Evaluation of the Earth Gravitational Model 2008 using GPS-Leveling and Gravity data in China

Jiancheng Li, Jinsheng Ning, Dingbo Chao, Weiping Jiang

The Key Laboratory of Geospace Environment and Geodesy, Ministry of Education
School of Geodesy and Geomatics, Wuhan University, 129 Luoyu Road, Wuhan 430079, China
E-mail: jcli@whu.edu.cn; Tel: +86-27-68778801; Fax: +86-27-68778371

Abstract

The evaluation of both PGM07A and EGM08 has been carried out in China using the observed data sets and high resolution regional geoid models including the observations of 652 GPS/Leveling points within Chinese national A/B-order GPS networks and 1160 GPS/Leveling points distributed over seven provincial regions, as well as the data sets of 183201 2′×2′ gridded mean gravity anomalies collected from five provincial regions. In the evaluation of PGM07A and EGM08, the other recent released Earth Geopotential Models (EGMs) including EIG01C, EIG03C, EIG04C, GGM01C, GGM02C, GGM01C* and GGM02C* are also used for comparisons.

The statistic results of the comparisons show that the RMS and Std.D of the differences between the quasi-geoid heights derived from PGM07A/EGM08 and their corresponding ones determined from the GPS/Leveling data of 652 A/B-order testing points are ±0.358m, ±0.338m for PGM07A, and ±0.284m, ±0.257m for EGM08 respectively, which are remarkably less than the RMS and Std.D corresponding to the other EGMs used in the comparisons. The RMS and Std.D of the differences between the quasi-geoid heights derived from PGM07A/EGM08 and their corresponding ones determined from the GPS/Leveling data of total 1160 points in seven provincial networks are in the range of ±0.09m ~±0.31m with a mean of ±0.19m for PGM07A, and ±0.07m ~±0.24m with a mean of ±0.16m for EGM08. For the other seven EGMs, however, the corresponding range of the statistics is ±0.26m ~±0.80m with a mean of ±0.44m. The comparisons of the quasi-geoid derived from PGM07A and EGM08 as well as the other EGMs with those determined from the GPS/Leveling data of all 1812 points within both A/B-order GPS/Leveling networks and seven provincial ones are also made. The RMS and Std.D of the differences obtained from the comparisons are ±0.269m, ±0.243m for

PGM07A, ±0.222m, ±0.186m for EGM08, respectively, and for the other seven EGMs, the corresponding statistics are in the range of ±0.375m ~±0.680m. The results of comparisons above show that the quasi-geoid derived from PGM07A and EGM08 can provide a better approximation to the quasi-geoids determined from Chinese GPS/Leveling data including both the data of national A/B-order networks and the data of provincial GPS/leveling networks than an approximation to the same quasi-geoids provided by the quasi-geoids derived from the other seven EGMs. According to all statistical results of comparisons between the EGMs-derived quasi-geoids and GPS/Leveling based ones, however, EGM08 is better than PGM07A as applied in Chinese mainland. The quasi-geoid heights derived from EGM08 are more accurate than those derived from PGM07A by a range of ±0.01m ~±0.07m with an average of ±0.03m in the RMS and Std.D of comparisons.

In addition, the comparisons of gravity anomalies derived from PGM07A and EGM08 with those measured in five provincial regions are made, and the statistical results of the comparisons show that the RMS and Std.D of the differences between PGM07A/EGM08-derived gravity anomalies and those measured in the regions are within the range of ±13 ~29 mGal, with a mean of ±18 mGal. It also indicates that the gridded mean anomalies derived from EGM08 are more accurate than those derived from PGA07 by a range of ±1~4 mGal with a mean of ±2.7 mGal in the RMS and Std.D comparison.

In the general, the quasi-geoid and gravity anomalies computed from PGM07A and EGM08 have significantly improved the representation of the Chinese local gravity field as compared with the other seven models used in the evaluation. However, our testing results show that for both EGM08 and PGM07, there are some large (or small) biases of the quasi-geoids which deviate from the general level of the biases in some regions.

1. Introduction

Since 2004, the National Geospatial-Intelligence Agency (NGA) of the USA has embarked upon the development of a new Earth Gravitational Model (EGM) to support future realizations of NGA’s World Geodetic System (Pavlis et al, 2004), and NGA along with its partner SGT, Inc. has been leading an effort to develop a Preliminary Gravitational Model (PGM) series in yearly succession including PGM04A through PGM07A complete to degree and order 2160 or higher degree. The PGM07A complete to degree 2190 and order 2160, which is to be used as reference model in a last iteration leading to the final EGM, has been provided to geodetic community and related earth scientists only for evaluation of the PGM. Now the final EGM, i.e. EGM08, has been completed in the early 2008, so PGM07A along with EGM08 need to be evaluated according to the information from a meeting held in Chania, Greece in June of 2008.

The IAG/IGFS Joint Working Group (JWG) is commissioned for the organization and guidance of the evaluation affairs. This report will present an evaluation of the models PGM07A and EGM08 by use of the GPS/Leveling and the terrestrial gravity data within the Chinese territory. We adopt the evaluation methods and some necessary ancillary models/information for the quality assessment of the PGM and the EGM including the computational models, geodetic parameters, as well as software, etc., provided by JWG. In this report, the testing for the evaluation of PGM07 and EGM08 is focused on two kinds of data comparisons, i.e. GPS/Leveling data and terrestrial gravity anomaly data in China. However, besides PGM07A and EGM08, some recent released satellite combined gravitational models including two series of EIGEN01-04C and GGM01-02C are also included in the comparisons.

2. Data used for the evaluation

2.1 GPS/Leveling data

(1) National data

652 GPS/Leveling points within Chinese national A/B-order GPS networks are used for the evaluation of PGM07A and EGM08, among the points, 28 A-order points and 624 B-order points are included, respectively (see Fig. 1). The A-order GPS campaign was carried out during two separately operational periods, i.e. in 1992 and in 1996. The GPS results are referred to ITRF93 at epoch 1996.365 and WGS84. The mean accuracy of GPS ellipsoidal heights at B-order GPS points is about 0.10m. The leveling at the A/B order GPS points, referred to the China Yellow Mean Sea Level 1985 Datum, was performed before the period of GPS campaigns, and the mean accuracy of the normal heights derived from the leveling is better than the level of 0.10m. Finally, the mean accuracy of the height anomalies (quasi-geoid heights) derived from the GPS/Leveling is the level of 0.14m.

Fig. 1 The distribution of 652 national A/B-order GPS/Leveling points

(2) Provincial data

Seven regional GPS/Leveling data sets collected from the provincial regions including Gansu, Guangdong, Guangxi, Hebei, Jiangsu, Qinghai and Shanxi, are used for the tests and evaluation (see Fig. 2). The total number of the regional GPS/Leveling points is 1160, and the mean accuracy of the GPS/Leveling-derived quasi-geoid heights from the data sets is the level of 0.05m. The GPS ellipsoidal heights are also referred to WGS84. The information about the regional GPS/Leveling points in detail is shown in Table 1.

