Progress Towards a New Geodetic Datum for Australia

Nic DONNELLY, New Zealand; John DAWSON, Gavin EVANS, Roger FRASER, Joel HAASDYK, Matt HIGGINS, Linda MORGAN, Chris RIZOS, Rob SARIB, Scott STRONG and Steve TURNER, Australia

Key words: Reference Frame, Geodetic Datum, GeodesyML, Least Squares Estimation, ICSM

SUMMARY

For several years, the government jurisdictions which comprise the Permanent Committee on Geodesy (PCG) of the Australia/New Zealand Committee on Surveying and Mapping (ICSM) have been undertaking preparatory work towards a modernised geodetic datum for Australia. There are several premises for a modernised datum. Firstly, Australia's official datum, the Geocentric Datum of Australia 1994 (GDA94), is failing to support the ever increasing accuracy needs of Australia's geospatial community, due to ongoing crustal dynamics and regional deformation. Secondly, most if not all absolute positioning technologies and applications provide positioning information in terms of the latest version of the International Terrestrial Reference Frame (ITRF). As the use of absolute positioning increases, more users will be faced with the problem that even after their data is transformed to GDA94, there will be small but potentially significant misalignments with the plethora of existing GDA94 spatial information. Thirdly, improvements in relative measurement techniques have highlighted widespread distortions in GDA94. Finally, the generation of survey control mark coordinates is currently handled independently by the responsible State or Territory, which often results in inconsistencies at the borders. Collectively, these issues warrant comprehensive modernisation of Australia's geodetic datum.

Work to prepare for a modernised datum is well underway. It is proposed that the datum will be aligned with the latest version of ITRF through the regional realisation provided by the Asia-Pacific Reference Frame (APREF). The datum will be designed to adapt quickly to the availability of new measurements and better models, ensuring that it remains fit-for-purpose even as technology and applications continue to advance. Crustal dynamics and regional deformation will be managed via a rigorous deformation model. One of the key features of the modernised datum will be the management of a single, contiguous national adjustment comprised of each jurisdiction's geodetic datasets. Using rigorous least squares estimation software operating on high-performance computing infrastructure, the new approach will lead to homogenous coordinates and uncertainties for all marks in Australia's survey control network. This approach will ensure strong connections to the national Global Navigation Satellite System (GNSS) Continuously Operating Reference Station (CORS) network, remove the distortions in the existing datum, be responsive to changing measurement technologies, and for the first time enable the rigorous calculation of positional uncertainty.

Progress Towards a New Geodetic Datum for Australia

Nic DONNELLY, New Zealand; John DAWSON, Gavin EVANS, Roger FRASER, Joel HAASDYK, Matt HIGGINS, Linda MORGAN, Chris RIZOS, Rob SARIB, Scott STRONG and Steve TURNER, Australia

1. INTRODUCTION

Responsibility for managing the Australian National Geospatial Reference System (NGRS) sits with the Permanent Committee on Geodesy (PCG) of the Australia/New Zealand Committee on Surveying and Mapping (ICSM). The NGRS includes the geodetic datum, the coordinates that realise it, the infrastructure and data that facilitate connections to it, as well as the tools, recommendations and standards to assist with its use (Johnston & Morgan, 2010).

A national geodetic datum underpins most land-related datasets, and it is the fundamental positioning reference system for a country. As such, it must have sufficient precision for the most demanding positioning applications, and maintain (or improve) this precision over time. In a dynamic world, this implies the use of a 'dynamic' datum. That is, a datum which adapts to continual change in the real world and incorporates improved measurements as they become available. Dynamic datums, such as the International Terrestrial Reference Frame (ITRF), have been widely used in the geodetic community for more than two decades.

The geospatial world is changing. High-precision absolute positioning techniques are rapidly becoming the preferred means for spatial data acquisition and geospatial datasets are increasingly national in scope. If a national geodetic datum fails to support such datasets, users will inevitably adopt an alternative, non-official datum which they perceive (perhaps wrongly) to be better than the national datum. If users do choose to align their datasets with a less precise national geodetic datum, the internal precision of the dataset must be degraded. Either way, the national spatial data infrastructure becomes compromised and integration of geospatial data at high levels of precision becomes very challenging.

It is in this context that the PCG is actively planning a modernised, dynamic geodetic datum, the working name of which is the Australian Terrestrial Reference Frame (ATRF). To assist with the transition to a dynamic datum, a new interim static datum will first be introduced based on the new national adjustment and the latest ITRF. This paper outlines the reasons a new datum is required, details some of the work already carried out and presents a high-level plan for its implementation.

2. DRIVERS FOR A NEW DATUM

Changing datums is not a task to be undertaken lightly. As well as presenting a range of challenging technical issues to resolve, a datum change can be a substantial burden for geospatial users, many of whom are not spatial professionals and have only limited knowledge of geodesy. Strong drivers are therefore necessary to justify a datum change.

