Nguyen Quoc Long - Pham Thi Lan
Nguyen Viet Nghia - Khuong The Hung
Le Thi Thu Ha - La Phu Hien

Geo-spatial Technologies and Earth Resources (GTER 2017)

Publishing House for Science and Technology

Geo-spatial Technologies and Earth Resources
©2017 Publishing House for Science and Technology, Vietnam, ISBN 978-604-913-618-4

Determination of location and height difference at crossover points in satellite altimetry data processing using a direct method

Nguyen Van Lam[a*], Nguyen Van Sang[a], Tran Thi Thu Trang[a], Le Thi Thanh Tam[a]
[a]*Hanoi University of Mining and Geology, Hanoi, Vietnam*
[*]*Corresponding author: nguyenvanlam88@humg.edu.vn*

ABSTRACT: Altimetry satellite is an effective tool to research characteristics of sea and ocean. When processing satellite altimetry, a dynamic topography component is removed by using crossover adjustment theory. According to this theory, locations and height differences at crossover points are used as the input data. At crossover point locations, there are two values of sea surface height, one is interpolated from ascending track and the other from descending track. The satellite altimetry network is adjusted using the difference between these values. There are some methods to determine the location of crossover points. However, they also determine approximate locations and after that, determine extract locations. The paper suggests a new contribution to determine the location and difference of crossover points directly without the approximate locations. The result shows that using this way, the crossover locations and height differences are accuracy.

KEY WORDS: crossover, satellite altimetry

1. INTRODUCTION

The application of satellite altimetry data in studying the Earth and the environment is in many documents (Kim M. C., 1997; Wenmin Hu et al., 2011) and popular in many countries such as Australia (Amos M. J., 2005) or England (Andersen O. B., 2013). Satellite altimetry data can be used to study the climate change, sea level rise and so on. Satellite altimetry also has provided measurements of sea surface quickly with high resolution. It plays an important role in studying the Earth's sciences in general and the ocean's state in particular.

At a crossover location, there are two values of sea surface height, one is interpolated from ascending track and the other is from descending track. According to crossover adjustment theory, the accuracy of satellite altimetry measurements can be estimated based on the different values at crossover locations (Amos M.J., 2005; Andersen O.B., 2013). Therefore, determination of crossover location is necessary to adjust the satellite altimetry network.

Some methods are used to determine the crossover locations. For example, using quadratic equation (Sang N. V., 2012; Sang N. V., 2013) or simulating vector equation (Ky D. X., 2014), but its characteristics are similar. Firstly, satellite tracks are simulated using equations such as quadratic or vector function. Secondly, approximate crossover locations are determined by other tracks intersecting together. Finally, the exact locations will be determined by comparing the approximate locations with adjacent point locations of tracks.

By using this method, crossover locations can be determined directly without approximate location. This method includes three steps: (1) estimate two consecutive-points line equation; (2) determine the intersection of the lines (the extract locations) and (3) determine the height difference at the crossover locations. The results are compared with other results that are calculated by using quadratic and vector equation. The calculated results are similar.

2. METHODOLOGY

Suppose that we have four points on two tracks: two points are on the ascending and two points are on the descending track respectively (Fig 1). The coordinate components of A, B, C and D are A (φ_A, λ_A), B (φ_B, λ_B), C (φ_C, λ_C) and D (φ_D, λ_D).

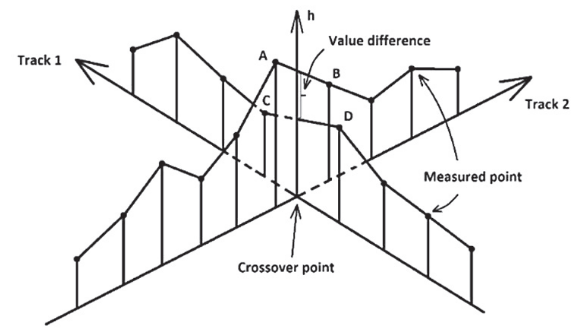

Fig 1. The different value at crossover point location

The AB line equation can be represented by the following equation:

$$\frac{x-\varphi_A}{\varphi_B-\varphi_A}=\frac{y-\lambda_A}{\lambda_B-\lambda_A} \qquad (1)$$

$$\Leftrightarrow y=\frac{\lambda_B-\lambda_A}{\varphi_B-\varphi_A}x+(\varphi_A\lambda_B-\varphi_B\lambda_A) \qquad (2)$$

