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Determination of sea surface anomaly on the East Sea from Satellite altimetry data and DTU13MSS

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Abstract

Sea Level Anomaly – SLA is difference between the observed sea surface height (SSH) and the mean sea surface (MSS). The SLA allows us to monitor ocean variability due to seasonal variations and climatic phenomena such as El Nino. SSH is sea surface height, determined from geoidal height and dynamic sea surface topography. Because observed sea surface does not coincide with the MSS model, interpolated MSS at the same location as the observation was used to compute SLA.

Key words: satellite altimetry; sea level anomaly; DTU13MSS.

1. Introduction

In these current years, satellite altimetry is applied widely and effectively on the world. Based on satellite altimetry data, sea surface height, sea geoid, sea gravity anomaly, mean sea surface, sea level anomaly can be determined [Lee-Lueng Fu, Anny Cazenave, 2001]. In Vietnam, several researches have applied satellite altimetry data for East Sea studies. Some of them applied results of foreign research, such as: application of mean dynamic topography model [Bui Cong Que, 2008][Bui Khac Luyen, Nguyen Van Sang, 2014], sea gravity anomaly mode, some deeply researches about processing of satellite altimetry data on the East Sea, such as: determining crossover location, crossover adjustment, determining gravity anomaly [Nguyen Van Sang, 2012][Nguyen Van Sang, 2011][Nguyen Van Sang, 2013], determining mean dynamic topography [Nguyen Van Sang, Le Thi Thanh Tam, 2014], have been conducted.

Sea level anomaly (SLA) is a difference between time-variable sea level and mean sea level. Determination of SLA will aid researches of seasonal sea level changes, ocean climate researches, tide-race forecast and tide researches. The European Space Agency said that: if you knew the results of the sea level anomaly, you could determine the kinetic energy of the sea on The Mexico Bay; there had been the very high values in the 10 days before the hurricane Katrina appeared in 2005; when the tide at The Indian Ocean appeared on the 26 December 2014, the results of Jason-1 satellite observation (- period 129) and ENVISAT satellite (- period 352) – all set down the high value of the sea level anomaly. This study applied data derived from SARAL/ALTIKA satellite to determine SLA on the East Sea.

2. Determination of sea level anomaly

Mean Sea Surface (MSS) was height between the mean sea level and Ellipsoid WGS-84 surface. Sea Surface Height (SSH) height between the variable-sea level and Ellipsoid WGS-84 surface. The Sea Level Anomaly (SLA) was determined by the formula [Nguyen Van Sang, 2013]:

$$\mathrm{SLA} = \mathrm{SSH} - \mathrm{MSS} \qquad (1)$$

Nowadays, there are some mean sea level models, which were built in a type of grid, such as DNSC08MSS model, models DTU10MSS, DTU12MSS, DTU13MSS … The variable sea level can be determined from satellite altimetry data. However, these measured points were not coincided with nodes of grid of MSS models. Therefore, to determine SLA by the formula (1), it is needed to interpolate the mean sea level from MSS model at satellite altimetry points. Because SSH have been received at the measured time, SLA have been determined at this time, too. Determination of observe sea level anomalies (- or real time) depends on availability of satellite data, which can be ordered from providing data centre

2.1. Interpolation of the mean sea level at the satellite points by Colocation method

Guess at a researched area have n points, which has value of mean sea level $MSS_{i,}$ with coordinates are (B_i, L_i), $i = 1, 2, \ldots, n$. $y^T = (MSS_1, MSS_2, \ldots, MSS_n)$ is height vector of the mean sea surface. Then, the height at mean sea surface of point P in the researched area was determined by the formula

$$MSS_p = K_P^T K^{-1} y \qquad (2)$$

While: K and K_P were covariance matrix

$$K = \begin{bmatrix} k_{11} & k_{12} & \cdots & k_{1n} \\ k_{12} & k_{22} & \ldots & k_{2n} \\ \ldots & \ldots & \ldots & \ldots \\ k_{n1} & k_{n2} & \ldots & k_{nn} \end{bmatrix}.$$

$$k_{ij} = K(i,j)\ ; \qquad i,j = 1,2,\ldots,n \qquad (3)$$

$$K_p = \begin{bmatrix} k_{P_1} \\ k_{P_2} \\ \cdots \\ k_{P_n} \end{bmatrix} \qquad (4)$$

$k_{P_i} = K(P,i); \qquad i = 1,2,\ldots,n$

$K(i,j)$ and $K(P,i)$ were covariance matrix of heights at mean sea level.

