SWOT Dynamical Mapping – Perspectives for S3-NGT

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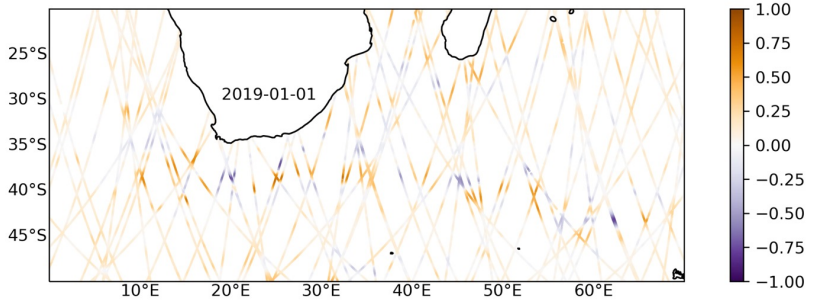
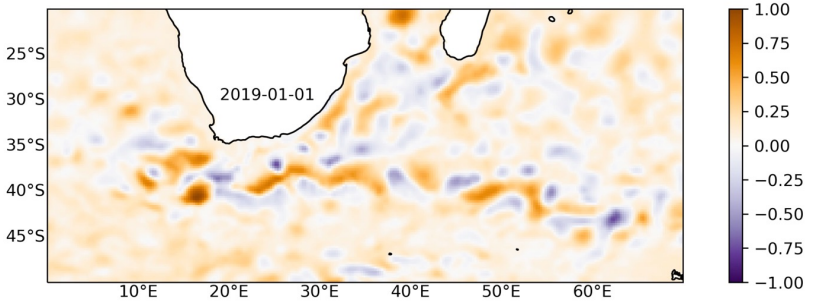
Context – why would we need dynamical mapping?

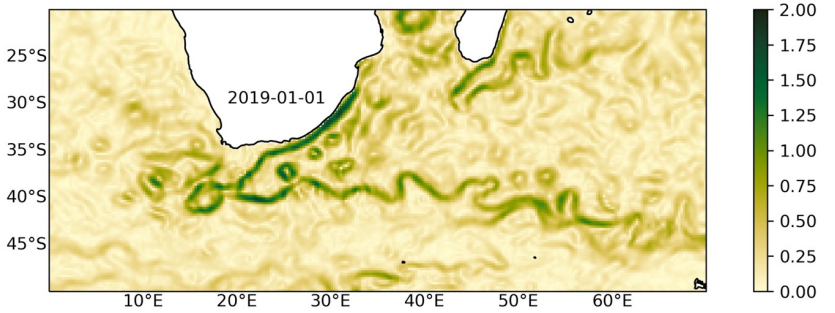
Along track SLA (L3)



Gridded SLA (L4)



Geostrophic currents



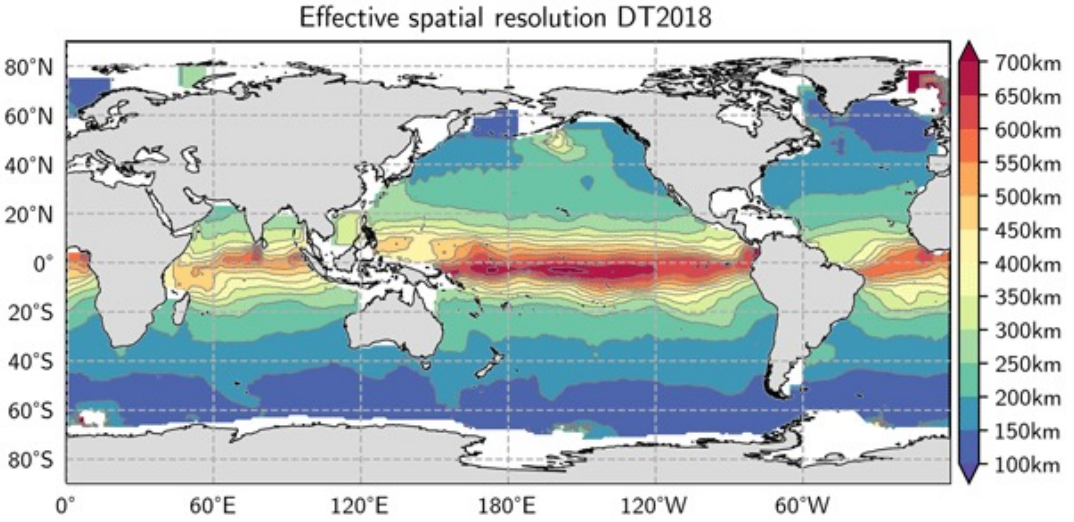
Optimal interpolation

cnes CLS

Space-time resolution of gridded L4 products limited to 200km – 10 days at mid latitudes.

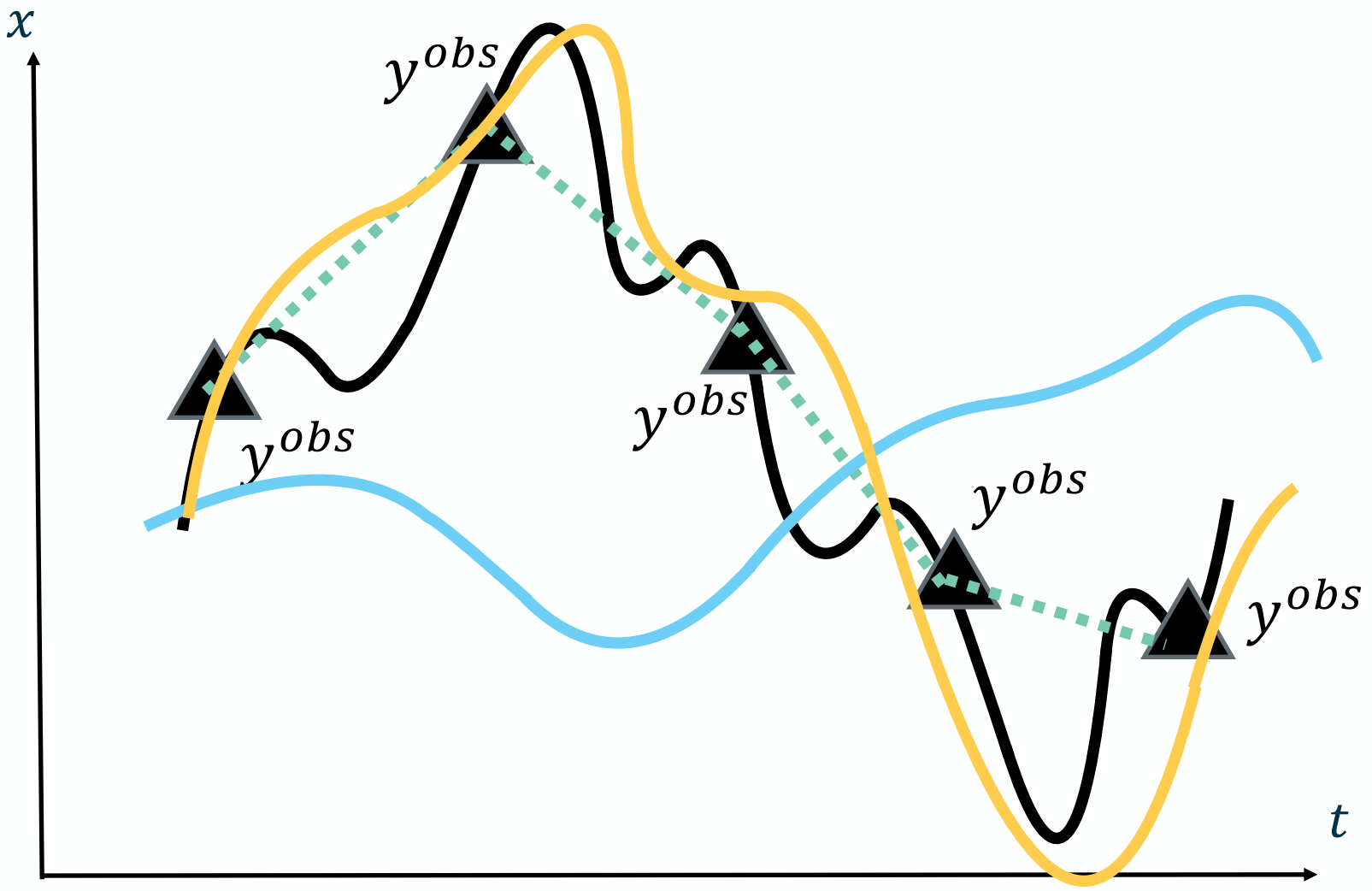
With the advent of wide-swath altimetry, conventional mapping methods need to be improved to cope for the **mismatch of temporal/spatial sampling**.

