SWOT TRAINING SESSION: OCEAN PRODUCTS

30 Years of Progress in Radar Altimetry Symposium

September 2-7, 2024

C. Germineaud, G. Dibarboure and the AVISO Team

CNES, Toulouse, France

Outline: SWOT Ocean Data Training Session

SWOT Low Rate (LR, Oceanography) products (40')

- Dataset overview & related applications
- Data access & usage services

Ready-to-use tutorials (Jupyter notebooks) (20')

- How to explore and manipulate SWOT LR data, etc.
- Oceanography dedicated use cases

SWOT ocean products and data usage perspectives & Questions (30')

SWOT Ocean Product Cheat Sheet

Two orbits

- Cal/Val : 1-day repeat, sparse coverage, Spring 2023
- Science : 21-day repeat, global coverage, since Aug 2023

Two instruments

- Old-school 1D nadir altimeter (Jason-class)
- KaRIn 2D interferometer

Two timeliness levels

- Near Real Time (3 hours to 3 days)
- Reprocessed Data (more precise than NRT)

Two resolutions

- Ocean @ 250-m to 2-km: Low Resolution
- Hydrology @ 10 to 60 m: High Resolution

Versions released

- Version B (Nov 23) : beta release for early CalVal evaluation
- Version C (March 24) : first "science" release
- Version C declared as validated by the SWOT Project (Aug 24)

Low Rate (Ocean) Product Levels

Level-1B LR
(interferograms)

↓

Level-2 Unsmoothed
(250m, technical)

↓

Level-2 Basic & Expert
(2-km, accessible)

↓

Level-3
(250-m & 2-km, simple,
new geophysical standards,
multi-mission calibrated)

SWOT Ocean Products: an overview

SWOT Level-2 Ocean Products

- Nadir Altimeter and Radiometer (O/I)GDR products (similar to Jason-2/3)
- KaRIn L2_LR_SSH (2km & 250m)

KaRIn L2_LR_SSH	Grid	Volume /day - /year
Basic SSH ['Basic']	2km geographically fixed swath-aligned grid	< 1GB – 365 GB
Wind and Wave ['WindWave']	2km geographically fixed swath-aligned grid	< 1GB – 365 GB
Expert SSH with Wind and Wave ['Expert']	2km geographically fixed swath-aligned grid	1GB – 365 TB
Unsmoothed SSH ['Unsmoothed']	250m sampling grid	< 25 GB – 10 TB

SWOT KaRIn Level-2 Ocean L2_LR_SSH Products

Accuracy →
Latency →

Data sets	OGDR	IGDR	GDR
Reduced 1 Hz	OGDR-SSHA	IGDR-SSHA	GDR-SSHA
1 Hz + 20 Hz	OGDR	IGDR	GDR
1 Hz + 20 Hz + waveforms	Not generated	S-IGDR	S-GDR
Latency	3-5 hours	1-2 days	~90 days

Size and Complexity ↓

SWOT Nadir Altimeter Level-2 products

SWOT Level-3 Ocean Products (2km & 250m)

- Level-3 (KaRIn & Nadir) Basic 2km Product (SSHA and MDT only)
- Level-3 (KaRIn & Nadir) Expert 2km Product (unedited SSHA + all calibration/corrections and geostrophic velocity anomaly)
- Level-3 (KaRIn only) Unsmoothed 250m Product

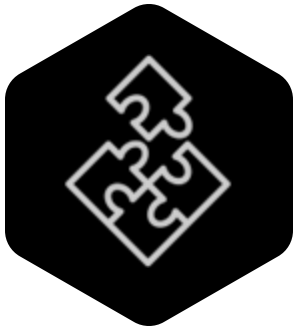
Level-4 Ocean Multi-Mission Products

- Using SWOT Level-3 (KaRIn & Nadir) + CMEMS L3 along-track datasets

Context : KaRIn Level-3 altimeter products

For ocean applications

- L3 along-track/swath: calibrated with other missions
- L4 gridded: merging measurements from different missions



Complementary to the L2 products

- L2 LR product (2km & 250m) used upstream
- Evolves quickly to use state-of-the art R&D

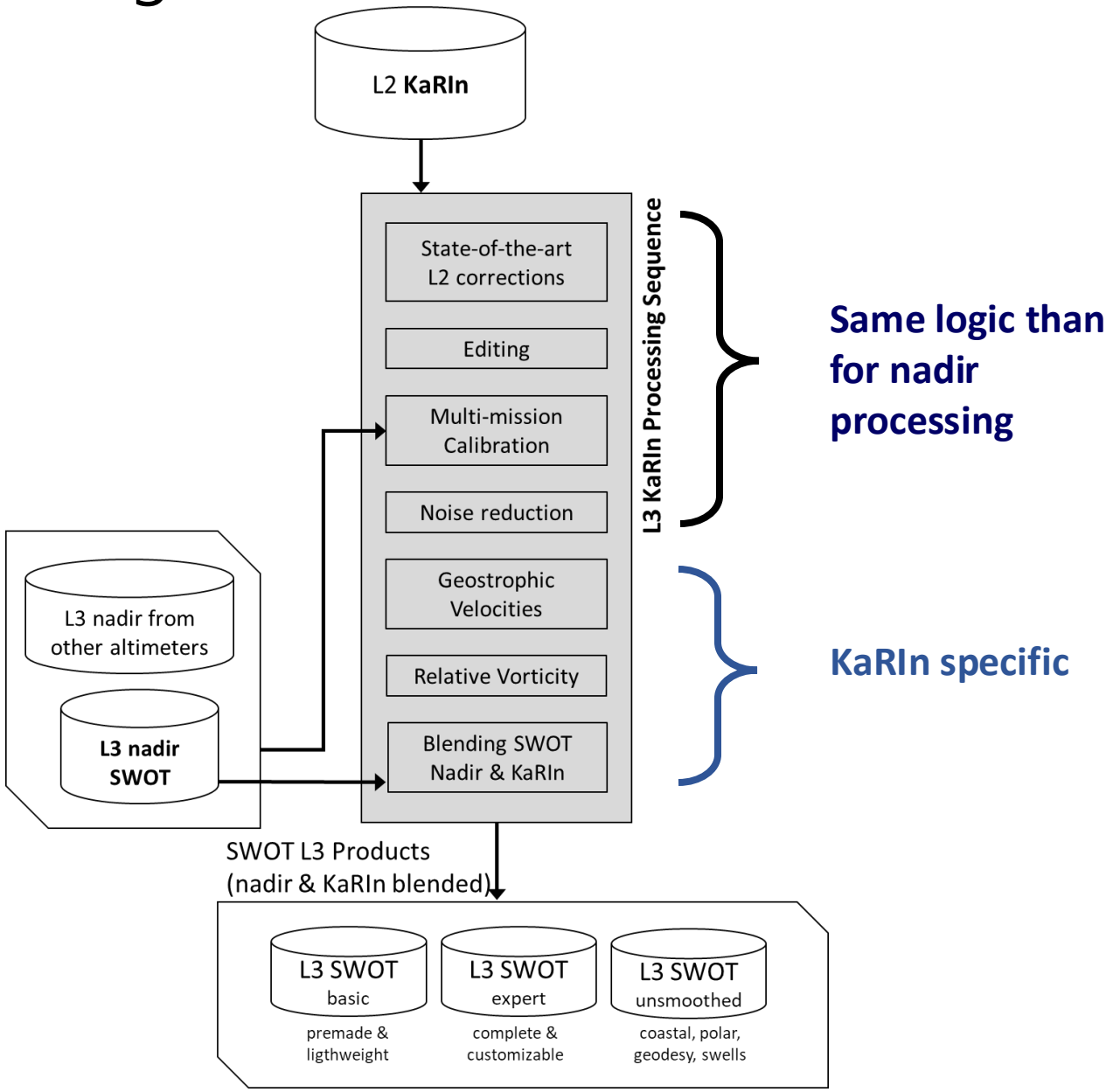
Serve a large community

- Flexible to the needs of different communities (SWOT-ST, OSTST, …)
- Consistent with other nadir products (DUACS)
- Available in DT & NRT

Credits: G. Dibarboure (CNES) & M.I. Pujol (CLS)

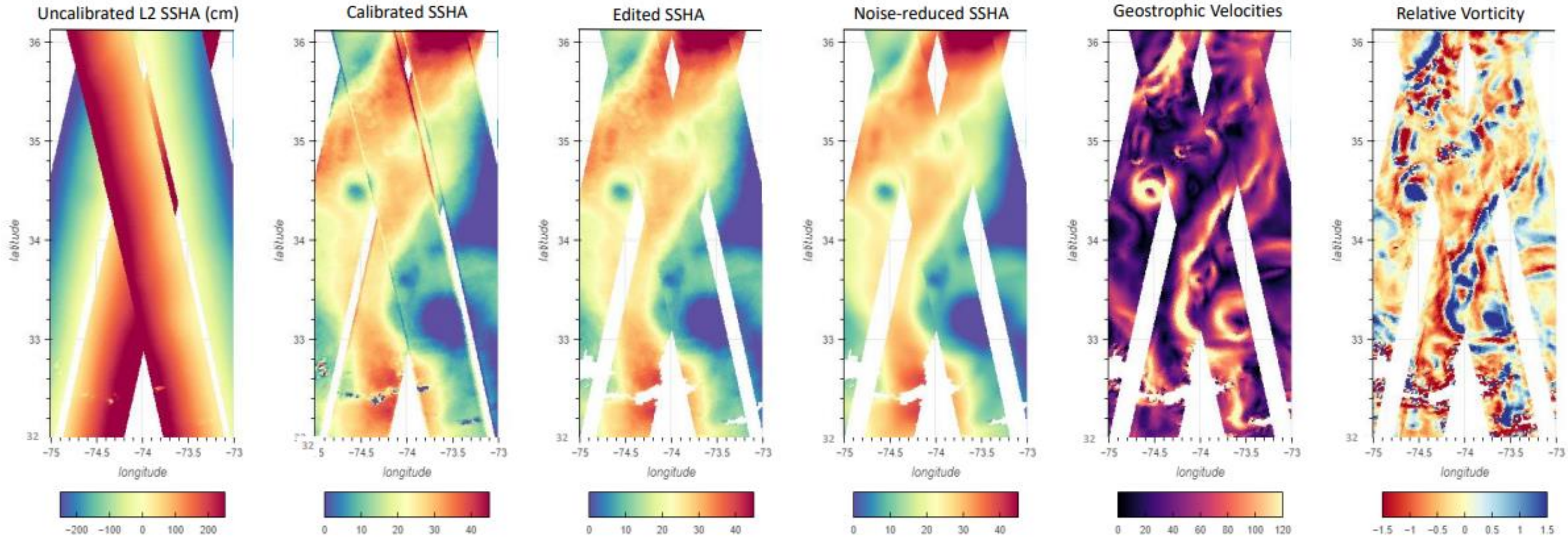
Level-3 KaRIn processing sequence

- Uses L3 from upstream nadir altimeters
- Follow nearly the same sequence than for nadir processing



Credits: G. Dibarboure (CNES) & M.I. Pujol (CLS)

Level-3 KaRIn end-to-end example



Credits: G. Dibarboure (CNES) & M.I. Pujol (CLS)

- Small mesoscales remain visible in Level-3 SSHA
- Denoising allows access to a first raw estimate of geostrophic currents & vorticity
- /!\ Denoising is likely to smooth out submesoscale physical features

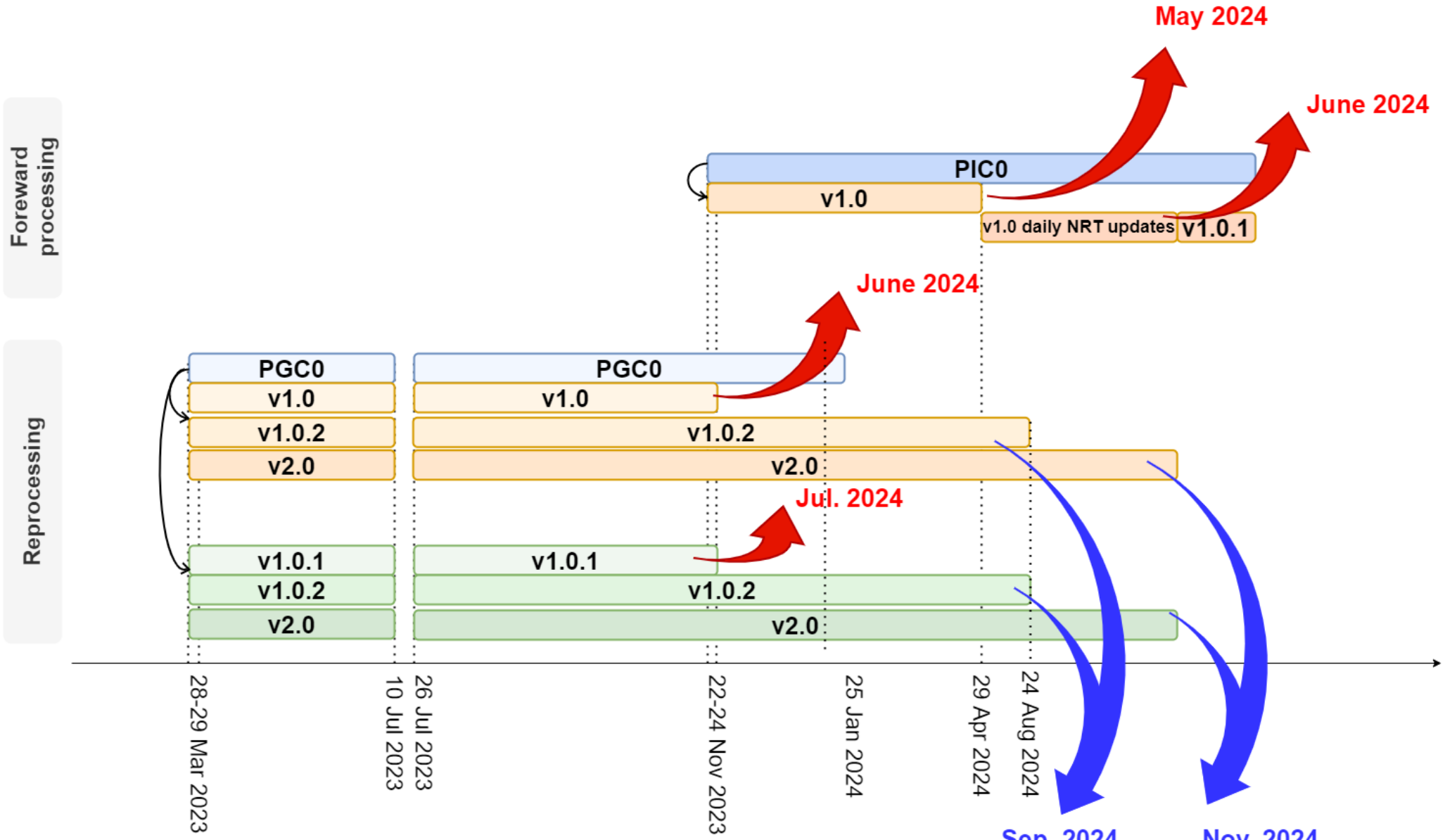
Level-3 KarRIn: Standards & Corrections

	Level-3 SWOT KaRIn v0.3	Level-3 SWOT KaRIn v1.0
Product standard ref	PIA1 before 2023/09/06; PIB0 between 2023/09/06 and 2023/11/20; PIC0 after	PGC0 before 23/11/2023 PIC0 after
Orbit	MOE-F	POE-F until 30/04/2023 MOE-F after
Ionospheric	GIM model computed from vertical Total Electron Content maps (Chou et al. 2023) rescaled on the orbit altitude with IRI95 model (https://irimodel.org/)	
Wet troposphere	Model computed from ECMWF Gaussian grids	
Sea State Bias	Non-parametric SSB from AltiKa GDR-F (Tran 2019)	
Mean Profile/ Mean Sea Surface	Hybrid MSS (SIO22,CNES/CLS22,DTU21) (Schaeffer et al. 2023; Laloue et al., s. d.)	
Mean Dynamic Topography	MDT CNES_CLS_2022 (Jousset et Mulet 2020; Jousset et al. 2022) available on AVISO+ (https://doi.org/10.24400/527896/a01-2023.003)	
Dry troposphere	Model computed from ECMWF Gaussian grids (new S1 and S2 atmospheric tides are applied)	
DAC	DAC v4.0: TUGO forced with ECMWF pressure and wing fields (S1 and S2 were excluded) + inverse barometer computed from rectangular grids	
Ocean tide	FES2022: (Lyard et al. 2023; Loren Carrère et al. 2023)	
Internal tide	(Zaron 2019)(HRETv8.1 tidal frequencies: M2, K1, S2, O1)	
Pole tide	(Desai, Wahr, et Beckley 2015)& Mean Pole Location	
Solid earth tide	Elastic response to tidal potential (Cartwright et Edden 1973; Cartwright et Tayler 1971)	
Loading tide	FES2022: (Lyard et al. 2023; Loren Carrère et al. 2023)	

