Combination of altimetry and modelling to assess the capability of different observing scenarios to describe coastal dynamics

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Limitations to the use of altimetry in coastal zones

① Instrumental limitations :

• Measurements are contaminated by the presence of land in altimeter and radiometer footprints.

• Lost-tracking of a few kms at transitions between land and ocean.

➡ No reliable data just next to the coast.

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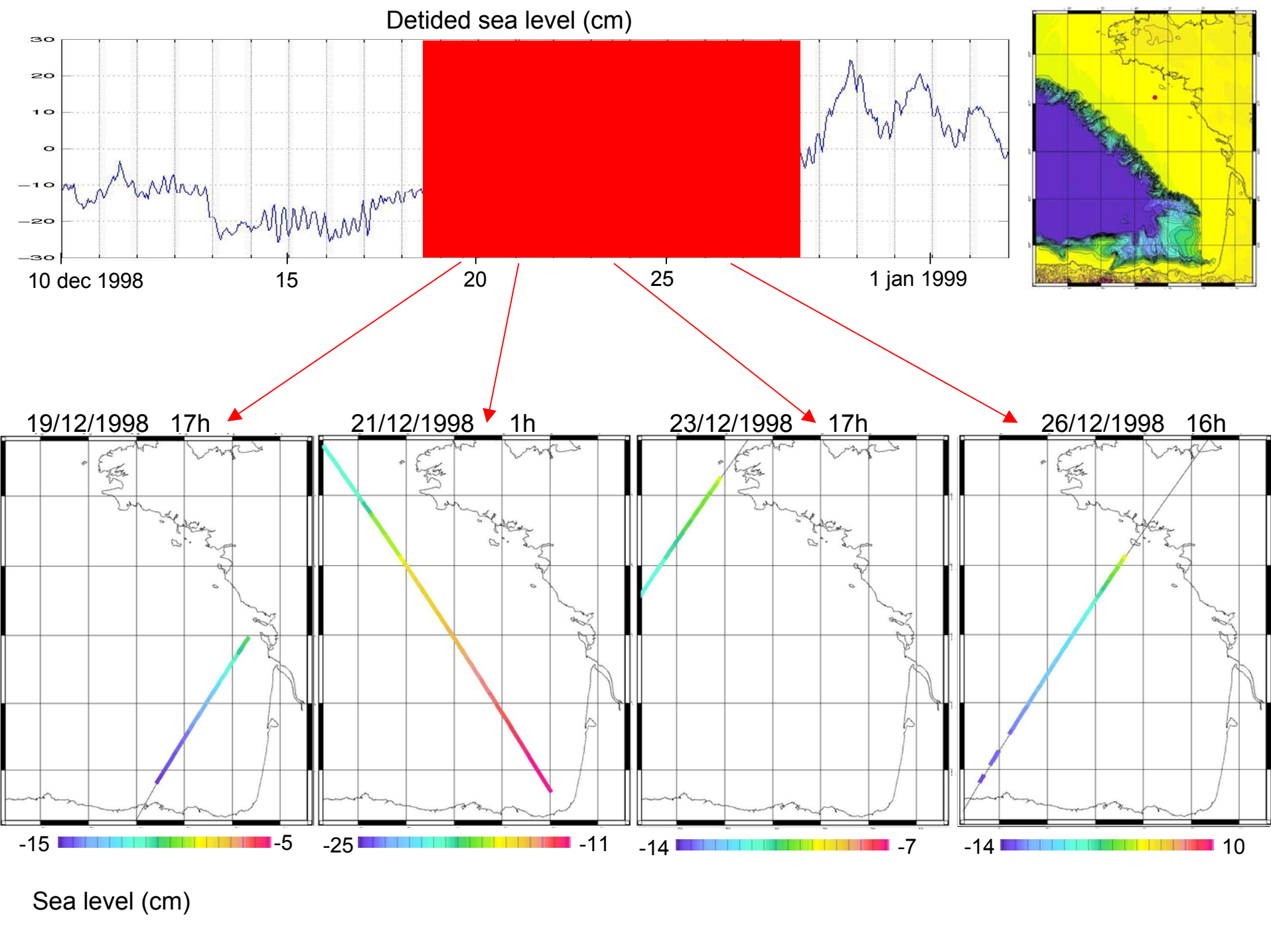
② Spatio-temporal scales of dynamical processes are much smaller in coastal zones than in the deep ocean, so that the sampling provided by present altimeter satellites is insufficient in these areas.


Detided sea level (cm)
30
20
10
0
−10
−20
−30
10 dec 1998
15
20
25
1 jan 1999
19/12/1998 17h
21/12/1998 1h
23/12/1998 17h
26/12/1998 16h
-15
-5
-25
-11
-14
-7
-14
10
Sea level (cm)

➡ What spatio-temporal sampling is then required ?

