Sistemi regionali di previsione oceanografica a breve e medio termine al CMRE: stato e prospettive

A. Storto,
P. Oddo, S. Falchetti, I. Borrione,

Centre for Maritime Research and Experimentation (CMRE)
La Spezia, Italy
andrea.storto@cmre.nato.int

Improving ocean prediction systems for regions where CMRE sea-trials are performed

Main Scientific Goals:

1] Exploiting exceptional observational capabilities (using observational campaign data) in a high-resolution data assimilation context, i.e. exploiting the sea-trail as a “Data Assimilation Lab”

- Investigating optimal synergy of different observing networks
- Optimizing a network through validation against another

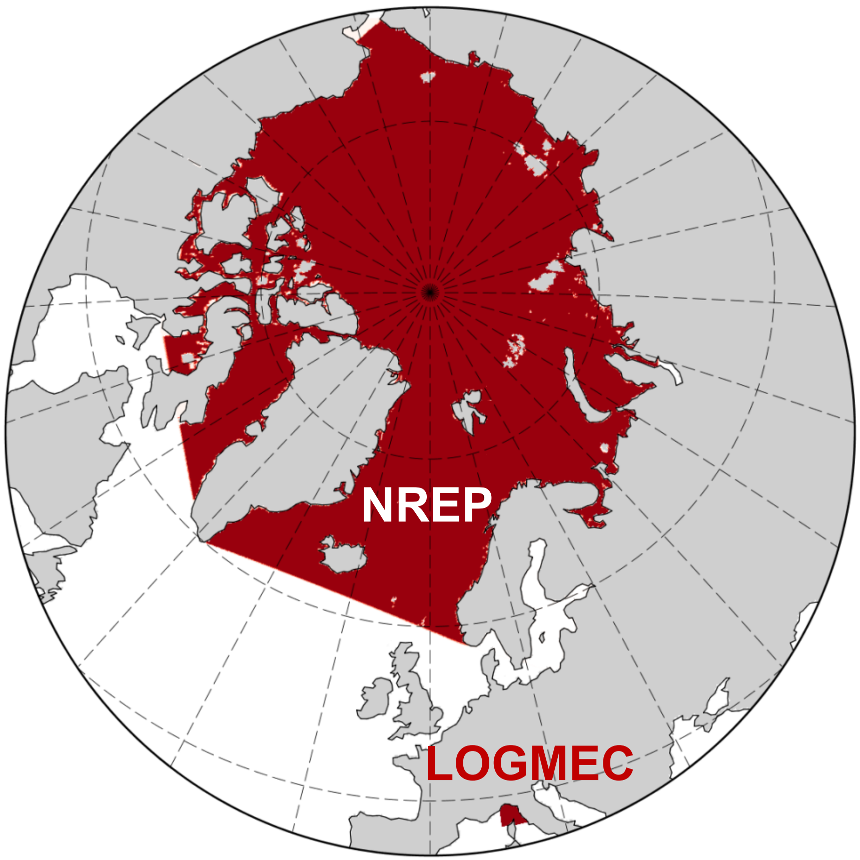
2] Supporting observational campaigns with a state-of-the-art hybrid ensemble-variational oceanographic forecasting system

3] Long-term and methodological research objectives

- Impact of small-scale (ADCP, Scanfish) physical data assimilation on i) synoptic characterization ii) acoustic characterization (multi-scale DA)
- Assimilation of acoustic measurements into ocean analysis systems (Strongly coupled oceanic/acoustic data assimilation)

A few examples will be given in this talk

CMRE Physical Ocean Modeling framework



Two main analysis and forecast system:

Arctic Ocean model for NREP/HN

Ligurian Sea model for LOGMEC

Similar strategy for the two prediction systems:

Parent model with data assimilation of all available data

One-way nested children models to reach (sub-)mesoscale resolution without data assimilation

NREP Models

*Pan-Arctic "**Parent**" model with data assimilation (7kmL91)*

NEMO primitive equation ocean model
Forced by Mercator Ocean global model
+
LIM2 thermodynamic-dynamic sea-ice model
+
3DVAR data assimilation scheme

Assimilation of L4 SST product (infrared sensors), SIC (microwave sensors), SLA (altimetry), In-situ profiles (Argo, CTDs, XBTs, gliders, etc. from CMEMS and NREP)

*2 one-way nested "**Children**" models (2KmL91, with dynamical downscaling)*

focusing on the main research areas and with tides and non-linear free-surface

All models are forced by ECMWF operational analyses and forecasts

Data assimilation scheme

Sea level balance operator:
Dynamic height

Vertical covariances:
Pointwise multi-variate EOFs

Horizontal correlations:
Inhomogeneous 3D length-scales with 1st order Rec. Filter

Quality Control:
Variational Quality Control

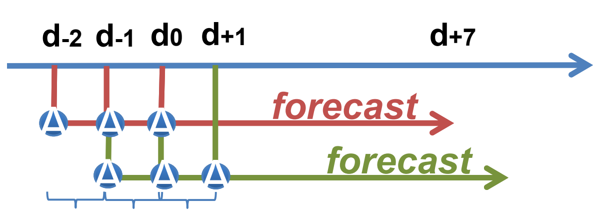
SLA Assimilation:
CMEMS global MDT with basin-averaged mean innovation removal

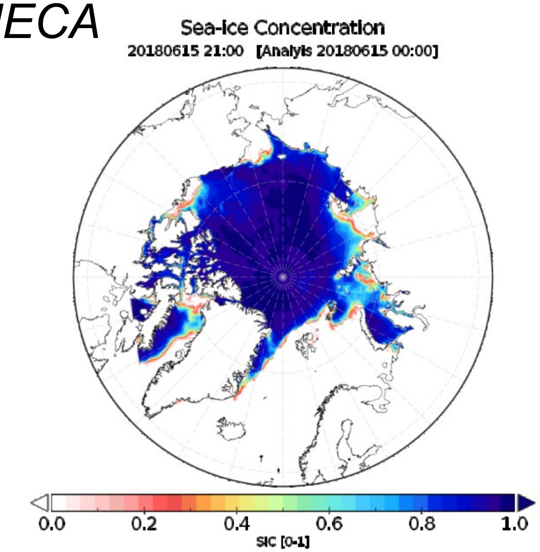
Glider Assimilation:
1D+3D Super-obbing

Standard 3DVAR/FGAT scheme
With incremental formulation

Real-time production:
Every day the system restarts three days earlier, implements daily cycle of assimilation and produces 10-day forecasts delivered to NRV Alliance and partners