Similarly, the line equation through C and D is:

$$y=\frac{\lambda_D-\lambda_C}{\varphi_D-\varphi_C}x+(\varphi_C\lambda_D-\varphi_D\lambda_C) \qquad (3)$$

2.1. Two line's intersection determination

The crossover location M (φ_M, λ_M) can be achieved by finding the answer following function system:

$$\begin{cases}\lambda_M=\dfrac{\lambda_B-\lambda_A}{\varphi_B-\varphi_A}\varphi_M+(\varphi_A\lambda_B-\varphi_B\lambda_A)\\ \lambda_M=\dfrac{\lambda_D-\lambda_C}{\varphi_D-\varphi_C}\varphi_M+(\varphi_C\lambda_D-\varphi_D\lambda_C)\end{cases} \qquad (4)$$

The location of crossover point M can be determined by the following equation:

$$\begin{cases}\varphi_M=\dfrac{c_2b_1-c_1b_2}{a_1b_2-a_2b_1}\\ \lambda_M=\dfrac{a_2c_1-a_1c_2}{a_1b_2-a_2b_1}\end{cases};(a_1b_2\neq a_2b_1) \qquad (5)$$

where,

$$\begin{cases}a_1=\lambda_B-\lambda_A\\ b_1=\varphi_A-\varphi_B\\ c_1=\lambda_A\varphi_B-\varphi_A\lambda_B\end{cases};\begin{cases}a_2=\lambda_D-\lambda_C\\ b_2=\varphi_C-\varphi_D\\ c_2=\lambda_C\varphi_D-\varphi_C\lambda_D\end{cases} \qquad (6)$$

2.2. The difference between two tracks at intersection location determination

Suppose h_A, h_B, h_C, h_D are the sea surface height at A, B, C and D respectively; h'_M, h''_M are two values calculated from ascending and descending track at crossover location.

Because M is on the ascending track that includes A and B, so we have the equation:

$$\begin{cases}a\varphi_A+b\lambda_A=h_A\\ a\varphi_B+b\lambda_B=h_B\\ a\varphi_M+b\lambda_M=h'_M\end{cases}\Rightarrow\begin{cases}a=\dfrac{h_A\lambda_B-h_B\lambda_A}{\varphi_A\lambda_B-\varphi_B\lambda_A}\\ b=\dfrac{h_A\varphi_B-h_B\varphi_A}{\lambda_A\varphi_B-\lambda_B\varphi_A}\end{cases} \qquad (7)$$

Similarly, we have:

$$\begin{cases}a'\varphi_C+b'\lambda_C=h_C\\ a'\varphi_D+b'\lambda_D=h_D\\ a'\varphi_M+b'\lambda_M=h''_M\end{cases}\Rightarrow\begin{cases}a'=\dfrac{h_C\lambda_D-h_D\lambda_C}{\varphi_C\lambda_D-\varphi_D\lambda_C}\\ b=\dfrac{h_C\varphi_D-h_D\varphi_C}{\lambda_C\varphi_D-\lambda_D\varphi_C}\end{cases} \qquad (8)$$

Combining (7) and (8), we have the equation:

$$\left[\begin{array}{l}h'_M=\dfrac{h_A\lambda_B-h_B\lambda_A}{\varphi_A\lambda_B-\varphi_B\lambda_A}\varphi_M+\dfrac{h_A\varphi_B-h_B\varphi_A}{\varphi_B\lambda_A-\varphi_A\lambda_B}\lambda_M\\ h''_M=\dfrac{h_C\lambda_D-h_D\lambda_C}{\varphi_C\lambda_D-\varphi_D\lambda_C}\varphi_M+\dfrac{h_C\varphi_D-h_D\varphi_C}{\varphi_D\lambda_C-\varphi_C\lambda_D}\lambda_M\end{array}\right. \qquad (9)$$

If ***n*** is the number of crossovers, the difference of sea surface height at the i^{th} crossover point can be determined by the equation:

$$dh_i=h'_i-h''_i\ ;\quad i=1\div n \qquad (10)$$

3. RESULT

3.1. The data

The data used in this study are the satellite altimetry data in the part of the East Sea, its boundary is 08^0N ÷ 22^0N and 100^0E ÷ 114^0E. The data is the 86^{th} cycle of ENVISAT satellite and downloaded from the AVISO website (AVISO, 2017).