2.1 The Changing Geospatial World

The users and use of geospatial data are changing rapidly. The generation of precise positions is no longer the sole domain of the surveyor. Technological advancements mean that users with only basic training can determine position to an accuracy of a few centimetres, using GNSS techniques such as 'real-time kinematic'. Positioning to an accuracy of a few metres is easily achieved by any user with a GNSS-enabled device. In the near future, billions of devices worldwide may have the capability to determine position to an accuracy of perhaps a decimetre. The positions determined by these users will be in terms of the reference frame of the satellite system(s) being used, which will be aligned to ITRF at the epoch of data capture. That is, the positions will be time-dependent. For example, measuring the position of a location today, and then again five years later, will result in coordinates which are noticeably different due to tectonic motion. The challenges are compounded if we also consider that low-cost and highly mobile lidar-based and photogrammetry-based mapping technologies are likely to be widely available. The volume of data collected by these non-traditional devices will rapidly dwarf all existing geospatial data. The national datum as a consequence needs to support new positioning devices and technologies, their users and their data.

2.2 Limitations of the Current Datum

The current official datum is the Geocentric Datum of Australia 1994 (GDA94). It is a static datum, aligned to ITRF92 at epoch 1994 (ICSM, 2006). Johnston & Morgan (2010) identify two major problems with GDA94: a lack of consistency with contemporary ITRF definitions and its inability to support user desire for ever increasing accuracy and precision. The latter problem is caused by the lack of a robust adjustment of Australia's geodetic data, as well as being an inherent limitation of a static datum. In a dynamic world, a datum cannot have both static coordinates and high accuracy over long time periods.

Haasdyk *et al.* (2014) compile a detailed summary of the limitations of the datum, which are categorised in Table 1.

Limitation Category	Limitation	Impact	Proposed solution
Static Datum	Movement of Australian plate of about 0.07m per year means that Australia has drifted approximately 1.4m from GDA94 by 2014. See Figure 1.	Mass-market smart devices, using absolute positioning in terms of current ITRF, will provide positions that do not align with GDA94.	New dynamic datum.
	The rotation of the Australian plate is introducing errors into the datum which are detectable in precise measurements (7mm difference for a 30km vector over 20 years).	Currently not significant for most applications, but will become more problematic with time.	
	Large-scale subsidence, such as that caused by water, coal or gas extraction, cannot be adequately accounted for.	Connections to datum are difficult, as users cannot easily determine whether marks are reliable.	
ITRF92 Reference Frame	Large uncertainties in coordinates and velocities, compared with current ITRF.	Limits the precision of the datum, especially apparent with GNSS CORS.	New datum aligned to contemporary ITRF.
	Systematic vertical error of 0.09m.	Additional complexity when using absolute positioning techniques to calculate heights.	
Large Uncertainties	Coordinates for lower levels of control generated in a piecemeal fashion, due to previous software and hardware limitations.	Inconsistencies among adjacent coordinates generated by different adjustments and between jurisdictions.	National adjustment of all data.
	Distortions of up to 0.3m have been detected in the existing network.	Distortions propagate into connecting datasets, causing problems with relative accuracies and alignment with ITRF.	Readjust geodetic network and collect additional data.
	Significant additional precise geodetic measurements available, but not rigorously incorporated.	Potential increased datum precision not realised.	Readjust geodetic network, incorporating all new measurements.

Table 1: Limitations of GDA94, with proposed solutions

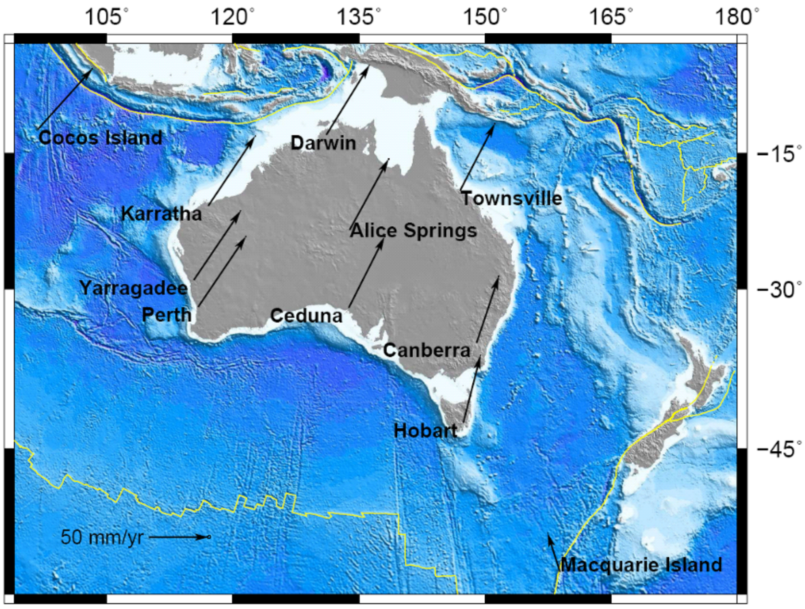

Figure 1: Australian tectonic movement

2.3 Requirements for a New Geodetic Datum

The proposed solutions to the limitations of GDA94, identified in Table 1, indicate that a new national datum for Australia must:

- be a dynamic datum, featuring coordinate, uncertainty and velocity estimates at all marks;
- align to the latest version of ITRF; and
- feature a rigorous, nationwide adjustment of ALL geodetic data.

