EGU2020-16484
EGU General Assembly 2020

Processing steps for the compilation of AAGRG gravity maps

Pavol Zahorec[1], Juraj Papčo[2], Roman Pašteka[3]
and the AlpArray Gravity Research Group[*]

[1]Earth Science Institute, Slovak Academy of Sciences, Banská Bystrica, Slovakia
[2]Department of Theoretical Geodesy, Slovak University of Technology, Bratislava, Slovakia
[3]Department of Applied and Environm. Geophysics, Comenius University, Bratislava, Slovakia
[*]A complete list of authors is given at the end of the presentation

Online presentation

Basic info:

First unified complete Bouguer anomaly (CBA) map of AlpArray area compiled from terrestrial gravity data is currently in preparation, consisting of the following steps:

1. Unification of different spatial, height and gravity systems

2. Getting available detailed elevation models (mainly LiDAR-based)

3. Quality control of input data

4. Calculation of mass corrections (gravity effect of the topography between the surface and ellipsoid level)

5. Calculation of bathymetric corrections for water masses below the ellipsoid

6. Calculation of lake corrections for great Alpine lakes

7. Atmospheric correction – comparison of different approaches

8. Calculation of the final CBA, innovative concept of ellipsoidal heights used

9. Merging individual databases into a single map (with the addition of Global Geopotential Models to fill data gaps)

1. Unification of different spatial, height and gravity systems

Position: Local – National Positioning Reference Systems transformed to European Terrestrial Reference System 1989 (ETRS89) and Universal Transversal Mercator (UTM)

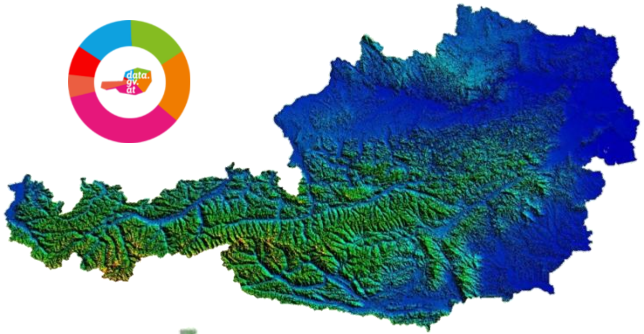
Height: Local – National Height Systems transformed to Ellipsoidal Heights (ETRS89, ellipsoid GRS80) using local geoid models

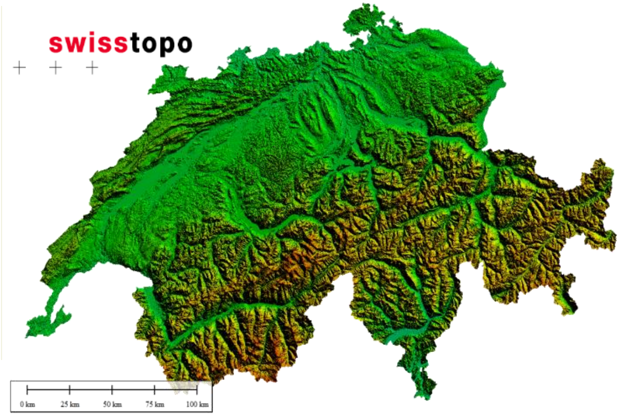
Marine areas – transformation to Ellipsoidal Heights using EIGEN-6C4 model

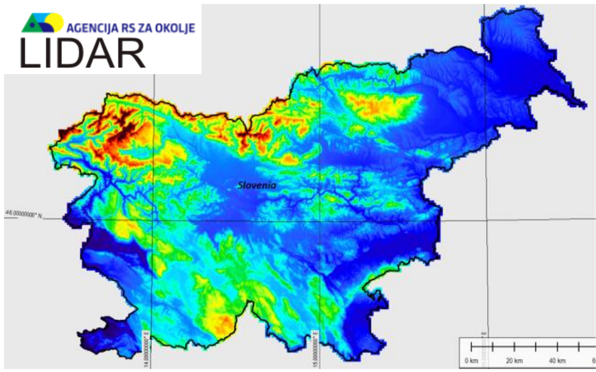
Gravity: old Potsdam Gravity System transformed to Absolute Gravity Systems (a few countries)

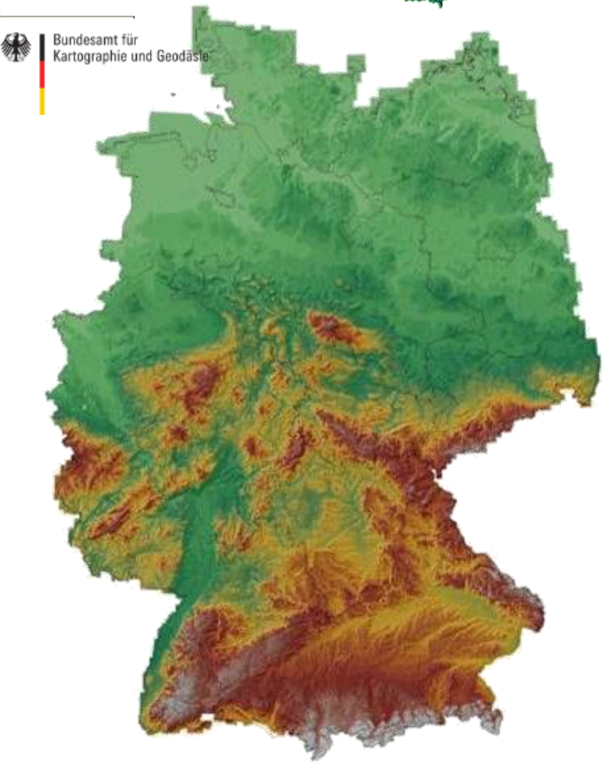
2. Getting available detailed elevation models

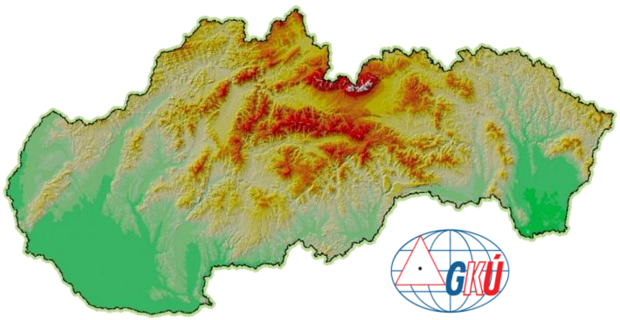
For most countries we were able to use local detailed DEMs with the resolution of 10 – 20 m for the nearest area.