Approach

➡ Due to these small spatio-temporal scales, contribution of numerical models is necessary.

But models are also limited !
(due to several sources of errors such as meteorological forcing, bathymetry or boundary conditions)

➡ The way to get the best estimate of the state of the ocean in these areas is to use models as dynamical interpolators, both in space and time, of altimeter observations, with the help of data assimilation techniques.

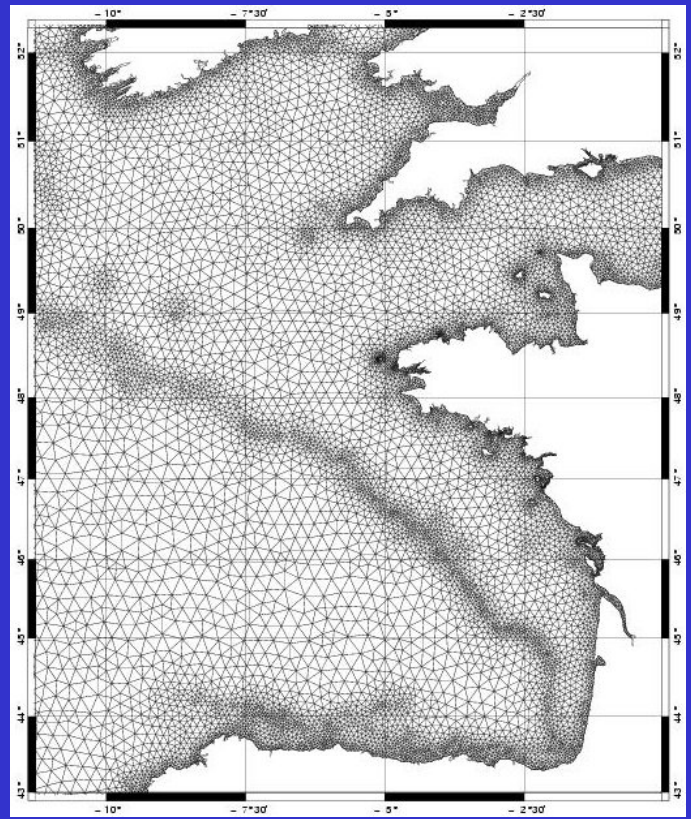
➡ What kind of satellite sampling is required to best correct model errors ?

To what extent can we hope to correct these errors ?

Application

Model MOG2D

- Finite elements
- Barotropic
- Nonlinear
- Implemented on the European shelf
- Meteorological forcing



Focus on errors due to uncertainties on bathymetry

Data assimilation experiments require a specification of error statistics in the model … tricky point in coastal areas !

