Revision of Bouguer gravity anomalies of Slovak Republic and interpretation of their enhanced higher derivatives

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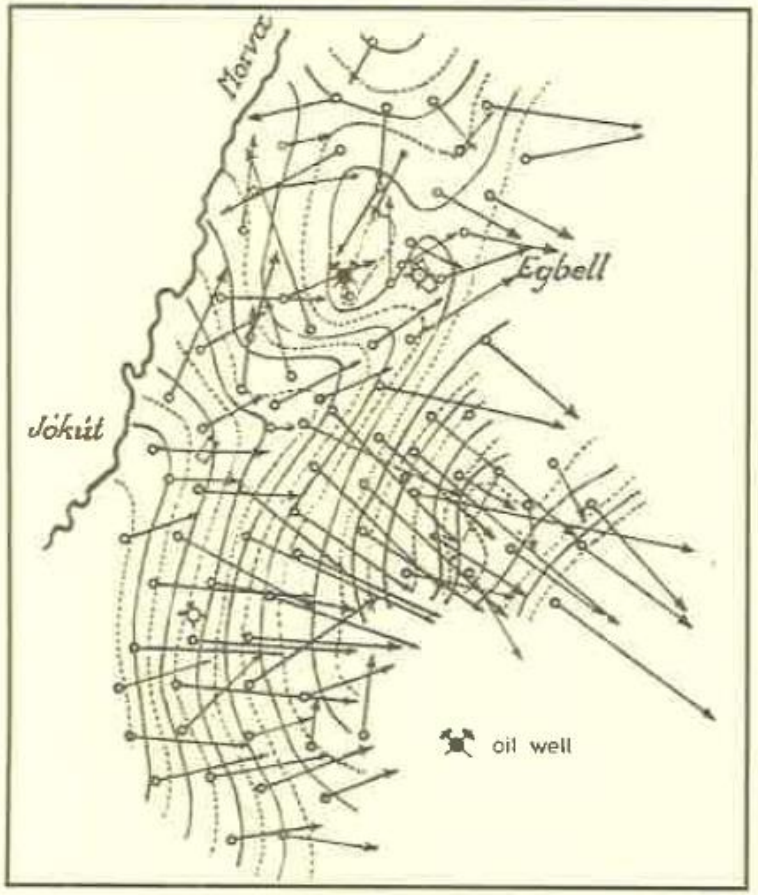
Outline:

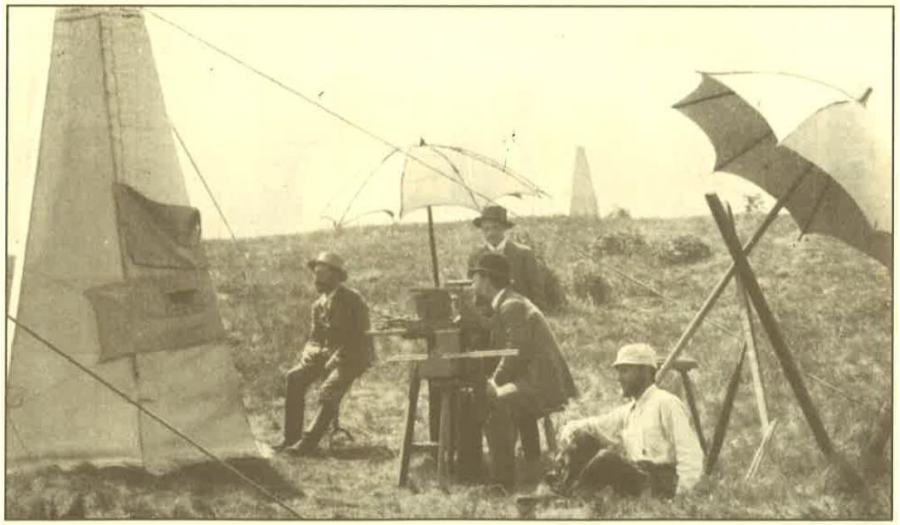
- in honour of Loránd Eötvös
- gravity database in Slovak Republic
- new version of the Complete Bouguer Anomalies map (CBA)
- transformations of CBA, based on higher derivatives calculation
- regularization concept in numerical derivatives evaluation
- qualitative interpretation of transformed fields
- summary and outlooks

in honour of Loránd Eötvös:

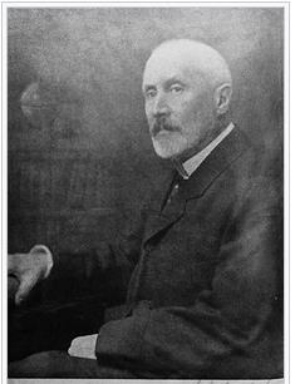
He has realized first gravimetrical measurements in the present territory of Slovakia – at the oil deposit structure Gbely (Egbell).



Gradient map in the region of Egbell (Gbely, Slovakia): the first successful oil exploration project by torsion balance, 1916



The first torsion balance field measurements (on Ság hill, Transdanubia, Hungary) in 1891. EÖTVÖS can be seen at the telescope

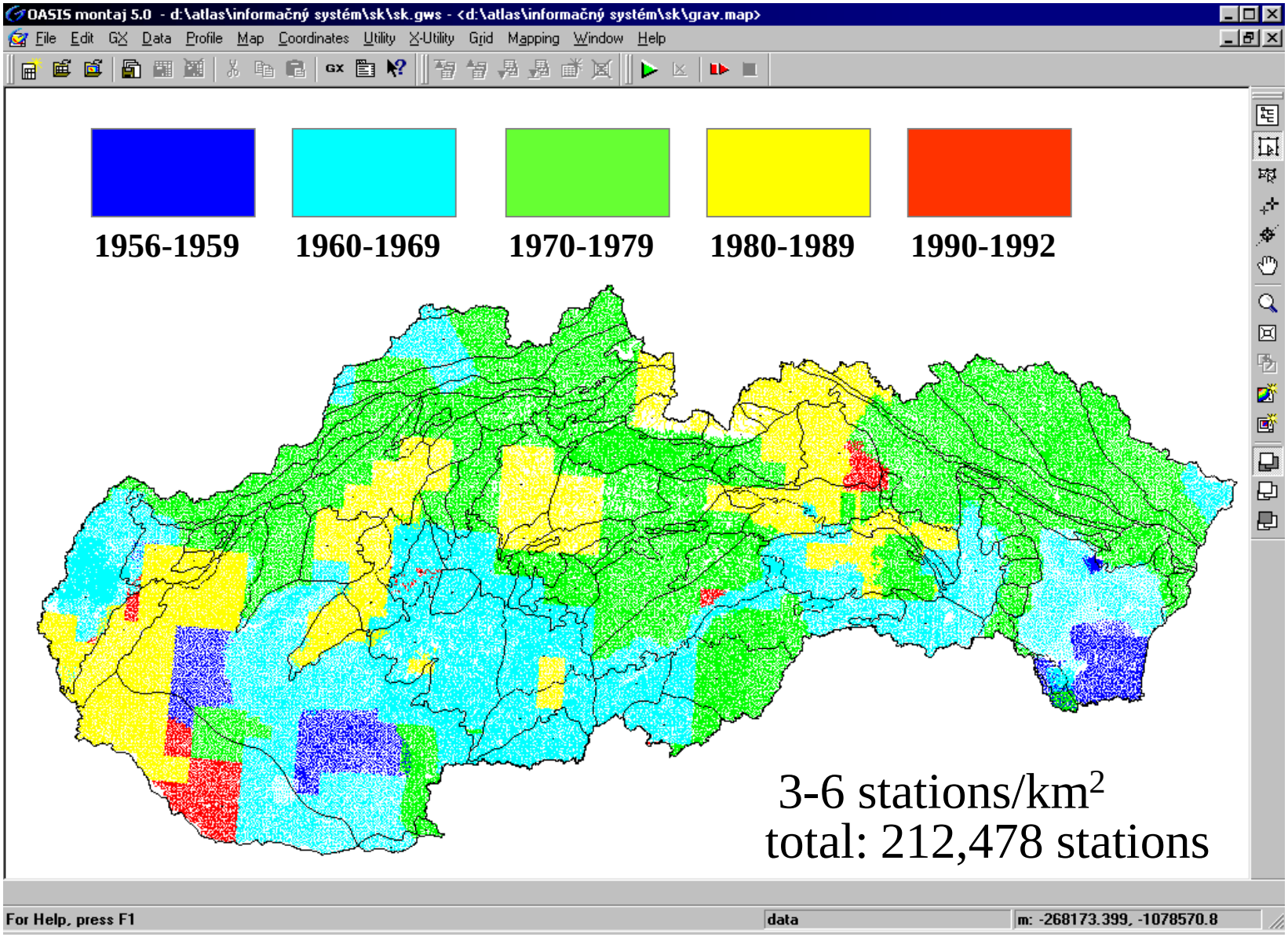


scans from the book of Zoltán Szabó, chapter „Eötvös: The man, the scientist, the organizer“
(our thanks for this copies belong to Veronika Barta and Istvan Bondar)

Gravity database in Slovak Republic

Measured with relative spring gravity meters (Worden, Scintrex CG-2,...)