Recent studies (e.g. Ubelmann et al., 2015) **advocate for using dynamical constrains in the mapping procedure to improve the space/time resolutions of the maps.**



Ballarotta et al. (2019)

Dynamical mapping – big picture



Observations (SWOT or S3-NGT)

Linear inteterpolation (DUACS)

Model free run
$x(t) = \mathcal{M}(t, y^{obs})$

Model assimilated run
$x(t) = \mathcal{M}(t, y^{obs})$

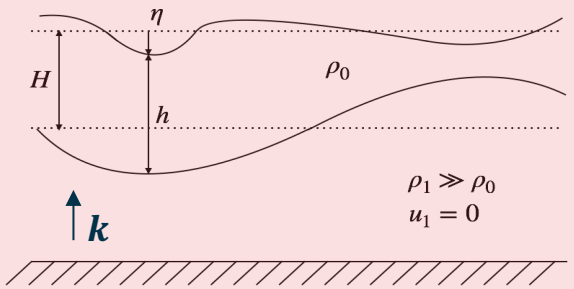
My approach: use simple physical models, focus on specific dynamical regimes, with a complexity balanced with observations' density.

Dynamical mapping – 4DvarQG

1.5-layer quasi-geostrophic model

$$\boldsymbol{\eta}_{[t,x,y]} = QG(\boldsymbol{\eta}_{[0,x,y]}, t)$$

$$QG \begin{cases} \psi = \frac{g}{f}\eta \\ \boldsymbol{u_g} = \boldsymbol{k}\times\boldsymbol{\nabla}\psi \\ q = \nabla^2\psi - \frac{1}{{L_R}^2}\psi \\ \partial_t q + \boldsymbol{u_g}\cdot\boldsymbol{\nabla} q = 0 \end{cases}$$



4D-Variational Data Assimilation

Correct the space/time QG reconstruction by a controlled forcing term:

$$\boldsymbol{\eta}_{[t,x,y]} = QG\left(\boldsymbol{\eta_0}_{[x,y]}, t\right) + \boldsymbol{\epsilon_{QG}}_{[t,x,y]}$$

Cost function minimization:

$$J(\eta_0, \epsilon_{QG}) = \left\|\eta_0 - \eta_0^b\right\|^2 + \left\|\epsilon_{QG}\right\|^2 + \left\|\eta^{obs} - \eta\right\|^2$$

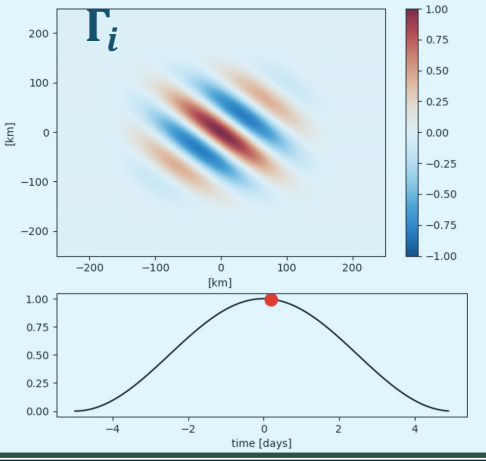
Order reduction

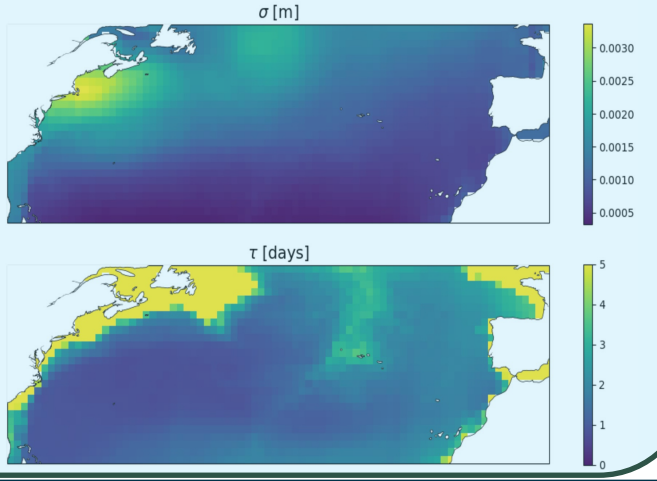
Control vector size: $\eta_0: N_x * N_y$, $\boldsymbol{\epsilon_{QG}}: \boldsymbol{N_t * N_x * N_y}$

Projection to a reduced space:

$$\boldsymbol{\epsilon_{QG}} = \begin{pmatrix} \boldsymbol{\epsilon_{QG}}_1 \\ . \\ . \\ \boldsymbol{\epsilon_{QG}}_m \end{pmatrix} = \sum_{i=1}^{r} \phi_i \boldsymbol{\Gamma_i} = \boldsymbol{\Gamma} \cdot \begin{pmatrix} \phi_1 \\ . \\ \phi_r \end{pmatrix} = \boldsymbol{\Gamma} \cdot \boldsymbol{\phi} \quad with\, r \ll m$$

