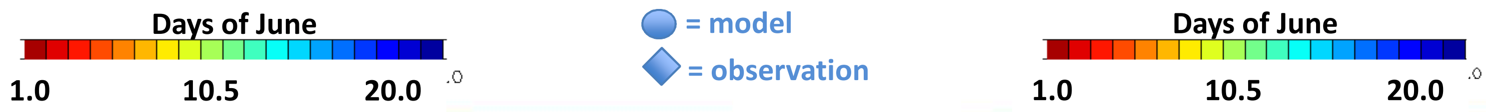
On the night of 1st June 2009, a Rio-Paris Air France flight (AF447) disappeared in the western tropical Atlantic Ocean. The first debris was located 5 days after the accident…

Previous system



New system





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Conclusions and Perspectives

- The new global system has a quite good statistical behavior with a accurate representation of the water masses, the surface fields and the mesoscale activity.
- Most of the components of the new system are improved: global mass balance, 3D T/S, SSH sea-ice, currents, …
- 10 years of homogeneous products are now available → "little reanalysis" at 1/12°.

Some other topics on which we have started to work and we want to continue in the future…

- Improvement of coastal runoff, atmospheric forcing, inclusion of the tide in the system,
- Use of the LIM3 sea-ice model,
- Assimilation of velocity observations,
- Assimilation of SSS satellite observations,
- From weekly to Daily Analysis,
- Production of a global 1/12° reanalysis covering the altimetric period,
- Take into account in the system the interaction between currents and waves,
- Extend the Data Assimilation to the ocean biogeochemical component.

Extra Slides

Current SLA observation operator

Assimilated SLA:

- Filtering (cutoff ~ 64km everywhere) and subsampling (1 out of every 2 points everywhere)
- Reference: 20 years (1993-2012)
- Use of a hybrid (home-made) MDT « corrected »

In order to obtain a consistent **model equivalent for SLA**, different space/time filters are applied.

These time filters act both on the sea level height and the barotropic height computed by the ocean model in order to remove high frequency barotropic signals.

First, the SSH is averaged over a one day window, and two running means of barotropic height spatially averaged (over a box of ~5°) are removed from it.

The model equivalent for SLA is :

$$SLA_{eq}{}^{f} = \overline{SSH}_{1day} - \text{LargeScale}\,(\overline{HBAR}_{1day} - \overline{HBAR}_{21days}) - \text{MDT}$$

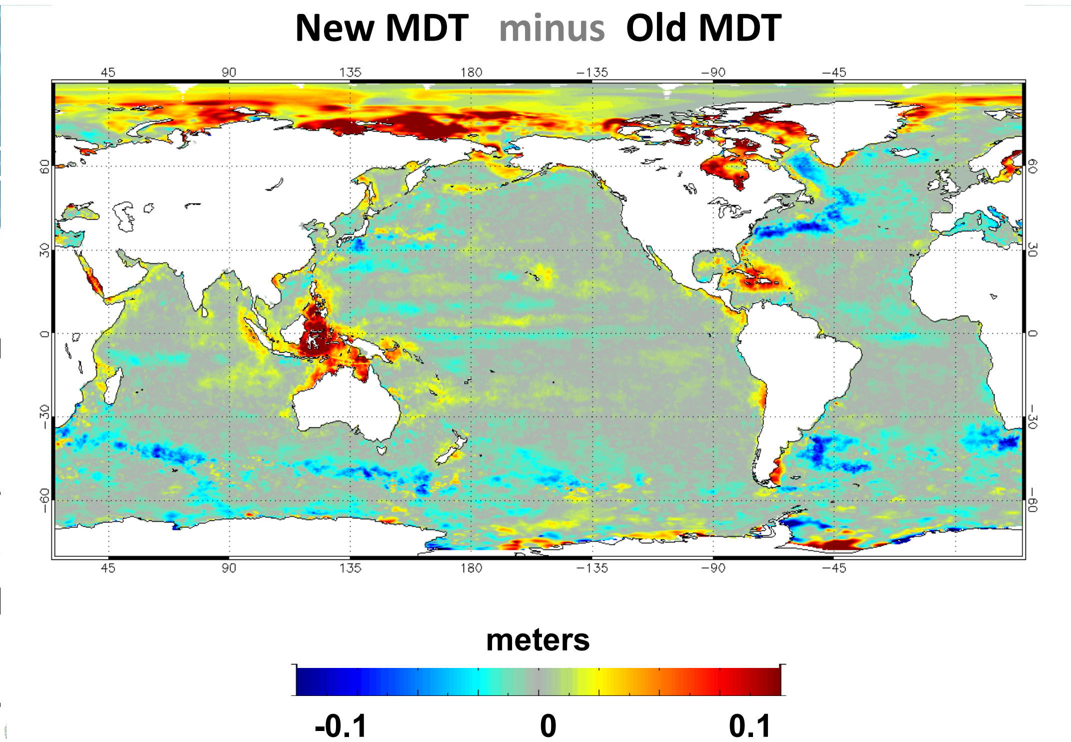
where MDT is the Mean Dynamic Topography

