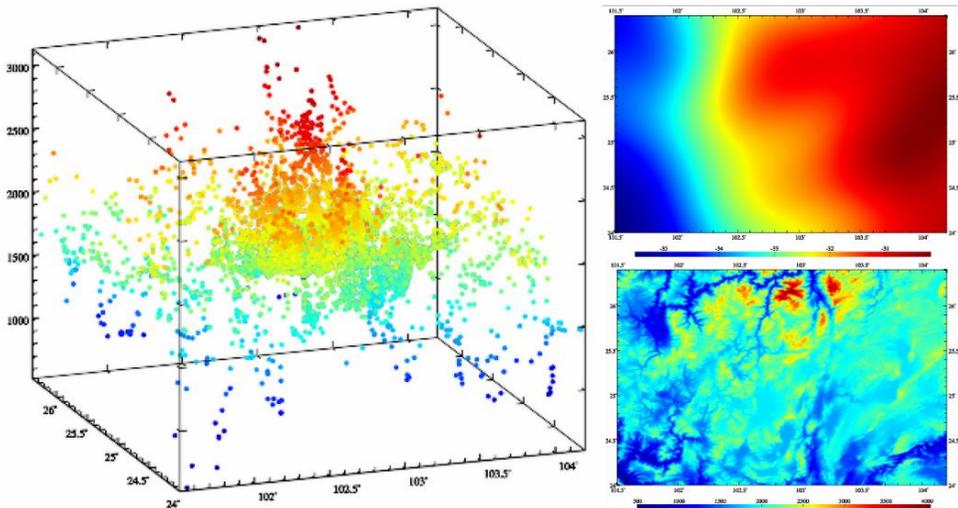


The observed gravity disturbances (mGal) and observed GNSS-levelling geoidal heights (m)



The distribution of gravity points, 2~180th degree model geoidal height and ellipsoidal height of the terrain surface

It should be noted that since the observed geoidal height by GNSS-leveling is essentially the height anomaly on the geoid in orthometric height system, the geoidal height at GNSS-leveling sites must be the geoidal height, which can be employed by the observed GNSS-leveling geoidal height or the model geoidal height from the EGM2008 model (the 2~180th degree).

- **The ellipsoidal height grid of calculation surface:**

The model geoidal height grid file mdlgeoidh30s.dat calculated from the 2~180th degree geopotential model, which is employed for modeling on gravity field on geoid.

The ellipsoidal height grid file surfhgt30s.dat of the land/sea surface equal to the sum of the digital elevation model grid DEM30s.dat and the model geoidal height grid mdlgeoidh30s.dat, which is employed for modeling on ground gravity field.

Here, it is required that the grid range of the calculation surface is larger than the range of the target area to absorb edge effects.

(1) Remove reference model value from all the observations and then construct the heterogeneous observation residual file.

Call the function [Calculation of gravity field elements from global geopotential

model], let the minimum degree 2 and maximum degree 540, and input the file EGM2008.gfc, observed gravity disturbance file obsdistgrav.txt and observed GNSS-leveilling geoidal height file obsGNSSlgeoid.txt, calculate and remove the 2~540th degree model value of these observations to generate the heterogeneous observation file obsresiduals0.txt according to the agreed format.

(1) Remove reference model value from all the observations and then construct the heterogeneous observation residual file

Calculation of gravity field elements from global geopotential model | Calculation of model value for residual terrain (complete Bouguer) effects | Global geopotential coefficient model Calculator | Calculation and analysis of spectral character of Earth's gravity field

Open global geopotential coefficient model file | Save computation process as | Algorithmic Formulas

Select calculation file format: Discrete calculation points file

Open space calculation points file: C:\PA\Grav4_5_win64en\examples\Gravmdl\exercise\SRBF\apprgeoid\exercise\obsGNSSlgeoidh.txt

Set input point file format: Number of rows of file header: 1 | Column ordinal number of ellipsoidal height in the record: 5

Select elements to be calculated: height anomaly (m) | gravity anomaly (mGal) | gravity disturbance (mGal) | vertical deflection (", SW) | disturbing gravity gradient (E, radial) | tangential gravity gradient (E, NW) | Laplace operator (E)

Minimum degree: 2 | Maximum degree: 540

Save the results as: Import setting parameters | Start Computation

Save the results as: C:\PA\Grav4_5_win64en\examples\Gravmdl\exercise\SRBF\apprgeoid\exercise\obsGNSSlgeoidh_GM540.txt

Save the results as: C:\PA\Grav4_5_win64en\examples\Gravmdl\exercise\SRBF\apprgeoid\exercise\obsGNSSlgeoidh_GM540.txt

Behind the record of the calculation point file, appends one or more columns of model values of anomalous field elements, and keeps 4 significant figures.