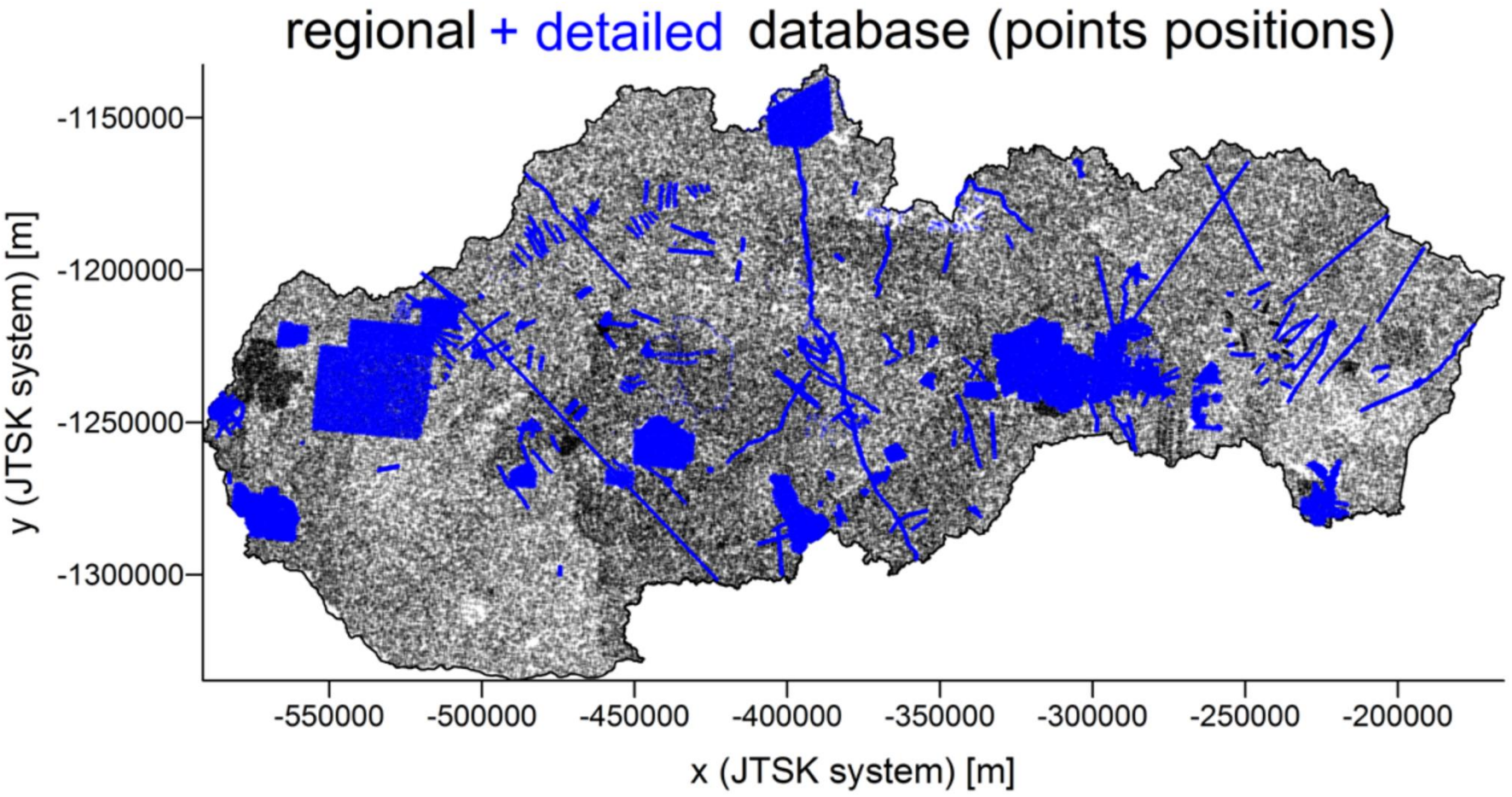
(reprocessed in 1999-2000 by Grand et al.)



Gravity database in Slovak Republic

Next reprocessing stage (focused mainly on terrain corrections re-calculation)

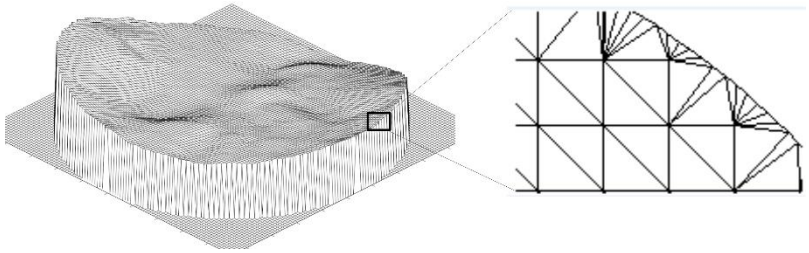
- in the frame of project „Bouguer anomalies of new generation and the gravimetrical model of Western Carpathians“ (2011-2014, Pašteka et al.)

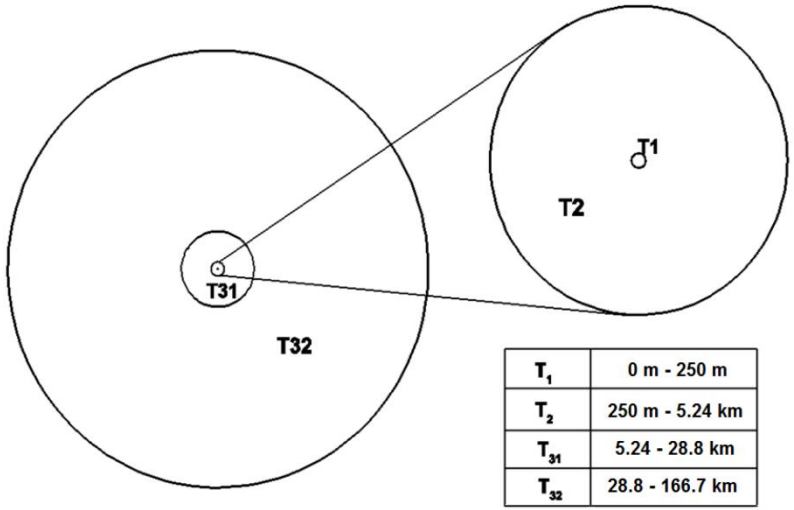


approx. 107.000 stations were added (107.000)

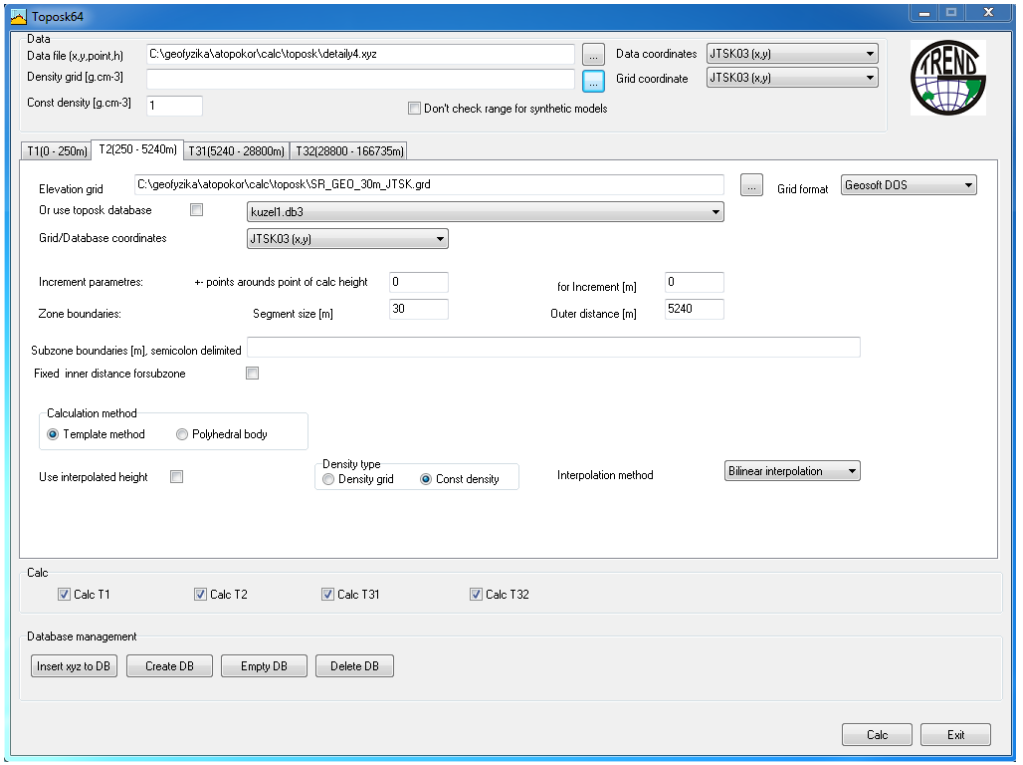
Gravity database in Slovak Republic

reprocessing of terrain corrections (or topographical effects)





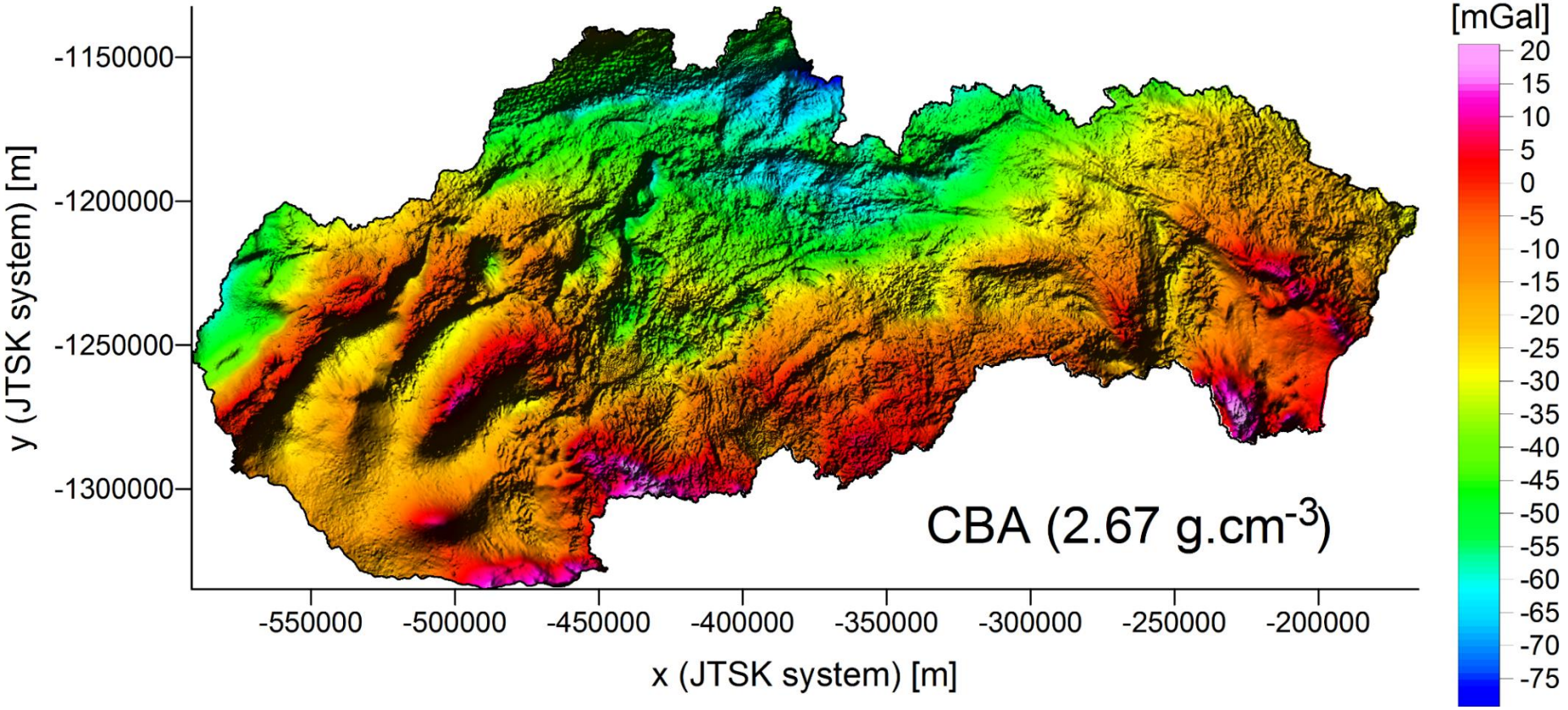
T_1	0 m - 250 m
T_2	250 m - 5.24 km
T_{31}	5.24 - 28.8 km
T_{32}	28.8 - 166.7 km