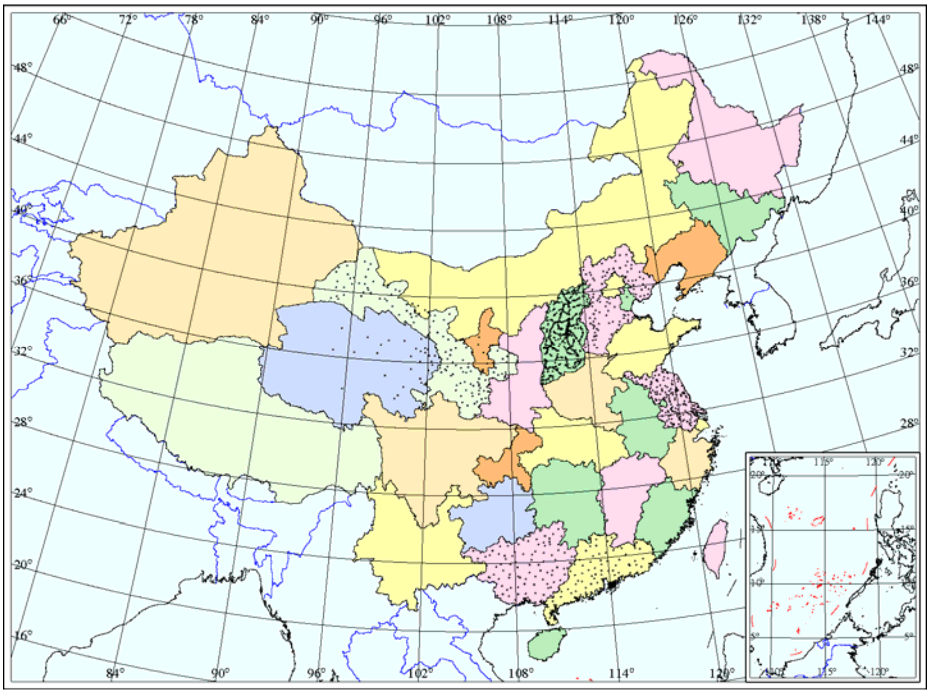

Fig. 2 The distribution of the provincial GPS/Leveling points

Table 1. The number of GPS/leveling points for each provincial region

province	Gansu	Guangdong	Guangxi	Hebei	Jiangsu	Qinghai	Shanxi	total
number	131	88	94	114	177	31	525	1160

2.2 Digital Terrain Model (DTM)

The digital terrain models with 3″×3″ resolution generated from SRTM (Shuttle Radar Topography Mission) are used for provincial gravity reductions.

2.3 Terrestrial gravity data

Five regional terrestrial point gravity data sets are used for the evaluation, which are distributed over five provincial regions including Gansu, Guangdong, Guangxi, Qinghai and Shanxi. The total number of the gravity point values used is 746,135, which were tied to IGSN71 gravity datum, but their accuracies in detail are not clear enough. The method of topographic-isostatic gravity reduction is adopted for generating high-resolution gridded mean free air gravity anomaly set on the Earth's surface based on remove-restore principle and an approach of interpolation/extrapolation (*Heiskanen W.A. & H. Moritz, 1967*). In the gravity reduction computations, a spherical integral formula taking account of the Earth's curvature is used for both terrain corrections and isostatic compensation corrections with the SRTM 3″×3″ DTM. The related information for the provincial data sets is shown in Table 2.

Table 2. The number of the terrestrial gravity point values for each provincial region

Province	Gansu	Guangdong	Guangxi	Qinghai	Shanxi	total
Number	55,467	417,336	28,372	213,862	31,098	746,135

3. Quasi-geoid comparisons

Hereafter, the comparisons are to compute the differences of observed values minus corresponding model ones.

3.1 National GPS/Leveling-derived quasi-geoid vs. quasi-geoids derived from PGM07A, EGM08 and other EGMs

The observed quasi-geoid heights are computed at all testing points in national A/B-order GPS/Leveling networks, and the corresponding model ones are derived from the Earth gravitational models, including PGM07A, EGM08 and some recent released models derived from the data of satellite and terrestrial gravity (EIG01C, EIG03C, EIG04C, GGM01C, GGM02C, GGM01C*, and GGM02C*). The results of the comparisons are tabulated in Table 3. From Table 3, we can see that the RMS and Std.D of the differences between the quasi-geoid heights derived from the EGMs (PGM07A and EGM08) and their corresponding observed ones determined from the data of GPS/Leveling at 652 A/B order testing points are ±0.358m and ±0.338m for PGM07A, ±0.284m and ±0.257m for EGM08, respectively, which are remarkably better than the RMS and Std.D corresponding to the other seven models used in the tests. For the latter models, the order of magnitude is in the range ±0.499m to ±0.764m with a mean of ±0.584m (RMS) and ±0.435m to ±0.699m with a mean of ±0.521m (Std.D), respectively. The result of the above comparisons shows that the accuracy of PGM07A-derived quasi-geoid as applied in China in the sense of its approximation to the observed quasi-geoid by GPS/Leveling, is significantly improved by about 0.2 m versus the recent released combined satellite EGMs, and the accuracy of EGM08-derived quasi-geoid is higher than that of PGM07A-derived one by about 0.08m.

Table 3. The statistics of the comparisons of the quasi-geoid heights derived from PGM07A/EGM08 and the other EGMs with those determined from the GPS/Leveling data of 652 A/B-order points (Unit: m)

Model	Max	Min	Bias	RMS	Std. D
EIG01C	1.670	-2.314	-0.250	±0.527	±0.464
EIG03C	1.670	-2.020	-0.250	±0.502	±0.435
EIG04C	1.805	-2.262	-0.247	±0.504	±0.439
GGM01C	1.408	-3.221	-0.249	±0.596	±0.541
GGM02C	1.788	-2.539	-0.236	±0.499	±0.440
GGM01C*	2.903	-4.730	-0.308	±0.764	±0.699
GGM02C*	3.295	-4.048	-0.296	±0.695	±0.629
PGM2007A	1.989	-2.441	-0.117	±0.358	±0.338
EGM2008	1.641	-1.886	-0.121	±0.284	±0.257

3.2 Provincial GPS/Leveling-based quasi-geoids vs. quasi-geoids derived from PGM07A, EGM08 and the other EGMs

Comparisons of the quasi-geoid heights derived from PGM07A and EGM08 as well as the other seven EGMs used in the evaluation with those determined based on the GPS/Leveling data of the regional networks are performed. The statistic results of the comparisons are shown in Table 4 ~ Table10.

These tables show that the RMS and Std.D of the differences between PGM07-derived quasi-geoid heights and the corresponding GPS/Leveling-based ones are in the range ±0.107m to ±0.309m with a mean of ±0.214m (RMS) and ±0.090m to ±0.308m with a mean of ±0.172m (Std.D), respectively; for EGM08, the corresponding RMS and Std.D are in the range ±0.099m to ±0.238m with a mean of ±0.188m (RMS) and ±0.073m to ±0.237m with a mean of ±0.138m (Std.D), respectively; for the other seven EGMs used in the evaluation, the corresponding RMS and Std.D are in the range ±0.263m to ±0.805m with a mean of ±0.439m (RMS) and ±0.190m to ±0.740m with a mean ±0.373m (Std.D).

According to these tables and the above simple statistical analyses, Firstly, we can see that the quasi-geoids derived from both PGM07A and EGM08 can provide a better approximation to those determined by the GPS/Leveling data of provincial networks than the approximation provided by the quasi-geoids derived from the other seven EGMs used in the comparisons, with respect to the order of magnitude of the improved approximation, for PGM07A, it is the level of 0.21m in both RMS and Std.D on an average; for EGM08, is 0.24m in both RMS and Std.D on an average. We can also see that EGM08 is better than PGM07A. The statistical results of the differences between EGM08-derived quasi-geoid heights and the corresponding provincial GPS/Leveling-based ones are smaller than the corresponding statistical results for PGM07A by the level of 0.03m in both RMS and Std.D on average, however, in the provincial regions such as Gansu, Jiangsu and Qinghai, the results for EGM08 are much less than the corresponding results to PGM07A by the level of 0.06m in both RMS and Std.D on an average.

Secondly, the results show that the statistics (RMS, Std.D) of the differences between the PGM07A or EGM08-derived quasi-geoid and the provincial GPS/Leveling-based quasi-geoid are smaller than those between PGM07A or EGM08-derived quasi-geoid and the national A/B-order GPS/Leveling-based quasi-geoid by about 0.1~0.2m on average(comparing Table 3 with Table 4~10), for this case, one reason is the fact that the density of provincial GPS/Leveling points is higher than that of the used A/B-order GPS/Leveling points, and the mean accuracy of the former is also higher than the latter, and other causes may be included; Thirdly, the comparisons also indirectly show that the accuracies of the quasi-geoids determined from the data of GPS/Leveling in the networks of three provinces, i.e. Guangdong, Guangxi and Shanxi, are higher than the accuracies of those in the networks of the other provinces by about the level of 0.1~0.2m; Finally, the biases between all EGM-derived quasi-geoids and GPS/Leveling-based ones in some regions are stably within about -0.1~-0.2m.