The calculation process need wait, during which you can open the output file to look at the calculation results.

ID	lon (degree decimal)	lat	ellip(m)	rsnt	kind	weight
1	102.4424	24.4717	1973.56	-32.7525	-32.6525	1
2	102.5467	24.4580	1659.69	-32.9577	-32.5340	1
3	102.6324	24.4552	2360.99	-32.5792	-32.4433	1
4	102.7259	24.4605	2112.80	-32.3917	-32.3324	1
5	102.4208	24.5663	1991.50	-32.6038	-32.5734	1
6	102.5286	24.5627	1937.23	-32.5636	-32.4239	1
7	102.6344	24.5656	2193.72	-32.3822	-32.3129	1
8	102.7258	24.5819	2304.57	-32.2197	-32.2069	1
9	102.8326	24.5755	1978.11	-32.5408	-32.0934	1

The ellipsoidal height here at GNSS-leveilling point is the observed or model geoidal height, not the observed ellipsoidal height.

The model geoidal height (m) at the GNSS-leveilling points

ID	lon (degree decimal)	lat	ellip(m)	rsnt	kind	weight
1	102.3929	24.4944	2228.19	54.9765	0	1
2	102.3959	24.5089	2170.20	50.0971	0	1
3	102.3927	24.5296	2013.33	28.3652	0	1
4	102.3966	24.5453	2022.50	38.3822	0	1
5	102.3966	24.5453	2022.50	38.3822	0	1
6	102.3966	24.5453	2022.50	38.3822	0	1
7	102.3966	24.5453	2022.50	38.3822	0	1
8	102.3966	24.5453	2022.50	38.3822	0	1
9	102.3931	24.6178	1997.72	14.9731	0	1
10	102.3935	24.6384	1916.15	7.4068	0	1
4221	102.4424	24.4717	-32.6525	-0.1056	1	1
4222	102.5467	24.4580	-32.5340	-0.4237	1	1
4223	102.6324	24.4552	-32.4433	-0.1359	1	1
4224	102.7259	24.4605	-32.3324	-0.0593	1	1
4225	102.4208	24.5663	-32.5734	-0.0304	1	1
4226	102.5286	24.5627	-32.4239	-0.1397	1	1
4227	102.6344	24.5656	-32.3822	-0.0694	1	1
4228	102.7258	24.5819	-32.2197	-0.0128	1	1
4229	102.8326	24.5755	-32.5408	-0.4474	1	1
4230	102.3455	24.6689	-32.6394	-0.2903	1	1
4231	102.4239	24.6529	-32.4801	-0.0740	1	1
4232	102.5297	24.6670	-32.3057	-0.2186	1	1

The agreed format of the heterogeneous observation file record: ID (point no / name), longitude (degree decimal), latitude, ellipsoidal height (m), observation, ..., observation type (0 ~ 5), weight, ... The order of the first five attributes is fixed by convention.

The observation types and units: 0 - residual gravity disturbance (mGal), 1 - residual geoidal height (m).

It should be noted that the ellipsoidal height of GNSS-leveilling must be the geoidal height and not the ellipsoidal height at GNSS-leveilling site.

(2) Detect the gross errors of the observations and then reconstruct the heterogeneous observation residual file.

Call the program [Full element modelling on gravity field using SRBFs from heterogeneous observations], select the height anomaly as the adjustable observation, let the contribution $\kappa = 0$, and input the heterogeneous residual file obsresiduals0.txt and model geoidal height grid file mdlgeoidh30s.dat to estimate the residual gravity field grid rntSRBFgeoidh30s0.xxx on geoid, and get the remaining residual file rntSRBFgeoidh30s0.chs.

Where, $xx=ksi$ stands for residual geoidal height (m), $xxx=rga$ stands for residual gravity disturbance (mGal), $xxx=gra$ stands for residual gravity anomaly (mGal), $xxx=grr$ stands for residual disturbing gravity gradient (radial, E) and $xx=dft$ stands for residual vertical deflection (SW, ").

(2) Detect the gross errors of the observations and then reconstruct the heterogeneous observation residual file.

