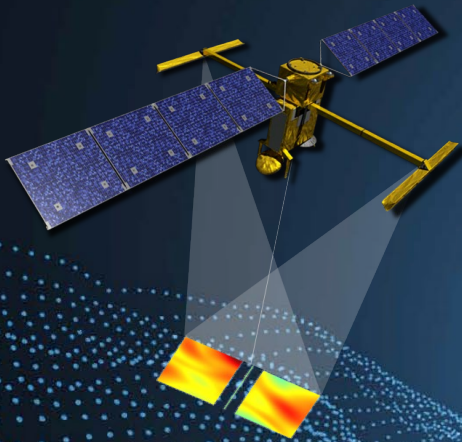# SWOT in DUACS multimission products

Yannice Faugere, M Ballarotta, A Treboutte, V Bellemin, C Peliasco, M Pujol, A Delepoulle (CLS)

Clement Ubelmann (Datlas), Ronan Fablet (IMT Atlantique)

Gerald Dibarboure (CNES)

DUACS Sea Level observed products:

Sea Level Anomalies and Absolute topography

Along track (for assimilation) & Gridded

Global & regional products

Derived products FSLE, Eddy Atlas

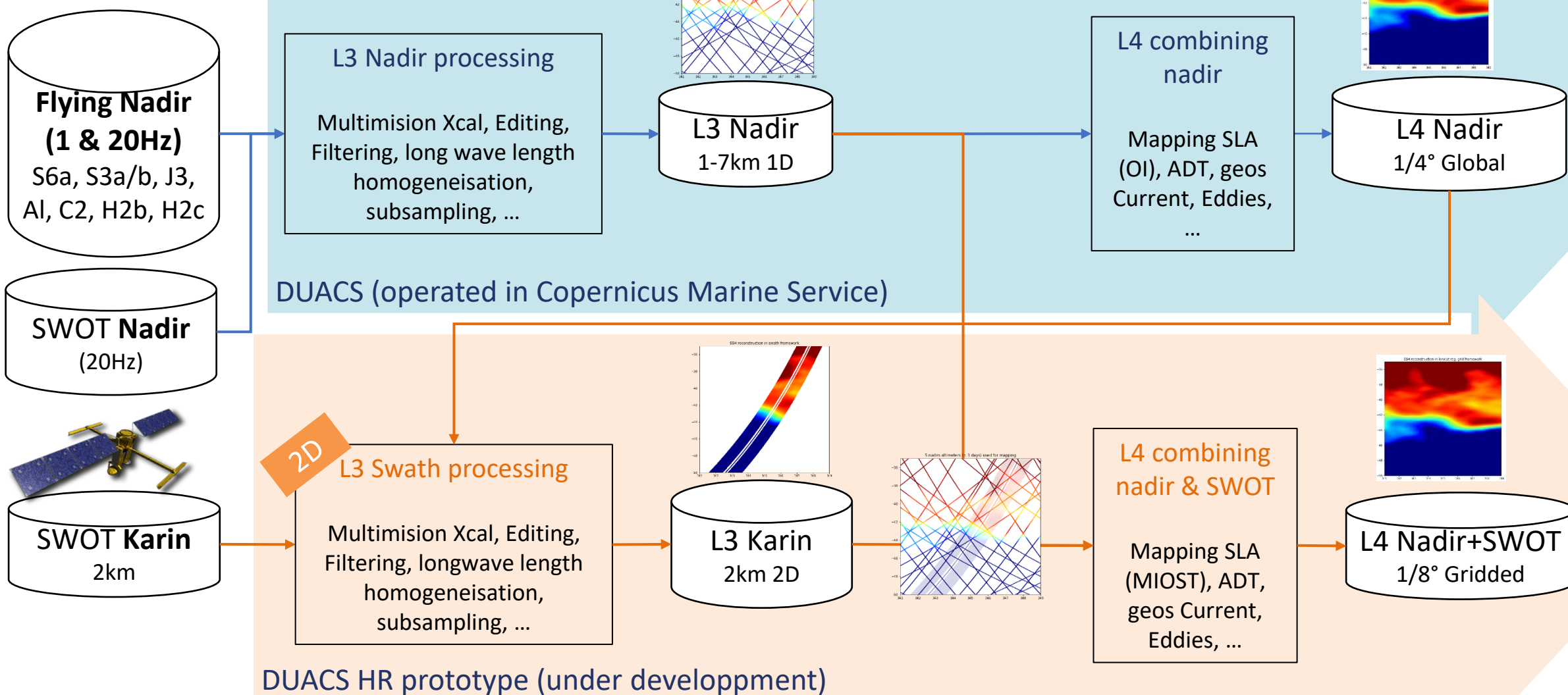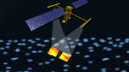3 product timeliness to address various applications

Copernicus Marine Service

Climate Change

AVISO⁺
Satellite Altimetry Data

Reprocessed	Delayed Time	NRT(RT)
every 3 yrs	4-6 month delay	6h delay

Climate studies   *Ocean studies*   *Ocean forecast*

DUACS

Flying Nadir (1 & 20Hz)
S6a, S3a/b, J3, Al, C2, H2b, H2c

SWOT **Nadir** (20Hz)