desktop of the newly developed software Toposk

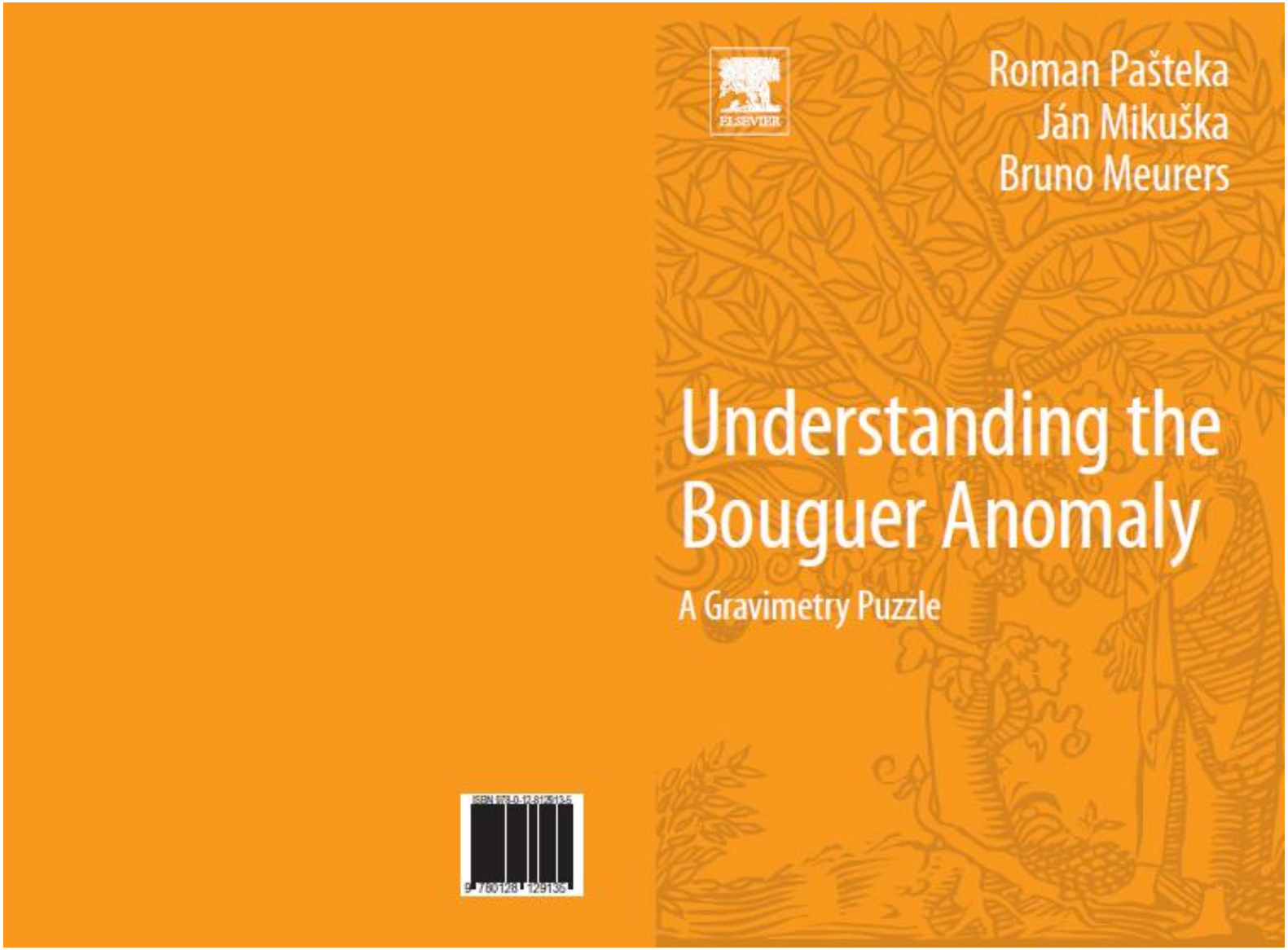
Gravity database in Slovak Republic

Final result – new version of the Complete Bouguer Anomalies map (CBA) (interpolated with 200 × 200 m segment dimensions)



Great variety of qualitative and quantitative gravimetric (and joined) geological interpretation was realized, based on the Complete Bouguer Anomalies field.

Gravity database in Slovak Republic



These results were published in an invited short format monograph in ELSEVIER publishing house.

Transformations based on higher derivatives of potential fields

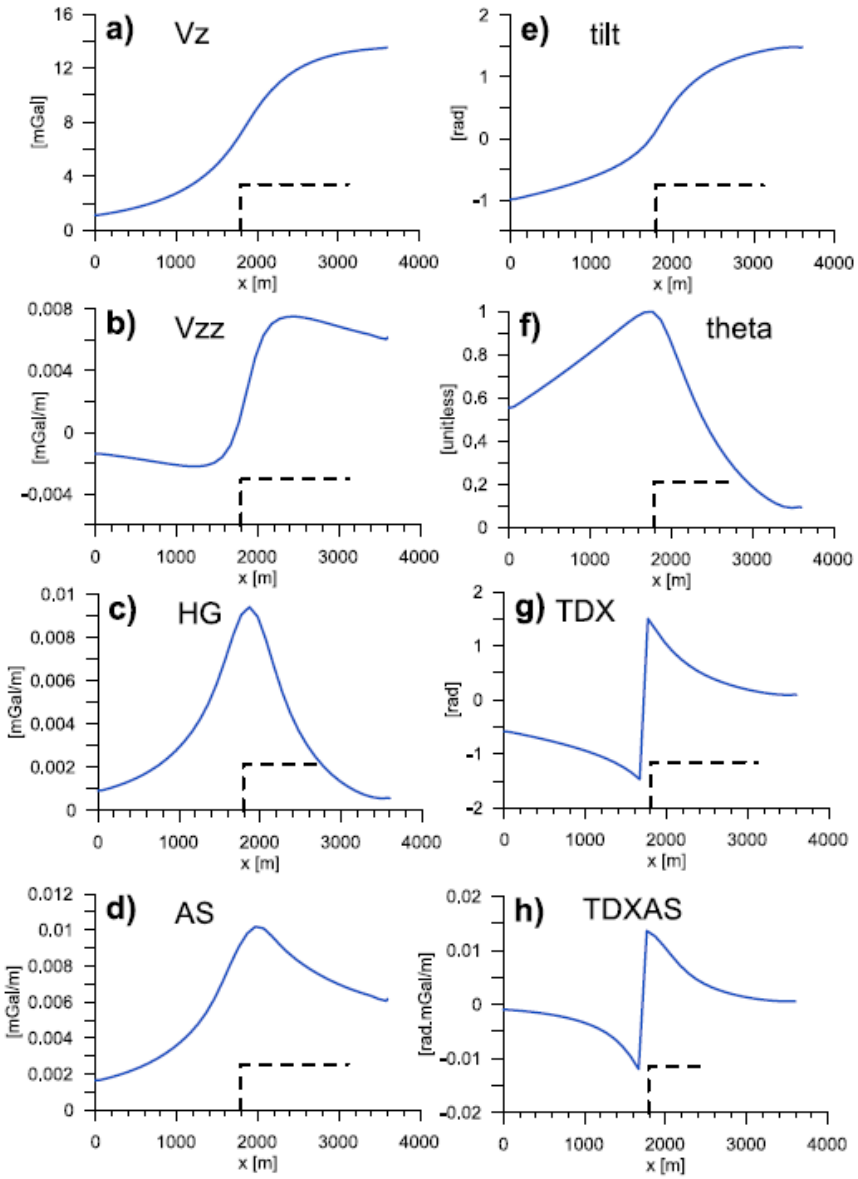
Properties of these kind of enhanced transformations
(often called as edge-detectors):

- are based mostly on ratios of different derivatives (x-, y- and z-direction),
- emphasize shallower structures, contacts and tectonics.

- derivatives of the input field: $\partial f/\partial x$, $\partial f/\partial y$ and $\partial f/\partial z$,
- horizontal gradient: $HG = \sqrt{(\partial f/\partial x)^2 + (\partial f/\partial y)^2}$,
- analytical signal: $AS = \sqrt{(\partial f/\partial x)^2 + (\partial f/\partial y)^2 + (\partial f/\partial z)^2}$,
- tilt derivative: $tilt = \mathrm{arctg}\dfrac{\partial f/\partial z}{HG}$, (Miller and Singh, 1994; Verduzco et al., 2004)
- theta derivative: $\cos(\theta) = \dfrac{HG}{AS}$, (Wijns et al., 2005)
- TDX derivative: $TDX = \mathrm{arctg}\dfrac{HG}{\partial f/\partial z}$, (Cooper and Cowan, 2006)
- TDXAS transformation: $TDXAS = TDX \cdot AS$, (Stampolidis and Tsokas, 2012)

list of mostly used transformations

Transformations based on higher derivatives of potential fields



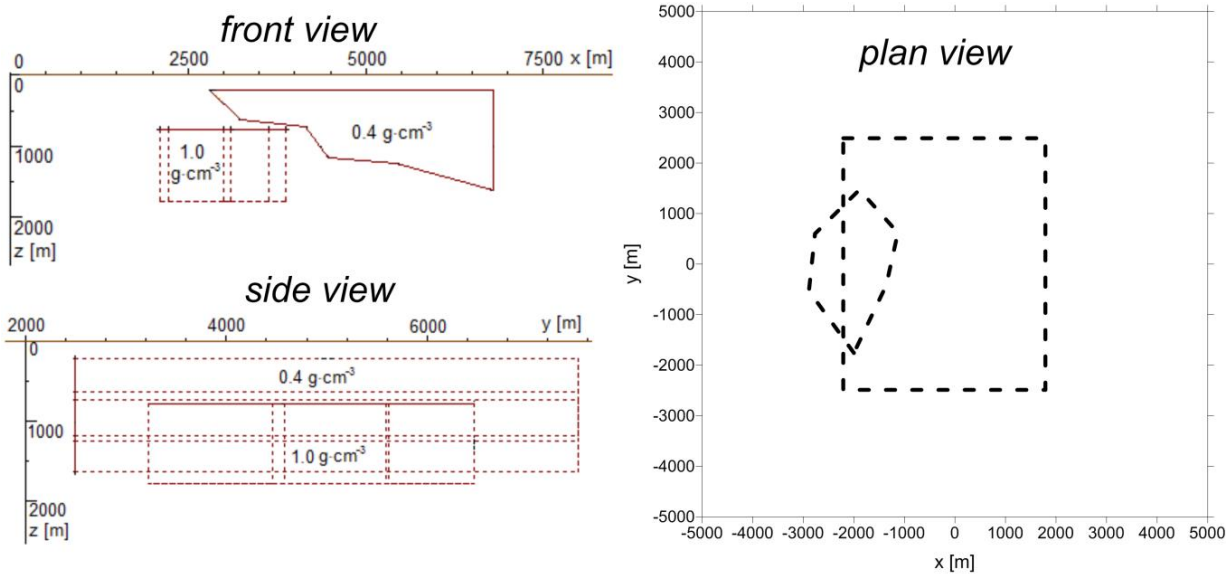
model curves over a contact:

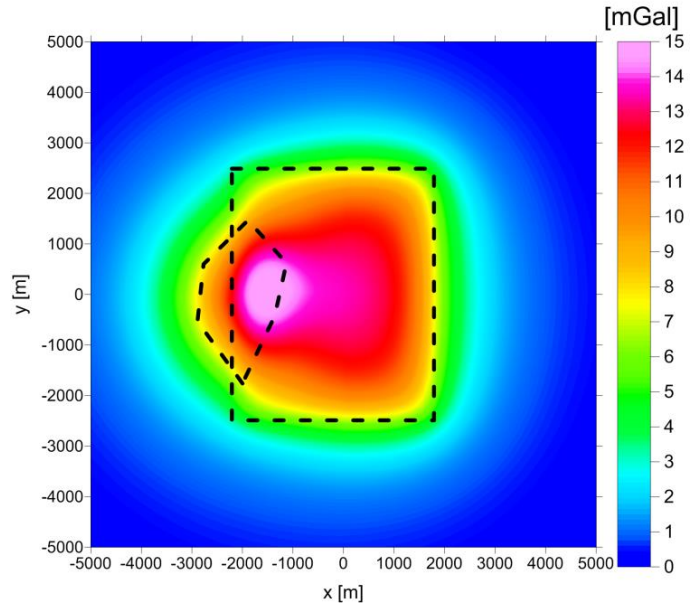
a) have a sharper gradient (than CBA),

b) reach maxima.

Transformations based on higher derivatives of potential fields

- synthetic model (2 overlying bodies)

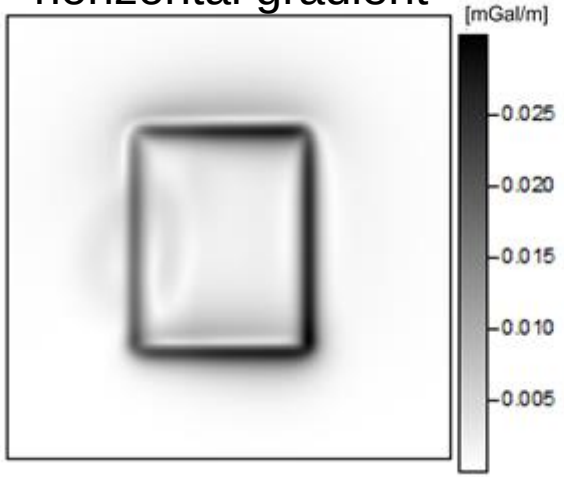




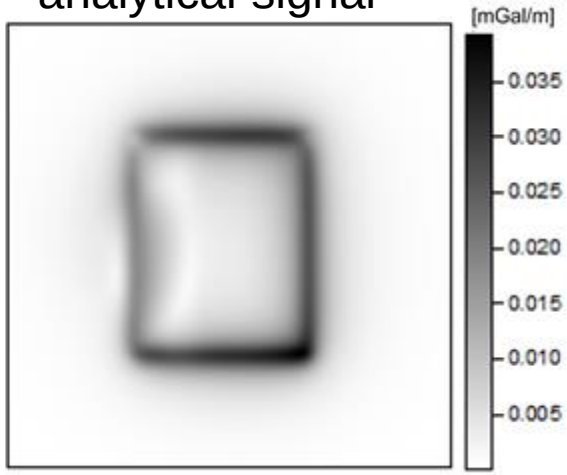
synthetic field – vertical component of gravitational acceleration

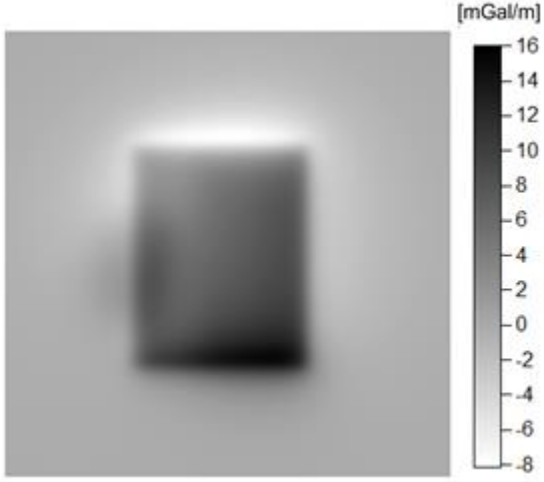
- synthetic model (2 overlying bodies)

