Frequently Asked Question on Geodetic Datum Definition and Realisation

451-337 Satellite Positioning and Geodesy

1. Why are there multiple geodetic datums in Australia?

Over time, advances in geodesy (particularly measurement techniques, computational and adjustment strategies and the ability to model previously ignored errors) have tended to highlight deficiencies in historical datums such as AGD66. The emergence of these deficiencies creates the need for a new realisation of the datum (e.g. AGD84) or even the establishment of a totally new datum (e.g. GDA94). The new realisation (or new datum) is defined/realised in a way that it is better able to support modern technology and positioning capabilities.

Ideally the introduction of a new datum or a new realisation would be accompanied by the abandonment of the old. However, in practice it must be recognised that many organisations retain data referred to the old datum and this creates the need to know about and to be able to work with multiple datums.

2. Why did Australia move to GDA94?

Firstly, there were a number of shortcomings in existing datums as well as incompatibilities between states caused by the fact that some states used AGD66 (Victoria, NSW, Tasmania and NT) and others used AGD84 (Qld, WA and SA).

Secondly, it was argued that the adoption of a geocentric datum would produce consistency both nationally and internationally and would give Australia a datum that would be compatible with space based positioning techniques such as GPS (and the emerging Galileo system).

3. How do you choose which datum to use (is it dictated by location or by application)?

Within Australia, datum choice is generally dictated by application. The first preference should always be to work on GDA94 and to abandon AGD66/84. GDA94 is a better and more consistent datum and the compatibility with GPS makes things much easier in practise. However some applications will still require use of the old datum, e.g. if a client is asking for new points to be established which are compatible with exiting points on an old datum.

4. What is the relationship between GRS80, WGS84 and GDA94?

GRS80 is an ellipsoid. It is defined by its size (a – semi-major axis) and shape (f – flattening). GRS80 is widely used as the ellipsoid for many geocentric datums (e.g. GDA94 and the ITRF*xx* realisations).

WGS84 is both an ellipsoid and a realised geodetic datum (this duplication of terminology is often the cause of some confusion). WGS84 is a military datum developed in support of GPS – all positions and baselines measured using GPS receivers are related to WGS84.

GDA94 is Australia's version of a geocentric datum. It is a realisation of ITRF92 (at epoch 1994.0) across Australia, achieved by the computation of the coordinates of stations in the Australian Fiducial Network (more about this in lectures).

5. How are measurements used to achieve the realisation of a geodetic datum?

The realisation of any geodetic datum requires at least the following steps :

(a) Establishment of monumented points on the ground (geodetic control points)
(b) Measurement between those points (e.g. angles, distances, GPS baselines, SLR, VLBI, etc…). The measurements must also connect the new points to the point(s) that have been used in the datum *definition* (thus the Johnston Geodetic Origin in the case of AGD66/84 and the Australian Fiducial Network in the case of GDA94 – more in lectures)
(c) Computation (via least squares network adjustment) of the coordinates of those points
(d) Publication of the coordinates for public use

The coordinates thus produced are the realisation of the datum.

Measurements (of whatever type – terrestrial or space based) allow the points on the ground to be interconnected and thus coordinates to be computed.

6. Explain the ellipsoid parameters

An ellipsoid is a *solid of revolution* created by rotating an ellipse about its semi-minor (short) axis. The size and the shape of the ellipsoid (sometimes called a *spheroid* in geodesy – thus ANS) are established by two parameters – the semi-major axis (a) and the flattening (f). All other ellipsoid parameters can be derived from these two and express other geometric features of the ellipsoid. In geodesy, the flattening is most commonly used rather than (say) the first eccentricity squared (e^2) because it quantifies the non-sphericity of the ellipsoid.

For example a typical geodetic flattening of 1/298.26 = 0.34%. This means that the semi-minor axis (b) is only 0.34% shorter than the semi-major axis (a) – thus the ellipsoid is very nearly spherical. [calculation: (a-b)/a*100 = 0.34]

7. What is the difference between a geocentric and a non-geocentric datum?

A geocentric datum has the centre of the relevant geodetic ellipsoid and thus the origin of the associated cartesian axes (X,Y,Z) located at the earth's centre of mass. In recent years there has been a move toward the adoption of geocentric datums around the world. This has been prompted by the compatibility between geocentric datums and space based positioning techniques such as GPS. GDA94, WGS84 and ITRF*xx* are all examples of geocentric datums.

Non-geocentric datums are not earth centred. They are generally historical (old) and are usually defined with the intention of minimising the separation between the geoid and the ellipsoid on a national scale. Positioning the ellipsoid to minimise the geoid-ellipsoid separation was done to allow geoid undulations and deflections of the vertical to be ignored in geodetic computations. In Australia, AGD66 and AGD84 are realisation of the non-geocentric AGD. The AGD is based on the Australian National Spheroid (ANS) which was positioned by adopting coordinates of the Johnston Geodetic Origin which minimised the separation between the surface of the ANS and the geoid across Australia.

8. Will there be more datums in the future?

The short answer is *yes*. Geodetic techniques will continue to improve and thus highlight the deficiencies in existing datums (even if they are geocentric). More importantly, crustal motion and plate tectonics mean that in reality point coordinates are *continuously* changing within in a global reference frame. Thus *static* datums like GDA94 quickly lose their global consistency. In tectonic terms, Australia is moving to the north-east at a rate of about 6-7 cm per year, meaning that GDA94 coordinates are moving away from their true global values at the same rate.

9. What is the geoid undulation? (define the geoid)

The geoid undulation (N) is the separation between the ellipsoid and the geoid.

The geoid itself is a relatively regular surface. It is a surface of equal gravitational potential (thus it is *level*) that coincides with Mean Sea Level in the open oceans. An equipotential surface is *level* by definition because at all points the direction of gravity is at right angles to the surface (more about this in lectures – Chapter 10).

10. What is a Laplace station?

A Laplace station is a geodetic station at which astronomic observations have been taken to allow the determination of astronomic latitude, longitude and azimuth. Note that these astronomic quantities are related to the geoid through the plumbline and are consequently related to their geodetic equivalents via the two components of the deflection of the vertical.

$$\varphi = \Phi - \xi$$
$$\lambda = \Lambda - \eta \sec\varphi$$
$$\alpha = A - (\eta \tan\varphi + (\xi \sin\alpha - \eta \cos\alpha)\cot\zeta)$$

where;

- φ is the geodetic latitude of the point of observation
- λ is geodetic longitude of the point of observation
- α is the geodetic azimuth to a nominated target point
- Φ is astronomic latitude
- Λ is astronomic longitude
- A is the astronomic azimuth
- ξ is the meridian (north-south) component of the deflection of the vertical
- η is the prime-vertical (east-west) component of the deflection of the vertical
- ζ is the zenith angle to the target point

11. A summary

Definition	Datum type	Ellipsoid	Realisation(s)
Australian Geodetic Datum (AGD)	Regional	Australian National Spheroid (ANS)	AGD66 AGD84
World Geodetic System 1984 (WGS84)	Geocentric	World Geodetic System 1984 (WGS84)	For example : WGS84 (*G873*) WGS84 (*G1150*)
Geocentric Datum of Australia (GDA)	Geocentric	Geodetic Reference System 1980 (GRS80)	GDA94 (ITRF92 @ 1994.0)
International Terrestrial Reference System (ITRS)	Geocentric	GRS80	For example : ITRF92 ITRF94 ITRF00