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Bathymetry predicted from vertical gravity gradient anomalies and ship soundings

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Abstract: In this paper, the admittance function between seafloor undulations and vertical gravity gradient anomalies was derived. Based on this admittance function, the bathymetry model of 1 minute resolution was predicted from vertical gravity gradient anomalies and ship soundings in the experimental area from the northwest Pacific. The accuracy of the model is evaluated using ship soundings and existing models, including ETOPO1, GEBCO, DTU10 and V15.1 from SIO. The model's STD is 69.481m, comparable with V15.1 which is generally believed to have the highest accuracy.

Key words: bathymetry; vertical gravity gradient; admittance function; ship soundings; isostasy

1 Introduction

The high resolution bathymetry model is needed for researching on ocean geophysics, biology, and climate science, but ship soundings still cover the ocean sparsely even after decades of years of surveying. It will be very difficult to create a 1 minute bathymetry model just relying on ship soundings in the near future. The technological advance of satellite altimetry provides a new approach to high resolution bathymetry model construction. Dixon et al[1] showed that bathymetry of the ocean can be predicted from altimetry data. The following studies show that altimetric gravity anomalies can be used to predict bathymetry at the waveband 20-200 km[2-5]. Smith and Sandwell[6] developed a method to construct a high resolution bathymetry model from ship soundings and altimetric gravity anomalies. According to S&S method, the long wavelengths (>200 km) bathymetry models were constrained by ship soundings, and bathymetry of shorter wavelengths (20-200 km) was predicted from gravity anomalies.

At present, nearly all the high resolution global bathymetry models were constructed from ship soundings and satellite altimetry gravity anomalies. The bathymetry model will depend on gravity anomalies at the waveband 20-200 km, and must be careful when analyzing the isostatic mechanism of sea floor with these models and gravity anomalies. Wang[7] pointed out that this problem of depending can be avoided if the bathymetry model can be predicted from vertical gravity gradient anomalies (VGG), and derives equations used to finish the work in the space domain. The method of Wang was not implemented because of low signal-to-noise ratio of VGG. Wu et al[8] constructed a 2 minute bathymetry model in the South China Sea with VGG and ship soundings, but its accuracy is lower than ETOPO2. Hu et al[9] studied this issue using simulated data.

In this paper, a 1 minute bathymetry model is constructed using ship soundings and VGG in a 2×2 degree region in the northwest Pacific. The ship sound-

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ings are obtained from National Geophysics Data Center (NGDC), and used to establish long wavelength (>200 km) bathymetry. The VGG is downloaded from SIO (Scripps Institute of Oceanography), UCSD, V20.1, and used to predict bathymetry at the waveband 20–200 km. The model accuracy is evaluated by comparing the result with ship soundings and the existing models, and the result can show that a high resolution and accuracy bathymetry model can be predicted from VGG and ship soundings.

2 Method

Parker[10] derived an equation which can be used to calculate gravity anomalies from seafloor undulations. Based on the derivative theorem of Fourier Transform and formula (4) in Parker's paper, we generate the equation for calculating VGG from seafloor undulations directly:

$$\Delta G_z(k) = (2\pi G(\rho_c - \rho_w)e^{-kd}k\{H(k) + \sum_{n=2}^{\infty}\frac{k^n}{n!}F[h^n(x)]\} \quad (1)$$

where, $k=2\pi/\lambda$ is the wave number, λ is the wavelength, $\Delta G_z(k)$ is the Fourier Transform of VGG, G is the gravitational constant, ρ_c is the density of seafloor crust, ρ_w is the density of sea water, d is the mean water depth, $H(k)$ is the Fourier Transform of seafloor undulations, $h(x)$ is the seafloor undulations in space domain, F is the symbol of Fourier Transform. There is no isostatic effect in equation (1), which will be used at the waveband 20–200 km. If we take into account the upward continuation of ocean depth, the equation (1) can be simplified to:

$$\Delta G_z(k) = 2\pi G(\rho_c - \rho_w)e^{-kd}kH(k) \quad (2)$$

The admittance function between seafloor undulations and VGG is:

$$Z(k) = 2\pi G(\rho_c - \rho_w)e^{-kd}k \quad (3)$$

We use VGG to predict bathymetry at the waveband 20–200 km, therefore:

$$H(k) = Z(k)^{-1}\Delta G_z(k) \quad (4)$$

According to equation (4), after downward continuation and divided by k, the relationship between $\Delta G_z(k)$ and $H(k)$ will be linear. Due to inhomogeneity of seafloor density, the linear coefficient will be computed from ship soundings and VGG.

The predicted model will be the sum of the long wavelength model from ship soundings and residual bathymetry predicted from VGG. That means:

$$h_{pred}(x) = h_{long}(x) + h_{VGG}(x) \quad (5)$$

where, $h_{pred}(x)$ is the predicted result, $h_{long}(x)$ can be gotten by low-pass filter of grids from ship soundings, and $h_{VGG}(x)$ is predicted from VGG.

The data processing procedure can be illustrated by figure 1. According to figure 1, firstly, ship soundings were processed to form grids and which are then filtered by 200 km low-pass Gaussian filter to establish $h_{long}(x)$. Secondly, residual depths on ship tracks ($h_{residual}(x')$) should be prepared for calculating $S(x')$. The reference depths of ship points are interpolated

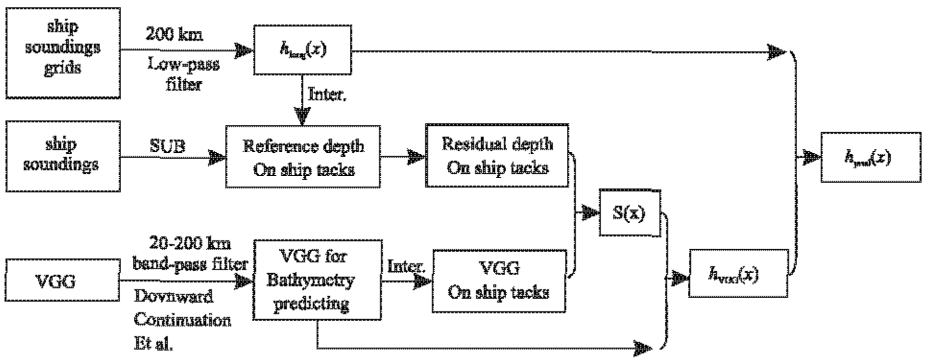

Figure 1 Flowchart of data processing procedure