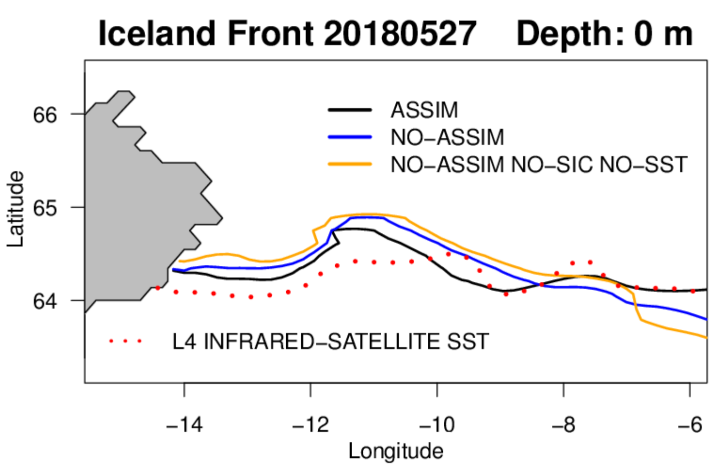
Operational During the sea-trial period (15 May – 15 July 2018), Running at MARCONI@CINECA



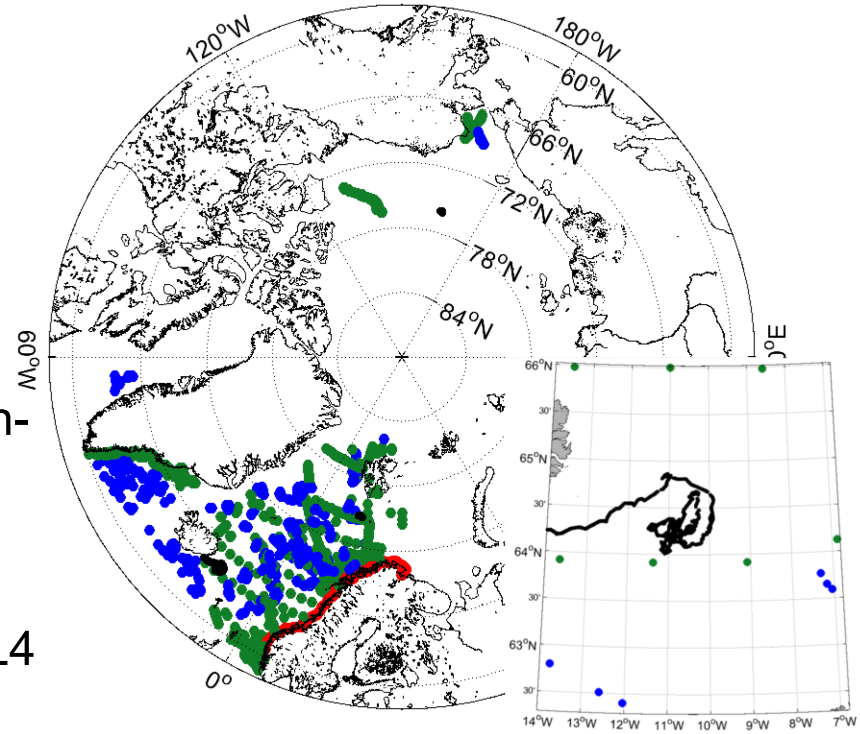


Retrospective assessment

Summer-time short-term predictability of Icelandic front:



At the surface, introducing first SST and then in-situ generally improved the front location forecast (w.r.t. L4 satellite data)



Data-denial assimilative experiments

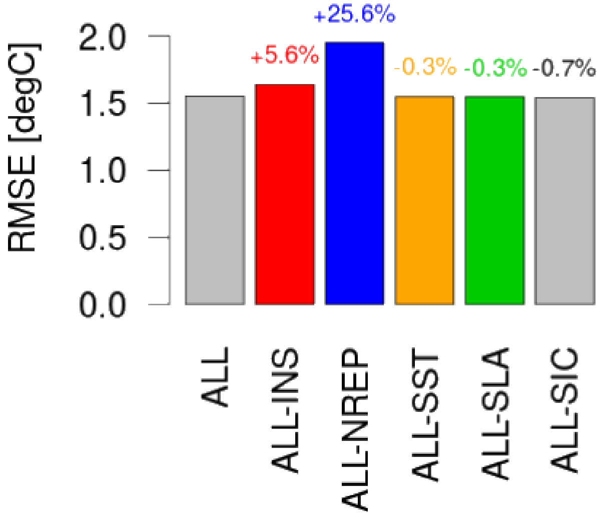
Nested forecasts

- SST
- SIC
- In-situ
- SLA
- NREP

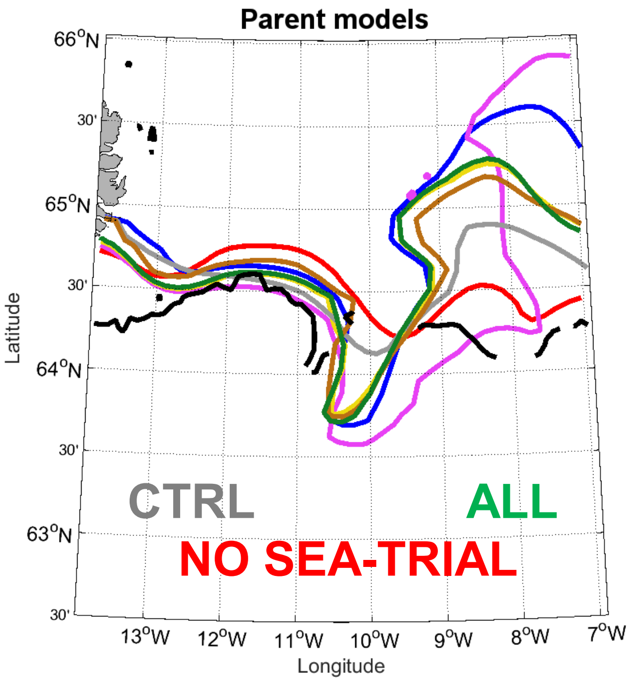
→ Parent Model Hindcasts and Forecasts → Child Model Forecasts →

