THE NEED FOR DYNAMIC DATUMS*

Paul Tregoning[1]
Russell Jackson[2]

1. Research School of Earth Sciences
The Australian National University
Canberra, ACT, 0200, Australia
E-mail: pault@rses.anu.edu.au

2. Department of Surveying and Land Studies
The Papua New Guinea University of Technology,
Locked Mail Bag
Lae, Morobe Province
Papua New Guinea
E-mail: rjackson@survey.unitech.ac.pg

ABSTRACT

We have investigated the geodetic adjustment of two separate measurements of continental-scale GPS networks separated by two years in order to assess the suitability of static versus dynamic geocentric datums. We studied a network which resides within a single rigid plate and one which spans several plate boundaries. In the case of a network which does not cross any plate boundaries or deformation zones, the application of a static or dynamic datum will produce the same level of accuracy of the geodetic adjustment although, for the static datum, the adjusted coordinates will only be valid at the time of the reference epoch. When the network spans a plate boundary or deformation zone, a dynamic/kinematic computational reference frame must be implemented in order to avoid distorting the geodetic measurements by the tectonic motion which may have occurred. The inclusion in the network adjustment of site velocities derived from a tectonic model will result in a more accurate adjustment from the same input geodetic observations. We show the magnitudes of errors which may result if tectonic motion is not accounted for in geodetic adjustments and present the tectonic model which we generated to create the dynamic datums for Australia and Papua New Guinea.

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1 Introduction

Until recently, the notion of tectonic motion affecting geodetic measurements has been considered an "academic" problem which has no major ramifications for national- and state-based geodetic datums. With the availability of GPS as a geodetic tool and because of the high level of accuracy which may be achieved using GPS, geodetic measurements are more readily sensitive to the effects of tectonic motion. Therefore, there may be a need to account for tectonic motion by including a time dependent component into the coordinates of a geodetic datum. Such a datum has been called a "dynamic datum" (e.g. Grant, 1995; Pearse, 1997; Grant and Blick, 1998) because it evolves with time. A definition of what is meant by "dynamic" is given below.

Accounting for tectonic motion is of particular relevance to the Southeast Asian and western Pacific regions where the tectonic convergence of the Australian, Eurasian and Pacific Plates is accommodated by several small microplates. There are many countries in southeast Asia (e.g. Indonesia, Papua New Guinea, Phillipines, Japan) whose national borders span at least one tectonic boundary or deformation zone, and distortion of geodetic networks has been reported from a scientific perspective (e.g. Prawirodirdjo et al., 1997; Kato et al., 1998; Tregoning et al., 1998; Lee et al., 1998; Simons et al., 1998). The focus of this paper is to show how the inclusion of a simple tectonic model can significantly improve the accuracy of the adjustment of geodetic observations.

We have developed a program for estimating the effects of tectonic motion on geodetic measurements. This program consists of a database of site coordinates and a tectonic model, and allows users to compute site velocities and baseline components at any epoch as well as compute new site coordinates while accounting for tectonic motion. When used in conjunction with any geodetic adjustment program which incorporates the velocity components of site coordinates, the effects of tectonic motion can be modelled when adjusting geodetic observations, thereby allowing a dynamic datum to be realized. This is examined below from a computational perspective; we do not consider the issues related to the implementation of a time-varying geodetic datum.

Below, we consider two types of national geodetic networks and investigate the effects of adjusting two measurements of a network separated by two years. The first network lies wholly within a single, rigid plate while the second network contains sites located on several plates as well as in a strain accumulation region (Figure 1). We show that distortions can be introduced into a static datum if tectonic motion is ignored whereas such errors can be significantly reduced by adopting a dynamic datum that accounts for tectonic motion of the sites in the observed network.

2 What is a Dynamic Datum?

In this paper, we wish to consider two types of geodetic datums. A "static" datum is thought of as a traditional geodetic datum where all sites are assumed to

