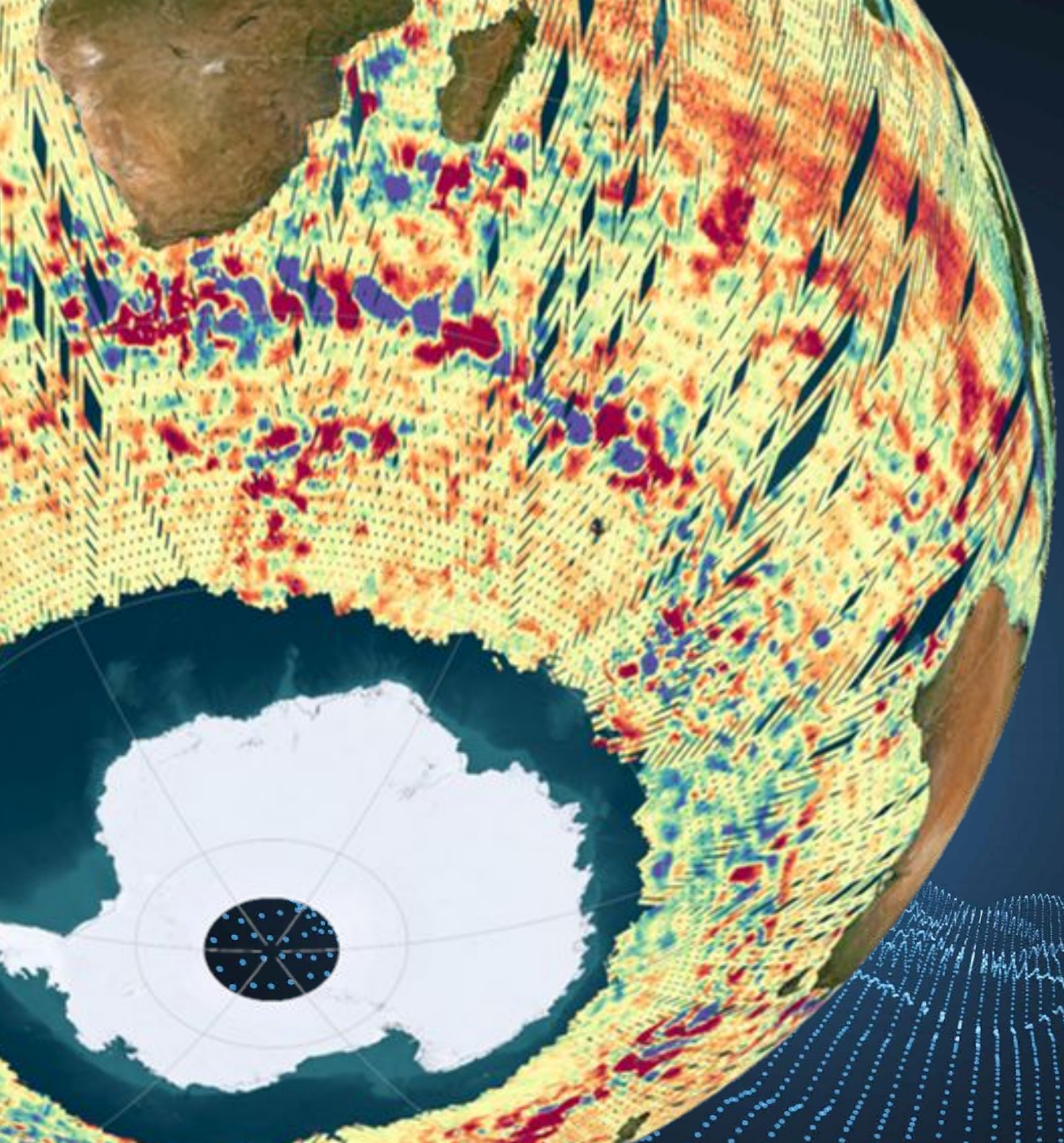
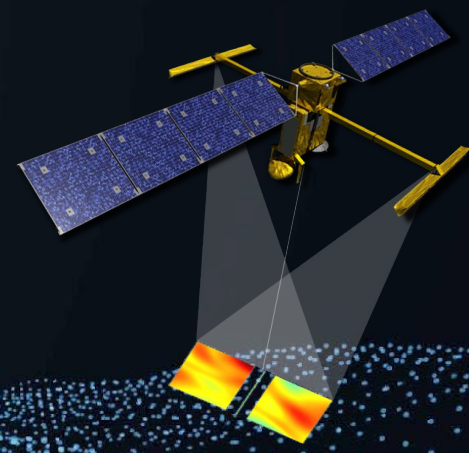


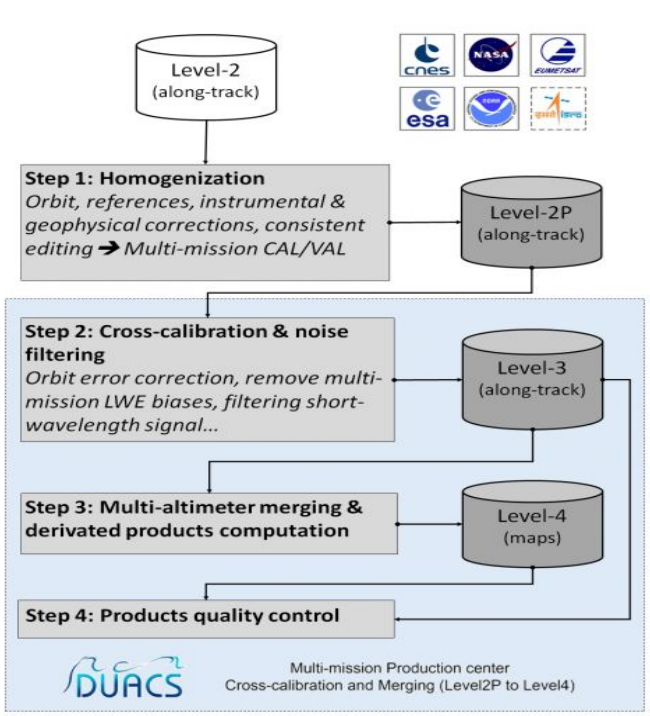
# From low resolution gridded altimetry maps to fine scales in KaRIn images

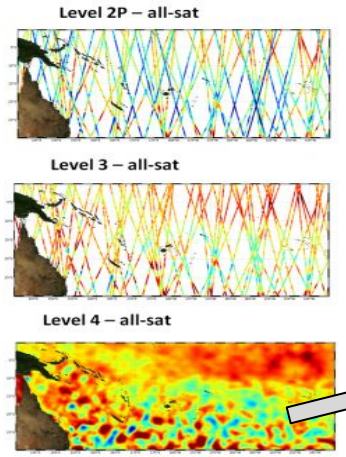
Clement Ubelmann (Datlas), Gerald Dibarboure (CNES)
Antoine Delepoulle, Anaelle Treboutte, Yannice Faugere (CLS)

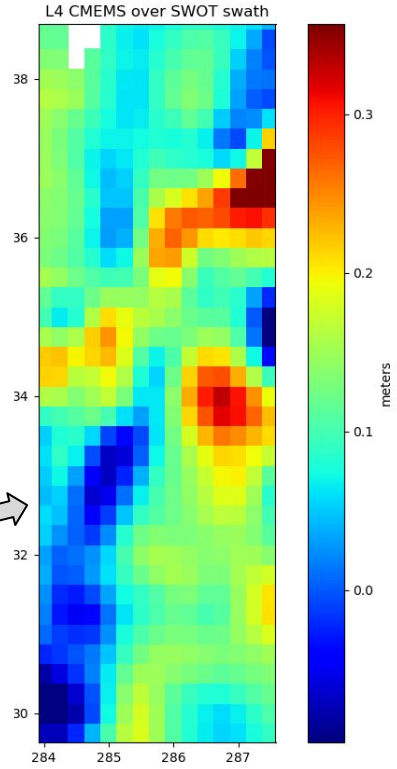


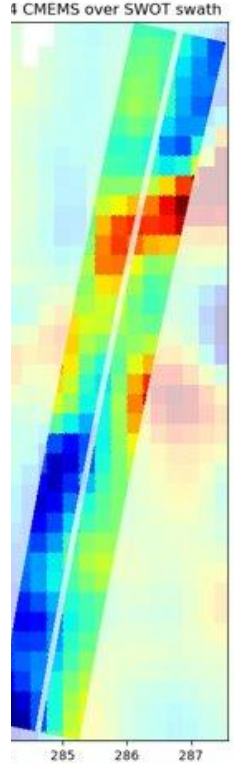
OSTST Meeting, PUERTO RICO, Nov. 7 to Nov. 11, 2023

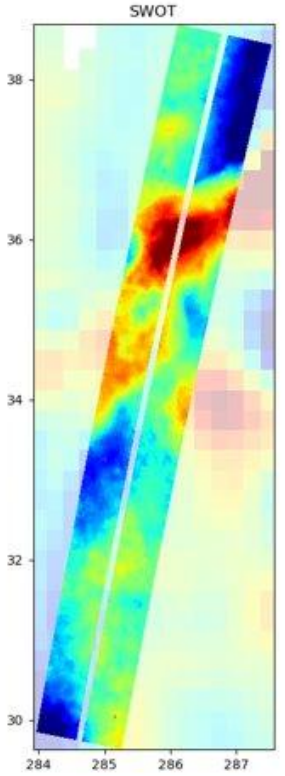
# Intro : from standard Altimetry to highly resolved 2D images, in a nutshell



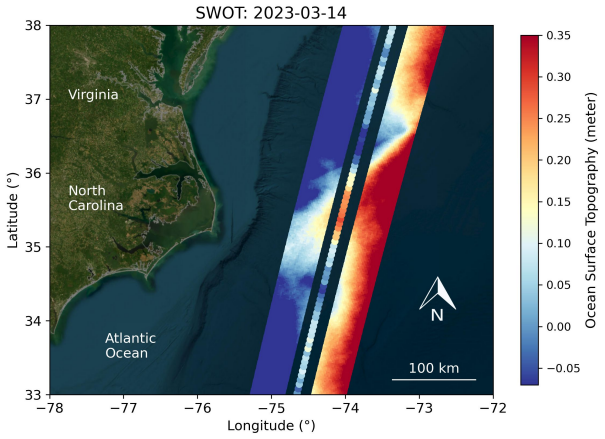



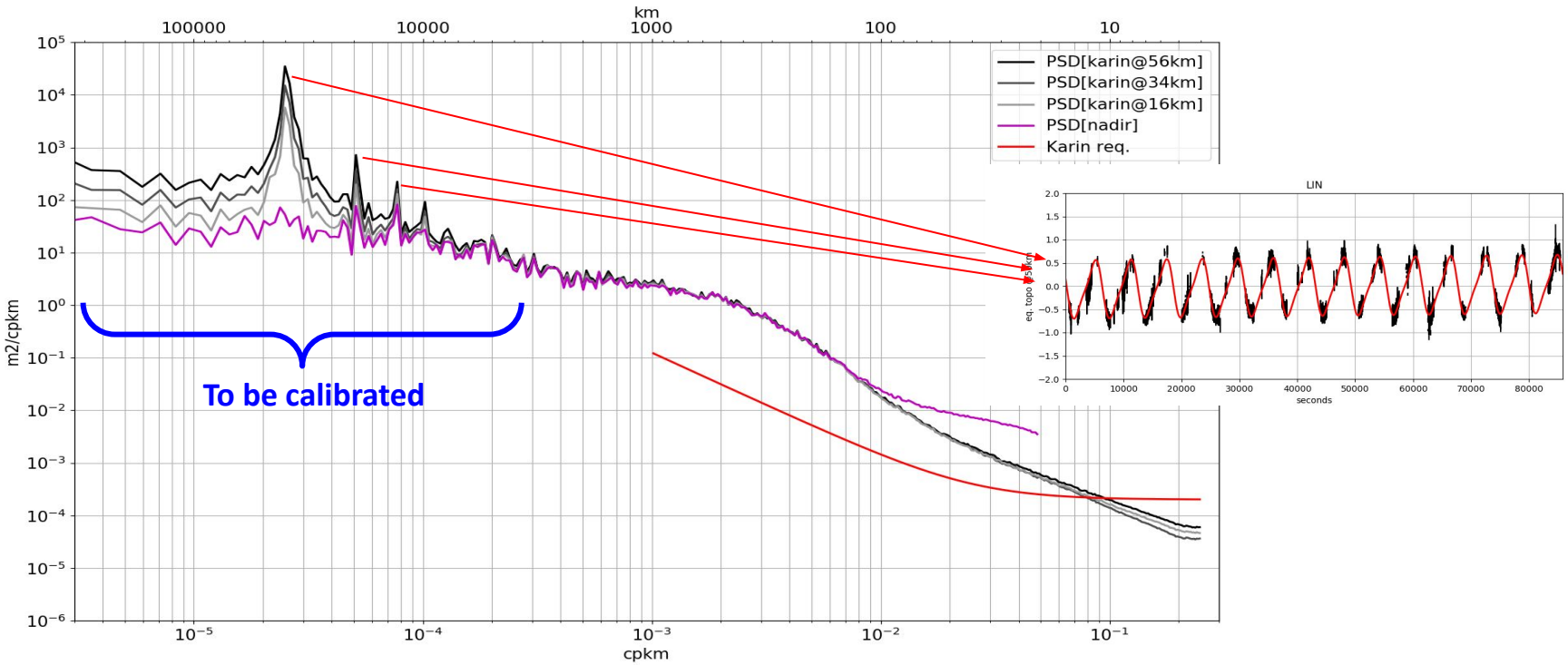

- Nadir altimetry is limited to ~70km wavelength in 1D local profiles, and ~150km in the reconstructed 2D images
- SWOT : ~15km wavelength direct 2D images : a breakthrough

