

Antarktida

**Co družicová gravitační a další data prozrazují o tom,
co je našim zrakům ukryto pod ledem Antarktidy**

Jaroslav Klokočník

a kolektiv:

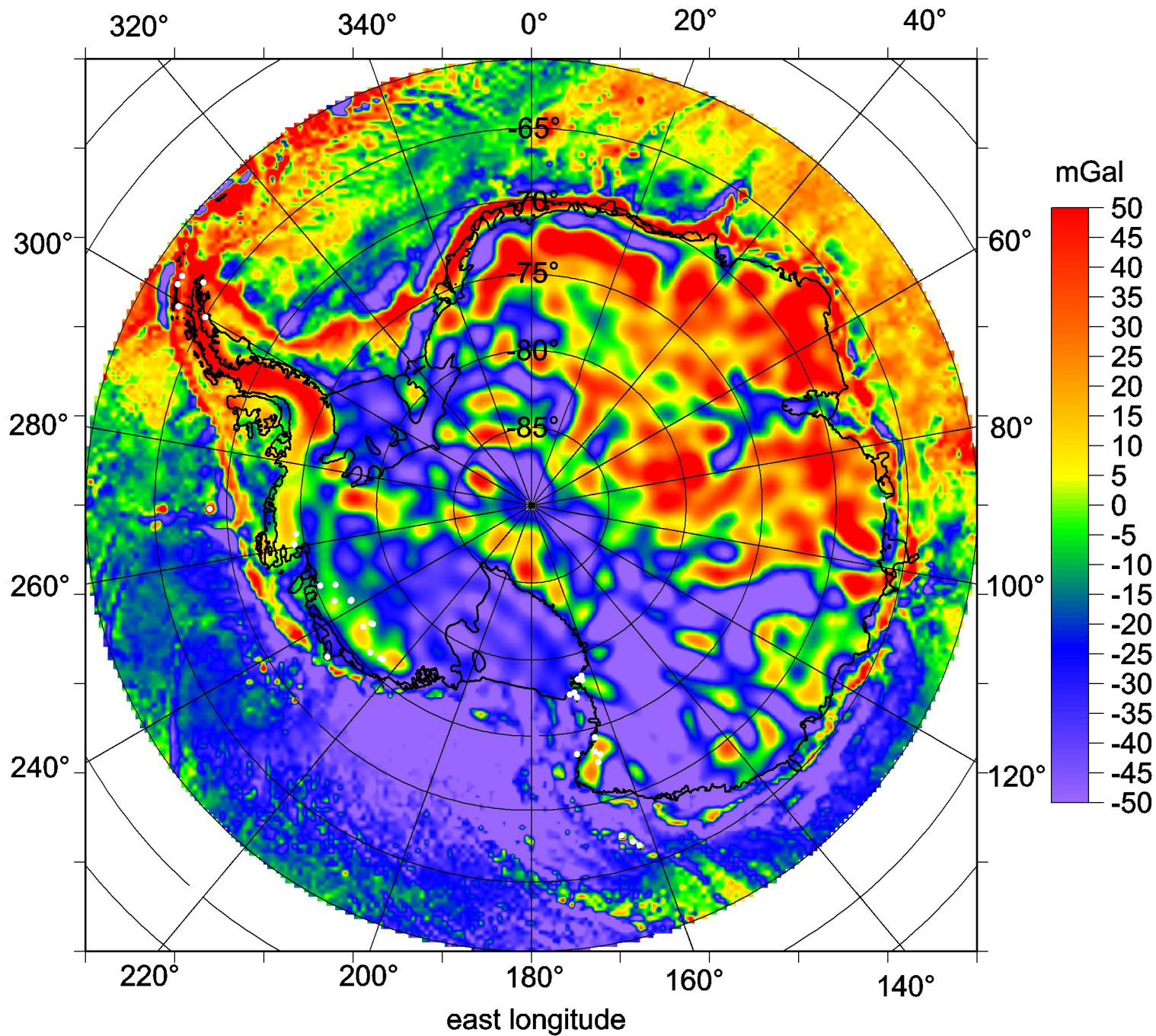
Jan Kostecký, Aleš Bezděk, Blažej Bucha a Ivan Pešek

konzultace:

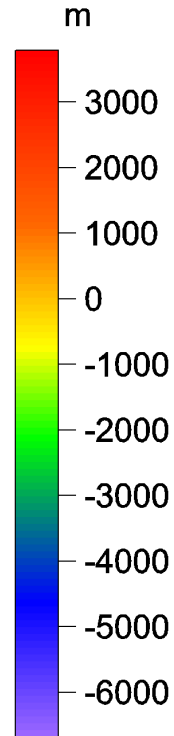
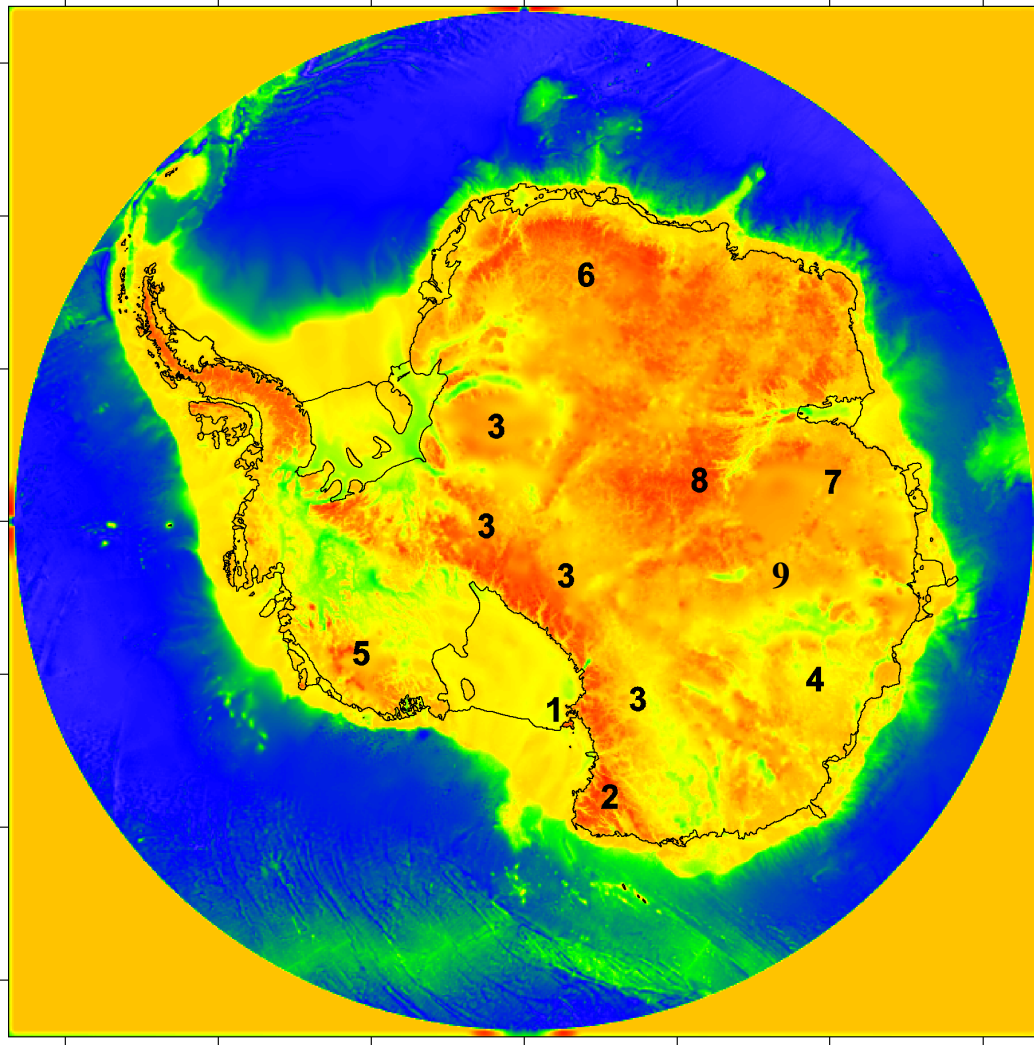
**Christoph Foerste, Nikolaos Pavlis, Hamish D. Pritchard, Carl A. Wagner,
Václav Cílek, Lev Eppelbaum, C. K. Shum a další**



Eigen-6C4 - Antarctica - delta g

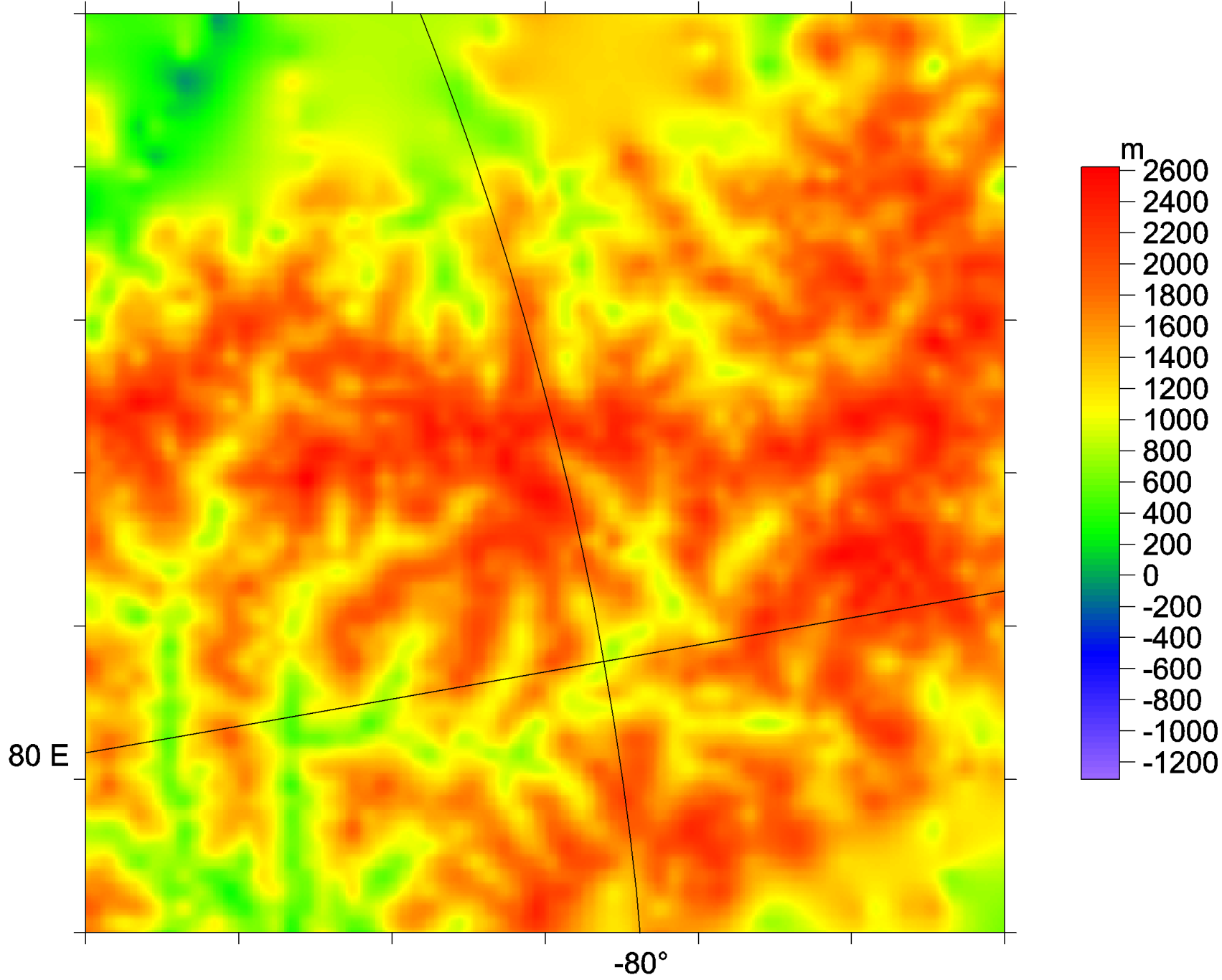


Bedmap2 bedrock topography

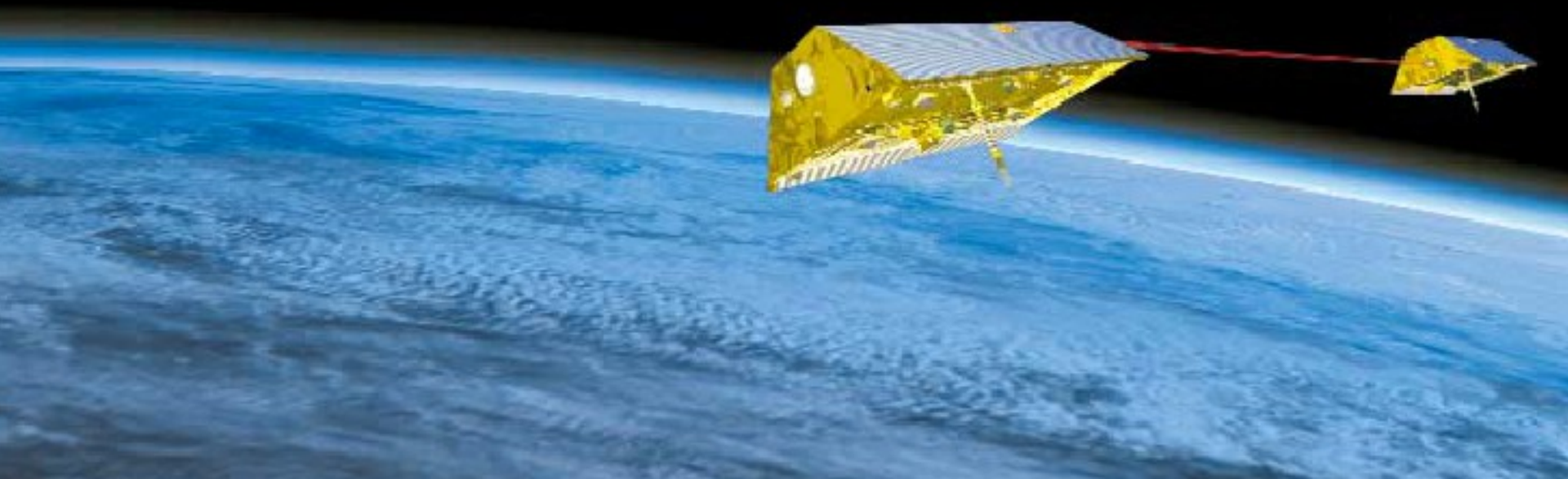


- 1 Ross shelf glacier and Ross Island,
- 2 Victoria Land
- 3 Transantarctic Mountains
- 4 Wilkes Land
- 5 Marie Byrd Land
- 6 Queen (Dronning) Maud Land
- 7 Princess Elizabeth Land
- 8 Gamburtsev Mountains (under the ice).
- 9 Lake Vostok

Antarktida - Gamburtsev - Topografie

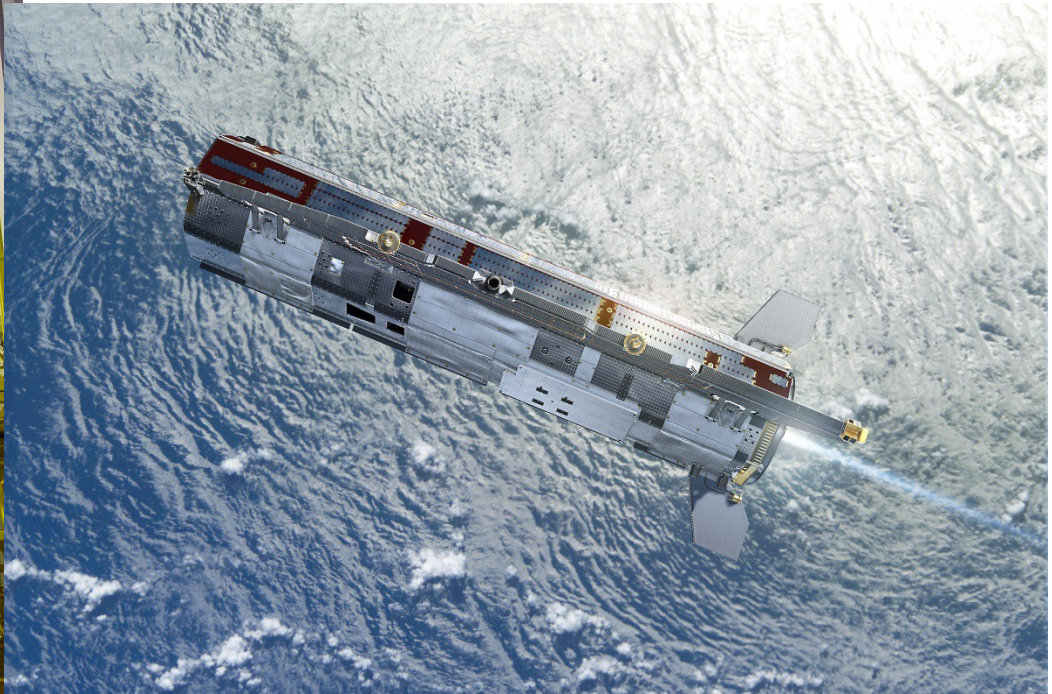


Grace A and B, 2002-



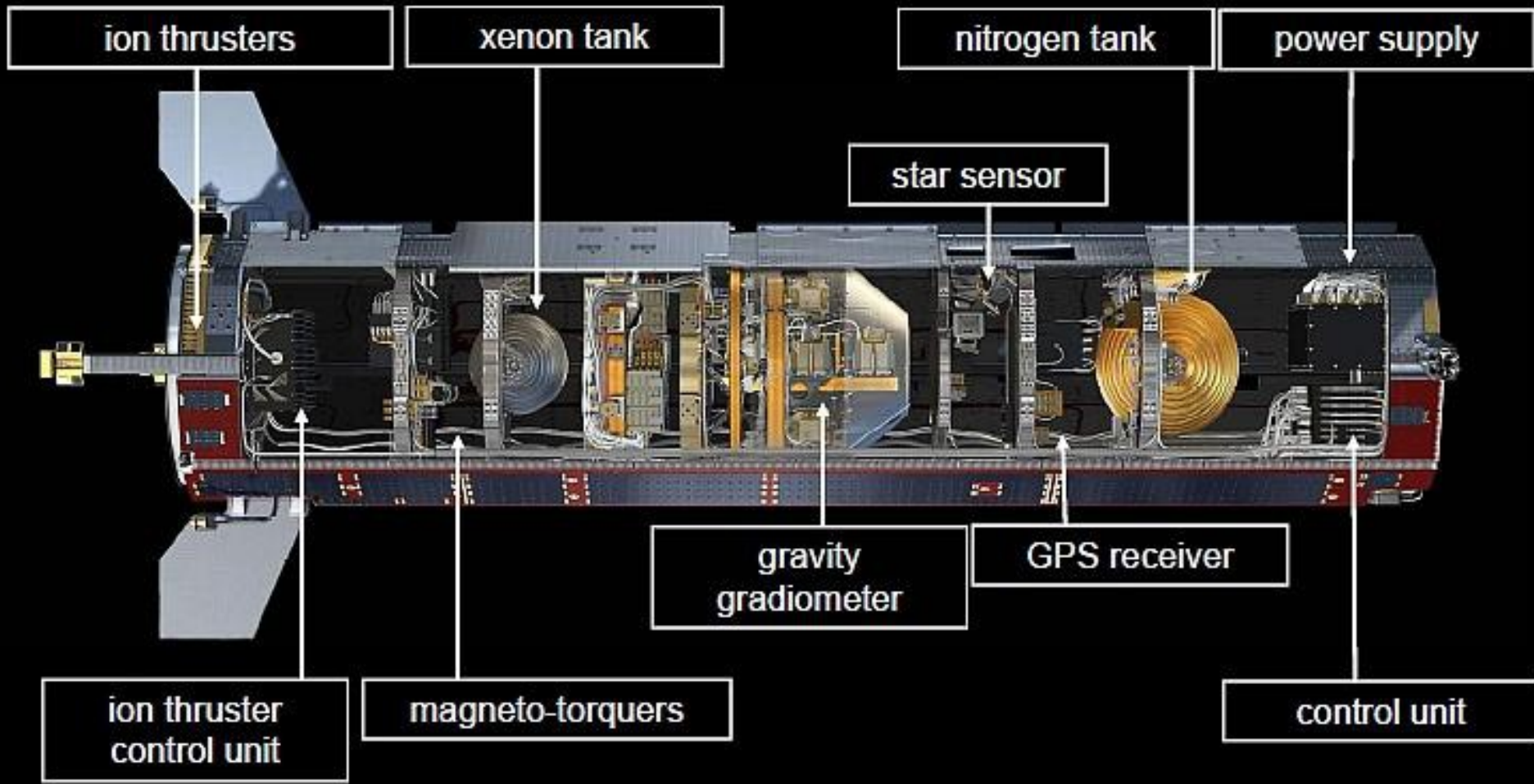
GOCE 2009-2013

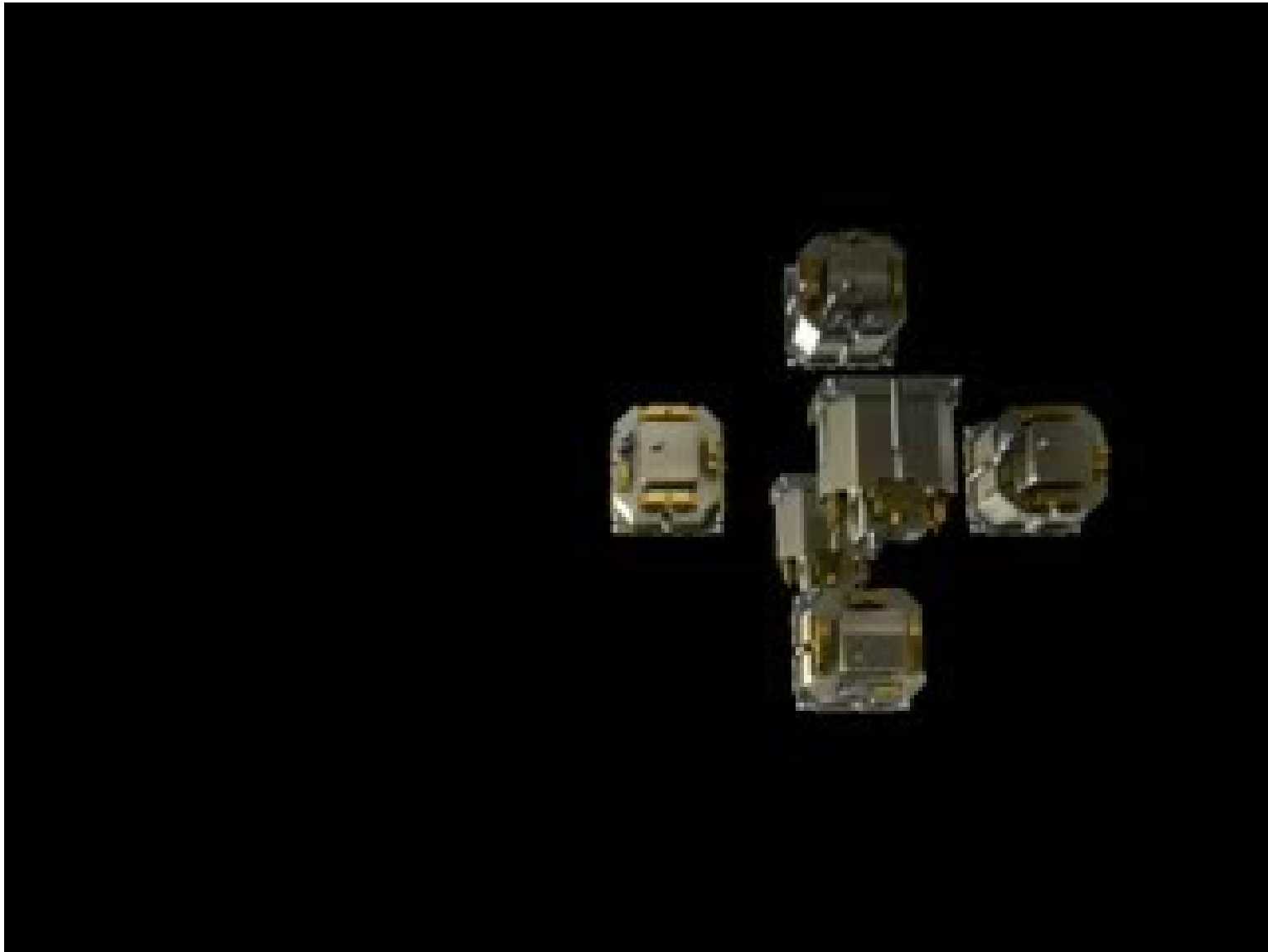
(Gravity field and steady-state Ocean Circulation Explorer, ESA)

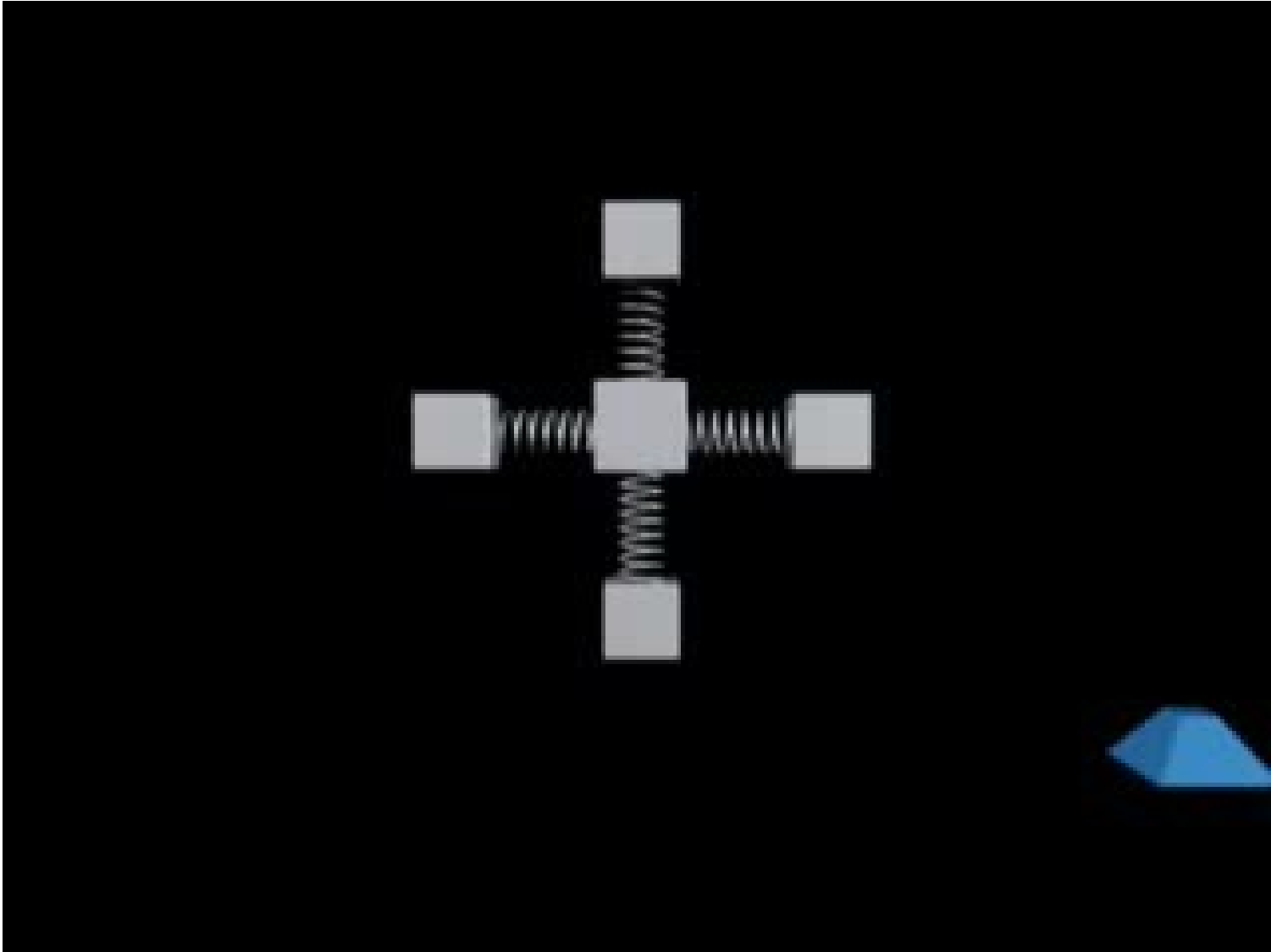


1 mGal = 10^{-5} ms⁻², 1 E = 1 Eötvös = 10^{-9} s⁻²

1 mE = 10^{-12} s⁻²







Tohoku Earthquake

11 March 2011

latitude 38.32°N , longitude 142.37°E

magnitude 9.1



- 1. Notes on theory**
Poznámky k teorii
- 2. Data – Earth's gravity field models,
bedrock topography model of A. and
their combination, GPR**
**Data - modely tíhového pole Země,
model topografie skalního podloží A.
a jejich kombinace, GPR**
- 3. Typical gravitational signal of diverse
geological and geophysical structures**
**Typický gravitační signál rozmanitých
geologických a geofyzikálních struktur**
- 4. Aplikace: Volcanoes in Antarctica**
Ukázka použití: Sopky v Antarktidě

Disturbing static gravitational potential outside the Earth masses in spherical harmonic expansion

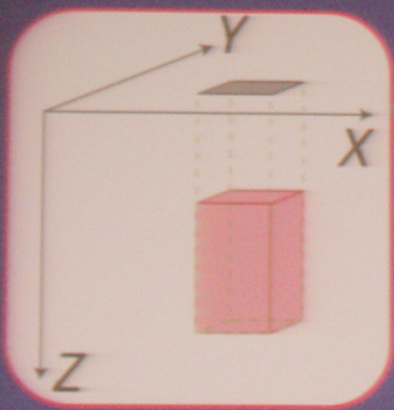
where GM is a product of the universal gravitational constant and the mass of the Earth (also known as the geocentric gravitational constant), r is the radial distance of an external point where T is computed, R is the radius of the Earth (which can be approximated by the semi-major axis of a reference ellipsoid), $P_{l,m}(\sin \varphi)$ are the Legendre associated functions, l and m are the degree and order of the harmonic expansion, (φ, λ) are the geocentric latitude and longitude, $C'_{l,m}$ and $S'_{l,m}$ are the harmonic geopotential coefficients (Stokes parameters), fully normalized, $C'_{l,m} = C_{l,m} - C_{ell,m}$, where $C_{ell,m}$ belongs to the reference ellipsoid.

The spherical approximation of the *gravity anomaly* Δg is computed

or one can use the *gravity disturbance* (it is the same but without the second term).