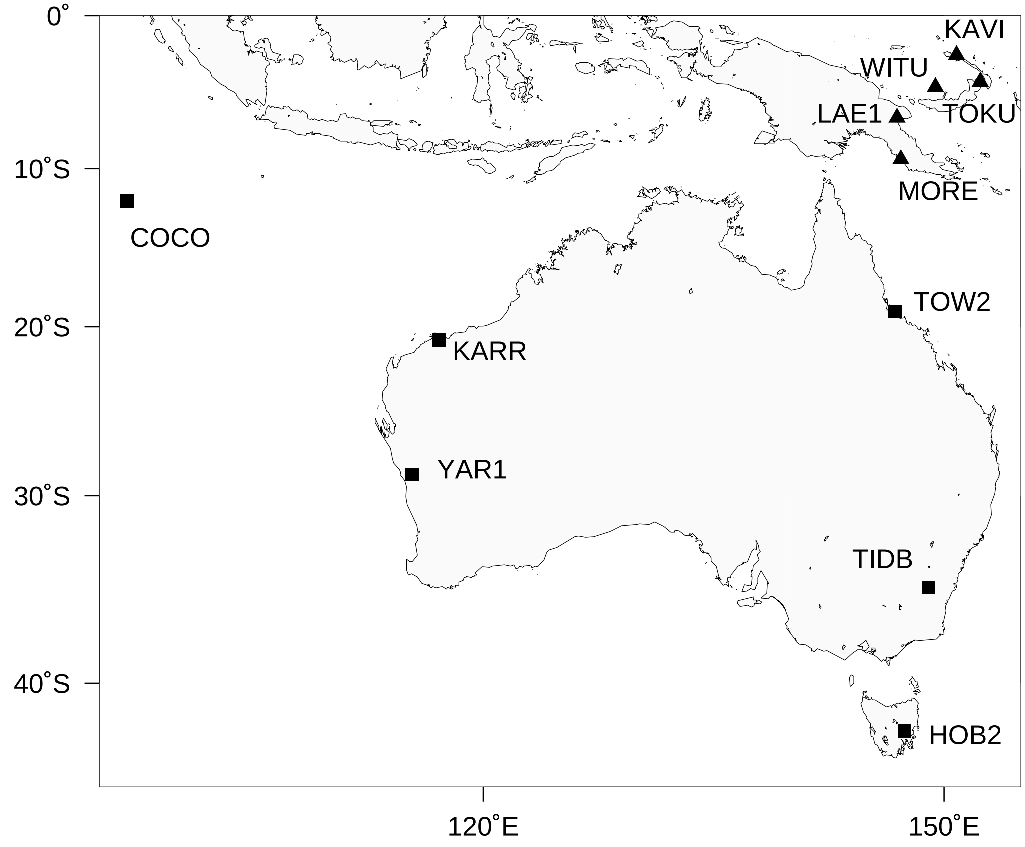

Figure 1: Location of sites in the Australian (squares) and PNG (triangles) networks.

have coordinates which are "fixed" or unchanging with time. This is an incorrect assumption since the surface of the earth is constantly changing because of tectonic motion.

The concept of a "dynamic" (or kinematic) datum has been introduced to represent a coordinate datum where the coordinates of sites change as a function of time (e.g. Grant, 1995; Morgan et al., 1996; Pearse, 1997; Grant and Blick, 1998). This is not a new concept in geodesy; for many years the International Earth Rotation Service has used time-evolving coordinate systems in generating the International Terrestrial Reference System (e.g. Boucher and Altamimi, 1993; Boucher et al., 1998). There are numerous publications which employ time-varying coordinate systems in the adjustment of geodetic data when investigating regional or global tectonic motion (see e.g. Feigl et al., 1993; Larson et al., 1997; Herring et al., 1990, Watkins et al., 1994). These investigations are generally not concerned with the geodetic datum itself; rather, the analysis is driven by the desire to understand the tectonic processes which are occurring.

Morgan et al. (1996) adopted the International Terrestrial Reference Frame 92 (ITRF92) (Boucher et al., 1993) in defining the coordinates of the Geocentric Datum of Australia (GDA94). This is a static datum with the coordinates of the sites defined at epoch 1994.0. However, tectonic motion was accounted for in the adjustment of the geodetic observations by fixing the velocities of 9 global tracking sites to the values defined in ITRF92. There are no provisions for tectonic motion to be accounted for in GDA94; however, it will be shown below that this is not likely to cause distortions in the coordinates of the sites.

Pearse (1997) modelled the tectonic motion occurring between the Australian and Pacific Plates in New Zealand by adopting site velocities from the No-Net-Rotation NUVEL1-A plate motion model (DeMets et al., 1990, 1994) and used the predicted velocities in conjunction with derived transformation parameters to transform NZGD49 coordinates (Jones, 1981) to WGS84 coordinates. The inclusion of the velocities improved the accuracy of the transformation. Recommendations were made that any new reference system adopted for New Zealand should have mechanisms incorporated into the design to enable tectonic motion to be accounted for and that an improved velocity field be derived for New Zealand.

