Lunar Gravity Model 2011 (LGM2011)

LGM2011 (Hirt and Featherstone 2012) is a lunar gravity field model that resolves features down to spatial scales of 1.5 km. The model is constructed as a composite of Newtonian forward-modelling and a recent SELENE gravity field model (SGM100i). LGM2011 surface gravity accelerations (Fig. 1) and free-air anomalies (Fig. 2), selenoid undulations and vertical deflections (Fig. 3) are provided at 0.05° resolution (3600 x 7200 = 25.92 million points) over the entire lunar surface.

LGM2011 sources the low- and medium frequency constituents from SGM100i (Goossens et al. 2011) in spectral band 2 to 70 (~78 km resolution). The high-frequency gravity field constituents are obtained from Newtonian forward-modelling using high-resolution topography from LOLA (Lunar Orbiter Laser Altimeter), Smith et al. (2010). The low-frequency signals of the LOLA topography are removed by subtracting a spherical harmonic reference surface (to degree 70) from LOLA elevations, yielding a residual terrain model (RTM) of the lunar topography

The LOLA residual elevations represent elementary mass-prisms of constant density that are converted to gravity accelerations, selenoid undulations and vertical deflections by closed-form expressions for Newtonian forward modelling. The topography-implied gravity field component, called LRTM70 (Lunar RTM gravity field with the spectrum to degree 70 removed), augments SELENE SGM100i or any other lunar spherical-harmonic model beyond spherical harmonic degree 70. The detail added through LRTM70 is exemplified in Fig. 4 and 5. LRTM70 is based on the key assumptions of constant mass-density and uncompensated high-frequency topography.

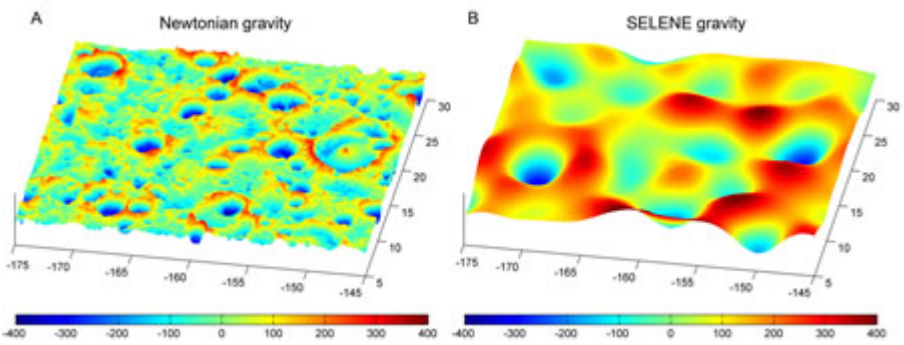


Fig. 4 3D-views of LGM2011 input data (30°x25° area over the lunar far-side) A: Newtonian gravity (LRTM70). B: SELENE gravity (SGM100i evaluated at the LOLA-topography in spectral band 2 to 70). Units in 10^{-5} ms^{-2}

Click for larger image

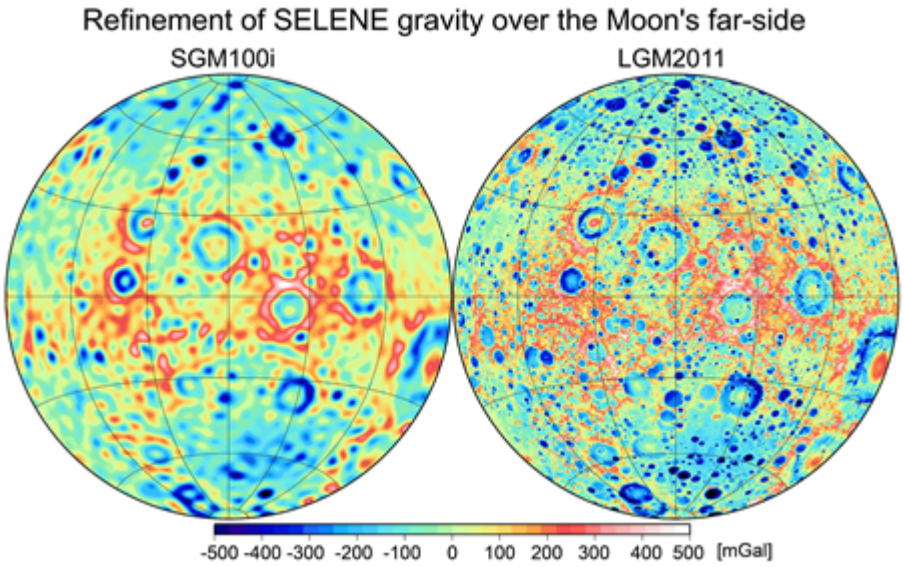
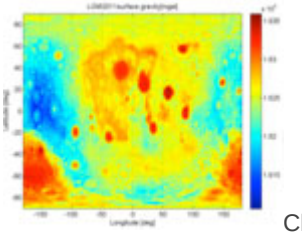
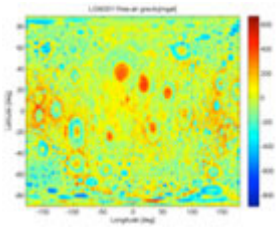


