Generation of DEMs for the new tracking mode using DIODE real-time navigator information onboard Poseidon-3 and AltiKa

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Summary

The Poseidon-2 tracker onboard Jason-1 altimeter has proved to be very accurate over open ocean surfaces, which corresponds to the mission objective. In order to extend new generation altimeters (Poseidon-3 and AltiKa) capabilities over other surfaces, like coastal areas, inland waters, and ice sheets, an experimental tracking mode has been designed by CNES. It consists in combining the satellite height provided by the DIODE real-time navigator and a Digital Elevation Model stored in the altimeter memory[1].

The study, supported by CNES and performed by NOVELTIS in collaboration with CNES and LEGOS, has been focused on the generation of two DEMs (one for each altimeter) aimed at following the ocean and land topography. Several input DEMs have been merged to build an accurate global DEM (in particular the LEGOS continental water level database), and a sampling algorithm has been implemented to generate the onboard DEMs at a constant sampling step along the orbit path (0.01° ~ 1 km). This algorithm takes into account the radar spot extension on the ground and includes an optimisation method to improve off-nadir observations occurring when passing along, entering or exiting regions of interest. This new tracking mode will be assessed during the Jason-2 in-flight commissioning phase (2008) and has also been adopted as an experimental mode onboard AltiKa.

1. Global DEM generation

A 30" resolution global DEM has been built by merging several input DEMs and databases depending on the pixel location and surface type (figure 1). The input data used to generate this DEM are (a) the CLS01 mean sea level[2] for ocean pixels, (b) the Bamber DEM[3] for Greenland pixels and the RAMP DEM[4] for Antarctic pixels, (c) the LEGOS altimetric inland water level database[5] for lakes and rivers pixels, and (d) the ACE DEM[6] for all other pixels.

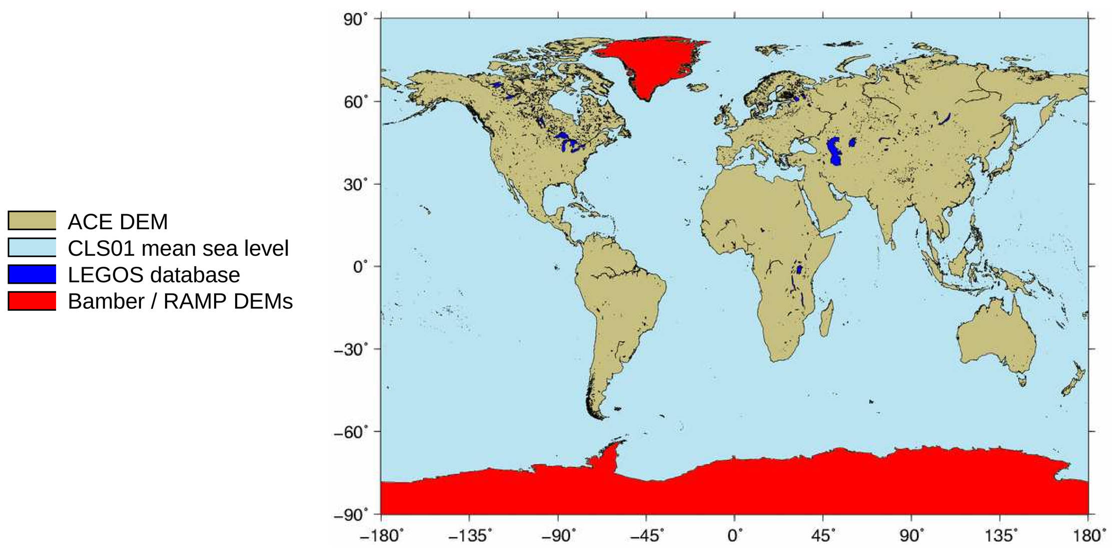


Figure 1: Input data used to generate the global DEM.

2. DEM sampling and optimisation

This three step processing deals with the generation of the DEM along the satellite orbit path:

(1) The satellite orbit cycle has been simulated and sampled at a constant angular step (one sample every 0.01° ~ 1 km). A Jason-1 orbit has been simulated for the Poseidon-3 DEM (10 day cycle), and an Envisat orbit has been considered for AltiKa (35 day cycle).

(2) For each simulated orbit position, the radar spot is projected on the ground and an "equivalent" altitude is assigned to the orbit point. On land surfaces, depending on the user's choice, the equivalent altitude can be (a) the mean altitude of the pixels located in the radar spot, (b) the median altitude or (c) the altitude of the earliest detected point.

