Calculation and Analysis of Global-Scale Earth Gravity Field Parameters Based on EIGEN-5C Model

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Abstract. There are many calculation model schemes with practical value for calculating the critical parameters of the earth's gravity field. However, the research work of systematically using the EIGEN-5C model for global-scale inversion of the earth's gravity field needs to be supplemented. To solve the above problems, this study uses the 360-order EIGEN-5C model to calculate the four parameters of the earth's gravity field: disturbance potential, geoid height, gravity anomaly, and gravity disturbance. This study first calculates the normalized associated Legendre function, reads the coefficients of the EIGEN-5C gravity field model, then calculates the normal gravity and converts the geodetic coordinate system into the spherical coordinate system. On this basis, the spherical harmonic series expansion of the gravity field parameters is carried out. Through experiments, it is found that the calculation process introduced in this study can better calculate and express the critical parameters of the global-scale earth's gravity field. The calculation results can sufficiently express the geophysical situation of the study area. This study systematically explains using the EIGEN-5C model to carry out the inversion and result in the expression of global-scale earth's gravity field parameters.

Keywords: Earth gravity field · Disturbance potential · Geoid height · Gravity anomaly · Gravitational disturbance · EIGEN-5C

1 Introduction

The EIGEN-5C model is widely used in earthquake research, land hydrology, glacier ice cover research, and other fields and has achieved good results. The gravity gradient experiment of Johannes Bouman et al. [4, 5] shows that EIGEN-5C has strong consistency with the current general ultra-high order gravity field model EGM2008 in the ocean but low consistency on the continent. On this basis, Alexandre Bernardino Lopes et al. [6] made an oceanographic evaluation of EIGEN-5C. Using this model and the EGM2008 model, the geostrophic current at the Brazil Malvinas junction was calculated, respectively. The results were similar to those of the numerical hydrodynamic model, which proved the consistency of the two models in large-scale aspects. Dimitrios Tsoulis et al. [7] used GOCE satellite orbit analysis to evaluate different gravity models. They found that EIGEN-5C has the smoothest root mean square change in the whole

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spectral range, proving the stability of the model. Christoph Förste et al. [8] improved the combination procedure of satellite and ground data because of the shortcomings of EIGEN-5C in the Andes, Africa, and the Himalayas due to the low quality of surface observation data and significant model errors.

Although significant progress has been made in the inversion of the earth's gravity field, there is still some research space for understanding the gravity field and its application at global-scale. Therefore, it is necessary to explore the feasibility of the calculation results of the gravity field model at global-scale and further give the gravity field calculation process and related software models operational significance. Among them, for the EIGEN-5C gravity field model used in this paper, how to give a complete set of calculation flow and calculation software in global-scale so that it can better analyse and inverse the critical parameters of the earth's gravity field in the global area to be studied, the research on the above content is still insufficient. The critical parameters of the earth's gravity field mentioned above mainly include disturbance potential, geoid height, gravity anomaly, gravity disturbance, and other vital parameters, which will be discussed in our research. Therefore, this study will discuss the above problems.

The structure of this study is as follows:

(1) Aiming at the EIGEN-5C gravity field model, this study introduces the download platform of the model in the second part.
(2) Describes the gravity field inversion algorithm based on the model and gives the implementation process.
(3) Introduces the results of the calculation of the critical parameters of the gravity field using the method in this paper at global-scale, and further discusses and analyses them.
(4) Give a summary and outlook of the full text.

2 Calculation Method of Gravity Field Inversion Based on Eigen-5C Model

2.1 Algorithm Flow

First, download the EIGEN-5C gravity field model file in the international Global Earth Model Center (ICGEM, http://icgem.gfz-potsdam.de/tom_longtime). Prepare the data:

(1) Recursively calculate the normalized Legendre function value corresponding to each series expansion.
(2) Normalize the gravity field coefficient.
(3) Calculate the normal gravity at each latitude.
(4) Convert the geodetic coordinates into the spherical coordinate system.
(5) Substitute these data into the spherical harmonic series expansion of the gravity field parameters for the calculation.
(6) Finally, map and display the gravity field parameter data for analysis (Fig. 1).

