

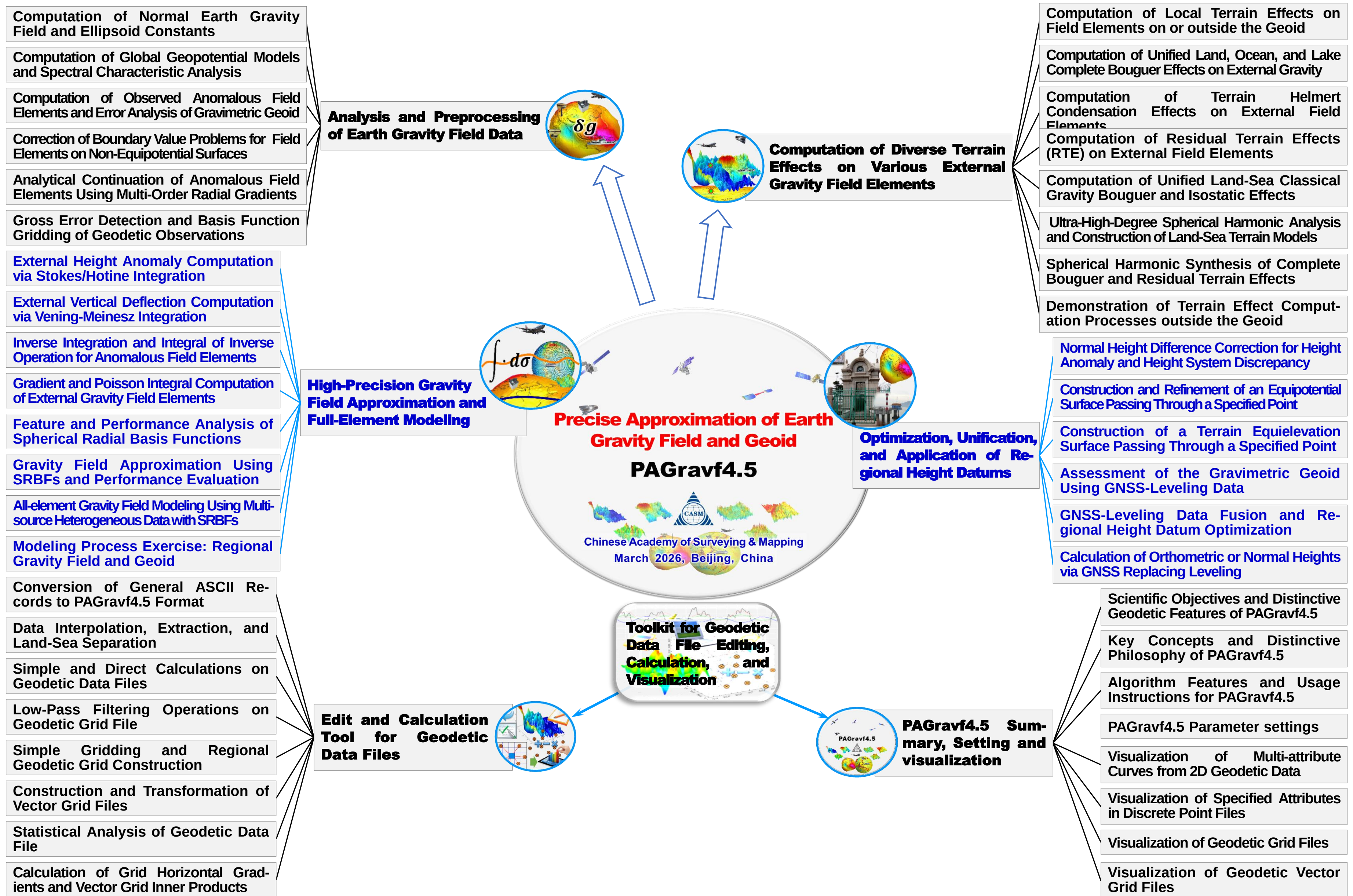


The screenshot displays the PAGravf4.5 software interface. A central circular window features the title "Precise Approximation of Earth Gravity Field and Geoid" and "PAGravf4.5", along with the logo of the Chinese Academy of Surveying & Mapping (CASM) and the text "Chinese Academy of Surveying & Mapping March 2026, Beijing, China". Surrounding this central window are several smaller panels. On the left, a panel titled "Summary, Parameter Settings and Visualization for PAGravf4.5" shows a globe with satellite orbits. On the right, a panel titled "Computation of Diverse Terrain Effects on Various External Gravity Field Elements" displays a 3D terrain model with a color-coded gravity field. Below these, a panel titled "Tutorial Examples & Self-Study Guide:" lists various example files and their purposes. At the bottom, a panel titled "High-Precision Gravity Field Approximation and Full-Element Modeling" shows a globe with a color-coded gravity field. The main title "Program examples for Precise Approximation of Earth Gravity Field and Geoid" is overlaid in large blue text. Below the title, a list of six bullet points describes the program's capabilities, each preceded by a globe icon. At the bottom, the text "ZHANG Chuanyin, March 2026, Beijing, China" is displayed in large blue text.

Program examples for Precise Approximation of Earth Gravity Field and Geoid

- Multi-type data from terrestrial, maritime, aerial, or space-based observations
- Diverse Terrain Effects on Various gravity field Elements on or outside the Geoid
- Closed-Loop Analytical Operations between External Gravity Field Elements
- All-Element Analytical Modeling of Local Gravity Field in Full External Space
- Observation Error Assessment & Precise Computational Performance Control
- Gravity Exploration Modeling from Multi-Source Heterogeneous Observations

ZHANG Chuanyin, March 2026, Beijing, China



Computation of Normal Earth Gravity Field and Ellipsoid Constants

Computation of Global Geopotential Models and Spectral Characteristic Analysis

Computation of Observed Anomalous Field Elements and Error Analysis of Gravimetric Geoid

Correction of Boundary Value Problems for Field Elements on Non-Equipotential Surfaces

Analytical Continuation of Anomalous Field Elements Using Multi-Order Radial Gradients

Gross Error Detection and Basis Function Gridding of Geodetic Observations

External Height Anomaly Computation via Stokes/Hotine Integration

External Vertical Deflection Computation via Vening-Meinesz Integration

Inverse Integration and Integral of Inverse Operation for Anomalous Field Elements

Gradient and Poisson Integral Computation of External Gravity Field Elements

Feature and Performance Analysis of Spherical Radial Basis Functions

Gravity Field Approximation Using SRBFs and Performance Evaluation

All-element Gravity Field Modeling Using Multi-source Heterogeneous Data with SRBFs

Modeling Process Exercise: Regional Gravity Field and Geoid

Conversion of General ASCII Records to PAGravf4.5 Format

Data Interpolation, Extraction, and Land-Sea Separation

Simple and Direct Calculations on Geodetic Data Files

Low-Pass Filtering Operations on Geodetic Grid File

Simple Gridding and Regional Geodetic Grid Construction

Construction and Transformation of Vector Grid Files

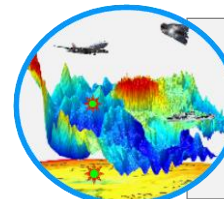
Statistical Analysis of Geodetic Data File

Calculation of Grid Horizontal Gradients and Vector Grid Inner Products

Analysis and Preprocessing of Earth Gravity Field Data



Computation of Diverse Terrain Effects on Various External Gravity Field Elements



Computation of Local Terrain Effects on Field Elements on or outside the Geoid

Computation of Unified Land, Ocean, and Lake Complete Bouguer Effects on External Gravity

Computation of Terrain Helmert Condensation Effects on External Field Elements

Computation of Residual Terrain Effects (RTE) on External Field Elements

Computation of Unified Land-Sea Classical Gravity Bouguer and Isostatic Effects

Ultra-High-Degree Spherical Harmonic Analysis and Construction of Land-Sea Terrain Models

Spherical Harmonic Synthesis of Complete Bouguer and Residual Terrain Effects

Demonstration of Terrain Effect Computation Processes outside the Geoid

Normal Height Difference Correction for Height Anomaly and Height System Discrepancy

Construction and Refinement of an Equipotential Surface Passing Through a Specified Point

Construction of a Terrain Equielevation Surface Passing Through a Specified Point

Assessment of the Gravimetric Geoid Using GNSS-Leveling Data

GNSS-Leveling Data Fusion and Regional Height Datum Optimization

Calculation of Orthometric or Normal Heights via GNSS Replacing Leveling

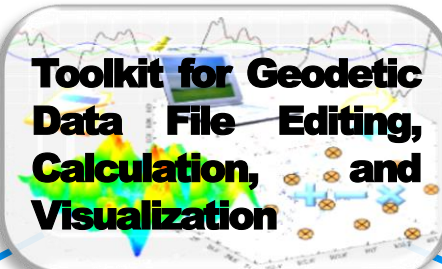
Optimization, Unification, and Application of Regional Height Datums



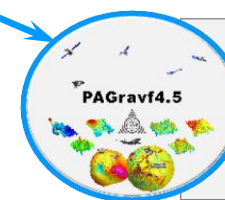
**Precise Approximation of Earth Gravity Field and Geoid
PAGravf4.5**

Chinese Academy of Surveying & Mapping
March 2026, Beijing, China

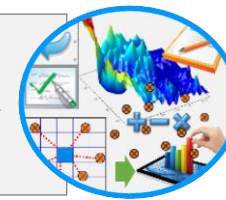
Toolkit for Geodetic Data File Editing, Calculation, and Visualization

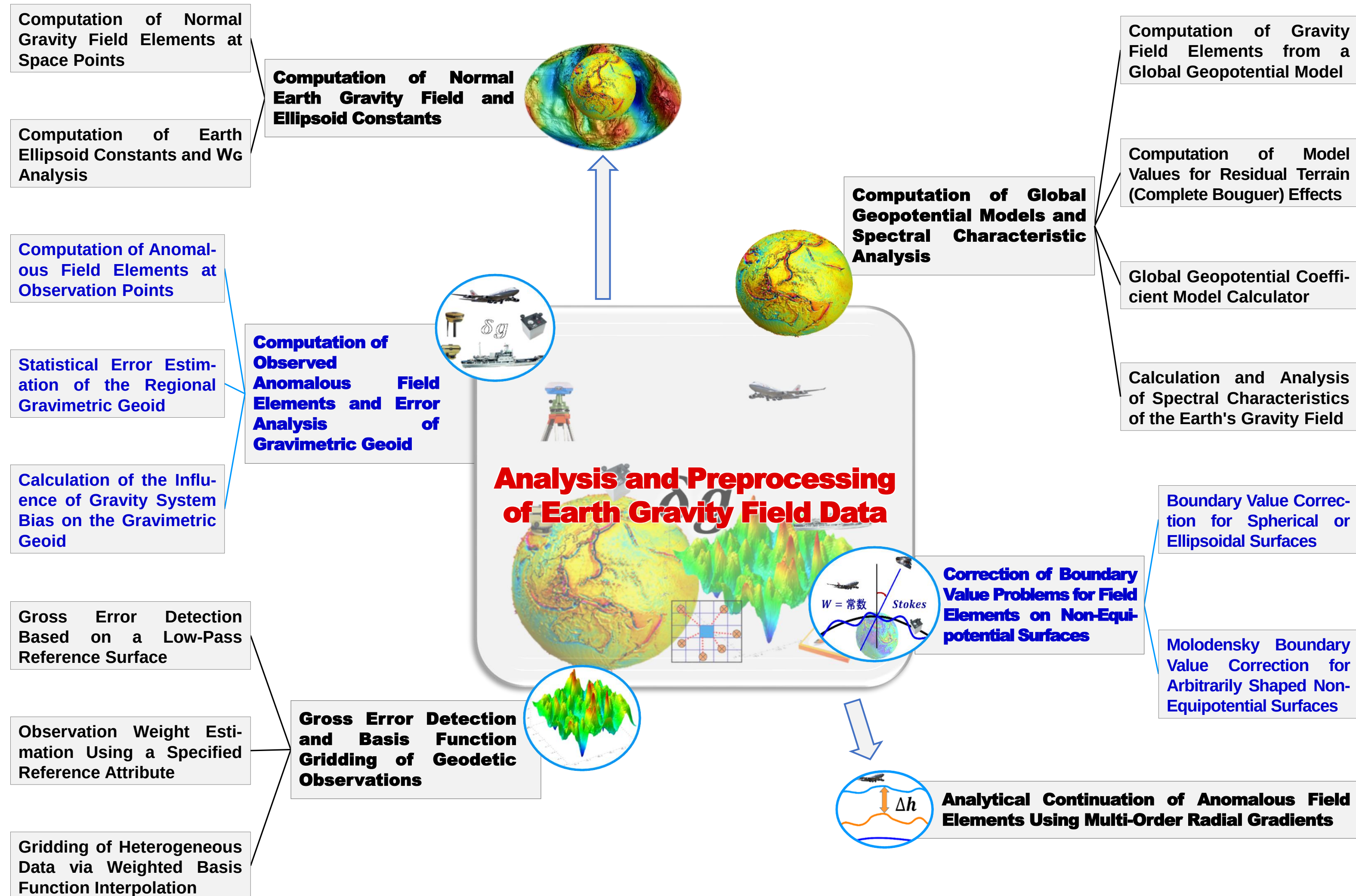


PAGravf4.5 Summary, Setting and visualization



Edit and Calculation Tool for Geodetic Data Files





Computation of Normal Gravity Field Elements at Space Points

Open Computation Points

Import parameters

Save as

Start computation

Ellipsoid Computation

Follow example


Computation of Normal Gravity Field Elements at Space Points

Computation of Earth Ellipsoid Constants and Wg Analysis

Computation Formulas of Normal Gravity Field

Open Space Computation Point File

Set input point file format

Number of rows of file header 1

Ellipsoidal Height Column Index 4

Select elements to be computed

- ☒ Normal Geopotential (m^2/s^2)
- ☒ Normal Gravity (mGal)
- ☒ Normal Gravity Gradient (E)
- ☒ Direction of Normal Gravity Vector (')
- ☒ Direction of Normal Gravity Gradient (')



Save the results as



Import setting parameters



Start Computation

Display of the input-output file↓

no	lon(deg)	lat(deg)	ellipheight(m)						
3248	103.671939	31.938051	2743.9394	62609994.0026	978633.0022	3074.9063	-10.3533	5.1183	
3249	103.696944	31.864721	2501.2449	62612369.3305	978701.8741	3075.2510	-10.3399	5.1446	
3250	103.718330	31.831114	2435.4206	62613013.6271	978719.4456	3075.3432	-10.3339	5.1567	
3251	103.735559	31.795280	2366.5700	62613687.5573	978737.7722	3075.4395	-10.3273	5.1696	
3252	103.777216	31.776390	2294.0304	62614397.5729	978758.6092	3075.5429	-10.3239	5.1764	
3253	103.822773	31.758333	2233.2317	62614992.6837	978775.8948	3075.6293	-10.3206	5.1828	
3254	103.849717	31.724168	2215.6606	62615164.7271	978778.5505	3075.6515	-10.3144	5.1951	
3255	103.816666	31.650003	2242.9951	62614897.3184	978764.1322	3075.6047	-10.3009	5.2217	
3256	103.783335	31.616667	2297.3654	62614365.2277	978744.6783	3075.5227	-10.2949	5.2337	
3257	103.740556	31.581110	2218.6104	62615136.1113	978766.0935	3075.6335	-10.2883	5.2464	
3258	103.703884	31.560833	2207.1173	62615248.6381	978768.0029	3075.6482	-10.2846	5.2537	
3259	103.682782	31.531391	2245.2634	62614875.3318	978753.8691	3075.5901	-10.2793	5.2643	
3260	103.651939	31.510554	2219.9076	62615123.5409	978760.0091	3075.6248	-10.2754	5.2717	
3261	103.613883	31.491662	2080.5161	62616487.9108	978801.4694	3075.8251	-10.2718	5.2784	

>> Computation Process ** Operation Prompts

>> [Purpose] To compute normal gravity field elements at arbitrary points in Earth space, the geometric and physical constants of the normal Earth ellipsoid, and the geoidal geopotential (W_g) utilizing rigorous analytical algorithms based on spherical harmonic expansion

>> Select the computation function from the two control buttons on the left-top of the interface...

>> [Function] Utilizing the spherical harmonic expansion formula, this module calculates: Normal Geopotential (unit: m^2/s^2); Normal Gravity (unit: mGal); Normal Gravity Gradient (unit: Eötvös, E); Direction of the Normal Gravity Vector (unit: arcminutes ['], expressed as the north declination relative to the Earth's center of mass); or, Direction of the Normal Gravity Gradient (unit: arcminutes ['], expressed as the north declination relative to the Earth's center of mass).

** Click on the control button [Open Space Computation Point File] or the tool button [Open Computation Points] ...

>> Open Space Computation Point File C:/PAGravf4.5_win64en/examples/PrNormalgravfdcalc/calcpnt.txt.

** Look at the file information in the window below, set the input file format parameters, select the elements to be computed, and click the [Import setting parameters] button to input the parameters into the system...

>> Save Computation Result File as C:/PAGravf4.5_win64en/examples/PrNormalgravfdcalc/result.txt.

** Appends one or more columns of computed values to each record of the source Space Computation Point File. Values are formatted to 4 significant figures.

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-16 21:16:52

>> Complete the computation of the normal gravity field parameters!

>> Computation end time: 2026-04-16 21:16:53



Save data in the text box as

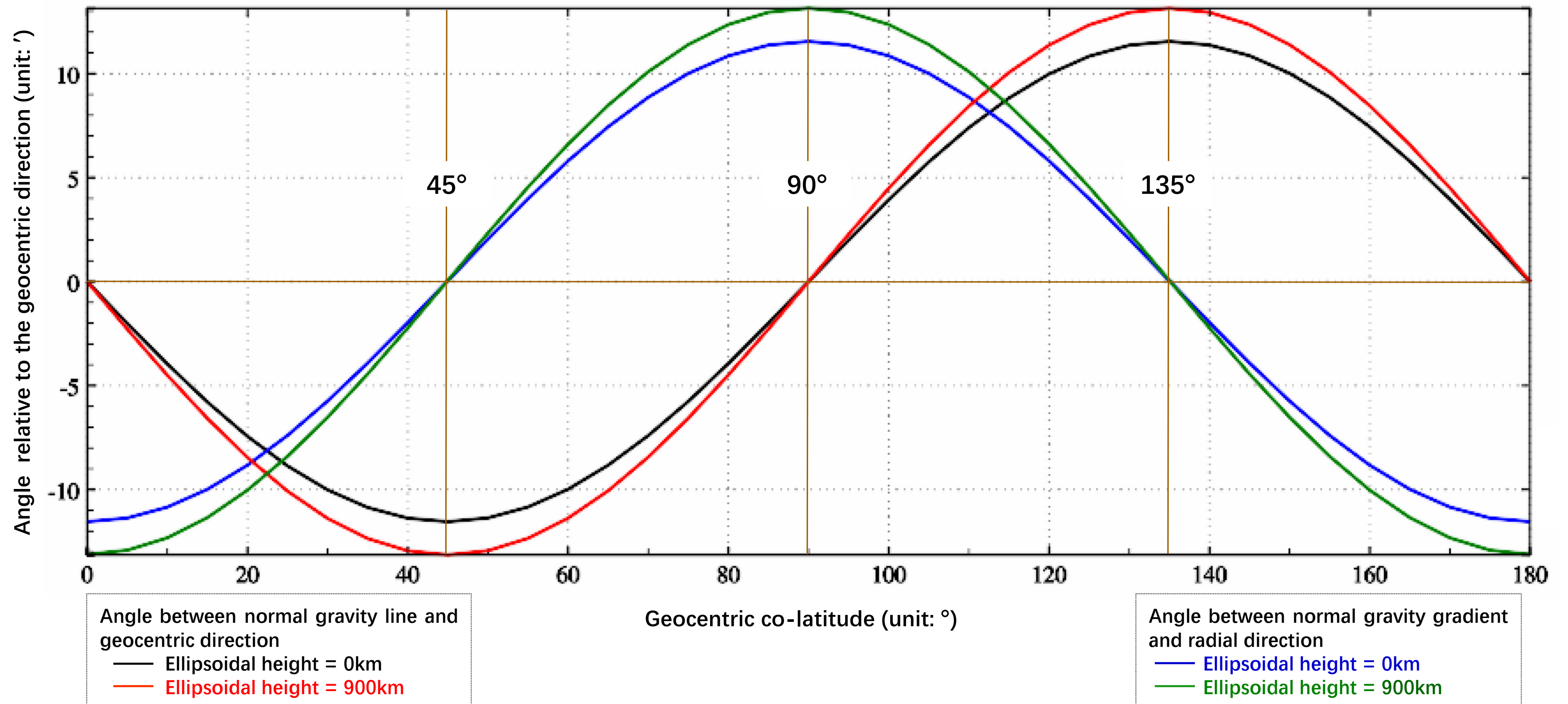


Figure 7.2: Variation of northward deflection angles of the normal gravity line and gradient direction relative to the geocentric direction, versus co-latitude

Computation of Earth Ellipsoid Constants and Wg Analysis

Computation of Earth Ellipsoid Constants and Wg Analysis

Set four fundamental parameters of Earth ellipsoid

Geocentric gravitational constant $GM(10^{14}m^3/s^2)$ of the Earth Mean angular velocity $\omega(10^{-5}/s)$ of the Earth Major semi-axis $a(m)$ of the Earth
Select the fourth basic parameter from $\bar{C}_{20}(10^{-3})$, $J_2(10^{-3})$, $1/f$ and U_0

Enter the four basic parameters of Earth ellipsoid

Geometric derived constants of Earth ellipsoid

Reciprocal flattening $1/f$
Minor semi axis of the Earth $b(m)$
Radius of sphere of same volume $R(m)$
Linear eccentricity $E(m)$
Square of first eccentricity e^2
Square of second eccentricity e'^2
Equatorial curvature radius $M(m)$
Polar radius of curvature $c(m)$

Physical derived constants of Earth ellipsoid

Dynamic form factor J_2 Normal potential at ellipsoid $U_0=Wg(m^2/s^2)$
Geodetic parameter m Normal gravity at equator $g_a(m/s^2)$

>> Computation Process ** Operation Prompts

>> [Function] From four basic parameters of the Earth ellipsoid, calculate the main geometric and physical derived constants. This tool can be used for classroom teaching demonstrations.

** The fourth basic parameter can be selected from the second-degree zonal harmonic coefficient C_{20} from global geopotential model, the ellipsoid normal geopotential U_0 , or the coefficient C_{20} from global geopotential model is selected currently as the fourth basic parameter.

>> The dynamic form factor J_2 selected as the fourth basic parameter.

>> The four basic parameters of the Earth ellipsoid have been entered into the system!

** Click the [Calculation of the derived constants of Earth ellipsoid] control button, or the [Calculation of ellipsoid constants] tool button.

>> Complete the calculation of the main geometric and physical derived constants of the Earth ellipsoid!

>> Summary of the calculation results of the Earth ellipsoid constants (see the interface for units):

Geocentric gravitational constant of the Earth (including the atmosphere) $GM = 3.986004415$
Major semi axis of the Earth $a = 6378136.3000$
Dynamical form factor of the Earth $J_2 = 1.0826362774$
Mean angular velocity of the Earth $\omega = 7.292115$
Reciprocal flattening $1/f = 298.2564115287$
Minor semi axis of the Earth $b = 6356751.5584$
Radius of sphere of same volume $R = 6371000.0713$
Linear eccentricity $E = 521854.6604$
Square of first eccentricity $e^2 = 0.006694398185686744$
Square of second eccentricity $e'^2 = 0.006739363787947453$
Equatorial curvature radius $M = 6335438.5159$
Polar radius of curvature $c = 6399592.9820$
Normal potential at ellipsoid $U_0 = 62636858.7088$
Gravity flattening reciprocal $1/f_a = 517.6435137498$
Geodetic parameter $m = 0.0034497853420$
Normal gravity at equator $g_a = 9.7803275820$
Normal gravity at pole $g_p = 9.8321870774$

It is recommended to define the normal ellipsoid using the following four fundamental parameters: (a) The scale parameters (GM , a) of the global geopotential model; (b) The second-degree zonal harmonic coefficient ($\bar{C}_{20}$); and (c) The mean angular velocity of rotation (ω).

The tide system of the normal ellipsoid is consistent with $\bar{C}_{20}$ or J_2 .

Computation of Earth Ellipsoid Constants and Wg Analysis

Set four fundamental parameters of Earth ellipsoid

Geocentric gravitational constant $GM(10^{14}m^3/s^2)$ of the Earth Mean angular velocity $\omega(10^{-5}/s)$ of the Earth Major semi-axis $a(m)$ of the Earth
Select the fourth basic parameter from $\bar{C}_{20}(10^{-3})$, $J_2(10^{-3})$, $1/f$ and U_0

Enter the four basic parameters of Earth ellipsoid

Geometric derived constants of Earth ellipsoid

Reciprocal flattening $1/f$
Minor semi axis of the Earth $b(m)$
Radius of sphere of same volume $R(m)$
Linear eccentricity $E(m)$
Square of first eccentricity e^2
Square of second eccentricity e'^2
Equatorial curvature radius $M(m)$
Polar radius of curvature $c(m)$

Physical derived constants of Earth ellipsoid

Dynamic form factor J_2 Normal potential at ellipsoid $U_0=Wg(m^2/s^2)$ Gravity flattening reciprocal $1/f_a$
Geodetic parameter m Normal gravity at equator $g_a(m/s^2)$ Normal gravity at pole $g_p(m/s^2)$

>> Computation Process ** Operation Prompts

Equatorial curvature radius $M = 6335438.5159$
Polar radius of curvature $c = 6399592.9820$
Normal potential at ellipsoid $U_0 = 62636858.7088$
Gravity flattening reciprocal $1/f_a = 517.6435137498$
Geodetic parameter $m = 0.0034497853420$
Normal gravity at equator $g_a = 9.7803275820$
Normal gravity at pole $g_p = 9.8321870774$

>> The coefficient C_{20} from global geopotential model selected as the fourth basic parameter.

>> The four basic parameters of the Earth ellipsoid have been entered into the system!

** Click the [Calculation of the derived constants of Earth ellipsoid] control button, or the [Calculation of ellipsoid constants] tool button...

>> Complete the calculation of the main geometric and physical derived constants of the Earth ellipsoid!

>> Summary of the calculation results of the Earth ellipsoid constants (see the interface for units):

Geocentric gravitational constant of the Earth (including the atmosphere) $GM = 3.986004415$
Major semi axis of the Earth $a = 6378136.3000$
Dynamical form factor of the Earth $J_2 = 1.0826362774$
Mean angular velocity of the Earth $\omega = 7.292115$
Reciprocal flattening $1/f = 298.2564115288$
Minor semi axis of the Earth $b = 6356751.5584$
Radius of sphere of same volume $R = 6371000.0713$
Linear eccentricity $E = 521854.6604$
Square of first eccentricity $e^2 = 0.006694398185684310$
Square of second eccentricity $e'^2 = 0.006739363787944986$
Equatorial curvature radius $M = 6335438.5159$
Polar radius of curvature $c = 6399592.9820$
Normal potential at ellipsoid $U_0 = 62636858.7088$
Gravity flattening reciprocal $1/f_a = 517.6435137492$
Geodetic parameter $m = 0.0034497853420$
Normal gravity at equator $g_a = 9.7803275820$
Normal gravity at pole $g_p = 9.8321870774$

It is recommended to define the normal ellipsoid using the following four fundamental parameters: (a) The scale parameters (GM , a) of the global geopotential model; (b) The second-degree zonal harmonic coefficient ($\bar{C}_{20}$); and (c) The mean angular velocity of rotation (ω).

Table 2.1: The scale parameters of several global geopotential models and the results of their geoidal geopotential calculations $W_G = U_0$

Geopotential Models	Scale Parameters		$\bar{C}_{20} \times 10^{-4}$	$W_G = U_0 (\text{m}^2/\text{s}^2)$	Tide System
	$GM \times 10^{14} \text{m}^3/\text{s}^2$	$a(\text{m})$			
EGM2008	3.986004415	6378136.3	-4.84165143791	62636858.392	tide free
EIGEN-6C4	3.986004415	6378136.46	-4.84165217061	62636856.834	zero tide
SGG-UGM2	3.986004415	6378136.3	-4.84168732275	62636858.644	zero tide
GOCO05c	3.986004415	6378136.3	-4.84169458843	62636858.694	zero tide
XGM2019	3.986004415	6378136.3	-4.84169494748	62636858.697	zero tide

Computation of Gravity Field Elements from a Global Geopotential Model

Geopotential Model Open Computation Points Import parameters Save as Start Computation Follow example

Computation of Gravity Field Elements from a Global Geopotential Model

Computation of Model Values for Residual Terrain (Complete Bouguer) Effects

Global Geopotential Coefficient Model Calculator

Calculation and Analysis of Spectral Characteristics of the Earth's Gravity Field

Open Global Geopotential Coefficient Model File

Select computation file format

Discrete computation point file

Open Space Computation Point File

Set input point file format

Header Rows 1

Ellipsoidal Height Column Index 4

Select elements to be computed

- ☒ 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 1

Maximum degree 360

Extract elements to be plot

Plot↓

Save computation process as

Algorithmic Formulas

>> [Function] Utilizing a global geopotential coefficient model, this module computes model values for (residual) height anomaly (m), gravity anomaly (mGal), gravity disturbance (mGal), vertical deflection vector (" , south, west components), disturbing gravity gradient(E, radial component), tangential gravity gradient vector(E, north, west components), or Laplace operator (E).

** Click the [Open Global Geopotential Coefficient Model File] control button, or the [Open Geopotential Model] tool button...

>> Open Global Geopotential Coefficient Model File C:/PAGrav4.5_win64en/data/EGM2008.gfc.

** The window below only shows the geopotential coefficients data with no more than 2000 rows in it.

>> Open Space Computation Point File C:/PAGrav4.5_win64en/examples/PrModelgravfdcalc/calcpnt.txt.

** Look at the file information in the window below and set the discrete point file format...

>> Save the results as C:/PAGrav4.5_win64en/examples/PrModelgravfdcalc/result.txt.

** Appends one or more columns of computed values to each record of the source file, formatted to 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: 2026-04-08 14:39:37

>> Complete the computation of the model value of (residual) gravity field element!

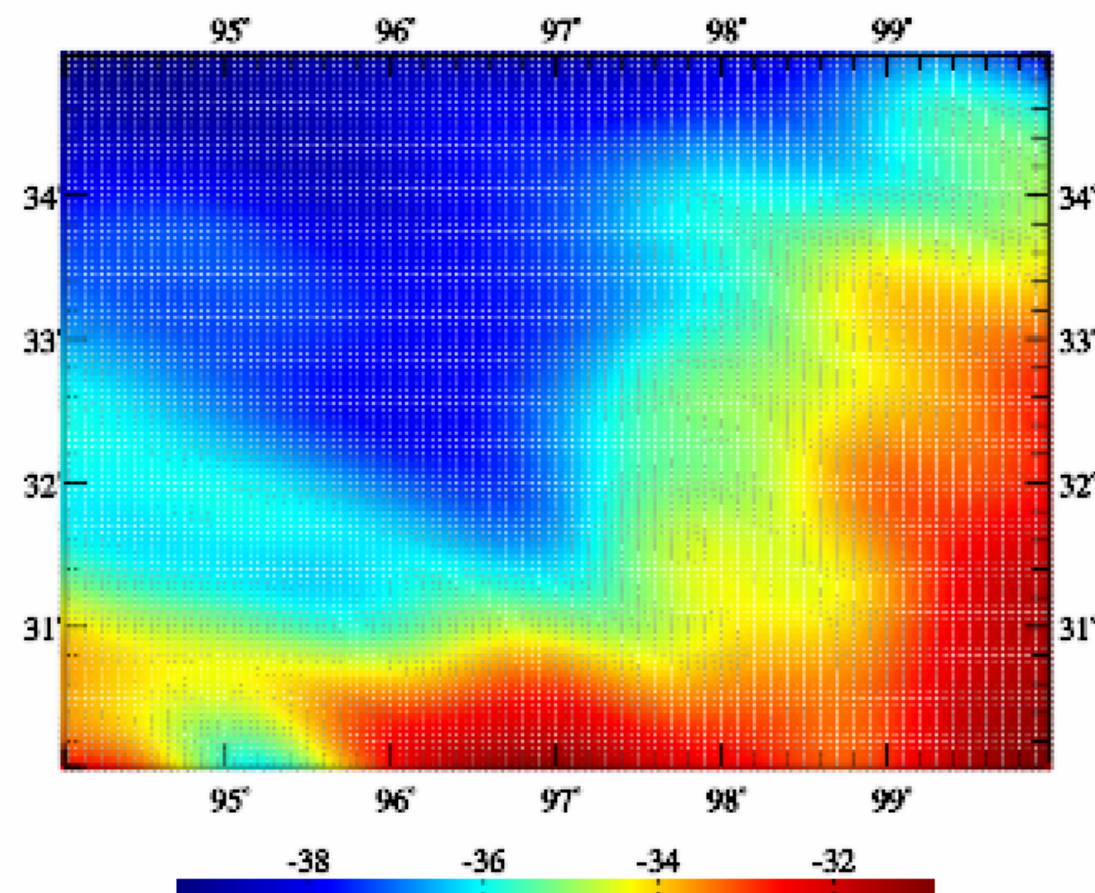
>> Computation end time: 2026-04-08 14:41:51

Save the results as

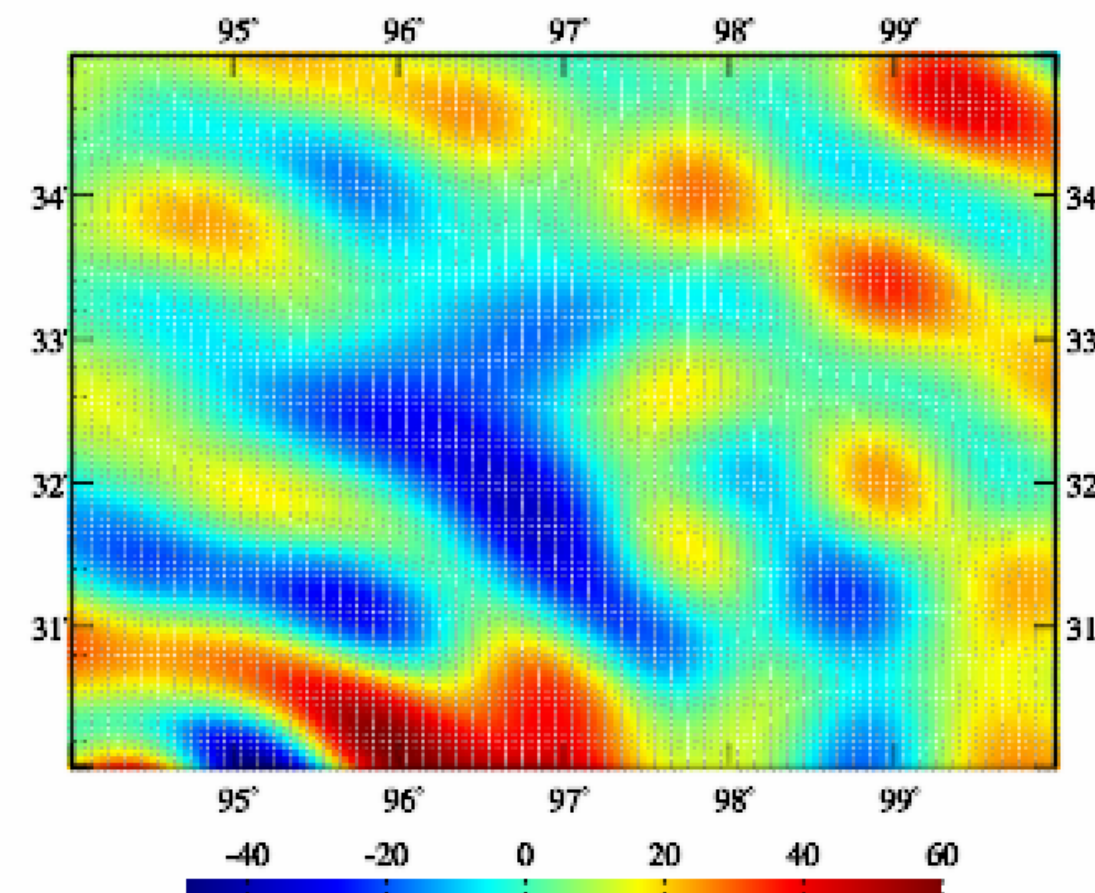
Import setting parameters

Start Computation

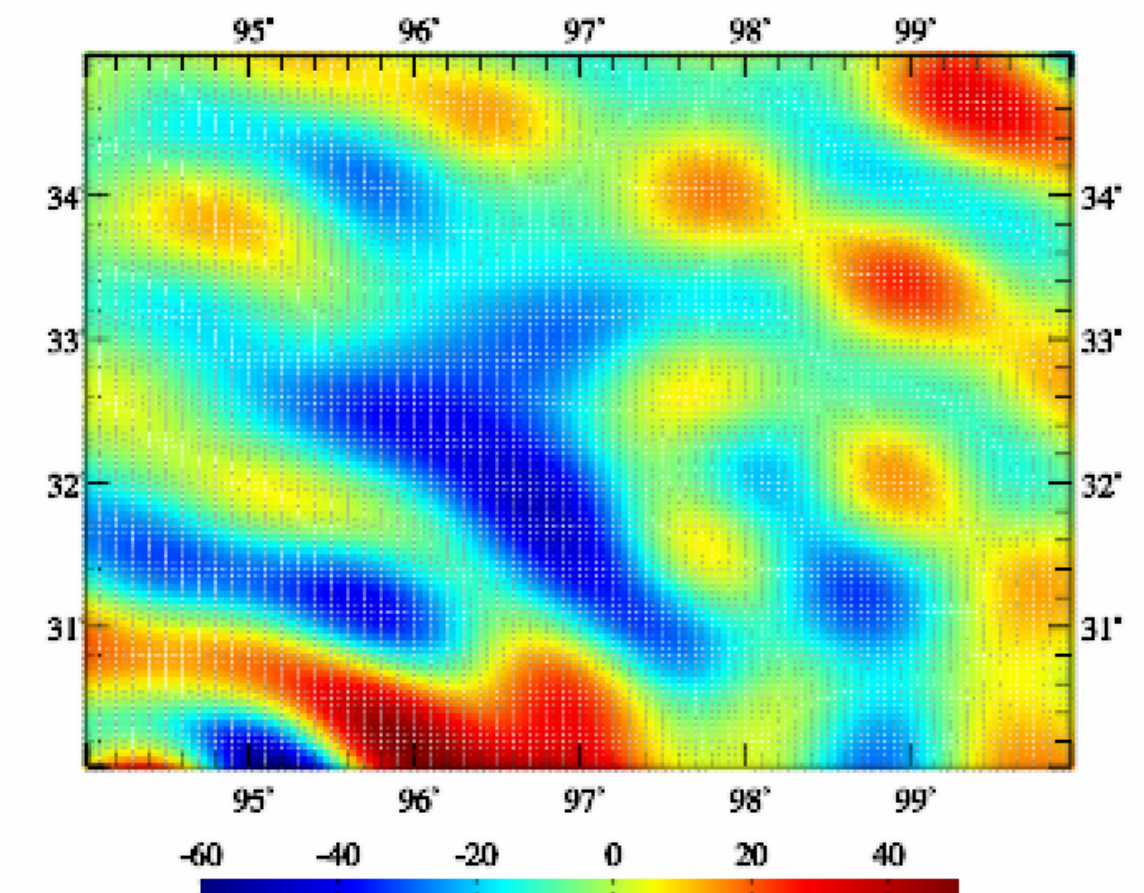
no	lon(deg)	lat(deg)	ellipheight(m)							
1	94.025000	30.025000	3984.353	-32.5696	19.9216	9.9303	9.8411	0.2382	-7.0	
2	94.075000	30.025000	4226.989	-32.5825	23.2867	13.2926	10.1203	0.4328	-5.1	
3	94.125000	30.025000	4461.719	-32.6027	26.5988	16.5996	10.3528	0.8171	-3.1	
4	94.175000	30.025000	4422.914	-32.6266	29.5890	19.5823	10.6133	1.3564	-1.2	
5	94.225000	30.025000	4335.893	-32.6637	32.1549	22.1364	10.8198	2.0788	0.5	



height anomaly (m)



gravity anomaly (mGal)



gravity disturbance (mGal)

Computation of Gravity Field Elements from a Global Geopotential Model

Computation of Gravity Field Elements from a Global Geopotential Model

Computation of Model Values for Residual Terrain (Complete Bouguer) Effects

Global Geopotential Coefficient Model Calculator

Calculation and Analysis of Spectral Characteristics of the Earth's Gravity Field

Open Global Geopotential Coefficient Model File

Select computation file format

Surface Ellipsoidal height grid file

Open Computation Surface Ellipsoidal Height Grid File

Select elements to be computed

- ☒ 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

1

Maximum degree

360

Save computation process as

>> [Function] Utilizing a global geopotential coefficient model, this module computes model values for (residual) height anomaly (m), gravity anomaly (mGal), gravity disturbance (mGal), vertical deflection vector (" , south, west components), disturbing gravity gradient(E, radial component), tangential gravity gradient vector(E, north, west components), or Laplace operator (E).

** 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 Computation Surface Ellipsoidal Height Grid File C:/PAGravf4.5_win64en/examples/PrModelgravfdcalc/surfhgt.dat.

>> Save the results as C:/PAGravf4.5_win64en/examples/PrModelgravfdcalc/Gravfd3

** The record format: ID (point no/name), longitude, latitude, ellipsoidal height, seven elements.

** The program automatically generates corresponding (residual) model value grid file extensions based on the selected element: height anomaly (*.ksi), gravity anomaly (*.g), vector (*.dft), disturbing gravity gradient (*.grr), tangential gravity gradient vector (*.hg

directory. Where * is the user-defined output filename prefix

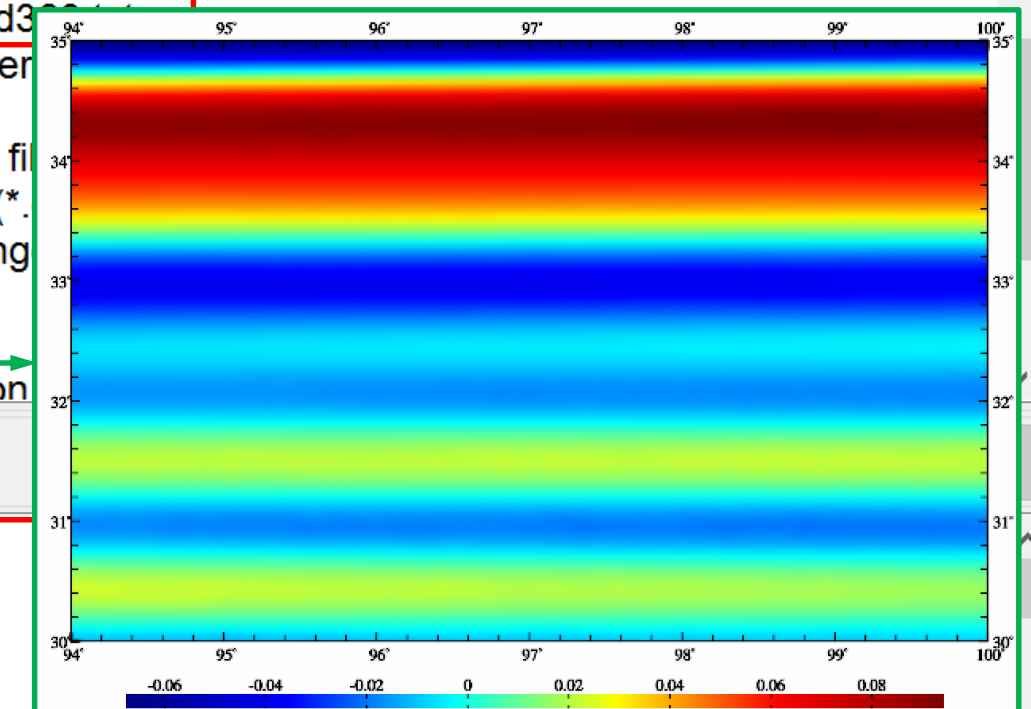
>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button or the [Start Computation] tool button

Save the results as

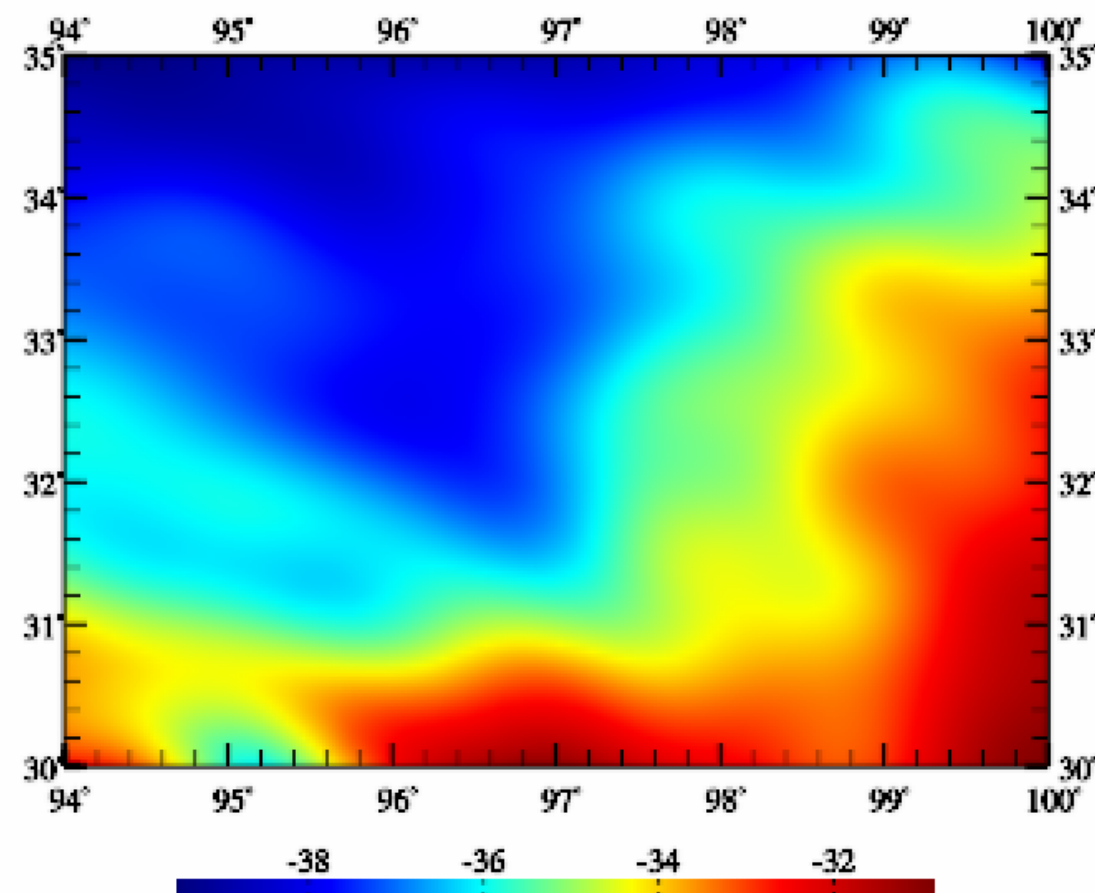
Import setting parameters

1	94.02500	30.02500	3984.353	-32.5696	19.9216
2	94.07500	30.02500	4226.989	-32.5825	23.2867
3	94.12500	30.02500	4461.719	-32.6027	26.5988
4	94.17500	30.02500	4422.914	-32.6266	29.5890
5	94.22500	30.02500	4335.893	-32.6637	32.1549
6	94.27500	30.02500	4463.689	-32.7271	34.0272

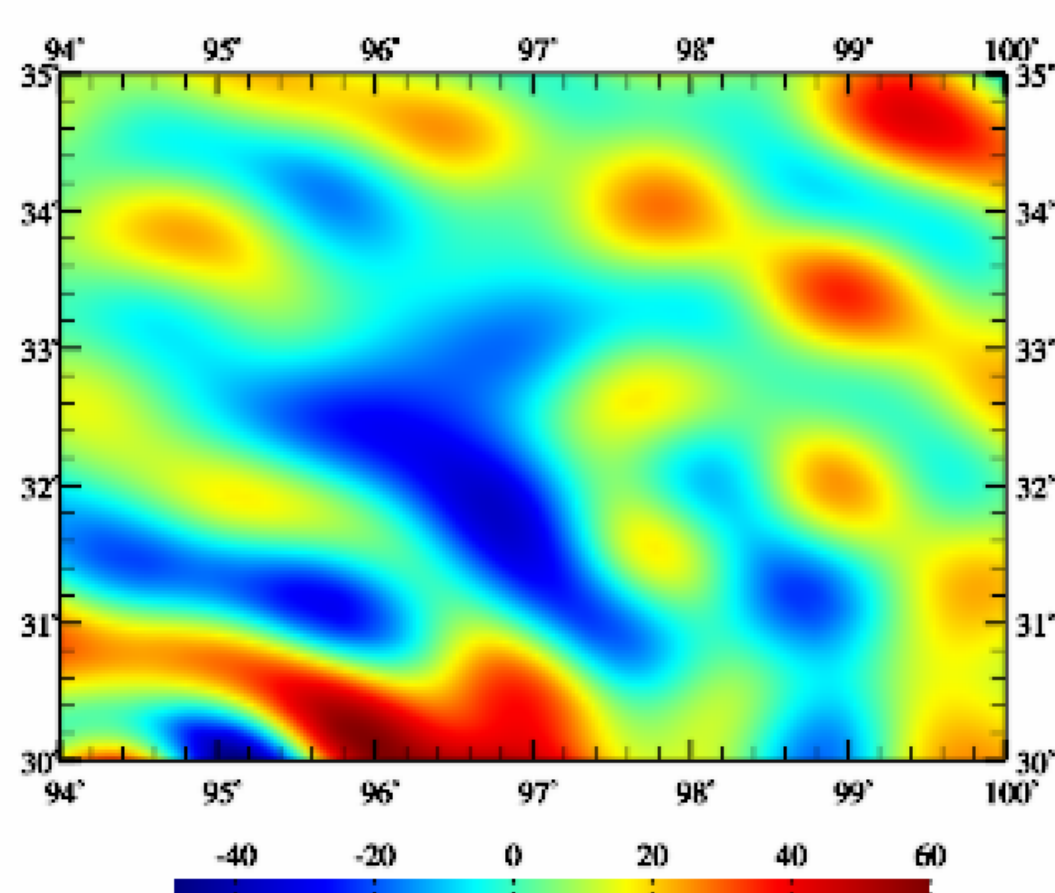


Extract elements to be plot

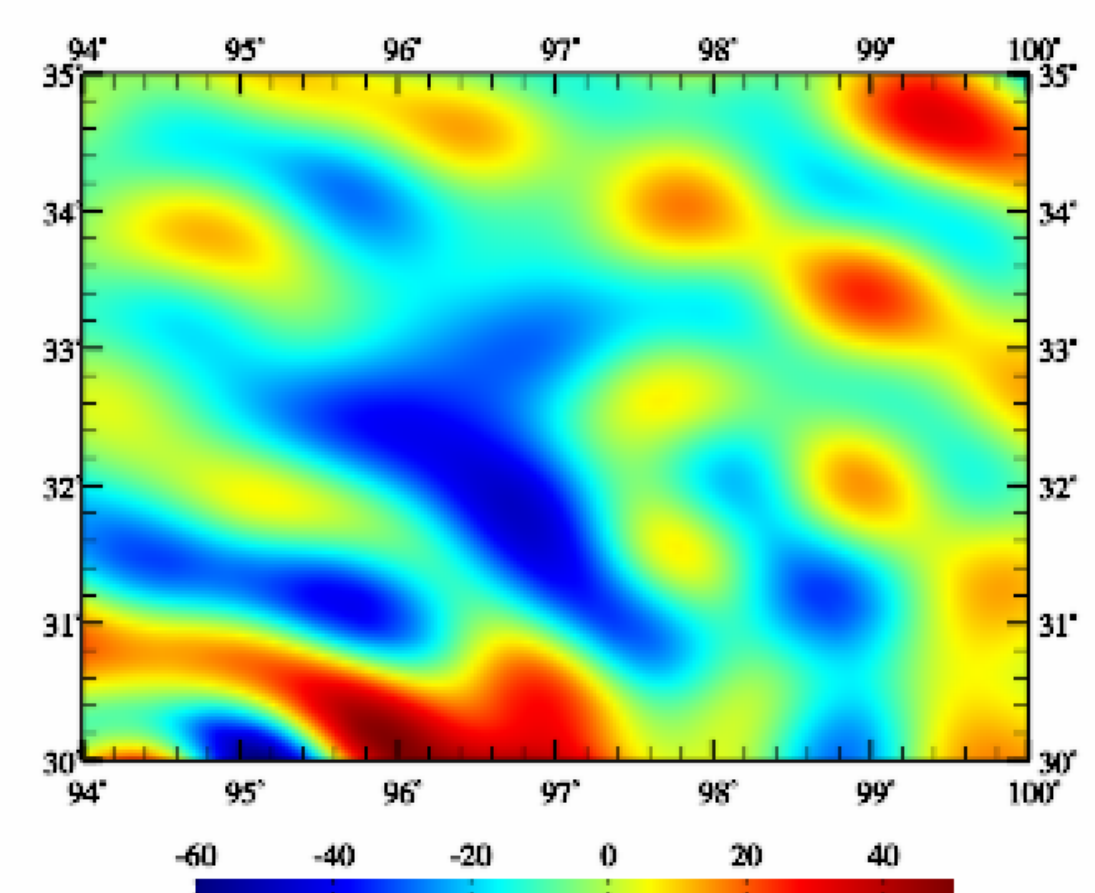
Plot↓



height anomaly (m)



gravity anomaly (mGal)



gravity disturbance (mGal)

Computation of Model Values for Residual Terrain (Complete Bouguer) Effects

Computation of Gravity Field Elements from a Global Geopotential Model

Computation of Model Values for Residual Terrain (Complete Bouguer) Effects

Global Geopotential Coefficient Model Calculator

Calculation and Analysis of Spectral Characteristics of the Earth's Gravity Field

Open Landsea Terrain Geopotential Model File

Select computation file format

Surface Ellipsoidal height grid file

Open Computation Surface Ellipsoidal Height Grid File

Select elements to be computed

- ☒ 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 361

Maximum degree 720

Save computation process as

>> [Function] From the global land-sea terrain geopotential coefficient model (m, the first degree term is set to zero), calculate the model value of residual terrain (complete Bouguer) effects on the height anomaly (m), gravity anomaly (mGal), gravity disturbance (mGal), vertical deflection vector (" , south, west), disturbing gravity gradient (radial, E), tangential gravity gradient vector (E, north, west) or Laplace operator.

** Click the [Open Landsea Terrain Geopotential Model File] control button, or the [Open Geopotential Model] tool button...

>> Open Landsea Terrain Geopotential Coefficient Model File C:/PAGravf4.5_w

** The window below only shows the geopotential coefficients data with no mo

>> Open Computation Surface Ellipsoidal Height Grid File C:/PAGravf4.5_win6

>> Save the results as C:/PAGravf4.5_win64en/examples/PrModelgravfdcalc/R

** The record format: ID (point no/name), longitude, latitude, ellipsoidal height, (complete Bouguer) effects.

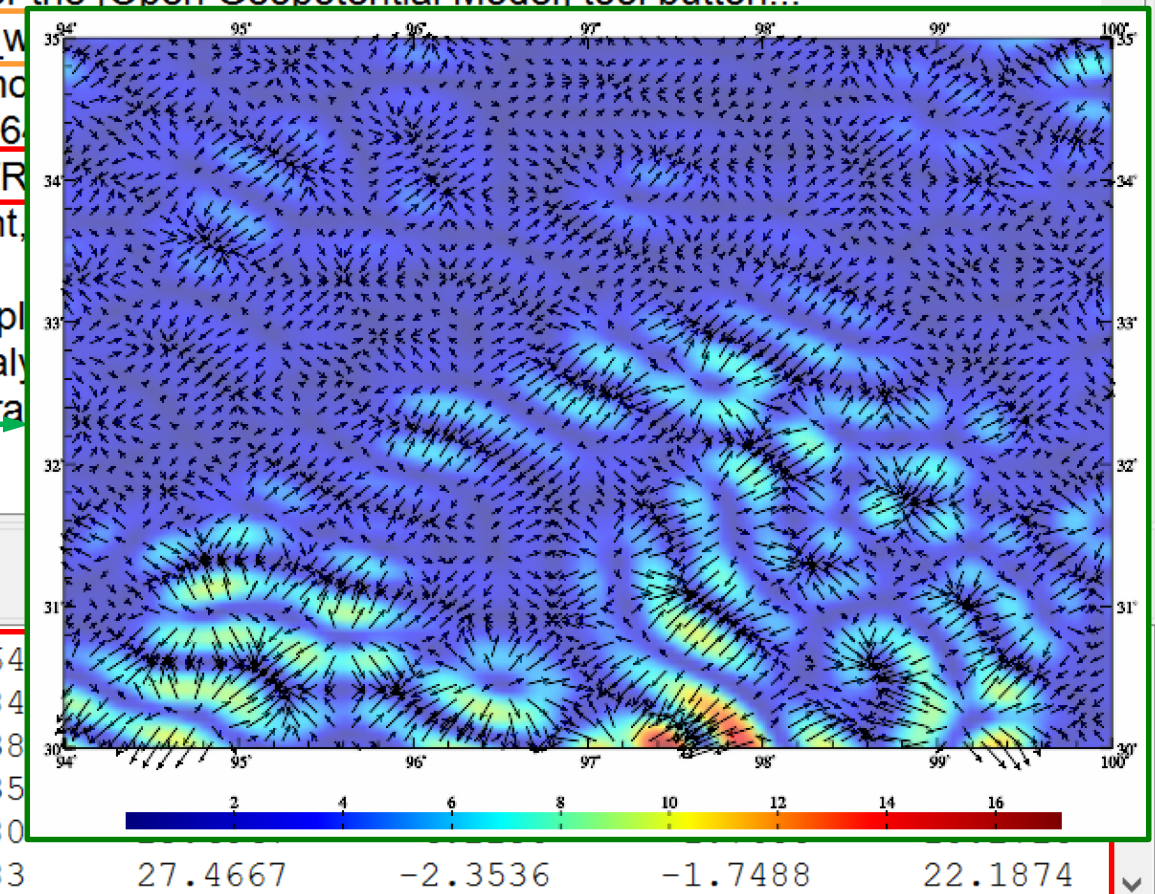
** The program automatically generates corresponding residual terrain (compl the following extensions based on the selected element (effect): height anomaly, vertical deflection vector (* dft), disturbing gravity gradient (* grr), tangential gra the current directory. Where * is the user-defined output filename prefix

>> The parameter settings have been entered into the system!

Save the results as

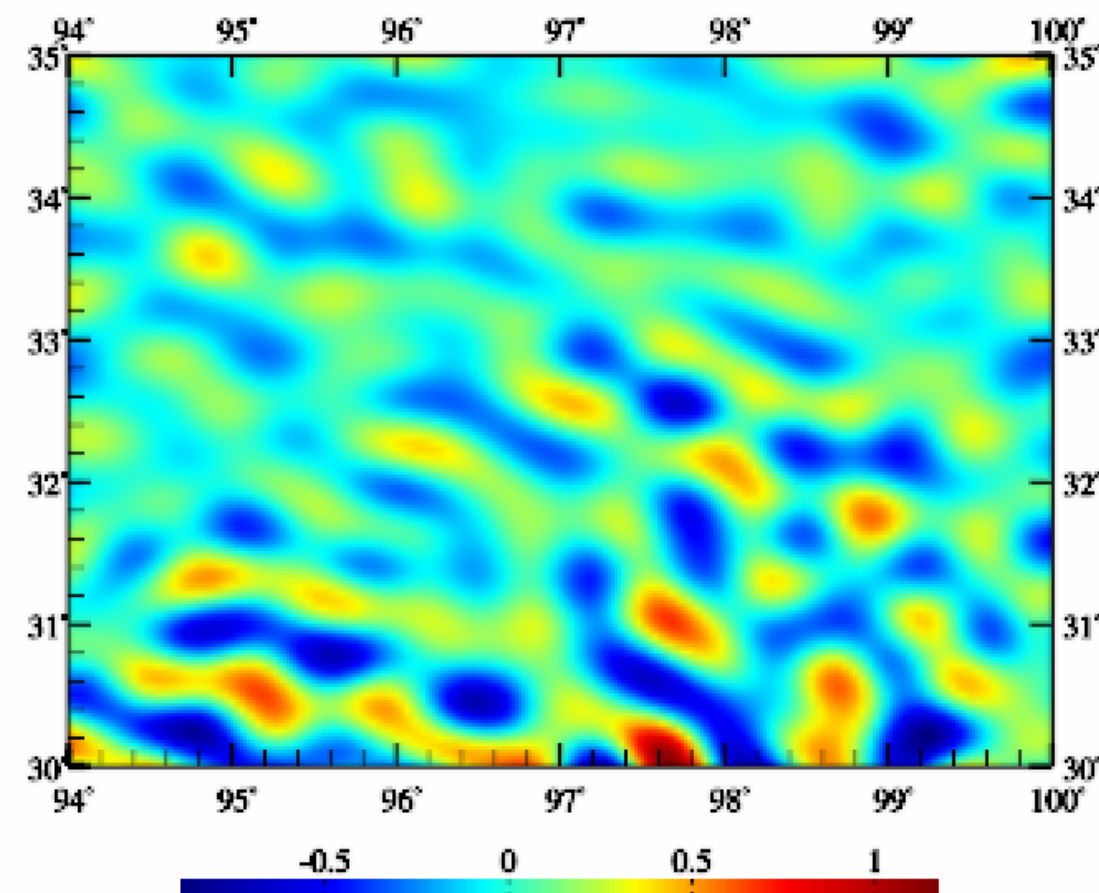
Import setting parameters

1	94.02500	30.02500	3984.353	0.1440	11.2464
2	94.07500	30.02500	4226.989	0.1739	13.6484
3	94.12500	30.02500	4461.719	0.2040	16.1838
4	94.17500	30.02500	4422.914	0.2411	19.4635
5	94.22500	30.02500	4335.893	0.2829	23.3980
6	94.27500	30.02500	4463.689	0.3210	27.3683

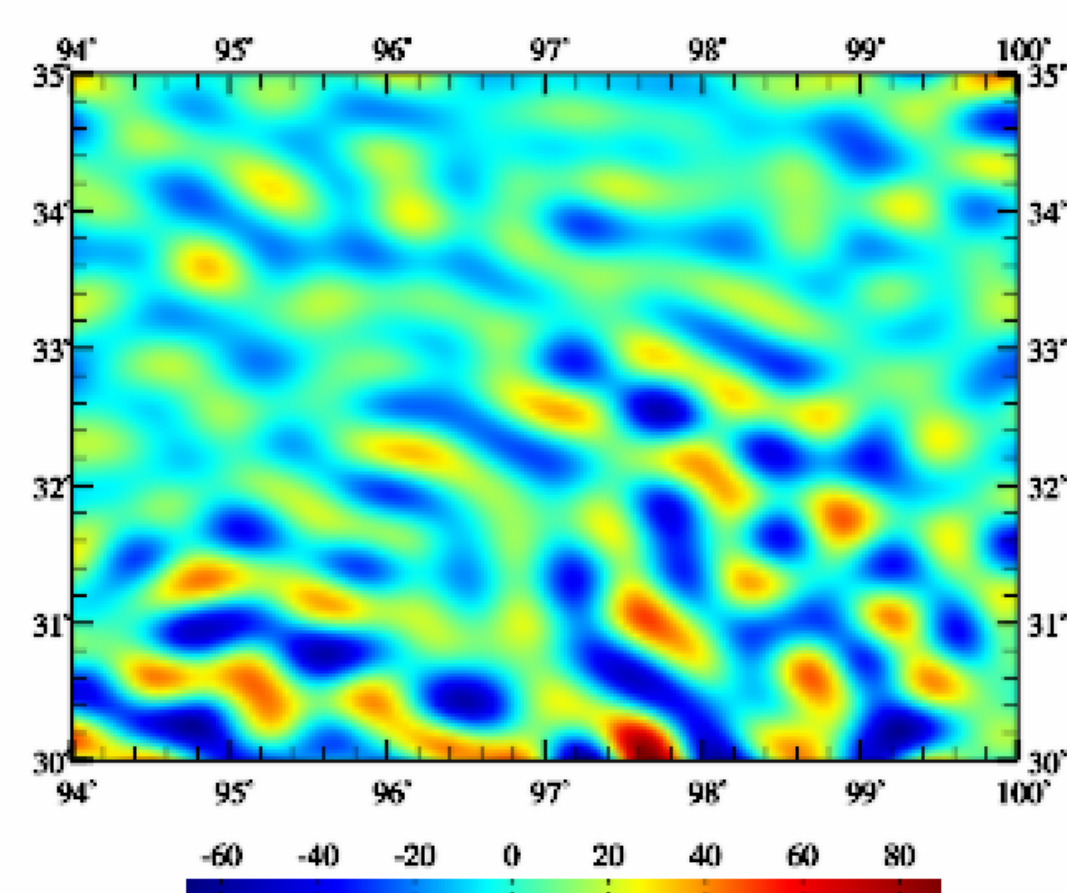


Extract elements to be plot

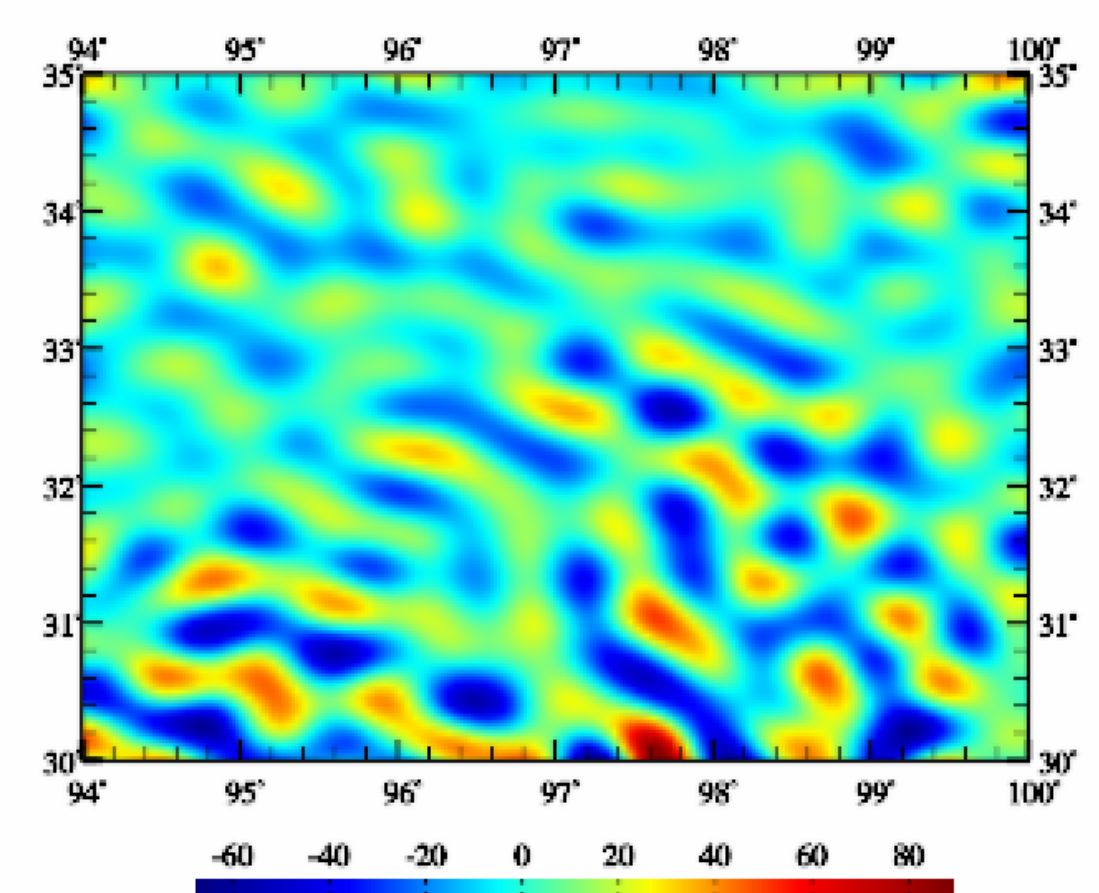
Plot↓



height anomaly (m)



gravity anomaly (mGal)



gravity disturbance (mGal)

Global Geopotential Coefficient Model Calculator



Input the geodetic coordinates of calculation point

Longitude 87.240000°

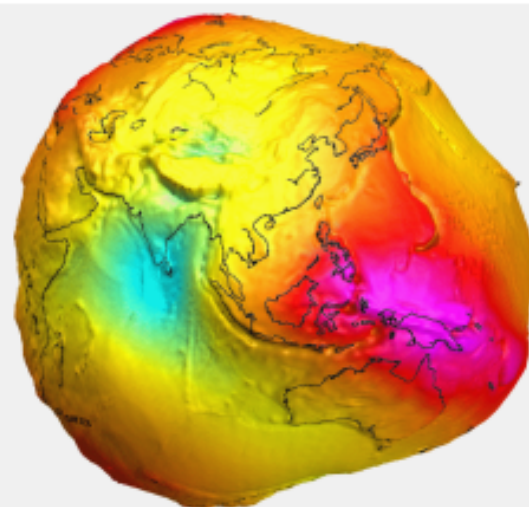
Latitude 31.428100°

Ellipsoidal height 5417.8300 m



Open Global Geopotential Coefficient Model File

When loading an ultra-high-degree geopotential coefficient model, the system requires time to read and initialize the data. Please wait...



Set maximum computation degree 1800



Verification procedure that the geoidal geopotential W_g is identically equal to the normal potential U_0 of reference ellipsoid:

- Initialization: Given the latitude and longitude of an arbitrary point, initially set the ellipsoidal height to zero and compute the height anomaly.
- Iteration: Use the computed height anomaly from Step 1 as the new ellipsoidal height input for a subsequent computation.
- Convergence: When the newly computed height anomaly converges with the input ellipsoidal height, the point lies on the geoid. The geopotential value derived at this stage represents W_g , the potential of the gravimetric geoid.



Start Computation

Model gravity field elements calculated

height anomaly/geoidal height (m)	-28.6109	gravity anomaly (mGal)	35.8449	gravity m/s ²	9.777951466
gravity disturbance (mGal)	27.0723	vertical deflection S (")	5.0582	vertical deflection W (")	-1.0667
disturbing gravity gradient (E)	1.9139	tangential gradient N (E)	-30.5760	tangential gradient W (E)	28.7014
Laplace operator (E)	0.0393	gravity gradient (E)	3072.8990	geopotential (m ² /s ²)	62583559.925

Global geopotential coefficient model

```
3.986004415d0 6378136.3d0 tide_free
2 0 -4.841651437908E-04 0.000000000000E+00 5.2900E-12 0.0000E+00
2 1 -2.066155090742E-10 1.384413891380E-09 4.9948E-12 5.1961E-12
2 2 2.439383573283E-06 -1.400273703859E-06 5.1125E-12 5.2508E-12
3 0 9.571612070935E-07 0.000000000000E+00 4.0527E-12 0.0000E+00
3 1 2.030462010479E-06 2.482004158569E-07 4.0493E-12 4.2262E-12
3 2 9.047878948095E-07 -6.190054751776E-07 4.5076E-12 4.5268E-12
3 3 7.213217571216E-07 1.414349261929E-06 4.2632E-12 4.2627E-12
4 0 5.399658666390E-07 0.000000000000E+00 3.1333E-12 0.0000E+00
4 1 -5.361573893889E-07 -4.735673465181E-07 3.2301E-12 3.3121E-12
4 2 3.505016239626E-07 6.624800262758E-07 3.7532E-12 3.6671E-12
4 3 9.908567666723E-07 -2.009567235675E-07 3.9824E-12 3.9741E-12
```

The scale parameters. Here, the surface harmonic functions are defined on the spherical surface whose radius is equal to the semi-major axis a of the Earth.

Global Geopotential Coefficient Model Calculator

Input the geodetic coordinates of calculation point

Longitude 130.240000°

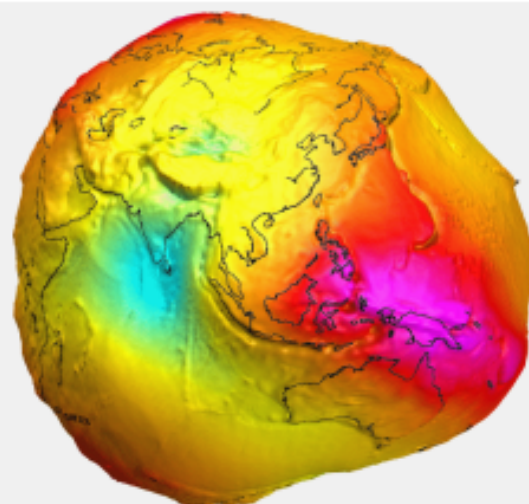
Latitude 21.428100°

Ellipsoidal height -12.8300 m



Open Global Geopotential Coefficient Model File

When loading an ultra-high-degree geopotential coefficient model, the system requires time to read and initialize the data. Please wait...



Set maximum computation degree 1800



Verification procedure that the geoidal geopotential W_g is identically equal to the normal potential U_0 of reference ellipsoid:

- Initialization: Given the latitude and longitude of an arbitrary point, initially set the ellipsoidal height to zero and compute the height anomaly.
- Iteration: Use the computed height anomaly from Step 1 as the new ellipsoidal height input for a subsequent computation.
- Convergence: When the newly computed height anomaly converges with the input ellipsoidal height, the point lies on the geoid. The geopotential value derived at this stage represents W_g , the potential of the gravimetric geoid.



Start Computation

Model gravity field elements calculated

height anomaly/geoidal height (m)	36.5056	gravity anomaly (mGal)	-4.5954	gravity m/s ²	9.787328443
gravity disturbance (mGal)	6.6132	vertical deflection S (")	2.3445	vertical deflection W (")	-1.9065
disturbing gravity gradient (E)	-4.4925	tangential gradient N (E)	0.9086	tangential gradient W (E)	3.5330
Laplace operator (E)	-0.0508	gravity gradient (E)	3073.5172	geopotential (m ² /s ²)	62637341.569

Global geopotential coefficient model

```
3.986004415d0 6378136.3d0 tide_free
2 0 -4.841651437908E-04 0.000000000000E+00 5.2900E-12 0.0000E+00
2 1 -2.066155090742E-10 1.384413891380E-09 4.9948E-12 5.1961E-12
2 2 2.439383573283E-06 -1.400273703859E-06 5.1125E-12 5.2508E-12
3 0 9.571612070935E-07 0.000000000000E+00 4.0527E-12 0.0000E+00
3 1 2.030462010479E-06 2.482004158569E-07 4.0493E-12 4.2262E-12
3 2 9.047878948095E-07 -6.190054751776E-07 4.5076E-12 4.5268E-12
3 3 7.213217571216E-07 1.414349261929E-06 4.2632E-12 4.2627E-12
4 0 5.399658666390E-07 0.000000000000E+00 3.1333E-12 0.0000E+00
4 1 -5.361573893889E-07 -4.735673465181E-07 3.2301E-12 3.3121E-12
4 2 3.505016239626E-07 6.624800262758E-07 3.7532E-12 3.6671E-12
4 3 9.908567666723E-07 -2.009567235675E-07 3.9824E-12 3.9741E-12
```

The scale parameters. Here, the surface harmonic functions are defined on the spherical surface whose radius is equal to the semi-major axis a of the Earth.

Calculation and Analysis of Spectral Characteristics of the Earth's Gravity Field



Open the 1st global geopotential coefficient model file



Open the 2nd global geopotential coefficient model file



Save the results as



Start Computation

The current number of global geopotential models input

0



Chart plot↓

Start end row number

30



720



curve type

Geop

Geopotential coefficient degree variance curves

After clicking [Start Computation], you need to wait until [Chart plot] becomes available.

The program can plot up to ten spectral curves of the global geopotential model.

```
3.986004415d0 6378136.46d0 tide_free
2 0 -4.84165217061e-04 0.000000000000e+00 1.1081e-13 0.0000e+00
3 0 9.57173592933e-07 0.000000000000e+00 6.5264e-14 0.0000e+00
4 0 5.39998754738e-07 0.000000000000e+00 2.9945e-14 0.0000e+00
5 0 6.86465403533e-08 0.000000000000e+00 2.2918e-14 0.0000e+00
6 0 -1.49975580611e-07 0.000000000000e+00 1.8644e-14 0.0000e+00
7 0 9.04993977725e-08 0.000000000000e+00 1.6557e-14 0.0000e+00
8 0 4.94771152555e-08 0.000000000000e+00 1.5132e-14 0.0000e+00
9 0 2.80189081183e-08 0.000000000000e+00 1.4193e-14 0.0000e+00
10 0 5.33423116338e-08 0.000000000000e+00 1.3564e-14 0.0000e+00
11 0 -5.07611016973e-08 0.000000000000e+00 1.3111e-14 0.0000e+00
12 0 3
13 0 4
14 0 -2
15 0 2
16 0 -4
17 0 1
18 0 6
19 0 -3
20 0 2
21 0 6
22 0 -1
23 0 -2
```



Open the 3th global geopotential coefficient model file

The program can plot up to ten spectral curves of the global geopotential model.

1	3.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.0000
2	3.125000E-01	7.911381E-02	1.336401E-12	1.132710E-05	7.373306E-05	7.911290E-02	5.7318	
3	8.641975E-02	8.823035E-02	1.278378E-12	1.584411E-05	1.031363E-04	8.823024E-02	5.1312	
4	3.515625E-02	2.289217E-02	1.193316E-12	1.912071E-05	1.244651E-04	2.289248E-02	5.2544	
5	1.760000E-02	1.366044E-02	1.028261E-12	2.154812E-05	1.402662E-04	1.365972E-02	5.2227	
6	1.003086E-02	8.191773E-03	9.314054E-13	2.353173E-05	1.531784E-04	8.191840E-03	4.6443	
7	6.247397E-03	5.675256E-03	8.969146E-13	2.529529E-05	1.646582E-04	5.675040E-03	6.0828	
8	4.150391E-03	2.379274E-03	8.857627E-13	2.692380E-05	1.752588E-04	2.379201E-03	4.1747	
9	2.895900E-03	1.819157E-03	8.972851E-13	2.847869E-05	1.853803E-04	1.819042E-03	6.6549	
10	2.100000E-03	1.264171E-03	9.295262E-13	3.000461E-05	1.953132E-04	1.264069E-03	4.8878	
11	1.570931E-03	6.892058E-04	9.267179E-13	3.145230E-05	2.047369E-04	6.891495E-04	6.3386	
12	1.205633E-03	2.284380E-04	9.893414E-13	3.292766E-05	2.143406E-04	2.284436E-04	6.3453	
13	9.453451E-04	5.736342E-04	1.073660E-12	3.445735E-05	2.242980E-04	5.736203E-04	5.8004	
14	7.548938E-04	2.158315E-04	1.157452E-12	3.603376E-05	2.345596E-04	2.158393E-04	5.3293	
15	6.123457E-04	1.950448E-04	1.323097E-12	3.775523E-05	2.457654E-04	1.950386E-04	4.7335	
16	5.035400E-04	1.898962E-04	1.398471E-12	3.949329E-05	2.570792E-04	1.898916E-04	4.5364	
17	4.190563E-04	1.308700E-04	1.562868E-12	4.134931E-05	2.691608E-04	1.308675E-04	6.0347	
18	3.524615E-04	1.393244E-04	1.715295E-12	4.329485E-05	2.818252E-04	1.393118E-04	8.7300	
19	2.992611E-04	1.033262E-04	1.923900E-12	4.537787E-05	2.953845E-04	1.033288E-04	9.1430	
20	2.562500E-04	9.200739E-05	2.143124E-12	4.759102E-05	3.097909E-04	9.200352E-05	1.3341	
21	2.211013E-04	9.555692E-05	2.409070E-12	4.996190E-05	3.252240E-04	9.555385E-05	1.2128	
22	1.920975E-04	8.205035E-05	2.696481E-12	5.248877E-05	3.416725E-04	8.205169E-05	1.5534	



Save the results as



Start Computation

The current number of global geopotential models input

2



Chart plot↓

Start end row number

60



180



curve type

Geopotential coefficient degree variance

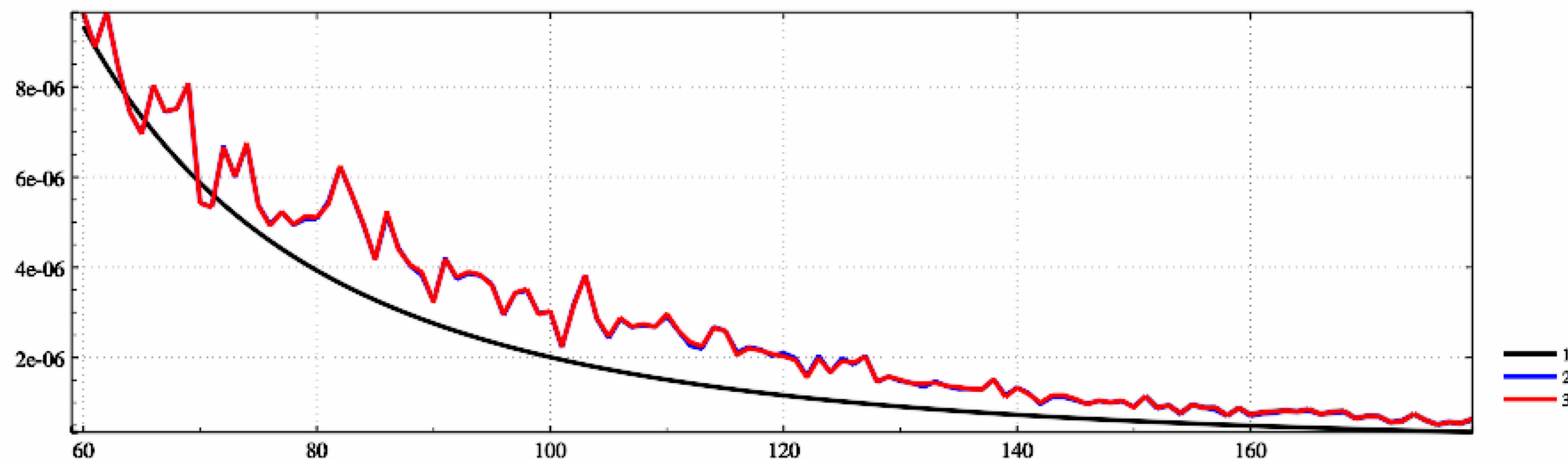
line thickness

3



Save current plot as

Geopotential coefficient degree variance curves



Calculation and Analysis of Spectral Characteristics of the Earth's Gravity Field

Open the 4th global geopotential coefficient model file

Save the results as

Start Computation

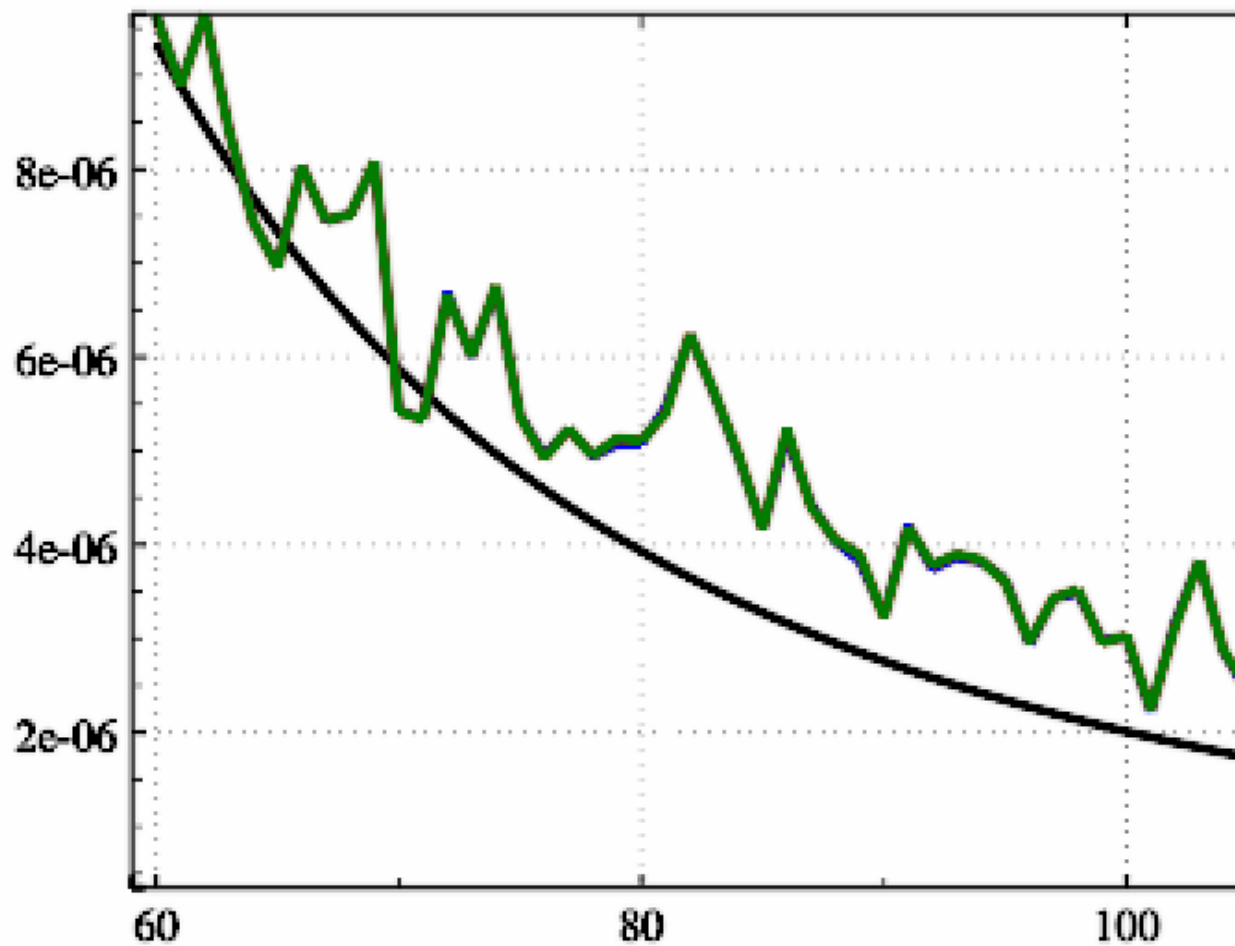
The current number of global geopotential models input 3

Chart plot↓

Start end row number 60 180

curve type Geopot

Geopotential coefficient degree variance curves



The program can plot up to ten spectral curves of the global geopotential model.

1	3.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.0000
2	3.125000E-01	7.911381E-02	1.336401E-12	1.132710E-05	7.373306E-05	7.911290E-02	5.7318
3	8.641975E-02	8.823035E-02	1.278378E-12	1.584411E-05	1.031363E-04	8.823024E-02	5.1312
4	3.515625E-02	2.289217E-02	1.193316E-12	1.912071E-05	1.244651E-04	2.289248E-02	5.2544
5	1.760000E-02	1.366044E-02	1.028261E-12	2.154812E-05	1.402662E-04	1.365972E-02	5.2227
6	1.003086E-02	8.191773E-03	9.314054E-13	2.353173E-05	1.531784E-04	8.191840E-03	4.6443
7	6.247397E-03	5.675256E-03	8.969146E-13	2.529529E-05	1.646582E-04	5.675040E-03	6.0828
8	4.150391E-03	2.379274E-03	8.857627E-13	2.692380E-05	1.752588E-04	2.379201E-03	4.1747
9	2.895900E-03	1.819157E-03	8.972851E-13	2.847869E-05	1.853803E-04	1.819042E-03	6.6549
10	2.100000E-03	1.264171E-03	9.295262E-13	3.000461E-05	1.953132E-04	1.264069E-03	4.8878
11	1.570931E-03	6.892058E-04	9.267179E-13	3.145230E-05	2.047369E-04	6.891495E-04	6.3386
12	1.205633E-03	2.284380E-04	9.893414E-13	3.292766E-05	2.143406E-04	2.284436E-04	6.3453
13	9.453451E-04	5.736342E-04	1.073660E-12	3.445735E-05	2.242980E-04	5.736203E-04	5.8004
14	7.548938E-04	2.158315E-04	1.157452E-12	3.603376E-05	2.345596E-04	2.158393E-04	5.3293
15	6.123457E-04	1.950448E-04	1.323097E-12	3.775523E-05	2.457654E-04	1.950386E-04	4.7335
16	5.035400E-04	1.898962E-04	1.398471E-12	3.949329E-05	2.570792E-04	1.898916E-04	4.5364
17	4.190563E-04	1.308700E-04	1.562868E-12	4.134931E-05	2.691608E-04	1.308675E-04	6.0347
18	3.524615E-04	1.393244E-04	1.715295E-12	4.329485E-05	2.818252E-04	1.393118E-04	8.7300
19	2.992611E-04	1.033262E-04	1.923900E-12	4.537787E-05	2.953845E-04	1.033288E-04	9.1430
20	2.562500E-04	9.200739E-05	2.143124E-12	4.759102E-05	3.097909E-04	9.200352E-05	1.3341
21	2.211013E-04	9.555692E-05	2.409070E-12	4.996190E-05	3.252240E-04	9.555385E-05	1.2128
22	1.920975E-04	8.205035E-05	2.696481E-12	5.248877E-05	3.416725E-04	8.205169E-05	1.5534

Calculation and Analysis of Spectral Characteristics of the Earth's Gravity Field

Open the 4th global geopotential coefficient model file

Save the results as

Start Computation

The current number of global geopotential models input 3

Chart plot↓

Start end row number 30 540

The program can plot up to ten spectral curves of the global geopotential model.

1	3.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.0000
2	3.125000E-01	7.911381E-02	1.336401E-12	1.132710E-05	7.373306E-05	7.911290E-02	5.7318
3	8.641975E-02	8.823035E-02	1.278378E-12	1.584411E-05	1.031363E-04	8.823024E-02	5.1312
4	3.515625E-02	2.289217E-02	1.193316E-12	1.912071E-05	1.244651E-04	2.289248E-02	5.2544
5	1.760000E-02	1.366044E-02	1.028261E-12	2.154812E-05	1.402662E-04	1.365972E-02	5.2227
6	1.003086E-02	8.191773E-03	9.314054E-13	2.353173E-05	1.531784E-04	8.191840E-03	4.6443
7	6.247397E-03	5.675256E-03	8.969146E-13	2.529529E-05	1.646582E-04	5.675040E-03	6.0828
8	4.150391E-03	2.379274E-03	8.857627E-13	2.692380E-05	1.752588E-04	2.379201E-03	4.1747
9	2.895900E-03	1.819157E-03	8.972851E-13	2.847869E-05	1.853803E-04	1.819042E-03	6.6549
10	2.100000E-03	1.264171E-03	9.295262E-13	3.000461E-05	1.953132E-04	1.264069E-03	4.8878
11	1.570931E-03	6.892058E-04	9.267179E-13	3.145230E-05	2.047369E-04	6.891495E-04	6.3386
12	1.205633E-03	2.284380E-04	9.893414E-13	3.292766E-05	2.143406E-04	2.284436E-04	6.3453
13	9.453451E-04	5.736342E-04	1.073660E-12	3.445735E-05	2.242980E-04	5.736203E-04	5.8004
14	7.548938E-04	2.158315E-04	1.157452E-12	3.603376E-05	2.345596E-04	2.158393E-04	5.3293
15	6.123457E-04	1.950448E-04	1.323097E-12	3.775523E-05	2.457654E-04	1.950386E-04	4.7335
16	5.035400E-04	1.898962E-04	1.398471E-12	3.949329E-05	2.570792E-04	1.898916E-04	4.5364
17	4.190563E-04	1.308700E-04	1.562868E-12	4.134931E-05	2.691608E-04	1.308675E-04	6.0347
18	3.524615E-04	1.393244E-04	1.715295E-12	4.329485E-05	2.818252E-04	1.393118E-04	8.7300
19	2.992611E-04	1.033262E-04	1.923900E-12	4.537787E-05	2.953845E-04	1.033288E-04	9.1430
20	2.562500E-04	9.200739E-05	2.143124E-12	4.759102E-05	3.097909E-04	9.200352E-05	1.3341
21	2.211013E-04	9.555692E-05	2.409070E-12	4.996190E-05	3.252240E-04	9.555385E-05	1.2128
22	1.920975E-04	8.205035E-05	2.696481E-12	5.248877E-05	3.416725E-04	8.205169E-05	1.5534

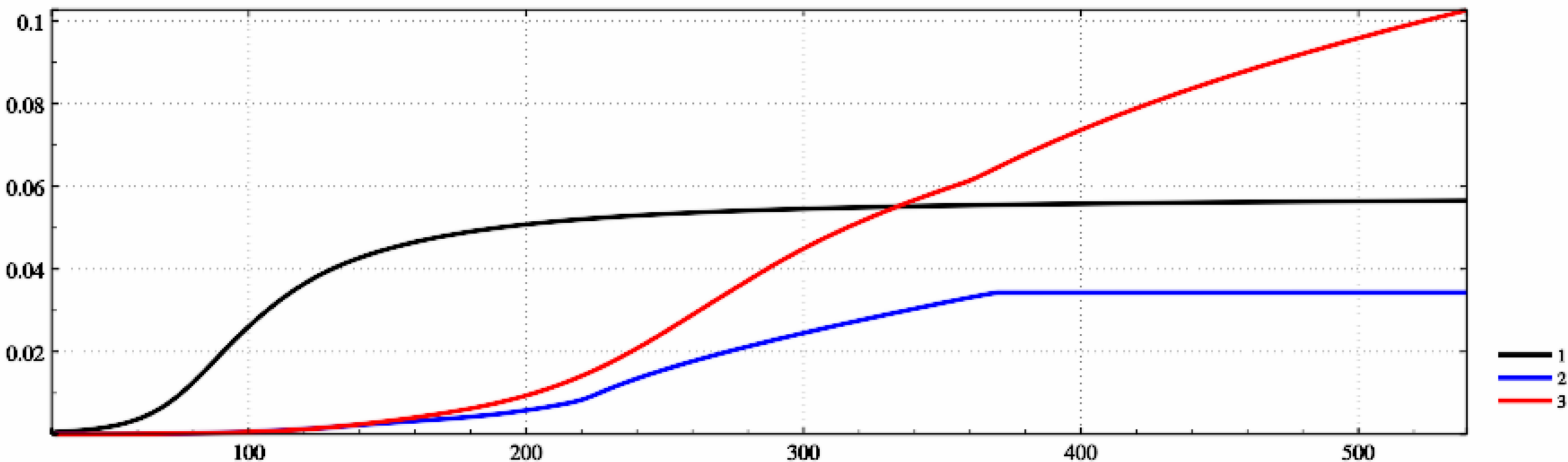
Start end row number 30 540

curve type The cumulative error of the geoidal height

line thickness 3

Save current plot as

The cumulative error curves of the geoidal height



Computation of Anomalous Field Elements at Observation Points

Open observations Save as Import parameters Start Computation Save process Follow example

Computation of Anomalous Field Elements at Observation Points

Statistical Error Estimation of the Regional Gravimetric Geoid

Calculation of the Influence of Gravity System Bias on the Gravimetric Geoid

Open Observed Gravity Data File

>> Computation Process ** Operation Prompts

Save computation process as

Set input point file format

Number of rows of file header 1

Column index of height 4

Column index of observation 6

Select calculation type

gravity disturbance (mGal)

Save the results as

Import setting parameters

Start Computation

>> [Function] Utilizing a rigorous spherical harmonic expansion formula to calculate normal gravity field elements, this module derives the anomalous observational field elements from observed gravity (mGal) or observed gravity gradients (E): Gravity Anomaly (mGal), Gravity Disturbance (mGal), or Disturbing Gravity Gradient (E, Radial component)

** Click the [Open Observed Gravity Data File] control button, or the [Open observation file] tool button...

>> Open Observed Gravity Data File C:/PAGravf4.5_win64en/examples/ProbsAnomousgrav/obsgrav.txt.

** Look at the file information in the window below, set the input file format parameters, select the anomalous field element, and click the [Import setting parameters] button to input the parameters into the system...

** If the input height is Orthometric Height: The program computes the Gravity Anomaly; and If the input height is Ellipsoidal Height: The program computes the Gravity Disturbance or Disturbing Gravity Gradient.

>> Calculate the gravity disturbance at the observed point form the observed gravity and ellipsoidal height...

>> Save the results as C:/PAGravf4.5_win64en/examples/ProbsAnomousgrav/result.txt.

** Appends a single column of computed values (gravity anomaly, disturbance, or gradient) to each record of the input file. The values are formatted to 4 significant figures.

>> The parameter settings have been entered into the system!

** Prepare to calculate gravity disturbance (mGal)...

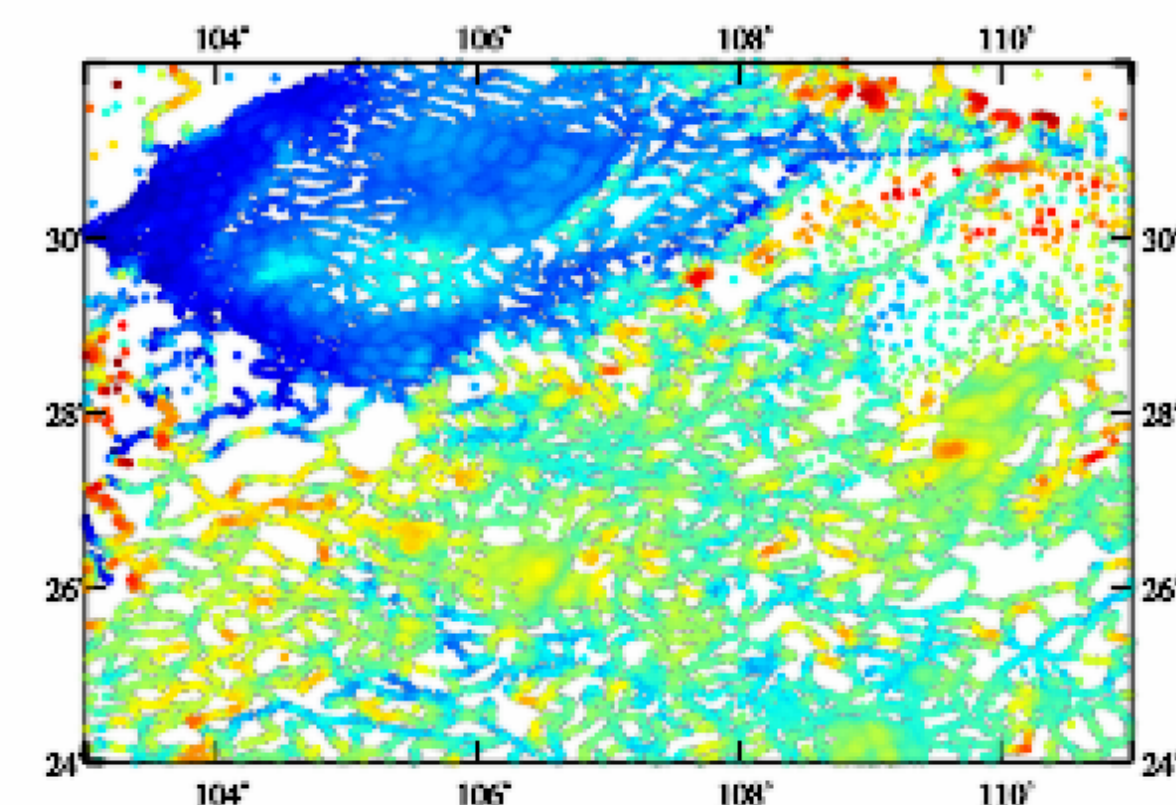
** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-08 15:44:51

no	lon (degree/decimal)	lat	ellipHeight (m)	normalHeight (m)	obsGrav (mGal)
3248	103.671939	31.938051	2743.9394	2774.9485	978685.3537
3249	103.696944	31.864721	2501.2449	2532.6723	978711.5370
3250	103.718330	31.831114	2435.4206	2467.0248	978720.1941
3251	103.735559	31.795280	2366.5700	2398.2238	978757.9613
3252	103.777216	31.776390	2294.0304	2325.9778	978784.3962
3253	103.822773	31.758333	2233.2317	2265.6064	978787.9523
3254	103.849717	31.724168	2215.6606	2248.2924	978780.1624
3255	103.816666	31.650003	2242.9951	2275.1975	978785.6408
3256	103.783335	31.616667	2297.3654	2329.3256	978762.6285
3257	103.740556	31.581110	2218.6104	2250.3209	978787.4579
3258	103.703884	31.560833	2207.1173	2238.6600	978797.9046
3259	103.682782	31.531391	2245.2634	2276.8015	978786.2913
3260	103.651939	31.510554	2219.9076	2251.4497	978780.8011
3261	103.613883	31.491662	2080.5161	2112.0781	978799.7103
3262	103.545003	31.444998	2051.8797	2083.3689	978803.4042
3263	103.516664	31.386384	2187.5689	2219.2172	978769.9887
3264	103.499170	31.362780	2175.1817	2206.9690	978758.0577
3265	103.474724	31.325836	2075.9238	2107.9969	978756.2234
3266	103.469164	31.282503	1931.3869	1963.8325	978794.8112
3267	103.486671	31.251384	1935.5737	1968.3811	978806.5352

Extract elements to be plot

Plot



gravity disturbance (mGal))

Statistical Error Estimation of the Regional Gravimetric Geoid ? X

The grid mean gravity representative error 4.0 mGal

The grid mean gravity spatial resolution 5 km

Gravimetric geoid error 3.09 cm

Statistical Error Estimation of the Regional Gravimetric Geoid ? X

The grid mean gravity representative error 2.0 mGal

The grid mean gravity spatial resolution 5 km

Gravimetric geoid error 1.54 cm

Calculation of the Influence of Gravity System Bias on the Gravimetri... ? X

System bias of gravity anomaly (disturbance) 80.0 μ Gal

Local Stokes/Hotine integral radius 220 km

System bias influence on geoid 1.79 cm

Calculation of the Influence of Gravity System Bias on the Gravimetri... ? X

System bias of gravity anomaly (disturbance) 80.0 μ Gal

Local Stokes/Hotine integral radius 800 km

System bias influence on geoid 6.53 cm

Boundary Value Correction for Spherical or Ellipsoidal Surfaces

Open calculation points

Import parameters

Save as

Start Computation

Save process

Follow example



Boundary Value Correction for Spherical or Ellipsoidal Surfaces



Molodensky Boundary Value Correction for Arbitrarily Shaped Non-Equipotential Surfaces



Open Global Geopotential Coefficient Model File



Open Boundary Surface Computation Point File

Set input point file format

Number of rows of file header 1

Column index of ellipsoidal height 4

Select type of field element

gravity disturbance (mGal)

Select type of boundary surface

ellipsoidal surface

Maximum calculation degree 360



Save the results as



Import setting parameters



Start Computation

number (value or str)	long (degree/decimal)	lat (degree/decimal)	ellipHeight (m)
3248	103.671939	31.938051	2743.9394
3249	103.696944	31.864721	2501.2449
3250	103.718330	31.831114	2435.4206
3251	103.735559	31.795280	2366.5700
3252	103.777216	31.776390	2294.0304
3253	103.822773	31.758333	2233.2317
3254	103.849717	31.724168	2215.6606
3255	103.816666	31.650003	2242.9951
3256	103.783335	31.616667	2297.3654
3257	103.740556	31.581110	2218.6104
3258	103.703884	31.560833	2207.1173
3259	103.682782	31.531391	2245.2634
3260	103.651939	31.510554	2219.9076
3261	103.613883	31.491662	2080.5161
3262	103.545003	31.444998	2051.8797
3263	103.516664	31.386384	2187.5689
3264	103.499170	31.362780	2175.1817
3265	103.474724	31.325836	2075.9238

>> Computation Process ** Operation Prompts



Save computation process as

>> [Function] Utilizing a global geopotential model, this module computes correction values (mGal) to reduce gravity disturbances/anomalies from a non-equipotential boundary (sphere/ellipsoid) to an equipotential surface. This mathematical transformation facilitates the conversion from a Molodensky-type problem to a Stokes-type problem.

>> (a) Ellipsoidal Reduction: Primarily employed for ellipsoidal harmonic analysis of the global gravity field using the Fast Fourier Transform (FFT) integral method. (b) Spherical Reduction: Commonly used for solving the Bjerhammar BVP (downward continuation to a reference Bjerhammar sphere).

** Input Global Geopotential Coefficient Model File and Boundary Surface Computation Point File...

>> 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.

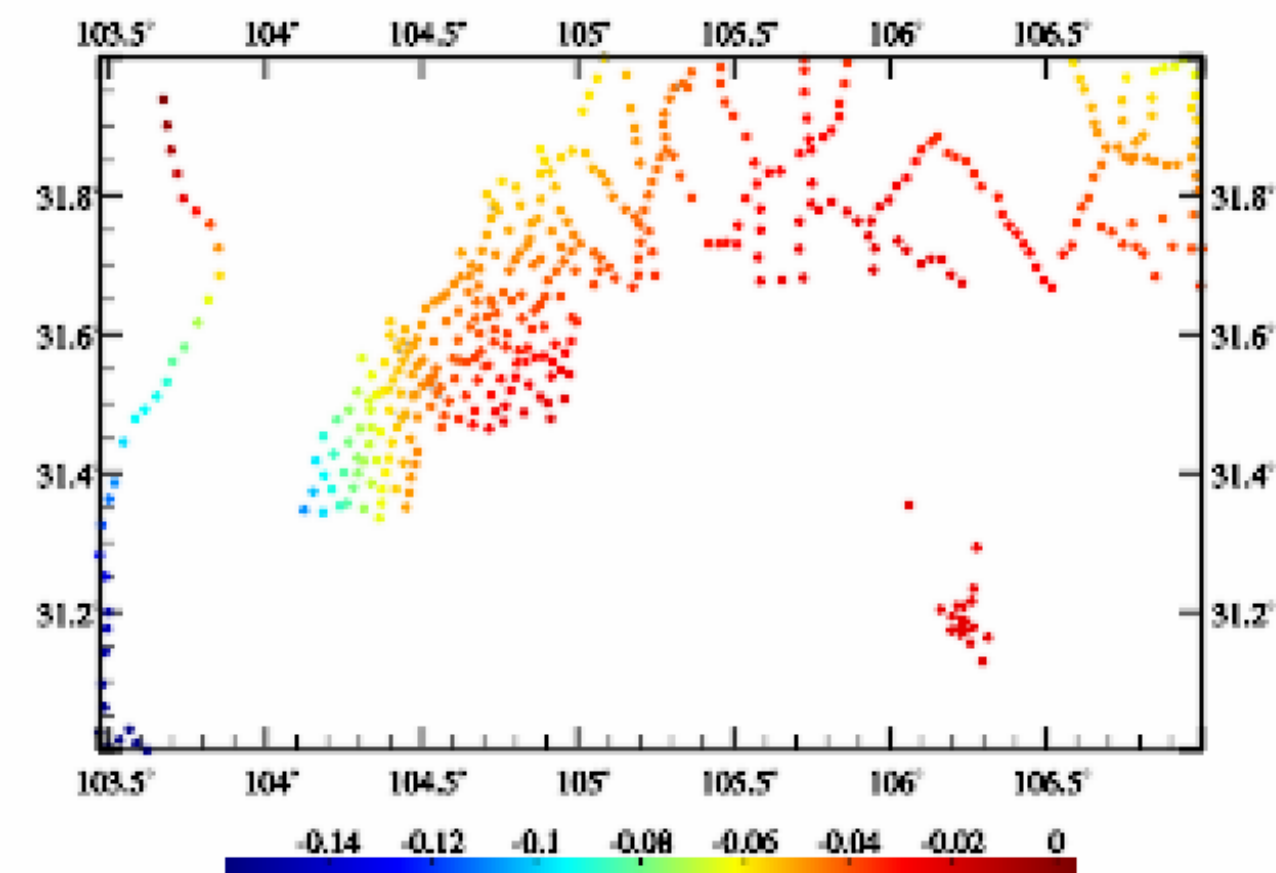
>> Open Boundary Surface Computation Point File C:/PAGravf4.5_win64en/examples/PrBoundaryvalueAdj/calcpnt.txt.

** Look at the file information in the window below, set the input file format parameters, select the field element and boundary surface, enter the output file name, click the [Import setting parameters] button to input the parameters into the system...

>> Save the results as C:/PAGravf4.5_win64en/examples/PrBoundaryvalueAdj/result.txt.

Extract corrections

Plot



Boundary Value Correction for Spherical or Ellipsoidal Surfaces

Open calculation points

Import parameters

Save as

Start Computation

Save process

Follow example

Boundary Value Correction for Spherical or Ellipsoidal Surfaces

Molodensky Boundary Value Correction for Arbitrarily Shaped Non-Equipotential Surfaces

Open Global Geopotential Coefficient Model File

Open Boundary Surface Computation Point File

Set input point file format

Number of rows of file header 1

Column index of ellipsoidal height 4

Select type of field element

gravity disturbance (mGal)

Select type of boundary surface

spherical surface

Maximum calculation degree 360

>> Computation Process ** Operation Prompts

Save computation process as

>> [Function] Utilizing a global geopotential model, this module computes correction values (mGal) to reduce gravity disturbances/anomalies from a non-equipotential boundary (sphere/ellipsoid) to an equipotential surface. This mathematical transformation facilitates the conversion from a Molodensky-type problem to a Stokes-type problem.

>> (a) Ellipsoidal Reduction: Primarily employed for ellipsoidal harmonic analysis of the global gravity field using the Fast Fourier Transform (FFT) integral method. (b) Spherical Reduction: Commonly used for solving the Bjerhammar BVP (downward continuation to a reference Bjerhammar sphere).

** Input Global Geopotential Coefficient Model File and Boundary Surface Computation Point File...

>> 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 Boundary Surface Computation Point File C:/PAGravf4.5_win64en/examples/PrBoundaryvalueAdj/calcpnt.txt.

** Look at the file information in the window below, set the input file format parameters, select the field element and boundary surface, enter the output file name, click the [Import setting parameters] button to input the parameters into the system...

>> Save the results as C:/PAGravf4.5_win64en/examples/PrBoundaryvalueAdj/result1.txt.

Save the results as

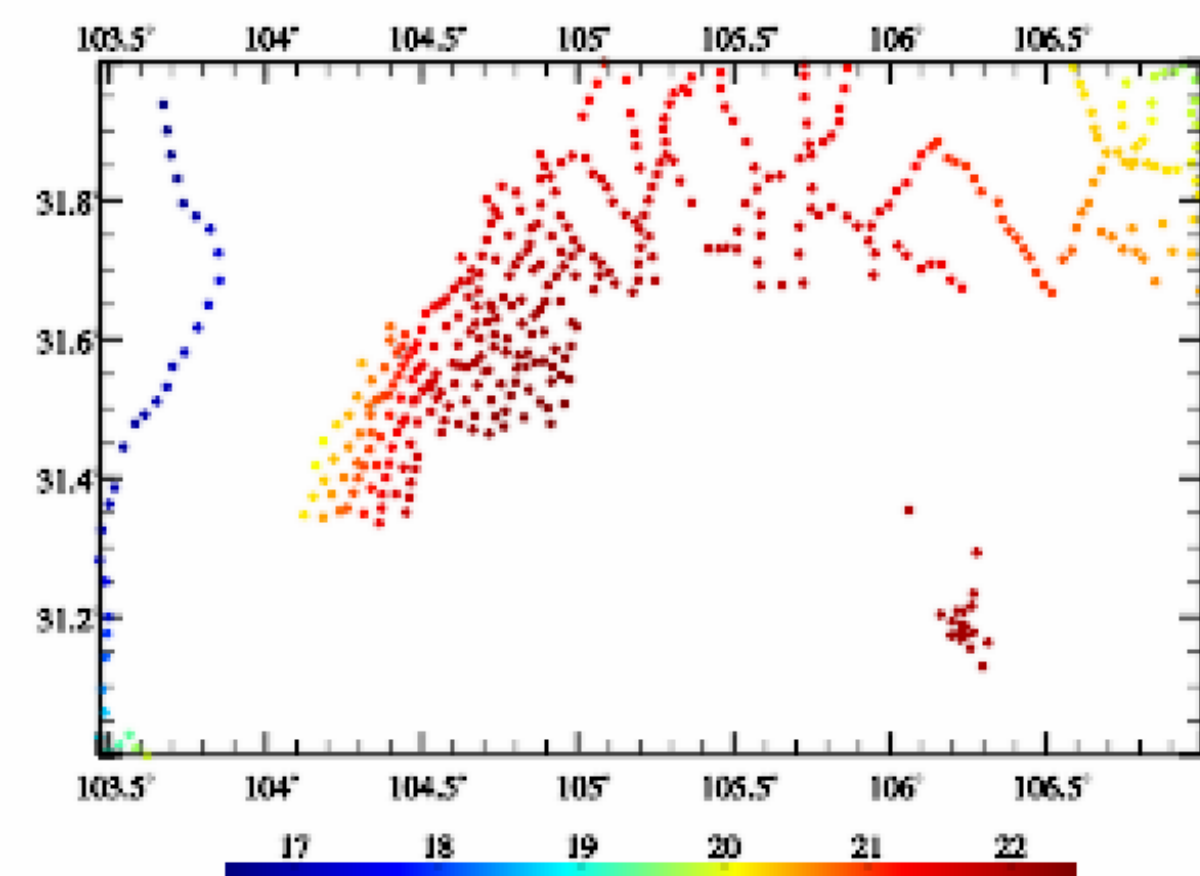
Import setting parameters

Start Computation

(value or str)	long(degree/decimal)	lat(degree/decimal)	ellipHeight(m)
103.671939	31.938051	2743.9394	0.0035
103.696944	31.864721	2501.2449	-0.0075
103.718330	31.831114	2435.4206	-0.0149
103.735559	31.795280	2366.5700	-0.0233
103.777216	31.776390	2294.0304	-0.0307
103.822773	31.758333	2233.2317	-0.0380
103.849717	31.724168	2215.6606	-0.0476
103.816666	31.650003	2242.9951	-0.0645
103.783335	31.616667	2297.3654	-0.0718
103.740556	31.581110	2218.6104	-0.0794
103.703884	31.560833	2207.1173	-0.0825
103.682782	31.531391	2245.2634	-0.0892
103.651939	31.510554	2219.9076	-0.0924
103.613883	31.491662	2080.5161	-0.0940
103.545003	31.444998	2051.8797	-0.0982
103.516664	31.386384	2187.5689	-0.1092
103.499170	31.362780	2175.1817	-0.1123

Extract corrections

Plot



Molodensky Boundary Value Correction for Arbitrarily Shaped Non-Equipotential Surfaces

Open Boundary Surface Computation Point File

Set input point file format

Number of rows of file header 1

Column index of ellipsoidal height 4

Input Grid Data on Boundary Surface

Open Boundary Surface Ellipsoidal Height Grid File

Open Boundary Gravity Field Element Grid File

Open Boundary Height Anomaly Grid File

Open Equipotential Surface Ellipsoidal Height Grid File

Select type of field element

gravity disturbance (mGal)

Molodensky I integral radius 120 km

Save the results as

Import setting parameters

Start Computation

number lon(degree/decimal) ellipHeight(m) disturbGrav(mGal)

11569	106.020833	27.020833	1217.221	-31.0162	-16.9791
11570	106.062500	27.020833	1201.227	-33.8392	-17.6360
11571	106.104167	27.020833	1185.247	-33.9853	-20.2563
11572	106.145833	27.020833	1210.287	-30.7623	-4.1946
11573	106.187500	27.020833	1228.340	-25.5689	4.8681
11574	106.229167	27.020833	1247.396	-21.2304	12.9911
11575	106.270833	27.020833	1244.440	-20.7500	14.9438
11576	106.312500	27.020833	1199.469	-25.2967	4.2342
11577	106.354167	27.020833	1183.494	-32.6787	11.5857
11578	106.395833	27.020833	1109.535	-37.6863	-13.3403
11579	106.437500	27.020833	1000.613	-35.4965	-71.7708
11580	106.479167	27.020833	1135.735	-25.6242	-12.2591
11581	106.520833	27.020833	1249.869	-14.5582	17.4047
11582	106.562500	27.020833	1251.986	-8.4721	8.4197
11583	106.604167	27.020833	1289.077	-9.8491	13.5657
11584	106.645833	27.020833	1292.154	-14.3500	14.5885
11585	106.687500	27.020833	1228.242	-15.3480	-1.8611
11586	106.729167	27.020833	1211.352	-9.6375	-7.4584
11587	106.770833	27.020833	1339.471	-1.0725	11.7773
11588	106.812500	27.020833	1366.572	4.1638	10.5712

>> Computation Process ** Operation Prompts

Save computation process as

grid files...

>> Open Boundary Surface Computation Point File C:/PAGravf4.5_win64en/examples/PrBoundaryvalueAdj/dbmrga.txt.

** Look at the file information in the window below, set the input file format parameters...

>> Open Boundary Surface Ellipsoidal Height Grid File C:/PAGravf4.5_win64en/examples/PrBoundaryvalueAdj/dbmhgt150s.dat.

>> Open Boundary Gravity Field Element Grid File C:/PAGravf4.5_win64en/examples/PrBoundaryvalueAdj/dbmGM1800150srga.dat.

>> Open Boundary Height Anomaly Grid File C:/PAGravf4.5_win64en/examples/PrBoundaryvalueAdj/dbmGM1800150sksi.dat.

>> Open Reference Equipotential Surface Ellipsoidal Height Grid File C:/PAGravf4.5_win64en/examples/PrBoundaryvalueAdj/dwmhgt150s.dat.

>> Save the results as C:/PAGravf4.5_win64en/examples/PrBoundaryvalueAdj/result2.txt.

** Appends a column of Molodensky boundary value correction values after the record of the source computation point file, keeping 4 significant figures.

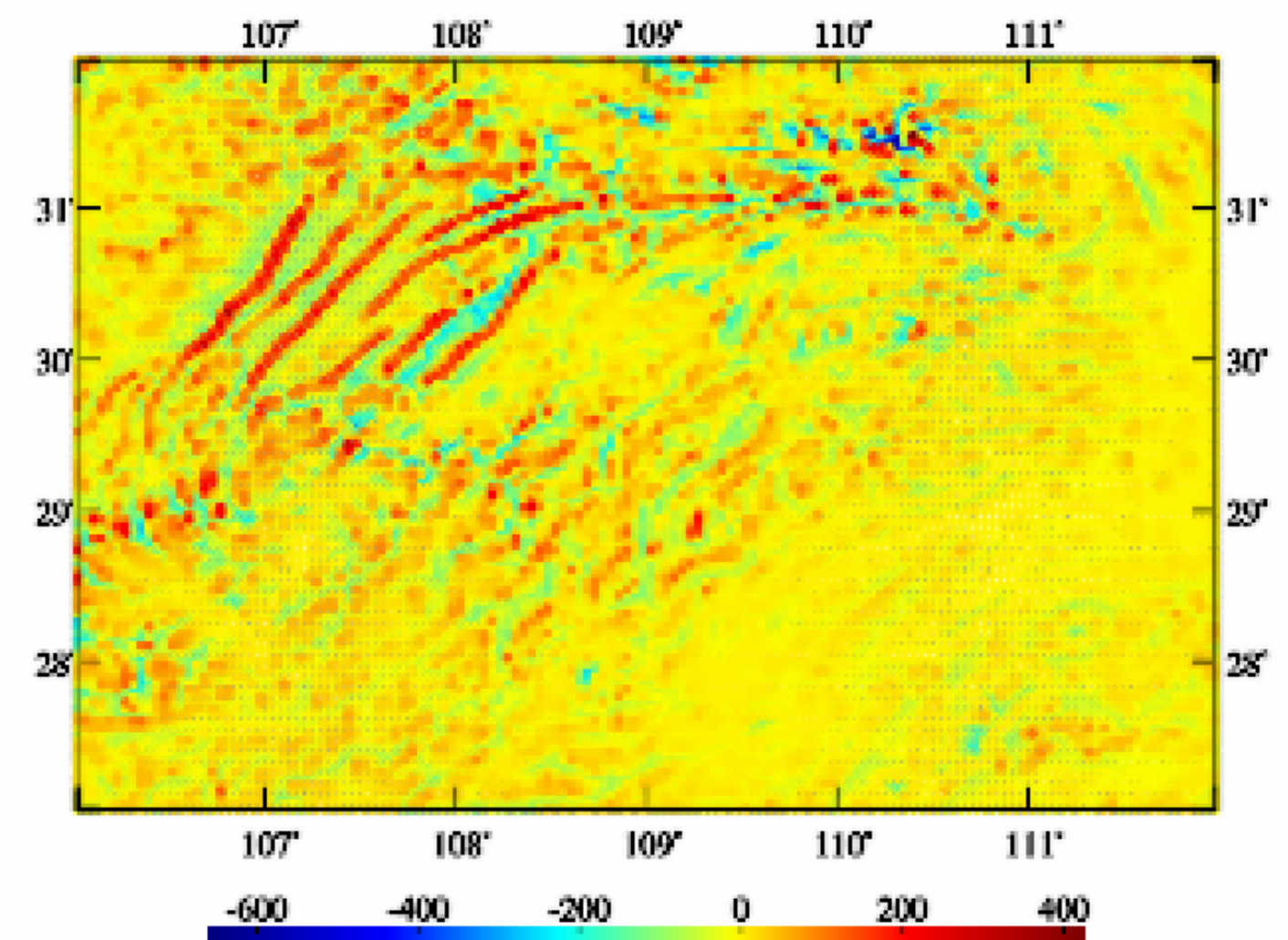
>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-08 17:00:57

Extract corrections

Plot↓



Analytical Continuation of Anomalous Field Elements Using Multi-Order Radial Gradients

Open Space Points Import parameters Save as Start Computation Save process Follow example

Open Space Point File for anomalous field elements

Set input point file format

Header Rows 1

Column Index of ellipsoidal height for current field element 4

Column Index of ellipsoidal height for target field element 5

Open Anomalous Field Element Grid File (Current Altitude Surface)

Open Ellipsoidal Height Grid File (Current Altitude Surface)

Gradient Order 1

Radial gradient integral radius 30 km

>> Computation Process ** Operation Prompts

>> [Function] BBased on the ellipsoidal height grid and the corresponding anomalous field element grid of the current altitude surface, this module computes 1st to 3rd order radial gradients using a rigorous radial gradient integral formula. Subsequently, it calculates the continuation corrections required to transform field elements from the current altitude to a target altitude.

** Click the [Open Space Point File for anomalous field elements] control button, and input the ellipsoidal height and anomalous field element grid data on the current altitude surface...

>> Open Space Point File for anomalous field elements C:/PAGravf4.5_win64en/examples/PrGradcontinuation/dbmgra.txt.

** Look at the file information in the window below and set the discrete point file format...

>> Open Anomalous Field Element Grid File (Current Altitude Surface) C:/PAGravf4.5_win64en/examples/PrGradcontinuation/dbmchgra.dat.

>> Open Ellipsoidal Height Grid File (Current Altitude Surface) C:/PAGravf4.5_win64en/examples/PrGradcontinuation/dbmhgt150s.dat.

>> Save the results as C:/PAGravf4.5_win64en/examples/PrGradcontinuation/result.txt.

** Appends 1 to 3 columns of gradient continuation correction values to each record of the source Computation Point File. The values are formatted to 4 significant figures, and their units are identical to the input field element units.

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-09 09:20:10

Save computation process as

Save the results as

Import setting parameters

Start Computation

no	lon(degree/decimal)	lat	ellipHeight(m)	geoidheight(m)	disturbGrav(mGal)
11569	106.020833	27.020833	1217.221	-30.8082	-14.8212
11570	106.062500	27.020833	1201.227	-30.8052	-16.1491
11571	106.104167	27.020833	1185.247	-30.7849	-14.8039
11572	106.145833	27.020833	1210.287	-30.7411	-10.1454
11573	106.187500	27.020833	1228.340	-30.6802	-3.6100
11574	106.229167	27.020833	1247.396	-30.6183	1.9480
11575	106.270833	27.020833	1244.440	-30.5729	3.5017
11576	106.312500	27.020833	1199.469	-30.5503	-0.1382
11577	106.354167	27.020833	1183.494	-30.5360	-6.8208
11578	106.395833	27.020833	1109.535	-30.4998	-11.3515
11579	106.437500	27.020833	1000.613	-30.4157	-8.9350
11580	106.479167	27.020833	1135.735	-30.2841	0.8626
11581	106.520833	27.020833	1249.869	-30.1357	11.6378
11582	106.562500	27.020833	1251.986	-30.0096	17.2750
11583	106.604167	27.020833	1289.077	-29.9216	15.2947
11584	106.645833	27.020833	1292.154	-29.8523	10.0757
11585	106.687500	27.020833	1228.242	-29.7662	8.2597
11586	106.729167	27.020833	1211.352	-29.6471	13.0764
11587	106.770833	27.020833	1339.471	-29.5138	20.7468
11588	106.812500	27.020833	1366.572	-29.4038	25.1434

Extract corrections

Plot

- Suitable for both upward and downward continuation from terrestrial, airborne, and near-Earth surfaces (within a 10 km range).
- Since field element gradients are predominantly composed of short-wavelength and ultra-short-wavelength signals, the required integration radius for radial gradient computation is typically compact.

Analytical Continuation of Anomalous Field Elements Using Multi-Order Radial Gradients

Open Space Point File for anomalous field elements

Set input point file format

Header Rows 1

Column Index of ellipsoidal height for current field element 4

Column Index of ellipsoidal height for target field element 5

Open Anomalous Field Element Grid File (Current Altitude Surface)

Open Ellipsoidal Height Grid File (Current Altitude Surface)

Gradient Order 3

Radial gradient integral radius 30 km

Save the results as

Import setting parameters

Start Computation

Save computation process as

>> Computation Process ** Operation Prompts

>> Save the results as C:/PAGrav4.5_win64en/examples/PrGradicontinuation/result.txt.
 ** Appends 1 to 3 columns of gradient continuation correction values to each record of the source Computaion Point File.The values are formatted to 4 significant figures, and their units are identical to the input field element units.

>> The parameter settings have been entered into the system!
 ** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-09 09:20:10

>> Complete the computation of continuation correction of field elements!

>> Computation end time: 2026-04-09 09:20:13

>> Save the results as C:/PAGrav4.5_win64en/examples/PrGradicontinuation/result1.txt.
 ** Appends 1 to 3 columns of gradient continuation correction values to each record of the source Computaion Point File.The values are formatted to 4 significant figures, and their units are identical to the input field element units.

>> The parameter settings have been entered into the system!
 ** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-09 09:21:51

>> Complete the computation of continuation correction of field elements!

>> Computation end time: 2026-04-09 09:22:08

no	lon(degree/decimal)	lat	ellipHeight(m)	geoidheight(m)	disturbGrav(mGal)
11569	106.020833	27.020833	1217.221	-30.8082	-14.8212
11570	106.062500	27.020833	1201.227	-30.8052	-16.1491
11571	106.104167	27.020833	1185.247	-30.7849	-14.8039
11572	106.145833	27.020833	1210.287	-30.7411	-10.1454
11573	106.187500	27.020833	1228.340	-30.6802	-3.6100
11574	106.229167	27.020833	1247.396	-30.6183	1.9480
11575	106.270833	27.020833	1244.440	-30.5729	3.5017
11576	106.312500	27.020833	1199.469	-30.5503	-0.1382
11577	106.354167	27.020833	1183.494	-30.5360	-6.8208
11578	106.395833	27.020833	1109.535	-30.4998	-11.3515
11579	106.437500	27.020833	1000.613	-30.4157	-8.9350
11580	106.479167	27.020833	1135.735	-30.2841	0.8626
11581	106.520833	27.020833	1249.869	-30.1357	11.6378
11582	106.562500	27.020833	1251.986	-30.0096	17.2750
11583	106.604167	27.020833	1289.077	-29.9216	15.2947
11584	106.645833	27.020833	1292.154	-29.8523	10.0757
11585	106.687500	27.020833	1228.242	-29.7662	8.2597
11586	106.729167	27.020833	1211.352	-29.6471	13.0764
11587	106.770833	27.020833	1339.471	-29.5138	20.7468

Extract corrections

Plot

- Suitable for both upward and downward continuation from terrestrial, airborne, and near-Earth surfaces (within a 10 km range).
- Since field element gradients are predominantly composed of short-wavelength and ultra-short-wavelength signals, the required integration radius for radial gradient computation is typically compact.

Gross Error Detection Based on a Low-Pass Reference Surface

Open file Save as Import parameters Start Computation Save process Follow example

Gross Error Detection Based on a Low-Pass Reference Surface

Open Discrete Geodetic Observation File

Number of rows of file header 1

Column ordinal number of the attribute to be detect 5

Threshold Multiplier 3.0

Open Low-Pass Reference Surface Grid File

Save the results as

Save gross error as

Import setting parameters

Start Computation

Observation Weight Estimation Using a Specified Reference Attribute

Gridding of Heterogeneous Data via Weighted Basis Function Interpolation

Save computation process as

>> Select the computation function from the three control buttons at the top of the interface...

>> [Function] This module selects a low-pass grid as a reference surface to interpolate reference values for a specified attribute at discrete observation points. Subsequently, it detects and isolates records containing gross errors by analyzing the statistical properties of the residuals (differences between observed and reference values).

** The reference surface can be generated either by applying a low-pass filter to a simply gridded discrete dataset or by constructing a specific attribute grid via weighted basis function gridding.

>> Open Discrete Geodetic Observation File C:/PAGravf4.5_win64en/examples/PrGerrweighgridding/pntdata.txt.

** Look at the file information in the window below and set the discrete point file format...

>> Open Low-Pass Reference Surface Grid File C:/PAGravf4.5_win64en/examples/PrGerrweighgridding/lowpass.dat.

>> Save the results as C:/PAGravf4.5_win64en/examples/PrGerrweighgridding/pntdatanoerr.txt.

>> Save no gross error results as C:/PAGravf4.5_win64en/examples/PrGerrweighgridding/pntdataerror.txt.

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-09 10:04:16

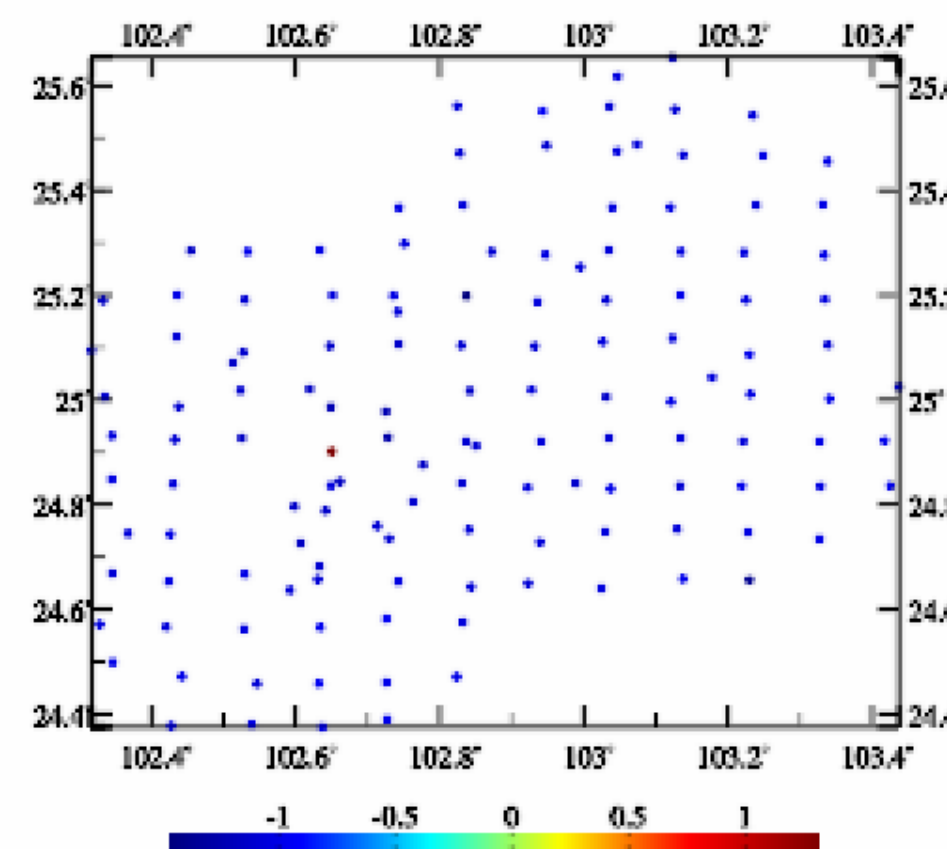
>> Complete computation!