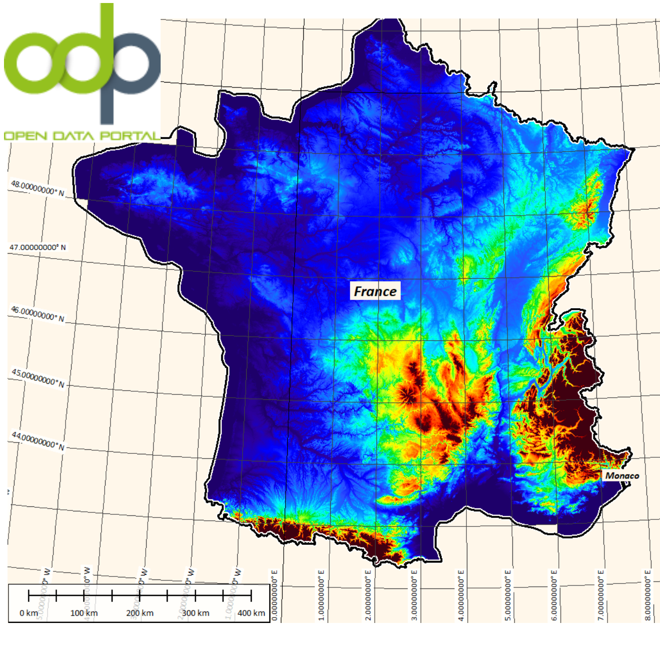






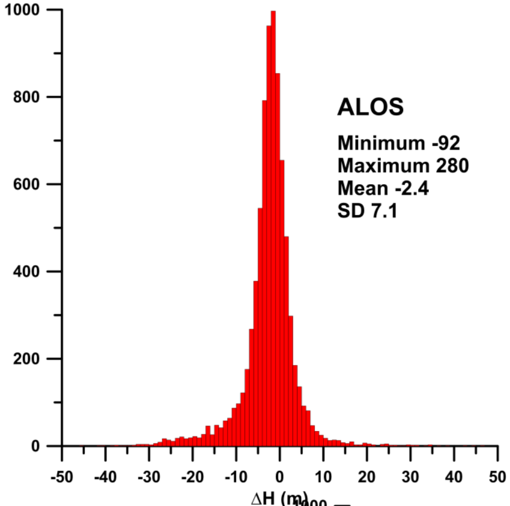


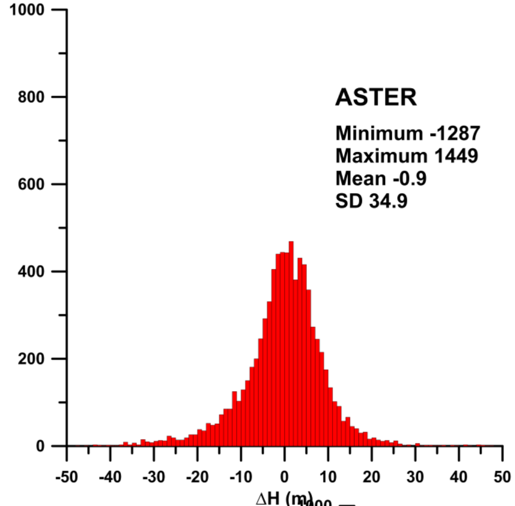


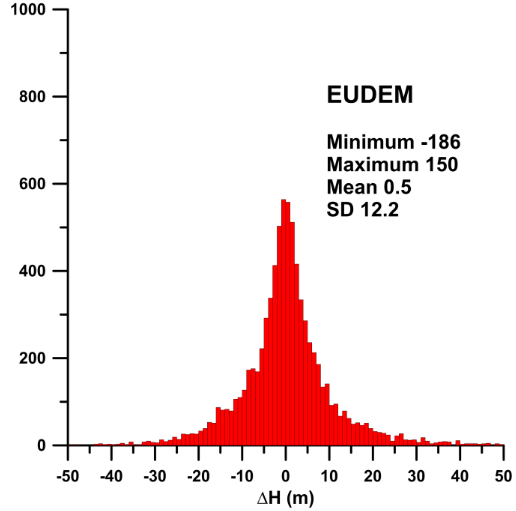


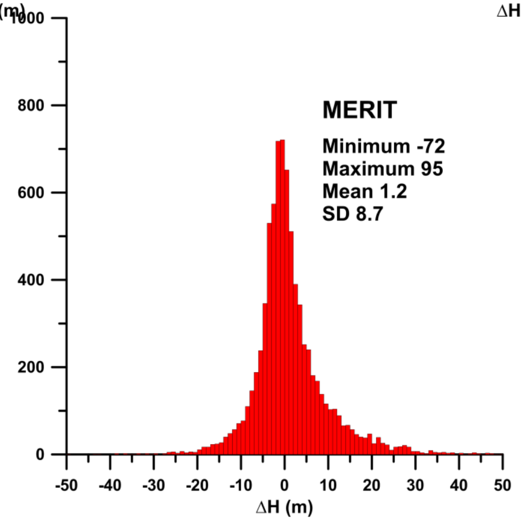
2. Getting available detailed elevation models

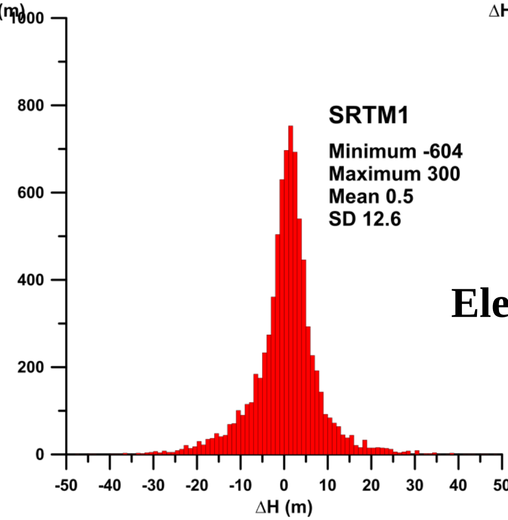
In the case of unavailability of local models, we had to choose the best available global DEM. MERIT model was selected based on the analysis.









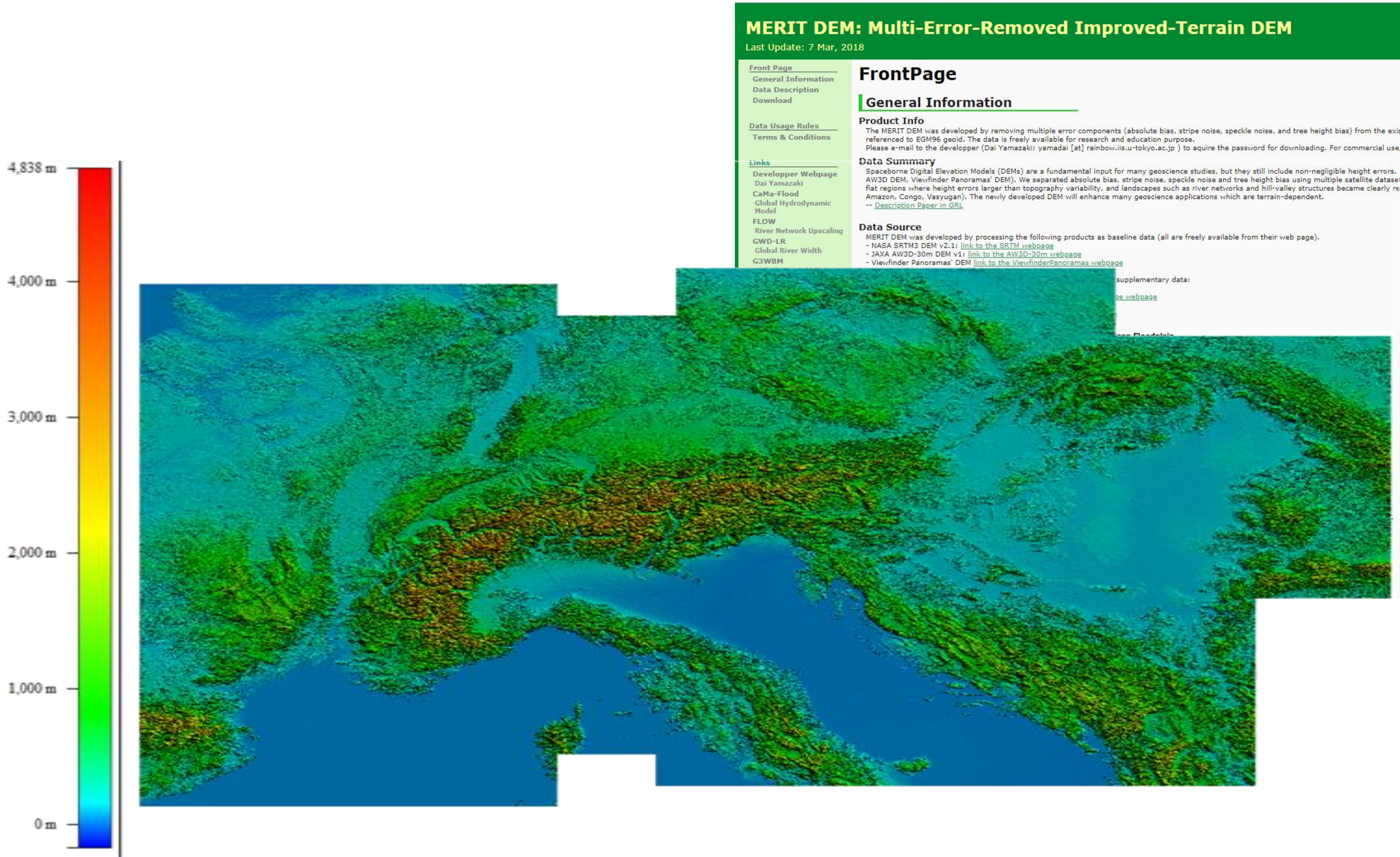


Elevation test - Swiss database

(7962 points)

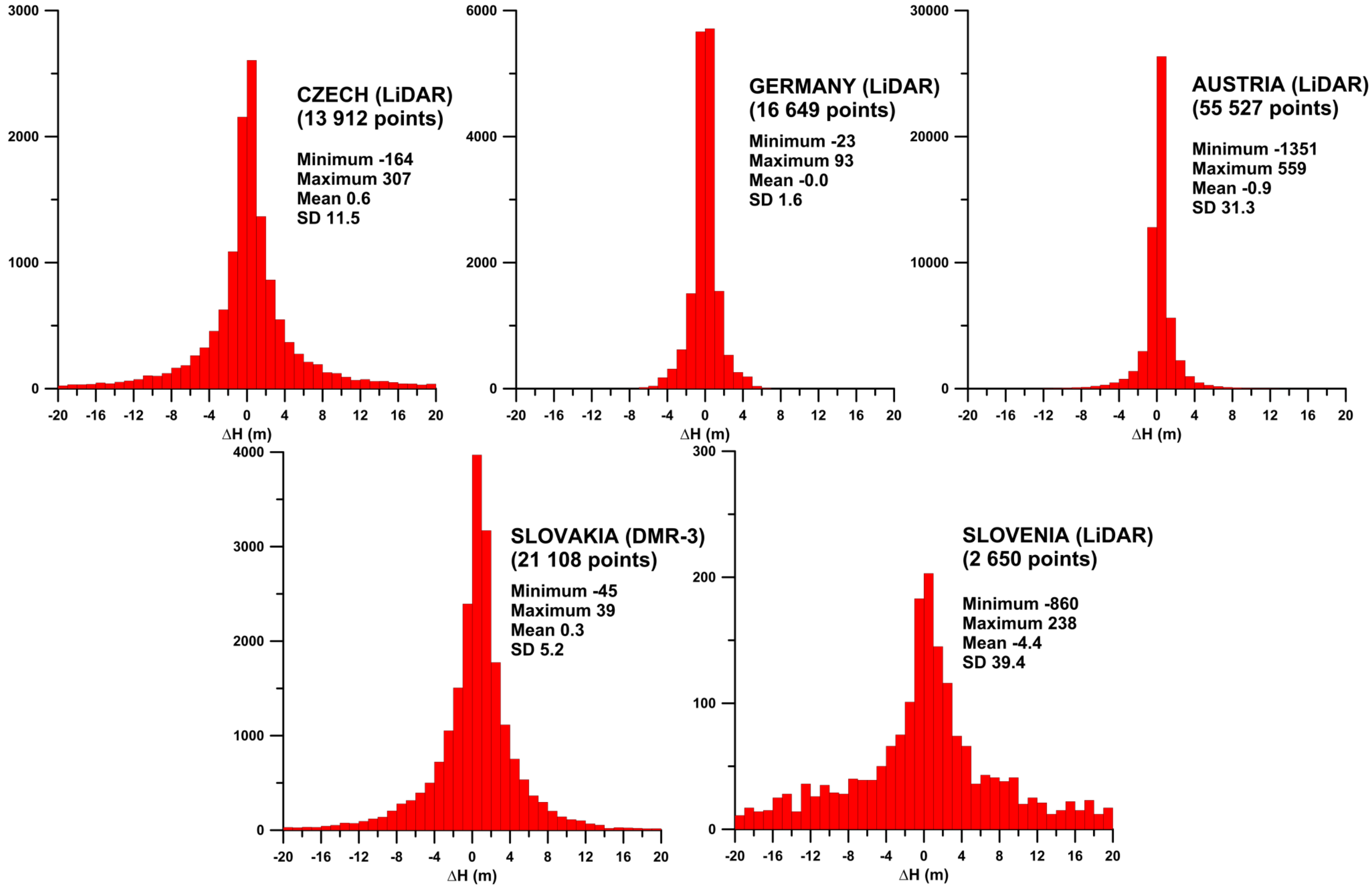
2. Getting available detailed elevation models

