Use of IA in SWOT data processing

Atelier IA ODATIS

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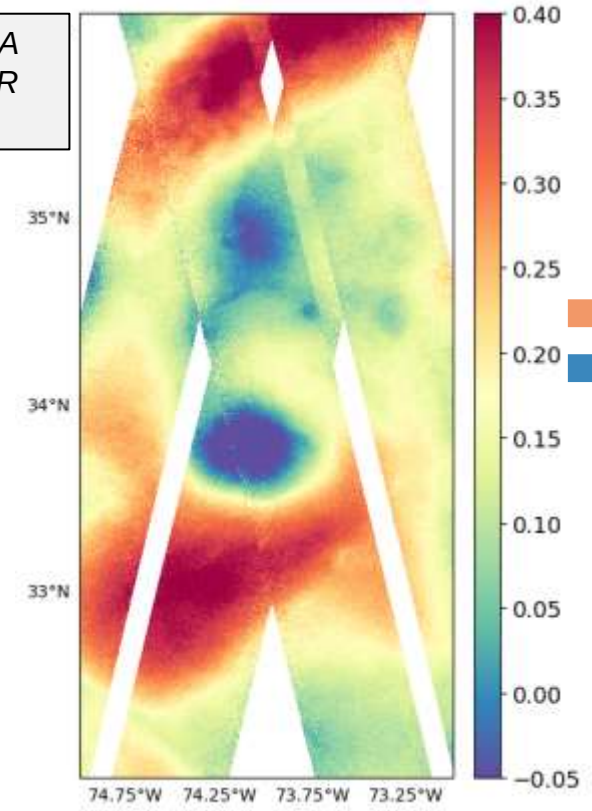
SWOT KaRIn Level-3 (L3) denoising processing

KaRIn L3 denoising

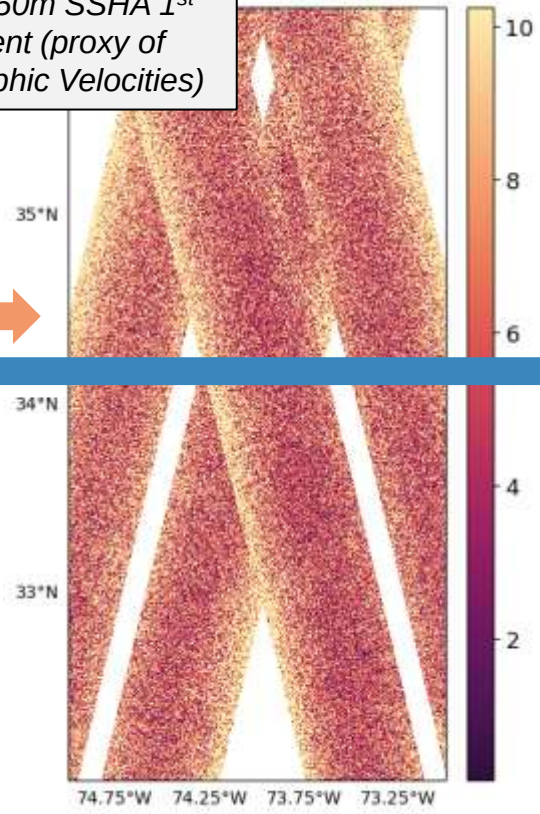
This study is supported by CNES through Gérald Dibarboure, in collaboration with CLS (Gaétan Meis, Anaëlle Tréboutte, Cécile Anadon, Maxime Ballarotta et Marie-Isabelle Pujol)

- Context & objectives
  - SWOT mission is currently providing unpreceded high-resolution measurements of (SSH)
  - 2D observations of KaRIn altimeter of SWOT suffer from **instrumental and geophysical correction errors**.
  - This noise degradation is polluting the high frequencies of SWOT signal → Sub-mesoscale dynamics are too degraded for oceanographers.
  - For this reason, Tréboutte et al. (2023) has developed a convolutional neural network (CNN) based on UNet architecture to **separate the noise from the physical signals contained in the SSH**.

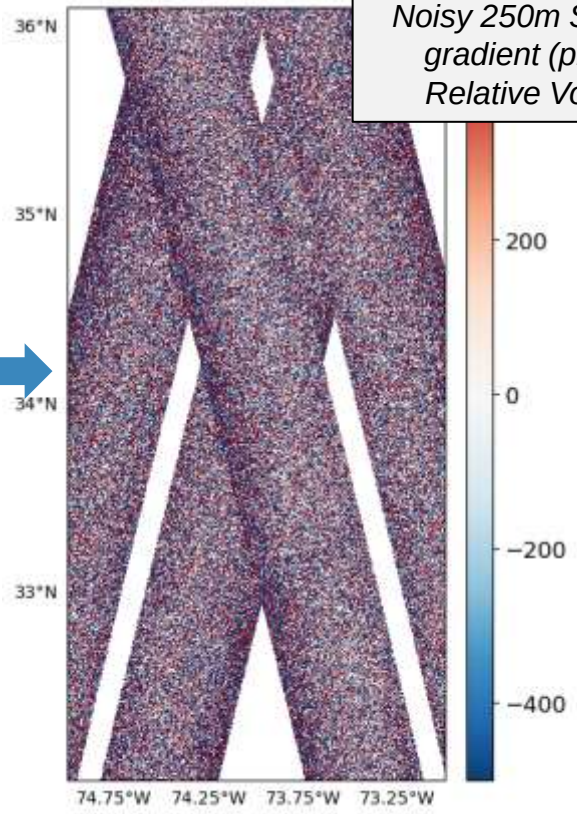
Noisy 250m SSHA from SWOT L3 LR product (V2.0.1)



