Ensemble assimilation of JASON and ENVISAT altimetric observations with stochastic parameterization of model dynamical uncertainties

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Outline of the presentation

1. Stochastic parameterization
   of model uncertainties
   (in the large-scale benchmark)

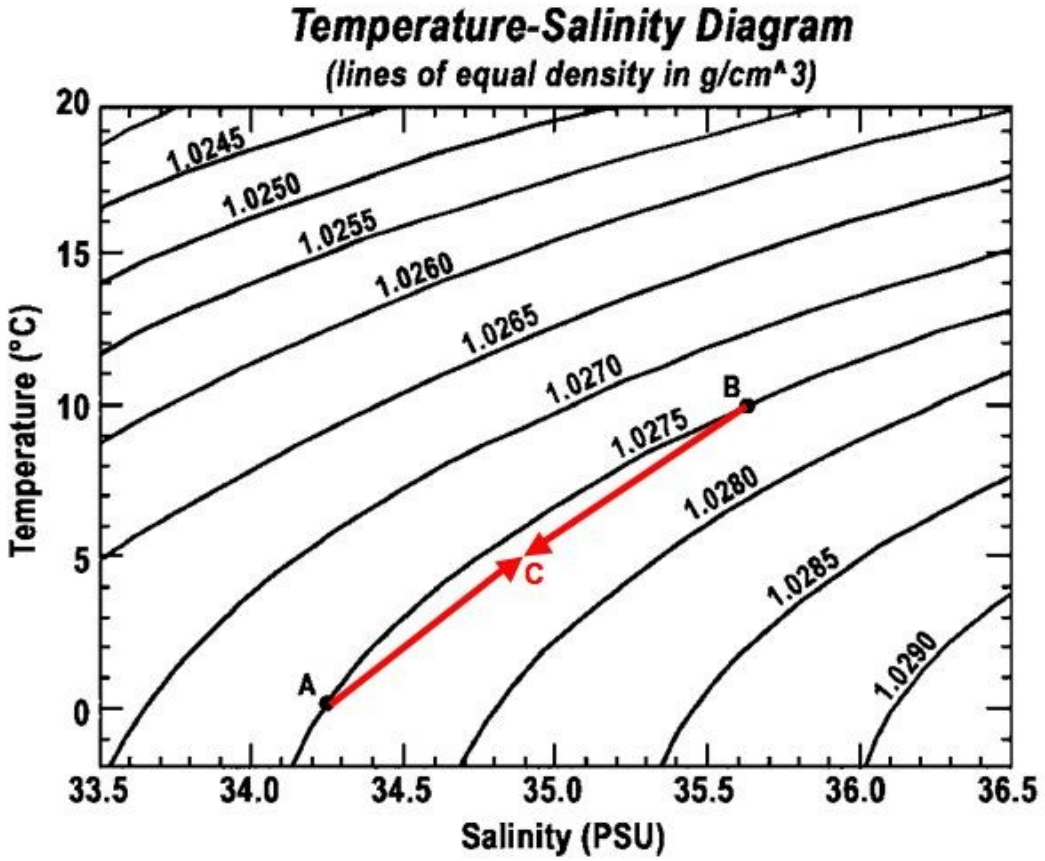
2. Ensemble simulation,
   without data assimilation

3. Data assimilation experiment

1. Stochastic parameterization of model uncertainties

4.3 Uncertainties in the computation of density

In the model, the large-scale density is computed form large-scale temperature and salinity, using the sea-water equation of state.



(a)
Mixing waters of equal density but different T&S systematically increases density (cabbeling)

(b)
Averaging T&S equations systematically overestimates density (in a fluctuating, non-deterministic way)

However, because of the nonlinearity of the equation of state, unresolved scales produce an average effect on density.

Stochastic equation of state for the large scales

Stochastic parameterization

using a set of random T&S fluctuations
ΔT_i et ΔS_i , i=1,...,p
to simulate unresolved T&S fluctuations

$$\rho = \frac{1}{2p}\sum_{i=1}^{p}\left\{\rho\left[T+\Delta T_i, S+\Delta S_i, p_0(z)\right]+\rho\left[T-\Delta T_i, S-\Delta S_i, p_0(z)\right]\right\}$$