MERIT DEM – 3 sec (resampled to 1 sec / 25 m)



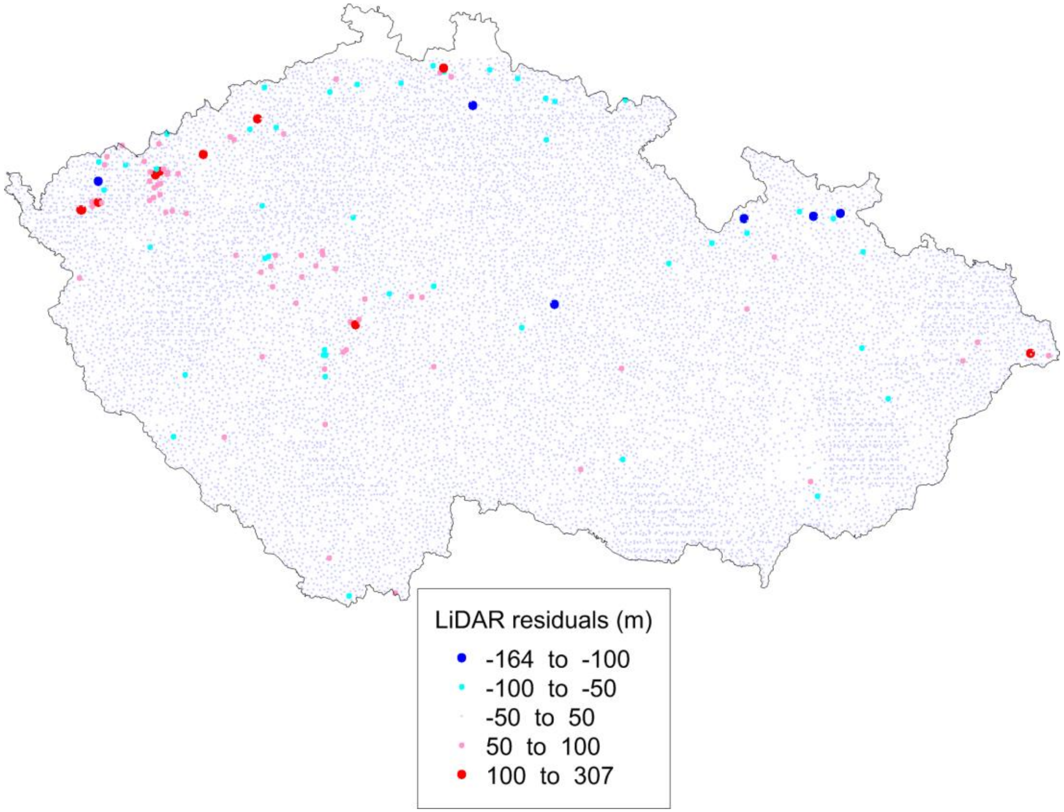
3. Quality control of input data

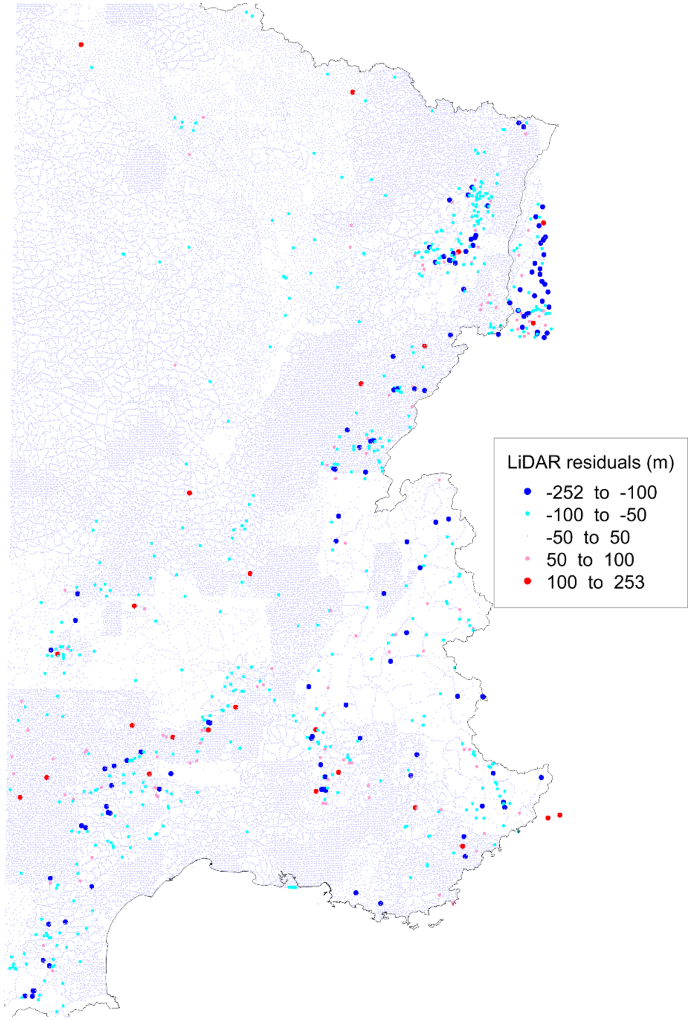
Quality control was performed based on the height differences between the point data and particular local elevation model.



3. Quality control of input data

Several thousand points with height residuals higher than chosen threshold (± 50 m) were excluded.

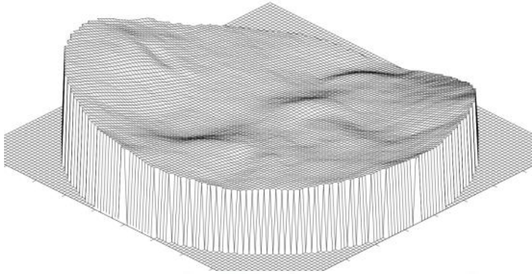




Quality control of input data – examples from the Czech and French databases

4. Mass correction calculation

Mass correction (topographic effect) calculated up to 166.7 km, density 2670 kg/m^3, ellipsoidal heights and ellipsoidal DEMs used



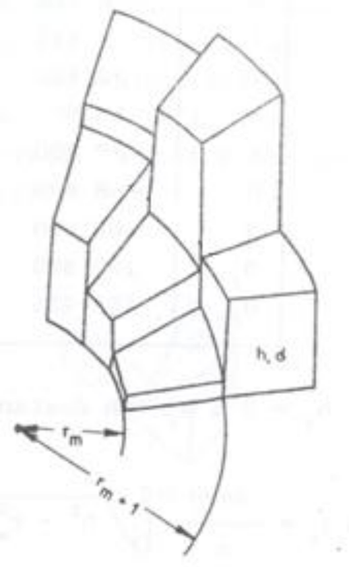
Program Toposk (Slovak group) – four concentric zones:

- inner zone T1 (0-250m) – 3D polyhedral body

- intermediate zone T2 (250-5240 m) – vertical cylinder segments

- outer zones T31 (5.24-28.8km) and T32 (28.8-166.7km) –

spherical layer segments



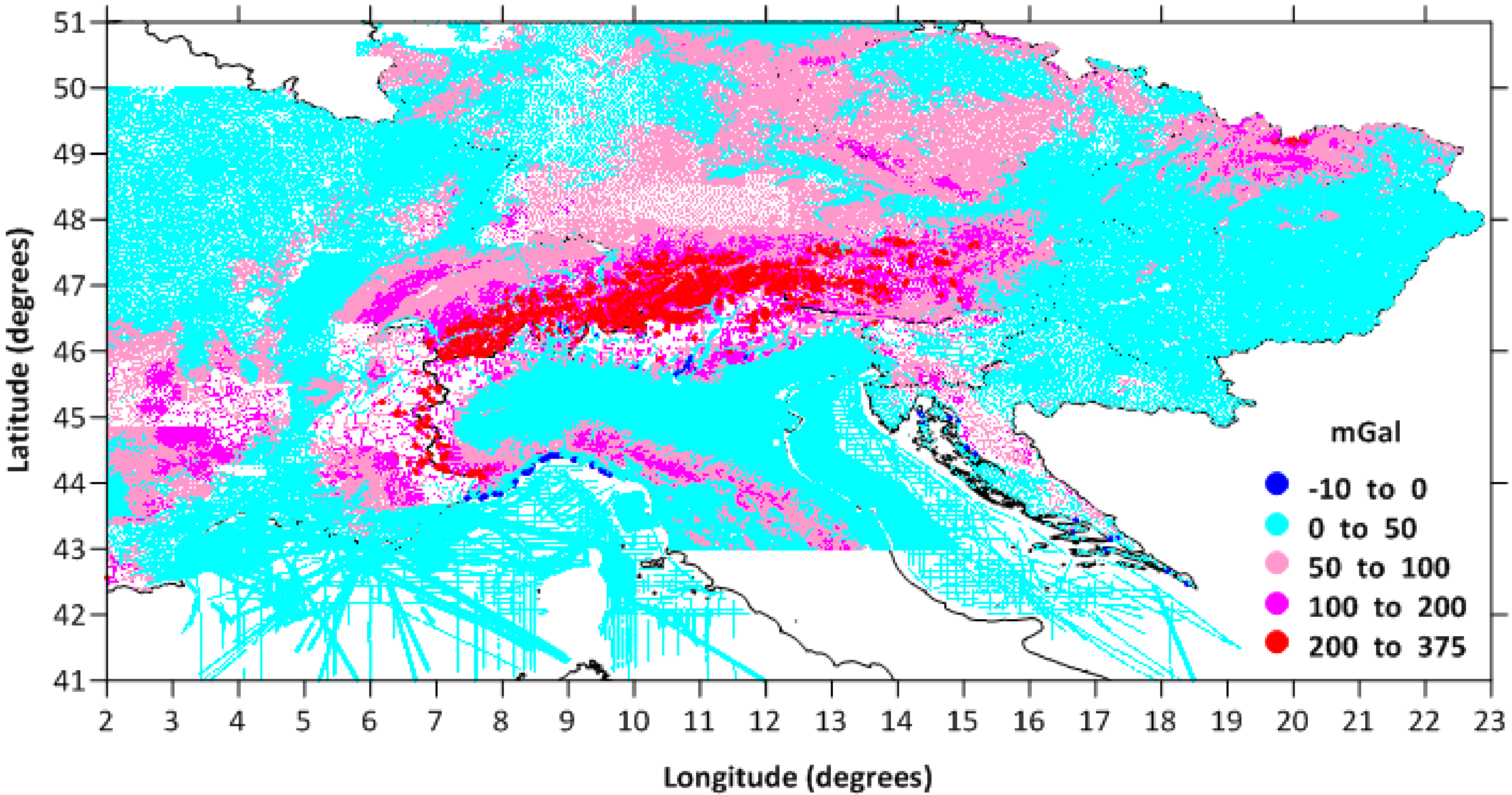
Inner zone (0-250m) - local DEMs (LiDAR) or MERIT (1x1 sec),

