The Geocentric Datum of Australia - A Step in the Right Direction

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Introduction

A new, framework has been adopted for spatial data in Australia. It is known as the Geocentric Datum of Australia (GDA) and is to be implemented by the year 2000.

A geodetic datum is a mathematical reference surface of defined size and orientation that provides the framework for all spatial positions, including maps. Since 1966 the reference for most Australian mapping has been the Australian Geodetic Datum (AGD) (Bomford, 1967). This datum is essentially based on astronomic positions realised by the position of the Johnston Origin, as published in the Australian Commonwealth Gazette in October 1966.

The AGD was adopted as the best fitting reference for Australia at the time and has served this purpose well for more than thirty years. However, because it was a best fit only for the Australian region, it has difficulty fitting into a global context, particularly with technology such as hand-held GPS (Global Positioning System) receivers.

What is a Geocentric Datum?

Modern positioning technology, particularly the increasingly popular GPS, is based on satellites. These satellites orbit around the earth's centre of mass (the geo-centre).

A geocentric, or earth–centred, datum is a reference surface whose centre coincides with the earth's centre of mass and is therefore compatible with GPS and other satellite technology. Although this means that the new datum is no longer a best fit for the Australian region (like the Australian Geodetic Datum), it is a best fit for the whole world, which is the arena in which we now operate.

Why change to a Geocentric Datum?

The need for a change to a geocentric datum was first recognised in 1984 when the National Mapping Council adopted a readjustment of AGD coordinates and *"recognised the need for Australia to eventually convert to a geocentric datum*". This was a commendable anticipation of the pressure that has since come from the common acceptance of GPS. GPS is now widely used by individuals and organisations at all levels and these, often non-technical people, have a reasonable expectation that the spatial products they use will be compatible with their positioning system. While it can be argued that these positioning systems can be made to work with the existing AGD, often the users are not even aware of the need to do so. It is therefore the task of the spatial data providers to ensure that their products meet the needs of the users.

The move to a geocentric datum is supported, and in some cases required, by international organisations. In 1990, the International Federation of Surveyors recommended that its members promote and support the adoption of a global geocentric reference system proposed by the International Association of Geodesy. In 1991, the 56 member maritime nations of the International Hydrographic Organisation (IHO) recommended the production of future navigational charts on a

geocentric datum. On 1 January 1998, the International Civil Aviation Authority (ICAO) moved its operations to a geocentric datum.
In May 1994, at the UN Regional Cartographic Conference for Asia and the Pacific, all member countries resolved to adopt a geocentric datum as soon as possible. This conference also established the "Permanent Committee on GIS Infrastructure for Asia and the Pacific" to facilitate a common datum in the region. Some countries in this region have already adopted a geocentric datum (e.g. New Guinea, New Zealand, and Indonesia) as have other major regions in the world (e.g. North America and Europe).

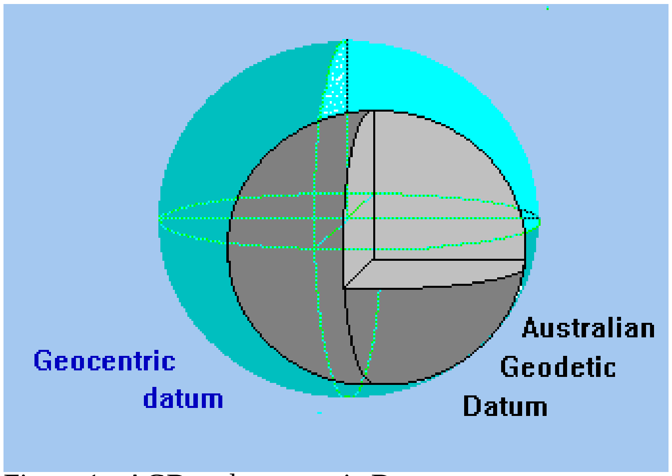

Figure 1 - AGD and geocentric Datum

What is the effect of GDA?