One element at 100km scale

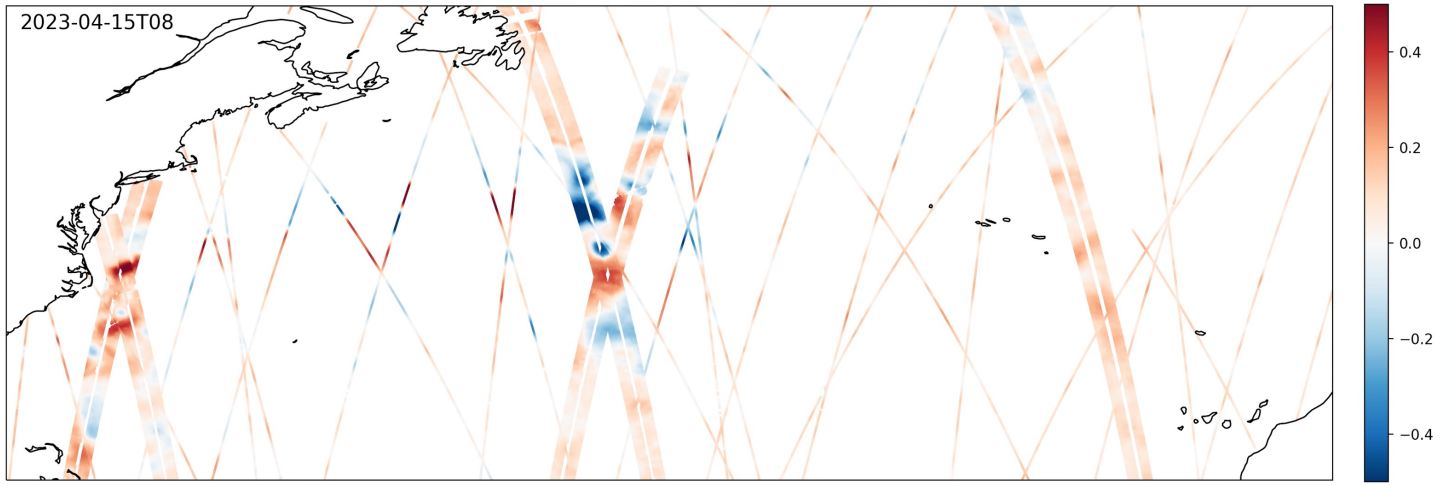




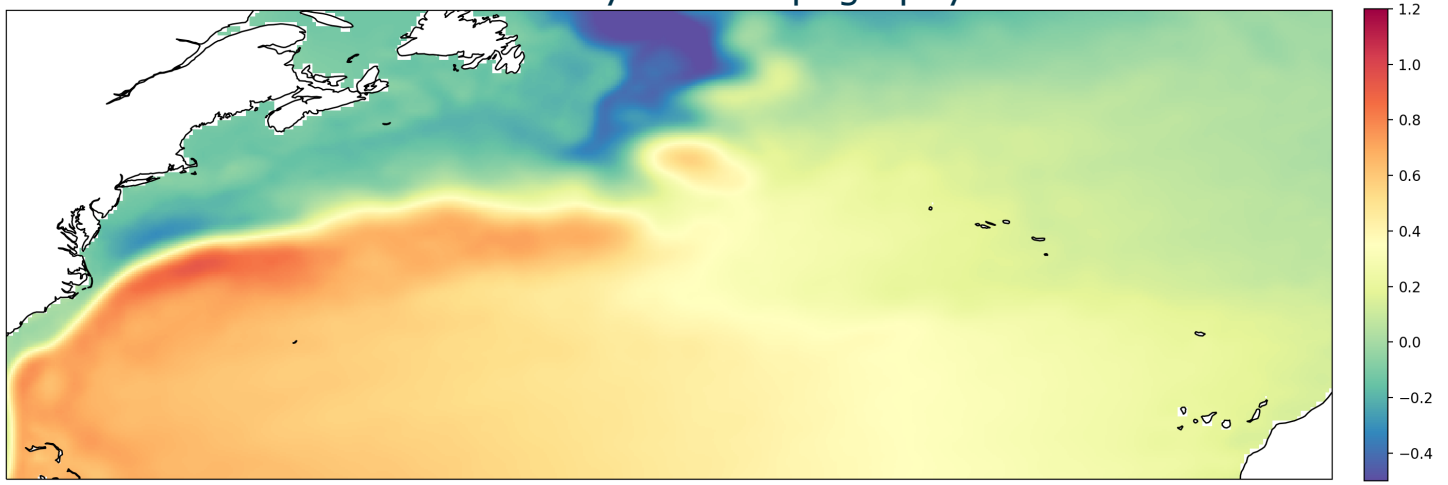
Experimental Setup

- **Focus on the North Atlantic region** (80°W – 10°W, 25°N – 50°N)
- Time period: **SWOT Fast Sampling Phase** (2023-04-01 – 2023-07-10)
- **Nadir altimeters**:
  C2, J3, H2 , S3a, S3b, S6, AL
- **CNES/CLS MIOST L4 products**:
  - Nadirs
  - SWOT L3 + Nadirs
- **SARAL/AltiKa** AL is left aside for validation purposes