outer zones – MERIT (3x3 sec), SRTM (30x30 sec)

Independent comparison with TriTop software (German group) was performed in selected areas. A good coincidence was achieved.

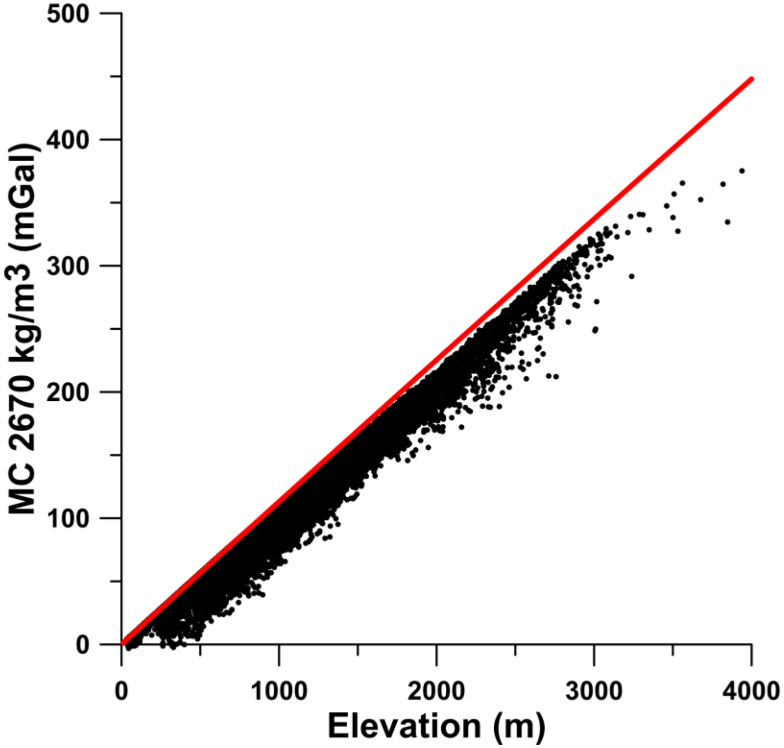
4. Mass correction calculation

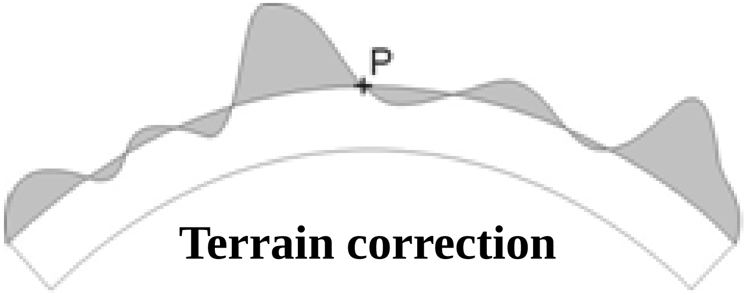
Mass corrections (density 2670 kg/m^3) reach values up to 375 mGal, with small negative values appearing along the coast or in deep valleys



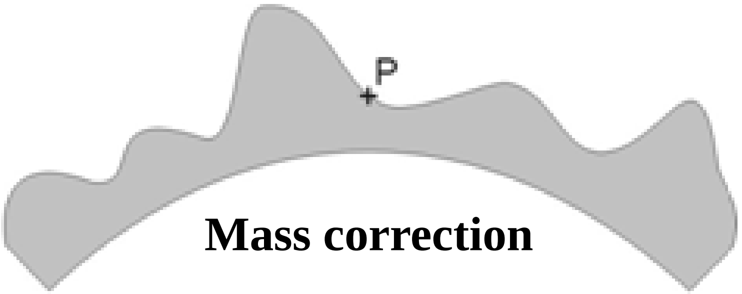
4. Mass correction vs. terrain correction

Mass corrections show obvious height dependence. Their differences from the gravitational effect of truncated spherical layer (= classic terrain correction) reach almost 100 mGal