More specifically, it has been determined that the datum should:

- support +/- 0.02m user positioning (positional uncertainty at a 95% confidence level), relative to the latest ITRF;
- be a fully three-dimensional datum (that is, include ellipsoidal heights);
- enable the calculation of positional uncertainty at every survey control mark and relative uncertainty between any two survey control marks;
- be updated continuously as new measurements are introduced and blunders detected;
- support deformation models to maintain datum precision over time; and
- have tools and services that facilitate its use by the mass-market (for example, time-based transformations).

3. FOUNDATIONS OF A MODERNISED GEODETIC DATUM

Any modern geodetic datum should be aligned with the global geodetic reference frame. As well as ensuring the datum has the highest levels of traceability, this ensures that it is compatible with the reference frame used by positioning technologies such as GNSS.

3.1 International Terrestrial Reference System and Frames

The International Terrestrial Reference System (ITRS) is a set of agreed conventions (Petit & Luzum, 2010), describing an idealised system for referencing positions on Earth. ITRS is realised by the International Terrestrial Reference Frame (ITRF), the latest version being ITRF2008 (Altamimi *et al.*, 2011).

The International GNSS Service (IGS) provides data and products which make ITRF accessible to the spatial community. This includes GNSS observation data, coordinates, precise orbits and clock corrections, used to generate ITRF positions. It is this role of making ITRF easily accessible that means the IGS products and services are the foundation of any modernised datum. IGS maintains its own realisation of ITRS, which is aligned to ITRF. The current realisation, aligned to ITRF2008, is IGb08 (IGS, 2014). For all practical purposes, ITRF2008 and IGb08 may be considered identical.

3.2 Asia-Pacific Reference Frame

The main objective of the Asia-Pacific Reference Frame (APREF) is to densify ITRF in the Asia-Pacific region. It also encourages and supports the sharing of data and its analysis (APREF, 2013). Observations at APREF CORS are processed by several APREF analysis centres and combined at the Central Bureau (hosted at Geoscience Australia, the organisation with responsibility for geodesy at the national level in Australia). Alignment with ITRF2008 is maintained by including all IGb08 reference stations in the APREF processing. The dense network of APREF stations in Australia (see Figure 2) provides improved access to the global reference frame. The full audit trail between the proposed ATRF and ITRS is summarised in Figure 3.

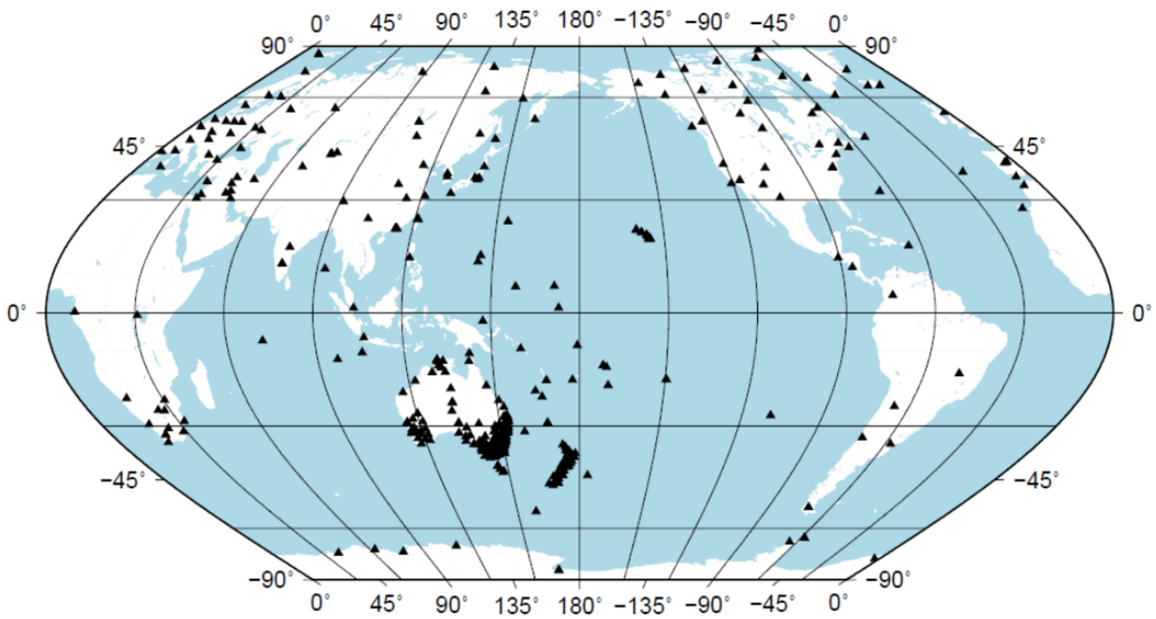

Figure 2: APREF network at June 2013 (Dawson & Hu, 2013)