SWOT **Karin** 2km

L3 Nadir processing

Multimision Xcal, Editing, Filtering, long wave length homogeneisation, subsampling, …

L3 Nadir
1-7km 1D

L4 combining nadir

Mapping SLA (OI), ADT, geos Current, Eddies, …

L4 Nadir
1/4° Global

DUACS (operated in Copernicus Marine Service)

2D

L3 Swath processing

Multimision Xcal, Editing, Filtering, longwave length homogeneisation, subsampling, …

L3 Karin
2km 2D

L4 combining nadir & SWOT

Mapping SLA (MIOST), ADT, geos Current, Eddies, …

L4 Nadir+SWOT
1/8° Gridded

DUACS HR prototype (under developpment)
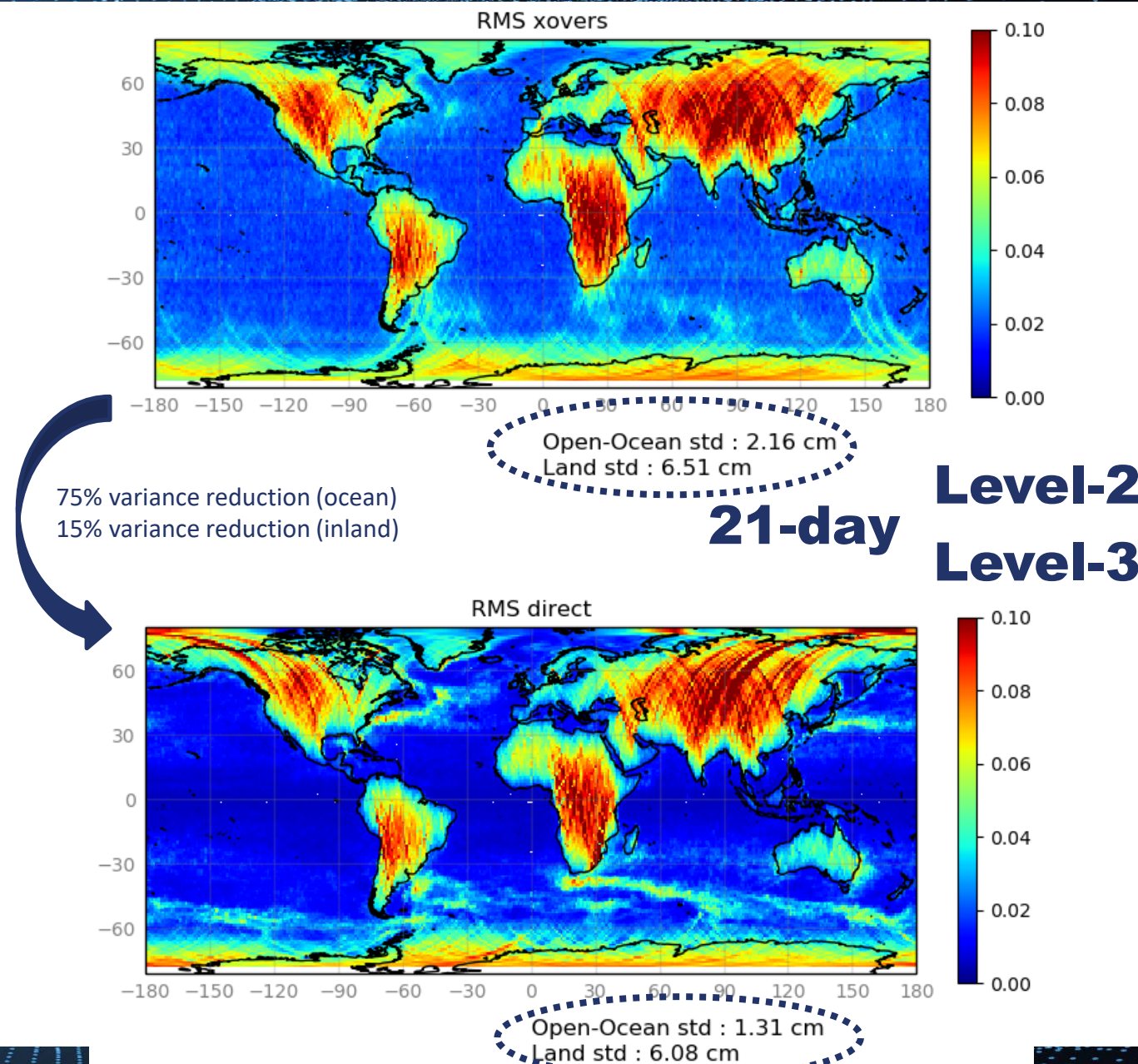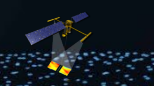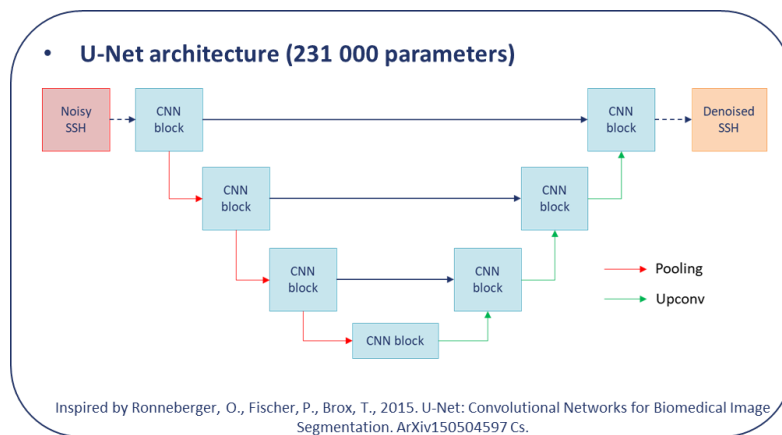
- Calibration is a crucial step

