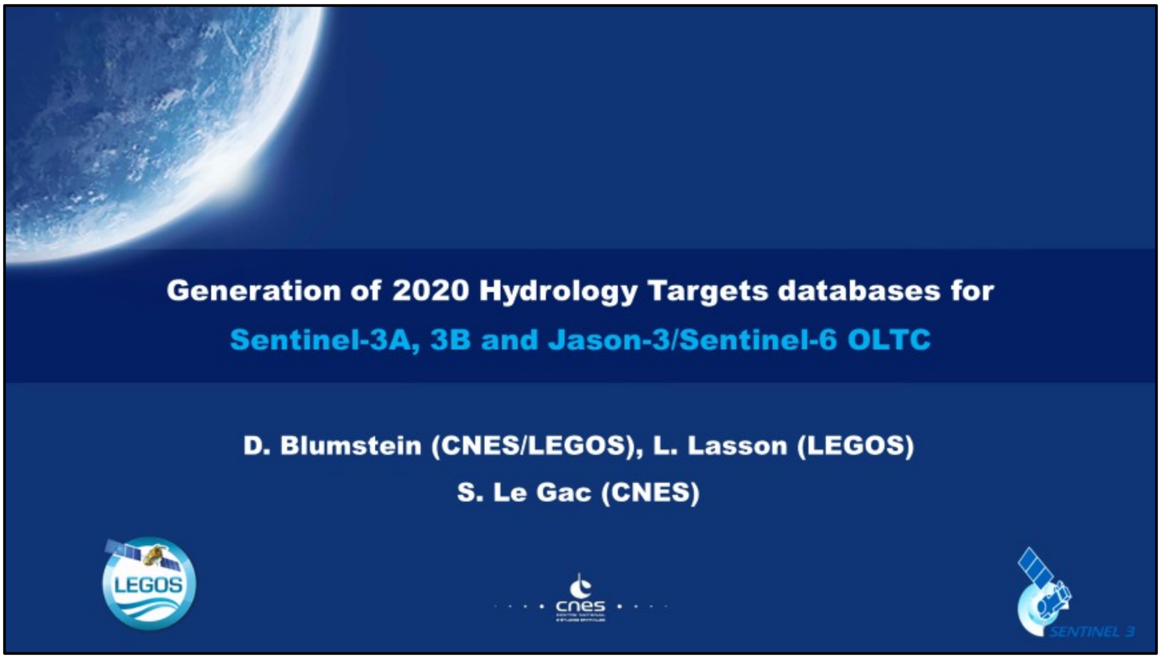


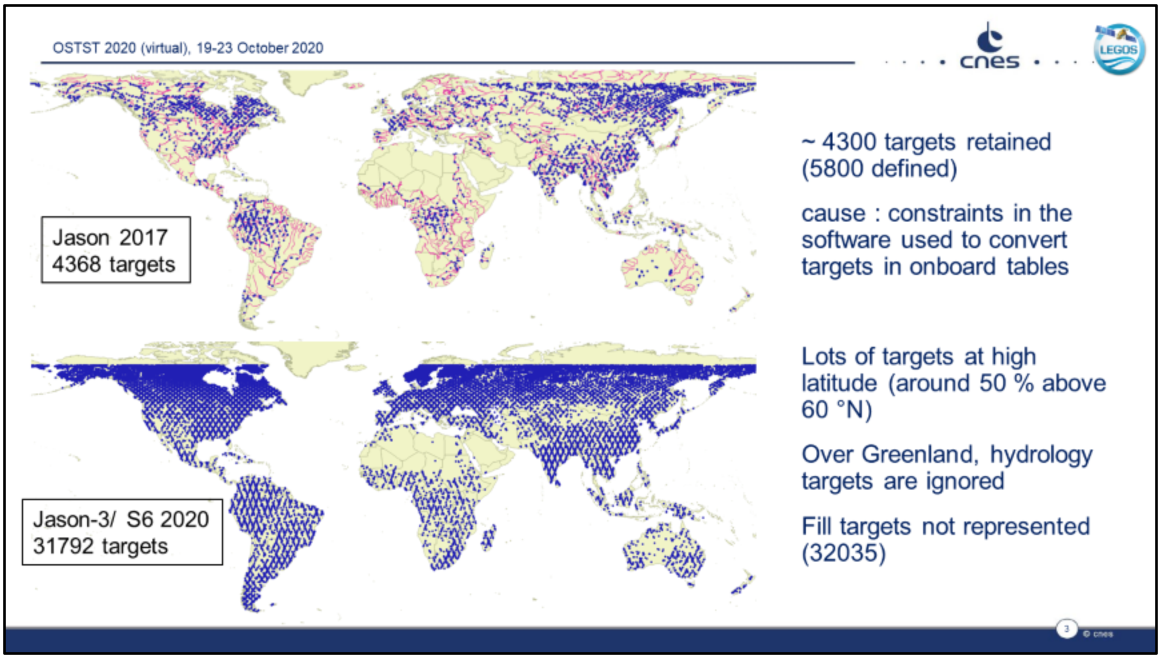
OLTC (Open Loop Tracking Command) main objectives and first validation results for the last generation is provided in Sophie Le Gac presentation (this OSTST)

The data selection, processing and control was performed by Léa Lasson and Denis Blumstein. Sophie Legac provided necessary inputs about the constraints of the 4 altimeters, reference orbits and interfaces with the software used to compute the onboard tables.