Goals of this presentation :

- Show that **calibration can bring Karin images consistent with nadir Altimetry, from basin to mesoscales**: ready to be processed for higher level applications (mapping, … see next presentation by Yannice Faugère)
- Show promising 2D SSH (and derivatives) signatures not seen before SWOT : short-to-sub-mesoscales

# Karin medium to large scale signal compared with Nadir Altimeter



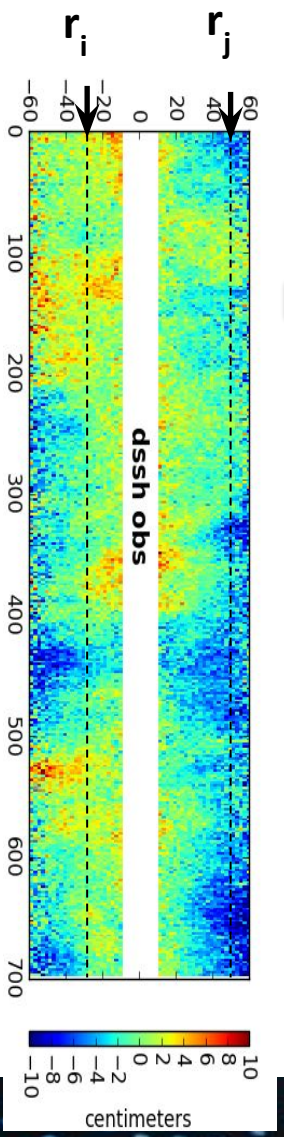




- **Very good consistency with nadir data at mesoscales**
- Large scale bias **~50cm roll** at far range, oscillating at Orbital frequency and its sub-harmonics
- Other smaller signatures (phase errors, quadratic-shapes, nadir-Karin biases…) at >2000km

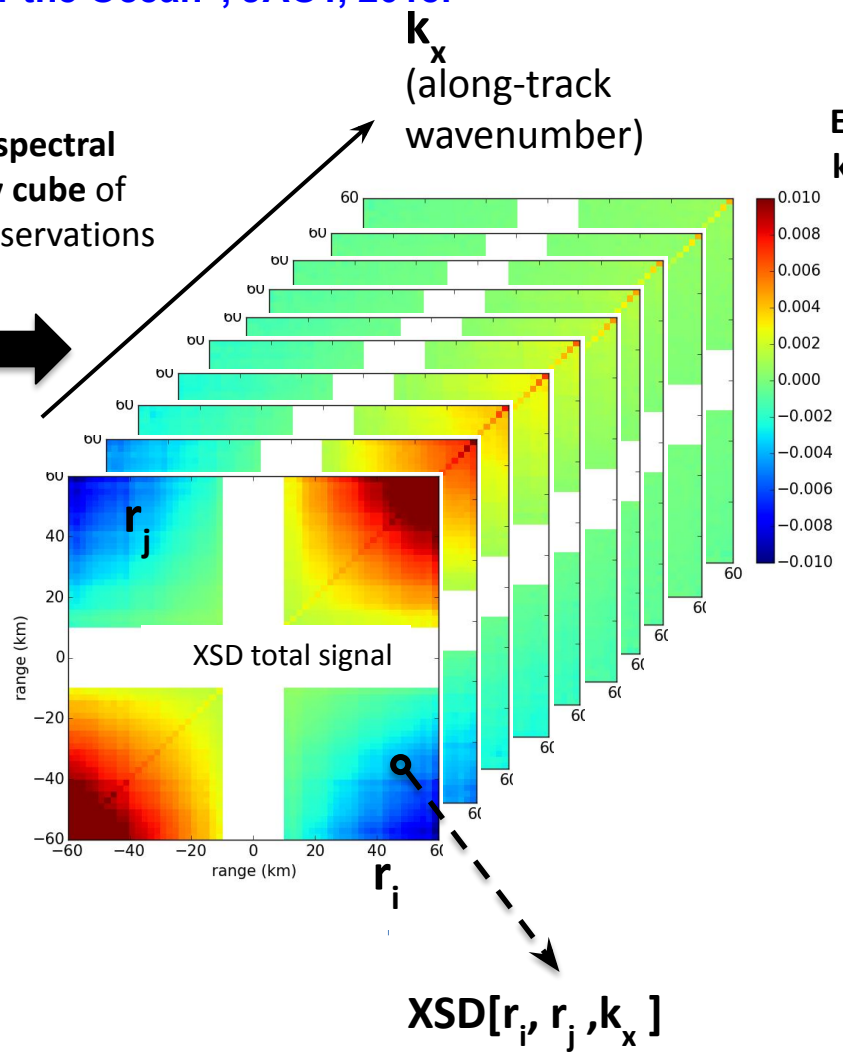
→ **A calibration is needed, along with a detailed assessment of large-scale errors**

# Estimation of the systematic error budget with a cross-spectral analysis

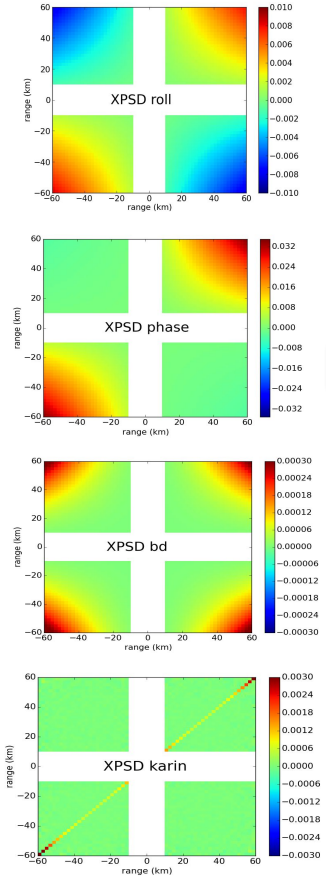
**Details in "A Cross-Spectral Approach to Measure the Error Budget of the SWOT Altimetry Mission over the Ocean", JAOT, 2018.**



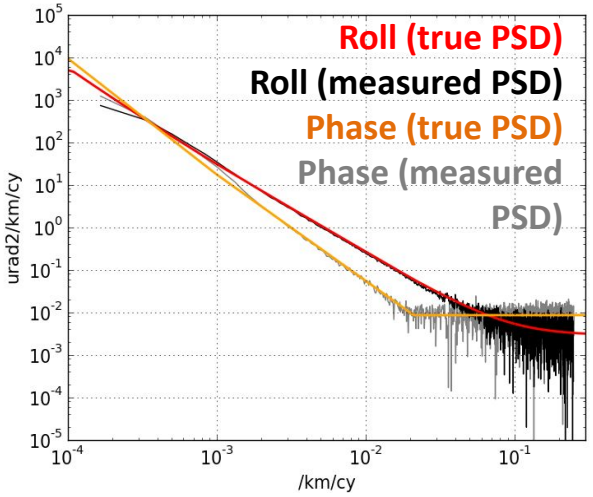

**Cross-spectral density cube** of SWOT observations




**Extraction of known error shapes**

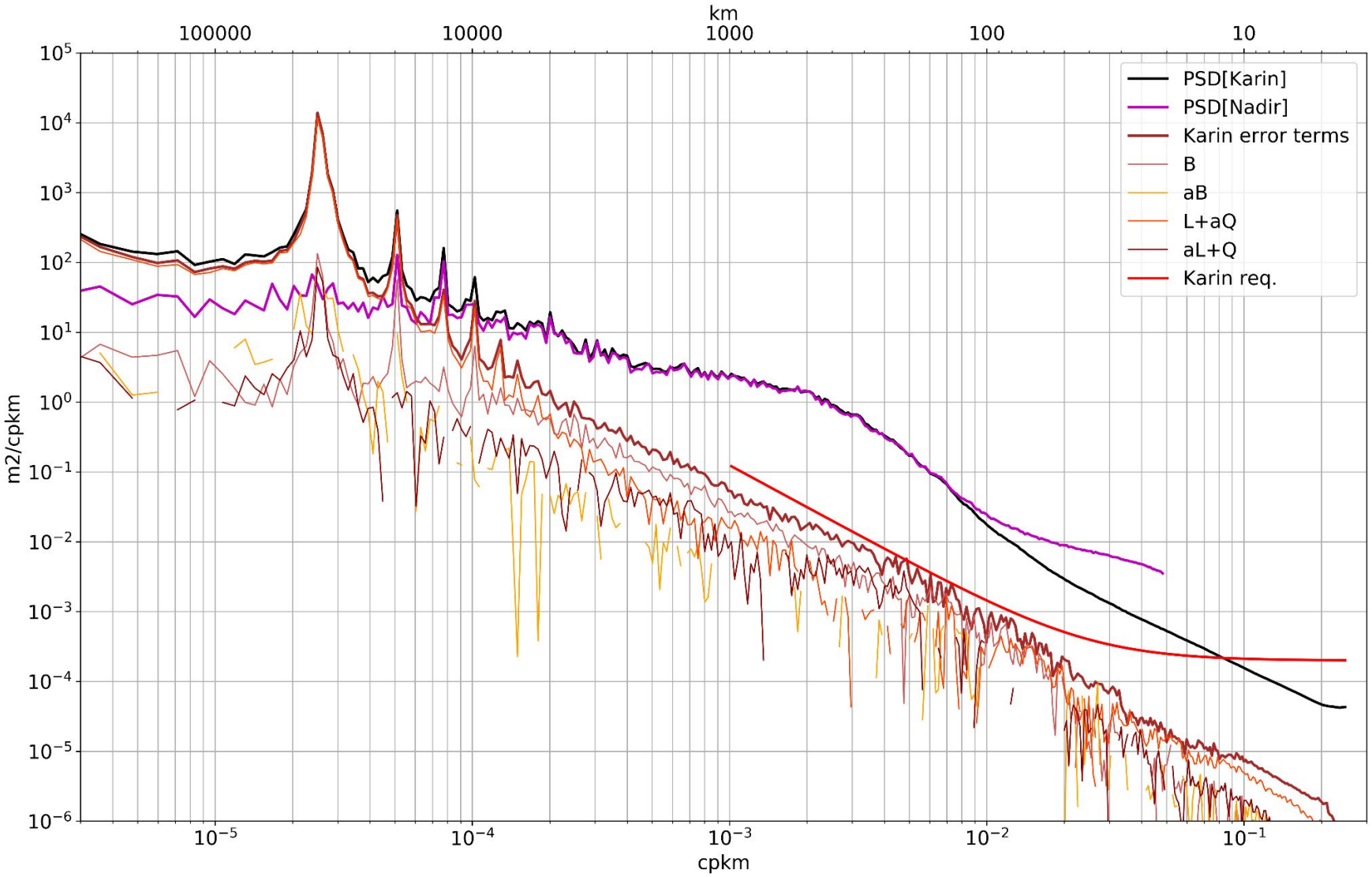



**Estimation of error spectra**




**Now applicable to real SWOT data**

# Application to the real SWOT data




Systematic errors looks near expectations (these are upper bounds and ongoing work):

