Review of OSSE/OSE performed at Mercator-Ocean

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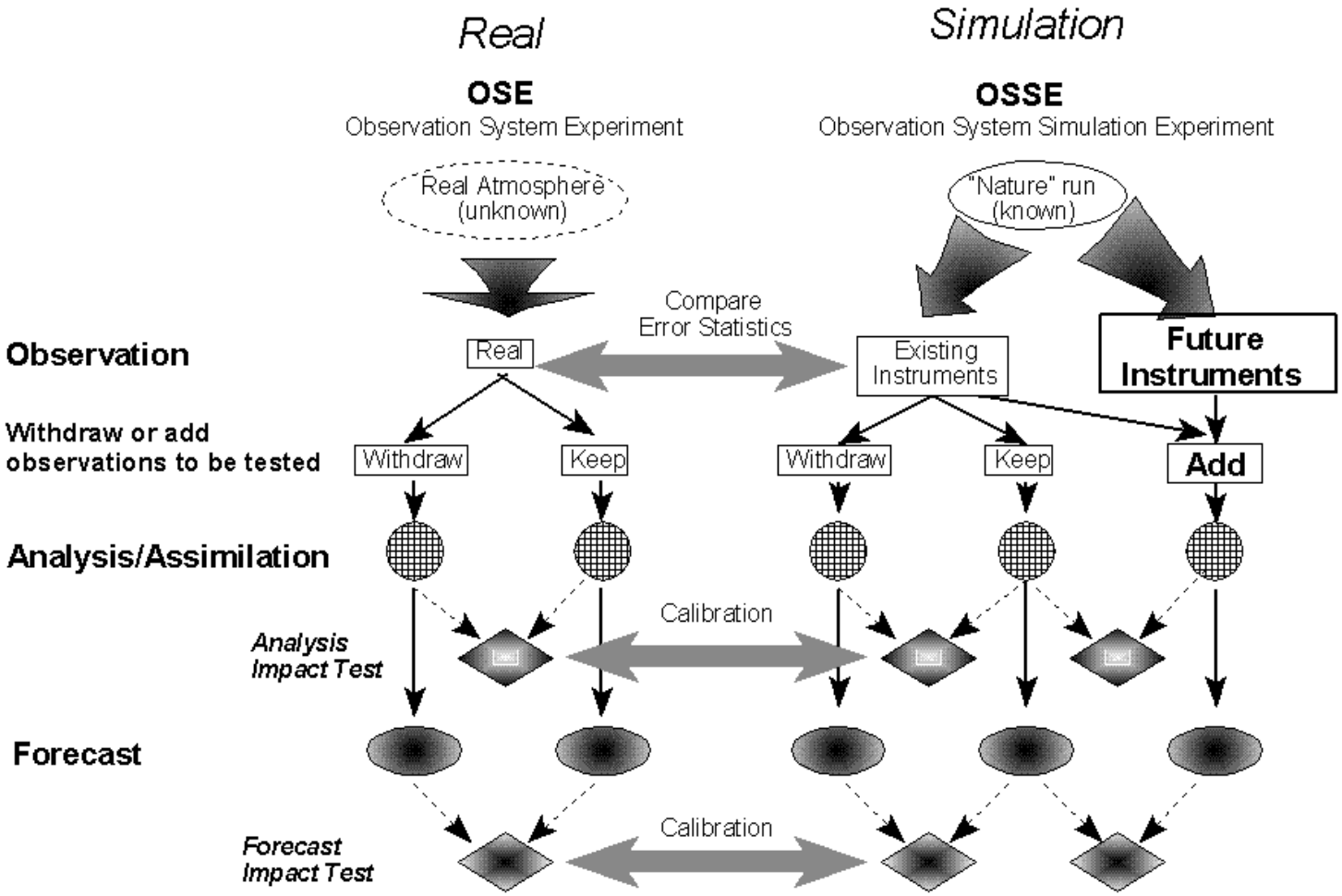
Didier Jourdan and Stephanie Vrac

Talk outline

- A few words about **OSE** and **OSSE methodologies**

- Focus on **two impact studies** done at Mercator Océan
  - **OSSE**: potential impact of **surface velocities** derived from SAR and/or optical flow methods applied to SST and/or ocean color on an **eddy permitting** system (1/3°)
  - **OSE**: Impact of altimeter data (1, 2, 3, 4 satellites) on an **eddy resolving** forecasting system (0(1/15°))

OSE/OSSE, a well defined methodology to assess the impact existing and future measurements



From R. Atlas 97

OSE/OSSE characteristics

- « **OSE** » Observing System Experiment
  - Use **real data**, withdraw or keep components of the observation system in paralell assimilation run and measure the impact
  - The **truth is unknown**, need for an external assessment protocol (for exemple use of independant observations)
  - Allow to assess the **relative impact** of **existing** observing systems on analysis and forecast produced by a given assimilative system

- « **OSSE** » Observing System **Simulation** Experiment
  - Use **simulated data** instead of real data
  - **Truth is** simulated, and assumed to be **known** (identical/fraternal twin experiments)
  - Allow to assess the **potential impact** of **future** observing systems
  - **Results depend on the experimental protocol**, and the confidence one may have in quality of the observations simulation. Results have to be consolidated afterwards with real data

Impact studies done with Mercator systems

- 2003: Impact of MSSH (Davidson et al.)
  - **OSE**
  - 1/3° North and Tropical Atlantic, ROOI (alt only)
- 2005: Impact of Pirata (Hernandez et al.)
  - **OSE**
  - 1/3° North and Tropical Atlantic, ROOI (multi data)
- 2005: Impact of SMOS and AQUARIUS (Tranchant et al.)
  - Mix of **OSE**/**OSSE** (fraternal twin)
  - ¼° North and Tropical Atlantic, SEEK
- 2006: Impact of altimeter data, ARGO, etc… (Benkiran et al.)
  - **OSE**
  - 1/3° North and Tropical Atlantic, ROOI (multi data)
- 2006: Impact of surface velocities derived from SAR (Giraud et al.)
  - **OSSE** (fraternal twin)
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- 2007 (ongoing): Impact of altimeter data (Benkiran et al.)
  - **OSE**
  - 5-7 km North Atlantic and Mediterranean, ROOI (multi data)

Impact studies done with Mercator systems shown here

- 2003: Impact of MSSH (Davidson et al.)
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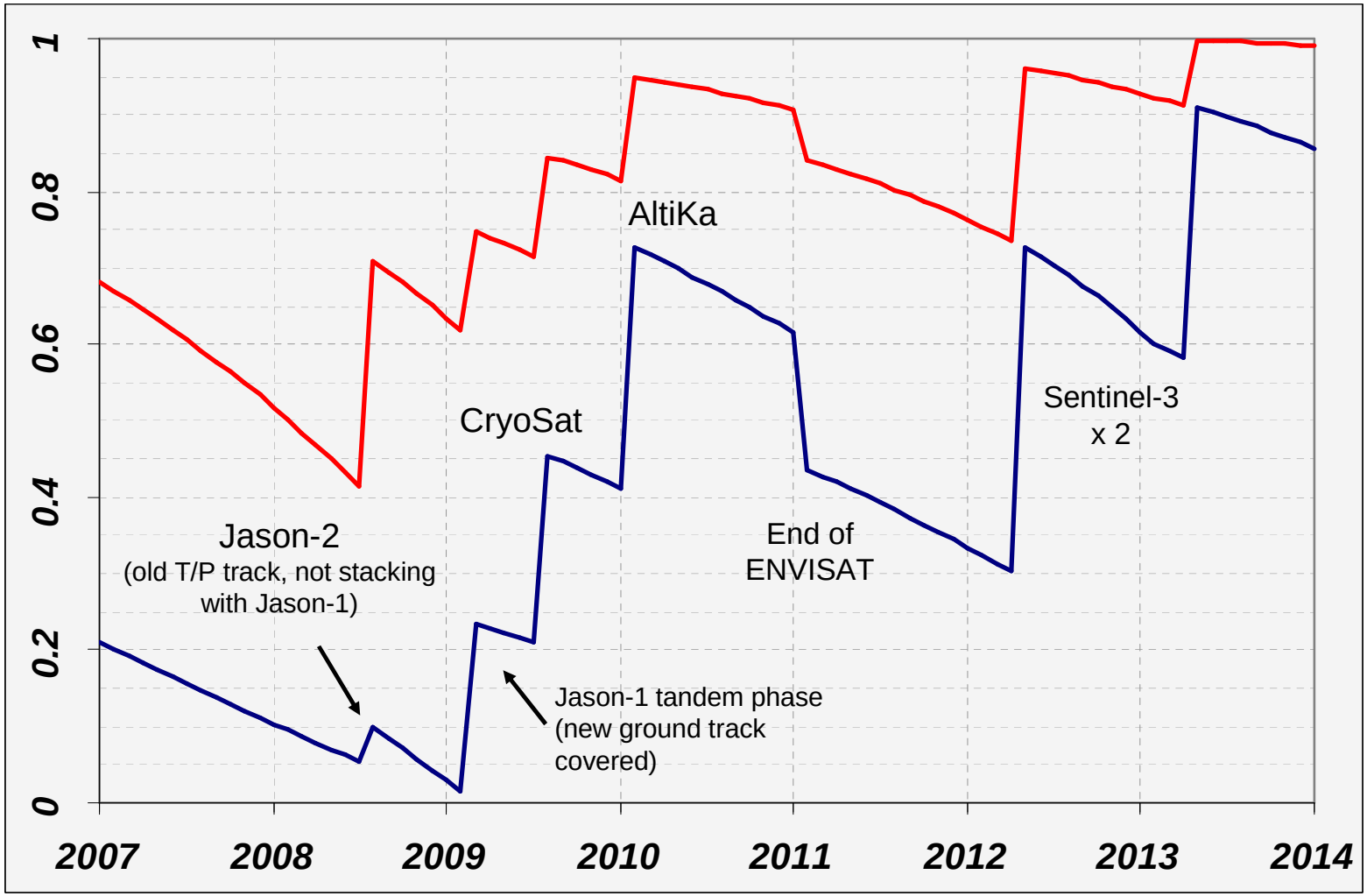
  - 1/3°North and Tropical Atlantic, ROOI (multi data)
- 2005: Impact of SMOS and AQUARIUS (Tranchant et al.)
  - Mix of OSE/OSSE (with real data except simulated SSS from fraternal twin)
  - ¼°North and Tropical Atlantic, SEEK
- 2006: Impact of altimeter data, ARGO, etc… (Benkiran et al.)
  - OSE
  - 1/3°North and Tropical Atlantic, ROOI (multi data)
- **2006: Impact of surface velocities derived from SAR (Giraud et al.)**
  - **OSSE (fraternal twin)**
  - **1/3°North and Tropical Atlantic, ROOI (multi data)**
- **2007 (ongoing): Impact of altimeter data (Benkiran et al.)**
  - **OSE**
  - **5-7 km North Atlantic and Mediterranean, ROOI (multi data)**

