HydroCoastAI

PM13 – 16 May 2023

Processing case study: FF-SAR

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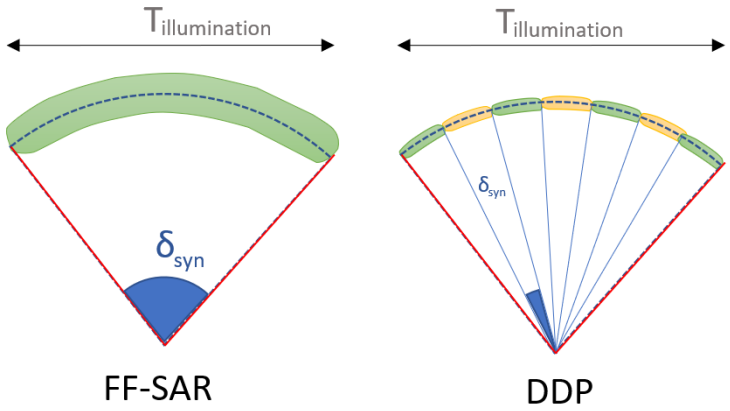
FF-SAR case study

- The proposed study is part of WP3110 Fully Focussed SAR (FF-SAR) (WP3000 Impact Assessment)
- The goal of this study is to assess the impact of new products in altimetry (FF-SAR products)
- isardSAT has performed an analysis over one of the HYDROCOASTAL areas (Ebre) to demonstrate the capabilities of FF-SAR in terms of water level measurements.
- Since proposal drafting (May 2019), the FF-SAR capabilities over different kind of scenarios have already been proven. Amongst other:
  - Over inland waters
    - With CS2: M. Kleinherenbrink 2020
    - With S6: R. Molina EGU-2023
  - Over ocean: O. Altiparmaki 2022
  - For calibration purposes: F. Gibert 2023

- FF-SAR algorithm:
  - Coherent processing of the full illumination time
    - Full synthetic aperture ~2-5 s → Max along-track resolution ~0.5 m
  - Differences wrt to Delay-Doppler Processing (DDP):
    - In DDP, only the pulses within each burst are processed fully coherently (burst length ~3.5 ms) → Max along-track resolution ~300 m
    - The full illumination time in DDP is only used to provide more independent observations, which are combined 'incoherently' (average at power level)
  - Over inland waters, FF-SAR improved resolution allows to better isolate and remove contamination from nearby scatters.



FF-SAR case study

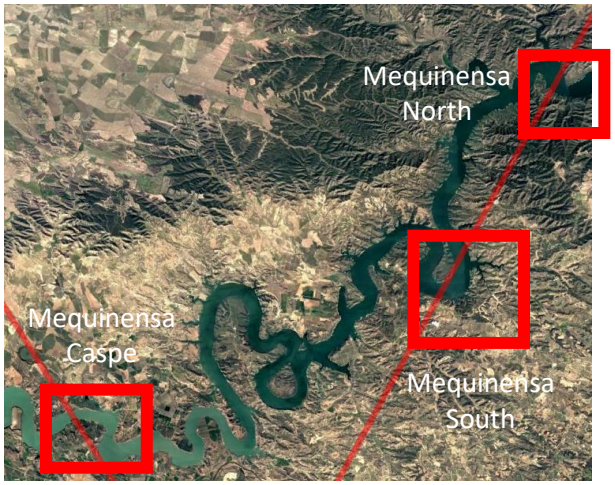
- Preferrable pulse sequence mode for FF-SAR: open burst
  - CryoSat-2 and Sentinel-3 operate in closed burst mode:
    - Strong presence of along-track replicas every ~92 m, decaying with antenna pattern.
  - Sentinel-6 operates in (almost) open burst
    - Calibration pulse + C band pulse break the natural continuous operation scheme every 64 pulses.
    - Minimal presence of replicas along-track due to calibration pulses

- In order to fully exploit FF-SAR capabilities over in land waters, Sentinel-6 data has been considered for this study case

