

Continued, enhanced ocean altimetry and climate monitoring from space

31 October > 4 November 2022

IDS workshop OSTST meeting

Venice - Italy

https://ostst-altimetry-2022.com/

cnes, Copernicus, EUMETSAT, NASA, JPL, esa

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Nadir altimetry over land: achievements using the Open-Loop Tracking Command (OLTC)

Benefits for inland waters users

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cnes, LEGOS, NOVELTIS, esa European Space Agency

Hi, thank you for reading my presentation !



I am presenting in this document the status of the OLTC tables onboard nadir altimeters

- This work is performed by a **great team** of several individuals from CNES (my colleagues François Boy and Nicolas Picot), LEGOS (Denis Blumstein and Malik Boussaroque), Noveltis (Simon Boitard and then Alexandre Homerin) with the continuous support of Pierre Féménias from ESA/ESRIN.
- I want to thank Denis Blumstein for his tremendous contribution to this work and efforts to develop the use of altimetry data over inland waters ! Denis is now retired and this activity is being pursued by Malik Boussaroque.
- I also want to thank Simon Boitard for his great work over the last 4 years which have seen major upgrades to the OLTC tables. We are now welcoming Alexandre Homerin and Jean-Baptiste Barneix into the OLTC team !

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- Background on OLTC for inland waters
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- OLTC updates in 2022
- Validation results
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- OLTC website
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- Conclusion
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This is the outlook of my presentation.

Overview

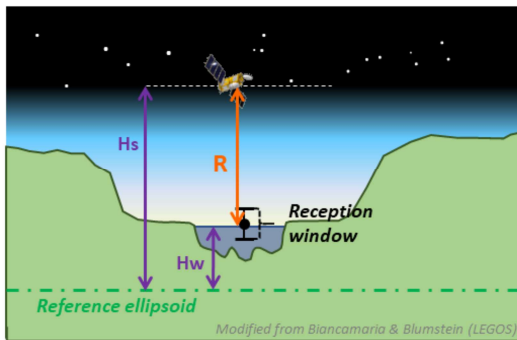
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Section 1 of this presentation :

Some useful reminders on the **principles of the altimeters**
Open-Loop Tracking Command (OLTC), also known as
Diode/DEM mode, and its use for inland waters measurement

Altimetry over inland waters : principles



R = Range distance between satellite and water surface
 Hs = Altitude of satellite above ref. ellipsoid
 Hw = Altitude of water surface above ref. ellipsoid

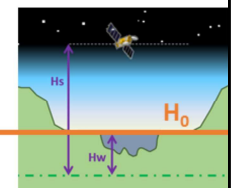
- The size of the reception window of the altimeter is 60 meters by design
 - Closed-Loop mode has some drawbacks e.g. loss of tracking or tracking of the wrong surface
- Defining on-board *a priori* water body average elevation H_0 is key to acquire measurements in all terrain configurations

Radar altimeters provide accurate **range** measurement between the instrument and the surface.

The range estimation **R** results from **on-board operations (tracking)** and **on-ground post-processing (retracking)** of the waveforms.

Waveforms are acquired in the altimeter **reception window**, which is set by the **on-board tracking mode** :

- « Closed-Loop » mode aka *autonomous mode*
- « Open-Loop » aka *Diode/DEM*



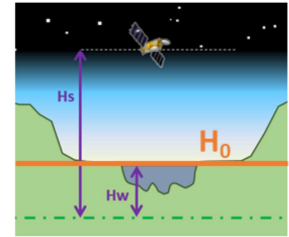
Modified from Biancamaria & Blumstein (LEGOS)

- I recall here some reminders of how altimeters work over hydrology (already presented in previous meetings)
- The Open-Loop mode uses onboard OLTC tables which contain a priori information elevation. It is used by the altimeter to control and center the waveforms reception window.
- The a priori information H_0 contained in OLTC tables is key to acquire measurements in all terrain configurations.
- If this H_0 is not correctly set, no signal is recorded.
 « No signal, no data... »