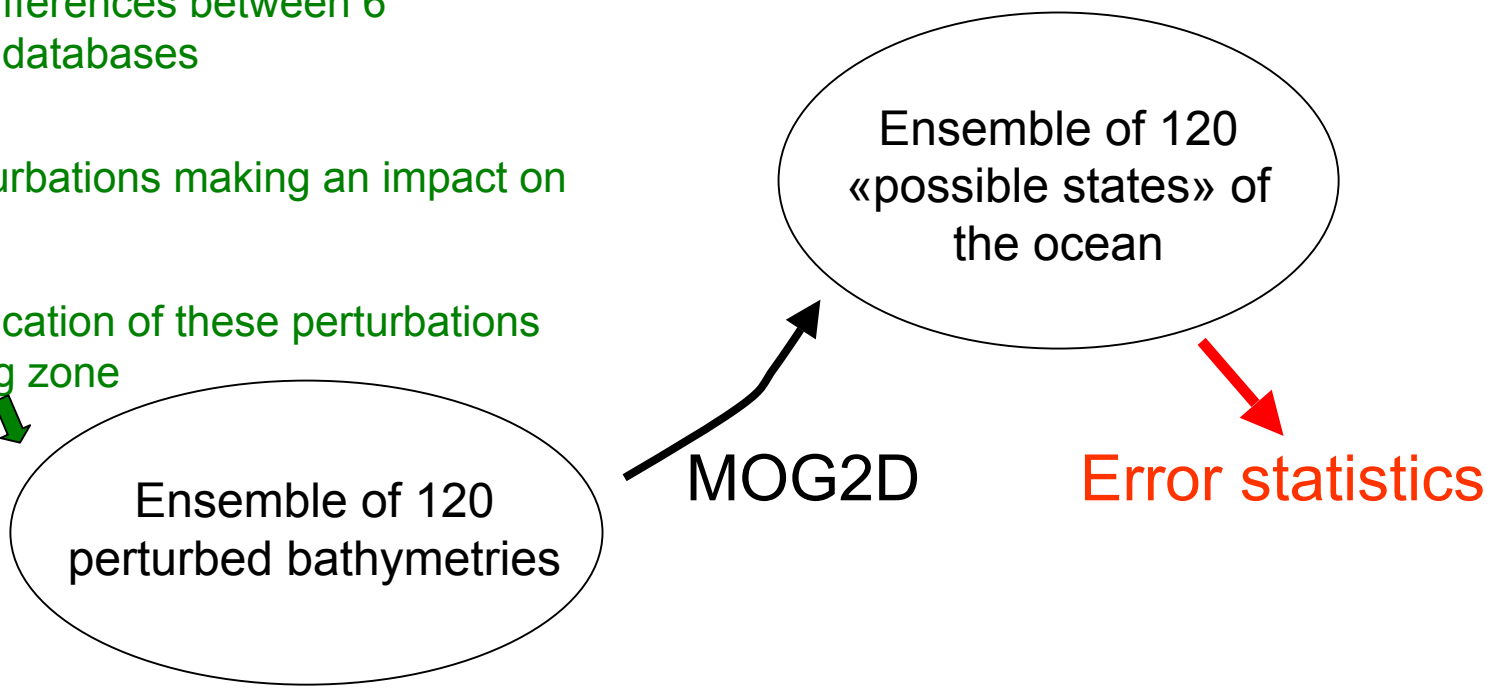
Use of Ensemble methods

statistics are computed empirically from an ensemble of “possible states” of the ocean
=> no simplification on the dynamics
(*Evensen JGR 1994 ; Echevin et al. JPO 2000)*

Examination of the differences between 6 different bathymetric databases

Selection of perturbations making an impact on model dynamics

Random application of these perturbations on the working zone



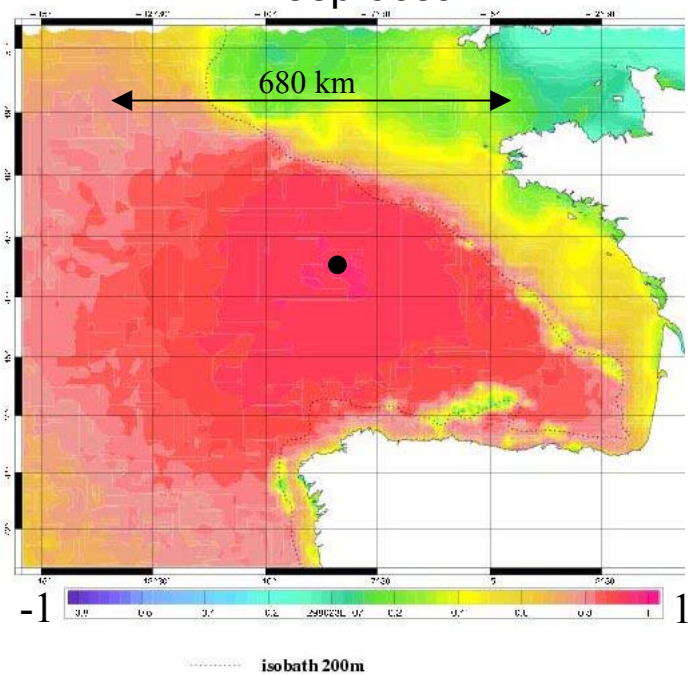
Representers of altimeter observations

(Bennett 1992, Echevin et al. JPO 2000)

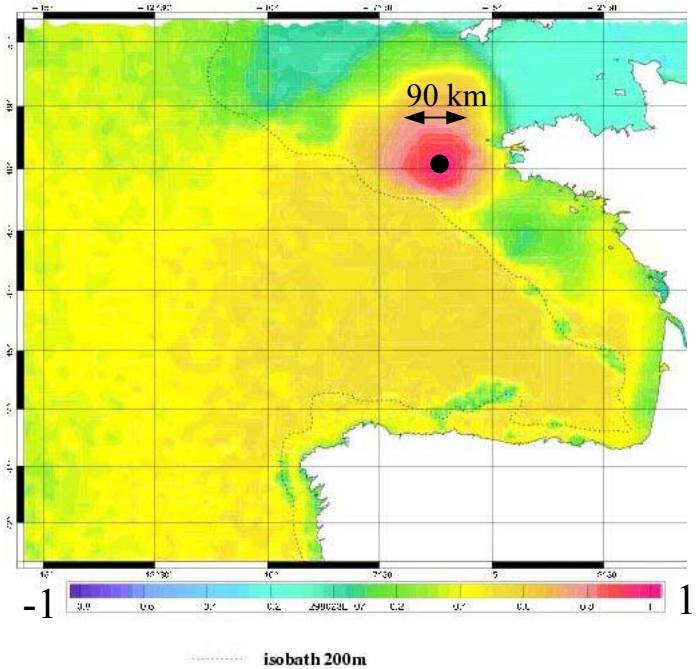
- To each observation is associated one representer (influence function), which contains covariances between the observed variable at the observation point and all other model variables at every other points of the domain.
- The zone of influence (zone of significant correlations) is the zone in which the observation allows us to correct the model.

