The Sentinel-3 Next Generation Topography (S3NG-TOPO) Mission; Enhancing Continuity, Performance and Hydrology Capabilities

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S3NG-T Mission Aim and Objectives

- Mission aim and Objectives stem from the analysis of User needs (EC) and CSC LTS
- Target is to **guarantee the continuity of S3 today**
  - For **ALL** topography variables SSH, Hs, U10, Sigma0, sea ice, land ice, river and lakes…

- **Then, to enhance S3** and address:
  - **Sampling and coverage → time AND space sampling (#1 User Need – for everyone working with altimetry)**
  - **Hydrology** sampling and performance (now primary Objective by EC request)
  - Provide **new products** to meet evolving Copernicus User Needs.

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4 S3NG-T MISSION AIMS AND OBJECTIVES

4.1 S3NG-T Mission Aim

Considering the User needs expressed by the European Commission and concisely articulated in the previous sections, the **aim** of the Copernicus Next Generation Sentinel-3 Topography (S3NG-T) Mission is:

To ensure continuity of Sentinel-3 in flight performance topography capability in the 2030-2050 timeframe.

4.2 S3NG-T Objectives

Mission requirements are then derived from mission Objectives.

The primary objectives of the S3NG-T mission are to:

PRI-OBJ-1. **Guarantee continuity of Sentinel-3 topography measurements** for the 2030-2050 time frame **with performance at least equivalent to Sentinel-3 in-flight performance** as defined in Table 2.4-1 ('baseline mission').

PRI-OBJ-2. Respond to evolving user requirements and **improve sampling, coverage and revisit** of the Copernicus Next Generation Topography Constellation (S3NG-T and Sentinel-6NG) to ≤50 km and ≤5 days (CMEMS, 2017) in support of Copernicus User Needs.

PRI-OBJ-3. **Enhance sampling coverage, revisit and performance for Hydrology Water Surface Elevation** measurements in support of Copernicus Services.

PRI-OBJ-4. Respond to evolving user requirements and **enhance topography Level-2 product measurement performance**.

The **secondary objectives**[9] of the S3NG-T mission are to:

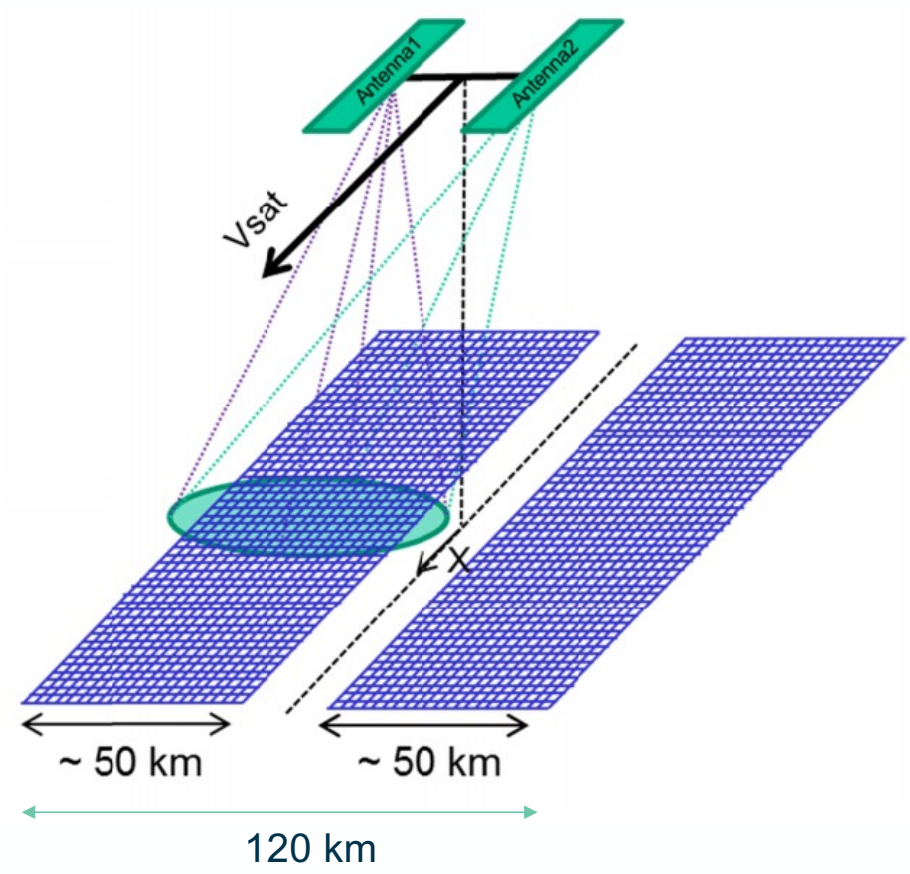
SEC-OBJ-1. Provide directional wave spectrum products that address evolving Copernicus user needs.

SEC-OBJ-2. Provide new products[10] that address evolving Copernicus user needs.

Sentinel-3 NG-TOPO Mission Hydro Requirements

- Hydrology targets mask established for in-land water targets:
  - River width: open, non-vegetated water ≥ 0.1 km (TBC) including seasonal variations
  - River length: ≥ 10 km (TBC)
  - Open water bodies (non-vegetated water e.g. lakes reservoirs, wetlands etc) ≥ 250 m x 250 m
- Surface water elevation dynamic range of ≤50m (enhanced goal: ≤60 m)
- Water Surface Elevation for all targets within the Hydrology Target Mask with a total standard uncertainty of ≤24 cm (TBC) (zero mean, 1 sigma) (enhanced goal: ≤10 cm (TBC)).
- All data latency requirements apply for Hydro as well (NRT3H, STC, NTC).