(3) If several pixel surface types are located in the radar spot (eg. water and land pixels, figure 2a) altitude computation is performed by considering only pixels of highest priority (the surfaces priorities, in descending order, are: Oceans, ice sheets, inland waters, dry surfaces) and the altitudes are corrected with respect to the slant view of the area of interest. This optimisation algorithm leads to extend regions of interest (figure 2b).

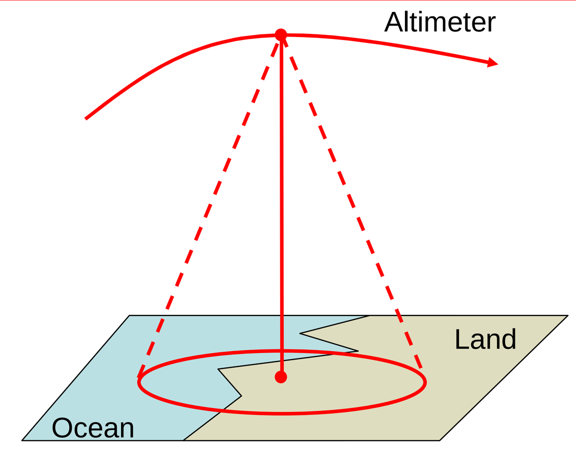


Figure 2a: DEM sampling along the orbit path. As oceans have a higher priority than lands, the nadir point is assigned to an ocean point.

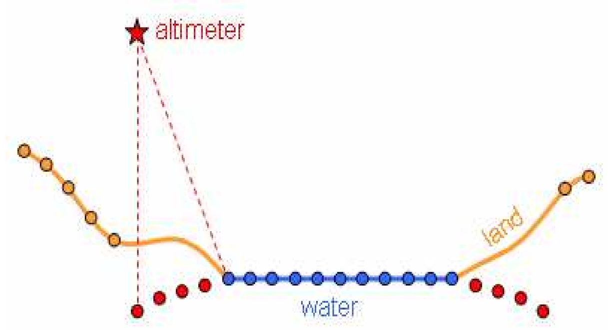


Figure 2b: DEM sampling along the orbit path. Extension of areas of interest (water) and slant view correction.

3. Altitude correction

(1) Altitude data have been corrected in order to be referenced with respect to the DIODE altimetric reference: Eigen geoid truncated at order 78 (EIGEN-GL04S) (figure 3).

(2) Ionosphere and troposphere delays have been estimated as a function of latitude from actual Jason-1 altimetry products (Ku measurements) (figure 4). Then they have been added to the Poseidon-3 DEM altitudes. Concerning the AltiKa DEM, estimated delays have been converted in Ka band before being added to the altitudes with the formula :

$$IonoDelay_{Ka} = IonoDelay_{Ku} \cdot \left(\frac{f_{Ku}}{f_{Ka}}\right)^2 \approx 0.144 \cdot IonoDelay_{Ku}$$

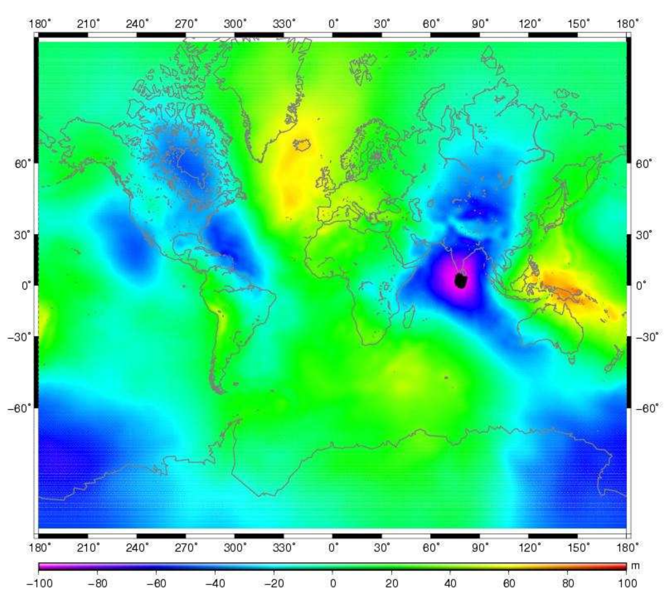


Figure 3: Elevations of the Eigen geoid truncated at order 78 wrt WGS 84 ellipsoid.

