
SRTM2gravity topographic gravity/terrain correction model - Readme file v2

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1. SUMMARY
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1.1 What is SRTM2gravity?

SRTM2gravity is a global gravity map with 3" spatial resolution. It represents the gravity field generated by the MERIT topography model and a mass-density assumption of 2670 kg m^(-3). The model can be viewed as a topographic gravity model and a model of gravimetric terrain corrections. Different to "standard" terrain corrections, our model represents the total gravitational signal of the Earth's global topography in spherical approximation, and is not limited to, e.g., 167 km zones, as is the case in classical terrain corrections.

The SRTM2gravity model is an improved successor of the gravity component of the ERTM2160 short-scale gravity model (Hirt et al. 2014 Comp. Geosc.), and a precursor for a future update of the GGMplus gravity maps (Hirt et al. 2013, GRL). The improvements of SRTM2gravity over previous efforts are threefold: improved methodology, improved data and improved resolution (see Hirt et al. 2019 for details).

1.2 Citation:

Hirt, C., M. Yang, M. Kuhn, B. Bucha, et al. (2019), SRTM2gravity: A 3" resolution global model of complete gravimetric terrain corrections, submitted to Geophysical Research Letters.

1.3 Permanent link to the SRTM2gravity data sets and paper

http://ddfe.curtin.edu.au/models/SRTM2gravity2018

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2. DATA and METHODS used for SRTM2gravity
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2.1 INPUT DATA

SRTM2gravity is based on the MERIT (Multi-Error-Removed Improved-Terrain) DEM (digital elevation model) data set Version v1.0.1 by Yamazaki et al.(2017). MERIT primarily relies on SRTM elevations. It also uses Viewfinder Panorama data for SRTM hole-filling and AW3D elevations in high latitudes (north of 60°). The SRTM tree-canopy signal and other error sources have been reduced by Yamazaki et al. (2017), which is why MERIT represents the bare-ground in good approximation. A total of 120 elevation outliers have been removed by Hirt (2018) prior to our forward modelling.

2.2 PROCESSING PROCEDURES

In brief, the SRTM2gravity model is a transformation of SRTM heights to implied gravity effects via evaluation of Newton's integral. We combined state-of-the-art spectral and spatial domain techniques for efficient yet accurate computation of

gravity effects. Important aspects:
- A uniform mass-density of 2670 kg/m3 was adopted in all computations.
- Any of the ~28 billion computation points resides at the surface of the MERIT topography, that is, where gravity can be measured at the terrain surface.

More details are described in detail in Hirt et al. (2019). A pdf is available via http://ddfe.curtin.edu.au/models/SRTM2gravity2018/Hirt2019_SRTM2gravity.pdf

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3. SRTM2gravity PRODUCTS, FILE FORMATS AND DIRECTORIES

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3.1 What's available?

1) FullScaleGravity: Gravimetric terrain corrections reflecting the gravitational attraction of Earth's global topography. If you want to remove the (total) topographic effect from gravity measurements, that's the right product.

2) ResidualGravity: High-frequency gravity effects reflecting the gravitational attraction of Earth's global topography residual to a degree-2160 spherical-harmonic reference surface. If your application is the refinement of gravity from GGMs such as EGM2008 at scales less than 10 km, then that's your product.

Note: The difference between both products is the gravitational attraction of the degree-2160 MERIT topography in spectral band of degrees 0 to 2160, evaluated at the 3" MERIT topography.

3.2 Accuracy

The overall computational accuracy of the SRTM2gravity transformation has been estimated to be at the level of 0.1 to 0.2 mGal. This estimate stems from a comparison of SRTM2gravity full-scale gravity with gravity from global numerical integration of topographic mass-density effects over test areas around the globe, and assumption that the approximation errors are comparable over areas with similar topography. Over extremely rugged terrain (Himalayas), the accuracy is reduced to the level of ~1.0 mGal, and over Alpine terrain (such as European Alps or Rocky Mountains), the accuracy level is ~0.5 mGal. Over rather gently undulating terrain (such as the Australian Alps), the accuracy is ~0.1-0.2 mGal. For any area with smoother topography than that of the Australian Alps, ~0.1 mGal accuracy can be expected.

3.3 Directories

The SRTM2gravity data is organised in directories as follows.

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/data                    .. directory for all SRTM2gravity data files
  |--> FullScaleGravity  .. subdir with gravimetric terrain corrections
       |--> N00E060      .. subdirs containing data files for 30 deg regions
       |--> N00E090
        ...                    a total of 59 subdirs
       |--> S60E120

  |--> ResidualGravity   .. subdir with high-frequency gravity values
       |--> N00E060      .. subdirs containing data files for 30 deg regions
       |--> N00E090
        ...                    a total of 59 subdirs
       |--> S60E120
/software
       s2g2018_v2.m      .. Matlab skript for seamless extraction of gravity data
       TestAccess_s2g.m  .. Matlab test driver showing how to access data
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Each of the 57 30x30° regions contains up to 900 1° data files in binary format and up to 900 png image files visualising the file content.

With a total of 19,402 1deg data tiles and 5.625 MB/tile (see Table 2), there are ~112 GB storage needed for all tiles of the full-scale gravity model and another ~112 GB for the residual gravity model.

