How to Properly Apply Antenna Information and Datum Transformations in order to use a Mix of CORS and IGS Stations within a Single Project

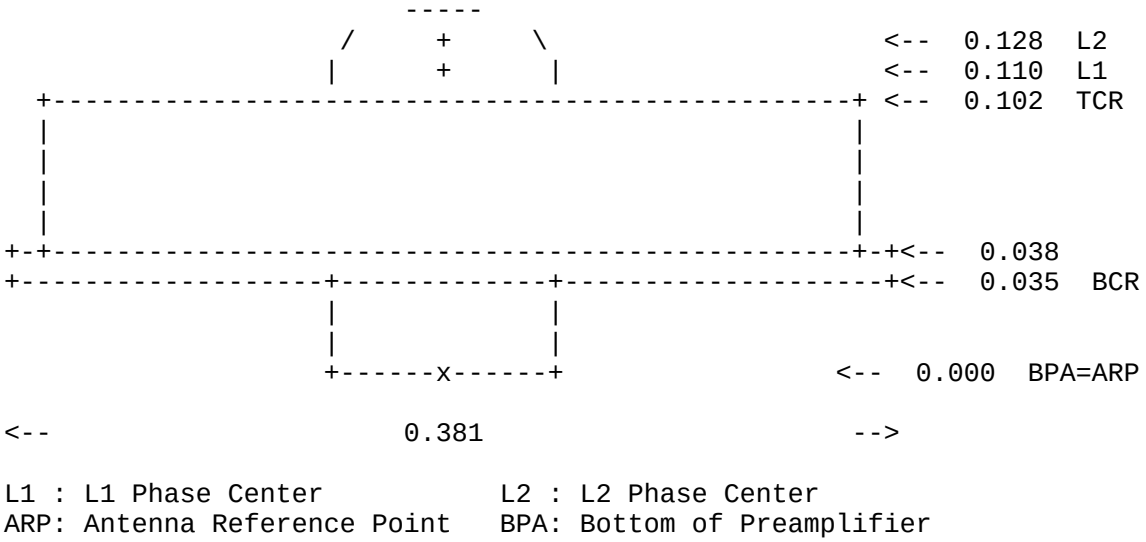
Waypoint Consulting
September 2005

The CORS (Continuously Operating Reference Station) and IGS (International GPS Service) networks consist of hundreds of GPS stations for which RINEX data are freely available for download over the internet. These stations have precisely established coordinates which are published on their respective websites (http://www.ngs.noaa.gov/CORS/ and http://sopac.ucsd.edu/).

Confusion often arises due to how both sites publish their coordinates. The coordinates of CORS sites are usually published both in the ITRF 2000 (epoch 1997.0) and NAD83 (epoch 2002.0) datums. Both phase center and ARP (antenna reference point) coordinates are given. For some sites, the monument position is also given. The coordinates of IGS sites are currently published in ITRF 2000 (XYZ) and WGS84 (decimal degrees) at epoch 2005.0014 and are referenced to the monument position.

Given a project area in the continental USA, it is not uncommon to have several CORS and IGS stations nearby. Many IGS stations within the USA are also available for download on the CORS network; however this is not always the case. The purpose of this report is to show how users can properly take published coordinates from both CORS and IGS stations and utilize them within one project.

Shown below is a typical antenna diagram which distinguishes phase center and antenna reference point locations of an antenna. This profile was taken from ftp://igscb.jpl.nasa.gov/igscb/station/general/antenna.gra, the official IGS antenna dimension webpage.



GPS measurements are always made directly to the phase center(s) of the antenna. The antenna profile both relates these measurements down to the ARP as well as providing elevation based corrections. The antenna height then relates the measurements from the ARP to the ground location. All commonly known antenna profiles are available within GrafNav/Net, and users have the ability to create their own profiles.

It can therefore be deduced what information must be entered for a CORS or IGS station given either monument, ARP or phase center coordinates. If using monument positions then both the antenna height and antenna profile should be selected within GrafNav/Net. This will have the effect of properly relaying the measurements at the phase center(s) of the antenna to the ARP and then down to the monument position.

