Improvement of the Topex/Poseidon altimetric data processing for hydrological purposes and investigations on the performances of Jason over continental waters (CASH Project)

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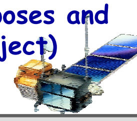


ABSTRACT

Over non-ocean surfaces the accuracy of the altimetric measurements is degraded to several cm or tens of cm, mainly because of the heterogeneity of the reflecting surface (a mix of water and emerged lands). For Jason, the situation is much more problematic since the GDR only contain a very few amount of data over continental waters. Another important source of error lies in the propagation of the signal through the atmosphere.

In the framework of the CASH project (Contribution de l'Altimétrie Satellitaire à l'Hydrologie) founded by the French Ministry of Research, a global re-processing of the Topex/Poseidon data (1992-2005) that is dedicated to the constitution of an hydrology-oriented altimetric data, has been performed. (see: **http://www.hydrospace-cash.fr**)

Over continental water bodies, emerged lands within the footprint generate complex radar echoes (waveforms) over which the height retrieval process is not as accurate as it is for oceanic echoes. As a first step, we applied to the Topex waveforms the same 4 retracking algorithms that are routinely applied to the ENVISAT measurements. These retracking algorithms are known as "Ocean", "Ice1", "Ice2" and "SeaIce" in the ENVISAT processing. Although not specifically dedicated to the large variety of waveforms that can be found over continental waters and therefore not fully optimized for hydrological purposes, these algorithms nevertheless provide promising results in terms of accuracy improvement and recovering of data that are missing in the Topex/Poseidon MGDRs. An example over the Amazon river is presented.

Early users of Jason data over the continental water bodies spotted out the depletion of the GDR with respect to the corresponding T/P products. We therefore investigated the SGDR products that contain the altimetric waveforms over two sites: lake Chad and TonleSap. It appears that those radar echoes are most of the time either largely missing over area-limited water bodies or present but deeply deformed.

Simultaneously, we investigated the wet tropospheric correction. This correction can amount 50 cm, with an annual cycle amplitude of up to 20 cm, and is usually computed over oceans with simultaneous radiometric measurements. Such measurements generally default over non-ocean surfaces and may be superseded by a correction computed from meteorological model outputs (usually the ECMWF model). We first show that the model correction included in the widespread altimetric T/P data sets is not reliable over non-ocean areas because the changes in the altitude of the reflecting surface (and thus the thickness of the atmosphere column) are not taken into account. Then, we demonstrate that a computation based on the use of a gridded Digital Elevation Model is not adequate. We finally propose a new method where the altitude of the reflecting surface is deduced from the altimetric measurement itself. This method is applied (with the NCEP Reanalysis model outputs) and is evaluated via comparisons with radiometric measurements acquired over a selection of large inland water bodies.

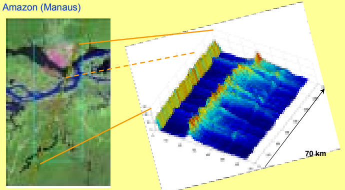
T/P Waveform retracking

1. T/P waveform examples

We have chosen the example of the T/P track 063 over the Amazon basin, near the city of Manaus.

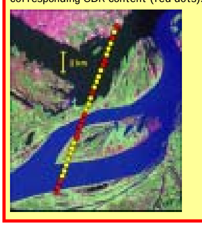
All the waveforms acquired in 1998 are averaged in 0.05° latitude boxes along-track, over a 70-km long segment (blue frame).
Note the narrow-peaked waveforms over the forest or the small water bodies. The peak generally widens over large rivers.

Amazon (Manaus)



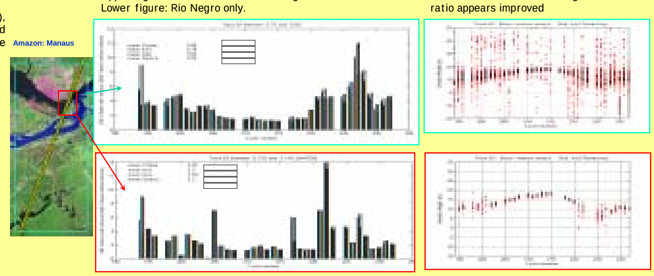
2. Data recovery

The retracking of the T/P waveforms allows the recovery of a significant amount of data.
In the example below (June 2002), yellow dots correspond to the recovered 10-Hz data with respect to the corresponding GDR content (red dots).



The figures below show the ratio between the number of data after and before (i.e. in the GDR) retracking, for each retracking algorithm, and for the year 1998.
Larger values are observed during low water season.
Upper figure: the whole 70-km track segment.
Lower figure: Rio Negro only.

