

A new generation Magnetic Anomaly Grid Database of Australia (MAGDA)

– use of independent data increases the accuracy of long wavelength components of continental-scale merges

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Abstract

A new Geoscience Australia Magnetic Anomaly Grid Database of Australia (MAGDA) has been developed. This database contains publicly available airborne magnetic grid data for on-shore and near-offshore Australia. Flight-line magnetic data for each survey have been optimally gridded and the grids matched in one inverse process. New composite grids at 250 m and 400 m grid spacing form the basis for the new fourth edition of the Magnetic Anomaly Map of Australia.

Aeromagnetic traverses flown around Australia during 1990 and 1994 are used in both quality control of the grids they intersect, and also to constrain grid merging by forcing grid data, where intersected, to the level of the traverse data.

Although matching and merging of many grids into a seamless compilation produces a pleasing result, without obvious short-wavelength artefacts, accurate long wavelength components of crustal origin are more difficult to obtain. Errors in the “tilt” of individual surveys, due either to older instrumentation, or errors in processing, or incomplete core-field removal, can lead to large long-wavelength errors when hundreds of surveys are combined across thousands of kilometres.

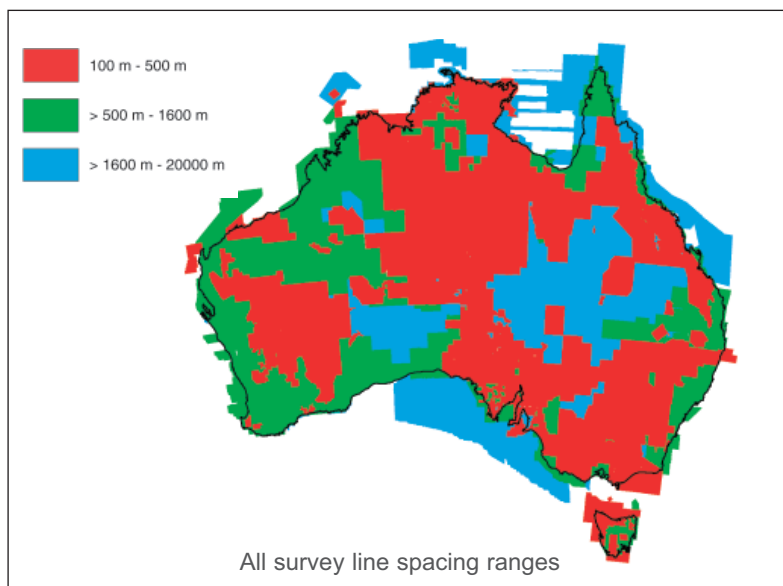


Fig. 1. The distribution of original survey line-spacings. Red represents line-spacings less than or equal to 500 m, green represents line-spacings greater than 500 m and less than or equal to 1600 m and blue represents line-spacings greater than 1600 m.

Quantification of the accuracy of long-wavelength components is only possible by comparison with independent datasets. A low-pass filtered composite grid of the Australian region has been compared with CHAMP satellite magnetic data, and it shows a considerable improvement in the correlation of long-wavelength components compared with the previous edition.

Introduction

Geoscience Australia has developed a new airborne Total Magnetic Intensity (TMI) crustal anomaly grid database of Australia (MAGDA). The original survey line data, from which the grids are derived, were acquired by Geoscience Australia, the state and territory government geological surveys and exploration companies. Most of the data are publicly available, although a few datasets provided by two companies have restrictions on their distribution.

It is estimated that 19 million line-km of survey flight-line data were acquired to provide the grids. Most of the more recent data (post-1995) have been acquired by the geological surveys, in many cases through their “Exploration Initiatives”.

Most of the original survey line data were processed to “final form” by standard processing methods (Luyendyk, 1997). These methods include removal of time variations of the geomagnetic field (diurnal correction), removal of the Earth’s core field (IGRF removal) and levelling (using line/tie cross-over intersections to minimise network differences). In most cases, “micro-levelling” has been performed to remove residual elongate along-line artefacts (Minty, 1991).

Each grid in the database has been optimally derived from the corresponding survey data using a minimum curvature algorithm (Briggs, 1974). In most cases the grid cell spacing is 1/5 of the survey line spacing. The grid data have a range of specifications and errors reflecting the variability of the original survey data. While most of the data were acquired post-1990, and are considered to be of high quality, there are still areas where only lower-quality older regional data are available (Figure 1).

