Observation impact studies on ocean analysis and forecast at Mercator Ocean

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(1) Mercator Ocean, (2) CLS, (3) IFREMER

Mercator Ocean

Ocean Forecasters

Mercator Ocean integrated systems

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Analyser et prévoir l'océan

Espaces projets | Espace Premium
Identifiant OK

MERCATOR OCÉAN | APPLICATIONS | PRODUITS & SERVICES | ACTUALITÉS & AGENDA | SCIENCE | OK | EDUCATION | PRESSE | MÉDIATHEQUE

- Composantes systèmes
- Systèmes opérationnels
  - Prévision numérique
- Qualification et validation
- GLORYS
- Bibliographie
- GMMC

Accueil > Science > Systèmes opérationnels

Les systèmes opérationnels

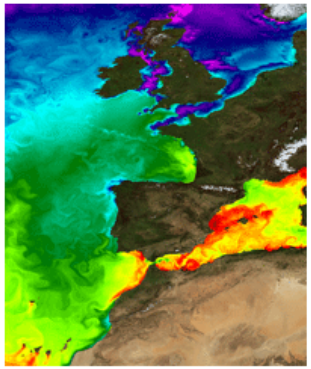
Mercator Océan a développé depuis plus de 15 ans ses filières globales et régionales de modèles de prévisions. Ces modèles sont dynamiques et donnent donc des prévisions jusqu'à 14 jours.

Un système opérationnel de prévision numérique est l'association entre une configuration modèle et un système d'assimilation temps réel. Chaque semaine, Mercator Océan fait tourner une gamme de systèmes opérationnels menant à des analyses et prévisions de l'océan dans ses trois dimensions.

Les systèmes actuellement opérationnels à Mercator Océan :

Résolution horizontale/ Zone couverte	1/36°	1/12°	1/4°	1°
Océan global		PSY4V2R2 PSY4QV2R2	PSY3V3R3 PSY3QV3R3 GLORYS2V1	PSY2G3R3 BIOMER1V2
Atlantique et Méditerranée		PSY2V4R4 PSY2QV4R4		
Atlantique Nord Est et Méditerranée Occidentale	IBI36QV2R1			

La prévision numérique opérationnelle à Mercator Océan



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Les actionnaires de Mercator Océan

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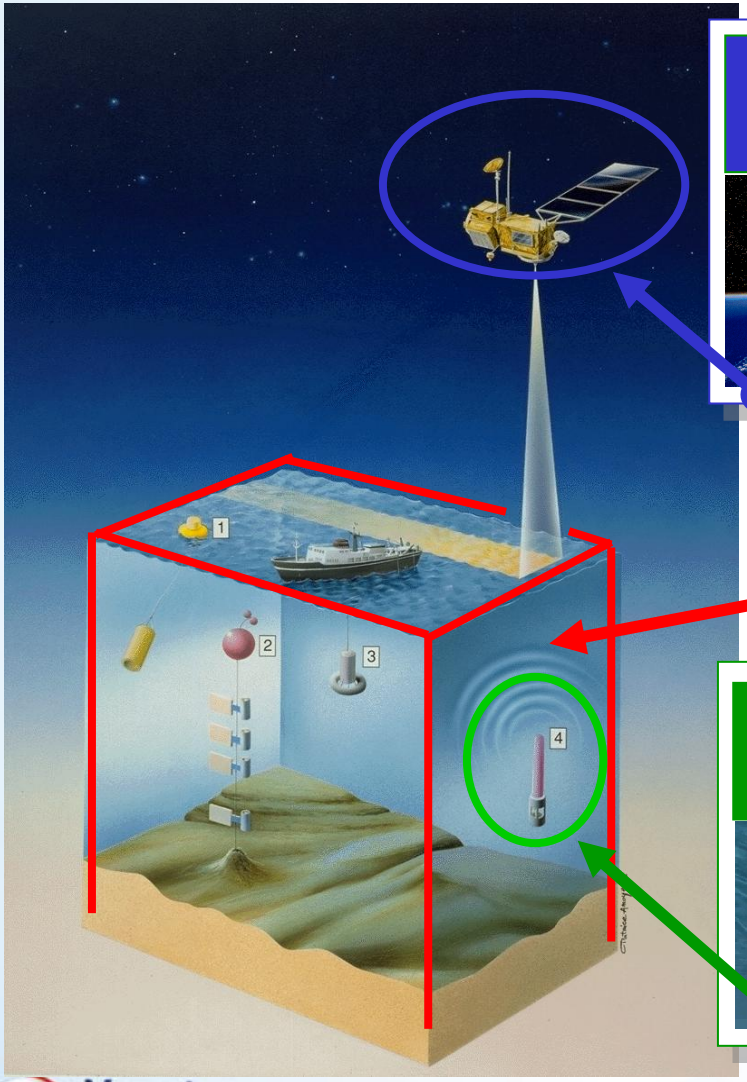
Mercator Océan est partenaire des programmes

