Fit for purpose:

GDA94-GDA2020 transformation grids fit for NSW

NICHOLAS GOWANS AND VOLKER JANSSEN

The Geocentric Datum of Australia 2020 (GDA2020) is now the official national datum of Australia, but how should surveyors bring their existing datasets from GDA94 to GDA2020?

The Intergovernmental Committee on Surveying and Mapping (ICSM) recommends transformation grids, which can be easily obtained online and used with existing software, as a simple and nationally consistent method for transforming between Australian datums. Consequently, two grids have been produced to cater for different realisations of GDA94.

With a focus on NSW, this article explains the composition and purpose of each GDA94-GDA2020 transformation grid. It identifies accuracy and data origin as the two key factors determining their appropriate use.

Performance analysis results indicate that both grids are fit for purpose in NSW when used in the appropriate circumstances. Prior to transformation, users must know if their existing GDA94 dataset is affected by known GDA94 distortions (present in the Survey Control Information Management System, SCIMS), or if those distortions have already been removed by other methods.

Background

In October 2017, GDA2020 was gazetted as Australia's new, improved national datum. When spatial information users wish to adopt the new datum, they may consider transforming their legacy datasets from the now superseded GDA94 to GDA2020. The following recommendations apply whether transforming data permanently to GDA2020, or instead using a transformation on-the-fly to combine data from multiple datums at the time of application.

In recent years, spatial data utilisation has soared, aided by open-source Geographic Information Systems (GIS) and government efforts to deliver open spatial data. As a consequence, the important role datum plays in meaningfully aligning data from a variety of sources is highlighted.

Failure to correctly manage datum across multiple datasets could compromise any analysis. Further, decimetre-accurate or better real-time positioning (e.g. RTK, DGNSS or SBAS-based positioning) now means tagging datasets with appropriate metadata, such as datum and even date observed, has become critical. The user must know their data, know their date and know their datum.

In Australia's previous datum modernisation efforts, transformation grids were utilised as a simple and efficient method for transforming datasets to the new national standard. This strategy is now continued to aid uptake of GDA2020 from GDA94 with the development of two transformation grids and a number of tools, plug-ins and services.

GDA94-GDA2020 transformation: The harder way

A conformal (often called a similarity) transformation can be used to transform between reference frames. This transformation owes its name to its characteristic of preserving angle and shape throughout the process.

The 3-dimensional conformal transformation between GDA94 and GDA2020 is described in the GDA2020 technical manual and accounts for the difference in scale, rotation and translation between reference frames. This transformation method is suitable for 3D data and requires coordinates to be expressed in an earth-centred Cartesian (XYZ) system.

The transformation can be computed using just seven parameters. However, the formula can appear daunting to users without a background in geodesy and cannot be applied to 2D data. Furthermore, conformal transformations cannot compensate for localised survey network distortion because this method only accounts for simple mathematical differences, and tectonic plate motion, between the frames.

GDA94-GDA2020 transformation: The easier way

A grid transformation is a two-dimensional method of transforming between reference frames and is ICSM's preferred method of transforming between Australian datums. When creating the grid, transformation components (i.e. a series of latitude and longitude shifts across all of Australia) are initially computed across a grid at a set interval.

Given a transformation grid, various interpolation methods can then be applied at the user end to compute shifts at an exact user-determined location (Figure 1). Bi-linear interpolation is adopted by most GIS packages, but other interpolation strategies are possible.

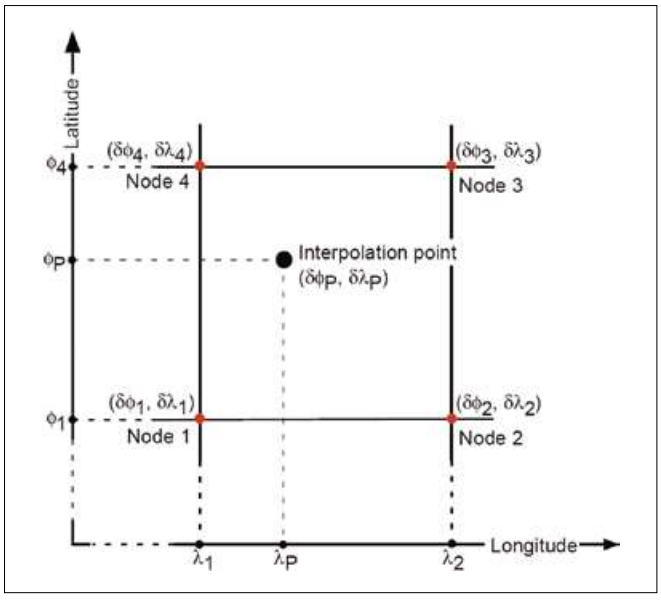


Figure 1: Grid interpolation principle (courtesy of Phil Collier).