horizontal gradient



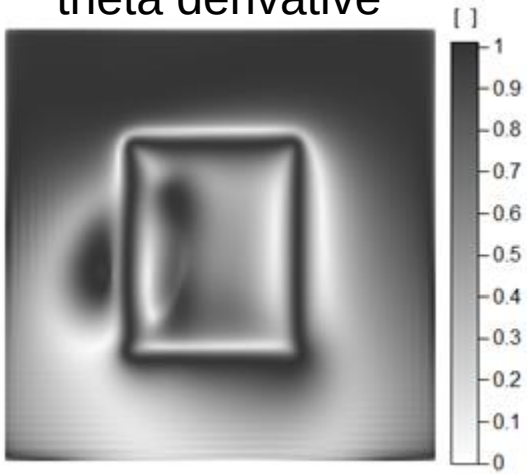
analytical signal



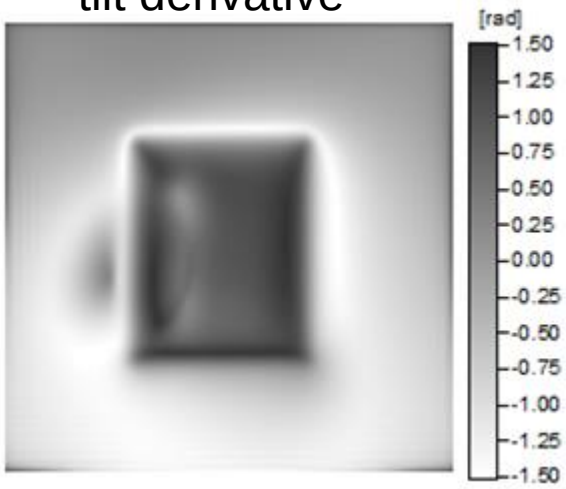


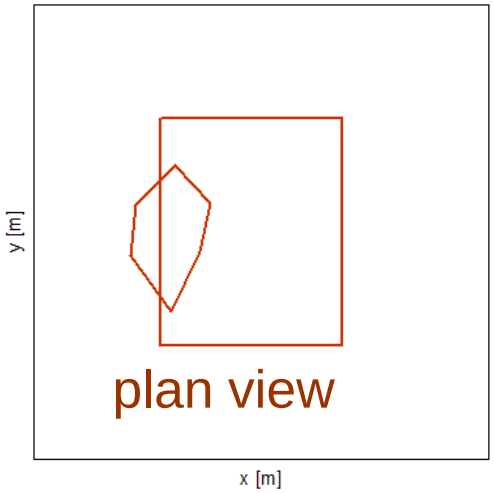
1. vertical derivative

theta derivative



tilt derivative

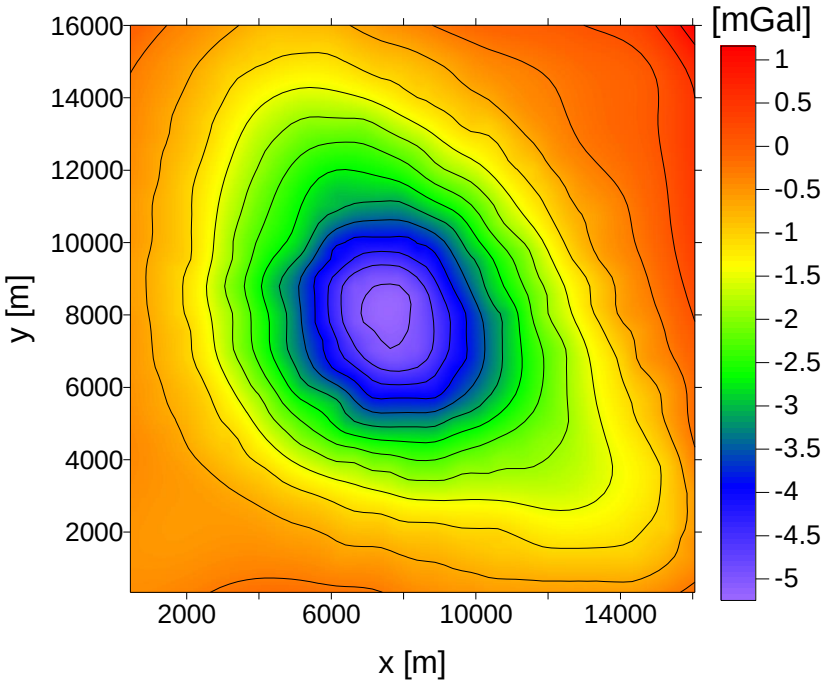




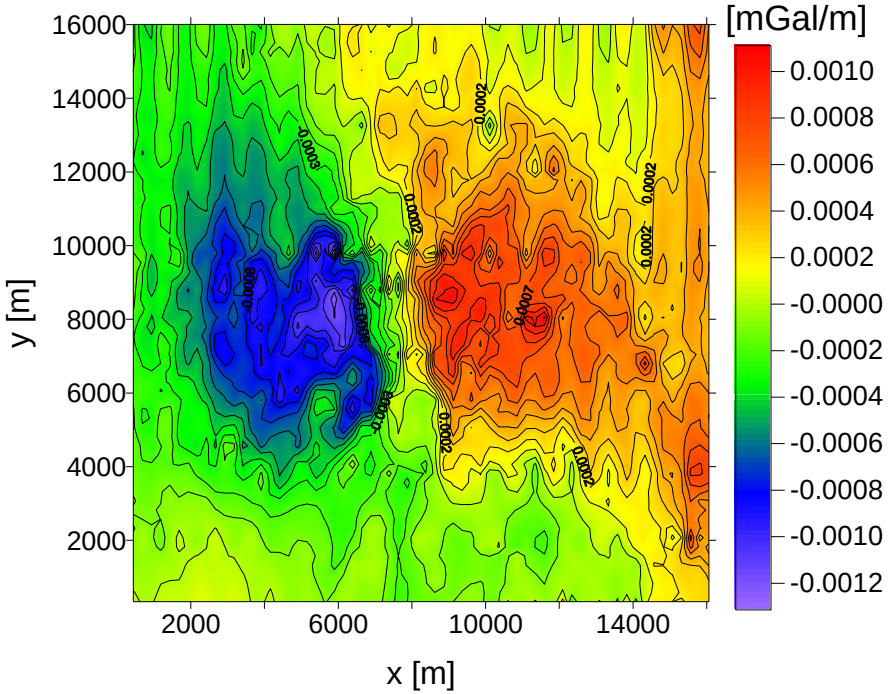
selected transformations
(used BW colour scale)

Transformations based on higher derivatives of potential fields

We have a crucial problem with numerical derivatives calculation (in spatial or spectral domain) – its instability.

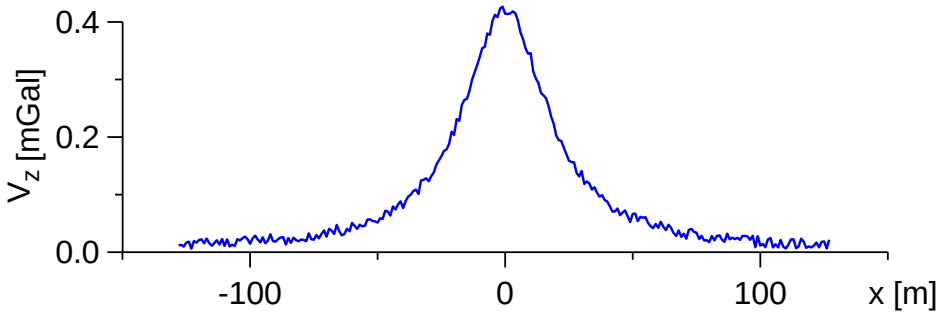


x-derivative



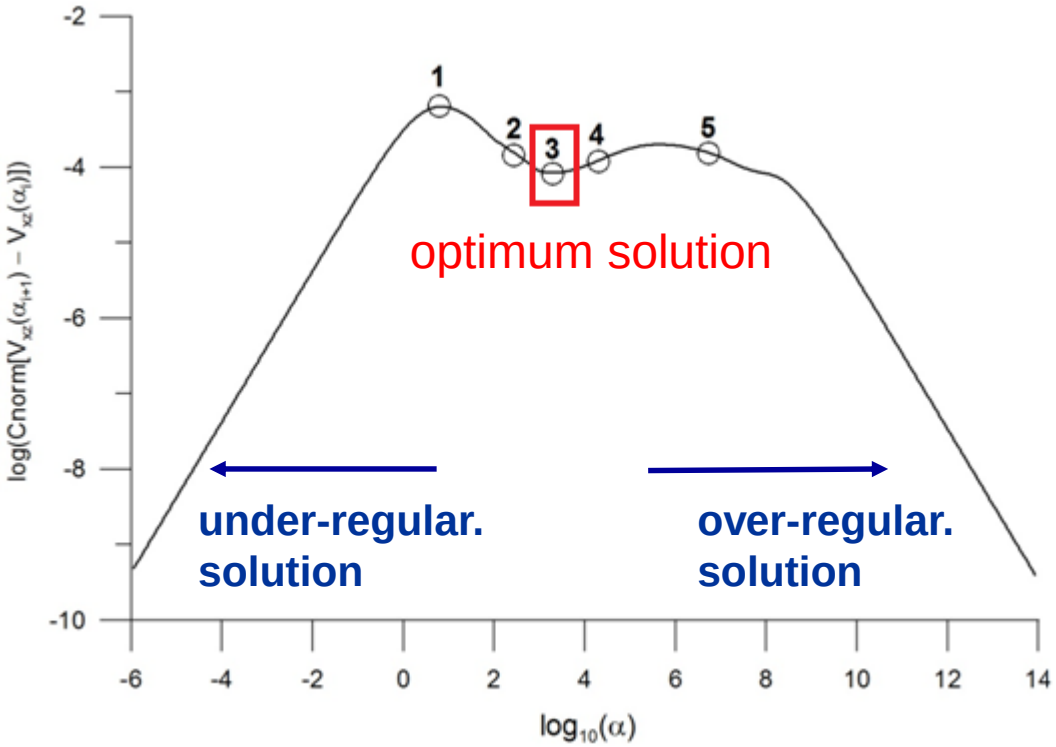
residual Bouguer anomaly map of a salt structure Louisiana, USA (after Nettleton, 1979)

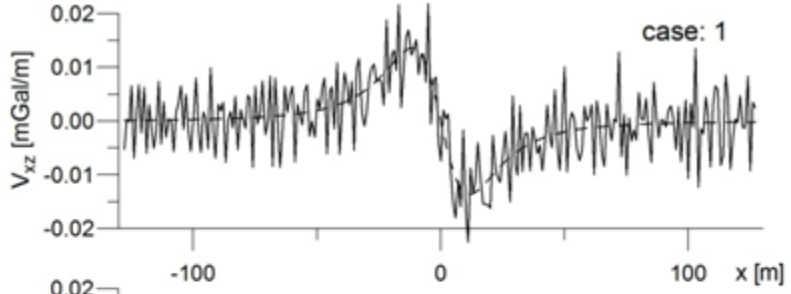
One possible solution is the use of Tikhonov regularization concept (Pašteka et al., 2009, *Geoph. Prospecting*).

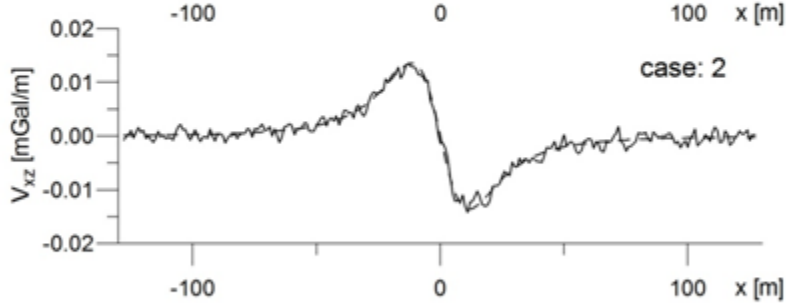


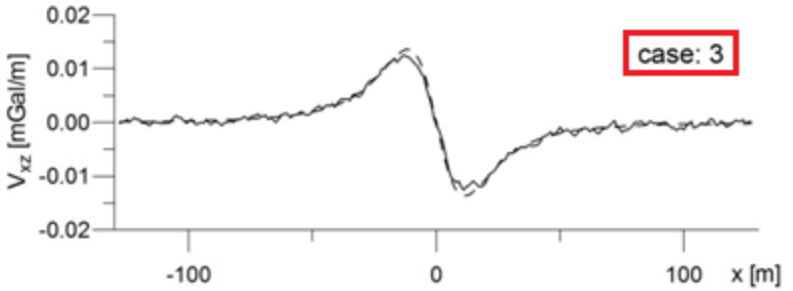
Example: analysis of C-norms

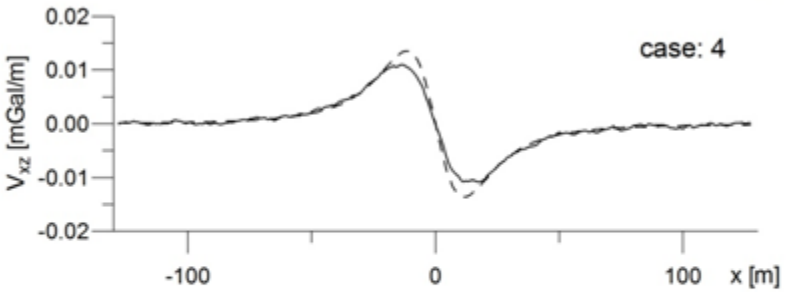
(here for x-derivative, synthetic field for a horiz. cylinder)

