COMPARATIVE STUDY OF THREE WAVEFORM RE-TRACKING METHODS TEST FIELD: LOUISIANA WETLAND

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ABSTRACT: Satellite radar altimetry has been known as one of the major techniques for ocean studies in recent decades. This technique is applied to study inland waters, which are the major factor on the surrounding ecosystem. In this study, application of satellite altimetry for inland water level monitoring is studied. More specifically, two groups of TOPEX altimetry data, namely SDR (Sensor Data Record) and GDR (Geophysical Data Record) are used and based on returned signal power and waveform re-tracking; corrections for measured ranges are derived. As the waveform re-tracking methods OCOG (Offset Center Of Gravity), Threshold and NASA β are implemented in order to increase the accuracy of satellite altimetry for the inland waters. As the calibration field for verification of these methods, Louisiana wetland is selected. Numerical tests show 35% increase in the accuracy of the satellite altimetry, after implementation of the re-tracking methods.

1. INTRODUCTIONS

The inland waters are among the most important natural factors affecting the survival of the human and other creatures on Earth. Because of that, for many decades, the study of inland waters has started and has been continued up to now, since there are many unknown phenomena which are needed to be recognized in order to analyze their effects. The study of inland waters has many aspects. Water level monitoring can be considered as a way to achieve this goal and is precisely the purpose of this article too. In other words, we have studied inland waters; Louisiana wetland specifically as the case study by its water level monitoring. In this study to achieve the mentioned goal, satellite radar altimetry technique is applied.

The decades old satellite radar altimetry, having achieved successful experiences such as TOPEX/Poseidon and ENVISAT missions, has been functioning as an acceptable and reliable technique for the study of ocean waters. Despite the primary and main purpose of satellite altimetry, the experts' attention has been drawn to utilize the observations of this technique to study the inland waters such as lakes, rivers and wetlands for more than a decade. This modern branch of study has been very valuable and 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(Rapley, GUZKOWSKA et al. 1987), the production of the first counter map from the marsh surface(Cudlip, Ridley et al. 1990), the monitoring of elevation changes of Chad basin by the application of TOPEX/Poseidon data (Coe and Birkett 2004) and the study of inland waters by the utilization of satellite altimetry data (Lee 2008; Zhang 2009). In this article, Louisiana wetland water level monitoring is performed by the utilization of TOPEX altimeter data, belonging to TOPEX/Poseidon mission. The TOPEX altimeter data is presented in two groups namely GDR and SDR. GDR dataset contains all the information that is needed for any routine ocean study project, but in such case, SDR dataset that is containing all the row altimeter data, should be available too, because waveform re-tracking is feasible if SDR dataset is available. 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.

The second section considers the methodology and the implementation procedure of the study. The third section is allocated to the numerical results and validation. In the last part the conclusion is presented.

2. METHODOLOGY

The procedure of applying the satellite radar altimetry technique to study the oceans and inland waters depends on the physical properties of the region under 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 waveform 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. Figure 2.1 and 2.2 illustrate waveform samples from ocean (predicted shape) and inland water. Therefore the efficiency of satellite altimetry and the Range accuracy decrease. To compensate these defects, waveform re-tracking is performed. In this article, the three routine re-tracking methods, namely OCOG (Offset Center Of Gravity), NASA β and Threshold are implemented and the results have been presented for each of them separately that are comparable with each other. These methods are described in details in(Davis 1997; Deng 2003; Lee 2008; Zhang 2009).

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 performance, it is not permitted to use all of the data because all of the observations are not reliable and credible for computing the

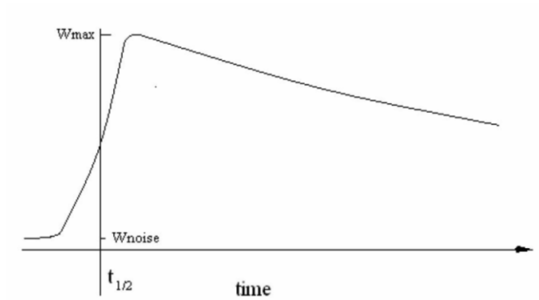

Figure 2.1, The average waveform of the returned signal(Zhang 2009)

