Practical AUSPOS tips and tricks

The CORS station at Port Kembla on the NSW south coast. *All images courtesy DCS Spatial Services unless specified.*

The powerful AUSPOS service is an essential element of Australian surveying — here's a guide on how to use it.

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AUSPOS is Geoscience Australia's free, cloud-based, online GPS processing service. Its local and worldwide usage continues to accelerate.

In a previous article, we looked under the bonnet of AUSPOS and explained how AUSPOS datasets are used to help maintain and improve the NSW survey control network.

This article provides a practical guide for novice and regular AUSPOS users, offering clarifications, reminders and tips related to common issues and challenges (including those pesky antennas!).

Preparing RINEX data

AUSPOS accepts static, dual-frequency GPS data of at least one hour duration (recommended minimum two hours) in Receiver Independent Exchange (RINEX) format. The thorough preparation of RINEX data files, whilst tedious, not only facilitates smooth AUSPOS processing but also enables efficient and unambiguous archiving of the data and associated metadata in one place.

The raw observation file in (binary) proprietary format collected by the GNSS receiver needs to be converted to RINEX and ideally should be decimated to a sampling rate of 30 seconds to decrease the file size. For data archival, or more importantly, data sharing or submission to third parties (especially where machine-to-machine processes are likely to be employed), the RINEX header should then be checked and edited.

Particular attention should be paid to marker name and number, receiver (not controller!) type and serial number, antenna type and serial number, and vertical antenna height to the Antenna Reference Point (ARP) (see Figure 1). Note that the

The importance of this metadata cannot be understated, particularly if multiple survey crews and/or a mix of equipment are involved.

RINEX header often contains incorrect or incomplete information when initially generated, e.g. the manufacturer's receiver and antenna names not following the International GNSS Service (IGS) naming convention, a default antenna type or a zero antenna height.

Each RINEX file must only contain a single occupation on a single mark. Raw binary data files are compact and should always be permanently archived — they can be re-RINEXed and edited again if required.

If the antenna height was not measured directly and vertically to the ARP in the field, then it must be converted to the vertical distance between the ground mark and the ARP using the offsets and method specified in the GNSS equipment manual or provided by the manufacturer.

The correctness of antenna height and antenna type is crucial to enable the correct antenna model to be applied correctly. An error in the antenna height will directly translate into an error in the resulting GNSS-derived ellipsoidal height and AHD height.

The antenna height should therefore be measured to the millimetre at the start and at the end of the observation session. A useful independent check is to always take a second measurement using imperial units (decimal inches) and convert to metres (multiply by 0.0254).

Using the incorrect antenna type for AUSPOS processing can cause the resulting height to be in error by several centimetres and introduce noise into the computed coordinates. The authoritative source for resolving antenna queries is provided by the frequently updated IGS files rcvr_ant.tab and antenna.gra (available at https://files.igs.org/pub/station/general/).

The file rcvr_ant.tab details the international naming conventions for GNSS receivers, antennas and radomes (antenna covers), which are also used by AUSPOS. Note that the RINEX format stipulates the antenna type as a 20-character name (columns 21-40 of line 9 in Figure 1) including several spaces and ending with a 4-character indication of the radome (NONE meaning that no radome is present).

The file antenna.gra provides graphs with physical dimensions of GNSS antennas, including the position of the ARP (generally the bottom of the antenna) and vertical offsets to other features.

As an aside, the file igs14.atx (and now igs20.atx) containing the IGS antenna models recommended for baseline processing, can be found at the same location. If still in doubt, users should contact their equipment provider for the required information.

If session length is critical to contractual arrangements and/or data acceptance by a third party, always extend it by a few minutes. Visually inspect the start and end of the observation section in the RINEX file (the data following the header), particularly to ensure that the first and last few epochs contain reasonably complete data blocks.

If epochs at the start/end of the observation are deleted, the time of the first/last observation in the RINEX header should be modified accordingly. Frequent dropouts of satellite signals in the RINEX file may also indicate poor sky view conditions.