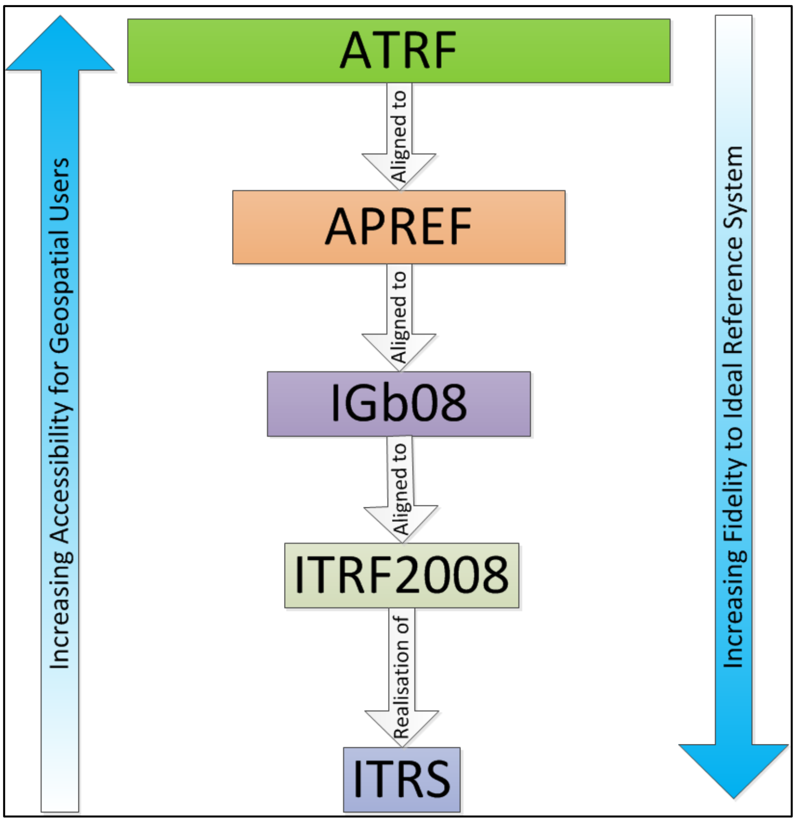

Figure 3: Relationship between ATRF and ITRS

4. PROGRESS TOWARDS DATUM MODERNISATION

PCG member jurisdictions have been actively refining the datasets, tools, standards and methods required for datum modernisation since it was first proposed by Johnston & Morgan (2010). While the various activities described below are considered essential to enable a new dynamic datum, they are equally relevant to countries seeking to modernise existing datums. Most of these activities will first be employed for the creation of an interim static datum for Australia based on the new national adjustment and the latest ITRF. Research into the rigorous inclusion of dynamics and deformation will allow the final transition to a fully dynamic datum.

4.1 Standards Development

4.1.1 Standard for the Australian Survey Control Network

In 2013, a fully revised *Standard for the Australian Survey Control Network* was published (ICSM, 2013). This outcomes-based standard is used by datum managers to ensure the integrity of survey control marks in the NGRS. It does this principally by standardising the use of uncertainty to describe the positional and relative quality of marks. This is a departure from previous geodetic standards in Australia, which used classifications (such as 'Class' and 'Order') to describe quality.

The use of uncertainty represents a more sophisticated, flexible and internationally consistent approach to datum management. It can be propagated in a well-defined, rigorous manner into other spatial datasets (such as the cadastre) and is an output of technologies such as GNSS which make many redundant measurements. Therefore, using uncertainty enables existing and newly acquired data to be integrated in a consistent way that enables the detection of significant changes. Previously a user was provided with only a broad indication of position quality, through the use of classifications. However, practitioners involved in precise survey work usually have ready access to least squares estimation packages which are designed to propagate datum uncertainties into their new work, giving a far more reliable estimation of the precision of new coordinates. The removal of qualitative classifications also provides the datum manager with more flexibility to describe and include even low quality survey control marks in the datum, where user requirements dictate that such marks have value. For example, a large radio antenna may be ideal as a reference object for a bearing origin, but the positional fix using intersection is likely to be poor. Under the framework of the new standard, the uncertainty of its coordinates would be published, enabling the user to make a judgement as to whether the mark is suitable for their intended purpose.

The standard contains no numerical tolerances. It is up to the user of the standard (often the agency managing the datum) to select appropriate maximum uncertainty values for the work they are doing. By defining a framework, rather than numerical values, the standard will have greater longevity during times when technological advances mean that prescriptive standards often have relatively short life spans.