- Requirements are met with the Level 2 calibration (using SWOT only)

- But performances are improved using the whole constellation & refined methods (Level 3):

  - For the 21-day orbit, the Level-3 algorithm yields a variance reduction of 70% with residuals (results for the Current Best Estimate Scenario)
    => 1 year of residual after calibration made available within the **DESMOS-II** project

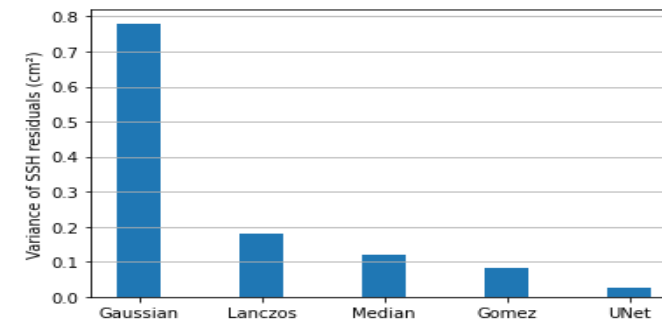 - For the 1-day orbit, we get a massive 85% variance reduction of the error on ocean.

More details in G. Dibarboure presentation

RMS xovers

Open-Ocean std : 2.16 cm
Land std : 6.51 cm

75% variance reduction (ocean)
15% variance reduction (inland)

21-day

Level-2
Level-3

RMS direct

Open-Ocean std : 1.31 cm
Land std : 6.08 cm

- Use of IA-based method to mitigate the Karin noise

- U-Net was trained on 1-year of simulated KaRIN data with eNATL60 as « ocean truth »

U-Net architecture (231 000 parameters)

Inspired by Ronneberger, O., Fischer, P., Brox, T., 2015. U-Net: Convolutional Networks for Biomedical Image Segmentation. ArXiv150504597 Cs.
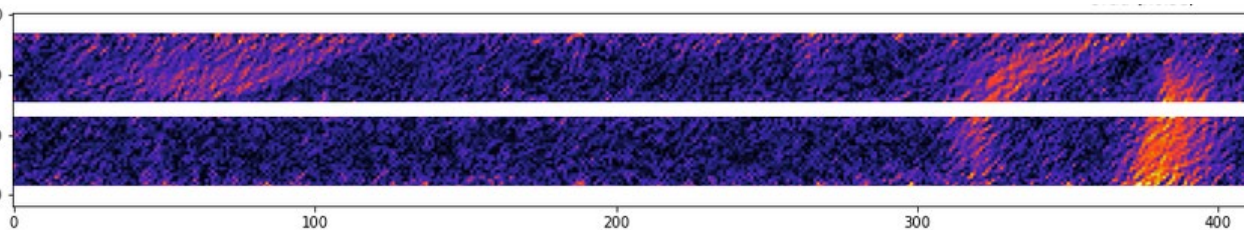
→ U-Net model has better results than classical filters (Gaussian, Lanczos, Median filters)

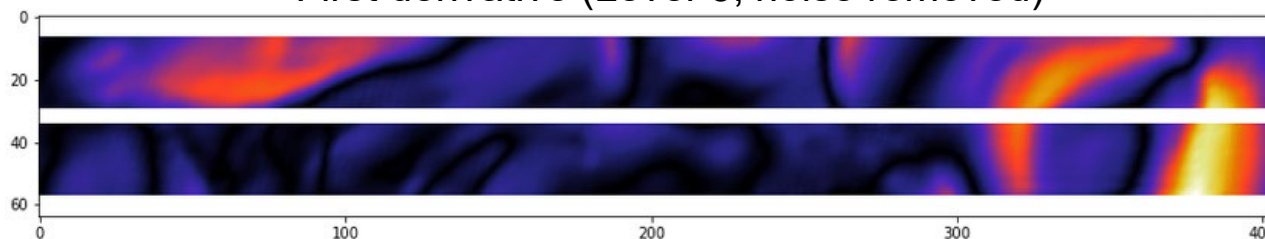And lso good performance at global scale on MITgcm and GLORYS models (independent from training)
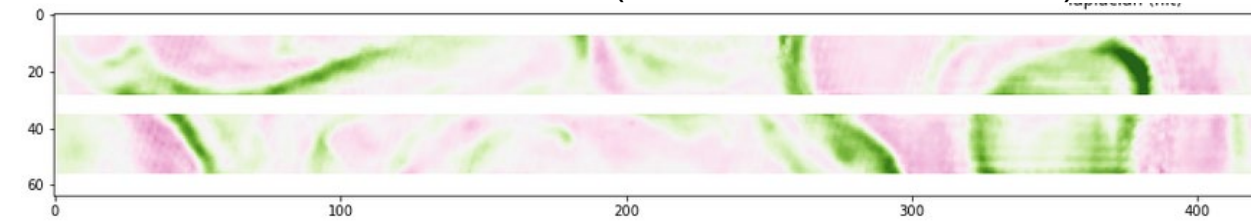
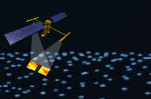First derivative (Level-2 with noise)