Table 4. The statistics of the comparisons of the quasi-geoid heights from PGM07A/EGM08 and other EGMs with those from GPS/Leveling (131 points) in Gansu (Uint: m)

Model	**Max**	**Min**	**Bias**	**RMS**	**Std. D**
EIG01C	0.717	-1.283	-0.268	±0.495	±0.417
EIG03C	0.620	-1.330	-0.252	±0.479	±0.407
EIG04C	0.662	-1.270	-0.228	±0.456	±0.395
GGM01C	0.988	-1.678	-0.211	±0.535	±0.491
GGM02C	0.636	-1.077	-0.205	±0.421	±0.368
GGM01C*	1.509	-2.399	-0.234	±0.776	±0.740
GGM02C*	1.282	-2.121	-0.227	±0.672	±0.632
PGM2007A	0.734	-0.491	-0.069	±0.229	±0.219
EGM2008	0.663	-0.502	-0.077	±0.184	±0.167

Table 5. The statistics of the comparisons of the quasi-geoid heights from PGM07A/EGM08 and the other EGMs with those from GPS/Leveling (88points) in Guangdong (Unit: m)

Model	Max	Min	Bias	RMS	Std. D
EIG01C	0.583	-0.780	-0.157	±0.301	±0.257
EIG03C	0.576	-0.749	-0.177	±0.321	±0.268
EIG04C	0.458	-0.825	-0.194	±0.322	±0.257
GGM01C	0.760	-0.817	-0.148	±0.391	±0.362
GGM02C	0.376	-0.739	-0.186	±0.316	±0.256
GGM01C*	0.699	-0.859	-0.148	±0.358	±0.326
GGM02C*	0.546	-0.763	-0.186	±0.336	±0.279
PGM2007A	0.142	-0.369	-0.154	±0.179	±0.090
EGM2008	0.131	-0.416	-0.163	±0.186	±0.091

Table 6. The statistics of the comparisons of the quasi-geoid heights from PGM07A/EGM08 and the other EGMs with those from GPS/Leveling (94points) in Guangxi (Unit: m)

Model	Max	Min	Bias	RMS	Std. D
EIG01C	0.478	-0.718	-0.130	±0.263	±0.228
EIG03C	0.292	-0.635	-0.119	±0.264	±0.236
EIG04C	0.500	-0.615	-0.131	±0.274	±0.240
GGM01C	1.121	-0.917	-0.147	±0.396	±0.367
GGM02C	0.520	-0.686	-0.129	±0.265	±0.231
GGM01C*	0.948	-1.087	-0.148	±0.403	±0.375
GGM02C*	0.536	-0.857	-0.130	±0.299	±0.270
PGM2007A	0.140	-0.485	-0.051	±0.107	±0.094
EGM2008	0.107	-0.275	-0.066	±0.099	±0.073

Table 7. The statistics of the comparisons of the quasi-geoid heights from PGM07A/EGM08 and the other EGMs with those form GPS/Leveling (114points) in Hebei (Unit: m)

Model	Max	Min	Bias	RMS	Std. D
EIG01C	0.529	-0.832	-0.158	±0.355	±0.318
EIG03C	0.598	-1.004	-0.168	±0.385	±0.347
EIG04C	0.616	-0.930	-0.160	±0.366	±0.329
GGM01C	0.854	-0.898	-0.129	±0.464	±0.446

GGM02C	0.568	-0.903	-0.178	±0.373	±0.328
GGM01C*	0.895	-0.917	-0.174	±0.429	±0.393
GGM02C*	0.581	-0.921	-0.223	±0.388	±0.317
PGM2007A	0.131	-0.721	-0.142	±0.224	±0.174
EGM2008	0.136	-0.690	-0.160	±0.231	±0.167

Table 8. The statistics of the comparisons of the quasi-geoid heights from PGM07A/EGM08 and the other EGMs with those from GPS/Leveling (117points) in Jiangsu (Unit: m)

Model	Max	Min	Bias	RMS	Std. D
EIG01C	0.360	-0.820	-0.191	±0.344	±0.285
EIG03C	0.228	-0.719	-0.195	±0.272	±0.190
EIG04C	0.341	-0.681	-0.181	±0.282	±0.216
GGM01C	0.313	-0.909	-0.223	±0.351	±0.271
GGM02C	0.291	-0.741	-0.202	±0.284	±0.199
GGM01C*	0.447	-0.919	-0.219	±0.360	±0.285
GGM02C*	0.449	-0.754	-0.198	±0.307	±0.235
PGM2007A	0.366	-0.714	-0.213	±0.288	±0.194
EGM2008	0.268	-0.634	-0.190	±0.237	±0.140

Table 9. The statistics of the comparisons of the quasi-geoid heights from PGM07A/EGM08 and the other EGMs with those from GPS/Leveling (31points) in Qinghai (Unit: m)

Model	Max	Min	Bias	RMS	Std. D
EIG01C	0.510	-1.493	-0.323	±0.524	±0.412
EIG03C	0.458	-1.327	-0.257	±0.466	±0.389
EIG04C	0.538	-1.377	-0.305	±0.512	±0.411
GGM01C	1.011	-1.631	-0.337	±0.665	±0.573
GGM02C	0.798	-1.454	-0.305	±0.538	±0.443
GGM01C*	0.655	-1.801	-0.457	±0.805	±0.663
GGM02C*	0.442	-1.475	-0.425	±0.669	±0.516
GGM01S	2.085	-1.828	-0.429	±0.956	±0.854
GGM02S	2.876	-3.331	-0.421	±1.595	±1.539
PGM2007A	0.674	-0.747	0.021	±0.309	±0.308
EGM2008	0.585	-0.511	-0.015	±0.238	±0.237

Table 10. The statistics of the comparisons of the quasi-geoid heights from PGM07A/EGM08 and the other EGMs with those from GPS/Leveling (525points) in Shanxi (Unit: m)

Model	Max	Min	Bias	RMS	Std. D
EIG01C	0.822	-1.342	-0.301	±0.520	±0.424
EIG03C	0.635	-1.327	-0.304	±0.496	±0.391
EIG04C	0.618	-1.308	-0.307	±0.504	±0.400
GGM01C	0.785	-1.495	-0.350	±0.548	±0.421
GGM02C	0.703	-1.271	-0.285	±0.467	±0.370
GGM01C*	1.370	-1.966	-0.378	±0.760	±0.660
GGM02C*	1.196	-2.115	-0.313	±0.726	±0.655
PGM2007A	0.375	-0.375	-0.098	±0.160	±0.127
EGM2008	0.343	-0.368	-0.107	±0.140	±0.090

3.3 Overall comparisons

The overall comparisons of the quasi-geoids derived from PGM07A and EGM08 as well as the other seven EGMs with those determined from the data of GPS/Leveling of all used 1812 points distributed in the whole Chinese mainland are made. The distribution of the differences of the comparisons is plotted in Fig. 3a and Fig. 3b. The statistic results of the comparisons are shown in Table 11. From this table, we can see that the corresponding statistical results (RMS, Std.D) of the comparisons are better than those listed in Table 3, but somewhat worse than those listed in Table 4 ~ Table 10.