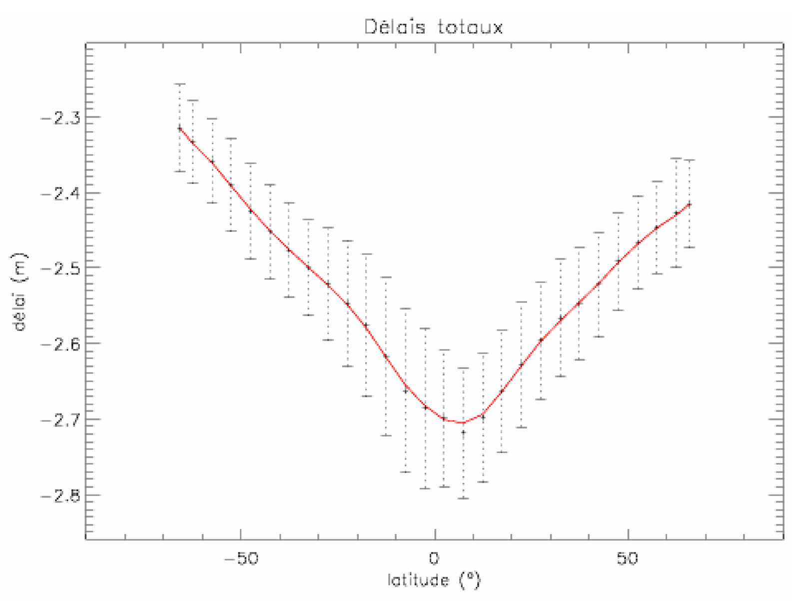


Figure 4: Estimated ionosphere and troposphere delays.

4. Selection of areas of interest

As the onboard memory is limited (1 MB for Poseidon-3 and 4 MB for AltiKa), the whole DEM cannot be uploaded. Therefore, areas of interest has been selected to reduce the DEM size. Due to the mission priority, all ocean pixels, ice sheet pixels, and inland water pixels have been selected. Dry land areas have been adjusted as follows:

(1) For the Poseidon-3 DEM, mountainous areas, like The Rocky mountains, the Andes, and the Himalaya, have been rejected.

(2) For the AltiKa DEM, potential flooded lands have been preferably selected (figure 5). This selection has been inspired by the Dartmouth Flood Observatory database available on the Internet (www.dartmouth.edu/~floods/archiveatlas/).

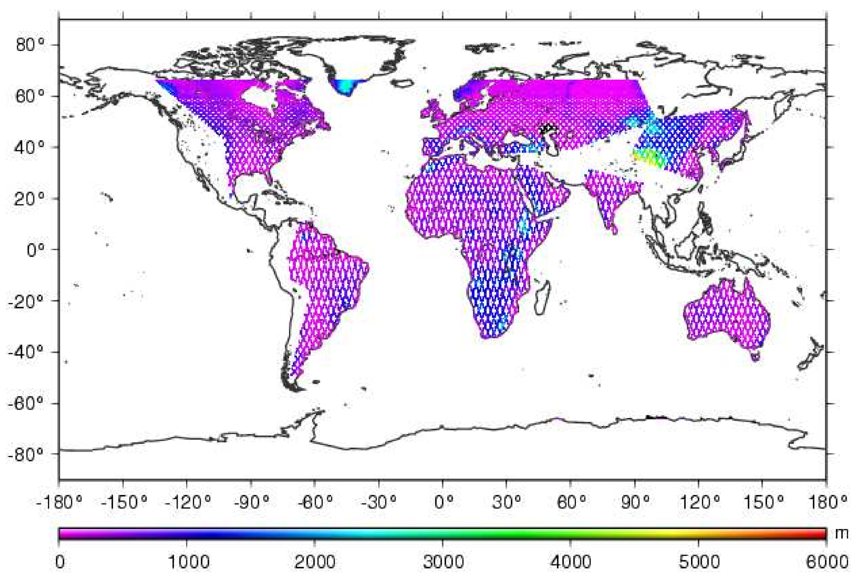
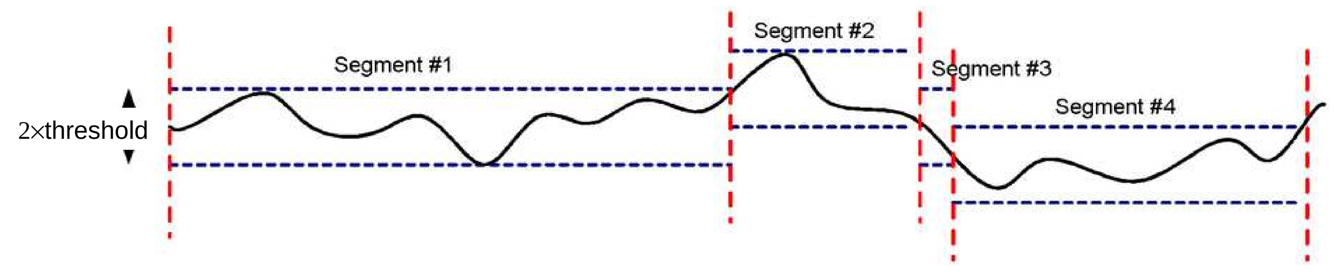


Figure 5: Dry land areas selected for the Poseidon-3 DEM.