Grant and Blick (1998) reported that Land Information New Zealand (LINZ) have decided to establish a new geodetic datum which they described as a "semi-dynamic" datum. This is essentially a static datum (or a datum fixed in time) but it has the provision to include large coordinate jumps which may have been caused by earthquake deformation or localised mark disturbance. In addition, the time-varying changes of site coordinates may be modelled during calculations in order to minimise systematic errors due to tectonic motion. The datum itself will be "static", although computations will be done in a dynamic reference system.

In this paper, we consider the application of a "dynamic" datum (Grant and Blick, 1998) which is a datum with a continuous and constant velocity component applied to the site coordinates. Both "dynamic" and "semi-dynamic" datums account for tectonic motion by applying a time-varying component to the site coordinates when performing calculations. The distinction between the two types of datums is that coordinates used in the latter case always refer to a specific epoch and do not vary, whilst the coordinates in a dynamic datum do actually change with time. Therefore, in a semi-dynamic datum, the users of the site coordinates must "correct" their measurements for tectonic motion in order to relate them to the epoch of the semi-dynamic datum. Users of a dynamic datum can directly compare their measurements to the site coordinates because the correction for tectonic motion is inherently applied to the coordinates rather than to the measurements.

This paper is not concerned with the relative merits of either a dynamic or semi-dynamic datum. The important issue is that the calculations and adjustment of geodetic data be performed in a manner which accounts for tectonic motion. For simplicity, we chose to use a dynamic datum.

3 Data Analysis

The GPS data used for this investigation were observed in September 1996 and September 1998 in Australia and Papua New Guinea (PNG), and we use one week of data in each of the two years. The regional data were combined with global tracking data from ~70 IGS sites in daily solutions using the GAMIT software (King and Bock, 1997) to produce loosely-constrained daily estimates of a global polyhedron of site coordinates along with estimates of satellite orbits, earth orientation parameters and tropospheric delays. The daily estimates of site coordinates were then used as quasi-observations in a Kalman filter (Herring, 1997) to generate a loosely-constrained global polyhedron of geodetic coordinates which includes a time dependence of the site coordinates.

Since we are interested in the adjustment of site coordinates using different definitions of the terrestrial datum, we chose to remove the rank defects of the terrestrial reference frame by fixing the coordinates of only two sites in the regional networks. We fixed the coordinates of TIDB and YAR1 in the Australian network and MORE and LAE1 in the PNG network (Figure 1). These sites have been chosen at random. The analysis and conclusions drawn below do not differ significantly with a different selection of fixed sites. We have used a subset of the total available GPS data in the two regions; the data used is sufficient to illustrate the effects of tectonic motion on datum definitions but we acknowledge that a more complete data set should be used if one was to compute a national adjustment.

While we used a global network of sites to compute the satellite orbits, we did not want the global polyhedron of sites to influence the definition of the terrestrial reference frame in terms of removing the rank deficiencies of the system. Similarly, while we combined the data of the Australian and PNG networks into a single solution, we wanted to investigate the behaviour of each network separately. This was achieved by applying stochastic variation to the coordinates of sites which were not part of the network we wished to investigate. Stochastic estimation of the daily estimates of these site coordinates leads to uncorrelated daily estimates, thereby removing any power of the external sites to influence the reference frame definition.

Therefore, the only sites which were able to affect the adjustment were the two fixed sites of each network in turn and the other sites of the respective networks which were estimated without stochastic noise. The same results could have been generated by computing only the regional networks using a precise orbit; however, the global approach is robust and, because the data for the two networks are embedded in the same input data files, we can be sure that the differences in the coordinate estimates of each network are caused by changes in datum definition rather than due to different processing of the data.

We computed the coordinates of the regional sites from the 1996 data only (Solution 1), the 1998 data only (Solution 2) as well as combining the data from both years. The combination for each network was performed for a static datum (where all velocities are fixed to zero) (Solution 3) and for a dynamic datum where the site velocities were fixed at values defined by a tectonic model (Solution 4). We have used only one week of data in each year in order to demonstrate the methodology and differences between a static and dynamic datum definition.

4 Creating a Dynamic Datum

There are three components required to generate a dynamic datum: a set of geodetic observations of a network of sites, a procedure for adjusting the geodetic observations and a velocity field for the network. The geodetic observations can be either traditional terrestrial measurements or space-based observations from any of the available techniques (e.g. VLBI, SLR, GPS, DORIS etc). The adjustment procedure must include the capacity to model a time varying component of site coordinates. The velocity field can be measured directly from geodetic observations or can be derived from a tectonic model. The latter is the most feasible option because a tectonic model is capable of providing velocity estimates at any site irrespective of whether there have previously been geodetic measurements made at the site. However, the accuracy of tectonic models may be limited near plate boundaries where localised strain accumulation may occur. Large-scale plate motion models may not model the velocity field accurately near plate boundaries and in regions of strain accumulation. In such cases, it may seem to be more appropriate to adopt discrete site velocities estimated from dense geodetic networks; however, if such information exists, the plate motion models could be improved to model accurately the estimated velocities.

