AUSPOS performance in New South Wales

DR. VOLKER JANSSEN AND SIMON MCELROY

AUSPOS is Geoscience Australia's free online Global Positioning System (GPS) processing service. It has successfully processed more than 1 million jobs worldwide over the last ten years and was ranked highest in a global comparison of free online post-processing services.

This article quantifies AUSPOS performance across NSW, showing that it routinely delivers Positional Uncertainty (PU) at the 0.02-0.03m level for horizontal position and 0.05-0.06m for ellipsoidal height. These results show that AUSPOS is a very handy tool to have in your toolbox and another option to establish, propagate and strengthen the NSW Survey Control Network.

Using AUSPOS

Static, dual-frequency, carrier phase and code data of at least 1 hour duration (recommended minimum 2 hours, maximum 7 consecutive days) is observed, and then submitted to the online web service, usually in 30-second RINEX data format. The user's antenna type (IGS naming format) is selected from a drop-down menu, and the height of instrument (measured vertically to the Antenna Reference Point, ARP) is manually entered.

AUSPOS then employs International GNSS Service (IGS) station data and products to compute precise 3D coordinates, using GPS data only. GDA2020, GDA94, ITRF2014 coordinates and an Australian Height Datum (AHD) height are contained in a report (pdf) emailed to the user, generally after a few minutes.

The report also includes the computed coordinate 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.

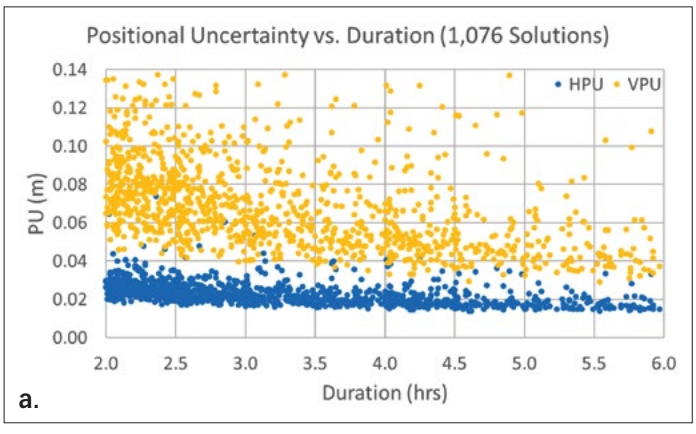
How AUSPOS processing works

The best available IGS products and services are used. Up to 15 surrounding IGS and Asia-Pacific Reference Frame (APREF) stations are selected as reference stations, generally the 7 closest IGS sites and the 8 closest APREF sites.

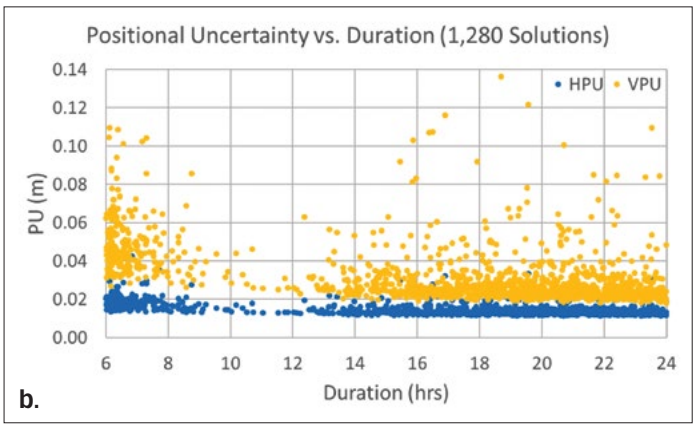
All CORSnet-NSW stations contribute to the AUSPOS service. Hence in NSW, this provides a relatively dense network for generating a reliable regional ionospheric delay model and tropospheric delay corrections to support ambiguity resolution. A precise solution is then computed using double-differencing techniques.

