Computation process demo of complete Bouguer anomaly outside geoid

From the ground digital elevation model and discrete observed gravity disturbance calculated from EGM2008 geopotential model, a remove-restore scheme with the residual terrain effects employed, calculate the complete Bouguer gravity disturbance grid on an equipotential surface which is also the observation reduction surface, to show the basic computation scheme and process of the land-sea unified complete Bouguer effects on various gravity field elements near-Earth space.

The complete Bouguer effect is defined as the variation of Earth gravity field because of the terrain mass above the geoid removed and the seawater density compensated to the terrain density.

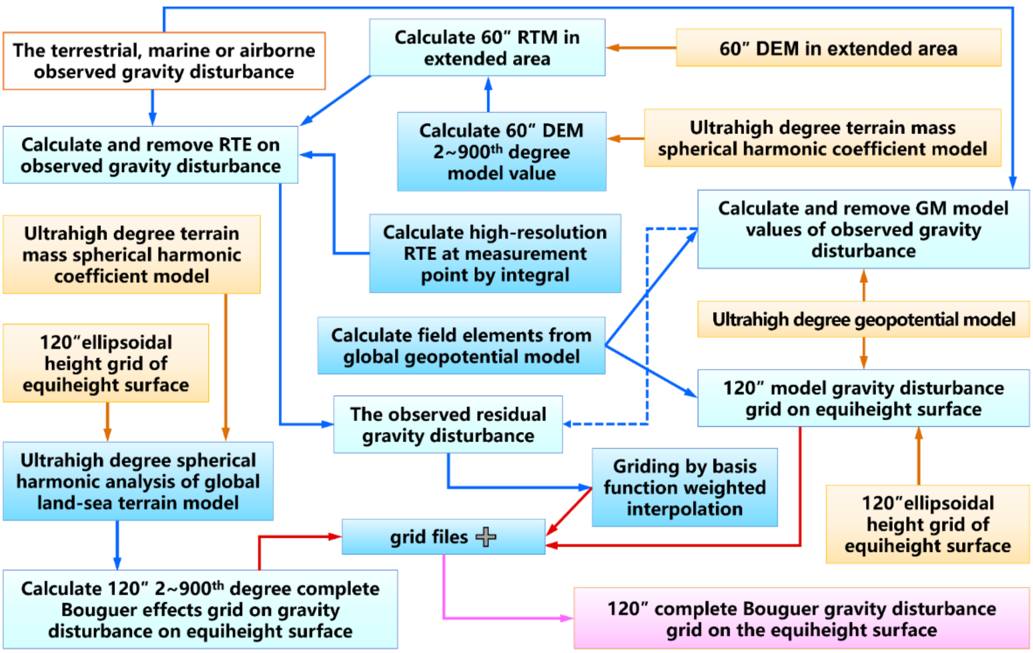
● **Input and output data and related terrain models**

Let terrain data range (extended area, E94.5~99.5°, N30.5~34.5°) ⊃ result range (measurement points distribution range / observation reduction surface range, E95.0 ~ 99.0°, N31.0 ~ 34.0°) to suppress the edge effect of integral.

(1) The observed gravity disturbance and disturbing gravity gradient file Obsgrav.txt.

The gravity disturbances are simulated from the 2~1800th degree EGM2008 model. PAGravf4.5 employs the exact same algorithms to process various terrestrial, marine, and airborne gravity data in a unified way, and there is no need to distinguish whether the observed point is on the ground, at the air altitude or in the sea area.

The format of the file record: ID, longitude (°), latitude (°), ellipsoidal height (m), gravity disturbance (mGal). The distribution of the observed points is shown in Fig.



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(2) The 1800-degree terrain mass spherical harmonic coefficient model file

ETOPOcs1800.dat and the 2190-degree EGM2008 geopotential coefficient model file EGM2008.gfc.

The two model files are stored in the directory C:\PAGravf4.5_win64en\data. The 1800-degree global land-sea terrain mass spherical harmonic coefficient model ETOPOcs1800.dat is generated by the PAGravf4.5 function [Ultrahigh degree spherical harmonic analysis of global land-sea terrain model] from the global 2′×2′ land-sea terrain model ETOPO2v2g.