Probability of having 2 (red) or 3 (blue) altimeters delivering data



From G. Dibarboure 2007

OSSE to evaluate the potential impact of surface velocities derived from SAR or optical flow methods on MERCATOR 1/3° North and Tropical Atlantic system

Eric Greiner, Mounir Benkiran,
Sylvie Giraud St Albin and Stéphanie Vrac

Work done by CLS, BOOST technology and Mercator-Océan
under contract with SHOM

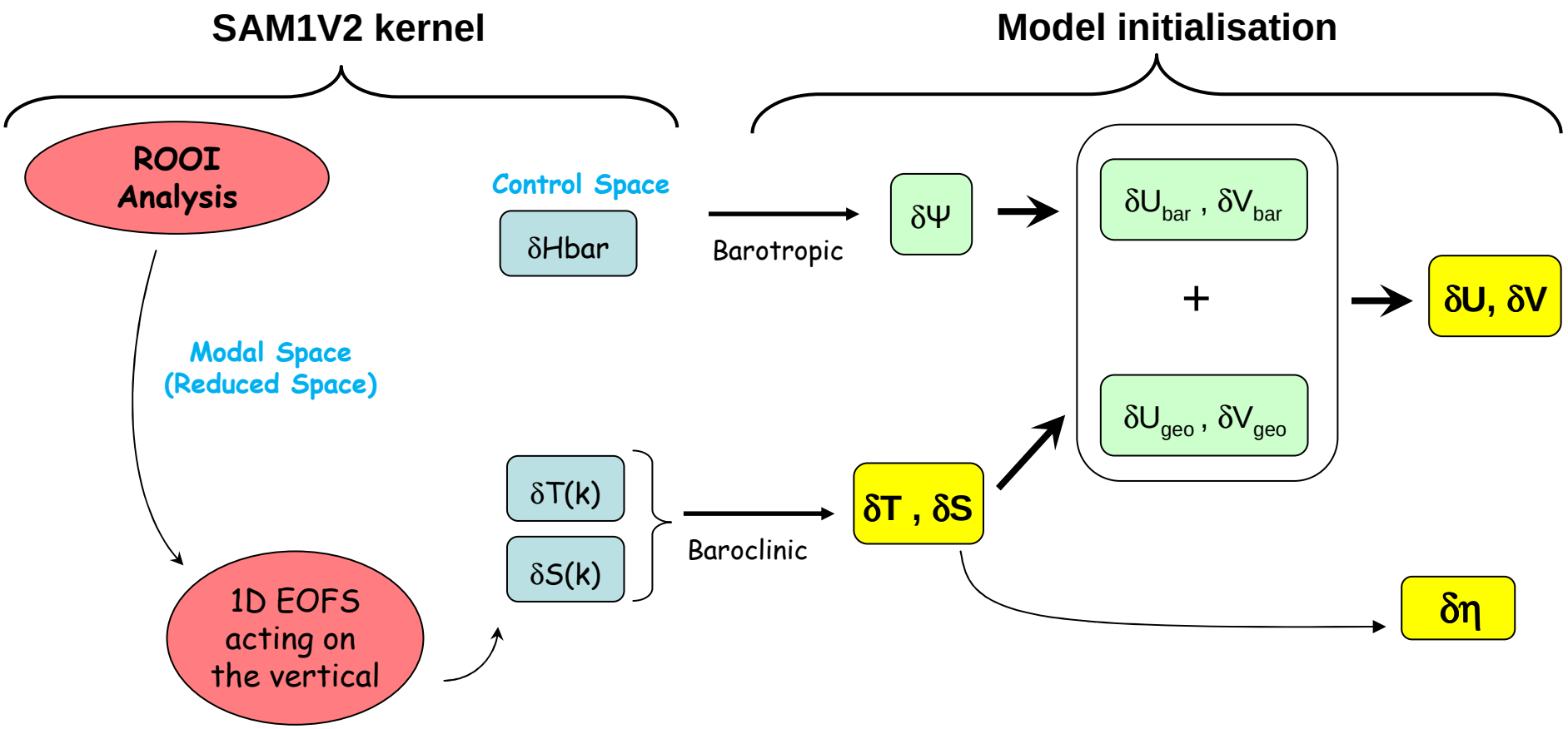
Objectives and experimental protocol

- Objective:
  - Assess the **potential impact of surface velocities** that could be deduced from **SAR** (radial velocities) and/or velocities obtained by the "**optical flow**" (OF) method from SST and/or ocean color.
  - Evaluate how this could **complement the altimeter data observing system** in the case of degradation in the coming years (or even be an *alternative* to it in the case of total loss).

- Experimental protocol **OSSE**:
  - Simulate observations: altimeter, in situ profiles, SST, SAR and OF velocities from a realistic high resolution forced model simulation: North Atlantic 1/12°
  - Implement the assimilation of velocities in the Mercator system
  - Run several simulation runs with different instrument combinations
  - Use an eddy permitting system to do that (North and Tropical Atlantic 1/3°)
  - Assess overall performances of the products

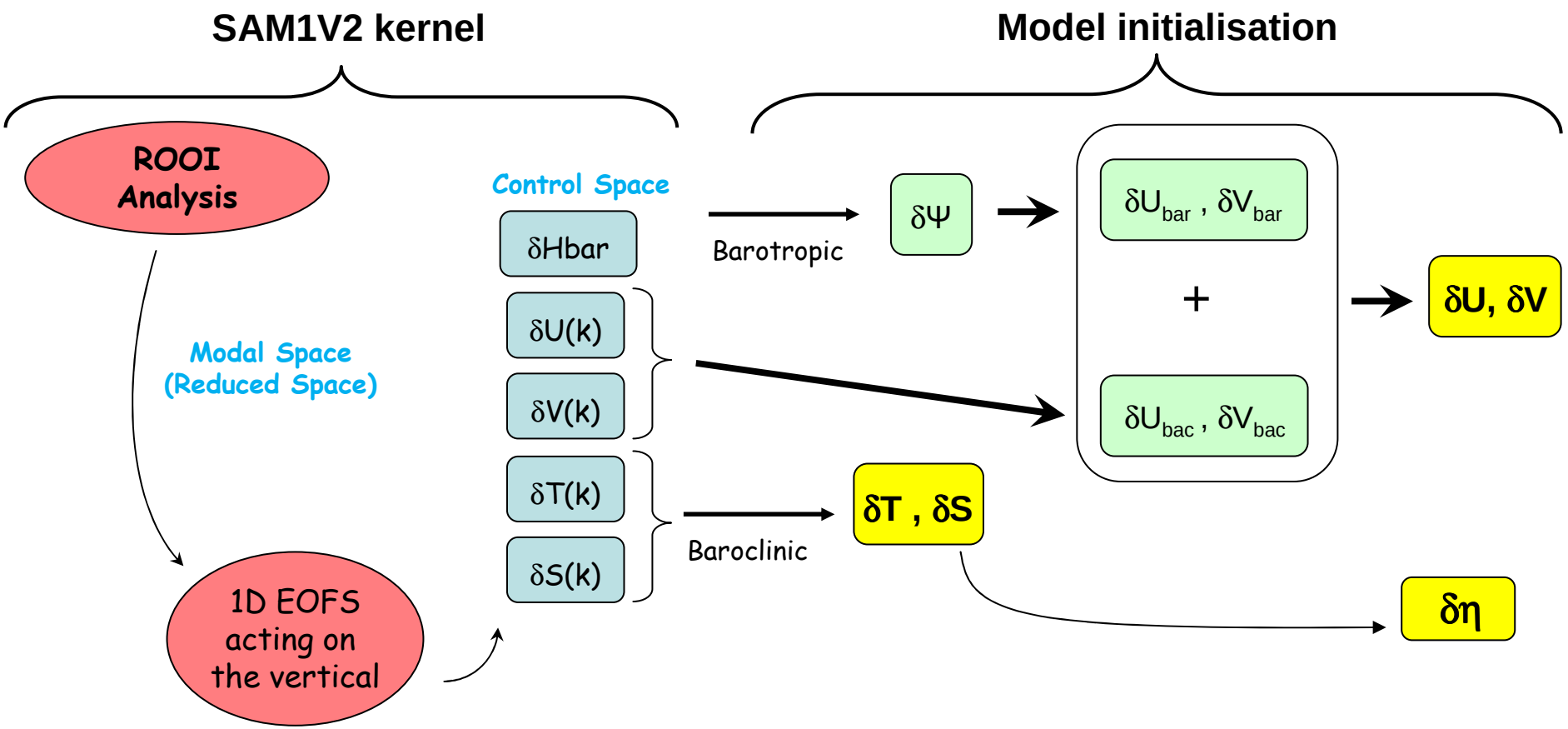
Upgrade of the assimilation system

SAM1v2: ROOI using multivariate 1D vertical EOF



Upgrade of the assimilation system

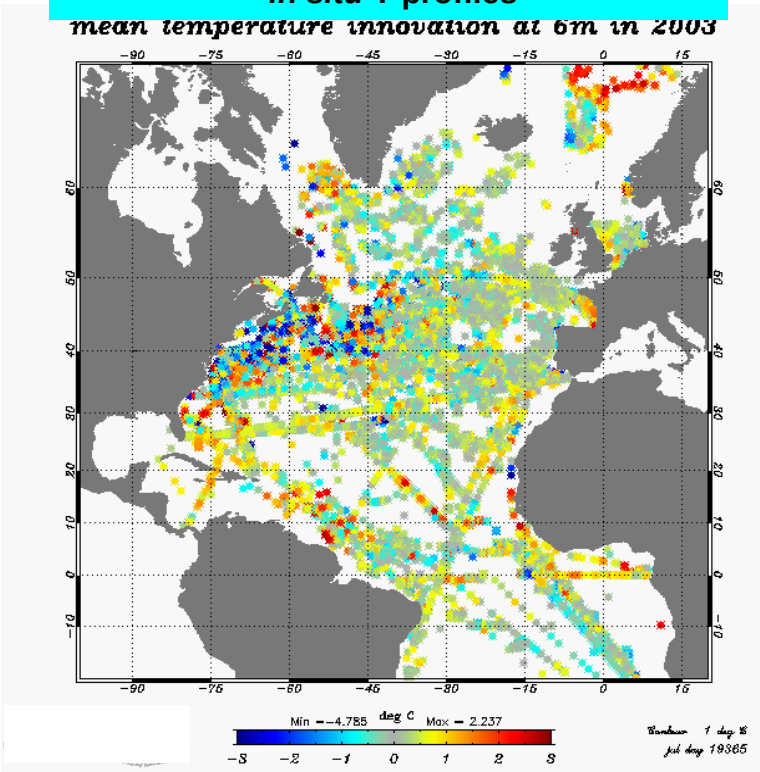
SAM1v3: ROOI using multivariate 1D vertical EOF



