SANGOMA WP5
Data assessment

NERSC, ULg, UREAD, CNRS-LEGI, CNRS-LEGOS

SANGOMA Final Meeting
November 2015

WP5 - Objectives

- Assess the impact of **new remote sensed ocean data on the model state estimations** and their potential in a data assimilation setup.
- A **preparatory step** before those observations are assimilated in an operational context.
- Focus on remote sensed data: ice concentration/thickness, SST and SSH, surface currents

WP5 – Reviewer Recommendation

- *The observing systems included in the SoW and their integration with models and DA schemes are well addressed. The nature of the work package is a little scattered and much* ***less harmonized*** *than other WP's. Hence it is recommended to reference the SANGOMA framework more clearly than only exploring new observation types and to specify a strategy for integration into the SANGOMA framework.*

- *In general this seems like a work package with a lot of freedom in implementation. Every partner testing impact of data in their own framework. The partners should* ***apply the SANGOMA tool box*** *as much as possible to exemplify/demonstrate its value. If it isn't used within it will never be valuable outside SANGOMA. More details should be integrated on Sentinel in next phase since this is basically a GMES/Copernicus project.*

SANGOMA

Tasks

- Task 5.1 Identify new data types
- Task 5.2 Assessing observing systems
- Task 5.3 Exp. Large-scale models
- Task 5.4 Exp. in regional scale models
- Task 5.5 Lagrangian sea ice parameters
- Task 5.6 Prior errors detection by observational arrays

Deliverables

- D5.1 List of remote-sensed variables with their associated characteristics (M12, **all**)
- D5.2 Report on the impact of new ecosystem data (M36, **CNRS-LEGI**, almost finished)
- D5.3, D5.4 (merged) Results of a data assimilation experiment with a large-scale ocean model (V1 at M36, V2 at M48**, CNRS-LEGI**)
- D5.5, D5.6 Results of a data assimilation experiment with a regional-scale ocean model (V1 at M36, V2 at M48, **ULg**)
- D5.7: Result of the data assimilation experiment aiming to estimate Lagrangian sea ice parameters (M48, **NERSC**)
- D5.8: RMSpectrum library and results of array performance analyses (M48, **CNRS-LEGOS**)

Deliverable DL5.3 – DL5.4

Results of a data assimilation experiment with a large-scale ocean model

The **two deliverables are merged** in one single report evaluating assimilation with two new altimetry missions (AltiKa and SWOT).

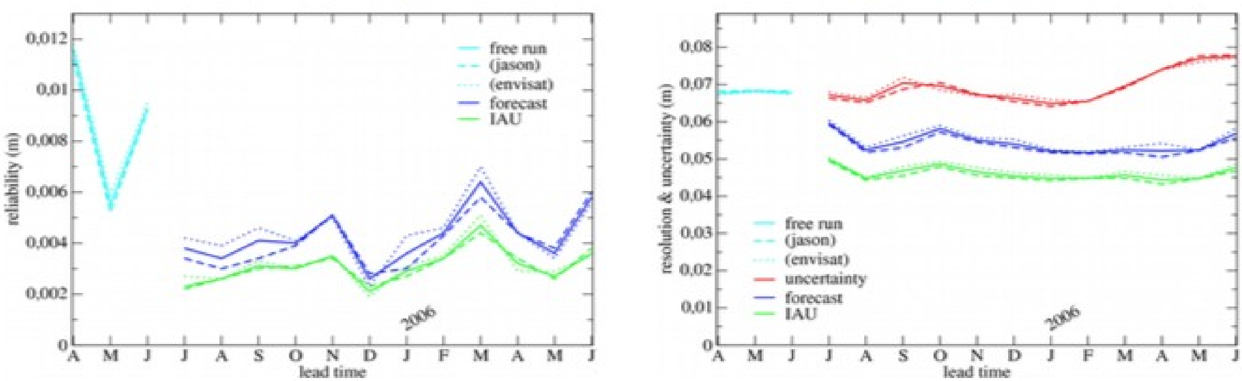
Part I AltiKa – Ensemble assimilation of **Jason/Envisat and Jason/Altika altimetry** observations with stochastic parameterizations of the model dynamical uncertainties

The objective of the study is

- explicitly model and **quantify the uncertainty related to the eddy-resolving ocean circulation models**
- **along-track altimetry data assimilation** into stochastic models

CRPS for SSH over Gulf Stream area:

reliability improvement and G = 30%



Ocean Model:
NATL025

Global probabilistic score:
CRPS = Reli + Resol

Deliverable DL5.3 – DL5.4

Results of a data assimilation experiment with a large-scale ocean model

Part II Future Swot Mission – An efficient way to account for **error correlations in the assimilation of observations** from the future SWOT High-Resolution altimeter mission

- Future: **wide-swath sea surface height measurements**, e.g. the Surface Ocean and Water Topography (SWOT) Mission
- Issue: **correlations** of the observational errors
- Proposed solution: linear **transformation of observations**
- Such that: corresponding transformed covariance matrix can be represented as a dignal matrix
- Efficient way to assimilate these observation suitable for operational models
- And still avoid to “overcontrain” the model

