Evaluating the Performance of AUSPOS Solutions in NSW

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ABSTRACT

AUSPOS is Geoscience Australia's free online Global Positioning System (GPS) processing service. It takes advantage of the International GNSS Service (IGS) network station data and products to compute precise coordinates, using static dual-frequency GPS carrier phase and code data of at least 1 hour duration (recommended minimum of 2 hours duration). This paper outlines how AUSPOS and CORSnet-NSW are used to support datum modernisation and to maintain and extend the Survey Control Network on behalf of the NSW Surveyor General. The quality of AUSPOS solutions is investigated using more than 2,400 successful datasets incorporating observation sessions ranging from 2 hours to 48 hours in length. It is shown that AUSPOS routinely delivers Positional Uncertainty (PU) values at the 0.02-0.03 m level for the horizontal component and about 0.05-0.06 m for the vertical (ellipsoidal) component. As expected, it is evident that a longer observation span improves PU, particularly in regards to the vertical component. The results illustrate why Geoscience Australia stipulates, and NSW supports, a minimum observation span of 6 hours for inclusion into the national GDA2020 adjustment to propagate the Survey Control Network. However, they also show that shorter observation sessions are of sufficient quality to strengthen and improve the State's survey infrastructure, justifying the approach taken by NSW Spatial Services to use AUSPOS as one of several suitable methods to maintain and extend the State's Survey Control Network.

KEYWORDS: *AUSPOS, Positional Uncertainty, CORSnet-NSW, datum modernisation, GDA2020, survey infrastructure.*

1 INTRODUCTION

Geoscience Australia's free online Global Positioning System (GPS) processing service, AUSPOS, was developed to provide an online positioning service primarily for Australian users (Jia et al., 2014; GA, 2020a). Since its initial release in 2000, it was frequently upgraded in order to incorporate improvements. For example, this included switching to the Bernese Global Navigation Satellite System (GNSS) software processing engine in 2010, introducing a more realistic assessment method of coordinate uncertainty in 2013 and upgrading to the latest Bernese software version 5.2 (Dach et al., 2015) in 2015 (Jia et al., 2016). In order to support national datum modernisation efforts, AUSPOS started delivering results in both GDA94 and GDA2020 (ICSM, 2020a), as well as ITRF2014 (Altamimi et al., 2016), with version 2.3 in November 2017. However, it remains GPS-only. AUSPOS was ranked highest in a comparison of free online services for GPS post-processing (Gakstatter and Silver, 2013) and has successfully processed more than 1 million jobs worldwide over the last 10 years (M. Jia, pers. comm.).

AUSPOS takes advantage of the International GNSS Service (IGS) network station data and products (e.g. final, rapid or ultra-rapid orbits depending on availability – see IGS, 2020) to compute precise coordinates, using static dual-frequency GPS carrier phase and code data of at least 1 hour duration (recommended minimum of 2 hours, maximum of 7 consecutive days). When submitting 30-second Receiver Independent Exchange (RINEX) data, users are required to specify the antenna type (using the IGS naming convention) and the antenna height to the Antenna Reference Point (ARP). Following processing, an AUSPOS report (pdf) is emailed to the user (generally within a few minutes), which includes the computed coordinates and their uncertainties, ambiguity resolution statistics, and an overview of the GPS processing strategy applied. For advanced users, Solution Independent Exchange (SINEX) files containing more detailed information are also available for download.

CORSnet-NSW is Australia's largest state-owned and operated Continuously Operating Reference Station (CORS) network (e.g. Janssen et al., 2016; NSW Spatial Services, 2020a). It is built, owned and operated by Spatial Services, a unit of the NSW Department of Customer Service. CORSnet-NSW currently consists of 203 stations, providing fundamental positioning infrastructure that is authoritative, accurate, reliable and easy-to-use for a wide range of applications. CORSnet-NSW sites comprise a fundamental, high-density and long-term component of AUSPOS infrastructure within the State. In February 2019, CORSnet-NSW started delivering services in both GDA94 and GDA2020. Since May 2019, it provides all-in-view, all-signals, multi-constellation GNSS data (i.e. GPS, GLONASS, BeiDou, QZSS and Galileo), making it the nation's first CORS network to reach this milestone. At any given time, CORSnet-NSW stations typically deliver at least 40 satellites in view.

All CORSnet-NSW stations are part of the Asia-Pacific Reference Frame (APREF – see GA, 2020b), including 13 concrete-pillared NSW sites incorporated in the IGS network. AUSPOS uses up to 15 surrounding CORS as the reference stations, generally the 7 closest IGS sites and the 8 closest APREF sites (Jia et al., 2014). This approach provides a relatively dense network for generating a reliable regional ionospheric delay model and tropospheric delay corrections to support ambiguity resolution. Based on these reference stations, a precise solution for the user data is then computed using double-differencing techniques. The coordinates of the IGS stations are constrained with uncertainties of 1 mm for horizontal position and 2 mm for the vertical, while lower-tier CORS coordinates are constrained with uncertainties of 3 mm for horizontal position and 6 mm for the vertical (due to the shorter CORS operation time span, lower data quality and/or lower-grade monumentation).

The GPS data is processed in the IGS realisation of the ITRF2014 reference frame and then transformed to GDA2020 via the Australian Plate Motion Model. Derived Australian Height Datum (AHD – see Roelse et al., 1971) heights are computed by applying a gravimetric-geometric quasigeoid model (AUSGeoid2020 – see Brown et al., 2018; Janssen and Watson, 2018; Featherstone et al., 2019) to the GDA2020 ellipsoidal heights. Legacy GDA94 coordinates are obtained from GDA2020 by coordinate transformation. More information about GDA94 and GDA2020, along with their technical manuals, can be found on the Intergovernmental Committee on Surveying and Mapping (ICSM) website (ICSM, 2020a).

Positional Uncertainty (PU) is calculated based on the East, North and ellipsoidal height coordinate uncertainties according to the Guideline for Adjustment and Evaluation of Survey

Control, which is part of ICSM's Standard for the Australian Survey Control Network (SP1), version 2.1 (ICSM, 2014). The coordinate uncertainties of the East, North and ellipsoidal height components are scaled using an empirically derived model, which is a function of duration, data quality and geographical location (latitude and CORS density), and expressed at the 95% confidence level (Jia et al., 2016).

