Applying Satellite Altimetry to Wetland Water Levels Monitoring (Case Study: Louisiana Wetland)

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Abstract—The idea of the application of satellite radar altimetry for inland water study has been considered for about two decades. It has always been much challenging, because the returned signal from inland water, in comparison to the ocean one, is very different. Thus the onboard satellite processing unit would not be able to determine the exact tracking point. Therefore, the execution of waveform re-tracking is efficient to correct the presented Range. The purpose of this letter is the application of the three of waveform re-tracking methods, namely OCOG, NASA β and Threshold and known as common methods, in order to monitor the Louisiana wetland water level. The validation is done by calculating the Correlation coefficient between the satellite altimetry and the tide gauge observations. The correlation coefficient has calculated between the two time series made from tide gauge data and satellite data. The coefficient value without exerting re-tracking is 0.4758 and with re-tracking is 0.6462. Numerical results shows, accuracy of water level monitoring increase up to 35.81% by the waveform re-tracking execution. In addition the results of all methods are compared with each other.

Index Terms—Classifying, re-tracking, satellite altimetry, wave-altimetry, wetland.

I. INTRODUCTION

T HE inland waters are among the most important natural factors affecting the survival of the human and other creatures on earth. Because of that, for decades, many efforts have been made in order to study such waters and to analyze the related subjects. Water level monitoring is one way to study inland waters and is precisely the purpose of this letter. We specifically study Louisiana wetland as the case study by its water level monitoring. For this purpose satellite radar altimetry technique is also applied.

The satellite altimetry has proved its credibility and reliability to study the ocean waters. Although main purpose of satellite altimetry is ocean study, the experts’ made attention to utilize the observations of this technique to study inland waters such as lakes, rivers and wetlands for many years. This modern branch of study has always been associated with many challenges. For these reasons, many efforts have been performed, like the study of wetlands by the application of SEASAT satellite altimetry data [1], the production of the first counter map from the marsh surface [2], the monitoring of elevation changes of Chad basin by the application of TOPEX/Poseidon data [3] and the study of inland waters through the utilization of satellite altimetry data [4], [5]. In fact the reflected signal from inland water surface has very different shape compared to the ocean one. Thus, the adaptive tracking unit (ATU) would not be able to determine the accurate tracking point and the computed Range would be biased [5]. Therefore, in order to correct the Range, waveform re-tracking is necessary. In this letter, the TOPEX altimeter data, belonging to TOPEX/Poseidon mission, is utilized which is presented in two groups, namely GDR (Geophysical Data Record) and SDR (Sensor Data Record) [6]. The final result, by the application of each re-tracking method, is a time series that shows the water level fluctuations. The results are comparable with tide gauge observations, as the validation reference.

II. METHODOLOGY

The procedure of applying satellite radar altimetry to study the oceans and inland waters depends on the physical properties of the case study. To understand the reason, one should notice the Range determination by the onboard processing unit. The precise wave return time and also the Range is determined based on the echo shape which is a function of footprint characteristics. Thus, the waveform that is returned from the inland water is much different from that of the ocean and the onboard processing unit is not able to recognize the true return time. Thematically, Fig. 1 shows Brown model as the normal samples that is selected randomly. Therefore, the efficiency of satellite altimetry and the Range accuracy decrease. To
compensate these defects, waveform re-tracking is performed. In this letter, the three common re-tracking methods, namely Offset Center Of Gravity (OCOG), NASA $\beta$, and Threshold are implemented and the results have been presented for each of them separately that are comparable with each other. The computation for Threshold method is illustrated in

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Waveform\ Amplitude\ A_{\text{max}} = \max (R(n))
\]

\[
\text{Termal noise } DC = \frac{1}{3} \sum_{n=5}^{7} R(n)
\]

\[
\text{Threshold level } TL = DC + Tcoeff (A_{\text{max}} - DC)
\]

\[
\text{Tracking gate } \beta_3 = (\hat{n} - 1) + \frac{TL - R(\hat{n} - 1)}{R(\hat{n}) - R(\hat{n} - 1)}.
\]

These methods are described in detail in [4], [5], [7], [8].

Although the application of satellite radar altimetry to study the oceans is not very complicated, but regarding inland waters there are many complications that should be considered. In addition to waveform re-tracking, it is not permitted to use all of the data because not all of the observations are reliable and credible for computing the Range correction by the application of waveform re-tracking.