Zone of influence of two different observations :
- Deep ocean
- Continental shelf

Deep ocean

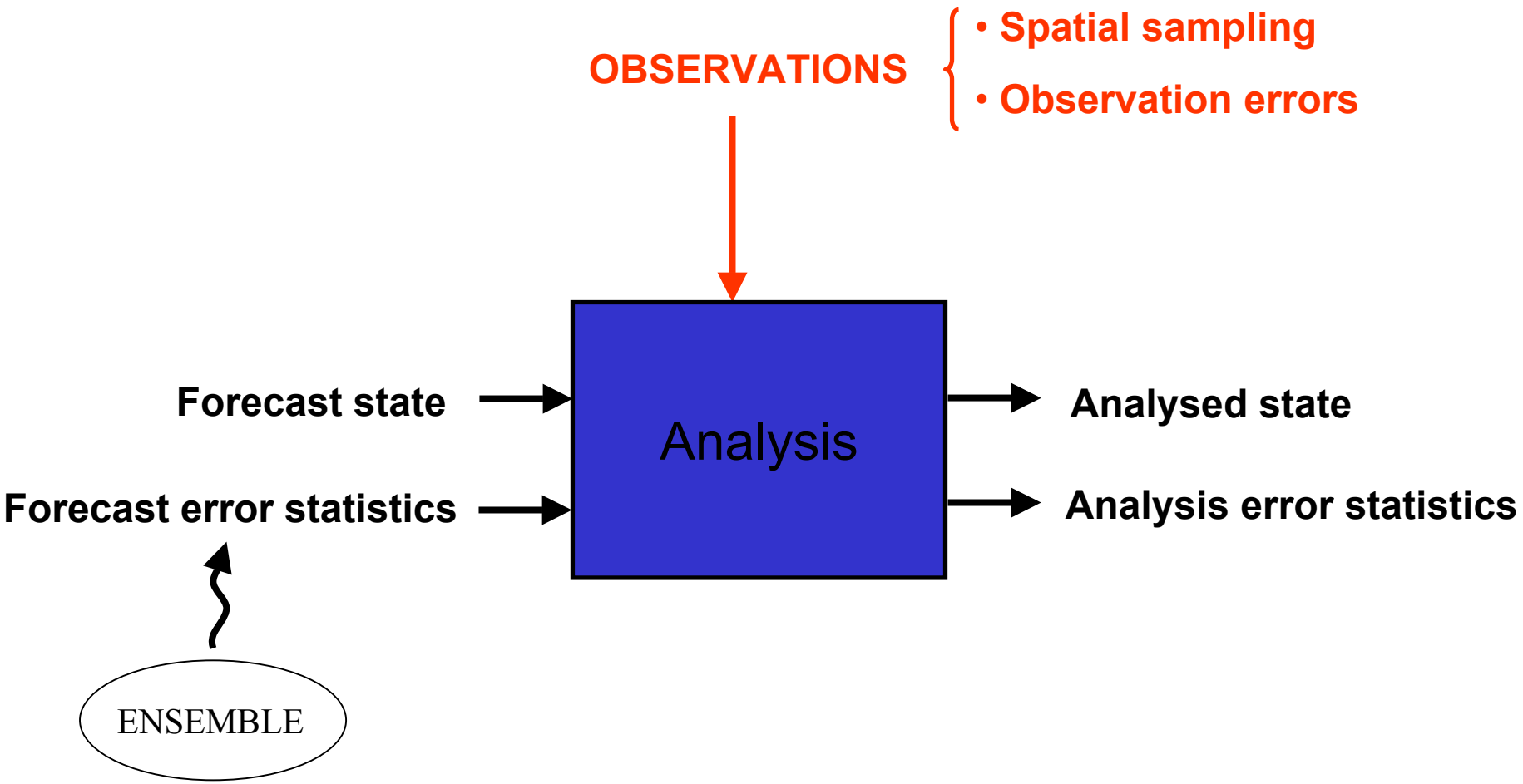


Continental shelf

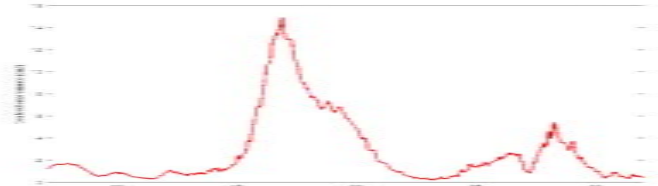


Correlation scale

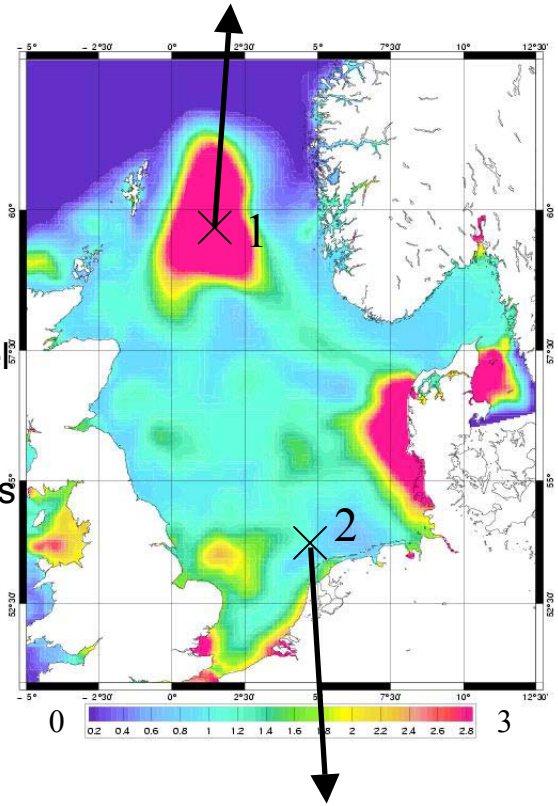
Analysis experiments



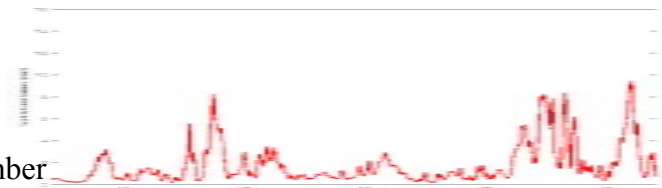