Mercator Ocean integrated systems



SATELLITE observations

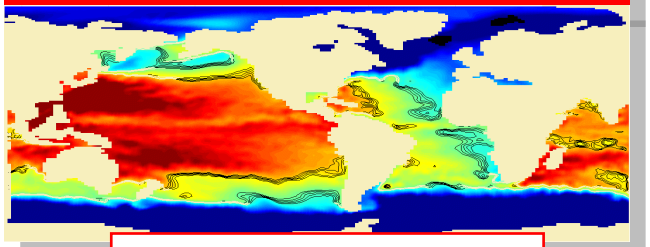
SSALTO

SLA, SST

MODELLING ASSIMILATION

(control vector {Hbar,T, S, U, V})

➔Hindasts & forecasts



MERCATOR

IN SITU observations

CORIOLIS

T, S profiles

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Outline

- **Motivations**

- **Dedicated experiments**:

  - OSE: illustrated with ARGO OSE experiments,

  - OSSE: illustrated with altimetry OSSE.

- **Alternative approaches**:

  - Information content computation test (DFS),

  - Adjoint sensitivity diagnostics.

- **Summary**

Dedicated experiments

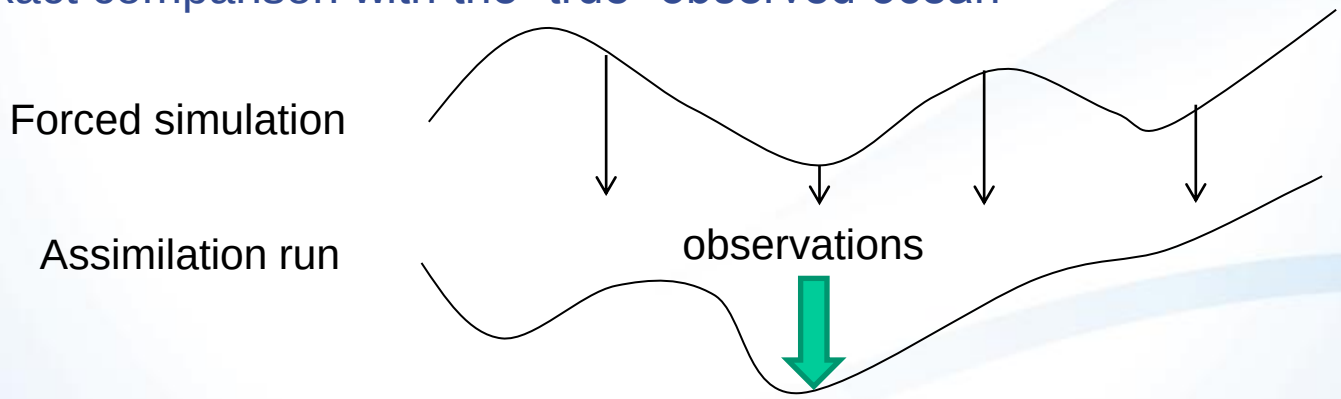
Observing System Evaluation

Evaluation of the changes in the analysis and forecast when some data set is **withheld**,

Observing System Simulation Experiment

Ability of the system to reconstruct the mean and variability of the simulated ocean depending on the assimilated observations.

- Simulation of the observations and errors
- Exact comparison with the “true” observed ocean



Results are dependent of the model configuration, the assimilation scheme and the prescribed a priori errors.

Motivations

Why doing observation impact studies?

To quantify the impact of the present observation network in our analysis/forecasts

To verify that observation information is « optimally » used in the analysis step:

- Improve the assimilation components (H,R)

To help designing the future observation network and improving the current ones:

- OSSE, adjoint sensitivity analysis

To demonstrate the value of the observation network for the operational ocean analysis and forecasts.

Mercator Ocean is involved in observation impact studies through different projects:

- evolution of the ARGO array (*E-AIMS),*
- evolution of the altimetry constellation (*CNES),*
- use of the Sea Surface Salinity,
- discussions within the GODAE OSE/OSSE task team.