- Some standards are specific to the L3
- The quality of some corrections have a significant impact on KaRIn L3 product quality
- Some standards are susceptible to change from a L3 version to the other

Credits: G. Dibarboure (CNES) & M.I. Pujol (CLS)

Level-3 KaRIn products versions (2023-2024)

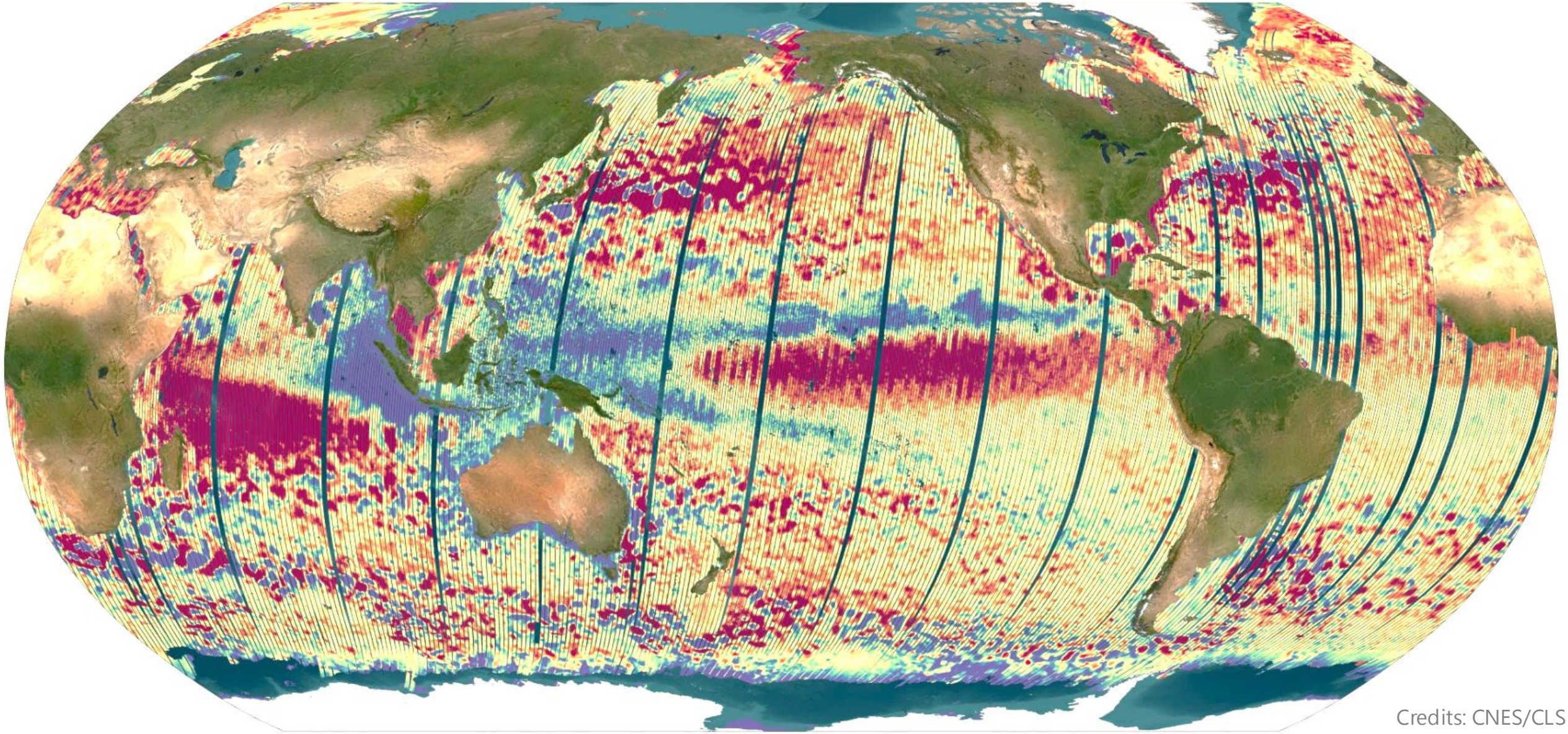


Product version

- L2_LR_SSH
- L3_LR_SSH 2km
- L3_LR_SSH 250m

Ocean circulation: First results

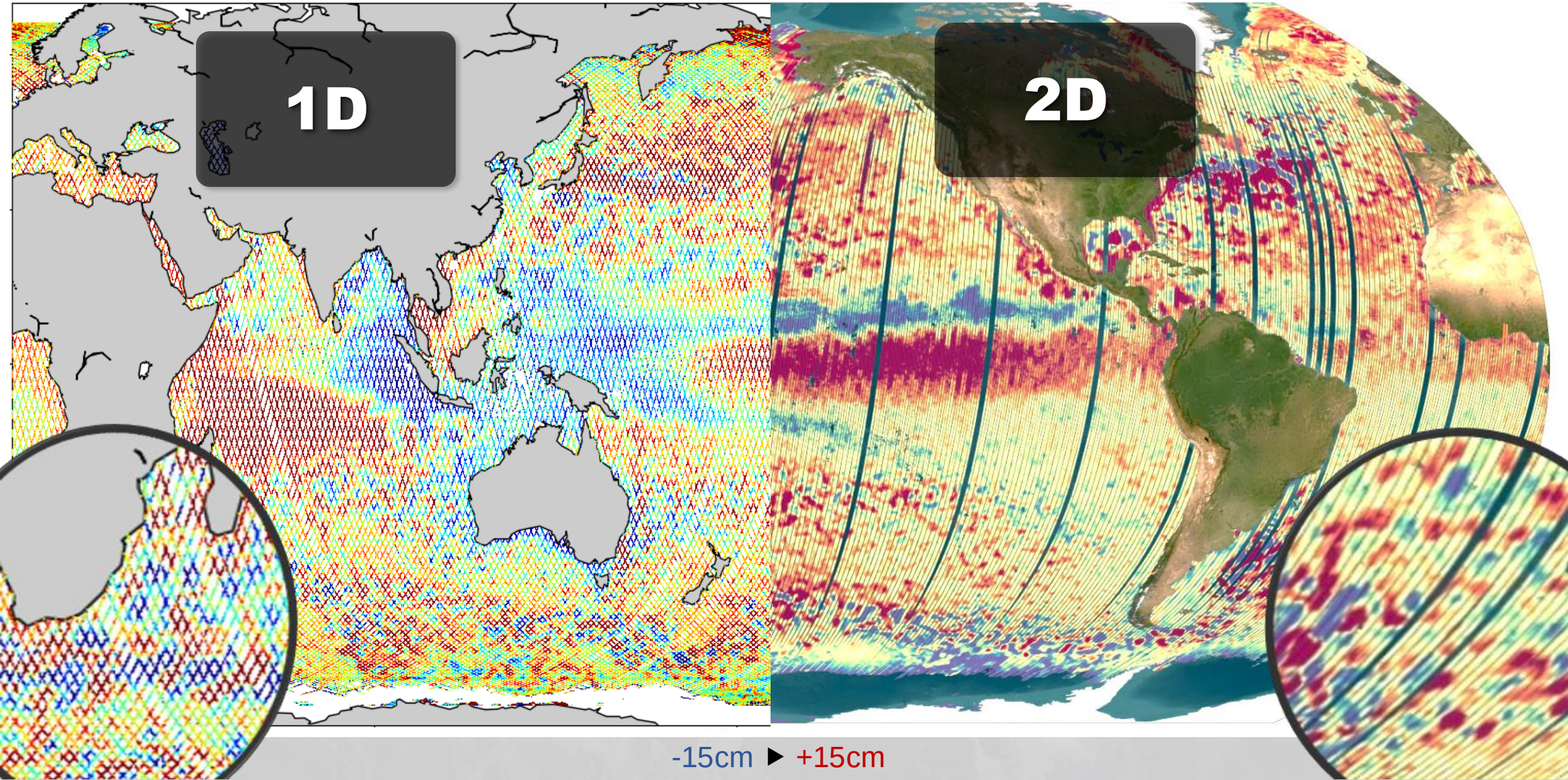
Ten days worth of SSHA in November 2023 from SWOT

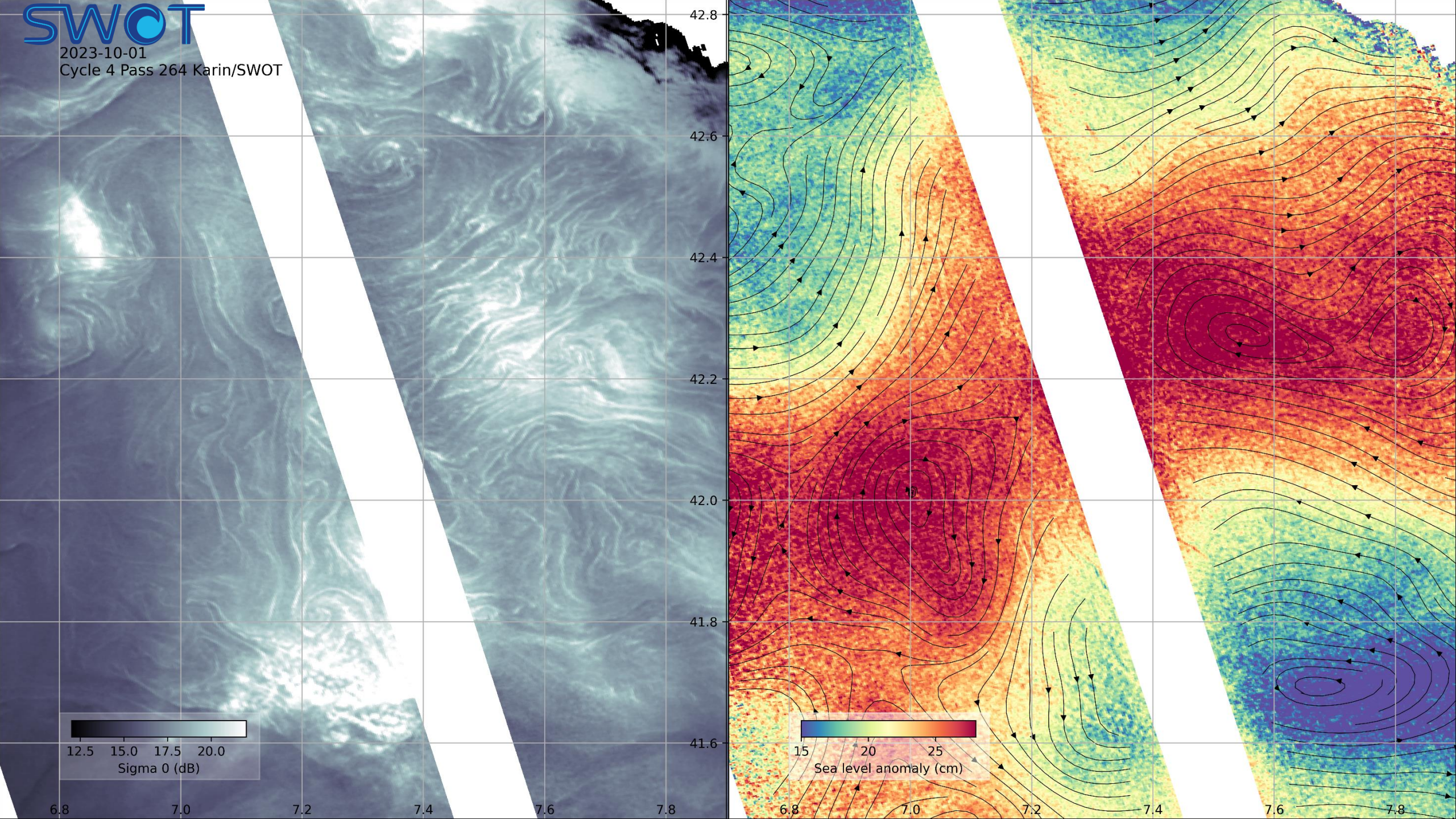


Credits: CNES/CLS

-15cm ▶ +15cm

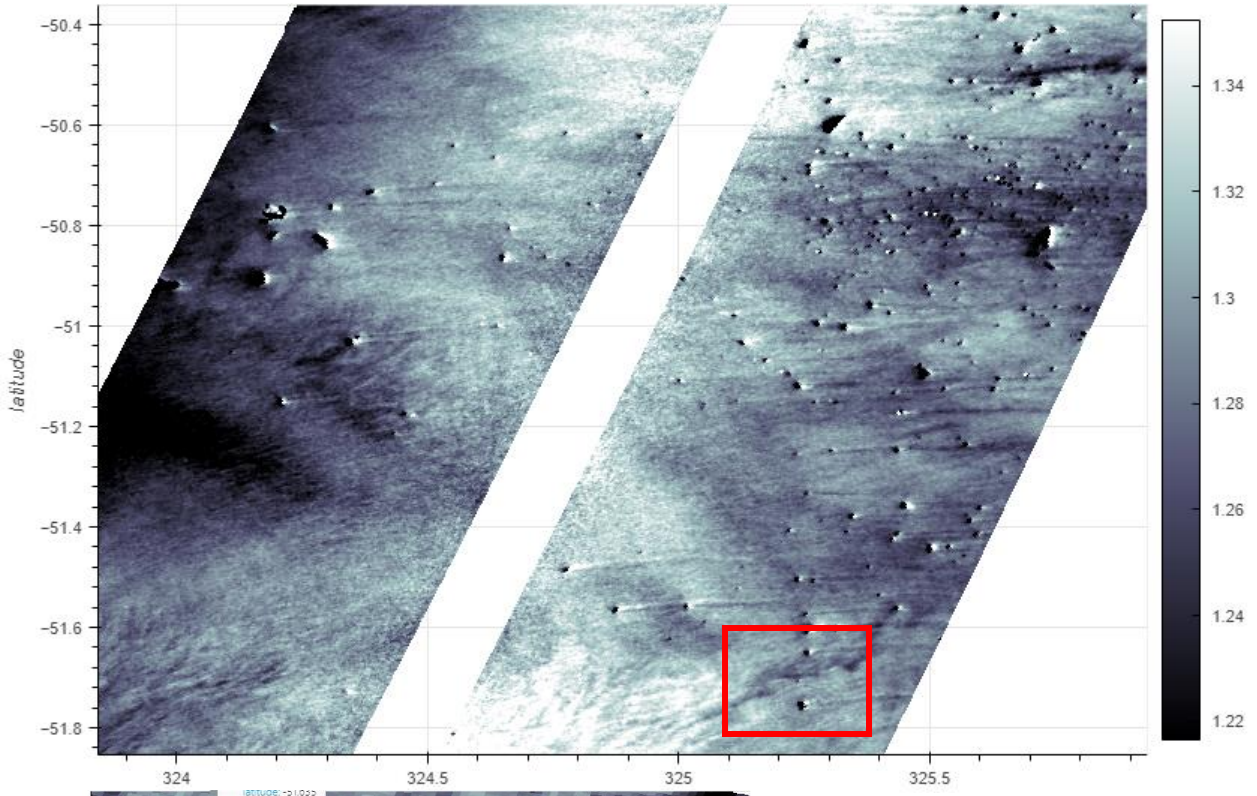
Ten days worth of SSHA in November 2023: Sentinel-6 & Jason-3 vs SWOT