Analysis experiments



December 1998



Sea level forecast error variances (cm2)



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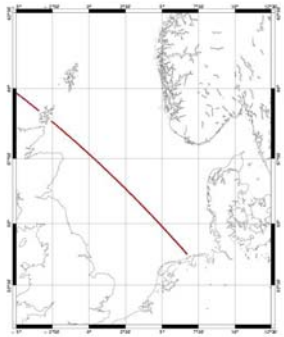
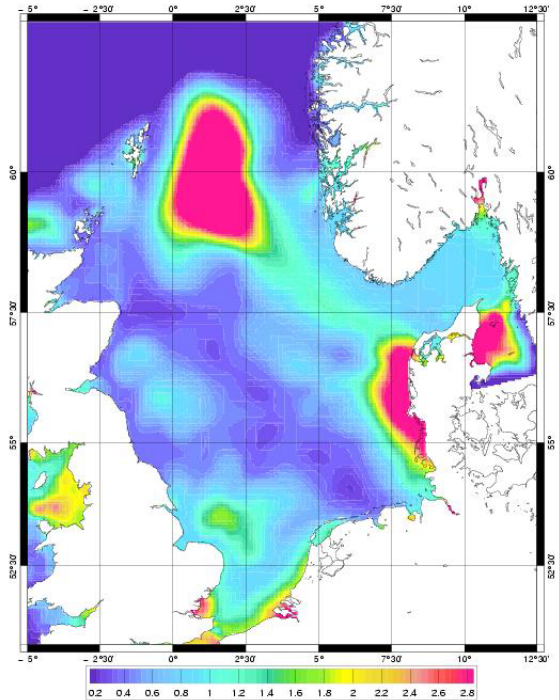


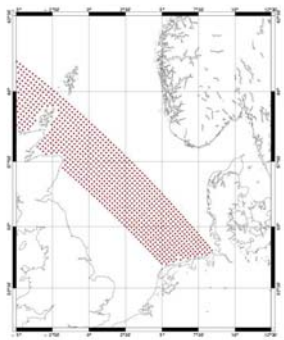
Jason

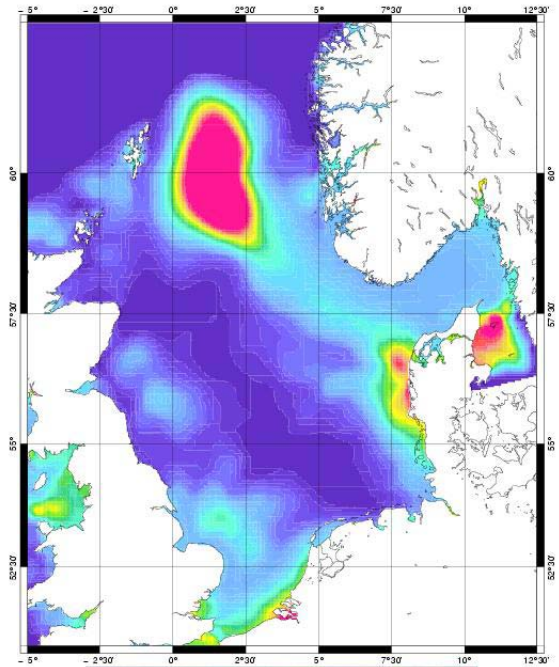


Analysis error variances (cm2)