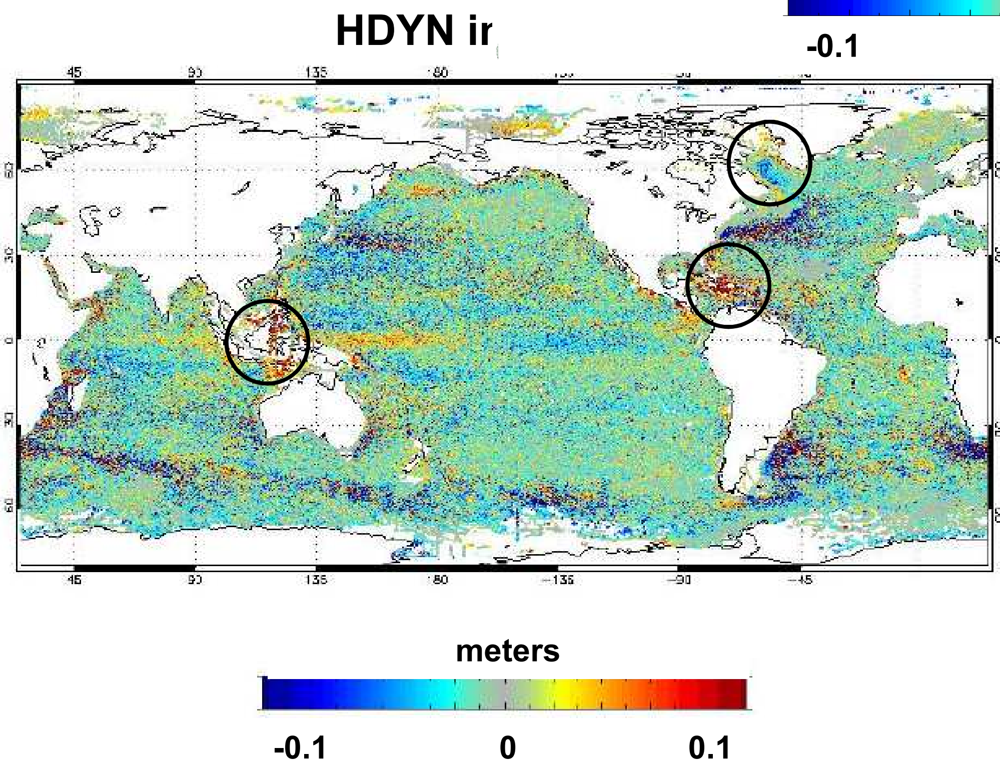
The running mean over a one day window eliminates barotropic high frequencies (period < 1 day) and the one over a 21 day window eliminates barotropic signals with periods < 21 days, which correspond to the low pass filter (Lanczos) applied to along track altimetric data.

