SOCIB Sistema de Observación y Predicción Costero de las Illes Balears

MINISTERIO DE CIENCIA E INNOVACIÓN | CSIC | GOVERN ILLES BALEARS

Comparing High Frequency Radar radial and total derived observations capability to correct surface currents using Data Assimilation

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Ocean Predict. Toulouse 13 June 2023

Objectives

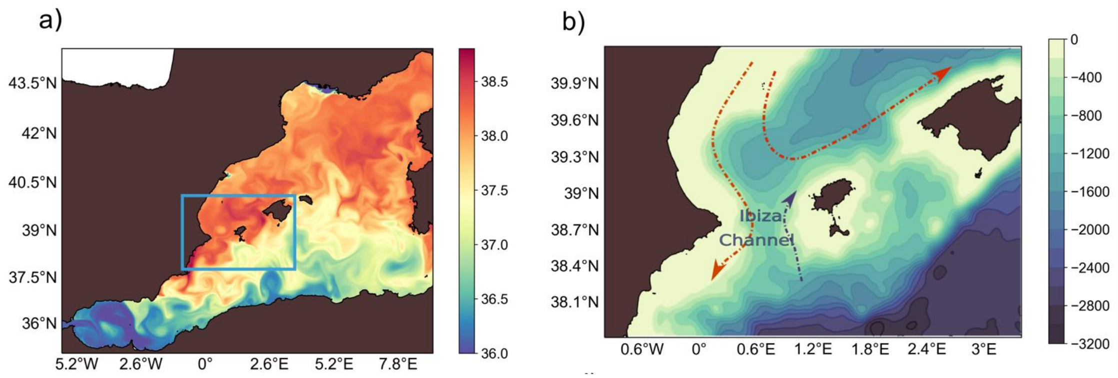
- To what extent do HF Radar data assimilation help to correct surface currents in the Ibiza Channel?
- Does the assimilation of radial currents outperform that of total reconstructed currents?

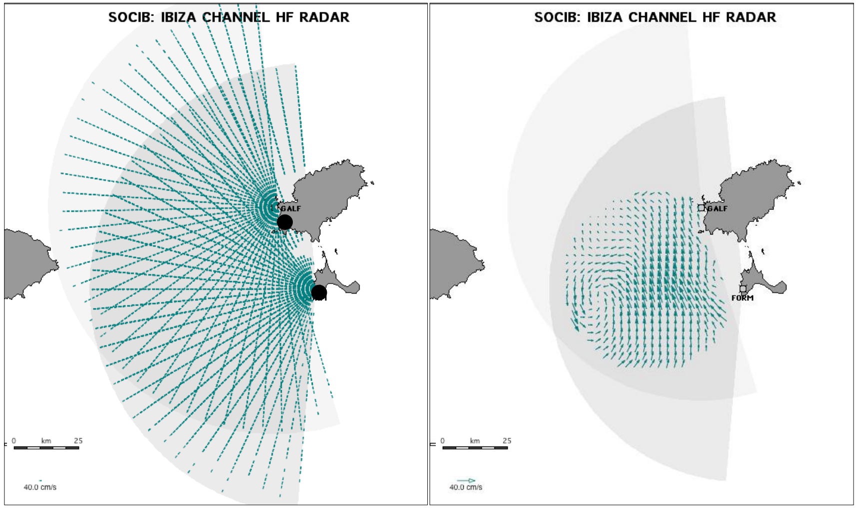
Ibiza Channel HFR system

Radials: Distance between measures ~1.6km and 5º bearing difference.

Total velocity vectors computed by combining the radial velocities with overlapping coverage, on a regular 3 × 3 km grid.

Radial velocities within a 6km radius around each grid point.





Radials have a wider coverage and theoretically contain more information.

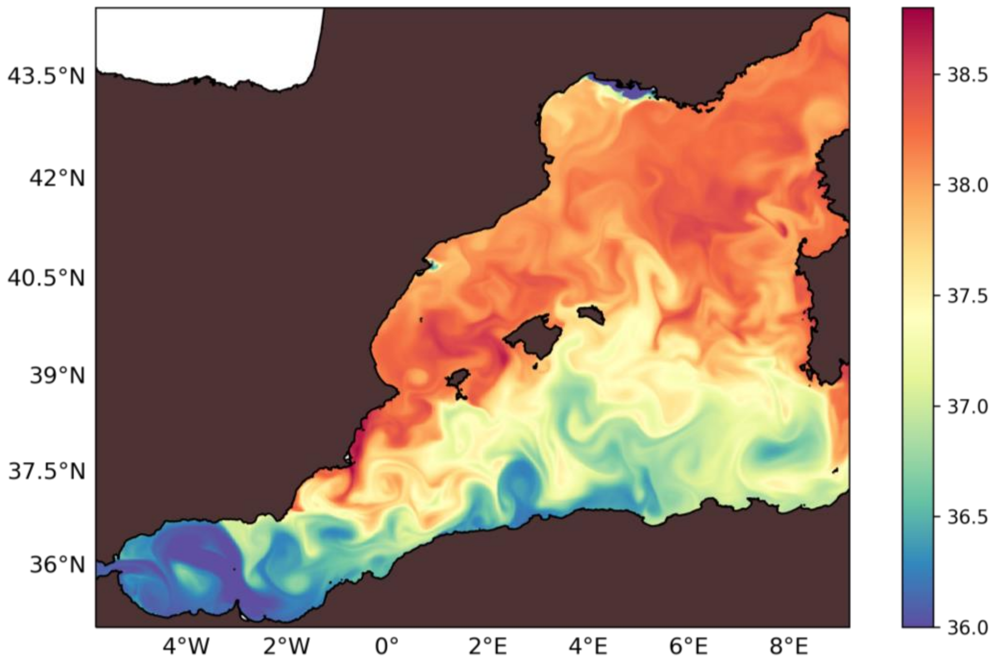
Model and data assimilation system

WMOP – Western Mediterranean OPerational system

(Juza et al.2016, Mourre et al 2018)

Hydrodynamics	ROMS
Spatial domain	Western Mediterranean (Gibraltar to Sardinia-Corsica)
Horizontal & vertical resolution	2km (~1/50º) 32 σ-levels
Surface forcings	HIRLAM model (1h, 5km)
Initial & boundary conditions	CMEMS Med Rea (6km, daily)

WMOP Salinity. 16-Oct-2014



Daily forecasts available @www.socib.es
Hindcasts (2009-2018 free run): Mourre et al 2018, Aguiar et al. 2020
Short-term reanalysis

Data Assimilation scheme

Multimodel Local Ensemble Optimal Interpolation

- Ensemble anomalies sampled from three WMOP hindcast simulations (2009-2015) with different initial/boundary forcing and mixing parameters.

- 80 ensemble realizations.

- Anomalies selected within the same season as the analysis date after having removed the seasonal cycle.

→ Multivariate, inhomogeneous and anisotropic 3-dimensional model error covariances characteristic of the mesoscale variability.

- Domain localization with a 200-km radius.