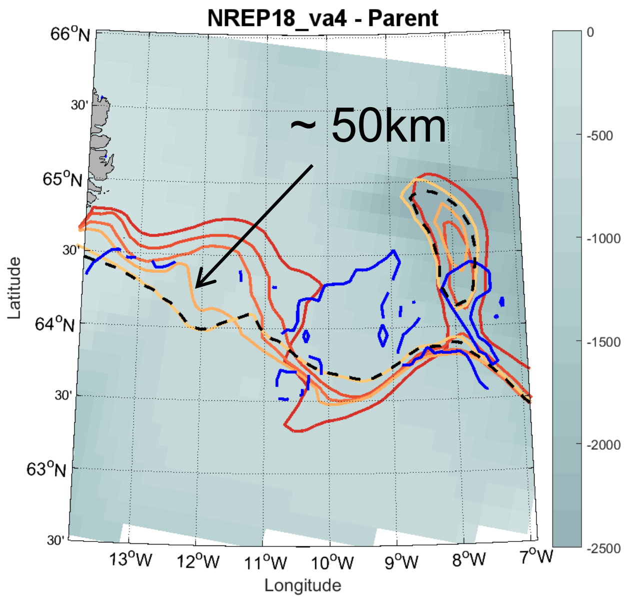
Predictability of the front position

1. Verification against in-situ T [0-100m]: 5-day forecasts



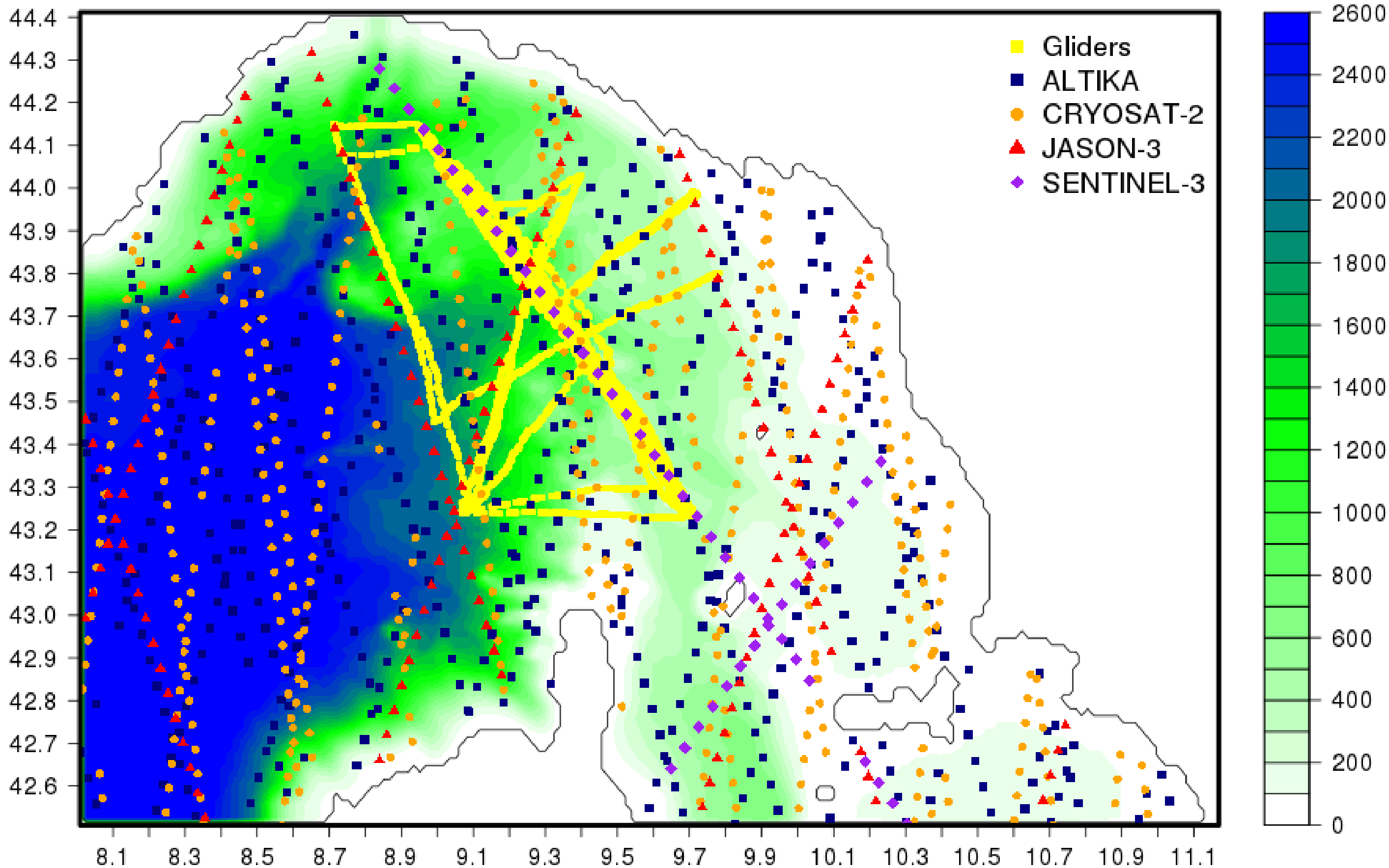
2. As a function of observing networks denied for a particular event (21/JUN/18)





3. As a function of forecast ranges (0 to 5, valid at the same date) for particular events (2/JUL/18)

LOGMEC17: Observational dataset considered here



+ *Scanfish data, ADCP profiles from LOGMEC17 + HF radar*
+ SST (IR/MW) + a very few Argo floats, drifters, SSS, etc.