Noisy 250m SSHA 1st gradient (proxy of Geostrophic Velocities)

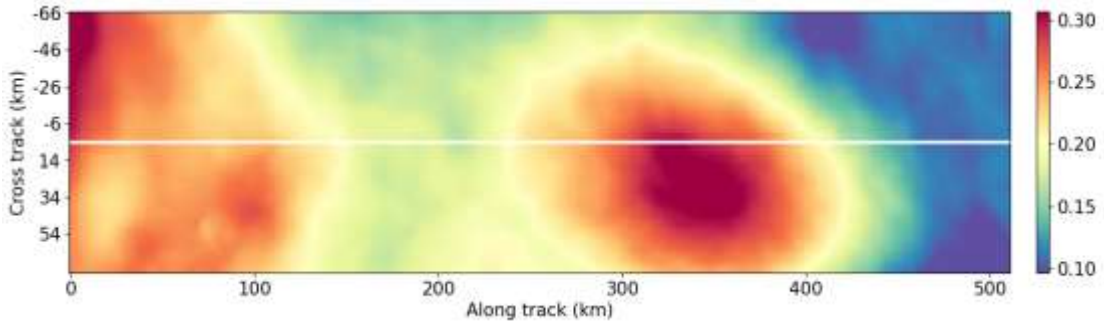


Noisy 250m SSHA 2nd gradient (proxy of Relative Vorticity)

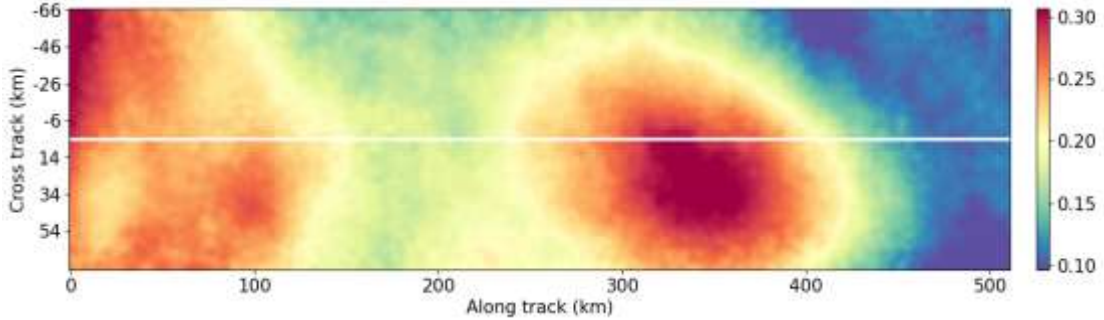


KaRIn L3 denoising

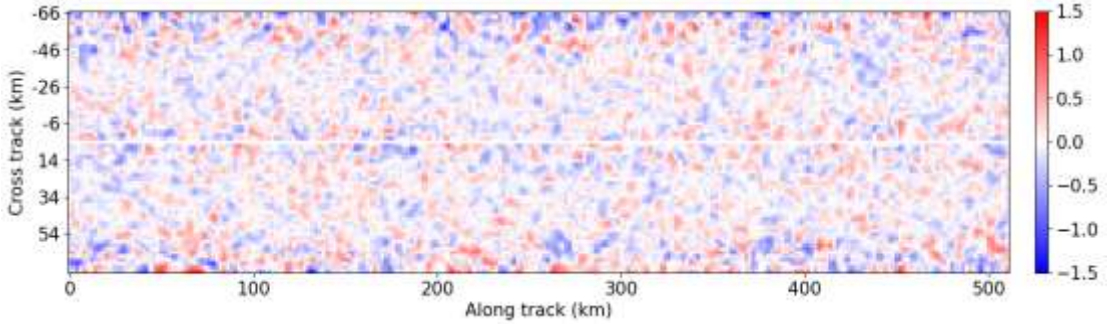
- Method: Example with 2km denoising (same approach for 250m)
  - Supervised training of a CNN (UNet architecture) with simulated SSHA swaths from eNATL60 model



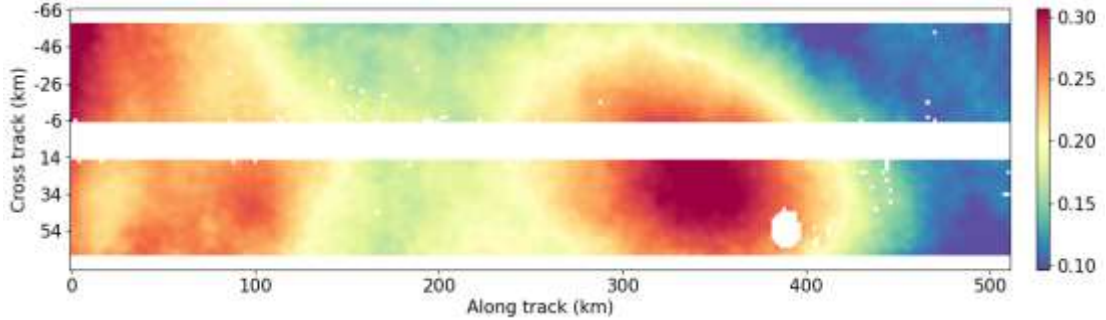
  - The addition of simulated noiseless SSHA with the simulated noise creates a realistic noisy SSHA.