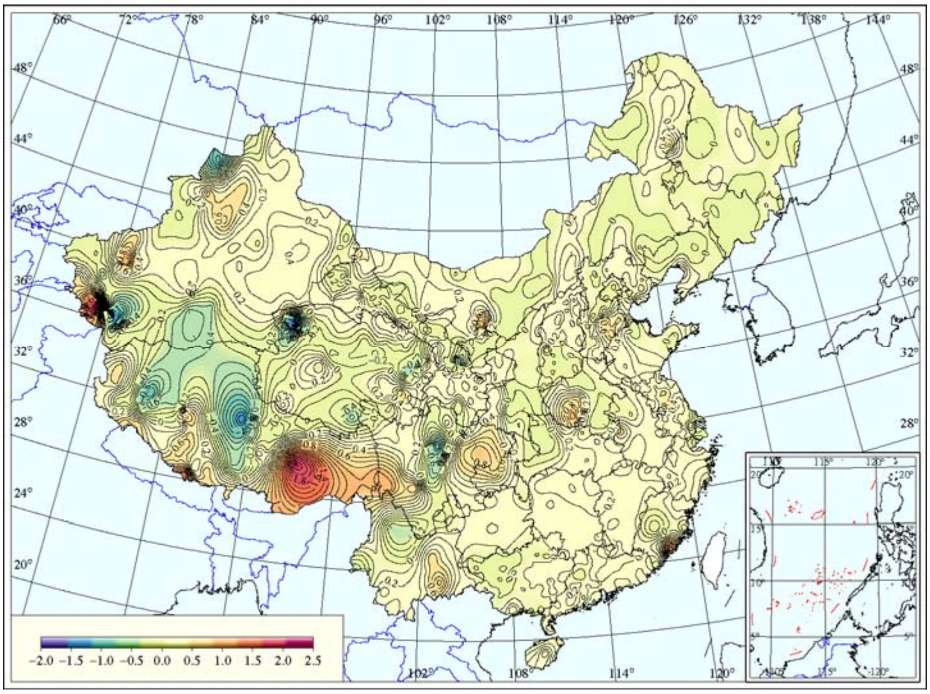

Fig. 3a The differences of the comparisons with PGM07A (Unit: m)

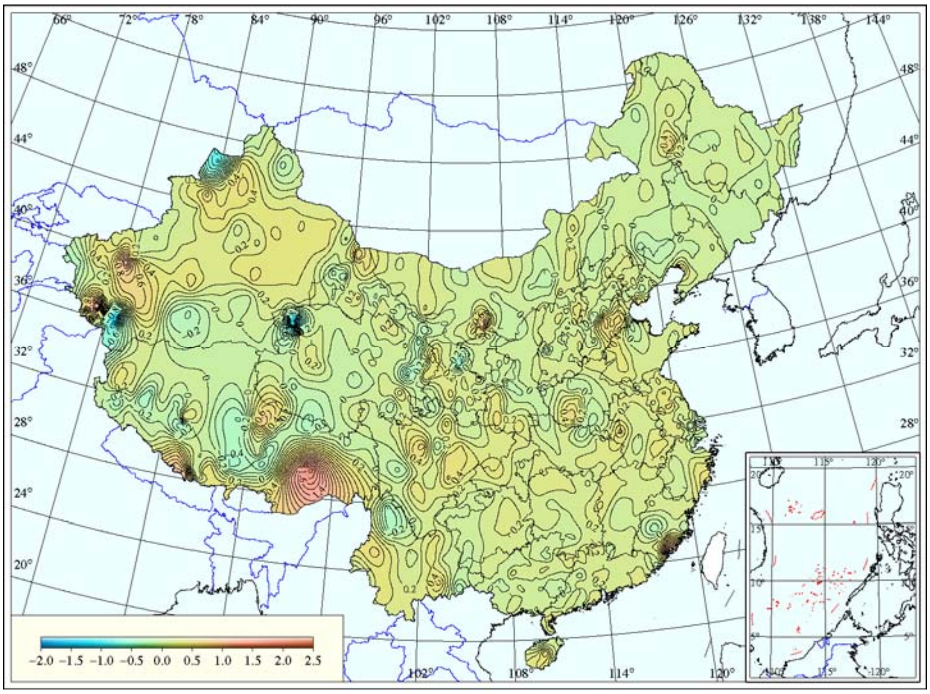

Fig. 3b The differences of the comparisons with EGM08 (Unit: m)

Table 11. The statistics of the overall comparisons of the quasi-geoids from PGM07A/EGM08 and the other EGMs with those from all 1812 used GPS/Leveling in Chinese mainland (Unit: m)

Model	Max	Min	Bias	RMS	Std. D
EIG01C	1.670	-2.314	-0.245	±0.478	±0.410
EIG03C	1.670	-2.020	-0.245	±0.455	±0.384
EIG04C	1.805	-2.262	-0.243	±0.458	±0.388
GGM01C	1.408	-3.221	-0.257	±0.533	±0.467
GGM02C	1.788	-2.539	-0.234	±0.443	±0.375
GGM01C*	2.903	-4.730	-0.292	±0.686	±0.621
GGM02C*	3.295	-4.048	-0.270	±0.629	±0.568
PGM2007A	1.989	-2.441	-0.115	±0.269	±0.243
EGM2008	1.641	-1.886	-0.120	±0.222	±0.186

4. Gravity anomaly comparisons

The comparisons of PGM07A/EGM08-derived free air gravity anomalies with those in-situ measurements in the five provincial regions are made using 2'×2' gridded mean value data sets. The distribution of the differences between PGM07A/EGM08-derived gridded mean free air gravity anomalies and those corresponding gridded observation values in the regions is shown in Fig. 4 ~ Fig. 8 respectively. The statistics of the comparisons with total 183201 gridded values are listed in Table 12.

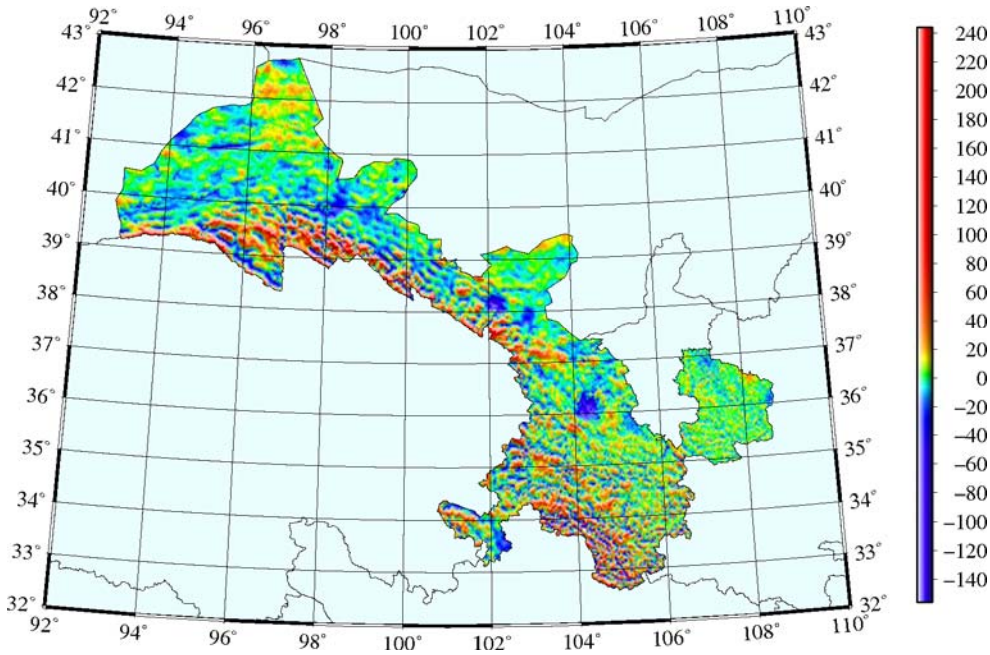

Fig. 4a The differences between 2'×2' gridded free-air gravity anomalies from PGM07A and the corresponding observation values in Gansu province region (Unit: mGal)

