BENEFITS OF THE "ADAPTIVE RETRACKING SOLUTION" FOR THE JASON-3 GDR-F REPROCESSING CAMPAIGN

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ABSTRACT

The purpose of this paper is to accompany the release of the Jason-3 GDR-F products delivered as part of the GDR-F reprocessing campaign and to explain its main benefits for the users of altimetry products. This reprocessing campaign has a twofold objective: improve the quality of the products and share common standards with Sentinel-6/Jason-CS. Illustrations of the different benefits for the users of altimetry products are provided.

Index Terms— Altimetry, ocean, retracking, Jason

1. INTRODUCTION

In addition to evolutions related to orbit or geophysical corrections (tides, mean sea surface, meteorological corrections, …), a new retracking solution called "Adaptive retracking" has been implemented. The outputs of the Adaptive solution are provided in the Jason-3 GDR-F products in addition to historical MLE3 and MLE-4 ones. Altimeter parameters (e.g. range, significant wave-height, backscattering coefficient, etc...) and related geophysical parameters (e.g. sea surface height, ionosphere correction, sea state bias correction, wind speed, etc…) derived from the Adaptive retracker are provided with the extension "_adaptive". In-depth analyses of the differences between MLE3/4 and Adaptive solutions have been performed confirming the promising result that have been presented for a few years at OSTST [10]. A list of benefits and drawbacks is provided hereafter. A paper detailing the performances of this algorithm on Jason-3 measurements will be published in 2021 when a sufficient number of GDR-F data cycles will be produced. Before disseminating GDR-F products, a particular attention was paid to analyzing the behavior of this solution when used for estimating the global mean sea level and its accuracy. A detailed description of the GDR-F standards and evolutions is provided in the Jason-3 Products Handbook (issue 2.0) and Jason-3 User Products (v.2.1). A synthesis of GDR-F evolutions can also be found in [3].

2. Brief description of the Adaptive retracker

The Adaptive retracker is an algorithm that benefits from four major evolutions with respect to the classical MLE3 and MLE4 retracking solutions described in [2] and [9], solutions that are currently provided in the Jason-3 GDR-D products. Firstly, a parameter correlated to the mean square slope of the reflective surface has been introduced in the mathematical formulation of the backscattered energy. The mean square slope parameter is describing the sea surface roughness [5]. Its value mostly impacts the trailing edge of the waveform. Estimating its value allows fitting many types of echoes, from diffuse ones (acquired over ocean) to very peaky echoes observed over specular surfaces such as leads in the Arctic Ocean or calm lakes and rivers. Secondly, the Adaptive algorithm directly accounts for the real in-flight Point Target Response of the instrument, by numerically convolving its discretized values to the analytical model of backscattered energy. The third specificity of the algorithm is that a true Maximum Likelihood Estimation method (using the exact likelihood function) is used that accounts for the statistics of the speckle noise corrupting the radar echoes [7]. Note that the estimation method currently implemented in the MLE4 retracker is in fact a simple Least Square Estimation method. The minimization method in the Adaptive solution is a geometrical method called Nelder-Mead algorithm. Finally, the algorithm adapts the width of the window on which the fitting procedure is performed in order to reject spurious reflections coming from off nadir directions, in particular when the satellite is approaching the coastlines. Many advantages brought by the Adaptive algorithms have already been described in [10], [11] and [12].

3. Main benefits of the Adaptive Retracker

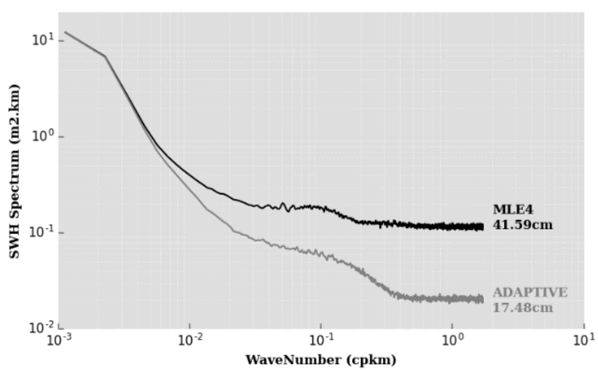
The many benefits of the Adaptive retracker are listed hereafter and briefly explained. They are sorted depending on which parameter is considered.

a) General benefits

The current retracking algorithms are applied on 20Hz waveforms. They are considering a Gaussian approximation of the radar Point Target Response. This approximation is then compensated by using Look Up Table corrections computed at 1Hz (for range and SWH). One important improvement of the Adaptive algorithm is that these post corrections are not required anymore. By introducing the real PTR in the waveform model, residuals between the measured waveform and the model fitted on it are considerably reduced. The Mean Quadratic Error (summation of the residuals) is reduced as well. All parameters solved by the retracker are largely improved as described hereafter.

b) Benefits on significant wave height (SWH) estimates

Three major improvements can be mentioned concerning the waves: firstly, wave height estimates are provided at 20Hz without the need of any additional correction computed from Look Up Tables at 1Hz. Secondly, accounting for the real PTR in the retracking algorithm allows a much better fit of the beginning of the leading edge of the waveforms especially for small waves. Thirdly, a reduction of about 60% of the SWH noise level is observed with the Adaptive solution mainly due to the use of an exact MLE criterion in the estimation procedure.