Deliverable DL5.5 – DL5.6

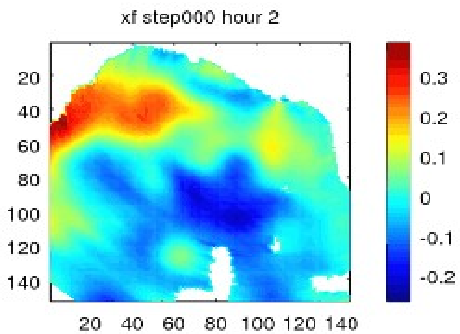
Results of a data assimilation experiment with a regional-scale ocean model

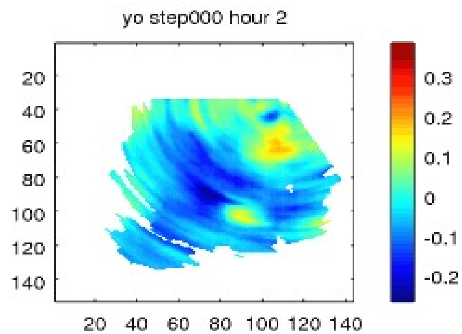
Impact of High-Frequency radar current observations to improve models

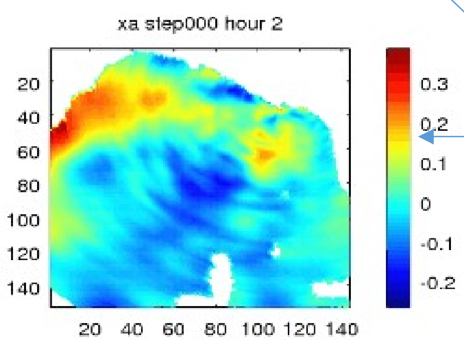
- **Ensemble of 100 ROMS models** of the Ligurian Sea (1/60°)
- Model currents (u,v) are transformed into radial current with the **Sangoma Radar Observation Operator**
- The assimilation state vector **x** may contain these (projected) velocities (and other model variables) at one time-step, or at multiple timesteps during an « assimilation window » (EnKS, AEnKF), or forcing variables (wind, open-sea BC)
- Some variables need tuning to obtain decent results :
  - representativity error : [0 – 2,50] m/s ?
  - localization radius at which to cut-off (irrealistic) long-range covariances
  - window length : 12h, 24h, 48h, 72h ?
  - update all variables or just velocities ?
  - optimize model trajectory (model variables) or the forcing variables ?
- Free model results are usually relatively close to observations (RMS ~ 0.15 m/s)
- DA still **improves these results when deviations are large**

Deliverable DL5.5 – DL5.6

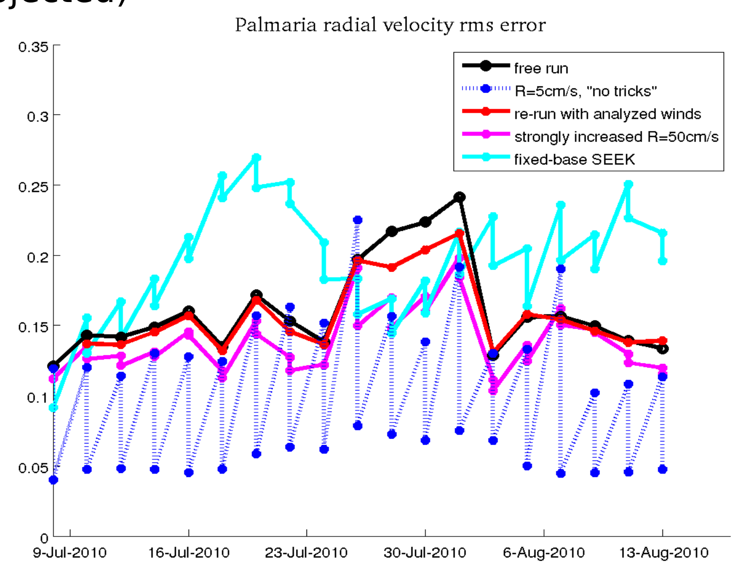
Results of a data assimilation experiment with a regional-scale ocean model