The grids in the database have been “matched” together with a new process, using independent data as a constraint, and a new composite merged grid of the Australian region forms the basis for the fourth edition of the Magnetic Anomaly Map of Australia. The long-wavelength components of this composite have been compared with satellite magnetic data.

Processing procedures

(a) Constrained grid-matching using independent AWAGS data

Due to the nature of the processing, the grids have arbitrary base levels, and baseline offsets between grids need to be resolved if composite seamless products are to be generated. This involves calculating a shift for each grid based on the statistics of the data differences for the area of overlap with neighbouring grids. For earlier versions of the Magnetic Anomaly Map of Australia this was achieved by using a sequential process, in which pairs of grids were matched at a time using a one-pixel overlap of their common borders, and all grids had the same cell spacing (Tarlowski *et al.*, 1996a). If this process was continued to match large areas of grids, long-wavelength warps would be introduced. For example, if the process was done in a circular fashion, the last grid would not match with the first grid.

To help overcome this problem, a new merging method was developed by Geoscience Australia. In this method, grid area overlap differences for all of the grids are minimised in one inverse operation (Minty *et al.*, 2003; Milligan *et al.*, 2001). While this new method helps reduce long-wavelength errors, it does not eliminate them. To further reduce such errors, control must be provided by using other independent data. This is partly achieved by using the AWAGS (Australia-Wide Array of Geomagnetic Stations; Chamalaun and Barton, 1990) airborne traverse data (Tarlowski *et al.*, 1996b). These data were acquired using two loops flown around mainland Australia in early 1990, and a further loop flown around southern Victoria and northern Tasmania in 1994 (Figure 2). The grids that are intersected by the traverse data are brought to the traverse data level and subsequently held there as “base grids” in the remainder of the processing.

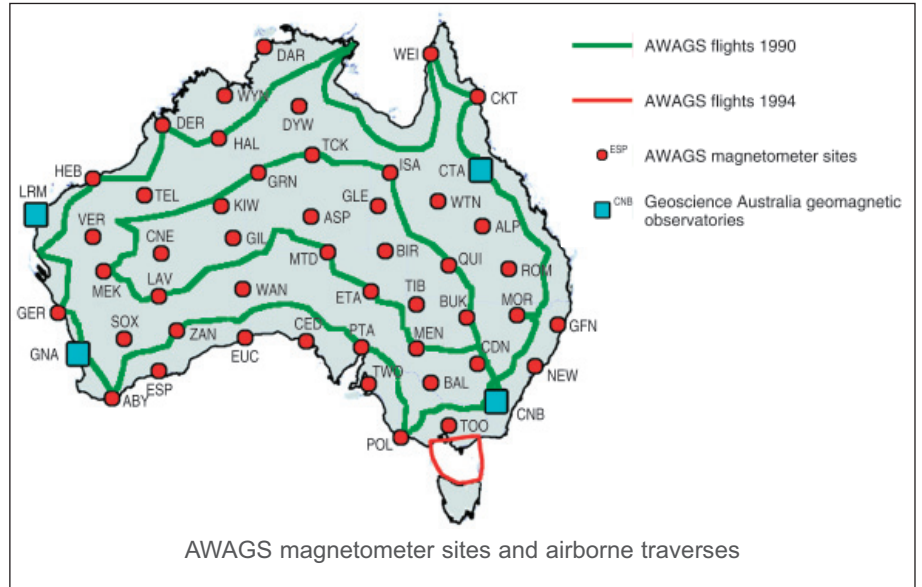


Fig. 2. The AWAGS magnetometer sites, Geoscience Australia magnetic observatory sites and the AWAGS airborne magnetic traverse locations.

A further option within the matching process is to calculate higher-order surfaces from the grid boundary differences and subtract them from the grid under consideration. Such “tilting” of grids needs to be used with caution, and is further discussed in the next section.

A significant improvement is expected in the accuracy of intermediate wavelength magnetic anomalies (about 100 to 500 km wavelengths) with the levelling of the survey grids to the AWAGS datum. There are significant advantages that could result from improving the intermediate wavelength anomalies for

lithospheric magnetic investigations looking into the variations in temperature regime and the rheological nature of the Australian lithosphere. However, we are yet to rigorously test these improvements.

(b) Data quality control and indexing

The grid database currently contains over 680 separate grids, with a combined size of nearly 6 gigabytes (IEEE4ByteReal format data). With this number of grids, an automated indexing and quality control system is essential, and software has been developed for this purpose (Figure 3).