Observation error covariance matrix

Redefine the variational cost function to allow for along-track observation error correlations

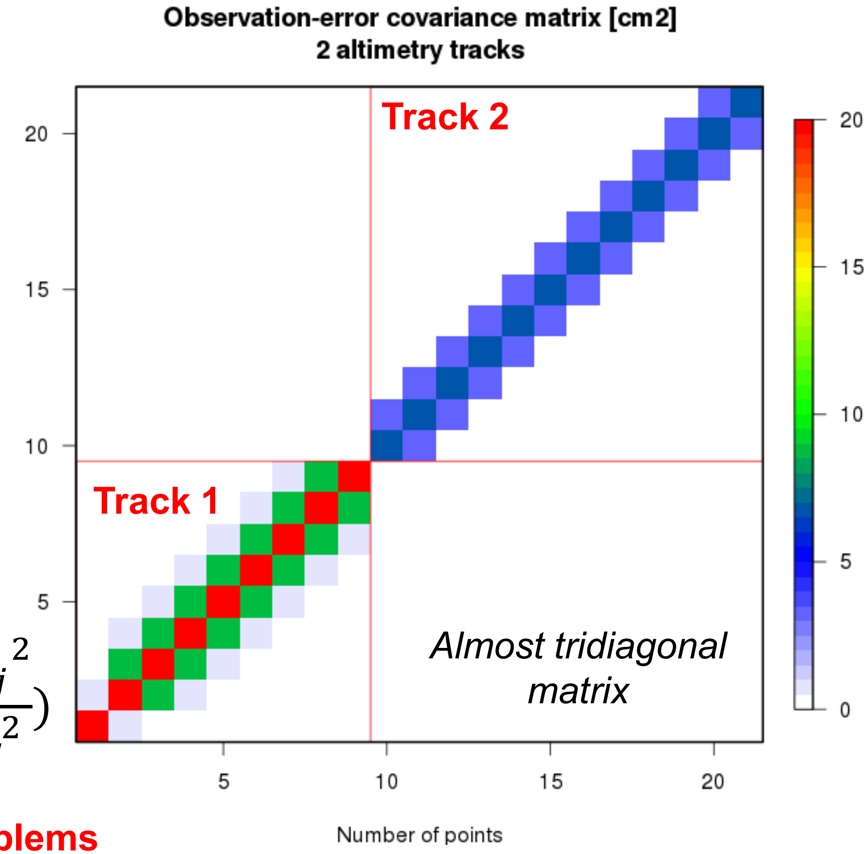
Usual term for background

Usual term for in-situ obs

$$J(\delta x) = \frac{1}{2}\delta x^T (\mathbf{B})^{-1}\delta x + \frac{1}{2}(\mathbf{H}_i\delta x - \mathbf{d}_i)^T \mathbf{R}_i^{-1}(\mathbf{H}_i\delta x - \mathbf{d}_i) + \frac{1}{2}\sum_{k=0}^{N}(\mathbf{H}_k\delta x - \mathbf{d}_k)^T \mathbf{R}_k^{-1}(\mathbf{H}_k\delta x - \mathbf{d}_k)$$

Terms for the *N* satellite tracks

with $\mathbf{R}_k = \boldsymbol{O}_k + \boldsymbol{D}_k^{1/2}\,\boldsymbol{C}_k\,\boldsymbol{D}_k^{1/2}$ and $C_{i,j} = exp\left(-\frac{d_{i,j}^{\,2}}{2L^2}\right)$



Allowing only along-track errors reduces potential problems linked to i) explicit inversion of R, ii) preconditioning of the minimization and iii) spurious correlations

Estimating the along-track observation-error length-scale through analysis of glider-altimetry differences,
By looking at the differences between sea level anomaly from altimetry and dynamic height from gliders: $d_i = SLA_i - DH_i = e_i^{\ SLA} - e_i^{\ DH}$

If it is assumed that errors between SLA and DH are not correlated and that the spatial correlations of DH errors are negligible

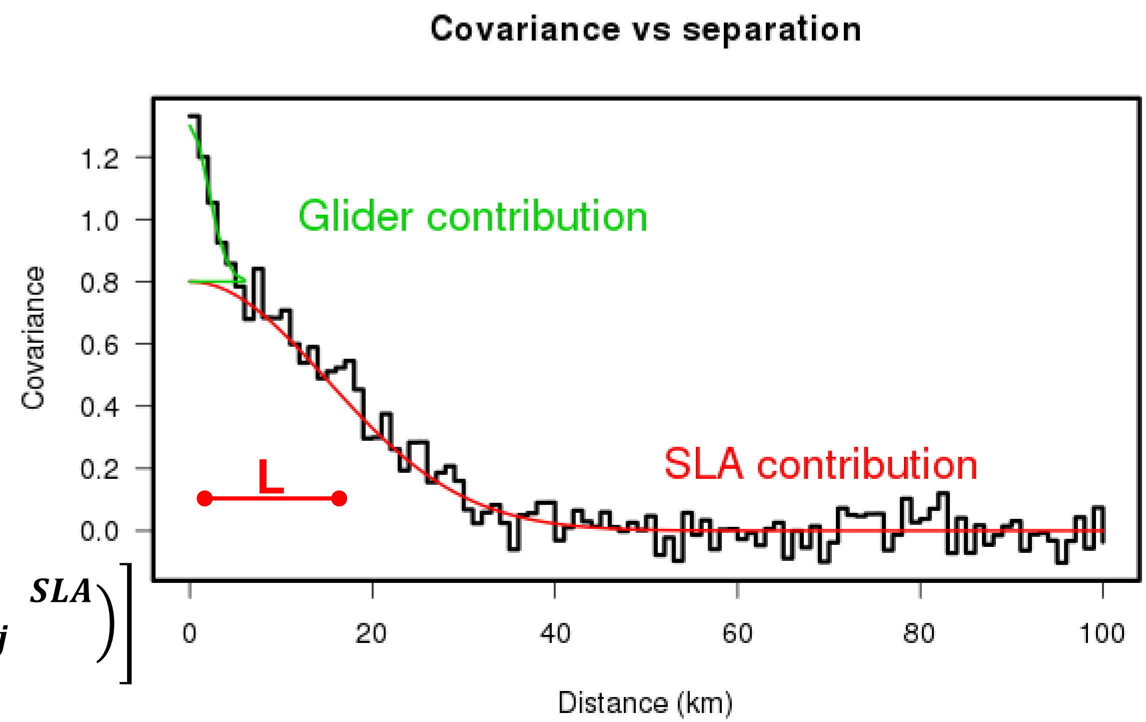
Then:

$i \neq j$:

$$E[(d_i)^T(d_j)] \cong E\left[\left(e_i^{\ SLA}\right)^T\left(e_j^{\ SLA}\right)\right]$$

$i = j$:

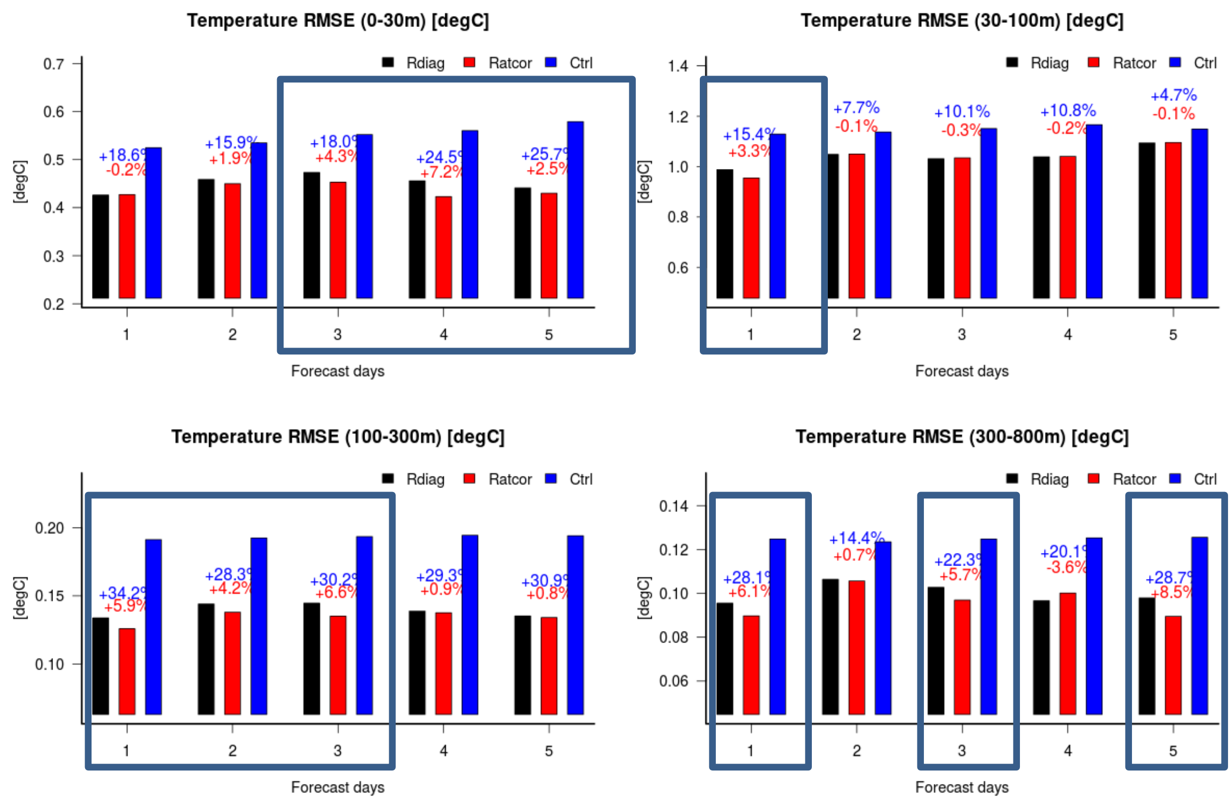
$$E[(d_i)^T(d_j)] \cong E\left[\left(e_i^{\ SLA}\right)^T\left(e_j^{\ SLA}\right)\right] + E\left[\left(e_i^{\ DH}\right)^T\left(e_j^{\ DH}\right)\right]$$



LOGMEC17 RESULTS (AUG-NOV 2017)

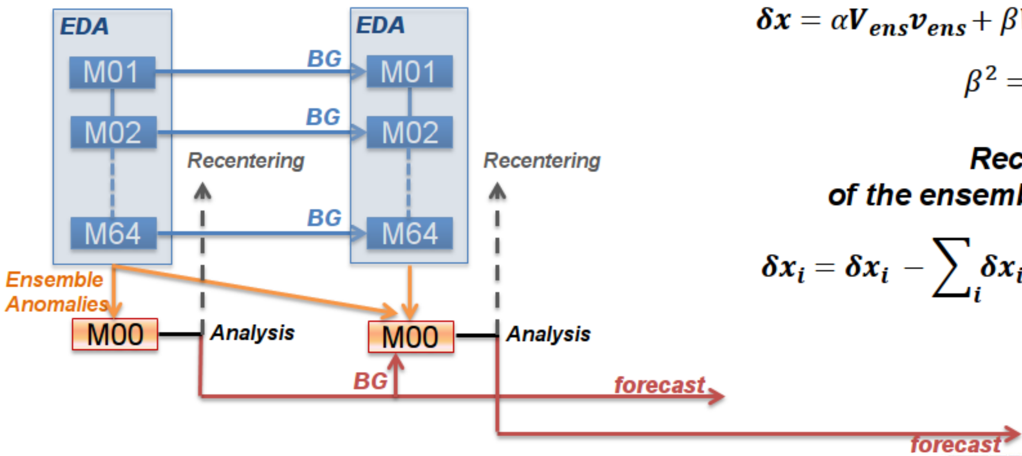
Assessment from 8 tracks (111 co-located obs)

The co-location method indicates that about half of the covariance has spatial scale of the order of 12 km (assuming a Gaussian shape)



The Ligurian Sea enhanced DA system

A prototypical hybrid system



Formulation (augmented control vector)