Outline

- **Evolutions 2017/2018 → 2020**
- **Methodology improvements**
  - New Datasets
  - New Methods
  - Global coverage of land surfaces
- **Quality Control**
- **Conclusion and perspectives**

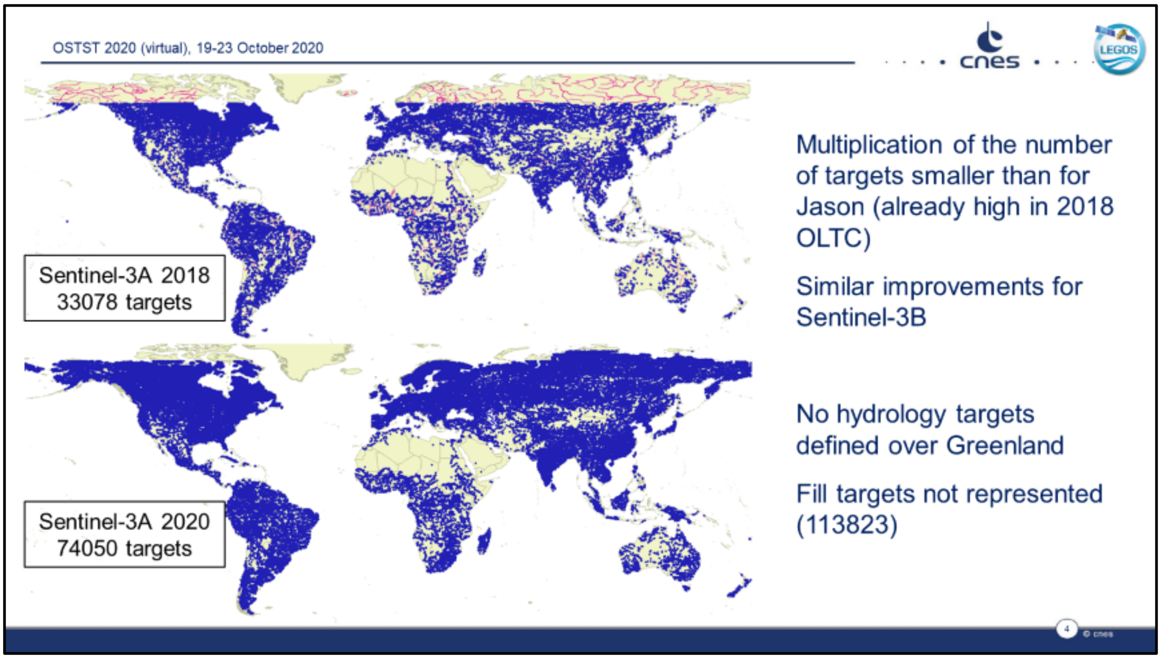
Acknowledgements : this work was performed in the frame of the VOLODIA project funded by CNES with contribution of ESA Sentinel-3 Mission Performance Center



The 2017 generation for Jason-3 was conservative as the altimeter on Jason-3 can switch very rapidly between Close Loop (CL) and Open Loop (OL) modes (in less than 1 second). Then, it is not necessary to define hydrology target everywhere over land. When no hydrology target is defined the altimeter switches automatically in CL mode. The hydrology targets were then generated for Jason-3 only where we already had a good knowledge of the position and the elevation of the waterbodies.
Some hydrology targets could not be integrated in the OLTC tables because of limitations of the OLTC generation software at this date. These limitations were removed in further versions of the software.

On the contrary the altimeter onboard Sentinel-6 (aka Jason-CS) tracking mode must be kept constant for long parts of the orbit (either CL or OL). It is then necessary to define targets almost everywhere. Indeed, when no elevation is defined for a point on the ground, then the elevation of the previous target is kept. Therefore it was necessary to improve a lot the methodologies used as well as the data sets (waterbodies masks or shapefiles, Digital Elevation Models) in order to be able to define elevations for much smaller waterbodies than in 2017. With the willingness to use OLTC at high latitudes (above 60°N), this explains the large increase of the number of hydrology targets computed in 2020 with respect to 2017.

Fill targets are discussed in slides 8 and 9.



The SRAL altimeters onboard Sentinel-3A and 3B must be kept in the same tracking mode for long parts of the orbits (like the Sentinel-6 one, cf previous slide).

The 2020 databases have been densified and extended above 60°N with respect to the 2018 ones.