Simulation of the “true ocean”: Conventional data

- **Use a multi year 1/12° North and Tropical Atlantic, + Mediterranean sea simulation**
  - NEMO, ORCA1/12°, 50 levels, free surface (implicit), bulk formulae, ECMWF forcing, partial cells, prognostic ice, …
  - An evaluation of the “nature run” has been performed
- **Observations simulated for the year 2004:**
  - Actual coverage
  - Along-track SLA:
    - Jason 1, Envisat and Gfo
  - CORIOLIS *in situ* profiles :
    - CTD : T+S
    - PF : T+S
    - TESAC : T+S
    - MO : T+S
    - BATHY : T only
    - XBT : T only
  - SST (RTG_SST)
- **Add typical noise to observations**
- **Apply real processing to simu. alti. data**
  - remove along track long wavelength signals

Typical coverage (@surface) for year 2004
***in situ* T profiles**

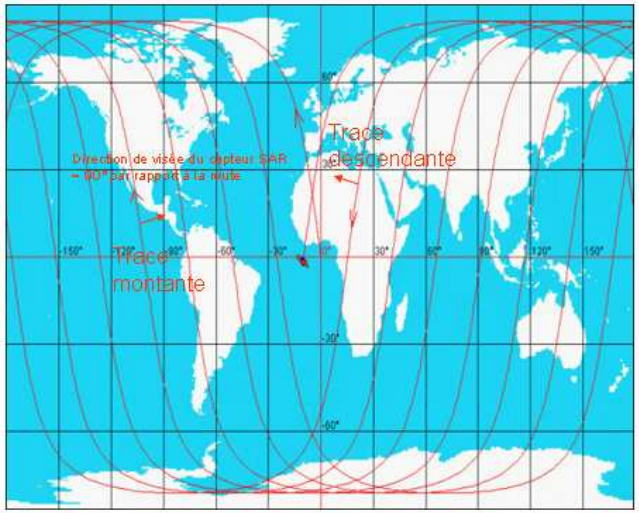


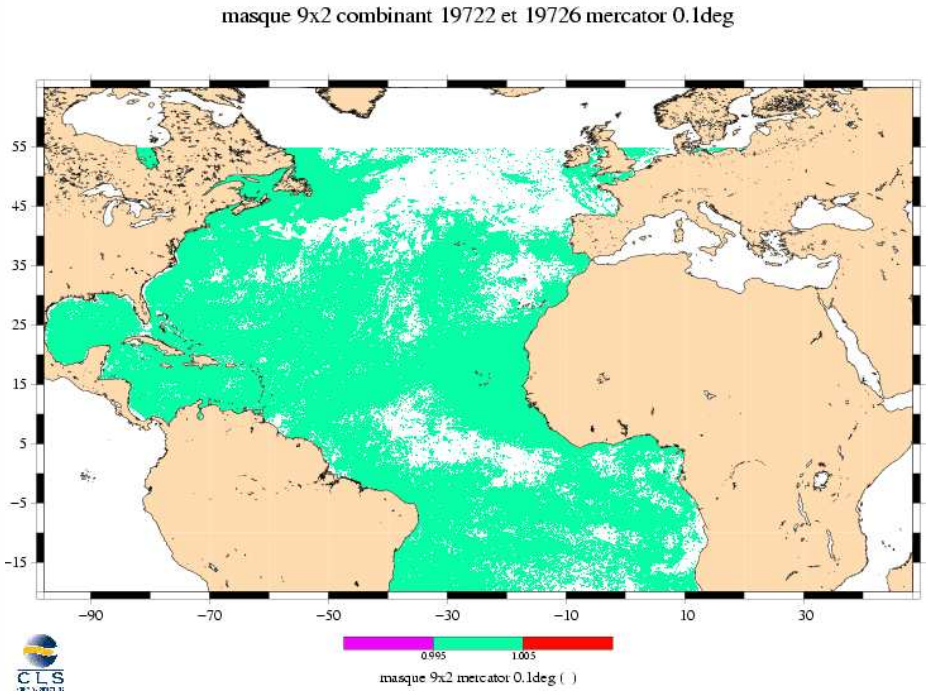
Simulation of the “true ocean”: non conventional data

Specifications provided by BOOST technology

- SAR data (Envisat)
  - Radial velocity 400km offshore
  - Repeat time = 3 days
  - Instrumental noise = 30 cm/s
    - + test with 10 cm/s
  - 10-20 km spatial resolution
- Optical flow data
  - Weekly U and V
  - Cloud + Ice mask
  - wind threshold (2 cm/s)
  - Instrumental noise = 30 cm/s
    - + test with 10 cm/s

Zonal velocity better observed than meridian

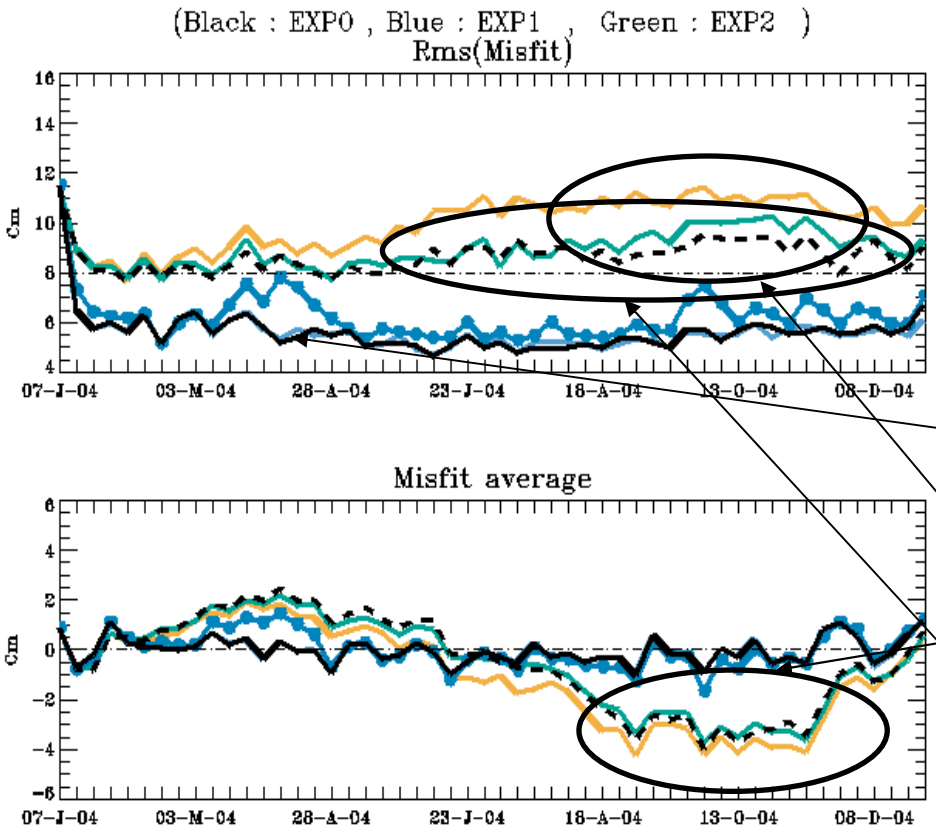




Fraternal twin experiments done

	Coriolis	Jason	Envisat	Gfo	SST	radial U (SAR)	Weekly U,V (OF)
Operational	REAL	REAL	REAL	REAL	REAL		
RUN01 Control	Simulated	Simulated	Simulated	Simulated	Simulated		
RUN02 +SAR	Simulated	Simulated	Simulated	Simulated	Simulated	Simulated Err=30cm/s	
RUN03 No alti +SAR	Simulated				Simulated	Simulated Err=10cm/s	
RUN04 No alti +SAR	Simulated				Simulated	Simulated Err=30cm/s	
RUN05 One alti +SAR	Simulated			Simulated	Simulated	Simulated Err=30cm/s	
RUN06 No alti, +SAR+OF					Simulated	Simulated Err=30cm/s	Simulated Err=30cm/s
RUN07 No alti, +SAR+OF					Simulated	Simulated Err=30cm/s	Simulated Err=10cm/s