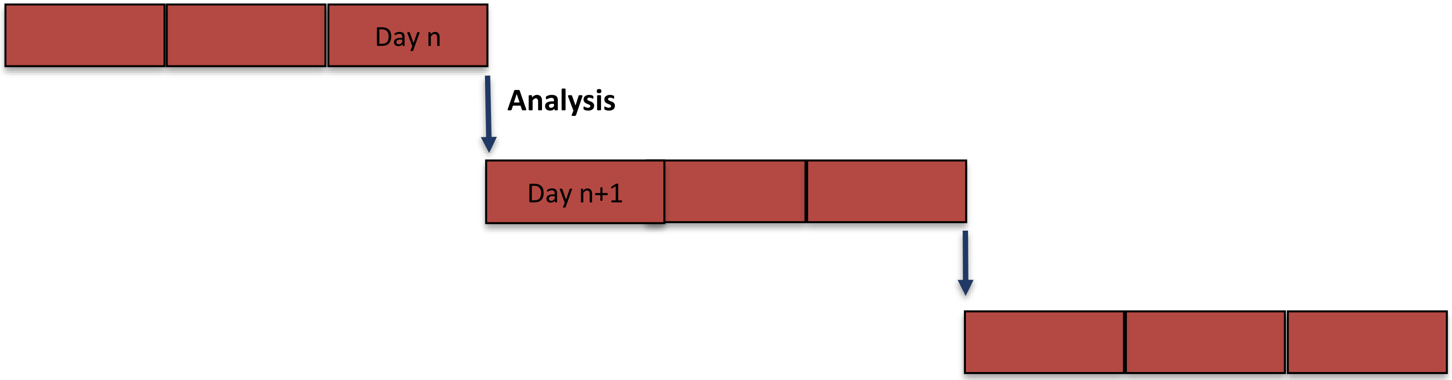
Initialization methods after analysis

Initialization after analysis is problematic in any sequential DA scheme.

Instabilities or spurious waves may be created when restarting after analysis.

Two Initialization methods are explored

a) **Direct restart from analysis**



Initialization methods after analysis

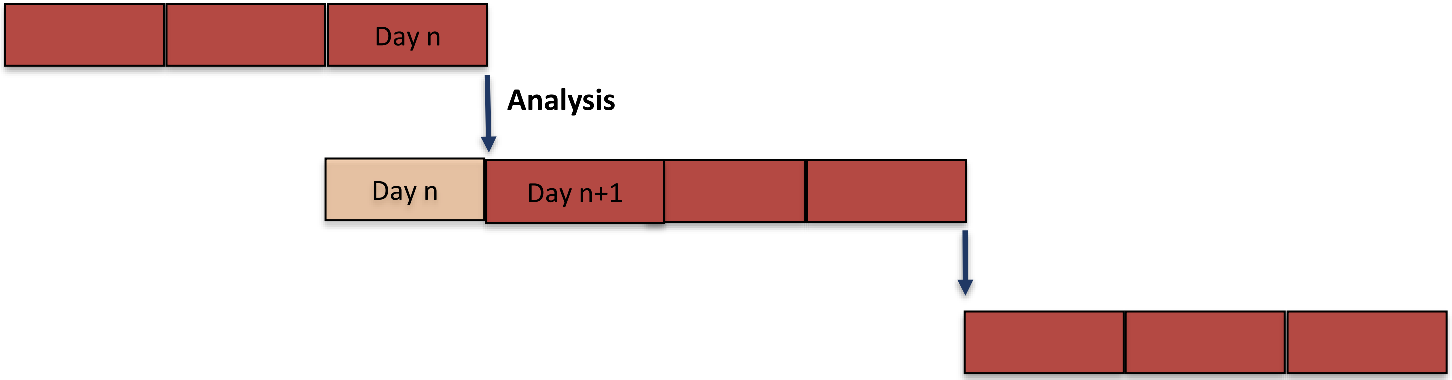
Problematic in any sequential DA scheme.

Instabilities or spurious waves may be created when restarting after analysis.

Two Initialization methods are explored

a) Direct restart from analysis.
b) **Nudging step:** Day n is simulated again applying a strong nudging towards T-S and SSH analysed values.

Reduces the model correction but limits instabilities.



Observing System Experiments

Long-run (1-month) experiments set-up to assess the impact of real HF Radar observations in an operational basis.

7 Simulations: 3 Datasets x 2 Initialization methods + CR

30 days (21 Sep to 20-Oct 2014), period with available drifters in the area.
3 day assimlation cycles.
Different datasets, including different kinds of radar observations.

Name	Observations
CR	None
GNR	SLA, SST, Argo TS
TOT	SLA, SST, Argo TS, HFR totals
RAD	**SLA, SST, Argo TS, HFR radials**

Simulations

CR: Control-run. No Data Assimilation

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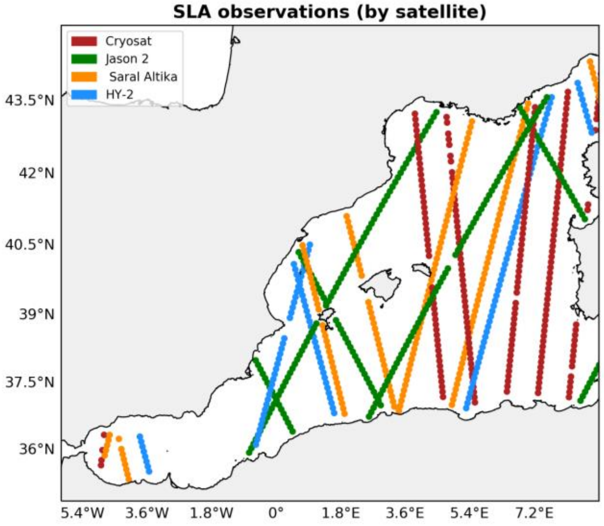
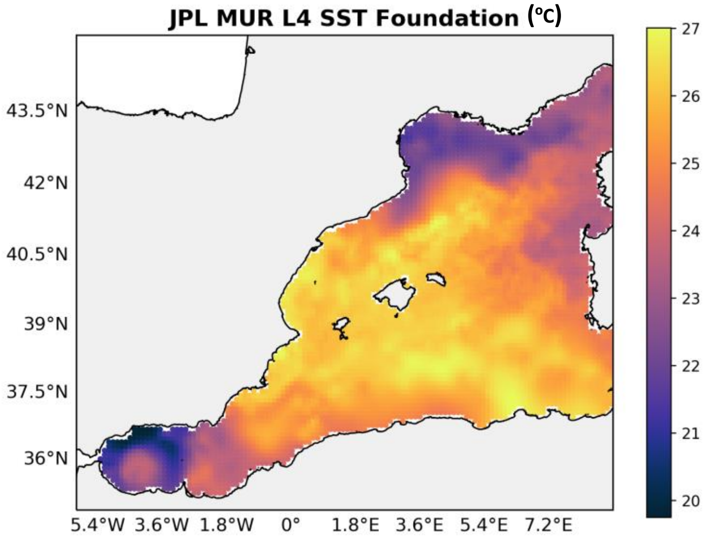
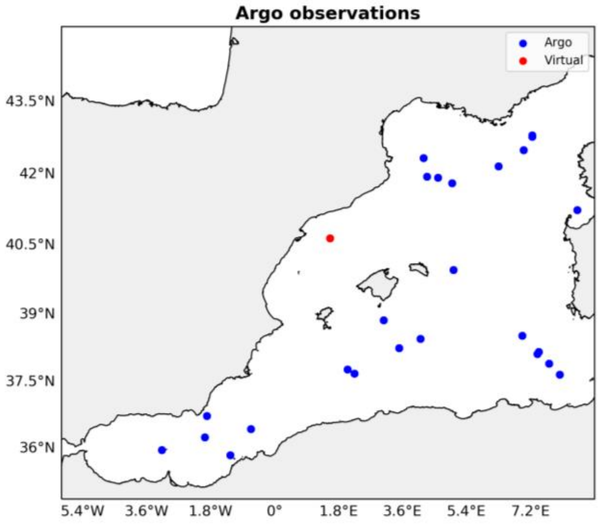
GNR: "generic" DA observing sources → SLA + SST + Argo