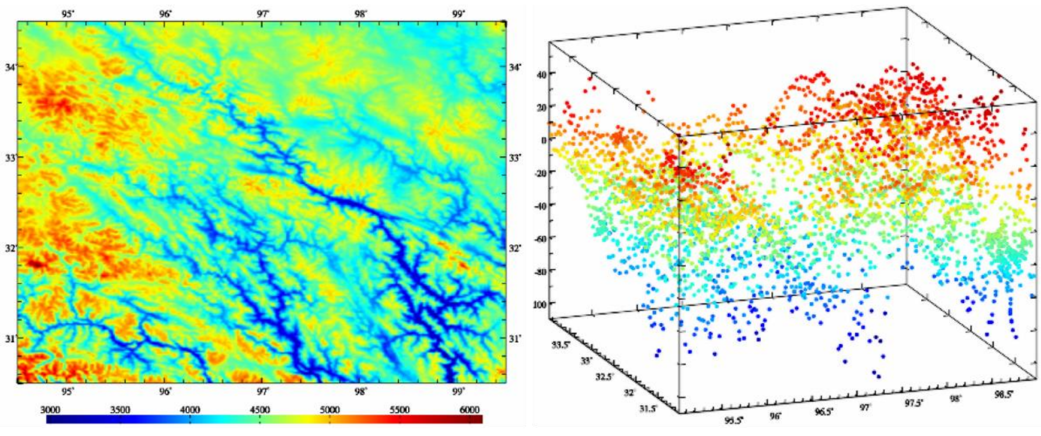
(3) The ground digital elevation model (DEM)

It is required that the DEM grid range (extended area) be larger than the calculation area to eliminate the integral edge effect.

Two kinds of DEM resolutions are required. The high-resolution is employed for the observed data reduction, that is, to calculate and remove the residual terrain effects on the observations. The other resolution is consistent with the calculation result resolution and is employed to restore the residual terrain effects on the result. In this example, they are 60" and 120" respectively, and the corresponding files are extdtm60s.dat and extdtm120s.dat. 339.5

(4) 60″ ground ellipsoidal height grid file surfhgt60s.dat

The ground ellipsoidal height grid is employed to give the space location of the residual terrain mass (the integral move cell) which is indispensable for high-precision calculations. In this example, the 60" ground ellipsoidal height grid file surfhgt60s.dat is for the 60" residual terrain model.



Ground digital elevation model (m) and gravity measurement point distribution

(5) 120″ ellipsoidal height grid file equihgt120s.dat of terrain equiheight surface.

The terrain equiheight surface is the reduction surface of the ground observations and calculation surface of the result grid, which is regarded as an equipotential surface. The ellipsoidal height of the terrain equiheight surface is equal to the sum of the 2~180th degree EGM2008 model geoidal height and mean of DEM.

The griding operation is not analytical, which is easy to weaken the analytical nature of the gravity field. Non-analytical operations are required to be performed on some an equipotential surface to minimize the negative effects on gravity field. In this example, the terrain equiheight surface is regarded as an equipotential surface.

When the normal (orthometric) heights of the surface are zero, namely whose ellipsoidal height are the geoidal height, the reduction surface and calculation surface are the geoid in the traditional sense.

(6) The result products: 120″×120″ complete Bouguer gravity disturbance grid file on the terrain equiheight surface.