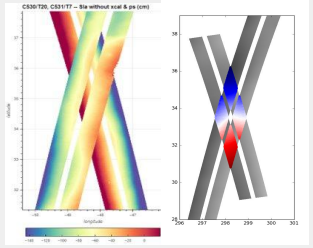
We can apply the pre-launch algorithms calibration with a good confidence

# Calibration schemes (L2 and experimental-multi-mission L3)

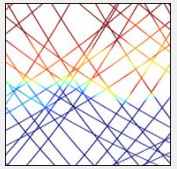
***Algorithm description in "Data-Driven Calibration Algorithm and Pre-Launch Performance Simulations for the SWOT Mission", Remote Sensing, 2022***

## Input variables of calibration

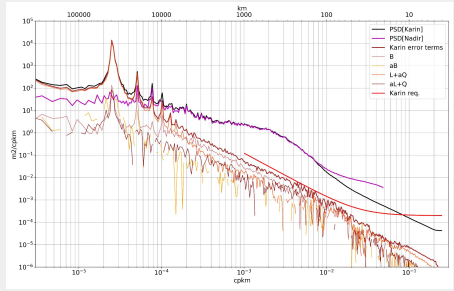
SWOT,SWOT Crossovers



Nadir altimeter constellation *(L3 only)*



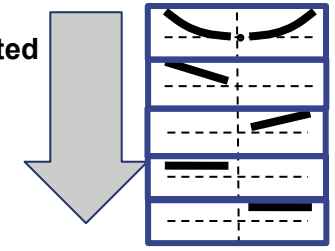
## Systematic error statistics (PSDs)



calibrated L2 : SWOT self-consistent, robust

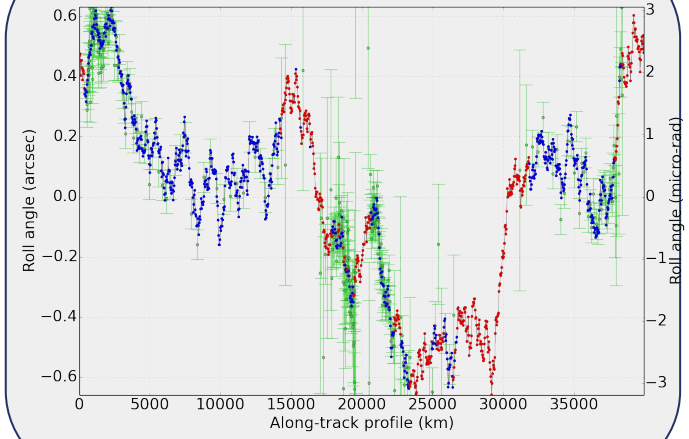
L3 : SWOT consistent with the calibrated constellation

**Local Calibrated parameters**



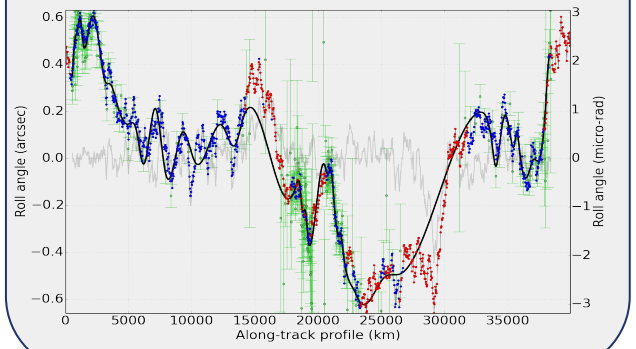
**External parameters**
Orbital-peak filters,
low-pass filter for roll,
phase, baseline dilation, …
Kalman filters (L3 only)