Gravity gradient tensor Γ (the Marussi tensor) is a tensor of the second derivatives of the disturbing potential T :

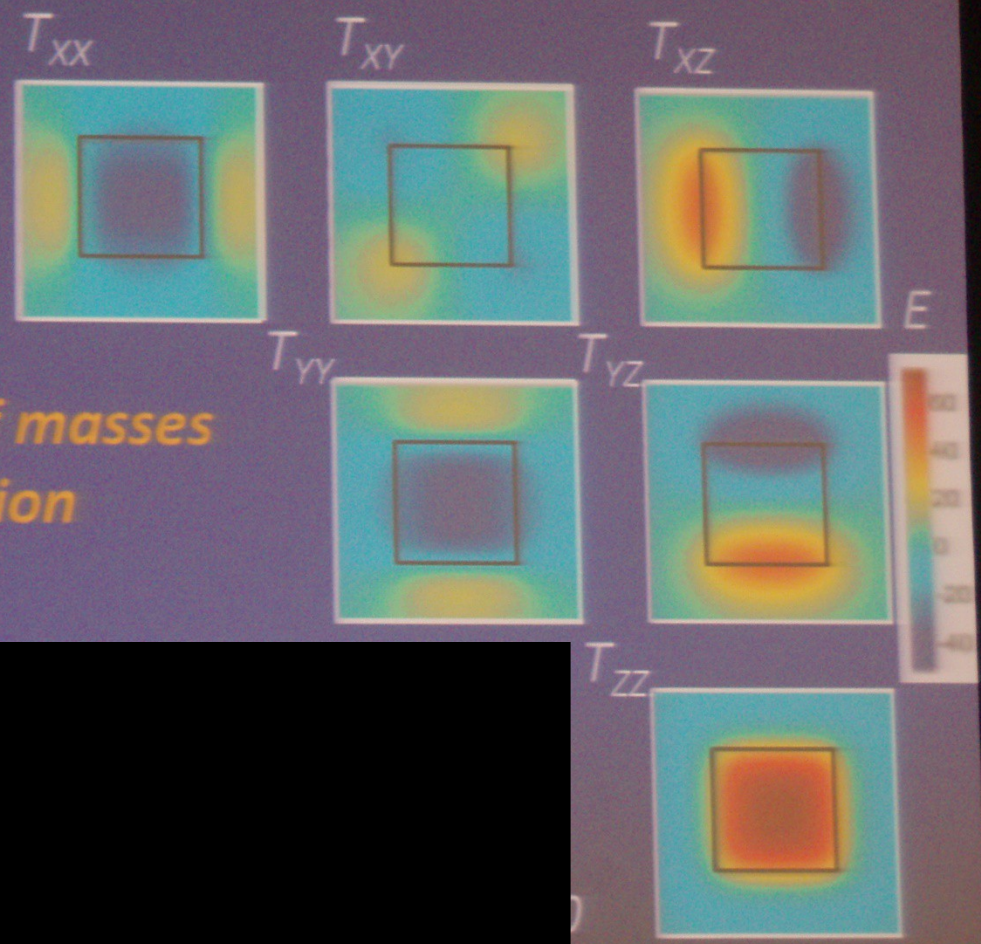
Obsah ob

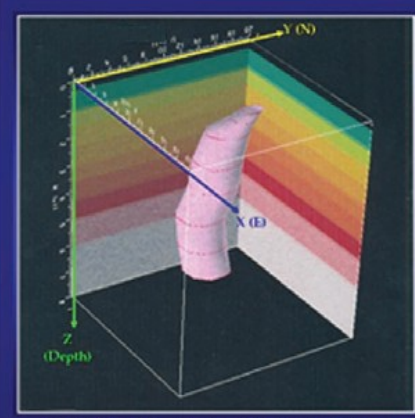
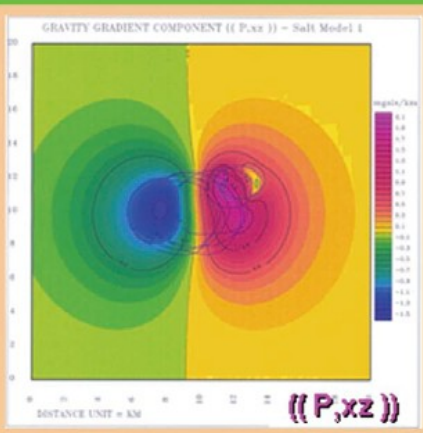
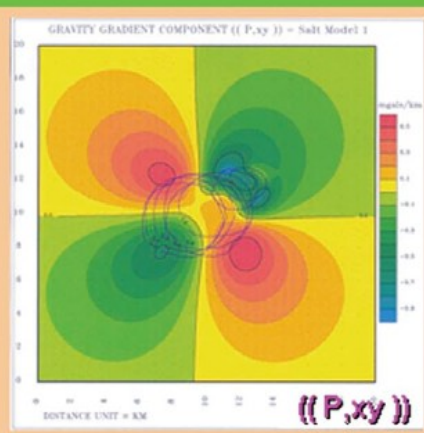
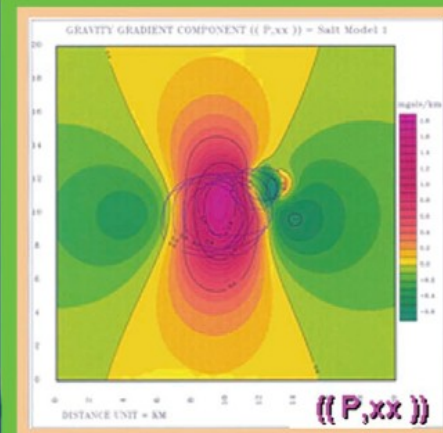
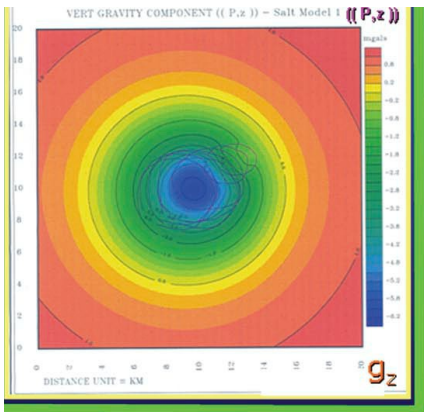


Geometry of masses
High resolution

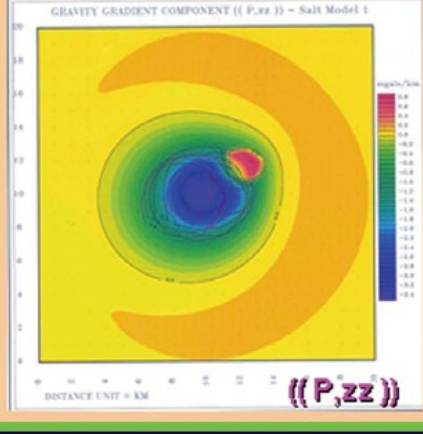
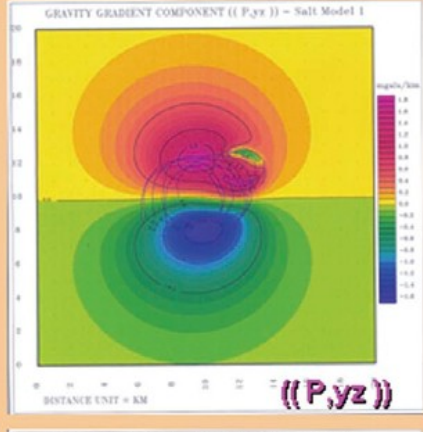
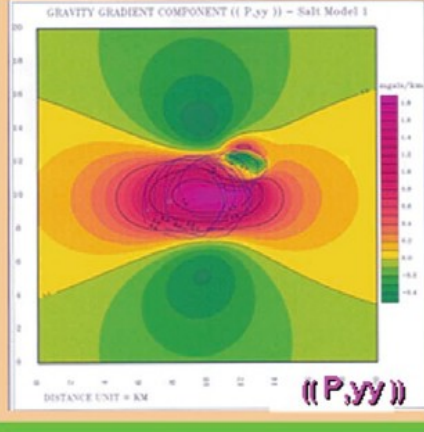
Gravity

Gradients tensor





GOCAD SALT MODEL



GRAVITY GRADIENTS

(2nd DERIVATIVES OF POTENTIAL)

Under any coordinate transformation, Γ preserves just 3 *INVARIANTS*

$$I_2 = \det(\Gamma) = (T_{xx}(T_{yy}T_{zz} - T_{yz}^2) + T_{xy}(T_{yz}T_{xz} - T_{xy}T_{zz}) + T_{xz}(T_{xy}T_{yz} - T_{xz}T_{yy})).$$

Pedersen & Rasmussen (1990) showed that the *ratio I of I1 and I2* defined as

lies between zero and unity for any potential field. If the causative body is strictly 2D, then $I = 0$.

Huge impact crater Vredefort, Africa

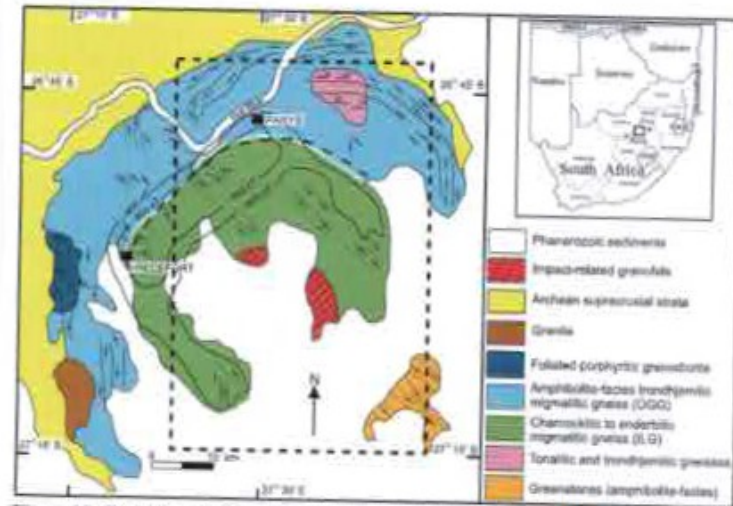
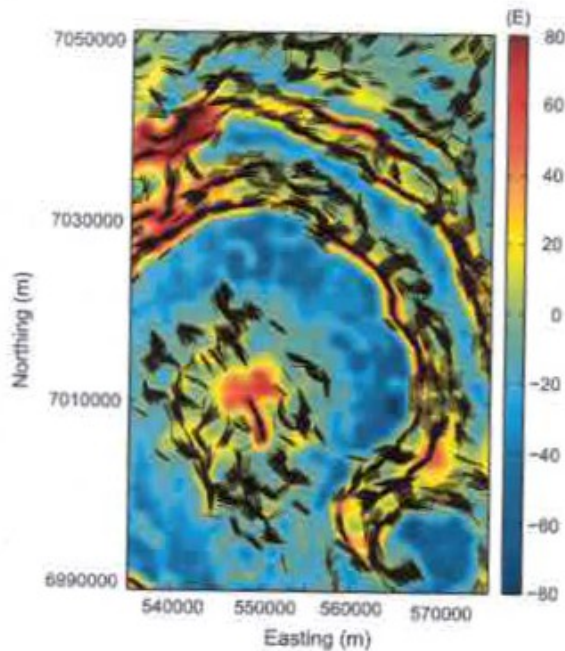


Figure 10. Geology map of the Vredefort impact area (after Lana et al., 2003). The study area is shown as a dashed rectangle.

Beiki and Pedersen 2011

Virtual deformations (Kalvoda *et al.* 2012, Klokočník *et al.* 2013)

Virtuální deformace ukazují, jak by se příslušný materiál roztekl, kdyby byl dokonale tekutý

directions of such a deformation due to “erosion” brought about solely by “gravity origin”.

If there would be a tidal potential T , then the horizontal shifts (deformations) would exist due to it and they could be expressed

in north-south direction (latitude direction) ... [left]

and in east-west direction (longitudinal direction) ... [right]

where g is the gravity acceleration $9.81 \text{ m}\cdot\text{s}^{-2}$,

IS is the elastic coefficient (Shida number) expressing the elastic properties of the Earth as a planet ($IS = 0.08$),

φ and λ are the geocentric coordinates (latitude and longitude) of a point P where we measure T

The apparatus of mechanics of continuum to derive the main directions of the tension is applied (see, e.g., Brdička *et al.* 2000).

The tensor of (small) deformation \mathbf{E} is defined as a gradient of shift. It holds that

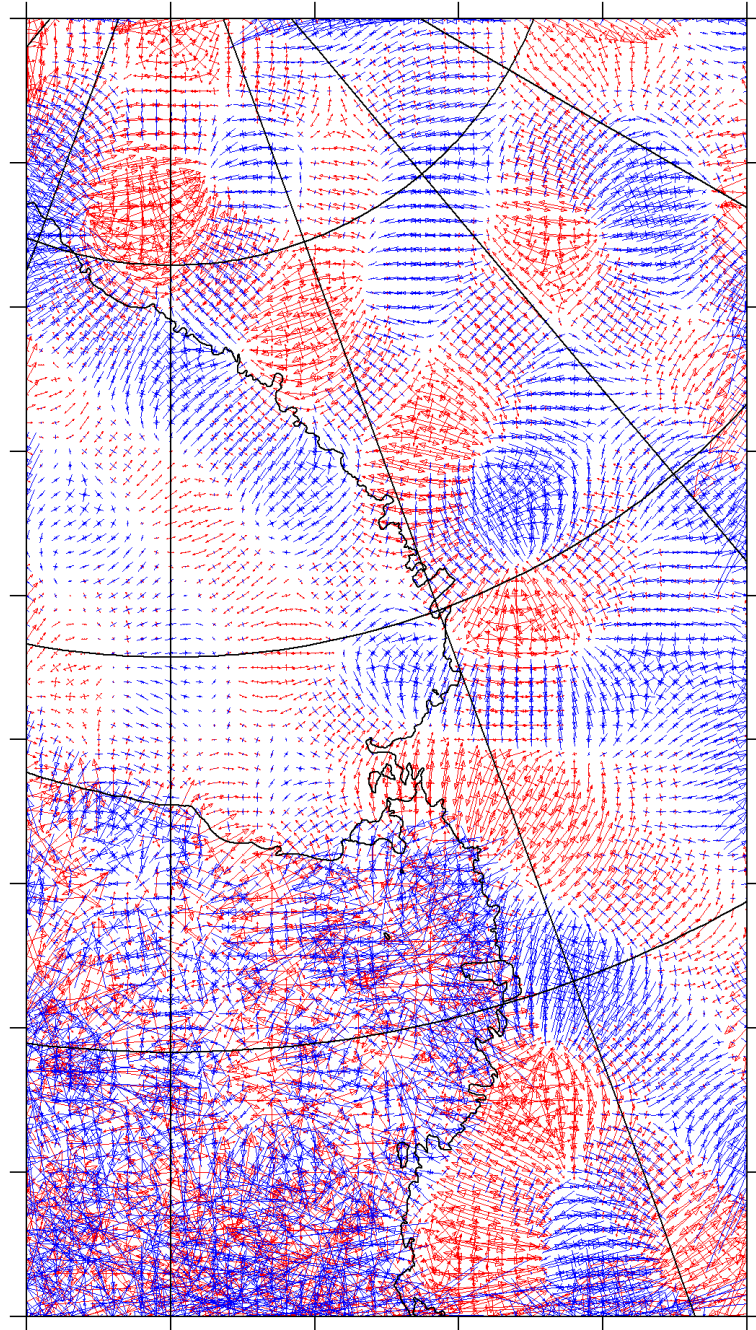
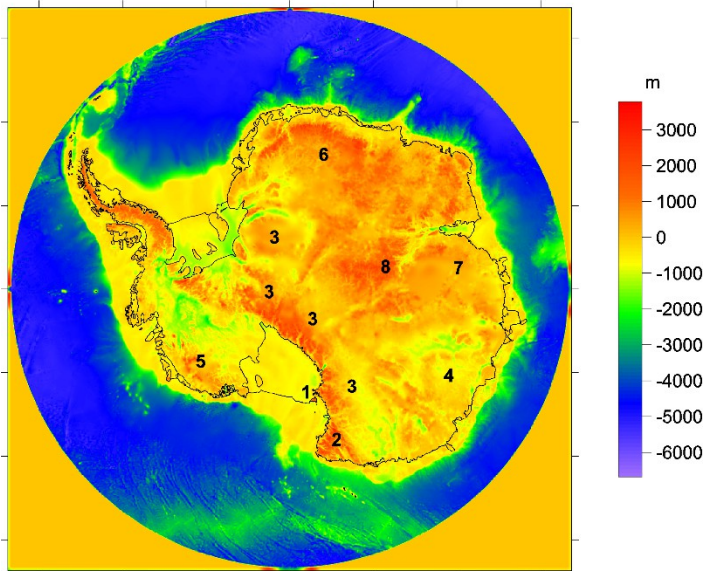
The tensor \mathbf{E} can be separated into two parts:

where \mathbf{e} is the symmetrical tensor and $\mathbf{\Omega}$ the anti-symmetrical tensor of deformation, respectively. The symmetrical tensor is

and the parameters of deformation are:

$\Delta = e_{11} + e_{22}$	total dilatation	$\mathbf{a} = \frac{1}{2} (\Delta + \gamma)$	major semi-axis of ellipse of deformation
$\gamma_1 = e_{11} - e_{22}$	pure cut	$\mathbf{b} = \frac{1}{2} (\Delta - \gamma)$	minor semi-axis of ellipse of deformation
$\gamma_2 = 2e_{12}$	technical cut	$\alpha = \frac{1}{2} \text{atan}(\gamma_2 / \gamma_1)$	direction of main axis of deformation
$\gamma = (\gamma_1^2 + \gamma_2^2)^{1/2}$	total cut		

Antarctis - segment 1 - virtual deformations



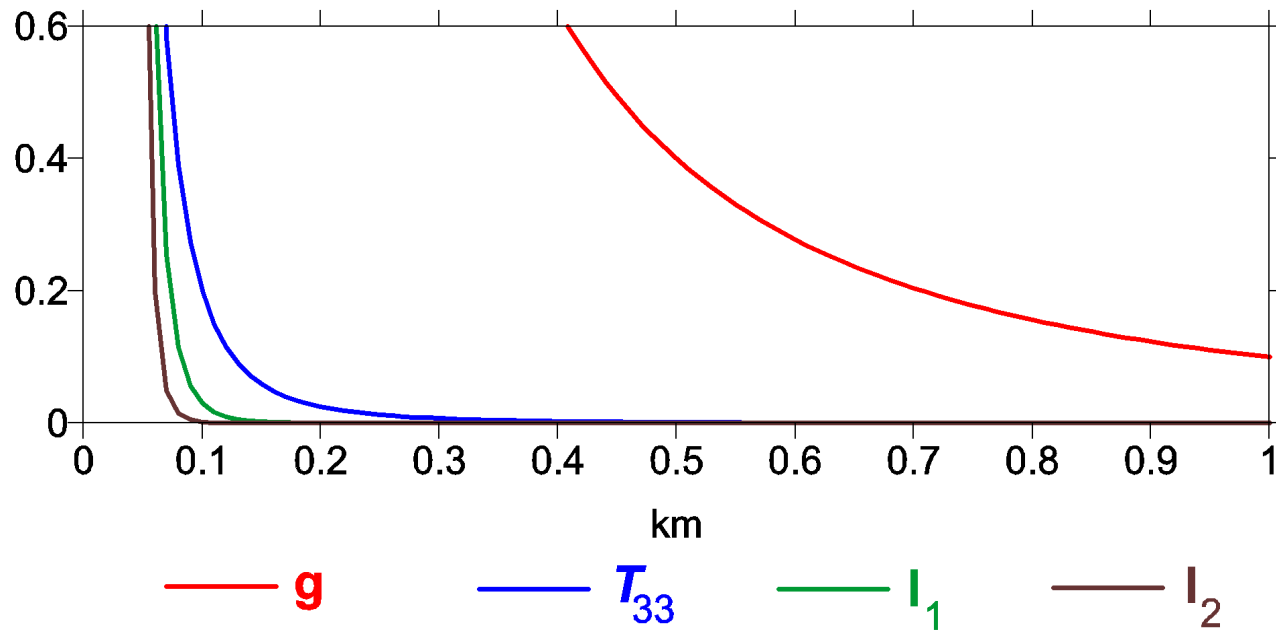
Eigen 6C4 - Havaj - velký ostrov - vd

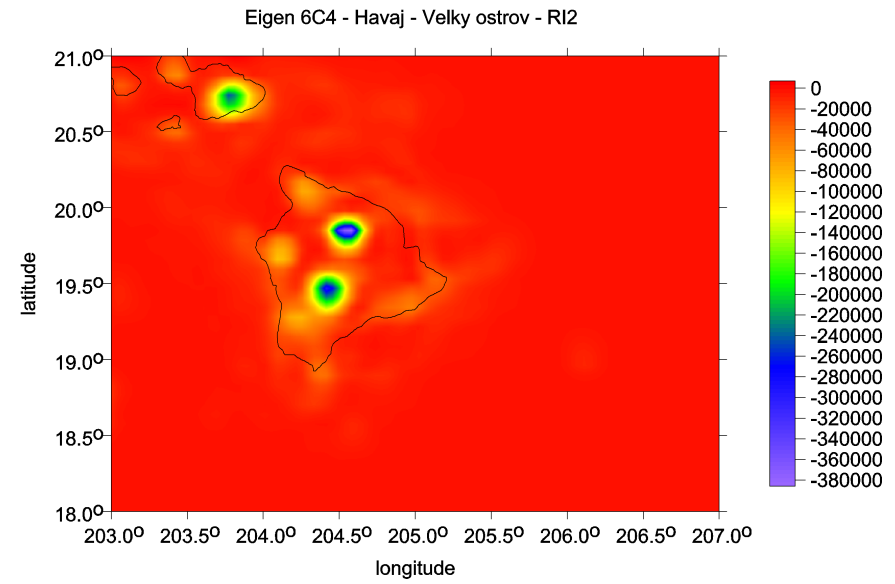
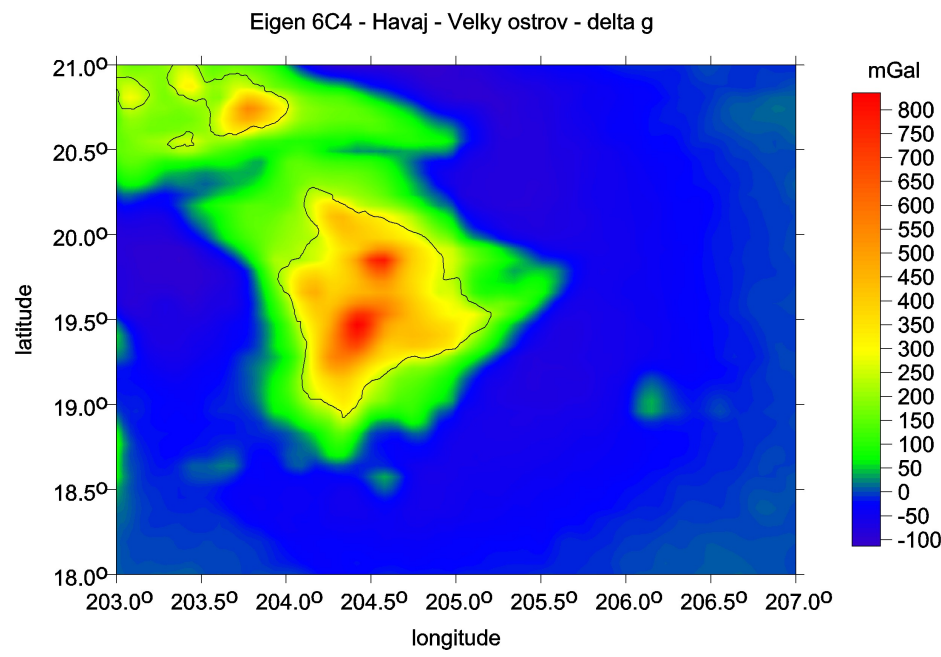
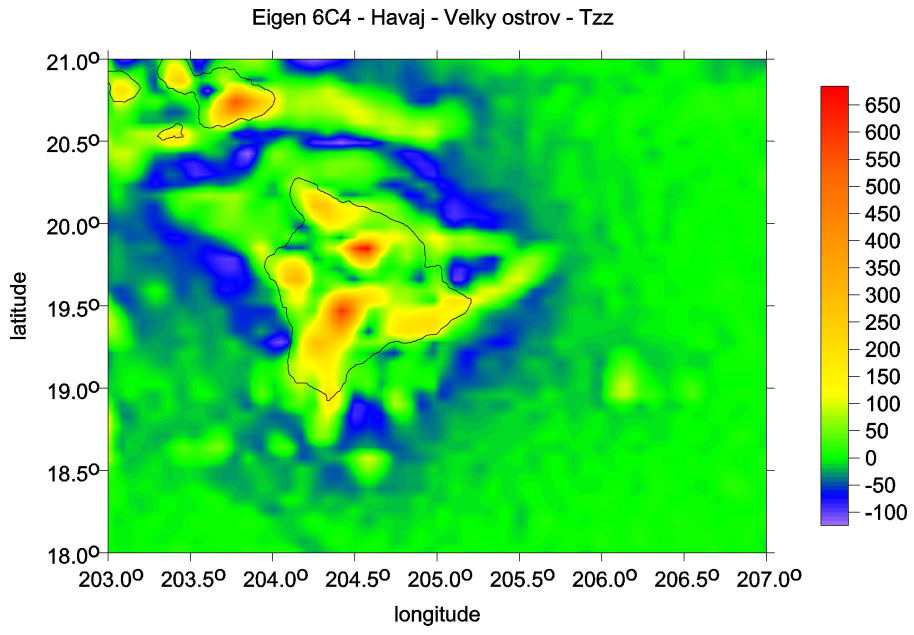
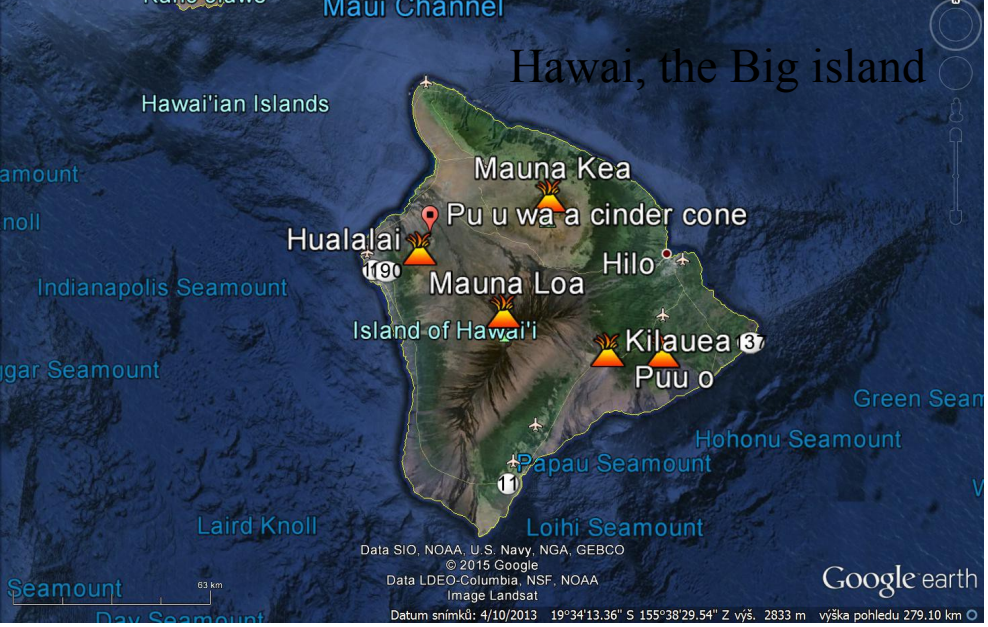


Comparison of sensitivity of various functions
of the disturbing potential
mass point case / an illustrative simplification

*x axis depth beneath surface [km], y axis reference value of functionals
for given gravitational constant Gm describing respective point mass body*

$$Gm = 100000 \text{ m}^3 \text{ sec}^{-2}$$





Data – recent gravity field models satellite bedrock topography and their combination

EGM 2008 *

EIGEN 6C4 **

BEDMAP 2 bedrock topography ***

- Pavlis, N. K., Holmes, S. A., Kenyon, S. C. & Factor, J. K. 2008a. An Earth Gravitational Model to degree 2160: EGM 2008. EGU General Assembly 2008, Vienna, 13–18 April 2008.

Pavlis, N. K., Holmes, S. A., Kenyon, S. C. & Factor, J. K. 2008b. EGM2008: An overview of its development and evaluation. National Geospatial-Intelligence Agency, USA, conf.: Gravity, Geoid and Earth Observation 2008, Chania, Crete, Greece, 23–27 June 2008.

Pavlis, N. K., Holmes, S. A., Kenyon, S. C. & Factor, J. K. 2012. The development and evaluation of the Earth Gravitational Model 2008 (EGM2008). *J. Geophys. Res.* 17, B04406, doi: 10.1029/2011JB008916, 2012.

** Förste Ch., Bruinsma S., Abrykosov O., Lemoine J-M. *et al* 2014. The latest combined global gravity field model including GOCE data up to degree and order 2190 of GFZ Potsdam and GRGS Toulouse (EIGEN 6C4). 5th GOCE user workshop, Paris 25 – 28, Nov. 2014.

*** Fretwell P, Pritchard H, Vaughan D, Bamber J, *et al.* 2013. Bedmap2: improved ice bed, surface and thickness datasets for Antarctica. *The Cryosphere*, 7, 375–393, 2013, doi: 10.5194/tc-7-375-2013; <https://secure.antarctica.ac.uk/data/-bedmap2/>

cont./pokrač.

SatGrav RET 2014

Hirt Ch. et al 2016,
A new degree-2190 (10 km resolution) gravity field model for Antarctica
Developed from GRACE, GOCE and Bedmap 2 data,
J Geod 90: 105-127.

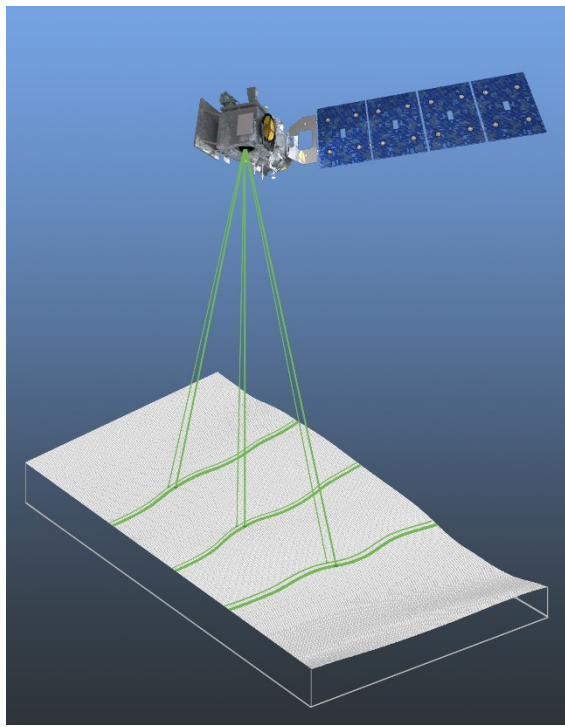
G(I)PR

Vlnová délka radaru ~ 1 m
Použití na družicích i letadlech

SIRAL: SAR Interferometer Radar Altimeter
DORIS: Doppler Orbitography and Radiopositioning
Integration by Satellite
LRR: Laser Retroreflector

Cryosat (2) ESA, 2010-

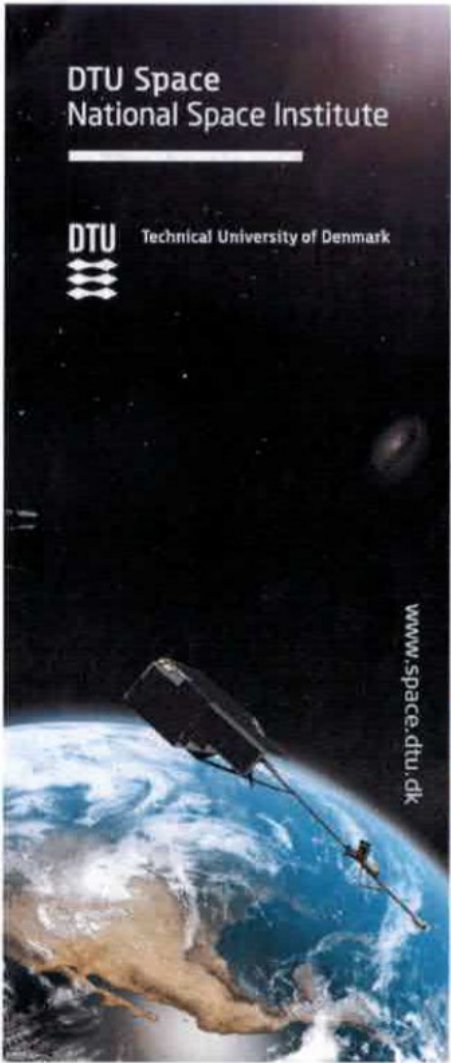




ICESAT 2 2017-

The sole instrument on ICESat-2 will be the Advanced Topographic Laser Altimeter System (ATLAS). The ATLAS laser will emit visible, green laser pulses at a wavelength of 532 nm.

As a result of ICESat's success, the National Research Council's (NRC) 2007 Earth Science Decadal Survey recommended a follow-on mission to continue the ICESat observations. In response, NASA tasked its Goddard Space Flight Center (GSFC) with developing and deploying the ICESat-2 mission - now scheduled for launch in 2017. The primary goals of the ICESat-2 mission are consistent with the NRC's directives: *to deploy a spaceborne sensor to collect altimetry data of the Earth's surface optimized to measure ice sheet elevation change and sea ice thickness, while also generating an estimate of global vegetation biomass.*



British Antarctic Survey
NATIONAL ENVIRONMENT RESEARCH COUNCIL



DTU Space
National Space Institute



GOCE polar gaps now filled - first results of the ESA Polargap project

Rene Forsberg, Arne Olesen
DTU-Space, Denmark
Fausto Ferracioli, Tom Jordan
British Antarctic Survey
Kenichi Matsuoka
Norwegian Polar Institute



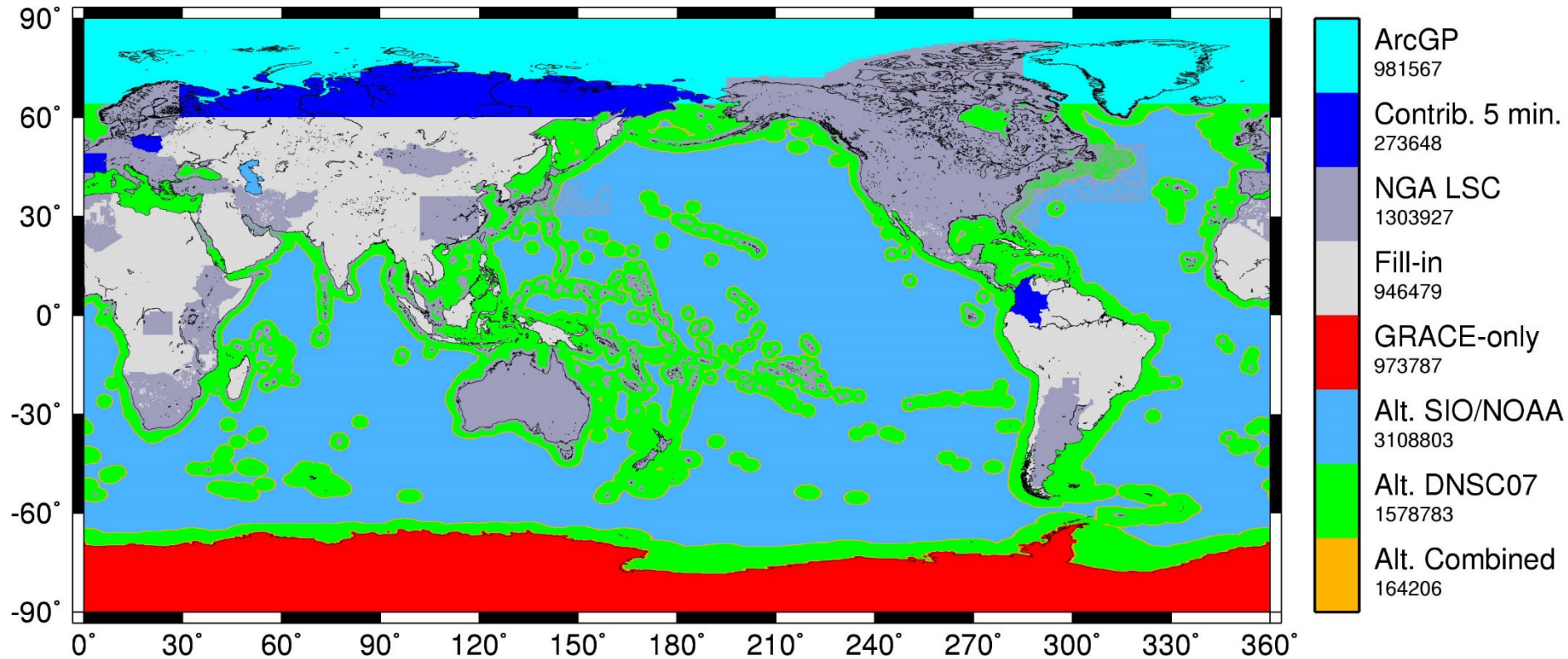
Gravity data (Models of the Earth Gravitational Field)

EGM 2008 is a high resolution static gravity field model (Pavlis et al, 2008, 2012), a combination solution to degree and order 2160; it contains additional coefficients extending to degree 2190 and order 2159.