No hydrology targets is defined over Greenland in order to not change the behavior of the altimeter over the icesheet.

Methodology Improvements : new input datasets

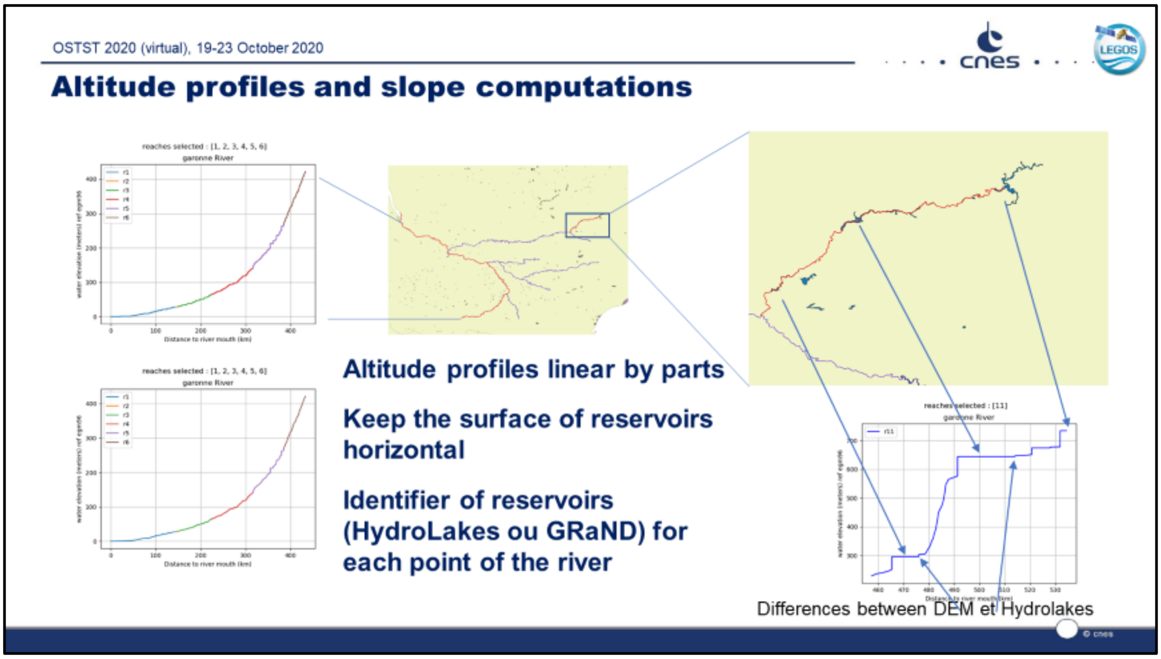
- Lakes : Use of HydroLakes et GRaND v1.3 database
  - After detailed analysis and comparison between GLWD, HydroLakes and GRaND v1.3
  - Hydrolakes : more than 10 millions of lakes (> 10 ha)
  - Polygons and reference altitudes
- Large extension and improvements of the VOLODIA / CLS rivers database
  - Integration and merge with the optimized CLS river centerlines database
  - Improvements in the computation of rivers altitude profiles
  - Conversion of the SWOT project river database (SWORD V01) to VOLODIA format (Courtesy of the SWOT PI Tamlin Pavelsky, SWORD not public yet)
  - Creation of connections between rivers and reservoirs

Many public databases provide position, extension and elevation of lakes and reservoirs.
We used data from HydroLakes and GRaND v1.3 after a careful examination and comparison of different data sets.

River centerlines and elevation profiles are a prerequisite for the definition of the hydrology targets over rivers. Even if we do not need very accurate elevations (around 5 meters accuracy is sufficient), this computation at a global scale is not a trivial task. However, using the constraint that the altitude profile must decrease monotonically in the downstream direction, we can remove many errors caused by :

- DEM and river centerline not coherent (because river centerlines derived from water masks not always consistent with DEM),
- Errors in DEM altitude

We have developed such a dataset since 2017 and merge it with others developed in parallel efforts.