Dedicated experiments: OSE

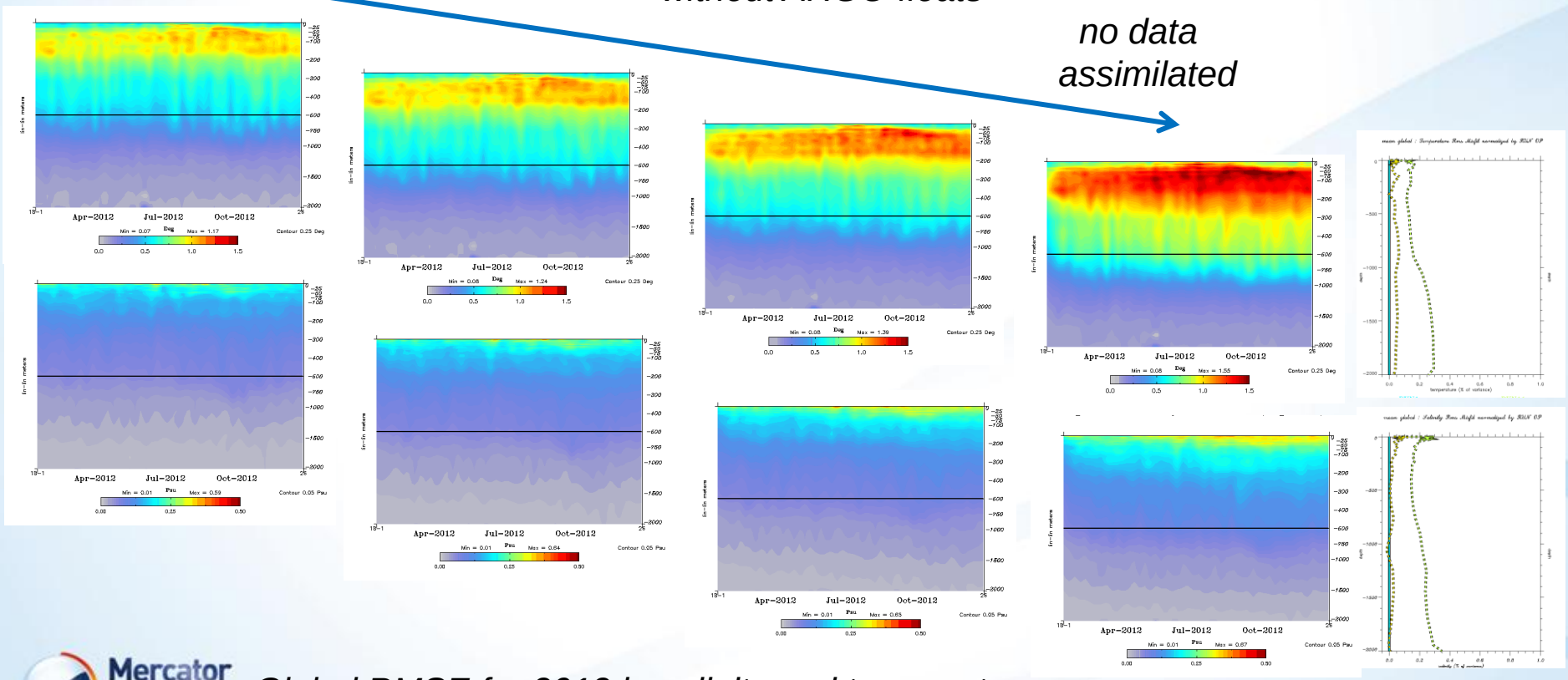
Impact of the current ARGO network on the global ¼° analysis system: simulation comparisons in terms of observation minus model **forecast** misfits for all in situ T,S data in 2012.

Operational run

without ½ ARGO floats

without ARGO floats

no data assimilated



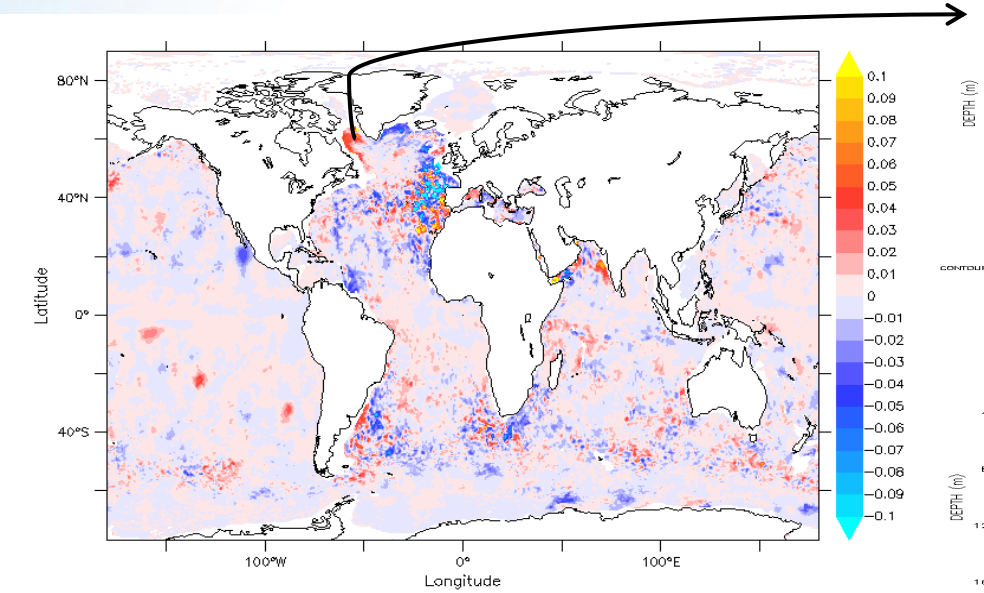
Global RMSE for 2012 in salinity and temperature