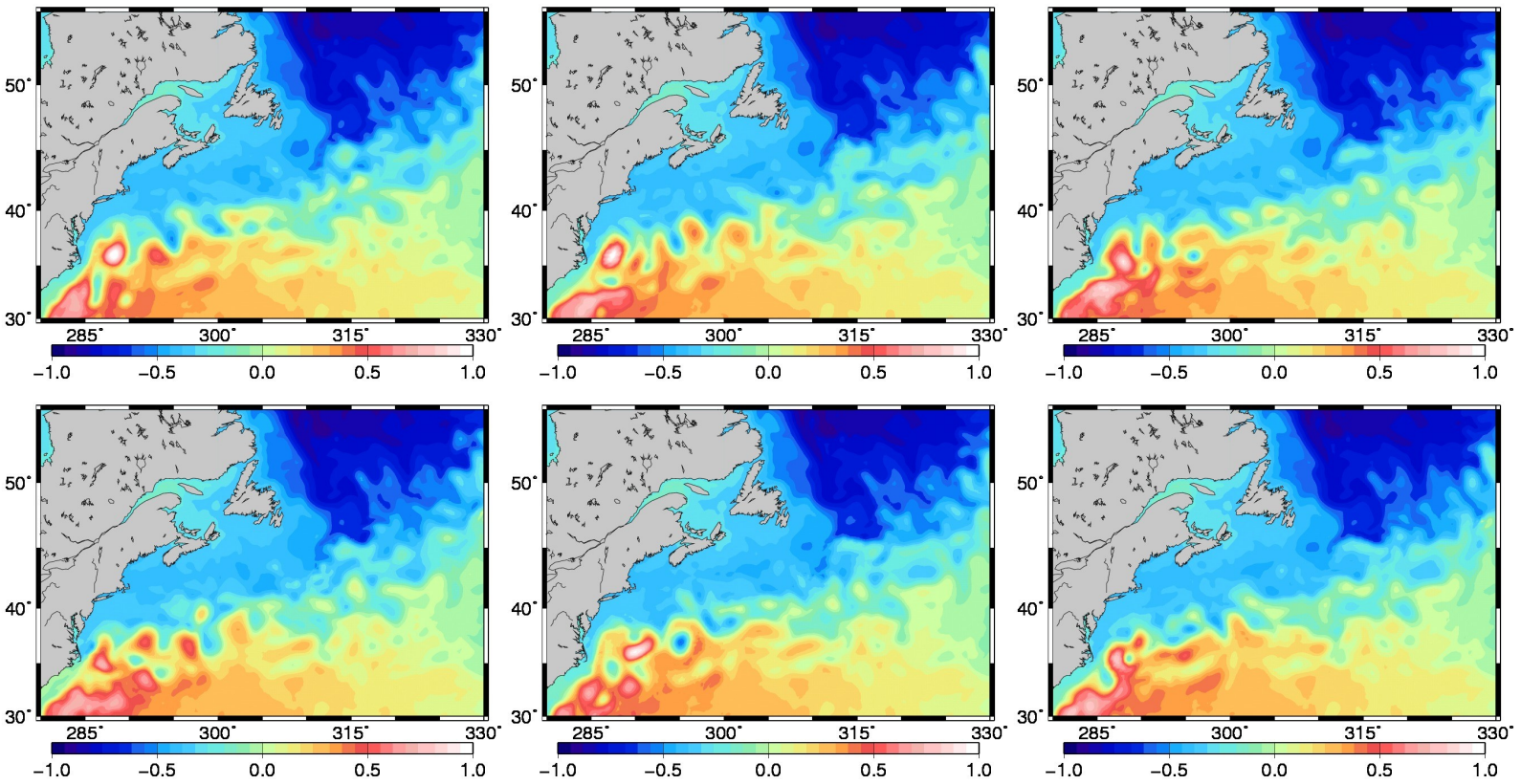
Leading behaviour of Δρ:

$$\Delta\rho = \frac{\partial^2\rho}{\partial T^2}\left(\frac{1}{2p}\sum_{i=1}^{p}\Delta T_i^2\right)+2\frac{\partial^2\rho}{\partial T\partial S}\left(\frac{1}{2p}\sum_{i=1}^{p}\Delta T_i\Delta S_i\right)+\frac{\partial^2\rho}{\partial S^2}\left(\frac{1}{2p}\sum_{i=1}^{p}\Delta S_i^2\right)$$

No effect if the equation of state is linear.
Proportional to the square of unresolved fluctuations.

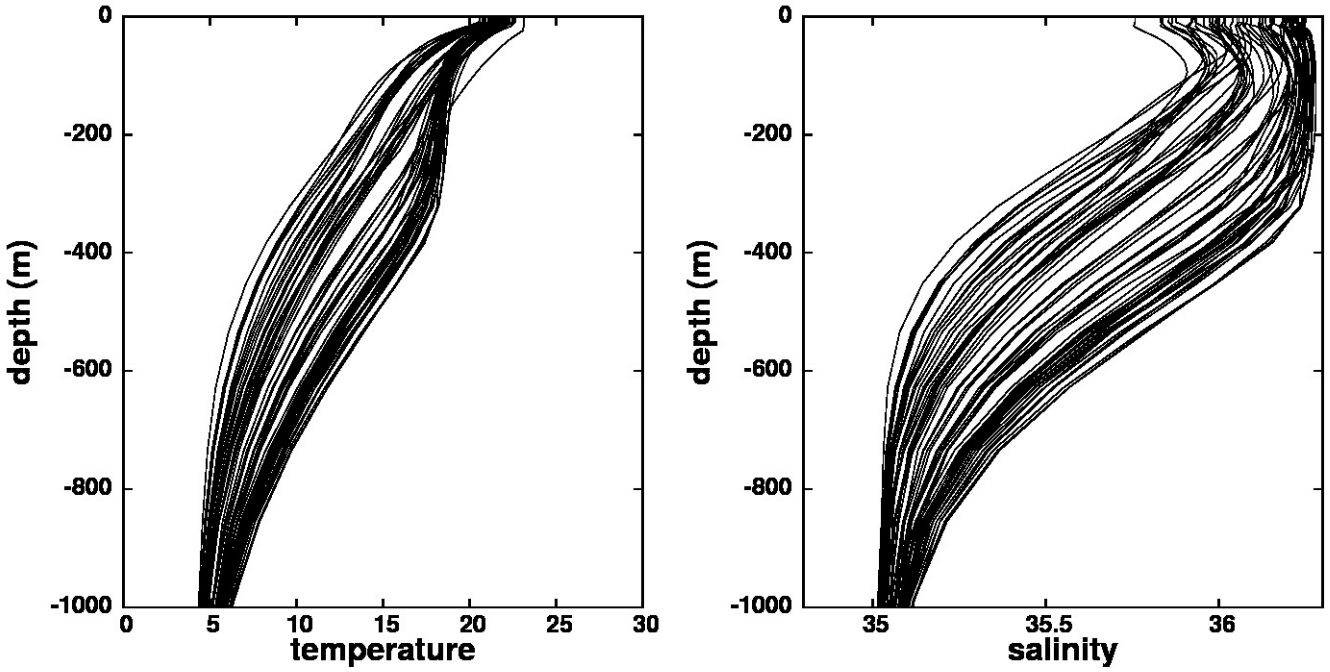
2. Ensemble simulation, without data assimilation