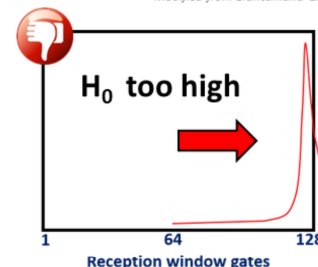
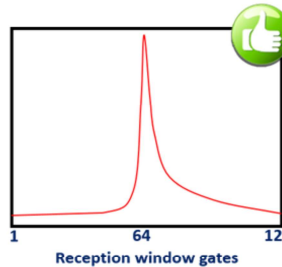
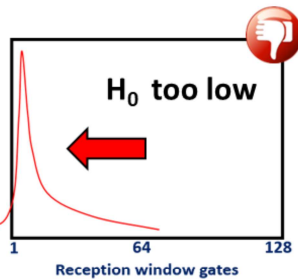
Altimeter onboard optimization : OLTC tables

A database of hydrological targets serves as input for on-board OLTC tables generation :

- Only for water bodies located under the satellite ground track (nadir altimetry)
- Define water body center position and size (along-track width)
- Define average elevation command H_0 with a possible variability of about ± 10 m to fall in the tracking window and allow retracking



Modified from Biancamaria & Blumstein (LEGOS)



The website <https://www.altimetry-hydro.eu> allows you to view onboard elevations and contribute to the virtual stations database !

- H_0 used by the altimeter is stored in the onboard memory
 - A database of hydrology targets is used to compute the OLTC tables.
 - **All users can view the elevation information contained in current OLTC tables (Sentinel-3) through the OLTC web portal : <https://www.altimetry-hydro.eu>.**
 - Anyone can also contribute by submitting new targets ! (login required)
- (more details in section 4 of this presentation)*

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Switch to section 2 of this presentation :

Summary of OLTC updates performed in 2022

OLTC updates in 2022 : context

Sentinel-3A, Sentinel-3B and Jason-3 have been updated with new onboard OLTC tables in 2022

- **No changes over ocean** to ensure continuity
- **Correction of elevation command for a new number of hydrological targets** (see next slides) to maximize the capability of nadir altimeters to acquire measurements over inland waters
- Upload of a new DEM for Jason-3 on the interleaved orbit

Organization

- LEGOS team and hydrology users provide targets to be included in OLTC tables
- NOVELTIS generates and validates the new OLTC onboard tables
- CNES coordinates the delivery of upgraded OLTC tables to the operational agency and reporting to the missions project teams
 - CNES/NOAA for Jason-3
 - S3MPC/Eumetsat and ESA for Sentinel-3
- NOVELTIS provides CNES with first validation results (successful acquisition score – see next section)
- LEGOS scientists provide scientific validation in the frame of Volodia project (ESA/CNES project)
- All hydrology users are invited to dive into the new data !

May 14, 2019



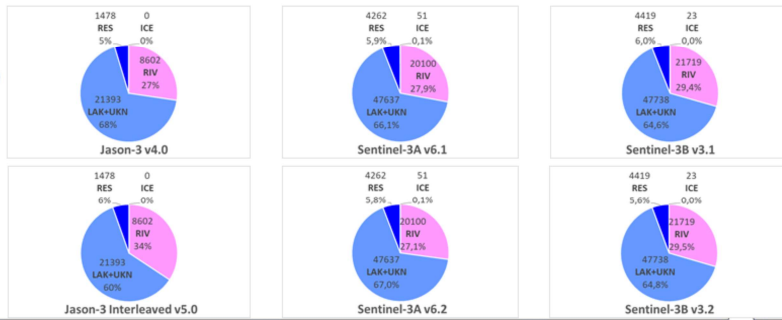
- This year, new OLTC versions have been uploaded on Sentinel-3A, Sentinel-3B, and Jason-3-interleaved!
- The main objective of these updates was to **correct some elevation commands for a small number of targets** over inland waters (less than 5%).
- **We also have uploaded a brand new DEM onboard Jason-3 on the interleaved orbit, who was operating in Closed-Loop since the orbit change (April-September 2022).**
- I provide in the « Organization » section some information on how new versions of OLTC are generated, uploaded and validated, and who is involved.