1-rmse/rmse$_{oper}$

Dedicated experiments: OSE

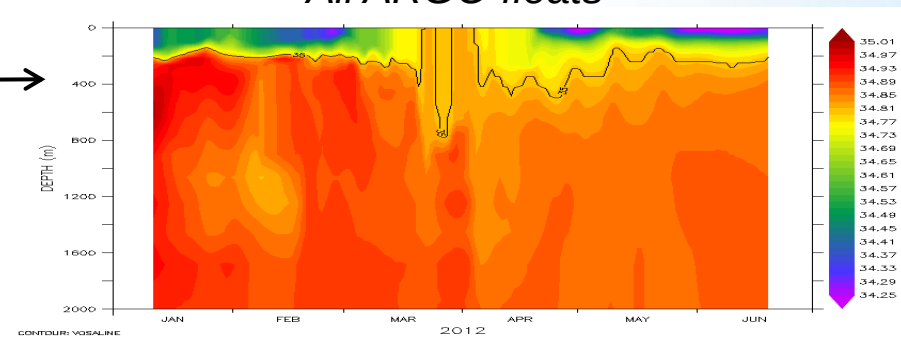
Impact of the current ARGO network on the global ¼° analysis system:

Water mass representation

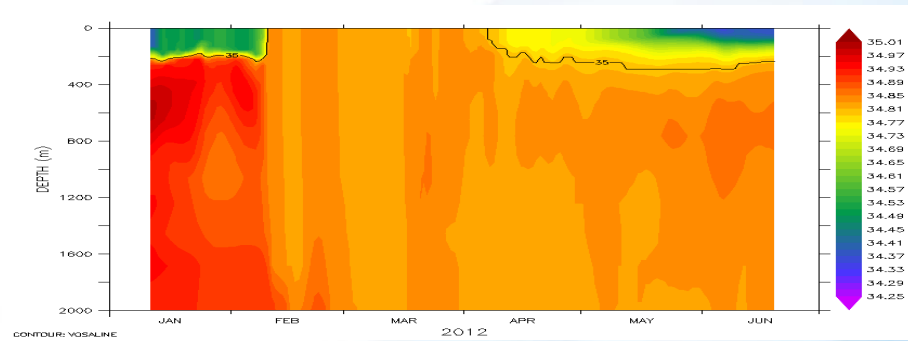


Differences in 1000-2000 m salt content for June 2012 between the simulation with all ARGO and no ARGO floats assimilated (in PSU).

All ARGO floats



No ARGO floats



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

Victor Turpin, ongoing work (E-AIMS),

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Dedicated experiments: OSE

Conclusion for ARGO OSEs:

The system reacts as we expected to the ARGO floats 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,
- keeping only half of the ARGO floats degrades significantly the analysis.

Next step : OSSE for testing the impact of future deep ARGO floats and better sampling of the Western Boundary Currents.

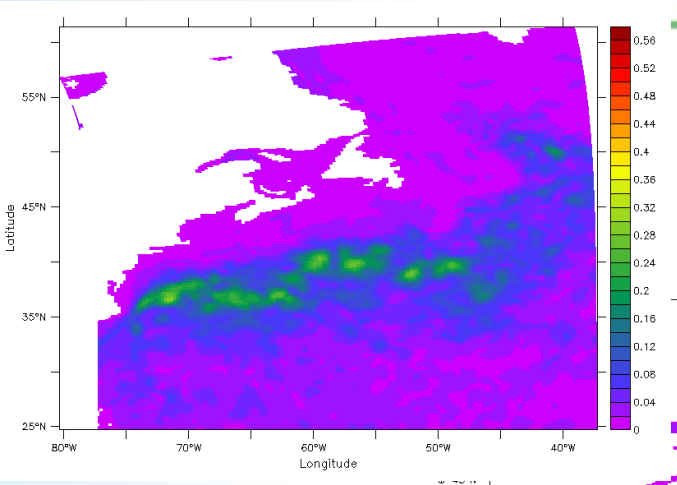
Others OSEs:

- High resolution/high frequency along track SLA (TAPAS) (see M. Benkiran poster),
- High resolution SST (2 km) (see M. Benkiran poster),
- Sea Surface Salinity (B. Tranchant, ongoing work),
- Tropical moorings.

OSE requires a good knowledge of the observation and model physical content, they are useful to identify weaknesses in the assimilation system.

