Coordinates and CORSnet-NSW: Dealing with distortions in GDA94

VOLKER JANSSEN AND SIMON MCELROY

CORSnet-NSW is a rapidly growing network of Global Navigation Satellite System (GNSS) Continuously Operating Reference Stations (CORS), providing fundamental positioning infrastructure for New South Wales now and into the future. Currently consisting of over 50 permanent stations tracking multiple satellite constellations, CORSnet-NSW will expand to over 70 stations within a year and plans are on the drawing board for the network to increase to nearly 120 stations shortly after that.

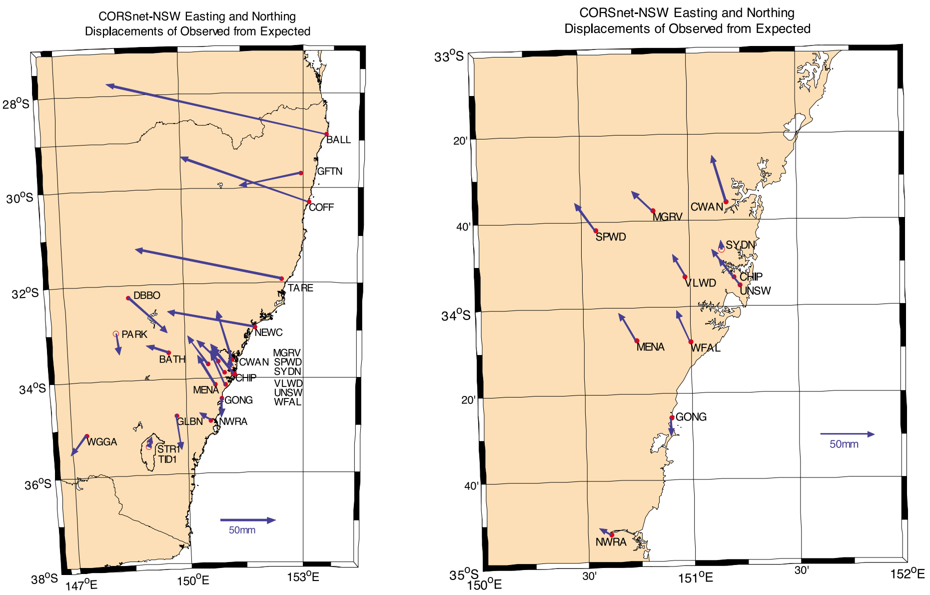
CORS networks are being introduced across Australia and internationally not only to provide services for traditional spatial applications, but also to support new applications, particularly in the agriculture, construction and mining sectors. In fact, projections indicate that surveying will represent a small minority of CORS users in Australia. The new applications represent distinctly different user requirements from surveyors and other spatial professionals, which must all be catered for to maximise the benefits of this positioning infrastructure. The non-specialist nature of these new users also means that issues of reference frames and any apparent distortions need to be catered for by the network provider, rather than the user.

For spatial professionals, the introduction of CORS or 'active' control marks will revolutionise positioning, but they must work in tandem with the traditional 'passive' marks in the ground. Issues arise for high-accuracy applications simply because the new control marks are far more accurate than the old. This should not be a surprise and certainly nothing to worry about if we remember a few basic rules. Cadastral surveyors overcome a very similar problem every day when trying to fit today's observations into those that were taken, say, a hundred years ago by Gunter's Chain and Vernier Theodolite. It's the old "me vs. Per Original" saga. Today we find ourselves working in that challenging transition period between old and new, and this will continue until the introduction of a new datum (GDA2015) sometime in the next half dozen years.

So what's the burning issue? Well, to provide CORS users with new services that will modernise existing GNSS positioning techniques and revolutionise traditional surveying (Virtual DGPS, Network RTK [NRTK] and Virtual RINEX to name a few) and to ensure that they are accurate, reliable and easy to use, it was decided to introduce a new set of highly accurate and consistent 3-dimensional coordinates for use in CORSnet-NSW. It was also important to ensure that these new coordinates were consistent with those from other states, so we can share CORS infrastructure and provide seamless positioning across the nation. Having different railway gauges or jumps/steps in coordinates at state borders is simply not acceptable for today's expanding spatial sector.