Open the discrete heterogeneous residual observations file

number of rows of file header: 1
 column ordinal number of ellipsoidal height in the record: 6
 column ordinal number of weight: 7

Select SRBF: radial multipole kernel
 Order m: 5
 Minimum degree: 360
 Maximum degree: 1800
 Burial depth of Bjerrum's sphere: 10.0km
 Action distance of SBRF center: 100km
 Reuter network level K: 3600

Select the adjustable observations: height anomaly (m)
 Contribution rate κ of adjustable observations: 0.00

Open the ellipsoidal height grid file of calculation surface

Algorithm of gravity field approach using SRBFs

- After the first estimation is completed, it is recommended to employ the output residual observation file *.chs as the input observation file again to refine target field element. Generally, the stable solution can be achieved by 1 to 3 times cumulative SRBF approach, and the target field element is equal to the sum of these SRBF approach solutions.
- The validity principle of once SRBF approach: (1) The residual target field element grid is continuous and differentiable, and whose standard deviation is as small as possible. (2) The statistical mean of residuals tends to zero with the increase of cumulative approach times, and there is no obvious reverse sign.

Extract data to be plot Plot

- The program is a high performance and adaptable modeling tool on gravity field. Various observations with heterogeneity, different altitudes, cross-distribution, and land-sea coexisting can be directly employed to estimate the full element models of gravity field without reduction, continuation, and gridding.
- The program has strong ability on the observation gross error detection, measurement of external accuracy indexes, computation performance control and result quality assessment.

>> The parameter settings have been entered into the system
 ** Click the [Start Computation] control button, or the [Start Computation] tool button...
 >> Computation start time: 2023-03-21 10:14:40
 >> Complete the computation!
 >> Computation end time: 2023-03-21 10:19:52
 >> The program outputs the full elements grid files into the current directory. These grid files include the residual residual gravity disturbance *.rga (mGal), residual height anomaly *.ksi (m), residual gravity anomaly *.gra (mGal), residual disturbing gravity gradient *.grr (E, radial) and residual vertical deflection vector *.dft (" SW), where * is the output file name
 >> The program also outputs SRBF center file *.center.txt into the current directory. The file header format: Reuter grid level, SRBF center number, cell grid number in meridian circle direction, maximum cell grid number in prime vertical circle direction, latitude interval ("). The record format: point no, longitude (degree decimal), geocentric latitude, cell grid area deviation percentage, longitude interval of cell grid in prime vertical circle direction (")

>> Type 0 of source observations: mean 0.3186 standard deviation 42.1772 minimum -296.0915 maximum 165.2611
 residual observations: mean 0.7368 standard deviation 16.9838 minimum -105.2639 maximum 114.8811
 ** Type 1 of source observations: mean -0.3510 standard deviation 0.2774 minimum -0.9952 maximum 0.3436
 residual observations: mean -0.0410 standard deviation 0.0287 minimum -0.1943 maximum 0.0132

Solution of normal equation LU triangular decomposition Save the results as Import setting parameters Start Computation

ID	lon	lat	ellipsoid height	rga	ksi	gra	grr	dft
1	101.50417	24.1	0	0.3186	42.1772	-296.0915	165.2611	0.7368
2	101.51250	24.1	1	-0.3510	0.2774	-0.9952	0.3436	-0.0410
3	101.52083	24.1	2	1.023.39290	24.49440	2228.190	16.4199	54.9765
4	101.52917	24.1	3	102.39590	24.50890	2170.200	-4.7688	50.0971
5	101.53750	24.1	4	102.39270	24.52960	2013.330	-10.1876	20.3652
6	101.54583	24.1	5	102.39660	24.54530	2122.500	1.0011	1.0011
7	101.55417	24.1	6	102.39690	24.56360	1971.280	-0.0346	1.0000
8	101.56250	24.1	7	102.39390	24.58130	1940.310	-12.0941	1.0000
9	101.57083	24.1	8	102.39520	24.60360	1965.580	12.1550	1.0000
10	101.57917	24.1	9	102.39310	24.61780	1997.720	20.5312	1.0000
11	101.58750	24.1	10	102.39350	24.63840	1916.150	3.5946	1.0000
12	101.59583	24.1	10	102.39710	24.65350	2010.670	10.7239	1.0000

Select the remaining residuals (column 5) as the statistical reference.

residual height anomaly (m) residual disturbing gradient (E) residual vertical deflection S (")

Separate the remaining residual records of the observed GNSS-leveling and observed gravity disturbance from the remaining residual file `rntSRBFgeoidh30s0.chs`, detect and remove the observation gross error points beyond 3 times standard deviation range of the remaining residuals for the GNSS-leveilling sites and beyond 5 times standard deviation range for the disturbance gravity points, and then reconstruct the new heterogeneous observation residual file `obsresiduals01.txt`.