IGS station coordinates are constrained with uncertainties of 1mm for horizontal position and 2mm for ellipsoidal height. Lower-tier Continuously Operating Reference Station (CORS) coordinates are constrained with uncertainties of 3mm for horizontal position and 6mm for the vertical, due to the shorter CORS operation time span, lower data quality or lower-grade monumentation.

The GPS data is processed in ITRF2014 and then transformed to GDA2020 via the Australian Plate Motion Model. Derived AHD heights are computed by applying AUSGeoid2020 to the GDA2020 ellipsoidal heights. Legacy GDA94 coordinates are obtained from GDA2020 by transformation.



a.



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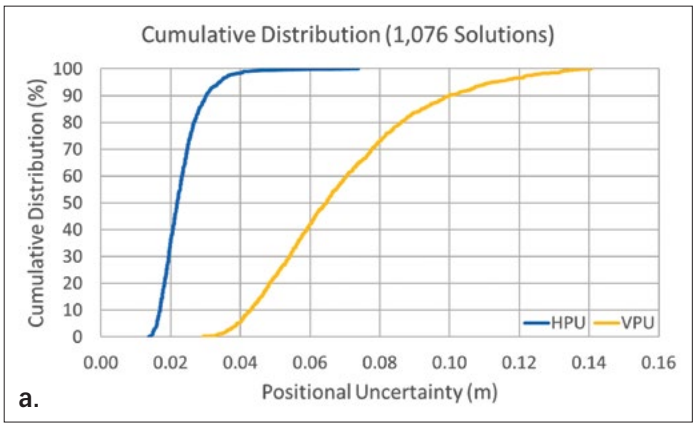


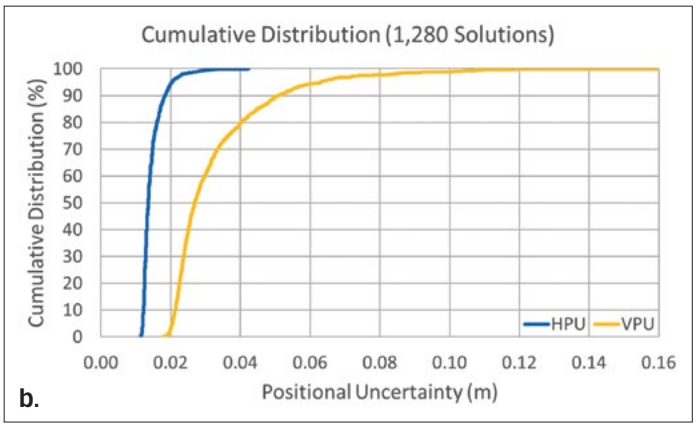


Figure 1 (bottom left): Positional Uncertainty (PU) vs. duration for (a) 2-6 hour data, and (b) 6-24 hour data.

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

Positional Uncertainty (PU) is calculated according to SP1 version 2.1. The coordinate uncertainties of East, North and ellipsoidal height are scaled using an empirically derived model, which is a function of duration, data quality and geographical location, and expressed at the 95% confidence level.

Evaluating AUSPOS performance in NSW

We used 2,618 GNSS datasets observed by Spatial Services, a unit of the NSW Department of Customer Service, over the last 5 years (November 2014 to August 2019).

Data was collected under typical conditions generally encountered in the field, with observation session lengths ranging from 2 to 48 hours. Each dataset was processed individually with AUSPOS version 2.3, using final IGS products.

Some AUSPOS solutions were 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, descriptive statistics were used to evaluate the uncertainties of the resulting GDA2020 coordinates.

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 datum. A description of the practical implementation of PU in NSW can be found in Position 103 (October 2019).

We performed three tests:

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 height to levelled AHD heights on public record and investigating the AHD-PU reported by AUSPOS.

The results of two further tests can be immediately summarised:

- Whilst AUSPOS PU values are known to be affected (scaled) by latitude, the variation is negligible for user results within 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.