Results: SLA assimilation diags

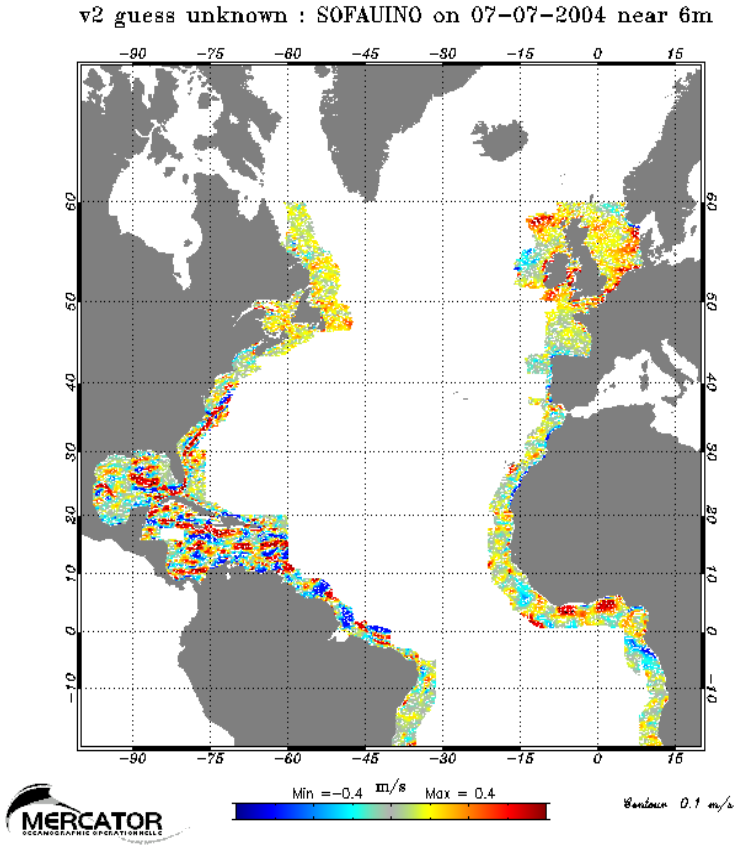


- **Black plain line**
  - **RUN01/CONTROL (conventional obs)**
- **Blue plain line :**
  - **RUN02 (+ SAR) (superimposed to black line)**
- **Green plain line :**
  - **RUN03 (no alti, +SAR 10 cm/s)**
- **Orange plain line:**
  - **RUN04 (no alti, +SAR 30 cm/s)**
- **Blue dotted line :**
  - **RUN05 (One alti only, +SAR 30 cm/s)**
- **Black dotted line :**
  - **RUN06 (no alti, +SAR+OF 30 cm/s)**

- SAR has almost no additional impact when altimetry is assimilated
- SAR and OF are not sufficient to compensate altimeters
- Assimilating SAR + OF with 30cm/s errors performs like assimilating SAR with 10cm/s errors

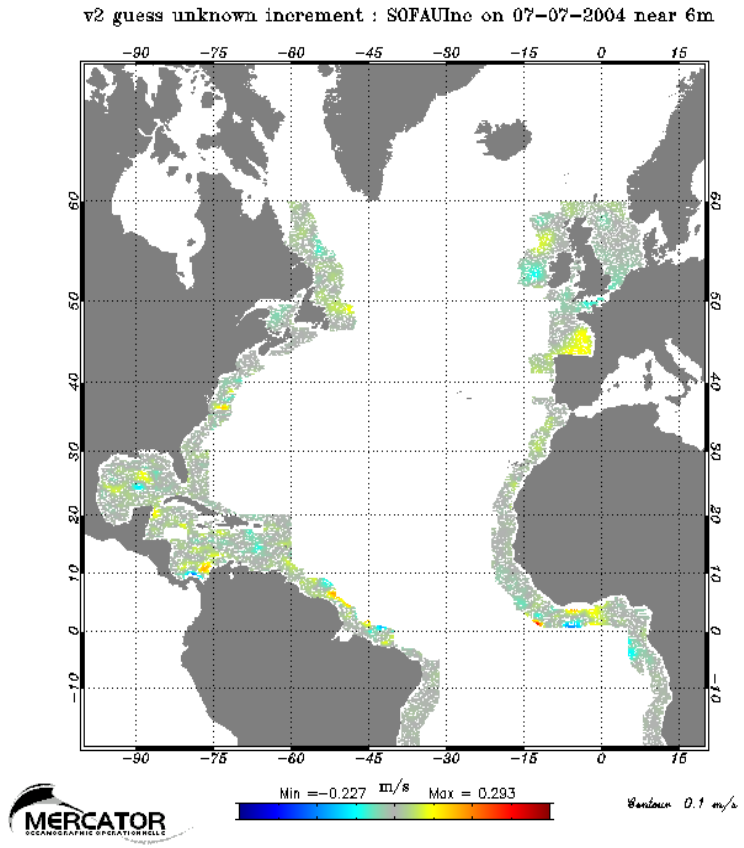
Impact of SAR in addition to altimetry RUN02

Little impact on analysis increments at the surface due to obs errors



-40cm +40cm

Innovation

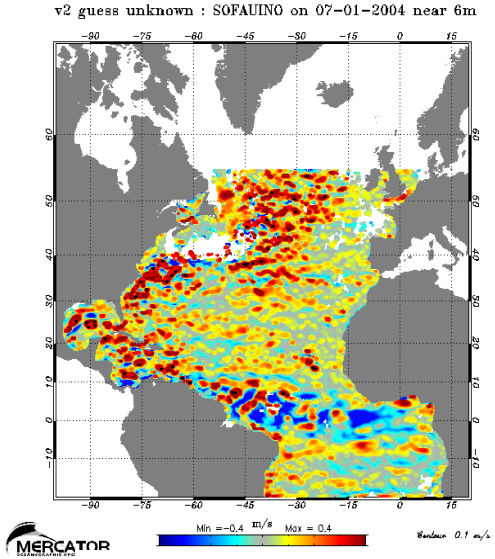


-40cm +40cm

Increment

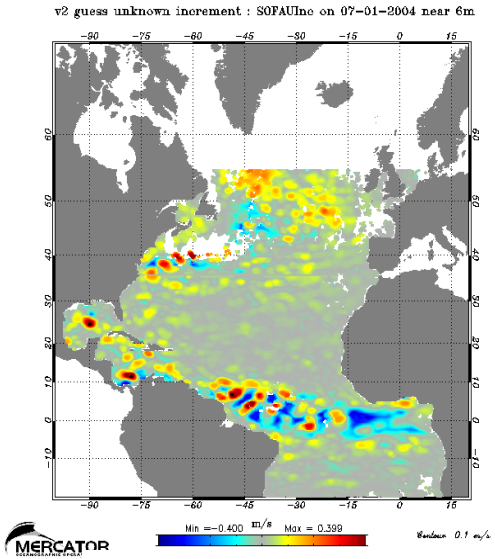
Impact of OF in addition to altimetry RUN06 and RUN07

Little impact on analysis increments at the surface due to obs errors
Good agreement in tropical region between innovation and increment
- **Velocities derived from OF method seem to be well adapted to tropical dynamics**



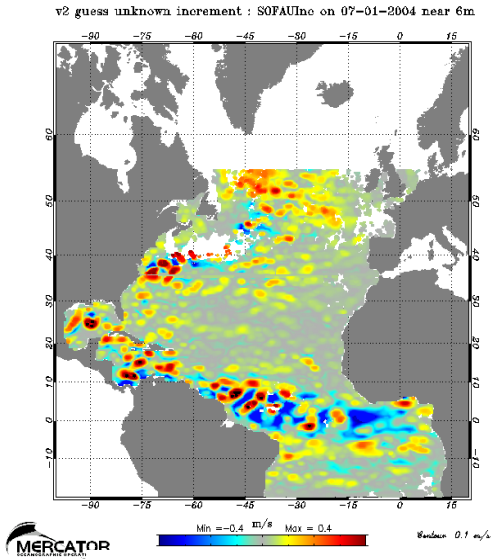
-40cm +40cm

Innovation



-40cm +40cm

Increment (Err=30cm/s)



-40cm +40cm

Increment (Err=10cm/s)

Eric Dombrowsky - 25 Octobre 2007

Conclusions of this OSSE

- SAR derived surface velocities have marginal impact on performances of Mercator 1/3° North and Tropical At lantic system when altimeter data are assimilated (3 altimeters)
- Error on velocity estimated should not exceed 7cm/s if we want them to have an impact comparable to other data
- In the case of loss of altimeter capacity, SAR derived velocity would not enable to compensate the loss
  - Too local, and too noisy
  - Corrections made upstream (“coastal” gulf stream) degrades the situation in the open ocean after advection
  - No control over large parts of the ocean
- Assimilation of optical flow velocities has positive impact

*Future work will include use of real data (**OSE**)*

OSE to measure the impact of altimeter data on MERCATOR 5-7km resolution system in the North Atlantic and Mediterranean

M. Benkiran, E. Greiner, Eric Dombrowsky

and D. Jourdan

Work done by Mercator Océan and CLS
under contract with SHOM

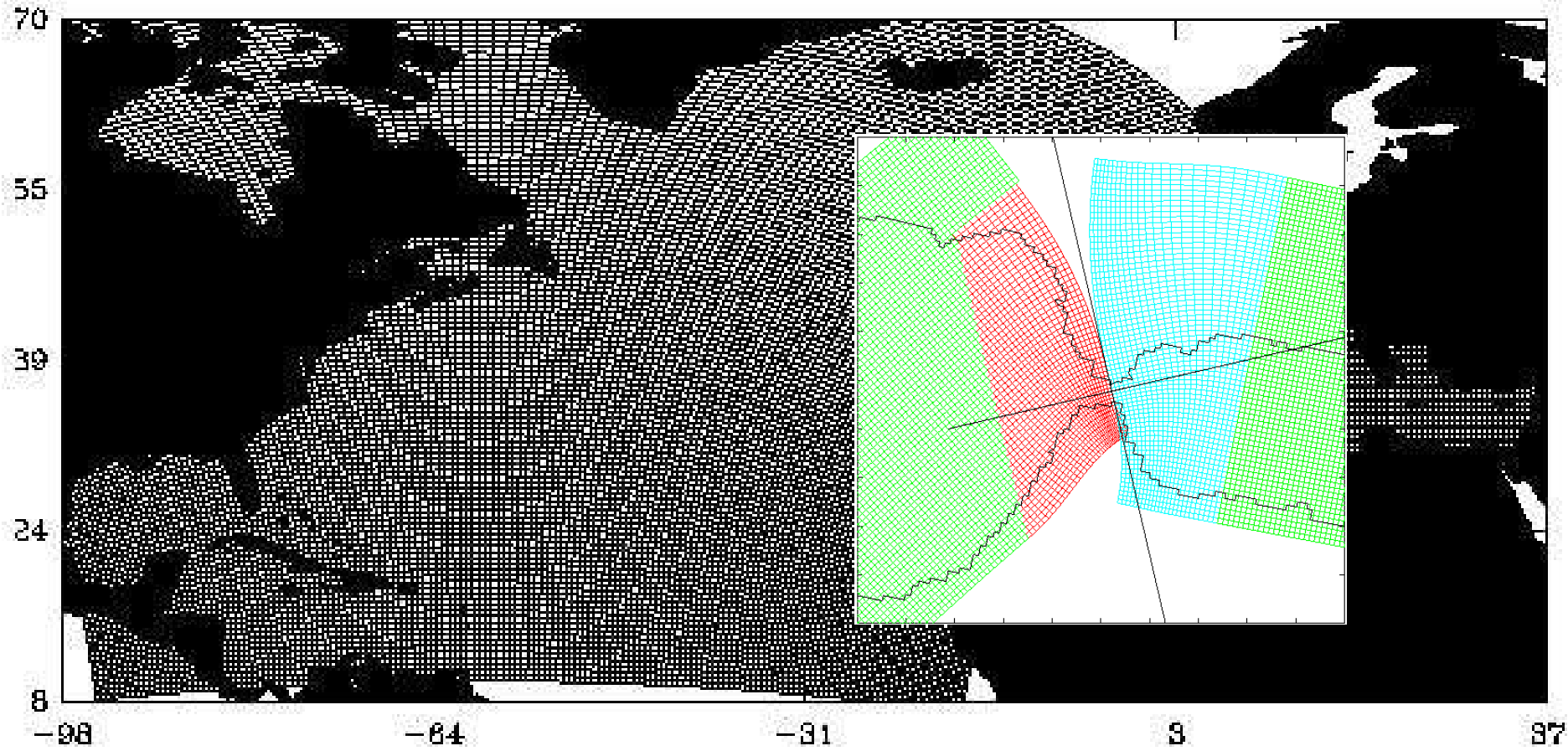
Objectives and experimental protocol

- Objective:
  - Assess the **impact** of the **probable altimeter coverage degradation** on products delivered to the **French Navy** using Mercator Océan forecasting systems

