Comparison of GPS Base Station Positions - City of Madison, WI

Department of Public Works, Engineering Division, City of Madison, Wisconsin
Compiled March 2005, updated September 14, 2005

PURPOSE / DISCLAIMER: This information is provided for historical reference and to help users better understand vertical and horizontal datums. GPS users must refer to the web site for current information.

Base location / website: 1120 Sayle Street, Madison, WI http://gis.cityofmadison.com/Madison_GPS/

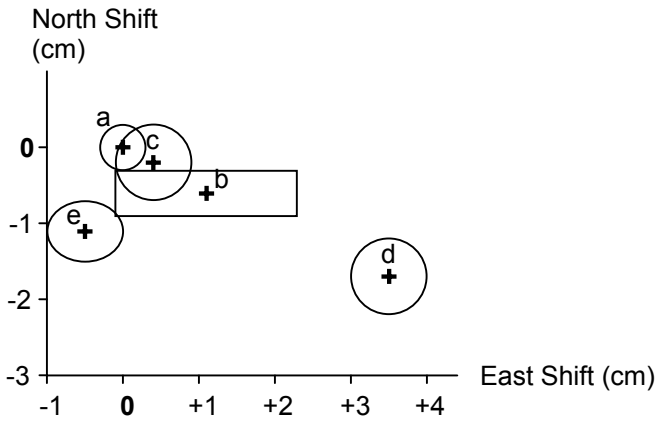
	Source	Latitude	Longitude	Ellipsoid Height
a.	AYRES 2003	43°03'17.13293"	89°22'57.67546"	232.626 m
b	OPUS	43°03'17.13272"	89°22'57.67497"	232.673 m
c.	UW NAD83(97)	43°03'17.13287"	89°22'57.67528"	232.679 m
d.	UW NAD83(91)	43°03'17.13239"	89°22'57.67394"	232.789 m
e.	AYRES 2005	43°03'17.13258"	89°22'57.67569"	232.645 m

HORIZONTAL SUMMARY:

The AYRES 2005 position (e) is the broadcast position as of Sept. 6, 2005. The AYRES 2003 position (a) was broadcast previously. Positions (a,c,e) are in the NAD83(97) datum; (e) probably differs from (a & c) because it was tied to nearby control rather than HARN stations. Position (b) is technically in a different datum, but very close to NAD83(97). Position (d) is in NAD83(91). The shift between NAD83(91) and NAD83(97) is similar at nearby NGS HARN stations.

HORIZONTAL POSITIONS (actual size)

Circles are approximate 95% confidence intervals



HORIZONTAL NOTES:

a: The AYRES 2003 position was determined by Ayres and Associates, Inc. in 2003 from the NAD83(97) latitude and longitude of three A-Order High Accuracy Reference Network (HARN) stations in Dane County: ROCK, KOLLATH and COTTAGE GROVE GPS.