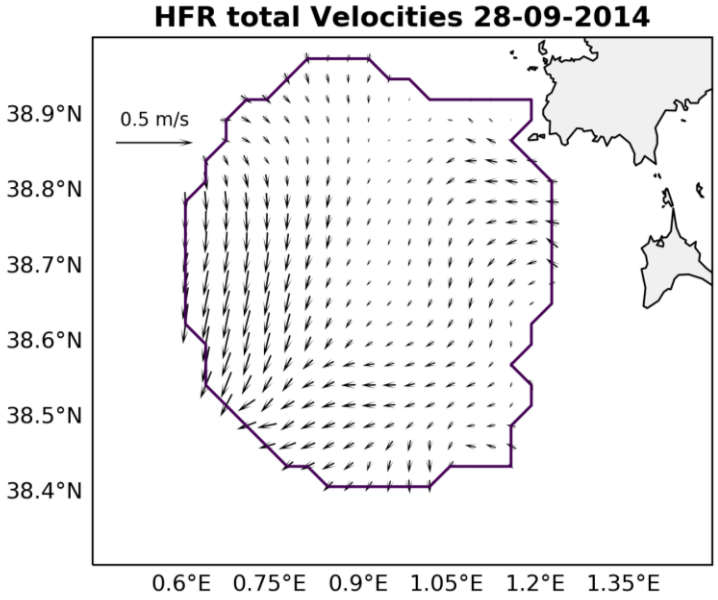
Simulations

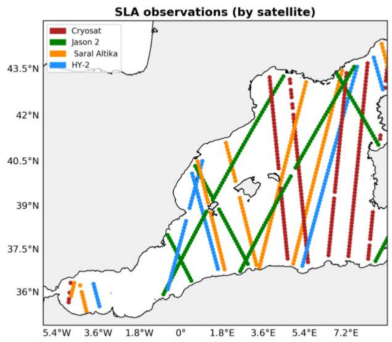
CR: Control-run. No Data Assimilation

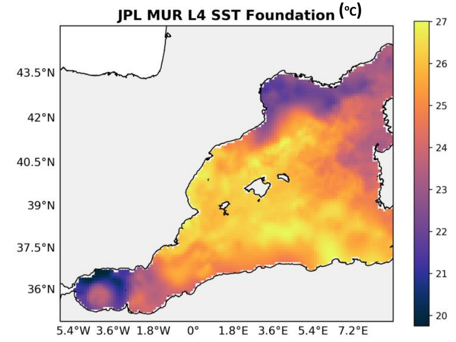
GNR: "generic" DA observing sources → SLA + SST + Argo

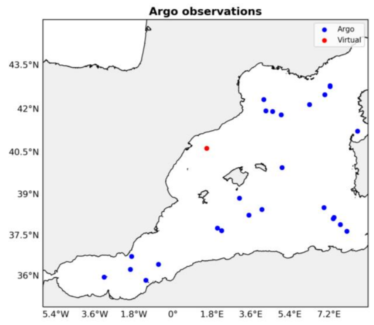
TOT: SLA + SST + Argo TS + HFR totals (u,v)

HFR Totals
Daily mean fields
50% temporal availability









Simulations

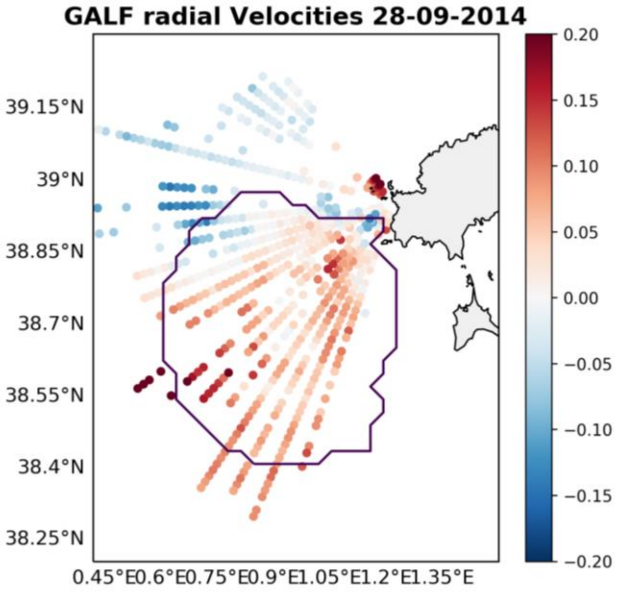
CR: Control-run. No Data Assimilation

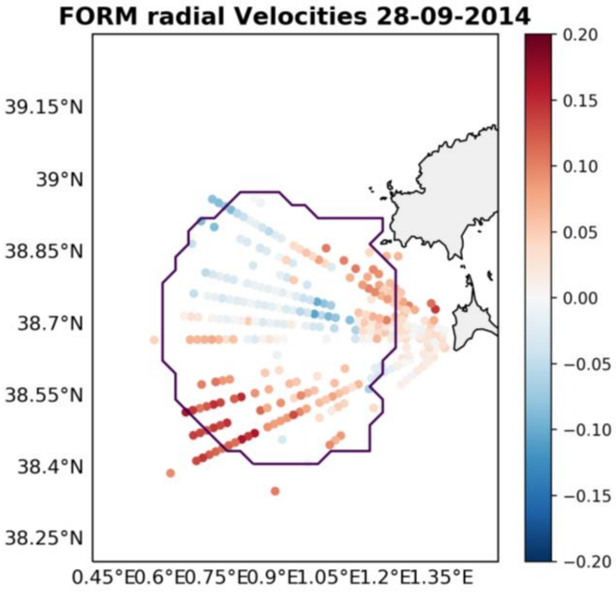
GNR: "generic" DA observing sources → SLA + SST + Argo

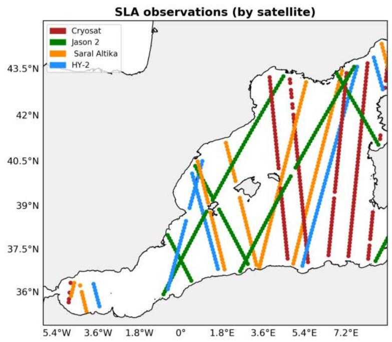
TOT: SLA + SST + Argo TS + HFR totals (u,v)

