GDA2020, AUSGeoid2020 & ATRF explained

Amid all the confusion, this article spells out Australia's move from plate-fixed to earth-fixed datums, and the growing number of acronyms spatial professionals need to know.

DR VOLKER JANSSEN

A modernised geodetic foundation will allow users to make the most of modern satellite-based positioning, open up new industries and increase productivity.

The Geocentric Datum of Australia 1994 (GDA94) has been our national datum since its adoption in 2000. Significant improvements in positioning technology in the recent past have revealed that it is no longer capable of providing the required quality of datum for modern-day positioning applications. Consequently, Federal and State and Territory Governments have worked towards modernising Australia's datum for some time. We are now on the cusp of these changes coming into effect.

The Geocentric Datum of Australia 2020 (GDA2020) is a new, much improved Australian national datum that will replace GDA94 by 1 January 2020. It is to be used in conjunction with the new AUSGeoid2020 to connect to the Australian Height Datum (AHD). By 2020, GDA2020 will be complemented (and possibly one day replaced) by the time-dependent, earth-fixed Australian Terrestrial Reference Frame (ATRF). To explain that properly, however, we must go much deeper.

Coordinate systems & datums

A coordinate reference system is a methodology to define the specific location of a feature in space. Routinely, we use an ellipsoid to approximate the shape of the Earth. Positions on the ellipsoid are usually expressed in Cartesian coordinates (X, Y, Z) or curvilinear geographic coordinates (φ, λ, h), i.e. latitude, longitude and ellipsoidal height.

Since a coordinate system is an idealised abstraction, it can only be accessed in practice through its physical materialisation (or realisation) called a reference frame or datum. The datum effectively defines the origin and orientation of the coordinate system at a certain instant in time (epoch), generally by adopting a set of station coordinates.

Nowadays this is usually provided by a network of Global Navigation Satellite System (GNSS) Continuously Operating Reference Stations (CORS). Over time, different techniques with varying levels of sophistication have been applied to approximate the shape of the Earth's surface, resulting in the adoption of many different datums.

A geocentric datum uses the Earth's centre of mass as its origin and is therefore compatible with GNSS-based positioning. The current ellipsoid of choice in Australia (and indeed for the International Terrestrial Reference Frame – ITRF) is the Geodetic Reference System 1980 (GRS80), a geocentric ellipsoid designed to approximate the Earth on a global scale.

Projections & transformations

In practice, it is often required to express positions on a flat surface in the form of grid coordinates, i.e. in a 2-dimensional Cartesian coordinate system such as easting and northing. This is achieved by map projections according to a recognised set of mathematical rules, resulting in an ordered system of projected meridians (lines of constant longitude) and parallels (lines of constant latitude).

The most common projection used in Australia is the Universal Transverse Mercator (UTM) projection, which utilises a zone width of 6° and ensures that the scale is very close to unity across the entire zone. When applied to GDA94 coordinates in Australia, the resulting projected coordinates are known as the Map Grid of Australia 1994 (MGA94).

As new datums are defined based on increased amounts of data and improved processing techniques, new and better transformation parameters are published. While there may be a significant delay between their initial availability and eventual adoption in software via updates or patches, it is important for users to apply the latest set of transformation parameters in order to achieve the highest possible quality of output coordinates.

Drivers for datum modernisation

Datum modernisation is required in order to accommodate the increasing accuracy and improved spatial and temporal resolution available from modern positioning technologies to an ever-broadening user base. The goal of datum modernisation is to supply all users with the most complete yet most straightforward datum products that can define a locally consistent set of coordinates, such that their positioning device agrees with the physical world and associated spatial data to an acceptable level of accuracy.

It is important to emphasise that geodetic control underpins all spatial data, including applications such as mapping, surveying, construction and mining, agriculture, environmental and asset management, transport, insurance, emergency services, communication and research.

The growing trend to 'big data' and 'open data' is only possible if these datasets across these areas are built on a solid foundation provided by geodetic control, so they actually fit together and can facilitate meaningful results.

The main drivers for datum modernisation in Australia include:

- Including up-to-date geodetic observations and increased precision
- Removing known distortions
- Providing seamless coordinates across state border
- Accounting for tectonic plate motion
- Accounting for tectonic plate rotation
- Introducing a truly 3D datum defined by ellipsoidal heights

Plate-fixed datums

A plate-fixed datum is attached to the tectonic plate and therefore also known as a static datum. It is 'frozen' at a certain instant in time (the reference epoch), essentially preventing the coordinates from changing over time due to (normal) tectonic plate motion.

However, as the time difference between the reference epoch and the current epoch increases, the plate-fixed datum deviates more and more from the true position of the plate (and the earth-fixed datum used for GNSS). Consequently, it needs to be updated at frequent intervals. GDA94 and GDA2020 are examples of plate-fixed datums.

GDA94

GDA94 was defined in the then state-of-the-art global reference frame, the International Terrestrial Reference Frame 1992 (ITRF92) at epoch 1994.0.