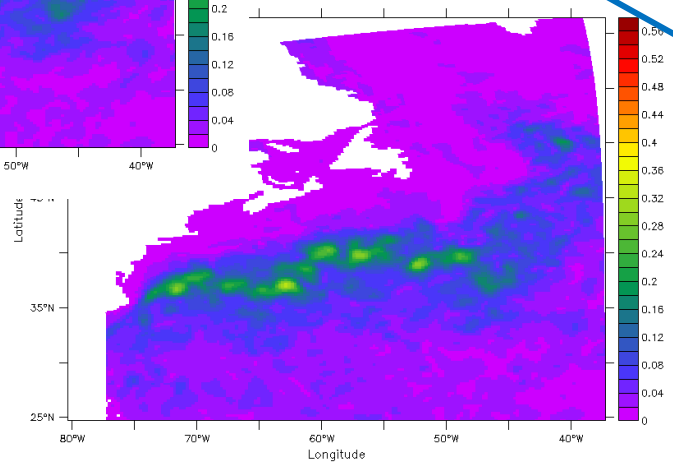
It can be difficult to validate changes seen in the different analysis for poorly or non observed regions/variables: are changes closer to real ocean or artefact of assimilation?

Dedicated experiments: OSSE



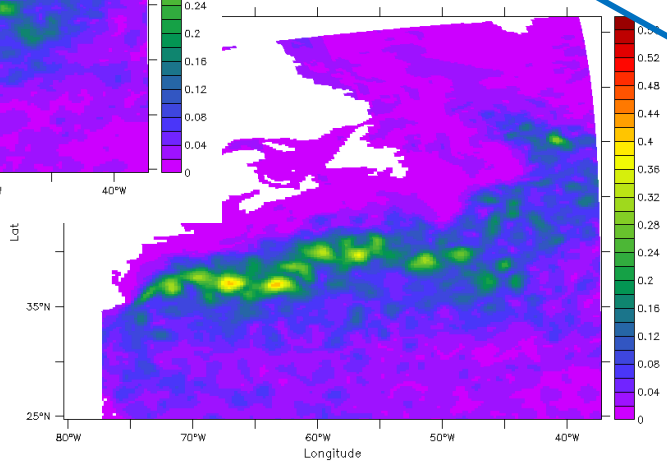
3 altimeters

2 altimeters

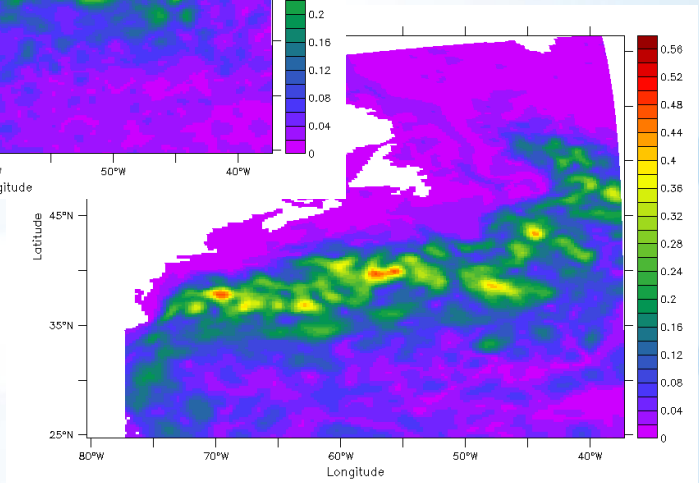


OSSE on altimetry constellation: Impact of the altimeter number on model SSH estimation with the global ¼°system when no other data are assimilated.

1 altimeter



no altimeter



Standard deviation of the error on the analysed SSH model fields compared to the « true » SSH (in meter).

6-month experiments with simulated altimeters : Jason 1, Jason 2 and Envisat.

Simon Verrier, ongoing work

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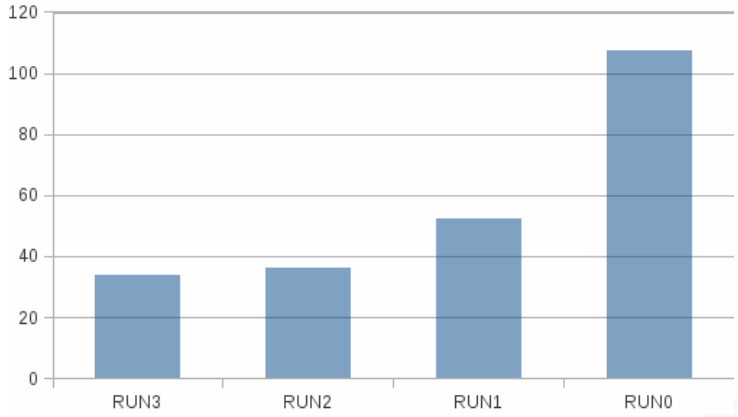
Dedicated experiments: OSSE

OSSE on altimetry constellation

Impact of the altimeter number on model SSH estimation with the global ¼° system (no other data are assimilated).



