Observation impact in nonlinear data assimilation

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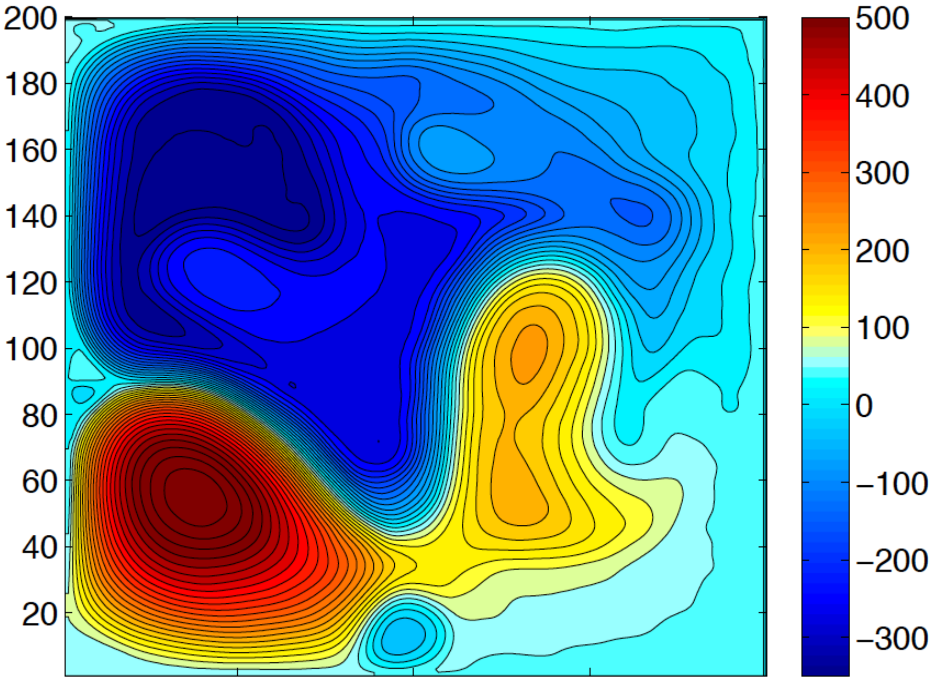
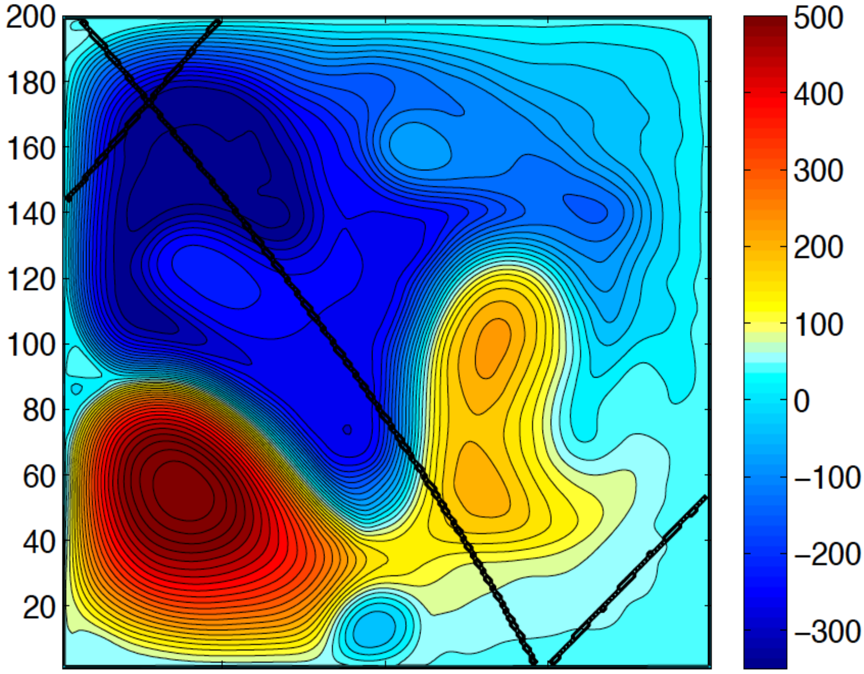
Motivation

- We want to infer the usefulness of (satellite) observations (both in orbit and from future missions).
- We do have impact tools for linear systems with linear/linearised data assimilation.
- But systems are nonlinear and data-assimilation methods will become more and more nonlinear.