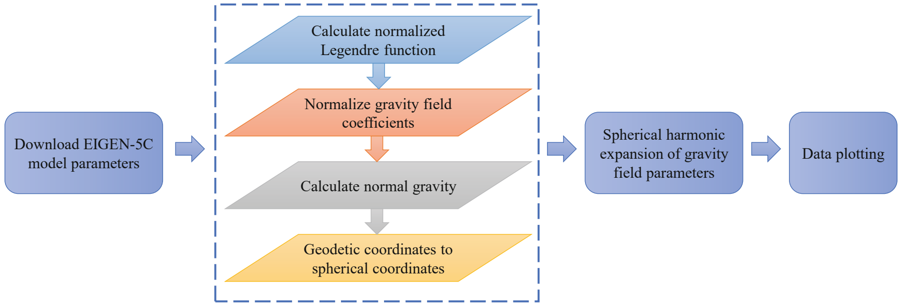

Fig. 1. Algorithm flow diagram.

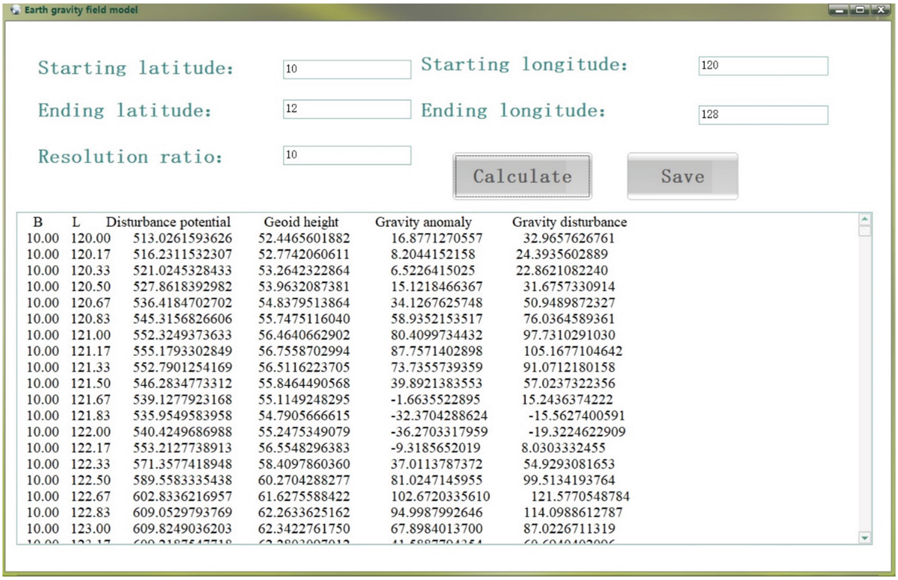

Fig. 2. Software interface.

3 Experiment and Verification

The self-developed software is used to calculate the parameters of the earth's gravity field. The software interface is shown in Fig. 2.

3.1 Inversion of Gravity Field Parameters at Global-Scale

EIGEN-5C model can get competitive results at a global-scale (resolution of 1°), as shown in Fig. 3.

It can be seen from Fig. 3 that the distribution of disturbance potential and geoid height is complex. It changes violently in the Pacific Rim seismic belt, Mediterranean Himalayan seismic belt, and seismic ridge belt. The maximum disturbance potential can