- Experimental protocol **OSE**:
  - Run several hindcast runs starting from an operational restart file with 0, 1, 2, 3, and 4 altimeters (baseline 3 satellites, operational setup)
  - Use high resolution system to do that (Natl+Med 5-7 km resolution)
  - Assess overall performances of Mercator system products
  - For a selected set of dates, simulate forecasts, apply Navy post processing, and measure the impact on the service delivery to the Navy

The system used: 1) eddy resolving model configuration

- OPA OGCM, ECMWF surface forcing (fluxes)
- 5 to 7 km rotated grid in the Atlantic, 1/16° in t he Med
- 43 levels in both basins (19 at Gibraltar Strait)

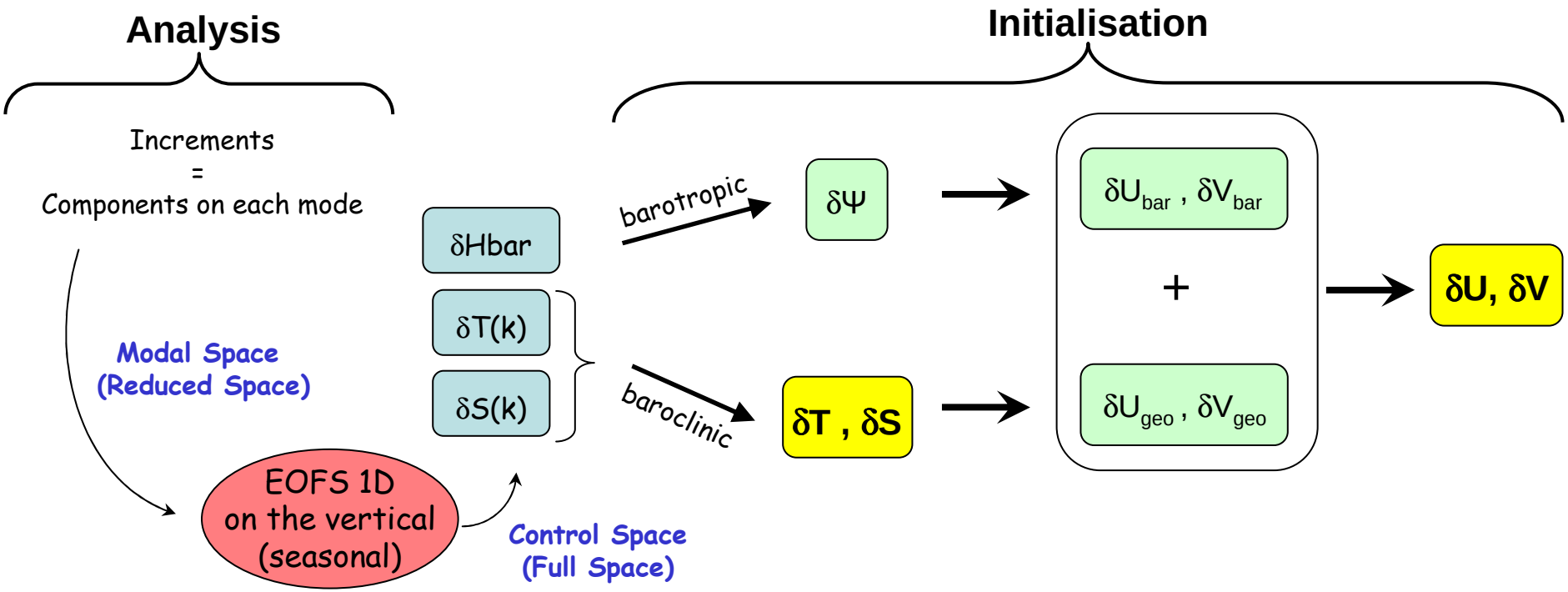


The system used: 2) multivariate multidata OI assimilation system

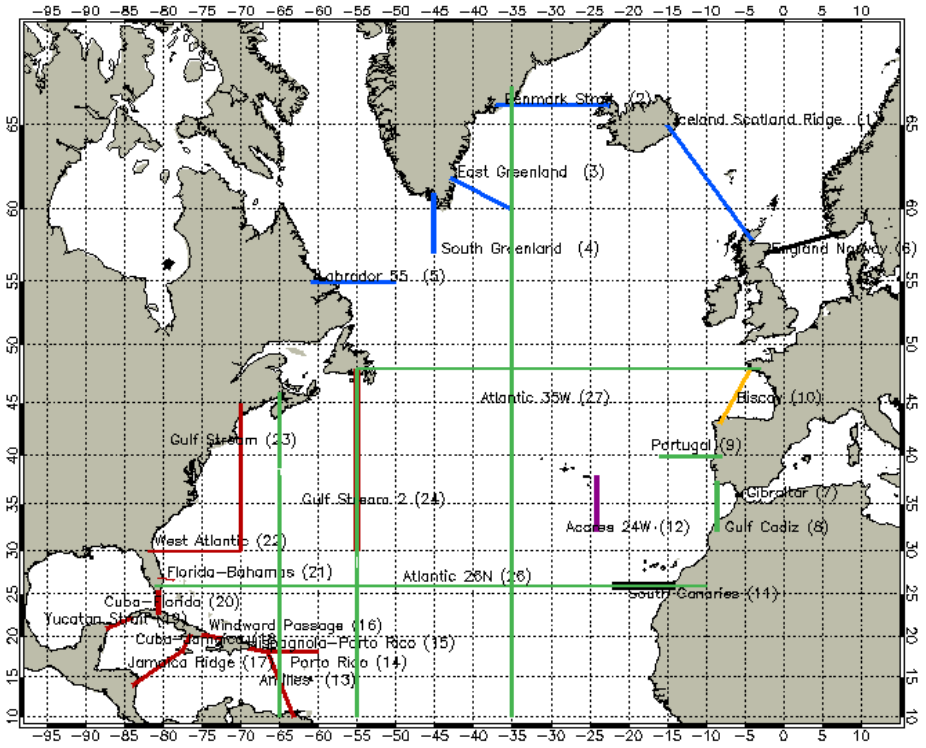
multivariate multidata optimal interpolation

Statistical representation of the forecast error = 2D analytical (horiz.) + EOFs 1D (vert.)

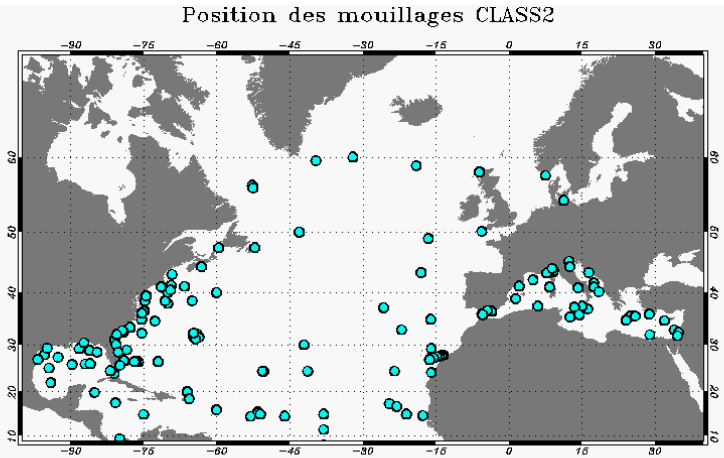
- ✓ Altimetry along track SLA (+ MSSH from Rio et al.)
- ✓ RTG SST
- ✓ T/S vertical profiles



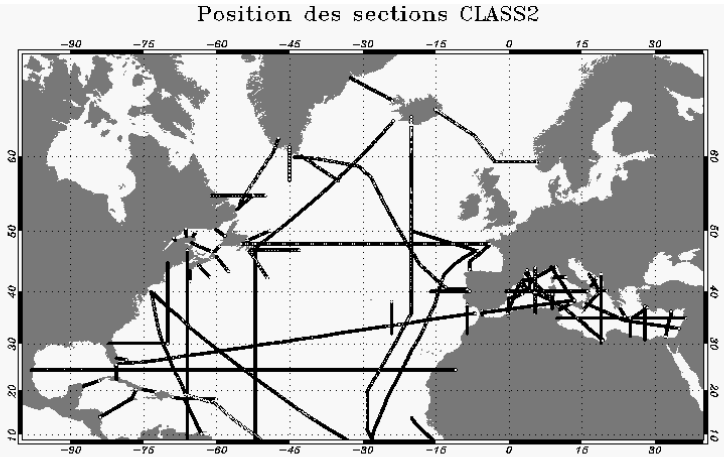
The system used: 3) GoDAE validation and assessment protocols