observation
ensemble mean forecast (projected)
ensemble mean analysis

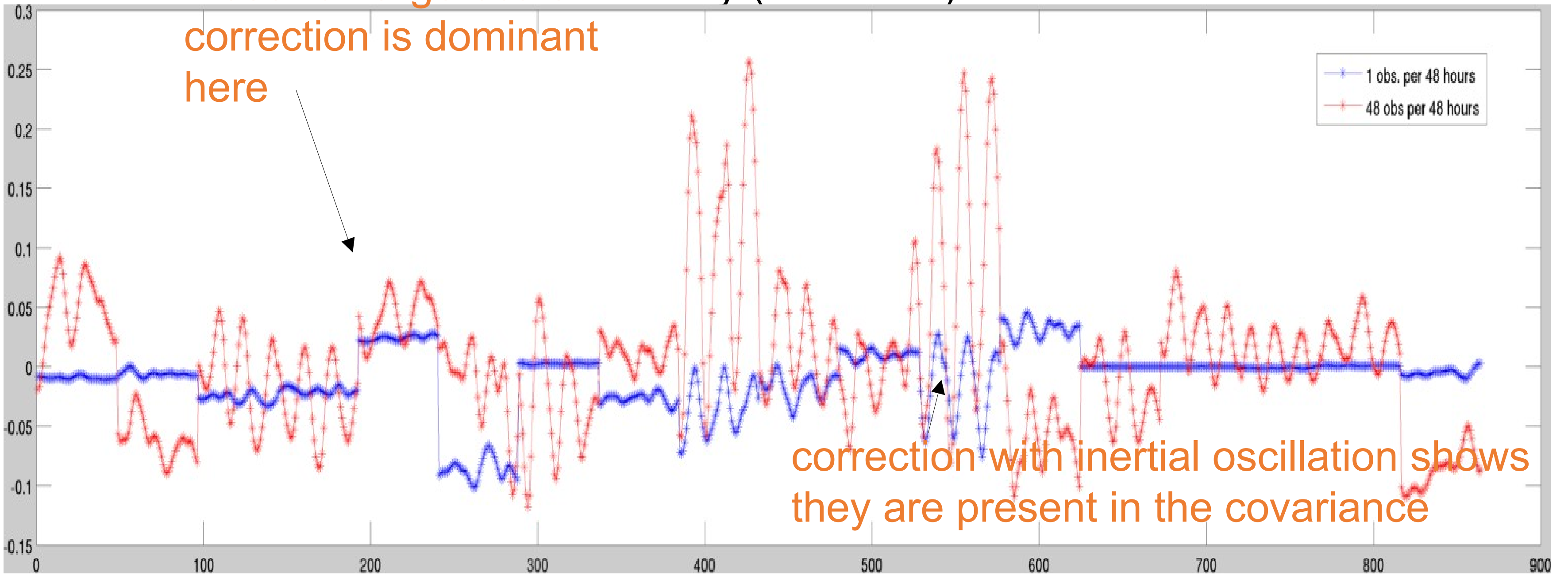


Deliverable DL5.5 – DL5.6

Results of a data assimilation experiment with a regional-scale ocean model

How long does a correction impacts the forecast ? How much data do we need ?

assimilation at 1 location, just 1 per window (blue curve) observation, or hourly (red curve)



The correction has a large impact during ~10 hours (not shown)

Assimilating radar data does not improve T,S – this can be improved by assimilating other data (not shown)

Comparisons with drifter data are not conclusive (large discrepency with radar data)

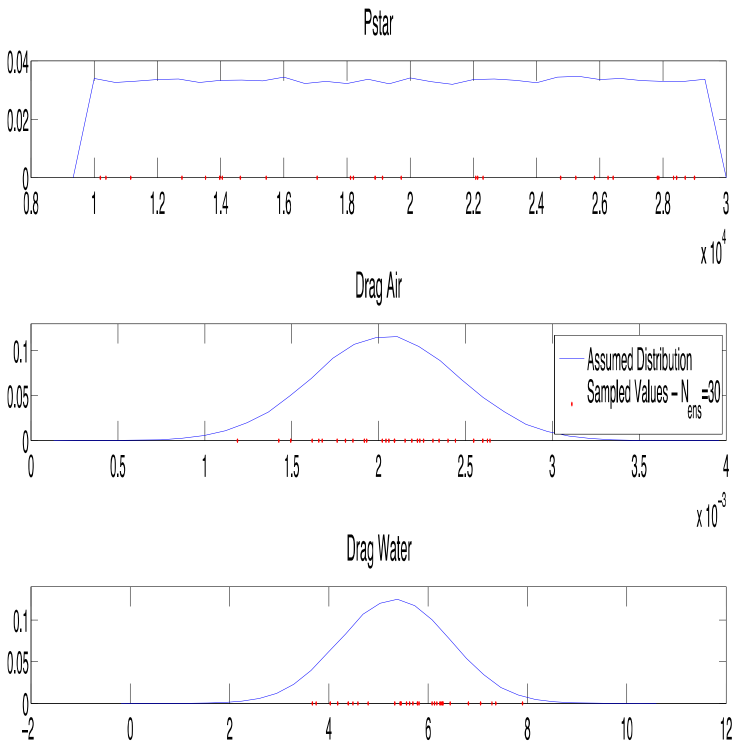
Deliverable DL5.7

Result of the data assimilation experiment aiming to estimate Lagrangian sea ice parameters

- **Calibration of parameters** based on the ensemble Asynchronous Kalman filter.
- Three dynamic parameters are estimated:
  - the **ice strength parameter** P^*,
  - the **ocean-sea ice drag parameter** C_w, and
  - the **atmosphere-sea ice drag parameter** C_a.
- **Perfect twin-experiment** scenario
- The simulation span the period from 1989 to 1996, while parameter estimation is performed after the 1st year, starting from 1990.
- The **observations of sea-ice thickness** location from real observations (ICESat).
- An ensemble of **24 members** is used, with an multiplicative inflation of 1% and a localization via a Gaspari-Cohn modulating function with spatial scale equal to 800 Km.