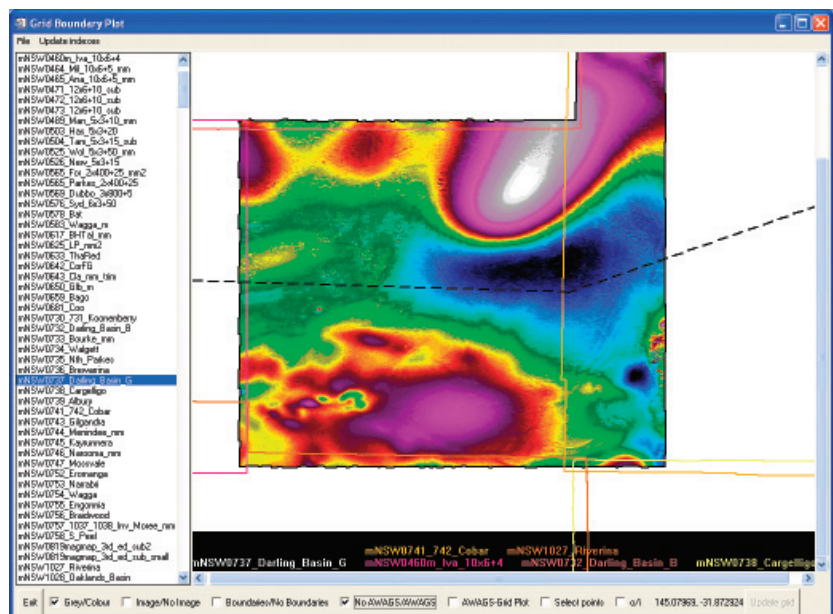


Fig. 3. The main interface into program Grid_boundary_view. The dashed black line represents the position of an AWAGS traverse.

At the heart of the system is a directory of exact grid boundary files and thumbnail tiff images. Any grid can be selected and displayed, together with its boundary and the overlapping boundaries of neighbouring grids. There is provision for interactive polygonal sectioning of the grid, as it is best to have “clean” boundaries without excessive overlap. The grid boundary plots are carefully examined to ensure that there are no redundant grid data. AWAGS traverse paths may be overlain on the image (Figure 3).

Comparison plots of AWAGS traverse data with grid data that they intersect are particularly important for quality control. Example plots are shown in Figure 4. Profile (a) is the AWAGS traverse data (diurnally corrected) and profile (b) the grid data interpolated at the positions of the AWAGS data. Profile (c) shows the diurnal data for the time of the AWAGS profile data acquisition. These have been calculated by interpolating the AWAGS profile data in a time-space volume of the AWAGS magnetometer data (Figure 2). The last profile, (d), shows the

data in profile (b) subtracted from those in profile (a), and is diagnostic mainly of the quality of the grid data.

For example, if the difference in profile (d) shows a significant linear trend (e.g. Figure 4(b)), then the grid is “tilted” with respect to the AWAGS profile data. For modern data, this would most likely be due to an incorrect removal of the IGRF field. In old data, for example in surveys flown with fluxgate magnetometers, such tilts and higher-degree warps could easily have come from instrument drift and errors in levelling.

It is best to correct modern data for such errors, once diagnosed, and regrid the data. For older data, this may not be possible and, quite often, older survey grids do show significant tilts and warps. As previously mentioned, there is provision within the GRIDMERGE program to attempt a correction of such errors by calculating higher-order correction surfaces from the boundary overlap differences. This option is used with great caution; no higher than

a degree 1 surface is removed, and modern surveys are not corrected in this way.

An automated index map generator has also been developed. This uses the Geoscience Australia four figure project codes, which are part of every grid filename, to relate to information in the master Oracle survey index. The index program has options for generating ASCII list files, with grid names ordered by such criteria as line spacing, date and ownership. These lists may then be used to control the ordering of grids when merging data into composite grids, or to produce colour images of the various criteria.

Further developments

(a) *Magnetic Anomaly Map of Australia, 4th Edition*

A major product being released by Geoscience Australia is a new fourth edition of the Magnetic Anomaly Map of Australia. Hardcopy products at 1:5 million and 1:25 million scales will be available, together with