  - A realistic correlated noise is generated to mimic the real noise on SWOT data



  - To bring closer simulation to reality, the L3 editing mask is applied to the training dataset

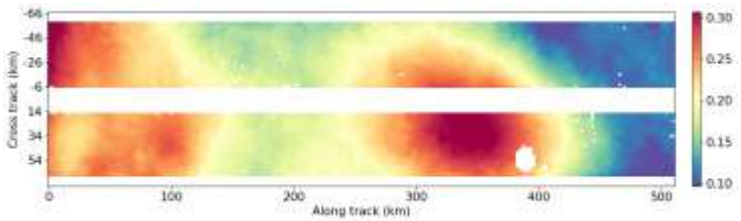


KaRIn L3 denoising

For more details about the methodology, the training process, the results etc feel free to contact Gaétan Meis (gmeis@groupcls.com) or Anaëlle Tréboutte (atreboutte@groupcls.com)

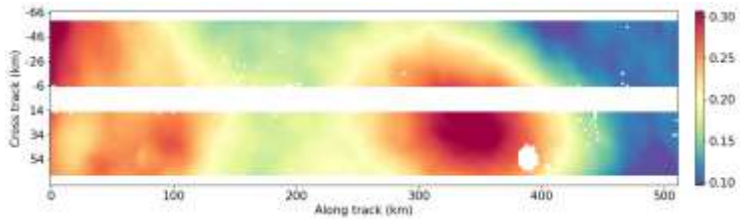
- Method: Example with 2km denoising (same approach for 250m)
  - The simulated noisy SSHA from eNATL60 model is the input of the network
  - The network minimizes the RMSE between its prediction and the noiseless SSHA
  - The loss also contains first and second gradient of SSHA to better retrieve the oceanic dynamics