Sentinel-3 NG-TOPO Mission Concept

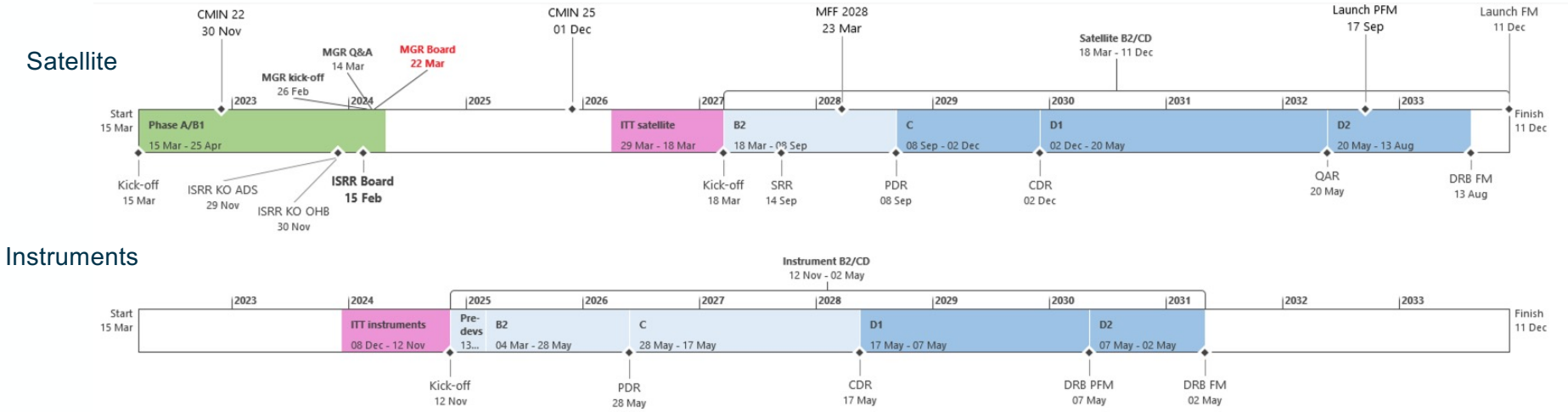


- Constellation of **2 large satellites,** flying in formation **in sun-synchronous dawn-dusk (LTAN 6pm) orbit.** Same ground-track as Sentinel-3 A/B.
- ka-band across-track interferometer, *a la SWOT*.
- 2 operation modes: LR for open ocean and land ice, and HR for ocean and hydro/sea ice.

- POS-5 Ku-band Nadir SAR altimeter to measure Hs and long wavelength roll error, provides baseline continuity.
- Constellation can achieve global 5-day revisit with an effective ocean spatial resolution of 50 km (key driving requirements for mission design).

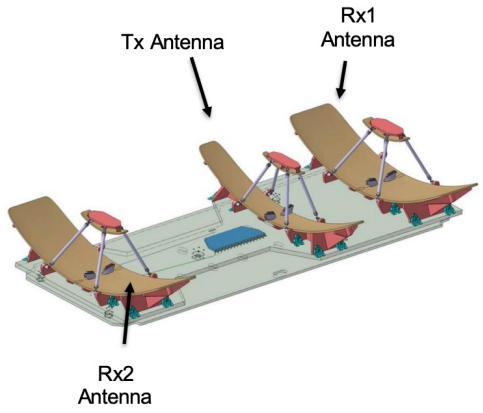
Sentinel-3NGT Programatics and Schedule

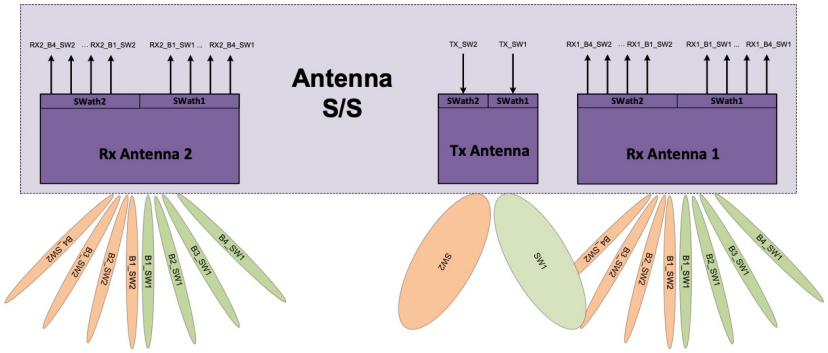
- ESA Member States funding subscribed at Ministerial'22.
  - EU funding in next MFF, from 2028.
- Overall timeline



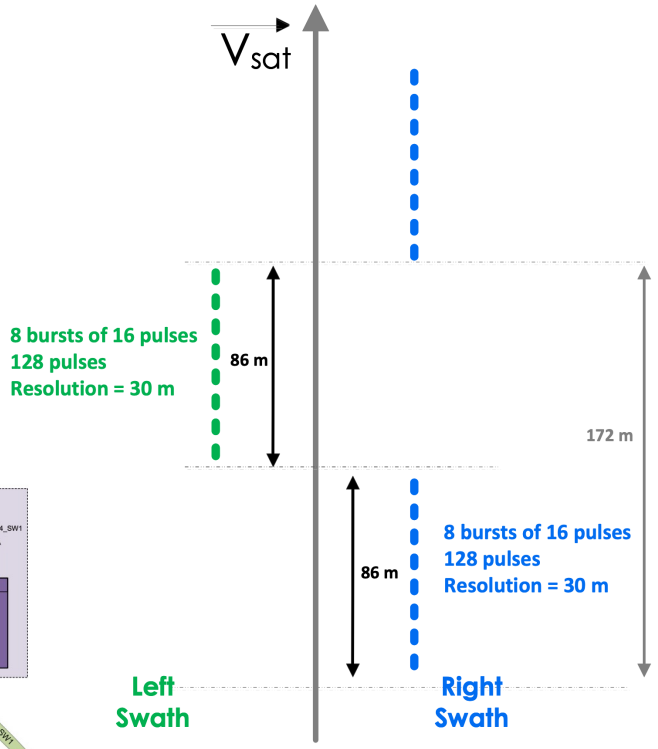
- Intermediate System Requirements Review – 29th 30th Nov kick-off – 15th Feb Board
- Mission Gate Review – 14th March Q&A session – 22nd March Board
- "Instrument first" development phase B2 from 2024
- Launch, 2nd half 2032