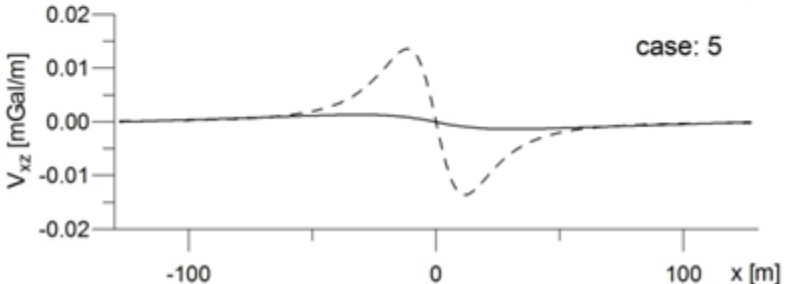




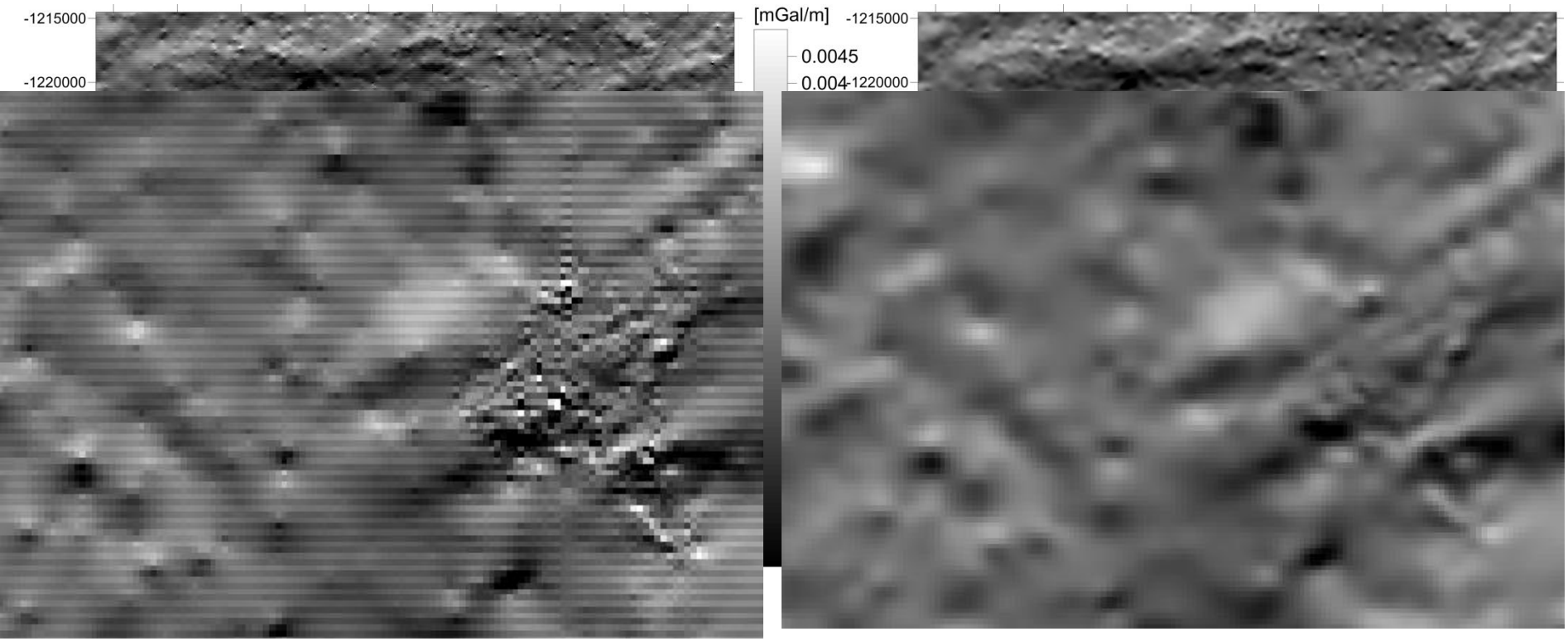






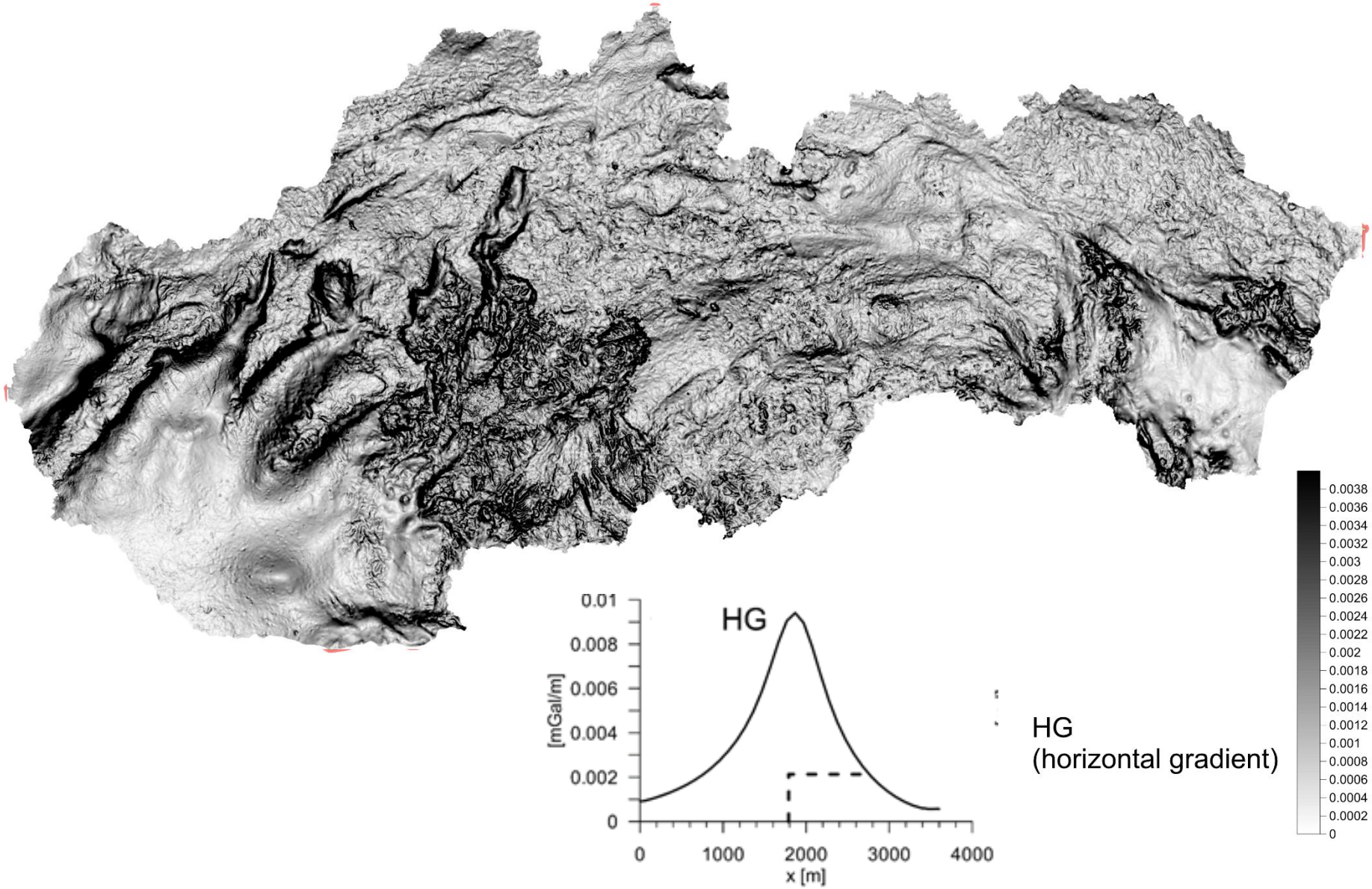


differences – between standard and regularized derivatives

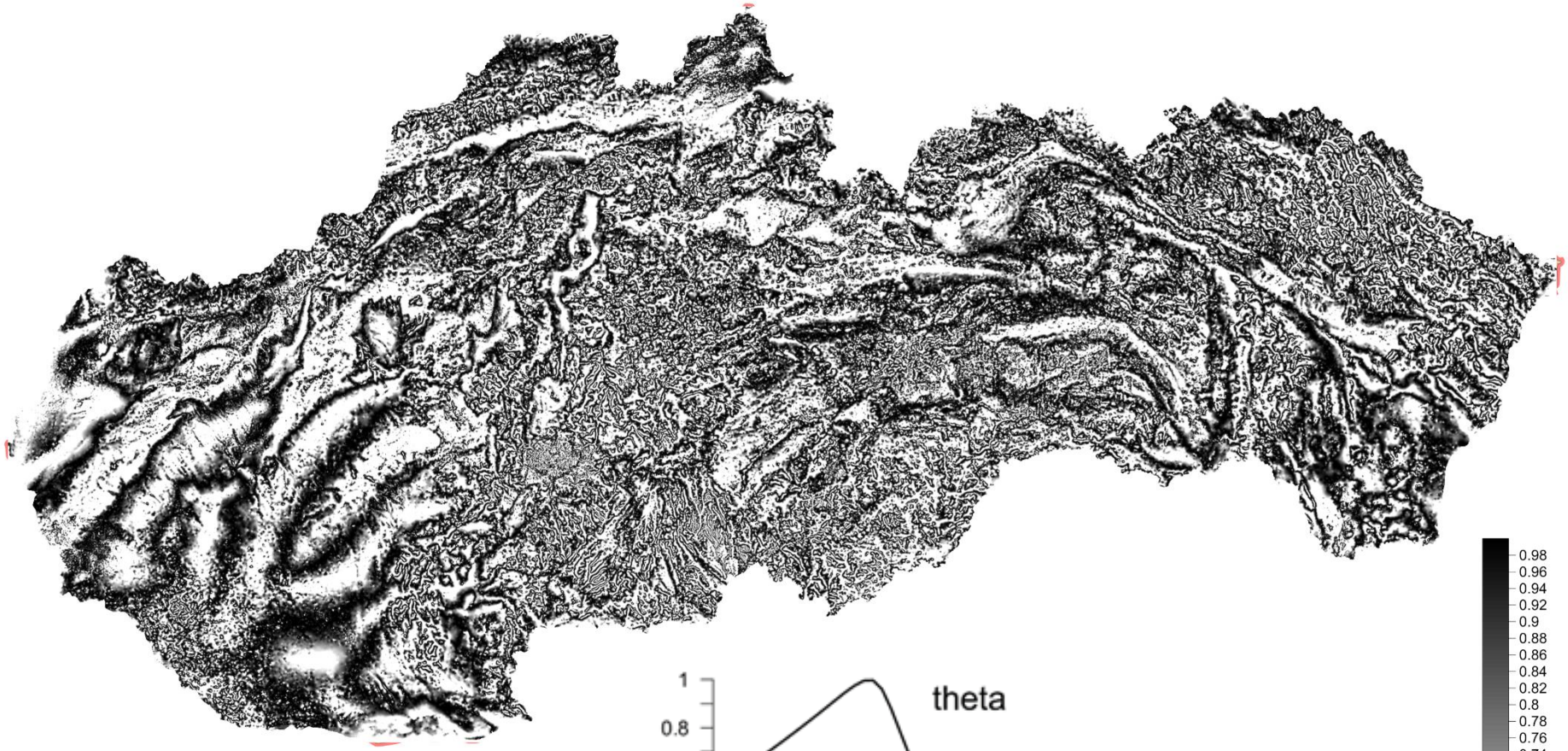


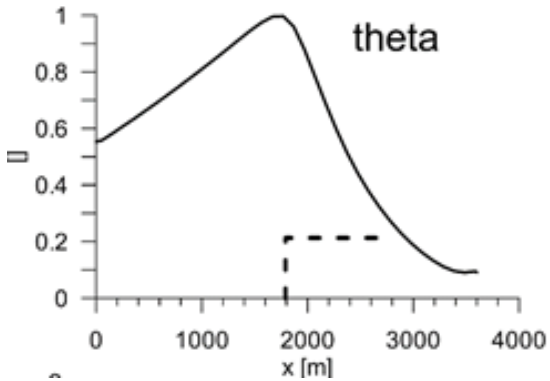
standard y-derivative
(non-regularized)

regularized y-derivative
(smoothed)