Observed Sea Level Anomalies

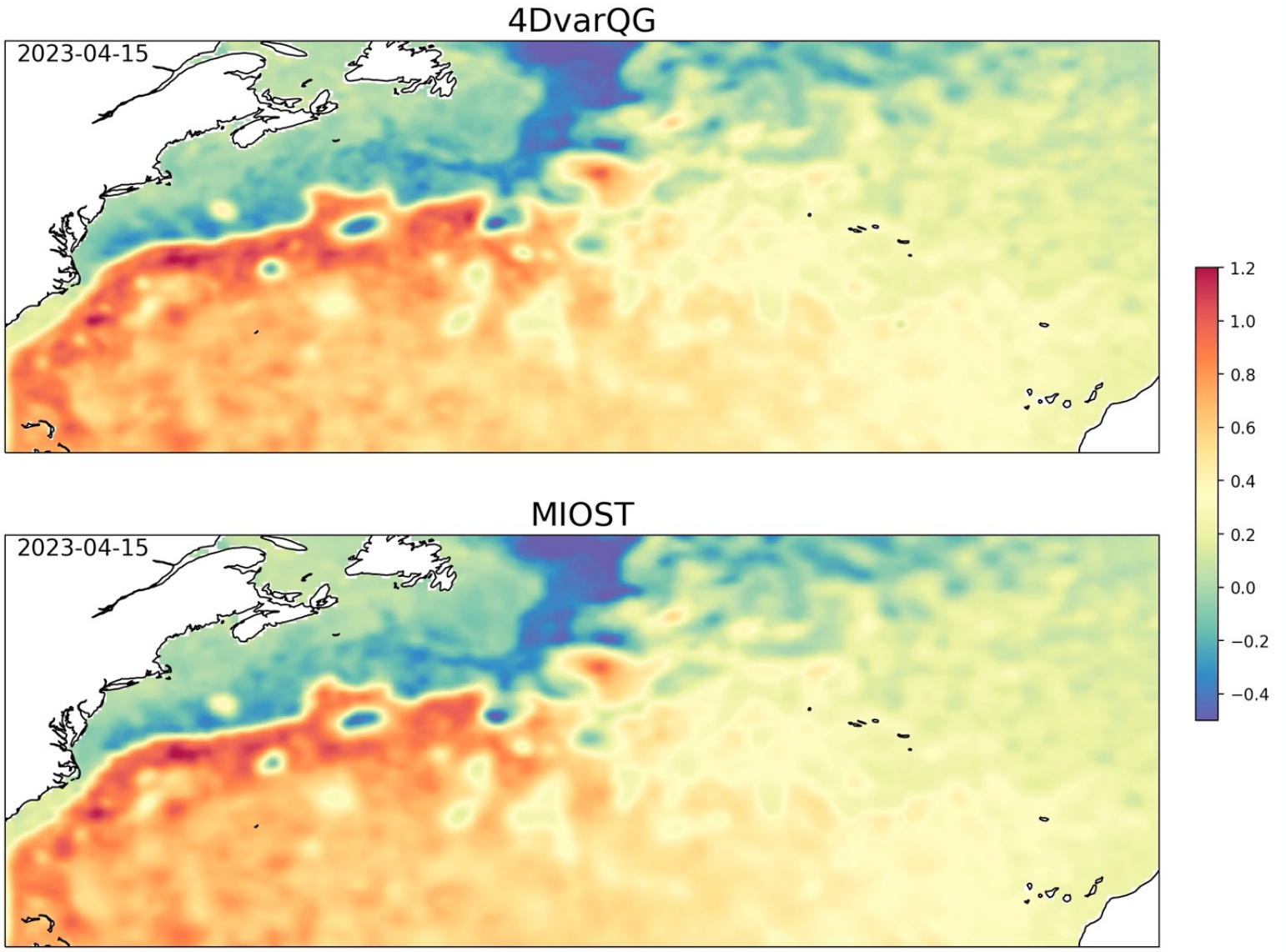


Mean Dynamic Topography



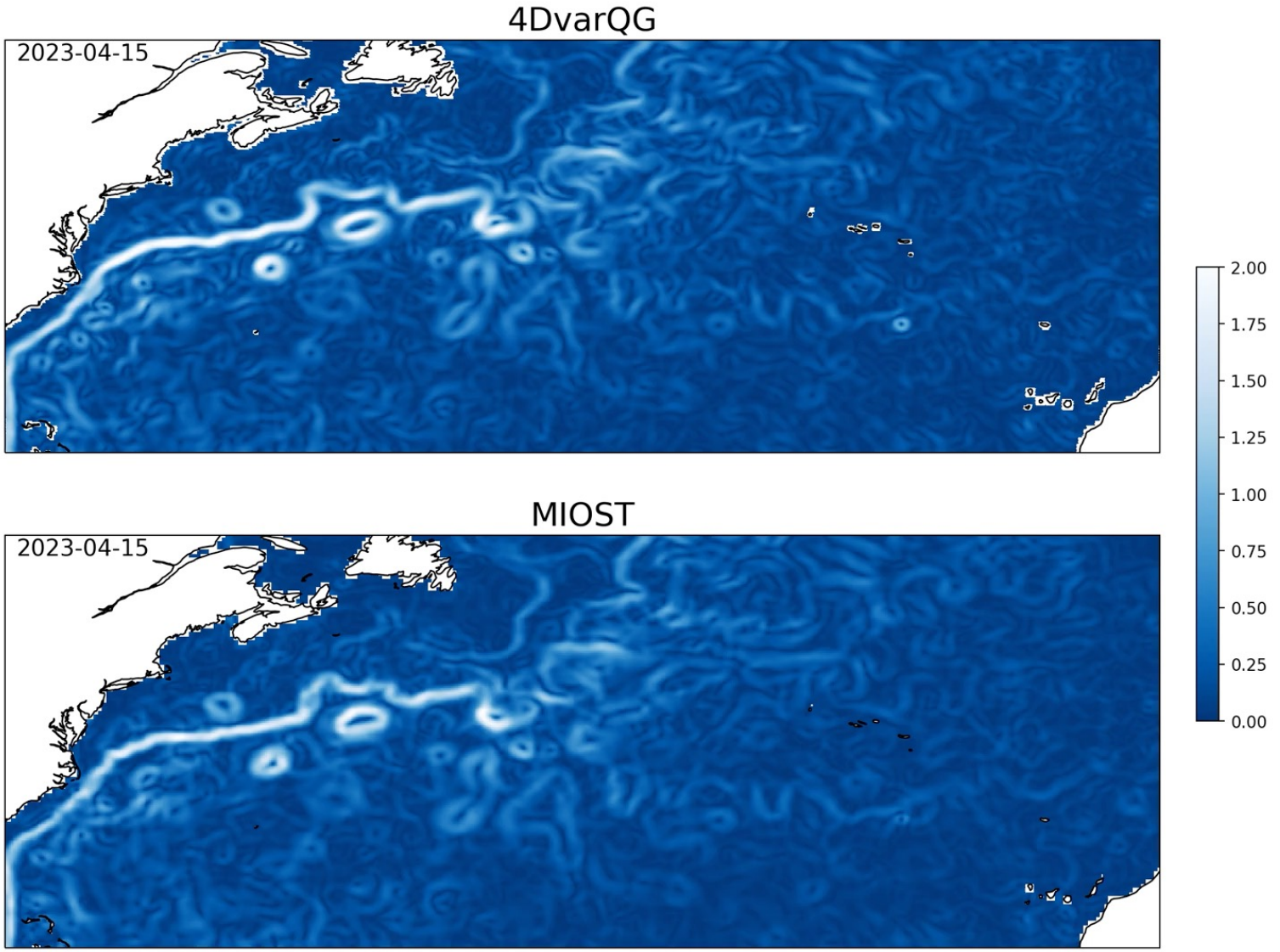
Results – mapping with Nadirs only

Qualitative evaluation (SSH)



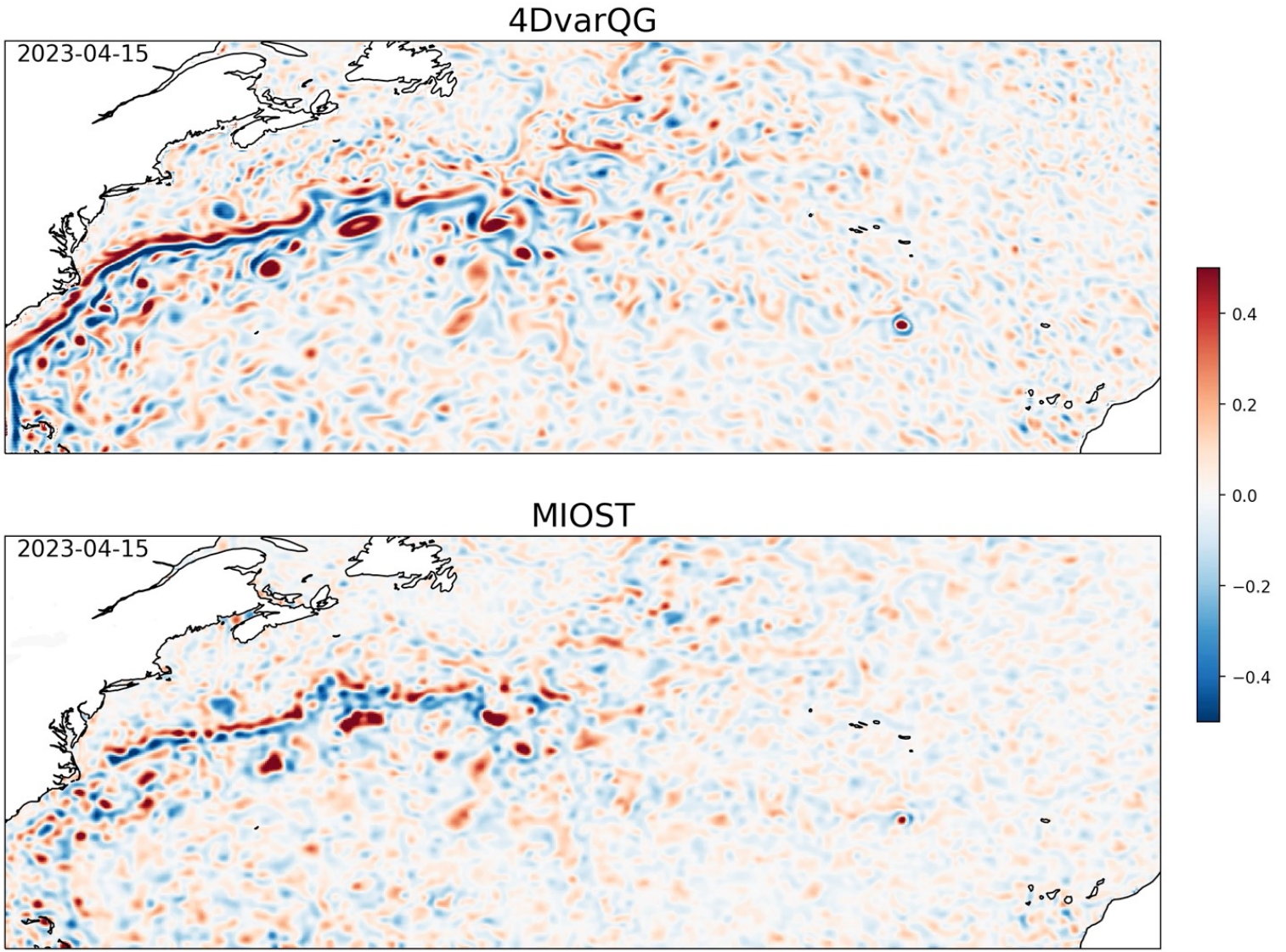
Results – mapping with Nadirs only

Qualitative evaluation (Geostrophic currents)