This paper outlines how AUSPOS and CORSnet-NSW are used to support datum modernisation and improve state survey infrastructure across NSW. The quality of AUSPOS solutions is investigated using more than 2,400 successful datasets, incorporating observation sessions ranging from 2 hours to 48 hours in length.

2 USING AUSPOS TO SUPORT DATUM MODERNISATION AND IMPROVE SURVEY INFRASTRUCTURE IN NSW

Datum modernisation and further improvement of survey infrastructure is required in order to accommodate the increasing accuracy and improved spatial and temporal resolution available from modern positioning technologies to an ever-broadening user base concerned with surveying, mapping, navigation, engineering, machine guidance and precision agriculture, to name but a few.

All CORSnet-NSW stations contribute to the AUSPOS service, i.e. most NSW users are close to a dense network of surrounding CORS. As demonstrated in the next section, this results in strong AUSPOS processing results even for shorter observation sessions of at least 2 hours, provided sky view conditions are reasonable. Consequently, the use of AUSPOS campaigns has developed into a very capable and reliable alternative to conducting traditional static GNSS baseline surveys (e.g. Gowans et al., 2015; Janssen and Watson, 2018), simplifying logistics by removing the requirement of field crews having to occupy particular survey marks at a set time. As a consequence, processing, adjustment and report writing efforts have been significantly reduced or removed, and office time is typically cut to 1 hour per day per survey crew in the field. AUSPOS also forms a new and fundamental component of vertical datum modernisation and the propagation of the Australian Vertical Working Surface (AVWS – see ICSM, 2020b) in the State.

NSW Spatial Services will therefore continue to apply, expand and accelerate this proven approach to improve the State's Survey Control Network, with appropriate Class being assigned in accordance with ICSM (2007) and Surveyor General's Direction No. 12 (Control Surveys and SCIMS) (NSW Spatial Services, 2019), and uncertainty as described in Janssen et al. (2019). To this end, AUSPOS data of at least 6 hours duration is used to propagate the datum in NSW, while AUSPOS data of less than 6 hours duration strengthens the datum. The profession is encouraged to contribute to these efforts by submitting suitable AUSPOS data and related metadata (NSW Spatial Services, 2020b) in order to facilitate the update of survey information on public record in the Survey Control Information Management System (SCIMS). SCIMS is the State's database containing about 250,000 survey marks across NSW, including coordinates, heights, accuracy classifications and other metadata, provided in GDA94, GDA2020 and AHD (Janssen et al., 2019).

At present, the GDA2020 state adjustment incorporates approximately 30,000 survey control marks across NSW, i.e. 12% of all marks in SCIMS. Consequently, 88% of the marks in SCIMS are currently transformed from GDA94 to GDA2020. Uncertainties of these transformed

GDA2020 coordinates are given null values until these are calculated via inclusion in the state adjustment. As shown in this paper, AUSPOS is a suitable method to accelerate the process of including additional survey marks into the state adjustment in order to improve user access to GDA2020 coordinates and uncertainties across the State.

In support of these datum modernisation efforts, NSW Spatial Services is currently building an updated 'passive' Survey Control Network (in the Eastern and Central Divisions) with a minimum of one fundamental survey mark observed by 6+ hour AUSPOS every 10 km. Its vision is to ensure that any future user is no further than 5 km (and often much less) from such a fundamental mark providing direct connection to datum. Similarly, levelled AHD marks are observed by 6+ hour AUSPOS every 10 km, often at a far greater density. This will allow users to achieve NSW Spatial Services' vision of a Positional Uncertainty (PU) of 20 mm in the horizontal and 50 mm in the vertical (ellipsoidal height) component anywhere in the State and easily apply transformation tools to move between current, future and various historical datums and local working surfaces (e.g. railway datum or standard datum).

Following successful AUSPOS processing (GPS-only, using final IGS products) by NSW Spatial Services, GNSS data of more than 6 hours duration (with a maximum observation length of 48 hours) is submitted to Geoscience Australia toward the National GNSS Campaign Archive (NGCA) database of 6+ hour AUSPOS datasets. Currently, this data is grouped into simultaneously observed sessions and processed through an *offline* AUSPOS engine with the results expressed as baselines to nearby CORS, rather than absolute measurements of position. This avoids introducing additional adjustment constraints outside of APREF.

GNSS data of 2-6 hour duration is handled according to a similar principle but brought about by slightly different means. Again following successful AUSPOS processing by NSW Spatial Services to verify the required data quality, the *online* AUSPOS results are converted to be expressed as baselines to nearby CORS.

3 QUALITY OF AUSPOS SOLUTIONS ACROSS NSW

3.1 Data and Testing Methodology

The quality of AUSPOS solutions was investigated using 2,618 GNSS datasets observed by NSW Spatial Services over the last 5 years, between November 2014 and August 2019, under typical conditions generally encountered in the field and incorporating observation sessions ranging from 2 hours to 48 hours in length. These datasets were processed individually with *online* AUSPOS version 2.3 (GA, 2020a), using final IGS products.

A small number of AUSPOS solutions was rejected for this analysis due to warnings in the AUSPOS report, referring to poor ambiguity resolution and/or large uncertainties. Overall, 154 sessions (5.9%) were rejected, including 121 (10.1%) of the 2-6 hour sessions and 33 (2.3%) of the 6-48 hour sessions. Upon investigation of site photos and other metadata, this was generally attributed to ambitious attempts to observe survey marks in locations with substantial tree cover, resulting in poor sky view conditions. As expected, shorter observation sessions were more prone to be negatively affected by these unfavourable conditions.

For all 2,464 successful AUSPOS solutions (with almost 44% of these being 2-6 hour sessions), descriptive statistics were then used to evaluate the uncertainties of the resulting GDA2020 coordinates. Positional Uncertainty (PU) is defined as the uncertainty of the horizontal and/or vertical coordinates of a point, at the 95% confidence level, with respect to the defined reference frame (datum) (ICSM, 2014). A description of the practical implementation of PU in NSW (particularly SCIMS) can be found in Janssen et al. (2019).