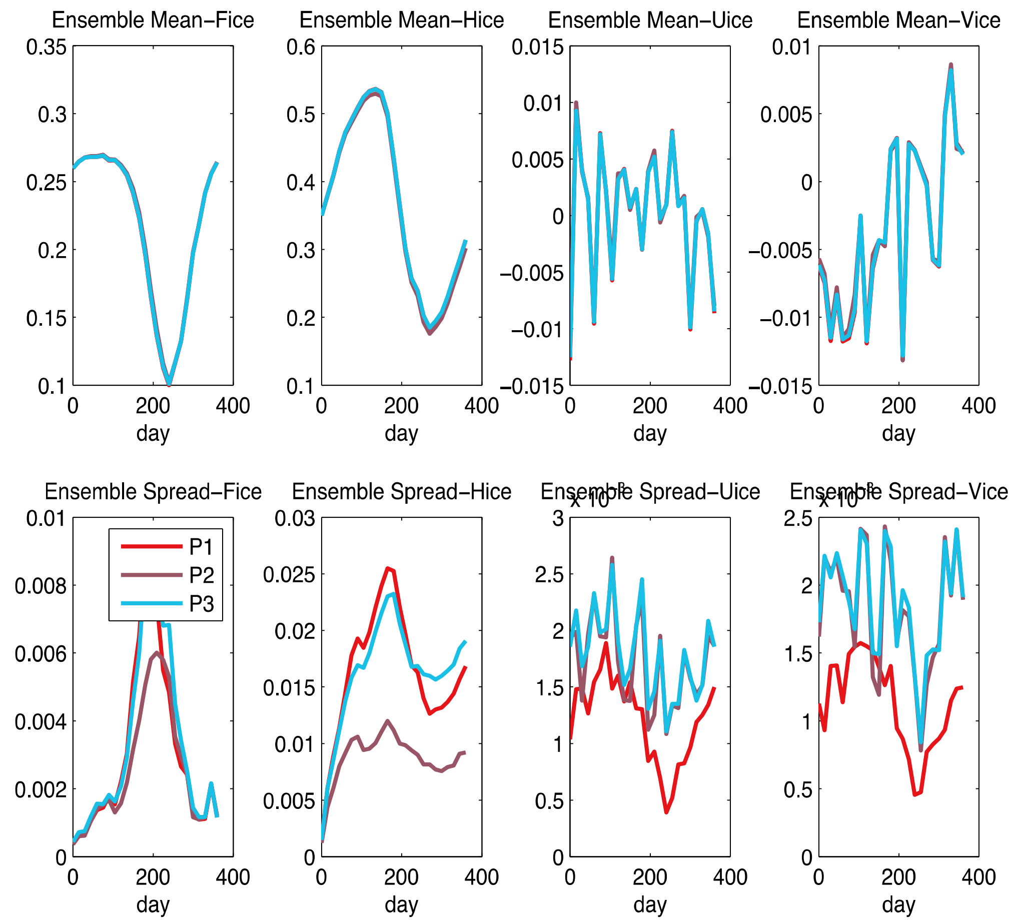
Parameters Sensitivity - Simulation of N=30 members (Free Run – 10yrs)