Just like the similarity transformation, a grid transformation is considered 'reversible', i.e. each transformation can be undone by applying the grid parameters in the opposite direction. It is also 'traceable' and 'reproducible' by all users.

Transformation grids in exactly the same format were produced to aid users in the transition from the Australian Geodetic Datum (e.g. AGD66, AGD84) to GDA94. As such, the new GDA94-GDA2020 transformation grids are backward compatible with any existing software that can accept a user-input grid.

Two GDA94-GDA2020 transformation grids have been developed: 'conformal only' and 'conformal and distortion'.

Transformation grids

For some time, DFSI Spatial Services has been simultaneously providing two realisations of GDA94 for use in NSW. The first, based on the original GDA94 adjustment, termed GDA94(1997) in NSW, is available via SCIMS and suffers from adjustment deficiencies in the original GDA94 definition, and the subsequent accumulation of distortion in further adjustments.

The second realisation, based on the most recent national realisation of GDA94, termed GDA94(2010) in NSW, is available via more modern positioning technologies such as AUSPOS and CORSnet-NSW, and is effectively distortion-free. Because of this difference, the NSW Surveyor General's directions recommend performing site localisations to align CORSnet-NSW-based surveys (distortion-free) to SCIMS (with inherent GDA94 distortion).

Consequently, two transformation pathways from GDA94 to GDA2020 were required: one which assumes distortion-free input data, i.e. GDA94(2010), and one which compensates for the localised distortions embodied in SCIMS, i.e. GDA94(1997).

Regarding 'site localisation' versus 'site transformation' terminology: In previous articles, DFSI Spatial Services used the term 'site transformation' to describe the process of matching GDA94(2010) to GDA94(1997), e.g. from CORSnet-NSW to SCIMS. This article uses the term 'site localisation' to avoid any potential confusion regarding transforming between reference frames compared to transforming a site to match local survey control.

Conformal only transformation grid

The conformal only transformation grid, often denoted 'con', is simply a grid representation of the similarity transformation. It contains the latitude and longitude shifts between GDA94 and GDA2020 for each grid node, based solely on the seven-parameter similarity transformation parameters.