The SAOOH Instrument





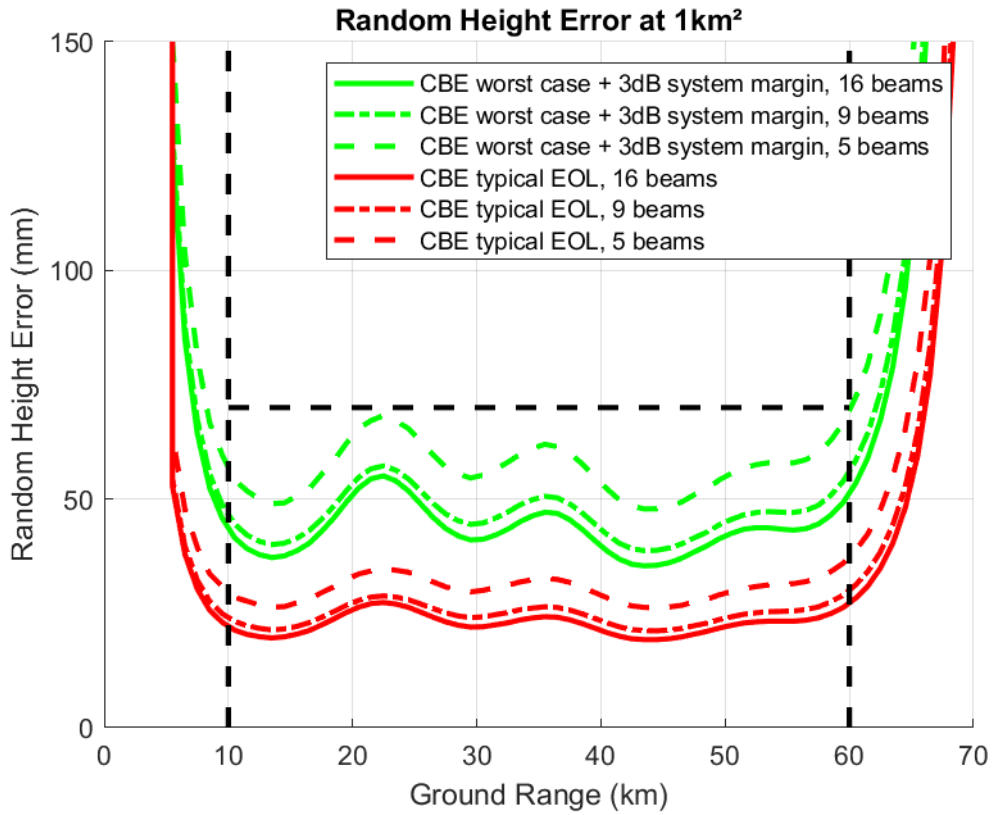
Courtesy TAS-F



Courtesy TAS-F

- **HR mode**
  - **max. resolution along-track ~ 35 metres**
  - **Across-track resolution: 70m near range, ~10m far range**
- **LR Mode**
  - **Along-track resolution ~ 365 metres**
  - **Across-track resolution ~ 166 metres**
- **HRFF Mode (not operational)**
  - **Specialized mode, continuous acquisition on one side only.**
  - **Along-track resolution ~ 2 meters.**

The SAOOH Instrument
Expected performance



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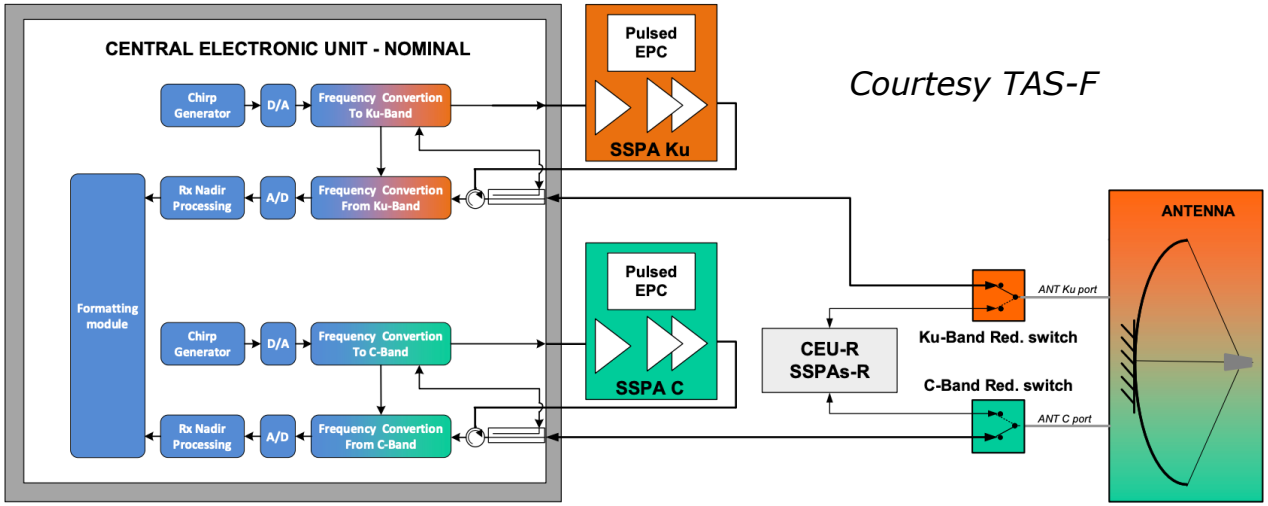
The POS-5 Instrument