Satellite data in EGM 2008 come from the GRACE A/B SST (low-low satellite-to-satellite tracking).

Terrestrial data base of EGM 2008 is very extensive and consists of several sources. Nevertheless, there is not homogeneous gravity anomaly field yet. No terrestrial data in EGM 2008 are available over Antarctica, poorer data (of low precision and reliability) over high mountain belts (s/c „fill-in data“, derived from topography). For these zones, like Himalaya, we have fortunately very large values of the signal (the values of gravity anomalies or other functionals of the geopotential) so that even their larger commission error over these areas does not mean any serious problem.

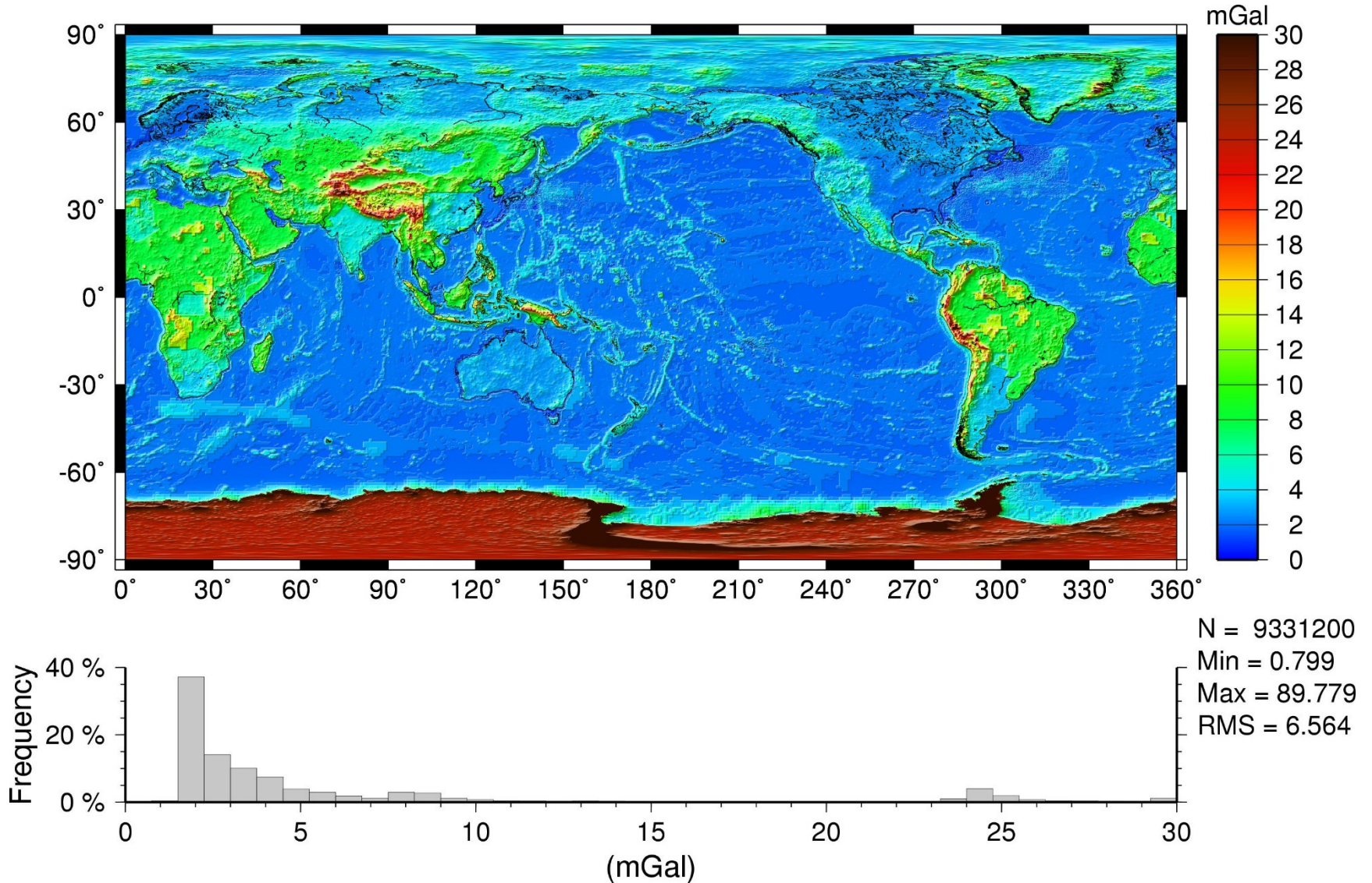
► 5'×5' Δg Data Sources (v010808)



Description of a part of input data (terrestrial gravity anomalies) to EGM 2008 by Pavlis et al 2008

- “ArcGP”: 5 x 5 minute mean gravity anomalies which were estimated as part of the Arctic Gravity Project.
- “Contrib. 5 min”: 5 x 5 minute mean gravity anomalies which were contributed to the project “ready-made”. These mean values were estimated by the contributing person or agency.
- “NGA LSC”: 5 x 5 minute mean gravity anomalies which were estimated using Least Squares Collocation (LSC) by NGA.
- **“Fill-in”: 5 x 5 minute mean gravity anomalies which were computed from the spectral “cut-and-paste” set of coefficients, where, up to $l = 720$ the coefficients represent the (proprietary) 5 x 5 minute mean gravity anomalies, and from $l=721$ to $L_{max} = 2159$ they represent the gravity anomalies implied by the Residual Terrain Model effects.**
- “Alt. SIO/NOAA”: 5 x 5 minute mean gravity anomalies which were estimated by D. Sandwell and W. Smith, using altimetry data.
- “Alt. DNSC07”: 5 x 5 minute mean gravity anomalies which were estimated by O. Andersen and P. Knudsen, using altimetry data.
- “Alt. Comb.”: 5 x 5 minute mean gravity anomalies which were estimated as a linear combination of the SIO/NOAA and DNSC07 values (to avoid jump discontinuities).

► **5'×5' Δg Commission Error: EGM2008 (Nmax=2159)**



EIGEN-6C4 is a high resolution static global combined gravity field model up to degree and order 2190. It has been elaborated jointly by GFZ Potsdam and GRGS Toulouse (Foerste et al. 2014) and contains the following satellite and ground data:

- LAGEOS (for degrees of harmonics from 2 to 30)
high orbiting geodynamic satellite: 1985 – 2010
- Previous gravity model GRACE RL03 GRGS (deg. 2 - 130):
ten years 2003 – 2012
- GOCE-SGG data, processed by the direct approach incl. the gravity gradient components T_{xx} , T_{yy} , T_{zz} and T_{xz} throughout whole life of the GOCE satellite.
The GOCE polar gaps were stabilized by the
- *Terrestrial data* (max degree 370): DTU12 ocean geoid data and an EGM2008 geoid height grid for the continents.

The combination of these different satellite and surface data sets has been done by a band-limited combination of normal equations (to max degree 370), which are generated from observation equations for the spherical harmonic coefficients. The resulted solution to degree/order 370 has been extended to degree/order 2190 by a block diagonal solution using the DTU10 global gravity anomaly data grid.

Using the harmonic geopotential coefficients of the global gravitational model EGM 2008, the following physical quantities are computed: the gravity anomalies Δg (or disturbances) [scale $1\text{mGal} = 10^{-5} \text{ms}^{-2}$], the full Marussi tensor Γ of the second derivatives of the disturbing potential [$1\text{E} = 1 \text{Eötvös} = 10^{-9} \text{s}^{-2}$], namely its radial component, sometimes denoted T_{zz} or T_{rr} , the invariants of the gravity field $I_0, I_1, I_2 = \det(\Gamma)$, computable from the components of the Marussi tensor, their specific ratio I and the strike angle θ . These quantities are known from theory of Pedersen & Rasmussen (1990) and Beiki & Pedersen (2010). A “virtual deformation” has been added (Kalvoda et al. 2013, following Brdička et al 2000). Some of these quantities are functionals of the geopotential in a mathematical sense and some of them are not. Therefore, they are concisely designated in the paper as *aspects* of the geopotential.

Plotting

Plotting is important for visualizing our results; we make use of **strongly non-linear scales to emphasize various features** which otherwise might remain hidden.

A note about the units of plotted aspects:

mGal (miligals) for the *gravity anomalies* and/or disturbances,
E ... Eötvös for the second order potential derivatives,
components of *Marussi tensor*.

The *invariants* I_1 and I_2 have units [s⁻⁴] and [s⁻⁶] and their ratio I is dimensionless.

The *strike angle* θ is expressed in degrees and its demonstration in red means its direction to the East and in blue to the West of the local meridian.

The *virtual deformations* (vd) are dimensionless and express a direction of dilatation (red) or compression (blue). These units are used in all figures presented below.

$$1\text{mGal} = 10^{-5} \text{ ms}^{-2}, 1\text{E} = 1 \text{ Eötvös} = 10^{-9} \text{ s}^{-2}$$

**Examples of
typical gravitational signal (trace, signature)
of diverse geological/geomorphological/geophysical
structures**

Typical volcanoes

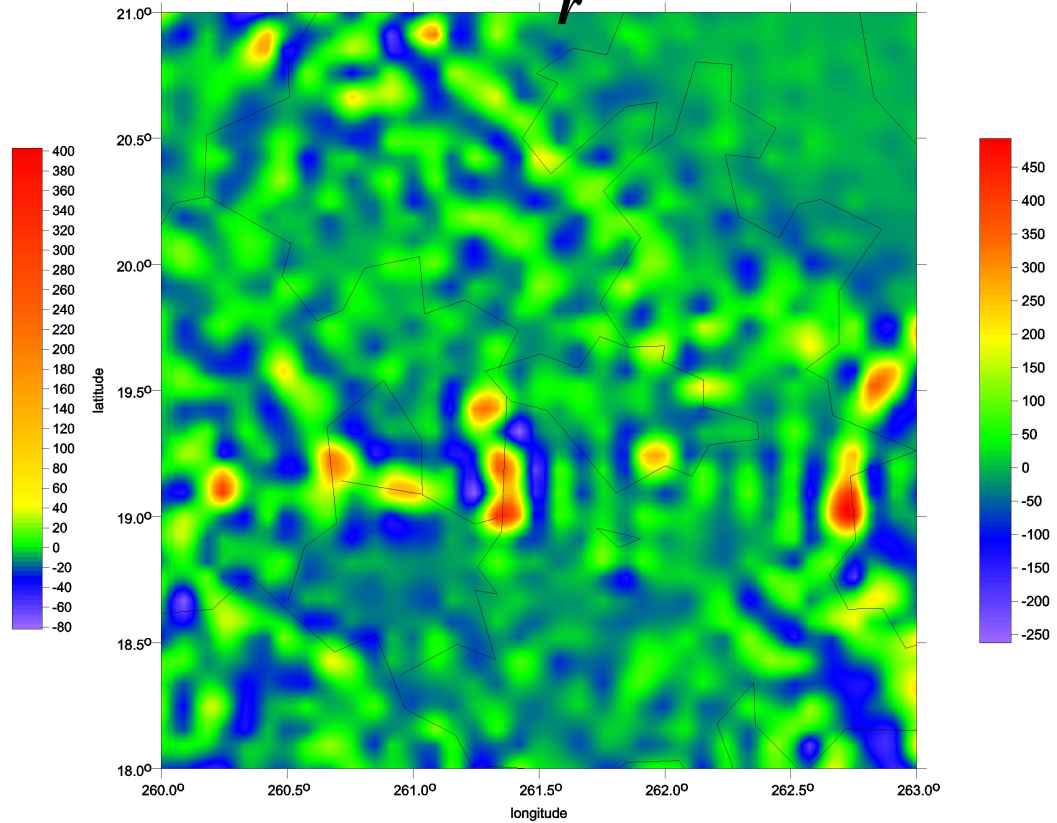
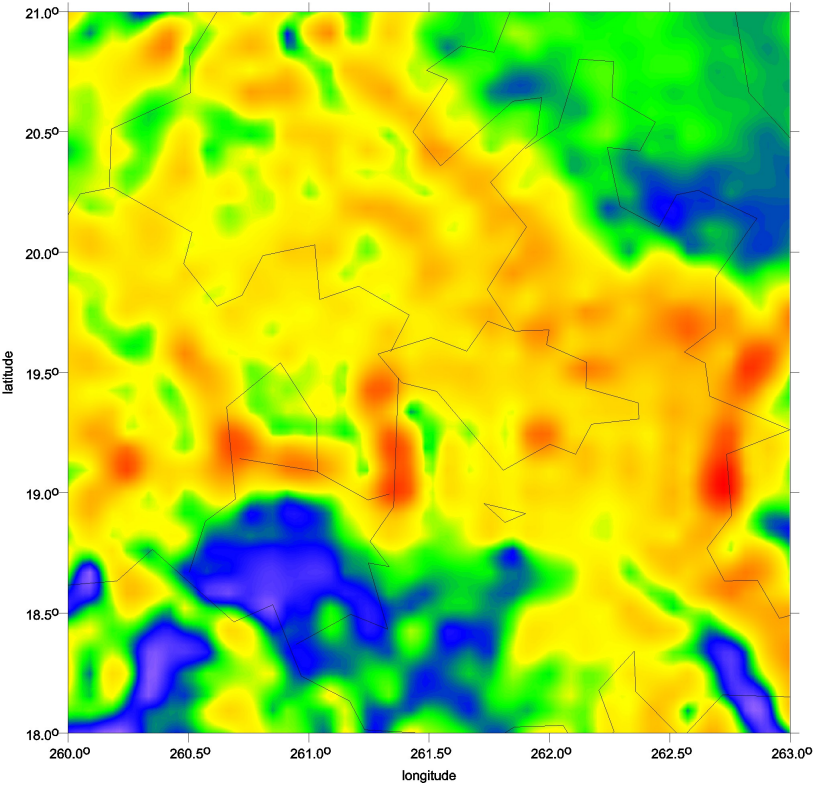


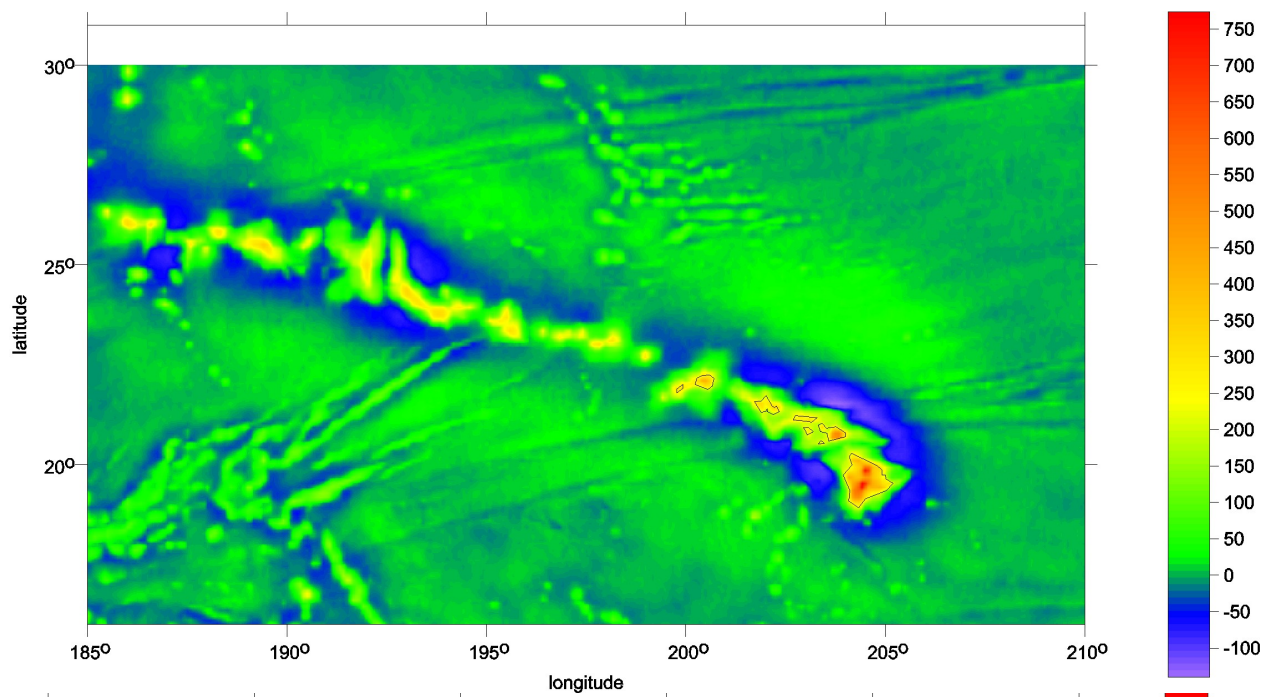
**Popocatepetl
Itzaccihuatl**

Δg

Tr

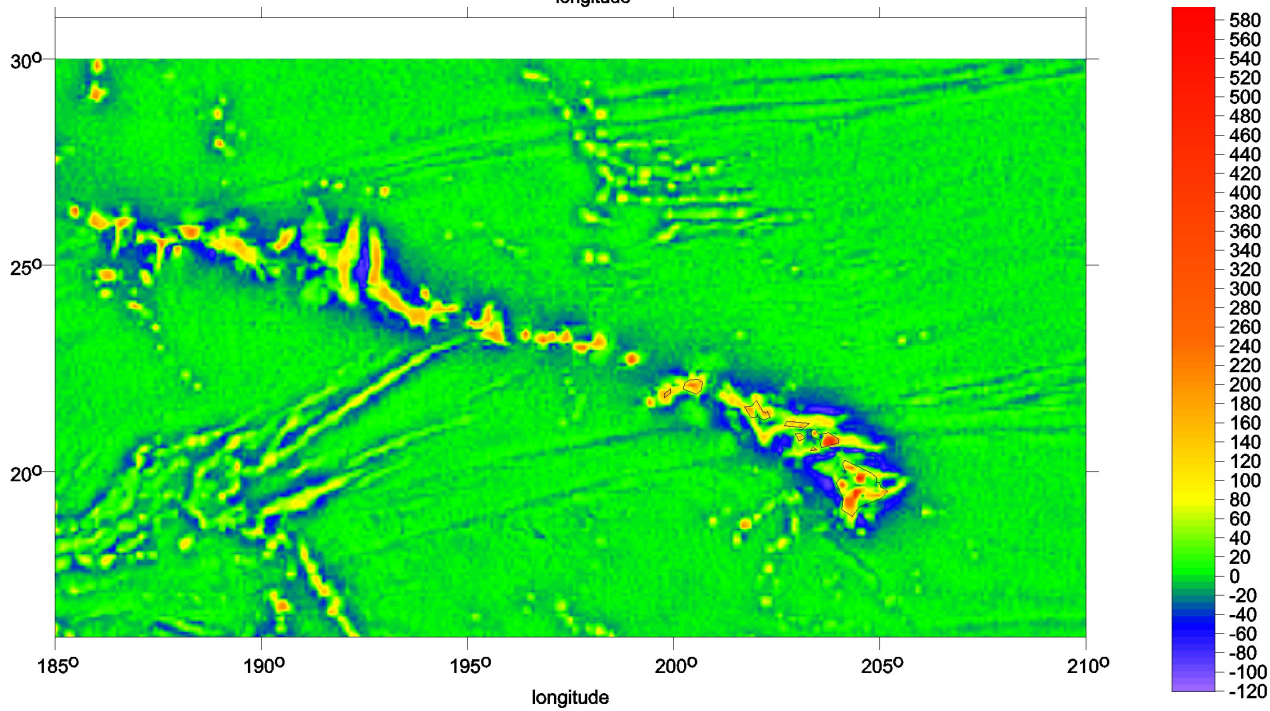
r





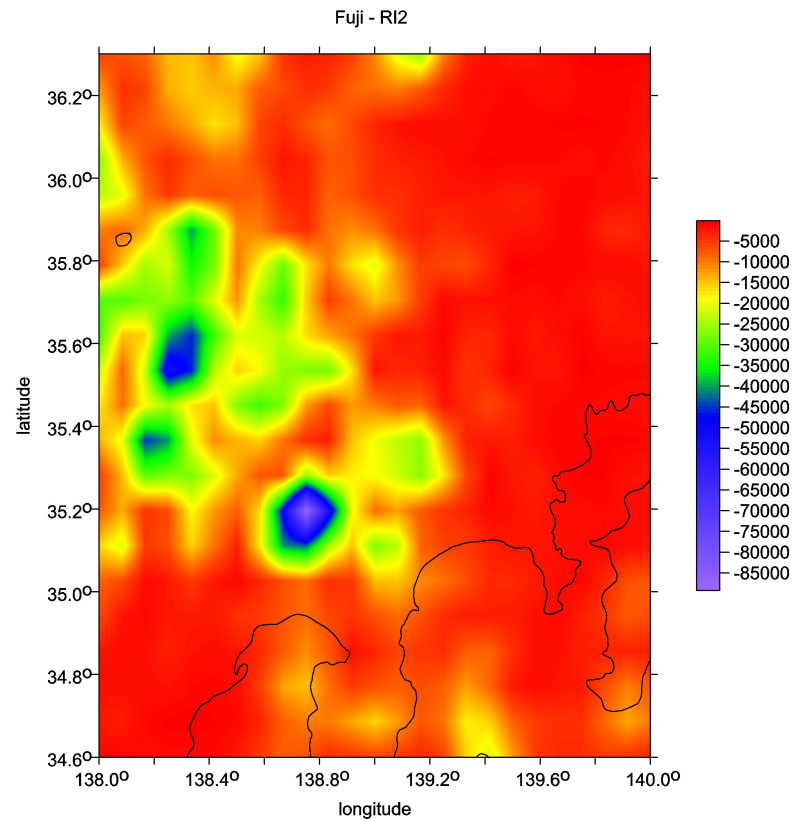
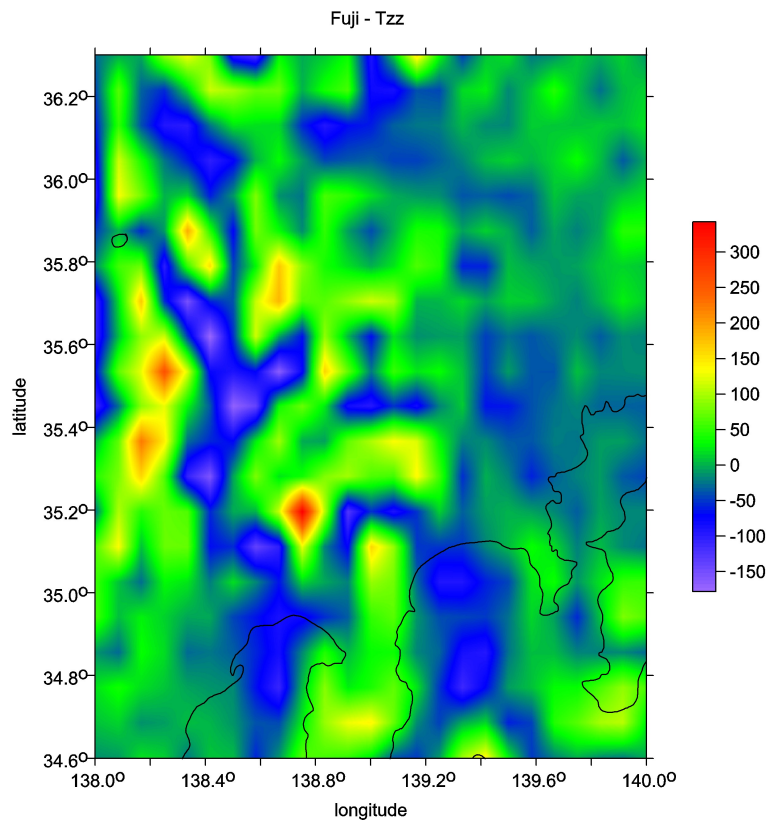
Hawai

gravity disturbance



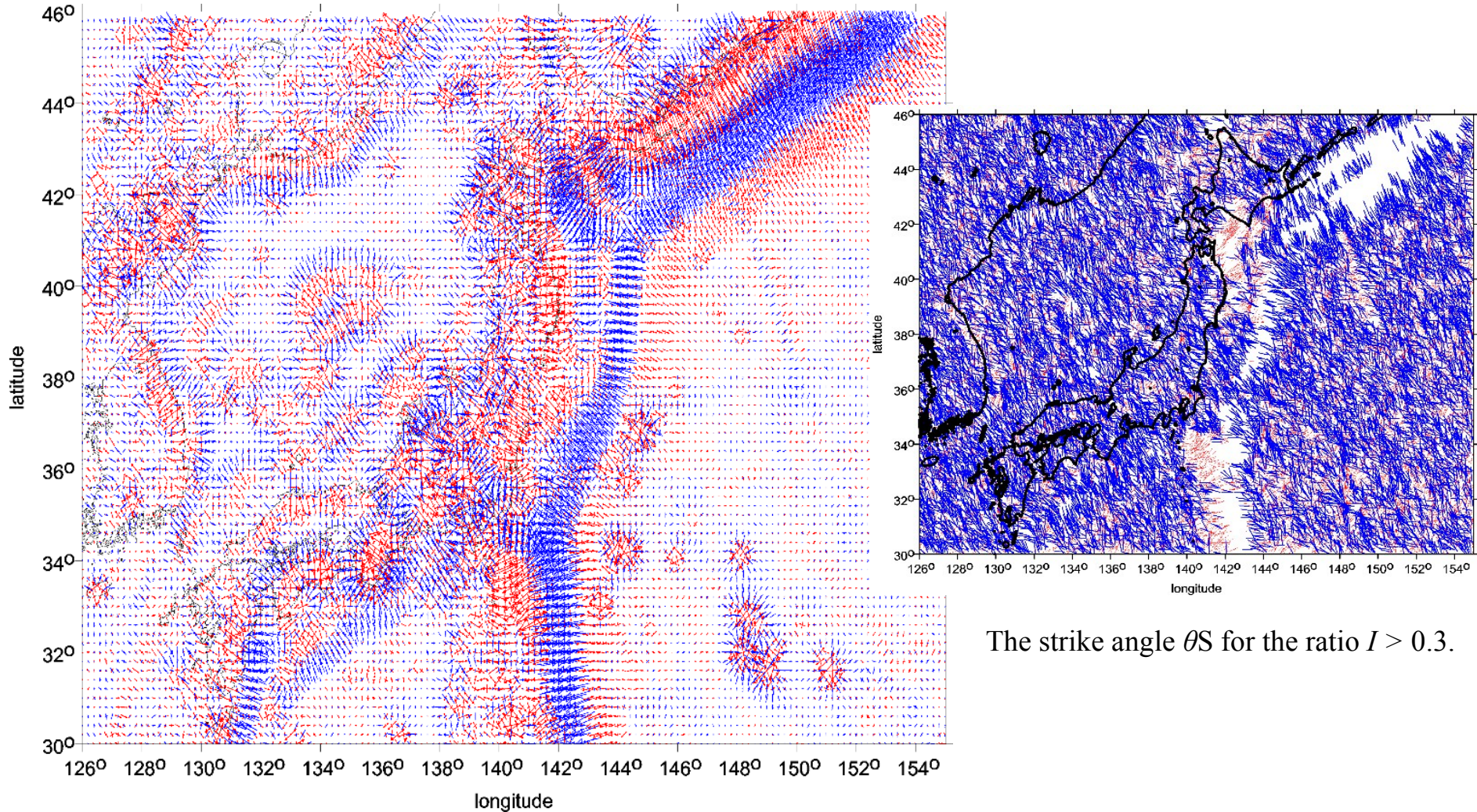
Tzz

Fuji, Japan



subduction zone, volcanoes under sea SE of Japan virtual deformations

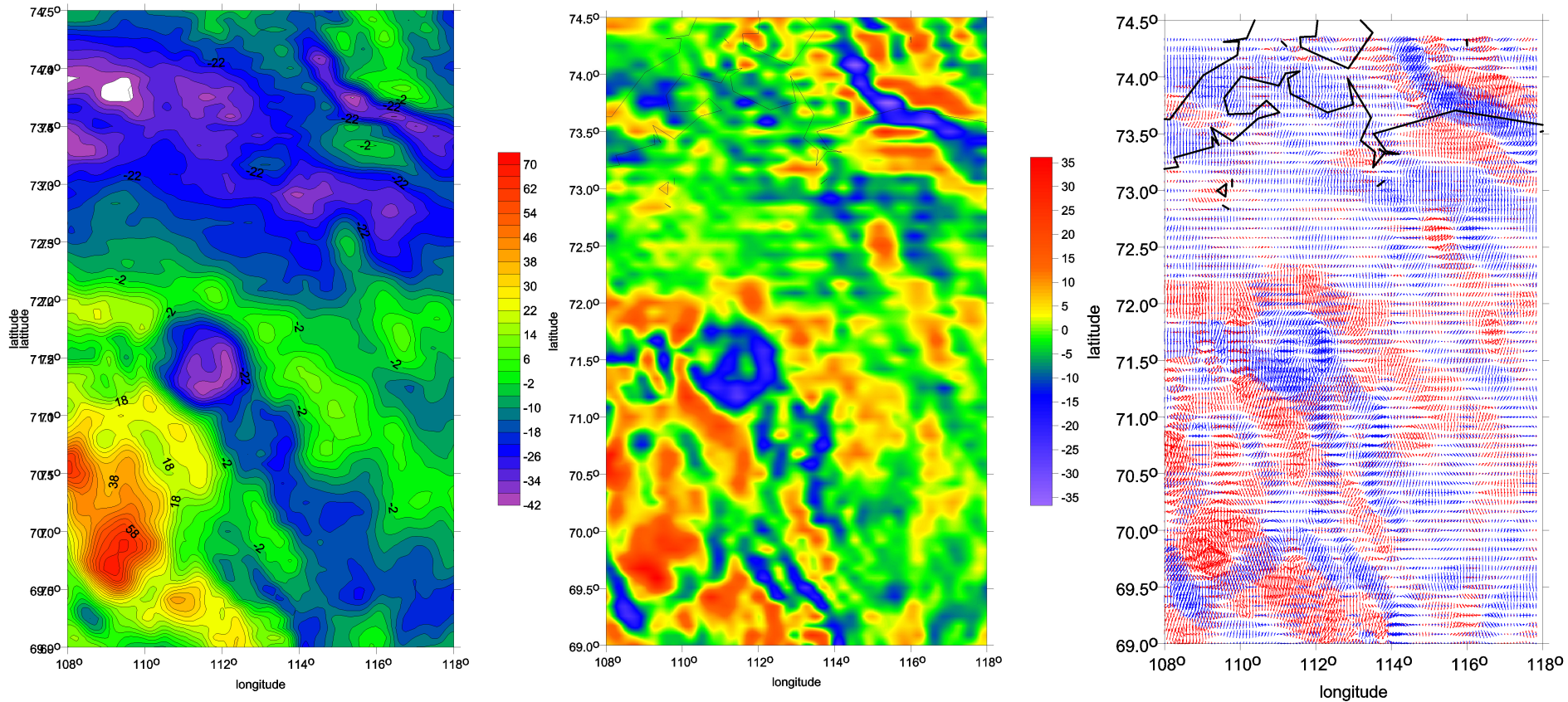
Japan - virtual deformations
red - dilatation, blue - compression



The strike angle θ_S for the ratio $I > 0.3$.