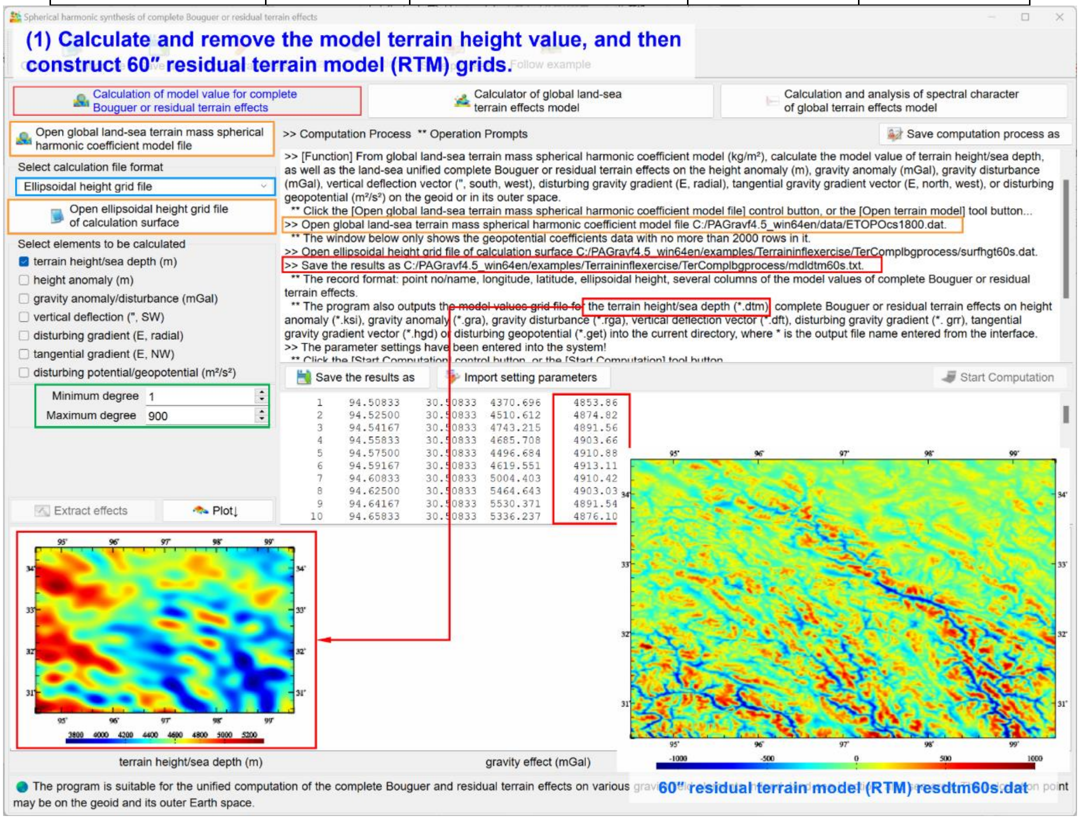
● **Programs call and input-output data flow**

(1) Calculate and remove the model terrain height value, and then construct 60″ residual terrain model (RTM) grid.

Call the function [Calculation of model value for complete Bouguer or residual terrain effects] with the minimum degree 1 and the maximum degree 900, select the calculation type ‘terrain height/sea depth (m)’, input the land-sea terrain mass spherical harmonic coefficient model file ETOPOcs1800.dat and ground ellipsoidal height grid file surfhgt60s.dat, and generate 60″ model terrain height grid files mdldtm60s.dtm.

Let extdtm60s.dat minus mdldtm60s.dat, the residual terrain models (RTM) resdtm60s.dat in the extended area are obtained, as shown in the figure.

	mean	standard deviation	minimum	maximum
30″ RTM (m)	0.0053	175.5869	-959.5450	59.0160
60″ RTM (m)	0.0053	175.5869	-959.5450	886.2500