The fact that, input values were the heights at mean sea surface, usually did not ensure a condition $MSS_{ave} = \sum_{i=1}^{n} MSS_i = 0$ and did not satisfy conditions of Colocation tasks. So, input data needed to be removed average value before interpolated. Therefore, interpolation the mean sea surface has been done by these steps:

1.Remove the average value MSS_{ave} from the input data as the mean sea surface height.

2.Take the covariance matrix K from its input data – covariance function $K(l)$

3.Determine the mean sea level MSS_p for each point P in the researched area.

4.Restore the average value MSS_{ave} for interpolation points.

When interpolated by the Colocation method, needed to inverse a square matrix, which had size of the input data points. If the number of input points was high, then it would have many difficulty in the calculated process. Otherwise, interpolation value of P had been depended on nearly points (node points). The further distance of node interpolation points, the lower influence to interpolation value of point P. Therefore, interpolation of the mean sea surface height needn't use all of n points in the researched area, just need use m points (m<n) in the R radius around point P. Follow [Nguyen Van Sang, Vu Trung Thanh, 2015], we can choose R= $0{,}5^0$. So, the number of hidden values in the standard equation was lower, but at each interpolation points needed to inverse one matrix, which has size is the number of points in the circle radius R.

2.2. Determining values of experimental covariance function of the mean sea surface heights and make it suitable with the theory function

Determination of values k in the covariance matrix K and Kp need to be done with determining of values of experimental covariance matrix. With the mean sea surface, experimental covariance matrix were determined by the formula:

$$\begin{cases} K(0) = \frac{1}{n_0}\sum_{i=1}^{n_0} MSS_i^2 \\ K(1.\Delta l) = \frac{1}{n_1}\sum_{m=1}^{n_1} MSS_i.MSS_j \\ K(2.\Delta l) = \frac{1}{n_2}\sum_{m=1}^{n_2} MSS_i.MSS_j \\ \dots \\ K(k.\Delta l) = \frac{1}{n_k}\sum_{m=1}^{n_k} MSS_i.MSS_j \\ K(p.\Delta l) = \frac{1}{n_p}\sum_{m=1}^{n_p} MSS_i.MSS_j \end{cases} \quad (5)$$

With condition: $k.\Delta l - \frac{\Delta l}{2} < |l_{i,j}| \leq k.\Delta l + \frac{\Delta l}{2}$ *(6)*

Where

l_{ij} – distance between two points i and j

Δl- the nearest distance between points, in this issue, it is the nearest distance between node points. With MSS model, size 1' x 1', choose $\Delta l = 1'$; p – positive natural numbers, depended on a width of the researched area.

$R = 0.5^0$ could choose p = 10

$n_k(k = 1,2 \dots p)$ – the number of pairs of points i and j, satisfy the condition (6)

n_0 - the numbers of points, which have had mean sea surface height in the researched area.

Condition (6) was described on a figure 1. From this, experimental covariance values were calculated by formula (5), just used j points in a cross section.

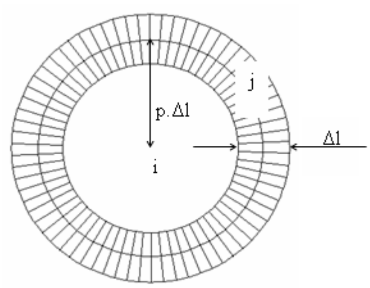

Figure 1. Scheme points, used for calculating experimental covariance values.

After receiving the experimental covariance values, parameters of the theory covariance function were calculated by coinciding the values of the theory and experimental covariance functions with principle of least squares. The theory covariance functions may be chosen by Maxkov or Gaussian.

3. Experimental results:

Based on the theory mentioned above, we calculated the sea level anomaly, and used data, which have been measured on the East Sea. (latitude from 8^0 to 22^0, longitude from 105^0 to 114^0). MSS model was DTU13MSS, which was set up by Denmark cosmos Centre. Satellite altimetry data was SARAL/ALTIKA satellite data, period 18 (working from 30th Oct. 2014 to 06 Nov. 2014). Data were provided by AVISO [AVISO,2010].

Mean sea level height DTU13MSS and sea level height, measured by satellite SARAL/ALTIKA on the East Sea were shown in Figure 2 and 3, respectively.