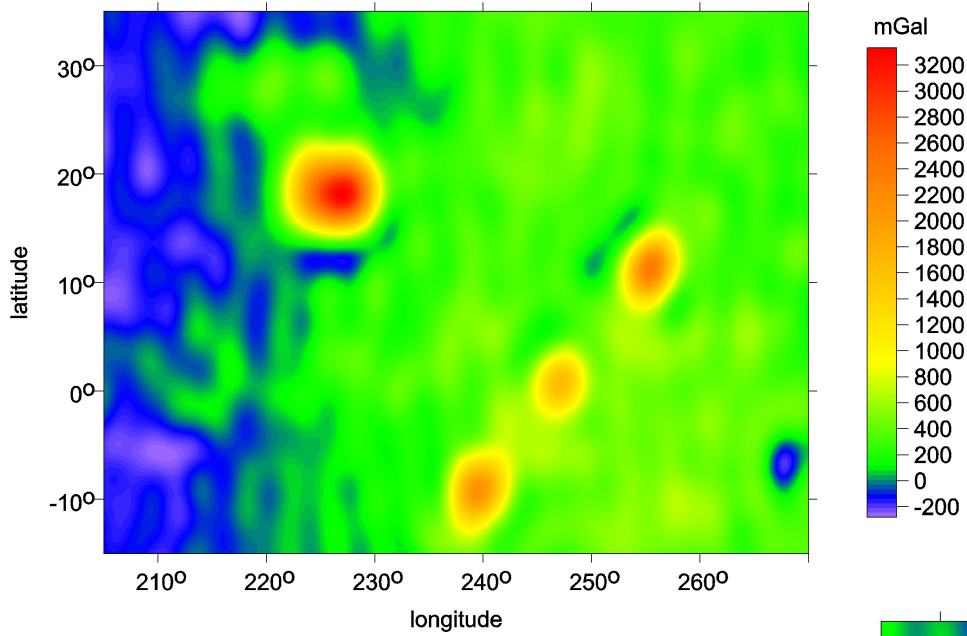
Large impact crater on the Earth

Popigai, Siberia, diameter ~ 100 km



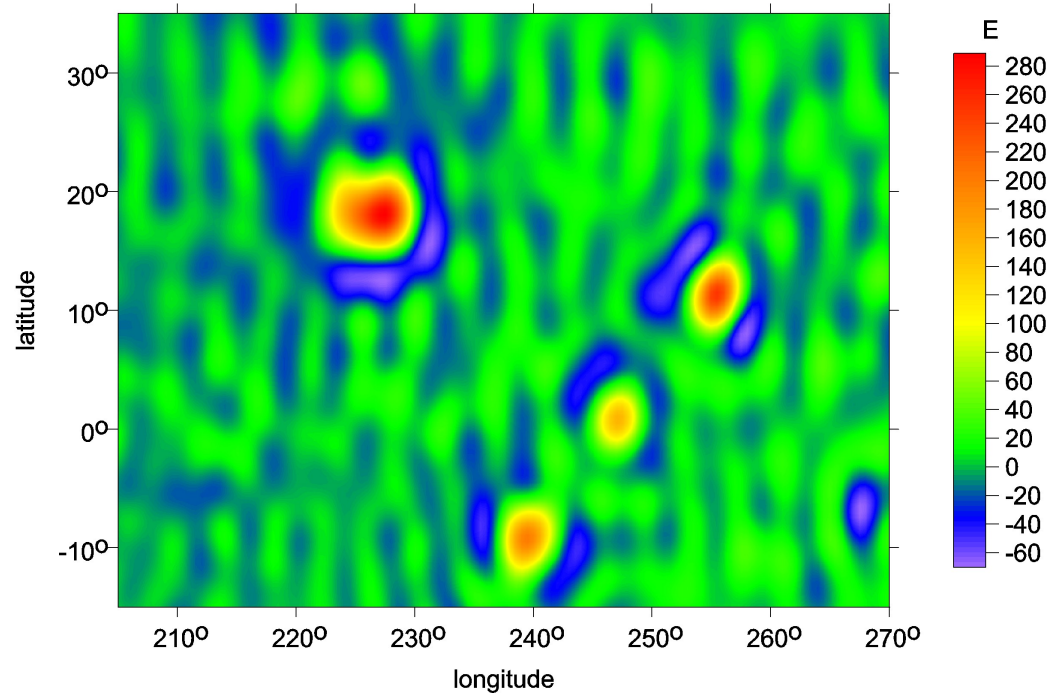
more in Klokočník et al. 2010

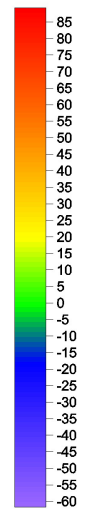
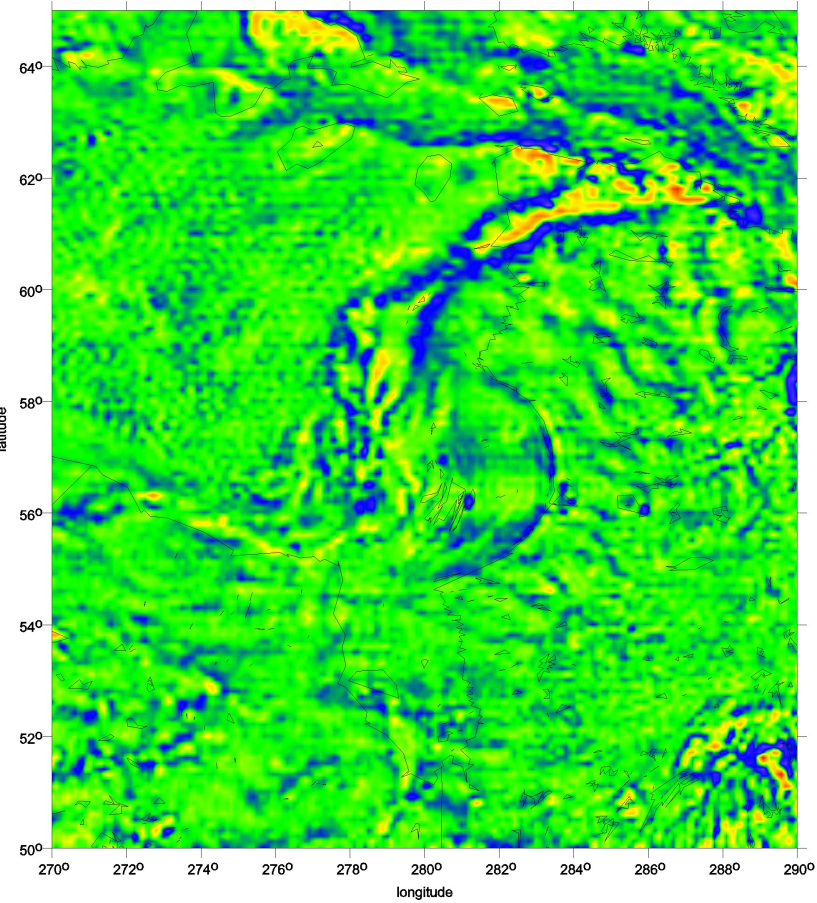
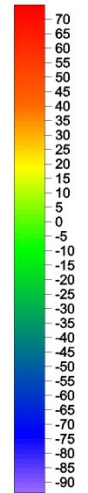
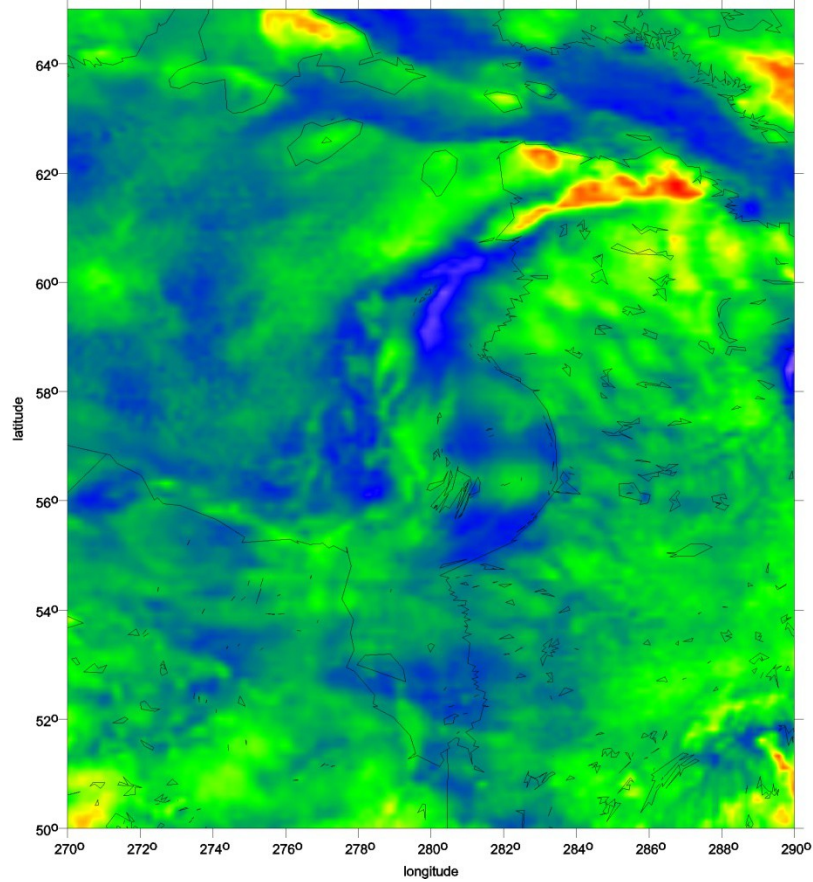
Mars - Olympus - delta g



Mt Olymp, Mars
Marty et al,
potential to 95

Mars - Olympus - Tzz

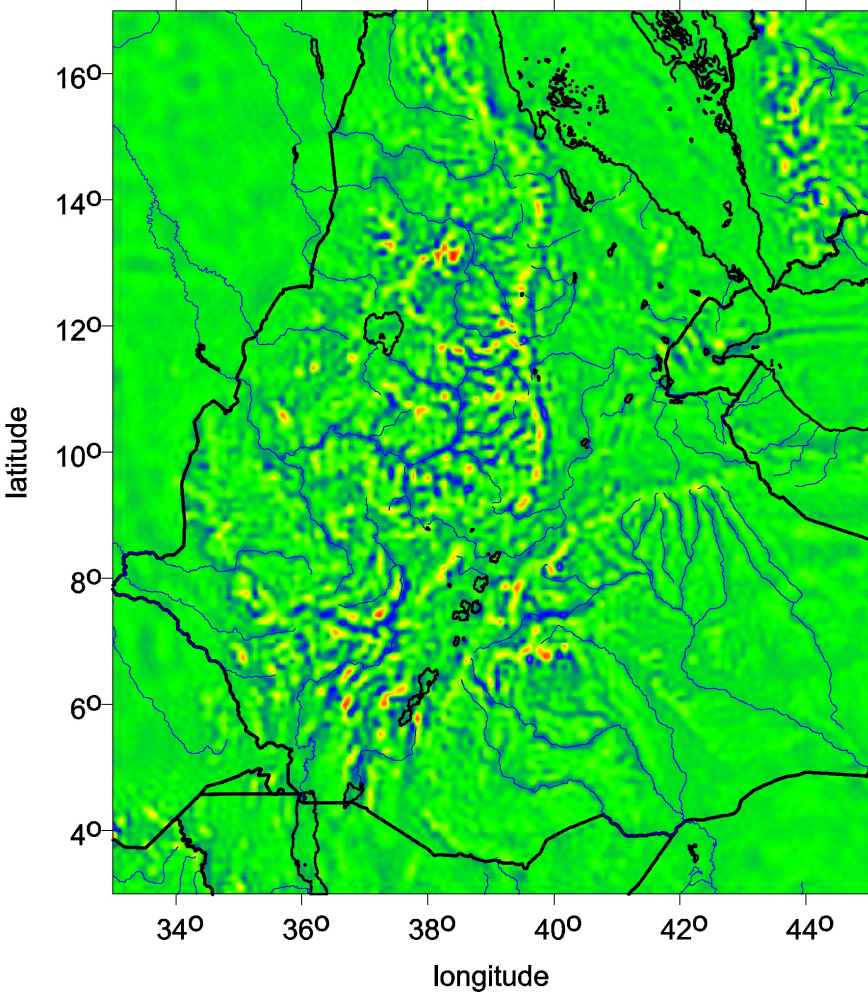




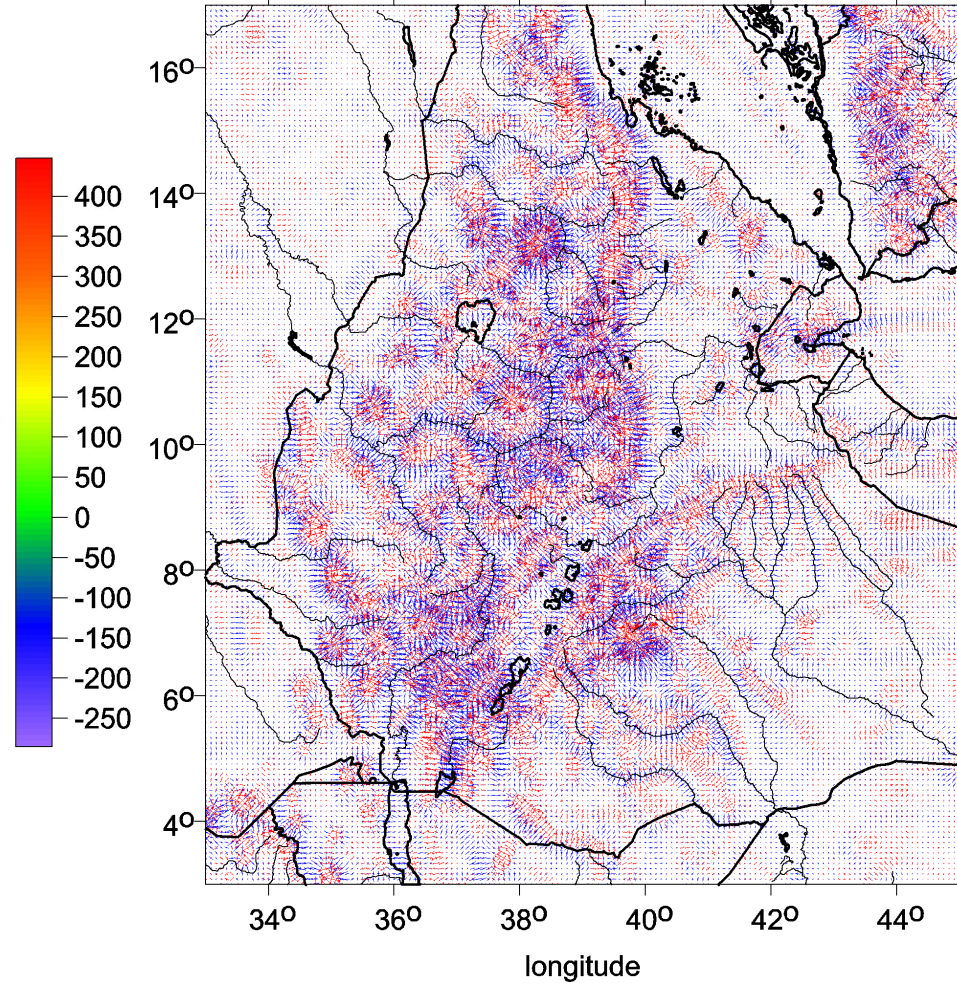
Canada – Hudson
bay

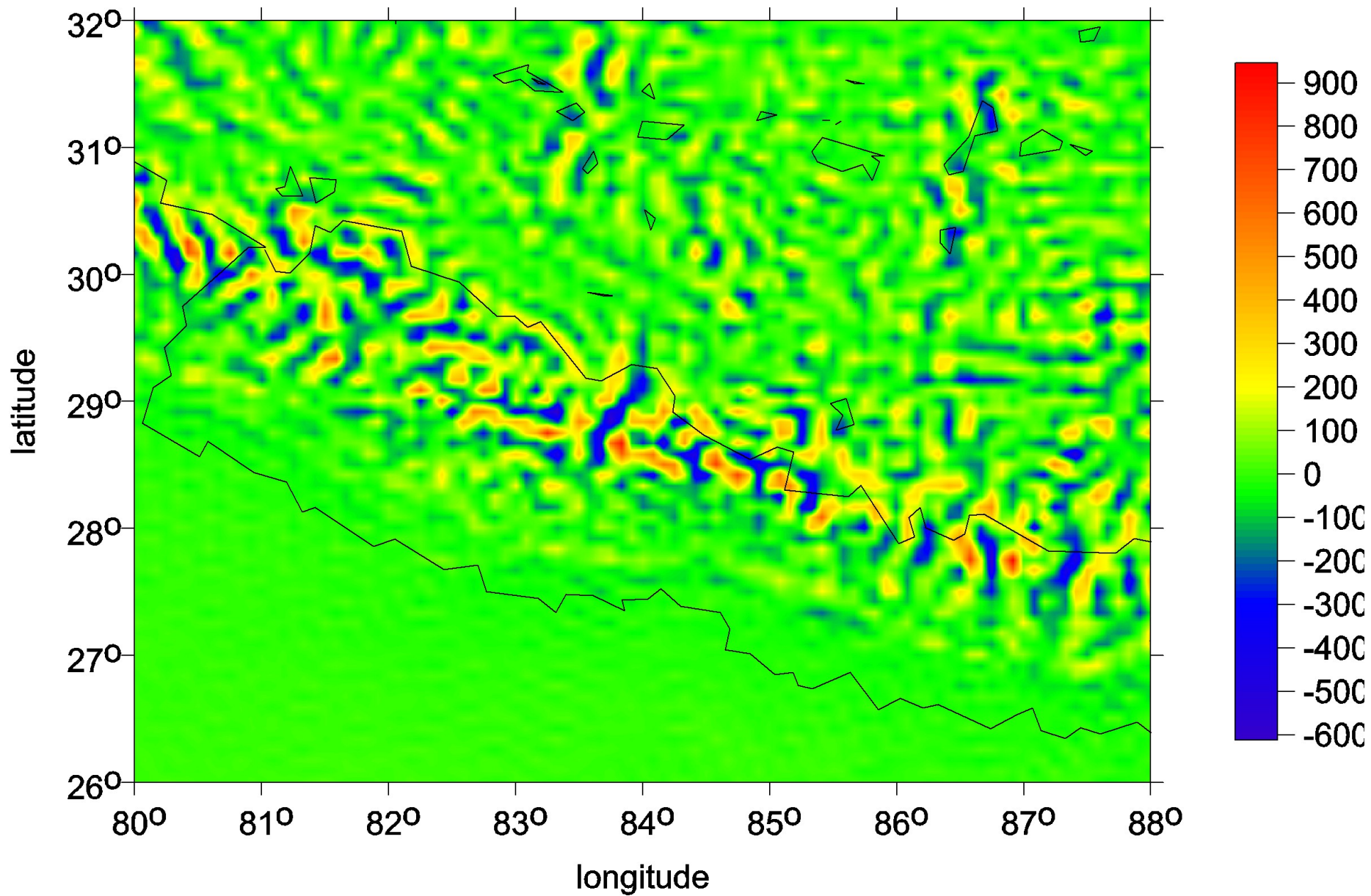
Ethiopia

African land with quality terrestrial data in EGM 2008,
Ethiopia - Tzz



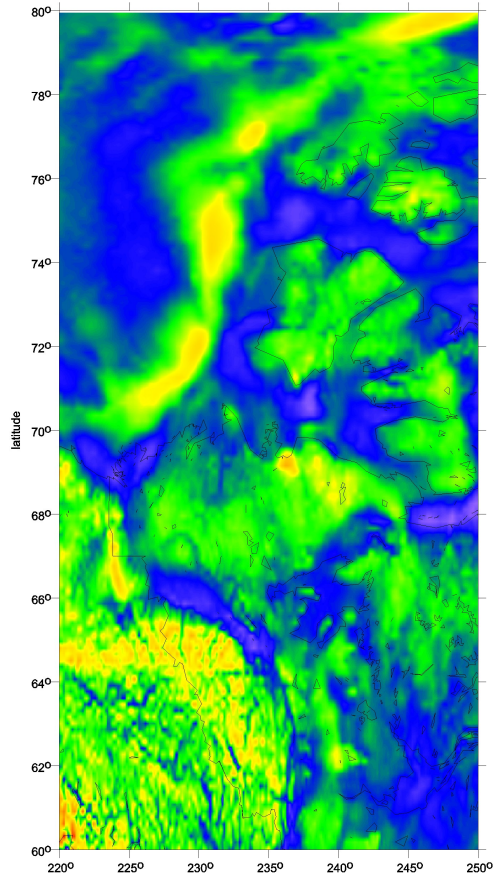
Ethiopia - virtual deformation



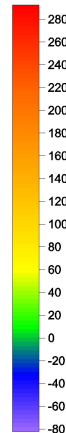


Yucon - Alaska

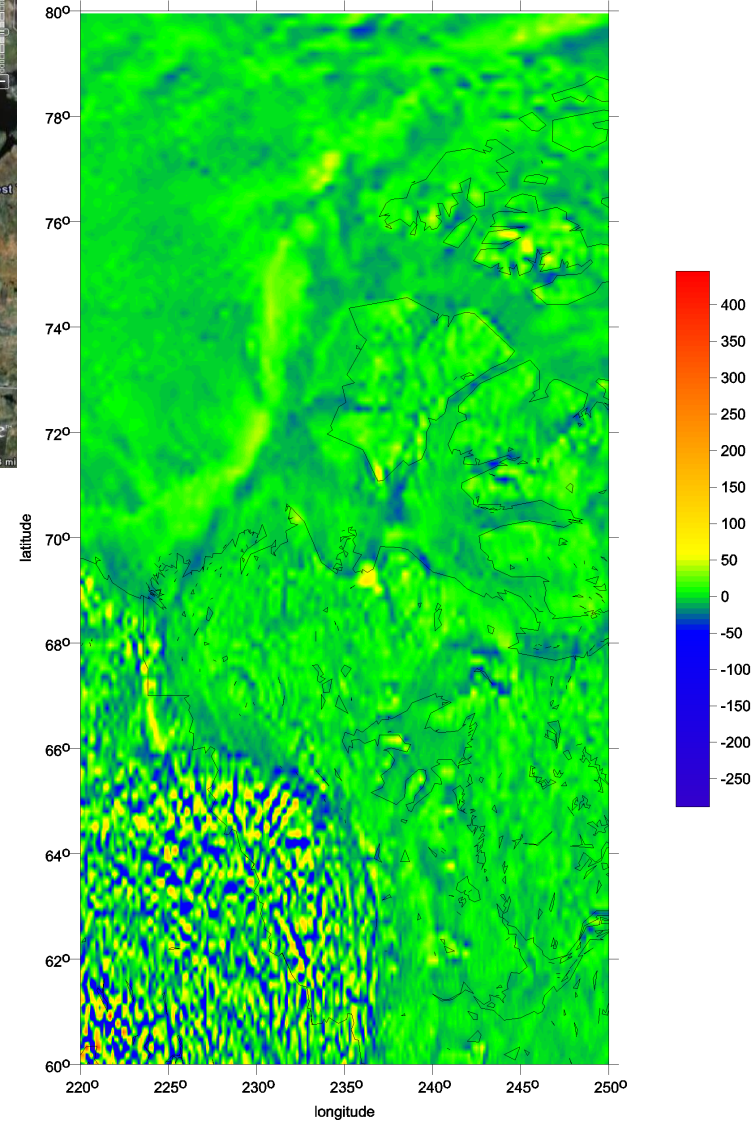
Δg



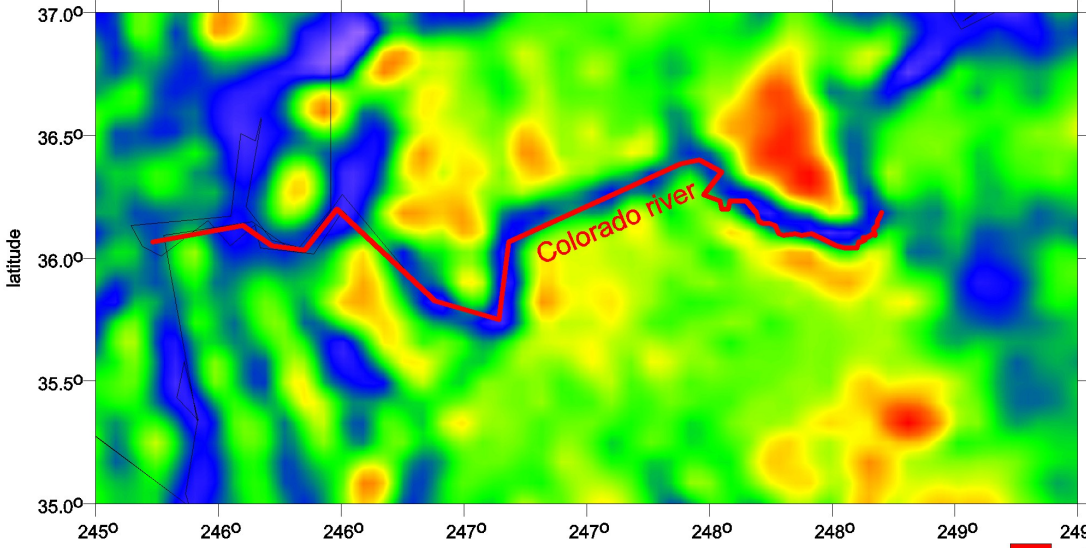
Google Earth



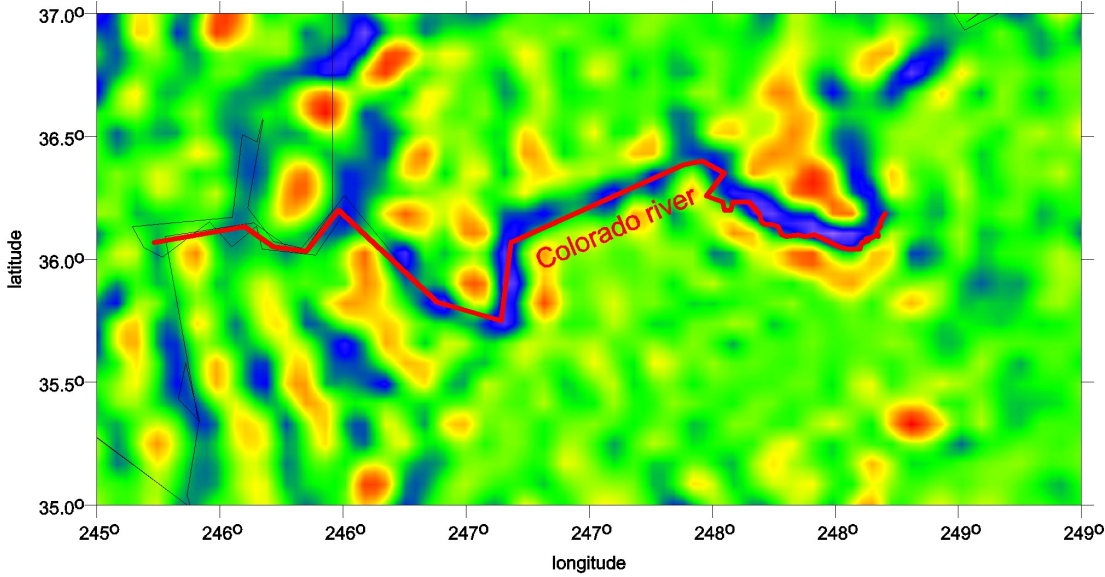
Tr
 r



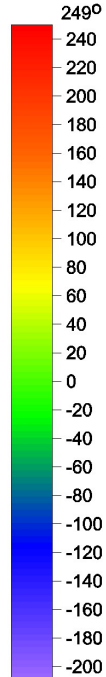
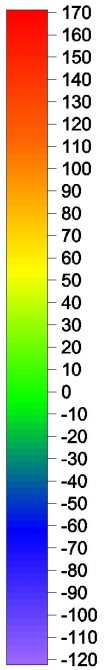
Grand Canyon



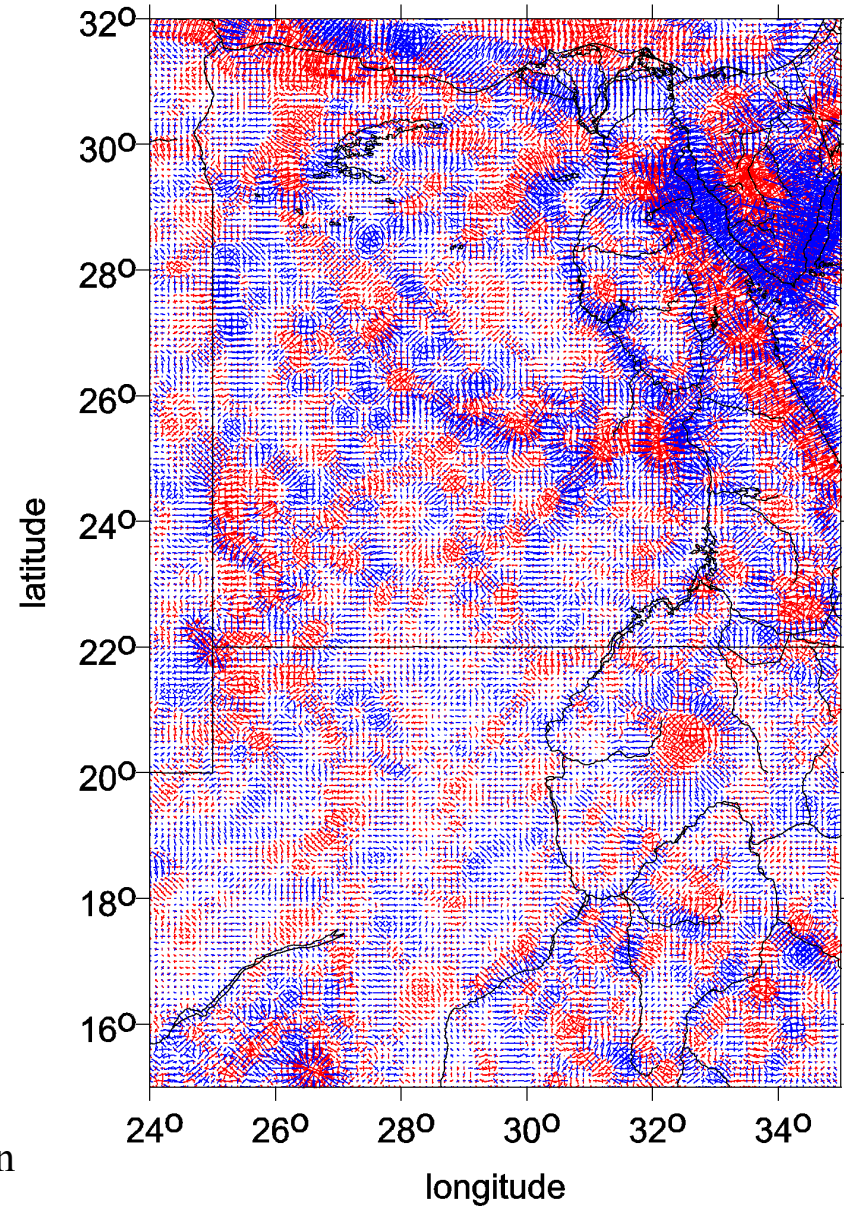
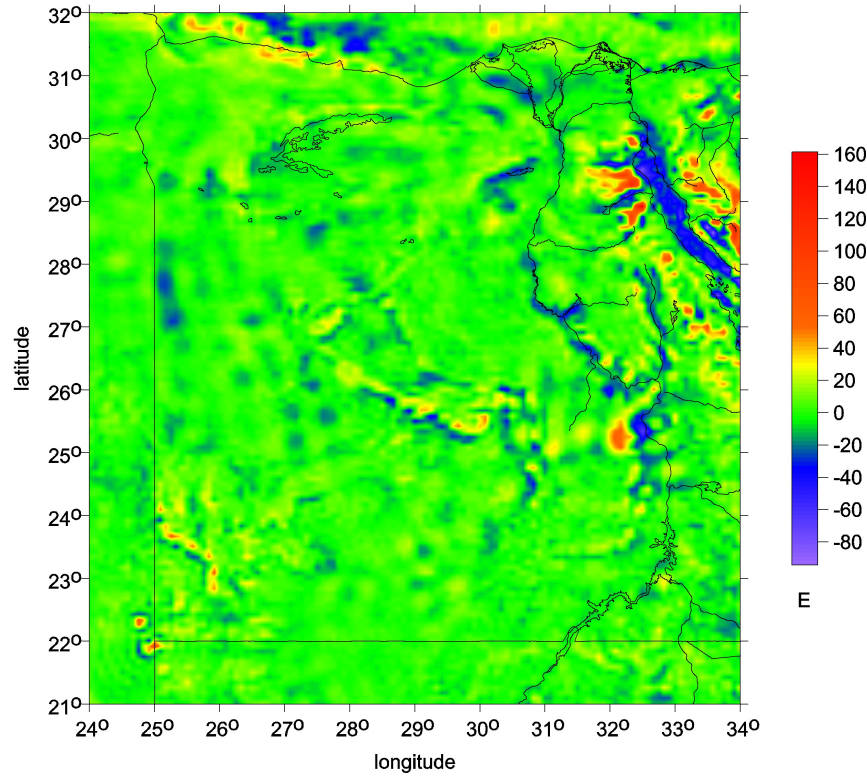
Δg