ANALYSIS

WSOA





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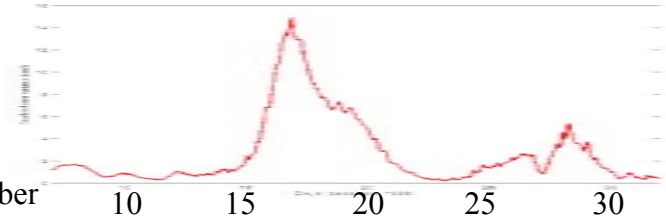
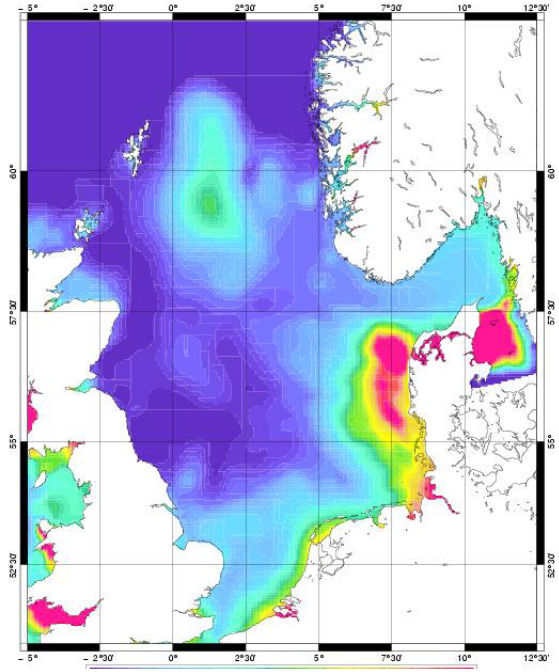
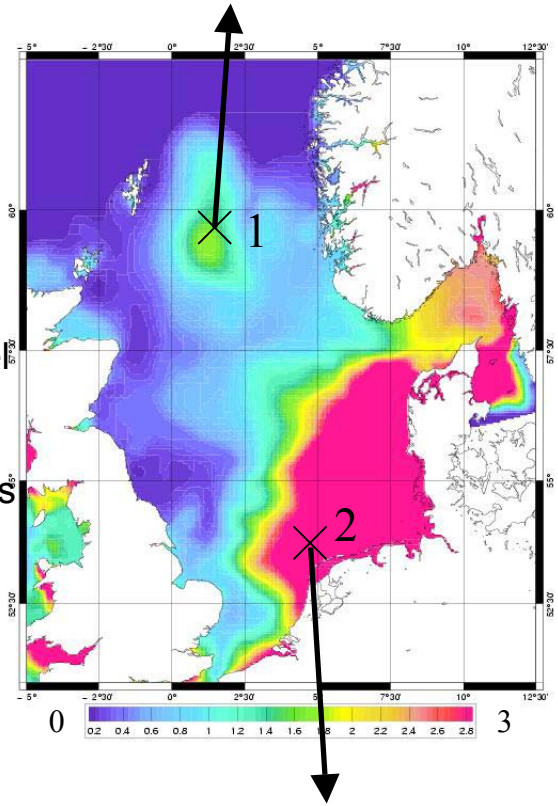




Jason

Analysis error variances (cm2)

Sea level forecast error variances (cm2)



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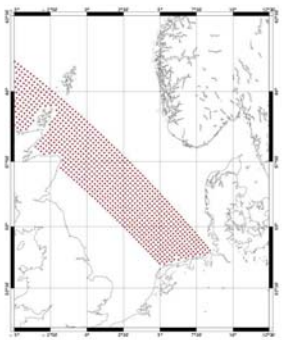
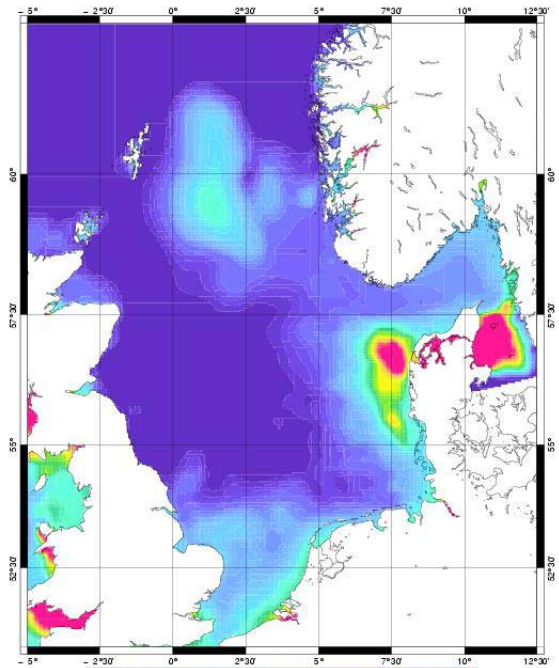
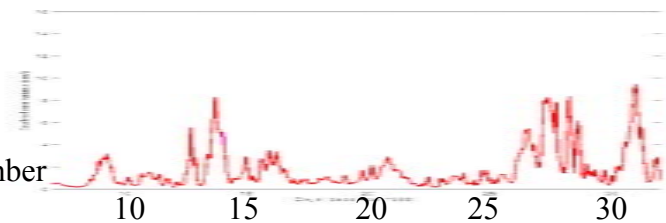