Case study targets: 2 reservoirs within Ebre basin

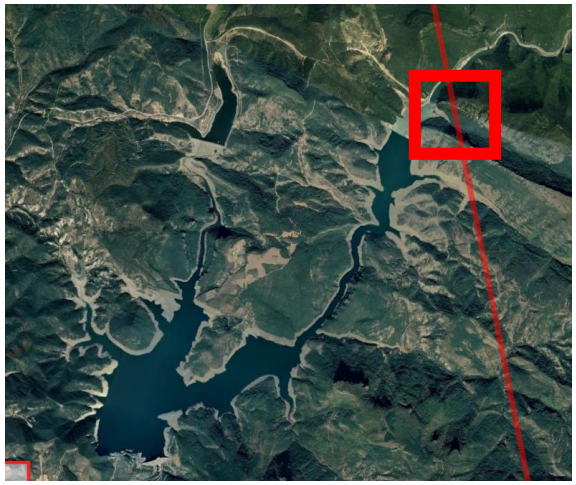
- Period: 08/08/2021 – 16/08/2022
- Also monitored by S3/CS2

Mequinensa



Pass	Track num.	Coordinates	Track length
Mequinensa – North	111	[41.4, 0.172]	700 - 1000 m
Mequinensa – South	111	[42.32, 0.114]	800 - 2000 m
Mequinensa – Caspe	248	[41.27, -0.08]	450 m

Itoiz



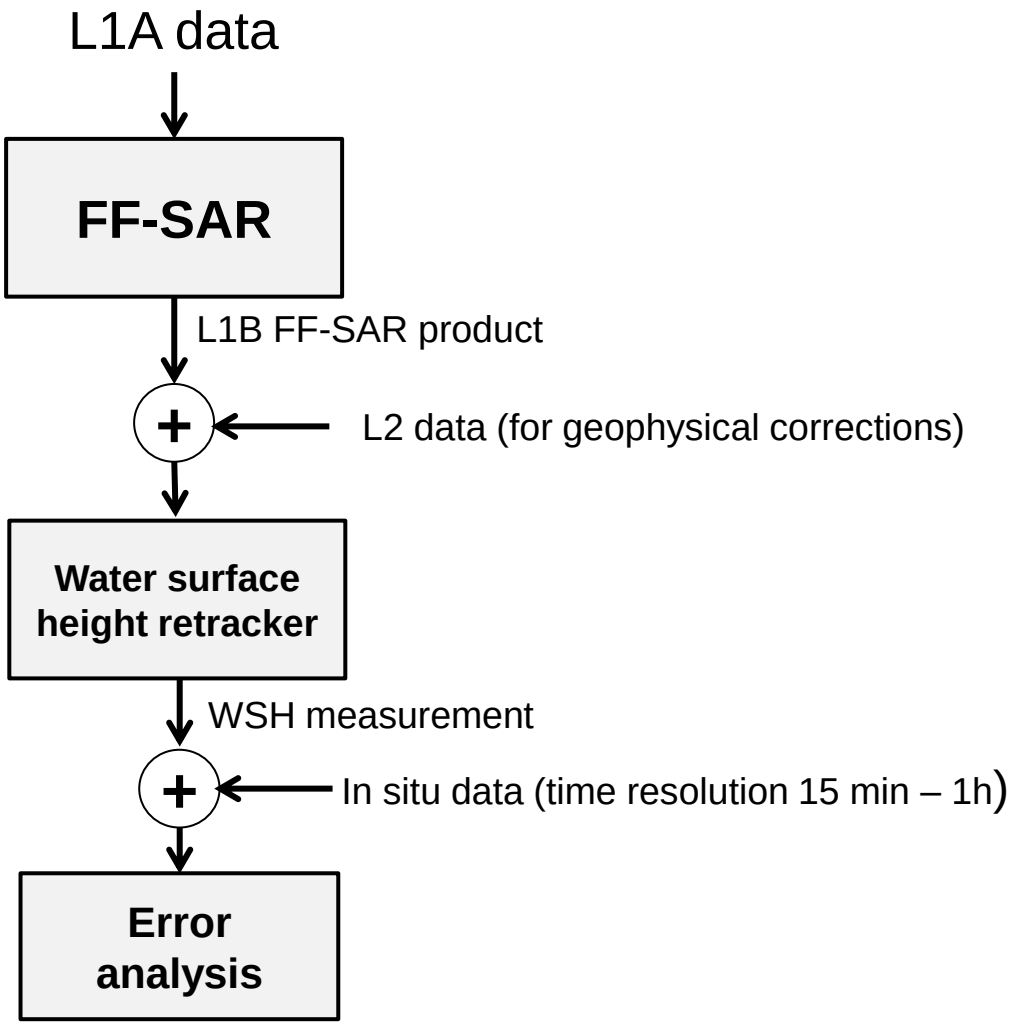
Location	Track number	Coordinates	Track length
Itoiz	248	[42.872, -1.331]	100 – 125 m