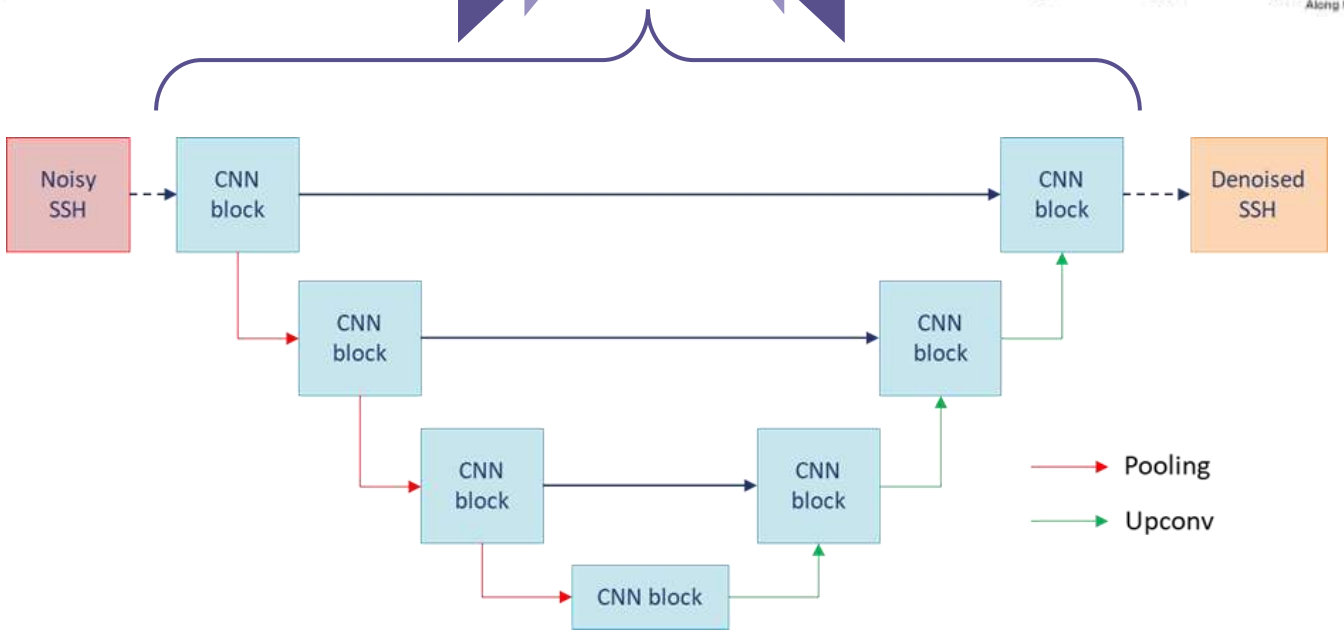
Input : Noisy simulated SSHA



U-Net

Output : Denoised simulated SSHA

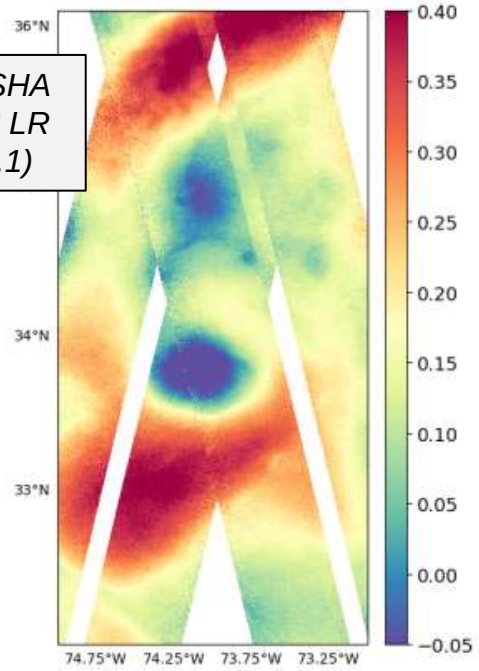




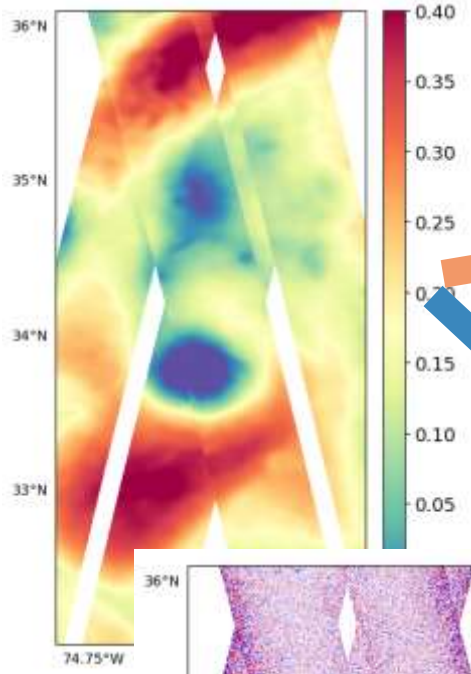
KaRIn L3 denoising

- Results

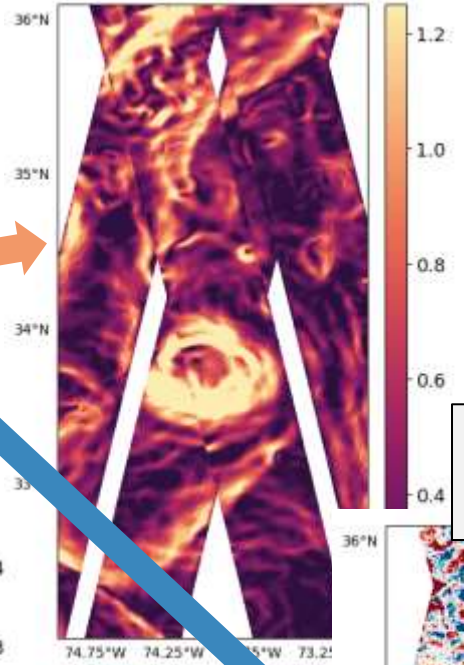
Noisy 250m SSHA from SWOT L3 LR product (V2.0.1)



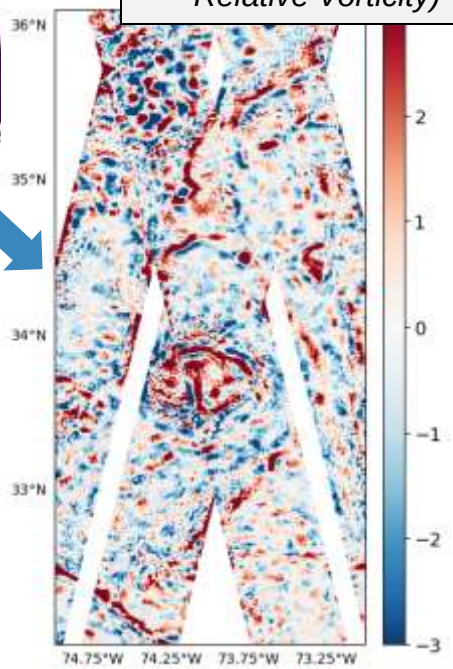
Denoised 250m SSHA



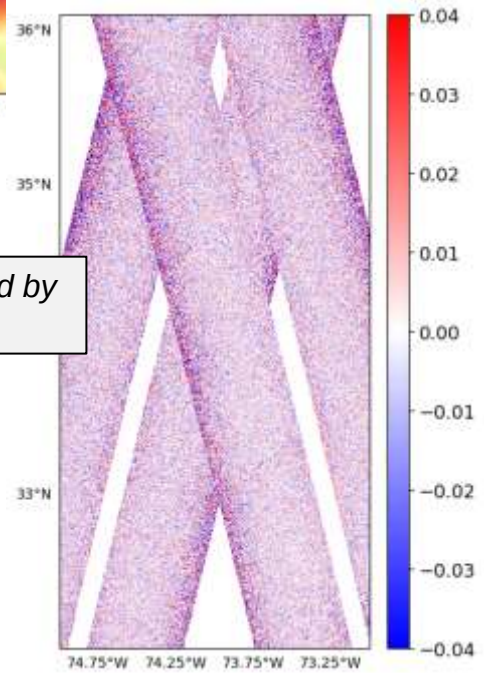
Denoised 250m SSHA 1st gradient (proxy of Geostrophic Velocities)