Fully nonlinear assimilation of altimeter observations every day

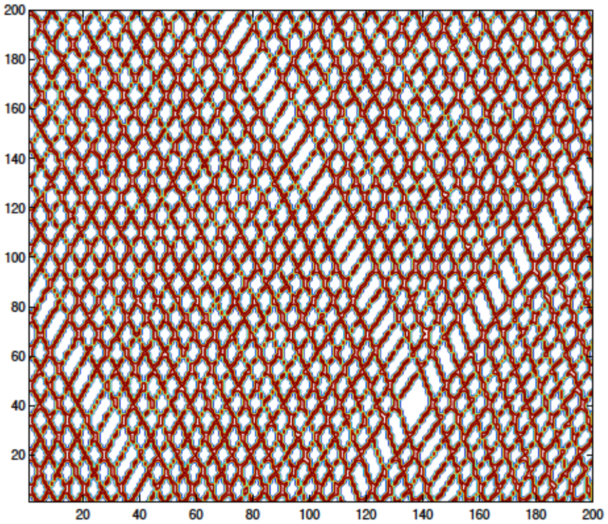


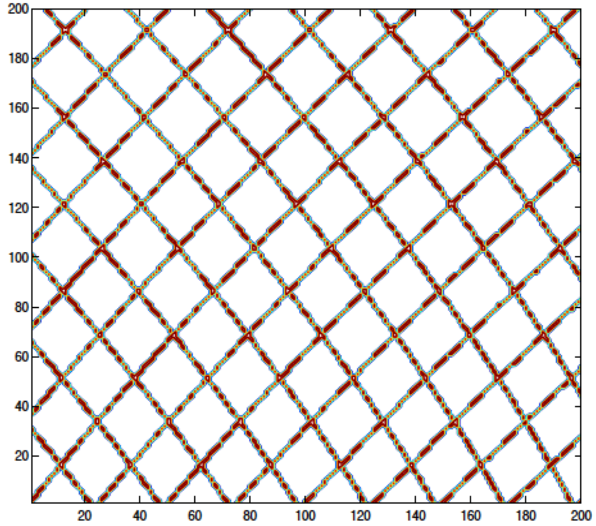
True model state at day 100

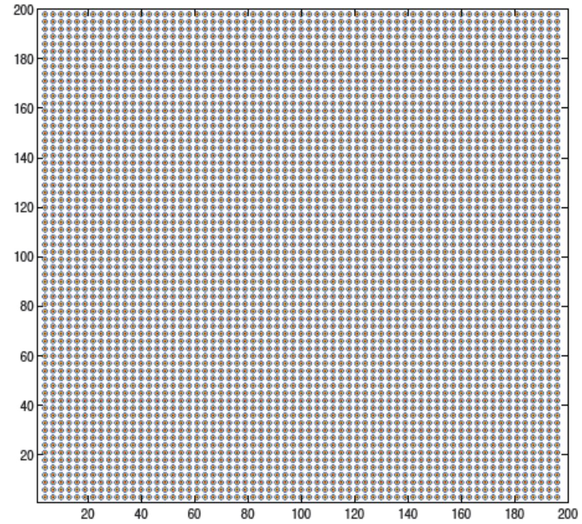


Mean of particle filter using JASON altimeter observations at day 100.