Terrain correction

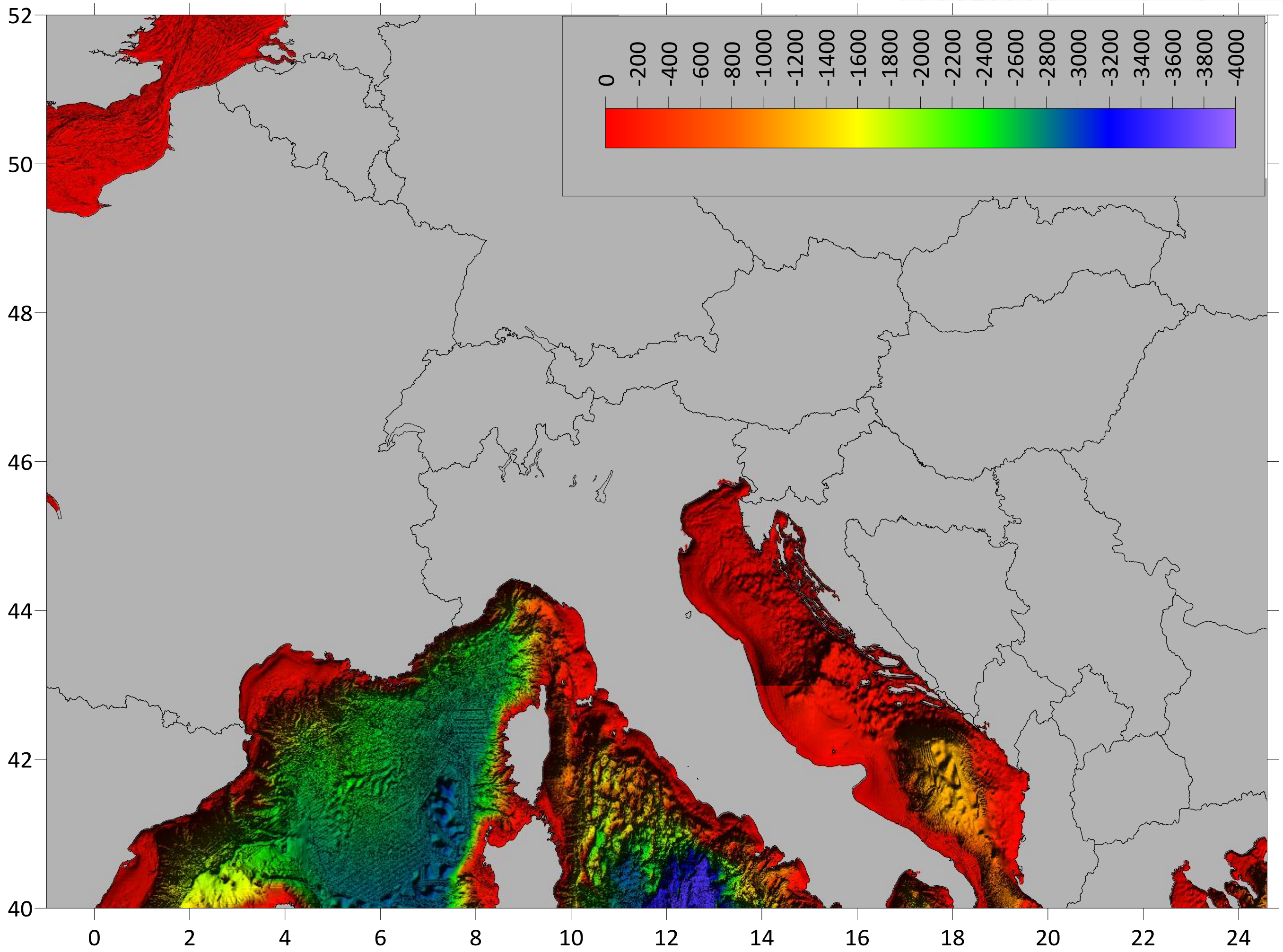


Mass correction

5. Bathymetric correction calculation

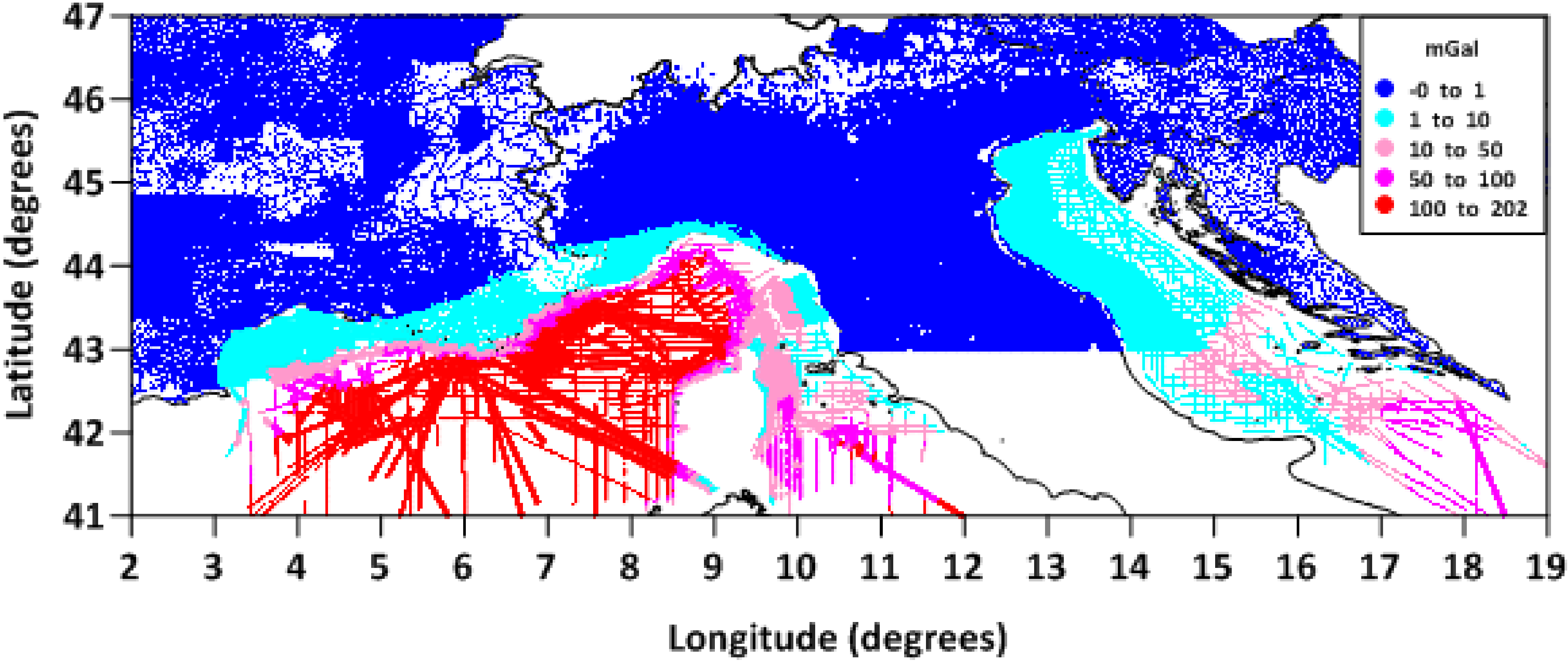
Bathymetric correction calculated up to 166.7 km, density -1640 kg/m^3, bathymetry model EMODnet - 3.75 sec used

EMODnet BATHYMETRY
Understanding the topography of the European seas



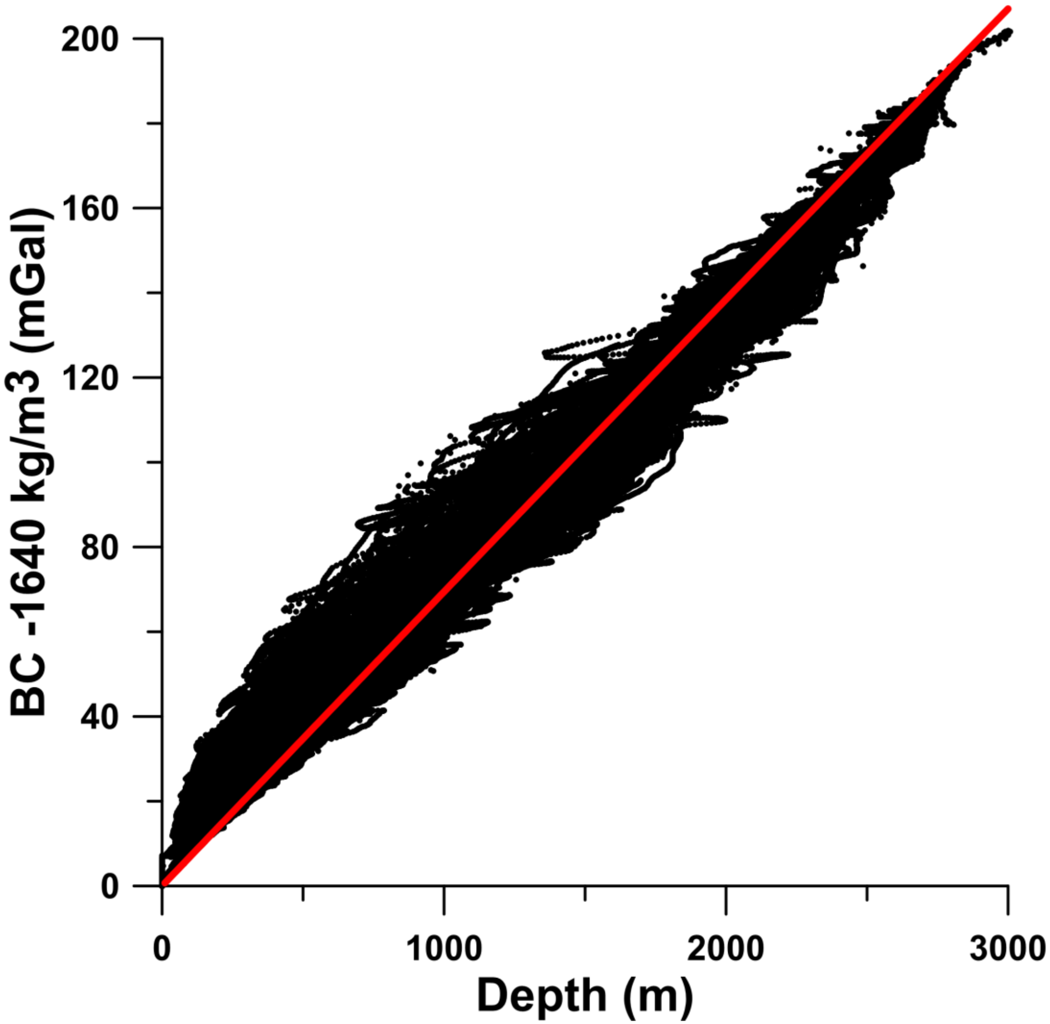
5. Bathymetric correction calculation

Bathymetric corrections (density -1640 kg/m^3) reach values up to 202 mGal (marine areas)



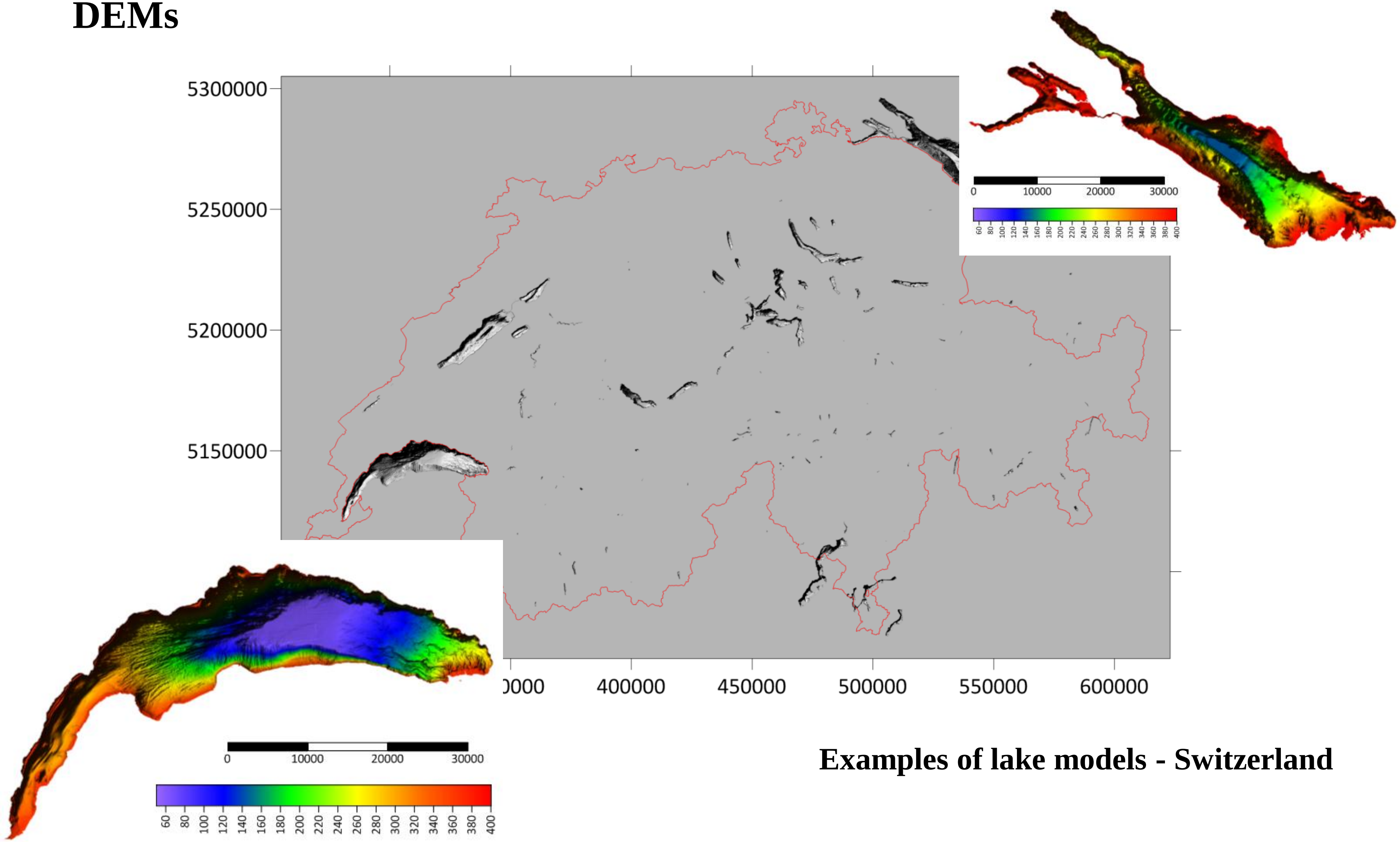
5. Bathymetric correction – Toposk vs. “Bouguer”approximation