Denoised 250m SSHA 2nd gradient (proxy of Relative Vorticity)



Noise removed by denoising



- L3 denoising is able to remove precisely noise from SWOT data. The denoising strength varies in space and time
- The denoising is robust to various oceanic conditions (High SWH, high variability…)
- A consequent effort of validation has been done to evaluate the performance of denoising against a benchmark of metrics (Spectral behavior, residuals analysis, comparison to independent measurements…)

KaRIn L3 denoising

- Limits & perspectives
  - The denoising is currently depending on a simulation model to learn. These models are imperfect and it is a key element to ensure that the model is not influencing the prediction on real SWOT data
  - Some very small-scale oceanic features are still hard to denoise (e.g. fine-scale internal tides)
  - Denoising is also very impacted by previous processing step of the L3 chain
  - The lack of a reference noiseless real SSHA is making this study particularly hard. It is preventing us from knowing with confidence whether the denoising worked accurately

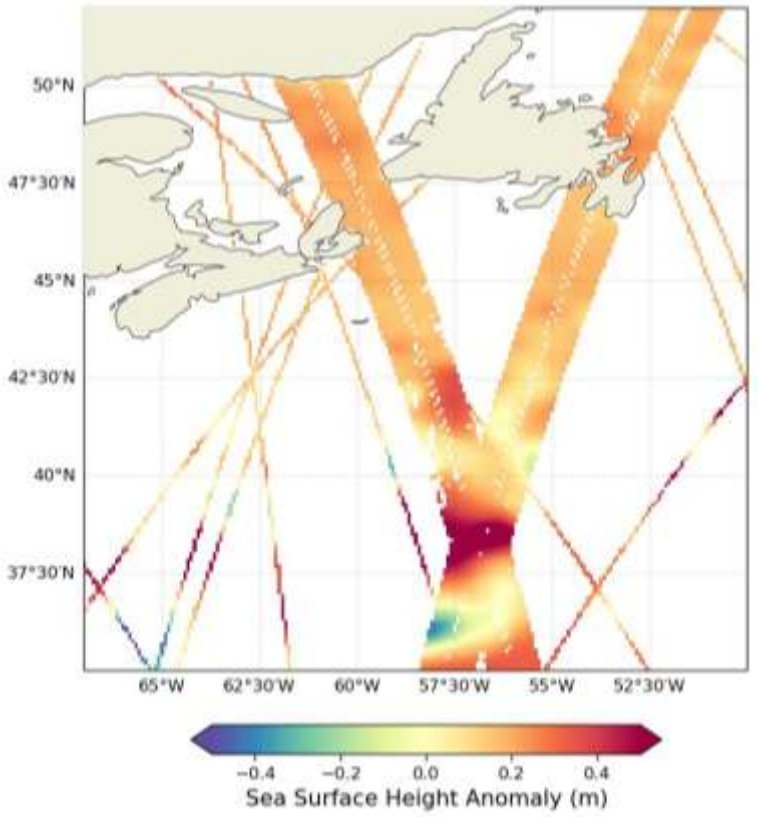
  - Self-supervised denoising approaches are emerging and are promising (The network learns from only real noisy SSHA to denoise). Simulation models would not be necessary anymore
  - A collaborative work with SWOT-ST members is initiated to further evaluate the denoising with other sources of data (drifters, moorings, airborne data…)
  - With different architecture, training data, or preprocessing step we might be able to retrieve the smaller scales better than we currently do. There is room for improvements!