FF-SAR case study

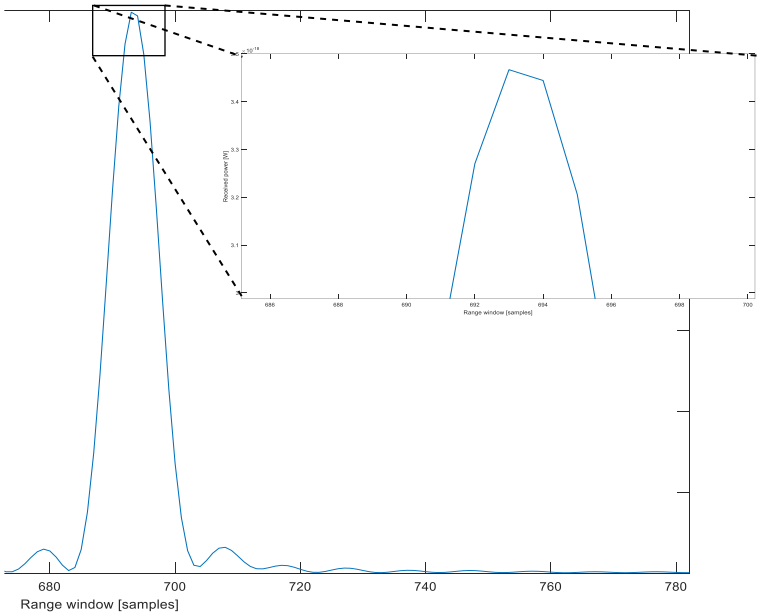
- FF-SAR processor
  - Processor based on the backprojection algorithm.
    - Egido and Smith, 2017
    - Available for different platforms (CS2, S3A/B, S6)
    - Validated over point targets (transponder & corner reflectors)

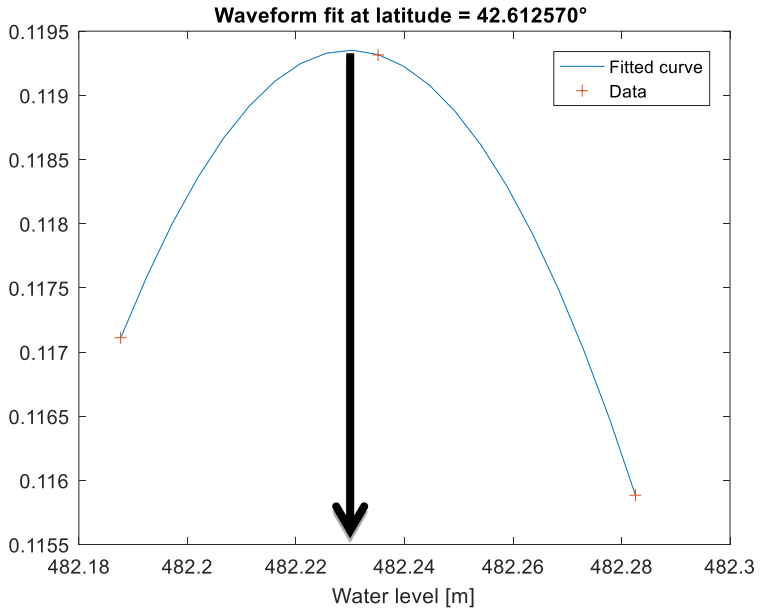
- Processing configuration:
  - Integration time: 3 s
  - Single Look spacing: ~0.6 m
  - Multi-looked spacing: 5 m