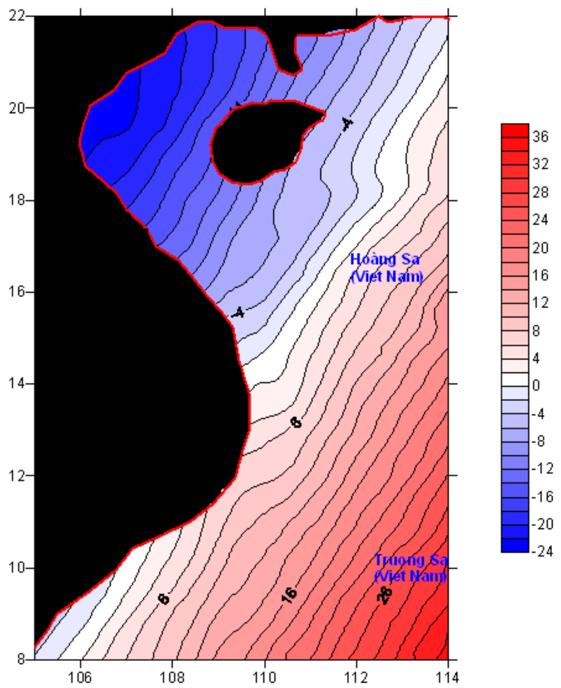

Figure 2: Mean sea level height on the East Sea from DTU13MSS model

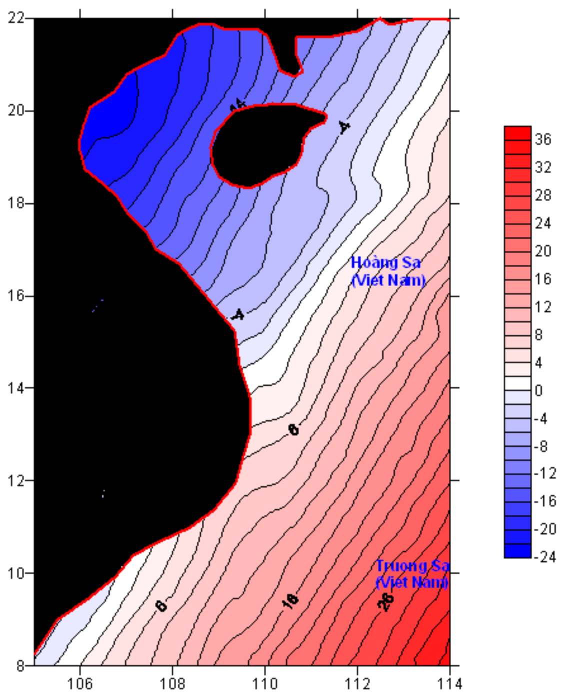

Figure 3: Sea surface height – have been determined from satellite altimetry SARAL/ALTIKA, period 18.

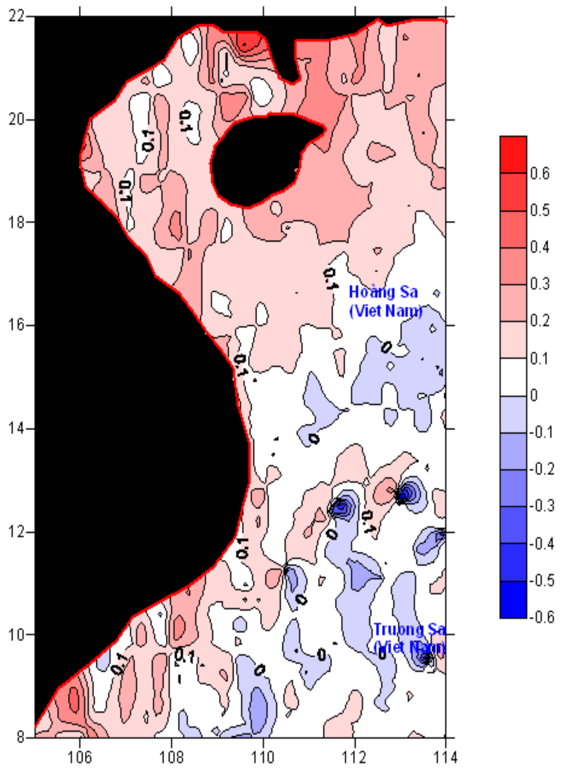

Figure 4: sea level anomaly – have been determined from DTU13MSS model and satellite altimetry data SARAL/ALTIKA, period 18 on The East Sea.

In the figure 4, SLA of the East Seas was determined from satellite altimetry data SARAL/ALTIKA period 18 and DTU13MSS. The result showed that minimum SLA was 1.581 m, maximum SLA was 0.649 m, and its average value was 0.108 m.

4.Conclusion

SLA on The East Sea could be determined from mean sea surface MSS and satellite altimetry data. For SARAL/ALTIKA data at period 18 and the mean sea surface model DTU13MSS, SLA changed its values from -1.581 m to 0.649 m, average value was 0.108 m.

Colocation method can be used to interpolate sea surface height MSS. To decrease the calculation quantity, when interpolating the mean sea surface height for 1 point, just need to use data within radius of 0.5^0, it is not necessary to use all data in the researched area.

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