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Bathymetry predicting using the altimetry gravity anomalies in South China Sea

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A B S T R A C T

In South China Sea (112°E–119°E, 12°N–20°N), 81159 ship soundings published by NGDC (National Geophysics Data Center) and the altimetry gravity anomalies published by SIO (Scripps Institute of Oceanography) were used to predict bathymetry by GGM (gravity-geologic method) and SAS (Smith and Sandwell) method respectively. The residual 40576 ship soundings were used to estimate precisions of the predicted bathymetry models. Results showed that: the standard deviation of difference between the GGM model and ship soundings was 59.75 m and the relative accuracy was 1.86%. The SAS model is 60.07 m and 1.87%. The power spectral densities of the ETOPO1, SIO, GGM and SAS models were also compared and analyzed. At last, we presented an integrated bathymetry model by weighted averaging method, the weighted factors were determined by precisions of the ETOPO1, SIO, GGM, and SAS model respectively.

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1. Introduction

Seafloor topography or bathymetry has traditionally been mapped by shipborne echo sounding measurements, which were time-consuming and cost a lot [1,2]. However, the advent of satellite radar altimetry had made it possible to estimate global bathymetry economically and accurately [3–5]. In 1960s, Parker showed how a series of Fourier transforms can be used to calculate the magnetic or gravity anomaly caused by an uneven, non-uniform layer of material. The invented Parker formula changed the discontinuity of models inversed by equivalent source method, and improved the computational efficiency [6]. Watts analyzed the relationship between gravity and bathymetry on 14 profiles of the Hawaiian Emperor Seamount chain using the Cross-spectral technique, and the transfer functions between gravity and bathymetry had been used to evaluate the state of isostasy along the chain. These functions can also be explained by simple models in which the oceanic lithosphere is treated as a thin elastic plate overlying a weak fluid [7]. Based on the Parker formula and Watts plates theoretical model, Smith and Sandwell proposed a new technology to predict bathymetry by altimetry gravity anomalies and ship soundings, which made use of the Geosat GM data fully, and avoided the structure compensation assumptions. The same method was used by Smith and Sandwell again in 1997, the improvement was the differences between ship soundings and bathymetry model were gridded to be a correction to the original model [8]. Mingzhang Hu [9,10] formed a global bathymetry model using vertical gravity gradient anomalies and ship soundings based on the response function, this method was improved in 2015, he combined ship sounding, gravity anomalies and vertical gravity gradient anomalies, formed a $1' \times 1'$ bathymetry model over China sea and its adjacent areas.

The GGM (Gravity Geological method) was originally developed for predicting the basement depth of low density glacial drift deposits [11], but as the subsurface material density was always changing, the GGM method is not suitable in land areas. The

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density difference between the oceanic crust and seawater changed small, this method is quite suitable to predict bathymetry by altimetry gravity anomalies. Presently, this method had been successfully used to inverse bathymetry in East Sea of Japan, Emperor Seamount, South of Greenland and Southern Area of Alaska. The precision of inversed model even reached 20–40 m [12–16].

In this paper, we constructed 1′ × 1′ bathymetry models in South China Sea (112°E–119°E, 12°N–20°N), by the GGM method and the SAS method, the input datum were altimetry gravity anomalies published by SIO and ship soundings published by NGDC, we compared the results and presented an integrated model at last.

2. Methodology

2.1. GGM (Geology Gravity Method)

The relationship between the free air gravity anomaly and bathymetry is nonlinear. In general, a nonlinear problem can be linearized by defining a suitable "reference field" and "residual field" in many geodetic computations [17]. Thus, the altimetry gravity anomalies on the sea surface (g_{obs}) can be divided into a short wavelength residual field (g_{short}) generated by seafloor undulation and a long wavelength reference field (g_{long}) generated by deeper mass variations:

$$g_{obs} = g_{short} + g_{long} \tag{1}$$

Fig. 1 illustrates the principle of GGM, and j_n ($n = 1,2,3\ldots$) are the control points with ship sounding depths.

The control points j_n in Fig. 1 are used to estimate the residual gravity field that generated from a simple Bouguer slab formula:

$$g^{jn}_{short} = 2\pi G \Delta\rho (E_{jn} - D) \tag{2}$$

where, G is a gravitational constant ($6.672 \times 10^{-8} cm^3/gs^2$),$\Delta\rho$ is the density contrast between seawater and bedrock,E_{j_n} is the water depth at the j_n, D is the reference datum depth, which is usually referenced to the deepest depth at the j_n control points. Both E_{j_n} and $D$are measured in meters.