Three tests were performed to investigate the quality of AUSPOS solutions in NSW:
1) Analysing Horizontal PU (HPU) and Vertical PU (VPU) of the AUSPOS solutions for GDA2020 horizontal coordinates and GDA2020 ellipsoidal heights, respectively.
2) Analysing the repeatability of AUSPOS solutions for reoccupations on the same mark.
3) Analysing AHD results by comparing the AUSPOS-derived AHD heights (using AUSGeoid2020) to levelled AHD heights of sufficient quality on public record and investigating the AHD-PU reported by AUSPOS.

The results of these three tests are presented and discussed in the following sections. Figure 1 shows the location of the 2,464 successful AUSPOS solutions analysed in this study, colour-coded to indicate observation length.

Two further tests were conducted, the results of which can be immediately summarised:
- Whilst AUSPOS uncertainty is known to be affected (scaled) by latitude, the variation is negligible for user results within the bounds of NSW.
- Whilst IGS products have continuously improved and CORS density has increased, AUSPOS version 2.3 performance has remained stable, predictable, repeatable and of high quality within NSW in the recent past.

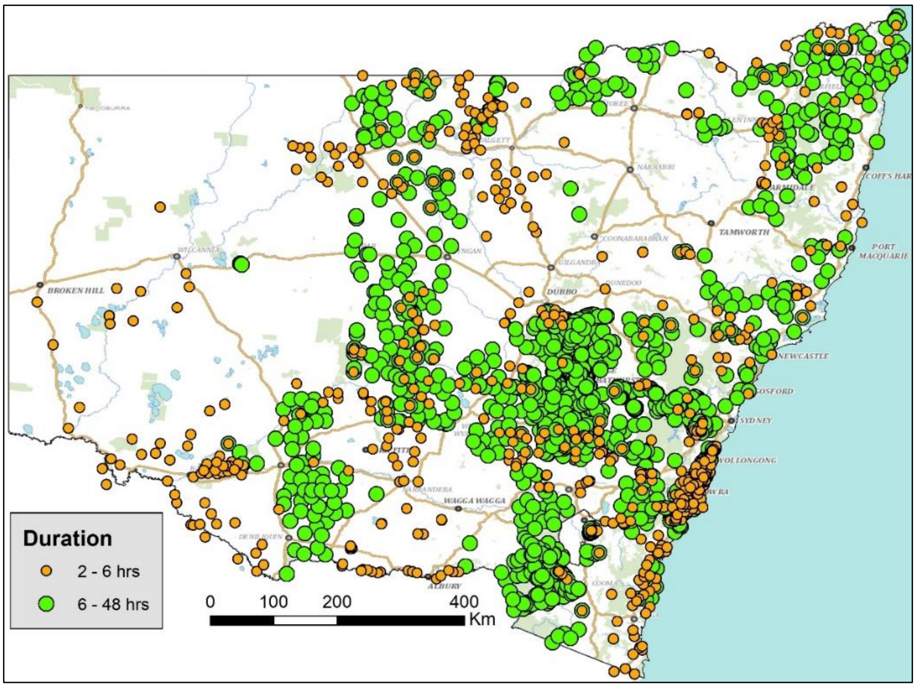

Figure 1: Location of the 2,464 successful AUSPOS solutions analysed across NSW, colour-coded to indicate observation length.

3.2 PU of AUSPOS Solutions

Horizontal PU (HPU) and Vertical PU (VPU) of the AUSPOS-derived GDA2020 horizontal coordinates and GDA2020 ellipsoidal heights were obtained from the SINEX file associated with each AUSPOS solution (these values are also stated in the AUSPOS report). Table 1 summarises descriptive statistics regarding HPU and VPU for the entire dataset of 2,464 successful AUSPOS solutions (2-48 hour duration), also providing this information for the 2-6 hour and 6-24 hour subsets, respectively, to allow examination of the effect the observation session length has on the resulting uncertainties. Figure 2 provides a graphical visualisation of the results, showing PU as a function of observation session length.

Table 1 and Figure 2 show that the majority of solutions meet or are better than the 20 mm HPU and 50 mm VPU thresholds targeted by NSW Spatial Services. The benefit of longer observation sessions is demonstrated by mean values of 0.023 m ± 0.006 m (1 sigma) for HPU and 0.069 m ± 0.022 m (1 sigma) for VPU when using 2-6 hour data, compared to values of 0.015 m ± 0.003 m (1 sigma) for HPU and 0.033 m ± 0.016 m (1 sigma) for VPU when using 6-24 hour data. This supports the notion that AUSPOS data of 6+ hour duration is used to propagate the datum, while AUSPOS data of less than 6 hours duration supplements the datum. The median values indicate that no significant offsets caused by possible outliers are present.

Table 1: Descriptive statistics for the HPU and VPU analysis (all values in metres).

Dataset	Statistic	HPU	VPU
Entire dataset: 2,464 solutions	**Min.**	0.011	0.015
	Max.	0.074	0.161
	Range	0.063	0.146
	Median	0.017	0.042
	Mean	0.018	0.048
	STD	0.006	0.026
2-6 hour data: 1,076 solutions	**Min.**	0.014	0.029
	Max.	0.074	0.141
	Range	0.060	0.111
	Median	0.022	0.065
	Mean	0.023	0.069
	STD	0.006	0.022
6-24 hour data: 1,280 solutions	**Min.**	0.011	0.018
	Max.	0.042	0.161
	Range	0.031	0.143
	Median	0.014	0.027
	Mean	0.015	0.033
	STD	0.003	0.016

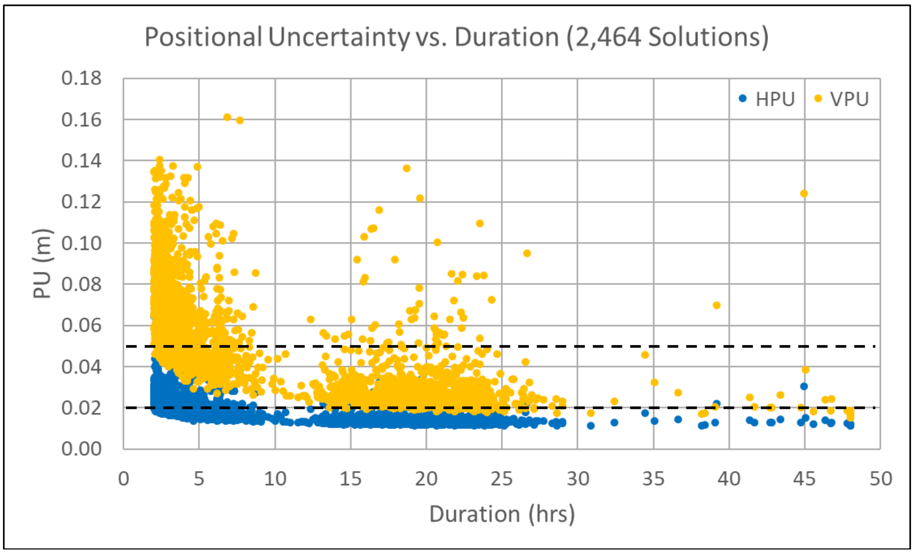

Figure 2: Positional Uncertainty (PU) vs. duration for the entire dataset.