SWOT KaRin Level-4 (L4) mapping

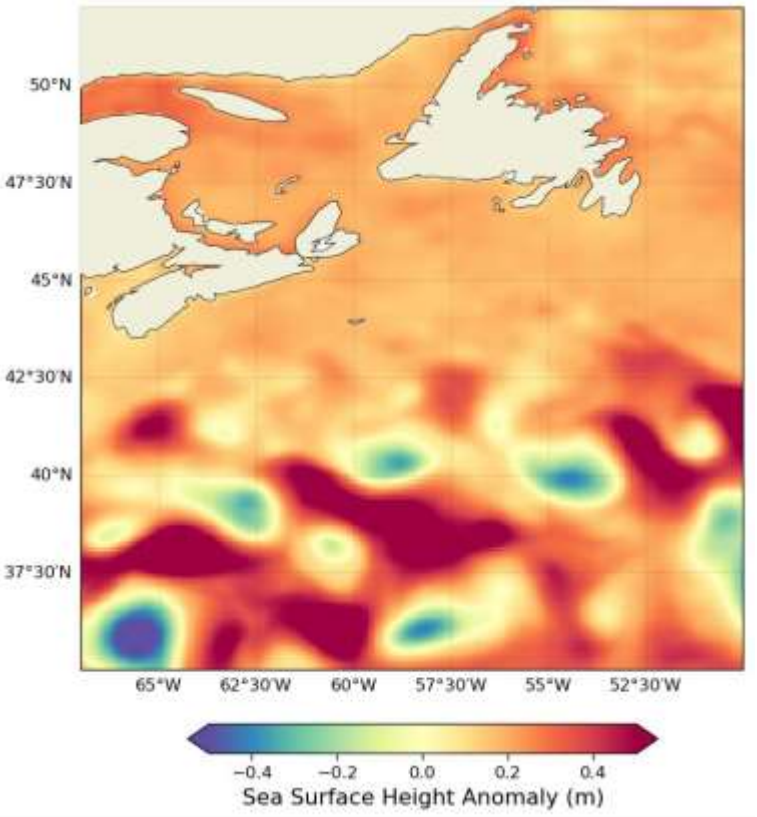
SWOT KaRIn L4 mapping

- Context & objectives
  - L3 altimetry data are along-track (1D) data for nadir satellites and a 120 km wide swath for KaRIn. The data therefore have **significant gaps, both geographically and temporally.**
  - L4 products consist of **fully filled daily gridded maps**.
  - L4 products are currently produced in CMEMS using a multiscale interpolation framework called MIOST. A deep learning algorithm is being developed to **improve mapping resolution**.

Level-3 altimetry product



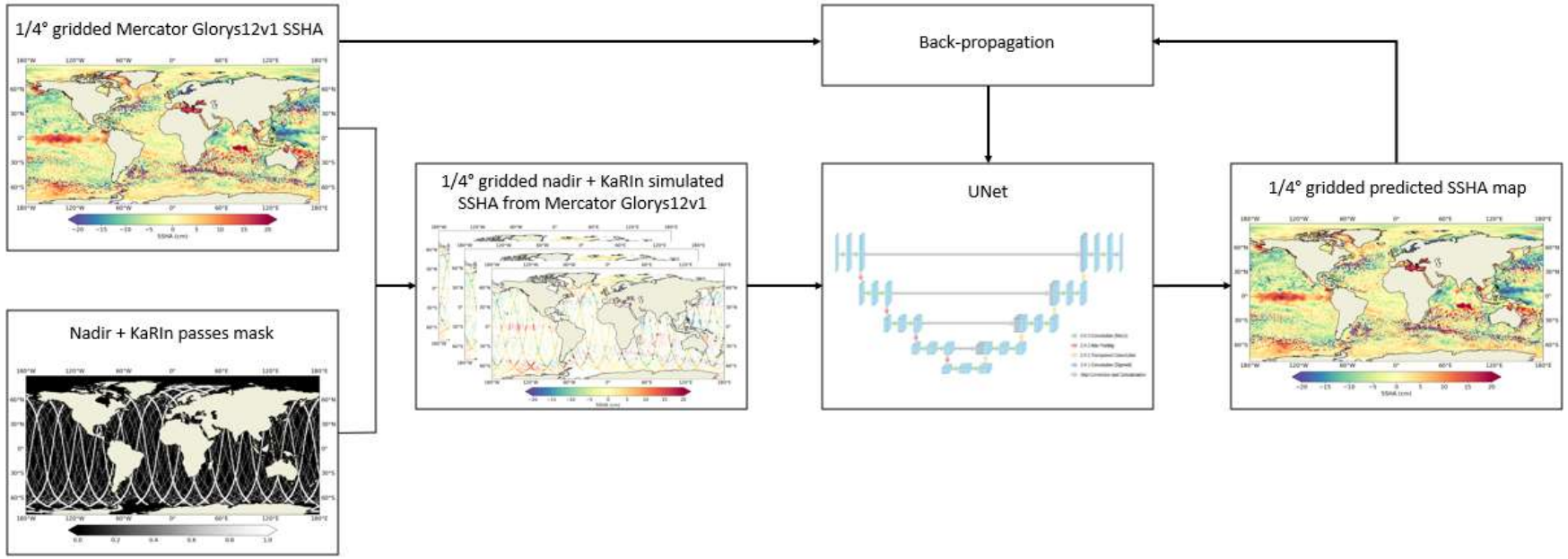
Level-4 altimetry product



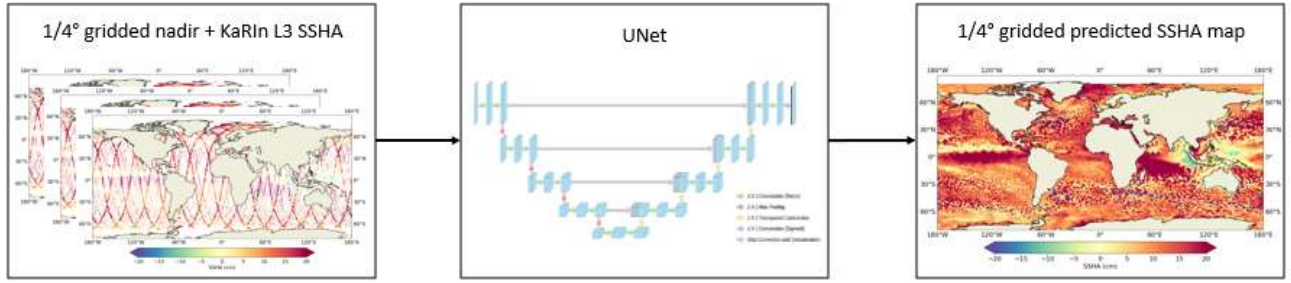
KaRIn L4 mapping

- Method
  - **Supervised learning** on simulated data (Glorys12v1 model) and inference on real L3 SSHA data
  - Deep learning model: UNet with 12 million parameters; other architectures (4DVarNet, Flow matching, etc.) are also being tested