(3) Measure the regional height datum difference and GNSS-leveling external accuracy index.

Replace the input file `obsresiduals0.txt` with the new heterogeneous observation residual file `obsresiduals01.txt` and repeat the step (2) to re-estimate the residual gravity field grid `rntSRBFdatum30s.xxx` on geoid and get the new remaining residual file `rntSRBFdatum30s.chs`.

Since the contribution rate of GNSS-leveilling $\kappa = 0$ is set in advance, it is essentially here directly to measure the external accuracy index of the observed GNSS levelling only using the observed gravity disturbances. Before and after gross error removed, the statistical results on the observation residuals are as follows.

(3) Measure the regional height datum difference and GNSS-leveling external accuracy index.

Open the discrete heterogeneous residual observations file

number of rows of file header: 1
 column ordinal number of ellipsoidal height in the record: 6
 column ordinal number of weight: 7

Select SRBF: radial multipole kernel
 Order m: 3
 Minimum degree: 240
 Maximum degree: 1800
 Burial depth of Bjerrhammar sphere: 10.0km
 Action distance of SRBF center: 100km
 Reuter network level K: 3600

Select the adjustable observations: height anomaly (m)
 Contribution rate k of adjustable observations: 0.00

Open the ellipsoidal height grid file of calculation surface

>> The parameter settings have been entered into the system
 ** Click the [Start Computation] control button, or the [Start Computation] control button.
 >> Computation start time: 2023-03-21 10:27:20
 >> Complete the computation!
 >> Computation end time: 2023-03-21 10:32:36
 >> The program outputs the full elements grid files into the current directory. These grid files include the residual residual gravity disturbances * rgs (mGal), residual height anomaly * ksi (m), residual gravity anomaly * gra (mGal), and residual vertical deflection * dft (* SW), where * is the output file name
 >> The program also outputs SRBF center file * center.txt into the current directory. The file header format: Reuter grid level, SRBF center number, cell grid number in meridian circle direction, maximum cell grid number in prime vertical circle direction, latitude interval (*). The record format: point no, longitude (degree decimal), geocentric latitude, cell grid area deviation percentage, longitude interval of cell grid in prime vertical circle direction (*).
 >> Type 0 of source observations: mean 0.2695 standard deviation 42.0737 minimum -296.0915 maximum 165.2611
 residual observations: mean -0.3482 standard deviation 13.2986 minimum -61.1040 maximum 64.8276
 >> Type 1 of source observations: mean -0.3482 standard deviation 0.2768 minimum -0.9982 maximum 0.3435
 residual observations: mean -0.0070 standard deviation 0.0243 minimum -0.1327 maximum 0.0561

Solution of normal equation LU triangular decomposition

Save the results as Import setting parameters Start Computation

ID	lon	lat	ellipsoid height (m)	gravity disturbance (mGal)	height anomaly (m)	gravity gradient (E)	vertical deflection (S,W)
1	101.50417	24.00417	-35.528	-28.0425	-0.4155	-27.9147	9.2237 4.0106
2	101.51250	24.00417	-35.519	-36.6455	-0.4692	-36.5212	-31.9193 3.9492
3	101.52083	24.00417	-35.510	-43.9560	-0.5174	-43.7969	-44.4147 10.7054 3.7923
4	101.52917	24.00417	-35.501	-52.5941	-0.5707	-52.5711	-52.5711 10.7054 3.7923
5	101.53750	24.00417	-35.491	-62.9602	-0.6294	-62.9602	-62.9602 10.7054 3.7923
6	101.54583	24.00417	-35.481	-63.3818	-0.6825	-63.3818	-63.3818 10.7054 3.7923
7	101.55417	24.00417	-35.471	-67.1305	-0.7256	-67.1305	-67.1305 10.7054 3.7923
8	101.56250	24.00417	-35.461	-73.7600	-0.7625	-73.7600	-73.7600 10.7054 3.7923
9	101.57083	24.00417	-35.450	-79.1701	-0.7625	-78.9356	-97.3310 13.7653 2.1200

Only using the observed gravity disturbances.

Algorithm of gravity field approach using SRBFs

After the first estimation is completed, it is recommended to employ the output residual observation file *chs as the input observation file again to refine target field element. Generally, the stable solution can be achieved by 1 to 3 times cumulative SRBF approach, and the target field element is equal to the sum of these SRBF approach solutions.

The validity principle of once SRBF approach: (1) The residual target field element grid is continuous and differentiable, and whose standard deviation is as small as possible. (2) The statistical mean of residuals tends to zero with the increase of cumulative approach times, and there is no obvious reverse sign.

