Updates to CSRS-PPP Antenna Handling

Beginning with CSRS-PPP v5, the Galileo constellation will be supported for data collected beginning Sunday, 27 November 2022 when processed with either the Rapid or Final products. Submissions processed with the Ultra-rapid products will continue to support only GPS and GLONASS observations. Since some Galileo datasets are collected with antennas lacking Galileo Phase Centre Offset (PCO) calibrations, a new processing strategy, as well as some minor changes to the output reports, has been implemented.

Background

GNSS estimated positions are not referenced to a physical point on the antenna but instead to the electrical phase centre. The location of this Antenna Phase Centre (APC) is different for each type of antenna and varies by signal frequency. To account for the offset between the physical Antenna Reference Point (ARP), and the mean APC, CSRS-PPP adopts the absolute antenna calibrations provided by either the International GNSS service (IGS) or the U.S. National Geodetic Survey (NGS), where existing. These antenna calibrations include the PCO values for each constellation and frequency which were calibrated, as well as the Phase Centre Variations (PCVs), as a function of elevation and azimuth. Figure 1 shows the ARP and approximate PCO for a typical geodetic antenna.



Figure 1: Image of a typical geodetic antenna showing the location of the Survey Marker, ARP, and approximate PCO

To get the calibration information for a specific antenna, CSRS-PPP extracts the antenna and dome types from the RINEX observation header. Therefore the antenna and dome types need to be encoded correctly following the RINEX standard and the <u>IGS antenna naming convention</u>. For details on GNSS antenna calibrations, or to see if your antenna type has a calibration value, you can visit the <u>NGS antenna calibration website</u>. Figure 2 shows an example of a RINEX header with the antenna type "AOAD/M_T" and dome type "NONE" which is encoded in the RINEX header "ANT # / TYPE" line in columns 21-40. When including the antenna dome type it must be right-justified (i.e., in columns 37-40), and when no dome type is provided CSRS-PPP will apply a dome type of "NONE". For additional information, please find detailed descriptions of the various RINEX formats at the <u>IGS formats and standards</u> website.

2.11 OBSERVATION DATA M (MIXED) RINEX VERSION / TYPE teqc 2018Mar15 20250423 16:10:14UTCPGM / RUN BY / DATE Linux 2.6.32-573.12.1.x86 64|x86 64|gcc|Linux 64|=+ COMMENT CGSRTCMCL 1.2.25 NRCan 20250422 00:17:14UTCCOMMENT FILE MERGE 20250423 001636 UTC COMMENT gfzrnx-1.11-7352 -1659602.2400 -3676726.9600 4925493.4600 APPROX POSITION XYZ GPS - L1 Phase aligned to CA and L2 aligned to P2 COMMENT GLONASS- L1 Phase aligned to C1 and L2 aligned to P2 COMMENT 18 LEAP SECONDS 1 WAVELENGTH FACT L1/2 1 02784 JAVAD TRE 3N DELTA 3.7.5pl Jan,23,2019 REC # / TYPE / VERS PRDS CACS-GSD 756047 Calgary AB Canada MARKER NAME 0.0000 0.1000 0.0000 ANTENNA: DELTA H/E/N 40124M001 MARKER NUMBER OBSERVER / AGENCY ACSOPS NRCan KW-9493-01 AOAD/M T NONE ANT # / TYPE C2 L1 L2 # / TYPES OF OBSERV 8 C1 P1 P2 **S**1 S2 30.0000 INTERVAL tegc edited: GLONASS # 25 & 26 excluded COMMENT tegc edited: all SBAS satellites excluded COMMENT 2025 4 22 0 0 0.0000000 GPS TIME OF FIRST OBS END OF HEADER

Figure 2: Example RINEX header for antenna type AOAD/M_T with dome type NONE

Antenna handling examples

When CSRS-PPP reads the antenna/dome type from the RINEX header and tries to apply the corresponding PCO/PCV calibrations, there are various situations which may occur. For example, there may be PCO/PCV calibrations for all constellations, some constellations, or no constellations. In all cases, CSRS-PPP will specify the reference PCO(s) used on page one of the PDF report in the antenna section under "APC to ARP". Figure 3 shows an example for the "AOAD/M_T NONE" antenna/dome combination which includes calibration information for GPS and GLONASS. When constellations are processed without PCO/PCV calibrations, such as the example in Figure 3 which included Galileo

observations, the following note will be included on page one of the PDF report: "^For signals without PCO calibrations, CSRS-PPP applies and/or estimates the PCOs relative to the REF PCO".

Antenna Model	APC to ARP	ARP to Marker					
AOAD/M_T NONE	REF PCO ^A : GPS GLONASS	H:0.100m / E:0.000m / N:0.000m					
(APC = antenna phase center; ARP = antenna reference point; REF PCO = reference phase center offset)							
^For signals without PCO calibrations, CSRS-PPP applies and/or estimates the PCOs relative to the REF PCO							

Figure 3: Extract from page one of a sample CSRS-PPP PDF report showing the antenna information

To help understand which PCO/PCV calibrations were available, applied, and/or estimated, the following describes, with examples, the hierarchy employed within CSRS-PPP to deal with no or incomplete calibration information.

Case 1: Antenna calibration information available and complete

Calibration values are found for the provided antenna/dome type and include all constellations processed. In this scenario, calibrated PCO/PCV values are applied for all signals, and no warnings are returned.