Fig. 5. Improvement of SELENE free-air gravity over the Moon's far-side. Left: SELENE-only free-air gravity to degree 70. Right: LGM2011 free-air gravity, obtained as sum of SELENE (SGM100i) and Newtonian (LRTM70) gravity. From left to right, the resolution of the gravity model is increased from 80 km to 1.5 km. Units in 10^{-5} ms^{-2}

Click for larger image

LGM2011 Products

-  Click for larger image LGM2011 surface gravity accelerations (SGM100i spectral band 2 to 70 gravity disturbances + LRTM70 gravity + LGM2011 normal gravity), unit in 10^{-5} ms^{-2}. Note: a constant value of 162468 x 10^{-5} ms^{-2} must be added to this data set. Download

-  Click for larger image LGM2011 free-air gravity anomalies (SGM100i spectral band 2 to 70 gravity disturbances + LRTM70 gravity) unit 10^{-5} ms^{-2}.

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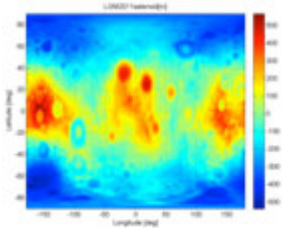
-  Click for larger image LGM2011 selenoid undulations (SGM100i spectral band 2 to 70 selenoid undulations, plus LRTM70 selenoid), unit is 10^{-1} m.

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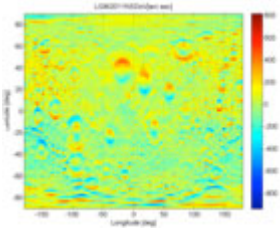
-  Click for larger image LGM2011 North-South surface vertical deflection (SGM100i spectral band 2 to 70 + LRTM70 NS vertical deflection), unit is seconds of arc.

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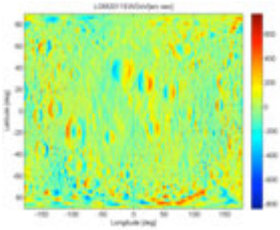
-  Click for larger image LGM2011 East-West surface vertical deflection (SGM100i spectral band 2 to 70 + LRTM70 EW vertical deflection), unit is seconds of arc.

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Note: In case of the LGM2011 surface gravity accelerations, free-air anomalies and surface vertical deflections, SGM100i was evaluated at the lunar topography, as is required for modelling of gravity field functionals at the surface. As for the LGM2011 selenoid undulations, SGM100i was evaluated at a constant radius of R = 1738000 m.

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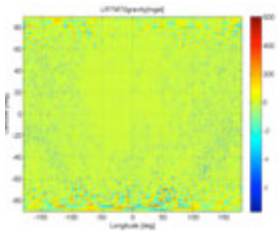
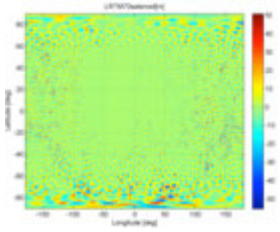
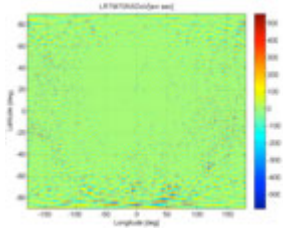
LGM2011 Input Data Sets

LRTM70 Functionals

LRTM70 (Lunar RTM gravity field with the spectrum to degree 70 removed) are a set of gravity field functionals from Newtonian forward-modelling using the LOLA residual topography. LRTM70 complements any lunar spherical harmonic model beyond harmonic degree 70. Those users who wish to use LRTM70 gravity field functionals can download following files:

-  Click for larger image LRTM70 gravity accelerations, unit 10^{-5} ms^{-2}.
  Download
-  Click for larger image LRTM70 selenoid undulations, unit 10^{-1} m.
  Download
-  Click for larger image LRTM70 NS vertical deflection, unit seconds of arc.
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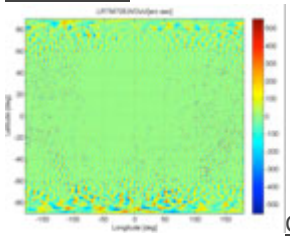
-  Click for larger image LRTM70 EW vertical deflection, unit seconds of arc.
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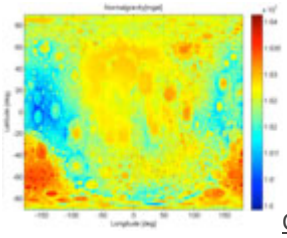
Normal Gravity