46 class3 transport sections, daily



147 Class2 moorings, 4h



85 Class2 sections, daily

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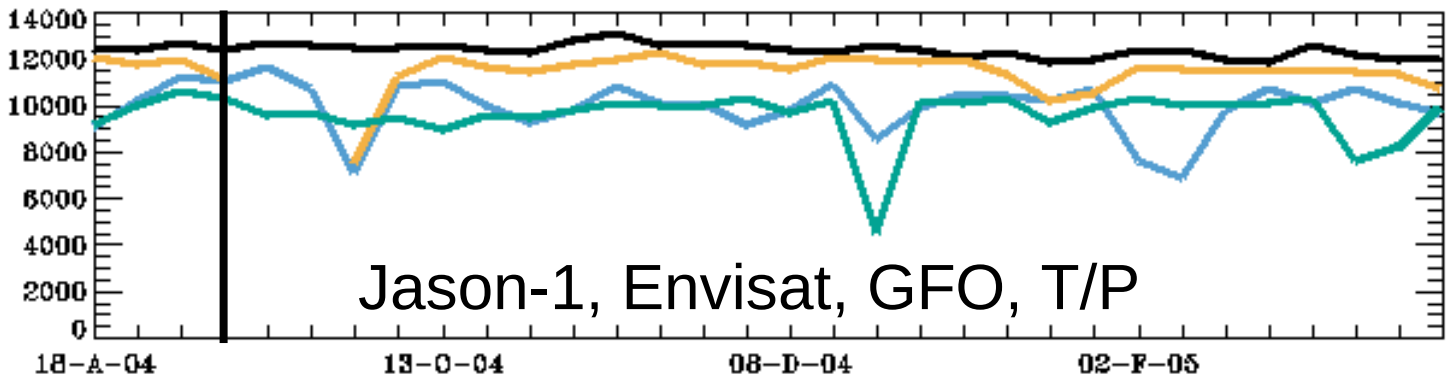
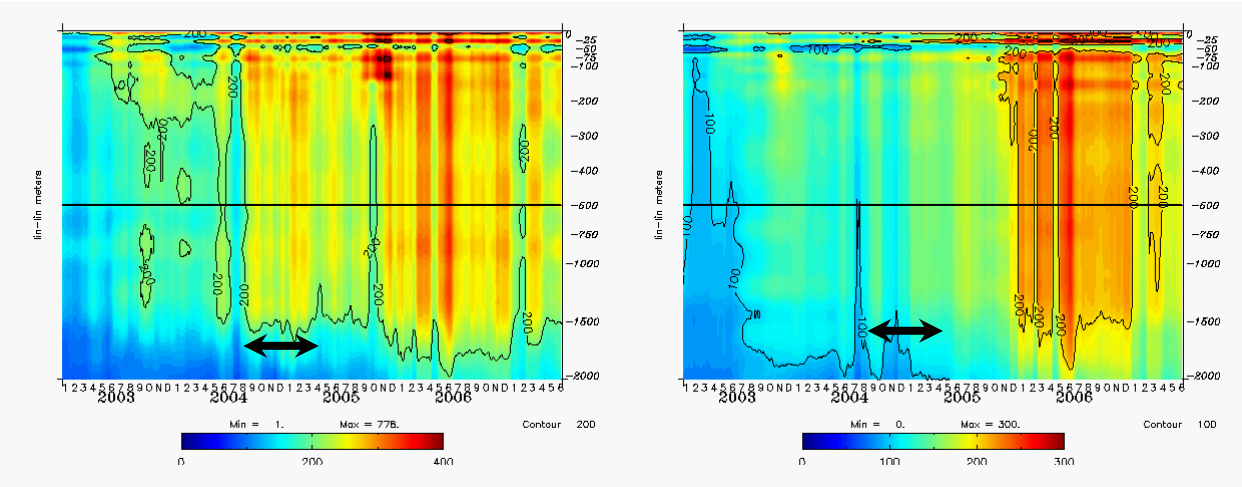
6-month period selected: Sept 22nd 2004 to March 23rd 2005

22/09/2004 **Number SLA obs per week over the domain** 23/03/2005



Number of T/S valid profiles per week over the domain(2003-2006)



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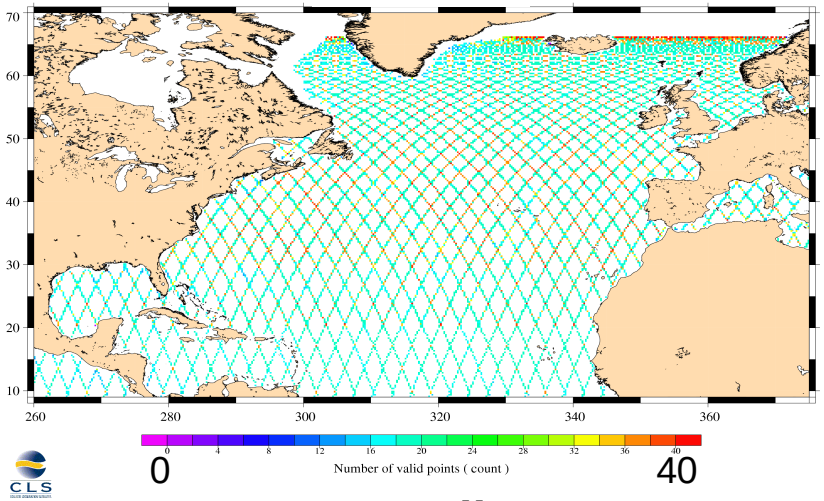
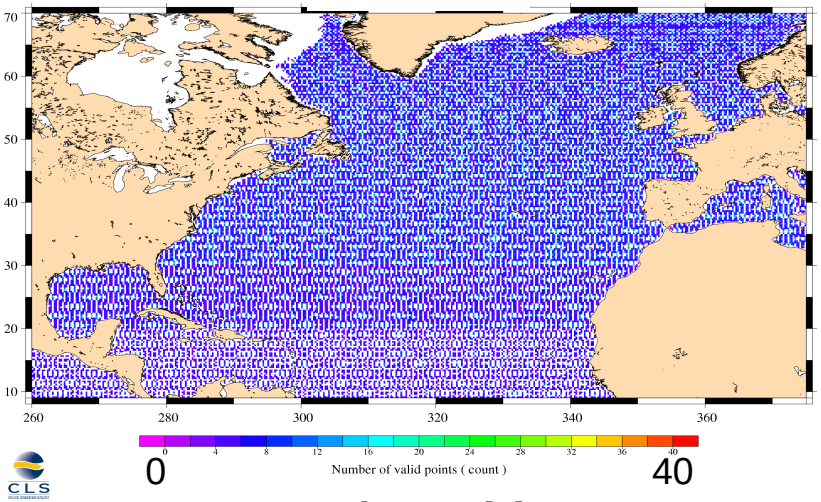
Number of valid SLA data per satellite for the period

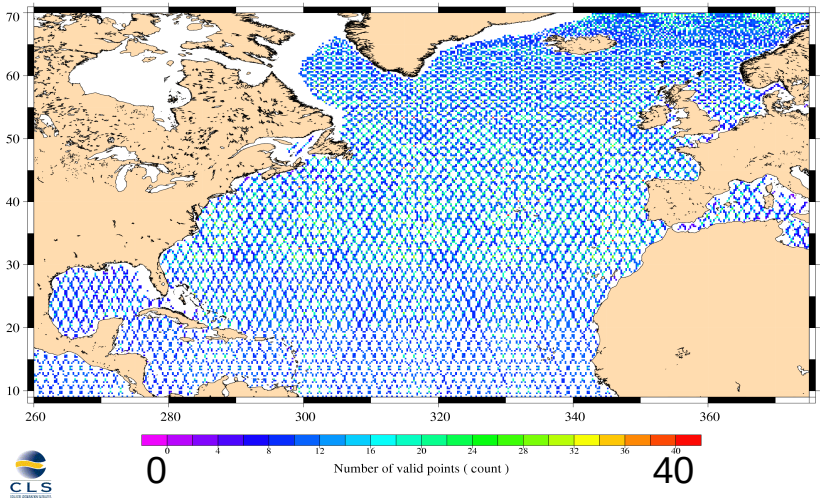
Jason1



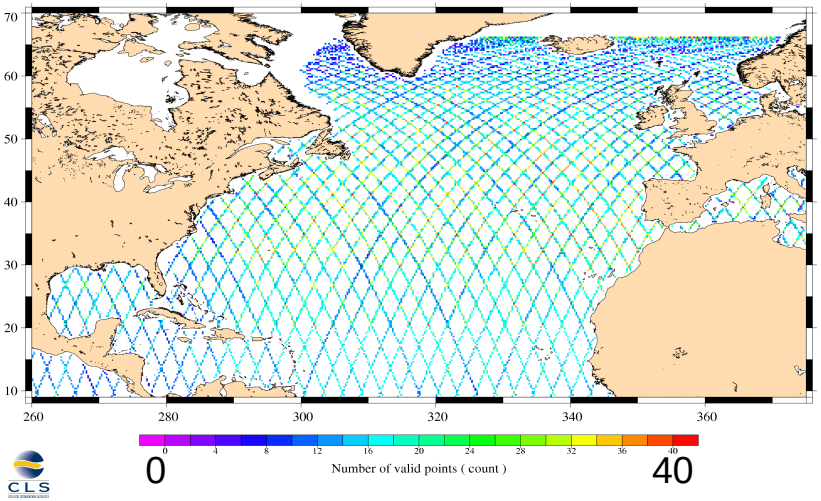
Envisat



Geosat Follow-On



Topex/Poseidon



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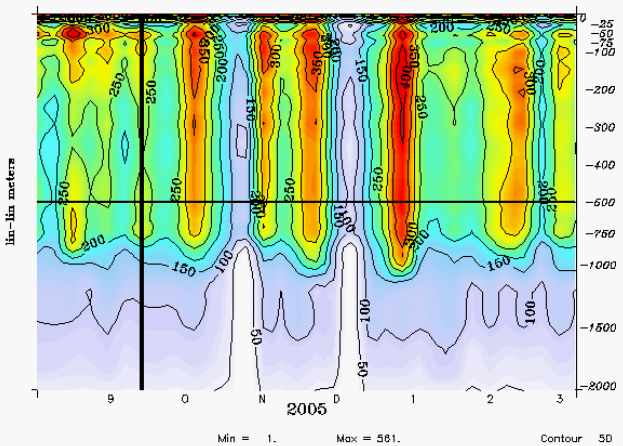
Overall performances in temperature and salinity for the baseline: innovation statistics