PU of AUSPOS solutions

First, we investigated the AUSPOS-derived HPU and VPU values. Descriptive statistics (i.e. minimum, maximum, range, median, mean and standard deviation) were examined for the entire dataset of 2,464 successful AUSPOS solutions (2-48 hour duration).

To allow examination of the effect the observation session length has on the resulting uncertainties, we also investigated these descriptive statistics for the 2-6 hour and 6-24 hour subsets. **Figure 1** presents a graphical visualisation of the results, showing PU as a function of observation session length for the 2-6 hour and 6-24 hour datasets.

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, with minor but not insignificant improvement when it is increased to 24 hours and beyond.

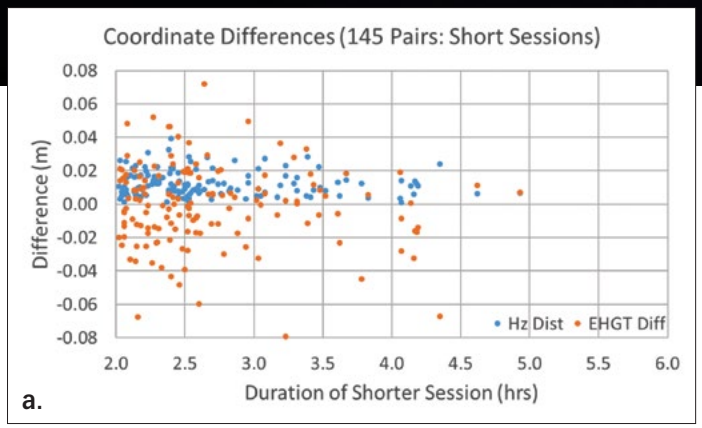
Observation sessions exceeding 12 hours provide AUSPOS solutions of substantially higher quality in the vertical component. An investigation of site photos and other metadata attributed the larger VPU values evident for several solutions greater than 15 hours duration to poor sky view conditions caused by substantial tree cover. In spite of these poor conditions, AUSPOS solutions generally achieve acceptable HPU and heights with a VPU of better than 0.1m.

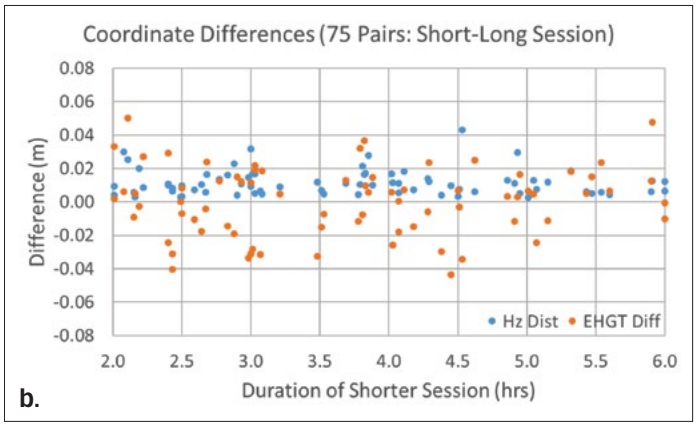
Cumulative distribution

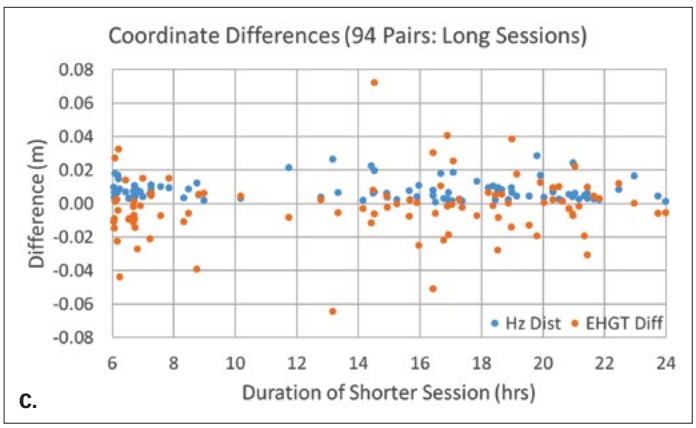
The cumulative distribution allows us to quantify the percentage of AUSPOS solutions meeting a particular PU threshold. **Figure 2** visualises the cumulative distribution in regards to HPU and VPU for the 2-6 hour and 6-24 hour datasets, indicating the relationship between uncertainty and reliability achievable with AUSPOS.