Figure 3 investigates the data shown in Figure 2 in more detail. As expected, a longer observation span generally improves PU. Most of the improvement is gained by increasing the observation length from 2 hours to about 4-5 hours (Figure 3a), with minor but not insignificant improvement when the observation span is increased to 24 hours (Figure 3b). Observation sessions exceeding 12 hours provide AUSPOS solutions of substantially higher quality in the vertical component.

An investigation of site photos and other metadata attributed the larger VPU values evident for solutions greater than 15 hours duration to poor sky view conditions caused by substantial tree cover. As an example, Figure 4 illustrates the conditions encountered at the sites producing the largest three VPU values in Figure 3b. In spite of these poor sky view conditions, AUSPOS solutions generally achieve acceptable HPU and heights with a VPU of better than 0.1 m.

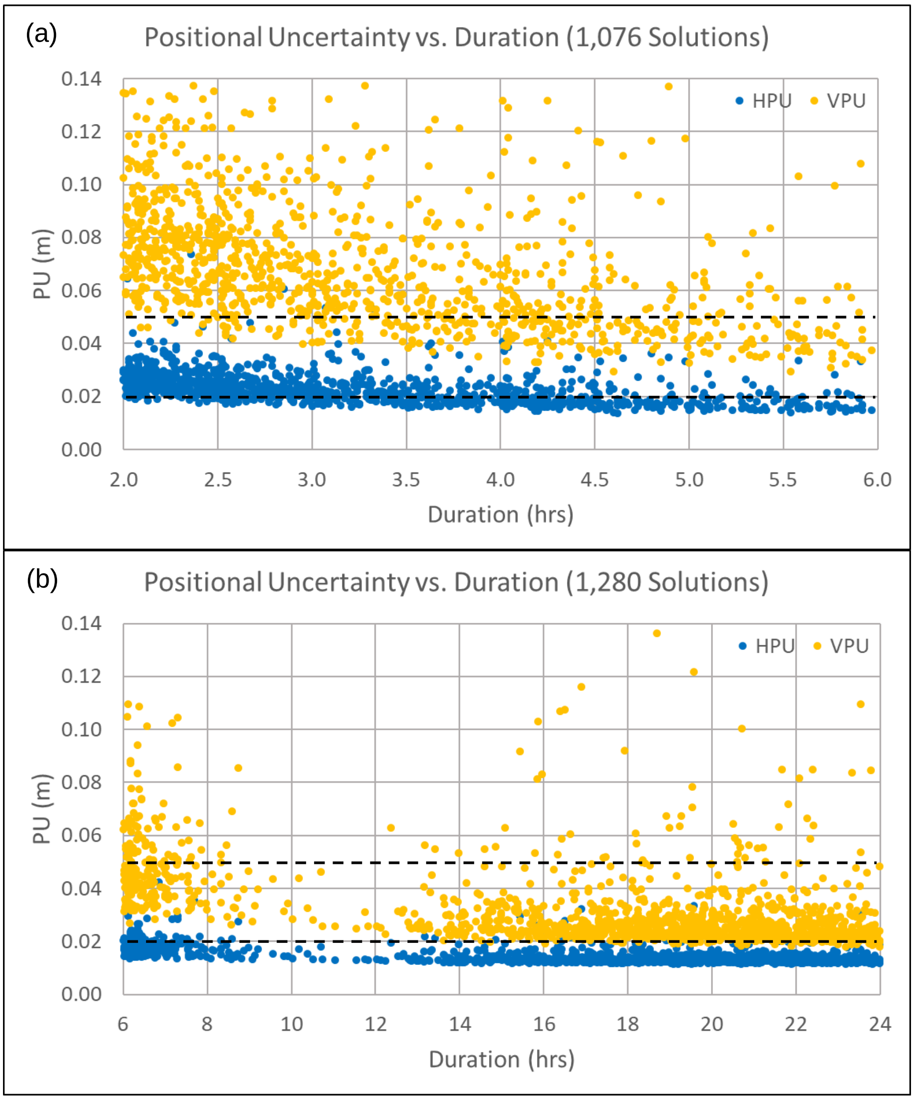

Figure 3: Positional Uncertainty (PU) vs. duration for (a) 2-6 hour data, and (b) 6-24 hour data.

Figure 4: Pushing the boundaries of reasonable sky view conditions in the field: TS486, SS4115, MM3634.

The cumulative distribution allows us to quantify the percentage of AUSPOS solutions meeting a particular PU threshold. Figure 5 visualises the cumulative distribution in regards to HPU and VPU for the 2-6 hour and 6-24 hour subsets. These graphs can be used as a simple 'look-up' tool to estimate the likelihood of achieving any specified HPU or VPU threshold with 2-6 hour and 6+ hour observation sessions.