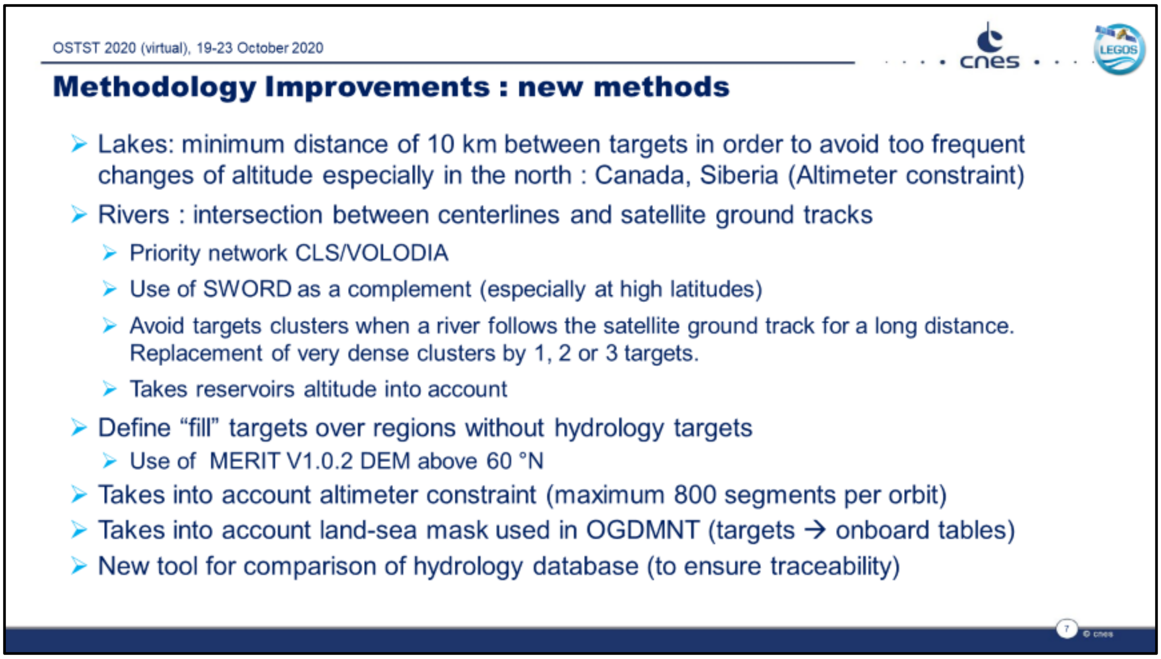


Here is an example of river centerlines and altitude profile over the Garonne watershed.

The left figures show the altitude profile along the main course of the Garonne river. On the bottom figure the altitude profile was smoothed (linearly by part). This is important for some rivers in order to obtain the required accuracy of better than +/- 10 meters.

A few precautions must be taken when doing this smoothing in order to:

- Preserve the horizontality of reservoirs/lakes along the river (see right figures)
- Preserve real falls



Here is a summary of the improvements brought to our methods since the last generation done in 2018 for the Sentinel-3A and 3B OLTC.

We have reached some limits of the onboard OLTC software because of the extension of coverage and densification of the targets database (limits induced by the size of the memory used for the storage of the OLTC tables in the altimeter). These limitations are present for Jason-3, Sentinel-3A and 3B. Sentinel-6, Sentinel-3C and 3D will not have such limitations in the future. In order to respect the constraints imposed by the altimeters we avoid lake/reservoir targets closer than 10 kilometers from each other. This is especially important for lakes at high latitude in the northern hemisphere (e.g. Canada).

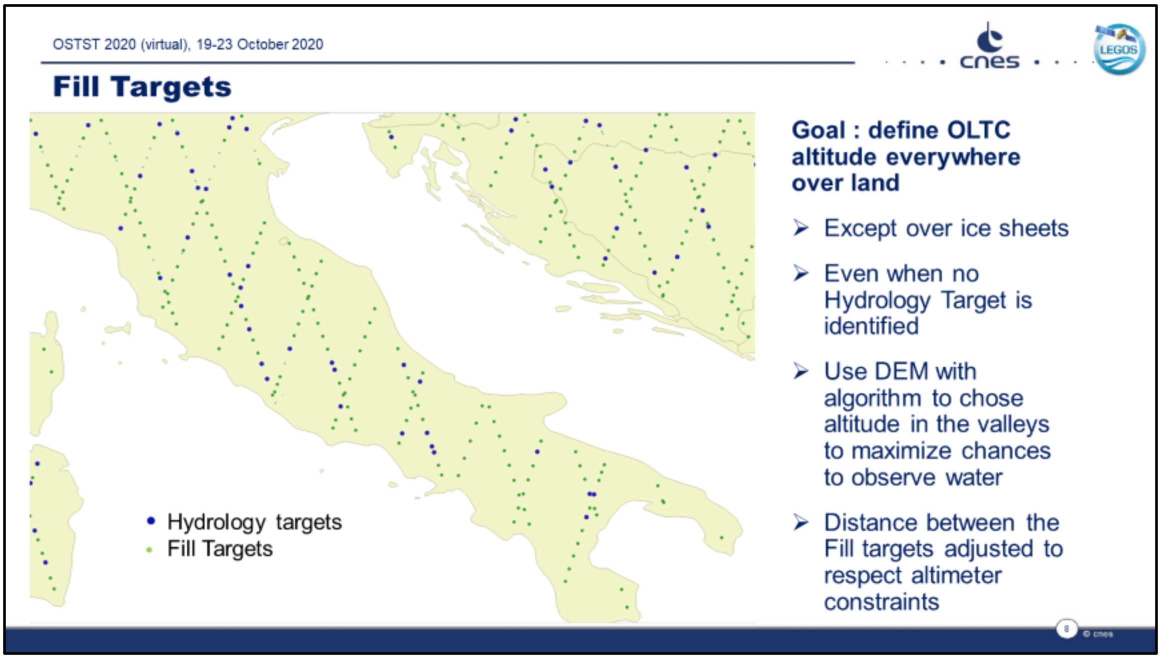
For the river the minimum distance between hydrology targets is 6 kilometers. One special circumstance when river targets could be close to each other is when the satellite track follows a meandering river. In that case we merge many river crossings into the same hydrology target (with an along track extension) when the altitudes of the various crossings are close enough to each other. If the river has a high slope, then we put many targets along the river (keeping the minimum distance of 6 kilometers).