$$\delta x = \alpha V_{ens} v_{ens} + \beta V_{clm} v_{clm}$$

$$\beta^2 = (1-\alpha)^2$$

Recentering of the ensemble mean

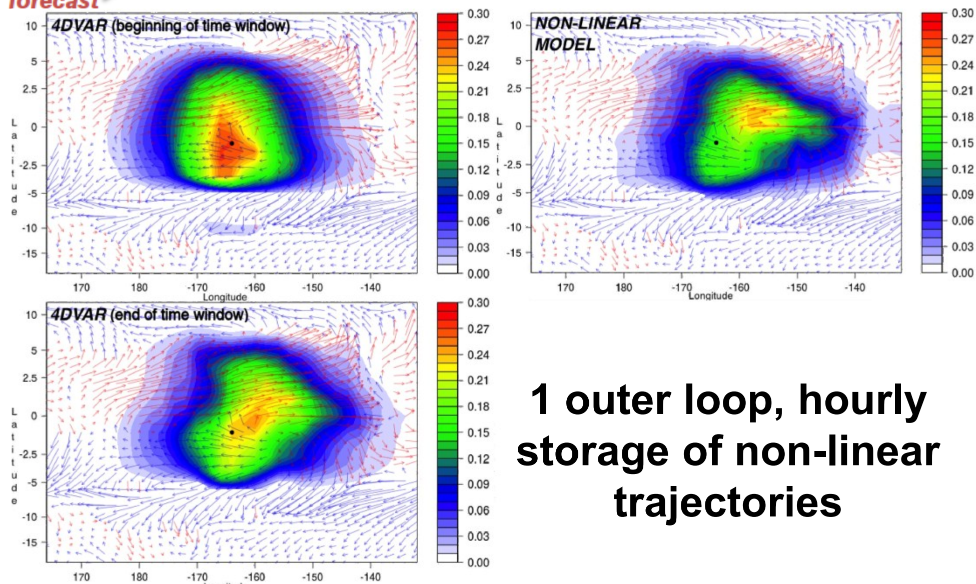
$$\delta x_i = \delta x_i - \sum_i \delta x_i + \delta x_{M00}$$

Simplified 4DVAR formulation

- **In-house TL/AD model with only main processes accounted for (diffusion, advection, air-sea fluxes)**
- **~ 20 times more expensive than 3DVAR**

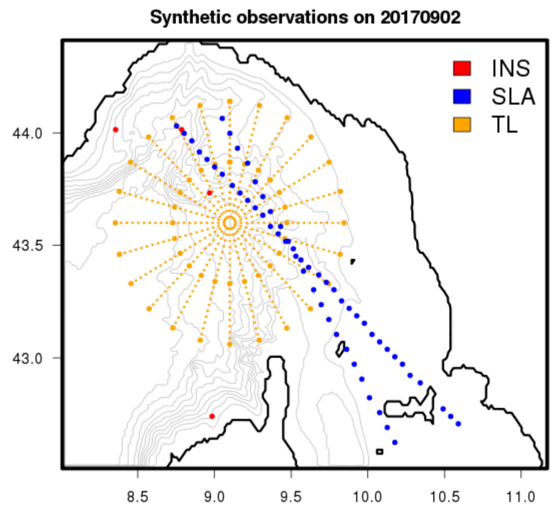
- **Perturbation of SST (OSTIA vs CNR)**
- **Perturbation of atmospheric forcing data (ECMWF vs NCEP)**
- **Perturbation of LBCs (GLO vs CMCC)**
- **Perturbation of bulk formulas**
- **Stochastic physics (in-house SPPT+SPP package)**

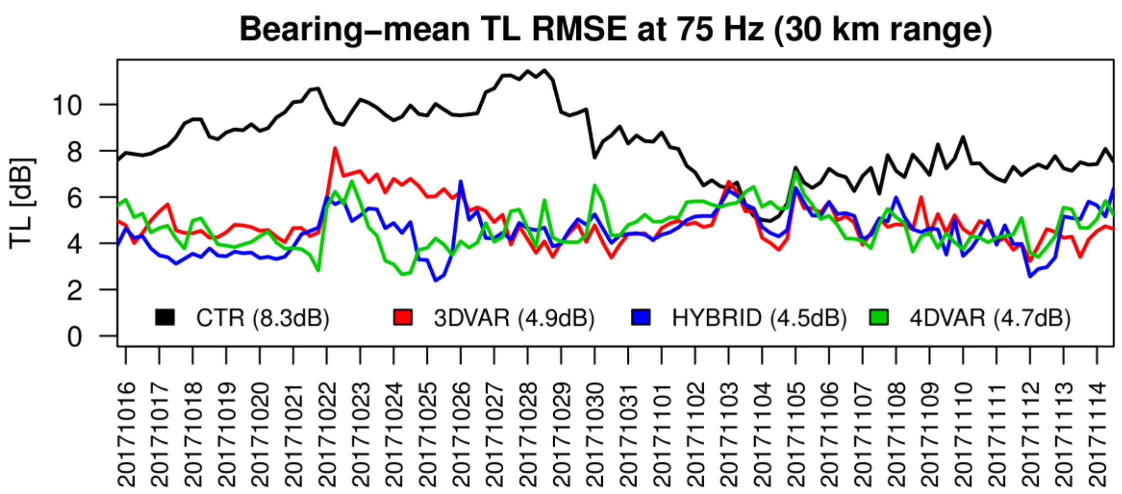
64 members

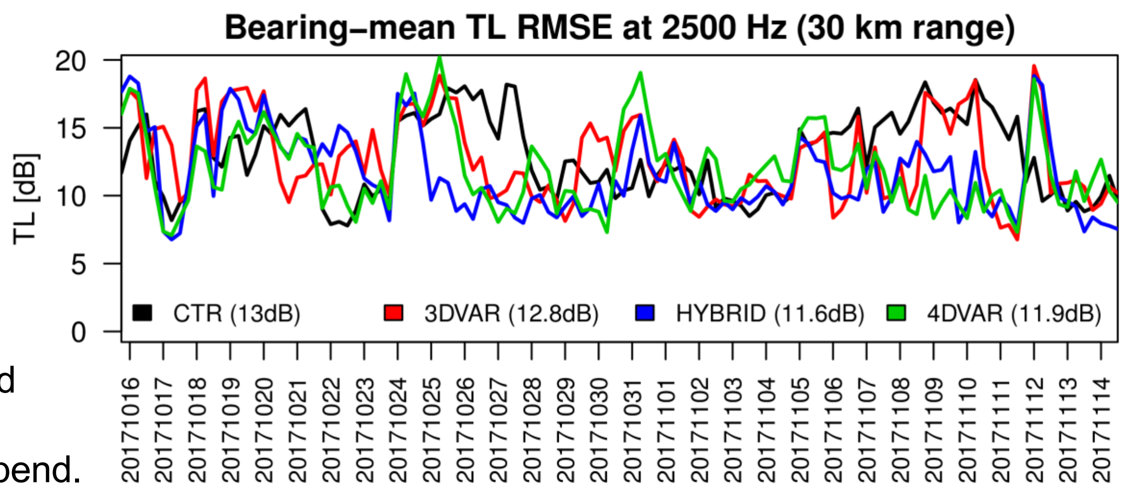


1 outer loop, hourly storage of non-linear trajectories

OSSEs to determine the impact of the oceanic analysis schemes on Transmission Loss (TL) @75Hz and 2.5 kHz in weakly coupled oceanic-acoustic experiments