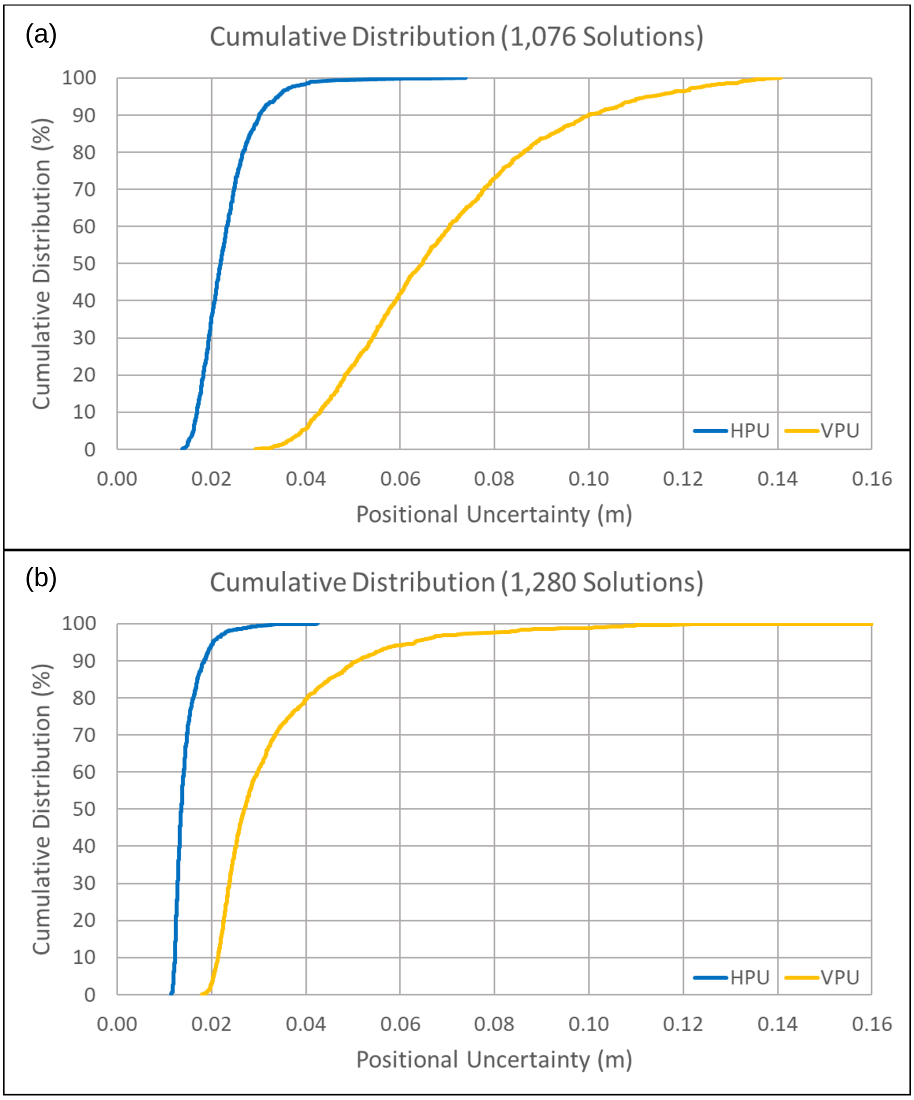

Figure 5: Cumulative distribution of PU for (a) the 2-6 hour data, and (b) 6-24 hour data.

Across the entire dataset, 70.6% of the AUSPOS solutions have HPU values of 0.02 m or better, i.e. these survey marks have an absolute horizontal accuracy slightly larger than the size of a 50c piece (radius of 16 mm) with respect to the national datum. This includes 38.6% of the 2-6 hour AUSPOS solutions and 95.2% of the 6-24 hour solutions with HPU values at this level. Similarly, 95.7% of all solutions have HPU values of 0.03 m or better, including 90.8% of the 2-6 hour solutions and 99.5% of the 6-24 hour solutions.

In regards to the vertical component (ellipsoidal height), 61.0% of the AUSPOS solutions have VPU values of 0.05 m or better across the entire dataset in absolute terms. This includes 23.3% of the 2-6 hour AUSPOS solutions and 89.7% of the 6-24 hour solutions with VPU values at this level. These results are impressive, remembering that the uncertainties are stated at the 95% confidence level. Again, as expected, it is evident that a longer observation span improves PU, particularly in regards to the vertical component. Similarly, 71.8% of all solutions have VPU values of 0.06 m or better, including 42.7% of the 2-6 hour solutions and 94.3% of the 6-24 hour solutions.

These results clearly show the important role of AUSPOS in propagating and strengthening the Survey Control Network in NSW. This investigation confirms and expands on earlier findings by Jia et al. (2014), illustrating why Geoscience Australia stipulates (and NSW supports) a minimum observation span of 6 hours for direct inclusion into the national GDA2020 adjustment via the NGCA. It also shows that shorter observation sessions are of sufficient quality to improve the State's survey infrastructure, justifying the approach taken by NSW Spatial Services to use AUSPOS as one of several suitable methods that can be used for this purpose (see section 2).

3.3 Repeatability

This section investigates the repeatability of AUSPOS solutions for independent reoccupations on the same mark. Where possible from the dataset discussed in section 3.2, independent pairs of sessions on the same mark were selected for three scenarios: two short sessions (2-6 hrs), one short (2-6 hrs) and one long session (6+ hrs), and two long sessions (6+ hrs). In each case, each session was only paired once. Since it is necessary to consider coordinate differences of opposite signs, the Root Mean Square (RMS) is deemed appropriate to quantify the average agreement in the vertical component.

Table 2 summarises descriptive statistics referring to the horizontal distance between the two AUSPOS solutions, as well as the difference in ellipsoidal height (shorter session minus longer session). Figure 6 visualises these results graphically. Again, it is evident that AUSPOS produces high-quality positioning results. While longer observation sessions improve the precision (repeatability) and reduce the risk of outliers (range), shorter sessions provide results suitable for improving state survey infrastructure. The median values indicate that no significant offsets caused by possible outliers are present.

It should be noted that the AUSPOS results are not compared to the marks' GDA2020 coordinates on public record in SCIMS because such an investigation of accuracy would only be possible for shorter sessions on established marks that are part of the NSW state adjustment. An independent appraisal of accuracy for shorter AUSPOS sessions may be undertaken at a later stage, once more SCIMS marks are included in the state adjustment.

Table 2: Descriptive statistics for reoccupied pairs (all values in metres).