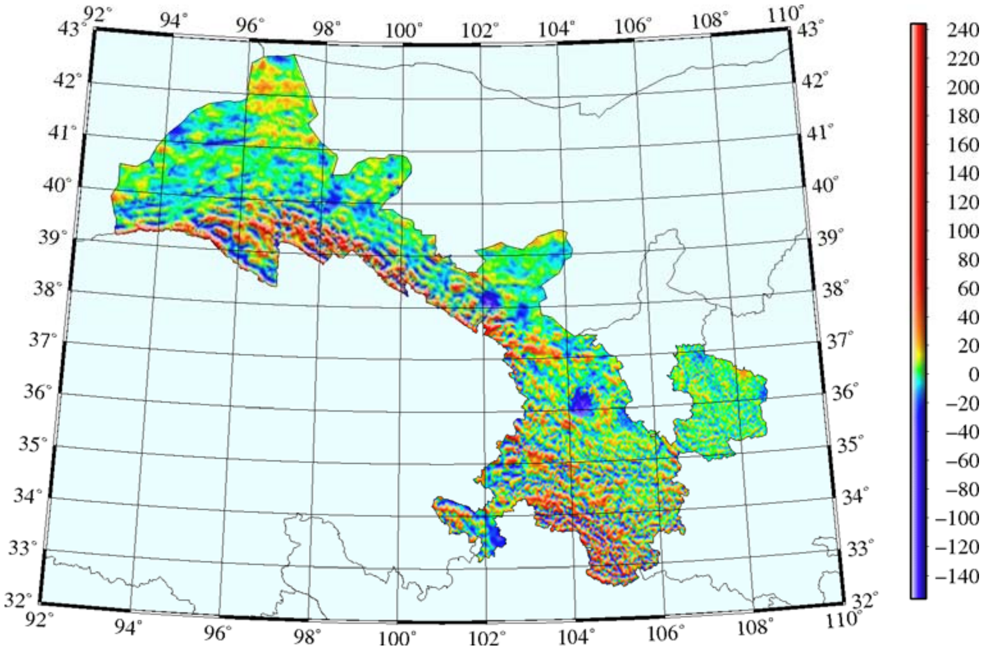

Fig. 4b The differences between 2'×2' gridded free-air gravity anomalies from EGM08 and the corresponding observation values in Gansu province region (Unit: mGal)

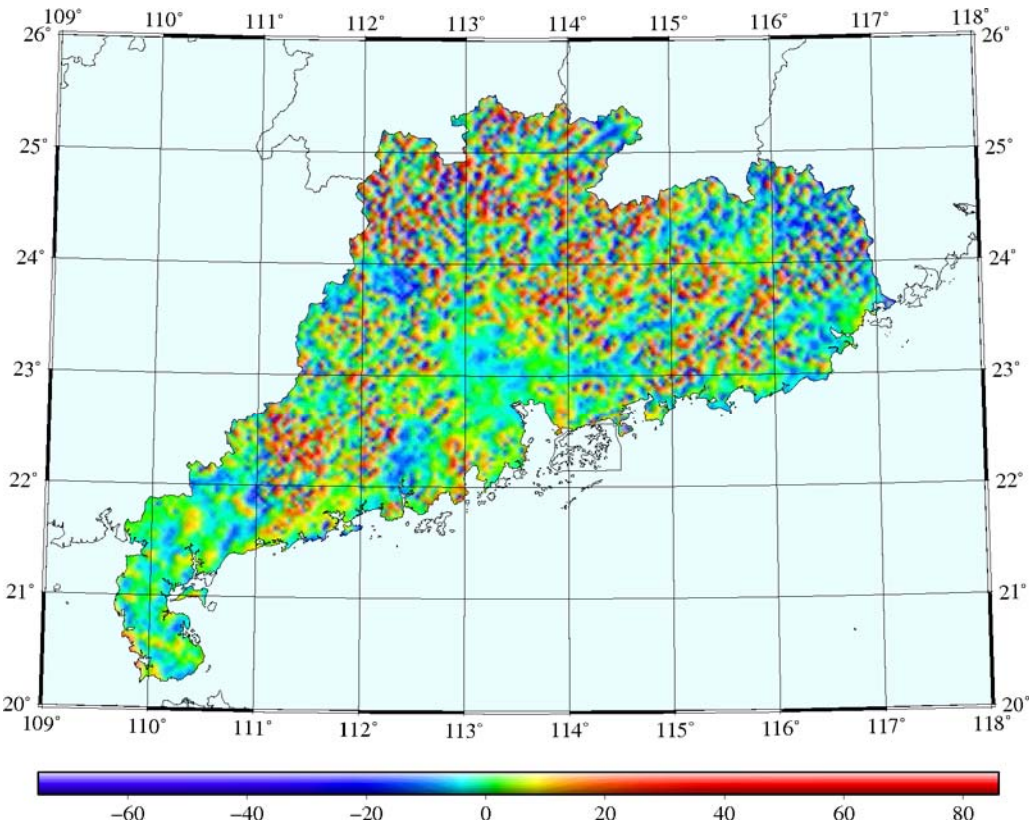

Fig. 5a The differences between 2'×2' gridded free-air gravity anomalies from PGM07A and the corresponding observation values in Guangdong province region (Unit:

mGal)

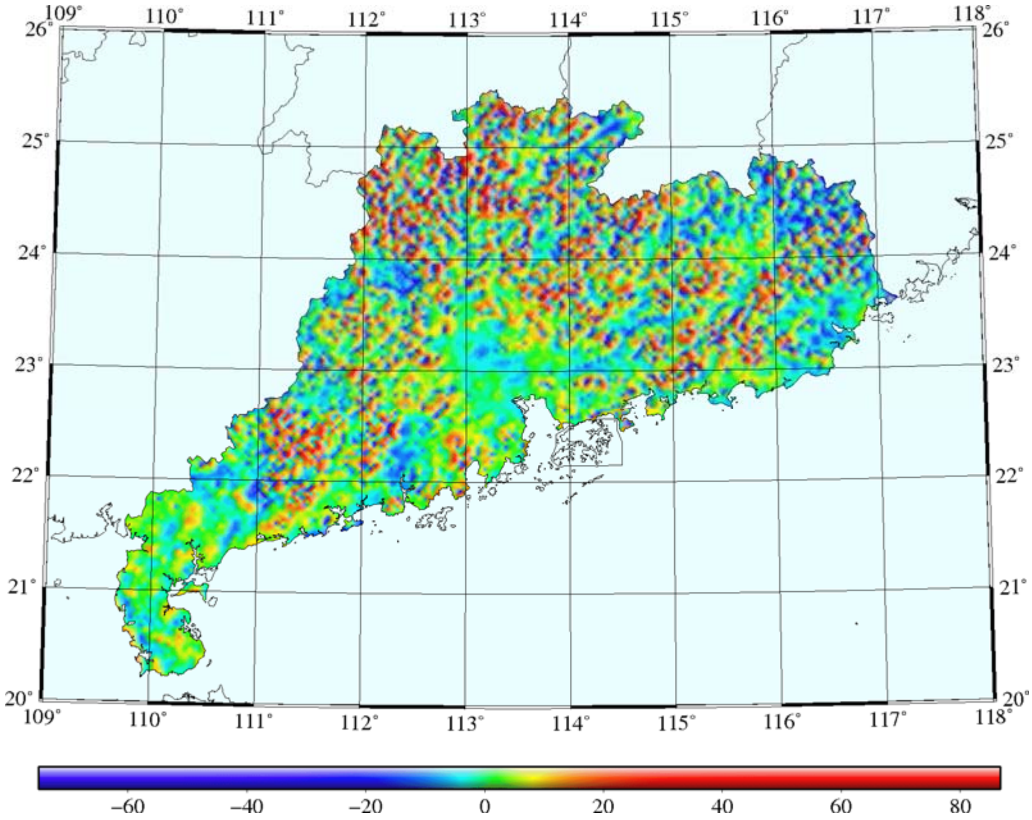

Fig. 5b The differences between 2'×2' gridded free-air gravity anomalies from EGM08 and the corresponding observation values in Guangdong province region (Unit: mGal)