## Local calibration variables

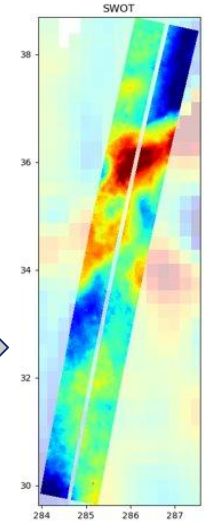



Inter(extra)polation

## Global calibration variables




Projection of corrections

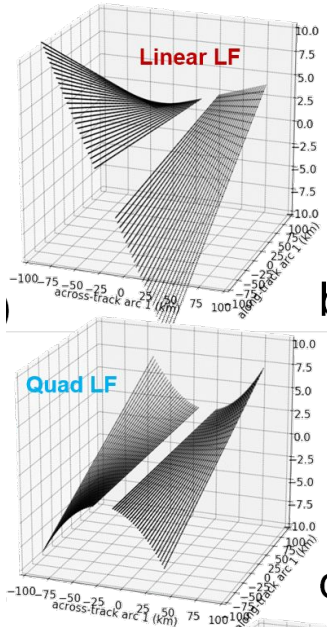


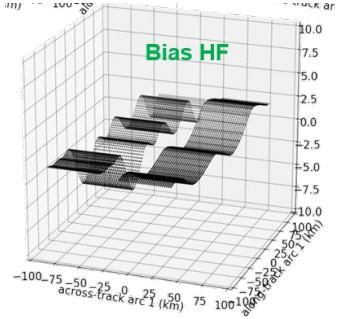

Calibrated data

# SWOT calibration : illustration

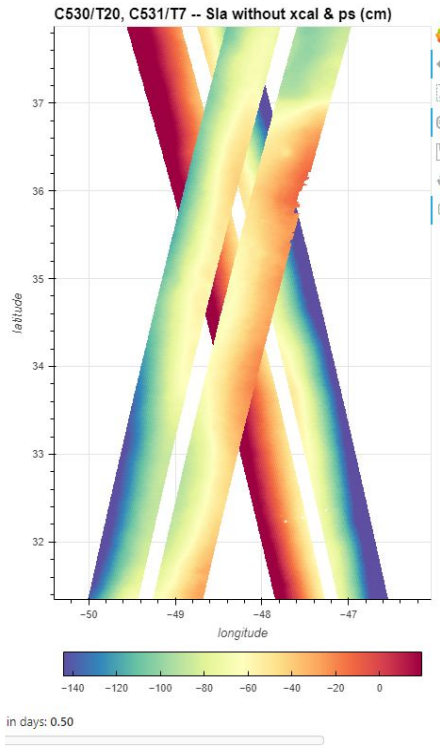
## Calibration

- Roll+phase
- Baseline dilation
- Timing
- Pseudo Phase Screen

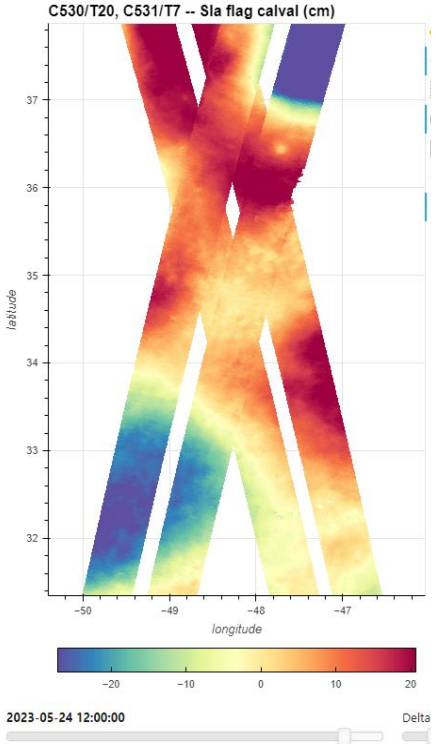


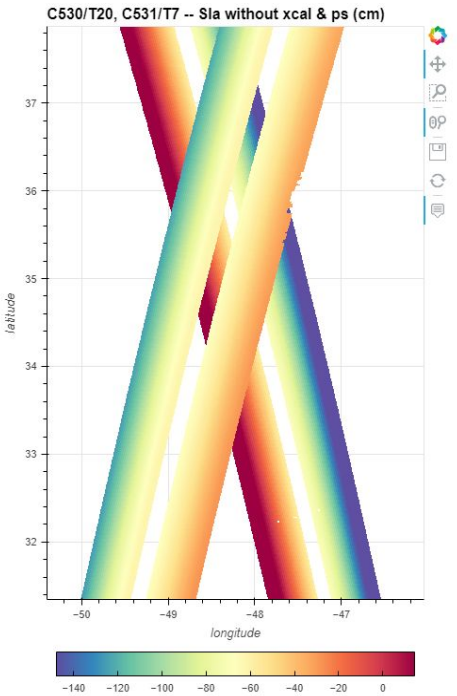

Uncalibrated SWOT L2 data




Calibrated SWOT L2 data

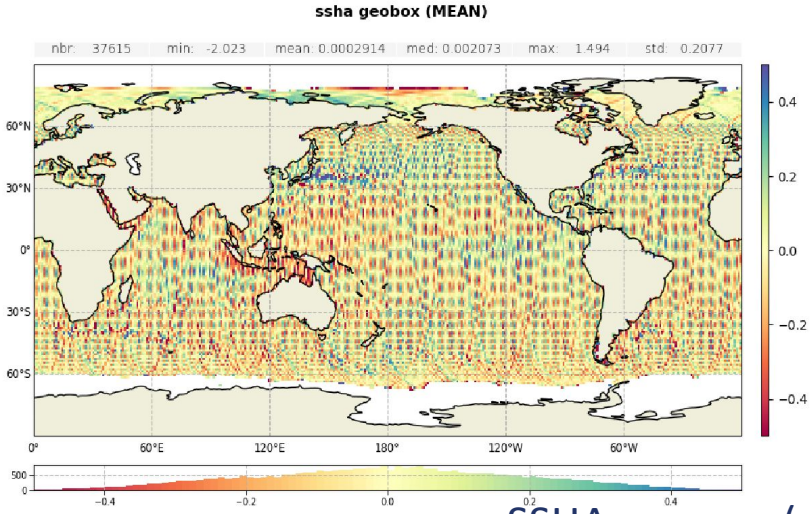


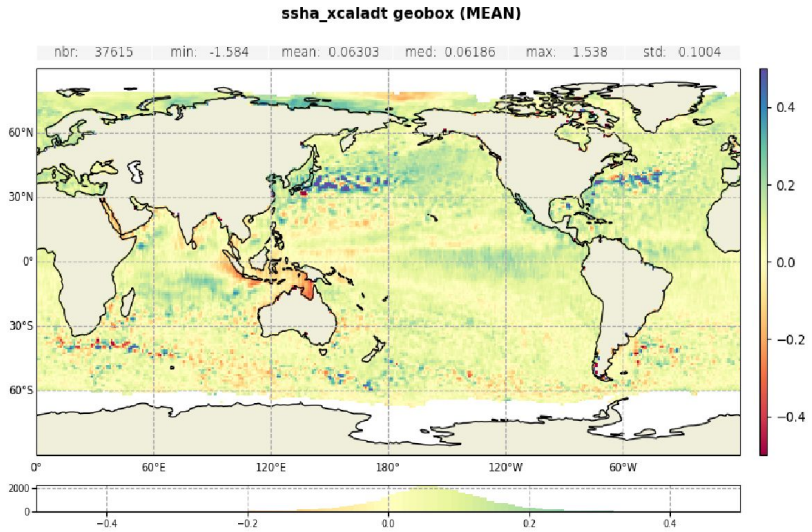

Correction signal




correction >2500km wavelength : **does not affect the Ocean short scales**

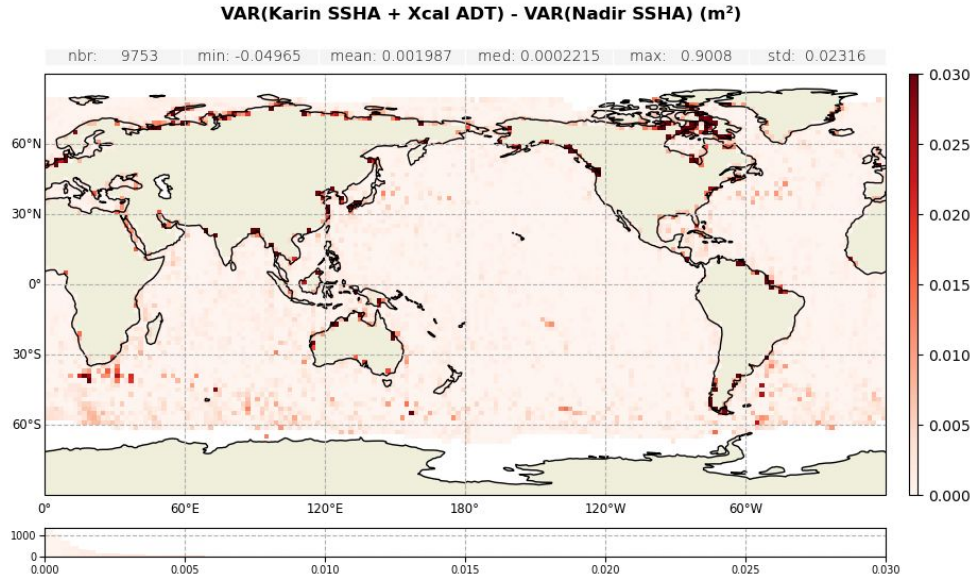
# Karin before and after calibration



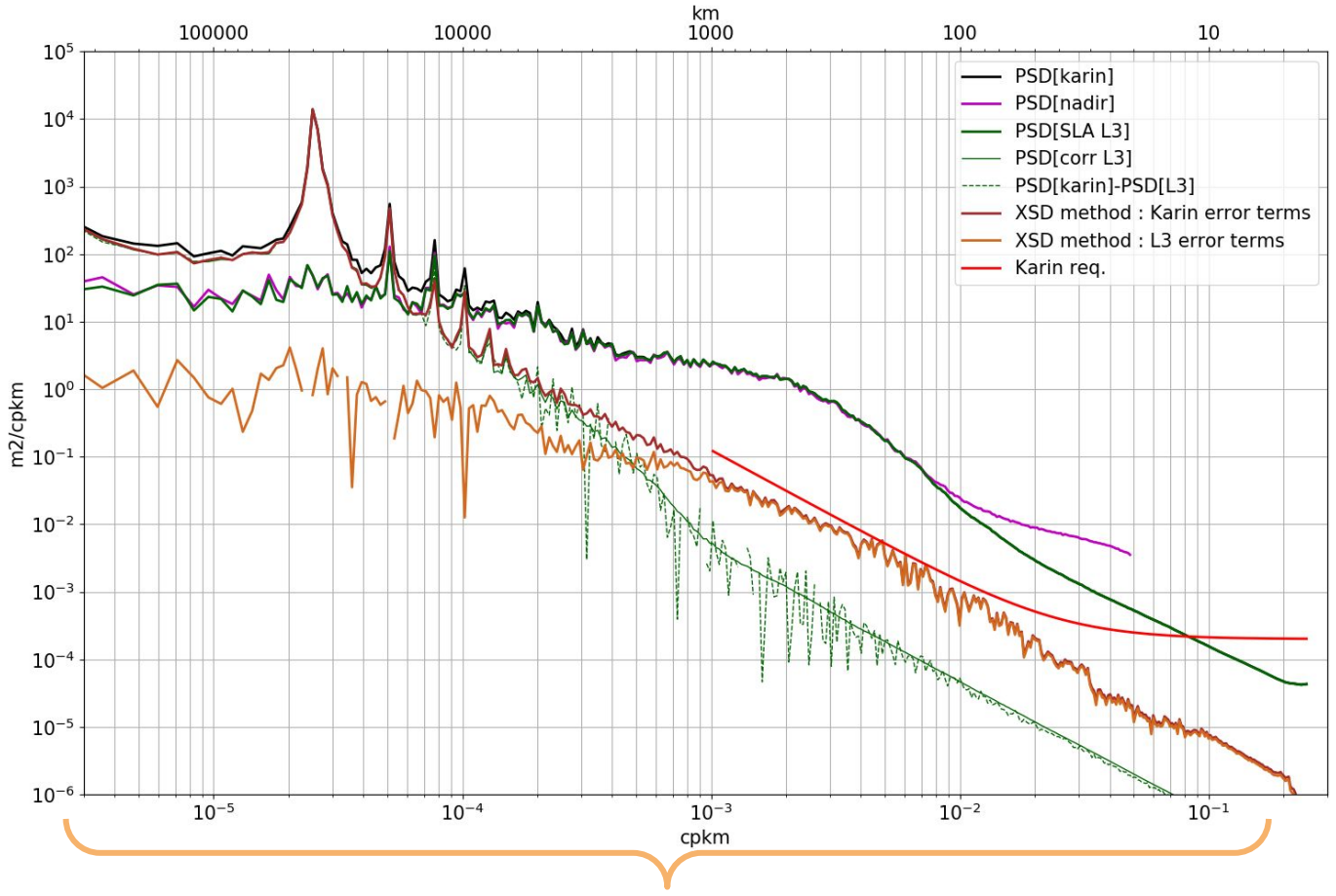




SSHA average (m) before and after calibration

**The calibrated L2 is very consistent with SWOT's nadir**



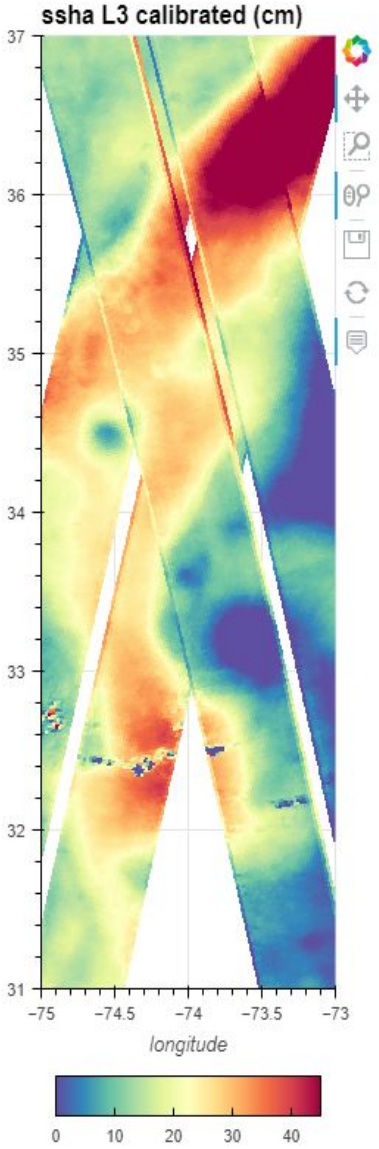
# XSD analysis on calibrated signal : estimation of residual errors



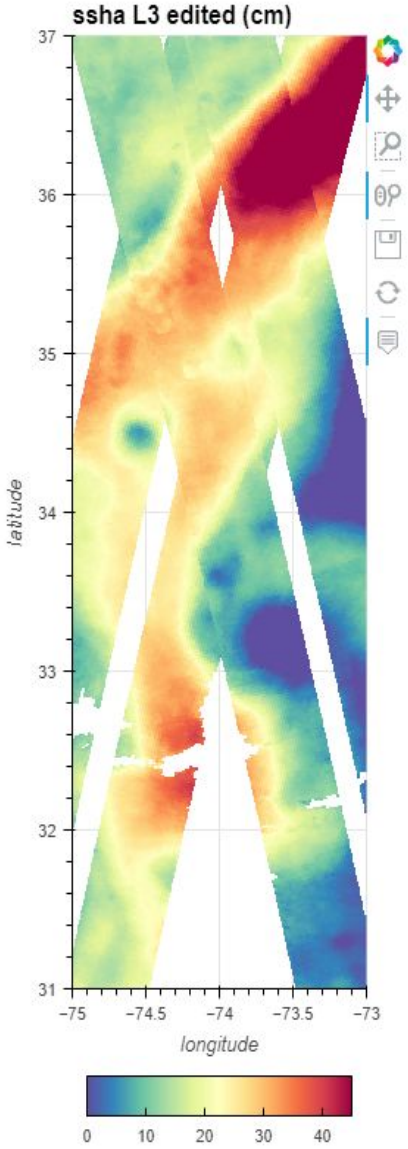

Integral of post-calibrated systematic errors : **1.96cm**

# Editing, denoising, and derived variables (L3 at the science-team level)

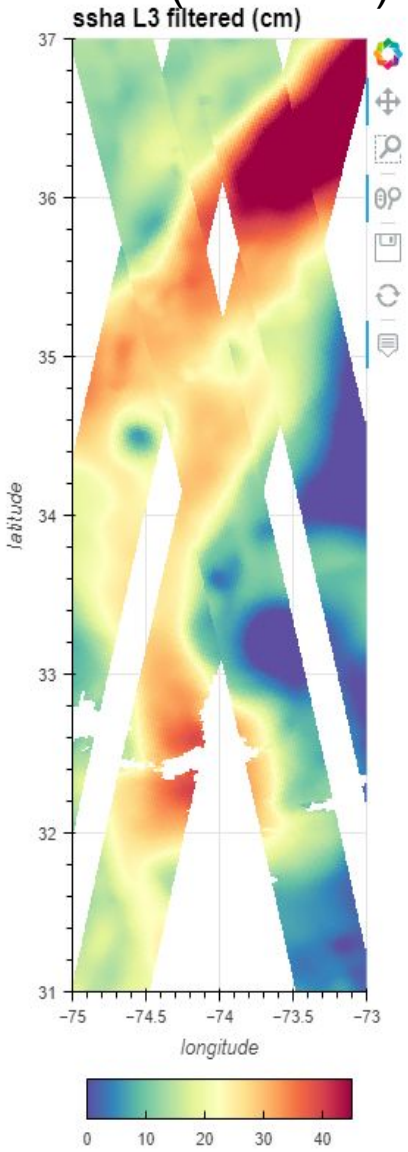
Calibrated SSHA



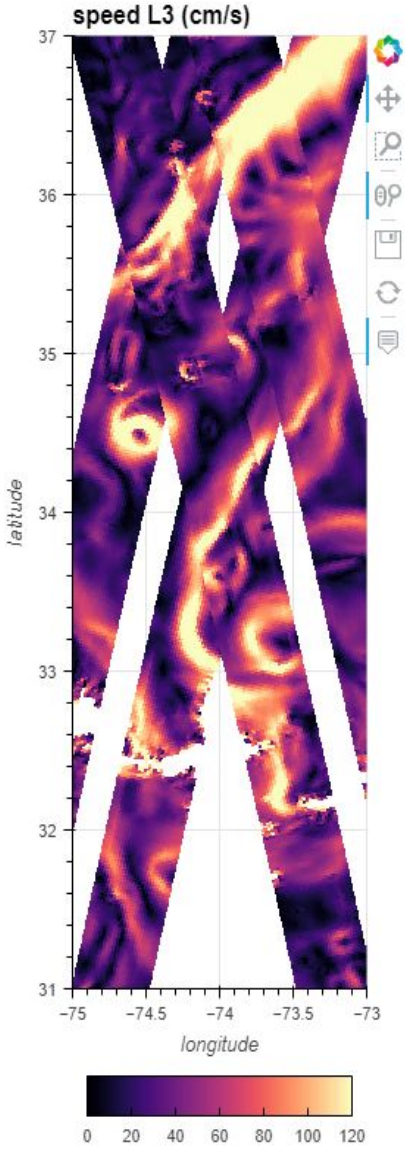

Edited SSHA



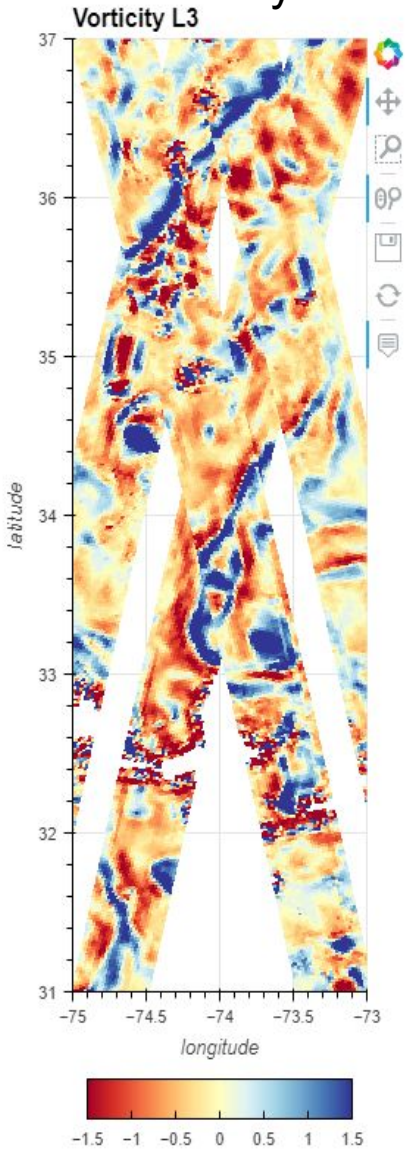

Noise-reduced SSHA (AI based)