Accompanying the standard is a set of six guidelines which describe how the standard can be achieved. The guidelines focus on how various widely used geodetic survey techniques may be used to demonstrate compliance with the standard. This provides certainty to users, without precluding the use of innovative techniques that are not described in the guidelines. The modular form of the guidelines means that one guideline can be updated in isolation from the others. Guidelines can also be added as required, ensuring a quick response to changing technologies and techniques.

4.1.2 GeodesyML – a GML Application Schema

In Australia, geodetic responsibilities are split among the Commonwealth, State and Territory governments, meaning that geodetic data often needs to be shared. This data sharing will increase dramatically for the new geodetic datum, where for the first time repeated geodetic adjustments will be undertaken as new measurements become available. For this approach, State and Territory jurisdictions will need to share geodetic data near their borders, and all will need to transfer data to and from Geoscience Australia, which will undertake the national adjustment. A range of software is used by the jurisdictions for geodetic tasks, each of which has its own formats, making data sharing difficult.

In order to overcome these and many other data sharing obstacles, an application-independent means of automatically transferring geodetic data and metadata is required. To this end, PCG has developed a Geography Markup Language (GML) application schema, named GeodesyML (Donnelly *et al*., 2013). It is based on a comprehensive logical model of geodetic survey data, which includes classes for stations/marks, measurements, data quality and adjustments. The schema is readily extensible, and is compatible with other geodesy-related schemas such as the IGSSiteLog XML schema (SOPAC, 2014). While GeodesyML has been developed by New Zealand and Australia, it is sufficiently generic for international adoption and procedures are in place to facilitate revisions and enhancements through regional and international collaboration.

The full potential of GeodesyML will only be realised if it is widely adopted beyond the Australian and New Zealand Governments. If it is incorporated into commonly used software, for example, third party suppliers would easily be able to provide new measurements to datum managers and have them incorporated into the datum. Innovative approaches to data collection, such as crowd-sourcing initiatives, also become more viable if data is easy to transfer. If built into web services, GeodesyML will facilitate the automated sharing of geodetic data, enabling a full, up-to-date set of geodetic data to be accessed directly from the authoritative source. Automated data transfer of this nature is a pre-requisite to the automated or semi-automated data processing and analysis procedures that are likely to be a core part of a modernised datum.

4.2 Infrastructure Development and Data Collection

4.2.1 Continuously Operating Reference Stations

An Australian Government initiative called AuScope was established to provide integrated national infrastructure for earth science in Australia. Part of this was the provision of a national GNSS CORS network across the country (AuScope, 2014). In addition to building CORS as part of the AuScope programme, a number of States have built their own networks, providing further densification. GNSS CORS will be the primary means of realising and monitoring the new datum, and will increasingly provide the means by which users access or connect to the datum.

4.2.2 Passive Mark Surveys

Passive survey control marks (for example, brass plaques in concrete) will still provide a valuable means of connecting to the datum for many users. Other users will position themselves directly from the satellite constellation(s), relying on various models to obtain suitably accurate coordinates. However, these users of absolute positioning techniques will still need to ensure that they express positions with respect to the national datum, in order to align with the multitude of other datasets expressed in that datum. Occupying passive survey control marks provides a reliable and efficient means of obtaining or confirming this alignment. Thus there is an ongoing requirement for a reasonably dense network of passive survey control marks.

Additional passive control surveys over the last few years have been carefully targeted to ensure maximum benefit for minimum effort, recognising that most jurisdictions already have about 20 years of GNSS observations which can be incorporated into the new datum. Connecting each CORS through measurements to existing local survey control is a high priority. Direct connections allow the precision of the APREF solution at the CORS to greatly reduce the positional uncertainties of connected passive marks, as well as increasing their consistency with absolute positioning techniques. Another high priority is to connect 'islands' of GNSS surveys, which are only connected to the geodetic network through terrestrial measurements.

4.2.3 Passive Mark National GNSS Data Archive and Processing

To provide a level of consistency for the processing of high-quality GNSS observations, a national GNSS data archive has been established. The archive consists of all GNSS occupations, at passive marks, of at least six hours duration. Each jurisdiction supplies this data to Geoscience Australia, which manages the archive and processes the data. The processing results are returned as SINEX files to the State or Territory that submitted the data, for testing against their jurisdictional adjustment. In future, this data archive can be easily re-processed if warranted by improvements to processing techniques. It allows further densification of the solution provided by APREF and ensures a level of homogeneity throughout the country for the coordinates of passive survey control marks.

4.3 Coordinate (and Uncertainty) Generation for ATRF

4.3.1 Jurisdictional Adjustments

Each jurisdiction is responsible for managing its own geodetic data. Therefore, each jurisdiction will complete a single, simultaneous adjustment of its own data. The primary purposes of these adjustments are to identify and resolve any gross errors, determine appropriate weightings for the data and assess areas of weakness in the network for further observations. Measurements to survey control marks that are common between jurisdictions will be closely scrutinised to minimise problems once the multiple datasets are combined in a national adjustment.