>> Computation end time: 2026-04-09 10:04:16

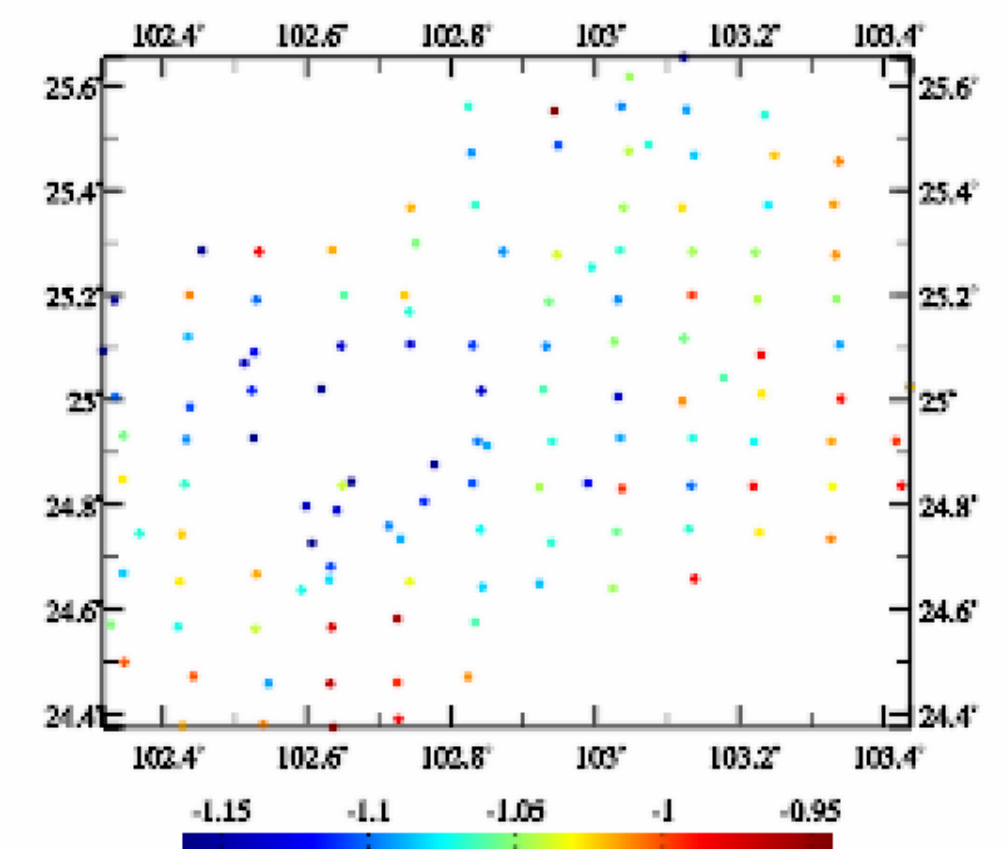
	-0.9976	0.0517	-1.1347	-0.8754	
38	102.650330	24.901415	1906.8332	1.3251	-2.4011
39	102.728540	24.928290	1854.5060	-1.2841	-0.5680
51	102.725170	24.977718	1855.6502	-1.2383	-0.6228
70	102.837115	25.198024	1936.8741	-1.4671	-2.1049
112	103.229955	24.655854	1609.7162	-1.3869	-1.8896
2001	102.648977	24.986605	1856.7693	-1.2340	-1.4254

Extract plot data

Plot↓



Source observations input



Observations without grass error

Observation Weight Estimation Using a Specified Reference Attribute

Gross Error Detection Based on a Low-Pass Reference Surface

Observation Weight Estimation Using a Specified Reference Attribute

Gridding of Heterogeneous Data via Weighted Basis Function Interpolation

Open Discrete Geodetic Observation File

Number of rows of file header 1
 Column ordinal number of the reference attribute 6
 Smoothing factor of weight function a 2.0

Save the results as

Import setting parameters

Start Computation

Weight Function $w(x, a) = 10\sigma\sqrt{\sigma^2 + (ax)^2}$. Here: x is the reference attribute value, a is smoothing factor, σ is the standard deviation of x computed by the program..

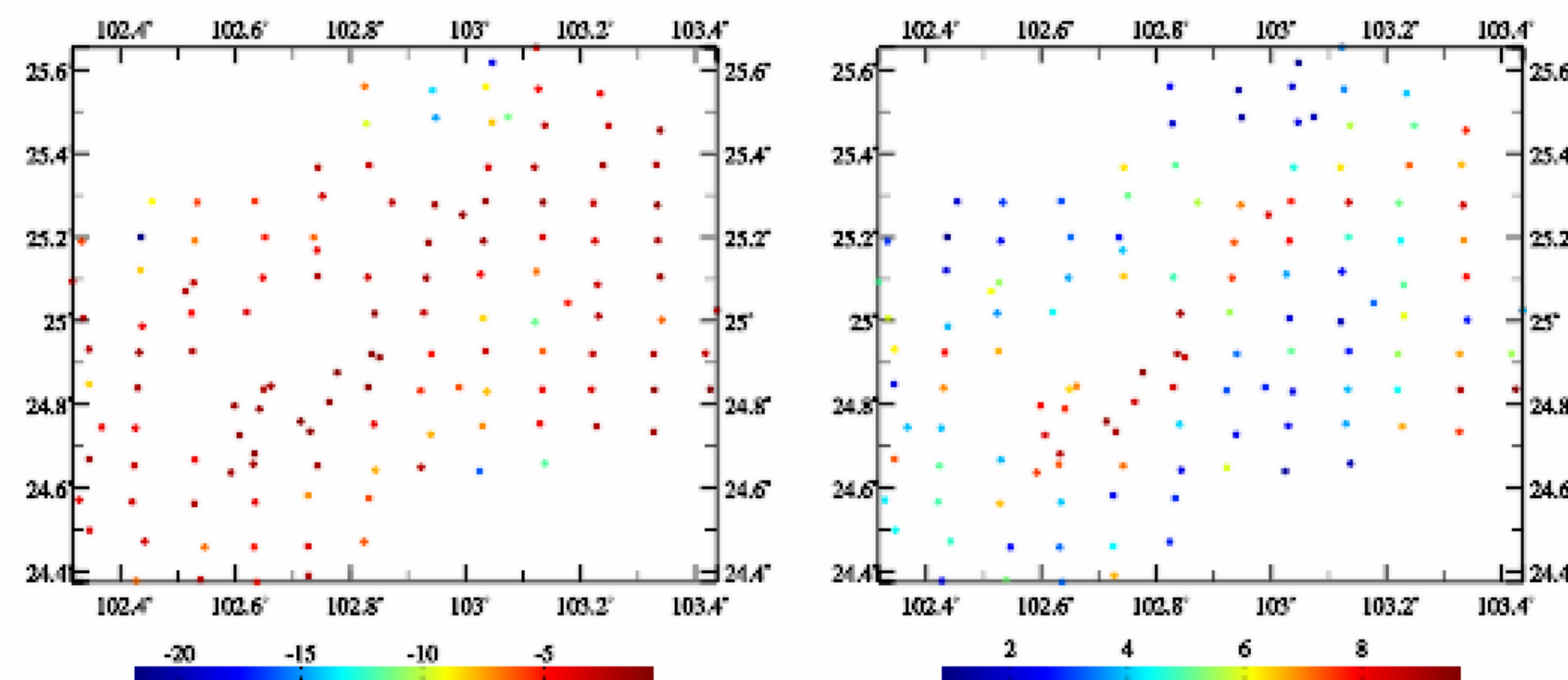
Save computation process as

```
>> Save the results as C:/PAGravf4.5_win64en/examples/PrGerrweighgrdate/pntdatanoerr.txt.
>> Save no gross error results as C:/PAGravf4.5_win64en/examples/PrGerrweighgrdate/pntdataerror.txt.
>> The parameter settings have been entered into the system!
** Click the [Start Computation] control button, or the [Start Computation] tool button...
>> Computation start time: 2026-04-09 10:04:16
>> Complete computation!
>> Computation end time: 2026-04-09 10:04:16
>> [Function] Estimates observation weights based on the statistical properties of a specified reference attribute within the input geodetic record file, utilizing the proprietary weight function defined by PAGravf4.5.
>> Open Discrete Geodetic Observation File C:/PAGravf4.5_win64en/examples/PrGerrweighgrdate/pntdatanoerr.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/PrGerrweighgrdate/pntwghrst.txt.
>> The parameter settings have been entered into the system!
** Click the [Start Computation] control button, or the [Start Computation] tool button...
>> Computation start time: 2026-04-09 10:05:48
>> Complete computation!
>> Computation end time: 2026-04-09 10:05:48
```

lon(deg/decimal)	lat	ellipHeight(m)	rntKsi(m)	TexEff(mGal)
102.442457	24.471769	1972.7703	-1.0013	-3.3508
102.546777	24.458002	1659.0410	-1.0916	-6.6124
102.632412	24.458211	2120.2558	-0.9639	-5.0422
102.725921	24.460578	2111.3872	-0.9936	-3.6867
102.420803	24.566357	1990.6386	-1.0706	-3.1489
102.528697	24.562786	1936.4260	-1.0402	-2.0473
102.634437	24.565660	2192.9271	-0.9743	-4.0534
102.725888	24.581970	2303.7797	-0.9566	-7.1388
102.832641	24.575505	1977.4949	-1.0619	-5.9858
102.345532	24.668953	1919.7825	-1.0840	-1.6645
102.423972	24.652933	1959.3369	-1.0281	-3.0476
102.529771	24.667079	2157.7877	-1.0165	-4.2396
102.631063	24.657055	1906.3415	-1.0806	-1.6637
102.742718	24.652871	1935.7882	-1.0343	-1.7419
102.843573	24.642787	1880.7707	-1.0819	-7.7294
103.137778	24.658224	1838.4387	-0.9843	-11.7862
102.426305	24.743284	1929.0475	-1.0229	-4.1779
102.729945	24.734909	1856.2213	-1.0884	-0.8096
102.840819	24.752018	2117.8582	-1.0735	-3.9704
102.939253	24.728089	2050.9590	-1.0675	-7.6863

Extract plot data

Plot



Reference value of attribute

Observation weights

Gridding of Heterogeneous Data via Weighted Basis Function Interpolation

 Gross Error Detection Based on a Low-Pass Reference Surface

 Observation Weight Estimation Using a Specified Reference Attribute

 Gridding of Heterogeneous Data via Weighted Basis Function Interpolation

Open Discrete Geodetic Observation File

Number of rows of file header

Column ordinal number of the attribute to be grid

Select the basis function

☐ Equal weight

Save computation process as

```
>> Computation end time: 2026-04-09 10:14:28
>> [Function] Generates a regular grid for a specified attribute from an input discrete geodetic point file using the Weighted Basis Function Interpolation method, subject to user-defined grid specifications (extent and spatial resolution) and a selected basis function.
>> Open Discrete Geodetic Observation File C:/PAGravf4.5_win64en/examples/PrGerrweighgrdate/pntwghrst.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/PrGerrweighgrdate/pntgrid.dat.
>> The parameter settings have been entered into the system!
** Click the [Start Computation] control button, or the [Start Computation] tool button...
>> Computation start time: 2026-04-09 10:15:17
>> Complete computation!
>> Computation end time: 2026-04-09 10:15:17
```

 Save the results as

 Import setting parameters

 Start Computation

Set parameters

Column ordinal number of weight

Number of neighboring points

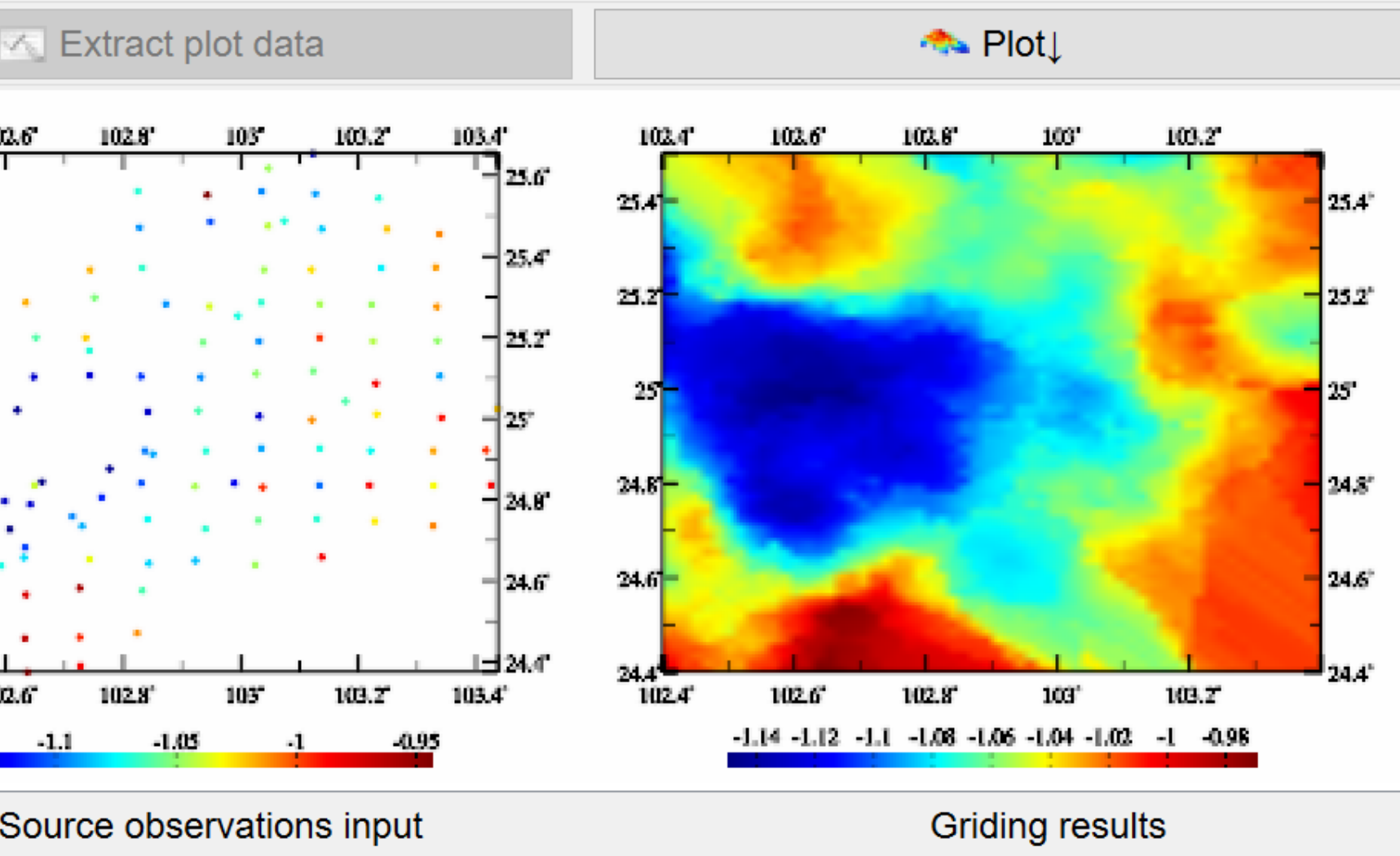
Kurtosis of basis function [1,20]

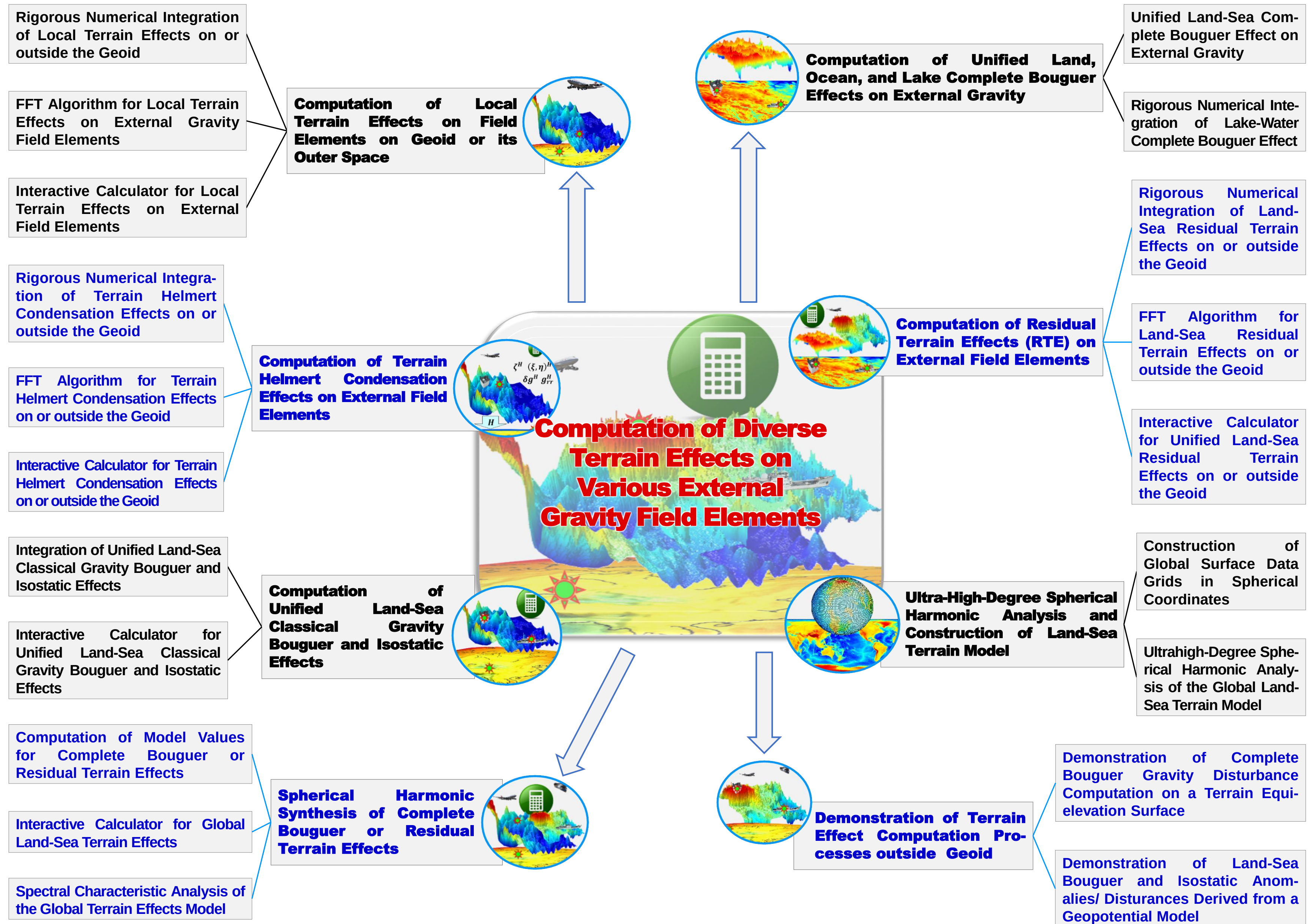
Grid specification

resolution

102.400000	103.400000	24.400000	25.500000	0.01666667	0
-1.0064	-1.0080	-1.0124	-1.0143	-1.01	
-0.9698	-0.9707	-0.9786	-0.9814	-0.98	
-1.0043	-1.0079	-1.0113	-1.0158	-1.01	
-1.0593	-1.0544	-1.0509	-1.0242	-1.02	
-1.0057	-1.0060	-1.0154	-1.0136	-1.02	
-0.9723	-0.9784	-0.9811	-0.9822	-0.98	
-1.0082	-1.0116	-1.0267	-1.0162	-1.03	
-1.0545	-1.0558	-1.0459	-1.0215	-1.01	
-1.0095	-1.0103	-1.0153	-1.0198	-1.02	
-0.9740	-0.9786	-0.9803	-0.9820	-0.98	
-1.0119	-1.0268	-1.0272	-1.0485	-1.04	

number	lon(deg/decimal)	lat	ellipHeight(m)	pntKsi(m)	TerEff(mGal)	
1	102.442457	24.471769	1972.7703	-1.0013	-3.3508	4.70
2	102.546777	24.458002	1659.0410	-1.0916	-6.6124	2.60
3	102.632412	24.458211	2120.2558	-0.9639	-5.0422	3.33
4	102.725921	24.460578	2111.3872	-0.9936	-3.6867	4.35
5	102.420803	24.566357	1990.6386	-1.0706	-3.1489	4.93
6	102.528697	24.562786	1936.4260	-1.0402	-2.0473	6.57
7	102.634437	24.565660	2192.9271	-0.9743	-4.0534	4.02
8	102.725888	24.581970	2303.7797	-0.9566	-7.1388	2.42
9	102.832641	24.575505	1977.4949	-1.0619	-5.9858	2.85





Rigorous Numerical Integration of Local Terrain Effects on External Field Elements

Rigorous Numerical Integration of Local Terrain Effects on External Field Elements

FFT Algorithm for Local Terrain Effects on External Gravity Field Elements

Interactive Calculator for Local Terrain Effects on External Field Elements

Algorithms of local terrain effect

Save computation process as

Open Ground DEM File

Open Ground Ellipsoidal Height Grid File

Select computation file format

space computation point file

Open Space Computation Point File

Set input point file format

Header Rows 1

Ellipsoidal Height Column Index 4

Select gravity field elements

- ☒ height anomaly (m)
- ☒ gravity (anomaly/disturbance, mGal)
- ☒ vertical deflection (")
- ☒ disturbing gravity gradient (E, radial)

>> Computation Process ** Operation Prompts

>> [Function] Utilizing a rigorous numerical integration algorithm, this module computes local terrain effects on various field elements at points located on or outside the geoid. Inputs include a Ground Digital Elevation Model (DEM) and a Ground Ellipsoidal Height Grid. Target Elements: Height Anomaly (m), Gravity (Anomaly/Disturbance, mGal), Vertical Deflection ("; South/West components), or (Disturbing) Gravity Gradient (Eötvös; Radial component).

** Input Ground DEM File and Ground Ellipsoidal Height Grid File with the same grid specifications...

>> Open Ground DEM File C:/PAGrav4.5_win64en/examples/TerLocalterraininfl/landtm1m.dat.

>> Open Ground Ellipsoidal Height Grid File C:/PAGrav4.5_win64en/examples/TerLocalterraininfl/landbmsurfhgt.dat.

>> Open Space Computation Point File C:/PAGrav4.5_win64en/examples/TerLocalterraininfl/surfhgt.txt.

** Look at the file information in the window below, set the input file format parameters...

>> Save the results as C:/PAGrav4.5_win64en/examples/TerLocalterraininfl/surfhntg.txt.

** Appends columns of local terrain effect values to the source record, formatted to 4 significant figures.

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

Integral radius 90 km

Save the results as

Import setting parameters

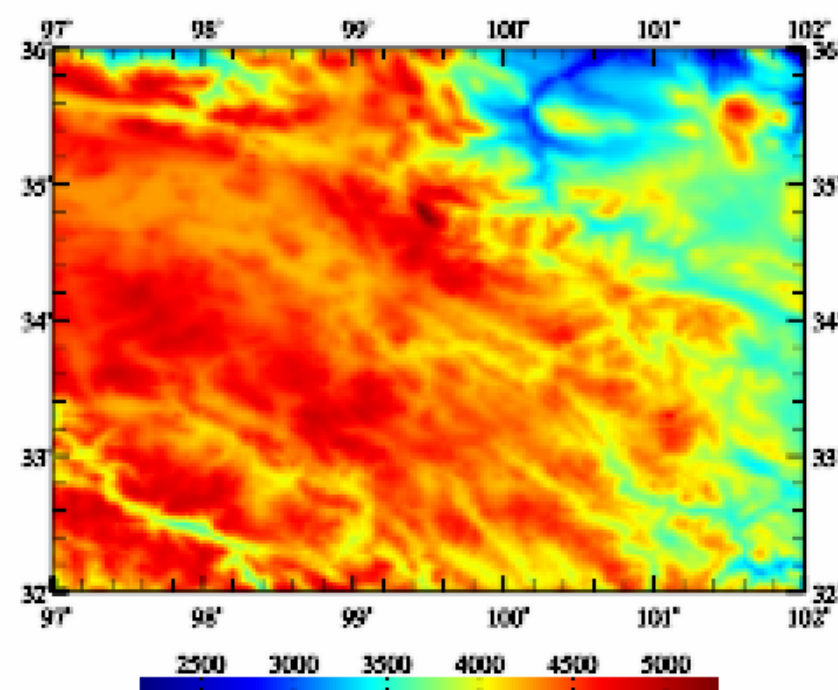
Start Computation

number long(deg/decimal) lat ellipHeight(m)

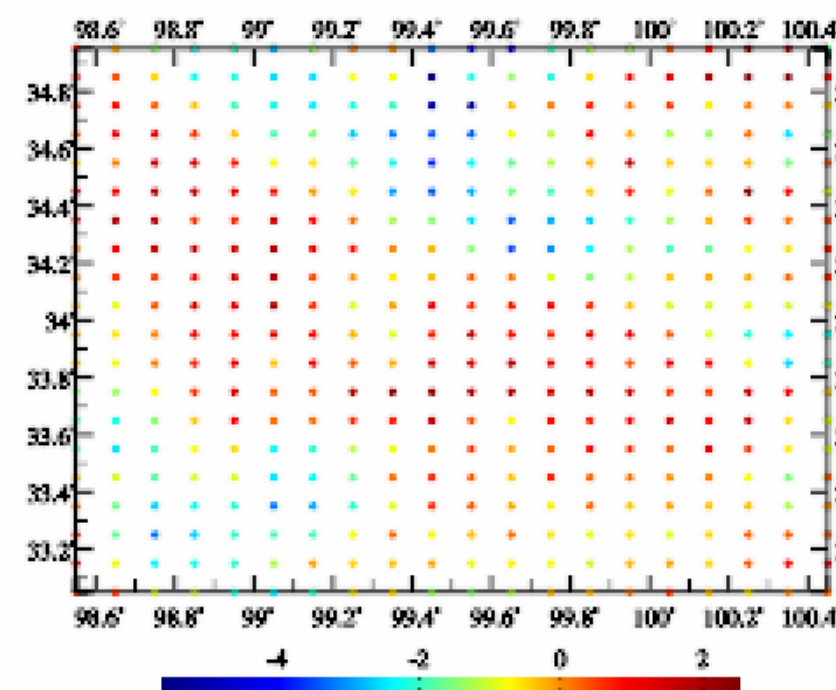
1	98.550000	33.050000	4372.431	0.4748	-0.6543	-4.3693	0.2496	1.4964
2	98.650000	33.050000	4372.834	0.6019	-0.3868	-5.4945	-3.2741	0.2816
3	98.750000	33.050000	4530.959	-1.0367	-2.0958	-6.5741	-4.6892	-1.4646
4	98.850000	33.050000	4567.407	-1.0858	-2.0675	-6.9916	-1.1745	22.7751
5	98.950000	33.050000	4646.551	-2.1223	-3.3753	-7.5768	-2.4547	7.9308
6	99.050000	33.050000	4672.380	-2.4157	-2.7630	-4.5712	1.0716	11.8263
7	99.150000	33.050000	4611.765	-2.0435	-2.6243	-0.6258	2.7601	-6.5803
8	99.250000	33.050000	4475.199	-0.5338	-1.0328	-0.5357	3.5542	7.0332

Extract effects

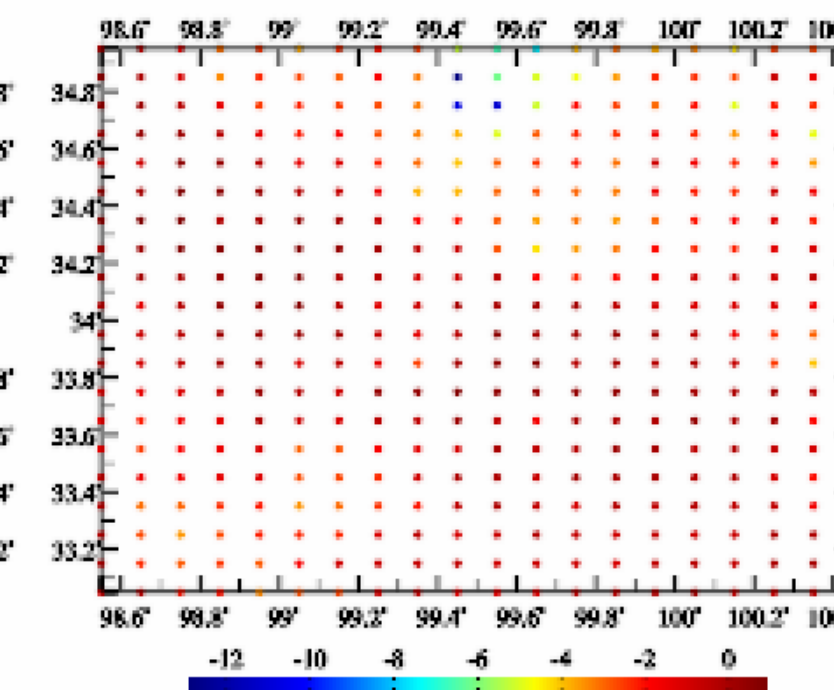
Plot



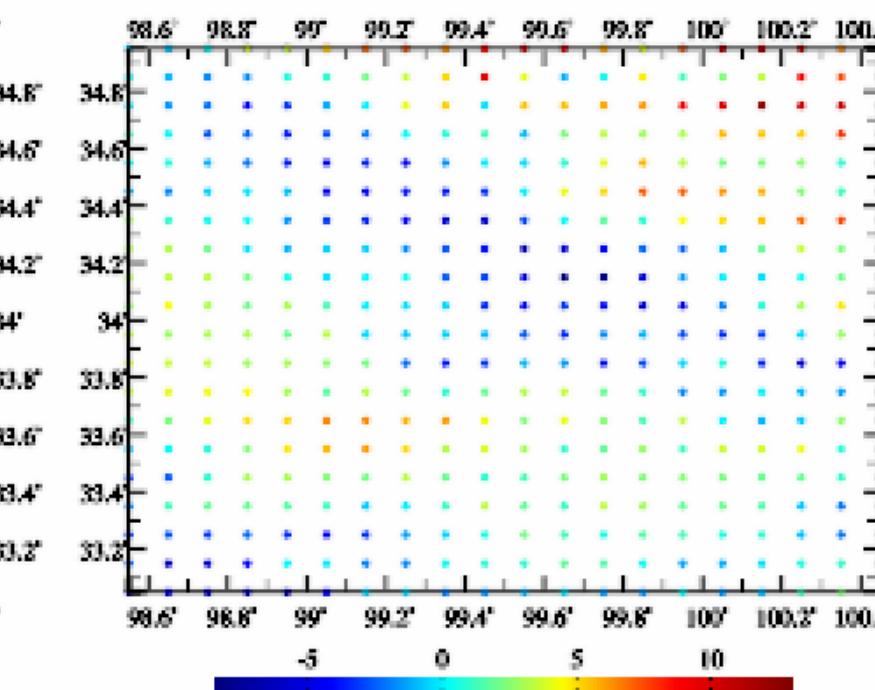
Digital elevation model (m)



height anomaly (m)



gravity (anomaly, mGal)



vertical deflection (", S)

- Given the invariance of the normal gravity field, the terrain effects on gravity disturbance and gravity anomaly are strictly equal to the terrain effect on gravity itself.
- The terrain effect on a field element is defined as the negative of the classic terrain correction: Local Terrain Effect = - Local Terrain Correction.

Rigorous Numerical Integration of Local Terrain Effects on External Field Elements

Rigorous Numerical Integration of Local Terrain Effects on External Field Elements

FFT Algorithm for Local Terrain Effects on External Gravity Field Elements

Interactive Calculator for Local Terrain Effects on External Field Elements

Algorithms of local terrain effect

Save computation process as

Open Ground DEM File

Open Ground Ellipsoidal Height Grid File

Select computation file format

surface ellipsoidal height grid file

Open Computation Surface Ellipsoidal Height Grid File

Select gravity field elements

- ☒ height anomaly (m)
- ☒ gravity (anomaly/disturbance, mGal)
- ☒ vertical deflection (")
- ☒ disturbing gravity gradient (E, radial)

>> Computation Process ** Operation Prompts

>> [Function] Utilizing a rigorous numerical integration algorithm, this module computes local terrain effects on various field elements at points located on or outside the geoid. Inputs include a Ground Digital Elevation Model (DEM) and a Ground Ellipsoidal Height Grid. Target Elements: Height Anomaly (m), Gravity (Anomaly/Disturbance, mGal), Vertical Deflection ("; South/West components), or (Disturbing) Gravity Gradient (Eötvös; Radial component).

** Input Ground DEM File and Ground Ellipsoidal Height Grid File with the same grid specifications...

>> Open Ground DEM File C:/PAGravf4.5_win64en/examples/TerLocalterraininfl/landtm1m.dat.

>> Open Ground Ellipsoidal Height Grid File C:/PAGravf4.5_win64en/examples/TerLocalterraininfl/landbmsurfhgt.dat.

>> Open Computation Surface Ellipsoidal Height Grid File C:/PAGravf4.5_win64en/examples/TerLocalterraininfl/landbmsurfhgt.dat.

>> Save the results as C:/PAGravf4.5_win64en/examples/TerLocalterraininfl/landsurfnintg.txt.

** Automatically generates grid files in the current directory with specific extensions based on the selected element: Height Anomaly: .ksi, Gravity: .gra, Vertical Deflection: .dft, and Gravity Gradient: .grr. The base filename is user-defined via the interface.

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

Integral radius 90 km

Save the results as

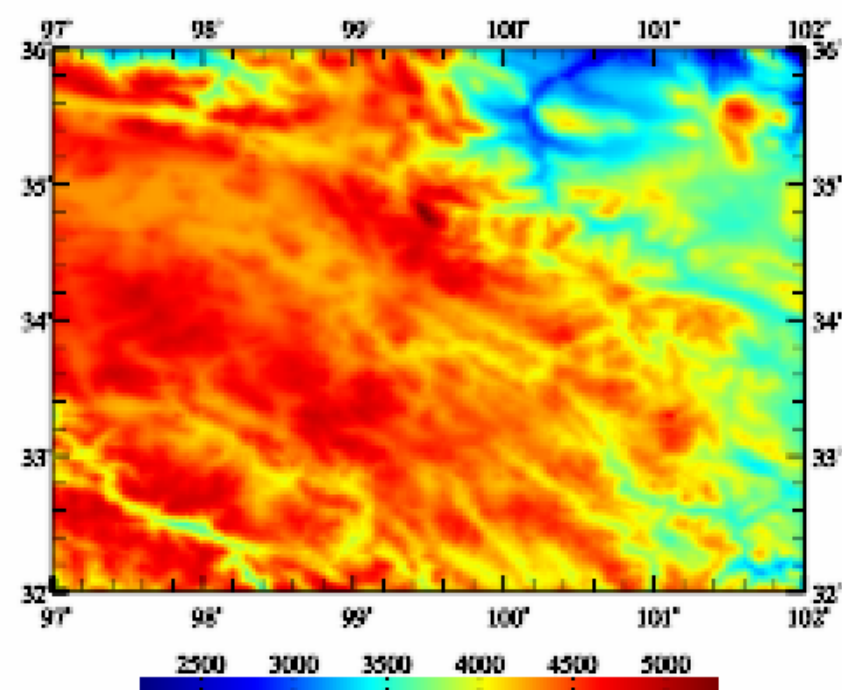
Import setting parameters

Start Computation

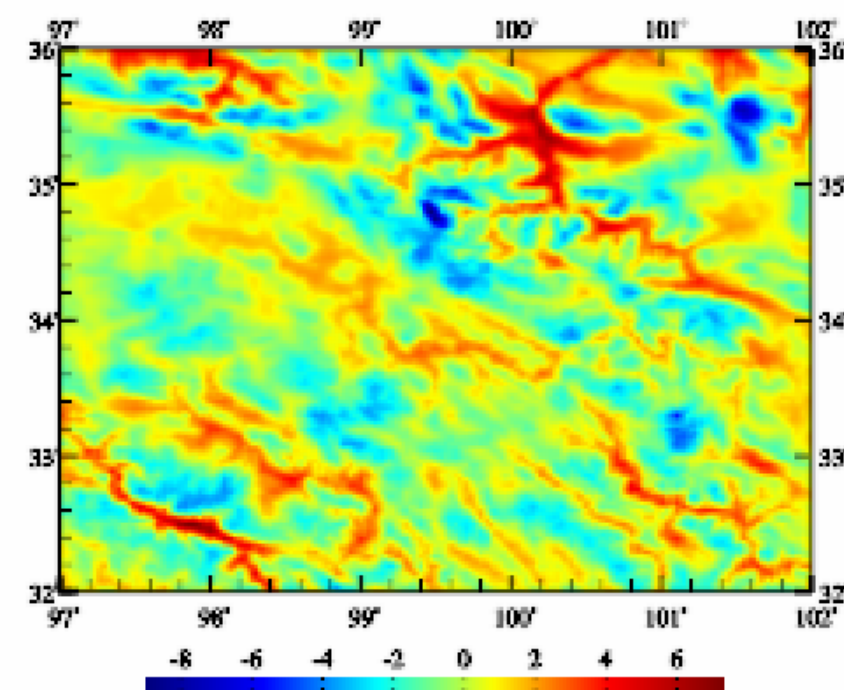
C:/PAGravf4.5_win64en/examples/TerLocalterraininfl/landsurfnintg.ksi
C:/PAGravf4.5_win64en/examples/TerLocalterraininfl/landsurfnintg.gra
C:/PAGravf4.5_win64en/examples/TerLocalterraininfl/landsurfnintg.dft
C:/PAGravf4.5_win64en/examples/TerLocalterraininfl/landsurfnintg.grr

Extract effects

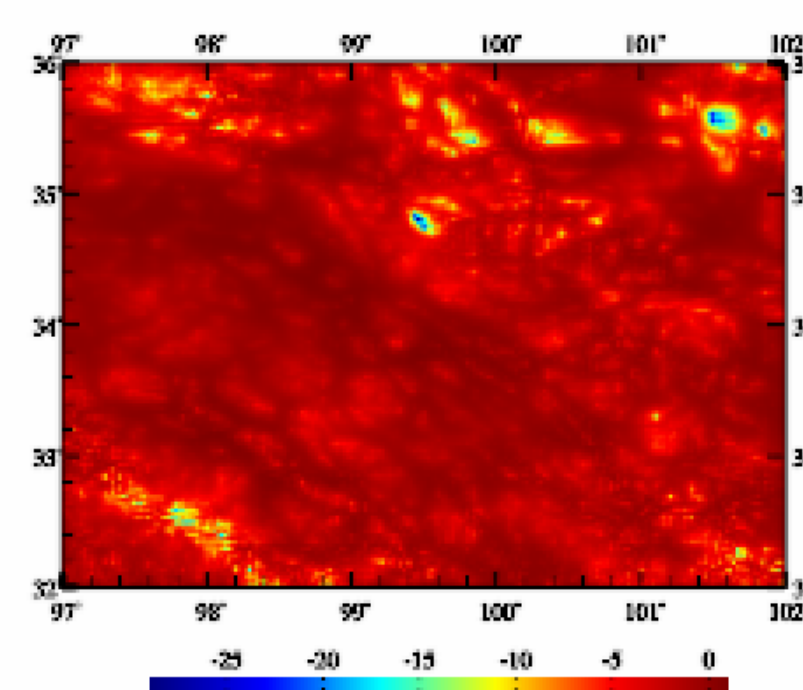
Plot



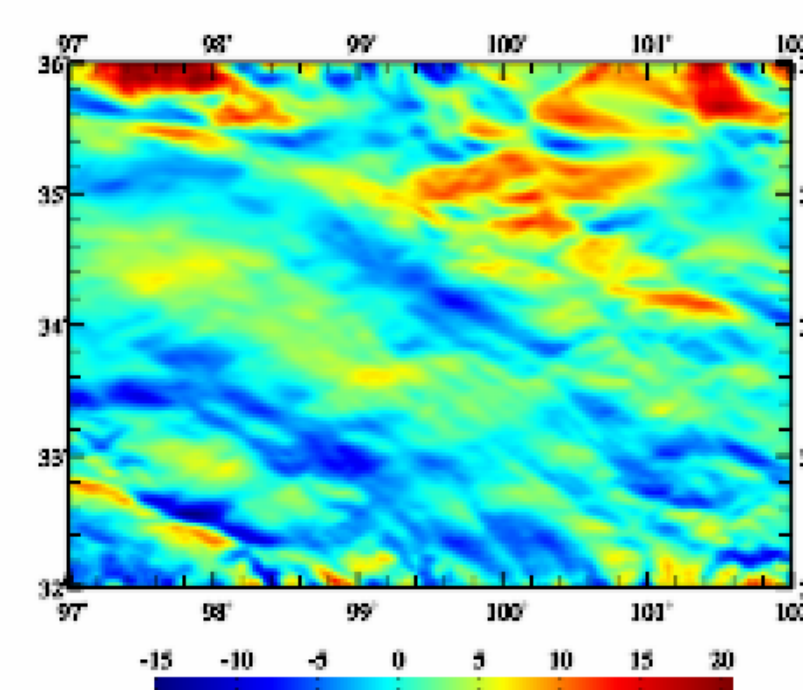
Digital elevation model (m)



height anomaly (m)



gravity (anomaly, mGal)



vertical deflection (", S)

- Given the invariance of the normal gravity field, the terrain effects on gravity disturbance and gravity anomaly are strictly equal to the terrain effect on gravity itself.
- The terrain effect on a field element is defined as the negative of the classic terrain correction: Local Terrain Effect = - Local Terrain Correction.

Table 3.1: Statistical Results of the Local Terrain Effects on Various Ground Gravity Field Elements

Field element type /Unit	Mean	Std. Dev. (ϵ)	Minimum	Maximum	D/ ϵ
height anomaly (m)	-0.2233	1.4995	-8.9709	4.9249	9.3
gravity (anomaly, disturbance) (mGal)	-0.5364	0.7599	-14.3238	0.5061	19.5
vertical deflection (" , South)	1.0139	3.2809	-8.7789	13.2512	6.7
vertical deflection (" , West)	1.7161	3.2445	-6.8166	14.4212	6.5
gravity gradient (E)	1.3980	83.1923	-368.3504	493.4792	10.4

Significance of D/ϵ : A high ratio indicates that ultra-short-wavelength signals, while minor in total energy, exhibit prominent amplitudes (extreme local anomalies).

Applicability: A larger magnitude of terrain effect (higher D/ϵ) implies greater efficacy for correcting that specific field element.

Conclusion: Gravity disturbance yields the highest ratio (19.5), demonstrating its high suitability for terrain correction. Conversely, vertical deflection shows the lowest ratios (~6.5), suggesting that local terrain effects are less dominant or effective for refining vertical deflection data in this context.

FFT Algorithm for Local Terrain Effects on External Gravity Field Elements

Rigorous Numerical Integration of Local Terrain Effects on External Field Elements

FFT Algorithm for Local Terrain Effects on External Gravity Field Elements

Interactive Calculator for Local Terrain Effects on External Field Elements

Algorithms of local terrain effect

Save computation process as

Open Ground DEM File

Open Ground Ellipsoidal Height Grid File

Open Computation Surface Ellipsoidal Height Grid File

Select gravity field elements

- ☒ height anomaly (m)
- ☒ gravity (anomaly/disturbance, mGal)
- ☒ vertical deflection (")
- ☒ disturbing gravity gradient (E, radial)

Fast algorithm 2D FFT

>> Computation Process ** Operation Prompts

>> [Function] Computes local terrain effects using the Fast Fourier Transform (FFT) integration algorithm, based on the Ground DEM and Ground Ellipsoidal Height Grid.

** Input Ground DEM File and Ground Ellipsoidal Height Grid File with the same grid specifications...

>> Open Ground DEM File C:/PAGravf4.5_win64en/examples/TerLocalterraininfl/landtm1m.dat.

>> Open Ground Ellipsoidal Height Grid File C:/PAGravf4.5_win64en/examples/TerLocalterraininfl/landbmsurfhgt.dat.

>> Open Computation Surface Ellipsoidal Height Grid File C:/PAGravf4.5_win64en/examples/TerLocalterraininfl/landbmsurfhgt.dat.

>> Compute the local terrain effects using 2D FFT algorithm...

>> Save the results as C:/PAGravf4.5_win64en/examples/TerLocalterraininfl/surfFFT2.txt.

** Automatically generates grid files in the current directory with specific extensions based on the selected element: Height Anomaly: .ksi, Gravity: .gra, Vertical Deflection: .dft, and Gravity Gradient: .grr. The base filename is user-defined via the interface.

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

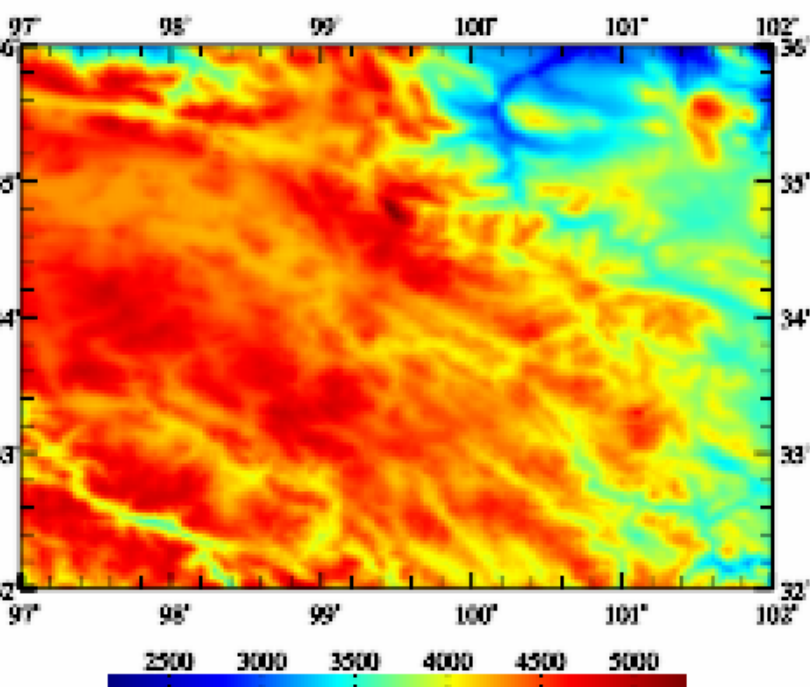
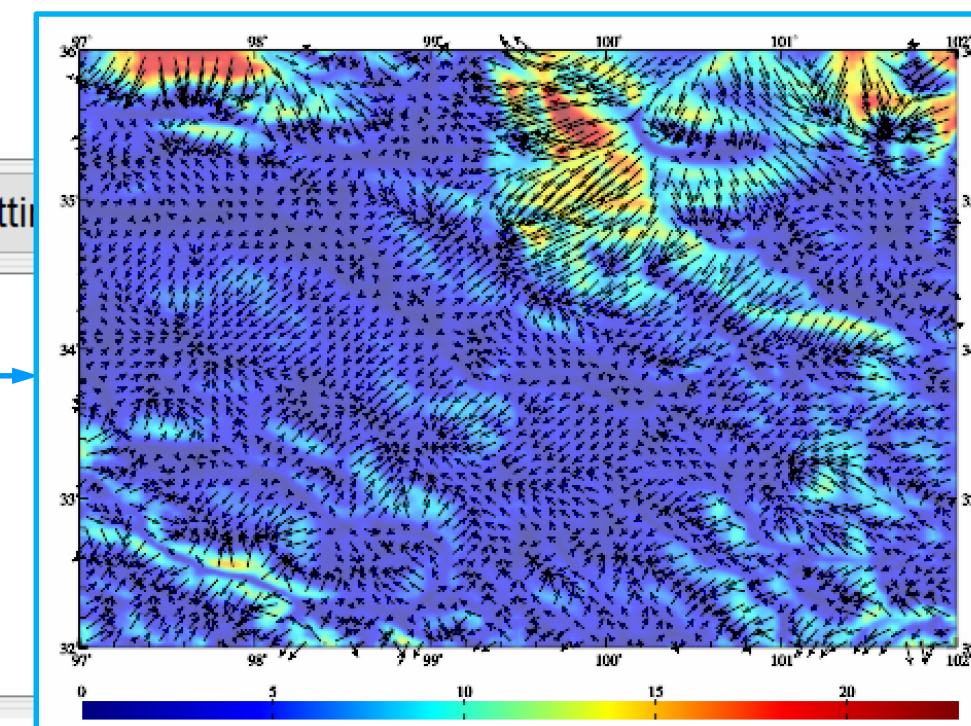
>> Computation start time: 2026-04-09 16:22:04

Integral radius 90 km

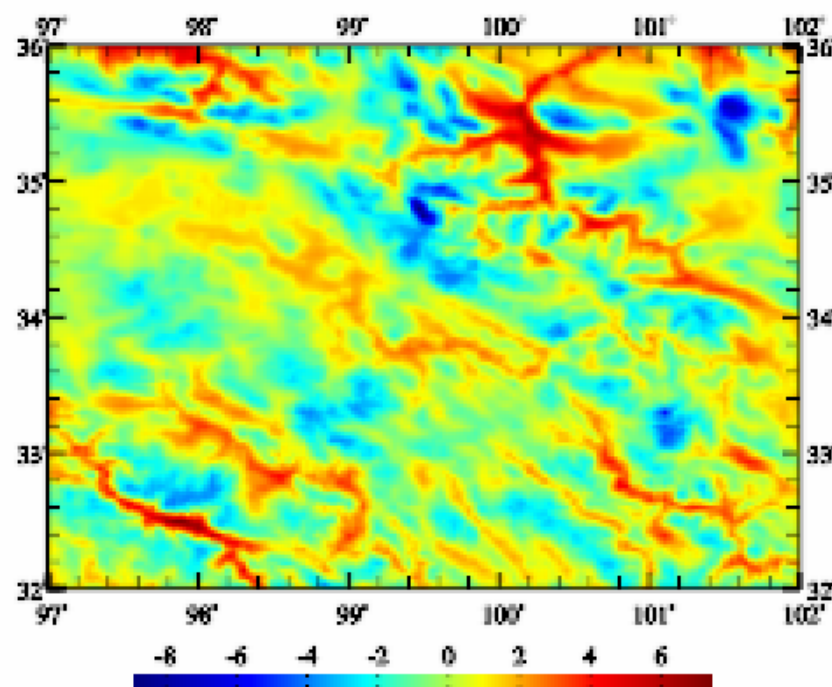
Save the results as

Import settings

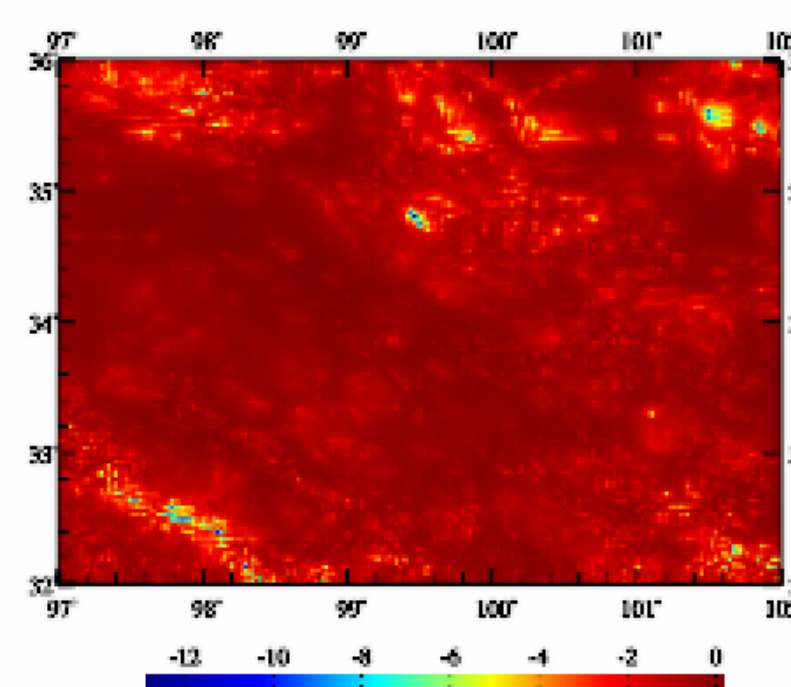
C:/PAGravf4.5_win64en/examples/TerLocalterraininfl/surfFFT2.ksi
C:/PAGravf4.5_win64en/examples/TerLocalterraininfl/surfFFT2.gra
C:/PAGravf4.5_win64en/examples/TerLocalterraininfl/surfFFT2.dft
C:/PAGravf4.5_win64en/examples/TerLocalterraininfl/surfFFT2.grr



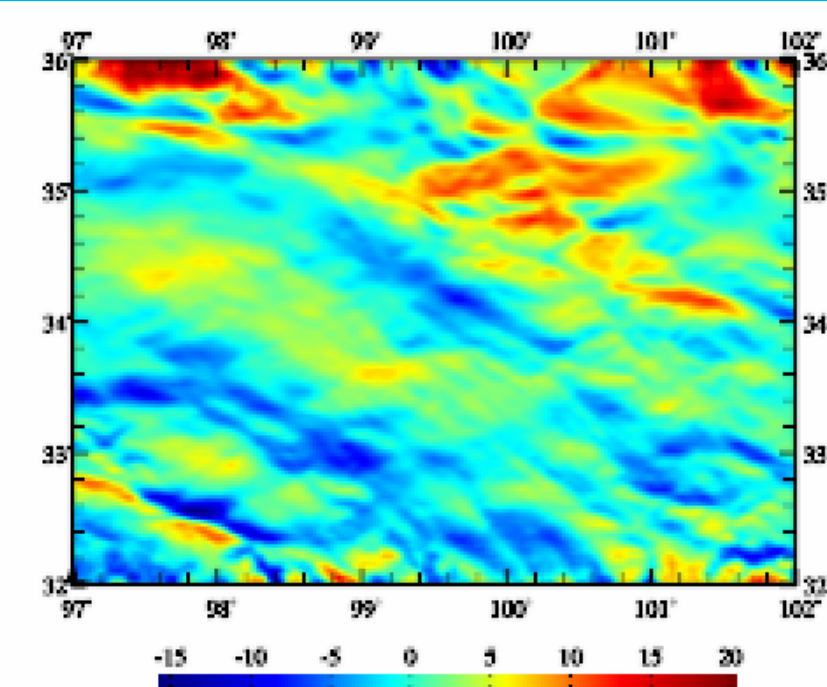
Digital elevation model (m)



height anomaly (m)



gravity (anomaly, mGal)



vertical deflection (", S)

- Given the invariance of the normal gravity field, the terrain effects on gravity disturbance and gravity anomaly are strictly equal to the terrain effect on gravity itself.
- The terrain effect on a field element is defined as the negative of the classic terrain correction: Local Terrain Effect = - Local Terrain Correction.

FFT Algorithm for Local Terrain Effects on External Gravity Field Elements

Rigorous Numerical Integration of Local Terrain Effects on External Field Elements

FFT Algorithm for Local Terrain Effects on External Gravity Field Elements

Interactive Calculator for Local Terrain Effects on External Field Elements

Algorithms of local terrain effect

Save computation process as

Open Ground DEM File

Open Ground Ellipsoidal Height Grid File

Open Computation Surface Ellipsoidal Height Grid File

Select gravity field elements

- ☒ height anomaly (m)
- ☒ gravity (anomaly/disturbance, mGal)
- ☒ vertical deflection (")
- ☒ disturbing gravity gradient (E, radial)

Fast algorithm 1D FFT

>> Computation Process ** Operation Prompts

>> [Function] Computes local terrain effects using the Fast Fourier Transform (FFT) integration algorithm, based on the Ground DEM and Ground Ellipsoidal Height Grid.

** Input Ground DEM File and Ground Ellipsoidal Height Grid File with the same grid specifications...

>> Open Ground DEM File C:/PAGravf4.5_win64en/examples/TerLocalterraininfl/landtm1m.dat.

>> Open Ground Ellipsoidal Height Grid File C:/PAGravf4.5_win64en/examples/TerLocalterraininfl/landbmsurfhgt.dat.

>> Open Computation Surface Ellipsoidal Height Grid File C:/PAGravf4.5_win64en/examples/TerLocalterraininfl/landbmsurfhgt.dat.

>> Compute the local terrain effects using 1D FFT algorithm...

>> Save the results as C:/PAGravf4.5_win64en/examples/TerLocalterraininfl/surfFFT1.txt.

** Automatically generates grid files in the current directory with specific extensions based on the selected element: Height Anomaly: .ksi, Gravity: .gra, Vertical Deflection: .dft, and Gravity Gradient: .grr. The base filename is user-defined via the interface.

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-09 16:23:37

Integral radius 90 km

Save the results as

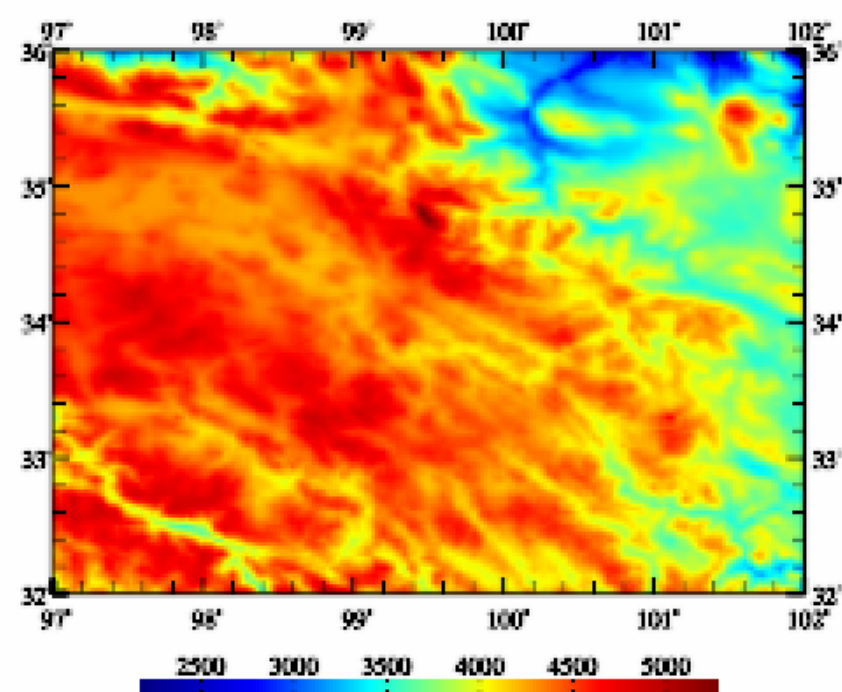
Import setting parameters

Start Computation

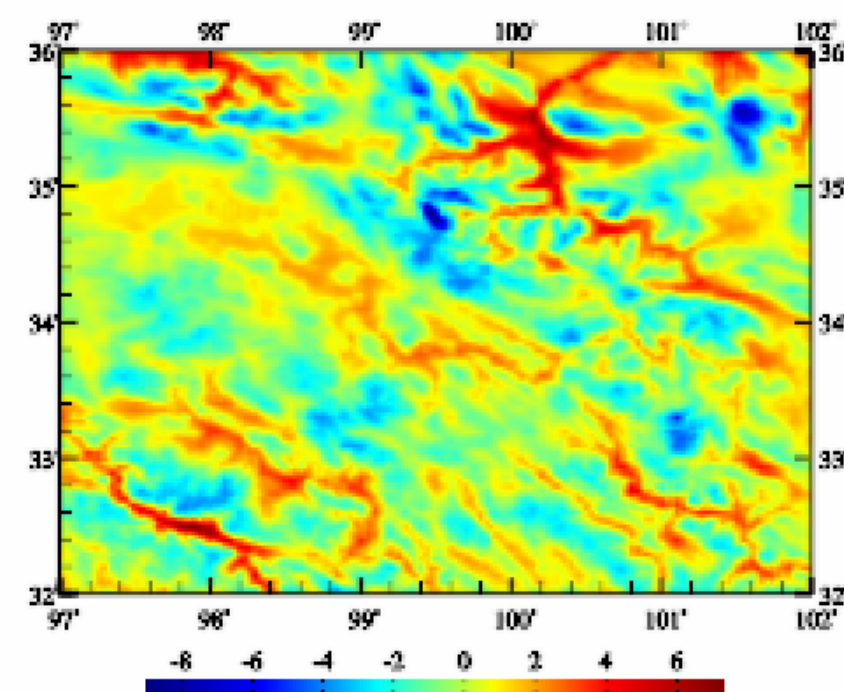
C:/PAGravf4.5_win64en/examples/TerLocalterraininfl/surfFFT1.ksi
C:/PAGravf4.5_win64en/examples/TerLocalterraininfl/surfFFT1.gra
C:/PAGravf4.5_win64en/examples/TerLocalterraininfl/surfFFT1.dft
C:/PAGravf4.5_win64en/examples/TerLocalterraininfl/surfFFT1.grr

Extract effects

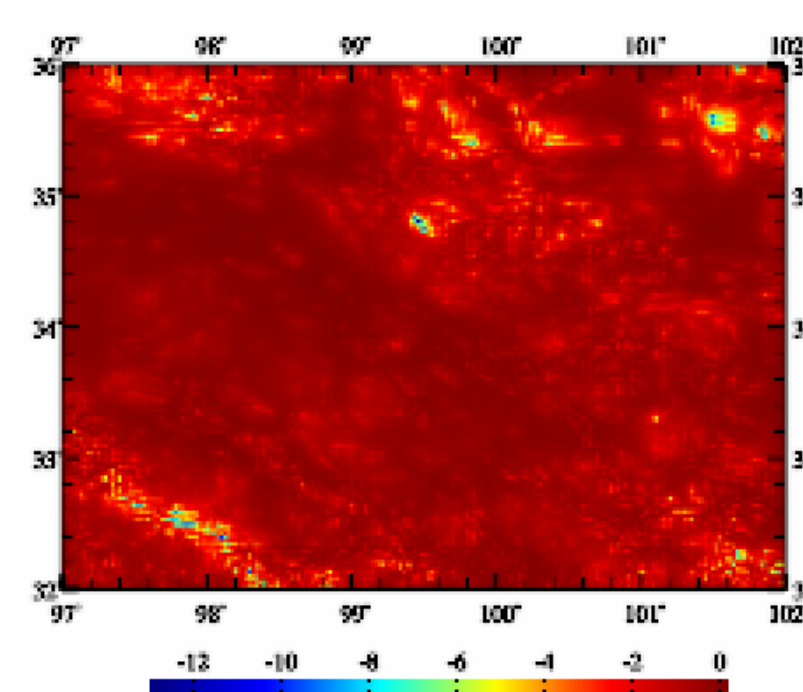
Plot



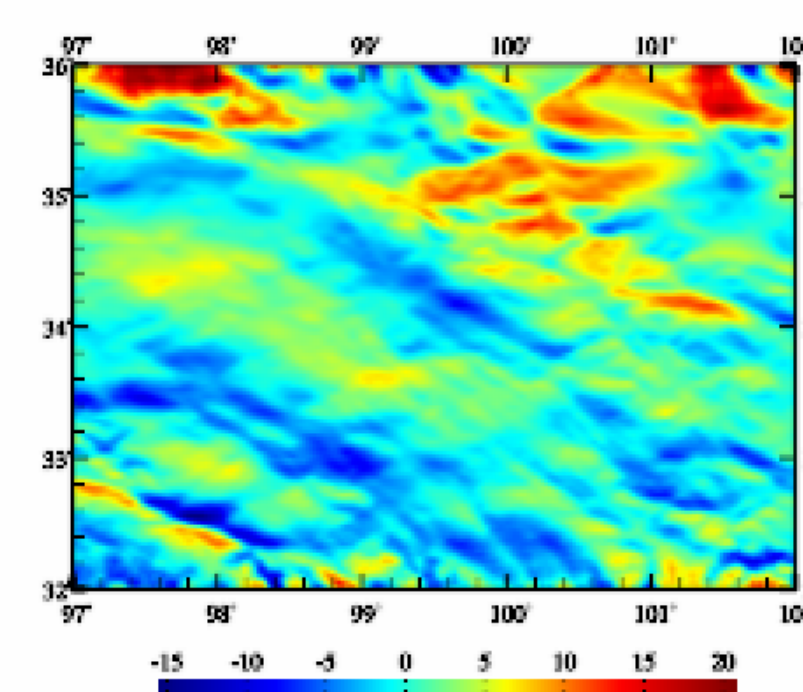
Digital elevation model (m)



height anomaly (m)



gravity (anomaly, mGal)



vertical deflection (\", S)

- Given the invariance of the normal gravity field, the terrain effects on gravity disturbance and gravity anomaly are strictly equal to the terrain effect on gravity itself.
- The terrain effect on a field element is defined as the negative of the classic terrain correction: Local Terrain Effect = - Local Terrain Correction.

Table 3.2: Statistics for the differences between FFT results and rigorous numerical integration

Field Element / Unit	Algorithm	Mean Diff	Std. Dev. Diff	Min Diff	Max Diff
height anomaly (m)	FFT2	-0.0001	0.0138	-0.0686	0.0883
	FFT1	0.0012	0.0027	-0.0115	0.0110
gravity (anomaly, disturbance) (mGal)	FFT2	0.0352	0.2316	-0.7410	1.4406
	FFT1	0.0341	0.2298	-0.7602	1.3356
vertical deflection (" , South)	FFT2	-0.0082	0.0197	-0.1176	0.1275
	FFT1	-0.0026	0.0138	-0.1616	0.1538
vertical deflection (" , West)	FFT2	0.0018	0.0400	-0.3873	0.1555
	FFT1	0.0051	0.0198	-0.4444	0.2844
gravity gradient (E)	FFT2	0.0042	0.5176	-19.6242	10.5354
	FFT1	0.0036	0.5859	-21.2847	12.1181

The discrepancies between the rigorous numerical integration and the fast FFT algorithms are negligible.

No significant difference exists between the 1D-FFT and 2D-FFT implementations.

Interactive Calculator for Local Terrain Effects on External Field Elements

Open Ground DEM File

Open Ground Ellipsoidal Height Grid File

Input geodetic coordinates of calculation point

longitude

98.240000°

latitude

32.428000°

ellipsoidal height

2017.830m

Integral radius

90 km

Start calculation

Ground digital elevation model

97.000000	102.000000	32.000000	36.000000	0.01666667	0.01666667
3988.0003	4048.9987	4129.9921	4151.9956	4155.9995	4177.9961
4277.9980	4373.9953	4466.9865	4479.9931	4520.9918	4547.9825
4242.0005	4229.0008	4211.0001	4165.0004	4150.0047	4157.0059
4429.0008	4511.9959	4529.9991	4537.9993	4539.9993	4531.9988
4273.0028	4221.0056	4196.0075	4251.0050	4251.0050	4337.9987
4643.9962	4607.0000	4605.9999	4457.0003	4379.9835	4150.9999
4500.0065	4593.9999	4593.9999	4593.9999	4473.0101	4473.0101
4272.0146	4409.9999	4409.9999	4409.9999	4729.0038	4829.0038
4530.9966	4456.9999	4456.9999	4456.9999	4071.0117	4071.0117
4371.0006	4429.9974	4429.9974	4429.9974	4520.9942	4480.9942
3868.0107	3964.9992	3964.9992	3964.9992	4124.0006	4124.0006
4243.0076	4270.0056	4270.0056	4270.0056	4347.9933	4280.9933
4161.9980	4189.9937	4189.9937	4189.9937	4040.0077	4040.0077
4050.9965	4023.0057	4012.0000	4012.0000	4171.9934	4235.0039
4051.0030	4022.0027	3977.0121	4029.9996	4032.9988	3996.0025
4299.0025	4415.9991	4516.9921	4514.9967	4458.0037	4431.9971
3672.0205	3912.9978	4073.9952	4159.0051	4313.9938	4374.9940
4389.9975	4386.9989	4385.9985	4382.9957	4358.9980	4337.9925
4185.9964	4135.0004	4099.9998	4073.9998	4073.9986	4110.9920
4310.9929	4297.9951	4309.9918	4309.9894	4250.9985	4242.9906
3884.0033	3950.0001	4024.9995	4076.0000	4119.0000	4160.9984
4240.0001	4300.0001	4352.9995	4350.0033	4355.0002	4373.0002

Local terrain effect calculation results

height anomaly (m)

-0.1400

gravity (anomaly/disturbance, mGal)

-0.8197

vertical deflection (" , S)

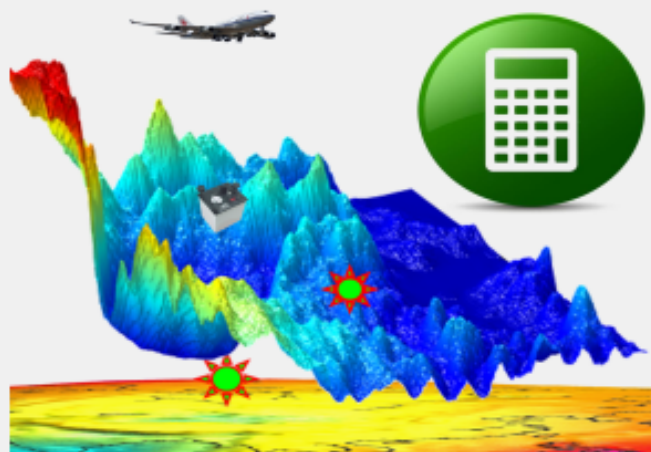
-7.0751

vertical deflection (" , W)

-0.6231

(disturbing) gradient (E, radial)

17.4820



Workflow

- Data Loading: Load the Ground DEM and Ground Ellipsoidal Height Grid (must share grid specs). The [Start Calculation] button activates upon successful loading.
- Real-Time Computation: Enter geodetic coordinates for computation points. The system instantly calculates and displays the local terrain effects for all selected field elements.
- Dynamic Updates: Users can dynamically swap input DEM/Height Grid files or adjust the Integration Radius via the interface. Changes take effect immediately for subsequent calculations.

Interactive Calculator for Local Terrain Effects on External Field Elements

Open Ground DEM File

Open Ground Ellipsoidal Height Grid File

Input geodetic coordinates of calculation point

longitude100.240000°

latitude34.428000°

ellipsoidal height201.830m

Integral radius90 km

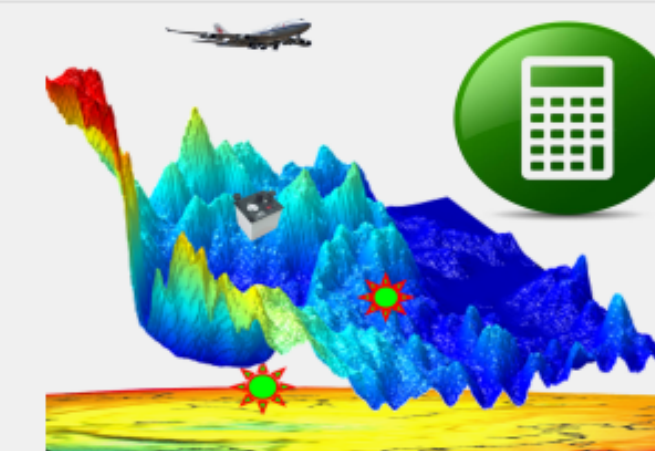
Start calculation

Ground digital elevation model

97.000000	102.000000	32.000000	36.000000	0.01666667	0.01666667
3988.0003	4048.9987	4129.9921	4151.9956	4155.9995	4177.9961
4277.9980	4373.9953	4466.9865	4479.9931	4520.9918	4547.9825
4242.0005	4229.0008	4211.0001	4165.0054	4150.0047	4157.0059
4429.0008	4511.9959	4529.9991	4531.0014	4539.9993	4531.9988
4273.0028	4211.0056	4196.0075	4196.0093	4251.0050	4337.9987
4643.9962	4607.0004	4605.9967	4587.9986	4457.0003	4379.9835
4500.0065	4513.9997	4650.9957	4601.9957	4585.9976	4473.0101
4272.0146	4409.0057	4548.9957	4515.9957	4647.0046	4729.0038
4530.9966	4416.9957	4412.9957	4412.9957	4160.0042	4071.0117
4371.0006	4419.9957	4419.9957	4419.9957	4493.9994	4520.9942
3868.0107	3901.9957	3901.9957	3901.9957	4166.0037	4124.0006
4243.0076	4270.9957	4270.9957	4270.9957	4166.0037	4347.9933
4161.9980	4189.9957	4189.9957	4189.9957	4166.0037	4040.0077
4050.9965	4023.0017	4023.0017	4023.0017	4166.0037	4235.0039
4051.0030	4022.0027	4022.0027	4022.0027	4166.0037	3996.0025
4299.0025	4415.9991	4415.9991	4415.9991	4458.0037	4431.9971
3672.0205	3912.9978	4073.9957	4159.9951	4313.9938	4374.9940
4389.9975	4386.9989	4385.9955	4382.9967	4358.9980	4337.9925
4185.9964	4135.0004	4099.9998	4073.9998	4073.9986	4110.9920
4310.9929	4297.9951	4309.9918	4309.9894	4250.9985	4242.9906
3884.0033	3950.0001	4024.9995	4076.0000	4119.0000	4160.9984
4240.0001	4300.0001	4352.9995	4350.0033	4355.0002	4373.0002

Local terrain effect calculation results

height anomaly (m)	2.3837	gravity (anomaly/disturbance, mGal)	-12.3434
vertical deflection (" , S)	3.5957	vertical deflection (" , W)	5.5401
(disturbing) gradient (E, radial)	-23.6988		



Workflow

- Data Loading: Load the Ground DEM and Ground Ellipsoidal Height Grid (must share grid specs). The [Start Calculation] button activates upon successful loading.
- Real-Time Computation: Enter geodetic coordinates for computation points. The system instantly calculates and displays the local terrain effects for all selected field elements.
- Dynamic Updates: Users can dynamically swap input DEM/Height Grid files or adjust the Integration Radius via the interface. Changes take effect immediately for subsequent calculations.

Unified Land-Sea Complete Bouguer Effect on External Gravity

Unified Land-Sea Complete Bouguer Effect on External Gravity

Rigorous Numerical Integration of Lake-Water Complete Bouguer Effect

Formulas of land-sea unified complete Bouguer effect

Open Land-Sea Terrain Model File

Open Land-Sea Surface Ellipsoidal Height Grid File

Select computation file format

space computaion point file

Open Space Computation Point File

Set input point file format

Number of rows of file header 1

Ellipsoidal Height Column Index 4

>> Computation Process ** Operation Prompts

to that on gravity itself.

>> [Function] Computes the unified land-sea complete Bouguer effect on gravity (mGal) using rigorous numerical integration or FFT, based on a land-sea terrain model and the land-sea surface ellipsoidal height grid.

** Input Land-Sea Terrain Model and Land-Sea Surface Ellipsoidal Height Grid with the same grid specifications...

>> Open Land-Sea Terrain Model File C:/PAGrav4.5_win64en/examples/TerCompleteBougure/dtm5m.dat.

>> Open Land-Sea Surface Ellipsoidal Height Grid File C:/PAGrav4.5_win64en/examples/TerCompleteBougure/dbmhgt5m.dat.

>> Open Space Computation Point File C:/PAGrav4.5_win64en/examples/TerCompleteBougure/surfhgt.txt.

** Look at the file information in the window below, set the input file format parameters...

>> Save the results as C:/PAGrav4.5_win64en/examples/TerCompleteBougure/bgpnt.txt.

>> Appends four columns to the source record (formatted to 4 significant figures): local terrain effect, spherical shell Bouguer effect, seawater complete Bouguer effect, and unified land-sea complete Bouguer effect.

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-10 08:53:42

>> Complete computation of the unified land-sea complete Bouguer effects!

>> Computation end time: 2026-04-10 08:53:54

Land integral radius 90 km

Sea integral radius 300 km

Save the results as

Import setting parameters

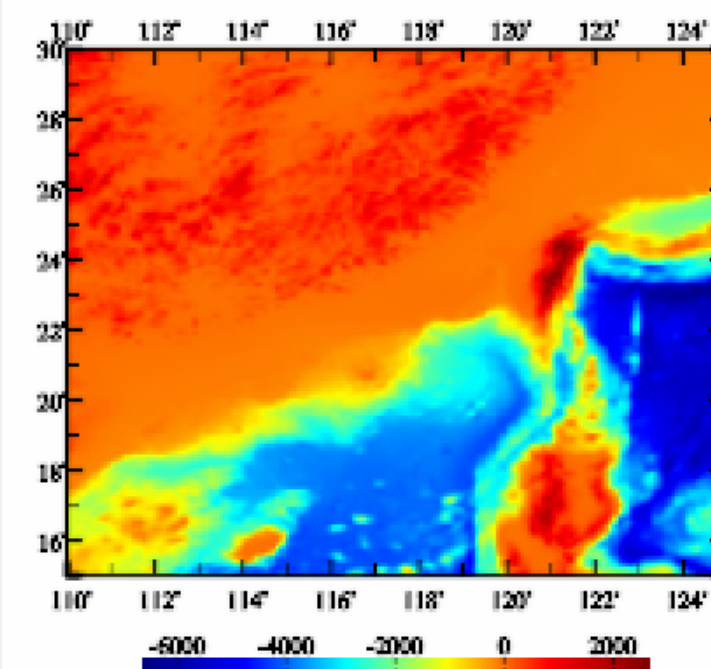
Start Computation

n lat hgt

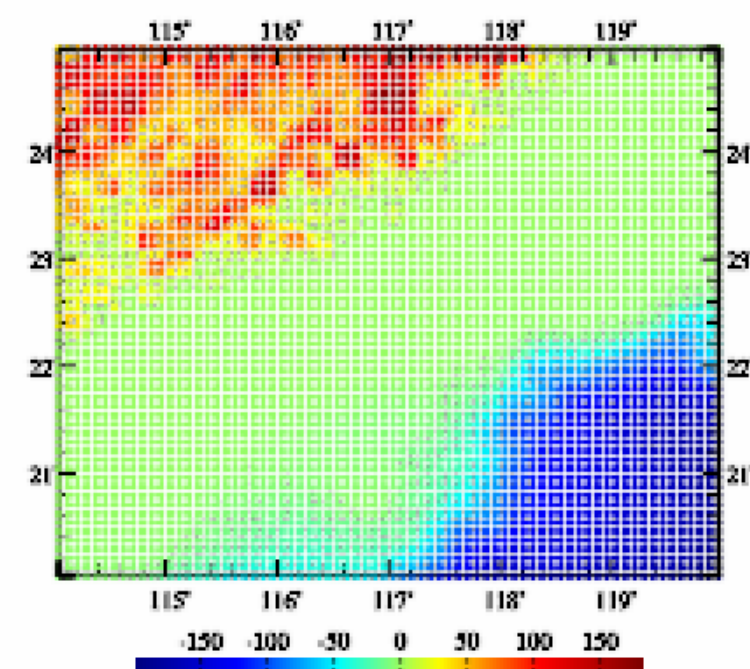
49	114.041667	20.041667	2.5061	0.0000	0.0000	-4.9874	-4.9874
50	114.125000	20.041667	2.8389	0.0000	0.0000	-5.7603	-5.7603
51	114.208333	20.041667	3.1673	0.0000	0.0000	-6.1912	-6.1912
52	114.291667	20.041667	3.4899	0.0000	0.0000	-5.7768	-5.7768
53	114.375000	20.041667	3.8056	0.0000	0.0000	-5.3795	-5.3795
54	114.458333	20.041667	4.1136	0.0000	0.0000	-5.3887	-5.3887
55	114.541667	20.041667	4.4137	0.0000	0.0000	-5.7310	-5.7310
56	114.625000	20.041667	4.7058	0.0000	0.0000	-6.4732	-6.4732
57	114.708333	20.041667	4.9907	0.0000	0.0000	-7.4594	-7.4594
58	114.791667	20.041667	5.2696	0.0000	0.0000	-10.2158	-10.2158
59	114.875000	20.041667	5.5440	0.0000	0.0000	-14.0367	-14.0367
60	114.958333	20.041667	5.8158	0.0000	0.0000	-17.8961	-17.8961
61	115.041667	20.041667	6.0875	0.0000	0.0000	-26.1346	-26.1346
62	115.125000	20.041667	6.3615	0.0000	0.0000	-31.5650	-31.5650
63	115.208333	20.041667	6.6404	0.0000	0.0000	-33.8370	-33.8370
64	115.291667	20.041667	6.9265	0.0000	0.0000	-33.5514	-33.5514
65	115.375000	20.041667	7.2221	0.0000	0.0000	-33.4861	-33.4861

Extract effects

Plot↓



land-sea terrain model (m)



complete Bouguer effects (mGal)

Designed for the unified computation of Complete Bouguer effects across terrestrial regions, land-sea transition zones, and marine areas. Computation points may span from the geoid up to typical airborne altitudes.

Seawater Bouguer effects persist in offshore terrestrial areas, while local terrain effects exist in coastal marine regions. If sea bathymetrys are set to zero, the program computes the land complete Bouguer effect. If terrain heights are set to zero, the program computes the seawater complete Bouguer effect.

The complete Bouguer effect is defined as the variation in the Earth's gravity field resulting from: The removal of topographic masses above the geoid; and the density compensation of seawater to the standard terrain density.

Unified Land-Sea Complete Bouguer Effect on External Gravity

Unified Land-Sea Complete Bouguer
Effect on External Gravity

Rigorous Numerical Integration of Lake-Water
Complete Bouguer Effect

Formulas of land-sea unified
complete Bouguer effect

Open Land-Sea Terrain Model File

Open Land-Sea Surface Ellipsoidal
Height Grid File

Select computation file format

surface ellipsoidal height grid file

Open Computation Surface Ellipsoidal
Height Grid File

Select integral algorithm

numerical integral

>> Computation Process ** Operation Prompts

>> Complete computation of the unified land-sea complete Bouguer effects!

>> Computation end time: 2026-04-10 08:53:54

>> [Function] Computes the unified land-sea complete Bouguer effect on gravity (mGal) using rigorous numerical integration or FFT, based on a land-sea terrain model and the land-sea surface ellipsoidal height grid.

** Input Land-Sea Terrain Model and Land-Sea Surface Ellipsoidal Height Grid with the same grid specifications...

>> Open Land-Sea Terrain Model File C:/PAGrav4.5_win64en/examples/TerCompleteBougure/dtm5m.dat.

>> Open Land-Sea Surface Ellipsoidal Height Grid File C:/PAGrav4.5_win64en/examples/TerCompleteBougure/dbmhgt5m.dat.

>> Open Computation Surface Ellipsoidal Height Grid File C:/PAGrav4.5_win64en/examples/TerCompleteBougure/dbmhgt5m.dat.

>> Compute the land-sea unified complete Bouguer effects using numerical integral...

>> Save the results as C:/PAGrav4.5_win64en/examples/TerCompleteBougure/Indseanintg.txt.

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-10 08:56:57

>> Complete computation of the unified land-sea complete Bouguer effects!

>> Computation end time: 2026-04-10 08:58:10

Land integral radius

90 km

Sea integral radius

300 km

Save the results as

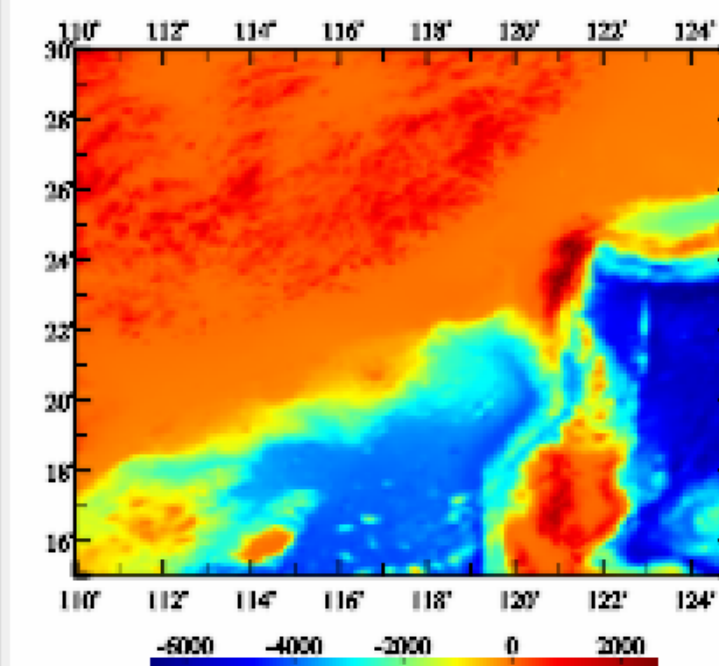
Import setting parameters

Start Computation

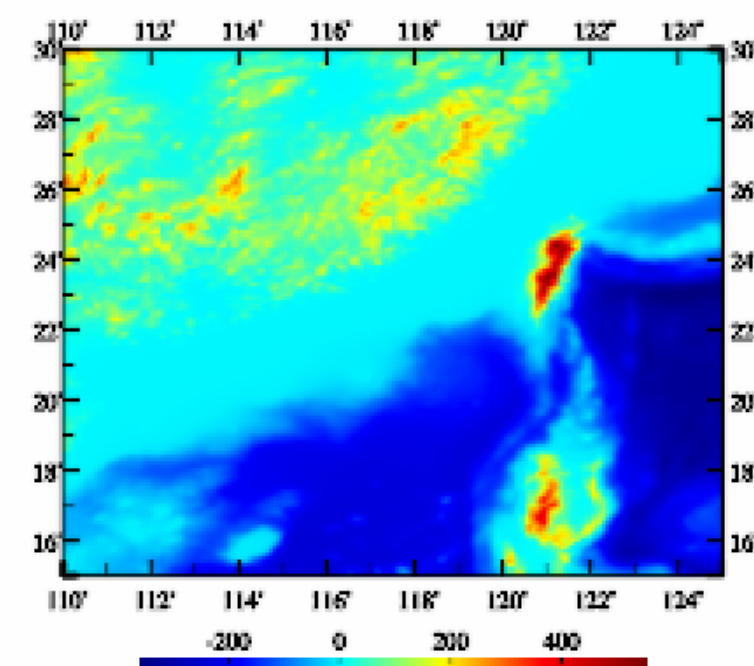
110.000000	125.000000	15.000000	30.000000	0.08333333	0.08333333	
-7.8971	-7.8766	-9.1329	-13.9564	-17.1850	-18.6294	-20.8450
-44.6578	-46.2931	-47.8725	-49.2206	-49.7490	-52.1642	-58.2028
-122.3702	-130.1366	-140.1488	-153.4317	-160.9914	-163.4580	-162.3793
-191.4158	-194.5725	-195.9800	-197.2639	-198.6141	-200.3888	-202.6294
-200.4928	-205.5214	-206.6093	-205.9741	-204.5037	-202.9258	-202.5885
-178.2261	-149.0168	-128.2677	-123.2072	-148.5989	-171.0931	-190.9696
-171.9145	-151.3418	-131.5769	-117.4720	-134.9318	-155.1051	-177.0088
-205.7689	-213.4690	-219.2022	-222.2357	-217.2625	-201.2612	-170.7498
-2.2319	37.0377	49.9421	103.4139	109.8637	67.4917	9.9533
107.4283	80.5898	76.5395	-2.8018	-3.8227	-5.0755	-5.0368
-55.8005	-60.4478	-68.3144	-80.9337	-82.7537	-79.9747	-69.3090
-80.1272	-109.2082	-131.7292	-159.3266	-177.3378	-194.1377	-219.8577
-9.7228	-9.3627	-9.8369	-13.9679	-17.8883	-19.5395	-21.4966
-44.6752	-46.2503	-47.7995	-50.0060	-49.1645	-50.0281	-49.0029
-134.8074	-139.8302	-146.6228	-160.3309	-172.5591	-178.2125	-178.0323
-193.4552	-198.5444	-202.4213	-206.8460	-210.7303	-213.6701	-216.0972
-222.1076	-225.8486	-226.2187	-224.2652	-222.6408	-222.4899	-223.7217

Extract effects

Plot↓



land-sea terrain model (m)



complete Bouguer effects (mGal)

Designed for the unified computation of Complete Bouguer effects across terrestrial regions, land-sea transition zones, and marine areas. Computation points may span from the geoid up to typical airborne altitudes.

Seawater Bouguer effects persist in offshore terrestrial areas, while local terrain effects exist in coastal marine regions. If sea bathymetrys are set to zero, the program computes the land complete Bouguer effect. If terrain heights are set to zero, the program computes the seawater complete Bouguer effect.

The complete Bouguer effect is defined as the variation in the Earth's gravity field resulting from: The removal of topographic masses above the geoid; and the density compensation of seawater to the standard terrain density.

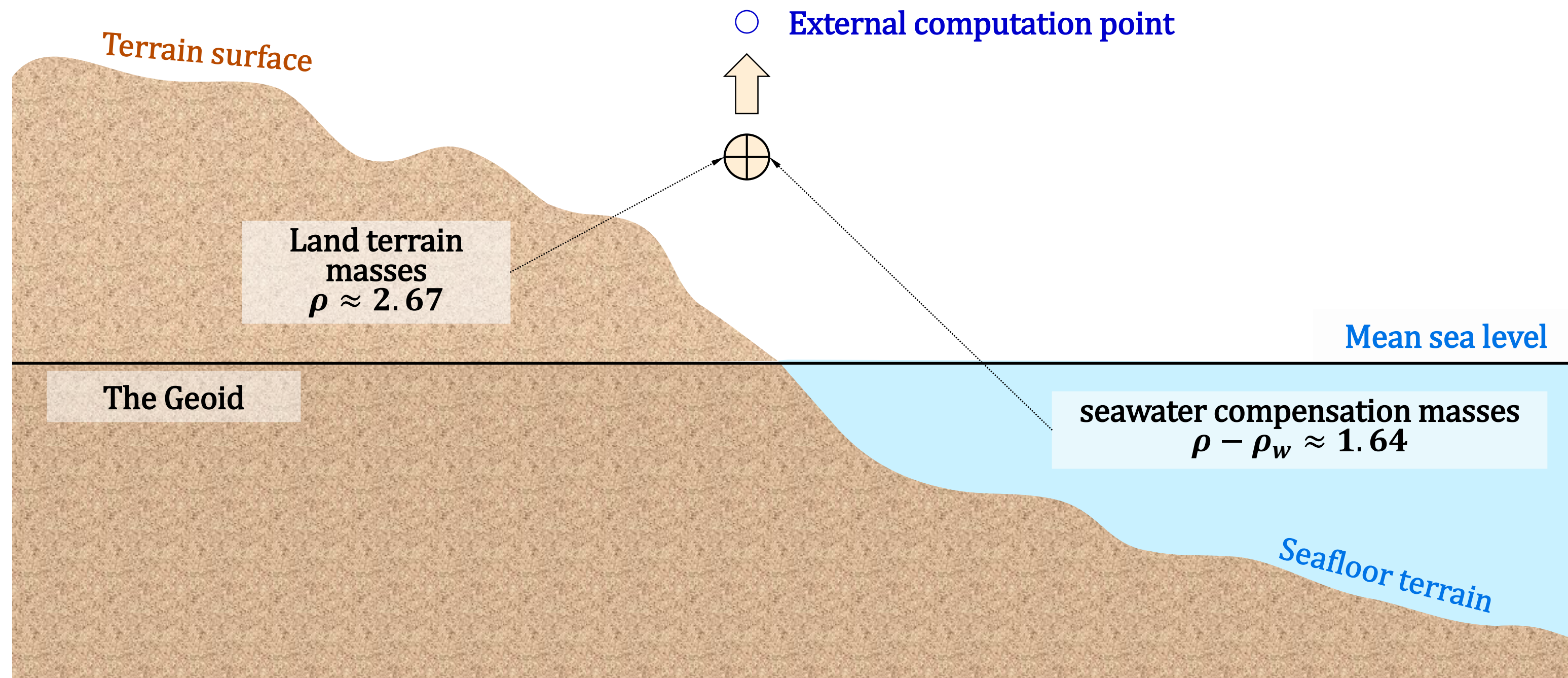


Figure 7.4: Fundamental Principle of Unified Land-Sea Complete Bouguer Effect

Unified Land-Sea Complete Bouguer Effect on External Gravity – 2D FFT

Unified Land-Sea Complete Bouguer
Effect on External Gravity

Rigorous Numerical Integration of Lake-Water
Complete Bouguer Effect

Formulas of land-sea unified
complete Bouguer effect

Open Land-Sea Terrain Model File

Open Land-Sea Surface Ellipsoidal
Height Grid File

Select computation file format

surface ellipsoidal height grid file

Open Computation Surface Ellipsoidal
Height Grid File

Select integral algorithm

2D FFT algorithm

>> Computation Process ** Operation Prompts

>> Complete computation of the unified land-sea complete Bouguer effects!

>> Computation end time: 2026-04-10 08:58:10

>> [Function] Computes the unified land-sea complete Bouguer effect on gravity (mGal) using rigorous numerical integration or FFT, based on a land-sea terrain model and the land-sea surface ellipsoidal height grid.

** Input Land-Sea Terrain Model and Land-Sea Surface Ellipsoidal Height Grid with the same grid specifications...

>> Open Land-Sea Terrain Model File C:/PAGravf4.5_win64en/examples/TerCompleteBougure/dtm5m.dat.

>> Open Land-Sea Surface Ellipsoidal Height Grid File C:/PAGravf4.5_win64en/examples/TerCompleteBougure/dbmhgt5m.dat.

>> Open Computation Surface Ellipsoidal Height Grid File C:/PAGravf4.5_win64en/examples/TerCompleteBougure/dbmhgt5m.dat.

>> Compute the land-sea unified complete Bouguer effects using 2D FFT algorithm...

>> Save the results as C:/PAGravf4.5_win64en/examples/TerCompleteBougure/IndseaFFT2.dat.

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-10 09:01:22

>> Complete computation of the unified land-sea complete Bouguer effects!

>> Computation end time: 2026-04-10 09:01:30

Land integral radius

90 km

Sea integral radius

300 km

Save the results as

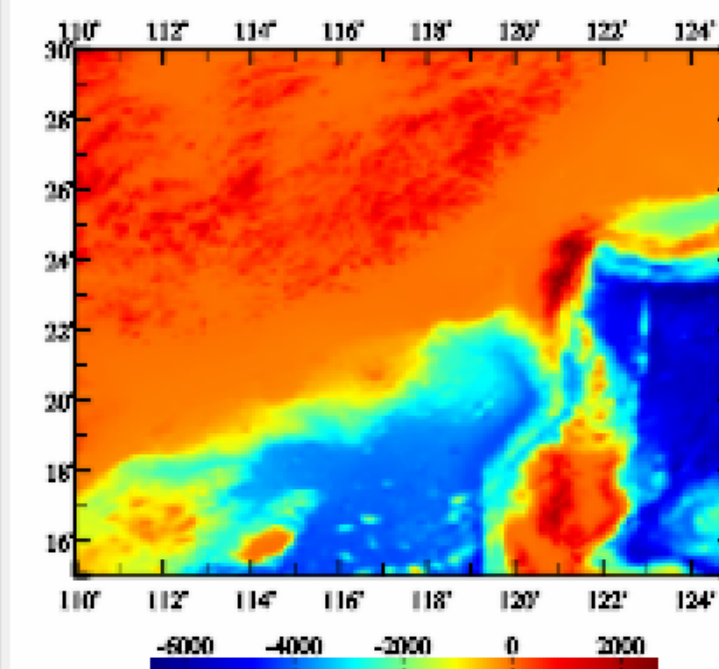
Import setting parameters

Start Computation

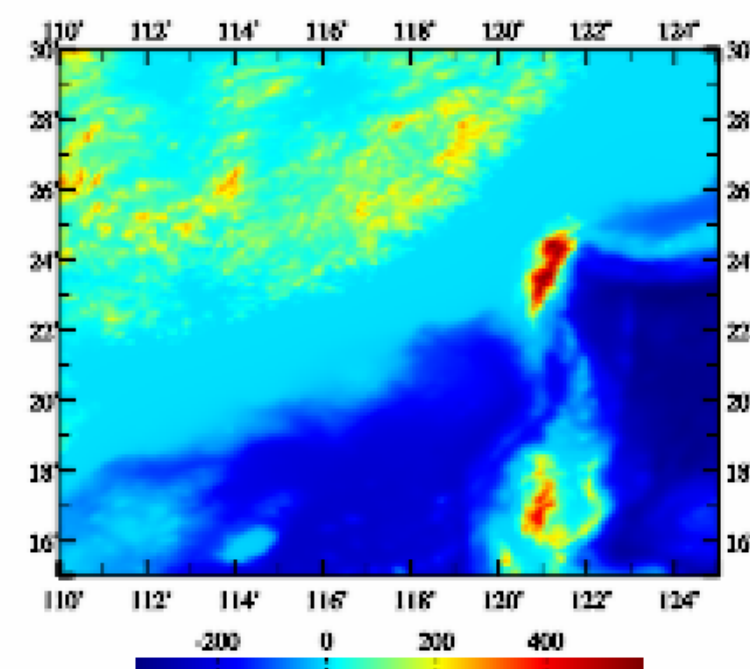
110.000000	125.000000	15.000000	30.000000	0.08333333	0.08333333	
-8.3840	-8.4310	-9.7492	-14.6251	-17.9147	-19.4227	-21.6795
-46.0804	-47.7576	-49.3916	-50.7882	-51.3851	-53.8891	-59.9925
-125.7561	-133.7616	-144.0685	-157.5015	-165.2193	-167.7783	-166.8387
-196.6335	-199.8166	-201.3186	-202.6456	-204.0432	-205.8578	-208.1285
-206.3994	-211.4598	-212.6164	-212.0782	-210.6699	-209.1409	-208.8170
-183.9449	-154.6824	-133.6509	-128.7657	-154.2202	-177.0351	-196.9064
-177.6384	-157.0008	-136.9625	-122.9076	-140.2510	-160.7115	-182.6198
-211.3937	-218.8423	-224.2816	-227.0769	-221.9265	-205.9211	-175.6084
-3.9094	36.0852	49.2404	103.5004	110.1038	67.2428	8.8891
107.7201	80.4641	76.8699	-4.1631	-5.4744	-6.7966	-6.8071
-58.3003	-63.0309	-71.0464	-83.7201	-85.6414	-82.8324	-72.1778
-83.4268	-112.8950	-135.9738	-163.8406	-182.2737	-199.3464	-224.3924
-10.2471	-9.9652	-10.5049	-14.6940	-18.6774	-20.3997	-22.3998
-46.1861	-47.8194	-49.4312	-51.6749	-50.9006	-51.7915	-50.7816
-138.4751	-143.8311	-150.9153	-164.7942	-177.1894	-182.9933	-182.9549
-198.9392	-204.1574	-208.1467	-212.6239	-216.5529	-219.5346	-221.9885
-228.5733	-232.2644	-232.7040	-230.8908	-229.3755	-229.2764	-230.5015

Extract effects

Plot↓



land-sea terrain model (m)



complete Bouguer effects (mGal)

Designed for the unified computation of Complete Bouguer effects across terrestrial regions, land-sea transition zones, and marine areas. Computation points may span from the geoid up to typical airborne altitudes.

Seawater Bouguer effects persist in offshore terrestrial areas, while local terrain effects exist in coastal marine regions. If sea bathymetrys are set to zero, the program computes the land complete Bouguer effect. If terrain heights are set to zero, the program computes the seawater complete Bouguer effect.

The complete Bouguer effect is defined as the variation in the Earth's gravity field resulting from: The removal of topographic masses above the geoid; and the density compensation of seawater to the standard terrain density.

Unified Land-Sea Complete Bouguer Effect on External Gravity – 1D FFT

Unified Land-Sea Complete Bouguer
Effect on External Gravity

Rigorous Numerical Integration of Lake-Water
Complete Bouguer Effect

Formulas of land-sea unified
complete Bouguer effect

Open Land-Sea Terrain Model File

Open Land-Sea Surface Ellipsoidal
Height Grid File

Select computation file format

surface ellipsoidal height grid file

Open Computation Surface Ellipsoidal
Height Grid File

Select integral algorithm

1D FFT algorithm

>> Computation Process ** Operation Prompts

>> Complete computation of the unified land-sea complete Bouguer effects!

>> Computation end time: 2026-04-10 09:01:30

>> [Function] Computes the unified land-sea complete Bouguer effect on gravity (mGal) using rigorous numerical integration or FFT, based on a land-sea terrain model and the land-sea surface ellipsoidal height grid.

** Input Land-Sea Terrain Model and Land-Sea Surface Ellipsoidal Height Grid with the same grid specifications...

>> Open Land-Sea Terrain Model File C:/PAGravf4.5_win64en/examples/TerCompleteBougure/dtm5m.dat.

>> Open Land-Sea Surface Ellipsoidal Height Grid File C:/PAGravf4.5_win64en/examples/TerCompleteBougure/dbmhgt5m.dat.

>> Open Computation Surface Ellipsoidal Height Grid File C:/PAGravf4.5_win64en/examples/TerCompleteBougure/dbmhgt5m.dat.

>> Compute the land-sea unified complete Bouguer effects using 1D FFT algorithm...

>> Save the results as C:/PAGravf4.5_win64en/examples/TerCompleteBougure/IndseaFFT1.dat.

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-10 09:02:14

>> Complete computation of the unified land-sea complete Bouguer effects!

>> Computation end time: 2026-04-10 09:02:38

Land integral radius

90 km

Sea integral radius

300 km

Save the results as

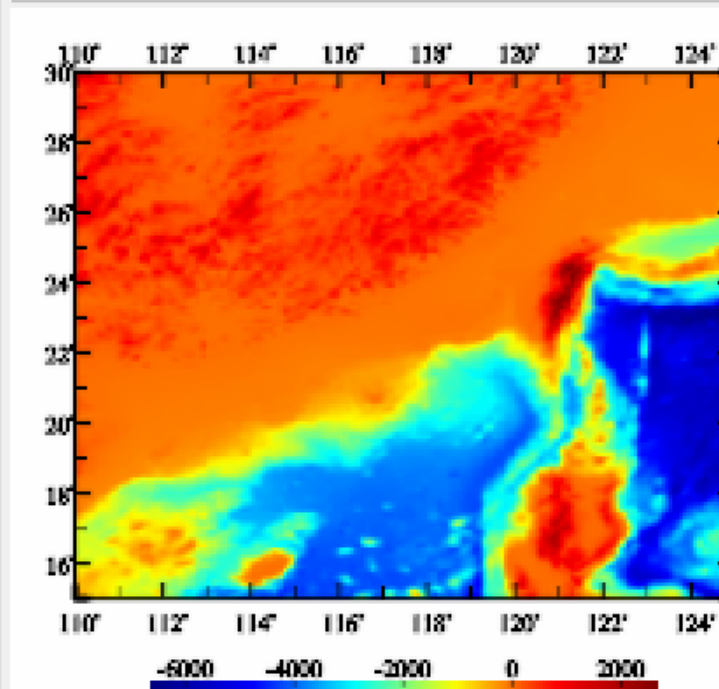
Import setting parameters

Start Computation

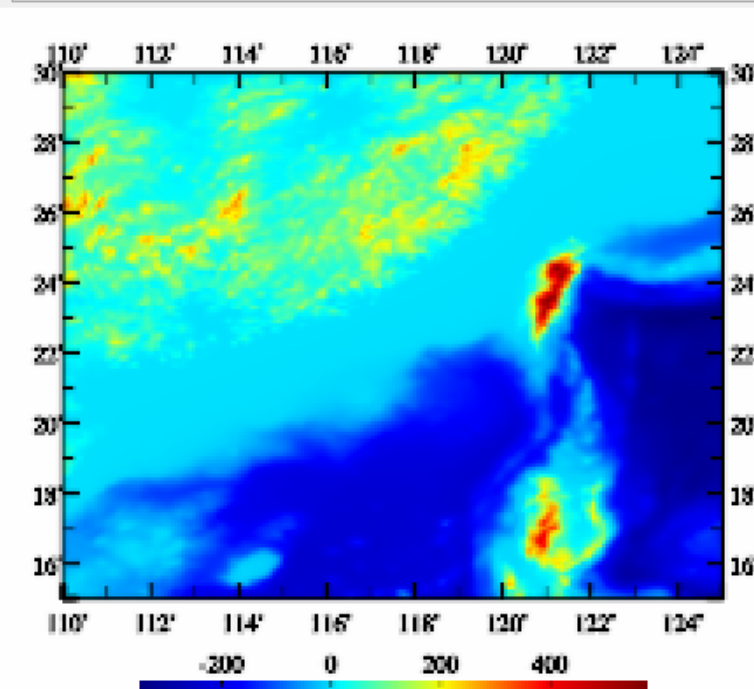
110.000000	125.000000	15.000000	30.000000	0.08333333	0.08333333	
-8.2859	-8.2979	-9.5859	-14.4386	-17.6973	-19.1729	-21.4192
-45.5102	-47.1726	-48.7790	-50.1541	-50.7128	-53.1583	-59.2286
-123.6301	-131.4323	-141.4338	-154.6832	-162.1845	-164.6695	-163.6497
-192.5911	-195.6108	-197.0458	-198.3330	-199.6909	-201.4540	-203.7060
-202.1460	-207.0358	-208.1123	-207.5622	-206.1675	-204.6629	-204.3039
-180.3762	-151.5508	-130.9900	-125.9695	-151.2787	-173.5002	-193.1195
-174.2465	-153.8247	-134.2208	-120.1139	-137.5049	-157.4718	-179.0607
-206.9287	-214.2794	-219.6096	-222.4735	-217.4892	-202.0047	-172.0155
-3.4159	36.5032	49.6341	103.8896	110.4780	67.5950	9.2229
108.0989	80.8370	77.2701	-3.7790	-5.1007	-6.4139	-6.4107
-57.4799	-62.1677	-70.0703	-82.7109	-84.5577	-81.8098	-71.1878
-82.0921	-111.1265	-133.5695	-161.0260	-178.8618	-195.2426	-219.8860
-10.1361	-9.8124	-10.3213	-14.4839	-18.4358	-20.1202	-22.1095
-45.5731	-47.1780	-48.7561	-50.9909	-50.1816	-51.0756	-50.0823
-136.0776	-141.1197	-147.9200	-161.5592	-173.7014	-179.3393	-179.1977
-194.5959	-199.6421	-203.4520	-207.8225	-211.6475	-214.5354	-216.9526
-223.4237	-227.0499	-227.4504	-225.6176	-224.1094	-224.0079	-225.2122

Extract effects

Plot↓



land-sea terrain model (m)



complete Bouguer effects (mGal)

Designed for the unified computation of Complete Bouguer effects across terrestrial regions, land-sea transition zones, and marine areas. Computation points may span from the geoid up to typical airborne altitudes.

Seawater Bouguer effects persist in offshore terrestrial areas, while local terrain effects exist in coastal marine regions. If sea bathymetrys are set to zero, the program computes the land complete Bouguer effect. If terrain heights are set to zero, the program computes the seawater complete Bouguer effect.

The complete Bouguer effect is defined as the variation in the Earth's gravity field resulting from: The removal of topographic masses above the geoid; and the density compensation of seawater to the standard terrain density.

Rigorous Numerical Integration of Lake-Water Complete Bouguer Effect

Unified Land-Sea Complete Bouguer Effect on External Gravity

Rigorous Numerical Integration of Lake-Water Complete Bouguer Effect

Formulas of land-sea unified complete Bouguer effect

Save computation process as

Open Lake Water-Depth Grid File

Open Lake Surface Ellipsoidal Height Grid File

Open Space Computation Point File

Set input point file format

Number of rows of file header 1

Ellipsoidal Height Column Index 4

>> Computation Process ** Operation Prompts

>> Computation end time: 2026-04-10 09:02:38

>> [Function] Computes the lake-water complete Bouguer effect on gravity (mGal) using a rigorous numerical integration algorithm, based on a lake water-depth grid (zero over land) and the lake surface ellipsoidal height grid.

>> Open Lake Water-Depth Grid File C:/PAGravf4.5_win64en/examples/TerCompleteBougure/TerLakeSeabouginflu/lakedepth.dat.

>> Open Lake Surface Ellipsoidal Height Grid File C:/PAGravf4.5_win64en/examples/TerCompleteBougure/TerLakeSeabouginflu/lakehgt.dat.

>> Open Space Computation Point File C:/PAGravf4.5_win64en/examples/TerCompleteBougure/TerLakeSeabouginflu/calcpnt.txt.

** Look at the file information in the window below, set the input file format parameters...

>> Save the results as C:/PAGravf4.5_win64en/examples/TerCompleteBougure/TerLakeSeabouginflu/rstlake.txt.

>> Appends a single column of lake-water complete Bouguer effect values to the source record, formatted to 4 significant figures.

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-10 09:03:35

>> Complete computation of the lake-water complete Bouguer Effects!

>> Computation end time: 2026-04-10 09:03:47

Land integral radius 60 km

Save the results as

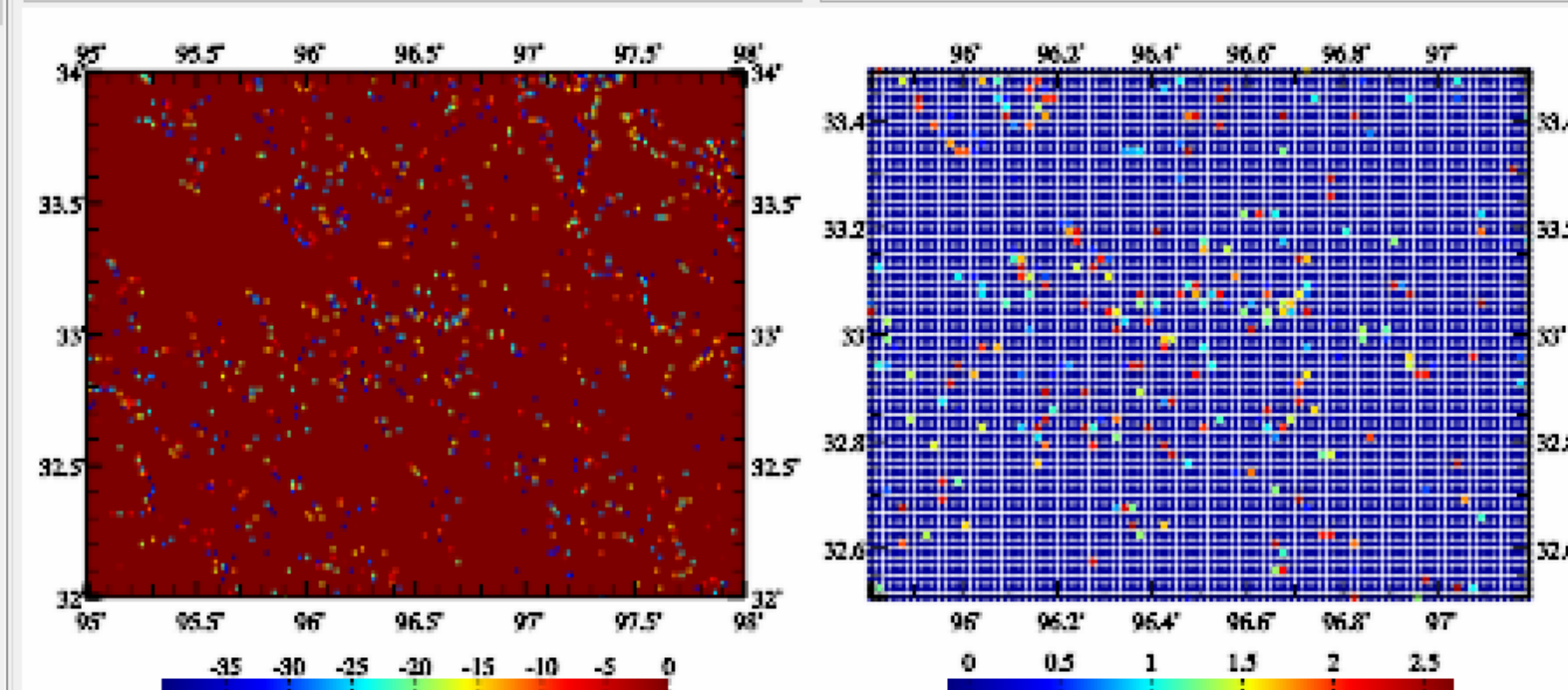
Import setting parameters

Start Computation

no	lon	lat	hgt		
1	95.808333	32.508333	4287.928	0.0084	
2	95.825000	32.508333	4393.299	0.0082	
3	95.841667	32.508333	4472.533	-0.0019	
4	95.858333	32.508333	4455.904	-0.0005	
5	95.875000	32.508333	4449.265	-0.0012	
6	95.891667	32.508333	4381.011	0.0001	
7	95.908333	32.508333	4330.999	0.0004	
8	95.925000	32.508333	4388.620	-0.0012	
9	95.941667	32.508333	4361.609	-0.0008	
10	95.958333	32.508333	4261.231	0.0008	
11	95.975000	32.508333	4152.346	0.0024	
12	95.991667	32.508333	4138.344	0.0019	
13	96.008333	32.508333	4174.044	0.0007	
14	96.025000	32.508333	4193.084	-0.0001	
15	96.041667	32.508333	4078.828	0.0003	
16	96.058333	32.508333	3984.327	0.0004	
17	96.075000	32.508333	4052.948	-0.0003	
18	96.091667	32.508333	4094.322	-0.0007	

Extract effects

Plot↓



lake water-depth grid (m)

complete Bouguer effects (mGal)

Designed for the unified computation of Complete Bouguer effects across terrestrial regions, land-sea transition zones, and marine areas. Computation points may span from the geoid up to typical airborne altitudes.

Seawater Bouguer effects persist in offshore terrestrial areas, while local terrain effects exist in coastal marine regions. If sea bathymetrys are set to zero, the program computes the land complete Bouguer effect. If terrain heights are set to zero, the program computes the seawater complete Bouguer effect.

The complete Bouguer effect is defined as the variation in the Earth's gravity field resulting from: The removal of topographic masses above the geoid; and the density compensation of seawater to the standard terrain density.

Rigorous Numerical Integration of Terrain Helmert Condensation Effects on or outside the Geoid

Rigorous Numerical Integration of Terrain Helmert Condensation Effects on or outside the Geoid

FFT Algorithm for Terrain Helmert Condensation Effects on or outside the Geoid

Interactive Calculator for Terrain Helmert Condensation Effects on or outside the Geoid

Algorithm formulas

Open Ground DEM File

Open Ground Ellipsoidal Height Grid File

Select computation file format

space computation point file

Open Space Computation Point File

Set input point file format

Number of rows of file header 1

Ellipsoidal Height Column Index 4

Select gravity field elements

☒ height anomaly (m)

☒ gravity (anomaly/disturbance, mGal)

☒ vertical deflection (" , SW)

☒ disturbing gravity gradient (E, radial)

Integral radius 90 km

>> Computation Process ** Operation Prompts

>> [Function] Computes Terrain Helmert Condensation effects using a rigorous numerical integration algorithm based on Ground DEM and Ground Surface Ellipsoidal Height Grid.

** Input Ground DEM File and Ground Surface Ellipsoidal Height Grid File with the same grid specifications...

>> Open Ground DEM File C:/PAGrav4.5_win64en/examples/TerHelmertcondensat/landtm1m.dat.

>> Ground Surface Ellipsoidal Height Grid File C:/PAGrav4.5_win64en/examples/TerHelmertcondensat/landbmsurfhgt.dat.

>> Open Space Computation Point File C:/PAGrav4.5_win64en/examples/TerHelmertcondensat/surfhgt.txt.

** Look at the file information in the window below, set the input file format parameters...

>> Save the results as C:/PAGrav4.5_win64en/examples/TerHelmertcondensat/result.txt.

** Appends columns of effect values to the source record (4 significant figures).

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-10 10:20:17

>> Complete the computation of terrain Helmert condensation effects!

>> Computation end time: 2026-04-10 10:20:23

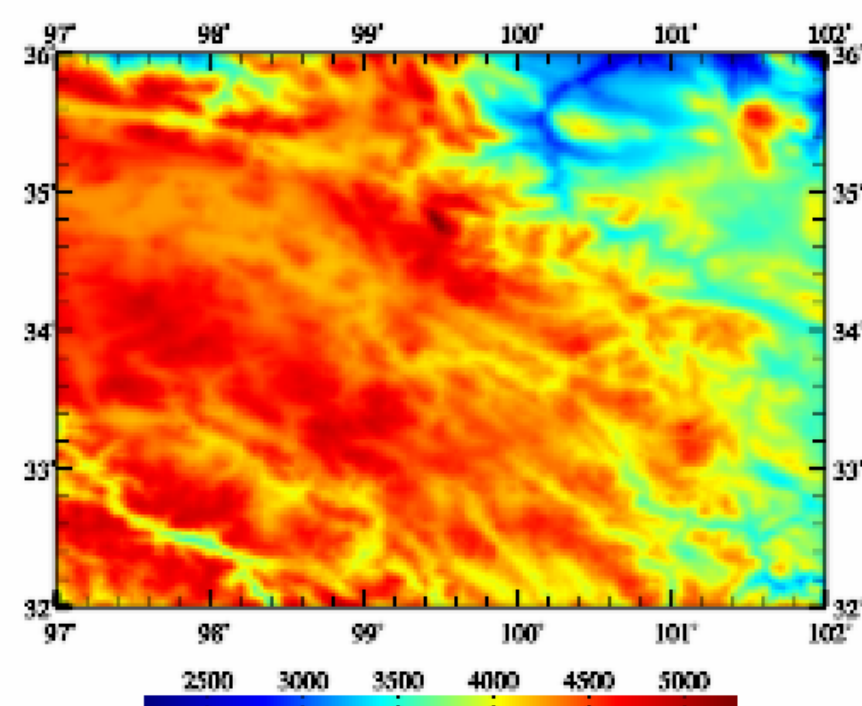
Save the results as

Import setting parameters

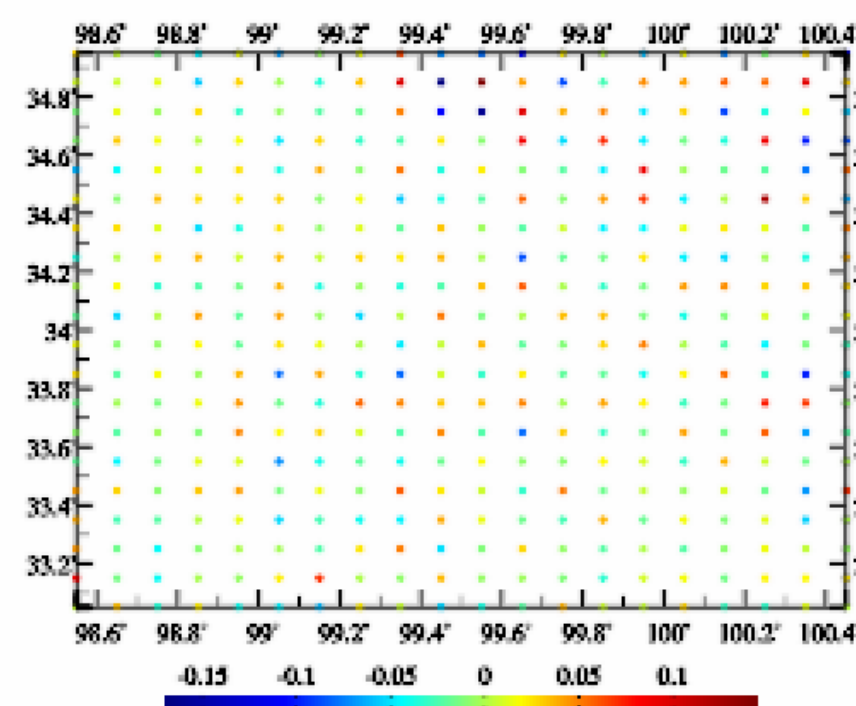
Start Computation

no lon(deg/decimal) lat ellipHeight(m)

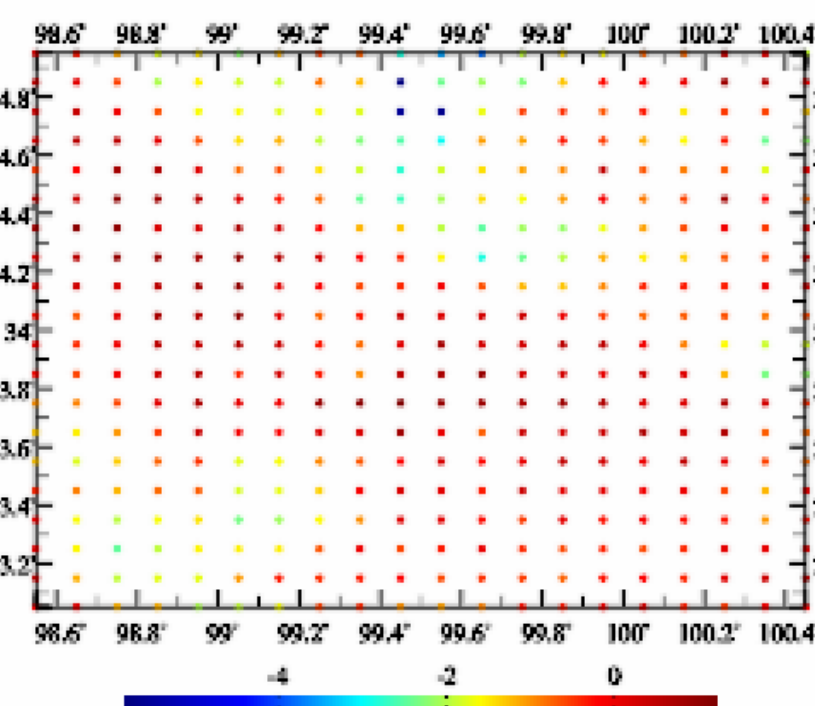
1	98.550000	33.050000	4372.431	0.0056	-0.0969	-8.7481	0.5033	-1.2229
2	98.650000	33.050000	4372.834	0.0347	0.0307	-10.9996	-6.5552	-5.9075
3	98.750000	33.050000	4530.959	-0.0336	-1.1852	-13.1633	-9.3919	5.9238
4	98.850000	33.050000	4567.407	0.0234	-1.1791	-14.0034	-2.3475	-4.6099
5	98.950000	33.050000	4646.551	-0.0401	-2.0462	-15.1799	-4.9229	7.2632
6	99.050000	33.050000	4672.380	-0.0463	-1.9176	-9.1527	2.1447	8.2814



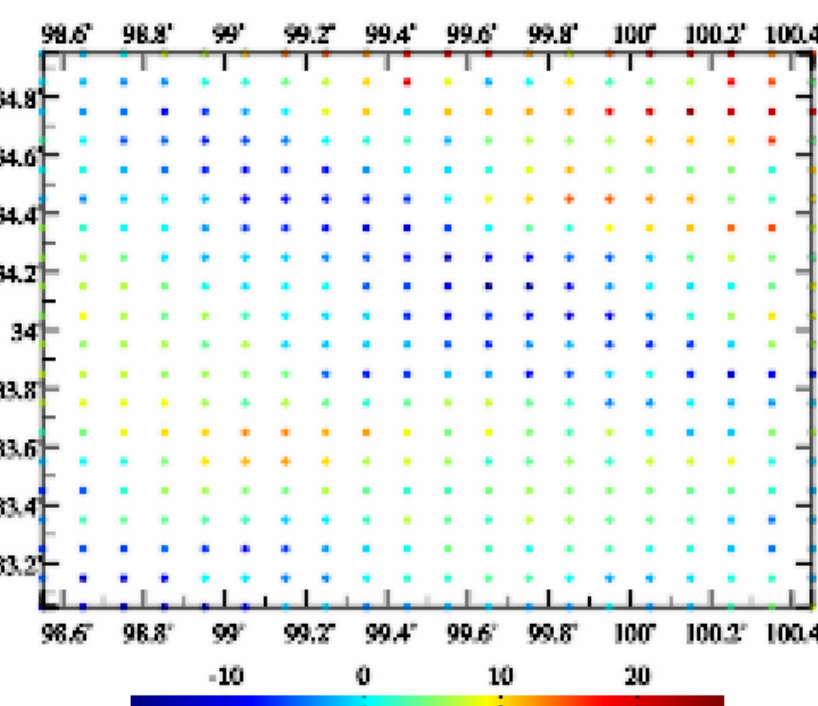
digital elevation model (m)



height anomaly (m)



gravity (anomaly, mGal)



vertical deflection (" , S)

- Since the normal gravity field is invariant, the Terrain Helmert Condensation effects on gravity, gravity disturbance and gravity anomaly are strictly identical.
- Unlike local terrain or complete Bouguer effects, Helmert condensation preserves the total topographic mass. Consequently, the vertical component of the Helmert condensation effect is generally significantly smaller than both the complete Bouguer effect and the local terrain effect.

Rigorous Numerical Integration of Terrain Helmert Condensation Effects on or outside the Geoid

[Rigorous Numerical Integration of Terrain Helmert Condensation Effects on or outside the Geoid](#)

[FFT Algorithm for Terrain Helmert Condensation Effects on or outside the Geoid](#)

[Interactive Calculator for Terrain Helmert Condensation Effects on or outside the Geoid](#)

[Algorithm formulas](#)

Open Ground DEM File

Open Ground Ellipsoidal Height Grid File

Select computation file format

surface ellipsoidal height grid file

Open Computation Surface Ellipsoidal Height Grid File

Select gravity field elements

- ☒ height anomaly (m)
- ☒ gravity (anomaly/disturbance, mGal)
- ☒ vertical deflection (" , SW)
- ☒ disturbing gravity gradient (E, radial)

Integral radius 90 km

>> Computation Process ** Operation Prompts

>> [Function] Computes Terrain Helmert Condensation effects using a rigorous numerical integration algorithm based on Ground DEM and Ground Surface Ellipsoidal Height Grid.

** Input Ground DEM File and Ground Surface Ellipsoidal Height Grid File with the same grid specifications...

>> Open Ground DEM File C:/PAGravf4.5_win64en/examples/TerHelmertcondensat/landtm1m.dat.

>> Ground Surface Ellipsoidal Height Grid File C:/PAGravf4.5_win64en/examples/TerHelmertcondensat/landbmsurfhgt.dat.

>> Open Computation Surface Ellipsoidal Height Grid File C:/PAGravf4.5_win64en/examples/TerHelmertcondensat/landbmsurfhgt.dat.

>> Save the results as C:/PAGravf4.5_win64en/examples/TerHelmertcondensat/surfnintg.dat.

** Automatically generates files with extensions: .ksi (Height Anomaly), .gra (Gravity Anomaly), .rga (Gravity Disturbance), .dft (Vertical Deflection), and *.grr (Gravity Gradient).

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-10 10:22:15

>> Complete the computation of terrain Helmert condensation effects!

>> Computation end time: 2026-04-10 10:35:11

Save the results as

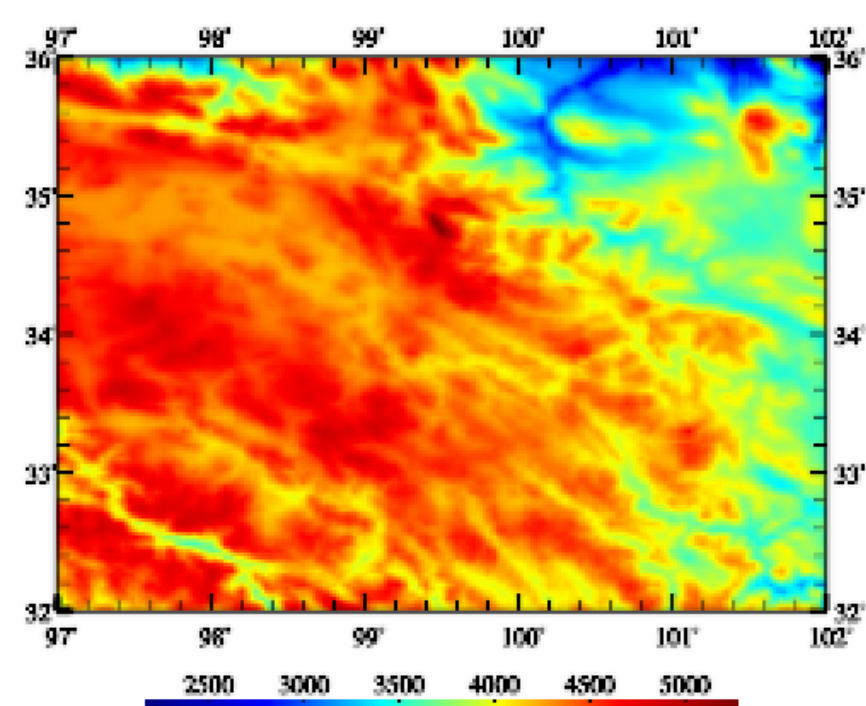
Import setting parameters

Start Computation

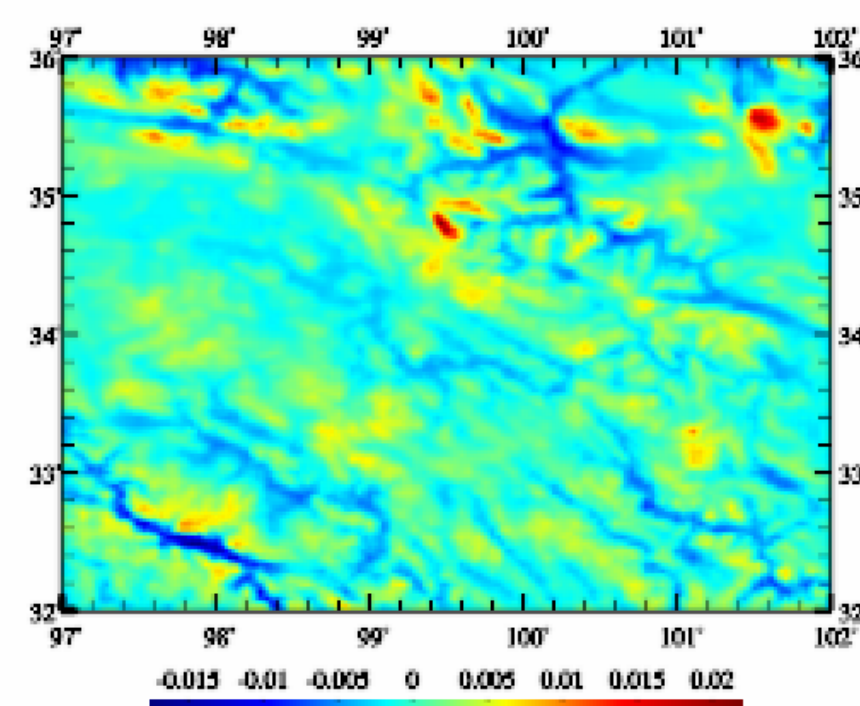
C:/PAGravf4.5_win64en/examples/TerHelmertcondensat/surfnintg.ksi
C:/PAGravf4.5_win64en/examples/TerHelmertcondensat/surfnintg.gra
C:/PAGravf4.5_win64en/examples/TerHelmertcondensat/surfnintg.dft
C:/PAGravf4.5_win64en/examples/TerHelmertcondensat/surfnintg.grr

Extract effects

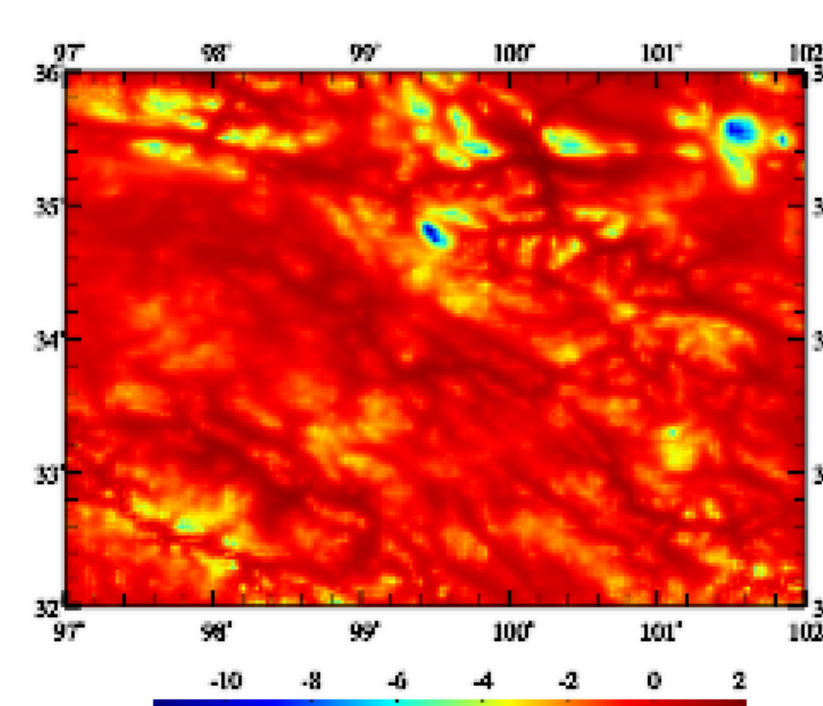
Plot



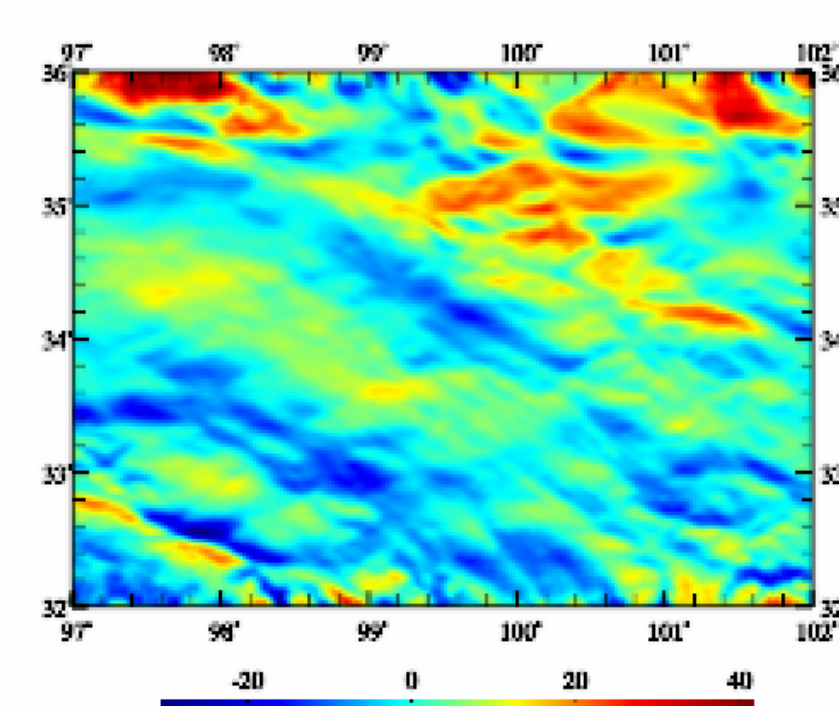
digital elevation model (m)



height anomaly (m)



gravity (anomaly, mGal)



vertical deflection (" , S)

- Since the normal gravity field is invariant, the Terrain Helmert Condensation effects on gravity, gravity disturbance and gravity anomaly are strictly identical.
- Unlike local terrain or complete Bouguer effects, Helmert condensation preserves the total topographic mass. Consequently, the vertical component of the Helmert condensation effect is generally significantly smaller than both the complete Bouguer effect and the local terrain effect.