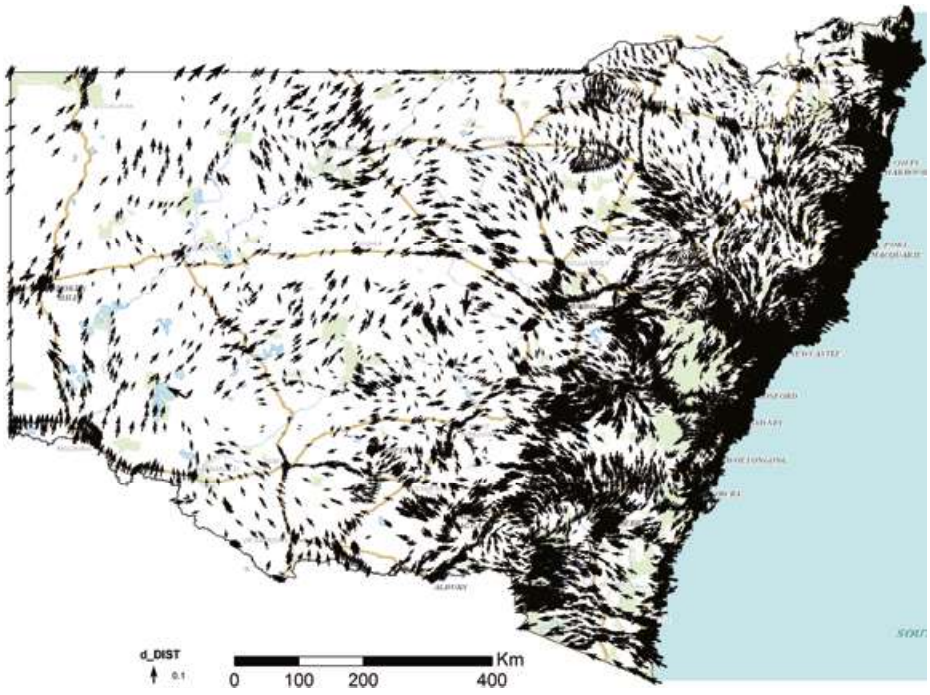


Figure 2: GDA94(1997) to GDA94(2010) distortion vectors across NSW in metres.

Conformal and distortion transformation grid

The conformal and distortion grid, often denoted 'cpd' for conformal plus distortion, is designed to compensate for any known localised distortions present in the control survey networks of each state and territory in Australia. In NSW, DFSI Spatial Services has contributed approximately 26,000 marks, which are common between the GDA94 and GDA2020 networks, in order to compute the localised distortion across NSW (Figure 2).

The distortion component at each grid node has been computed based on the surrounding input data falling within a search radius of 45.5 kilometres. If there are no input data points within this critical distance, the computation reverts to a conformal only solution and no distortion will be apparent.

Grid composition and extent

Both national transformation grids are divided into five non-overlapping sub-grids, with grid nodes every 54 arc seconds (about 1.5 kilometres). Currently, the transformation grids cover mainland Australia and Tasmania.

NTv2 format

The National Transformation version 2 (NTv2) format was developed by the Canadian Geodetic Survey of National Resources Canada. It has been adopted for datum transformations by many international survey organisations and is supported in most GIS software packages.

The NTv2 format provides a simple, efficient and comprehensive file structure for storing latitude and longitude shift parameters for each grid node. It is compatible with sub-grids, which can be used to alter the overall coverage area or densify areas with high rates of change.

NTv2 also provides space to report on the known or estimated accuracy of these shifts. In the GDA94-GDA2020 conformal and distortion transformation grid, this is a measure of the consistency (i.e. reliability) of the distortion surrounding the grid node rather than an absolute accuracy statement.

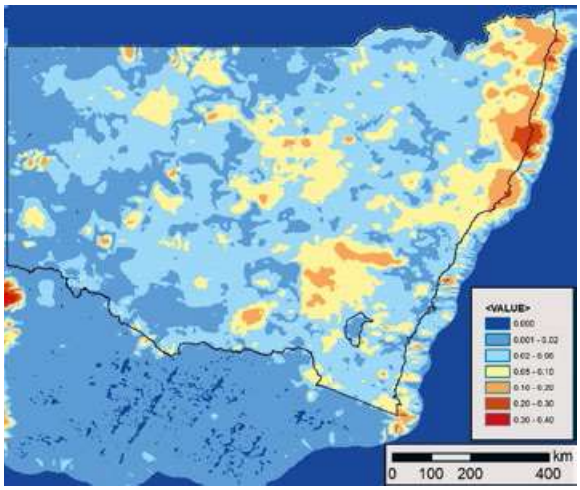
Furthermore, reliability figures can only be computed where distortion is modelled. It should be noted that the GDA94-GDA2020 transformation grids are supplied as binary grid shift (.gsb) files and are not human readable unless converted to text.

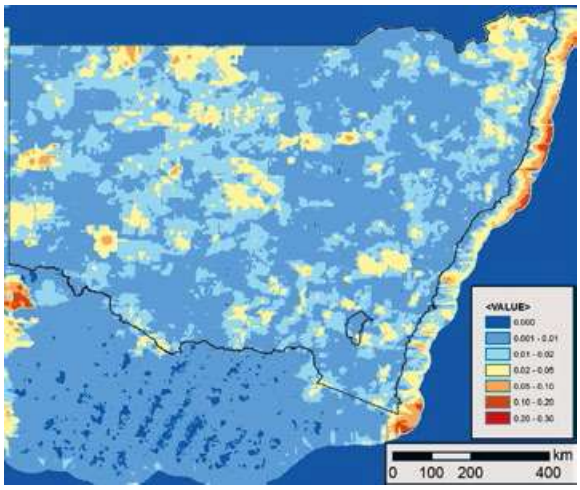
EAST sub-grid (conformal and distortion) behaviour

NSW users will primarily be concerned with the performance of the EAST sub-grid, which covers the whole of NSW, ACT and Victoria, as well as some of Queensland and South Australia. The performance of the conformal only grid is uniform and does not require further review.

