Australian Government
Geoscience Australia

AUSGEO news
ISSUE 97 Mar 2010

AUSGeoid09: Converting GPS heights to AHD heights

Improving access to Australia's vertical datum

Nicholas Brown

Knowing your height above sea level is important. Height information is essential for a wide range of activities: town planners use it to avoid building hospitals in flood zones, mountain climbers use it to ensure they have enough oxygen for their trip and aircraft pilots need it to land safely. In Australia, heights above mean sea level (MSL) are referenced to the Australian Height Datum (AHD). The AHD was established by setting the mean value observed at 32 tide gauges around Australia between 1966 and 1968 to a height of 0.000 metres. Levelling techniques were then used to transfer heights relative to MSL across Australia.

Global Positioning System (GPS) receivers, which are now widely used for accurate positioning and navigation in Australia, use a different reference surface known as the ellipsoid. The ellipsoid is a simplified approximation of the Earth that looks like a basketball which has been slightly squashed at the top and bottom. Unfortunately, the ellipsoid is not directly compatible with the AHD. Consequently, there has been an increasing demand for a method of combining the speed of GPS data acquisition and the practicality of the AHD. AUSGeoid09 is the answer; it offers significant productivity gains for GPS users by allowing them to compute AHD heights either in the field in real time or back in the office.

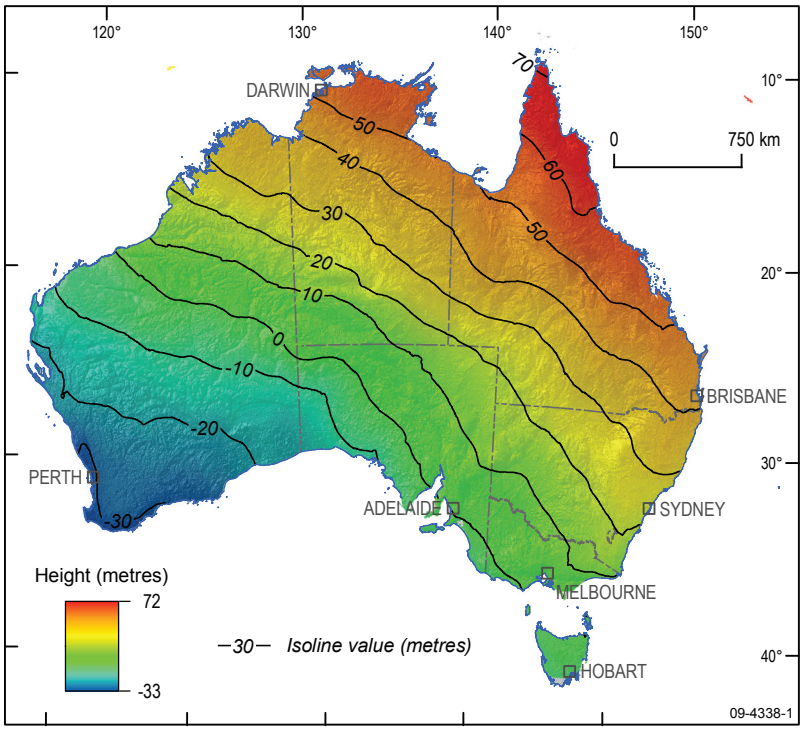

Figure 1. AUSGeoid09 allows GPS users to convert between GPS heights and AHD heights. In southwest Australia, the AHD is up to 33 metres below the ellipsoid and in northwest Australia the AHD is up to 72 metres above the ellipsoid.

AUSGeoid09 is a three dimensional model used to convert ellipsoidal heights (as observed by GPS) to AHD heights to within ±0.050 metres accuracy across most of Australia (figure 1). For example, if you use a GPS receiver to compute the height of your house, it will provide you with the ellipsoidal height. By subtracting the value of the AUSGeoid09 model at the latitude and longitude of your house, you can compute the AHD height. AUSGeoid09 is still undergoing final testing before its release in mid-2010. Before describing how AUSGeoid09 was developed, it is worth explaining some basic concepts and how they are interrelated.

Understanding the Geoid

What is a geoid?

A geoid is a three dimensional surface of equal gravity (equipotential). Although there are an infinite number of these equipotential surfaces for the Earth, 'The Geoid' is often used to describe the equipotential surface which best corresponds with MSL. Across Australia, MSL and its onshore realisation, the AHD, correspond to within approximately ±0.5 metres of 'The Geoid'; however, there is an offset mainly caused by the way the AHD was computed.

Why the AHD and The Geoid do not coincide

In establishing the AHD, the mean sea level at 32 tide gauges from all around the Australian coastline were assigned a value of 0.000 metres AHD. Given that the warmer/less dense water off the coast of northern Australia is approximately one metre higher than the cooler/denser water off the coast of southern Australia, the AHD is about 0.5 metres above The Geoid in northern Australia and roughly 0.5 metres below The Geoid in southern Australia (figures 2 and 3).