Table 3.4: Statistical Results of Terrain Helmert Condensation Effects on Various Ground Gravity Field Elements

Field element type /Unit	Mean	Std. Dev. (ϵ)	Minimum	Maximum	D/ ϵ
height anomaly (m)	-0.0005	0.0029	-0.0134	0.0180	1.6
gravity (anomaly, disturbance) (mGal)	0.2932	0.4168	-0.4313	3.1693	8.6
vertical deflection (" , South)	2.0301	6.5718	-17.5982	26.6152	6.8
vertical deflection (" , West)	3.4358	6.5000	-13.6625	28.9665	6.8
gravity gradient (E)	-0.3677	16.5856	-257.5543	112.1249	22.3

Optimal for Gravity Gradients: Due to its enhanced sensitivity to high-frequency signals, the Helmert condensation method demonstrates superior suitability for processing (disturbing) gravity gradient data ($D/\epsilon=22.3$), outperforming the Local Terrain Effect.

Suboptimal for Long-Wavelength Fields: The method is less favorable for elements dominated by medium- and long-wavelength components. Specifically, it is not recommended for geoid refinement, as the excessive high-frequency noise may obscure the broader geoidal undulations required for precise modeling ($D/\epsilon=1.6$).

FFT Algorithm for Terrain Helmert Condensation Effects on or outside the Geoid

Rigorous Numerical Integration of Terrain Helmert Condensation Effects on or outside the Geoid

FFT Algorithm for Terrain Helmert Condensation Effects on or outside the Geoid

Interactive Calculator for Terrain Helmert Condensation Effects on or outside the Geoid

Algorithm formulas

Open Ground DEM File

Open Ground Ellipsoidal Height Grid File

Open Computation Surface Ellipsoidal Height Grid File

Select gravity field elements

- ☒ height anomaly (m)
- ☒ gravity (anomaly/disturbance, mGal)
- ☒ vertical deflection (" , SW)
- ☒ disturbing gravity gradient (E, radial)

Integral radius 90 km

>> Computation Process ** Operation Prompts

```
>> [Function] Computes Terrain Helmert Condensation effects using the Fast Fourier Transform (FFT) integration algorithm.
** Input Input Ground DEM File, Ground Surface Ellipsoidal Height Grid File and Computation Surface Ellipsoidal Height Grid File with the same grid specifications...
>> Open Ground DEM File C:/PAGravf4.5_win64en/examples/TerHelmertcondensat/landtm1m.dat.
>> Ground Surface Ellipsoidal Height Grid File C:/PAGravf4.5_win64en/examples/TerHelmertcondensat/landbmsurfhgt.dat.
>> Open Computation Surface Ellipsoidal Height Grid File C:/PAGravf4.5_win64en/examples/TerHelmertcondensat/landbmsurfhgt.dat.
** Look at the file information in the window below, set the input file format parameters...
>> Compute the terrain Helmert condensation effects using 2D FFT algorithm...
>> Save the results as C:/PAGravf4.5_win64en/examples/TerHelmertcondensat/surfFFT2.txt.
** Automatically generates files with extensions: .ksi (Height Anomaly), .gra (Gravity Anomaly), .rga (Gravity Disturbance), .dft (Vertical Deflection), and *.grr (Gravity Gradient).
>> The parameter settings have been entered into the system!
** Click the [Start Computation] control button, or the [Start Computation] tool button...
>> Computation start time: 2026-04-10 10:39:09
>> Complete the computation of terrain Helmert condensation effects!
```

Fast algorithm 2D FFT

Save the results as

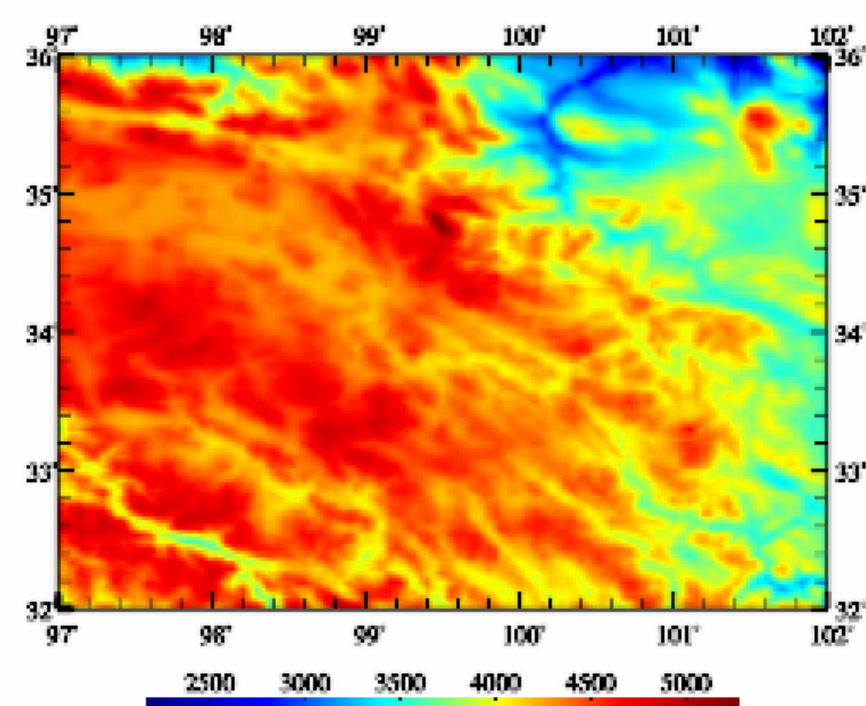
Import setting parameters

Start Computation

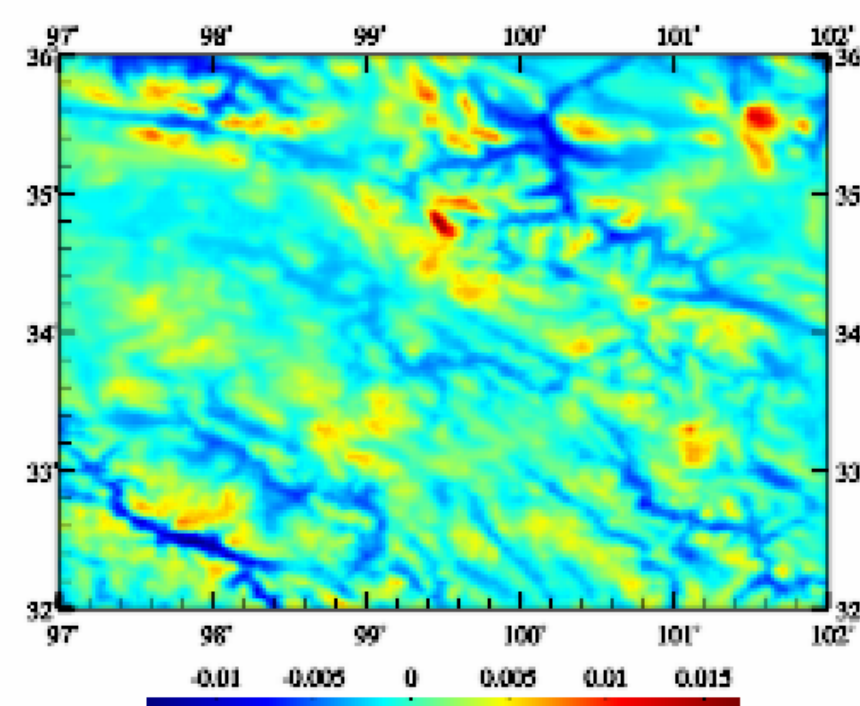
```
C:/PAGravf4.5_win64en/examples/TerHelmertcondensat/surfFFT2.ksi
C:/PAGravf4.5_win64en/examples/TerHelmertcondensat/surfFFT2.gra
C:/PAGravf4.5_win64en/examples/TerHelmertcondensat/surfFFT2.dft
C:/PAGravf4.5_win64en/examples/TerHelmertcondensat/surfFFT2.grr
```

Extract effects

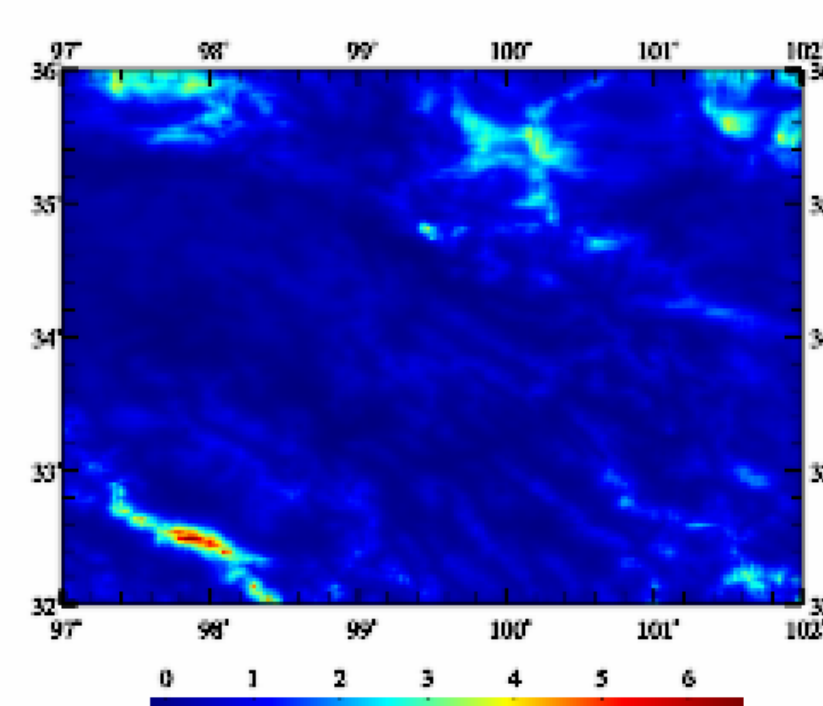
Plot



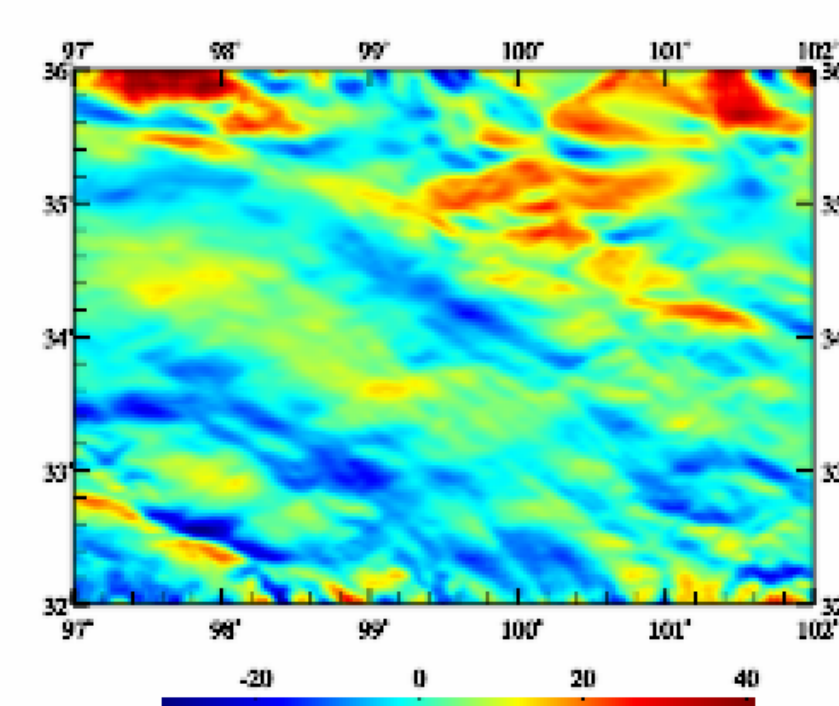
digital elevation model (m)



height anomaly (m)



gravity (anomaly, mGal)



vertical deflection (" , S)

- Since the normal gravity field is invariant, the Terrain Helmert Condensation effects on gravity, gravity disturbance and gravity anomaly are strictly identical.
- Unlike local terrain or complete Bouguer effects, Helmert condensation preserves the total topographic mass. Consequently, the vertical component of the Helmert condensation effect is generally significantly smaller than both the complete Bouguer effect and the local terrain effect.

FFT Algorithm for Terrain Helmert Condensation Effects on or outside the Geoid

Rigorous Numerical Integration of Terrain Helmert Condensation Effects on or outside the Geoid

FFT Algorithm for Terrain Helmert Condensation Effects on or outside the Geoid

Interactive Calculator for Terrain Helmert Condensation Effects on or outside the Geoid

Algorithm formulas

Open Ground DEM File

Open Ground Ellipsoidal Height Grid File

Open Computation Surface Ellipsoidal Height Grid File

Select gravity field elements

- ☒ height anomaly (m)
- ☒ gravity (anomaly/disturbance, mGal)
- ☒ vertical deflection (" , SW)
- ☒ disturbing gravity gradient (E, radial)

Integral radius 90 km

>> Computation Process ** Operation Prompts

>> [Function] Computes Terrain Helmert Condensation effects using the Fast Fourier Transform (FFT) integration algorithm.

** Input Input Ground DEM File, Ground Surface Ellipsoidal Height Grid File and Computation Surface Ellipsoidal Height Grid File with the same grid specifications...

>> Open Ground DEM File C:/PAGravf4.5_win64en/examples/TerHelmertcondensat/landtm1m.dat.

>> Ground Surface Ellipsoidal Height Grid File C:/PAGravf4.5_win64en/examples/TerHelmertcondensat/landbmsurfhgt.dat.

>> Open Computation Surface Ellipsoidal Height Grid File C:/PAGravf4.5_win64en/examples/TerHelmertcondensat/landbmsurfhgt.dat.

** Look at the file information in the window below, set the input file format parameters...

>> Compute the terrain Helmert condensation effects using 1D FFT algorithm...

>> Save the results as C:/PAGravf4.5_win64en/examples/TerHelmertcondensat/surfFFT1.txt.

** Automatically generates files with extensions: .ksi (Height Anomaly), .gra (Gravity Anomaly), .rga (Gravity Disturbance), .vdf (Vertical Deflection), and *.grr (Gravity Gradient).

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button.

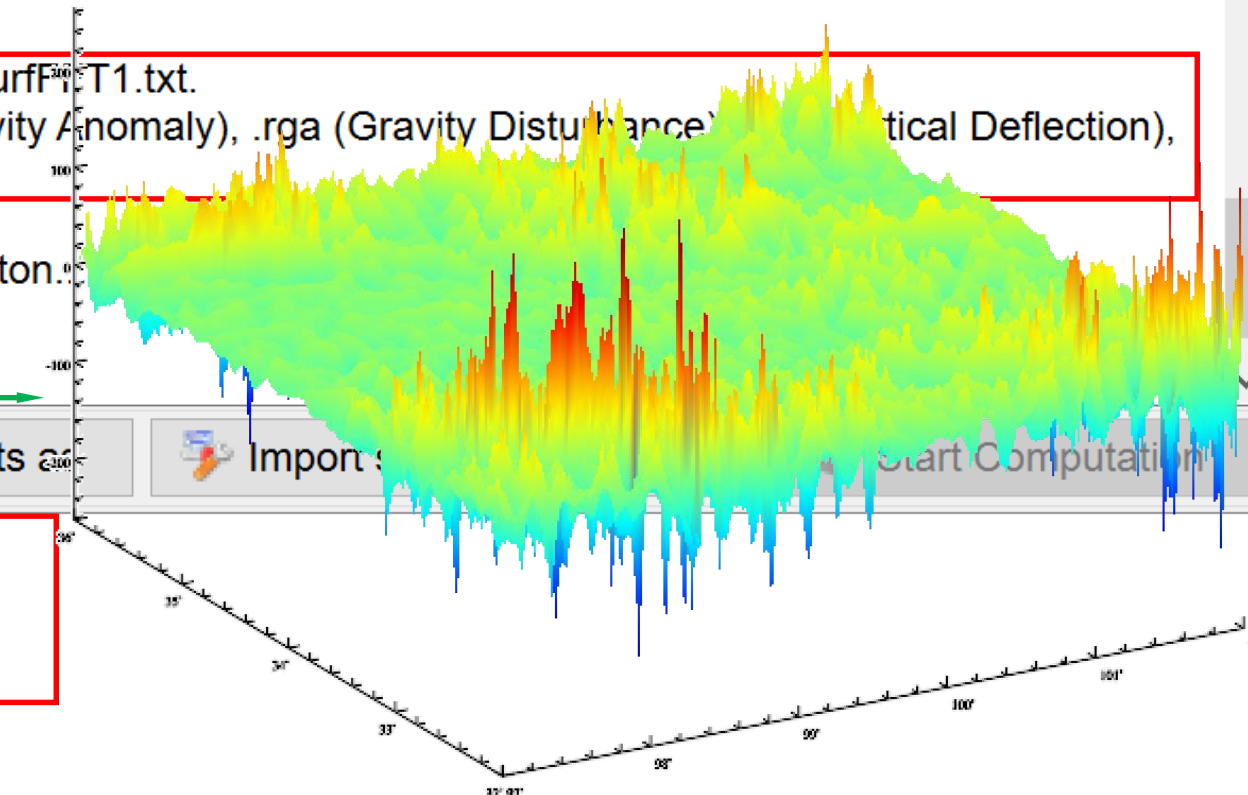
>> Computation start time: 2026-04-10 10:42:06

>> Complete the computation of terrain Helmert condensation effects!

Fast algorithm 1D FFT

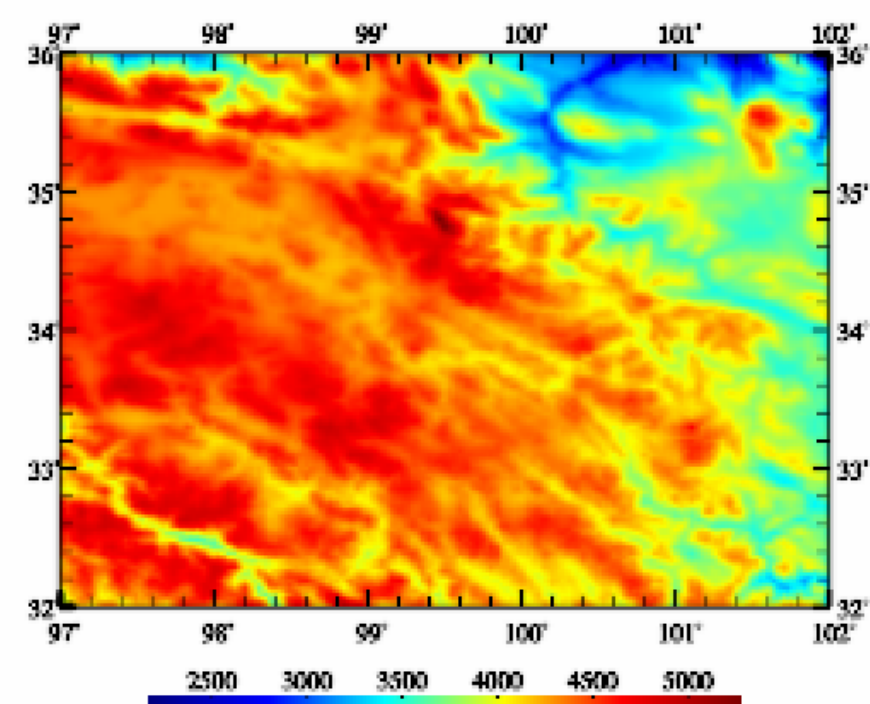
Save the results as

C:/PAGravf4.5_win64en/examples/TerHelmertcondensat/surfFFT1.ksi
C:/PAGravf4.5_win64en/examples/TerHelmertcondensat/surfFFT1.gra
C:/PAGravf4.5_win64en/examples/TerHelmertcondensat/surfFFT1.dft
C:/PAGravf4.5_win64en/examples/TerHelmertcondensat/surfFFT1.grr

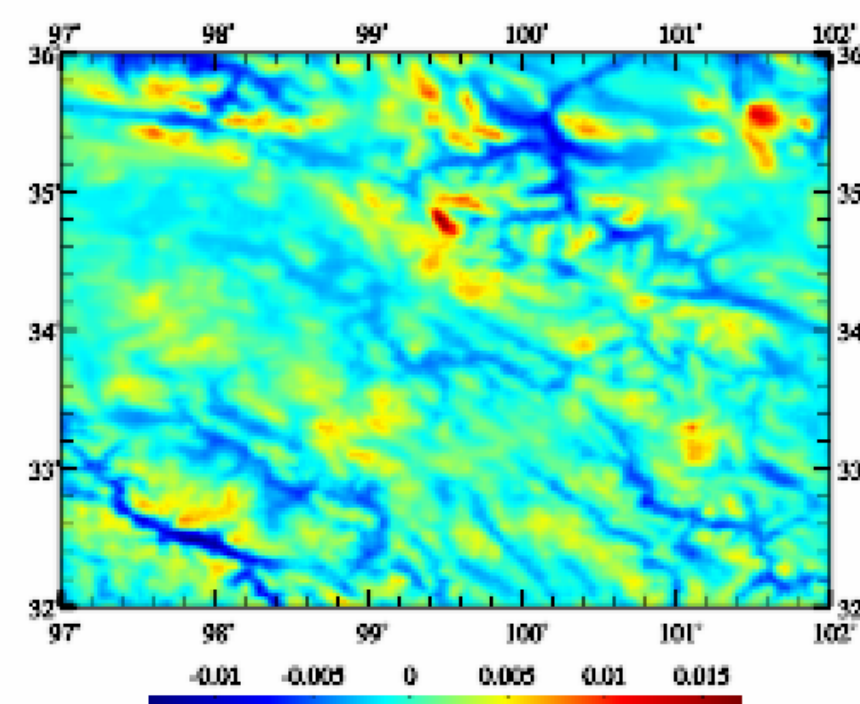


Extract effects

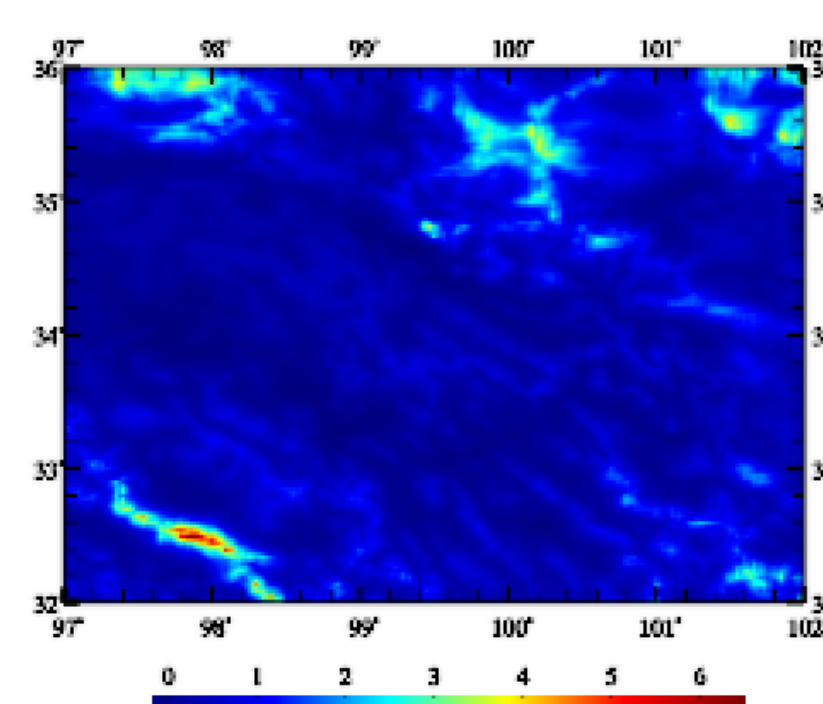
Plot↓



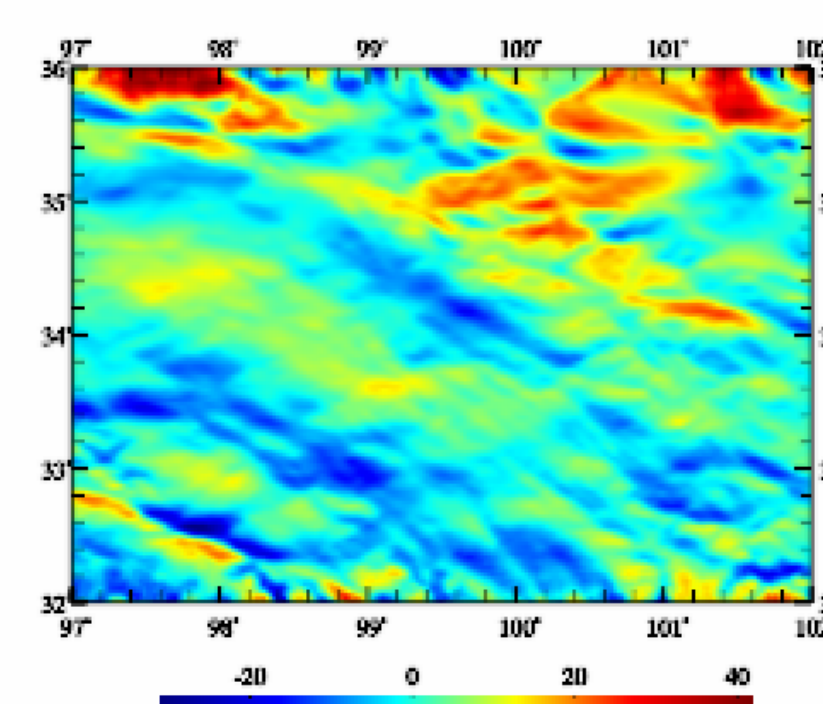
digital elevation model (m)



height anomaly (m)



gravity (anomaly, mGal)



vertical deflection (" , S)

- Since the normal gravity field is invariant, the Terrain Helmert Condensation effects on gravity, gravity disturbance and gravity anomaly are strictly identical.
- Unlike local terrain or complete Bouguer effects, Helmert condensation preserves the total topographic mass. Consequently, the vertical component of the Helmert condensation effect is generally significantly smaller than both the complete Bouguer effect and the local terrain effect.

Table 3.5: Statistics for the differences between FFT results and rigorous numerical integration

Field Element / Unit	Algorithm	Mean Diff	Std. Dev. Diff	Min Diff	Max Diff
height anomaly (m)	FFT2	0.0008	0.0015	-0.0026	0.0064
	FFT1	0.0007	0.0015	-0.0027	0.0063
gravity (anomaly, disturbance) (mGal)	FFT2	0.0009	0.1262	-0.5535	0.6116
	FFT1	0.0025	0.1255	-0.5085	0.6768
vertical deflection (" , South)	FFT2	-0.0174	0.0404	-0.2220	0.1438
	FFT1	-0.0062	0.0240	-0.2359	0.2179
vertical deflection (" , West)	FFT2	0.0025	0.0804	-0.5046	0.2902
	FFT1	0.0093	0.0306	-0.6211	0.4129
gravity gradient (E)	FFT2	0.0062	0.4810	-17.1773	9.8987
	FFT1	0.0062	0.4799	-16.8811	9.8312

The discrepancies between the rigorous numerical integration and the fast FFT algorithms are negligible.

No significant difference exists between the 1D-FFT and 2D-FFT implementations.

Interactive Calculator for Terrain Helmert Condensation Effects on or outside the Geoid

 Open Ground DEM File

 Open Ground Ellipsoidal Height Grid File

Input geodetic coordinates of calculation point

longitude

latitude

ellipsoidal height

Integral radius

 Start calculation

Ground digital elevation model

97.000000	102.000000	32.000000	36.000000	0.01666667	0.01666667
3988.0003	4048.9987	4129.9921	4151.9956	4155.9995	4177.9995
4277.9980	4373.9953	4466.9865	4479.9931	4520.9918	4547.9918
4242.0005	4229.0008	4211.0001	4165.0054	4150.0047	4157.0047
4429.0008	4511.9959	4529.9991	4531.0014	4539.9993	4531.9993
4273.0028	4221.0056	4196.0075	4196.0093	4251.0050	4337.9993
4643.9962	4607.0004	4607.0004	4607.0004	4457.0003	4379.9993
4500.0065	4593.9997	4593.9997	4593.9997	4585.9976	4473.0003
4272.0146	4409.0000	4409.0000	4409.0000	4647.0046	4729.0000
4530.9966	4409.0000	4409.0000	4409.0000	4160.0042	4071.0000
4371.0006	4423.0000	4423.0000	4423.0000	4520.9994	4520.9994
3868.0107	3954.9993	3954.9993	3954.9993	4124.0000	4124.0000
4243.0076	4270.0056	4270.0056	4270.0056	4347.9993	4347.9993
4161.9980	4182.9937	4182.9937	4182.9937	4040.0000	4040.0000
4050.9965	4023.0017	4023.0017	4023.0017	4235.0000	4235.0000
4051.0030	4022.0027	4022.0027	4022.0027	3996.0000	3996.0000
4299.0025	4415.9991	4415.9991	4415.9991	4431.9993	4431.9993
3672.0205	3912.9978	3912.9978	3912.9978	4374.9993	4374.9993
4389.9975	4386.9989	4386.9989	4386.9989	4337.9993	4337.9993
4185.9964	4135.0004	4135.0004	4135.0004	4110.9993	4110.9993
4310.9929	4297.9951	4297.9951	4297.9951	4242.9993	4242.9993
3884.0033	3950.0001	3950.0001	3950.0001	4160.9993	4160.9993
4240.0001	4300.0001	4300.0001	4300.0001	4373.0000	4373.0000

Terrain Helmert condensation effect results

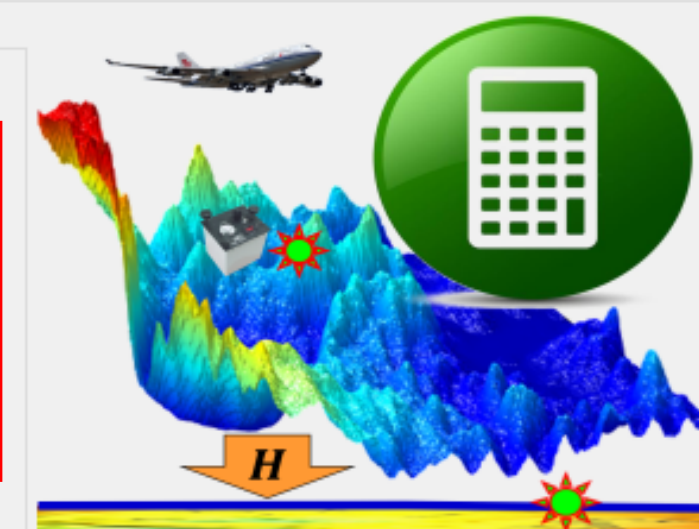
height anomaly (m)

gravity (anomaly/disturbance, mGal)

vertical deflection (" , S)

vertical deflection (" , W)

(disturbing) gradient (E, radial)



Workflow

- (1) Data Loading: Load DEM and Ground Ellipsoidal Height Grid (share grid specs). The [Start Calculation] button activates upon loading.
- (2) Real-Time Computation: Enter geodetic coordinates; the system instantly calculates and displays effects for all selected elements.
- (3) Dynamic Updates: Users can dynamically swap input files or adjust the Integration Radius. Changes take effect immediately.

Interactive Calculator for Terrain Helmert Condensation Effects on or outside the Geoid

 Open Ground DEM File

 Open Ground Ellipsoidal Height Grid File

Input geodetic coordinates of calculation point

longitude

latitude

ellipsoidal height

Integral radius

 Start calculation

Ground digital elevation model

97.000000	102.000000	32.000000	36.000000	0.01666667	0.01666667
3988.0003	4048.9987	4129.9921	4151.9956	4155.9995	4177.9995
4277.9980	4373.9953	4466.9865	4479.9931	4520.9918	4547.9918
4242.0005	4229.0008	4211.0001	4165.0054	4150.0047	4157.0047
4429.0008	4511.9959	4529.9991	4531.0014	4539.9993	4531.9993
4273.0028	4221.0056	4196.0075	4195.0093	4251.0050	4337.9993
4643.9962	4607.0004	4605.9961	4595.9886	4457.0003	4379.9993
4500.0065	4593.9997	4655.9959	4655.9989	4585.9976	4473.0003
4272.0146	4221.0057	4196.0075	4195.0081	4647.0046	4729.0003
4530.9966	4530.9966	4530.9966	4530.9966	4160.0042	4071.0003
4371.0006	4371.0006	4371.0006	4371.0006	4493.9994	4520.9993
3868.0107	3868.0107	3868.0107	3868.0107	4071.0003	4124.0003
4243.0076	4243.0076	4243.0076	4243.0076	4157.0047	4347.9993
4161.9980	4161.9980	4161.9980	4161.9980	4157.0047	4040.0003
4050.9965	4023.0003	4023.0003	4023.0003	4157.0047	4235.0003
4051.0030	4022.0003	4022.0003	4022.0003	4157.0047	3996.0003
4299.0025	4415.9991	4415.9991	4415.9991	4458.0037	4431.9993
3672.0205	3912.9978	3912.9978	3912.9978	4313.9938	4374.9993
4389.9975	4386.9989	4386.9989	4382.9967	4358.9980	4337.9993
4185.9964	4135.0004	4099.9998	4073.9998	4073.9986	4110.9993
4310.9929	4297.9951	4309.9918	4309.9894	4250.9985	4242.9993
3884.0033	3950.0001	4024.9995	4076.0000	4119.0000	4160.9993
4240.0001	4300.0001	4352.9995	4350.0033	4355.0002	4373.0003

Terrain Helmert condensation effect results

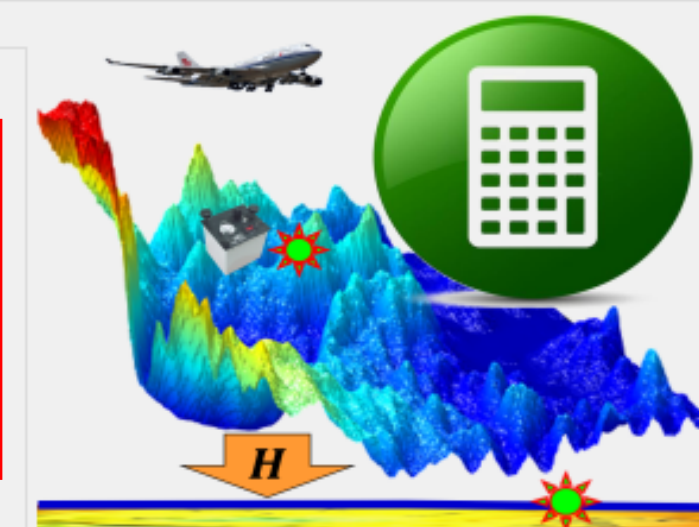
height anomaly (m)

gravity (anomaly/disturbance, mGal)

vertical deflection (" , S)

vertical deflection (" , W)

(disturbing) gradient (E, radial)



Workflow

- (1) Data Loading: Load DEM and Ground Ellipsoidal Height Grid (share grid specs). The [Start Calculation] button activates upon loading.
- (2) Real-Time Computation: Enter geodetic coordinates; the system instantly calculates and displays effects for all selected elements.
- (3) Dynamic Updates: Users can dynamically swap input files or adjust the Integration Radius. Changes take effect immediately.

Rigorous Numerical Integration of Land-Sea Residual Terrain Effects on or outside the Geoid

 **Rigorous Numerical Integration of Land-Sea Residual Terrain Effects on or outside the Geoid**

 **FFT Algorithm for Land-Sea Residual Terrain Effects on or outside the Geoid**

 **Interactive Calculator for Unified Land-Sea Residual Terrain Effects on or outside the Geoid**

 **Algorithm formulas**

 **Open High-Resolution Land-Sea Terrain Model File**

 **Open Low-Pass Land-Sea Terrain Model File**

 **Open Land-Sea Surface Ellipsoidal Height Grid File**

Select computation file format

space computation point file

 **Open Space Computation Point File**

Set input point file format

Number of rows of file header 1

Ellipsoidal Height Column Index 4

Select gravity field elements

☒ height anomaly (m)

☒ gravity (anomaly/disturbance, mGal)

☒ vertical deflection (" , SW)

☒ disturbing gravity gradient (E, radial)

Integral radius 90 km

>> Computation Process ** Operation Prompts

long-wavelength signals, thereby optimizing the approximation performance of the gravity field.

>> [Function] Computes RTEs using rigorous numerical integration based on the high-resolution and low-pass terrain models.

** The program computes the Residual Terrain Model (RTM) by subtracting the low-pass model from the high-resolution model (both must share identical grid specs). The high-resolution model is employed to distinguish terrestrial and marine domains.

>> Open High-Resolution Land-Sea Terrain Model File C:/PAGrav4.5_win64en/examples/Renterrianeffect/landtm1m.dat.

>> Open Low-Pass Land-Sea Terrain Model File C:/PAGrav4.5_win64en/examples/Renterrianeffect/landtm1mlvb.dat.

>> Open Land-Sea Surface Ellipsoidal Height Grid File C:/PAGrav4.5_win64en/examples/Renterrianeffect/landbmsurfhgt.dat.

>> Open Space Computation Point File C:/PAGrav4.5_win64en/examples/Renterrianeffect/surfhgt.txt.

** Look at the file information in the window below, set the input file format parameters...

>> Save the results as C:/PAGrav4.5_win64en/examples/Renterrianeffect/result.txt.

** Appends RTE values (4 significant figures) to discrete records.

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-10 11:14:52

>> Complete the computation of land-sea unified residual terrain effects!

>> Computation end time: 2026-04-10 11:14:55

 Save the results as

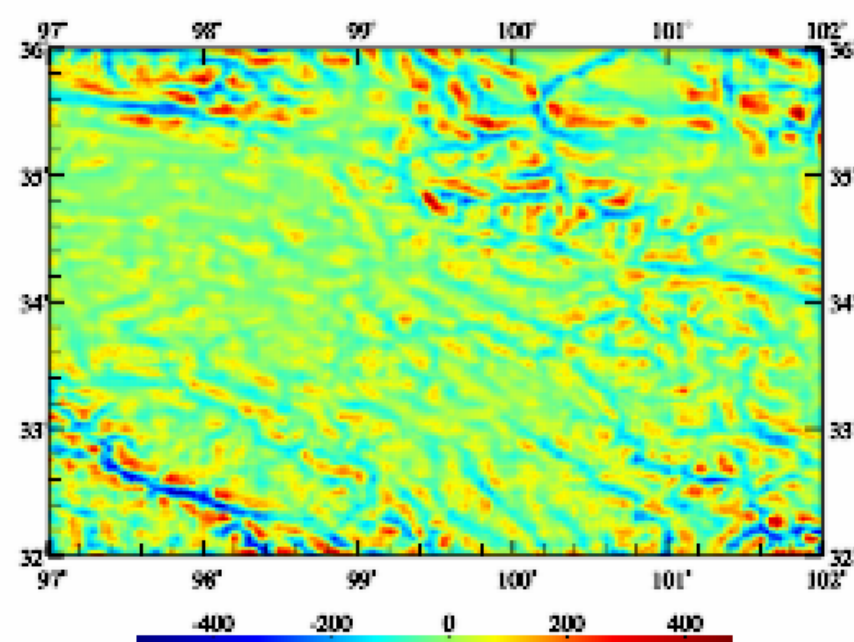
 Import setting parameters

 Start Computation

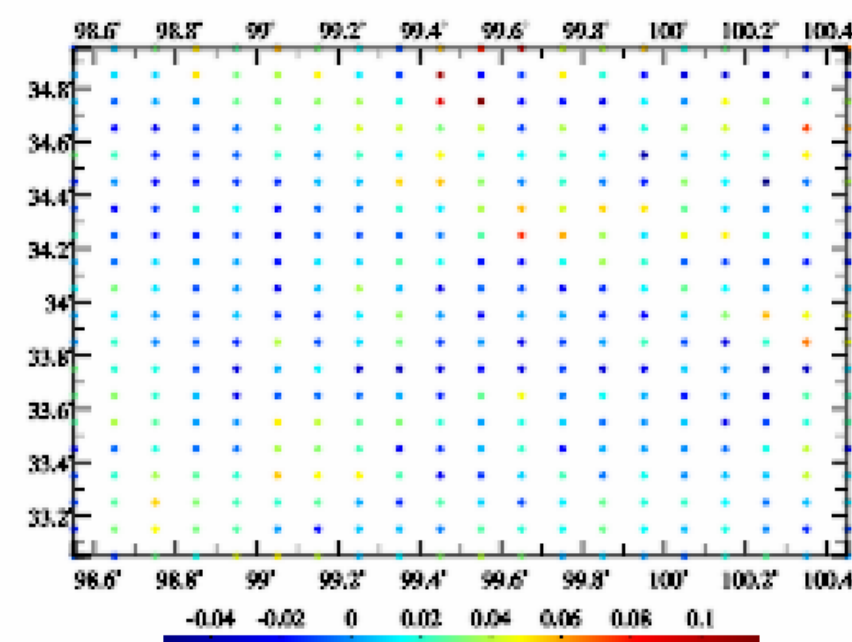
number	long(deg/decimal)	lat	ellipHeight(m)					
1	98.550000	33.050000	4372.431	-0.0064	-0.0821	-0.4948	1.6642	9.6285
2	98.650000	33.050000	4372.834	-0.0128	-0.0748	-0.1234	0.1747	53.4893
3	98.750000	33.050000	4530.959	0.0292	-0.3837	-0.3162	-1.3952	-50.7005
4	98.850000	33.050000	4567.407	0.0166	-0.5441	-0.6622	0.5086	66.8856
5	98.950000	33.050000	4646.551	0.0452	-0.7076	-1.6590	-1.6979	-60.9009
6	99.050000	33.050000	4672.380	0.0490	-0.6732	-0.4186	0.3348	-75.5007
7	99.150000	33.050000	4611.765	0.0407	-1.0746	1.6103	0.5141	-111.7206
8	99.250000	33.050000	4475.199	0.0054	-0.2256	1.0146	0.8318	38.8497

 Extract effects

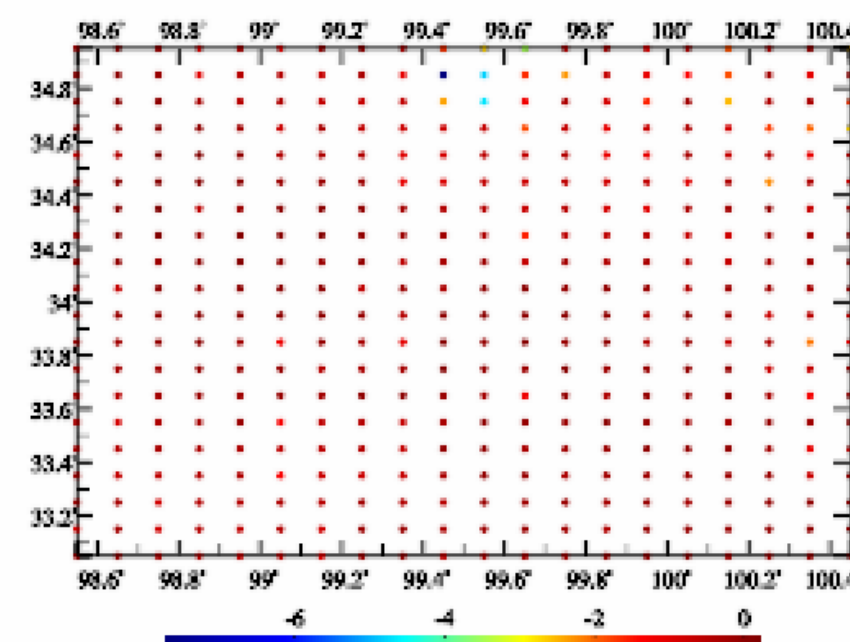
 Plot↓



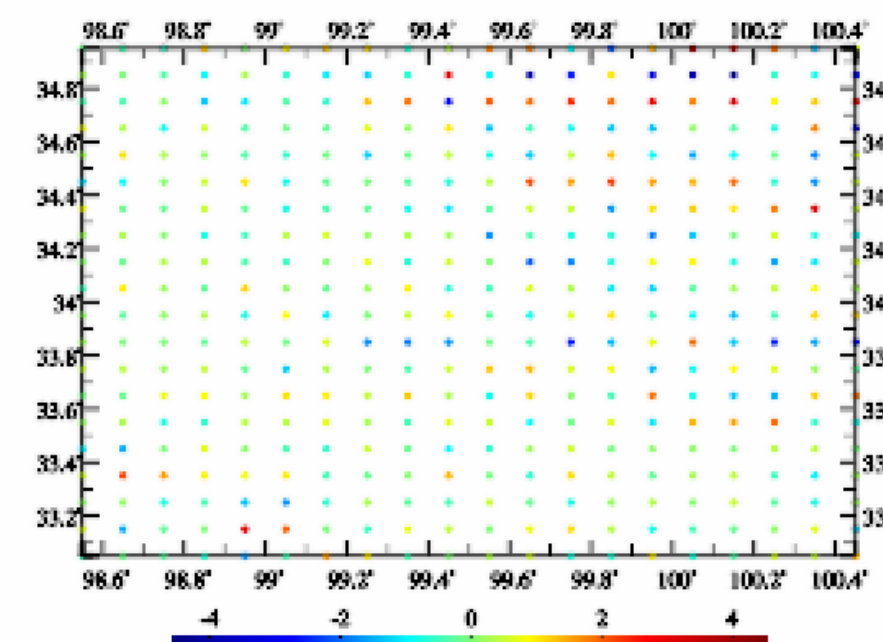
residual terrain model (m)



height anomaly (m)



gravity (anomaly, mGal)



vertical deflection (" , S)

 The Land-Sea Residual Terrain Effect is defined as the aggregate of the short-wavelength and ultra-short-wavelength spectral components of the land-sea complete Bouguer effect.

 Given the invariance of the normal gravity field, RTEs on gravity disturbance and gravity anomaly are strictly equivalent to the RTE on gravity itself.

Rigorous Numerical Integration of Land-Sea Residual Terrain Effects on or outside the Geoid

Rigorous Numerical Integration of Land-Sea Residual Terrain Effects on or outside the Geoid

FFT Algorithm for Land-Sea Residual Terrain Effects on or outside the Geoid

Interactive Calculator for Unified Land-Sea Residual Terrain Effects on or outside the Geoid

Algorithm formulas

Open High-Resolution Land-Sea Terrain Model File

Open Low-Pass Land-Sea Terrain Model File

Open Land-Sea Surface Ellipsoidal Height Grid File

Select computation file format

surface ellipsoidal height grid file

Open Computation Surface Ellipsoidal Height Grid File

Select gravity field elements

- ☒ height anomaly (m)
- ☒ gravity (anomaly/disturbance, mGal)
- ☒ vertical deflection (" , SW)
- ☒ disturbing gravity gradient (E, radial)

Integral radius 90 km

>> Computation Process ** Operation Prompts

```
>> Complete the computation of land-sea unified residual terrain effects!
>> Computation end time: 2026-04-10 11:14:55
>> [Function] Computes RTEs using rigorous numerical integration based on the high-resolution and low-pass terrain models.
    ** The program computes the Residual Terrain Model (RTM) by subtracting the low-pass model from the high-resolution model (both must share identical grid specs). The high-resolution model is employed to distinguish terrestrial and marine domains.
>> Open High-Resolution Land-Sea Terrain Model File C:/PAGravf4.5_win64en/examples/Renterrianeffect/landtm1m.dat.
>> Open Low-Pass Land-Sea Terrain Model File C:/PAGravf4.5_win64en/examples/Renterrianeffect/landtm1mlvb.dat.
>> Open Land-Sea Surface Ellipsoidal Height Grid File C:/PAGravf4.5_win64en/examples/Renterrianeffect/landbmsurfhgt.dat.
>> Open Computation Surface Ellipsoidal Height Grid File C:/PAGravf4.5_win64en/examples/Renterrianeffect/landbmsurfhgt.dat.
>> Save the results as C:/PAGravf4.5_win64en/examples/Renterrianeffect/surfnintg.txt.
    ** Generates .ksi, .gra, .dft, .grr grid files in the current directory.
>> The parameter settings have been entered into the system!
    ** Click the [Start Computation] control button, or the [Start Computation] tool button...
>> Computation start time: 2026-04-10 11:16:38
>> Complete the computation of land-sea unified residual terrain effects!
>> Computation end time: 2026-04-10 11:24:23
```

Save the results as

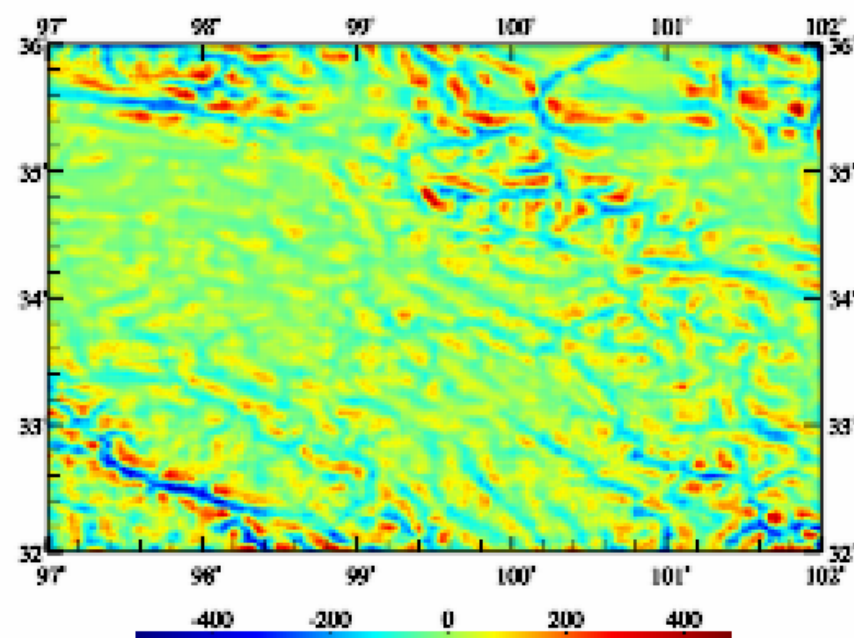
Import setting parameters

Start Computation

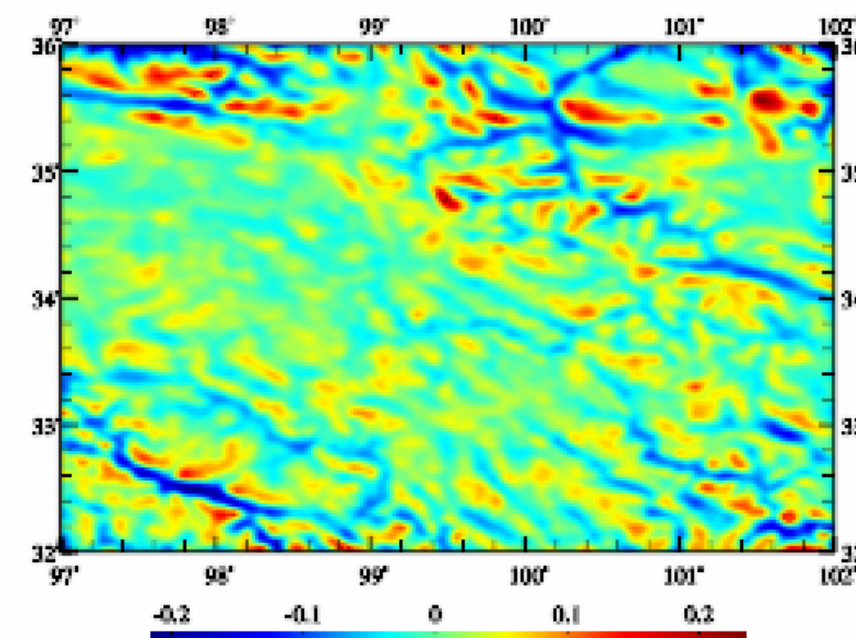
```
C:/PAGravf4.5_win64en/examples/Renterrianeffect/surfnintg.ksi
C:/PAGravf4.5_win64en/examples/Renterrianeffect/surfnintg.gra
C:/PAGravf4.5_win64en/examples/Renterrianeffect/surfnintg.dft
C:/PAGravf4.5_win64en/examples/Renterrianeffect/surfnintg.grr
```

Extract effects

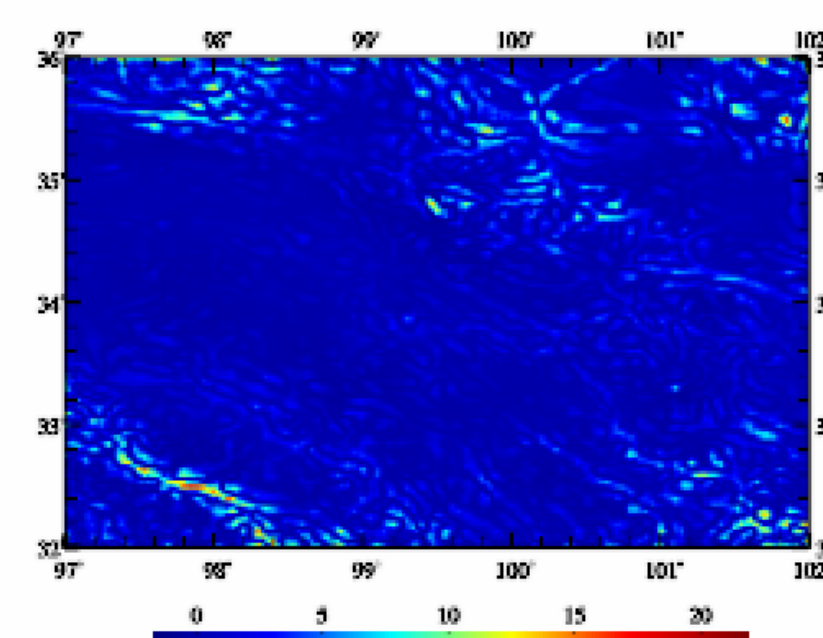
Plot↓



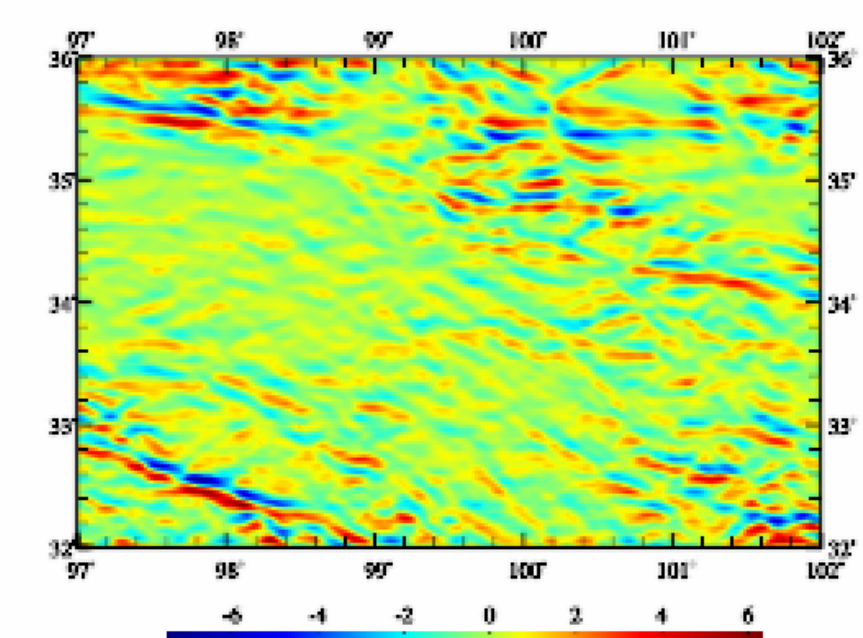
residual terrain model (m)



height anomaly (m)



gravity (anomaly, mGal)



vertical deflection (" , S)

- The Land-Sea Residual Terrain Effect is defined as the aggregate of the short-wavelength and ultra-short-wavelength spectral components of the land-sea complete Bouguer effect.
- Given the invariance of the normal gravity field, RTEs on gravity disturbance and gravity anomaly are strictly equivalent to the RTE on gravity itself.

Table 3.6: Statistical Results of Land-sea Residual Terrain Effects on Various Ground Gravity Field Elements

Field element type /Unit	Mean	Std. Dev. (ϵ)	Minimum	Maximum	D/ ϵ
height anomaly /m	0.0188	0.0566	-0.2151	0.3835	10.2
gravity(anomaly, disturbance) /mGal	0.5342	1.0570	-1.6605	13.2024	14.1
vertical deflection /S''	-0.0000	0.8730	-4.7838	4.6030	10.8
vertical deflection /W''	-0.0075	0.8157	-6.2512	5.1511	14.0
(disturbing) gravity gradient /E	-7.0310	300.1898	-928.6079	884.6364	6.0

Geoid Modeling: RTE is highly favorable for height anomaly determination ($D/\epsilon=10.2$), as it preserves relevant medium-to-long wavelengths while removing smooth references.

Vertical Deflection: Suitable for processing vertical deflection data (e.g., satellite altimetry), showing balanced signal content ($D/\epsilon \approx 10.8$ to 14.0).

Gravity Gradients: Less favorable($D/\epsilon=6.0$).

FFT Algorithm for Land-Sea Residual Terrain Effects on or outside the Geoid

Rigorous Numerical Integration of Land-Sea Residual Terrain Effects on or outside the Geoid

FFT Algorithm for Land-Sea Residual Terrain Effects on or outside the Geoid

Interactive Calculator for Unified Land-Sea Residual Terrain Effects on or outside the Geoid

Algorithm formulas

Open High-Resolution Land-Sea Terrain Model File

Open Low-Pass Land-Sea Terrain Model File

Open Land-Sea Surface Ellipsoidal Height Grid File

Open Computation Surface Ellipsoidal Height Grid File

Select gravity field elements

- ☒ height anomaly (m)
- ☒ gravity (anomaly/disturbance, mGal)
- ☒ vertical deflection (" , SW)
- ☒ disturbing gravity gradient (E, radial)

Integral radius 90 km

>> Computation Process ** Operation Prompts

```
>> Computation end time: 2026-04-10 11:24:23
>> [Function] Computes RTEs using the Fast Fourier Transform (FFT) integration algorithm.
** The program computes the Residual Terrain Model (RTM) by subtracting the low-pass model from the high-resolution model (both must share identical grid specs). The high-resolution model is employed to distinguish terrestrial and marine domains.
>> Open High-Resolution Land-Sea Terrain Model File C:/PAGravf4.5_win64en/examples/Renterrianeffect/landtm1m.dat.
>> Open Low-Pass Land-Sea Terrain Model File C:/PAGravf4.5_win64en/examples/Renterrianeffect/landtm1mlvb.dat.
>> Open Land-Sea Surface Ellipsoidal Height Grid File C:/PAGravf4.5_win64en/examples/Renterrianeffect/landbmsurfhgt.dat.
>> Open Computation Surface Ellipsoidal Height Grid File C:/PAGravf4.5_win64en/examples/Renterrianeffect/landbmsurfhgt.dat.
>> Compute the land-sea unified residual terrain effects using 2D FFT algorithm...
>> Save the results as C:/PAGravf4.5_win64en/examples/Renterrianeffect/surfFFT2.txt.
** Generates .ksi, .gra, .dft, .grr grid files in the current directory.
>> The parameter settings have been entered into the system!
** Click the [Start Computation] control button, or the [Start Computation] button.
>> Computation start time: 2026-04-10 11:31:54
>> Complete the computation of land-sea unified residual terrain effects!
>> Computation end time: 2026-04-10 11:32:49
```

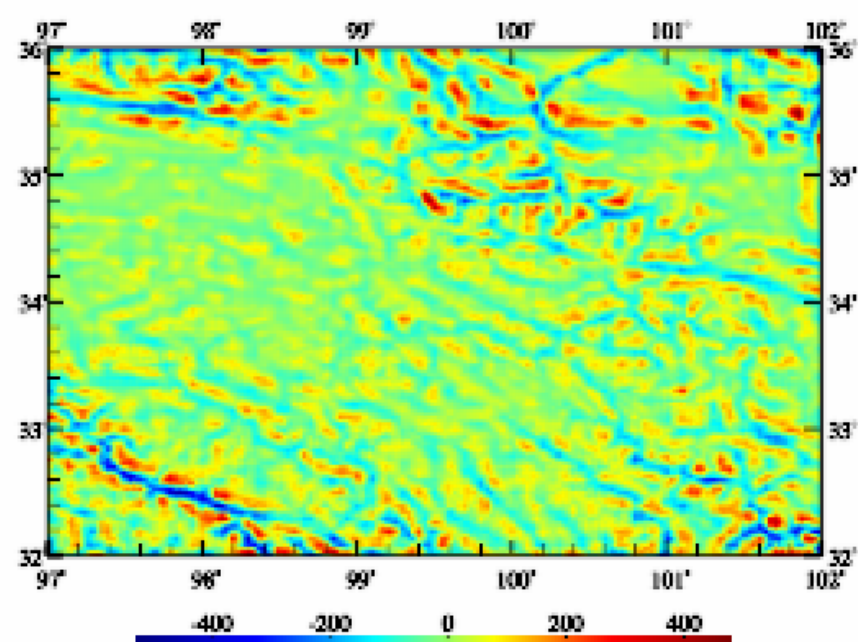
Fast algorithm 2D FFT

Save the results as

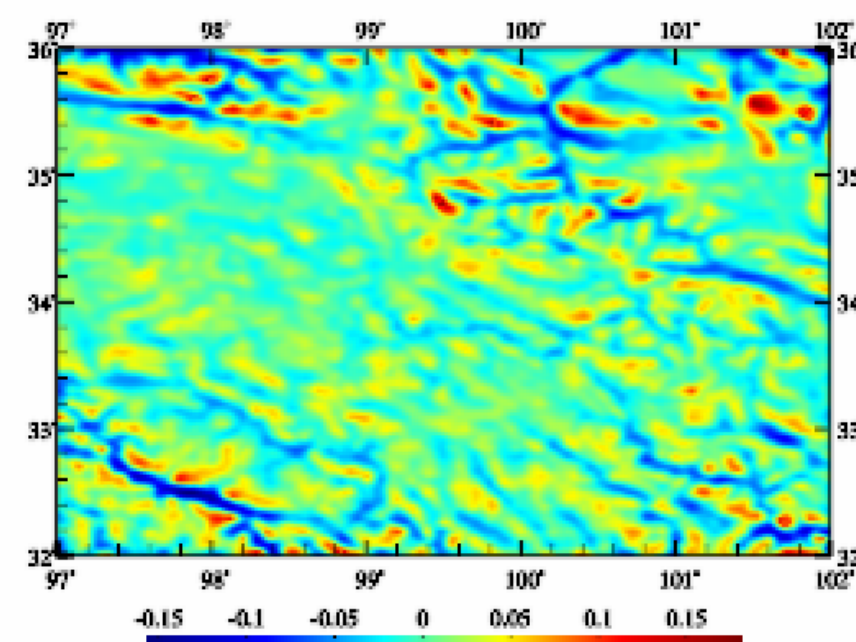
```
C:/PAGravf4.5_win64en/examples/Renterrianeffect/surfFFT2.ksi
C:/PAGravf4.5_win64en/examples/Renterrianeffect/surfFFT2.gra
C:/PAGravf4.5_win64en/examples/Renterrianeffect/surfFFT2.dft
C:/PAGravf4.5_win64en/examples/Renterrianeffect/surfFFT2.grr
```

Extract effects

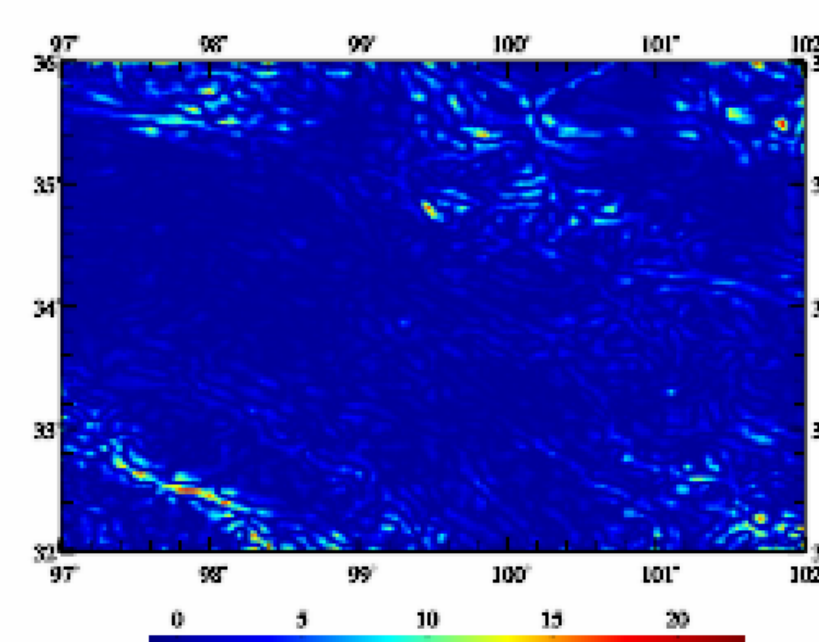
Plot



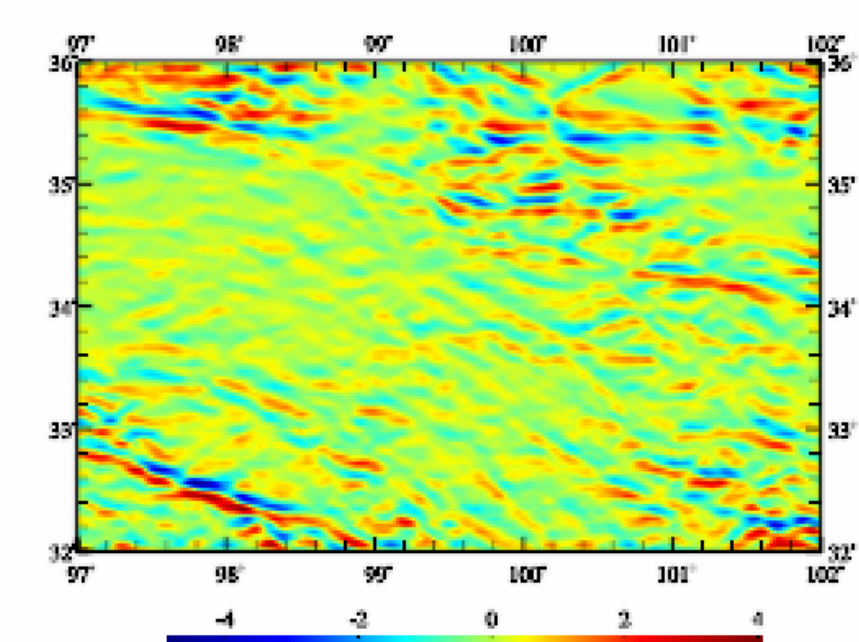
residual terrain model (m)



height anomaly (m)



gravity (anomaly, mGal)



vertical deflection (" , S)

- The Land-Sea Residual Terrain Effect is defined as the aggregate of the short-wavelength and ultra-short-wavelength spectral components of the land-sea complete Bouguer effect.
- Given the invariance of the normal gravity field, RTEs on gravity disturbance and gravity anomaly are strictly equivalent to the RTE on gravity itself.

FFT Algorithm for Land-Sea Residual Terrain Effects on or outside the Geoid

Open DTM Import parameters Save as Start computation Save process Follow example

Rigorous Numerical Integration of Land-Sea Residual Terrain Effects on or outside the Geoid

FFT Algorithm for Land-Sea Residual Terrain Effects on or outside the Geoid

Interactive Calculator for Unified Land-Sea Residual Terrain Effects on or outside the Geoid

Algorithm formulas

Open High-Resolution Land-Sea Terrain Model File

Open Low-Pass Land-Sea Terrain Model File

Open Land-Sea Surface Ellipsoidal Height Grid File

Open Computation Surface Ellipsoidal Height Grid File

Select gravity field elements

- ☒ height anomaly (m)
- ☒ gravity (anomaly/disturbance, mGal)
- ☒ vertical deflection (" , SW)
- ☒ disturbing gravity gradient (E, radial)

Integral radius 90 km

>> Computation Process ** Operation Prompts

```
>> Computation end time: 2026-04-10 11:32:49
>> [Function] Computes RTEs using the Fast Fourier Transform (FFT) integration algorithm.
** The program computes the Residual Terrain Model (RTM) by subtracting the low-pass model from the high-resolution model (both must share identical grid specs). The high-resolution model is employed to distinguish terrestrial and marine domains.
>> Open High-Resolution Land-Sea Terrain Model File C:/PAGravf4.5_win64en/examples/Renterrianeffect/landtm1m.dat.
>> Open Low-Pass Land-Sea Terrain Model File C:/PAGravf4.5_win64en/examples/Renterrianeffect/landtm1m/vb.dat.
>> Open Land-Sea Surface Ellipsoidal Height Grid File C:/PAGravf4.5_win64en/examples/Renterrianeffect/landbmsurfhgt.dat.
>> Open Computation Surface Ellipsoidal Height Grid File C:/PAGravf4.5_win64en/examples/Renterrianeffect/landbmsurfhgt.dat.
>> Compute the land-sea unified residual terrain effects using 1D FFT algorithm...
>> Save the results as C:/PAGravf4.5_win64en/examples/Renterrianeffect/surfFFT1.txt
** Generates .ksi, .gra, .dft, .grr grid files in the current directory.
>> The parameter settings have been entered into the system!
** Click the [Start Computation] control button, or the [Start Computation] control button.
>> Computation start time: 2026-04-10 11:34:24
>> Complete the computation of land-sea unified residual terrain effects
>> Computation end time: 2026-04-10 11:36:36
```

Fast algorithm 1D FFT

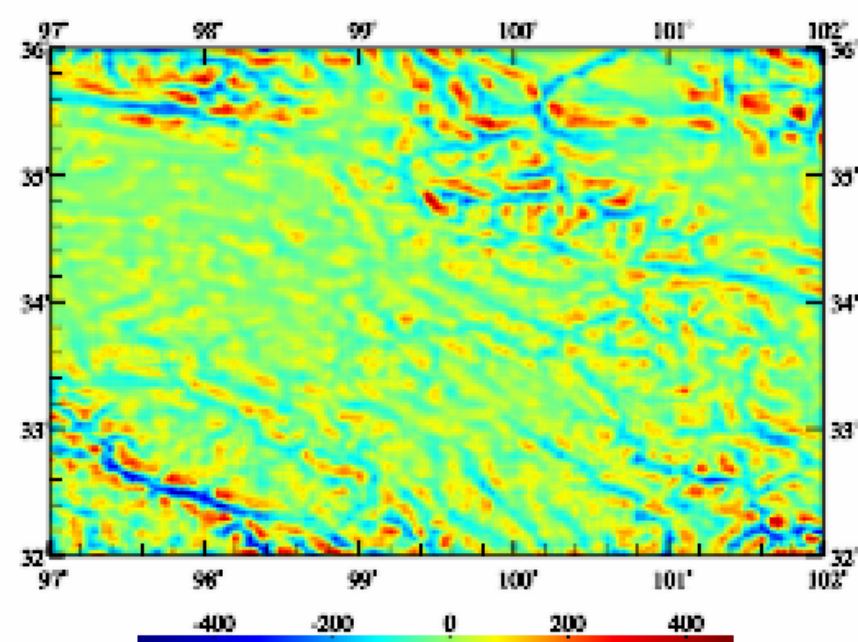
Save the results as

Start Computation

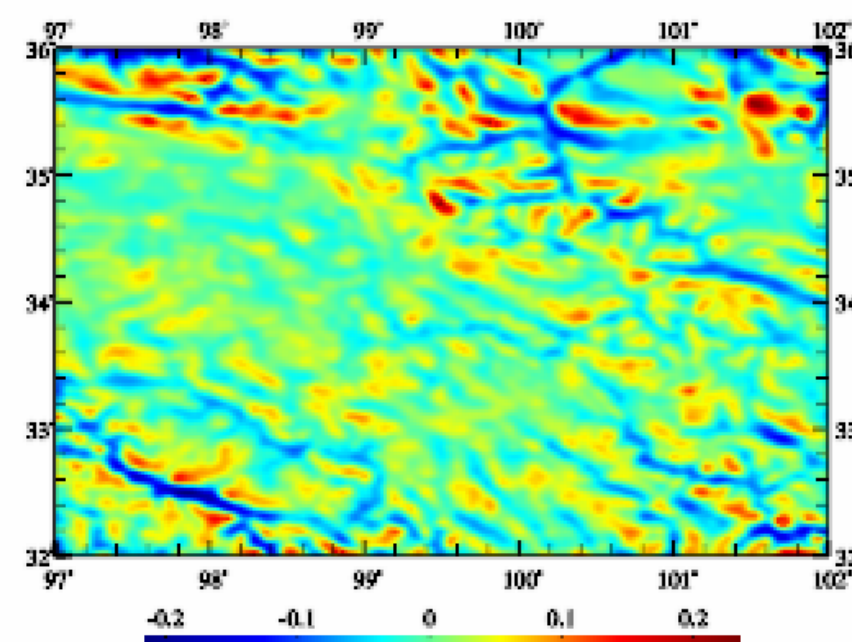
```
C:/PAGravf4.5_win64en/examples/Renterrianeffect/surfFFT1.ksi
C:/PAGravf4.5_win64en/examples/Renterrianeffect/surfFFT1.gra
C:/PAGravf4.5_win64en/examples/Renterrianeffect/surfFFT1.dft
C:/PAGravf4.5_win64en/examples/Renterrianeffect/surfFFT1.grr
```

Extract effects

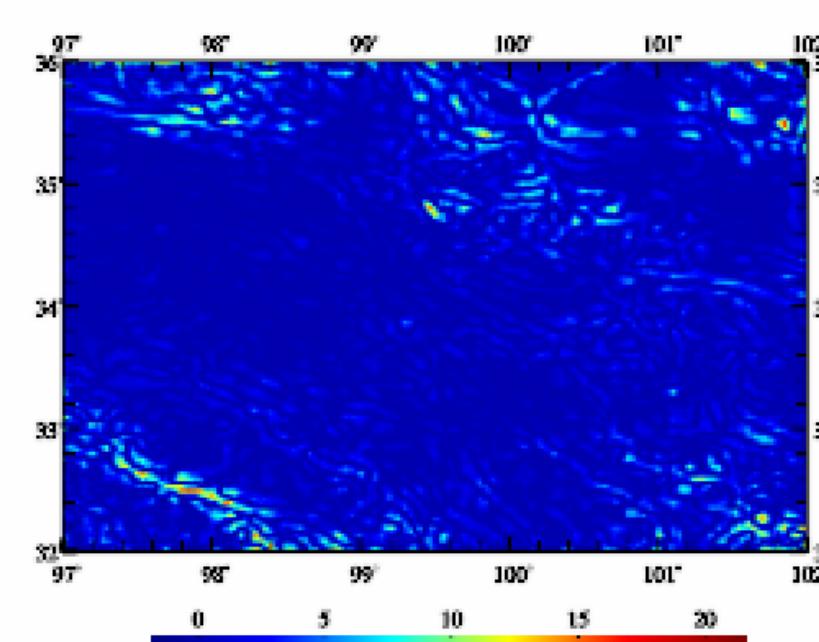
Plot



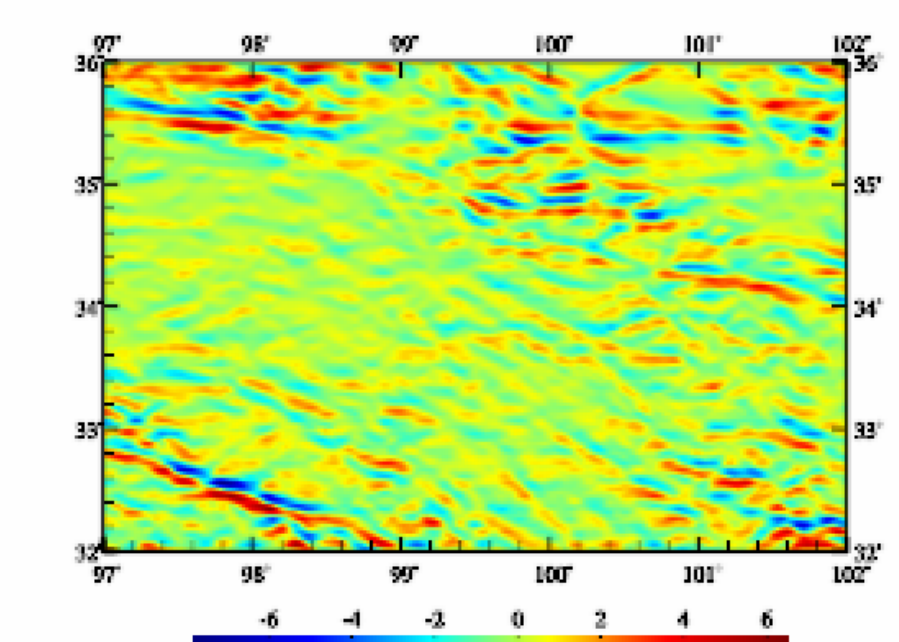
residual terrain model (m)



height anomaly (m)



gravity (anomaly, mGal)



vertical deflection (" , S)

- The Land-Sea Residual Terrain Effect is defined as the aggregate of the short-wavelength and ultra-short-wavelength spectral components of the land-sea complete Bouguer effect.
- Given the invariance of the normal gravity field, RTEs on gravity disturbance and gravity anomaly are strictly equivalent to the RTE on gravity itself.

Table 3.7: Statistics for the differences between FFT results and rigorous numerical integration

Field Element / Unit	Algorithm	Mean Diff	Std. Dev. Diff	Min Diff	Max Diff
height anomaly (m)	FFT2	-0.0129	0.0335	-0.2051	0.1237
	FFT1	-0.0096	0.0242	-0.1514	0.0870
gravity (anomaly, disturbance) (mGal)	FFT2	0.1031	0.2585	-0.4320	3.0334
	FFT1	0.0328	0.2266	-0.7472	1.3431
vertical deflection (" , South)	FFT2	0.0001	0.3380	-1.7813	1.8500
	FFT1	0.0002	0.0021	-0.0248	0.0334
vertical deflection (" , West)	FFT2	0.0029	0.3145	-1.9819	2.3883
	FFT1	0.0001	0.0040	-0.1178	0.0822
gravity gradient (E)	FFT2	0.4968	15.1962	-67.4822	97.0052
	FFT1	-0.0239	0.3995	-10.3352	4.9832

The discrepancies between the rigorous numerical integration and the fast FFT algorithms are negligible.

No significant difference exists between the 1D-FFT and 2D-FFT implementations.

Interactive Calculator for Unified Land-Sea Residual Terrain Effects on or outside the Geoid

 Open High-Resolution Land-Sea Terrain Model File

 Open Low-Pass Land-Sea Terrain Model File

 Open Land-Sea Surface Ellipsoidal Height Grid File

Input geodetic coordinates of calculation point

longitude 98.240000°

latitude 32.428000°

ellipsoidal height 2017.830m

Integral radius 90 km

 Start calculation

High-resolution land-sea terrain model

97.000000	102.000000	32.000000	36.000000	0.01666667	0.01666667
3988.0003	4048.9987	4129.9921	4151.9956	4155.9995	4177.9995
4277.9980	4373.9953	4466.9865	4479.9931	4520.9918	4547.9918
4242.0005	4229.0008	4211.0001	4165.0054	4150.0047	4157.0047
4429.0008	4511.9959	4529.9991	4531.0014	4539.9993	4531.9993
4273.0028	4221.0056	4196.0075	4196.0093	4251.0050	4337.9993
4643.9962	4607.0004	4605.9991	4587.9886	4457.0003	4379.9993
4500.0065	4593.9997	4650.9991	4620.9999	4585.9976	4473.0003
4272.0146	4409.0057	4409.0057	4409.0057	4547.0046	4729.0046
4530.9966	4409.0057	4409.0057	4409.0057	4409.0042	4071.0042
4371.0006	4409.0057	4409.0057	4409.0057	4409.0094	4520.9994
3868.0107	4409.0057	4409.0057	4409.0057	4409.0094	4124.0094
4243.0076	4409.0057	4409.0057	4409.0057	4409.0094	4347.9994
4161.9980	4409.0057	4409.0057	4409.0057	4409.0094	4040.0094
4050.9965	4023.0017	4023.0017	4023.0017	4171.9934	4235.0017
4051.0030	4022.0027	3977.0011	3977.0011	4032.9988	3996.0011
4299.0025	4415.9991	4516.9921	4414.9967	4458.0037	4431.9991
3672.0205	3912.9972	4073.9952	4159.0051	4313.9932	4374.9972
4389.9975	4386.9989	4385.9985	4382.9967	4358.9980	4337.9989
4185.9964	4135.0004	4135.0004	4135.0004	4073.9986	4110.9986
4310.9929	4297.9951	4309.9918	4309.9894	4250.9985	4242.9951
3884.0033	3950.0001	4024.9995	4076.0000	4119.0000	4160.9995
4240.0001	4300.0001	4352.9995	4350.0033	4355.0002	4373.0001
4236.9985	4228.0000	4229.9976	4212.9986	4207.0000	4262.9976

Residual terrain effect results

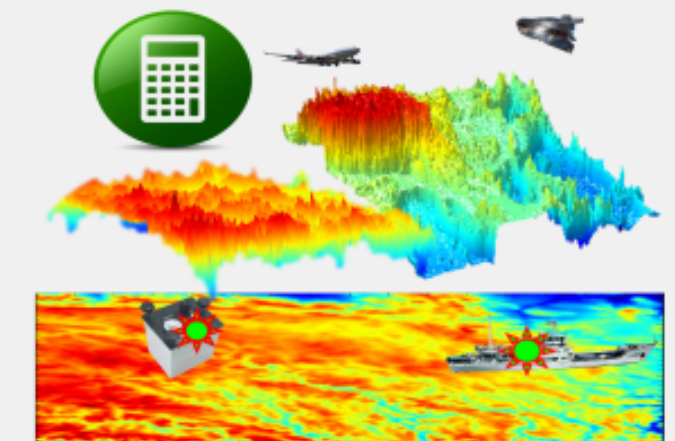
height anomaly (m) 0.0094

gravity (anomaly/disturbance, mGal) -7.1398

vertical deflection (" , S) -2.3612

vertical deflection (" , W) -0.9987

(disturbing) gradient (E, radial) 13.2737



Workflow Interaction

- (1) Initialization: Upon loading the three required grid files (with matching specifications), the [Start Calculation] button is automatically activated.
- (2) Real-Time Computation: Users can iteratively input geodetic coordinates. The system instantly computes and displays the Residual Terrain Effects (or Complete Bouguer Effects, depending on the configuration) for all selected field elements at the specified location.
- (3) Dynamic Reconfiguration: (a) Users may replace any of the three input grid files or modify the integration radius at any time via the interface. (b) All parameter updates take immediate effect, allowing for rapid sensitivity analysis without restarting the session.

Interactive Calculator for Unified Land-Sea Residual Terrain Effects on or outside the Geoid

 Open High-Resolution Land-Sea Terrain Model File

 Open Low-Pass Land-Sea Terrain Model File

 Open Land-Sea Surface Ellipsoidal Height Grid File

Input geodetic coordinates of calculation point

longitude 100.450000°

latitude 34.428000°

ellipsoidal height 417.830m

Integral radius 90 km

 Start calculation

High-resolution land-sea terrain model

97.000000	102.000000	32.000000	36.000000	0.01666667	0.01666667
3988.0003	4048.9987	4129.9921	4151.9956	4155.9995	4177.9995
4277.9980	4373.9953	4466.9865	4479.9931	4520.9918	4547.9918
4242.0005	4229.0008	4211.0001	4165.0054	4150.0047	4157.0047
4429.0008	4511.9959	4529.9991	4531.0014	4539.9993	4531.9993
4273.0028	4221.0056	4196.0075	4196.0093	4251.0050	4337.9995
4643.9962	4607.0004	4605.9995	4587.9884	4457.0003	4379.9995
4500.0065	4593.9997	4658.9995	4658.9995	4585.9976	4473.0000
4272.0146	4109.0000	4109.0000	4109.0000	4647.0046	4729.0000
4530.9966	4530.9966	4530.9966	4530.9966	4530.0042	4071.0000
4371.0006	4371.0006	4371.0006	4371.0006	4371.0006	4520.9995
3868.0107	3868.0107	3868.0107	3868.0107	3868.0107	4124.0000
4243.0076	4243.0076	4243.0076	4243.0076	4243.0076	4347.9995
4161.9980	4161.9980	4161.9980	4161.9980	4161.9980	4040.0000
4050.9965	4023.0017	4023.0017	4023.0017	4171.9934	4235.0000
4051.0030	4022.0027	3977.0121	4021.9996	4032.9988	3996.0000
4299.0025	4415.9991	4516.9921	4514.9967	4458.0037	4431.9995
3672.0205	3912.9978	4073.9952	4159.0051	4313.9938	4374.9995
4389.9975	4386.9989	4385.9985	4382.9967	4358.9980	4337.9995
4185.9964	4135.0004	4099.9998	4073.9996	4073.9986	4110.9995
4310.9929	4297.9951	4309.9910	4309.9894	4250.9985	4242.9995
3884.0033	3950.0001	4024.9995	4076.0000	4119.0000	4160.9995
4240.0001	4300.0001	4352.9995	4350.0033	4355.0002	4373.0000
4236.9985	4228.0000	4229.9976	4212.9986	4207.0000	4262.9995

Residual terrain effect results

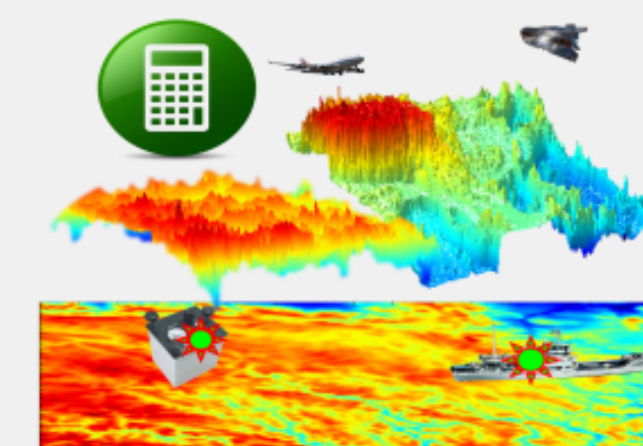
height anomaly (m) 0.0206

gravity (anomaly/disturbance, mGal) -9.2450

vertical deflection (" , S) -0.3546

vertical deflection (" , W) -0.2634

(disturbing) gradient (E, radial) 7.7494



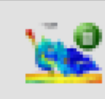
Workflow Interaction

- (1) Initialization: Upon loading the three required grid files (with matching specifications), the [Start Calculation] button is automatically activated.
- (2) Real-Time Computation: Users can iteratively input geodetic coordinates. The system instantly computes and displays the Residual Terrain Effects (or Complete Bouguer Effects, depending on the configuration) for all selected field elements at the specified location.
- (3) Dynamic Reconfiguration: (a) Users may replace any of the three input grid files or modify the integration radius at any time via the interface. (b) All parameter updates take immediate effect, allowing for rapid sensitivity analysis without restarting the session.

Integration of Unified Land-Sea Classical Gravity Bouguer and Isostatic Effects



Integration of Unified Land-Sea Classical Gravity Bouguer and Isostatic Effects



Interactive Calculator for Unified Land-Sea Classical Gravity Bouguer and Isostatic Effects



Algorithms land-sea unified classic Bouguer and equilibrium effects



Save computation process as



Open Land-Sea Terrain Model File



Open Land-Sea Surface Ellipsoidal Height Grid File

Select computation point file format

discrete computation point file

Land-sea Surface Computation Point File

Number of rows of file header 1

Integral radius for local terrain effect 90 km

Integral radius for seawater Bouguer / equilibrium effect 300 km

Equilibrium compensation depth 30 km

>> Computation Process ** Operation Prompts

>> [Function] Computes the unified land-sea classical Bouguer and isostatic effects on surface gravity (mGal) based on the input land-sea terrain model and land-sea surface ellipsoidal height grid files.

>> Open Land-Sea Terrain Model File C:/PAGrav4.5_win64en/examples/TerSurfacegravinfl/dtm5m.dat.

>> Open Land-Sea Surface Ellipsoidal Height Grid File C:/PAGrav4.5_win64en/examples/TerSurfacegravinfl/dbmhgt5m.dat.

>> Open Land-sea Surface Computation Point File C:/PAGrav4.5_win64en/examples/TerSurfacegravinfl/dbmhgt.txt.

** Look at the file information in the window below, set the input file format parameters...

>> Save the results as C:/PAGrav4.5_win64en/examples/TerSurfacegravinfl/rstpnt.txt.

** Appends seven columns of effect values to the source record (4 significant figures): Local Terrain, Plane Layer, Seawater Bouguer, Land Isostatic, Ocean Isostatic, Total Bouguer, Total Isostatic.

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-10 15:17:27

>> Complete the computation of land-sea unified classical Bouguer / equilibrium effects!



Save the results as



Import setting parameters



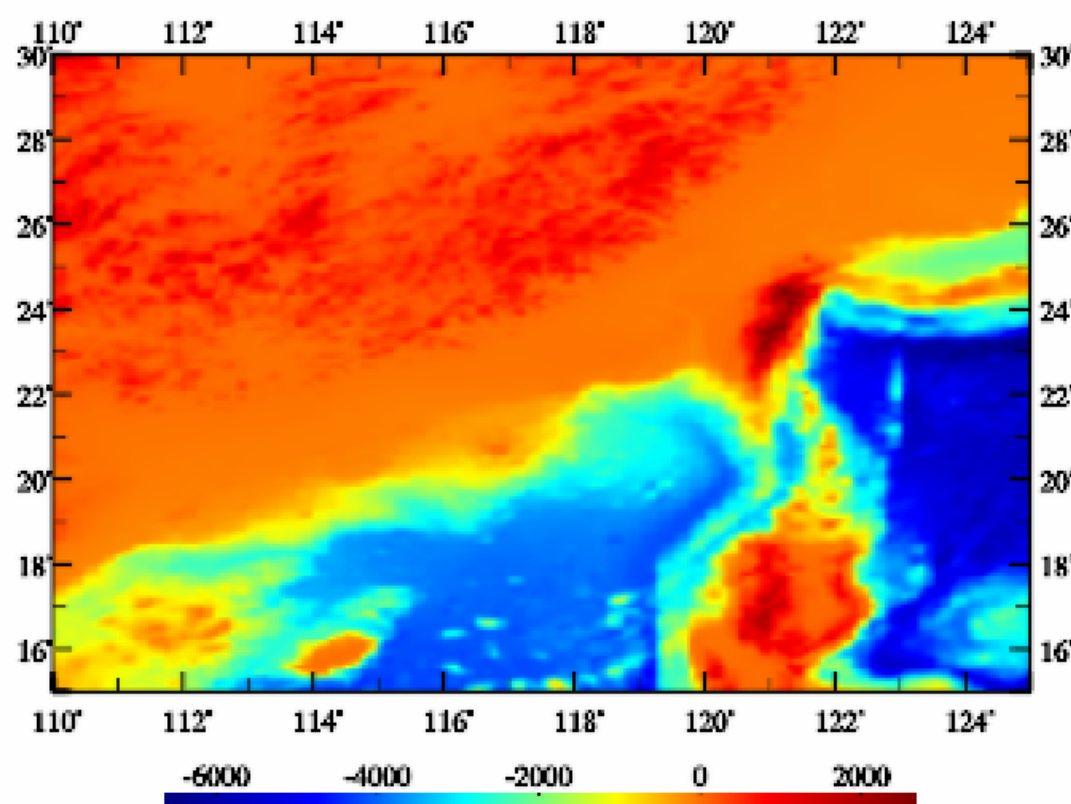
Start Computation

height/depth, local terrian, plane layer, sea-water Bouguer, land equilibrium...

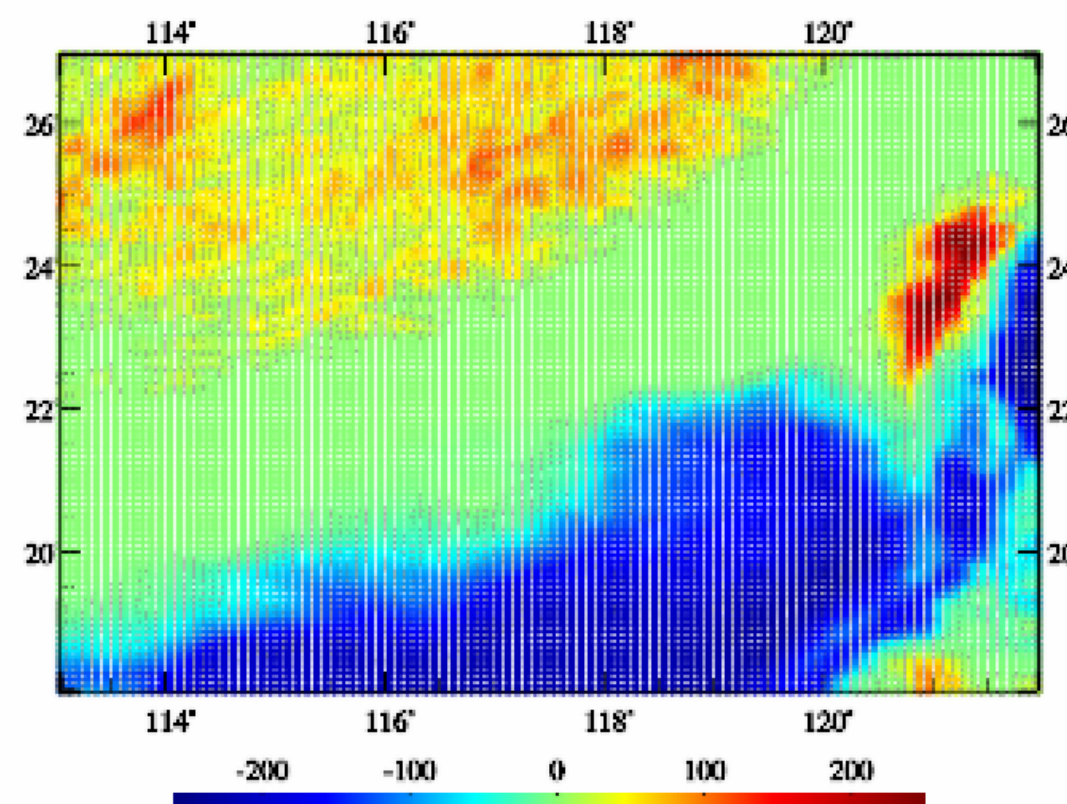
6517	113.041667	18.041667	1.4605	-2191.889	0.0000	0.0000	-109.5704	-0.0009	122.0600	-109.5704
6518	113.125000	18.041667	1.7831	-2072.111	0.0000	0.0000	-103.9803	-0.0003	122.3674	-103.9803
6519	113.208333	18.041667	2.1041	-1926.889	0.0000	0.0000	-97.4649	-0.0000	122.9345	-97.4649
6520	113.291667	18.041667	2.4240	-1638.222	0.0000	0.0000	-89.4900	0.0000	124.4235	-89.4900
6521	113.375000	18.041667	2.7435	-1914.444	0.0000	0.0000	-96.2755	0.0000	126.2211	-96.2755

Extract effects

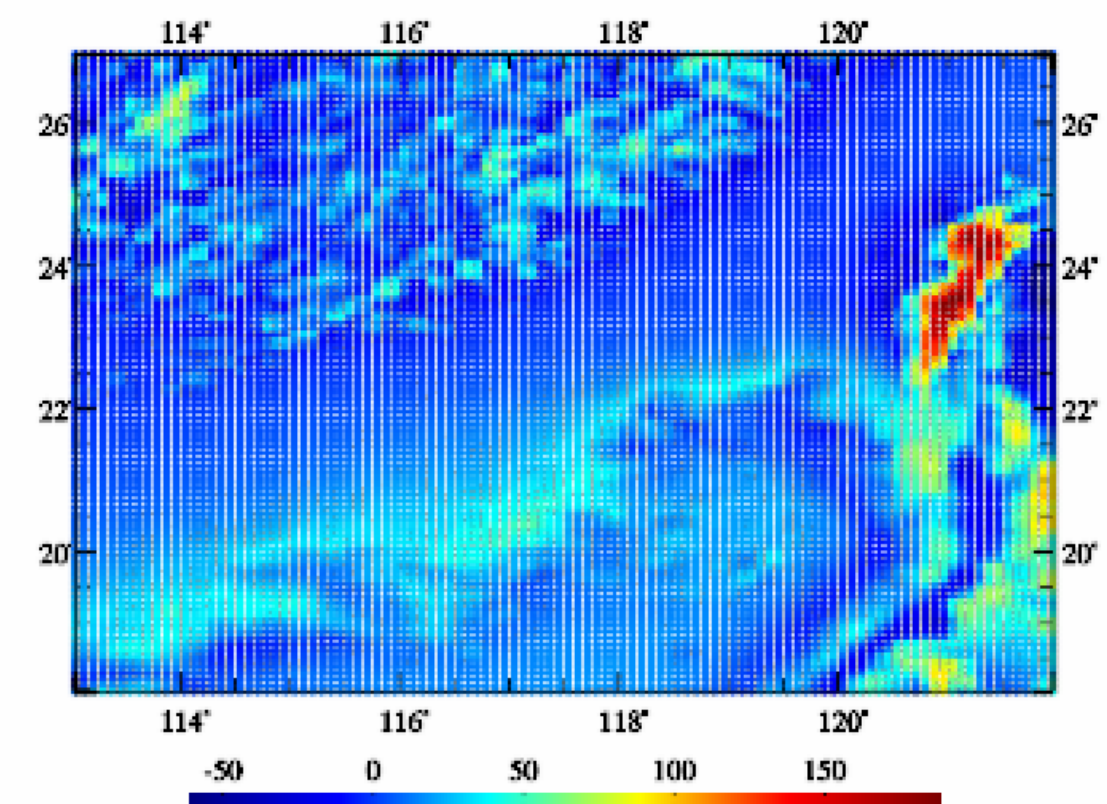
Plot



land-sea terrain model (m)



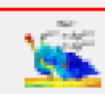
total Bouguer effect (mGal)



total equilibrium effect (mGal)

- Classic Bouguer gravity anomaly on geoid = gravity anomaly at the observed point – total Bouguer effect – analytical continuation of gravity anomaly from the observed point to geoid. Classic Bouguer gravity disturbance on geoid = gravity disturbance at the observed point – total Bouguer effect – analytical continuation of gravity disturbance from the observed point to geoid.
- Classic equilibrium gravity anomaly on geoid = gravity anomaly at the observed point – total equilibrium effect – analytical continuation of gravity anomaly from the observed point to geoid. Classic equilibrium gravity disturbance on geoid = gravity disturbance at the observed point – total equilibrium effect – analytical continuation of gravity disturbance from the observed point to geoid.

Integration of Unified Land-Sea Classical Gravity Bouguer and Isostatic Effects



Integration of Unified Land-Sea Classical Gravity Bouguer and Isostatic Effects



Interactive Calculator for Unified Land-Sea Classical Gravity Bouguer and Isostatic Effects



Algorithms land-sea unified classic Bouguer and equilibrium effects



Open Land-Sea Terrain Model File



Open Land-Sea Surface Ellipsoidal Height Grid File

Select computation point file format

surface ellipsoidal height grid file



Open Land-sea Computation Surface Ellipsoidal Height Grid File

Integral radius for local terrain effect

90 km

Integral radius for seawater Bouguer / equilibrium effect

300 km

Equilibrium compensation depth

30 km

>> Computation Process ** Operation Prompts

>> [Function] Computes the unified land-sea classical Bouguer and isostatic effects on surface gravity (mGal) based on the input land-sea terrain model and land-sea surface ellipsoidal height grid files.

>> Open Land-Sea Terrain Model File C:/PAGrav4.5_win64en/examples/TerSurfacegravinfl/dtm5m.dat.

>> Open Land-Sea Surface Ellipsoidal Height Grid File C:/PAGrav4.5_win64en/examples/TerSurfacegravinfl/dbmhgt5m.dat.

>> Open Land-sea Computation Surface Ellipsoidal Height Grid File C:/PAGrav4.5_win64en/examples/TerSurfacegravinfl/dbmhgt5m.dat.

>> Save the results as C:/PAGrav4.5_win64en/examples/TerSurfacegravinfl/result.txt.

** Outputs formatted records: ID, Lon, Lat, h, [Seven Effect Values...].

** Automatically generates: Unified Land-Sea Total Bouguer Effect: .bgr, and Unified Land-Sea Total Isostatic Effect: .ist.

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-10 15:20:58

>> Complete the computation of land-sea unified classical Bouguer / equilibrium effects!

>> Computation end time: 2026-04-10 15:22:58



Save the results as



Import setting parameters



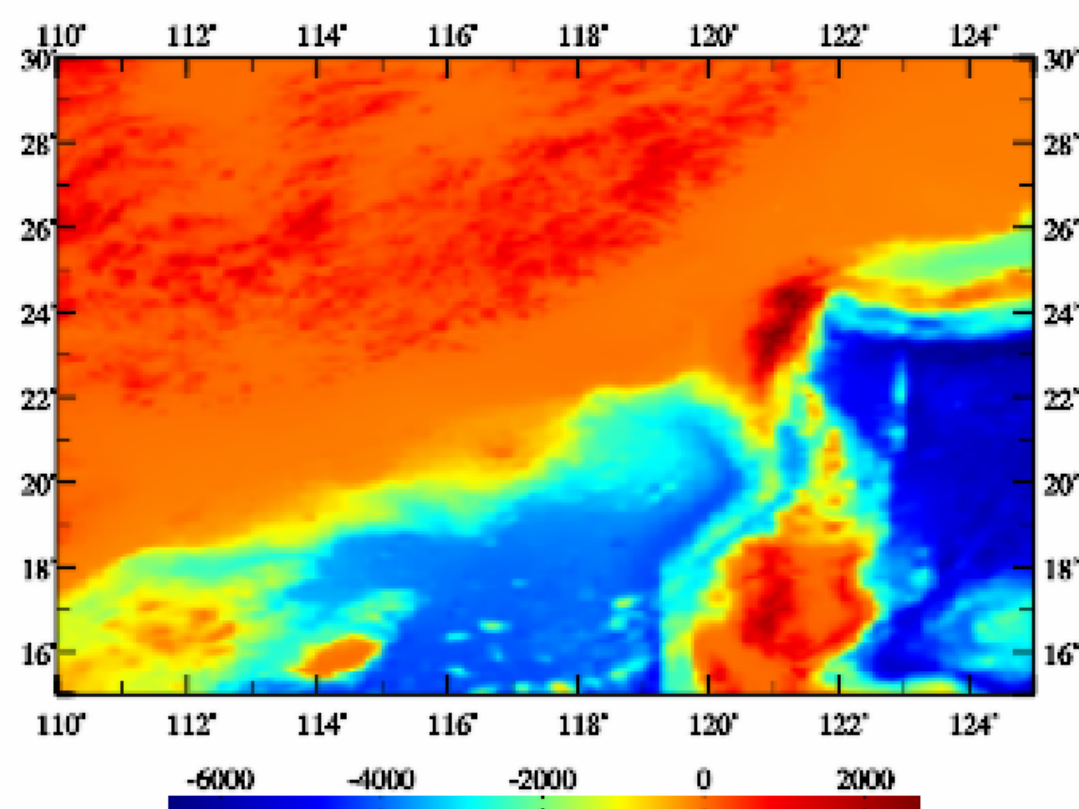
Start Computation

no lon(deg/decimal) lat height/depth local terrain, plane layer, sea-water Bouguer effect, ...

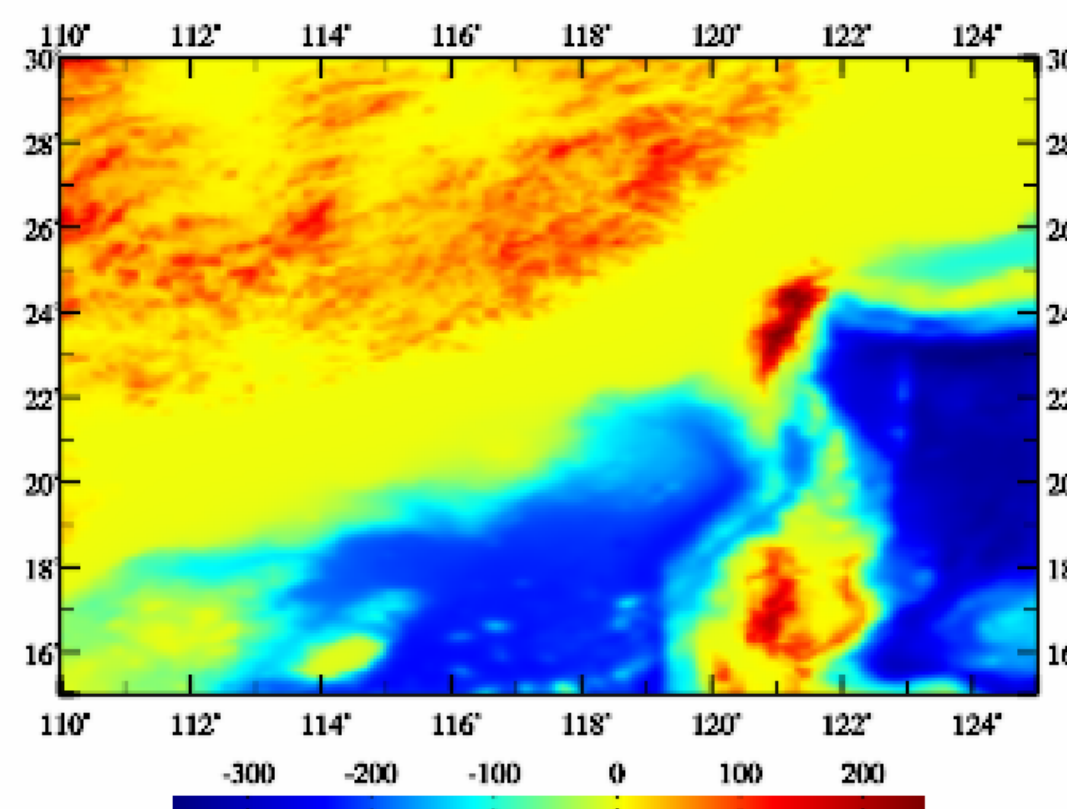
1	110.04167	15.04167	-456.500	0.0000	0.0000	-7.8971	0.0000	12.2480	-7.8971	4.3510
2	110.12500	15.04167	-434.667	0.0000	0.0000	-7.8766	0.0000	14.7200	-7.8766	6.8435
3	110.20833	15.04167	-465.667	0.0000	0.0000	-9.1329	0.0000	17.0115	-9.1329	7.8787
4	110.29167	15.04167	-638.167	0.0000	0.0000	-13.9564	0.0000	19.0292	-13.9564	5.0728
5	110.37500	15.04167	-723.167	0.0000	0.0000	-17.1850	0.0000	21.0073	-17.1850	3.8223

Extract effects

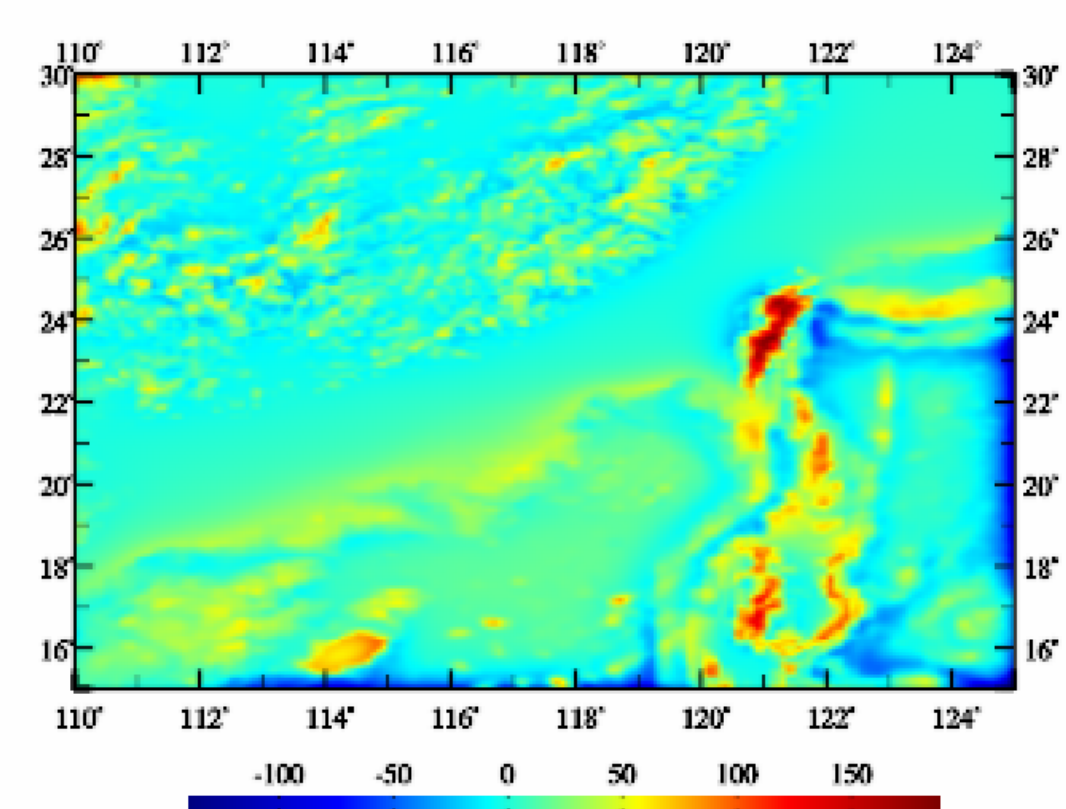
Plot↓



land-sea terrain model (m)



total Bouguer effect (mGal)



total equilibrium effect (mGal)

● Classic Bouguer gravity anomaly on geoid = gravity anomaly at the observed point – total Bouguer effect – analytical continuation of gravity anomaly from the observed point to geoid. Classic Bouguer gravity disturbance on geoid = gravity disturbance at the observed point – total Bouguer effect – analytical continuation of gravity disturbance from the observed point to geoid.

● Classic equilibrium gravity anomaly on geoid = gravity anomaly at the observed point – total equilibrium effect – analytical continuation of gravity anomaly from the observed point to geoid. Classic equilibrium gravity disturbance on geoid = gravity disturbance at the observed point – total equilibrium effect – analytical continuation of gravity disturbance from the observed point to geoid.

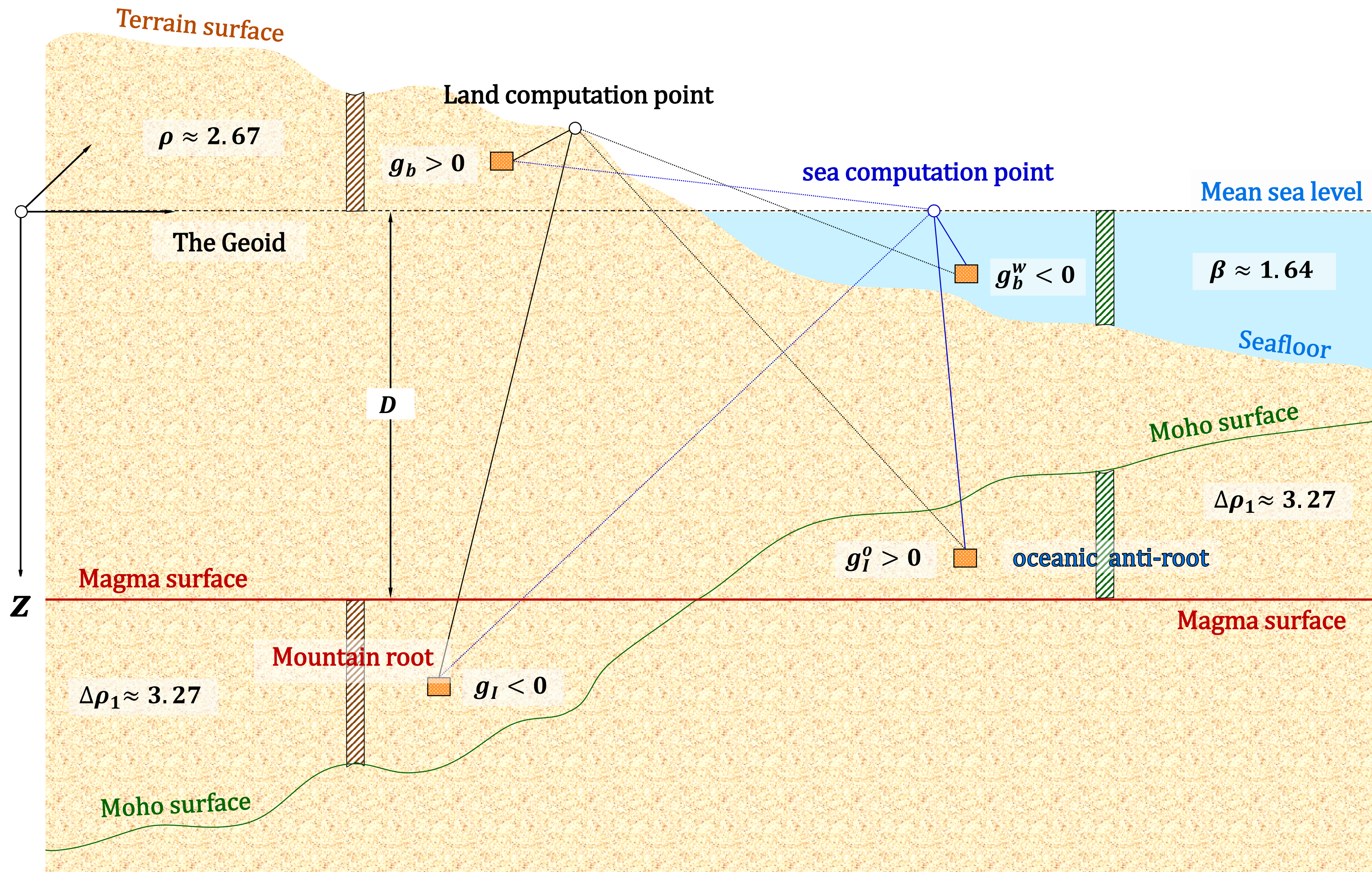
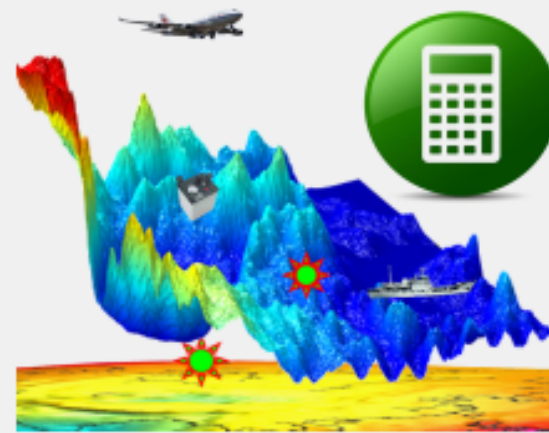


Figure 7.6: Calculation Principle for Unified Land-Sea Bouguer and Isostatic Effects on Surface Gravity

Interactive Calculator for Unified Land-Sea Classical Gravity Bouguer and Isostatic Effects

 Open Land-Sea Terrain Model File

 Open Land-Sea Surface Ellipsoidal Height Grid File



Integral radius for local terrain effect 90 km

Integral radius for seawater Bouguer /equilibrium effect 300 km

Equilibrium compensation depth 30 km

Input geodetic coordinates of calculation point on land-sea surface

longitude 116.240000°

latitude 26.428100°

 Start calculation

Terrain effects (mGal) at the calculation point on

land height/sea depth 400.3811 m

plane layer effect 44.8300

land equilibrium effect -39.2525

total Bouguer effect 44.3896

local terrain effect -0.4405

seawater Bouguer effect -0.0000

ocean equilibrium effect 0.0000

total equilibrium effect 5.1370

Land-sea terrain model

110.000000	125.000000	15.000000	30.000000	08333333
-456.5000	-434.6667	-465.6667	-1282.8333	-802.6667
-1253.8333	-1290.3333	-1321.6667	-1594.5000	-1622.6667
-2604.3333	-2767.5000	-2971.5000	-3351.0000	-3388.0000
-4315.0000	-4281.8333	-4269.0000	-4345.0000	-4336.3333
-4158.6667	-4285.5000	-4289.1667	-4061.1667	-4231.1667
-3536.6667	-2641.6667	-2227.0000	-4248.8333	-4260.8333
-4036.8333	-3508.1667	-3080.6667	-2477.1667	-3081.3333
-4273.1667	-4475.5000	-4593.3333	-1821.3333	-4687.5000
7.1667	180.3333	237.8333	479.6667	508.6667
				315.5000
				55.0000
				23.8333
				13.83

Look at the $\pm$ sign relationship between different modes of terrain effects.

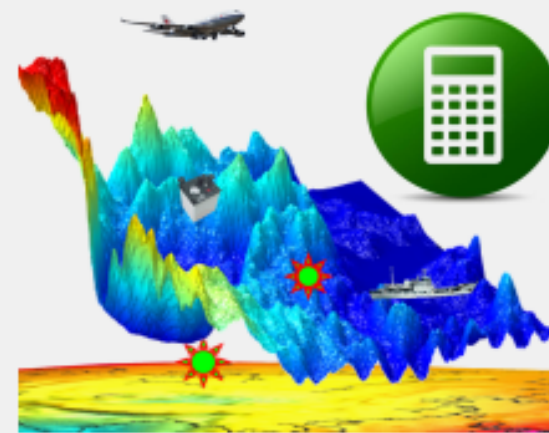
 Using + to indicate greater than zero, and - to indicate less than zero, there are always: plane layer effect (+), seawater Bouguer effect (-), land equilibrium effect (-), ocean equilibrium effect (+).

 In the coastal sea area, there are local terrain effects and land equilibrium effects. In the offshore land area, there are also seawater Bouguer effects and ocean equilibrium effects.

Interactive Calculator for Unified Land-Sea Classical Gravity Bouguer and Isostatic Effects

Open Land-Sea Terrain Model File

Open Land-Sea Surface Ellipsoidal Height Grid File



Integral radius for local terrain effect 90 km

Integral radius for seawater Bouguer /equilibrium effect 300 km

Equilibrium compensation depth 30 km

Input geodetic coordinates of calculation point on land-sea surface

longitude 121.240000°

latitude 21.428100°

Start calculation

Terrain effects (mGal) at the calculation point on

land height/sea depth -2187.1242 m

plane layer effect 0.0000

land equilibrium effect -1.2635

total Bouguer effect -61.3503

local terrain effect 0.0017

seawater Bouguer effect -61.3520

ocean equilibrium effect 129.3990

total equilibrium effect 66.7853

Land-sea terrain model

110.000000 125.000000 15.000000 30.000000 0.083333 33.000000 0.083333 33.000000 0.083333 33.000000
-456.5000 -434.6667 -465.5000 -434.6667 -434.6667 -434.6667 -434.6667 -434.6667 -434.6667 -434.6667
-1253.8333 -1290.3333 -1321.6667 -1321.6667 -1321.6667 -1321.6667 -1321.6667 -1321.6667 -1321.6667 -1321.6667
-2604.3333 -2767.5000 -2971.5000 -2971.5000 -2971.5000 -2971.5000 -2971.5000 -2971.5000 -2971.5000 -2971.5000
-4315.0000 -4281.8333 -4269.5000 -4269.5000 -4269.5000 -4269.5000 -4269.5000 -4269.5000 -4269.5000 -4269.5000
-4158.6667 -4285.5000 -4289.1667 -4289.1667 -4289.1667 -4289.1667 -4289.1667 -4289.1667 -4289.1667 -4289.1667
-3536.6667 -2641.6667 -2227.0000 -2090.0000 -2090.0000 -2090.0000 -2090.0000 -2090.0000 -2090.0000 -2090.0000
-4036.8333 -3508.1667 -3080.6667 -2477.1667 -2477.1667 -2477.1667 -2477.1667 -2477.1667 -2477.1667 -2477.1667
-4273.1667 -4475.5000 -4593.3333 -4821.3333 -4821.3333 -4821.3333 -4821.3333 -4821.3333 -4821.3333 -4821.3333
7.1667 180.3333 237.8333 179.6667 508.6667 15.5000 55.0000 23.8333 13.8333 13.8333

Look at the ± sign relationship between different modes of terrain effects.

Using + to indicate greater than zero, and - to indicate less than zero, there are always: plane layer effect (+), seawater Bouguer effect (-), land equilibrium effect (-), ocean equilibrium effect (+).

In the coastal sea area, there are local terrain effects and land equilibrium effects. In the offshore land area, there are also seawater Bouguer effects and ocean equilibrium effects.

Construction of Global Surface Data Grids in Spherical Coordinates

Open file Save as Import parameters Start Computation Save process Follow example

Construction of Global Surface Data Grids in Spherical Coordinates

Ultrahigh-Degree Spherical Harmonic Analysis of the Global Land-Sea Terrain Model

Algorithm of spherical harmonic analysis and synthesis of land-sea terrain masses

Open Global Land-Sea Surface Discrete Point File

Set file format

Header Rows 0

Target Column Index 4

Grid Resolution 30.0'

>> Computation Process ** Operation Prompts

Save computation process as

>> [Purpose] To conduct spherical harmonic analysis on global land-sea terrain grids (encompassing topographic elevation and oceanic bathymetry) and construct a fully normalized global land-sea terrain mass spherical harmonic coefficient model. This model serves as the fundamental basis for computing unified land-sea complete Bouguer effects or residual terrain effects (RTE) on various gravity field elements, both on the geoid and throughout the exterior space of the Earth.

>> Select the function module from the two control buttons at the top left of the interface...

>> [Function] Generates a spherical coordinate grid model from global discrete land-sea surface point data at a user-specified resolution. Grid cells containing no valid discrete data points are assigned a value of zero.

>> Open Global Land-Sea Surface Discrete Point File C:/PAGravf4.5_win64en/examples/TerGloharmanalysis/ETOPO30m.txt.

** Look at the file information in the window below, set the input file format parameters...

>> Save the results as C:/PAGravf4.5_win64en/examples/TerGloharmanalysis/ETOPO30msph.dat.

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-10 16:19:40

>> Complete the construction of global surface data grid in spherical coordinates!

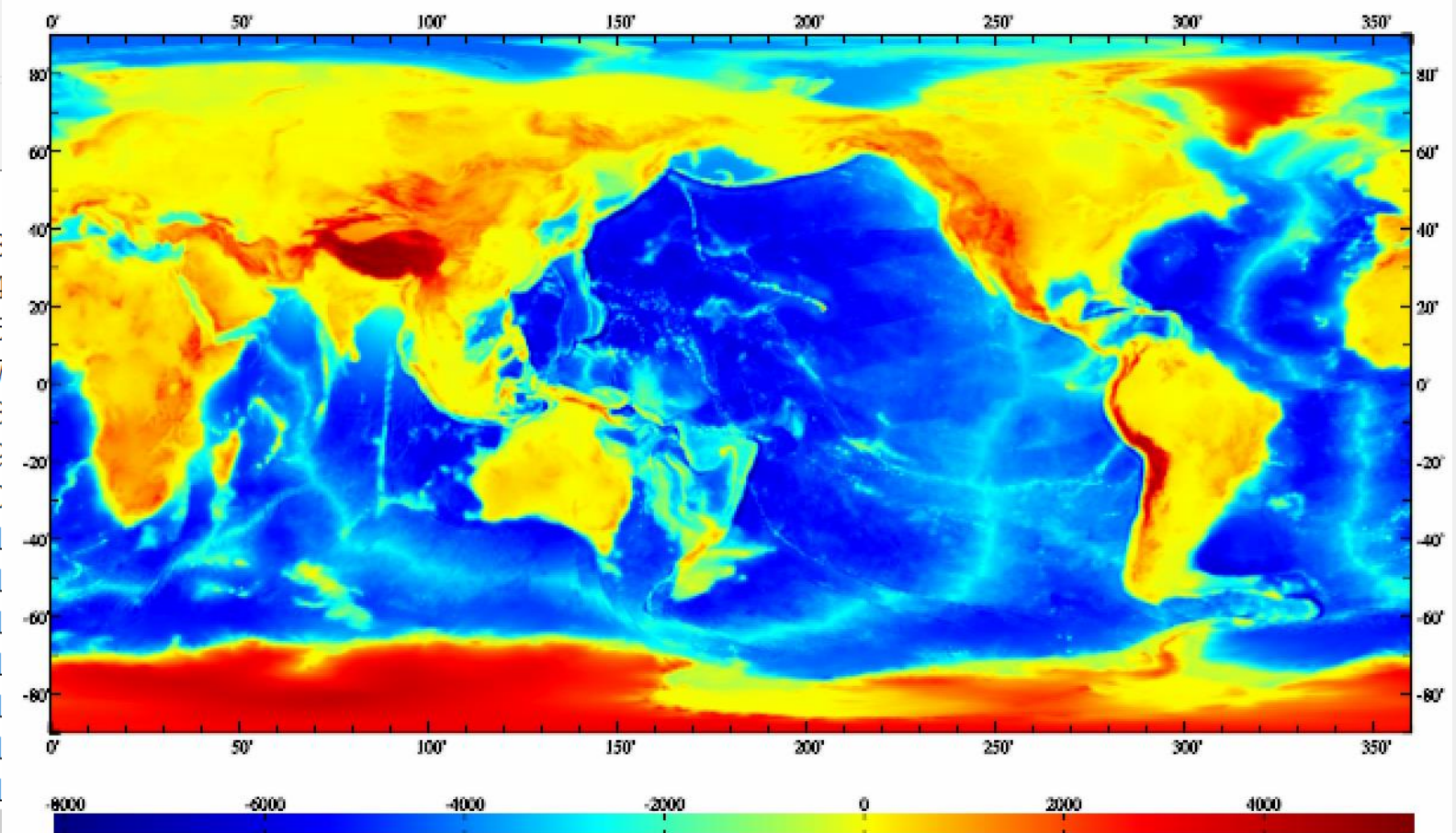
>> Computation end time: 2026-04-10 16:19:45

Save the results as

Import setting parameters

Display of the input-output file↓

0.0	360.0	-90.0	90.0	0.50000000	0.50000000					
2734.91	2735.40	2735.93	2736.53	2737.08	2737.61	2738.27	2738.96	273		
2743.65	2744.20	2744.92	2745.57	2746.21	2746.86	2747.48	2747.99	274		
2753.34	2754.16	2754.80	2755.49	2756.19	2756.79	2757.52	2758.14	275		
2764.09	2764.85	2765.68	2766.57	2767.32	2768.02	2768.78	2769.53	277		
2776.18	2776.96	2777.86	2778.81	2779.69	2780.46	2781.33	2782.24	278		
2789.14	2790.07	2791.04	2791.81	2792.59	2793.41	2794.25	2795.05	279		
2801.59	2802.21	2802.88	2803.60	2804.26	2804.90	2805.58	2806.37	280		
2811.06	2811.66	2812.18	2812.57	2813.07	2813.50	2813.96	2814.55	281		
2817.19	2817.38	2817.57	2817.83	2818.18	2818.39	2818.57	2818.62	281		
2819.57	2819.61	2819.63	2819.63	2819.68	2819.74	2819.74	2819.70	281		
2819.26	2819.25	2819.13	2819.09	2819.18	2819.03	2819.02	2818.97	281		
2818.12	2818.11	2818.07	2818.07	2818.10	2817.92	2817.83	2817.89	281		
2817.71	2817.74	2817.67	2817.64	2817.63	2817.64	2817.68	2817.72	281		
2818.56	2818.71	2818.88	2819.04	2819.15	2819.25	2819.36	2819.57	281		



The maximum degree n of the spherical harmonic model corresponds to the number of grid cells in the North-South (SN) direction. For example, for a $0.25^\circ \times 0.25^\circ$ grid (720 cells N-S), the model degree is $n=720$.

Land Terrain Areal Density ($\beta < 0$): Represents the topographic mass per unit area.

Ocean Terrain Areal Density ($\beta > 0$): Represents the compensation mass (mass deficit) of seawater per unit area relative to the rock reference.

Ultrahigh-Degree Spherical Harmonic Analysis of the Global Land-Sea Terrain Model

Construction of Global Surface Data Grids in Spherical Coordinates

Ultrahigh-Degree Spherical Harmonic Analysis of the Global Land-Sea Terrain Model

Open Global Land-Sea Terrain Grid File in spherical coordinates

Iteration Convergence Criteria

Relative Residual Threshold (%) 1.0 ‰

Convergence Rate Threshold (‰) 1.0 ‰

☒ Simultaneously output terrain geopotential coefficient model

>> Computation Process ** Operation Prompts

** 9th iteration. the residual standard deviation = 8.59e+04
 ** 10th iteration. the residual standard deviation = 8.315e+04
 ** 11th iteration. the residual standard deviation = 8.099e+04
 ** 12th iteration. the residual standard deviation = 7.923e+04
 ** 13th iteration. the residual standard deviation = 7.778e+04
 ** 14th iteration. the residual standard deviation = 7.66e+04
 ** 15th iteration. the residual standard deviation = 7.561e+04
 ** 16th iteration. the residual standard deviation = 7.479e+04
 ** 17th iteration. the residual standard deviation = 7.406e+04
 ** 18th iteration. the residual standard deviation = 7.343e+04
 ** 19th iteration. the residual standard deviation = 7.286e+04
 ** 20th iteration. the residual standard deviation = 7.235e+04
 ** 21th iteration. the residual standard deviation = 7.19e+04
 ** standard deviation of global land-sea terrain = 41.76m.

>> The header includes critical scale and quality parameters: Geocentric Gravitational Constant (GM , $10^{14}m^3/s^2$), Equatorial Radius (a , m), Zero-Degree Term ($a\Delta C$, kg/m^2), and Relative Error ($\Theta\%$, Percentage ratio of the final residual STD to the source grid STD).

>> The program automatically generates a Geopotential Coefficient the mass model filename).

>> Complete the ultrahigh degree spherical harmonic analysis of glo

Save the results as

Save residual DTM as

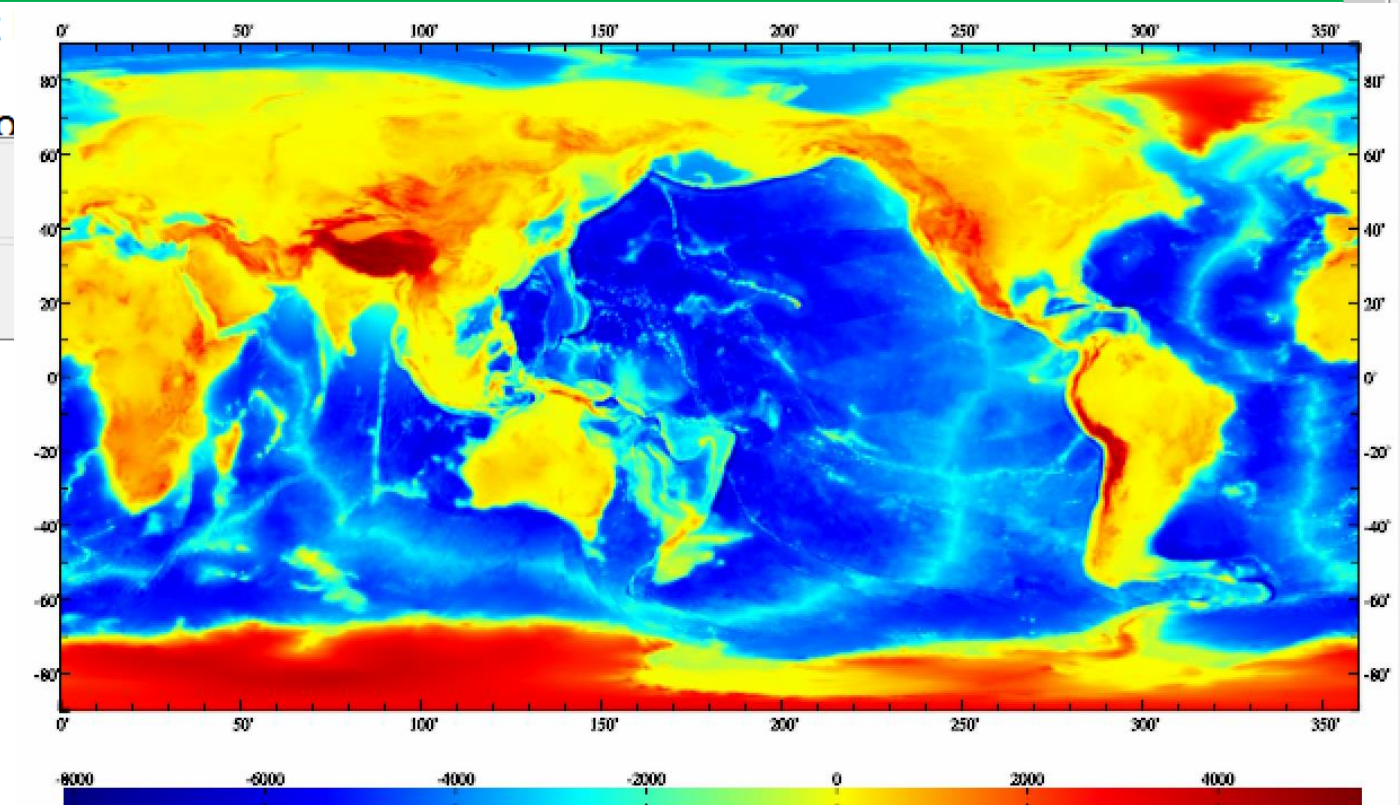
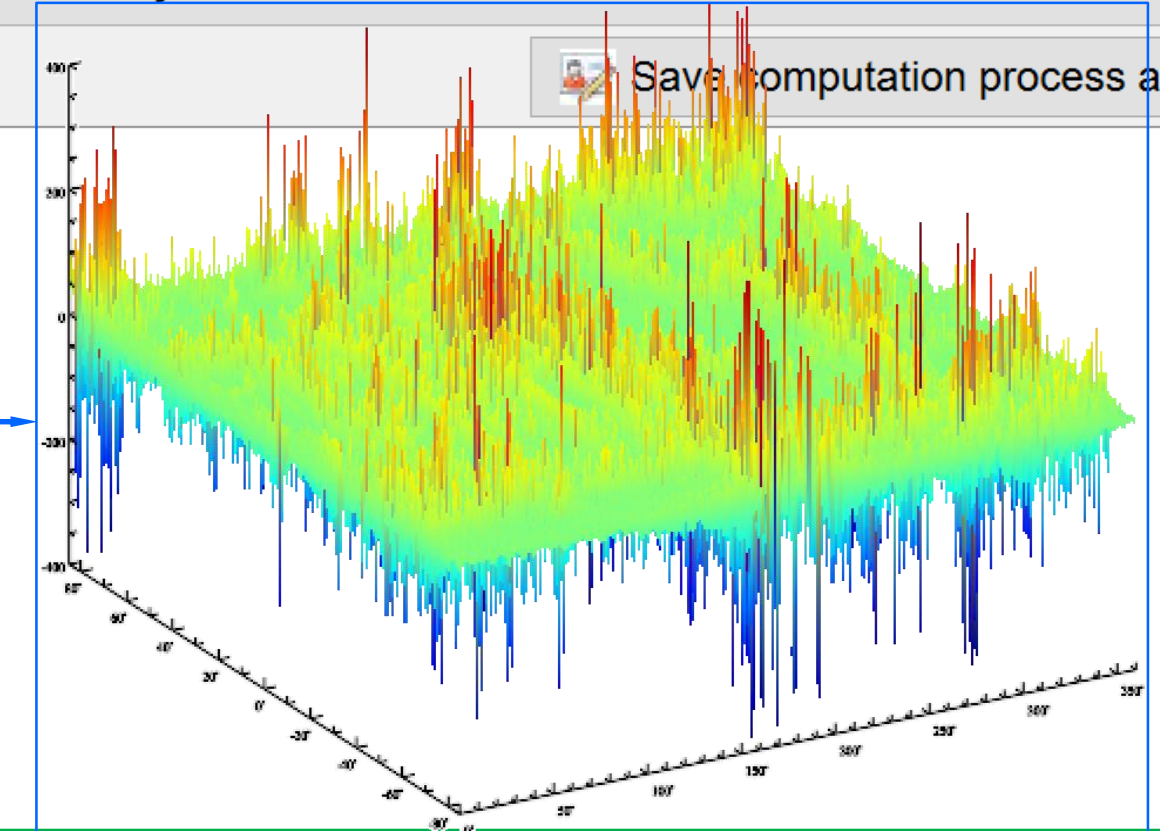
Import setting parameters

Display of the input-output file↓

```
3.986004415 6378136.30 -3667855.469 2.610
1 0 1.7136622041989011E-01 0.0000000000000000E+00
1 1 1.6662830435045770E-01 1.1455495759997025E-01
2 0 1.6336321585390826E-01 0.0000000000000000E+00
2 1 8.4790437441031680E-02 9.1248955794424561E-02
2 2 -1.1820159432747772E-01 -1.6730453760131058E-02
3 0 -6.4915217548611917E-02 0.0000000000000000E+00
3 1 -4.4601488606264006E-02 4.0150215896509141E-02
3 2 -1.3058410613118987E-01 1.2619038828975734E-01
3 3 3.7363651282929698E-02 1.5252641909794915E-01
4 0 1.0060932875109302E-01 0.0000000000000000E+00
4 1 -5.9865764618243812E-02 -8.3251300050875374E-02
4 2 -1.1442732935775231E-01 1.9235264166853054E-02
4 3 1.0098478651498156E-01 -4.2950380278059239E-02
4 4 -1.1646562236291090E-02 1.2919605986189286E-01
5 0 -1.6569483324103185E-01 0.0000000000000000E+00
```

Algorithm of spherical harmonic analysis and synthesis of land-sea terrain masses

Save computation process as



```
0.0 360.0 -90.0 90.0 0.50000000 0.50000000
2734.91 2735.40 2735.93 2736.53 2737.08 2737.61
2743.65 2744.20 2744.92 2745.57 2746.21 2746.86
2753.34 2754.16 2754.80 2755.49 2756.19 2756.79
2764.09 2764.85 2765.68 2766.57 2767.32 2768.02
2776.18 2776.96 2777.86 2778.81 2779.69 2780.46
2789.14 2790.07 2791.04 2791.81 2792.59 2793.41
2801.59 2802.21 2802.88 2803.60 2804.26 2804.90
2811.06 2811.66 2812.18 2812.57 2813.07 2813.50
2817.19 2817.38 2817.57 2817.83 2818.18 2818.39
2819.57 2819.61 2819.63 2819.63 2819.68 2819.74
2819.26 2819.25 2819.13 2819.09 2819.18 2819.03
```

The maximum degree n of the spherical harmonic model corresponds to the number of grid cells in the North-South, the model degree is $n=720$.