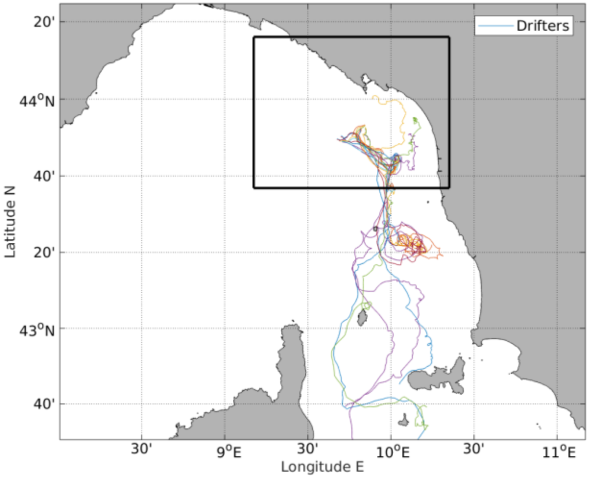


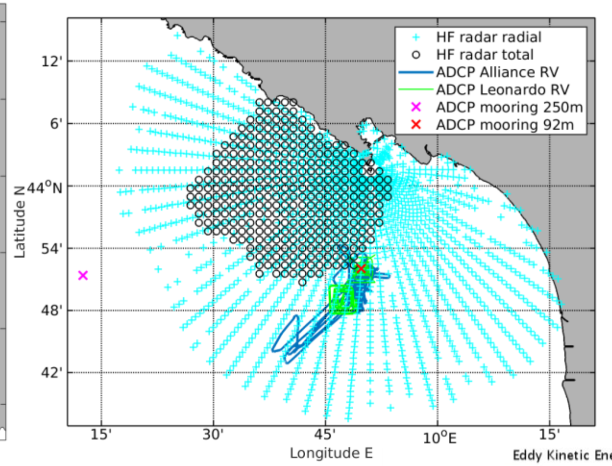


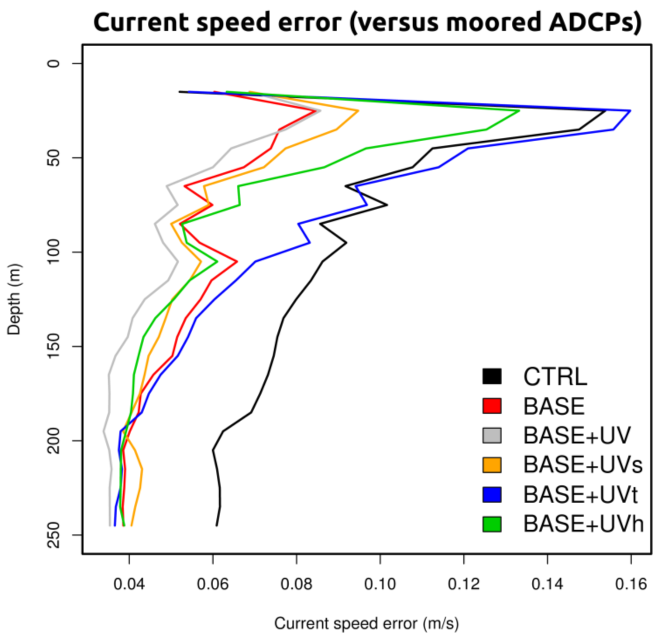


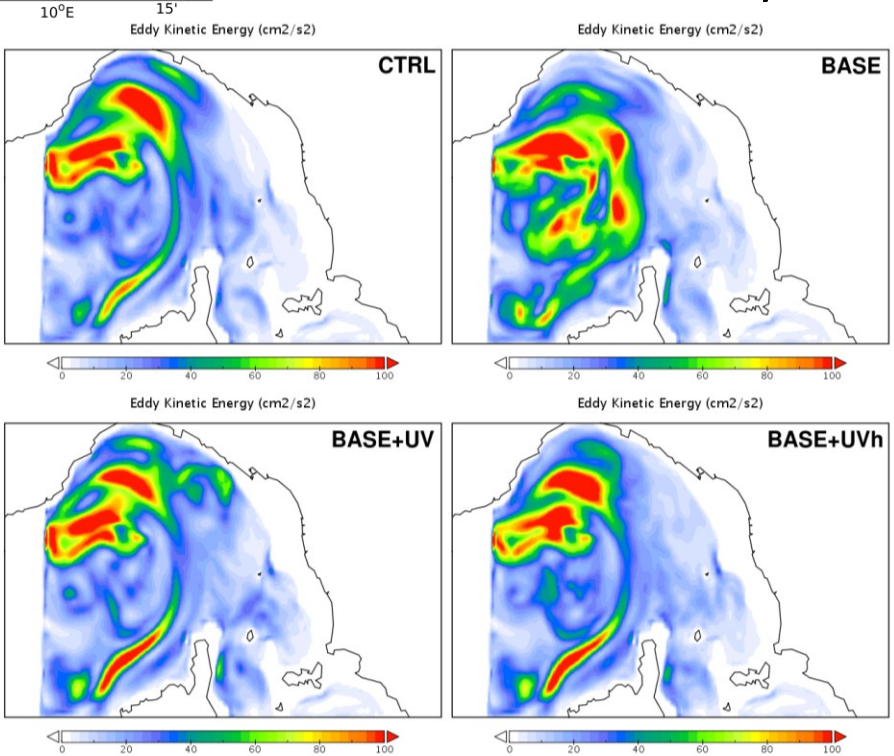
Nature run: Coupled simulation with perturbed physics and SBC
Acoustic propagation model: RAM, range-depend.
Source: 10m deep / Receiver: 60m deep
Range 30 Km