Dataset	Statistic	Diff in Hz	Diff in EHGT
Short sessions: 145 pairs	**Min.**	0.001	-0.079
	Max.	0.083	0.119
	Range	0.082	0.199
	Median	0.010	0.000
	Mean	0.013	0.000
	STD	0.009	0.026
	RMS	0.016	0.026
Short-long sessions: 75 pairs	**Min.**	0.003	-0.044
	Max.	0.043	0.050
	Range	0.041	0.094
	Median	0.010	0.003
	Mean	0.011	0.000
	STD	0.008	0.021
	RMS	0.015	0.021
Long sessions: 94 pairs	**Min.**	0.001	-0.064
	Max.	0.029	0.072
	Range	0.028	0.137
	Median	0.006	-0.002
	Mean	0.008	-0.002
	STD	0.006	0.019
	RMS	0.010	0.019

In July/August 2019, TS3663 PANORAMA (located in Bathurst, close to NSW Spatial Services) was occupied 38(!) times, providing an opportunity to investigate the repeatability of AUSPOS solutions on this high-quality, concrete-pillared mark with excellent sky view (Figure 7). The longest observation session (48 hours) was assumed ground truth, with the AUSPOS results of the shorter sessions being compared against it (Figure 8). The average agreement is found to be 0.006 m ± 0.003 m (1 sigma) in the horizontal component, and the RMS in the vertical component (ellipsoidal height) is 0.010 m (1 sigma), showing that observation sessions of less than 6 hours in length have high reliability and repeatability. A bullseye plot of the difference in horizontal position from the 48-hour solution is shown in Figure 9, providing a spatial perspective and illustrating the high precision of these results.

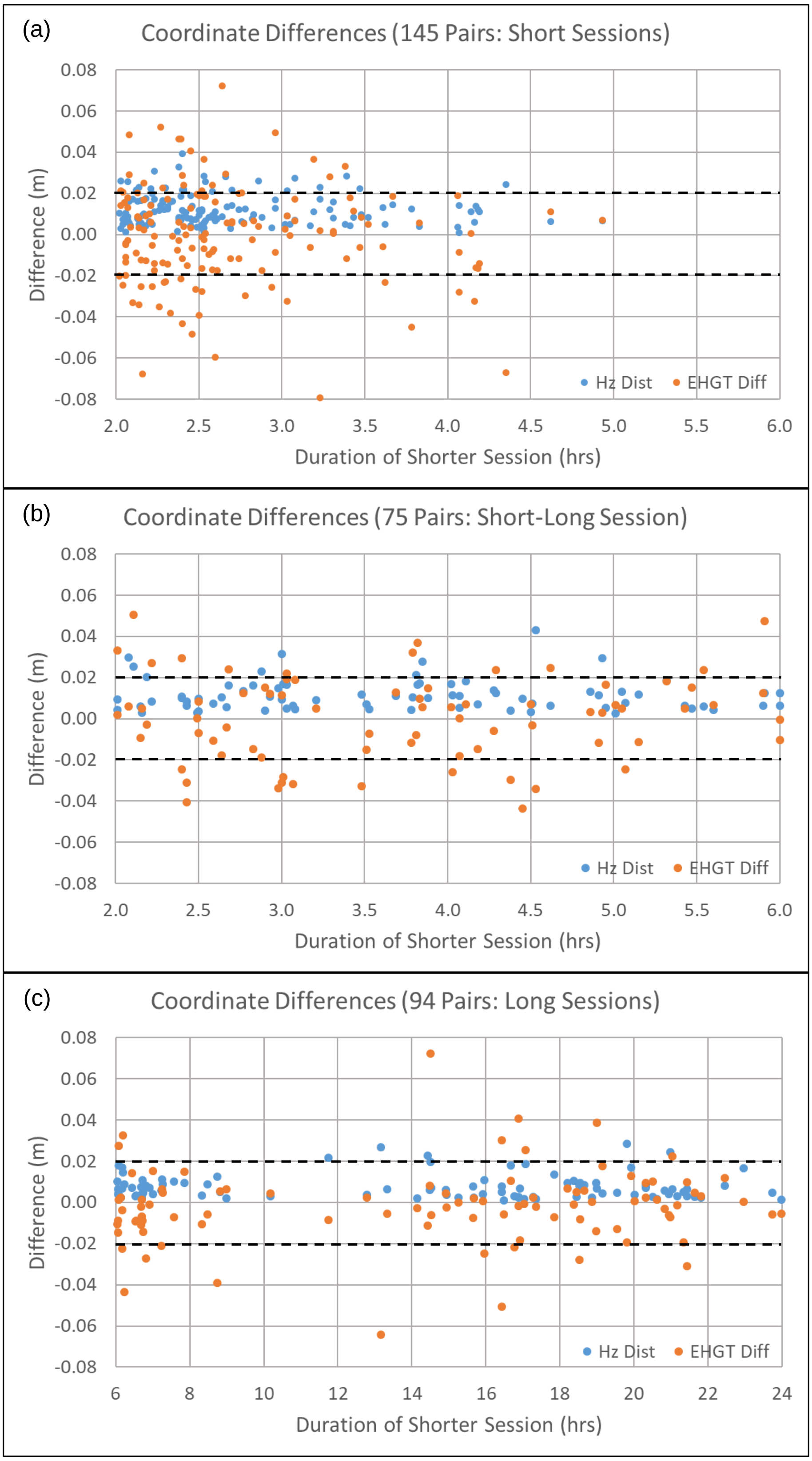

Figure 6: Difference in horizontal and vertical coordinates vs. duration for (a) 145 short-session pairs, (b) 75 short-long-session pairs, and (c) 94 long-session pairs.

Figure 7: TS3663 PANORAMA.

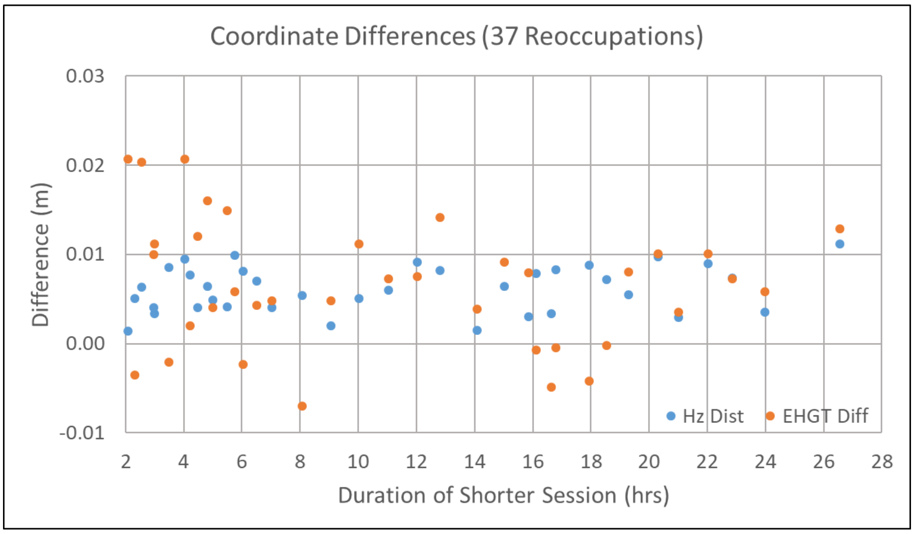

Figure 8: Difference in horizontal and vertical coordinates vs. duration for TS3663 PANORAMA.