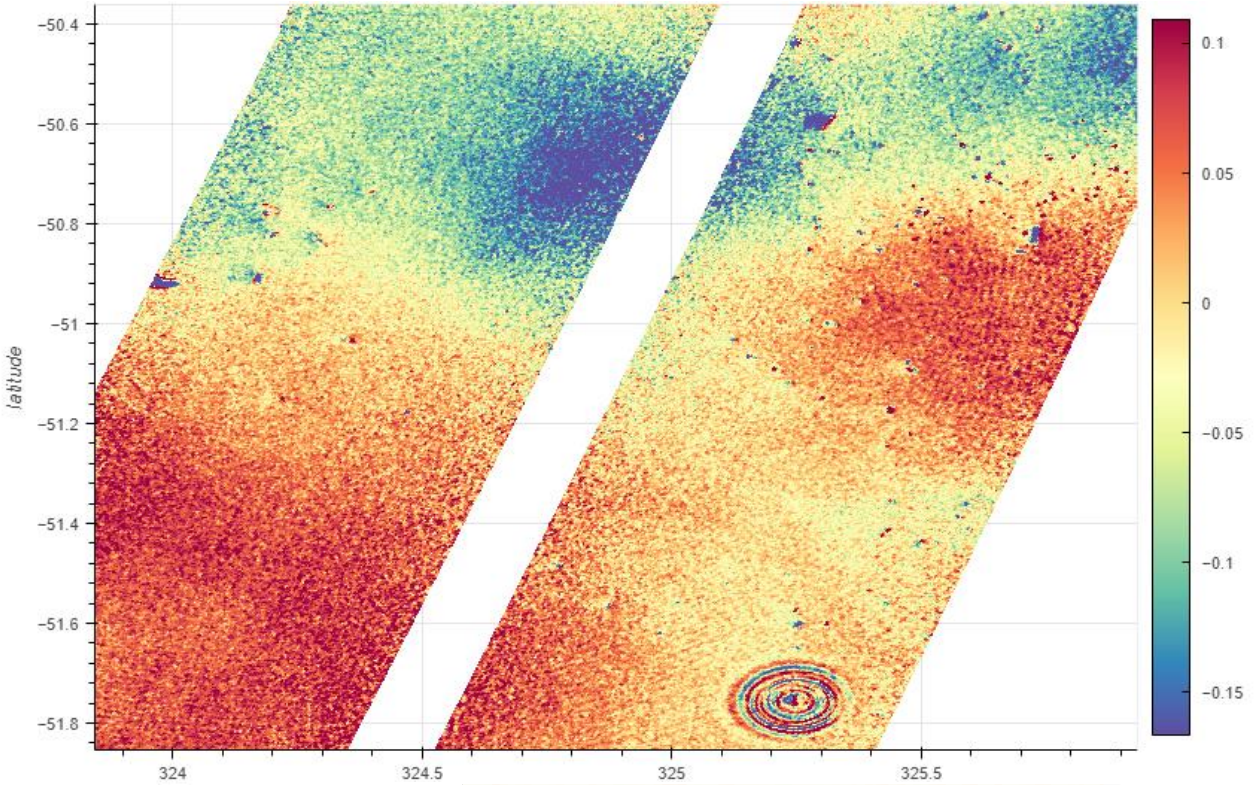


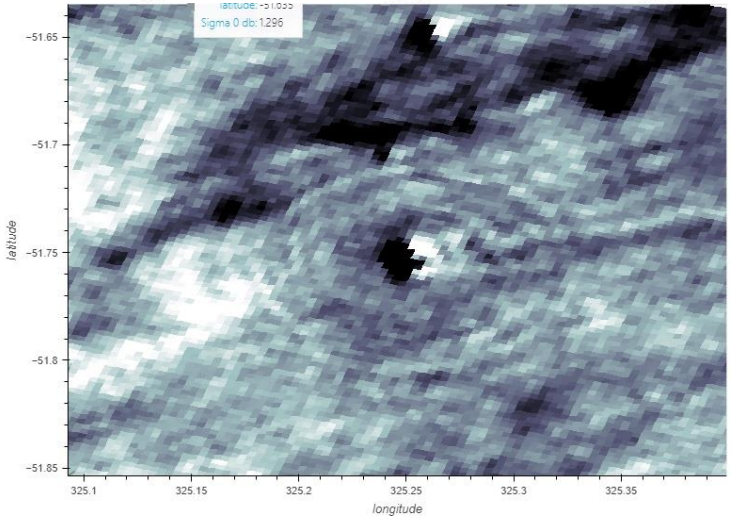

SWOT
2023-10-01
Cycle 4 Pass 264 Karin/SWOT
42.8
42.6
42.4
42.2
42.0
41.8
41.6
12.5 15.0 17.5 20.0
Sigma 0 (dB)
15 20 25
Sea level anomaly (cm)
6.8 7.0 7.2 7.4 7.6 7.8


SWOT
Unbalanced motions: tsunamis to internal waves

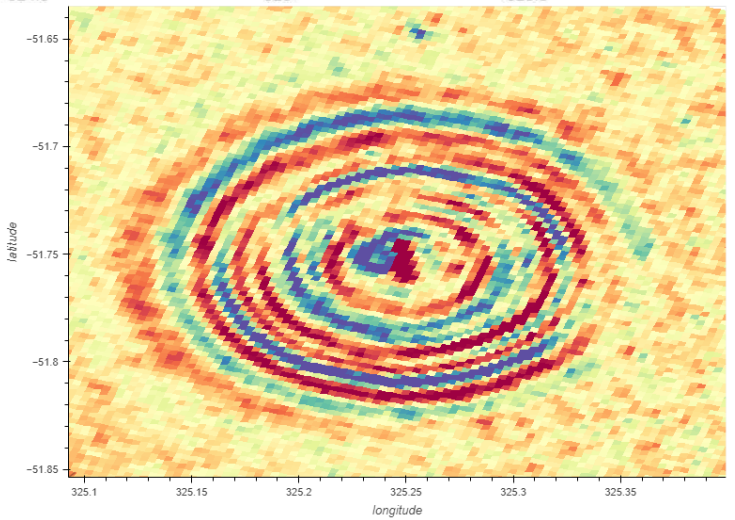
Occasional circular waves near icebergs





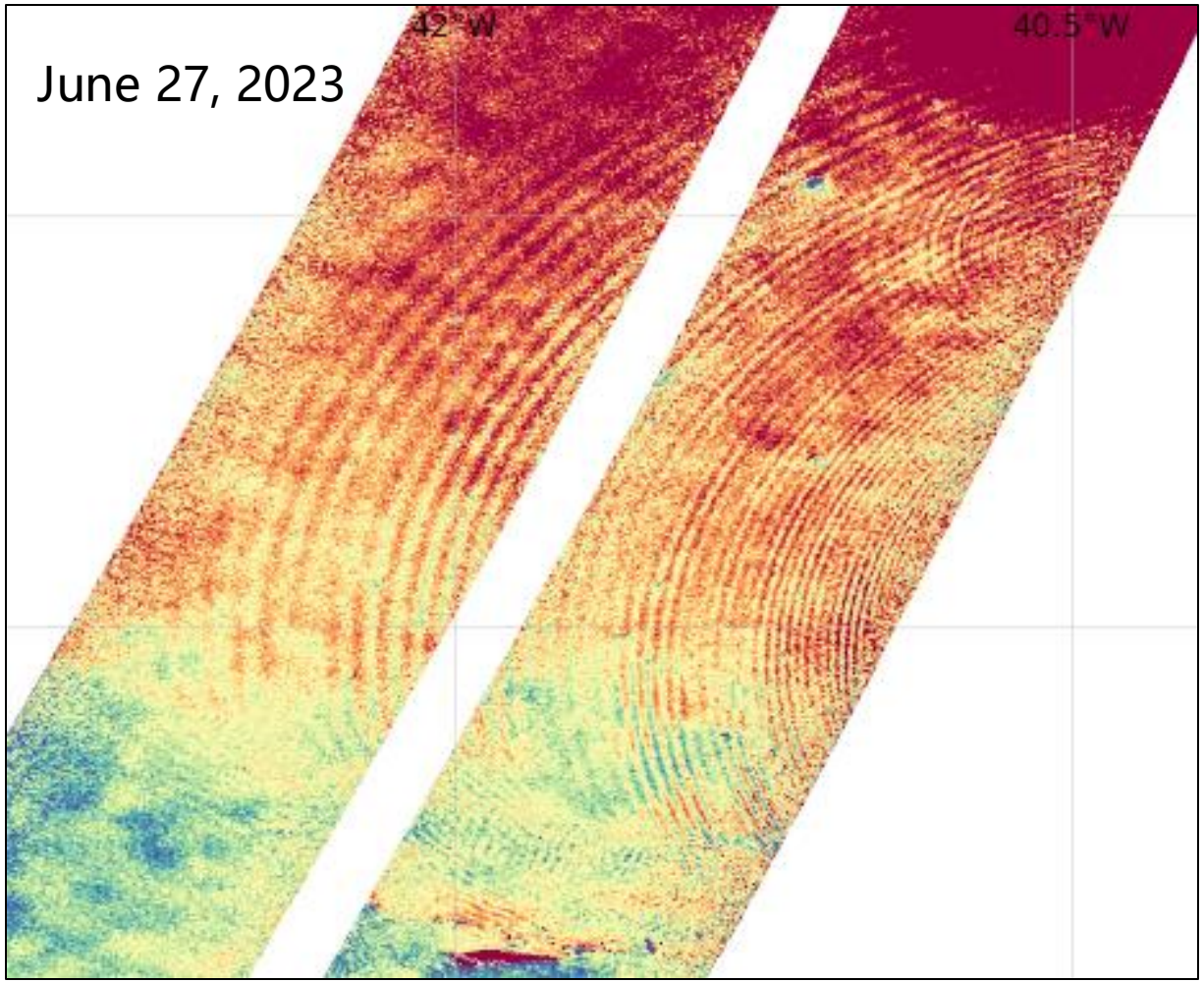


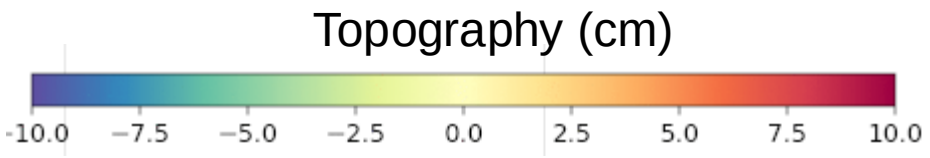
Mini-tsunamis occur as the iceberg capsizes (massive water displacement)



Credits: CNES/CLS

Some waves can be massive in extension and amplitude





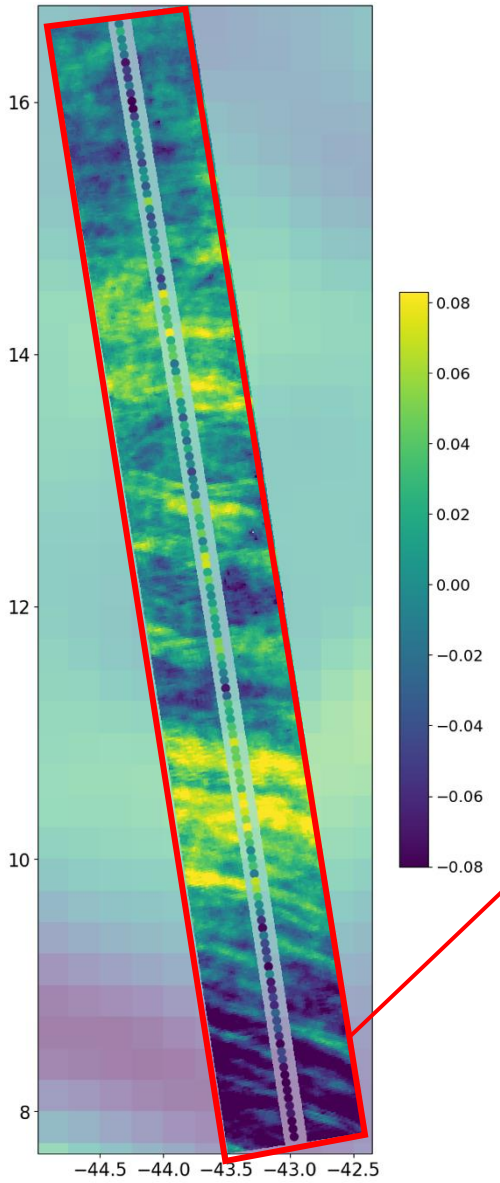
Amplitude up to 10+ cm

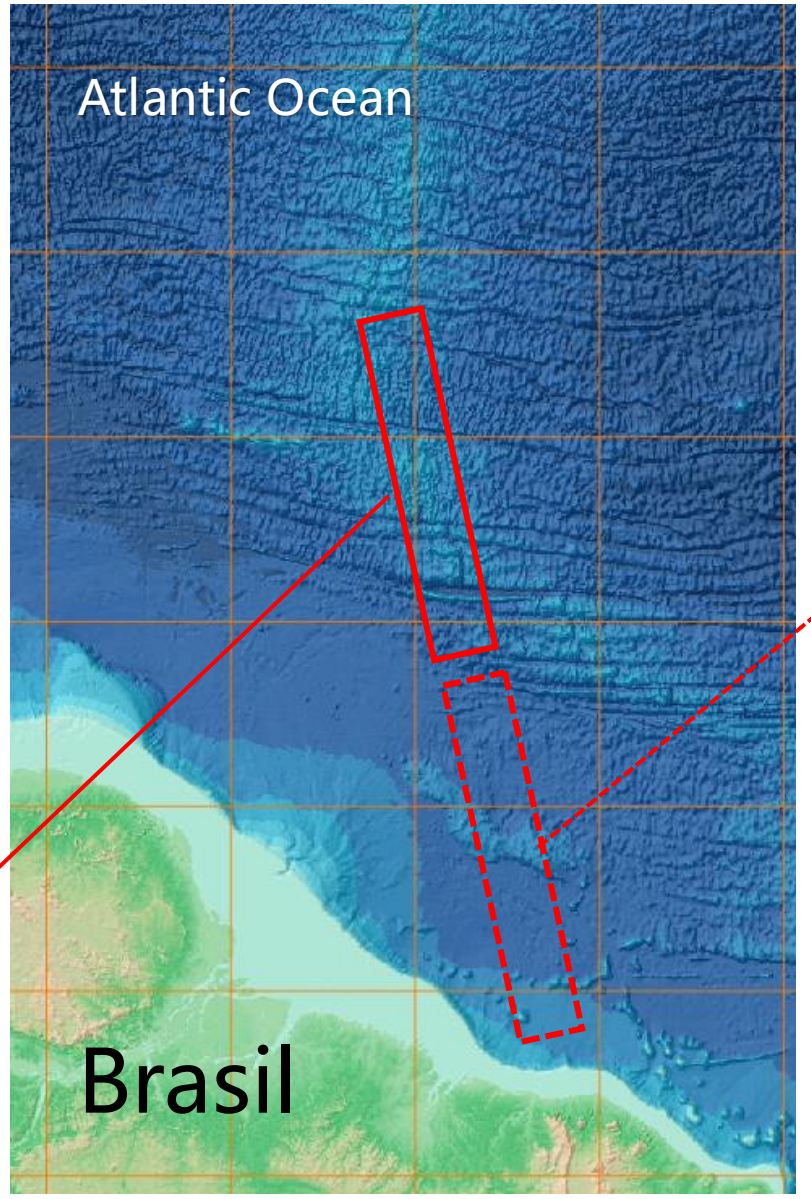
Radius up to 200km

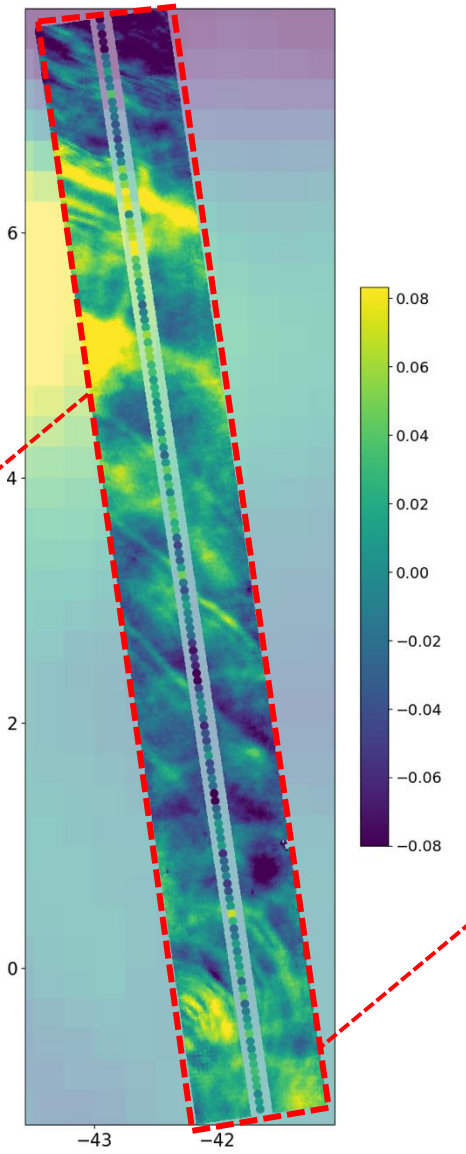
Widening of wave front from 250m to 10km