The performance of the conformal and distortion transformation grid, however, varies with location. This variation is mapped in Figure 4 and provides a useful indication of the magnitude of distortion across NSW and Victoria.

In addition, reliability figures have also been mapped (Figure 5), which indicate the consistency of distortion within each grid node computation.





LEFT: Figure 4: Distortion component across the EAST sub-grid in metres.

RIGHT: Figure 5: Reliability component across the EAST sub-grid in metres.

How to access and apply the grids

A suite of transformation products and tools has been published online by ICSM (http://www.icsm.gov.au/datum/gda-transformation-products-and-tools). Users are guided towards the grid (.gsb) files, an online transformation service that can be operated with simple 'drag-and-drop' functionality, as well as software and plug-ins.

How to decide which grid to use

The accuracy and the origin (i.e. provenance) of the dataset both need to be considered when applying a transformation grid from GDA94 to GDA2020. The difference between GDA94 and GDA2020 horizontal positons in NSW is about 1.5 metres. Therefore, any dataset referenced to GDA94 with an accuracy of worse than a few metres is already GDA2020 compatible and does not require transformation.

However, users may still choose to transform this data to avoid introducing an extra 1.5 metres of known error. In addition, as with all decisions regarding dataset transformation, it is important to consider the topological relationship between your datasets, e.g. if your GIS has established coincident locations between different datasets. Regardless of their accuracy, it is best to transform all related datasets using the same transformation parameters.

In NSW, the largest known horizontal distortions are in the order of about 0.3 metres. The conformal only transformation grid is sufficient for any GDA94 data with an accuracy of 0.5 metres (but either grid could be applied at these accuracy levels).

For data more accurate than 0.5 metres, the origin of the data must be considered. If the data is derived from local (SCIMS) survey control, then the conformal and distortion transformation grid is appropriate.

If the data is derived directly in GDA94(2010), e.g. from CORSnet-NSW (without a site localisation) or from AUSPOS, then distortions in local survey control are already eliminated and the conformal only transformation grid is appropriate. Figure 6 provides a decision-making flow chart to guide NSW users in this regard.

If the origin of a GDA94 dataset is unknown, then it is not possible to transform to GDA2020 and retain a nominal accuracy better than the known local distortions. For this reason, metadata is critical and has been affectionately described as a "love note to the future".

Where the original survey measurements (with connections to GDA2020 stations) are available, a new least squares network adjustment based on GDA2020 control will provide the most accurate and rigorous solution. However, this can be far more time consuming and is not applicable to point-based datasets.

Evaluation of the conformal only transformation grid

The conformal only transformation grid was evaluated by transforming the 250,000 marks across Australia comprising the GDA2020 national adjustment from GDA2020 to GDA94 using the seven-parameter conformal transformation, and then back to GDA2020 with the conformal only transformation grid. The resulting coordinates were compared against the original GDA2020 coordinates.

The results show that the conformal grid will introduce a negligible amount of computational error when compared to the 7-parameter conformal transformation: a maximum difference in Easting and Northing of ±0.001 metres, with standard deviations of 0.0003 metres.

The conformal only transformation grid is considered fit for purpose for use in NSW. It may be simpler to use than the alternative seven-parameter conformal transformation method.

