A new era for the Australian National Gravity Grids – adding airborne data to the mix

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SUMMARY

Since 1976, Geoscience Australia has produced grids of gravity anomalies to support geological mapping and exploration applications across Australia. The five editions of the national grids up to 2016 have been based on ground gravity observations, supplemented by marine gravity derived from satellite altimetry and once with marine ship track gravity data.

In the planning for the sixth edition of the national grids in 2019, and for the first time, the ground gravity observations were supplemented with airborne survey data and marine gravity derived from satellite altimetry. The addition of airborne data required a completely different processing sequence to be devised. An important part of this processing was to vertically continue all observations to a single smooth drape surface defined across the entire extent of the grids.

The results show clear benefits over previous editions stemming from the inclusion of the airborne data. Three grids were produced: the Free Air Anomaly (FAA), the Complete Bouguer Anomaly (CBA) and the De-trended Global Isostatic Residual (DGIR) grid. The DGIR grid, which was produced for the first time, is a better product to use for the interpretation of mid and upper crustal features since most long wavelength anomalies have been removed. This outcome points to further airborne data being acquired and included in future national grids. Data from airborne surveys acquired by non-government organisations that meet size and quality criteria will also be considered for inclusion.

Key words: national gravity grid, Australia, airborne gravity, upward continuation.

INTRODUCTION

In the last 60 years, Geoscience Australia (GA) and its predecessors, in collaboration with State and Territory government agencies, has acquired gravity data across Australia. Following rigorous processing and quality control, these data are used to produce national gravity grids for the continent. The 2019 Australian National Gravity Grids produced by GA are two sets of grids (the "A" and "B" Series) covering the continent of Australia and surrounding region (108 to 164 degrees East Longitude, -48 to -8 degrees North Latitude) (Lane *et al.*, 2020a).

The "A" Series grids were produced from a combination of ground gravity data for onshore Australia sourced from the Australian National Gravity Database (ANGD) (Tracey and Nakamura, 2010; Tracey *et al*., 2007; Murray, 1997), gravity data derived from satellite altimetry (Sandwell *et al*., 2014) for offshore locations and, for the onshore locations in countries other than Australia, gravity data from the EGM2008 global gravity model (Pavlis *et al*., 2012).

For the first time, we combine ground, marine, satellite and airborne gravity data to produce the national gravity grids, "B" Series. The grids contain the gravity data used in the "A" Series but also include data from a number of airborne gravity and airborne gravity gradiometer surveys acquired by GA and State and Territory government agencies. These grids provide the most up to date information, with a more equally and continuously sampled gravity field of Australia and surrounding regions. The grids are the best currently available support for geological interpretation and mineral exploration in Australia.

DATA SOURCES

The 2019 national gravity grids (B series) were produced from three main data sources: onshore, offshore and airborne gravity data (Figure 1).

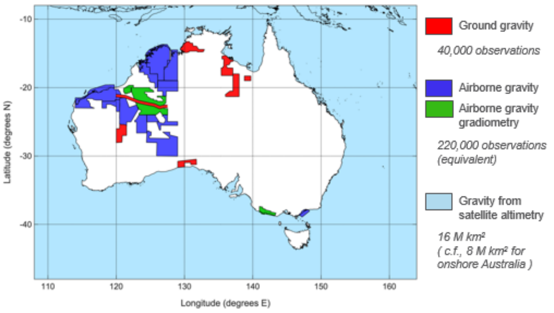

Figure 1. New gravity data used for the production of the 2019 national gravity grids. These data supplemented the existing ground gravity data (white) used in the 2016 edition of the national grids.

Onshore data

A total of 1,430,447 ground gravity observation values covering the Australian mainland, Tasmania, and a number of offshore islands were sourced in September 2019 from the Australian National Gravity Database (ANGD) (Tracey and Nakamura, 2010; Tracey *et al.*, 2007; Murray, 1997). These observations are tied to the Australian Absolute Gravity Datum 2007 (AAGD07) (Tracey *et al.*, 2007). A total of approximately 40,000 new ground gravity stations were added to the ANGD since the 2016 edition of the national grids. The gravity station spacing varies from approximately 11 kilometres over much of northern and western Australia to 1.5 kilometres in Victoria. Recent Federal, State and Territory

Government initiatives have funded systematic infill at a grid station spacing of 2, 2.5 or 4 kilometres to provide improved coverage in areas of greater prospectivity or scientific interest.

Offshore data

Offshore gravity data were sourced from the global gravity grid developed at Scripps Institution of Oceanography, University of California San Diego using data from SIO, NOAA and NGA (Sandwell *et al.*, 2014). These data, referred to here as “Sandwell et al. v28.1”, provide valuable context for the onshore ground gravity data. The gravity values in Sandwell et al. v28.1 are referenced to the International Gravity Standardization Net 1971 (I.G.S.N.71) (Morelli *et al.*, 1972). The Sandwell et al. v28.1 grid has a cell size of approximately 1.7 km. For processing, the grid was decomposed into points, one per cell using the centre of each cell as the location.