5. Onboard DEM coding

The onboard DEM is a series of points of various altitudes. Two coding algorithms have been defined:

Absolute coding: Points of altitudes within a given threshold (typically 2 metres) can be 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).



Incremental coding: For memory size optimization, successive points with higher altitude variations are coded as follows: Altitude of the first point (2 bytes), then altitude increments (1 byte each).

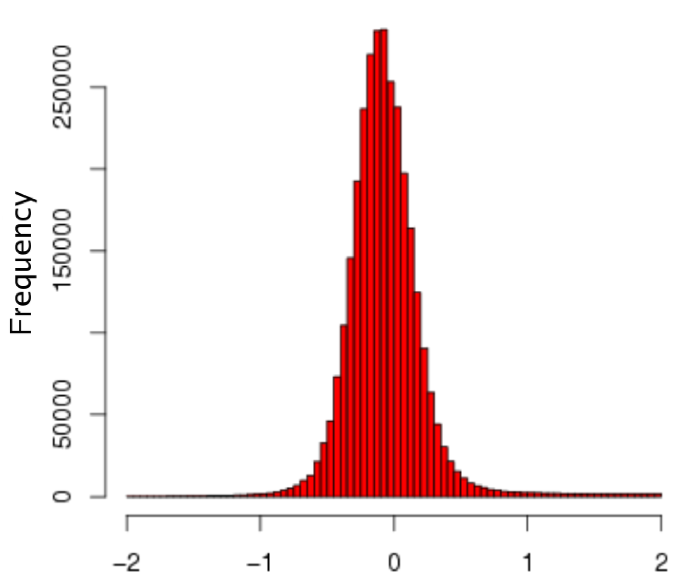


Figure 6: Difference between DEM and Jason-1 data.

Validation and conclusion

A good agreement has been found between the Poseidon-3 DEM and Jason-1 altimetric data (figure 6). Over ocean surfaces, the error is less than 1 meter for 95% of data points. As the onboard DEMs are static, dynamic phenomena like tides are not taken into account in the onboard tracking computation. Excepted for coastal areas where strongest tides could reach locally 6 m, the impact would be limited since the standard deviation of the tides over all ocean areas is only 36 cm (simulation performed with FES 2004 for a 10 year Poseidon-3 orbit cycle, figure 7). This new tracking concept could benefit future altimetry missions.

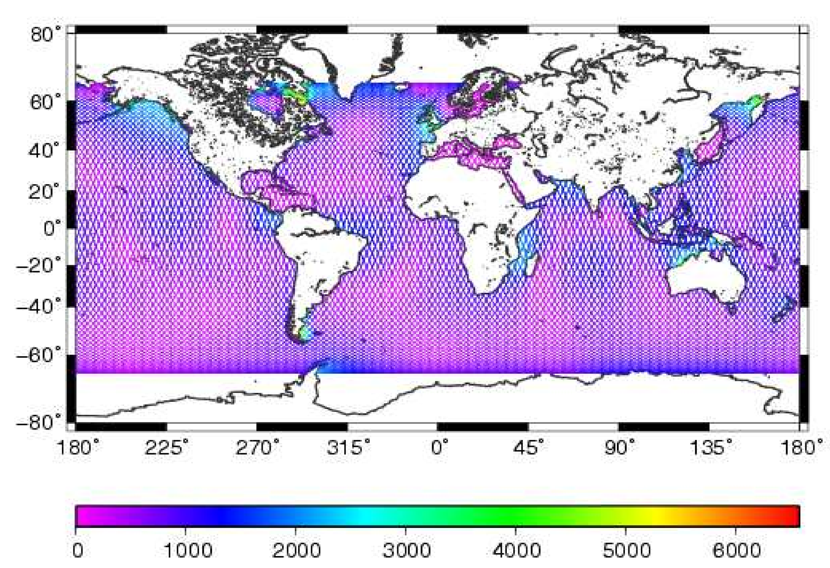


Figure 7: Maximal tide height (mm) over 10 year Poseidon-3 orbit cycle.

References:
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