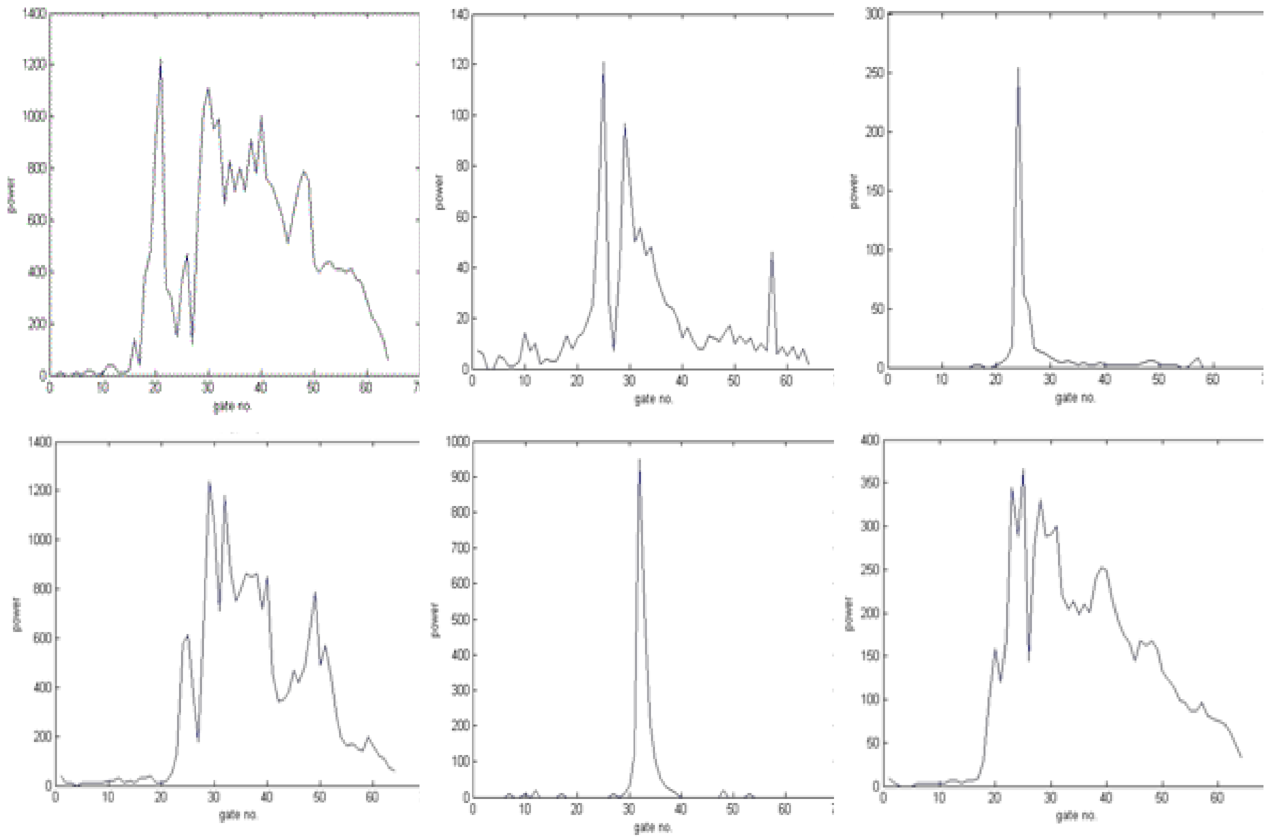

Figure 2.2, some waveform samples from Louisiana wetland (selected randomly)

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 (Berry, Garlick et al. 2005)). Therefore the classification of data acts an important role in such study and is not ignorable. Another noticeable point is that, the satellite measurements have been performed in 10Hz format (10 measurements through each frame), but they have been averaged 10 to 1, presented in the GDR and SDR dataset. In this study, for the purpose of using the data more completely, all of the observations have been converted into 10Hz and then utilized.

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

- Producing the 10Hz dataset by the application of GDR and SDR datasets, belonging to TOPEX/Poseidon mission;
- Separating the data which are appropriate and proportional to the article purposes, based on the waveform shapes;
- Performing the waveform re-tracking and computing the Range correction;
- Producing a time series of the water level fluctuations by the implementation of each re-tracking methods;
- Displaying the achieved results;

3. LOUISIANA WETLAND AS CASE STUDY

Wetlands are valuable to society and surrounding ecosystems. To make it obvious, the functions of wetlands, like decreasing flood, 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 (Costanza 1997). If wetlands are lost, the cost of retrieving 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 article 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 America wetland loss has occurred at the Louisiana region(Army). 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 (29.70N, 92.12w). The pass number 128 of the TOPEX/Poseidon mission goes through this area. In this paper the data referring to this pass from cycle 158 to 306 (from 1997 to 2000), belonging to TOPEX altimeter and including SDR and GDR datasets, are collected as our unique dataset.