OLTC updates in 2022 : detailed numbers

Mission	OLTC version	Date of activation	Cycle / Pass	Number of hydro targets (total)	Number of hydro targets by type : rivers / lakes / reservoirs / glaciers, identified as such for OLTC definition	Applicable geographical area
Jason-3	V3.0	August 31, 2017	cycle 57 pass 160	4,721	4,366 / 355 / - / 0	Global
Sentinel-3B	V2.0	November 27, 2018	cycle 19 pass 219	32,515	17,016 / 14,245 / 1,231 / 23	Latitudes inside ±60°
Sentinel-3A	V5.0	March 19, 2019	cycle 42 pass 317	33,261	17,409 / 14,427 / 1,386 / 39	Latitudes inside ±60°
Sentinel-3B	V3.0	June 18, 2020	cycle 40, pass 277	73,899	21,719 / 47,738 / 4,419 / 23	Global
Sentinel-3A	V6.0	August 27, 2020	cycle 62 pass 244	72,050	20,100 / 47,637 / 4,262 / 51	Global
Jason-3	V4.0	September 3, 2020	cycle 168 pass 109	31,473	8,602 / 21,393 / 1,478 / 0	Global
Jason-CS/Sentinel-6A	V1.1	December 18, 2020	Cycle 4 pass 16	31,805	8,655 / 21,666 / 1,484 / 0	Global
Sentinel-3A	v6.2	September 8, 2022	cycle 89 pass 623	74,054	20,102 / 49,637 / 4,264 / 51	Global
Sentinel-3B	V3.2	September 15, 2022	cycle 70 pass 528	73,630	21,720 / 47,738 / 4,149 / 23	Global
Jason-3 Interleaved	V5.0	September 29, 2022	cycle 316 pass 113	31,217	10,696 / 18,814 / 1,707 / 0	Global

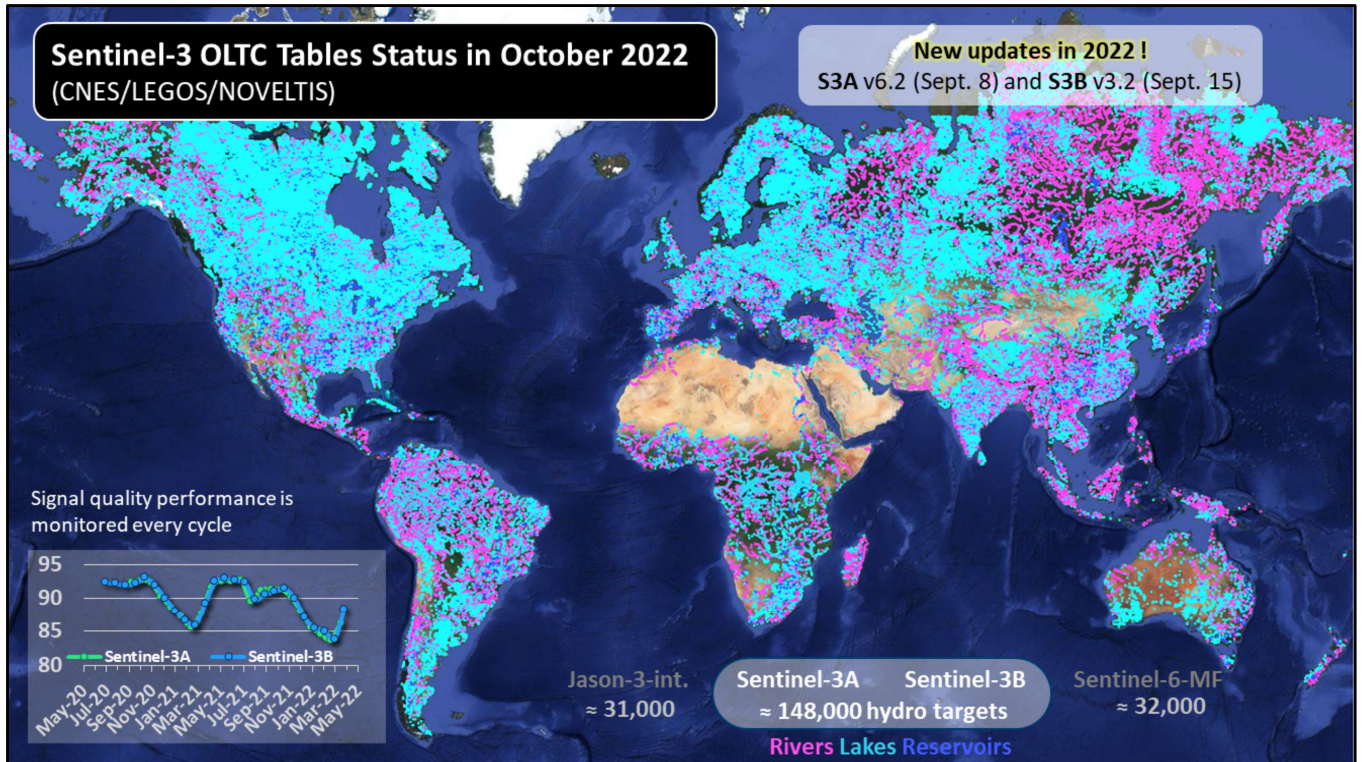
Proportion of each type of hydro targets in the database before (top) and after (bottom) OLTC update

