Precise Approach of Earth Gravity Field and Geoid

PAGravf4.5

Chinese Academy of Surveying & Mapping

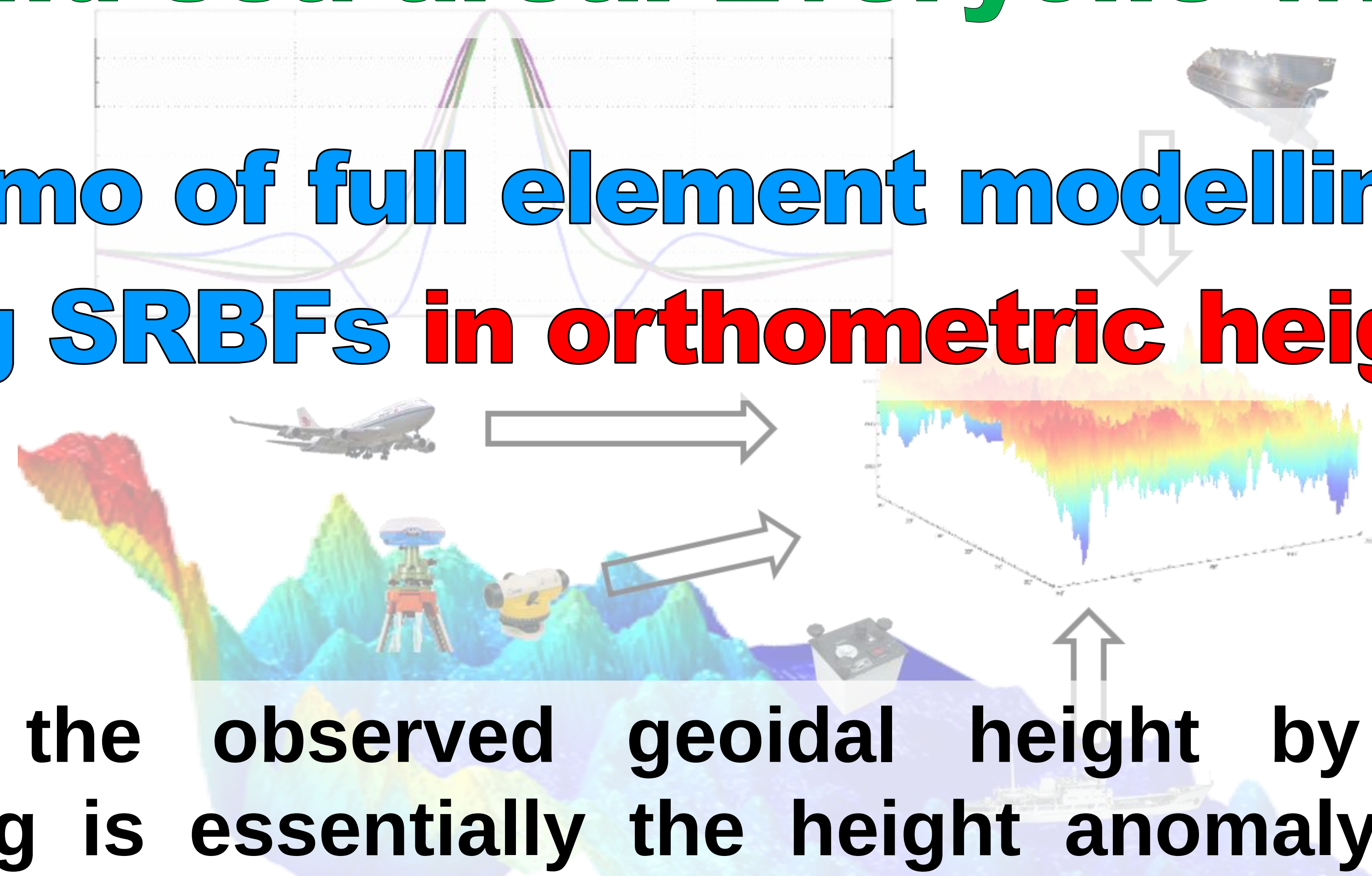
October 2024, Beijing, China

Process demo of all-element modelling on gravity field using SRBFs

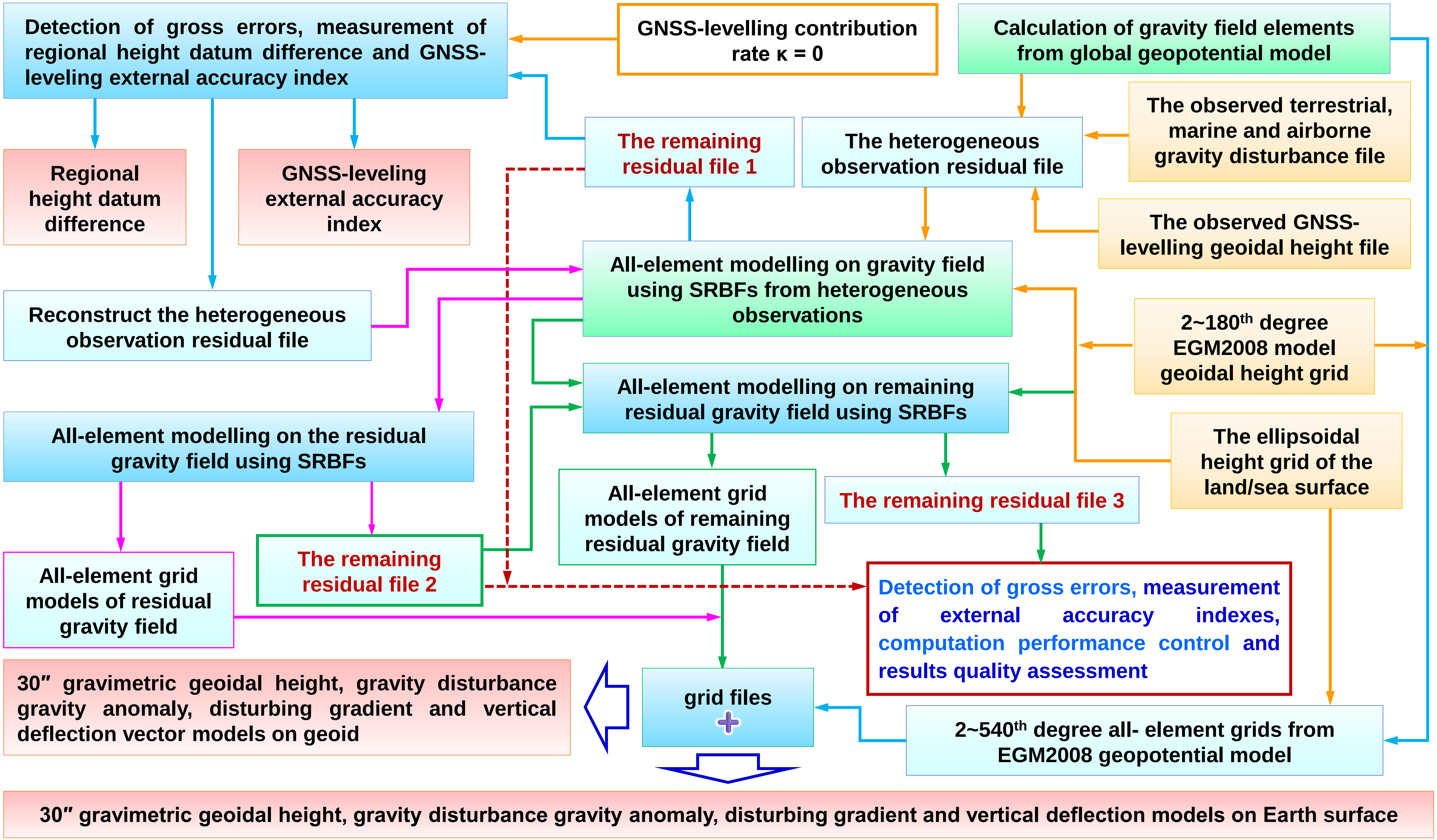
- Various heterogeneous observations can be directly employed to model all-element gravity field without reduction, continuation and griding.
- Has the strong ability in detection of gross errors, measurement of external accuracy indexes and control of computational performance.
- Synchronously realize the all-element analytical modeling on gravity field in whole space on or outside geoid.
- The analytical relationships between gravity field elements are strict, and the approach performance has nothing to do with observation errors.

Only six steps universal in global land-sea area. Everyone will !

Process demo of full element modelling on gravity field using SRBFs in orthometric height system



Since the observed geoidal height by GNSS-leveling is essentially the height anomaly on the geoid in orthometric height system, the height at GNSS-leveling sites must be the geoidal height rather than the ellipsoidal height of GNSS-points.



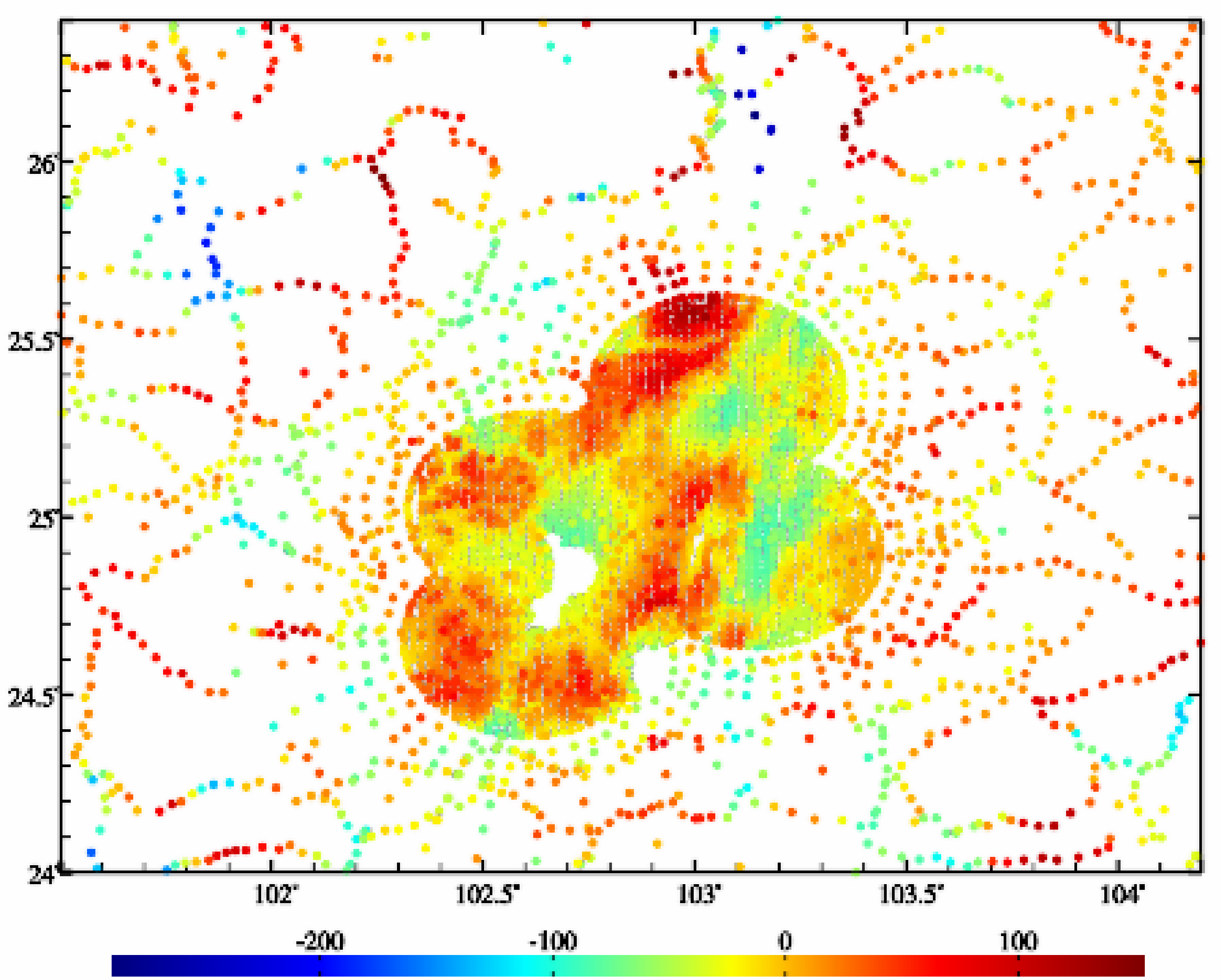
Simple process demo of All-element modelling on gravity filed using SRBFs in orthometric height system

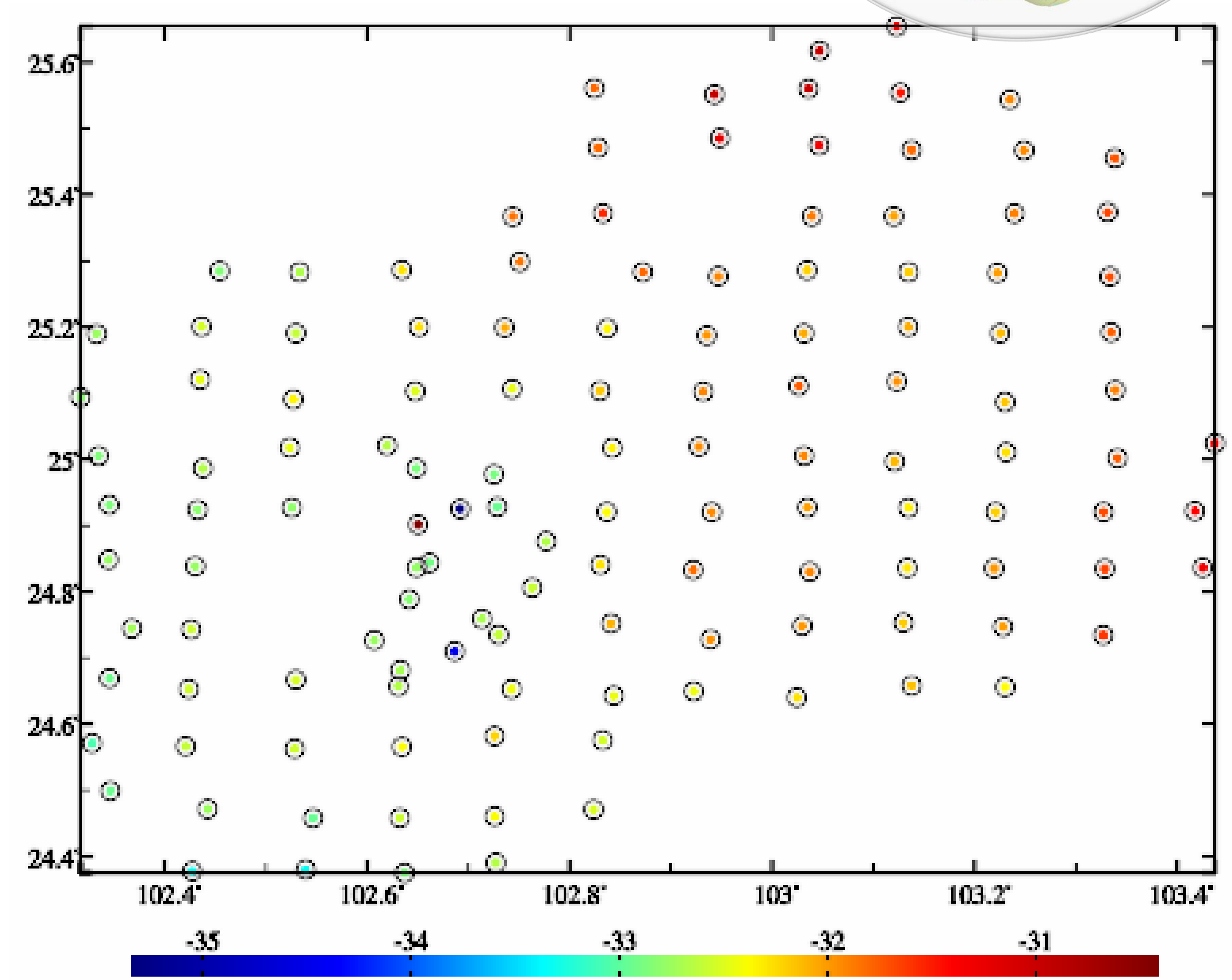
Precise Approach of Earth Gravity Field and Geoid

PAGravf4.5

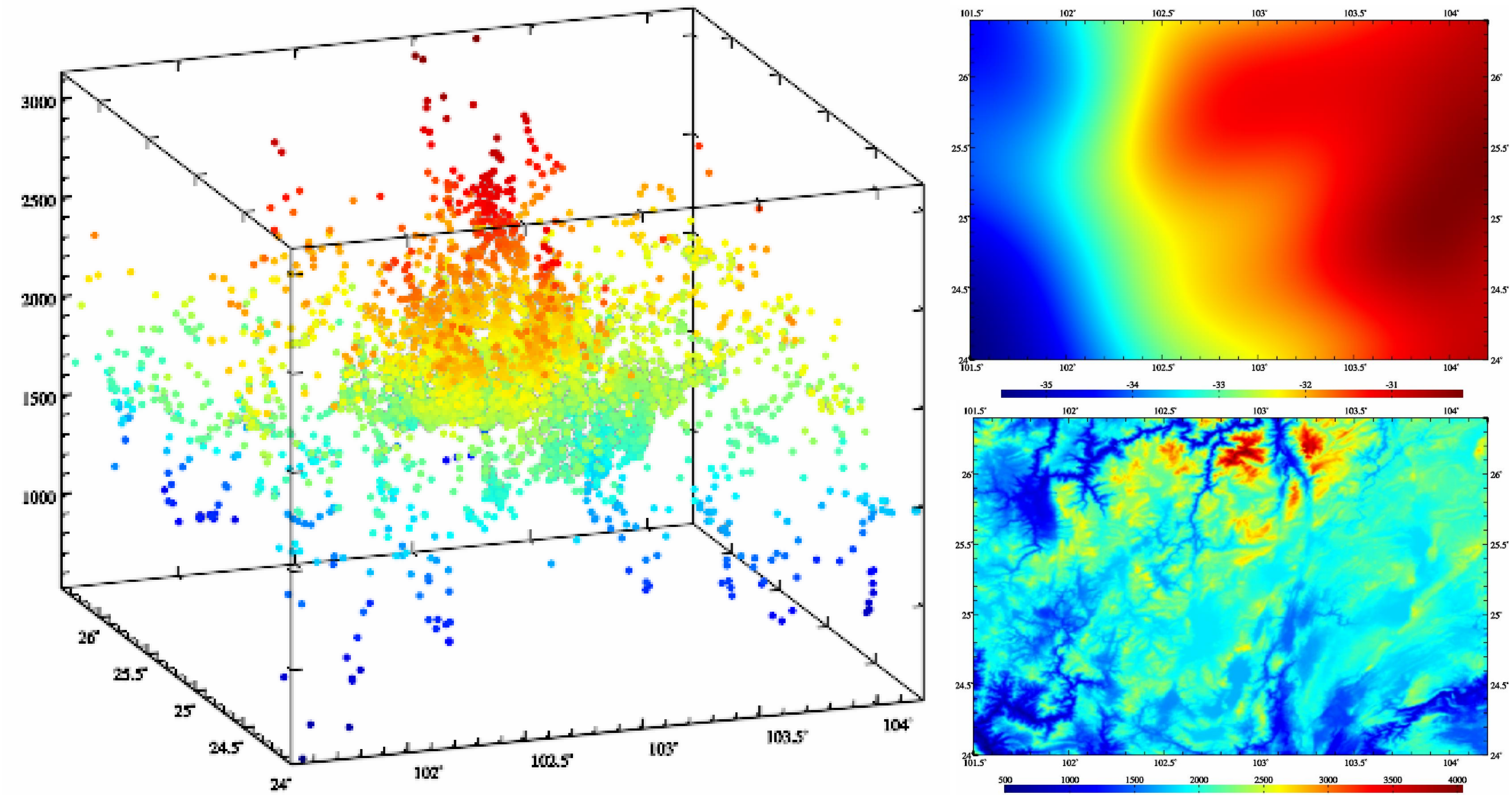
Chinese Academy of Surveying & Mapping

October 2024, Beijing, China

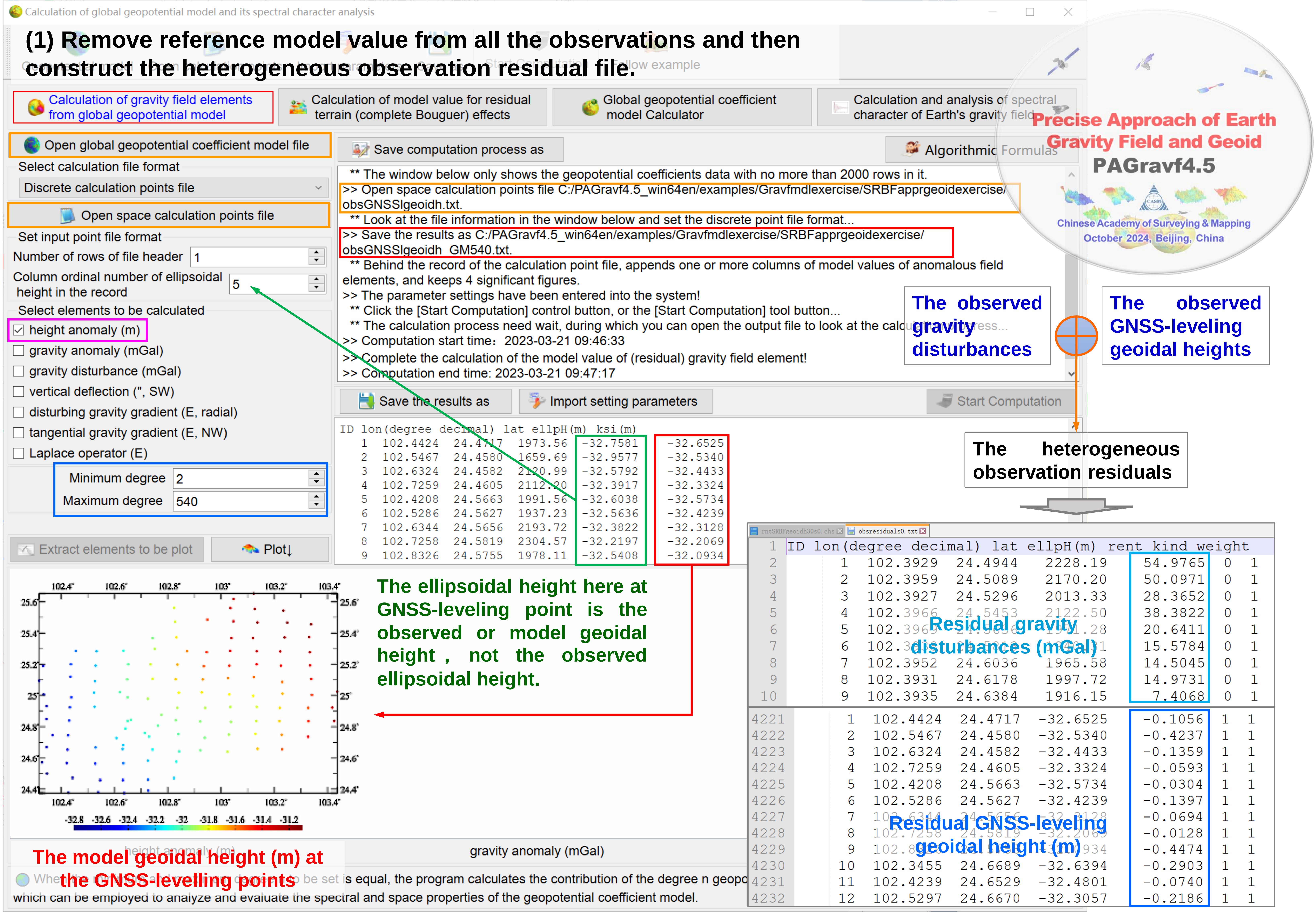




The observed gravity disturbances (mGal) and observed GNSS-levelling geoidal heights (m)



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



Calculation of global geopotential model and its spectral character analysis
(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
Precise Approach of Earth Gravity Field and Geoid
PAGravf4.5
Chinese Academy of Surveying & Mapping
October 2024, Beijing, China
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
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
Extract elements to be plot
Plot↓
** The window below only shows the geopotential coefficients data with no more than 2000 rows in it.
>> Open space calculation points file C:/PAGravf4.5_win64en/examples/Gravfmdlexercise/SRBFapprgeoidexercise/obsGNSSlgeoidh.txt.
** Look at the file information in the window below and set the discrete point file format...
>> Save the results as C:/PAGravf4.5_win64en/examples/Gravfmdlexercise/SRBFapprgeoidexercise/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 parameter settings have been entered into the system!
** Click the [Start Computation] control button, or the [Start Computation] tool button...
** The calculation process need wait, during which you can open the output file to look at the calc
>> Computation start time: 2023-03-21 09:46:33
>> Complete the calculation of the model value of (residual) gravity field element!
>> Computation end time: 2023-03-21 09:47:17
Save the results as
Import setting parameters
Start Computation
The observed gravity disturbances
The observed GNSS-leveling geoidal heights
The heterogeneous observation residuals
ID lon(degree decimal) lat ellpH(m) ksi(m)
1 102.4424 24.4717 1973.56 -32.7581 -32.6525
2 102.5467 24.4580 1659.69 -32.9577 -32.5340
3 102.6324 24.4582 2120.99 -32.5792 -32.4433
4 102.7259 24.4605 2112.20 -32.3917 -32.3324
5 102.4208 24.5663 1991.56 -32.6038 -32.5734
6 102.5286 24.5627 1937.23 -32.5636 -32.4239
7 102.6344 24.5656 2193.72 -32.3822 -32.3128
8 102.7258 24.5819 2304.57 -32.2197 -32.2069
9 102.8326 24.5755 1978.11 -32.5408 -32.0934
The ellipsoidal height here at GNSS-leveling point is the observed or model geoidal height, not the observed ellipsoidal height.
The model geoidal height (m) at the GNSS-levelling points
gravity anomaly (mGal)
ID lon(degree decimal) lat ellpH(m) rent 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 2122.50 38.3822 0 1
5 20.6411 0 1
6 15.5784 0 1
7 102.3952 24.6036 1965.58 14.5045 0 1
8 102.3931 24.6178 1997.72 14.9731 0 1
9 102.3935 24.6384 1916.15 7.4068 0 1
Residual gravity disturbances (mGal)
1 102.4424 24.4717 -32.6525 -0.1056 1 1
2 102.5467 24.4580 -32.5340 -0.4237 1 1
3 102.6324 24.4582 -32.4433 -0.1359 1 1
4 102.7259 24.4605 -32.3324 -0.0593 1 1
5 102.4208 24.5663 -32.5734 -0.0304 1 1
6 102.5286 24.5627 -32.4239 -0.1397 1 1
7 -0.0694 1 1
8 -0.0128 1 1
9 -0.4474 1 1
10 102.3455 24.6689 -32.6394 -0.2903 1 1
11 102.4239 24.6529 -32.4801 -0.0740 1 1
12 102.5297 24.6670 -32.3057 -0.2186 1 1
Residual GNSS-leveling geoidal height (m)
which can be employed to analyze and evaluate the spectral and space properties of the geopotential coefficient model.