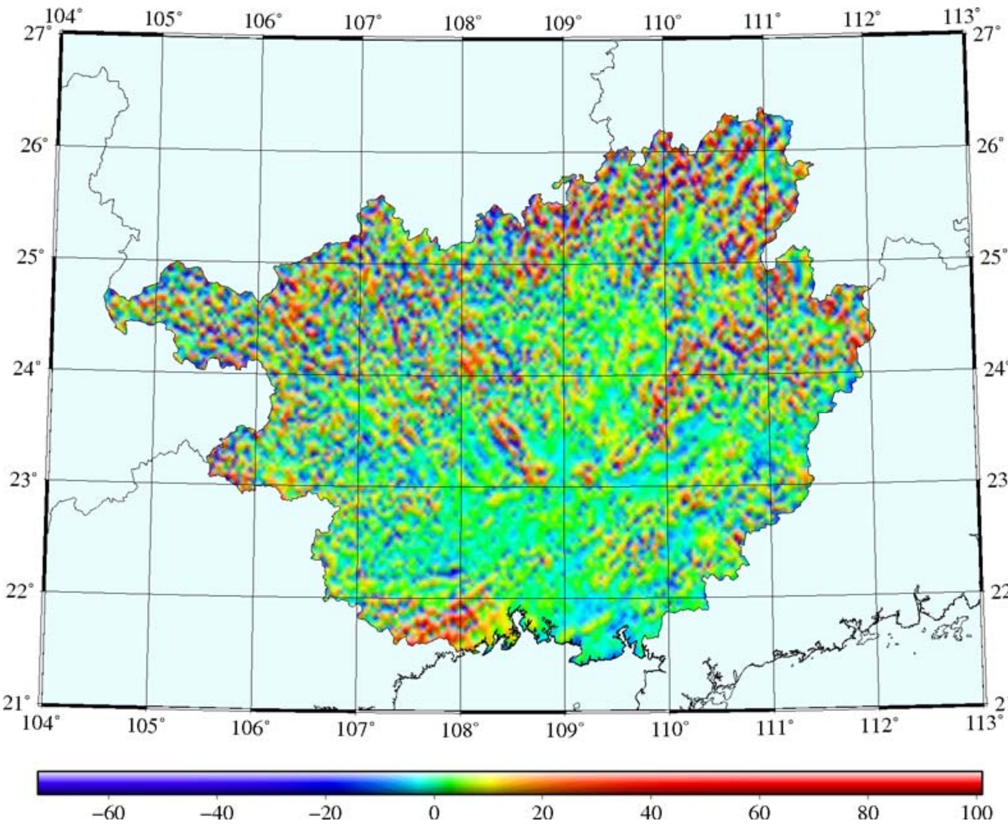

Fig. 6a The differences between 2'×2' gridded free-air gravity anomalies from PGM07A and the corresponding observation values in Guangxi province region (Unit: mGal)

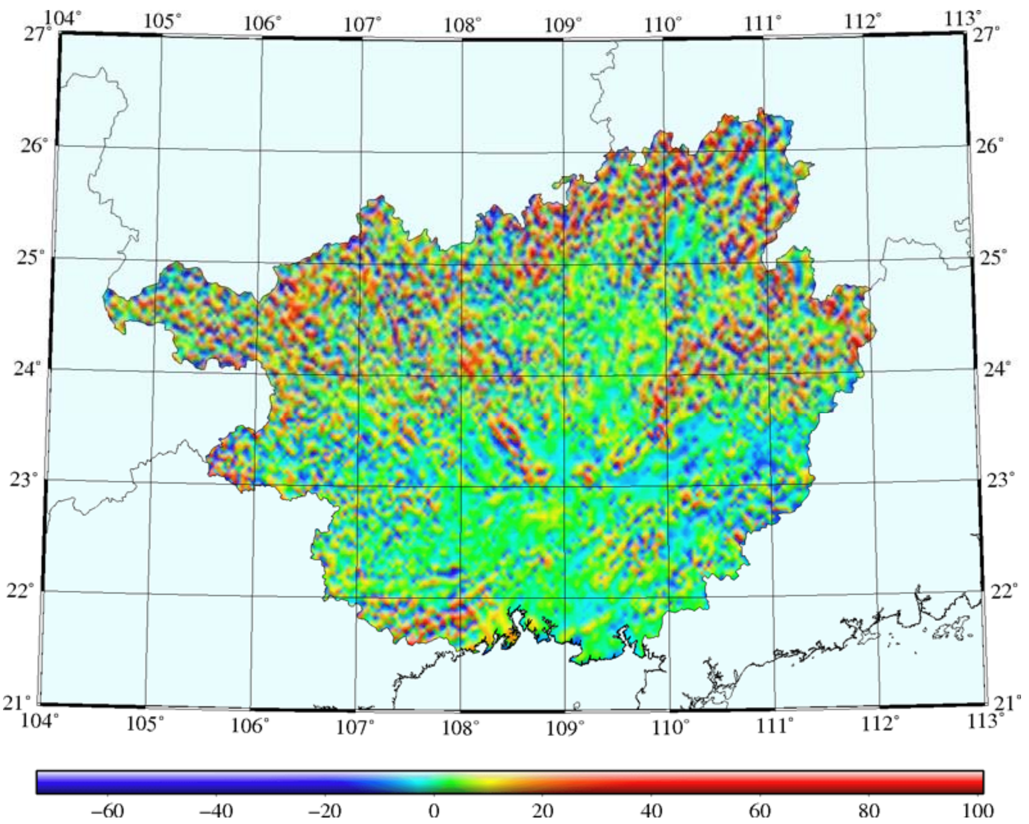

Fig. 6b The differences between 2'×2' gridded free-air gravity anomalies from EGM08 and the corresponding observation values in Guangxi province region (Unit: mGal)

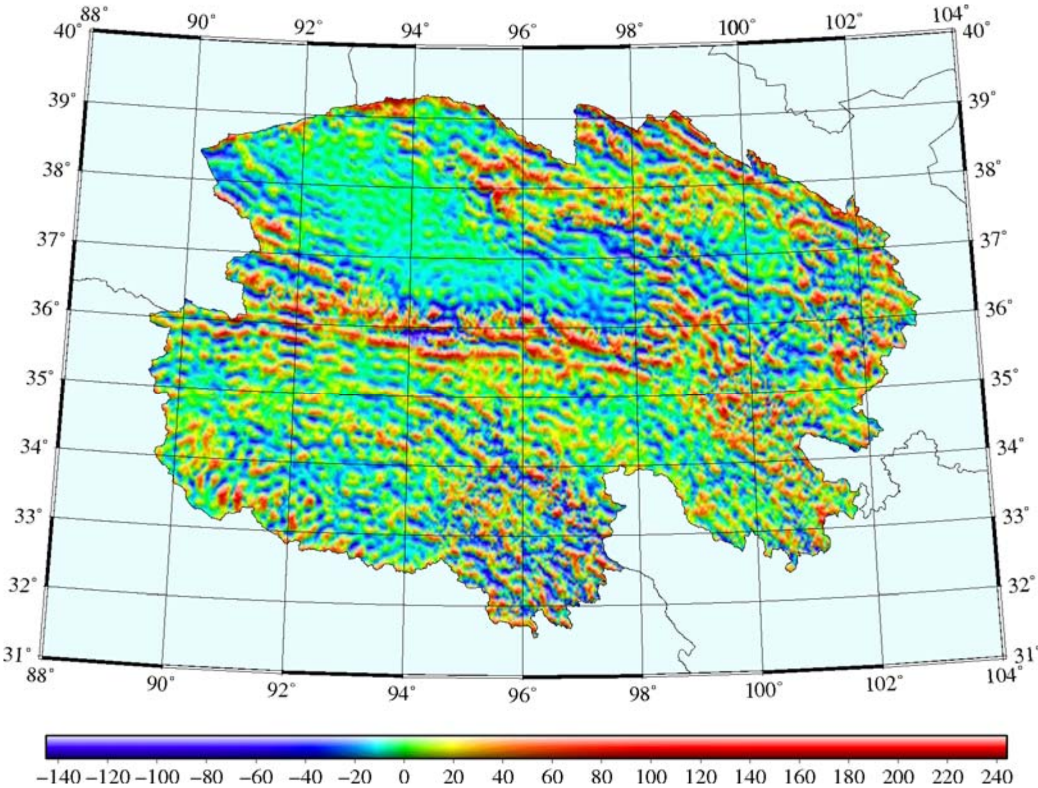

Fig. 7a The differences between 2'×2' gridded free-air gravity anomalies from PGM07A and the corresponding observation values in Qinghai province region (Unit: mGal)