Supervised learning on simulated model:

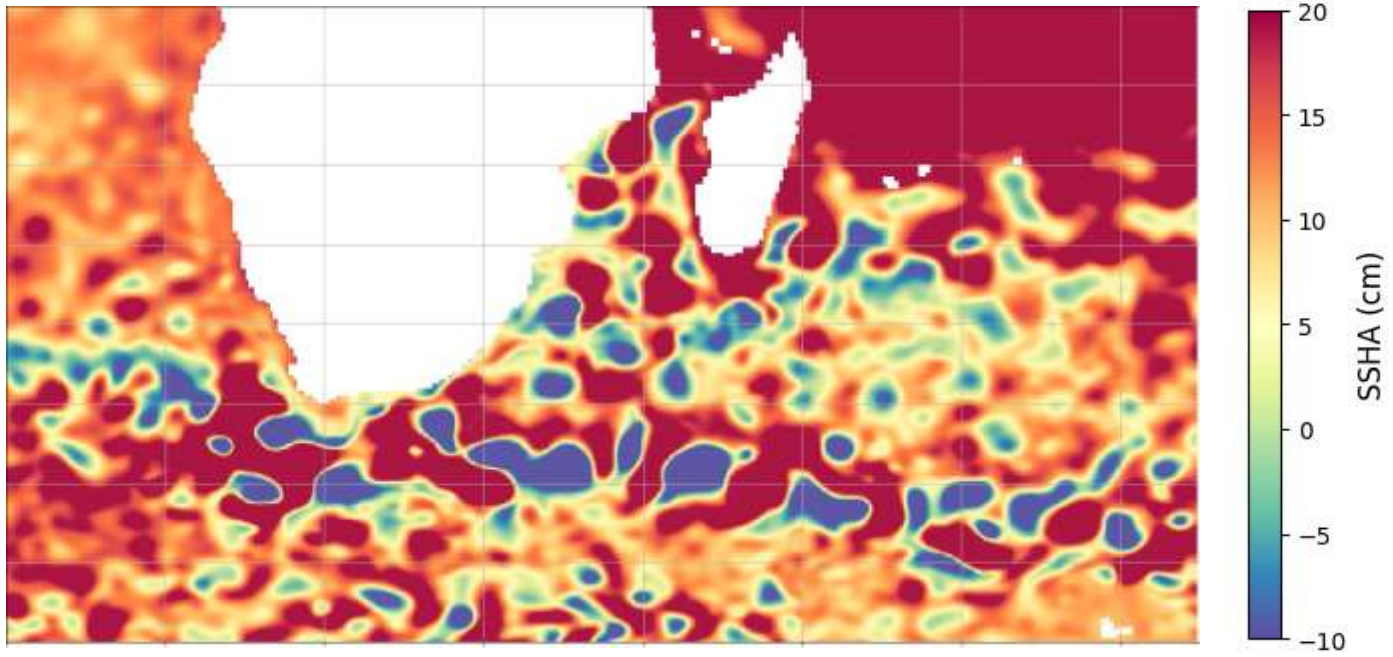


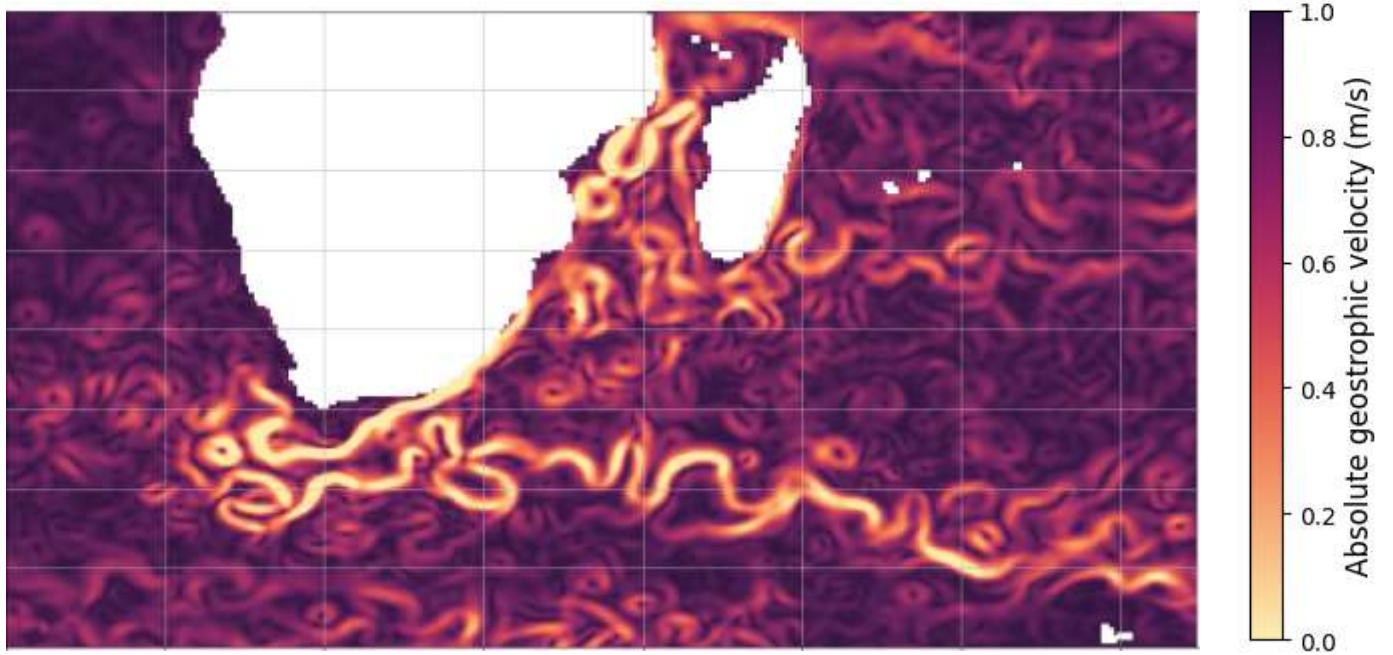
Inference on real L3 SSHA:



KaRIn L4 mapping

- Results
  - The L4 maps have great **geographical and temporal continuity**.
  - The method can be used to generate **global maps** and is suitable for **all types of oceanic regimes** (high variability, low variability, equatorial zone, polar zone).
  - By deriving the SSHA, we obtain the **absolute geostrophic velocity**, which is also **geographically and temporally continuous**.
  - The **computation time** is greatly **accelerated** compared to current methods: a year of maps is generated in just 10 minutes.





KaRIn L4 mapping

- Limits & perspectives
  - The network does not include KaRIn data less than 50 km from the coast, otherwise the mapping is significantly degraded at the coastline.
  - The method does not manage inter-mission biases and uses data corrected for Long Wavelength Error (LWE) calculated by MIOST as input.
  - The UNet method outperforms the MIOST framework. However, other mapping methods handle some ocean conditions better: for example, VarDyn reduces mapping errors in areas of high ocean variability

  - The method is currently being improved with numerous tests being carried out: changes of network to better integrate geographical and temporal coherence, changes of the noise model in training, changes of normalization.
  - The addition of other geophysical fields (sea surface temperature, sea surface salinity, or ocean color) is being considered to improve mapping.
  - The method continues to be developed, including some work to enable near real-time data processing so that it can potentially be implemented operationally in the future (for CMEMS products).

Quelle offre de services ODATIS pour l'IA ?

contact@odatis-ocean.fr | www.odatis-ocean.fr

Offre de services du Pôle ODATIS

Stockage

L'infrastructure informatique du pôle ODATIS repose sur 2 centres de données et calcul de type **HPC** alliant ressources de **calcul et stockage** dédié à l'hébergement et l'exploitation massive de données.

Entrepôt

Les entrepôts de données marines Seanoe et ceux des CDS ODATIS permettent le **dépôt, la description, la conservation, la recherche et la diffusion** des jeux de données.

Catalogue

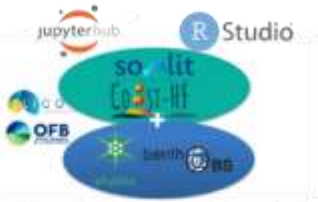
Le catalogue ODATIS moissonne plusieurs catalogues existants dans les CDS, OSU, projets et Seanoe avec des données multidisciplinaires en océanographie, avec application des principes FAIR sur les métadonnées.

Visualisation

Le catalogue ODATIS sur l'interface Sextant permet la création de services de visualisation interopérables et des cartes thématiques interactives.

VRE

Accès à des environnements de recherche virtuels avec données multidisciplinaires et toolbox pour manipulation et exploration des données multidisciplinaires



VRE pour Niche Ecologique Optimale

Accompagnement des communautés

Pour les producteurs et utilisateurs des données : support organisationnel et techniques (PGD), support pour enrichir les métadonnées, harmoniser les formats, publier les données, FAIRiser les données,...

CESSDA Data Archiving Guide

Ateliers

Ateliers techniques et thématiques pour former aux bonnes pratiques de gestion des données, prise en main d'outils, diffuser des retours d'expérience, ...

Webinaires

Des webinaires pour valoriser les activités des CDS du pôle, pour partager des retours d'expériences sur l'utilisation des données ou pour présenter des outils et services utiles à la communauté scientifique.

L'IA et les services du pole ODATIS

Calcul & Stockage

Infrastructure de **calcul (noeuds GPU) et stockage (BD + sorties)** dédiée aux **projets IA**

Entrepôt

Dépôt, description, conservation, recherche et diffusion des **BD et produits générés avec IA**

Catalogue

Nouveau **services** de **recherche** (*chatbots*, agents IA…)

Visualisation

Services de visualisation interactifs des réseaux de neurones, produits IA…

VRE

VRE pour **déployer/développer** des **modèles** et **conduire** des projets IA

VRE pour Niche Ecologique Optimale

Accompagnement des communautés

Aide à la **FAIRisation** des produits IA et métadonnées…

CESSDA Data Archiving Guide

Ateliers IA

Ateliers techniques et thématiques, prise en main d'outils, mise en relation expertise IA…

Webinaires

Webinaires pour **presenter/valoriser** les **activités IA**, formation à des outils…