Figure 2 shows a typical RINEX observation data block for the epoch 00:37:30 hours on 1 June 2021. Eighteen satellites were observed (eight GPS, six GLONASS and four Galileo) with six types of observations recorded for all but the Galileo satellites (the L2 frequency is not used by Galileo).

Line 13 in Figure 1 specifies the corresponding observation types in the RINEX header (L1, L2, C1, P2, S1, S2), i.e. carrier phase measurements, code measurements and signal strengths on the L1 and L2 frequency, respectively.

Submitting RINEX data

Up to 20 RINEX files can be submitted to AUSPOS simultaneously and processed as a cluster, provided their observation sessions contain an overlap of at least one hour. However, for simplicity, we will only discuss submission of a single RINEX file.

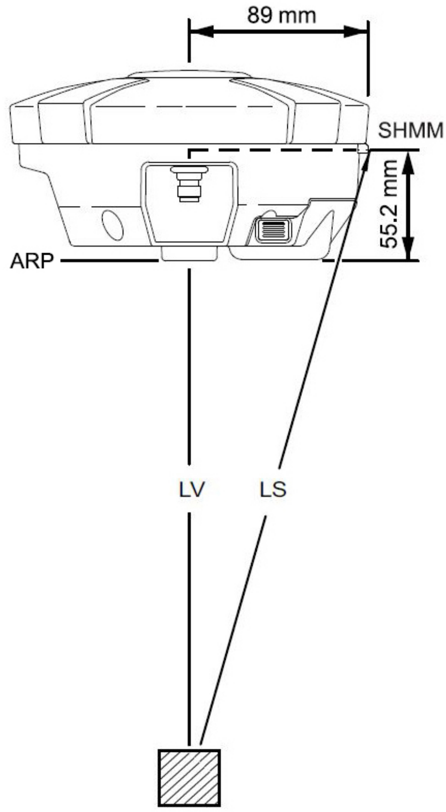
The timing of submission affects your results because AUSPOS uses the best available IGS orbit product for processing, having a choice of three (final, rapid

```
1       2.11           OBSERVATION DATA    M (MIXED)           RINEX VERSION / TYPE
2  teqc  2016Nov7                          20210617 05:02:57UTCPGM / RUN BY / DATE
3  Linux2.6.32-279.el6.x86_64|x86_64|gcc|Win64-MinGW64|=       COMMENT
4  BIT 2 OF LLI FLAGS DATA COLLECTED UNDER A/S CONDITION       COMMENT
5  48DE                                                        MARKER NAME
6  PM183662                                                    MARKER NUMBER
7  NSW                 NSW                                     OBSERVER / AGENCY
8  1516405             LEICA GS15          8.00/7.500          REC # / TYPE / VERS
9  1516405             LEIGS15.R2      NONE                    ANT # / TYPE
10  -4585969.9235  2736510.8223 -3477269.8581                  APPROX POSITION XYZ
11         1.5190        0.0000        0.0000                  ANTENNA: DELTA H/E/N
12      1     1                                                WAVELENGTH FACT L1/2
13      6    L1    L2    C1    P2    S1    S2                  # / TYPES OF OBSERV
14     30.0000                                                 INTERVAL
15 Source: 6405_0601_103528.m00                                COMMENT
16 Forced Modulo Decimation to 30 seconds                      COMMENT
17 DefaultJobName                                              COMMENT
18 DefaultUserDiscription                                      COMMENT
19 Project creator:                                            COMMENT
20  SNR is mapped to RINEX snr flag value [0-9]                COMMENT
21   L1 & L2: min(max(int(snr_dBHz/6), 0), 9)                  COMMENT
22   2021     6     1     0    37   30.0000000     GPS         TIME OF FIRST OBS
23     18                                                      LEAP SECONDS
24                                                             END OF HEADER
```