Distribution of parameter values among members

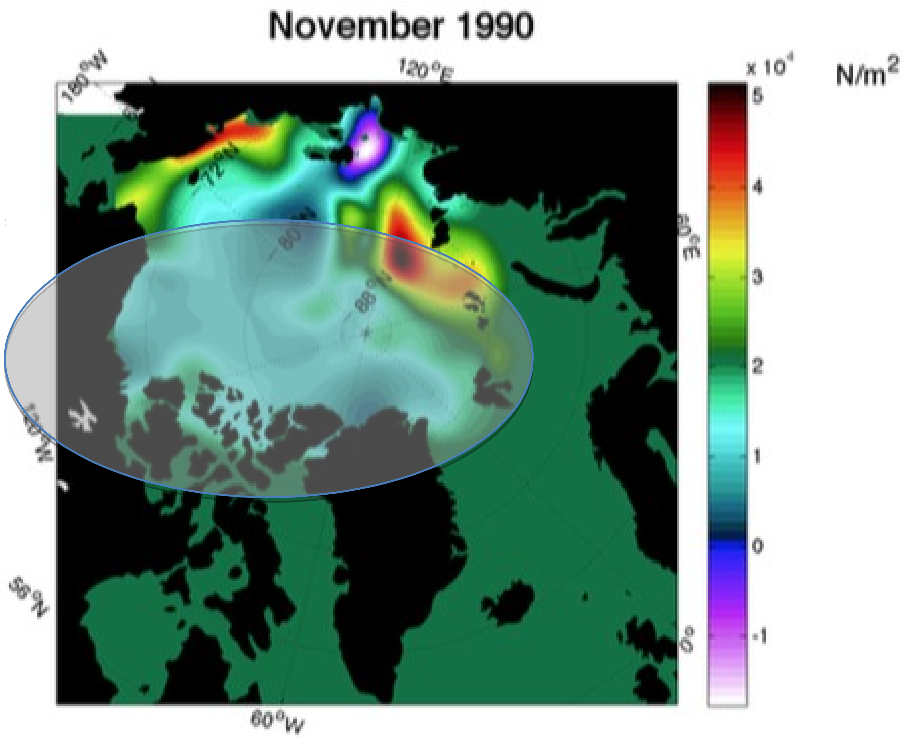


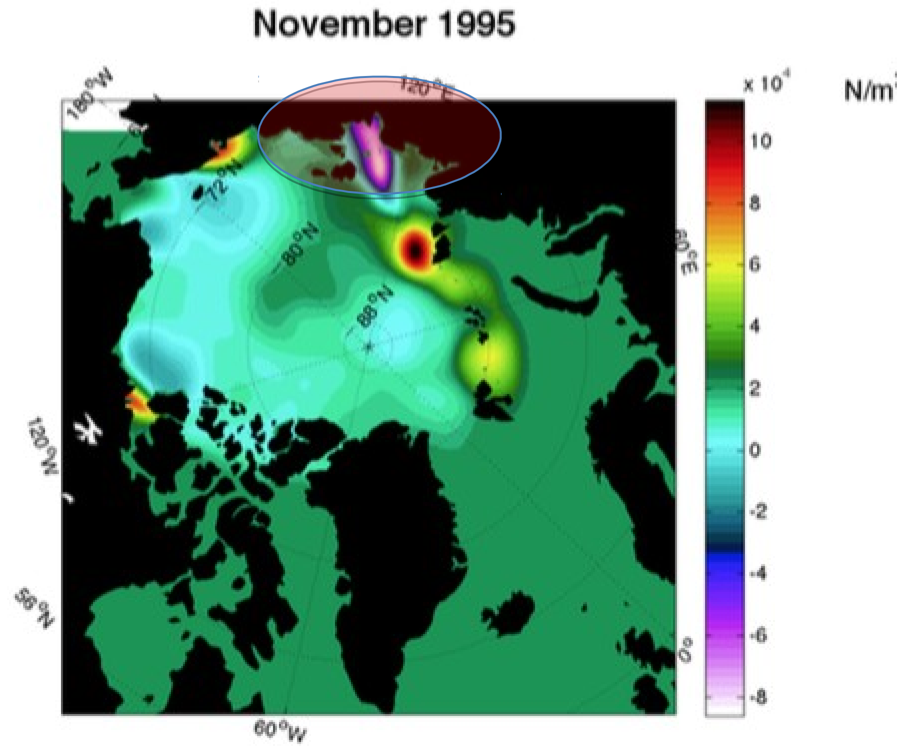
P1 – Pstar
P2 – DragA and DragW
P3 – Pstar, DragA and DragW

Evolution of Ensemble -Mean and –Spread



Parameter Estimation – Preliminary Experiments





<u>*Estimation of sea-ice strength P**</u> - TWIN EXPERIMENTS

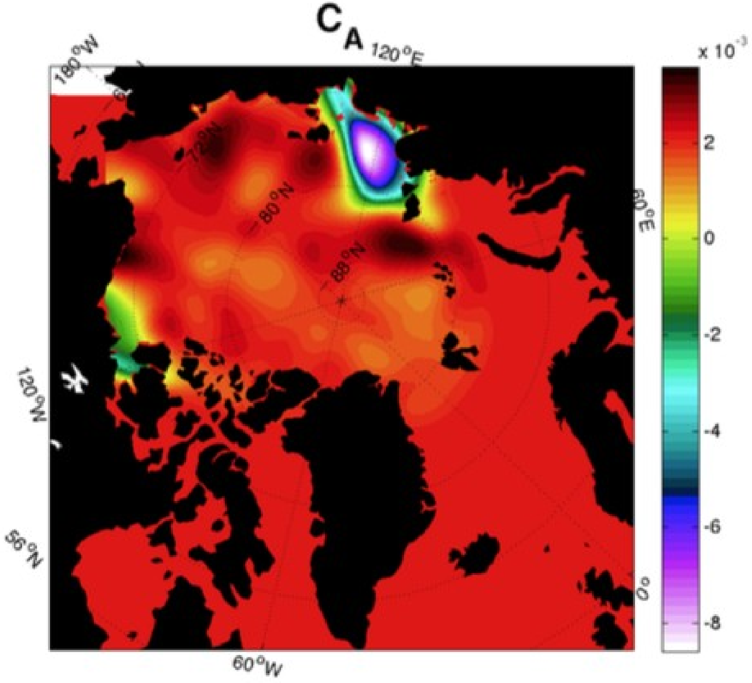
DA method: AEnKF (24 members)

Sea-Ice Thickness Observation every 6 months

Reference value P*=14623

Errors is reduced with respect to the reference in large areas BUT areas with unphysical values are still present -> Work need to be done to correct this issue

Parameter Estimation – Preliminary Experiments



__Simultaneous estimation of P and of the drag coefficients C_a and C_W__*- TWIN EXPERIMENTS

The figure shows the estimation of Ca at November 1995
Errors is only slightly reduced and some areas with small unphysical values appear
(ref. value C_A=0.0021526)

Fc and An Error in P*

	1990	1991	1992	1993	1994	1995
Fc Err	5.9e+03	5.9e+03	5.9e+03	5.9e+03	5.9e+03	5.9e+03
An Err	5.4e+03	5.2e+03	5.0e+03	5.2e+03	5.4e+03	5.2e+03

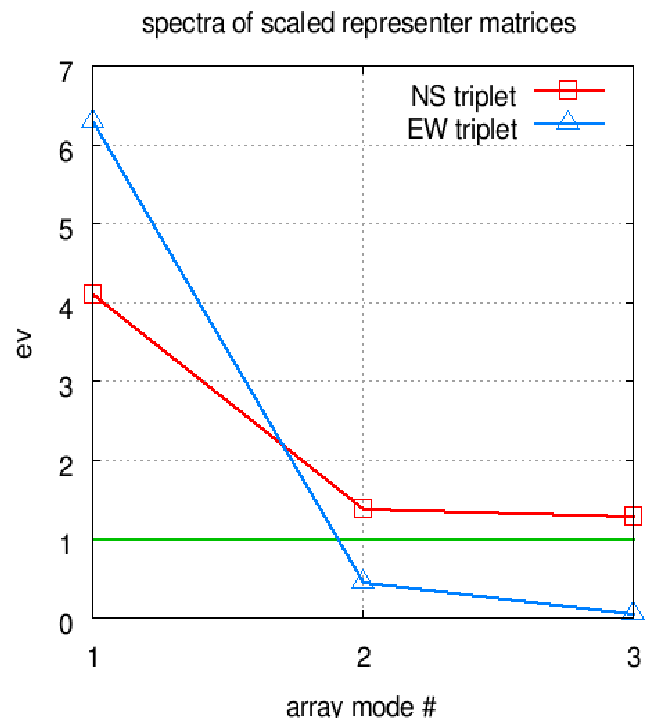
The estimation of the drag coefficients is only marginally improved by using sea-ice thickness observations