Credits: CNES/CLS

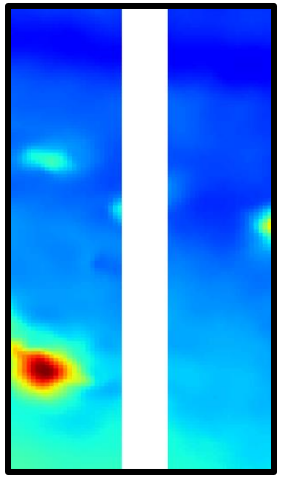
Internal tide patterns in the Tropical Atlantic

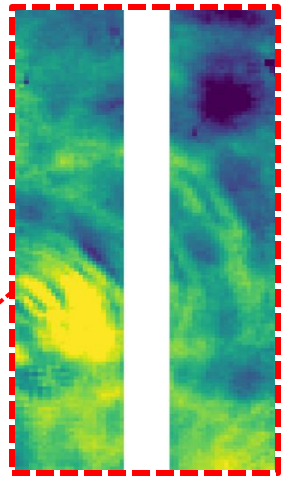






Bathymetry
(sea mount in red)





Waves radiating from the sea mount

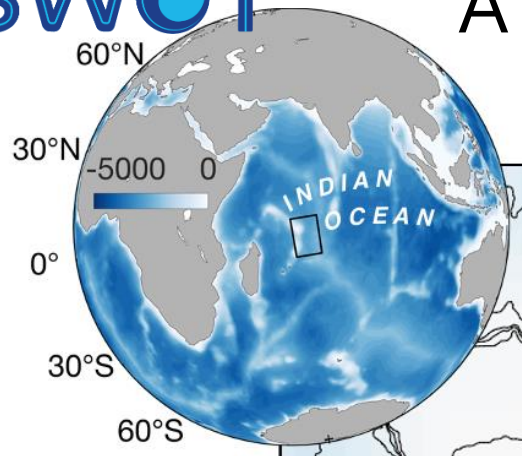
Well-structured wave trains scrambled as they reach rough bathymetry

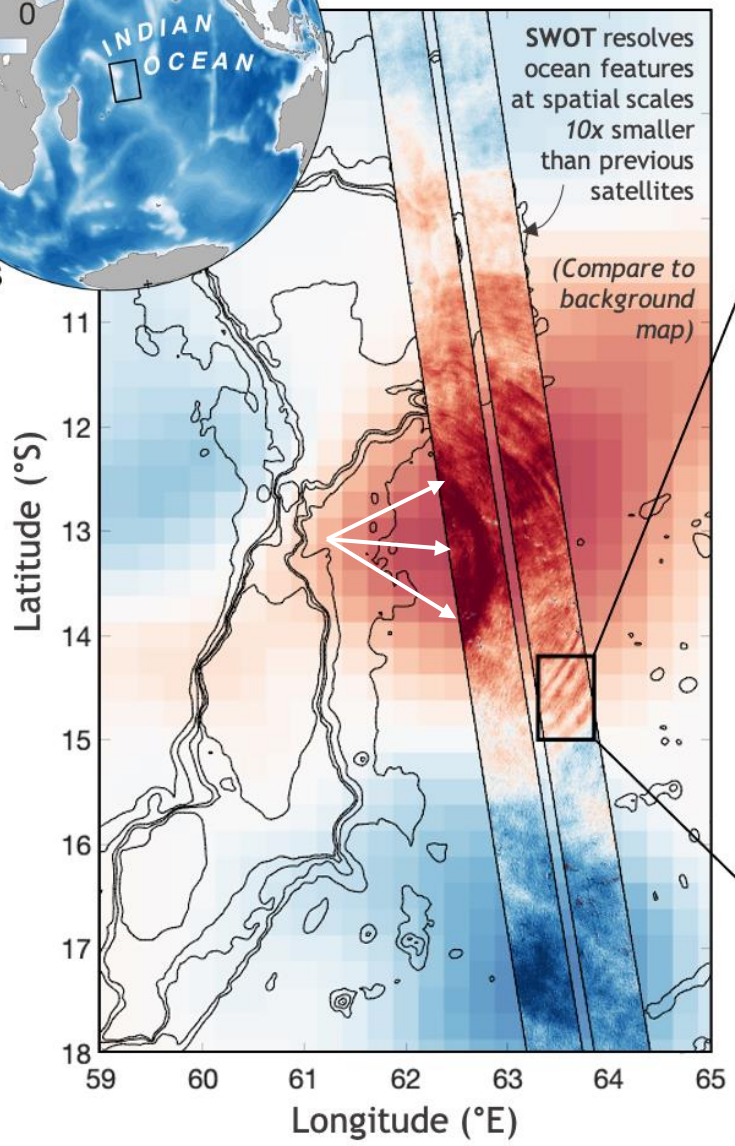
Credits: CNES

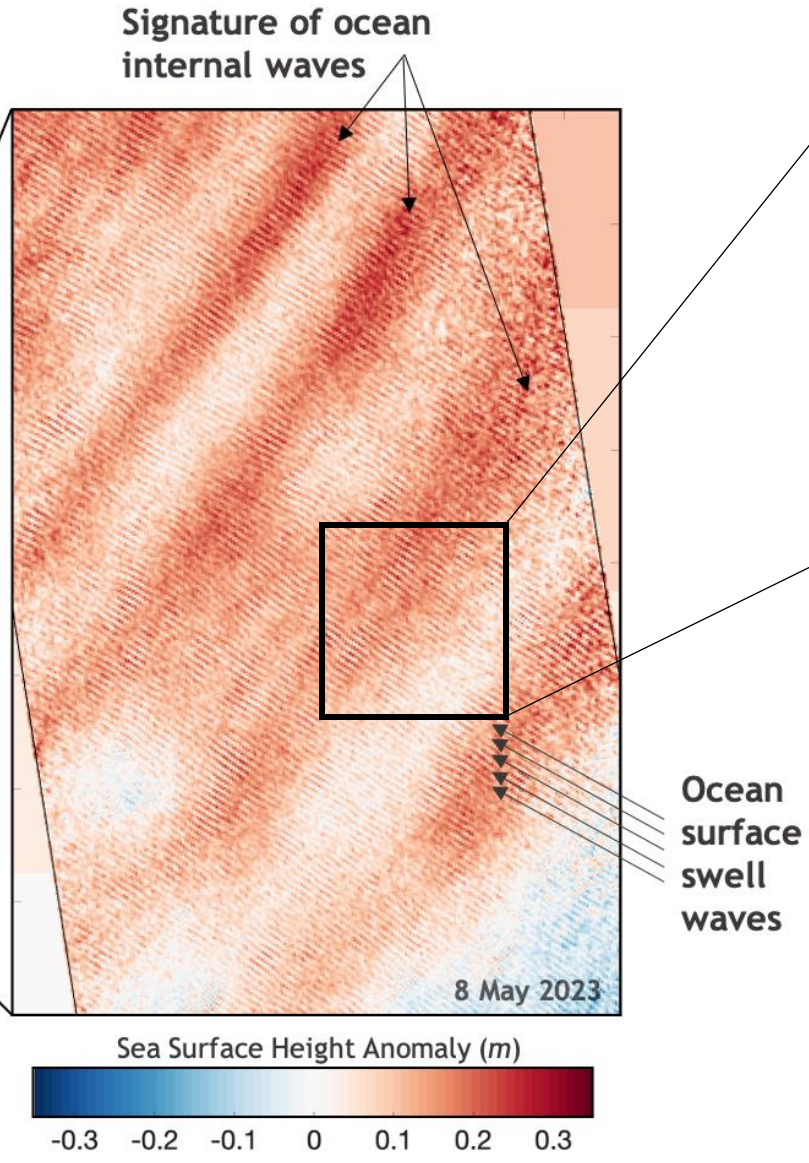
SWOT

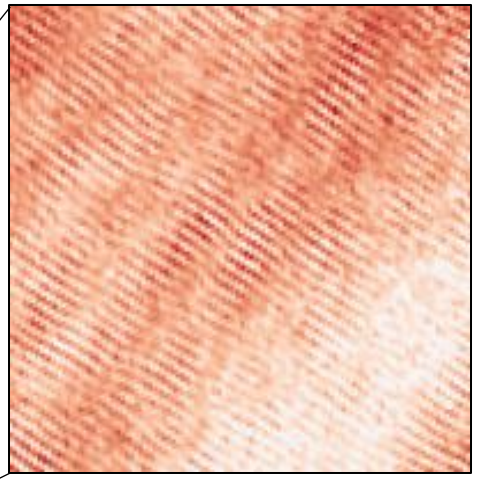
Resolved ocean swells

A Richness of resolved scales by SWOT (L2 KaRIn 250m)







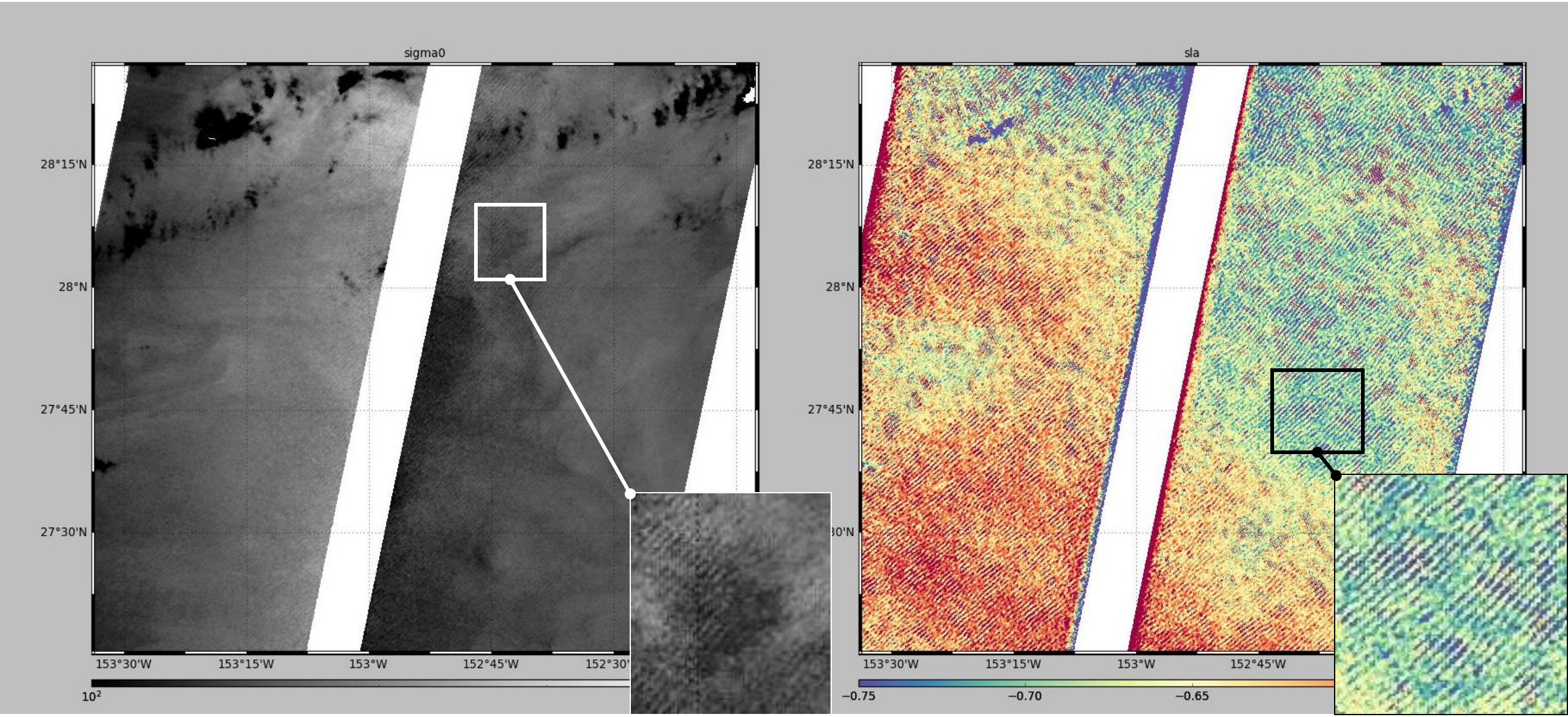


Ocean Swell Wavelengths ~ 1 km

Ocean surface swell waves

Courtesy of M.Archer, NASA/JPL

Swell signature in 250m product: stripes & wave groups



Credits: CNES/CLS

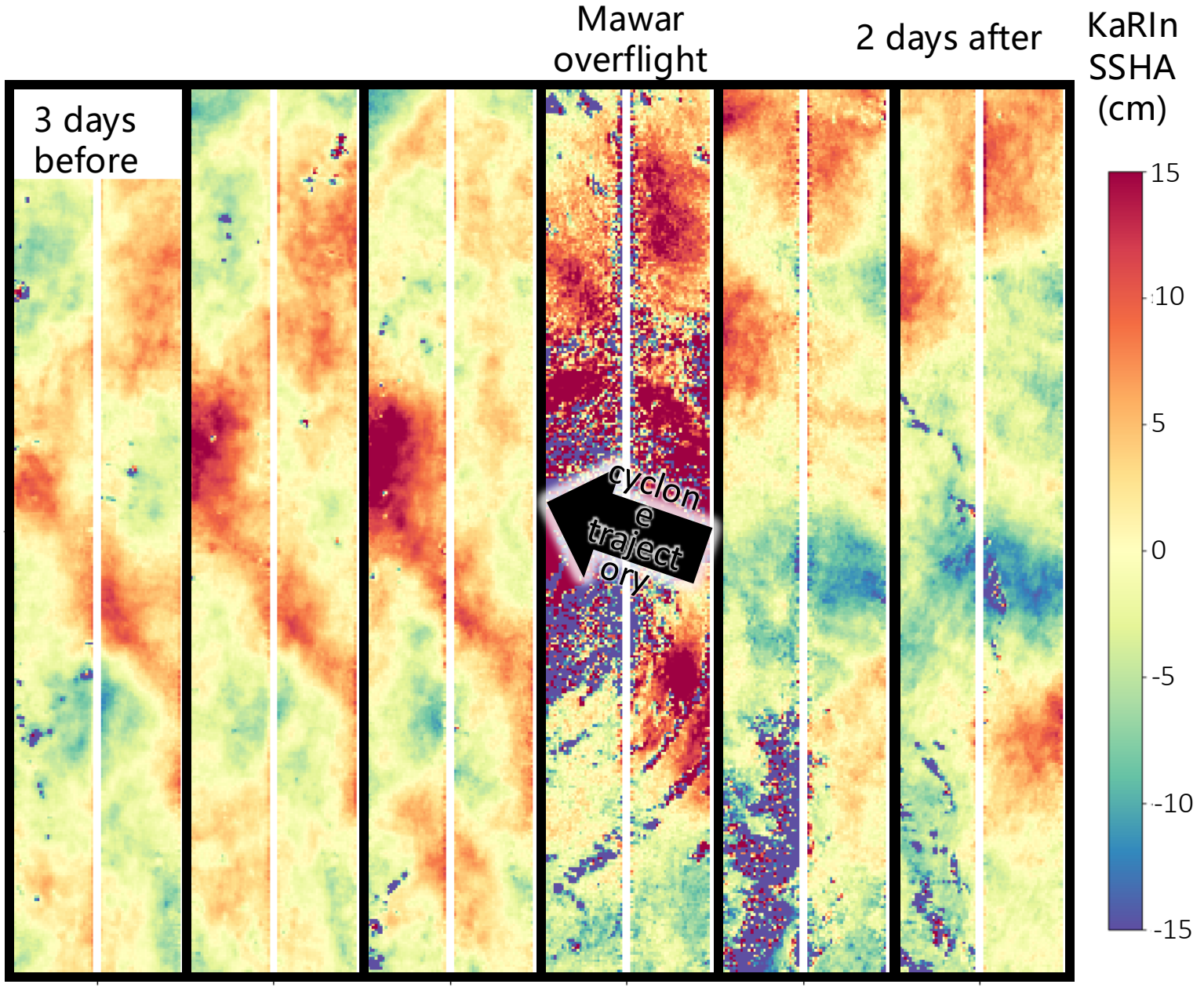
6-day sequence of the MAWAR crossing (2-km)