As mentioned before, the Sentinel-6 (aka Jason-CS) altimeter has not the same constraints as Jason-3. Then a denser database could have been generated for Sentinel-6. However, in order to ease the comparisons between Jason-3 and Sentinel-6 during the commissioning and the Cal/Val of Sentinel-6, it was decided to use the same hydrology target database for both altimeters. Only the conversion process into OLTC tables is different for the 2 altimeters.

In order to maximize the number of hydrology targets we have used the real number of segments and the ocean mask used by the OGDMNT software to generate the OLTC tables.

FILL targets are discussed in next slide 8.

The tools used to insure traceability between the versions of the hydrology database will be further discussed in slide 9.



As mentioned in slide 3, the altimeter onboard Sentinel-6 tracking mode must be kept constant for long parts of the orbit (either CL or OL). This is the same for Sentinel-3A and 3B altimeters. When no elevation is defined for a point on the ground, then the elevation of the previous target is kept. As shown on the figure, there are large gaps between hydrology targets derived from the input databases (blue points). When the altitude varies a lot along track, this can prevent the acquisition of useful data if the waterbody was not identified in the input databases that we used.

Therefore some FILL targets have been defined in these gaps so that an elevation is defined in the OLTC tables for each point over land. Because of the memory constraints of the current altimeters (Jason-3, Sentinel-3A and 3B) the distance between these FILL targets is around 20 km. In these FILL areas the OLTC elevation will then be defined as constant for positions +/- 10 km around each of these FILL targets (which is roughly the diameter of the zone lightened by the S3A and S3B altimeters).

To define the elevations in these FILL areas, we have used a strategy whose goal is to maximize the probability of acquiring signal over a waterbody if there is actually one in the proximity of the FILL target : the elevation is set to the elevation of the local minimum of the reference DEM closest to the FILL target.

It has to be noted that this strategy maximizes the probability to acquire useful signal for hydrology but does not try to follow the ground surface as close as possible. Anyway, this would be impossible given the constraints of the altimeter and this would not provide useful information if the terrain slopes are high.