Colorcode: Rivers, Lakes, Reservoirs



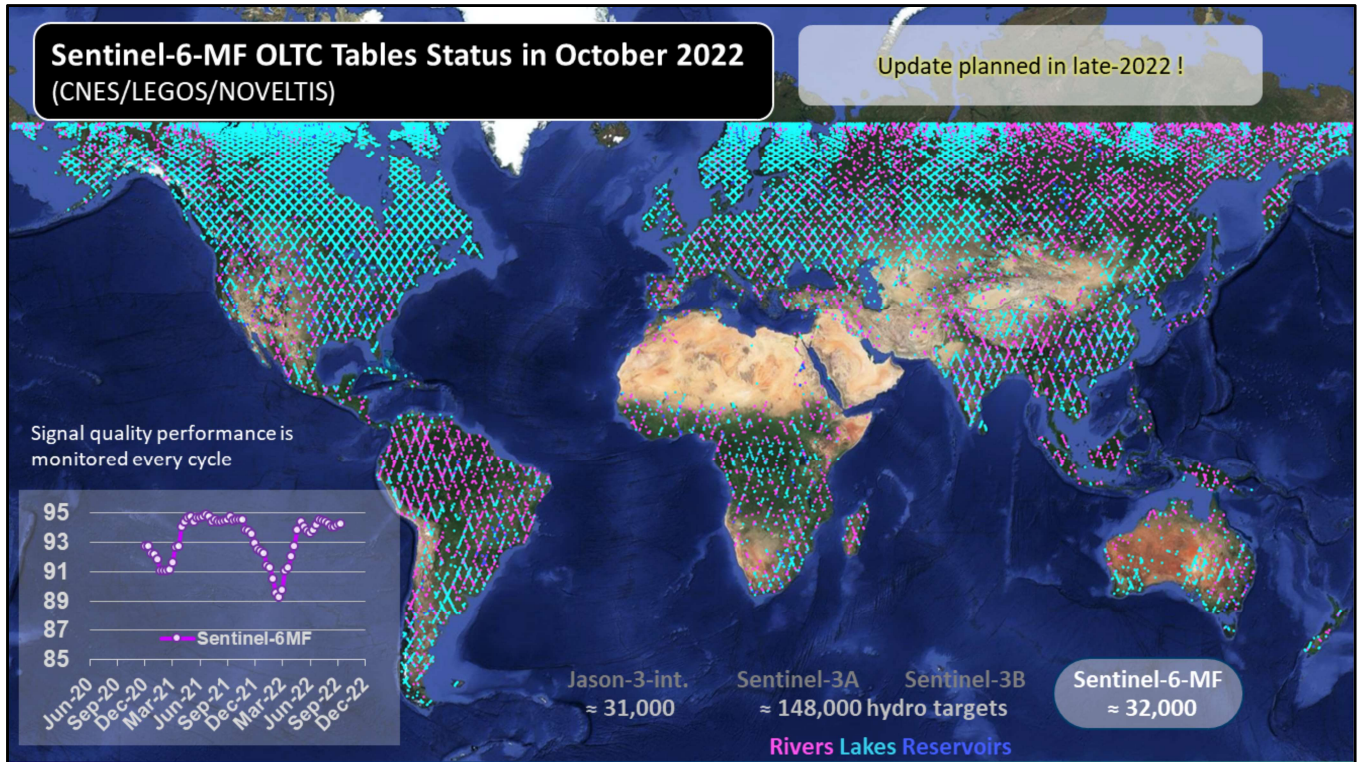
[Please zoom-in to better see the table and charts]