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

Follow example

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 Bjerhammar 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

of file header, whose format: observation type (0~5), source observation mean, standard deviation, minimum, maximum, residual observation mean, standard deviation, minimum, maximum. The record format: ID, longitude, latitude, ellipsoidal height, residual observation, source observation, observation type, weight.
>> The parameter settings have been entered into the system!
** Click the [Start Computation] control button, or the [Start Computation] tool button...
>> Computation start time：2024-09-28 18:03:50
>> Complete the computation!
>> Computation end time: 2024-09-28 18:10:25
>> The program outputs the all-element grid files into the current directory. These grid files include the 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, and whose grid specification are the same as the input ellipsoidal height grid of calculation surface.
>> 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: ID, 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 -105.2839 maximum 114.8811
>> Type 1 of source observations: mean -0.3510 standard deviation 0.2774 minimum -0.9982 maximum 0.3435
** Residual observations: mean -0.0410 standard deviation 0.0287 minimum -0.1943 maximum 0.0132

Precise Approach of Earth Gravity Field and Geoid
PAGravf4.5
Chinese Academy of Surveying & Mapping
October 2024, Beijing, China

Solution of normal equation LU

ID	lon	lat	ellipshgt	gra
1	101.50417	24.0		
2	101.51250	24.0		
3	101.52083	24.0		
4	101.52917	24.0		
5	101.53750	24.0		
6	101.54583	24.0		

rntSRBForth30s0.chs

0	0.3186	42.1772	-296.0915	165.2611	residuals:	0.7368	16.9838	-105.2839	114.8811
1	-0.3510	0.2774	-0.9982	0.3435	residuals:	-0.0410	0.0287	-0.1943	0.0132
1	102.39290	24.49440	2228.190	16.4199	54.9765	0	1.000		
2	102.39590	24.50890	2170.200	-4.7688	50.0971	0	1.000		
3	102.39270	24.52960	2013.330	-18.3876	[illegible]	0	1.000		
4	102.39660	24.54530	2122.500	1.0011	[illegible]	0	1.000		
5	102.39690	24.56360	1971.280	-0.0346	20.6411	0	1.000		
6	102.39380	24.58130	1940.310	-12.0941	[illegible]	0	1.000		
7	102.39520	24.60360	1965.580	12.1550	14.5045	0	1.000		
8	102.39310	24.61780	1997.720	20.5312	[illegible]	0	1.000		
9	102.39350	24.63840	1916.150	3.5948	7.4068	0	1.000		

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

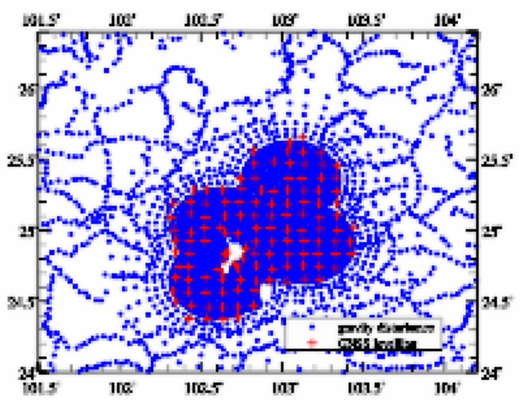
Algorithm of gravity field approach using SRBFs

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 elements. Generally, the stable solution can be achieved by 1 to 3 times cumulative SRBF approach, and the target field elements are qual to the sum of these SRBF approach solutions.

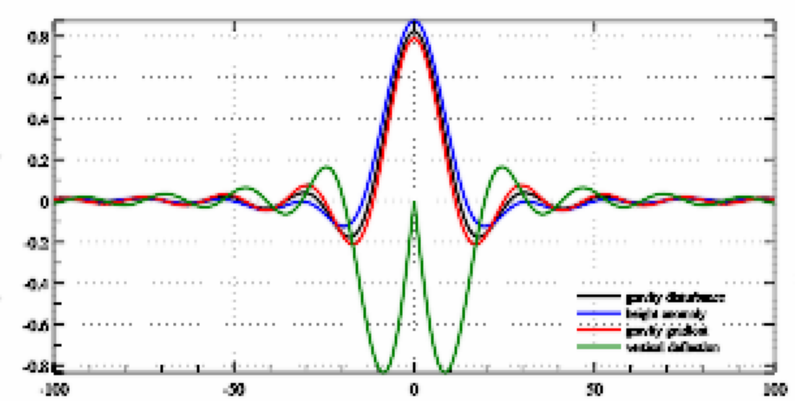
The validity principle of once SRBF approach: (1) The residual target field element grid are continuous and differentiable, and whose standard deviation is as small as possible. (2) The statistical mean of residuals tends to zero with the increase of cumulative approach times, and there is no obvious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

Extract data to be plot | Plot →

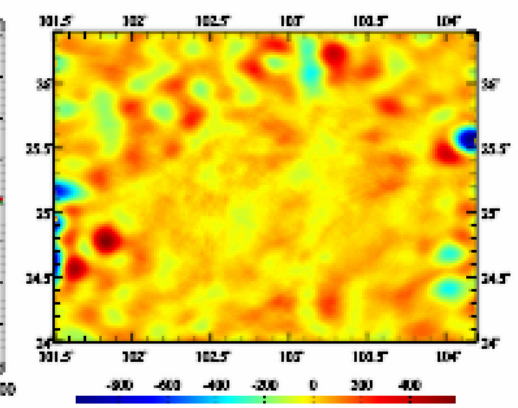
Spatial distribution of observations

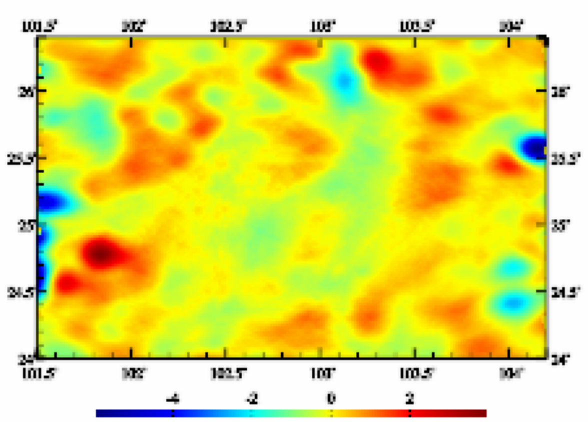


spherical radial basis function spatial curve

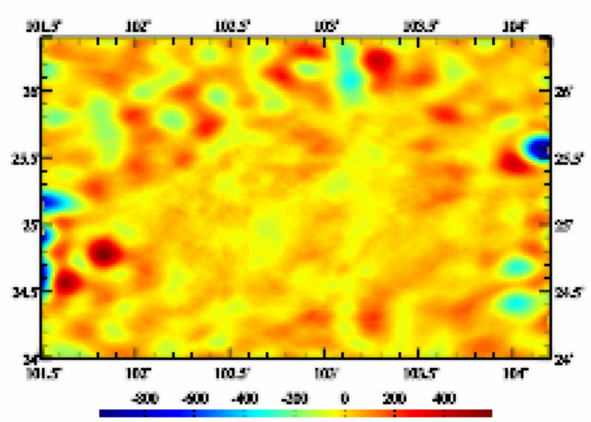


residual gravity disturbance (mGal)

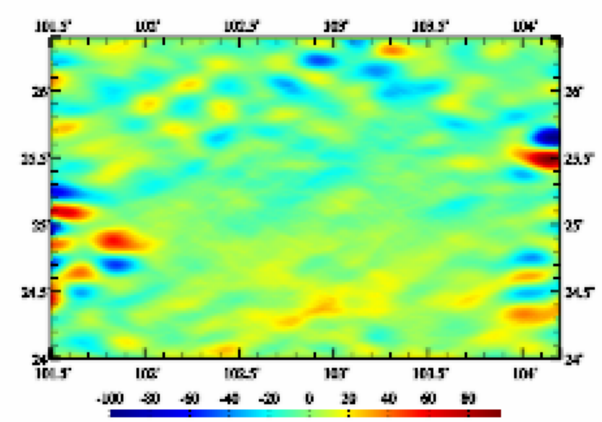




residual height anomaly (m)



residual disturbing gradient (E)

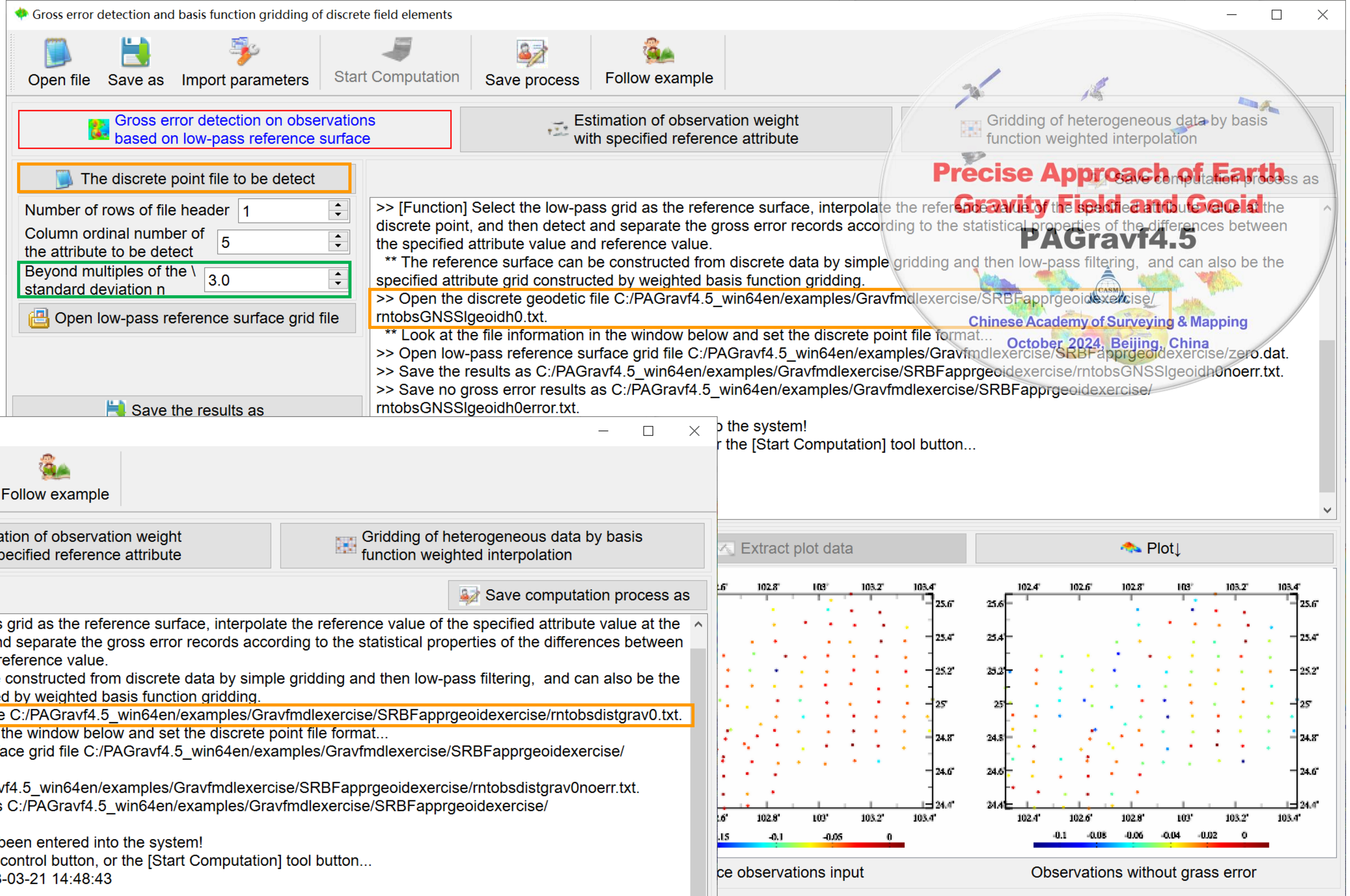


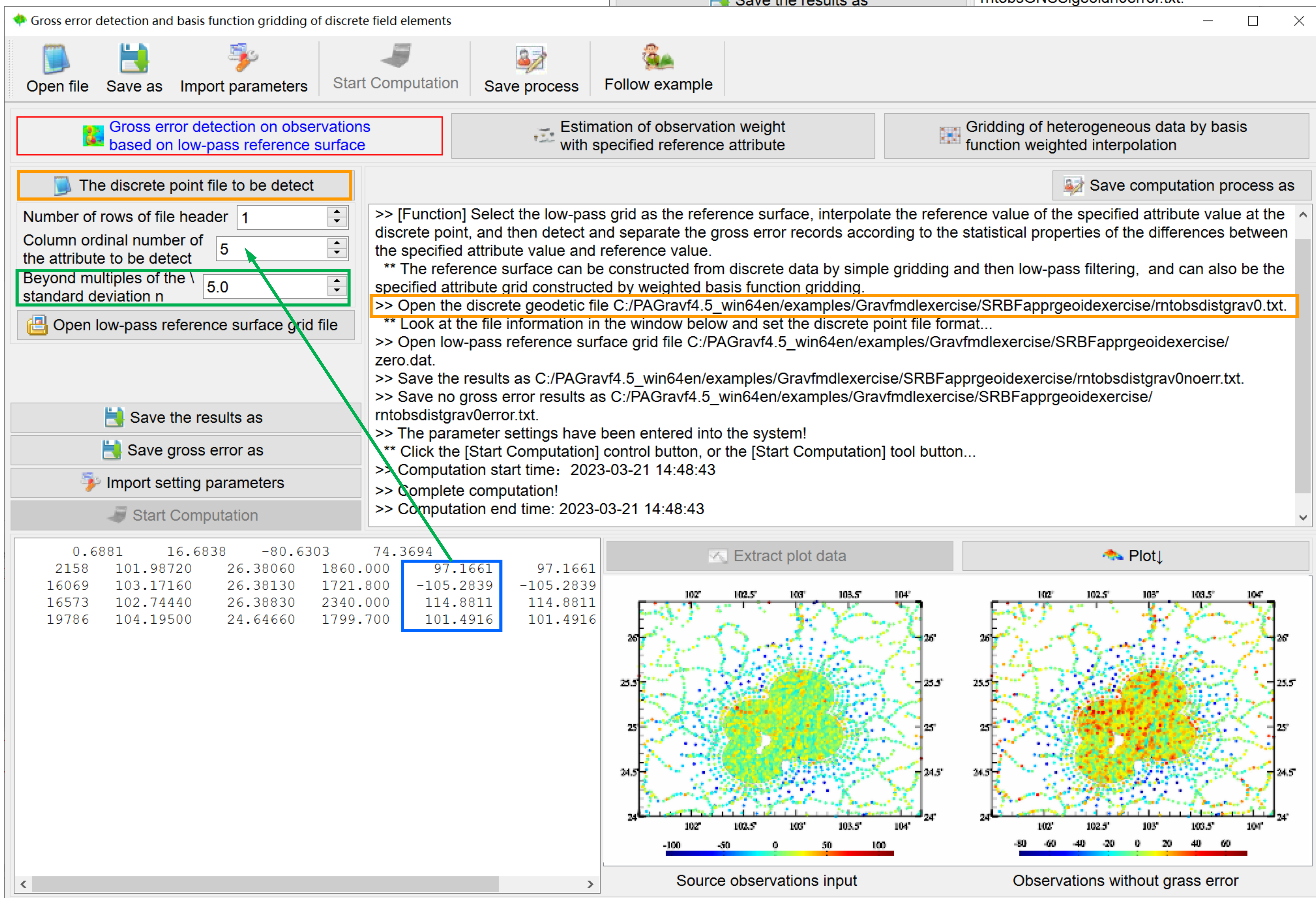
residual vertical deflection S (″)

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

The program has strong capacity on the detection of observation gross errors, measurement of external accuracy indexes and control of computation performance.

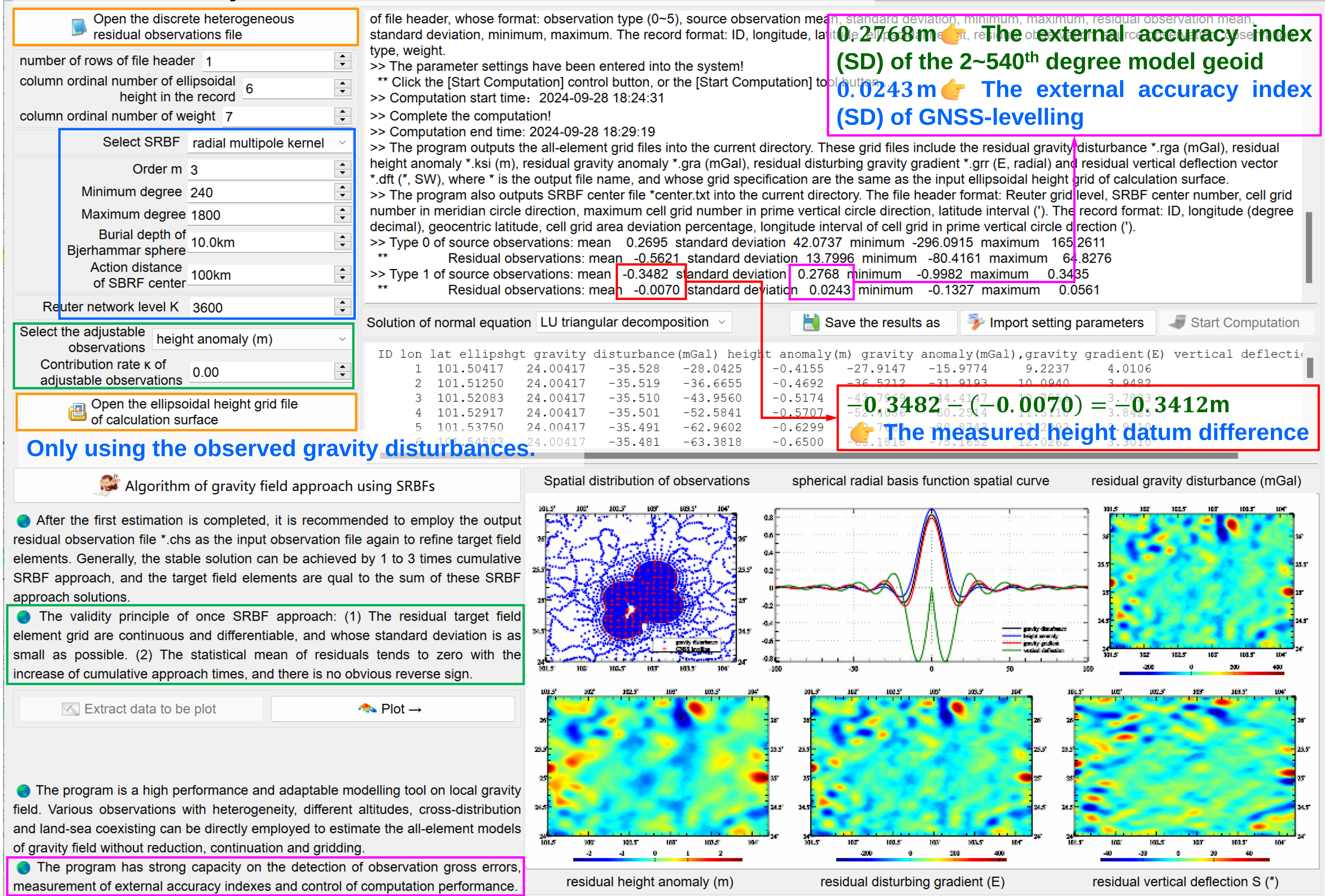
Separate the remaining residuals of the observed GNSS-leveling and observed gravity disturbances from rntSRBFgeoidh30s0.chs.





Reconstruct the heterogeneous observation residual file obsresiduals01.txt.