T_{zz}

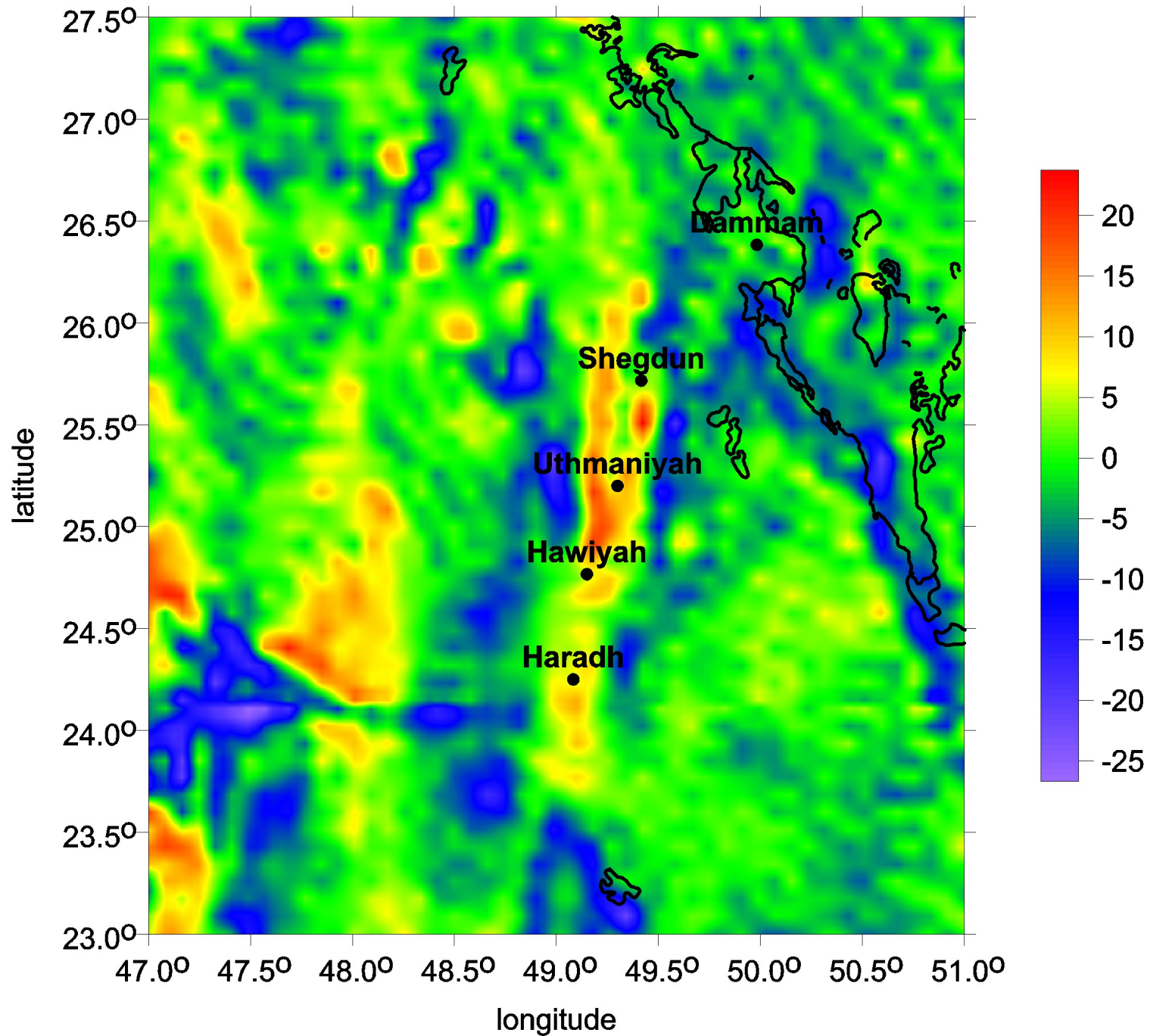


Eigen-6C4 - Egypt - Tzz

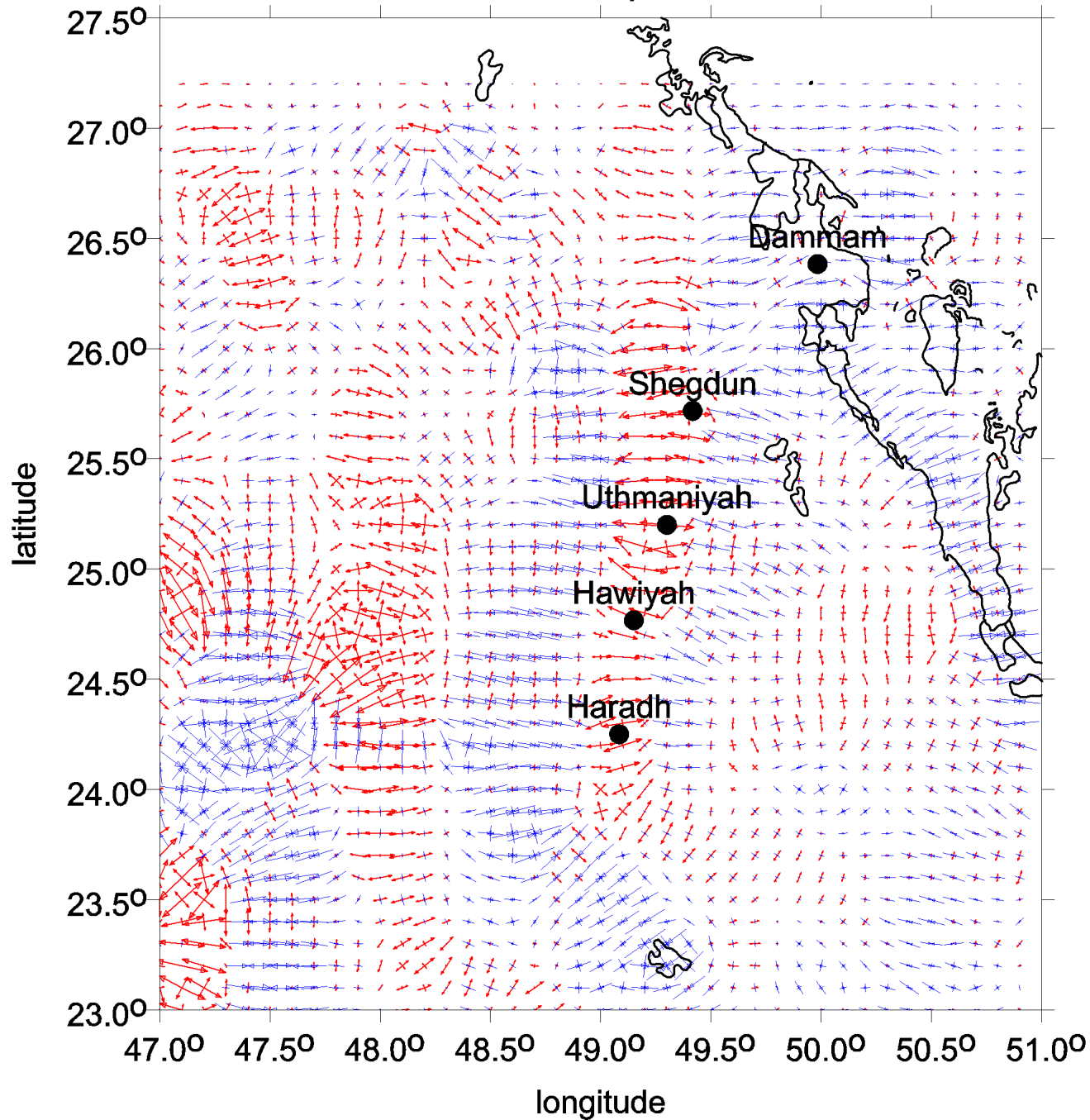


red... dilatation
blue ...compression

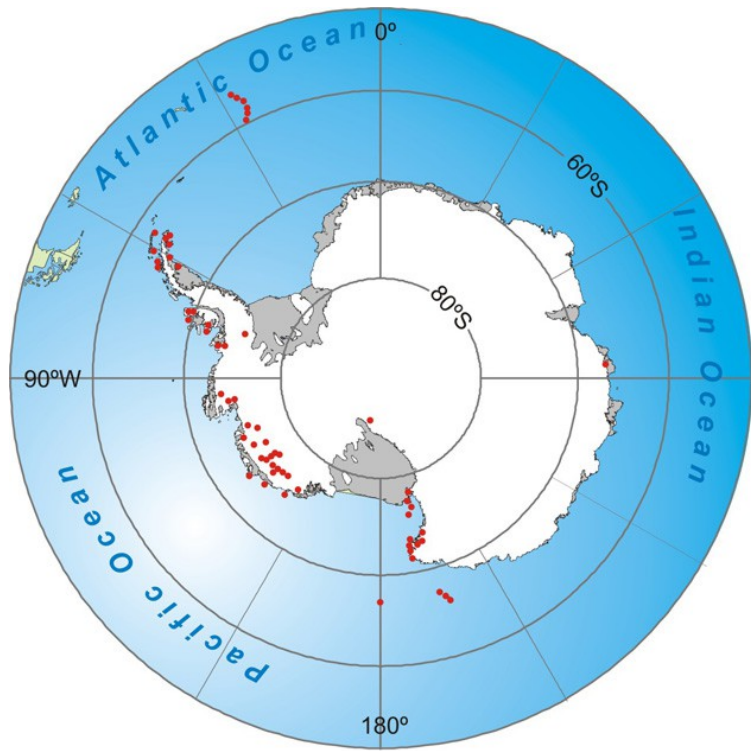
Ghawar - Tzz



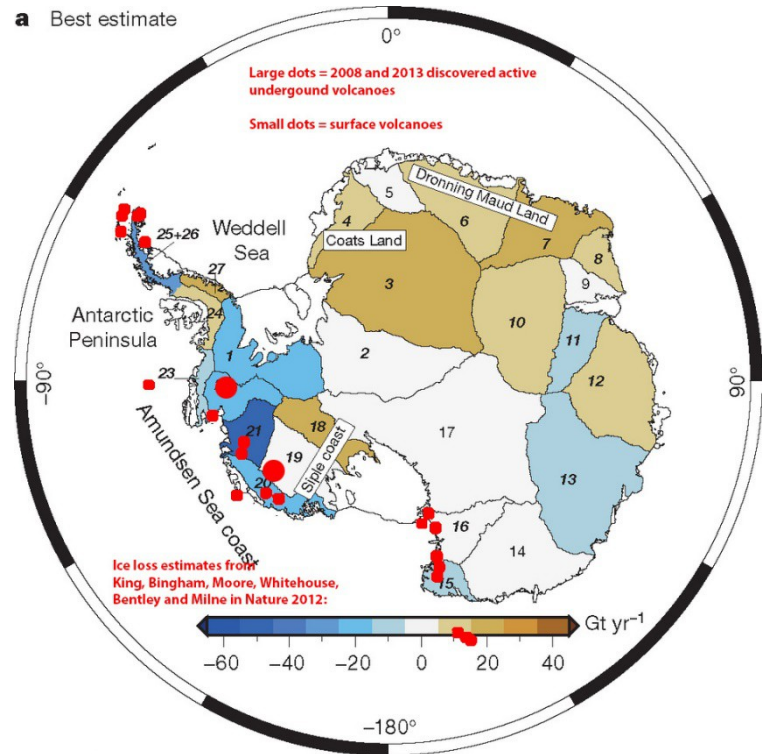
Ghawar - virtual deformation based on EGM2008
dilatation - red, compression - blue



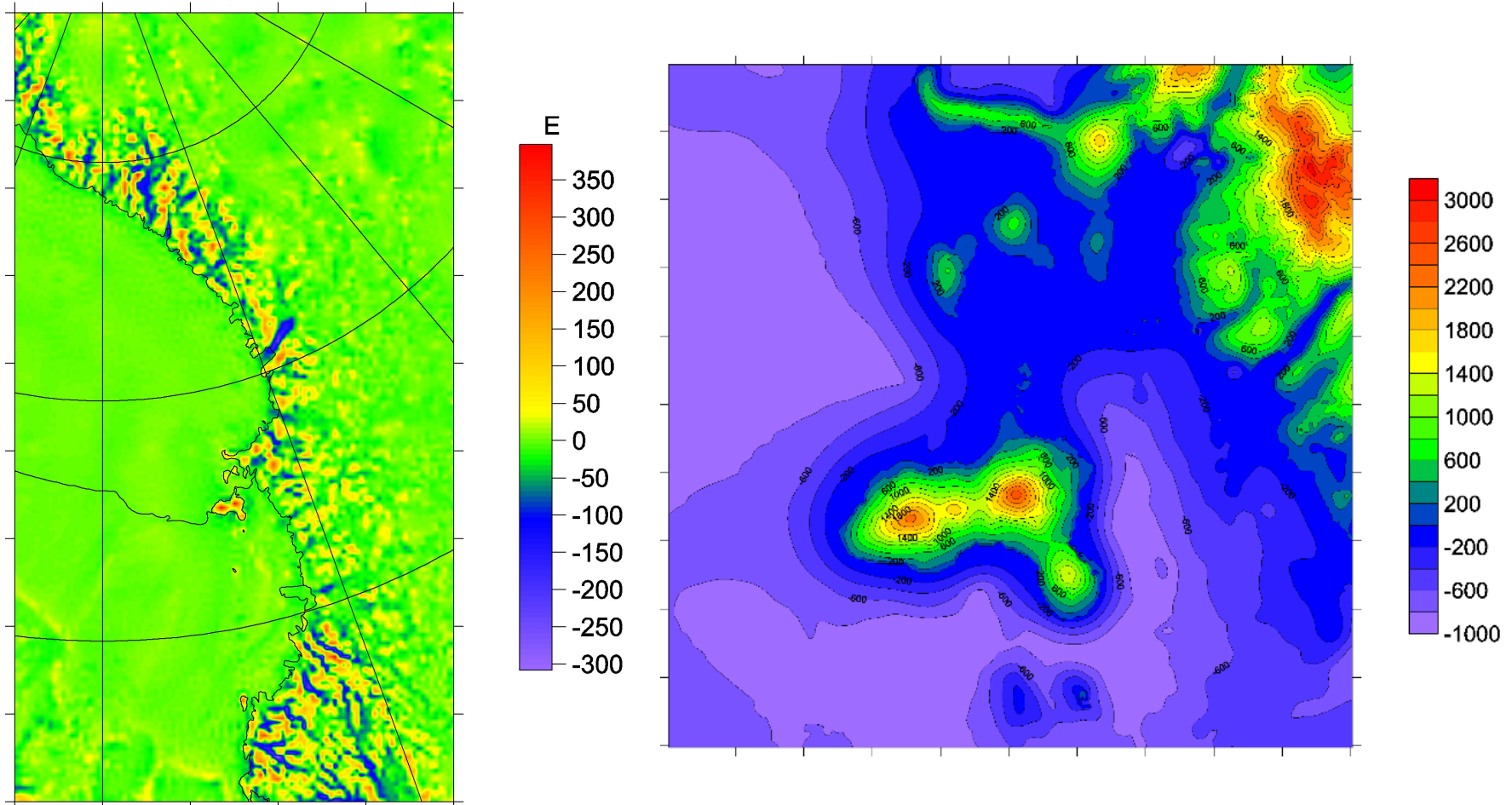
Volcanoes in Antarctica
known and suspected



a Best estimate

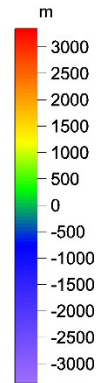
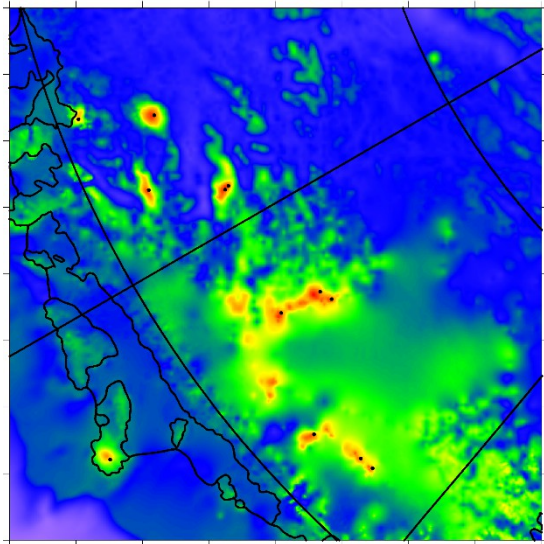


Mount Erebus is the second highest volcano in Antarctica (after Mount Sidley) and the southernmost active volcano on earth. It is the sixth highest mountain on an island. With a summit elevation of 3,794 metres, it is located on Ross Island, which is also home to three inactive volcanoes, Mount Terror, Mount Bird, and Mount Terra Nova. The volcano has been active since c. 1.3 million years ago and is the site of the Mount Erebus Volcano Observatory run by the New Mexico Institute of Mining and Technology]

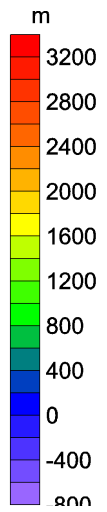
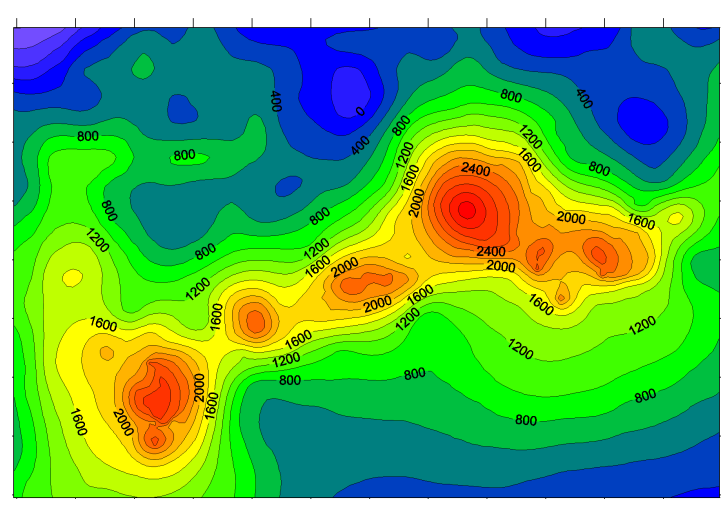


the RAT14 combination of the gravity from the EIGEN 6C4 and the topography from the Bedmap 2 in T_{zz} , the Ross Island topography detail.

f



g



Regions: Antarctica
 Objects: **Mt. Sidley** (4181m)
 Activities: Mountaineering
 Service: VIP
 Program's difficulty: **3**, relatively easy (technical **2** + altitudinal **1**)
 Group size: **6-10**
 Price: 56 990 USD
or see cheaper option »
 Deposit for reservations **5 000 USD**
 Full payment **90 days** before
 No refund if you cancel less than **90 days!**
 Buy it **CHEAPER - TODAY!!!**
 Next month the price will rise.
 The price is fixed at the moment of prepayment.
Dates (Days **17** / Nights **16**).....

Two questions:

Dvě otázky:

resolution

rozlišení

attenuation of the gravity signal under ice

tlumení tíhového signálu pod ledem

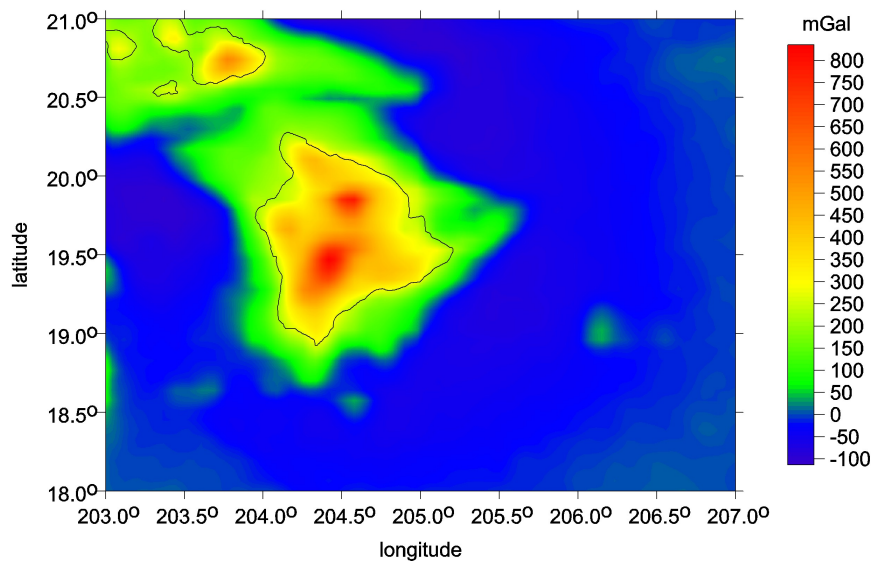
No principal obstacle to detect volcanoes under the ice?

Není tu žádná principiální překážka k detekci sopek pod ledem?

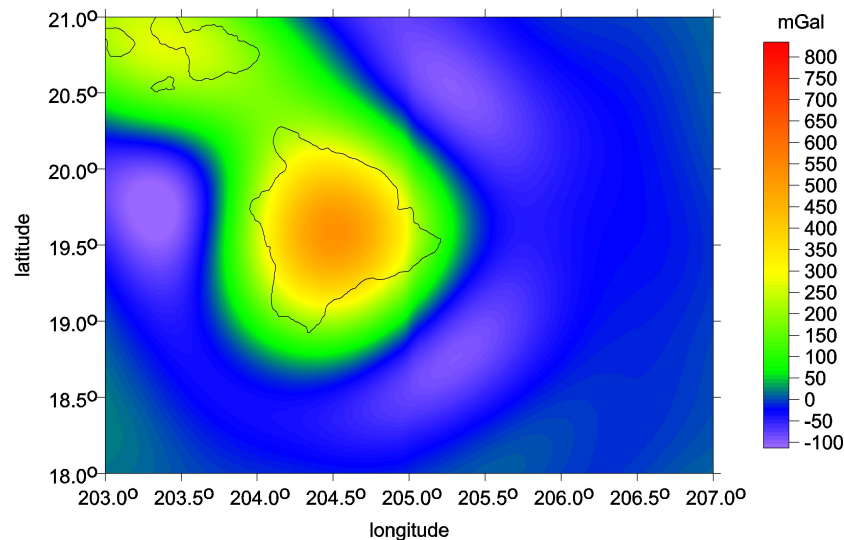
Havaj, Velký ostrov

Full model to 2190 vs cut at 300

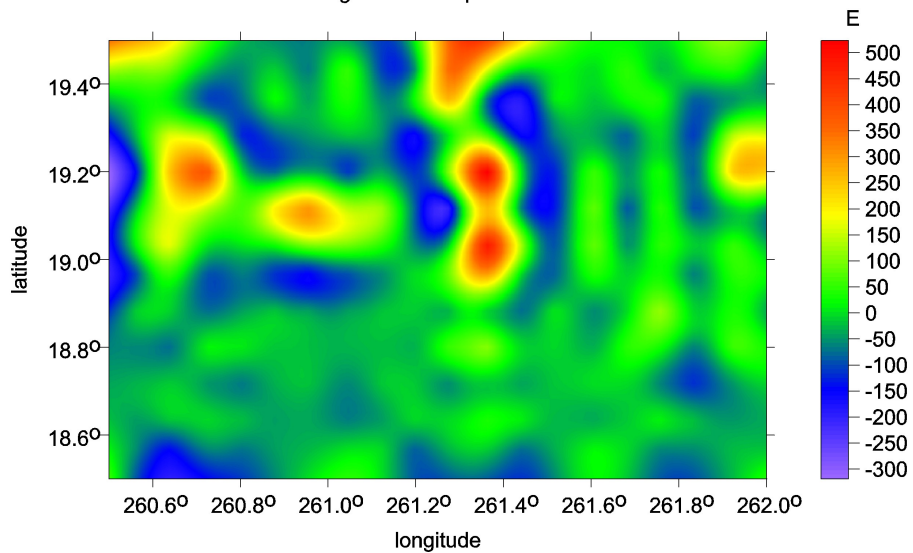
Eigen 6C4 - Havaj - Velky ostrov - delta g



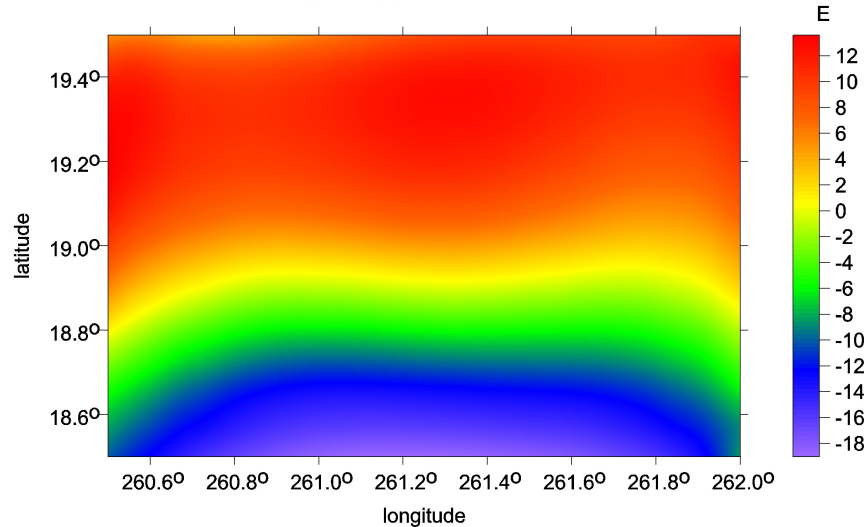
Eigen 6C4_300 - Havaj - Velky ostrov - delta g



Eigen 6C4 - Popo - Tzz



Eigen 6C4_300 - Popo - Tzz



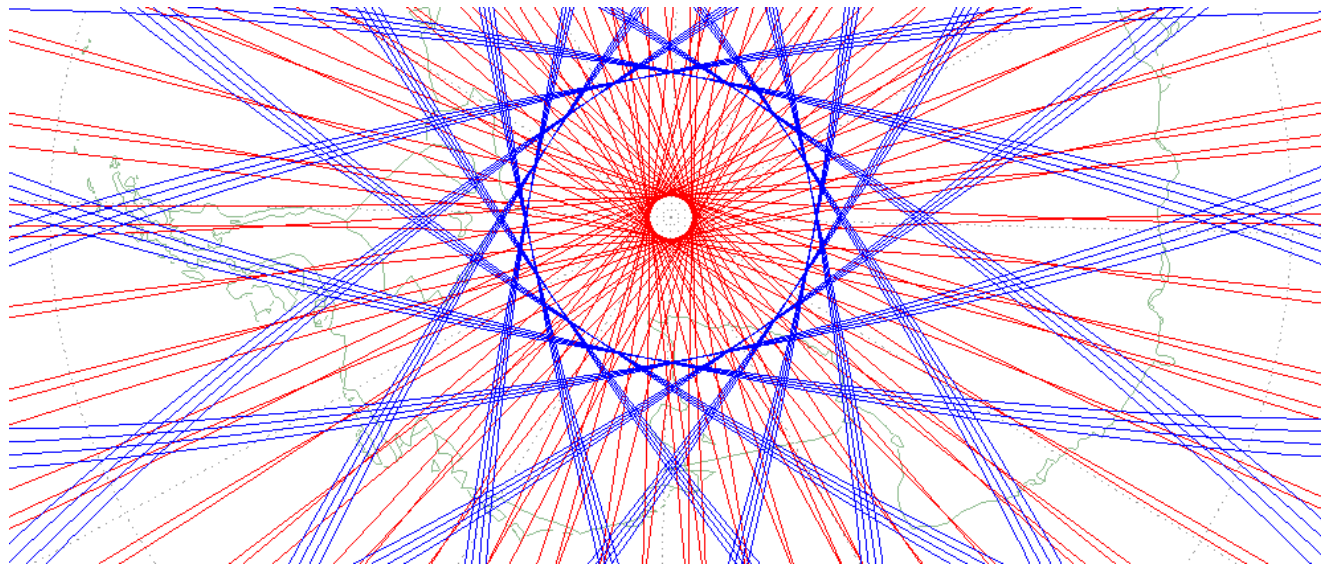
A usual simple estimation of the smallest representable feature of the gravity field or the shortest half-wavelength L_{half} (as a distance on the sphere) that can be resolved with all C_{lm} , S_{lm} to L_{max} , is

$$L_{half} = \pi R / L_{max}$$

or equivalently, taking the circumference $2\pi R = 40\,050$ km:

$$L_{half} = 2\pi R / 2 L_{max} = 40\,050 / 2 L_{max}$$

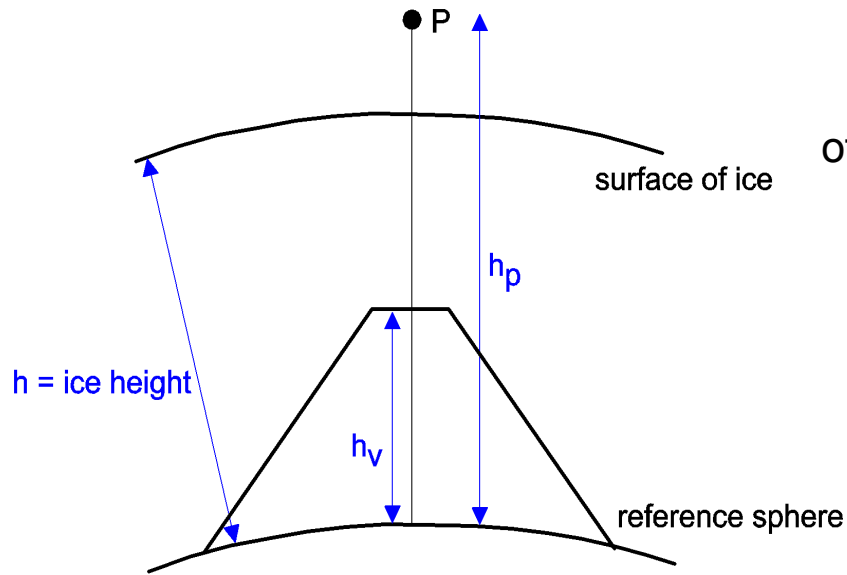
For $L_{max} = 300$ and 2190 , we have $L_{half} = 67$ and 9 km, respectively. BUT:



GOCE
and GRACE
groundtrack
densification
at poles

Example: Ground tracks of satellite missions GRACE (red) and GOCE (blue) near the South Pole. The latitude turning points result from orbit inclination, which is 89° for GRACE and 96.7° for GOCE. The ground track points of both missions are displayed for 5 days in December 2010.

Model of volcano under ice - attenuation of the signal



A model of volcano for investigation of the attenuation of the gravitational signal (in Δg and T_{zz}) under a layer of ice, as observed from the point P .

The volcanoes are modelled by a homogeneous truncated cone, with a "crater" of diameter 0.5 km on its top.

Both Δg and T_{zz} due to the ice layer are given by closed formulae, namely

$$\Delta g = 2 \pi G \sigma R^2 h r^{-2} (1 - \cos \Theta/2)$$

$$T_{zz} = -2 \Delta g r^{-1},$$

where G is the universal gravitational constant, σ density, r distance from the Earth's centre to the computed point P , and Θ denotes the central angle of the spherical cap.

The slopes of the volcano model are taken as 83% and 15% for a stratovolcano and a shield volcano, respectively. The base of the cone depends on the volcano height and the slope. A constant density of 3.4 tons per km³ is used, but in the part of the volcano embedded in ice, it is reduced by the density of ice to avoid duplication of the ice contribution. The effect of the volcano model has to be obtained by numerical integration.

The anomalies Δg are calculated for a set of points distributed at an altitude of $h_P=2.5$ km over the volcano basis. The altitude strongly affects the resolution, e.g. at altitude $h_P=10$ km, the effect of the volcano is practically not detectable. The ice layers affect Δg by $5.6h$ [mGal] and their influence is small, while the relevant changes in T_{zz} [E] are negligible.

Stratovolcano (height h_v 2 km)				
ice height h [km]	Dg [mGal]			Tzz [E]
	volcan o+ice	ice cap	volcan o- ice	
0	79	0	79	752
1	72	6	66	675
2	67	11	56	531

Shield volcano (hv 0.67 km ; the same volume as the stratovolcano)				
ice height h [km]	Dg [mGal]			Tzz [E]
	volcan o+ice	ice cap	volcan o- ice	
0	35	0	35	150
1	31	6	25	106
2	36	11	25	106

Shield volcano (height h_v 1 km)				
ice height h [km]	Dg [mGal]			Tzz [E]
	volcano + ice	ice cap	volcano - ice	
0	71	0	71	242
1	56	6	50	271
2	62	11	51	174

Shield volcano (hv 2 km)				
ice height h [km]	Dg [mGal]			Tzz [E]
	volcano + ice	ice cap	volcano - ice	
0	220	0	220	544
1	188	6	182	501
2	167	11	156	384

The attenuation in gravity disturbances is low, of about 20 % of the original value. The second radial derivative T_{zz} is not affected at all.