History of AUSGeoid models

All AUSGeoid models have been designed to assist GPS users to convert ellipsoidal heights to AHD heights. Older versions of AUSGeoid ('93, '98) are predominantly based on satellite and terrestrial gravity observations which were a best fit of The Geoid over Australia (Featherstone et al 2001). These AUSGeoid versions, referred to as gravimetric geoids, do not account for the one metre offset trend between The Geoid and the AHD. As a result, when using these versions GPS users can only retrieve AHD heights to within ±0.5 metres.

AUSGeoid09 is slightly different. Instead of only using gravity data, it also includes a geometric component developed from GPS and AHD data which describes the approximate one metre offset trend between the AHD and the gravimetric geoid. The gravimetric and geometric components are combined together into a single national grid with two kilometre resolution.

The addition of the geometric component means that the AUSGeoid09 model is no longer a true representation of The Geoid because it is not an equipotential surface. However, the AUSGeoid name is retained for familiarity.

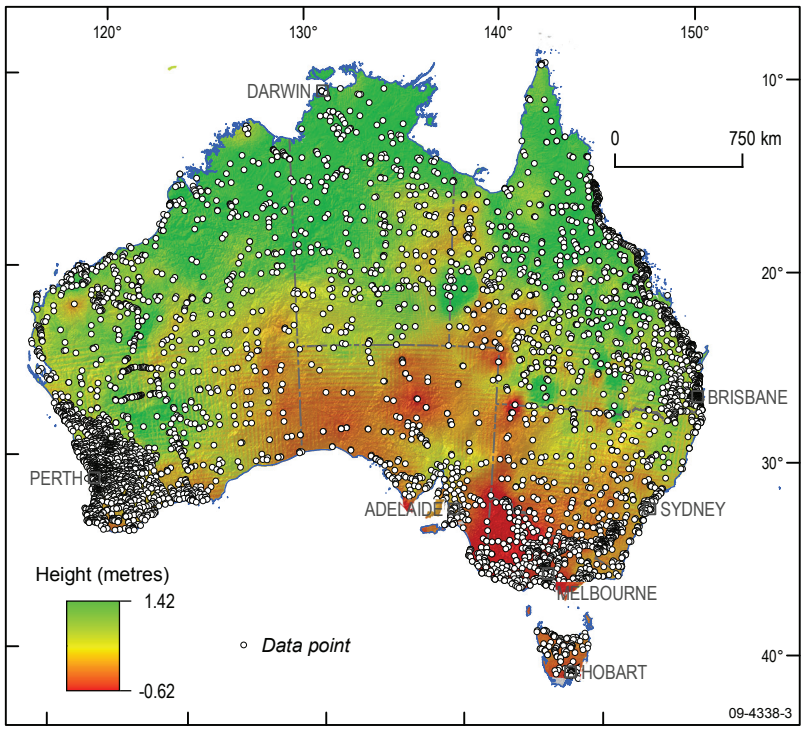

Figure 2. The offset between the AHD and The Geoid in Australia is caused predominantly by the difference in ocean temperature between northern and southern Australia.

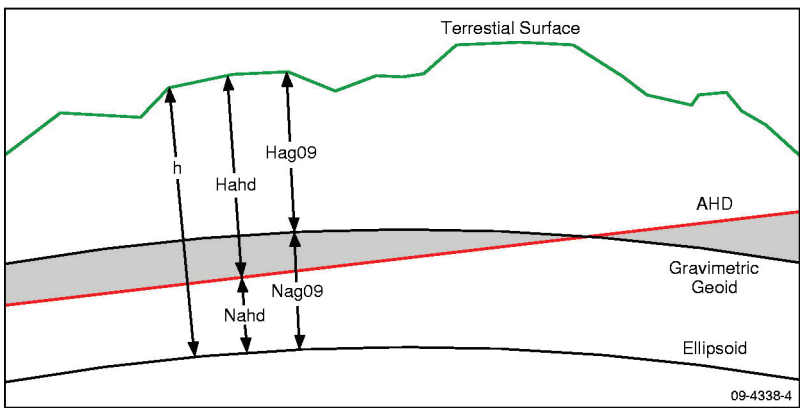

Figure 3. The different heights used to compute AUSGeoid09.

Computing AUSGeoid09

The gravimetric component of AUSGeoid09 is a spherical harmonic synthesis of the Earth Geopotential Model 2008 (EGM2008), developed from satellite gravity observations plus 1.3 million points from Geoscience Australia's land gravity database. The geometric component of AUSGeoid09 sets it apart from its predecessors. The offset (O) between the AHD and the gravimetric geoid, which is positive when the AHD is above the gravimetric geoid, was derived at over 5000 points

across Australia: $O = h - N_{ag} - H_{ahd}$ where h is the ellipsoidal height (from GPS observations), N_{ag} is the gravimetric geoid - ellipsoid separation (from the gravimetric geoid), and H_{ahd} is the AHD height (see figure 3). The geostatistical interpolation technique of Kriging was used to compute a regular grid of offsets which were added to the gravimetric geoid to produce AUSGeoid09.