Land Terrain Areal Density ($\beta < 0$): Represents the topographic mass per unit area.

Ocean Terrain Areal Density ($\beta > 0$): Represents the compensation mass (mass deficit) of seawater per unit area relative to the land terrain.

Computation of Model Values for Complete Bouguer and Residual Terrain Effects

Computation of Model Values for Complete Bouguer and Residual Terrain Effects

Interactive Calculator for Global Land-Sea Terrain Effects

Spectral Characteristic Analysis of the Global Terrain Effects Model

Algorithmic Formulas

Open Global Land-Sea Terrain Mass Spherical Harmonic Coefficient Model

Select computation file format

Space computation point file

Open Space Computation Point File

Set input point file format

Header Rows 1

Ellipsoidal Height Column Index 4

Select elements to be calculated

☐ terrain elevation/sea bathymetry (m)

☒ height anomaly (m)

☒ gravity (anomaly/disturbance, mGal)

☐ vertical deflection (" , SW)

☒ (disturbing) gradient (E, radial)

☐ tangential gradient (E, NW)

☐ disturbing potential/geopotential (m^2/s^2)

Minimum degree 361

Maximum degree 720

Extract effects

Plot↓

>> Computation Process ** Operation Prompts

>> [Function] Computes model values for terrain elevation/ sea bathymetry and unified land-sea effects (Complete Bouguer or RTE) on the following elements using spherical harmonic synthesis: Height Anomaly (m), Gravity (Anomaly/Disturbance, mGal), Vertical Deflection Vector ("; South/West components), Disturbing Gravity Gradient (E; Radial component), Tangential Gravity Gradient Vector (E; North/West components), and Disturbing Geopotential (m^2/s^2).

** Click the [Open Global Land-Sea Terrain Mass Spherical Harmonic Coefficient Model File]...

>> Open Global Land-Sea Terrain Mass Spherical Harmonic Coefficient Model File C:/PAGravf4.5_win64en/data/ETOPOcs1800.dat.

** The window below only shows the spherical harmonic coefficients data with no more than 2000 rows in it.

>> Open Space Computation Point File C:/PAGravf4.5_win64en/examples/TerHarmntinfluence/calcpnt.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/TerHarmntinfluence/rstpnt.txt.

** Appends selected model values (4 significant figures) to source records.

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

** Computation may take time; users can monitor progress via the output file.

>> Computation start time: 2026-04-11 09:18:59

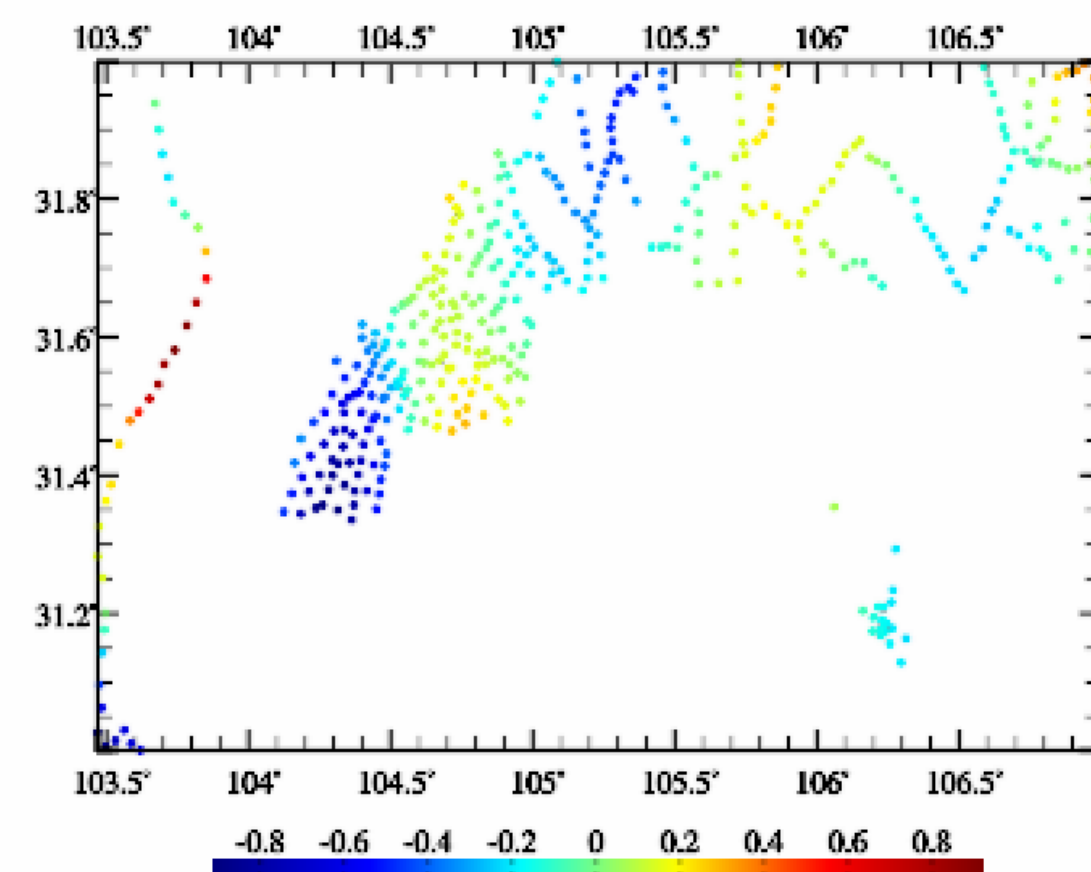
>> Complete the calculation of the model value for residual terrain (complete Bouguer) effects!

Save the results as

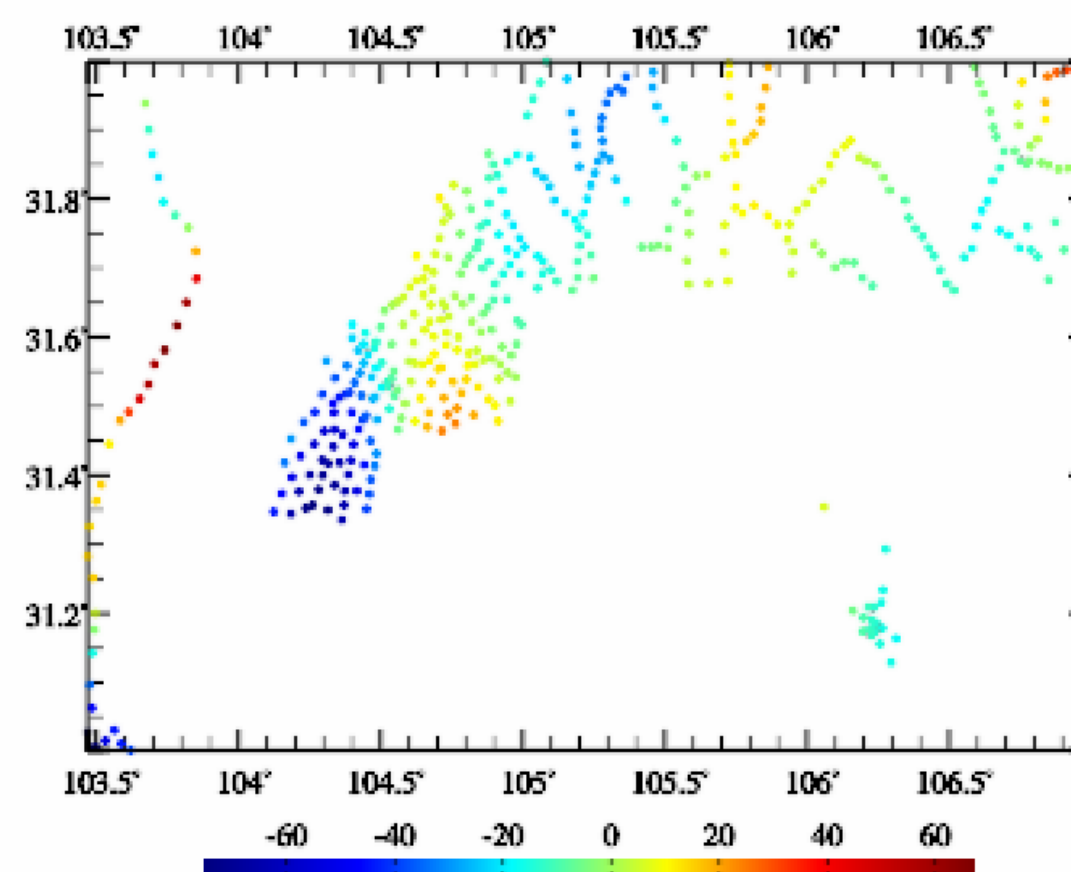
Import setting parameters

Start Computation

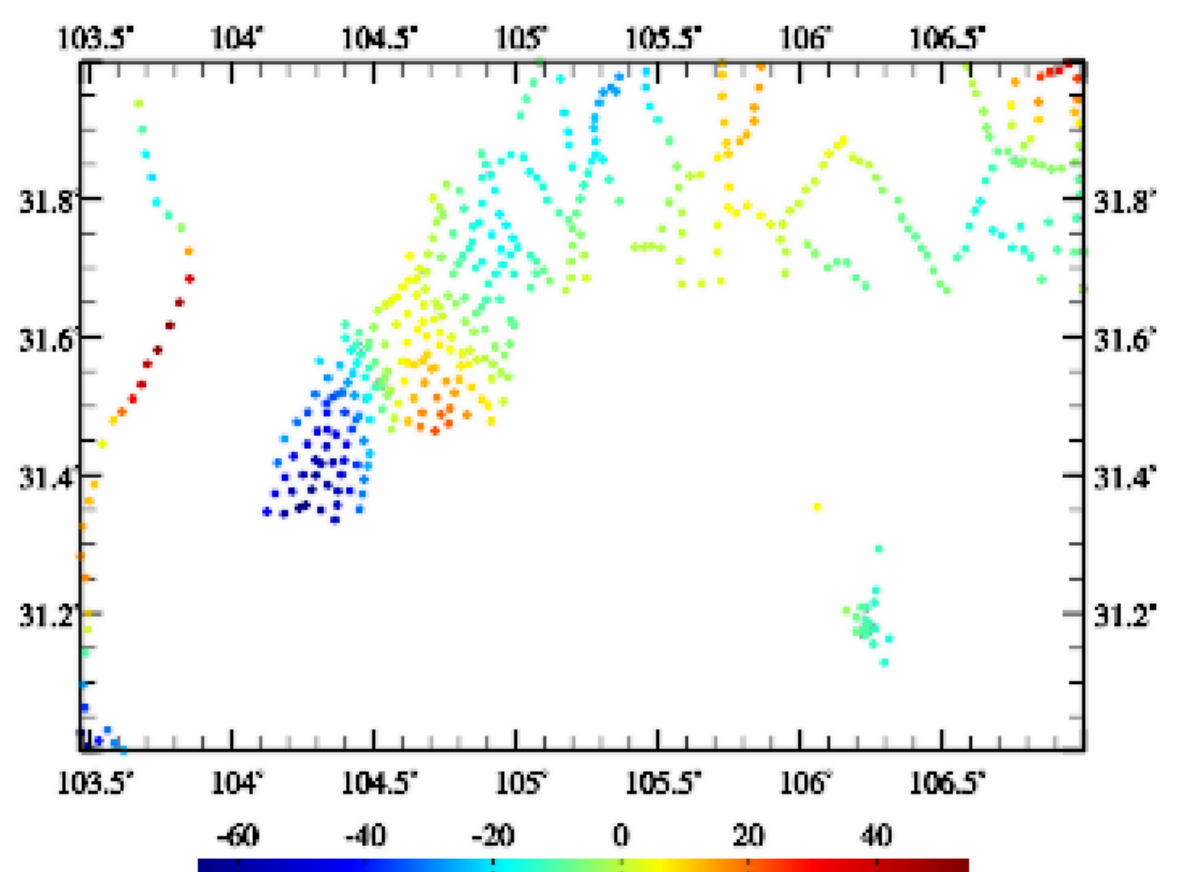
number (value or str)	long (degree/decimal)	lat (degree/decimal)	ellipHeight (m)
3248	103.671939	31.938051	2743.9394
3249	103.696944	31.864721	2501.2449
3250	103.718330	31.831114	2435.4206
3251	103.735559	31.795280	2366.5700
3252	103.777216	31.776390	2294.0304
3253	103.822773	31.758333	2233.2317



height anomaly (m)



gravity effect (mGal)



disturbing gradient (E, R)

Computation of Model Values for Complete Bouguer and Residual Terrain Effects

Computation of Model Values for Complete Bouguer and Residual Terrain Effects

Interactive Calculator for Global Land-Sea Terrain Effects

Spectral Characteristic Analysis of the Global Terrain Effects Model

Algorithmic Formulas

Open Global Land-Sea Terrain Mass Spherical Harmonic Coefficient Model

Select computation file format

Surface ellipsoidal height grid file

Open Computation Surface Ellipsoidal Height Grid File

Select elements to be calculated

☒ terrain elevation/sea bathymetry (m)

☒ height anomaly (m)

☒ gravity (anomaly/disturbance, mGal)

☒ vertical deflection (" , SW)

☒ (disturbing) gradient (E, radial)

☒ tangential gradient (E, NW)

☒ disturbing potential/geopotential (m^2/s^2)

Minimum degree 361

Maximum degree 720

Extract effects

Plot

>> Computation Process ** Operation Prompts

>> [Function] Computes model values for terrain elevation/ sea bathymetry and unified land-sea effects (Complete Bouguer or RTE) on the following elements using spherical harmonic synthesis: Height Anomaly (m), Gravity (Anomaly/Disturbance, mGal), Vertical Deflection Vector ("; South/West components), Disturbing Gravity Gradient (E; Radial component), Tangential Gravity Gradient Vector (E; North/West components), and Disturbing Geopotential (m^2/s^2).

** Click the [Open Global Land-Sea Terrain Mass Spherical Harmonic Coefficient Model File]...

>> Open Global Land-Sea Terrain Mass Spherical Harmonic Coefficient Model File C:/PAGrav4.5_win64en/data/ETOPOcs1800.dat.

** The window below only shows the spherical harmonic coefficients data with no more than 2000 rows in it.

>> Open Computation Surface Ellipsoidal Height Grid File C:/PAGrav4.5_win64en/examples/TerHarmrntinfluence/height.dat

>> Save the results as C:/PAGrav4.5_win64en/examples/TerHarmrntinfluence/result.txt.

** Outputs formatted records: ID, Lon, Lat, h, [Values...].

** Automatically generates specific grid files in the current directory: Terrain/Bathymetry (.dft), Radial Gravity Gradient (.grr), Tangential Gravity Gradient (.hgd), and Disturbing Potential/Geopotential (.gpo).

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] toolbar button.

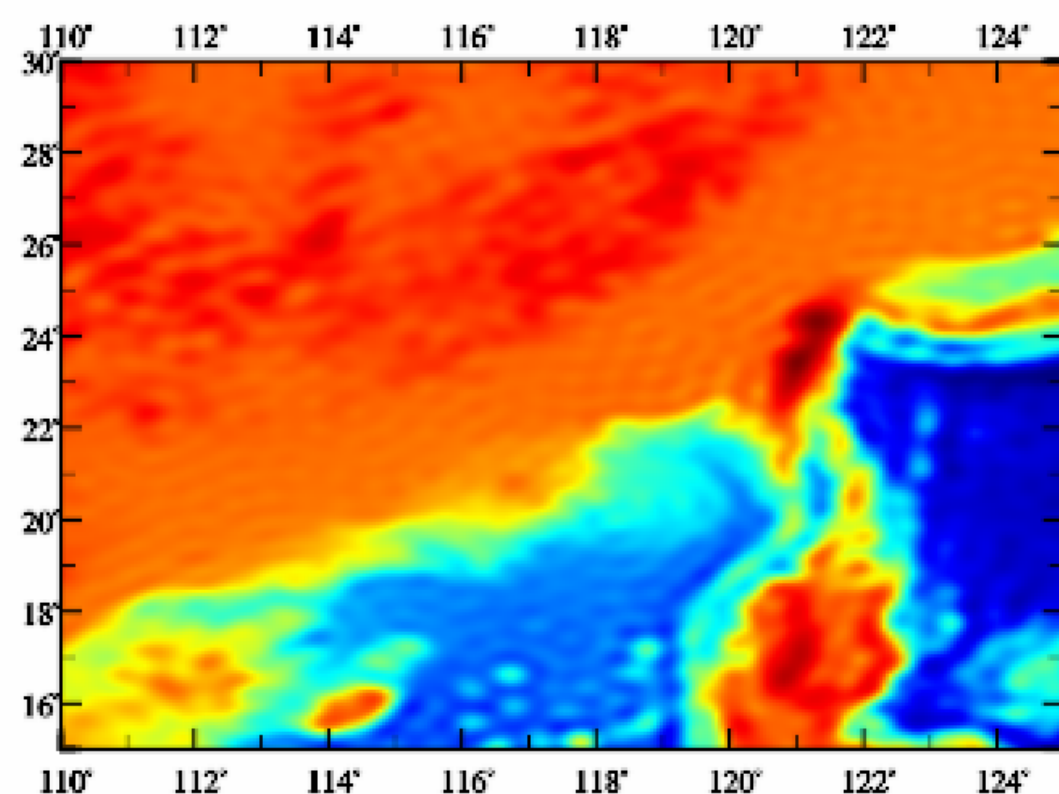
** Computation may take time; users can monitor progress via the output file.

>> Computation start time: 2026-04-11 09:25:23

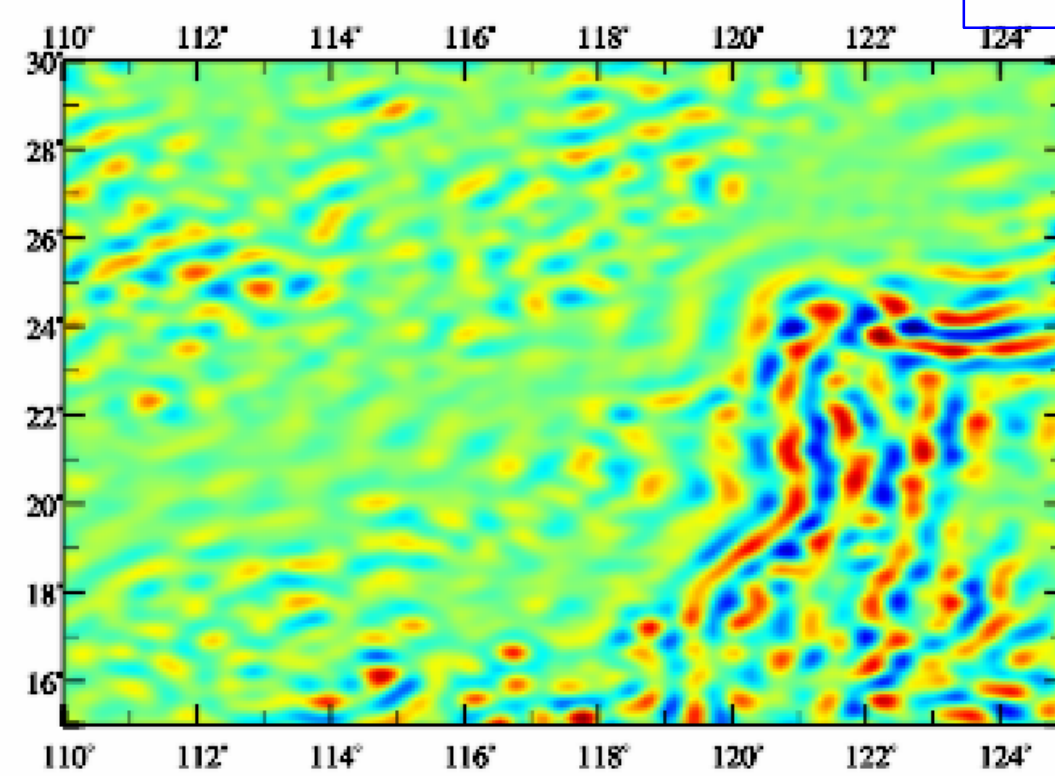
Save the results as

Import setting parameters

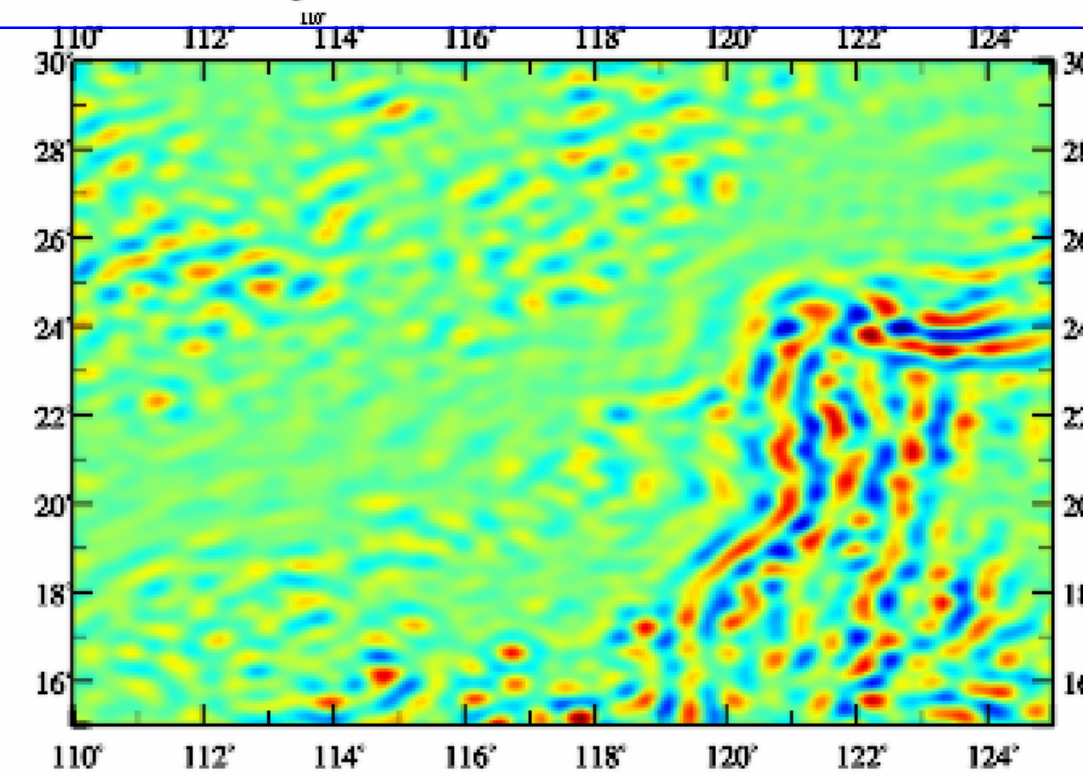
1	110.04167	15.04167	-1.947	-452.21	0.1195	7.4827	1.3856	-0.4563
2	110.12500	15.04167	-1.724	-483.72	0.1476	8.8020	6.7343	-0.1548
3	110.20833	15.04167	-1.484	-540.20	0.1315	1302	1.8229	4.1054
4	110.29167	15.04167	-1.222	-609.93	0.0825	3.5005	-0.7508	1.3415
5	110.37500	15.04167	-0.937	-675.48	0.0231	-0.0144	-0.5011	1.3018
6	110.45833	15.04167	-0.628	-724.62	-0.0245	-2.1472	-0.0988	0.8433



terrain elevation/bathymetry (m)



height anomaly (m)



gravity effect (mGal)

Interactive Calculator for Global Land-Sea Terrain Effects



Open Global Land-Sea Terrain Mass Spherical Harmonic Coefficient Model

Loading ultra-high-degree models requires initialization; please wait during this process.

Minimum degree 361

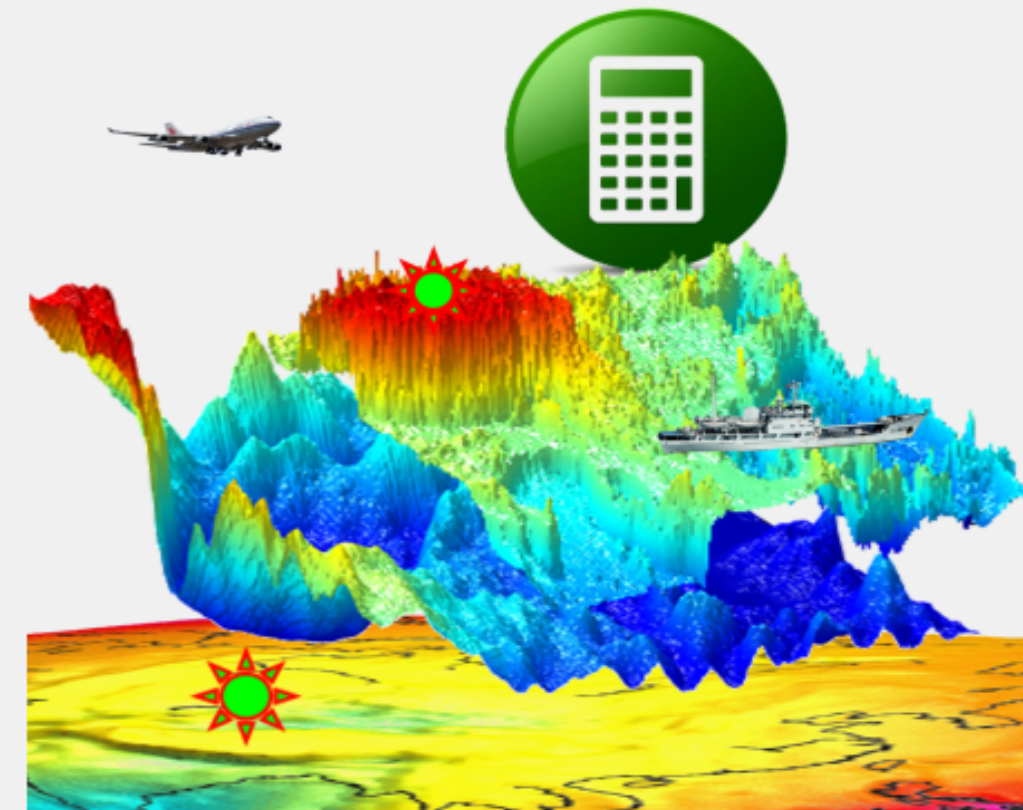
Maximum degree 1800

Input the geodetic coordinates of calculation point

longitude 121.240000°

latitude 29.428100°

ellipsoidal height 17.830m



Start Calculation

Model values of land-sea unified complete Bouguer or residual terrain effects

terrain elevation/sea bathymetry (m) 520.04

gravity (anomaly/disturbance, mGal) 57.9119

height anomaly (m) 0.4661

vertical deflection (" , S) 0.2286

vertical deflection (" , W) 1.3582

(disturbing) gradient (E, radial) 94.2959

tangential gradient (E, N) -16.2491

tangential gradient (E, W) -77.8878

(disturbing) geopotential (m^2/s^2) 4.5643

Global land-sea terrain mass spherical harmonic coefficient model

3.986004415	6378136.30	-3666611.637	1.478
1	0	1.7073567878991658E-01	0.0000000000000000E+00
1	1	1.6633036628733813E-01	1.1479210613310797E-01
2	0	1.6429313329998932E-01	0.0000000000000000E+00
2	1	8.5035152210278894E-02	9.1333502848550255E-02
2	2	-1.1793912586067470E-01	-1.7411465069800628E-02
3	0	-6.5349154204352972E-02	0.0000000000000000E+00
3	1	-4.4184211923815692E-02	4.0618031845130055E-02
3	2	-1.3069109856940694E-01	1.2578589265181686E-01
3	3	3.6582125575328230E-02	1.5294533153047263E-01
4	0	1.0192376884714217E-01	0.0000000000000000E+00
4	1	-5.9905008831126150E-02	-8.3292685493168567E-02
4	2	-1.1471261607043508E-01	1.9460308775542352E-02
4	3	1.0120760875721654E-01	-4.2251224280108600E-02

The relative error Θ
(%) of the model

Interactive Calculator for Global Land-Sea Terrain Effects



Open Global Land-Sea Terrain Mass Spherical Harmonic Coefficient Model

Loading ultra-high-degree models requires initialization; please wait during this process.

Minimum degree 361

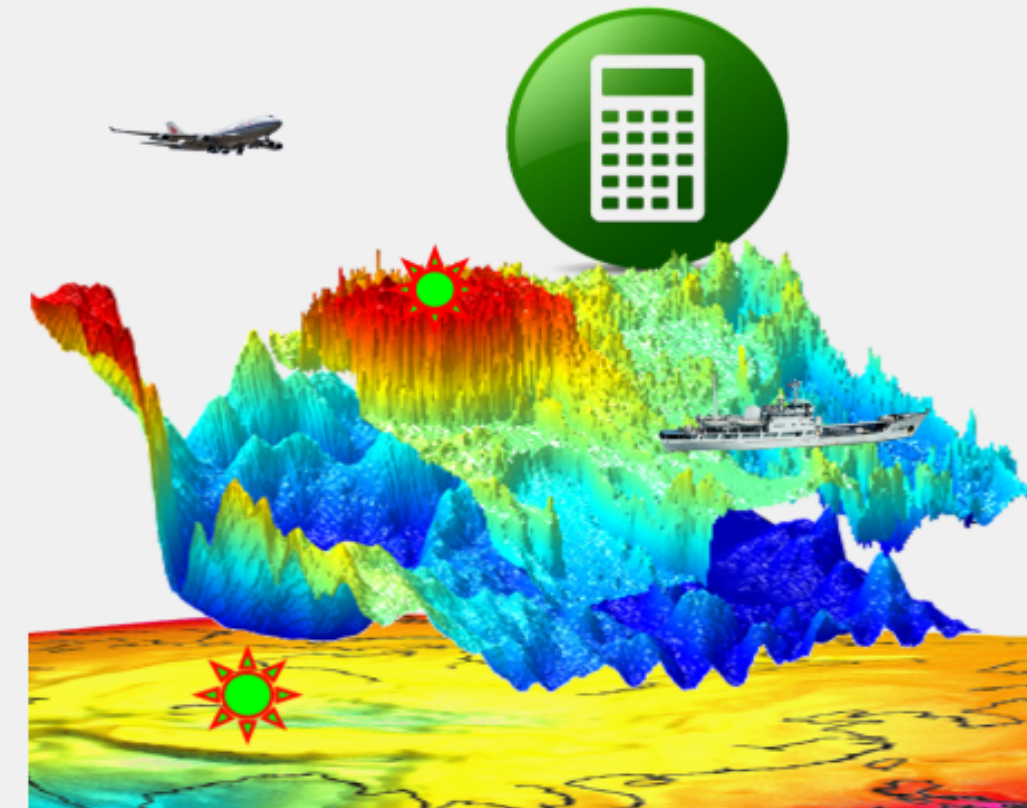
Maximum degree 1800

Input the geodetic coordinates of calculation point

longitude 132.240000°

latitude 21.428100°

ellipsoidal height 1.830m



Start Calculation

Model values of land-sea unified complete Bouguer or residual terrain effects

terrain elevation/sea bathymetry (m) -5950.95

gravity (anomaly/disturbance, mGal) -40.4123

height anomaly (m) -0.2083

vertical deflection (" , S) -5.2269

vertical deflection (" , W) -0.7046

(disturbing) gradient (E, radial) -91.6757

tangential gradient (E, N) 67.2680

tangential gradient (E, W) 24.2020

(disturbing) geopotential (m²/s²) -2.0384

Global land-sea terrain mass spherical harmonic coefficient model

```
3.986004415 6378136.30 -3666611.637 1.478
1 0 1.7073567878991658E-01 0.0000000000000000E+00
1 1 1.6633036628733813E-01 1.1479210613310797E-01
2 0 1.6429313329998932E-01 0.0000000000000000E+00
2 1 8.5035152210278894E-02 9.1333502848550255E-02
2 2 -1.1793912586067470E-01 -1.7411465069800628E-02
3 0 -6.5349154204352972E-02 0.0000000000000000E+00
3 1 -4.4184211923815692E-02 4.0618031845130055E-02
3 2 -1.3069109856940694E-01 1.2578589265181686E-01
3 3 3.6582125575328230E-02 1.5294533153047263E-01
4 0 1.0192376884714217E-01 0.0000000000000000E+00
4 1 -5.9905008831126150E-02 -8.3292685493168567E-02
4 2 -1.1471261607043508E-01 1.9460308775542352E-02
4 3 1.0120760875721654E-01 -4.2251224280108600E-02
```

The relative error Θ
(%) of the model

Spectral Characteristic Analysis of the Global Terrain Effects Model

 Open Global Land-Sea Terrain Mass Spherical Harmonic Coefficient Model

 Open High-degree Geopotential Model File

 Save the results as

 Start Calculation

Display of the input-output file

1	3.000000E+00	2.299603E+01	0.000000E+00
2	3.125000E-01	6.715451E+00	7.911381E-02
3	8.641975E-02	3.952913E+00	8.823035E-02
4	3.515625E-02	2.312997E+00	2.289217E-02
5	1.760000E-02	1.416801E+00	1.366044E-02
6	1.003086E-02	4.389914E-01	8.191773E-03
7	6.247397E-03	2.654210E-01	5.675256E-03
8	4.150391E-03	9.823847E-02	2.379274E-03
9	2.895900E-03	1.038844E-01	1.819157E-03
10	2.100000E-03	7.850419E-02	1.264171E-03
11	1.570931E-03	3.775911E-02	6.892058E-04
12	1.205633E-03	2.646725E-02	2.284380E-04
13	9.453451E-04	2.874715E-02	5.736342E-04
14	7.548938E-04	2.222554E-02	2.158315E-04
15	6.123457E-04	1.544843E-02	1.950448E-04
16	5.035400E-04	1.479913E-02	1.898962E-04
17	4.190563E-04	1.517999E-02	1.308700E-04

Start end row number 150

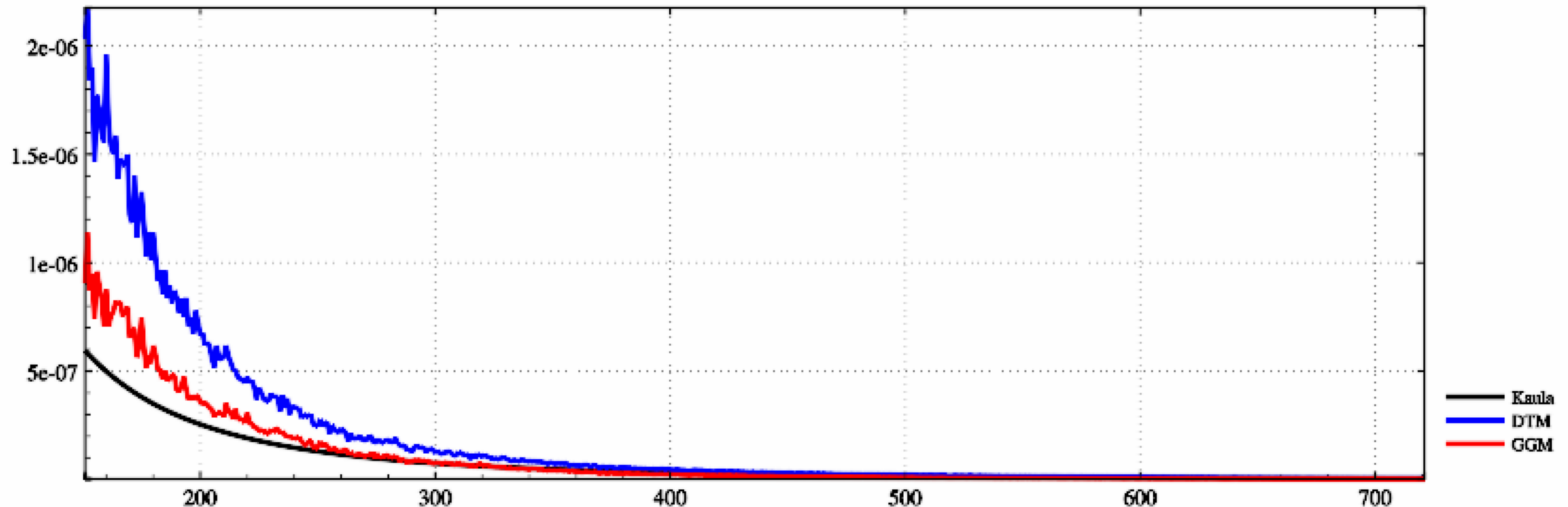
720

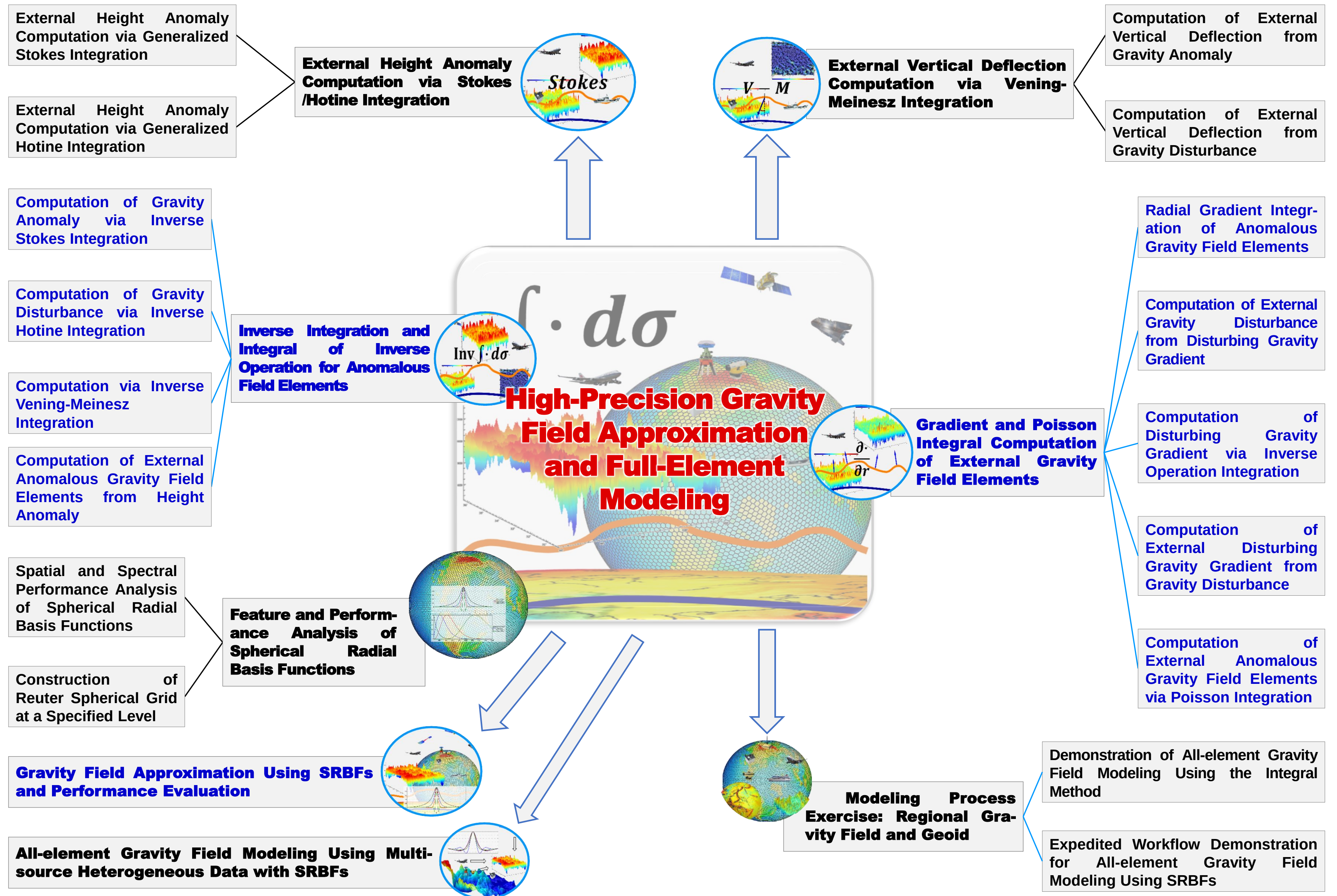
Line thickness 3

 Chart plot↓

 Save current plot as

Degree variance curves





External Height Anomaly Computation via Generalized Stokes Integration

External Height Anomaly Computation
via Generalized Stokes Integration

External Height Anomaly Computation
via Generalized Hotine Integration

Stokes and Hotine integral formulas

Open Equipotential Surface Ellipsoidal
Height Grid File

Open Residual Gravity Anomaly Grid File

Select computation file format

space computation point file

Open Space Computation Point File

Set input point file format

number of rows of file header 1

Ellipsoidal Height Column Index 4

Integral radius 180 km

Save the results as

Import setting parameters

Start Computation

>> Computation Process ** Operation Prompts

>> [Purpose] To compute height anomalies (m) on the geoid or in its outer space using generalized rigorous numerical integration or Fast Fourier Transform (FFT) algorithms based on Stokes or Hotine theory. Inputs include an ellipsoidal height grid defining an equipotential boundary surface and the corresponding gravity anomaly or gravity disturbance grid (mGal) on that surface.

>> On the geoid, the height anomaly is equivalent to the geoid undulation (geoidal/ ellipsoidal height).

>> To perform integration over a finite radius in local regions, a Remove-Restore scheme based on a reference global geopotential model is employed.

>> [Function] Computes the external residual height anomaly (m) via Stokes integration, utilizing an ellipsoidal height grid of an equipotential boundary surface and the corresponding residual gravity anomaly grid (mGal) on that surface.

>> Open Equipotential Surface Ellipsoidal Height Grid File C:/PAGravf4.5_win64en/examples/IntgenStokesHotine/landgeoidhgt.dat.

>> Open Residual Gravity Anomaly Grid File C:/PAGravf4.5_win64en/examples/IntgenStokesHotine/resGMIgeoid541_1800.gra.

>> Open Space Computation Point File C:/PAGravf4.5_win64en/examples/IntgenStokesHotine/calcpnt.txt.

** Look at the file information in the window below, set the input file format parameters...

>> Save the results as C:/PAGravf4.5_win64en/examples/IntgenStokesHotine/rststk.txt.

** Appends a column of computed residual height anomalies to the source file, retaining 4 significant figures.

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

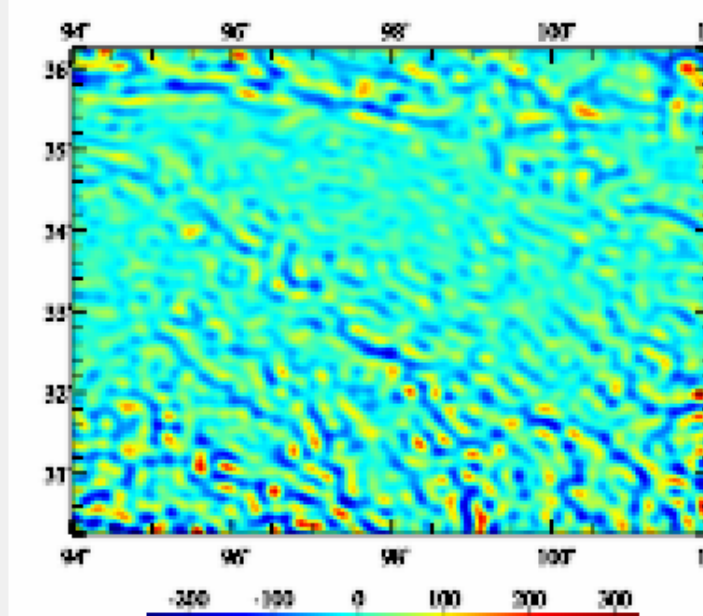
>> Computation start time: 2026-04-12 11:34:16

>> Complete the computation of external height anomaly!

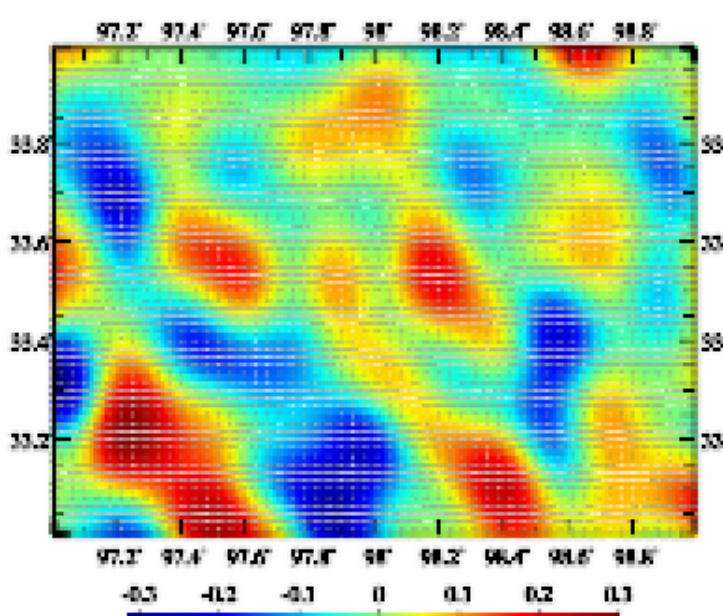
no	lon(degree/decimal)	lat	ellipHeight(m)	
1	97.008333	33.008333	3942.764	-0.0294
2	97.025000	33.008333	3989.787	-0.0340
3	97.041667	33.008333	4034.817	-0.0404
4	97.058333	33.008333	4070.847	-0.0485
5	97.075000	33.008333	4106.877	-0.0582
6	97.091667	33.008333	4119.913	-0.0693
7	97.108333	33.008333	4115.946	-0.0817
8	97.125000	33.008333	4090.977	-0.0952
9	97.141667	33.008333	4070.007	-0.1090
10	97.158333	33.008333	3991.047	-0.1235
11	97.175000	33.008333	3985.070	-0.1362
12	97.191667	33.008333	3956.107	-0.1475
13	97.208333	33.008333	3965.137	-0.1552
14	97.225000	33.008333	3964.173	-0.1592
15	97.241667	33.008333	3983.205	-0.1581
16	97.258333	33.008333	3953.251	-0.1526

Extract height anomaly

Plot



gravity anomaly (mGal)



height anomaly (m)

- Stokes Boundary Value Theory mandates that the boundary surface be an equipotential boundary surface; thus, input gravity anomalies/disturbances must reside on such a surface.
- Typically constructed from a global geopotential model (degree ≤ 360). For equipotential surfaces within an altitude of 10 km, a normal (or orthometric) equiheight surface may serve as a valid approximation.

External Height Anomaly Computation via Generalized Stokes Integration – 2D FFT

External Height Anomaly Computation
via Generalized Stokes Integration

External Height Anomaly Computation
via Generalized Hotine Integration

Stokes and Hotine integral formulas

Open Equipotential Surface Ellipsoidal
Height Grid File

Open Residual Gravity Anomaly Grid File

Select computation file format

surface ellipsoidal height grid file

Open Computation Surface Ellipsoidal
Height Grid File

Select integral algorithm

2D FFT algorithm

>> Computation Process ** Operation Prompts

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-12 11:34:16

>> Complete the computation of external height anomaly!

>> Computation end time: 2026-04-12 11:35:43

>> [Function] Computes the external residual height anomaly (m) via Stokes integration, utilizing an ellipsoidal height grid of an equipotential boundary surface and the corresponding residual gravity anomaly grid (mGal) on that surface.

>> Open Equipotential Surface Ellipsoidal Height Grid File C:/PAGrav4.5_win64en/examples/IntgenStokesHotine/landgeoidhgt.dat.

>> Open Residual Gravity Anomaly Grid File C:/PAGrav4.5_win64en/examples/IntgenStokesHotine/resGMlgeoid541_1800.gra.

>> Open Computation Surface Ellipsoidal Height Grid File C:/PAGrav4.5_win64en/examples/IntgenStokesHotine/landbmsurfhgt.dat.

>> Compute external residual height anomaly by 2D FFT algorithm...

>> Save the results as C:/PAGrav4.5_win64en/examples/IntgenStokesHotine/stokesFFT2.dat.

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-12 11:38:54

>> Complete the computation of external height anomaly!

>> Computation end time: 2026-04-12 11:38:55

Integral radius 180 km

Save the results as

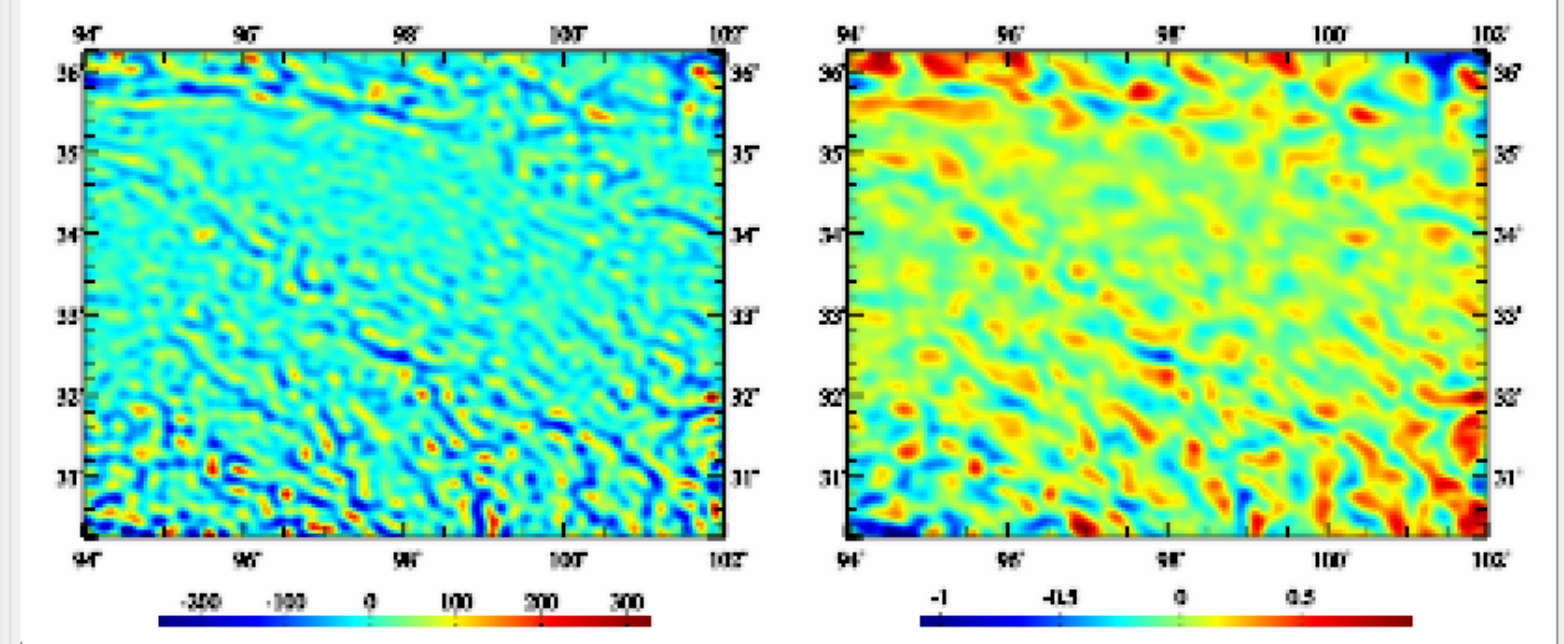
Import setting parameters

Start Computation

94.000000	102.000000	30.250000	36.250000	0.01666667	0.01666667	
-0.0801	-0.0775	-0.0825	-0.0952	-0.1146	-0.1390	-0.1667
-0.3914	-0.4036	-0.4126	-0.4191	-0.4241	-0.4292	-0.4362
-0.7545	-0.7992	-0.8366	-0.8651	-0.8842	-0.8944	-0.8971
-0.8988	-0.8960	-0.8837	-0.8596	-0.8213	-0.7679	-0.7000
0.0897	0.1378	0.1713	0.1904	0.1958	0.1884	0.1697
-0.2694	-0.3182	-0.3601	-0.3932	-0.4158	-0.4257	-0.4217
0.1558	0.2243	0.2769	0.3098	0.3208	0.3092	0.2763
-0.2183	-0.2149	-0.1962	-0.1656	-0.1276	-0.0868	-0.0479
-0.0505	-0.0730	-0.0945	-0.1144	-0.1326	-0.1492	-0.1642
-0.2305	-0.2288	-0.2252	-0.2196	-0.2115	-0.2005	-0.1861
0.0563	0.0686	0.0703	0.0607	0.0397	0.0086	-0.0306
-0.2157	-0.1802	-0.1347	-0.0816	-0.0234	0.0371	0.0978
0.3944	0.3889	0.3769	0.3592	0.3374	0.3126	0.2862
0.0878	0.0701	0.0532	0.0379	0.0251	0.0160	0.0116
0.1639	0.1731	0.1734	0.1640	0.1448	0.1166	0.0807

Extract height anomaly

Plot



gravity anomaly (mGal)

height anomaly (m)

- Stokes Boundary Value Theory mandates that the boundary surface be an equipotential boundary surface; thus, input gravity anomalies/disturbances must reside on such a surface.
- Typically constructed from a global geopotential model (degree ≤ 360). For equipotential surfaces within an altitude of 10 km, a normal (or orthometric) equiheight surface may serve as a valid approximation.

External Height Anomaly Computation via Generalized Stokes Integration – 1D FFT

External Height Anomaly Computation
via Generalized Stokes Integration

External Height Anomaly Computation
via Generalized Hotine Integration

Stokes and Hotine integral formulas

Save computation process as

Open Equipotential Surface Ellipsoidal
Height Grid File

Open Residual Gravity Anomaly Grid File

Select computation file format

surface ellipsoidal height grid file

Open Computation Surface Ellipsoidal
Height Grid File

Select integral algorithm

1D FFT algorithm

>> Computation Process ** Operation Prompts

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-12 11:38:54

>> Complete the computation of external height anomaly!

>> Computation end time: 2026-04-12 11:38:55

>> [Function] Computes the external residual height anomaly (m) via Stokes integration, utilizing an ellipsoidal height grid of an equipotential boundary surface and the corresponding residual gravity anomaly grid (mGal) on that surface.

>> Open Equipotential Surface Ellipsoidal Height Grid File C:/PAGravf4.5_win64en/examples/IntgenStokesHotine/landgeoidhgt.dat.

>> Open Residual Gravity Anomaly Grid File C:/PAGravf4.5_win64en/examples/IntgenStokesHotine/resGMIgeoid541_1800.gra.

>> Open Computation Surface Ellipsoidal Height Grid File C:/PAGravf4.5_win64en/examples/IntgenStokesHotine/landbmsurfhgt.dat.

>> Compute external residual height anomaly by 1D FFT algorithm...

>> Save the results as C:/PAGravf4.5_win64en/examples/IntgenStokesHotine/stokesFFT1.dat.

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-12 11:40:19

>> Complete the computation of external height anomaly!

>> Computation end time: 2026-04-12 11:40:40

Integral radius 180 km

Save the results as

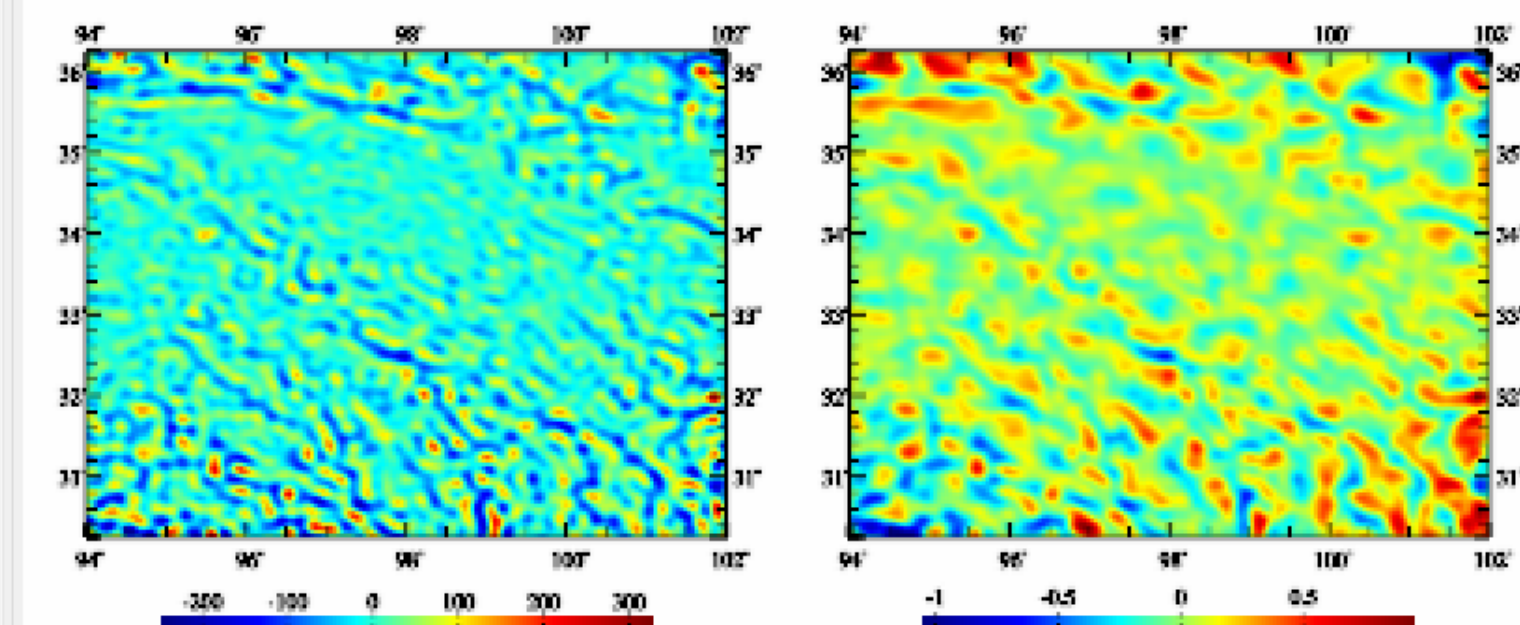
Import setting parameters

Start Computation

94.000000	102.000000	30.250000	36.250000	0.01666667	0.01666667	
-0.0952	-0.0880	-0.0882	-0.0965	-0.1123	-0.1340	-0.1600
-0.3732	-0.3838	-0.3920	-0.3989	-0.4053	-0.4126	-0.4224
-0.7210	-0.7623	-0.7987	-0.8291	-0.8527	-0.8694	-0.8802
-0.8921	-0.8822	-0.8643	-0.8363	-0.7968	-0.7448	-0.6806
0.0945	0.1479	0.1862	0.2089	0.2161	0.2087	0.1878
-0.2825	-0.3320	-0.3751	-0.4100	-0.4351	-0.4483	-0.4479
0.1639	0.2432	0.3053	0.3456	0.3612	0.3510	0.3162
-0.2177	-0.2100	-0.1866	-0.1515	-0.1100	-0.0683	-0.0304
-0.0415	-0.0652	-0.0882	-0.1099	-0.1299	-0.1480	-0.1642
-0.2320	-0.2323	-0.2309	-0.2270	-0.2199	-0.2087	-0.1924
0.0941	0.1026	0.0979	0.0796	0.0488	0.0077	-0.0403
-0.2009	-0.1641	-0.1212	-0.0745	-0.0260	0.0228	0.0710
0.4179	0.4290	0.4295	0.4189	0.3977	0.3672	0.3294
0.0566	0.0509	0.0472	0.0443	0.0414	0.0385	0.0360
0.1418	0.1571	0.1655	0.1650	0.1543	0.1328	0.1010

Extract height anomaly

Plot



gravity anomaly (mGal)

height anomaly (m)

- Stokes Boundary Value Theory mandates that the boundary surface be an equipotential boundary surface; thus, input gravity anomalies/disturbances must reside on such a surface.
- Typically constructed from a global geopotential model (degree ≤ 360). For equipotential surfaces within an altitude of 10 km, a normal (or orthometric) equiheight surface may serve as a valid approximation.

Table 4.1: Statistics of Model Reference Truth (Unit: m)

Item	Mean	Std. Dev.	Minimum	Maximum
Ground Height Anomalies (Deg 541 – 1800)	0.0010	0.1182	-0.6745	0.4760

Table 4.2: Differences between Stokes Computed Results and Reference Truth (m)

Algorithm	Mean	Std. Dev.	Minimum	Maximum
Numerical Integration	-0.0002	0.0324	-0.1159	0.1211
FFT2	0.0018	0.0326	-0.1150	0.1280
FFT1	0.0018	0.0327	-0.1178	0.1251

Algorithm Performance: The ratio of the standard deviation of Differences in Table 4.2 to the standard deviation of Reference Truths in Table 4.1 reflects the approximation capability of the corresponding algorithm.

External Height Anomaly Computation via Generalized Hotine Integration

External Height Anomaly Computation
via Generalized Stokes Integration

External Height Anomaly Computation
via Generalized Hotine Integration

Stokes and Hotine integral formulas

Save computation process as

Open Equipotential Surface Ellipsoidal
Height Grid File

Open Residual Gravity Disturbance Grid File

Select computation file format

space computation point file

Open Space Computation Point File

Set input point file format

number of rows of file header 1

Ellipsoidal Height Column Index 4

>> Computation Process ** Operation Prompts

>> Complete the computation of external height anomaly!

>> Computation end time: 2026-04-12 11:40:40

>> [Function] Computes the external residual height anomaly (m) via Hotine integration, utilizing an ellipsoidal height grid of an equipotential boundary surface and the corresponding residual gravity disturbance grid (mGal) on that surface.

>> Open Equipotential Surface Ellipsoidal Height Grid File C:/PAGrav4.5_win64en/examples/IntgenStokesHotine/landgeoidhgt.dat.

>> Open Residual Gravity Anomaly Grid File C:/PAGrav4.5_win64en/examples/IntgenStokesHotine/resGMIgeoid541_1800.rga.

>> Open Space Computation Point File C:/PAGrav4.5_win64en/examples/IntgenStokesHotine/calcpnt.txt.

** Look at the file information in the window below, set the input file format parameters...

>> Open Space Computation Point File C:/PAGrav4.5_win64en/examples/IntgenStokesHotine/calcpnt.txt.

** Look at the file information in the window below, set the input file format parameters...

>> Save the results as C:/PAGrav4.5_win64en/examples/IntgenStokesHotine/rsthtn.txt.

** Appends a column of computed residual height anomalies to the source file, retaining 4 significant figures.

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-12 11:42:19

>> Complete the computation of external height anomaly!

>> Computation end time: 2026-04-12 11:44:04

Integral radius 180 km

Save the results as

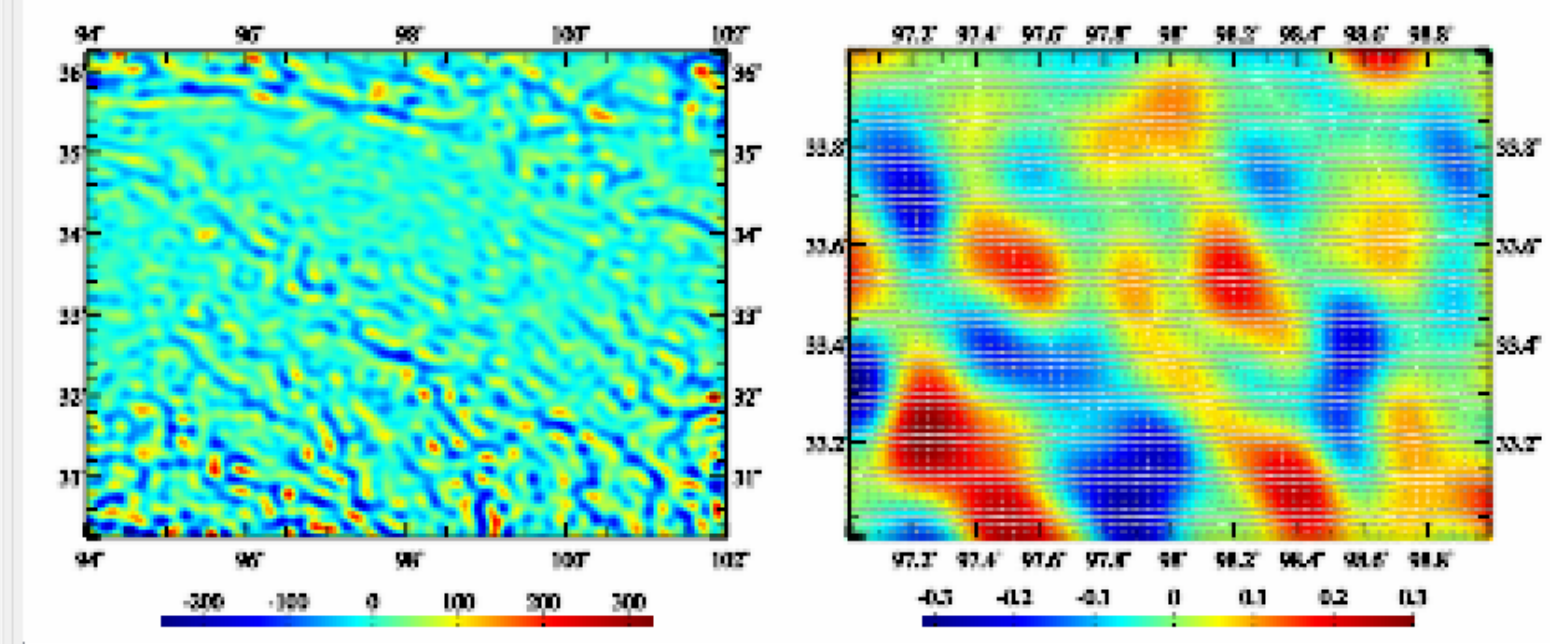
Import setting parameters

Start Computation

no	lon(degree/decimal)	lat	ellipHeight(m)	
1	97.008333	33.008333	3942.764	-0.0297
2	97.025000	33.008333	3989.787	-0.0343
3	97.041667	33.008333	4034.817	-0.0407
4	97.058333	33.008333	4070.847	-0.0488
5	97.075000	33.008333	4106.877	-0.0585
6	97.091667	33.008333	4119.913	-0.0697
7	97.108333	33.008333	4115.946	-0.0821
8	97.125000	33.008333	4090.977	-0.0955
9	97.141667	33.008333	4070.007	-0.1094
10	97.158333	33.008333	3991.047	-0.1239
11	97.175000	33.008333	3985.070	-0.1366
12	97.191667	33.008333	3956.107	-0.1479
13	97.208333	33.008333	3965.137	-0.1556
14	97.225000	33.008333	3964.173	-0.1596
15	97.241667	33.008333	3983.205	-0.1585
16	97.258333	33.008333	3953.251	-0.1530

Extract height anomaly

Plot



gravity disturbance (mGal)

height anomaly (m)

- Stokes Boundary Value Theory mandates that the boundary surface be an equipotential boundary surface; thus, input gravity anomalies/disturbances must reside on such a surface.
- Typically constructed from a global geopotential model (degree ≤ 360). For equipotential surfaces within an altitude of 10 km, a normal (or orthometric) equiheight surface may serve as a valid approximation.

External Height Anomaly Computation via Generalized Hotine Integration – 2D FFT

External Height Anomaly Computation
via Generalized Stokes Integration

External Height Anomaly Computation
via Generalized Hotine Integration

Stokes and Hotine integral formulas

Open Equipotential Surface Ellipsoidal
Height Grid File

Open Residual Gravity Disturbance Grid File

Select computation file format

surface ellipsoidal height grid file

Open Computation Surface Ellipsoidal
Height Grid File

Select integral algorithm

2D FFT algorithm

>> Computation Process ** Operation Prompts

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-12 11:42:19

>> Complete the computation of external height anomaly!

>> Computation end time: 2026-04-12 11:44:04

>> [Function] Computes the external residual height anomaly (m) via Hotine integration, utilizing an ellipsoidal height grid of an equipotential boundary surface and the corresponding residual gravity disturbance grid (mGal) on that surface.

>> Open Equipotential Surface Ellipsoidal Height Grid File C:/PAGravf4.5_win64en/examples/IntgenStokesHotine/landgeoidhgt.dat.

>> Open Residual Gravity Anomaly Grid File C:/PAGravf4.5_win64en/examples/IntgenStokesHotine/resGMIgeoid541_1800.rga.

>> Open Computation Surface Ellipsoidal Height Grid File C:/PAGravf4.5_win64en/examples/IntgenStokesHotine/landbmsurfhgt.dat.

>> Compute external residual height anomaly by 2D FFT algorithm...

>> Save the results as C:/PAGravf4.5_win64en/examples/IntgenStokesHotine/HotineFFT2.dat.

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-12 11:45:59

>> Complete the computation of external height anomaly!

>> Computation end time: 2026-04-12 11:46:00

Integral radius 180 km

Save the results as

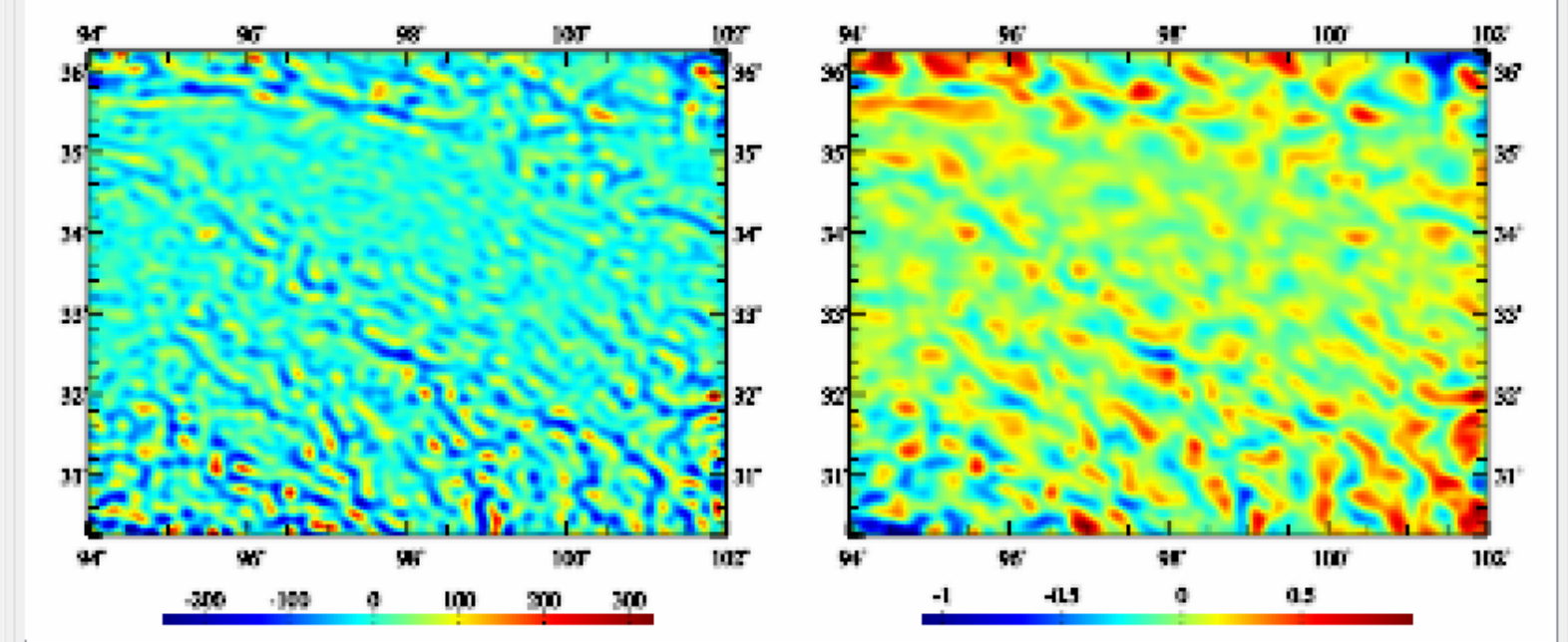
Import setting parameters

Start Computation

94.000000	102.000000	30.250000	36.250000	0.01666667	0.01666667	
-0.0804	-0.0778	-0.0828	-0.0956	-0.1150	-0.1395	-0.1672
-0.3925	-0.4048	-0.4138	-0.4203	-0.4253	-0.4304	-0.4375
-0.7564	-0.8011	-0.8386	-0.8672	-0.8863	-0.8965	-0.8993
-0.9010	-0.8982	-0.8859	-0.8617	-0.8233	-0.7698	-0.7018
0.0895	0.1377	0.1713	0.1905	0.1959	0.1886	0.1698
-0.2700	-0.3189	-0.3609	-0.3941	-0.4166	-0.4267	-0.4226
0.1560	0.2246	0.2772	0.3102	0.3212	0.3097	0.2768
-0.2186	-0.2152	-0.1965	-0.1658	-0.1278	-0.0870	-0.0480
-0.0506	-0.0732	-0.0948	-0.1147	-0.1330	-0.1496	-0.1646
-0.2312	-0.2296	-0.2260	-0.2203	-0.2122	-0.2013	-0.1869
0.0560	0.0683	0.0701	0.0604	0.0395	0.0083	-0.0309
-0.2158	-0.1803	-0.1347	-0.0814	-0.0231	0.0376	0.0984
0.3955	0.3901	0.3780	0.3603	0.3384	0.3135	0.2871
0.0882	0.0704	0.0535	0.0382	0.0254	0.0163	0.0120
0.1644	0.1736	0.1739	0.1645	0.1453	0.1170	0.0811

Extract height anomaly

Plot



gravity disturbance (mGal)

height anomaly (m)

- Stokes Boundary Value Theory mandates that the boundary surface be an equipotential boundary surface; thus, input gravity anomalies/disturbances must reside on such a surface.
- Typically constructed from a global geopotential model (degree ≤ 360). For equipotential surfaces within an altitude of 10 km, a normal (or orthometric) equiheight surface may serve as a valid approximation.

External Height Anomaly Computation via Generalized Hotine Integration – 1D FFT

External Height Anomaly Computation
via Generalized Stokes Integration

External Height Anomaly Computation
via Generalized Hotine Integration

Stokes and Hotine integral formulas

Open Equipotential Surface Ellipsoidal
Height Grid File

Open Residual Gravity Disturbance Grid File

Select computation file format

surface ellipsoidal height grid file

Open Computation Surface Ellipsoidal
Height Grid File

Select integral algorithm

1D FFT algorithm

>> Computation Process ** Operation Prompts

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-12 11:45:59

>> Complete the computation of external height anomaly!

>> Computation end time: 2026-04-12 11:46:00

>> [Function] Computes the external residual height anomaly (m) via Hotine integration, utilizing an ellipsoidal height grid of an equipotential boundary surface and the corresponding residual gravity disturbance grid (mGal) on that surface.

>> Open Equipotential Surface Ellipsoidal Height Grid File C:/PAGravf4.5_win64en/examples/IntgenStokesHotine/landgeoidhgt.dat.

>> Open Residual Gravity Anomaly Grid File C:/PAGravf4.5_win64en/examples/IntgenStokesHotine/resGMlgeoid541_1800.rga.

>> Open Computation Surface Ellipsoidal Height Grid File C:/PAGravf4.5_win64en/examples/IntgenStokesHotine/landbmsurfhgt.dat.

>> Compute external residual height anomaly by 1D FFT algorithm...

>> Save the results as C:/PAGravf4.5_win64en/examples/IntgenStokesHotine/HotineFFT1.dat.

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-12 11:47:16

>> Complete the computation of external height anomaly!

>> Computation end time: 2026-04-12 11:47:38

Integral radius 180 km

Save the results as

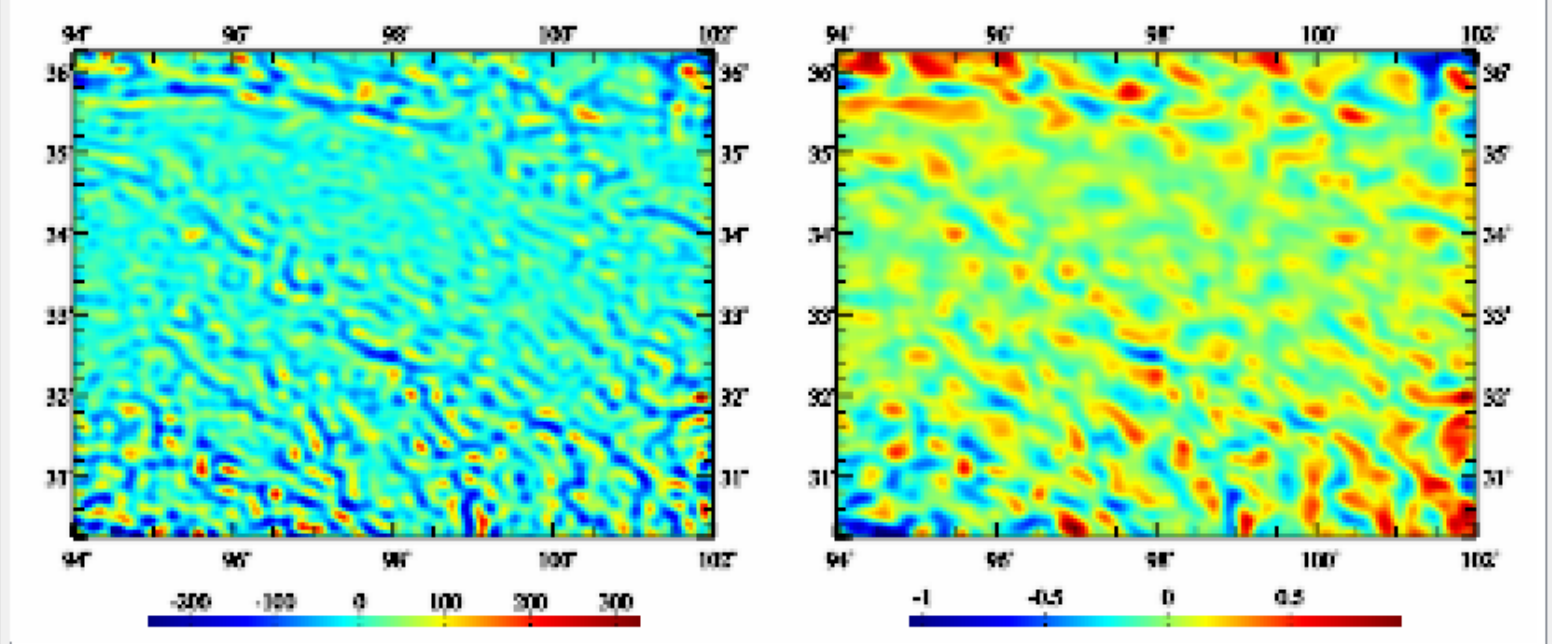
Import setting parameters

Start Computation

94.000000	102.000000	30.250000	36.250000	0.01666667	0.01666667	
-0.0955	-0.0883	-0.0885	-0.0969	-0.1127	-0.1345	-0.1605
-0.3743	-0.3849	-0.3932	-0.4000	-0.4065	-0.4139	-0.4236
-0.7228	-0.7642	-0.8007	-0.8311	-0.8547	-0.8715	-0.8824
-0.8943	-0.8844	-0.8664	-0.8384	-0.7988	-0.7467	-0.6824
0.0943	0.1478	0.1862	0.2091	0.2163	0.2088	0.1880
-0.2832	-0.3327	-0.3759	-0.4109	-0.4360	-0.4493	-0.4489
0.1640	0.2435	0.3057	0.3460	0.3617	0.3515	0.3167
-0.2180	-0.2103	-0.1868	-0.1517	-0.1102	-0.0684	-0.0304
-0.0416	-0.0654	-0.0884	-0.1102	-0.1302	-0.1483	-0.1646
-0.2327	-0.2331	-0.2316	-0.2278	-0.2207	-0.2095	-0.1932
0.0938	0.1024	0.0977	0.0794	0.0485	0.0074	-0.0406
-0.2011	-0.1642	-0.1211	-0.0743	-0.0257	0.0232	0.0716
0.4191	0.4302	0.4307	0.4201	0.3988	0.3682	0.3303
0.0570	0.0513	0.0475	0.0446	0.0418	0.0388	0.0363
0.1424	0.1576	0.1660	0.1655	0.1547	0.1332	0.1013

Extract height anomaly

Plot



gravity disturbance (mGal)

height anomaly (m)

- Stokes Boundary Value Theory mandates that the boundary surface be an equipotential boundary surface; thus, input gravity anomalies/disturbances must reside on such a surface.
- Typically constructed from a global geopotential model (degree ≤ 360). For equipotential surfaces within an altitude of 10 km, a normal (or orthometric) equiheight surface may serve as a valid approximation.

Table 4.1: Statistics of Model Reference Truth (Unit: m)

Item	Mean	Std. Dev.	Minimum	Maximum
Ground Height Anomalies (Deg 541 – 1800)	0.0010	0.1182	-0.6745	0.4760

Table 4.4: Differences between Hotine Computed Results and Reference Truth (m)

Algorithm	Mean	Std. Dev.	Minimum	Maximum
Numerical Integration	-0.0001	0.0256	-0.0915	0.0957
FFT2	0.0019	0.0259	-0.0911	0.1065
FFT1	0.0018	0.0261	-0.0934	0.1036

The performance of the Hotine integration algorithm is slightly better than that of the Stokes integration algorithm.

Computation of External Vertical Deflection from Gravity Anomaly

Computation of External Vertical Deflection from Gravity Anomaly

Computation of External Vertical Deflection from Gravity Disturbance

Vening-Meinesz integral formulas

Open Equipotential Surface Ellipsoidal Height Grid File

Open Residual Gravity Anomaly Grid File

Select computation file format

space computation point file

Open Space Computation Point File

Set input point file format

number of rows of file header 1

Ellipsoidal Height Column Index 4

Integral radius 180 km

Extract vertical deflection

Plot

>> Computation Process ** Operation Prompts

>> [Function] Computes the external residual vertical deflection (" , south and west components) via the generalized Vening-Meinesz integration, utilizing an ellipsoidal height grid of an equipotential boundary surface and the corresponding residual gravity anomaly grid (mGal).

>> Open Equipotential Surface Ellipsoidal Height Grid File C:/PAGravf4.5_win64en/examples/IntgenVeningMeinesz/landgeoidhgt.dat.

>> Open Residual Gravity Anomaly Grid File C:/PAGravf4.5_win64en/examples/IntgenVeningMeinesz/resGMIgeoid541_1800.gra.

>> Open Space Computation Point File C:/PAGravf4.5_win64en/examples/IntgenVeningMeinesz/calcpnt.txt.

** Look at the file information in the window below, set the input file format parameters...

>> Save the results as C:/PAGravf4.5_win64en/examples/IntgenVeningMeinesz/rstrga.txt.

** Record format: Appends two columns (southward and westward components) of computed residual vertical deflections to the source file, retaining 4 significant figures.

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

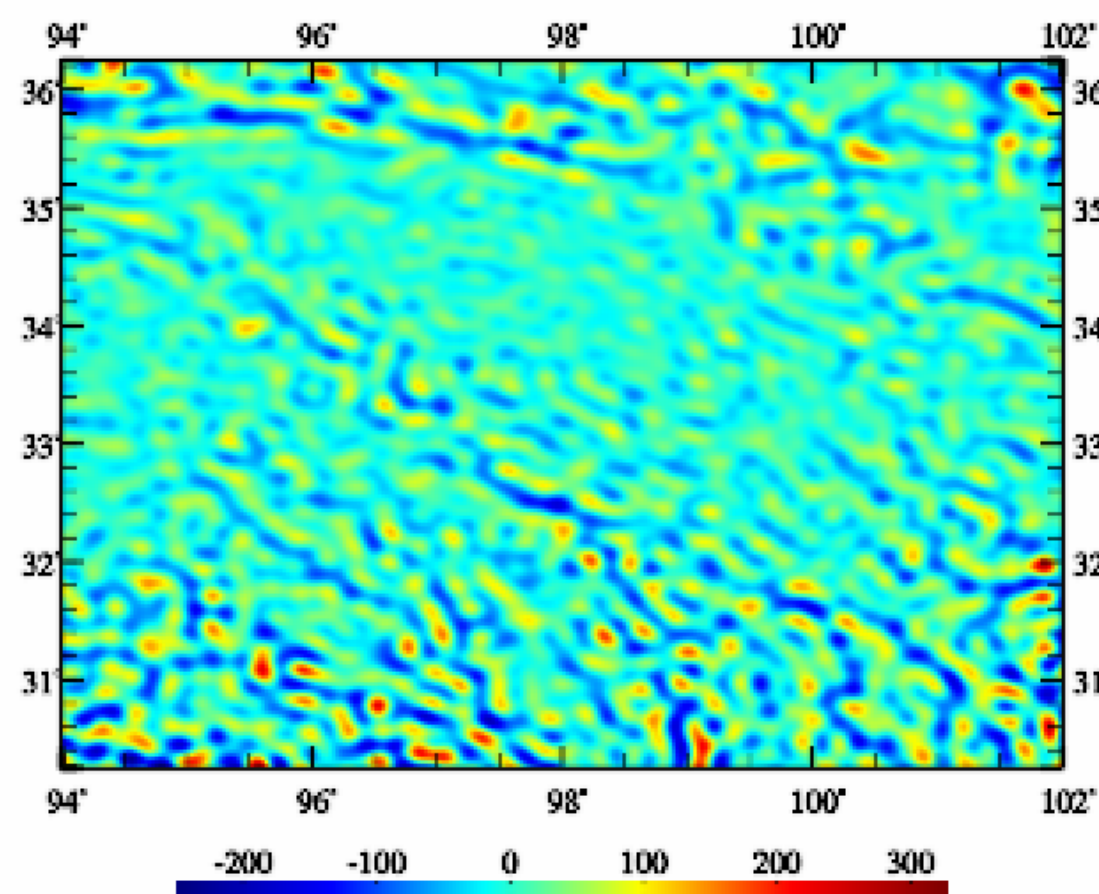
>> Computation start time: 2026-04-12 15:04:16

Save the results as

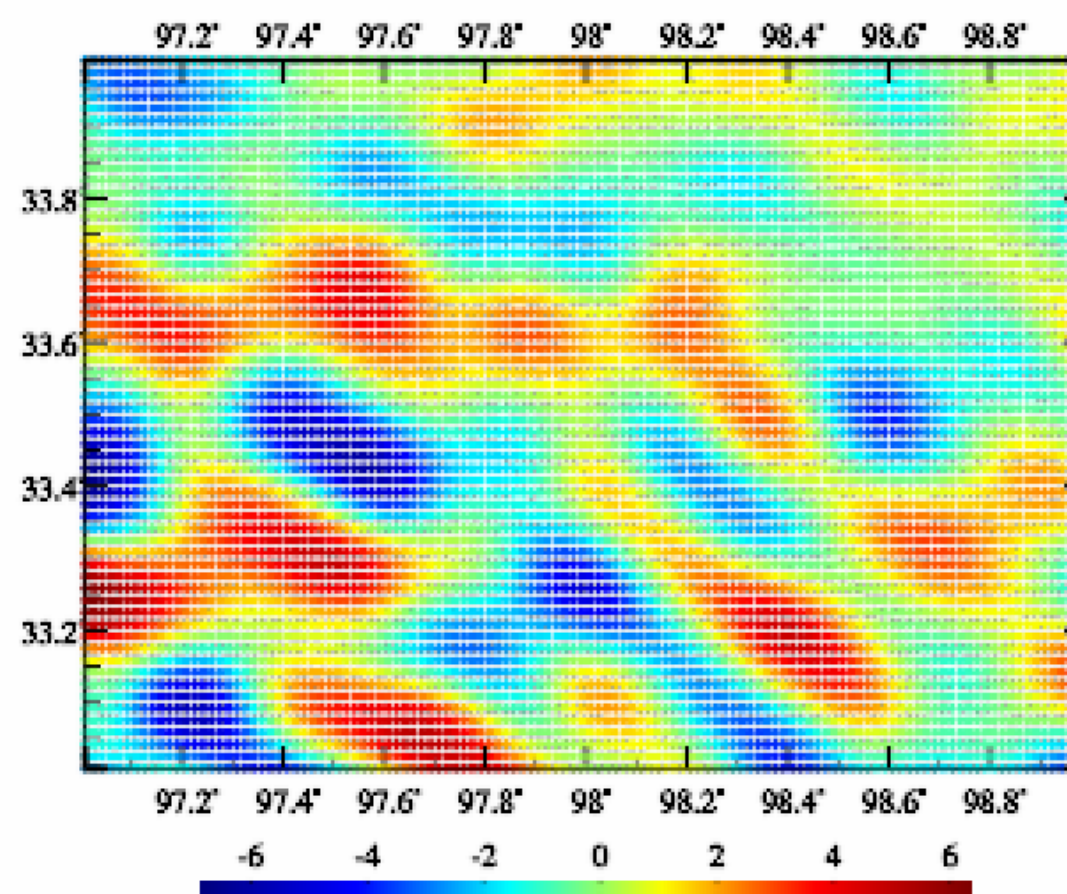
Import setting parameters

Start Computation

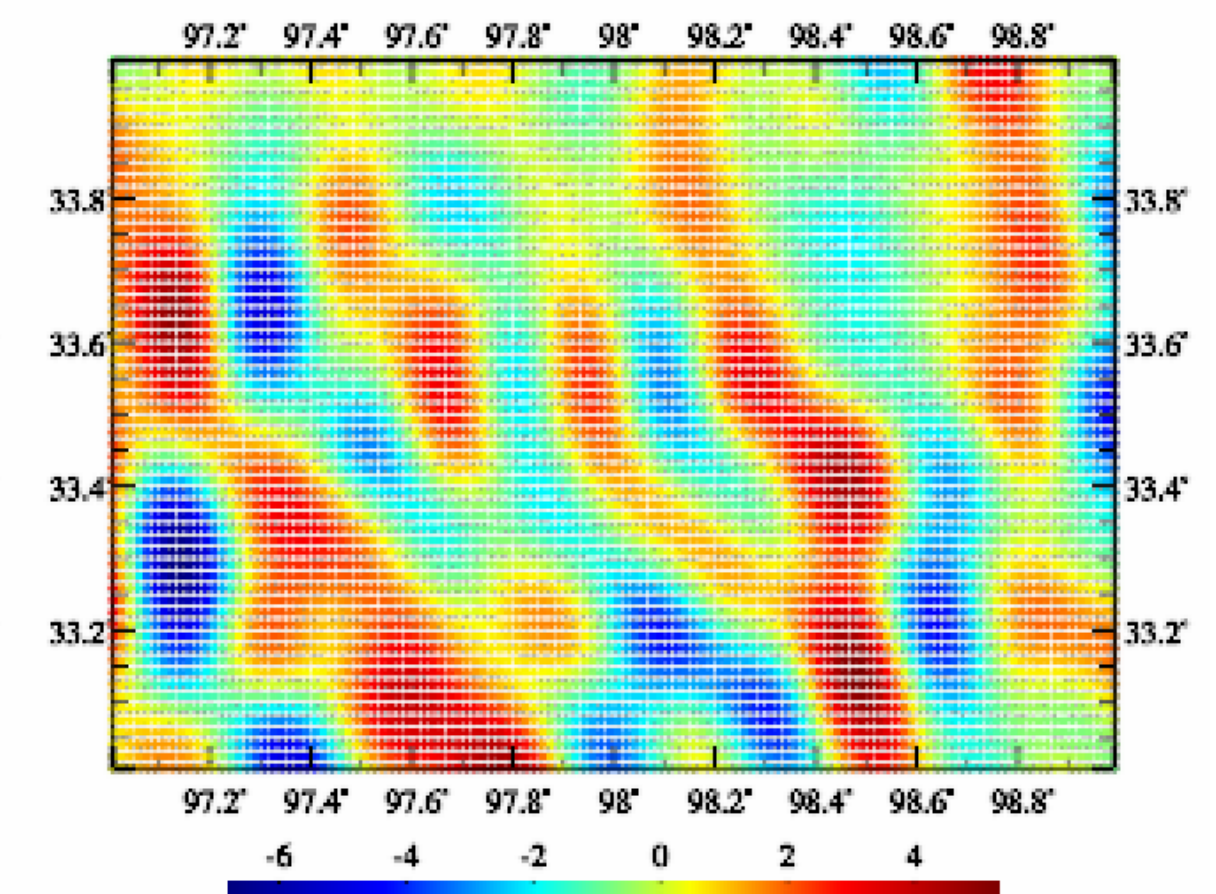
no	lon(degree/decimal)	lat	ellipHeight(m)		
1	97.008333	33.008333	3942.764	-2.4975	0.4726
2	97.025000	33.008333	3989.787	-2.4200	0.6841
3	97.041667	33.008333	4034.817	-2.3012	0.9131
4	97.058333	33.008333	4070.847	-2.1495	1.1375
5	97.075000	33.008333	4106.877	-1.9758	1.3348
6	97.091667	33.008333	4119.913	-1.7943	1.4946
7	97.108333	33.008333	4115.946	-1.6197	1.6015



gravity anomaly (mGal)



vertical deflection (" , S)



vertical deflection (" , W)

Computation of External Vertical Deflection from Gravity Anomaly – 2D FFT

Computation of External Vertical Deflection from Gravity Anomaly

Computation of External Vertical Deflection from Gravity Disturbance

Vening-Meinesz integral formulas

Open Equipotential Surface Ellipsoidal Height Grid File

Open Residual Gravity Anomaly Grid File

Select computation file format

surface ellipsoidal height grid file

Open Computation Surface Ellipsoidal Height Grid File

Select integral algorithm

2D FFT algorithm

Integral radius 180 km

>> Computation Process ** Operation Prompts

>> [Function] Computes the external residual vertical deflection (" , south and west components) via the generalized Vening-Meinesz integration, utilizing an ellipsoidal height grid of an equipotential boundary surface and the corresponding residual gravity anomaly grid (mGal).

>> Open Equipotential Surface Ellipsoidal Height Grid File C:/PAGravf4.5_win64en/examples/IntgenVeningMeinesz/landgeoidhgt.dat.

>> Open Residual Gravity Anomaly Grid File C:/PAGravf4.5_win64en/examples/IntgenVeningMeinesz/resGMIgeoid541_1800.gra.

>> Open Computation Surface Ellipsoidal Height Grid File C:/PAGravf4.5_win64en/examples/IntgenVeningMeinesz/landbmsurfhgt.dat.

>> Compute external residual vertical deflection by 2D FFT algorithm...

>> Save the results as C:/PAGravf4.5_win64en/examples/IntgenVeningMeinesz/gratovmFFT2.dat.

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-12 15:08:28

>> Complete the computation of external vertical deflection!

>> Computation end time: 2026-04-12 15:08:30

Save the results as

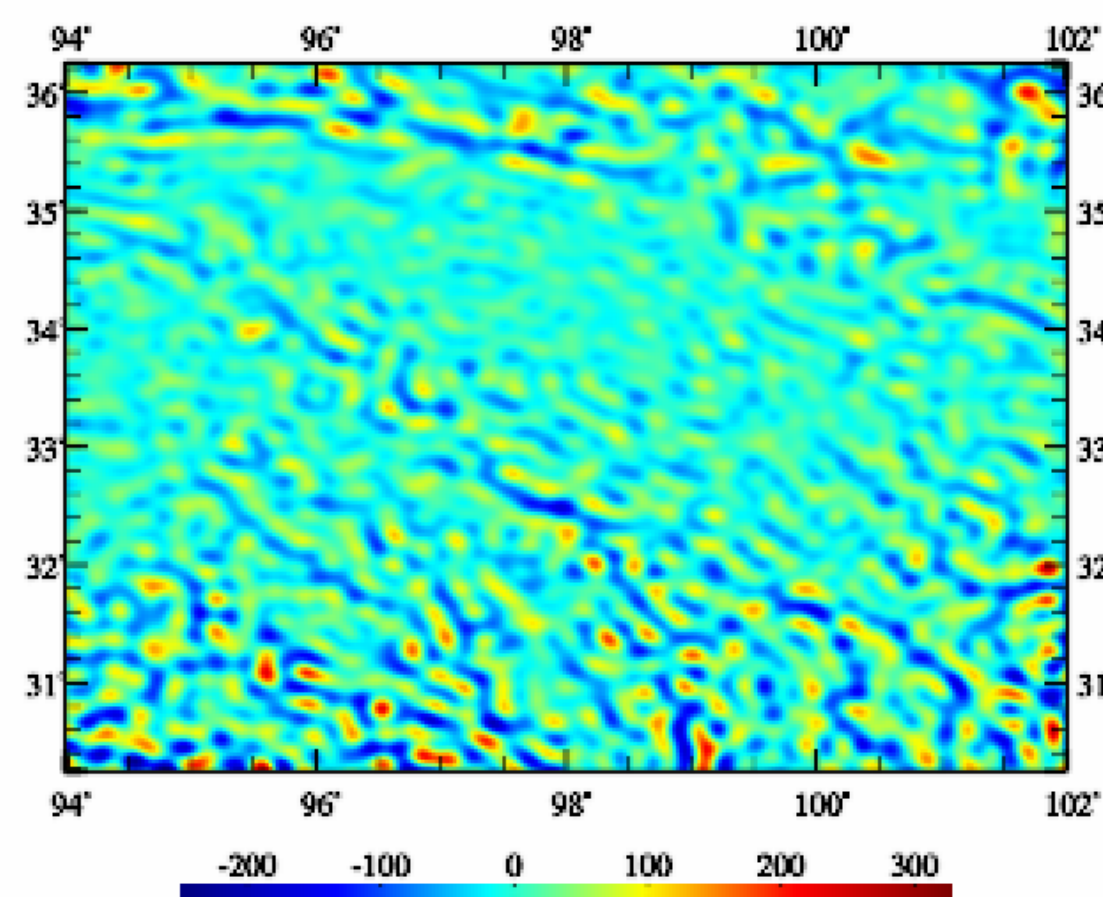
Import setting parameters

Start Computation

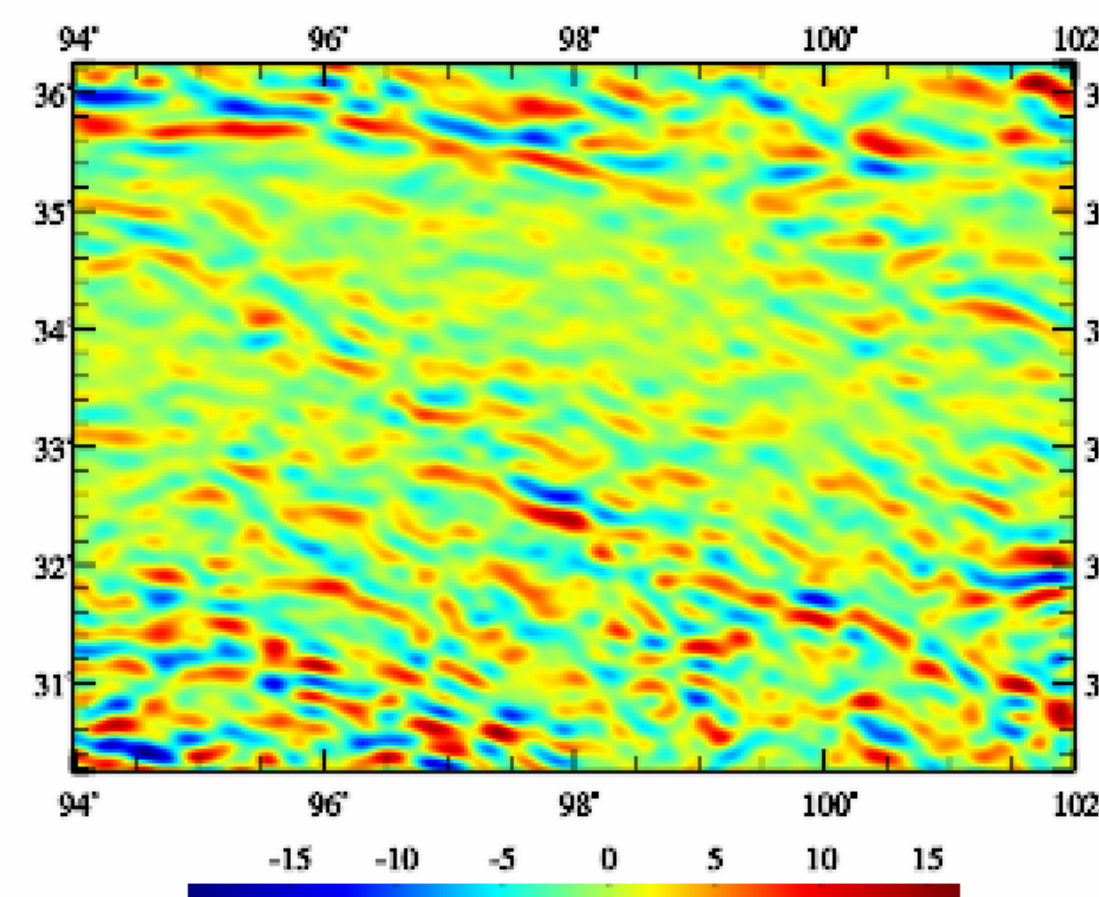
94.000000	102.000000	30.250000	36.250000	0.01666667	0.01666667			
-2.2955	-2.5663	-2.5312	-2.2038	-1.6530	-0.9588	-0.1916	0.5943	1.3597
4.4045	4.3352	4.1336	3.8281	3.4637	3.0993	2.8020	2.6392	2.6689
8.1418	8.9666	9.5719	9.9219	10.0144	9.8802	9.5792	9.1888	8.7932
9.2908	9.5062	9.5374	9.3162	8.7965	7.9607	6.8206	5.4140	3.7999
-7.1705	-7.9937	-8.5383	-8.7986	-8.7766	-8.4811	-7.9276	-7.1379	-6.1402
3.4382	4.6931	5.8090	6.7512	7.4831	7.9666	8.1626	8.0351	7.5542

Extract vertical deflection

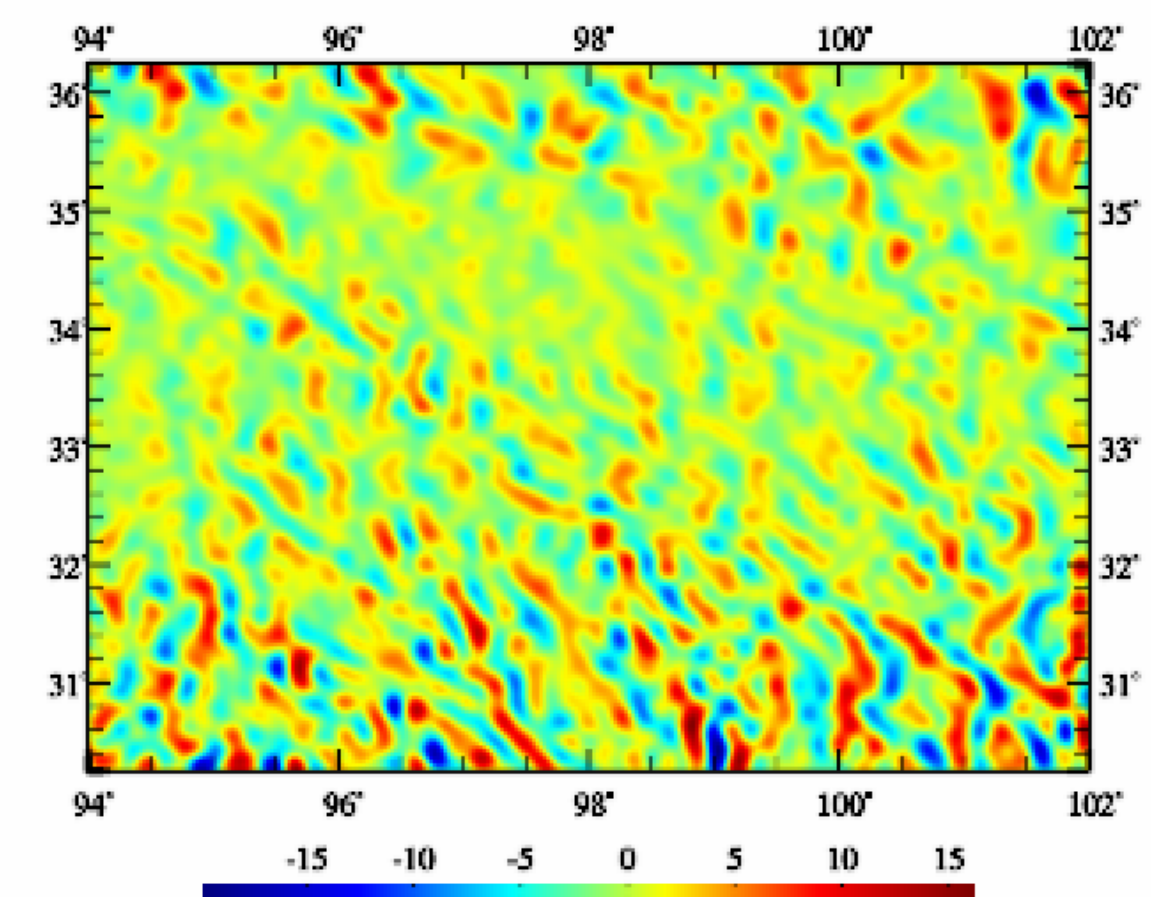
Plot



gravity anomaly (mGal)



vertical deflection (" , S)



vertical deflection (" , W)

Computation of External Vertical Deflection from Gravity Anomaly – 1D FFT

Computation of External Vertical Deflection from Gravity Anomaly

Computation of External Vertical Deflection from Gravity Disturbance

Vening-Meinesz integral formulas

Open Equipotential Surface Ellipsoidal Height Grid File

Open Residual Gravity Anomaly Grid File

Select computation file format

surface ellipsoidal height grid file

Open Computation Surface Ellipsoidal Height Grid File

Select integral algorithm

1D FFT algorithm

Integral radius 180 km

>> Computation Process ** Operation Prompts

>> [Function] Computes the external residual vertical deflection (" , south and west components) via the generalized Vening-Meinesz integration, utilizing an ellipsoidal height grid of an equipotential boundary surface and the corresponding residual gravity anomaly grid (mGal).

>> Open Equipotential Surface Ellipsoidal Height Grid File C:/PAGravf4.5_win64en/examples/IntgenVeningMeinesz/landgeoidhgt.dat.

>> Open Residual Gravity Anomaly Grid File C:/PAGravf4.5_win64en/examples/IntgenVeningMeinesz/resGMIgeoid541_1800.gra.

>> Open Computation Surface Ellipsoidal Height Grid File C:/PAGravf4.5_win64en/examples/IntgenVeningMeinesz/landbmsurfhgt.dat.

>> Compute external residual vertical deflection by 1D FFT algorithm...

>> Save the results as C:/PAGravf4.5_win64en/examples/IntgenVeningMeinesz/gratovmFFT1.dat.

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-12 15:09:58

>> Complete the computation of external vertical deflection!

>> Computation end time: 2026-04-12 15:10:23

Save the results as

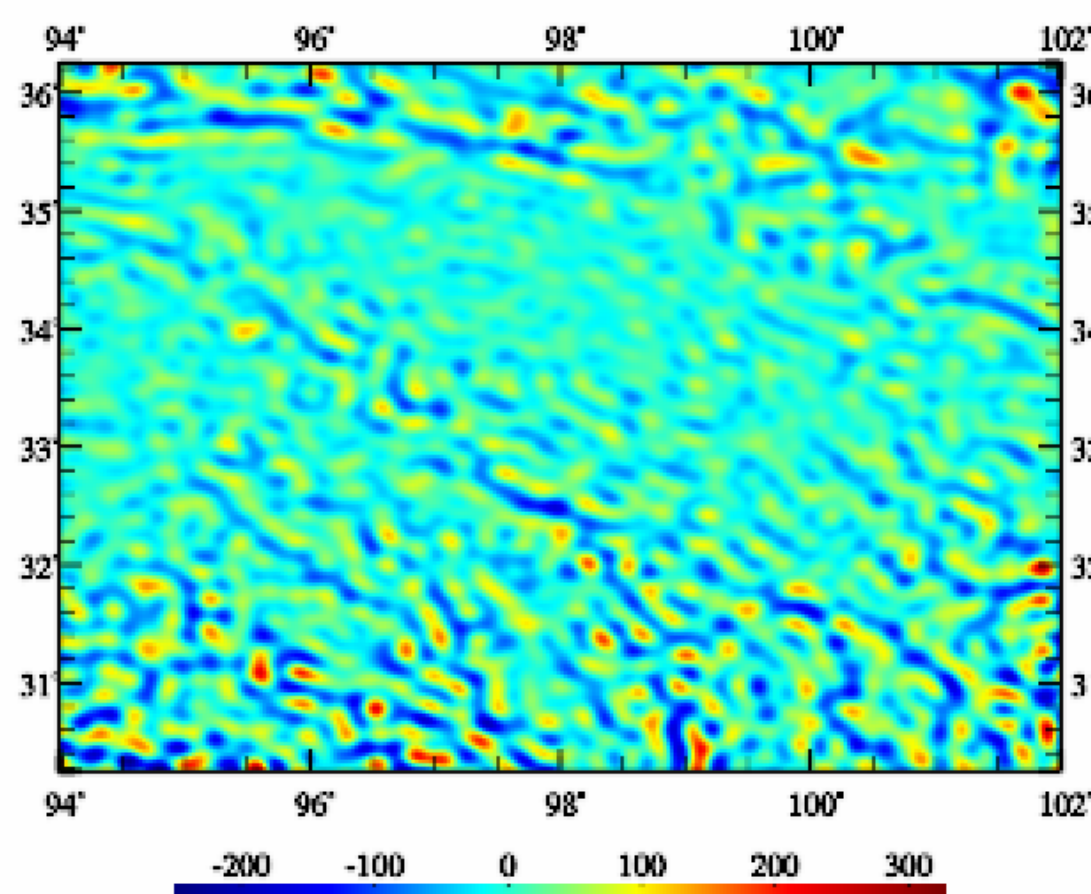
Import setting parameters

Start Computation

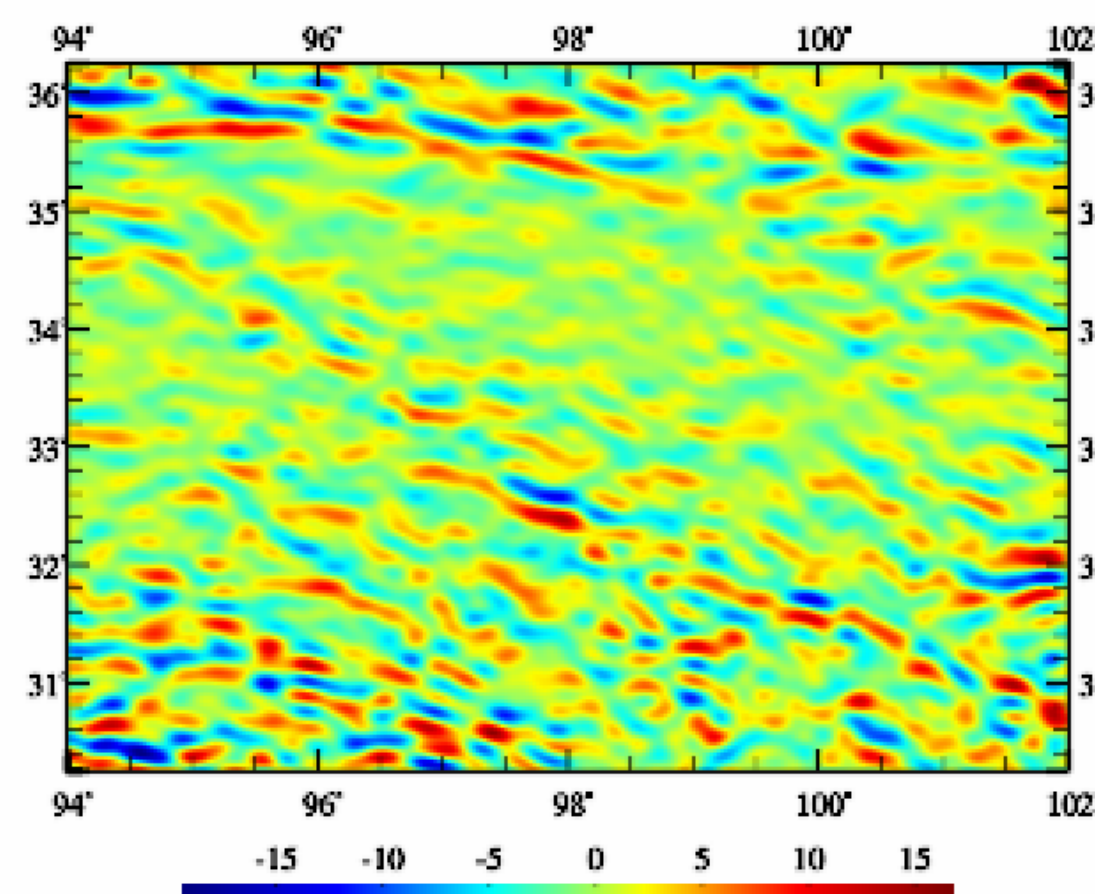
94.000000	102.000000	30.250000	36.250000	0.01666667	0.01666667			
-2.2866	-2.5693	-2.5365	-2.2060	-1.6513	-0.9553	-0.1892	0.5928	1.3523
4.3578	4.2812	4.0701	3.7522	3.3727	2.9908	2.6747	2.4928	2.5043
7.9132	8.7324	9.3302	9.6709	9.7517	9.6042	9.2891	8.8855	8.4788
9.0235	9.2631	9.3211	9.1282	8.6380	7.8323	6.7225	5.3462	3.7619
-7.0608	-7.8788	-8.4227	-8.6862	-8.6706	-8.3840	-7.8409	-7.0624	-6.0762
3.4219	4.6659	5.7721	6.7067	7.4337	7.9155	8.1136	7.9915	7.5192

Extract vertical deflection

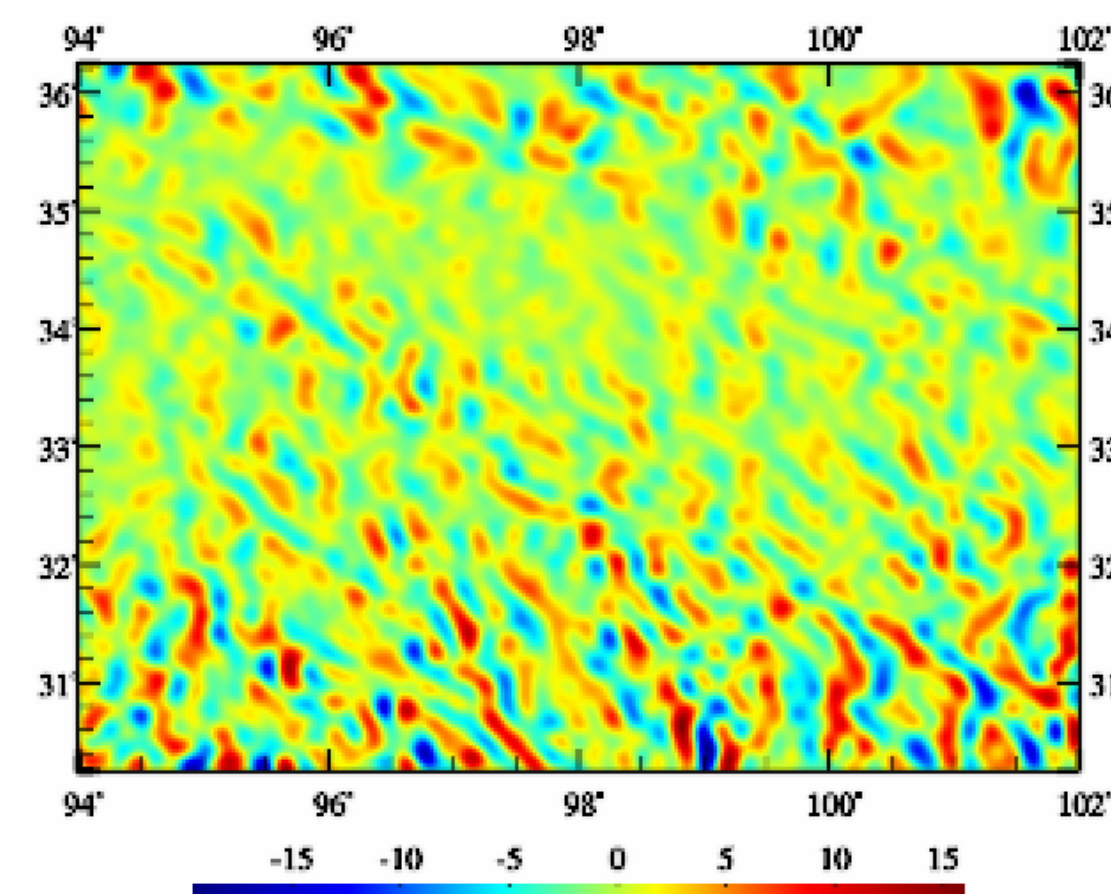
Plot↓



gravity anomaly (mGal)



vertical deflection (" , S)



vertical deflection (" , W)

Table 4.6: Statistics of Model Reference Truth (Unit: ")

Component	Mean	Std. Dev.	Min	Max
Ground Vertical Deflection (South, ξ)	0.0014	2.4951	-12.7789	14.2346
Ground Vertical Deflection (West, η)	0.0097	2.1772	-9.1577	10.4499

Table 4.7: Differences between Computed Results (Anomaly-based) and Reference Truth (")

Algorithm	Component	Mean	Std. Dev.	Min	Max
Numerical integral	South (ξ)	0.0003	0.0380	-0.1061	0.1387
	West (η)	0.0011	0.0289	-0.0830	0.1091
FFT2	South (ξ)	0.0002	0.1107	-0.8974	0.7395
	West (η)	0.0011	0.1003	-0.6887	1.0743
FFT1	South (ξ)	0.0007	0.1090	-0.8189	0.6581
	West (η)	0.0011	0.0984	-0.6078	1.0866

Algorithm Performance: The ratio of the standard deviation of Differences in Table 4.7 to the standard deviation of Reference Truths in Table 4.6 reflects the approximation capability of the corresponding algorithm.

Computation of External Vertical Deflection from Gravity Disturbance

Save as Import parameters Start Computation Save process Follow example

Computation of External Vertical Deflection from Gravity Anomaly

Computation of External Vertical Deflection from Gravity Disturbance

Vening-Meinesz integral formulas

Open Equipotential Surface Ellipsoidal Height Grid File

Open Residual Gravity Disturbance Grid File

Select computation file format

space computation point file

Open Space Computation Point File

Set input point file format

number of rows of file header 1

Ellipsoidal Height Column Index 4

Integral radius 180 km

>> Computation Process ** Operation Prompts

>> [Function] Computes the external residual vertical deflection (" , south and west components) via the generalized Vening-Meinesz integration, utilizing an ellipsoidal height grid of an equipotential boundary surface and the corresponding residual gravity disturbance grid (mGal)

>> Open Equipotential Surface Ellipsoidal Height Grid File C:/PAGravf4.5_win64en/examples/IntgenVeningMeinesz/landgeoidhgt.dat.

>> Open Residual Gravity Disturbance Grid File C:/PAGravf4.5_win64en/examples/IntgenVeningMeinesz/resGMIgeoid541_1800.rga.

>> Open Space Computation Point File C:/PAGravf4.5_win64en/examples/IntgenVeningMeinesz/calcpnt.txt.

** Look at the file information in the window below, set the input file format parameters...

>> Save the results as C:/PAGravf4.5_win64en/examples/IntgenVeningMeinesz/rstgra.txt.

** Record format: Appends two columns (southward and westward components) of computed residual vertical deflections to the source file, retaining 4 significant figures.

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-12 15:11:46

Save the results as

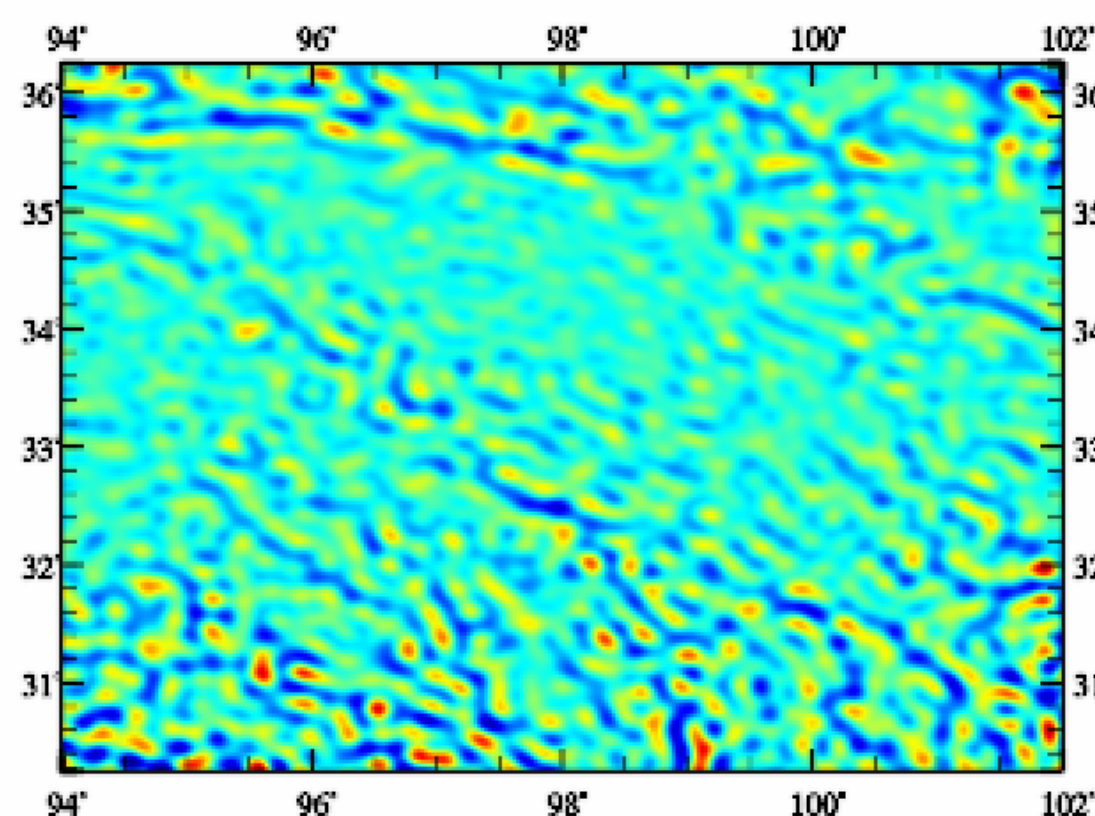
Import setting parameters

Start Computation

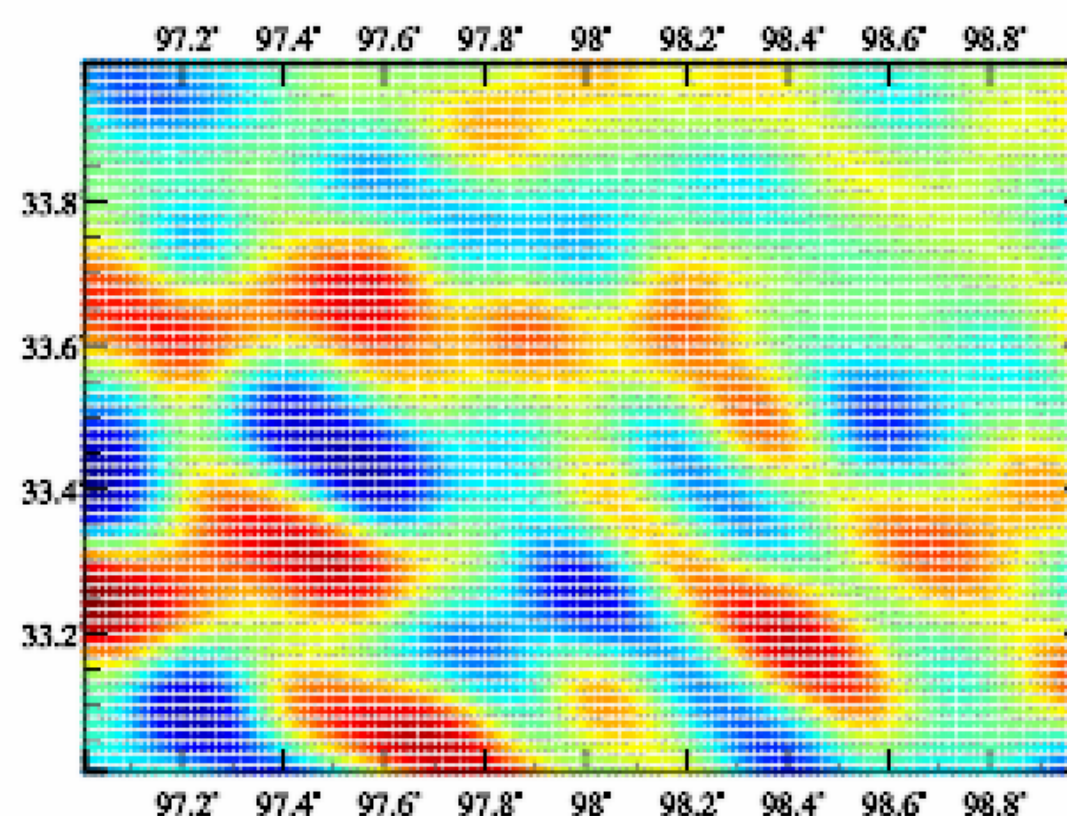
no	lon(degree/decimal)	lat	ellipHeight(m)		
1	97.008333	33.008333	3942.764	-2.4923	0.4718
2	97.025000	33.008333	3989.787	-2.4149	0.6833
3	97.041667	33.008333	4034.817	-2.2964	0.9122
4	97.058333	33.008333	4070.847	-2.1450	1.1367
5	97.075000	33.008333	4106.877	-1.9717	1.3340
6	97.091667	33.008333	4119.913	-1.7905	1.4938
7	97.108333	33.008333	4115.946	-1.6162	1.6008

Extract vertical deflection

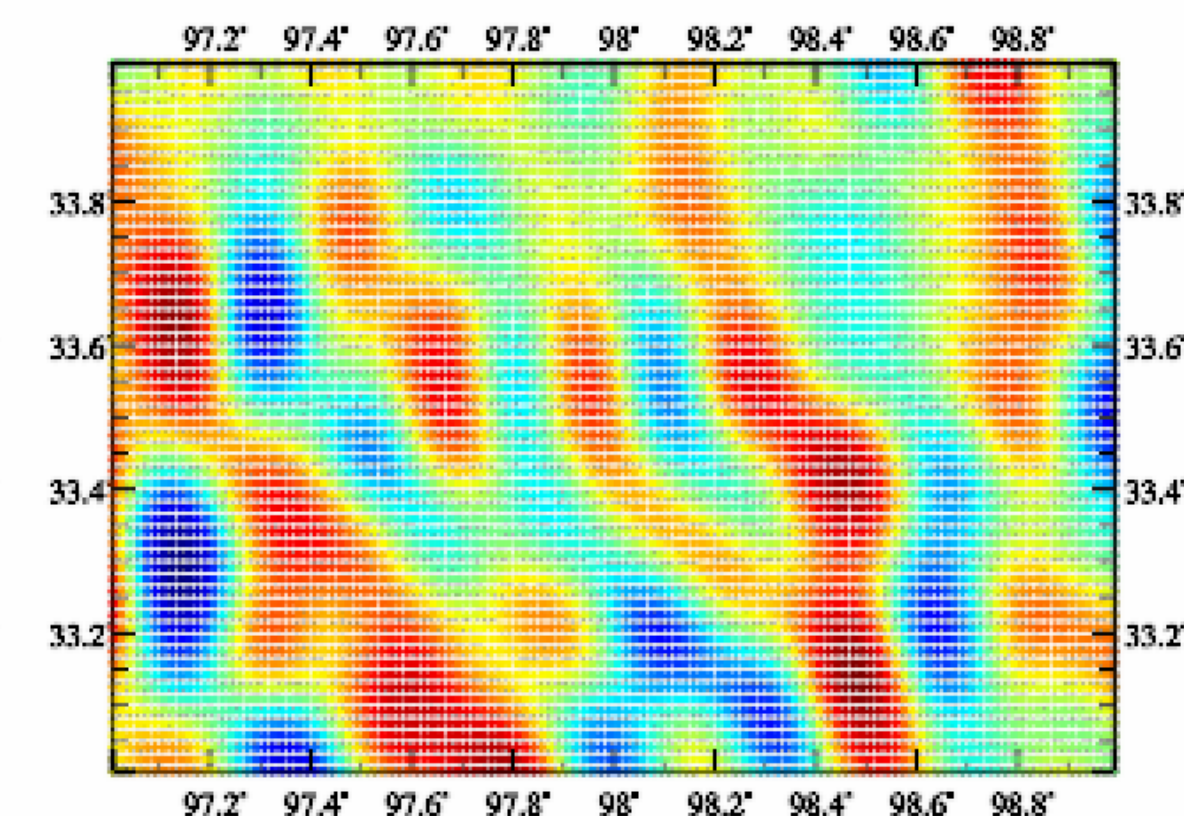
Plot



gravity disturbance (mGal)



vertical deflection (" , S)



vertical deflection (" , W)

Computation of External Vertical Deflection from Gravity Disturbance – 2D FFT

Computation of External Vertical Deflection from Gravity Anomaly

Computation of External Vertical Deflection from Gravity Disturbance

Vening-Meinesz integral formulas

Open Equipotential Surface Ellipsoidal Height Grid File

Open Residual Gravity Disturbance Grid File

Select computation file format

surface ellipsoidal height grid file

Open Computation Surface Ellipsoidal Height Grid File

Select integral algorithm

2D FFT algorithm

Integral radius 180 km

>> Computation Process ** Operation Prompts

>> [Function] Computes the external residual vertical deflection (" , south and west components) via the generalized Vening-Meinesz integration, utilizing an ellipsoidal height grid of an equipotential boundary surface and the corresponding residual gravity disturbance grid (mGal)

>> Open Equipotential Surface Ellipsoidal Height Grid File C:/PAGravf4.5_win64en/examples/IntgenVeningMeinesz/landgeoidhgt.dat.

>> Open Residual Gravity Disturbance Grid File C:/PAGravf4.5_win64en/examples/IntgenVeningMeinesz/resGMIgeoid541_1800.rga.