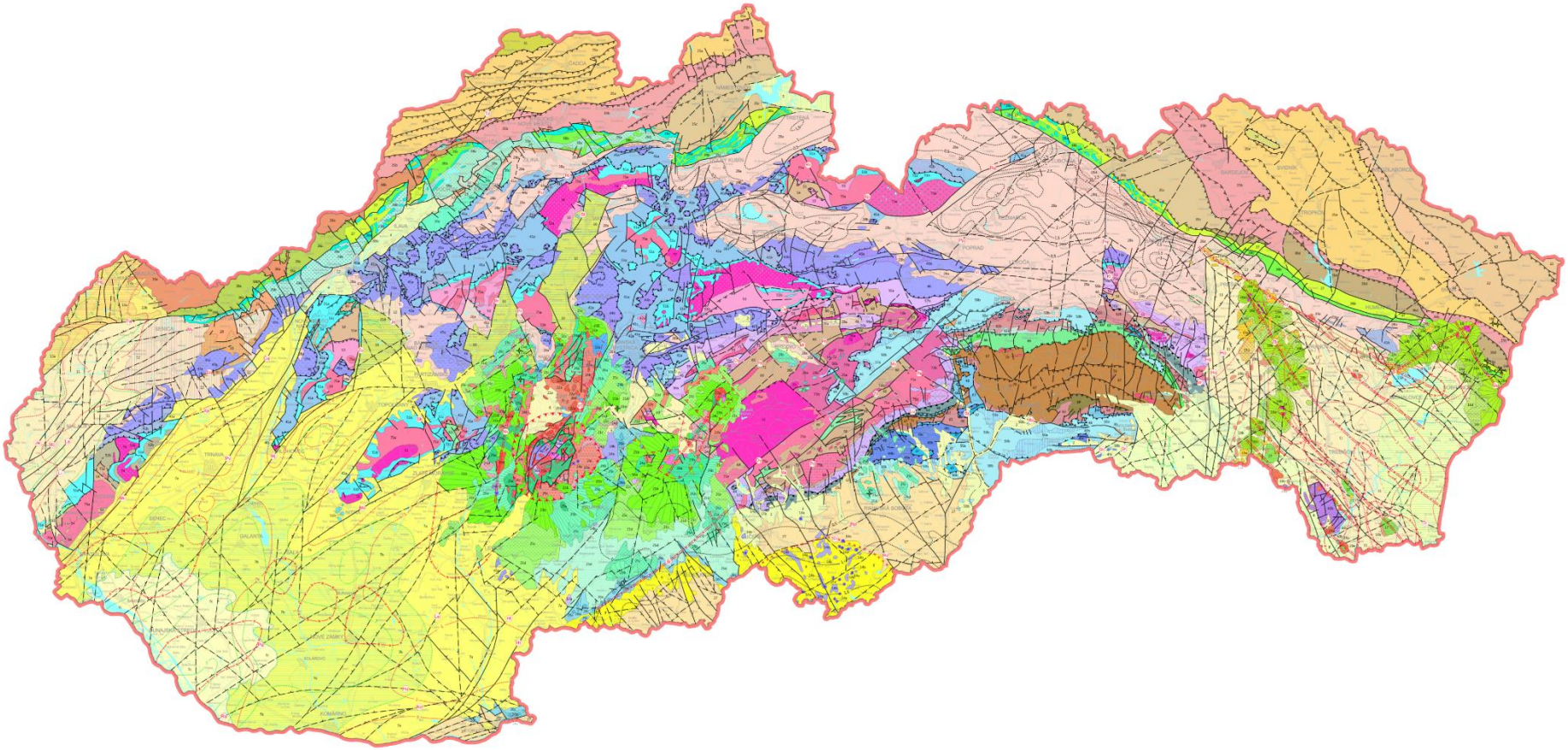


HG
(horizontal gradient)

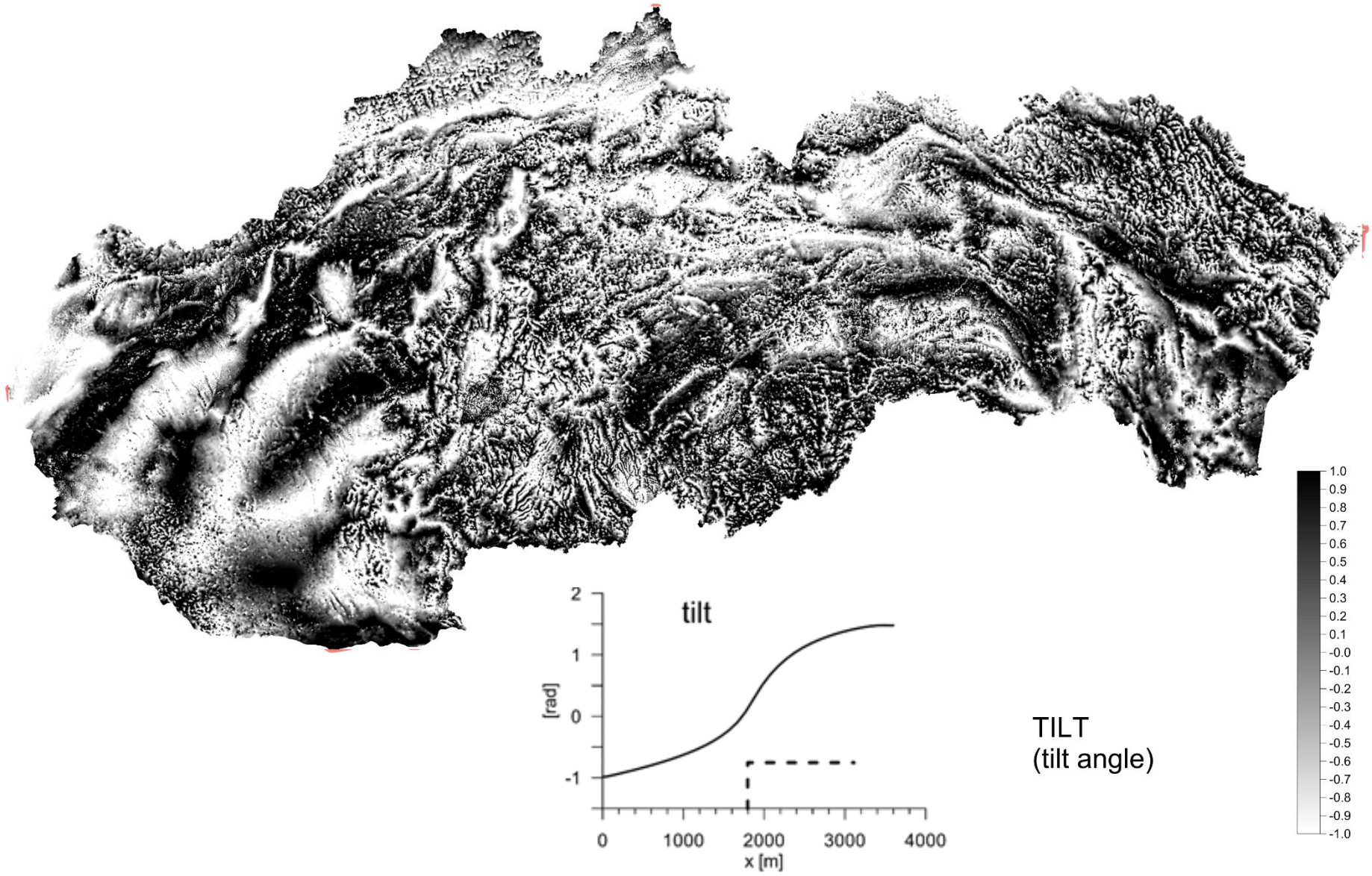




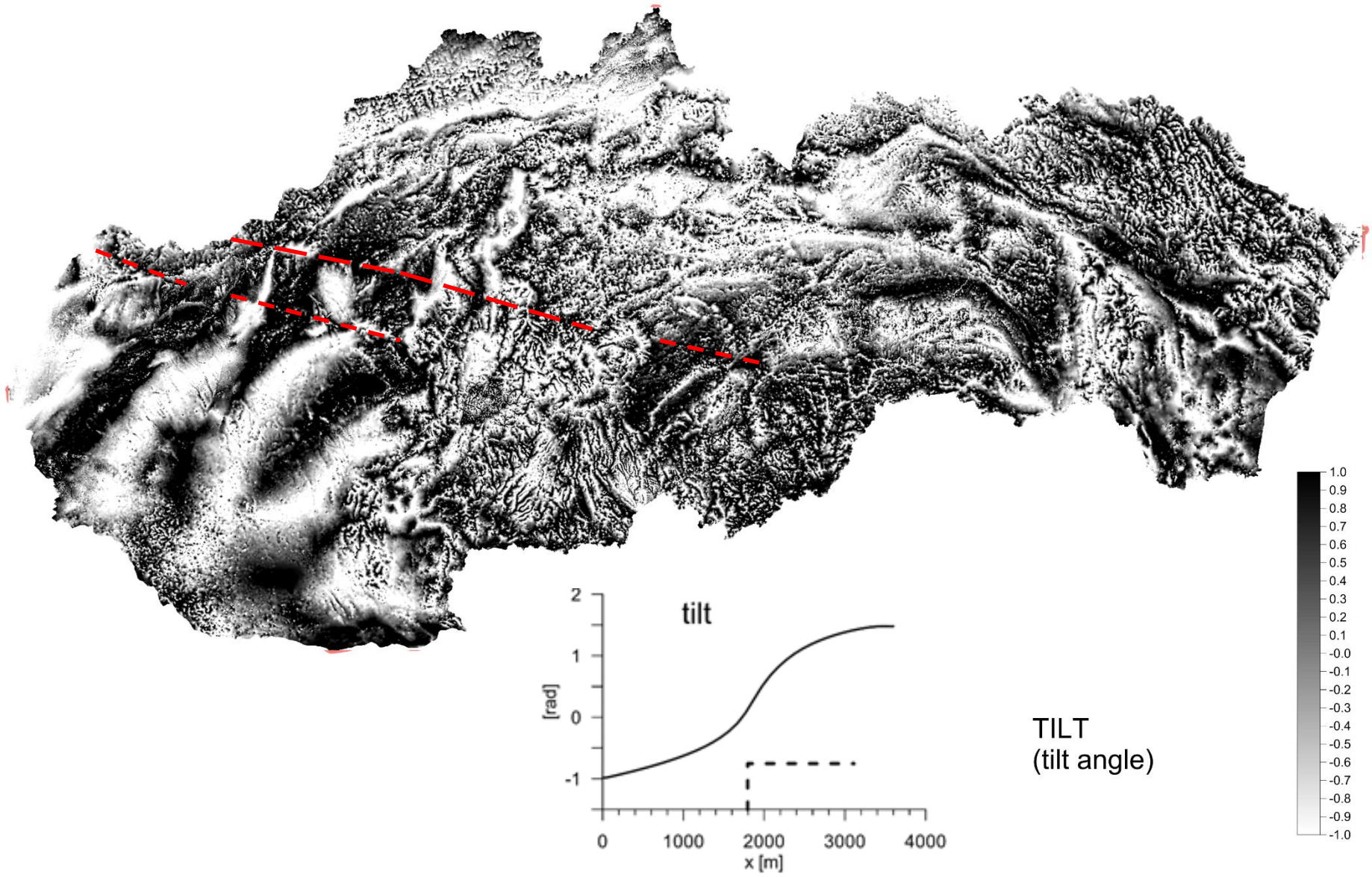
THETA
(theta derivative)