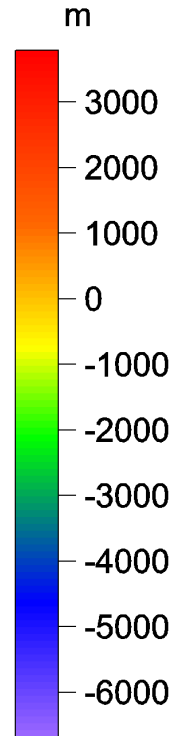
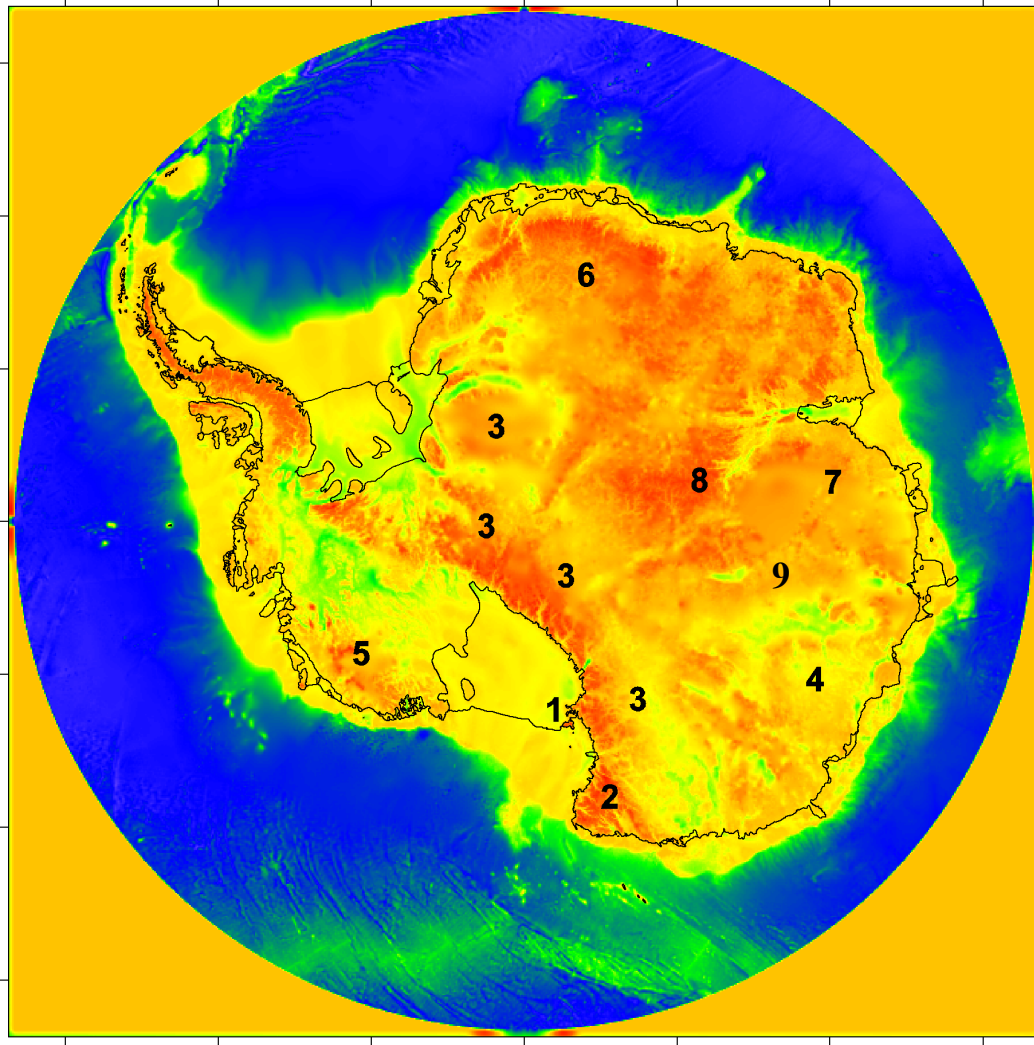
Two answers:

resolution

attenuation of the gravity signal under ice

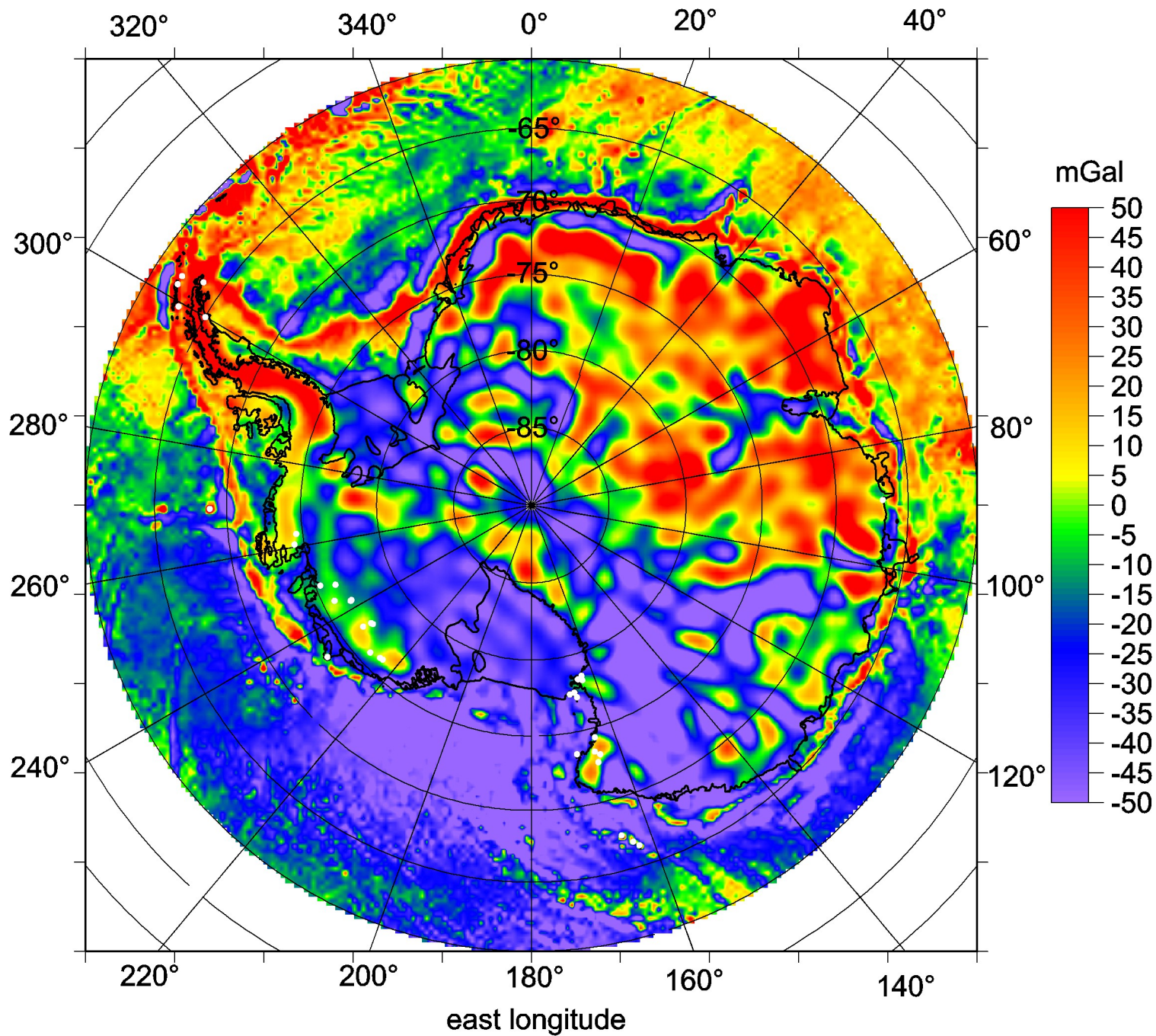
No principal obstacle to detect volcanoes under the ice

Bedmap2 bedrock topography

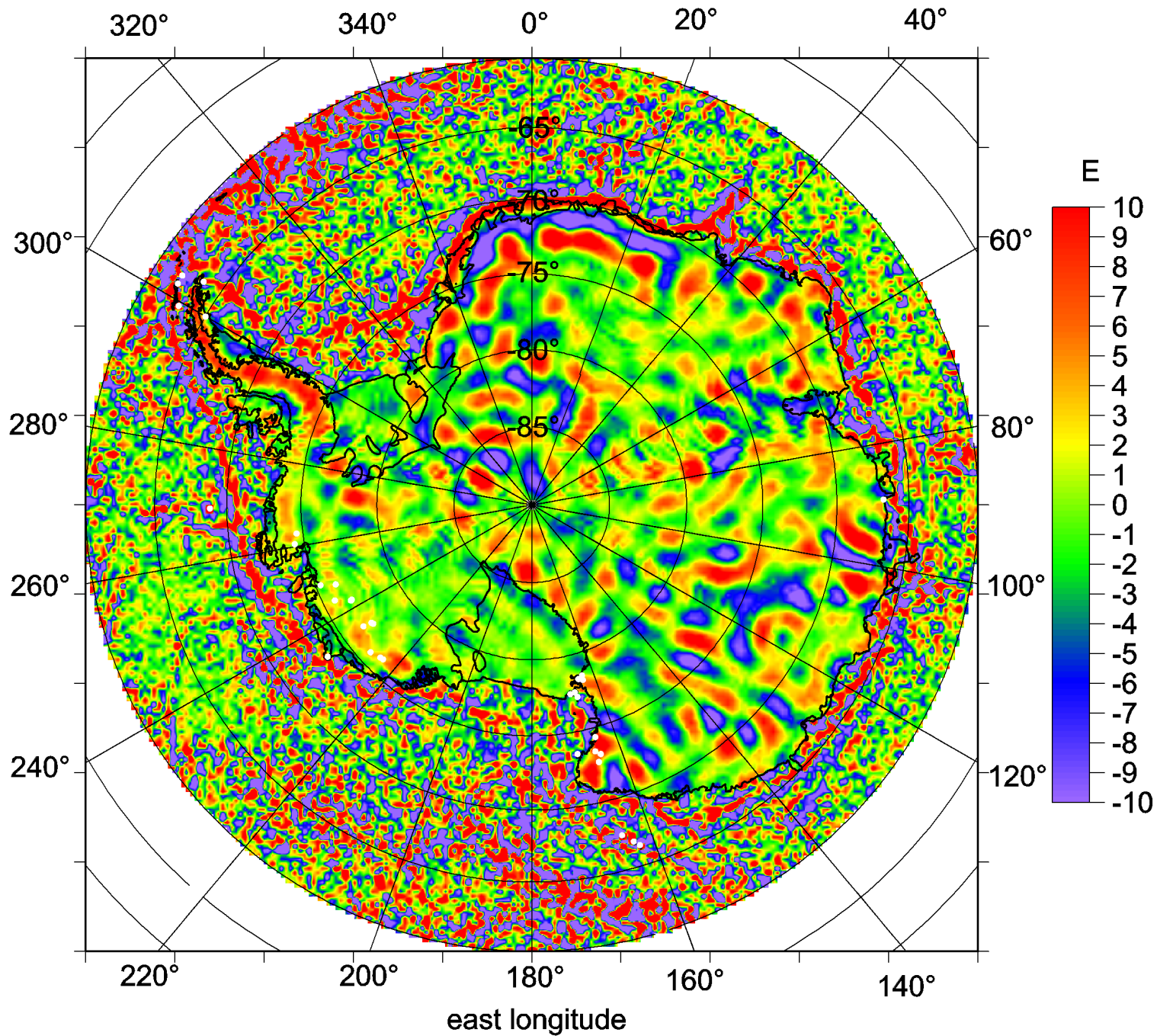


- 1 Ross shelf glacier and Ross Island,
- 2 Victoria Land
- 3 Transantarctic Mountains
- 4 Wilkes Land
- 5 Marie Byrd Land
- 6 Queen (Dronning) Maud Land
- 7 Princess Elizabeth Land
- 8 Gamburtsev Mountains (under the ice).
- 9 Lake Vostok

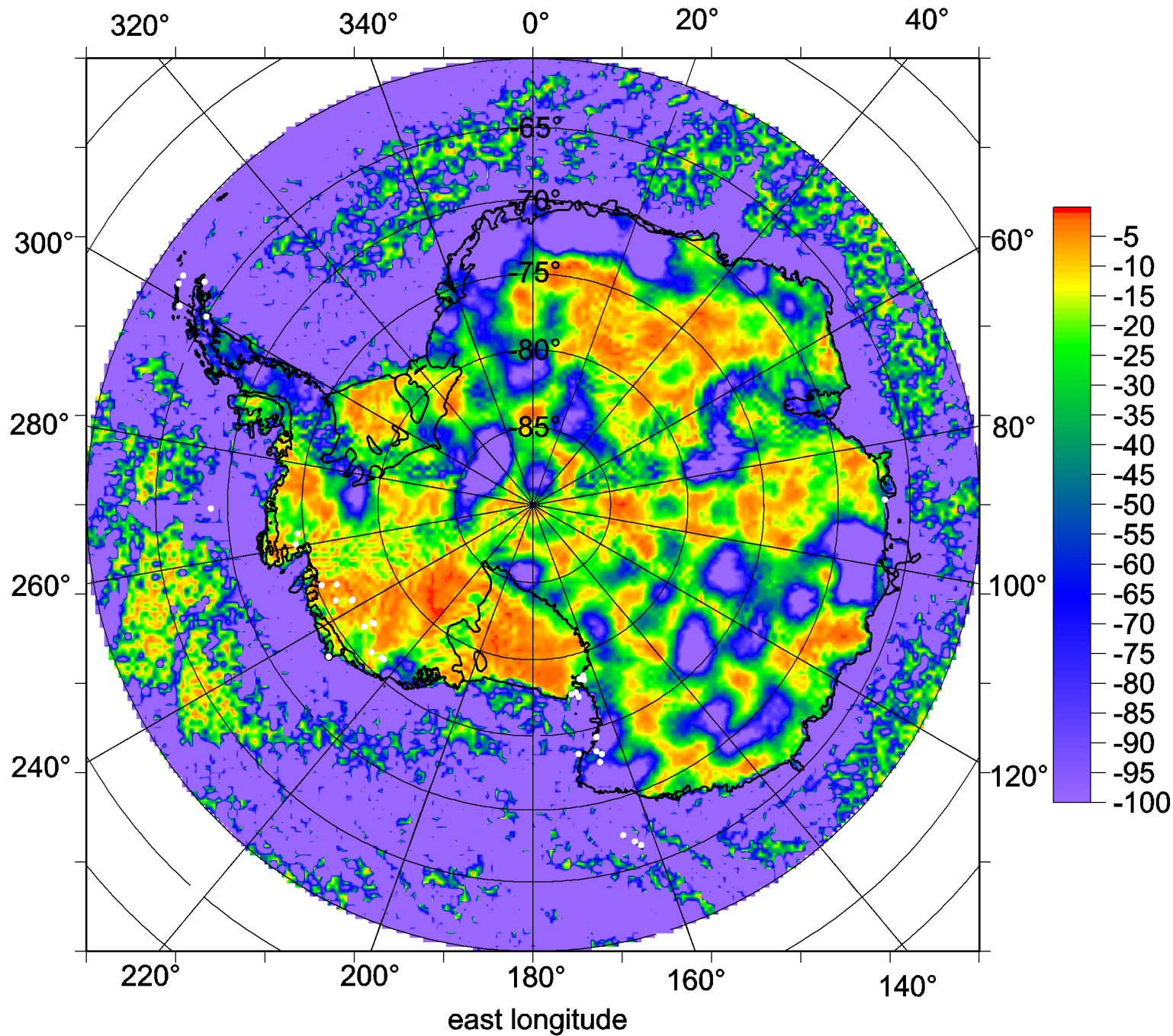
Eigen-6C4 - Antarctica - delta g



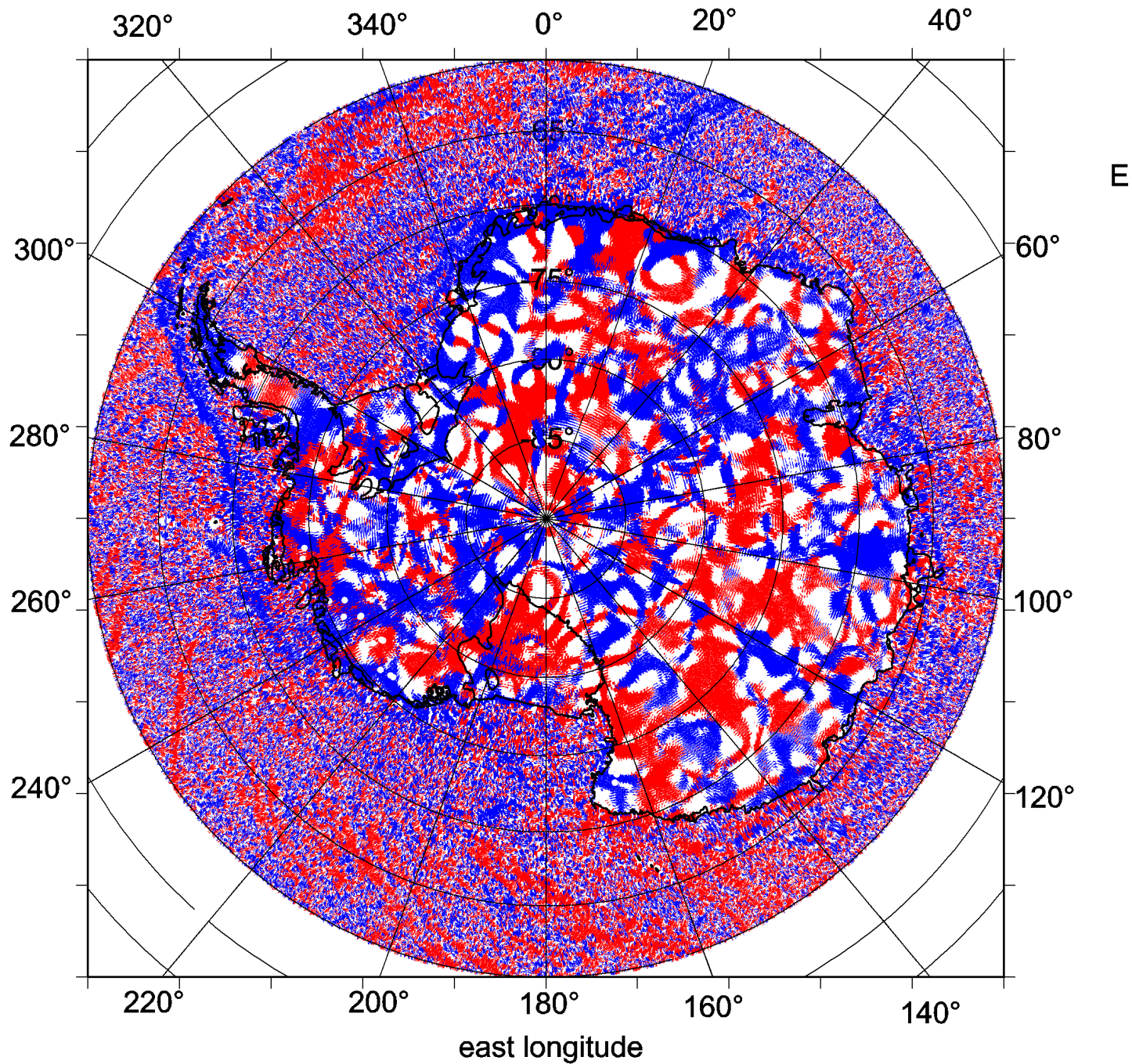
Eigen-6C4 - Antarctica - Tzz



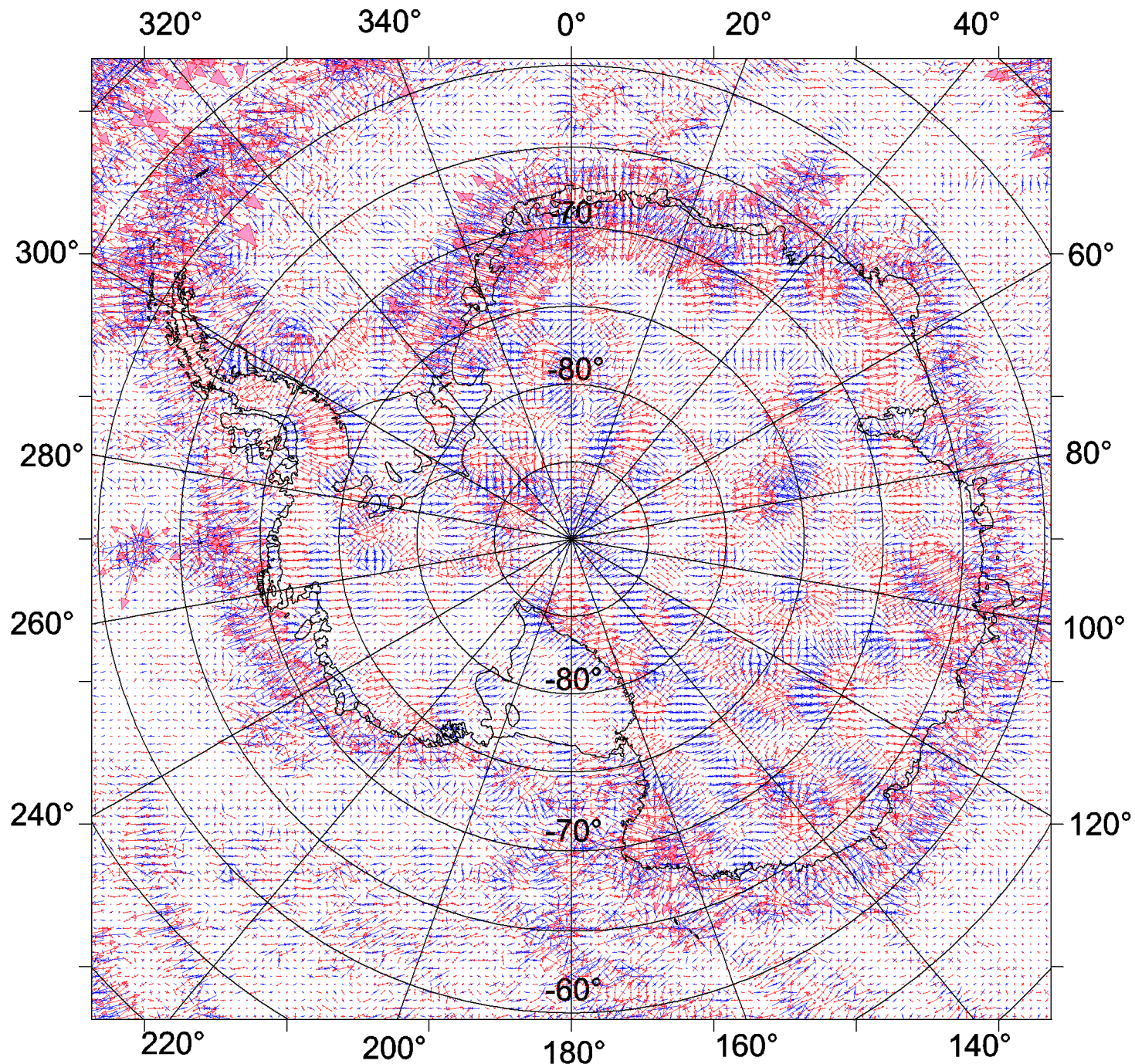
Eigen-6C4 - Antarctica - RI2

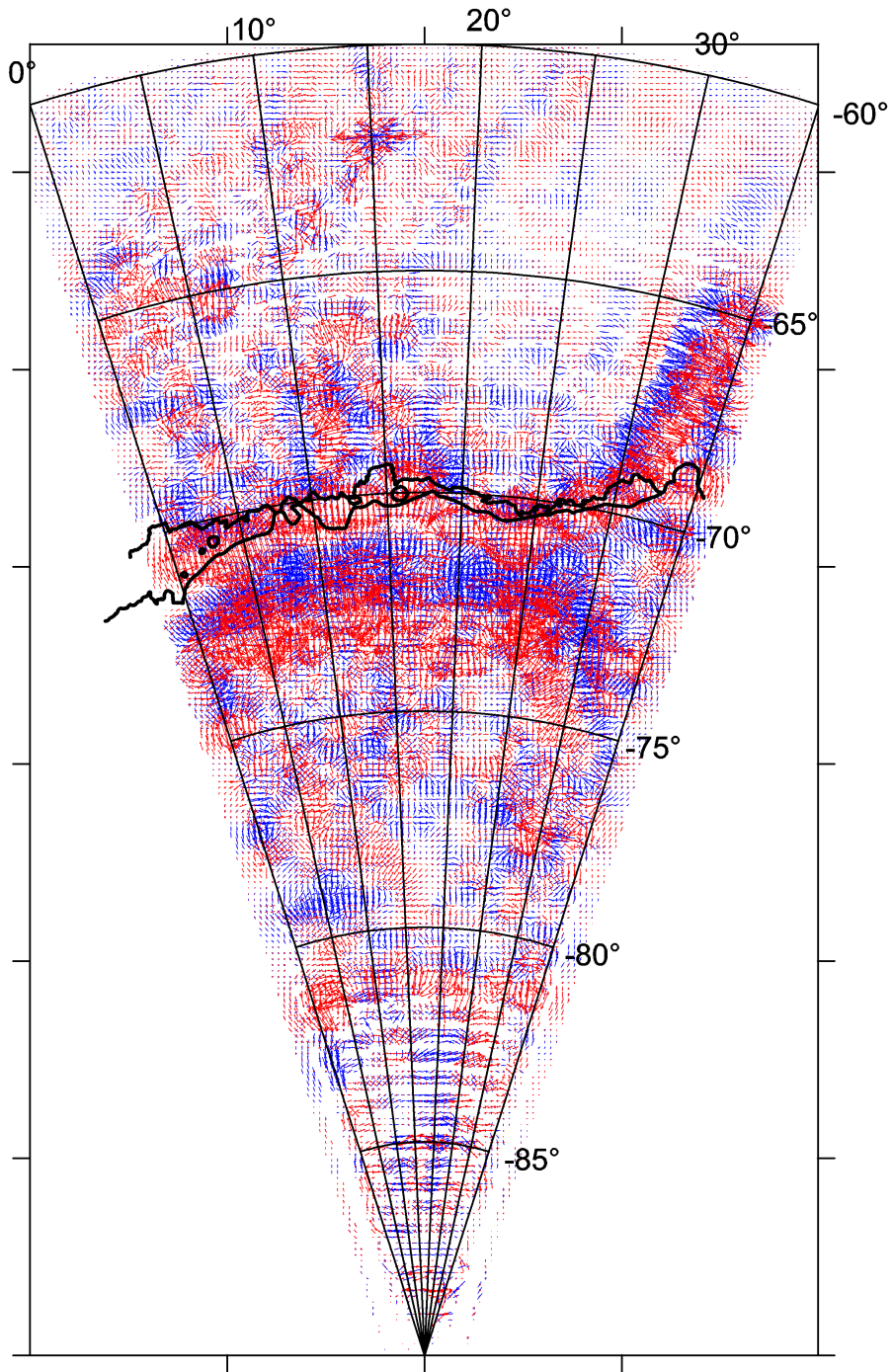


Eigen-6C4 - Antarctica - Theta for RI < 0.3

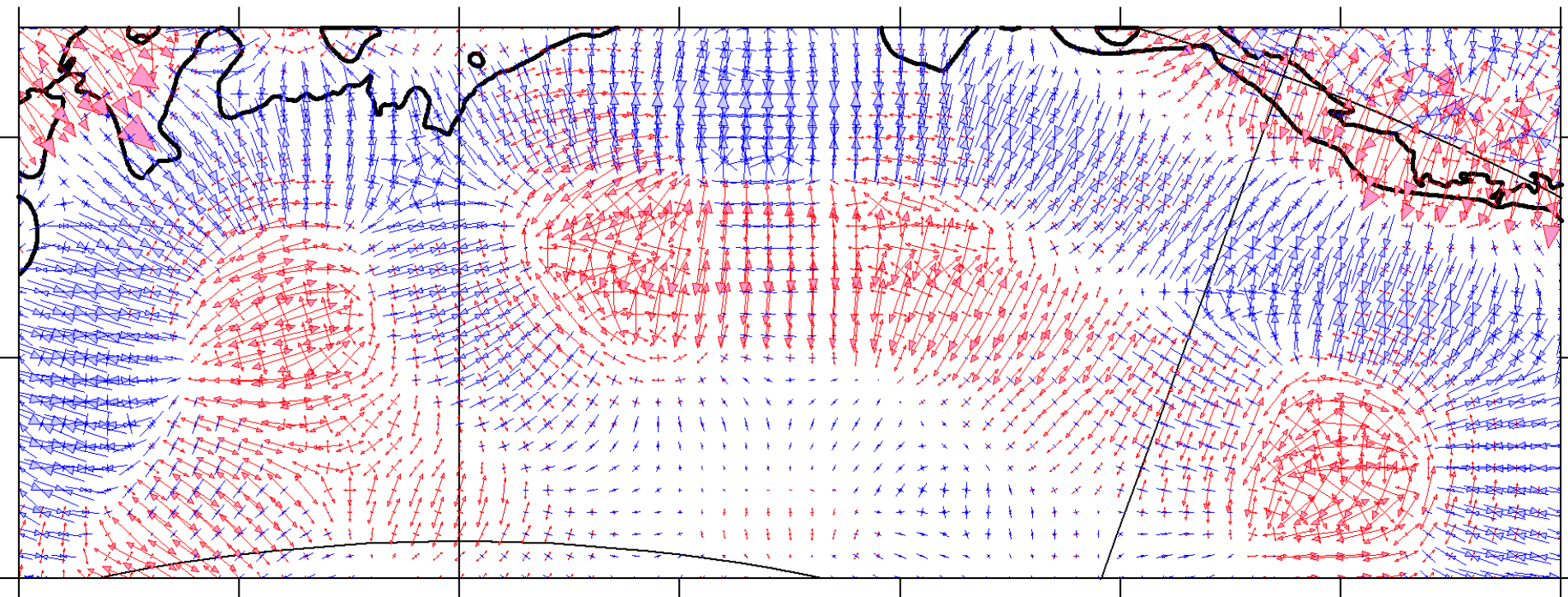


Antarktis - virtual deformations

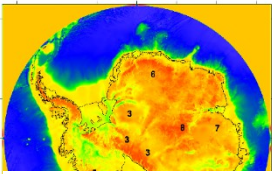




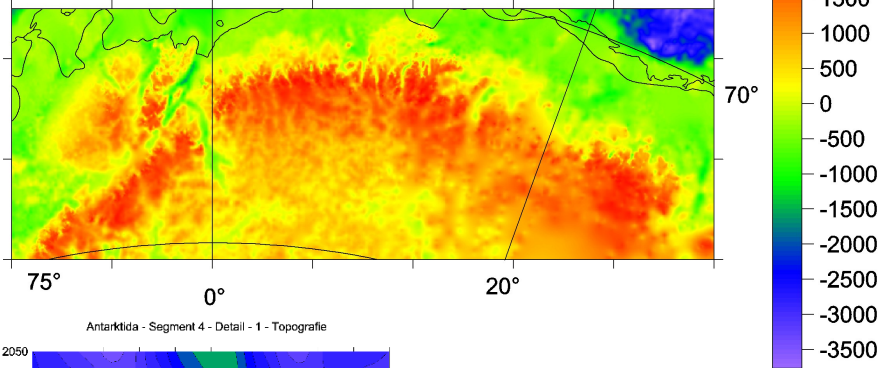
Antarctis - Segment 4 - virtual deformations



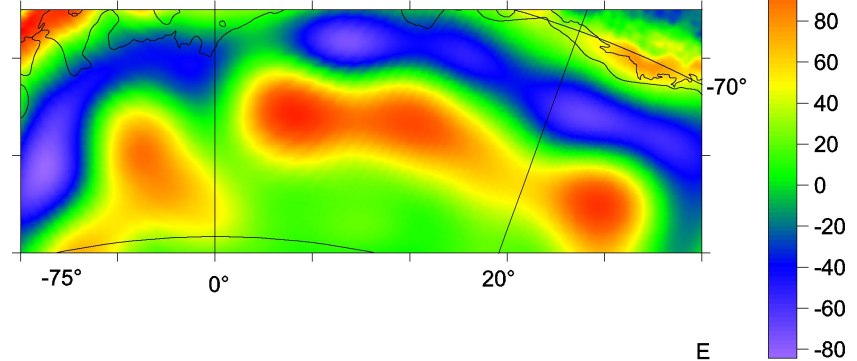
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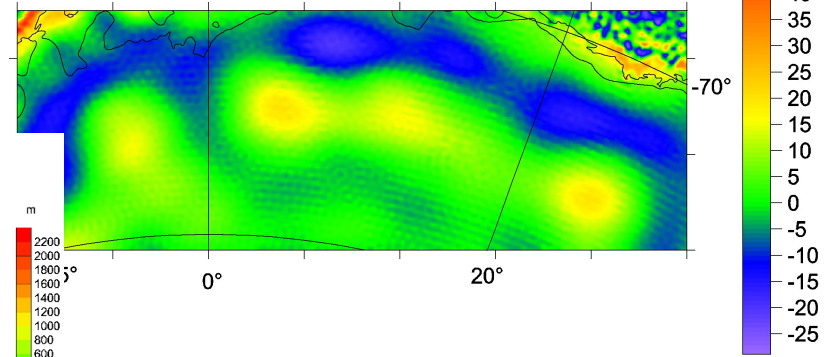
Antarktida - Segment 4 - Topografie