Figure 1: A typical RINEX v2.11 header.

```
25  21  6  1  0 37 30.0000000  0 18G01G03G04G10G21G22G31G32R02R03R04R13
26                                R18R19E05E09E11E36
27  110137934.272 8  85821775.74248  20958552.220    20958554.400          53.300
28         53.550
29  119766659.544 7  93324688.12247  22790840.660    22790843.240          45.200
30         45.100
31  124156873.931 7  96745619.03746  23626267.600    23626269.980          43.200
32         40.100
33  130281153.04615 101517801.02255  24791680.380    24791685.800          35.450
34         34.100
35  107660051.087 8  83890939.09847  20487029.500    20487028.240          51.400
36         45.600
37  109924937.177 8  85655784.12247  20918020.040    20918017.020          52.900
38         44.550
39  109426889.942 8  85267704.15548  20823245.920    20823244.660          53.300
40         53.250
41  122182552.628 7  95207188.87447  23250567.920    23250568.700          47.650
42         42.200
43  122656371.420 6  95399420.181 6  22985753.460    22985758.360          38.500
44         39.000
45  109283847.384 8  84998559.602 8  20415141.460    20415142.640          52.450
46         48.900
47  114565531.929 6  89106523.251 5  21394302.360    21394302.020          38.150
48         33.950
49  110306911.273 6  85794276.777 7  20656940.920    20656944.020          39.850
50         42.650
51  114943294.330 8  89400354.336 7  21532750.260    21532755.080          50.650
52         47.400
53  112735465.036 6  87683135.364 6  21074705.120    21074707.020          38.950
54         41.550
55  129830473.839 8                  24705917.480                          48.750
56
57  117250086.174 9                  22311949.220                          54.400
58
59  133045175.973 7                  25317654.460                          42.450
60
61  128710168.325 8                  24492734.840                          52.900
62
63  21  6  1  0 38  0.0000000  0 20G01G03G04G10G21G22G31G32R02R03R04R12
64                                R13R14R18R19E05E09E11E36
```

Figure 2: A typical RINEX v2.11 observation block.



$$LV\ (m) = \sqrt{LS^2 - 0.089^2} - 0.055$$

Figure 3: Determining the vertical antenna height to the ARP from a SHMM measurement to the housing of the antenna (adapted from TPS Hiper II Operator's Manual).

and ultra-rapid). The final orbit product is available approximately two to three weeks after the observation day, with the weekly product generally being available to AUSPOS on Monday morning.

The rapid orbit product is available two days after the observation. If both are unavailable, the much-less-accurate ultra-rapid orbit product is used. Consequently, it is recommended to submit data to AUSPOS at least two days after the observation to get the benefit of the IGS rapid orbits.

At DCS Spatial Services, a unit of the NSW Department of Customer Service (DCS), we almost exclusively use final orbits (the best available product) for AUSPOS processing. However, AUSPOS solutions using rapid orbits are typically very close to final-orbit solution quality and therefore more suited to industry due to their much faster availability.

After selecting the RINEX file for upload, the user manually inputs the antenna height (to the ARP) and selects the antenna type (IGS naming convention) from the drop-down menu. Alternatively, clicking the 'scan' button interrogates the RINEX file header for the required information — this option should only be used if you are certain that the RINEX header is correct.

Finally, the user provides their email address and submits the data. A status message then appears indicating successful submission and stating the job number, which will be quoted in the automated email messages that follow.

The first email is sent to the user when AUSPOS starts data processing, generally within a few minutes but depending on current workload. This also includes a list of reminders to ensure successful processing (identical to the submission checklist on the AUSPOS website).

If AUSPOS encounters problems during processing, a further automated email is sent providing some indication of the issue in the subject. These errors are generally caused by RINEX format issues (e.g. RINEX header information not in the correct columns or multiple observation sessions present in a single file) or bad data quality (e.g. short observation session at a site severely affected by tree cover).

Interpreting the results

Following processing, an automated AUSPOS report (PDF) is emailed to the user. The results should be checked to ensure that the solution is reliable:

Section 1 (User Data): Check antenna type and antenna height (measured vertically to the ARP) are correct.

Section 2 (Processing Summary): Check the number of reference stations is appropriate (close to 15 CORS). Check there is a good mix of distant and local CORS (about 7 and 8). Check IGS final or rapid orbits are used.