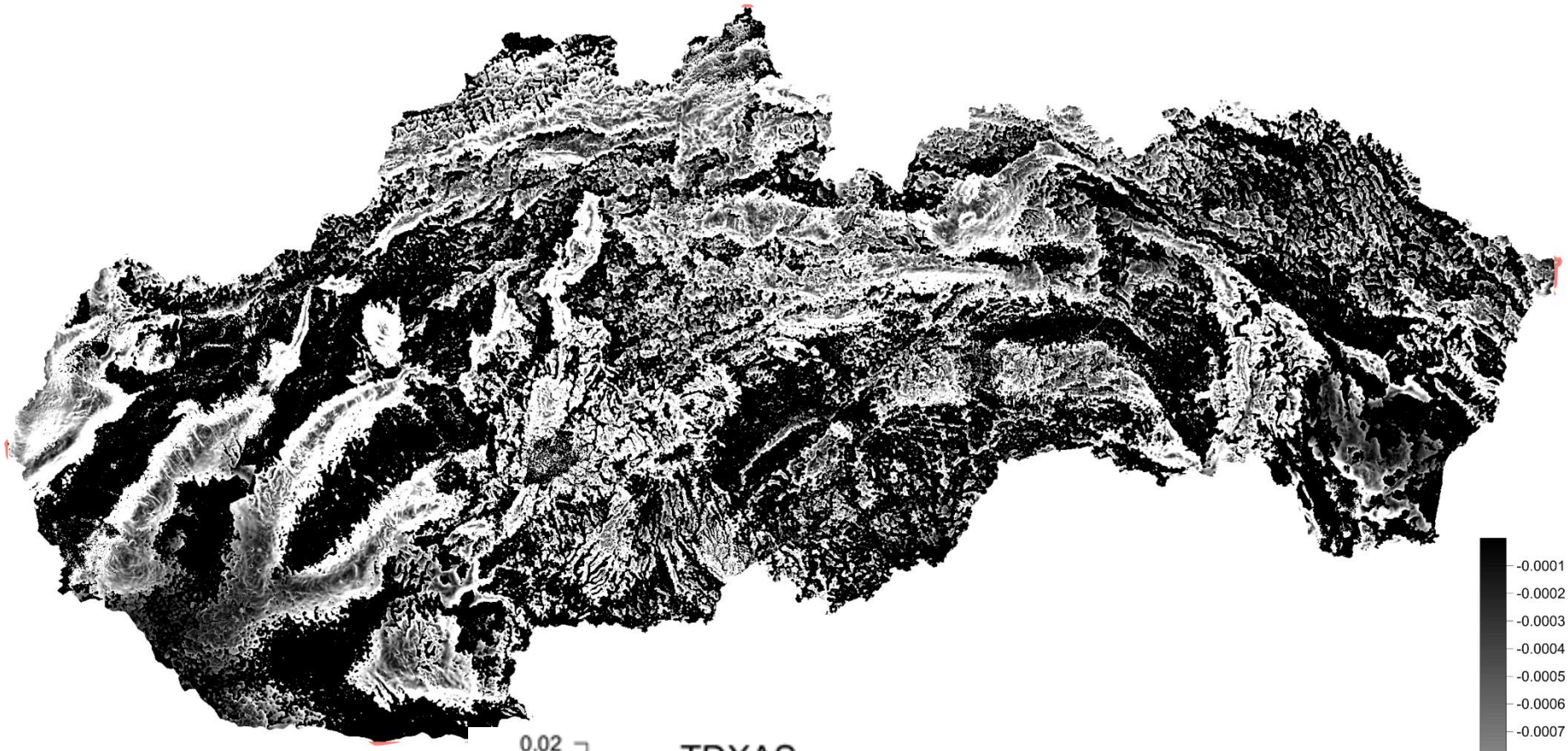
Bezák et al., 2004: Tectonic map of Slovak Republic

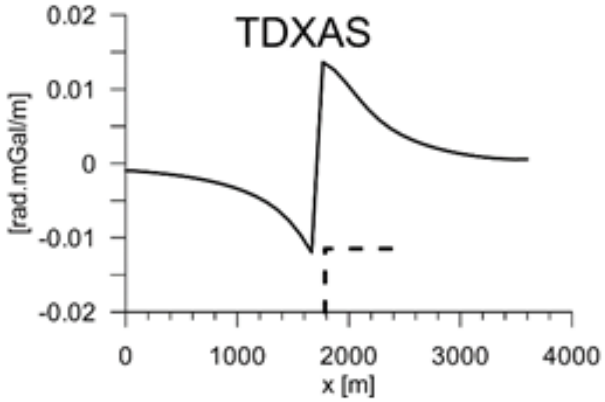


TILT
(tilt angle)



TILT
(tilt angle)





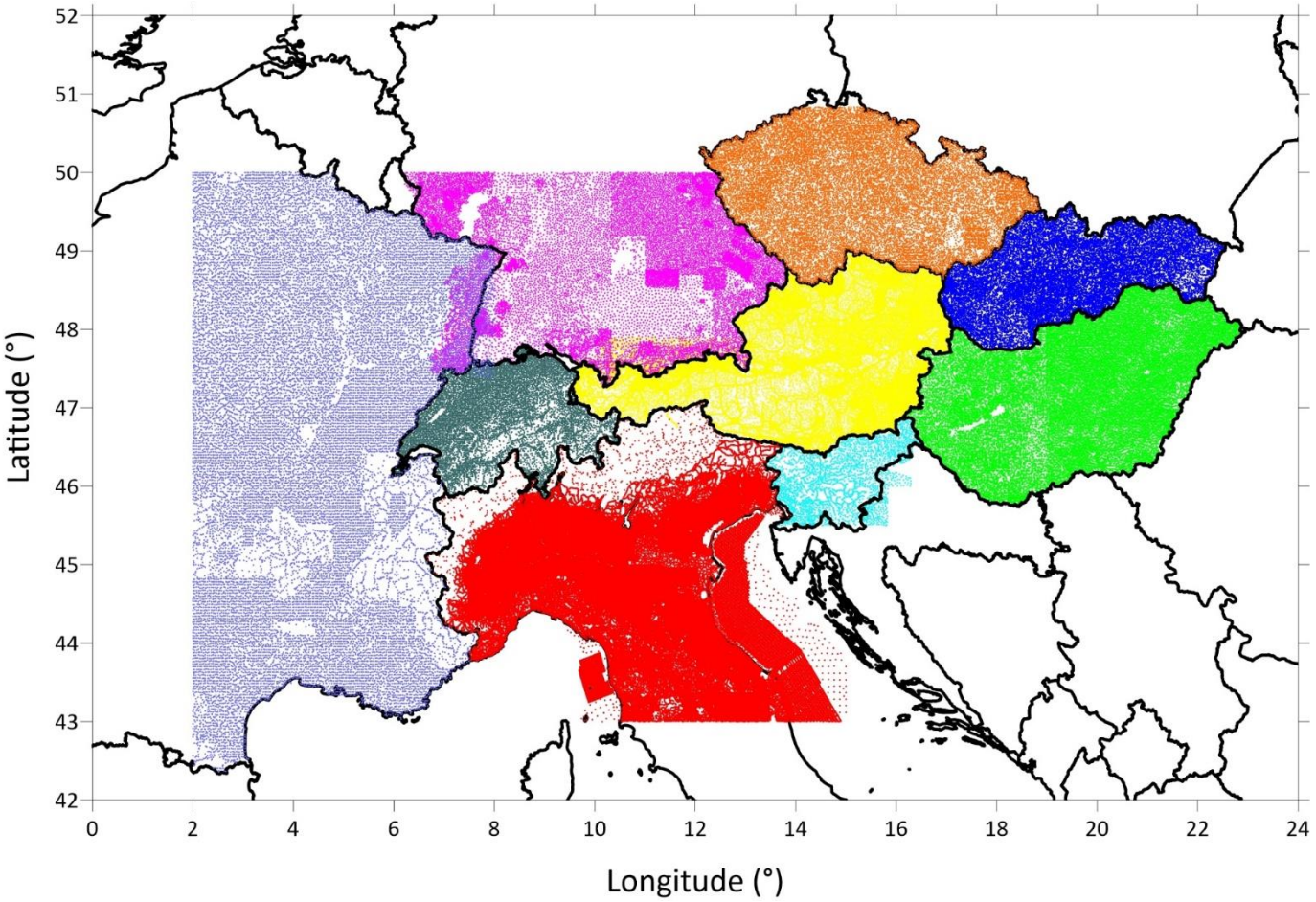
TDXAS
(balanced horizontal gradient
time analytical signal)
(selected values are displayed)

Summary:

- transformations, based on higher derivatives are more sensitive for contacts and tectonics detection and interpretation,
- stabilisation of numerical derivatives by means of the Tikhonov regularization concept helps to improve the properties of derivatives in the interpretation process,
- software solution of regularized derivatives calculation (MATLAB script REGTILT is free for academic use),
- results of enhanced transformations should be analysed in more details in the future,
- the role of higher derivatives of potential fields was recognized by Eötvös more than 100 years ago (now a part of many FTG projects, also in airborne and satelite geophysics and geodesy)

Outlooks:

- scientific initiative AlpArray Gravity Research Group
- under the management of G. Hetényi and H.J. Götze



Thank you very much for your attention.