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



All-element modelling on gravity field using SRBFs from heterogeneous observations

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

Observation file | Save as | Import parameters | Start Computation | Save process | Follow example

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 Bjerhammar 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

of file header, whose format: observation type (0~5), source observation mean, standard deviation, minimum, maximum, residual observation mean, standard deviation, minimum, maximum. The record format: ID, longitude, latitude, ellipsoidal height, residual observation, source observation, observation type, weight.
>> The parameter settings have been entered into the system!
 ** Click the [Start Computation] control button, or the [Start Computation] tool button...
>> Computation start time: 2024-09-28 18:36:27
>> Complete the computation!
>> Computation end time: 2024-09-28 18:41:35
>> The program outputs the all-element grid files into the current directory. These grid files include the 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, and whose grid specification are the same as the input ellipsoidal height grid of calculation surface.
>> 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: ID, 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 0.0196 standard deviation 12.9866 minimum -80.4161 maximum 64.8276
>> Type 1 of source observations: mean -0.0071 standard deviation 0.2768 minimum -0.6571 maximum 0.6846
 ** Residual observations: mean -0.0002 standard deviation 0.0276 minimum -0.1059 maximum 0.0768

Precise Approach of Earth Gravity Field and Geoid
PAGravf4.5
Chinese Academy of Surveying & Mapping
October 2024, Beijing, China

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

ID	lon	lat	ellipshgt	gravity disturbance(mGal)	height anomaly(m)	gravity anomaly(mGal)	gravity gradient(E)	vertical deflection
1	101.50417	24.00417	-35.528	-40.8686	-0.3641	-40[illegible]	[illegible]	[illegible]
2	101.51250	24.00417	-35.519	-47.9108	-0.4135	-47.7036	-69.2552	3.2540
3	101.52083	24.00417	-35.510	-55.2656	-0.4640	-55[illegible]	[illegible]	[illegible]
4	101.52917	24.00417	-35.501	-64.0905	-0.5229	-63.9296	-97.2660	10.2425
5	101.53750	24.00417	-35.491	-73.4852	-0.5848	-73[illegible]	[illegible]	[illegible]
6	101.54583	24.00417	-35.481	-72.3357	-0.5786	-72.1577	-106.5435	10.3880	2.3703

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

Algorithm of gravity field approach using SRBFs

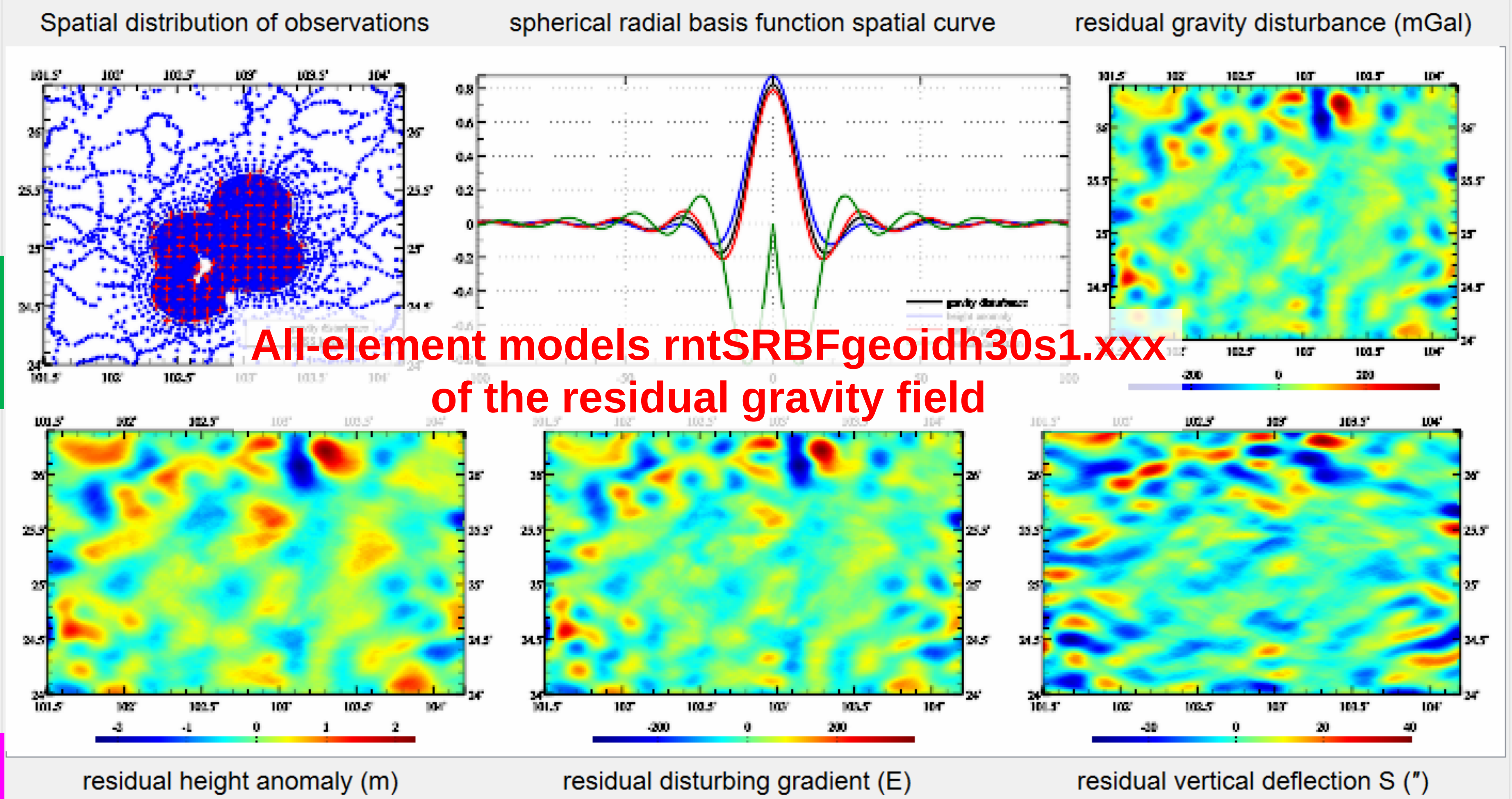
After the first estimation is completed, it is recommended to employ the output residual observation file *.chs as the input observation file again to refine target field elements. Generally, the stable solution can be achieved by 1 to 3 times cumulative SRBF approach, and the target field elements are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

The validity principle of once SRBF approach: (1) The residual target field element grid are 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 modelling tool on local gravity field. Various observations with heterogeneity, different altitudes, cross-distribution and land-sea coexisting can be directly employed to estimate the all-element models of gravity field without reduction, continuation and gridding.

The program has strong capacity on the detection of observation gross errors, measurement of external accuracy indexes and control of computation performance.



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

All-element modelling on gravity field using SRBFs from heterogeneous observations

Observation file | Save as | Import parameters | Start Computation | Save process | Follow example

Open the discrete heterogeneous residual observations file

- number of rows of file header: 2
- column ordinal number of ellipsoidal height in the record: 7
- column ordinal number of weight: 8
- Select SRBF: Poisson wavelet kernel
- Order m: 5
- Minimum degree: 540
- Maximum degree: 5400
- Burial depth of Bjerhammar sphere: 6.0km
- Action distance of SRBF center: 60km
- Reuter network level K: 5400
- Select the adjustable observations: height anomaly (m)
- Contribution rate κ of adjustable observations: 1.00

Open the ellipsoidal height grid file of calculation surface

of file header, whose format: observation type (0~5), source observation mean, standard deviation, minimum, maximum, residual observation mean, standard deviation, minimum, maximum. The record format: ID, longitude, latitude, ellipsoidal height, residual observation, source observation, observation type, weight.
>> The parameter settings have been entered into the system!
** Click the [Start Computation] control button, or the [Start Computation] tool button.
>> Computation start time: 2024-09-28 19:56:11
>> Complete the computation!
>> Computation end time: 2024-09-28 20:03:11
>> The program outputs the all-element grid files into the current directory. These grid files include the 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, and whose grid specification are the same as the input ellipsoidal height grid of calculation surface.
>> 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: ID, 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

Input the file rntSRBFgeoidh30s1.chs output from the previous step.

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

ID	lon	lat	ellipshgt	gravity disturbance(mGal)	height anomaly(m)	gravity anomaly(mGal)	gravity gradient(E)	vertical deflecti
1	101.50417	24.00417	-35.528	-12.7117	-0.0168	-12.7065	-97.1597	-0.6515	-0.5321
2	101.51250	24.00417	-35.519	-6.6258	-0.0077	-6.6234	-54.9695	-1.2702	-1.0260
3	101.52083	24.00417	-35.510	2.3531	0.0053	2.3515	9.9592	-2.0661	-1.4528
4	101.52917	24.00417	-35.501	11.0246	0.0174	11.01[illegible]	[illegible]	[illegible]	[illegible]
5	101.53750	24.00417	-35.491	16.8356	0.0255	16.827[illegible]	117.3662	-3.7229	-1.4204
6	101.54583	24.00417	-35.481	17.2077	0.0259	17.19[illegible]	[illegible]	[illegible]	[illegible]

$0.0147m \approx 1.5\,cm$ 👉 The accuracy index (SD) of geoid modeling.

Algorithm of gravity field approach using SRBFs

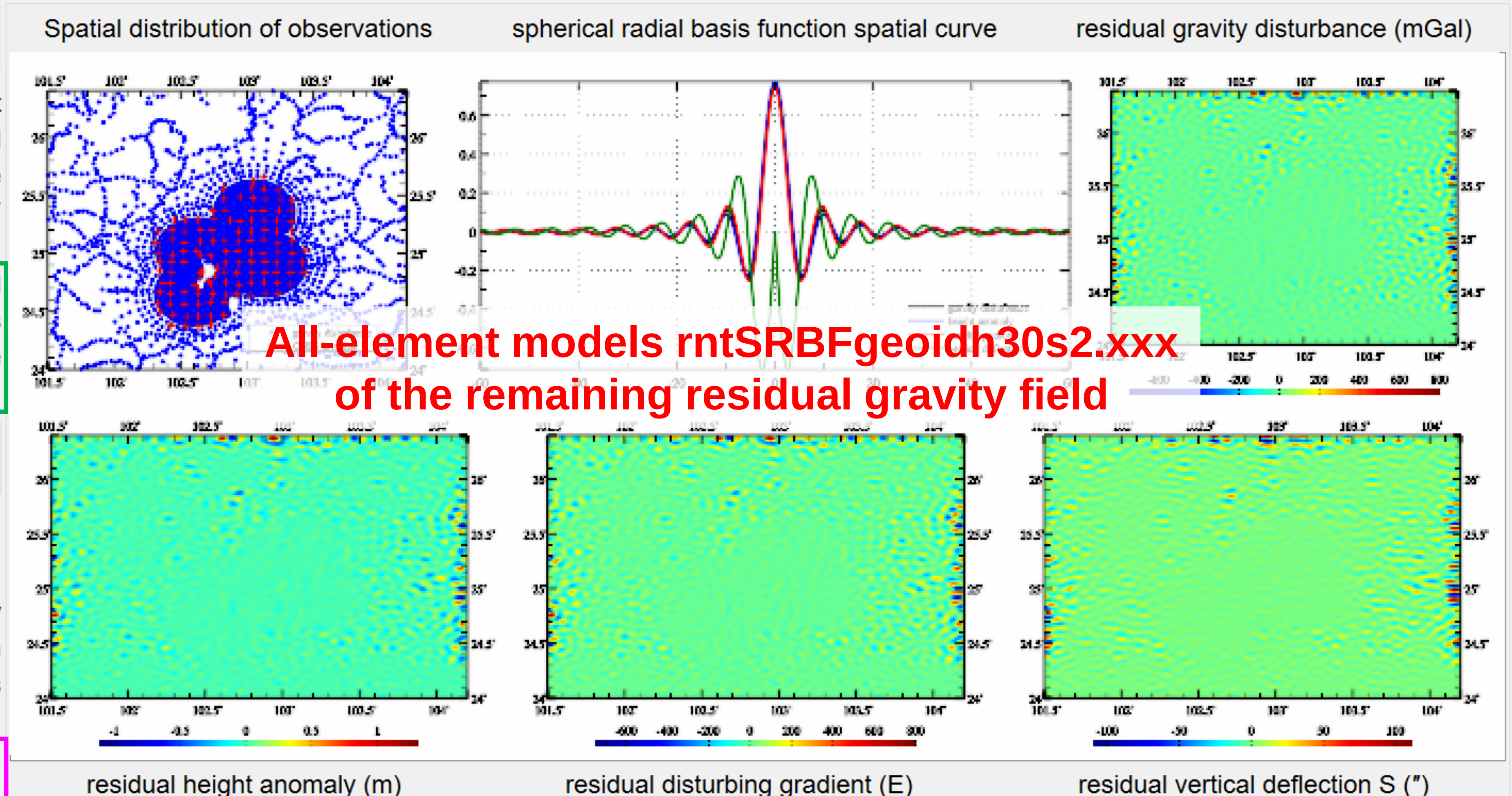
After the first estimation is completed, it is recommended to employ the output residual observation file *.chs as the input observation file again to refine target field elements. Generally, the stable solution can be achieved by 1 to 3 times cumulative SRBF approach, and the target field elements are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

The validity principle of once SRBF approach: (1) The residual target field element grid are 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.

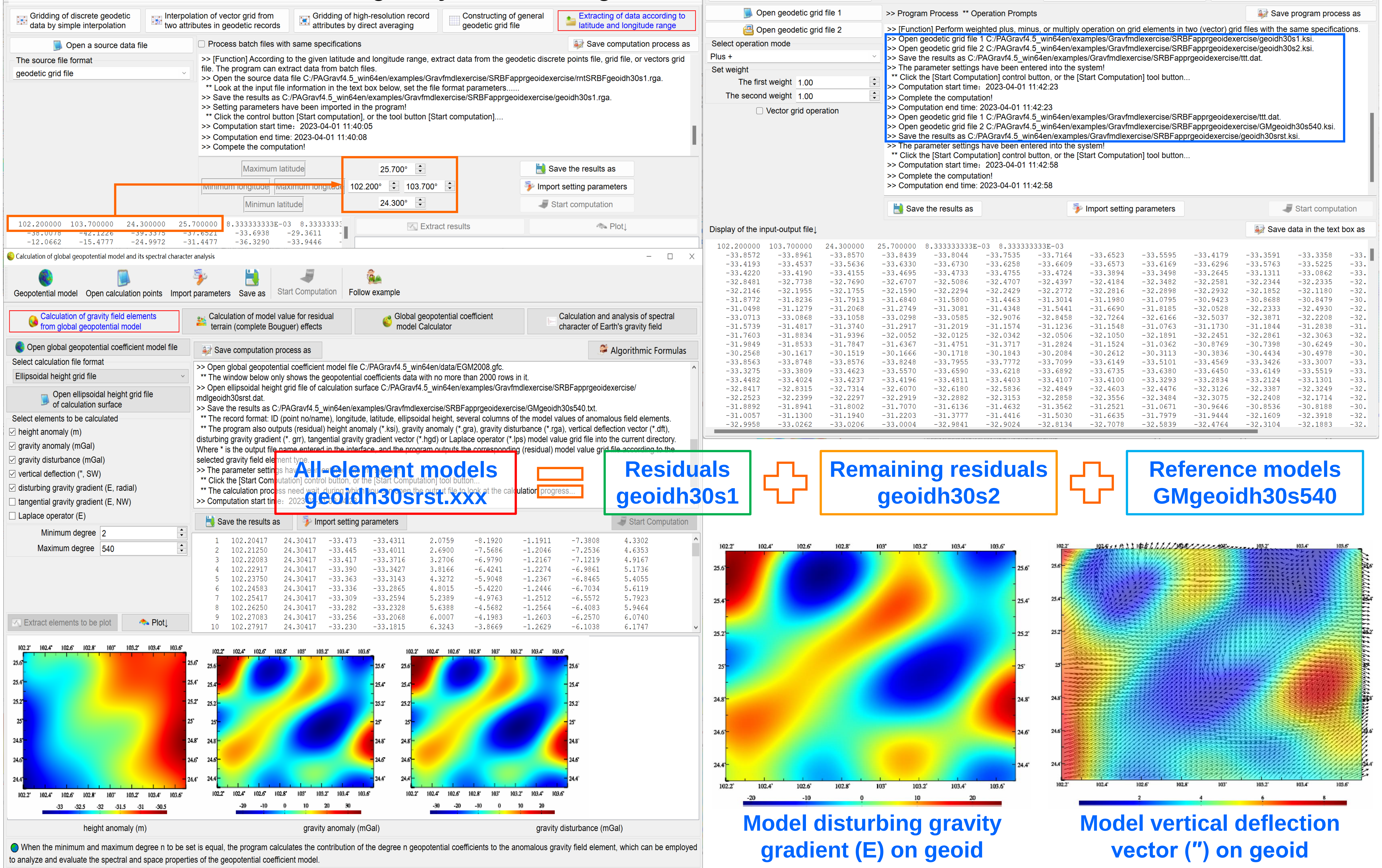
Extract data to be plot | Plot →

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

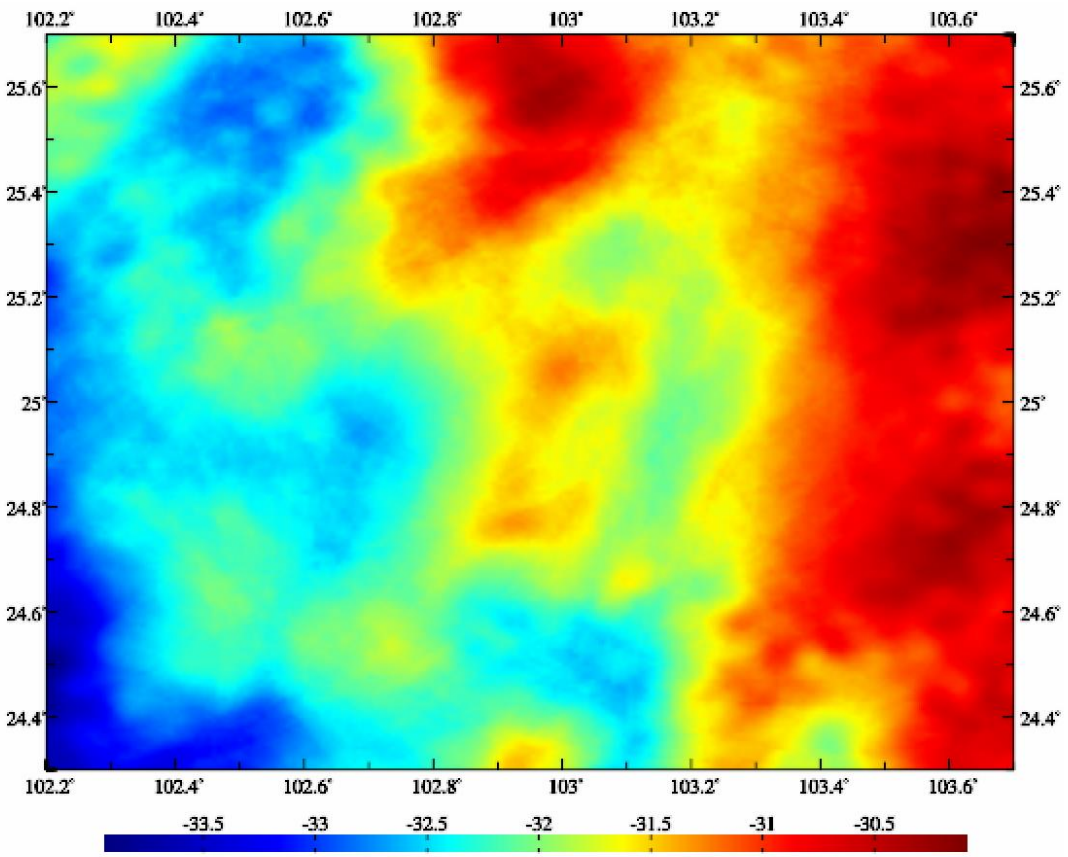
The program has strong capacity on the detection of observation gross errors, measurement of external accuracy indexes and control of computation performance.



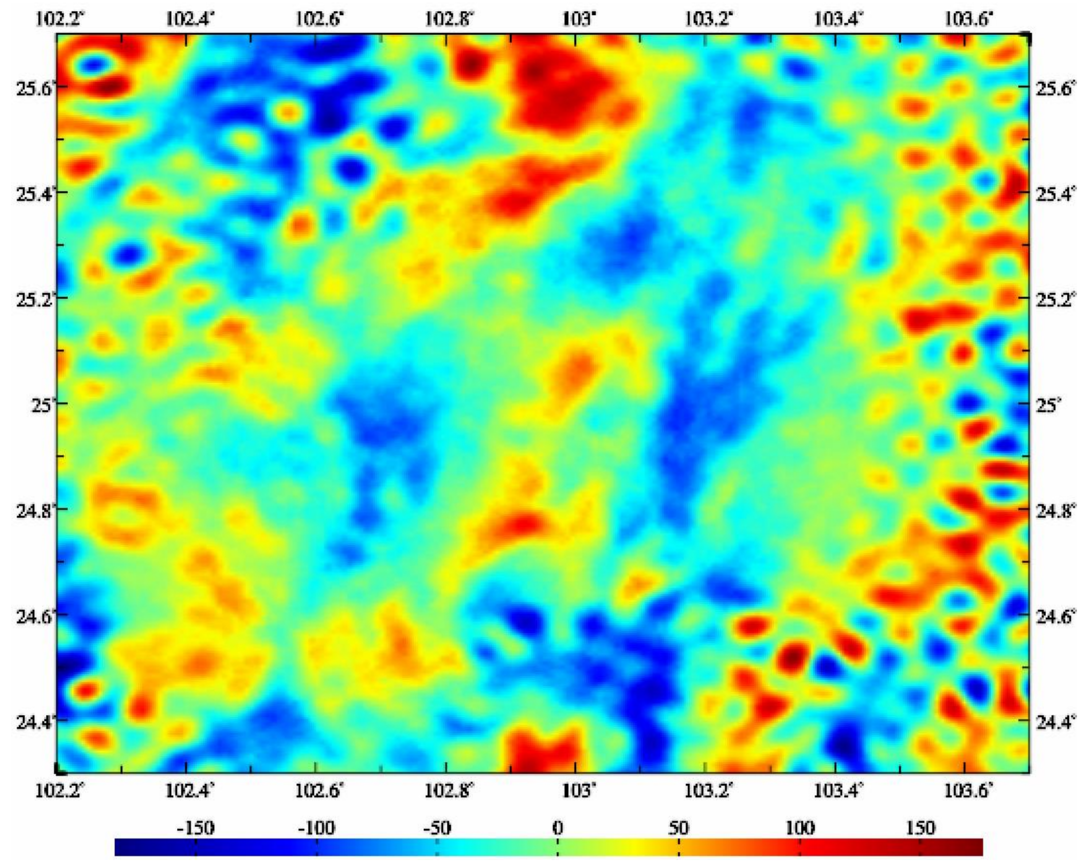
(6) Restore the reference gravity field and generate the 30″ all-element models of the gravity field on the geoid.



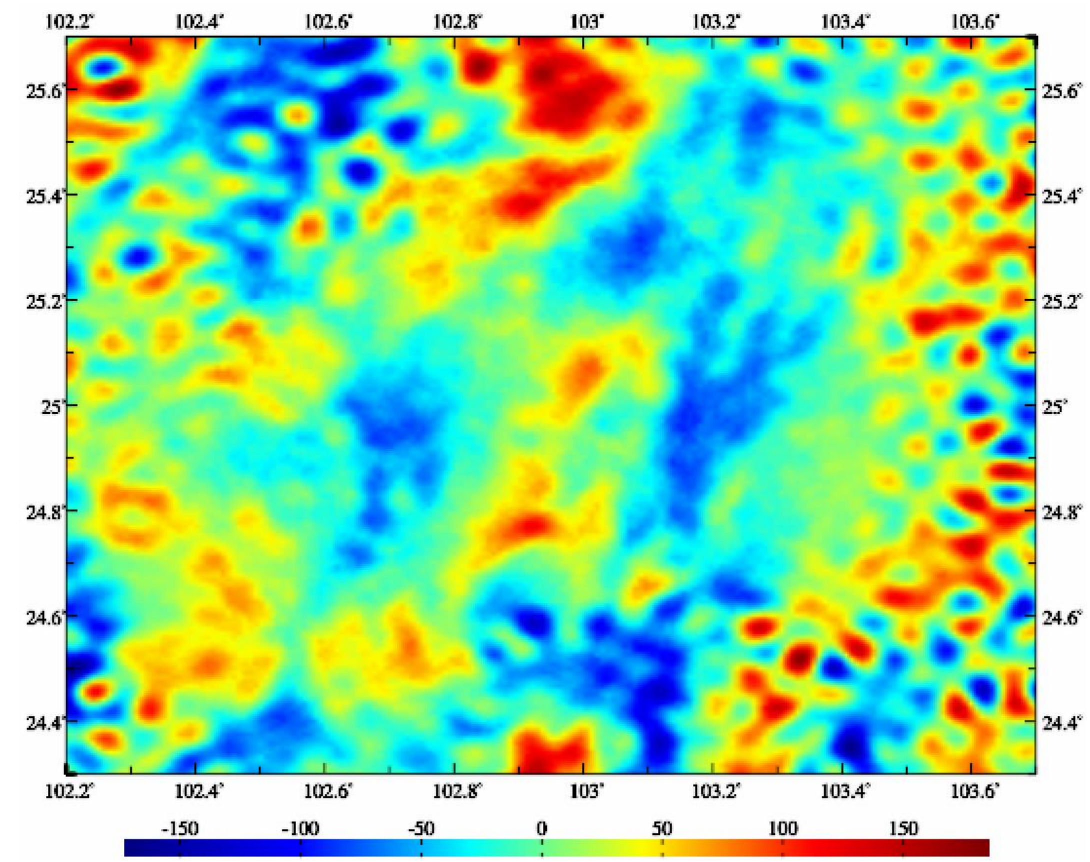
30″×30″ all-element models of gravity field on geoid



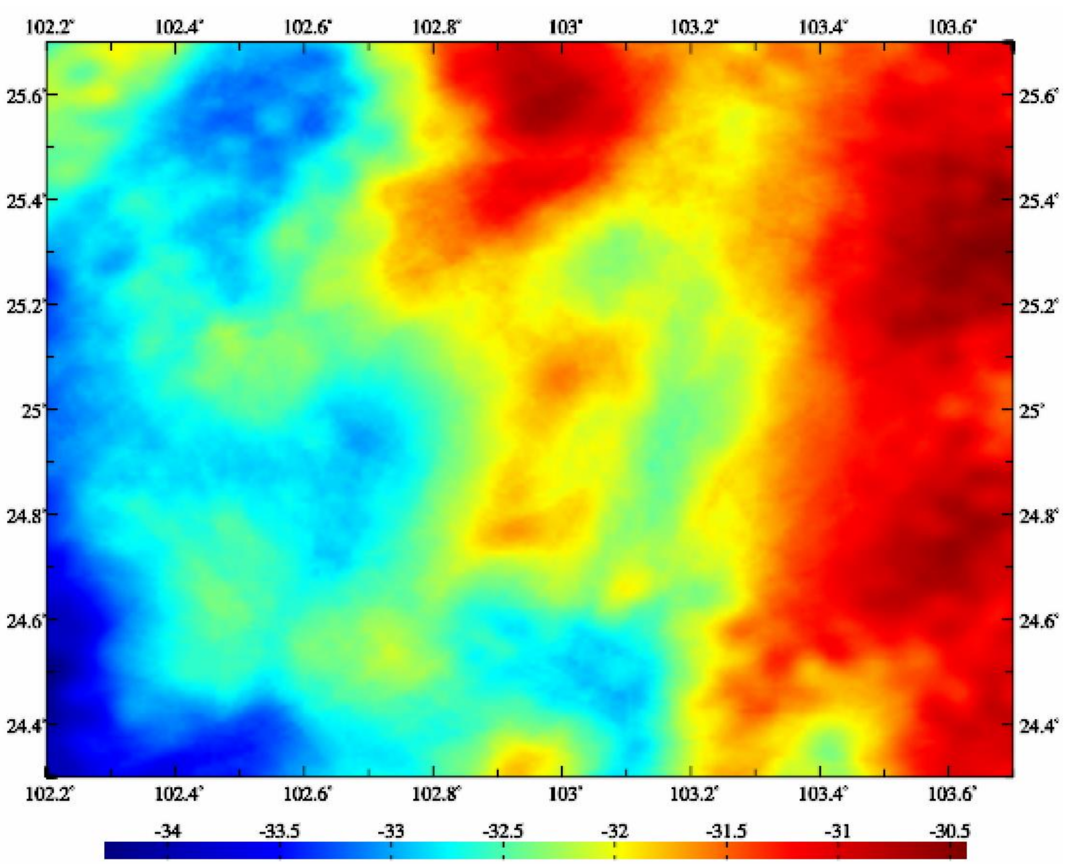
Geoid (m, Global datum)