Sea level decreases suddenly in the cyclone wake (20 cm): heat potential was siphoned

Positive bias in the storm area: inverse barometer residuals from ECMWF model

Noise before /after the cyclone enters the SWOT swath (high waves around the storm)

Circular and wake patterns behind the cyclone

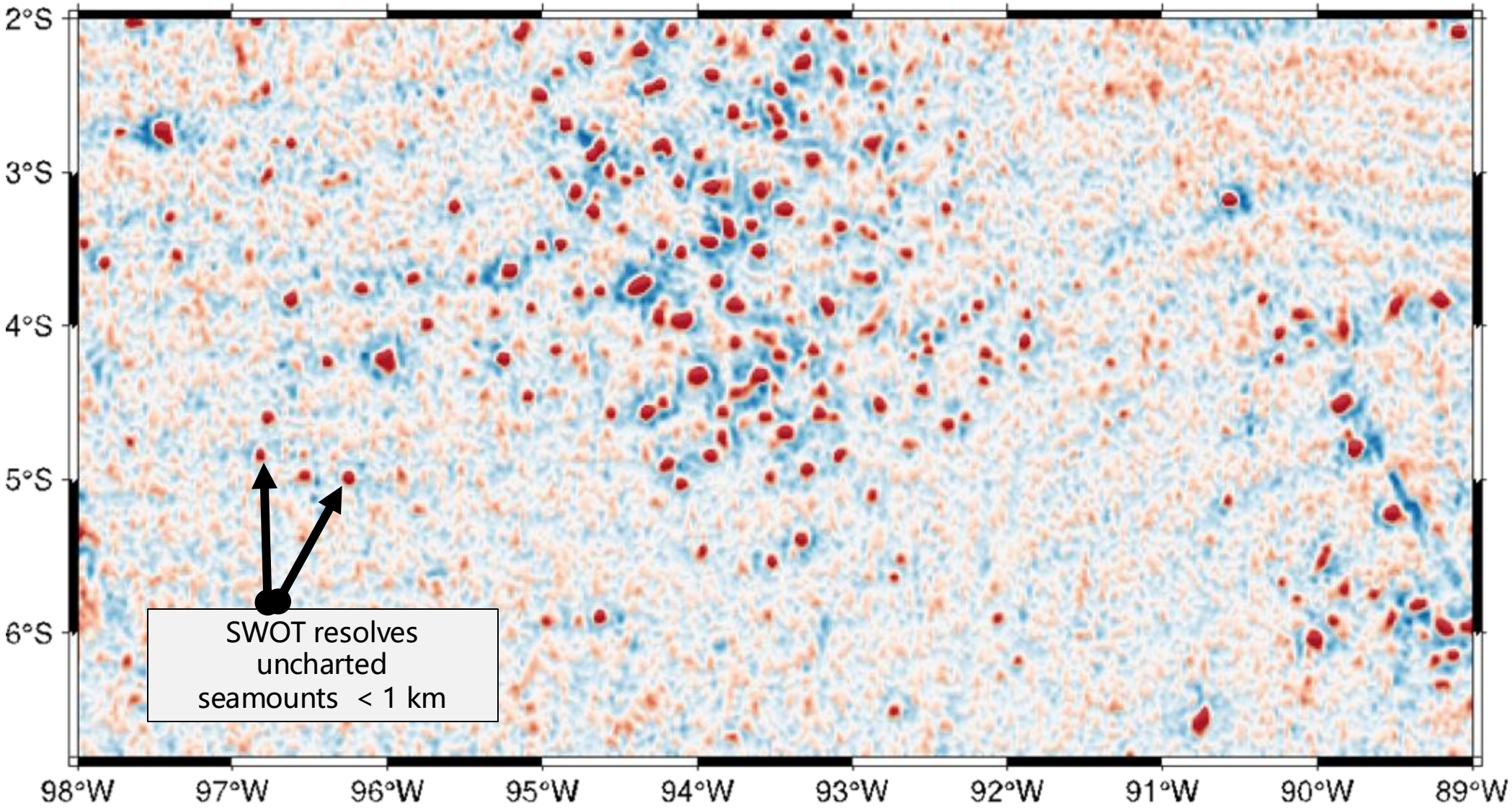


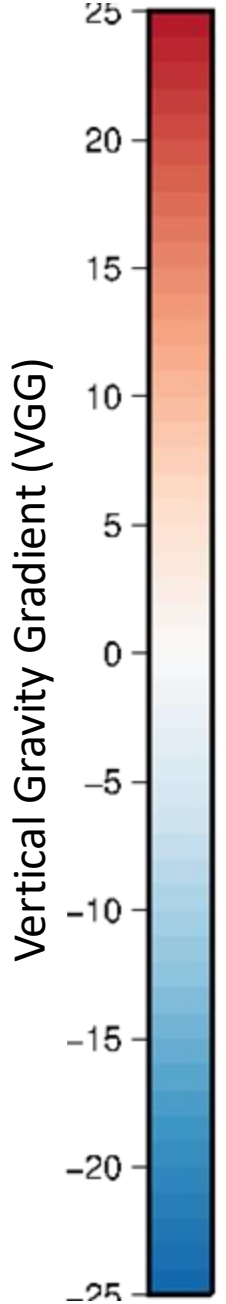
Credits: CNES/CLS

Marine Geodesy

Hundreds of seamounts charted by SWOT in < 1 year

(thousands of uncharted seamount to be discovered)





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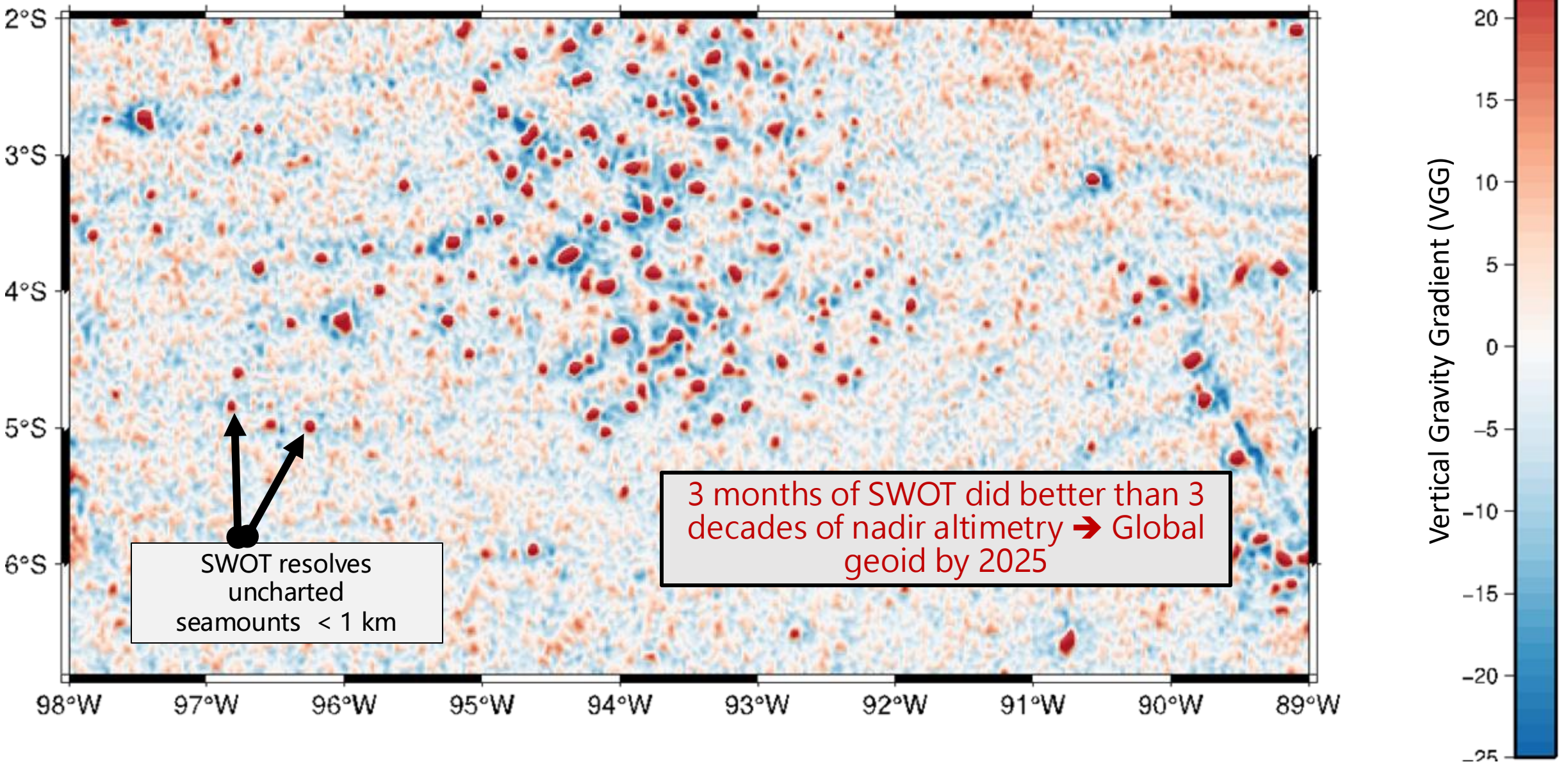
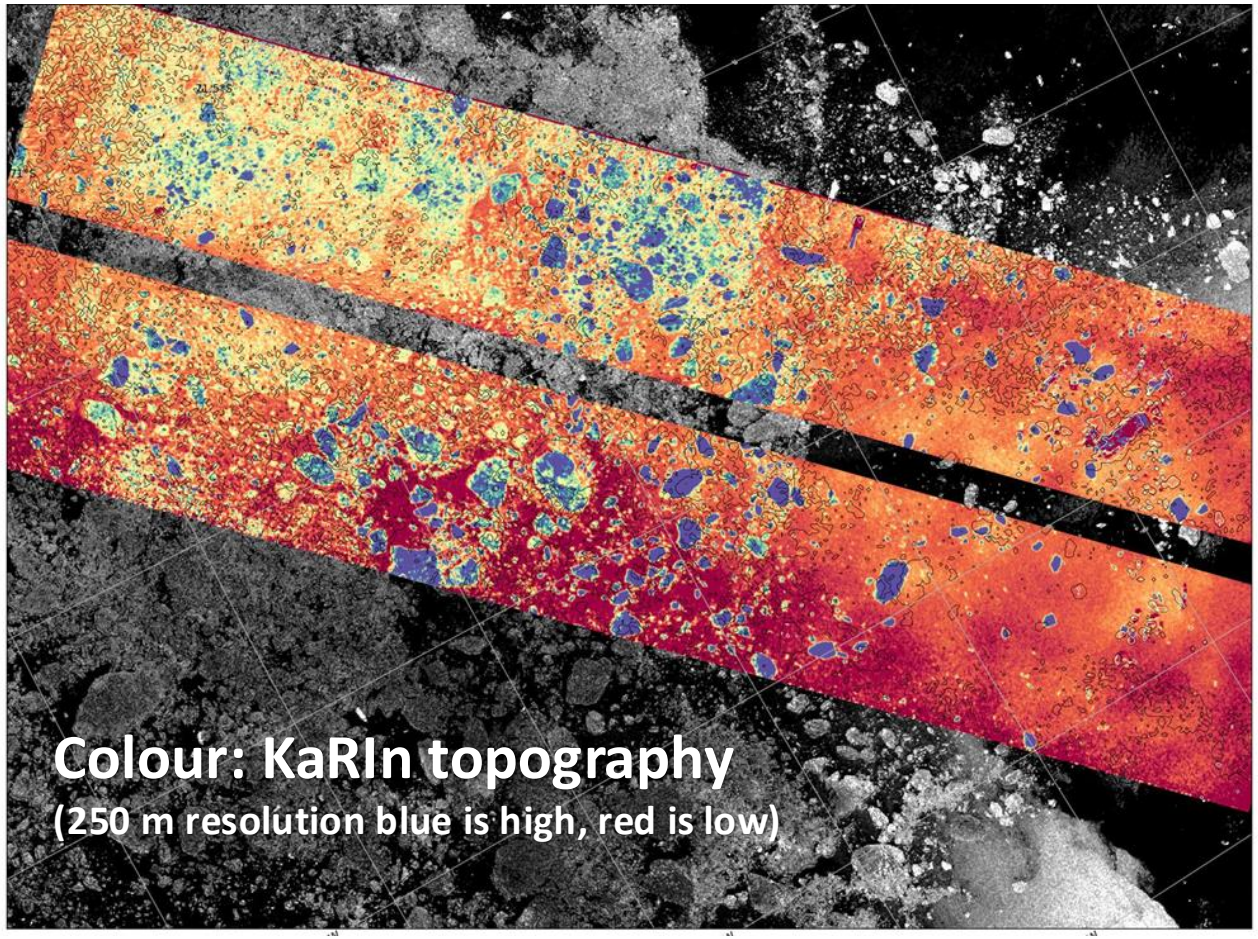
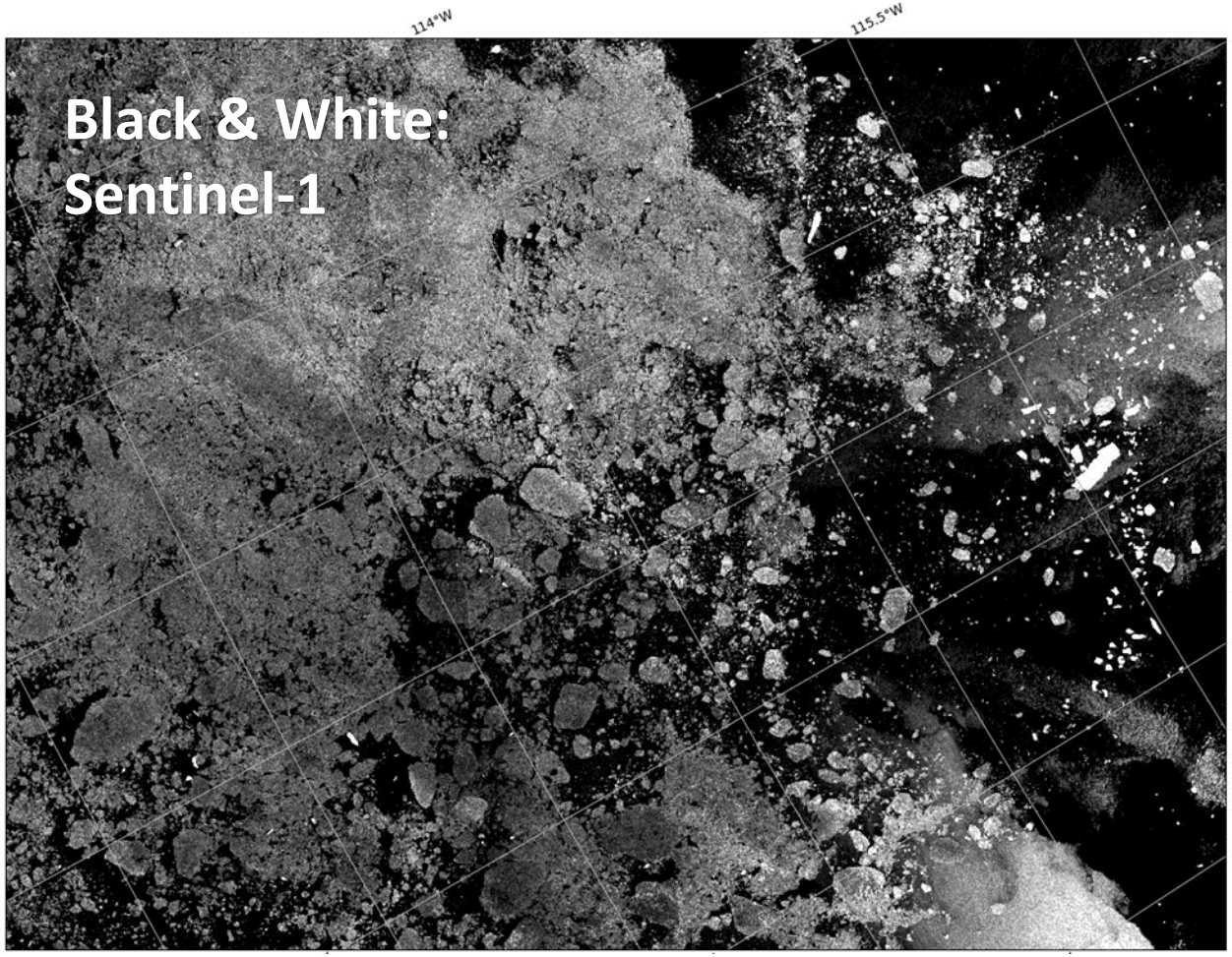