- The table describes the previous (light & dark grey lines) and **new** (blue lines) OLTC versions and contents, and associated activation dates with corresponding cycle/pass numbers.
- The pie charts indicate the **proportion of each type of hydro targets** (top row = before, bottom row = 2022, for Jason-3, Sentinel-3A and Sentinel-3B (left to right, respectively)).
- No major increase has been performed this year in terms of hydro targets numbers (the major increase was already performed in 2020, see *Le Gac et al. OSTST 2020*), only corrections to the onboard elevation command.



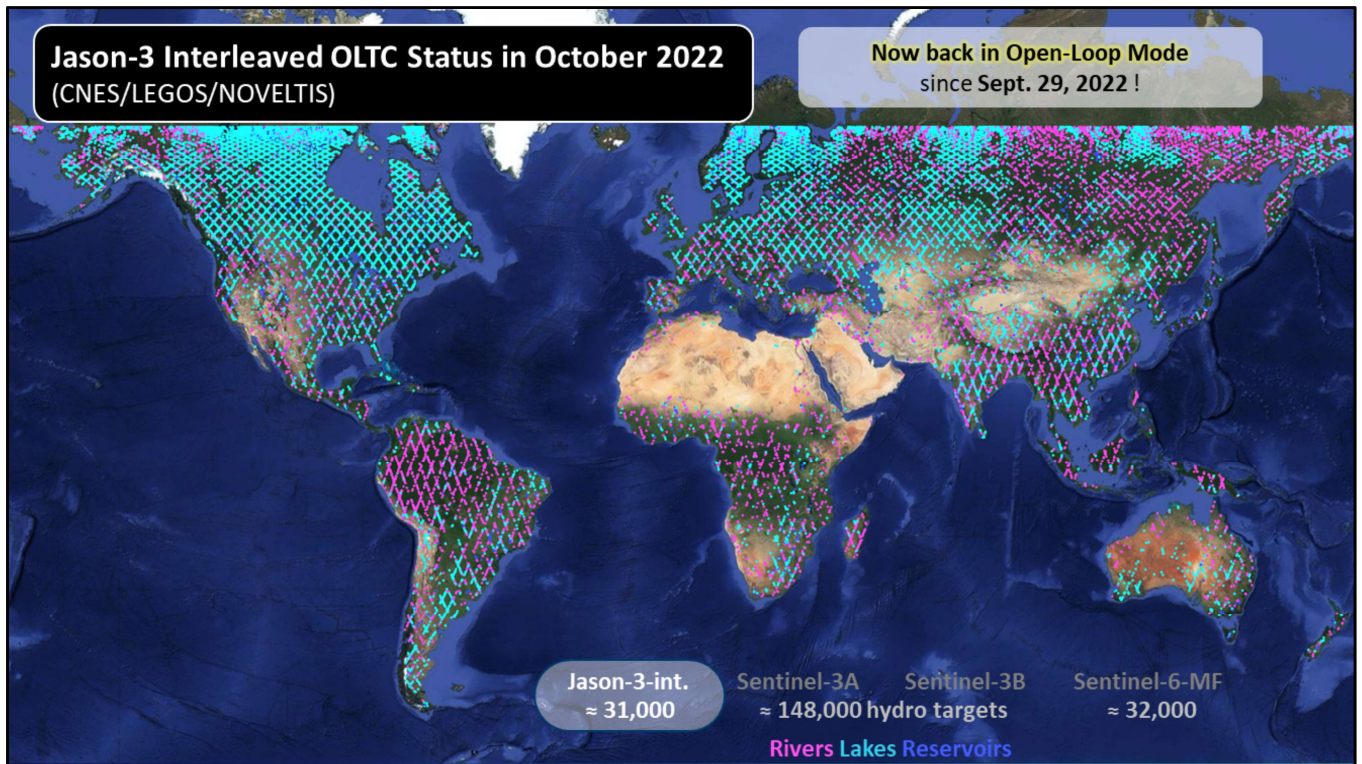
[Please zoom in to better see the figure]

