



# Surface Water and Ocean Topography (SWOT) Mission

Science Team Meeting

Toulouse, 19 September 2023

Roger Fjørtoft (on behalf of the ADT)



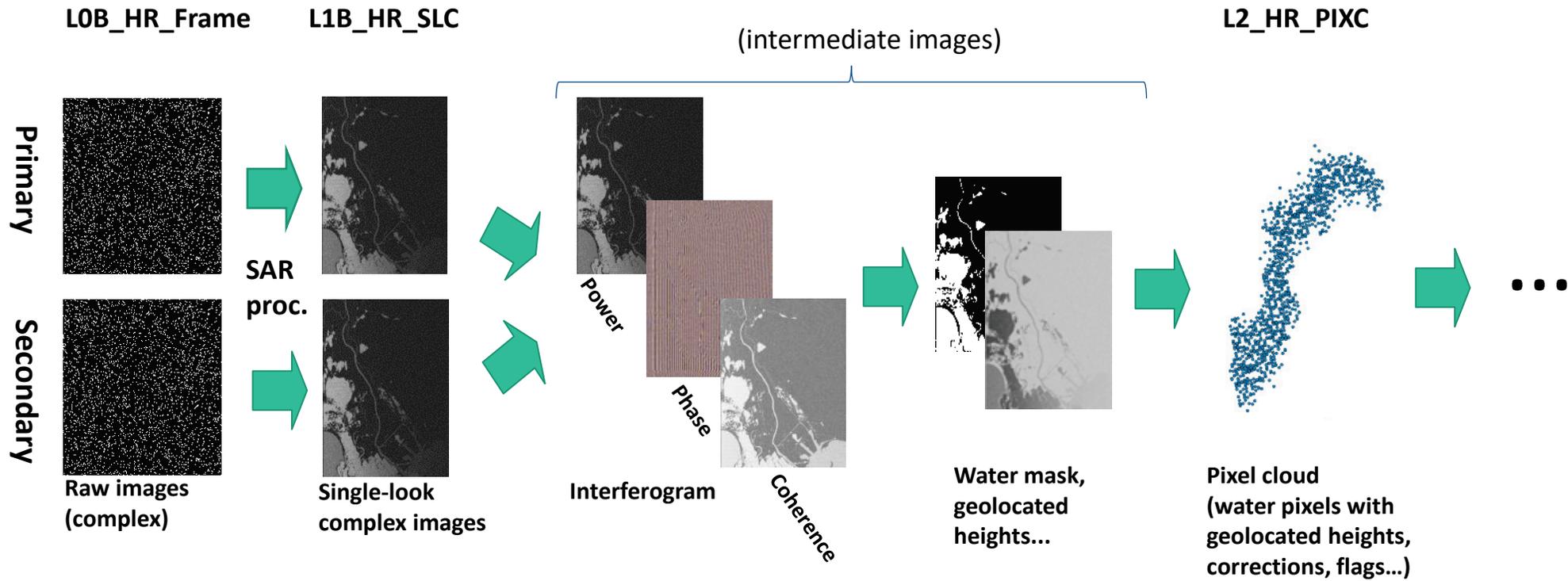
## KaRIn HR Hydrology Products Status and Examples

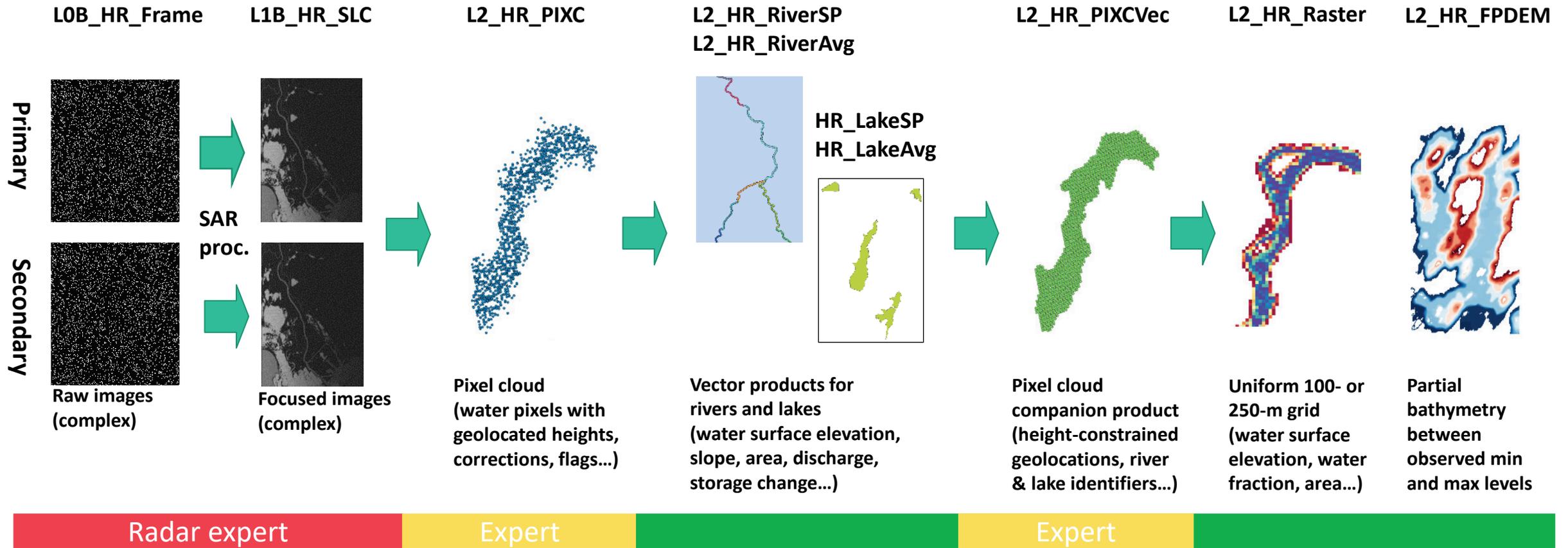
9 months after launch...

- ❖ Forward processing up to L2 HR vector products from the beginning of HR data acquisition
- ❖ Many bug-fixes and algorithm improvements
- ❖ Calibration and tuning of processing parameters
- ❖ New versions of auxiliary data
- ❖ Minor modifications in product format
- ❖ Updates to quality flags and how they are used in downstream processing
- ❖ Room for further improvements in algorithms and product quality
  
- ❖ Forward processing and reprocessing campaigns: as described for LR data

Remainder of presentation: Examples based on real SWOT HR products (mainly favorable cases...)

- ❖ Detailed descriptions of products provided at previous ST meetings
- ❖ Production Description Documents (PDDs) and Algorithm Theoretical Basis Documents (ATBDs) available





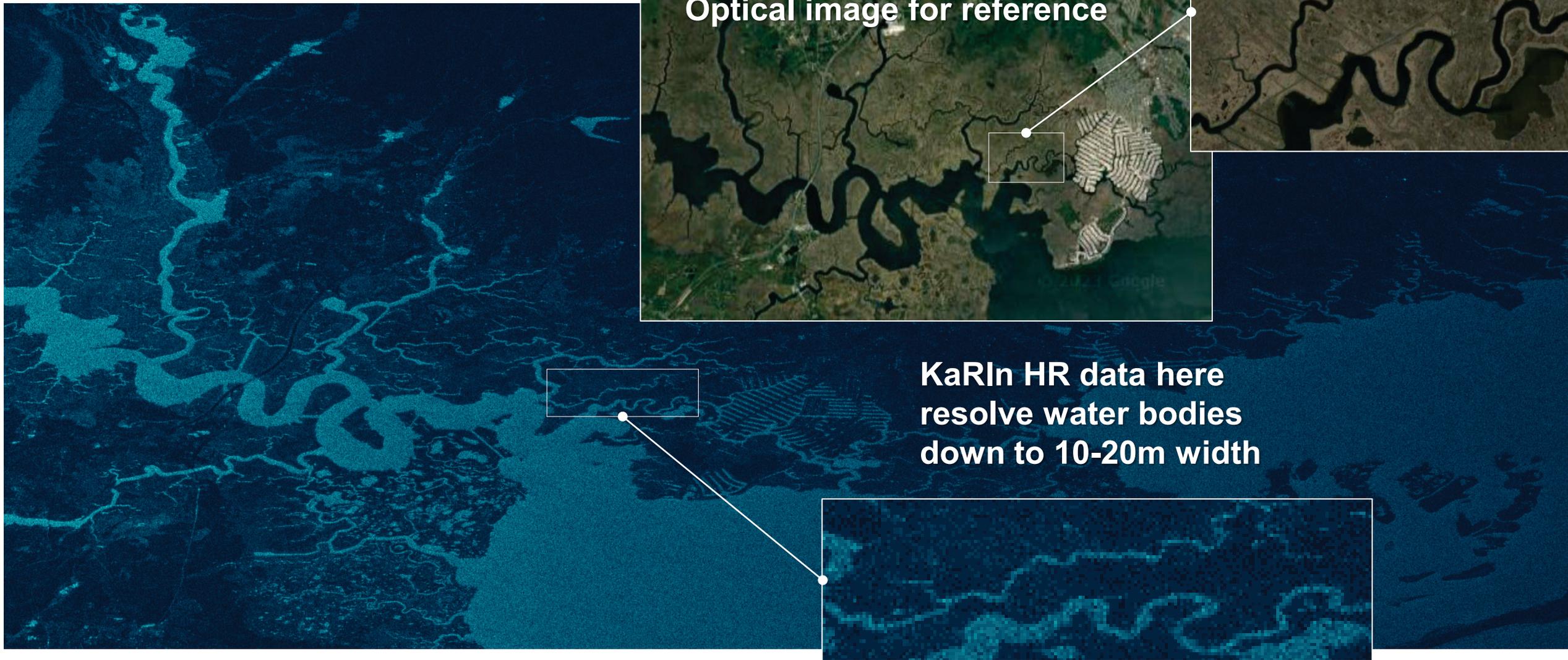
**L1B\_HR\_SLC → L2\_HR\_PIXC**

INTERMEDIATE IMAGES (NOT ARCHIVED/DISTRIBUTED)

PHENOMENOLOGY

# KaRIn HR data January 21<sup>st</sup> 2023 (New Jersey)

## Extract of power image



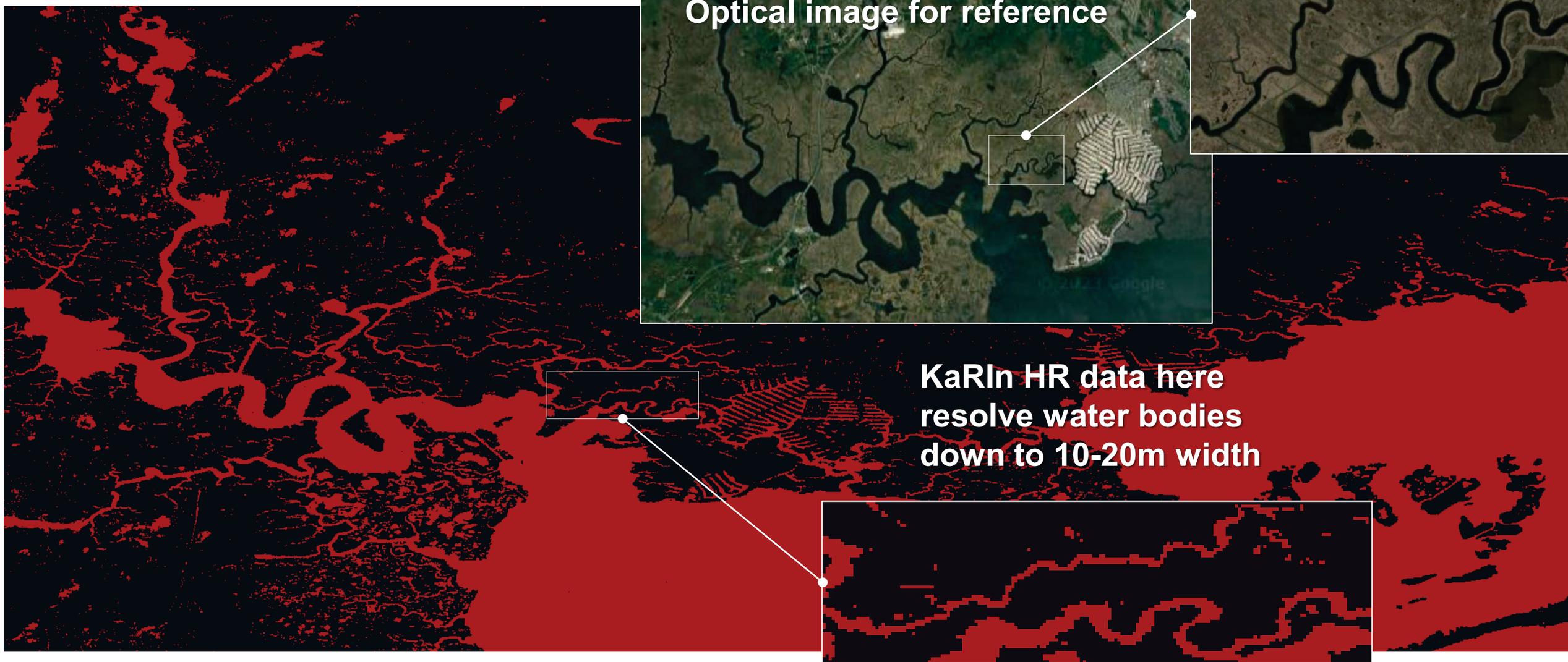
Optical image for reference

KaRIn HR data here resolve water bodies down to 10-20m width

SWOT science requirement is to monitor rivers larger than 100m (goal 50m) and lakes larger than 250x250m<sup>2</sup> (goal 100x100m<sup>2</sup>)

# KaRIn HR data January 21<sup>st</sup> 2023 (New Jersey)

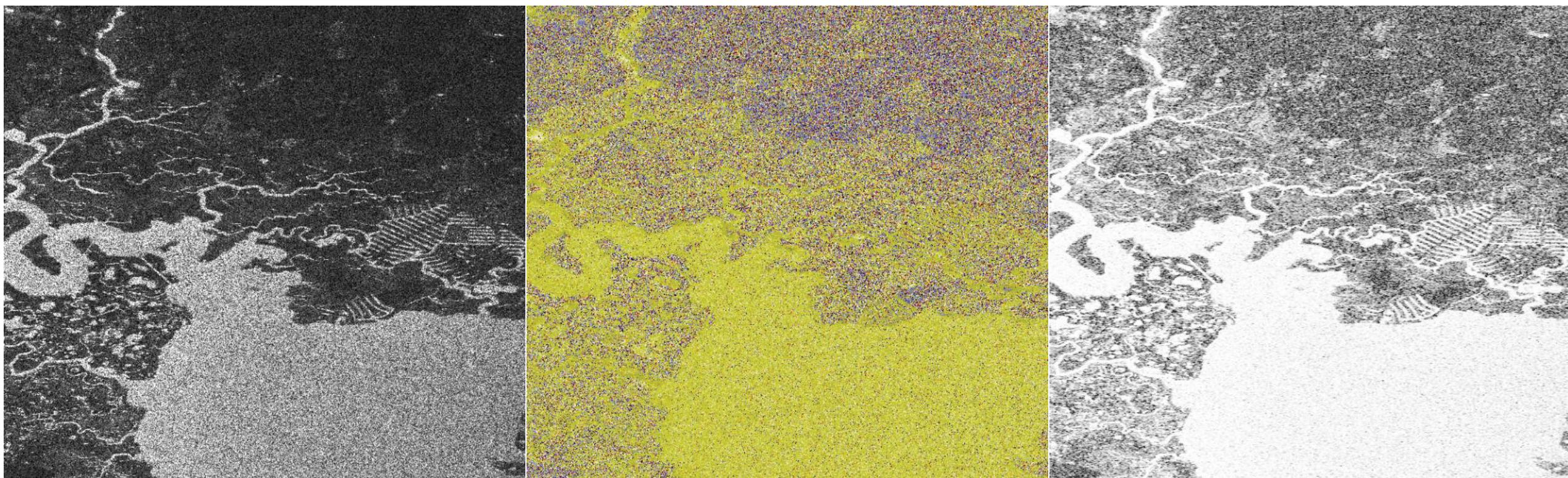
## Extract of detected water mask



SWOT science requirement is to monitor rivers larger than 100m (goal 50m) and lakes larger than 250x250m<sup>2</sup> (goal 100x100m<sup>2</sup>)

# KaRIn HR data January 21<sup>st</sup> 2023 (New Jersey)

## Extract of interferogram



Power

Interferometric phase  $[0, 2\pi]$

Interferometric coherence  $[0,1]$

Favorable conditions w.r.t. water roughness (wind speed  $\sim 3$  m/s) and landcover (mostly vegetation)

- Strong water/land contrast yielding excellent water detection (previous page)
- Interferometric coherence (quality indicator of interferometric phase) over water is very high ( $\sim 0.9-0.95$ ), enabling precise height extraction from the interferometric phase

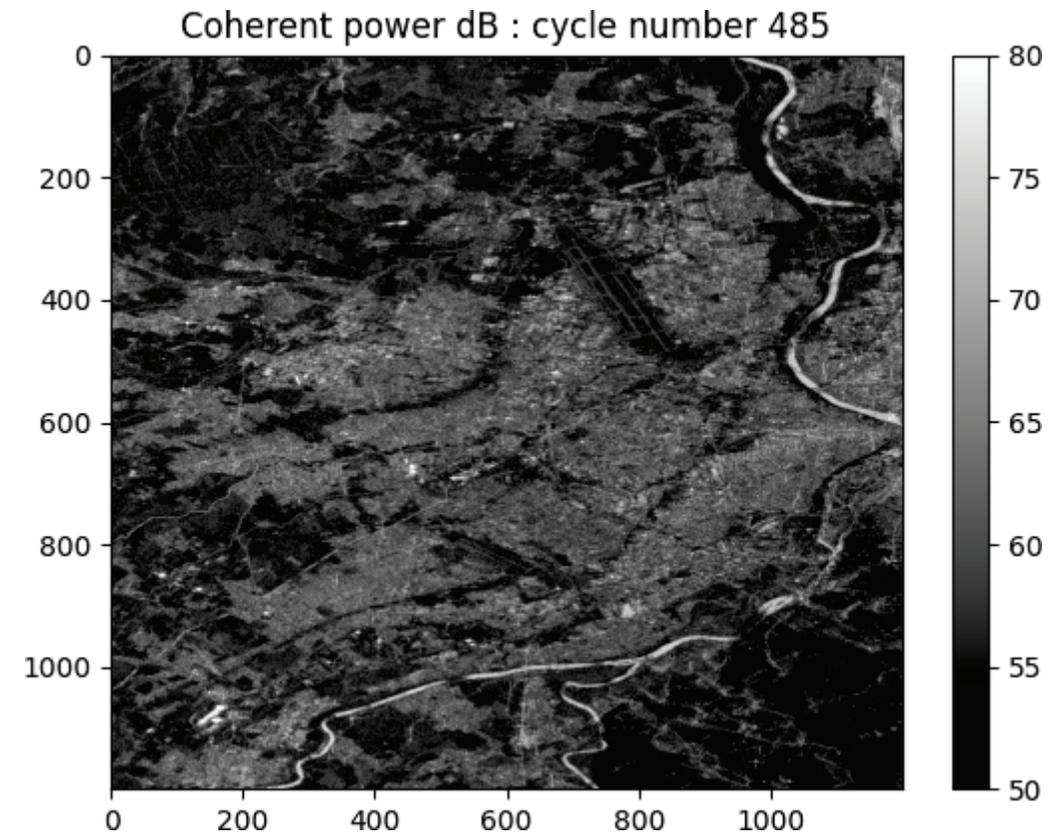
# KaRIn HR image of Toulouse: March 16<sup>th</sup> 2023

## Coherent power



### Dark water phenomenon

- The backscattering of water surfaces becomes very weak when there is neither wind nor swirl (no roughness).
- We see here that for some dates, there are lakes and river portions that become very dark.
- No signal = no height information...
- SWOT HR products for rivers and lakes have a certain robustness against partial dark water.