Extract data to be plot Plot

The program is a high performance and adaptable modeling tool on gravity field. Various observations with heterogeneity, different altitudes, cross-distribution, and land-sea coexisting can be directly employed to estimate the full element models of gravity field without reduction, continuation, and gridding.

The program has strong ability on the observation gross error detection, measurement of external accuracy indexes, computation performance control and result quality assessment.

Spatial distribution of observations

spherical radial basis function spatial curve

residual gravity disturbance (mGal)

residual height anomaly (m)

residual disturbing gradient (E)

residual vertical deflection S (")

0.2768m The external accuracy index (SD) of the 2~540th degree model geoid
 0.0243m The external accuracy index (SD) of GNSS-levelling
 -0.3482 (-0.0070) = -0.3412m The measured height datum difference

		number of points	mean	standard deviation	minimum	maximum
Gravity disturbance (mGal)	Original residuals	4219	0.3186	42.1772	-296.0915	165.2611
	Residuals without error	4215	0.2695	42.0737	-296.0915	165.2611
	Remaining residuals	4215	-0.4584	13.6071	-61.1040	64.8276
GNSS levelling geoidal height (m)	Original residuals	125	-0.3510	0.2774	-0.9982	0.3435
	Residuals without error	124	-0.3482 ^①	0.2768	-0.9982	0.3435
	Remaining residuals	124	-0.0070 ^②	0.0243 ^③	-0.1328	0.0561

The statistical mean ① minus ② of the GNSS-leveling remaining residuals in the table, that is, $-0.3482^{\text{①}} - (-0.0070^{\text{②}}) = -0.3412$ m, is the difference between the regional height datum and global height datum (gravimetric geoid). Here provides the SRBF measurement method for regional height datum difference.

In the table, 0.0243^③m is the external accuracy index of the observed GNSS-leveling expressed as standard deviation, that is, 2.43 cm. Here provides the SRBF

measurement method for the external accuracy index of GNSS-levelling. The result indicates that the external accuracy of the observed GNSS-levelling is not bad than 2.43 cm (standard deviation).

In general, it is necessary to make 1 to 2 cumulative SRBF approach with *.chs as the input file to obtain the minimum of the standard deviation of the GNSS-levelling remaining residuals as the external accuracy index, and this process is omitted in this example.

After removing the regional height datum difference of -0.3411m from the GNSS-levelling residuals, the new heterogeneous observation residual file obsresiduals1.txt is reconstructed again.

(4) Full element modelling on the residual gravity field using SRBFs

Call the program [Full element modelling on gravity field using SRBFs from heterogeneous observations], let the contribution rate $\kappa = 1$, and input the heterogeneous residual file obsresiduals1.txt and the model geoidal height grid file mdlgeoidh30s.dat to estimate the 30" residual gravity field grid rntSRBFgeoidh30s1.xxx on geoid, and get the remaining residual file rntSRBFgeoidh30s1.chs.

(4) Full element modelling on the residual gravity field using SRBFs

Open the discrete heterogeneous residual observations file

number of rows of file header 1
column ordinal number of ellipsoidal height in the record 6
column ordinal number of weight 7

Select SRBF radial multipole kernel
Order m 3
Minimum degree 360
Maximum degree 1800
Burial depth of Bjerrhammar sphere 10.0km
Action distance of SRBF center 100km
Reuter network level K 3600

Select the adjustable observations height anomaly (m)
Contribution rate κ of adjustable observations 1.00

Open the ellipsoidal height grid file of calculation surface

>> The parameter settings have been entered into the system!
** Click the [Start Computation] control button, or the [Start Computation] tool button...
>> Computation start time: 2023-03-21 10:42:16
>> Complete the computation!
>> The program outputs the full elements grid files into the current directory. These grid files include the residual residual gravity disturbance *.rga (mGal), residual height anomaly *.ksi (m), residual gravity anomaly *.gra (mGal), residual disturbing gravity gradient *.gr (E, radial) and residual vertical deflection vector *.dt (*, SW), where * is the output file name
>> The program also outputs SRBF center file *.center.txt into the current directory. The file header format: Reuter grid level, SRBF center number, cell grid number in meridian circle direction, maximum cell grid number in prime vertical circle direction, latitude interval (°), the record format: point no, longitude (degree decimal), geocentric latitude, cell grid area deviation percentage, longitude interval of cell grid in prime vertical circle direction (°)