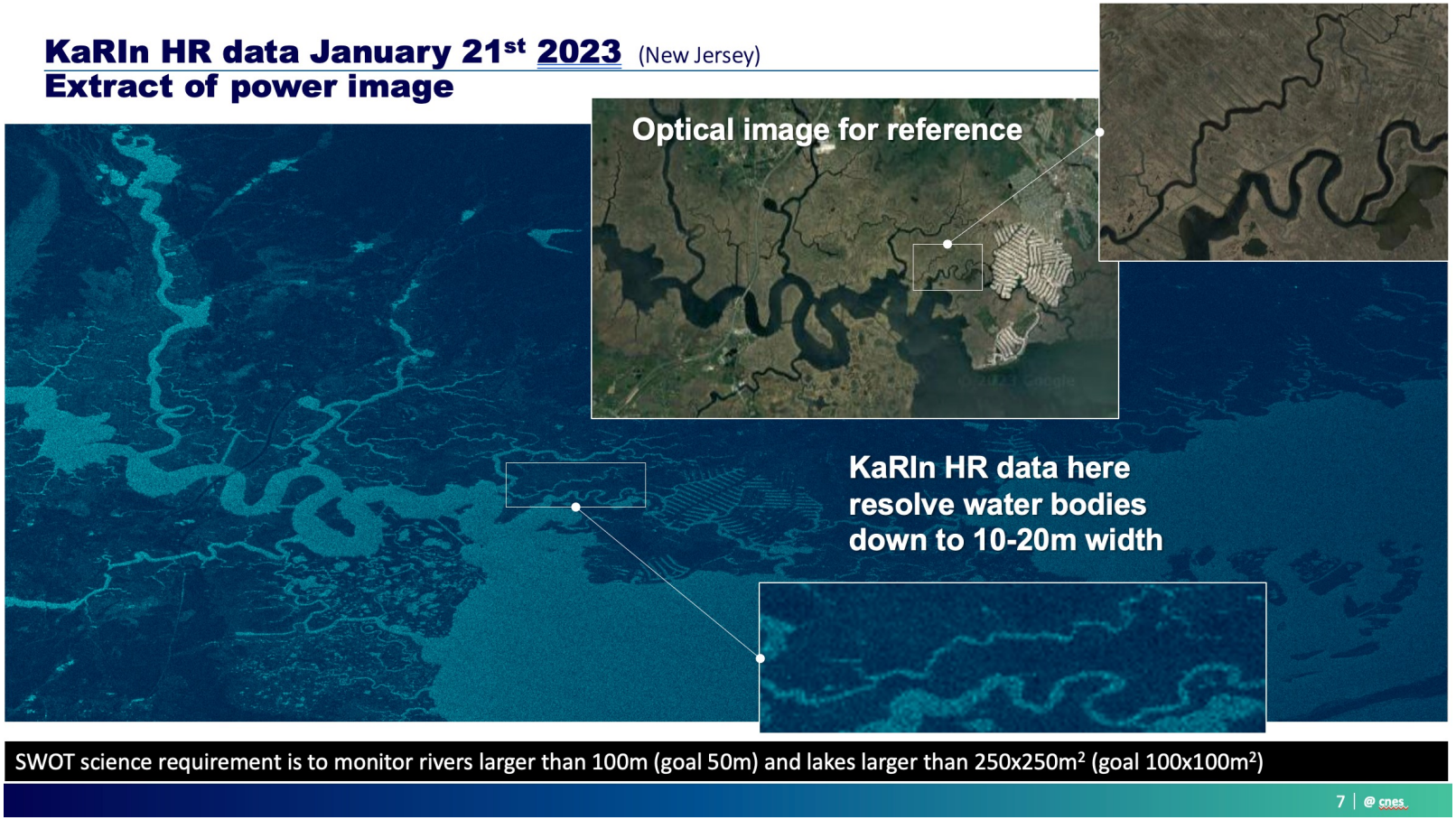
Courtesy TAS-F

Figure 5-9 : Poseidon5 functional architecture

- Dual Tx/Rx chain for Ku and C band, with dual chirp generator, allowing simultaneous transmission of Ku- and C- band pulses.
- About 8 times more C-band pulses than POS-4 ➔ improvement in iono estimation.

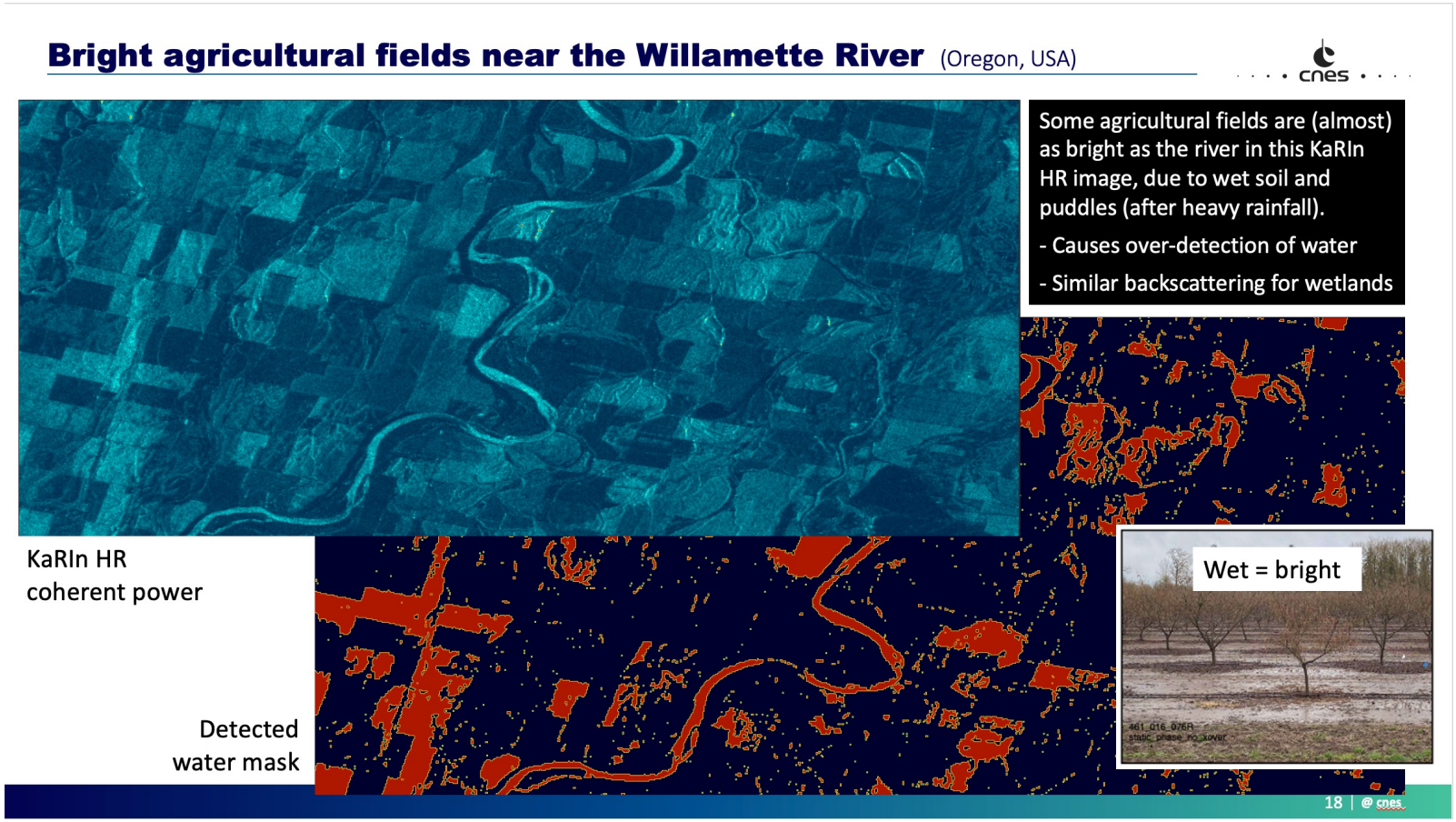
- Single mode SAR altimeter operating at an intermediate PRF 12.6 kHz.
  - All calibration pulses interleaved in the open-burst chronogram.
  - Improvement over open-ocean (initially proposed as Half-PRF ~9 kHz).
  - No degradation over inland water targets…improvement due to continuous sampling.