Assuming one has all of the above components, an existing static datum can be converted to a dynamic datum by assigning a velocity to each site in the geodetic network, fixing the site velocities in the network adjustment program and then computing an adjustment of all the geodetic observations. The "dynamic" component of the adjustment is mathematically implemented by adjusting the observation equations to account for the tectonic motion of the sites. That is, the *a priori* site coordinates are "corrected" for tectonic motion prior to computing the difference between the observed and the calculated distance/direction between the sites. The velocity field could be estimated simultaneously with the site coordinates; however, since at least two occupations are required at each site in order to compute a velocity, it is likely that there will be insufficent data in most national networks to generate an accurate velocity field at all sites and a better result would be achieved by adopting an external model of the tectonic motion (assuming such a model exists).

The resulting network adjustment will be free of distortions from tectonic motion and the estimated coordinates will refer to a particular date. However, using the assigned velocities for each site, the coordinates of any site can be calculated for any date. The users of a dynamic datum could be presented with a datum which consisted of coordinates and velocities of the sites, along with the date to which the coordinates refer. Such a datum would provide users with realistic positions of sites within a network which is changing as a result of tectonic motion. To within the limits of the accuracy of the tectonic model and the geodetic adjustment, comparisons of observed positions of sites made at any date would agree with the datum coordinates for the sites irrespective of the required accuracy of the users.

It is acknowledged that a wide range of users of a geodetic datum require different levels of accuracy of the datum. As will be shown below, in regions with large and complicated tectonic regimes, unmodelled tectonic motion could be as large as 0.5 m in a few years. In PNG, shortening of $\sim$30 mm/yr can occur between sites separated by as little as 12 km. Such rapid distortion of a static datum would quickly become apparent to any users of the datum who require coordinate accuracy of better than 20 mm and who are working in or near tectonic deformation zones.

Geodetic datums are comprised of many different components and geodesists are familiar with the concept of updating datum definitions when new information leads to improved models (e.g. new gravity models, new GM values for the earth, new definitions of reference ellipsoids). It is only a small extension of this concept to include a tectonic model as a component of the geodetic datum. When modelling of the tectonic motion within a particular region of the earth improves significantly, the geodetic datum could be updated by adopting the improved tectonic model and readjusting all the observations. There would be no requirement to recompute the geodetic observations; simply updating individual site velocities using the new model and re-running the adjustment would suffice to generate an improved datum.

5 Tectonic Model

We have developed a tectonic model which, given the cartesian coordinates of a site, determines on which plate the site resides and calculates the appropriate cartesian velocity. The model consists of a series of polygons which define tectonic "blocks". Snay et al. (1988) used a similar approach in dividing the San Diego region in California into "districts" for which they solved for translations and rotations, while Snay et al. (1996) used bilinear interpolation to transfer crustal deformation information from geodetic sites to nodes on a 15' x 15' two-dimensional grid. In our model, the motion of each block is calculated as a rotation, ω_p, about an Euler pole ϕ_p, λ_p. Tregoning et al. (1998) calculated Euler vectors from site velocities estimated from GPS measurements in the Australasian region. We used the same data plus additional data observed since 1996 to re-estimate Euler vectors for the Australian, Pacific, South Bismarck and Woodlark Plates in the ITRF96 terrestrial reference frame (Boucher et al., 1998). Figure 2 shows the tectonic blocks defined in the model and the respective Euler vectors are listed in Table 1.

Recent GPS surveys have shown that the eastern end of New Britain is not moving as part of the rigid South Bismarck Plate; rather, there is a strain deformation pattern which is indicative of a strike-slip deformation zone. We have modelled the deformation in this region by correcting the rigid South Bismarck Plate predicted velocity for a strain component in the direction parallel to the assumed plate

Table 1: Euler Vectors for Tectonic Blocks. Rotation of ω°/My is in an anti-clockwise direction about the pole located at ϕ, λ.