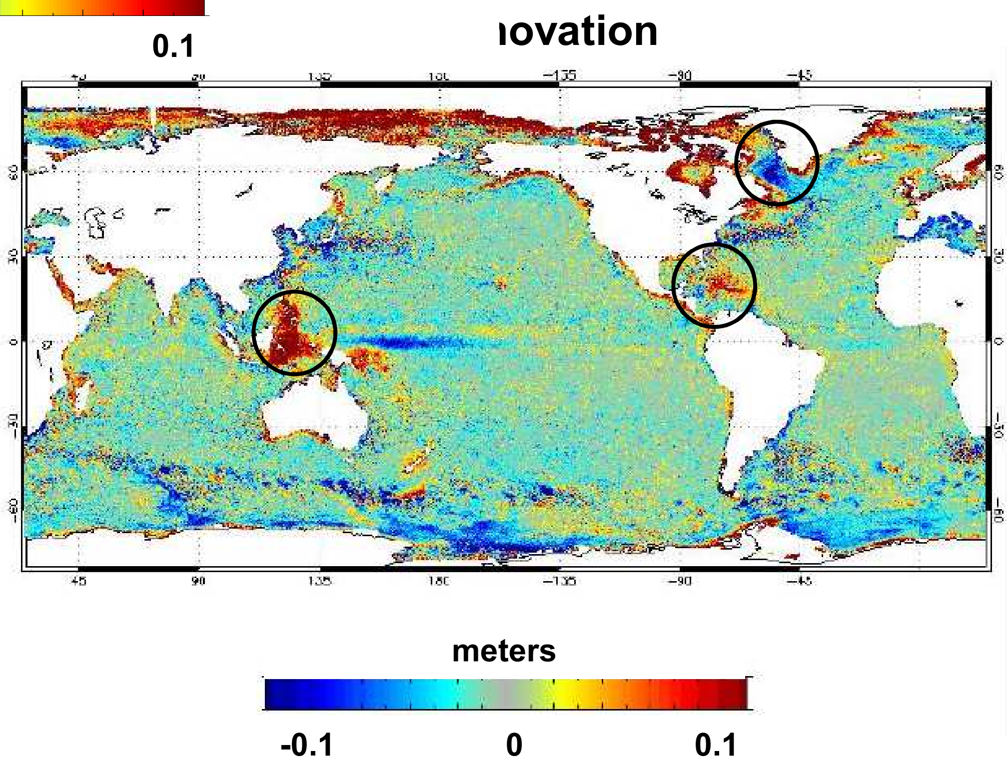
A «

The objective was to co[...] vious systems, taking into account:

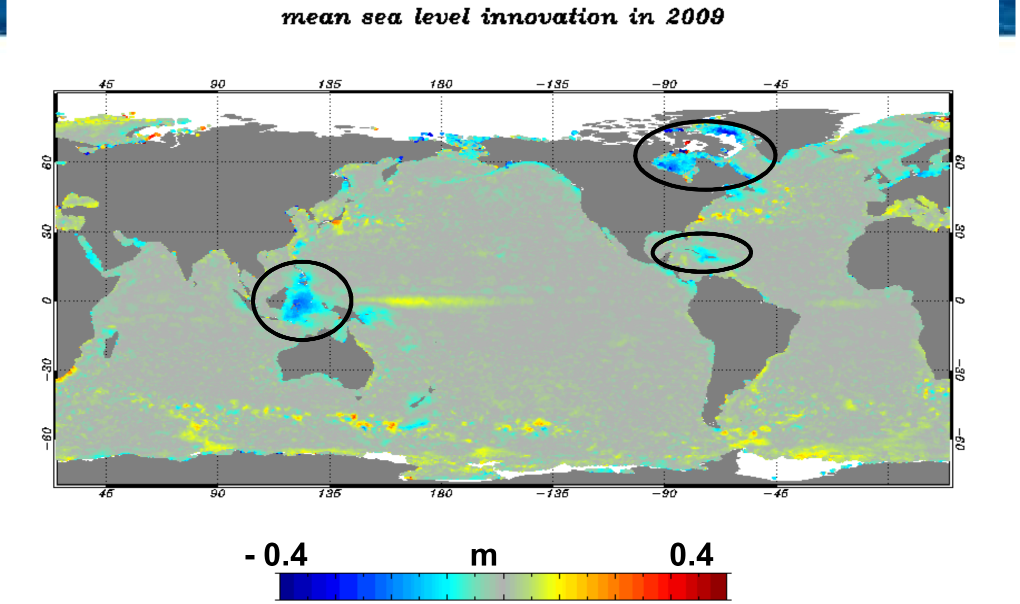
- SLA innovations,
- HDYN innovations cor[...] gy is used),
- Most recent satellite-
- Latest CNES-CLS13 MI