- Processing approach



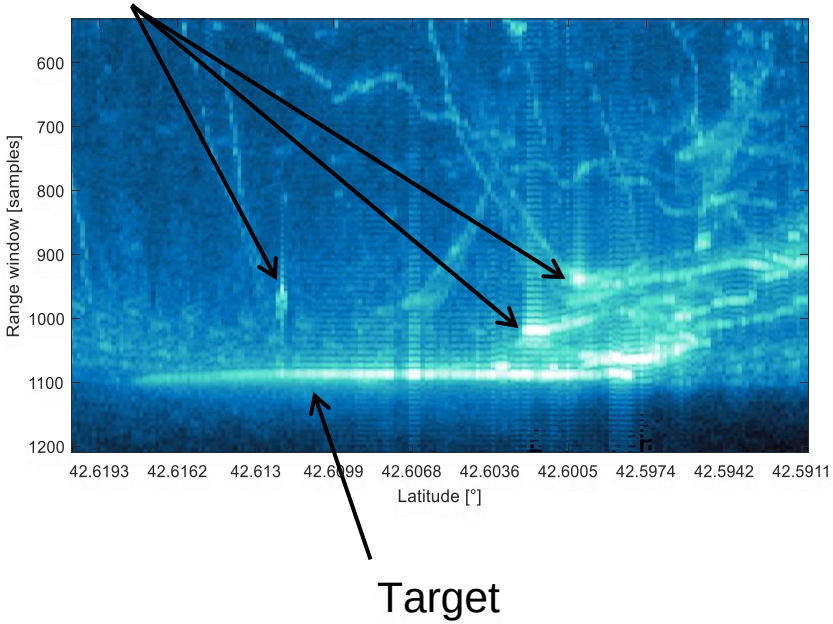
- Retracker
  - Based on simple Gaussian fit over maximum power of the waveform



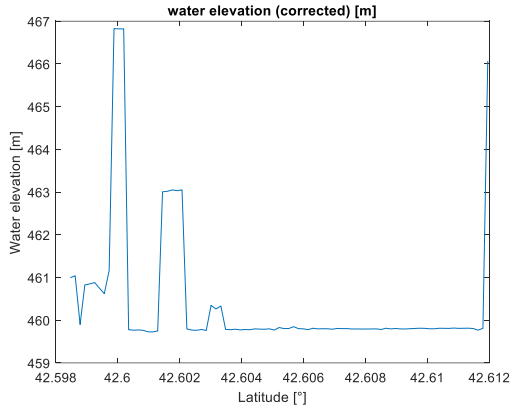


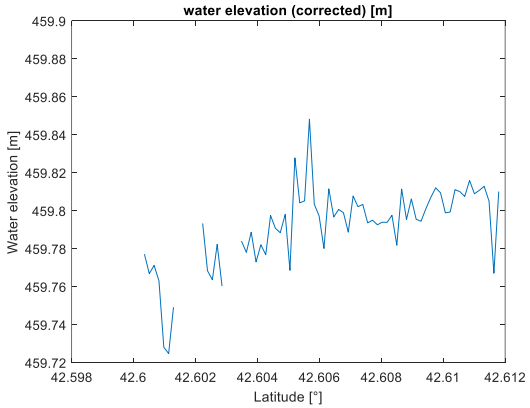
- Waveform filtering
  1. Discard waveforms with maximums coming from other scatters
  2. Discard waveforms with high peakiness