>> Open Computation Surface Ellipsoidal Height Grid File C:/PAGravf4.5_win64en/examples/IntgenVeningMeinesz/landbmsurfhgt.dat.

>> Compute external residual vertical deflection by 2D FFT algorithm...

>> Save the results as C:/PAGravf4.5_win64en/examples/IntgenVeningMeinesz/rgatovmFFT2.dat.

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-12 15:16:01

>> Complete the computation of external vertical deflection!

>> Computation end time: 2026-04-12 15:16:03

Save the results as

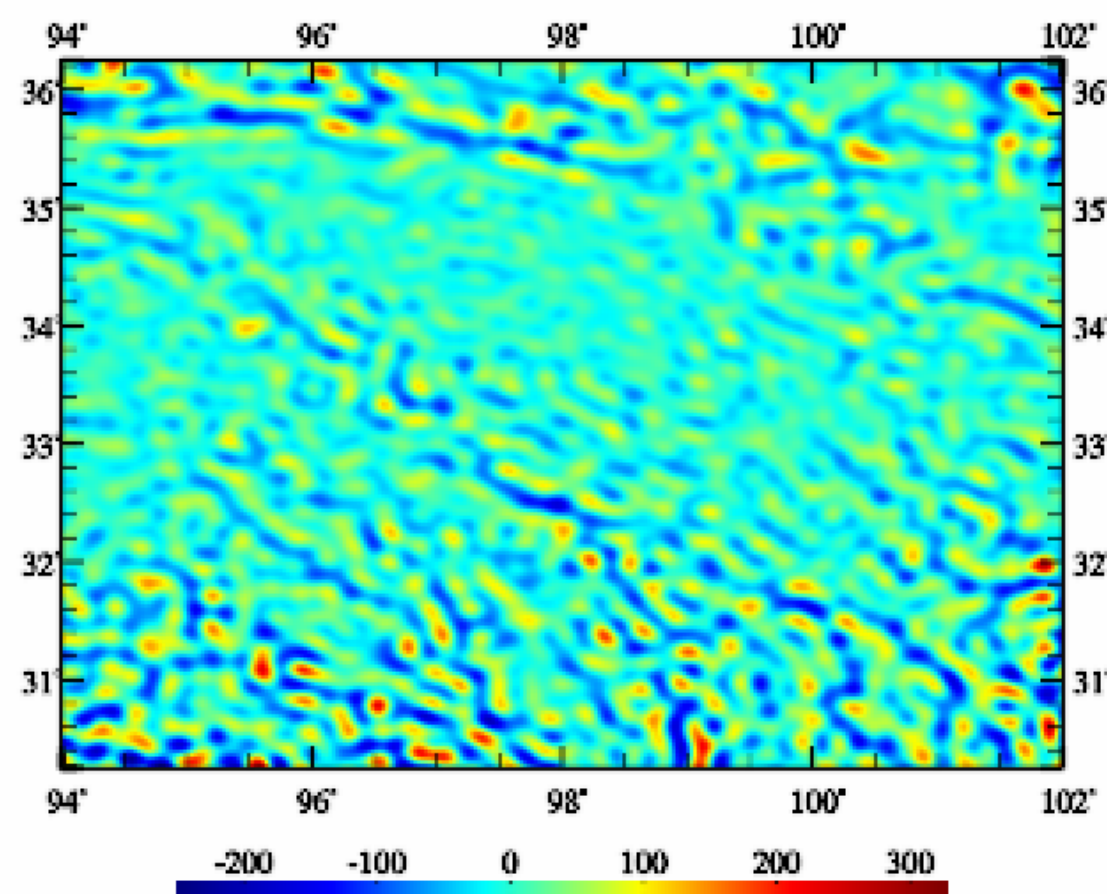
Import setting parameters

Start Computation

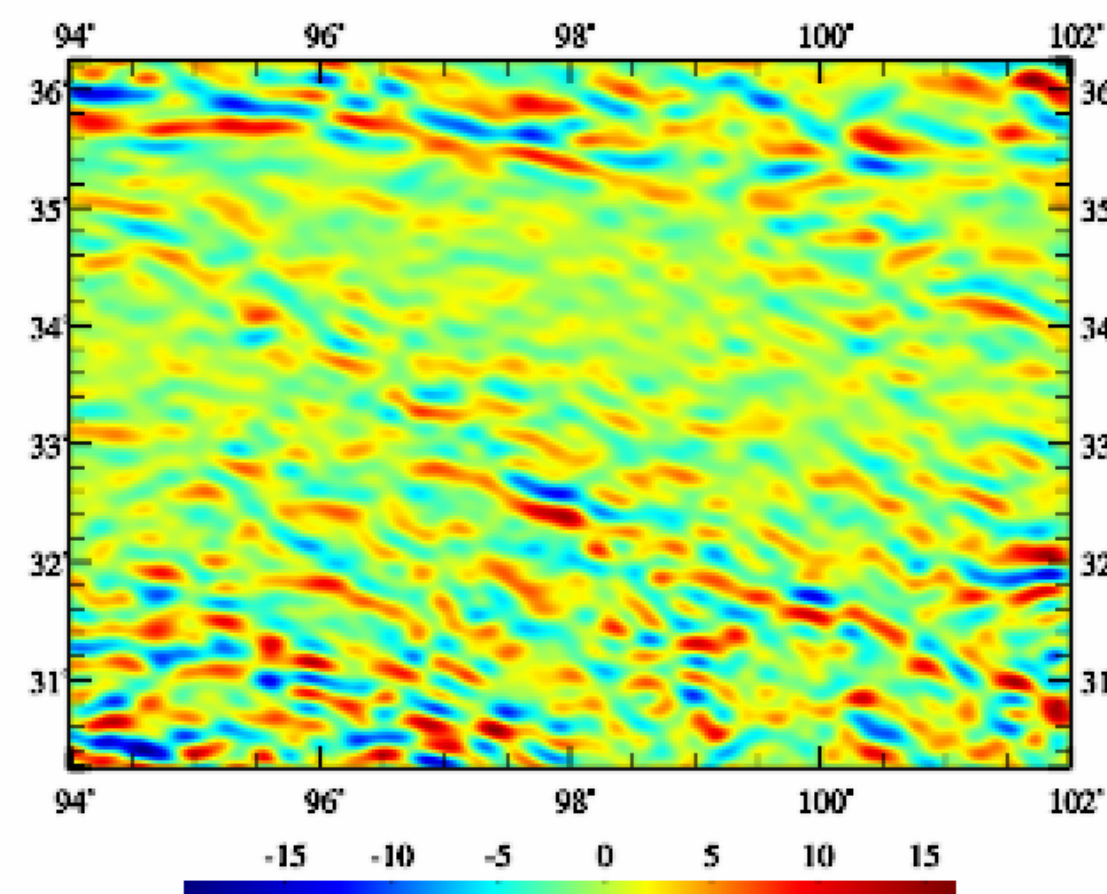
94.000000	102.000000	30.250000	36.250000	0.01666667	0.01666667			
-2.2983	-2.5692	-2.5347	-2.2082	-1.6585	-0.9656	-0.1997	0.5849	1.3491
4.3900	4.3211	4.1201	3.8155	3.4521	3.0887	2.7923	2.6303	2.6604
8.1264	8.9502	9.5548	9.9047	9.9975	9.8642	9.5643	9.1752	8.7810
9.2803	9.4953	9.5263	9.3052	8.7862	7.9515	6.8129	5.4083	3.7964
-7.1600	-7.9825	-8.5270	-8.7875	-8.7662	-8.4717	-7.9195	-7.1314	-6.1356
3.4291	4.6825	5.7972	6.7385	7.4698	7.9529	8.1491	8.0220	7.5421

Extract vertical deflection

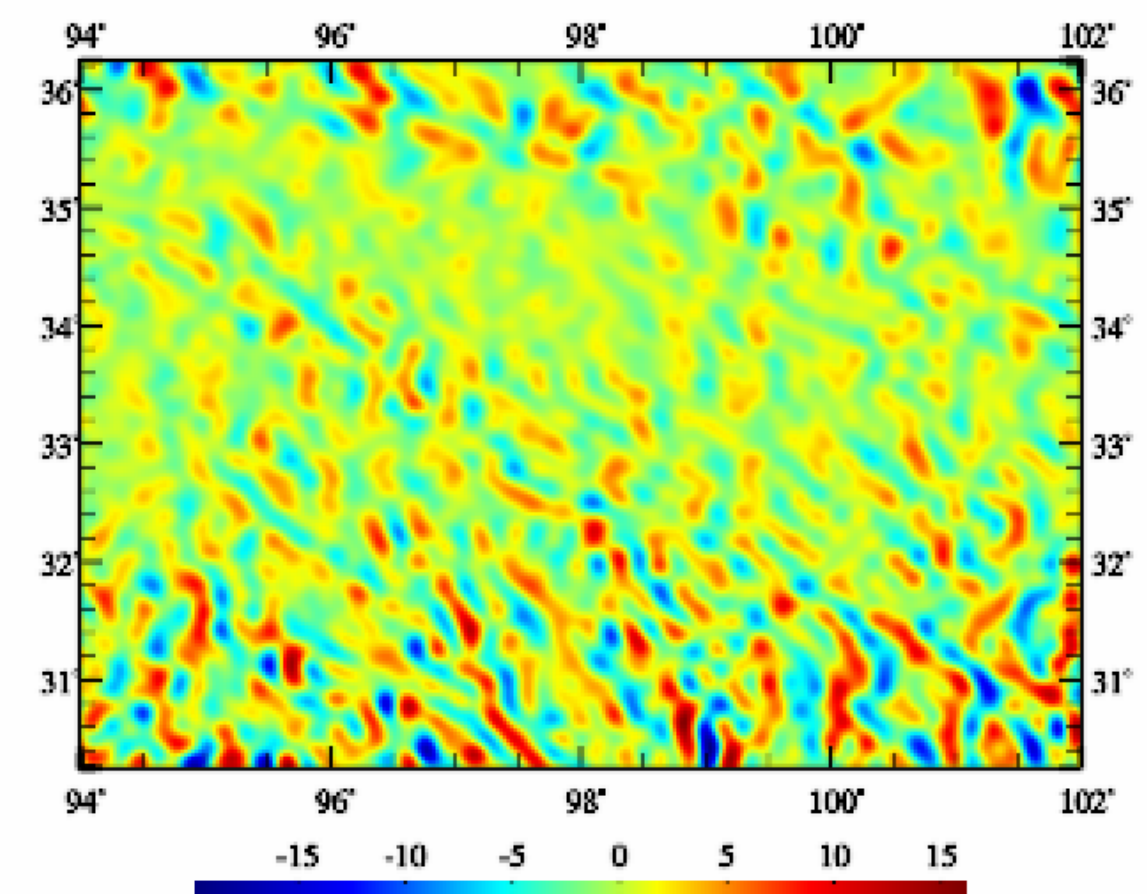
Plot



gravity disturbance (mGal)



vertical deflection (" , S)



vertical deflection (" , W)

Computation of External Vertical Deflection from Gravity Disturbance – 1D FFT

Computation of External Vertical Deflection from Gravity Anomaly

Computation of External Vertical Deflection from Gravity Disturbance

Vening-Meinesz integral formulas

Open Equipotential Surface Ellipsoidal Height Grid File

Open Residual Gravity Disturbance Grid File

Select computation file format

surface ellipsoidal height grid file

Open Computation Surface Ellipsoidal Height Grid File

Select integral algorithm

1D FFT algorithm

Integral radius 180 km

>> Computation Process ** Operation Prompts

>> [Function] Computes the external residual vertical deflection (" , south and west components) via the generalized Vening-Meinesz integration, utilizing an ellipsoidal height grid of an equipotential boundary surface and the corresponding residual gravity disturbance grid (mGal)

>> Open Equipotential Surface Ellipsoidal Height Grid File C:/PAGravf4.5_win64en/examples/IntgenVeningMeinesz/landgeoidhgt.dat.

>> Open Residual Gravity Disturbance Grid File C:/PAGravf4.5_win64en/examples/IntgenVeningMeinesz/resGMIgeoid541_1800.rga.

>> Open Computation Surface Ellipsoidal Height Grid File C:/PAGravf4.5_win64en/examples/IntgenVeningMeinesz/landbmsurfhgt.dat.

>> Compute external residual vertical deflection by 1D FFT algorithm...

>> Save the results as C:/PAGravf4.5_win64en/examples/IntgenVeningMeinesz/rgatovmFFT1.dat.

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-12 15:17:57

>> Complete the computation of external vertical deflection!

>> Computation end time: 2026-04-12 15:18:51

Save the results as

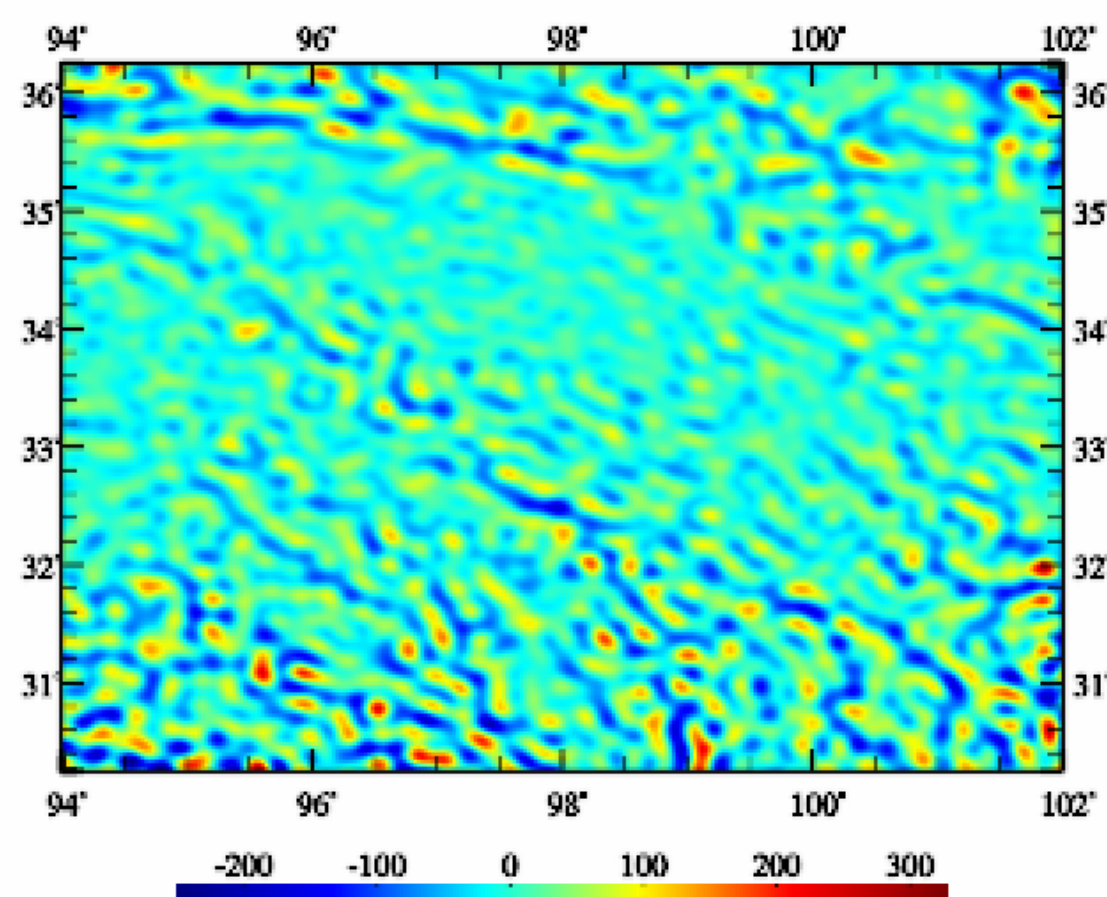
Import setting parameters

Start Computation

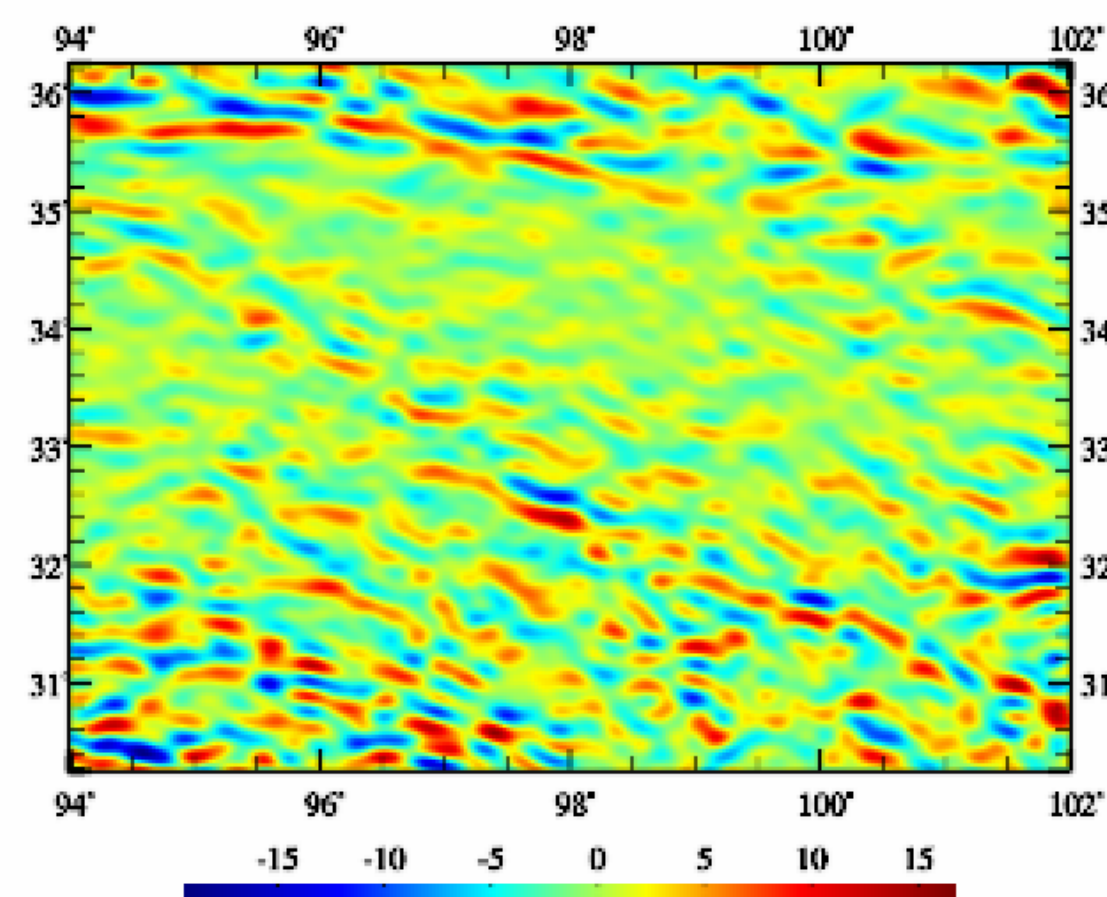
94.000000	102.000000	30.250000	36.250000	0.01666667	0.01666667			
-2.2902	-2.5728	-2.5404	-2.2106	-1.6569	-0.9620	-0.1970	0.5837	1.3422
4.3438	4.2677	4.0572	3.7402	3.3616	2.9808	2.6656	2.4845	2.4963
7.8987	8.7168	9.3140	9.6544	9.7356	9.5887	9.2746	8.8722	8.4667
9.0128	9.2522	9.3100	9.1173	8.6277	7.8231	6.7148	5.3404	3.7583
-7.0502	-7.8673	-8.4108	-8.6744	-8.6593	-8.3737	-7.8319	-7.0551	-6.0709
3.4117	4.6540	5.7589	6.6925	7.4188	7.9003	8.0984	7.9768	7.5056

Extract vertical deflection

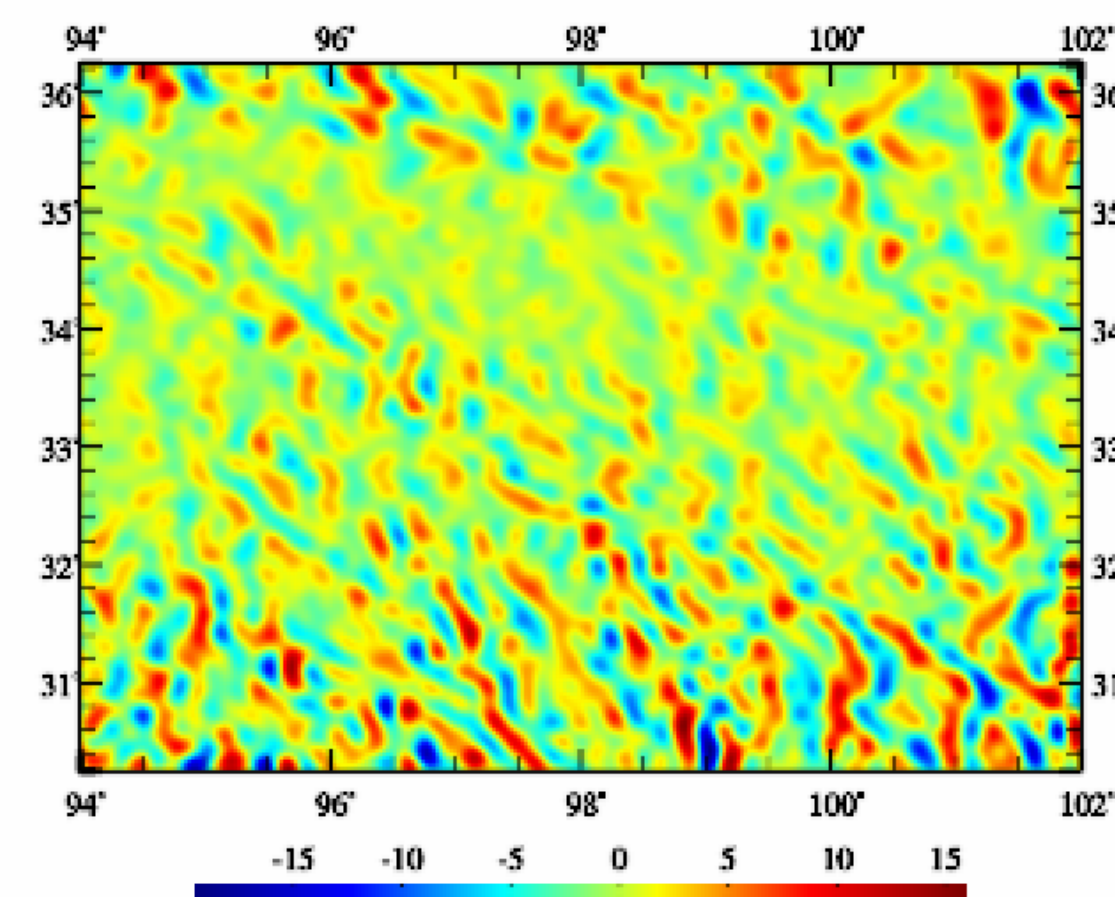
Plot



gravity disturbance (mGal)



vertical deflection (" , S)



vertical deflection (" , W)

Table 4.6: Statistics of Model Reference Truth (Unit: ")

Component	Mean	Std. Dev.	Min	Max
Ground Vertical Deflection (South, ξ)	0.0014	2.4951	-12.7789	14.2346
Ground Vertical Deflection (West, η)	0.0097	2.1772	-9.1577	10.4499

Table 4.8: Differences between Computed Results (Disturbance-based) and Reference Truth (")

Algorithm	Component	Mean	Std. Dev.	Min	Max
Numerical integral	South (ξ)	-0.0003	0.0274	-0.0872	0.0994
	West (η)	0.0005	0.0200	-0.0646	0.0836
FFT2	South (ξ)	0.0002	0.1072	-0.8692	0.7094
	West (η)	0.0010	0.0959	-0.6204	1.0981
FFT1	South (ξ)	0.0007	0.1058	-0.7910	0.6481
	West (η)	0.0010	0.0959	-0.6204	1.0981

The performance of the integration using gravity disturbance is slightly better than that using gravity anomaly.

Computation of Gravity Anomaly via Inverse Stokes Integration

Save as Import parameters Start Computation Save process Follow example

Computation of Gravity Anomaly via Inverse Stokes Integration

Computation of Gravity Disturbance via Inverse Hotine Integration

Computation via Inverse Vening-Meinesz Integration

Computation of External Anomalous Field Elements from Height Anomaly

Integral Formulas

Open Equipotential Surface Ellipsoidal Height Grid File

Open Height Anomaly Grid File

Select computation point file format

discrete computation point file

Open Discrete Computation Point File

Set input point file format

number of rows of file header 1

>> Computation Process ** Operation Prompts

using either the Inverse Integration method or the Integral of Inverse Operation method.

>> Select the computation function from the 4 control buttons at the top of the interface...

>> [Function] Computes the residual gravity anomaly (mGal) on an equipotential boundary surface via Inverse Stokes Integration, utilizing the surface's ellipsoidal height grid and the corresponding residual height anomaly (m) grid.

>> Open Equipotential Surface Ellipsoidal Height Grid File C:/PAGrav4.5_win64en/examples/Integralgrainverse/landgeoidhgt.dat.

>> Open Height Anomaly Grid File C:/PAGrav4.5_win64en/examples/Integralgrainverse/resGMlgeoid541_1800.ksi.

>> Open Discrete Computation Point File C:/PAGrav4.5_win64en/examples/Integralgrainverse/calcpnt.txt.

** Look at the file information in the window below, set the input file format parameters...

>> Save the results as C:/PAGrav4.5_win64en/examples/Integralgrainverse/invstk.txt.

>> Appends two columns to the source file: Interpolated Ellipsoidal Height of the computation point, and Computed Residual Gravity Anomaly value.

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-13 10:37:01

>> Complete the computation!

>> Computation end time: 2026-04-13 10:38:15

Integral radius 150 km

Save the results as

Import setting parameters

Start Computation

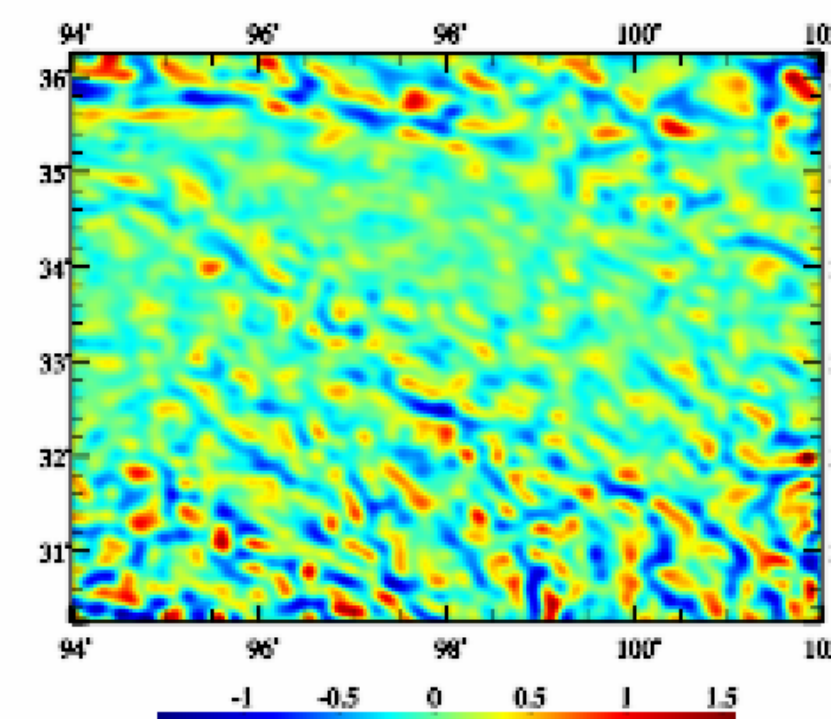
no lon(degree/decimal) lat ellipHeight (m)

1	97.008333	33.008333	3942.764	-37.2501	67.6375
2	97.025000	33.008333	3989.787	-37.2203	67.3423
3	97.041667	33.008333	4034.817	-37.1899	62.7938
4	97.058333	33.008333	4070.847	-37.1590	53.7191
5	97.075000	33.008333	4106.877	-37.1276	40.5471
6	97.091667	33.008333	4119.913	-37.0959	23.9785
7	97.108333	33.008333	4115.946	-37.0640	4.3967
8	97.125000	33.008333	4090.977	-37.0318	-16.7515
9	97.141667	33.008333	4070.007	-36.9990	-38.8489
10	97.158333	33.008333	3991.047	-36.9665	-60.2521
11	97.175000	33.008333	3985.070	-36.9327	-80.1620
12	97.191667	33.008333	3956.107	-36.8988	-96.9897
13	97.208333	33.008333	3965.137	-36.8642	-110.2047
14	97.225000	33.008333	3964.173	-36.8295	-118.0853
15	97.241667	33.008333	3983.205	-36.7943	-120.4004
16	97.258333	33.008333	3953.251	-36.7595	-116.0276
17	97.275000	33.008333	4016.279	-36.7238	-104.8662
18	97.291667	33.008333	4054.318	-36.6883	-87.1099
19	97.308333	33.008333	4090.360	-36.6528	-63.3095

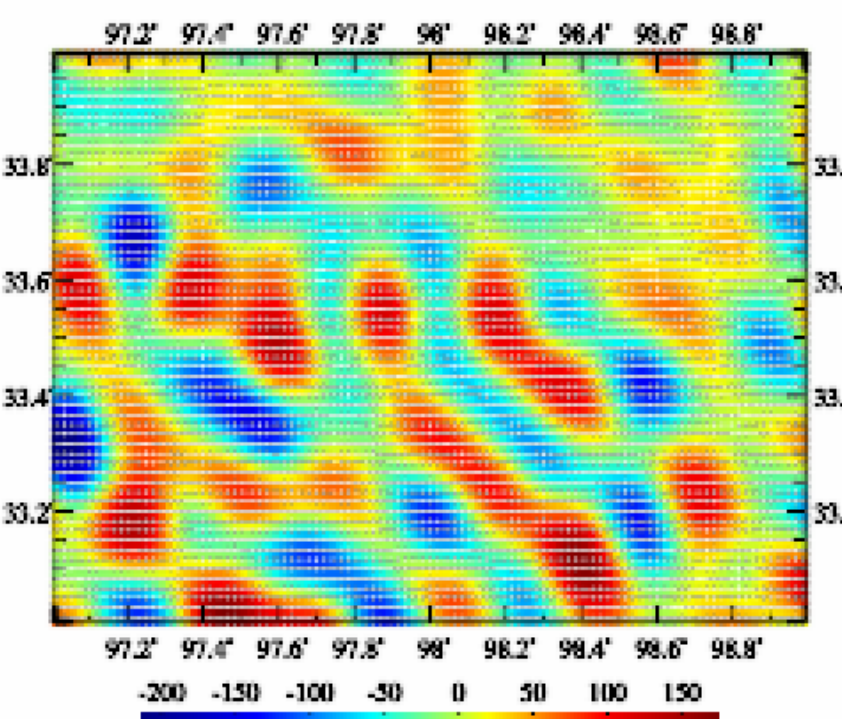
Ignore the ellipsoidal height

Extract result element

Plot



height anomaly (m)



gravity anomaly (mGal)

Integral of Inverse Operation: A rigorous solution to the Stokes-type Boundary Value Problem. It strictly requires the integrand (height anomaly or vertical deflection) to reside on an equipotential boundary surface.

Inverse Integration: Employs a hybrid algorithm combining Poisson integration with the differentiation of anomalous field elements. This approach is more flexible and does not mandate the boundary surface to be an equipotential boundary surface.

Computation of Gravity Anomaly via Inverse Stokes Integration – 2D FFT

Computation of Gravity Anomaly via Inverse Stokes Integration

Computation of Gravity Disturbance via Inverse Hotine Integration

Computation via Inverse Vening-Meinesz Integration

Computation of External Anomalous Field Elements from Height Anomaly

Integral Formulas

Open Equipotential Surface Ellipsoidal Height Grid File

Open Height Anomaly Grid File

Select computation point file format

surface ellipsoidal height grid file

Select integral algorithm

2D FFT algorithm

>> Computation Process ** Operation Prompts

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-13 11:02:42

>> Complete the computation!

>> Computation end time: 2026-04-13 11:11:09

>> The program computation process have saved to the file C:/PAGravf4.5_win64en/examples/Integralgrainverse/process.txt!

>> [Function] Computes the residual gravity anomaly (mGal) on an equipotential boundary surface via Inverse Stokes Integration, utilizing the surface's ellipsoidal height grid and the corresponding residual height anomaly (m) grid.

>> Open Equipotential Surface Ellipsoidal Height Grid File C:/PAGravf4.5_win64en/examples/Integralgrainverse/landgeoidhgt.dat.

>> Open Height Anomaly Grid File C:/PAGravf4.5_win64en/examples/Integralgrainverse/resGMlgeoid541_1800.ksi.

>> Compute by 2D FFT algorithm...

>> Save the results as C:/PAGravf4.5_win64en/examples/Integralgrainverse/invstokesFFT2.dat.

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-13 11:15:05

>> Complete the computation!

>> Computation end time: 2026-04-13 11:15:07

Integral radius 150 km

Save the results as

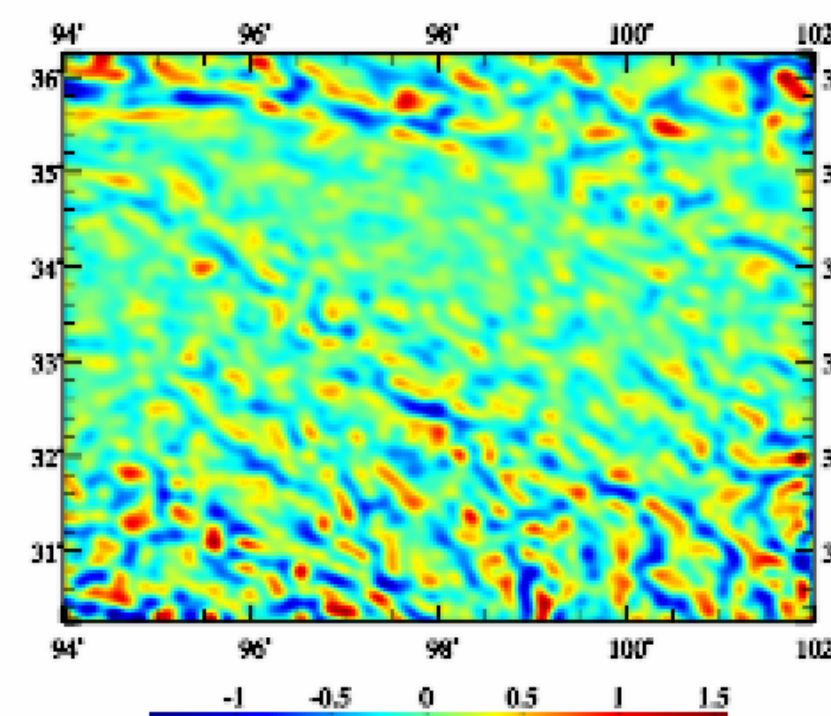
Import setting parameters

Start Computation

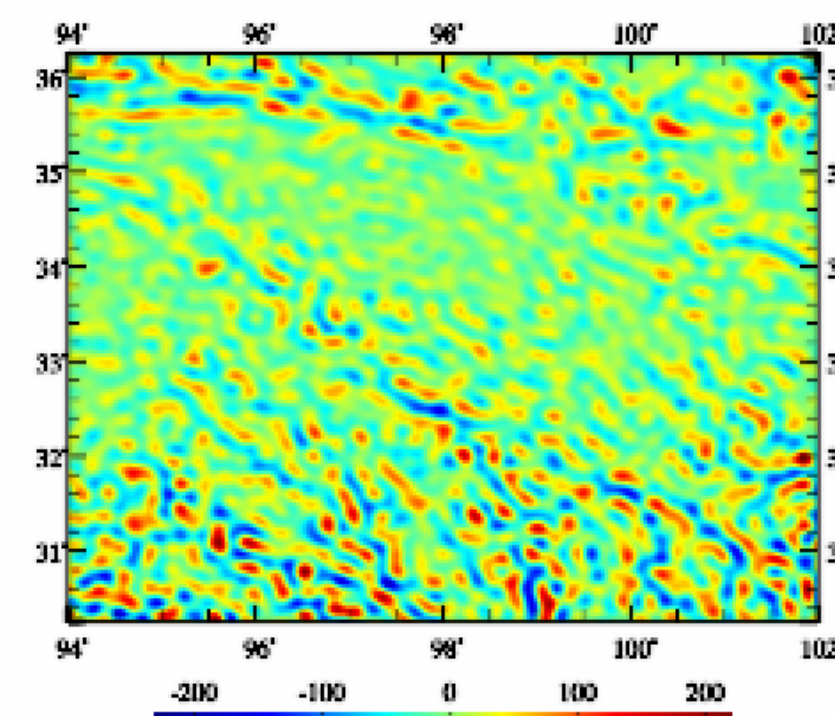
94.000000	102.000000	30.250000	36.250000	0.01666667	0.01666667
-39.6477	-31.7555	-23.0010	-13.3460	-3.1905	7.3758
68.7137	66.2175	63.6459	61.8294	61.1919	61.9060
85.4454	88.5755	92.8940	98.3290	104.2779	109.8428
-20.5549	-42.5148	-60.3258	-73.0308	-80.1262	-81.5883
1.5651	3.2947	3.7253	3.2002	2.3803	1.7674
50.4526	51.4144	47.9648	39.6026	26.4345	9.2700
41.7132	78.7630	112.9903	140.3739	157.4710	161.9463
-116.6430	-108.3396	-89.6918	-63.5529	-33.3099	-2.4602
34.2004	25.2184	18.4197	13.7955	11.4404	10.9439
58.3004	57.9660	54.0121	46.0891	34.5079	20.1147
12.7681	30.0333	44.9480	55.6834	61.1593	60.9161
-35.4209	-39.1119	-43.6884	-50.2486	-59.2394	-70.9157
-141.6149	-133.2776	-123.9171	-114.2731	-104.7800	-95.4982
36.9525	44.8229	47.4242	44.3201	35.6144	22.1620
-16.0591	5.5549	28.0217	49.7083	68.9606	84.7837
53.8984	38.1050	20.1477	0.2555	-21.0772	-43.0778
-54.1878	-31.6831	-10.0942	8.7349	23.4213	33.2218
10.4447	14.6742	19.5786	23.8960	26.8234	27.6294

Extract result element

Plot



height anomaly (m)



gravity anomaly (mGal)

Integral of Inverse Operation: A rigorous solution to the Stokes-type Boundary Value Problem. It strictly requires the integrand (height anomaly or vertical deflection) to reside on an equipotential boundary surface.

Inverse Integration: Employs a hybrid algorithm combining Poisson integration with the differentiation of anomalous field elements. This approach is more flexible and does not mandate the boundary surface to be an equipotential boundary surface.

Computation of Gravity Anomaly via Inverse Stokes Integration – 1D FFT

Computation of Gravity Anomaly via Inverse Stokes Integration

Computation of Gravity Disturbance via Inverse Hotine Integration

Computation via Inverse Vening-Meinesz Integration

Computation of External Anomalous Field Elements from Height Anomaly

Integral Formulas

Open Equipotential Surface Ellipsoidal Height Grid File

Open Height Anomaly Grid File

Select computation point file format

surface ellipsoidal height grid file

Select integral algorithm

1D FFT algorithm

>> Computation Process ** Operation Prompts

```
>> The parameter settings have been entered into the system!
** Click the [Start Computation] control button, or the [Start Computation] tool button...
>> Computation start time: 2026-04-13 10:40:32
>> Complete the computation!
>> Computation end time: 2026-04-13 10:40:33
>> [Function] Computes the residual gravity anomaly (mGal) on an equipotential boundary surface via Inverse Stokes Integration, utilizing the surface's ellipsoidal height grid and the corresponding residual height anomaly (m) grid.
>> Open Equipotential Surface Ellipsoidal Height Grid File C:/PAGravf4.5_win64en/examples/Integralgrainverse/landgeoidhgt.dat.
>> Open Height Anomaly Grid File C:/PAGravf4.5_win64en/examples/Integralgrainverse/resGMlgeoid541_1800.ksi.
>> Compute by 1D FFT algorithm...
>> Save the results as C:/PAGravf4.5_win64en/examples/Integralgrainverse/invstokesFFT1.dat.
>> The parameter settings have been entered into the system!
** Click the [Start Computation] control button, or the [Start Computation] tool button...
>> Computation start time: 2026-04-13 10:41:16
>> Complete the computation!
>> Computation end time: 2026-04-13 10:41:48
```

Save computation process as

Integral radius 150 km

Save the results as

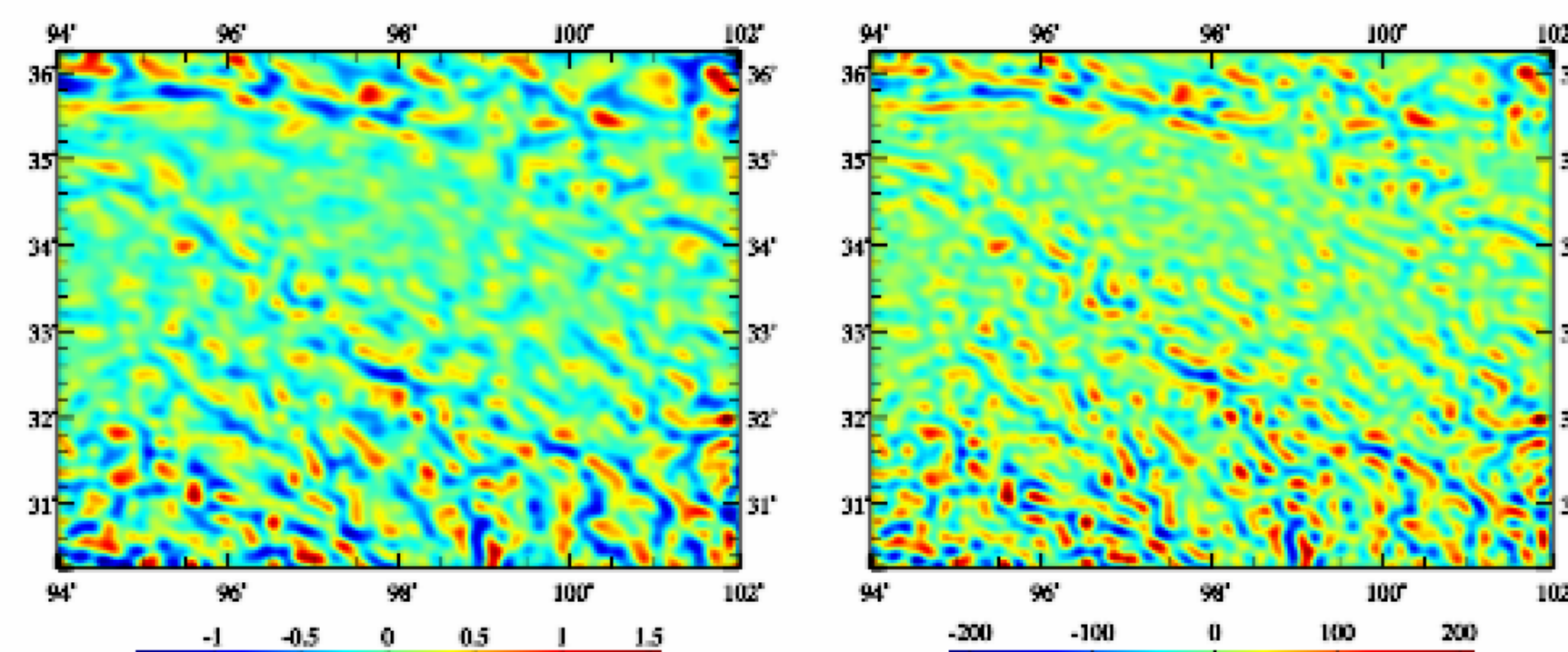
Import setting parameters

Start Computation

94.000000	102.000000	30.250000	36.250000	0.01666667	0.01666667
-38.8436	-31.6669	-23.1151	-13.5783	-3.5313	6.8983
67.0584	64.6259	62.0594	60.1520	59.3231	59.7621
83.3528	86.6034	90.8779	96.0863	101.6546	106.7426
-18.5990	-39.3488	-56.1960	-68.2546	-75.0628	-76.6044
-0.4045	1.1473	1.5172	1.0340	0.3231	-0.1369
49.1110	50.2744	47.2085	39.4367	27.0601	10.8463
39.0631	73.8112	105.9681	131.7520	147.9208	152.2701
-109.3804	-101.8005	-84.4823	-60.0815	-31.7596	-2.7911
33.1716	24.7000	18.2457	13.8216	11.5360	11.0218
56.3368	56.0106	52.2388	44.6968	33.6809	19.9907
11.0672	27.2974	41.4079	51.6809	57.0925	57.1928
-32.8821	-36.8786	-41.7506	-48.4961	-57.5067	-68.9966
-137.5939	-129.7212	-120.8182	-111.5682	-102.3731	-93.2874
35.8661	43.3681	45.8191	42.8191	34.4810	21.6239
-16.0694	4.4015	25.7657	46.4817	64.9832	80.3144
52.9143	37.6282	20.2416	0.9994	-19.6029	-40.8092
-52.5338	-31.1322	-10.5583	7.4401	21.5472	31.0469
9.8553	13.7442	18.3160	22.3948	25.2230	26.1047

Extract result element

Plot



height anomaly (m)

gravity anomaly (mGal)

- Integral of Inverse Operation: A rigorous solution to the Stokes-type Boundary Value Problem. It strictly requires the integrand (height anomaly or vertical deflection) to reside on an equipotential boundary surface.
- Inverse Integration: Employs a hybrid algorithm combining Poisson integration with the differentiation of anomalous field elements. This approach is more flexible and does not mandate the boundary surface to be an equipotential boundary surface.

Table 4.10: Statistics of Model Reference Truth (Unit: mGal)

Item	Mean	Std. Dev.	Min	Max
Residual Gravity Anomalies (Deg 541 – 1800)	0.4334	34.0852	-170.9556	177.8780

Table 4.11: Differences between Inverse Operation Integration Results and Reference Truth (Unit: mGal)

Algorithm	mean	standard deviation	minimum	maximum
Numerical Integral	-0.0415	2.9285	-15.2734	14.6970
FFT2	-0.0433	2.8208	-11.9201	13.3607
FFT1	-0.0444	3.0509	-15.7950	15.5242

Algorithm Performance: The ratio of the standard deviation of Differences in Table 4.11 to the standard deviation of Reference Truths in Table 4.10 reflects the approximation capability of the corresponding algorithm.

Computation of Gravity Anomaly via Inverse Hotine Integration

Save as Import parameters Start Computation Save process Follow example

Computation of Gravity Anomaly via Inverse Stokes Integration

Computation of Gravity Disturbance via Inverse Hotine Integration

Computation via Inverse Vening-Meinesz Integration

Computation of External Anomalous Field Elements from Height Anomaly

Integral Formulas

Open Equipotential Surface Ellipsoidal Height Grid File

Open Height Anomaly Grid File

Select computation point file format

discrete computation point file

Open Discrete Computation Point File

Set input point file format

number of rows of file header 1

>> Computation Process ** Operation Prompts

>> Computation start time: 2026-04-13 10:41:16

>> Complete the computation!

>> Computation end time: 2026-04-13 10:41:48

>> [Function] Computes the residual gravity disturbance (mGal) on the surface via the Integral of Inverse Hotine Operation, utilizing the ellipsoidal height grid of the equipotential boundary surface and the corresponding residual height anomaly (m) grid.

>> Open Equipotential Surface Ellipsoidal Height Grid File C:/PAGrav4.5_win64en/examples/Integralgrainverse/landgeoidhgt.dat.

>> Open Height Anomaly Grid File C:/PAGrav4.5_win64en/examples/Integralgrainverse/resGMIgeoid541_1800.ksi.

>> Open Discrete Computation Point File C:/PAGrav4.5_win64en/examples/Integralgrainverse/calcpnt.txt.

** Look at the file information in the window below, set the input file format parameters...

>> Save the results as C:/PAGrav4.5_win64en/examples/Integralgrainverse/invhtn.txt.

>> Appends columns for interpolated Ellipsoidal Height and computed Residual Gravity Disturbance.

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-13 10:43:55

>> Complete the computation!

>> Computation end time: 2026-04-13 10:45:10

Integral radius 150 km

Save the results as

Import setting parameters

Start Computation

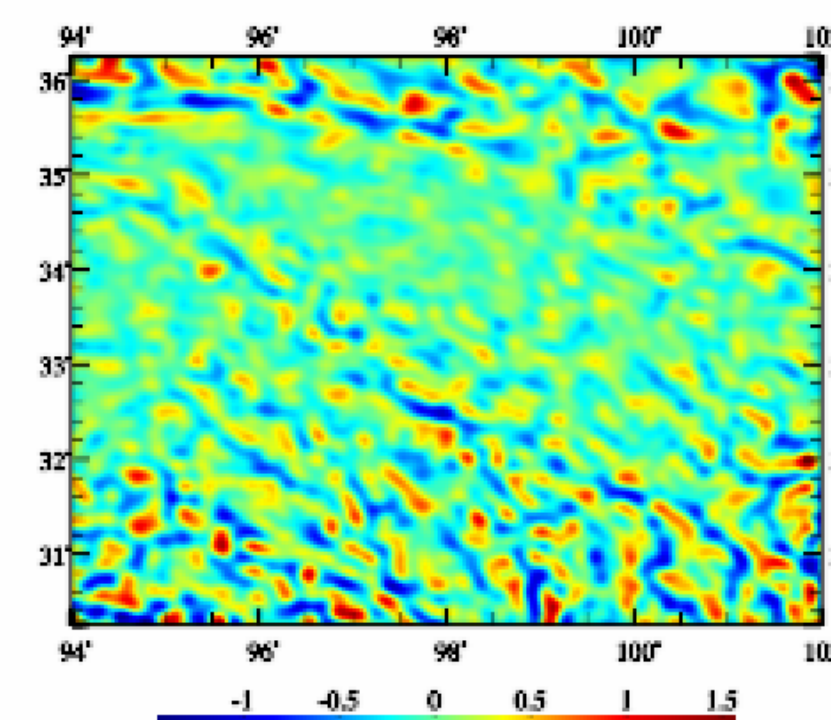
no lon(degree/decimal) lat ellipHeight (m)

1	97.008333	33.008333	3942.764	-37.2501	67.6349
2	97.025000	33.008333	3989.787	-37.2203	67.3400
3	97.041667	33.008333	4034.817	-37.1899	62.7924
4	97.058333	33.008333	4070.847	-37.1590	53.7191
5	97.075000	33.008333	4106.877	-37.1276	40.5490
6	97.091667	33.008333	4119.913	-37.0959	23.9828
7	97.108333	33.008333	4115.946	-37.0640	4.4036
8	97.125000	33.008333	4090.977	-37.0318	-16.7417
9	97.141667	33.008333	4070.007	-36.9990	-38.8361
10	97.158333	33.008333	3991.047	-36.9665	-60.2365
11	97.175000	33.008333	3985.070	-36.9327	-80.1437
12	97.191667	33.008333	3956.107	-36.8988	-96.9693
13	97.208333	33.008333	3965.137	-36.8642	-110.1827
14	97.225000	33.008333	3964.173	-36.8295	-118.0627
15	97.241667	33.008333	3983.205	-36.7943	-120.3779
16	97.258333	33.008333	3953.251	-36.7595	-116.0064
17	97.275000	33.008333	4016.279	-36.7238	-104.8475
18	97.291667	33.008333	4054.318	-36.6883	-87.0946
19	97.308333	33.008333	4090.360	-36.6528	-63.2988

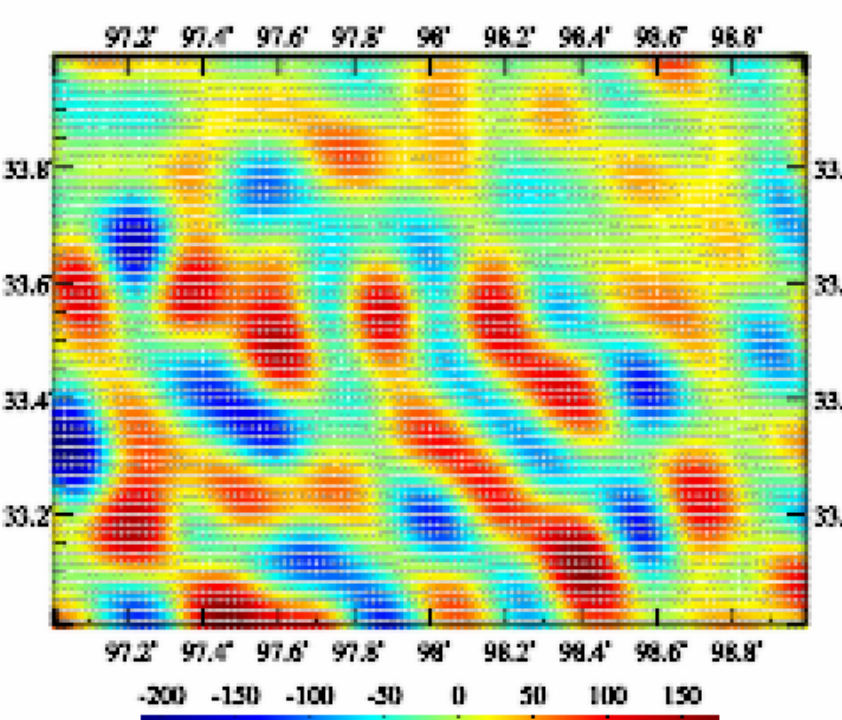
Ignore the ellipsoidal height

Extract result element

Plot



height anomaly (m)



gravity disturbance (mGal)

Integral of Inverse Operation: A rigorous solution to the Stokes-type Boundary Value Problem. It strictly requires the integrand (height anomaly or vertical deflection) to reside on an equipotential boundary surface.

Inverse Integration: Employs a hybrid algorithm combining Poisson integration with the differentiation of anomalous field elements. This approach is more flexible and does not mandate the boundary surface to be an equipotential boundary surface.

Computation of Gravity Disturbance via Inverse Hotine Integration – 2D FFT

Computation of Gravity Anomaly via Inverse Stokes Integration

Computation of Gravity Disturbance via Inverse Hotine Integration

Computation via Inverse Vening-Meinesz Integration

Computation of External Anomalous Field Elements from Height Anomaly

Integral Formulas

Open Equipotential Surface Ellipsoidal Height Grid File

Open Height Anomaly Grid File

Select computation point file format

surface ellipsoidal height grid file

Select integral algorithm

2D FFT algorithm

>> Computation Process ** Operation Prompts

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-13 10:43:55

>> Complete the computation!

>> Computation end time: 2026-04-13 10:45:10

>> [Function] Computes the residual gravity disturbance (mGal) on the surface via the Integral of Inverse Hotine Operation, utilizing the ellipsoidal height grid of the equipotential boundary surface and the corresponding residual height anomaly (m) grid.

>> Open Equipotential Surface Ellipsoidal Height Grid File C:/PAGravf4.5_win64en/examples/Integralgrainverse/landgeoidhgt.dat.

>> Open Height Anomaly Grid File C:/PAGravf4.5_win64en/examples/Integralgrainverse/resGMlgeoid541_1800.ksi.

>> Compute by 2D FFT algorithm...

>> Save the results as C:/PAGravf4.5_win64en/examples/Integralgrainverse/invhotineFFT2.dat.

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-13 10:47:17

>> Complete the computation!

>> Computation end time: 2026-04-13 10:47:19

Integral radius 150 km

Save the results as

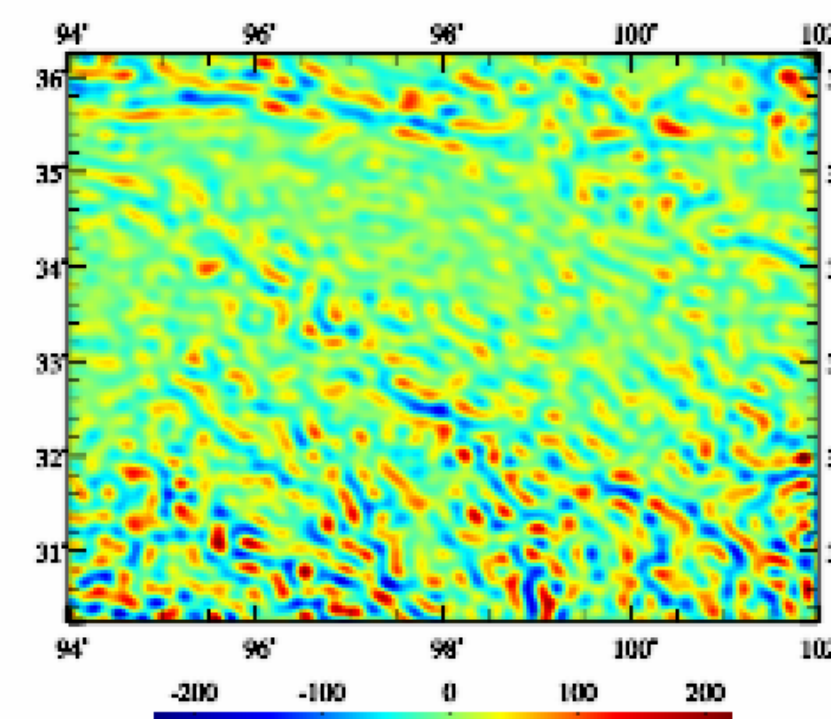
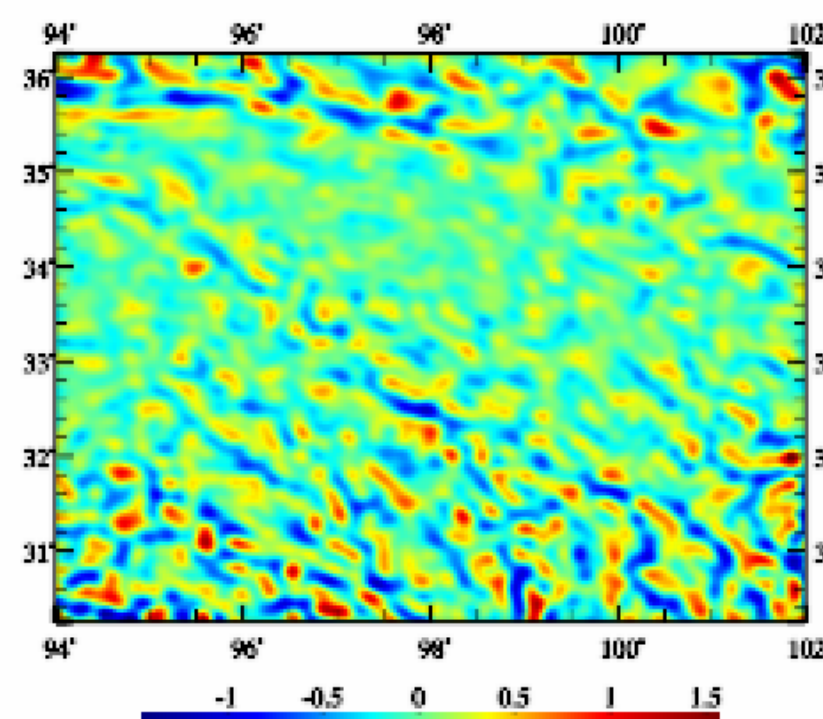
Import setting parameters

Start Computation

94.000000	102.000000	30.250000	36.250000	0.01666667	0.01666667
-39.6723	-31.7828	-23.0297	-13.3751	-3.2193	7.3476
68.6958	66.2006	63.6293	61.8125	61.1742	61.8872
85.4591	88.5938	92.9155	98.3523	104.3015	109.8659
-20.4677	-42.4183	-60.2231	-72.9255	-80.0225	-81.4903
1.5178	3.2397	3.6650	3.1371	2.3165	1.7048
50.4502	51.4207	47.9804	39.6280	26.4697	9.3145
41.6604	78.6860	112.8925	140.2611	157.3504	161.8263
-116.5733	-108.2735	-89.6355	-63.5110	-33.2851	-2.4532
34.1834	25.2076	18.4141	13.7940	11.4418	10.9471
58.2936	57.9596	54.0072	46.0869	34.5094	20.1203
12.7326	29.9892	44.8982	55.6314	61.1093	60.8720
-35.3719	-39.0639	-43.6423	-50.2046	-59.1971	-70.8742
-141.5860	-133.2540	-123.8984	-114.2587	-104.7690	-95.4896
36.9439	44.8132	47.4147	44.3125	35.6102	22.1623
-16.0796	5.5231	27.9794	49.6573	68.9034	84.7234
53.9134	38.1295	20.1815	0.2984	-21.0256	-43.0180
-54.1560	-31.6638	-10.0865	8.7326	23.4111	33.2061
10.4285	14.6561	19.5591	23.8760	26.8041	27.6124

Extract result element

Plot



Integral of Inverse Operation: A rigorous solution to the Stokes-type Boundary Value Problem. It strictly requires the integrand (height anomaly or vertical deflection) to reside on an equipotential boundary surface.

Inverse Integration: Employs a hybrid algorithm combining Poisson integration with the differentiation of anomalous field elements. This approach is more flexible and does not mandate the boundary surface to be an equipotential boundary surface.

Computation of Gravity Disturbance via Inverse Hotine Integration – 1D FFT

Computation of Gravity Anomaly via Inverse Stokes Integration

Computation of Gravity Disturbance via Inverse Hotine Integration

Computation via Inverse Vening-Meinesz Integration

Computation of External Anomalous Field Elements from Height Anomaly

Integral Formulas

Open Equipotential Surface Ellipsoidal Height Grid File

Open Height Anomaly Grid File

Select computation point file format

surface ellipsoidal height grid file

Select integral algorithm

1D FFT algorithm

>> Computation Process ** Operation Prompts

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-13 10:47:17

>> Complete the computation!

>> Computation end time: 2026-04-13 10:47:19

>> [Function] Computes the residual gravity disturbance (mGal) on the surface via the Integral of Inverse Hotine Operation, utilizing the ellipsoidal height grid of the equipotential boundary surface and the corresponding residual height anomaly (m) grid.

>> Open Equipotential Surface Ellipsoidal Height Grid File C:/PAGravf4.5_win64en/examples/Integralgrainverse/landgeoidhgt.dat.

>> Open Height Anomaly Grid File C:/PAGravf4.5_win64en/examples/Integralgrainverse/resGMlgeoid541_1800.ksi.

>> Compute by 1D FFT algorithm...

>> Save the results as C:/PAGravf4.5_win64en/examples/Integralgrainverse/invhotineFFT1.dat.

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-13 10:48:47

>> Complete the computation!

>> Computation end time: 2026-04-13 10:49:21

Integral radius 150 km

Save the results as

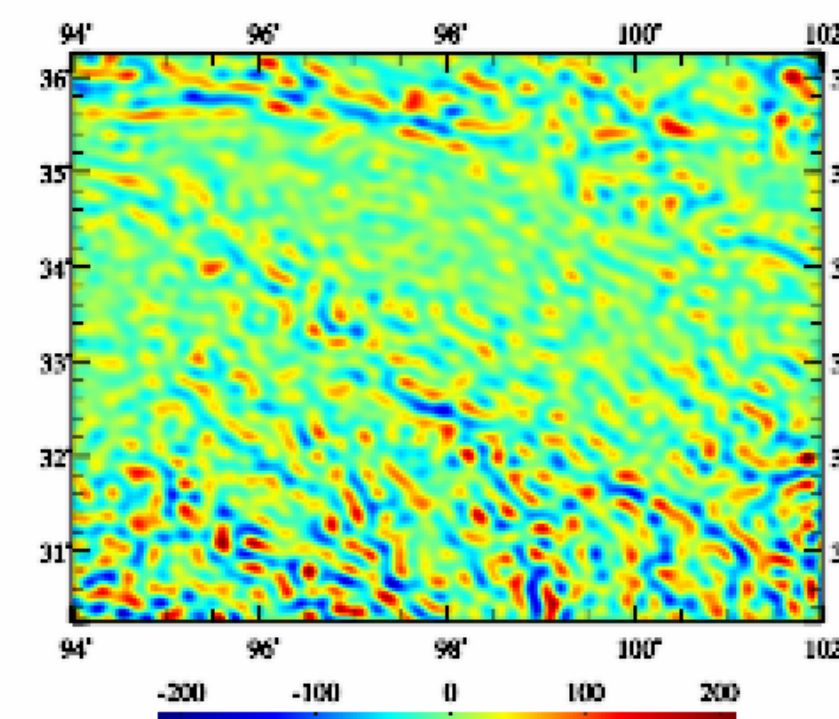
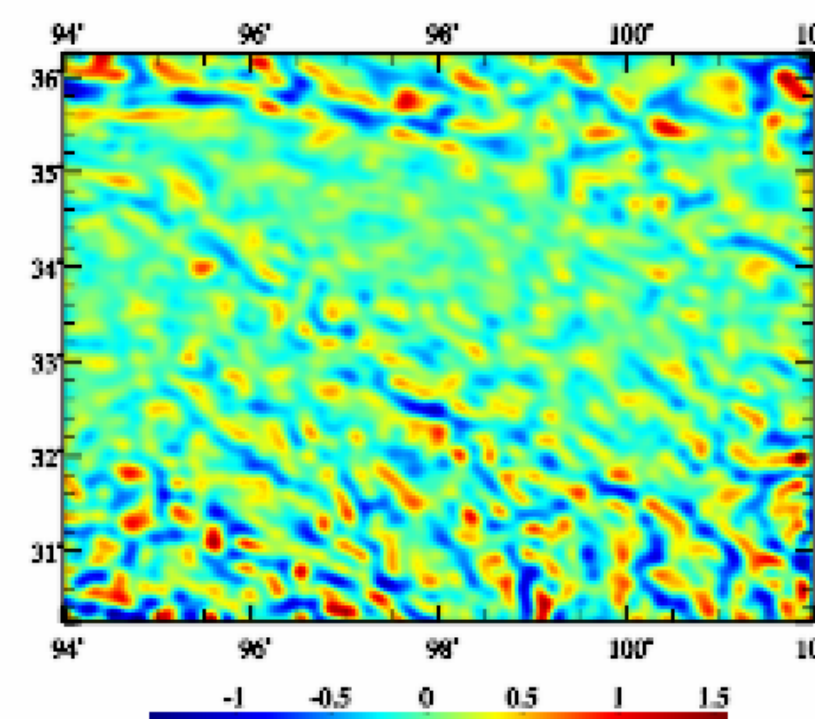
Import setting parameters

Start Computation

94.000000	102.000000	30.250000	36.250000	0.01666667	0.01666667
-38.8682	-31.6941	-23.1438	-13.6073	-3.5601	6.8701
67.0406	64.6090	62.0428	60.1351	59.3054	59.7434
83.3665	86.6217	90.8994	96.1095	101.6782	106.7658
-18.5118	-39.2524	-56.0933	-68.1493	-74.9591	-76.5065
-0.4518	1.0922	1.4569	0.9709	0.2593	-0.1994
49.1086	50.2807	47.2241	39.4621	27.0953	10.8908
39.0104	73.7341	105.8704	131.6391	147.8002	152.1501
-109.3107	-101.7344	-84.4260	-60.0396	-31.7348	-2.7841
33.1546	24.6893	18.2401	13.8202	11.5374	11.0251
56.3300	56.0042	52.2339	44.6946	33.6823	19.9963
11.0317	27.2532	41.3580	51.6289	57.0424	57.1487
-32.8331	-36.8306	-41.7045	-48.4521	-57.4644	-68.9551
-137.5650	-129.6975	-120.7996	-111.5539	-102.3621	-93.2787
35.8576	43.3584	45.8096	42.8115	34.4767	21.6241
-16.0898	4.3696	25.7234	46.4307	64.9261	80.2540
52.9293	37.6527	20.2755	1.0423	-19.5513	-40.7495
-52.5020	-31.1128	-10.5506	7.4378	21.5370	31.0312
9.8390	13.7261	18.2965	22.3748	25.2038	26.0876

Extract result element

Plot



Integral of Inverse Operation: A rigorous solution to the Stokes-type Boundary Value Problem. It strictly requires the integrand (height anomaly or vertical deflection) to reside on an equipotential boundary surface.

Inverse Integration: Employs a hybrid algorithm combining Poisson integration with the differentiation of anomalous field elements. This approach is more flexible and does not mandate the boundary surface to be an equipotential boundary surface.

Table 4.12: Statistics of Model Reference Truth (Unit: mGal)

Item	Mean	Std. Dev.	Min	Max
Residual Gravity Disturbances (Deg 541 – 1800)	0.4334	34.0852	-170.9556	177.8780

Table 4.13: Differences between Inverse Operation Integration Results and Reference Truth (Unit: mGal)

Algorithm	Mean	Std. Dev.	Min	Max
Numerical Integral	-0.0415	2.9285	-15.2734	14.6970
FFT2	-0.0433	2.8208	-11.9201	13.3607
FFT1	-0.0444	3.0509	-15.7950	15.5242

Algorithm Performance: The ratio of the standard deviation of Differences in Table 4.13 to the standard deviation of Reference Truths in Table 4.12 reflects the approximation capability of the corresponding algorithm.

The Inverse Hotine numerical integration yields a standard deviation of ~2.93 mGal, comparable to the Inverse Stokes method but with a slightly reduced maximum error range (± 9.7 mGal vs. ± 15.3 mGal). This suggests marginally better numerical stability when solving for gravity disturbances directly.

Computation via Inverse Vening-Meinesz Integration

Save as Import parameters Start Computation Save process Follow example

Computation of Gravity Anomaly via Inverse Stokes Integration

Computation of Gravity Disturbance via Inverse Hotine Integration

Computation via Inverse Vening-Meinesz Integration

Computation of External Anomalous Field Elements from Height Anomaly

Integral Formulas

Open Equipotential Surface Ellipsoidal Height Grid File

Open Vertical Deflection Vector Grid File

Select computation point file format

discrete computation point file

Open Discrete Computation Point File

Set input point file format

number of rows of file header 1

>> Computation Process ** Operation Prompts

>> Computation end time: 2026-04-13 10:49:21

>> [Function] Computes the residual height anomaly (m), gravity anomaly (mGal), and gravity disturbance (mGal) on an equipotential boundary surface. This is achieved via Inverse Vening-Meinesz Integration, utilizing the surface's ellipsoidal height grid and the corresponding residual vertical deflection vector grid (" , south and west components).

>> Open Equipotential Surface Ellipsoidal Height Grid File C:/PAGravf4.5_win64en/examples/Integralgrainverse/landgeoidhgt.dat.

>> Open Vertical Deflection Vector Grid File C:/PAGravf4.5_win64en/examples/Integralgrainverse/resGMIgeoid541_1800.dft.

>> Open Discrete Computation Point File C:/PAGravf4.5_win64en/examples/Integralgrainverse/calcpnt.txt.

** Look at the file information in the window below, set the input file format parameters...

>> Save the results as C:/PAGravf4.5_win64en/examples/Integralgrainverse/invVM.txt.

>> Appends four columns to the source file: Interpolated Ellipsoidal Height, Residual Height Anomaly, Gravity Anomaly, and Gravity Disturbance.

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-13 10:51:09

>> Complete the computation!

>> Computation end time: 2026-04-13 10:52:39

Integral radius 150 km

Save the results as

Import setting parameters

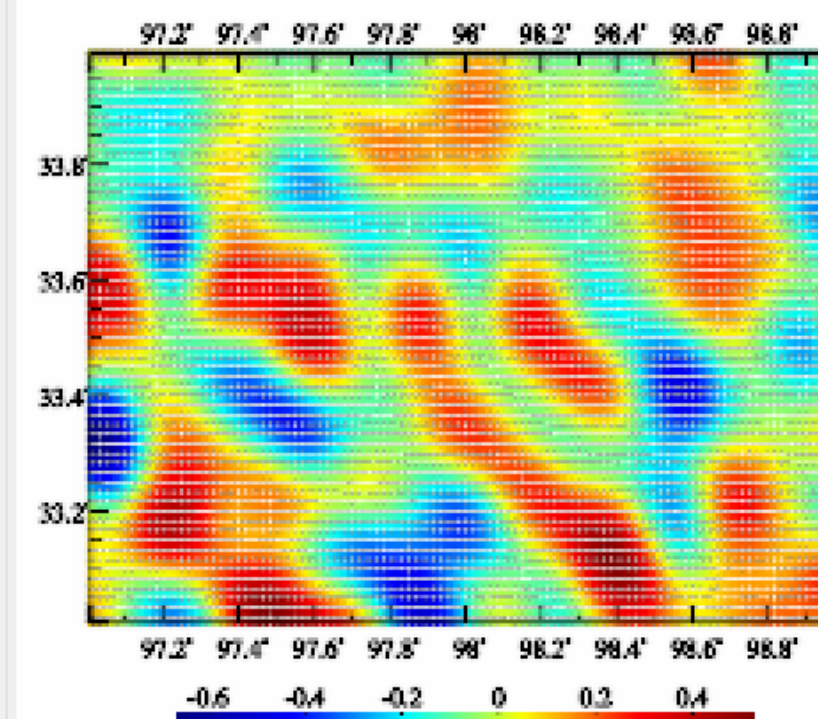
Start Computation

no	lon(degree/decimal)	lat	ellipHeight (m)			
1	97.008333	33.008333	3942.764	-37.2501	0.0986	2
2	97.025000	33.008333	3989.787	-37.2203	0.0846	2
3	97.041667	33.008333	4034.817	-37.1899	0.0639	2
4	97.058333	33.008333	4070.847	-37.1590	0.0366	1
5	97.075000	33.008333	4106.877	-37.1276	0.0033	1
6	97.091667	33.008333	4119.913	-37.0959	-0.0351	-
7	97.108333	33.008333	4115.946	-37.0640	-0.0772	-
8	97.125000	33.008333	4090.977	-37.0318	-0.1213	-1
9	97.141667	33.008333	4070.007	-36.9990	-0.1655	-1
10	97.158333	33.008333	3991.047	-36.9665	-0.2077	-2
11	97.175000	33.008333	3985.070	-36.9327	-0.2458	-3
12	97.191667	33.008333	3956.107	-36.8988	-0.2773	-4
13	97.208333	33.008333	3965.137	-36.8642	-0.2999	-4
14	97.225000	33.008333	3964.173	-36.8295	-0.3115	-5
15	97.241667	33.008333	3983.205	-36.7943	-0.3100	-5
16	97.258333	33.008333	3953.251	-36.7595	-0.2941	-5
17	97.275000	33.008333	4016.279	-36.7238	-0.2629	-4
18	97.291667	33.008333	4054.318	-36.6883	-0.2165	-3

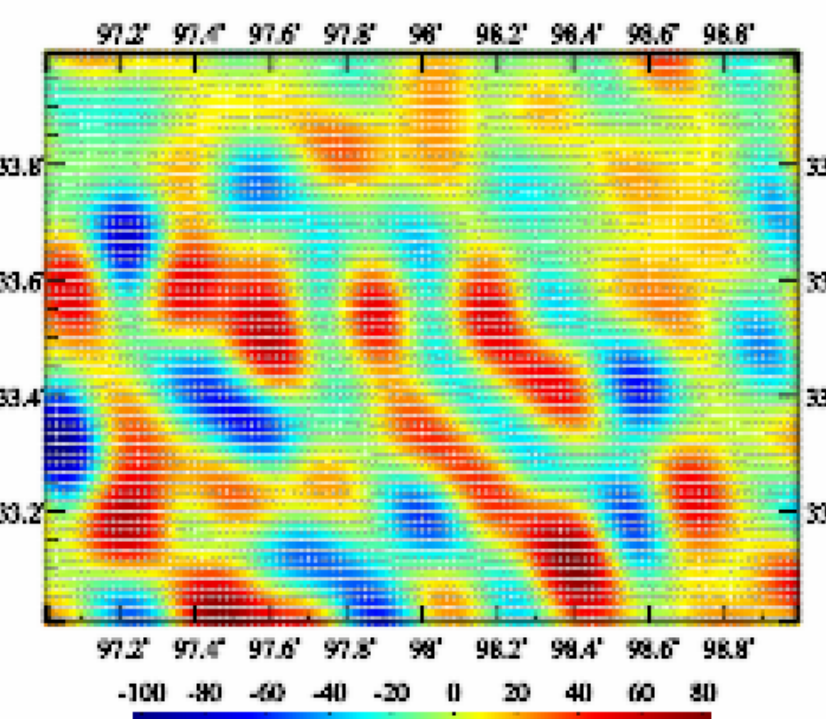
Ignore the ellipsoidal height

Extract result element

Plot



height anomaly (m)



gravity disturbance (mGal)

Integral of Inverse Operation: A rigorous solution to the Stokes-type Boundary Value Problem. It strictly requires the integrand (height anomaly or vertical deflection) to reside on an equipotential boundary surface.

Inverse Integration: Employs a hybrid algorithm combining Poisson integration with the differentiation of anomalous field elements. This approach is more flexible and does not mandate the boundary surface to be an equipotential boundary surface.

Computation via Inverse Vening-Meinesz Integration – 2D FFT

Computation of Gravity Anomaly via Inverse Stokes Integration

Computation of Gravity Disturbance via Inverse Hotine Integration

Computation via Inverse Vening-Meinesz Integration

Computation of External Anomalous Field Elements from Height Anomaly

Integral Formulas

Open Equipotential Surface Ellipsoidal Height Grid File

Open Vertical Deflection Vector Grid File

Select computation point file format

surface ellipsoidal height grid file

Select integral algorithm

2D FFT algorithm

>> Computation Process ** Operation Prompts

>> Computation end time: 2026-04-13 10:52:39

>> [Function] Computes the residual height anomaly (m), gravity anomaly (mGal), and gravity disturbance (mGal) on an equipotential boundary surface. This is achieved via Inverse Vening-Meinesz Integration, utilizing the surface's ellipsoidal height grid and the corresponding residual vertical deflection vector grid (" , south and west components).

>> Open Equipotential Surface Ellipsoidal Height Grid File C:/PAGravf4.5_win64en/examples/Integralgrainverse/landgeoidhgt.dat.

>> Open Vertical Deflection Vector Grid File C:/PAGravf4.5_win64en/examples/Integralgrainverse/resGMIgeoid541_1800.dft.

>> Compute by 2D FFT algorithm...

>> Save the results as C:/PAGravf4.5_win64en/examples/Integralgrainverse/invVMFFT2.txt.

>> Save Height Anomaly Grid as C:/PAGravf4.5_win64en/examples/Integralgrainverse/invVMFFT2.ksi.

>> Save Gravity Disturbance Grid as C:/PAGravf4.5_win64en/examples/Integralgrainverse/invVMFFT2.rga.

>> Save Gravity Anomaly Grid as C:/PAGravf4.5_win64en/examples/Integralgrainverse/invVMFFT2.gra.

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-13 10:56:58

>> Complete the computation!

>> Computation end time: 2026-04-13 10:57:02

Integral radius 150 km

Save the results as

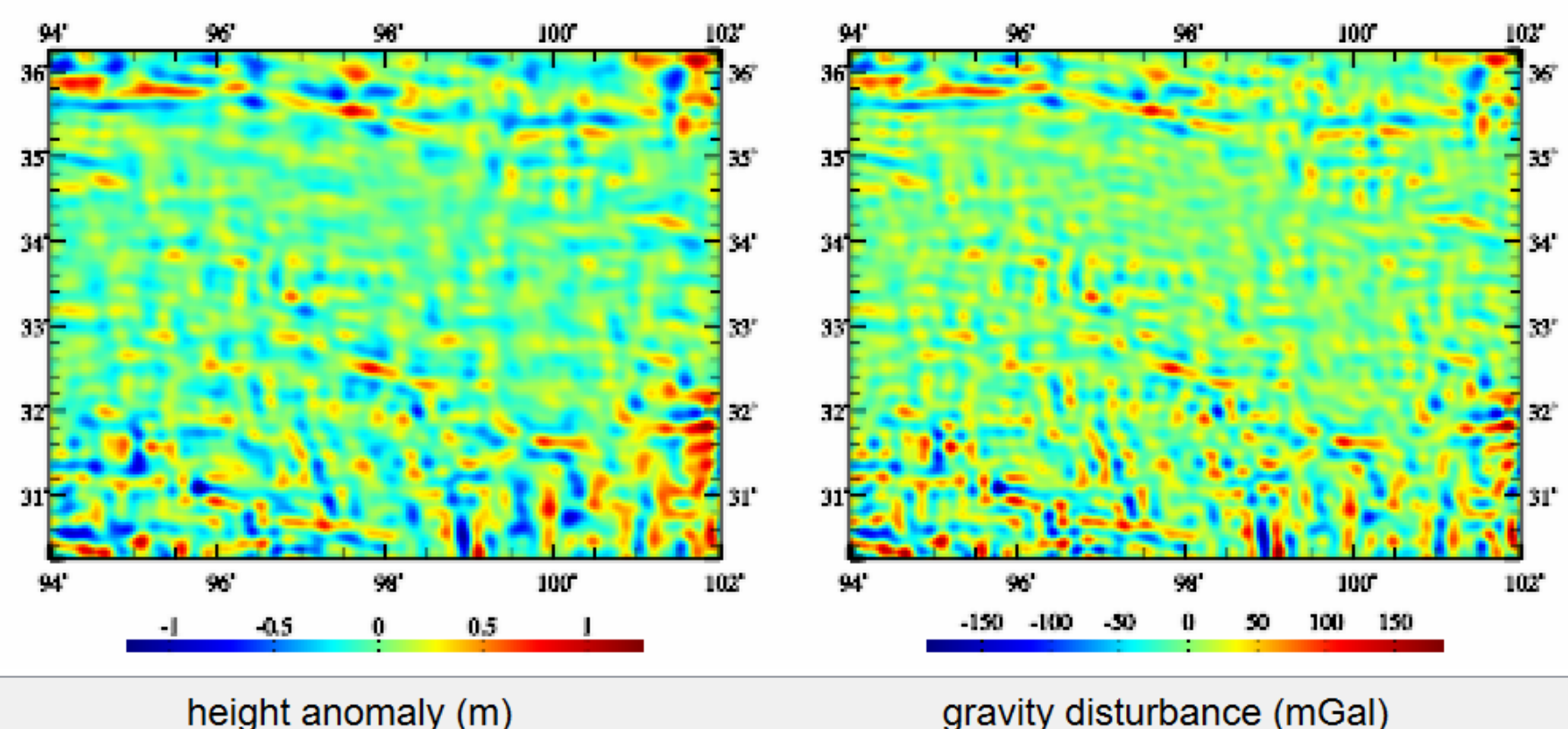
Import setting parameters

Start Computation

94.000000	102.000000	30.250000	36.250000	0.01666667	0.01666667
0.1280	0.1327	0.0986	0.0433	-0.0224	-0.0910
-0.4254	-0.3999	-0.3598	-0.3066	-0.2436	-0.1756
-0.1179	-0.1453	-0.1565	-0.1483	-0.1207	-0.0768
-0.0151	-0.0785	-0.1354	-0.1797	-0.2064	-0.2132
0.3349	0.3741	0.4003	0.4122	0.4089	0.3904
-0.3038	-0.3751	-0.4408	-0.5001	-0.5515	-0.5929
0.0786	0.2103	0.3196	0.3958	0.4316	0.4235
-0.2695	-0.2007	-0.1085	-0.0047	0.0984	0.1893
0.0264	-0.0020	-0.0203	-0.0307	-0.0365	-0.0410
-0.2177	-0.2401	-0.2634	-0.2873	-0.3108	-0.3316
0.0467	0.0913	0.1121	0.1052	0.0701	0.0100
-0.1209	0.0013	0.1284	0.2511	0.3614	0.4538
0.6658	0.6550	0.6320	0.5938	0.5387	0.4673
-0.1721	-0.1628	-0.1465	-0.1274	-0.1089	-0.0926
0.1315	0.1496	0.1536	0.1402	0.1083	0.0588
-0.2766	-0.2228	-0.1617	-0.0990	-0.0397	0.0128
0.2671	0.2814	0.2876	0.2833	0.2677	0.2411
0.0669	0.0819	0.0903	0.0883	0.0736	0.0461

Extract result element

Plot



Integral of Inverse Operation: A rigorous solution to the Stokes-type Boundary Value Problem. It strictly requires the integrand (height anomaly or vertical deflection) to reside on an equipotential boundary surface.

Inverse Integration: Employs a hybrid algorithm combining Poisson integration with the differentiation of anomalous field elements. This approach is more flexible and does not mandate the boundary surface to be an equipotential boundary surface.

Computation via Inverse Vening-Meinesz Integration – 1D FFT

Computation of Gravity Anomaly via Inverse Stokes Integration

Computation of Gravity Disturbance via Inverse Hotine Integration

Computation via Inverse Vening-Meinesz Integration

Computation of External Anomalous Field Elements from Height Anomaly

Integral Formulas

Open Equipotential Surface Ellipsoidal Height Grid File

Open Vertical Deflection Vector Grid File

Select computation point file format

surface ellipsoidal height grid file

Select integral algorithm

1D FFT algorithm

>> Computation Process ** Operation Prompts

>> Computation end time: 2026-04-13 10:57:02

>> [Function] Computes the residual height anomaly (m), gravity anomaly (mGal), and gravity disturbance (mGal) on an equipotential boundary surface. This is achieved via Inverse Vening-Meinesz Integration, utilizing the surface's ellipsoidal height grid and the corresponding residual vertical deflection vector grid (" , south and west components).

>> Open Equipotential Surface Ellipsoidal Height Grid File C:/PAGrav4.5_win64en/examples/Integralgrainverse/landgeoidhgt.dat.

>> Open Vertical Deflection Vector Grid File C:/PAGrav4.5_win64en/examples/Integralgrainverse/resGMLgeoid541_1800.dft.

>> Compute by 1D FFT algorithm...

>> Save the results as C:/PAGrav4.5_win64en/examples/Integralgrainverse/invVMFFT1.txt.

>> Save Height Anomaly Grid as C:/PAGrav4.5_win64en/examples/Integralgrainverse/invVMFFT1.ksi.

>> Save Gravity Disturbance Grid as C:/PAGrav4.5_win64en/examples/Integralgrainverse/invVMFFT1.rga.

>> Save Gravity Anomaly Grid as C:/PAGrav4.5_win64en/examples/Integralgrainverse/invVMFFT1.gra.

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-13 10:58:06

>> Complete the computation!

>> Computation end time: 2026-04-13 11:00:12

Integral radius 150 km

Save the results as

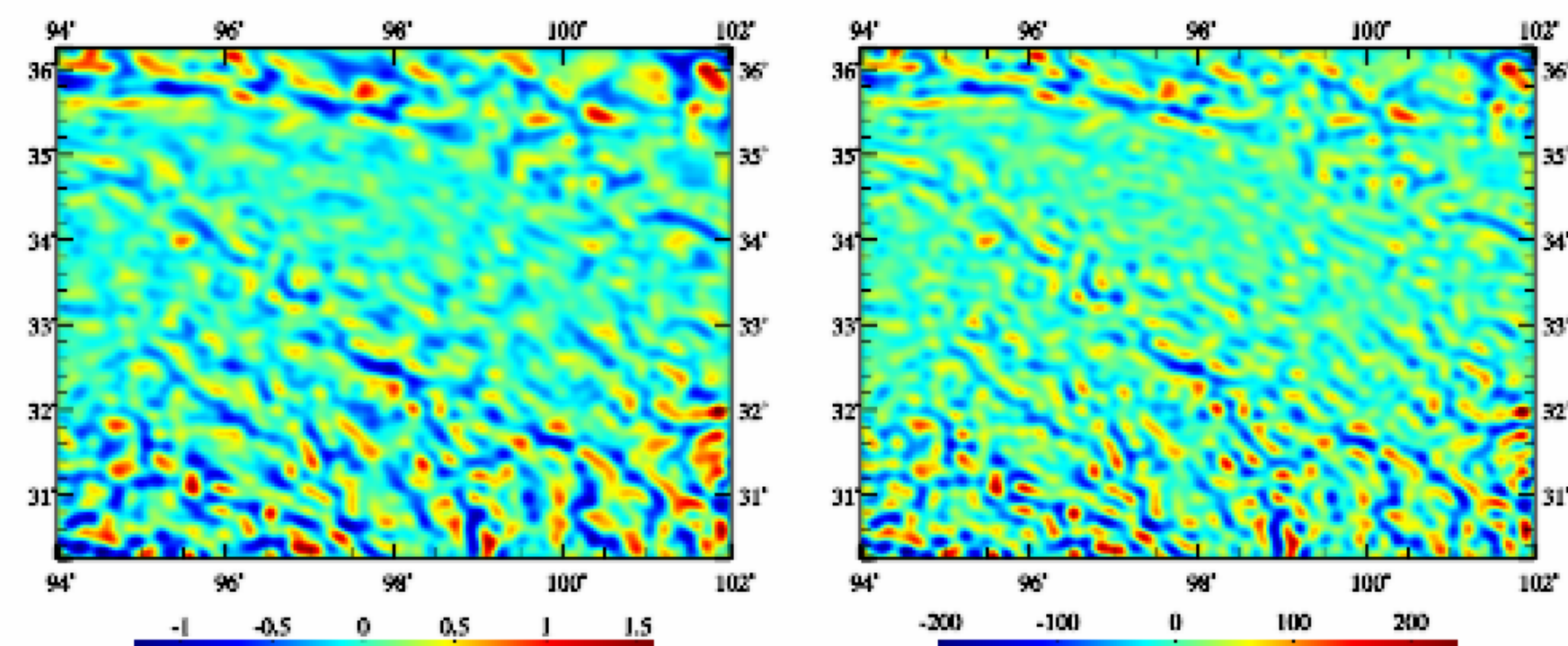
Import setting parameters

Start Computation

94.000000	102.000000	30.250000	36.250000	0.01666667	0.01666667
0.0580	0.0564	0.0585	0.0612	0.0638	0.0665
0.0288	0.0192	0.0142	0.0145	0.0196	0.0275
-0.2325	-0.2663	-0.2868	-0.2930	-0.2868	-0.2721
-0.6373	-0.6958	-0.7310	-0.7377	-0.7127	-0.6565
0.4076	0.4529	0.4809	0.4930	0.4911	0.4768
-0.0231	-0.0915	-0.1622	-0.2336	-0.3027	-0.3653
0.4099	0.5883	0.7397	0.8481	0.9025	0.8942
-0.5901	-0.5632	-0.4873	-0.3747	-0.2404	-0.1003
0.1089	0.0615	0.0211	-0.0111	-0.0350	-0.0515
0.0047	0.0079	0.0040	-0.0074	-0.0250	-0.0461
0.2976	0.3571	0.3940	0.4020	0.3780	0.3228
-0.3702	-0.3424	-0.3057	-0.2670	-0.2321	-0.2049
-0.0947	-0.0690	-0.0468	-0.0309	-0.0231	-0.0235
-0.0131	0.0018	0.0096	0.0082	-0.0031	-0.0230
0.1404	0.2157	0.2854	0.3430	0.3836	0.4036
-0.1584	-0.2263	-0.2908	-0.3517	-0.4083	-0.4590
-0.2058	-0.1199	-0.0404	0.0281	0.0820	0.1198
0.1510	0.1570	0.1570	0.1483	0.1292	0.0996

Extract result element

Plot



height anomaly (m)

gravity disturbance (mGal)

Integral of Inverse Operation: A rigorous solution to the Stokes-type Boundary Value Problem. It strictly requires the integrand (height anomaly or vertical deflection) to reside on an equipotential boundary surface.

Inverse Integration: Employs a hybrid algorithm combining Poisson integration with the differentiation of anomalous field elements. This approach is more flexible and does not mandate the boundary surface to be an equipotential boundary surface.

Table 4.14: Statistics of Model Reference Truths

Field Element(Deg 541 – 1800)	Unit	Mean	Std. Dev.	Min	Max
Residual Geoidal Heights	m	0.0045	0.2172	-1.1490	0.9110
Residual Gravity Disturbances	mGal	0.4348	34.1479	-171.3088	178.1561
Residual Gravity Anomalies	mGal	0.4334	34.0852	-170.9556	177.8780

Algorithm Performance: The ratio of the standard deviation of Differences in Table 4.15 to the standard deviation of Reference Truths in Table 4.14 reflects the approximation capability of the corresponding algorithm.

Geoidal Height Recovery: All three algorithms demonstrate comparable performance in recovering geoidal heights, with standard deviations around 3.3 cm and maximum errors within ± 13 cm. This confirms the high stability of the Inverse Vening-Meinesz formula.

Internal Consistency: The nearly identical error statistics for gravity anomalies and gravity disturbances validate the internal logical consistency of the algorithm implementation.

Table 4.15: Differences between Inverse Operation Integration Results and Reference Truth

Algorithm	Field Element	Unit	Mean	Std. Dev.	Min	Max
Numerical integral	Residual Geoidal Heights	m	-0.0002	0.0331	-0.1066	0.1266
	Residual Gravity Disturbances	mGal	-0.0281	3.5304	-19.8306	15.5799
	Residual Gravity Anomalies	mGal	-0.0280	3.5293	-19.8233	15.5701
FFT2	Residual Geoidal Heights	m	0.0001	0.0337	-0.1057	0.1271
	Residual Gravity Disturbances	mGal	-0.0131	2.4732	-12.3026	9.8919
	Residual Gravity Anomalies	mGal	-0.0131	2.4729	-12.2973	9.8831
FFT1	Residual Geoidal Heights	m	-0.0001	0.0332	-0.1068	0.1263
	Residual Gravity Disturbances	mGal	-0.0283	3.5527	-19.9907	15.7164
	Residual Gravity Anomalies	mGal	-0.0283	3.5516	-19.9830	15.7072

Computation of External Anomalous Gravity Field Elements from Height Anomaly

Computation of Gravity Anomaly via Inverse Stokes Integration

Computation of Gravity Disturbance via Inverse Hotine Integration

Computation via Inverse Vening-Meinesz Integration

Computation of External Anomalous Field Elements from Height Anomaly

Integral Formulas

Open Boundary Surface Ellipsoidal Height Grid File

Open Height Anomaly Grid File

Select computation point file format

discrete computation point file

Open Space Computation Point File

Set input point file format

number of rows of file header

1

>> Computation Process ** Operation Prompts

>> Computation end time: 2026-04-13 11:00:12

>> [Function] Computes the residual gravity anomaly (mGal), residual gravity disturbance (mGal), and residual vertical deflection vector (" south and west components) on or outside the geoid. Inputs include an ellipsoidal height grid of a boundary surface and the corresponding residual height anomaly (m) grid.

>> Open Computation Surface Ellipsoidal Height Grid File C:/PAGrav4.5_win64en/examples/Integralgrainverse/landgeoidhgt.dat.

>> Open Height Anomaly Grid File C:/PAGrav4.5_win64en/examples/Integralgrainverse/resGMIgeoid541_1800.ksi.

>> Open Space Computation Point File C:/PAGrav4.5_win64en/examples/Integralgrainverse/calcpnt.txt.

** Look at the file information in the window below, set the input file format parameters...

>> Save the results as C:/PAGrav4.5_win64en/examples/Integralgrainverse/invksiouter.txt.

>> Appends four attribute columns to the source file: Residual Gravity Anomaly, Residual Gravity Disturbance, Residual Vertical Deflection (Southward), and Residual Vertical Deflection (Westward).

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-13 11:02:42

>> Complete the computation!

>> Computation end time: 2026-04-13 11:11:09

Integral radius

150 km

Save the results as

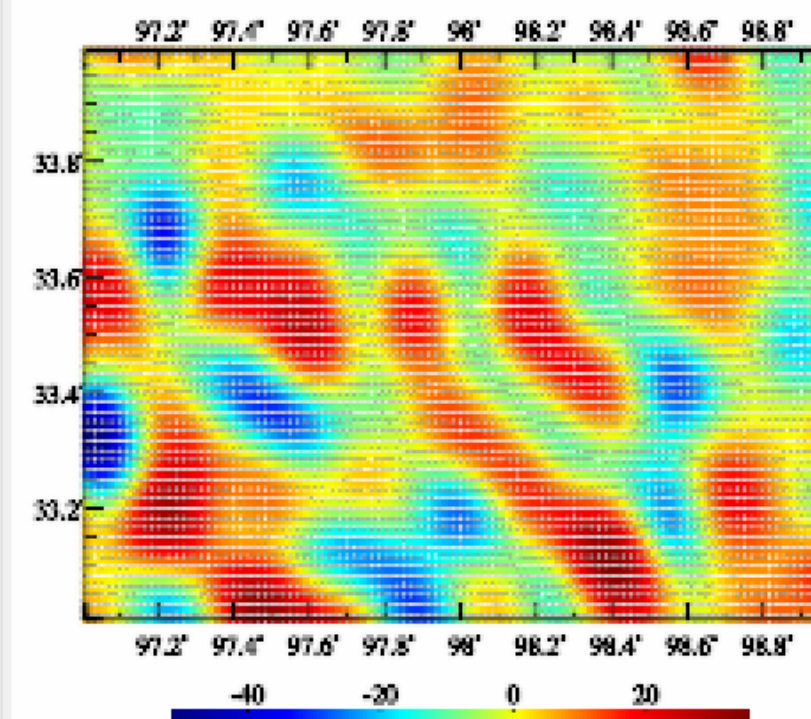
Import setting parameters

Start Computation

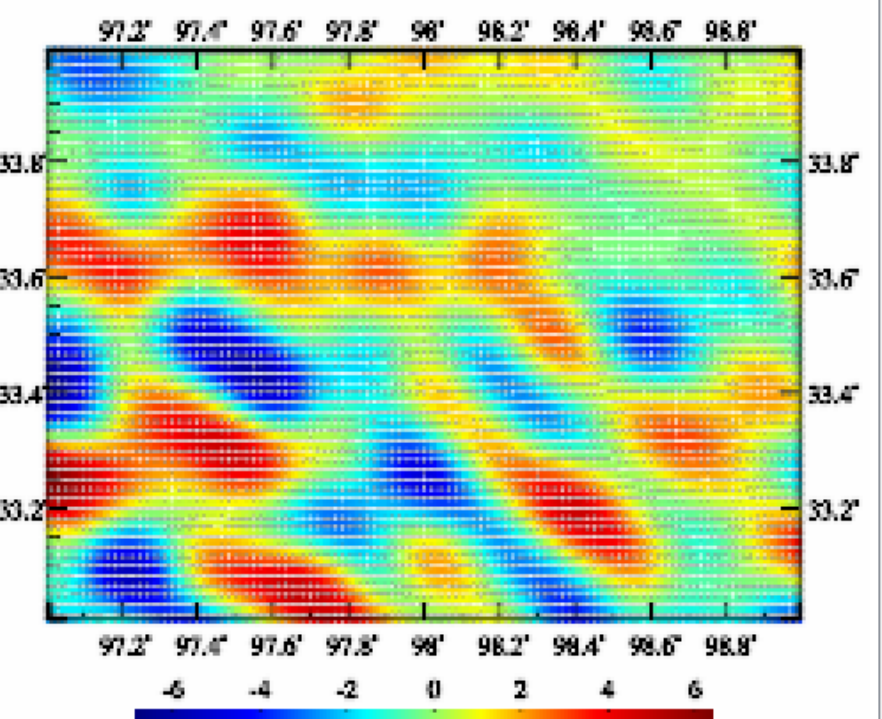
imal)	lat	ellipHeight (m)				
333	33.008333	3942.764	6.2612	6.2592	-2.5007	0.4847
000	33.008333	3989.787	6.0388	6.0365	-2.4248	0.6987
667	33.008333	4034.817	5.2179	5.2151	-2.3076	0.9304
333	33.008333	4070.847	3.8190	3.8156	-2.1573	1.1571
000	33.008333	4106.877	1.8631	1.8588	-1.9846	1.3566
667	33.008333	4119.913	-0.5421	-0.5472	-1.8034	1.5177
333	33.008333	4115.946	-3.3350	-3.3411	-1.6284	1.6250
000	33.008333	4090.977	-6.4301	-6.4372	-1.4752	1.6670
667	33.008333	4070.007	-9.6925	-9.7007	-1.3639	1.6181
333	33.008333	3991.047	-13.0955	-13.1048	-1.3008	1.4939
000	33.008333	3985.070	-16.1623	-16.1724	-1.3230	1.2209
667	33.008333	3956.107	-18.9050	-18.9158	-1.4222	0.8360
333	33.008333	3965.137	-20.8767	-20.8879	-1.6097	0.3179
000	33.008333	3964.173	-22.0755	-22.0867	-1.8711	-0.3092
667	33.008333	3983.205	-22.1895	-22.2002	-2.1941	-1.0304
333	33.008333	3953.251	-21.4492	-21.4591	-2.5624	-1.8234
000	33.008333	4016.279	-19.0783	-19.0868	-2.9355	-2.6206
667	33.008333	4054.318	-15.7055	-15.7122	-3.2973	-3.3943

Extract result element

Plot



gravity disturbance (mGal)



vertical deflection S (")

Integral of Inverse Operation: A rigorous solution to the Stokes-type Boundary Value Problem. It strictly requires the integrand (height anomaly or vertical deflection) to reside on an equipotential boundary surface.

Inverse Integration: Employs a hybrid algorithm combining Poisson integration with the differentiation of anomalous field elements. This approach is more flexible and does not mandate the boundary surface to be an equipotential boundary surface.

Table 4.16: Statistics of Model Reference Truths

Field Element	Unit	Mean	Std. Dev.	Min	Max
Ground Residual Gravity anomalies	mGal	-0.0349	15.7184	-93.7784	66.5507
Ground Residual Gravity disturbances	mGal	-0.0346	15.7527	-93.9854	66.6638
Ground Residual Vertical Deflection (S)	"	0.0014	2.4951	-12.7789	14.2346
Ground Residual Vertical Veflection (W)	"	0.0097	2.1772	-9.1577	10.4499

Table 4.17: Differences between Computed Results and Reference Truth

Field Element	Unit	Mean	Std. Dev.	Min	Max
Ground Residual Gravity anomalies	mGal	-0.0104	2.0577	-8.2097	10.7064
Ground Residual Gravity disturbances	mGal	-0.0100	2.0929	-8.3217	10.8982
Ground Residual Vertical Deflection (S)	"	0.0004	0.0075	-0.0357	0.0388
Ground Residual Vertical Veflection (W)	"	0.0003	0.0076	-0.0362	0.0358

Algorithm Performance: The ratio of the standard deviation of Differences in Table 4.17 to the standard deviation of Reference Truths in Table 4.16 reflects the approximation capability of the corresponding algorithm.

Exceptional Inversion Accuracy: The inversion from height anomalies to ground gravity field elements demonstrates exceptional precision. The standard deviations for gravity anomalies and disturbances are merely $\sim 2.06 - 2.09$ mGal, representing a significant signal-to-noise improvement over the original field variability (~ 15.7 mGal).

High-Precision Vertical Deflection Recovery: The recovery of vertical deflections is remarkably accurate, with standard deviations of only $0.0075''$ (7.5 mas) and maximum errors confined within $\pm 0.04''$. This underscores the superior numerical stability and high-frequency preservation capabilities of the combined Poisson integration and differentiation algorithm when transforming geoidal heights to vertical deflections.

Algorithm Robustness: Given that this method does not require an equipotential boundary, these results further validate the algorithm's robustness and reliability for practical applications involving quasi-geoids or non-strict reference surfaces.

Radial Gradient Integration of Anomalous Gravity Field Elements

Save as Import parameters Start computation Save process Follow example

Radial Gradient Integration
of Anomalous Gravity
Field Elements

Computation of External Gravity
Disturbance from
Disturbing Gravity Gradient

Computation of Disturbing
Gravity Gradient via
Inverse Operation Integration

Computation of External Disturbing
Gravity Gradient
from Gravity Disturbance

Computation of External Anomalous
Gravity Field Elements
via Poisson Integration

Open Equipotential Surface Ellipsoidal
Height Grid File

Open Residual Field Element Grid File

Select computation point file format

discrete computation point file

Open Discrete Computation Point File

Set input point file format

number of rows of file header

1

>> Computation Process ** Operation Prompts

>> [Purpose] To perform radial gradient integration, integral inverse operations, inverse operation integrations, and Poisson integrations on anomalous gravity field elements using rigorous numerical integration methods.

>> Select the computation function from the 5 control buttons at the top of the interface...

>> [Function] Computes the radial gradient (/km) of a specific field element on a surface via numerical integration, utilizing the ellipsoidal height grid of the equipotential boundary surface and the corresponding anomalous gravity field element grid.

>> Open Equipotential Surface Ellipsoidal Height Grid File C:/PAGrav4.5_win64en/examples/Intgendistgradient/landgeoidhgt.dat.

>> Open Residual Field Element Grid File C:/PAGrav4.5_win64en/examples/Intgendistgradient/resGMIgeoid541_1800.ksi.

>> Open Discrete Computation Point File C:/PAGrav4.5_win64en/examples/Intgendistgradient/calcpnt.txt.

** Look at the file information in the window below, set the input file format parameters...

>> Save Radial Gradient as C:/PAGrav4.5_win64en/examples/Intgendistgradient/rgradient.txt.

>> Appends two columns to the source file: Interpolated Ellipsoidal Height, and Computed Radial Gradient value (/km).

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-14 07:02:30

>> Complete the computation!

>> Computation end time: 2026-04-14 07:03:19

Integral radius

120 km

Save the results as

Import setting parameters

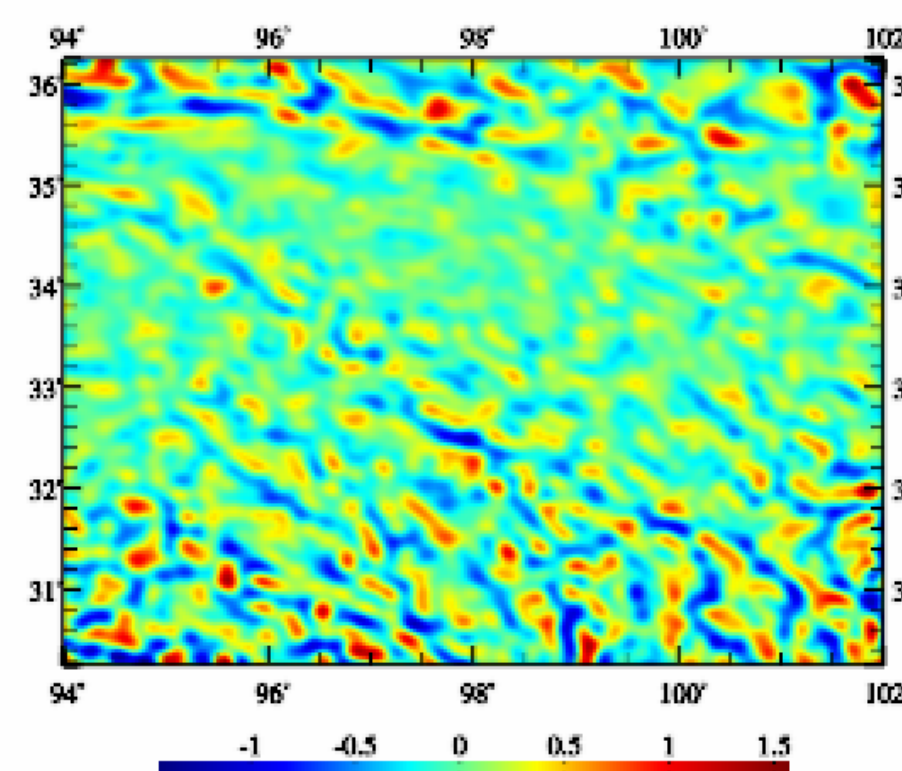
Start Computation

no lon(degree/decimal) lat ellipHeight (m)

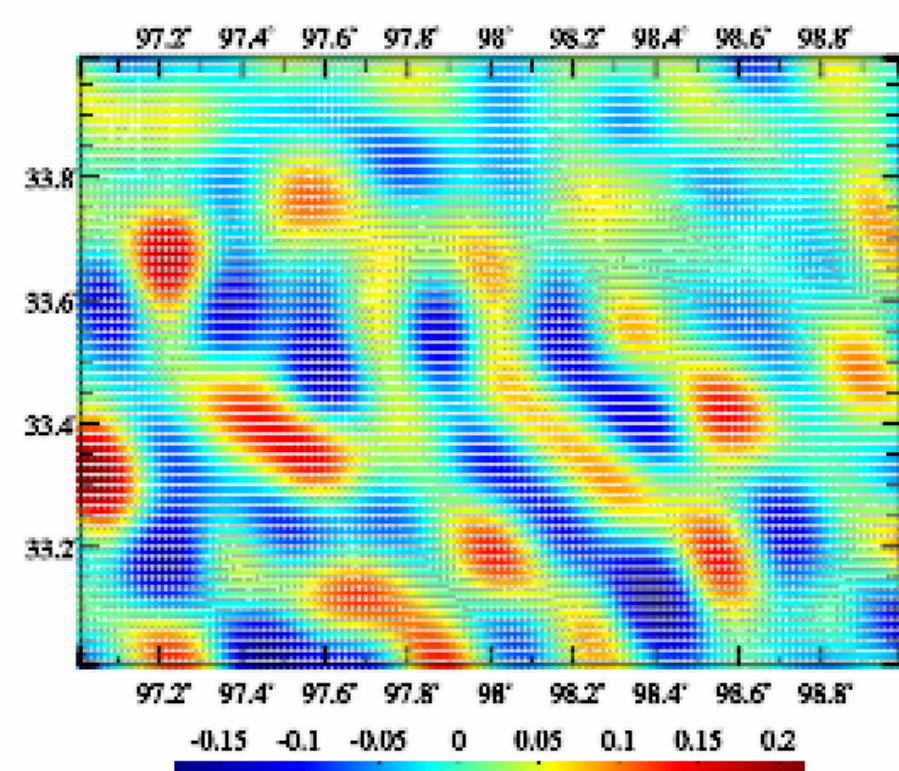
1	97.008333	33.008333	3942.764	-37.2501	-0.0690
2	97.025000	33.008333	3989.787	-37.2203	-0.0687
3	97.041667	33.008333	4034.817	-37.1899	-0.0641
4	97.058333	33.008333	4070.847	-37.1590	-0.0548
5	97.075000	33.008333	4106.877	-37.1276	-0.0414
6	97.091667	33.008333	4119.913	-37.0959	-0.0246
7	97.108333	33.008333	4115.946	-37.0640	-0.0046
8	97.125000	33.008333	4090.977	-37.0318	0.0169
9	97.141667	33.008333	4070.007	-36.9990	0.0394
10	97.158333	33.008333	3991.047	-36.9665	0.0612
11	97.175000	33.008333	3985.070	-36.9327	0.0814
12	97.191667	33.008333	3956.107	-36.8988	0.0986
13	97.208333	33.008333	3965.137	-36.8642	0.1120
14	97.225000	33.008333	3964.173	-36.8295	0.1200
15	97.241667	33.008333	3983.205	-36.7943	0.1224
16	97.258333	33.008333	3953.251	-36.7595	0.1180
17	97.275000	33.008333	4016.279	-36.7238	0.1066
18	97.291667	33.008333	4054.318	-36.6883	0.0886
19	97.308333	33.008333	4090.360	-36.6528	0.0644
20	97.325000	33.008333	4192.388	-36.6171	0.0351
21	97.341667	33.008333	4287.429	-36.5816	0.0020

Extract radial gradient of element

Plot↓



anomalous field element on surface



radial gradient (/km) of element

Radial Gradient Integration algorithm is derived from the solution to the Stokes Boundary Value Problem, this requires the integrand field elements to reside on an equipotential boundary surface.

Equipotential Surface Construction: Typically constructed from a global geopotential model (degree ≤ 360). For equipotential surfaces within an altitude of 10 km, a normal (or orthometric) equiheight surface may serve as a valid approximation.

Radial Gradient Integration of Anomalous Gravity Field Elements

Radial Gradient Integration
of Anomalous Gravity
Field Elements

Computation of External Gravity
Disturbance from
Disturbing Gravity Gradient

Computation of Disturbing
Gravity Gradient via
Inverse Operation Integration

Computation of External Disturbing
Gravity Gradient
from Gravity Disturbance

Computation of External Anomalous
Gravity Field Elements
via Poisson Integration

Open Equipotential Surface Ellipsoidal
Height Grid File

Open Residual Field Element Grid File

Select computation point file format

surface ellipsoidal height grid file

>> Computation Process ** Operation Prompts

>> Appends two columns to the source file: Interpolated Ellipsoidal Height, and Computed Radial Gradient value (/km).

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-14 07:02:30

>> Complete the computation!

>> Computation end time: 2026-04-14 07:03:19

>> [Function] Computes the radial gradient (/km) of a specific field element on a surface via numerical integration, utilizing the ellipsoidal height grid of the equipotential boundary surface and the corresponding anomalous gravity field element grid.

>> Open Equipotential Surface Ellipsoidal Height Grid File C:/PAGrav4.5_win64en/examples/Intgendistgradient/landgeoidhgt.dat.

>> Open Residual Field Element Grid File C:/PAGrav4.5_win64en/examples/Intgendistgradient/resGMIgeoid541_1800.ksi.

>> Save Radial Gradient as C:/PAGrav4.5_win64en/examples/Intgendistgradient/rgradient.dat.

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-14 07:05:14

>> Complete the computation!

>> Computation end time: 2026-04-14 07:21:28

Integral radius 120 km

Save the results as

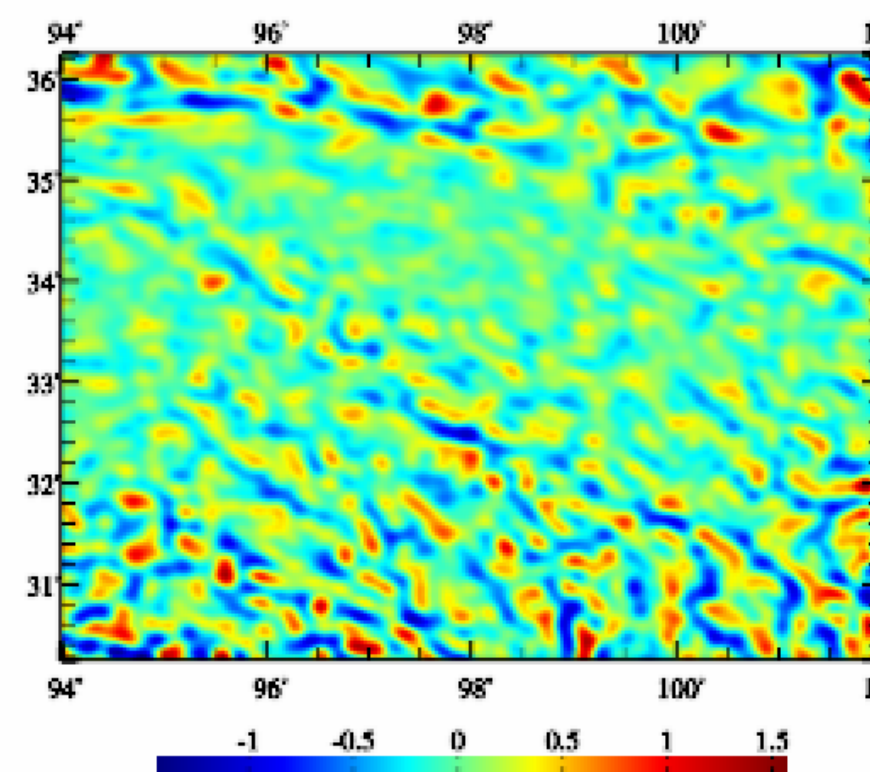
Import setting parameters

Start Computation

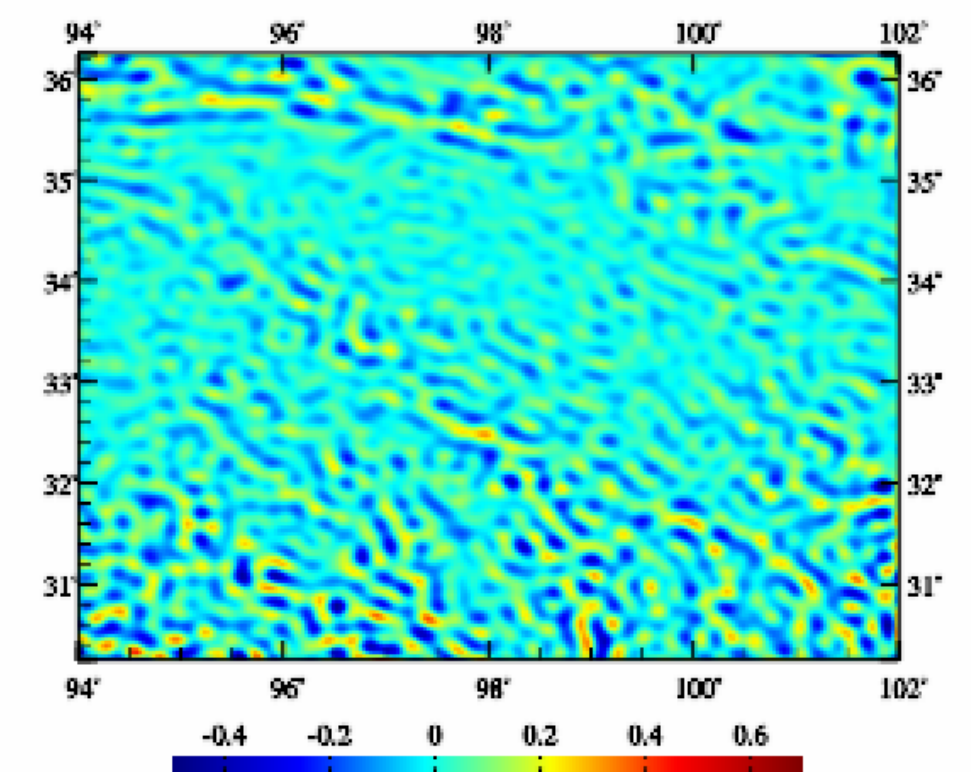
94.000000	102.000000	30.250000	36.250000	0.01666667	0.01666667
0.1994	0.1616	0.1299	0.0966	0.0618	0.0187
-0.2230	-0.2129	-0.2012	-0.1909	-0.1838	-0.1814
-0.3206	-0.3410	-0.3625	-0.3845	-0.4051	-0.4217
-0.0254	0.0381	0.0910	0.1313	0.1579	0.1710
0.0889	0.0928	0.0974	0.1016	0.1035	0.1017
-0.1844	-0.2024	-0.2053	-0.1910	-0.1595	-0.1125
-0.0629	-0.1566	-0.2467	-0.3222	-0.3733	-0.3932
0.2883	0.2679	0.2207	0.1538	0.0761	-0.0035
-0.1036	-0.0806	-0.0632	-0.0514	-0.0454	-0.0445
-0.1906	-0.1900	-0.1781	-0.1537	-0.1175	-0.0717
0.0379	-0.0101	-0.0551	-0.0921	-0.1179	-0.1305
0.0444	0.0620	0.0847	0.1145	0.1522	0.1975
0.4743	0.4530	0.4273	0.3990	0.3692	0.3379
-0.1393	-0.1662	-0.1758	-0.1670	-0.1400	-0.0975
0.0919	0.0327	-0.0318	-0.0970	-0.1582	-0.2123
-0.2250	-0.1789	-0.1243	-0.0623	0.0052	0.0756
0.1622	0.0982	0.0360	-0.0190	-0.0626	-0.0924
-0.0143	-0.0254	-0.0398	-0.0541	-0.0659	-0.0729
0.0383	0.0427	0.0461	0.0490	0.0522	0.0552
-0.1294	-0.1505	-0.1593	-0.1532	-0.1318	-0.0968

Extract radial gradient of element

Plot↓



anomalous field element on surface



radial gradient (/km) of element

Radial Gradient Integration algorithm is derived from the solution to the Stokes Boundary Value Problem, this requires the integrand field elements to reside on an equipotential boundary surface.

Equipotential Surface Construction: Typically constructed from a global geopotential model (degree ≤ 360). For equipotential surfaces within an altitude of 10 km, a normal (or orthometric) equiheight surface may serve as a valid approximation.

Computation of External Gravity Disturbance from Disturbing Gravity Gradient

Save as Import parameters Start Computation Save process Follow example

Radial Gradient Integration
of Anomalous Gravity
Field Elements

Computation of External Gravity
Disturbance from
Disturbing Gravity Gradient

Computation of Disturbing
Gravity Gradient via
Inverse Operation Integration

Computation of External Disturbing
Gravity Gradient
from Gravity Disturbance

Computation of External Anomalous
Gravity Field Elements
via Poisson Integration

Open Equipotential Surface Ellipsoidal
Height Grid File

Open Residual Gravity Gradient Grid File

Select computation point file format

discrete computation point file

Open Space Computation Point File

Set input point file format

number of rows of file header

1

>> Computation Process ** Operation Prompts

>> [Purpose] To perform radial gradient integration, integral inverse operations, inverse operation integrations, and Poisson integrations on anomalous gravity field elements using rigorous numerical integration methods.

>> Select the computation function from the 5 control buttons at the top of the interface...

>> [Function] Computes the residual gravity disturbance (mGal) on or outside the geoid via numerical integration, utilizing the ellipsoidal height grid of the equipotential boundary surface and the corresponding residual disturbing gravity gradient grid (E, radial component).

** This function performs the inversion (downward/upward continuation) from gravity gradients to gravity disturbances.

>> Open Equipotential Surface Ellipsoidal Height Grid File C:/PAGrav4.5_win64en/examples/Intgendistgradient/landgeoidhgt.dat.

>> Open Residual Gravity Gradient Grid File C:/PAGrav4.5_win64en/examples/Intgendistgradient/resGMIgeoid541_1800.grr.

>> Open Space Computation Point File C:/PAGrav4.5_win64en/examples/Intgendistgradient/calcpnt.txt.

** Look at the file information in the window below, set the input file format parameters...

>> Save Gravity Disturbance as C:/PAGrav4.5_win64en/examples/Intgendistgradient/grrtorgadbm.txt.

>> Appends one column containing the residual gravity disturbance value.

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-14 07:26:58

>> Complete the computation!

>> Computation end time: 2026-04-14 07:27:47

Integral radius

120 km

Save the results as

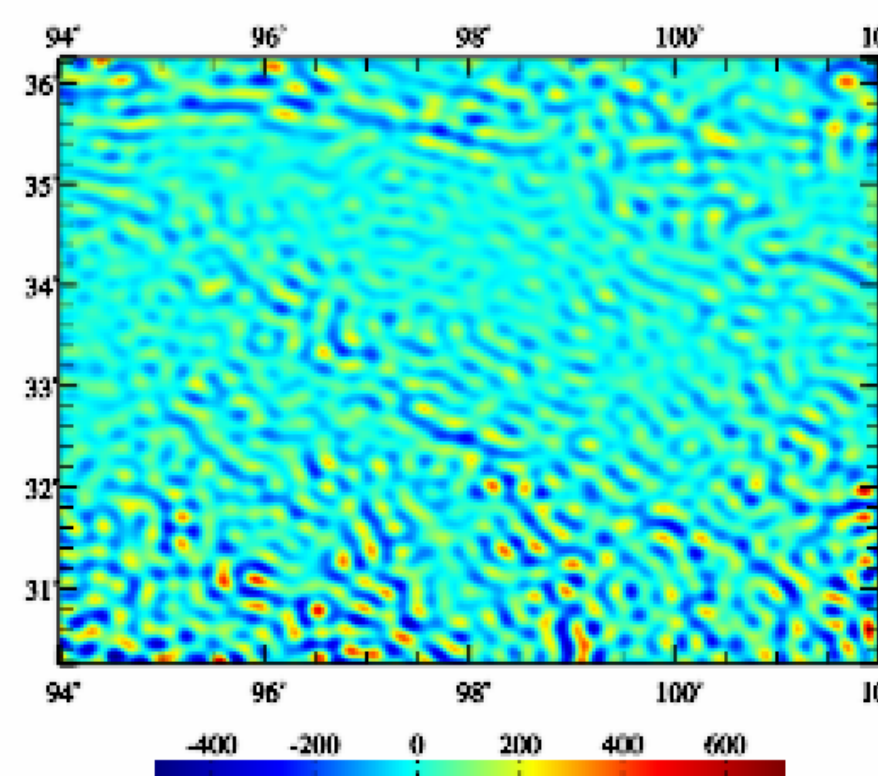
Import setting parameters

Start Computation

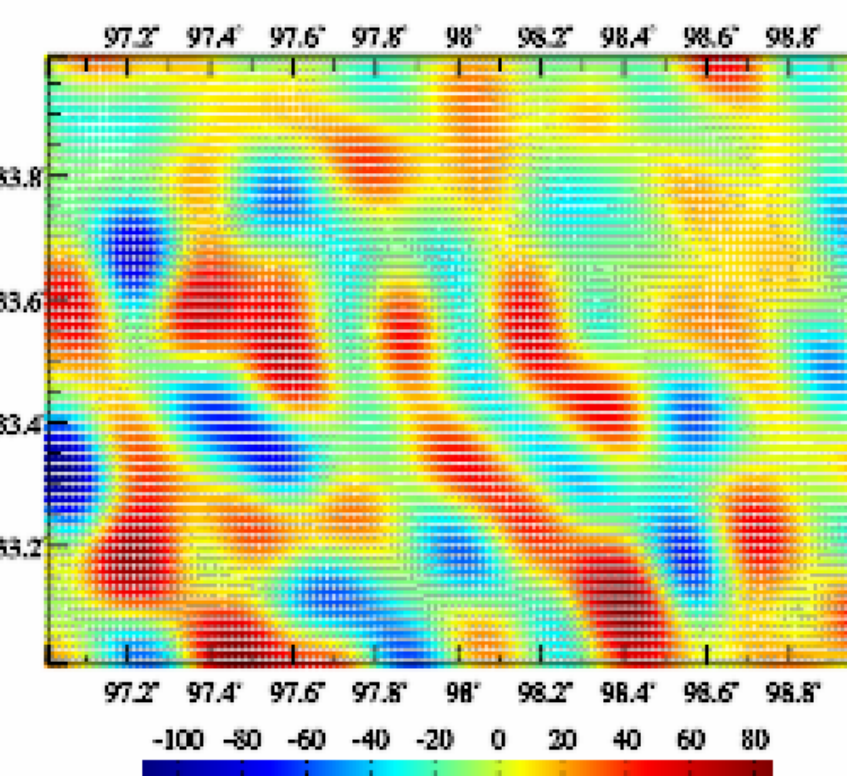
no	lon(degree/decimal)	lat	ellipHeight(m)	
1	97.008333	33.008333	3942.764	22.5501
2	97.025000	33.008333	3989.787	22.5614
3	97.041667	33.008333	4034.817	20.8934
4	97.058333	33.008333	4070.847	17.5000
5	97.075000	33.008333	4106.877	12.4499
6	97.091667	33.008333	4119.913	5.9167
7	97.108333	33.008333	4115.946	-1.8356
8	97.125000	33.008333	4090.977	-10.4680
9	97.141667	33.008333	4070.007	-19.5753
10	97.158333	33.008333	3991.047	-28.6981
11	97.175000	33.008333	3985.070	-37.3345
12	97.191667	33.008333	3956.107	-44.9514
13	97.208333	33.008333	3965.137	-51.0062
14	97.225000	33.008333	3964.173	-54.9764
15	97.241667	33.008333	3983.205	-56.3949
16	97.258333	33.008333	3953.251	-54.8958
17	97.275000	33.008333	4016.279	-50.2604
18	97.291667	33.008333	4054.318	-42.4609
19	97.308333	33.008333	4090.360	-31.6924
20	97.325000	33.008333	4192.388	-18.3837
21	97.341667	33.008333	4287.429	-3.1899

Extract external gravity disturbance

Plot



disturbing gravity gradient (E, radial)



external gravity disturbance (mGal)

Radial Gradient Integration algorithm is derived from the solution to the Stokes Boundary Value Problem, this requires the integrand field elements to reside on an equipotential boundary surface.

Equipotential Surface Construction: Typically constructed from a global geopotential model (degree ≤ 360). For equipotential surfaces within an altitude of 10 km, a normal (or orthometric) equiheight surface may serve as a valid approximation.

Computation of External Gravity Disturbance from Disturbing Gravity Gradient

Radial Gradient Integration
of Anomalous Gravity
Field Elements

Computation of External Gravity
Disturbance from
Disturbing Gravity Gradient

Computation of Disturbing
Gravity Gradient via
Inverse Operation Integration

Computation of External Disturbing
Gravity Gradient
from Gravity Disturbance

Computation of External Anomalous
Gravity Field Elements
via Poisson Integration

Open Equipotential Surface Ellipsoidal
Height Grid File

Open Residual Gravity Gradient Grid File

Select computation point file format

surface ellipsoidal height grid file

Open Computation Surface Ellipsoidal
Height Grid File

>> Computation Process ** Operation Prompts

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-14 07:26:58

>> Complete the computation!

>> Computation end time: 2026-04-14 07:27:47

>> [Function] Computes the residual gravity disturbance (mGal) on or outside the geoid via numerical integration, utilizing the ellipsoidal height grid of the equipotential boundary surface and the corresponding residual disturbing gravity gradient grid (E, radial component).

** This function performs the inversion (downward/upward continuation) from gravity gradients to gravity disturbances.

>> Open Equipotential Surface Ellipsoidal Height Grid File C:/PAGrav4.5_win64en/examples/Intgendistgradient/landgeoidhgt.dat.

>> Open Residual Gravity Gradient Grid File C:/PAGrav4.5_win64en/examples/Intgendistgradient/resGMIgeoid541_1800.grr.

>> Open Computation Surface Ellipsoidal Height Grid File C:/PAGrav4.5_win64en/examples/Intgendistgradient/landbmsurfhgt.dat.

>> Save Gravity Disturbance as C:/PAGrav4.5_win64en/examples/Intgendistgradient/grrtorgadbm.dat.

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-14 07:29:24

>> Complete the computation!

>> Computation end time: 2026-04-14 07:45:40

Integral radius 120 km

Save the results as

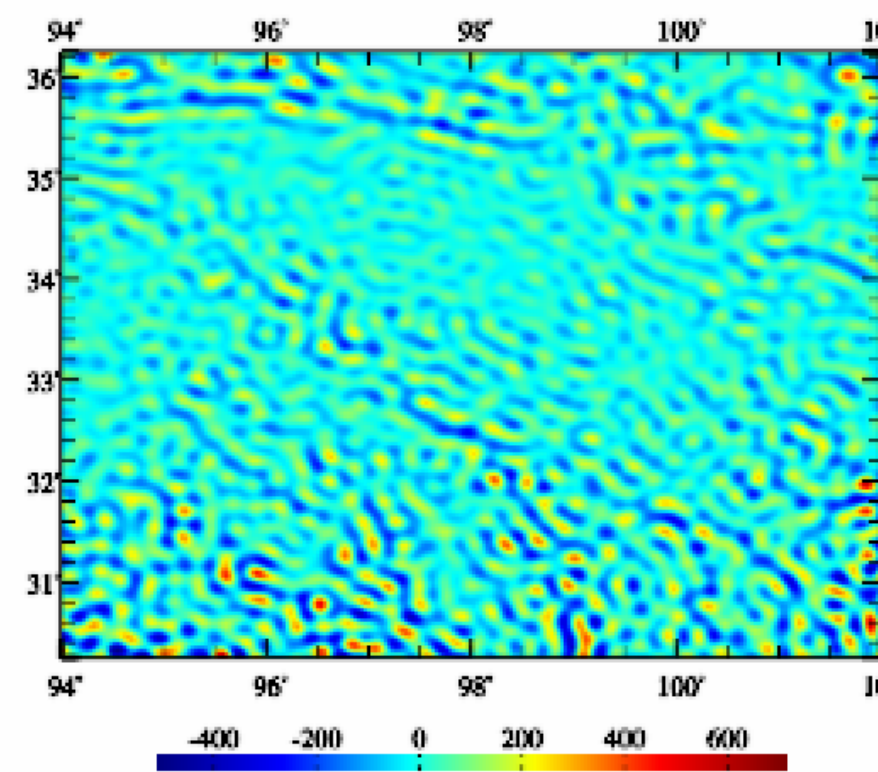
Import setting parameters

Start Computation

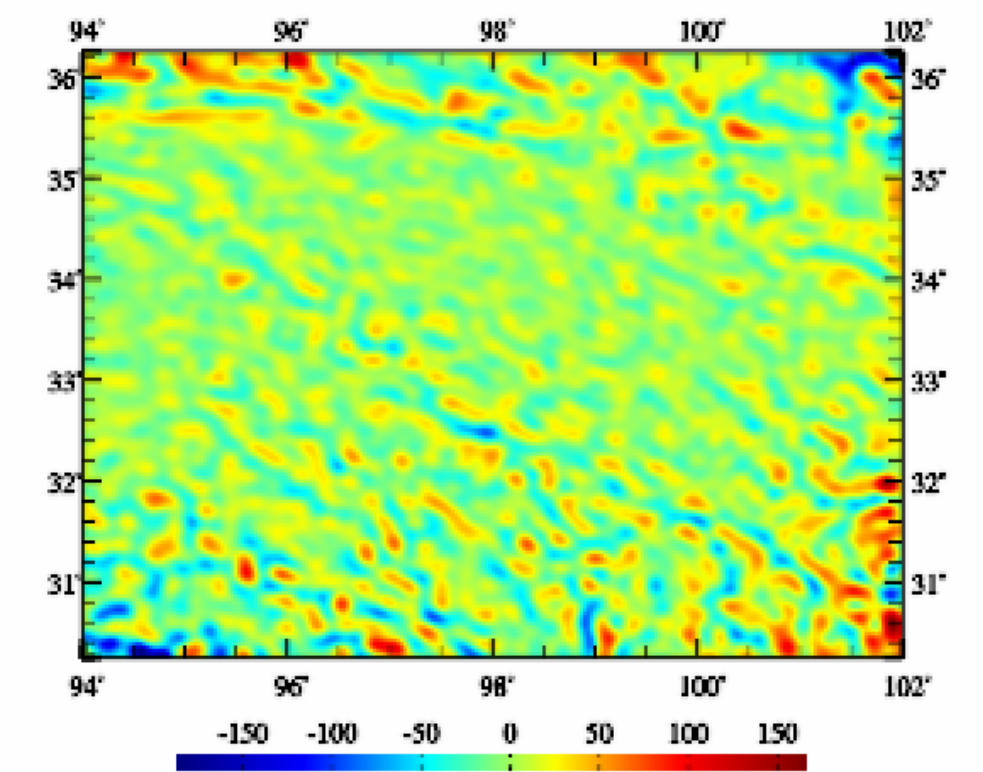
94.000000	102.000000	30.250000	36.250000	0.01666667	0.01666667
-5.8779	-6.8887	-9.0490	-12.2946	-16.1783	-20.4347
-48.7033	-48.3274	-47.1508	-45.5078	-43.9008	-42.2746
-101.6110	-110.1029	-118.1538	-124.3369	-128.4160	-132.2481
-149.3842	-152.4005	-152.8367	-147.3838	-136.6681	-123.3897
41.2586	48.8025	53.1999	55.8075	56.6694	54.4517
-41.5562	-52.3111	-62.2337	-69.9137	-76.8626	-81.6524
23.1595	36.1268	46.9121	53.8192	56.4041	56.5276
-51.6454	-47.2762	-38.7213	-27.7525	-15.5018	-4.4056
-7.9294	-12.8406	-16.6274	-19.1768	-20.5113	-20.6005
-2.4648	-2.0945	-2.1912	-2.7243	-3.4289	-4.0043
34.6174	37.4087	37.7245	35.7470	31.0625	23.9802
-52.2752	-47.5792	-41.7309	-35.3883	-28.6450	-22.6639
34.0288	39.2193	43.6125	46.9344	48.6715	48.6397
1.7688	-2.1718	-5.7483	-8.9916	-11.8712	-14.2903
11.1982	16.5337	20.6686	23.5081	24.6648	23.9631
-58.2206	-65.1046	-69.5639	-71.7567	-72.8949	-72.0902
-12.2046	-8.7767	-6.9390	-6.4350	-6.9716	-8.1888
-8.5910	-8.2107	-8.6697	-10.0133	-12.1953	-14.9998
-13.0860	-10.5907	-9.2138	-9.2451	-10.7382	-13.5382
-19.1313	-16.2120	-14.5117	-14.5602	-16.4463	-20.2273

Extract external gravity disturbance

Plot↓



disturbing gravity gradient (E, radial)



external gravity disturbance (mGal)

Radial Gradient Integration algorithm is derived from the solution to the Stokes Boundary Value Problem, this requires the integrand field elements to reside on an equipotential boundary surface.

