European Alps Gravity Model 2011 (EurAlpGM2011)

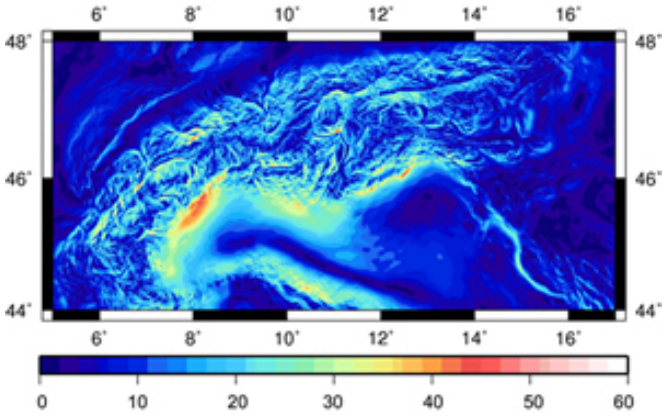


Fig. 1 Total vertical deflection at 12,000,000 points over the European Alps, unit in arc seconds. Maximum vertical deflections are expected to be about or in excess of 50 arc seconds near 46.590°N, 8.010°E.

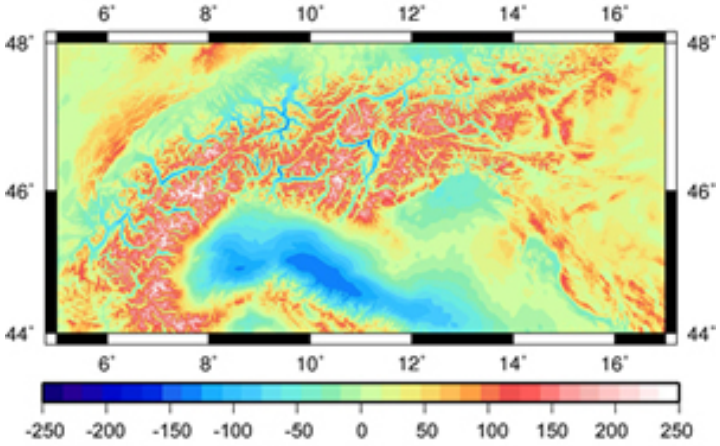


Fig. 2 Gravity disturbances at 12,000,000 points over the European Alps, unit in mGal.

General

EurAlpGM2011 (Hirt 2012) is a high-resolution description of the gravity field over the European Alps. It is constructed as composite model using EGM2008 (Pavlis et al. 2008) in spectral band of spherical harmonic degrees 2 to 2190 and topography-implied gravity effects from residual terrain model (RTM, Forsberg 1984) data beyond harmonic degree 2190.

The innovation of EurAlpGM2011 lies in the use of a new approach for the evaluation of EGM2008 gravity functionals at densely-spaced points at the Earth's topography, as represented through the SRTM elevation model. The so-called gradient approach, an efficient and accurate technique for high-degree SHS at multiple points at the Earth's surface, was used to incorporate

SRTM data into the spherical harmonic synthesis of EGM2008. For a detailed description see Hirt (2012).

EurAlpGM2011 is the sum of EGM2008 and the RTM functionals which serve as high-frequency augmentation beyond the EGM2008 resolution, at spatial scales of ~5 arc minutes to ~7 arc seconds. EurAlpGM2011 products include total vertical deflection over the European Alps (Fig 1) and gravity disturbances (Fig 2) at unprecedented resolution of 7.2 seconds (~220 m in latitude and ~155 m in longitude). The pictures provide an impression of the expected gravity field over an Alpine region, at all spatial scales.