Hydrology from swath altimetry



Courtesy CNES

Hydrology from swath altimetry – SWOT results



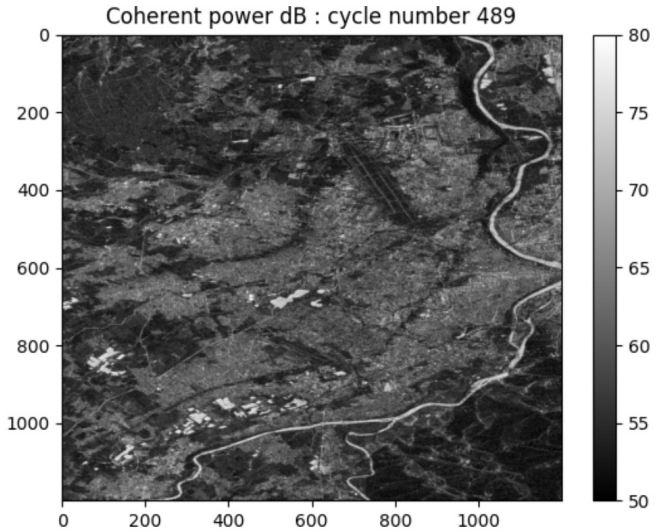
Courtesy CNES

Hydrology from swath altimetry – SWOT results

KaRIn HR image of Toulouse: multitemporal series
Coherent power

Dark water phenomenon

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



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Hydrology from swath altimetry – SWOT results

KaRIn HR image of Toulouse: multitemporal series
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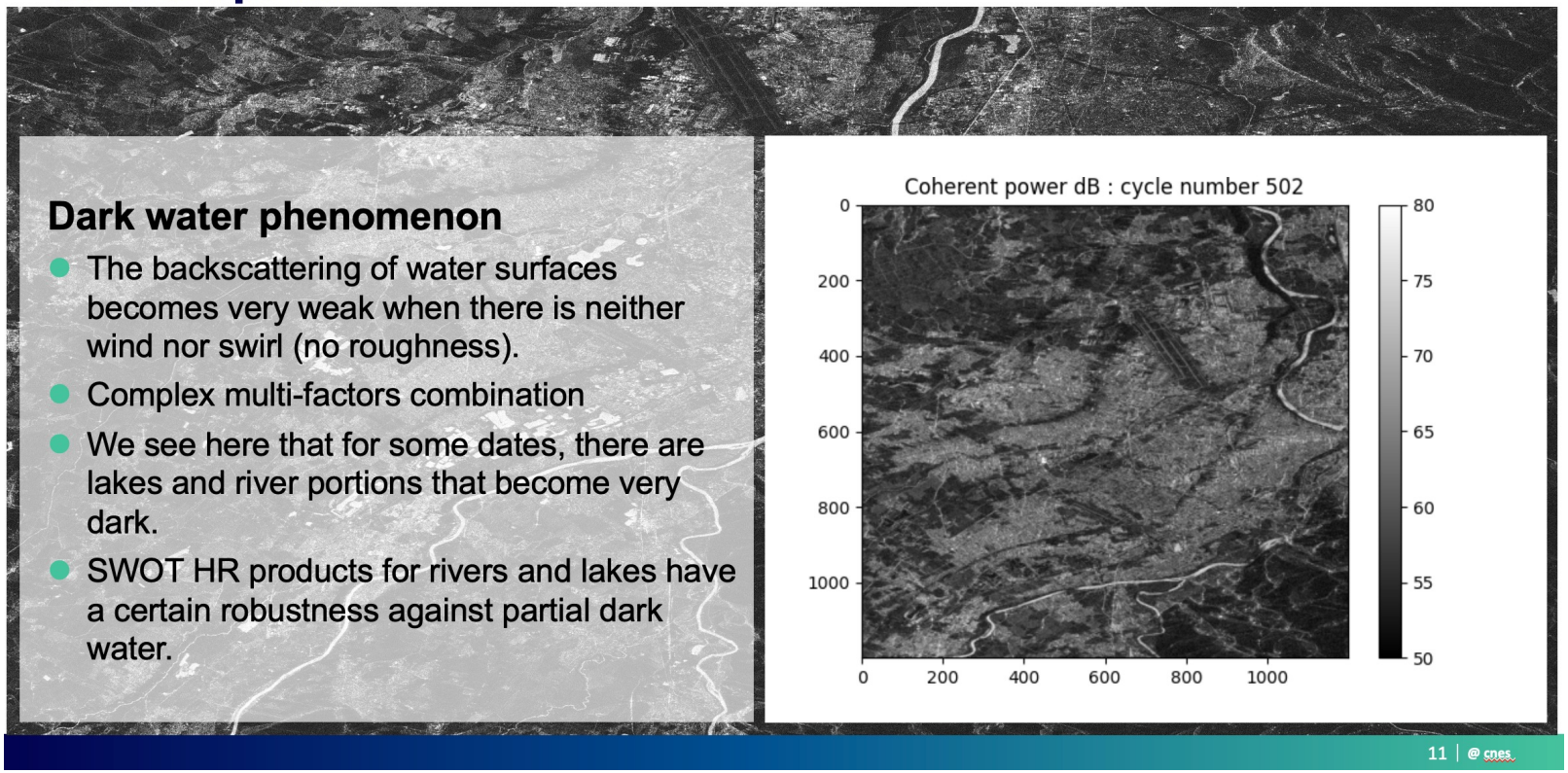

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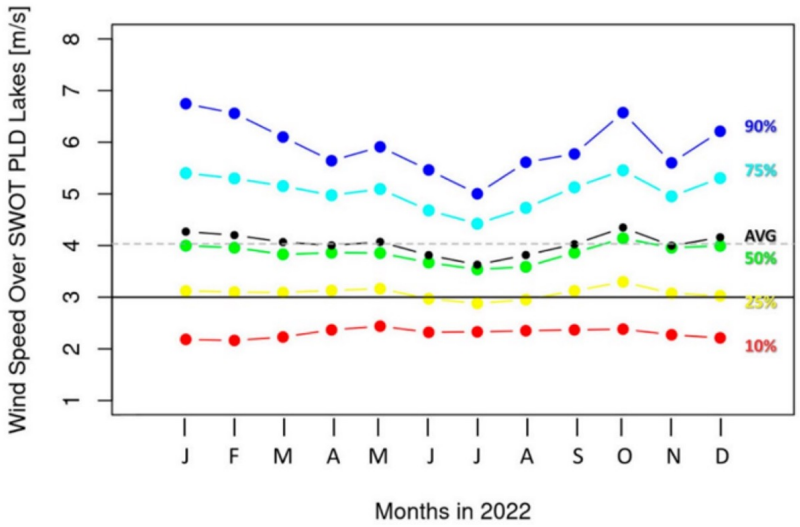
Hydrology from swath altimetry – SWOT results

How does wind impact Ka-band backscatter? Comparison of ERA-5 wind speed (10m) with observed Ka-band backscatter for ~11,000 lakes (Jessica Fayne)

The mean Prior Lakes Database (PLD) wind speed globally was 4.03 m/s in 2022.