Because the centre of the AGD is about 200 metres from the earth's centre of mass, coordinates of a point in terms of the new Geocentric Datum will be different from the equivalent AGD coordinates. As shown in figure 2, the size and orientation of the change varies with location, but on average is about 200 metres to the north-east. This is equivalent to moving the graticule about 200 metres to the south-west.

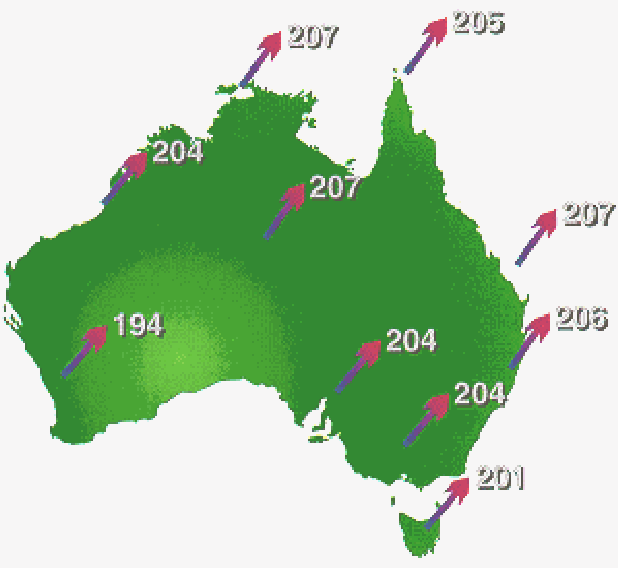

Figure 2 Change from AGD to GDA (m)
The effect on maps of the move to GDA will depend on their scale. As shown in Table 1, it is negligible for maps with a scale smaller than 250,000, but must be allowed for with larger scale maps.

Scale of Map	**Effect of change from AGD to GDA**
1;1,000,000	0.2 mm
1:500,000	0.4 mm

1:250,000	0.8 mm
1:100,000	2 mm
1:50,000	4 mm
1:25,000	8 mm
1:10,000	20 mm
1:5,000	40 mm

Table 1 – Effect of GDA at map scale

How was GDA produced?

In 1992, as part of the world-wide International GPS Service (IGS) campaign, continuous GPS observations were undertaken at eight geologically stable marks at sites across Australia which form the Australian Fiducial Network (AFN). During this campaign GPS observations were also carried out at a number of existing geodetic survey stations across Australia. These were supplemented by further observations in 1993 and 1994, producing a network of about 70 well determined GPS sites, with a nominal 500 km spacing. These sites are collectively known as the Australian National Network (ANN).

Figure 3 - Australian Fiducial and National Networks

The GPS observations at both the AFN and ANN sites were combined in a single regional GPS solution in terms of the International Terrestrial Reference Frame 1992 (ITRF92) and the resulting coordinates were adjusted to a common date of 1 January 1994. The positions for the AFN sites are estimated to have an absolute accuracy of about 2 cm at 95% confidence (Morgan, 1996), while the ANN positions are estimated to have an absolute accuracy of about 5 cm. These positions of the AFN sites were used to define the Geocentric Datum of Australia (GDA) and were published in the Commonwealth of Australia Government Gazette on 6 September 1995.

The positions of both the AFN and ANN sites were used to constrain a re-adjustment of the Australian geodetic networks. This adjustment included all observations from the previous 1966 and 1984 AGD adjustments, conventional observations added since that time, and the extensive GPS networks established by the State and Territory authorities at about 100 km spacing between the ANN sites. This resulted in a data set of more than 70,000 observations and produced GDA coordinates at almost 8,000 stations. These GDA coordinates are now being used by the State and Territory authorities to re-adjust their subsidiary survey networks onto GDA. This will provide many hundreds of thousands of additional GDA coordinates.

The GDA latitudes and longitudes generated by this process are known as GDA94 coordinates, because they are referred to the common epoch of 1 January 1994. Universal Transverse Mercator coordinates, projected from the GDA94 positions with the GRS80 ellipsoid, are known as Map Grid of Australia 1994 coordinates (MGA94).

