DEM generation for the OLTC / DIODE tracking mode on board AltiKa, Jason-3 and Sentinel-3

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Introduction

The **autonomous median trackers** on-board the satellite altimetry missions have **lower performances in the coastal zones and over the continental ice caps and waters** (rivers, lakes, reservoirs), mainly because of perturbed tracker behavior and the land contamination in the radar waveforms. As the number of satellite altimetry applications in these regions has significantly grown for a decade, some techniques have been developed in order to improve the observation of coasts, continental ice caps and inland waters. In particular, the **DIODE/DEM or OLTC (Open Loop Tracking Command) mode** has been implemented with the objective to **obtain a larger number of exploitable radar waveforms over these areas of interest**, compared to the classical median autonomous tracker.

The principle of the OLTC (Open Loop Tracking Command) mode consists in **driving the altimeter with a priori information available on-board**: real-time estimates of the satellite orbit with the DIODE navigator and theoretical height of the point located under the satellite, provided by a Digital Elevation Model (DEM) stored in the on-board memory.

The Jason-2 and SARAL/AltiKa missions are currently flying with an on-board DEM. The analyses of these missions' cycles operated in OLTC mode have shown the great interest of this technique in the areas of interest, as well as some possibilities of improvements resulting in **more accurate on-board DEMs for the Jason-3 and Sentinel-3 missions**. The OLTC mode will be the operational tracking mode for these two missions.

This poster describes how the on-board DEM is generated for each particular mission.

1. Generation of a global DEM

A 30"resolution **global DEM** has been built by merging several sources of DEMs and databases depending on the pixel location and the surface type (Figure 1). The input data used to generate this DEM are:

- the **CLS01 mean sea surface** for the ocean pixels ;
- the **Bamber DEMs** for the Greenland and Antarctic pixels ;
- the **LEGOS altimetric inland water level database HYDROWEB** for the lakes and rivers pixels ;
- the **ACE DEM** for all the other pixels.

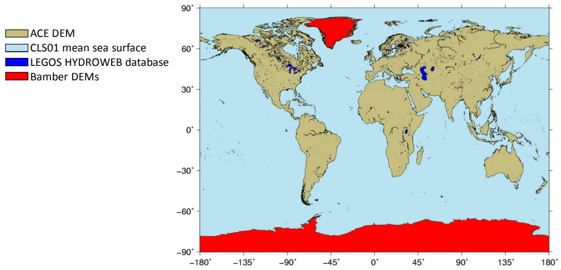

***Figure 1:** Input data used to generate the global DEM.*

2. Sampling and optimisation of the DEM

First, all the DEM sources are referenced to the same ellipsoid or geoid.

The global DEM is **sampled along the satellite orbit path** in a three-step process:

(1) The satellite orbit is simulated at a **constant position-in-orbit angular step sampling** (0.01°, equivalent to about 1 km) ;

(2) For each simulated orbit position, the radar footprint is projected on the ground and **an altitude is assigned to the nadir point**. Depending on the operator's choice, the equivalent altitude can be either:

- the lowest altitude of the pixels located in the radar footprint ;
- the highest altitude of the pixels located in the radar footprint ;
- the altitude of the minimal distance between the antenna and the ground (Cartesian distance).

(3) If the pixels located in the radar footprint have different surface types (eg. water and land pixels as in Figure 2a), the altitude computation is performed by considering only the pixels that have the **highest surface type priority**. The surface type priorities are configurable and depend on the missions.

- Jason-3: oceans > inland waters > dry surfaces
- Sentinel-3: oceans > inland waters > ice sheets > dry surfaces.

This optimisation algorithm leads to some **extensions of the regions of interest** (Figure 2b).

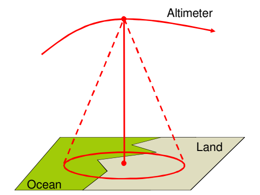

***Figure 2a:** DEM altitude selection in the altimeter footprint. As oceans have higher priority than land, the altitude assigned to the nadir point is the altitude of an ocean point.*

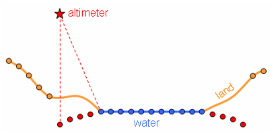

***Figure 2b:** Extension of an area of interest due to surface type priority (water) and slant view correction.*

3. Selection of the areas of interest

As the **on-board memory is limited** (1 MB for JASON-3 and 4 MB for AltiKa/Sentinel-3), the whole along-track DEM cannot be uploaded on-board the satellites. Therefore, **areas of interest** have been defined in order to reduce the DEM size, depending on the mission priorities. For Sentinel-3, all the ocean pixels, the ice sheets pixels and the inland waters pixels have been selected. The pixel type at each point of the satellite orbit is identified thanks to the Globcover global surface map.