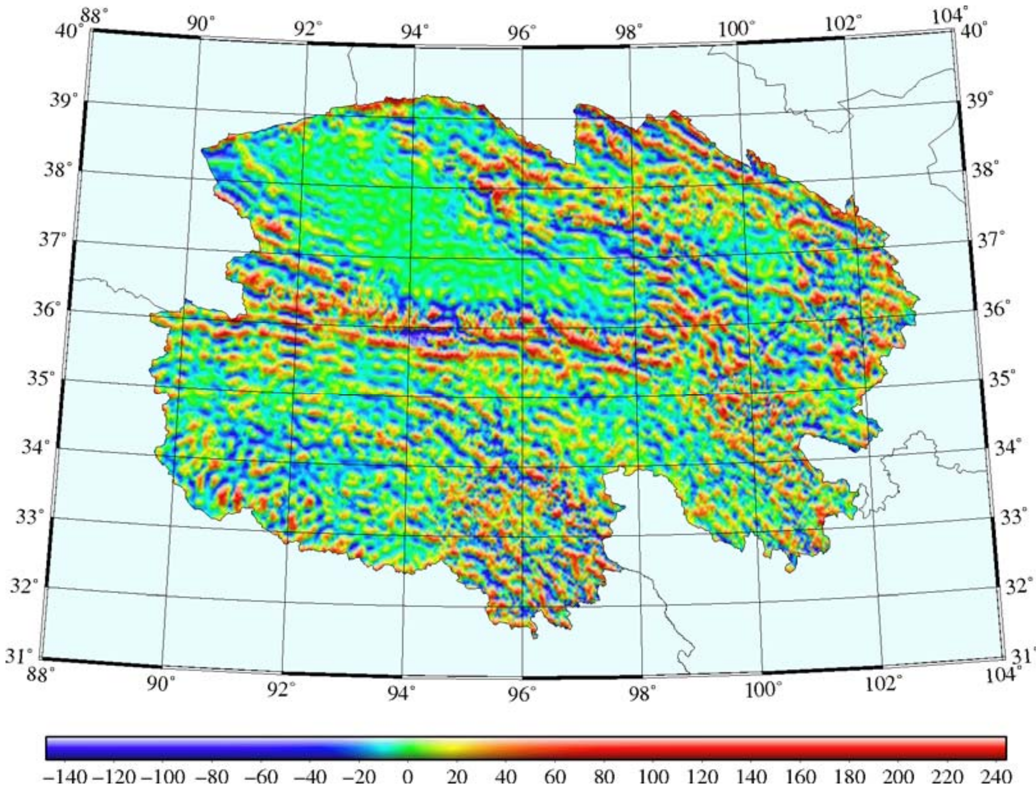

Fig. 7b The differences between 2'×2' gridded free-air gravity anomalies from EGM08 and the corresponding observation values in Qinghai province region (Unit: mGal)

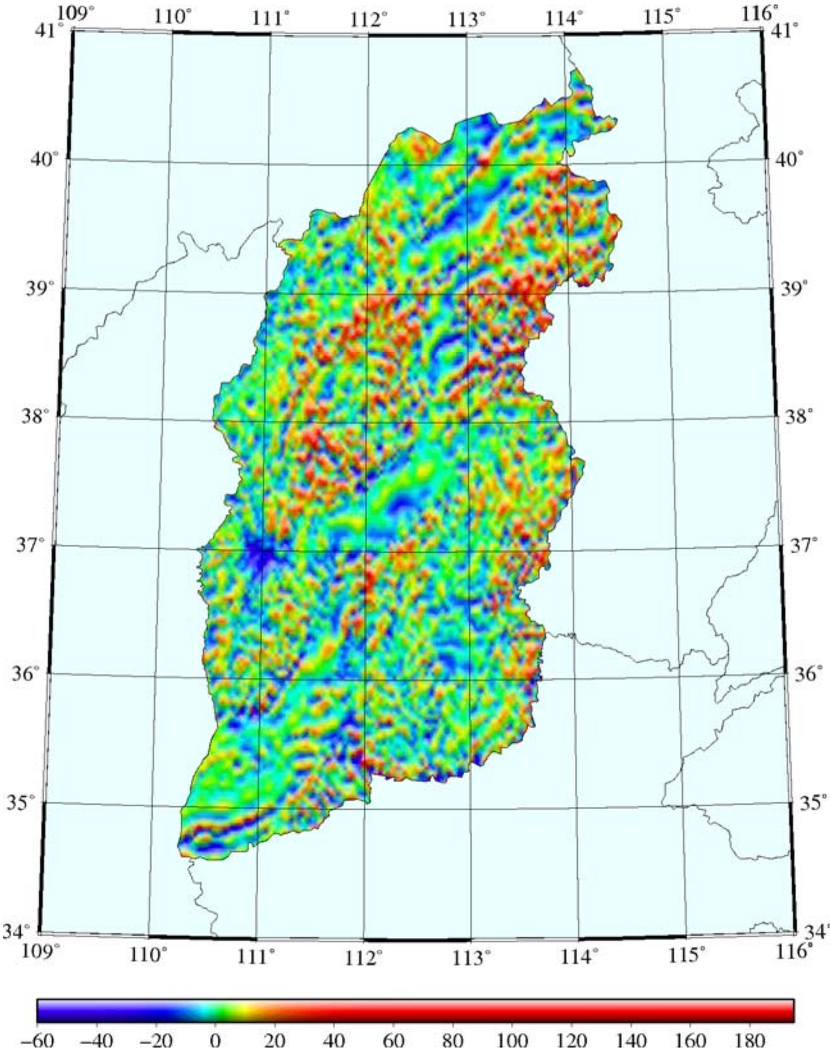

Fig. 8a The differences between 2'×2' gridded free-air gravity anomalies from PGM07A and the corresponding observation values in Shanxi province region (Unit: mGal)