~75% of PLD lake areas meet or exceed the necessary 3 m/s



(Fayne & Smith, 2023)

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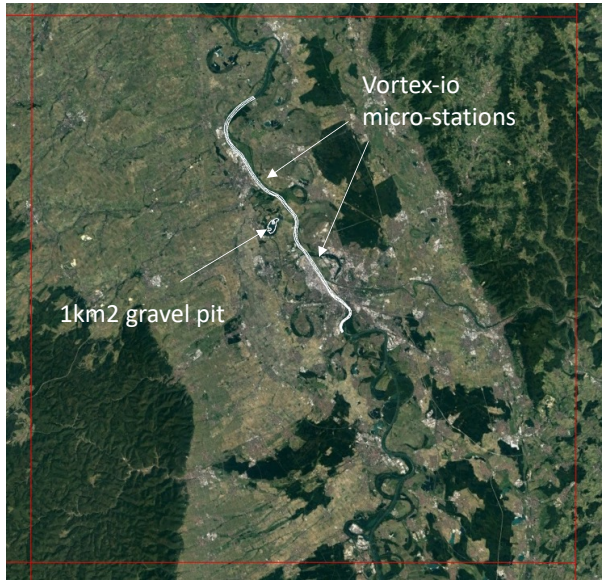
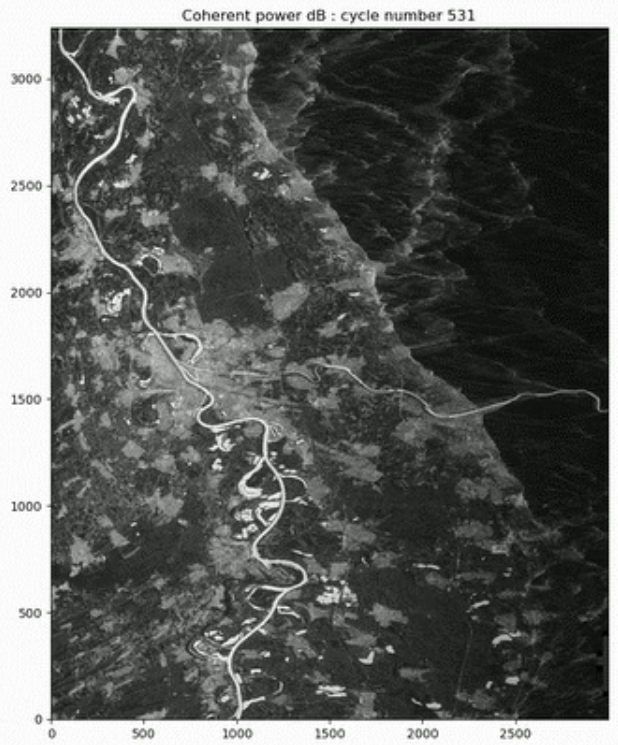
Hydrology from swath altimetry – SWOT results

SWOT CALVAL – RIVERS & LAKES

Manheim – Germany

Rhine river – 300m width - middle-range





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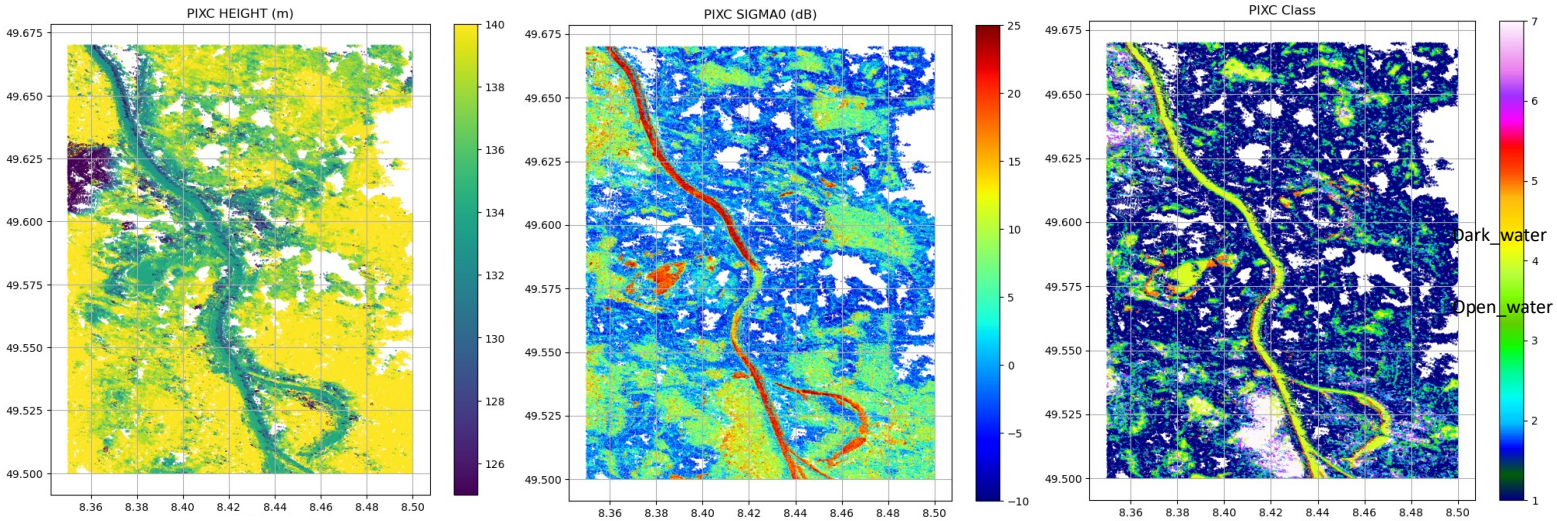
Hydrology from swath altimetry – SWOT results

Manheim – Germany

PIXC Product overview



Very high sig0 (~20dB) over the Rhin river and the gravel pit
Dark water occurs sporadically

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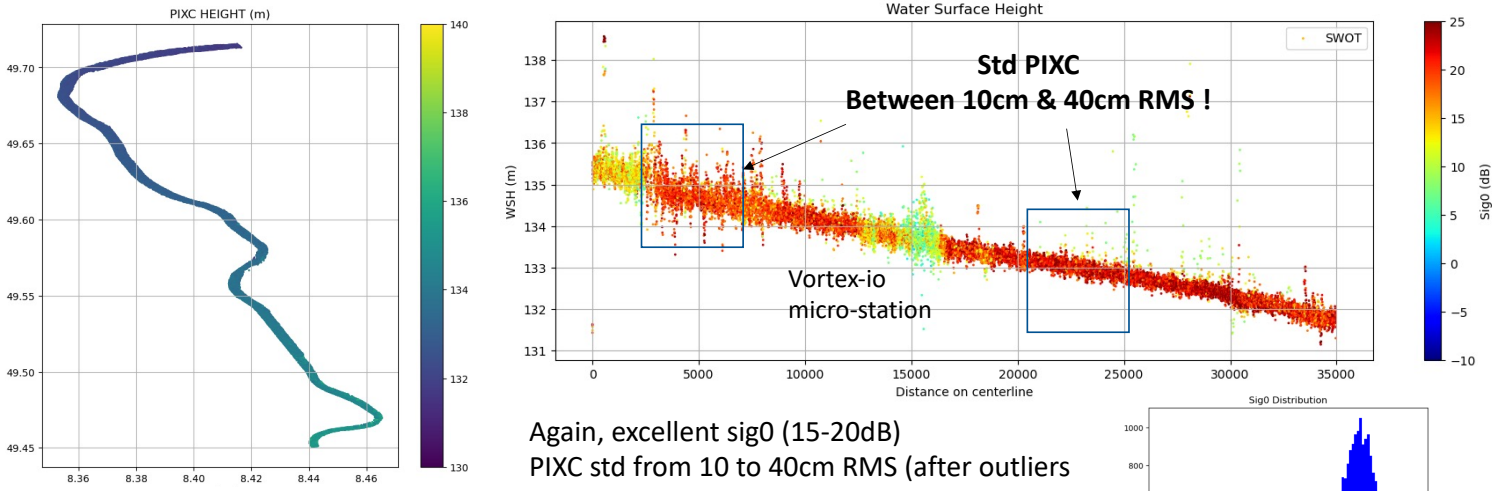
Hydrology from swath altimetry – SWOT results