Section 3.4 (Positional Uncertainty): Check the PU values of the GDA2020 coordinates and derived AHD height are reasonable. DCS Spatial Services aims for horizontal PU < 0.02 m and vertical (ellipsoidal) PU < 0.05 m under good sky view conditions and routinely obtains a reported AHD-PU < 0.19 m. Check the report is void of any warning messages (e.g. large uncertainty).

Section 6 (Ambiguity Resolution): Check the ambiguity resolution statistics are reasonable (at least 50% of ambiguities resolved per baseline, particularly those to your rover). DCS Spatial Services routinely encounters values above 70% in its work.

If warning messages occur, the problem needs to be assessed by investigating the magnitude of PU values, session length, sky view conditions and data quality. In most cases, warnings are due to short or 'dirty' sessions at sites affected by tree cover or other obstructions, resulting in poor sky view conditions and bad data quality (including low or failed ambiguity resolution).

Remember that AUSPOS is GPS-only, so the solution does not use as many satellites as you may be accustomed to. Repeating the observation with a longer session length generally provides a better result without any warning messages (e.g. increasing duration from two hours to about four to five hours).

Height hook measurement

The height hook allows a vertical measurement from the ground mark to a point below the tripod. A vertical offset is then added to obtain the antenna height to the ARP. However, this offset depends on the equipment used, i.e. the type of tribrach and antenna carrier.

For standard equipment, the offset can be obtained from the equipment manual and the manufacturer. This offset may then be automatically applied in the rover for real-time applications or the GNSS baseline processing software for post-processing applications.

However, AUSPOS does not apply such offsets because this is simply not workable for the vast number of GNSS antenna makes and models supported. Following the international standard, AUSPOS expects input of the antenna height vertically measured between the ground mark and the ARP because all antenna phase centre variation models (applied during processing) refer to the ARP.