If ARP coordinates are used, a zero antenna height must be entered as well as the correct antenna profile. This will relate the GPS measurements down from the phase center(s) to the ARP coordinates entered. If phase center coordinates are used, both an antenna height of zero must be entered and no offset should be applied to bring the coordinates from the phase center down to the ARP. This can be accomplished by selecting the "Generic" antenna profile, or optionally you can select the correct antenna profile (in order to preserve the elevation based corrections) but be sure to select the check box "measurement to L1 phase center". An example of this scenario is shown below for a GrafNet user:

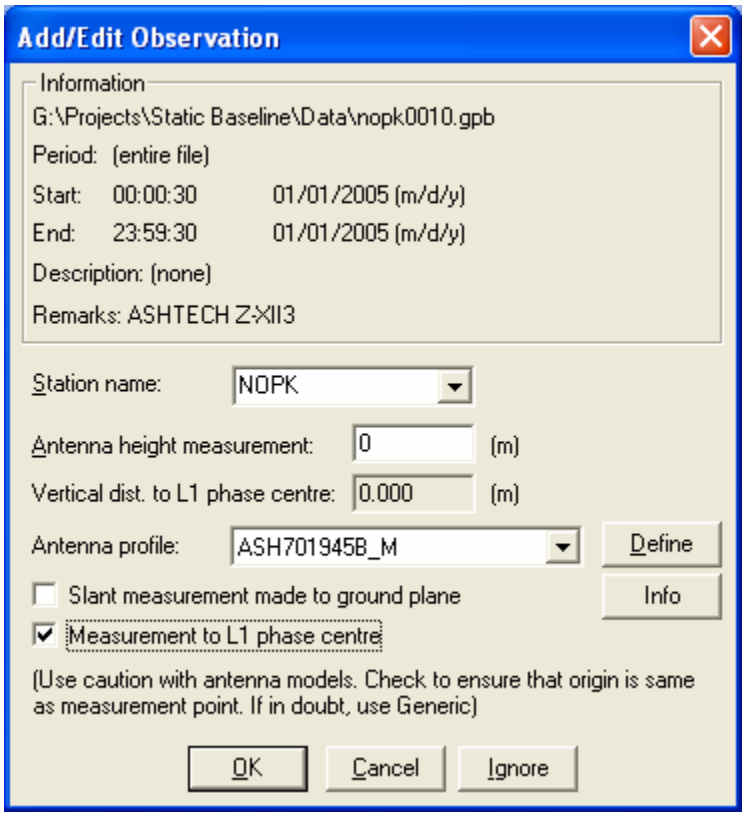


Figure 1: Using L1 Phase Center Coordinates within GrafNet

The next major source of potential error and confusion lies in converting between coordinates systems. A common example of this is when a user wants to perform a survey using both CORS and IGS stations as control, and wishes to use the NAD83 (epoch 2002.0) datum. The user must now convert the IGS stations in his network to NAD83. Many software packages provide conversions between datums, however few provide the user the opportunity to not only specify the input and output datums but the input and output epoch as well.

HTDP (Horizontal Time Dependent Positioning) is a freely available program developed by the Government of the United States of America which allows a user to transform positions between reference frames such that both the continuous and episodic components of crustal motion are addressed. The continuous component of crustal motion can be represented as a constant velocity and the episodic component is the relatively rapid displacements that occur following a major earthquake.

HTDP supports the NAD83 datum as well as all official realizations of ITRF and WGS84. HTDP can thus be used to transform published WGS84 coordinates from epoch 2005.0014 to NAD83 epoch 2002.0 with a very high degree of precision. For more information about HTDP and to download the program see http://www.ngs.noaa.gov/TOOLS/Htdp/Htdp.html.

Note that the latest GrafNav/Net manufacturer files (which can be downloaded either from the "Download Internet Service Data" utility or the help screen within GrafNav or GrafNet) also contain transformations between all official realizations of WGS84 and ITRF as well as NAD83. If you cannot find these transformations, please contact Waypoint technical support.

These transformations are fourteen parameter time-dependent transformations that include XYZ translation, XYZ rotation, XYZ spatial velocity, XYZ rotational velocity, scale factor as well as scale factor rate. All of these transformations were created using large coordinate lists generated from HTDP and thus GrafNav/Net users should be able to obtain nearly identical solutions from within the coordinate conversion utilities provided within GrafNav/Net as they would from actually from using HTDP. The difference lies in that HTDP asks the user for the input and output epochs, and the conversion utilities in GrafNav/Net assume that the input coordinates are at a specific reference epoch (2005.62).

Example Project

Four GPS stations near the California/Nevada boarder were selected for this test. The four digit designations of these stations are GABB, CMBB, MINS and DYER. They were selected due to their proximity to each other and that they are all available on both the CORS and IGS networks. A network using four hours of data from each station on January 1st 2005 was processed two different ways to show how CORS and IGS stations can be integrated into one project.