Airborne gravity data

A total of 345,000 line km of Airborne Gravity data (AG) from 12 survey blocks and 106,000 line km of Airborne Gravity Gradiometer data (AGG) from 2 survey blocks were included in this project (Bates *et al.*, 2011; Howard *et al.*, 2018; Bates *et al.*, 2019a; 2019b; Carter *et al.*, 2019). These data were acquired with a number of different systems, with line spacing from 0.5 to 2.5 km, and terrain clearance generally between 150 and 200 m.

DATA PROCESSING

To produce the B series of the national gravity grids (addition of airborne data), all observations needed to be brought to a common drape surface. All of the gravity observations were vertically continued to a smooth airborne drape surface referred to as “AusDrape2019”. This airborne drape surface was generated to have characteristics similar to the flight path of a typical airborne survey. This meant that there would be minimal vertical continuation of data from the airborne surveys to locate the data on the drape surface.

The Shuttle Radar Topography Mission (SRTM) surface elevation data with 3 second grid cell size (CGIAR-CSI, 2019) was used as the terrain data. The minimum terrain clearance was set to 250 m to avoid amplification of short wavelength noise in the airborne data. A modified version of the Extended Drape Lift algorithm described by Fossati and Wolvaardt (2001) was used to impose maximum climb and descent rates whilst maintaining the minimum surface clearance. The maximum climb and descent rates were set to 25 m per km. Some post-calculation smoothing was applied to the drape surface to approximate second order constraints (i.e., limits on the rates of change of climb or descent rates).

The heights in the SRTM data are referenced to the WGS84 ellipsoid. EGM96 was used during the production of SRTM data to convert elevations from the WGS84 ellipsoid to the geoid (AusDrape2019_geoid) (Lemoine *et al.*, 1998). We thus used EGM96 to essentially reverse this conversion to obtain AusDrape2019 heights with respect to the GRS80 ellipsoid, GDA94 datum (AusDrape2019_ellipsoid).

The Free Air Anomaly (FAA) and Complete Bouguer Anomaly (CBA) grids from the A series were upward continued to the AusDrape2019 surface and low pass filtered with the conforming filter (Dransfield, 2010) to better match the low pass filtering applied to the airborne data. AusDrape2019 elevation values were added from the AusDrape2019 grid. Water depth values for use in the spherical cap Bouguer corrections were added from the AusBath09 grid (Whiteway, 2009).

The airborne surveys were processed in a specific order from the older, lower resolution, lower accuracy surveys to the more recent, higher resolution, more accurate surveys. The process was the same for FAA and CBA data. The conforming process was completed by adding the high pass filtered airborne survey grid to the low pass filtered onshore-offshore grid. The conformed grid was then merged with the base grid using a weighted combination of the two grids in a buffer zone around the margins of each airborne survey, a process referred to as either “grid merging” or “grid stitching”. The output would become the new base grid if there were more airborne surveys to process, or the final FAA and CBA grids if all of the airborne surveys had been processed (Lane *et al.*, 2020b).

RESULTS

We have produced national gravity grids by combining ground, satellite, marine and airborne gravity data for Australia and the surroundings. The standard gravity grids provide Free Air Anomaly (FAA, Figure 2) and Complete Bouguer Anomaly (CBA, Figure 3). An important addition to the grid series is the production of the De-trended Global Isostatic Residual (DGIR, Figure 4) grid. Near-field and far-field isostatic corrections were subtracted from the CBA grid values to produce a global isostatic residual grid, ΔgGIR. It is noted that the near-field and far-field regional values were calculated on the geoid surface. The De-trended Global Isostatic Residual, ΔgDGIR, was produced by removing a first order trend surface from the ΔgGIR grid. To avoid distorting the trend surface calculation with gravity values from the complex collision zone between northern Australia and Indonesia and Papua New Guinea, data for latitudes north of -13 degrees north were excluded from the trend surface calculation. This calculation was performed using a least squares objective and geodetic coordinates. The Isostatic residual data, or DGIR grid is the preferred data to use for interpretation of mid and upper crustal features since the majority of the long wavelength anomalies contributing to the gravity data have been removed.

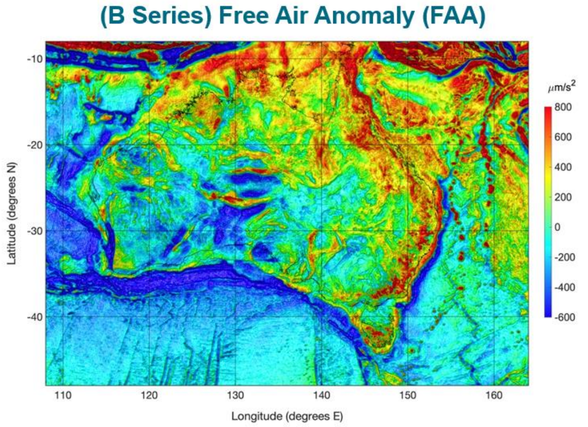

Figure 2. Image of the B series Free Air Anomaly (FAA) grid.