Polar Regions

Sea-ice: 250m freeboard and thickness in 2D





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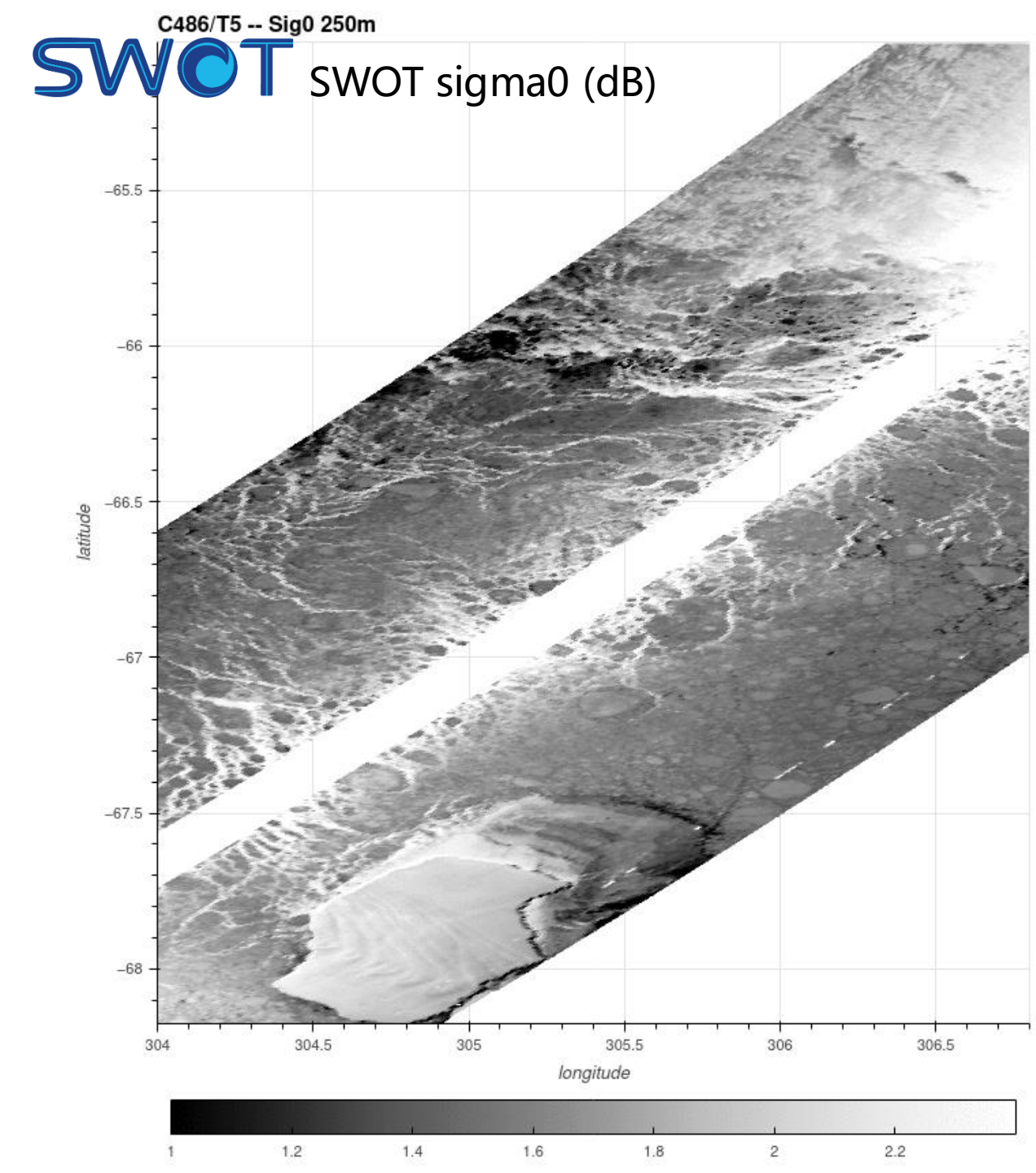

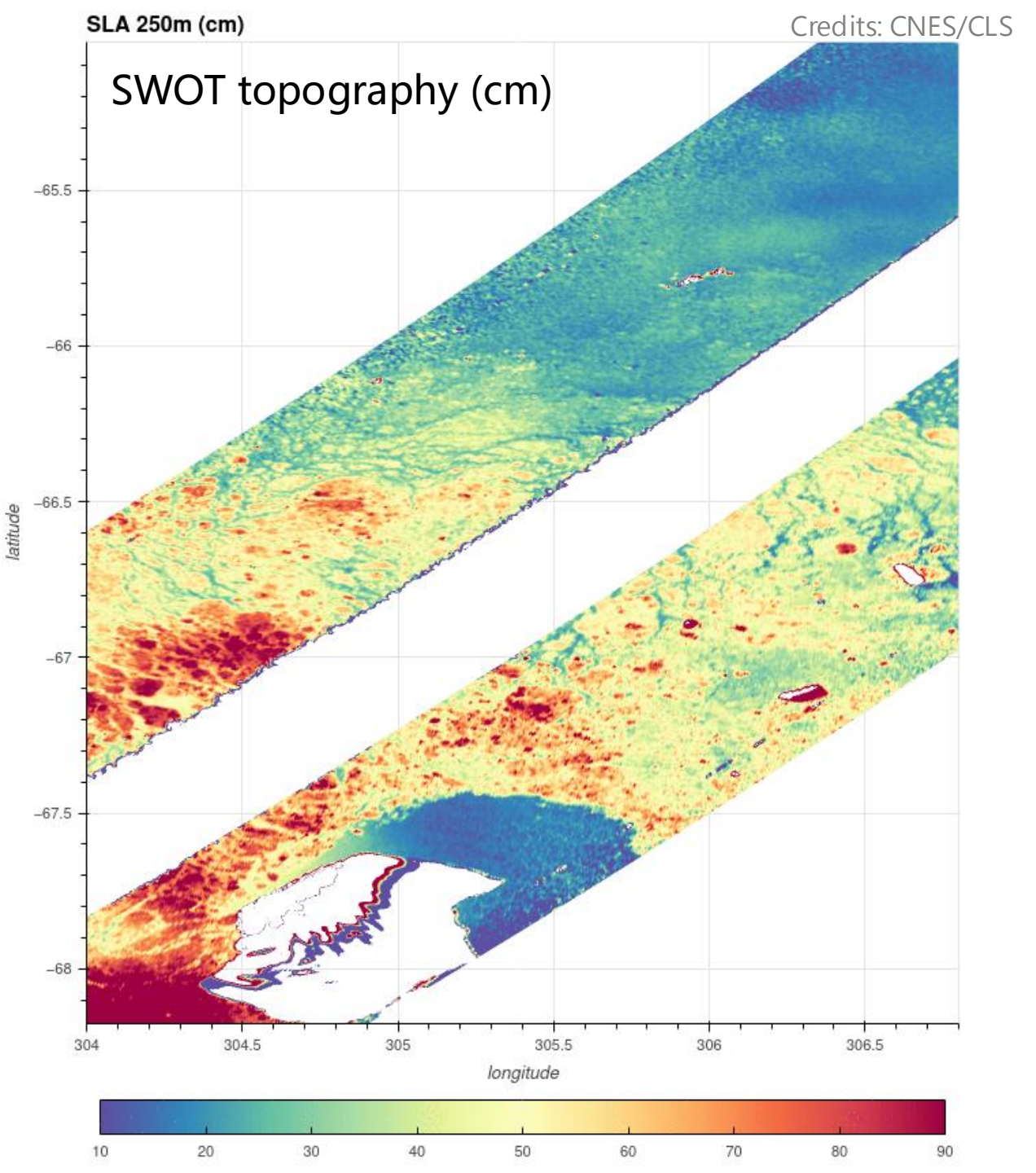

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SWOT OCEAN DATA ACCESS & SERVICES

WHERE TO GET SWOT OCEAN PRODUCTS?

AVISO

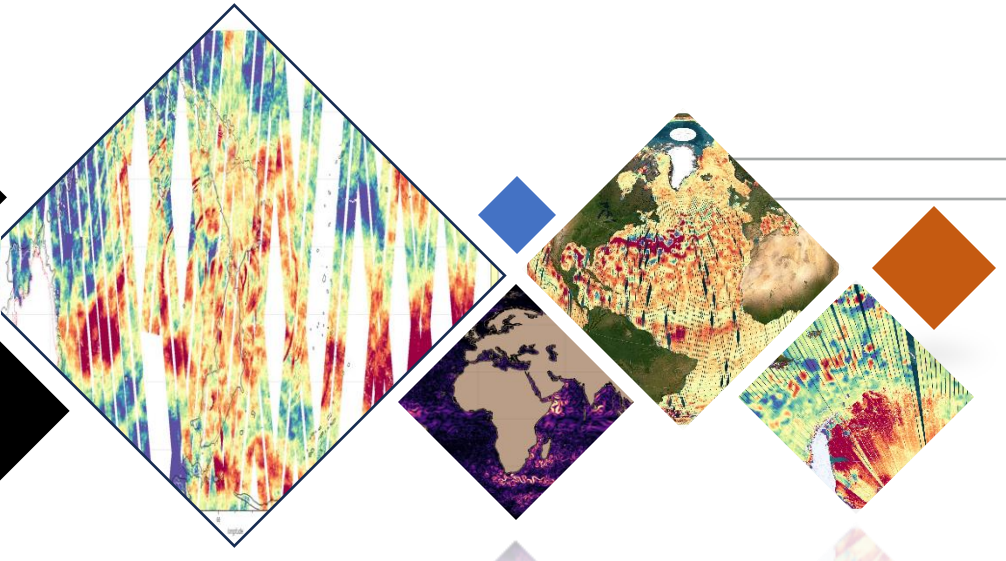
L2, L3 & L4 Products

OPeNDAP / HTTPServer / (S)FTP / WMS / Viewers / ...

PODAAC

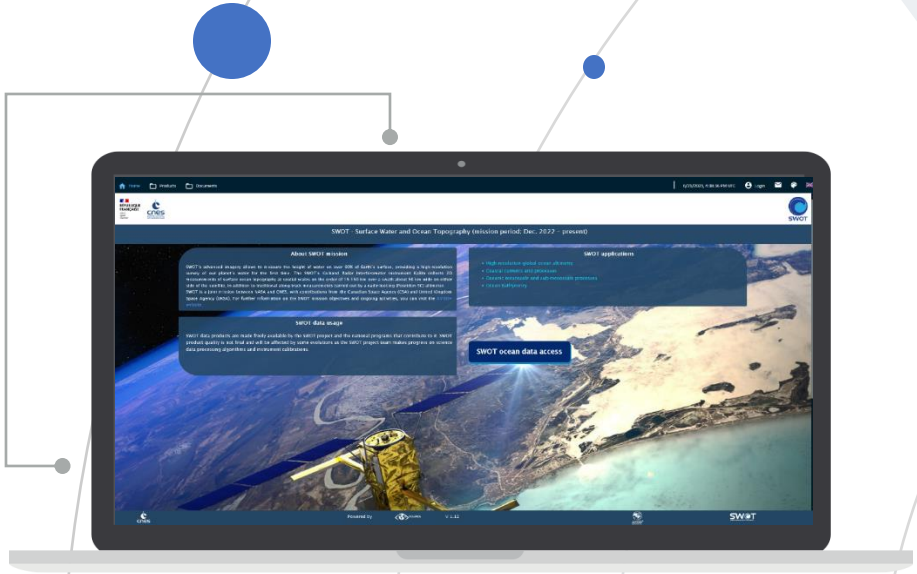
L1B, L2 Products

SWOT OCEAN DATA ACCESS & SERVICES



Data Access on ODATIS/AVISO

Protocols/APIs for exposing/querying metadata and have access to related data sets based on FAIR (Findable, Accessible, Interoperable and Reusable) principles

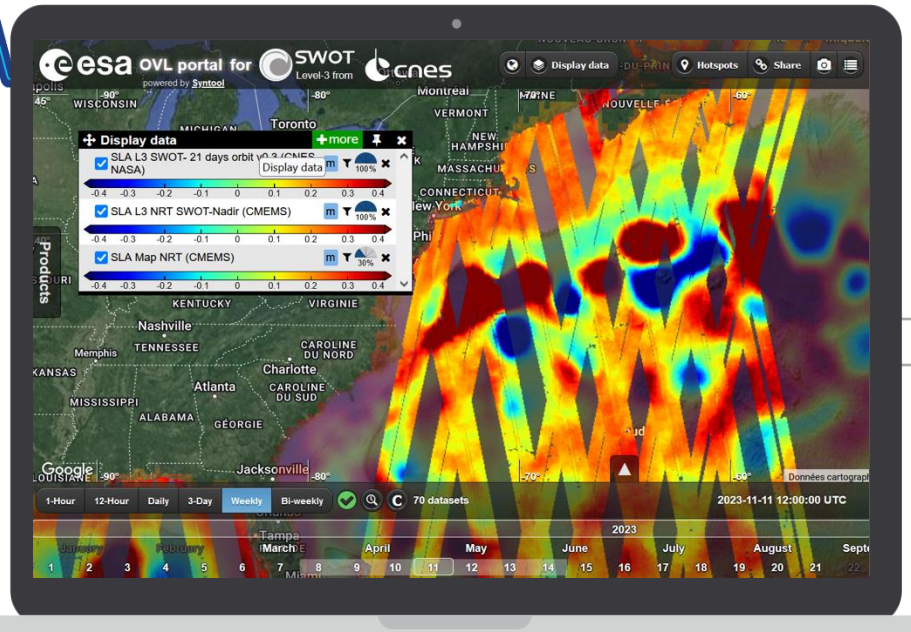


Data Access Services:

- AVISO CNES Data Center (archive catalog)
- THREDDS (OPeNDAP, WMS, and HTTP)
- FTP/SFTP,…

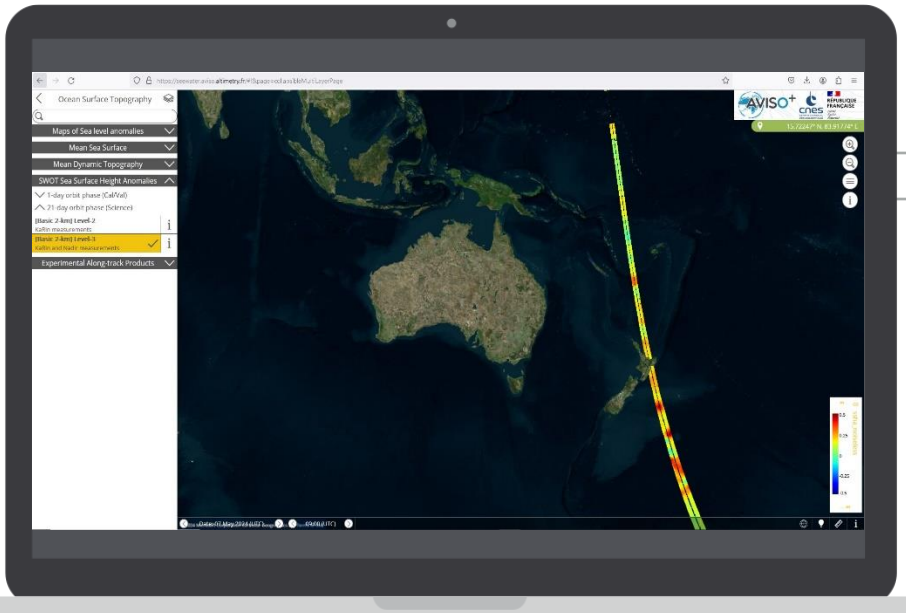
PRIOR REGISTRATION IS REQUIRED USING AVISO+ CREDENTIALS

SWOT OCEAN
DATA ACCESS & SERVICES



OVL WEB PORTAL

Exploration web portal for CNES Level-3 SWOT products (in collaboration with ESA and Ocean Data Lab)



SEEWATER AVISO WEB PORTAL

Seewater provides an interactive web interface for exploring AVISO products (MSS, MDT, SLA,...)

SWOT OCEAN DATA ACCESS & SERVICES

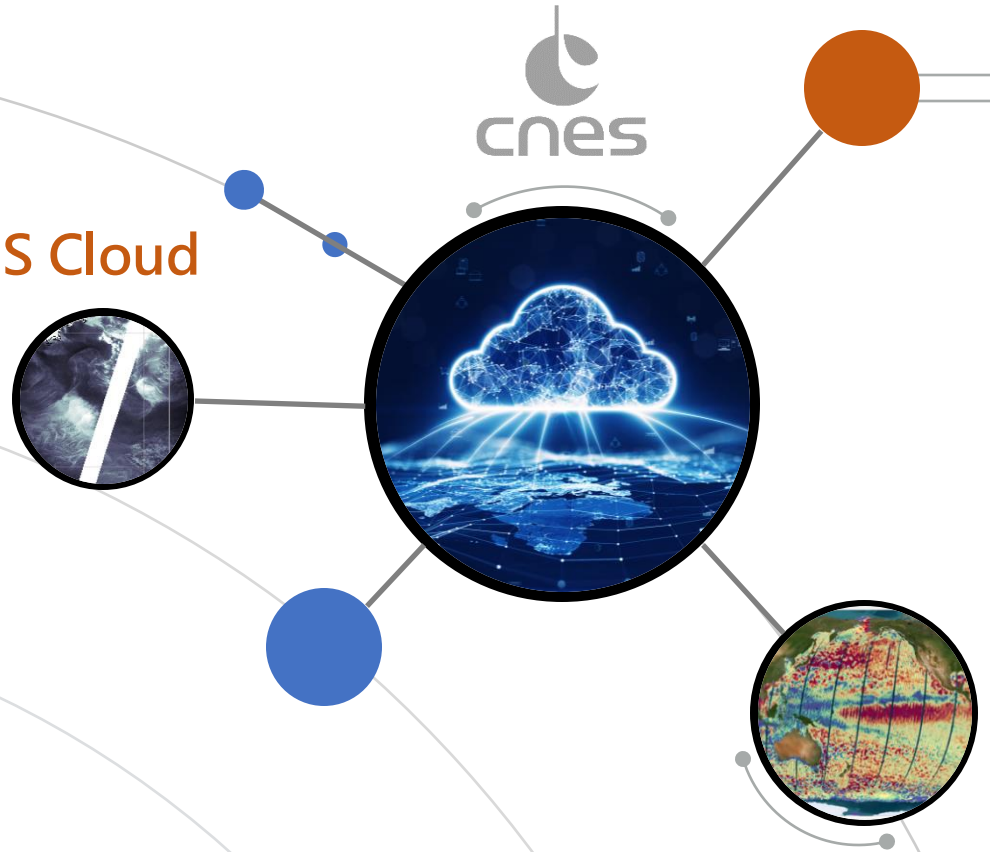
DATA PRODUCTS

Catalog requests and download tools

Small volumetry downloads

STORAGE ON LOCAL MACHINE

Free Hosting of SWOT Projects on CNES Cloud



CNES CLOUD

- FREE HOSTING ON CNES CLOUD/HPC INFRASTRUCTURE
- HIGH PROCESSING POWER (CPU & GPU)
- VERY FAST I/O FOR SWOT 250-M & 2-KM
- A SERIES OF SIMPLE EXAMPLES, POWERFUL TOOLS & EXTERNAL DATA
- PRIVACY FOR PROJECT MEMBERS (OR OPEN REPOSITORY IF YOU PREFER)
- HELPDESK & TECHNICAL SUPPORT FOR SMOOTH SAILING

aviso-swot@altimetry.fr

JupyterHub

https://jupyterhub.cnes.fr/hub/login?next=%2Fhub%2F

cnes

CENTRE DE CALCUL

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Access to the CNES scientific information system. Obligation to close your session when you leave your workstation.

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Vous pouvez vous connecter avec vos identifiants du Système d'Information Scientifique. Une fois identifié, vous aurez accès à un serveur de notebook Jupyter ou Jupyterlab lancé sur un noeud de calcul. Vous pourrez ainsi explorer vos données et réaliser des calculs de manière interactive. Pour plus d'information sur le fonctionnement du Hub et des notebooks, c'est sur le Wiki du Centre de Calcul.

Welcome on CNES Computing Center's Jupyterhub!
You can connect with your CNES Scientific Information System user account. Once logged in, you'll hae access to a Jupyter notebook server started on a computing node. You'll thus be able to analyse your data or submit computations interactively. For more information, please see the Computing Center Wiki (in french).

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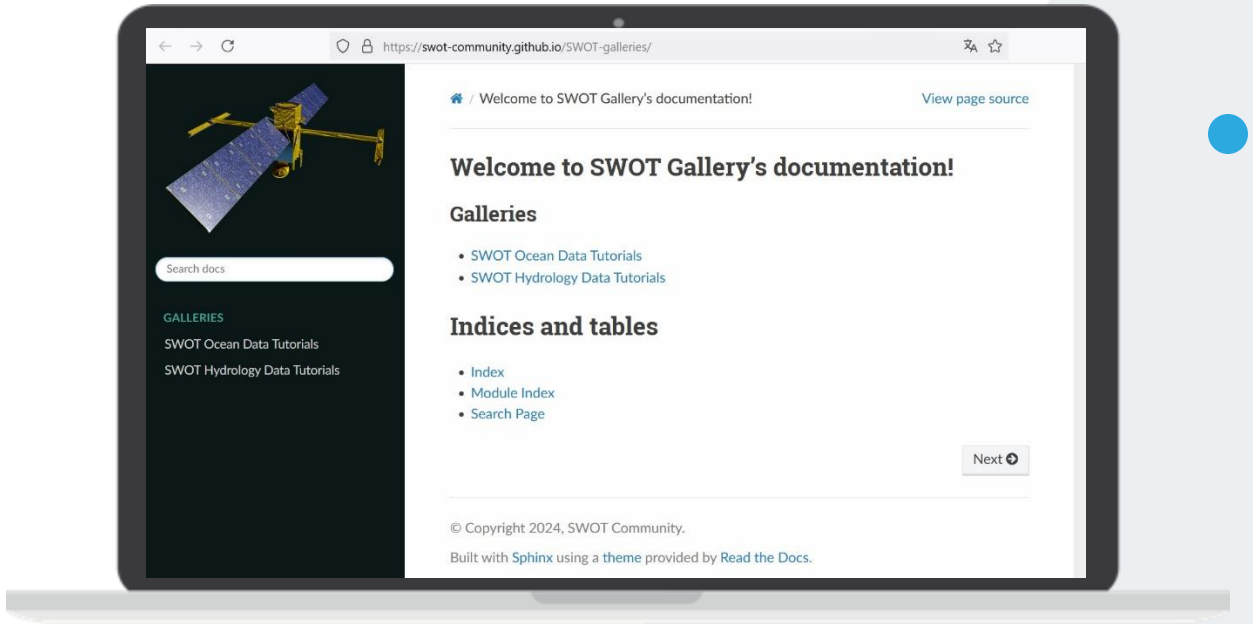
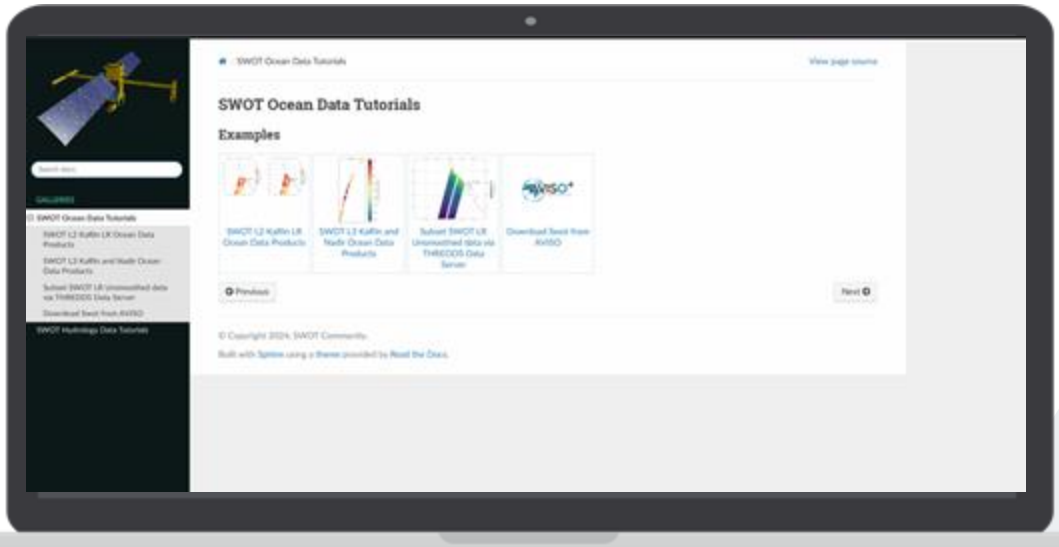
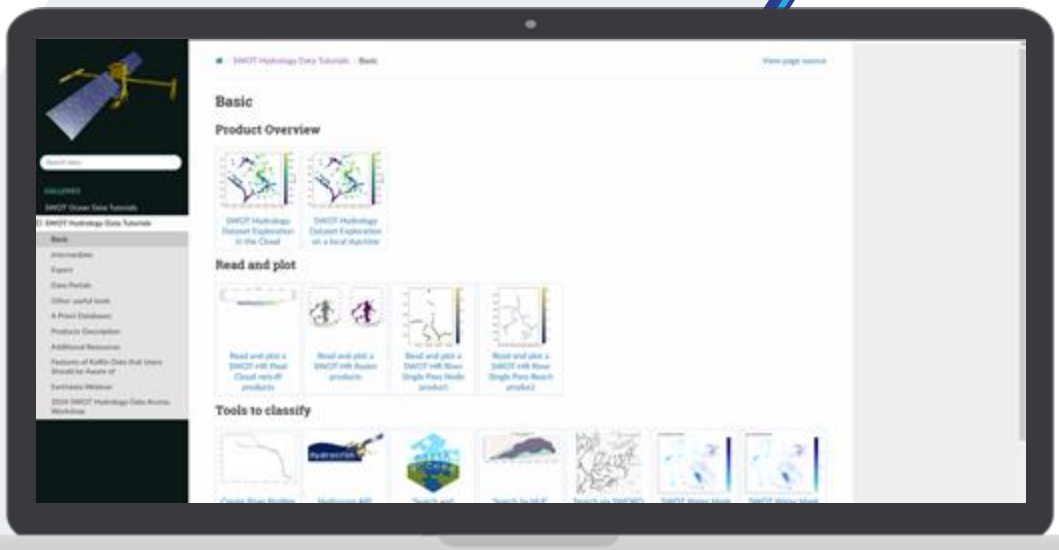
10:17
28/08/2024