Ensemble with the large-case SANGOMA benchmark



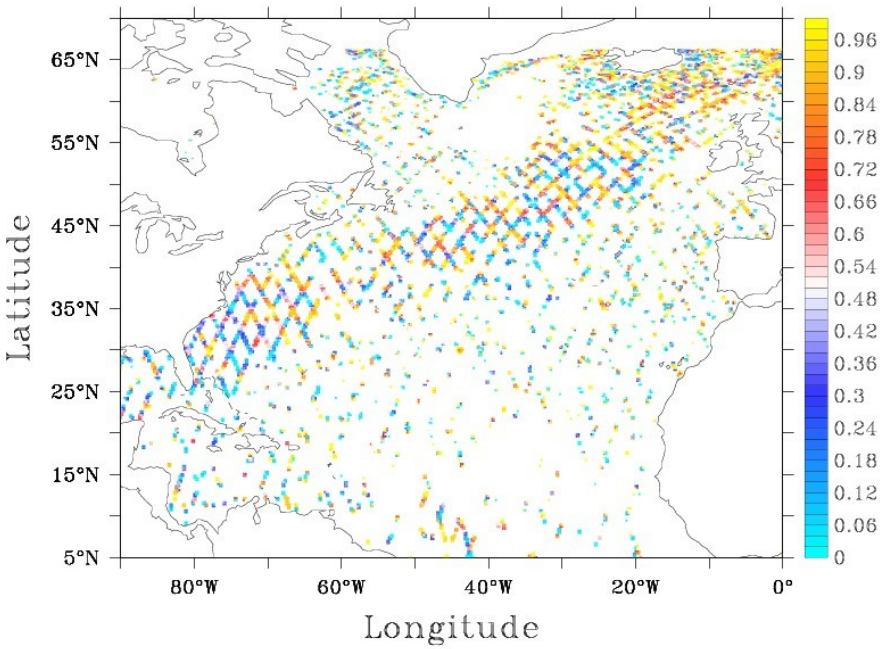
Ensemble spread in the Gulf Stream region after 6 months (6 members among 96)

Spread on the TS vertical structure

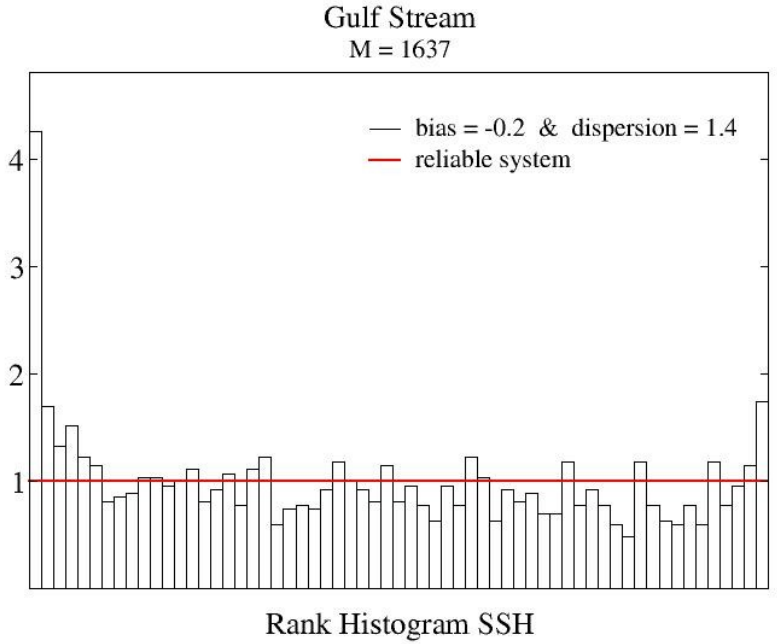


Ensemble spread in the Gulf Stream region after 6 months

Rank histogram, after 6 months



Rank of JASON-1 altimetric observations in the ensemble simulation



Histogram of ranks in the Gulf Stream region

→ We can start assimilating altimetric observations

3. Data assimilation experiment

Description of the experiment

Method: ensemble update with SEEK algorithm (~LETKF)