How accurate is AUSGeoid09?

The AUSGeoid09 model has significantly improved a GPS user's ability to compute AHD heights across Australia. However, there are still some points which have 'misfits' exceeding a decimetre because of errors in the levelling network (Filmer and Featherstone 2009), land subsidence, long wavelength geoid anomalies, GPS errors or a lack of data (figure 4). Geoscience Australia and the state and territory survey authorities endeavour to resolve the cause of these misfits; however, given that in most cases the largest misfits occur in sparsely populated areas, the impact on the user is minimal.

The AUSGeoid98 gravimetric geoid is capable of converting a GPS ellipsoidal height to an AHD height within ±0.364 metres across 65 per cent of Australia (Featherstone et al 2001). Through modelling the north-south trend between the gravimetric geoid and the AHD plus improvements in the underlying gravimetric geoid, AUSGeoid09 has reduced this uncertainty to less than ±0.050 metres.

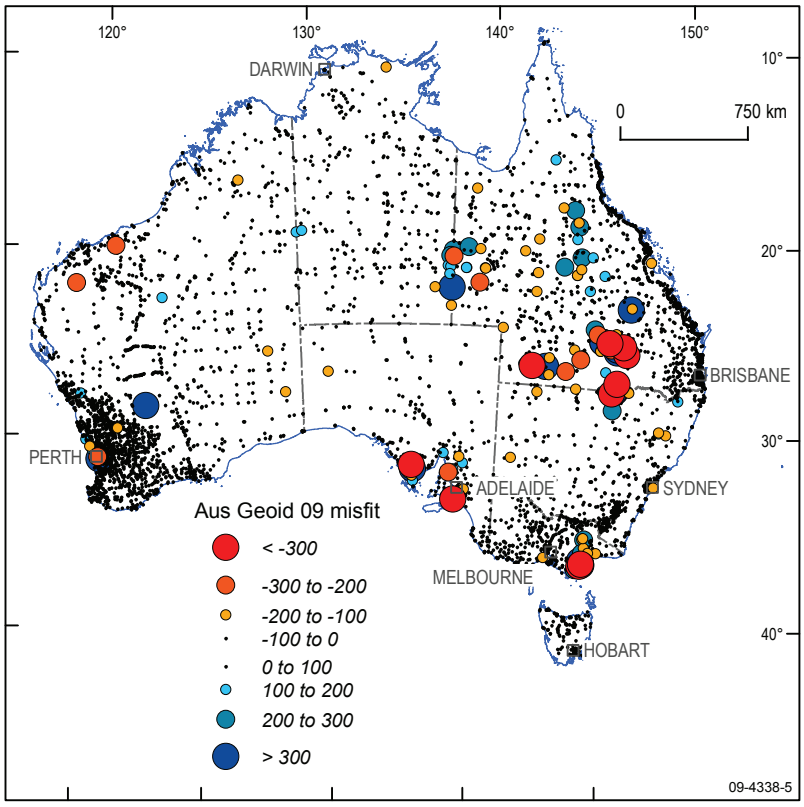

Figure 4. AUSGeoid09 fits well in the population centres, however large misfits still exist in some areas (units in millimetres).

The advantages for GPS Users

Until now, the capacity to accurately relate GPS heights to Australia's vertical datum has been the missing link for positioning. AUSGeoid09 now allows GPS users to compute an accurate AHD height in real time offering significant efficiency gains for industries such as mining, agriculture and construction. There are also advantages for those working in areas such as environmental management or natural hazard modelling as they are now able to easily and accurately capture AHD heights to generate new datasets or augment existing ones. In addition, AUSGeoid09 can be used with satellite imagery to shift the vertical datum of the imagery from the gravimetric geoid to the AHD. This increases the utility and potential applications of the imagery in areas such as tsunami inundation modelling, flood mapping and bush fire response.

References

Featherstone WE, Kirby JF, Kearsley AHW, Gilliland JR, Johnston GM, Steed J, Forsberg R & Sideris MG. 2001. The AUSGeoid98 geoid model of Australia: data treatment, computations and comparisons with GPS-levelling data. Journal of Geodesy 75(5–6): 313–30.

Filmer MS & Featherstone WE. 2009. Detecting spirit-levelling errors in the AHD: recent findings and issues for any new Australian height datum. Australian Journal of Earth Sciences, 56(4): 559–69.

For more information

phone Nicholas Brown on +61 2 6249 9831
email nicholas.brown@ga.gov.au