Number of profiles

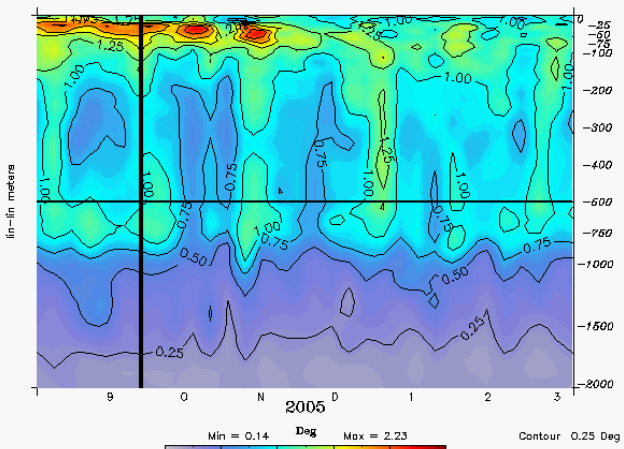
RMS diff

RMS diff

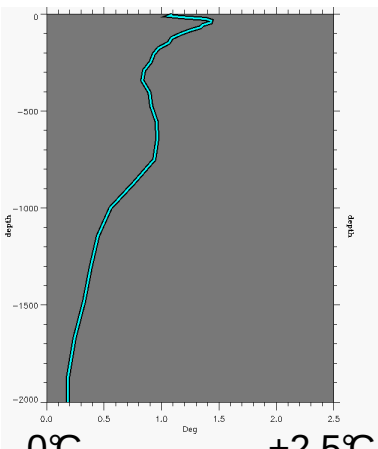
T



0 400



0℃ +2.5℃



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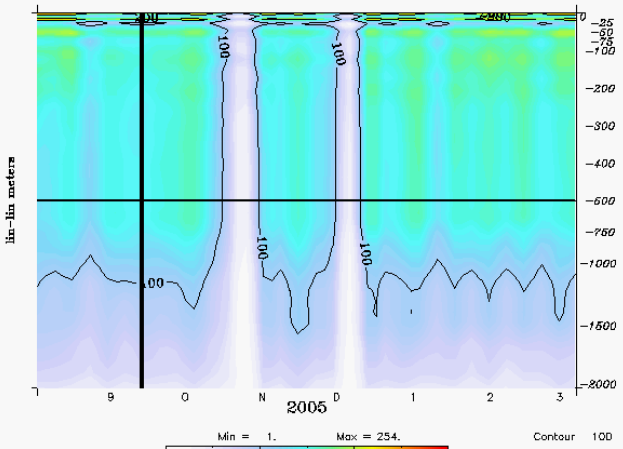

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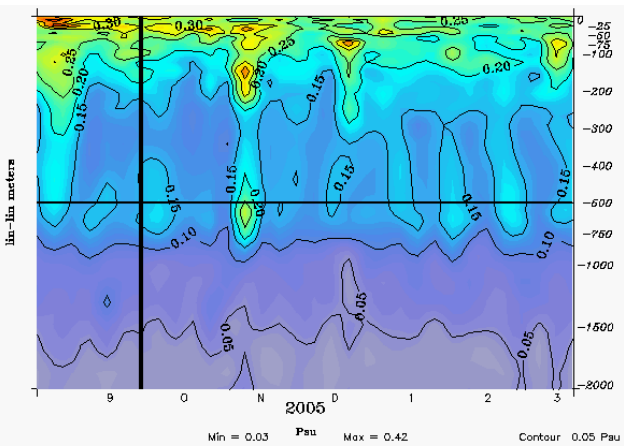
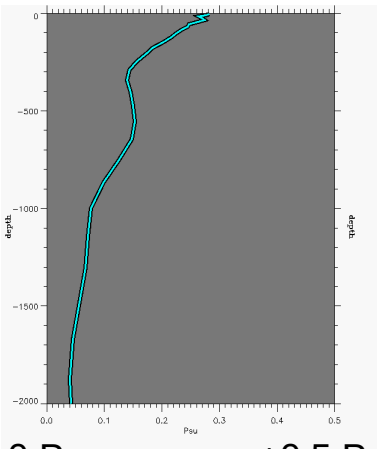


0 Psu +0.5 Psu



0 Psu +0.5 Psu

The experiments

	Coriolis	JASON	ENVISAT	GFO	TOPEX	SST
Jason+Envisat+GFO EXP0	**x**	**x**	**x**	**x**	**verif**	**RTG**
Jason only EXP1	x	x	verif	verif	verif	RTG
Jason + Envisat EXP2	x	x	x	verif	verif	RTG
without altimeters EXP3	x	verif	verif	verif	verif	RTG
Jason+Envisat+GFO+T/P EXP4	x	x	x	x	x	RTG
Progressive loss EXP5	x	First 4.5 month	First 3 month	First 1.5 month	verif	RTG

OSE: Impact of multi-mission altimeters on North Atlantic + Mediterranean 5-7 km Mercator forecasting system

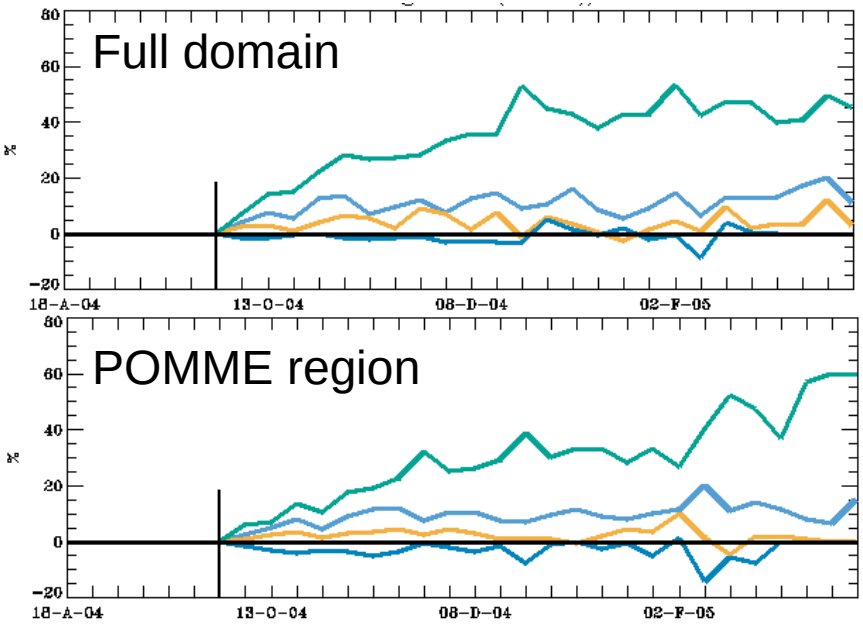
- OSE in 2004 (6 month)

EXP0: Jason + Envisat + GFO
EXP1: Jason + Envisat
EXP2: Jason
EXP3: No alt
EXP4: Jason + Envisat + GFO + T/P

Shown here diags from innovation: forecast – obs (not yet assimilated)

All EXP: In situ T/S + RTG SST

$$\frac{\text{RMS(EXPi-obs)-RMS(EXP0-obs)}}{\text{RMS(obs)}}$$



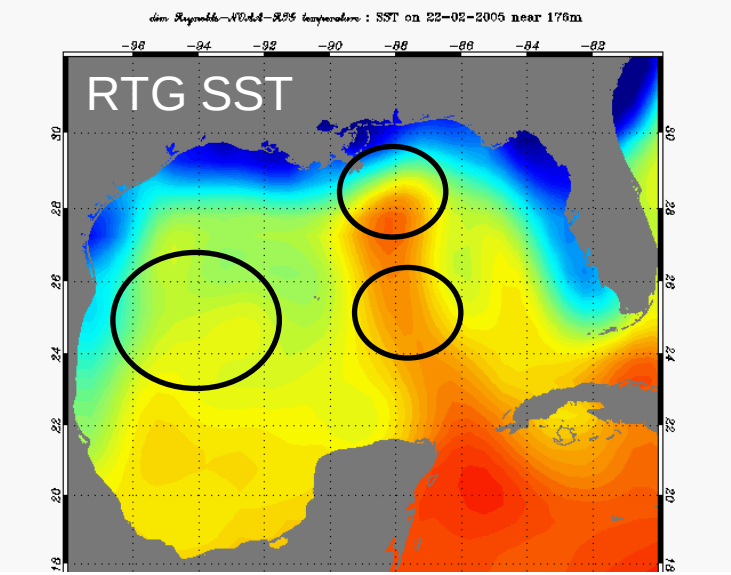
> 0 means degradation in %

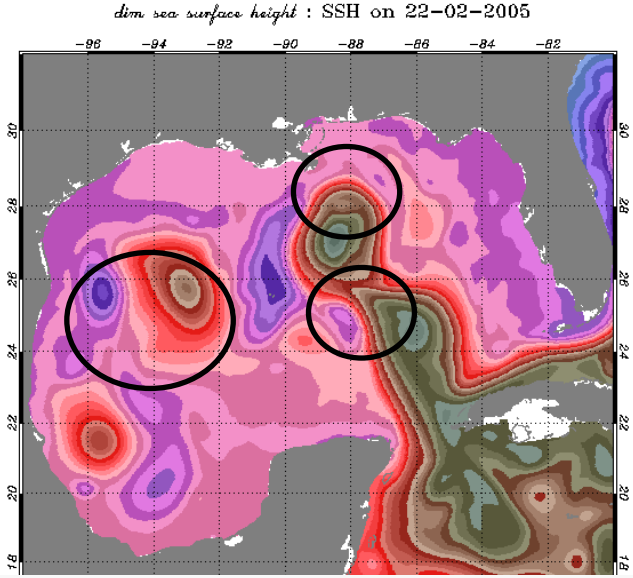
0 is the baseline (3 sats)