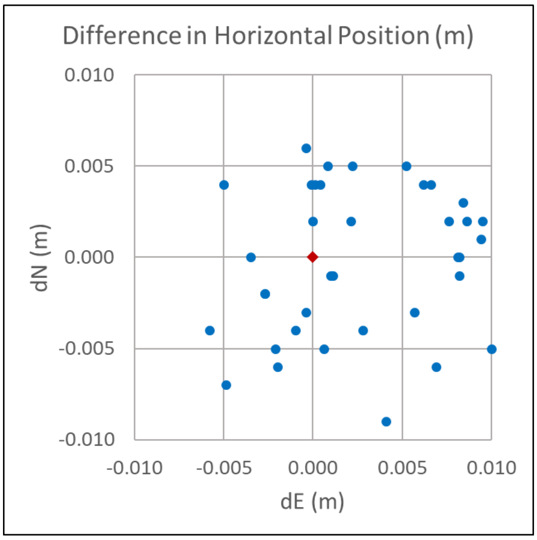

Figure 9: Difference in horizontal position from 48-hour solution for TS3663 PANORAMA (37 reoccupations).

Figure 10 depicts the AUSPOS-reported PU values corresponding to these AUSPOS solutions, again illustrating the benefit of longer observation sessions. The 'smoothness' of the PU curves also confirms that the PU values provided by AUSPOS are calculated (scaled) with significant influence and predictability of the observation session length.

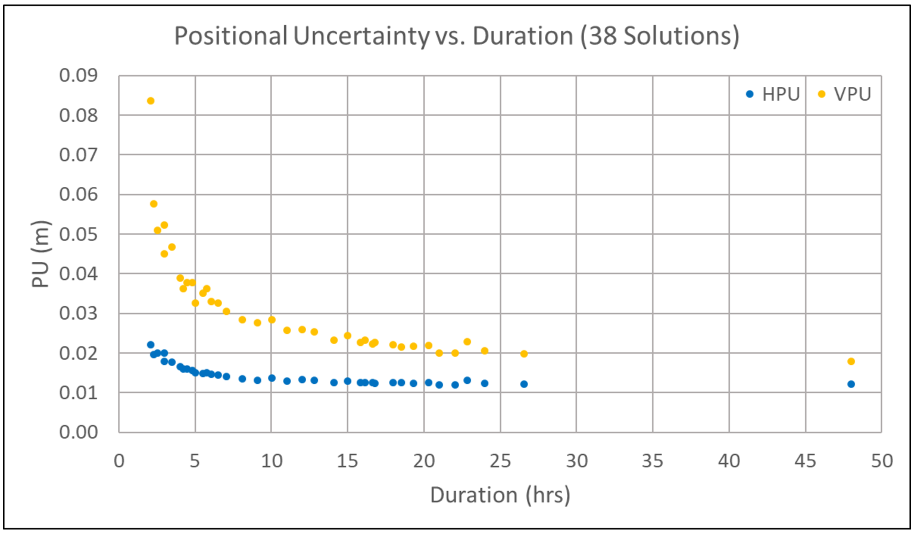

Figure 10: Positional Uncertainty (PU) vs. duration for TS3663 PANORAMA.

3.4 Connecting to AHD via AUSPOS

The quality of AUSPOS solutions with regards to providing a connection to AHD was investigated by comparing the AUSPOS-derived AHD height (using AUSGeoid2020) to levelled AHD heights of sufficient quality on public record in SCIMS.

The data investigated is a subset of the AUSPOS solutions analysed in section 3.2 and independent of the data used to produce the current version of AUSGeoid2020 (version 01/02/2018). This subset comprises marks that have AHD heights of class LC or better in SCIMS. To ensure full independence, observation sessions exceeding 6 hours duration are only considered for data collected after 1 February 2018, i.e. the date the current version of AUSGeoid2020 was computed. Again, since it is necessary to consider coordinate differences of opposite signs, the RMS is used to quantify the average agreement to AHD.

Table 3 summarises descriptive statistics referring to the difference between the AUSPOS-derived AHD height (using AUSGeoid2020) and the levelled AHD height on public record in SCIMS, as well as the derived AHD-PU provided by AUSPOS. These statistics are provided separately for the entire subset, the 2-6 hour data and the 6-24 hour data, respectively. Figure 11 visualises these results graphically.

It can be seen that the AUSPOS solutions are consistent across all marks and observation durations, delivering AHD heights with an RMS of about 0.040 m (1 sigma) or 0.078 m (95% confidence level) and a range of about 0.35 m (-0.20 m to +0.15 m). It is also evident that the derived AHD-PU reported by AUSPOS appears to be overly conservative for the data investigated, providing a mean AHD-PU of 0.182 m, which is more than double the RMS value for the difference to the levelled AHD height at the 95% confidence level (i.e. about 0.078 m). This can be explained by the conservative AUSGeoid2020 uncertainty grid values applied (the best-case official AUSGeoid2020 uncertainty in NSW is about 0.14 m at the 95% confidence level). The interested reader is referred to Brown et al. (2018), Janssen and Watson (2018) and

Featherstone et al. (2019) for more information and discussion on this topic. It is pleasing to see that AUSPOS provides a much better connection to AHD across NSW than reported.

Table 3: Descriptive statistics for AHD analysis, considering levelled marks only (all values in metres).