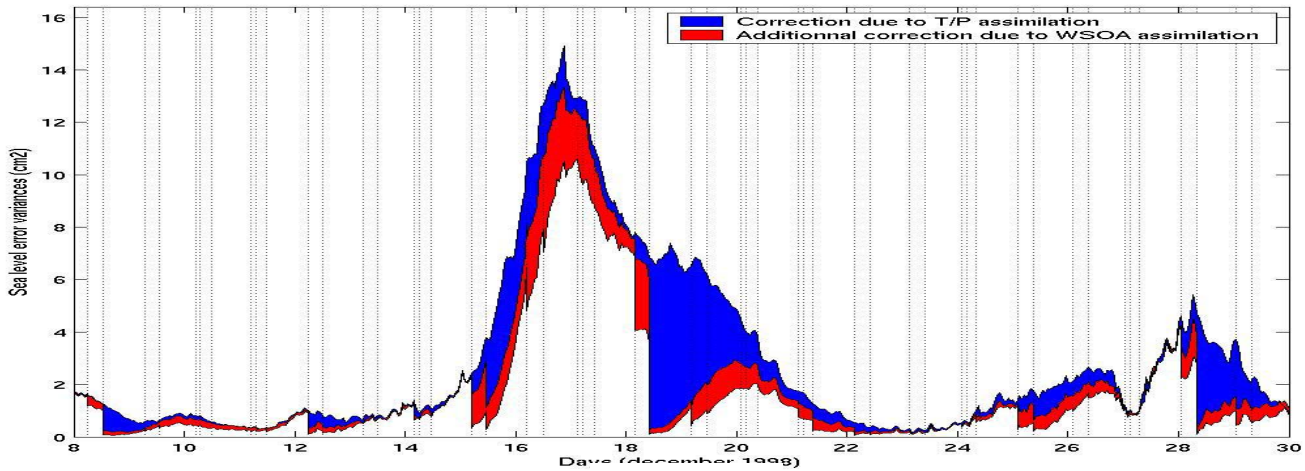




Sequential assimilation of altimeter data

Comparisons Jason / WSOA

Point 1

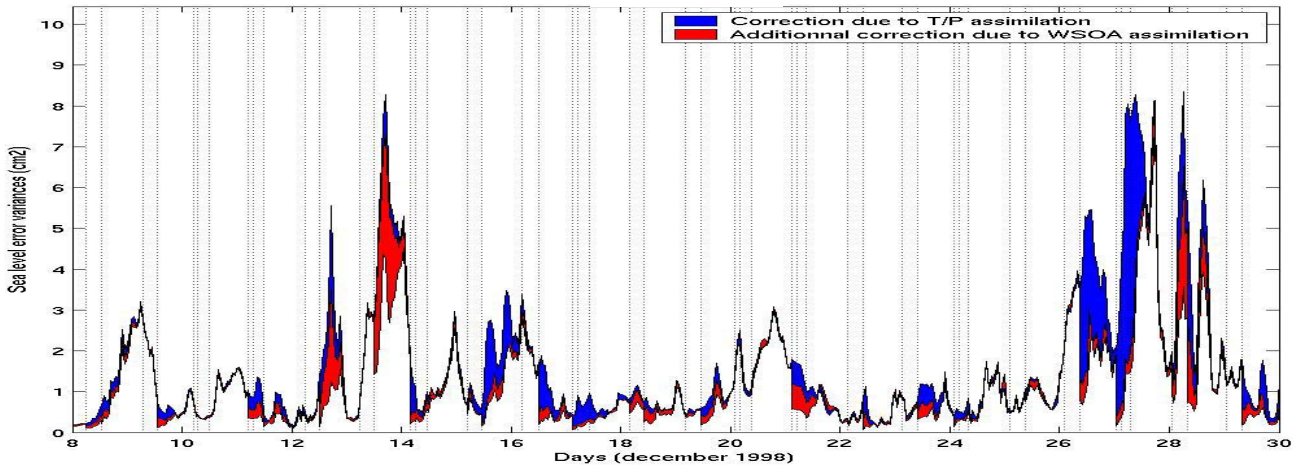


Error reduction :