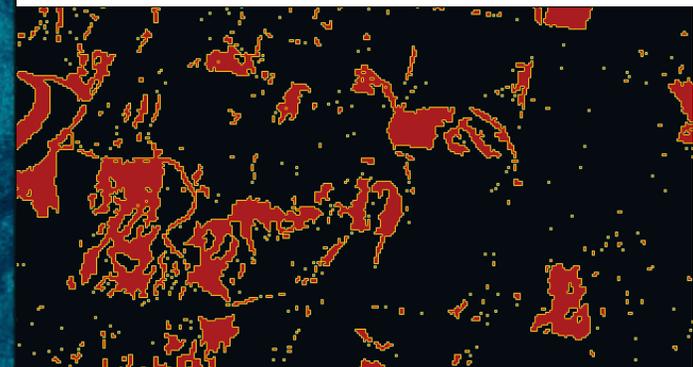


# Bright agricultural fields near the Willamette River (Oregon, USA)



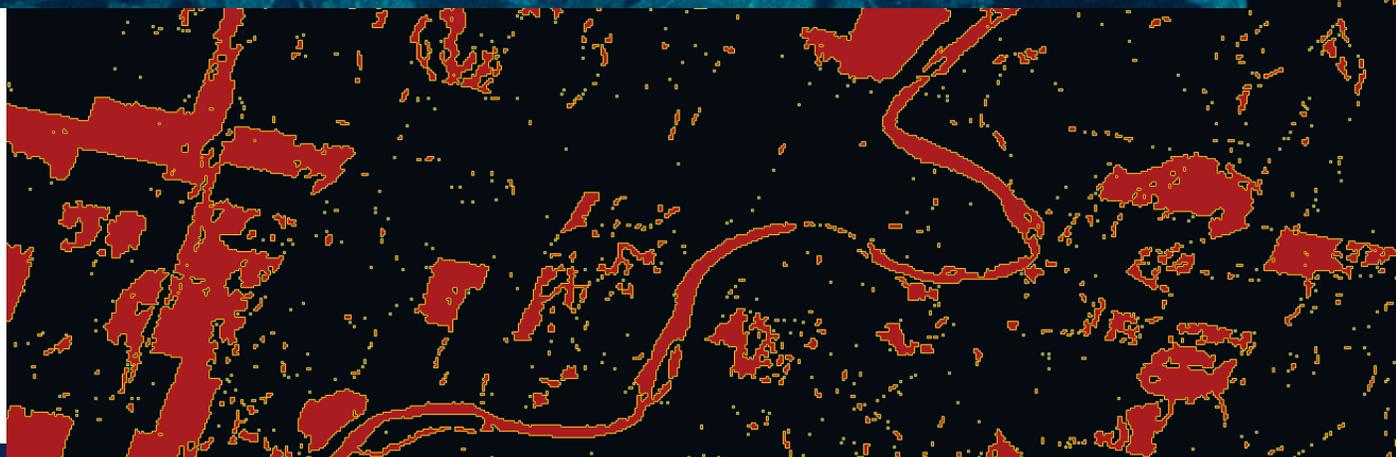
Some agricultural fields are (almost) as bright as the river in this KaRIn HR image, due to wet soil and puddles (after heavy rainfall).

- Causes over-detection of water
- Similar backscattering for wetlands

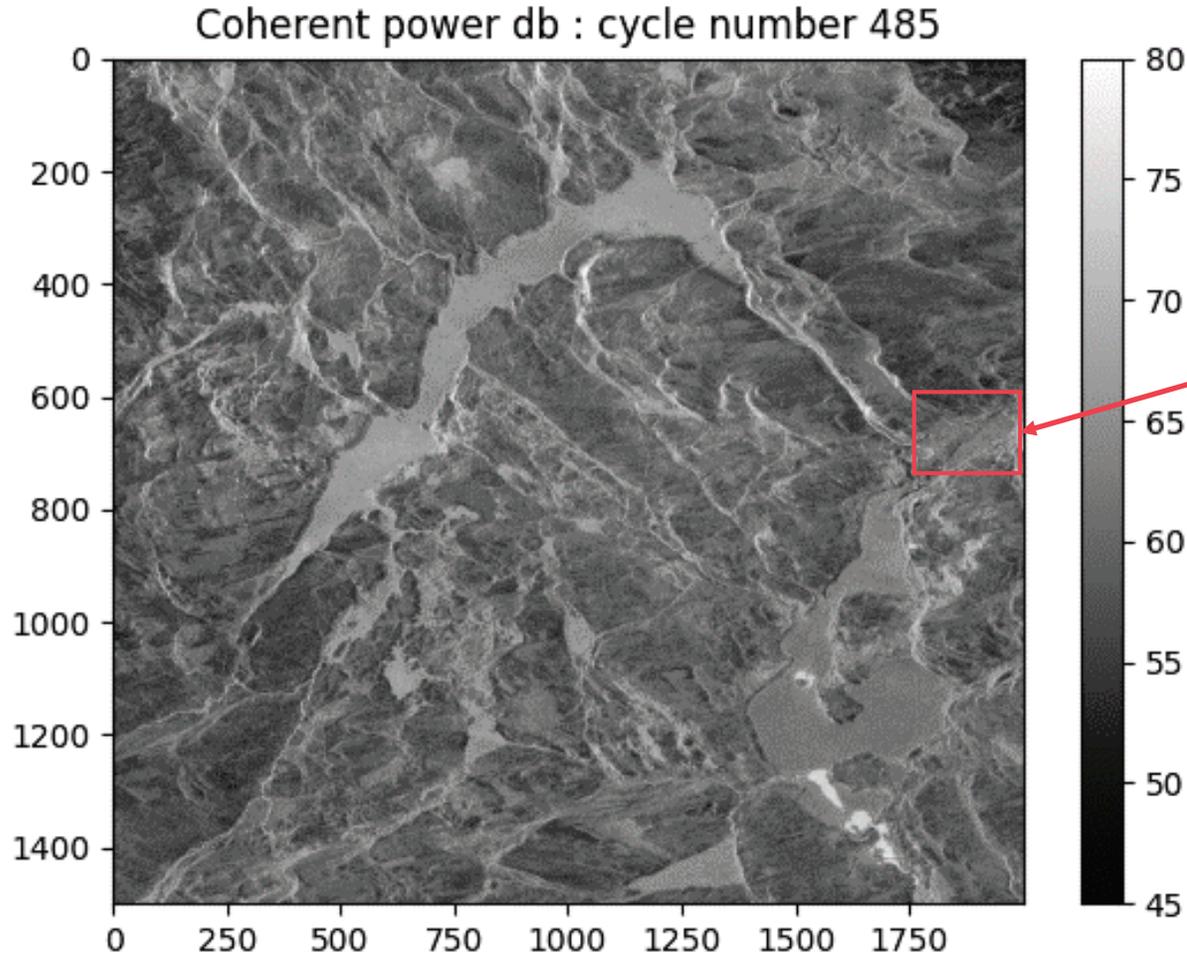


KaRIn HR  
coherent power

Detected  
water mask

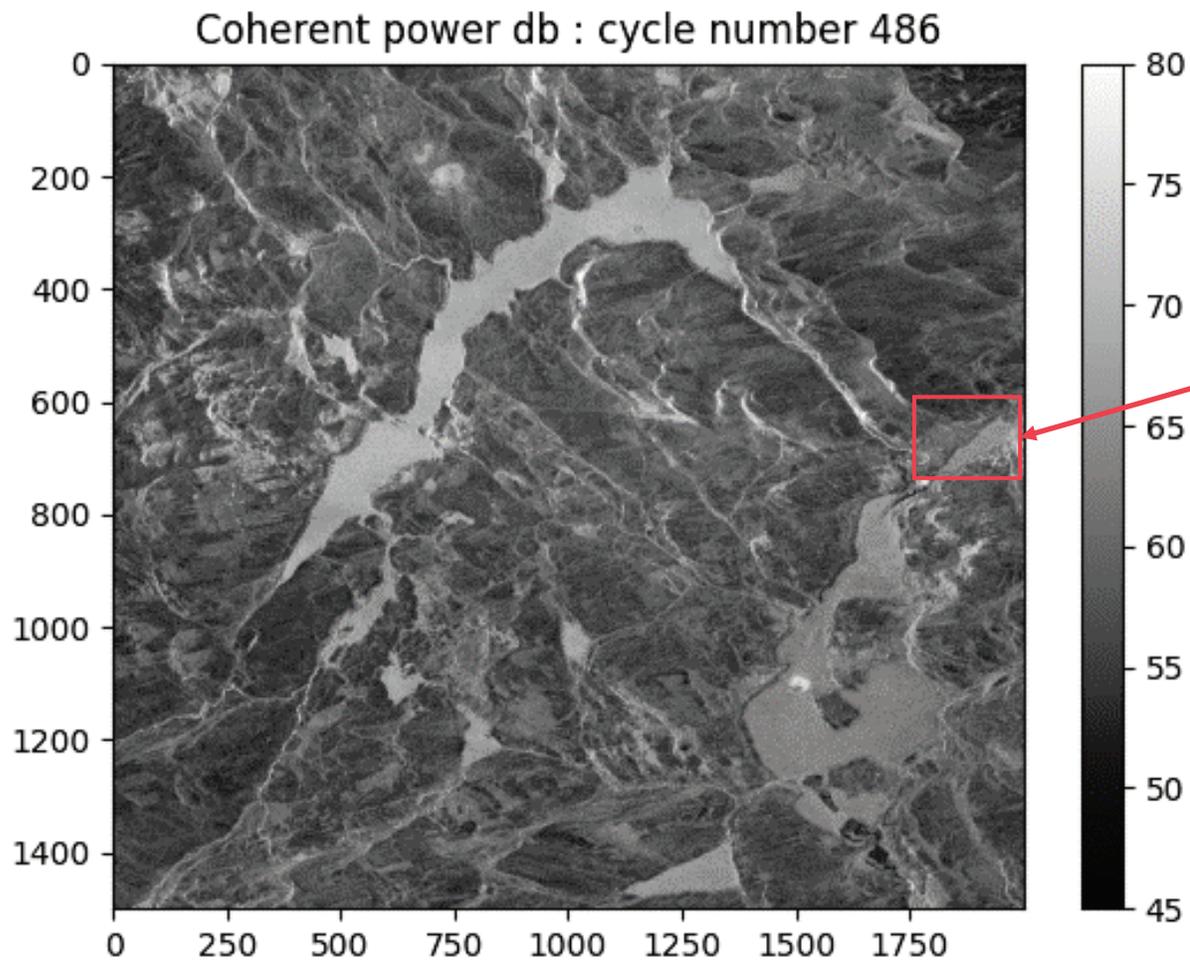


# Ice melting: Lake Aylmer and Lake Saint François (Canada)



(Images provided by University of Sherbrooke, Canada)

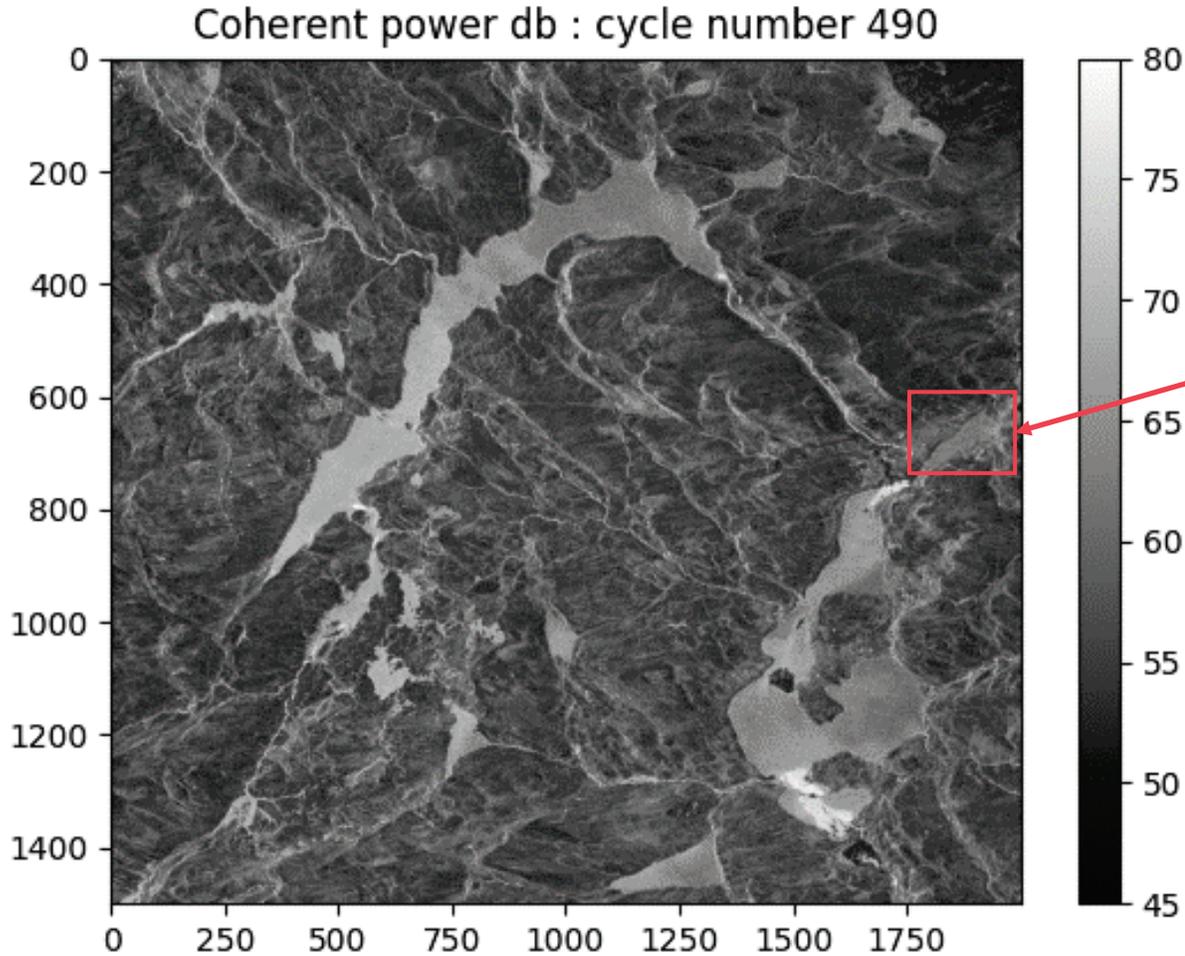
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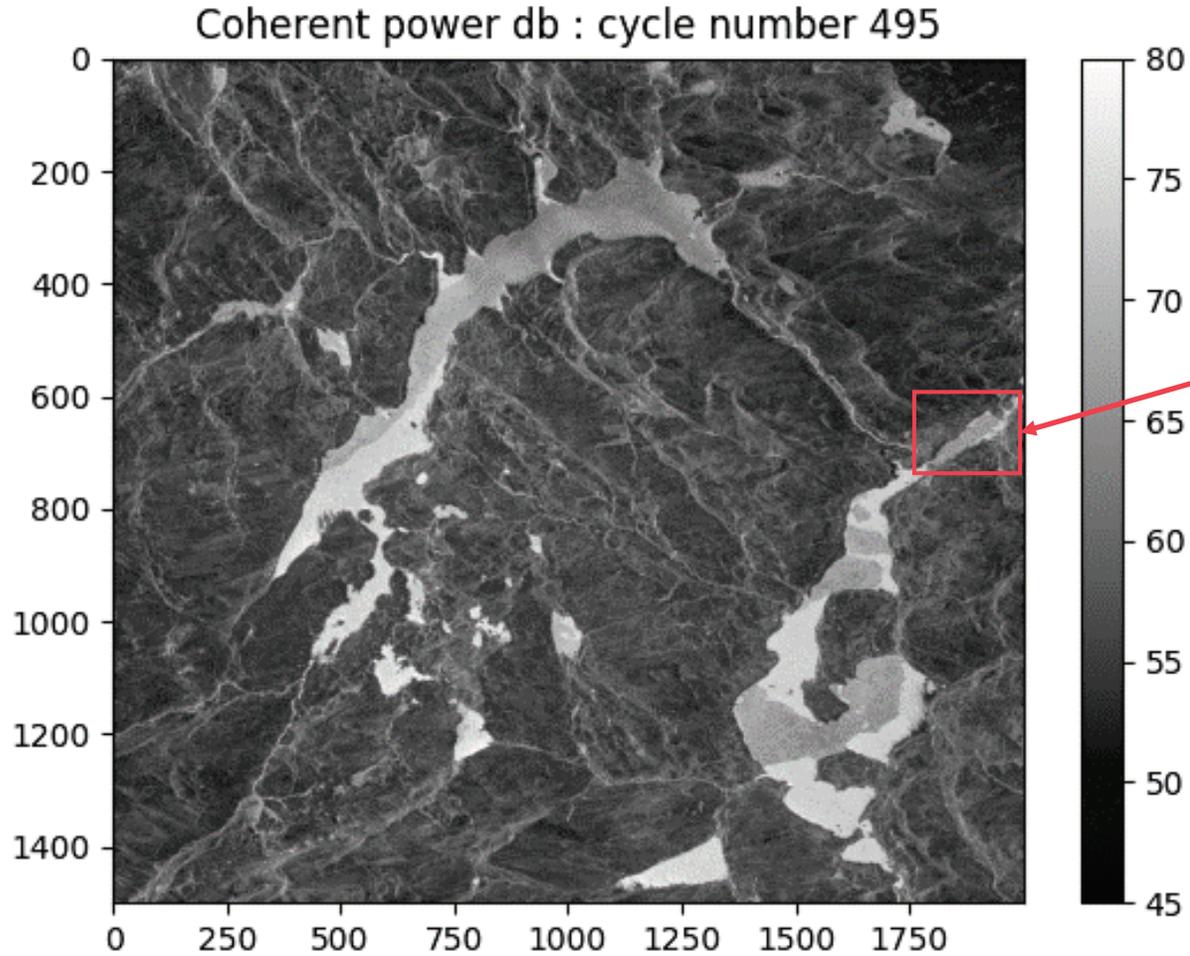