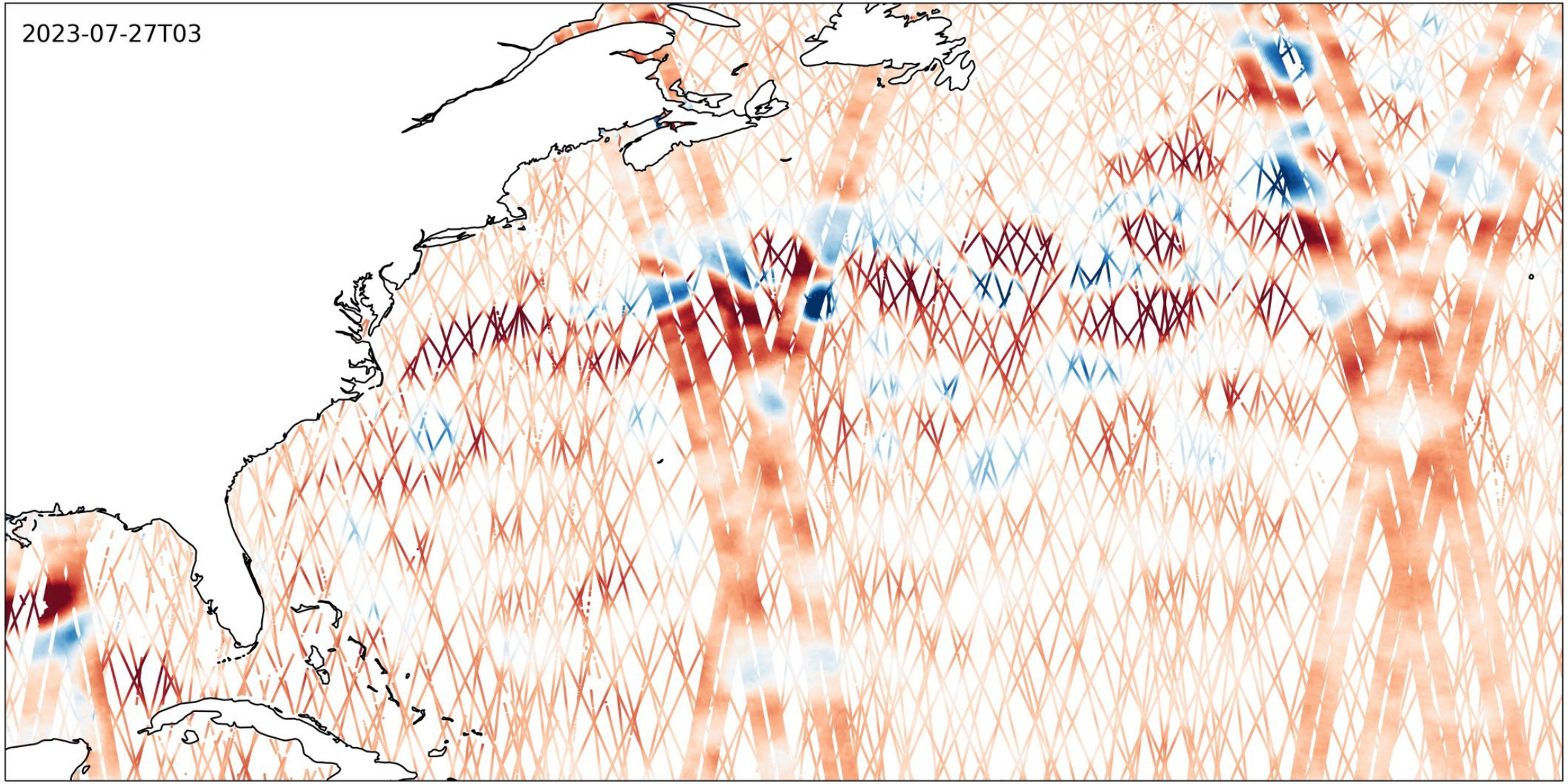

Geostrophic Velocities




Relative Vorticity



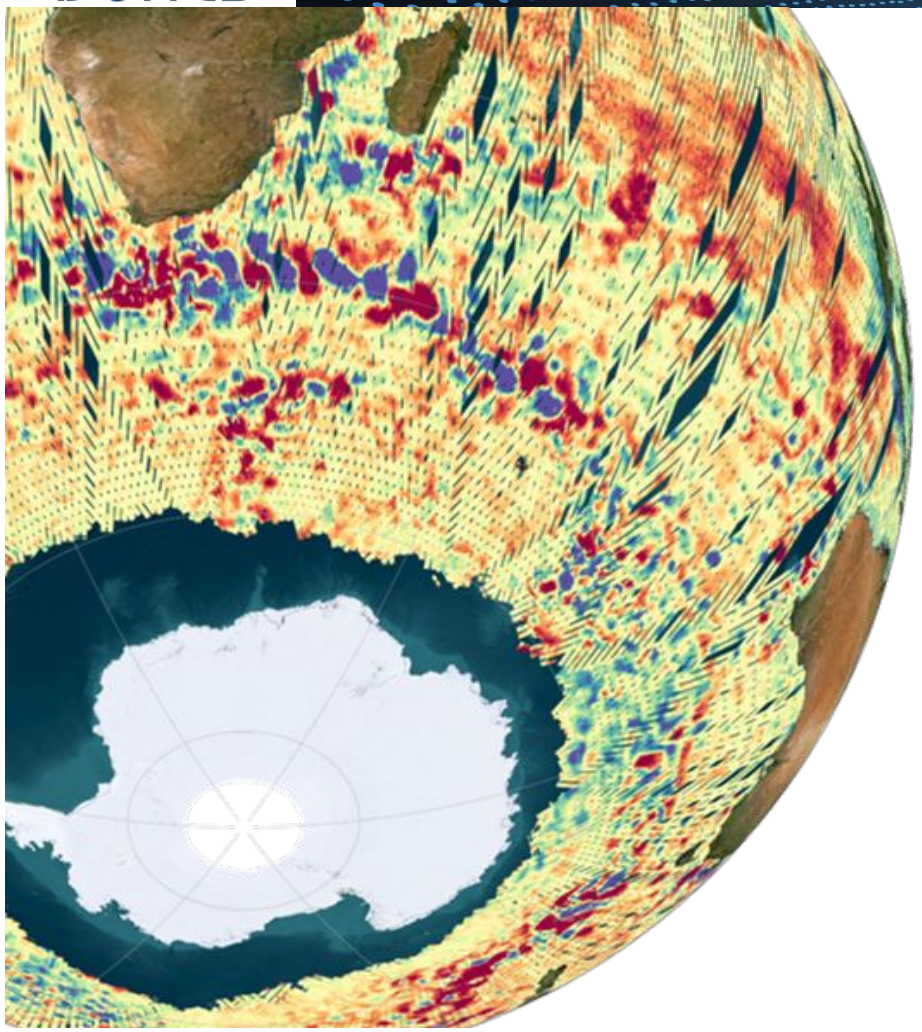
**Karin calibrated : SWOT consistency with the nadir constellation** (here with experimental L3):

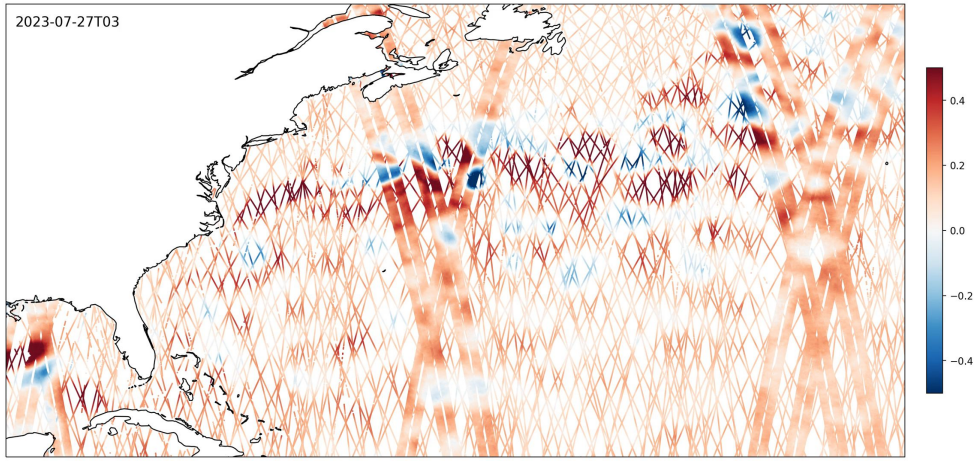



*Animation from F. Leguillou, ESA*

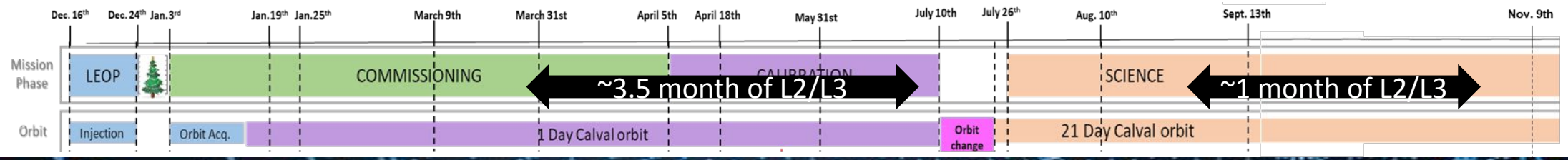
An homogeneized dataset is ready for higher level processings of the whole nadir+SWOT constellation (mesoscale mapping, data-assimilation, … see next presentation)

