Analysis and Retracking Altimeter Coastal Sea Waveform in Chinese and Neighbouring Seas (SG.4 - 028)

Le Yang*[a,b], Mingsen Lin[c], Delu Pan[a]

a. State Key Laboratory of Satellite Ocean Environment Dynamics, Second Institute of Oceanography, State Oceanic Administration, Hangzhou, 310012, China

b. Science Department, Nanjing University of Science and Technology, Nanjing, 210094, China

c. National Satellite Ocean Application Service, State Oceanic Administration, Beijing 10008, China

(*yle1024@gmail.com)

Abstract:

One limiting factor of traditional altimetry is that most data in the coastal sea are flagged as useless partly due to land contamination of the altimeter return waveforms. Retracking algorithms are employed to derive geophysical parameters instead of the standard processing algorithm. In this paper, we compared five retrackers: Ocean, Ice-2, OCOG (Offset Centre of Gravity), Threshold, and Beta5 using one year (March, 2006 to February, 2007; cycle 155 to cycle 188) Jason1 waveform around the China coast (14~45° N, 105~130° E). In order to compare five retracking algorithms, in situ Sea Surface Height (SSH) measurements from tide gauge stations are used. However, only the range is determined by the retracking algorithms and the altimetry SSH is derived from range, atmospheric and other geophysical corrections, it is necessary to valid the retracking results independly. Because the altimetry Significant Wave Height (SWH) is determined by the waveform leading edge slope of the ocean return signal and not affected by the atmospheric and ocean conditions, we calculated additional SWH using Ocean fitting algorithm again and compare the altimetry retracking SWH results with coastal in situ SWH measurements.

1. INTRODUCTION

Most coastal altimetry data are unusable because of the effect of the surrounding land on the radar echo; the proximity of the land also makes it impossible to perform some geophysical corrections, such as wet tropospheric correction, ocean tide correction, atmospheric high-frequency forcing correction, and so on, as ones would for the open ocean. Wet troposphere corrections to Range are calculated using the radiometer brightness temperature measurements, however, the radiometer measurements are also affected by land signals over coastal water. To deal with the problem of radar altimeter measurement itself is our primary concern in this study.

Fig.1 shows Jason1 ground tracks in the area of 14° N -45° N, 105° E -130° E. The red on the tracks represent where SSH measurements are flagged by standard edit processing, and the black ones represent where they are retained. The flagged distances of Jason1 cycle 164 measurements are in Table 1. It can be seen from the second and third columns of Table 1 that areas, where distances to land are around and more than 50 km are flagged, because the larger footprint of radiometer are affected by land signal. The distances where the altimeter measurements itself are affected by land is around 10 km.

In order to make improved use of the altimetry waveform data near the coastal area, we derived the altimeter ranges from one year (March, 2006 to February, 2007; cycle 155 to cycle 188) of Jason1 waveform off the China coast (14-45° N, 105-130° E) by using five specialized retrackers: Ocean, Ice-2, OCOG (Offset Centre of Gravity), Threshold, and Beta5 retracking algorithms.

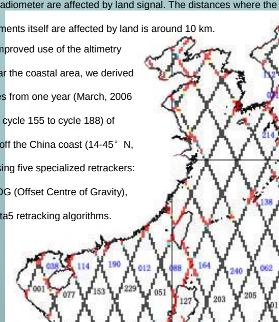

Fig.1 Jason1 ground tracks in the area of 14° N -45° N, 105° E -130° E. Three digit numbers are numbers of track.

Track No.	A	B	A	B
001	82.6	129.8	5.9	3.0
077	76.7	59.0	5.9	5.9
	76.7	64.9	35.4	5.9
153	59.0	94.4	23.6	11.8
	41.3	123.9	17.7	17.7
		100.3		17.7
229		94.4		11.8
	47.2	76.7	11.8	23.6
051		76.7		35.4
	88.5	94.4	17.7	53.1
038	47.2		5.9	
114	112.1	112.1	29.9	29.9
	53.1		11.8	
190	70.8		17.7	
012	53.1		5.9	
088	70.8		17.7	
164	88.5	70.8	47.2	17.7
	118.0		5.9	
240	53.1		11.8	
062	100.3	100.3	11.8	11.8
	59.0		11.8	
138	47.2	212.4	11.8	29.9
	70.8		5.9	
214	88.5		11.8	
Mean	62.7	58.8	13.5	11.5

Table 1 Flagged distances of Jason1 cycle 164 measurements. The first column is the track number; the second and third columns with background color of pink are flagged distances using data edit criterion of Rad_surf_type=1; the fourth and fifth columns with background color of orange are flagged distances only using Alt_echo_type=1 as data edit criterion. A: Flagged Distances from Land to Ocean in km; B: Flagged Distances from Ocean to land in km.