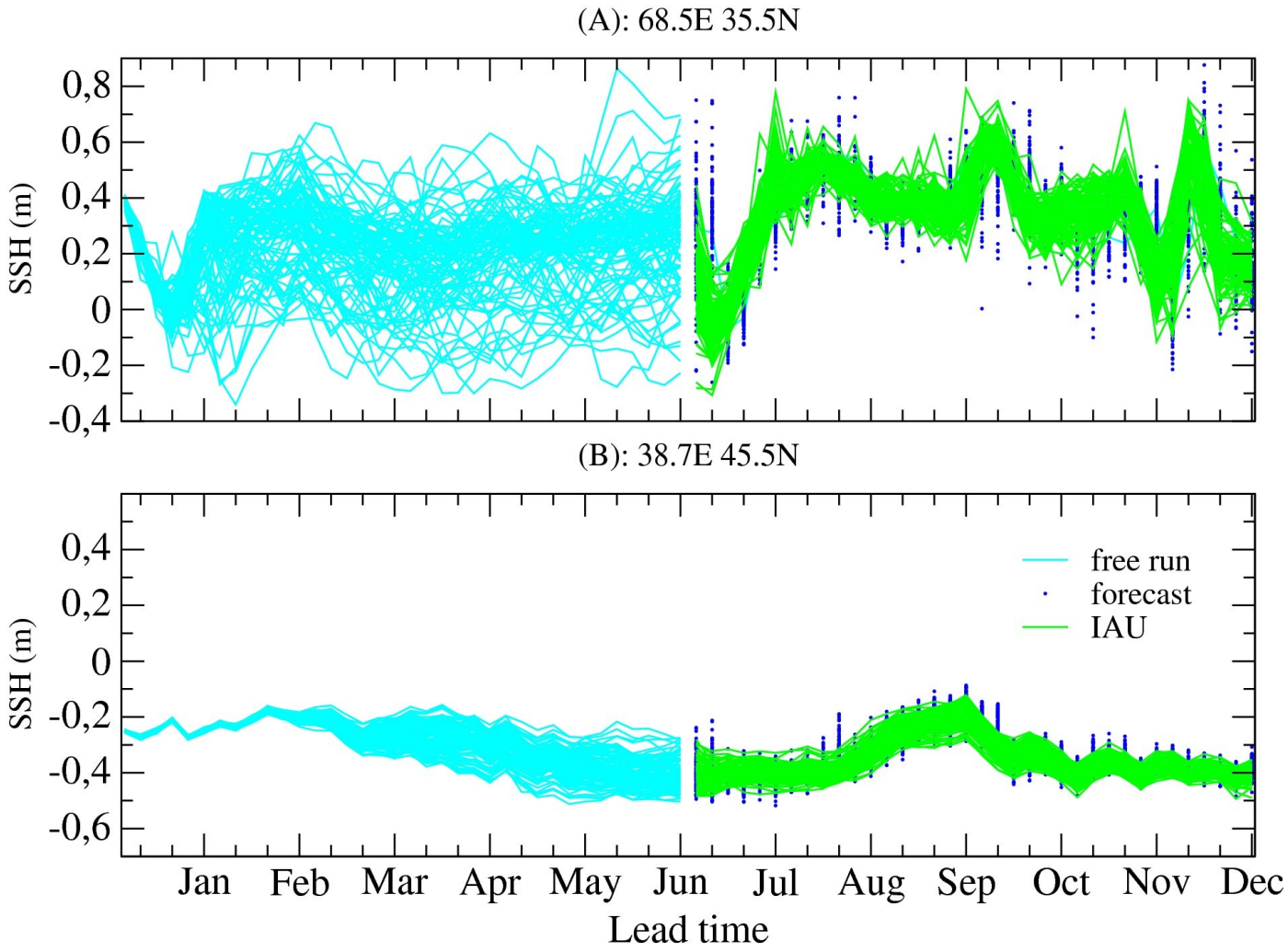
Specificities: localization (~433km), IAU, observation equivalent of ensemble at appropriate time