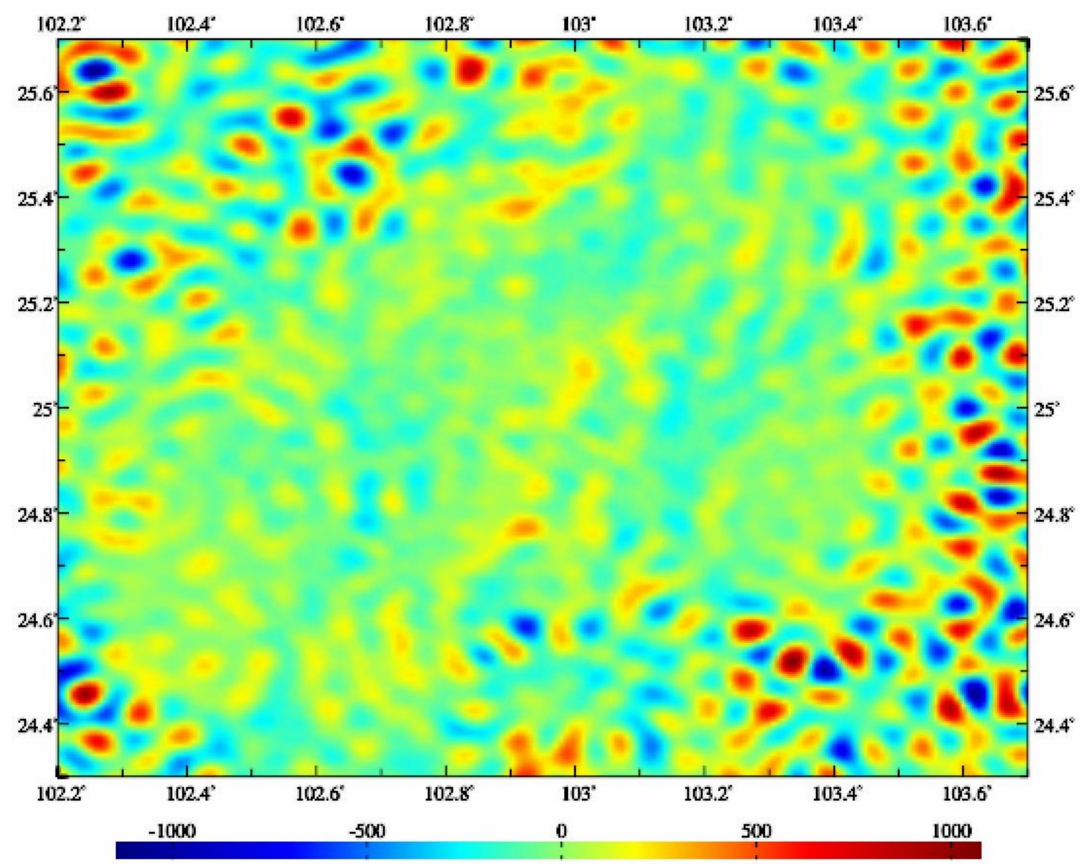
gravity disturbance (mGal)



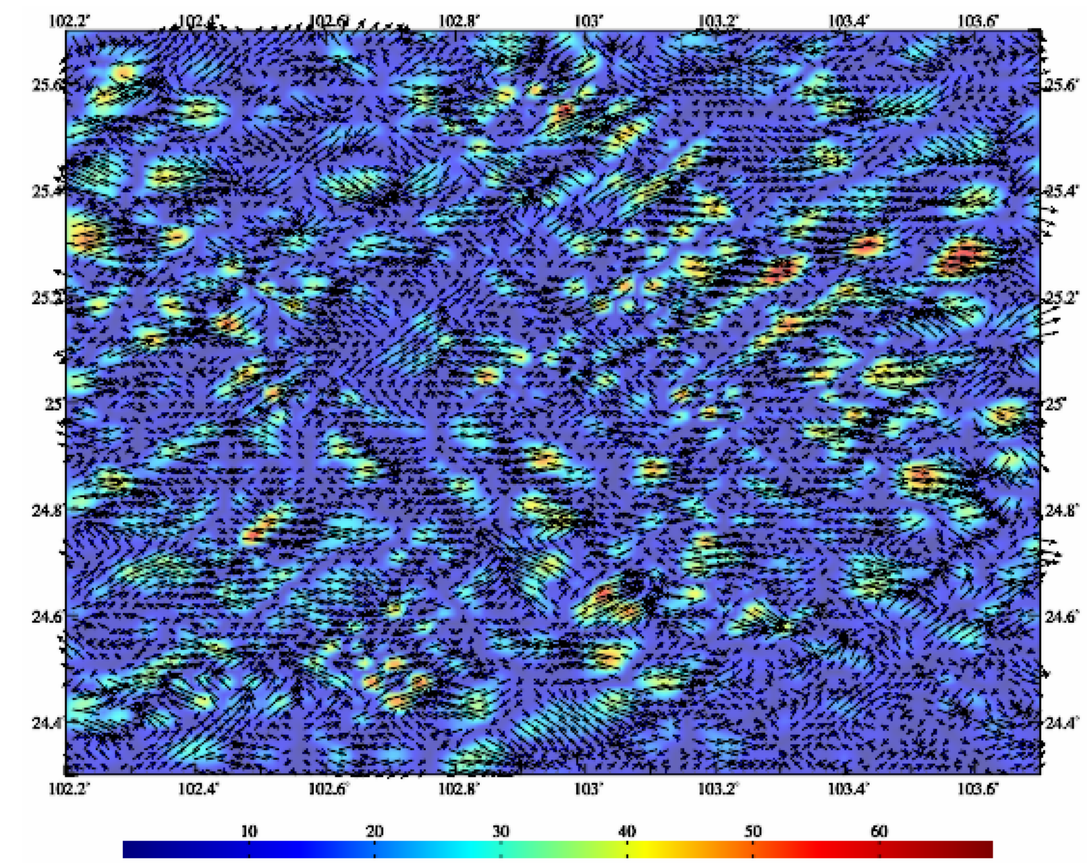
gravity anomaly (mGal)



Geoid (m, Regional datum)

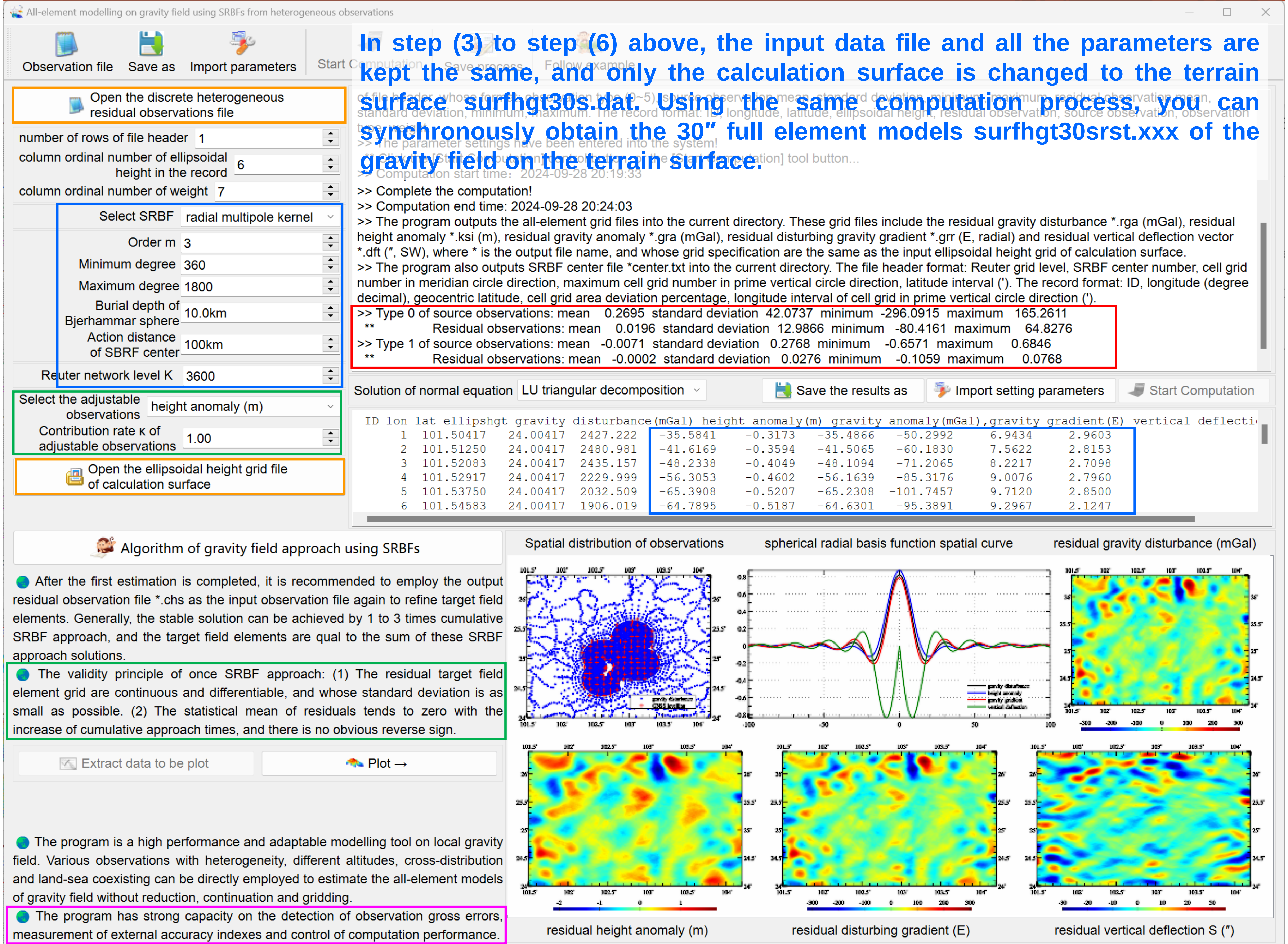


disturbing gravity gradient (E)

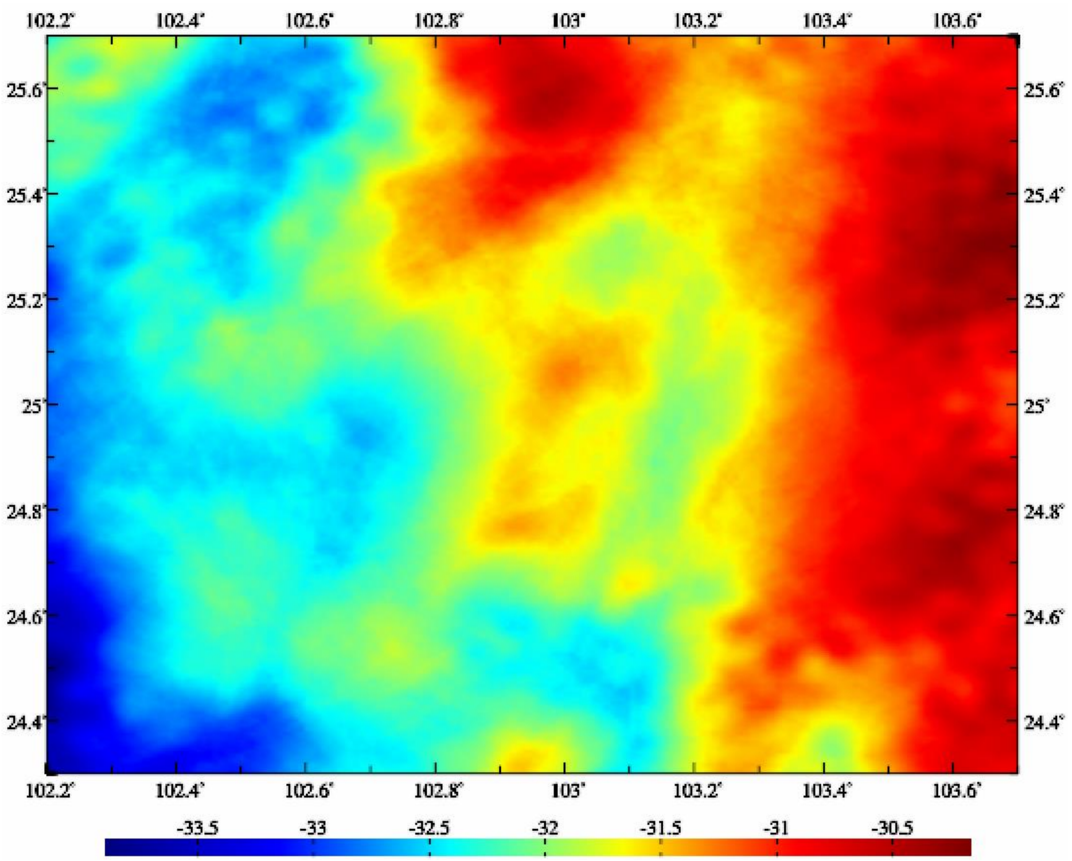


vertical deflection vector (″)

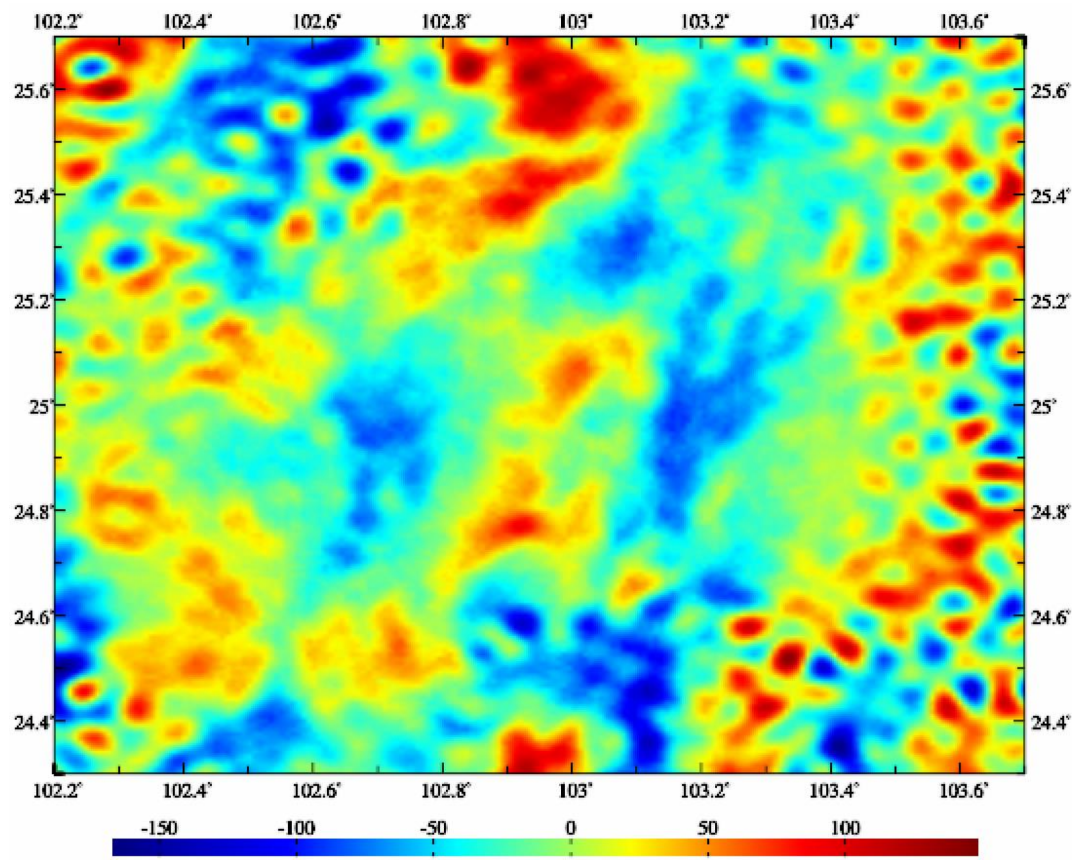
In step (3) to step (6) above, the input data file and all the parameters are kept the same, and only the calculation surface is changed to the terrain surface surfhgt30s.dat. Using the same computation process, you can synchronously obtain the 30″ full element models surfhgt30srst.xxx of the gravity field on the terrain surface.



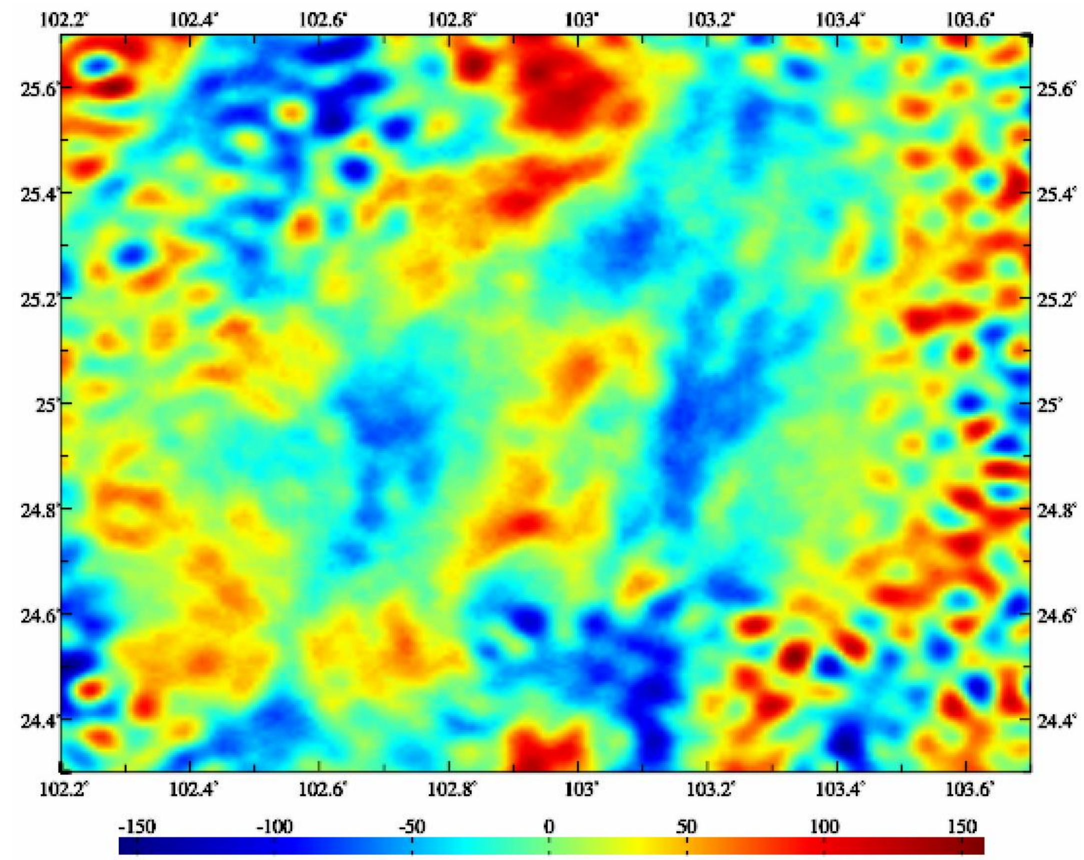
30″×30″ full element models of gravity field on terrain surface



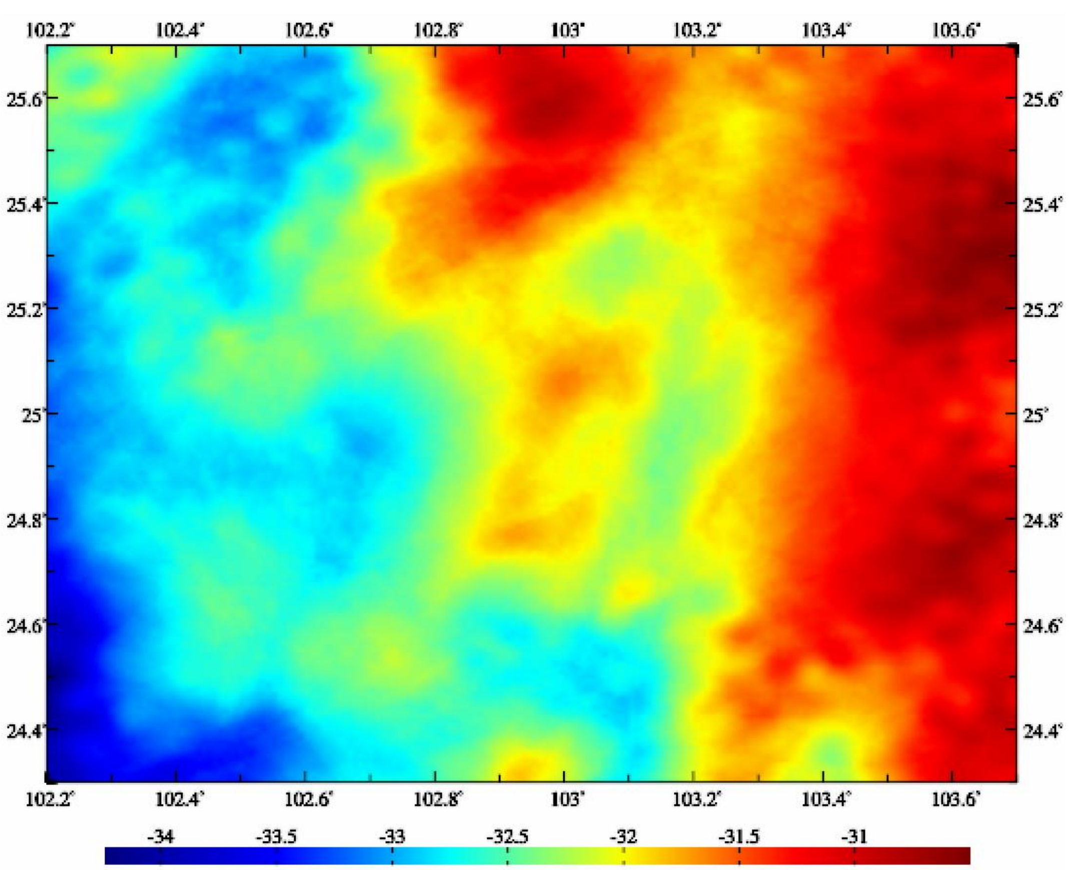
Height anonaly (m, Global datum)