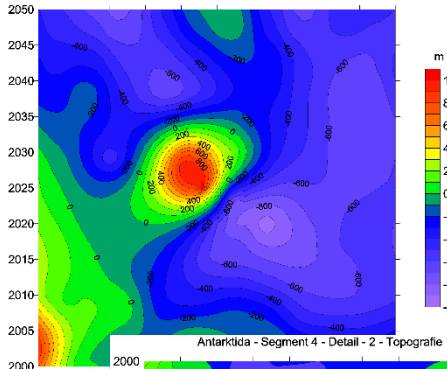
Antarktida - Segment 4 - delta g



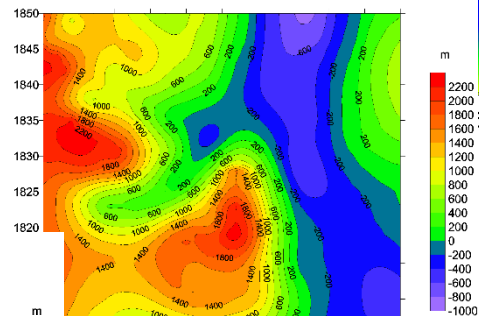
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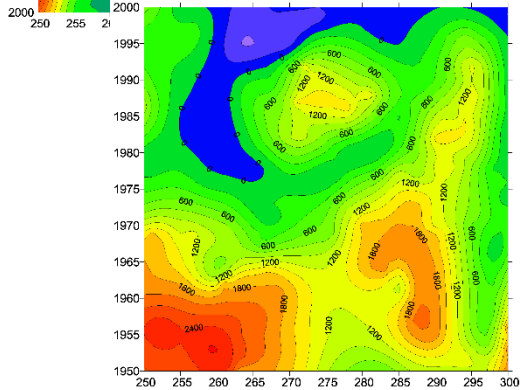
Antarktida - Segment 4 - Detail - 1 - Topografie



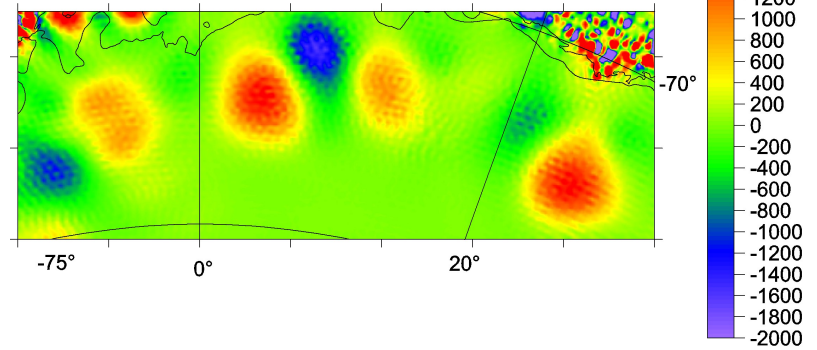
Antarktida - Segment 4 - Detail - 6 - Topografie



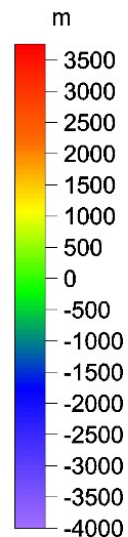
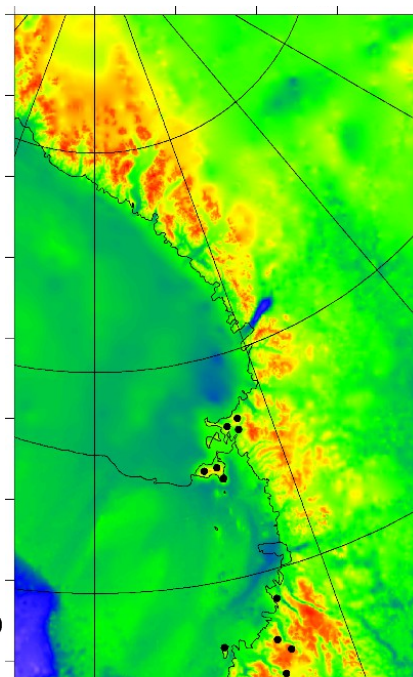
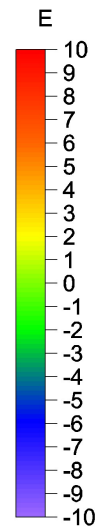
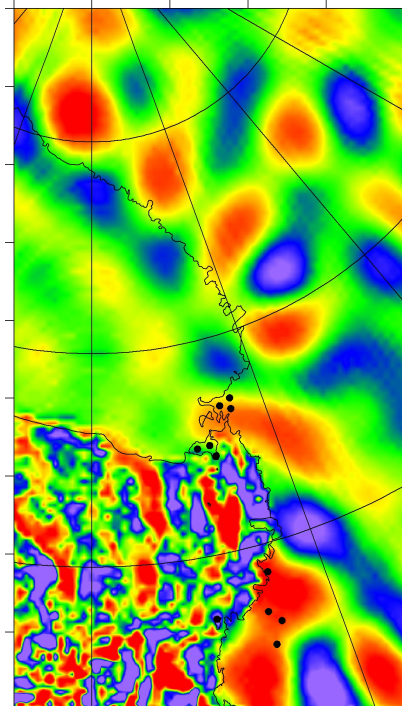
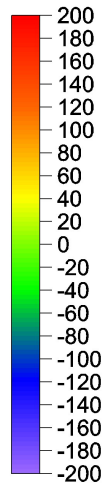
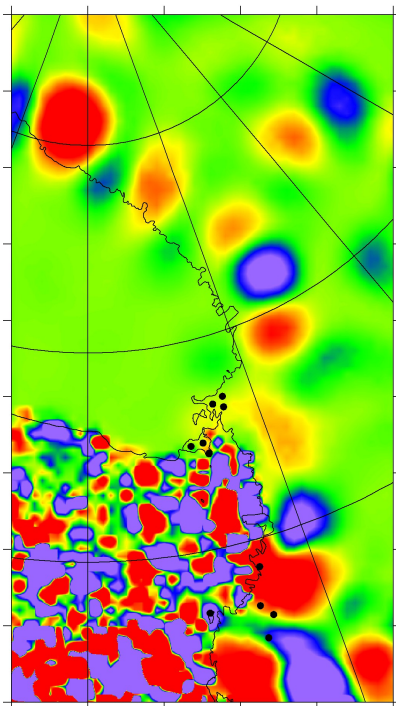
Antarktida - Segment 4 - Detail - 2 - Topografie



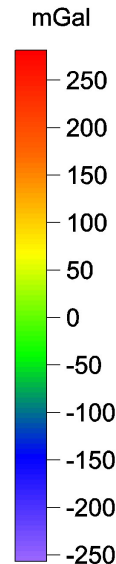
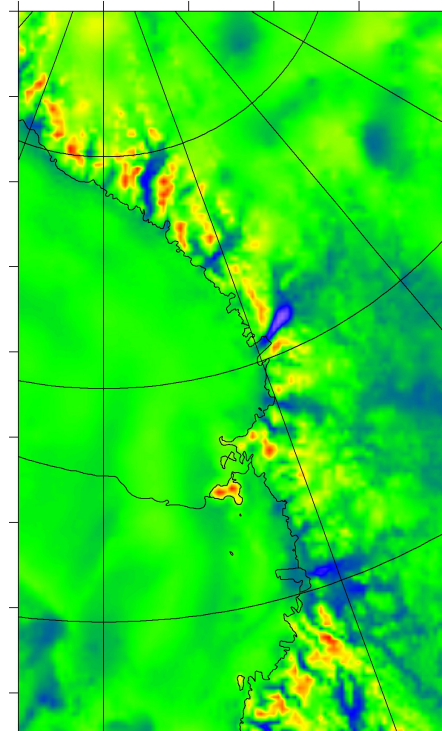
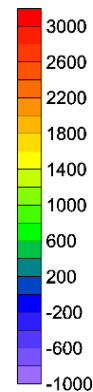
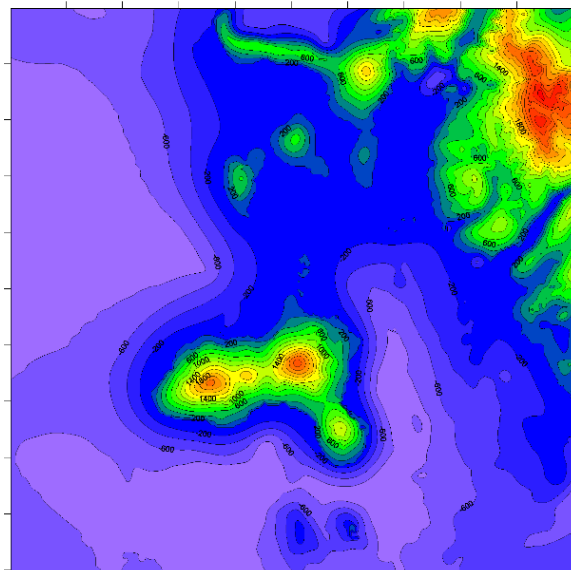
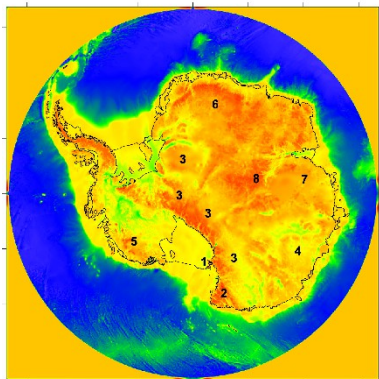
Antarktida - Segment 4 - RI3



1
2
3

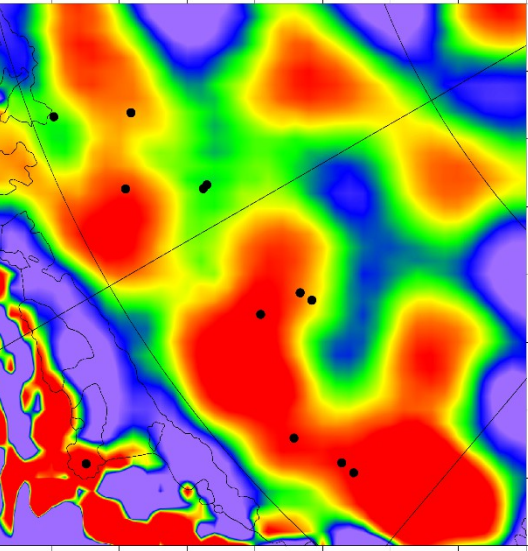


RET2014 - Segment 1 - delta g

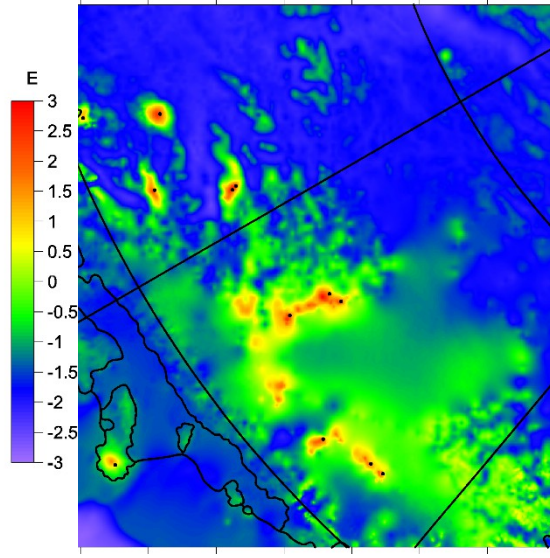


(a) T_{zz} , (b) I_2 ,
(c) the topography
from Badmap2,
(d) the Ross Island
topography detail.
(e) RET 14

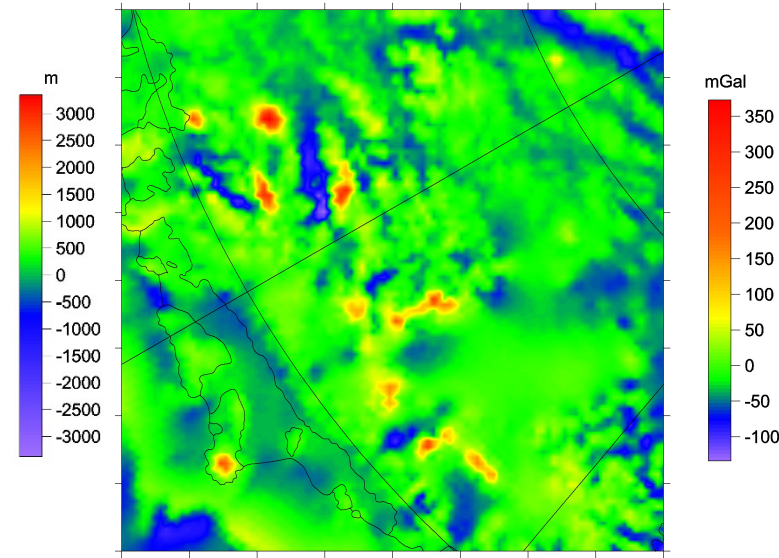
Antarktida - Sidley - Tzz



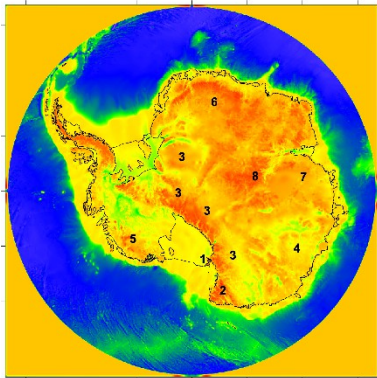
Antarktida - Sidley - topografie



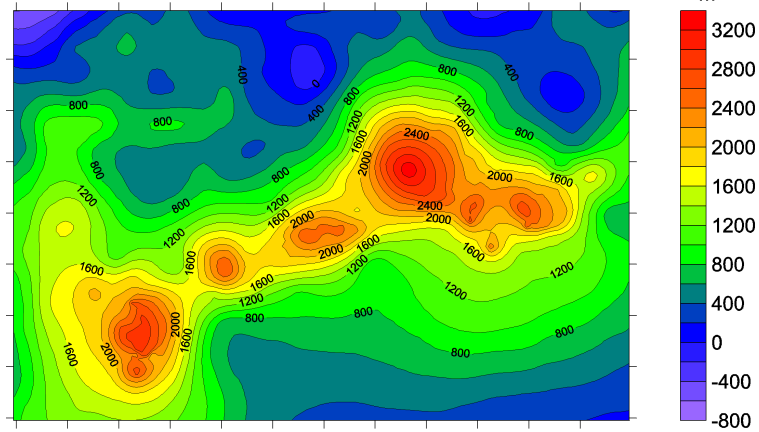
RET2014 - Sidley - delta g



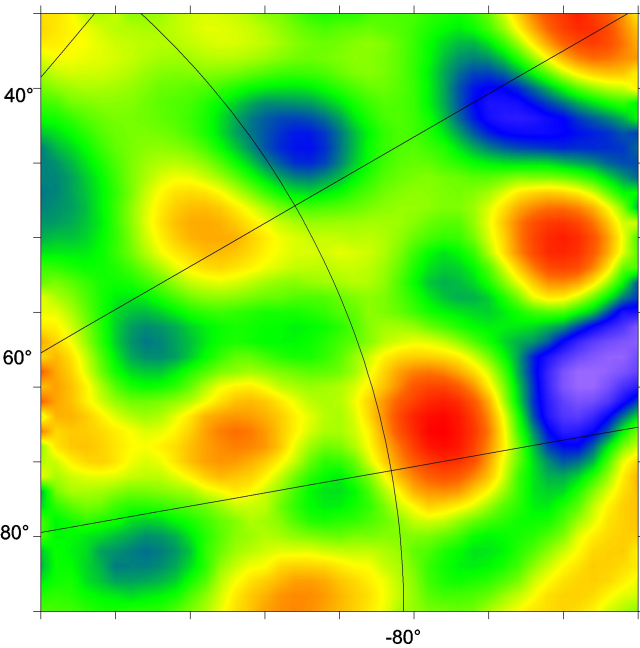
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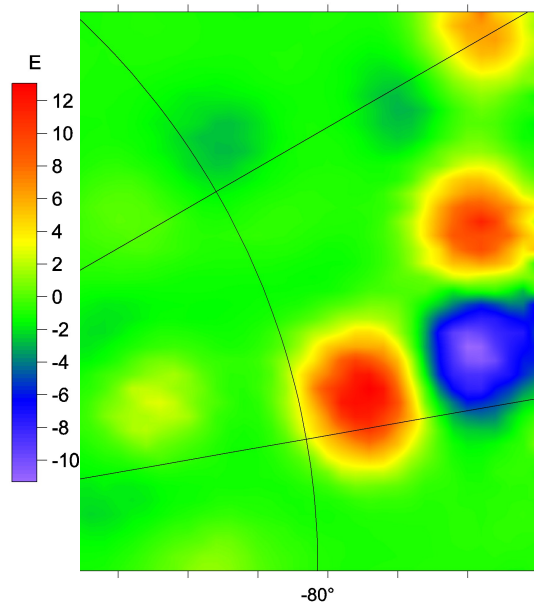
Antarktida - Sidley - Topografie



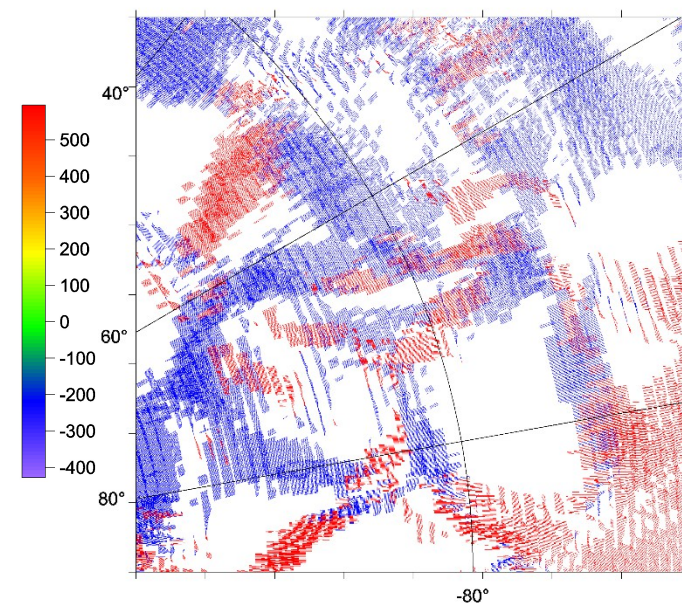
Antarktida - Segment3 - Tzz



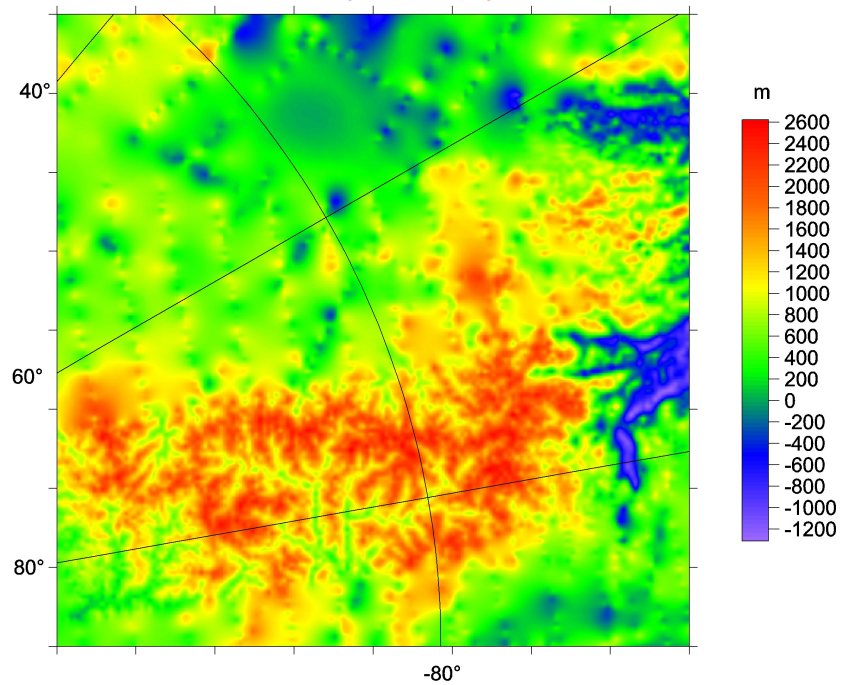
Antarktida - Segment3 - RI3



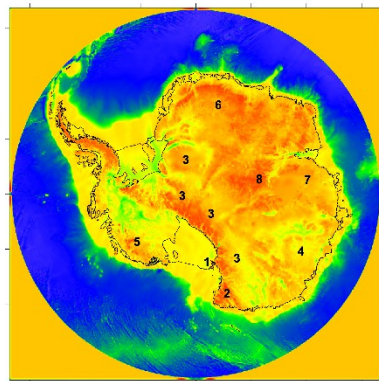
Antarktida - Segment3 - Theta for RI < 0.3



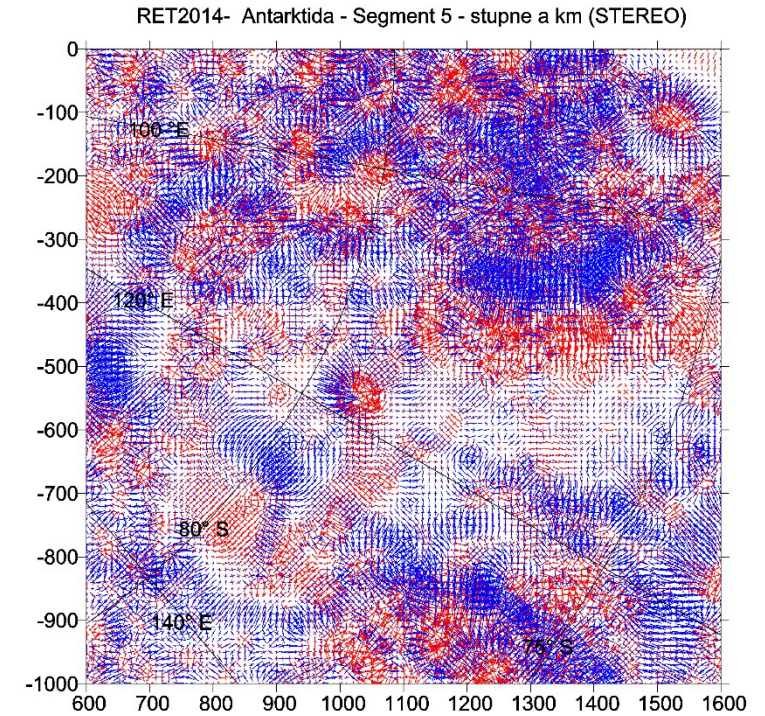
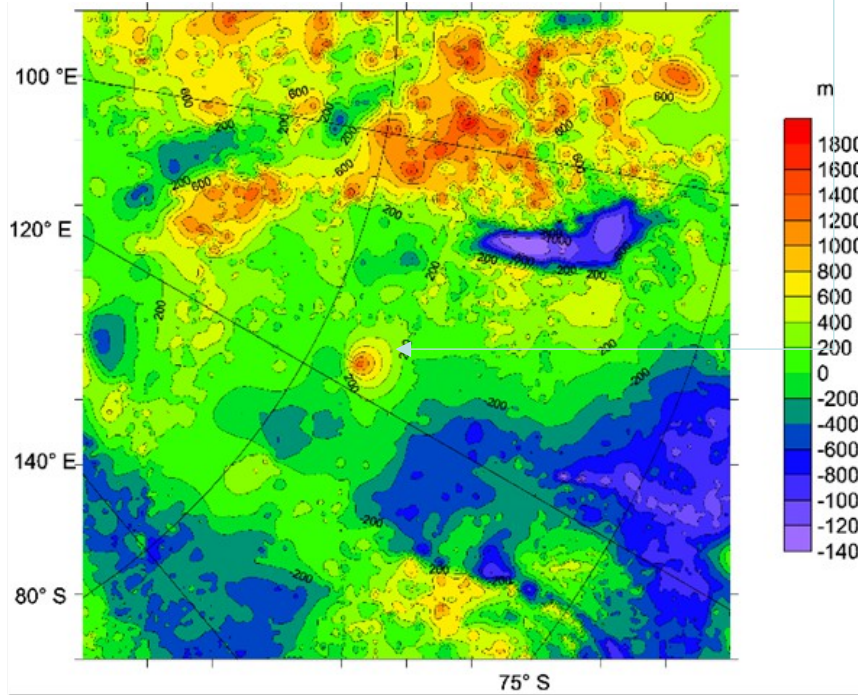
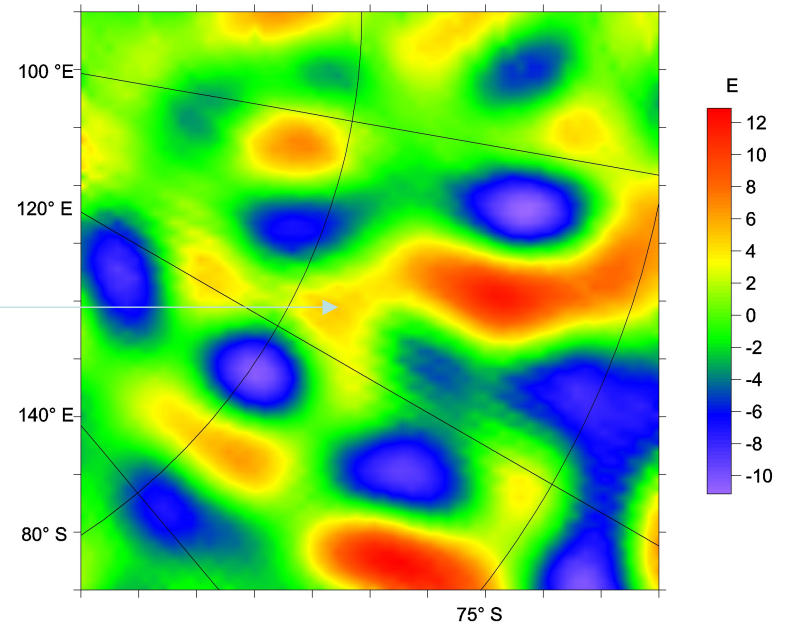
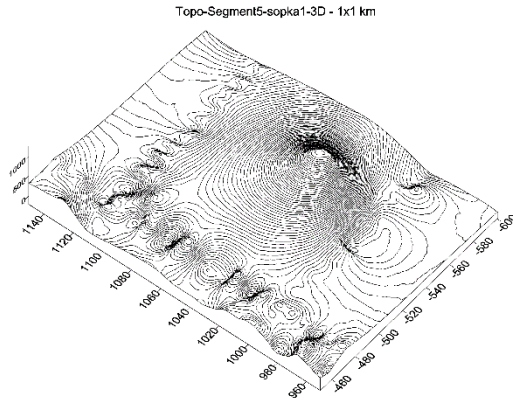
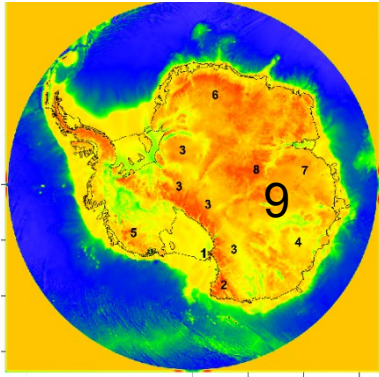
Antarktida - Segment 3 - Topografie

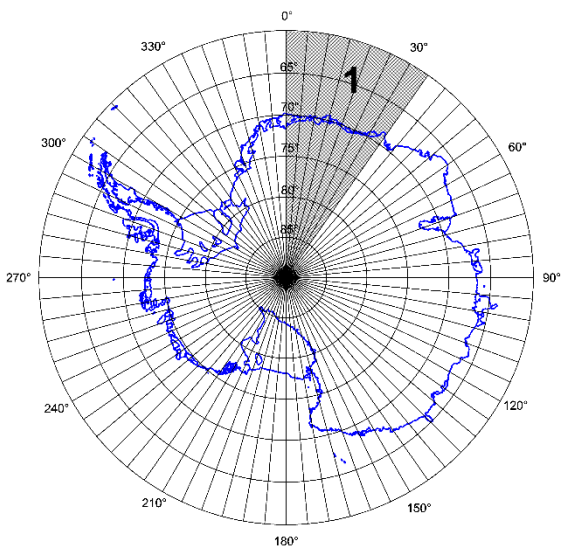
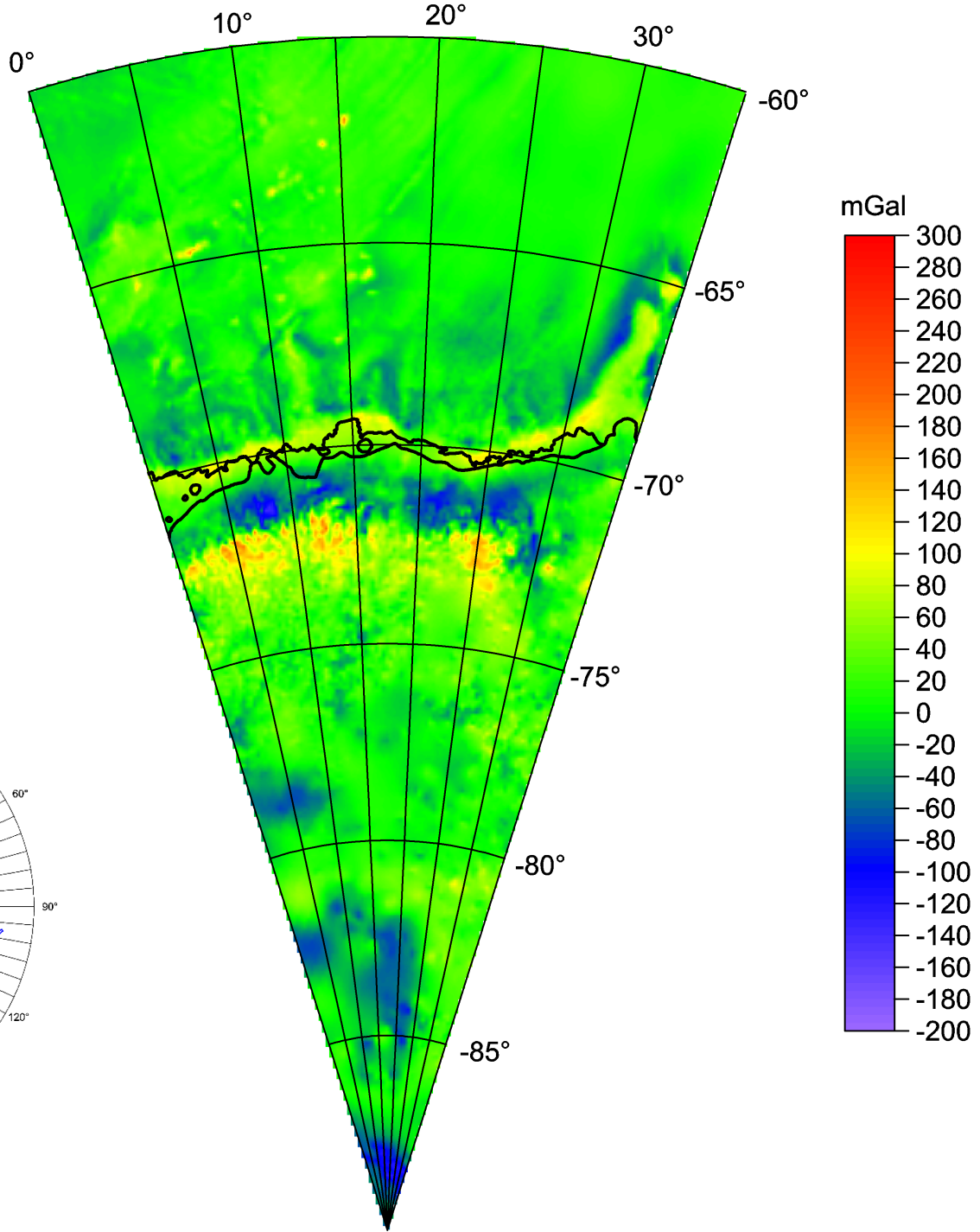