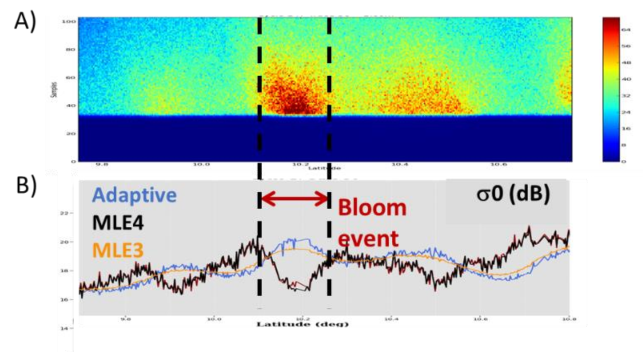


MLE4 and Adaptive Spectral analysis for Jason-3 SWH

Similar results have been reported by [12] based on CFOSAT/SWIM dataset. An evaluation of this algorithm with respect to other solutions (in terms of SWH only) has been done in the frame of the Sea State CCI project and the Adaptive algorithm has been ranked first according to many different criteria [8].

c) Benefits on normalized radar cross-section (s0) estimates

The sigma naught values provided by the MLE4 are clearly unsatisfactory. This issue has been reported a long time ago [10] leading to the addition of a MLE3 algorithm in the GDR-D product release (sept. 2016). The MLE3 retracker provides better sigma naught and thus better wind speed values. The Adaptive solution is providing s0 values that are very consistent with MLE3 ones for diffuse echoes over sea surfaces and much better for peaky echoes over sea ice for instance. Clear benefits of the Adaptive algorithm can be also observed when looking at measurements corrupted by rain cells (decrease of the backscattered energy) or sigma0 blooms (increase of the backscattered energy) or any phenomenon corrupting the homogeneity of the backscattering properties at the water surface (internal waves, …). The example shown below illustrates the performances of the Adaptive retracker (very close to MLE3 ones) when the altimeter is overflying a sigma-0 bloom event characterized by a strong increase of the reflected energy due to the high reflectivity of the surface.

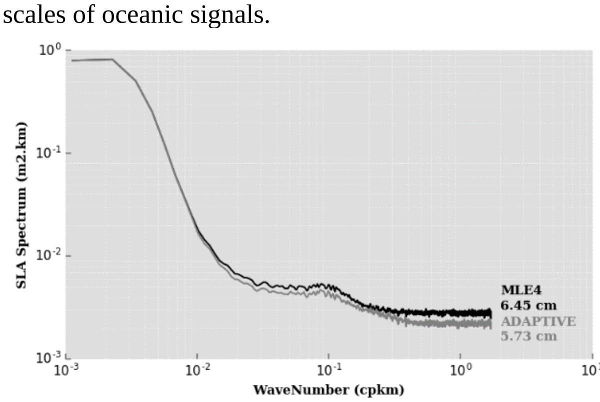


Backscattering coefficient when overflying a sigma-0 bloom event (Jason-3, Cycle 17, Pass 56)

A) Jason-3 echogram, B) sigma-0 estimates from MLE-3, MLE4 and Adaptive retrackers

d) Benefits on range/SSH estimates

As for the other parameters, range estimates provided at 20Hz can be used directly without any additional correction accounting for PTR approximation. Then, a significant reduction of the SLA noise level of about 10% can be observed as shown in the next plot. This performance improvement is important when considering the objective to observe smaller and smaller scales of oceanic signals.



MLE4 and Adaptive Spectral analysis for Jason-3 SLA

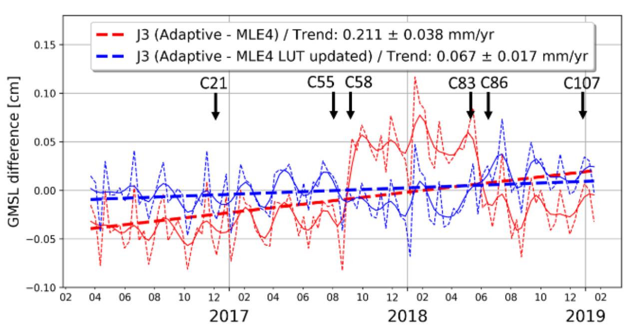
Many other statistics are showing the benefits of this algorithm (such as variance of SSH differences at cross-overs, variance of along-track SLA, number of rejected points, etc…). They will be provided on the final dataset once the reprocessing campaign will be run over a sufficient number of cycles.