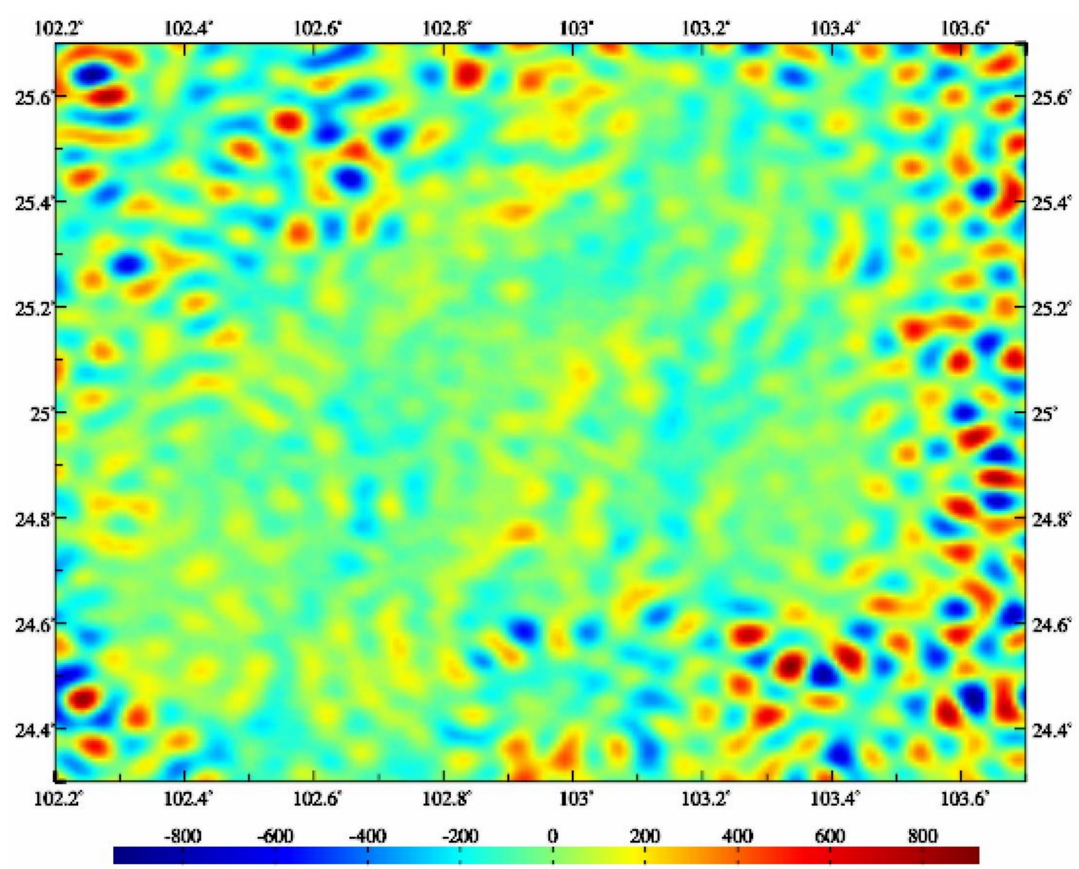
gravity disturbance (mGal)



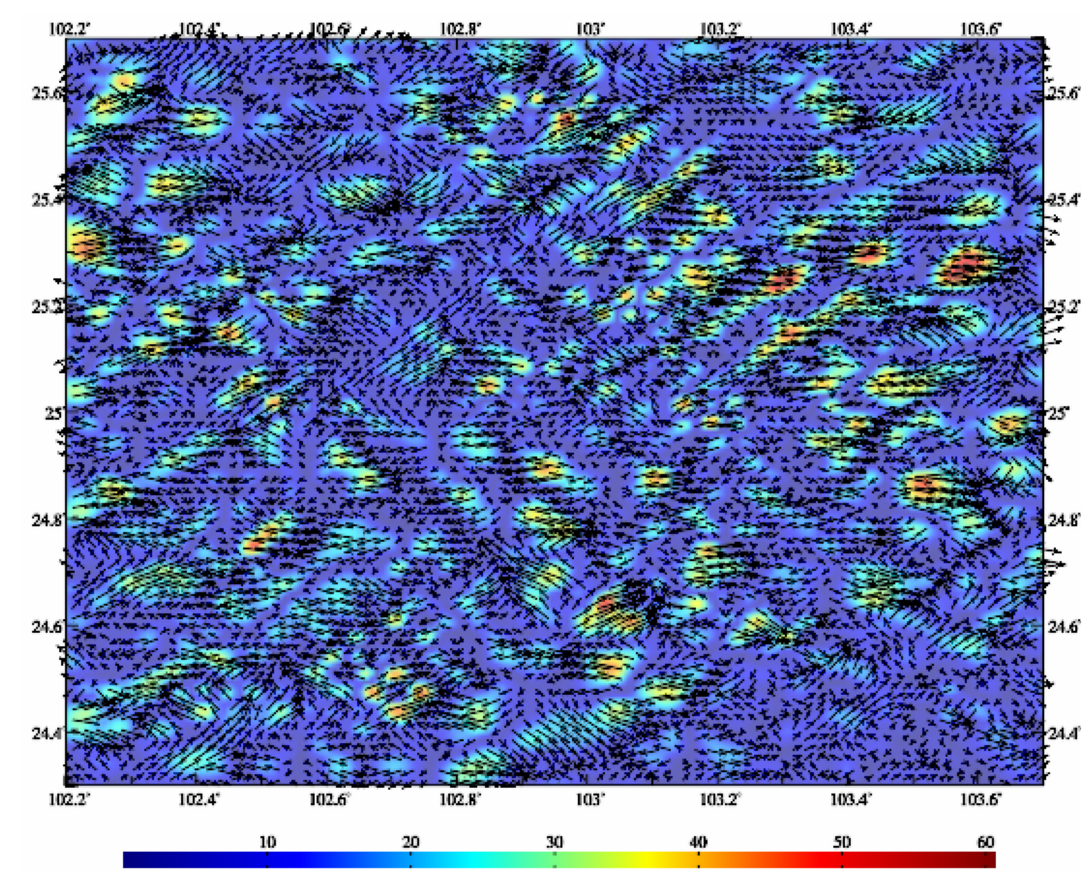
gravity anomaly (mGal)



Height anomaly (m, Regional datum)



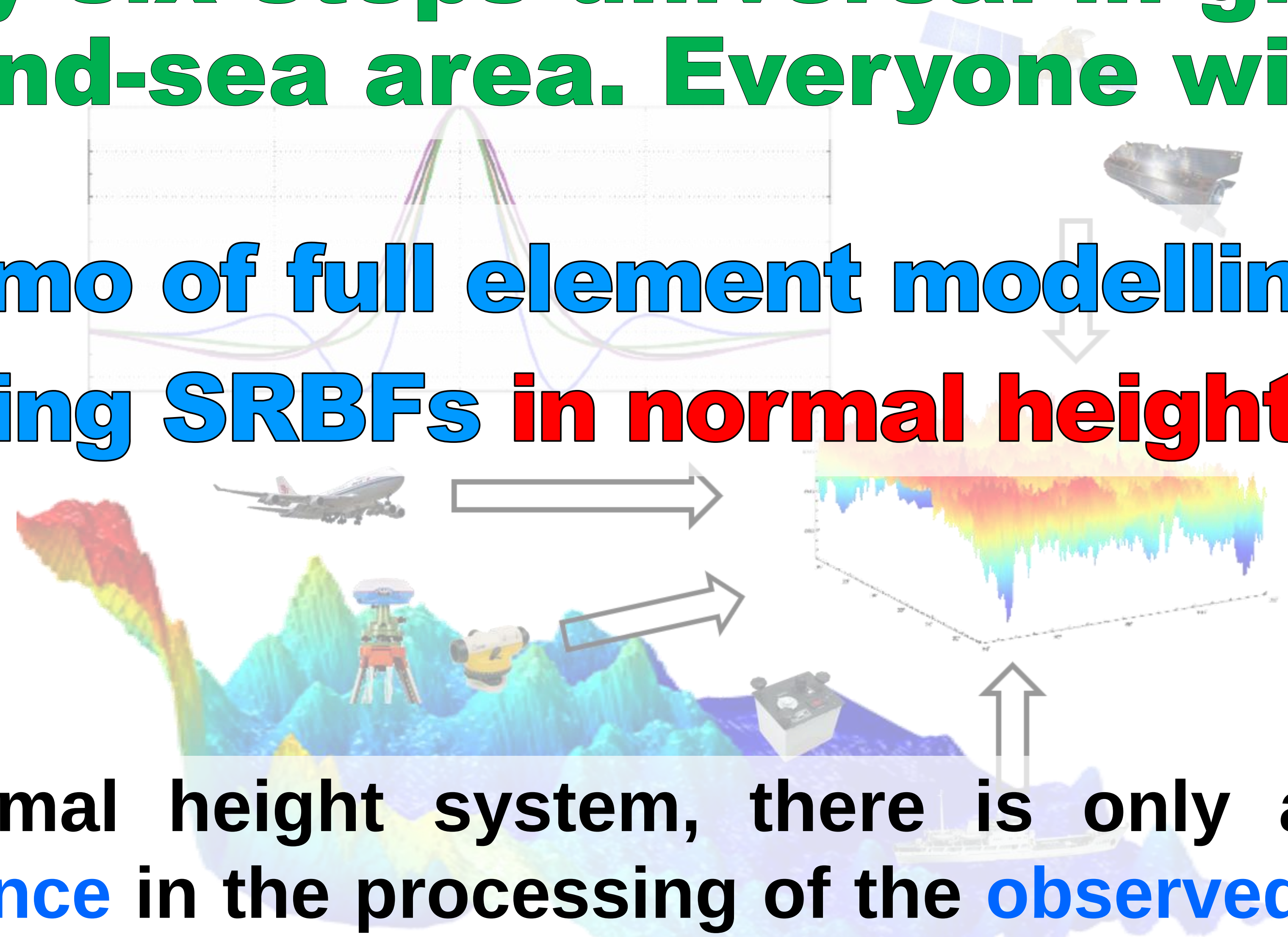
disturbing gravity gradient (E)



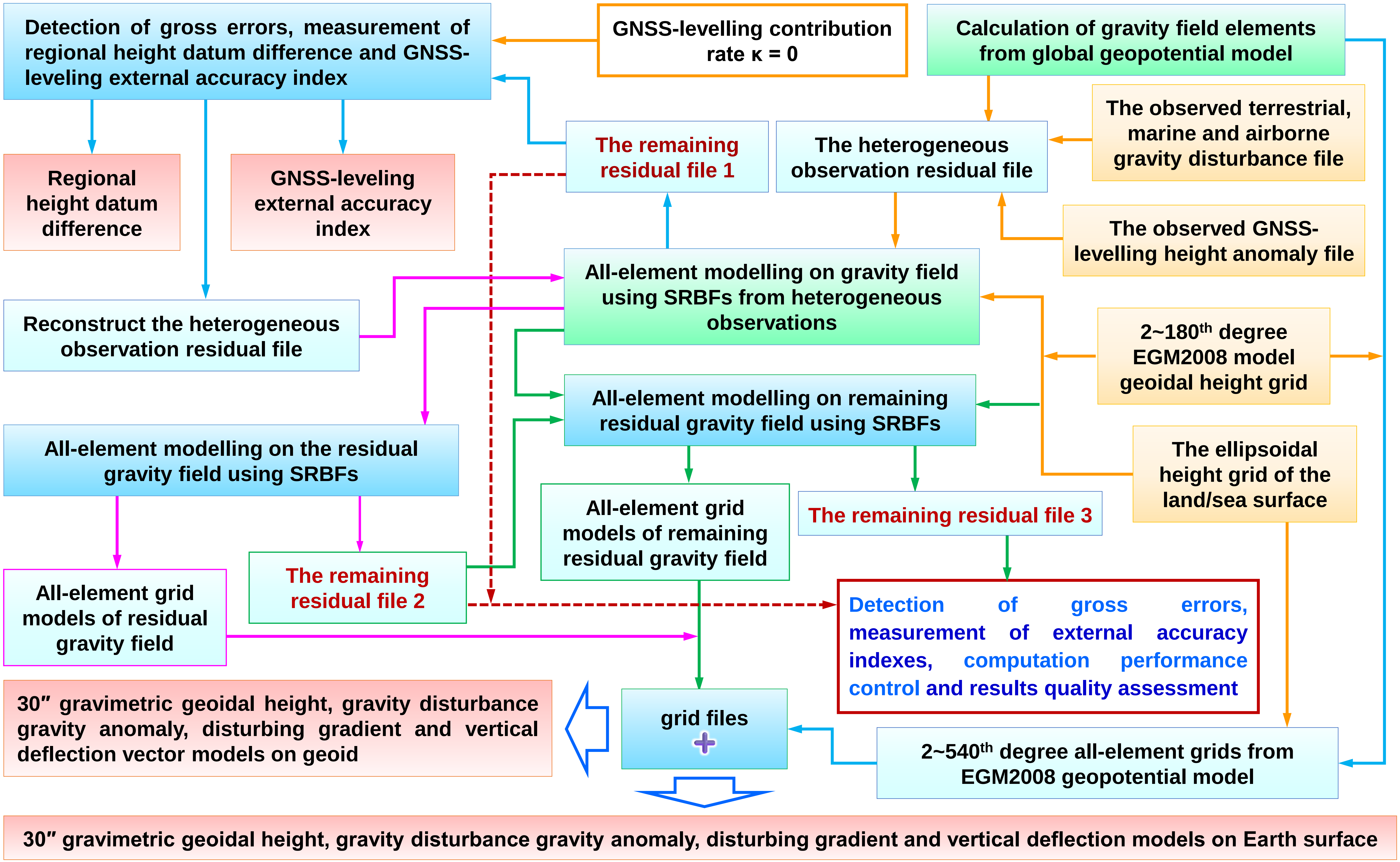
vertical deflection vector (″)

Only six steps universal in global land-sea area. Everyone will !

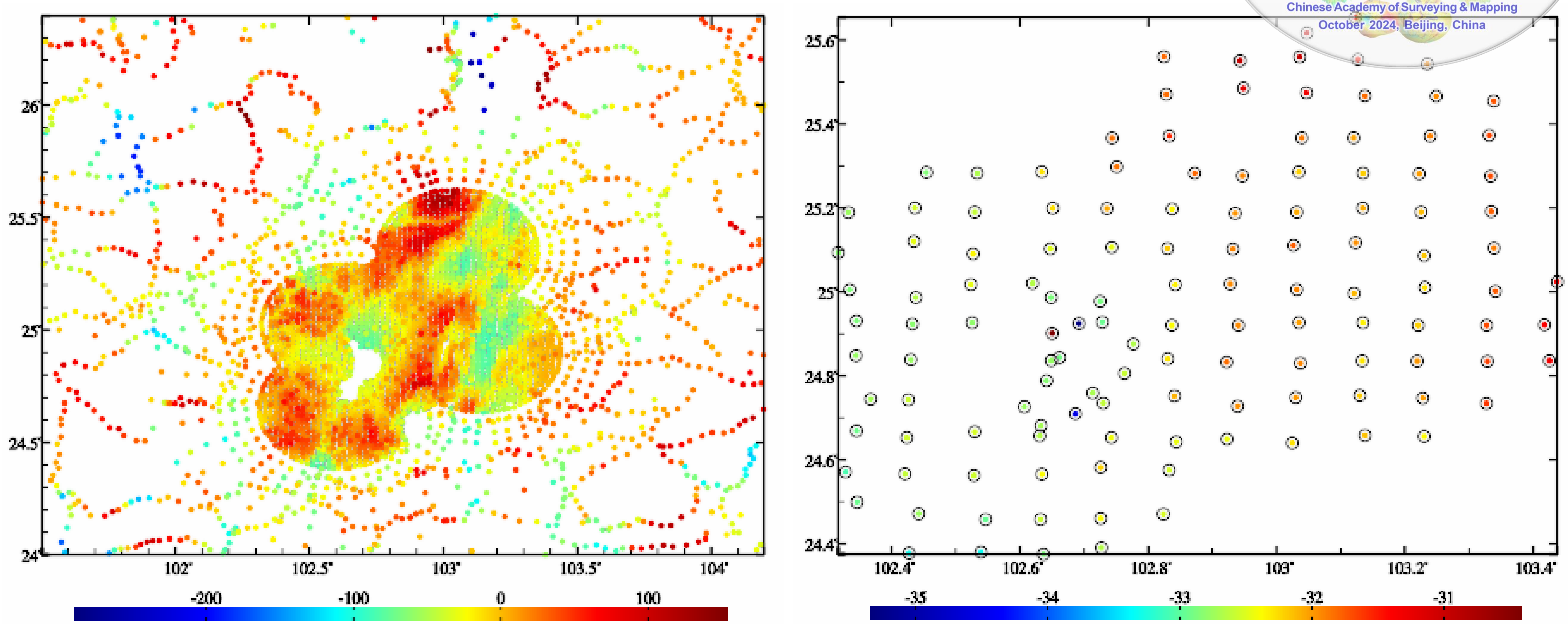
Process demo of full element modelling on gravity field using SRBFs in normal height system



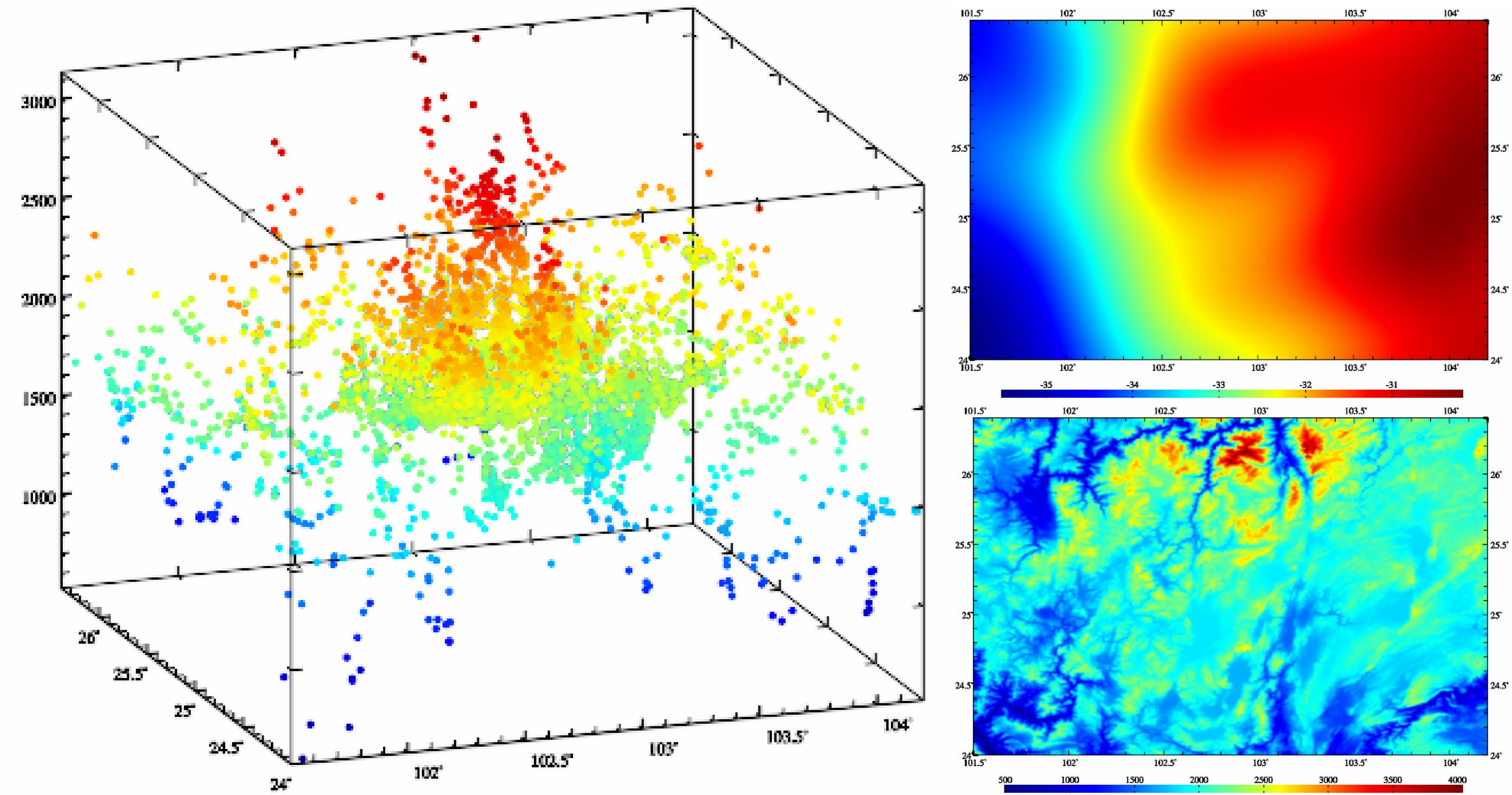
In normal height system, there is only a slight difference in the processing of the observed GNSS-levelling data, and the other modelling processes are same with that in orthometric height system.



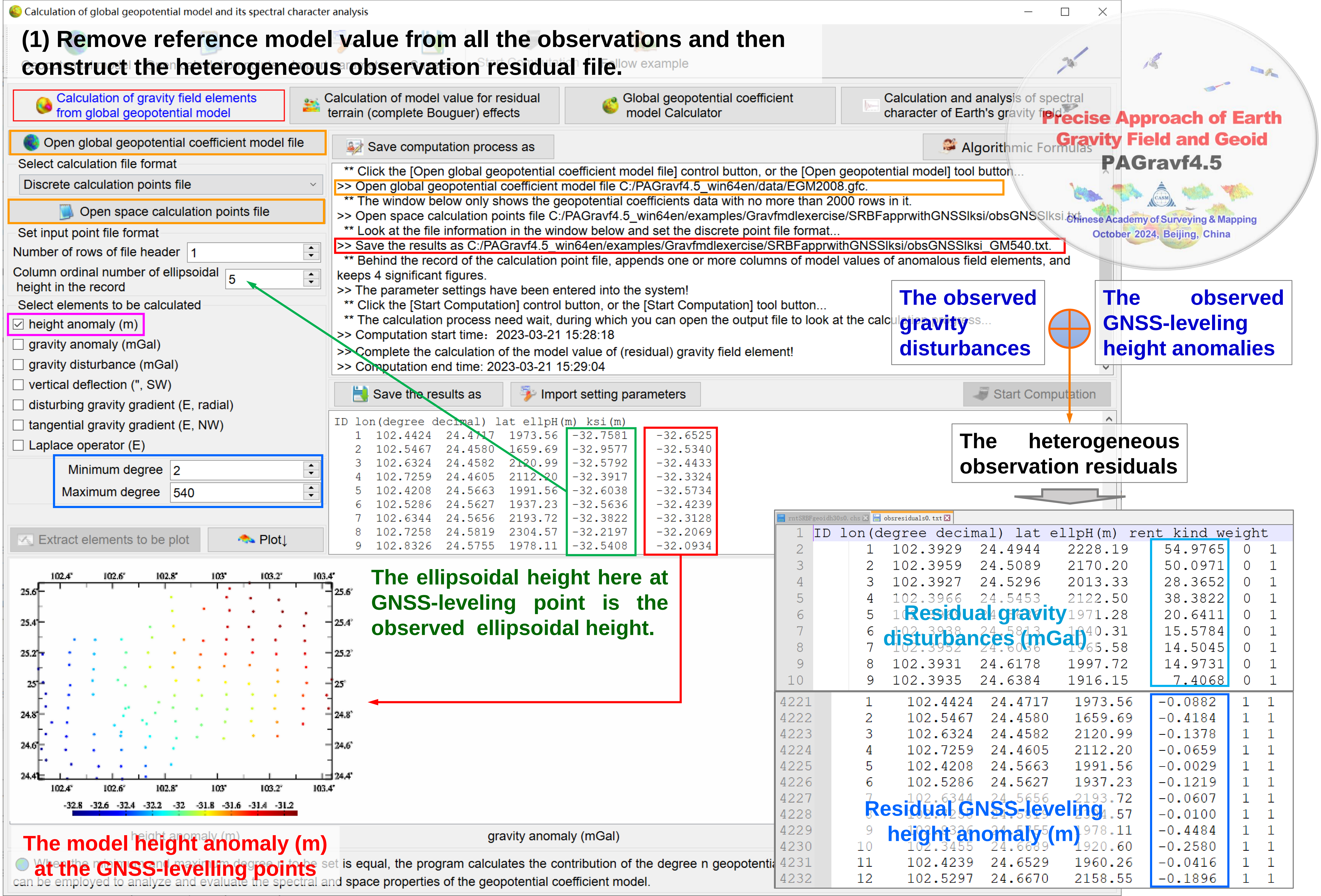
Simple process demo of all-element modelling on gravity filed using SRBFs in normal height system