The reference gravity anomalies at j_n can be calculated by:

$$g^{j_n}_{long} = g^{j_n}_{obs} - g^{j_n}_{short} \tag{3}$$

where $g^{j_n}_{long}$ will be gridded to a 1 min model. The reference gravity anomaly at any point $i(g^{i}_{long})$ can be interpolated from this grid, and the residual gravity will be:

$$g^{i}_{short} = g^{i}_{obs} - g^{i}_{long} \tag{4}$$

By rearranging Eq. (2), the water depth at i can be:

$$E_i = \frac{g^{i}_{short}}{2\pi G \Delta\rho} + D \tag{5}$$

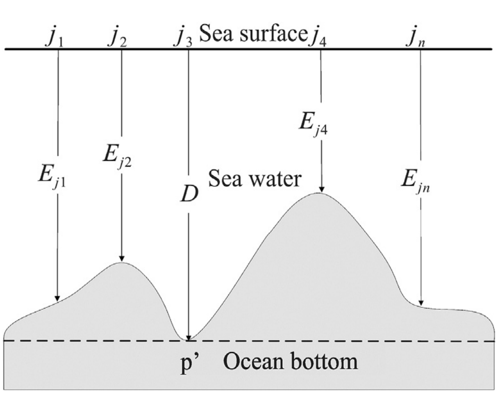

Fig. 1. Principle of the GGM

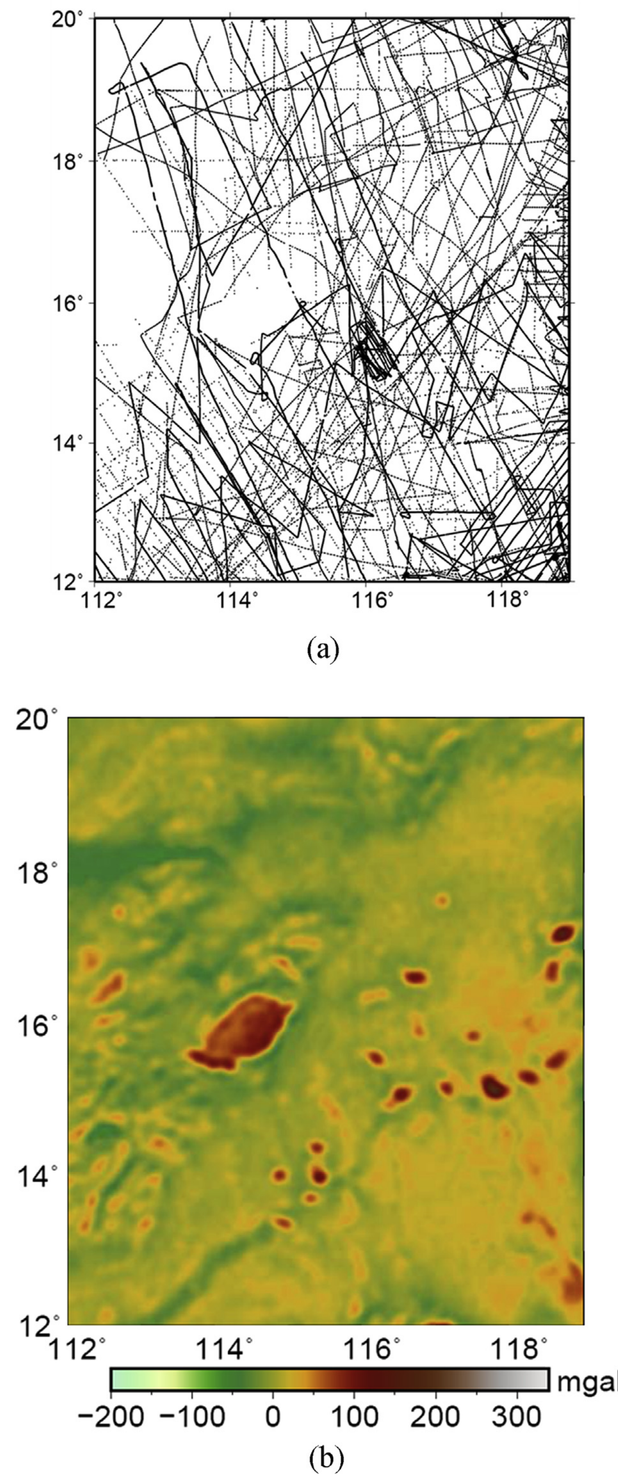

Fig. 2. The gravity anomalies and the shipboard cruises in study areas.

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