- The map shows all hydro targets defined under Sentinel-3A and Sentinel-3B orbits combined (about 148,000 !).
- The color code is explained in the bottom :
Rivers Lakes Reservoirs
- The bottom left plot shows the overall performance of altimeter signal quality over all nadir targets (<60°N)
- Sentinel-3A and Sentinel-3B both get similar performances over hydro, globally.
- *An updated version of this plot is available on slide 14*



[Please zoom in to better see the figure]

- The map shows all hydro targets defined under **Sentinel-6-MF** orbit (about 32,000)
- The color code is explained in the bottom :
Rivers Lakes Reservoirs
- The bottom left plot shows the overall performance of altimeter signal quality over all nadir targets (<60°N)
- A seasonal decrease is observed in winter (most probably due to ice-covered water bodies), but the acquisition score reaches 95% of success in spring-summer.



[Please zoom in to better see the figure]

- The map shows all hydro targets defined under **Jason-3 interleaved orbit (in Open-Loop mode since Sept. 29, 2022)**
- The color code is explained in the bottom :
Rivers Lakes Reservoirs
- **Between April and September 2022, Jason-3 was operating in Closed-Loop Mode**, giving us the opportunity to further validate the performance of Open-Loop with respect to Closed-Loop mode, by comparing the same targets before/after OLTC tables upload.
- **Jason-3 interleaved** is still performing very well and constitutes an **additional valuable dataset in preparation for SWOT Cal/val over hydrology.**

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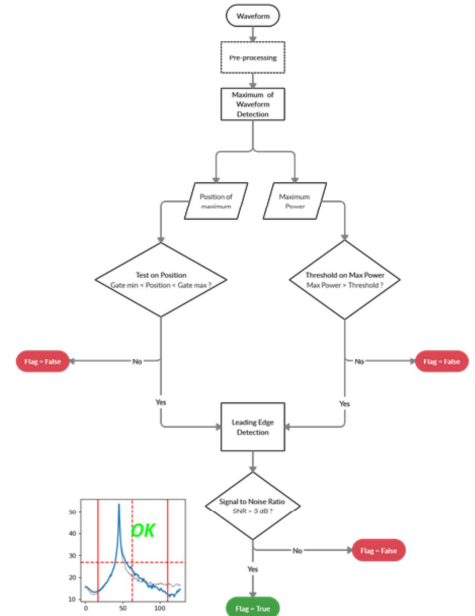
Switch to section 3 of this presentation :