Undesired scatters

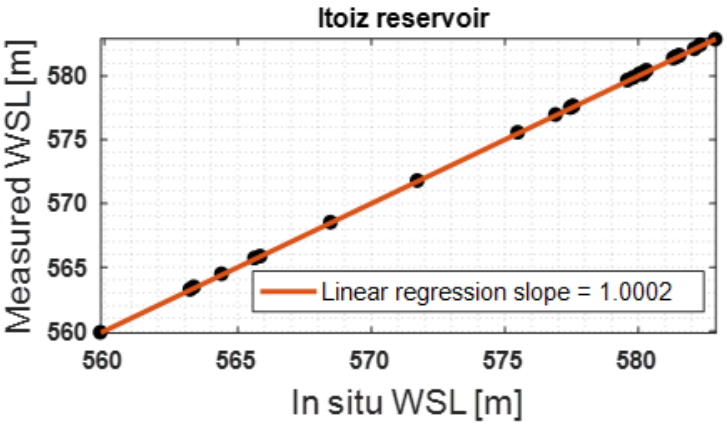


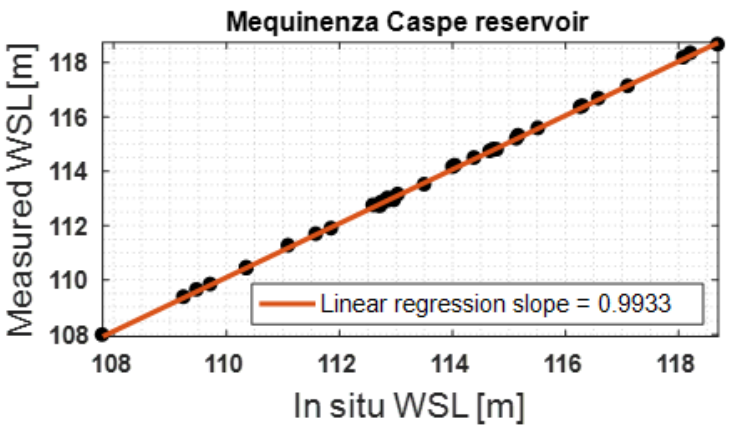
Target

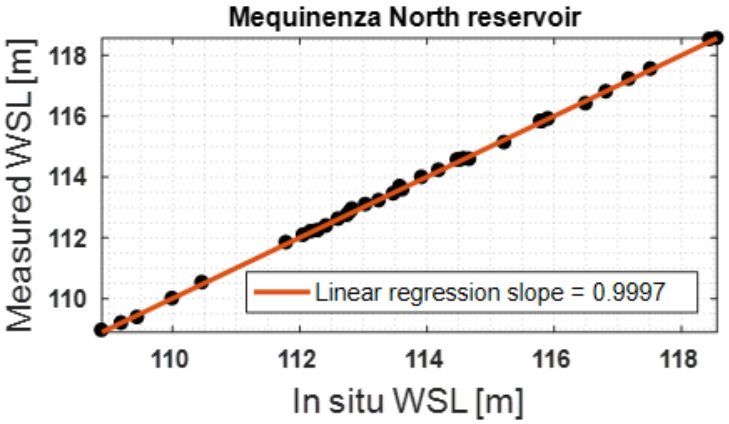


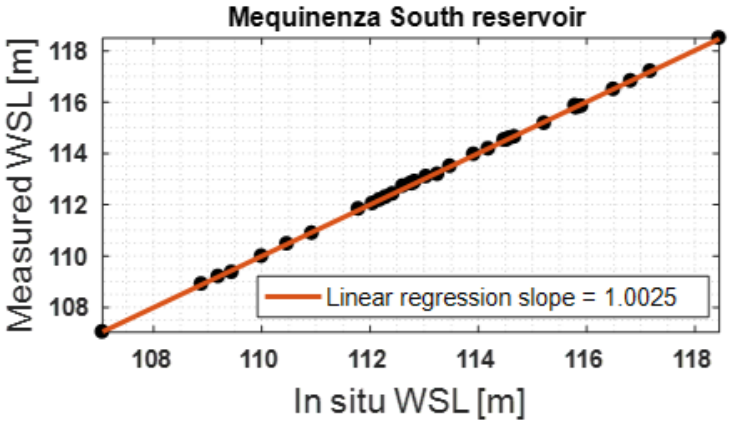


- Measurements vs. in situ data

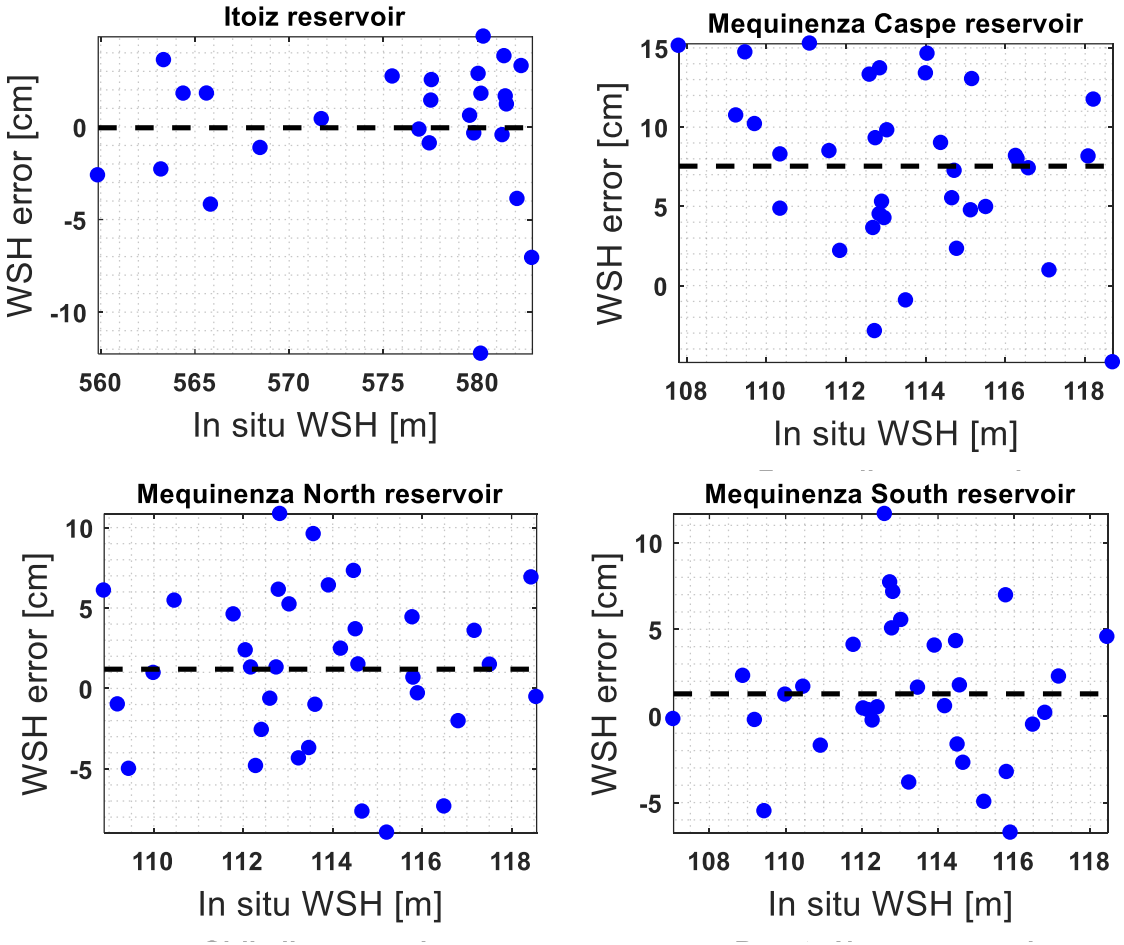








- Errors wrt to in-situ levels



- Results
  - Average error std below 5 cm
  - Average intra-pass std below 4 cm
    - FF-SAR waveform spacing of 5 m (ML of 5 m)

Location	Error bias [cm]	Error std [cm]	Intra-pass std [cm]
Itoiz	-0.1	3.7	4.5
Mequinensa – North	1.2	4.9	3.8
Mequinensa – South	1.3	4.1	3.3
Mequinensa – Caspe	7.5	5.2	2.9
AVERAGE	**2.5**	**4.5**	**3.6**

FF-SAR case study

- Comparison with L2 products (ESA)
  - Precision improvement between factor 3.7 and ~30

Reservoir	Method	Error bias [cm]	Error std [cm]	Avg. number of waveforms per pass
Itoiz	**FF-SAR**	**-0.1**	**3.7**	**20.3**
	L2 OCOG	77.5	109	1.7
	L2 ocean	-115	911	1.7
Mequinensa – North	**FF-SAR**	**1.2**	**4.9**	**100.1**
	L2 OCOG	23.2	19	4.4
	L2 ocean	32.3	18.3	4.4
Mequinensa – South	**FF-SAR**	**1.3**	**4.1**	**95**
	L2 OCOG	48.2	57.7	3.3
	L2 ocean	49	60.4	3.3
Mequinensa – Caspe	**FF-SAR**	**7.5**	**5.15**	**103.3**
	L2 OCOG	44.9	102	2.6
	L2 ocean	44.5	118.5	2.6