Manheim – Germany

River Longitudinal Profile (35km) – selection of « water class » pixels

21st, June, 2023



Again, excellent sig0 (15-20dB)
PIXC std from 10 to 40cm RMS (after outliers rejection)

Let's focus around the Vortex Micro-station.

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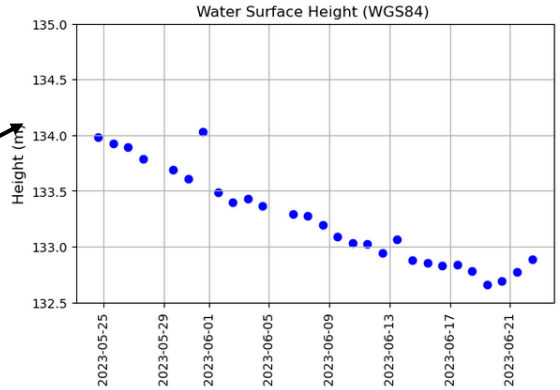
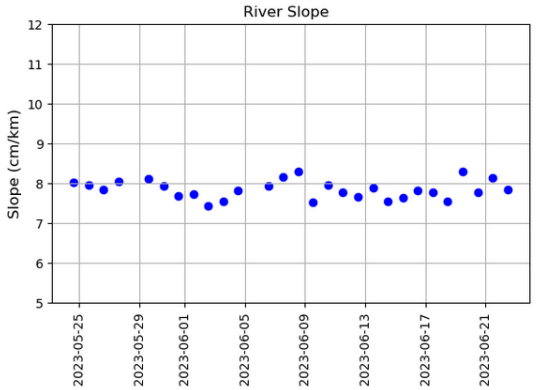
Hydrology from swath altimetry – SWOT results

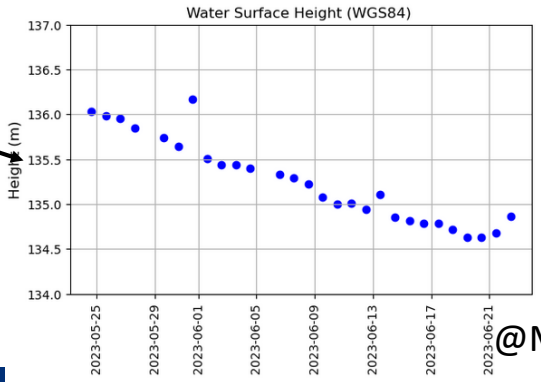
Manheim – Germany

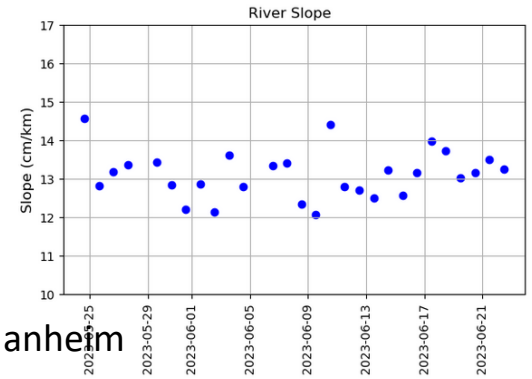
@Worms

WSH & slopes time-series









@Manheim

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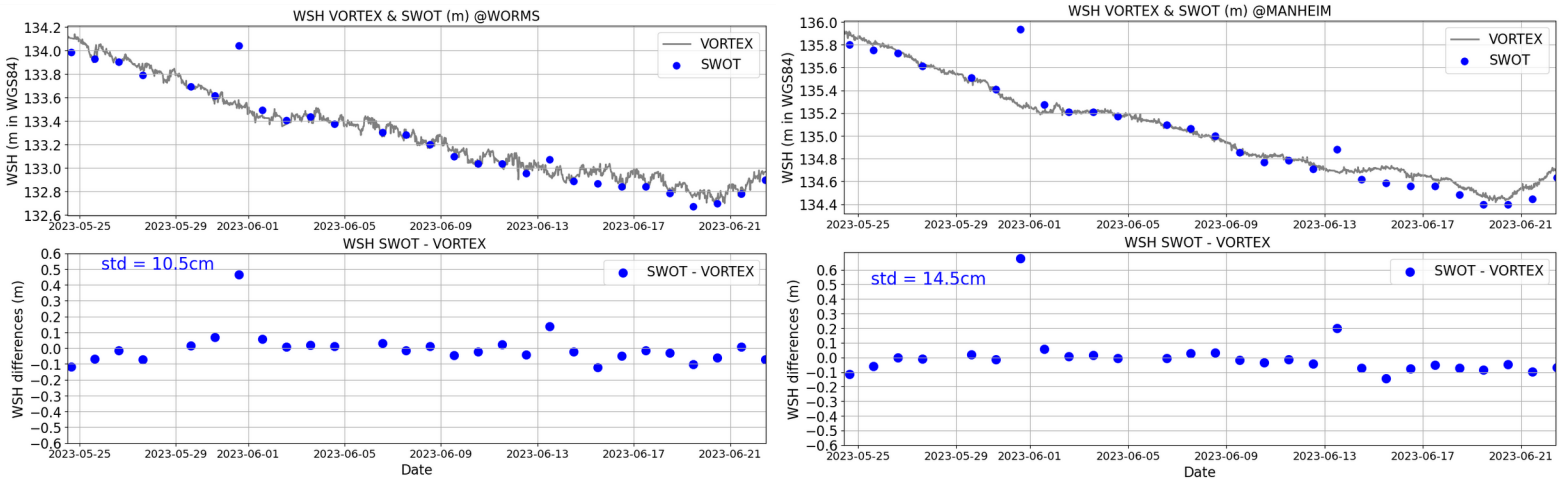
Hydrology from swath altimetry – SWOT results

Manheim – Germany

WSH time-series comparison with Vortex micro-station



Excellent performances! 10cm & 14cm RMS

Close to mission requirement.