Deliverable DL5.8

The ArM toolbox in SANGOMA in brief (1) – General points

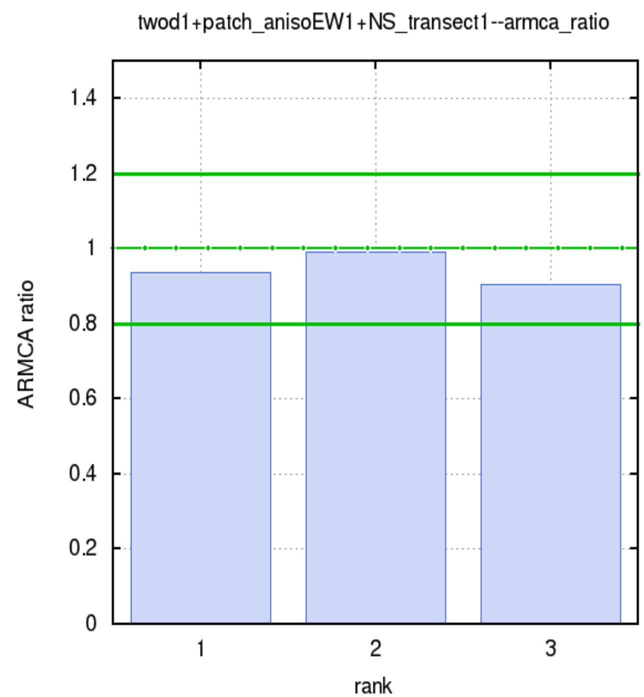
- The tools propose simple criteria to characterise
  - (1) **array performance** at detecting forecast errors,
  - (2) **consistency** between forecast Ensemble statistics and innovation statistics. The tools work in space/time and across variables. The observational errors can be correlated.
- **WP2**: ArM diagnostic tools are included in the SANGOMA toolbox
  - `sangoma_arm()` Ensemble-based criterion of array performance
  - `sangoma_armca()` Array-space criterion of Ensemble consistency
- **WP5**: Participation in D5.8
  - Mostly transferred to LGGE but harmonise approaches.

- Array performance with `sangoma_arm()`



Count singular values of $\mathbf{S}$ larger than 1:

$$\mathbf{S} = \frac{1}{\sqrt{m-1}}\mathbf{R}^{-1/2}\mathbf{Y}^f$$



Count array-space ranks k for which $1-\tau \le \frac{\sigma_k + 1}{\mathrm{var}_k(\Delta^o)} \le 1+\tau$

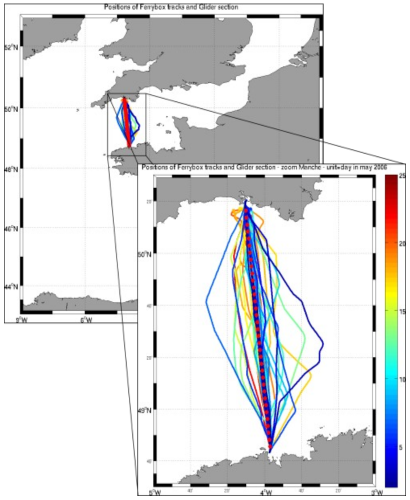
with τ =tolerance

The ArM toolbox in SANGOMA in brief (3) – Uses and publication

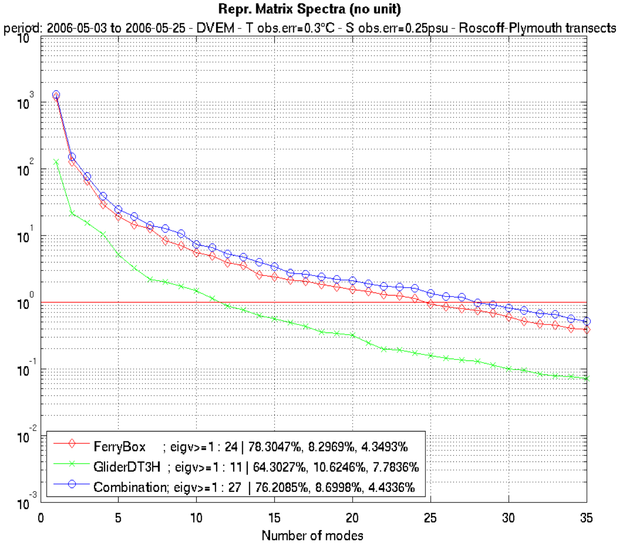
- The ArM tool has been used in the JERICO EU project (fishing net sensors, gliders, etc.) and will be used in JERICO Next (HF radars). Two publications so far (SANGOMA explicitly cited in Ackn.):

  1. *Lamouroux, J., G. Charria, P. De Mey, S. Raynaud, C. Heyraud, P. Cranegu, F. Dumas, M. Le Hénaff, 2015: Assessment of RECOPESCA network contribution for the monitoring of 3D coastal model errors in the Bay of Biscay and the English Channel. Ocean Dynamics, submitted. (joint SANGOMA/JERICO paper)*
  2. *Charria, G., J. Lamouroux, and P. De Mey, 2015: Optimizing observational networks combining gliders, 1 moored buoys and FerryBox in the Bay of Biscay and English Channel. J. Marine Sys., submitted. (JERICO paper)*

- *The ArMCA tool is int*ended to be used in a CMEMS Open Call proposal later this year (co-led by PDM).