3.2. Checking the locations of crossovers

In order to check the accuracy of crossover's locations, we present all the altimetry points on the AutoCAD program. After that, we determine the location of crossover points manually. At the end of the stage, we compare these locations with positions that are calculated by the direct method. The result is compared and shown in the following figure.

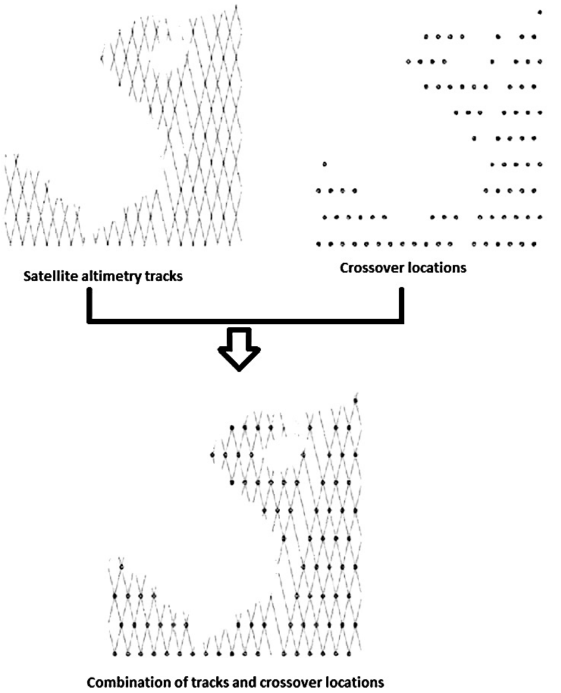

Fig 2. The crossover locations and tracks

3.3. Calculating height difference at crossover locations

From the theory in the previous section, we have calculated the different height at the locations of crossovers. The results are in the following table:

Table 1. The height difference at the crossover locations

Intersection tracks	Latitude (degree)	Longitude (degree)	dh (m)
21 - 236	8.098	106.8483	0.0967
36 - 737	11.3029	102.5377	0.2952
36 - 823	8.0961	101.8188	0.2238
49 - 64	19.0715	112.2376	0.033
49 - 436	14.4623	113.3148	-0.0206
49 - 522	17.5554	112.5962	0.14
49 - 894	12.8905	113.6738	0.0177
49 - 980	16.021	112.9548	0.0481
64 - 135	16.0138	111.5192	0.0787
64 - 221	12.8877	110.8008	0.1353
64 - 307	9.7025	110.0818	0.1648
64 - 507	20.5725	112.5974	0.1858
64 - 593	17.5516	111.8789	0.3203
64 - 679	14.4589	111.1605	0.0479

Intersection tracks	Latitude (degree)	Longitude (degree)	dh (m)
64 - 765	11.3059	110.4417	0.0806
64 - 851	8.0983	109.7228	0.0081
107 - 322	8.1011	105.4107	0.1552
122 - 365	9.7049	100.7403	0.1715
122 - 823	11.3051	101.1005	0.2278
122 - 909	8.0984	100.3818	0.1113
135 - 150	19.073	110.8007	-0.096
135 - 350	8.0999	113.3147	0.0525
135 - 436	11.3056	112.5962	0.0086
135 - 522	14.462	111.8775	0.0032
135 - 894	9.7087	112.9556	-0.1462
135 - 980	12.8936	112.2366	-0.1436
150 - 221	16.0158	110.0824	0.0018
150 - 393	9.7054	108.6447	0.1727
150 - 593	20.5746	111.1598	0.2616
150 - 679	17.5539	110.4414	0.0819
150 - 765	14.4611	109.7233	0.033
150 - 937	8.0995	108.2859	0.2431
193 - 408	8.0994	103.9741	0.0487
193 - 952	9.7098	103.6141	0.2057
221 - 436	8.102	111.8781	-0.1054
221 - 522	11.3081	111.1594	0.0133
221 - 694	17.5585	109.7217	0.1484
221 - 780	20.5787	109.0034	0.1554
221 - 980	9.7104	111.5181	-0.1843
236 - 307	16.0147	108.6446	0.0837
236 - 479	9.7061	107.2072	0.0924
236 - 765	17.555	109.0045	0.0696
279 - 494	8.099	102.5361	0.1335
279 - 580	11.3061	101.8172	0.0234
307 - 322	19.074	107.9254	-0.1769
307 - 522	8.1003	110.4404	0.0297
307 - 780	17.5561	108.2845	0.0027
307 - 866	20.5779	107.5657	-0.2518
322 - 765	20.5784	108.2854	0.1189
322 - 851	17.5579	107.5669	0.2155
350 - 593	9.7088	113.6738	-0.0106
365 - 580	8.099	101.0988	-0.0048
365 - 666	11.305	100.3801	-0.0714
393 - 408	19.0754	106.4886	0.0397
393 - 866	17.5569	106.8477	0.0458