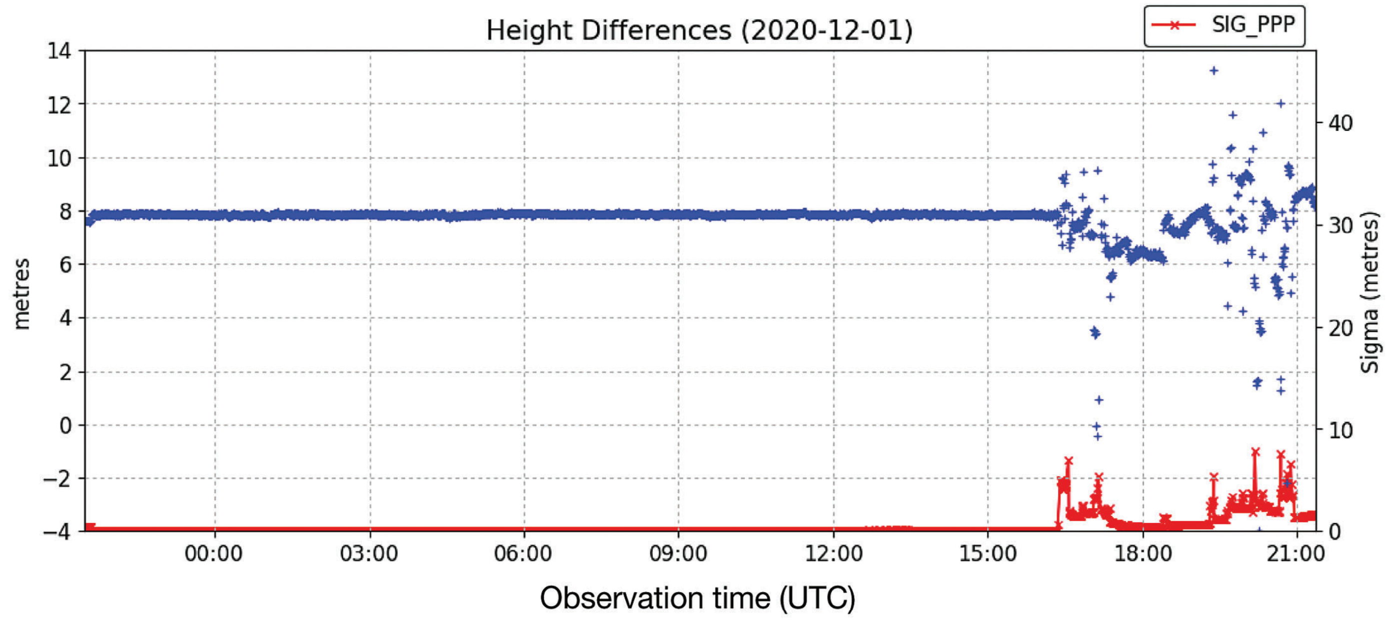


Figure 4: Kinematic CSRS-PPP output identifying disturbance at around 16:15 UTC, showing height differences in blue and their standard deviations in red.

Slant height measurement

Some instruments include a Slant Height Measurement Mark (SHMM), located on the housing of the antenna or at the tip of a horizontal bar attached to the bottom of the antenna. Others utilise a distinct marking on the antenna housing (sometimes known as the bumper) as a reference for the slant height measurement. The GNSS equipment manual should include a diagram with the relevant dimensions and instructions on the required calculations, including the applicable offsets.

Generally, Pythagoras is applied in conjunction with a vertical offset to convert the slant measurement to the vertical height between ground mark and ARP (see Figure 3). For typical instrument heights between 1.400 m and 2.000 m, ignoring Pythagoras and applying only the vertical offset can introduce an error of several millimetres (antenna height is too large), depending on the radius of the antenna.

While this may be acceptable for cadastral purposes, it certainly is not for control surveys and geodetic purposes because this error will translate directly into the resulting GNSS-derived height. The validity of any approximation needs to be assessed on a case-by-case basis and should be clearly stated on the GNSS log sheet because it may not be suitable when the data is later used for other purposes or submitted to third parties.

Furthermore, some antennas may be used in conjunction with a quick release adapter. The antenna height is then sometimes measured vertically from the ground mark to the bottom of the quick release, only necessitating a vertical offset for reduction to the ARP.

This illustrates the importance of clearly stating what type of measurement was taken (vertical or slant) to where and how this was then reduced to the ARP. The importance of this metadata cannot be understated, particularly if multiple survey crews and/or a mix of equipment are involved.

Thankfully, the required information can easily and effectively be provided by adapting the generic DCS Spatial Services GNSS log sheet (see resource pack for Surveyor-General's Direction No. 12) for a specific receiver-antenna combination with a particular antenna height measuring process.

Observation data recovery

Sometimes the instrument is disturbed during the observation session, e.g. by people, livestock or storm events bumping the tripod, pushing it over or removing it altogether. For longer sessions, useful data may still be salvaged if it can be determined when the unfortunate intervention occurred.

Processing the data in kinematic mode (epoch by epoch) using the Precise Point Positioning (PPP) technique is very useful in identifying when the disturbance occurred. One option is the CSRS-PPP online positioning service provided by Natural Resources Canada, which requires registration but is free.

It works similarly to AUSPOS but can process data in both static and kinematic mode, delivering ITRF2014 positions and graphs that can be used to identify the time of intervention. For example, Figure 4 shows the kinematic CSRS-PPP output for the ellipsoidal height differences of a 24-hour session where the tripod was intentionally placed on the ground by a good Samaritan at around 16:15 UTC. The latitude and longitude differences produce very similar plots.

Inspecting the observation data blocks of the RINEX file corresponding to this time clearly identified the epoch of intervention through the loss of satellite signals, resulting in almost 19 hours of usable data being retained. Using a variety of software, the offending epochs can then simply be edited out.

Conclusion

Using AUSPOS campaigns has developed into a capable and reliable alternative or addition to conducting traditional static GNSS baseline surveys in some situations, particularly in NSW with all CORSnet-NSW stations contributing to the AUSPOS service.

This article has provided some practical tips and tricks for AUSPOS users. In addition, the AUSPOS website contains background information, a submission checklist, a step-by-step submission guide and frequently asked questions.

Hopefully, this contribution has shown how easy it is to use AUSPOS and will encourage the profession to contribute industry-observed AUSPOS datasets to further improve the NSW survey control network for the benefit of all. ■

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