The process of compiling jurisdictional adjustments has highlighted issues which were not always obvious under the previous practice of carrying out campaign adjustments independently. For example, areas of potential deformation can now be more readily identified, since all information for the geographic area is in a single network. Quantifying the spatial and temporal extents of localised deformation may still be difficult, as typically there are few repeated occupations of any given mark. However, identification of potential problems means that targeted observations can be made, perhaps using innovative methods such as crowd-sourcing or differential radar measurements (Haasdyk & Roberts, 2013).

4.3.2 National Adjustment

Historically, software and hardware limitations have made it impractical to rigorously compute coordinates and uncertainties for all of Australia's geodetic marks in a single simultaneous adjustment. In recent years, the adjustment software 'DynaNet' has been developed with the capability to adjust an almost unlimited number of observations and survey control mark coordinates. DynaNet implements a phased adjustment algorithm (Fraser *et al.*, 2014), which enables extremely large networks to be efficiently segmented and adjusted in blocks in a rigorous fashion. DynaNet has been installed on Australia's high-performance National Computational Infrastructure (NCI), and testing indicates that regular readjustments of hundreds of thousands of marks and millions of measurements are feasible.

Under the modernised datum maintenance approach, each jurisdiction will supply their adjustment to Geoscience Australia for integration with the national adjustment. This will ensure absolute and relative consistency for all survey control mark coordinates, as well as ensure that reliable uncertainties are calculated. Jurisdictions will remain responsible for their data. If the national adjustment identifies problems, these will be referred to the relevant State or Territory for resolution. The jurisdictional adjustments will be combined together with the APREF CORS solution and the national GNSS archive solution to produce the ATRF coordinates (Figure 4).

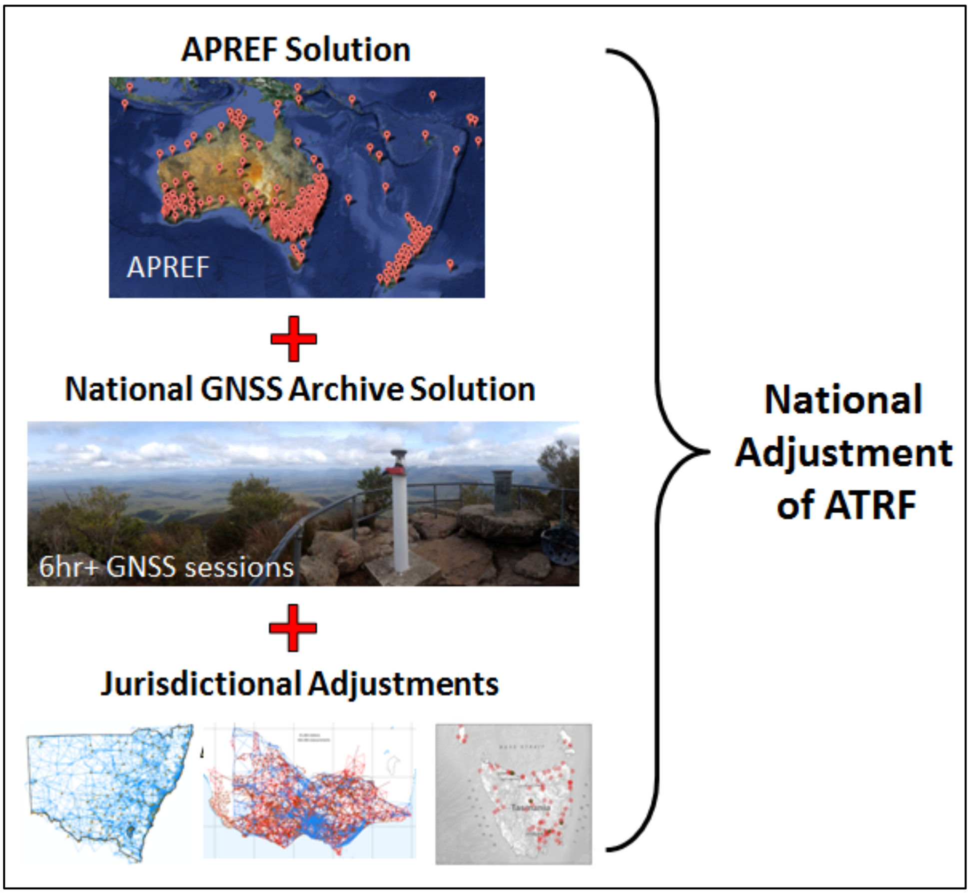

Figure 4: Producing the national datum

5. PATH TO A MODERNISED DYNAMIC DATUM FOR AUSTRALIA

The official decision on whether Australia adopts a modernised, dynamic datum (or indeed any new datum) is expected in mid-2014. The high-level proposal has been widely discussed with the geospatial community in Australia and is generally positively received. Concerns typically relate to the cost of changing datums, understanding the tangible benefits of a dynamic datum, the mechanics of how one uses a dynamic datum and the geospatial tools or utilities required to manage datasets.