# Ice melting: Lake Aylmer and Lake Saint François (Canada)



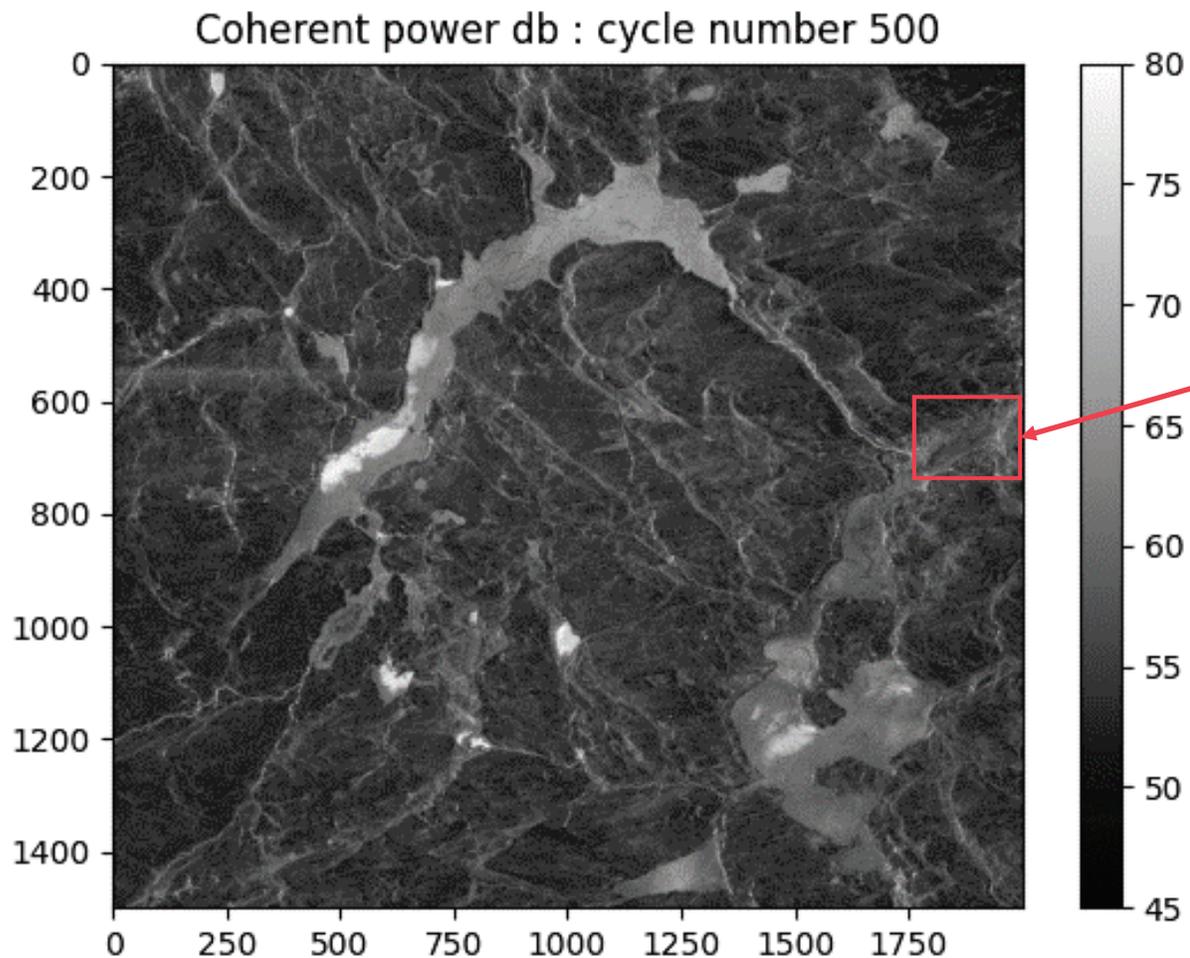
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# Ice melting: Lake Aylmer and Lake Saint François (Canada)



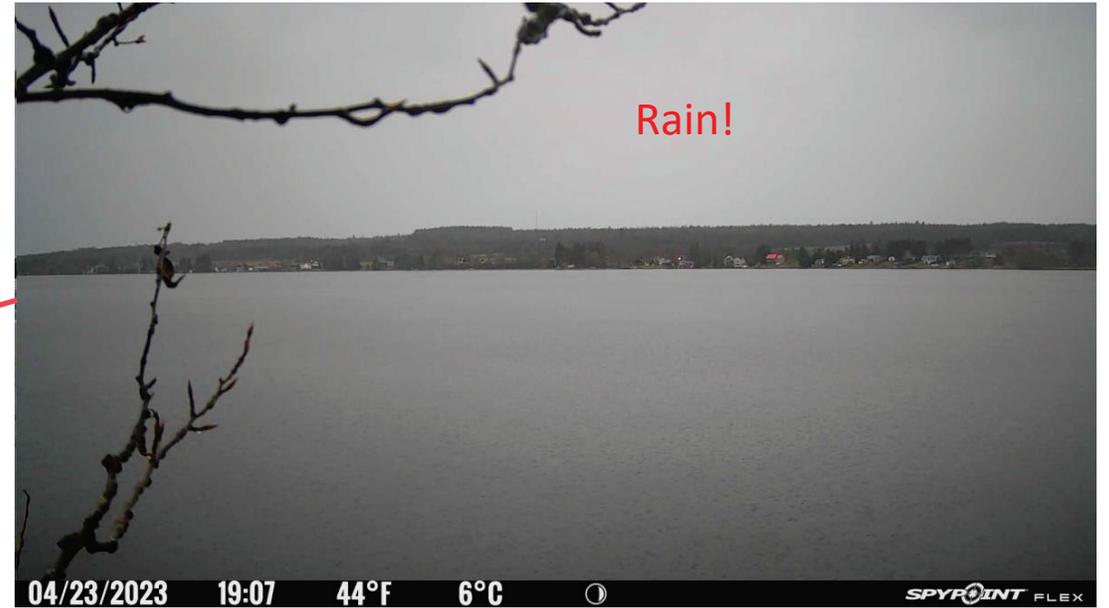
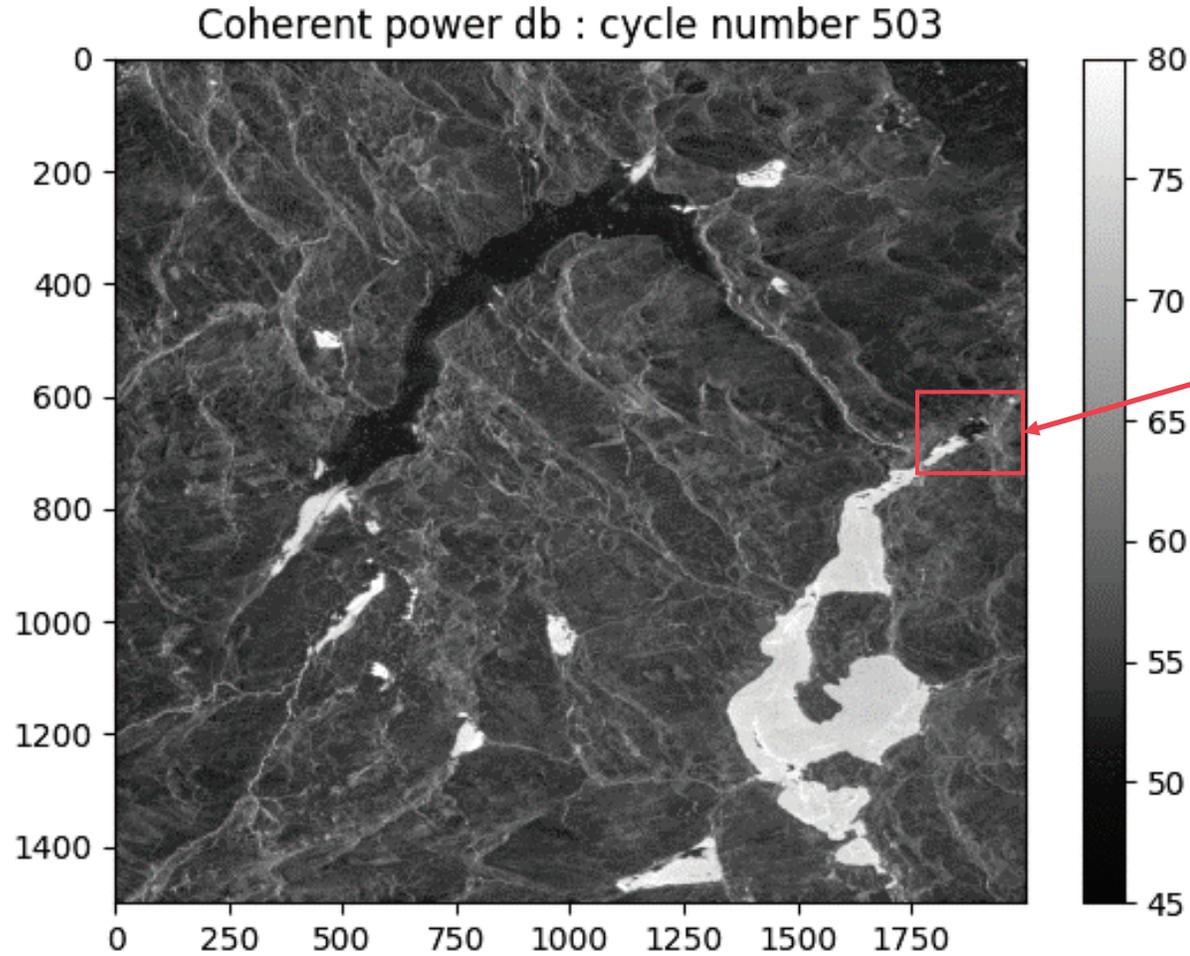
(Images provided by University of Sherbrooke, Canada)

# Ice melting: Lake Aylmer and Lake Saint François (Canada)



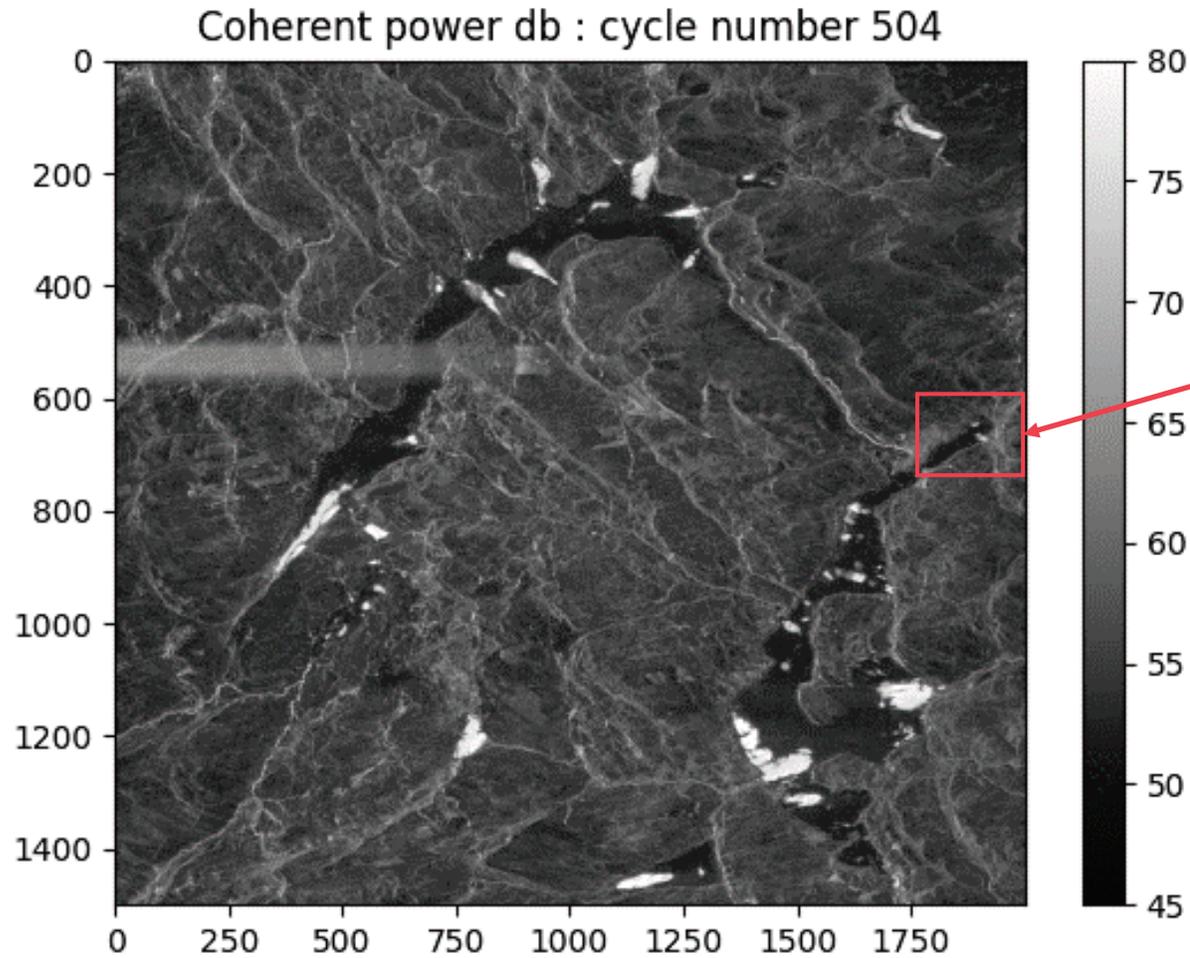
(Images provided by University of Sherbrooke, Canada)