Comparing sea-surface altimeter missions





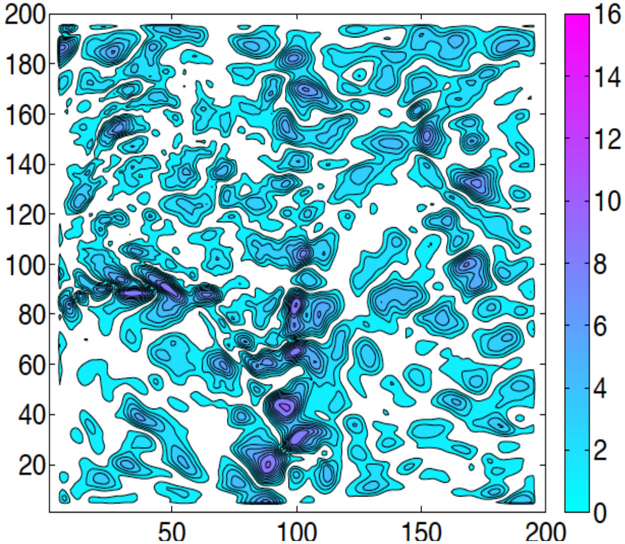


ERS/ENVISAT
35 days
50 km

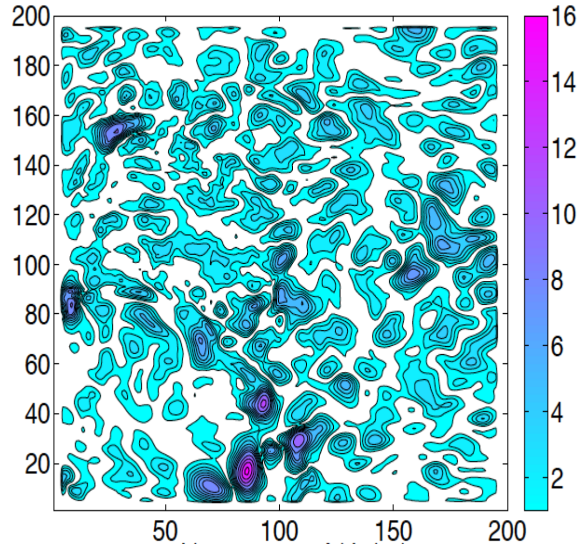
TOPEX/JASON
10 days
150 km

High-frequency
1 day
30 km

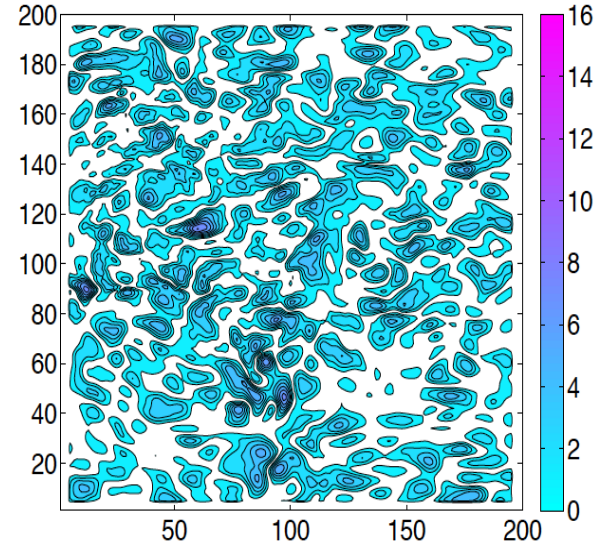
Errors in ensemble mean at day 100



ERS/ENVISAT
35 days
50 km



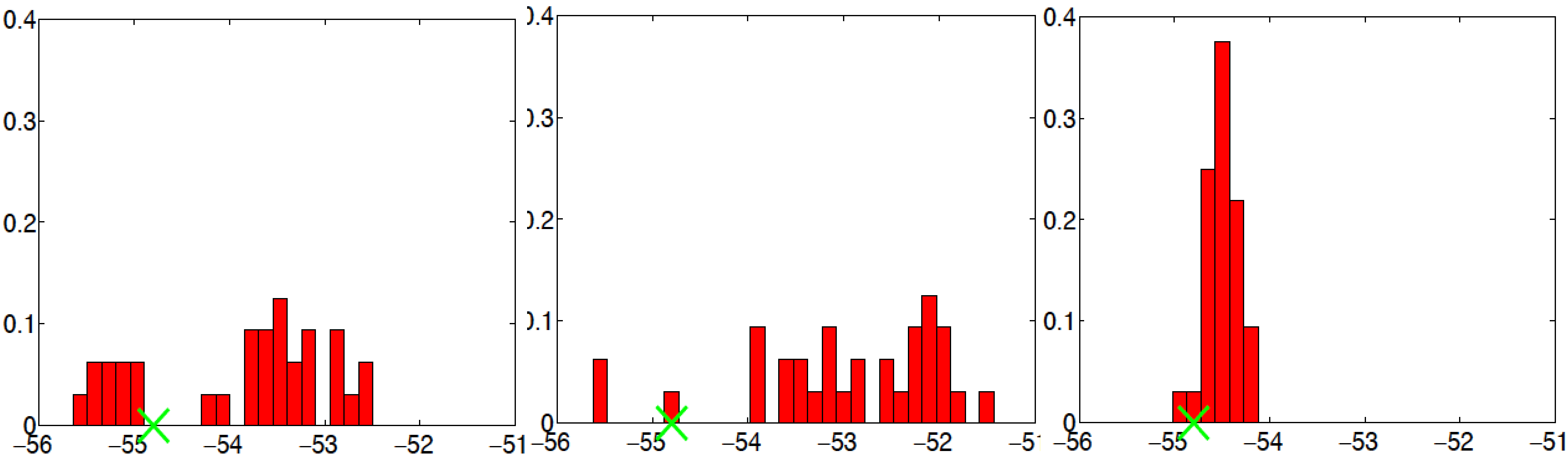
TOPEX/JASON
10 days
150 km



High-frequency
1 day
30 km

ENVISAT and JASON up to 7.5 cm error, High-frequency up to 4 cm error

Accuracy of estimates: pdf's at day 100