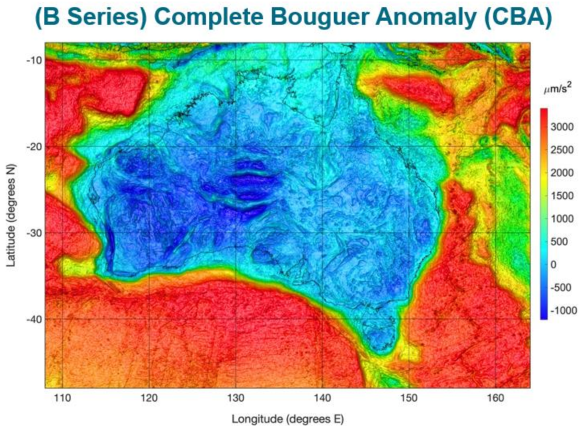

Figure 3. Image of the B series Complete Bouguer Anomaly (CBA) grid.

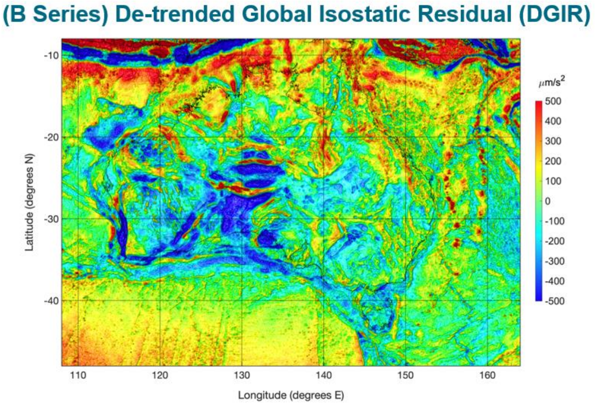

Figure 4. Image of the B series De-trended Global Isostatic Residual (DGIR) grid.

Two supplementary grids were also produced and provide the elevation values that define the observation surface for the gravity grids. One of these grids has elevations referenced to the geoid (AusDrape 2019_geoid) whilst the other contains elevation values referenced to the GRS80 ellipsoid for the GDA94 datum (AusDrape 2019_ellipsoid).

The addition of airborne data has greatly improved the resolution of the grids. The image in Figure 5 shows the Tanami region, straddling the border between Western Australia (WA) and the Northern Territory (NT). This image is based solely on ground gravity data. The station spacing was a mixture of 2 and 4 km in the Northern Territory, and a very sparse 11 km in Western Australia.

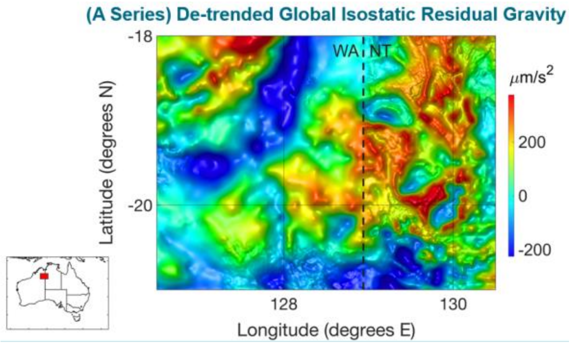

Figure 5. Example of the A series De-trended Global Isostatic Residual Gravity anomaly in the Tanami region, WA/NT produced using only ground gravity data.

Figure 6 shows the same area as in Figure 5, with the addition of airborne data within the black outline. The equivalent station spacing of these airborne data is 2.5 km compared to 11 km for the ground data. This figure shows the improvement of the image in WA after the addition of the airborne data.

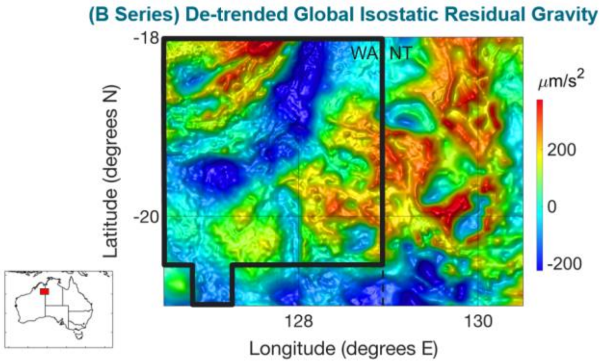

Figure 6. Example of the B series De-trended Global Isostatic Residual Gravity anomaly in the Tanami region, WA/NT produced with the addition of airborne gravity data within the black outline.

CONCLUSIONS

For the first time, we have combined ground, marine, satellite and airborne data to produce the national gravity grids of Australia and the surroundings, including the new De-trended Global Isostatic Residual (DGIR) grid.

The addition of airborne data has greatly improved the resolution of the grids, providing explorers with a better product to use for geological interpretation and the discovery of new resources. Adding airborne data has also highlighted the continuity of some geological structures that were not evident in the previous editions of the national gravity grids. As more precompetitive gravity data become available, Geoscience Australia will continue to produce high resolution, high quality gravity grids for the continent.

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