Relative SSH error variance in % of the SSH variance itself in the Gulf Stream region depending on the number of altimeter assimilated (0 to 3)

Ongoing work for improving the SLA observation assimilation:

- use of the Desroziers ratio to adjust the observation error variance,
- take better advantage of highly covered areas,
- improve the model equivalent in high resolution model (1/12°).

Desroziers et al., 2005: *Diagnosis of observation, background and analysis error statistics in observation space*, QJRMS.

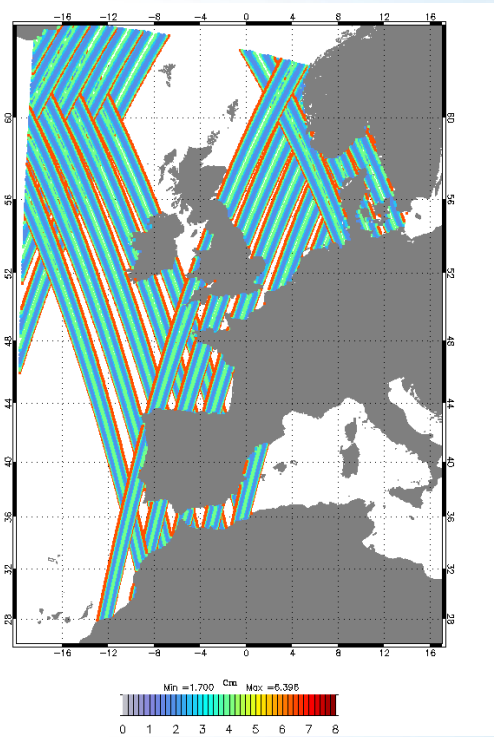
Dedicated experiments: OSSE

OSSE for the future large swath mission : SWOT (CNES)

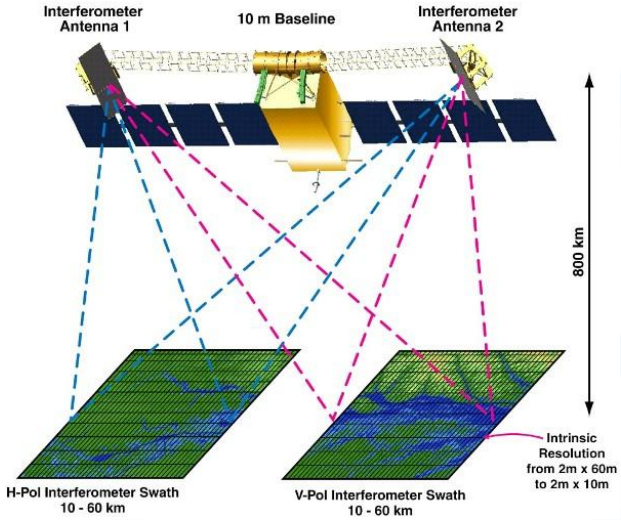
Assimilation of simulated SWOT tracks with the expected across track errors in the Iberic Biscay and Irish seas 1/12° analysis and forecast system (IBI) .

- To prepare the assimilation framework,
- To estimate the benefit of large swath altimetry to constrain the ocean model mesoscale features ?

ongoing work (M. Benkiran)



5-day SWOT tracks and error level in cm.



SWOT KaRIN instrument draft (http://swot.jpl.nasa.gov/science/technology/).

Dedicated experiments: OSSE

OSSEs are useful tool to prepare an assimilation system to new data and estimate their impact on ocean analysis and forecasts.
They also provide insight on the assimilation performance in an ideal framework.

OSSEs require a careful setup:

- simulation of the observations and their errors,
- potential changes of the representativity error depending on how observations were simulated, …

Advantage : exact comparison with the full 3D ocean state.

Planned OSSEs at Mercator Ocean:

- deep ARGO floats,
- SWOT SLA, LRM/SAR satellite number/constellation.