Ensemble size: 96

Perturbation: in the equation of state

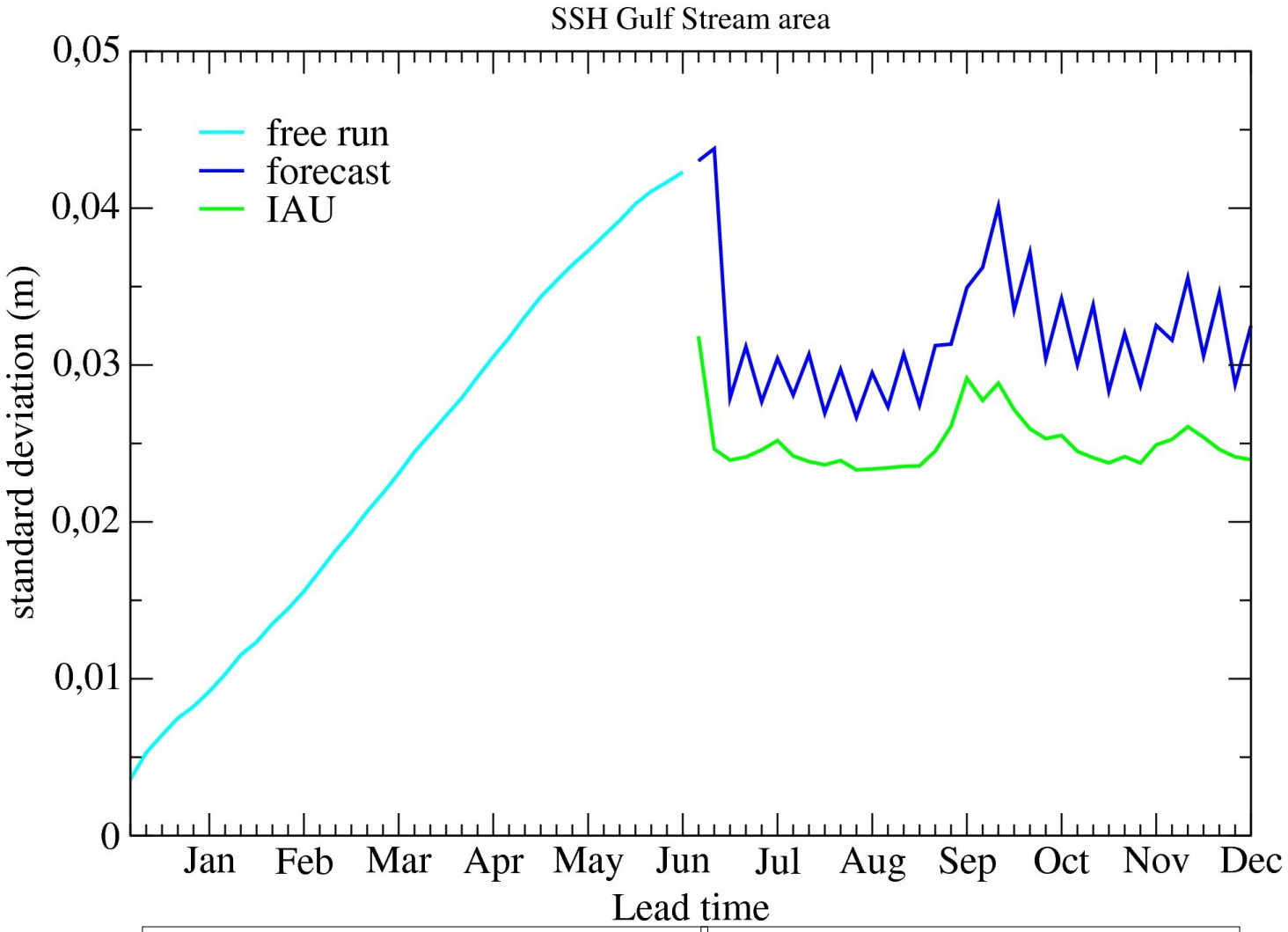
Assimilated data: Jason-1, Envisat

Evolution of SSH ensemble spread



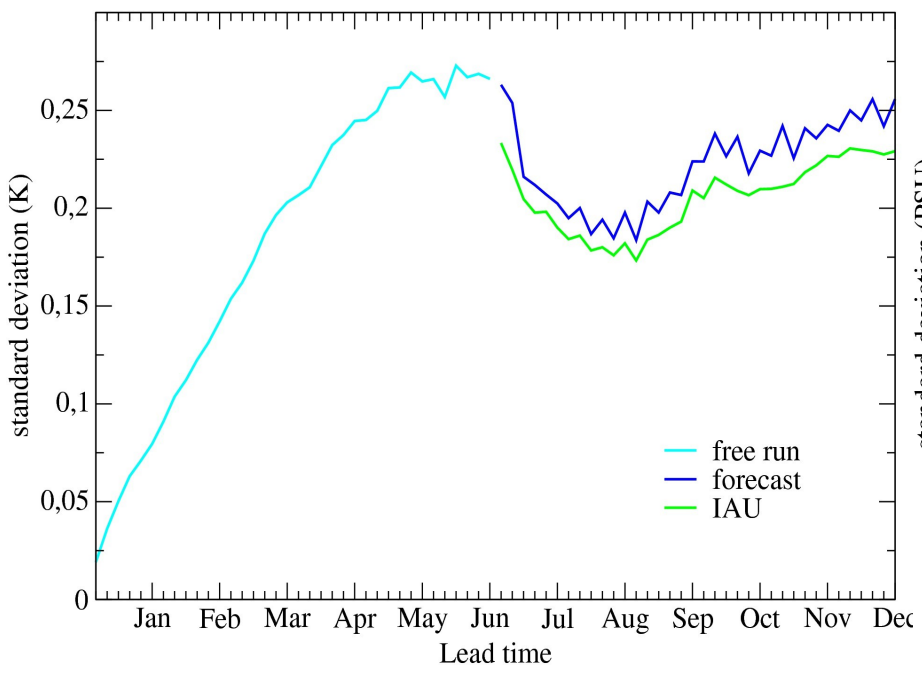