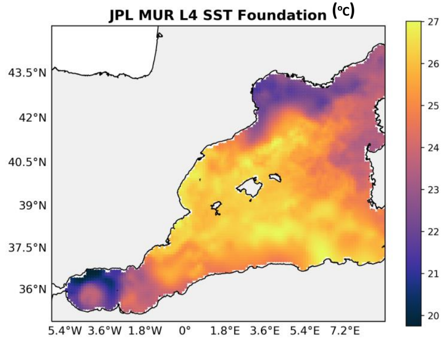
RAD : SLA + SST + Argo TS + HFR radials

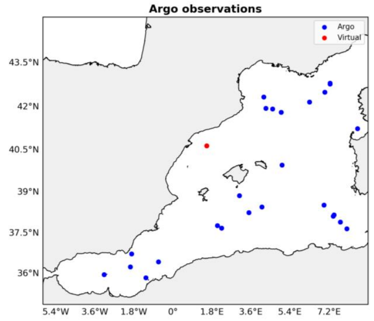
HFR Radials:
Daily mean fields 25% temporal availability







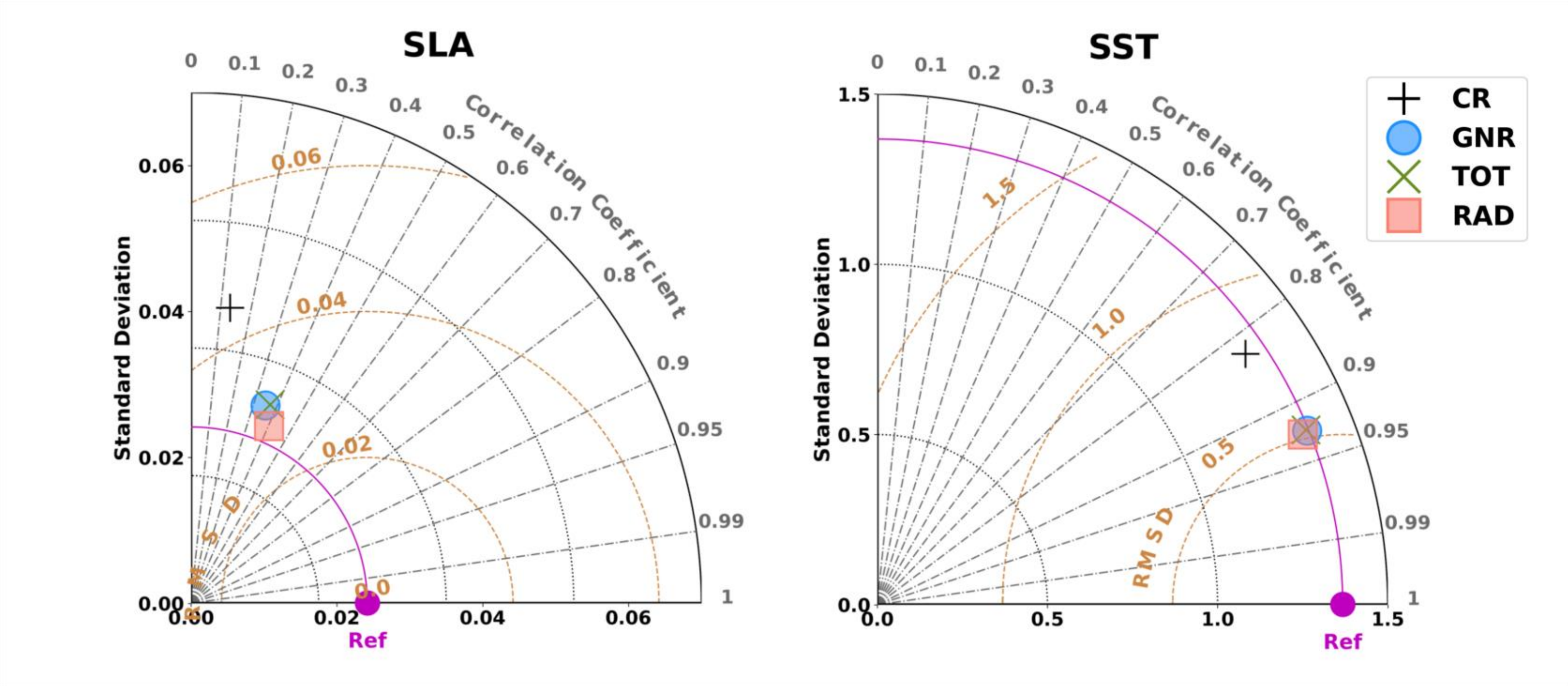




Impact of DA on SST, SLA and T-S profiles over the whole domain

Strong improvement in terms of **CRMSD** and **Correlation** against **SLA** and **SST** fields.

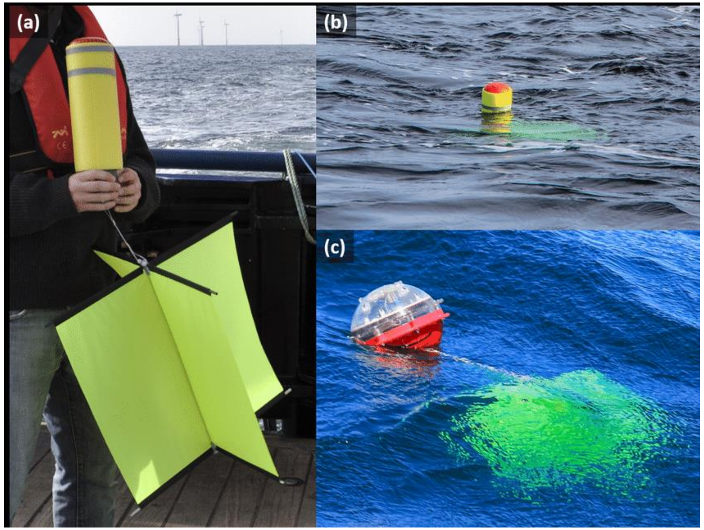
HFR observations do not degrade the fields.