Many modern spatial professionals are also using the free AUSPOS online GPS processing service operated by Geoscience Australia. Ideal for use in remote areas with no or poor control, it provides highly accurate coordinates with respect to the Australian Regional GNSS Network (ARGN). However, these results are often not compatible with local ground control.

To solve these issues for GNSS users in NSW, we have introduced what some may see as a new realisation of the existing national horizontal datum. Others will argue these are only refined coordinates with superior positional uncertainty. Whatever your



Horizontal distortions in GDA94(1997) at selected CORSnet-NSW sites across eastern NSW.

view, the geodetic experts at the NSW Land and Property Management Authority (LPMA) have dubbed this new horizontal system GDA94(2010). To avoid confusion, the original definition of GDA94 that people have been using for the last 15 years or so is referred to as GDA94(1997). Both will have to work in tandem for a few more years. This article helps explain the reasoning behind this introduction and outlines how the new realisation should be dealt with in practice, in the field.

Ground control to GDA94

The concept of different and regular realisations of the same datum is very familiar to geodesists, scientists and surveyors working in the offshore sector. They work with International Terrestrial Reference Frame, or ITRF, coordinates. This global datum is refined, or realised, every three or so years in order to improve its accuracy, based on increasing amounts of data, and improved modelling and processing techniques. In Australia, we have only realised a new datum every 30 years or so, and, let's face it, GDA94(1997) is looking a bit stale and shabby around the edges… and is well overdue for a makeover.

GDA94(1997) is the familiar, original realisation of the current national datum, which was adjusted in 1997. It is sometimes also termed 'local' GDA94 because it is based on local connections to surrounding control marks, mainly based on rather old (i.e. AGD66-era) terrestrial observations. Shortcomings in the initial datum definition (that were not obvious at the time) and the process of propagating coordinates through many layers of measurements and adjustments over the years have caused significant distortions in the GDA94(1997). Across NSW, known distortions reach up to 0.3 metres in the horizontal component. (Figure 1.)

GDA94(2010) is a later, ad-hoc realisation of the national datum. The year in brackets was chosen somewhat arbitrarily to set it apart from the earlier realisation and indicates the date of its introduction. It is sometimes also termed 'global' GDA94, although 'regional' or 'national' would be more correct. GDA94(2010) provides a *direct* connection to the Australian Fiducial Network (AFN) and its successor, the ARGN, exclusively via GNSS observations. The directness of this GNSS-based connection removes many potential sources of error and facilitates virtually distortion-free (a millimetre or two every ten kilometres) spatial control across the network, thereby providing at least an order of magnitude improvement in the positioning framework. This realisation should also future-proof CORSnet-NSW and its users for the introduction of GDA2015, as the two should be highly compatible.

Spatial professionals must work within the constraints of current legislation, which requires them to connect to local ground control. In order to support them, all CORSnet-NSW sites are coordinated with both GDA94(1997) and GDA94(2010) coordinates.