Glider vs. Ferrybox with ArM *(Charria et al., 2015)*



Delivrable 5.8: Performance assessment of observational arrays at detecting prior errors

- Characterise which observational network detects most degrees of freedom in background vector via computation of tr(HK)*.

- Reduced rank approach using 96-member ensemble (2005-2005) with NATL025, perturbed in the equation of state : Large uncertainty in Gulf Stream (Candille et al. 2015).

<u>- Obs </u>: Sea Surface Height from ENVISAT and JASON,

Temperature- and Salinity- profiles from ARGO

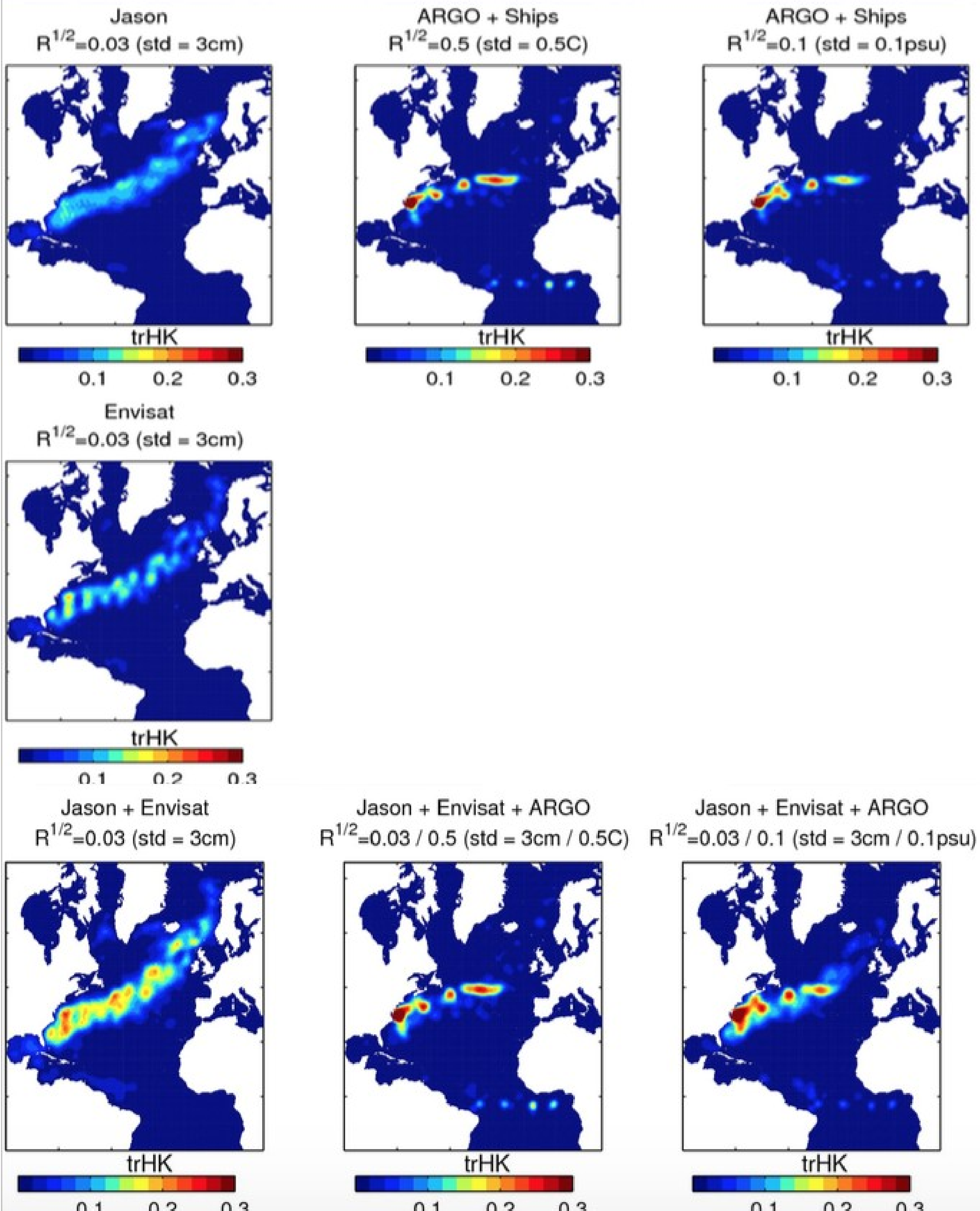
$$x^a = x^f + K(y - Hx^f)$$

$$K = P^f H^T (HP^f H^T + R)^{-1}$$

tr(HK) = sum of singular values of HK matrix

*tr(HK) is compatible with the RMSpectrum method (LeHenaff et al. 2009) and is localised

Free run ensemble, 5-day obs window



- **Free run ensemble :**

  - Obs bring info over Gulf Stream (where P^f is large) + tropical Atlantic for ARGO