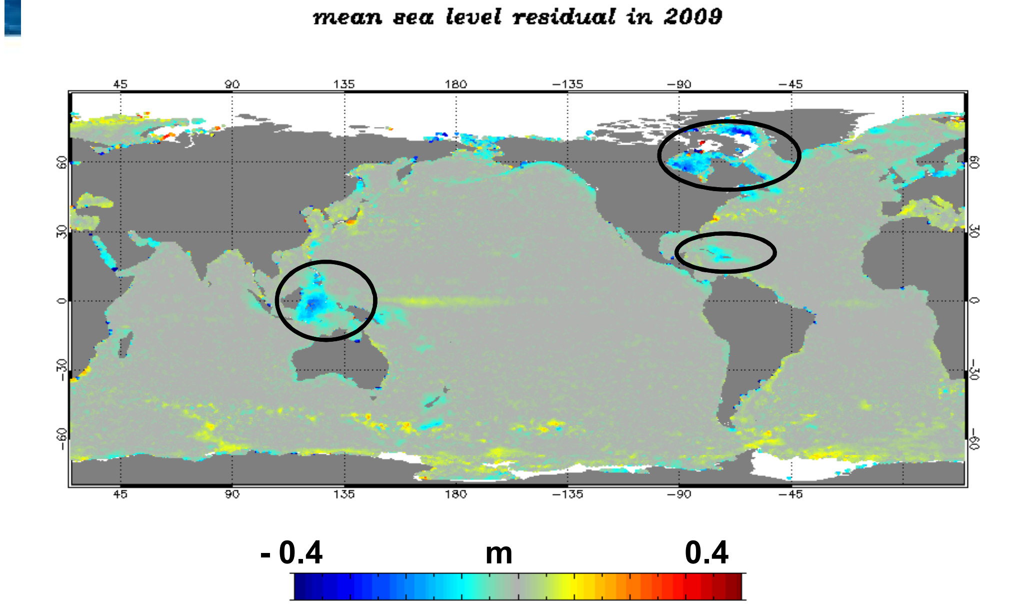


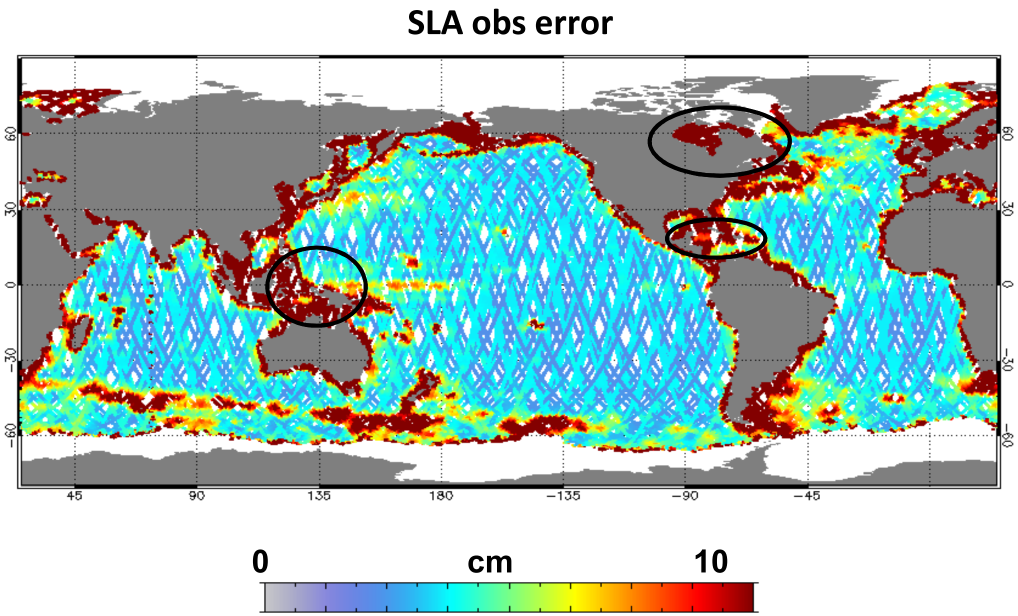




Some diagnostics with the previous system





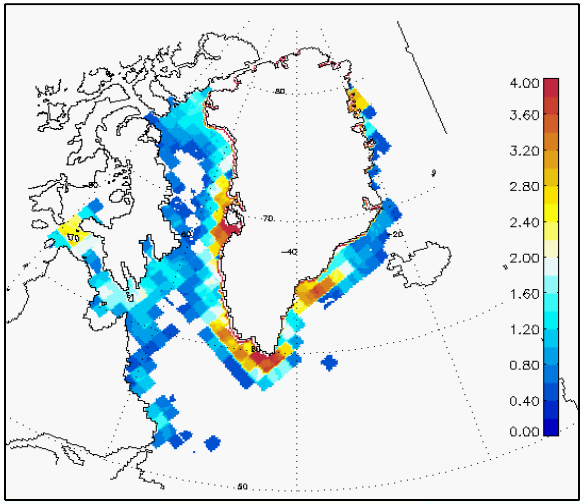


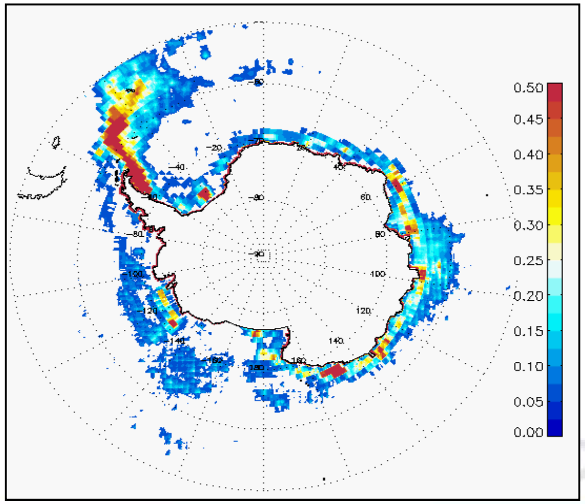
Reduce SLA error ??

New runoffs file

- ✓ Use of Dai and Trenberth 2009 rivers runoff database (instead of Dai and Trenberth 2002) : New data (mostly from recent years) from several sources, 925 collected rivers (73% of global total runoff), use streamflow simulated by Community Land Model version 3 (CLM3) to fill the gaps, all land areas except Antarctica and Greenland.
- ✓ Construction of a freshwater flux from ice-sheets melting in Greenland and Antarctica using Altiberg icebergs database project (Tournadre *et al.*, 2013).

Mean annual freshwater flux in mm/year (x 1.E06)





Future use of altimetry

Current Observations: VFEC (Verified, Filtered, SubSampled and Corrected)