The reader can use these graphs as a simple 'look-up' tool to determine the likelihood of achieving any specified HPU or VPU threshold with 2-6 hour and 6+ hour observation sessions. ➤

Figure 3 (below): Difference in horizontal and vertical coordinates vs. duration for (a) short-session pairs, (b) short-long-session pairs, and (c) long-session pairs.







Across the entire dataset (2-48 hrs), 70.6% of AUSPOS solutions have HPU values of 0.02m or better, i.e. these solutions have an absolute reported horizontal accuracy slightly larger than the size of a 50c piece (radius of 16mm) 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.

Regarding ellipsoidal height, 61.0% of the AUSPOS solutions have VPU values of 0.05m or better across the entire dataset. 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. 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 are impressive, remembering that the uncertainties are stated at the 95% confidence level. As expected, a longer observation span improves PU, particularly in the vertical component.

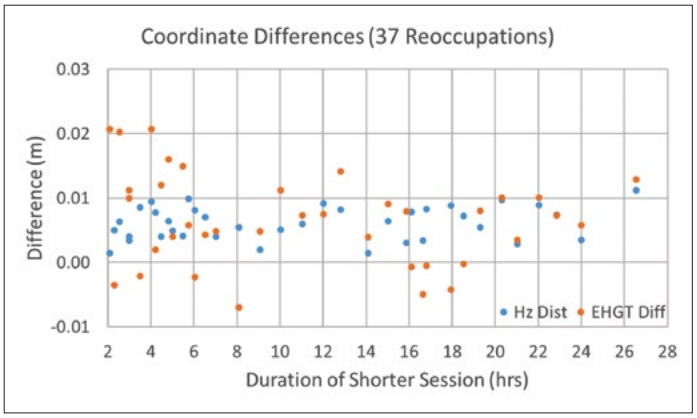
Repeatability

We investigated repeatability by comparing independent reoccupations on the same mark. Where possible, 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 scenario, each session was only paired once. Since it is necessary to consider coordinate differences of opposite signs, the Root Mean Square (RMS) is appropriate to quantify the average agreement in the vertical component.

Figure 3 visualises the results graphically, referring to the horizontal distance between the two AUSPOS solutions, as well as the difference in ellipsoidal height (shorter minus longer session).

Again, it is evident that AUSPOS produces high-quality positioning results with good repeatability. While longer observation sessions improve the precision (repeatability) and reduce the risk of outliers (range), shorter sessions provide suitable results. The median values indicate that no significant offsets caused by possible outliers are present.



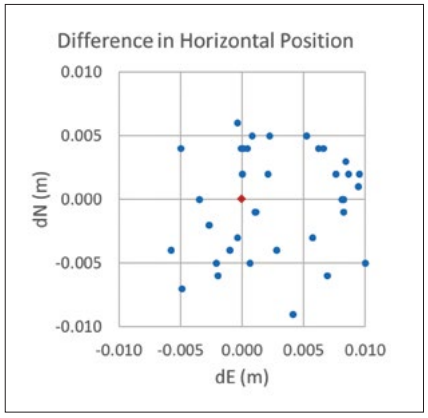


Figure 4 (top left): Difference in horizontal and vertical coordinates vs. duration for TS3663 Panorama (37 reoccupations).

Figure 5 (top right): Difference in horizontal position from 48-hour solution for TS3663 Panorama (37 reoccupations).

TS3663 Panorama

In July/August 2019, trigonometrical station 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.