# Conclusions



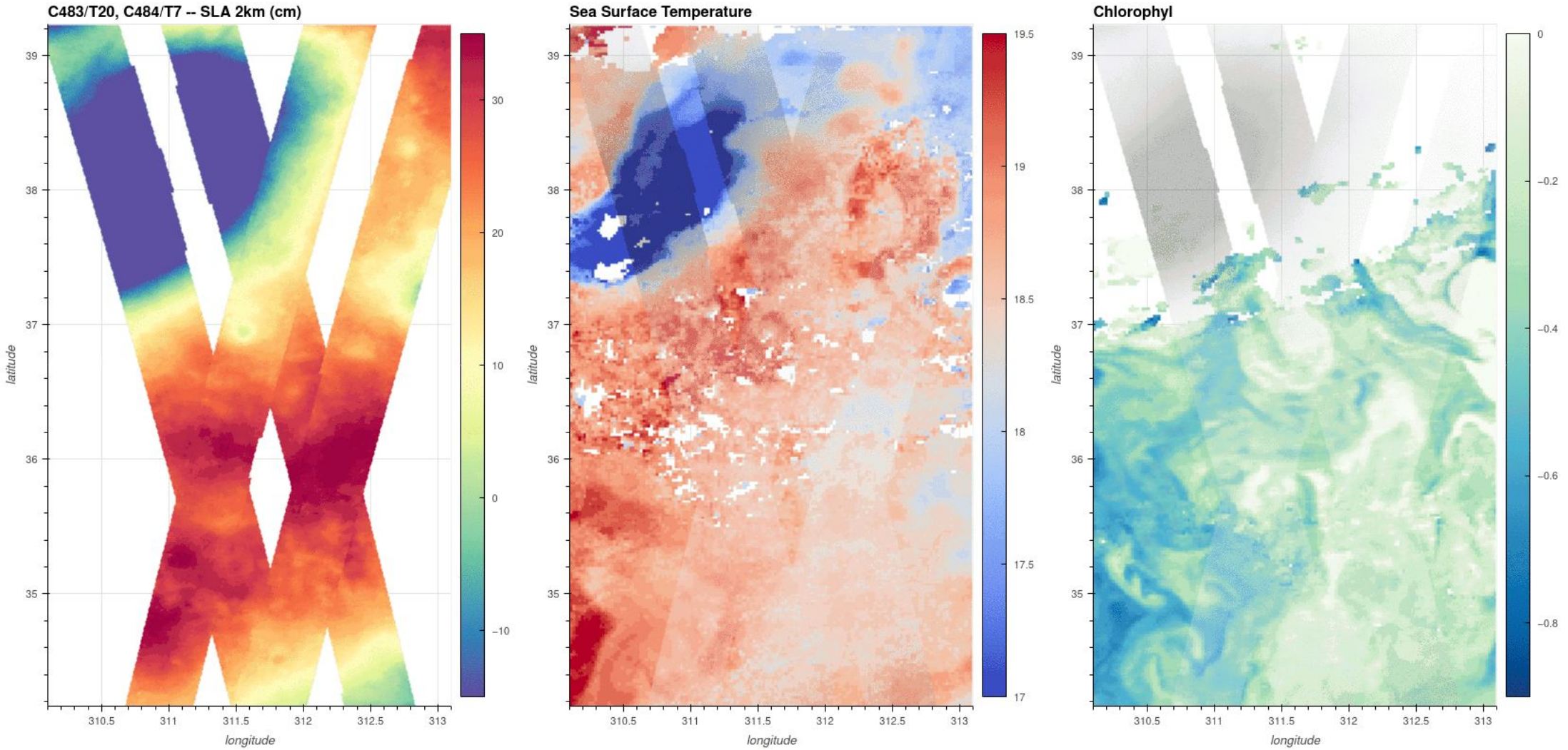



- Karin reveals short-to-sub-mesoscale eddies in motion, also many internal wave signatures, MSS signatures, …
- **SWOT Karin images can be calibrated with very good consistency w.r.t. SWOT nadir (L2) and the existing nadir constellation (experimental L3 from the cience team)** :
  →ready for high-level (mapping, data-assimilation…) applications !

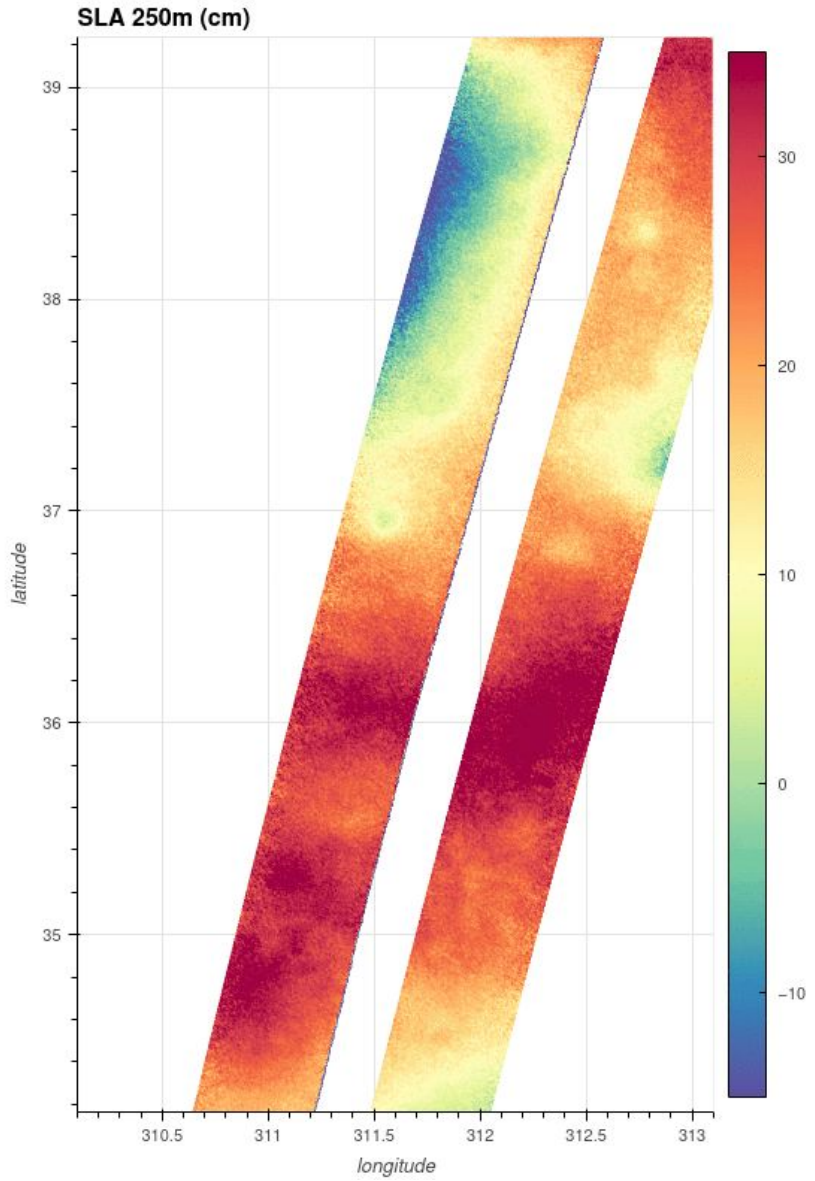


# BACKUP

# Multi-sensor comparison



# Sequences of images : an excellent qualitative validation for short mesoscales




- 15km wavelength eddies coherently moving day-to-day, advected by a larger mesoscale flow

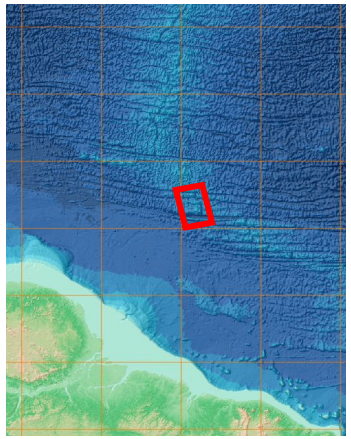
- Some additional processings (next slide) proposed to edit, denoise, ...

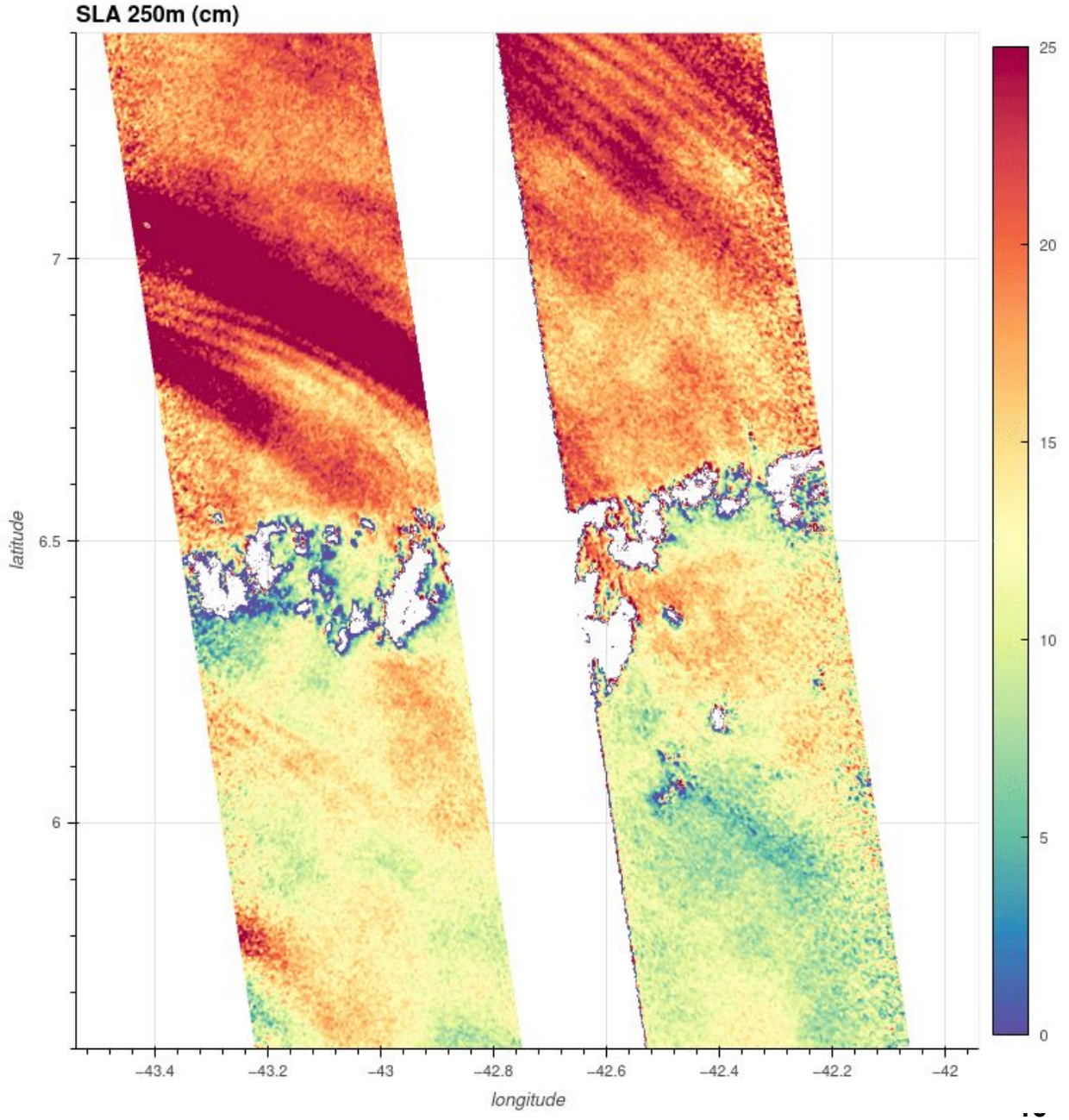
# Also Internal waves...

Multiple wavelengths (the smallest can only be seen on 250m data)