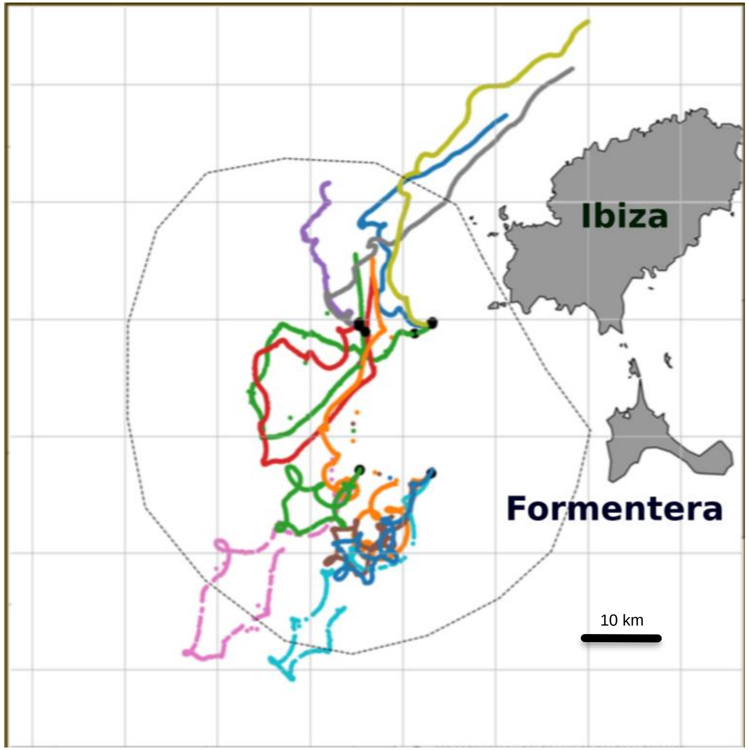
Impact of DA on surface currents

- **Eulerian assessment:** comparing against HFR daily mean fields
- **Lagrangian assessment:** 14 independent drifters

Drifters have a 50cm drogue, to measure surface currents



Drifter types MD03i (panels a and b) and ODi (panel c). Image from: Ullrich Callies et al. 2017

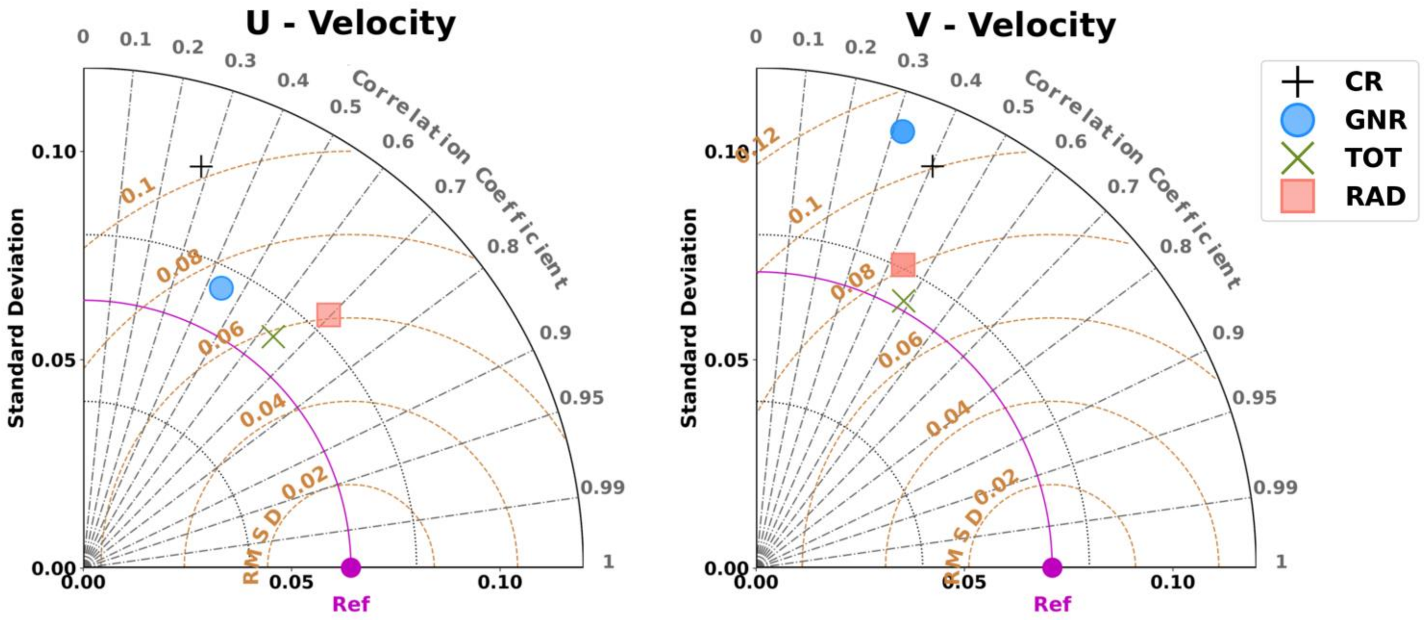


Eulerian Assessment

For **U-component** DA improves **correlation** with observations while decreasing the **CRMSD.**

For **V-component**, only the employment of HFR observations implies a reduction of **CRMSD.**