Those users who wish to use the LGM2011 normal gravity field can download following file:

- 
Click for larger imageLGM2011 normal gravity, unit 10^{-5} ms^{-2}. Note: a constant value of 162468 x 10-^{5} ms^{-2} must be added to this data set.
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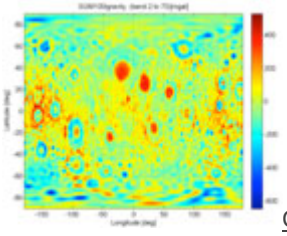
The LGM2011 normal gravity field takes into account the gravitational attraction of the Moon's total mass and the decay of gravity with height. LGM2011 normal gravity uses GM = 4902.80080 x 10^{9} $m^{3}s^{-2}$, the gravitational parameter from SGM100i (Gossens et al. 2011) and R = 1737153 m, best-estimate of the mean lunar radius from LOLA (Smith et al. 2010) as defining parameters.

The normal gravity at the surface of a sphere with radius R is then $\gamma_0 = GM/R^2$ =1.624681 ms^{-2}. The LGM2011 normal gravity field also models the height-dependency of the gravity acceleration using first - ($\partial\gamma/\partial R = -2\gamma/R$ = -1.8705 x 10^{-6} s^{-2}) and second-order ($\partial 2\gamma/\partial R^2 = 6\gamma/R^2$ = 3.23 x 10^{-12} $m^{-1}s^{-2}$) free-air gradients. Albeit small, the centrifugal acceleration (maximum of ~1.2 x 10^{-5} ms^{-2} at the lunar equator) is taken into account. The lunar surface elevations, used in the construction of the LGM2011 normal gravity field, are from LOLA and referred to R.

SGM100i Functionals

Those users who wish to use the SGM100i (Goossens et al. 2011) functionals used in the construction of LGM2011 can download following files:

- 
Click for larger image SGM100i gravity disturbances (SGM100i spectral band 2 to 70, evaluated at the LOLA topography), unit 10^{-5} ms^{-2}.
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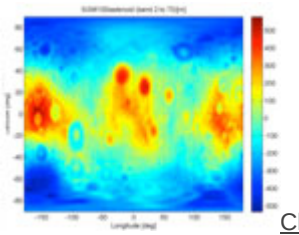
-  Click for larger image SGM100i selenoid undulations (SGM100i spectral band 2 to 70, evaluated at a constant radius of R = 1738000 m), unit 10^{-1} m.

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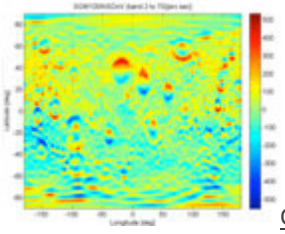
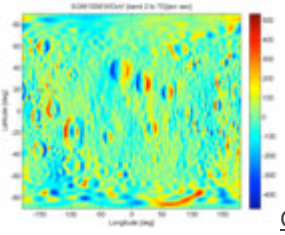
-  Click for larger image SGM100i NS vertical deflection (SGM100i spectral band 2 to 70, evaluated at the LOLA topography), unit seconds of arc.

  Download
-  Click for larger image SGM100i EW vertical deflection (SGM100i spectral band 2 to 70, evaluated at the LOLA topography), unit seconds of arc.

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File and format description

Each file (50,625 KB) contains 7,200 x 3,600 =25,920,000 values stored in 2-byte integer big-endian format (int16, ieee-be). The grid resolution is 0.05 deg (3 arc min). Records proceed along meridians from South to North and columns proceed from West to East. The first record is the South-West corner (-89.975° latitude, -179.975° longitude), the second record is (-89.925° latitude, -179.975° longitude) and the last record is the North-East corner (89.975° latitude, 179.975° longitude).

Software to read LGM2011 data files

Here we provide a simple Matlab-script that can be used to read and display the 14 LGM2011 product and input files, and custumized by users for further use.

- Matlab-script to access LGM2011 data files
  Download

Contact and Feedback

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

References

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- Goossens S, Matsumoto K, Liu Q, Kikuchi F, Sato K, Hanada H, Ishihara Y, Noda H, Kawano N, Namiki N, Iwata T, Lemoine FG, Rowlands DD, Harada Y, Chen M (2011) Lunar gravity field determination using SELENE same-beam differential VLBI tracking data. Journal of Geodesy 85(4), 205-228, DOI: 10.1007/s00190-010-0430-2
- Smith DE, Zuber, MT, Neumann GA, Lemoine FG (2010) Initial observations from the Lunar Orbiter Laser Altimeter (LOLA), Geophysical Research Letters 37, L18204, doi: 10.1029/2010GL043751.

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