Before assimilation	With assimilation

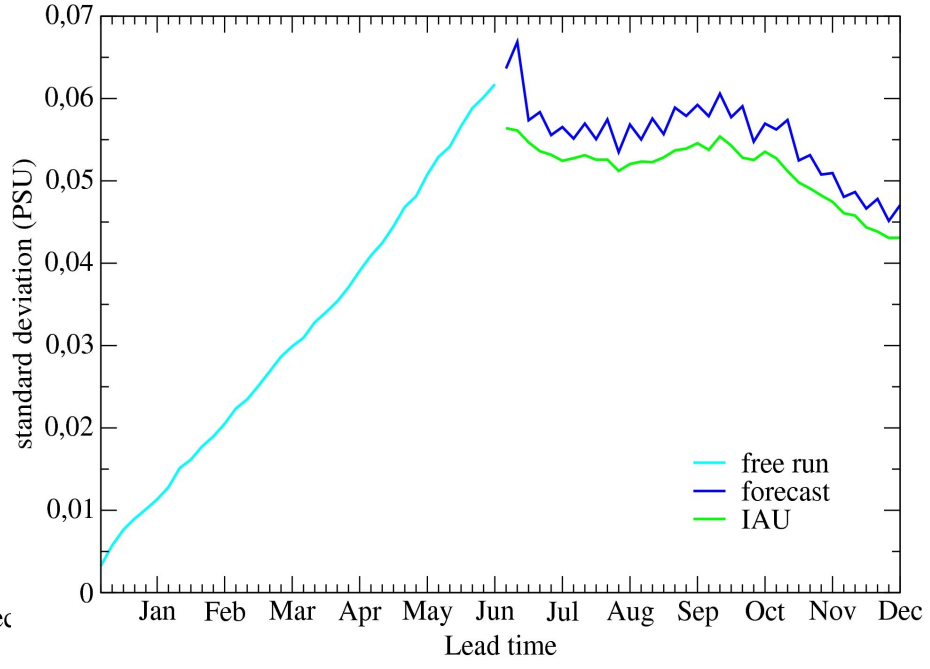
Ensemble standard deviation (SSH)



Before assimilation	With assimilation

Ensemble standard deviation (SST and SSS)