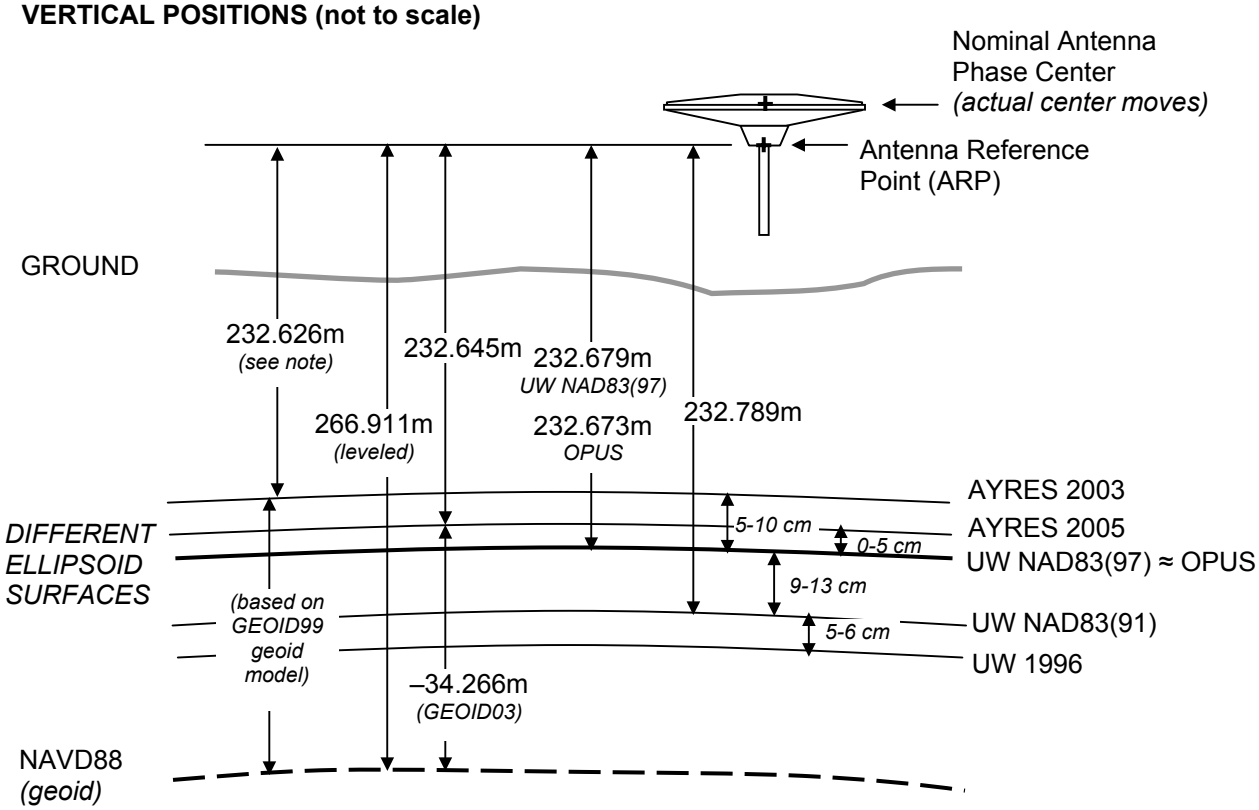
b: The OPUS position was determined from fifteen 24-hour observations between September 2004 and February 2005 using the Online Positioning User Service (OPUS) of the National Geodetic Survey (NGS). Base stations BLRW, LCDT and MIL1 were used. The OPUS datum was NAD83(CORS96)(EPOCH 2002.0000), which is very close to NAD83(97). The uncertainty box shows the largest latitude and longitude "peak-to-peak" errors. These are the range of coordinate solutions from the different base stations (centering of the box is approximate).

c: The UW NAD83(97) position was determined by graduate students in the UW Civil & Environmental Engineering Department from an August 2004 GPS survey. It is solved from the same NAD83(97) latitude and longitude of the same three HARN stations as the AYRES 2003 position.

d: The UW NAD83(91) position uses the same GPS data as the UW NAD83(97) solution, but is solved from the NAD83(91) positions of the three HARN stations. A similar shift, mostly east-west, is seen between the NAD83(91) and NAD83(97) positions of the three HARN stations.

e: The Ayres 2005 position was determined by Ayres and Associates, Inc. in August 2005 from the NAD83(97) latitude and longitude of First-Order NGS stations Burr Jones GPS, Emil GPS, Edina-Taylor GPS and Owen Park GPS in the City of Madison. The shift of (e) relative to (a & c) could indicate a small systematic shift of the city stations relative to the HARN stations. By using (e) as the current base position, GPS users should obtain results most consistent with other control stations in the city area.

VERTICAL POSITIONS (not to scale)



VERTICAL SUMMARY: The AYRES 2005 ellipsoid height is the height broadcast as of Sept. 6, 2005. It is computed so that GPS receivers with the GEOID03 geoid model loaded can produce more reliable NAVD88 elevations. The City of Madison derived ellipsoid height of 232.573 m was broadcast previously (see AYRES 2003 vertical note below).

In general, GPS-derived elevations are hindered by 1) inherent accuracy limitations of GPS-measured ellipsoid heights; 2) different ellipsoid reference surfaces; 3) imperfect and varying geoid models for converting ellipsoid heights to orthometric (NAVD88) elevations; and 4) critical details like antenna heights and phase center variation. Since NAVD88 is the desired vertical datum, the diagram above considers there to be one NAVD88 geoid surface, and various ellipsoids positioned relative to it. The different ellipsoids are not necessarily parallel to each other, but they are close. The ellipsoid-to-ellipsoid separations shown on the diagram are ranges based on measured ellipsoid heights at various stations. Note that while the ellipsoids might be considered approximately parallel, the NAVD88 geoid is tilted (roughly 2 cm per km) and even undulates (is warped) relative to the ellipsoids.