Block	ϕ	λ	ω
Australian	34.1	38.6	0.64
Pacific	-62.7	115.1	0.66
South Bismarck	6.8	-31.9	8.06
Woodlark	2.1	124.8	1.49

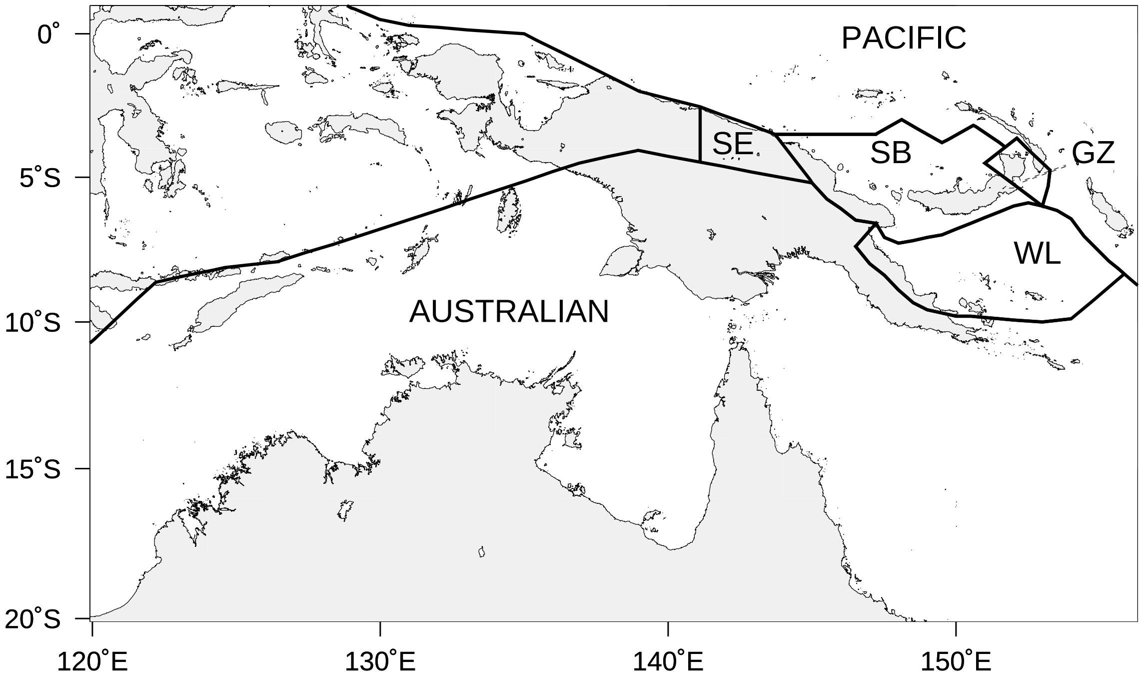

Figure 2: The plate tectonic blocks as defined in the tectonic model. Only the northern boundary of the Australian Plate is plotted, the other boundaries of the Australian plate lie beyond the GPS network. SE: Sepik Block; SB: South Bismarck Plate; GZ: Gazelle Block; WL: Woodlark Plate.

boundary, the Weitin Fault. We model the strain component according to:

$$\text{Along-strike strain} = 1/\pi \times \operatorname{atan}(7/\text{dist})$$

where dist is the perpendicular distance from the site to the fault with the fault modelled as a line between (4.75°S 153.25°E) and (3.63°S 152.1°E). The exact region which is affected by strain accumulation is not yet known; however, this simple model fits the observed GPS velocities in this region to within ~5 mm/yr. The model will be revised when additional GPS velocities in the region will be estimated.

Evidence from GPS velocities in the northwestern region of Papua New Guinea and Irian Jaya suggest that this part of PNG is not moving as part of the Australian Plate (Mobbs, 1997). We have no definitive data to allow an accurate estimation of the plate motion but choose to define a region, the "Sepik Block", which has the same Euler pole as the Australian Plate but a rotation rate which is 25% slower.

There are limitations to our tectonic model. In general, modelling of site velocities located on the stable interiors of blocks will be accurate to ~2 mm/yr. However, there are several regions near plate boundaries which are either known or suspected to be regions of strain accumulation, for example, the Markham Valley and Finisterre Range, the region either side of the Bismarck Sea Seismic Lineation near Wewak, the Sepik Block to the north of the Highlands. The exact nature of the plate coupling is not yet known; therefore, it is not yet possible to model accurately the site velocities in such regions. Nonetheless, the current model represents a significant improvement over the assumption that tectonic motion can be ignored, an assumption which may introduce errors greater than 100 mm/yr. We estimate that the magnitude of the differences between actual and modelled velocities near the plate boundaries will be less than 20 mm/yr, while ~80% of Papua New Guinea will be modelled to better than 5 mm/yr.