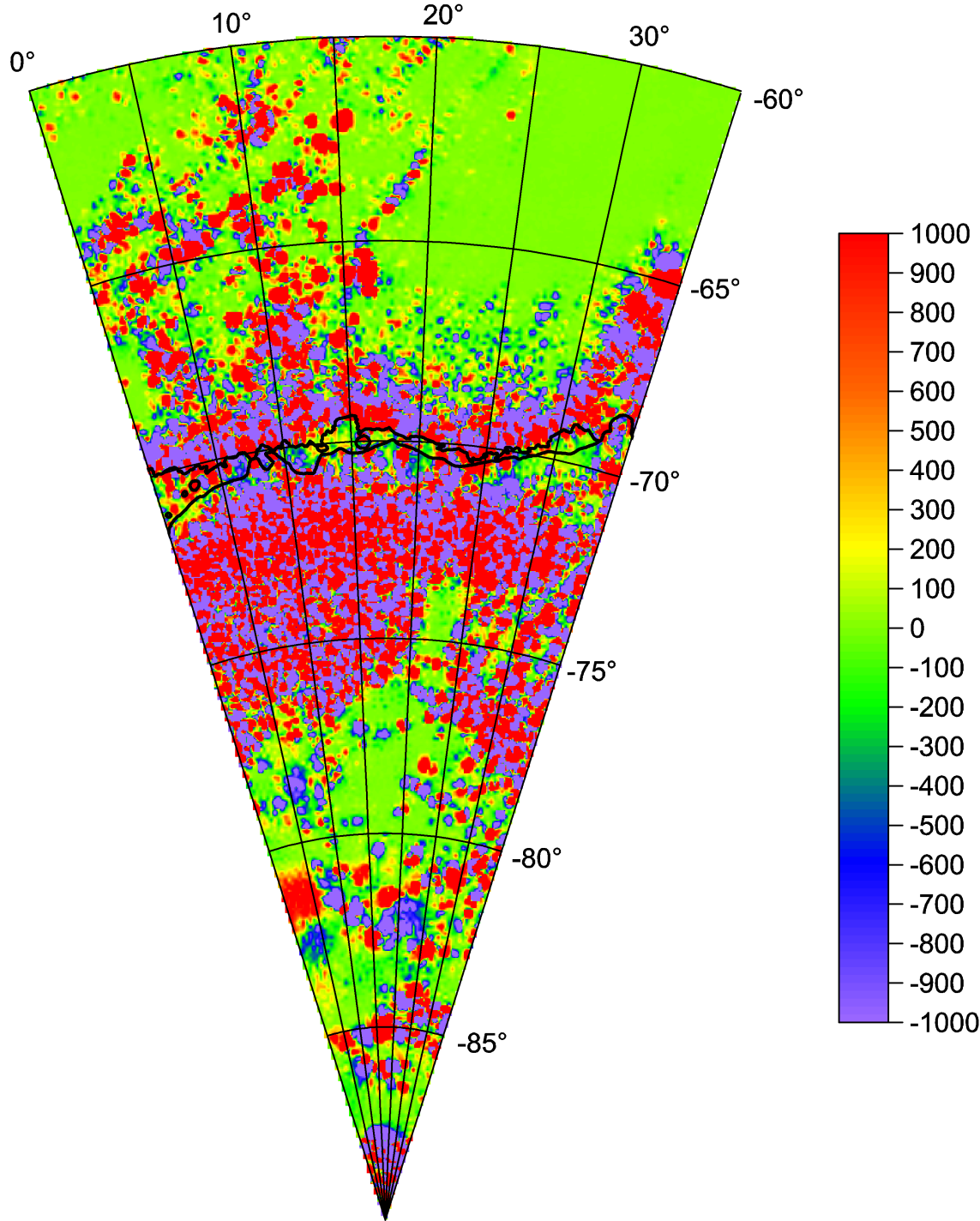
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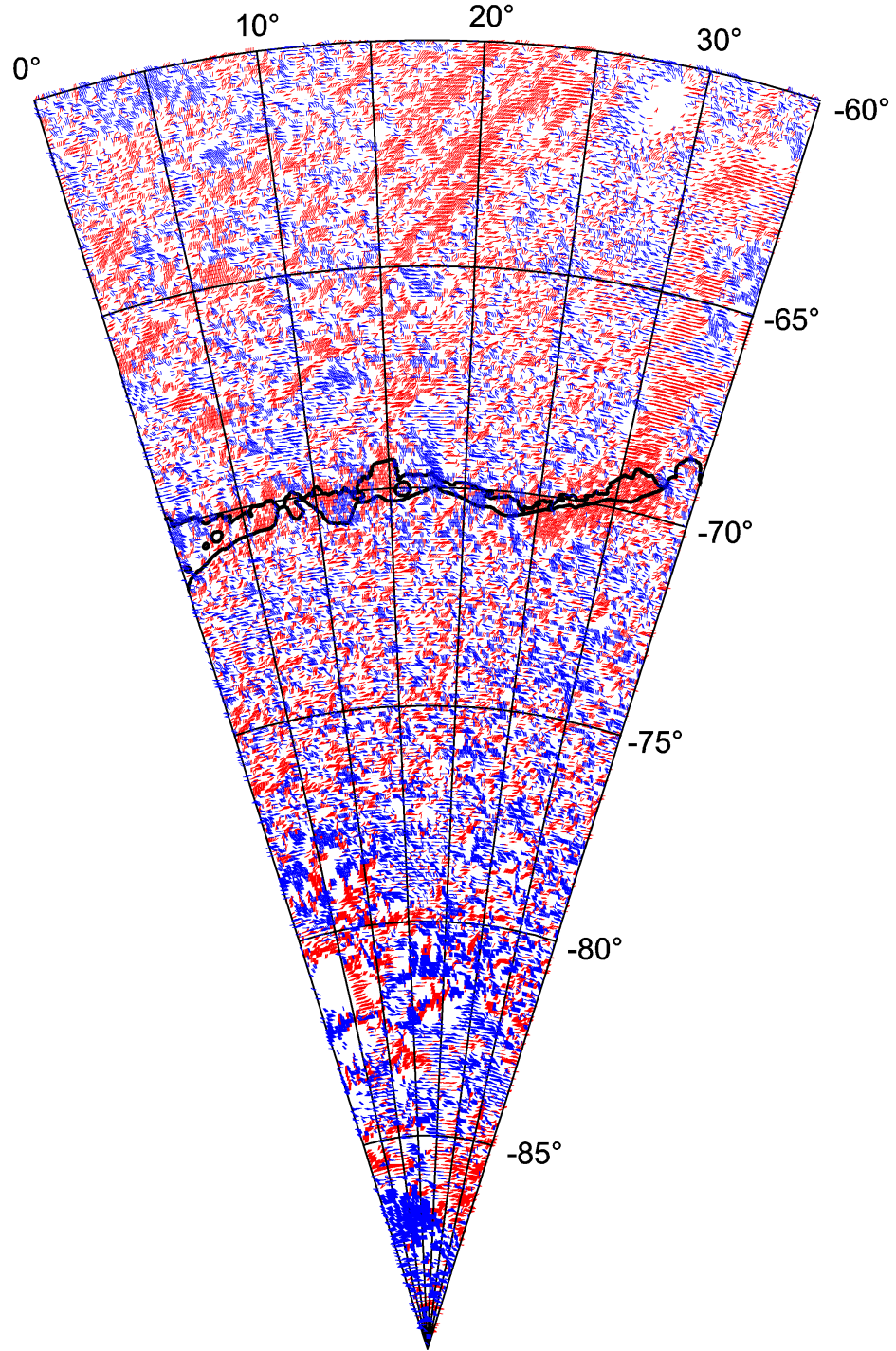


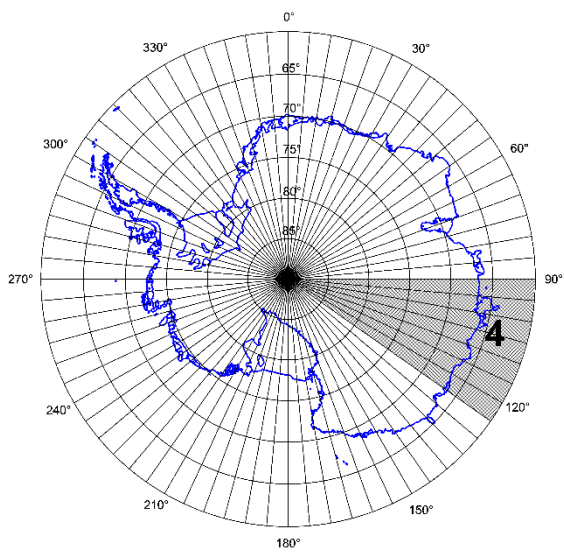
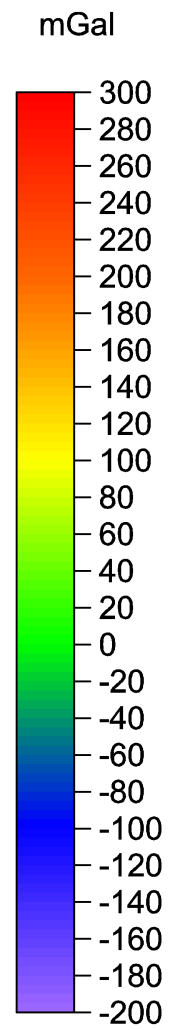
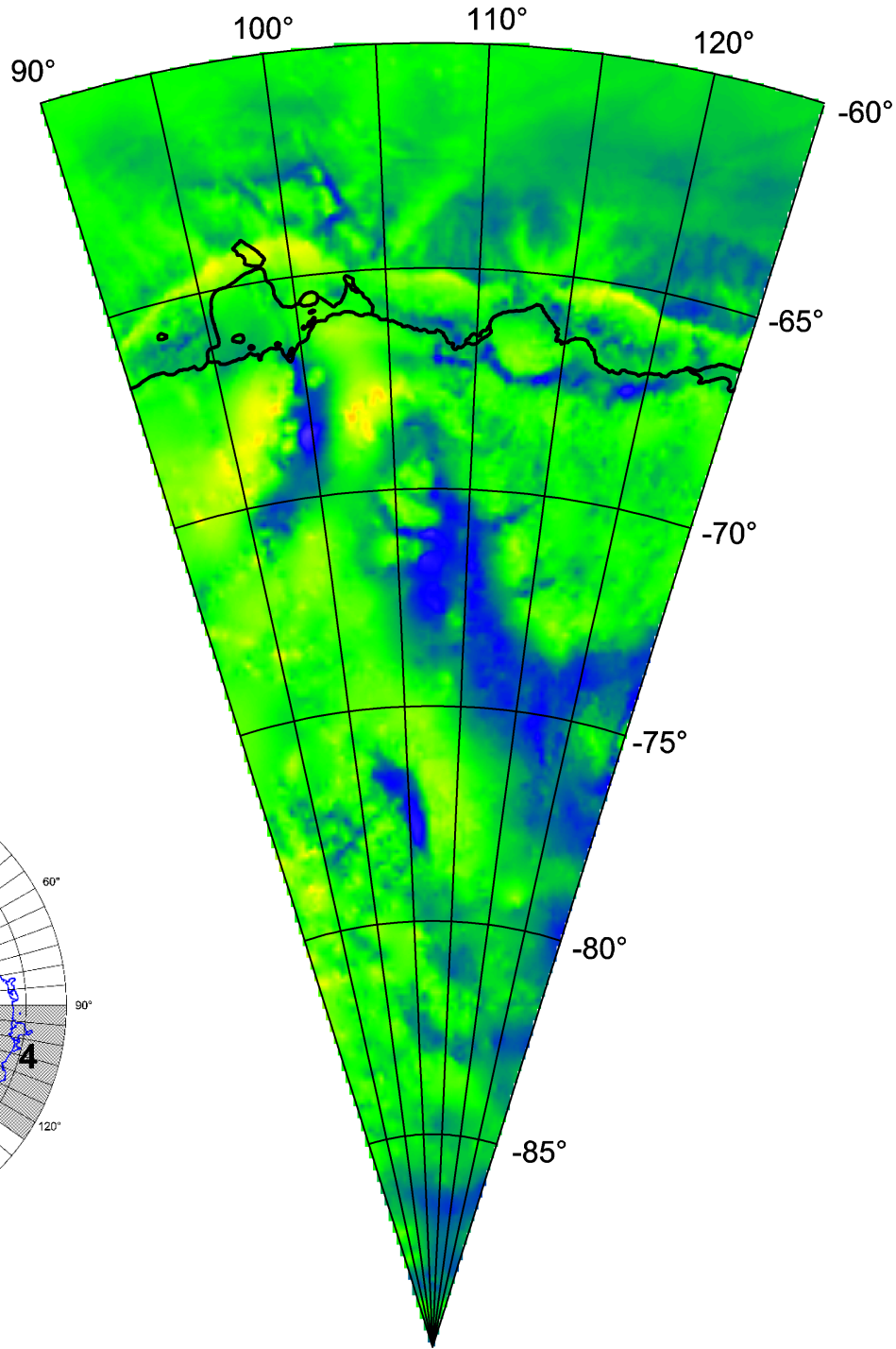
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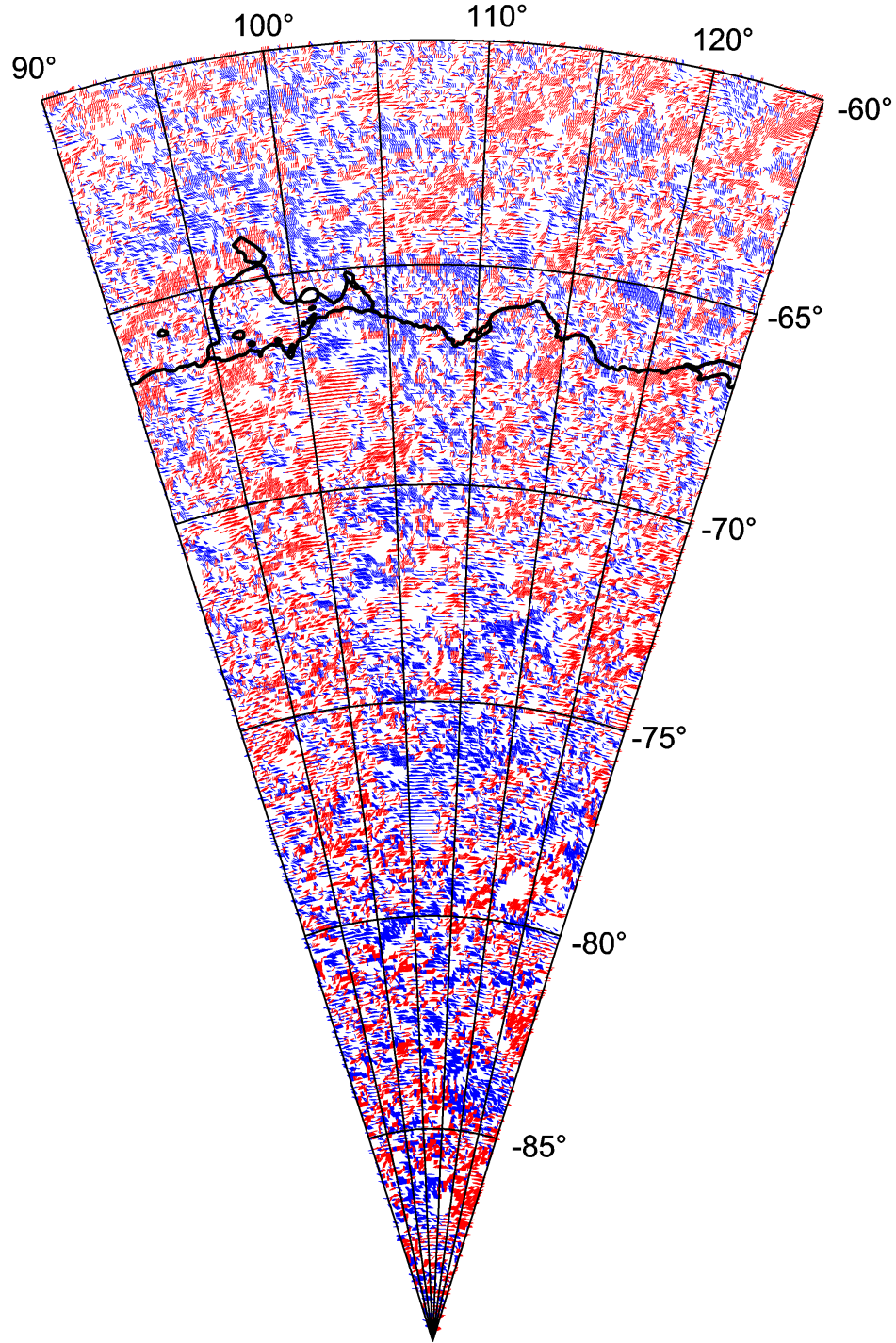


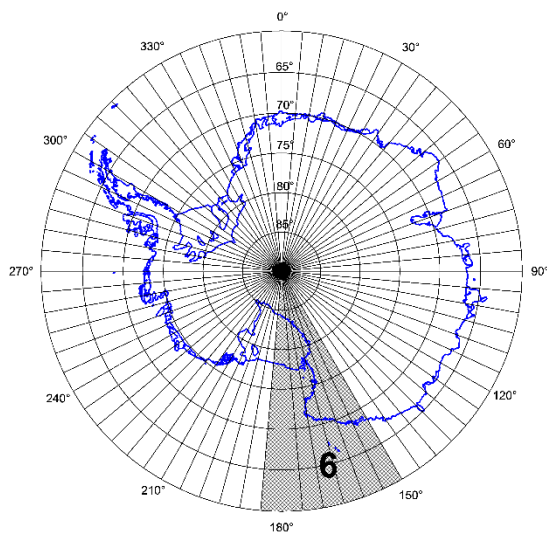
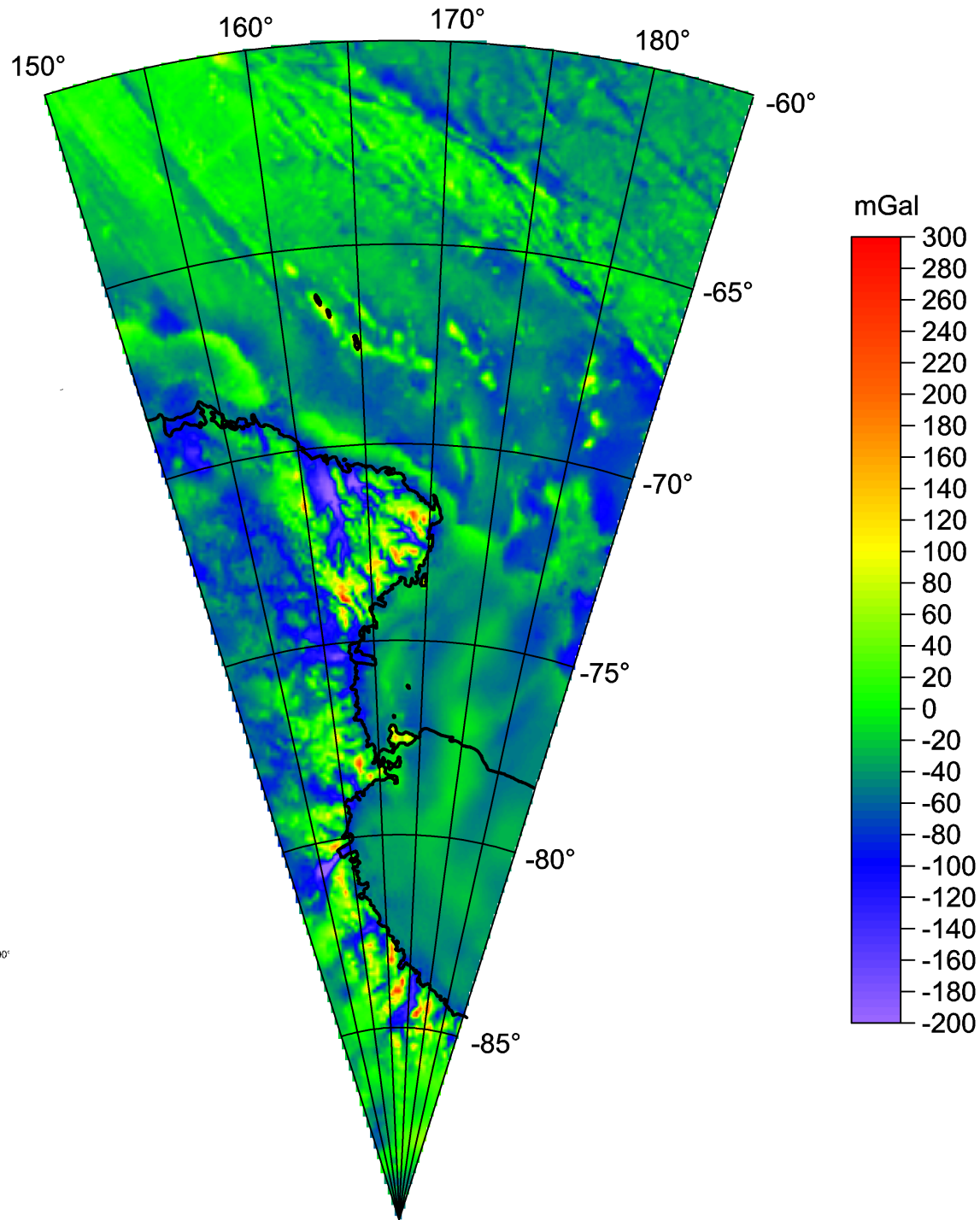


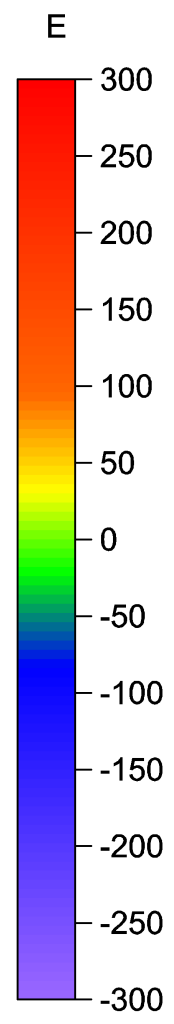
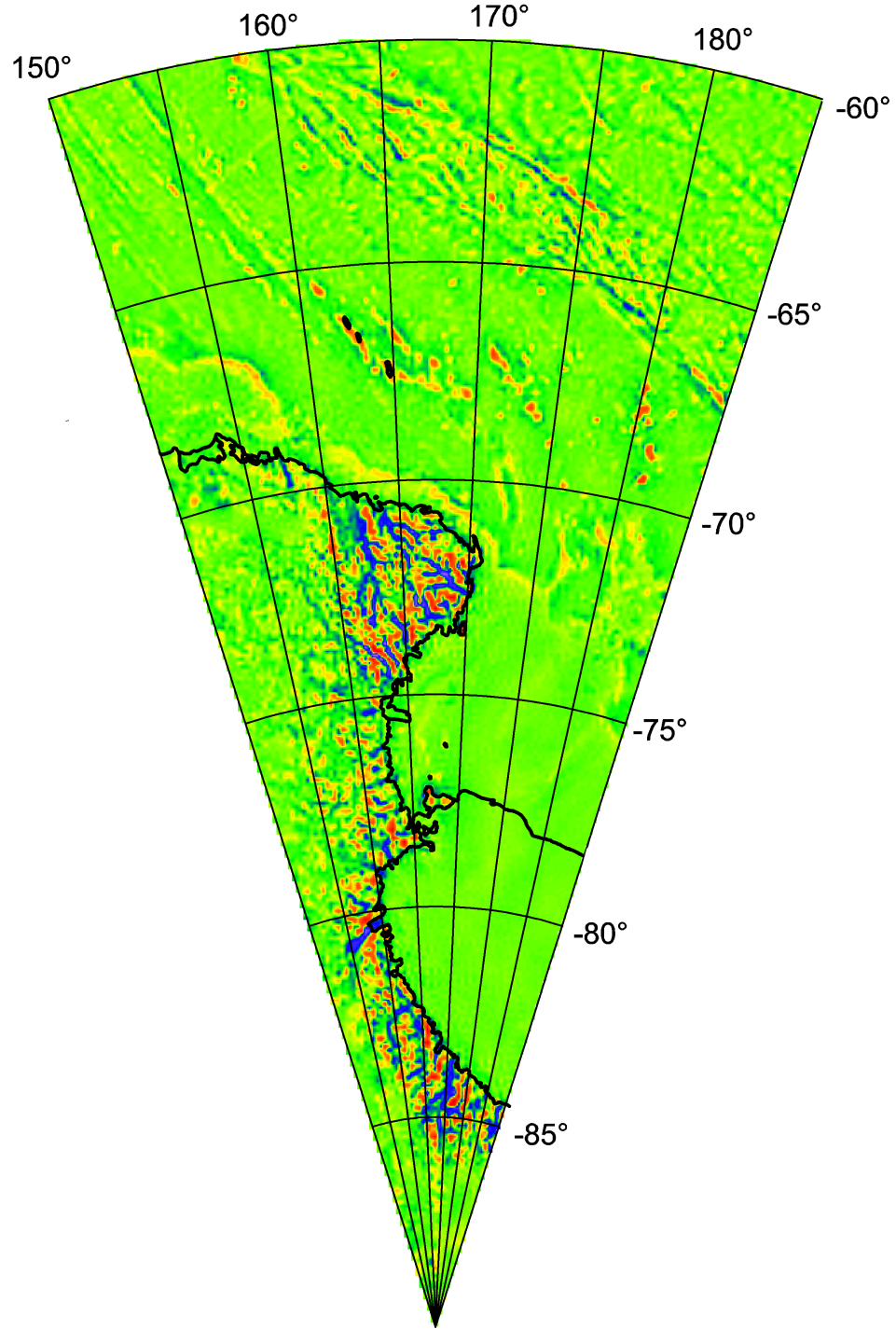


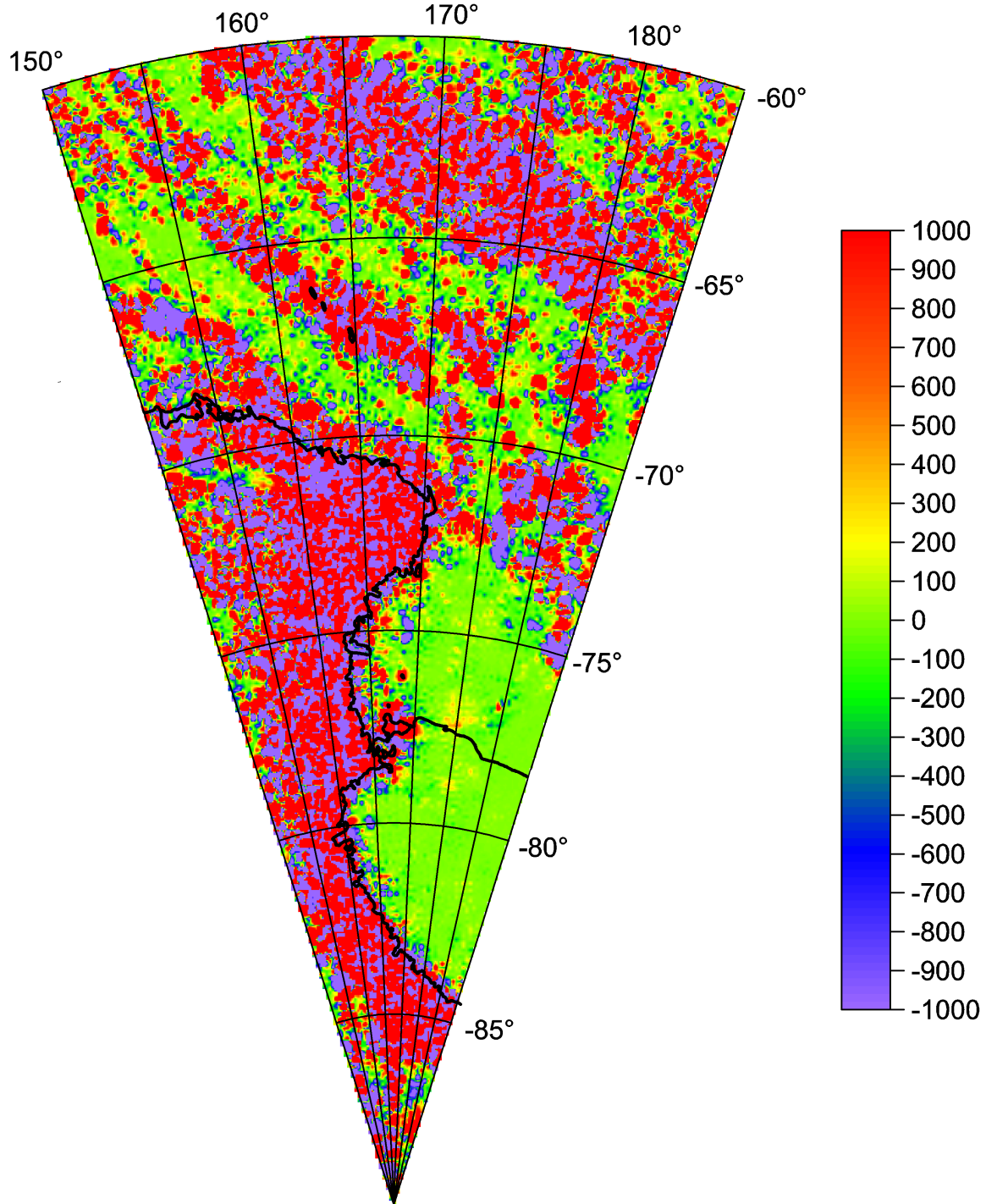


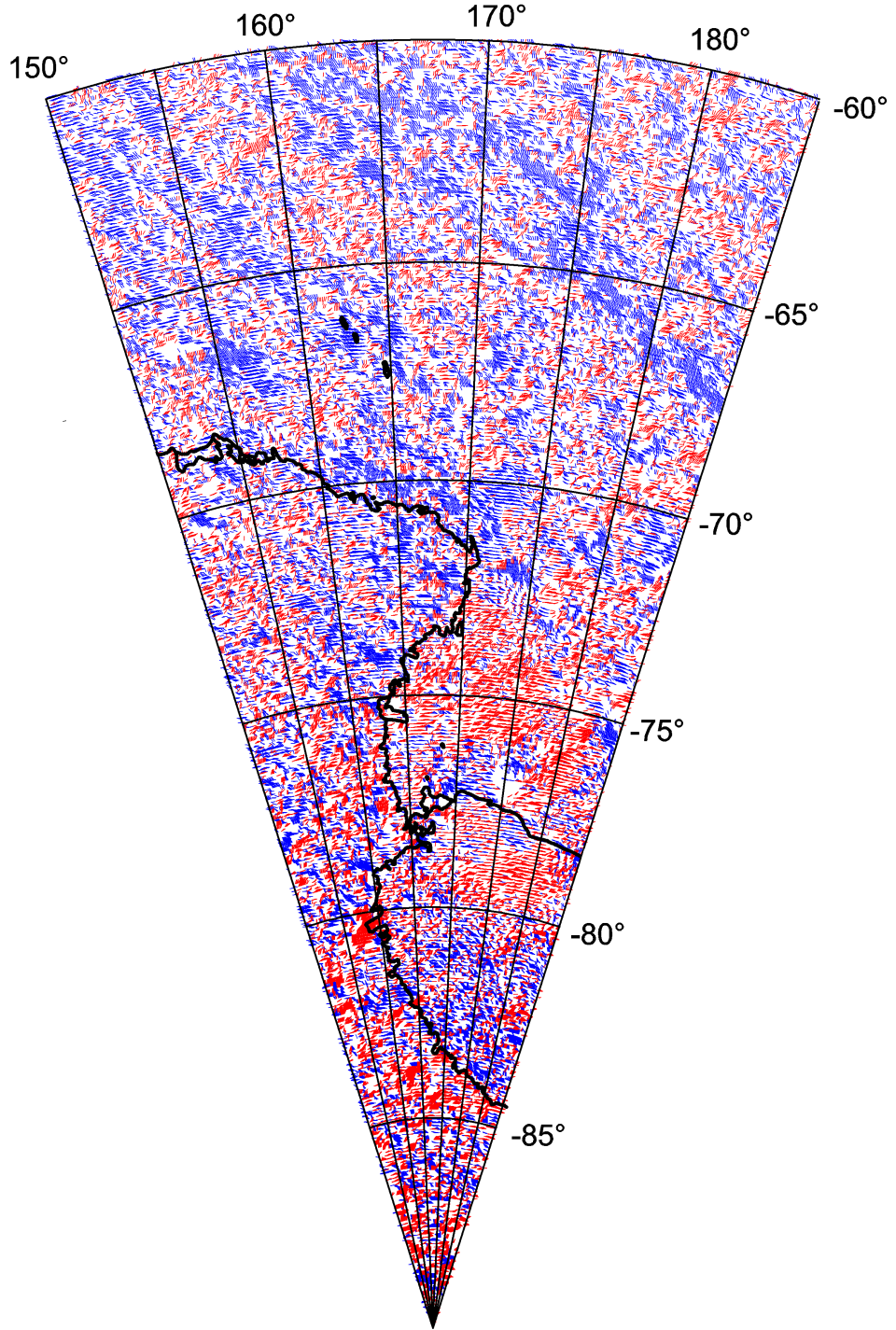










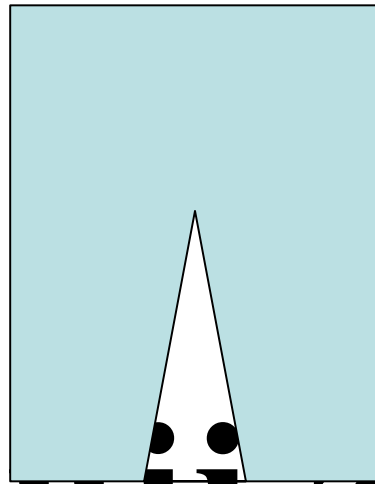


Conclusions

No principal obstacle to detect volcanoes and other objects under the ice of A.

1. Low resolution today but progress expected in future.
2. Attenuation of the gravity signal under the ice not significant.
3. Use of various functions of the disturbing potential (EIGEN C64), not only traditional gravity anomalies.
4. A combination of gravitational (EIGEN C64) and topographic (BEDMAP 2) data.
5. Tentative results for Queen Maud Land and area around Lake Vostok.
6. Testing of any other area on your request.

závěr si udělejte sami



tak děkuji za výdrž



Thank you for your attention
Děkuji Vám za pozornost

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Please visit

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