AUSTRALIAN SYNTHETIC EARTH GRAVITY FIELD MODEL (AusSEGM) - A REGIONAL EARTH GRAVITY FIELD MODEL

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Abstract

- The Australian Synthetic Earth Gravity Model (AusSEGM) is a high-resolution (1-arc-min by 1-arc-min) regional source/effects SEGM over the Australian continent.
- The long-wavelength source part (spherical harmonic degree and order N,M ≤ 360) is taken from EGM96 global geopotential model and the short-wavelength part (N,M > 360) is derived from the effect of a high-resolution (3-arc-sec) digital elevation model (DEM) based on GLOBE v1 DEM and JGP95E.
- AusSEGM provides exact and self-consistent high-resolution gravity filed functional (gravity, gravity anomaly, geoid height) on regular geographic grid nodes (1-arc-min by 1-arc-min) as well as arbitrary points with similar distribution as observed gravity points. Thus, it is ideal for validating theories, techniques and computer software for regional geoid determination.
- The precision of AusSEGM (after a first iteration) is estimated to be better than 30µGal for gravity and gravity anomaly and 3 mm for geoid heights.
- Comparisons with real data show that AusSEGM is realistic.

Hybrid Source-Effects Model

- **Source models** take a (realistic or simulated) mass-density distribution of the solid Earth into account using Newtonian integration. Here a high-resolution (3-arc-sec by 3-arc-sec) simulated DEM has been used to model the (local) high-resolution content of the gravity field over Australia.
- **Effects models** do not make any assumptions about the mass-density, but do conform with real observations of the Earth's shape and gravity field. Here EGM96, JGP95E, and GLOBE v1 DEM have been used to provide the global gravity field and topography.
- **Hybrid source-effects models** use a combination of source and effects models, where the former is usually taken to model the (global) long-wavelength structure and the latter to model the (local) short-wavelength constituents of the Earth's gravity field (see Figure 1).

Figure 1 (on the right): A schematic view of the global (long-wavelength) and local (short-wavelength) components of AusSEGM in the concept of a source-effects model SEGM.

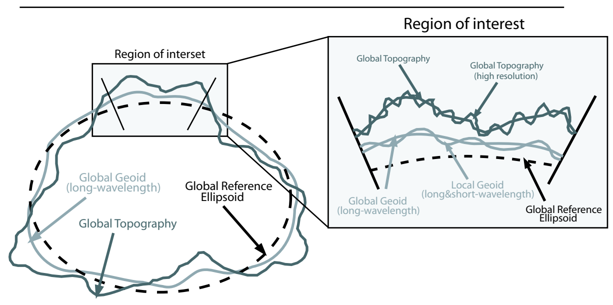
Models and Data Used

Effects Model

- **EGM96** (Lemoine et al. 1998)
- Evaluated up to the max. degree and order N,M = 360.
- Ensures that the global gravity field structure is realistic.

Source Models

- **JGP95E** (Lemoine et al. 1998)
- **Simulated (3-arc-sec) DEM**
- Both used to model the effect on gravitational attraction and potential by Newtonian integration.



The Simulated (3-arc-sec by 3-arc-sec) DEM (SDEM)

- A simulated high-resolution (3-arc-sec by 3-arc-sec, ~ 100m) DEM (SDEM) has been constructed over Australia (112°E-155°E, 8°S-45°S) using an isotropic two-dimensional fractal surface imposed on top of the (30-arc-sec) GLOBE v1 DEM (Hastings and Dunbar 1999).
- The horizontal and vertical variation of the fractal surface is associated with the roughness (expressed by standard deviation) of GLOBE, which ensures a reasonably realistic fractal contribution to the final SDEM.
- Figures 2 and 3 (below) show the high-resolution SDEM as well as a comparison with an existing 9-arc-sec by 9-arc-sec DEM over Australia (Geoscience Australia, http://www.ga.gov.au).

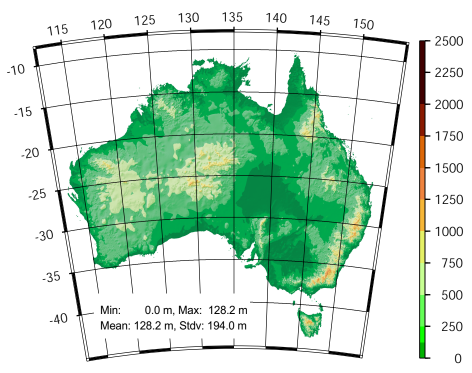


Figure 2: The simulated 3-arc-sec DEM (SDEM) over Australia, which shows the broad structure of the Australian topography, as defined by GLOBE v1.