4. RESULTS AND VALIDATION

Obviously, each kind of research needs to be validated to maintain whether it’s efficient enough. In this study, 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 (29.71N, 91.88W) 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 validation would be better and more credible.
The utilized tide gauge date is accessible at the following internet address. Figure 4.1 shows the Louisiana region, satellite pass and tide gauge station positions.
http://tidesandcurrents.noaa.gov/station_retrieve.shtml?type=Historic+Tide+Data

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 4.1 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

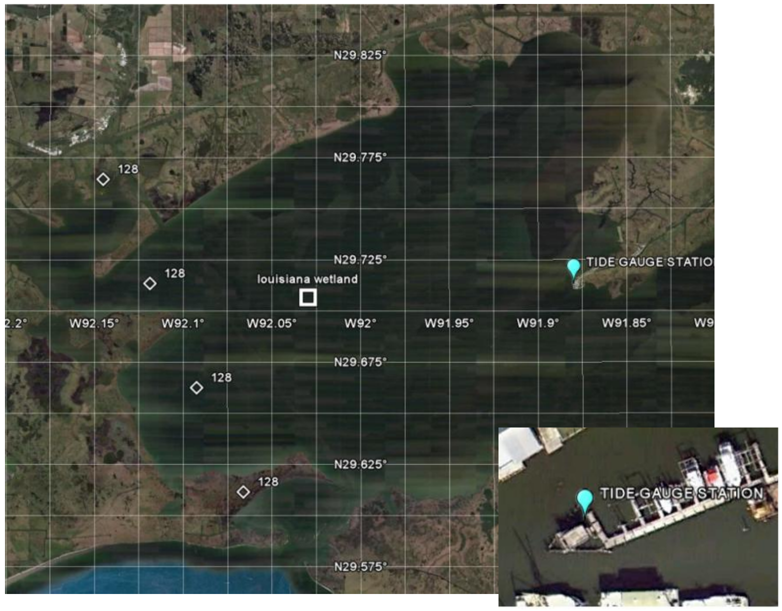

Figure 4.1, LOUISIANA WETLAND region, satellite pass position and the tide gauge station position.

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.

The applied method	The value of correlation coefficient
Not re-tracked	0.4758
Threshold (50%)	0.6269
Threshold (45%)	0.6380
Threshold (40%)	0.6462
Threshold (35%)	0.3767
Threshold (30%)	0.4213
Threshold (25%)	0.4584
OCOG	0.6319
NASA β	0.6319

Table4.1, Correlation Coefficient between the tide gauge and satellite altimetry time series, for some re-tracking methods as applied to LOUISIANA WETLAND

By figure 4.2, 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 the year 1997 through 2000.

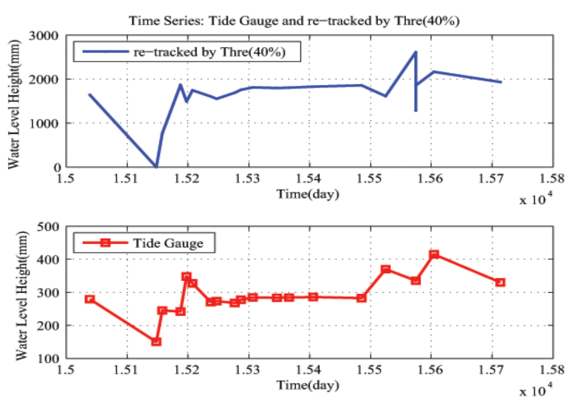

Figure 4.2 a, Re-tracked by Threshold (40%)