e) Benefits for observing different surfaces with continuity

The Adaptive solution is using an analytical modelling of the waveforms able to fit different kinds of echoes, from diffuse ones to very peaky ones, with the same mathematical formulation. It thus allows to run the same estimation processing and to retrieve continuous signals over regions where the backscattering surface properties are changing (transition from deep ocean to sea ice zones, leads and sea ice floes; transition between estuaries and rivers).

f) Benefits for the GMSL estimation

Jason-3 is the current reference mission used to compute the global mean sea level (GMSL) and to monitor its evolution. It is thus crucial that instrumental drifts are accurately accounted for, regardless of the retracking solution used. The following plot is showing in blue the differences of GMSL time series computed with the MLE4 and with the Adaptive solutions as it can be observed in the products (thin red dotted line corresponds to raw values, thick red dotted line corresponds to filtered values over 2 months). Both solutions are providing very consistent results. However, a step of about 0.8 mm is clearly visible between the cycles 58 and 83. The latter creates a slope of about 0.2 mm/year over the considered period (~1.5 year). When considering longer period, e.g., greater than 5 years, the resulting slope is reduced to less than 0.05 mm/yr. Such a level of error is not significant compared to the state-of-the-art GMSL uncertainties [1]. Moreover, the impact on other climate indicators such as ocean heat uptake and the earth's energy imbalance is negligible [6]. The same is true for the sea-level closure budget [4].



GMSL difference between Adaptive and MLE4 solutions (thin red dotted line corresponds to raw values, thick red dotted line corresponds to filtered values over 2 months; Thin blue dotted line corresponds to raw values computed with regularly updated LUTs, thick blue dotted line corresponds to filtered values over 2 months with regularly updated LUTs). The tendencies are obtained by a Least Square fitting procedure.

On the one hand, the Adaptive solution is a numerical solution that fully accounts for the real Point Target Response of the instrument. Any drift or modification of the PTR is thus natively accounted for when estimating the sea level.

On the other hand, for the MLE4 retracking solution, instrumental drifts are taken into account by adding the internal path delay correction (IPD) derived from the PTR measurements and daily updated. However, subtle modifications of the shape of the PTR (as for instance, asymmetrical distortions of the energy in the secondary lobes of the PTR) cannot be perfectly accounted for by the IPD correction in particular when the Look Up Tables are kept stable. We recall that Look Up Table corrections have been computed once at the beginning of the mission and have never been updated since then, considering that the evolutions of the shape of the PTR were too small to cause SLA or SWH drifts.

A jump can be observed on the red curves matching with the date of a DEM upload on August 31st, 2017 (Cycle 57) including a modification of the centering of the echo in the on-board tracking window (shift of about 3 m). The centering has been turned back to its nominal position on May 30th, 2018 (cycle 85) when the difference between MLE4 and Adaptive goes back to nominal. It is clear from that figure (red curves) that the on-board instrumental modifications have caused this “step”.

When computing again the GMSL difference accounting for regularly updated LUT, the blue curves of the same figure are obtained, not showing any-more significant jump and drift between both solutions (0.07 mm/yr over 1.5 years).

The demonstration evidences that the Adaptive and the MLE4 solutions are fully aligned in terms of GMSL if and only if LUTs (that are part of the MLE4 solution) are regularly updated. Because a regular update of the LUTs cannot be done operationally, the Adaptive retracking solution clearly appears to be an excellent candidate for deriving GMSL estimates.

g) Potential drawbacks of the Adaptive method

Very few drawbacks have been identified at the moment but a potential weakness of the algorithm can be reported when the waveforms are corrupted by spurious returns (as off-nadir reflections) and deviate from their theoretical shapes whether they are observed over diffuse or specular surfaces. For this reason, the Adaptive algorithm is using the information provided by the waveform classifier and reduces its fitting window when the echo has not been classified as a typical ocean waveform (class 1). This is the case when the satellite is approaching the coastlines or over inland water where the field of view of the instrument (corresponding to the entire waveform) doesn’t illuminate surfaces with homogeneous backscattering properties.

4. CONCLUSION

A major evolution that concerns the retracking algorithm has been introduced in the Jason-3 GDR-F release. The "**Adaptive solution**" outputs are provided together with the classical MLE3 and MLE4 ones bringing many improvements in terms of geophysical signals (SLA, Waves, winds, etc …). Users are encouraged to have a look at this solution, analyze its benefits, identify potential weaknesses and report on their results to agencies or during future meetings. Illustrations of the benefits of this reprocessing will be shown during the meeting.

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