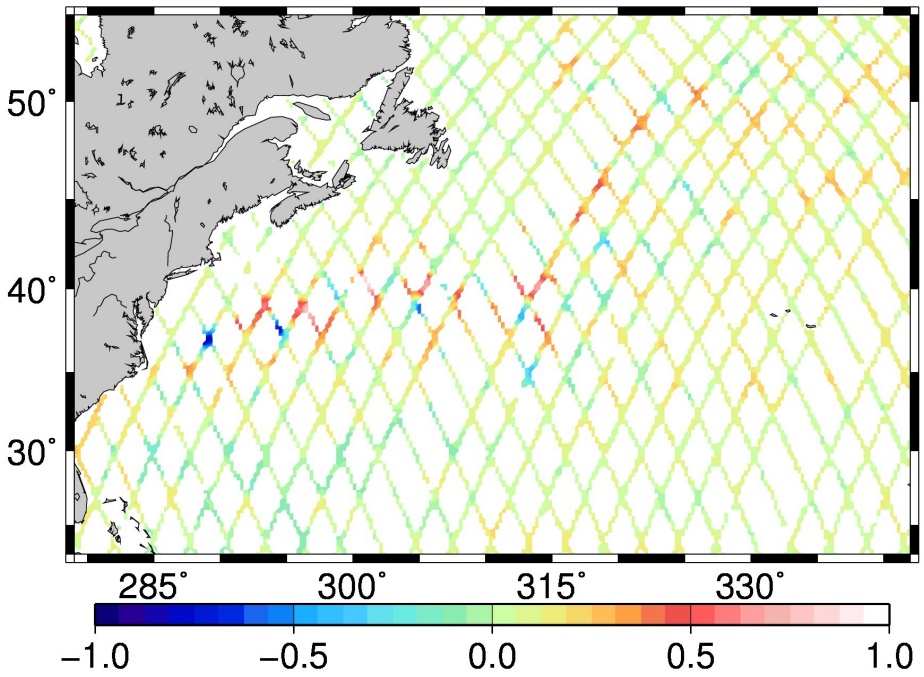




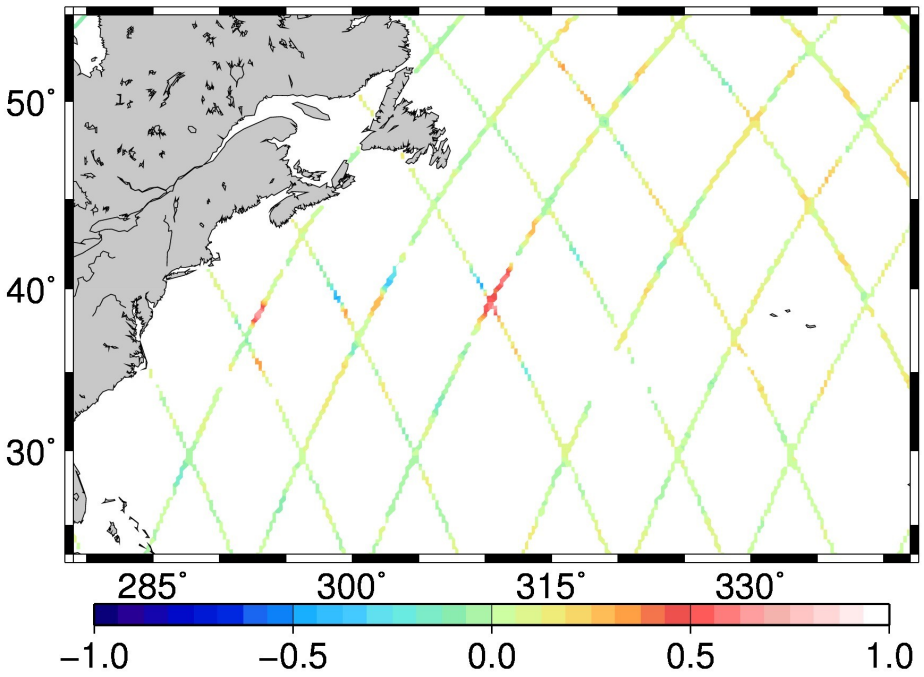
Sea surface temperature

Sea surface salinity

Jason-1 observations: September 2005



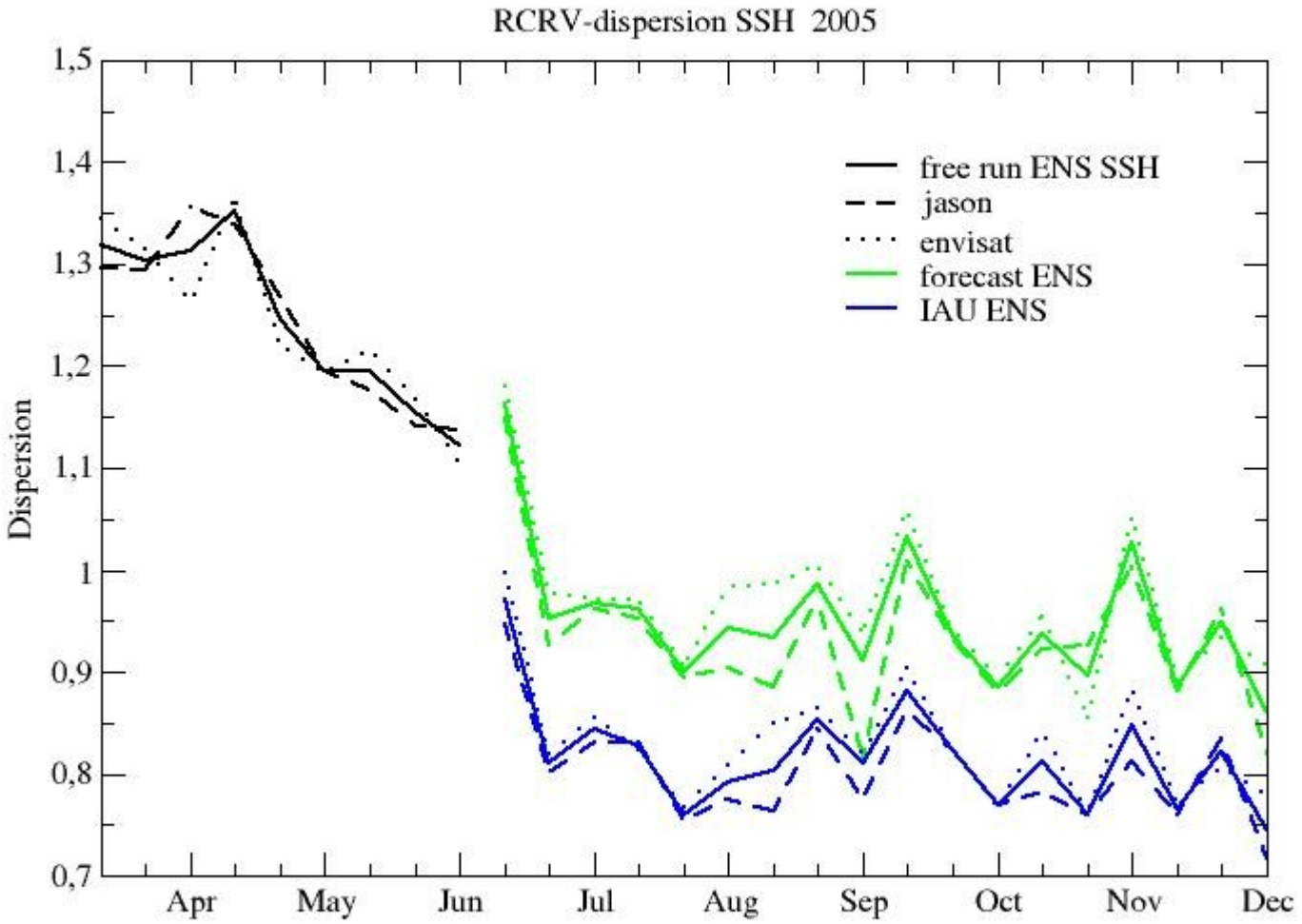
Normal coverage



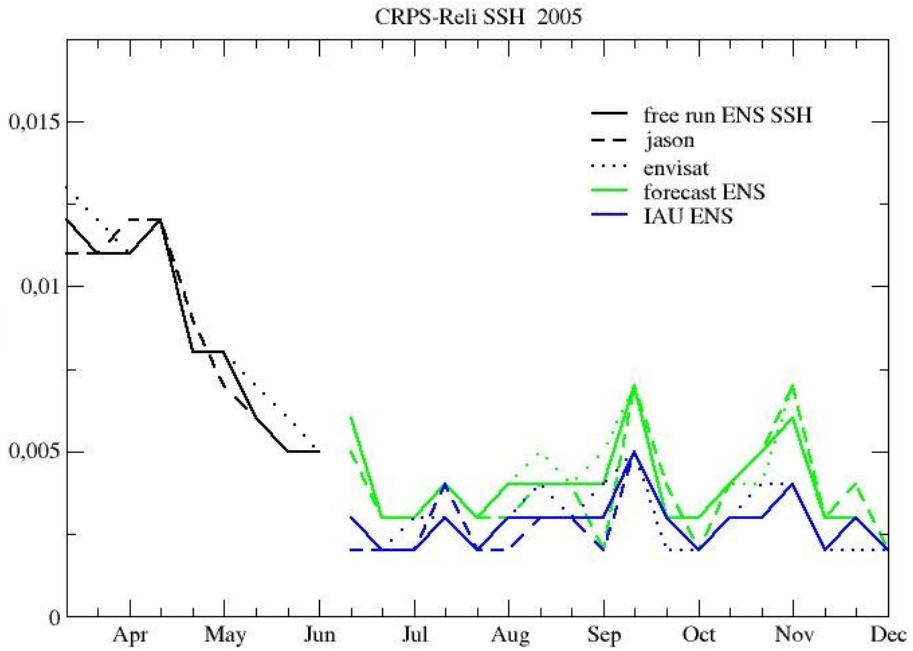
Missing tracks around 27/9/2005

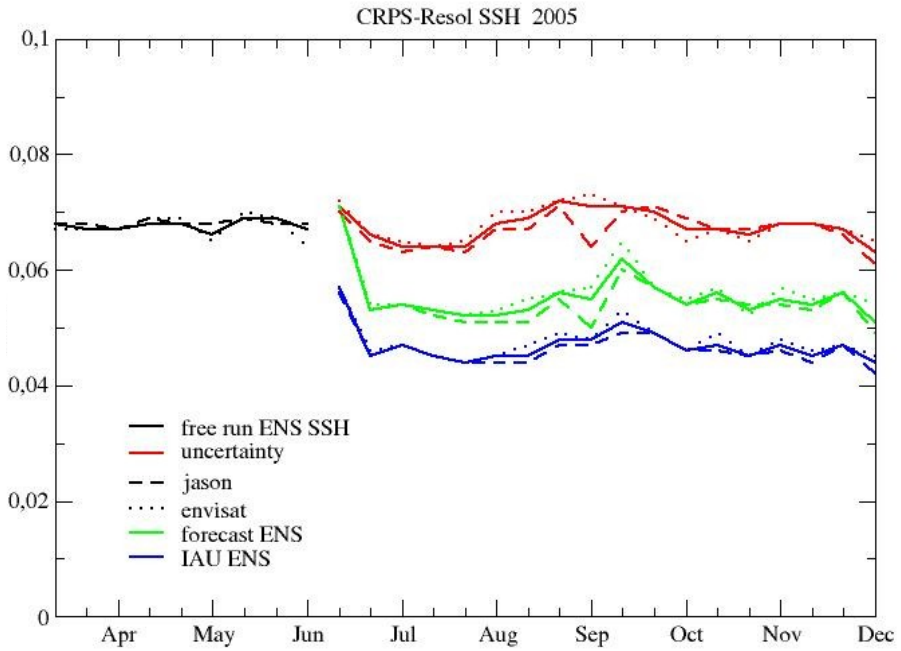
→ Missing JASON-1 observations explaining the larger spread in September 2005

RCRV metrics



CRPS metrics





RELIABILITY **RESOLUTION**

→ We improve resolution, without losing reliability with respect to free ensemble

Conclusions

Main characteristics of the method:

1) Stochastic parameterization of model uncertainties
(→ no inflation factor in the assimilation system)
2) Observation equivalent of all ensemble members at appropriate time (→ 4D observational update)
3) Ensemble incremental analysis update (IAU)
(→ no time discontinuities in the updated ensemble)

Main outcomes of the experiment:

1) The ensemble spread is sufficient to account for altimetric observations in the Gulf Stream region (↔ RH)
2) After assimilation has started, both forecast and IAU ensembles remain reliable (↔ CRPS reliability score)
3) Assimilation substantially improves the resolution of the ensemble (↔ CRPS resolution score)