2. WAVEFORM ANALYSIS

The typical ocean return echo is the Brown model waveform. The altimeter determines the range and Significant Wave Height (SWH) by tracking the midpoint and estimating the slope of the leading edge of the return waveform, respectively. However, in a coastal region, because of the reflection from land is much stronger than the reflection from the ocean, when an altimeter ground track approaches, recedes, or runs parallel to the coastline, even though the altimeter's nadir point is over the sea, the altimeter will tend to track the off-nadir return from the land. Fig.2 shows the ground tracks and three series of consecutive 20 waveforms as Jason1 cycle164 track 229 across the eastern China mainland moving from south to north. Each waveform was separated by 0.05 s, corresponding to 290 m in the ground. Based on visual inspection, Fig.2 (c) is the typical land returns, which are sharp and strong, while Fig.2 (b) and (d) consist of both typical return of ocean and land. Fig.2 (b) is waveforms when Jason1 approached the Fujian province of China from ocean. Fig.3 shows twenty waveforms in Fig.2 (b). The beginning waveforms around latitude of 23.68° E is typical ocean return and the distance from land is 10.63 km. As the Jason1 ground track get much closer to the land, the stronger land return appeared in the right of the waveform and gradually moves forward. The leading edge of the 20th waveform (distance to land is 5.03km) is completely contaminated by the land return.

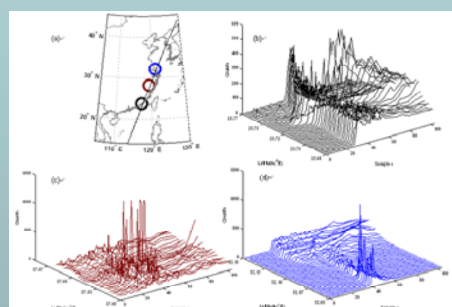

Fig.2 Series of 20Hz return waveforms of Jason1 cycle 164 track 229 across east mainland of China. (a) Black line indicates the ground track of 229. Three circles (black, red, blue) indicate the locations where waveforms in (b), (c), (d) are recorded, respectively; (b) A series of waveforms when Jason1 moved from ocean to land; (c) A series of waveforms when Jason1 is over land; (d) A series of waveforms when Jason1 moved from land to ocean.

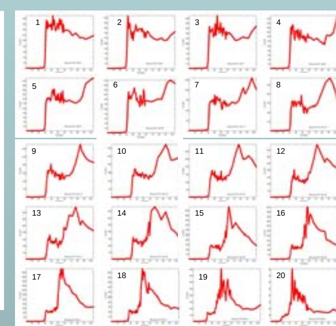

Fig.3 Twenty 20Hz return waveforms of Jason1 cycle 164 track 229 record 2122.

3. WAVEFORM RETRACKING ALGORITHMS

Accurate range estimates are obtained using refined procedures known as altimeter waveform retracking. Many retracking algorithms are developed for specific surfaces. We performed **Ocean** [1], **Ice-2** [2], **OCOG** [3], **Threshold** [4], and **Beta5** [5] retracking algorithms using one year Jason1 waveform measured in Chinese and neighbouring seas.

4. RESULTS

In order to compare five retracking algorithms, in situ Sea Surface Height (SSH) and Significant Wave Height (SWH) measurements from tide gauge stations are used. The information of tide gauge stations are in Table 2 and 3.

No.	Name	Latitude (°N)	Longitude (°E)	Distance to Land (km)	Jason1 track No.	Distance to Jason1 track (km)
s1	SSN	30.75	122.8	1.897	062	4.08
s2	KMN	26.08	121.28	83.792	051	19.63
s3	TGU	38.55	117.82	17.858	062	21.39
s4	LSI	32.13	121.62	5.754	077	34.28
s5	SYA	18.23	109.53	0.053	138	3.73

Table 2 Information of tide gauge stations, the Sea Surface Height measurements from which were used to compare with altimetry SSH.