3.4 File formats

Table 1: SRTM2gravity data files, exemplified for tile N27E086

Product	Filename	Directory	Filesize	Unit	Format (binary)
Full-scale gravity	N27E086_full.bin	1)	5.625 MB	0.01 mGal	Int32, "ieee-be"
Residual gravity	N27E086_res.bin	2)	5.625 MB	0.01 mGal	Int32, "ieee-be"

1) data\FullScaleGravity\N00E060
2) data\ResidualGravity\N00E060

The integer meridian and parallel located closest to the South-Westernmost data point of each 1 deg x 1 deg determines the filename. Each binary file contains 1200 x 1200 values in cell-centred registration. For instance, the 1 deg tile N27E086 contains computation points with the geographical coordinates ranging from 27°+1.5" to 28°-1.5" latitude and 86°+1.5" to 87°-1.5" longitude.

Records proceed along meridians from South to North and columns proceed from West to East. The first record is the South-West corner (27°+1.5" deg latitude, 86°+1.5" deg longitude in the example), and the last record is the North-East corner (28°-1.5" latitude, 87°-1.5" longitude).

Note that the gravity data is held in the unit 0.01 mGal in the binary files. Accordingly, a conversion factor of 1/100 must be applied to scale the data to basic unit mGal, and a factor of 1/10000000 for unit m/s^2. When extracting SRTM2gravity data with the Matlab scripts provided, the conversion factors are automatically taken into account.

4. A simple How-to-use guide - two examples

4.1 Terrain corrections

Assuming you'd like to reduce a gravimetric survey covering the area -40 to -30° latitude and 140 to 150° longitude (= parts of the Australian Alps).

Step 1: Find out the 30°x 30° region of this data set -> S60E120
Step 2: Go to SRTM2gravity/data/FullScaleGravity/S060E120 and choose all 1° tiles covered by your survey, or just download folder /S60E120 in its entirety.
Step 3: Download the access scripts s2g2018_v2.m and TestAccess_s2g.m (from folder /software).
Step 4: Modify the TestAccess_s2g.m script with the geographical coordinates of your test area and run the script in Matlab. The result are three matrices, X containing the longitudes, Y the latitudes and Z containing the extracted topographic gravity effects.
Step 5: Interpolate Z bicubically at the locations of your gravity stations and subtract from the observed gravity disturbances, yielding complete Bouguer gravity values.

4.2 GGM augmentation

Assuming you'd like to enhance gravity from a degree-2160/2190 GGM (e.g.,EGM2008) with topography-implied gravity information at scales of 10 km to ~90 m (same working area as above):

Step 1: Go to SRTM2gravity/data/ResidualGravity/S60E120 and choose all 1° tiles needed, or just download folder /S60E120 in its entirety.
Step 2: Download the access scripts s2g2018_v2.m and TestAccess_s2g.m (from folder /software).
Step 3: Modify only the TestAccess_s2g.m script with the geographical coordinates of your test area and run the script in Matlab. The result are three matrices, X containing the longitudes, Y the latitudes and Z containing the extracted residual gravity effects.
Step 4: Add a) gravity values (or disturbances) from a spherical harmonic synthesis of EGM2008 over its complete band-width at the MERIT topographic surface and b) residual gravity effects from step 3. The result are gravity values (containing signals at scales of ~10,000 km to ~90 m) which will be in good agreement with measured gravity, e.g., at the lower mGal-level over most EGM2008 good-data areas.

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5 KNOWN LIMITATIONS AND IMPERFECTIONS

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1) SRTM2gravity is a pure topography-implied gravity field model. It does not contain any observed gravity values. At short spatial scales, our model approximates the real gravity field, but it cannot be an exact description of what can be measured with gravimetric techniques.

2) While due attempts have been made to remove spurious artefacts from the topographic input model (Hirt 2018), we cannot exclude the presence of further smaller artefacts in the topography data (e.g., steps or spikes), and, in turn, in the forward-modelled gravity.

3) SRTM2gravity models the topographic gravity effect. Mass-density anomalies (relative to the reference density of 2670 kg m^-3) have not been modelled: Examples of unmodelled density anomalies include, but are not limited to, the density contrasts associated with a) lake water, b) ocean water, c) ice sheets, d) sediments. Users with mass density models at hand can forward model and add/subtract the effect from the SRTM2gravity values.

4) The restrictions from 3) especially apply to all of Antartica (not modelled) Greenland (no ice-density contrast modelled) and to coastlines around the world. Clearly an inclusion of ice-sheets and bathymetry in detailed forward modelling is very desirable as it would better approximate Earth's real gravity field. We note that this would require substantial resources (money, time, computing power) for data cleaning, data homogenization, forward modelling and validation. A good uptake of SRTM2gravity might help us to justify such efforts in the future.

5) Over narrow and deep mountain valleys (e.g., 2 km height difference w.r.t. surrounding summits), SRTM2gravity approximation errors will be largest. This is a consequence of the harmonic correction approach applied in the residual gravity forward modelling. As a rule of thumb, approximation errors can be constrained not to exceed ~0.006 mGal/m, e.g., ~6 mGal for a 1 km deep very narrow valley relative to the summit topography. The wider the valley, the smaller will be the maximum approximation errors.

6) The effect from 5) leads to worst-case RMS approximation errors of ~1.0mGal (computed over 1200 x 1200 gravity values over 1 deg tile) and maximum error amplitudes of ~10 mGal for points located in very deep mountain valleys found over parts of the Himalayas representing Earth's roughest topography.

By using SRTM2gravity products users agree to have read and understood the model limitations and imperfections. If you encounter imperfections other than those listed here, we would be pleased to receive your feedback. Thank you!

REFERENCES

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DISCLAIMER