The retrieved heights are presented as a function of time (Ice 2 results).
Some recovered values are clearly erroneous. However the signal to noise ratio appears improved

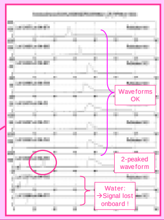


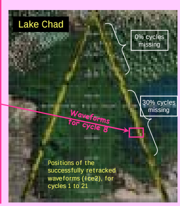
Jason

Investigations on the data depletion in Jason GDR's

Early users of Jason data over the continental water bodies spotted out the depletion of the GDR with respect to the corresponding T/P products. We therefore investigated the Jason SGDR products (cycles 1 to 21) that contain the altimetric waveforms over two sites: lake Chad and TonleSap, for which T/P offers a valuable hydrological monitoring.

For TonleSap, exploitable waveforms are acquired before and after the main water body. It appears that the altimeter looses the signal when reaching the water surface ! <u>This situation is not recoverable since the radar echo is not recorded</u>!
For Lake Chad, the situation is less critical. However 1/3 of the cycles are lost above the main water body, whereas numerous waveforms are acquired over the dryer surroundings.





Wet and dry tropo corrections

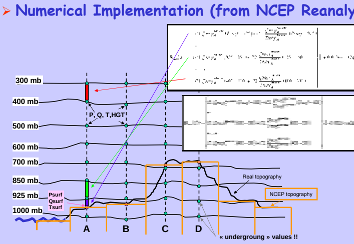
1. Classical computation from meteo model outputs

➢ Basic formula

$$\delta h_{wet} = -\left\{ 1.116454\,10^{-3} \int_{Psat}^{Psurf} q\,dp + 17.66543928 \int_{Psat}^{Psurf} \frac{q}{T}\,dp \right\} . \left[1 + 0.0026 \cos(2\phi)\right]$$

with
- δh_{wet}: wet tropo. correction (m)
- q: specific humidity (kg/kg)
- p: atmospheric pressure (hPa)
- Psurf: surface atm. pressure
- Psat: atm. press. at the satellite
- T: air temperature (K)
- Φ: latitude

➢ Numerical Implementation (from NCEP Reanalysis)



Description of the NCEP model outputs used in this study

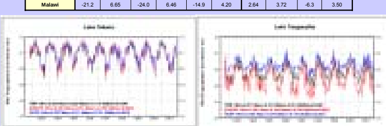
- Freely accessible on the Internet
- 2.5°x2.5° daily mean grids
- Required fields available on 8 levels
- Surface values interpolated / extrapolated from « underground » values or computed with specific formulae

NB: improvement in the accuracy can be expected by using:
- 4x-daily values instead of daily mean
- ECMWF outputs instead of NCEP ones (finer horizontal and vertical resolution)

2. Results from classical computation

For each lake studied with TOPEX/POSEIDON altimetric data, the correction computed from NCEP Reanalysis outputs is compared to both the radiometric correction (TMR, considered as "the truth") and the ECMWF correction, at the points where those 2 values are available in the M-GDR. A mean value is computed for each orbital cycle to construct the time series presented below. The mean and the standard deviation of each time series are finally computed and given in the table.

Name of the Lake	TMR		ECMWF		NCEP		TMR-ECMWF		TMR-NCEP	
	Mean	StdDev	Mean	StdDev	Mean	StdDev	Mean	StdDev	Mean	StdDev
Superior	-9.4	4.56	-9.4	5.58	-8.9	4.82	0.05	1.47	-0.5	1.36
Michigan	-10.4	5.14	-10.8	6.05	-10.5	5.22	0.31	1.46	0.07	1.58
Huron	-10.2	5.30	-10.1	6.01	-9.8	5.30	-0.1	1.36	-0.4	1.64
Erie	-11.7	5.73	-11.6	6.46	-11.0	5.35	-0.1	1.69	-0.7	1.98
Ontario	-11.3	5.46	-10.5	6.00	-10.1	5.19	-0.7	1.34	-1.2	1.72
Tana	-15.0	4.21	-27.3	8.82	-14.9	4.51	12.2	6.82	0.0	3.03
Turkana	-23.2	5.09	-25.9	4.13	-17.9	2.84	2.83	4.10	-5.2	4.24
Victoria	-21.8	3.16	-30.4	3.92	-16.1	2.67	8.61	3.10	-5.7	2.64
Tanganyika	-21.4	4.61	-25.8	6.23	-17.0	3.21	4.38	3.59	-4.3	2.65
Mweru	-18.5	5.86	-25.3	7.68	-17.0	4.19	6.75	4.65	-1.5	3.30
Malawi	-21.2	6.65	-24.0	6.46	-14.9	4.20	2.64	3.72	-6.3	3.50