Type 0 of source observations: mean 0.2695 standard deviation 42.0737 minimum -236.0915 maximum 165.2611
esidual observations: mean 0.0196 standard deviation 12.9865 minimum -80.4161 maximum 64.8276
Type 1 of source observations: mean -0.0071 standard deviation 0.2768 minimum -0.6571 maximum 0.6846
esidual observations: mean -0.0002 standard deviation 0.0276 minimum -0.1059 maximum 0.0768

ID	lon	lat	ellipsoid height	gravity disturbance (mGal)	height anomaly (m)	gravity gradient (E)	vertical deflection (S, W)
1	101.50417	24.00417	-35.528	40.8686	-0.3641	-40.7566	-57.8306 7.9481 3.4054
2	101.51250	24.00417	-35.519	-47.9108	-0.4135	-47.7836	-69.2552 8.7393 3.2540
3	101.52083	24.00417	-35.510	-55.2656	-0.4640	-55.1220	-81.5702 9.3575 3.1155
4	101.52917	24.00417	-35.501	-64.0905	-0.5229	-63.9294	-93.8848 9.9375 2.9770
5	101.53750	24.00417	-35.491	-73.4852	-0.5848	-73.3055	-106.1994 10.5375 2.8385
6	101.54583	24.00417	-35.481	-72.3357	-0.5786	-72.1577	-118.5140 11.1375 2.7000
7	101.55417	24.00417	-35.471	-76.9013	-0.6113	-76.7132	-130.8286 11.7375 2.5615
8	101.56250	24.00417	-35.461	-84.2142	-0.6615	-84.0106	-143.1432 12.3375 2.4230
9	101.57083	24.00417	-35.450	-88.9580	-0.6936	-88.7444	-155.4578 12.9375 2.2845

Algorithm of gravity field approach using SRBFs

After the first estimation is completed, it is recommended to employ the output residual observation file *.chs as the input observation file again to refine target field element. Generally, the stable solution can be achieved by 1 to 3 times cumulative SRBF approach, and the target field element is equal to the sum of these SRBF approach solutions.

The validity principle of once SRBF approach: (1) The residual target field element grid is continuous and differentiable, and whose standard deviation is as small as possible. (2) The statistical mean of residuals tends to zero with the increase of cumulative approach times, and there is no obvious reverse sign.

Extract data to be plot Plot →

The program is a high performance and adaptable modeling tool on gravity field. Various observations with heterogeneity, different altitudes, cross-distribution, and land-sea coexisting can be directly employed to estimate the full element models of gravity field without reduction, continuation, and gridding.

The program has strong ability on the observation gross error detection, measurement of external accuracy indexes, computation performance control and result quality assessment.

Spatial distribution of observations spherical radial basis function spatial curve residual gravity disturbance (mGal)

Full element models rntSRBFgeoidh30s1.xxx of the residual gravity field

residual height anomaly (m) residual disturbing gradient (E) residual vertical deflection S (°)

Can furtherly detect and remove the observation gross errors from *.chs, and then repeat the step (4).

[The quality control scheme] You can furtherly detect and remove the observation gross error points beyond 3 times standard deviation range of the remaining residuals for the GNSS-levelling sites and beyond 5 times standard deviation range for the disturbance gravity points from the remaining residual file rntSRBFgeoidh30s1.chs, and

then repeat the step (4). This process is omitted in this example.

(5) Full element modelling on the remaining residual gravity field using SRBFs

Call the program [Full element modelling on gravity field using SRBFs from heterogeneous observations], let the contribution rate $\kappa = 1$, and input the remaining residual file `rntSRBFgeoidh30s1.chs` and model geoidal height grid file `mdlgeoidh30s.dat` to estimate the 30" remaining residual gravity field grid `rntSRBFgeoidh30s1.xxx` on geoid, and get the remaining residual file `rntSRBFgeoidh30s1.chs`.