# Ice melting: Lake Aylmer and Lake Saint François (Canada)



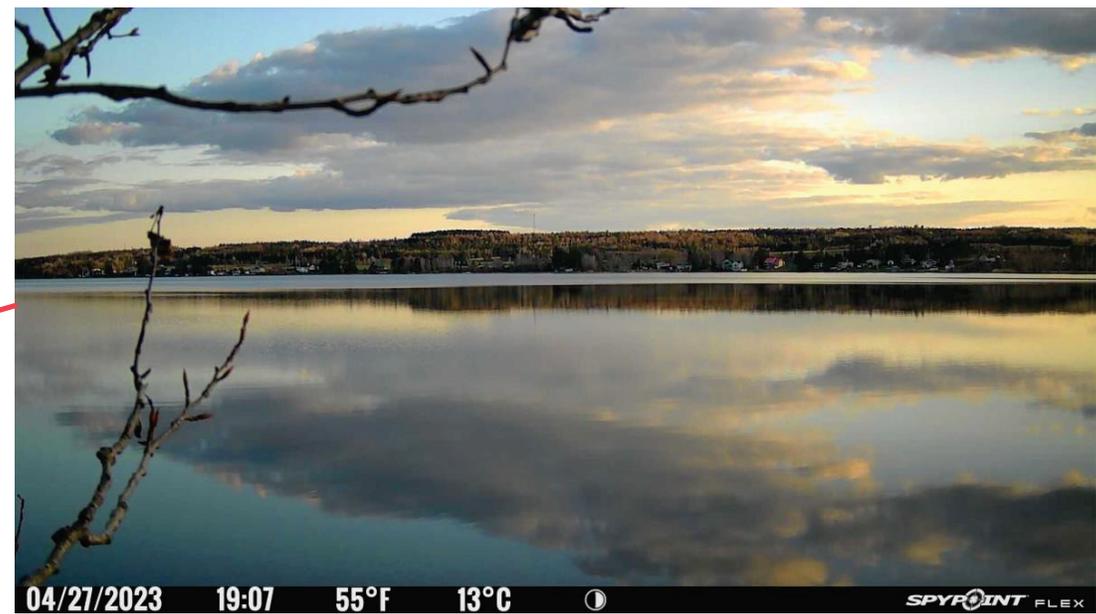
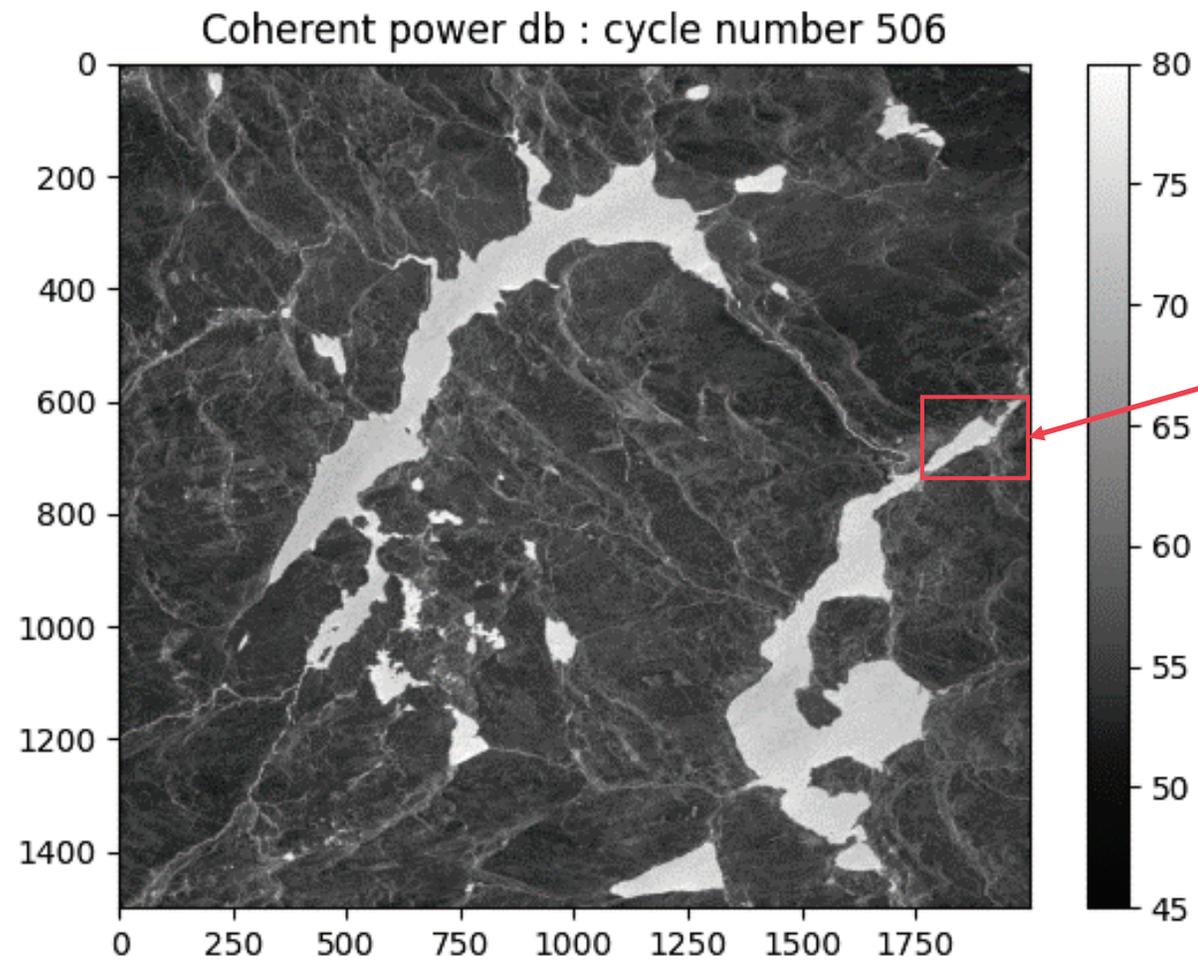
(Images provided by University of Sherbrooke, Canada)

# Ice melting: Lake Aylmer and Lake Saint François (Canada)



(Images provided by University of Sherbrooke, Canada)

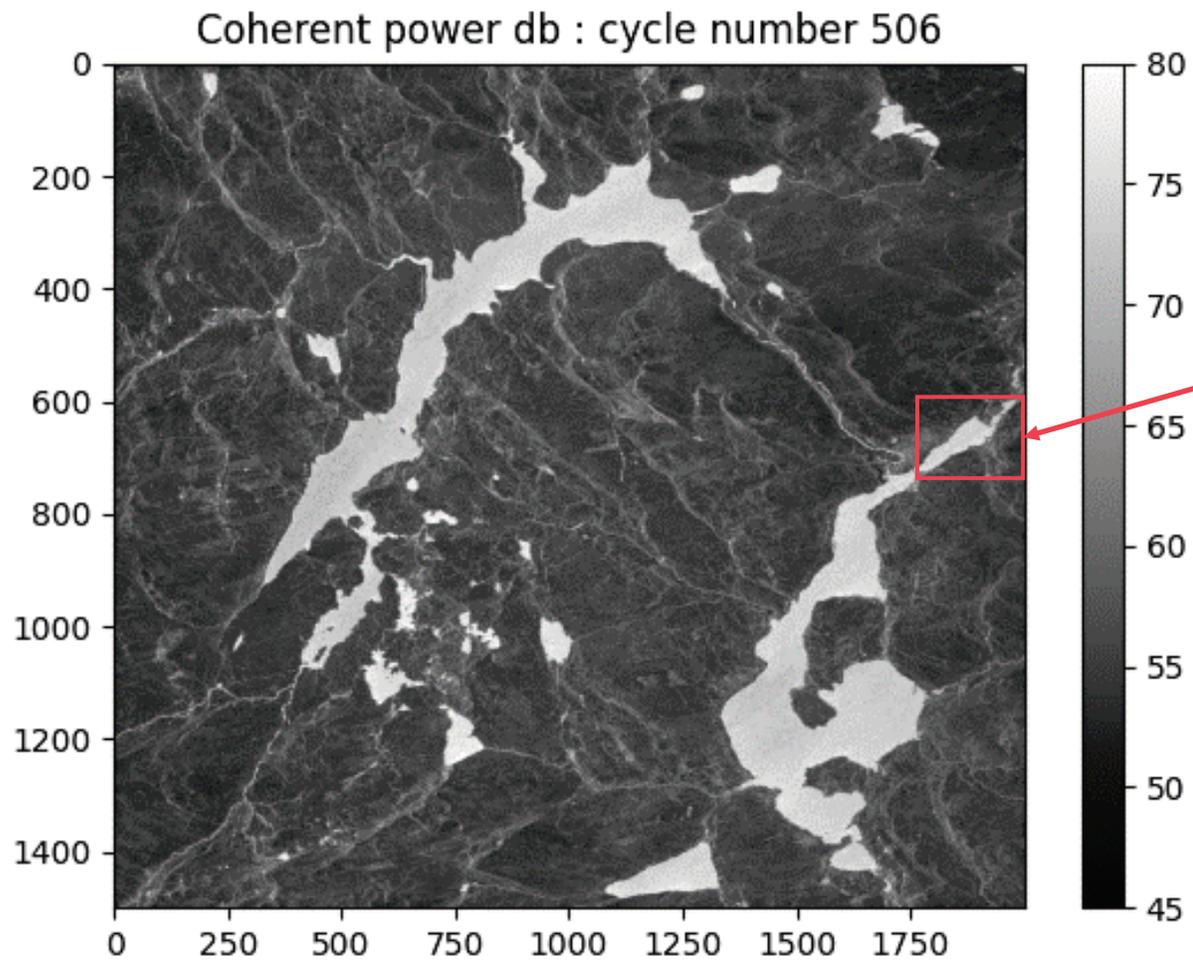
# Ice melting: Lake Aylmer and Lake Saint François (Canada)



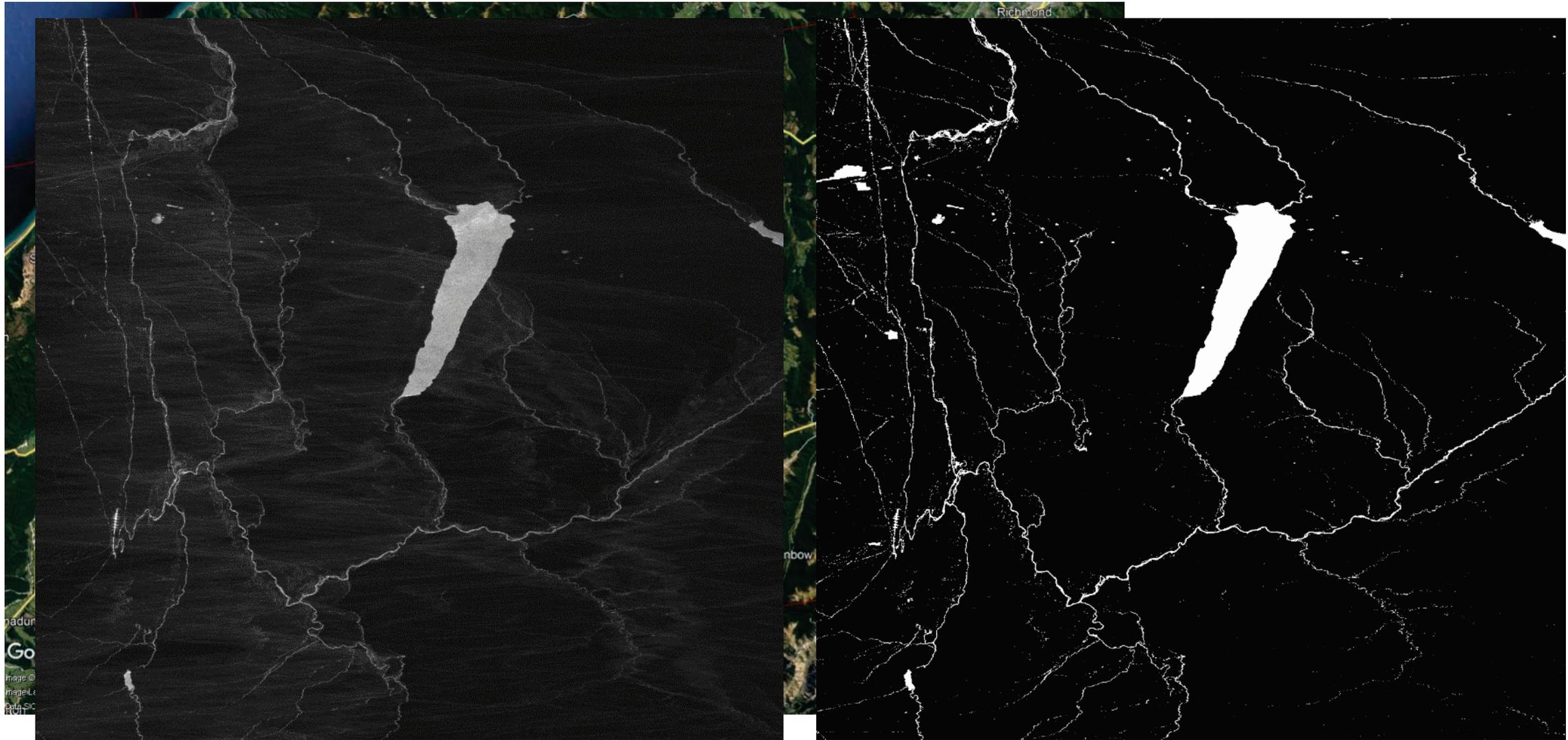
(Images provided by University of Sherbrooke, Canada)



# Ice melting: Lake Aylmer and Lake Saint François (Canada)



(Images provided by University of Sherbrooke, Canada)



KaRIn HR coherent power

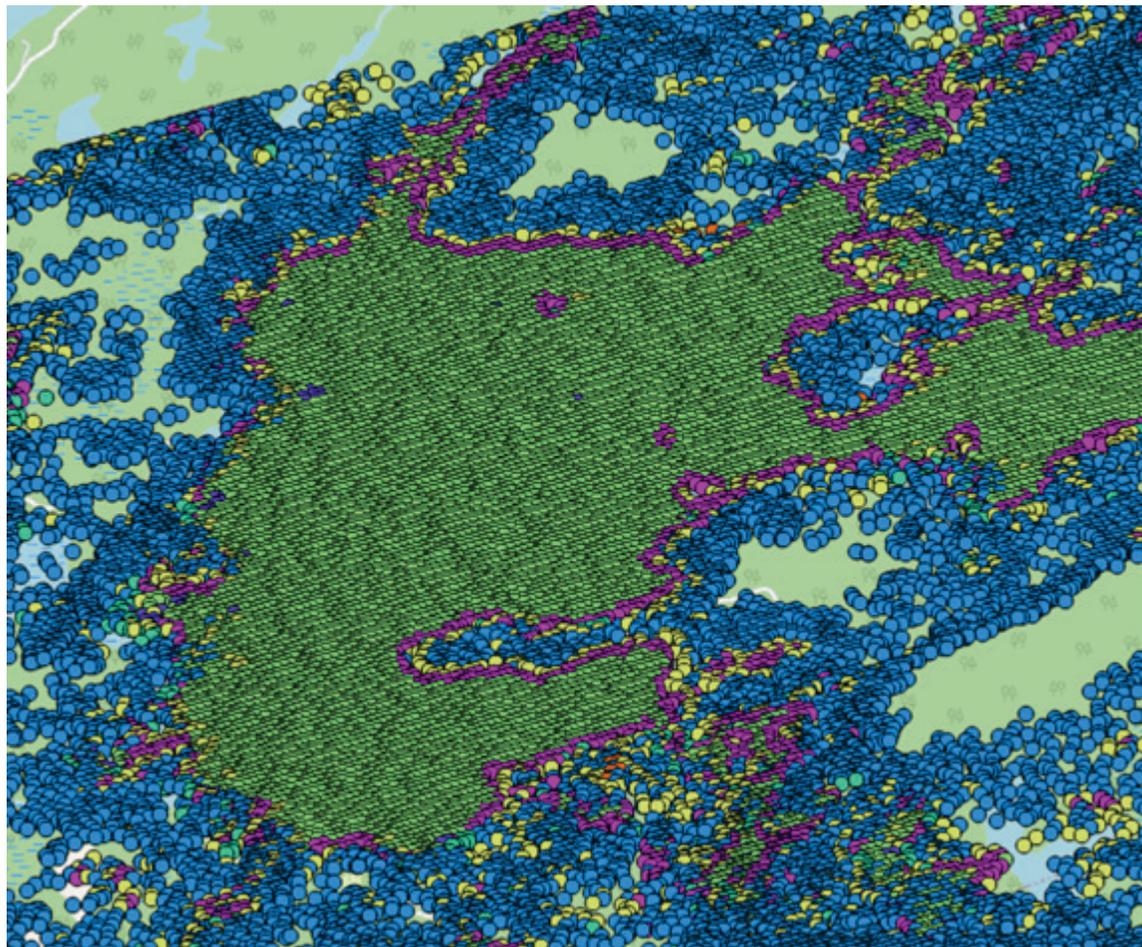
Detected water mask

- In this image, layover does not compromise water detection. Impact of layover on water height under investigation.



**L2\_HR\_PIXC**  
AND L2\_HR\_PIXCVec

## Gull Lake (Canada)



Pixel cloud = Point cloud of pixels

Granule: ~64 km x 64 km tile  
File format: netCDF

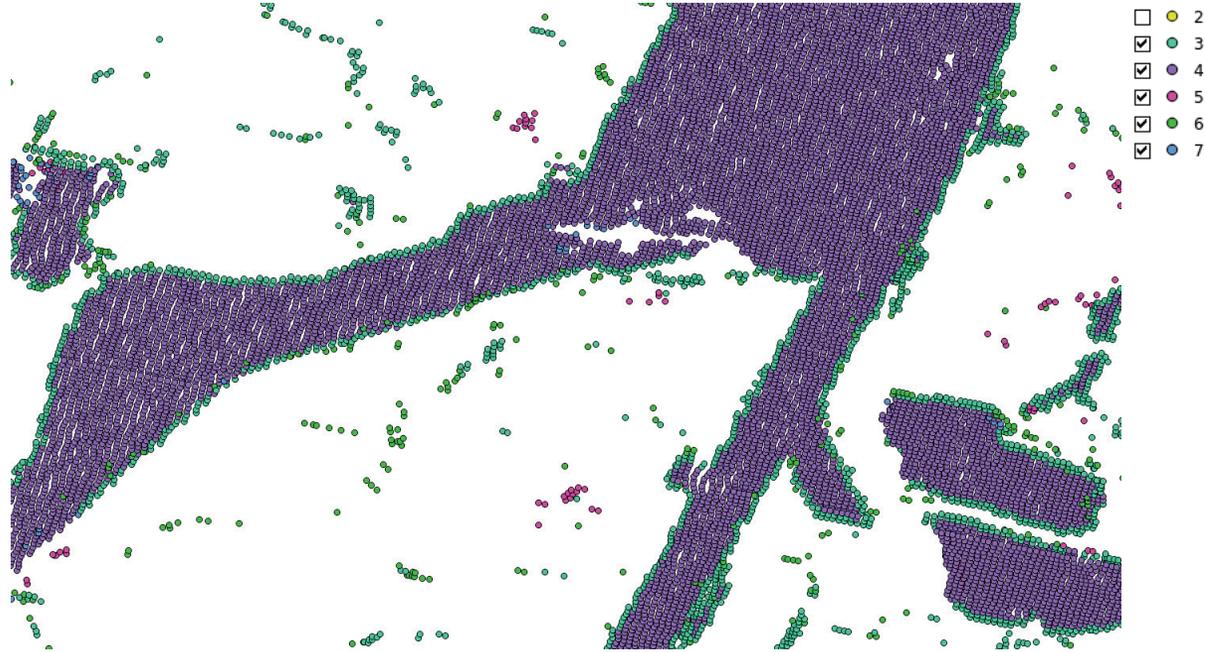
Pixel size:  
~22 m in azimuth  
~60 m to ~10 m in range (from near- to far-range of nominal swath)

For each pixel:

- **latitude/longitude** (and azimuth/range indices)
- **height w.r.t. ellipsoid (WGS84)**
- **classification**
- sigma0
- **uncertainties**
- geophysical corrections
- **flags**
- ...