Results – mapping with Nadirs only

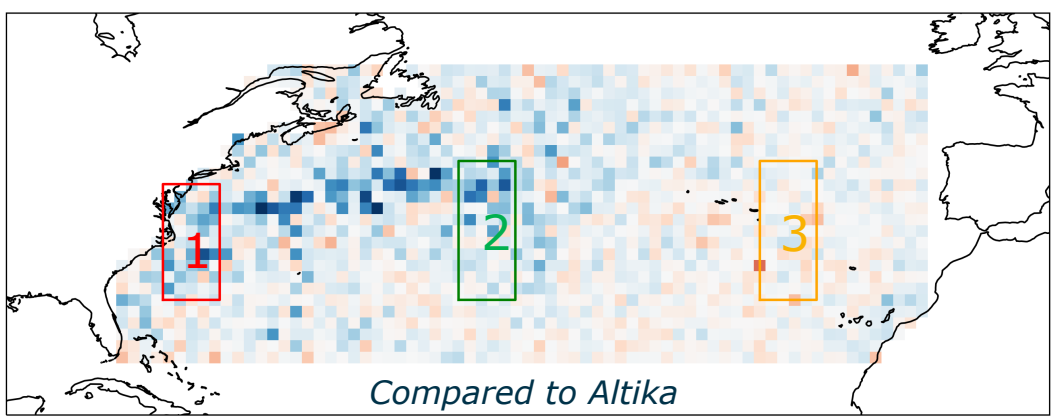
Qualitative evaluation (Relative vorticity)

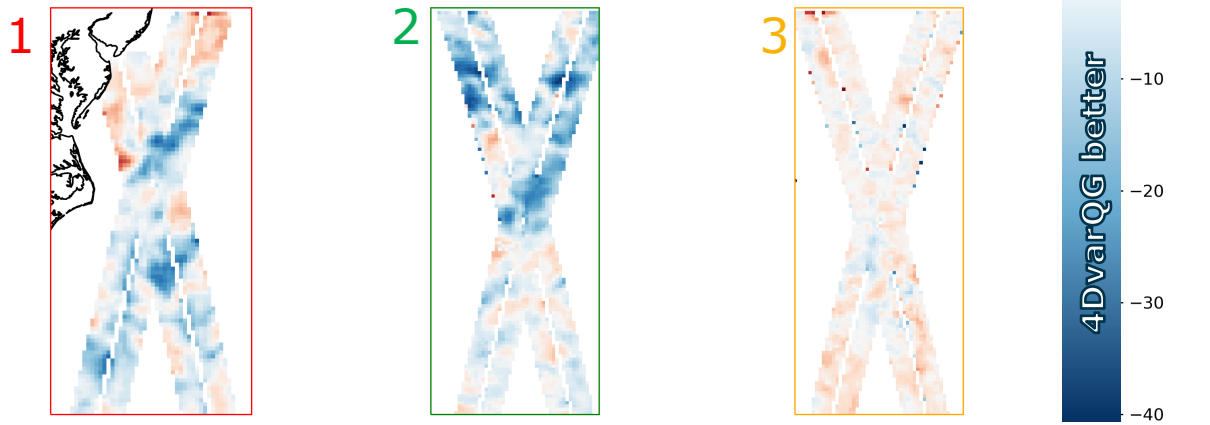


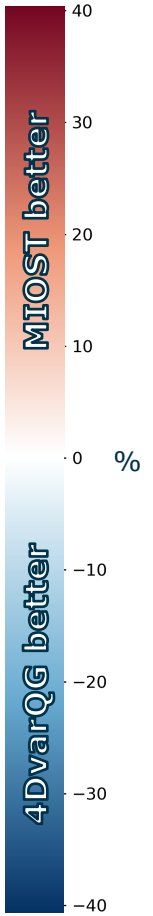
Results – mapping with Nadirs only

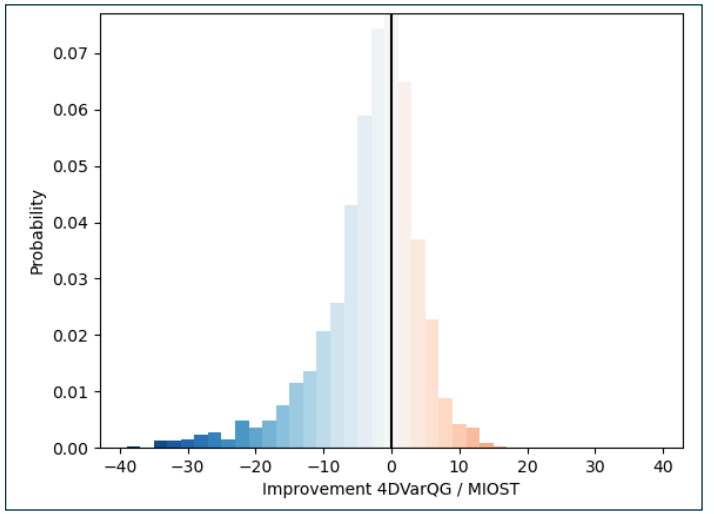
Performances against independent AltiKa and SWOT