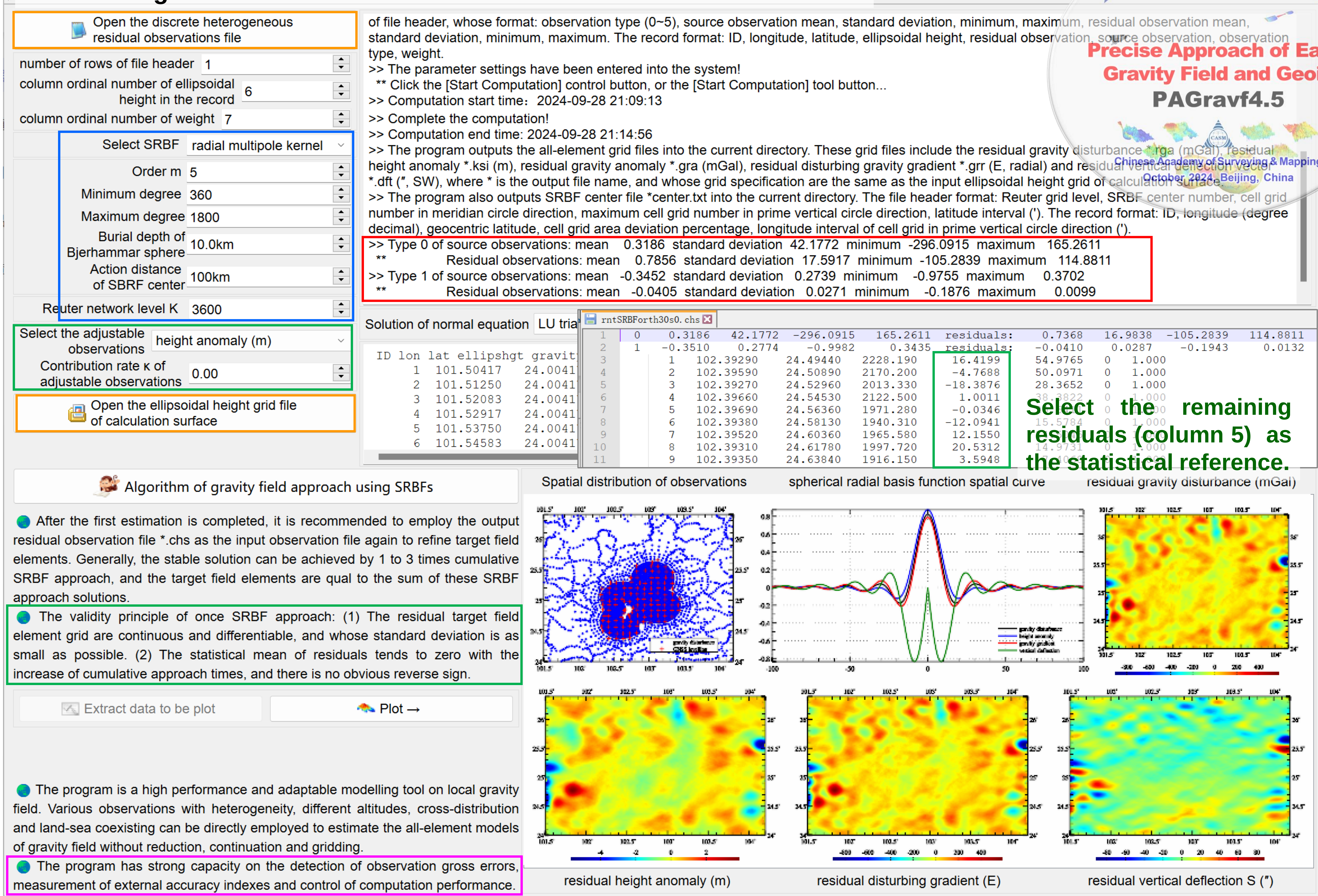
The observed gravity disturbances (mGal) and observed GNSS-levelling height anomalies (m)



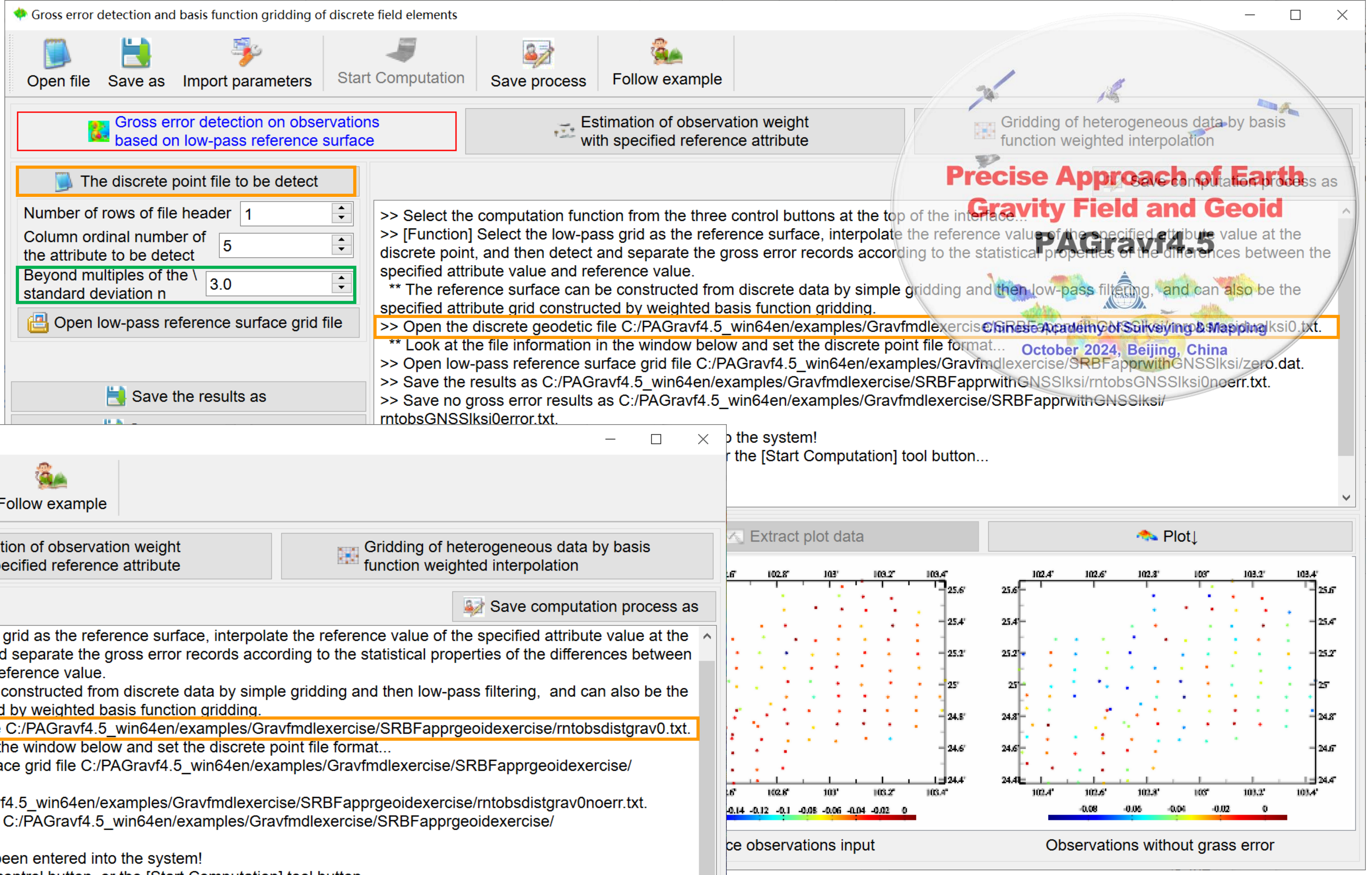
The distribution of gravity points, 2~180th degree model geoidal height and ellipsoidal height of the terrain surface

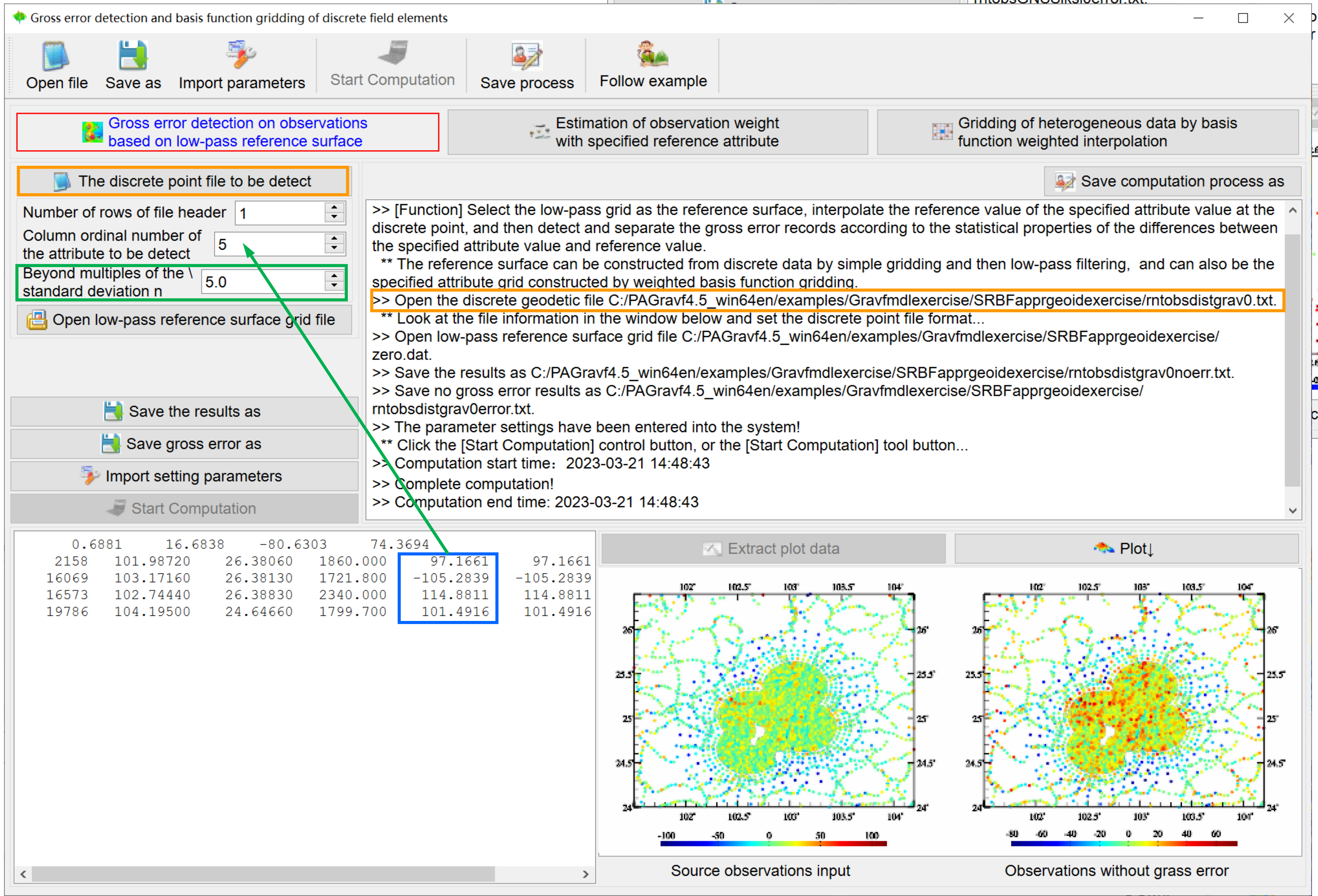

Calculation of global geopotential model and its spectral character analysis
(1) Remove reference model value from all the observations and then construct the heterogeneous observation residual file.
Calculation of gravity field elements from global geopotential model
Calculation of model value for residual terrain (complete Bouguer) effects
Global geopotential coefficient model Calculator
Calculation and analysis of spectral character of Earth's gravity field
Precise Approach of Earth Gravity Field and Geoid
PAGravf4.5
Chinese Academy of Surveying & Mapping
October 2024, Beijing, China
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
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
** Click the [Open global geopotential coefficient model file] control button, or the [Open geopotential model] tool button...
>> Open global geopotential coefficient model file C:/PAGravf4.5_win64en/data/EGM2008.gfc.
** The window below only shows the geopotential coefficients data with no more than 2000 rows in it.
>> Open space calculation points file C:/PAGravf4.5_win64en/examples/Gravfmdlexercise/SRBFapprwithGNSSlksi/obsGNSSlksi.txt
** Look at the file information in the window below and set the discrete point file format...
>> Save the results as C:/PAGravf4.5_win64en/examples/Gravfmdlexercise/SRBFapprwithGNSSlksi/obsGNSSlksi_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 parameter settings have been entered into the system!
** Click the [Start Computation] control button, or the [Start Computation] tool button...
** The calculation process need wait, during which you can open the output file to look at the calculation progress...
>> Computation start time: 2023-03-21 15:28:18
>> Complete the calculation of the model value of (residual) gravity field element!
>> Computation end time: 2023-03-21 15:29:04
The observed gravity disturbances
The observed GNSS-leveling height anomalies
Save the results as
Import setting parameters
Start Computation
The heterogeneous observation residuals
ID lon(degree decimal) lat ellpH(m) ksi(m)
1 102.4424 24.4717 1973.56 -32.7581 -32.6525
2 102.5467 24.4580 1659.69 -32.9577 -32.5340
3 102.6324 24.4582 2120.99 -32.5792 -32.4433
4 102.7259 24.4605 2112.20 -32.3917 -32.3324
5 102.4208 24.5663 1991.56 -32.6038 -32.5734
6 102.5286 24.5627 1937.23 -32.5636 -32.4239
7 102.6344 24.5656 2193.72 -32.3822 -32.3128
8 102.7258 24.5819 2304.57 -32.2197 -32.2069
9 102.8326 24.5755 1978.11 -32.5408 -32.0934
Extract elements to be plot
Plot↓
The ellipsoidal height here at GNSS-leveling point is the observed ellipsoidal height.
ID lon(degree decimal) lat ellpH(m) rent 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 2122.50 38.3822 0 1
5 1971.28 20.6411 0 1
6 102.3938 24.5813 1940.31 15.5784 0 1
7 102.3952 24.6036 1965.58 14.5045 0 1
8 102.3931 24.6178 1997.72 14.9731 0 1
9 102.3935 24.6384 1916.15 7.4068 0 1
Residual gravity disturbances (mGal)
1 102.4424 24.4717 1973.56 -0.0882 1 1
2 102.5467 24.4580 1659.69 -0.4184 1 1
3 102.6324 24.4582 2120.99 -0.1378 1 1
4 102.7259 24.4605 2112.20 -0.0659 1 1
5 102.4208 24.5663 1991.56 -0.0029 1 1
6 102.5286 24.5627 1937.23 -0.1219 1 1
7 102.6344 24.5656 2193.72 -0.0607 1 1
8 -0.0100 1 1
9 -0.4484 1 1
10 102.3455 24.6689 1920.60 -0.2580 1 1
11 102.4239 24.6529 1960.26 -0.0416 1 1
12 102.5297 24.6670 2158.55 -0.1896 1 1
Residual GNSS-leveling height anomaly (m)
102.4° 102.6° 102.8° 103° 103.2° 103.4°
25.6° 25.4° 25.2° 25° 24.8° 24.6° 24.4°
-32.8 -32.6 -32.4 -32.2 -32 -31.8 -31.6 -31.4 -31.2
The model height anomaly (m) at the GNSS-levelling points
gravity anomaly (mGal)
is equal, the program calculates the contribution of the degree n geopotential
can be employed to analyze and evaluate the spectral and space properties of the geopotential coefficient model.

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



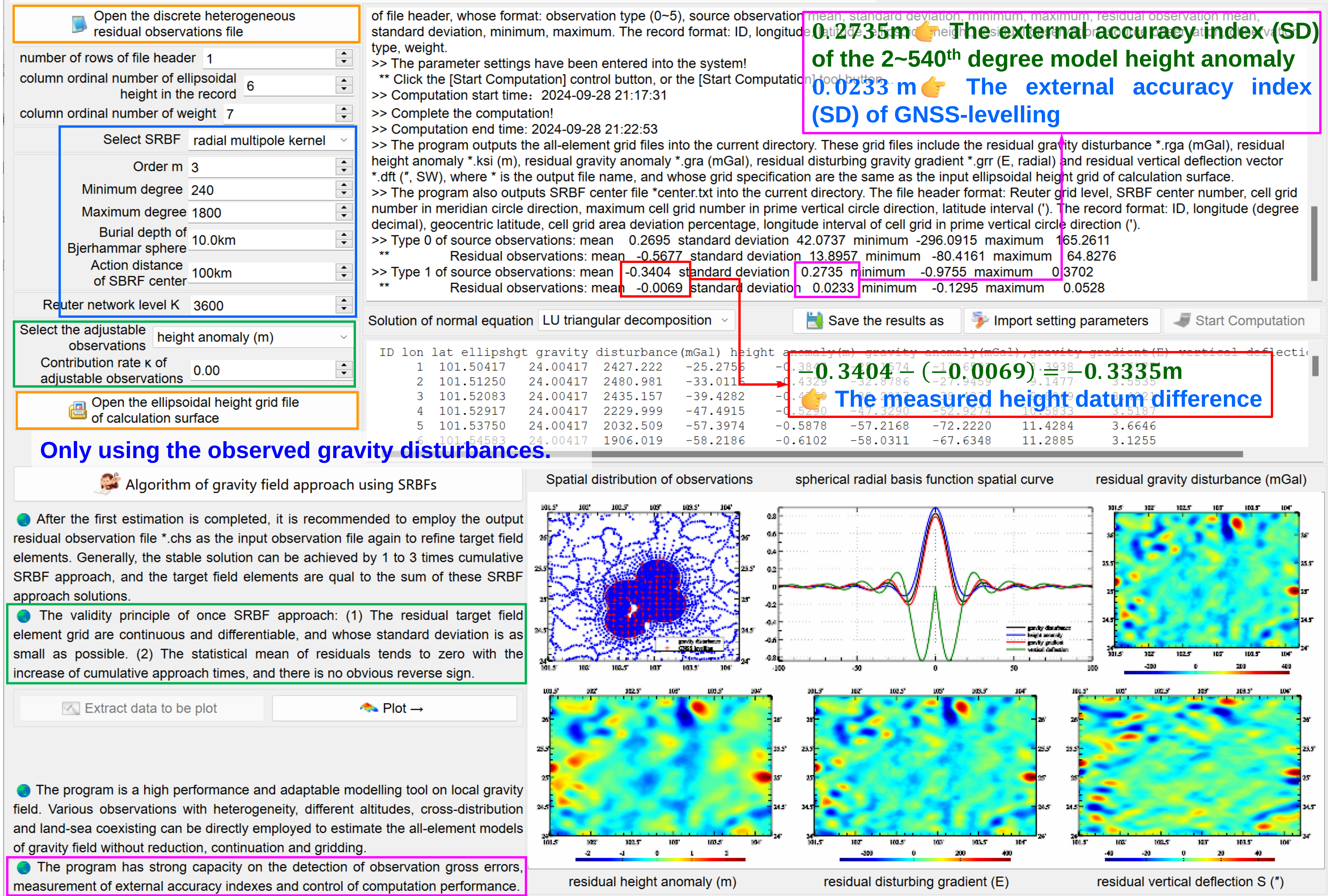
Separate the remaining residuals of the observed GNSS-leveling and observed gravity disturbance from rntSRBFgeoidh30s0.chs.

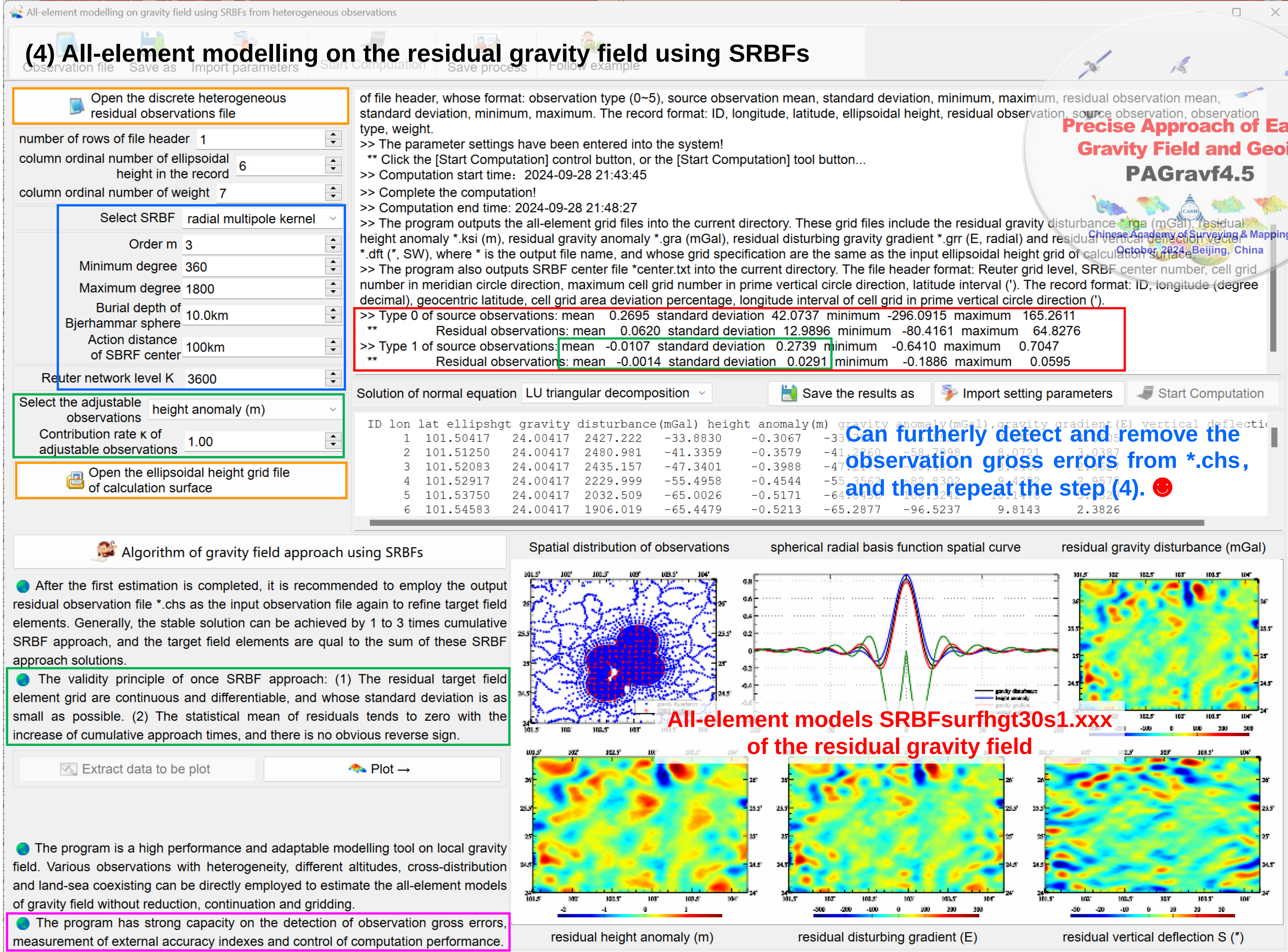




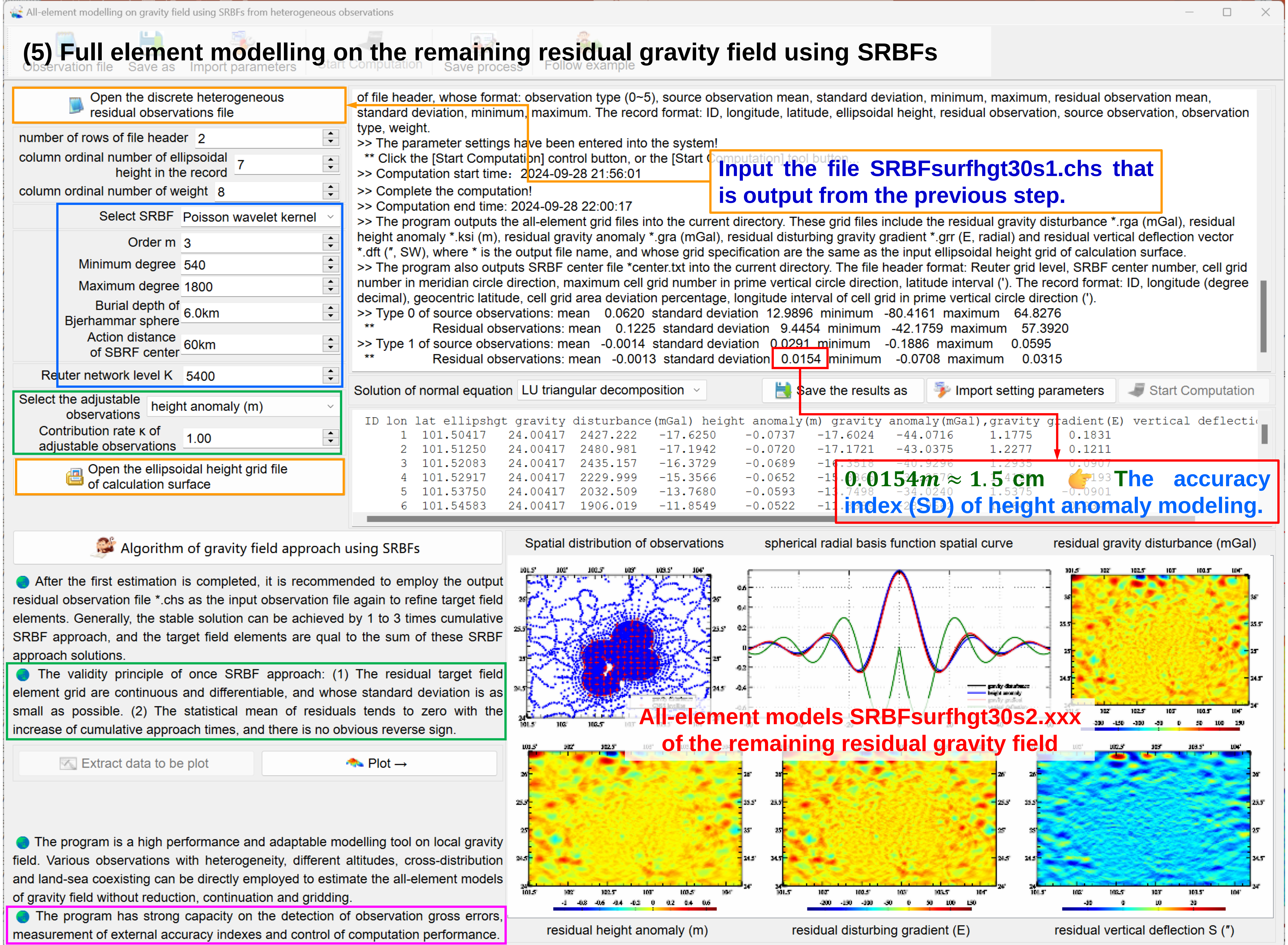
Reconstruct the heterogeneous observation residual file obsresiduals01.txt.