First derivative (Level-3, noise removed)

Second derivative (Level-2 with noise)

Second derivative (Level-3, noise removed)

More details in A. Treboutte presentation

- Complete the flags information of the Basic product using a combination of methods to : Sea Level thresholding , Contour based methods, …

- **a Generator of random errors** has been **Developed**: isolated / extreme values (yellow), biased region (blue), very noisy region (green)
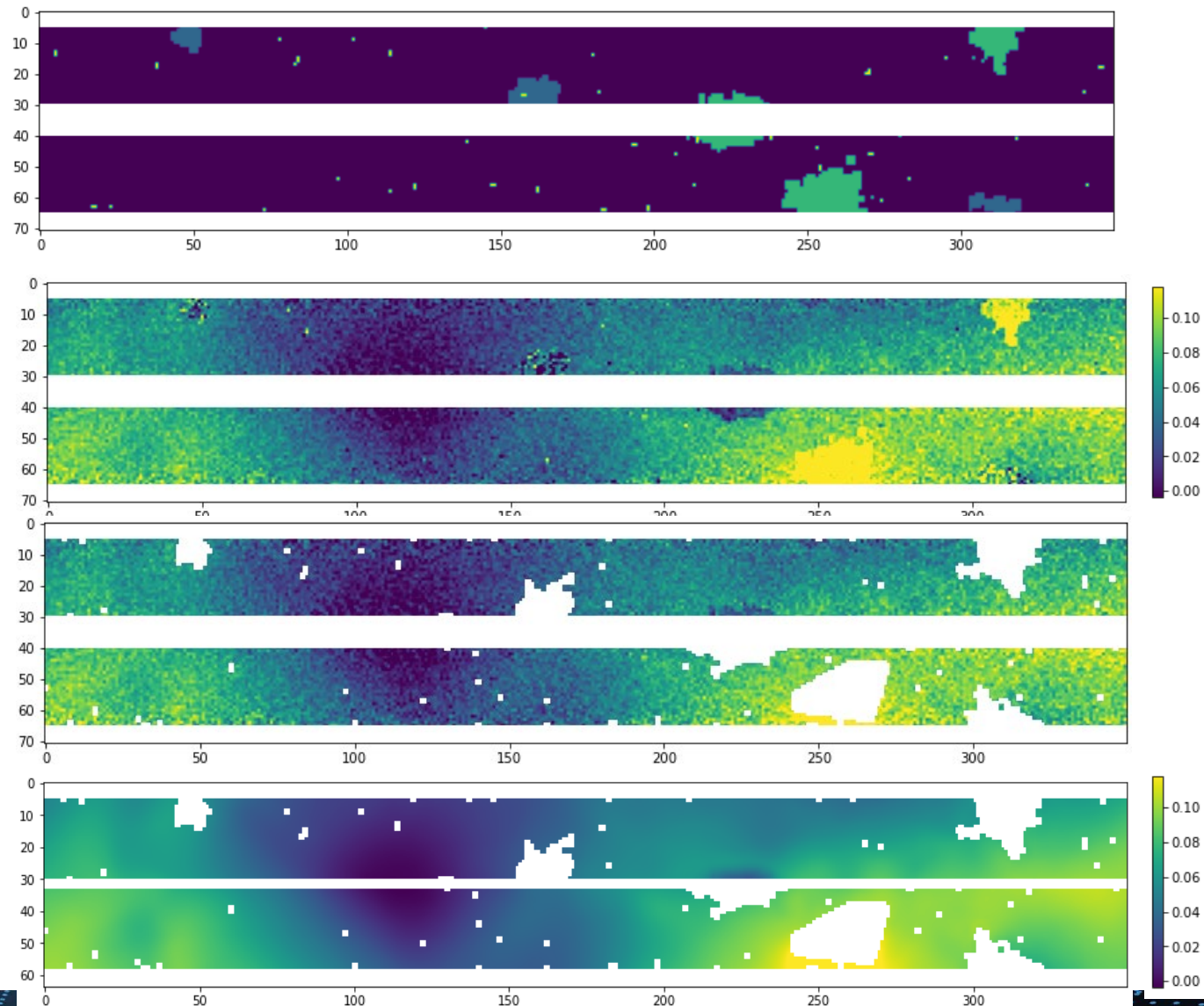