RMSE reduction compared to AtiKa and SWOT

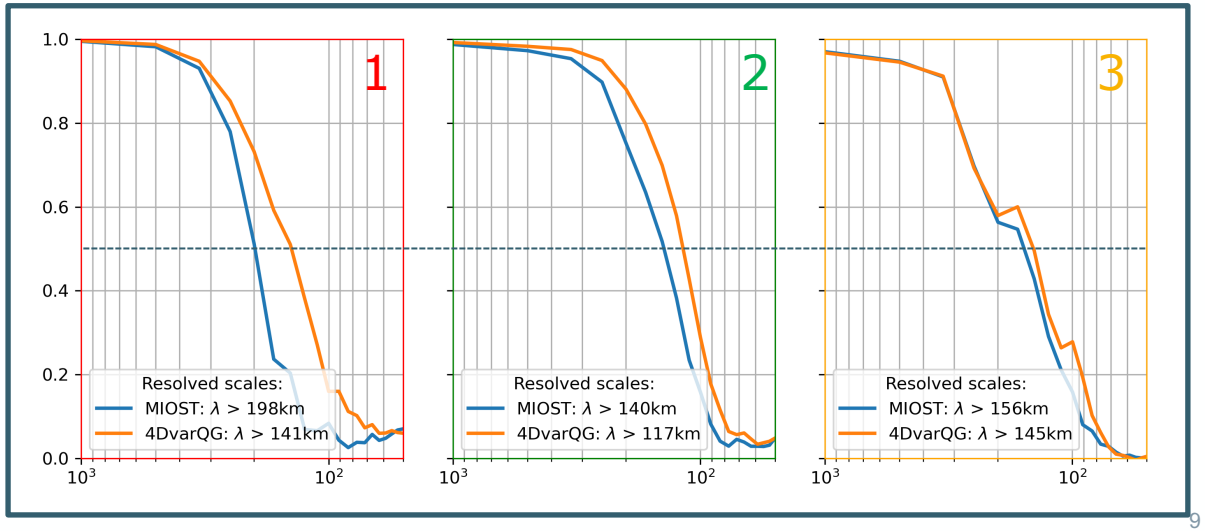






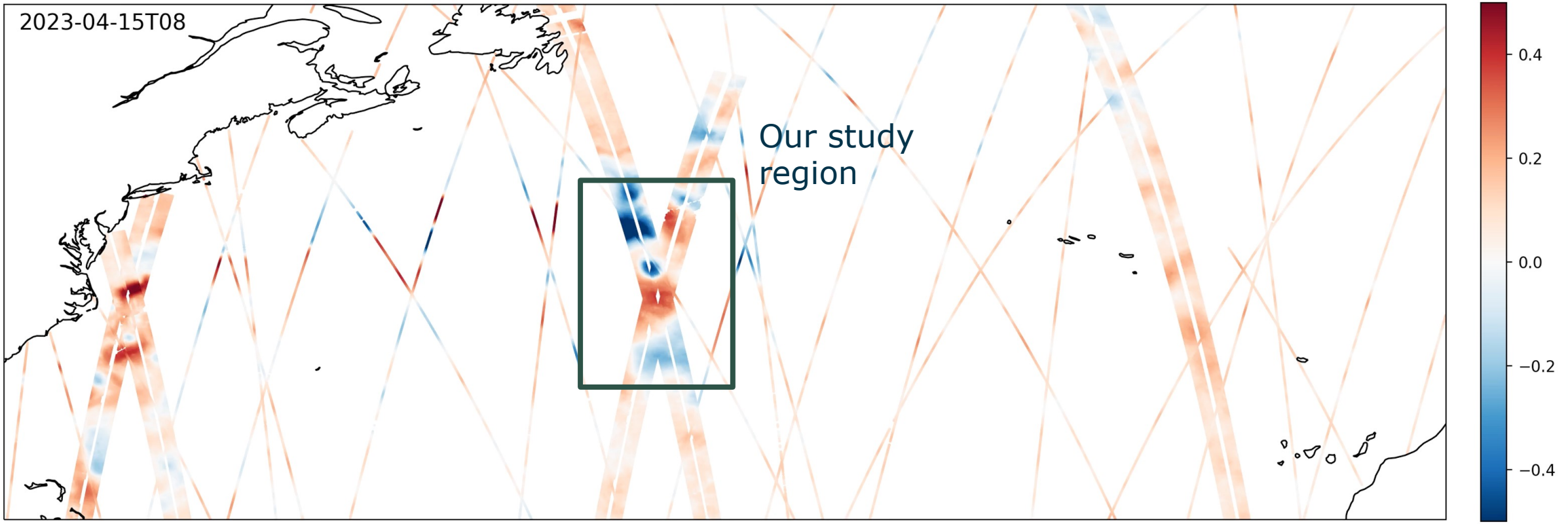


Resolved spatial scales compared to SWOT



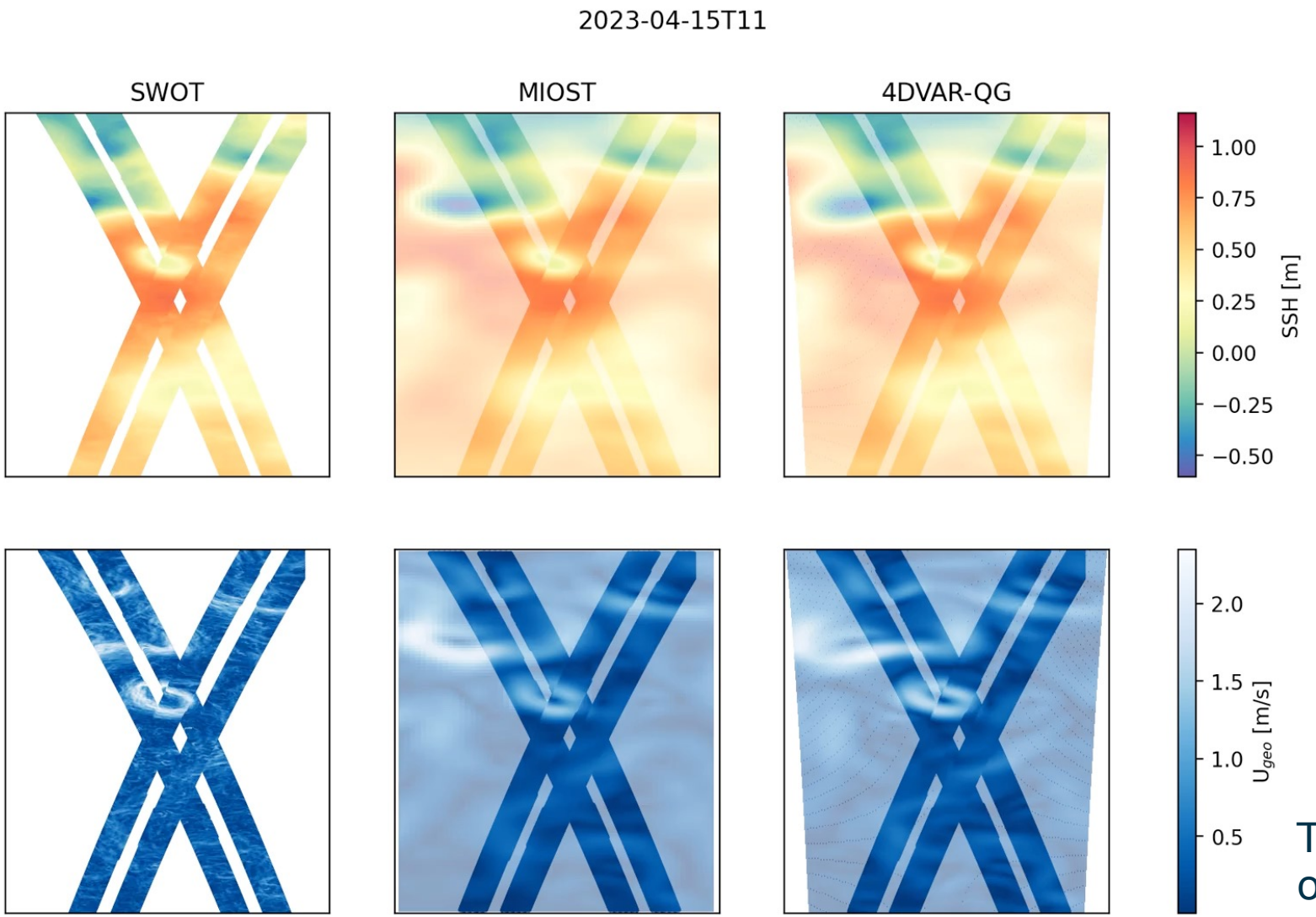
Results – mapping with Nadirs & SWOT

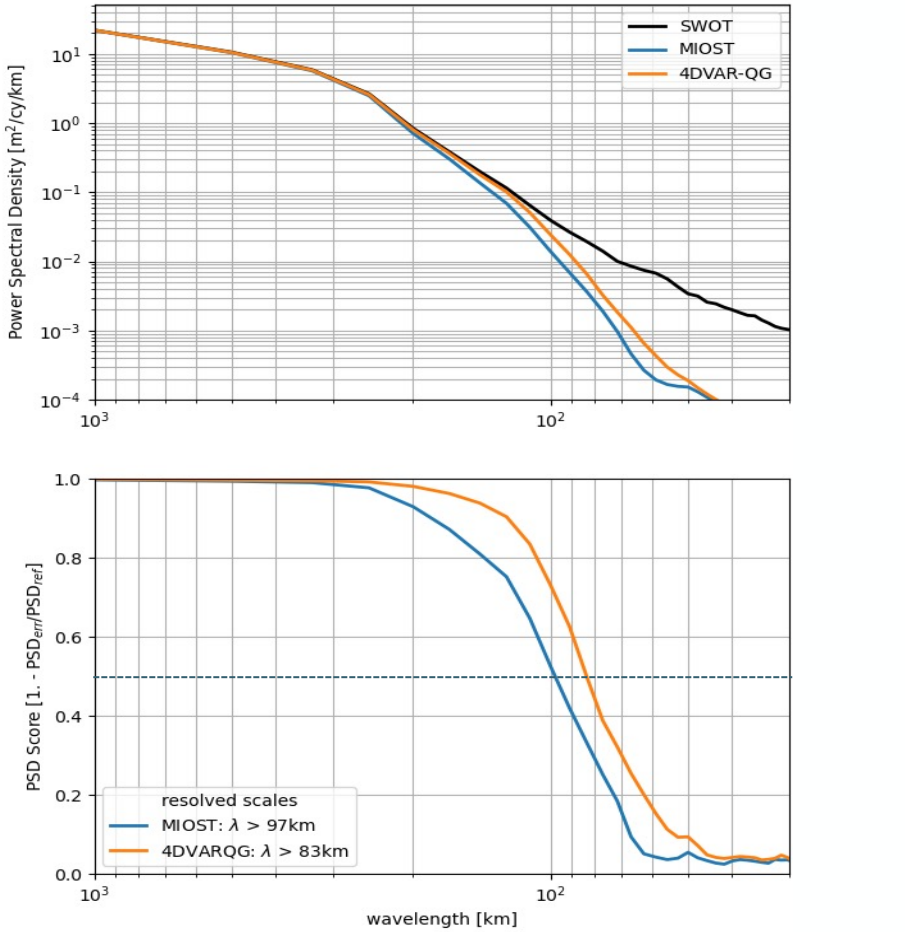
To what extent the 4DvarQG is able to map the SWOT data **in space**?