Construction of EurAlpGM2011

EurAlpGM2011 relies on the SRTM release 4.1 by Jarvis et al. (2008). The 250 m resolution version of this data set was used in the evaluation of EGM2008 with the gradient approach, and the construction of RTM data. The latter was derived by subtracting Pavlis et al. (2007)'s DTM2006 spherical harmonic elevations expanded to degree 2160. EGM2008 functionals and as well as their first- to third-order radial derivatives were computed in spectral band 2 to 2190 at a mean reference height of 2 km above the GRS80 reference ellipsoid. Taylor series expansions described in Hirt (2012) [Eqs. (15), (18), (19) and (20) ibid] were evaluated along with the SRTM-derived ellipsoidal heights of the Alpine topography to third-order to precisely account for the effect of gravity attenuation with height. The conversion of RTM elevations to RTM gravity functionals is based on brute-force numerical prism integration of

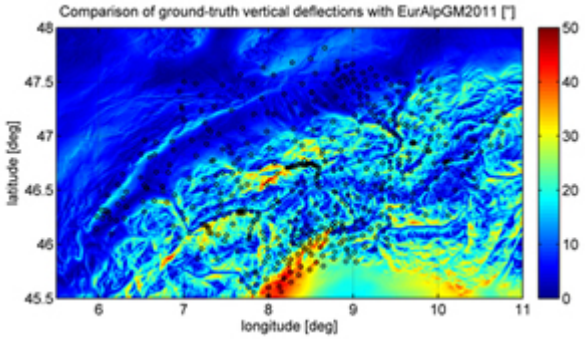
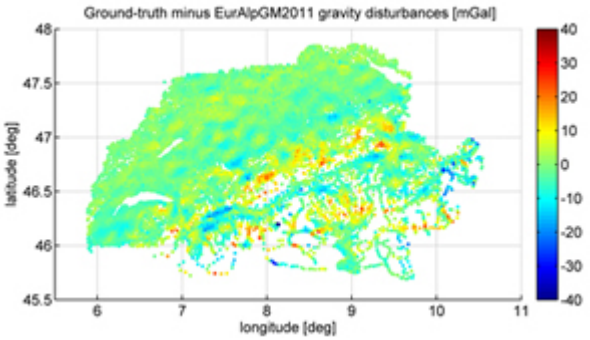


Fig. 3 Comparison between EurAlpGM2011 and observed total vertical deflections at 690 stations over Switzerland. Background image: EurAlpGM2011 total vertical deflections, Overlay: observed astrogeodetic deflections (data courtesy Swiss Geodetic Commission,



swisstopo, ETH Zurich). Unit in arc seconds. Fig. 4 Comparison between EurAlpGM2011 and observed gravity disturbances at 31,598 gravity stations over Switzerland (data courtesy Swiss Geodetic Commission, swisstopo). Unit in mGal gravity-effects using Forsberg's TC-software (Forsberg 1984), along with a constant mass-density assumption of 2670 kg m^{-3}, the assumption of uncompensated high-frequency topography, and an integration radius of 200 km for each computation point (see Hirt 2010, Hirt et al. 2010). The RTM functionals are denoted ERTM2160 (Earth RTM functionals with spectral information to ellipsoidal harmonic degree 2160 removed).

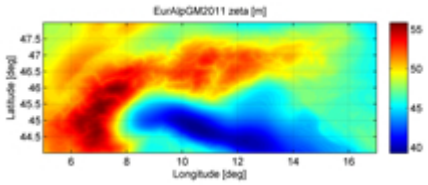
Accuracy and Applications

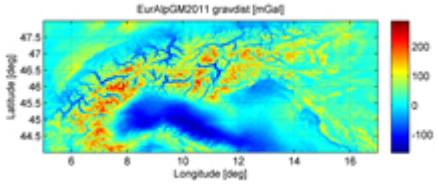
EurAlpGM2011 is a medium-accuracy gravity field that attempts to describe the entire gravity spectrum over the European Alps. The model agrees with ground-truth data at the level of few cm (quasigeoid heights), ~1.3 arc seconds (vertical deflections), and ~5 mGal (gravity disturbances), see also Hirt (2012). Fig. 3 shows the agreement of EurAlpGM2011 surface vertical deflections with astrogeodetic observations, and Fig. 4 compares EurAlp2011 gravity disturbances from terrestrial gravimetry over Switzerland.

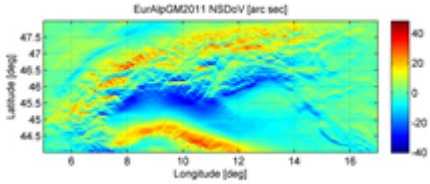
EurAlpGM2011 and its construction principles can be suitable, e.g., for planning of gravity field surveys, detection of gross errors in gravity data bases, GNSS (global navigation satellite system)-based height transfer, reduction of survey data or computation of levelling reductions without the need to perform field observations.