OSTST 2020 (virtual), 19-23 October 2020

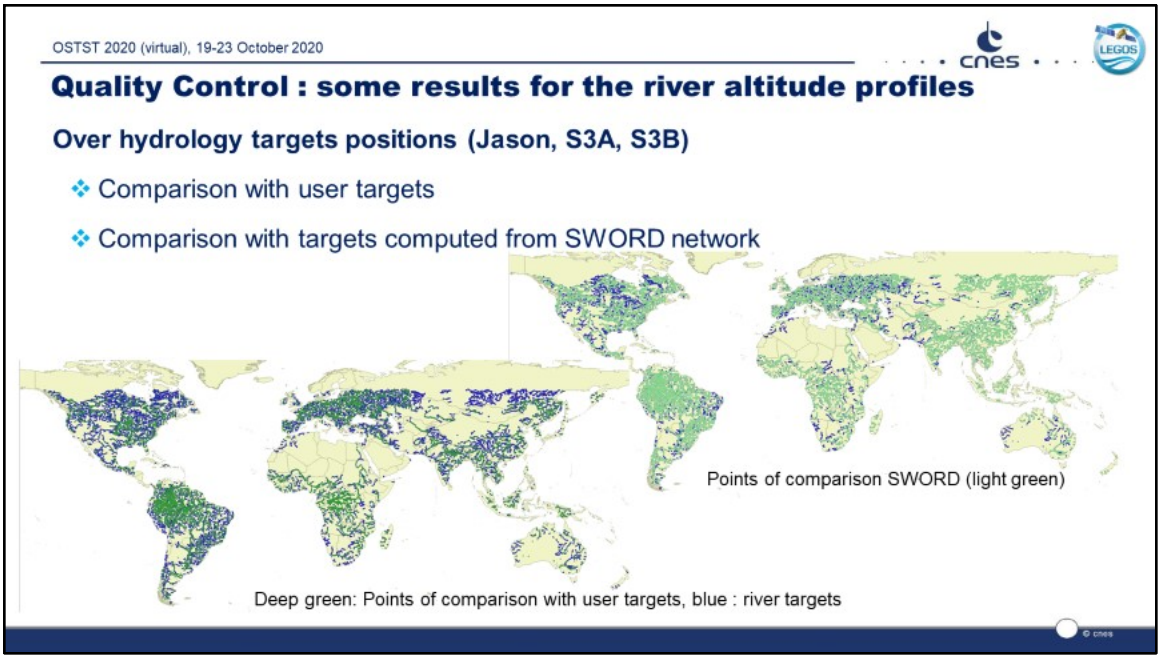
Quality Control

- All operations are « scripted »
- Codes and scripts are versioned (using Mercurial)
- Comparisons with respect to "validated" Virtual Stations provided by many users
  - External : LEGOS, CLS (HydroWeb et F.Mercier), Dahiti, Grealm, C.Birkett, DTU, IsarSat, …
  - Some manual comparisons over Senegal, Niger, Mekong wrt Google Earth
- Comparison with respect to the 2018 database (traceability) provides
  - Old target DELETED or observed differences (position and altitude)
- Tools for internal consistency control
  - Coherence of altitudes for all targets falling in a given lake / reservoir
  - Altitude profile controls (decreasing altitude downstream, coherence VOLODIA/SWORD over intersection of coverage)
- Warning: in spite of all controls, imperfections remain
  - Because of use of automatic methods, worldwide
  - Because of input data used (ex: new reservoirs that are not in the input database nor in DEM, reservoirs with large variations of water surface elevations, incoherences between various sources of input data)

9 © cnes

Quality control will be more and more important in the future as more users (or services) will rely on data measured by the altimeters.

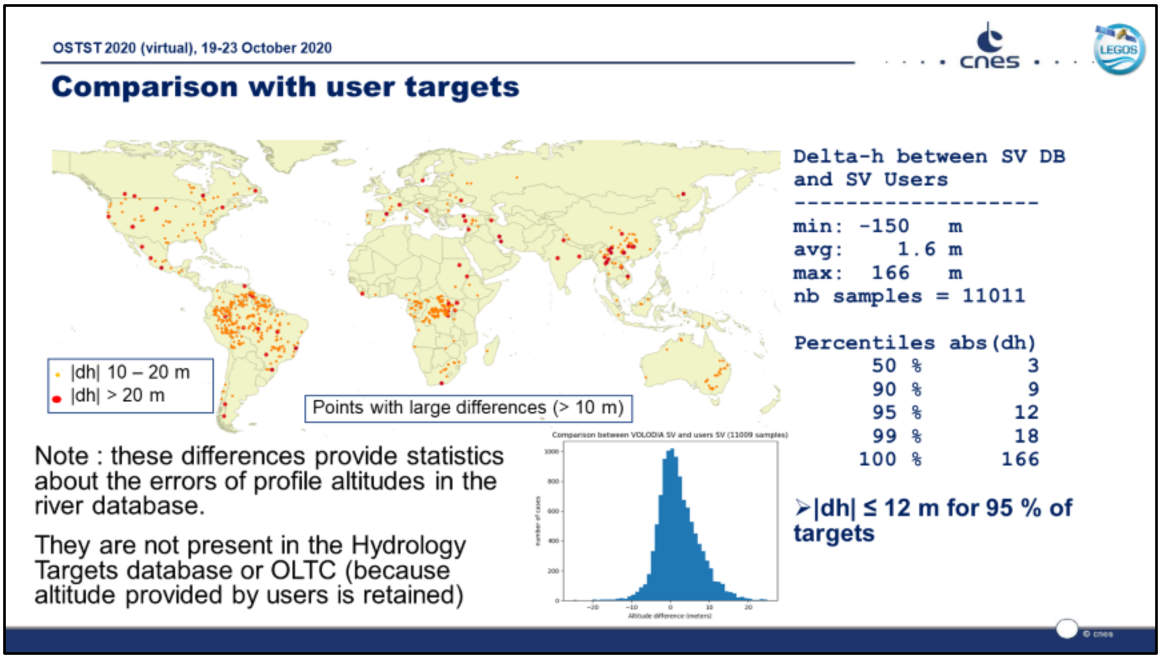
We have been as careful as possible not to degrade the data that are already in use (e.g. in public database of water surface elevations derived from radar altimetry). However, we are aware that not all the elevations are correct in the current OLTC tables (typically less than 10 or 15 % could be erroneous). We believe to be able to correct the majority of these errors in the next generation of the OLTC tables in 2021.
If you detect such error(s) you should report them using the site http://www.altimetry-hydro.eu set up by the CNES and ESA.



In order to quantify the fraction of errors in target elevations before the delivery of the databases to CNES and inflight verification, we performed a statistical check using two types of external data for validation.

The green points are points were external data are available and then where a direct comparison with external data (believed to be the "truth" in this experiment) can be performed. As the maps show, we have points of comparison almost all over the world.

This kind of comparison has only been possible over rivers.