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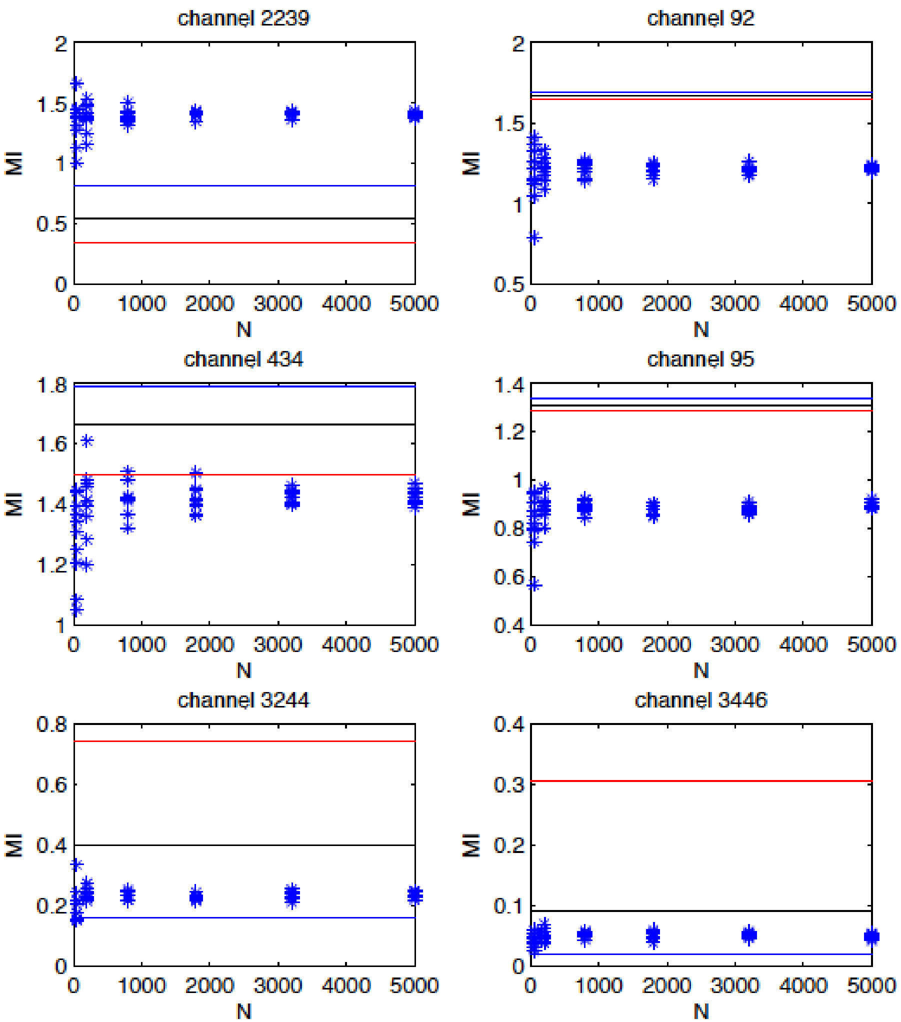
ENVISAT shows bimodal behaviour, JASON has a bias, High-frequency has narrow pdf

Channel selection using nonlinear information measures

- Multi-channel satellite data are typically thinned to avoid huge datasets with dependent information.
- Tools used are based on linear information measures like degrees of freedom and Gaussian mutual information.
- The problem is nonlinear because the pdfs involved are non-Gaussian.
- How does proper nonlinear treatment change channel selection?