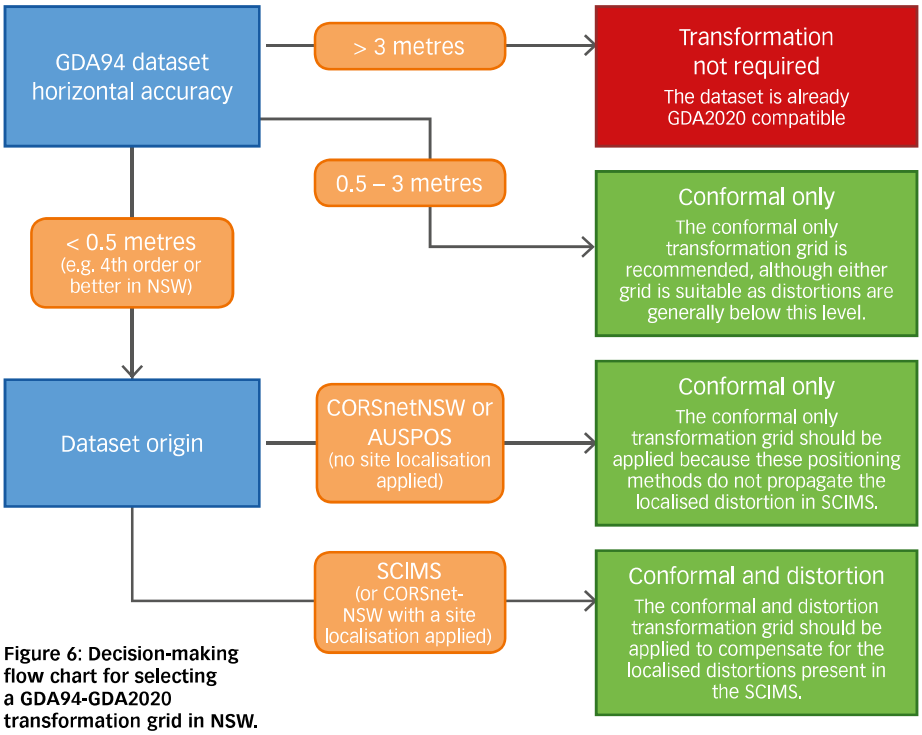


Figure 6: Decision-making flow chart for selecting a GDA94-GDA2020 transformation grid in NSW.

Evaluation of the conformal and distortion transformation grid

Two tests were conducted to evaluate the conformal and distortion grid across NSW, based on 26,000 common points as well as independent (terrestrial) data.

Test 1: Common stations between SCIMS and GDA2020

The conformal and distortion transformation grid was first evaluated by transforming the coordinates of approximately 26,000 SCIMS marks from GDA94 to GDA2020, and comparing against the adjusted GDA2020 coordinates. The chosen marks were part of the GDA2020 national adjustment and required SCIMS coordinates with horizontal Order 4 or better and GDA2020 coordinates with horizontal Positional Uncertainty (PU) of 0.1 metres or better (1 sigma).

We found that 86.3%, 96.4% and 99.6% of SCIMS-to-GDA2020 transformed coordinates are within 0.01 metres, 0.02 metres and 0.05 metres, respectively, of the expected GDA2020 adjusted coordinates. There are no notable differences between Easting and Northing components.

Differences of up to 0.27 metres are evident at a very small number of the marks analysed (i.e. < 0.1%). These rare outliers occur where SCIMS behaves inconsistently, e.g. where a remote trigonometrical station was re-surveyed and its position improved, but its eccentric marks were not updated in SCIMS, altering the relationship between trigonometrical station and eccentric marks.

Test 2: Independent data

CORSnet-NSW started delivering services in both GDA94 and GDA2020 in February 2019, while DFSI Spatial Services is preparing to enable (make available) GDA2020 in SCIMS later this year. Some early proof-of-concept studies were carried out to assess the value in transforming versus readjusting our terrestrial 'street corner' traversing networks in SCIMS, which currently are not in the GDA2020 national adjustment.

Terrestrial survey networks in six NSW towns containing a total of 1,881 direction sets, 4,337 distances and 2,635 height differences at 2,759 stations were examined in this evaluation.

Each network was readjusted based on constraints from the national GDA2020 adjustment. The results of the adjustments were compared with the results of simply transforming the SCIMS coordinates via the conformal and distortion transformation grid.

On average, the difference in horizontal position between the two methods was 0.006 metres, with the largest being 0.04 metres. This analysis provides a high level of assurance that transforming SCIMS control will deliver a result close to the more rigorous (and far more time-consuming) method of readjusting.

The conformal and distortion transformation grid is considered fit for purpose for use in NSW. Again, it may be simpler to use than the alternative seven-parameter conformal transformation method, which has the additional disadvantage that it cannot compensate for local distortions.

Nicholas Gowans and Dr Volker Janssen work at Spatial Services, a unit of the NSW Department of Finance, Services and Innovation (DFSI). ■