Jason : 28.8 %

WSOA : 45.3 %

Point 2



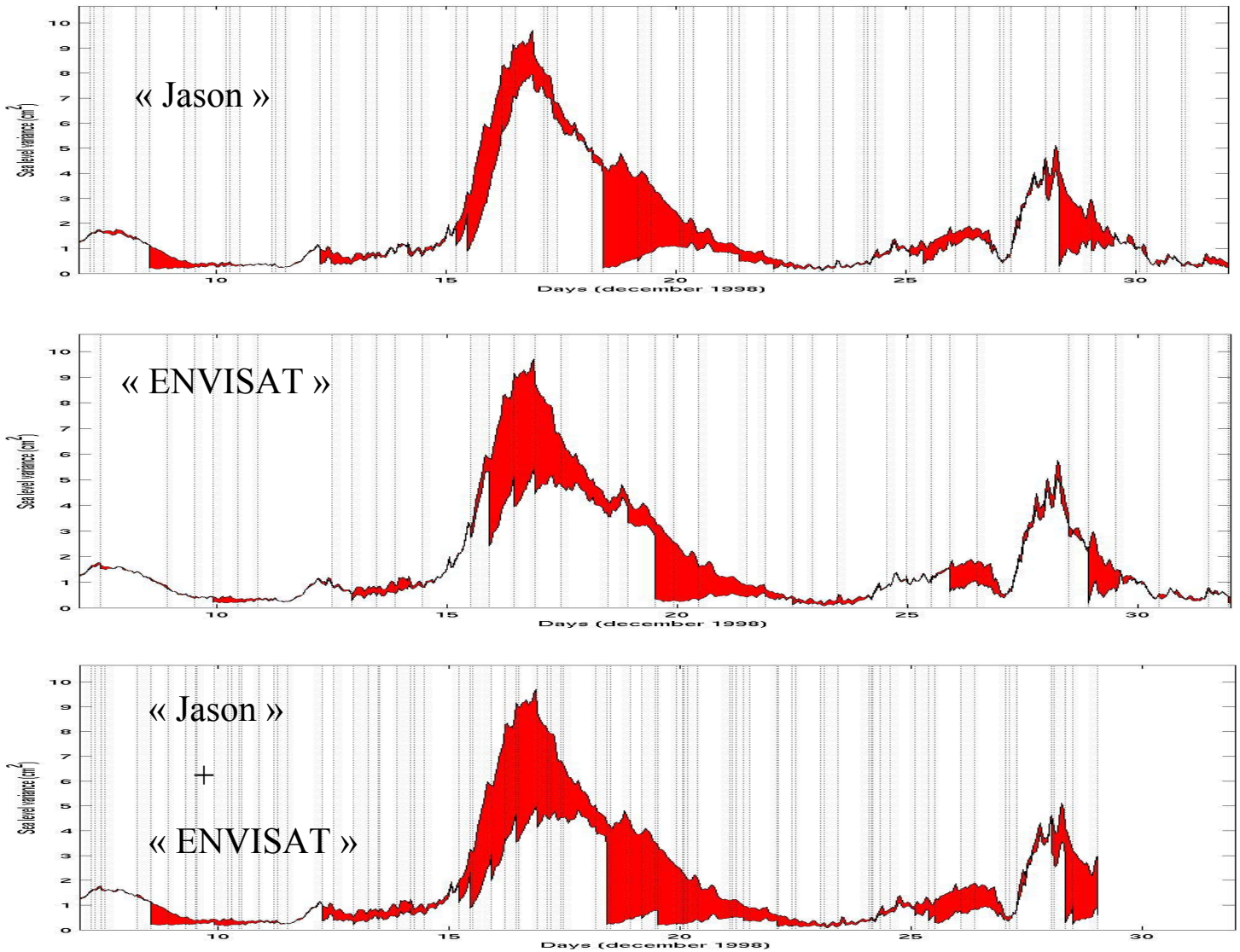
Error reduction :

Jason : 20.1 %

WSOA : 33.3 %

Sequential assimilation of altimeter data

Comparisons « Jason » / « ENVISAT »



Error reduction :

Jason : 30.9 %

ENVISAT : 27.3 %

Jason + ENVISAT : 47.8 %

Conclusions

- Model error reduction (22 days spatio-temporal mean over the North Sea) :

  Jason => 21.0 %

  WSOA => 32.1 %

  «Envisat» + «Jason» : 31.8 %

- WSOA and a constellation « Envisat + Jason » appear to have a similar efficiency in terms of model errors reduction.

- Even if the contribution of these systems is significant, a great part of model errors remains uncorrected, mainly due to the quick evolution of coastal processes in the model.