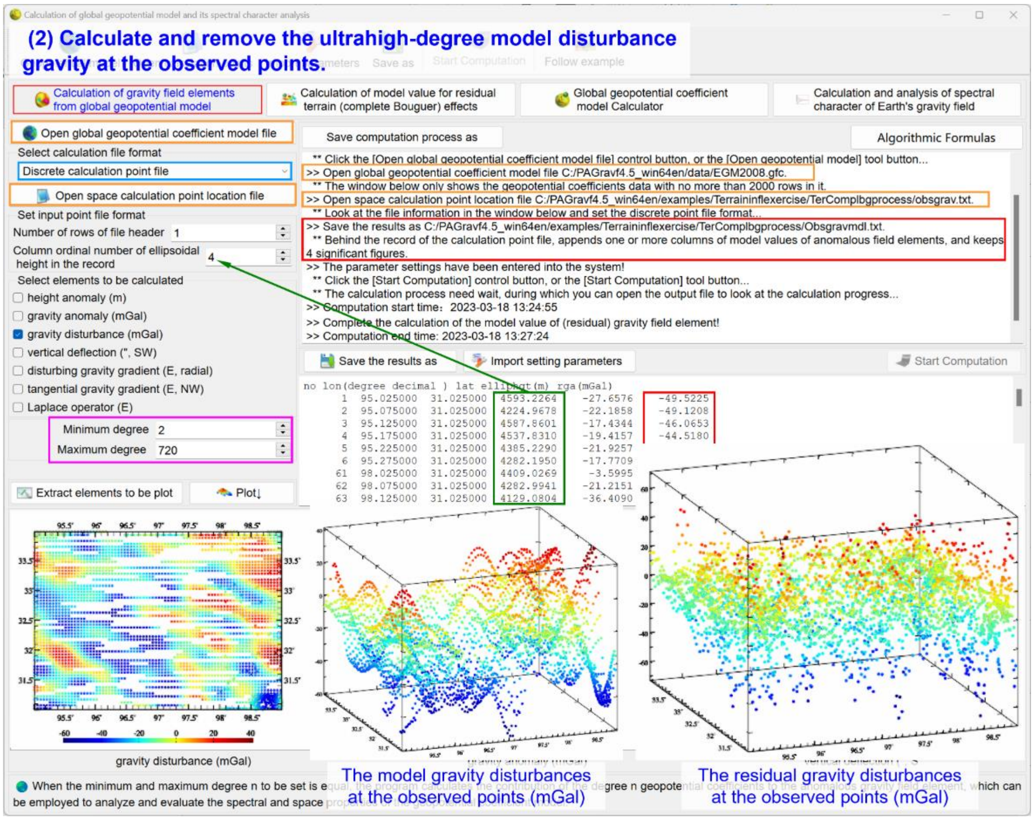
(2) Calculate and remove the ultrahigh-degree model gravity disturbances at the observed points.

Call the function [Calculation of gravity field elements from global geopotential model] with the minimum degree 2 and the maximum degree 720, input the file EGM2008.gfc and the observation file Obsgrav.txt, select the type ‘gravity disturbance’, and generate the model gravity disturbance file Obsgravmdl.txt (columns 6) at the observed points.

Subtract the observed gravity disturbance (column 5) and model gravity disturbance (column 6) to generate the model residual gravity disturbance (column 7) file Obsgravmdlresd.txt.

Table 2 shows the statistical results on the gravity disturbances after the 2~720th degree model values removed.

Measurement points	mean	standard deviation	minimum	maximum
Observed gravity disturbance mGal	-15.6106	25.5080	-110.7251	59.0160
Residual of gravity disturbance	-0.4881	17.4588	-74.6129	71.5003



(3) Calculate and remove the residual terrain effects on the gravity disturbance at

the observed points.

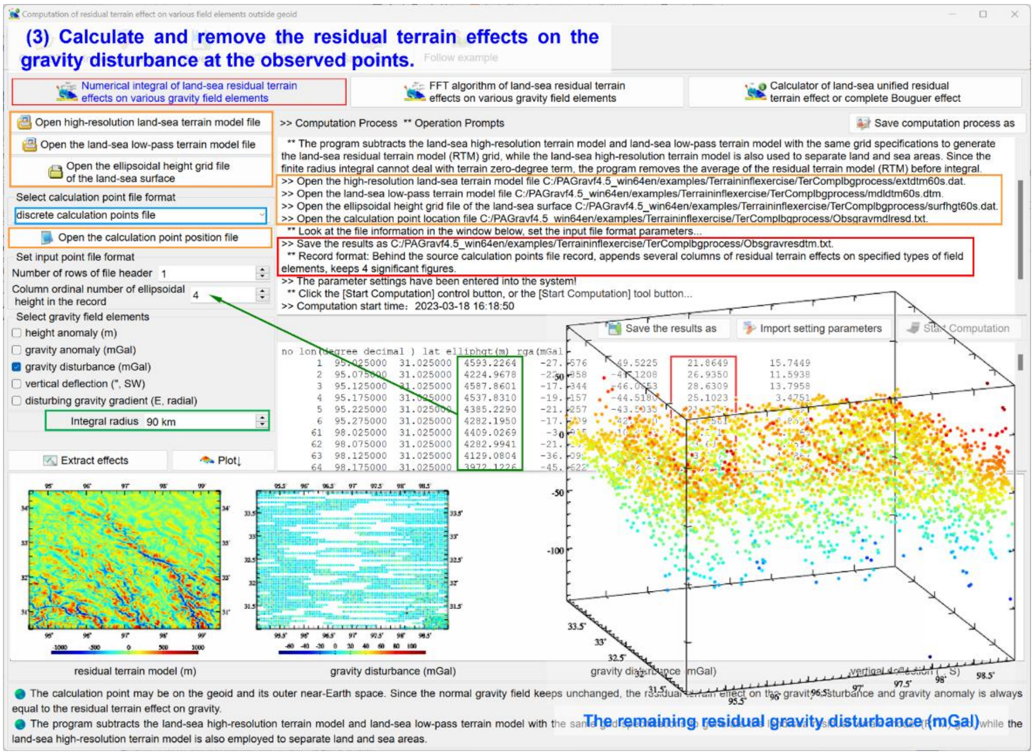
Call the function [Numerical integral of land-sea residual terrain effects on various gravity field elements], input the file Obsgravmdlresd.txt, the high-resolution DEM extdtm60s.dat, low-pass DEM mdldtm60s.dtm and the ground ellipsoidal height grid file surfhgt60s.dat, set the integral radius 90km, and generate the residual terrain effects (RTE) file on the gravity disturbance, Obsgravresdtm.txt (columns 8).