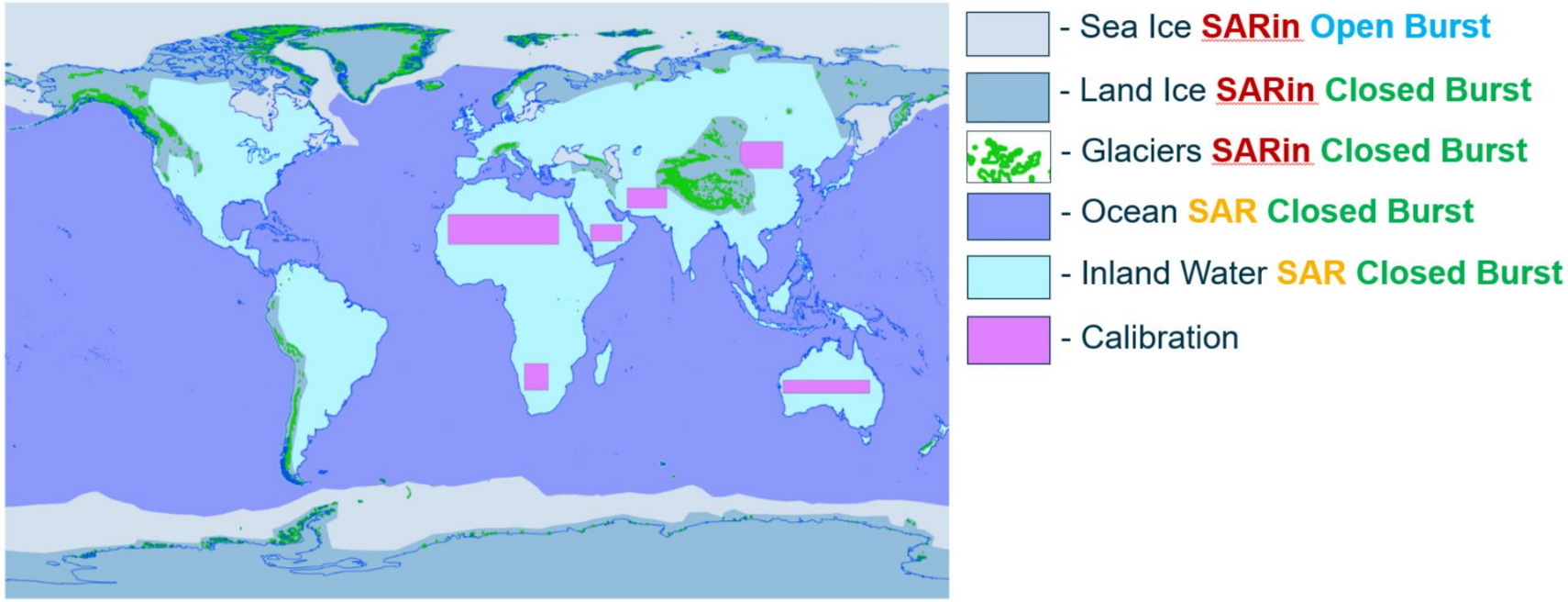
- Comparison with Sentinel-3 DDP-L2 products (HydroCoastal)

Reservoir	Width	Track	RMSE / Bias / MAD [m] (num. wf) (DTU retracker)
Ebro	1.8 km	S3A 014	0.71 / -0.67 / 0.67 (84)
Sotonera	4.5 km	S3A 222	11.61 / 2.21 / 2.41 (83)
Ribarroja	400 m	S3A 242 / S3B 336	1.47 / 0.07 / 0.43 (121)
Ullibarri	260 m	S3B 128	2.98 / 1.15 / 1.71 (21)
Canelles	260 m	S3B 299	0.37 / -0.33 / 0.33 (14)
Santa Ana	300 m-1.8 km	S3B 299	1.12 / 0.45 / 0.99 (10)
San Salvador	1.2 km	S3A 242	1.33 / 0.49 / 1.07 (5)
Itoiz	**0,4-1,7 km**	**S3A 165**	**0.48 / 0.37 / 0.42 (8)**
Irabia	130 m	S3A 242	11.89 / 1.8 / 1.88 (58)
Cavallers	800 m	S3A 299	13.8 / 2.95 / 3.47 (21)
Mequinenza	**600 m**	**S3A 279 / S3B 242**	**1.01 / -0.14 / 0.7 (28)**
Ebro	1.8 km	S3A 014	0.71 / -0.67 / 0.67 (84)

Conclusions

- Two reservoirs (actually 4 tracks) have been monitored for 1 year with Sentinel-6.
- A simple gaussian-based retracker has been applied.
- Average measurement precision around 5 cm has been observed
  - >10 factor of improvement wrt to DDP results on same targets
  - Note that the target size (< 2 km) implies very specular waveforms
- FF-SAR arises as a promising technique for water level estimates over inland water targets.

- Addendum
  - Preliminary CRISTAL mode mask:



Thank you!

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