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

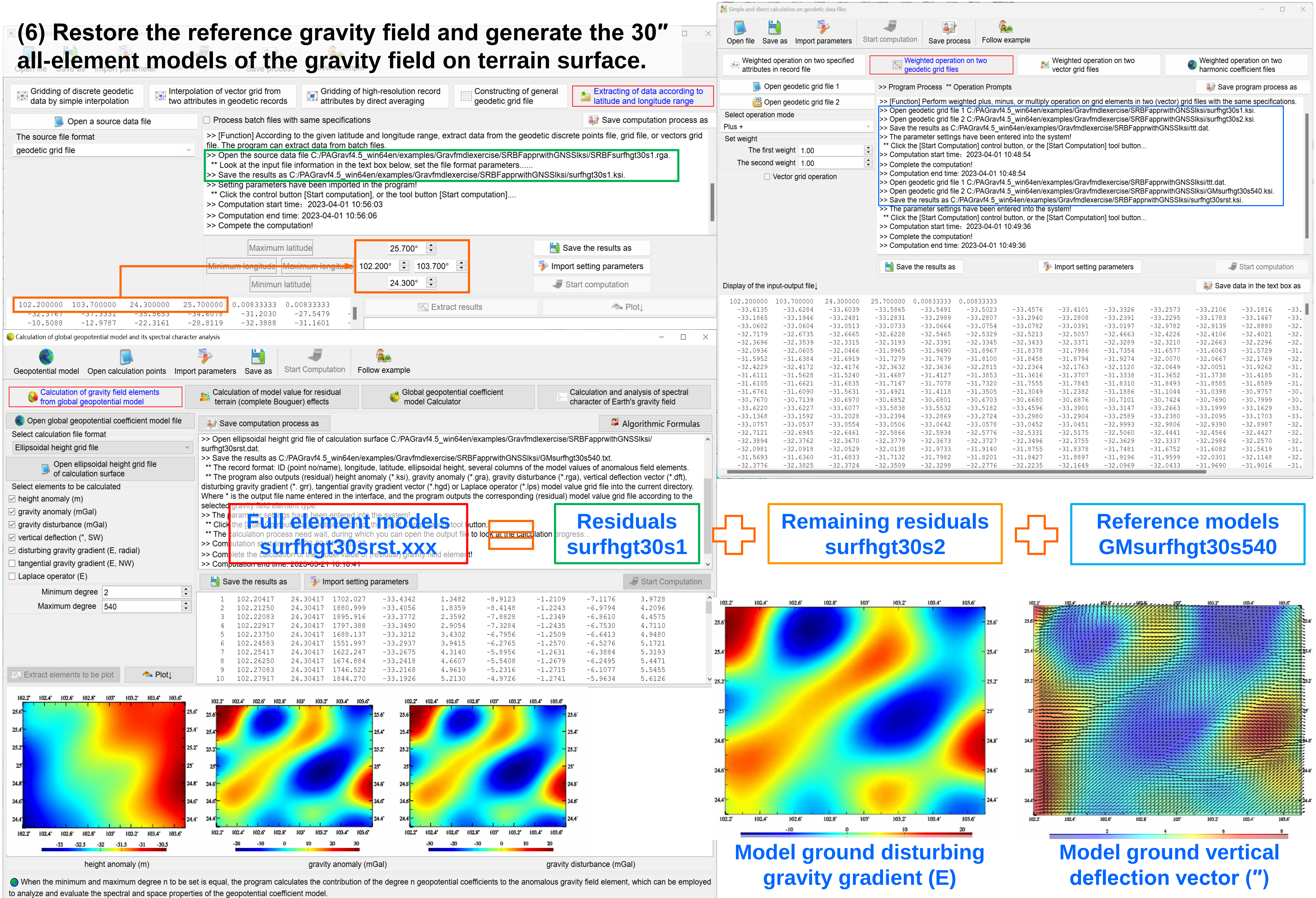



All-element modelling on gravity field using SRBFs from heterogeneous observations
(4) All-element modelling on the residual gravity field using SRBFs
Observation file
Save as
Import parameters
Start Computation
Save process
Follow example
Open the discrete heterogeneous residual observations file
number 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 Bjerhammar 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
of file header, whose format: observation type (0~5), source observation mean, standard deviation, minimum, maximum, residual observation mean, standard deviation, minimum, maximum. The record format: ID, longitude, latitude, ellipsoidal height, residual observation, source observation, observation type, weight.
>> The parameter settings have been entered into the system!
** Click the [Start Computation] control button, or the [Start Computation] tool button...
>> Computation start time: 2024-09-28 21:43:45
>> Complete the computation!
>> Computation end time: 2024-09-28 21:48:27
>> The program outputs the all-element grid files into the current directory. These grid files include the 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, and whose grid specification are the same as the input ellipsoidal height grid of calculation surface.
>> 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: ID, 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 0.0620 standard deviation 12.9896 minimum -80.4161 maximum 64.8276
>> Type 1 of source observations: mean -0.0107 standard deviation 0.2739 minimum -0.6410 maximum 0.7047
** Residual observations: mean -0.0014 standard deviation 0.0291 minimum -0.1886 maximum 0.0595
Precise Approach of Earth Gravity Field and Geoid
PAGravf4.5
Chinese Academy of Surveying & Mapping
October 2024, Beijing, China
Solution of normal equation LU triangular decomposition
Save the results as
Import setting parameters
Start Computation
ID lon lat ellipshgt gravity disturbance(mGal) height anomaly(m) gravity anomaly(mGal) gravity gradient(E) vertical deflection
1 101.50417 24.00417 2427.222 -33.8830 -0.3067
2 101.51250 24.00417 2480.981 -41.3359 -0.3579
3 101.52083 24.00417 2435.157 -47.3401 -0.3988
4 101.52917 24.00417 2229.999 -55.4958 -0.4544
5 101.53750 24.00417 2032.509 -65.0026 -0.5171
6 101.54583 24.00417 1906.019 -65.4479 -0.5213 -65.2877 -96.5237 9.8143 2.3826
Can furtherly detect and remove the observation gross errors from *.chs, and then repeat the step (4).
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 elements. Generally, the stable solution can be achieved by 1 to 3 times cumulative SRBF approach, and the target field elements are qual to the sum of these SRBF approach solutions.
The validity principle of once SRBF approach: (1) The residual target field element grid are 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 modelling tool on local gravity field. Various observations with heterogeneity, different altitudes, cross-distribution and land-sea coexisting can be directly employed to estimate the all-element models of gravity field without reduction, continuation and gridding.
The program has strong capacity on the detection of observation gross errors, measurement of external accuracy indexes and control of computation performance.
Spatial distribution of observations
spherical radial basis function spatial curve
residual gravity disturbance (mGal)
All-element models SRBFsurfhgt30s1.xxx of the residual gravity field
residual height anomaly (m)
residual disturbing gradient (E)
residual vertical deflection S (″)

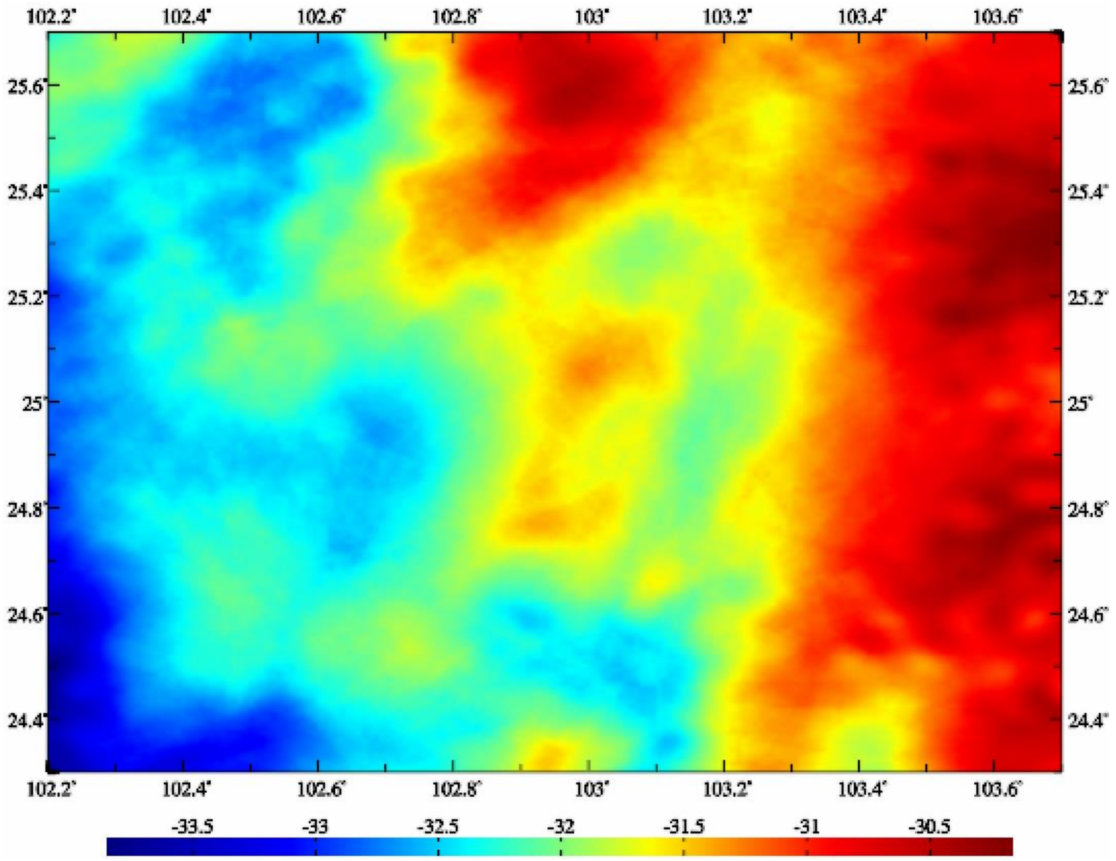
(5) Full element modelling on the remaining residual gravity field using SRBFs



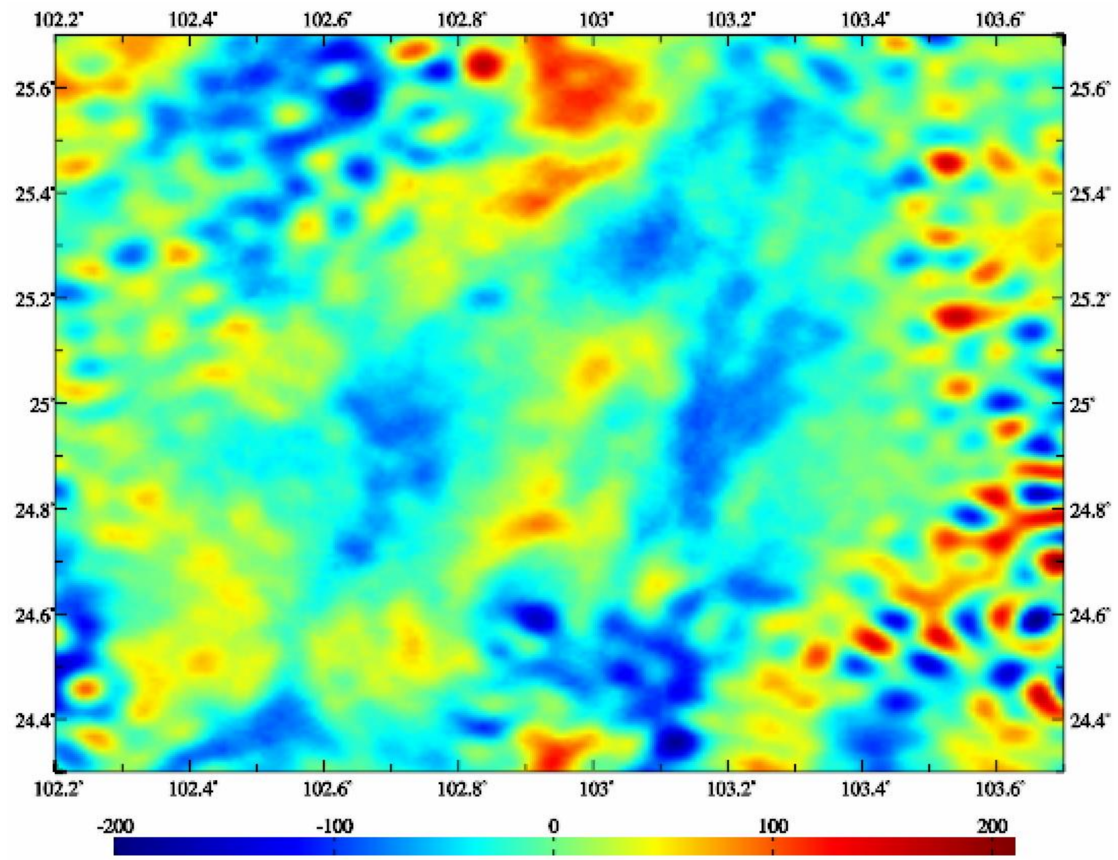
(6) Restore the reference gravity field and generate the 30″ all-element models of the gravity field on terrain surface.



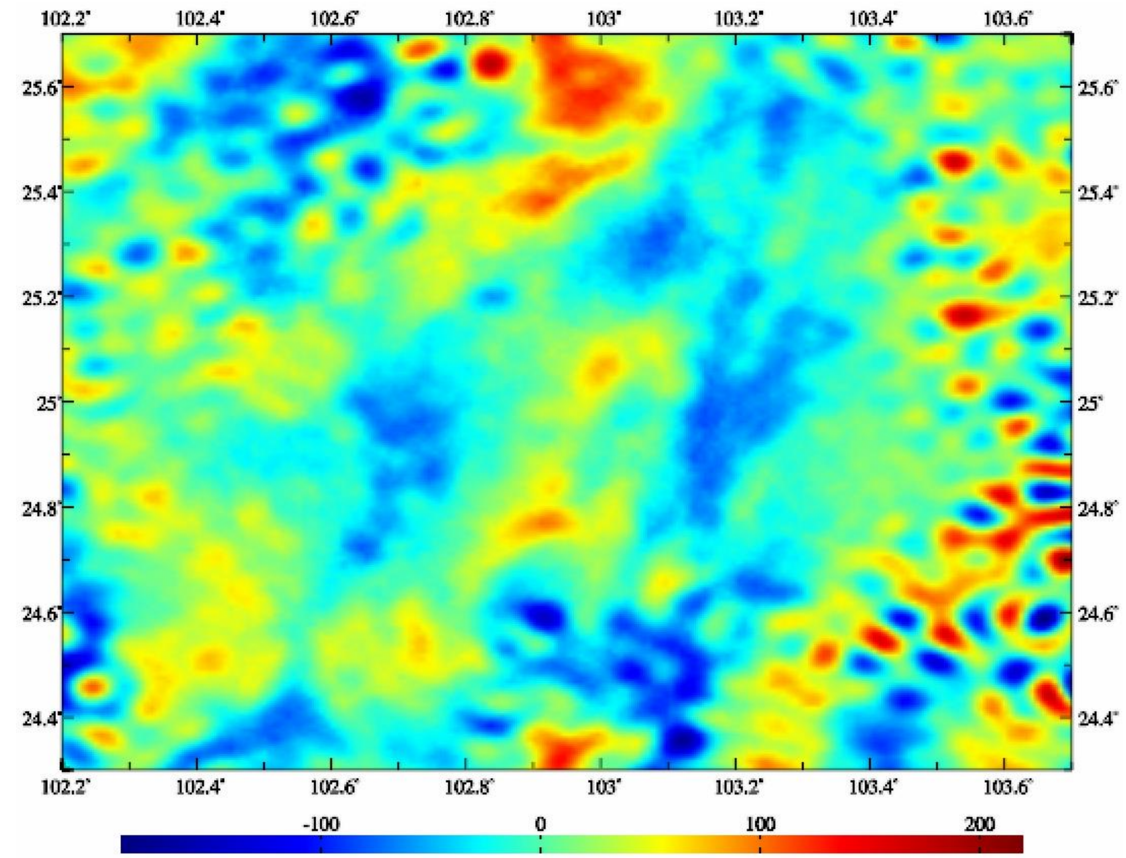
30″×30″ full element models of gravity field on terrain surface



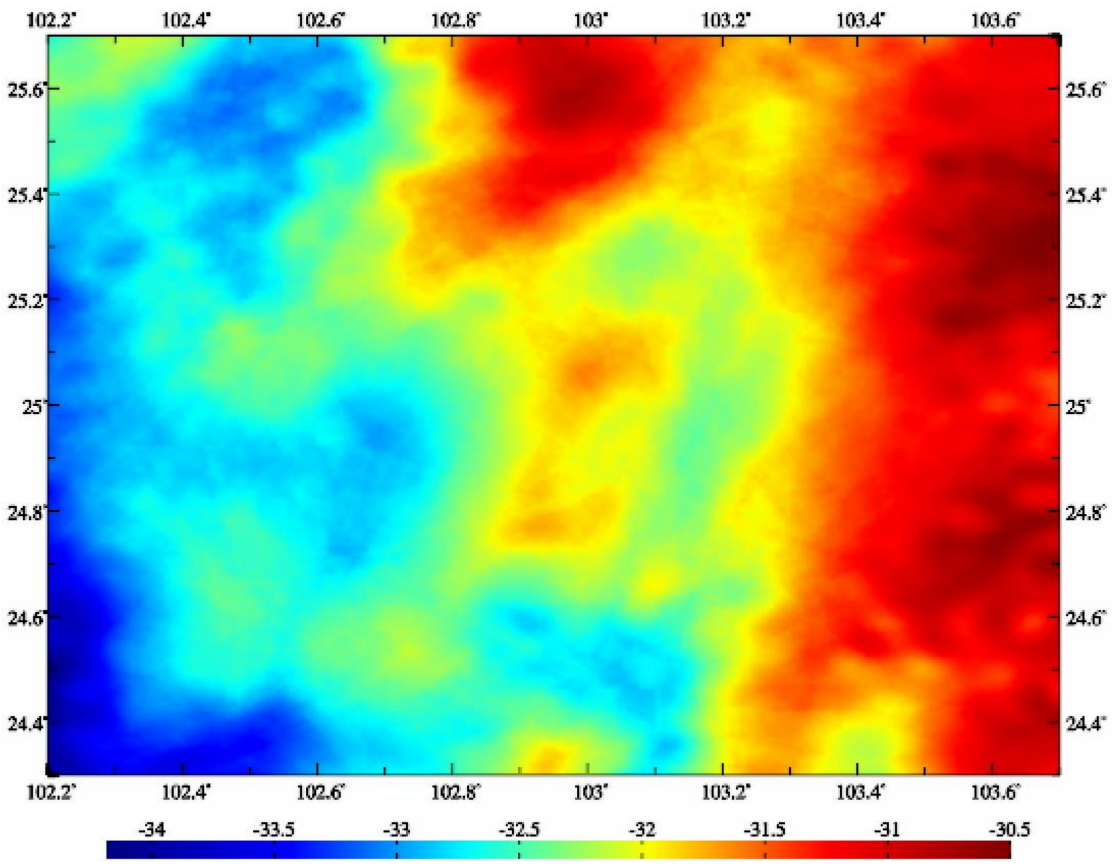
Height anonaly (m, Global datum)



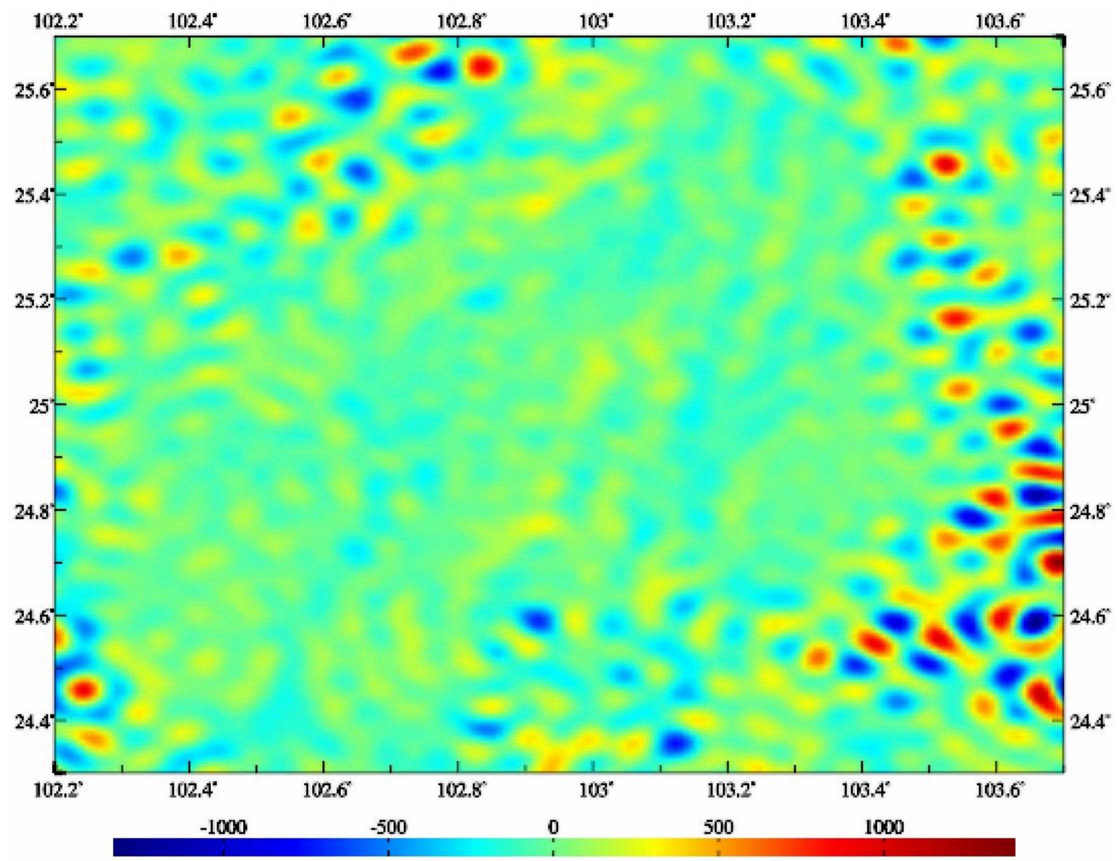
gravity disturbance (mGal)



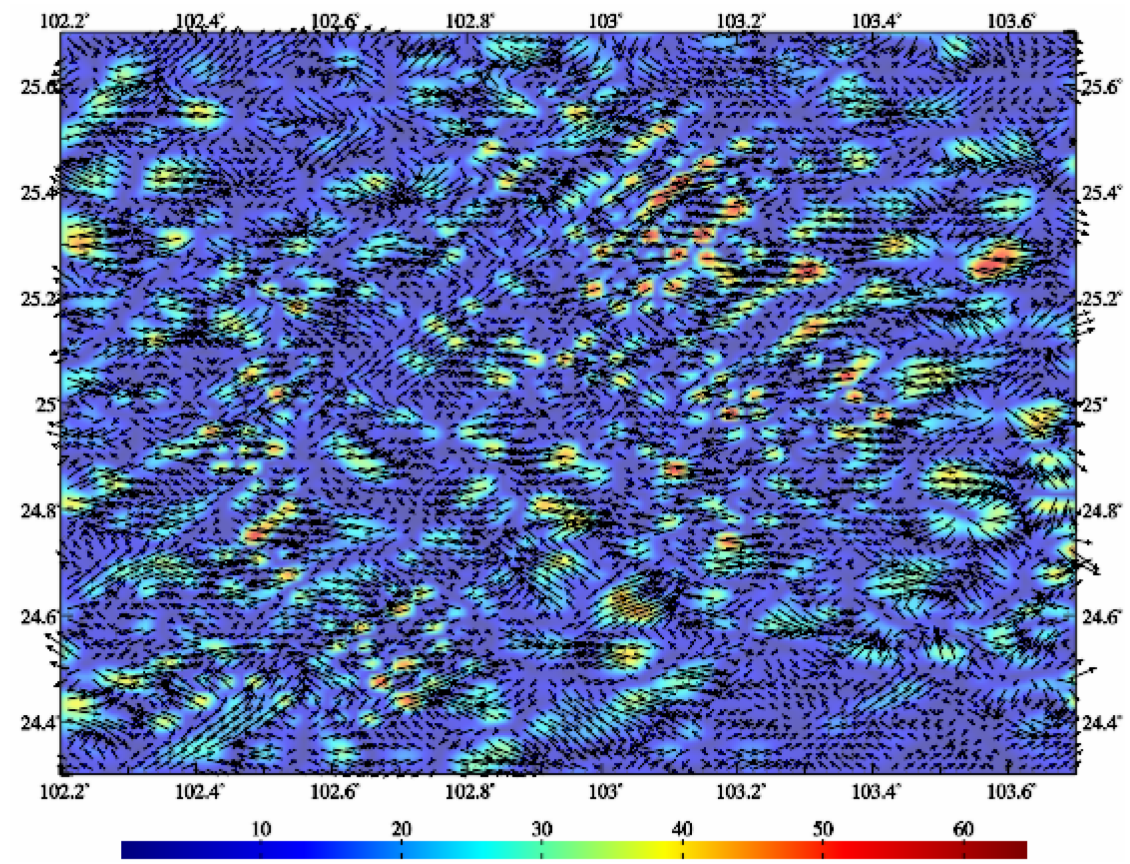
gravity anomaly (mGal)