4.1 Jason1-Ground Comparison of SSH

The Sea Surface Height measured by Jason1 is calculated by

$$SSH = H_{alt} - H_{range} - \Delta H_{atm} - \Delta H_{ss} - h_{solid\_earth\_tide} - h_{loading\_tide} - h_{pole\_tide}$$

$$\Delta H_{atm} = h_{wet\_tropo} + h_{dry\_tropo} + h_{iono}$$

Where $h_{solid\_earth\_tide}$, $h_{loading\_tide}$, h_{pole_tide} are solid earth tide correction, loading tide correction, and pole tide correction, respectively, which are movements of the earth's crust. It is necessary to apply the last three corrections when comparing the SSH measured by Jason1 and tide gauge station, because station is located at the earth crust. Furthermore, the SSH measured by satellite altimeter is relative to the reference ellipsoid, while the sea surface height measured by tide gauge station is relative to the local mean sea level. We examined the relative temporal-variation of the altimeter and in situ SSH. Except for H_{range}, the value of other parameters are from Jason1 SGDR product. The ECWMF estimation of wet troposphere correction is used in stead of the radiometer.

Sea surface heights derived from Jason1 measurements of track 062 and 077 near tide gauge station SSN and SYA using five retracking algorithms are plotted in Fig.4. When the nadir point of altimeter moved closer to land (the water depth becomes lower), the altimetry SSH decreased significantly. Fig.5 are one year Jason1 retracking SSH at location of A and C, and tide gauge Station SSN measurements. The correlation coefficients and standard deviations of the five results with in situ SSH are inside the figure. Fig.6 shows the results between latitude of 31.01° N and 30.43° N without results of the Ice-2 algorithms. The green symbols are results of comparing Jason1 GDR products with in site SSH variation, which are data averaged over one second (covering about 5.9 km on the ground), while others are 20Hz data (averaged over 1/20s, covering about 290 m on the ground). Therefore, higher sampling ratio data can be derived by waveform retracking. Between the two dash-line of Fig.6, for all the algorithms, the N and correlation coefficient decrease, while std increases because of the serious influence of islands to altimeter waveform. However, the N of Ocean and Beta5 algorithm decreased most significantly. Comparing the OCOG and Threshold algorithm, the correlation coefficient of OCOG is always higher than Threshold, while standard deviation of OCOG is lower than Threshold. Table 4 are average results without the date between the two dash lines. It can be seen that the OCOG algorithm is the most accurate.

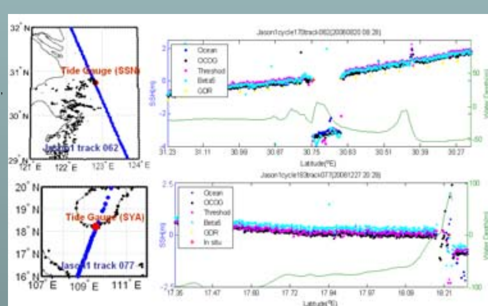

Fig.4 The sea surface heights derived from Jason1 measurements of track 062 (descending) and 077 (ascending) near tide gauge station SSN and SYA, respectively, using five retracking algorithms.

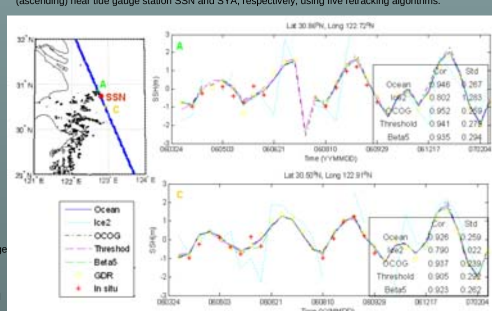

Fig.5 The time series of sea surface heights derived from Jason1 measurements using five retracking algorithms, and compared with in-situ measurements at tide gauge station SSN.

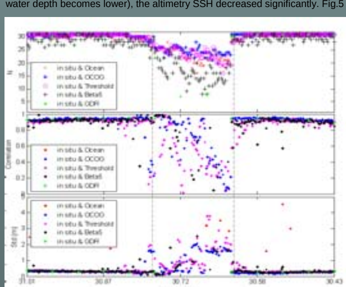

Fig.6 Jason1 ground tracks in the area of 14° N -45° N, 105° E -130° E. Three digit numbers are numbers of track.