- input data=True SSH + Karin noise + corrupted data


- After editing

First run on 3 days of KaRIN data :	Corrected flagging : 98 %	False alarms : 1.27 % Misses : 0.41 %	HK score : 0.93 Computing time : 22 s

- After editing + noise reduction

  Still under development

- New MIOST & multivariate mapping approach developed to improve the mapping performance:

  - Multiscale: decomposition of the observed signal into different physical contributions.
  - multivariate: able to exploit the geostrophic signature resulting from the synergy of altimetry and drifter observations.

- OSE studies showed the interest of SWOT : improvement of the MIOST maps compared to DUACS OI map (CMEMS)


Effective resolution DUACS

Gain/loss effective resolution
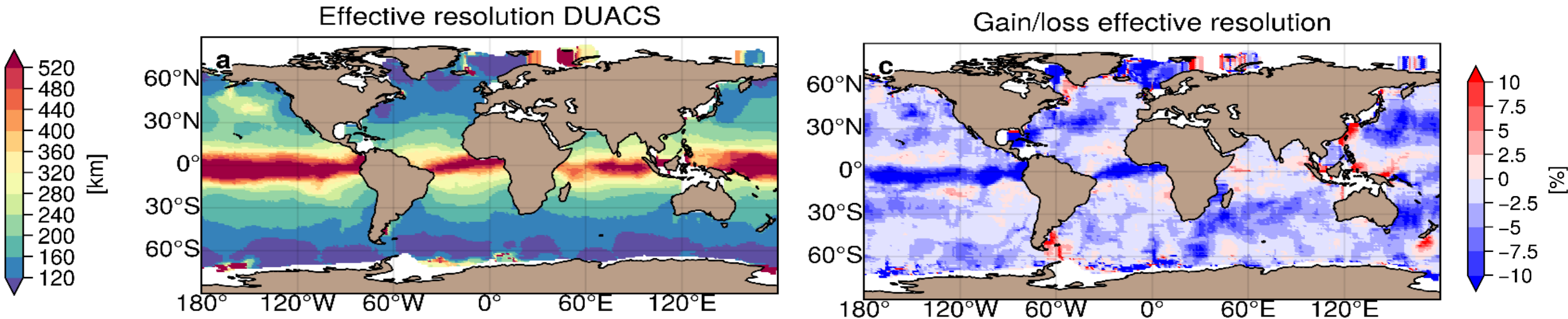
blue : MIOST have a better resolution