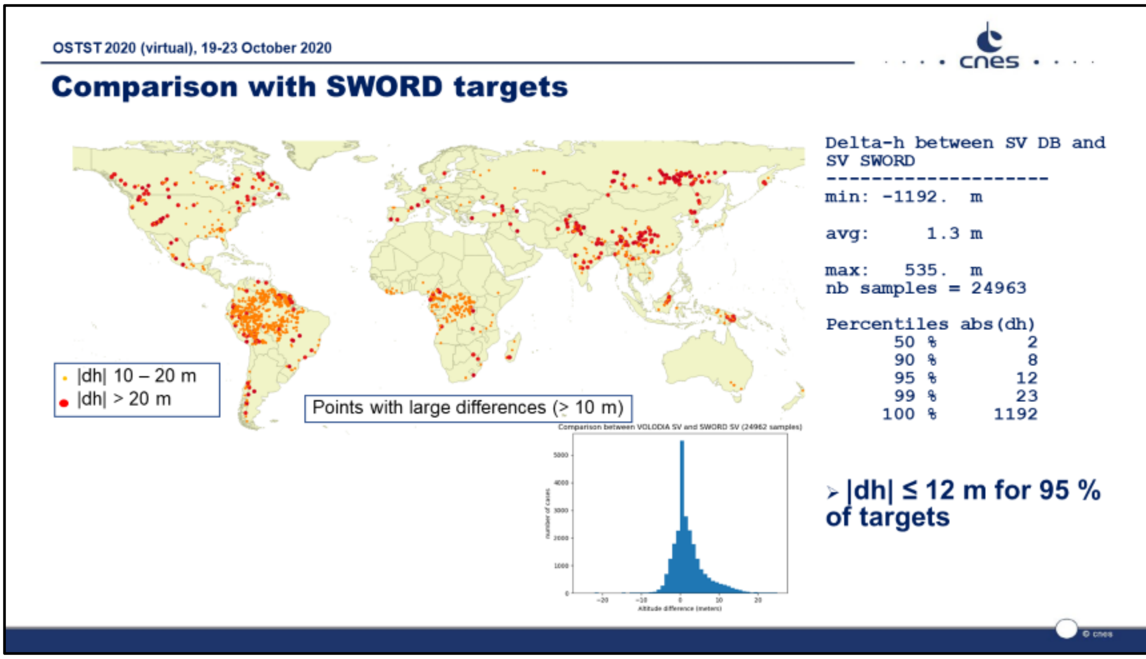


Comparison has been made mainly for Jason-3 and Sentinel-3A virtual stations.
The size of the sample for which the comparisons were possible is significant with respect to the number of hydrology targets (slightly more than 10 % of the targets could be checked with data available from external users)

Only points with large differences (>10 m) are shown on the map for the clarity of the figure.

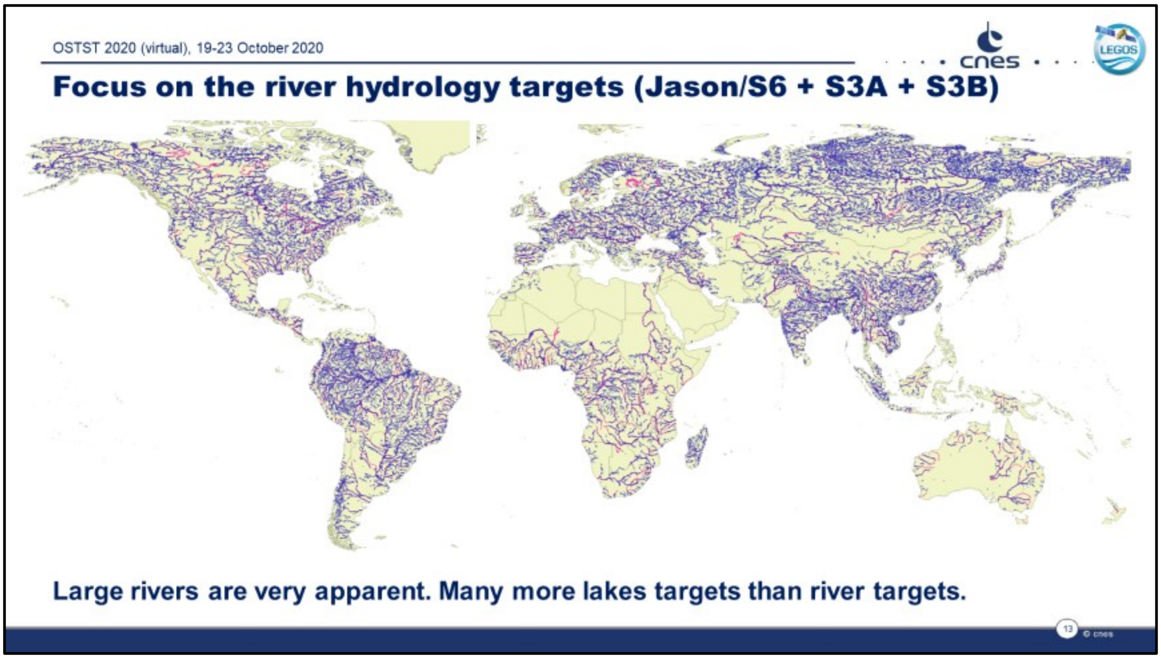
The histogram and the percentiles show that the comparison is very good for 95 % of the targets. If we can extrapolate this figure from the sample to the whole distribution, we should observe good results for this database.