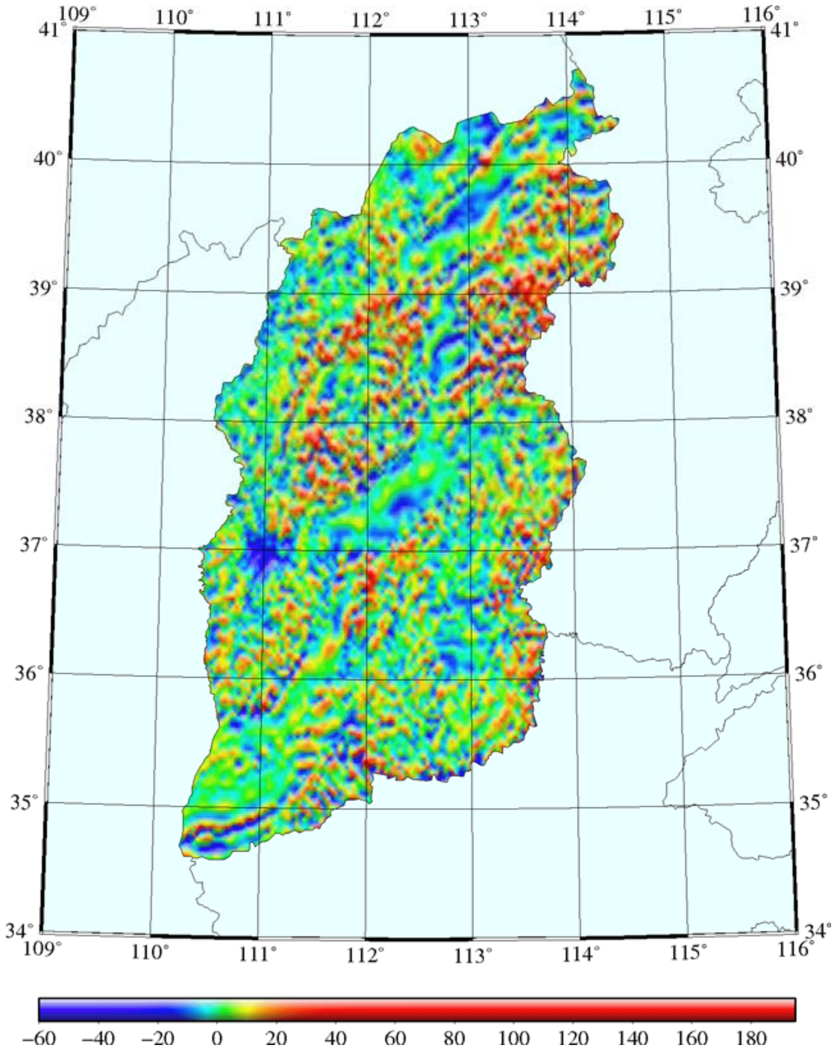

Fig. 8b The differences between 2'×2' gridded free-air gravity anomalies from EGM08 and the corresponding observation values in Shanxi province region (Unit: mGal)

Table 12a. The statistics of the differences in the comparisons of the total 183201 measured gravity anomalies with the corresponding ones from PGM07(Unit: mGal)

Area	Block	Max	Min	Bias	RMS	Std. D
Gansu	48929	243.996	-155.599	4.491	±24.751	±25.155
Guangdong	18860	85.897	-74.683	1.364	±12.664	±12.590
Guangxi	23673	100.108	-72.876	3.232	±14.078	±13.702
Qinghai	73432	243.996	-144.039	4.206	±29.161	±28.856
Shanxi	18307	194.780	-59.150	2.817	±13.464	±13.167

Table 12b. The statistics of the differences in the comparisons of the total 183201 measured gravity anomalies with the corresponding ones from EGM08 (Unit: mGal)

Area	Block	Max	Min	Bias	RMS	Std. D
Gansu	48929	218.938	-143.032	4.264	±24.167	±23.788
Guangdong	18860	86.801	-74.908	1.346	±12.547	±12.475
Guangxi	23673	95.884	-71.460	3.357	±14.015	±13.608
Qinghai	73432	218.938	-147.677	4.125	±27.683	±27.373
Shanxi	18307	194.375	-56.505	3.056	±13.111	±13.462

Table 12c. The statistics of the differences between the differences of EGM08-derived anomalies and PGM07A-derived ones from the corresponding total 183201 measured anomoalies(Unit: mGal)

Area	Block	Max	Min	Bias	RMS	Std. D
Gansu	48929	15.380	-25.058	-0.227	±3.247	±3.239
Guangdong	18860	6.561	-14.187	-0.018	±1.721	±1.721
Guangxi	23673	11.201	-29.411	0.126	±2.350	±2.347
Qinghai	73432	15.030	-25.058	-0.080	±4.718	±4.717
Shanxi	18307	4.426	-2.798	0.239	±1.368	±1.347

5. Conclusions

This report mainly focuses on the comparisons of the quasi-geoids derived from PGM07A and EGM08 as well as the other recent released Earth Gravitational Models (EGMs) with the quasi-geoids determined by the national A/B-order GPS/Leveling data and some provincial GPS/Leveling data. The statistical results of the comparisons show that the quasi-geoids derived from both PGM07A and EGM08 can provide a better approximation to the quasi-geoids determined from the provincial GPS/Leveling data than an approximation to the same quasi-geoids provided by the quasi-geoids derived from the other seven EGMs used in comparisons. The statistics (RMS and Std.D) of the differences of the above mentioned approximations is in the range of ±0.1~ ±0.5m. The statistical results of overall comparisons using all 1812 nationwide GPS/Leveling point data, also show that the quasi-geoids derived from PGM07A and EGM08 are better than those derived from the other seven EGMs in terms of the approximation level to the GPS/Leveling-based quasi-geoids by the range of ±0.1~ ±0.4m in RMS and Std.D.

According to the approximation levels to the GPS/Leveling-based quasi-geoids, the comparisons for the evaluations of EGM08 also indicate that the quasi-geoid derived from EGM08 is better than that derived from PGM07A by the range of ±0.01~ ±0.07m with an average of ±0.03m in RMS and Std.D.

In addition, the comparisons of gravity anomalies derived from PGM07A and EGM08 with corresponding ones measured in the five provincial regions are made, and the statistical results of the comparisons show that the RMS and Std.D of the differences between PGM07A/EGM08-derived gravity anomalies and those corresponding ones measured in the regions are within the range of ±13~±29 mGal with an average of ±18 mGal. According to the approximation levels to the in-situ measured gravity anomalies, the statistical results of the comparisons also indicate that the gridded mean anomalies derived from EGM08 are more accurate than those derived from PGM07A by the range of ±1~4 mGal with an average of ±2.7 mGal in RMS and Std.D of differences of comparisons.

In the general, the quasi-geoid and gravity anomalies computed from PGM07A /EGM08 have significantly improved the representation of the Chinese local gravity field as compared with the other seven EGMs used in the comparisons. However, there are some anomalous (large or small) biases of quasi-geoid which deviate from the general level of the biases in some regions. Therefore, the biases are locally inconsistent with each other, for example, the difference of biases between quasi-geoids of Jiangsu and Qinghai regions for both PGM07A and EGM08 is up to 0.2m, and the differences between even two adjacent provinces also have relatively large values, such as Guangdong and Guangxi, as well as Qinghai and Gansu. On the contrary, the biases of the quasi-geoids derived from both EIGEN and GGM series models, which deviate from the corresponding ones determined by GPS/Leveling, are basically consistent with each other in different regions of China. We know that there also exist some large bias differences of geoids in some states of USA, e.g., the maximum of the difference between Washington and Florida reaches 1.14m (*Roman et al, 2007*). The large biases variation of PGM07A/EGM08-derived geoid occurring in some regions may be a problem, and it will lead to inconsistency and incompatibility in regional quasi-geoid or geoid determination by the models.

Acknowledgements. This study is funded by Natural Science Foundation Committee of China and the National High Technology Research and Development Program of China (863 Program) under grants 40637034, 40474004 and 2006AA12Z309.

References

Heiskanen W.A., &H. Moritz, Physical Geodesy, W.H. Freeman and Company, San Francisco, 1967.

Jiancheng Li, The Spectral Methods in Physical Geodesy (in Chinese), Ph.D. dissertation, Wuhan Technical University of Surveying and Mapping, March, 1993.

NGA, EGM Harmonic Synthesis Software and “Test” Coefficient Sets, Document last modified July 28, 2006.

Pavlis, N.K., S.A. Holmes, S.C. Kenyon, and J.K. Factor, An Earth Gravitational Model to Degree 2160: EGM2008, presented at the 2008 General Assembly of the European Geosciences Union, Vienna, Austria, April 13-18, 2008

Daniel R. Roman. JarirSaleh. Yan M. Wang. PGM2007A Evaluation Report for the United States of America: Conterminous United States GPS/Leveling Data, in this Volume, 2007.