VERTICAL NOTES:

- The UW NAD83(97) ellipsoid height was established with GPS from the published 1999 ellipsoid heights at the three HARN stations. It is considered here to be the NAD83(97) datum, although the NGS does not call it that. Orthometric (NAVD88) elevations were not computed in this network. 95% confidence is +/- 0.01 m, although discrepancies of up to 4 cm relative to NGS published NAD83(97) ellipsoid heights were found at other stations in the network.
- The OPUS ellipsoid height was established with GPS from the published ellipsoid heights of the base stations, using the same OPUS observations used for horizontal positioning. (see HORIZONTAL NOTES). The OPUS ellipsoid datum is technically NAD83(CORS96)(EPOCH2002.0), which is appears to be essentially the same as the "NAD83(97)" ellipsoid, within GPS precision limits. The largest "peak-to-peak" error from the OPUS solutions (the range of height solutions from the different base stations) was 0.045 m.

- The UW NAD83(91) ellipsoid height was established with GPS from the published 1991 ellipsoid heights at the three HARN stations. It is considered here to be the NAD83(91) datum, although the NGS does not call it that. 95% confidence is +/- 1 cm from the network adjustment, although a discrepancy of 2 cm relative to the NGS published NAD83(91) ellipsoid height was found at one station in the network.
- The UW 1996 ellipsoid was established with GPS for the UW Campus Mapping Project. There was no height computed from this ellipsoid for the Madison base station – it is merely shown here for reference. The "NAD83(91)" ellipsoid as defined at the HARN stations was intended to be used, but an apparent mistake with antenna heights at station UWGP resulted in a systematic shift. This mistake did not affect NAVD88 elevations determined for campus stations, which were independently tied to NAVD88 benchmarks by differential leveling.
- The AYRES 2003 ellipsoid height was established with GPS by holding fixed NAVD88 orthometric elevations at the three HARN stations (Cottage Grove GPS, Rock and Kollath) as well as four additional NAVD88 benchmarks, and using the NGS's GEOID99 geoid model to compute ellipsoid heights. 95% confidence is +/- 0.003 m. This method was designed to eliminate systematic shifts between GEOID99 geoid separations and computed (NAD83 – NAVD88) geoid separations. Note that this creates an ellipsoid surface above the "NAD83(97)" ellipsoid (see UW NAD83(97) notes). The ellipsoid height produced by Ayres was 232.626 m, but it was uncertain whether this was to the nominal phase center or the Antenna Reference Point (ARP - base of antenna housing) because antennas from different manufacturers were used in the survey. The city subtracted the nominal phase center offset of 0.053 m from 232.626 m to compute a height of 232.573 m for the ARP. In retrospect, the leveled NAVD88 elevation of 266.911 of the ARP plus the GEOID99 geoid separation of (-34.282 m) gives an ARP ellipsoid height of 232.629 m, which is very close to 232.626 m. The later surveys better confirmed the height, and a more recent geoid model was used to establish the current height.
- The AYRES 2005 ellipsoid height was not determined by GPS. It was determined by differential leveling from nearby Second-Order NGS benchmark 2V02 and the NGS GEOID03 geoid model. Similar to the AYRES 2003 survey, an NGS geoid model was used to create the ellipsoid, so that systematic differences between modeled geoid separations (from GEOID03) and computed (NAD83 – NAVD88) geoid separations could be minimized. The diagram below shows similar differences at nearby Wisconsin Height Modernization Project station "Madison S GPS" (First-Order horizontal, Second-Order Class I vertical). Shifts similar in direction and magnitude are seen at other stations in the Madison area. Thus, precise GPS receivers using the Madison base station should use the GEOID03 geoid model to convert GPS-measured geoid heights back to NAVD88 elevations. Calibration of the roving receiver to local NAVD88 benchmarks may further minimize local discrepancies, but the user should realize that observed discrepancies of a few centimeters may be simply due to the inherent errors in GPS positioning.

"PARALLEL" ELLIPSOID CREATED BY GEOID03