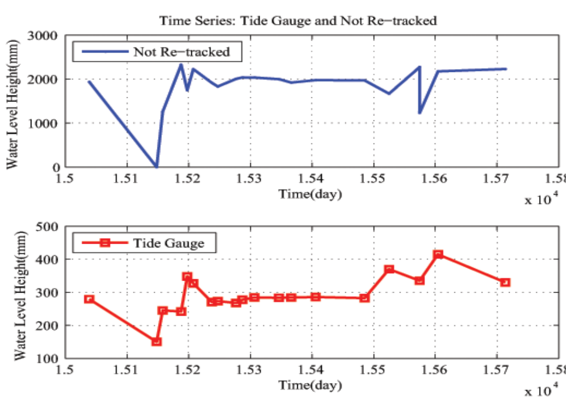

Figure 4.2 b, Not Re-tracked

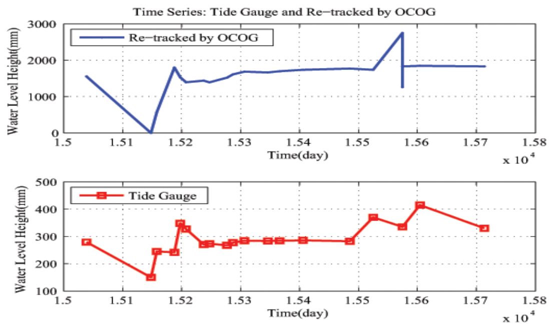

Figure 4.2 c, Re-tracked by OCOG

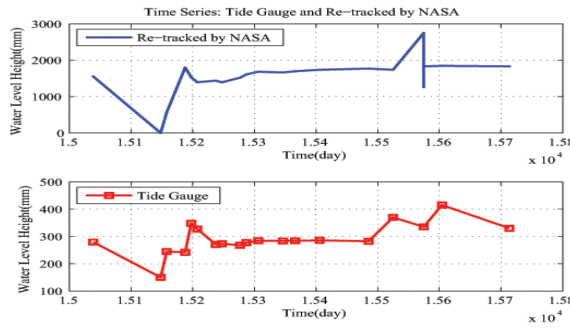

Figure 4.2 d, Re-tracked by NASA β

5. 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. Although like any other study methods it has some disadvantages that can point to the dependence of this technique to the physical situation of 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.

6. REFERENCES

Alsdorf, D. E., E. Rodríguez, et al. (2007). "Measuring surface water from space." Reviews of Geophysics 45(2): RG2002.

Anzenhofer, M., C. Shum, et al. (2000). "Coastal altimetry and applications." Ohio State University Geodetic Science and Surveying Report.

Army, U. "Corps of Engineers. 1987." Corps of Engineers Wetlands Delineation Manual.

Benada, R. (1997). "Merged GDR (TOPEX/Poseidon) users handbook." Jet Propulsion Laboratory Tech. Rep. JPL D-11007.

Berry, P., J. Freeman, et al. (2007). Near Real Time Global Lake and River Monitoring using the Envisat RA-2.".

Berry, P., J. Garlick, et al. (2005). "Global inland water monitoring from multi-mission altimetry." Geophysical Research Letters 32(16): L16401.

Chelton, D. B., J. C. Ries, et al. (2001). "Satellite altimetry." International Geophysics 69: 1-131, i-ii.

Coe, M. T. and C. M. Birkett (2004). "Calculation of river discharge and prediction of lake height from satellite radar altimetry: Example for the Lake Chad basin." Water resources research 40(10): W10205.

Costanza, R. (1997). "R. d'Arge, et al.(1997)." The value of the world's ecosystem services and natural capital."." Nature 387(15): 253-260.

Cudlip, W., J. Ridley, et al. (1990). The use of satellite radar altimetry for monitoring wetlands.

Davis, C. H. (1997). "A robust threshold retracking algorithm for measuring ice-sheet surface elevation change from satellite radar altimeters." Geoscience and Remote Sensing, IEEE Transactions on 35(4): 974-979.

Deng, X. (2003). "Improvement of geodetic parameter estimation in coastal regions from satellite radar altimetry."

Freeman, J. and P. A. M. Berry (2006). "A new approach to retracking ocean and coastal zone multi-mission altimetry." ESA SP-614.

Fu, L. L. and A. Cazenave (2001). Satellite altimetry and earth sciences: A handbook of techniques and applications, Academic Press.

Lee, H. K. (2008). Radar altimetry methods for solid earth geodynamics studies, The Ohio State University.

Ponchaut, F. and A. Cazenave (1998). "Continental lake level variations from Topex/Poseidon (1993-1996)." Comptes Rendus de l'Académie des Sciences-Series IIA-Earth and Planetary Science 326(1): 13-20.

Rapley, C., M. GUZKOWSKA, et al. (1987). "An exploratory study of inland water and land altimetry using Seasat data(Final Report)."

Zhang, M. (2009). Satellite radar altimetry for inland hydrologic studies, The Ohio State University.

Zieger, A. R., D. W. Hancock, et al. (1991). "NASA radar altimeter for the TOPEX/POSEIDON project." Proceedings of the IEEE 79(6): 810-826.