Intersection tracks	Latitude (degree)	Longitude (degree)	dh (m)
408 - 651	9.7067	104.3329	0.0769
408 - 851	20.5768	106.8486	0.0769
421 - 522	22.0554	113.6739	0.0964
436 - 507	16.0167	113.6741	0.0933
436 - 593	12.8897	112.9558	0.1053
436 - 679	9.7069	112.2373	-0.0122
479 - 694	8.1008	107.5664	0.0217
494 - 737	9.707	102.896	0.027
507 - 522	19.0762	112.9553	-0.0962
507 - 980	17.5587	113.3142	-0.098
522 - 593	16.0189	112.2371	0.1004
522 - 679	12.8905	111.5187	-0.0234
522 - 765	9.7098	110.8	-0.1108
522 - 965	20.5779	113.3155	-0.0072
565 - 780	8.1005	106.1293	0.0065
580 - 823	9.7092	101.4587	0.0358
593 - 894	11.3086	113.3147	-0.1552
593 - 980	14.4664	112.5957	-0.1998
651 - 866	8.0998	104.6921	-0.0775
666 - 823	12.8938	100.7398	0.3191
679 - 894	8.1023	112.5964	-0.0154
679 - 980	11.3102	111.8774	-0.0594
694 - 765	16.0209	109.363	-0.0328
694 - 937	9.7097	107.9254	0.0256
737 - 952	8.102	103.2552	-0.0223
765 - 980	8.102	111.1589	-0.0867
851 - 866	19.0803	107.2076	-0.1019
937 - 952	19.0807	105.7696	-0.0065
965 - 980	19.083	113.674	0.0433

4. CONCLUSION

The direct method can determine the exact location of crossovers without the approximate location.

This method can be applied to determine the location not only the linear tracks such as satellite altimetry tracks, but also the nonlinear tracks such as a ship or airborne tracks when processing the data.

This method also can be coded to an automatically calculated programming in order to determine the locations of crossovers while processing the satellite altimetry data.

REFERENCES

Amos M. J., Featherstone W. E., Brett J., 2005. Crossover Adjustment of New Zealand Marine Gravity Data, and Comparisons with Satellite Altimetry and Global Geopotential Models. Gravity, Geoid and Space Missions, pp. 266-271.

Andersen O. B., 2013. Marine Gravity and Geoid from Satellite Altimetry. In Geoid Determination Theory and Methods (Fernando Sansò, Michael G. Sideris), Springer Heidelberg New York Dordrecht, London, pp. 413-418.

AVISO, 2017. viewed May 09, 2017, http://www.aviso.altimetry.fr/en/my-aviso.html

Kim M. C., 1997. Theory of satellite ground-track crossovers. Journal of Geodesy 71: 749-767.

Ky D. X., 2014. Determination crossover location on the East Sea. Master thesis, Hanoi University of Mining and Geology, Hanoi, Vietnam.

Sang N. V., 2012. Satellite altimetry crossover adjustment on the Vietnamese Sea. Journal of Geodesy and Cartography 3: 08-12.

Sang N. V., 2013. Determination crossover point location by simulating quadratic equation in processing satellite altimetry data. Scientific-Technical Journal of Mining and Geology, University of Mining and Geology 41: 43-47.

Wenmin Hu, Zongyu Yue, Kaichang Di, 2011. “Crossover analysis of chang’e-1 laser altimeter data”, Institute of Remote Sensing Applications, Chinese Academy of Sciences P. O. Box 9718, Datun Rd, Chaoyang District, Beijing 100101, P.R. China, 2011 <URL: https://www.researchgate.net/publication/276022153_Crossover_analysis_of_Chang'e-1_laser_altimeter_data