Comparison of Present SST Gravity Field Models

LUO Jia  SHI Chuang  ZOU Xiancai  WANG Haihong

ABSTRACT  Taking the main land of Europe as the region to be studied, the potential of the new satellite gravity technique; satellite-to-satellite tracking (SST) and improving the accuracy of regional gravity field model with the SST models are investigated. The drawbacks of these models are discussed. With GPM98C as the reference, the gravity anomaly residuals of several other models, the latest SST global gravity field models (EIGEN series and GGM series), were computed and compared. The results of the comparison show that in the selected region, some systematic errors with periodical properties exist in the EIGEN and GGM’s S series models in the high degree and order. Some information that was not shown in the classic gravity models is detected in the low and middle degree and order of EIGEN and GGM’s S series models. At last, the effective maximum degrees and orders of SST models are suggested.

KEYWORDS  satellite-to-satellite tracking; gravity field; CHAMP; GRACE

Introduction

Since 2000, with the launch of CHAMP satellite, several series of high-accuracy and high-resolution static Earth’s gravity field models have been created based on abundant SST data. With these models, the research in solid geophysics, oceanography, and geodesy can be promoted greatly. In this paper, the SST gravity models’ accuracy in various frequently domain is studied. Firstly, the difference among these models is computed and compared, and then their accuracy is analyzed. Finally, the references for the investigation of Earth’s gravity field with SST data and relative science research are given.

1 SST Earth’s gravity field models

GeoForschungsZentrum (GFZ) Potsdam and Center for Space Research of Texas University (CSR) have released series static Earth’s gravity field models with more than 4 years’ SST data. GFZ owns the EIGEN series, including EIGEN_ CHAMP01S, EIGEN_ CHAMP02S, EIGEN_ CHAMP03S, EIGEN_ GRACE01S, EIGEN_ GRACE02S, and EIGEN_ CG01C. While CSR owns the GGM series, including GGM01S, GGM01C, GGM02S and GGM02C. These models were named by the rule that the last letter of each model denotes the data source (S: satellite data only; C: combination of satellite and ground data). Besides in each model name, the CHAMP denotes CHAMP data only, the GRACE means GRACE data only, and if GRACE and CHAMP data are combined, CG is used in the model name. The sequent number, such as 01, 02, 03, and so on expresses the version number of the model.

In Table 1, the main SST Earth’s gravity field models are listed. The table is summarized from the relative materials from GFZ and CSR. The valid degrees and orders are given in same models. The valid degree and orders of EIGEN_
CHAMP03S and GGM02S are all less than the calculated ones. Moreover, the accuracy of GRACE models is higher than the CHAMP's. The higher frequency of the models is decided by the ground data resolution and accuracy, and it goes beyond the SST system ability. For instance, in EIGEN.CG01C model the 30' × 30' ground data are used, so its wavelength is 55 km with the accuracy of 20 cm in geoid and 5 mGal in gravity anomaly. On the contrary, in GGM02C model, the 60' × 60' ground data are adopted, so the resolution is only 200 km. In the future, the SST model accuracy will be improved with the adoption of more and more SST data, but in higher degree part, the improvement is not obvious. For example, the GGM02S model was computed with 363 d data, and the EIGEN_GRACE02S model is calculated with only 110 d data. Although the data is treble and the accuracies are in the same level, the resolution increases from 275 km to 200 km. The accuracy of each model is shown in Table 1 and Fig. 1(a).  

| Table 1 Main SST gravity field models |
|---------------------------------------|
| Model                  | EIGEN.CHAMP03S | EIGEN_GRACE02S | EIGEN.CG01C | GGM02S | GGM02C |
| Degree                 | 120            | 150            | 360         | 160    | 200    |
| Valid degree           | 60             | -              | -           | 110    | -      |
| Data                   | CHAMP          | -              | -           | 860 d  | -      |
| GRACE                  | -              | 110 d          | 109 d       | 363 d  | 363 d  |
| Ground                 | -              | -              | 30' × 30'   | -      | 60' × 60' |
| Accuracy               | Geoid/m        | 0.05           | 0.01        | 0.20   | 0.01   |
| Anomaly/mGal           | 0.50           | -              | 5.00        | -      | -      |
| Wavelength/km          | 400            | 275            | 55          | 200    | 200    |

2 Analysis of Earth’s gravity field models

To study the accuracy of SST model, the reference model should be chosen. Two models, EGM96 and GPM98C, are selected in the analysis. EGM96 model is well known as one of most accurate 360 degree and order models. The geoid accuracy is better than 1 m throughout almost global area. And GPM98C was developed on the basis of EGM96, but the degree and order is 1 800. It has very high accuracy in European region. So the rectangle region (N35°-N55°, E0°-E30°) in Europe is selected. Seeing Fig. 2, on the left, the relative location of the region is shown. And on the right, the geoid of this region is shown as well. And then, the full degree and order gravity anomaly of each model are calculated and shown in Fig. 3. Because the resolutions of these models are not uniform, the comparisons are implemented in the same degree and order. In Fig. 3, it could be found that EIGEN.CG01C, EGM96, GPM98C and GGM02C are alike except the resolution.