- 1 = land
  - 2 = land near water
  - 3 = water near land
  - 4 = open water
  - 5 = dark water
  - 6 = low-coherence water near land
  - 7 = open low-coherence water
- } **buffer of land pixels around detected water**
- ← **flagged ~GSWO**
- ← **detected as water**

## Rhine River (France)

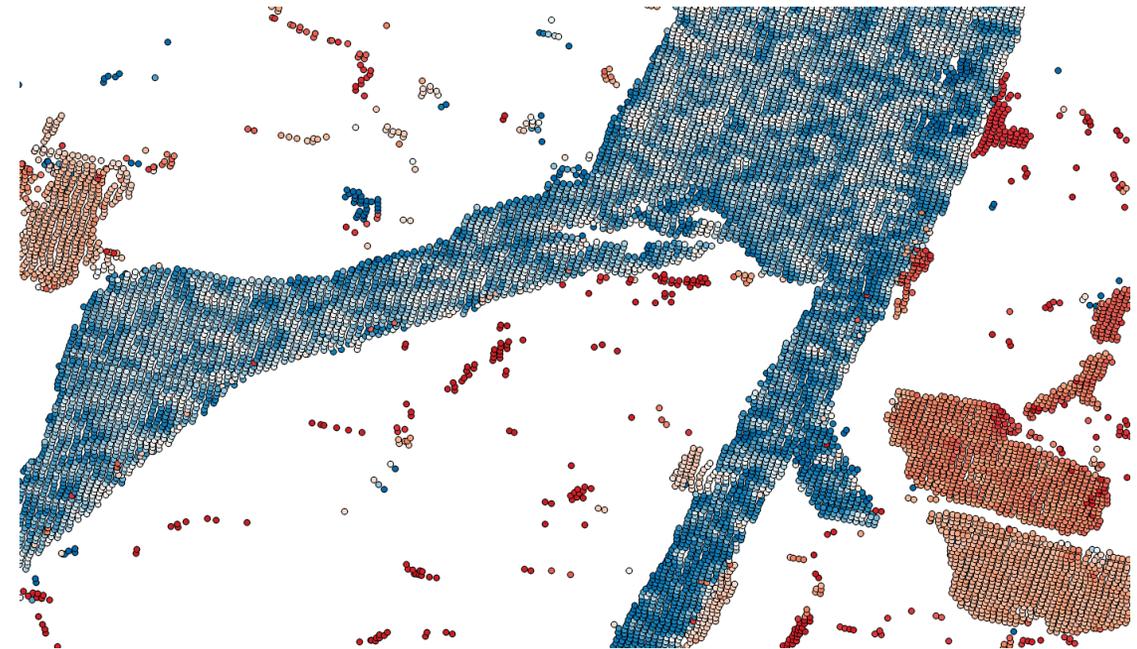


classification

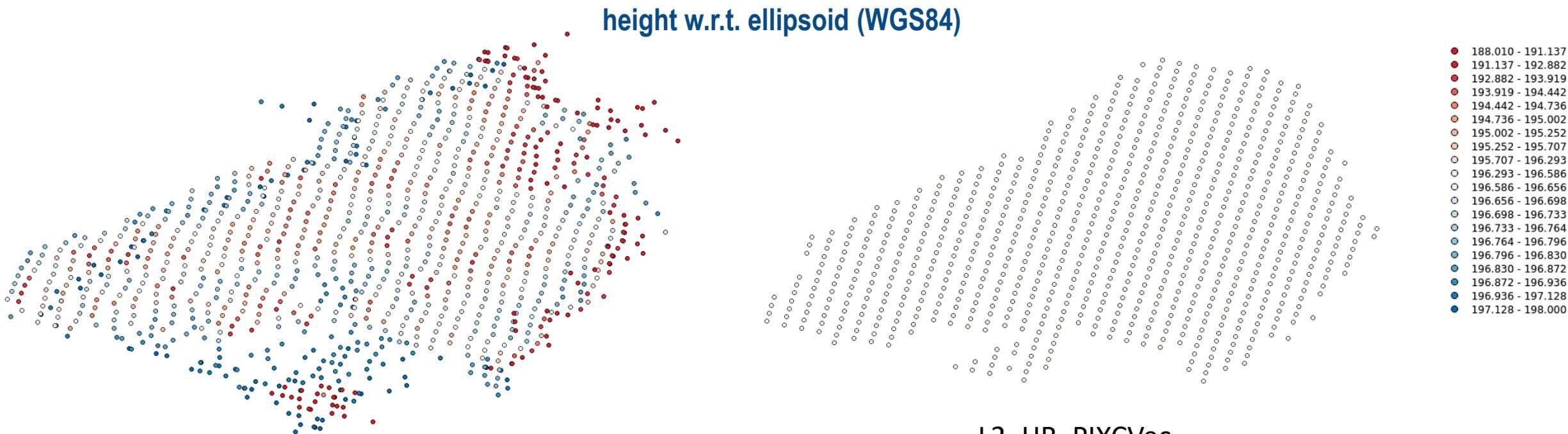
- 2
- 3
- 4
- 5
- 6
- 7

- 188.010 - 191.137
- 191.137 - 192.882
- 192.882 - 193.919
- 193.919 - 194.442
- 194.442 - 194.736
- 194.736 - 195.002
- 195.002 - 195.252
- 195.252 - 195.707
- 195.707 - 196.293
- 196.293 - 196.586
- 196.586 - 196.656
- 196.656 - 196.698
- 196.698 - 196.733
- 196.733 - 196.764
- 196.764 - 196.796
- 196.796 - 196.830
- 196.830 - 196.872
- 196.872 - 196.936
- 196.936 - 197.128
- 197.128 - 198.000

height w.r.t. ellipsoid (WGS84)



Zoom on small lake



L2\_HR\_PIXC

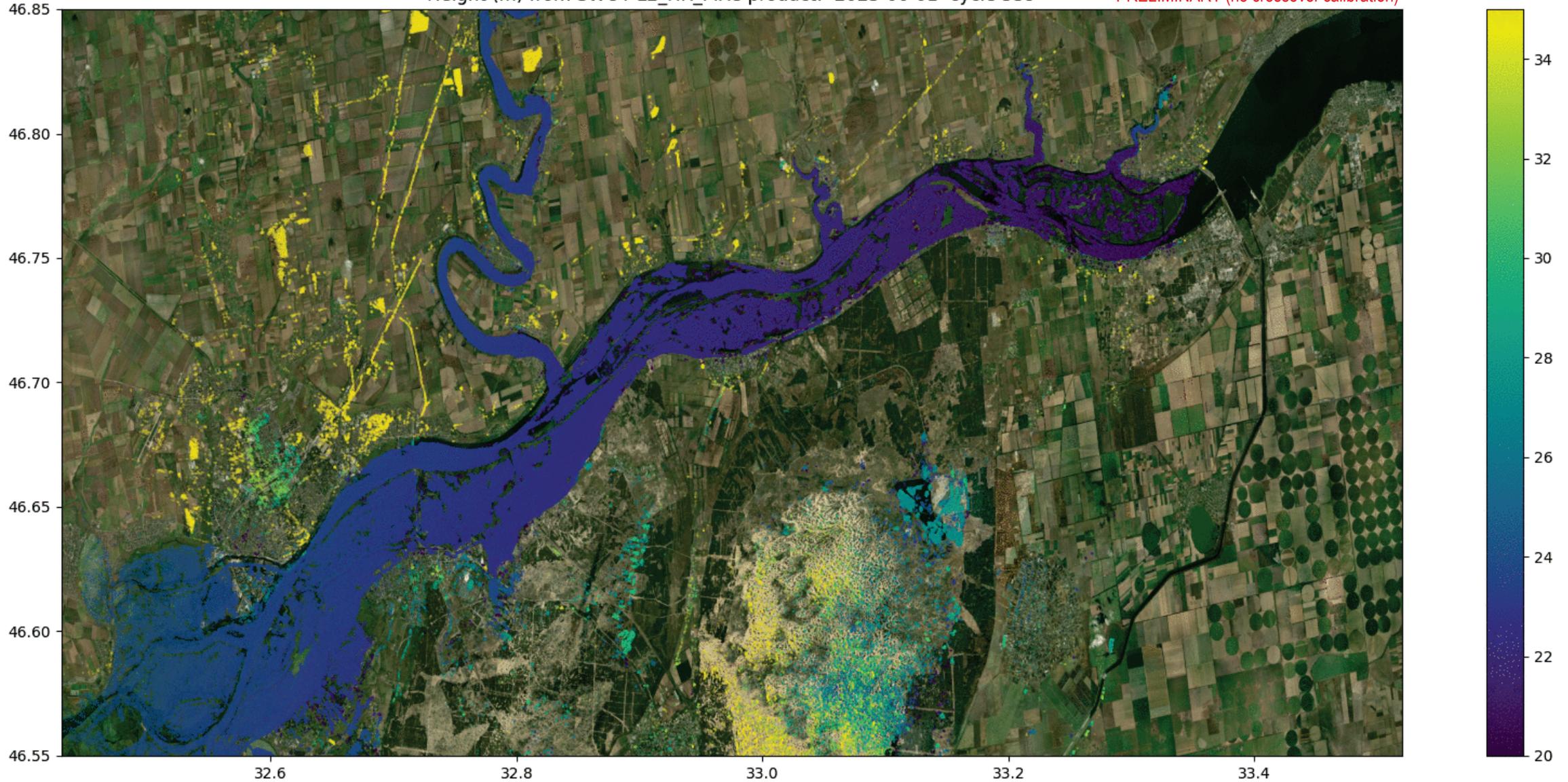
L2\_HR\_PIXCVec

- **height-constrained geolocations (latitude/longitude)**
- regularized height wrt ellipsoid (WGS84)
  - constant for very small lakes
  - regularized slopes for rivers and larger lakes
- **lake and river identifiers**
- ice flag
- ...

# L2\_HR\_PIXC: Flood following the destruction of the Kakhovka dam (Ukraine)

Height (m) from SWOT L2\_HR\_PIXC product: 2023-06-01 cycle 539

PRELIMINARY (no crossover calibration)



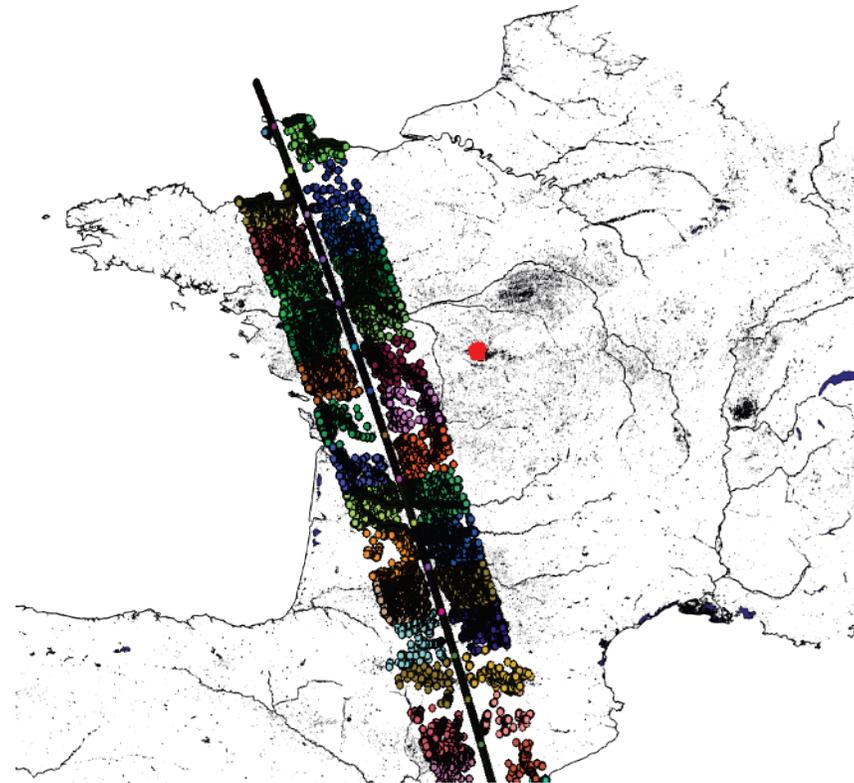
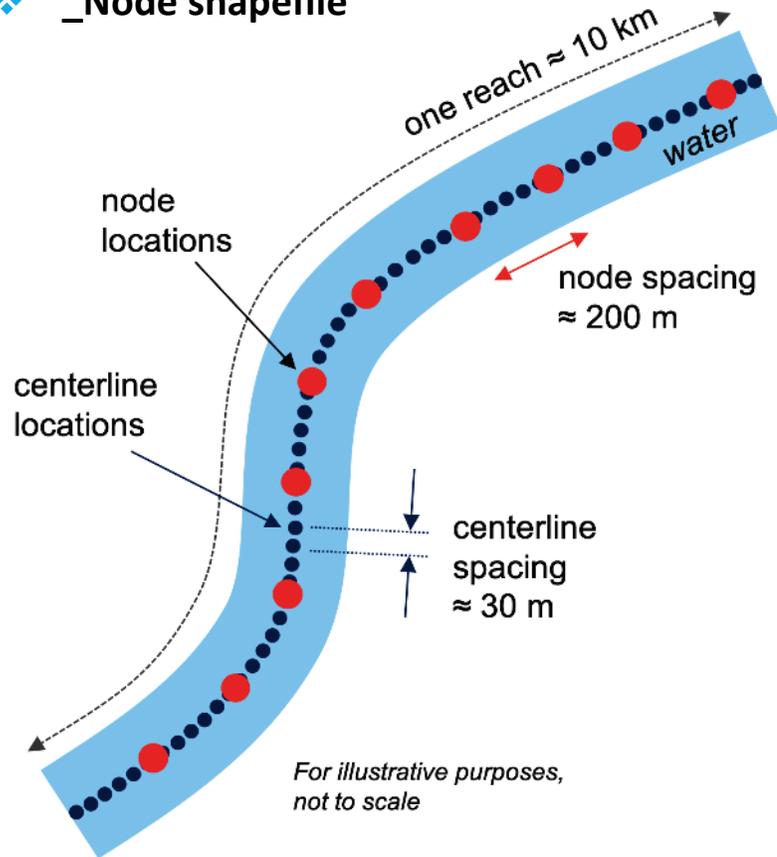


**L2\_HR\_RiverSP**

L2\_HR\_RiverSP products are organized in **2 shapefiles** based on the SWOT River Database (SWORD)

❖ **\_Reach shapefile**

❖ **\_Node shapefile**



RiverSP (and LakeSP) product granule:  
continent-pass, both half swaths

L2\_HR\_RiverSP = 2 shapefiles: **\_Reach**, **\_Node**

Granule: Continent pass, both half swaths

File format: ESRI shapefile (polyline, point)