Suppose such a classification is necessary to separate the appropriate observations. The mentioned classification is based on each observation waveform properties like having one peak through the Leading Edge region and being similar to the Quasi-Brown Model (to read about this model see [9]. Therefore, the data classification acts an important role in such study and is not ignorable. Another noticeable point is that, the satellite measurements have been performed in 10 Hz format (10 measurements through each frame), but they have been averaged 10 to 1, presented in the GDR and SDR data set. In
In this letter, for the purpose of using the data more completely, all of the observations have been converted into 10 Hz and then utilized.

In addition, the implementation procedure of the study can be outlined in these steps:

1) Producing the 10 Hz data set by the application of GDR and SDR data sets, belonging to TOPEX altimeter;
2) Separating the data which are appropriate and proportional to the letter purposes, based on the waveform shapes;
3) Performing the waveform re-tracking and computing the Range correction;
4) Producing a time series of the water level fluctuations by the implementation of each re-tracking methods;
5) Calculating the correlation coefficient and comparing the results to determine the best re-tracking method;

III. LOUISIANA WETLAND AS CASE STUDY

Wetlands are valuable to society and surrounding ecosystems. To make it obvious, the functions of wetlands, like flood prevention, removing pollutants from water, recharging groundwater, protecting shorelines, providing habitat for wildlife, and serving important recreational and cultural functions should be considered. It has been estimated that the services value that is generated by wetlands through the world is about 4.9$ trillions for each year [10]. If wetlands are lost, the cost of retrieving them would be extremely expensive, if at all possible. In fact, wetlands can be mentioned as productive ecosystems on earth. Louisiana Wetland is selected as the case study of this letter which can be known as one of the vital assets of the world. Unfortunately, in recent years it has been experiencing the most critical coastal wetland erosion. Nearly 80% of the wetland loss in America has occurred at the Louisiana region [11]. There are many causes for this loss but the main factors can be considered as the reductions in freshwater and sediment inputs stemming from changes in wetland hydrology. Louisiana wetland is located in the north of the Gulf of Mexico and at the approximate geographical position of (29.70 N, 92.12 W). The pass number 128 of the TOPEX/Poseidon mission goes through this area. In this letter, the data referring to this pass from cycle 158 to 306 (from 1997 to 2000), belonging to TOPEX altimeter and including SDR and GDR data sets, are collected as our unique data set. The results refer to the data cell within the radius of 1.5 km and centered at (29.7139 N, 92.1195 W).

IV. RESULTS AND VALIDATION

Obviously, each kind of research needs to be validated to maintain whether it is efficient enough. In this letter, the tide gauge observations have been considered as the validation reference. The data belonging to tide gauge station namely “Cypremort”
that is located at the geographical position (29.71 N, 91.88 W) and about 20 km far away from the satellite pass is employed. The correlation coefficient value is determined to compare the results (the time series which shows water level fluctuation), that is achieved from tide gauges and satellite altimetry observations. In fact, the nearer the correlation-coefficient value is to one, the more accurate the satellite altimetry observations will be. Of course, the closer the pass of satellite and tide gauge stations are to each other, the more credible the validation would be.

The tide gauge data\(^1\) referred to the Cypremort station located at “29.71 N, 91.88 W” and the satellite data referred to the pass No 128 collected at “29.70 N, 92.12 W” (north of Mexico Gulf) is utilized for processing.

Now, the results of inland water level monitoring, referring to Louisiana wetland, by the utilization of satellite radar altimeter data and its improvement by the application of waveform re-tracking methods are presented. As is obvious, each re-tracking method has its unique result. Each re-tracking method proportional to the region properties has a degree of efficiency and it would be known empirically. Table I shows the correlation coefficient between the water level fluctuations that is resulted by tide gauge observations and satellite altimetry observations, without applying any re-tracking and while the re-tracking is performed. In this region the Threshold re-tracking method, by 40% as Threshold value, has presented the biggest Correlation Coefficient value. That means, by using this re-tracking method the most accurate measurement of sea level by this technique will be achieved.

By Fig. 3, comparing the results and the effect of re-tracking is feasible. In fact this figure shows the water level fluctuation of the case study from 1997 through 2000.

V. CONCLUSION

The application of satellite radar altimetry has its unique complication but it can be considered as an acceptable technique to monitor inland water levels. According to the presented results, the waveform re-tracking execution and the data classification are not ignorable and it is necessary that they be done. Like any other study methods it has some disadvantages that can be referred to the dependence on the physical situation of the case study. In other words, for any region, the appropriate re-tracking method should be determined empirically and validated for a limited time period. Then it can be applied to the whole data. In this letter, Threshold (40%) is the best re-tracking method which improved the results.

REFERENCES


\(^1\)http://tidesandcurrents.noaa.gov