Comparison of Toposk-calculated bathymetric correction and its simple “Bouguer” approximation shows relatively significant differences (± 30 mGal)



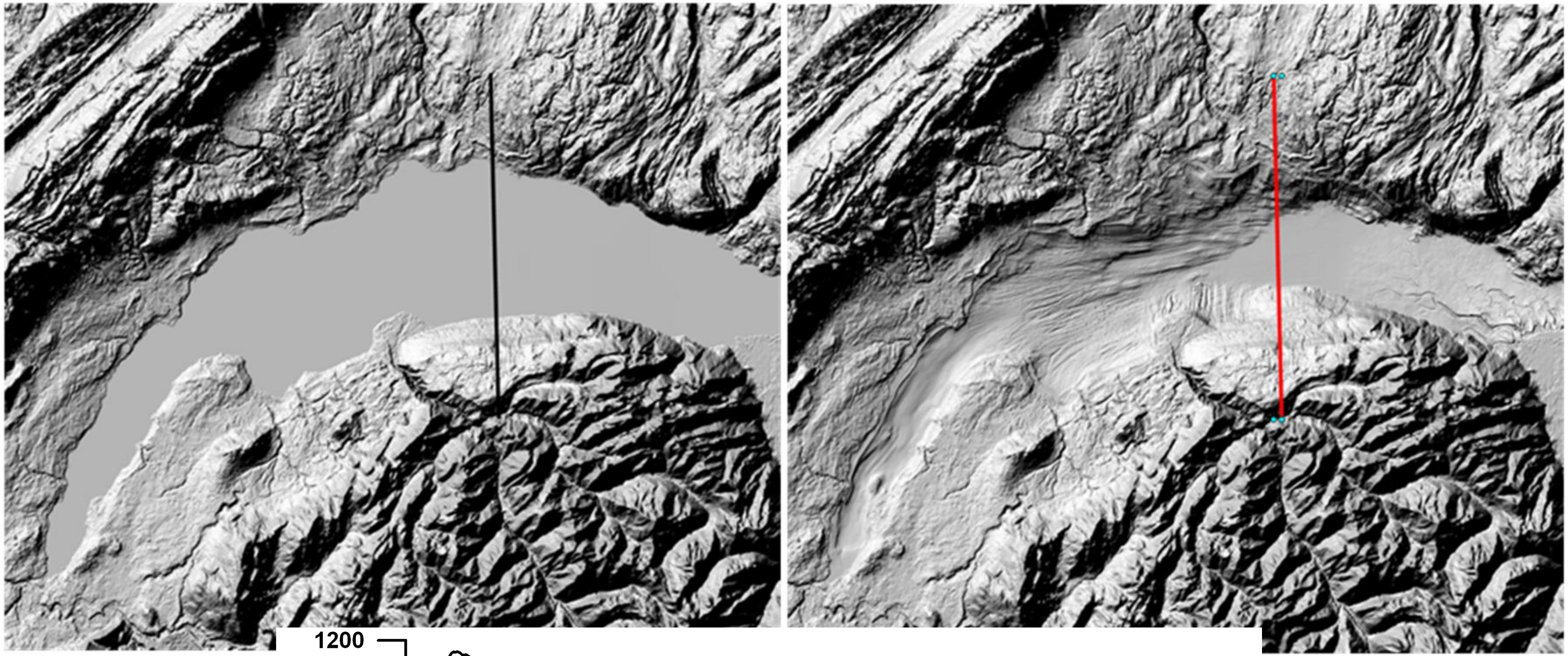
6. Lake corrections

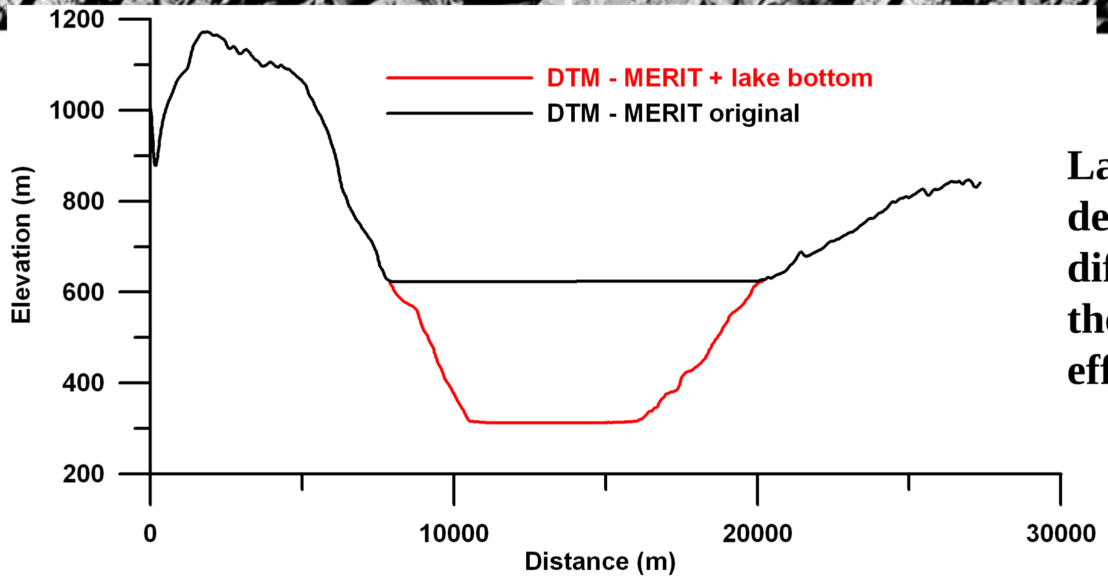
Local models of large alpine lakes were used in combination with existing DEMs



Examples of lake models - Switzerland

6. Lake corrections – calculation method

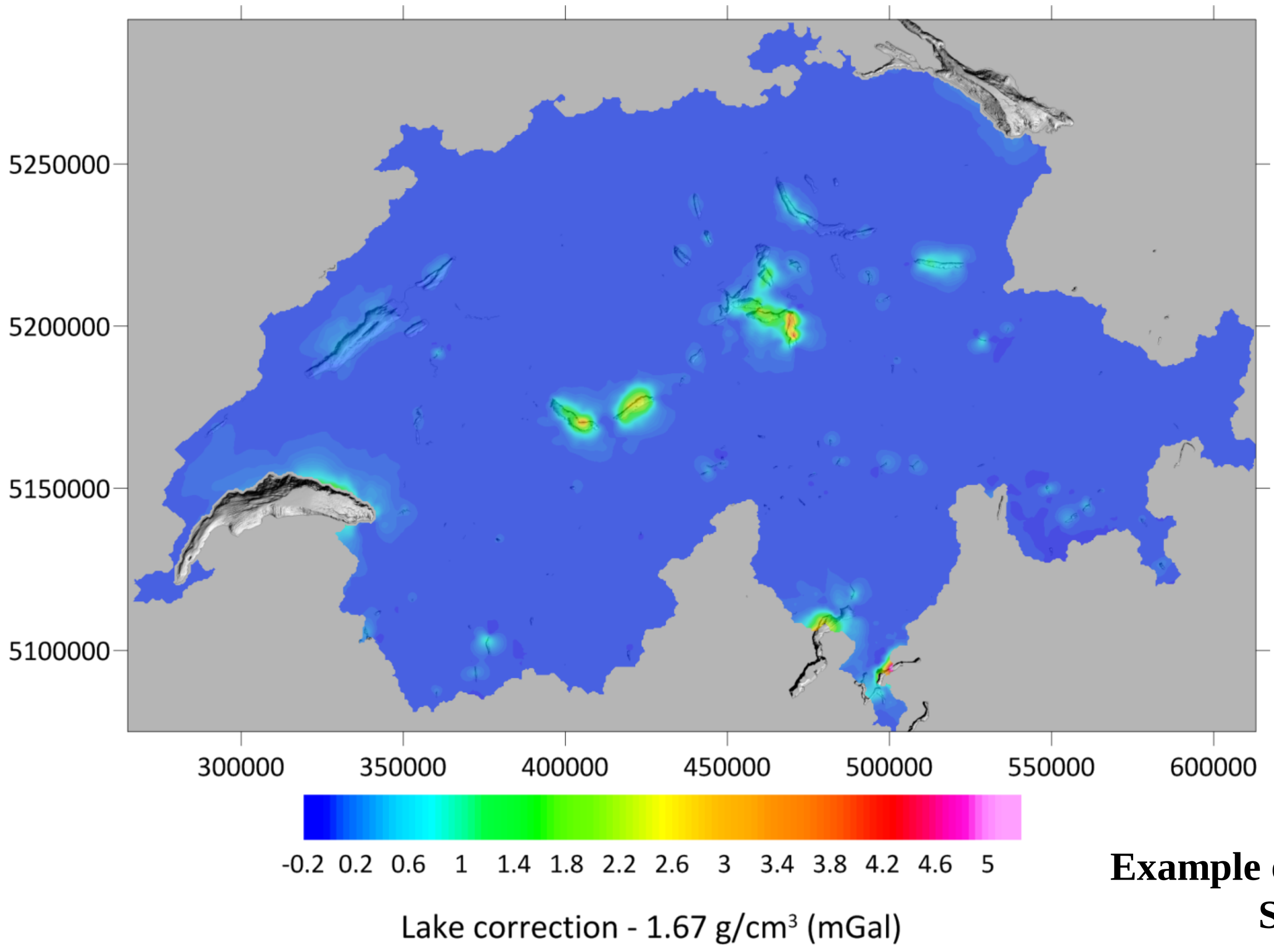




Lake correction is defined as the difference between the gravitational effect of two models