ALTERNATIVE APPROACHES: observation impact measures

Information content and Degree of Freedom of the Signal

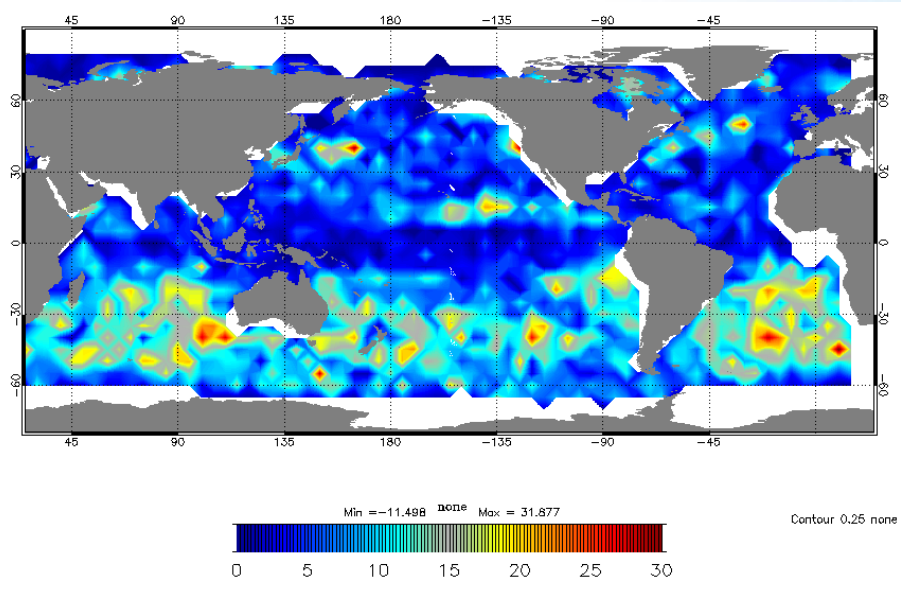
Statistical estimation of the observation « weights» without withholding them from the analysis:

$$DFS = tr\left(\frac{\partial H(x_{analysis})}{\partial yobs}\right) \quad (1)$$

Information content:

$$IC = 100 \times \frac{DFS}{Nb\ Obs}$$

Practical computation of the DFS is done by perturbing the observations (2): still requires additional analysis.



SST observation information content in % for a global ¼° analysis in september 2010

(1) Cardinali, C. et al., 2004: Influence matrix diagnostic of a data assimilation system, QJRMS)

(2) Chapnik, B. et al, 2006: Diagnosis and tuning of observational error in a quasi-operational data assimilation setting, QJRMS.

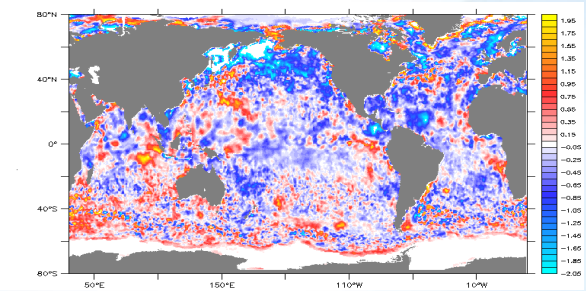
ALTERNATIVE APPROACHES: adjoint sensitivity

Forecast error sensitivity: estimation of potential forecast error sources. Helps designing observation array dedicated to reduce chosen forecast error: observation should be made in sensitive/large error growth regions.

SST forecast error sensitivity in the global ¼° ocean model to initial conditions errors (control variable) and the atmospheric forcing errors.

Measure of the SST forecast error with the observed ½° resolution AVHRR SST on the 4th day:

$$J = \frac{1}{2} \sum_{n=1,nSSTobs} \frac{(SST(x,y,t=4{,}5days) - SST^{obs})^2}{\sigma^2_{SSTobs}}$$



(SSTmod – SSTobs)

Sensitivity computation done with the adjoint of the NEMO ocean model (NEMOVAR code, ECMWF/CERFACS/MetOffice/INRIA)

Rabier F. et al., 1996: Sensitivity of forecast errors to initial conditions. QJRMS.