Example: The RINEX header antenna/dome type is specified to be "AOAD/M_T NONE" and only GPS and/or GLONASS observations are submitted so all signals have PCO/PCV calibrations applied during processing.

Case 2: Antenna calibration information available for antenna with dome type NONE

Calibration values are NOT found for the provided antenna/dome type, but they are found for the provided antenna type with dome type NONE and include all constellations. In this scenario, calibrated PCO/PCV values using dome type NONE are applied for all signals and a warning is included in both the return email and the errors.txt report.

Example: The RINEX header antenna/dome type is specified to be "AOAD/M_T SCIS" and only GPS and/or GLONASS observations were submitted. Since this antenna/dome combination does not have calibrated PCO/PCV values, CSRS-PPP will apply the "AOAD/M_T NONE" values to all signals during processing.

Case 3: Antenna calibration information available but incomplete

Calibration values are found for the provided antenna/dome type but do not include all constellations. An example of this would be an observation file for the antenna type "AOAD/M_T NONE" which includes Galileo observations since this antenna/dome type does not have Galileo calibrations. In this scenario, Table 1 shows how the PCO is handled for each observed constellation. Warning messages are included in both the return email and the errors.txt report. Note that estimated PCOs are always with respect to the reference PCOs.

Observation	Reference PCO	Estimated PCO	Applied PCO	Warning
constellations				messages
GPS/GLO/GAL	GPS and GLO	GAL	N/A	121
GPS/GAL	GPS	GAL	N/A	121
GLO/GAL	GLO	GAL	N/A	121
GAL	GPS	N/A	GPS	124

Table 1: PCO/PCV handling for a calibrated antenna/dome type without Galileo calibrations

Case 4: No antenna calibration information available

Either no antenna/dome type is provided in the RINEX header, or no calibration values can be found for the provided type. In this scenario, the reference PCO would be NULL, meaning no PCO/PCV are applied during processing for the first constellation in the observation file, and if any additional constellations are provided their PCOs will be estimated relative to the reference NULL PCO. Table 2 shows how the PCOs are handled for each observed constellation in this case. Warning messages are included in both the return email and the errors.txt report.

Observation constellations	Reference PCO	Estimated PCO	Estimated PCO	Warning messages
			relative to	
GPS/GLO/GAL	NULL	GLO/GAL	GPS	113, 120,
				121
GPS/GLO	NULL	GLO	GPS	113, 120
GPS/GAL	NULL	GAL	GPS	113, 121
GLO/GAL	NULL	GAL	GLO	113, 121
GPS	NULL	N/A	N/A	113
GLO	NULL	N/A	N/A	113
GAL	NULL	N/A	N/A	113

Table 2: PCO handling when no calibration values are available

Antenna related warning messages

As noted in examples 2 - 4 above, when CSRS-PPP is not able to apply PCO/PCV calibrations during processing, warnings are provided in the return email and in the errors.txt report. Here are the possible antenna related warning messages.

Warning 113 - No (NULL) APC to ARP was applied. This may be due to a missing or invalid antenna record in your RINEX file or the absence of phase centre information in the IGS/NGS ANTEX file for your antenna. Ensure that both the antenna type and the RINEX header record "ANT # / TYPE " are valid. Estimated height should be used with caution.

Warning 120 - No Phase Centre Offset (PCO) calibrations could be found for GLONASS signals, CSRS-PPP estimated GLONASS PCOs relative to [*SATSYS*] PCOs.

Warning 121 - No Phase Centre Offset (PCO) calibrations could be found for Galileo signals, CSRS-PPP estimated Galileo PCOs relative to [*SATSYS*] PCOs.

Warning 123 - No Phase Centre Offset (PCO) calibrations could be found for GLONASS signals, CSRS-PPP applied [*SATSYS*] PCOs.

Warning 124 - No Phase Centre Offset (PCO) calibrations could be found for Galileo signals, CSRS-PPP applied [*SATSYS*] PCOs.

Warning 125 - No calibrations were found for the combined antenna/dome type provided. CSRS-PPP applied the calibration values for your antenna with dome type NONE. Estimated height should be used with caution.

Note: In warnings 120 to 121, and 123 - 124, [*SATSYS*] is replaced by the applicable satellite system, i.e., GPS, GLONASS, or Galileo.

Additional antenna information

In addition to providing the antenna/dome type, it is recommended that CSRS-PPP users also provide the following information in the RINEX header when applicable.

ANTENNA: DELTA H/E/N – The antenna height, noted as the ARP to Survey Marker offset in Figure 1, as well as any small antenna East/North eccentricities should be provided in the RINEX header.

ANTENNA: ZERODIR AZI – Beginning with RINEX v3, an optional zero-direction angle can be included for fixed antennas which are not oriented towards the north (standard zero-direction in CSRS-PPP). This value is reported as the azimuth of the antenna zero-direction in degrees.

Supplementary Information

U.S. National Geodetic Survey (NGS)

 Antenna calibrations: <u>https://geodesy.noaa.gov/ANTCAL/</u>

International GNSS Service (IGS)

- The Antenna Exchange (ANTEX) Format, Version 1.4: https://files.igs.org/pub/data/format/antex14.txt
- Antenna calibrations: <u>https://files.igs.org/pub/station/general/igs20.atx</u>
- RINEX standards: <u>https://igs.org/formats-and-standards</u>