6. Lake corrections

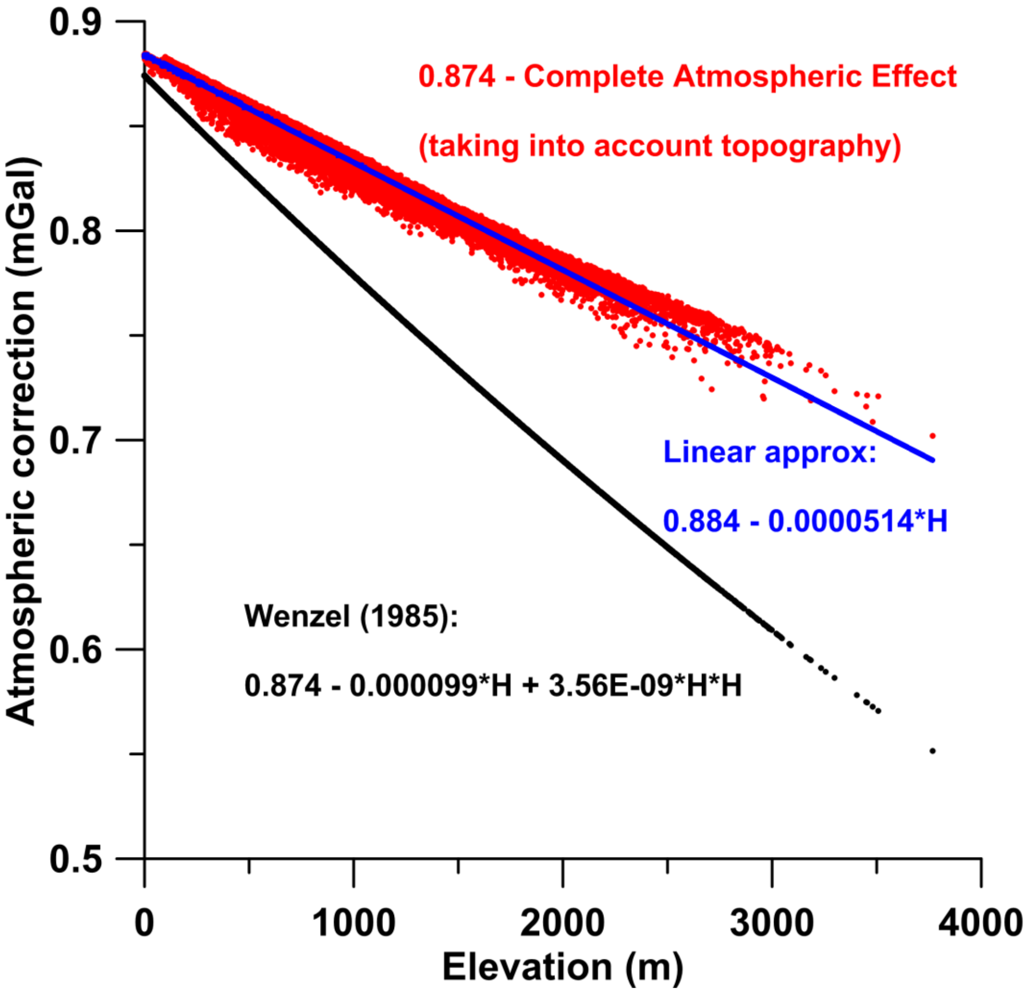
Lake corrections (density -1670 kg/m³) reach values up to approx. 5 mGal locally, with small negative values appearing in deep valleys (below lake level)



Example of lake corrections - Switzerland

7. Atmospheric correction – comparison of different approaches

Atmospheric correction based on the real atmosphere model taking into account real topography (after Mikuška et al. 2008); maximum differences of about 0.15 mGal compared to the classical approach (Wenzel, 1985).



8. Complete Bouguer anomaly calculation

Basic formula is adopted from the paper Meurers et al. (2001), with small changes:

$$BA(\lambda, \varphi, h_E) = g(\lambda, \varphi, h_E) - \gamma(\varphi, h_E) - \delta g_M(\lambda, \varphi, h_E) + \delta g_B(\lambda, \varphi, H) + \delta g_A(\lambda, \varphi, H), \qquad (1)$$

where: g() – observed absolute gravity acceleration value, γ() – normal gravity acceleration at height h_E, δg_M() – mass correction (gravitational effect of topographical masses) for density 2670 kg/m³, δg_B() – bathymetric correction for density 1640 kg/m³, δg_A() – simplified atmospheric correction, λ – longitude (ETRS89), φ – latitude (ETRS89), h_E – ellipsoidal height (GRS80), H – physical height.

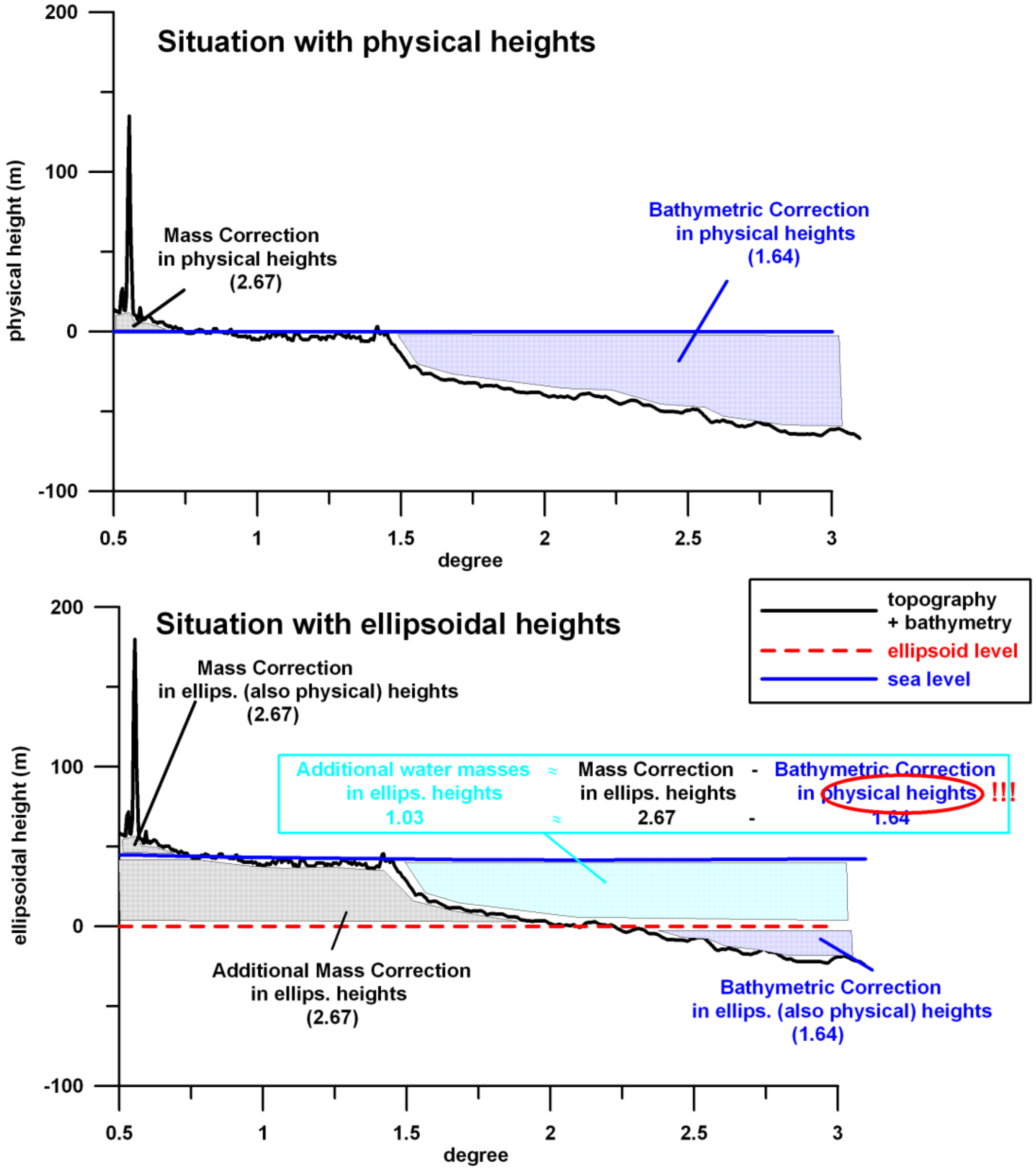
Normal gravity acceleration $\gamma(\lambda, \varphi, h_E)$ results from a Taylor series expansion to the 2nd order both in height and also geometrical flattening (Wenzel 1985, Li and Götze 2001):

$$\gamma(\varphi, h_E) = \gamma_0(\varphi) + \left.\frac{\partial \gamma}{\partial h_E}\right|_0 h_E + \frac{1}{2}\left.\frac{\partial^2 \gamma}{\partial h_E{}^2}\right|_0 h_E{}^2 \;, \qquad (2)$$

where γ_0() is the well-known Somigliana formula for the normal gravity acceleration of a rotational ellipsoid at its surface (Somigliana 1929, Heiskannen and Moritz 1967):