Ubelmann et al. (2021). Reconstructing ocean surface current combining altimetry and future spaceborne Doppler data. JGR
Ballarotta et al. (in review). Improved global sea surface height and currents maps from remote sensing and in situ observations. ESSD
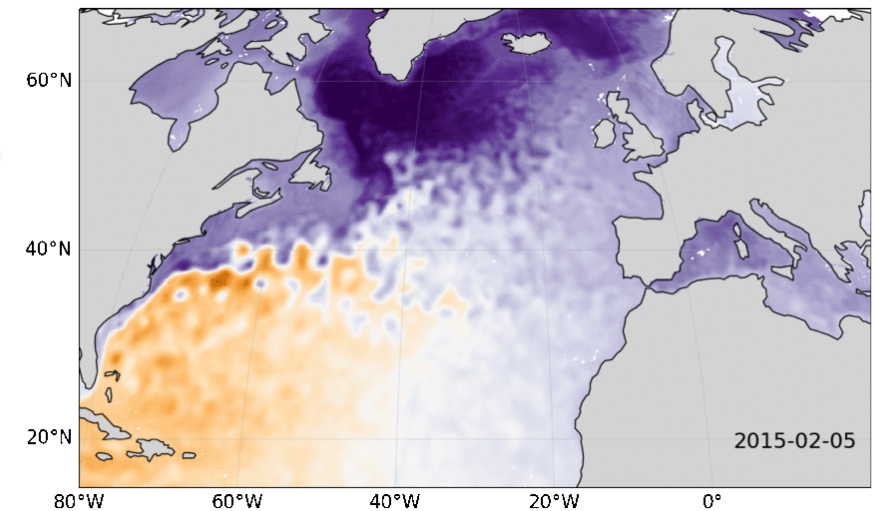
- OSSE studies showed the interest of SWOT for the map improvement in terms of effective resolution and small eddy observability
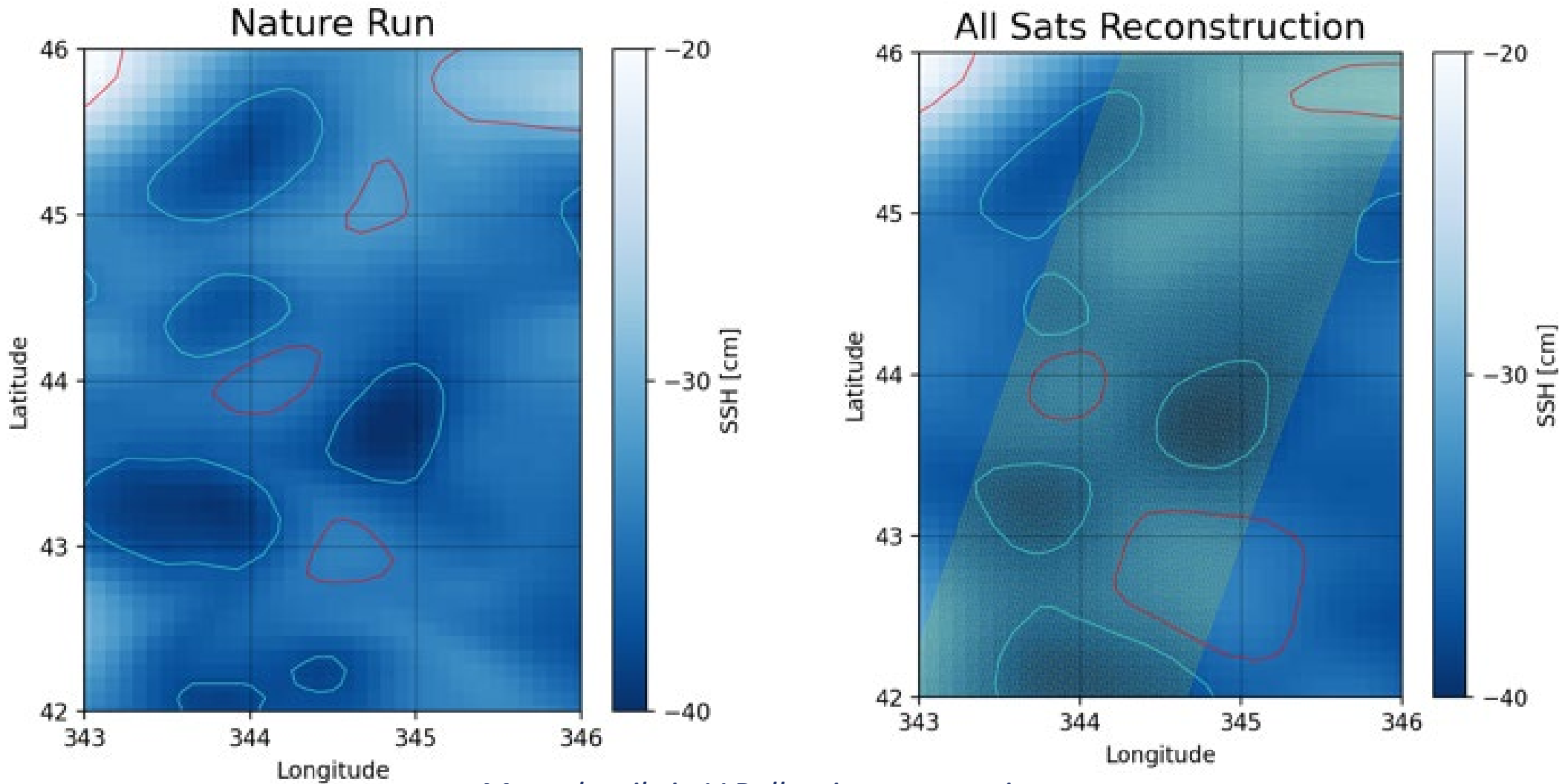
Spatial resolution difference between 3 Nadirs and All Sats