Subtract the residual gravity disturbance (column 7) and its residual terrain effect (column 8), to generate the remaining residual gravity disturbance (column 9) file Obsgravresidual.txt.

After the residual terrain effects removed, the statistical results on the residual gravity disturbances are shown in Table 3.

Measurement points	mean	standard deviation	minimum	maximum
RTE on gravity disturbance mGal	4.8843	7.2038	-73.7901	118.6158
Remaining residual gravity disturbance mGal	-5.3034	19.7638	-144.5444	92.4782

In this example, the analytical continuation correction of the residual radial gradient (within a height difference of 1000m, it is small) is ignore. In this case, the remaining residual gravity disturbance at the observed point is equal to that on the equipotential surface.



The basic purpose of the statistics in Tables 1 to 3 is to improve the residual terrain effect algorithm and relative parameters according to the griding optimization criteria. Since the simulated data lack sufficient ultrashort wave information of the real gravity field, the optimization criterion analysis process is omitted in this example.

So far, the reduction processing of the gravity disturbances from the observed points to the terrain equiheight surface has been completed.

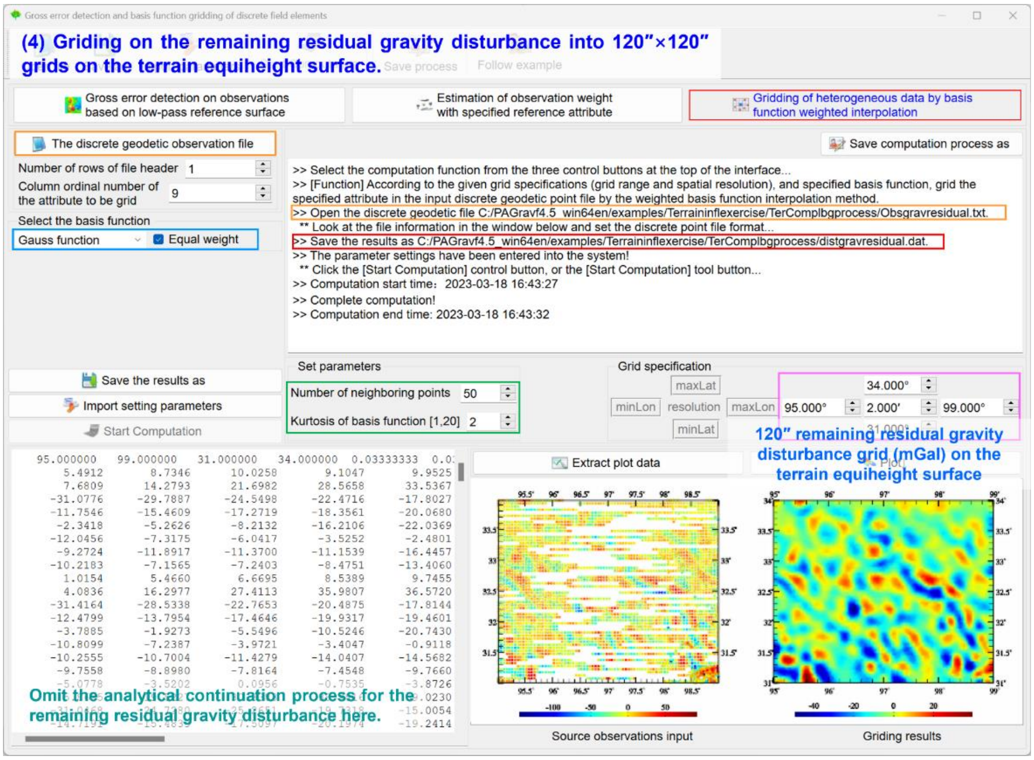
(4) Griding on the remaining residual gravity disturbance into 120″×120″ grids on the terrain equiheight surface.