< 0 means improvement in %

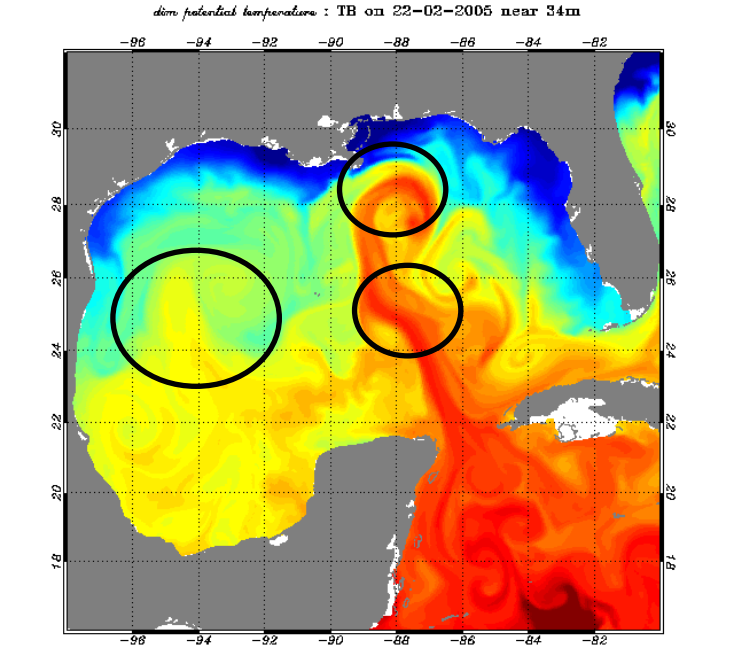
M. Benkiran 2007

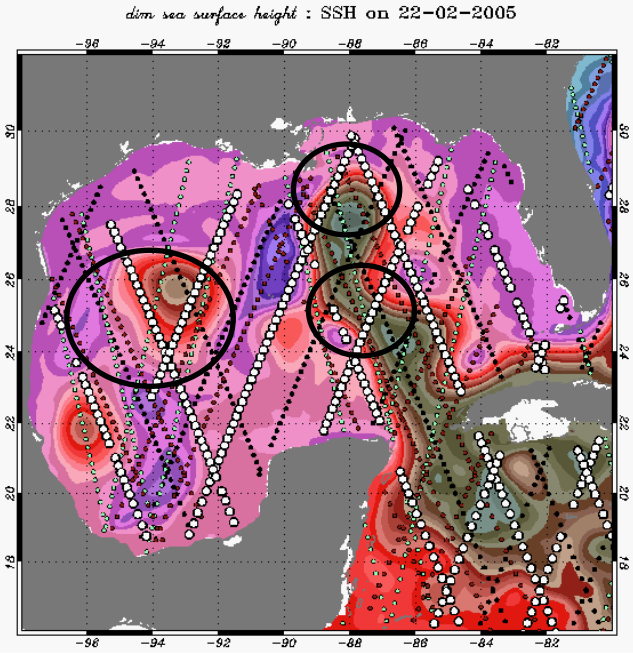
Impact of a fourth altimeter in the Gulf of Mexico 1-week forecast





In Situ T/S, RTG SST
Jason
+ Envisat
+ GFO



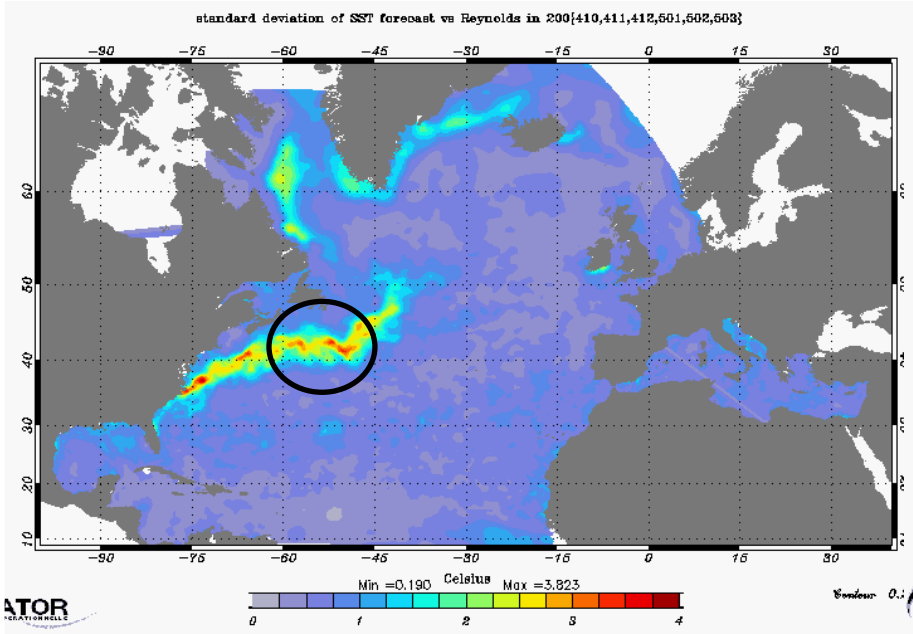


In Situ T/S, RTG SST
Jason
+ Envisat
+ GFO
+ TOPEX/POSEIDON

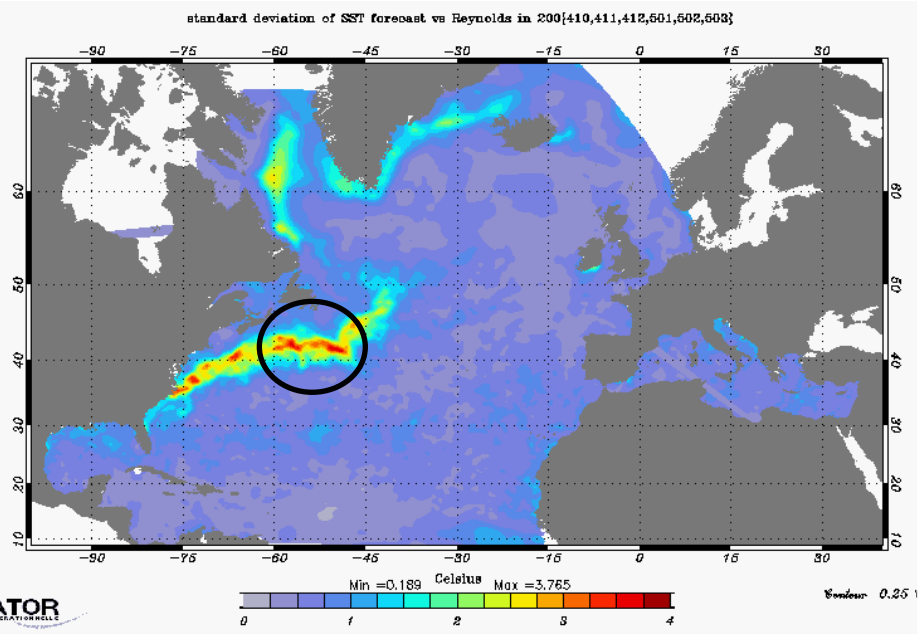
M. Benkiran 2007

Standard deviation of forecast SST Vs RTG SST

Jason Envisat GFO



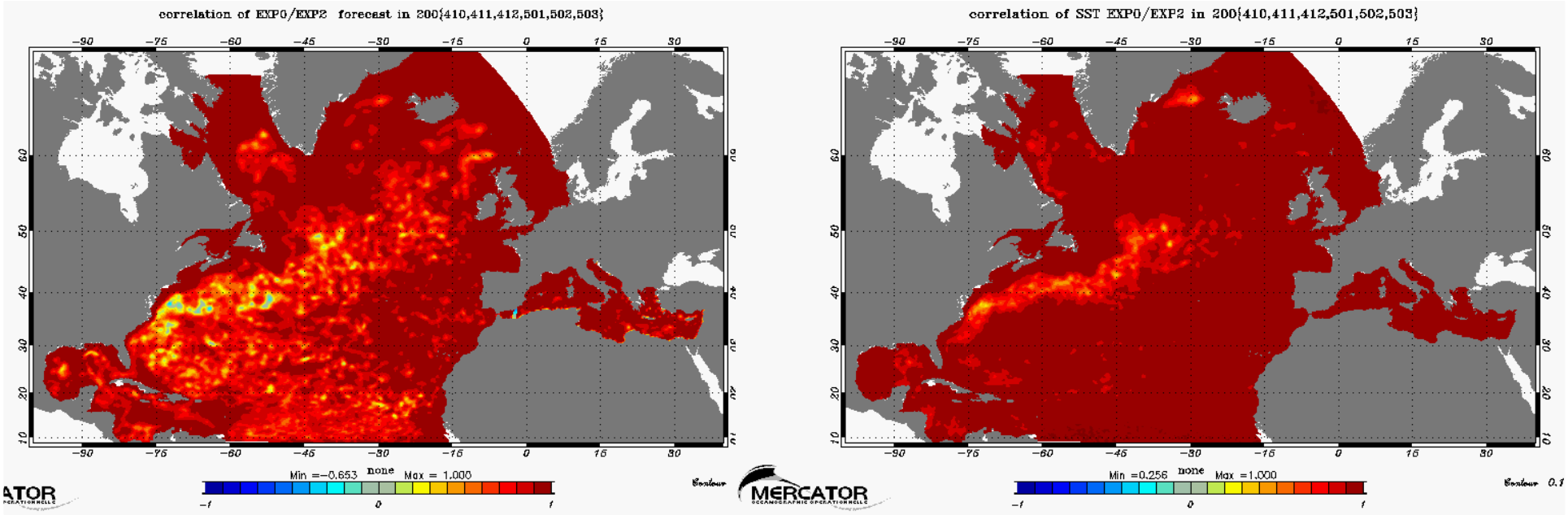
Jason only



SST and SLA correlation

SLA

SST



Jason+Envisat+GFO versus Jason+Envisat

Eric Dombrowsky - 25 Octobre 2007

Conclusions for this OSE

- High resolution systems see the impact of multi satellite missions
  - Even a fourth altimeter has impact
    - Where energy is low (Northeastern Atlantic)
    - Where signals are fast (Tropics)
    - Everywhere if we look locally and carefully (example gulf of Mexico)
- One single altimeter enables to get and keep some predictive skill, while there is no skill for mesoscale without altimeters

This is an ongoing work, further conclusions to follow, especially for the impact on Navy products

General conclusions

- **Operational oceanography assimilation systems are unique tools to perform observing systems impact studies**
  - They are designed to reproduce the real ocean
  - Their performances is generally well documented
  - The impact on applications can be assessed
- **Running OSE is "simple" if the system has a hindcast capacity**
  - Observations and forcing already in house
  - Operational chain and tools can be used
  - Evaluation protocol can be derived from the operational one
  - But need computer (and manpower) resources: several additional years of integration, CPU, storage, expertise…
- **Running OSSE is more complex and demanding**
  - Need to simulate data: better to involve the observation agencies and expert groups
  - System has to be adapted if new kind of data has to be assimilated
- **Evaluation protocol is an important issue and GoDAE or Post GoDAE could be a good framework to work together on that**