The tectonic model can predict a site velocity at any point which is located on the particular tectonic block. Once the tectonic model has been derived from individual GPS velocity vectors, it is not necessary to have estimated previously the velocity of any other site in order to assign a velocity to that site in a dynamic datum. Furthermore, residual measurement errors in individual site velocities are averaged when deriving the Euler vectors which then represent the motion of all points on the plate; therefore, the resulting velocity field from the tectonic model is smooth and internally consistent.

Our model can be used to calculate the relative position between sites at any particular epoch and the expected change in relative position between sites due to tectonic motion. In addition, the coordinates of a new site can be calculated if the cartesian components between a known site and the new site are measured. This can be done for either a semi-dynamic datum by "correcting" the measured baseline components or for a dynamic datum by correcting the coordinates of the known site for tectonic motion.

6 Results

Table 2 shows the changes in coordinates for Solutions 2-4 (see Section 3) relative to the coordinates of Solution 1. The formal precision of a single site estimate in either year is ~5 mm. Solution 2 indicates that the coordinates estimated from the second measurement of the Australian network were within ~10 mm of the Solution 1 estimate. Large adjustments have occurred to the coordinates from the second epoch of measurement of the PNG network in Solutions 2 and 3. These adjustments are due to tectonic motion but appear as "errors" in a static adjustment of the two network measurements. It is only by applying time variation in the site coordinates (Solution 4) that the adjustments to the site coordinates reach an acceptable level.

The χ^2/f values for the network adjustments were ~1 for all solutions of the Australian Network and for solutions 1,2 and 4 of the PNG network. This shows that there are no apparent inconsistencies in the data and that the *a priori* constraints are realistic. In contrast, the χ^2/f value for Solution 3 of the PNG network was ~50, indicating that there are significant strains or inconsistencies in the data which have invalidated the underlying assumptions that all physical effects contained in the data (e.g satellite orbits, tectonic and polar motion etc) have been properly modelled.

The adjustment of 36 mm to the East component of Kavieng in Solution 4 can be attributed to a reduced number of days of observations in 1998 (3 rather than 7) and a shorter observing period each day (~8 rather than 24 hours/day). Therefore, the 1998 estimate of the coordinates of Kavieng are not as precise as the other sites;

however, the data from this site, being located on a different plate, is still useful in demonstrating the effects of tectonic motion on network adjustments. Alternatively, the modelled velocity of KAVI may be inaccurate in the east component, thereby failing to remove all the tectonic motion which occurred at the site.

Since the data used are real rather than simulated data, one cannot expect to derive a perfect adjustment; therefore some of the differences in the coordinate estimates must be attributed to unmodelled errors in the data and analysis. These errors are beyond the scope of this paper and, in the light of the following analysis of tectonic motion, are negligible. There could also be errors associated with inaccuracies which may remain in the tectonic model used to calculate the individual site velocities.

7 Discussion

There are several issues to consider about adopting a static or a dynamic datum. Will tectonic motion distort a static datum? Are the magnitudes of dynamic changes in site coordinates detectable by the users of the datum? Will a dynamic datum improve or degrade a geodetic network? We will consider these questions by looking at the results for the Australian and PNG networks separately. We will not discuss or consider any issues related to the legal and/or political implementation of a geodetic datum.

7.1 Australian Network

A comparison of solutions 3 and 4 (Table 2) shows that there are no differences in the size of the adjustments to *a priori* site coordinates when the tectonic model is

Table 2: Change (in mm) in local North and East coordinates of Solution 2 (1998), Solution 3 (combined, static datum) and Solution 4 (combined, dynamic datum) relative to Solution 1 (1996).

Site	Code	Solution 2		Solution 3		Solution 4	
		δ_n	δ_e	δ_n	δ_e	δ_n	δ_e
Cocos Island	COCO	2	4	1	1	1	1
Hobart	HOB2	4	-7	1	-1	1	-1
Karratha	KARR	6	9	3	3	3	3
Townsville	TOW2	-4	12	-2	7	-2	7
Kavieng	KAVI	-81	-154	-70	-17	2	36
Tokua	TOKU	-204	-79	-111	-85	-19	-8
Witu	WITU	-171	24	-92	10	-1	-1