Global validation results

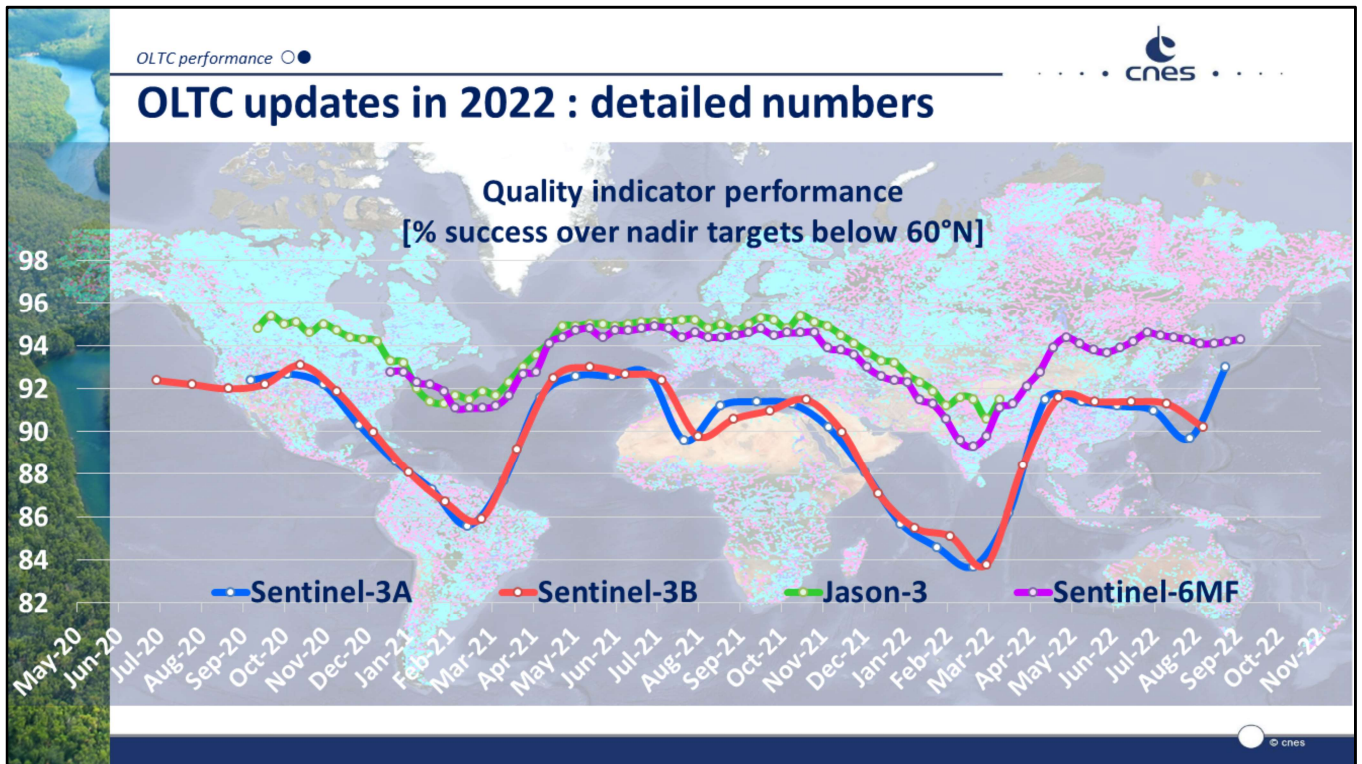
Global validation method

- Global validation is performed through a **performance indicator**
- **This indicator is based on the 20 Hz waveforms analysis** (position of the maximum, leading edge detection, signal to noise ratio)
- **Performance indicator** → global **rate of successful acquisitions**
- **OK** indicates that the OLTC elevation a priori information is correctly defined and a relevant WSH can be retrieved
- **NOK** indicates that the OLTC elevation command needs to be adjusted, or that the observed surface is complex with several water bodies, or that the altimeter was not able to acquire signal (calibration, platform manoeuvre,...)

More details in
Le Gac et al.
ASR 2019



- This slide explains how we proceed to validate a new OLTC version.
- The **acquisition indicator (OK/NOK)** is used to evaluate if **the received waveform is exploitable**, thus indicating that the OLTC elevation command is correctly set. This is a first quality indicator (not representative of the quality of the water surface height performance).
- More details on how this indicator is computed from the waveforms can be found in *Le Gac et al. ASR 2019*.



- This plot shows the temporal evolution of the quality indicator performance, for a selection of hydro targets located at nadir and under 60°N.
- A 90% success indicates that 90% of the targets have successfully been acquired by the altimeter, based on the quality indicator described on the previous slide
- Sentinel-3A and Sentinel-3B show a similar performance and evolution over time. Acquisition success is > 85% and reaches 92% in spring-summer. Performance decrease in winter is most probably due to ice-covered water bodies at high latitudes and / or variability of water surface height.
- Jason-3 followed by Sentinel-6-MF on the reference altimetry orbit also depict the same temporal variability, with a global performance higher than 90% throughout the period. A

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Switch to section 4 of this presentation :

Description of the OLTC website

<https://www.altimetry-hydro.eu>

A new version of the existing OLTC website will soon be available !

Updated features include:

- Display of hydro targets used in OLTC tables on Sentinel-3A, Sentinel-3B and Sentinel-6-MF (New!)
- Improved map interface
- Improved responsiveness
- Documentation and informations available

Everybody can contribute to the OLTC tables contents by proposing new hydro targets!