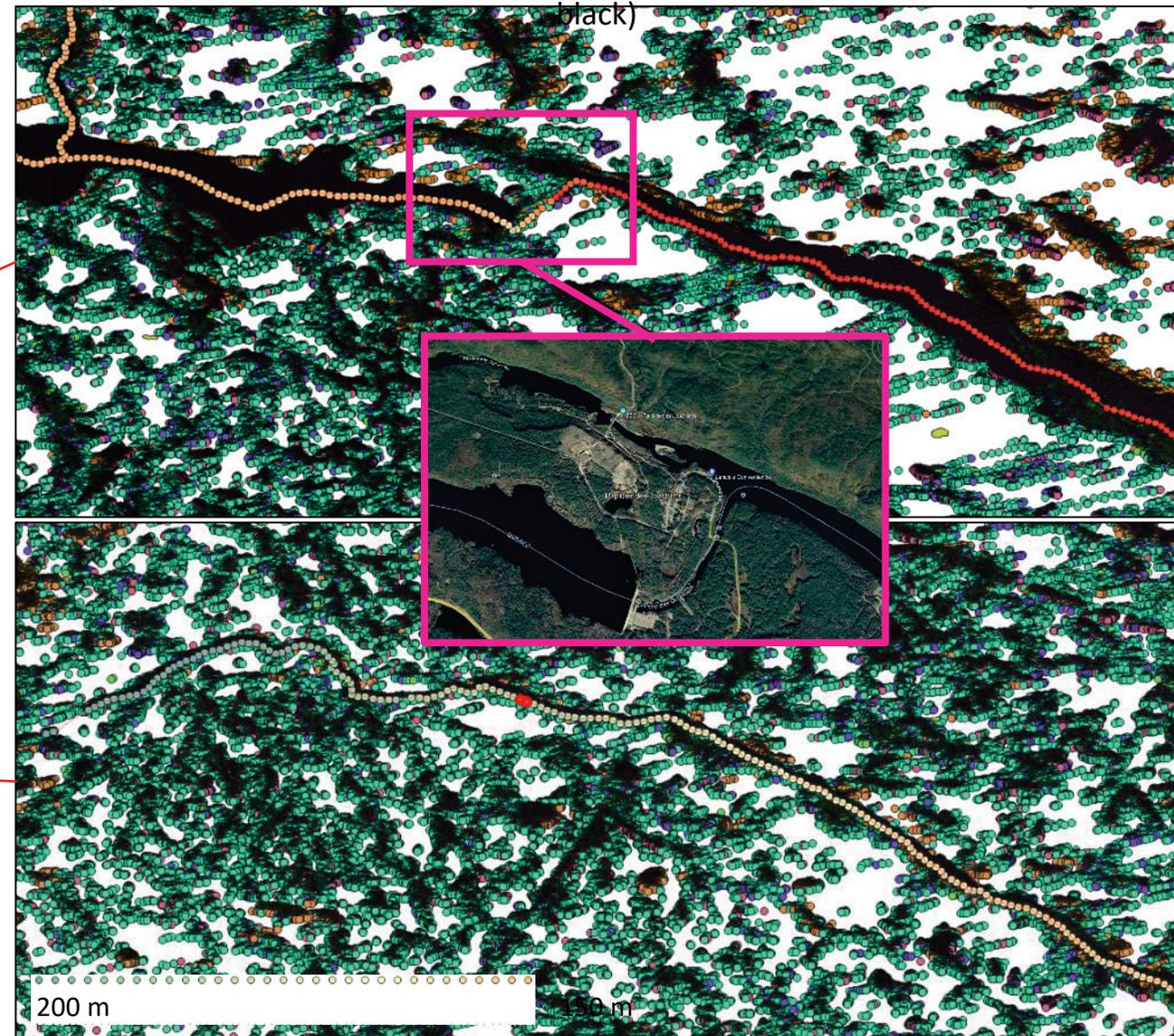
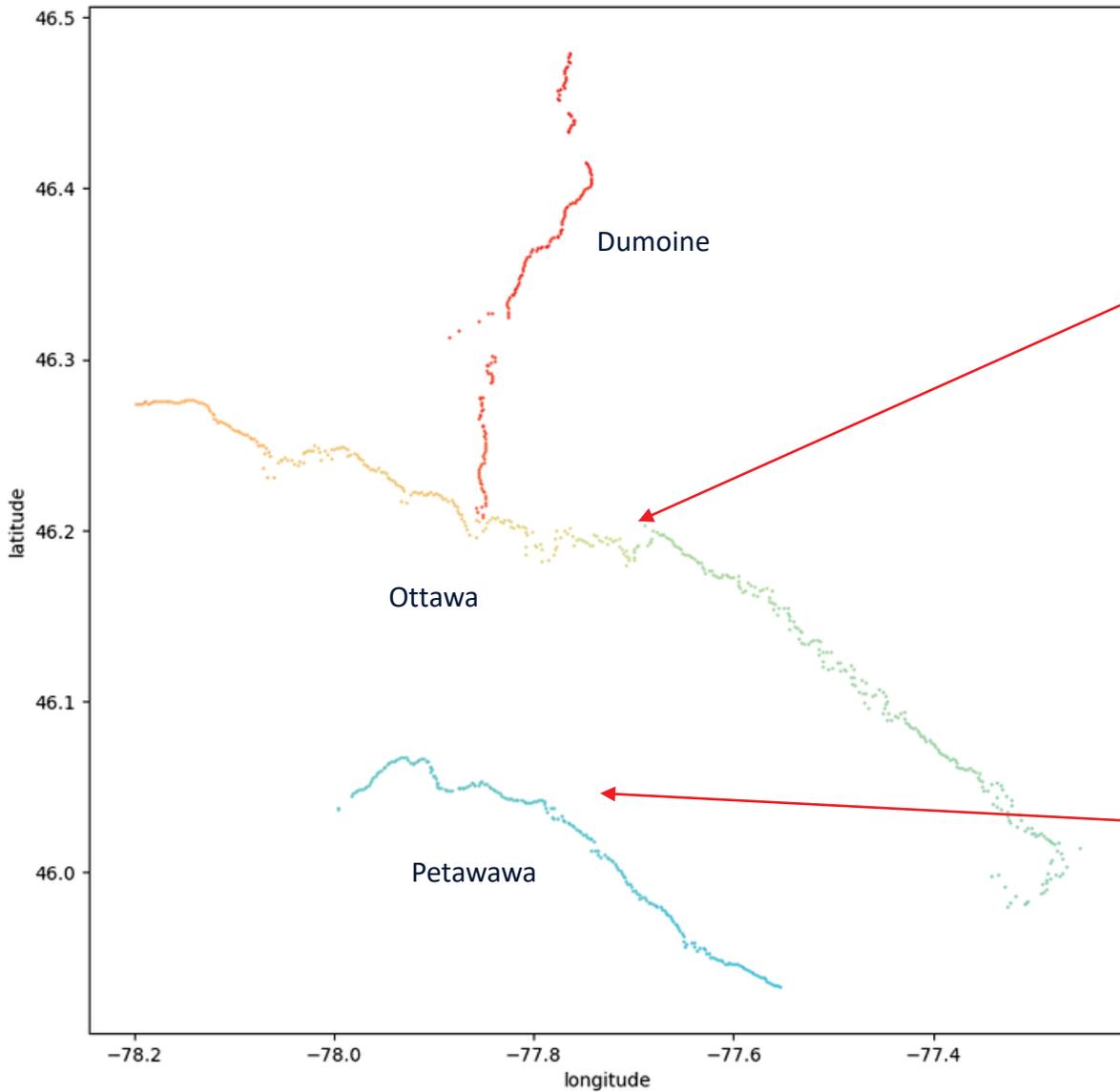
Sampling: reach ~10 km with centerline points every ~30 m, node spacing ~200 m

For each reach/node:

- **SWORD reach/node identifiers**
- **wse w.r.t. geoid (EGM2008)**
- **area/width**
- **slope, discharge (\_reach only)**
- **uncertainties**
- geophysical corrections
- **flags**
- ...

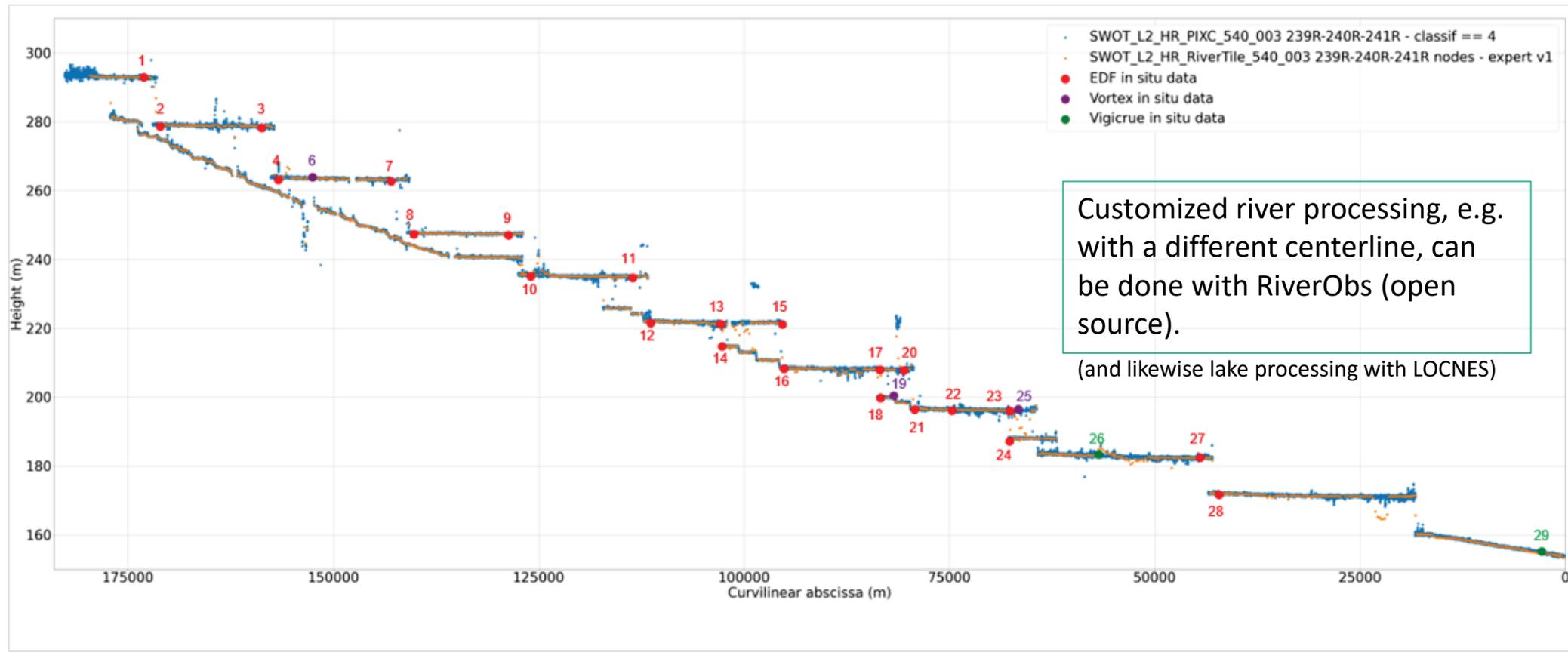
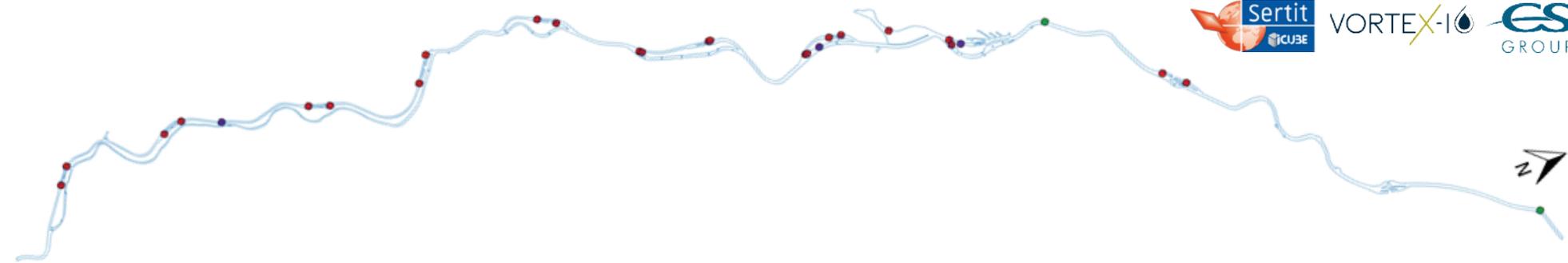
Water Surface Elevation (m) of L2\_HR\_RiverSP\_Node product

... superposed on L2\_HR\_PIXC product (open water in



# Customized River node vs. L2\_HR\_PIXC on Rhine River

id	stations	hgt_diff
1	Amont usine Kembs	0.075248
2	Aval usine Kembs	0.561192
3	Amont usine Ottmarsheim	0.435954
4	Aval usine Ottmarsheim	1.106802
6	chalampé_1	-0.294471
7	Amont usine Fessenheim	0.476292
8	Aval usine Fessenheim	0.382398
9	Amont usine Vogelgrun	0.444132
10	Aval usine Vogelgrun	1.072221
11	Amont usine Marckolsheim	0.361182
12	Aval usine Marckolsheim	0.600444
13	Amont barrage Rhinau	0.319173
14	Aval barrage Rhinau	4.537737
15	Amont usine Rhinau	-9.631517
16	Aval usine Rhinau	0.383870
17	Amont barrage Gerstheim	-2.210463
18	Aval barrage Gerstheim	6.577835
19	gerstheim_1	-0.549082
20	Amont usine Gerstheim	0.343086
21	Aval usine Gerstheim	0.271778
22	Plan d'eau Plobsheim	0.235636
23	Amont barrage Strasbourg	0.182276
24	Aval barrage Strasbourg	0.931380
25	strasbourg_1	-2.933493
26	Sémaphore nord	1.454343
27	Amont usine Gamsheim	-0.043665
28	Aval usine Gamsheim	0.397459
29	Lauterbourg	-0.366816



Customized river processing, e.g. with a different centerline, can be done with RiverObs (open source).

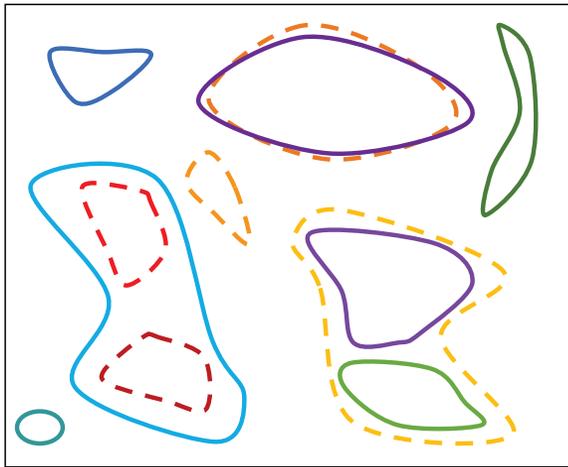
(and likewise lake processing with LOCNES)

4

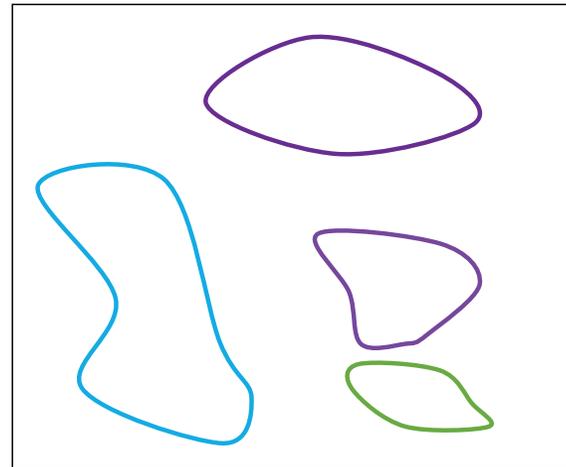
**L2\_HR\_LakeSP**

L2\_HR\_LakeSP products are organized in **3 shapefiles** based on intersection with the Prior Lake Database (PLD)

All observed features (solid polygons) and PLD lakes (dashed polygons) in an area.



(a)



(b)

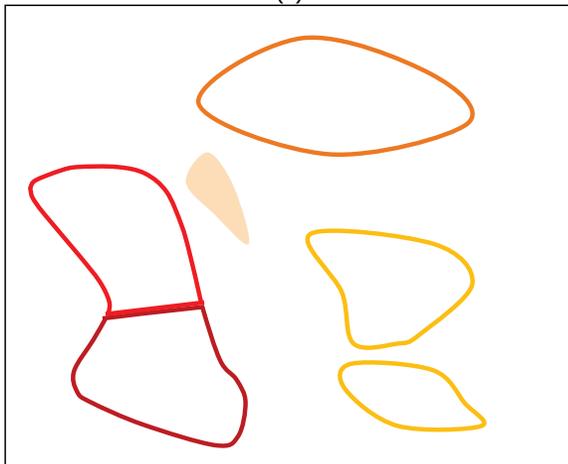
## **\_Obs**

Polygons of the observation-oriented lake shapefile (observed features intersecting one or more PLD lakes).

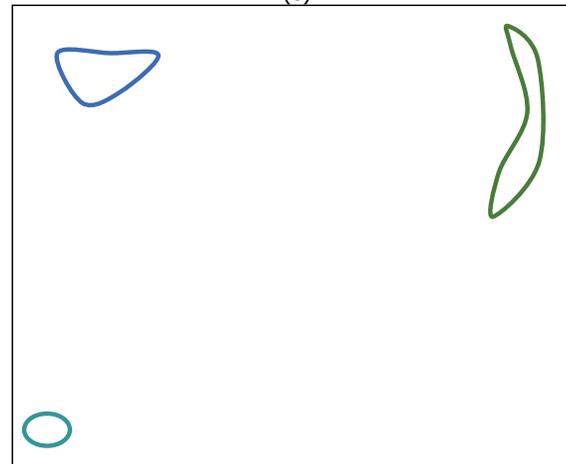
## **\_Prior**

Polygons of the PLD-oriented lake shapefile (the unobserved PLD lake is represented as an empty shape)

- Includes storage change



(c)



(d)

## **\_Unassigned**

Polygons of the observation-oriented unassigned features shapefile (neither assigned to SWORD rivers nor PLD lakes).

L2\_HR\_LakeSP = 3 shapefiles: `_Obs`, `_Prior` and `_Unassigned`

Granule: Continent pass, both half swaths

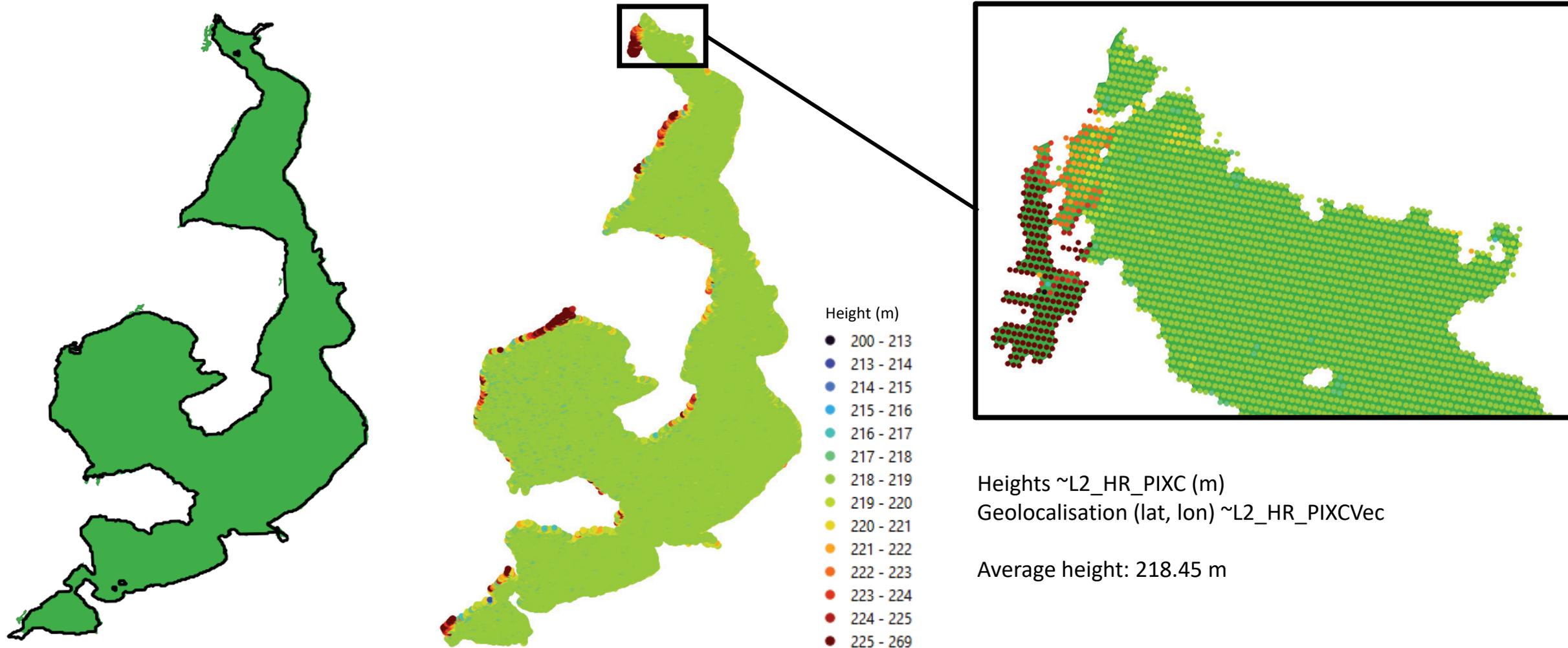
File format: ESRI shapefile (polygon)

Sampling: polygon nodes = PIXCVec water-near-land pixel geolocations (lat, lon) ~20 m

For each polygon:

- **PLD and observation identifiers**
- **wse w.r.t. geoid (EGM2008)**
- **area**
- **storage change (\_Prior only)**
- **uncertainties**
- geophysical corrections
- **flags**
- ...