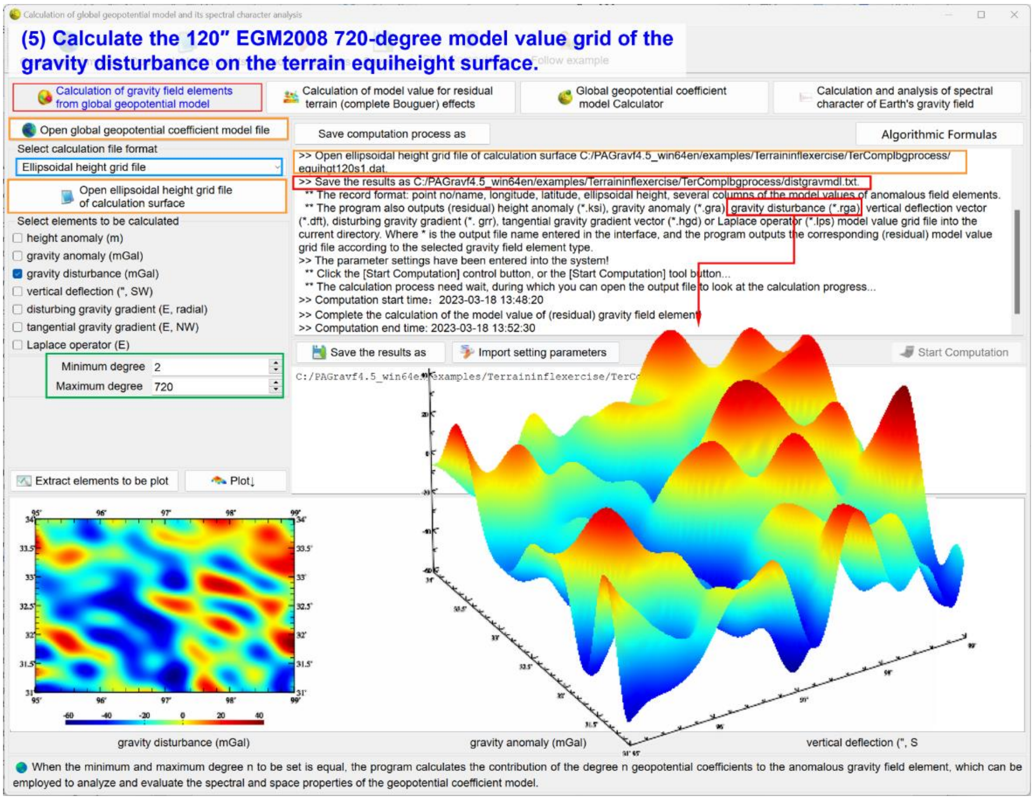
Call the function [Gridding of heterogeneous data by basis function weighted interpolation], select ‘equal weights of observations’ (the weights can be estimated with the residual terrain effects as the reference attribute in advance), and grid on the 9th column of attributes (from the file Obsgravresidual.txt), to generate 120″ remaining residual gravity disturbance file distgravresidual.dat on the terrain equiheight surface.

The range and resolution of the grid is the same as the result grid.

(5) Calculate the 120″ EGM2008 720-degree model value grid of the gravity disturbance on the terrain equiheight surface.