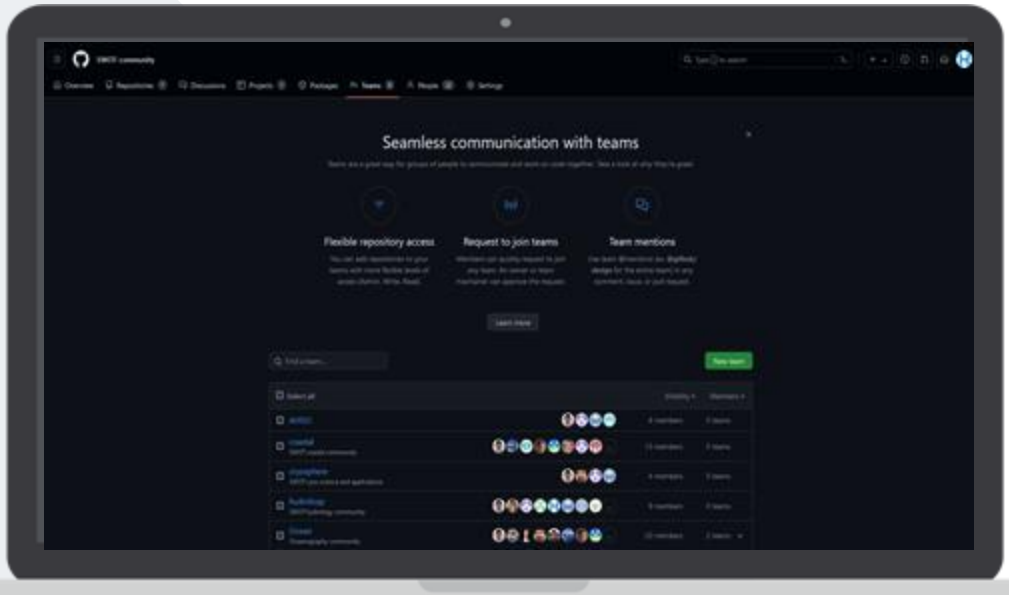
Use, Contribute, Ask for new tutorials

https://swot-community.github.io/SWOT-galleries

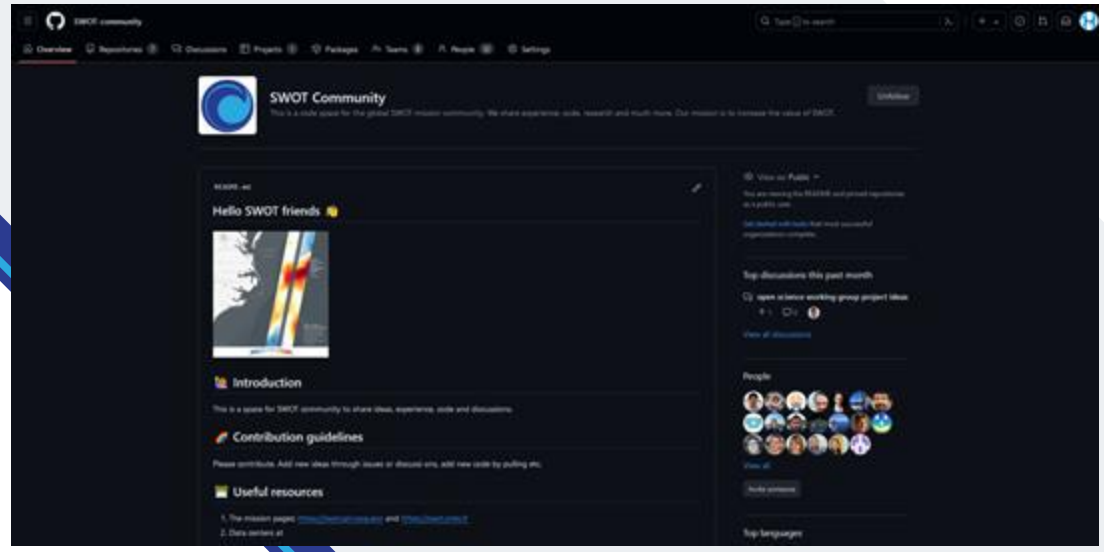


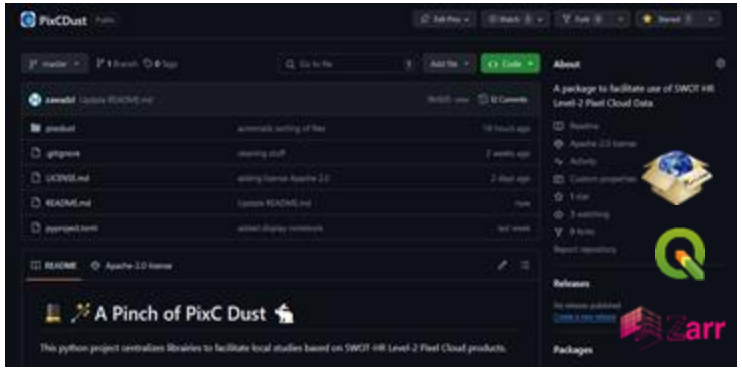






Join the teams and help promote the use of amazing SWOT data





Contacts:
Cyril: cyril.germineaud@cnes.fr
Lionel: lionel.zawadzki@cnes.fr
Cassie: cassandra.l.nickles@jpl.nasa.gov
Sarah: sgille@ucsd.edu

Outline: SWOT Ocean Data Training Session

SWOT Low Rate (LR, Oceanography) products (40')

- Dataset overview & related applications
- Data access & usage services

Ready-to-use tutorials (Jupyter notebooks) (20')

- How to explore and manipulate SWOT LR data, etc.
- Oceanography dedicated use cases

SWOT ocean products and data usage perspectives & Questions (30')

Visualize & Explore SWOT Ocean Data (L3 KaRIn 2km)

Visualise Swot L3 2-km

This notebook shows how to visualise Swot data using Vador: a tool allowing to Visualize and Aggregate Data from Ocean and River

[ ]:
```
import os
from datetime import datetime
from pprint import pprint

import geoviews.feature as gvf
import holoviews as hv
import numpy as np
import panel as pn
import panel.widgets

from ocean_tools.nadir.io import NetcdfFilesDatabaseNadir

from vador import Coast, Grid, Swath
from vador.plugins import ZcSwath

hv.extension("bokeh")
```

[ ]:
```
SWOT_DATA = '/work/HELPDESK_SWOTLR/commun/data/swot/L3_LR_SSH/zcollections/V1.0.2_SCIENCE'
MSLA_DATA = '/work/HELPDESK_SWOTLR/commun/data/cmems/SEALEVEL_GLO_PHY_L4_NRT_008_046/'
```

Dates range for data selection, used all along the notebook

[ ]:
```
t0 = np.datetime64("2024-06-15T00")
t1 = np.datetime64("2024-06-30T00")
```

Plot 2kms swath

Define a `vador.plugins.ZcSwath` object to directly visualize the zcollection with:

- the path to the folder containing the data
- the variables to display
- the time of interest
- the delta to apply : Number of day around reference time

[ ]:
```
# Add a *.options* to customize the plot
swath_2km = ZcSwath(
    SWOT_DATA,
```

Visualize SWOT Ocean Data (L3 KaRIn 2km) with Chlorophyll-a

ex_visu_kari... (2) - JupyterLab

https://jupyterhub.cnes.fr/user/tonneas/lab/tree/home/qt/tonneas/workspace/altimetry_symposium/ex_visu_karin_chl.ipynb

File Edit View Run Kernel Git Diagram Tabs Settings Help

ex_visu_karin_chl.ipynb

Code

Helpdesk SwotLR (DEV)

Visualise SWOT data with CMEMS Chlorophyl

This notebook shows how to overlay Swot data with CMEMS chlorophyl using Vador: a tool allowing to Visualize and Aggregate Data from Ocean and River

[ ]:
```
import cmocean
import dask_jobqueue
import holoviews as hv
import numpy as np
import panel as pn
import panel.widgets
from ocean_tools.io import NetcdfFilesDatabase
from ocean_tools.swath.io import FileNameParserCHL
from vador import Coast, Grid
from vador.plugins import ZcSwath

hv.extension("bokeh")
```

[ ]:
```
SWOT_DATA = (
    "/work/HELPDESK_SWOTLR/commun/data/swot/L3_LR_SSH/zcollections/V1.0.2_SCIENCE"
)
CHL_CMEMS_DATA = "/work/HELPDESK_SWOTLR/commun/data/cmems/OCEANCOLOUR_GLO_BGC_L3_MY_009_103/cmems_obs-oc_glo_bgc-plankton_my_l3-multi-4km_P1D_202311/"
```

[ ]:
```
period = (np.datetime64("2024-06-05"), np.datetime64("2024-06-08"))
kw_area = dict(x_range=(-40, 4), y_range=(30, 60))
```

Select and open chlorophyl data

[ ]:
```
cluster = dask_jobqueue.SLURMCluster(
    cores=1, memory="8GiB", account="swotce_guest", walltime="00:15:00"
)

cluster.adapt(minimum_jobs=1, maximum_jobs=15)
cluster.get_client()
```

[ ]:
```
db = NetcdfFilesDatabase(path=CHL_CMEMS_DATA, parser=FileNameParserCHL())

chl_ds = db.query(time=period, selected_variables=["CHL", "time", "lon", "lat"])

chl_ds = chl_ds.where(
    (
        (chl_ds.lon > kw_area["x_range"][0])
        & (chl_ds.lon < kw_area["x_range"][1])
        & (chl_ds.lat > kw_area["y_range"][0])
```

Simple 0 4 Helpdesk SwotLR (DEV) | Idle Mode: Command Ln 1, Col 1 ex_visu_karin_chl.ipynb 0

Colocate SWOT & Sentinel-1data

Co-locate SWOT with Sentinel 1 data

This notebook shows how to use `ocean_tools` to retrieve swath geometries and use it to co-locate SWOT data with Sentinel 1 data. We access Sentinel data via PEPS using Eodag, and we use Vador for visualisation.

[ ]:
```
from ocean_tools.swath.geometry import (
    LongitudeConvention,
    normalize_polygon,
    query_polygons,
)
import numpy as np

from eodag import EODataAccessGateway

import holoviews as hv
import vador

hv.extension("bokeh")
```

[ ]:
```
dag = EODataAccessGateway()
dag.set_preferred_provider("peps")
```

Define the orbit phase. Possibilities are:

- **science**
- **calval**

[ ]:
```
phase = "science"
```

•••

Colocalise Swot orbit with Sentinel 1

Get half orbit geometry

> **Note**
>
> KaRIn geometries for all half orbits for both orbit phases have been pre-calculated and are stored in geojson files located in `/work/HELPDESK_SWOTLR/commun/data/swot/KaRIn_geometries/`

[ ]:
```
half_orbits = 281
```

Investigate SWOT Ocean Data Quality Flags

ex_visualize... (2) - JupyterLab

https://jupyterhub.cnes.fr/user/tonneas/lab/tree/home/qt/tonneas/workspace/ex_visualize_quality_flag.ipynb

File Edit View Run Kernel Git Diagram Tabs Settings Help

ex_visualize_quality_flag.ipyn

Markdown

Helpdesk SwotLR (DEV)

Investigate missing or bad data

This notebook shows how to visualise the L3 data quality `duacs_editing_flag` flags values using Vador, and the `ssha_karin_2_qual` flags values when hovering the plot.

[ ]:
```
import swot_calval.io
from vador import Coast, Swath

from bokeh.models import CategoricalColorMapper, ColorBar, HoverTool, CustomJSHover
import holoviews as hv
from pprint import pprint

hv.extension("bokeh")
```

Select data

[ ]:
```
COLLECTION = "/work/HELPDESK_SWOTLR/commun/data/swot/L3_LR_SSH/zcollections/V1.0.2_SCIENCE"
collection = swot_calval.io.open_collection(COLLECTION)

zds = collection.query(
    cycle_numbers=17,
    pass_numbers=320,
    selected_variables=[
        "time",
        "longitude",
        "latitude",
        "duacs_ssha_karin_2",
        "duacs_ssha_karin_2_calibrated",
        "duacs_editing_flag",
        "ssha_karin_2_qual",
    ],
)
```

[ ]:
```
ds_karin = zds.to_xarray()
ds_karin.load()
ds_karin
```

[ ]:
```
# Mediterranean sea
kw_area = dict(x_range=(-2, 10), y_range=(36, 43))
```

DUACS editing flag

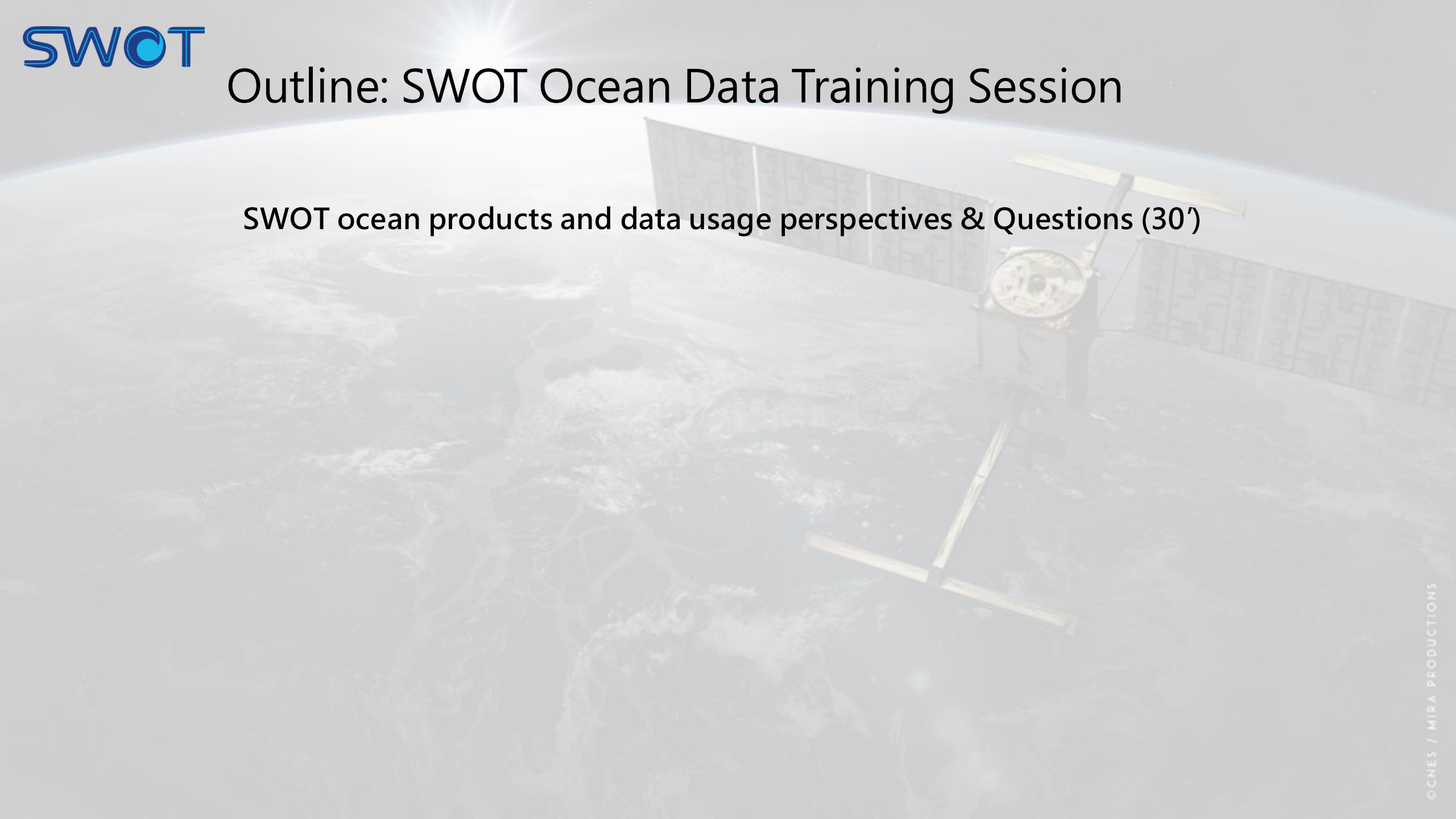
The quality flag `duacs_editing_flag` is declared from L3 DUACS processing. This is a boolean mask, using some of the L3 flags plus additionnal criteria to state if the data is good or bad

Simple 0 3 Helpdesk SwotLR (DEV) | Idle Mode: Command Ln 1, Col 1 ex_visualize_quality_flag.ipynb 0

14:13
29/08/2024

Outline: SWOT Ocean Data Training Session

SWOT ocean products and data usage perspectives & Questions (30')



SWOT Ocean Products & Data Usage Perspectives

- **New L3 KaRIn version releases**
  - Flag editing and tide correction updates (v1.0.2, sep 2024)
  - Improved calibration procedure, SSHA over eclipse events, SSHA in ice-leads (L3 250m) (v2.0, nov 2024)

- **Data usage support**
  - Internal tides, waves use case (ongoing)
  - Use cases for coastal and polar applications
  - Webinar sessions in 2025 (Q/A, specific application-oriented tutorials, tools, etc.)

SWOT OCEAN DATA ACCESS & SERVICES IN A NUTSHELL

DATA ACCESS

- SWOT ocean data (L2, L3 & L4 products)
- Easy access to other data sets
- Catalog requests & download tools…

DOCUMENTATION

- Dedicated use case examples
- User guides, FAQ,…

ENVIRONMENT

- Research-orientated Python libraries
- SWOT-dedicated toolbox (community-driven GitHub)
- Free hosting of SWOT Projects on CNES HPC

USER SUPPORTS

- SWOT data training
- Help for code optimization
- Helpdesk…

HELPDESK & TECHNICAL SUPPORT

aviso-swot@altimetry.fr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