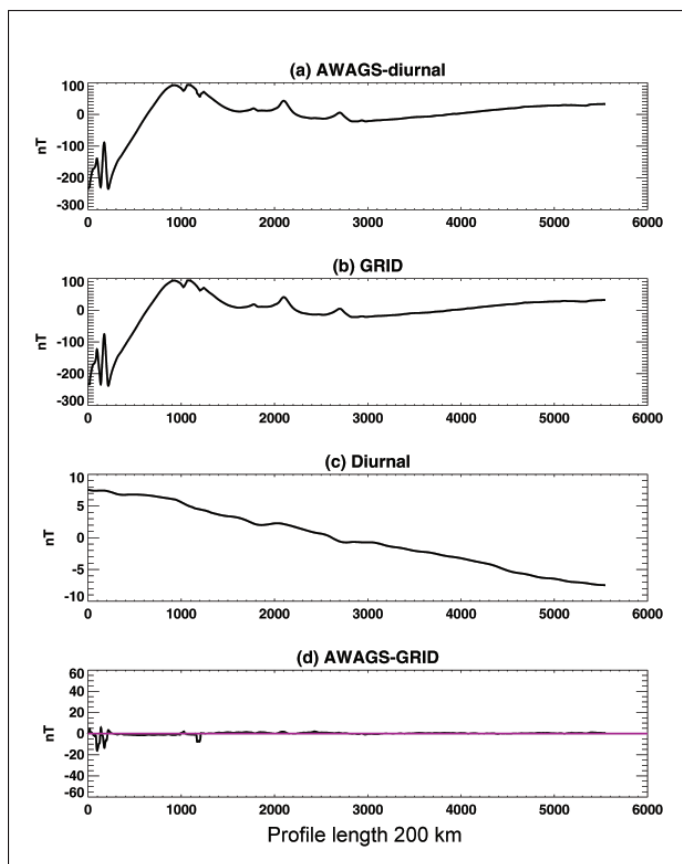


Fig. 4 (a). A good comparison of AWAGS traverse data with grid data. Profile (a) is diurnally corrected AWAGS traverse data, profile (b) is data interpolated off a grid at the AWAGS locations, profile (c) is the diurnal correction applied to the AWAGS data, and profile (d) is the difference between the data of (a) and (b).

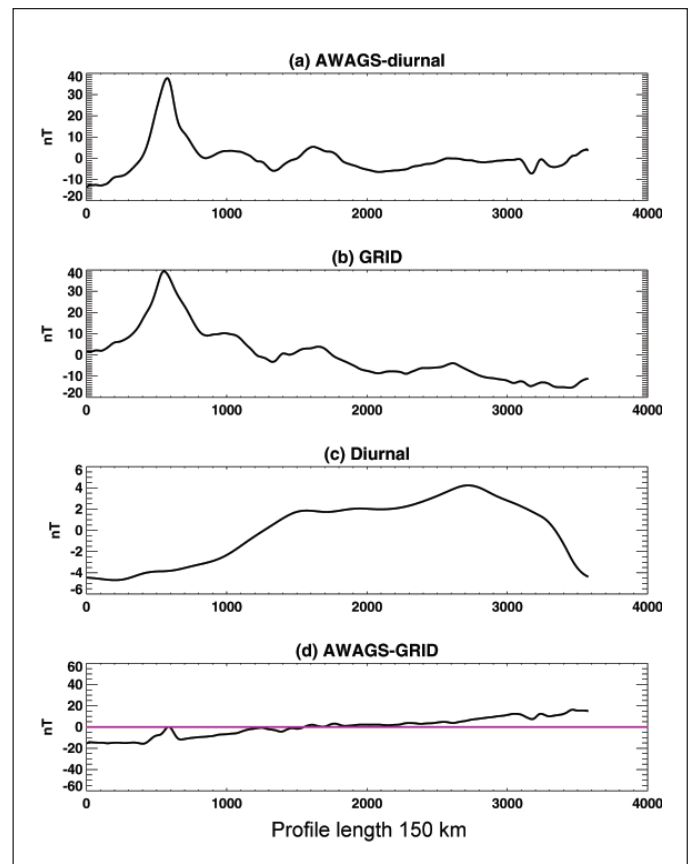


Fig. 4 (b). A poor comparison of AWAGS traverse data with grid data. Refer to Figure 4(a) for an explanation of profiles.