The longest observation session (48 hours) was assumed ground truth, with the AUSPOS results of the shorter sessions being compared against it **(Figure 4)**. The average agreement is 0.006m ± 0.003m (1 sigma) in the horizontal component, and the RMS in ellipsoidal height is 0.010m (1 sigma).

This shows that observation sessions of less than 6 hours in length have high reliability and repeatability under good sky view conditions. A bullseye plot of the difference in horizontal position from the 48-hour solution is shown in **Figure 5**, providing a spatial perspective and illustrating the high precision of these results.

AHD Results

For a subset of marks, we compared the derived AHD height determined by AUSPOS (using AUSGeoid2020) to levelled AHD heights of sufficient quality (class LC or better) on public record, ensuring full independence from the data used to produce AUSGeoid2020.

Figure 6 visualises the results for the 2-6 hour and 6-24 hour data, referring to the difference between the AUSPOS-derived AHD height and the levelled AHD height on public record.

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).

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 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. It is pleasing to see that AUSPOS provides a much better connection to AHD across NSW than reported.

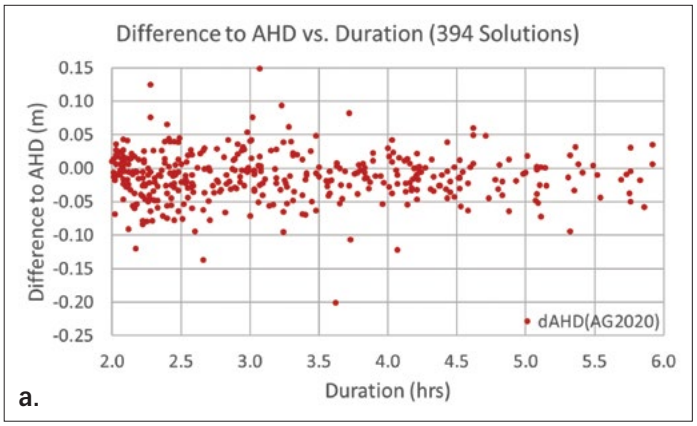
Conclusion

In NSW, AUSPOS routinely delivers PU values of 0.02-0.03m (horizontal) and 0.05-0.06m (vertical). PU is substantially improved by increasing the observation length from 2 hours to 4-5 hours. Observation sessions exceeding 12 hours provide much higher quality in ellipsoidal height.

AUSPOS results have a high degree of predictability/repeatability throughout the State at sites with good sky view, over at least the last 5 years. At sites with substantial tree cover, acceptable HPU and ellipsoidal heights with a VPU of better than 0.1 m can be achieved.

These results show that AUSPOS is a very handy tool to have in your toolbox and another alternative to establish, propagate and strengthen the NSW Survey Control Network.

Dr. Volker Janssen and Simon McElroy work at Spatial Services, a unit of the NSW Department of Customer Service. ■



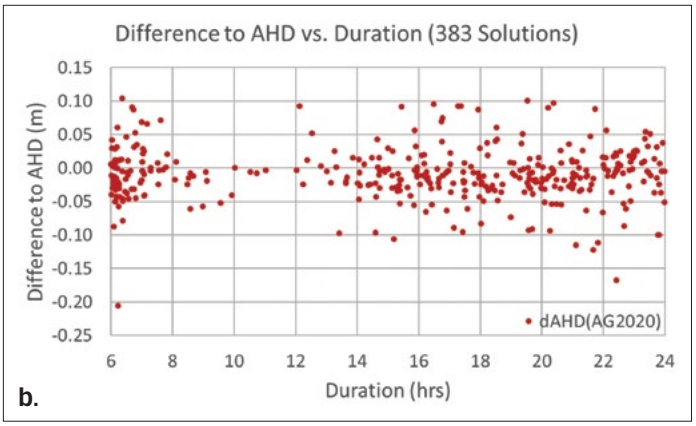


Figure 6 (below): Agreement to levelled AHD vs. duration for (a) 2-6 hour data, and (b) 6-24 hour data.