A demo of the new website is scheduled during OSTST (Outreach session)

- ☞ Tuesday @ 17:45
- ☞ Thursday @ 14:30

[Please read the slide]

A demo of the new website is scheduled during OSTST (Outreach session)

- ☞ Tuesday @ 17:45
- ☞ Thursday @ 14:30



- This is a preview of the new look of the OLTC website.
- The website is organized in 4 tabs :
 - Welcome to the OLTC portal
 - Get started
 - **Check & Tune the targets = current view (= map)**
 - Learn more on the OLTC
- The « Check & Tune the targets » tab allows you to view current onboard elevations defined in the OLTC tables for Sentinel-3A, Sentinel-3B and Sentinel-6-MF.
- The navigation is intuitive, you can move on the map, zoom in and display information through the right panel :
 - Choice of satellite mission
 - Choice of hydrological targets to be displayed
- On the bottom right there is also the « Contribute » tool (after login) that allows to propose new targets or modify existing ones !

OLTC website ○○○

<https://www.altimetry-hydro.eu>

NOVELTIS cnes esa Copernicus
 Altimeter Open Loop Tracking Command for Hydrology

Welcome to the OLTC portal | Get started | Check & Tune the targets | Learn more on the OLTC

Check and Tune the targets

Configuration

- Geoid GDM20C
- Ellipsoid WGS84

Configuration

- Missions
- S3A
- S3B
- S3A

Date/OLTC version

S3A v6.2 active onboard since September 08, 2022
 S3B v3.2 active onboard since September 15, 2022
 S3A v1.1 active onboard since December 18, 2020

Layers

- Off-nadir hydrological target
- Satellite Pass (zoom dependent)
- Hydrological Targets
 - Rivers
 - Lakes
 - Reservoirs
 - Wetlands
 - Glaciers
 - Unknown

Contribute

You must be logged in in order to contribute.

ID	Height (m)	Nadir	Orbit number	Satellite

- Zoom over the region selected in the previous slide (Northern Italy in this example)
- You have an overview of the different targets defined in this region, with the associated colorcode described on the right. Satellite ground tracks are also visible at a sufficient zoom level.
- The table on the bottom of the page lists all hydro targets available in the current zoom level.

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Switch to the last section of this presentation :

Conclusion and perspectives

Conclusion and perspectives

- **Open-Loop tracking mode is key to inland waters observation**
 - Onboard OLTC tables are used to **set the echo reception window**
 - A **database of inland water targets** is used to generate OLTC tables over land
 - Targets are defined with **elevation H_0** and **width** of the water body (lake, reservoir, river, glacier...)
- **OLTC tables have been recently updated**
 - No changes over ocean and coastal zones
 - Sentinel-3A updated on September 8, 2022
 - Sentinel-3B updated on September 15, 2022
 - **After moving to the interleaved orbit**, and operating in Closed-Loop mode during several months, **Jason-3 now holds new OLTC tables (~30,000 hydro targets)** and is back operating in Open-Loop Mode since September 29, 2022
 - **Sentinel-6-MF** holds the same targets database than Jason-3 during Tandem Phase
- **Global validation results show very good continuous performance !**
 - Performance is evaluated thanks to waveform shape and centering analysis (acquisition score)
 - Global performance is **>90% on Jason-3 and Sentinel-6-MF** for all inland water targets
 - Global performance is **~85% on Sentinel-3** for all inland water targets

[Please read the slide]

Conclusion and perspectives

- **OLTC Web portal available to the users** : <https://www.altimetry-hydro.eu>
 - View onboard elevations and contribute to new virtual stations !
 - **New version of the portal available soon !**
- **A massive amount of altimetry data is now available over inland waters worldwide**
 - The altimeters capability has been greatly enhanced over land thanks to OLTC tables optimization
 - Scientific data analyses and studies are required (see, for example, *Taburet et al. OSTST 2022*)
 - **Nadir altimetry over hydrology will provide quality data for SWOT cal/val**
- **OLTC is also used for other altimetry applications**
 - Ground calibration means, UAV-based measurements campaigns
 - Potential for continental glaciers and ice margins measurement
→ on-going studies on Sentinel-3 in preparation for CRISTAL
- **OLTC and targets database as inputs for innovative ground processing and services**
 - Fully-Focused SAR processing
 - Monitoring of inland waters through dedicated services e.g. Hydroweb/Hysope

[Please read the slide]

Thank you for your attention !

If you have any questions related to OLTC tables management and contents, please reach out to us !

 oltc@noveltis.fr

And don't forget to visit the OLTC web portal :
<https://www.altimetry-hydro.eu>