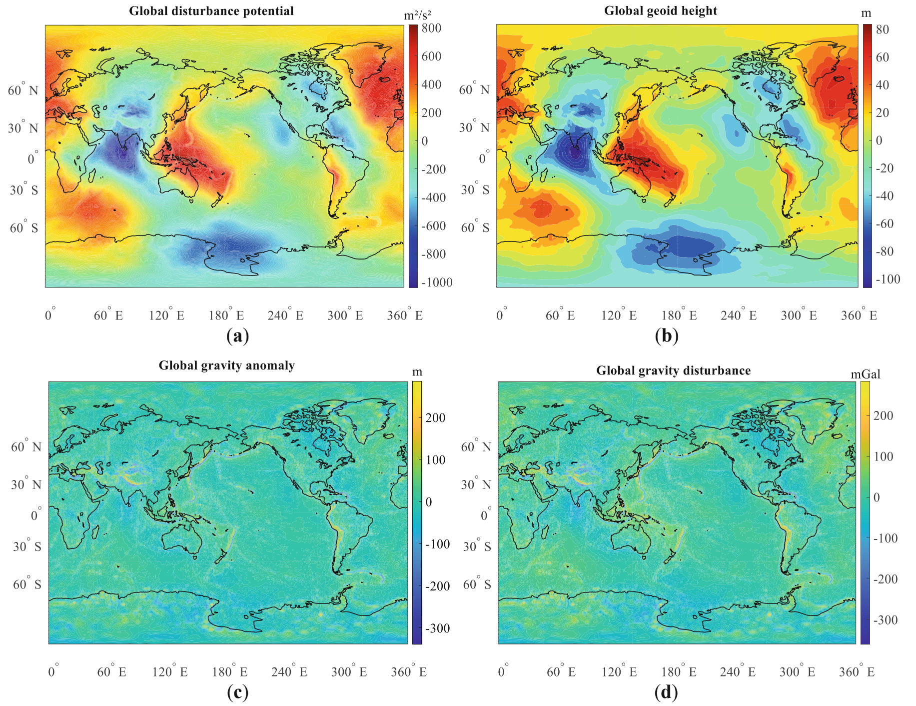

Fig. 3. Global gravity field parameters. (a) Global disturbance potential; (b) Global geoid height; (c) Global gravity anomaly; (d) Global gravity disturbance.

reach 819.3976 m^2/s^2, and the maximum geoid height can reach 83.7761 m. The lowest value appears in the sea area near the Maldives, of which the lowest value of disturbance potential is − 1040.7 m^2/s^2, and the lowest value of geoid height is − 106.3993 m. The distribution of gravity anomaly and gravity disturbance is relatively stable, and the value is relatively low. There are high values in the Qinghai Tibet region of China, Greenland, and the Andes mountains of South America. Among them, the maximum value of gravity anomaly is 289.7696 mgal, the maximum value of gravity disturbance is 285.9281 mgal, and the value around the seismic ridge belt is relatively low, in which the minimum value of gravity anomaly is − 338.6184 mgal, and the minimum value of gravity disturbance is − 360.0623 mgal. Among them, the larger values of gravity anomaly and gravity disturbance appear in the plate boundary zone, which clearly outlines the distribution of the eight plates, and further explains the correctness of the calculation results in this experiment.

3.2 Discussion

We extend the application of the EIGEN-5C model in calculating the earth's gravity field parameters to the numerical calculation of the global gravity field. From the calculation results, the disturbance potential and geoid height change violently in the Pacific Rim seismic belt, the Mediterranean Himalaya seismic belt, and the seismic ridge belt, with the highest values of 819.3976 m^2/s^2 and 83.7761 m, respectively, and the lowest values of − 1040.7 m^2/s^2 and − 106.3993 m respectively in the sea area near the Maldives. Gravity anomaly and gravity disturbance have the highest values in the Qinghai Tibet region of China, the Greenland rim, and the Andes mountains of South America. Their values are 289.7696 mgal and 285.9281 mgal, respectively. There are the lowest values around the seismic ridge belt, of which the lowest value of gravity anomaly is − 338.6184 mgal and the lowest value of gravity disturbance is − 360.0623 mgal. The calculation results of the following two indicators better reflect the distribution and junction of plates, which also shows the accuracy and correctness of the calculation results of this model and related software.

4 Conclusions

1. Based on the calculated data at the global-scale, we use Matlab to draw two-dimensional contour maps of different gravity field parameters at global -scale and make a quantitative and qualitative analysis of the images.
2. Using the 360 order EIGEN-5C gravity field model, the disturbance potential, geoid height, gravity anomaly, and gravity disturbance at global-scale are calculated.

5 Prospect

In this study, the EIGEN-5C model is used to carry out the inversion and result in the expression of the earth's gravity field parameters in global area. This work has a specific reference value for the field of gravity field parameter calculation and research, but limited to equipment factors, the accuracy of the calculation results of this study can be improved, and the calculation efficiency can be further improved.

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