$$RMSD^2 = CRMSD^2 + BIAS^2$$



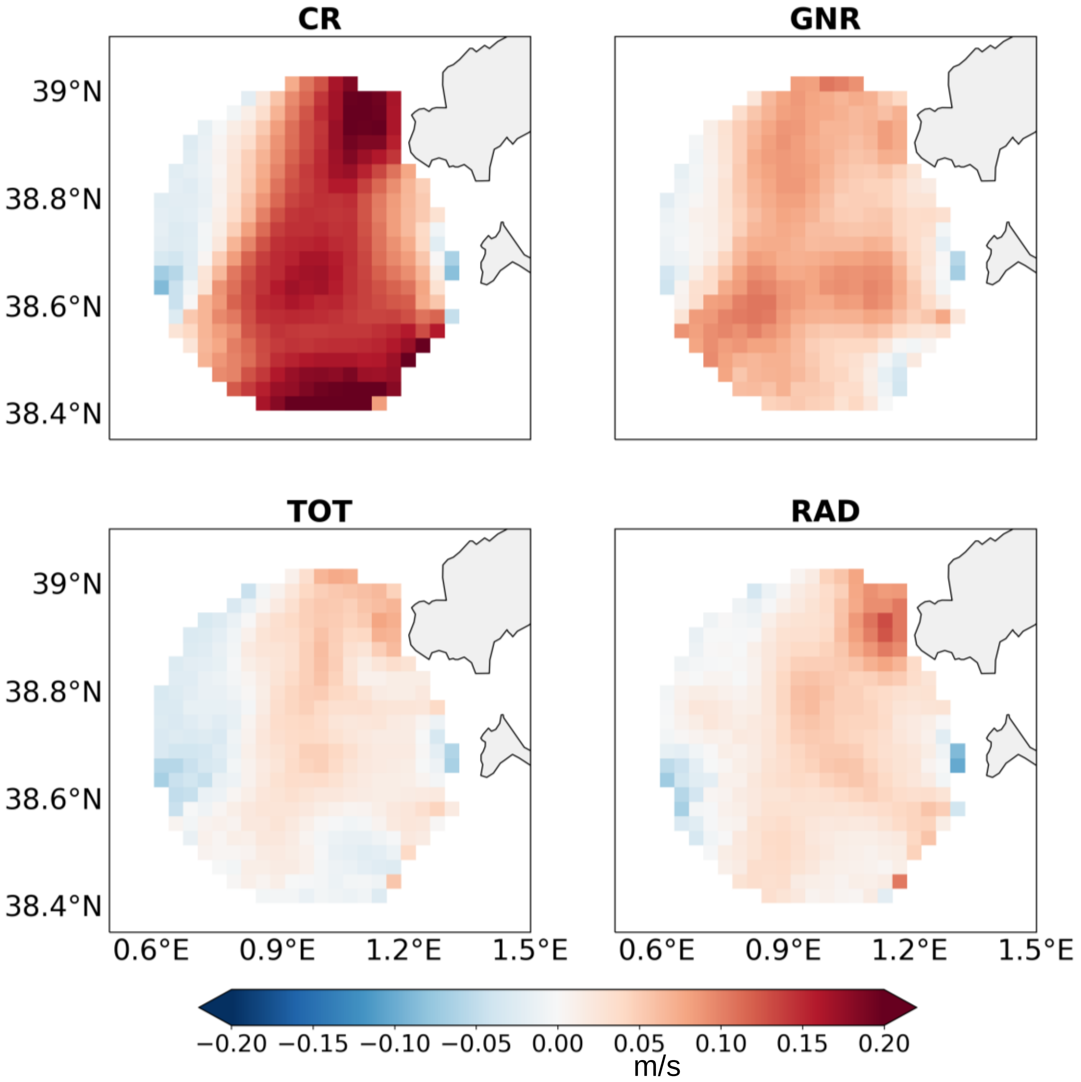
Eulerian Assessment

Mean error of the velocity module

CR overestimates the intensity of the current

A strong correction is obtained in the whole area with data assimilation.

HFR DA further reduces the mean error

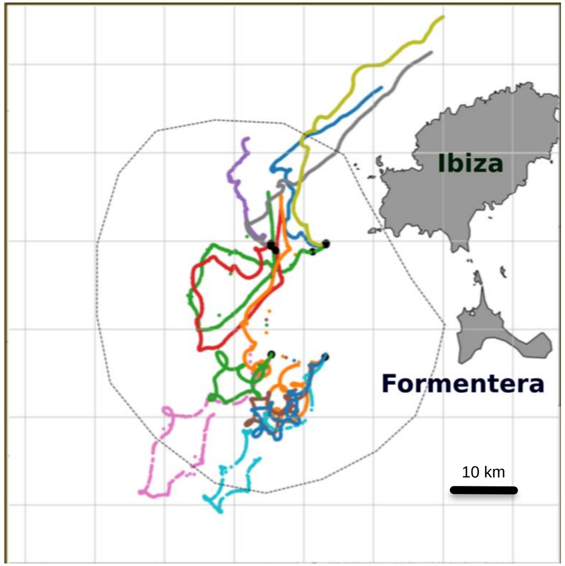


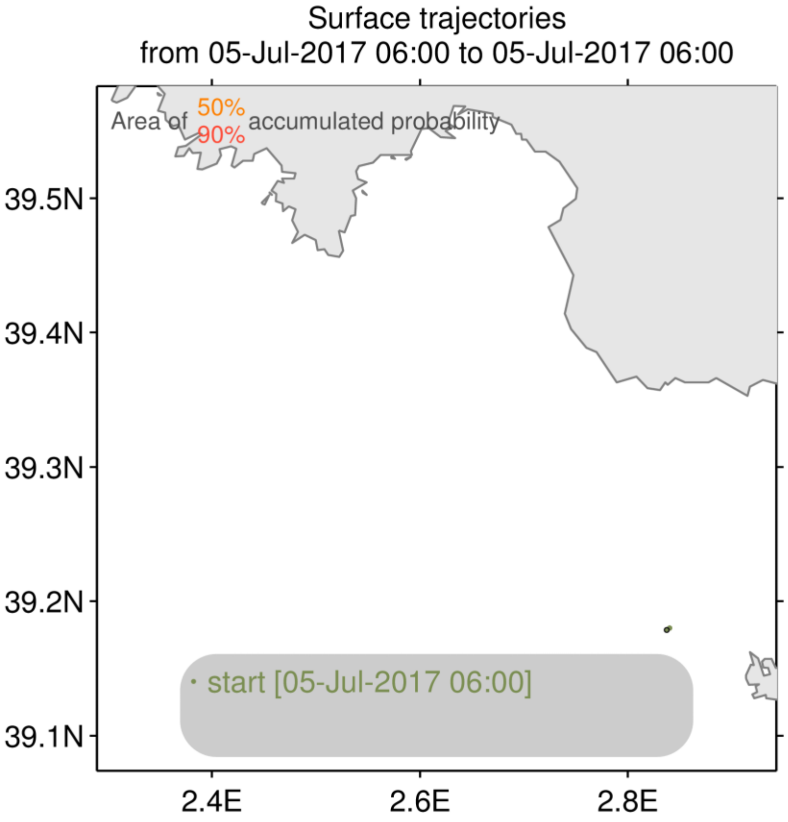
Lagrangian Assessment

Virtual model trajectories are compared to real drifter trajectories:

- **14 drifters** from 1 to 13 October 2018
- Each day, model trajectories are simulated starting from the updated real drifter positions.
- **1000 virtual particles/drifter**
- **5 days** simulation

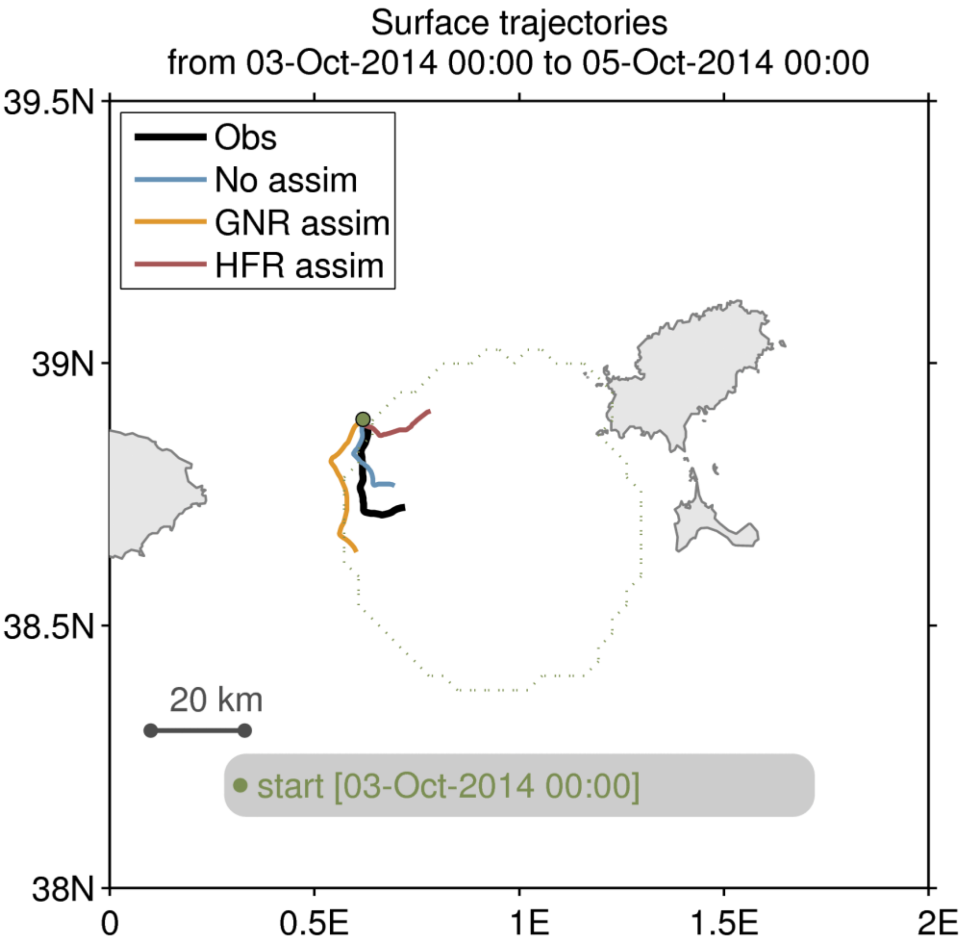
Oceans Parcels used to simulate the trajectories (Lange and Van Sebille 2017).