blue : SWOT improves the mapping
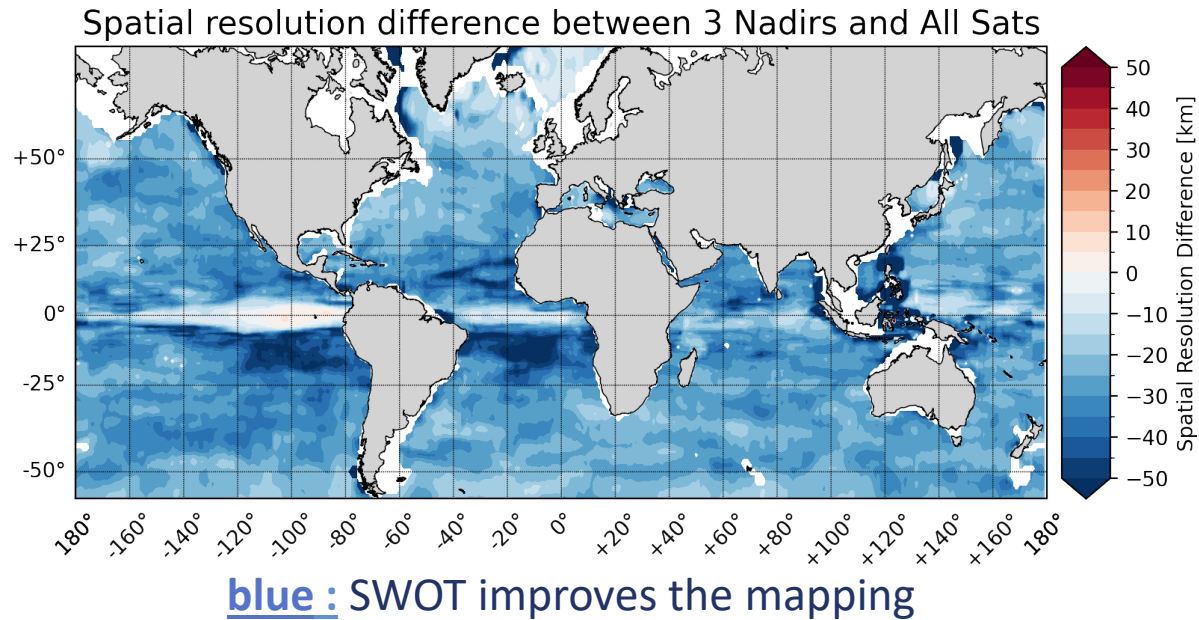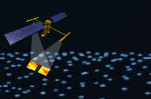
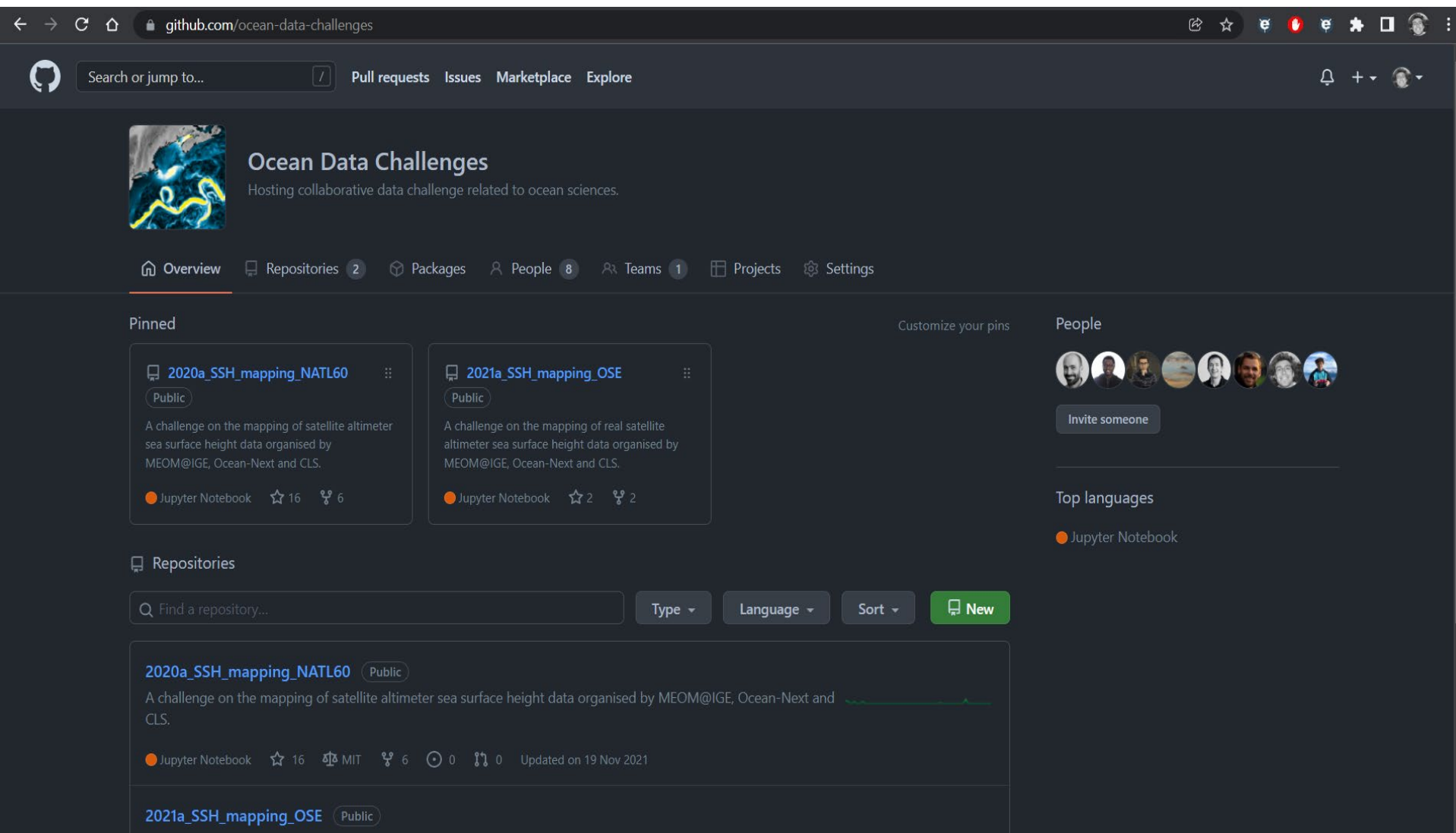MIOST SSH Mapping
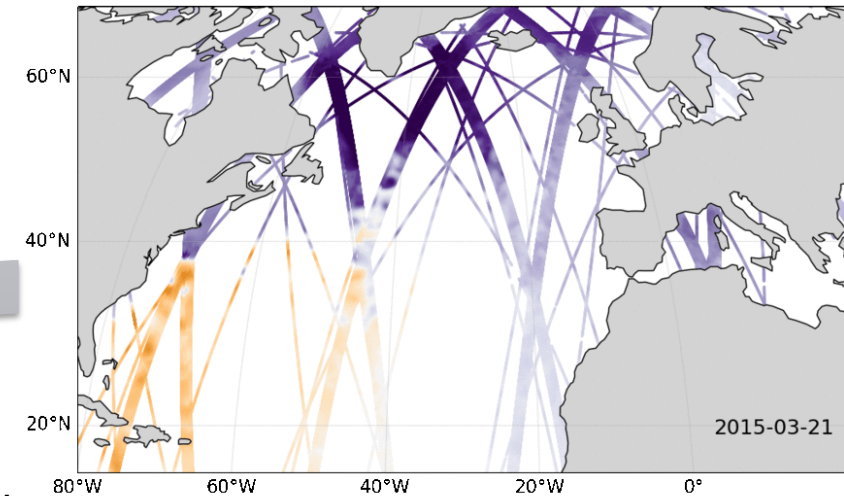
L3 Nadir+SWOT