To assist a smooth transition to a dynamic datum, PCG proposes an incremental implementation, as shown in Figure 5. For the period 2015-2019, a modernised static datum will be realised and updated annually. These updates will all be referenced to the same epoch (likely to be 2020.0). Use of 2020.0 would introduce a horizontal shift of approximately 1.8m compared to the GDA94 coordinates of the same point. After that initial shift, the coordinates associated with each annual update would reflect changes due to improved deformation models, additional observations and improvements to processing and adjustment strategies, and not due to large scale crustal motion. For most geospatial users the coordinate changes each year will be so small they can be ignored. Initially, these regular updates may not even be publically released, but will be used by PCG member jurisdictions to test and refine the systems and processes required to support the new datum.

From 2020, it is proposed that the datum will be fully dynamic. Appropriate velocity and/or deformation models will be used to propagate coordinates between any desired epochs. Many of the implementation details are still to be finalised, and some require further research and assessment of user requirements. Given the tools and services accompanying the new datum, the geospatial community will be afforded the flexibility to adopt a fixed reference epoch (whether by national convention or arbitrarily chosen on a project by project basis) without compromising data quality and data integration that would otherwise be inevitable with GDA94 and static datums.

Once implemented, the Australian Terrestrial Reference Frame will provide the Australian geospatial community with a sustainable, traceable, high-precision geodetic reference system capable of meeting the most demanding positioning requirements.

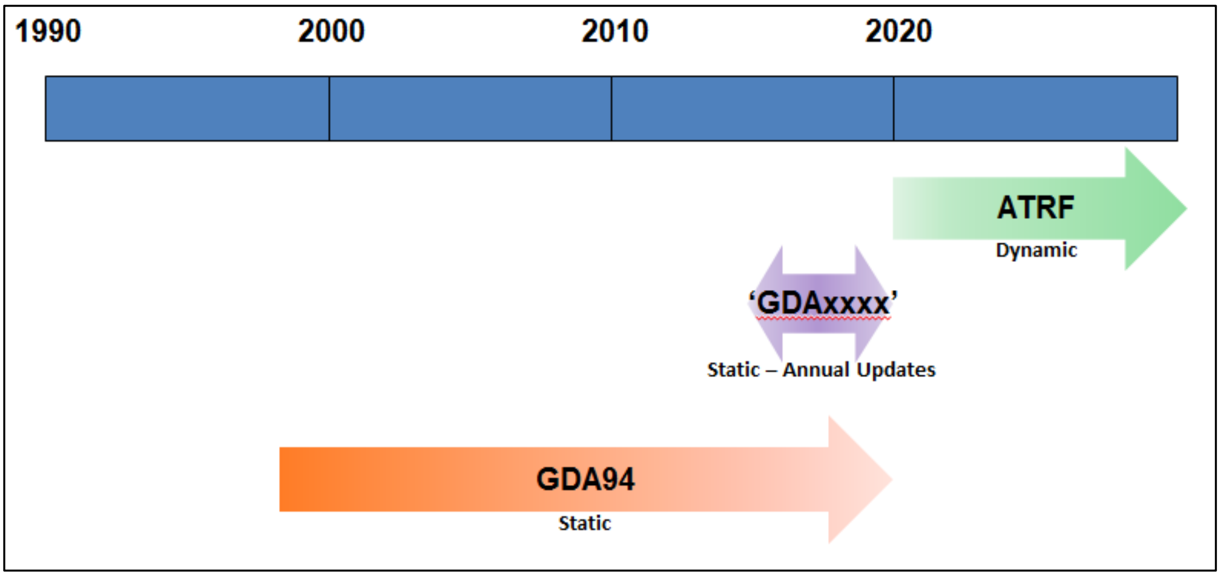

Figure 5: ATRF implementation timeline

REFERENCES

Altamimi, Z., Collilieux X. & Metivier L. (2011). ITRF2008: an improved solution of the international terrestrial reference frame, *Journal of Geodesy*, 85, 457-473.

APREF (2013). Asia-Pacific Reference Frame (APREF). http://www.ga.gov.au/earth-monitoring/geodesy/asia-pacific-reference-frame.html (accessed April 2014).

AuScope (2014). AuScope. http://www.auscope.org.au/site/auscope.php (accessed March 2014).

Dawson, J. & Hu, G. (2013). Asia Pacific Reference Frame (APREF). Presented at Reference Frame in Practice, 21-22 June, Manila, Philippines.
http://www.fig.net/commission5/events/2013_reference_frame_in_practice/1.3_apref_dawson

.pdf (accessed March 2014).

Donnelly, N., Fraser, F., Haasdyk, J. & Tarbit S. (2013). GeodesyML – A GML application schema for geodetic data transfer in Australia and New Zealand, *Proceedings of the Surveying and Spatial Sciences Conference 2013*, 17-19 April 2013, Canberra, Australia.

Fraser, R., Leahy, F. & Collier, P. (2014). *DynaNet 3.1 User's Guide*.