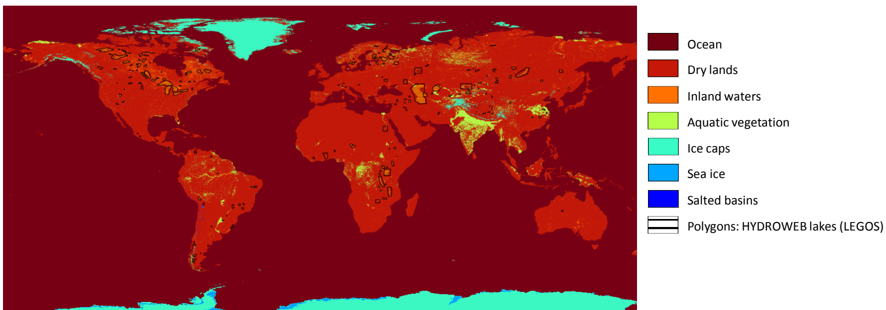

***Figure 4:** Globcover global surface map.*

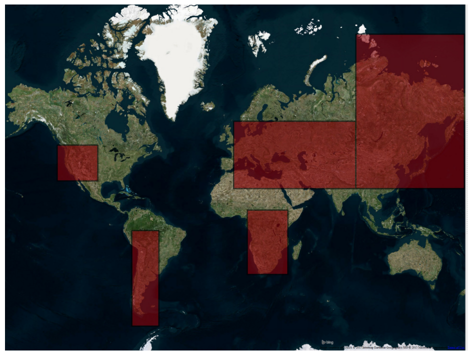

***Figure 5:** Sentinel-3 areas of interest for inland waters*

For the regions that are not selected as areas of interest, ie where the DEM mode gives similar performances as the autonomous tracker mode, the DEM is not defined. This is not a limitation because an algorithm has been developed, that allows to switch between the different altimeter modes (OLTC / autonomous median tracker) depending on the overflown region. The Jason-3 mission will use this switching mode, and will use the on-board DEM over the areas of interest and the autonomous tracker on other areas. This strategy allows to collect altimetric data everywhere without degrading the data quality.

4. Coding and compression of the on-board DEM

Once the sampling and the selection over regions of interest have been done, the on-board DEM is a series of points of various altitudes. In order to meet the size requirements for the on-board DEM file, two coding algorithms have been defined:

- **Incremental coding:** Consecutive points with large altitude variations are coded as follows: altitude of the first point (2 bytes), then altitude increments (1 byte each). Incremental coding is memory consuming but allows to code real altitudes. This algorithm is used on ice sheet areas with steep slopes, such as Antarctica.
- **Absolute coding:** The consecutive points with altitudes within a given threshold (typically 2 metres) are gathered in segments of same altitude (2 bytes for the altitude of the first point + 2 bytes for the number of points in the segment), as shown in Figure 6. Absolute coding allows to save memory space during on-board coding and to select more areas of interest but it is less accurate than the incremental coding because of the threshold.

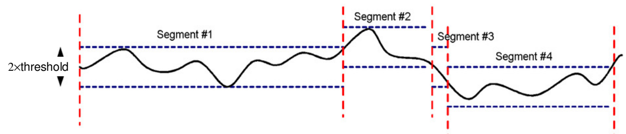

***Figure 6:** Absolute coding algorithm*

Validation tools

Jason-2 and SARAL/AltiKa are the first missions equipped with the OLTC mode. They have been used to **evaluate the performances of the DIODE/DEM mode** compared to the autonomous tracker mode. These analyses have shown some weaknesses and have led to **improvements in the processing strategy for the generation of the on-board DEM**, such as the selection of the point with the lowest altitude in the altimeter footprint during the sampling process (see example of Lake Wawa in Figure 7).

The analyses of the Jason-2 and SARAL missions in DEM mode have also led to the **implementation of a software for the operational validation of the Sentinel-3 and Jason-3** altimeter data in DEM mode (operational mode for both missions). The altimeter data will be analysed in near real time during the commissioning and the operational phases of the missions in order to **verify the consistency of the DEM over the time and the efficiency of the OLTC mode** to retrieve data in complex configurations (inland waters and continental ice).

The validation software includes facilities for comparisons between the tracking modes, statistics on global and regional bases, local and long term analyses. **Validation reports will be provided to CNES and ESA** for both Jason-3 and Sentinel-3 missions, on a cycle basis.

Example: Lake Wawa, Canada

→ Impact of the selection of the point of « lowest altitude»

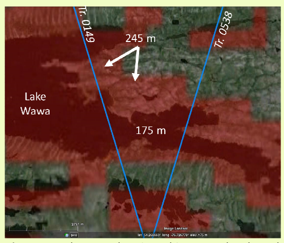

***Figure 7a:** Lake Wawa location, AltiKa groundtracks and surface type map from Globcover (inland waters in red)*

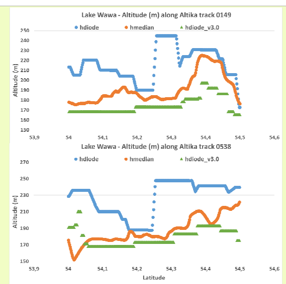

***Figure 7b:** Altitudes derived from the tracker range in DIODE/DEM and autonomous/median modes, and altitudes given by the new DEM generation algorithm (v3.0) over Lake Wawa (Canada).*

Lake Wawa is overflown by two SARAL/AltiKa tracks (0149 and 0538).

The altitude derived from the median tracker range is more consistent with the altitude of the lake, whereas the OLTC mode tracker range from the DEM on-board AltiKa is 70m too high because the "highest altitude point" algorithm selected the altitude of a hill nearby, defined as inland water in the surface type map.

The new "lowest altitude point" algorithm enables to select the real altitude of a lake in the DEM. It will be of particular use in the mountainous regions.

This result also shows the need for high quality surface type map as input.