For the compatibility, the GPM98C and EGM96 are truncated in 360 and 200 degree and order. In the comparison, 9 882 grid points are used, and the statistics are listed in Table 2. According to above rule, the difference pictures are shown in Fig. 4, and the statistics of 150 degree and order are listed in Table 3. The
difference between EGM96 and GPM98C is too small to see. And EIGEN\_GRACE02S is more coincident than GGM02S related to GPS98C or EGM96.
Table 3  Statistics of gravity anomaly difference.

| Degree | EGM96-GPM98C | EIGEN_GRACE02S-GPM98C | GGM02S-GPM98C |
|--------|---------------|------------------------|---------------|
| Mean   | 0.000         | -0.146                 | -0.071        |
| STD    | 0.000         | 10.067                 | 12.140        |

In Fig. 5, some interesting phenomena are presented. More than 110 degree and order, the differences between SST model and EGM96 or GPM98C have some systematic errors with periodical properties. To magnify the periodical events, 7 lines are chosen at random. 3 (N35°, N45° and N55°) are latitude along, while 4 (E0°, E10°, E20° and E30°) are longitude along. In Fig. 6, the periodical properties on the longitude along are not obvious with some irregular characteristic. On the contrary, the periodical properties on the latitude along are sharp, and the amplitude is about ±30 mGal. In author’s point of view, this is caused by that the present SST data’s resolution could not reach 150 or 160 degree. The latter analysis would prove the presumption.

Fig. 5  Gravity anomaly differences, 150 degree

Fig. 6  Difference of along latitude (top 3, N35°, N45° and N55°) and along longitude (bottom 4, E0°, E10°, E20° and E30°)

In GGM02S model report, there was a suggestion that the coefficients higher than 110 degree not be used. Refer to the actual analysis result, the GGM02S model with less than 110 degree shows better properties. In spite of no relative guide in EIGEN_GRACE02S model report, the result shows that the model is not very good with even 110 degree.

Because the GPM98C is almost the same as EGM96 in the low degree, the EGM96 will be regarded as the reference model’s in the next analyses.

In Fig. 7, some areas (for example, at N46°, E10° and N45°, E22°) are positive difference referred to EGM96. This may be caused by the SST model’s error. Alternatively, Fig. 7 shows that the SST model may display gravity signal more detailedly than the EGM96. It needs further studying to explain this phenomenon. In Table 4, the statistics of 9882 grid points are given. Integrating Fig. 7 and Table 4, present GRACE series models are coherent with EGM96 in less than 110 degree, and present CHAMP series models are coherent with EGM96 in less than 60 degree. As a result, the valid degree and order of each SST model are given in Table 5.
Fig. 7 Gravity anomaly differences, degree and order 110 ((a)-(e)) and 60 ((f)-(j))

Table 4 Statistics of gravity anomaly difference, degree and order 110 and 60/mGal

| Basis          | EIGEN_CHAMP03S-EGM96 | EIGEN_GRACE02S-EGM96 | GGM02S-EGM96 | EIGEN_CHAMP03S-EGM96 | GGM02S-EGM96 |
|----------------|----------------------|----------------------|--------------|----------------------|--------------|
| Mean in 110 degree | 0.129 7              | -0.058 3             | -0.101 7     | -0.071 4             | -0.043 4     |
| STD in 110 degree  | 15.458 1             | 3.345 9              | 3.297 5      | 16.211 0             | 0.952 5      |
| Mean in 60 degree  | -0.003 5             | -0.058 8             | -0.064 1     | 0.055 3              | -0.005 3     |
| STD in 60 degree   | 2.192 4              | 2.119 9              | 2.120 6      | 0.652 7              | 0.036 3      |

Table 5 Valid degree and order of main SST gravity field models

| Model            | Degree | Valid degree |
|------------------|--------|--------------|
| EIGEN_CHAMP03S   | 120    | 60           |
| EIGEN_GRACE02S   | 150    | 110          |
| EIGEN_CG01C      | 360    | 360          |
| GGM02S           | 160    | 110          |
| GGM02C           | 200    | 200          |

3 Conclusions

1) At the higher frequency part of SST models, SST’s C series model are coincident with EGM96 or GPM98C. It should attribute to that the ground data from the same source are adopted.

2) The given degree and order of each SST model are not proper. These SST model should be truncated to appropriate degree referring to Table 5 in application.

3) According to above study, the SST missions (CHAMP, GRACE and pending missions) can provide more abundant data to refine the medium and long wavelength parts of the gravity model.

REFERENCES

[1] Tapley B, Ries S, Bettadpur D, et al. (2005) GGM02: an improved Earth gravity field model from GRACE[J]. Journal of Geodesy, 79(8):467-478

[2] Reigber C, Schmidt R, Flechtner F, et al. (2005) An Earth gravity field model complete to degree and order 150 from GRACE: EIGEN-GRACE02S[J]. Journal of Geodynamics, 39(1):1-10

[3] Lemoine F G, Kenyon S C, Factor J K, et al. (1998) The development of the Joint NASA GSFC and NIMA geopotential model EGM96[R]. NASA Goddard Space Flight Center, Greenbelt, Maryland

[4] Wenzel G (1998) Ultra high degree geopotential models GPM98A, B and C to degree 1 800[C]. Joint Meeting of the International Gravity Commission and International Geoid Commission, Trieste