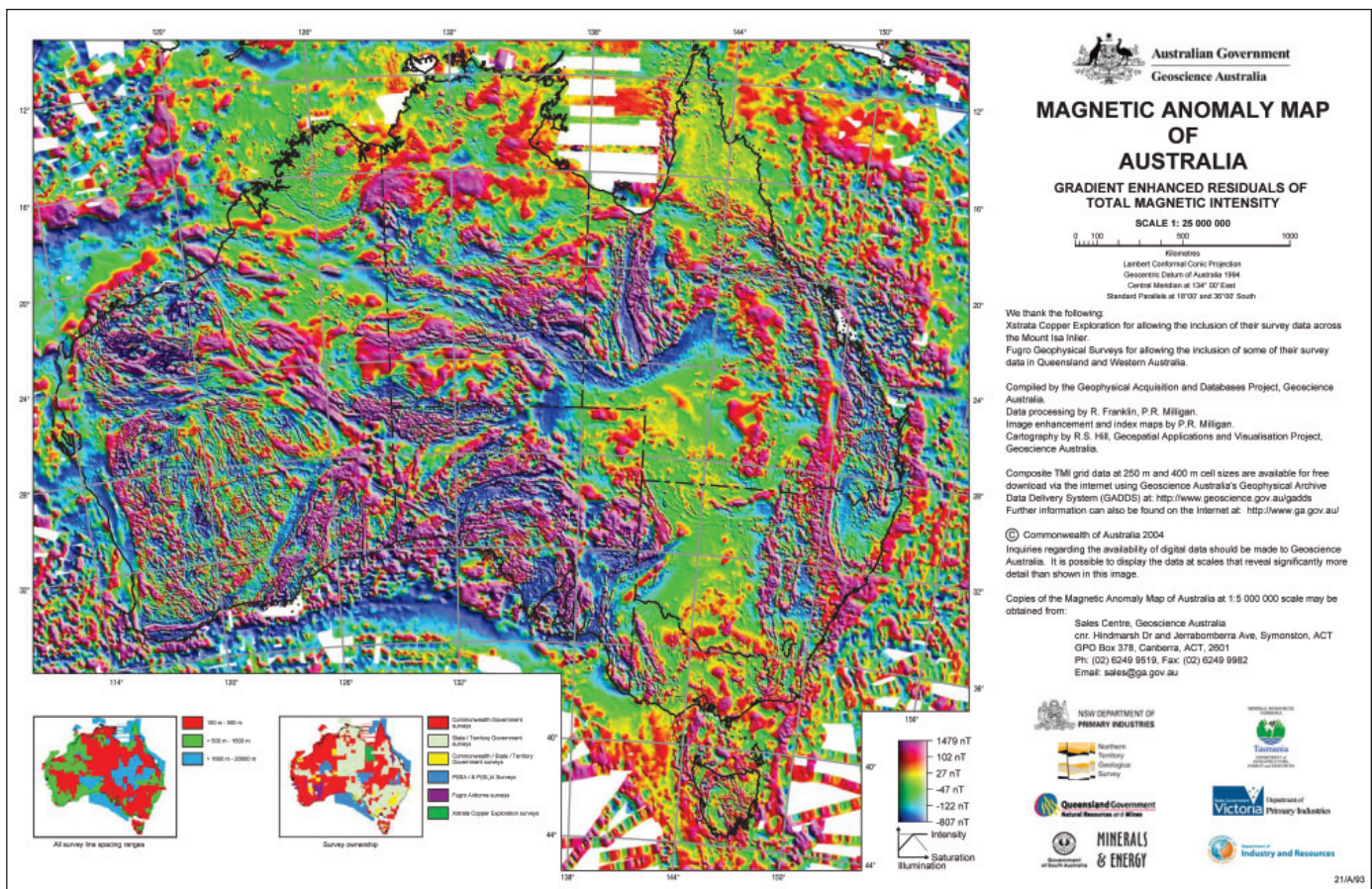


Fig. 5. The 1:25 million scale version of the fourth edition of the Magnetic Anomaly Map of Australia (A4 size handout).

composite grids of the Australian region at 250 m and 400 m grid cell spacings. With the addition of new data, and more accurate long-wavelength information, this map represents a significant advance in the representation of TMI data across the Australian region, compared with previous versions. Figure 5 shows the 1:25 million (A4 size handout) version of the map.

(b) Other derived products

Once a directory of matched grids has been produced, any number of further products can be automatically generated. For example, any region of interest may be chosen and the grids merged seamlessly to a user-specified cell spacing. Individual project grids of, for example, reduced-to-the-pole, vertical and horizontal gradients and the analytic signal can be calculated automatically. For continental-scale composite grid data at high resolution, preliminary reduced-to-the-pole and vertical derivative grids have been generated by using an overlapping tile system in a batch process.

(c) Comparison of Long Wavelengths with Satellite Magnetic Data

The “Decade of Geopotential Research” is now at the halfway stage, with perhaps the most impressive new worldwide magnetic data coming from the CHAMP satellite. This satellite was launched in 2000, at an initial altitude of 460 km. Although this is similar to the altitude of the older Magsat satellite, towards the end of CHAMP’s life in 2007 it should collect data from considerably lower altitudes (to less than 300 km). This will enable resolution of shorter spatial wavelengths of the crustal magnetic field than has been possible previously.