Haasdyk, J., Donnelly, N., Harrison, C., Rizos, C., Roberts, C. & Stanaway, R. (2014). Options for Modernising the Geocentric Datum of Australia. In: S. Winter and C. Rizos (Eds.): *Research@Locate'14*, Canberra, Australia, 7-9 April 2014. http://ceur-ws.org/Vol-1142 (accessed April 2014).

Haasdyk, J. & Roberts, C. (2013). Monitoring station movement using a state-wide simultaneous 'adjustment of everything' – implications for a next-generation datum. In: *Proceedings of IGNSS Symposium 2013*, Gold Coast, Australia.

ICSM (2006). Geocentric Datum of Australia technical manual, version 2.3, http://www.icsm.gov.au/gda/gdav2.3.pdf (accessed March 2014).

ICSM (2013). Standard for the Australian Survey Control Network, (SP1), version 2.0 http://www.icsm.gov.au/geodesy/sp1.html (accessed March 2014).

IGS (2014). The IGS Tracking Network: IGb08 Reference Frame sites, http://igscb.jpl.nasa.gov/network/refframe.html (accessed March 2014).

Johnston, G. & Morgan, L. (2010). The status of the National Geospatial Reference System and its contribution to global geodetic initiatives. In: *Proceedings of XXIV FIG World Congress*, 11-16 April 2010, Sydney, Australia. Available at http://www.fig.net/pub/fig2010/papers/ts06c%5Cts06c_johnston_morgan_4116.pdf (accessed March 2014).

Petit, G, & Luzum, B. (eds.) (2010). IERS Conventions (2010), *IERS Technical Note 36*.Verlagdes BundesamtsfürKartographie und Geodäsie, Frankfurt am Main, Germany.

SOPAC (2014). IGS Site Log Schema online at http://sopac.ucsd.edu/projects/xml/igsSiteLogSchema.html (accessed March 2014).

BIOGRAPHICAL NOTES

The authors are members of the Permanent Committee on Geodesy (PCG) of the Australia/New Zealand Committee on Surveying and Mapping (ICSM). ICSM is a committee of ANZLIC, the spatial information council responsible for stewardship of spatial information in Australia and New Zealand. The PCG comprises representatives from the Governments of Australia and New Zealand, as well as the Australian States and Territories, who have responsibility for the geodetic system within their own jurisdictions.

CONTACTS

Nic Donnelly
Land Information New Zealand
PO Box 5501
Wellington
NEW ZEALAND
Tel. + 64 4 460 0191
Email: ndonnelly @ linz.govt.nz
Web site: http://www.linz.govt.nz

John Dawson
Geoscience Australia
GPO Box 378
Canberra ACT 2601
AUSTRALIA
Email: John.Dawson @ ga.gov.au
Web site: http://www.ga.gov.au

Gavin Evans
Environment and Sustainable Development Directorate
GPO Box 1908
Canberra ACT 2601
AUSTRALIA
Email: Gavin.Evans @ act.gov.au
Web site: http://www.actpla.act.gov.au

Roger Fraser
Office of the Surveyor General Victoria
Level 17/570 Bourke Street
Melbourne VIC 3000
AUSTRALIA
Email: roger.fraser @ dtpli.vic.gov.au
Web site: http://www.dtpli.vic.gov.au

Joel Haasdyk
Land and Property Information
PO Box 143
Bathurst NSW 2795
AUSTRALIA
Email: Joel.Haasdyk @ lpi.nsw.gov.au
Web site: http://www.lpi.nsw.gov.au

Matt Higgins
Department of Natural Resources and Mines

GPO Box 2454
Brisbane QLD 4001
AUSTRALIA
Email: Matt.Higgins @ dnrm.qld.gov.au
Web site: http://www.dnrm.qld.gov.au

Linda Morgan
Landgate
PO Box 2222
Midland WA 6936
AUSTRALIA
Email: Linda.Morgan @ landgate.wa.gov.au
Web site: http://www.landgate.wa.gov.au

Chris Rizos
School of Civil and Environmental Engineering
University of New South Wales
Sydney NSW 2052
AUSTRALIA
Email: c.rizos @ unsw.edu.au
Web site: http://www.engineering.unsw.edu.au/civil-engineering/

Rob Sarib
Department of Lands, Planning and the Environment
GPO Box 1680
Darwin NT 0801
AUSTRALIA
Email: robert.sarib @ nt.gov.au
Web site: http://www.lands.nt.gov.au/land-info/survey

Scott Strong
Department of Primary Industries, Parks, Water and Environment
GPO Box 44
Hobart TAS 7001
AUSTRALIA
Email: Scott.Strong @ dpipwe.tas.gov.au
Web site: http://www.dpipwe.tas.gov.au

Steve Turner
Department of Transport, Energy and Infrastructure
PO Box 574
Marleston SA 5033
AUSTRALIA
Email: Steve.Turner2 @ sa.gov.au
Web site: http://www.environment.sa.gov.au