Animation from B.Mourre

Lagrangian Assessment: Comparing Drifter trajectories against virtual bouys



GNR:
assimilation of SLA, SST and Argo TS

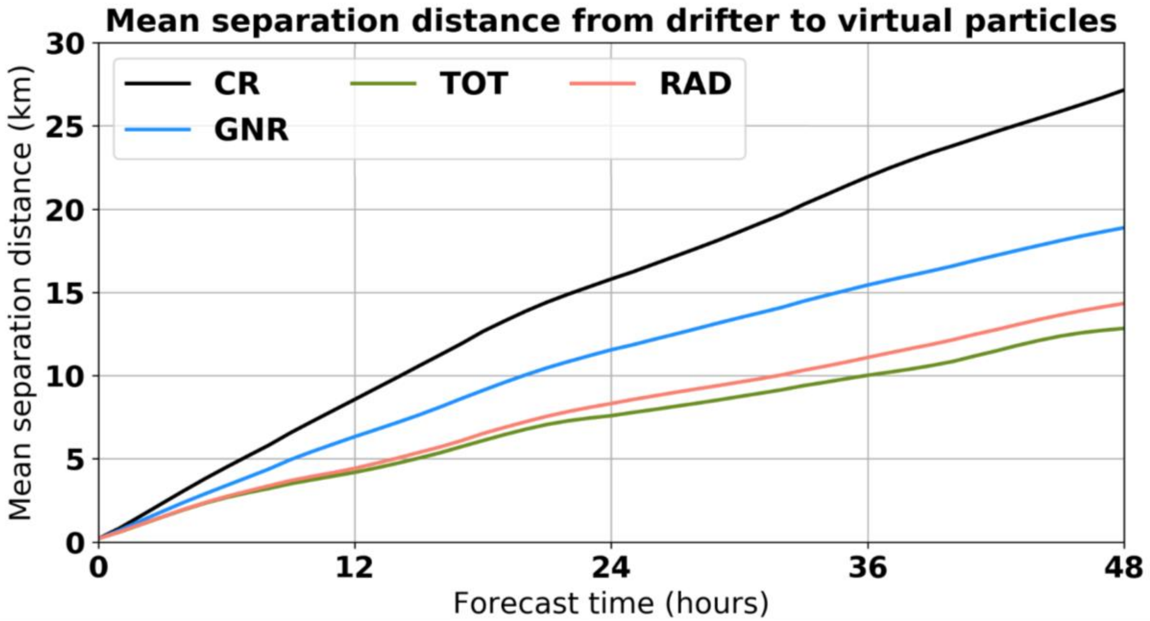
HFR:
assimilation of SLA, SST and Argo TS
+ HF radar

Figures from B.Mourre

Lagrangian Assessment

Average separation distance between model and real drifter trajectories according to forecast horizon:

$$d(t) = \frac{1}{n_{drif}} \sum_{i=1}^{n_{drif}} \left(\left| \mathbf{x_i}^{\mathbf{d}}(\mathbf{t}) - \frac{1}{n_{part}} \sum_{j=1}^{n_{part}} \mathbf{x_{ij}}^{\mathbf{v}}(\mathbf{t}) \right| \right)$$



After 48 hours, the average separtion distance is reduced from 27km to 18km thanks to **GNR** data assimilation, and is further reduced to 13km thanks to **HFR** data assimilation.

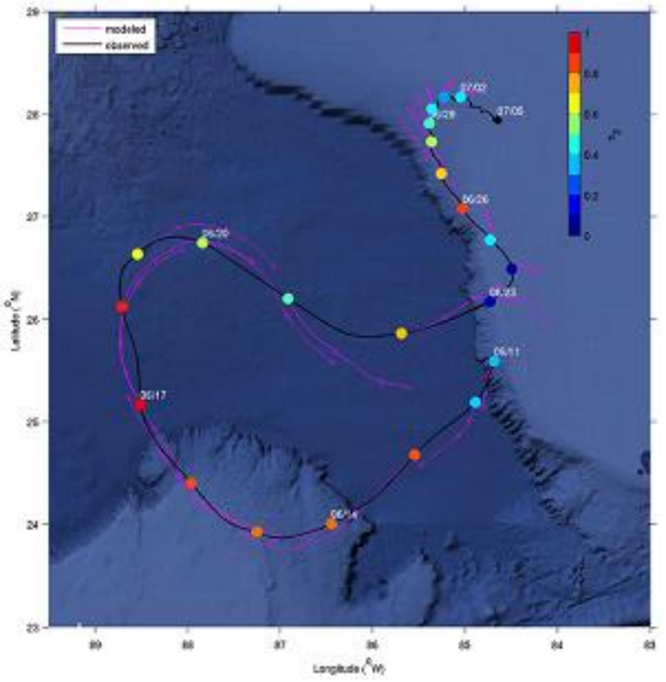
Lagrangian Assessment

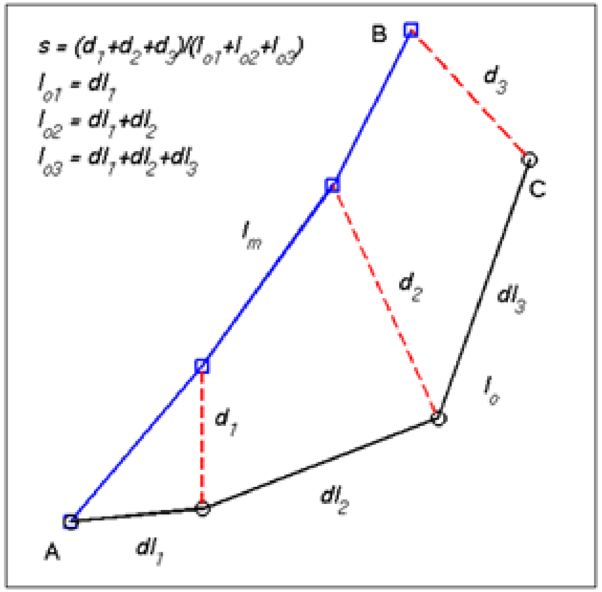
A skill score for model forecasting is given following the metric described by Liu and Weisberg 2011 along the drifter trajectory.

We calculate the skill score maps to understand how the model performs in the different areas.