Similar time-correlated errors (XCAL residual errors).

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Hydrology from swath altimetry – SWOT results

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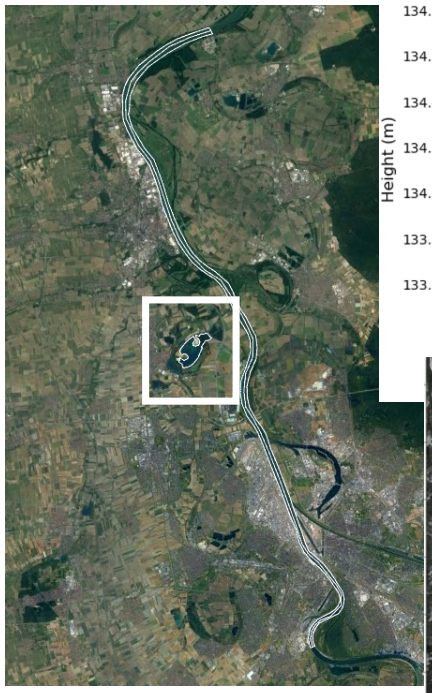
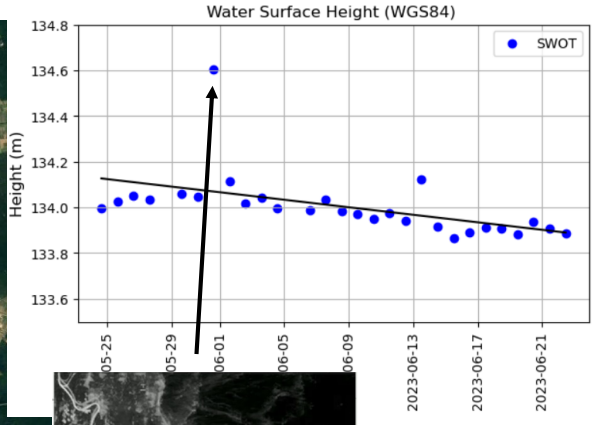
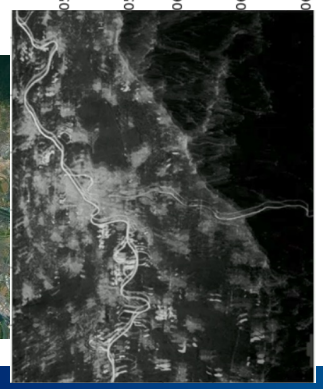
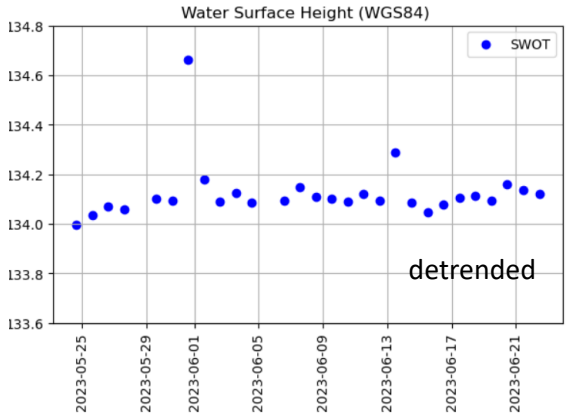
WSH & slopes time-series





@Gravel pit





WSH assumed to be very stable within a month over such gravel pit (slightly trended)

We observe the same time-correlated error pattern.
Outlier is related to a processing issue.

Lets use it (detrended) to correct previous stations!

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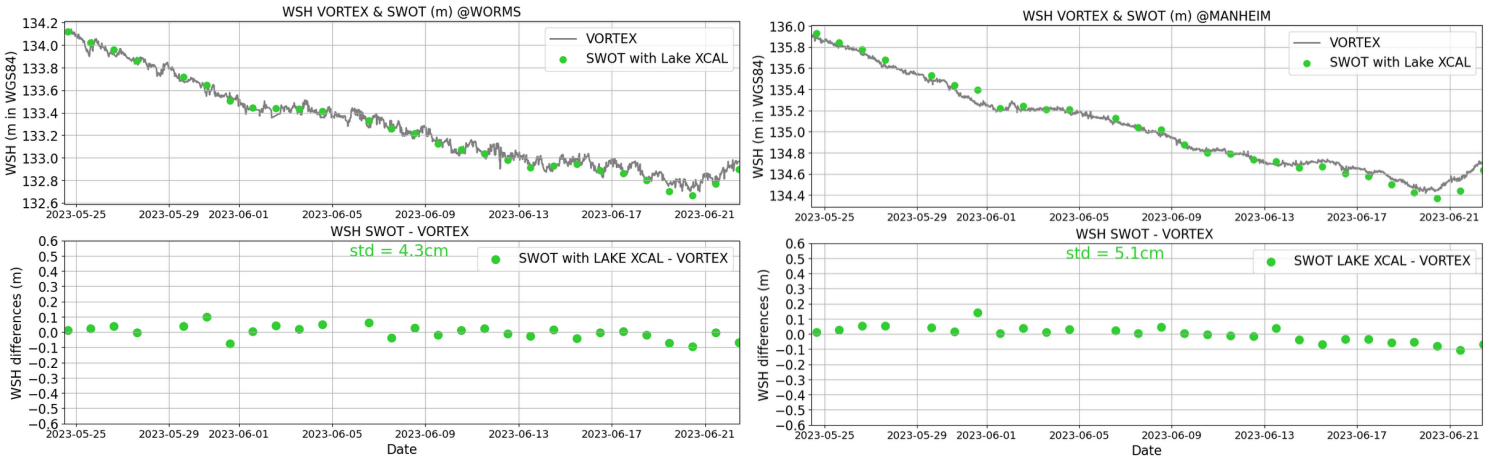
Hydrology from swath altimetry – SWOT results

Manheim – Germany

Applying an additionnal correction from the gravel pit

Performances are improved, down to 5cm RMS

Using land reference points opens clear perspectives for improving data quality over rivers & lakes



Courtesy CNES

Conclusions

- S3NG-TOPO is the Copernicus mission for continuity and enhancement of the current Sentinel-3 altimetry constellation
- S3NG-TOPO is designed as a constellation of two large spacecrafts embarking nadir and swath altimeters.
- From industry's current best estimates and SWOT inflight performances, S3NG-TOPO is on-track to comply with all requirements (and even goals) specified in the MRD.

Any questions ?

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