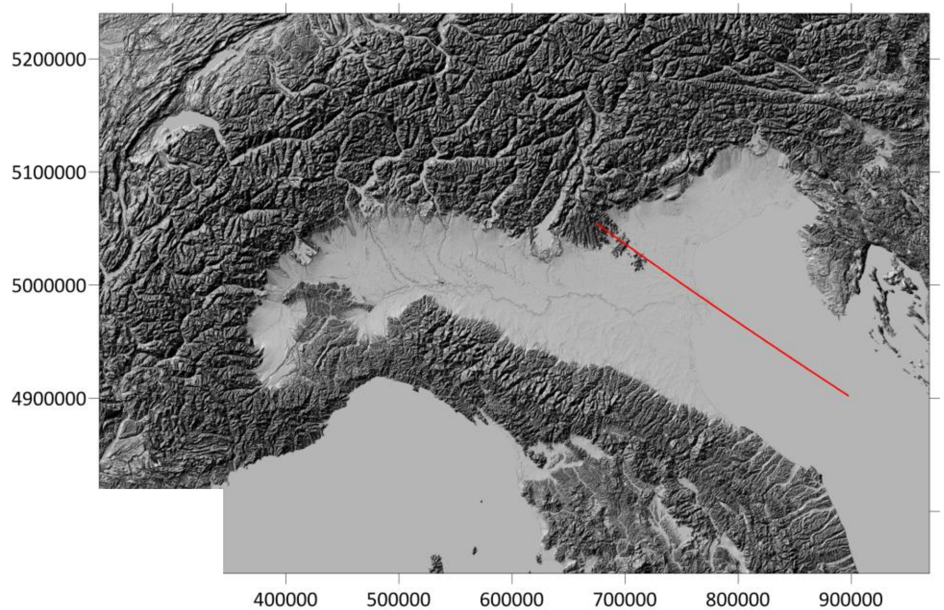
Innovative concept of ellipsoidal heights was used

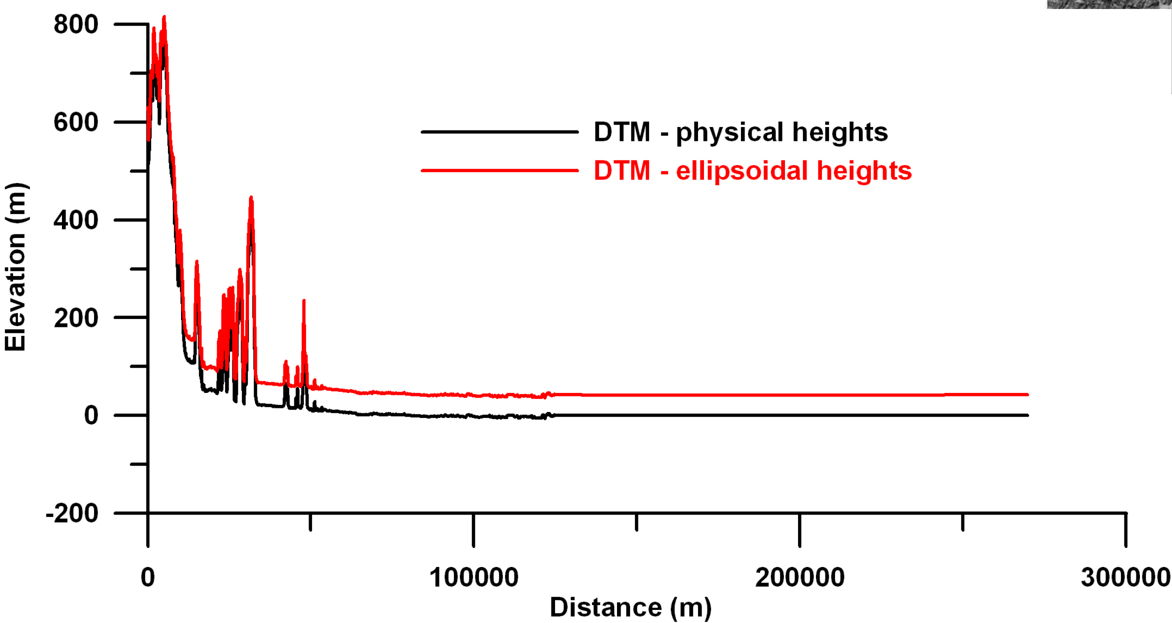
8. Ellipsoidal vs. physical heights concept



8. Ellipsoidal vs. physical heights concept

Additional topography/water masses need to be carefully considered (with the right density), depending on DEMs used



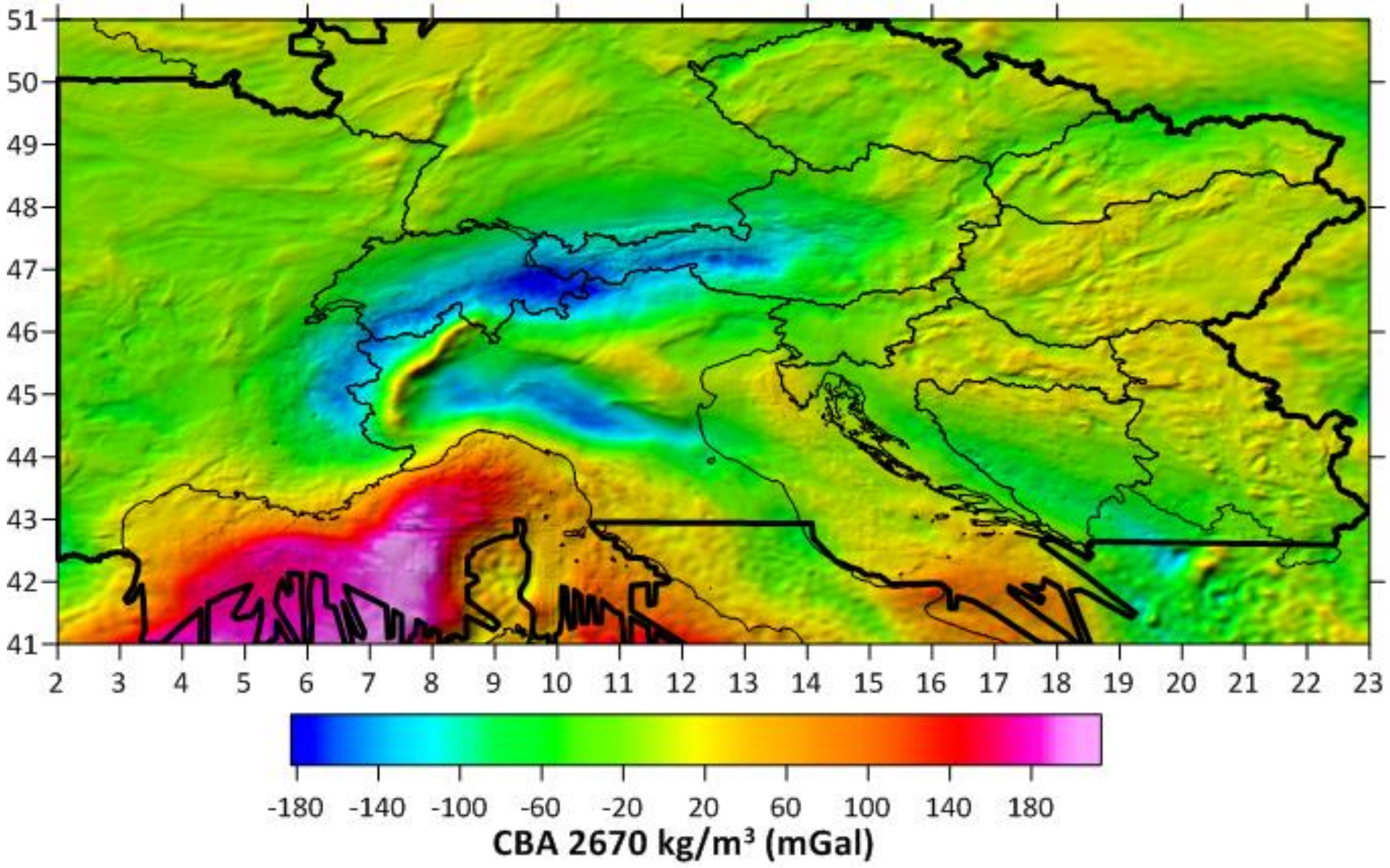


9. Merging individual databases into a single map

First version of the merged CBA map prepared.

Part of the former Yugoslavia was filled by digitizing an old CBA map

Peripheral areas (outside the thick black line) filled with data derived from EIGEN-6C4



AlpArray Gravity Research Group:

Miroslav Bielik – Comenius University, Slovakia

Sylvain Bonvalot, Lucia Seoane – Geosciences Environment Toulouse, France

Carla Braitenberg, Alberto Pastorutti – University of Trieste, Italy

Jörg Ebbing, Hans-Jürgen Götze, Nils Holzrichter, Josef Sebera –Kiel University, Germany

Gerald Gabriel, Peter Skiba – Leibniz Institute for Applied Geophysics, Germany

Andrej Gosar – Slovenian Environment Agency, Slovenia

György Hetényi, Matteo Scarponi – University of Lausanne, Switzerland

Edi Kissling – ETH Zurich, Switzerland

Urs Marti – Federal Office of Topography swisstopo, Switzerland

Bruno Meurers – University of Vienna, Austria

Jan Mrlina – Czech Academy of Sciences, Czech Republic

Pavel Novák – University of West Bohemia, Czech republic

Eszter Szűcs – Geodetic and Geophysical Institute, Hungary

Matej Varga – University of Zagreb, Croatia

Thank you for your attention!