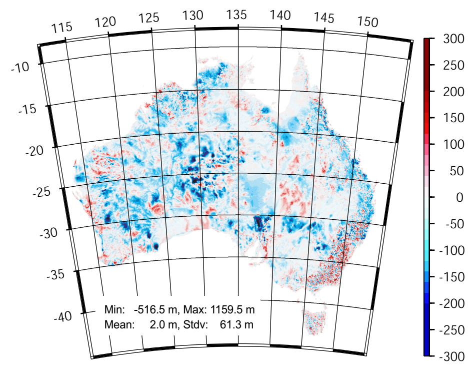


Figure 3: Differences between SDEM (averaged to 9-arc-sec by 9-arc-sec) with the 9-arc-sec by 9-arc-sec GeoData Version 2 DEM of Australia. Most of the differences (91.4% of all values) remain below 100m. The large differences are due to errors in the GLOBE v1 source data (see Hilton 2003).

The Effect of High-Resolution Topography

- While the long-wavelength information of AusSEGM is taken from EGM96 the short-wavelength information is derived from the effect of the local/global topography (modelled with ρ=2670 kg/m^3).
- The (total) effect on gravitational acceleration and potential is derived via Newton integration (including the global topography as given by JGP95E). Subsequently these effects are divided in their low- and high frequency constituents using an expansion into spherical harmonics.
- The long-wavelength component (up to degree/order 360) is not regarded further as this effect is already accounted for by EGM96.
- The short-wavelength component (beyond degree/order 360) is regarded as the short-wavelength source caused by the high-resolution topography (Figures 4 and 5).
- The contribution of the short-wavelength source part is generally small and remains in most cases (more than 99% of all values) below 20 mGal and 0.2 m for the gravitational attraction and geoid height, respectively. The highest values occur in the high mountains.

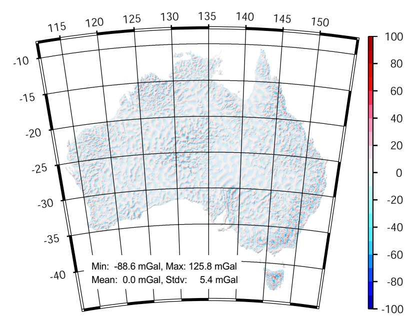


Figure 4: Short-wavelength part (N,M > 360) of the gravitational acceleration effect of the local/global topography at the Earth's surface.

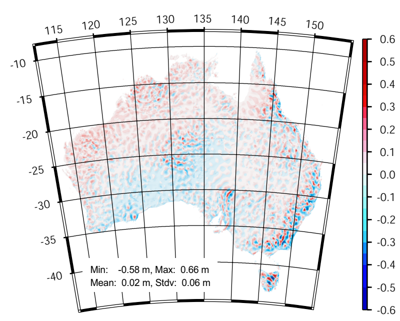


Figure 5: Short-wavelength part (N,M > 360) on the geoid height due to the gravitational potential effect of the local/global topography at the geoid (H=0).

Final Parameters of AusSEGM

- The current version of AusSEGM provides the following self-consistent gravity field parameters:
  - **Free-air gravity anomaly** at the Earth's surface* (Figure 6)
  - **Gravity** at the Earth's surface* (Figure 7)
  - **Geoid height** (Figure 8)

  *The Earth's surface is given here by the 3-arc-sec SDEM
- The structure of all gravity field parameters is similar to that given by EGM96 with additional high-frequency information.