This definition was justified by the relatively uniform drift of the Australian continent at about 7 cm/yr to the north-east. Tectonic plate motion causes the difference between ITRF coordinates and GDA94 coordinates to increase over time, amounting to about 1.6 m at present.

This is generally not an issue for differential GNSS applications, however the increasing number of real-time mass-market applications is causing this offset to introduce errors for the layperson.

GDA2020

GDA2020 is a much more homogeneous plate-fixed datum, based on a national least squares network adjustment that rigorously propagates uncertainty. GDA2020 is defined in the current state-of-the-art global ITRF2014 reference frame at epoch 2020.0. The coordinates are extrapolated into the future to 1 January 2020 in order to extend the lifespan of the datum.

GDA2020 is realised by gazetting an expanded AFN consisting of 109 GNSS CORS, mainly including stations contributing to the Australian Regional GNSS Network (ARGN) and the AuScope network.

The UTM projection will continue to be used to project latitude and longitude to grid coordinates (Easting, &Northing), albeit based on new equations. These grid coordinates will be expressed in the Map Grid of Australia 2020 (MGA2020).

Following a transition period, GDA2020 is to be adopted by 1 January 2020, although most jurisdictions may decide to move to the new datum earlier. This move from GDA94 to GDA2020 will cause the horizontal coordinates of a mark to shift by approximately 1.8 m to the north-east, while the ellipsoidal height will decrease by about 0.1 m.

AUSGeoid2020

In order to connect to the Australian Height Datum (AHD), it is therefore crucial to apply AUSGeoid2020 to GDA2020 ellipsoidal heights, while AUSGeoid09 must be used to convert GDA94 ellipsoidal heights. Due to the aforementioned 0.1 m difference in ellipsoidal heights between GDA94 and GDA2020, a user should never combine AUSGeoid2020 with GDA94 or AUSGeoid09 with GDA2020. While AUSGeoid2020 has the same extent and density as its predecessor AUSGeoid09, it is based on a much larger and much more homogeneous dataset. AUSGeoid2020 also provides a rigorous uncertainty value associated with the offset between the ellipsoid and AHD, varying as a function of location. In contrast, AUSGeoid09 only provides a constant uncertainty estimate.

Earth-fixed datums

An earth-fixed datum accounts for the Earth's dynamics by allowing tectonic plates to move within it over time, i.e. it is 4-dimensional. It is fixed to the Earth but not its crust and therefore also known as a 'dynamic datum', however this is a term to be avoided because the datum is not dynamic but the Earth is! Consequently, the coordinates of a given ground mark are constantly changing. It is critical to attach a time stamp to each position given in an earth-fixed datum, so a position given at a reference epoch can be propagated to the current or any other epoch using station velocities. ITRF, ATRF and WGS84 are examples of earth-fixed datums.

ITRF

The International Terrestrial Reference Frame (ITRF) is the most precise earth-centred, earth-fixed datum currently available – the global gold standard if you like. It was first introduced in 1988 and has since gone through 13 versions, including the current ITRF2014. The ITRF is updated regularly in order to account for the dynamics of the Earth.

ATRF

The Australian Terrestrial Reference Frame (ATRF) will be a regional realisation of the ITRF. As a consequence, Australian spatial information will be directly interoperable with GNSS measurements. It is anticipated that the ATRF will be implemented from January 2020 with adoption planned to be complete by 2023. However, it is important to note that GDA2020 and ATRF will exist in tandem for the foreseeable future. Over time GDA2020 will meet the fate of all plate-fixed datums and become outdated.

WGS84

The World Geodetic System 1984 (WGS84) is the nominal datum used by GPS. It is based on the WGS84 ellipsoid, which can generally be assumed identical to the GRS80. The WGS84 datum was introduced in 1987 and has since been refined several times to be closely aligned with the ITRF. For most purposes WGS84 and ITRF can be assumed identical, however, WGS84 is based on a much smaller number of reference stations and the level of agreement worsens as the time between realisation grows.

From GDA2020 to ATRF

It is anticipated that the transition from GDA94 to GDA2020 will be complete by 1 January 2020, i.e. the date ATRF is planned to be released. However, most states and territories are expected to move to GDA2020 before this date. The Intergovernmental Committee on Surveying and Mapping's (ICSM's) GDA Modernisation Implementation Working Group (GMIWG), which is overseeing the datum modernisation, has already released GDA94-GDA2020 and ITRF2014-GDA2020 transformation parameters and the GDA2020 Interim Release Note. The soon-to-be-released GDA2020 Technical Manual will provide more detailed information, while the official release of AUSGeoid2020 is also imminent.

Conclusion

Once adopted GDA2020 and ATRF will are expected to operate in tandem as a 'dual frame system' for the foreseeable future. The ongoing datum modernisation will provide a much improved Australian national datum that will ensure that Australia is well positioned into the future.

Dr Volker Janssen works at Spatial Services, a unit of the NSW Department of Finance, Services and Innovation (DFSI), which operates CORSnet-NSW. ■