It should be noted that the datum for heights in Australia has not changed and remains as the Australian Height Datum (AHD).

What is the difference between GDA and WGS84?

The International Terrestrial Reference Frame on which GDA is based, is a global network of accurate geocentric coordinates, maintained by the International Earth Rotation Service (IERS). Revised reference frames are produced, generally on an annual basis, but the system is sufficiently refined that the change between successive ITRFs is only of the order of a couple of centimetres (Boucher, 1994).

The WGS84 reference frame is well known because it is used by the GPS system (DMA, 1987). This reference frame was produced by the United States Defence Mapping Agency (now NIMA - National Imagery and Mapping Agency) but has been enhanced on several occasions, although the name has

stayed the same. It is *now "consistent with the prevailing ITRF at a level of the order of a few centimetres*" (Malys and Slater, 1997).
The end result is that WGS84 is the same as GDA94 (at the limit of the WGS84 accuracy) and GDA94 may be used as WGS84.

How do I convert to GDA?

The timing of the conversion to GDA94 by individual organisations will be influenced largely by user demand. The national framework is in place and GDA State & Territory geodetic networks are well in hand. Ideally all spatial data should be re-computed in terms of GDA, but this is often inefficient, or even impossible when the original source data is not available. In these cases a transformation from AGD to GDA is required.
Ideally, the transformation process should be easy, efficient, accurate and unique. However, in practice the easy methods are not accurate, and the accurate methods are not easy, so it is not possible to have a unique method that satisfies everyone. Therefore, a number of transformation strategies have been developed. The most efficient method with the appropriate accuracy should be chosen for each project, but it must be realised that the different methods will give slightly different results. Therefore, to prevent future confusion, the transformation method used should be stored with the meta-data for that product.

- The simplest method of transformation is to add a change in latitude and longitude (or easting and northing). The average size of the shifts between AGD and GDA94 has been computed for each 1:250,000 topographic map areas across Australia. These shifts have a limited accuracy of about 10 metres but are trivial to apply. They are available in the spreadsheet that is included in chapter 7 of the "GDA Technical Manual" (www.anzlic/icsm/gdatm/gdatm.htm).
- Molodensky’s formulae are also given with worked examples in the GDA Technical Manual. These formulae are relatively simple and convert directly from AGD latitude and longitude to GDA latitude and longitude by applying a 3 dimensional origin change and allowing for the change in ellipsoid. The estimated 5 metre accuracy and the simple but easily automated process makes this method ideal for conversions of large quantities of low accuracy data.
- The similarity transformation is more accurate than Molodensky’s formulae (estimated 1 metre), but also more complex because the transformation is carried out in terms of earth-centred Cartesian coordinates. It applies the 3 origin shifts, as well as three rotations and a scale parameter. This method too is given with worked examples in the GDA Technical Manual.
- As GDA94 is implemented in Australia, it is becoming apparent that there is a need for a transformation process with an accuracy of about a decimetre. Investigations for one of Australia’s State authorities have shown that it is possible to achieve this accuracy by including a distortion model. (Collier, 1997). This process involves obtaining sufficient common data to model the distortions in the data and fitting a surface to the distortions, to allow interpolation of local shifts in latitude and longitude. Several States have started on this process and results will be made available on the World Wide Web as soon as they are available, in the form of a grid of simple (but accurate) block shifts.

AUSLIG products

All new AUSLIG products are, or can be provided, in terms of GDA. As individual product transition strategies are refined, clients will be kept informed through AUSLIG's standard publications. In addition GDA policy for individual products is shown on AUSLIG’s web site (www.auslig.gov.au/ausgda/gdastrat.htm).

Conclusion

The Geocentric Datum of Australia is more accurate than AGD and is directly compatible with GPS, the latest global datum and an emerging regional datum. The national framework for GDA is already in place and processes to transform from the old AGD system to the new GDA are available. GDA products are already being produced and this process will accelerate as user demand increases and organisations gear up for the change.

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