The screenshot shows the software interface for geoid modeling. The command log contains the following text:

```
>>> The parameter settings have been entered into the system
Click the [Start Computation] control button, or the [Start Computation] button
>>> Computation start time: 2023-03-21 10:49:55
>>> Complete the computation!
>>> Computation end time: 2023-03-21 10:54:30
>>> The program outputs the full elements grid files into the current directory. These grid files include the residual residual gravity disturbance *.rga (mGal), residual height anomaly *.ksi (m), residual gravity anomaly *.gra (mGal), residual disturbing gravity gradient *.grg (E, radial) and residual vertical deflection vector *.dft (" SW), where " is the output file name
** The program also outputs SRBF center file *.center.txt into the current directory. The file header format: Reuter grid level, SRBF center number, cell grid number in meridian circle direction, maximum cell grid number in prime vertical circle direction, latitude interval ("). The record format: point no, longitude (degree decimal), geocentric latitude, cell grid area deviation percentage, longitude interval of cell grid in prime vertical circle direction (").
>>> Type 0 of source observations: mean 0.0196 standard deviation 12.9866 minimum -80.4161 maximum 64.8276
residual observations: mean 0.0200 standard deviation 8.4565 minimum -54.9649 maximum 58.6241
** Type 1 of source observations: mean 0.0002 standard deviation 0.0276 minimum -0.1059 maximum 0.0768
residual observations: mean 0.0008 standard deviation 0.0147 minimum -0.0511 maximum 0.0345
```

The data table at the bottom of the screenshot shows the following values:

	mean	standard deviation	minimum	maximum
Residual gravity disturbance (mGal)	0.3523	42.1561	-296.0915	165.2611
First SRBF	0.0196	12.9866	-80.4161	64.8276
Second SRBF	0.0200	8.4565	-54.9649	58.6241
Residual GNSS-levelling geoidal height (m)	-0.0071	0.2768	-0.6571	0.6846
First SRBF	-0.0002	0.0276	-0.1059	0.0768
Second SRBF	0.0008	0.0147 ^④	-0.0511	0.0345

In the table, $0.0147^{\textcircled{4}}\text{m} = 1.5\text{cm}$ can be considered as the accuracy index of geoid modeling.

[The quality control scheme] You can furtherly detect and remove again the

observation gross error points beyond 3 times standard deviation range of the remaining residuals for the GNSS-levelling sites and beyond 5 times standard deviation range for the disturbance gravity points from the remaining residual file SRBFgeoidheight30s2.chs, and then repeat from step (4). This process is omitted in this example.

You can also do further cumulative SRBF approach to improve the results. This example omits this process.

(6) Restore the reference gravity field and generate the 30" full element models of the gravity field on the geoid.

Call the function [Calculation of gravity field elements from global geopotential model], let the minimum degree 2 and maximum degree 540, input the file EGM2008.gfc, and the model geoidal height grid file mdlgeoidh30srst.dat (from mdlgeoidh30s.dat with grid edge removed), to calculate the full element grid GMgeoidh30s540.xxx of the reference gravity field on geoid.

The screenshot displays a software application for geoid calculations. Key components include:

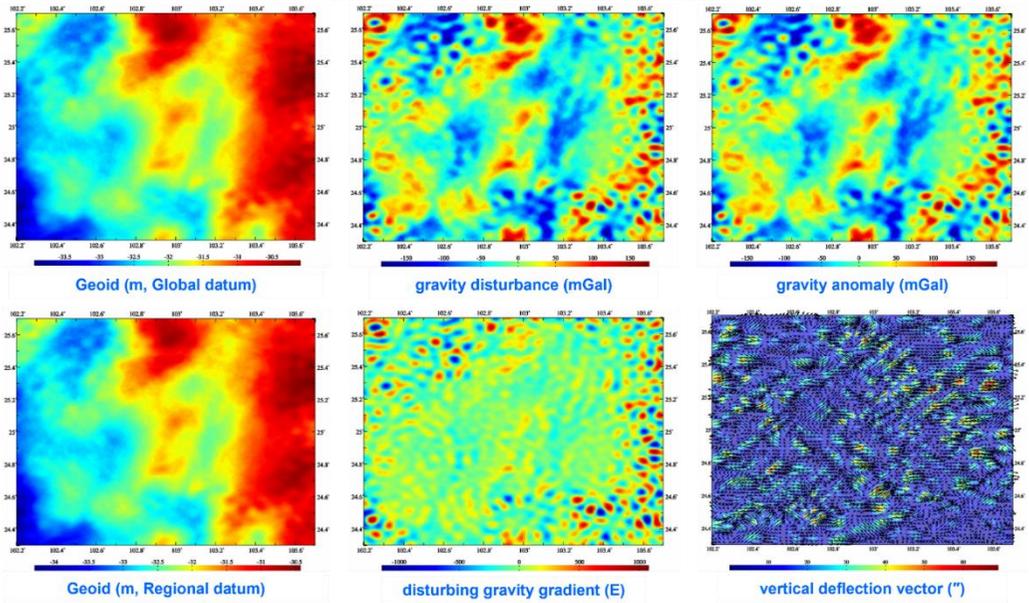
- Input Parameters:** Minimum degree: 2, Maximum degree: 540.
- Model List:** A table showing 'Full element models geoidh30srst.xxx' with associated 'Residuals geoidh30s1' and 'Remaining residuals geoidh30s2'.
- Visualizations:** Two heatmaps showing 'Model disturbing gravity gradient (E) on geoid' and 'Model vertical deflection vector (v) on geoid'.
- Output Data:** A table of numerical values for gravity field elements, including columns for 'Minimum value', 'Maximum value', and 'Standard deviation'.