Equipotential Surface Construction: Typically constructed from a global geopotential model (degree ≤ 360). For equipotential surfaces within an altitude of 10 km, a normal (or orthometric) equiheight surface may serve as a valid approximation.

Table 4.18: Statistics of Model Reference Truth

Field Element	Unit	Mean	Std. Dev.	Min	Max
Ground Residual Gravity Disturbances	mGal	-0.0346	15.7527	-93.9854	66.6638

Table 4.19: Differences between Computed Results and Reference Truth

Field Element	Unit	Mean	Std. Dev.	Min	Max
Ground Residual Gravity Disturbances	mGal	0.0071	4.2456	-18.5325	16.5266

Algorithm Performance: The ratio of the standard deviation of Differences in Table 4.19 to the standard deviation of Reference Truths in Table 4.18 reflects the approximation capability of the corresponding algorithm.

Robustness: The inversion from gravity gradients to disturbances yields a standard deviation of approximately 4.25 mGal. Given the ill-posed nature of differentiation and the high-frequency content of gradient data, this accuracy demonstrates the algorithm's effectiveness in suppressing noise amplification while successfully recovering medium-to-long wavelength gravity signals.

Computation of Disturbing Gravity Gradient via Inverse Operation Integration

Radial Gradient Integration of Anomalous Gravity Field Elements

Computation of External Gravity Disturbance from Disturbing Gravity Gradient

Computation of Disturbing Gravity Gradient via Inverse Operation Integration

Computation of External Disturbing Gravity Gradient from Gravity Disturbance

Computation of External Anomalous Gravity Field Elements via Poisson Integration

Open Equipotential Surface Ellipsoidal Height Grid File

Open Residual Gravity Disturbance Grid File

Select computation point file format

discrete computation point file

Open Discrete Computation Point File

Set input point file format

number of rows of file header 1

>> Computation Process ** Operation Prompts

>> Complete the computation!

>> Computation end time: 2026-04-14 07:45:40

>> [Function] Computes the residual disturbing gravity gradient (E, radial component) on a surface via inverse operation integration, utilizing the ellipsoidal height grid of the equipotential boundary surface and the corresponding residual gravity disturbance grid (mGal).

** This function effectively implements the differentiation of gravity field elements through an integral formulation.

>> Open Equipotential Surface Ellipsoidal Height Grid File C:/PAGrav4.5_win64en/examples/Intgendistgradient/landgeoidhgt.dat.

>> Open Residual Gravity Disturbance Grid File C:/PAGrav4.5_win64en/examples/Intgendistgradient/resGMlgeoid541_1800.rga.

>> Open Discrete Computation Point File C:/PAGrav4.5_win64en/examples/Intgendistgradient/calcpnt.txt.

** Look at the file information in the window below, set the input file format parameters...

>> Save Disturbing Gravity Gradient as C:/PAGrav4.5_win64en/examples/Intgendistgradient/rgatogrddwm.txt.

>> Appends two columns to the source file: Interpolated Ellipsoidal Height, and Computed residual disturbing gravity gradient value.

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-14 07:47:59

>> Complete the computation!

>> Computation end time: 2026-04-14 07:48:44

Integral radius 120 km

Save the results as

Import setting parameters

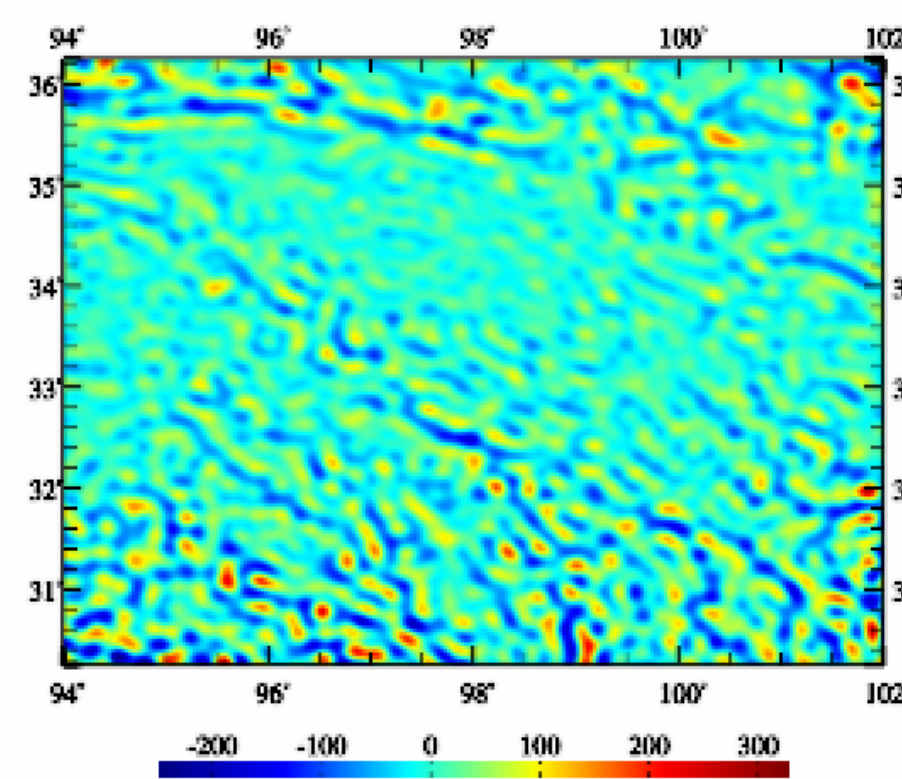
Start Computation

no lon(degree/decimal) lat ellipHeight (m)

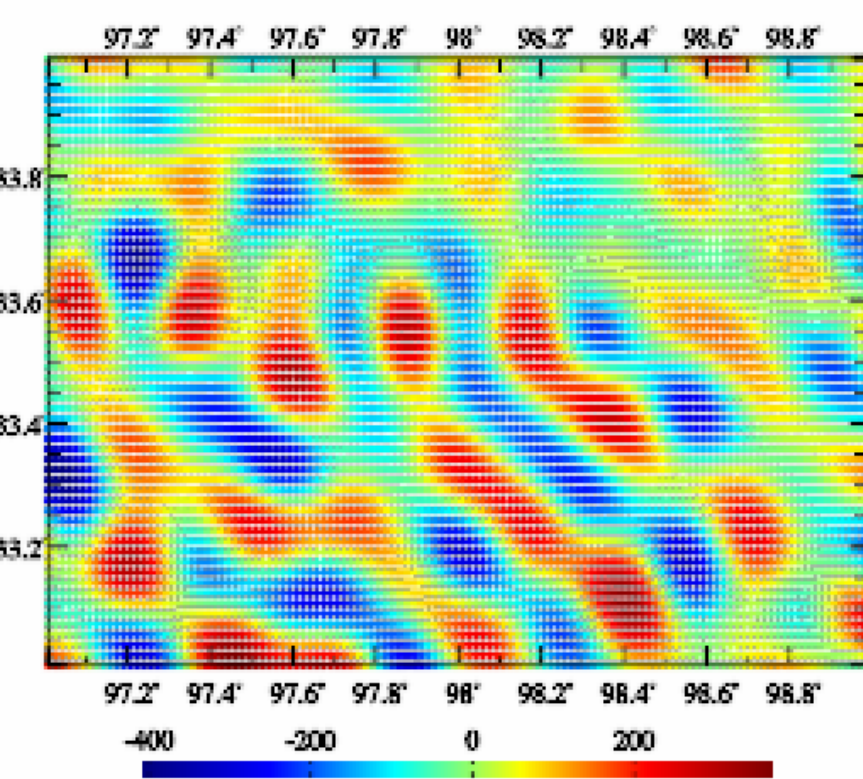
1	97.008333	33.008333	3942.764	-37.2501	196.3239
2	97.025000	33.008333	3989.787	-37.2203	195.2762
3	97.041667	33.008333	4034.817	-37.1899	182.6273
4	97.058333	33.008333	4070.847	-37.1590	158.4840
5	97.075000	33.008333	4106.877	-37.1276	123.7975
6	97.091667	33.008333	4119.913	-37.0959	80.2016
7	97.108333	33.008333	4115.946	-37.0640	29.8584
8	97.125000	33.008333	4090.977	-37.0318	-24.6377
9	97.141667	33.008333	4070.007	-36.9990	-80.4870
10	97.158333	33.008333	3991.047	-36.9665	-134.7652
11	97.175000	33.008333	3985.070	-36.9327	-184.4728
12	97.191667	33.008333	3956.107	-36.8988	-226.7272
13	97.208333	33.008333	3965.137	-36.8642	-258.8156
14	97.225000	33.008333	3964.173	-36.8295	-278.2994
15	97.241667	33.008333	3983.205	-36.7943	-283.2352
16	97.258333	33.008333	3953.251	-36.7595	-272.3134
17	97.275000	33.008333	4016.279	-36.7238	-245.0733
18	97.291667	33.008333	4054.318	-36.6883	-202.0572
19	97.308333	33.008333	4090.360	-36.6528	-144.8927
20	97.325000	33.008333	4192.388	-36.6171	-76.4053
21	97.341667	33.008333	4287.429	-36.5816	-0.3795

Extract disturbing gravity gradient

Plot



gravity disturbance (mGal) on surface



disturbing gravity gradient (E, radial)

Radial Gradient Integration algorithm is derived from the solution to the Stokes Boundary Value Problem, this requires the integrand field elements to reside on an equipotential boundary surface.

Equipotential Surface Construction: Typically constructed from a global geopotential model (degree ≤ 360). For equipotential surfaces within an altitude of 10 km, a normal (or orthometric) equiheight surface may serve as a valid approximation.

Computation of Disturbing Gravity Gradient via Inverse Operation Integration

Radial Gradient Integration
of Anomalous Gravity
Field Elements

Computation of External Gravity
Disturbance from
Disturbing Gravity Gradient

Computation of Disturbing
Gravity Gradient via
Inverse Operation Integration

Computation of External Disturbing
Gravity Gradient
from Gravity Disturbance

Computation of External Anomalous
Gravity Field Elements
via Poisson Integration

Open Equipotential Surface Ellipsoidal
Height Grid File

Open Residual Gravity Disturbance Grid File

Select computation point file format

surface ellipsoidal height grid file

>> Computation Process ** Operation Prompts

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-14 07:47:59

>> Complete the computation!

>> Computation end time: 2026-04-14 07:48:44

>> [Function] Computes the residual disturbing gravity gradient (E, radial component) on a surface via inverse operation integration, utilizing the ellipsoidal height grid of the equipotential boundary surface and the corresponding residual gravity disturbance grid (mGal).

** This function effectively implements the differentiation of gravity field elements through an integral formulation.

>> Open Equipotential Surface Ellipsoidal Height Grid File C:/PAGrav4.5_win64en/examples/Intgendistgradient/landgeoidhgt.dat.

>> Open Residual Gravity Disturbance Grid File C:/PAGrav4.5_win64en/examples/Intgendistgradient/resGMlgeoid541_1800.rga.

>> Save Disturbing Gravity Gradient as C:/PAGrav4.5_win64en/examples/Intgendistgradient/rgatogrddwm.dat.

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-14 07:51:25

>> Complete the computation!

>> Computation end time: 2026-04-14 08:06:35

Integral radius 120 km

Save the results as

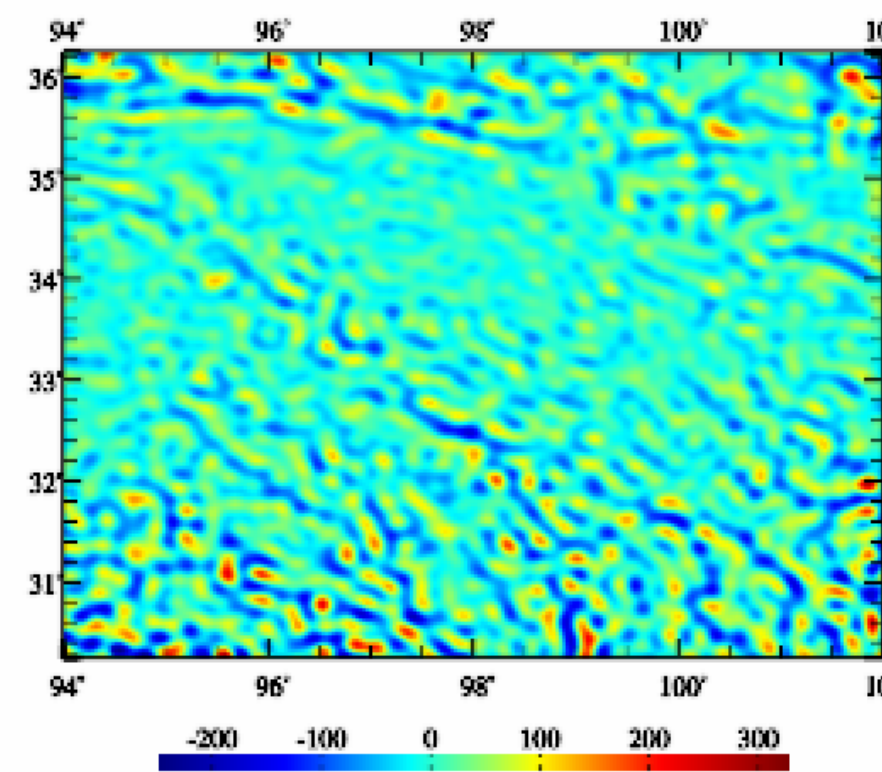
Import setting parameters

Start Computation

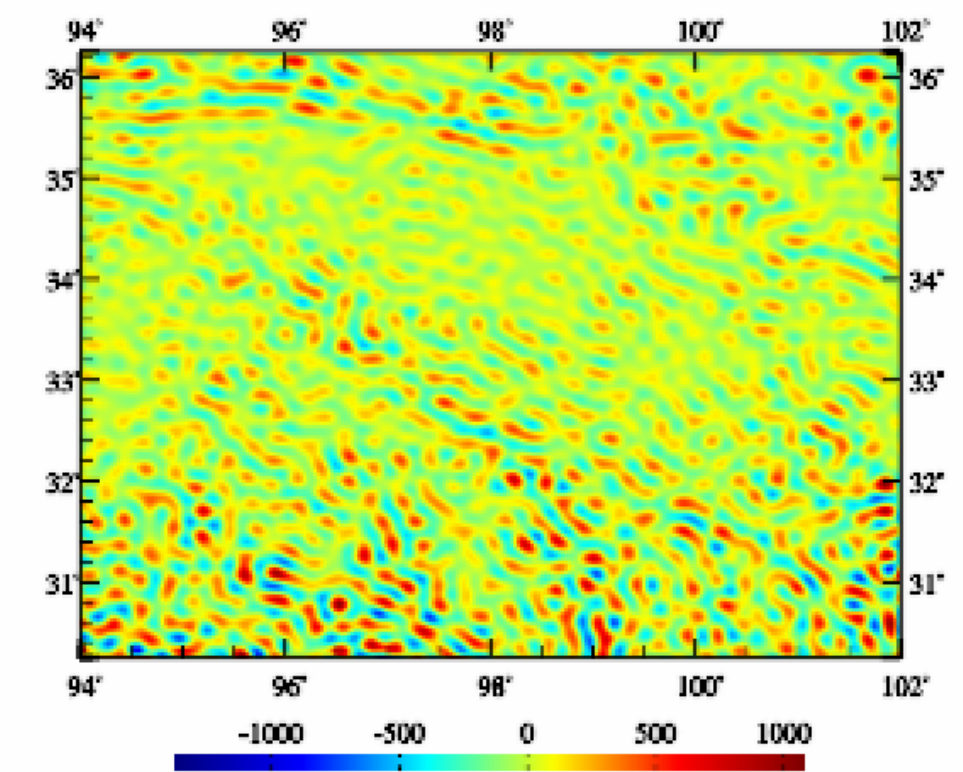
94.000000	102.000000	30.250000	36.250000	0.01666667	0.01666667
-505.4299	-429.7192	-375.1353	-318.9850	-259.0175	-178.4956
320.7604	295.5932	267.9471	244.0138	228.7793	225.3513
561.1932	609.1060	661.1394	715.1226	766.7232	809.7038
-133.4266	-279.6643	-397.6367	-481.6297	-529.7104	-543.6878
-224.3589	-233.7219	-247.5993	-262.5230	-274.9934	-281.5644
313.2648	368.5782	390.7834	373.2899	313.7112	214.9406
78.3233	312.9719	544.6997	746.3038	893.2953	967.2313
-509.5290	-464.7210	-359.7168	-211.5690	-40.9560	130.8348
202.3081	140.9889	91.4380	53.8376	27.1802	10.1833
284.4640	298.8265	286.6105	243.8790	170.3773	70.0537
-281.5145	-176.5681	-77.0418	5.5935	63.1846	91.8935
-127.7336	-134.1163	-153.4278	-191.2082	-250.1097	-329.2804
-831.1787	-784.8146	-733.7349	-681.9185	-630.9929	-580.0215
398.4436	460.7426	481.5642	456.7132	386.8177	277.5634
-314.8760	-189.4597	-51.4814	87.5984	217.8968	332.0093
437.3080	358.6982	261.0526	145.4304	15.2953	-123.2869
-230.4060	-91.7501	37.8178	145.7641	222.5161	262.6057
-103.3651	-67.1048	-20.6186	27.7371	70.0580	100.1148
-59.1371	-57.8878	-55.5052	-55.1573	-58.8136	-66.5979
246.8788	292.7210	312.0650	298.5954	250.2514	170.0304

Extract disturbing gravity gradient

Plot↓



gravity disturbance (mGal) on surface



disturbing gravity gradient (E, radial)

- Radial Gradient Integration algorithm is derived from the solution to the Stokes Boundary Value Problem, this requires the integrand field elements to reside on an equipotential boundary surface.
- Equipotential Surface Construction: Typically constructed from a global geopotential model (degree ≤ 360). For equipotential surfaces within an altitude of 10 km, a normal (or orthometric) equiheight surface may serve as a valid approximation.

Table 4.20: Statistics of Model Reference Truth

Field Element	Unit	Mean	Std. Dev.	Min	Max
Residual Disturbing Gravity Gradients (Radial) on Geoid	E	0.4763	68.2499	-288.1750	387.7286

Table 4.21: Differences between Computed Results and Reference Truth

Field Element	Unit	Mean	Std. Dev.	Min	Max
Residual Disturbing Gravity Gradients (Radial) on Geoid	E	-0.0562	6.6405	-37.1465	28.3557

Algorithm Performance: The ratio of the standard deviation of Differences in Table 4.21 to the standard deviation of Reference Truths in Table 4.20 reflects the approximation capability of the corresponding algorithm.

Stability of Differentiation: Computing gradients from gravity disturbances is a differentiation process, typically sensitive to high-frequency noise. In this case, while the true signal exhibits a large variability (Std. Dev. = 68.25 E), the error standard deviation is well-controlled at ~6.64 E (approximately 10% of the signal strength).

Conclusion: The inverse operation integration algorithm offers superior numerical stability for differentiation tasks. It effectively preserves high-frequency signal characteristics while avoiding the severe oscillations often associated with traditional finite difference methods, making it suitable for high-precision gravity gradient field modeling.

Computation of External Disturbing Gravity Gradient from Gravity Disturbance

Save as Import parameters Start Computation Save process Follow example

Radial Gradient Integration
of Anomalous Gravity
Field Elements

Computation of External Gravity
Disturbance from
Disturbing Gravity Gradient

Computation of Disturbing
Gravity Gradient via
Inverse Operation Integration

Computation of External Disturbing
Gravity Gradient
from Gravity Disturbance

Computation of External Anomalous
Gravity Field Elements
via Poisson Integration

Open Boundary Surface Ellipsoidal
Height Grid File

Open Residual Gravity Disturbance Grid File

Select computation point file format

discrete computation point file

Open Space Computation Point File

Set input point file format

number of rows of file header 1

>> Computation Process ** Operation Prompts

>> Complete the computation!

>> Computation end time: 2026-04-14 08:06:35

>> [Function] Computes the residual disturbing gravity gradient (E, radial component) on or outside the geoid. Inputs include an ellipsoidal height grid of a boundary surface and the corresponding residual gravity disturbance grid (mGal).

** The inverse integration of gravity disturbances employs a hybrid algorithm combining Poisson integration with differentiation. This approach does not require the boundary surface to be an equipotential surface.

>> Open Boundary Surface Ellipsoidal Height Grid File C:/PAGrav4.5_win64en/examples/Intgendistgradient/landgeoidhgt.dat.

>> Open Residual Gravity Disturbance Grid File C:/PAGrav4.5_win64en/examples/Intgendistgradient/resGMIgeoid541_1800.rga.

>> Open Space Computation Point File C:/PAGrav4.5_win64en/examples/Intgendistgradient/calcpnt.txt.

** Look at the file information in the window below, set the input file format parameters...

>> Save Poisson Integration Results as C:/PAGrav4.5_win64en/examples/Intgendistgradient/rgatogrrdbm.txt.

>> Appends one column containing the residual anomalous field element value.

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-14 08:09:04

>> Complete the computation!

>> Computation end time: 2026-04-14 08:09:49

Integral radius 120 km

Save the results as

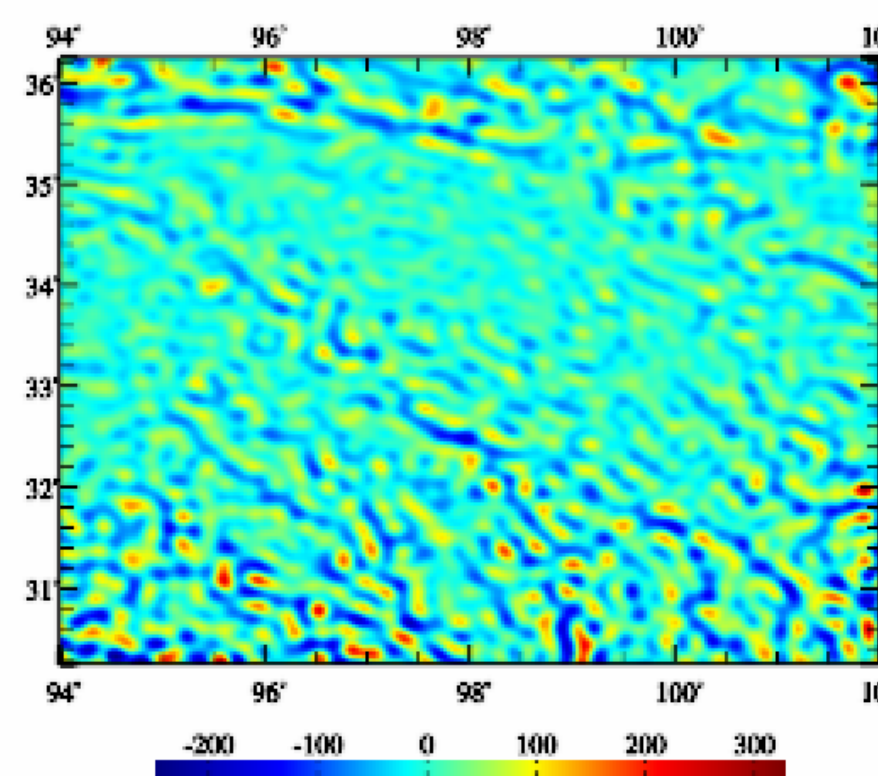
Import setting parameters

Start Computation

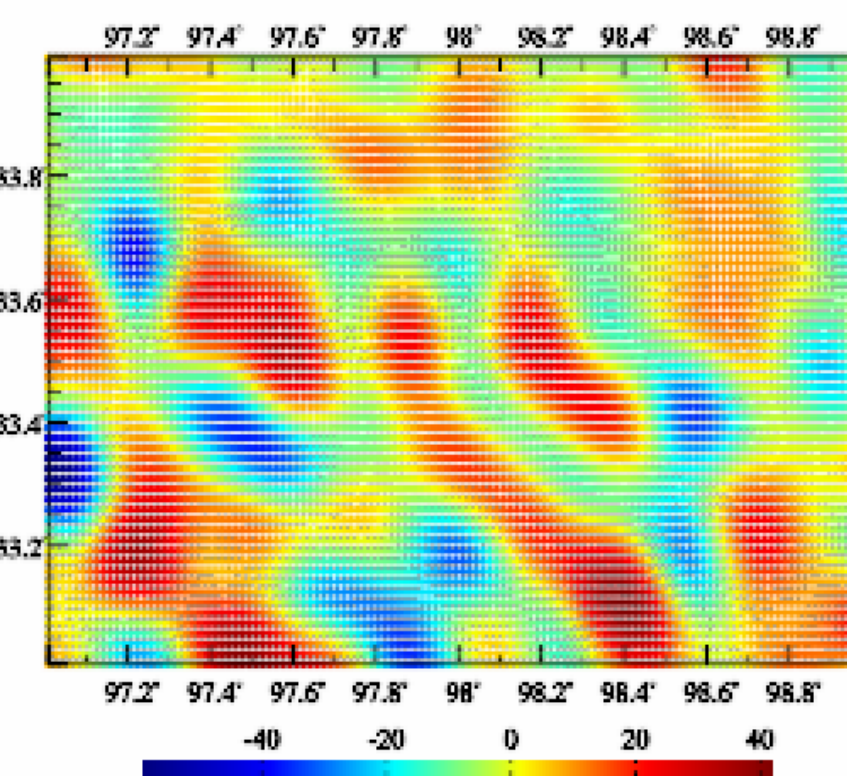
no	lon (degree/decimal)	lat	ellipHeight (m)	
1	97.008333	33.008333	3942.764	7.3569
2	97.025000	33.008333	3989.787	7.1106
3	97.041667	33.008333	4034.817	6.1598
4	97.058333	33.008333	4070.847	4.5194
5	97.075000	33.008333	4106.877	2.2173
6	97.091667	33.008333	4119.913	-0.6277
7	97.108333	33.008333	4115.946	-3.9317
8	97.125000	33.008333	4090.977	-7.5796
9	97.141667	33.008333	4070.007	-11.4084
10	97.158333	33.008333	3991.047	-15.3450
11	97.175000	33.008333	3985.070	-18.9119
12	97.191667	33.008333	3956.107	-22.0661
13	97.208333	33.008333	3965.137	-24.3539
14	97.225000	33.008333	3964.173	-25.7245
15	97.241667	33.008333	3983.205	-25.8555
16	97.258333	33.008333	3953.251	-24.9234
17	97.275000	33.008333	4016.279	-22.2078
18	97.291667	33.008333	4054.318	-18.2787
19	97.308333	33.008333	4090.360	-13.1378
20	97.325000	33.008333	4192.388	-6.8831
21	97.341667	33.008333	4287.429	-0.0506

Extract residual disturbing gradient

Plot



residual gravity disturbance



residual disturbing gradient

Radial Gradient Integration algorithm is derived from the solution to the Stokes Boundary Value Problem, this requires the integrand field elements to reside on an equipotential boundary surface.

Equipotential Surface Construction: Typically constructed from a global geopotential model (degree ≤ 360). For equipotential surfaces within an altitude of 10 km, a normal (or orthometric) equiheight surface may serve as a valid approximation.

Computation of External Disturbing Gravity Gradient from Gravity Disturbance

Save as Import parameters Start Computation Save process Follow example

Radial Gradient Integration of Anomalous Gravity Field Elements

Computation of External Gravity Disturbance from Disturbing Gravity Gradient

Computation of Disturbing Gravity Gradient via Inverse Operation Integration

Computation of External Disturbing Gravity Gradient from Gravity Disturbance

Computation of External Anomalous Gravity Field Elements via Poisson Integration

Open Boundary Surface Ellipsoidal Height Grid File

Open Residual Gravity Disturbance Grid File

Select computation point file format

surface ellipsoidal height grid file

Open Computation Surface Ellipsoidal Height Grid File

>> Computation Process ** Operation Prompts

>> Computation start time: 2026-04-14 08:09:04

>> Complete the computation!

>> Computation end time: 2026-04-14 08:09:49

>> [Function] Computes the residual disturbing gravity gradient (E, radial component) on or outside the geoid. Inputs include an ellipsoidal height grid of a boundary surface and the corresponding residual gravity disturbance grid (mGal).

** The inverse integration of gravity disturbances employs a hybrid algorithm combining Poisson integration with differentiation. This approach does not require the boundary surface to be an equipotential surface.

>> Open Boundary Surface Ellipsoidal Height Grid File C:/PAGrav4.5_win64en/examples/Intgendistgradient/landgeoidhgt.dat.

>> Open Residual Gravity Disturbance Grid File C:/PAGrav4.5_win64en/examples/Intgendistgradient/resGMIgeoid541_1800.rga.

>> Open Computation Surface Ellipsoidal Height Grid File C:/PAGrav4.5_win64en/examples/Intgendistgradient/landbmsurfhgt.dat.

>> Save Poisson Integration Results as C:/PAGrav4.5_win64en/examples/Intgendistgradient/rgatogrdbm.dat.

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-14 08:15:41

>> Complete the computation!

>> Computation end time: 2026-04-14 08:31:32

Save computation process as

Integral radius 120 km

Save the results as

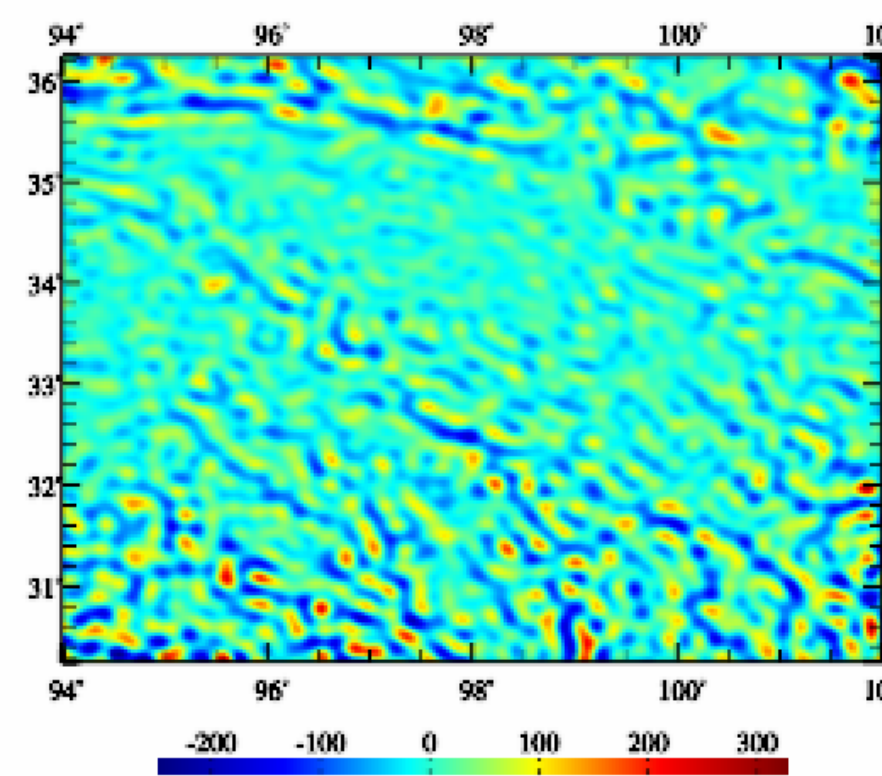
Import setting parameters

Start Computation

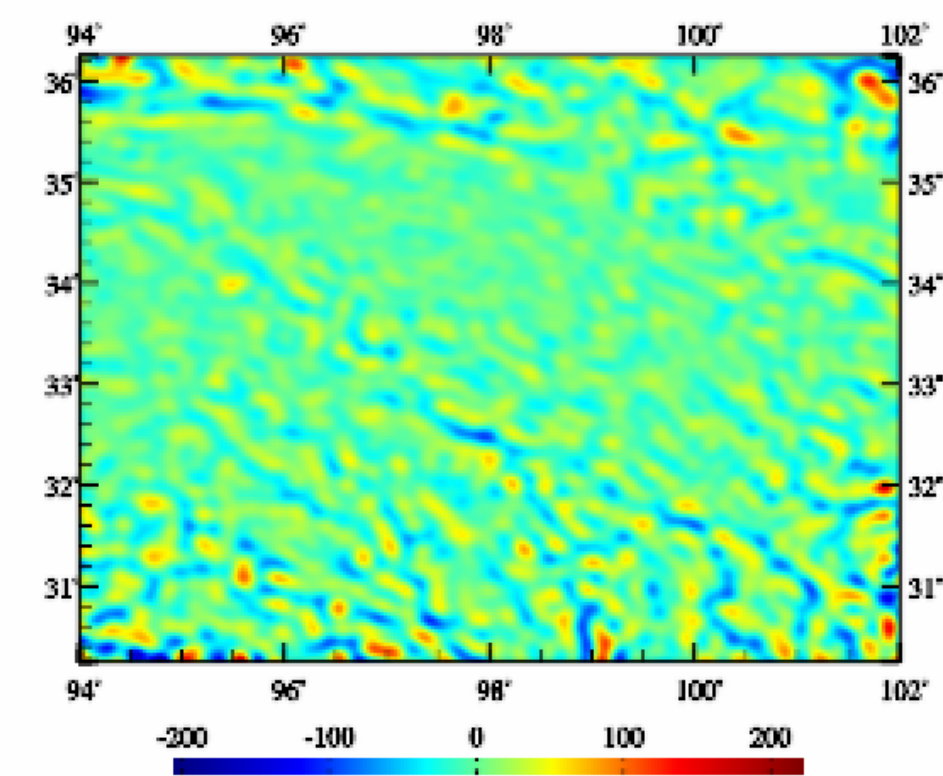
94.000000	102.000000	30.250000	36.250000	0.01666667	0.01666667
25.5482	32.2428	34.7751	34.4845	32.7565	30.5713
23.1387	24.0504	26.1586	29.2803	32.9778	37.0922
-40.9652	-52.4488	-60.2859	-64.0934	-64.2180	-61.8296
-168.9207	-188.2162	-201.5886	-205.7324	-200.1540	-186.4230
97.2243	108.0579	113.3779	114.2648	111.2597	104.2769
-22.5602	-36.0182	-50.5114	-65.5670	-81.4032	-96.6037
99.7997	144.4861	182.6666	209.9054	223.2932	222.6037
-129.9665	-120.0988	-98.2952	-68.4071	-34.2581	-0.6680
20.9084	8.9722	-0.7863	-8.2100	-13.4662	-16.8121
7.8213	9.7997	9.7165	7.2302	2.6829	-3.2340
68.8623	82.9914	91.4576	93.0122	86.6506	72.5596
-114.4181	-108.9383	-101.6061	-94.1016	-87.4459	-82.9561
-32.1668	-20.9009	-10.4904	-2.0746	3.9615	7.4281
22.0577	23.2345	21.5692	16.6097	8.4376	-2.2785
20.2172	40.4930	58.6649	73.1995	82.7652	86.6726
-46.1260	-58.3513	-69.5337	-80.0170	-90.5309	-100.4354
-36.7005	-17.3713	-0.7322	12.0406	20.1988	23.5788
2.8070	9.4586	15.4368	19.5678	20.9498	19.1877
-15.8866	-11.3266	-7.7563	-6.1785	-7.1564	-10.7033
4.9674	13.4445	17.6264	16.0554	8.2735	-5.6347

Extract residual disturbing gradient

Plot↓



residual gravity disturbance



residual disturbing gradient

Radial Gradient Integration algorithm is derived from the solution to the Stokes Boundary Value Problem, this requires the integrand field elements to reside on an equipotential boundary surface.

Equipotential Surface Construction: Typically constructed from a global geopotential model (degree ≤ 360). For equipotential surfaces within an altitude of 10 km, a normal (or orthometric) equiheight surface may serve as a valid approximation.

Table 4.22: Statistics of Model Reference Truth

Field Element	Unit	Mean	Std. Dev.	Min	Max
Ground Residual Disturbing Gravity Gradients (Radial)	E	-0.2872	26.9448	-148.0282	136.7864

Table 4.23: Differences between Computed Results and Reference Truth

Field Element	Unit	Mean	Std. Dev.	Min	Max
Ground Residual Disturbing Gravity Gradients (Radial)	E	-0.0361	2.7361	-14.2089	13.6802

Algorithm Performance: The ratio of the standard deviation of Differences in Table 4.23 to the standard deviation of Reference Truths in Table 4.22 reflects the approximation capability of the corresponding algorithm.

Comparative Analysis: The inversion integration of gravity disturbance demonstrates comparable performance and accuracy. Both approaches effectively achieve high-precision differential inversion from gravity disturbances to gradients, with error standard deviations controlled to approximately 10% of the signal strength, validating the consistency of the algorithms across different mathematical formulations.

Computation of External Anomalous Gravity Field Elements via Poisson Integration

Save as Import parameters Start Computation Save process Follow example

Radial Gradient Integration
of Anomalous Gravity
Field Elements

Computation of External Gravity
Disturbance from
Disturbing Gravity Gradient

Computation of Disturbing
Gravity Gradient via
Inverse Operation Integration

Computation of External Disturbing
Gravity Gradient
from Gravity Disturbance

Computation of External Anomalous
Gravity Field Elements
via Poisson Integration

Open Boundary Surface Ellipsoidal
Height Grid File

Open Residual Field Element Grid File

Select computation point file format

discrete computation point file

Open Space Computation Point File

Set input point file format

number of rows of file header 1

>> Computation Process ** Operation Prompts

>> Complete the computation!

>> Computation end time: 2026-04-14 08:31:32

>> [Function] Computes residual anomalous gravity field elements on or outside the geoid via Poisson integration. Inputs include an ellipsoidal height grid of a boundary surface and the corresponding residual anomalous field element grid on that surface.

** It does not require the boundary surface to be an equipotential surface, making it ideal for analytical continuation (both upward and downward) across arbitrary geometric boundaries.

>> Open Equipotential Surface Ellipsoidal Height Grid File C:/PAGrav4.5_win64en/examples/Intgendistgradient/landgeoidhgt.dat.

>> Open Residual Field Element Grid File C:/PAGrav4.5_win64en/examples/Intgendistgradient/resGMIgeoid541_1800.ksi.

>> Open Space Computation Point File C:/PAGrav4.5_win64en/examples/Intgendistgradient/calcpnt.txt.

** Look at the file information in the window below, set the input file format parameters...

>> Save the results as C:/PAGrav4.5_win64en/examples/Intgendistgradient/possonksi.txt.

>> Appends one column containing the residual disturbing gravity gradient value.

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-14 08:35:13

>> Complete the computation!

>> Computation end time: 2026-04-14 08:36:45

Save computation process as

Integral radius 120 km

Save the results as

Import setting parameters

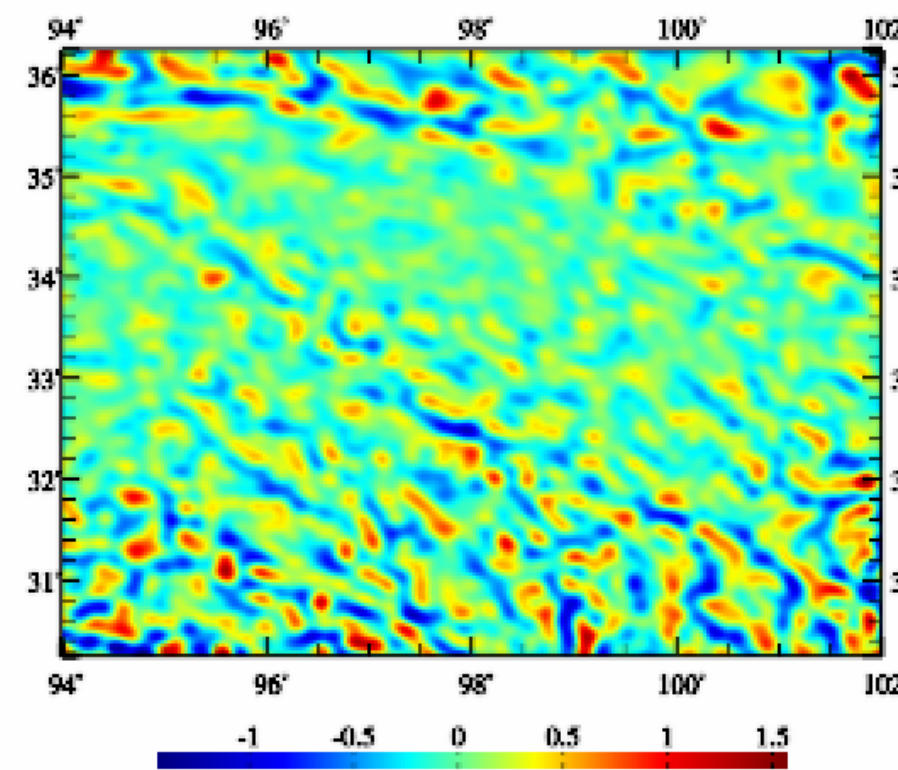
Start Computation

no lon(degree/decimal) lat ellipHeight(m)

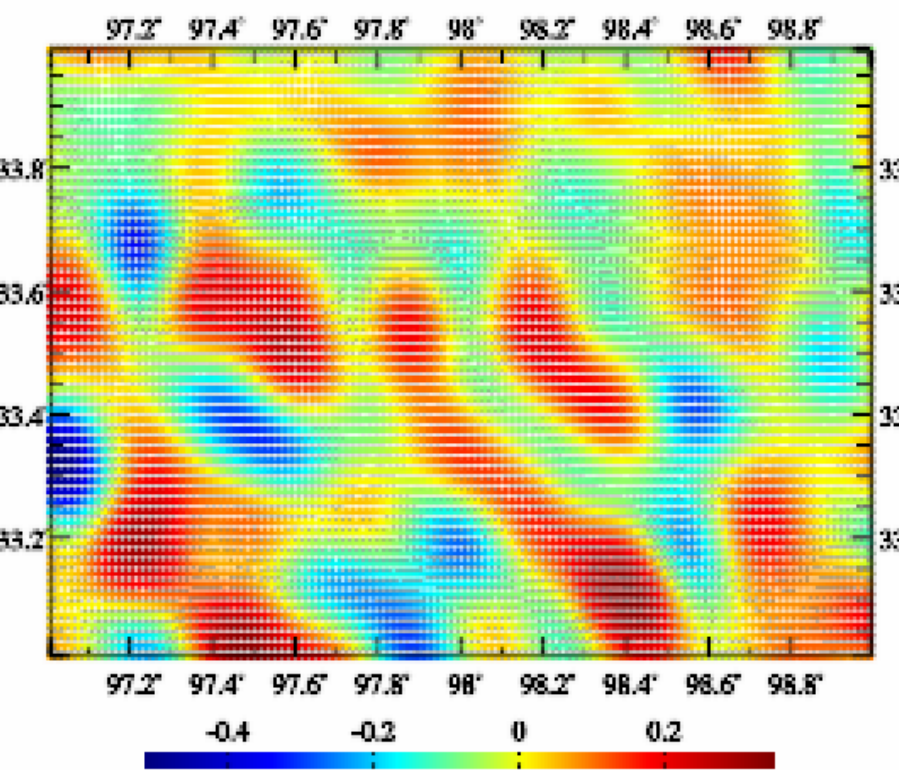
1	97.008333	33.008333	3942.764	0.0636
2	97.025000	33.008333	3989.787	0.0614
3	97.041667	33.008333	4034.817	0.0531
4	97.058333	33.008333	4070.847	0.0391
5	97.075000	33.008333	4106.877	0.0195
6	97.091667	33.008333	4119.913	-0.0046
7	97.108333	33.008333	4115.946	-0.0326
8	97.125000	33.008333	4090.977	-0.0637
9	97.141667	33.008333	4070.007	-0.0964
10	97.158333	33.008333	3991.047	-0.1305
11	97.175000	33.008333	3985.070	-0.1613
12	97.191667	33.008333	3956.107	-0.1889
13	97.208333	33.008333	3965.137	-0.2087
14	97.225000	33.008333	3964.173	-0.2208
15	97.241667	33.008333	3983.205	-0.2220
16	97.258333	33.008333	3953.251	-0.2146
17	97.275000	33.008333	4016.279	-0.1909
18	97.291667	33.008333	4054.318	-0.1572
19	97.308333	33.008333	4090.360	-0.1132
20	97.325000	33.008333	4192.388	-0.0596
21	97.341667	33.008333	4287.429	-0.0017

Extract external field element

Plot



field element on surface



external field element

Radial Gradient Integration algorithm is derived from the solution to the Stokes Boundary Value Problem, this requires the integrand field elements to reside on an equipotential boundary surface.

Equipotential Surface Construction: Typically constructed from a global geopotential model (degree ≤ 360). For equipotential surfaces within an altitude of 10 km, a normal (or orthometric) equiheight surface may serve as a valid approximation.

Computation of External Anomalous Gravity Field Elements via Poisson Integration

Radial Gradient Integration of Anomalous Gravity Field Elements

Computation of External Gravity Disturbance from Disturbing Gravity Gradient

Computation of Disturbing Gravity Gradient via Inverse Operation Integration

Computation of External Disturbing Gravity Gradient from Gravity Disturbance

Computation of External Anomalous Gravity Field Elements via Poisson Integration

Open Boundary Surface Ellipsoidal Height Grid File

Open Residual Field Element Grid File

Select computation point file format

surface ellipsoidal height grid file

Open Computation Surface Ellipsoidal Height Grid File

>> Computation Process ** Operation Prompts

>> Complete the computation!

>> Computation end time: 2026-04-14 08:36:45

>> [Function] Computes residual anomalous gravity field elements on or outside the geoid via Poisson integration. Inputs include an ellipsoidal height grid of a boundary surface and the corresponding residual anomalous field element grid on that surface.

** It does not require the boundary surface to be an equipotential surface, making it ideal for analytical continuation (both upward and downward) across arbitrary geometric boundaries.

>> Open Equipotential Surface Ellipsoidal Height Grid File C:/PAGrav4.5_win64en/examples/Intgendistgradient/landgeoidhgt.dat.

>> Open Residual Field Element Grid File C:/PAGrav4.5_win64en/examples/Intgendistgradient/resGMIgeoid541_1800.ksi.

>> Open Computation Surface Ellipsoidal Height Grid File C:/PAGrav4.5_win64en/examples/Intgendistgradient/possessionksi.dat.

>> Open Computation Surface Ellipsoidal Height Grid File C:/PAGrav4.5_win64en/examples/Intgendistgradient/landbmsurfhgt.dat.

>> Save the results as C:/PAGrav4.5_win64en/examples/Intgendistgradient/possessionksi.dat.

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-14 08:41:27

>> Complete the computation!

>> Computation end time: 2026-04-14 09:13:01

Integral radius 120 km

Save the results as

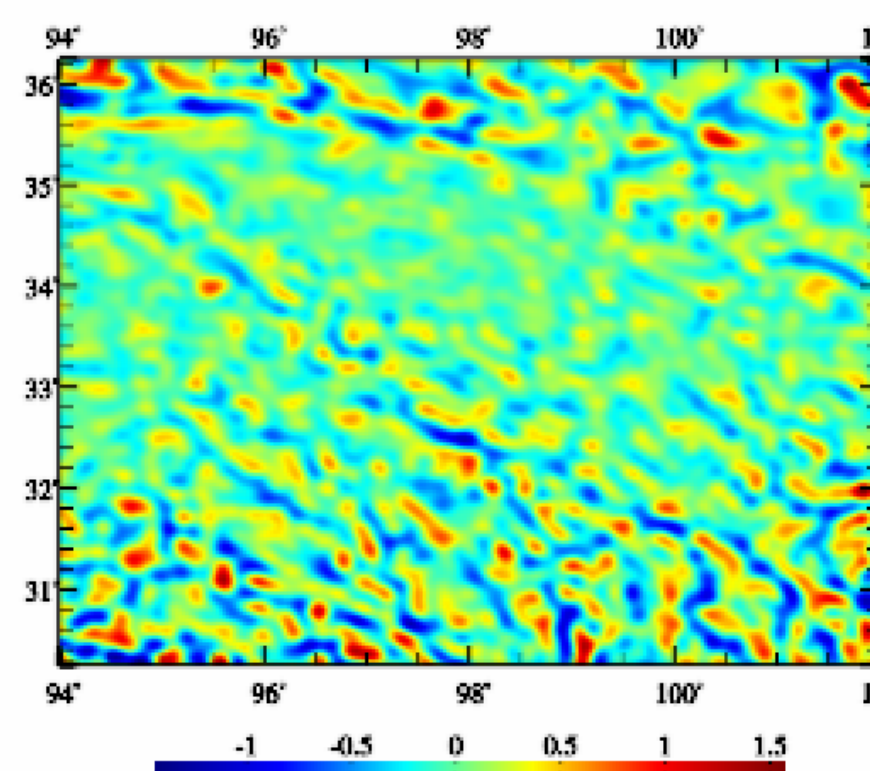
Import setting parameters

Start Computation

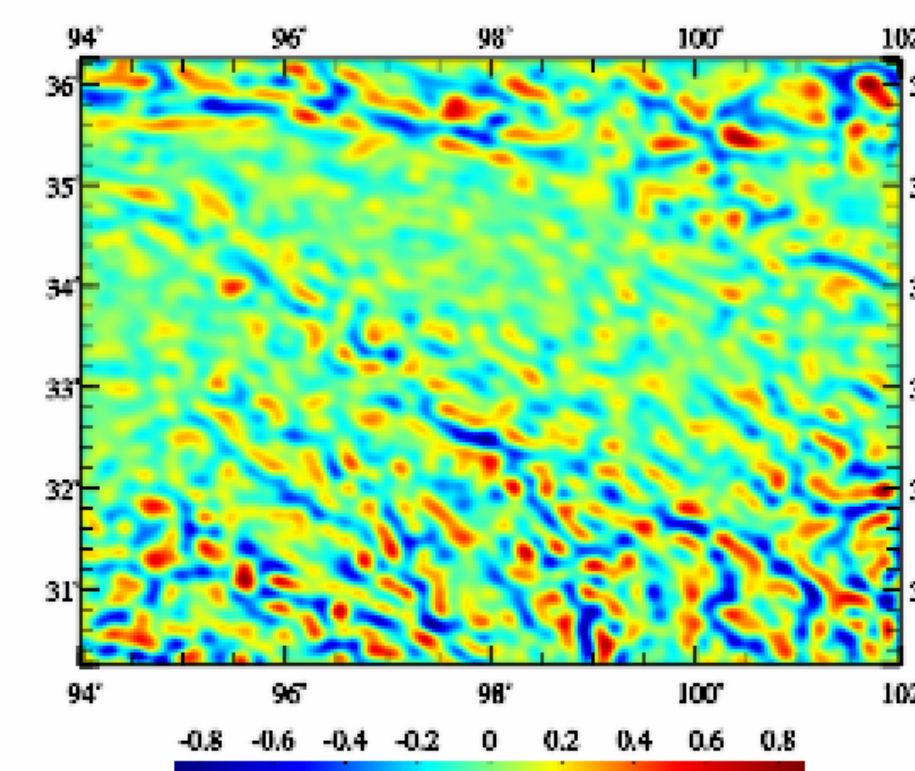
94.000000	102.000000	30.250000	36.250000	0.01666667	0.01666667
0.1157	0.1319	0.1369	0.1356	0.1311	0.1250
0.1244	0.1314	0.1401	0.1473	0.1512	0.1590
-0.0049	-0.0420	-0.0602	-0.0680	-0.0658	-0.0428
-0.3743	-0.4508	-0.5145	-0.5484	-0.5487	-0.5269
0.2770	0.3131	0.3341	0.3437	0.3429	0.3307
-0.0089	-0.0507	-0.0940	-0.1428	-0.1913	-0.2405
0.2850	0.3812	0.4591	0.5059	0.5179	0.5101
-0.4162	-0.3848	-0.3189	-0.2331	-0.1353	-0.0466
0.0699	0.0457	0.0258	0.0114	0.0022	-0.0027
0.0521	0.0519	0.0495	0.0406	0.0294	0.0177
0.2419	0.2725	0.2878	0.2879	0.2697	0.2346
-0.3044	-0.3000	-0.2908	-0.2811	-0.2715	-0.2698
-0.1457	-0.1294	-0.1080	-0.0928	-0.0774	-0.0647
-0.0071	-0.0030	-0.0050	-0.0138	-0.0288	-0.0475
0.1051	0.1566	0.1991	0.2315	0.2518	0.2596
-0.0938	-0.1315	-0.1692	-0.2057	-0.2443	-0.2838
-0.1469	-0.0852	-0.0329	0.0080	0.0377	0.0565
0.0687	0.0805	0.0893	0.0931	0.0897	0.0787
-0.0526	-0.0446	-0.0380	-0.0353	-0.0376	-0.0444
0.0321	0.0542	0.0632	0.0560	0.0352	-0.0037

Extract external field element

Plot



field element on surface



external field element

Radial Gradient Integration algorithm is derived from the solution to the Stokes Boundary Value Problem, this requires the integrand field elements to reside on an equipotential boundary surface.

Equipotential Surface Construction: Typically constructed from a global geopotential model (degree ≤ 360). For equipotential surfaces within an altitude of 10 km, a normal (or orthometric) equiheight surface may serve as a valid approximation.

Table 4.24: Statistics of Model Reference Truths

Field Element	Unit	Mean	Std. Dev.	Min	Max
Ground Residual Height Anomalies	m	0.0010	0.1182	-0.6745	0.4760
Ground Residual Gravity Disturbances	mGal	-0.0346	15.7527	-93.9854	66.6638

Table 4.25: Differences between Computed Results and Reference Truth

Field Element	Unit	Mean	Std. Dev.	Min	Max
Ground Residual Height Anomalies	m	0.0004	0.0074	-0.0326	0.0334
Ground Residual Gravity Disturbances	mGal	0.0476	1.1919	-5.0173	6.5138

Algorithm Performance: The ratio of the standard deviation of Differences in Table 4.25 to the standard deviation of Reference Truths in Table 4.24 reflects the approximation capability of the corresponding algorithm.

Superior Short-Wavelength Preservation: The algorithm effectively suppresses the attenuation of short-wavelength signals, demonstrating high fidelity for both upward and downward analytical continuation.

Iterative Strategy: Supports iterative execution to perform multi-step Poisson integrations. In general, a single iteration suffices to meet accuracy requirements for most applications. In scenarios involving extreme topography or large vertical separations, at most three iterations are typically required to achieve convergence.

Spatial and Spectral Performance Analysis of Spherical Radial Basis Functions

Spatial and Spectral Performance Analysis of Spherical Radial Basis Functions

Construction of Reuter Spherical Grid at a Specified Level

Select anomalous field element gravity disturbance

Algorithms of the spherical radial basis function and Reuter grid

Save computation process as

[SRBFs] Point-mass kernel, Poisson kernel, m-order radial multipole and m-order Poisson wavelet kernel functions.

degrees of the SRBF Legendre expansion, the burial depth of the reference surface (Bjerhammar sphere), and the order (m) of multipolar SRBFs – users can analyze and characterize the spatial localization and spectral behavior of SRBFs for diverse gravity field elements.

>> Save the results as C:/PAGrav4.5_win64en/examples/SRBFperformance/rgaSRBF.txt.

>> The program generates both spatial-domain and spectral-domain curve files. Contains the kernel values for the four SRBF types corresponding to the selected field element. Record Format: Spherical Angular Distance (Independent Variable), Point Mass Kernel Value, Poisson Kernel Value, m-order Radial Multipole Kernel Value, m-order Poisson Wavelet Kernel Value.

** Automatically saved to the current directory with the user-defined prefix (*). Contains the degree variances for the four SRBF types. Record Format: SRBF Legendre Degree (Independent Variable), Point Mass Degree Variance, Poisson Degree Variance, m-order Radial Multipole Degree Variance, m-order Poisson Wavelet Degree Variance.

Set SRBF parameters

Minimum Degree 30
Maximum Degree 1440
Bjerhammar Sphere Burial Depth 5km
Multipole/Wavelet Order 5
Action Distance of SBRF Center 1.5°
Spatial Sampling Interval 0.20'

Calculation and save

Display of the input-output file↓

1.446667	-0.004675	-0.006049	-0.008050	-0.017435
1.450000	-0.004839	-0.006275	-0.008335	-0.017861
1.453333	-0.004972	-0.006457	-0.008560	-0.018159
1.456667	-0.005075	-0.006593	-0.008723	-0.018330
1.460000	-0.005147	-0.006683	-0.008825	-0.018372
1.463333	-0.005188	-0.006726	-0.008864	-0.018285
1.466667	-0.005197	-0.006723	-0.008840	-0.018072
1.470000	-0.005174	-0.006674	-0.008755	-0.017735
1.473333	-0.005120	-0.006579	-0.008609	-0.017276
1.476667	-0.005037	-0.006440	-0.008404	-0.016700
1.480000	-0.004923	-0.006257	-0.008142	-0.016012
1.483333	-0.004781	-0.006032	-0.007824	-0.015217
1.486667	-0.004611	-0.005768	-0.007454	-0.014321
1.490000	-0.004416	-0.005466	-0.007034	-0.013332
1.493333	-0.004195	-0.005128	-0.006567	-0.012256
1.496667	-0.003952	-0.004758	-0.006058	-0.011102
1.500000	-0.003689	-0.004357	-0.005509	-0.009878

Curve type Spatial curves of SRBFs

Line thickness 3

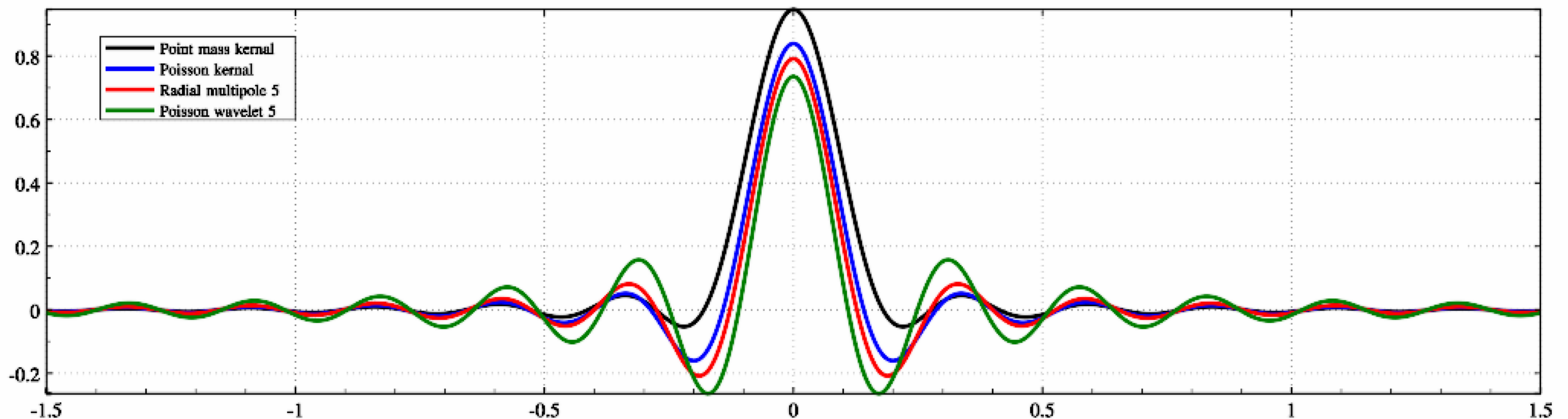
Start end row number 1 3600

Extract plot data

Chart plot↓

Spatial and spectral curves of spherical radial basis functions (SRBF)

Save current plot as



Spatial and Spectral Performance Analysis of Spherical Radial Basis Functions

Spatial and Spectral Performance Analysis of Spherical Radial Basis Functions

Construction of Reuter Spherical Grid at a Specified Level

Select anomalous field element gravity disturbance

Algorithms of the spherical radial basis function and Reuter grid

Save computation process as

[SRBFs] Point-mass kernel, Poisson kernel, m-order radial multipole and m-order Poisson wavelet kernel functions.

degrees of the SRBF Legendre expansion, the burial depth of the reference surface (Bjerhammar sphere), and the order (m) of multipolar SRBFs – users can analyze and characterize the spatial localization and spectral behavior of SRBFs for diverse gravity field elements.

>> Save the results as C:/PAGrav4.5_win64en/examples/SRBFperformance/rgaSRBF.txt.

>> The program generates both spatial-domain and spectral-domain curve files. Contains the kernel values for the four SRBF types corresponding to the selected field element. Record Format: Spherical Angular Distance (Independent Variable), Point Mass Kernel Value, Poisson Kernel Value, m-order Radial Multipole Kernel Value, m-order Poisson Wavelet Kernel Value.

** Automatically saved to the current directory with the user-defined prefix (*). Contains the degree variances for the four SRBF types. Record Format: SRBF Legendre Degree (Independent Variable), Point Mass Degree Variance, Poisson Degree Variance, m-order Radial Multipole Degree Variance, m-order Poisson Wavelet Degree Variance.

Set SRBF parameters

Minimum Degree 30
Maximum Degree 1440
Bjerhammar Sphere Burial Depth 5km
Multipole/Wavelet Order 5
Action Distance of SBRF Center 1.5°
Spatial Sampling Interval 0.20'

Calculation and save

Display of the input-output file↓

1424	0.991387	0.980618	0.958923	0.876948
1425	0.991223	0.981833	0.961462	0.884220
1426	0.991058	0.983047	0.964004	0.891546
1427	0.990892	0.984261	0.966550	0.898927
1428	0.990725	0.985475	0.969100	0.906362
1429	0.990557	0.986688	0.971653	0.913853
1430	0.990388	0.987900	0.974211	0.921399
1431	0.990219	0.989112	0.976773	0.929001
1432	0.990048	0.990324	0.979338	0.936660
1433	0.989876	0.991536	0.981907	0.944375
1434	0.989704	0.992746	0.984480	0.952147
1435	0.989531	0.993957	0.987057	0.959977
1436	0.989356	0.995167	0.989638	0.967864
1437	0.989181	0.996376	0.992223	0.975810
1438	0.989005	0.997585	0.994811	0.983814
1439	0.988828	0.998794	0.997404	0.991877
1440	0.988650	1.000002	1.000000	1.000000

Curve type Spectral curves of SRBFs

Line thickness 3

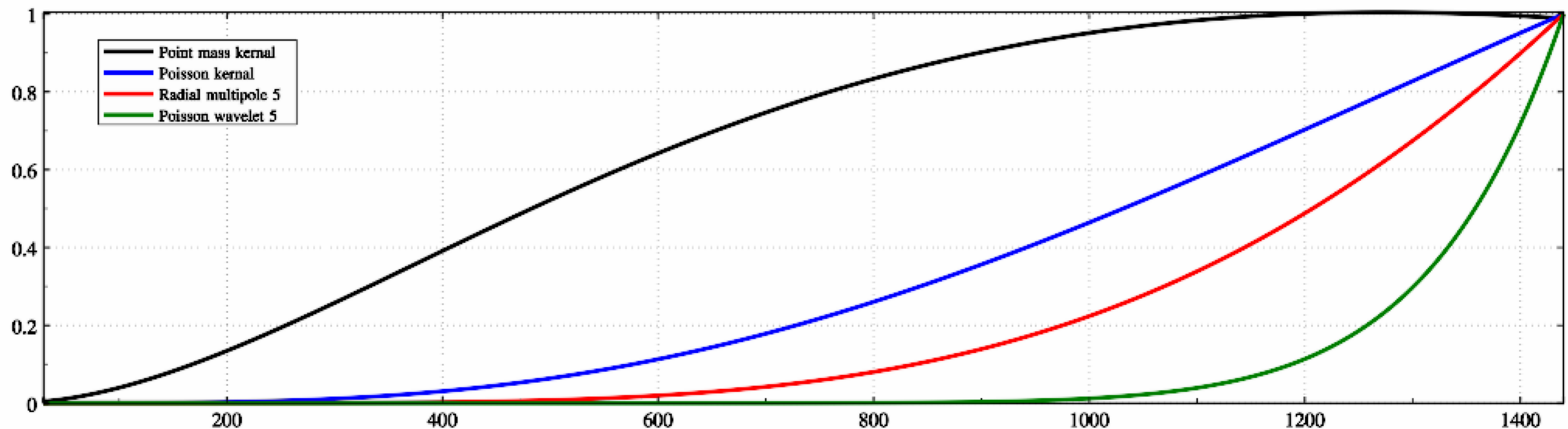
Start end row number 1 3600

Extract plot data

Chart plot↓

Spatial and spectral curves of spherical radial basis functions (SRBF)

Save current plot as



Spatial and Spectral Performance Analysis of Spherical Radial Basis Functions

Spatial and Spectral Performance Analysis of Spherical Radial Basis Functions

Construction of Reuter Spherical Grid at a Specified Level

Select anomalous field element : anomaly / disturbing potential

Algorithms of the spherical radial basis function and Reuter grid

Save computation process as

[SRBFs] Point-mass kernel, Poisson kernel, m-order radial multipole and m-order Poisson wavelet kernel functions.

** Automatically saved to the current directory with the user-defined prefix (*). Contains the degree variances for the four SRBF types. Record Format: SRBF Legendre Degree (Independent Variable), Point Mass Degree Variance, Poisson Degree Variance, m-order Radial Multipole Degree Variance, m-order Poisson Wavelet Degree Variance.

>> Save the results as C:/PAGravf4.5_win64en/examples/SRBFperformance/ksiSRBF.txt.

>> The program generates both spatial-domain and spectral-domain curve files. Contains the kernel values for the four SRBF types corresponding to the selected field element. Record Format: Spherical Angular Distance (Independent Variable), Point Mass Kernel Value, Poisson Kernel Value, m-order Radial Multipole Kernel Value, m-order Poisson Wavelet Kernel Value.

** Automatically saved to the current directory with the user-defined prefix (*). Contains the degree variances for the four SRBF types. Record Format: SRBF Legendre Degree (Independent Variable), Point Mass Degree Variance, Poisson Degree Variance, m-order Radial Multipole Degree Variance, m-order Poisson Wavelet Degree Variance.

Set SRBF parameters

Minimum Degree 30
Maximum Degree 1440
Bjerhammar Sphere Burial Depth 5km
Multipole/Wavelet Order 5
Action Distance of SBRF Center 1.5°
Spatial Sampling Interval 0.20'

Calculation and save

Display of the input-output file↓

1.446667	0.010961	-0.004686	-0.006052	-0.015008
1.450000	0.010781	-0.004850	-0.006278	-0.015414
1.453333	0.010616	-0.004984	-0.006460	-0.015710
1.456667	0.010464	-0.005087	-0.006597	-0.015894
1.460000	0.010327	-0.005158	-0.006687	-0.015967
1.463333	0.010204	-0.005199	-0.006730	-0.015928
1.466667	0.010097	-0.005207	-0.006727	-0.015778
1.470000	0.010004	-0.005185	-0.006678	-0.015519
1.473333	0.009925	-0.005131	-0.006583	-0.015153
1.476667	0.009860	-0.005047	-0.006443	-0.014685
1.480000	0.009810	-0.004933	-0.006260	-0.014117
1.483333	0.009773	-0.004791	-0.006035	-0.013455
1.486667	0.009749	-0.004622	-0.005771	-0.012703
1.490000	0.009738	-0.004426	-0.005468	-0.011868
1.493333	0.009738	-0.004205	-0.005130	-0.010955
1.496667	0.009749	-0.003962	-0.004759	-0.009972
1.500000	0.009770	-0.003698	-0.004359	-0.008927

Curve type Spatial curves of SRBFs

Line thickness 3

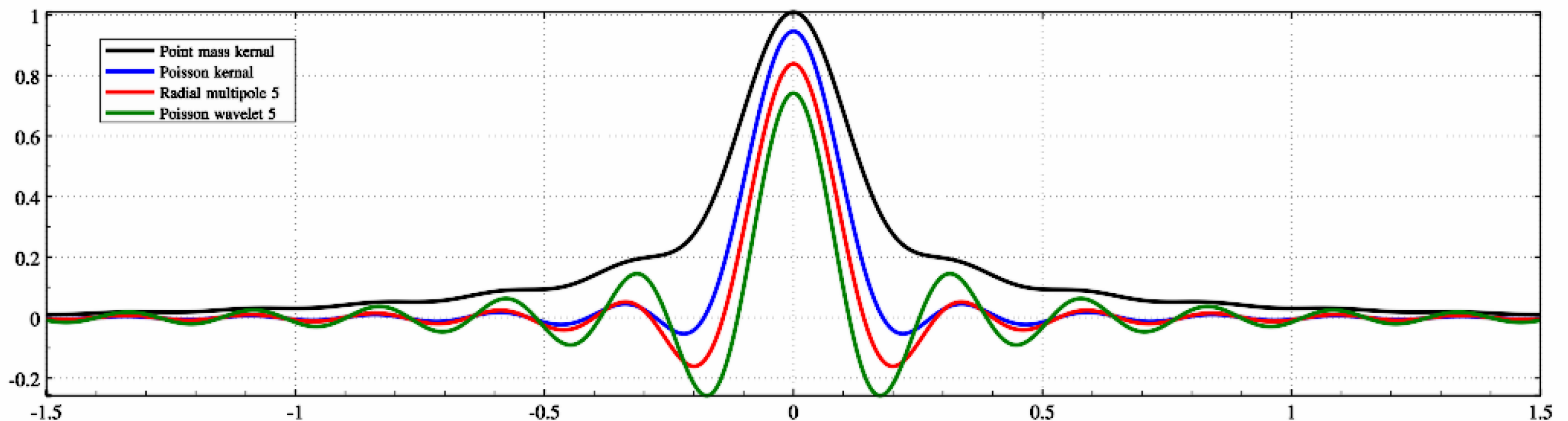
Start end row number 1 3600

Extract plot data

Chart plot↓

Spatial and spectral curves of spherical radial basis functions (SRBF)

Save current plot as



Spatial and Spectral Performance Analysis of Spherical Radial Basis Functions

Spatial and Spectral Performance Analysis of Spherical Radial Basis Functions

Construction of Reuter Spherical Grid at a Specified Level

Select anomalous field element : anomaly / disturbing potential

Algorithms of the spherical radial basis function and Reuter grid

Save computation process as

** Automatically saved to the current directory with the user-defined prefix (*). Contains the degree variances for the four SRBF types. Record Format: SRBF Legendre Degree (Independent Variable), Point Mass Degree Variance, Poisson Degree Variance, m-order Radial Multipole Degree Variance, m-order Poisson Wavelet Degree Variance.

>> Save the results as C:/PAGravf4.5_win64en/examples/SRBFperformance/ksiSRBF.txt.

>> The program generates both spatial-domain and spectral-domain curve files. Contains the kernel values for the four SRBF types corresponding to the selected field element. Record Format: Spherical Angular Distance (Independent Variable), Point Mass Kernel Value, Poisson Kernel Value, m-order Radial Multipole Kernel Value, m-order Poisson Wavelet Kernel Value.

** Automatically saved to the current directory with the user-defined prefix (*). Contains the degree variances for the four SRBF types. Record Format: SRBF Legendre Degree (Independent Variable), Point Mass Degree Variance, Poisson Degree Variance, m-order Radial Multipole Degree Variance, m-order Poisson Wavelet Degree Variance.

[SRBFs] Point-mass kernel, Poisson kernel, m-order radial multipole and m-order Poisson wavelet kernel functions.

Set SRBF parameters

Minimum Degree 30
Maximum Degree 1440
Bjerhammar Sphere Burial Depth 5km
Multipole/Wavelet Order 5
Action Distance of SBRF Center 1.5°
Spatial Sampling Interval 0.20'

Calculation and save

Display of the input-output file↓

1424	0.126130	0.991339	0.980579	0.896752
1425	0.125932	0.991175	0.981797	0.902920
1426	0.125735	0.991011	0.983013	0.909126
1427	0.125538	0.990846	0.984230	0.915368
1428	0.125341	0.990679	0.985446	0.921648
1429	0.125145	0.990512	0.986661	0.927966
1430	0.124949	0.990344	0.987876	0.934322
1431	0.124753	0.990174	0.989091	0.940715
1432	0.124557	0.990004	0.990305	0.947147
1433	0.124362	0.989833	0.991518	0.953617
1434	0.124167	0.989661	0.992732	0.960126
1435	0.123973	0.989488	0.993944	0.966674
1436	0.123778	0.989315	0.995157	0.973260
1437	0.123584	0.989140	0.996369	0.979886
1438	0.123391	0.988964	0.997580	0.986551
1439	0.123197	0.988787	0.998791	0.993256
1440	0.123004	0.988610	1.000002	1.000000

Curve type Spectral curves of SRBFs

Line thickness 3

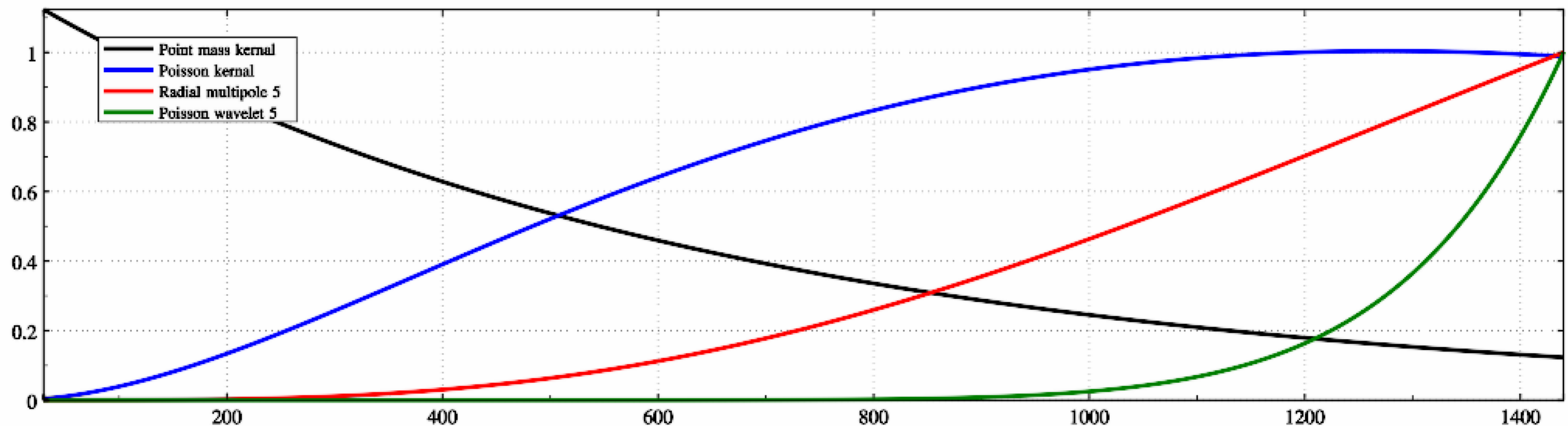
Start end row number 1 3600

Extract plot data

Chart plot↓

Spatial and spectral curves of spherical radial basis functions (SRBF)

Save current plot as



Construction of Reuter Spherical Grid at a Specified Level

Construction of Reuter Spherical Grid at a Specified Level

Minimum Maximum geocentric latitude

-90.0°

90.0°

Minimum Maximum longitude

0.0°

360°

Set Reuter level Q 90

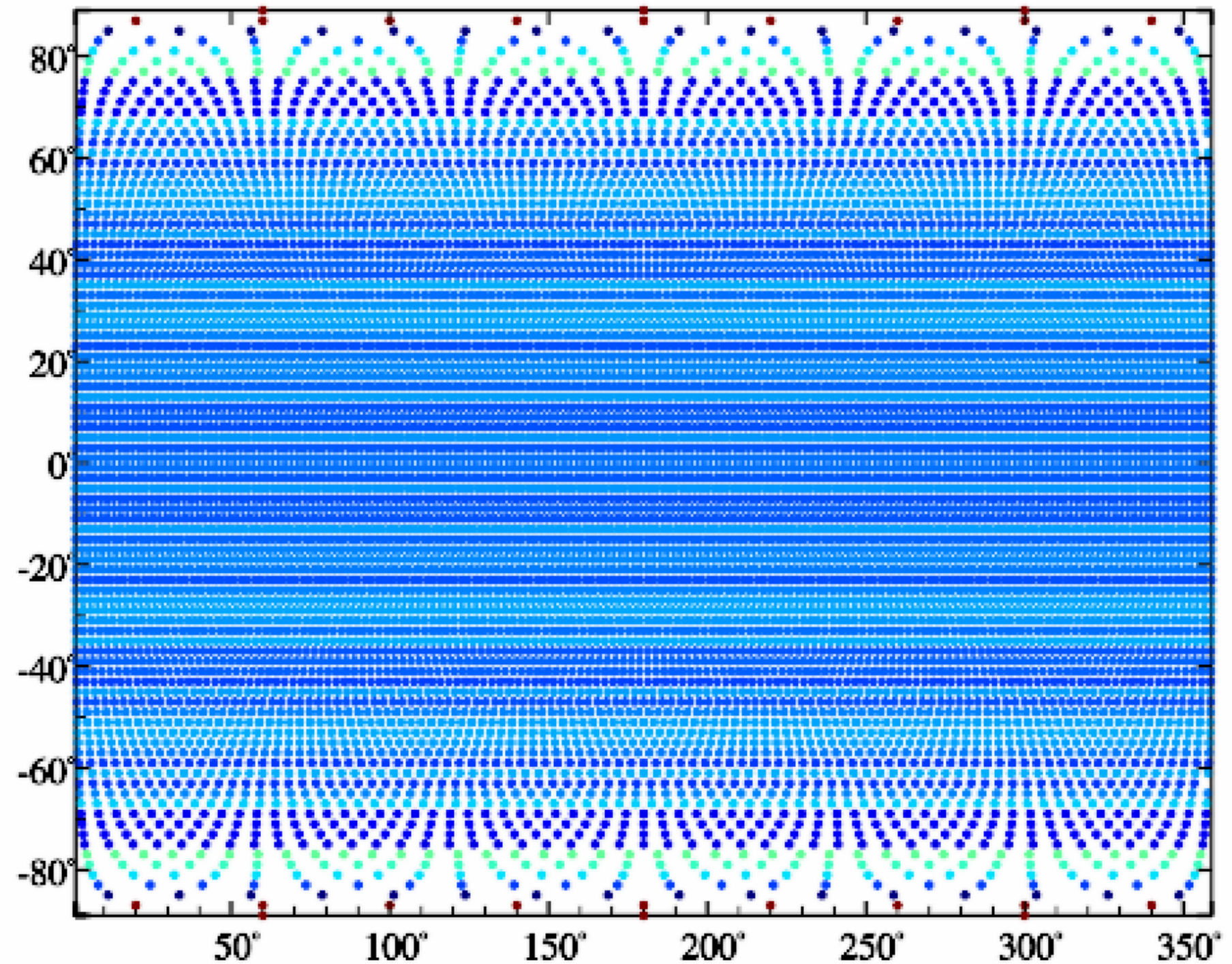
Plot mode longitude, latitude and area of the center of cell grid

Calculation and save

Extract plot data

Reuter grid plot →

Save current plot as



Reuter spatial grid results file

10291	191.250000	85.000000	-1.95	-0.085481	-0.017003	0.996195
10292	213.750000	85.000000	-1.95	-0.072467	-0.048421	0.996195
10293	236.250000	85.000000	-1.95	-0.048421	-0.072467	0.996195
10294	258.750000	85.000000	-1.95	-0.017003	-0.085481	0.996195
10295	281.250000	85.000000	-1.95	0.017003	-0.085481	0.996195
10296	303.750000	85.000000	-1.95	0.048421	-0.072467	0.996195
10297	326.250000	85.000000	-1.95	0.072467	-0.048421	0.996195
10298	348.750000	85.000000	-1.95	0.085481	-0.017003	0.996195
10299	20.000000	87.000000	4.67	0.049180	0.017900	0.998630
10300	60.000000	87.000000	4.67	0.026168	0.045324	0.998630
10301	100.000000	87.000000	4.67	-0.009088	0.051541	0.998630
10302	140.000000	87.000000	4.67	-0.040092	0.033641	0.998630

Construction of Reuter Spherical Grid at a Specified Level

Construction of Reuter Spherical Grid at a Specified Level

?

×

Minimum Maximum geocentric latitude

-90.0°

90.0°

Minimum Maximum longitude

0.0°

360°

Set Reuter level Q 90

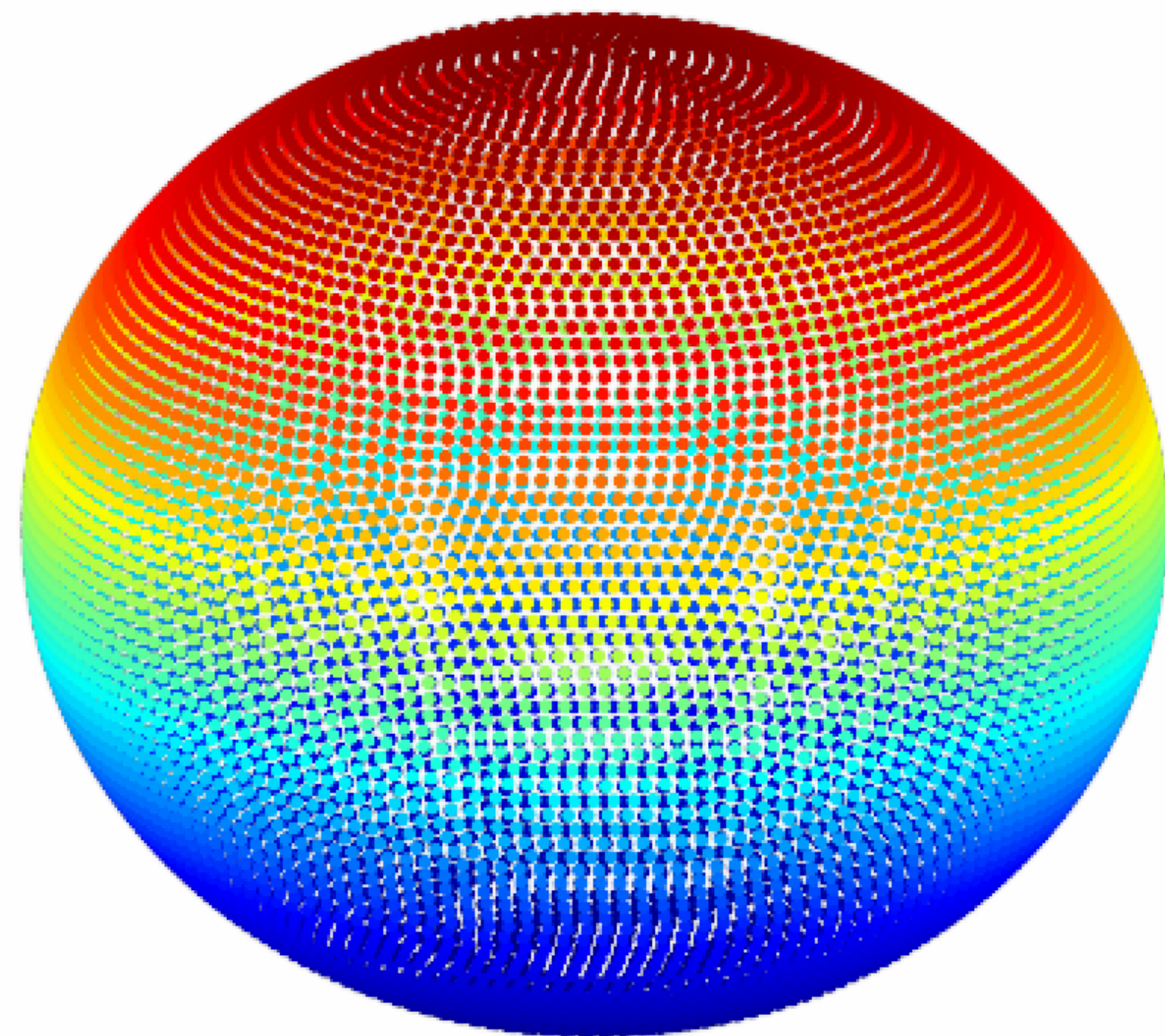
Plot mode Cartesian space coordinates of the center of cell grid

Calculation and save

Extract plot data

Reuter grid plot →

Save current plot as



Reuter spatial grid results file

10291	191.250000	85.000000	-1.95	-0.085481	-0.017003	0.996195
10292	213.750000	85.000000	-1.95	-0.072467	-0.048421	0.996195
10293	236.250000	85.000000	-1.95	-0.048421	-0.072467	0.996195
10294	258.750000	85.000000	-1.95	-0.017003	-0.085481	0.996195
10295	281.250000	85.000000	-1.95	0.017003	-0.085481	0.996195
10296	303.750000	85.000000	-1.95	0.048421	-0.072467	0.996195
10297	326.250000	85.000000	-1.95	0.072467	-0.048421	0.996195
10298	348.750000	85.000000	-1.95	0.085481	-0.017003	0.996195
10299	20.000000	87.000000	4.67	0.049180	0.017900	0.998630
10300	60.000000	87.000000	4.67	0.026168	0.045324	0.998630
10301	100.000000	87.000000	4.67	-0.009088	0.051541	0.998630
10302	140.000000	87.000000	4.67	-0.040092	0.033641	0.998630

Construction of Reuter Spherical Grid at a Specified Level

Construction of Reuter Spherical Grid at a Specified Level

Minimum Maximum geocentric latitude

28.0°

34.0°

Minimum Maximum longitude

96.0°

104°

Set Reuter level Q 1800

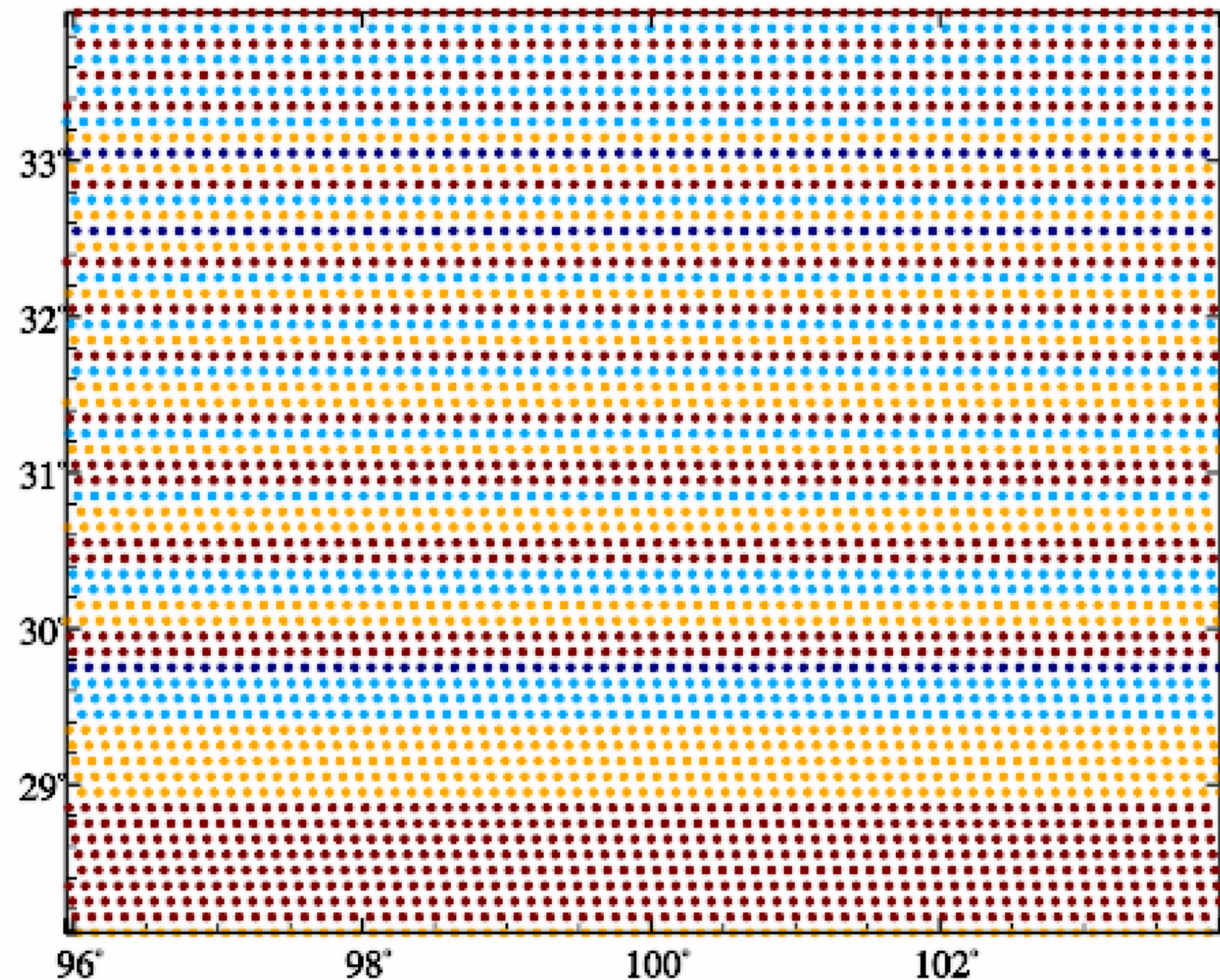
Plot mode longitude, latitude and area of the center of cell grid

Calculation and save

Extract plot data

Reuter grid plot →

Save current plot as



Reuter spatial grid results file

4094	102.297388	33.950000	0.01	-0.176677	0.810492	0.558469
4095	102.417950	33.950000	0.01	-0.178382	0.810118	0.558469
4096	102.538513	33.950000	0.01	-0.180086	0.809741	0.558469
4097	102.659076	33.950000	0.01	-0.181790	0.809361	0.558469
4098	102.779638	33.950000	0.01	-0.183493	0.808976	0.558469
4099	102.900201	33.950000	0.01	-0.185194	0.808588	0.558469
4100	103.020764	33.950000	0.01	-0.186895	0.808197	0.558469
4101	103.141326	33.950000	0.01	-0.188596	0.807802	0.558469
4102	103.261889	33.950000	0.01	-0.190295	0.807403	0.558469
4103	103.382451	33.950000	0.01	-0.191994	0.807001	0.558469
4104	103.503014	33.950000	0.01	-0.193691	0.806595	0.558469
4105	103.623577	33.950000	0.01	-0.195388	0.806186	0.558469

Gravity Field Approximation Using SRBFs: Gravity disturbance → Height anomaly

Open Single-Type Residual Observation File

Select type of observations

gravity disturbance (mGal)

Set observations file format

Number of rows of file header

1

Ellipsoidal Height Column Index

4

Observation Weight Column Index

0

Gravity Disturbance Column Index

7

Select SRBF

radial multipole kernel

Set SRBF parameters

Order m

1

Minimum degree

360

Maximum degree

1800

Burial depth of Bjerhammar sphere

10.0km

Action distance of SRBF center

100km

Reuter network level Q

1800

Open Computation Surface ellipsoidal Height grid File

Solution of normal equation

LU triangular decomposition

External Accuracy Evaluation

☐ Synchronous computation of target field elements at discrete points

By setting computation points identical to the observation points of the target field element, the program generates SRBF-based estimates using the input observation data. The residuals between the observed and estimated values are then employed for gross error detection and the assessment of external accuracy indices.

Extract data to be plot

Plot→

SRBF approach algorithms

>> [Purpose] Select a specific type of residual observation and a kind of Spherical Radial Basis Function (SRBF) kernel to evaluate the spatial, spectral, and analytical performance of the SRBF approximation algorithm. This is achieved by estimating specific residual gravity field elements – such as gravity disturbances, height anomalies, gravity anomalies, disturbing potential gradients, or vertical deflections – on or outside the geoid.

** Selecting different type of observations and constructing different figure of SRBF, we can calculate different type of target field elements, and then fully verify and analyze the spatial and spectral properties of gravity field approach algorithms using SRBFs.

>> The program itself can be employed for analytical continuation, gridding, type conversion and all-element modelling on gravity field from various single type of observed field elements.

>> Open Single-Type Residual Observation File C:/PAGrav4.5_win64en/examples/SRBFestimateVerify/resdbm541_1800.txt.

** Look at the file information in the window below and set the discrete point file format...

>> Open Computation Surface ellipsoidal Height grid File C:/PAGrav4.5_win64en/examples/SRBFestimateVerify/surfhgt.dat.

>> Save the results as C:/PAGrav4.5_win64en/examples/SRBFestimateVerify/rgatoksi.dat.

>> The program outputs Single-Type Observation Residual File (*.chs) into the current directory. The file header format: Original Obs (Mean, StdDev, Min, Max); Residuals (Mean, StdDev, Min, Max). Record format: Point ID, Lon, Lat, Height, Weight, Original Obs [, West Component if Vert. Defl.], Residual Value [, Residual West Component]. where * is the output file name.

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-03-26 10:25:38

>> Complete the computation!

>> Computation end time: 2026-03-26 10:26:00

>> The program also outputs various field elements' SRBF spatial curve file *spc.rbf, various field elements' SRBF spectral curve files *dgr.rbf and SRBF center file* center.txt into the current directory.

>> Mean -0.4113 standard deviation 21.8940 minimum -141.1997 maximum 112.4878 of the source observations.

** mean -0.0216 standard deviation 1.9088 minimum -54.0885 maximum 53.0770 of the result residuals.

Type of target element

height anomaly (m)

Save the results as

Import setting parameters

Start Computation

94.00000000	100.00000000	30.00000000	35.00000000	0.05000000	0.05000000	0.0000			
-0.4934	-0.4466	-0.3004	-0.1309	-0.0358	0.0254	0.0649	0.0679	0.0223	-0.0732
0.1289	0.2125	0.1641	-0.0056	-0.2094	-0.2817	-0.1712	0.0125	0.1665	0.2722
0.0273	-0.2539	-0.4608	-0.4318	-0.2215	0.0453	0.2281	0.2436	0.1685	0.0364
0.2761	0.2306	0.1674	0.1678	0.1902	0.2424	0.2110	0.0717	-0.1042	-0.2823
-0.5242	-0.5674	-0.6053	-0.6055	-0.5592	-0.4309	-0.2461	-0.0668	0.0980	0.2084

observed residual gravity disturbance (mGal)

spherical radial basis function spatial curve

target residual height anomaly (m)

- After the first estimation is completed, it is recommended to employ the output residual observation file *.chs as the input residual observations file again to refine target field elements by cumulative SRBF approximation scheme. Typically, stable and high-precision solutions are achieved after accumulating just 1 to 2 SRBF approximation steps.
- Validity Principles for Single SRBF Approximation: (1) The target field element grid should remain spatially continuous and differentiable, and the standard deviation of residual observations in file *.chs is as small as possible. (2) As cumulative steps proceed, the statistical mean of the residual observations must converge toward zero without exhibiting significant sign reversals.
- Observations with zero weights can be extracted from the *.chs file (indicating they were excluded from the SRBF coefficient estimation) to determine and evaluate their external accuracy.

Gravity Field Approximation Using SRBFs: cumulative SRBF approach

Open Single-Type Residual Observation File

Select type of observations

gravity disturbance (mGal)

Set observations file format

Number of rows of file header

1

Ellipsoidal Height Column Index

4

Observation Weight Column Index

5

Gravity Disturbance Column Index

7

Select SRBF

radial multipole kernel

Set SRBF parameters

Order m

1

Minimum degree

540

Maximum degree

1800

Burial depth of Bjerhammar sphere

6.0km

Action distance of SRBF center

75km

Reuter network level Q

3600

Open Computation Surface ellipsoidal Height grid File

Solution of normal equation

LU triangular decomposition

External Accuracy Evaluation

☐ Synchronous computation of target field elements at discrete points

By setting computation points identical to the observation points of the target field element, the program generates SRBF-based estimates using the input observation data. The residuals between the observed and estimated values are then employed for gross error detection and the assessment of external accuracy indices.

Extract data to be plot

Plot→

SRBF approach algorithms

Click the [Start Computation] control button, or the [Start Computation] tool button...

Computation start time: 2026-03-26 10:25:38

Complete the computation!

Computation end time: 2026-03-26 10:26:00

The program also outputs various field elements' SRBF spatial curve file *spc.rbf, various field elements' SRBF spectral curve files *dgr.rbf and SRBF center file* center.txt into the current directory.

Mean -0.4113 standard deviation 21.8940 minimum -141.1997 maximum 112.4878 of the source observations.

mean -0.0216 standard deviation 1.9088 minimum -54.0885 maximum 53.0770 of the result residuals.

Open Single-Type Residual Observation File C:/PAGrav4.5_win64en/examples/SRBFestimateVerify/rgatoksi.chs.

Look at the file information in the window below and set the discrete point file format...

Open Computation Surface ellipsoidal Height grid File C:/PAGrav4.5_win64en/examples/SRBFestimateVerify/surfhgt.dat.

Save the results as C:/PAGrav4.5_win64en/examples/SRBFestimateVerify/rgatoksi1.dat.

The program outputs Single-Type Observation Residual File (*.chs) into the current directory. The file header format: Original Obs (Mean, StdDev, Min, Max); Residuals (Mean, StdDev, Min, Max). Record format: Point ID, Lon, Lat, Height, Weight, Original Obs [, West Component if Vert. Defl.], Residual Value [, Residual West Component]. where * is the output file name.

The parameter settings have been entered into the system!

Click the [Start Computation] control button, or the [Start Computation] tool button...

Computation start time: 2026-03-26 10:29:20

Complete the computation!

Computation end time: 2026-03-26 10:30:44

The program also outputs various field elements' SRBF spatial curve file *spc.rbf, various field elements' SRBF spectral curve files *dgr.rbf and SRBF center file* center.txt into the current directory.

Mean -0.0216 standard deviation 1.9088 minimum -54.0885 maximum 53.0770 of the source observations.

mean -0.0044 standard deviation 0.6536 minimum -28.2780 maximum 11.2439 of the result residuals.

Type of target element

height anomaly (m)

Save the results as

Import setting parameters

Start Computation

94.00000000	100.00000000	30.00000000	35.00000000	0.05000000	0.05000000	0.0000			
0.0062	0.0156	0.0198	0.0140	0.0131	0.0070	0.0129	0.0219	0.0341	0.0222
-0.0377	-0.0595	-0.0418	-0.0222	-0.0199	-0.0378	-0.0153	-0.0140	-0.0054	-0.0043
-0.0170	-0.0175	-0.0034	0.0075	0.0119	0.0092	0.0314	0.0430	0.0474	0.0319
0.0164	0.0141	0.0022	-0.0088	0.0031	0.0067	0.0020	-0.0066	-0.0183	-0.0052
0.0253	0.0220	0.0056	0.0005	0.0232	0.0116	0.0053	-0.0034	-0.0063	0.0051

observed residual gravity disturbance (mGal)

spherical radial basis function spatial curve

target residual height anomaly (m)

After the first estimation is completed, it is recommended to employ the output residual observation file *.chs as the input residual observations file again to refine target field elements by cumulative SRBF approximation scheme. Typically, stable and high-precision solutions are achieved after accumulating just 1 to 2 SRBF approximation steps.

Validity Principles for Single SRBF Approximation: (1)The target field element grid should remain spatially continuous and differentiable, and the standard deviation of residual observations in file *.chs is as small as possible. (2) As cumulative steps proceed, the statistical mean of the residual observations must converge toward zero without exhibiting significant sign reversals.

Observations with zero weights can be extracted from the *.chs file (indicating they were excluded from the SRBF coefficient estimation) to determine and evaluate their external accuracy.

Gravity Field Approximation Using SRBFs: Vertical deflection → Height anomaly

Open Single-Type Residual Observation File

Select type of observations
vertical deflection vector ("")

Set observations file format

Number of rows of file header 1
Ellipsoidal Height Column Index 4
Observation Weight Column Index 0
Vertical Deflection Westward Column Index 8
Vertical Deflection Southward Column Index 9

Select SRBF radial multipole kernel

Set SRBF parameters

Order m 1
Minimum degree 360
Maximum degree 1800
Burial depth of Bjerhammar sphere 10.0km
Action distance of SRBF center 100km
Reuter network level Q 1800

Open Computation Surface ellipsoidal Height grid File

Solution of normal equation
LU triangular decomposition

External Accuracy Evaluation

☐ Synchronous computation of target field elements at discrete points

By setting computation points identical to the observation points of the target field element, the program generates SRBF-based estimates using the input observation data. The residuals between the observed and estimated values are then employed for gross error detection and the assessment of external accuracy indices.

Extract data to be plot

Plot→



SRBF approach algorithms

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-03-26 10:29:20

>> Complete the computation!

>> Computation end time: 2026-03-26 10:30:44

>> The program also outputs various field elements' SRBF spatial curve file *spc.rbf, various field elements' SRBF spectral curve files *dgr.rbf and SRBF center file* center.txt into the current directory.

>> Mean -0.0216 standard deviation 1.9088 minimum -54.0885 maximum 53.0770 of the source observations.

** mean -0.0044 standard deviation 0.6536 minimum -28.2780 maximum 11.2439 of the result residuals.

>> Open Single-Type Residual Observation File C:/PAGrav4.5_win64en/examples/SRBFestimateVerify/resdbm541_1800.txt.

** Look at the file information in the window below and set the discrete point file format...

>> Open Computation Surface ellipsoidal Height grid File C:/PAGrav4.5_win64en/examples/SRBFestimateVerify/surfhgt.dat.

>> Save the results as C:/PAGrav4.5_win64en/examples/SRBFestimateVerify/dfttoksi.dat.

>> The program outputs Single-Type Observation Residual File (*.chs) into the current directory. The file header format: Original Obs (Mean, StdDev, Min, Max); Residuals (Mean, StdDev, Min, Max). Record format: Point ID, Lon, Lat, Height, Weight, Original Obs [, West Component if Vert. Defl.], Residual Value [, Residual West Component]. where * is the output file name.

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-03-26 10:38:03

>> Complete the computation!

>> Computation end time: 2026-03-26 10:38:38

>> The program also outputs various field elements' SRBF spatial curve file *spc.rbf, various field elements' SRBF spectral curve files *dgr.rbf and SRBF center file* center.txt into the current directory.

>> Mean -0.0129 standard deviation 3.2354 minimum -19.8241 maximum 23.1114 of the source observations.

** mean 0.0039 standard deviation 0.3118 minimum -9.2421 maximum 10.5513 of the result residuals.

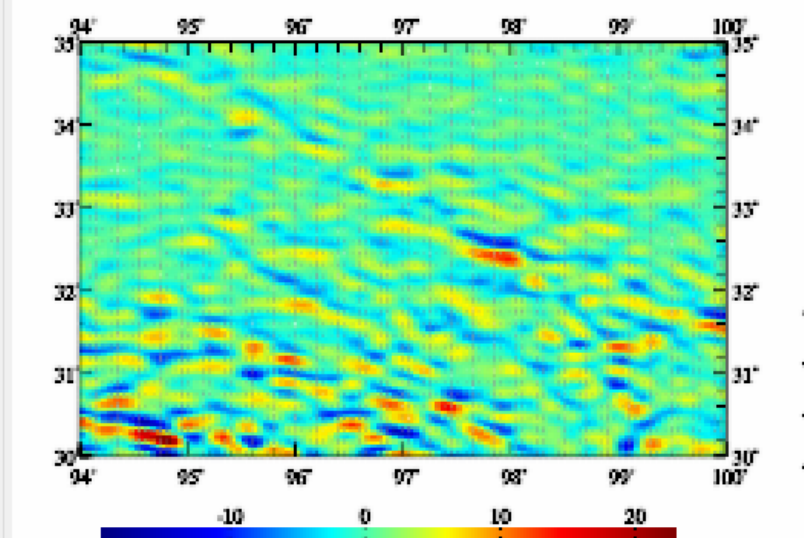
Type of target element height anomaly (m)

Save the results as

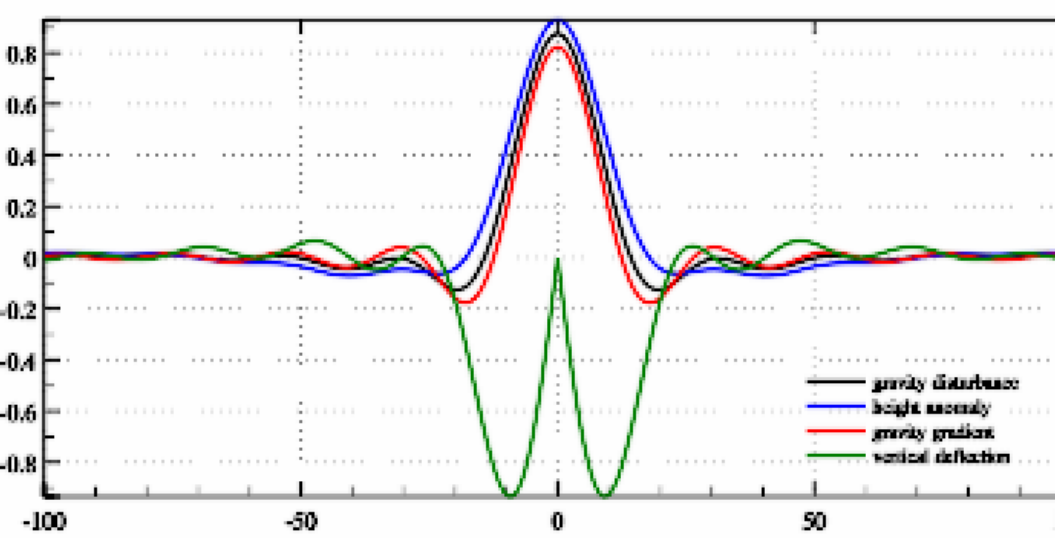
Import setting parameters

Start Computation

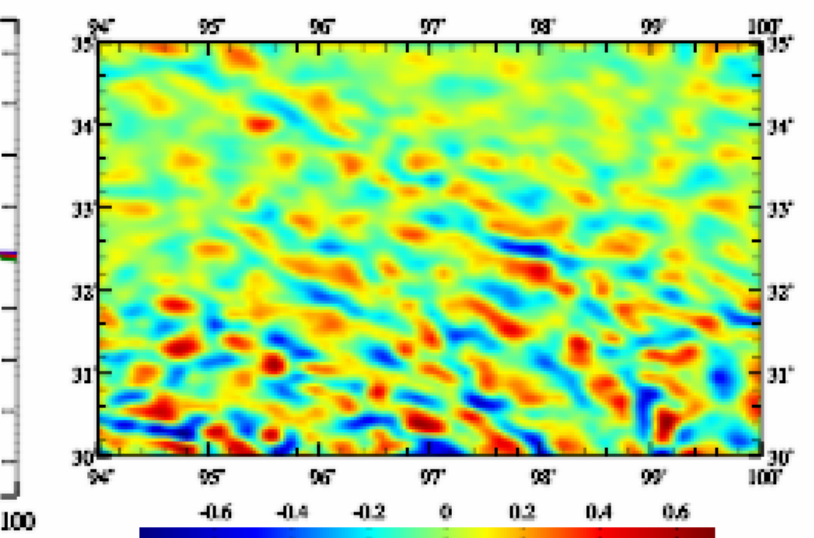
94.00000000	100.00000000	30.00000000	35.00000000	0.05000000	0.05000000	0.0000			
-0.4808	-0.4329	-0.2845	-0.1120	-0.0144	0.0492	0.0874	0.1029	0.0741	-0.0079
0.1176	0.2158	0.1885	0.0295	-0.1768	-0.2662	-0.1820	-0.0265	0.1247	0.2425
0.0318	-0.2592	-0.4819	-0.4693	-0.2501	0.0327	0.2356	0.2747	0.2107	0.0684
0.2274	0.1964	0.1420	0.1525	0.1764	0.2116	0.1653	0.0179	-0.1573	-0.3123
-0.4060	-0.4720	-0.5360	-0.5683	-0.5500	-0.4631	-0.3231	-0.1673	-0.0224	0.0857



observed residual vertical deflection (" , S)



spherical radial basis function spatial curve



target residual height anomaly (m)

After the first estimation is completed, it is recommended to employ the output residual observation file *.chs as the input residual observations file again to refine target field elements by cumulative SRBF approximation scheme. Typically, stable and high-precision solutions are achieved after accumulating just 1 to 2 SRBF approximation steps.

Validity Principles for Single SRBF Approximation: (1) The target field element grid should remain spatially continuous and differentiable, and the standard deviation of residual observations in file *.chs is as small as possible. (2) As cumulative steps proceed, the statistical mean of the residual observations must converge toward zero without exhibiting significant sign reversals.

Observations with zero weights can be extracted from the *.chs file (indicating they were excluded from the SRBF coefficient estimation) to determine and evaluate their external accuracy.

Gravity Field Approximation Using SRBFs: Disturbing gradient → Height anomaly

Open Single-Type Residual Observation File

Select type of observations

disturbing gradient (E, radial)

Set observations file format

Number of rows of file header

1

Ellipsoidal Height Column Index

4

Observation Weight Column Index

0

Disturbing Gradient Column Index

10

Select SRBF

radial multipole kernel

Set SRBF parameters

Order m

1

Minimum degree

360

Maximum degree

1800

Burial depth of Bjerhammar sphere

10.0km

Action distance of SRBF center

100km

Reuter network level Q

1800

Open Computation Surface ellipsoidal Height grid File

Solution of normal equation

LU triangular decomposition

External Accuracy Evaluation

☐ Synchronous computation of target field elements at discrete points

By setting computation points identical to the observation points of the target field element, the program generates SRBF-based estimates using the input observation data. The residuals between the observed and estimated values are then employed for gross error detection and the assessment of external accuracy indices.

Extract data to be plot

Plot→

SRBF approach algorithms

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-03-26 10:38:03

>> Complete the computation!

>> Computation end time: 2026-03-26 10:38:38

>> The program also outputs various field elements' SRBF spatial curve file *spc.rbf, various field elements' SRBF spectral curve files *dgr.rbf and SRBF center file* center.txt into the current directory.

>> Mean -0.0129 standard deviation 3.2354 minimum -19.8241 maximum 23.1114 of the source observations.

** mean 0.0039 standard deviation 0.3118 minimum -9.2421 maximum 10.5513 of the result residuals.

>> Open Single-Type Residual Observation File C:/PAGrav4.5_win64en/examples/SRBFestimateVerify/resdbm541_1800.txt.

** Look at the file information in the window below and set the discrete point file format...

>> Open Computation Surface ellipsoidal Height grid File C:/PAGrav4.5_win64en/examples/SRBFestimateVerify/surfhgt.dat.

>> Save the results as C:/PAGrav4.5_win64en/examples/SRBFestimateVerify/grrtoksi.dat.

>> The program outputs Single-Type Observation Residual File (*.chs) into the current directory. The file header format: Original Obs (Mean, StdDev, Min, Max); Residuals (Mean, StdDev, Min, Max). Record format: Point ID, Lon, Lat, Height, Weight, Original Obs [, West Component if Vert. Defl.], Residual Value [, Residual West Component]. where * is the output file name.

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-03-26 10:40:47

>> Complete the computation!

>> Computation end time: 2026-03-26 10:41:09

>> The program also outputs various field elements' SRBF spatial curve file *spc.rbf, various field elements' SRBF spectral curve files *dgr.rbf and SRBF center file* center.txt into the current directory.

>> Mean -0.8635 standard deviation 38.2935 minimum -262.7565 maximum 232.6519 of the source observations.

** mean -0.0373 standard deviation 3.7041 minimum -90.4115 maximum 78.2329 of the result residuals.

Type of target element

height anomaly (m)

Save the results as

Import setting parameters

Start Computation

94.00000000	100.00000000	30.00000000	35.00000000	0.05000000	0.05000000	0.0000			
-0.5445	-0.5102	-0.3560	-0.1739	-0.0708	-0.0012	0.0419	0.0482	-0.0085	-0.1114
0.1839	0.2645	0.1883	0.0030	-0.2013	-0.2539	-0.1254	0.0529	0.1988	0.2703
0.1064	-0.1544	-0.3614	-0.3513	-0.1629	0.0673	0.2065	0.1871	0.0870	-0.0395
0.2908	0.2241	0.1481	0.1425	0.1681	0.2248	0.2043	0.0655	-0.1207	-0.3326
-0.7192	-0.7325	-0.7358	-0.6986	-0.6140	-0.4451	-0.2224	-0.0131	0.1616	0.2708

observed residual disturbing gradient (E, R)

spherical radial basis function spatial curve

target residual height anomaly (m)

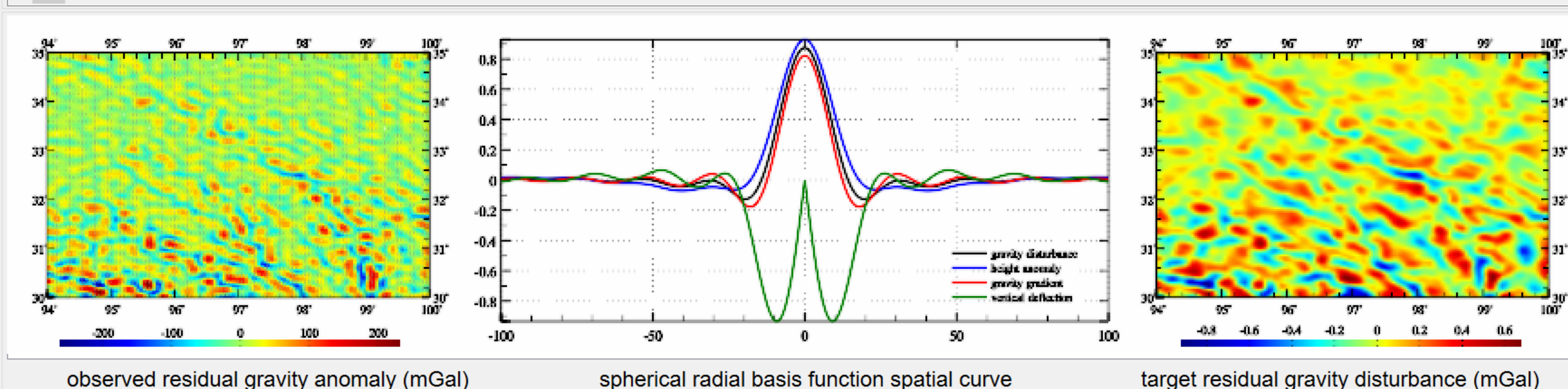
- After the first estimation is completed, it is recommended to employ the output residual observation file *.chs as the input residual observations file again to refine target field elements by cumulative SRBF approximation scheme. Typically, stable and high-precision solutions are achieved after accumulating just 1 to 2 SRBF approximation steps.
- Validity Principles for Single SRBF Approximation: (1)The target field element grid should remain spatially continuous and differentiable, and the standard deviation of residual observations in file *.chs is as small as possible. (2) As cumulative steps proceed, the statistical mean of the residual observations must converge toward zero without exhibiting significant sign reversals.
- Observations with zero weights can be extracted from the *.chs file (indicating they were excluded from the SRBF coefficient estimation) to determine and evaluate their external accuracy.

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



SRBF approach algorithms

94.00000000	100.00000000	30.00000000	35.00000000	0.05000000	0.05000000	0.0000			
-0.4274	-0.3868	-0.2398	-0.0702	0.0199	0.0651	0.0962	0.1104	0.0885	0.010
0.1013	0.1975	0.1669	0.0044	-0.2117	-0.3170	-0.2383	-0.0673	0.0919	0.209
-0.0204	-0.3159	-0.5152	-0.4741	-0.2542	0.0301	0.2403	0.2867	0.2114	0.069
0.2554	0.2373	0.1896	0.1880	0.2189	0.2546	0.2057	0.0555	-0.1233	-0.269
-0.3326	-0.3908	-0.4684	-0.5152	-0.5078	-0.4270	-0.2902	-0.1481	-0.0078	0.095



- After the first estimation is completed, it is recommended to employ the output residual observation file *.chs as the input residual observations file again to refine target field elements by cumulative SRBF approximation scheme. Typically, stable and high-precision solutions are achieved after accumulating just 1 to 2 SRBF approximation steps.
- Validity Principles for Single SRBF Approximation: (1)The target field element grid should remain spatially continuous and differentiable, and the standard deviation of residual observations in file *.chs is as small as possible. (2) As cumulative steps proceed, the statistical mean of the residual observations must converge toward zero without exhibiting significant sign reversals.
- Observations with zero weights can be extracted from the *.chs file (indicating they were excluded from the SRBF coefficient estimation) to determine and evaluate their external accuracy.

Gravity Field Approximation Using SRBFs: Gravity disturbance → Disturbing gradient

Open Single-Type Residual Observation File

Select type of observations

gravity disturbance (mGal)

Set observations file format

Number of rows of file header

1

Ellipsoidal Height Column Index

4

Observation Weight Column Index

0

Gravity Disturbance Column Index

7

Select SRBF

radial multipole kernel

Set SRBF parameters

Order m

1

Minimum degree

360

Maximum degree

1800

Burial depth of Bjerhammar sphere

10.0km

Action distance of SRBF center

100km

Reuter network level Q

1800

Open Computation Surface ellipsoidal Height grid File

Solution of normal equation

LU triangular decomposition

External Accuracy Evaluation

☐ Synchronous computation of target field elements at discrete points

By setting computation points identical to the observation points of the target field element, the program generates SRBF-based estimates using the input observation data. The residuals between the observed and estimated values are then employed for gross error detection and the assessment of external accuracy indices.

Extract data to be plot

Plot→

SRBF approach algorithms

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-03-26 10:42:54

>> Complete the computation!

>> Computation end time: 2026-03-26 10:43:14

>> The program also outputs various field elements' SRBF spatial curve file *spc.rbf, various field elements' SRBF spectral curve files *dgr.rbf and SRBF center file* center.txt into the current directory.

>> Mean -0.0020 standard deviation 0.1590 minimum -0.8621 maximum 0.6546 of the source observations.

** mean 0.0000 standard deviation 0.0131 minimum -0.3763 maximum 0.4258 of the result residuals.

>> Open Single-Type Residual Observation File C:/PAGrav4.5_win64en/examples/SRBFestimateVerify/resdbm541_1800.txt.

** Look at the file information in the window below and set the discrete point file format...

>> Open Computation Surface ellipsoidal Height grid File C:/PAGrav4.5_win64en/examples/SRBFestimateVerify/surfhgt.dat.

>> Save the results as C:/PAGrav4.5_win64en/examples/SRBFestimateVerify/rgatogrr.dat.

>> The program outputs Single-Type Observation Residual File (*.chs) into the current directory. The file header format: Original Obs (Mean, StdDev, Min, Max); Residuals (Mean, StdDev, Min, Max). Record format: Point ID, Lon, Lat, Height, Weight, Original Obs [, West Component if Vert. Defl.], Residual Value [, Residual West Component]. where * is the output file name.

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-03-26 10:45:06

>> Complete the computation!

>> Computation end time: 2026-03-26 10:45:30

>> The program also outputs various field elements' SRBF spatial curve file *spc.rbf, various field elements' SRBF spectral curve files *dgr.rbf and SRBF center file* center.txt into the current directory.

>> Mean -0.4113 standard deviation 21.8940 minimum -141.1997 maximum 112.4878 of the source observations.

** mean -0.0216 standard deviation 1.9088 minimum -54.0885 maximum 53.0770 of the result residuals.

Type of target element

disturbing gradient (E, radial)

Save the results as

Import setting parameters

Start Computation

94.00000000	100.00000000	30.00000000	35.00000000	0.05000000	0.05000000	0.0000			
-137.4913	-128.5689	-75.7644	-21.5254	-1.7301	0.0090	7.5791	20.3746	19.7973	-10.7891
-9.5433	43.9876	47.6359	-6.5605	-77.1569	-94.1416	-42.8307	15.0738	31.2255	9.8689
47.3224	-44.9296	-109.9247	-94.9134	-16.2553	76.4291	124.0372	104.8406	50.7895	-8.2329
45.1466	28.4229	2.7440	1.0298	24.3953	52.6813	41.2375	-13.0719	-74.3834	-113.3740
-26.6862	-32.8644	-62.8344	-90.7690	-98.7158	-80.0600	-48.4845	-19.0314	9.7789	27.5468

observed residual gravity disturbance (mGal)

spherical radial basis function spatial curve

target residual disturbing gradient (E, R)

- After the first estimation is completed, it is recommended to employ the output residual observation file *.chs as the input residual observations file again to refine target field elements by cumulative SRBF approximation scheme. Typically, stable and high-precision solutions are achieved after accumulating just 1 to 2 SRBF approximation steps.
- Validity Principles for Single SRBF Approximation: (1) The target field element grid should remain spatially continuous and differentiable, and the standard deviation of residual observations in file *.chs is as small as possible. (2) As cumulative steps proceed, the statistical mean of the residual observations must converge toward zero without exhibiting significant sign reversals.
- Observations with zero weights can be extracted from the *.chs file (indicating they were excluded from the SRBF coefficient estimation) to determine and evaluate their external accuracy.

Table 4.26: Statistics of Reference Truth Model (Degrees 541 – 1800)

Field Element	Unit	Mean	Std. Dev.	Min	Max
Residual Geoidal Heights	m	-0.0020	0.1590	-0.8621	0.6546
Residual Gravity Disturbances	mGal	-0.4113	21.8940	-141.1997	112.4878

Table 4.27: Differences between SRBF Approximation and Reference Model

Observation Residuals	Target Residual Element	1st SRBF Approx.		2nd SRBF Approx.	
		Mean	Std. Dev.	Mean	Std. Dev.
Gravity Disturbance	Ground Height Anomaly (m)	0.0201	0.0185	0.0189	0.0162
Vertical Deflection		0.0058	0.0147	0.0058	0.0072
Disturbing Gradient		-0.0055	0.0202	-0.0056	0.0185
Height Anomaly	Ground Gravity Disturbance (mGal)	0.1731	1.4421	0.2075	1.4382
Vertical Deflection		0.3550	1.6905	0.3566	1.6845
Disturbing Gradient		0.0840	1.5780	0.0906	1.5298

Algorithm Performance: The approximation capability of the algorithm is quantified by the ratio of the standard deviation of the approximation errors (Table 4.27) to the standard deviation of the reference truth (Table 4.26).

Comparative analysis against traditional gravity field integration algorithms reveals that even a single-step SRBF approximation surpasses integration methods in accuracy.

All-element Gravity Field Modeling Using Multi-source Heterogeneous Data with SRBFs

Open Multi-source Heterogeneous Residual Observations File

number of rows of file header 1
 Ellipsoidal Height Column Index 6
 Observation Weight Column Index 7
 System Weight Column Index 8

Select SRBF radial multipole kernel

Order m 3
 Minimum degree 360
 Maximum degree 1800
 Burial depth of Bjerhammar sphere 10.0km
 Action distance of SBRF center 100km
 Reuter network level Q 1800

Open Computation Surface ellipsoidal Height grid File

>> Save the results as C:/PAGrav4.5_win64en/examples/SRBFheterogeneous/rgagr_ksi.txt.

** Record Format: Point ID, Lon, Lat, Height (m), Res. Grav. Dist. (mGal), Res. Height Anom. (m), Res. Grav. Anom. (mGal), Res. Grad. Radial (E), Res. V.D. South ("), Res. V.D. West (").

>> The program also outputs Heterogeneous Observation Residual File *.chs into the current directory. Header Format: Field Element Type (0 – 5), System Weight, Number of Observations (Group), Original Obs (Mean, StdDev, Min, Max); Residuals (Mean, StdDev, Min, Max).

** Record Format: Point ID/Station Name, Longitude, Latitude, Ellipsoidal height, Residual Value, Original Observation, Field Element Type, Observation Weight, Observation System Weight.

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] control button.

>> Computation start time: 2026-03-26 15:50:21

>> Complete the computation!

>> Computation end time: 2026-03-26 15:51:29

>> The program outputs Result All Residual Gravity Field Element Grid Files (Prefix * specs match input grid): Residual Gravity Disturbance (*.rga), Residual Height Anomaly (*.ksi), Residual Gravity Anomaly (*.gra), Residual Disturbing Gravity Gradient (*.grr), and Residual Vertical Deflection Vector (*.dft)

>> The program also outputs SRBF center file *center.txt into the current directory.

>> Observation Type 0 System Weight 1.000 Number of observations 12000

** Source observations: mean -0.4107 standard deviation 21.8478 minimum -140.9351 maximum 112.3153

** Residual observations: mean -0.0149 standard deviation 2.0457 minimum -53.9731 maximum 52.9464

>> Observation Type 3 System Weight 1.000 Number of observations 12000

** Source observations: mean -0.8635 standard deviation 38.2935 minimum -262.7565 maximum 232.6519

** Residual observations: mean -0.0490 standard deviation 4.1126 minimum -90.4115 maximum 78.2329

Observation: gravity disturbance +
disturbing gravity gradient

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(S,")
1	94.02500	30.02500	3984.353	-77.1825	-0.4406	-77.0471	-150.3665	-2.8223 -0.6840
2	94.07500	30.02500	4226.989	-74.7742	-0.4196	-74.6452	-145.9857	-3.3652 1.4543
3	94.12500	30.02500	4461.719	-47.0745	-0.2759	-46.8897	-86.5023	-3.6640 0.0702
4	94.17500	30.02500	4422.914	-15.5930	-0.1036	-15.3612	22.0351	-3.8390 0.9292
5	94.22500	30.02500	4335.893	-2.4854	-0.0121	-2.4817	3.0334	-3.0188 0.5979
6	94.27500	30.02500	4463.689	0.5039	0.0290	0.4850	0.7881	-1.9157 1.1147

Output all-element estimations of residual gravity field on the computation 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 residual observations file again to refine target field elements by cumulative SRBF approximation scheme. Typically, stable and high-precision solutions are achieved after accumulating just 1 to 2 SRBF approximation steps.

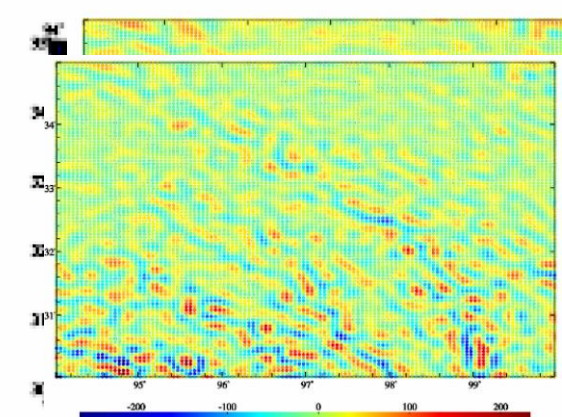
Validity Principles for Single SRBF Approximation: (1)The target field element grid should remain spatially continuous and differentiable, and the standard deviation of residual observations in file *.chs is as small as possible. (2) As cumulative steps proceed, the statistical mean of the residual observations must converge toward zero without exhibiting significant sign reversals.

Extract data to be plot

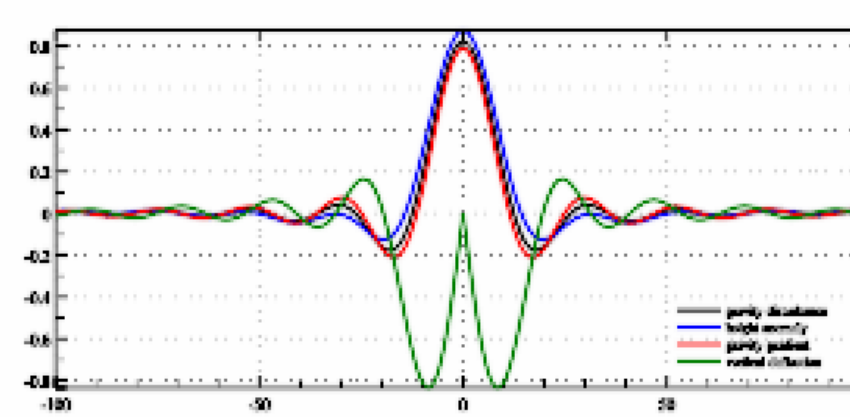
Plot →

Observations with zero observation weights or zero system weights can be extracted from the *.chs file (indicating they were excluded from the SRBF coefficient estimation) to determine and evaluate their external accuracy.

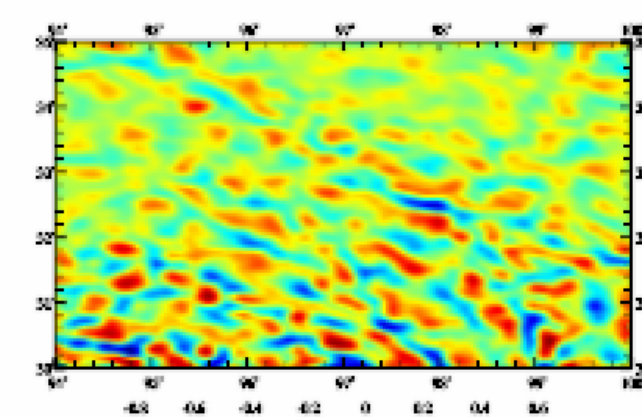
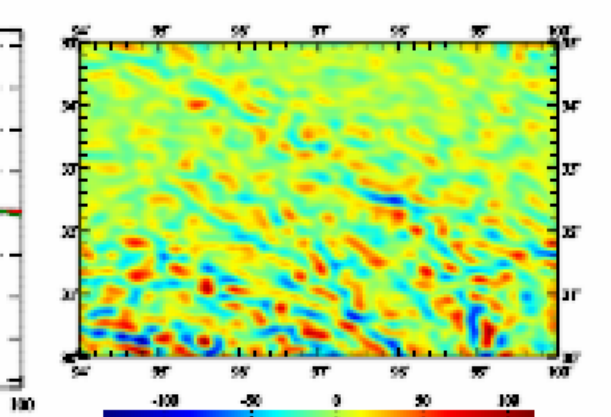
Spatial distribution of observations



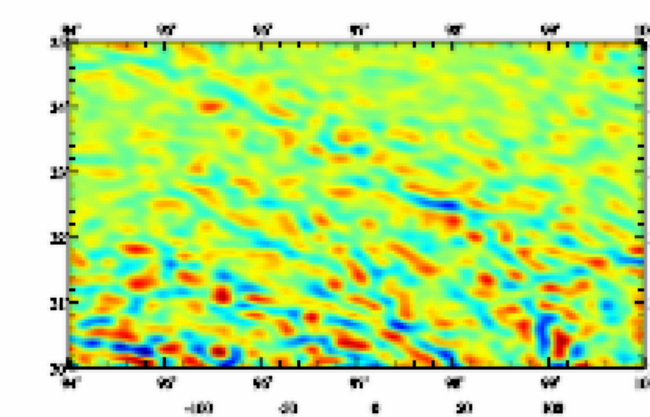
spherical radial basis function spatial curve



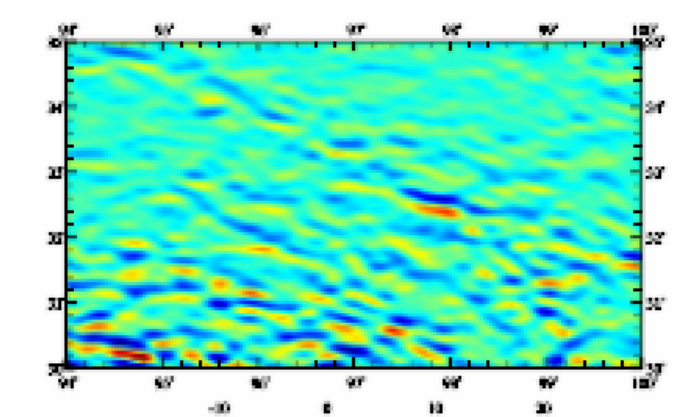
residual gravity disturbance (mGal)



residual height anomaly (m)



residual disturbing gradient (E)



residual vertical deflection S (")

All-element Gravity Field Modeling with SRBFs- cumulative SRBF approach

Open Multi-source Heterogeneous Residual Observations File

number of rows of file header 2
 Ellipsoidal Height Column Index 7
 Observation Weight Column Index 8
 System Weight Column Index 9

Select SRBF Poisson wavelet kernel

Order m 3
 Minimum degree 540
 Maximum degree 1800
 Burial depth of Bjerhammar sphere 6.0km
 Action distance of SBRF center 60km
 Reuter network level Q 3600

Open Computation Surface ellipsoidal Height grid File

>> Save the results as C:/PAGrav4.5_win64en/examples/SRBFheterogeneous/rgagr_ksi1.txt.