Change of dynamics/wavelengths near the end of the animation

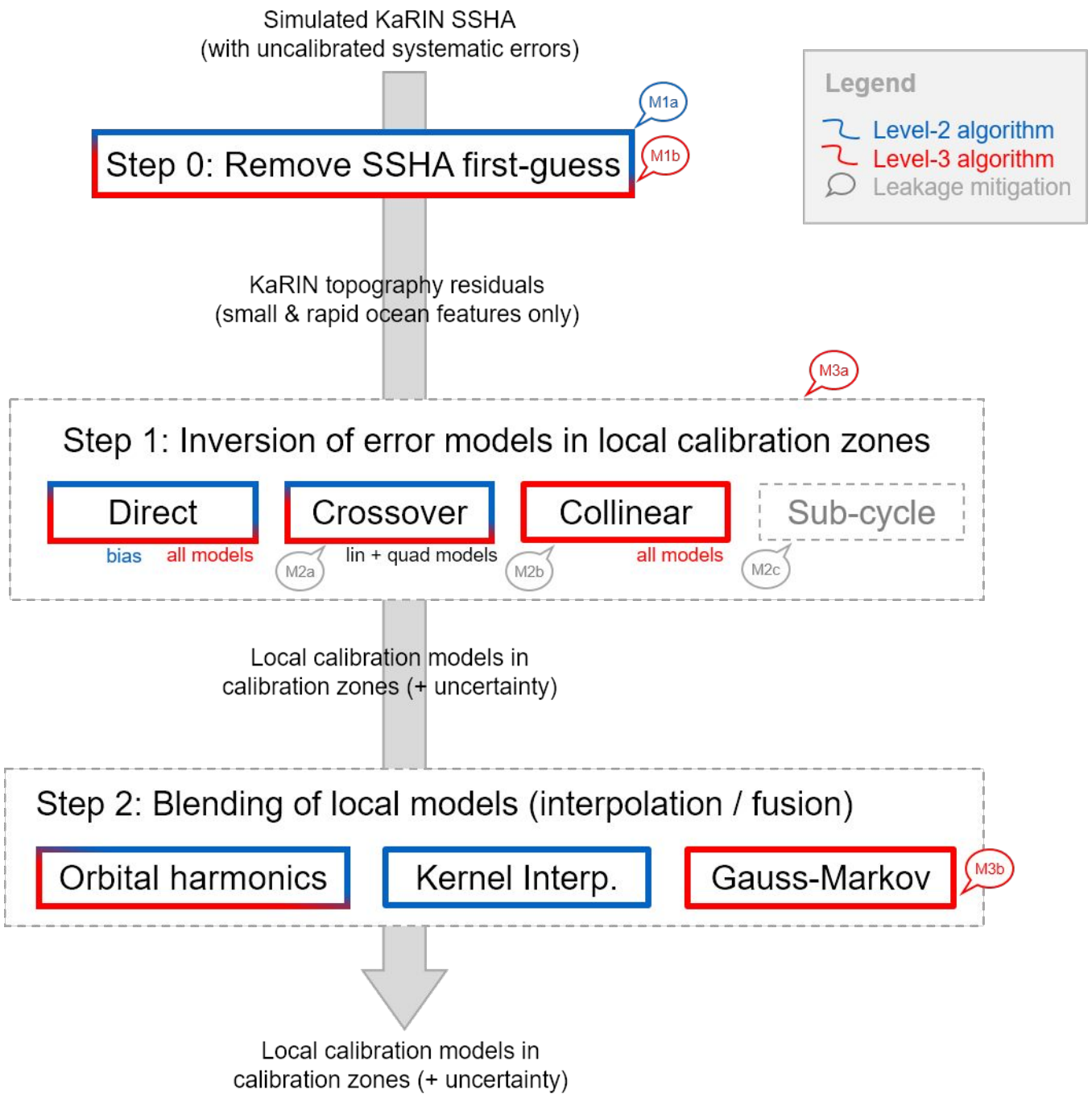
NB : the animation is reversed for convenience because IT waves are traveling backwards because of the aliasing of tidal frequencies





# Level-2 data-driven calibration (blue items)

- Step 0 & M1a: use SWOT altimeter only (SWOT must be self-sufficient)
- Step 1: use Direct for bias (w.r.t to nadir) and Crossover for other error components. Inversions done with least squares (robustness)
- Step 2: harmonic interpolator for for repeating error patterns (orbital revolution period and sub-harmonics)
- Step 2: weighted kernel smoother for broadband residual (robustness)
- The L2 sequence does not require any complex parameter (no covariance, no spectra, etc.) for the sake of robustness and simplicity

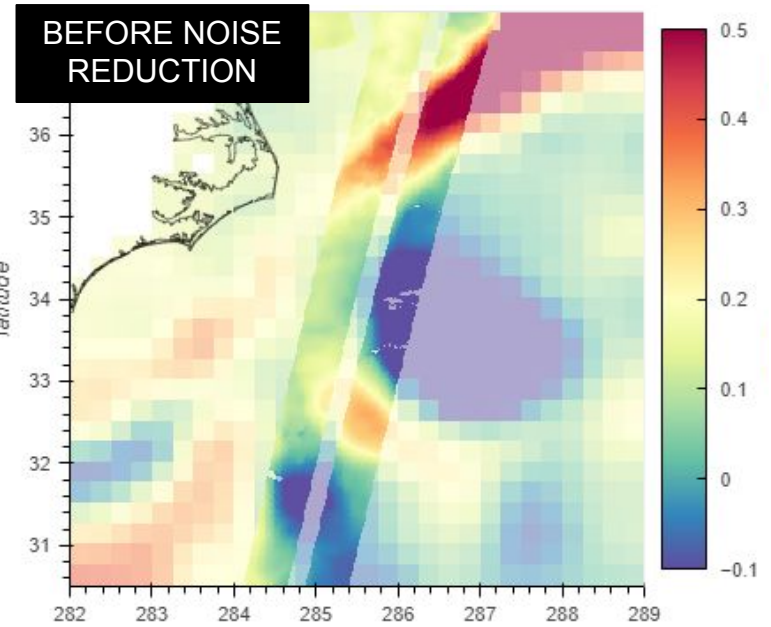


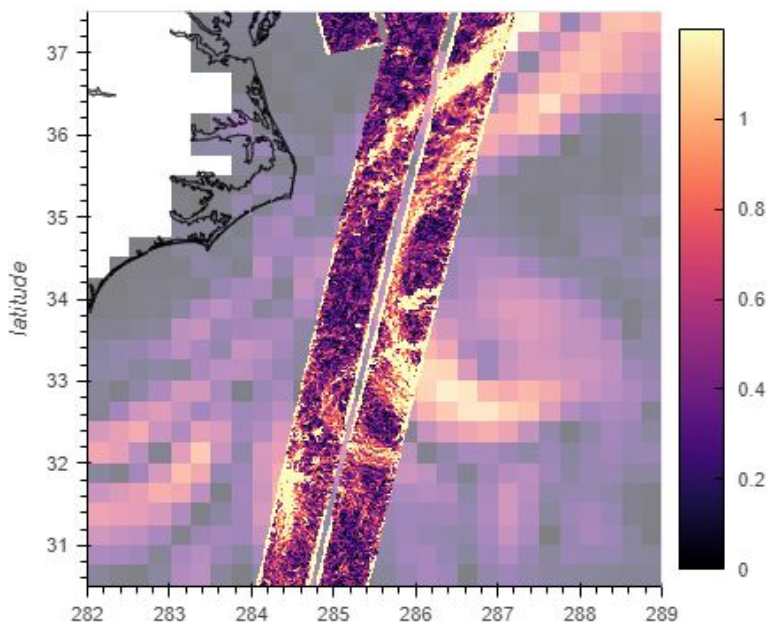
SSHA (m)

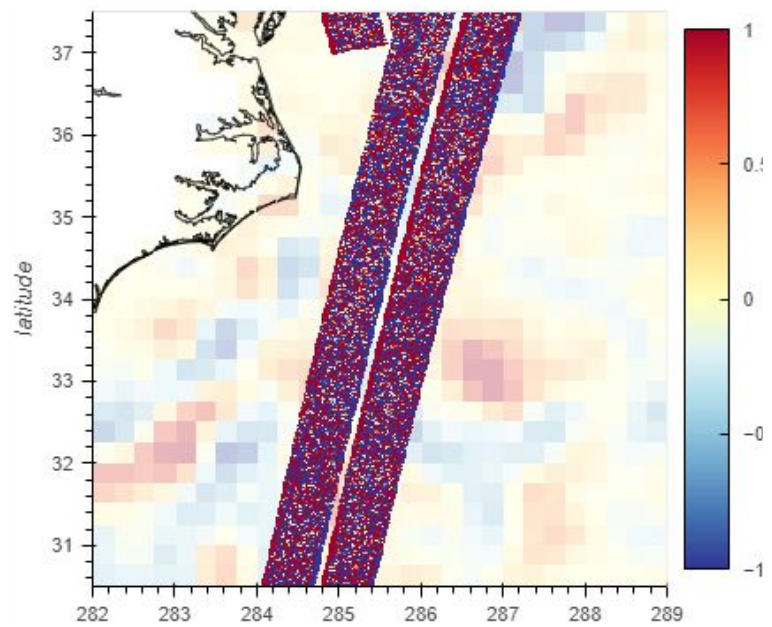
Geostrophic Velocities (m/s)