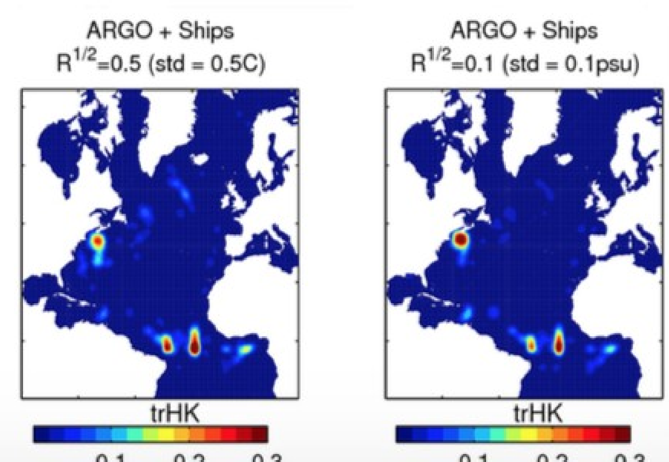
  - Assimilating both satellites bring twice as much info than assimilating just one

  - Quantitatively, ARGO seems to dominate when assimilated in addition to both satellites (R ARGO too small ?)

- **Assimilated ensemble :**

  - Assimilating ARGO in the assimilated ensemble does not bring a lot more info (P^f very small already)

Assimilated ensemble, 5-day obs window

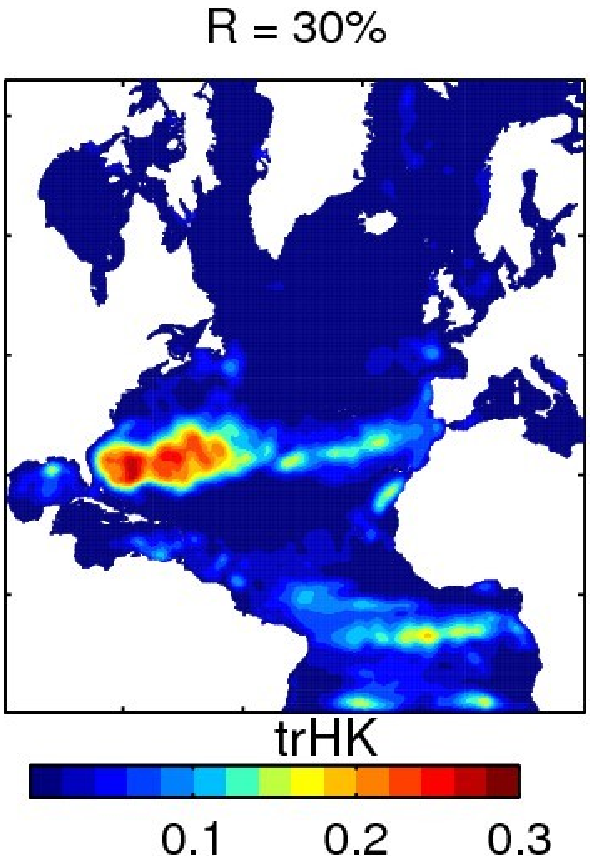


<u>More about ArM and tr(HK) methods</u> (comments by Pierre de Mey):

- ArM is part of the **SANGOMA toolbox** (WP2) -- it is the stochastic form of RMSpectrum
- ArM is **not localised at the moment**, as it is meant more for the assessment of localised arrays (mostly coastal)
- tr(HK) approach may work even if one does not use an Ensemble-based approach, not ArM
- ArM and the tr(HK) approaches do not study exactly the same thing.
  - ArM: **how an array "views" the prior errors** (indendently on the Kalman gain)
  - tr(HK): **effectiveness of the correction** in observation space
- Both approaches are similar in that they only deal with the **observation-space view of prior errors**, and **exclude the controllability aspect**. But they also are complementary in the way described above.

Deliverable DL5.2

Impact of ecosystem data



- 60-member ensemble with NATL025 coupled to the biogeochemical model PISCES
- Observations: SeaWIFS, AquaMODIS, MERIS
- Expected forecast errors are large Gulf Stream & tropical Atlantic
- As expected observation have a high impact in these areas
- The assimilation of Chlorophyll seems to have an impact larger and over a larger area than the assimilation of physical data
- Additional test with anamorphosis

Overall use of Sangoma tools

- Diagnostics:
  - CRPS, Reliability, Resolution
  - Array Modes
- Perturbations
  - Weakly Constrained Ensemble Perturbations
- Utilities:
  - HFRadarExtract
- Transformation:
  - Gaussian anamorphosis

Concluding Remarks

WP5 was structured along two interconnected lines of effort:

1. *Use of new ocean observations in DA, including remote sensed*
2. *A preparatory step before their operational use*

Points (1) and (2) have been the motivation behind the work done by the different partners in WP5.
Specific results and conclusion from WP5:

- **Along-track altimetry data** (Envisat and Altika)
  Stochastic parameterizations of the model dynamical uncertainties proved to be suitable
- **Wide-swath sea surface height measurements** (SWOT mission)
  Efficient method to account for the correlation of observational error
- **HF Radar current observation**
  Space-time covariance suitable to capture inertial osciallation
- **Sea-ice thickness**
  Useful to calibrate relevant parameters of the sea-ice

OUTLOOK: Sangoma WP5 links to the Sentinel missions in that:
- Task 5.3 prepares for using future ocean altimeter onboard the Sentinel-3 mission.
- Task 5.5 prepares for using sea ice altimeter onboard the Sentinel-3 mission
- Arising opportunities to include the methods in Copernicus Marine Services in H2020