$$SLA_{vfec} = SLA_{Sat} - DAC - LWE - TIDE$$

$$\textit{where} \quad DAC = IB_{LF} + MOG2D_{HF}$$

Assimilation : $SLA_{eq} = \overline{SSH}_{1day}$ - $\underbrace{\text{LargeScale}\,(\overline{HBAR}_{1day} - \overline{HBAR}_{21days})}_{\sim\ SSH_{MOG2D}}$ $- MDT$

For the future …

$$Model: \quad \frac{\partial U}{\partial t} = \ldots\ldots \cancel{-\frac{1}{\rho_0}\nabla p_A} + \ldots$$

If the model is forced by atmospheric pressure **+ tide in the model**

$$Assimilation: \begin{cases} SLA_{eq} = (\overline{SSH - \cancel{SSH_{TIDE}}}^{25h}) - [\cancel{SSH_{IB}} + SSH_{MOG2D}] - MDT \\ SSH_{IB} = -\dfrac{1}{g\rho}(p_A - \langle P \rangle): \text{ Inverse Barometer} \\ p_A: \text{Atmospheric pressure (From ECMWF model)} \\ \langle P \rangle: \text{Spatial Average (over the ocean)} \end{cases}$$

→ Our future need: SLA_{vfec} + $MOG2D_{HF}$ (+ IB_{LF} ?)