** Record Format: Point D, Lon, Lat, Height (m), Res. Grav. Dist. (mGal), Res. Height Anom. (m), Res. Grav. Anom. (mGal), Res. Grad. Radial (E), Res. V.D. South ("), Res. V.D. West (").

>> The program also outputs Heterogeneous Observation Residual File *.chs into the current directory. Header Format: Field Element Type (0 – 5), System Weight, Number of Observations (Group), Original Obs (Mean, StdDev, Min, Max); Residuals (Mean, StdDev, Min, Max).

** Record Format: Point D/Station Name, Longitude, Latitude, Ellipsoidal height, Residual Value, Original Observation, Field Element Type, Observation Weight, Observation System Weight.

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start] button.

>> Computation start time: 2026-03-26 15:54:44

>> Complete the computation!

>> Computation end time: 2026-03-26 15:57:03

>> The program outputs Result All Residual Gravity Field Element Grid Files (Prefix * specs match input grid): Residual Gravity Disturbance (*.rga), Residual Height Anomaly (*.ksi), Residual Gravity Anomaly (*.gra), Residual Disturbing Gravity Gradient (*.grg), and Residual Vertical Deflection Vector (*.dft)

>> The program also outputs SRBF center file *center.txt into the current directory.

>> Observation Type 0 System Weight 1.000 Number of observations 12000

** Source observations: mean -0.0149 standard deviation 2.0457 minimum -53.9731 maximum 52.9464

** Residual observations: mean -0.0046 standard deviation 0.8894 minimum -34.4709 maximum 16.1693

>> Observation Type 3 System Weight 1.000 Number of observations 12000

** Source observations: mean -0.0490 standard deviation 4.1126 minimum -90.4115 maximum 78.2329

** Residual observations: mean -0.0091 standard deviation 1.8594 minimum -66.0576 maximum 18.2884

Input the remaining residual file *.chs output by previous SRBF approach

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(S,")
1	94.02500	30.02500	3984.353	-2.4836	-0.0035	-2.4825	-8.9872	0.5849 1.0069
2	94.07500	30.02500	4226.989	2.6691	0.0184	2.6634	3.6244	1.2741 0.2913
3	94.12500	30.02500	4461.719	4.2047	0.0241	4.1973	7.7089	1.3746 0.6984
4	94.17500	30.02500	4422.914	-0.1919	0.0064	-0.1939	-3.7468	0.6048 -1.2965
5	94.22500	30.02500	4335.893	-1.8799	-0.0038	-1.8787	-6.0238	0.0455 0.6010
6	94.27500	30.02500	4463.689	-0.8672	-0.0040	-0.8659	-2.7805	-0.0567 0.4594

Output all-element estimations of residual gravity field on the computation 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 residual observations file again to refine target field elements by cumulative SRBF approximation scheme. Typically, stable and high-precision solutions are achieved after accumulating just 1 to 2 SRBF approximation steps.

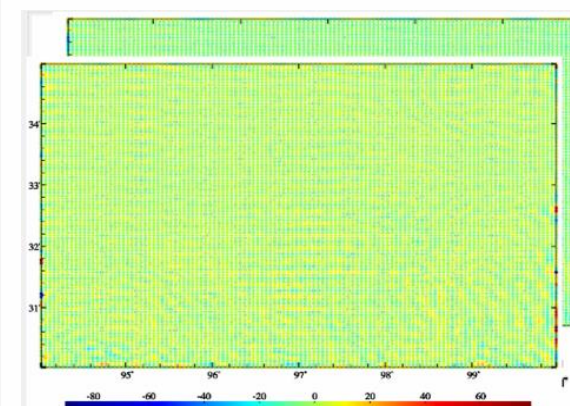
Validity Principles for Single SRBF Approximation: (1)The target field element grid should remain spatially continuous and differentiable, and the standard deviation of residual observations in file *.chs is as small as possible. (2) As cumulative steps proceed, the statistical mean of the residual observations must converge toward zero without exhibiting significant sign reversals.

Extract data to be plot

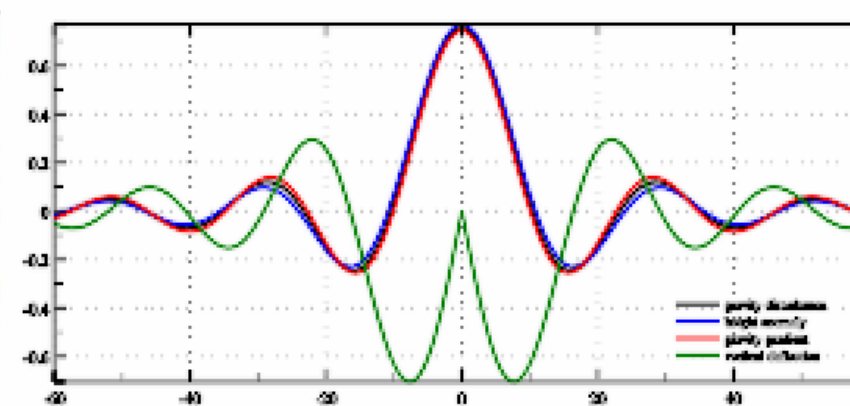
Plot →

Observations with zero observation weights or zero system weights can be extracted from the *.chs file (indicating they were excluded from the SRBF coefficient estimation) to determine and evaluate their external accuracy.

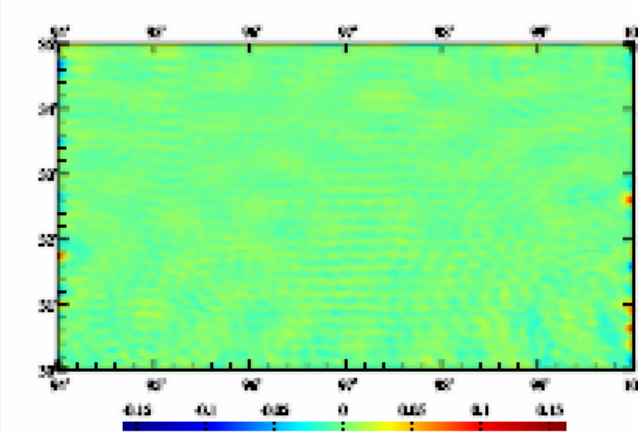
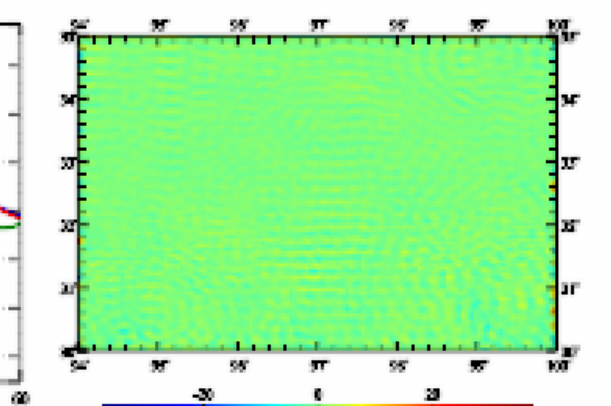
Spatial distribution of observations



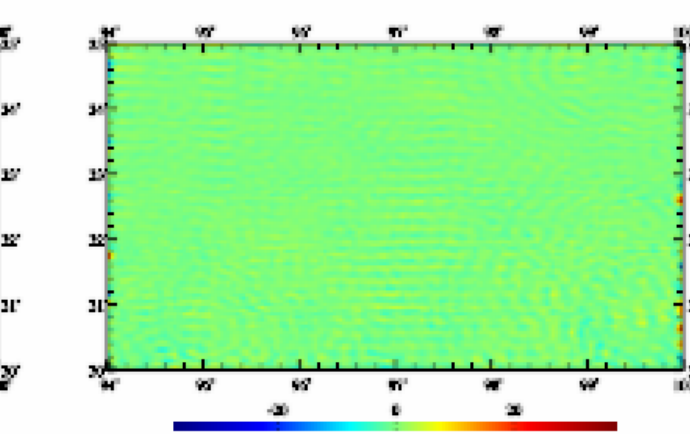
spherical radial basis function spatial curve



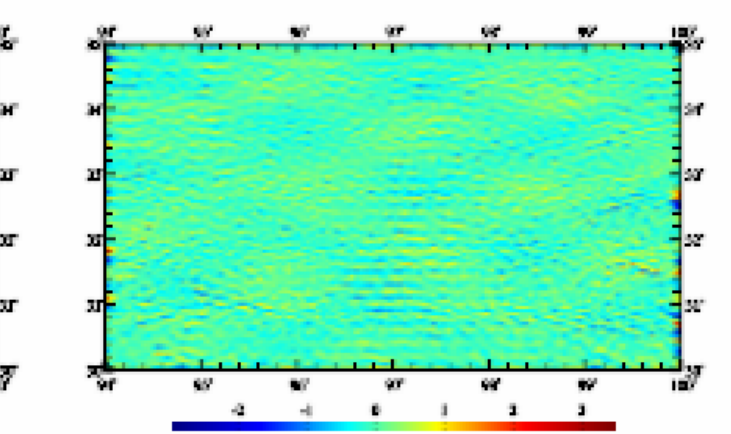
residual gravity disturbance (mGal)



residual height anomaly (m)



residual disturbing gradient (E)



residual vertical deflection S (")

All-element Gravity Field Modeling Using Multi-source Heterogeneous Data with SRBFs

Open Multi-source Heterogeneous Residual Observations File

number of rows of file header 1

Ellipsoidal Height Column Index 6

Observation Weight Column Index 7

System Weight Column Index 8

Select SRBF radial multipole kernel

Order m 3

Minimum degree 360

Maximum degree 1800

Burial depth of Bjerhammar sphere 10.0km

Action distance of SBRF center 100km

Reuter network level Q 1800

Open Computation Surface ellipsoidal Height grid File

>> The program also outputs Heterogeneous Observation Residual File *.chs into the current directory. Header Format: Field Element Type (0 – 5), System Weight, Number of Observations (Group), Original Obs (Mean, StdDev, Min, Max); Residuals (Mean, StdDev, Min, Max).
 ** Record Format: Point ID/Station Name, Longitude, Latitude, Ellipsoidal height, Residual Value, Original Observation, Field Element Type, Observation Weight, Observation System 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: 2026-03-26 16:00:10

>> Complete the computation!

>> Computation end time: 2026-03-26 16:01:39

>> The program outputs Result All Residual Gravity Field Element Grid Files (Prefix * specs match input grid): Residual Gravity Disturbance (*.rga), Residual Height Anomaly (*.ksi), Residual Gravity Anomaly (*.gra), Residual Disturbing Gravity Gradient (*.grr), and Residual Vertical Deflection Vector (*.dft)

>> The program also outputs SRBF center file *center.txt into the current directory.

>> Observation Type 0 System Weight 1.000 Number of observations 12000

** Source observations: mean -0.4107 standard deviation 21.8478 minimum -140.9351 maximum 112.3153

** Residual observations: mean -0.0748 standard deviation 2.1496 minimum -53.9731 maximum 52.9464

>> Observation Type 4 System Weight 1.000 Number of observations 12000

** Source observations: mean -0.0159 standard deviation 3.2930 minimum -19.5319 maximum 23.1114

** Residual observations: mean -0.0118 standard deviation 0.3797 minimum -9.0410 maximum 10.5513

>> Observation Type 5 System Weight 1.000 Number of observations 12000

** Source observations: mean -0.0098 standard deviation 3.1766 minimum -19.8241 maximum 17.6561

** Residual observations: mean -0.0021 standard deviation 0.2857 minimum -5.4896 maximum 6.1347

Observation: gravity disturbance
+ vertical deflection

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(S)
1	94.02500	30.02500	3984.353	-74.2232	-0.4258	-74.0924	-144.2746	-1.4992
2	94.07500	30.02500	4226.989	-70.1105	-0.3965	-69.9887	-136.1047	-2.3884
3	94.12500	30.02500	4461.719	-42.8068	-0.2539	-42.5289	-77.9105	-3.0800
4	94.17500	30.02500	4422.914	-12.7597	-0.0862	-12.7332	-17.1010	-3.3899
5	94.22500	30.02500	4335.893	-0.6512	0.0023	-0.6518	-0.2113	-2.8733
6	94.27500	30.02500	4463.689	2.7049	0.0452	2.6410	0.3265	-1.7001

Output all-element estimations of residual gravity field on the computation 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 residual observations file again to refine target field elements by cumulative SRBF approximation scheme. Typically, stable and high-precision solutions are achieved after accumulating just 1 to 2 SRBF approximation steps.

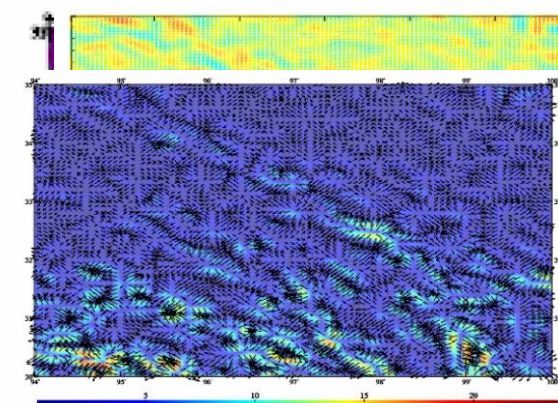
Validity Principles for Single SRBF Approximation: (1)The target field element grid should remain spatially continuous and differentiable, and the standard deviation of residual observations in file *.chs is as small as possible. (2) As cumulative steps proceed, the statistical mean of the residual observations must converge toward zero without exhibiting significant sign reversals.

Extract data to be plot

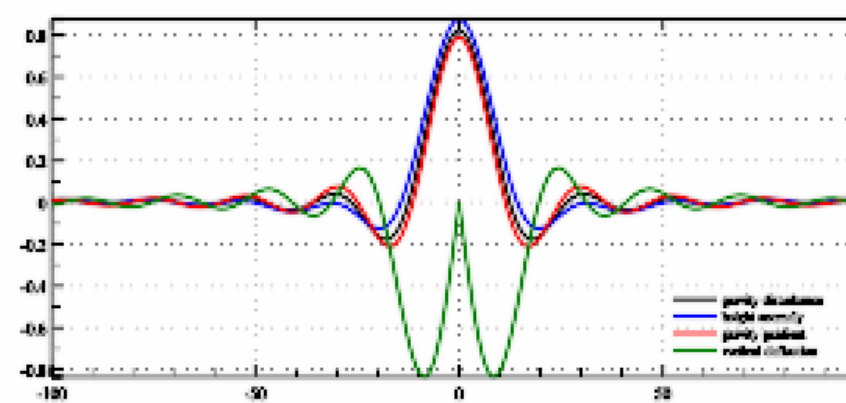
Plot →

Observations with zero observation weights or zero system weights can be extracted from the *.chs file (indicating they were excluded from the SRBF coefficient estimation) to determine and evaluate their external accuracy.

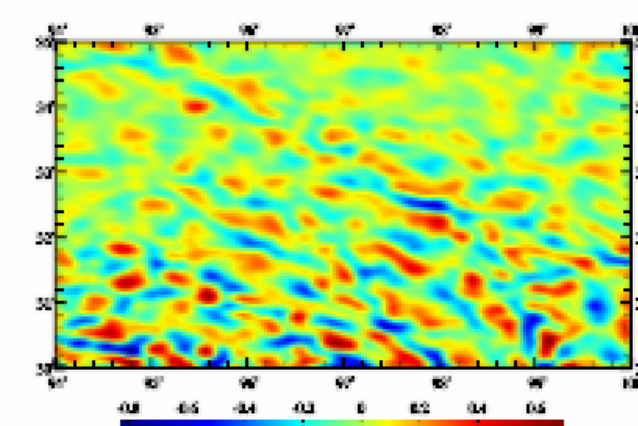
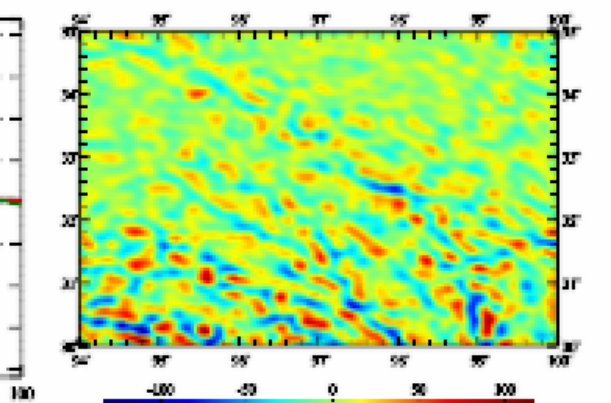
Spatial distribution of observations



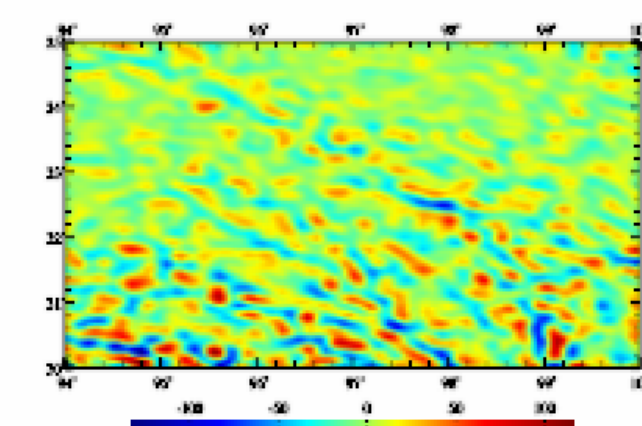
spherical radial basis function spatial curve



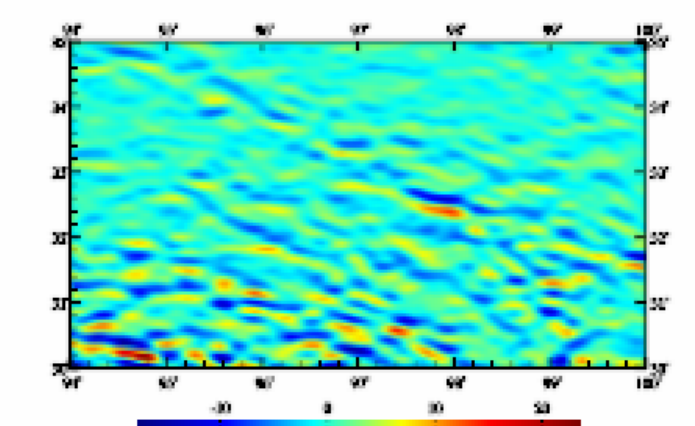
residual gravity disturbance (mGal)



residual height anomaly (m)



residual disturbing gradient (E)



residual vertical deflection S (")

All-element Gravity Field Modeling Using Multi-source Heterogeneous Data with SRBFs

Open Multi-source Heterogeneous Residual Observations File

number of rows of file header 1
Ellipsoidal Height Column Index 6
Observation Weight Column Index 7
System Weight Column Index 8

Select SRBF radial multipole kernel

Order m 3
Minimum degree 360
Maximum degree 1800
Burial depth of Bjerhammar sphere 10.0km
Action distance of SBRF center 100km
Reuter network level Q 1800

Open Computation Surface ellipsoidal Height grid File

>> Computation start time: 2026-03-26 16:05:24

>> Complete the computation!

>> Computation end time: 2026-03-26 16:07:28

>> The program outputs Result All Residual Gravity Field Element Grid Files (Prefix: specs match input grid): Residual Gravity Disturbance (*.rga), Residual Height Anomaly (*.ksi), Residual Gravity Anomaly (*.gra), Residual Disturbing Gravity Gradient (*.grr), and Residual Vertical Deflection Vector (*.dft)

>> The program also outputs SRBF center file *center.txt into the current directory.

>> Observation Type 0 System Weight 1.000 Number of observations 12000
** Source observations: mean -0.4107 standard deviation 21.8478 minimum -140.9351 maximum 112.3153
** Residual observations: mean -0.0605 standard deviation 2.0780 minimum -53.9731 maximum 52.9464
>> Observation Type 4 System Weight 1.000 Number of observations 12000
** Source observations: mean -0.0159 standard deviation 3.2930 minimum -19.5319 maximum 23.1114
** Residual observations: mean -0.0131 standard deviation 0.4016 minimum -9.0135 maximum 10.5513
>> Observation Type 5 System Weight 1.000 Number of observations 12000
** Source observations: mean -0.0098 standard deviation 3.1766 minimum -19.8241 maximum 17.6561
** Residual observations: mean -0.0006 standard deviation 0.2998 minimum -5.4896 maximum 6.1347
>> Observation Type 3 System Weight 1.000 Number of observations 12000
** Source observations: mean -0.8635 standard deviation 38.2935 minimum -262.7565 maximum 232.6519
** Residual observations: mean -0.1550 standard deviation 4.8631 minimum -90.4115 maximum 78.2329
>> Observation Type 1 System Weight 1.000 Number of observations 12000
** Source observations: mean -0.0020 standard deviation 0.1590 minimum -0.8621 maximum 0.6546
** Residual observations: mean 0.0003 standard deviation 0.0153 minimum -0.3763 maximum 0.4258

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(S)
1	94.02500	30.02500	3984.353	-75.3080	-0.4302	-75.1758	-146.8345	-1.8472
2	94.07500	30.02500	4226.989	-71.5472	-0.4018	-71.4237	-139.5876	-2.6240
3	94.12500	30.02500	4461.719	-43.7214	-0.2566	-43.5425	-80.1711	-3.1808
4	94.17500	30.02500	4422.914	-12.6373	-0.0841	-12.6114	-16.8881	-5.4288
5	94.22500	30.02500	4335.893	0.0479	0.0075	0.0456	-1.0237	-2.9855
6	94.27500	30.02500	4463.689	3.2054	0.0506	3.1999	-0.8232	-1.8272

Output all-element estimations of residual gravity field on the computation surface



Algorithm of gravity field approach using SRBFs

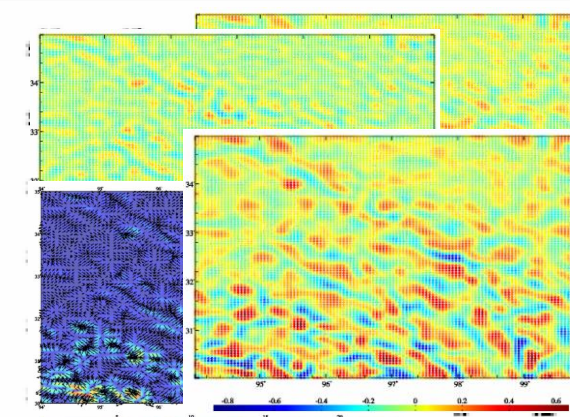
- After the first estimation is completed, it is recommended to employ the output residual observation file *.chs as the input residual observations file again to refine target field elements by cumulative SRBF approximation scheme. Typically, stable and high-precision solutions are achieved after accumulating just 1 to 2 SRBF approximation steps.
- Validity Principles for Single SRBF Approximation: (1)The target field element grid should remain spatially continuous and differentiable, and the standard deviation of residual observations in file *.chs is as small as possible. (2) As cumulative steps proceed, the statistical mean of the residual observations must converge toward zero without exhibiting significant sign reversals.

Extract data to be plot

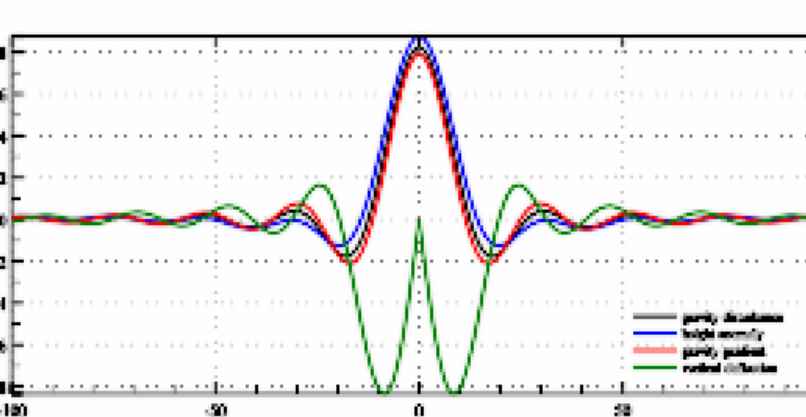
Plot →

- Observations with zero observation weights or zero system weights can be extracted from the *.chs file (indicating they were excluded from the SRBF coefficient estimation) to determine and evaluate their external accuracy.

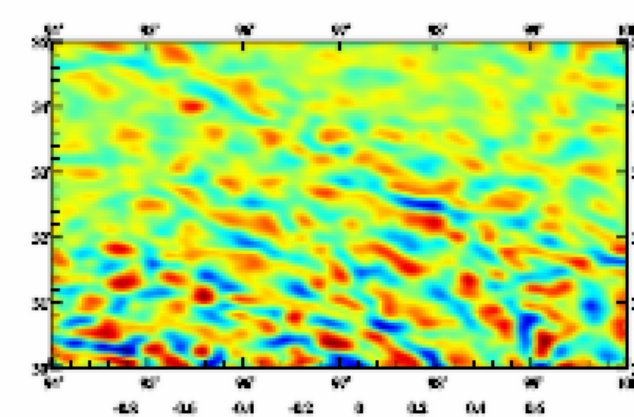
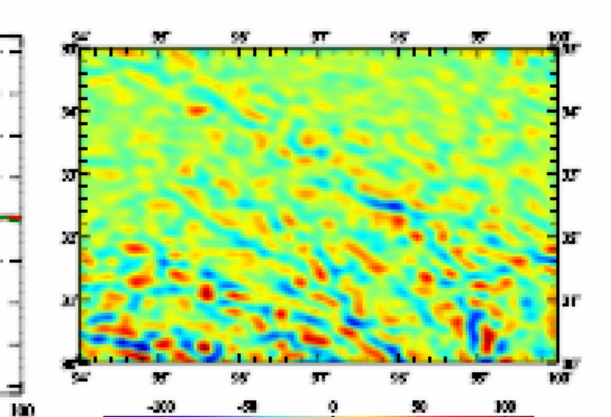
Spatial distribution of observations



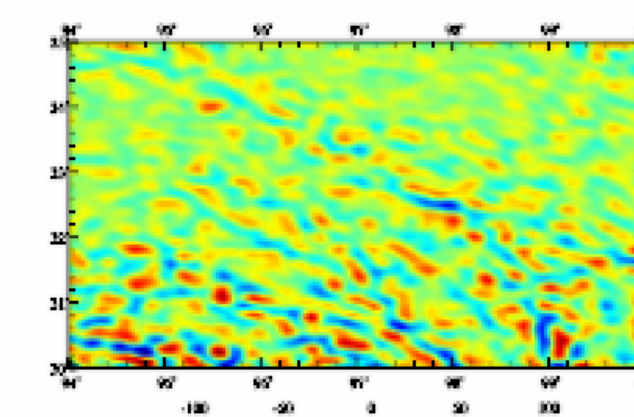
spherical radial basis function spatial curve



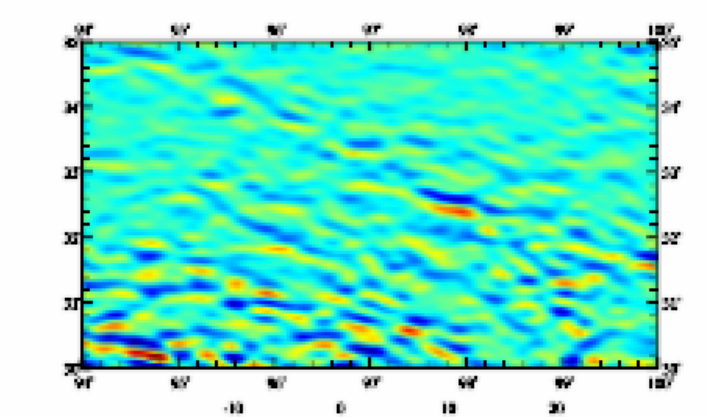
residual gravity disturbance (mGal)



residual height anomaly (m)



residual disturbing gradient (E)



residual vertical deflection S (")

Table 4.28: Statistics of Reference Truth Model (Degrees 541 – 1800)

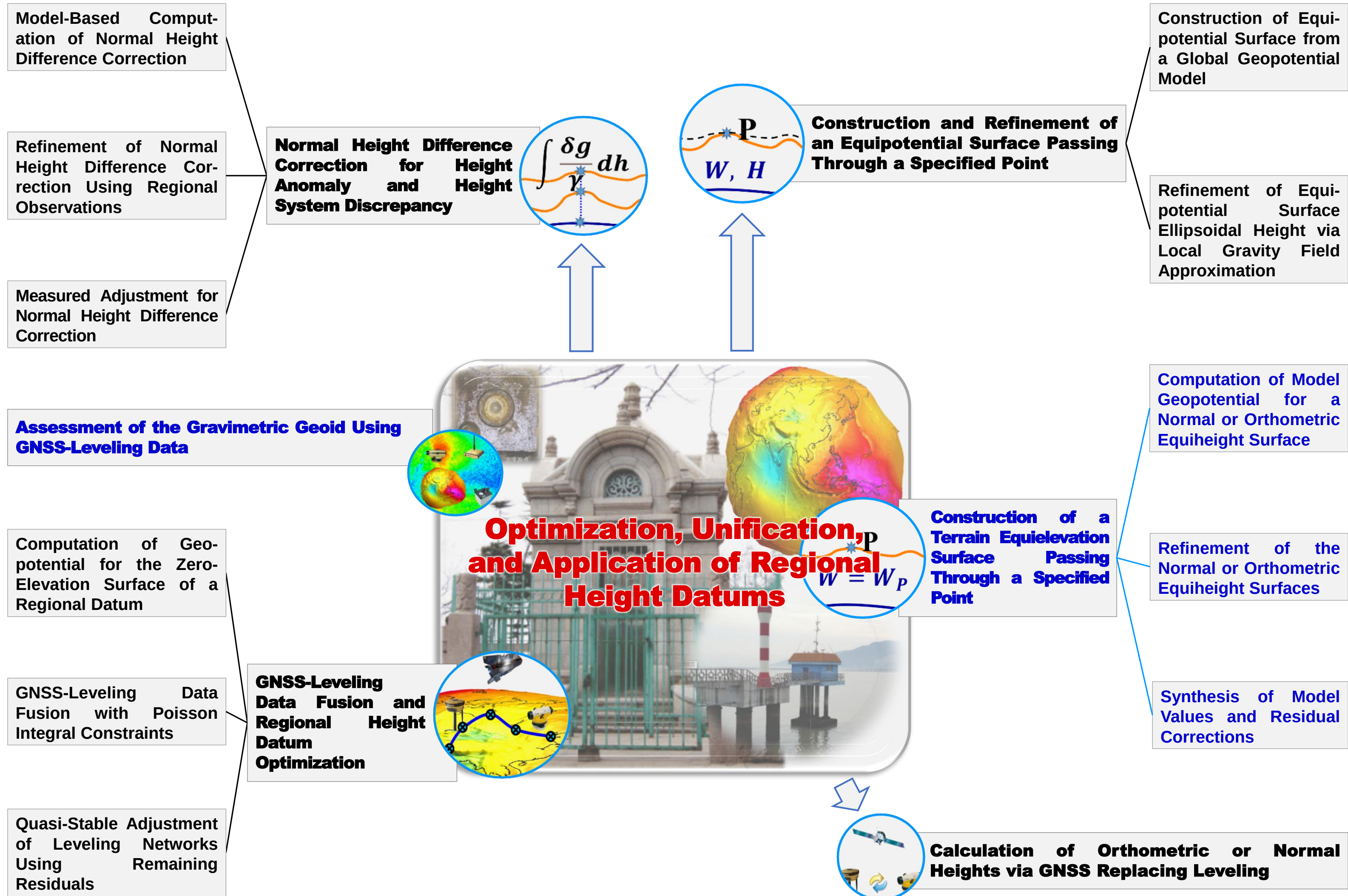
Field Element	Unit	Mean	Std. Dev.	Min	Max
Residual Geoidal Heights	m	-0.0020	0.1590	-0.8621	0.6546

Table 4.29: Differences between SRBF Approximation and Reference Model

Residual Observations	Target Residual Element	1st SRBF Approx.		2nd SRBF Approx.	
		Mean	Std. Dev.	Mean	Std. Dev.
Gravity Disturbances	Ground Height Anomaly (m)	0.0023	0.0095	0.0005	0.0093
Geoidal Heights					
Gravity Disturbances	Ground Height Anomaly (m)	0.0036	0.0190	0.0031	0.0158
Disturbing Gradients					

Algorithm Performance: The approximation capability of the algorithm is quantified by the ratio of the standard deviation of the approximation errors (Table 4.29) to the standard deviation of the reference truth (Table 4.28).

Multi-source fusion combined with a second approximation iteration further reduces standard deviations, enhancing overall accuracy.



Model-Based Computation of Normal Height Difference Correction

Model-Based Computation of Normal Height Difference Correction

Refinement of Normal Height Difference Correction Using Regional Observations

Measured Adjustment for Normal Height Difference Correction

Analytical Functional Relationship between Orthometric and Normal Heights

Open Space Computation Point File

Set input point file format

number of rows of file header 1

Current Ellipsoidal Height Column Index 4

Target Ellipsoidal Height Column Index 5

Open Global Geopotential Coefficient File

Maximum calcomputation degree for the geopotential model 360

>> Computation Process ** Operation Prompts

>> [Function] Computes the model radial gradient (cm/km) of height anomaly and model normal height difference correction (m) using the ellipsoidal heights of the current point and target point in near-Earth space. The computations are based on a reference global geopotential model.

>> Open Space Computation Point File C:/PAGrav4.5_win64en/examples/AppHgtsysdifferent/calcpnt.txt.

** Look at the file information in the window below, set the input file format parameters...

>> Open Global Geopotential Coefficient File C:/PAGrav4.5_win64en/data/EGM2008.gfc.

** The window below only shows the geopotential coefficients data with no more than 2000 rows in it

>> Save the results as C:/PAGrav4.5_win64en/examples/AppHgtsysdifferent/mdldiffst.txt.

** Appends two columns to the source file: Radial Gradient of Height Anomaly (cm/km), and Model Normal Height Difference Correction (m).

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-15 08:43:38

>> Complete to Calculate the model height difference correction of height anomaly!

>> Computation end time: 2026-04-15 08:46:23

Save the results as

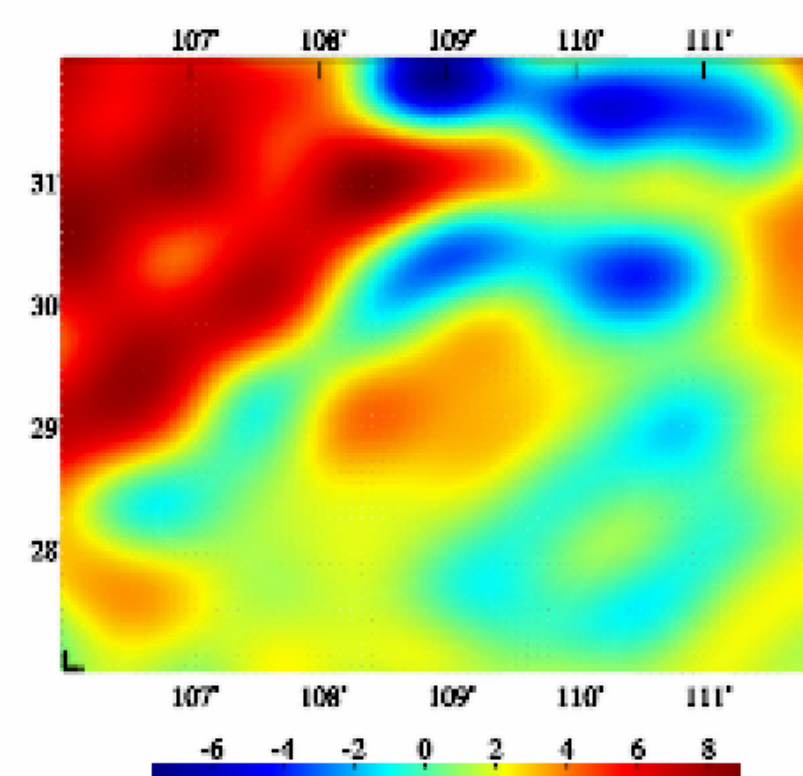
Import setting parameters

Start Computation

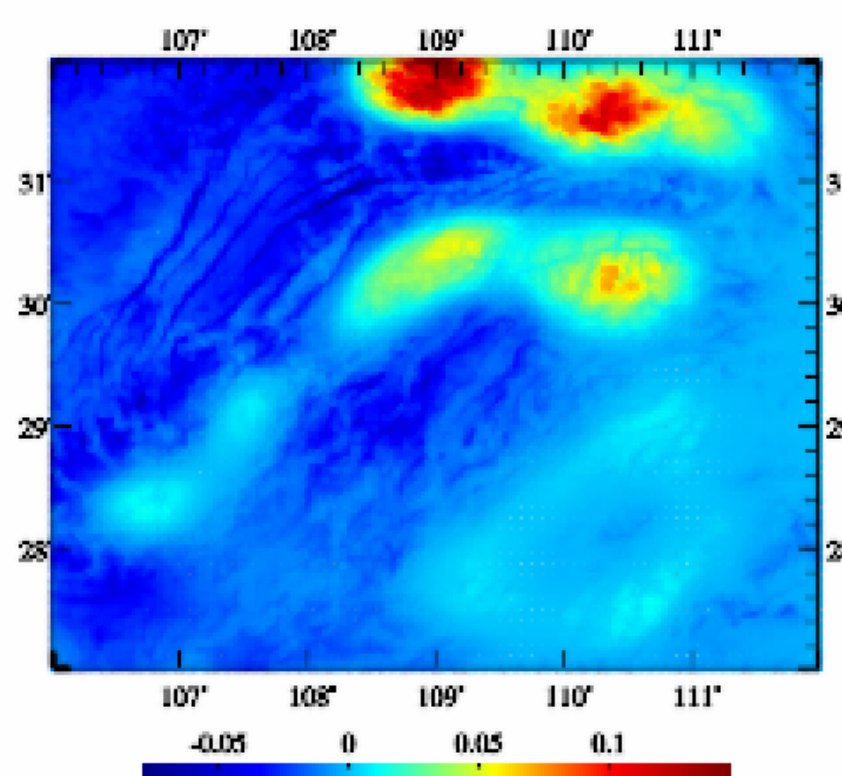
no	lon(degree/decimal)	lat	ellipHeight(m)	geoidheight(m)		
11569	106.020833	27.020833	1217.221	-30.8082	0.6721	-0
11570	106.062500	27.020833	1201.227	-30.8052	0.8284	-0
11571	106.104167	27.020833	1185.247	-30.7849	0.9847	-0
11572	106.145833	27.020833	1210.287	-30.7411	1.1368	-0
11573	106.187500	27.020833	1228.340	-30.6802	1.2800	-0
11574	106.229167	27.020833	1247.396	-30.6183	1.4102	-0
11575	106.270833	27.020833	1244.440	-30.5729	1.5240	-0
11576	106.312500	27.020833	1199.469	-30.5503	1.6184	-0
11577	106.354167	27.020833	1183.494	-30.5360	1.6906	-0
11578	106.395833	27.020833	1109.535	-30.4998	1.7396	-0
11579	106.437500	27.020833	1000.613	-30.4157	1.7646	-0
11580	106.479167	27.020833	1135.735	-30.2841	1.7631	-0
11581	106.520833	27.020833	1249.869	-30.1357	1.7393	-0
11582	106.562500	27.020833	1251.986	-30.0096	1.6959	-0
11583	106.604167	27.020833	1289.077	-29.9216	1.6347	-0
11584	106.645833	27.020833	1292.154	-29.8523	1.5599	-0
11585	106.687500	27.020833	1228.242	-29.7662	1.4754	-0
11586	106.729167	27.020833	1211.352	-29.6471	1.3857	-0
11587	106.770833	27.020833	1339.471	-29.5138	1.2962	-0

Extract correction

Plot



model radial gradient (km/cm)



model height anomaly correction (m)

When the current point is on the ground and the target point is on the geoid, the output represents the difference between Normal Height and Orthometric Height, which is numerically equivalent to the difference between Geoidal Height and Height Anomaly..

Height difference correction of height anomaly (m) = model correction, or model correction + residual correction, or model correction + residual correction + measured adjustment.

Radial gradient of height anomaly (cm/km) = model radial gradient, or model radial gradient+ residual radial gradient, or model radial gradient+ residual radial gradient + measured adjustment.

Refinement of Normal Height Difference Correction Using Regional Observations

Model-Based Computation of Normal Height Difference Correction

Refinement of Normal Height Difference Correction Using Regional Observations

Measured Adjustment for Normal Height Difference Correction

Analytical Functional Relationship between Orthometric and Normal Heights

Open Space Computation Point File

Set input point file format

number of rows of file header 1

Current Ellipsoidal Height Column Index 4

Target Ellipsoidal Height Column Index 5

Open Residual Gravity Disturbance Grid File

Open Equipotential Surface Ellipsoidal Height Grid File

Residual integral radius 150 km

>> Computation Process ** Operation Prompts

>> [Function] Computes the residual radial gradient (cm/km) of height anomaly at the computation point and the residual normal height difference correction (m) for the target point relative to the current point. This utilizes the ellipsoidal height grid of an equipotential surface and the corresponding residual gravity disturbance grid.

** Prerequisite: Residual gravity disturbances should locate on the equipotential boundary surface and be pre-computed via removing model gravity disturbances.

>> Open Space Computation Point File C:/PAGrav4.5_win64en/examples/AppHgtsysdifferent/mdldiffst.txt.

** Look at the file information in the window below, set the input file format parameters...

>> Open Residual Gravity Disturbance Grid File C:/PAGrav4.5_win64en/examples/AppHgtsysdifferent/dwmchrga.dat.

>> Open Equipotential Surface Ellipsoidal Height Grid File C:/PAGrav4.5_win64en/examples/AppHgtsysdifferent/dwmhgt150s.dat.

>> Save the results as C:/PAGrav4.5_win64en/examples/AppHgtsysdifferent/rntdiffst.txt.

** Appends two columns to the source file: Residual Radial Gradient, and Residual Normal Height Difference Correction.

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-15 08:50:21

>> Complete to Calculate residual height difference correction of height anomaly!

>> Computation end time: 2026-04-15 08:51:25

Save the results as

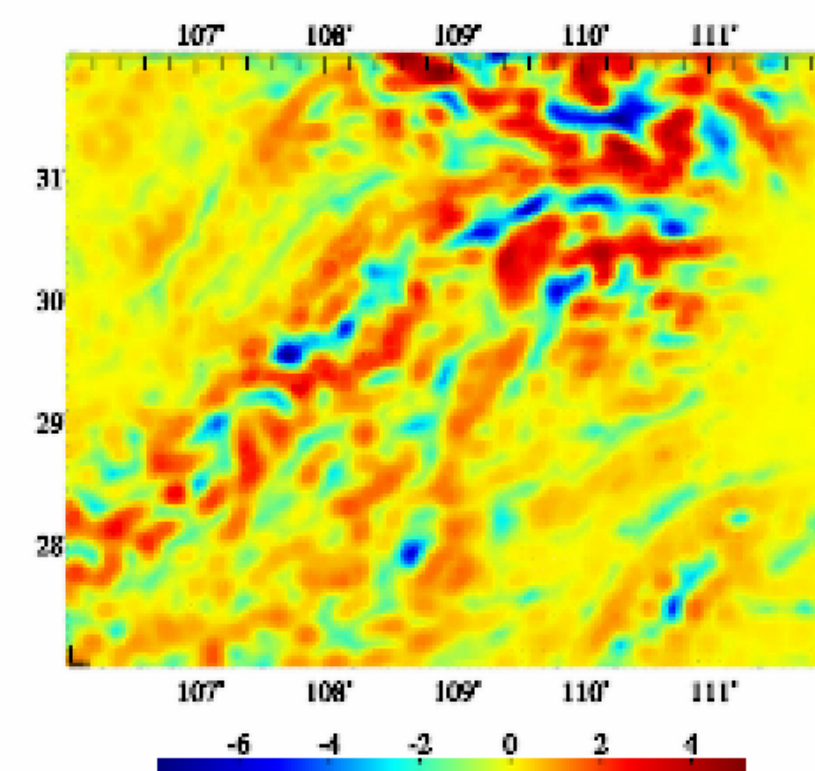
Import setting parameters

Start Computation

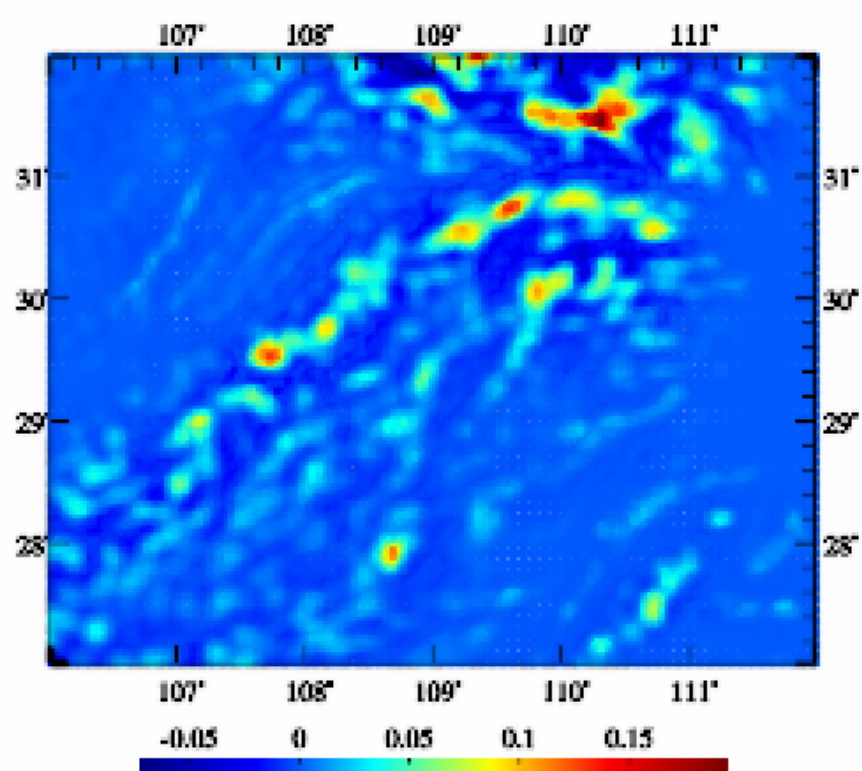
lipHeight (m)	geoidheight (m)				
0833	1217.221	-30.8082	0.6721	-0.0084	1.0239
0833	1201.227	-30.8052	0.8284	-0.0102	1.1014
0833	1185.247	-30.7849	0.9847	-0.0120	1.0145
0833	1210.287	-30.7411	1.1368	-0.0141	0.7312
0833	1228.340	-30.6802	1.2800	-0.0161	0.3232
0833	1247.396	-30.6183	1.4102	-0.0180	-0.0278
0833	1244.440	-30.5729	1.5240	-0.0194	-0.1268
0833	1199.469	-30.5503	1.6184	-0.0199	0.0985
0833	1183.494	-30.5360	1.6906	-0.0205	0.4995
0833	1109.535	-30.4998	1.7396	-0.0198	0.7431
0833	1000.613	-30.4157	1.7646	-0.0182	0.5545
0833	1135.735	-30.2841	1.7631	-0.0206	-0.0312
0833	1249.869	-30.1357	1.7393	-0.0223	-0.7351
0833	1251.986	-30.0096	1.6959	-0.0217	-1.1215
0833	1289.077	-29.9216	1.6347	-0.0216	-1.0465
0833	1292.154	-29.8523	1.5599	-0.0206	-0.7523
0833	1228.242	-29.7662	1.4754	-0.0186	-0.6524
0833	1211.352	-29.6471	1.3857	-0.0172	-0.9550
0833	1339.471	-29.5138	1.2962	-0.0177	-1.4728

Extract correction

Plot



residual radial gradient (km/cm)



height anomaly correction residual (m)

When the current point is on the ground and the target point is on the geoid, the output represents the difference between Normal Height and Orthometric Height, which is numerically equivalent to the difference between Geoidal Height and Height Anomaly..

Height difference correction of height anomaly (m) = model correction, or model correction + residual correction, or model correction + residual correction + measured adjustment.

Radial gradient of height anomaly (cm/km) = model radial gradient, or model radial gradient+ residual radial gradient, or model radial gradient+ residual radial gradient + measured adjustment.

Measured Adjustment for Normal Height Difference Correction

Computation points Save as Import parameters Start Computation Save process Follow example



Model-Based Computation of Normal Height Difference Correction



Refinement of Normal Height Difference Correction Using Regional Observations



Measured Adjustment for Normal Height Difference Correction



Analytical Functional Relationship between Orthometric and Normal Heights

Open Space Computation Point File

>> Computation Process ** Operation Prompts



Save computation process as

Set input point file format

number of rows of file header 1

Current Ellipsoidal Height Column Index 4

Target Ellipsoidal Height Column Index 5

Measured Remaining Residual Gravity Disturbance Column Index 6

>> Complete to Calculate residual height difference correction of height anomaly!

>> Computation end time: 2026-04-15 08:58:03

>> [Function] Sequentially invokes the previous two functions to derive the measured remaining residual measured gravity disturbance: $\delta_{grem} = \delta_{gobs} - \delta_{gmodel} - \delta_{gresidual}$. Then calculates the 'measured adjustment' for the radial gradient (cm/km) of height anomaly and the normal height difference correction (m). This step further refines the solution when in-situ gravity observation δ_{gobs} is available.

>> Open Space Computation Point File C:/PAGravf4.5_win64en/examples/AppHgtsysdifferent/calcpnt1.txt.

** Look at the file information in the window below, set the input file format parameters...

>> Save the results as C:/PAGravf4.5_win64en/examples/AppHgtsysdifferent/msrdiffadj.txt.

** Appends two columnsto the source file: Adjustment to Radial Gradient (cm/km), and Adjustment to Normal Height Difference Correction (m).

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-15 09:01:27

>> Complete to Calculate measured adjustment for height anomaly difference correction!

>> Computation end time: 2026-04-15 09:01:29



Save the results as



Import setting parameters

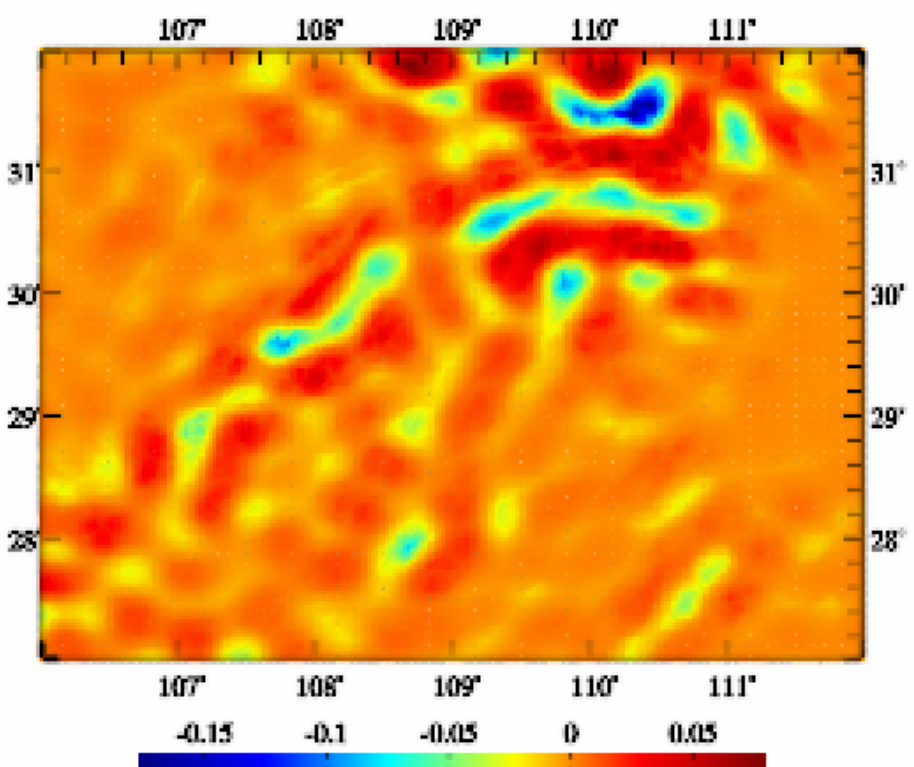
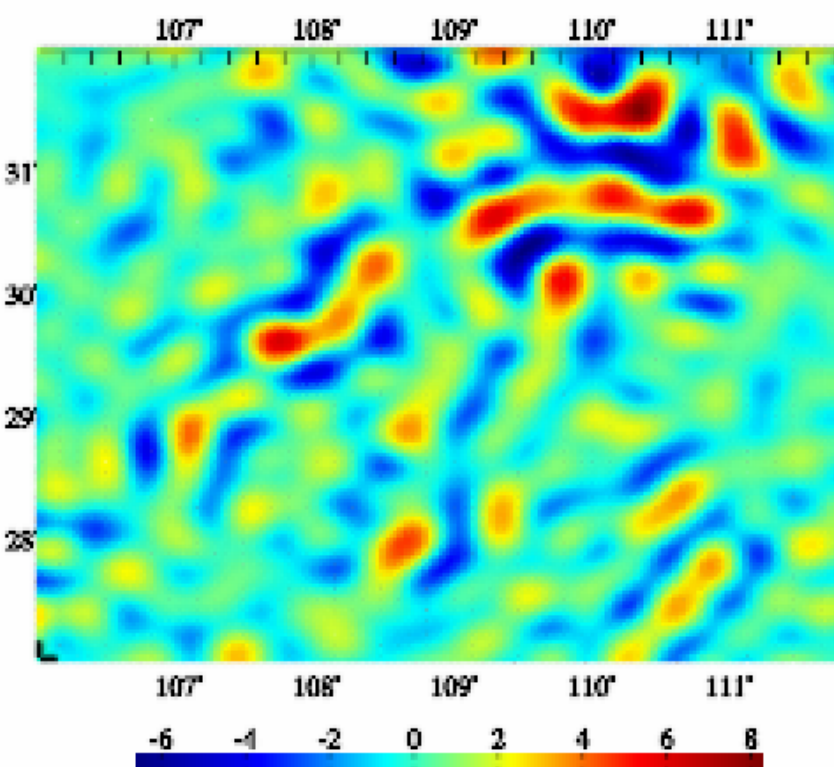


Start Computation

imal)	lat	ellipHeight (m)	geoidheight (m)			
0833	27.020833	1217.221	-30.8082	-2.9245	-0.2988	0.0037
2500	27.020833	1201.227	-30.8052	-3.4086	-0.3483	0.0043
4167	27.020833	1185.247	-30.7849	-4.4859	-0.4583	0.0056
5833	27.020833	1210.287	-30.7411	-5.8152	-0.5942	0.0074
7500	27.020833	1228.340	-30.6802	-7.0104	-0.7163	0.0090
9167	27.020833	1247.396	-30.6183	-7.7486	-0.7917	0.0101
0833	27.020833	1244.440	-30.5729	-7.8581	-0.8029	0.0102
2500	27.020833	1199.469	-30.5503	-7.3323	-0.7492	0.0092
4167	27.020833	1183.494	-30.5360	-6.2472	-0.6383	0.0077
5833	27.020833	1109.535	-30.4998	-4.8362	-0.4941	0.0056
7500	27.020833	1000.613	-30.4157	-3.2595	-0.3330	0.0034
9167	27.020833	1135.735	-30.2841	-1.5451	-0.1579	0.0018
0833	27.020833	1249.869	-30.1357	0.1969	0.0201	-0.0003
2500	27.020833	1251.986	-30.0096	2.0516	0.2096	-0.0027
4167	27.020833	1289.077	-29.9216	4.1339	0.4224	-0.0056
5833	27.020833	1292.154	-29.8523	6.4704	0.6611	-0.0087
7500	27.020833	1228.242	-29.7662	8.9864	0.9182	-0.0116
9167	27.020833	1211.352	-29.6471	11.3191	1.1565	-0.0144
0833	27.020833	1339.471	-29.5138	12.8393	1.3119	-0.0180

Extract correction

Plot↓



measured adjusment (km/cm) for radial gradient measured adjustment (m) for height anomaly correction

When the current point is on the ground and the target point is on the geoid, the output represents the difference between Normal Height and Orthometric Height, which is numerically equivalent to the difference between Geoidal Height and Height Anomaly..

Height difference correction of height anomaly (m) = model correction, or model correction + residual correction, or model correction + residual correction + measured adjustment.

Radial gradient of height anomaly (cm/km) = model radial gradient, or model radial gradient+ residual radial gradient, or model radial gradient+ residual radial gradient + measured adjustment.

Construction of Equipotential Surface from a Global Geopotential Model



Construction of Equipotential Surface
from a Global Geopotential Model



Refinement of Equipotential Surface Ellipsoidal Height
via Local Gravity Field Approximation



Save computation process as



Open Equipotential Surface Grid Extent File



Open Global Geopotential Coefficient File

Input geodetic coordinates of the specified point

longitude	110.24560000°
latitude	27.46720000°
ellipsoidal height	1346.0240 m

Maximum computation degree 360



Save the model gravity grid as



Save model ellipsoidal height as



Import setting parameters



Start Computation



Extract results



Plot↓

>> [Purpose] To first compute the model ellipsoidal height of a gravity equipotential surface from a reference global geopotential model, and subsequently refine this surface's ellipsoidal height grid using anomalous field elements via the remove-restore scheme.

** Select the computation function from the two control buttons at the top left of the interface...

>> [Function] Computes the model gravity (mGal) and model ellipsoidal height (m) grids for the equipotential surface passing through a specified point (B, L, H), based on a global geopotential coefficient model.

>> Open Equipotential Surface Grid Extent File C:/PAGravf4.5_win64en/examples/AppEquipotentialhgt/areagrid.dat.

>> Open Global Geopotential Coefficient 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

>> Save the model gravity grid as C:/PAGravf4.5_win64en/examples/AppEquipotentialhgt/eqpmdlgrav.dat.

>> Save model ellipsoidal height as C:/PAGravf4.5_win64en/examples/AppEquipotentialhgt/eqpmdlhgt.dat.

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

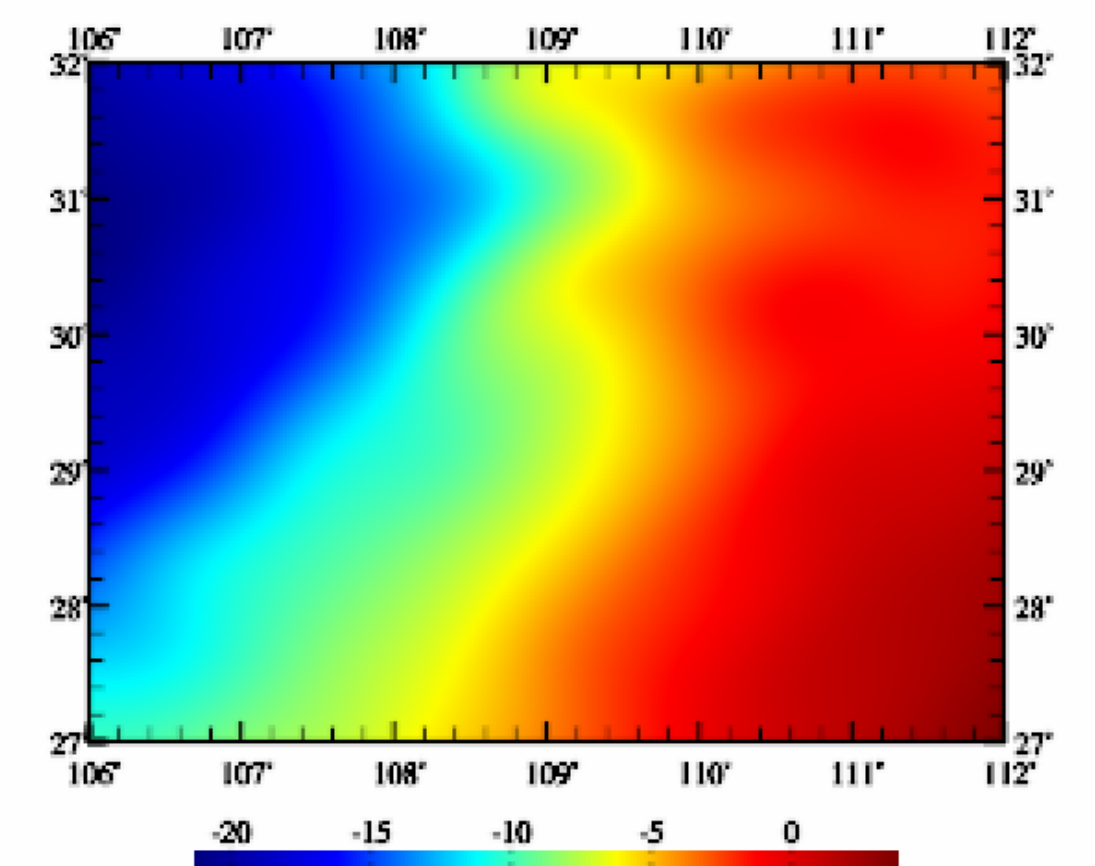
** The program needs to iteratively calculate the model ellipsoidal height grid of the equipotential surface, please wait...

>> Computation start time: 2026-04-15 09:27:58

>> Complete to compute the model equipotential surface!

>> Computation end time: 2026-04-15 09:35:31

106.000000	112.000000	27.000000	32.000000	0.04166667	0.04166667	110.245600	27.467200	1346
-10.0529	-10.0392	-10.0236	-10.0051	-9.9829	-9.9563	-9.9245	-9.8870	-9
-9.3656	-9.2779	-9.1876	-9.0958	-9.0034	-8.9112	-8.8202	-8.7311	-8
-8.1236	-8.0587	-7.9944	-7.9300	-7.8645	-7.7974	-7.7277	-7.6550	-7
-6.9202	-6.8099	-6.6966	-6.5808	-6.4632	-6.3442	-6.2243	-6.1039	-5
-5.1467	-5.0271	-4.9068	-4.7855	-4.6630	-4.5390	-4.4135	-4.2863	-4
-3.2228	-3.0881	-2.9540	-2.8210	-2.6891	-2.5586	-2.4296	-2.3020	-2
-1.3199	-1.1990	-1.0782	-0.9572	-0.8364	-0.7157	-0.5956	-0.4763	-0
0.3964	0.4892	0.5776	0.6616	0.7415	0.8176	0.8903	0.9602	1
1.5026	1.5788	1.6585	1.7421	1.8295	1.9208	2.0157	2.1139	2
2.9668	3.0750	3.1826	3.2896	3.3960	3.5020	3.6078	3.7138	3
-10.1508	-10.1392	-10.1255	-10.1090	-10.0889	-10.0642	-10.0344	-9.9988	-9
-9.4888	-9.4016	-9.3115	-9.2195	-9.1264	-9.0333	-8.9409	-8.8500	-8
-8.2166	-8.1476	-8.0794	-8.0110	-7.9419	-7.8712	-7.7983	-7.7226	-7
-6.9784	-6.8686	-6.7561	-6.6413	-6.5249	-6.4072	-6.2886	-6.1696	-6
-5.2172	-5.0969	-4.9755	-4.8528	-4.7286	-4.6026	-4.4747	-4.3449	-4
-3.2540	-3.1156	-2.9780	-2.8415	-2.7063	-2.5726	-2.4406	-2.3102	-2
-1.3138	-1.1921	-1.0706	-0.9492	-0.8281	-0.7073	-0.5871	-0.4679	-0
0.4000	0.4917	0.5788	0.6614	0.7398	0.8142	0.8851	0.9529	1



model ellipsoidal height (m)



Ellipsoidal Height = Grid Cell Value + 9th Parameter in File Header.

Refinement of Equipotential Surface Ellipsoidal Height via Local Gravity Field Approximation



Construction of Equipotential Surface
from a Global Geopotential Model



Refinement of Equipotential Surface Ellipsoidal Height
via Local Gravity Field Approximation



Save computation process as



Open Residual Gravity Disturbance Grid File



Open Equipotential Surface Ellipsoidal
Height Grid File

Input geodetic coordinates of the specified point

longitude	110.24560000°
latitude	27.46720000°
ellipsoidal height	1346.0240 m

Residual integral radius 150 km



Save the refined ellipsoidal height as



Import setting parameters



Start Computation

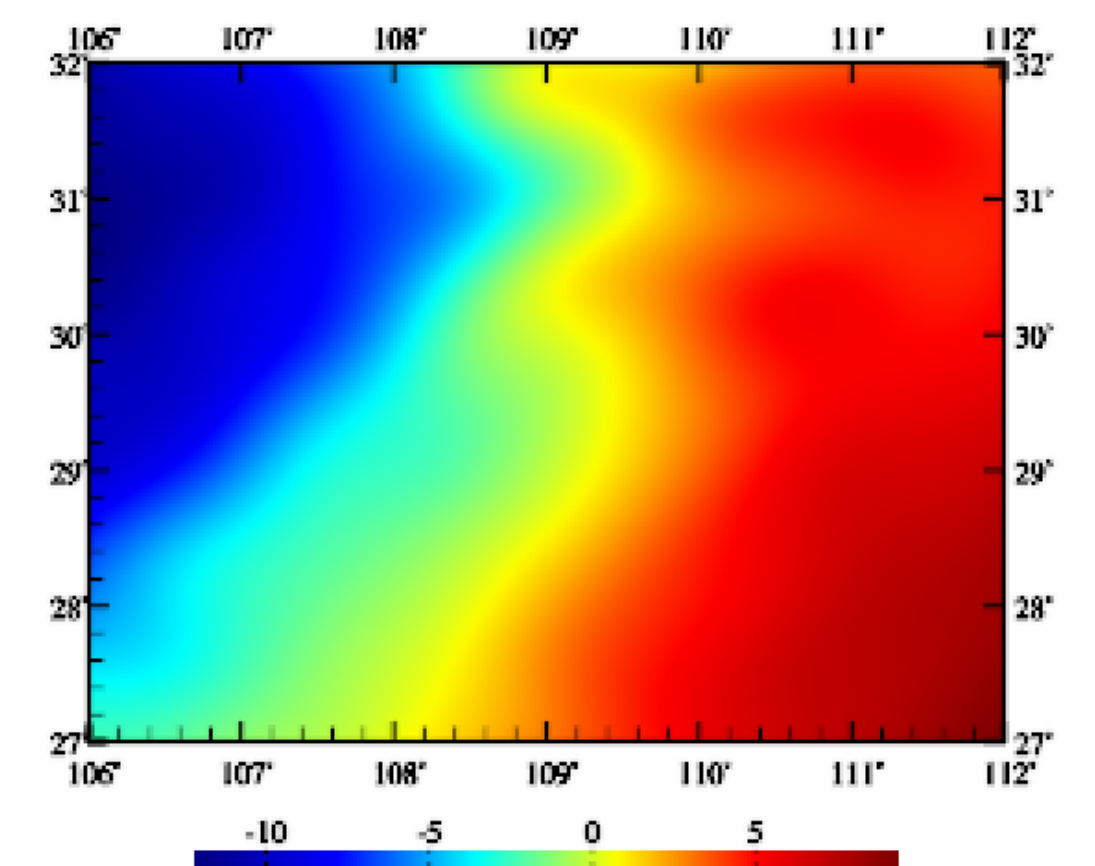


Extract results



Plot↓

106.000000	112.000000	27.000000	32.000000	0.04166667	0.04166667	110.245600	27.467200	1346
-2.3909	-2.3849	-2.3771	-2.3665	-2.3523	-2.3341	-2.3109	-2.2823	-2
-1.8412	-1.7644	-1.6851	-1.6043	-1.5230	-1.4421	-1.3625	-1.2848	-1
-0.7753	-0.7235	-0.6723	-0.6210	-0.5685	-0.5144	-0.4577	-0.3981	-0
0.2247	0.3198	0.4175	0.5175	0.6191	0.7219	0.8255	0.9295	1
1.7506	1.8525	1.9550	2.0583	2.1626	2.2682	2.3751	2.4835	2
3.3949	3.5108	3.6260	3.7403	3.8535	3.9654	4.0760	4.1854	4
5.0253	5.1288	5.2324	5.3363	5.4401	5.5440	5.6472	5.7497	5
6.4973	6.5761	6.6507	6.7211	6.7876	6.8503	6.9096	6.9662	7
7.4015	7.4642	7.5304	7.6004	7.6741	7.7516	7.8326	7.9169	8
8.6545	8.7478	8.8405	8.9325	9.0238	9.1145	9.2048	9.2951	9
-2.4770	-2.4730	-2.4671	-2.4585	-2.4465	-2.4302	-2.4091	-2.3825	-2
-1.9527	-1.8765	-1.7975	-1.7166	-1.6348	-1.5531	-1.4722	-1.3929	-1
-0.8590	-0.8032	-0.7483	-0.6933	-0.6375	-0.5800	-0.5203	-0.4578	-0
0.1732	0.2676	0.3644	0.4632	0.5634	0.6648	0.7671	0.8696	0
1.6860	1.7887	1.8923	1.9970	2.1030	2.2105	2.3197	2.4306	2
3.3679	3.4873	3.6059	3.7234	3.8398	3.9548	4.0683	4.1804	4
5.0344	5.1387	5.2429	5.3472	5.4513	5.5553	5.6587	5.7611	5
6.5030	6.5807	6.6541	6.7231	6.7881	6.8493	6.9070	6.9616	7



ellipsoidal height refined (m)



Ellipsoidal Height = Grid Cell Value + 9th Parameter in File Header.

Computation of Model Geopotential for a Normal or Orthometric Equipheight Surface

Grid extent Save as Import parameters Start Computation Save process Follow example

Computation of Model Geopotential for a Normal or Orthometric Equipheight Surface

Refinement of the Normal or Orthometric Equipheight Surface

Synthesis of Model Values and Residual Corrections

Save computation process as

Open Equipotential Surface Grid Extent File

Open Global Geopotential Coefficient File

Input coordinates of the specified point

Longitude 110.24560000°

Latitude 27.46720000°

Normal or orthometric height 1346.0240 m

Maximum computation degree 360

Height system normal height system

>> [Purpose] To first compute the model geopotential of an equipotential (normal or orthometric equipheight) surface from a reference global geopotential model, and subsequently refine this terrain equipotential surface using anomalous field elements via the remove-restore scheme.

** Select the computation function from the 3 control buttons at the top of the interface...

>> [Function] Computes the model geopotential, model ellipsoidal height (m), and model gravity (mGal) grids for the equipotential (normal or orthometric equipheight) surface passing through a specified point (B, L), based on a global geopotential coefficient model.

>> Open Equipotential Surface Grid Extent File C:/PAGrav4.5_win64en/examples/AppEquiphtpotential/areagrid.dat.

>> Open Global Geopotential Coefficient File C:/PAGrav4.5_win64en/data/EGM2008.gfc.

** The window below only shows the geopotential coefficients data with no more than 2000 rows in it

>> Save the model gravity grid as C:/PAGrav4.5_win64en/examples/AppEquiphtpotential/eqhgtmdlgrav.dat.

>> Save the model geopotential grid as C:/PAGrav4.5_win64en/examples/AppEquiphtpotential/eqhmpotential.dat.

>> Save the model ellipsoidal height as C:/PAGrav4.5_win64en/examples/AppEquiphtpotential/eqhgtmdlhgt.dat.

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

** The program needs to iteratively compute the model geopotential grid of the equipotential surface, please wait...

>> Computation start time: 2026-04-15 09:52:10

>> Complete to compute the model equipotential surface!

>> Computation end time: 2026-04-15 10:02:15

Save the model gravity grid as

Save the model geopotential grid as

Save model ellipsoidal height as

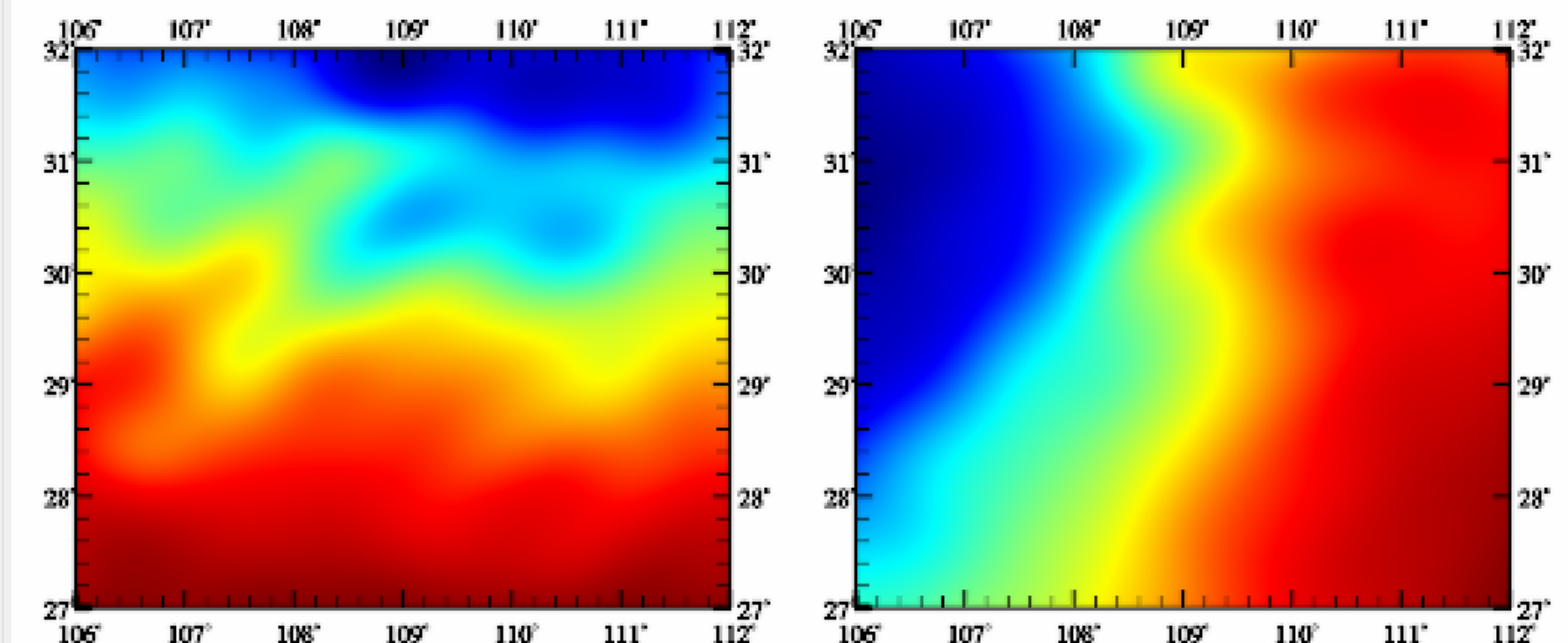
Import setting parameters

Start Computation

106.000000	112.000000	27.000000	32.000000	0.04166667	0.04166667
-47.0779	-48.5710	-50.0626	-51.5117	-52.8773	-54.1205
-55.6160	-54.8211	-53.9773	-53.1293	-52.3217	-51.5968
-53.7911	-54.8783	-56.0160	-57.1638	-58.2815	-59.3310
-61.6286	-61.0857	-60.4887	-59.8692	-59.2583	-58.6846
-57.8114	-58.0957	-58.3711	-58.6137	-58.8012	-58.9143
-54.9842	-54.2986	-53.6328	-53.0050	-52.4305	-51.9211
-50.1814	-50.1167	-50.0220	-49.8912	-49.7219	-49.5160
-48.2901	-48.6244	-49.0894	-49.6836	-50.3996	-51.2246
-59.9952	-60.3345	-60.5051	-60.5073	-60.3479	-60.0403
-54.5244	-54.3209	-54.2460	-54.2972	-54.4654	-54.7357
-43.9476	-45.5158	-47.0858	-48.6168	-50.0682	-51.4013
-53.8577	-53.1327	-52.3463	-51.5418	-50.7621	-50.0484
-51.4914	-52.4531	-53.4667	-54.4949	-55.5002	-56.4472
-58.5753	-58.0995	-57.5792	-57.0436	-56.5213	-56.0383
-55.7158	-55.9891	-56.2396	-56.4438	-56.5801	-56.6301
-51.6479	-50.8404	-50.0538	-49.3070	-48.6162	-47.9938
-45.3853	-45.2636	-45.1176	-44.9411	-44.7319	-44.4920
-43.3261	-43.7170	-44.2496	-44.9224	-45.7282	-46.6537
-56.7661	-57.2295	-57.5125	-57.6128	-57.5353	-57.2914
-51.3408	-51.0173	-50.8198	-50.7498	-50.8018	-50.9644
-40.9305	-42.5820	-44.2372	-45.8557	-47.3972	-48.8233

Extract results

Plot↓



model geopotential (m^2/s^2)

model ellipsoidal height (m)

Refinement of the Normal or Orthometric Equipheight Surface

Grid extent Save as Import parameters Start Computation Save process Follow example



Computation of Model Geopotential for a Normal or Orthometric Equipheight Surface



Refinement of the Normal or Orthometric Equipheight Surface



Synthesis of Model Values and Residual Corrections



Save computation process as



Open Equipotential Surface Ellipsoidal Height Grid File



Open Residual Gravity Disturbance Grid File

Input coordinates of the specified point

Longitude 110.24560000°

Latitude 27.46720000°

Normal or orthometric height 1346.0240 m

Residual integral radius 150 km

Height system normal height system

** Click the [Start Computation] control button, or the [Start Computation] tool button...

** The program needs to iteratively compute the model geopotential grid of the equipotential surface, please wait...

>> Computation start time: 2026-04-15 09:52:10

>> Complete to compute the model equipotential surface!

>> Computation end time: 2026-04-15 10:02:15

>> [Function] Refines the ellipsoidal height grid of the equipotential (normal or orthometric equipheight) surface passing through (B , L) using the Hotine Integral. Inputs include the ellipsoidal height of a chosen equipotential boundary surface, the residual gravity disturbance on that surface, and pre-calculated model grids.

** Methodology: Computes the residual geopotential correction and residual ellipsoidal height correction derived from residual gravity disturbances after removing reference model gravity disturbances.

>> Open Equipotential Surface Ellipsoidal Height Grid File C:/PAGravf4.5_win64en/examples/AppEquiphtpotential/dwmhgt150s.dat.

>> Open Residual Gravity Disturbance Grid File C:/PAGravf4.5_win64en/examples/AppEquiphtpotential/dwmchrga.dat.

>> Save geopotential correction grid as C:/PAGravf4.5_win64en/examples/AppEquiphtpotential/eqhpotentadj.dat.

>> Save ellipsoidal height corrections as C:/PAGravf4.5_win64en/examples/AppEquiphtpotential/eqhgtadj.dat.

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-15 10:05:05

>> Complete to refine the equipotential surface!

>> Computation end time: 2026-04-15 10:06:27



Save the geopotential corrections as



Save ellipsoidal height corrections as



Import setting parameters

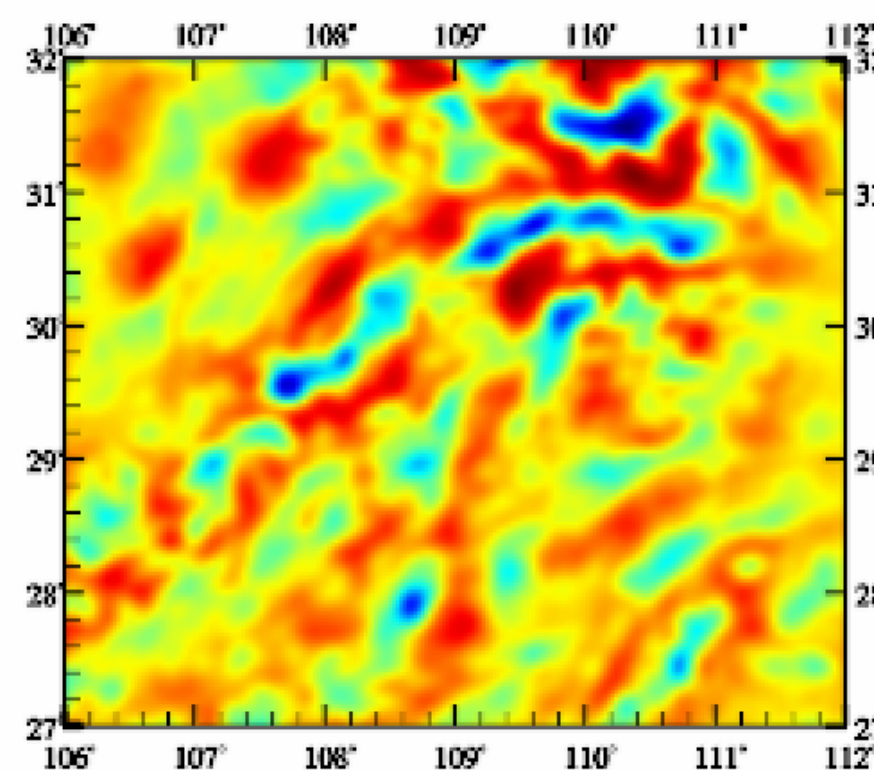


Start Computation

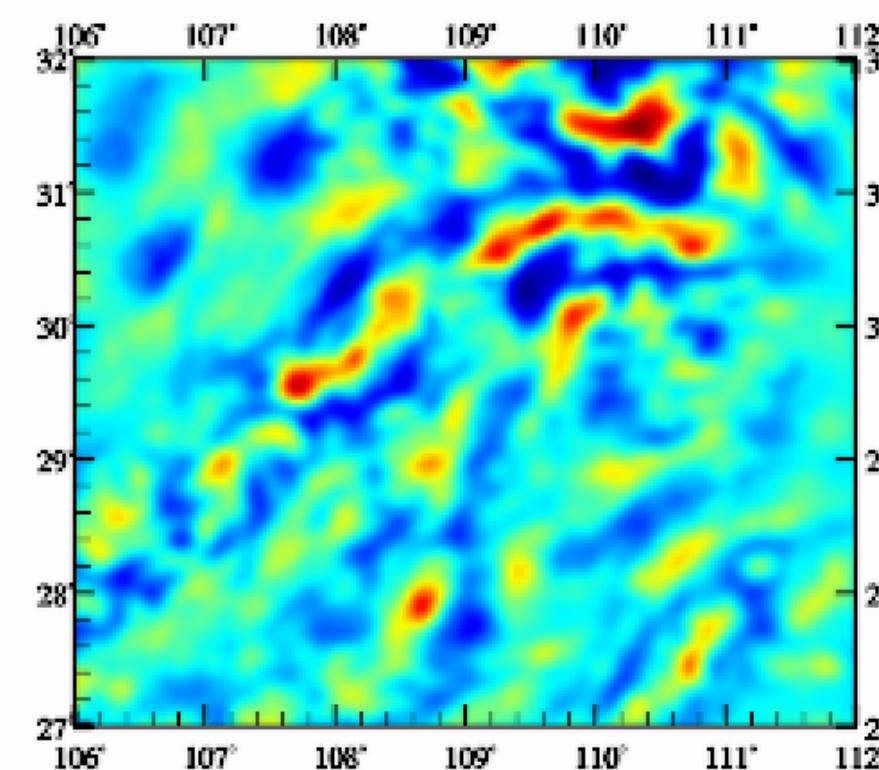
106.000000	112.000000	27.000000	32.000000	0.04166667	0.04166667
-47.0779	-48.5710	-50.0626	-51.5117	-52.8773	-54.1205
-55.6160	-54.8211	-53.9773	-53.1293	-52.3217	-51.5968
-53.7911	-54.8783	-56.0160	-57.1638	-58.2815	-59.3310
-61.6286	-61.0857	-60.4887	-59.8692	-59.2583	-58.6846
-57.8114	-58.0957	-58.3711	-58.6137	-58.8012	-58.9143
-54.9842	-54.2986	-53.6328	-53.0050	-52.4305	-51.9211
-50.1814	-50.1167	-50.0220	-49.8912	-49.7219	-49.5160
-48.2901	-48.6244	-49.0894	-49.6836	-50.3996	-51.2246
-59.9952	-60.3345	-60.5051	-60.5073	-60.3479	-60.0403
-54.5244	-54.3209	-54.2460	-54.2972	-54.4654	-54.7357
-43.9476	-45.5158	-47.0858	-48.6168	-50.0682	-51.4013
-53.8577	-53.1327	-52.3463	-51.5418	-50.7621	-50.0484
-51.4914	-52.4531	-53.4667	-54.4949	-55.5002	-56.4472
-58.5753	-58.0995	-57.5792	-57.0436	-56.5213	-56.0383
-55.7158	-55.9891	-56.2396	-56.4438	-56.5801	-56.6301
-51.6479	-50.8404	-50.0538	-49.3070	-48.6162	-47.9938
-45.3853	-45.2636	-45.1176	-44.9411	-44.7319	-44.4920
-43.3261	-43.7170	-44.2496	-44.9224	-45.7282	-46.6537
-56.7661	-57.2295	-57.5125	-57.6128	-57.5353	-57.2914
-51.3408	-51.0173	-50.8198	-50.7498	-50.8018	-50.9644
-40.9305	-42.5820	-44.2372	-45.8557	-47.3972	-48.8233

Extract results

Plot



residual geopotential (m^2/s^2)



residual ellipsoidal height (m)

Synthesis of Model Values and Residual Corrections

Grid extent Save as Import parameters Start Computation Save process Follow example



Computation of Model Geopotential for a Normal or Orthometric Equipotential Surface



Refinement of the Normal or Orthometric Equipotential Surface



Synthesis of Model Values and Residual Corrections



Save computation process as

Input coordinates of the specified point

Longitude 110.24560000°

Latitude 27.46720000°

Normal or orthometric height 1346.0240 m

Height system normal height system

** Methodology: Computes the residual geopotential correction and residual ellipsoidal height correction derived from residual gravity disturbances after removing reference model gravity disturbances.

>> Open Equipotential Surface Ellipsoidal Height Grid File C:/PAGrav4.5_win64en/examples/AppEquiphtpotential/dwmhgt150s.dat.

>> Open Residual Gravity Disturbance Grid File C:/PAGrav4.5_win64en/examples/AppEquiphtpotential/dwmchrga.dat.

>> Save geopotential correction grid as C:/PAGrav4.5_win64en/examples/AppEquiphtpotential/eqhpotentialadj.dat.

>> Save ellipsoidal height corrections as C:/PAGrav4.5_win64en/examples/AppEquiphtpotential/eqhgtdadj.dat.

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-15 10:05:05

>> Complete to refine the equipotential surface!

>> Computation end time: 2026-04-15 10:06:27

>> [Function] Generates the final refined values for the equipotential (normal or orthometric equipotential) surface by summing the model components and their respective corrections.

>> Save the geopotential grid as C:/PAGrav4.5_win64en/examples/AppEquiphtpotential/eqhpotentialrst.dat.

>> Save the ellipsoidal height grid as C:/PAGrav4.5_win64en/examples/AppEquiphtpotential/eqhgtrst.dat.

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-15 10:17:01

>> Complete summing the model and residuals!

>> Computation end time: 2026-04-15 10:17:01



Save the geopotential grid as



Save ellipsoidal height grid as



Import setting parameters

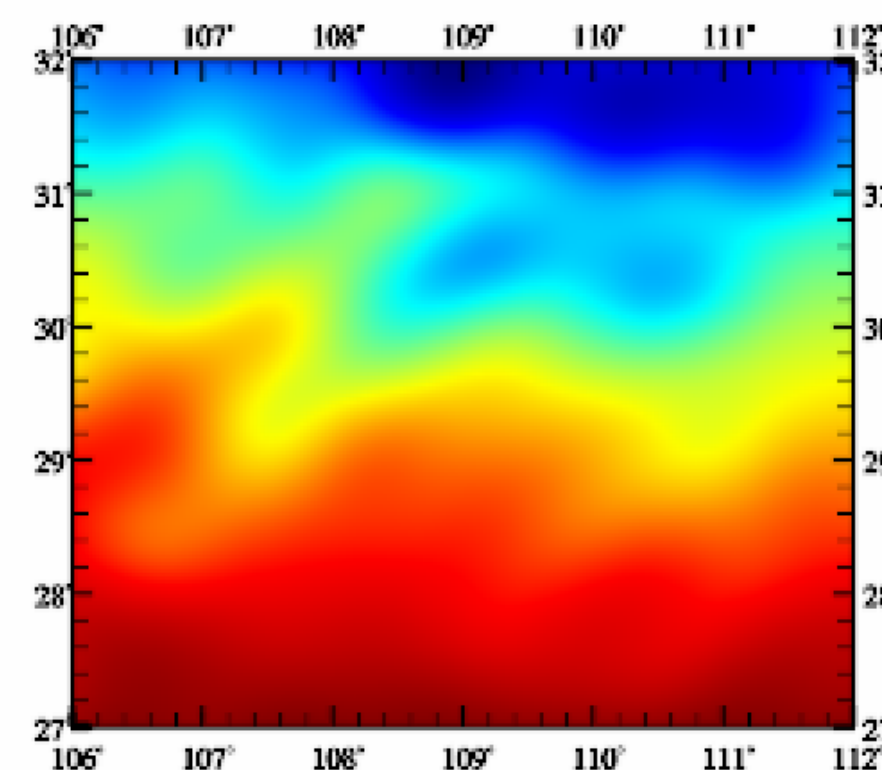


Start Computation

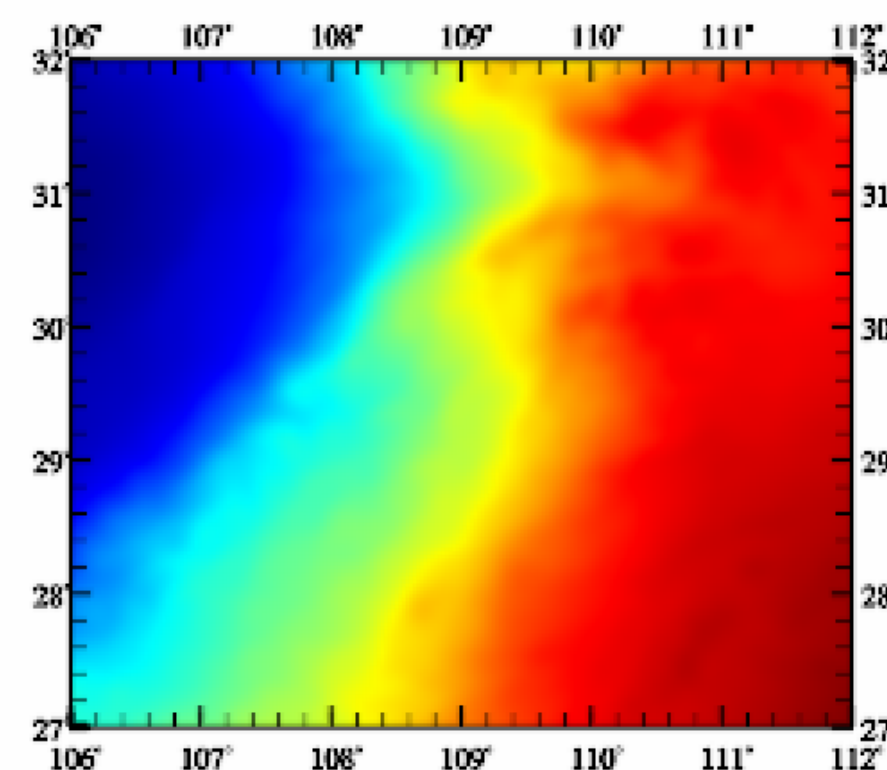
106.000000	112.000000	27.000000	32.000000	0.04166667	0.04166667
-47.0779	-48.5710	-50.0626	-51.5117	-52.8773	-54.1205
-55.6160	-54.8211	-53.9773	-53.1293	-52.3217	-51.5968
-53.7911	-54.8783	-56.0160	-57.1638	-58.2815	-59.3310
-61.6286	-61.0857	-60.4887	-59.8692	-59.2583	-58.6846
-57.8114	-58.0957	-58.3711	-58.6137	-58.8012	-58.9143
-54.9842	-54.2986	-53.6328	-53.0050	-52.4305	-51.9211
-50.1814	-50.1167	-50.0220	-49.8912	-49.7219	-49.5160
-48.2901	-48.6244	-49.0894	-49.6836	-50.3996	-51.2246
-59.9952	-60.3345	-60.5051	-60.5073	-60.3479	-60.0403
-54.5244	-54.3209	-54.2460	-54.2972	-54.4654	-54.7357
-43.9476	-45.5158	-47.0858	-48.6168	-50.0682	-51.4013
-53.8577	-53.1327	-52.3463	-51.5418	-50.7621	-50.0484
-51.4914	-52.4531	-53.4667	-54.4949	-55.5002	-56.4472
-58.5753	-58.0995	-57.5792	-57.0436	-56.5213	-56.0383
-55.7158	-55.9891	-56.2396	-56.4438	-56.5801	-56.6301
-51.6479	-50.8404	-50.0538	-49.3070	-48.6162	-47.9938
-45.3853	-45.2636	-45.1176	-44.9411	-44.7319	-44.4920
-43.3261	-43.7170	-44.2496	-44.9224	-45.7282	-46.6537
-56.7661	-57.2295	-57.5125	-57.6128	-57.5353	-57.2914
-51.3408	-51.0173	-50.8198	-50.7498	-50.8018	-50.9644
-40.9305	-42.5820	-44.2372	-45.8557	-47.3972	-48.8233

Extract results

Plot↓



geopotential refined (m²/s²)



ellipsoidal height refined (m)

Assessment of the Gravimetric Geoid Using GNSS-Leveling Data

Open GNSS-Leveling Residual Height Anomaly File

number of rows of file header 1

GNSS-Leveling Residual Column Index 5

Input GNSS-levelling network parameters

mean distance between GNSS benchmarks 20 km

Error Constant of ellipsoidal height difference of GNSS baseline 5 mm

Proportional Coefficient of ellipsoidal height difference of GNSS baseline 0.100 mm/km

Set the error curve parameters

Number of groups for pairwise combination of GNSS-Leveling benchmarks 50

maximum distance of Distance-Error Curve 200 km

distance interval for Distance-Error Curve 1.0 km

>> Computation Process ** Operation Prompts

Save computation process as

>> [Function] Performs a statistical analysis of GNSS-leveling residual height anomalies (m) based on the spectral-domain error characteristics of both GNSS-leveling data and local gravity field. The module estimates: (a) Error of gravimetric height anomalies (cm). (b) Internal coincidence error of hybrid height anomalies (cm). (c) Error of hybrid height anomaly differences. (d) Error of GNSS-leveling height anomaly differences.

>> Open GNSS-Leveling Residual Height Anomaly File C:/PAGravf4.5_win64en/examples/AppGeoiderrorestim/GNSSIksirent.txt.

** Look at the file information in the window below and set the discrete point file format parameters...

>> Save the results as C:/PAGravf4.5_win64en/examples/AppGeoiderrorestim/result.txt.

>> File Header (5 Parameters): Standard Deviation of GNSS-Leveling Residual Height Anomalies (cm), Standard Deviation of Differences in Paired GNSS-Leveling Residuals (cm), Estimated Error of Gravimetric Height Anomalies (cm), Internal Coincidence Error of Hybrid Height Anomaly Differences (cm), and Normal/Orthometric Height Difference Error per Kilometer (cm/km).

>> Data Records (3 Error Curves): Col 1 – Distance (km, Independent Variable), Col 2 – GNSS-Leveling Height Anomaly Error (cm), Col 3 – Gravimetric Height Anomaly Error (cm, Constant), Col 4 – Internal Coincidence Error of Hybrid Height Anomalies (cm).

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-15 10:29:08

>> Complete the assessment of gravimetric geoid!

>> Computation end time: 2026-04-15 10:29:08

Save the error curves as

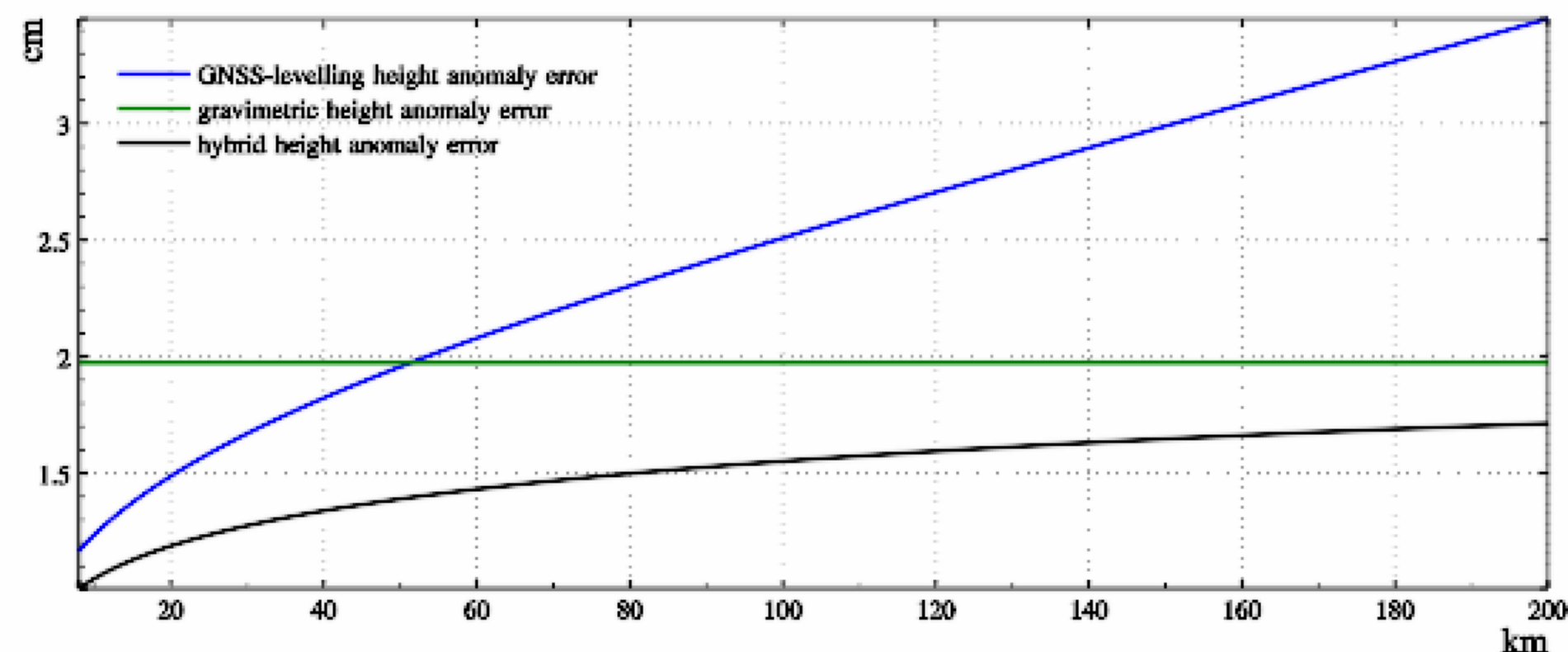
Import setting parameters

Start Computation

3.07963	4.32820	1.97371	1.56767	0.56426
8	1.16838	1.97371	1.00542	
9	1.20333	1.97371	1.02743	
10	1.23594	1.97371	1.04751	
11	1.26659	1.97371	1.06597	
12	1.29556	1.97371	1.08307	
13	1.32308	1.97371	1.09900	
14	1.34933	1.97371	1.11390	
15	1.37447	1.97371	1.12792	
16	1.39860	1.97371	1.14114	
17	1.42185	1.97371	1.15366	
18	1.44428	1.97371	1.16555	
19	1.46599	1.97371	1.17687	
20	1.48702	1.97371	1.18767	
21	1.50745	1.97371	1.19800	
22	1.52732	1.97371	1.20790	
23	1.54667	1.97371	1.21741	
24	1.56555	1.97371	1.22655	
25	1.58398	1.97371	1.23535	
26	1.60199	1.97371	1.24384	
27	1.61963	1.97371	1.25204	

Extract error curves

Plot



Theoretical Basis: The assessment relies on the principle that the error in GNSS-leveling height anomaly differences increases with distance, whereas the error in gravimetric height anomaly differences remains relatively constant regardless of distance.

Computation of Geopotential for the Zero-Elevation Surface of a Regional Datum

GNSS-leveling residuals Save as Import parameters Start Computation Save process Follow example

Computation of Geopotential for the Zero-Elevation Surface of a Regional Datum

GNSS-Leveling Data Fusion with Poisson Integral Constraints

Quasi-Stable Adjustment of Leveling Networks Using Remaining Residuals

Open GNSS-Leveling Residual File

Set input file format

number of rows of file header 1
 GNSS-leveling observation Column Index 5
 GNSS-leveling residual Column Index 6
 Weight Column Index 7
 Input Global geopotential (m^2/s^2) 62636853.400

>> Computation Process ** Operation Prompts

Save computation process as

** Look at the file information in the window below and set the discrete point file format parameters...

>> Save the remaining GNSS-leveling residuals as C:/PAGravf4.5_win64en/examples/AppGNSSIVhgtdatum/rntksich.txt.

** The file header has 6 attributes, namely W_r : Regional zero-elevation surface geopotential; U_0 : Normal potential of the normal ellipsoid, numerically equal to the geoid geopotential / global geopotential W_0 ; W_0 : Global geopotential (reference geopotential of global orthometric and normal zero-height surface); $W_r - U_0$: Geopotential difference relative to the normal ellipsoid; $W_r - W_0$: Geopotential difference relative to the global geoid; $U_0 - W_0$: Geopotential difference between the normal ellipsoid and the global geoid.

** Data Records: Appends a column for the 'Correction to Gravimetric Geoid'.

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-15 10:47:12

Regional zero-elevation surface geopotential $W_r = 62636850.846 \text{m}^2/\text{s}^2$

Normal potential of the normal ellipsoid $U_0 = 62636858.709 \text{m}^2/\text{s}^2$

Global geopotential $W_0 = 62636853.400 \text{m}^2/\text{s}^2$

Geopotential difference relative to the normal ellipsoid $W_r - U_0 = -7.863 \text{m}^2/\text{s}^2$

Geopotential difference relative to the global geoid $W_r - W_0 = -2.554 \text{m}^2/\text{s}^2$

Geopotential difference between the normal ellipsoid and the global geoid $U_0 - W_0 = 5.309 \text{m}^2/\text{s}^2$

>> Complete to calculate the geopotential differences of height datum!

>> Computation end time: 2026-04-15 10:47:12

Save the remaining GNSS-leveling residuals as

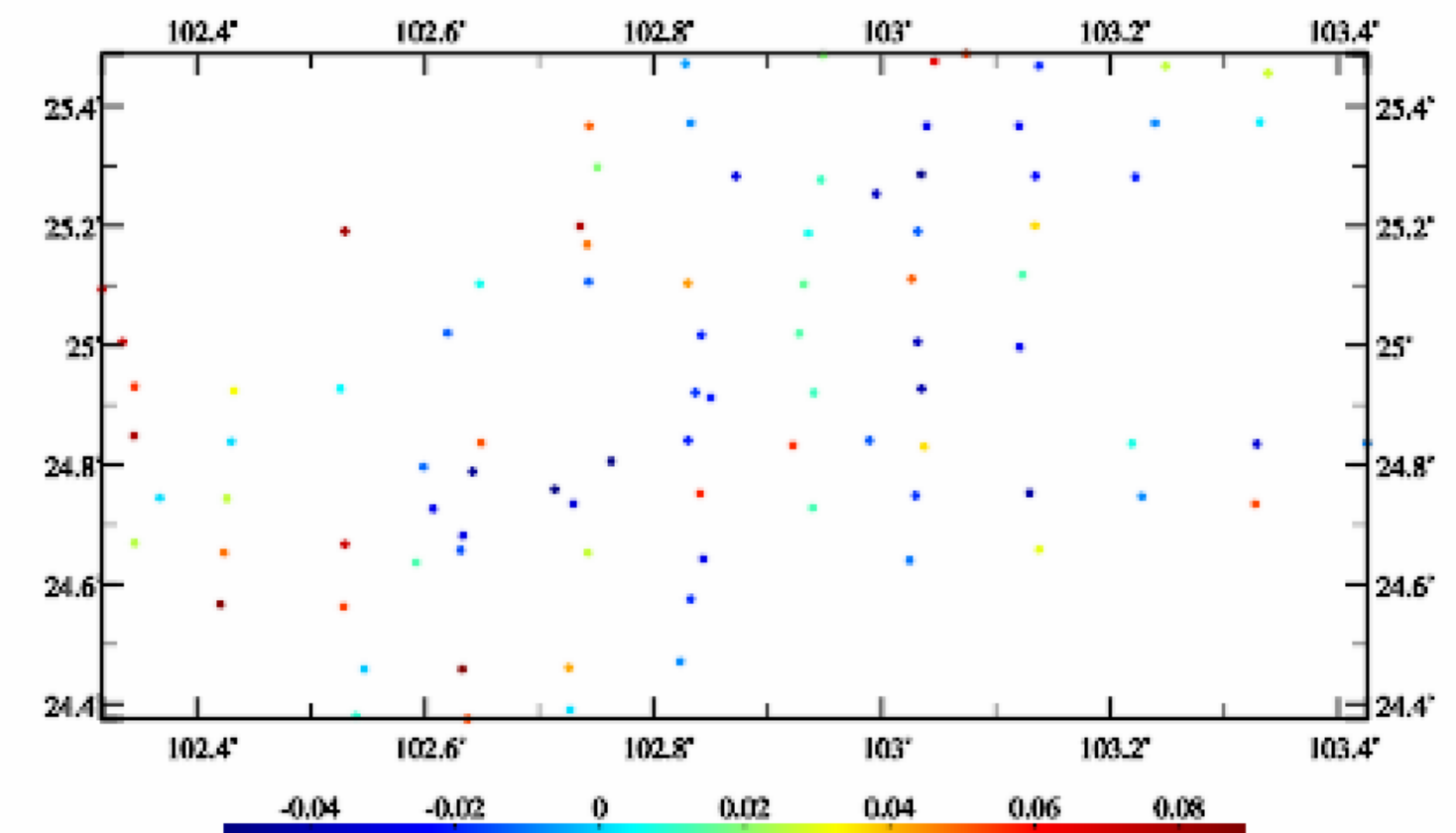
Import setting parameters

Start Computation

no	lon(degree/decimal)	lat	ellipHeight(m)	geoidheight(m)	resksi	weight
1	102.546777	24.458002	1659.0410	-33.6150	-0.8046	0.94
2	102.632412	24.458211	2120.2558	-33.3212	-0.7142	1.23
3	102.725921	24.460578	2111.3872	-33.2058	-0.7612	1.68
4	102.420803	24.566357	1990.6386	-33.5334	-0.7157	1.95
5	102.528697	24.562786	1936.4260	-33.3720	-0.7491	2.93
6	102.832641	24.575505	1977.4949	-33.1581	-0.8223	1.04
7	102.345532	24.668953	1919.7825	-33.7565	-0.7782	3.53
8	102.423972	24.652933	1959.3369	-33.4781	-0.7548	2.02
9	102.529771	24.667079	2157.7877	-33.2933	-0.7317	1.46
10	102.631063	24.657055	1906.3415	-33.3155	-0.8185	3.53
11	102.742718	24.652871	1935.7882	-33.1128	-0.7767	3.39
12	102.843573	24.642787	1880.7707	-33.1133	-0.8319	0.81
13	103.137778	24.658224	1838.4387	-32.7463	-0.7730	0.53
14	102.426305	24.743284	1929.0475	-33.4575	-0.7771	1.48
15	102.729945	24.734909	1856.2213	-33.2087	-0.8356	6.12
16	102.840819	24.752018	2117.8582	-32.8948	-0.7459	1.56
17	102.939253	24.728089	2050.9590	-32.8500	-0.7907	0.81
18	103.029713	24.748496	2034.1986	-32.8194	-0.8217	0.88
19	103.129600	24.753135	1575.0654	-32.8486	-0.8477	1.41
20	103.227846	24.747081	1668.7801	-32.6509	-0.8116	3.06

Extract remaining residuals

Plot↓



The normal and orthometric zero-height surfaces are theoretically coincident everywhere; no distinction is required.

Remaining GNSS-Leveling Residual File after GNSS-levelling data fusion can be employed to evaluate the quality of the measured GNSS-levelling data.

GNSS-Leveling Data Fusion with Poisson Integral Constraints

GNSS-leveling residuals Save as Import parameters Start Computation Save process Follow example

Computation of Geopotential for the Zero-Elevation Surface of a Regional Datum

GNSS-Leveling Data Fusion with Poisson Integral Constraints

Quasi-Stable Adjustment of Leveling Networks Using Remaining Residuals

Open GNSS-Leveling Residual File

Set input file format

number of rows of file header 2

Ellipsoidal Height Column Index 5

GNSS-leveling residual Column Index 6

Weight Column Index 7

Open Data Fusion Surface Ellipsoidal Height Grid File

Set calculation parameters

Computation Iterative Count 3

Residual Integration Radius 120 km

Laplace Operator Parameter 3

Edge Effect Suppression Parameter (n) 1

>> Computation Process ** Operation Prompts

** Look at the file information in the window below and set the discrete point file format parameters...

>> Open Data Fusion Surface Ellipsoidal Height Grid File C:/PAGravf4.5_win64en/examples/AppGNSSlvhgt datum/GeoidEGM150s.dat.

>> Save the remaining GNSS-leveling residuals as C:/PAGravf4.5_win64en/examples/AppGNSSlvhgt datum/rntksich01.txt.

>> Save the remaining residual grid results as C:/PAGravf4.5_win64en/examples/AppGNSSlvhgt datum/residualgeoid.dat.

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

** The iterative computation process needs to wait... During the period, you can open the file C:/PAGravf4.5_win64en/examples/AppGNSSlvhgt datum/rntksich01.txt and look at the iterative progress!

>> Computation start time: 2026-04-15 10:50:51

>> GNSS-levelling residuals: mean, standard deviation, minimum, maximum

>> Source GNSS-levelling residuals: -0.7932 0.0369 -0.8550 -0.7142

>> the 1th iterative remaining residuals: 0.0018 0.0238 -0.0398 0.0640

>> the 2th iterative remaining residuals: 0.0019 0.0202 -0.0401 0.0605

>> the 3th iterative remaining residuals: 0.0017 0.0178 -0.0384 0.0538

>> Complete GNSS-leveling data fusion!

** After the first iterative computation, the appropriate number of iterations should be selected according to the residual statistical properties of the iterative process, and the computation should be performed once again!

>> Computation end time: 2026-04-15 10:50:55

Save computation process as

Save the remaining GNSS-leveling residuals as

Save the remaining residual grid results as

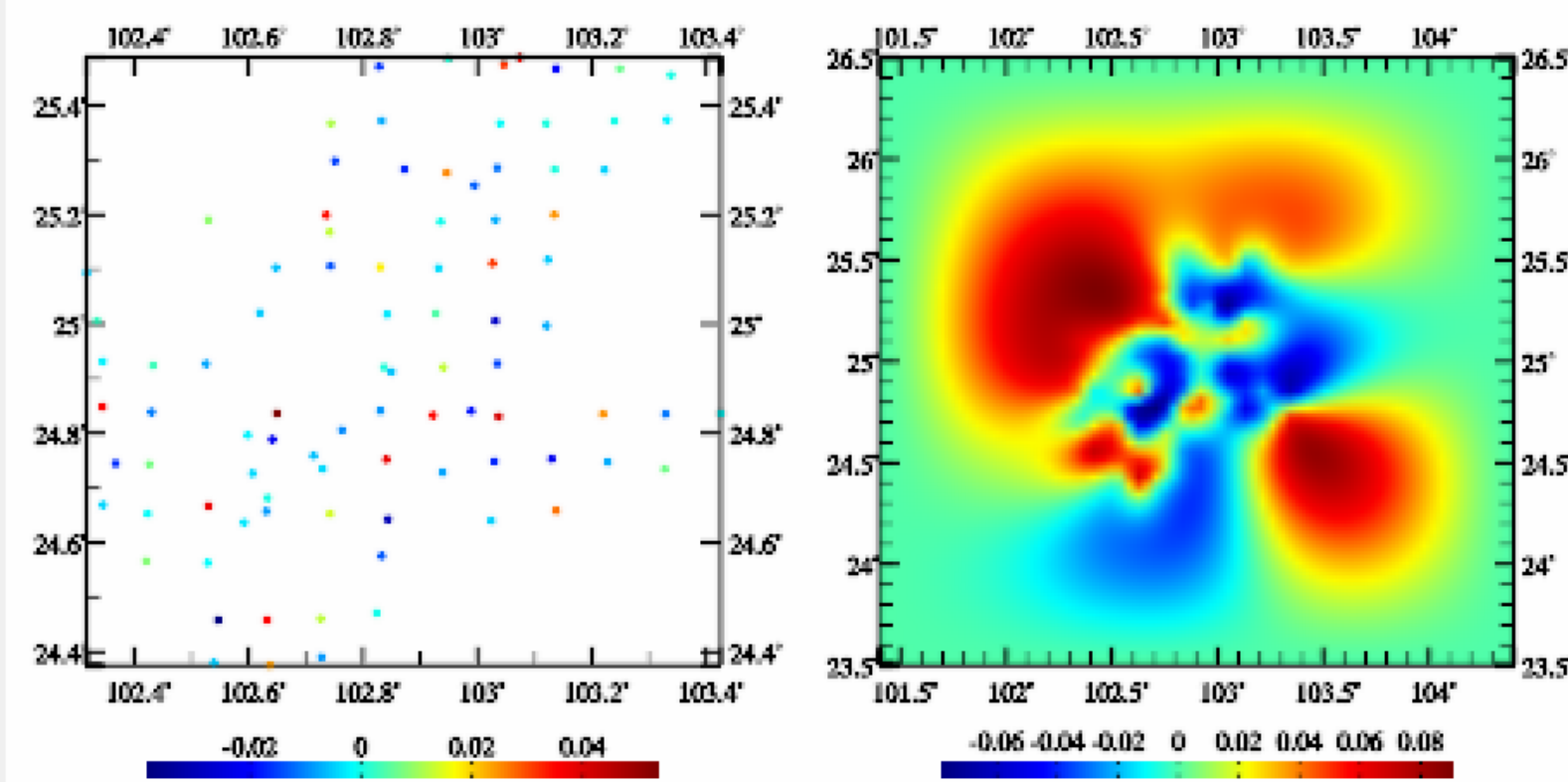
Import setting parameters

Start Computation

101.400000	104.400000	23.500000	26.500000	0.04166667	0.04166667	
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
-0.0000	-0.0000	-0.0000	-0.0000	-0.0000	-0.0000	-0.0000
-0.0000	-0.0000	-0.0000	-0.0000	-0.0000	-0.0000	-0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	-0.0000	-0.0000	-0.0000
0.0000	-0.0000	-0.0000	-0.0000	-0.0000	-0.0000	-0.0000
-0.0003	-0.0003	-0.0004	-0.0004	-0.0005	-0.0005	-0.0006
-0.0009	-0.0009	-0.0009	-0.0008	-0.0008	-0.0007	-0.0007
0.0002	0.0003	0.0004	0.0004	0.0005	0.0006	0.0006
0.0004	0.0003	0.0003	0.0002	0.0002	0.0001	0.0001
0.0000	-0.0000	-0.0000	-0.0000	-0.0001	-0.0001	-0.0001
-0.0008	-0.0009	-0.0010	-0.0012	-0.0013	-0.0015	-0.0016
-0.0025	-0.0025	-0.0024	-0.0024	-0.0022	-0.0021	-0.0019
0.0006	0.0008	0.0011	0.0013	0.0014	0.0016	0.0017
0.0011	0.0010	0.0008	0.0007	0.0005	0.0004	0.0003
0.0000	-0.0000	-0.0000	-0.0001	-0.0001	-0.0002	-0.0002
-0.0015	-0.0017	-0.0020	-0.0022	-0.0025	-0.0028	-0.0031
-0.0047	-0.0046	-0.0046	-0.0044	-0.0042	-0.0039	-0.0036
0.0011	0.0016	0.0020	0.0024	0.0027	0.0030	0.0032
0.0022	0.0019	0.0016	0.0013	0.0011	0.0008	0.0006

Extract fusion result grid

Plot↓



remaining residuals (m)

residual height anomaly (m)

- The normal and orthometric zero-height surfaces are theoretically coincident everywhere; no distinction is required..
- Remaining GNSS-Leveling Residual File after GNSS-levelling data fusion can be employed to evaluate the quality of the measured GNSS-levelling data.

Calculation of Normal Heights via GNSS Replacing Leveling

Select height system

normal height

☐ Batch point calculation Open Ground Height Anomaly Grid File Open Ground Ellipsoidal Height Grid File Open Ground Gravity Disturbance Grid File

>> Computation Process

 Save computation process as

gravity field and geoid modeling results.

** Please select height system firstly...

>> GNSS replaces leveling to calculate the normal height...

>> Open Ground Height Anomaly Grid File C:/PAGravf4.5_win64en/examples/AppGNSSrepleveling/dbmGM1800150sksi.dat.

>> Open Ground Ellipsoidal Height Grid File C:/PAGravf4.5_win64en/examples/AppGNSSrepleveling/dbmhgt150s.dat.

>> Open Ground Gravity Disturbance Grid File C:/PAGravf4.5_win64en/examples/AppGNSSrepleveling/dbmGM1800150srga.dat.

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-15 11:28:24

>> Computation end time: 2026-04-15 11:28:24

Input geodetic coordinates of GNSS positioning point

longitude 106.25000000°

latitude 28.42000000°

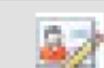
ellipsoidal height 321.0000m

The normal (orthometric) height calculated

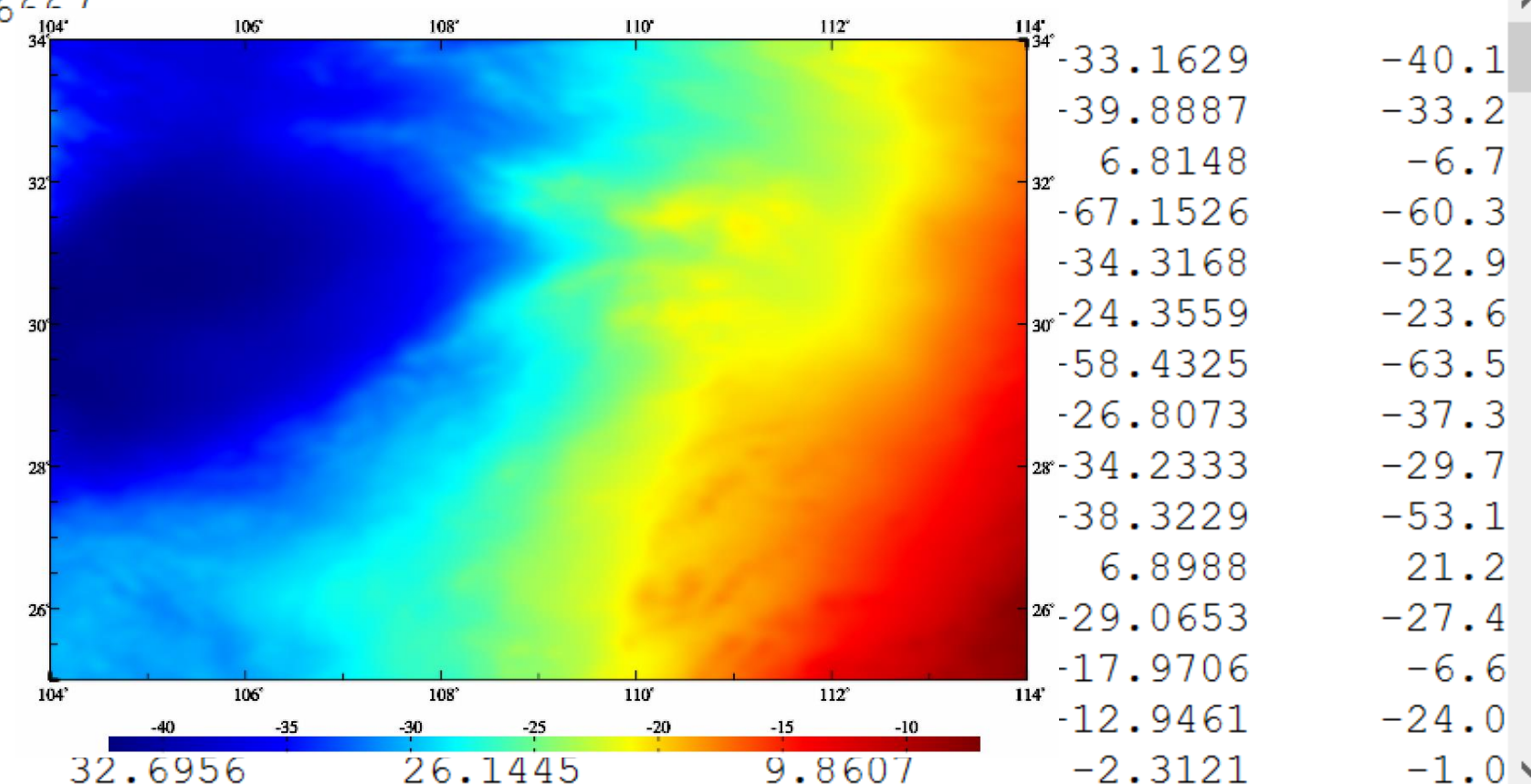
normal height 355.3384m

 Start Computation

Display of the input-output file↓

 Save data in the text box as

104.000000	114.000000	25.000000	34.000000	0.04166667	0.04166667
-12.7623	-6.6889	14.8378	14.3339	16.2927	
-21.3176	-16.3421	5.5626	4.8145		
-52.5462	-51.4715	-21.5136			
-69.6652	-75.2315	-57.9349			
-57.4727	-49.4815	-5.2174			
-36.3515	-38.9415	-0.0202			
-15.2298	-23.9715	0.0202			
-38.3638	-44.6641	-55.0764			
-61.9463	-51.8641	-5.3789			
-19.2718	-21.4892	-43.3358			
-54.4718	-52.8087	-43.5594			
-30.4888	-11.1962	-11.6624			
-23.8178	-18.1481	-4.8413			
-15.2151	-29.7543	-42.2650			
-10.2665	-14.8432	3.6363			
		22.0049			



Calculation of Orthometric Heights via GNSS Replacing Leveling

Import parameters

Start Computation

Save process

Follow example

Select height system

orthometric height

☐ Batch point calculation

Open Geoidal Height Grid File

>> Computation Process

Save computation process as

dbmGM1800150srga.dat.

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-15 11:28:24

>> Computation end time: 2026-04-15 11:28:24

>> GNSS replaces leveling to calculate the orthometric height....

>> Open Geoidal Height Grid File C:/PAGravf4.5_win64en/examples/AppGNSSreleveling/dwmGM1800150sksi.dat.

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-15 11:29:19

>> Computation end time: 2026-04-15 11:29:19

Input geodetic coordinates of GNSS positioning point

longitude 106.25000000°

latitude 28.42000000°

ellipsoidal height 321.0000m

The normal (orthometric) height calculated

orthometric height 355.3301m

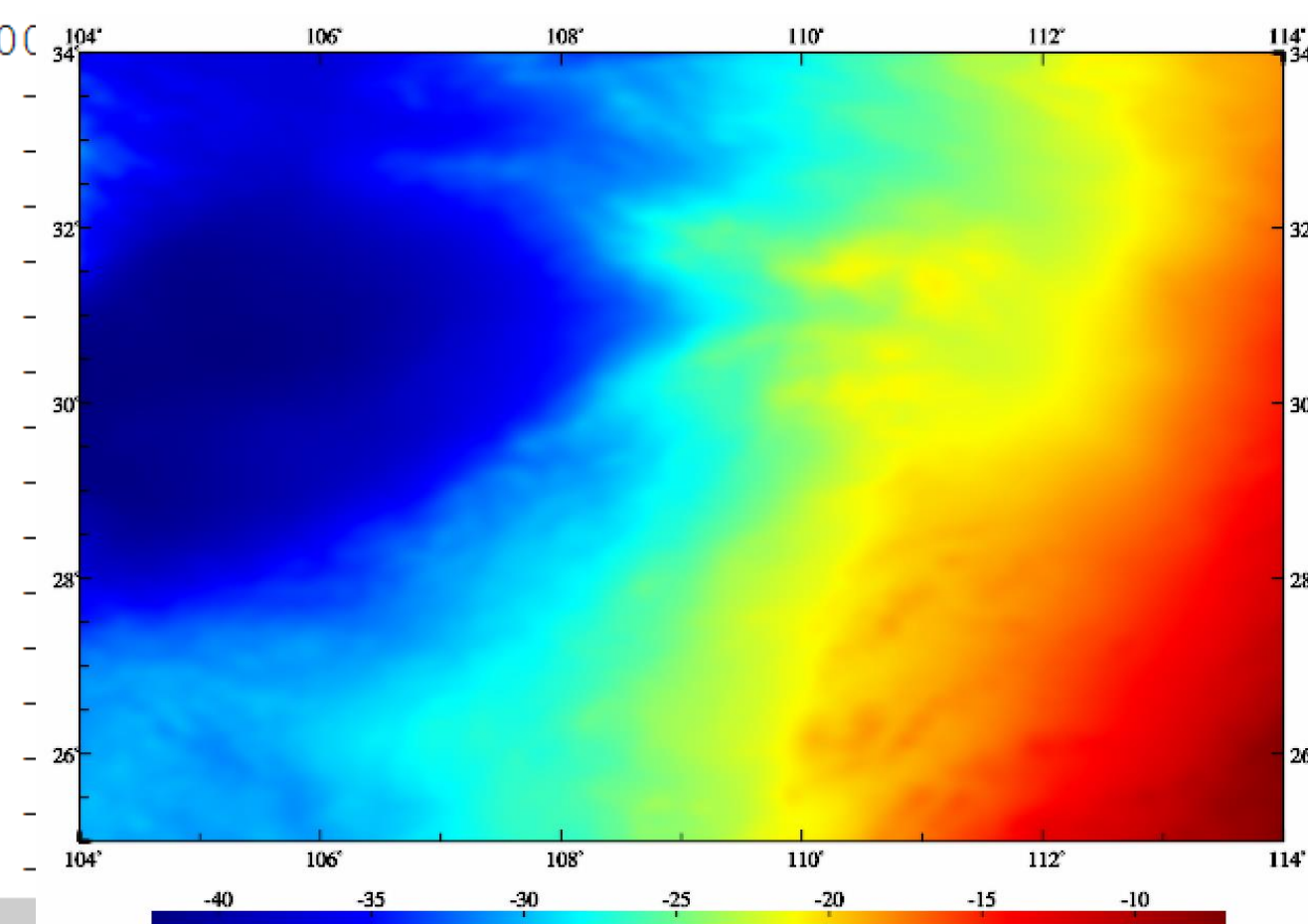
Start Computation

Import setting parameters

Display of the input-output file↓

Save data in the text box as

104.000000	114.000000	25.000000	34.000000
-30.3888	-30.3353	-30.2474	-
-30.5079	-30.4773	-30.4178	-
-30.9666	-30.9265	-30.8488	-
-30.7087	-30.7124	-30.6640	-
-29.4489	-29.3199	-29.2045	-
-28.0546	-27.9933	-27.9349	-
-26.6019	-26.6005	-26.6046	-
-25.5602	-25.4324	-25.2871	-
-24.0863	-23.9551	-23.8277	-
-21.7590	-21.6183	-21.4670	-
-20.2280	-20.0810	-19.9070	-
-17.5519	-17.2803	-17.0668	-
-15.2983	-15.0905	-14.8649	-
-12.8449	-12.8349	-12.7969	-
-10.8914	-10.7385	-10.5461	-



-30.4928	-30.6097	-30.6
-30.8459	-30.8988	-30.8
-30.1897	-30.2039	-30.2
-30.2657	-30.1592	-30.0
-28.6379	-28.6437	-28.6
-27.3588	-27.2144	-27.1
-26.5268	-26.4927	-26.4
-24.3811	-24.3680	-24.3
-23.1946	-22.9939	-22.8
-20.9193	-20.9265	-20.9
-18.7527	-18.4272	-18.1
-16.4921	-16.3651	-16.2
-13.9403	-13.7362	-13.5
-12.1088	-11.9898	-11.9
-9.6324	-9.5699	-9.4

Calculation of Normal and Orthometric Heights via GNSS Replacing Leveling

Import parameters

Start Computation

Save process

Follow example

Select height system

normal (orthometric) height

☐ Batch point calculation

Open Ground Height Anomaly Grid File

Open Ground Ellipsoidal Height Grid File

Open Ground Gravity Disturbance Grid File

Open Geoidal Height Grid File

>> Computation Process

Save computation process as

>> GNSS replaces leveling to calculate both the normal height and orthometric height....
>> Open Ground Height Anomaly Grid File C:/PAGravf4.5_win64en/examples/AppGNSSrepleveling/dbmGM1800150sksi.dat.
>> Open Ground Ellipsoidal Height Grid File C:/PAGravf4.5_win64en/examples/AppGNSSrepleveling/dbmhgt150s.dat.
>> Open Ground Gravity Disturbance Grid File C:/PAGravf4.5_win64en/examples/AppGNSSrepleveling/dbmGM1800150srga.dat.
>> Open Geoidal Height Grid File C:/PAGravf4.5_win64en/examples/AppGNSSrepleveling/dwmGM1800150sksi.dat.
>> The parameter settings have been entered into the system!
** Click the [Start Computation] control button, or the [Start Computation] tool button...
>> Computation start time: 2026-04-15 11:30:27
>> Computation end time: 2026-04-15 11:30:27

Input geodetic coordinates of GNSS positioning point

longitude 106.25000000°

latitude 28.42000000°

ellipsoidal height 321.0000m

The normal (orthometric) height calculated

normal height 355.3384m

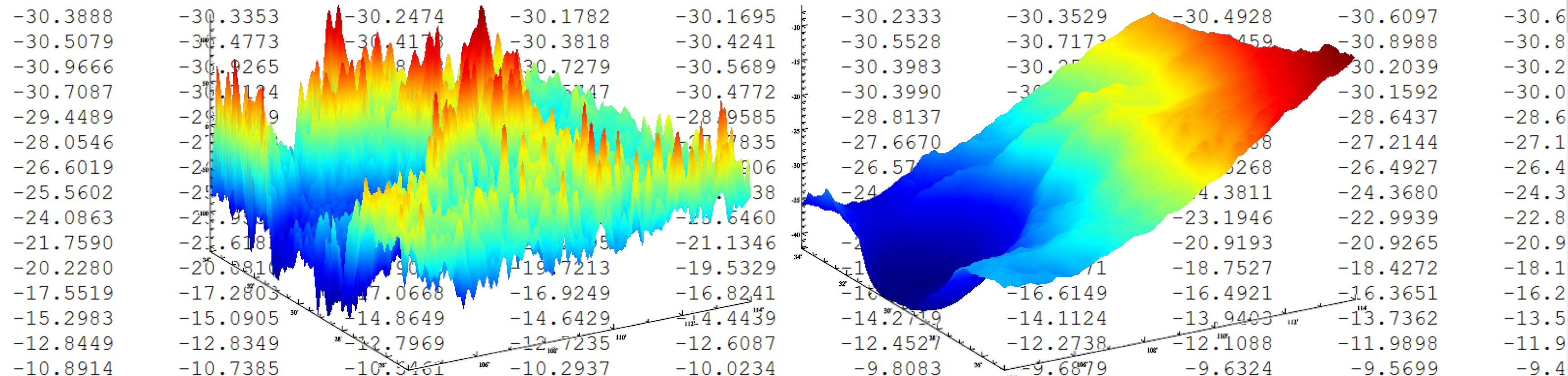
orthometric height 355.3301m

Start Computation

Display of the input-output file↓

Save data in the text box as

104.000000 114.000000 25.000000 34.000000 0.04166667 0.04166667



Batch Calculation of Normal and Orthometric Heights via GNSS Replacing Leveling

Import parameters

Start Computation

Save process

Follow example

Select height system

normal (orthometric) height

☒ Batch point calculation

Open Ground Height Anomaly Grid File

Open Ground Ellipsoidal Height Grid File

Open Ground Gravity Disturbance Grid File

Open Geoidal Height Grid File

Open Space GNSS position point file

Number of rows of file header 1

Ellipsoidal Height Column Index 4

Save the results as

Import setting parameters

Display of the input-output file↓

number	long(deg/decimal)	lat	ellipHeight(m)		
1	104.020833	25.020833	1880.623	1910.9997	1911.0118
2	104.062500	25.020833	1872.661	1902.9998	1902.9963
3	104.104167	25.020833	1910.720	1940.9997	1940.9674
4	104.145833	25.020833	1931.765	1961.9997	1961.9432
5	104.187500	25.020833	1992.766	2022.9995	2022.9355
6	104.229167	25.020833	1897.720	1928.0001	1927.9533
7	104.270833	25.020833	1807.631	1838.0000	1837.9839
8	104.312500	25.020833	1607.524	1638.0000	1638.0168
9	104.354167	25.020833	1451.430	1481.9998	1482.0397
10	104.395833	25.020833	1394.383	1424.9998	1425.0497
11	104.437500	25.020833	1303.391	1333.9999	1334.0425
12	104.479167	25.020833	1337.441	1368.0001	1368.0285
13	104.520833	25.020833	1477.493	1507.9999	1508.0154
14	104.562500	25.020833	1558.518	1589.0003	1589.0123

>> Computation Process

>> Computation end time: 2026-04-15 11:30:27

>> GNSS replaces leveling to calculate both the normal height and orthometric height....

>> Batch point calculation by GNSS replacing leveling...

>> Open Ground Height Anomaly Grid File C:/PAGravf4.5_win64en/examples/AppGNSSrepleveling/dbmGM1800150sksi.dat.

>> Open Ground Ellipsoidal Height Grid File C:/PAGravf4.5_win64en/examples/AppGNSSrepleveling/dbmght150s.dat.

>> Open Ground Gravity Disturbance Grid File C:/PAGravf4.5_win64en/examples/AppGNSSrepleveling/dbmGM1800150srga.dat.

>> Open Geoidal Height Grid File C:/PAGravf4.5_win64en/ex...