  The parameters are given on a regular 1-arc-min geographical grid. In addition, free-air gravity anomalies and gravity values are provided at 330,929 arbitrary locations with a similar distribution as measured gravity points.
- The final parameter are obtained by the superposition of the long- and short-wavelength parts for the gravitational acceleration on the Earth's surface and the effect on the geoid height (Bruns's formula applied to the change in gravitational potential).
- **It is essential to note that the synthetic gravity observations on the topography have not been used here to compute the synthetic geoid.**

Numerical Results

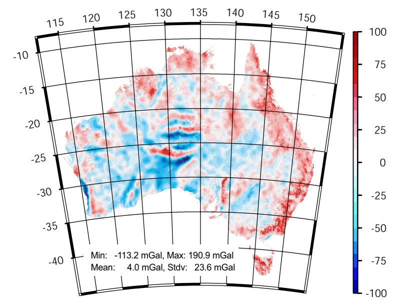


Figure 6: Free-air anomaly of AusSEGM given at the Earth's surface.

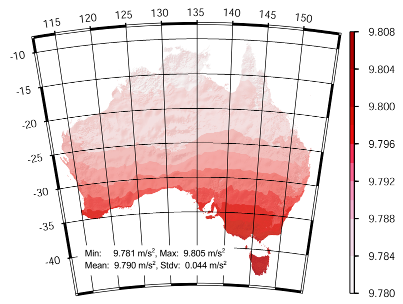


Figure 7: Gravity value of AusSEGM given at the Earth's surface.

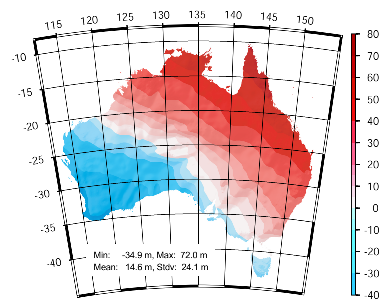


Figure 8: Geoid height of AusSEGM.

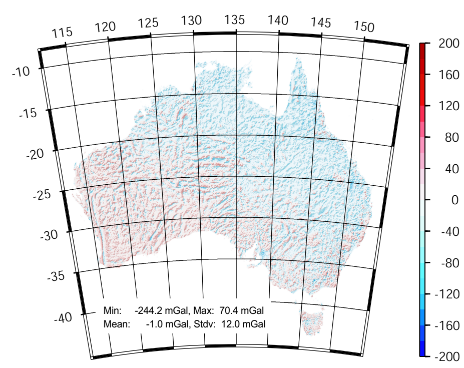


Figure 9: Comparison of the AusSEGM gravity value with measured gravity values over Australia.

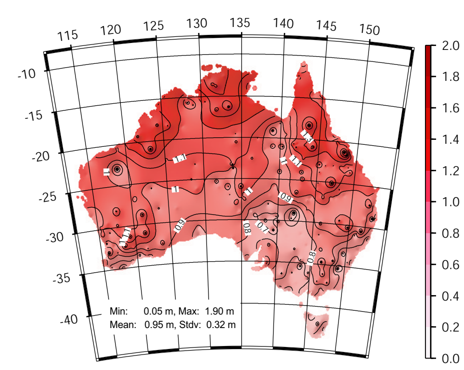


Figure 10: Comparison of the AusSEGM geoid height with the results of 254 GPS-levelling points.

Comparison with Real Data

- In order to demonstrate that AusSEGM provides realistic gravity field estimates, the results for gravity and geoid height have been compared with a total of 330,929 measured gravity stations and 254 GPS-levelling data, respectively (data supplied by Geoscience Australia, http://www.ga.gov.au).
- The comparison of the gravity data shows a reasonably good agreement (Figure 9) with most (99.3% of all values) of the differences being below 20 mGal. Furthermore the spatial distribution shows no significant systematic effect.
- The comparison of the AusSEGM geoid heights with the GPS-levelling results (Figure 10) shows mean differences of about 1 metre, which shows that AusSEGM reproduces the broad structure of the geoid. Remaining differences can be attributed to the fact that AusSEGM is a simulated model and to errors in the GPS and levelling data. Especially, the visible north-south trend can most likely be attributed to systematic errors in the Australian Height Datum.
- Overall, the comparison shows that AusSEGM is indeed realistic. Thus, it is useful for validating theories, techniques and software for regional geoid determination. Furthermore, it can be used for gravity field studies over Australia.

References

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Hilton RD, Featherstone WE, Berry PAM, Johnston CPD, Kirby JF (2003): Comparison of digital elevation models over Australia and external validation using ERS-1 satellite radar altimetry, Australian Journal of Earth Sciences 50(2): 157-168.

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Acknowledgements

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