Dataset	Statistic	Diff to AHD	Derived AHD-PU
Entire subset: 810 solutions	**Min.**	-0.206	0.147
	Max.	0.148	0.251
	Range	0.354	0.104
	Median	-0.012	0.179
	Mean	-0.012	0.182
	STD	0.038	0.016
	RMS	0.040	0.183
2-6 hour data: 394 solutions	**Min.**	-0.201	0.160
	Max.	0.148	0.233
	Range	0.349	0.073
	Median	-0.011	0.180
	Mean	-0.013	0.183
	STD	0.036	0.012
	RMS	0.039	0.183
6-24 hour data: 383 solutions	**Min.**	-0.206	0.147
	Max.	0.104	0.251
	Range	0.310	0.104
	Median	-0.011	0.175
	Mean	-0.010	0.181
	STD	0.040	0.019
	RMS	0.041	0.182

4 CONCLUDING REMARKS

Spatial Services, on behalf of the NSW Surveyor General, has a legislative, regulative responsibility to maintain and extend the Survey Control Network in NSW. This paper has outlined how AUSPOS and CORSnet-NSW are used together to support datum modernisation and improve state survey infrastructure across NSW. Using more than 2,400 successful AUSPOS datasets, incorporating observation session lengths between 2 hours and 48 hours, the quality of AUSPOS solutions was investigated.

It was shown that AUSPOS routinely delivers Positional Uncertainty values at the 0.02-0.03 m level for the horizontal component and about 0.05-0.06 m for the vertical component. As expected, a longer observation span improves PU. Most of the improvement is gained by increasing the observation length from 2 hours to about 4-5 hours. Observation sessions exceeding 12 hours provide AUSPOS solutions of substantially higher quality in the vertical component. Results vary negligibly with location (latitude) within the bounds of NSW and have a high degree of predictability/repeatability at sites with good sky view. AUSPOS solutions at those sites with substantial tree cover achieve acceptable HPU and heights with a VPU of better than 0.1 m. It was also shown that the derived AHD-PU values reported by AUSPOS appear to be overly conservative for the data investigated, due to the conservative AUSGeoid2020 uncertainty grid values applied.

In order to enhance the understanding of AUSPOS as a tool for everyone to use, NSW Spatial Services encourages Geoscience Australia to document and release detailed information on how PU values reported by AUSPOS are calculated and scaled.

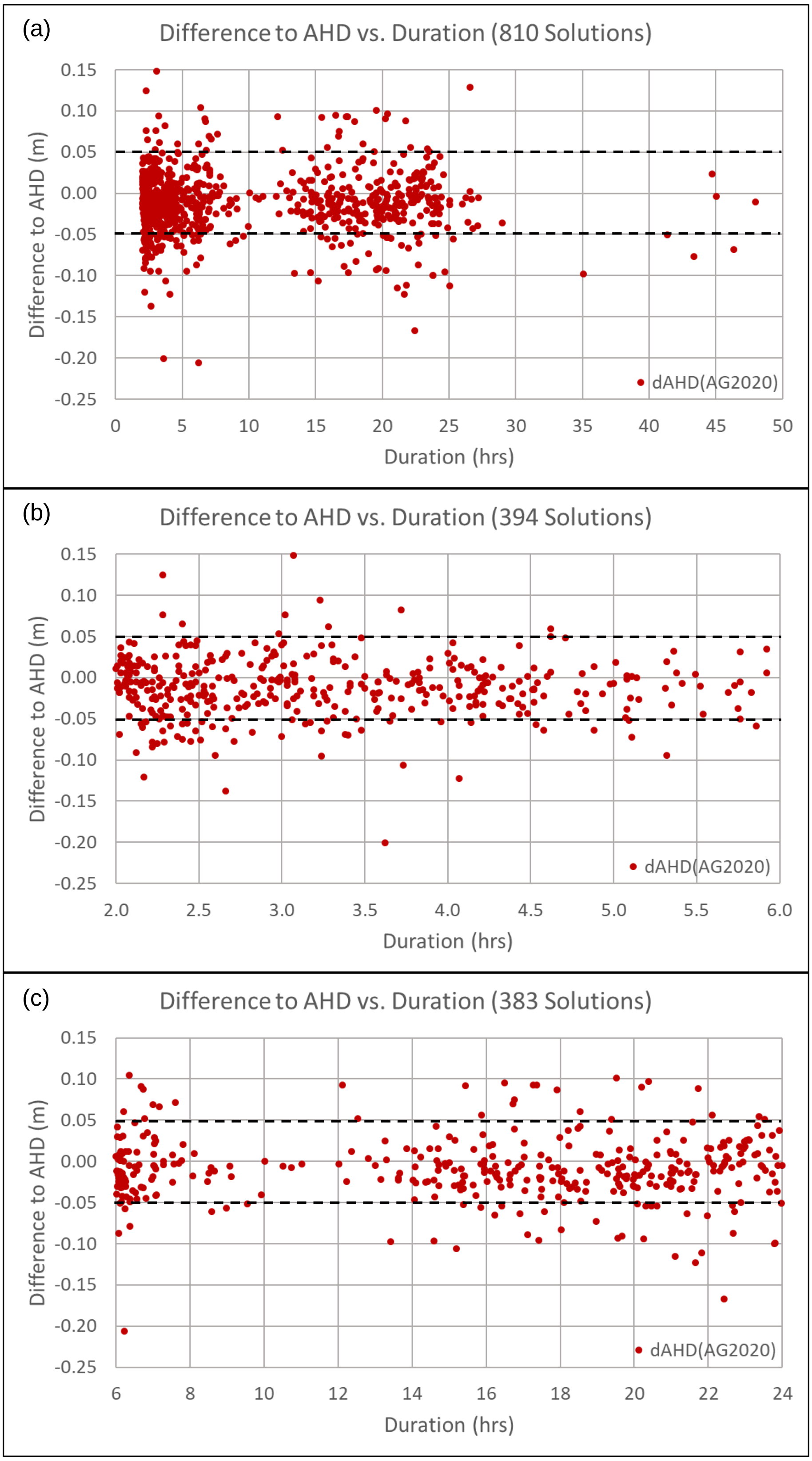

Figure 11: Agreement to levelled AHD vs. duration for (a) the entire subset, (b) 2-6 hour data, and (c) 6-24 hour data.

The results illustrate why Geoscience Australia stipulates, and NSW supports, a minimum observation span of 6 hours for direct inclusion into the national GDA2020 adjustment via the NGCA to propagate the Survey Control Network. They also show that shorter observation sessions are of sufficient quality to improve and strengthen the state survey infrastructure, provided sky view conditions are reasonable. This justifies the approach taken by NSW Spatial Services to use AUSPOS as one of several suitable methods to maintain and extend the State's Survey Control Network as well as the request for NSW users to submit data via our online collection tool to further the benefits for all.

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