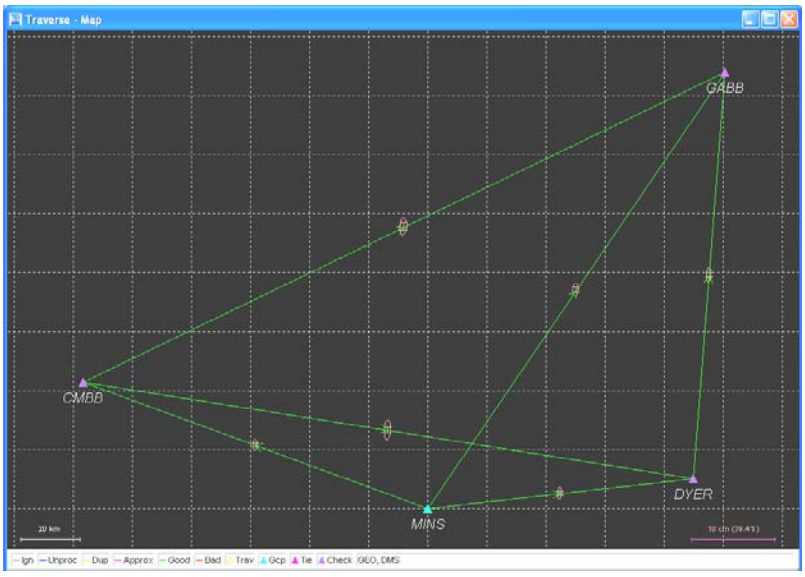


Figure 2: GrafNet network

A minimally constrained network was first processed using MINS as the control point. It's published NAD83 (epoch 2002.0) phase center coordinate was used. The other three stations were all used as check points. Care was taken when adding each station into GrafNet to enter a zero antenna height, and the "Generic" antenna profile was used for each station. Initially, the published NAD83 phase center coordinates were used for the checkpoint values. This was done in order to establish the processing accuracy in relation to published coordinates before introducing any other variables.

Shown below is a portion of the traverse report that shows the checkpoint residuals for each station:

Name/Session	Type	Result	DEast (m)	DNorth (m)	DHeight (m)
POINT CMBB	CheckPnt	Good	0.0094	-0.0105	0.0597
POINT DYER	CheckPnt	Good	0.0202	-0.0178	-0.0264
CMBB to DYER	LoopTie	Good	-0.0205	-0.0004	0.0022
POINT GABB	CheckPnt	Good	0.0237	-0.0254	0.0050
CMBB to GABB	LoopTie	Good	0.0001	0.0005	-0.0017
DYER to GABB	LoopTie	Good	-0.0037	0.0008	0.0012
			---	---	---
RMS (tie points)			0.0120	0.0006	0.0018
RMS (check points)			0.0188	0.0189	0.0378

A second project was then processed. Again, the NAD83 (epoch 2002.0) phase center coordinates of MINS were used as control. The published WGS84 (epoch 2005.0014) positions from the IGS website for the stations DYER, CMBB and GABB were transformed using HTDP to the NAD83 (epoch 2002.0) reference frame. These values were then entered as the checkpoint values. As the WGS84 positions refer to the monument position and not the phase center, care was taken to add both the antenna height of each of these stations as well as the appropriate antenna profile. The following is a portion of the traverse report from this adjustment.

Name/Session	Type	Result	DEast (m)	DNorth (m)	DHeight (m)
POINT CMBB	CheckPnt	Good	0.0108	-0.0195	0.0632
POINT DYER	CheckPnt	Good	0.0272	-0.0347	-0.0168
CMBB to DYER	LoopTie	Good	-0.0203	-0.0002	0.0026
POINT GABB	CheckPnt	Good	0.0279	-0.0439	0.0117
CMBB to GABB	LoopTie	Good	0.0000	0.0005	-0.0015
DYER to GABB	LoopTie	Good	-0.0039	0.0006	0.0012
RMS (tie points)			0.0120	0.0005	0.0018
RMS (check points)			0.0233	0.0342	0.0384

The residuals from the two methods of processing increased from a total horizontal RMS error of 2.7 cm in the first scenario to 4.1 cm in the second scenario. This represents only a 1.4 cm increase in error. Vertically, the increase in the RMS residual was negligible. This shows that using HTDP to transform published coordinates of IGS stations to the CORS NAD83 datum introduces only small amounts of error.