4.2 Jason1-Ground Comparison of SWH

Because the altimetry Significant Wave Height (SWH) is determined by the waveform leading edge slope of the ocean return signal and not affected by the atmospheric and ocean conditions, we calculated the Epoch using five retracking algorithms and additional SWH using Ocean fitting algorithm again (the values of Epoch is from the results of other four retrakers).

No.	Name	Latitude (°N)	Longitude (°E)	Jason1 track No.
w1	HLD	40.70	120.98	077
w2	CST	37.38	122.68	153
w3	XMD	36.05	120.42	062
w4	RZH	35.40	119.55	062
w5	LYG	34.78	119.43	062
w6	WZH	28.00	120.88	240
w7	ZPO	21.58	111.82	077
w8	NZU	20.95	110.58	077
w9	FCN	21.62	108.33	001
w10	YGH	18.52	108.68	038
w11	DFG	19.10	108.63	038

Table 3 Information of tide gauge stations, the Significant Wave Height measurements from which were used to compare with altimetry SWH.

For comparisons, in situ SWH measurements of 11 tide gauge stations are used. The locations and corresponding Jason1 ground tracks are in Table 3. Colocated altimetry data are selected when the closet approach of altimeter ground track is less than 1 hour, and averaged over 50km along track. Because of the limited situ SWH measurement, the number of colocated pair is 86. Fig.7 shows the results. The SWH from OCOG, Threshold, and Beta5 retracking algorithms are systematically higher. The SWH from the Jason1 GDR products are much close to the in situ data. This could be explained by the big time and space windows of comparison, but the altimetry waveforms are affected by land signal when the distance to land is around 10 km. However, because of the limited number of comparing data, more in situ data are needed to make a solid conclusion.

	N(31)	Cor	Std
Ocean	30.7	0.899	0.336
Ice2	27	0.431	1.257
OCOG	30.7	0.889	0.355
Thres-hold	30.7	0.868	0.387
Beta5	29.1	0.877	0.372

Table 4 The number of valid results, Correlation and Standard deviation of the comparison of five retracking algorithms and in situ SSH measurements at tide gauge station SSN.

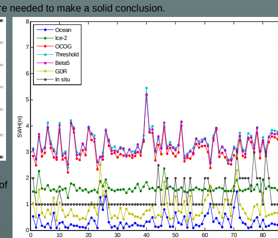

Fig.7 The Significant Wave Heigt derived from five retracking algorithm and in situ tide gauge station measurements.

5. CONCLUSIONS & FUTURE WORK

Because the altimetry sea surface height is derived from the range measured by altimeter and the range corrections, the altimetry sea surface heights are unusable where the distance to land is 50 to 100 km. However, the distance where the altimeter measurement itself is affected is only around 10 km to land, based on the analysis of the Jason1 data,.

As demonstrated, a significant number of coastal ocean return waveforms do not conform to the Brown model as the coast is approached, and the standard Ocean fitting algorithm cannot be used in the coastal altimeter waveform processing. The accuracy and the valid result percentage of the Ocean algorithm decreased rapidly. Especially when the distance is less than 10 km, the Ocean retracking algorithm rejects most of the data. When these distances are less than 10km, the OCOG retracking algorithm is appropriate considering both the accuracy and valid result percentage.

Together with further validation with longer term in situ SSH and SWH data, future work hopes to include waveform recognition and extraction. If the leading edge contributed by the ocean return can be recognized and extracted properly, the only one retracker (Ocean retracker) in needed to deal with the coastal altimetry waveforms.

Reference

[1] Dumont, J.P., "ALT_RET_OCE_01-To perform the ocean-1 retracking, Algorithm Definition, Accuracy and Specification, vol 4 CMA altimeter level 2 processing", SMM-ST-M2-EA-11005-CN (2001).

[2] Legresy, B., and Remy, F., "Surface characteristics of the Antarctic ice sheet and altimetric observations". Journal of Claciology, 43 (114), 197-206 (1997).

[3] Wingham, D.J., Rapley, C.G. and Griffiths, H., "New technique in satellite altimeter tracking systems", IGASS'86 Symposium Digest, 1, 185-190 (1986).

[4] Laxon, S., "Sea ice altimeter processing scheme at the EODC", International Journal of Remote Sensing, 15(4), 915-924 (1994).

[5] Martin T.V., Zwally H.J., Brenner A.C., and Bindschadler R.A., "Analysis and retracking of continental ice sheet radar altimeter waveform" , J.Geophys.Res., 88, 1608-1616 (1983).