Call the function [Calculation of gravity field elements from global geopotential model] with the minimum degree 2 and the maximum degree 720, input the file EGM2008.gfc and the ellipsoidal height grid file equihgt120s1.dat (from equihgt120s.dat with grid edge removed) of the terrain equiheight surface, and select the calculation type ‘gravity disturbance’, to generate 120″ model gravity disturbance grid file distgravmdl.rga on the terrain equiheight surface.





Here, the geopotential model, the minimum and maximum degree are required to be the same as in step (2).

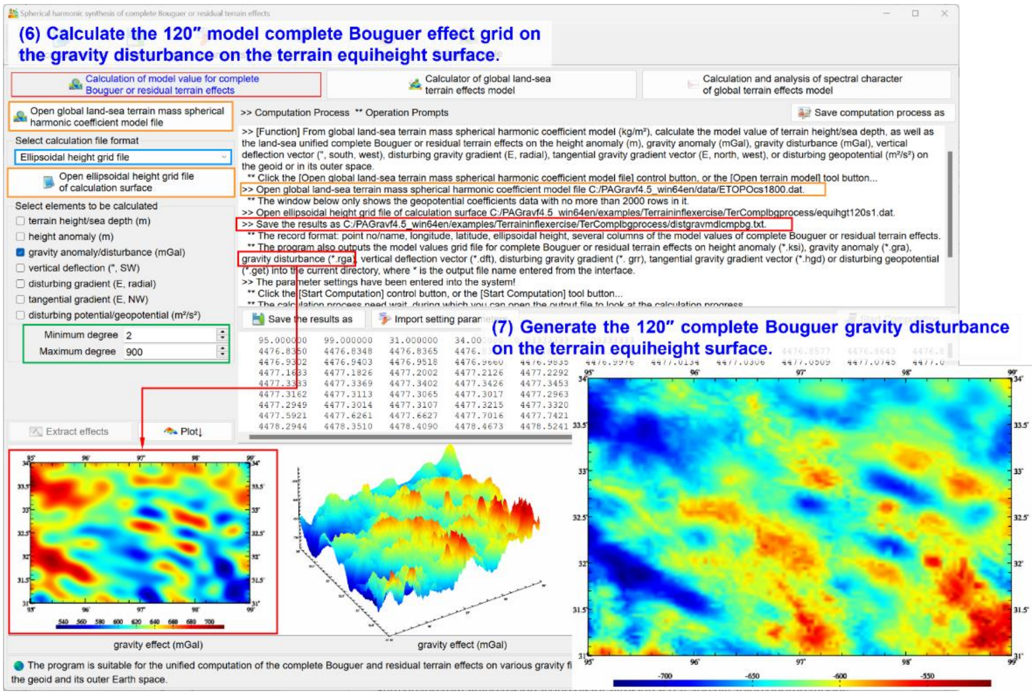
(6) Calculate the 120″ model complete Bouguer effect grid on the gravity disturbance on the terrain equiheight surface.

Call the function [Calculation of model value for complete Bouguer or residual terrain effects] with the minimum degree 2 and the maximum degree 900, select the type ‘gravity disturbance’ input the land-sea terrain mass spherical harmonic coefficient model file ETOPOcs1800.dat and 120″ ground ellipsoidal height grid file surfhgt120s1.dat of the terrain equiheight surface and, and then generate the 120″ model complete Bouguer effect grid file distgravmdlcmpbg.gra on the gravity disturbance on the terrain equiheight surface.

Here, the terrain mass spherical harmonic coefficient model and the maximum degree are required to be the same as in step (1).

(7) Generate the 120″ complete Bouguer gravity disturbance on the terrain equiheight surface.

Sum up the remaining residual grid distgravresidual.dat, the ultrahigh degree model value grid distgravmdl.dat, the residual terrain effect grid distgravresidtm.dat and the model complete Bouguer effect grid distgravmdlcmpbg.gra four grid files of the gravity disturbance with the same grid specifications, to generate the 120″ complete Bouguer gravity disturbance grid distgravcmpbg.dat on the terrain equiheight surface.


(6) Calculate the 120″ model complete Bouguer effect grid on the gravity disturbance on the terrain equiheight surface.
(7) Generate the 120″ complete Bouguer gravity disturbance on the terrain equiheight surface.
gravity effect (mGal)
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