Non-Gaussian mutual information



Mutual Information measures how much impact observations have on the data-assimilation result. Note observation operator is nonlinear!

$$MI = \int p(\mathbf{y}) \int p(\mathbf{x}|\mathbf{y}) \ln \frac{p(\mathbf{x}|\mathbf{y})}{p(\mathbf{x})} d\mathbf{x} d\mathbf{y}$$

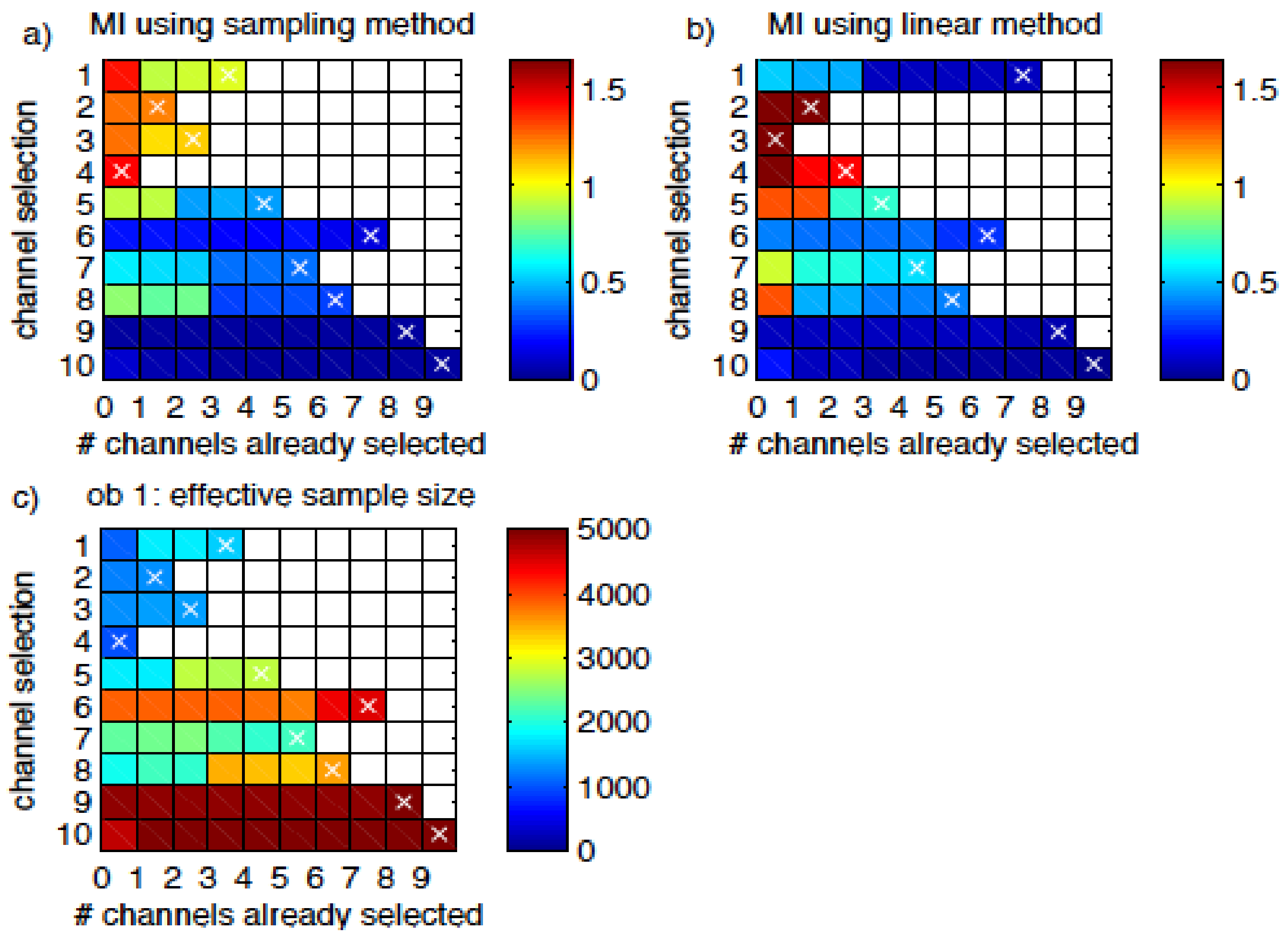
Gaussian MI, true

Gaussian MI, true + 1 s

Gaussian MI, true – 1 s

Non-Gaussian MI

Channel selection with MI using Gaussian Mixture sampling



Conclusions

- Higher space and time sampling of altimeters is highly beneficial: closer to truth and narrow pdf.
- Posterior pdf closer to Gaussian.
- Non-Gaussian channel selection method has been developed and tested on real IASI data.
- Gaussian assumption in MI for channel selection can lead to wrong channel selection order.