# Height and extent of Lake Aylmer (Canada)

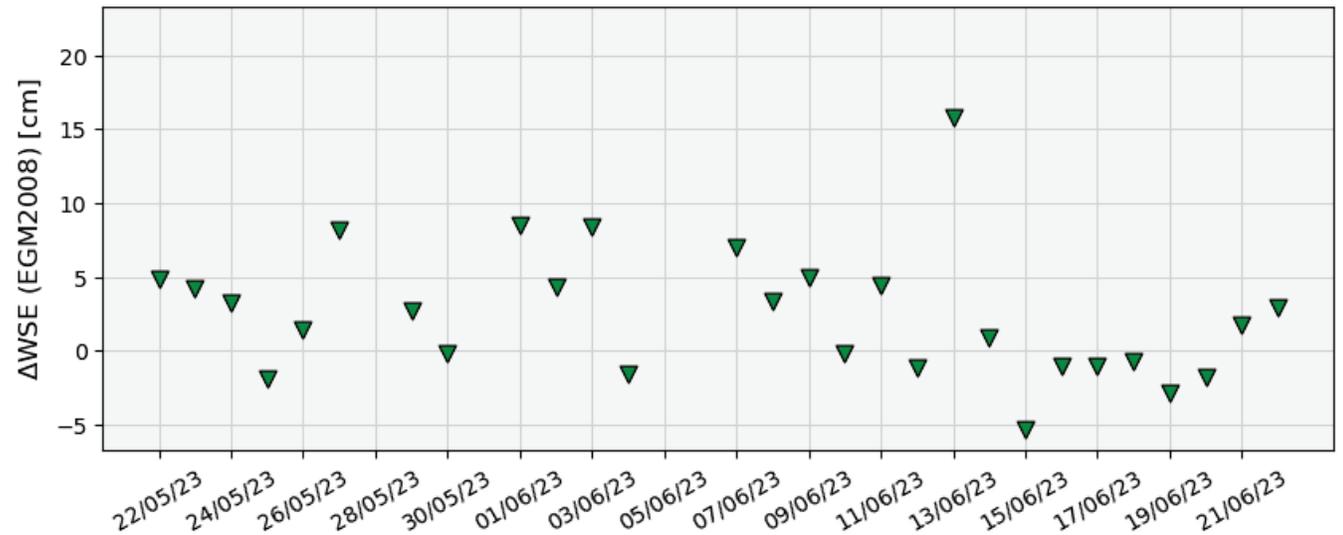
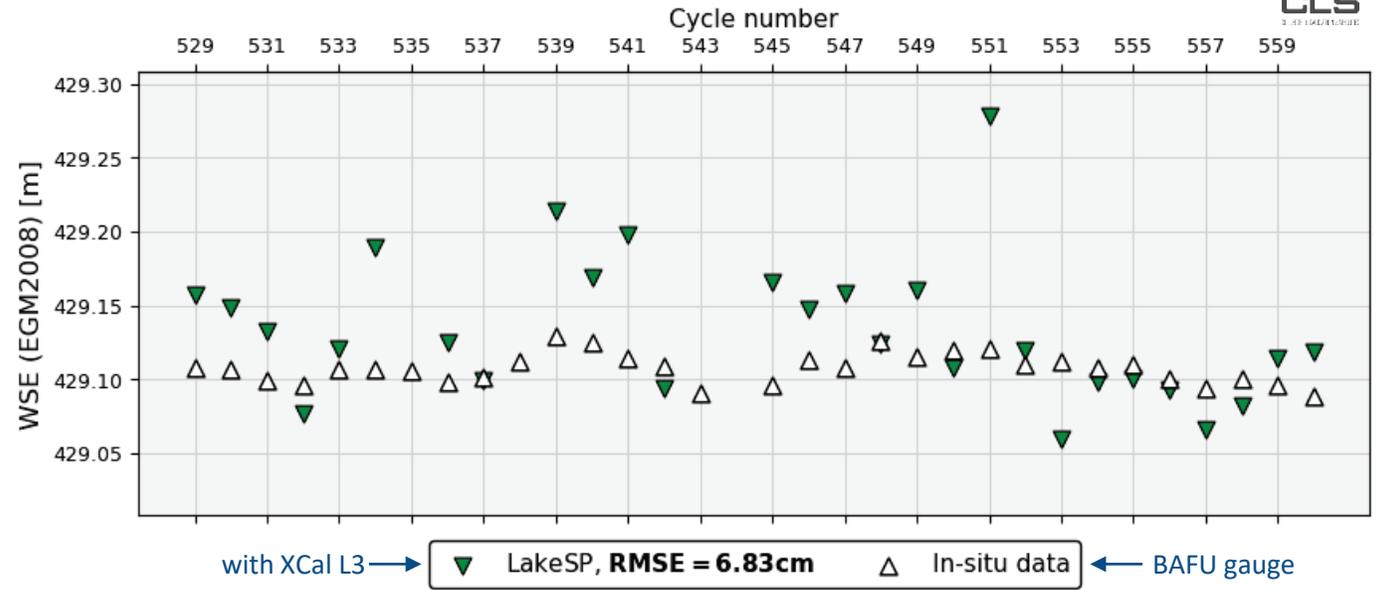
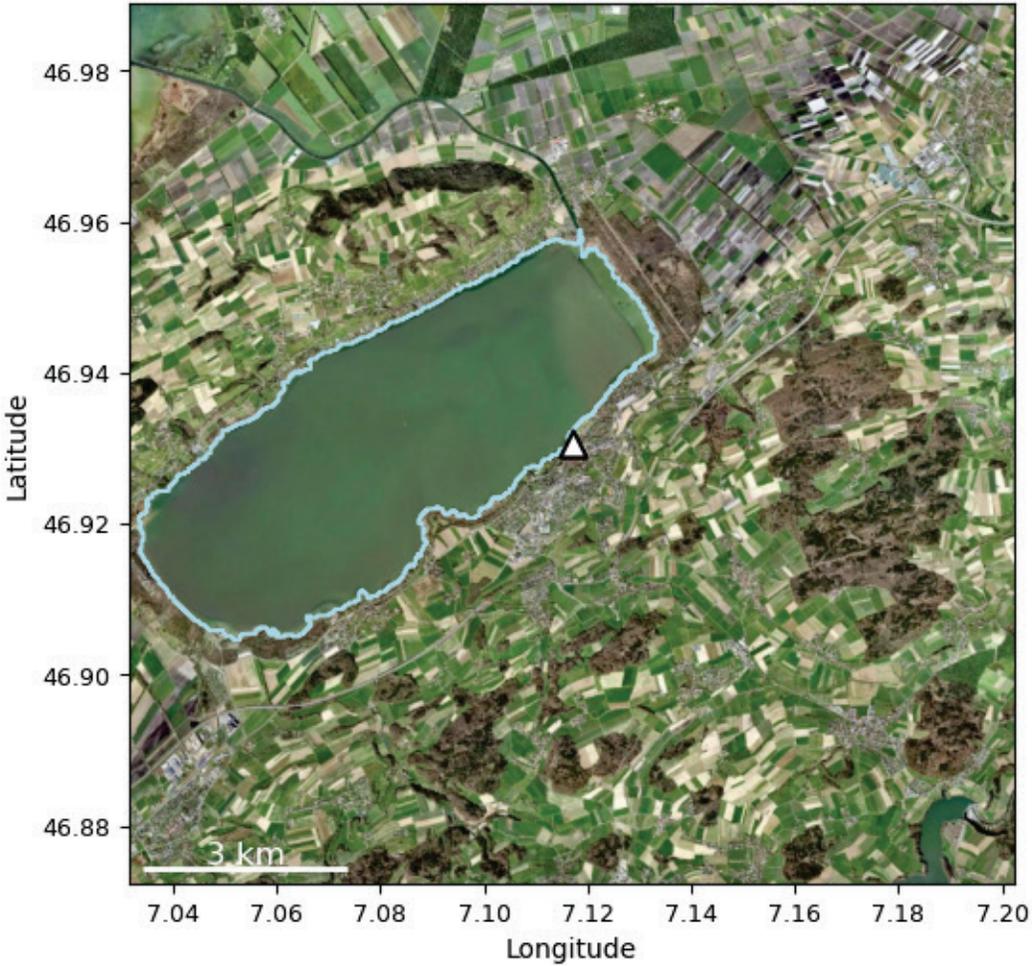


■ SWOT\_L2\_HR\_LakeSP\_Prior\_523\_009\_NA\_20230516T214903\_20230516T215448\_PIA1\_01  
□ PLD\_Aylmer (polygon of the Prior Lake Database)

# L2\_HR\_LakeSP vs. in situ on Morat Lake (Switzerland)

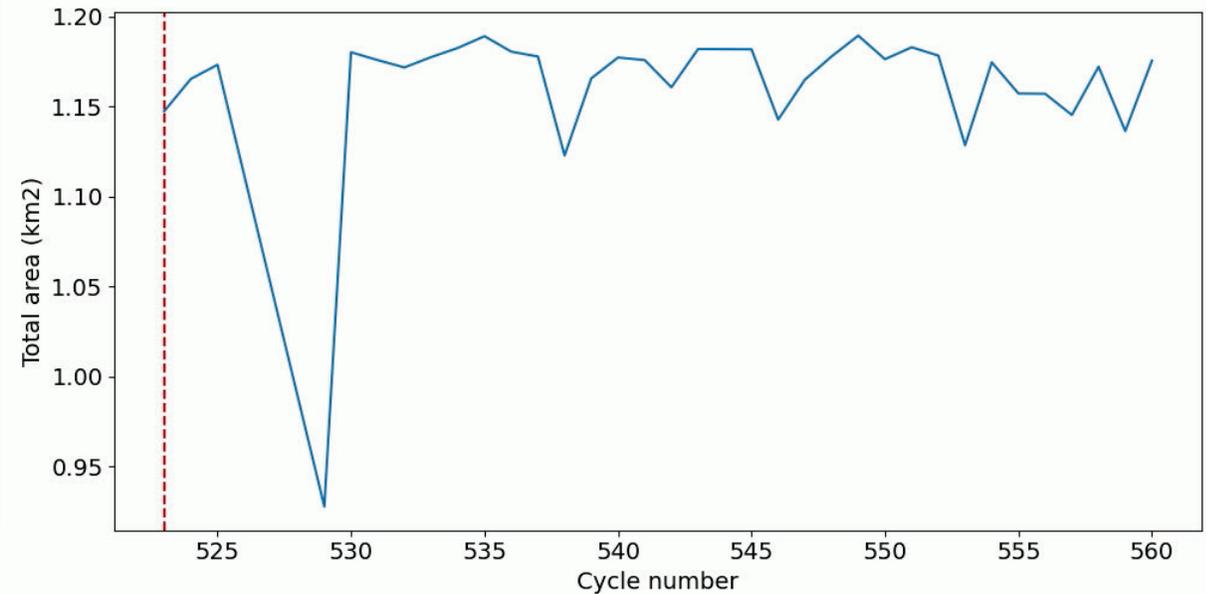
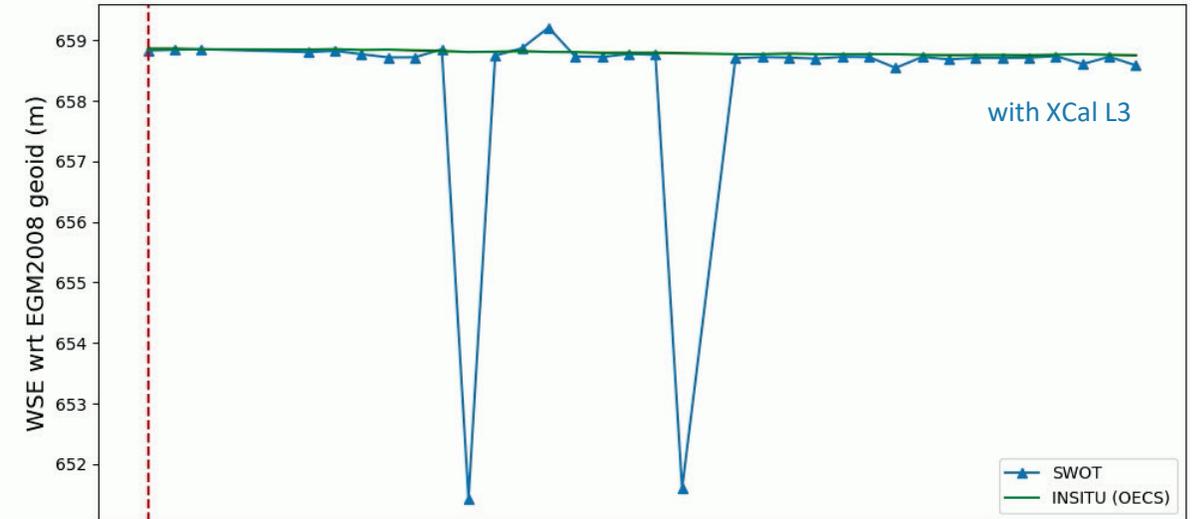
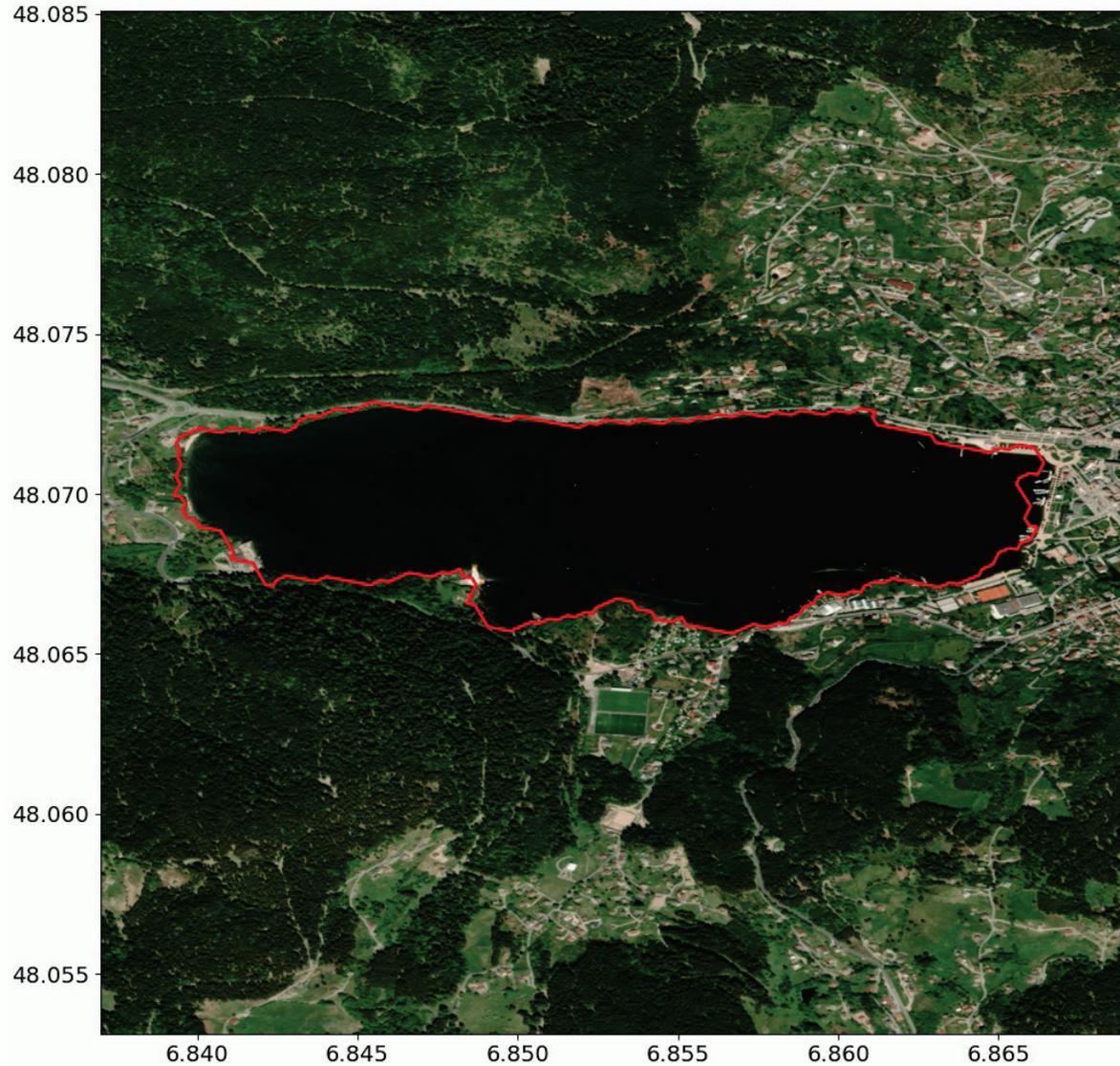
Time series of wse: 22 May – 21 June 2023 →