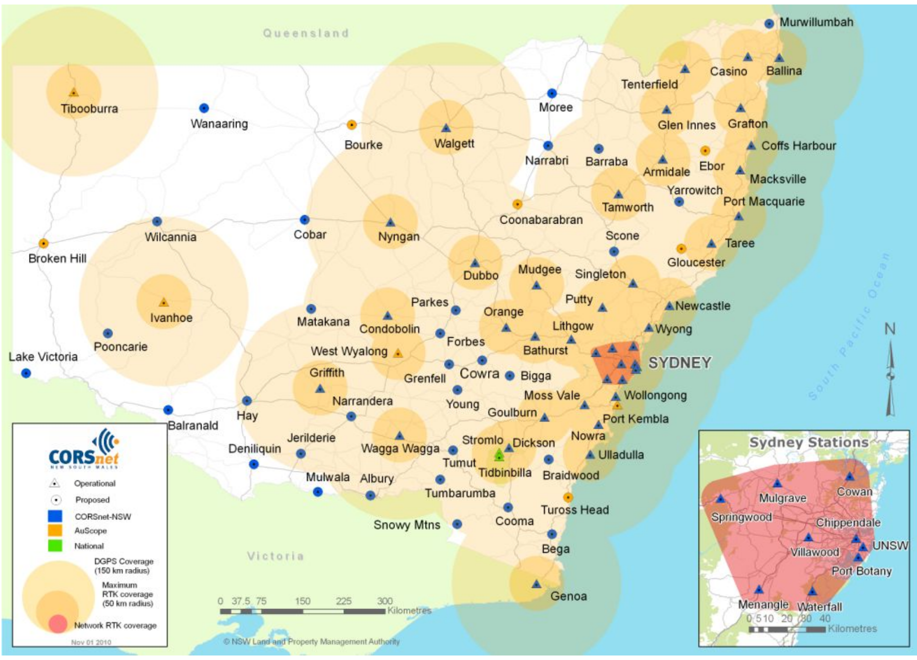
GDA94(1997) coordinates for each CORSnet-NSW site are determined by LPMA through a GNSS-based local tie survey in order to provide connections to the existing ground control network. These coordinates are made available via the Survey Control Information Management System (SCIMS) database. It should be noted that all coordinates in SCIMS are given in the GDA94(1997) realisation.

GDA94(2010) coordinates for all CORSnet-NSW sites are obtained via Regulation 13 certification. These so-called 'Reg 13' certificates are issued by Geoscience Australia, a facility accredited by the National Association of Testing Authorities (NATA). Geoscience Australia determines site coordinates, which are stated on these certificates, based on a week of GNSS data and highly traceable, standardised, scientific processing. Certificates are valid for five years and provide a Recognised Value Standard for positioning infrastructure with respect to the national datum. Through this facility the site coordinates are linked to a standard of measurement in accordance with the National Measurement Regulation 1999 and the National Measurement Act 1960. Consequently, it *assists* users in establishing some legal traceability of GNSS positions when CORS data are used. GDA94(2010) coordinates are available from the CORSnet-NSW website only (www.corsnet.com.au).

So, why doesn't CORSnet-NSW use the familiar GDA94(1997) coordinates? Well, we tried that and it didn't work. In fact, many other nations have tried the same and also found it doesn't work. This is due to the distortions present in the original realisation. Although these distortions may only be minute to the average user, i.e. a few millimetres per kilometre (i.e. a few ppm), over the 70-100 km between CORS they quickly become overwhelming chasms that can't be crossed.

Coordinating each CORS relative to the local geodetic ground mark network would lead to network distortions being incorporated into end user corrected Real Time Kinematic (RTK) and post-processed positions. Our CORS management software would find it extremely difficult to cope, and users would receive a myriad of errors at their rovers. For a reliable Network RTK or Virtual RINEX solution to be possible, GNSS reference station coordinates must have a *consistent* accuracy of better than about 15 mm, because multiple CORS are used to model ionospheric and tropospheric effects as well as geometric errors across the network. The GDA94(2010) realisation is therefore essential to provide real-time users with reliable, horizontal positioning at the 2-centimetre or better level.

This, of course, means that CORSnet-NSW users obtain positions referenced to GDA94(2010). This is suitable for non-specialist applications where users are interested only in absolute accuracy and repeatability. However, as mentioned earlier, spatial professionals are generally required to connect to the existing local survey control network due to legislative requirements or to be compatible with spatial data already referenced to local control. In order to obtain output that is consistent with local ground control marks, it is therefore essential to perform what is called a site calibration or localisation and/or to verify an existing one at the start of *every* real-time survey.



CORSnet-NSW coverage as of November 2010.

Site calibration

The site calibration is performed by observing several established ground control marks *surrounding* the survey area and calculating a local transformation between the CORSnet-NSW reference frame, i.e. GDA94(2010), and the local ground control network, i.e. GDA94(1997). This is typically done via a menu tool incorporated in the GNSS rover software. Once the site calibration is performed and found acceptable, this transformation is automatically applied and real-time GNSS positioning then refers to the existing local control network.