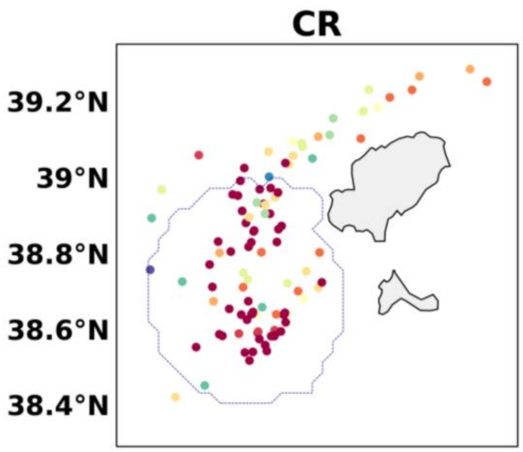
$$s = \sum_{i=1}^{N} d_i \Big/ \sum_{i=1}^{N} l_{oi}$$

$$SS = 1 - s$$



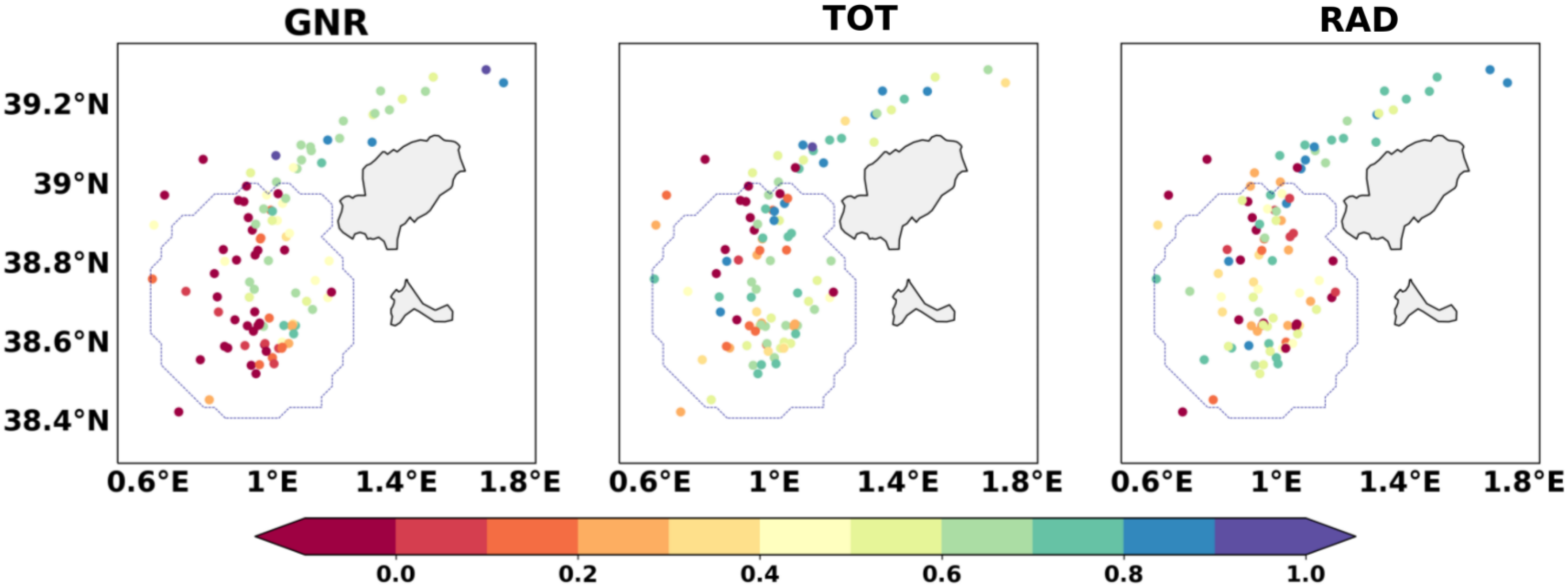


Lagrangian Assessment: Skill Score



Generic DA improves the representation of trajectories mostly in the northern region → Driven by geostrophy.

HFR DA enhances the performance and helps to correct the circulation in the coverage area.



Conclusions

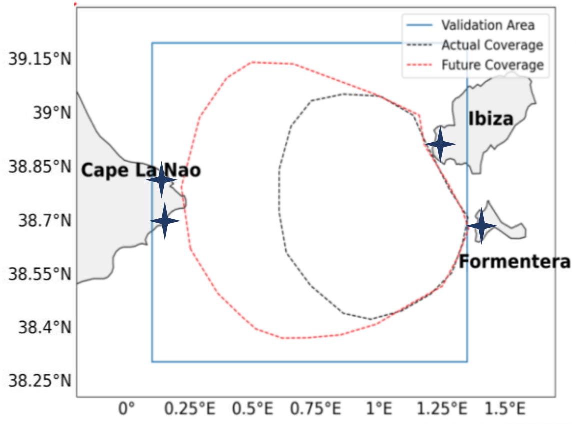
- WMOP DA system is able to correct currents in the Ibiza Channel.
- Assimilation of HFR does not degrade the improvement achieved on SLA, SST and T-S profiles over the whole domain.
- Assimilation of HFR Radial observations does not improve the results obtained when assimilating total currents.
- HFR data assimilation improves the prediction of lagrangian trajectories based on an independent validation using surface drifters.

***Paper available:** https://os.copernicus.org/articles/17/1157/2021/os-17-1157-2021.pdf

Continuation: HFR Observing System Simulation Experiment (OSSE)

Simulation of a potential future expansion of Ibiza Channel (IC) HFR system.

- **4 simulations** to evaluate the impact of the new antennas.



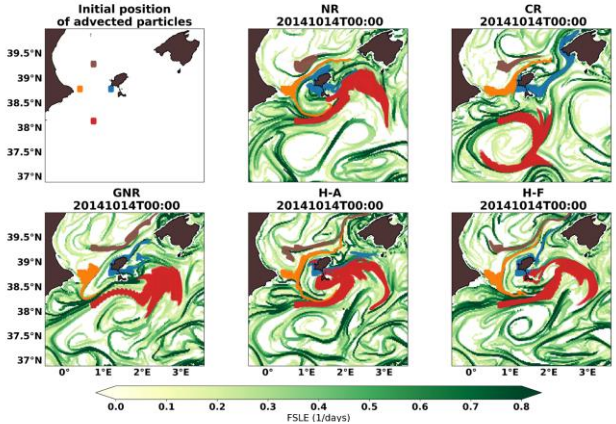
Outline:

1. **Fraternal twin approach** (Halliwell et al 2014), 2 different configurations of the same model.

2. **Validation comparing OSSE with previous HFR OSE** considering the same observation dataset.

3. **Two different simulation periods** analyzed:
   1. Same as previous OSE, for validation.
   2. Another period with different dynamical conditions.

4. **Lagrangian Assessment** → Evaluation of effects of DA in the transport
   - **Finite size lyapunov exponents**: Comparison of **LCS** (Lagrangian Coherent Structures) in different simulations.
   - Deployment of **particles from 4 different sites** in IC. See evolution along time



Thank you!

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