Such satellite data provide an independent dataset for comparison with continental-scale compilations of airborne magnetic data, for the longest wavelengths of greater than 500 km.

The new Australian composite grid has been compared with the CHAMP MF3 crustal field model (Maus *et al.*, 2004) using the method of Ravat *et al.*, 2002. In this method,

the satellite and aeromagnetic data are jointly inverted using an equivalent source layer. The jointly estimated anomaly fields at satellite and aeromagnetic altitudes are then compared with observed data to examine if they are compatible, or if there could be problems with one or both. If the same distribution of equivalent sources can reproduce (to a high level of correspondence) the potential fields over the same region at both aeromagnetic and satellite altitudes, then the data are compatible. If not, then one or both must have errors, at least in certain wavelength ranges, making them incompatible.

This comparison gives a correlation coefficient of 0.75 for the new Australian aeromagnetic data with the jointly estimated field (using wavelengths in a pass-band of 500 km to 3000 km) (Figure 6). But the amplitudes between the data sets do not match perfectly. However, this is much better than the correlation coefficient of 0.45 resulting from the comparison with the third edition grid of Australia. In computing the correlation, the aeromagnetic data is the independent variable and the satellite

data the dependent variable. Because we are using these correlation coefficients as a gross measure in a relative sense (i.e., in judging improvement with respect to another identical data set), rigorous consideration of errors in various data sets or data spacing is not critical.

For further insight into these numbers, some of the most compatible data sets in the world compared in this manner are the Canadian long profile data and the U.S. Project Magnet long profile data processed with the Comprehensive Model of Sabaka *et al.* (2002). Those comparisons yield correlation coefficients of >0.95 and the amplitudes among the data sets are also similar. It is very difficult to get the long wavelengths better in aeromagnetic data without making use of more long aeromagnetic profiles flown in a relatively short time.

Conclusions

A new database of matched grids for airborne TMI data has been developed by Geoscience Australia, using the independently-acquired AWAGS airborne traverse data as both a constraint in the merging process and as a test of grid quality. A variety of derivative products can easily be produced from this new dataset, and composite TMI grids at 250 m and 400 m grid spacing form the basis for the new fourth edition of the Magnetic Anomaly Map of Australia.

A low-pass filtered composite grid of the Australian region has been compared with CHAMP satellite magnetic data, and shows a considerable improvement in the correlation of long wavelength components compared with the previous edition.

A significant improvement is expected in the accuracy of intermediate wavelength magnetic anomalies (about 100 to 500 km wavelengths), but we are yet to rigorously test this improvement

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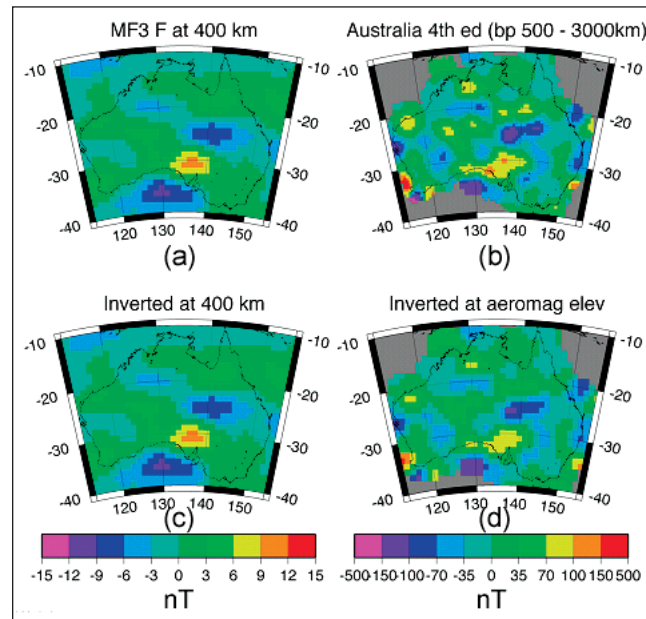


Fig. 6. Comparison of Australian composite magnetic grid with the MF3 CHAMP satellite data model for the total magnetic field. A correlation coefficient of 0.75 is obtained for the new composite TMI grid of Australia (b) with the jointly estimated field (d) (using wavelengths in a pass-band of 500 km to 3000 km).

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