Height anomaly (m, Regional datum)

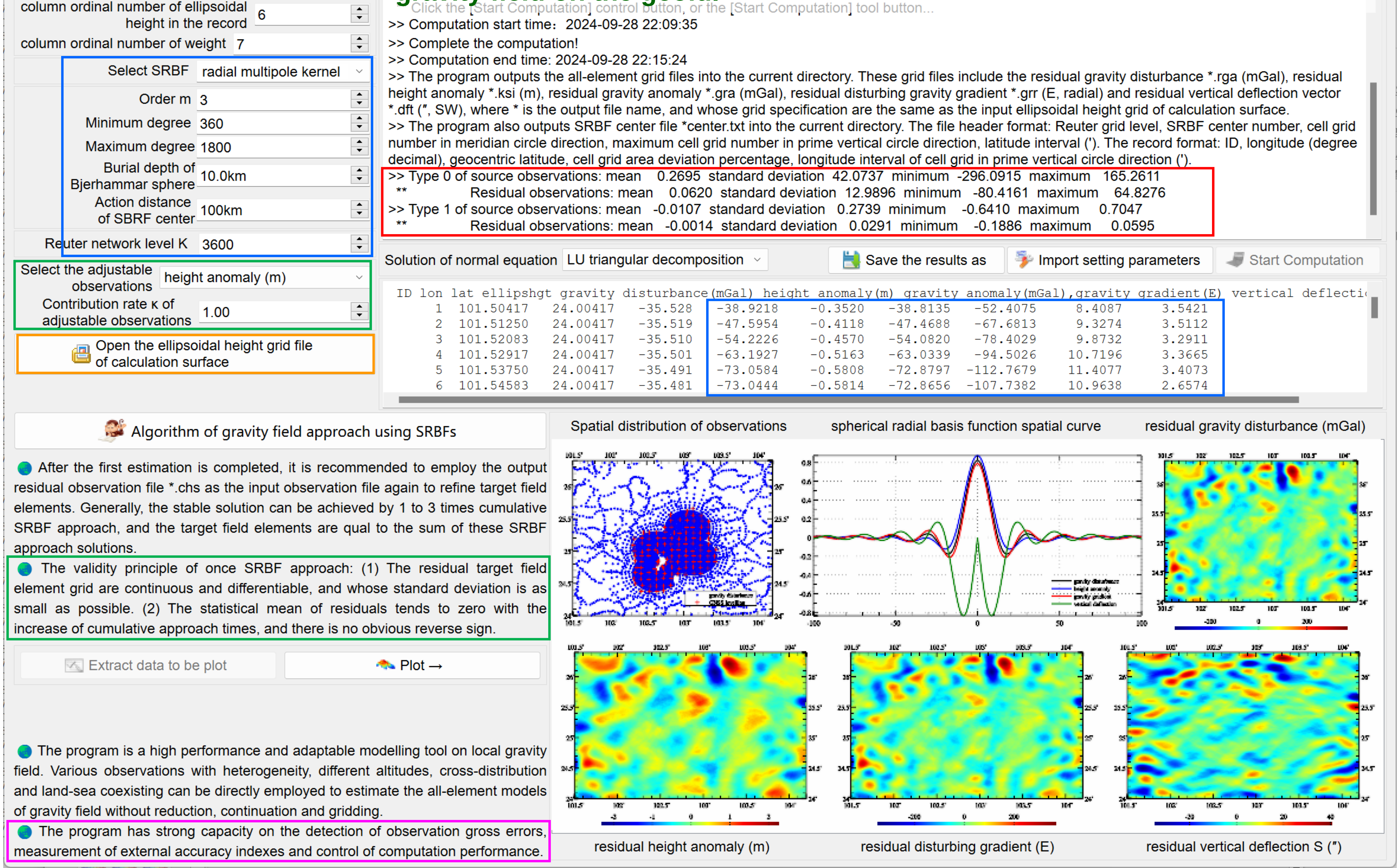


disturbing gravity gradient (E)

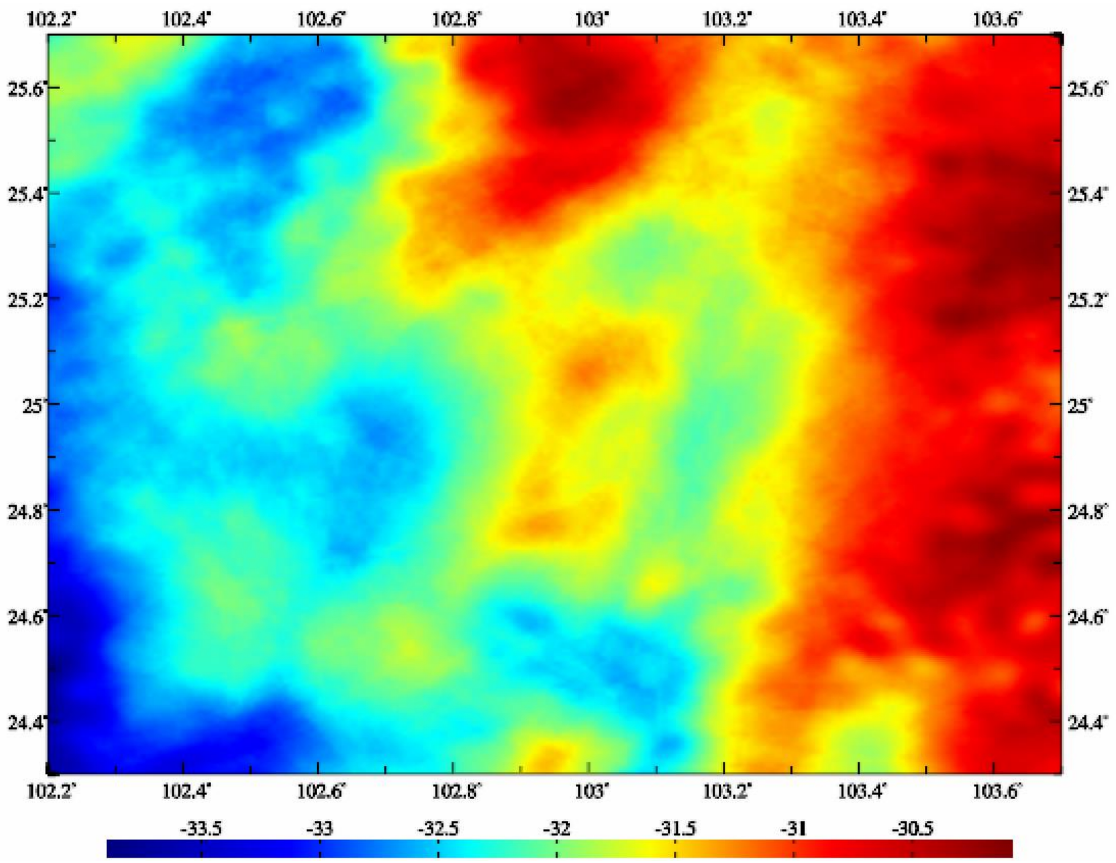


vertical deflection vector (″)

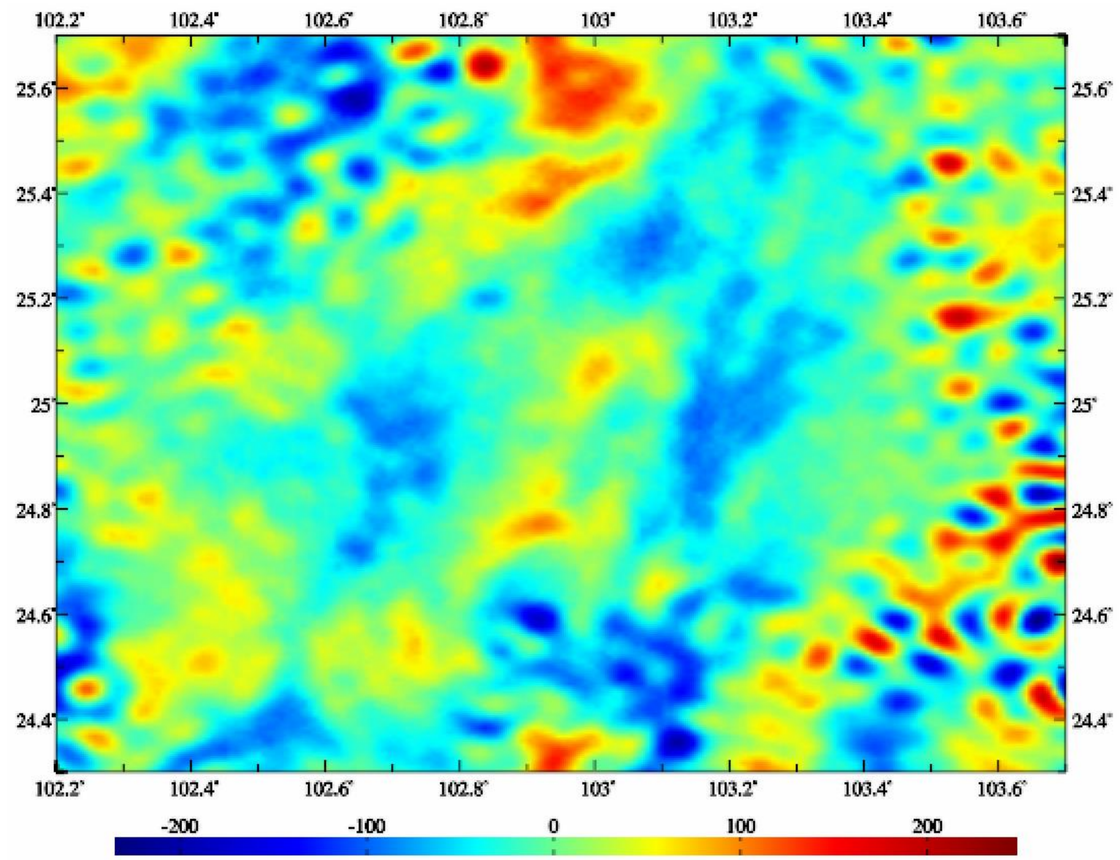
In step (3) to step (6) above, the input data file and all the parameter settings are kept the same, and only the calculation surface is changed to the geoid mdlgeoidh30s.dat. Using the same computation process, you can synchronously obtain the 30″ full element models geoidh30srst.xxx of the gravity field on the geoid.



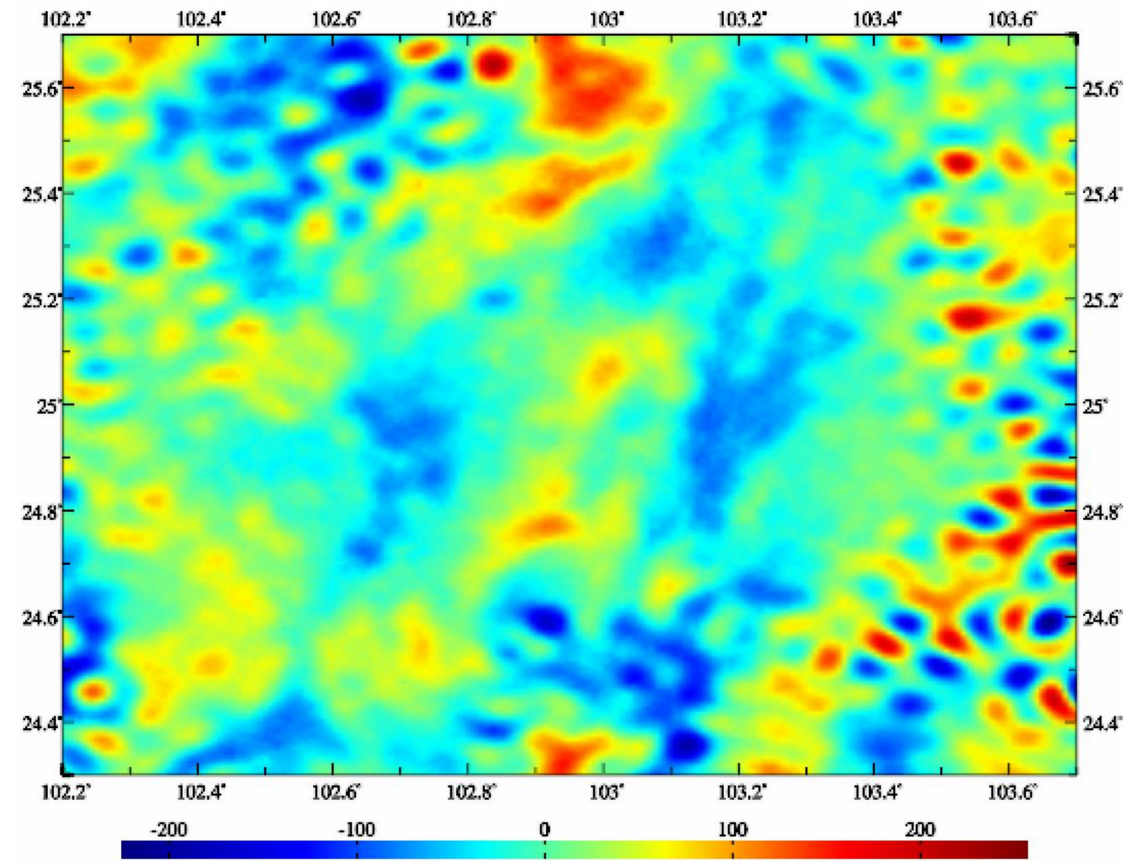
30″×30″ full element models of gravity field on geoid



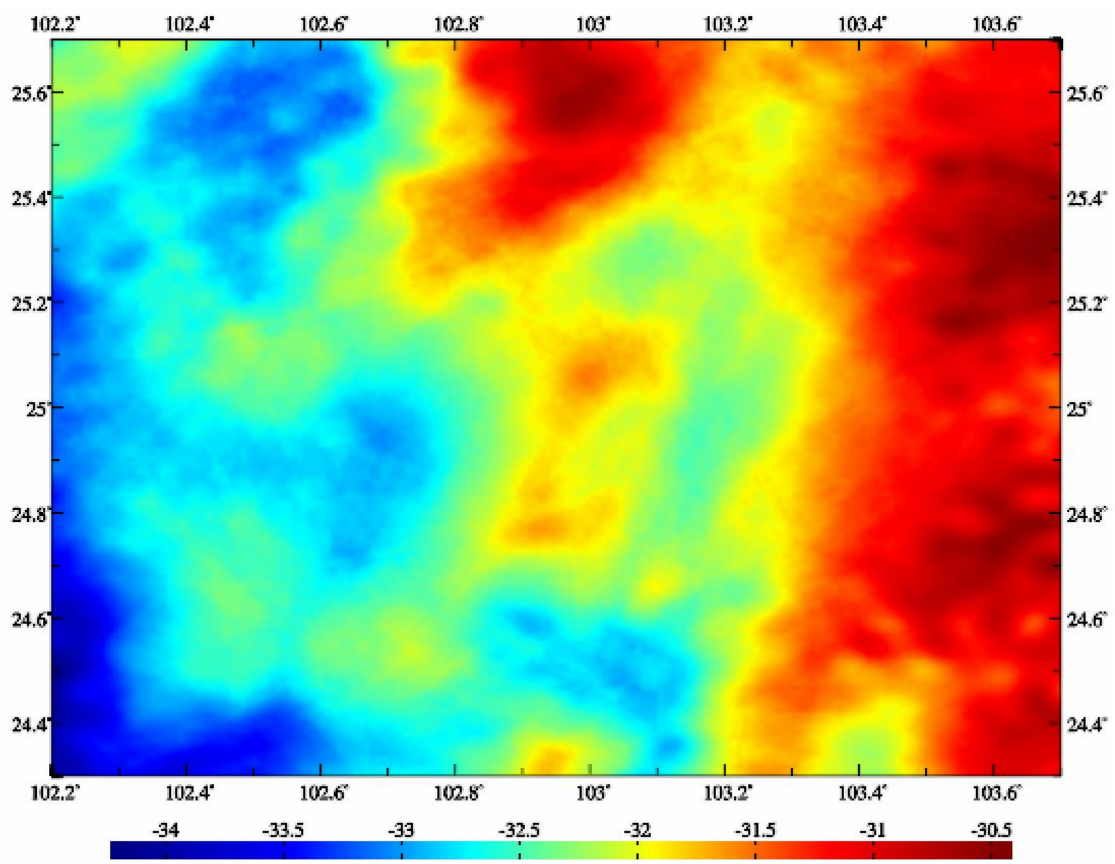
Geoid (m, Global datum)



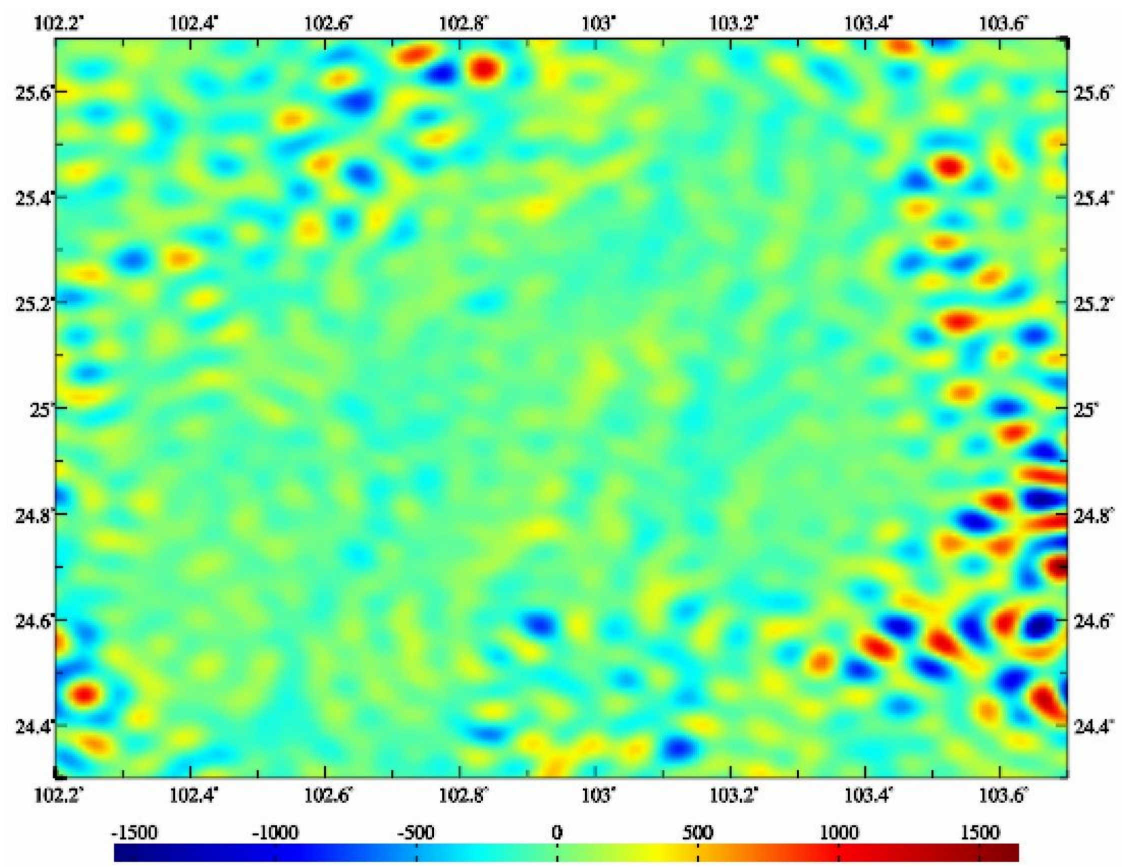
gravity disturbance (mGal)



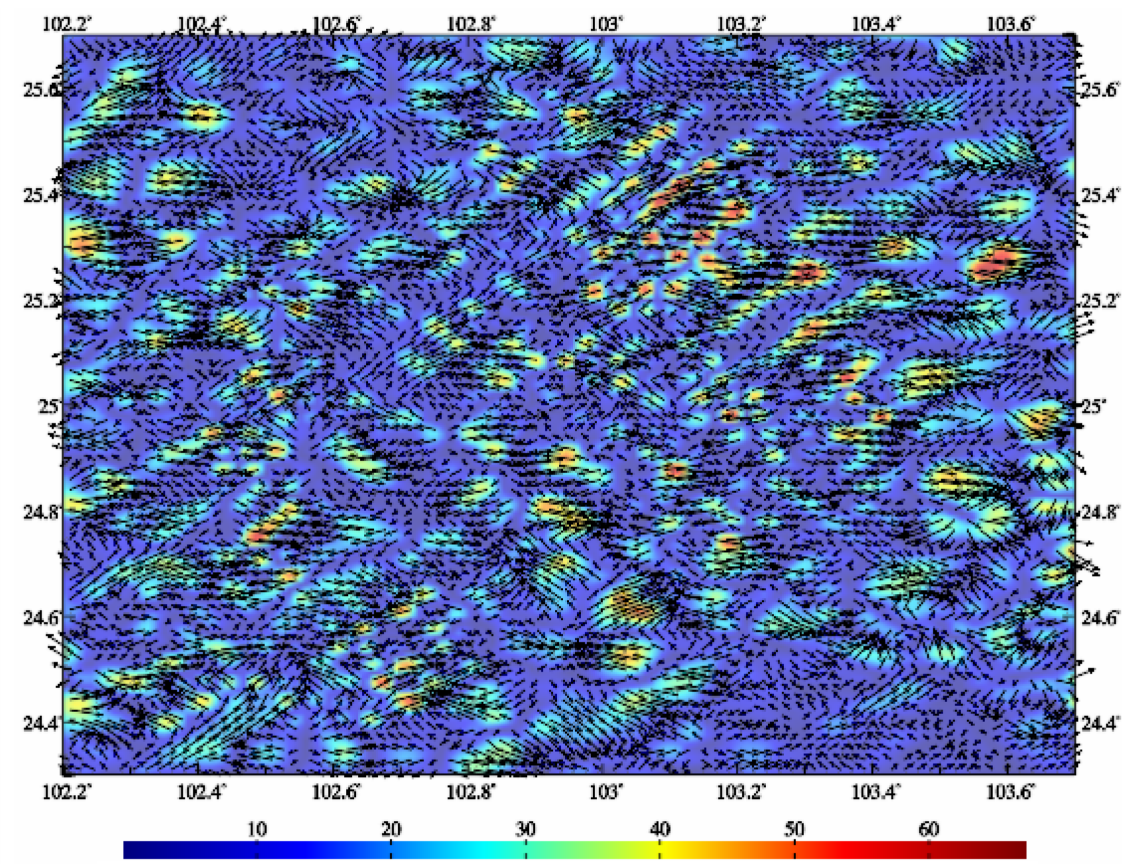
gravity anomaly (mGal)



Geoid (m, Regional datum)



disturbing gravity gradient (E)



vertical deflection vector (″)

① The analytical function relationships between gravity field elements are strict, and the SRBF approach performance has nothing to do with the observation errors.

② Various heterogeneous observations in the different altitudes, cross-distribution, and land-sea coexisting cases can be directly employed to model the all-element gravity field models on or outisde the geoid without reduction, continuation and griding.

③ Can integrate very few astronomical vertical deflection or GNSS-levelling data, and effectively absorb the edge effect.

④ Has the strong capacity in the detection of observation gross errors, measurement of external accuracy indexes and control of computational performance.

More innovation and application potential need to be discovered and excavated in the future computing practice !

Gravity Field and Geoid
Chinese Academy of Surveying & Mapping
October 2024, Beijing, China