As noted in the slide, this comparison was done as a statistical validation of our hydrology target database. However, even if large differences are real errors, there will not be present in the OLTC, because we chose to trust the user elevation and we put it in the OLTC tables instead of the elevation that was computed by our automatic methods.



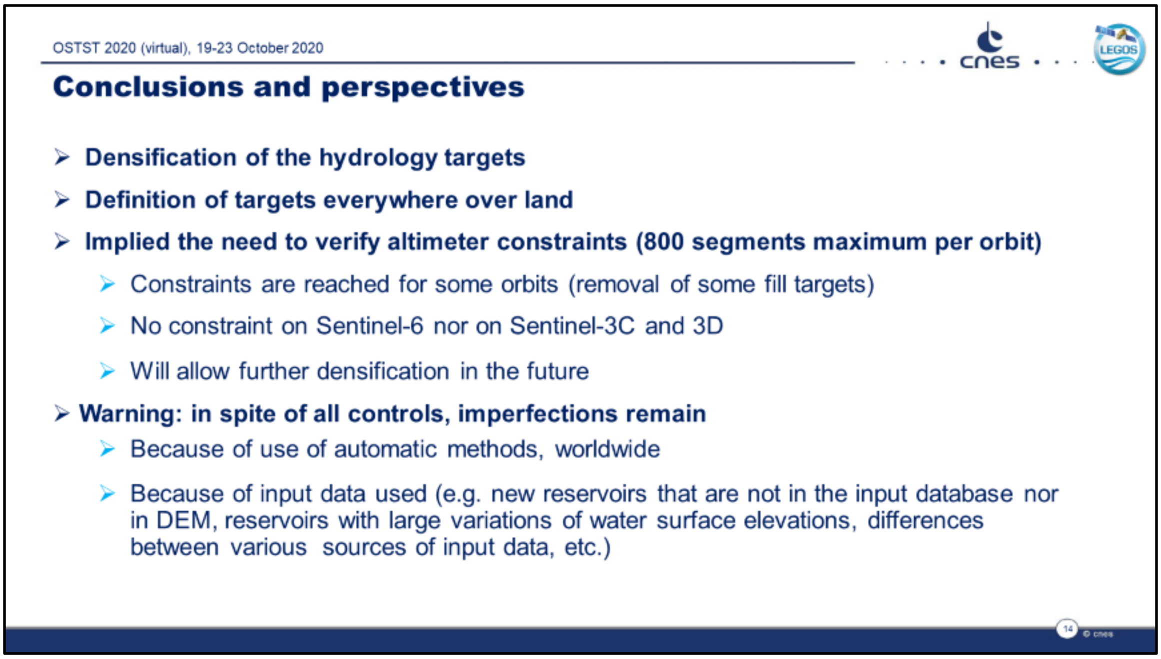
Only points with large differences (>10 m) are shown on the map for the clarity of the figure.

The size of the sample for which the comparisons were possible is even more significant than in the previous slide.
The results of the comparison are here also very good.



Here is a map showing all the hydrology targets defined over rivers for the 3 missions (Jason/S6 + S3A + S3B). As we can see on the figure most of the large rivers appear very clearly. Even large to medium tributaries of them are well covered. The next step for our community is to make a full use of this high number of available measurements.

The number of lake/reservoirs targets is even more impressive, especially in the north of the Canada.



As we can see on slide 13 most of the large rivers are very well covered by hydrology targets. Even large to medium tributaries of them are well covered. The next step for our community is to make a full use of this high number of available measurements.

For the first time, an elevation is now defined in the OLTC tables everywhere over land. This could allow the altimeter to make useful measurements of waterbodies which are not described in the databases that we used as input (either available from external sources or those that we built in the frame of the VOLODIA project). In order to do this we had for the first time to handle the limits of the Jason-3, S3A and S3B altimeters.

As the number of hydrology targets put in the three OLTC is now very large, we will focus our efforts for the next generation on the correction of identified errors rather than on further densification. And we will be waiting on the next nadir altimeter to be launched (on the SWOT satellite) to add another payload using the OLTC for better observation of inland waters.

While many papers have documented the overall improvements brought by the OLTC, at least one paper pointed out a particular case for which the OLTC tables for S3A (version V5) were not adequately set for a few dozens of new reservoirs. (**Zhang et al., On the Performance of Sentinel-3 Altimetry Over New Reservoirs: Approaches to Determine Onboard A Priori Elevation, GRL, 2020).** They provide a few approaches to overcome this difficulty. Such approaches will be used for the next release of the OLTC tables in 2021.

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