Whilst at first glance the adoption of GDA94(2010) and the need to perform a site calibration may appear to have increased fieldwork requirements, it has in fact significantly reduced them. If CORSnet-NSW had opted to use local coordinates instead, a site calibration would have been required for each and every CORS used. For example, a survey in Sydney would have required a site calibration for occupations using, say, Chippendale CORS, then a second complete site calibration for any occupations using, say, Villawood CORS, and a third site calibration for any additional occupations using, say, Port Botany CORS. The homogeneity of GDA94(2010) does away with the need for second or third site calibrations, meaning less fieldwork overall.

The use of site calibrations is already established good practice to iron out local distortions. However, it is now also essential, in order to account for the larger differences between the coordinates referring to the two realisations of GDA94. For high-quality positioning, it is strongly advised to *verify* any existing site calibration that may be used for later surveys in a given area, because local distortions vary from block to block, suburb to suburb, and shire to shire.

In rural areas without existing local survey control, users may be required to establish their own GDA94(1997) control, depending on the contract and accuracy requirements of the job. In NSW, the latest Surveying and Spatial Information Regulation, Surveyor

General's Direction No. 9 (currently under revision) and the "Control surveys and SCIMS: What is acceptable?" documents allow RTK GNSS methods to be used to coordinate a control mark (up to Class C only) for possible inclusion into SCIMS. The CORSnet-NSW infrastructure can be utilised for this task. Alternatively, local RTK base stations or static GNSS techniques may be used.

In an ideal world, it is desired that real-time GNSS positioning is compatible with coordinates specified on local survey ground control marks. Therefore a consistent, state-wide geodetic infrastructure based on GDA94(2010) coordinates, or something similar, is the ideal solution. Victoria already completed such a state-wide geodetic adjustment a few years ago, which provides excellent comparisons with CORS-derived positions across the entire state, typically at about a centimetre in metropolitan areas and at the sub-decimetre level in rural areas. Theoretically, this has done away with the need for site calibrations because they have already done the hard yards and moved to a new precise and consistent realisation of GDA94 for all of their control marks. In practice, of course, good practice principles still apply.

However, a complete re-adjustment of the geodetic ground control network in NSW to GDA94(2010) coordinates will not take place until after the new, 3-dimensional GDA2015 is implemented. This is due to the large amount of marks involved (SCIMS currently contains 235,000 points) and the enormous work effort that the re-adjustment would require, only to be re-adjusted yet again with the introduction of GDA2015. We may, however, do a few patches to resolve some of the bigger distortions in areas like the north coast of NSW. Another reason is that users dealing with large datasets (e.g. those handling GIS datasets) should not be forced to transform these multiple times. That's just extra work for everybody. Consequently, site calibrations will continue to be essential GNSS survey practice in NSW for some time to come, in order to relate the two realisations of GDA94 to each other.

So, there are a few take-home messages worth noting. We are all working in a transition period between an old and a new national datum. In the near future, CORS networks such as the rapidly expanding CORSnet-NSW will be the backbone of geodetic infrastructure in Australia, providing easy access to unprecedented accuracy and reliability. In this transition phase, it is essential that a site calibration is performed or verified for every job in order to achieve accurate 'local' coordinates with CORSnet-NSW. For applications that do not require a link to the existing ground control network (e.g. precision agriculture), GDA94(2010) coordinates are fully sufficient and a site calibration is therefore not necessary. Hopefully this article has shed some light on the reasons why there is a need to transition to a new datum and provided some useful information to make the change easier for everyone involved. ■

Dr Volker Janssen and Simon McElroy are with the Survey Infrastructure and Geodesy branch of the NSW Land and Property Management Authority, which operates CORSnet-NSW. You can contact them at Volker.Janssen@lpma.nsw.gov.au and Simon.McElroy@lpma.nsw.gov.au for more information.