3. Limitations of the classical computation

➢ North America's lakes (altitude < 200 m)
- good agreement between the 3 corrections
- ECMWF correction closer from TMR than NCEP

➢ African lakes (altitude between 360 and 1800 m)
- ECMWF correction usually overestimates the TMR correction (thus confirming the altitude of the lake is not taken into account in T/P data sets !)
- NCEP correction usually underestimates the TMR correction

Further investigations demonstrated that **the altitude of the water body is the key factor** since it determines the thickness of the atmospheric column on which the above formula is applied. The altitude of water surfaces are often overestimated in topographic grids due to their location in depressions on the Earth's surface. **(10 m in altitude ≈ 1 mm in the wet tropo correction)**

4. Principle of the NEW computation

The altitude of the water body is given by the altimetric measurement itself !!

"Classical" computation

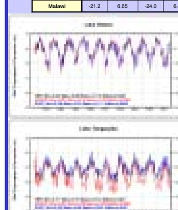
1. Computation of the wet tropospheric correction on the meteorological model grid.
2. Interpolation of the wet tropospheric correction from the grid at the location of the altimetric measurement

"New" computation

1. Interpolation/extrapolation of the meteorological fields at the location of the altimetric measurement (altitude given by the radar altimeter)
2. Computation of the wet tropospheric correction

5. Results from NEW computation

Name of the Lake	TMR		ECMWF		NCEP		TMR-ECMWF		TMR-NCEP	
	Mean	StdDev	Mean	StdDev	Mean	StdDev	Mean	StdDev	Mean	StdDev
Superior	-9.4	4.56	-9.4	5.58	-9.4	5.07	0.05	1.47	0.00	1.46
Michigan	-10.4	5.14	-10.8	6.05	-10.8	5.37	0.31	1.46	0.35	1.61
Huron	-10.2	5.30	-10.1	6.01	-10.2	5.50	-0.1	1.36	0.00	1.69
Erie	-11.7	5.73	-11.6	6.46	-11.8	5.73	-0.1	1.69	0.00	2.03
Ontario	-11.3	5.46	-10.5	6.00	-11.1	5.69	-0.7	1.34	-0.2	1.81
Tana	-15.0	4.21	-27.3	8.82	-14.0	4.26	12.2	6.82	-1.0	3.02
Turkana	-23.2	5.09	-25.9	4.13	-23.7	3.72	2.83	4.10	0.52	4.36
Victoria	-21.8	3.16	-30.4	3.92	-18.4	3.01	8.61	3.10	-3.4	2.77
Tanganyika	-21.4	4.61	-25.8	6.23	-20.2	3.87	4.38	3.59	-1.1	2.47
Mweru	-18.5	5.86	-25.3	7.68	-18.1	4.52	6.75	4.65	-0.3	3.16
Malawi	-21.2	6.65	-24.0	6.46	-20.4	5.56	2.64	3.72	-0.7	2.89



➢ North America's lakes
- good agreement between the 3 corrections
- NCEP correction always closer from TMR than ECMWF (at the exception of the lake Michigan)

➢ African lakes
- good agreement between the TMR and NCEP corrections

Clear improvement of the model wet tropospheric correction

6. Dry troposphere corrections

Similar considerations apply to the dry troposphere correction, that is computed using the Saastamoinen formula:

$$\Delta h_{dry} = -0.002277 * P_{surf} * (1 + 0.0026 * \cos(2 * \Phi))$$

where Φ is the latitude and Psurf is the surface pressure computed as explained above.

The amplitude of this correction is large: more than 2 m. However, temporal fluctuations are low (a few centimeters only), and are usually one order of magnitude lower than the intrinsic accuracy of the altimetric measurements over continental waters.

Conclusion

We applied the 4 retracking algorithms that are routinely applied to ENVISAT data to the entire Topex/Poseidon waveform (SDR) data base. This leads to the recovery of a large number a data (3 times more data than in the GDR) and to the improvement of the signal to noise ratio over continental waters.
We investigated Jason SGDR waveforms to understand the depletion of Jason GDR over continental waters: waveforms are frequently missing over inland water bodies. Therefore, this situation is unfortunately not recoverable !
Using the NCEP Reanalysis outputs, we implemented a new algorithm where the altitude of the water surface is deduced from the altimetric measurement itself. We show that the newly computed correction is in very good agreement with the radiometric correction, the latter being available only over very large water bodies. The same considerations apply to the dry troposphere correction. These results would probably be improved by using the ECMWF models outputs, which spatial resolution is finer.

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