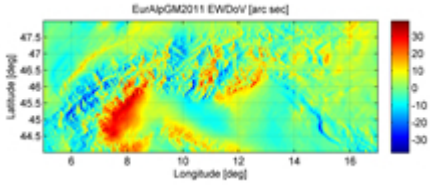
EurAlpGM2011 products

EurAlpGM2011 is provided as set of 15 files of gravity field functionals that resolves quasigeoid heights, gravity disturbances and vertical deflections at the Earth’s surface down to the resolution of the elevation data used. The main products are

- 

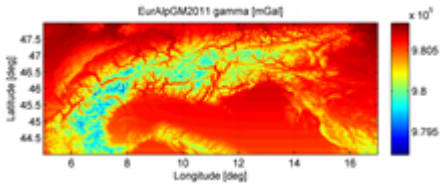
Click for larger image EurAlpGM2011 quasigeoid heights (sum of EGM2008 band of spherical harmonic degrees 2 to 2190 and ERTM2160 quasigeoid heights, unit in mm)
- 

Click for larger image EurAlpGM2011 gravity disturbance (sum of EGM2008 band 2 to 2190 and ERTM2160 gravity disturbances, unit in 0.1 mGals)
- 

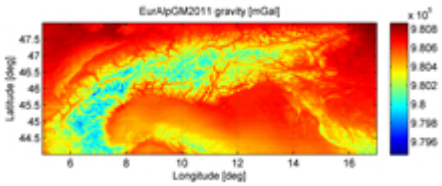
Click for larger image EurAlpGM2011 North-South vertical deflection (sum of EGM2008 band 2 to 2190 and ERTM2160 N-S deflections, unit in 0.1 arc seconds)
- 

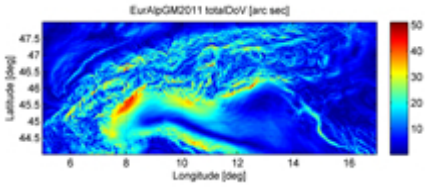
Click for larger image EurAlpGM2011 East-West vertical deflection (sum of EGM2008 band 2 to 2190 and ERTM2160 N-S deflections, unit in 0.1 arc seconds)

Specifically the maps of the gravity disturbances and vertical deflections show the high spatial variability of the entire Alpine gravity field. Also available are

- 

Click for larger image normal gravity (at the surface of terrain as defined by the SRTM ellipsoidal heights, unit of normal gravity in 0.1 mGal)

- 

Click for larger image surface gravity accelerations (sum of normal gravity and EurAlpGM2011 gravity disturbances,unit in 0.1 mGal)
- 

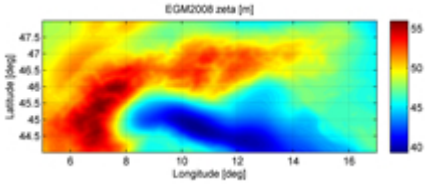
Click for larger image total vertical deflections (defined as square-root of the sum of squared EW and NS deflections, unit in 0.1 arc seconds) EurAlpGM2011_totalDOV.unit_tenthsofarcsec.7.2s.int16

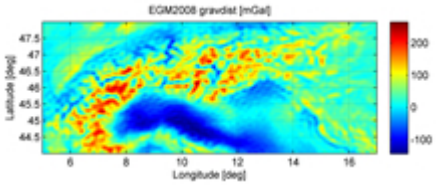
EurAlpGM2011 input data sets

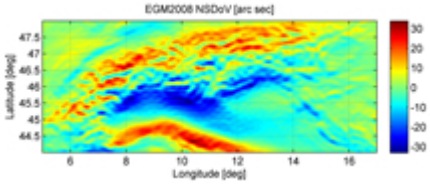
The input components used to construct the EurAlpGM2011 can be downloaded here:

EGM2008 functionals

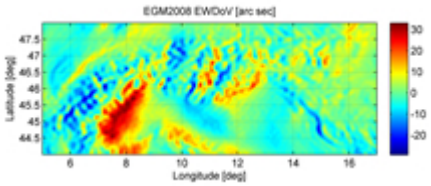
Functionals were evaluated in spectral band 2 to 2190 at the SRTM topography

- 

Click for larger image EGM2008 quasigeoid height(unit mm)
- 

Click for larger image EGM2008 gravity disturbance (unit 0.1 mGal)
- 

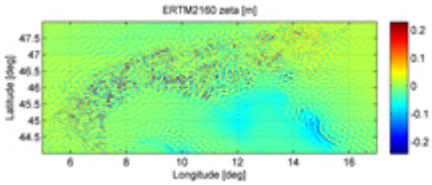
Click for larger image EGM2008 North-South deflection(unit 0.1 arc seconds)

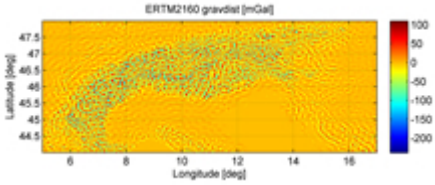
- 

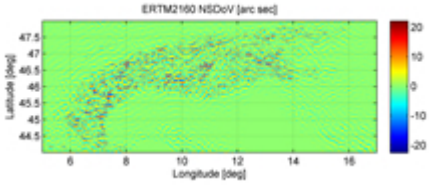
Click for larger image EGM2008 East-West deflection (unit 0.1 arc seconds) EGM2008_EWDOV.atTopo.unit_tenthsofarcsec.7.2s.int16

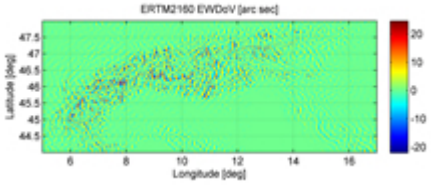
ERTM2160

The ERTM2160 forward-modelled functionals contain information on the gravity field at spatial scales of ~5 arc minutes to ~7 arc seconds. The following files can be used to augment EGM2008 beyond ellipsoidal harmonic degree 2160 (corresponding to spherical harmonic degree 2190)

- 

Click for larger image ERTM2160 quasigeoid height (unit mm)
- 

Click for larger image ERTM2160 gravity disturbance (unit 0.1 arc seconds)
- 

Click for larger image ERTM2160 North-South deflection (unit 0.1 arc seconds)
- 

Click for larger image ERTM2160 East-West deflection (unit 0.1 arc seconds)

File format and software

File format description

Each data file contains 2,000 x 6,000 =12,000,000 values. The grid resolution is 0.002 degree (7.2 arc seconds) with the grid equally spaced in terms of geodetic (GRS80) latitude and longitude. The area covered is

44.001 to 47.999 degree geodetic latitude,
5.001 to 16.999 degree geodetic longitude.

Records proceed along meridians from South to North and columns proceed from West to East. The first record is the South-West corner (44.001 deg latitude, 5.001 deg longitude), and the last record is the North-East corner (47.999 deg latitude, 16.999 deg longitude).

Depending on the dynamic range of each file, data is stored either in 2-byte integer big-endian format (int16, ieee-be), or 4-byte big-endian format (int32, ieee-be), whereby the file's storage format is included in the assigned filenames. The file sizes are 23.4 MB for int16 and 46.9 MB for int32 formats.

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Software to read EurAlpGM2011 data files

Here we provide a simple Matlab-script that can be used to read and display the 15 EurAlpGM2011 product and input files, and customized by users for further use.

- Matlab-script to access EurAlpGM2011 data files

Contact and Feedback

For further information or if you want to provide feedback please contact Christian Hirt

References

- Forsberg R (1984) A study of terrain reductions, density anomalies and geophysical inversion methods in gravity field modelling. Report 355, Department of Geodetic Science and Surveying, Ohio State University, Columbus
- Jarvis A, Reuter HI, Nelson A Guevara E (2008) Hole-filled SRTM for the globe Version 4. Available from the CGIAR-SXI SRTM 90m database: http://srtm.csi.cgiar.org
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