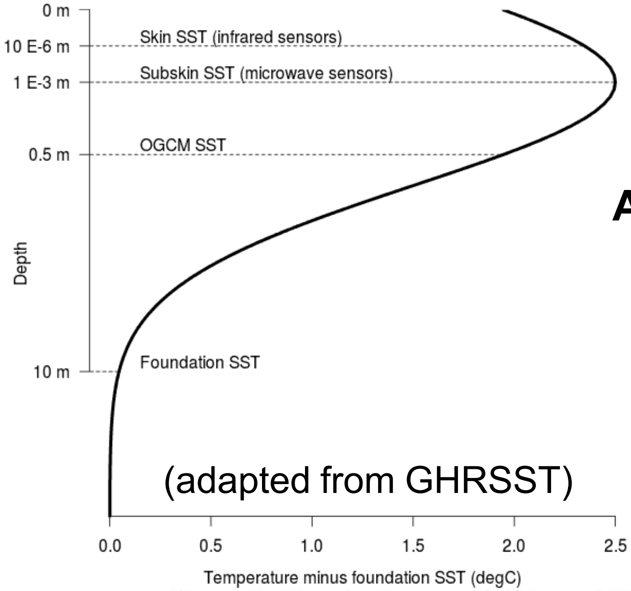
Assimilation of current data with an improved balance operator for the balanced velocity increments (barotropic+baroclinic in open ocean, statistical in shallow waters)



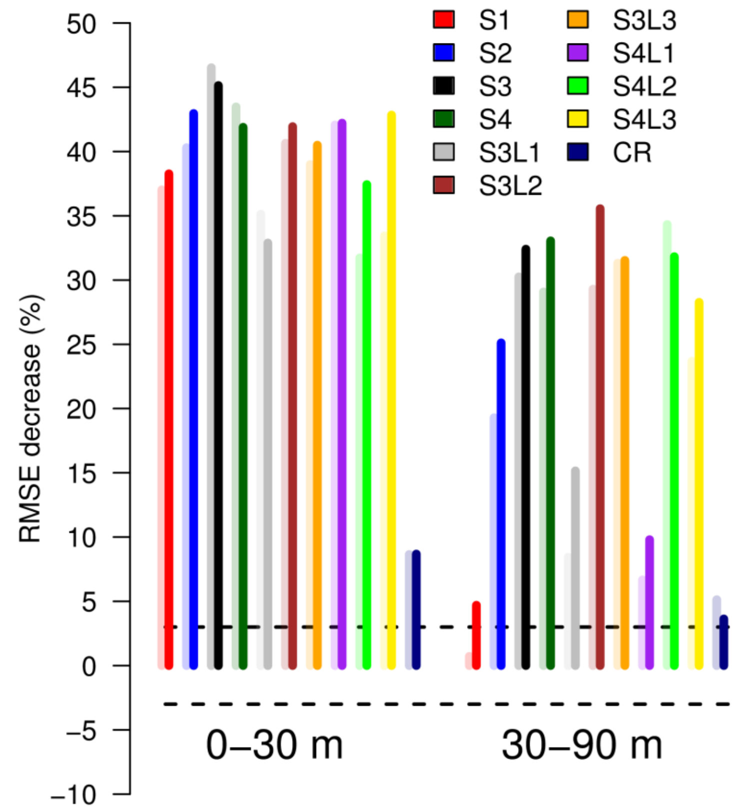


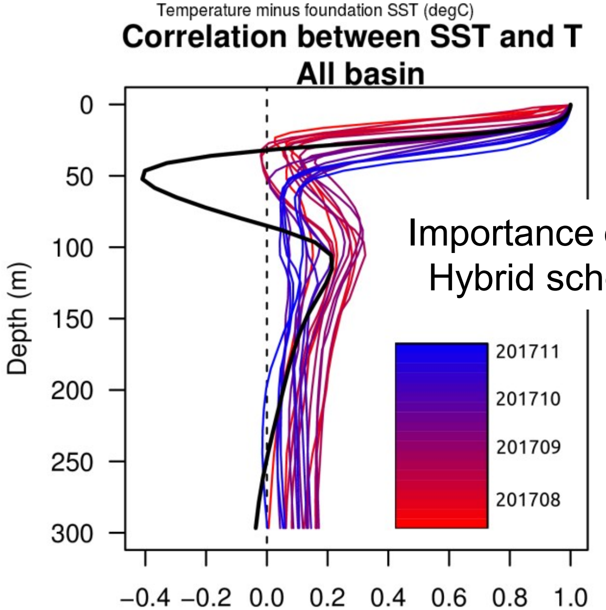






Assimilation of daytime SST (from MSG-10/SEVIRI) to improve Mixed/Sonic Layer Depth variability





Importance of the Hybrid scheme

We found significant improvements also in the MLD prediction when

i) SST Bias correction predictors include diagnosed skin SST (Takaya scheme)

ii) Vertical localization is performed

Summary: key messages

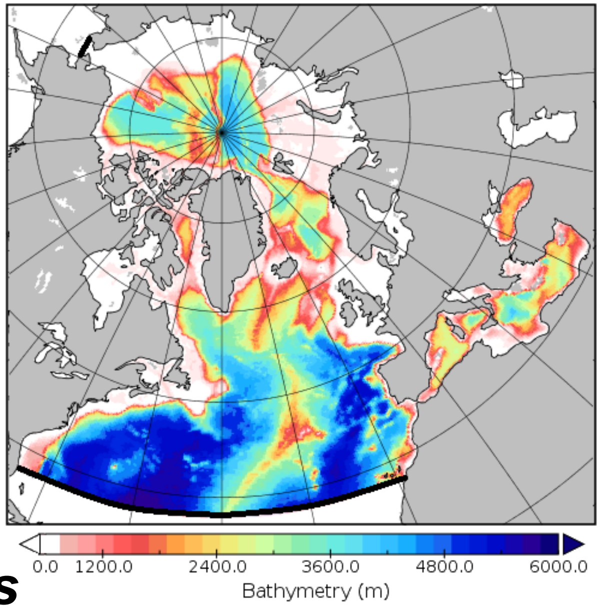
- ***Investing on advanced DA (multi-scale, hybrid, 4D) is key to exploit multiple observing systems in a coupled framework***

- ***Observational campaigns can be exploited to optimize data assimilation (synergy & cross-validation)***

Long-term developments

- ***Southwards extension of the North Atlantic Model (+Med&Black seas) -> 1 parent model***

- ***Coupled ocean-atm-acoustic (NEMO+WRF+RAM) modelling system in the Ligurian Sea for strongly coupled DA experiments***



Thank you for the attention

Contact: andrea.storto@cmre.nato.int

Recent References

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