>> Open Space GNSS position point file C:/PAGravf4.5_win64en/ex...

>> Open Space GNSS position point file C:/PAGravf4.5_win64en/ex... GNSShgt.txt.

** Look at the file information in the window below and...

>> Save the results as C:/PAGravf4.5_win64en/example/...

>> The parameter settings have been entered into the system...

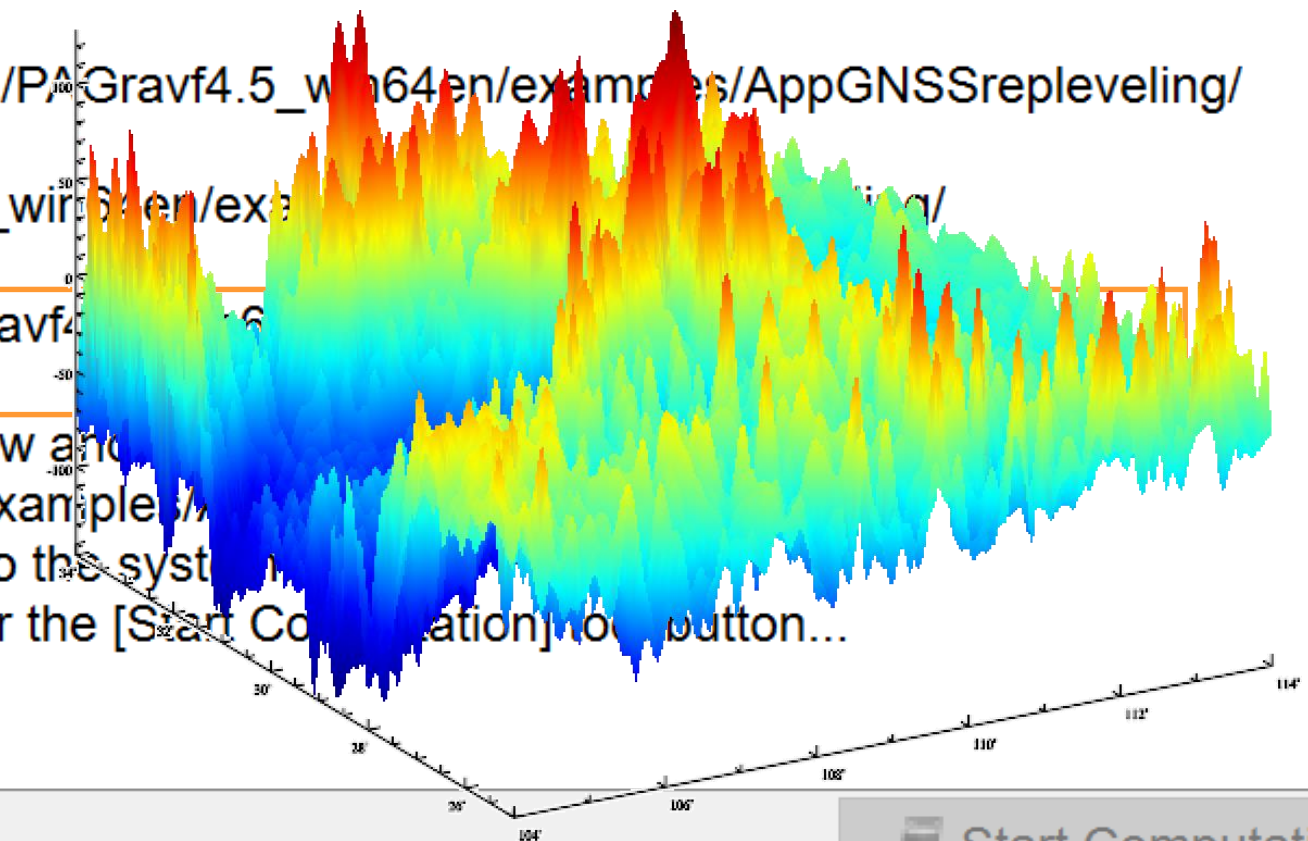
** Click the [Start Computation] control button, or the [Start Computation] of button...

>> Computation start time: 2026-04-15 11:31:57

>> Computation end time: 2026-04-15 11:32:02



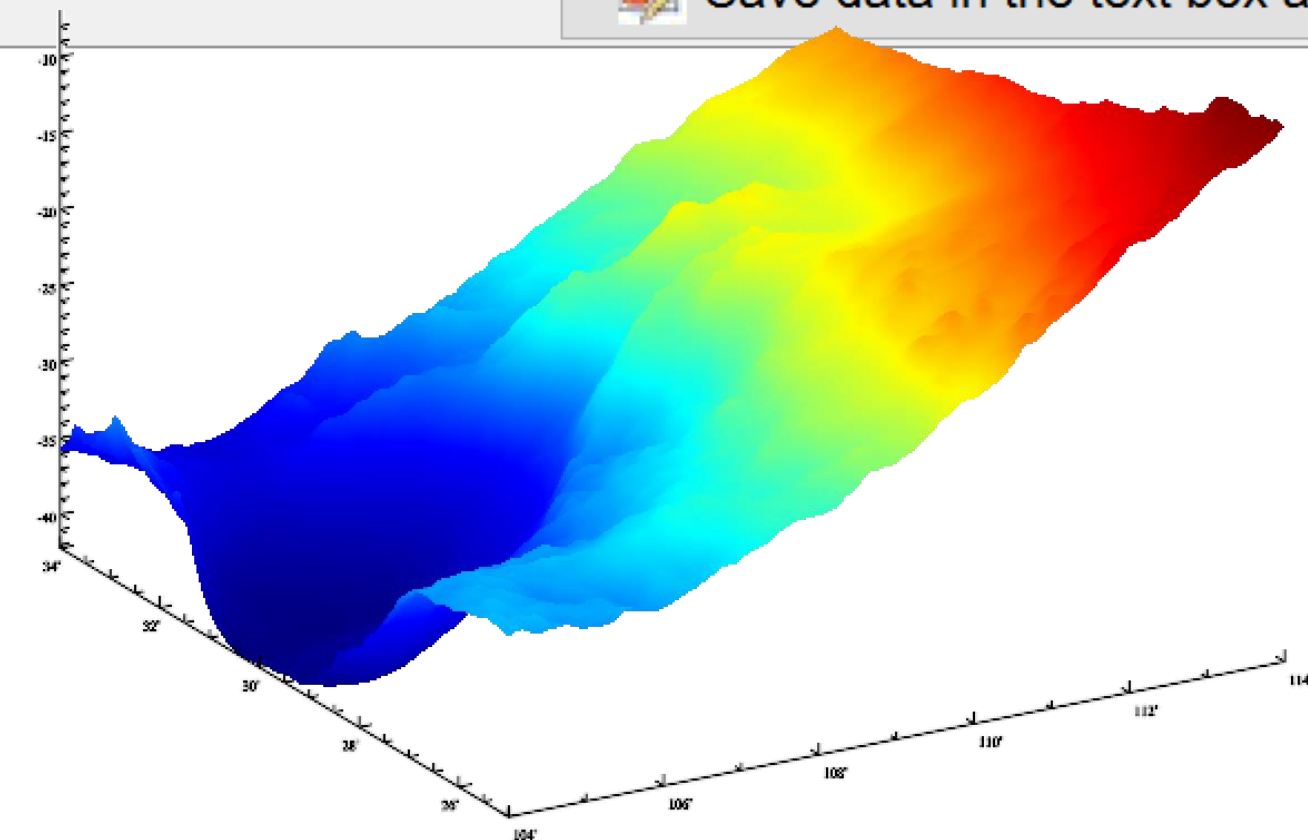
Save computation process as

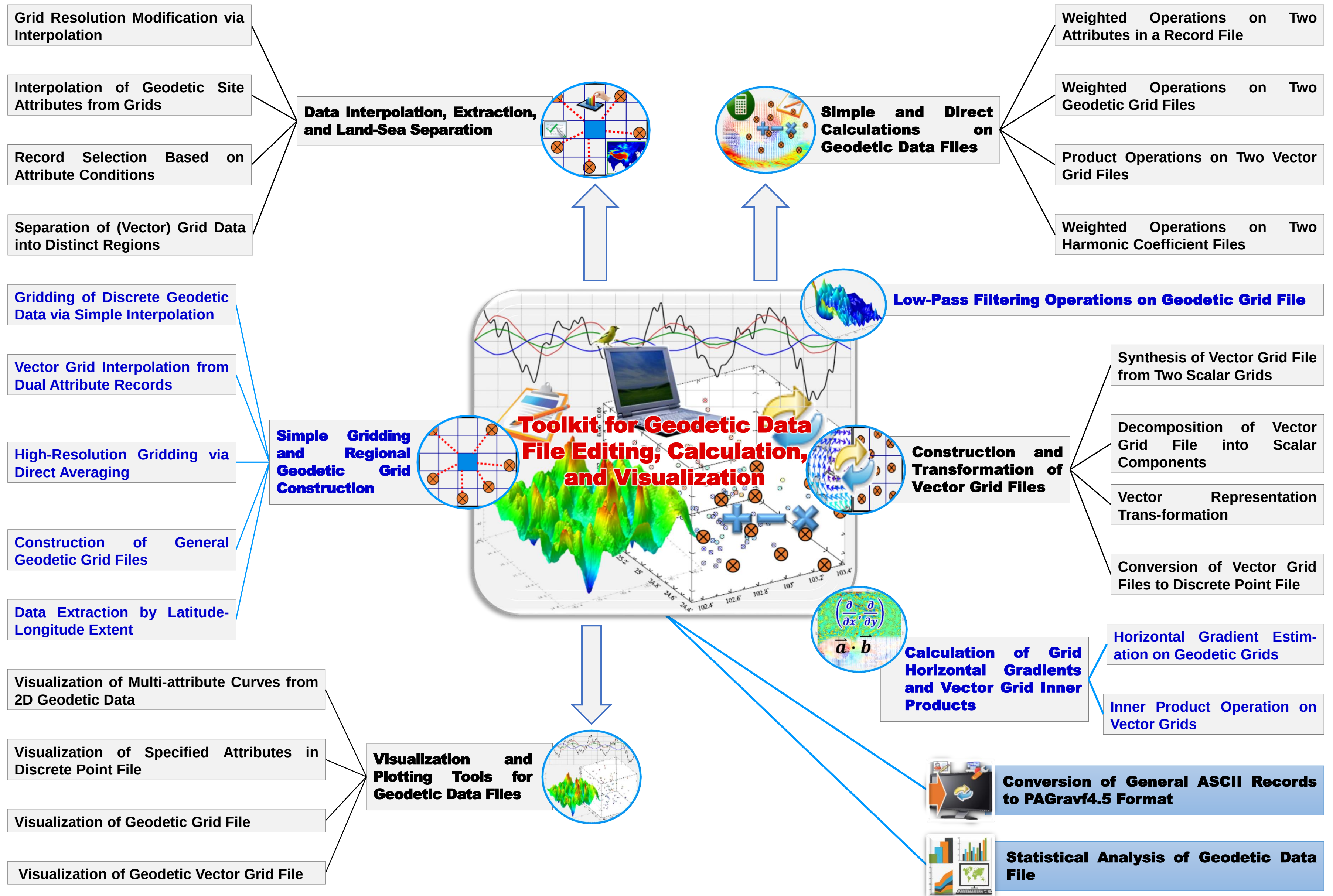


Start Computation



Save data in the text box as



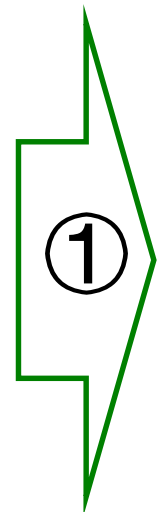


Conversion of General ASCII Records to PAGravf4.5 Format

Open text file Save as Save process Follow example

62636844.042	62636851.905	62636853.400	-7.8630	-9.3578	-1.4948		
2	102.546777	24.458002	1659.0410	-33.6150	-0.8046	0.94	-0.0014
3	102.632412	24.458211	2120.2558	-33.3212	-0.7142	1.23	0.0890
4	102.725921	24.460578	2111.3872	-33.2058	-0.7612	1.68	0.0420
5	102.420803	24.566357	1990.6386	-33.5334	-0.7157	1.95	0.0875
6	102.528697	24.562786	1936.4260	-33.3720	-0.7491	2.93	0.0541
9	102.832641	24.575505	1977.4949	-33.1581	-0.8223	1.04	-0.0191
10	102.345532	24.668953	1919.7825	-33.7565	-0.7782	3.53	0.0250
11	102.423972	24.652933	1959.3369	-33.4781	-0.7548	2.02	0.0484
12	102.529771	24.667079	2157.7877	-33.2933	-0.7317	1.46	0.0715
13	102.631063	24.657055	1906.3415	-33.3155	-0.8185	3.53	-0.0153
14	102.742718	24.652871	1935.7882	-33.1128	-0.7767	3.39	0.0265
15	102.843573	24.642787	1880.7707	-33.1133	-0.8319	0.81	-0.0287
16	103.137778	24.658224	1838.4387	-32.7463	-0.7730	0.53	0.0302
17	102.426305	24.743284	1929.0475	-33.4575	-0.7771	1.48	0.0261
20	102.729945	24.734909	1856.2213	-33.2087	-0.8356	6.12	-0.0324
21	102.840819	24.752018	2117.8582	-32.8948	-0.7459	1.56	0.0573
22	102.939253	24.728089	2050.9590	-32.8500	-0.7907	0.81	0.0125
23	103.029713	24.748496	2034.1986	-32.8194	-0.8217	0.88	-0.0185
24	103.129600	24.753135	1575.0654	-32.8486	-0.8477	1.41	-0.0445
25	103.227846	24.747081	1668.7801	-32.6509	-0.8116	3.06	-0.0084
26	103.327056	24.734505	1829.6718	-32.3302	-0.7499	3.77	0.0533

Open Source ASCII Text File Number of rows of the file header 1 Exact and Edit Data Organize and Display Result File



Exact and edit data from the source text file

The record attributes of source file

The record attributes of target file

Add attribute

Insert>>>

Delete---

Clear all

Set the target file header/Editable

62636844.042 62636851.905 62636853.400 -7.8630 -9.3578 -1.4948

Set the target record table header/Editable

ID lon lat height residual weight

Ok Cancel

Compliant with PAGravf4.5



Conversion of General ASCII Records to PAGravf4.5 Format

Open text file Save as Save process Follow example

62636844.042 62636851.905 62636853.400 -7.8630 -9.3578 -1.4948

ID lon lat height residual weight

2	102.546777	24.458002	1659.0410	-0.8046	0.94
3	102.632412	24.458211	2120.2558	-0.7142	1.23
4	102.725921	24.460578	2111.3872	-0.7612	1.68
5	102.420803	24.566357	1990.6386	-0.7157	1.95
6	102.528697	24.562786	1936.4260	-0.7491	2.93
9	102.832641	24.575505	1977.4949	-0.8223	1.04
10	102.345532	24.668953	1919.7825	-0.7782	3.53
11	102.423972	24.652933	1959.3369	-0.7548	2.02
12	102.529771	24.667079	2157.7877	-0.7317	1.46
13	102.631063	24.657055	1906.3415	-0.8185	3.53
14	102.742718	24.652871	1935.7882	-0.7767	3.39
15	102.843573	24.642787	1880.7707	-0.8319	0.81
16	103.137778	24.658224	1838.4387	-0.7730	0.53
17	102.426305	24.743284	1929.0475	-0.7771	1.48
20	102.729945	24.734909	1856.2213	-0.8356	6.12
21	102.840819	24.752018	2117.8582	-0.7459	1.56
22	102.939253	24.728089	2050.9590	-0.7907	0.81
23	103.029713	24.748496	2034.1986	-0.8217	0.88
24	103.129600	24.753135	1575.0654	-0.8477	1.41
25	103.227846	24.747081	1668.7801	-0.8116	3.06

Open Source ASCII Text File Number of rows of the file header 1 Exact and Edit Data Organize and Display Result File Save data in the textbox as Save program process as

Display of the input-output file↓

>> [Function] Converts standard ASCII data records from heterogeneous external sources or non-standard formats into discrete geodetic record files compliant with PAGravf4.5 specifications.
** Please click the button [Open Source ASCII Text File]...
>> C:/PAGravf4.5_win64en/examples/EdPntrecordstandard/rntksich.txt.
** look at the source file information in the text box above, enter the number of rows of the file header firstly, click the button [Exact and edit data]...
>> Set the format parameters about the target file header, record table header, and record attributes.
** Click the control button [Organize and Display Result File] to calculate the maximum character width for each target column. The upper editable text box displays the formatted target file header, table header, and all records.
** It takes some time to organize the target record attributes. Please wait...
>> Complete the statistics of the maximum number of characters of the target record attributes, and display the target file header, record table header and all the records in the editable textbox.
** Check the target records file displayed in the editable textbox. Click the control button [Save data in the textbox as] to save the contents in the textbox as the target file...

This utility is the primary gateway for loading external textual data into the PAGravf4.5 workflow.

Conversion of General ASCII Records to PAGravf4.5 Format

Open text file Save as Save process Follow example

62636844.042 62636851.905 62636853.400 -7.8630 -9.3578 -1.4948

2	102.546777	24.458002	1659.0410	-33.6150	-0.8046	0.94	-0.0014
3	102.632412	24.458211	2120.2558	-33.3212	-0.7142	1.23	0.0890
4	102.725921	24.460578	2111.3872	-33.2058	-0.7612	1.68	0.0420
5	102.420803	24.566357	1990.6386	-33.5334	-0.7157	1.95	0.0875
6	102.528697	24.562786	1936.4260	-33.3720	-0.7491	2.93	0.0541
9	102.832641	24.575505	1977.4949	-33.1581	-0.8223	1.04	-0.0191
10	102.345532	24.668953	1919.7825	-33.7565	-0.7782	3.53	0.0250
11	102.423972	24.652933	1959.3369	-33.4781	-0.7548	2.02	0.0484
12	102.529771	24.667079	2157.7877	-33.2933	-0.7317	1.46	0.0715
13	102.631063	24.657055	1906.3415	-33.3155	-0.8185	3.53	-0.0153
14	102.742718	24.652871	1935.7882	-33.1128	-0.7767	3.39	0.0265
15	102.843573	24.642787	1880.7707	-33.1133	-0.8319	0.81	-0.0287
16	103.137778	24.658224	1838.4387	-32.7463	-0.7730	0.53	0.0302
17	102.426305	24.743284	1929.0475	-33.4575	-0.7771	1.48	0.0261
20	102.729945	24.734909	1856.2213	-33.2087	-0.8356	6.12	-0.0324
21	102.840819	24.752018	2117.8582	-32.8948	-0.7459	1.56	0.0573
22	102.939253	24.728089	2050.9590	-32.8500	-0.7907	0.81	0.0125
23	103.029713	24.748496	2034.1986	-32.8194	-0.8217	0.88	-0.0185
24	103.129600	24.753135	1575.0654	-32.8486	-0.8477	1.41	-0.0445
25	103.227846	24.747081	1668.7801	-32.6509	-0.8116	3.06	-0.0084
26	103.327056	24.734505	1829.6718	-32.3302	-0.7499	3.77	0.0533

Open Source ASCII Text File Number of rows of the file header 1 Exact and edit data Organize and display results file Save data in the textbox as Save program process as

Display of the input-output file↓

>> [Function] Converts general ASCII data record files from diverse sources or non-standard formats into discrete geodetic record files compliant with PAGravf4.5 specifications.
** Please click the button [Open the source ASCII text file]...
>> C:/PAGravf4.5_win64en/examples/EdPntrecordstandard/rntksich.txt.
** look at the source file information in the text box above, enter the number of rows of the file header firstly, click the button [Exact and edit data]...
>> Set the format parameters about the target file header, record table header, and record attributes.
** Click the control button [Organize and display results file] to count the maximum number of each column characters of the target record attributes, the upper editable textbox will display target file header, record table header and all the records.
** It takes some time to organize the target record attributes. Please wait...

This utility is the primary gateway for loading external textual data into the PAGravf4.5 workflow.



Grid Resolution Modification via Interpolation

Open file

Save as

Import parameters

Start computation

Save process

Follow example



Grid Resolution Modification
via Interpolation



Interpolation of Geodetic Site
Attributes from Grid



Record Selection Based
on Attribute Condition



Separation of (Vector) Grid Data
into Distinct Regions



Open Geodetic Grid File

>> Program Process ** Operation Prompts



Save program process as

☐ Process Batch files in a folder

Grid spatial resolution 5.000'

Interpolation mode

Weighted inverse distance

>> Select the computation function from the 4 control buttons at the top of the interface...
 >> [Function] Modifies the spatial resolution of a geodetic grid based on a target resolution and a selected interpolation algorithm (Upsampling or Downsampling).
 >> Open Geodetic Grid File C:/PAGravf4.5_win64en/examples/Edatafsimpleprocess/dbmGM1800150sksi.dat.
 >> Save the results as C:/PAGravf4.5_win64en/examples/Edatafsimpleprocess/dbmGM1800300sksi.dat.
 >> The parameter settings have been entered into the system!
 ** Click the [Start Computation] control button, or the [Start Computation] tool button...
 >> Computation start time: 2026-04-15 14:46:25
 >> Complete the computation!
 >> Computation end time: 2026-04-15 14:46:27



Save the results as



Import setting parameters



Start computation

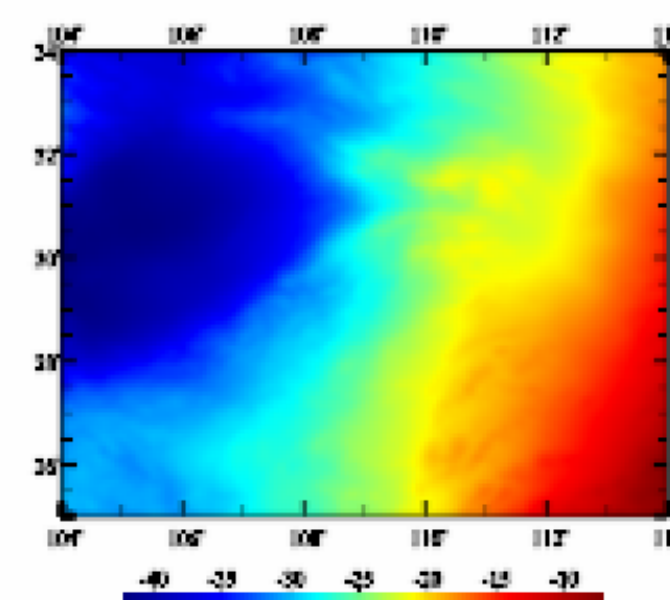
104.000000	114.000000	25.000000
-30.2919	-30.2668	-30.2778
-30.6576	-30.5428	-30.4278
-29.4737	-29.2776	-29.1069
-26.6049	-26.5548	-26.5321
-23.9284	-23.7268	-23.5718
-20.2001	-19.8410	-19.5237
-15.2558	-14.8489	-14.5217
-11.0481	-10.7002	-10.4082
-30.2686	-30.2461	-30.2499
-30.5727	-30.4886	-30.4152
-29.5261	-29.3636	-29.2124
-26.6002	-26.5250	-26.4927
-23.9027	-23.7075	-23.5598



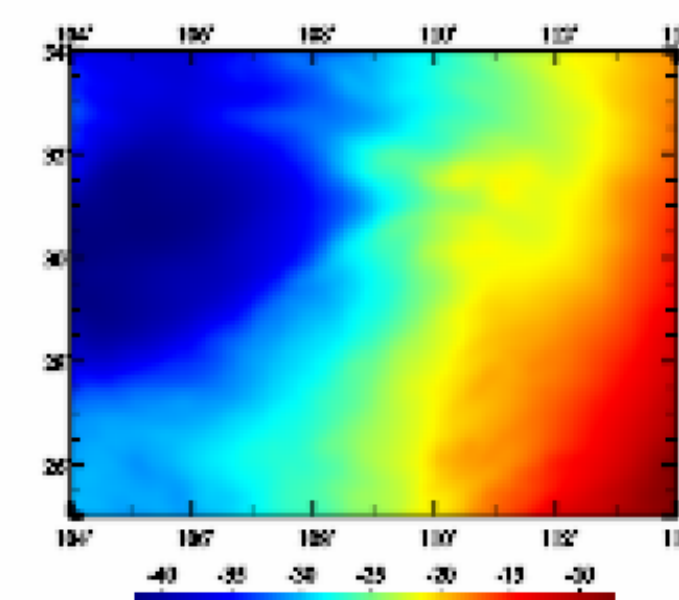
Extract results



Plot↓



input grid



result grid

Interpolation of Geodetic Site Attributes from Grid

Open file

Save as

Import parameters

Start computation

Save process

Follow example

Grid Resolution Modification
via InterpolationInterpolation of Geodetic Site
Attributes from GridRecord Selection Based
on Attribute ConditionSeparation of (Vector) Grid Data
into Distinct Regions

Open Discrete Geodetic Point File

Set format parameters of the file

Number of rows of the file header

1



Open Geodetic Grid File

Interpolation mode

Weighted inverse distance

>> Program Process ** Operation Prompts



Save program process as

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-15 14:46:25

>> Complete the computation!

>> Computation end time: 2026-04-15 14:46:27

>> [Function] Interpolates attribute values for specific geodetic sites from a numerical grid using a selected spatial interpolation method.

>> Open Discrete Geodetic Point File C:/PAGravf4.5_win64en/examples/Edatafsimpleprocess/pntdata.txt.

** Look at the input file information in the text box above, set the file format parameters...

>> Open Geodetic Grid File for interpolation C:/PAGravf4.5_win64en/examples/Edatafsimpleprocess/pntgrid.dat.

>> Save the results as C:/PAGravf4.5_win64en/examples/Edatafsimpleprocess/rstpnt.txt.

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-15 14:49:15

>> Complete the computation!

>> Computation end time: 2026-04-15 14:49:16



Save the results as



Import setting parameters



Start computation

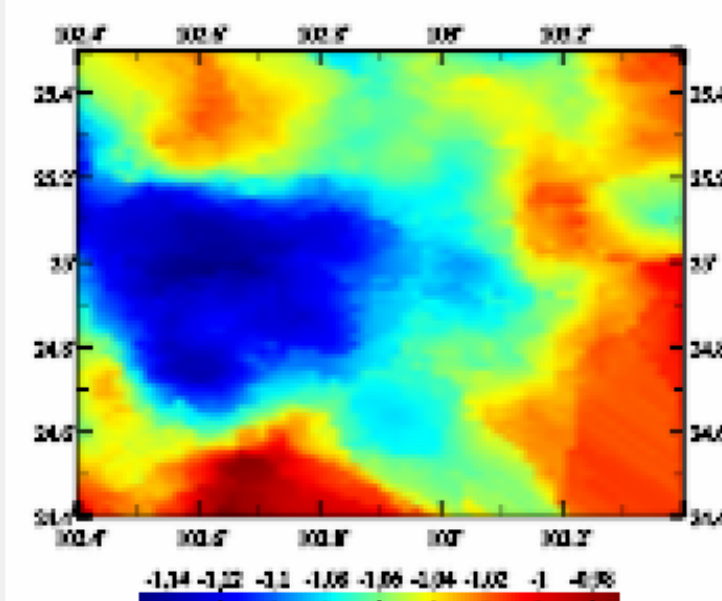
number	lon(deg/decimal)	lat	ellipHei
1	102.442457	24.471769	1972.7
2	102.546777	24.458002	1659.0
3	102.632412	24.458211	2120.2
4	102.725921	24.460578	2111.3
5	102.420803	24.566357	1990.6
6	102.528697	24.562786	1936.4
7	102.634437	24.565660	2192.9
8	102.725888	24.581970	2303.7
9	102.832641	24.575505	1977.4
10	102.345532	24.668953	1919.7
11	102.423972	24.652933	1959.3
12	102.529771	24.667079	2157.7
13	102.631063	24.657055	1906.3



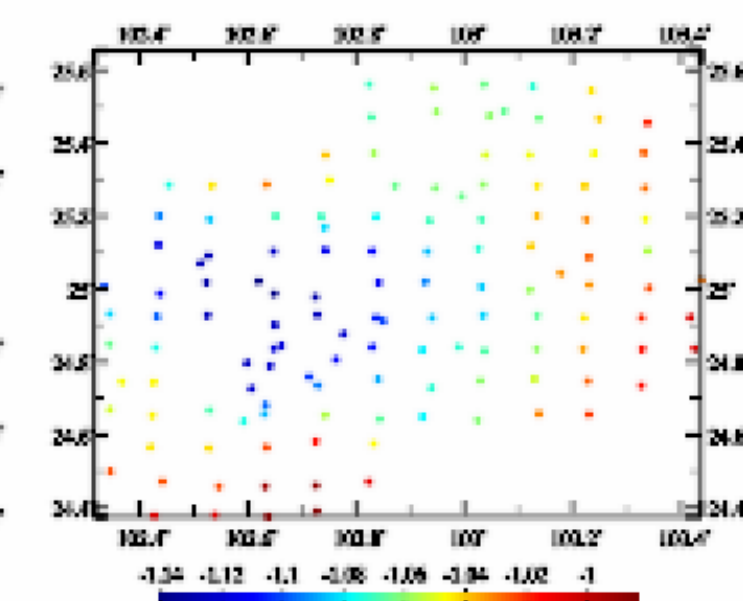
Extract results



Plot↓



input grid



results interpolated

Record Selection Based on Attribute Condition

Open file Save as Import parameters Start computation Save process

Follow example

Grid Resolution Modification
via Interpolation

Interpolation of Geodetic Site
Attributes from Grid

Record Selection Based
on Attribute Condition

Separation of (Vector) Grid Data
into Distinct Regions

Open Discrete Geodetic Point File

>> Program Process ** Operation Prompts

Save program process as

Set format parameters of the file

Number of rows of the file header 1

Condition Attribute Colmun Index 5

Minimum 0.00

Maximum 9000.00

>> Save the results as C:/PAGravf4.5_win64en/examples/Edatafsimpleprocess/rstpnt.txt.

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-15 14:49:15

>> Complete the computation!

>> Computation end time: 2026-04-15 14:49:16

>> [Function] Filters geodetic records from a file based on a specified minimum and maximum range for a selected attribute.

>> Open Discrete Geodetic Point File C:/PAGravf4.5_win64en/examples/Edatafsimpleprocess/chksinterp.txt.

** Look at the input file information in the text box above, set the file format parameters...

>> Save the results as C:/PAGravf4.5_win64en/examples/Edatafsimpleprocess/chksinterp_.txt.

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-15 14:50:47

>> Complete the computation!

>> Computation end time: 2026-04-15 14:51:03

Save the results as

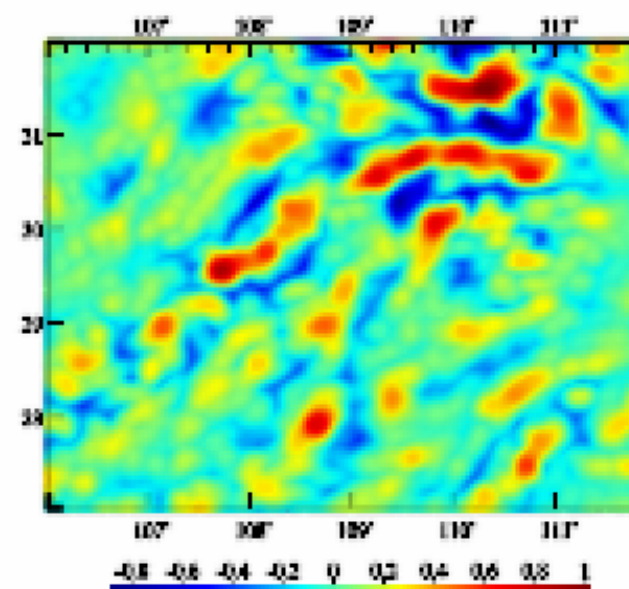
Import setting parameters

Start computation

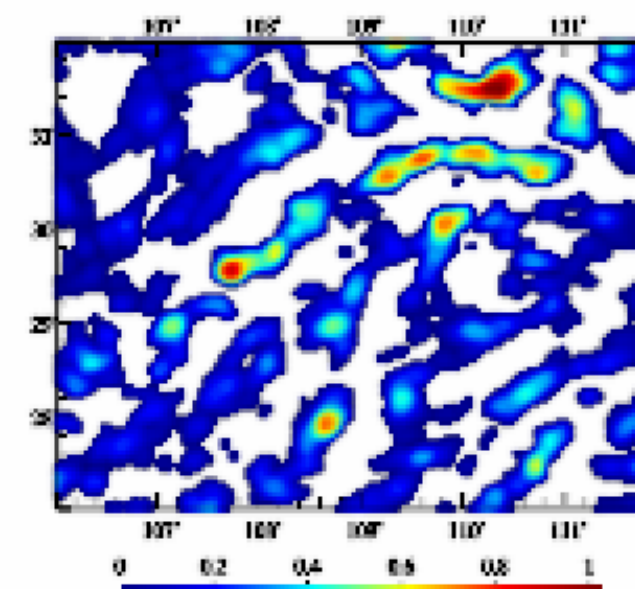
```
no lon(degree/decimal) lat ellipHeigh
11581 106.520833 27.020833
11582 106.562500 27.020833
11583 106.604167 27.020833
11584 106.645833 27.020833
11585 106.687500 27.020833
11586 106.729167 27.020833
11587 106.770833 27.020833
11588 106.812500 27.020833
11589 106.854167 27.020833
11590 106.895833 27.020833
11591 106.937500 27.020833
11598 107.229167 27.020833
11599 107.270833 27.020833
```

Extract results

Plot↓



input points



result points

Separation of (Vector) Grid Data into Distinct Regions

Open file Save as Import parameters Start computation Save process Follow example

Grid Resolution Modification
via Interpolation

Interpolation of Geodetic Site
Attributes from Grid

Record Selection Based
on Attribute Condition

Separation of (Vector) Grid Data
into Distinct Regions

Open Source Geodetic (Vector) Grid File

☐ Process Batch files in a folder

☐ Separate vector grid data

Constant cell grid value 9990.00

Open Reference Grid File

Minimum -99000.00

Maximum 0.00

Interpolation mode

Weighted inverse distance

>> Program Process ** Operation Prompts

Save program process as

>> Computation end time: 2026-04-15 14:51:03

>> [Function] Select reference grids that can distinguish different regions, and separate the target region (vector) grid data that meets the reference grid conditions in the (vector) grid by replacing the grid values that do not meet the conditions with constant grid values.

** Requirement: The reference grid must effectively delineate the target area via its cell value range. Reference Grid Spatial extent must be $\geq$ those of the source grid.

** Application: Enables the separation of Land or Sea (vector) grid. The source and reference grids may have different resolutions.

>> Open Geodetic Grid File C:/PAGrav4.5_win64en/examples/Edatafsimpleprocess/ETOPO30msph.dat.

>> Open Reference Grid File C:/PAGrav4.5_win64en/examples/Edatafsimpleprocess/ETOPO30msph.dat.

>> Save the results as C:/PAGrav4.5_win64en/examples/Edatafsimpleprocess/ETOPO30msea.dat.

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-15 14:52:52

>> Complete the computation!

>> Computation end time: 2026-04-15 14:53:36

Save the results as

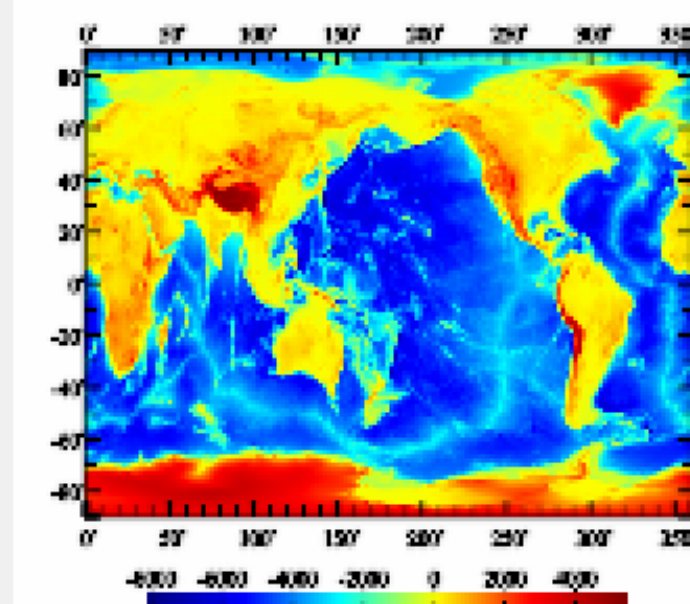
Import setting parameters

Start computation

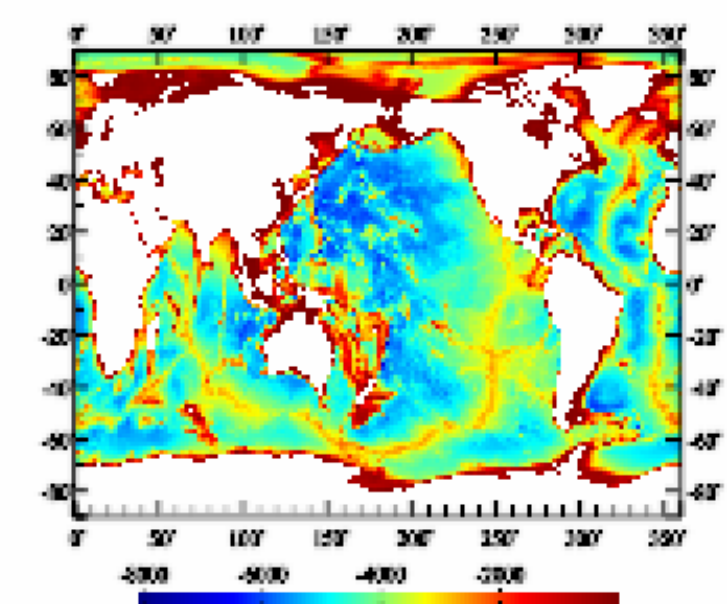
0.000000	360.000000	-90.000000
9990.0000	9990.0000	9990.0000
9990.0000	9990.0000	9990.0000
9990.0000	9990.0000	9990.0000
9990.0000	9990.0000	9990.0000
9990.0000	9990.0000	9990.0000
9990.0000	9990.0000	9990.0000
9990.0000	9990.0000	9990.0000
9990.0000	9990.0000	9990.0000
9990.0000	9990.0000	9990.0000
9990.0000	9990.0000	9990.0000
9990.0000	9990.0000	9990.0000
9990.0000	9990.0000	9990.0000
9990.0000	9990.0000	9990.0000
9990.0000	9990.0000	9990.0000

Extract results

Plot↓



input grid



output grid

Weighted Operations on Two Geodetic Grid Files

Open file Save as Import parameters Start computation Save process Follow example

Weighted Operations on Two Attributes in a Record File

Weighted Operations on Two Geodetic Grid Files

Product Operations on Two Vector Grid Files

Weighted Operations on Two Harmonic Coefficient Files

Open Geodetic Grid File 1

Open Geodetic Grid File 2

Select operation mode

Plus +

Set weight

The first weight 1.00

The second weight 1.00

☐ Vector grid operation

>> Program Process ** Operation Prompts

Save program process as

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-15 15:25:17

>> Complete the computation!

>> Computation end time: 2026-04-15 15:25:18

>> [Function] Performs weighted addition, subtraction, or multiplication on corresponding grid cell elements from two (vector) grid files with identical specifications (extent and resolution).

>> Open Geodetic Grid File 1 C:/PAGravf4.5_win64en/examples/EdFlgeodatacalculate/dbmGM1800150sksi.dat.

>> Open Geodetic Grid File 2 C:/PAGravf4.5_win64en/examples/EdFlgeodatacalculate/dbmchkski.dat.

>> Save the results as C:/PAGravf4.5_win64en/examples/EdFlgeodatacalculate/gridadd.dat.

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-15 15:26:18

>> Complete the computation!

>> Computation end time: 2026-04-15 15:26:18

Save the results as

Import setting parameters

Start computation

Display of the input-output file↓

Save data in the text box as

104.000000	114.000000	25.000000	34.000000	0.04166667	0.04166667						
-30.5114	-30.4199	-30.2768	-30.1549	-30.1146	-30.1663	-30.2994	-30.4668	-30.6075	-30.6567	-30.5988	-30.5988
-30.2285	-30.1796	-30.1031	-30.0819	-30.1804	-30.3922	-30.6776	-30.9177	-31.0410	-31.0551	-31.0455	-31.0455
-31.2116	-31.1329	-30.9873	-30.7682	-30.4890	-30.2022	-29.9693	-29.8488	-29.8569	-29.9773	-30.1552	-30.1552
-30.9218	-30.9751	-30.9505	-30.8489	-30.7290	-30.6380	-30.5924	-30.5286	-30.4036	-30.2163	-30.0523	-30.0523
-29.5465	-29.3812	-29.2298	-29.0822	-28.9055	-28.7129	-28.5705	-28.5345	-28.6044	-28.7092	-28.7470	-28.7470
-28.0867	-28.0710	-28.0436	-28.0049	-27.9269	-27.7917	-27.5879	-27.3584	-27.1547	-27.0015	-26.8789	-26.8789
-26.3895	-26.4266	-26.4807	-26.5259	-26.5591	-26.5960	-26.6364	-26.6562	-26.6736	-26.6858	-26.6641	-26.6641
-25.6038	-25.4717	-25.3106	-25.0365	-24.6829	-24.3692	-24.1817	-24.1522	-24.2168	-24.2804	-24.3117	-24.3117
-24.3442	-24.1732	-24.0196	-23.9211	-23.8547	-23.7500	-23.5559	-23.2878	-23.0098	-22.7667	-22.5529	-22.5529
-21.5201	-21.3819	-21.2244	-21.0385	-20.8604	-20.7475	-20.7275	-20.8133	-20.9472	-21.0369	-21.0245	-21.0245
-20.4280	-20.2711	-20.0634	-19.8359	-19.6151	-19.3574	-19.0150	-18.5757	-18.1577	-17.8564	-17.7474	-17.7474
-17.6619	-17.3095	-17.0684	-16.9475	-16.9047	-16.8685	-16.8012	-16.7072	-16.5981	-16.4777	-16.3356	-16.3356
-15.4390	-15.1688	-14.8677	-14.5807	-14.3366	-14.1429	-13.9759	-13.7864	-13.5438	-13.2528	-12.9617	-12.9617
-12.8860	-13.0102	-13.0730	-13.0600	-12.9626	-12.7783	-12.5554	-12.3529	-12.2342	-12.1999	-12.1691	-12.1691
-10.9134	-10.7357	-10.4881	-10.1450	-9.7851	-9.5001	-9.3878	-9.3820	-9.3707	-9.2674	-9.0932	-9.0932
-9.4250	-9.4103	-9.2795	-9.0997	-8.9259	-8.7736	-8.6343	-8.4985	-8.3479	-8.1760	-7.9786	-7.9786
-30.5179	-30.4099	-30.2541	-30.1283	-30.0803	-30.1226	-30.2586	-30.4353	-30.5967	-30.6568	-30.5947	-30.5947

Product Operations on Two Vector Grid Files

Open file Save as Import parameters Start computation Save process Follow example

Weighted Operations on Two Attributes in a Record File

Weighted Operations on Two Geodetic Grid Files

Product Operations on Two Vector Grid Files

Weighted Operations on Two Harmonic Coefficient Files

Open Vector Grid File 1

Open Vector Grid File 2

Select operation mode

Inner product •

Set weight

The first weight 1.00

The second weight 1.00

☒ The vector 1 is in SW system

>> Program Process ** Operation Prompts

Save program process as

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-15 15:26:18

>> Complete the computation!

>> Computation end time: 2026-04-15 15:26:18

>> [Function] Computes the outer product or inner product of corresponding cell vector elements from two vector grid files with identical specifications.

>> Open Vector Grid File 1 C:/PAGravf4.5_win64en/examples/EdFlgeodatacalculate/dwmchcpc.dat.

>> Open Vector Grid File 2 C:/PAGravf4.5_win64en/examples/EdFlgeodatacalculate/dtmhgradient.dat.

>> Save the results as C:/PAGravf4.5_win64en/examples/EdFlgeodatacalculate/vectinproduct.dat.

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-15 15:27:50

>> Complete the computation!

>> Computation end time: 2026-04-15 15:27:50

Save the results as

Import setting parameters

Start computation

Display of the input-output file↓

Save data in the text box as

```
104.000000 114.000000 25.000000 34.000000 0.04166667 0.04166667
4.5249E-03 -1.8612E-02 -1.0108E-01 -9.2410E-02 -4.5270E-02 -5.3433E-02 -1.5264E-01 -2.1435E-01 -6.5999E-02 1.7780E-02 3.1589E-02 -1.05
1.4971E-01 4.1972E-02 -1.4970E-01 5.4700E-02 2.3498E-01 -4.5193E-01 -1.7274E-01 -7.6354E-02 2.6210E-02 -5.1069E-02 -6.1332E-02 -3.44
-1.7099E-02 -6.8073E-02 -8.8371E-02 -1.1298E-01 -2.9868E-01 -1.0689E-01 -5.0087E-02 -6.3396E-02 -5.4548E-02 -1.1735E-01 -1.7619E-01 -1.84
-8.4274E-02 4.8267E-02 -6.5637E-03 -1.7074E-02 -2.9377E-02 -1.2714E-01 -4.0112E-02 -5.0957E-02 -8.9210E-03 -1.1984E-01 -1.7813E-02 -4.18
1.5090E-01 -2.9979E-02 3.3127E-03 1.7931E-02 -4.8375E-02 -3.0339E-02 -8.5672E-03 -7.6339E-02 -2.1667E-01 -1.8753E-01 3.8978E-02 -3.49
-1.0005E-01 5.6759E-02 -1.2759E-01 -7.7835E-02 -4.4242E-02 5.6767E-03 -9.5305E-02 -9.0244E-02 2.4269E-02 2.0665E-02 -3.2468E-03 -1.45
-2.3723E-02 -8.4503E-02 -2.8838E-02 1.7428E-02 1.4669E-02 -3.7745E-02 -1.8587E-01 8.7255E-02 1.6160E-02 -1.9504E-02 1.6234E-03 -1.50
8.6827E-03 8.8306E-03 3.5816E-03 -1.9019E-01 -2.4521E-01 -7.6810E-02 -4.3002E-02 -8.3902E-02 -3.9614E-02 -1.5691E-01 -7.2438E-02 1.20
-1.4300E-02 -3.8695E-02 -2.3024E-02 -3.5111E-02 -1.7776E-02 4.9347E-03 -3.4274E-02 -9.8438E-02 -8.3099E-02 4.8152E-02 1.2597E-01 -4.90
-4.9619E-02 2.7500E-03 -6.9311E-03 -3.8635E-02 -7.2906E-03 4.7353E-02 -1.5282E-01 -1.6887E-01 -1.4322E-01 -2.8888E-02 1.0281E-02 -1.76
-6.8843E-04 -1.3272E-02 -4.6801E-02 -1.2487E-02 1.2993E-03 -4.4001E-02 -1.7193E-01 -6.9525E-01 -5.0068E-01 -1.3448E-01 -1.4124E-01 -1.88
-1.6644E-01 2.8159E-01 1.0159E+00 3.1526E-01 5.5459E-02 1.1821E-02 -8.8003E-03 8.4806E-03 1.5612E-02 -9.4503E-04 -3.5233E-03 -4.46
1.9837E-02 -1.2693E-01 -4.2207E-02 1.4538E-02 2.5484E-02 -1.6916E-02 2.3931E-02 -4.1757E-02 -5.6356E-02 -1.3125E-01 -5.3239E-02 -2.80
-4.3253E-01 -3.3056E-01 -1.3669E-01 -5.5918E-02 -1.2527E-01 -1.3619E-01 -2.7279E-02 -9.0685E-02 -2.4020E-01 -1.8123E-01 -1.1543E-01 9.70
3.3104E-01 1.7683E-01 1.0685E-01 7.6371E-01 1.2521E+00 1.0653E-01 4.5900E-01 1.3034E-01 2.6995E-02 2.3780E-03 -8.9252E-03 4.70
-9.9292E-02 -7.8246E-04 -1.8947E-02 -2.3336E-02 -1.3941E-03 2.6332E-03 1.5848E-02 -2.0236E-03 1.6477E-03 -2.7693E-03 -2.7982E-02 -4.56
4.7103E-04 -1.8541E-02 -1.1186E-01 -7.7025E-02 3.6018E-02 -6.9270E-02 -1.3816E-01 -2.2983E-01 -6.1426E-02 -7.9945E-03 -2.6613E-02 -3.54
```


Weighted Operations on Two Harmonic Coefficient Files

Open file Save as Import parameters Start computation Save process Follow example

Weighted Operations on Two Attributes in a Record File

Weighted Operations on Two Geodetic Grid Files

Product Operations on Two Vector Grid Files

Weighted Operations on Two Harmonic Coefficient Files

Open spherical harmonic coefficients model file 1

Open spherical harmonic coefficients model file 2

Select operation mode

Plus +

Set weight

The first weight 1.00

The second weight 1.00

>> Program Process ** Operation Prompts

Save program process as

>> Computation end time: 2026-04-15 15:27:50

>> [Function] Performs weighted operations on two normalized spherical harmonic coefficient model files. File Header: Single row containing the scale parameters: the geocentric gravitational constant GM ($10^{14} \text{ m}^3/\text{s}^2$) and the Earth's semi-major axis a (m).

>> Open spherical harmonic coefficient model file 1 C:/PAGravf4.5_win64en/examples/EdFIgeodatacalculate/CS50.dat.

>> Open spherical harmonic coefficient model file 2 C:/PAGravf4.5_win64en/examples/EdFIgeodatacalculate/CS60.dat.

>> Save the results as C:/PAGravf4.5_win64en/examples/EdFIgeodatacalculate/CSadd60.dat.

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-04-15 15:28:47

>> Complete the computation!

>> Computation end time: 2026-04-15 15:28:50

Save the results as

Import setting parameters

Start computation

Display of the input-output file↓

Save data in the text box as

```
3.986004415d0 6378136.3d0
2 0 -9.683302875816E-04 0.000000000000E+00 7.4812E-12 0.0000E+00
2 1 -4.132310181484E-10 2.768827782760E-09 7.0637E-12 7.3484E-12
2 2 4.878767146566E-06 -2.800547407718E-06 7.2302E-12 7.4258E-12
3 0 1.914322414187E-06 0.000000000000E+00 5.7314E-12 0.0000E+00
3 1 4.060924020958E-06 4.964008317138E-07 5.7266E-12 5.9767E-12
3 2 1.809575789619E-06 -1.238010950355E-06 6.3747E-12 6.4019E-12
3 3 1.442643514243E-06 2.828698523858E-06 6.0291E-12 6.0284E-12
4 0 1.079931733278E-06 0.000000000000E+00 4.4312E-12 0.0000E+00
4 1 -1.072314778778E-06 -9.471346930362E-07 4.5681E-12 4.6840E-12
4 2 7.010032479252E-07 1.324960052552E-06 5.3078E-12 5.1861E-12
4 3 1.981713533345E-06 -4.019134471350E-07 5.6320E-12 5.6202E-12
4 4 -3.770392660460E-07 6.176077642984E-07 5.3729E-12 5.3832E-12
5 0 1.373405827473E-07 0.000000000000E+00 2.9102E-12 0.0000E+00
5 1 -1.258423846085E-07 -1.887396146792E-07 2.9891E-12 3.1434E-12
5 2 1.304156086352E-06 -6.467063850810E-07 3.8228E-12 3.6427E-12
5 3 -9.036943046576E-07 -4.299108166120E-07 4.7259E-12 4.6890E-12
5 4 -5.906575223512E-07 9.961411002048E-08 5.3322E-12 5.3026E-12
```


Low-Pass Filtering Operations on Geodetic Grid File

Open grid file

Import parameters

Save as

Start Computation

Save process

Follow example

Open Geodetic Numerical Grid File

Select low-pass filter

moving average filter

Set filter parameter n

2

Save the results as

Import setting parameters

Start Computation

>> Computation Process ** Operation Prompts

Save computation process as

>> [Function] Performs low-pass filtering to a geodetic numerical grid file using algorithms such as Moving Average, Gaussian, Exponential, or Butterworth. The grid specification (latitude-longitude extent and spatial resolution) remains invariant before and after filtering.

** Filter Parameter (n): For Moving Average filtering, Larger n values yield stronger smoothing (wider kernel). For Exponential / Butterworth filtering, Smaller n values yield stronger smoothing (lower cutoff frequency). For Gaussian filtering, Ignores the filtering parameter n .

>> Open Geodetic Numerical Grid File C:/PAGravf4.5_win64en/examples/EdGrdlowpassfilter/dbmGM1800150sgrr.dat.

>> Save the results as C:/PAGravf4.5_win64en/examples/EdGrdlowpassfilter/result.dat.

** The program output the low-pass filtered file with the same grid specification as the input file.

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-03-30 10:09:45

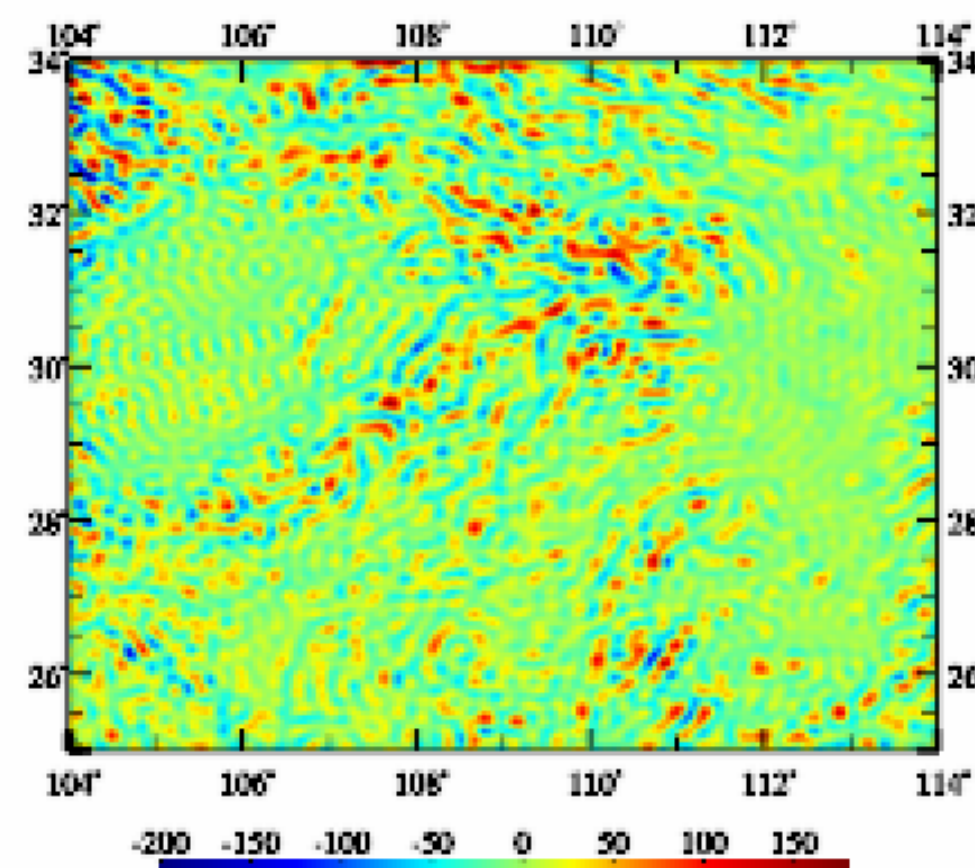
>> Complete the Low-pass filtering operation!

>> Computation end time: 2026-03-30 10:09:45

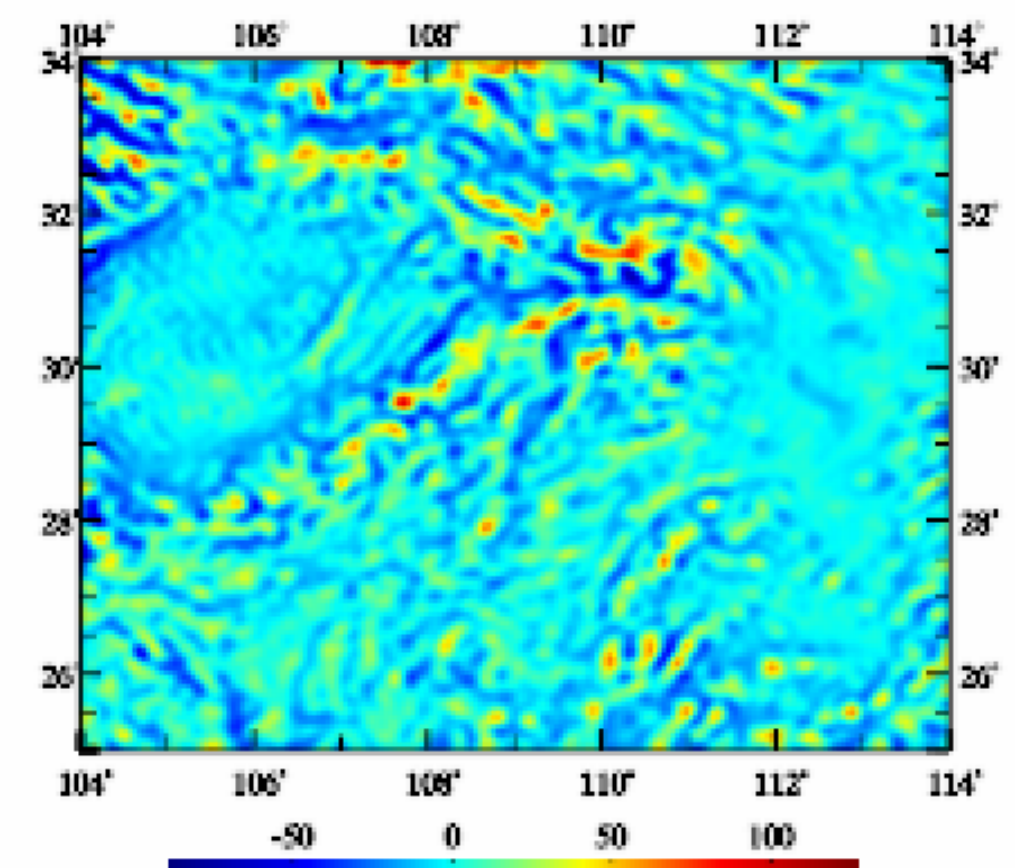
104.000000	114.000000	25.000000	34.000000	
-5.962	4.177	11.466	23.289	2
-10.021	-2.122	7.745	14.268	1
-6.945	-2.312	6.767	18.694	3
-36.281	-36.125	-29.339	-19.418	-1
-32.602	-28.244	-23.450	-17.043	-
2.814	7.501	6.571	1.403	-
11.234	8.115	3.029	-3.837	-1
2.271	-6.546	-13.002	-10.816	-
-18.356	-9.850	-3.663	-4.016	-
13.916	11.283	9.246	10.708	1
-20.631	-18.825	-17.034	-15.637	-1
-24.640	-23.201	-25.161	-31.713	-3
-6.841	-6.836	-4.822	-2.367	-
-3.447	-14.404	-21.274	-23.791	-2
-37.146	-36.745	-32.950	-24.857	-1
-35.635	-30.386	-17.813	-6.002	-
-8.413	0.194	6.596	17.027	2
-5.906	-1.114	6.188	10.945	

Extract filter result

Plot



input grid



low-pass filter grid

Low-Pass Filtering Operations on Geodetic Grid File

Open grid file

Import parameters

Save as

Start Computation

Save process

Follow example

Open Geodetic Numerical Grid File

Select low-pass filter

Gaussian filter

Set filter parameter n

2

Save the results as

Import setting parameters

Start Computation

>> Computation Process ** Operation Prompts

Save computation process as

** The program output the low-pass filtered file with the same grid specification as the input file.

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-03-30 10:09:45

>> Complete the Low-pass filtering operation!

>> Computation end time: 2026-03-30 10:09:45

>> Open Geodetic Numerical Grid File C:/PAGravf4.5_win64en/examples/EdGrdlowpassfilter/dbmGM1800150sgrr.dat.

>> Save the results as C:/PAGravf4.5_win64en/examples/EdGrdlowpassfilter/result1.dat.

** The program output the low-pass filtered file with the same grid specification as the input file.

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-03-30 10:11:21

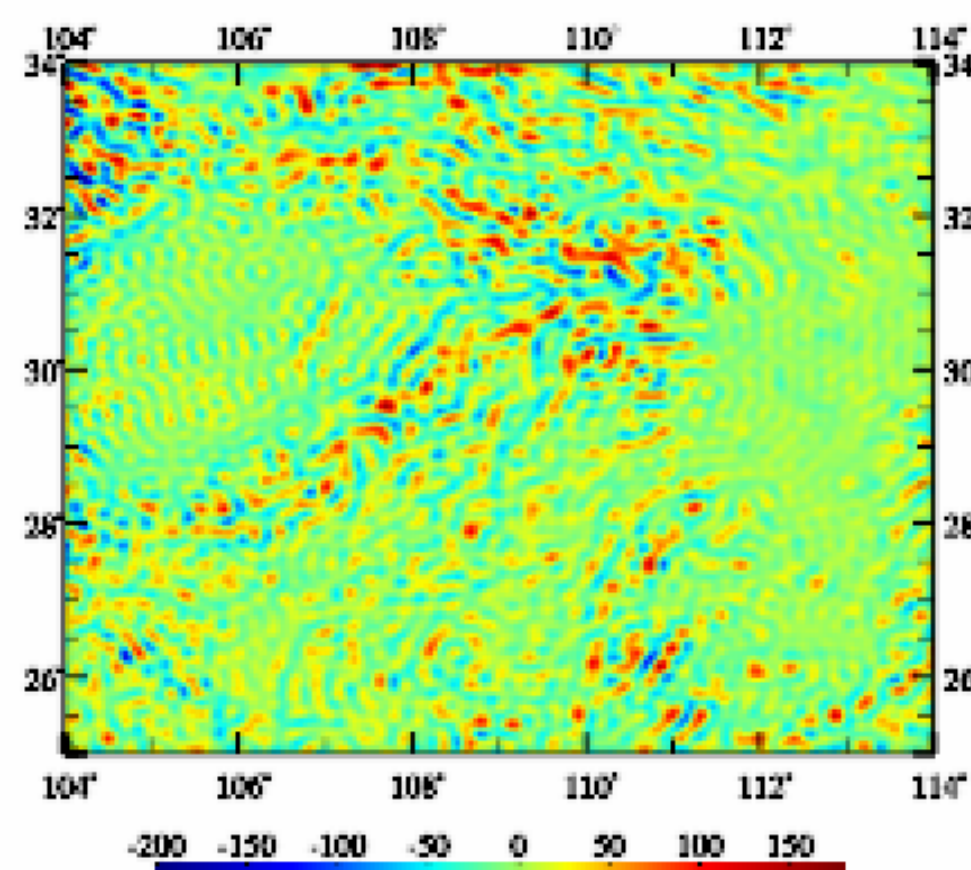
>> Complete the Low-pass filtering operation!

>> Computation end time: 2026-03-30 10:11:22

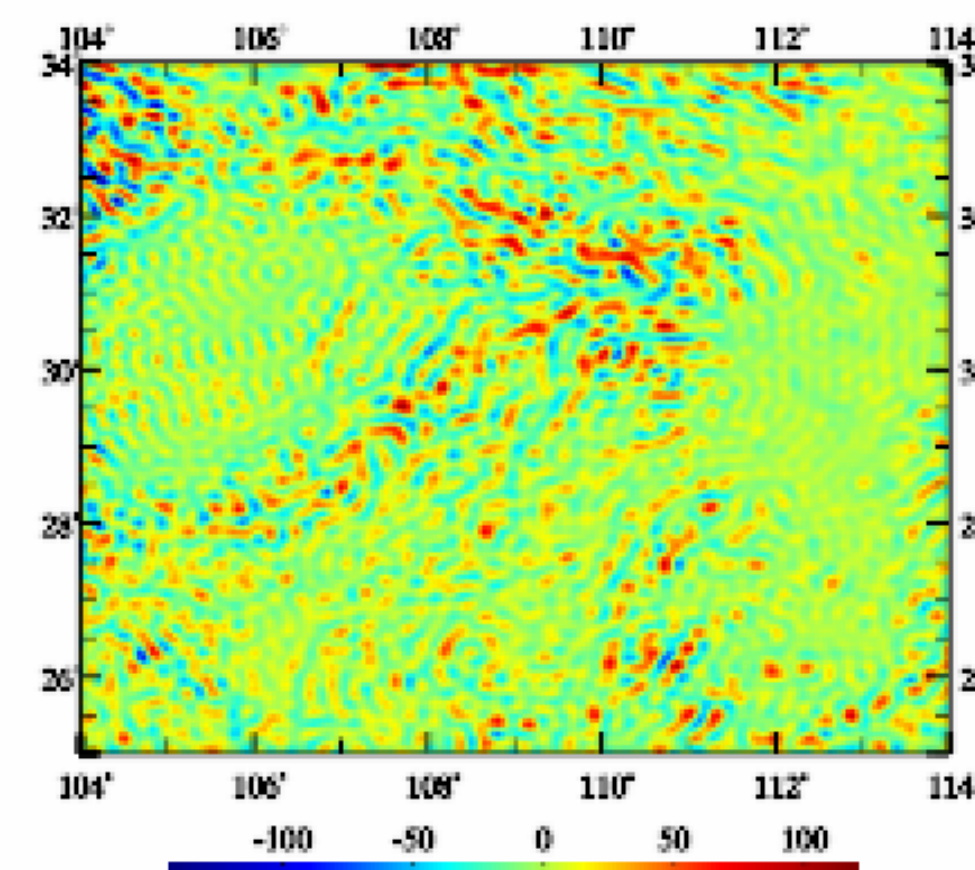
104.000000	114.000000	25.000000	34.000000	
-19.431	-7.879	11.413	26.825	3
-19.523	-14.984	4.138	24.059	2
-18.862	-18.524	-15.997	-7.949	
-29.674	-36.187	-30.500	-14.321	
-19.362	-8.006	-6.767	-8.914	
-6.860	-7.769	-6.066	-6.575	
17.310	5.179	-4.766	-8.772	
3.796	-11.765	-24.376	-16.442	
-28.917	-10.133	2.926	-0.675	-1
3.900	-1.687	-1.105	8.596	2
-18.939	-15.864	-6.493	-1.751	
-10.302	15.787	17.485	0.926	-2
-10.792	-3.370	5.604	11.021	
-14.854	-30.729	-39.021	-42.515	-4
-4.766	-17.662	-18.287	1.630	2
-29.743	-22.831	-7.968	2.368	
-18.081	-5.241	14.003	27.689	3
-19.205	-10.452	9.173	23.953	2

Extract filter result

Plot



input grid



low-pass filter grid

Gridding of Discrete Geodetic Data via Simple Interpolation

Gridding of Discrete Geodetic Data via Simple Interpolation

Vector Grid Interpolation from Dual Attribute Records

High-Resolution Gridding via Direct Averaging

Construction of General Geodetic Grid File

Data Extraction by Latitude-Longitude Extent

Open Discrete Geodetic Point File

Number of rows of the file header 1

Column ordinal number of the target attribute in the record 4

Select interpolation mode

weighted inverse distance

Interpolation search radius (multiple number of the cell grid) 5

☐ Process batch files with same specification

☐ Output spherical coordinate grid

Save computation process as

>> Select the computation function from the 5 control buttons on the top of the interface...

>> [Function] Generates a grid file for a specified attribute from a discrete geodetic point file based on a selected interpolation method and target grid specification. The function supports batch processing of multiple input files.

>> Open Discrete Geodetic Point File C:/PAGravf4.5_win64en/examples/Edareageodeticdata/dbmhgt150s.txt.

** Look at the input file information in the text box below, set the file format parameters.....

>> Save the results as C:/PAGravf4.5_win64en/examples/Edareageodeticdata/dbmhgt150s.dat.

>> Setting parameters have been imported in the program!

** Click the control button [Start computation], or the tool button [Start computation]....

>> Computation start time: 2026-03-30 11:11:54

>> Computation end time: 2026-03-30 11:12:04

>> Complete the computation!

Maximum latitude

34.000°

Minimum longitude

Resolution

Maximum longitude

104.000°

3.000'

114.000°

Minimum latitude

25.000°

Save the results as

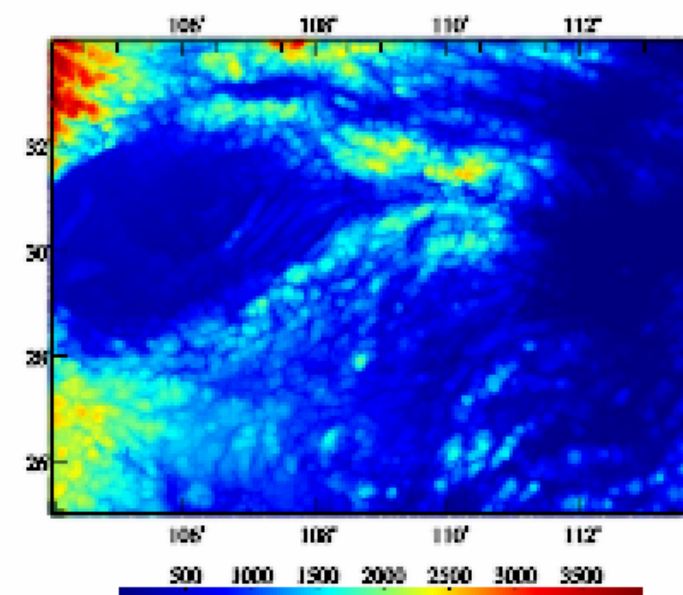
Import setting parameters

Start computation

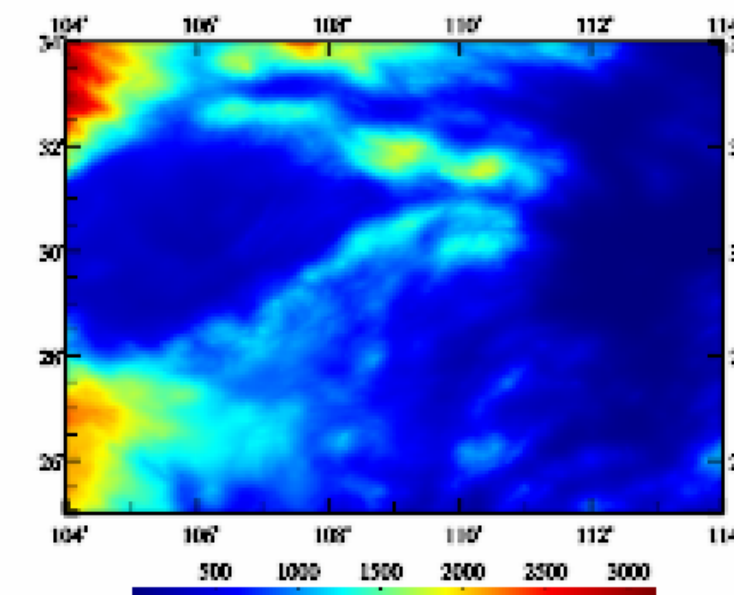
104.000000	114.000000	25.000000	34.000000	0.05000000	0.05000000	
1912.5904	1911.5703	1894.6598	1892.0005	1860.2780	1805.2358	1735.2501
1501.5751	1452.5959	1369.1316	1302.7811	1258.5839	1290.7015	1299.0390
1297.9370	1248.0554	1157.4627	1079.7218	990.4826	892.5431	813.1832
719.6808	722.9691	692.5029	653.0434	636.2823	639.1619	628.3186
649.0571	677.0091	700.1582	669.0468	671.2319	678.5258	687.5093
756.8666	695.5997	646.0431	612.9434	560.7456	477.7001	467.2389
572.2131	657.7112	674.5429	654.7447	632.3204	602.1491	553.7679
217.7440	253.5656	303.8334	335.2665	341.6214	368.5970	401.2640
237.8323	221.9884	206.2026	185.5597	176.4804	177.4285	207.1053
535.1840	503.6774	470.6640	458.6786	503.5616	445.9992	389.0096
373.2007	427.3413	507.7882	559.9410	598.3770	622.1065	697.8113
540.5047	560.0292	548.2523	541.3006	536.5536	466.8930	430.2204
591.4949	575.7512	559.5084	549.6903	521.3611	501.4113	442.4179
246.4003	274.4692	304.5733	333.6479	361.8329		
1927.1494	1922.9193	1912.6866	1912.1639	1873.0282	1827.8662	1762.1738
1482.2412	1432.5739	1366.1587	1311.1388	1296.6929	1311.1117	1311.2577

Extract results

Plot↓



input discrete points



output result grid

Synthesis of Vector Grid Files from Two Scalar Grids

Open file Save as Import parameters Start Computation Save process Follow example

Synthesis of Vector Grid Files
from Two Scalar Grids

Decomposition of Vector Grid File
into Scalar Components

Vector Grid Representation
Transformation

Conversion of Vector Grid File
to Discrete Point File

Open the grid file 1 with the same specification

Open the grid file 2 with the same specification

>> Computation Process ** Operation Prompts

Save computation process as

>> Select the function module from the four control buttons at the top of the interface...

>> [Function] Combines two scalar grid files with identical specifications into a single vector grid file, treating them as orthogonal components (e.g., U and V)

>> Open the grid file 1 with the same specification C:/PAGravf4.5_win64en/examples/EdVectorgridtrans/dbmchpcs.dat.

>> Open the grid file 2 with the same specification C:/PAGravf4.5_win64en/examples/EdVectorgridtrans/dbmchpcw.dat.

>> Save the results as C:/PAGravf4.5_win64en/examples/EdVectorgridtrans/dbmchcpc.dat.

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-03-30 11:51:12

>> Complete the computation!

>> Computation end time: 2026-03-30 11:51:12

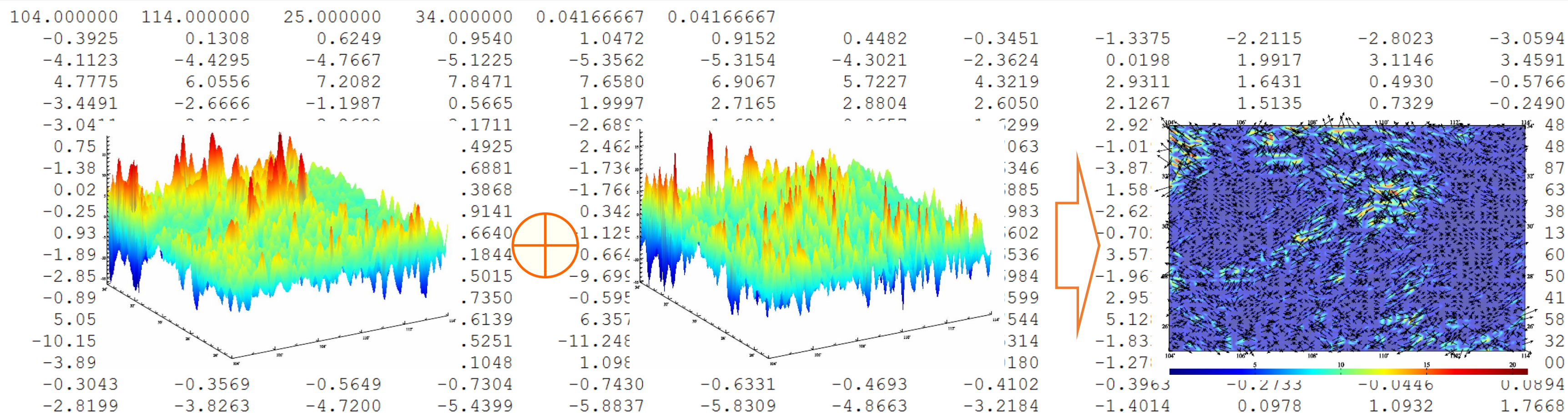
Save the vector grid as

Import setting parameters

Start Computation

Display of the input-output file↓

Save data in the text box as



Conversion of Vector Grid File to Discrete Point File

Open file Save as Import parameters Start Computation Save process Follow example

Synthesis of Vector Grid Files
from Two Scalar GridsDecomposition of Vector Grid File
into Scalar ComponentsVector Grid Representation
TransformationConversion of Vector Grid File
to Discrete Point File☐ Convert the grid into discrete points

>> Computation Process ** Operation Prompts

Save computation process as

Open a vector grid file

>> [Function] Decomposes a vector grid file into its two constituent scalar grid files.
>> Open a vector grid file C:/PAGravf4.5_win64en/examples/EdVectorgridtransf/dbmchcxcpc.dat.
>> Save the component 1 grid as C:/PAGravf4.5_win64en/examples/EdVectorgridtransf/component1.dat.
>> Save the component 2 grid as C:/PAGravf4.5_win64en/examples/EdVectorgridtransf/component2.dat.
>> The parameter settings have been entered into the system!
** Click the [Start Computation] control button, or the [Start Computation] tool button...
>> Computation start time: 2026-03-30 11:52:06
>> Complete the computation!
>> Computation end time: 2026-03-30 11:52:06
>> [Function] Raster-to-Vector conversion: transforms a (vector) grid file into a discrete point file. The latitude and longitude of each output point correspond to the centric coordinates of the respective grid cell.
>> Open a vector grid file C:/PAGravf4.5_win64en/examples/EdVectorgridtransf/vectorgrd.dat.
>> Save the results as C:/PAGravf4.5_win64en/examples/EdVectorgridtransf/vectorpnt.txt.
>> The parameter settings have been entered into the system!
** Click the [Start Computation] control button, or the [Start Computation] tool button...
>> Computation start time: 2026-03-30 11:53:29
>> Complete the computation!
>> Computation end time: 2026-03-30 11:53:31

Save the results as

Import setting parameters

Start Computation

Display of the input-output file↓

Save data in the text box as

1	104.020833	25.020833	-0.393	-1.433
2	104.062500	25.020833	0.131	-3.651
3	104.104167	25.020833	0.625	-4.249
4	104.145833	25.020833	0.954	-3.057
5	104.187500	25.020833	1.047	-0.814
6	104.229167	25.020833	0.915	1.428
7	104.270833	25.020833	0.448	2.818
8	104.312500	25.020833	-0.345	2.857
9	104.354167	25.020833	-1.337	1.308
10	104.395833	25.020833	-2.212	-1.287
11	104.437500	25.020833	-2.802	-3.650
12	104.479167	25.020833	-3.059	-4.430
13	104.520833	25.020833	-3.188	-3.322
14	104.562500	25.020833	-3.436	-1.513
15	104.604167	25.020833	-3.795	-0.477
16	104.645833	25.020833	-4.112	-0.864
17	104.687500	25.020833	-4.429	-1.834
18	104.729167	25.020833	-4.767	-1.618
19	104.770833	25.020833	-5.122	0.791
20	104.812500	25.020833	-5.356	4.234



vectorgrd. dat							
1	104.000000	114.000000	25.000000	34.000000	0.04166667	0.04166667	
2	-0.3925	0.1308	0.6249	0.9540	1.0472	0.9152	0.4482
3	-4.1123	-4.4295	-4.7667	-5.1225	-5.3562	-5.3154	-4.3021
4	4.7775	6.0556	7.2082	7.8471	7.6580	6.9067	5.7227
5	-3.4491	-2.6666	-1.1987	0.5665	1.9997	2.7165	2.8804
6	-3.0411	-3.2056	-3.2628	-3.1711	-2.6898	-1.6204	-0.0657
7	0.7549	2.7751	3.6802	3.4925	2.4620	1.1620	0.0232
8	-1.3899	-0.9508	-0.5012	-0.6881	-1.7360	-3.2512	-4.5168
9	0.0223	-0.7894	-1.8763	-2.3868	-1.7663	-0.4668	0.8935
10	-0.2582	0.3857	0.8903	0.9141	0.3425	-0.6010	-1.5352
11	0.9317	0.8853	0.1592	-0.6640	-1.1252	-1.1305	-0.9017
12	-1.8977	-1.1169	-0.6554	-0.1844	0.6645	1.9103	3.1100
13	-2.8537	-6.2001	-8.2377	-9.5015	-9.6995	-8.9175	-7.2034
14	-0.8920	-1.5237	-1.9587	-1.7350	-0.5952	1.0092	2.3268
15	5.0580	5.3817	6.1200	6.6139	6.3571	5.5005	4.8020
16	-10.1525	-9.9466	-9.9842	-10.5251	-11.2484	-11.3053	-9.1193
17	-3.8921	-1.6265	0.2080	1.1048	1.0989	0.4835	-0.3396
18	-0.3043	-0.3569	-0.5649	-0.7304	-0.7430	-0.6331	-0.4693

Statistical Analysis of Geodetic Data File

Select the file type to be statistic

The discrete point file

Open the discrete point file

Number of rows of the file header 1

Column ordinal number of the attribute to be statistic 5

Import setting parameters

Start statistic

>> [Purpose] Statistically calculates on the specified record attribute of a discrete point file, the cell values of a geodetic grid file, or the cell values of a vector grid file

Output metrics include: Geographic Extent (Lat/Lon bounds), Mean, Standard Deviation, Minimum, and Maximum values.

** Please select the file type for statistics firstly...

>> Statistics on the specified attributes...

>> Open the discrete point file C:/PAGravf4.5_win64en/examples/Tlstatisticalanalysis/GNSSlksirent.txt.

** Look at the input file information in the textbox above, set the file format parameters.....

>> Setting parameters have been imported into the program!

** Click the control button [Start statistic], or the tool button [Start statistic]....

>> Computation start time: 2026-03-30 13:57:17

>> Statistic results:

**Minimum longitude: 102.3455°

Maximum longitude: 103.4253°

Minimum latitude: 24.3751°

Maximum latitude: 25.4877°

**Mean: -0.1007

Standard deviation: 0.0310

Minimum: -0.1550

Maximum: -0.0459

>> Complete the statistical calculation!

>> Computation end time: 2026-03-30 13:57:17

Display of the input-output file↓

2	102.546777	24.458002	1659.0410	-0.1046
4	102.725921	24.460578	2111.3872	-0.0612
6	102.528697	24.562786	1936.4260	-0.0491
9	102.832641	24.575505	1977.4949	-0.1223
10	102.345532	24.668953	1919.7825	-0.0782
11	102.423972	24.652933	1959.3369	-0.0548
13	102.631063	24.657055	1906.3415	-0.1185
14	102.742718	24.652871	1935.7882	-0.0767
15	102.843573	24.642787	1880.7707	-0.1319
16	103.137778	24.658224	1838.4387	-0.0730
17	102.426305	24.743284	1929.0475	-0.0771
20	102.729945	24.734909	1856.2213	-0.1356
21	102.840819	24.752018	2117.8582	-0.0459
22	102.939253	24.728089	2050.9590	-0.0907
23	103.029713	24.748496	2034.1986	-0.1217
24	103.129600	24.753135	1575.0654	-0.1477
25	103.227846	24.747081	1668.7801	-0.1116

Statistical Analysis of Geodetic Data File

Select the file type to be statistic

The geodetic grid file

Open the geodetic grid file

Import setting parameters

Start statistic

Save statistic process as

Maximum latitude: 25.4877°

**Mean: -0.1007

Standard deviation: 0.0310

Minimum: -0.1550

Maximum: -0.0459

>> Complete the statistical calculation!

>> Computation end time: 2026-04-15 15:52:13

>> Statistics on the cell grid values...

>> Open the geodetic grid file C:/PAGravf4.5_win64en/examples/Tlstatisticalanalysis/dwmchrga.dat.

>> Setting parameters have been imported into the program!

** Click the control button [Start statistic], or the tool button [Start statistic]....

>> Computation start time: 2026-04-15 15:53:31

>> Statistic results:

**Minimum longitude: 104.0000°

Maximum longitude: 114.0000°

Minimum latitude: 25.0000°

Maximum latitude: 34.0000°

**Mean: -0.0578

Standard deviation: 22.9654

Minimum: -167.3475

Maximum: 175.2691

>> Complete the statistical calculation!

>> Computation end time: 2026-04-15 15:53:31

Display of the input-output file↓

104.000000	114.000000	25.000000	34.000000	0.04166667	0.04166667		
-25.7608	-13.3875	7.2186	24.7149	31.4088	25.8554	11.1546	
1.2492	8.2511	25.2000	40.5106	41.0960	24.1742	0.2044	
-29.8425	-27.6304	-21.0353	-8.0648	11.9223	35.0907	53.6553	
-28.0596	-34.3250	-31.7398	-22.5722	-14.7619	-14.9851	-22.2831	
-20.6078	-11.2485	-7.0605	-4.2518	3.7133	16.9466	26.6261	
-3.7192	-7.1358	-10.4737	-14.0606	-16.8846	-15.9327	-9.6025	
23.5480	14.7230	6.4201	0.9377	-2.7797	-6.1543	-9.0524	
0.9535	-7.9694	-13.4650	-5.3219	14.5052	32.3989	35.0476	
-27.3478	-15.9170	-7.6469	-8.9631	-16.5572	-21.0556	-16.2946	
15.2363	11.7503	12.4323	19.1381	28.3574	33.1812	28.0544	
-17.6659	-15.7030	-10.1794	-6.3843	-7.6680	-9.8771	-3.6331	
-17.7655	1.2673	5.9326	-3.5091	-17.4385	-26.5756	-28.4004	
-13.0422	-6.7514	1.6317	7.7796	7.9082	1.4472	-8.1695	

Statistical Analysis of Geodetic Data File

Select the file type to be statistic

The vector grid file

Open the vector grid file

Import setting parameters

Start statistic

Save statistic process as

Maximum latitude: 34.0000°

**Mean: -0.0578

Standard deviation: 22.9654

Minimum: -167.3475

Maximum: 175.2691

>> Complete the statistical calculation!

>> Computation end time: 2026-04-15 15:53:31

>> Statistics on the vector cell grid values...

>> Open the vector grid file C:/PAGravf4.5_win64en/examples/Tlstatisticalanalysis/resGMlandbm0541_1800.dft.

>> Setting parameters have been imported into the program!

** Click the control button [Start statistic], or the tool button [Start statistic]....

>> Computation start time: 2026-04-15 15:54:37

>> Statistic results:

**Minimum longitude: 96.0000°

Maximum longitude: 100.0000°

Minimum latitude: 32.0000°

Maximum latitude: 34.5000°

**Mean: 0.0028

Standard deviation: 2.3416

Minimum: -12.7789

Maximum: 14.2346

>> Complete the statistical calculation!

>> Computation end time: 2026-04-15 15:54:37

Display of the input-output file↓

96.000000	100.000000	32.000000	34.500000	0.01666667	0.01666667		
-3.6046	-4.2915	-4.9029	-5.4065	-5.7599	-5.9931	-6.1783	-6.2859
-4.6627	-4.2398	-3.7871	-3.3453	-2.8970	-2.4020	-1.8966	-1.3656
1.1812	1.1805	1.1440	1.0856	1.0235	0.9769	0.9582	0.9785
0.9881	0.7657	0.4784	0.1501	-0.1843	-0.4937	-0.7397	-0.9097
0.3502	0.5223	0.6141	0.6436	0.6073	0.5129	0.3946	0.2755
2.0717	2.5990	3.0951	3.5657	3.9377	4.2096	4.4398	4.5437
2.1746	1.8275	1.5054	1.2079	0.9146	0.6177	0.3119	-0.0032
-2.4943	-2.6935	-2.8752	-3.0489	-3.2248	-3.4194	-3.6464	-3.9091
-6.6488	-6.8384	-6.8983	-6.8149	-6.5502	-6.1338	-5.6610	-5.0543
0.0803	0.4602	0.7219	0.8689	0.9380	0.8862	0.7960	0.6004
-0.8692	-0.8351	-0.7915	-0.7624	-0.7777	-0.8597	-1.0187	-1.2620
-3.1621	-2.8238	-2.3799	-1.9354	-1.4092	-0.8585	-0.3258	0.1190
-0.1290	-0.6645	-1.2874	-1.9644	-2.6891	-3.4358	-4.1354	-4.7848
-5.3075	-4.6324	-3.8557	-3.0063	-2.1023	-1.1992	-0.3404	0.4510
1.0400	0.3775	-0.2854	-0.9226	-1.4987	-1.9740	-2.3412	-2.5724

Horizontal Gradient Estimation of Geodetic Grid

Open file Save as Import parameters Start Computation Follow example

Horizontal Gradient Estimation of Geodetic Grid

Inner Product Operation on Geodetic Vector Grids

Open Geodetic Grid File

Order number of
horizontal gradient first order (/km)

Vector form Polar Coordinates

Open Data Surface Ellipsoidal Heigh Grid File

Save the results as

Import setting parameters

Start Computation

>> Computation Process

Save computation process as

>> Select the function module from the two control buttons at the top right of the interface...

>> [Function] Estimates the first-order horizontal gradient vector (units: /km) or second-order horizontal gradient vector (units: /km²) grid from a geodetic parameter grid using the Least Squares Method.

>> Open Geodetic Grid File C:/PAGravf4.5_win64cn/examples/EdvgridiffInnercalc/dbmGM1800150sksi.dat.

>> Open Data Surface Ellipsoidal Heigh Grid File C:/PAGravf4.5_win64cn/examples/EdvgridiffInnercalc/dbmhgt150s.dat.

>> Save the results as C:/PAGravf4.5_win64cn/examples/EdvgridiffInnercalc/ksihgradient.dat.

>> The parameter settings have been entered into the system!

** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-03-30 14:57:00

>> Complete the computation!

>> Computation end time: 2026-03-30 14:57:00

Display of the input-output file↓

Save data in the textbox as

104.000000	114.000000	25.000000	34.000000	0.04166667	0.04166667				
1.0554E-09	-4.1271E-09	-1.6372E-09	8.5227E-09	9.9659E-09	1.0529E-08	8.1124E-09	4.4750E-09	-9.8440E-09	-1.5941E-09
-1.7870E-09	4.5964E-10	-1.7775E-09	-1.3117E-10	1.4141E-08	1.1935E-08	3.0592E-09	-6.4633E-09	3.4714E-10	1.0217E-09
1.5816E-08	1.8114E-08	1.9355E-08	1.9668E-08	1.9922E-08	-1.3374E-08	-5.5297E-09	-1.6853E-12	5.8485E-09	3.1893E-09
-1.7704E-08	8.1655E-09	-1.2663E-08	-5.1819E-09	8.0653E-10	4.2670E-09	6.3222E-10	-1.4990E-09	-3.5566E-09	3.3005E-09
2.2178E-08	2.3097E-08	2.3685E-08	2.2893E-08	2.2513E-08	2.3415E-08	2.0716E-08	-2.5776E-09	4.1601E-09	-4.8136E-09
2.8264E-09	5.4417E-09	9.1108E-09	7.3039E-09	-9.2552E-09	-7.6282E-09	9.7406E-10	2.7861E-09	2.5467E-09	8.6219E-09
1.0981E-09	1.4105E-09	2.6231E-09	3.0918E-09	1.7029E-09	3.2219E-09	-8.5079E-09	7.6468E-09	4.9581E-09	3.2906E-09
8.7785E-09	1.6169E-09	-7.6076E-09	2.0535E-10	5.9697E-09	8.4364E-09	1.4531E-08	1.4612E-08	1.0206E-08	6.7265E-09
-6.0218E-09	4.0654E-09	7.1870E-09	5.7915E-09	-6.4012E-10	-3.4162E-09	-9.4826E-09	7.1904E-09	1.2352E-08	1.4456E-09
8.6646E-10	-2.4004E-09	3.0736E-09	8.6234E-09	1.4142E-08	1.6663E-08	1.6557E-08	-6.9856E-09	-1.1414E-08	4.9702E-09
1.2336E-08	1.0677E-08	1.1709E-08	1.2546E-08	7.1873E-09	-1.0472E-08	-7.9990E-09	-4.5932E-10	4.7470E-09	9.2221E-09

Inner Product Operation on Geodetic Vector Grids

Open file Save as Import parameters Start Computation Follow example

Horizontal Gradient Estimation of Geodetic Grid

Inner Product Operation on Geodetic Vector Grids

Open Vector Grid File 1

>> Computation Process

Save computation process as

☒ First vector is vertical deflection vector

Open Vector Grid File 2

>> Computation start time: 2026-03-30 15:05:17
 >> Complete the computation!
 >> Computation end time: 2026-03-30 15:05:18
 >> [Function] Calculates the inner product (dot product) of two geodetic vector grids with identical specifications.

>> Open Vector Grid File 1 C:/PAGravf4.5_win64cn/examples/EdvgridiffInnercalc/dbmchcxpc.dat.

>> Open Vector Grid File 2 C:/PAGravf4.5_win64cn/examples/EdvgridiffInnercalc/dtmhgradient.dat.

>> Save the results as C:/PAGravf4.5_win64cn/examples/EdvgridiffInnercalc/innerproduct.dat.

>> The parameter settings have been entered into the system!
 ** Click the [Start Computation] control button, or the [Start Computation] tool button...

>> Computation start time: 2026-03-30 15:05:54

>> Complete the computation!

>> Computation end time: 2026-03-30 15:05:54

Save the results as

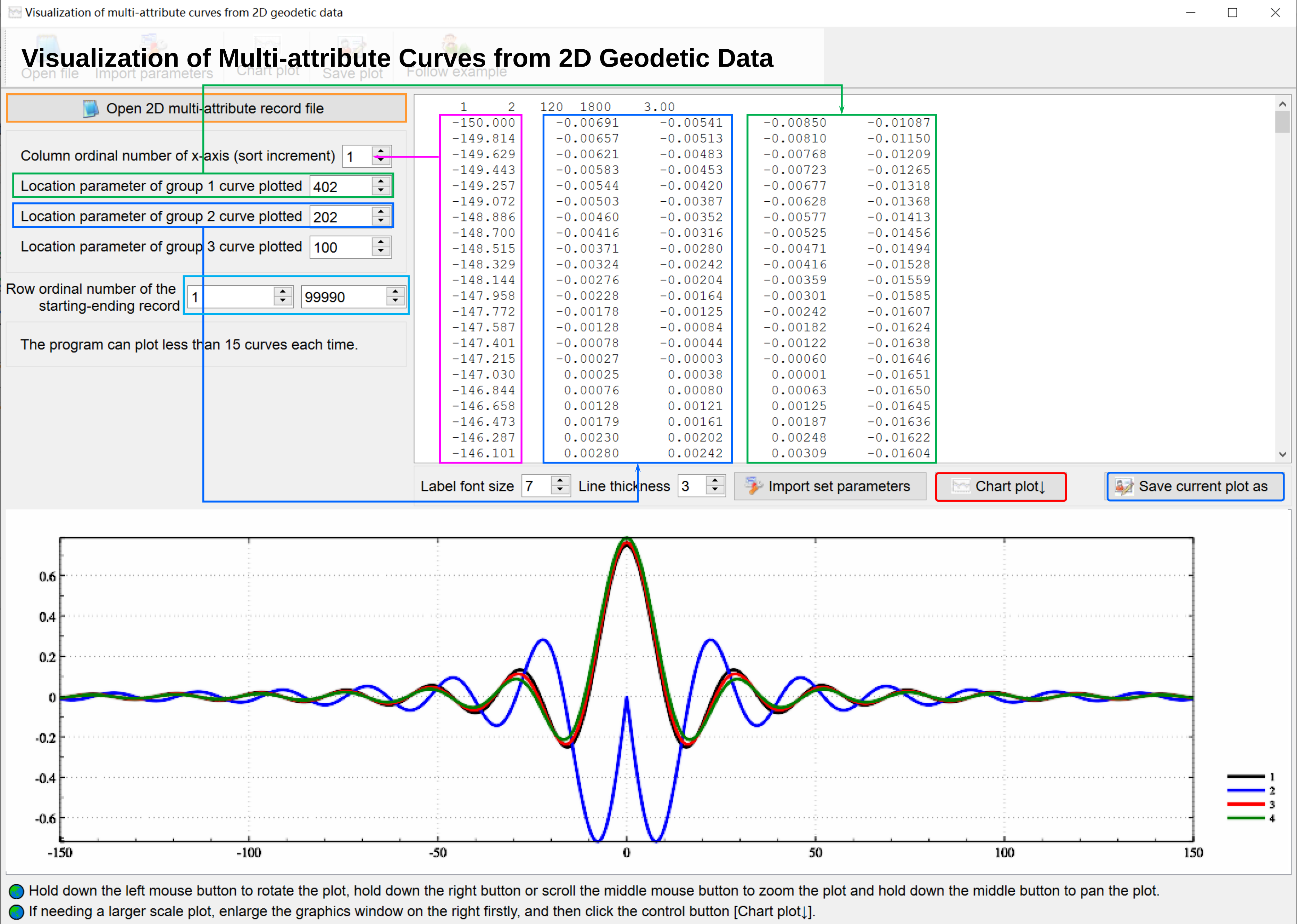
Import setting parameters

Start Computation

Display of the input-output file↓

Save data in the textbox as

104.000000	114.000000	25.000000	34.000000	0.04166667	0.04166667				
-3.1501E-03	1.3963E-02	7.1800E-02	6.4834E-02	2.2948E-02	3.3101E-02	9.9993E-02	1.4762E-01	4.2943E-02	-1.4100E-01
-1.2967E-01	-3.4489E-02	1.1482E-01	-6.0455E-02	-1.9406E-01	3.7521E-01	1.4649E-01	6.9311E-02	-2.5455E-02	2.4435E-01
1.5290E-02	5.9778E-02	7.6809E-02	9.8838E-02	2.5018E-01	8.9093E-02	4.2707E-02	5.5085E-02	4.0155E-02	9.4816E-01
7.8439E-02	-4.3313E-02	6.3805E-03	1.4252E-02	2.5164E-02	1.1407E-01	3.3992E-02	4.7342E-02	8.0237E-03	1.1273E-01
-1.4064E-01	2.7436E-02	-2.6850E-03	-1.6331E-02	4.2548E-02	2.2136E-02	5.2463E-03	6.3726E-02	1.8439E-01	1.6555E-01
8.9665E-02	-4.9831E-02	1.1029E-01	6.9421E-02	3.8941E-02	-5.6494E-03	8.8750E-02	8.3975E-02	-1.5944E-02	-1.9320E-01
1.9996E-02	7.6024E-02	2.7211E-02	-1.6401E-02	-1.3680E-02	3.9081E-02	1.7790E-01	-8.2112E-02	-1.5239E-02	1.8687E-01
-1.1418E-02	-1.2463E-02	-4.4665E-03	1.7725E-01	2.1836E-01	6.9173E-02	3.6360E-02	7.3462E-02	3.5955E-02	1.4876E-01
1.3533E-02	3.6271E-02	2.2070E-02	3.3495E-02	1.6518E-02	-4.9714E-03	3.3557E-02	9.5390E-02	8.0120E-02	-4.3035E-01
4.1187E-02	-3.2235E-03	6.3681E-03	3.3488E-02	2.9604E-03	-4.1388E-02	1.4389E-01	1.6094E-01	1.3890E-01	2.8242E-01
6.7131E-04	1.2941E-02	4.5237E-02	1.3002E-02	-1.1538E-03	4.3083E-02	1.6594E-01	6.3524E-01	4.3405E-01	1.3065E-01



Visualization of Specified Attributes in Discrete Point File

Open file Import parameters Scatter plot Save plot Follow example

Open Discrete Geodetic Point File

number of rows of file header 1 Column ordinal number of x 2
Column ordinal number of y 3 Column ordinal number of z 5
Minimum z -9990.0 Maximum z 9990.0

Display style Plane color scatter plot

Label font size 6

☐ Custom scale range (for batch plots)

Import parameters

Scatter plot →

Rotate: Hold and drag the Left Mouse Button; Zoom: Hold and drag the Right Mouse Button, or scroll the Middle Mouse Wheel; and Pan: Hold and drag the Middle Mouse Button.

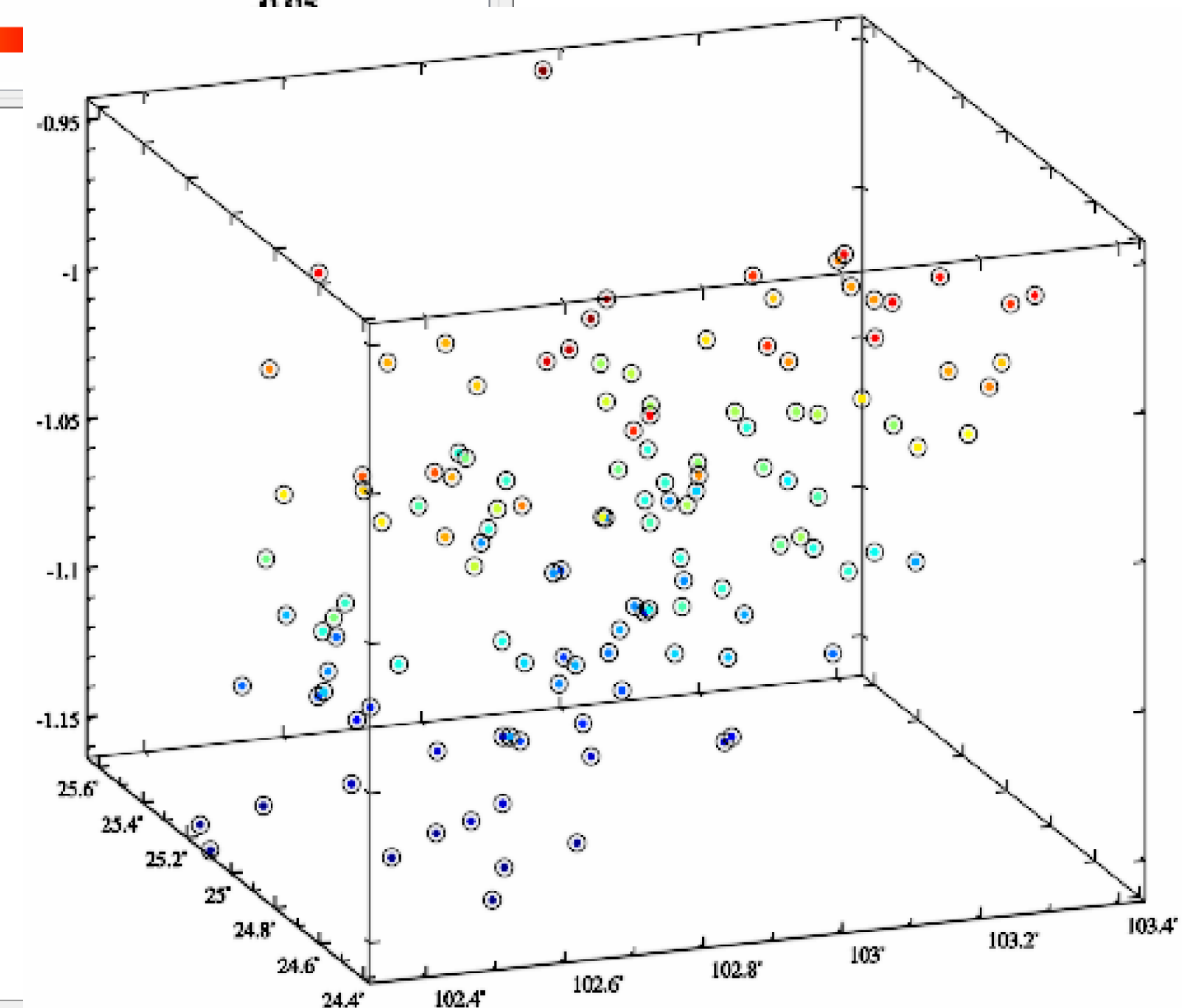
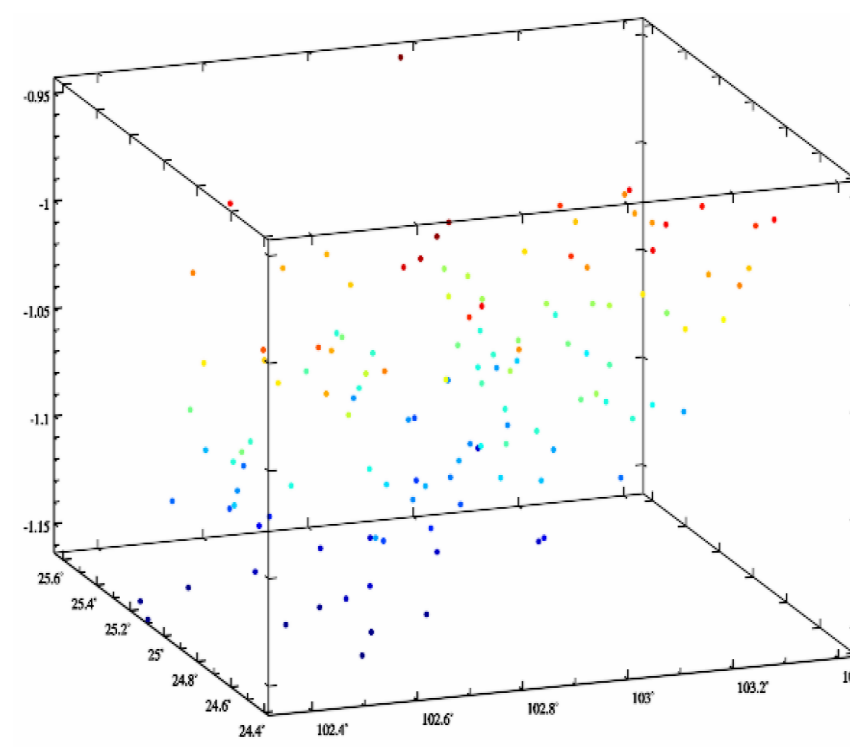
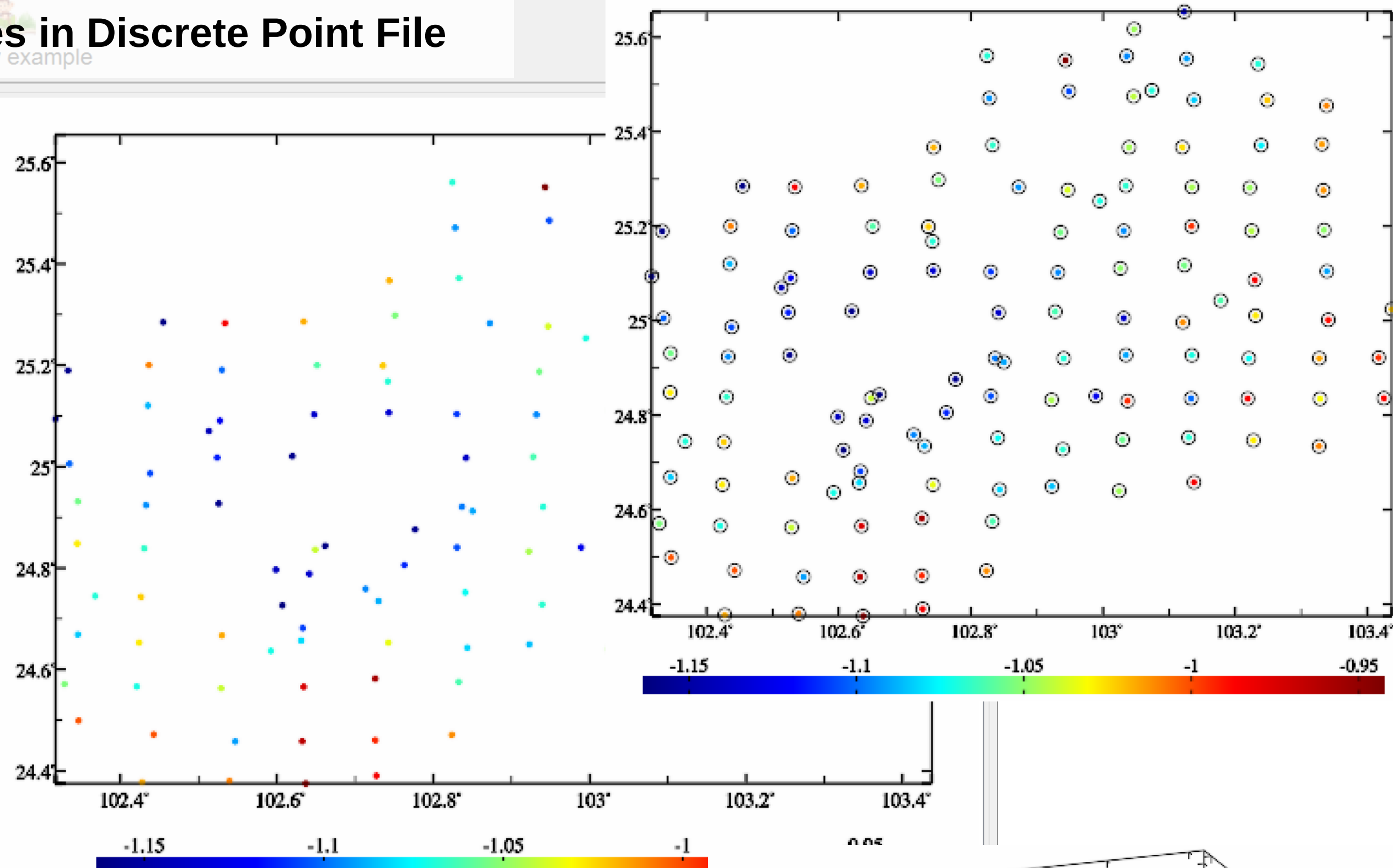
Refresh Mechanism: Upon changing the input file, Z-attribute, or other parameters, the user should re-click [Import Setting Parameters] to update the visualization.

Scale Unification: Batch plots can maintain a unified scale range by fixing the Minimum and Maximum threshold values.

Save current plot as

number long(deg/decimal) lat ellipHeight(m) rentKsi(m) TerEffect(mGal)

1	102.442457	24.471769	1972.7703	-1.0013	-3.3508
2	102.546777	24.458002	1659.0410	-1.0916	-6.6124
3	102.632412	24.458211	2120.2558	-0.9639	-5.0422
4	102.725921	24.460578	2111.3872	-0.9936	-3.6867
5	102.420803	24.566357	1990.6386	-1.0706	-3.1489
6	102.528697	24.562786	1936.4260	-1.0402	-2.0473
7	102.634437	24.565660	2192.9271	-0.9743	-4.0534
8	102.725888	24.581970	2303.7797	-0.9566	-7.1388
9	102.832641	24.575505	1977.4949	-1.0619	-5.9858
10	102.345532	24.668953	1919.7825	-1.0840	-1.6645
11	102.423972	24.652933	1959.3369	-1.0281	-3.0476
12	102.529771	24.667079	2157.7877	-1.0165	-4.2396
13	102.631063	24.657055	1906.3415	-1.0806	-1.6637
14	102.742718	24.652871	1935.7882	-1.0343	-1.7419
15	102.843573	24.642787	1880.7707	-1.0819	-7.7294
16	103.137778	24.658224	1838.4387	-0.9843	-11.7862
17	102.426305	24.743284	1929.0475	-1.0229	-4.1779
20	102.729945	24.734909	1856.2213	-1.0884	-0.8096
21	102.840819	24.752018	2117.8582	-1.0735	-3.9704
22	102.939253	24.728089	2050.9590	-1.0675	-7.6863



Visualization of Geodetic Grid File

Open Geodetic Grid File

Minimum -9000.0Maximum 9000.0

Plot parameters

Label font size 6

Display style 2D color map

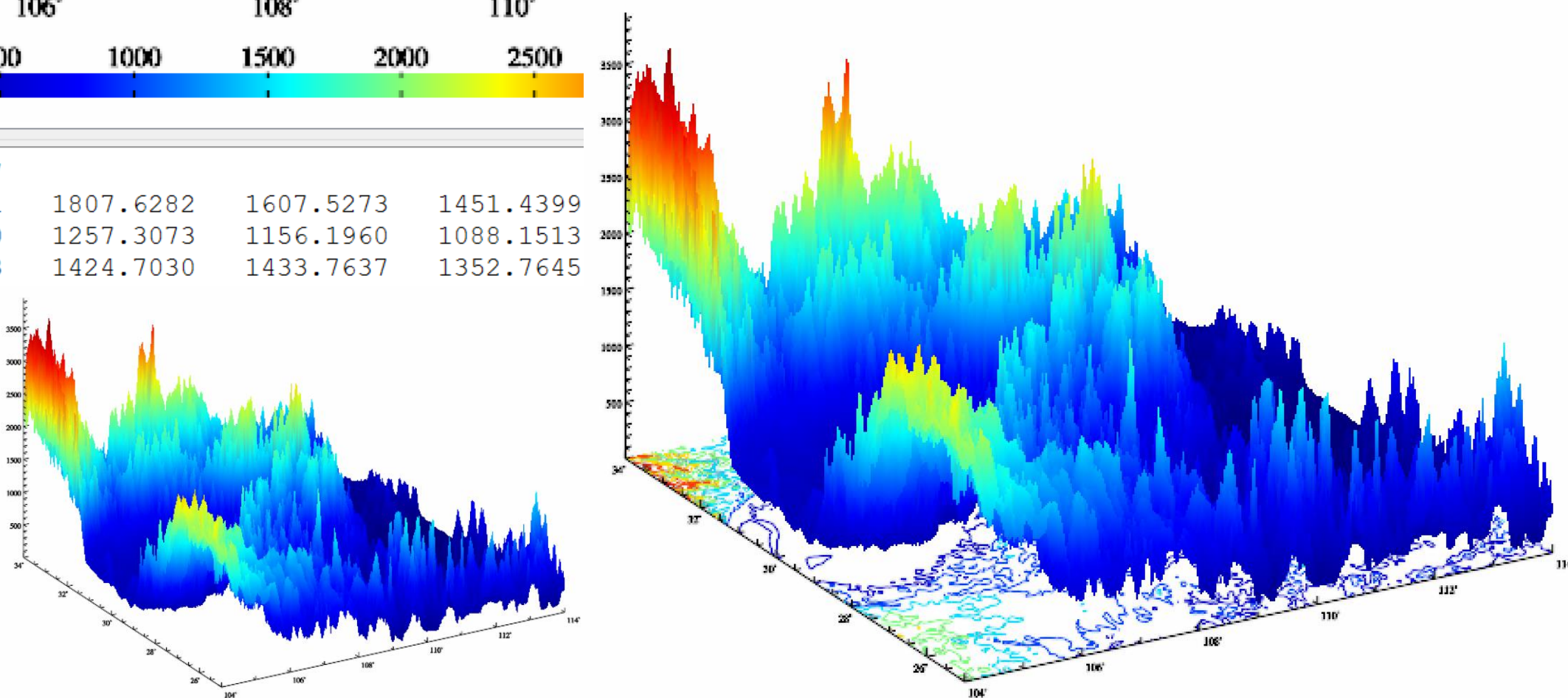
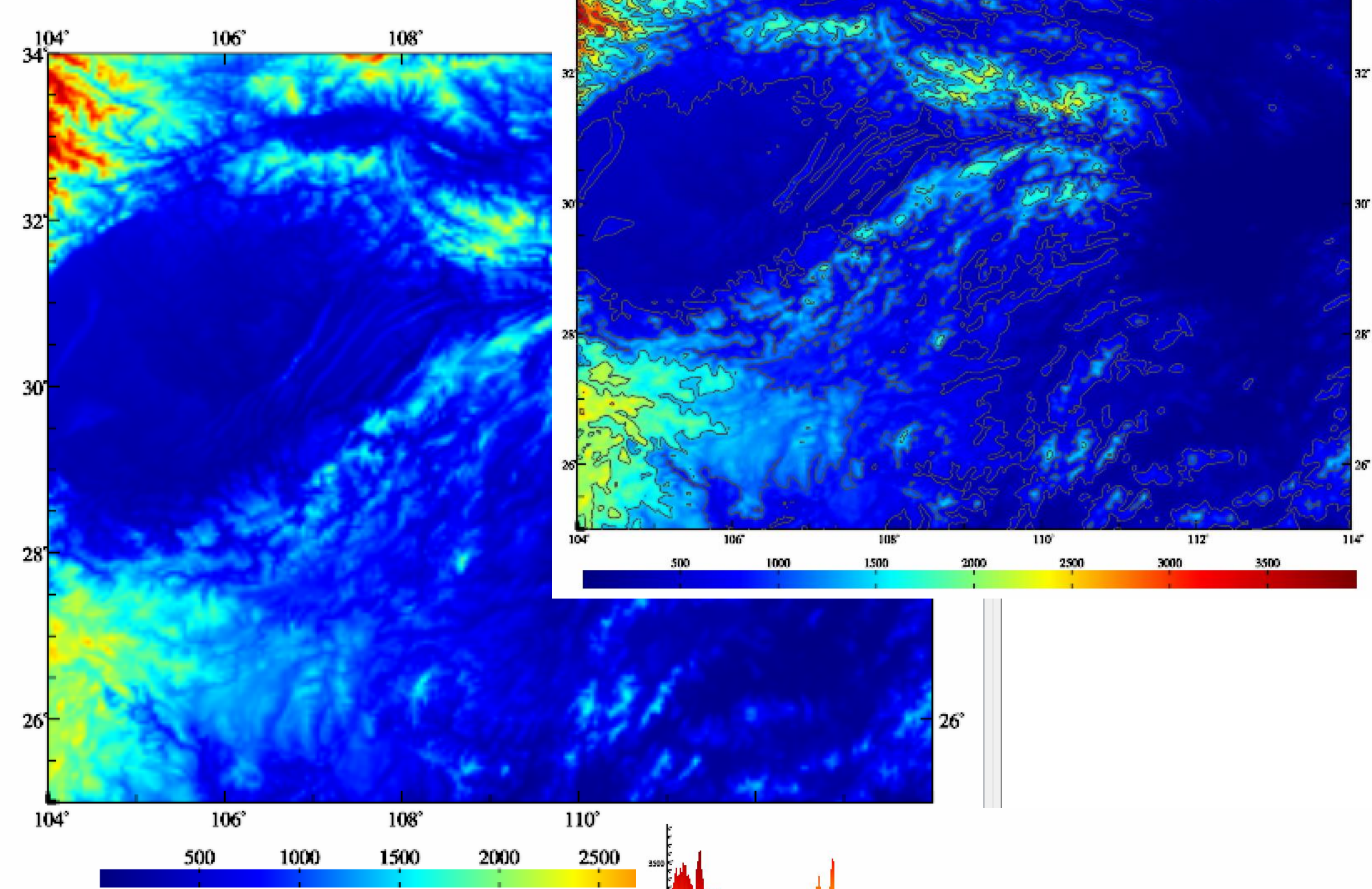
☐ Custom scale range (for batch plots)

Import parametersDraw plot →

- Rotate: Hold and drag the Left Mouse Button; Zoom: Hold and drag the Right Mouse Button, or scroll the Middle Mouse Wheel; and Pan: Hold and drag the Middle Mouse Button.
- Refresh Mechanism: Upon changing the input file, Z-attribute, or other parameters, the user should re-click [Import Setting Parameters] to update the visualization.
- Scale Unification: Batch plots can maintain a unified scale range by fixing the Minimum and Maximum threshold values.
- For high-resolution plot, maximize the graphics window the interface prior to clicking the [Draw Plot] button..

Save current plot as

104.000000	114.000000	25.000000	34.000000	0.04166667	0.04166667			
1880.6229	1872.6631	1910.7226	1931.7678	1992.7628	1897.7201	1807.6282	1607.5273	1451.4399
1579.5092	1478.5386	1457.5814	1610.5779	1703.5245	1392.4420	1257.3073	1156.1960	1088.1513
1127.0908	1141.1294	1156.2046	1181.3156	1335.4458	1400.5863	1424.7030	1433.7637	1352.7645
530.3341	562.3269	484.3763	478.4654	553.5572	717.6303			
642.5738	575.7033	629.8140	654.9278	694.0588	807.1893			
726.9660	439.0429	598.0917	604.1553	596.2404	510.3625			
820.3976	667.4142	588.4198	585.4228	661.4284	557.4446			
494.4589	433.5887	353.7412	430.9411	723.1664	821.3833			
128.9313	219.0568	175.1873	152.2870	137.3672	113.4730			
456.2484	331.3966	360.5464	451.7045	575.8571	698.9677			
151.7808	150.9295	208.1037	343.2835	296.4796	343.6928			
220.4672	560.7057	752.8913	548.0598	375.1793	295.2814			
267.7158	300.9213	596.1217	576.3492	569.5540	559.7308			
466.1732	254.1907	224.2331	236.3034	250.4140	331.5690			
509.0990	504.2612	607.4467	873.6645	972.9187	777.1467			



Visualization of Geodetic Vector Grid File

5

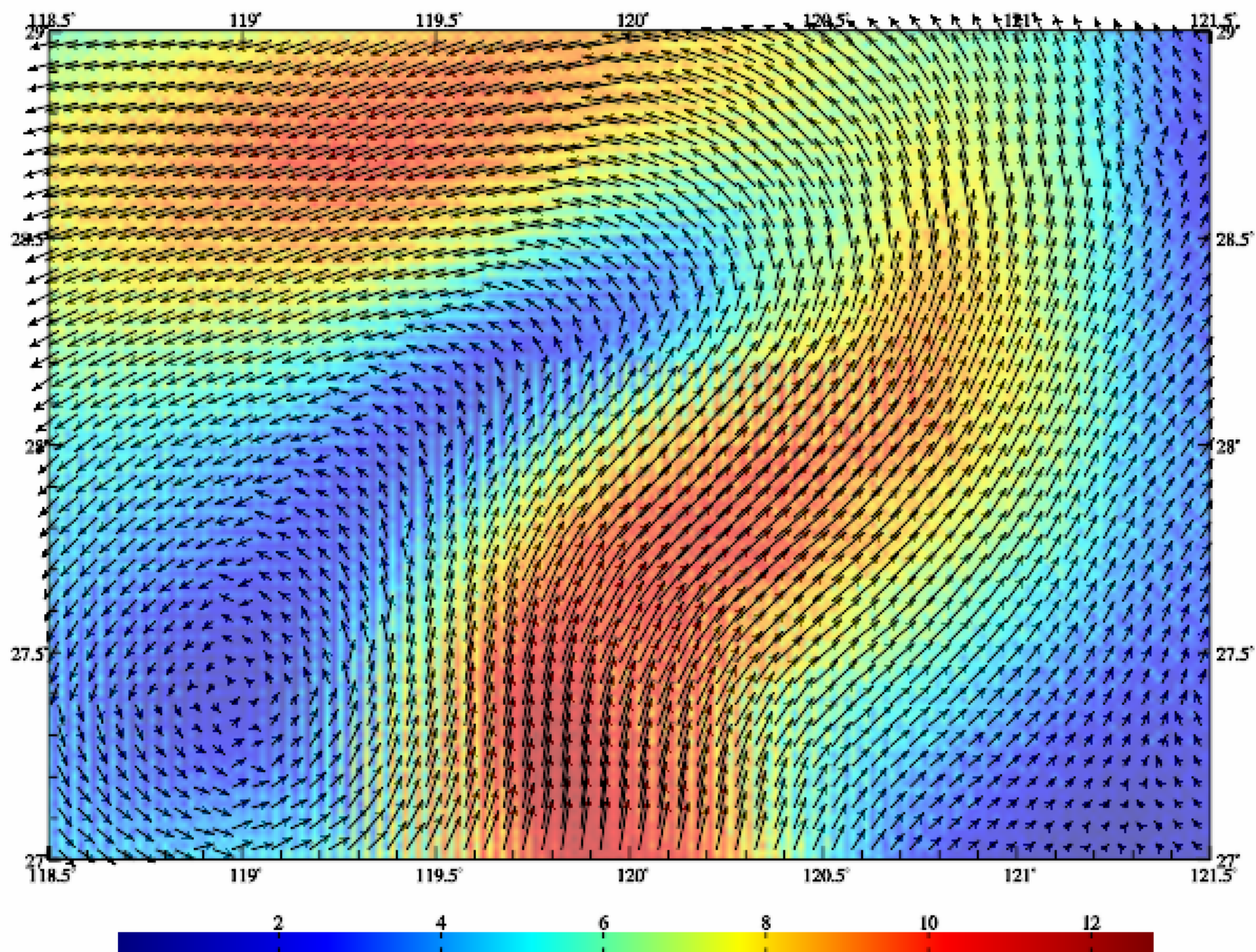
Vector parameters

60

18

18

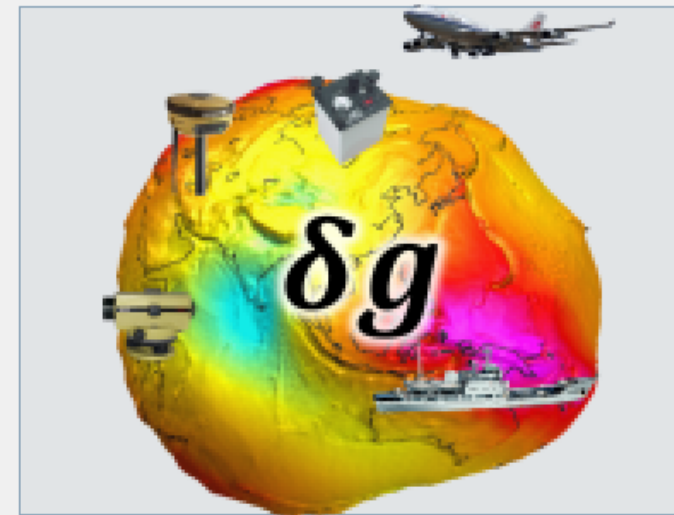
South - West (SW)



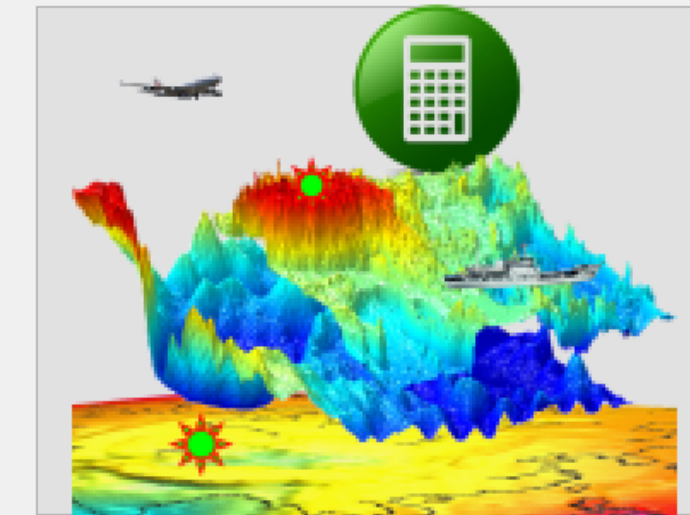
118.500000	121.500000	27.000000	29.000000	1.66666667E-02	1.66666667E-02	2015070106					
4.2017E+00	1.8364E+00	3.5829E+00	1.1078E+00	3.3135E+00	1.0280E+00	3.7127E+00	6.4872E-01	2.8045E+00	6.1878E-01	3.4332E+00	2.9941E-01
-1.6967E-01	2.8743E+00	-6.7866E-01	2.2256E+00	-1.2675E+00	2.1258E+00	-6.9862E-01	1.8563E+00	-1.9861E+00	1.9162E+00	-1.4072E+00	1.7166E+00
1.4771E+00	-2.1258E+00	9.9803E-01	-3.0041E+00	5.5890E-01	-3.0340E+00	1.0879E+00	-3.4732E+00	9.9803E-03	-3.5630E+00	5.4892E-01	-3.9622E+00
-4.7606E+00	-5.7886E-01	-5.4493E+00	-1.5669E+00	-6.2776E+00	-1.9761E+00	-6.0181E+00	-2.7646E+00	-7.5351E+00	-3.2037E+00	-7.2457E+00	-3.9622E+00
-5.2097E+00	-8.4234E+00	-5.8485E+00	-9.0821E+00	-6.5770E+00	-9.2518E+00	-6.2676E+00	-9.9404E+00	-7.7447E+00	-9.8606E+00	-7.3755E+00	-1.0170E+01
-1.0978E+01	-9.4813E+00	-1.1208E+01	-1.0489E+01	-1.1907E+01	-1.0879E+01	-1.0928E+01	-1.1427E+01	-1.2006E+01	-1.1368E+01	-1.0589E+01	-1.1228E+01
-1.1068E+01	-9.9304E+00	-1.1108E+01	-1.0090E+01	-1.1577E+01	-9.7009E+00	-1.0260E+01	-9.8007E+00	-1.1138E+01	-9.0122E+00	-1.0040E+01	-8.5132E+00
-7.7148E+00	-9.2418E+00	-7.3056E+00	-9.1320E+00	-7.3056E+00	-8.2837E+00	-5.6888E+00	-8.2038E+00	-6.2676E+00	-7.2757E+00	-4.7906E+00	-6.3475E+00



Summary, Parameter Settings and Visualization for PAGravf4.5



Analysis and Preprocessing of Earth Gravity Field Data



Computation of Diverse Terrain Effects on Various External Gravity Field Elements

Scientific Objectives of PAGravf4.5

PAGravf4.5 is engineered to rigorously adhere to the theoretical foundations of Earth's gravity field approximation. Its overarching scientific objectives are:

- (a) To comprehensively resolve the complex diverse terrain effects on various gravity field elements both on and outside the geoid;
- (b) To realize all-element, full-space analytical modeling of the gravity field and centimeter-level geoid;
- (c) To achieve closed-loop analytical operations for various external anomalous gravity field elements;
- (d) To significantly expand the computational capabilities and practical application scope of physical geodesy.

PAGravf4.5 is very helpful for empowering the exploration and resolution of complex geodetic challenges using physical geodetic ideas and thinking.

 PAGravf4.5 Scientific Computational Functional Architecture

<http://www.zcyphygeodesy.com/en/>

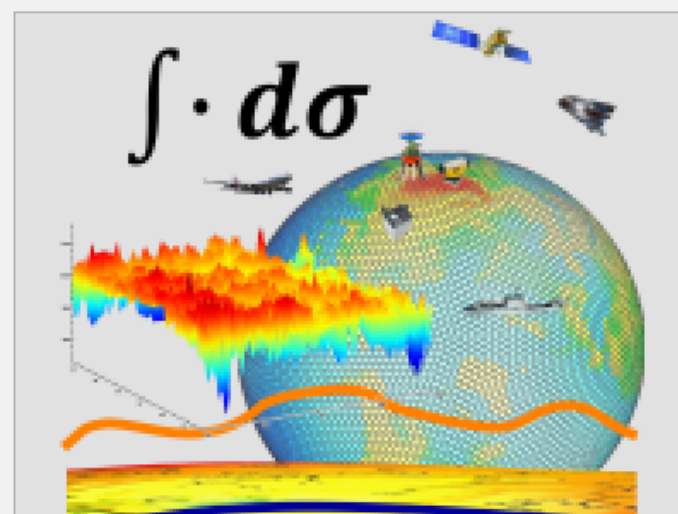


Target Audience & Disciplinary Scope

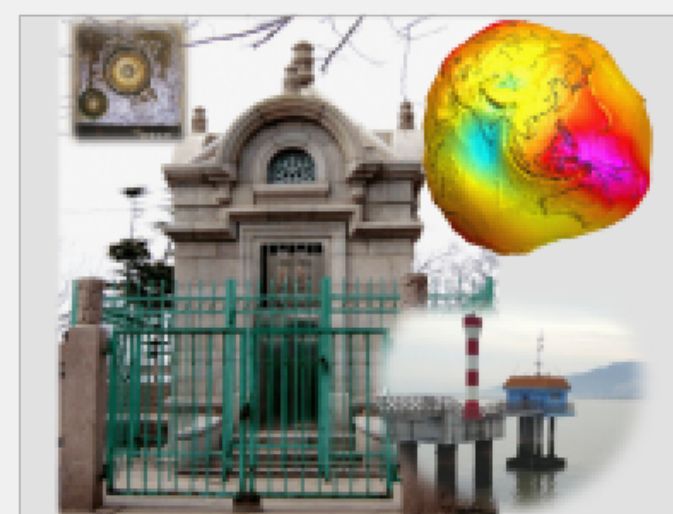
PAGravf4.5 is designed for senior undergraduate students, graduate students, research scientists, and engineering professionals in the fields of Geodesy and Geophysics, Geology and Earth Sciences, Geomatics and Geographic Information Systems (GIS), as well as Seismology and Geodynamics.

Tutorial Examples & Self-Study Guide:

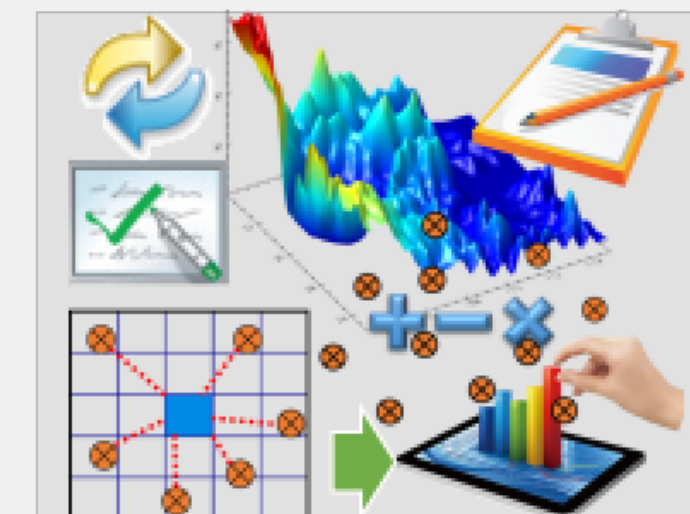
- Comprehensive example files for each module are provided in the directory C:\PAGravf4.5_win64enexamples: This folder includes : A step-by-step operational process file (process.txt); Example input and output data files; and Screenshots illustrating key interface operations.
- Approximately 7 working days are required to complete all tutorial exercises. Upon completion, users will be equipped to operate PAGravf4.5 independently for professional applications.



High-Precision Gravity Field Approximation and Full-Element Modeling



Optimization, Unification, and Application of Regional Height Datums



Edit and Calculation Tool for Geodetic Data Files

- Multi-type data from terrestrial, maritime, aerial, or space-based observations
- Closed-Loop Analytical Operations between External Gravity Field Elements
- Observation Error Assessment & Precise Computational Performance Control
- Diverse Terrain Effects on Various field Elements on or outside the Geoid
- All-Element Analytical Modeling of Local Gravity Field in Full External Space
- Gravity Exploration Modeling from Multi-Source Heterogeneous Observations