More details in V Bellemin presentation

Pegliasco, C.: META3.1exp : A new Global Mesoscale Eddy Trajectories Atlas derived from altimetry, ESSD

- Interest of « datachallenges » to intercompare the methods on a fair basis (same input, same diagnostics, …)
- Exemple of the BOOST-SWOT datachallenge (ANR project with MEOM-IGE, Ocean Next, IMT-Atlantique, CLS)

More info on
https://www.aviso.altimetry.fr/en/data/products/ocean-data-challenges.html

Follow up in a Copernicus Marine Service Evolution project

- Datachallenge over the GulfStream region (GF)

Method	µ(RMSE)	σ(RMSE)	λx (degree)	λt (days)
duacs 4 nadirs	0.92	0.01	1.42	12.0
bfn 4 nadirs	0.92	0.02	1.23	10.6
dymost 4 nadirs	0.91	0.01	1.36	11.79
miost 4 nadirs	0.93	0.01	1.35	10.19
4DVarNet 4 nadirs	**0.94**	**0.01**	**0.83**	**8.01**
duacs 1 swot + 4 nadirs	0.92	0.02	1.22	11.15
bfn 1 swot + 4 nadirs	0.93	0.02	0.8	10.09
dymost 1 swot + 4 nadirs	0.93	0.02	1.2	10.07
miost 1 swot + 4 nadirs	0.94	0.01	1.18	10.14
4DVarNet 1 swot + 4 nadirs	**0.95**	**0.01**	**0.62**	**5.29**
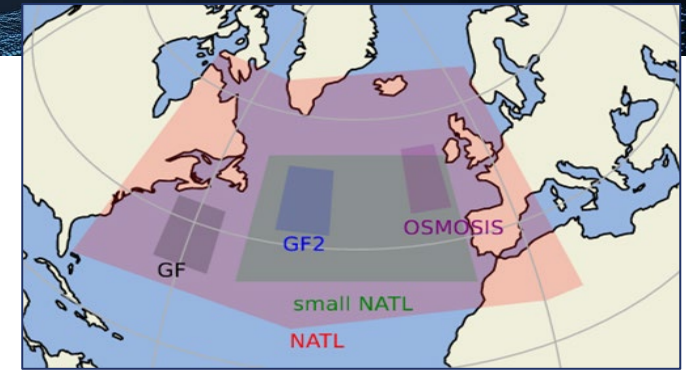
Best results for the AI based 4DVarNet algo (R. Fablet) trained on Natl60

- AI method 4DVarNet have very good mapping performances in OSSE: **50% improvement vs OI DUACS** in a « swot + 4 nadirs » configuration (spatial and temporal)
- **Application on real data is also positive**: 30% improvement in space resolution vs OI DUACS in a « 4 nadirs » configuration (spatial) =>also demonstrates the quality of eNatl60 fields
- Adding information of other sensors (eg **SSH+SST**) still improves the metrics
- **4VarNet is promising to optimize the use SWOT data in the gridded Sea Level products**

R. Fablet, et al, Joint interpolation and representation learning for irregularly sampled satellite-derived geophysical fields. Frontiers in Applied Mathematics and Statistics
M Beauchamp et al, Intercomparison of data-driven and learning-based interpolations of along-track nadir and wide-swath swot altimetry observations. Remote Sensing

- SWOT demo products target - **Fall 2023**
  - SWOT 21-day : demo products after release of prevalidated products by CNES
  - SWOT-1 day: after reprocessing by JPL

- Preoperational Products (on the fly) - **end 2023**

- SWOT operational in Copernicus Marine service - **2024+**

- We welcome any contribution for L3/L4 processing for intercomparison and possible integration