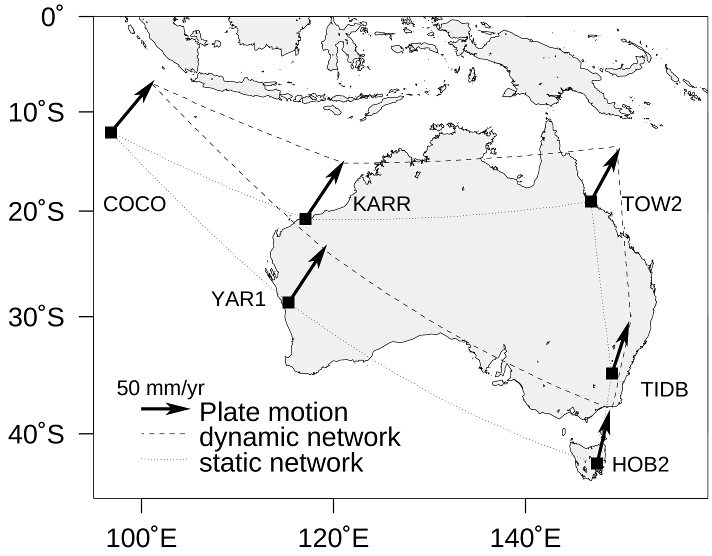

Figure 3: Illustration of the measured Australian network in a dynamic system (including plate motion) and how the network would be computed in a static datum. Plate motion vectors (solid arrows), measured network at epoch 1998.75 (dashed lines) and computation of the network in a static datum (dotted lines) are shown.

applied. This is not surprising because the whole network resides on the Australian Plate and there have been no change in relative baselines between the sites in this network. In fact, the estimation process has rotated the 1998 position of the network back to the 1996 position as defined by the fixed coordinates of TIDB and YAR1 (Figure 3).

Since the network effectively has the same shape (ie no changes in relative positions), the two estimates of the network are similar and "appear" to be invariant of tectonic motion. Therefore, one could conclude that if the users of a static datum in Australia compute positions relative to another point in the static datum, there will not be any introduction of network distortions as a result of tectonic motion. All coordinates computed in this manner will be valid at the date of the reference epoch for the static datum.

However, the network as a whole has rotated relative to the geocentre and the XYZ cartesian axes. Therefore, if a user were to compute an "absolute" point position or compute a position relative to a site (or sites) whose coordinates are not known in the static datum (for example, the coordinates of IGS tracking sites which are not located on the Australian Plate), the effects of tectonic motion would become apparent. This motion ranges from ~50 mm/yr in the eastern part to ~70 mm/yr in the western part of the Australian Plate.

One can argue that introducing a tectonic model (ie converting the static datum to a dynamic datum) does not degrade the accuracy of the datum in any way. Therefore, there is no mathematical justification for not adopting a dynamic datum for a country such as Australia where all sites within the country lie within a rigid plate whose motion can be modelled.

7.2 PNG Network

The situation is completely different for the PNG network. In this case, the network straddles three known plate boundaries and includes sites on three plates and a local strain accumulation zone. The adjustments to site coordinates between the 1996 and 1998 estimates are up to 150 mm in both the north and east components (Table 2). The static datum approach of simply combining the two campaigns (ignoring tectonic motion) increases the χ^2/f values from 1 to 50, indicating a significant increase in strain in the adjustment. There is clearly an unacceptable level of difference between the estimates of the coordinates of the network and this can be attributed to tectonic motion.

The network has changed shape in the two year interval between observations, resulting in changes in the relative positions of the sites. Therefore, when the network is rotated back to the static datum (by aligning the LAE1-MORE baseline with the 1996 position), the locations of the other sites no longer coincide with their 1996 positions (Figure 4), thereby introducing tension into the geodetic adjustment and producing coordinate errors greater than 100 mm (Table 2).

In the case of a dynamic datum, the plate motion model accounts for the tectonic motion which has occurred in the two year interval. The two estimates of the network can be superimposed with an apparent accuracy of ~30 mm (Solution 4 in Table 2) and no significant increase in the χ^2/f values occurs. The agreement of the