LakeSP polygon for 22 May 2023 ↘



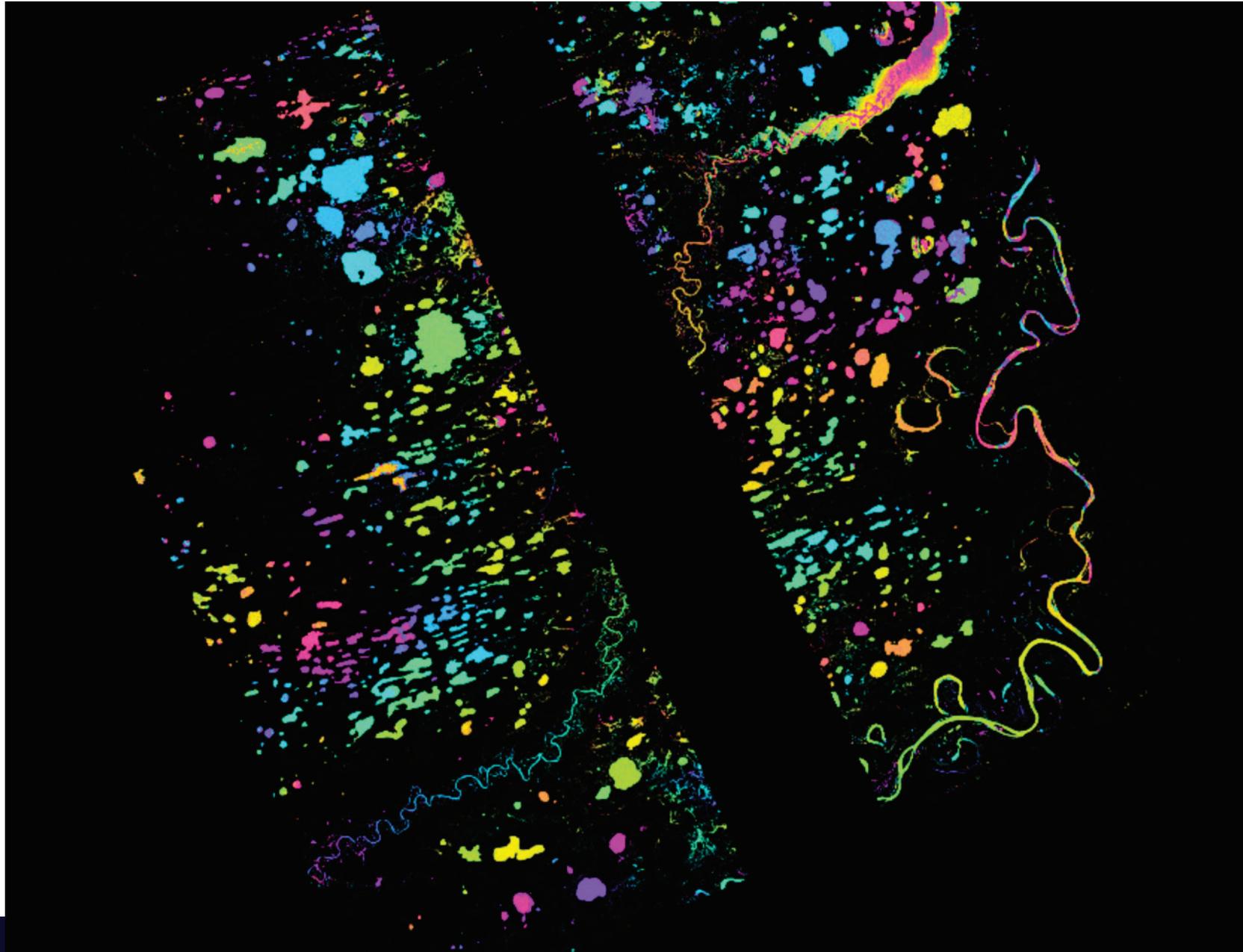
# L2\_HR\_LakeSP vs. in situ on Gerardmer Lake (France)

PLD lake = 2320165822 (Gerardmer Lake) - Cycle = 523 - Date = 2023/05/16 16:44:39 UTC





# **L2\_HR\_Raster**



495\_010\_024F

↑ cycle  
scene

↑ pass

↑

**wse w.r.t. geoid (EGM2008)**  
(shown with 10 m wrap)

Raster = geographically aligned uniform sampling grid (UTM or lat/lon)

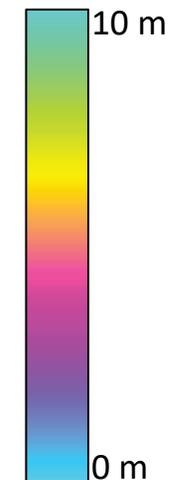
Granule: 128 km x 128 km  
or 256 km x 128 km scene

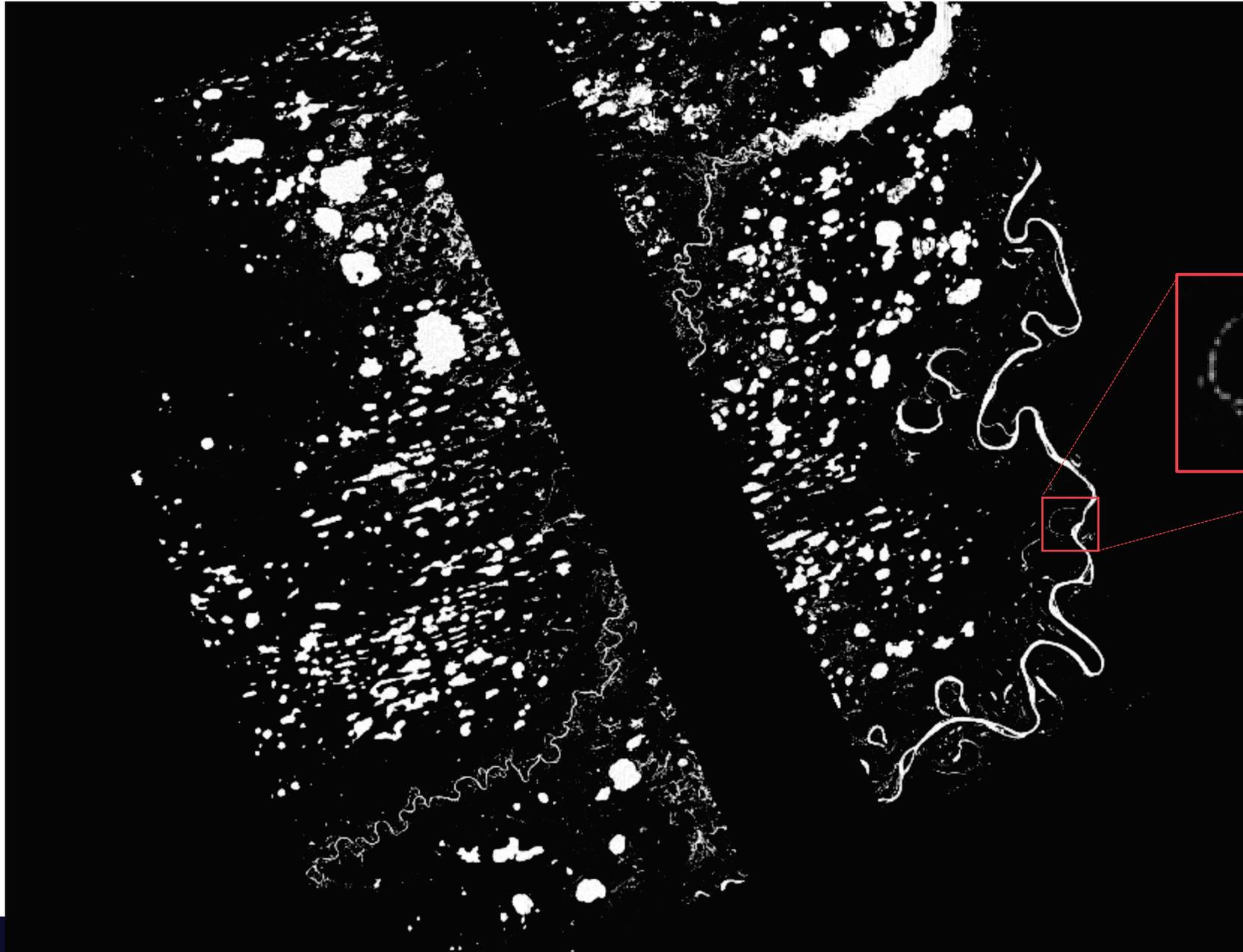
File format: netCDF

Pixel size: 100 or 250 m (or on-demand)

For each pixel (aggregated from underlying PIXC/PIXCVec pixels):

- **wse w.r.t. geoid (EGM2008)**
- **water fraction**
- **area**
- sigma0
- **uncertainties**
- geophysical corrections
- **flags**
- ...





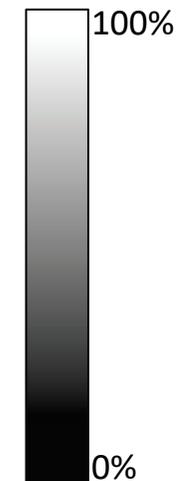
495\_010\_024F

↑ cycle  
scene

↑ pass

↑

**water fraction**



Raster = geographically aligned uniform sampling grid (UTM or lat/lon)

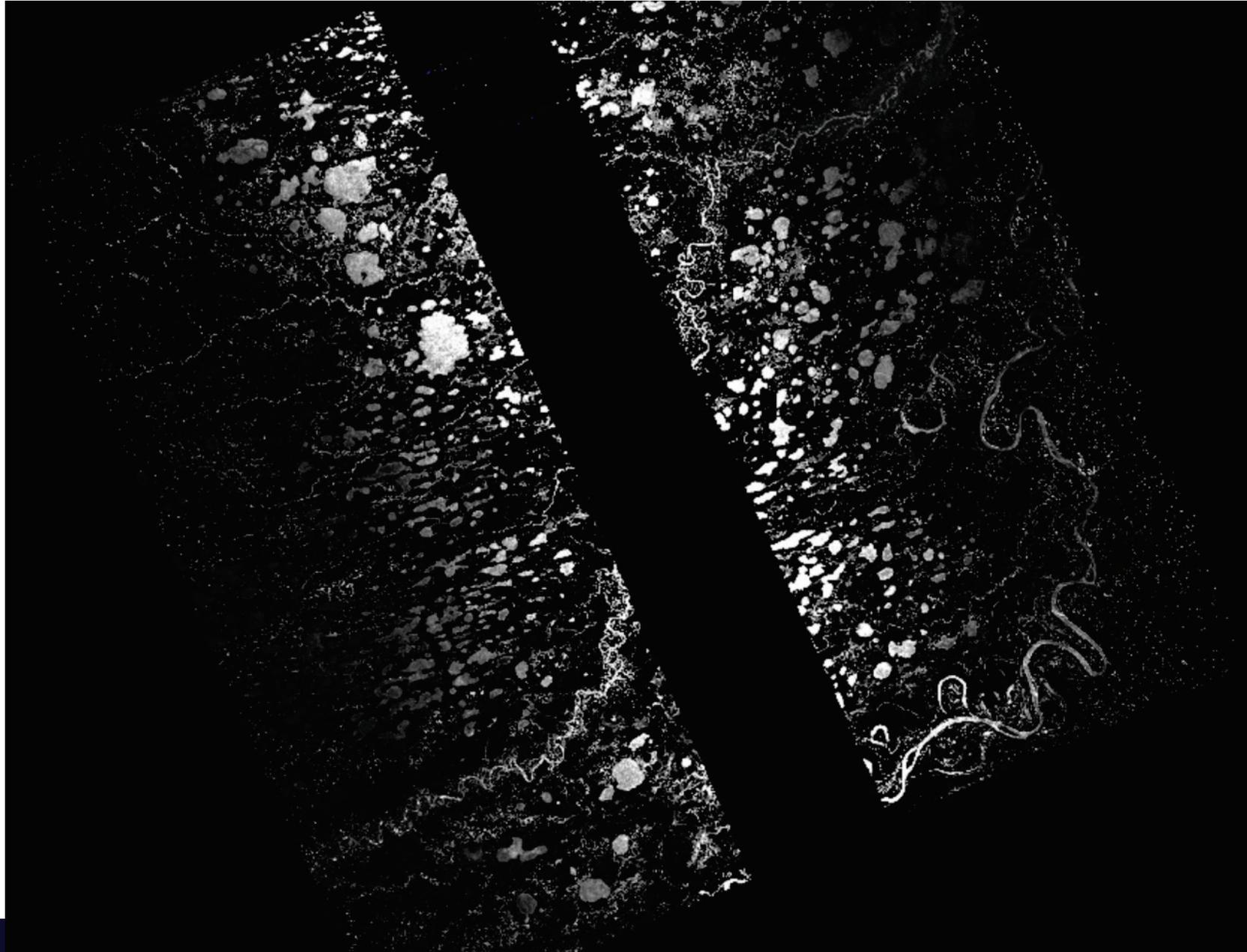
Granule: 128 km x 128 km  
or 256 km x 128 km scene

File format: netCDF

Pixel size: 100 or 250 m (or on-demand)

For each pixel (aggregated from underlying PIXC/PIXCVec pixels):

- **wse w.r.t. geoid (EGM2008)**
- **water fraction**
- **area**
- sigma0
- **uncertainties**
- geophysical corrections
- **flags**
- ...



495\_010\_024F

↑ cycle  
↑ pass  
↑ scene

**sigma0 (linear)**

Raster = geographically aligned uniform sampling grid (UTM or lat/lon)

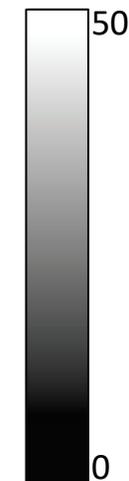
Granule: 128 km x 128 km  
or 256 km x 128 km scene

File format: netCDF

Pixel size: 100 or 250 m (or on-demand)

For each pixel (aggregated from underlying PIXC/PIXCVec pixels):

- **wse w.r.t. geoid (EGM2008)**
- **water fraction**
- **area**
- **sigma0**
- **uncertainties**
- **geophysical corrections**
- **flags**
- ...

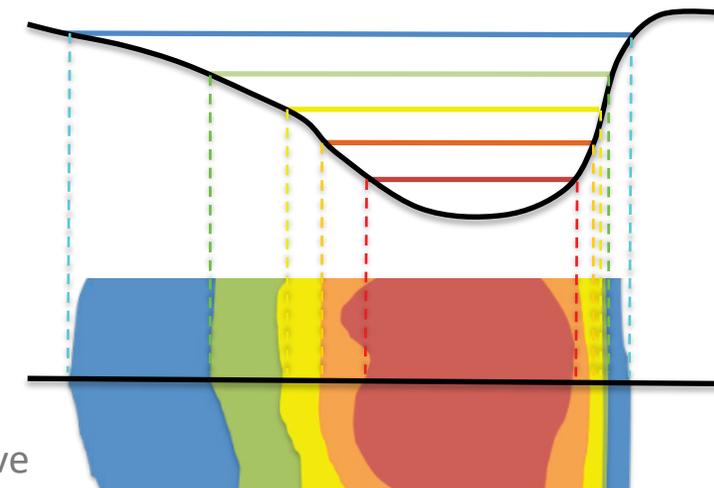




**L2\_HR\_FPDEM**

Not yet tested on real SWOT data

- ❖ **Product defined, algorithms prototyped and tested on simulated data**
- ❖ **Partial bathymetry derived from L2\_HR\_PIXCVec data**
  - At least one year of data needed
  - Between observed min and max water level only
- ❖ **Based on “bathtub ring” approach**
  - For each date, the edge pixels of a detected water body form an (iso-)elevation curve
- ❖ **First version may not have global coverage**



Gridded floodplain DEM in raster format:  
geographically aligned uniform sampling grid (UTM)

Granule: 1° x 1°

File format: netCDF

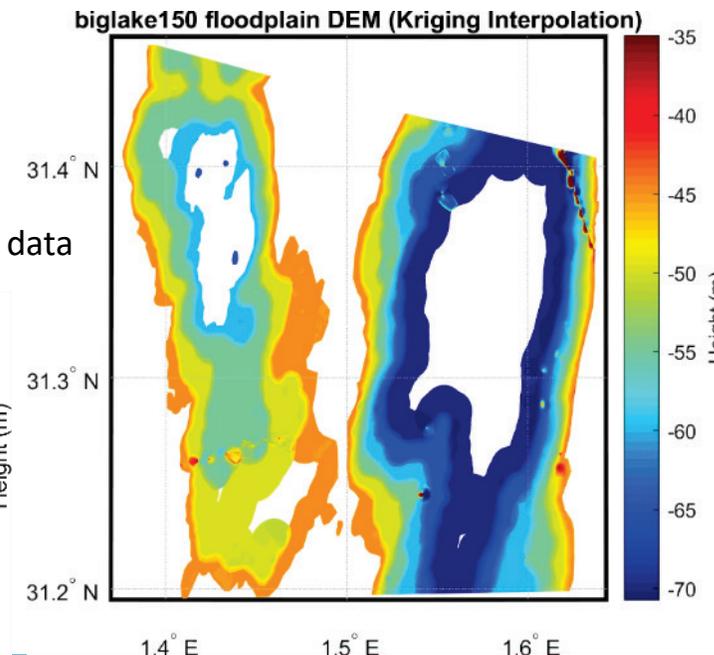
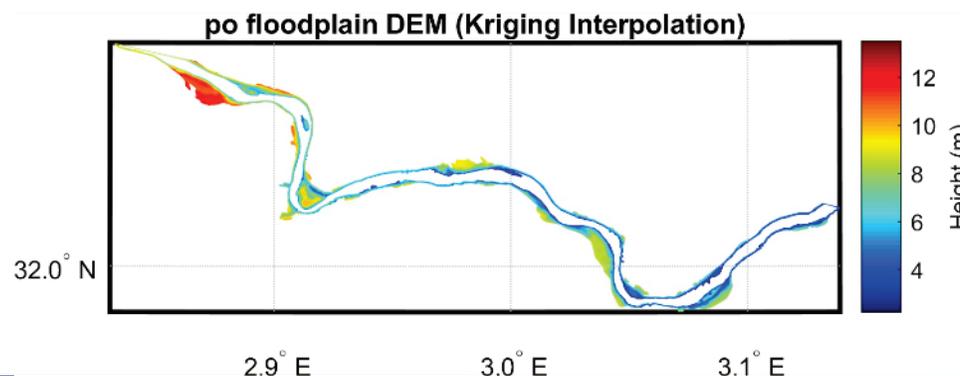
Pixel size: 50-100 m (TBC)

For each pixel:

- **elevation**
- elevation uncertainty
- quality flag
- ...

Ungridded floodplain DEM: Provides the point cloud of water/land edge pixels from which the raster floodplain DEM is built.

Examples based on simulated data





**Thank you for your attention!**