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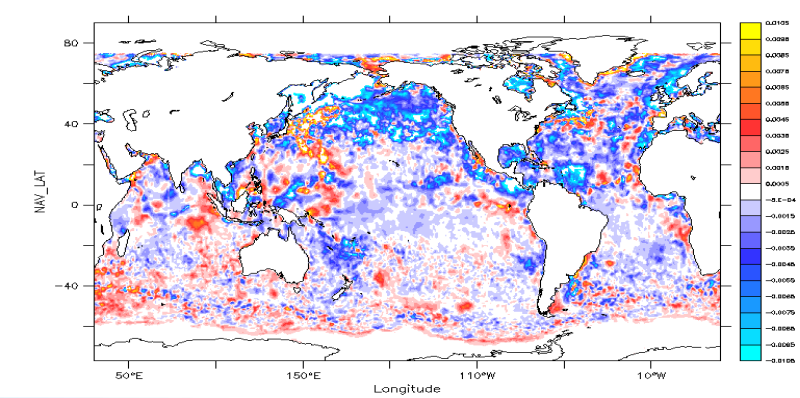
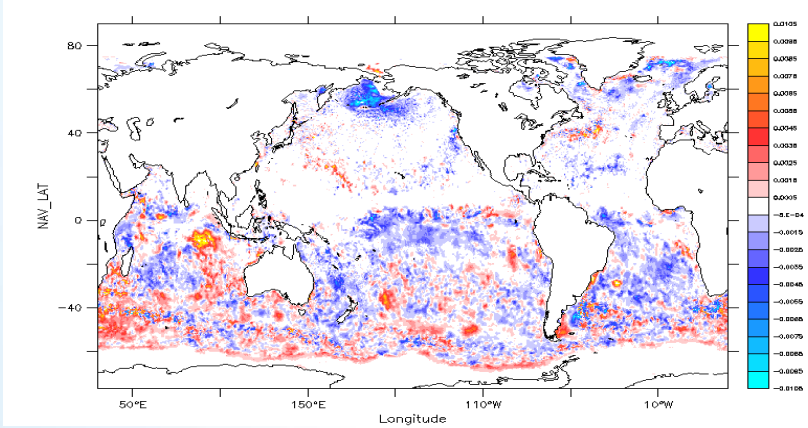
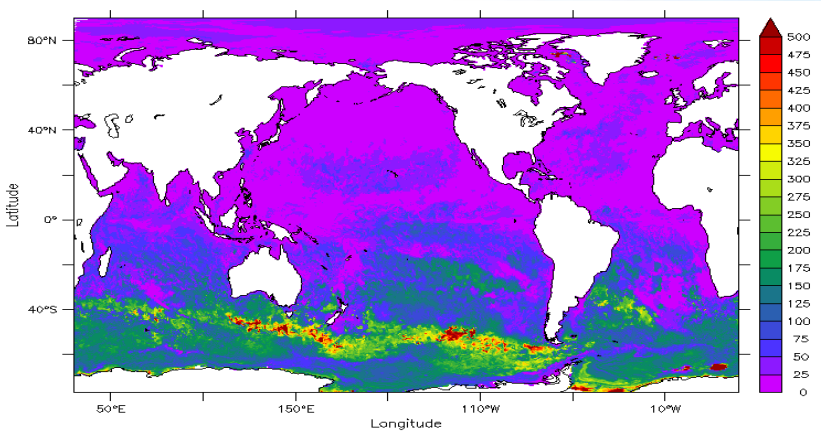
ALTERNATIVE APPROACHES: adjoint sensitivity



$\partial Jsst/\partial HeatFlux_{day4}$



$\partial Jsst/\partial T_{100m}$



Mixed layer depth in September

SST misfit sensitivity to heat flux on the same day and temperature initial conditions at 100 m depth. (september 2006)

At the time scale of few days and ¼ °spatial resolution, the SST sensitivity after 4 days of forecast is driven by the vertical dynamic.

Limitation : requires the adjoint of the model for exact computation.

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SUMMARY

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 to evaluate the changes for OSE
- can be far from the real situation (OSSE)

Experiments longer than at least 3 months are preferable.

Results will depend on the model configuration, prescribed model and observation error and assimilation scheme itself.

Alternative approaches

DFS / information content

+ show the equilibrium between the forecast and the different data set (does not require to withhold data),
- still requires additional analysis.

Sensitivity analysis: strong investment, not easy to interpret (choice of a norm)

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Thank you for your attention!

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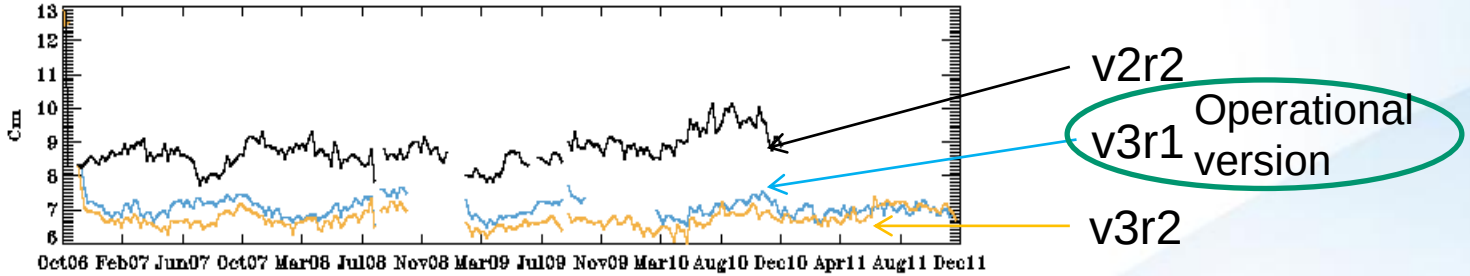
Evaluating the system performances

Monitoring the error misfit

Different diagnostics help measuring the efficiency of the SLA constrain, the quality of the estimated SSH in the products and identifying problems.



Jason1 SLA RMS misfit evolution for different versions of the global ¼° system (PSY3)