NB: We use the same 4DvarQG configuration as for the “only Nadirs” experiment

Results – mapping with Nadirs & SWOT

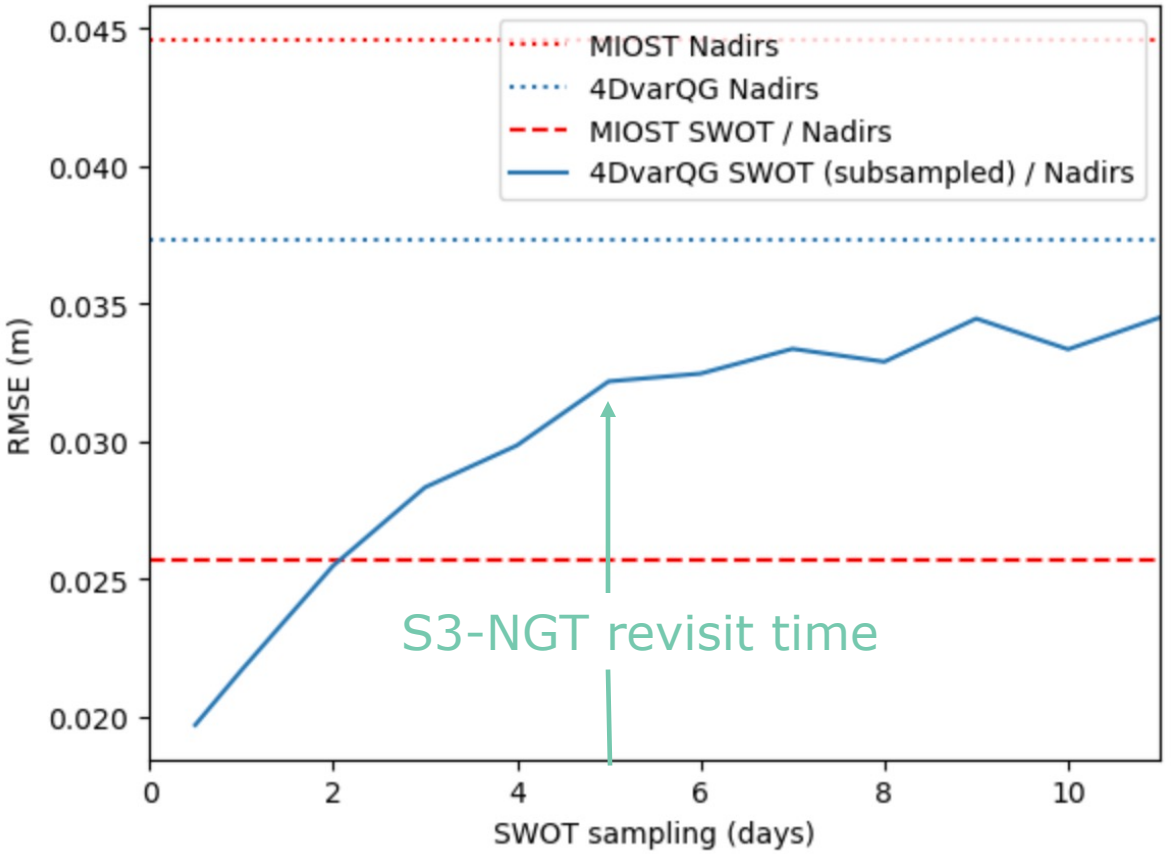


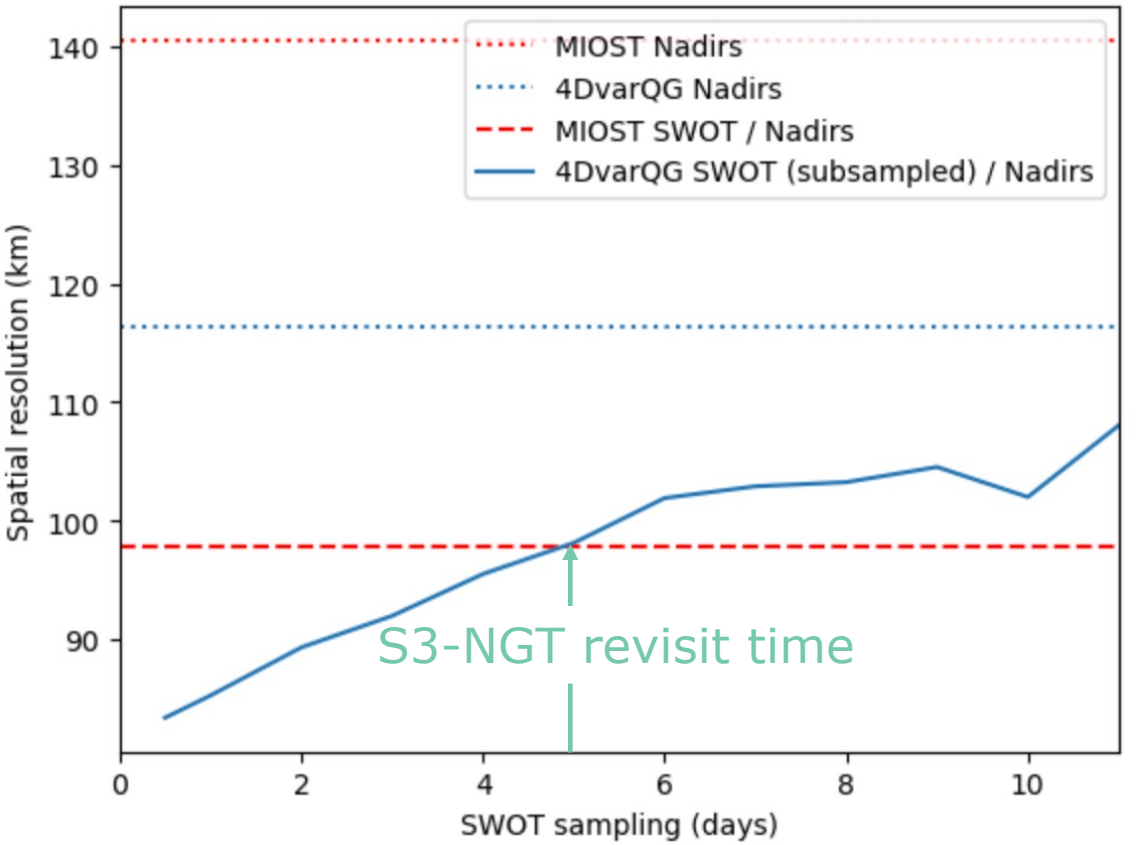


The 4DvarQG allows a better estimation of fine scale processes measured by SWOT

Results – mapping with Nadirs & SWOT

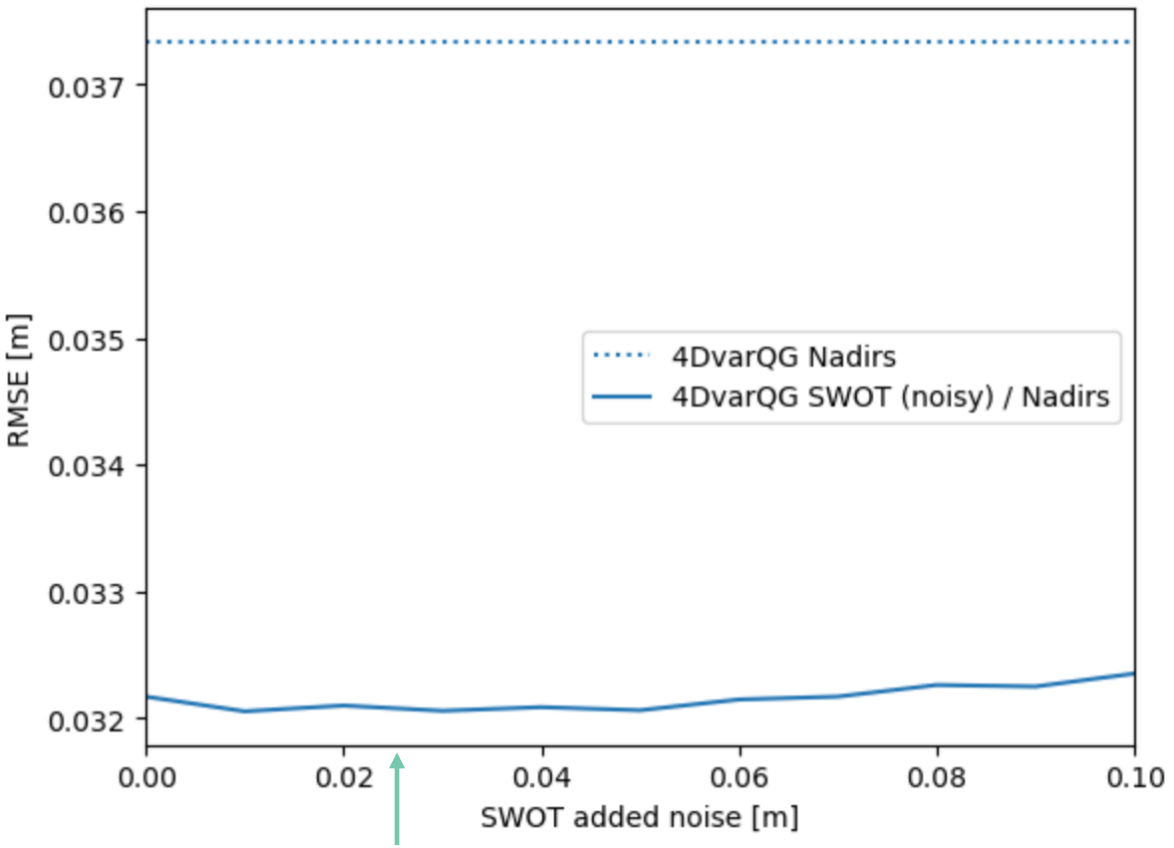
To what extent the 4DvarQG is able to map the SWOT data **in time**?



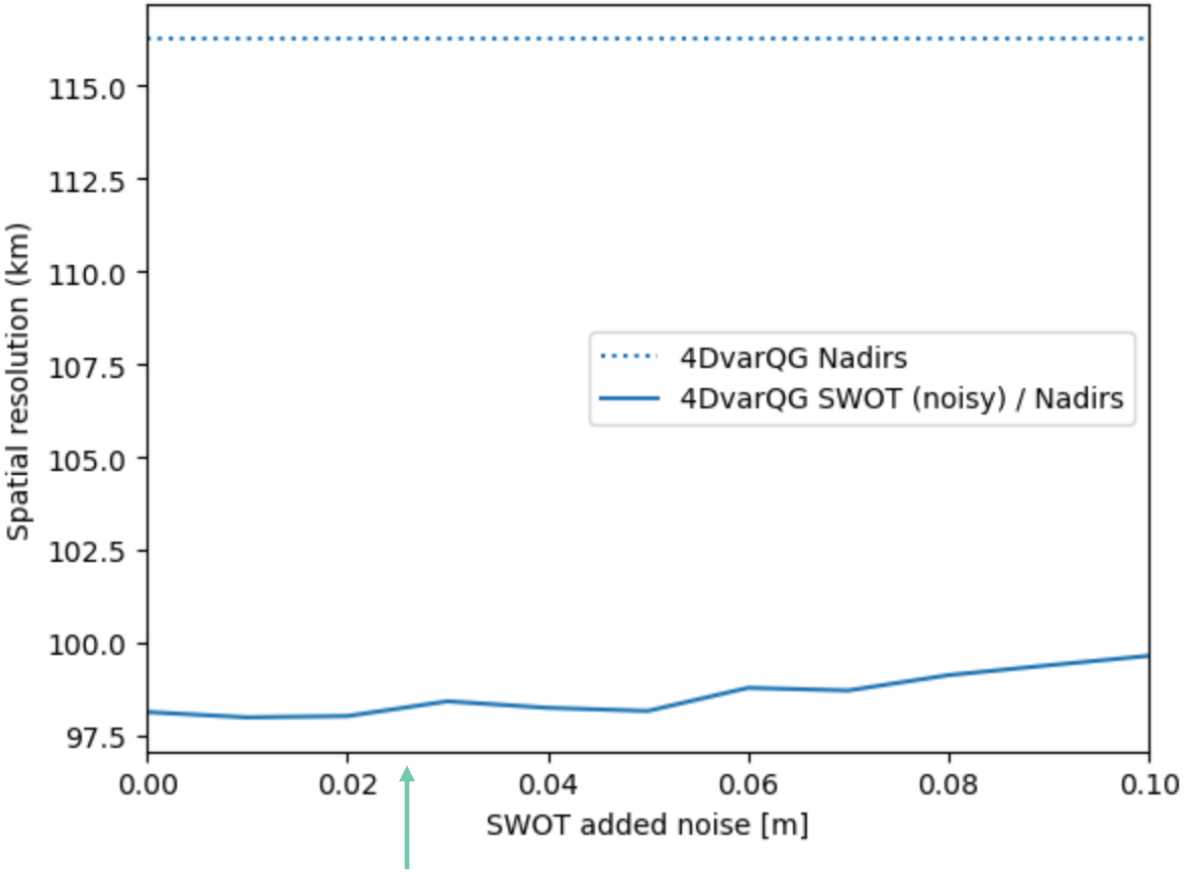


Results – mapping with Nadirs & SWOT

Adding random errors to the 5d-subsampled SWOT data



S3-NGT error worst case at 2kmx2km



S3-NGT errors worst case at 2kmx2km

Conclusions

- New dynamical mapping method 4DvarQG tested with real Nadir/SWOT data and compared to CLS/CNES MIOST product.

- Improved performances with Nadirs, especially in energetic regions.
  Contrasted performances in low energetic regions, mainly due to large scale barotropic processes.

- Improved estimation of fine scale processes measured by SWOT.

- Good performances with 5d SWOT sampling.

- Strong robustness of the method relative to added random noise.