Relative Vorticity

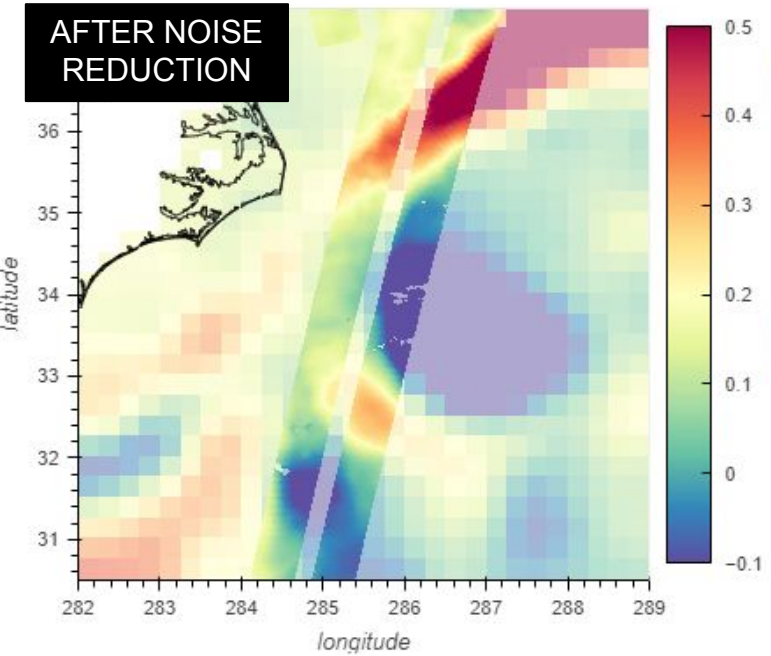
BEFORE NOISE REDUCTION

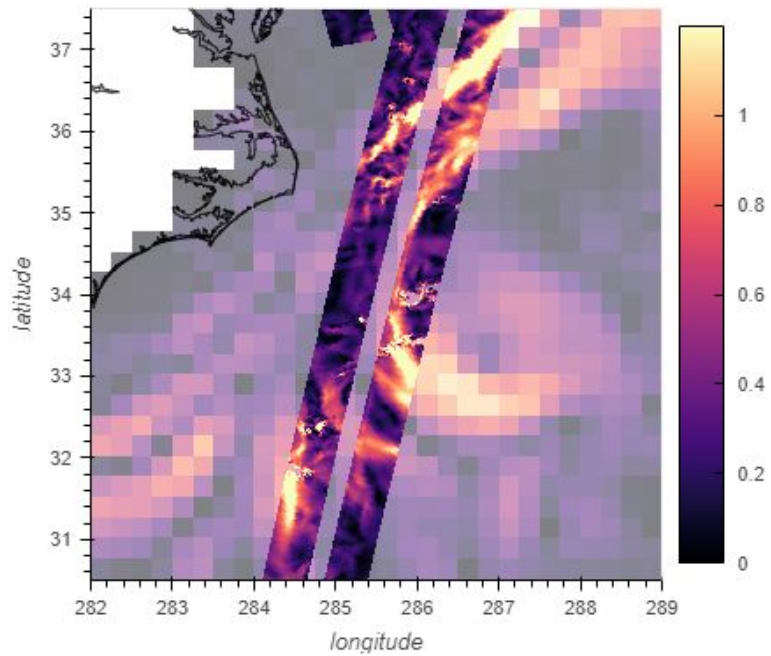


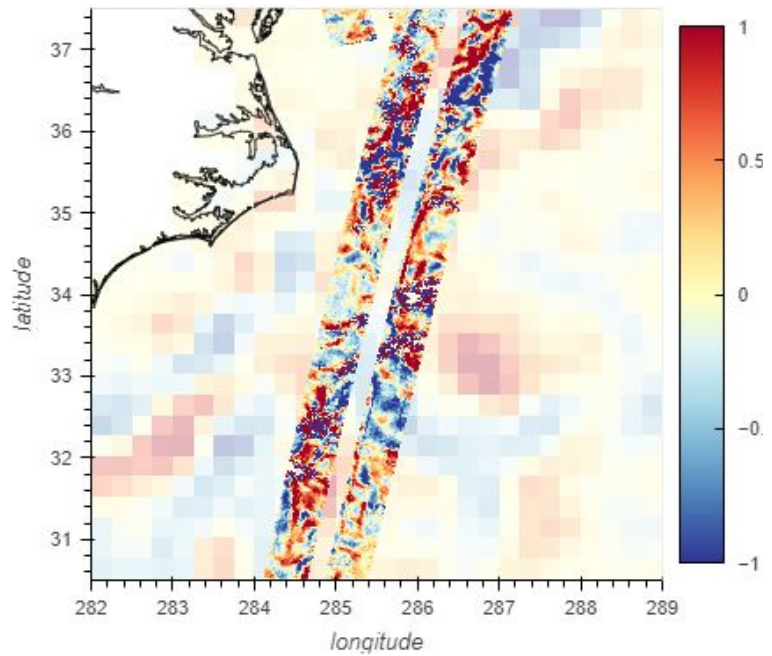



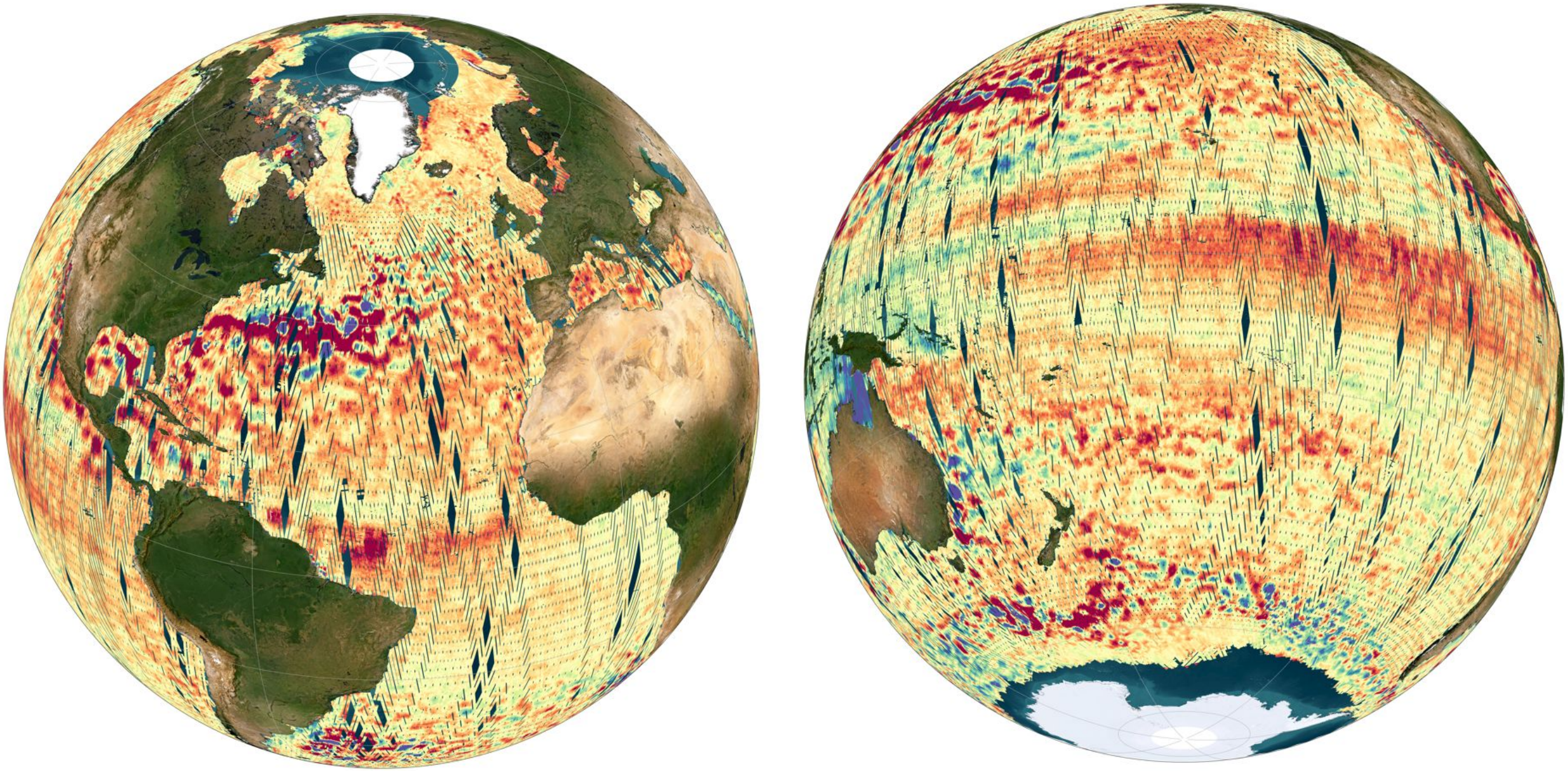

AFTER NOISE REDUCTION

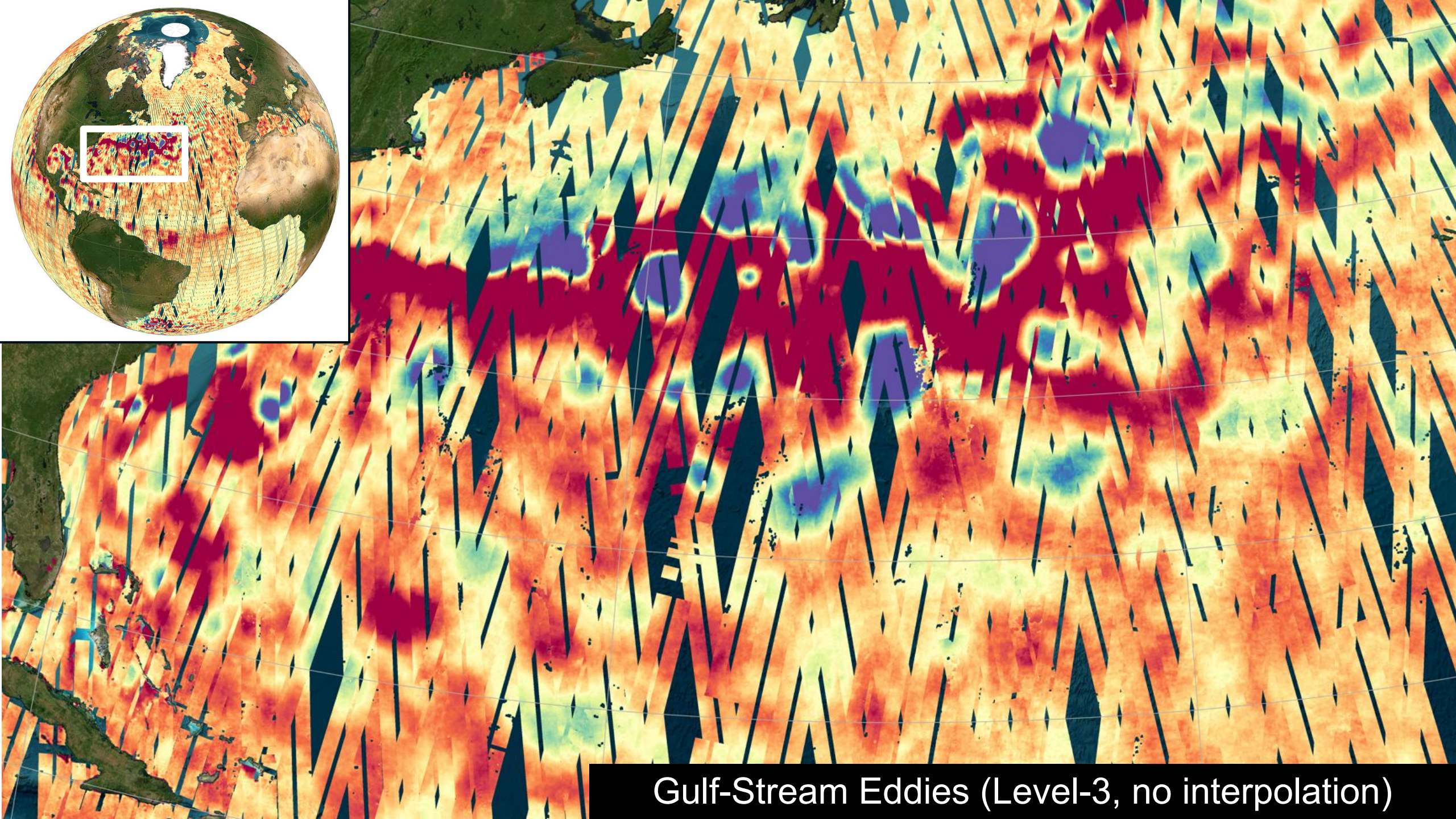


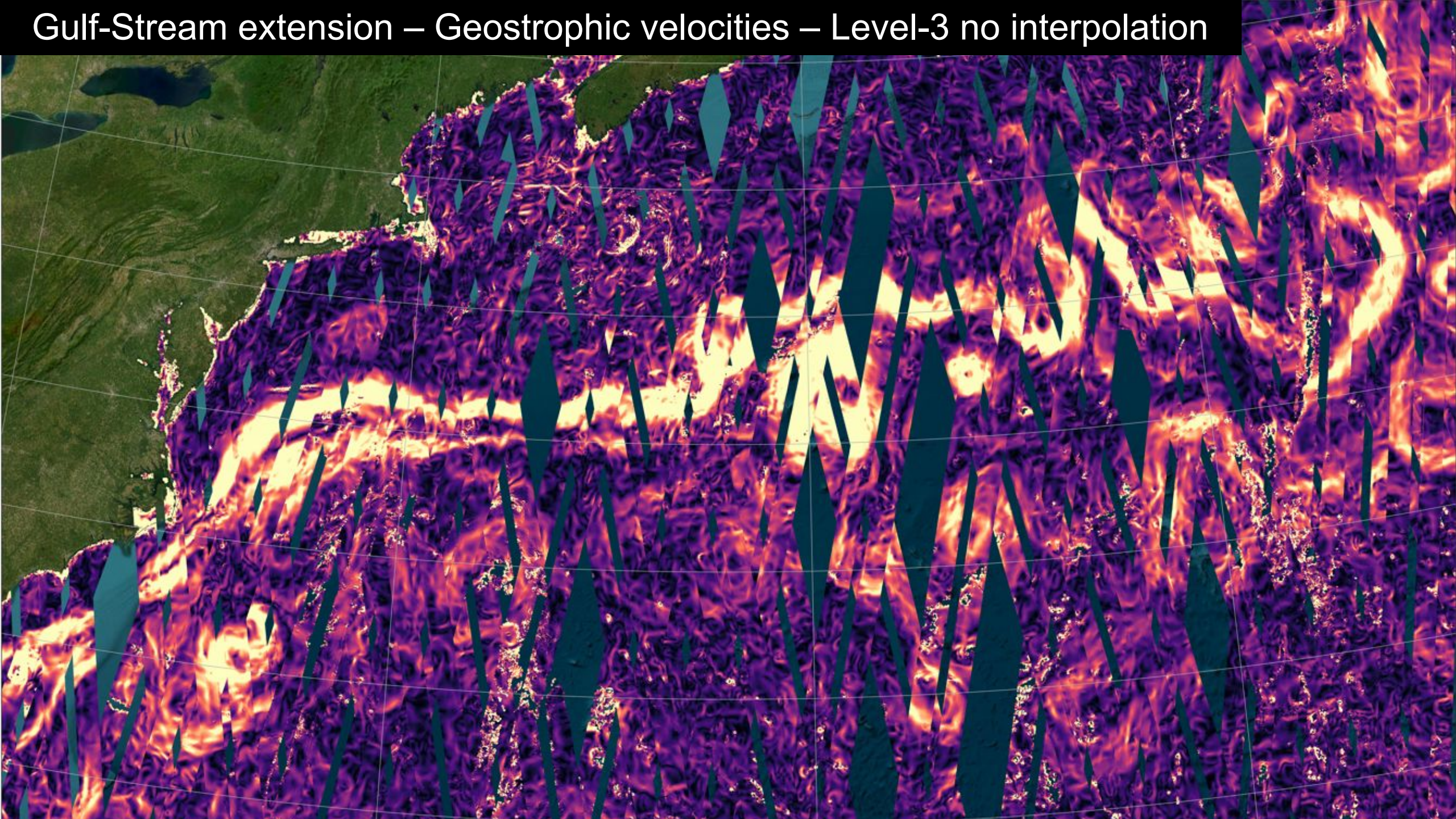



# 15 days of SWOT Level-3 SSHA (August 2023)




Gulf-Stream Eddies (Level-3, no interpolation)


Gulf-Stream extension – Geostrophic velocities – Level-3 no interpolation