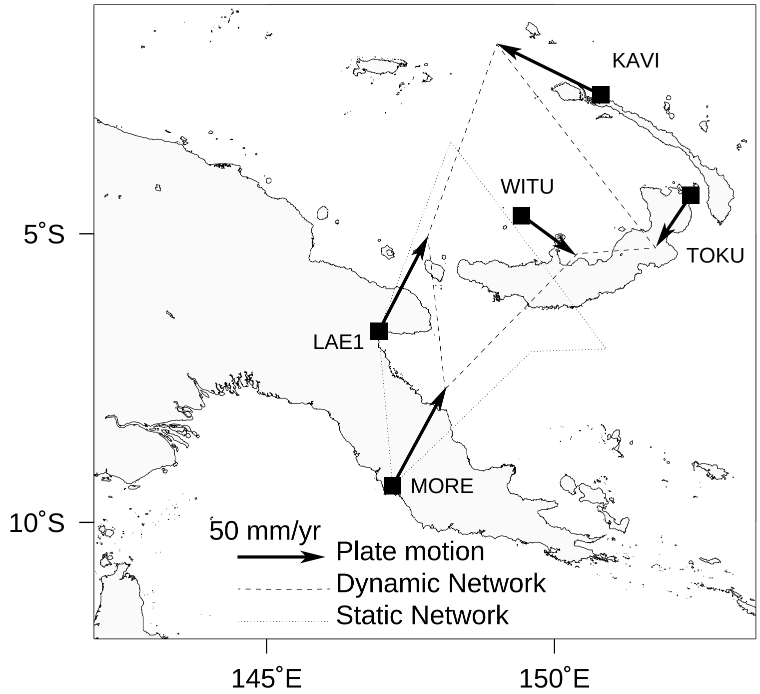

Figure 4: Illustration of the measured PNG network in a dynamic system (including plate motion) and how the network would be computed in a static datum. Plate motion vectors (solid arrows), measured network at epoch 1998.75 (dashed lines) and computation of the network in a static datum (dotted lines) are shown.

two networks in the PNG case is not as accurate as the Australian example which probably indicates that there are either larger errors in the actual GPS observations in the tropical environment or that the tectonic model is not completely accurate. However, performing the computations in a dynamic reference system is clearly superior to the static datum approach, with the remaining errors being at a second-order level.

8 Conclusions

We have shown that the adjustment of geodetic networks which reside wholly within one rigid tectonic plate will not be distorted by tectonic motion if a static datum is imposed providing all the input geodetic observations are relative to sites whose coordinates are known in the static datum. In this case alone, the effects of tectonic motion will not be apparent to the users of the datum. If any user has the capability of computing an "absolute" site position (or site coordinates relative to a site whose coordinates are not known in the static datum such as stations in the IGS network) then the tectonic motion will become evident and will seem to indicate errors in either the geodetic measurements or the static datum itself. Of course, any users who require only a low level of accuracy will not be sensitive to whether the underlying datum is a static, semi-dynamic or dynamic datum.

In the case of a network which spans at least one plate boundary (or a strain accumulation region), a geodetic adjustment which does not account for tectonic motion within the network will introduce errors into the estimation of geodetic coordinates. Subject to the magnitudes of the relative velocities of the sites, these errors may be detectable over a period as short as a few months to users with the capability to measure distances accurately. Introducing a tectonic model into the geodetic adjustment improves the accuracy of the adjustment significantly; in the example demonstrated in this paper the improvement in agreement of site coordinates is a factor of 10. While inaccuracies in the tectonic model will lead to some errors remaining in the adjusted site coordinates, the overall accuracy of the resulting dynamic datum will be significantly higher. The present-day tectonic motion which may be occurring will also be undectable to all users for much longer time periods, possibly up to several years.

A tectonic model can be incorporated into a geodetic datum by the addition of cartesian velocities in the geodetic adjustment. Fixing the site velocities to predetermined values leads to significant improvements in the accuracy of the adjustment when tectonic motion has caused distortion within a geodetic network. We have presented our tectonic model for Papua New Guinea and Australia and have shown that the implementation of a velocity field in the adjustment procedure is necessary for producing a geodetic datum which is not affected by the tectonic motion of sites within the network. When the understanding of the tectonic motion within a network is improved, the tectonic model (and hence the datum) can be revised by updating the velocity field and then readjusting the geodetic observations.

In the case where the network resides within one rigid plate and site velocities are defined by an external tectonic model, the adoption of a dynamic datum does not affect the accuracy of the geodetic adjustment of the observations in any way. The practicalities of implementing such a system are more complicated than a conventional static datum (see e.g. Grant, 1995); this was not considered in this paper.

An alternative approach to a dynamic datum is to adopt a semi-dynamic datum where computations are made using the dynamic approach but all coordinates are referred to a specific epoch. If a dynamic datum is adopted, the tectonic motion would be accounted for by time variation in the coordinates of the control stations. It is acknowledged that time-varying coordinates pose significant problems in other fields (e.g. GIS, maintaining cadastral databases etc). This paper has not attempted to address such issues; rather, we have focussed on the computational aspects of how tectonic motion can distort a geodetic datum and how such distortions can be minimised.

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