Add the residual gravity field grid geoidh30s1.xxx (from SRBFgeoidheight30s1.xxx with grid edge removed) and remaining residual gravity field grid geoidh30s2.xxx (from SRBFgeoidheight30s2.xxx with grid edge removed) to the reference gravity field grid GMgeoidh30s540.xxx, the 30" full element gravity field models geoidh30srst.xxx on the geoid are obtained, which include the 30" gravimetric geoidal height grid (geoidh30srst.ksi, m), gravity disturbance grid (geoidh30srst.rga, mGal), gravity anomaly grid (geoidh30srst.gra, mGal), disturbing gravity gradient grid (geoidh30srst.grr, radial, E) and vertical deflection vector grid (geoidh30srst.dft, SW, ").

Add the regional height datum difference -0.3411m to the 30" gravimetric geoidal

height grid geoidh30srst.ksi in global height datum, the 30" gravimetric geoidal height grid geoidh30srgrn.ksi in regional height datum can be obtained.

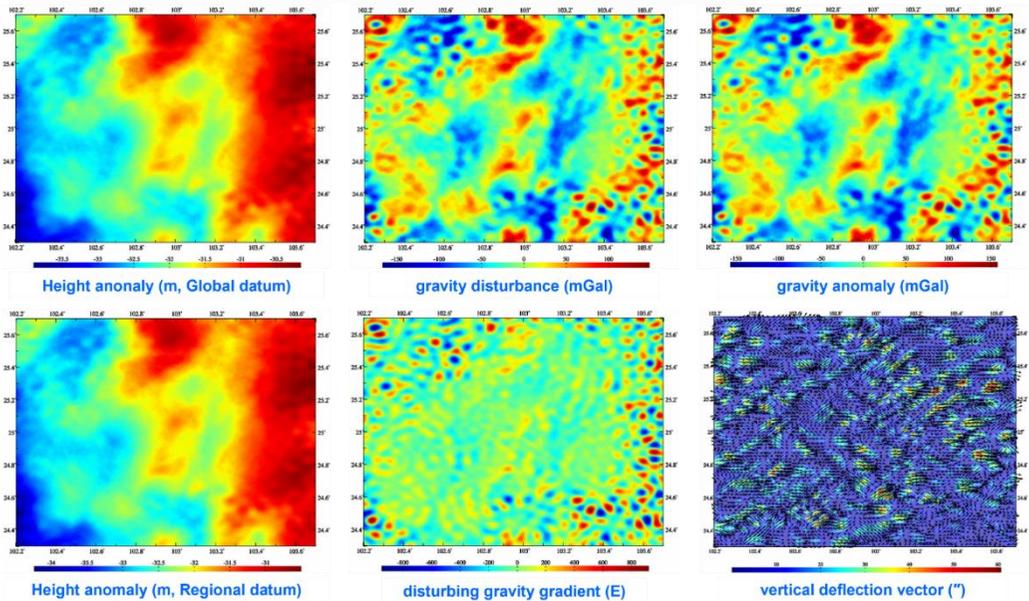
30"×30" full element models of gravity field on geoid



So far, the full element modeling on gravity field on the geoid have been completed.

- Let the terrain surface as the calculation surface, and directly generate the 30" full element models of the gravity field on the terrain surface.

30"×30" full element models of gravity field on terrain surface



In step (3) to step (6) above, the input data file and all the parameter settings are kept the same, and only the calculation surface is changed to the terrain surface surfhgt30s.dat. Using the same computation process, you can synchronously obtain the

30" full element models surfhgt30srst.xxx of the gravity field on the terrain surface, which include the 30" gravimetric ground height anomaly grid (surfhgt30srst.ksi, m, in global height datum), ground gravity disturbance grid (surfhgt30srst.rga, mGal), ground gravity anomaly grid (surfhgt30srst.gra, mGal), ground disturbing gravity gradient grid (surfhgt30srst.grr, radial, E), ground vertical deflection vector grid (surfhgt30srst.dft, SW, ") and ground height anomaly grid (surfhgt30srgn.ksi, m, in regional height datum).