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Evaluation of the Trimble ProXR GPS Receiver Under a Hardwood Canopy Using CORS Broadcast Real-Time DGPS Corrections

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During 1999, Ross Taylor, Lands Program Manager for the Hoosier National Forest, and Dale Weigel, Forester for the North Central Forest Research Station, conducted a test for the Missoula Technology and Development Center (MTDC). They evaluated the real-time accuracy of the Trimble ProXR GPS Receiver (Figure 1) using real-time broadcast signal corrections acquired from a Continuously Operating Reference Station (CORS) station 150 km (93.7 mi) away providing Differential GPS (DGPS) signals. The evaluation was conducted under a hardwood forest canopy at the Forest Service GPS Hardwoods Test Site on the Hoosier National Forest 48 km (30 mi) north of Bedford, IN. The CORS station was at Louisville, KY. This report compares the horizontal accuracy of data obtained using the differential broadcast corrections transmitted in real time to that obtained by differential postprocessing.

Figure 1—Trimble ProXR GPS receiver.

All stations are second-order class or better (first-order class is the highest precision). The course consists of a seven-station closed traverse. It starts at the top of a finger ridge and proceeds down the ridge into the bottom of a gully, then back up an adjoining ridge to the starting point. The polygon described by traversing from stations A through G has an area of 1.5045 ha (3.323 ac). These stations are located under a dense, uneven-age oak, beech, and hickory canopy, typical of the eastern hardwood forests. The top of the canopy is about 30.5 to 36.6 m (100 to 120 ft) above the ground.

The Trimble ProXR is a 12-channel, real-time differential GPS receiver that includes an integrated DGPS antenna. The antenna receives the GPS signal and real-time differential corrections broadcast by a radio beacon maintained by the U.S. Coast Guard or the

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U.S. Army Corps of Engineers. This test used the U.S. Army Corps of Engineers DGPS real-time broadcast signal from Louisville, KY.

The ProXR receiver used in the test contains Trimble firmware version 1.38. The receiver can output the real-time differentially corrected position and the raw data for each position. Data were collected using the Trimble System Controller (TSC1) data logger with Asset Surveyor software version 4.03. The data collection interval was set at 1 second, the PDOP (position dilution of precision) and SNR (signal-to-noise ratio) masks were set at 6, the elevation mask was set at 15 degrees, and the antenna was set at 2 m. Pathfinder Office software version 2.11 was used to differentially post-process the raw-position data and display both the postprocessed and the real-time-corrected position data. Base-station data for postprocessing were obtained from the Bedford base station PFCBS 2.68I. That station, just 18 km (11 mi) from the test site, records data at 5-second intervals.

The test course (under canopy) was traversed seven times with the ProXR receiver. At each station four different point files with about 150 position records were collected. Three different walk files were collected on the test course. Most of these records were real-time-corrected positions. At some locations, the canopy attenuated the DGPS correction signal. Position files from such locations contain both real-time-corrected and uncorrected positions. Table 1 shows that all the positions were real-time corrected at each station (A through G) for the R083118a data collection file. Figure 2 shows the horizontal position error for that file.

The Data Collector's Observations and Data—August 31

Observations for file R083118a: The first four stations (A through D) were collected quickly with 150 positions obtained in 20 minutes or less. At station E the five satellites were located almost directly above the position. Satellites located lower on the horizon were blocked out by tree canopy. The satellite geometry was poor, resulting in a high PDOP reading (6.3). Because the PDOP switch was set at 6.0, no readings with a PDOP were recorded. The point was abandoned with only 16 positions recorded. At stations F and G, satellites were not blocked out by the tree canopy and 150 positions were collected within 5 minutes. The DGPS real-time correction broadcast signal was always present.

The Data Collector's Observations and Data—September 1

The Trimble software includes a Quickplan program that indicates which satellites are visible and which signals are available at a given location for a given time. The software indicated that six to seven satellites should have been available to the GPS receiver at the test course. However, the alignment of those satellites did not allow the satellite signals to penetrate the tree canopy at stations A, B, and C. Data collection was abandoned the morning of September 1. Unless the satellites were positioned 35 degrees or higher over the horizon, the dense canopy attenuated the signal. Whenever signals from four satellites were received by the GPS receiver, the radio link from the DGPS real-time broadcast signal station was also present. On the afternoon of September 1, stations that had been

Table 1—Number of positions collected using real-time DGPS.

Station	A	B	C	D	E	F	G
Total number of positions recorded	152	156	154	153	16	155	154
Number of positions real-time DGPS corrected	152	156	154	153	16	155	154
Number of positions **not** real-time DGPS corrected	0	0	0	0	0	0	0

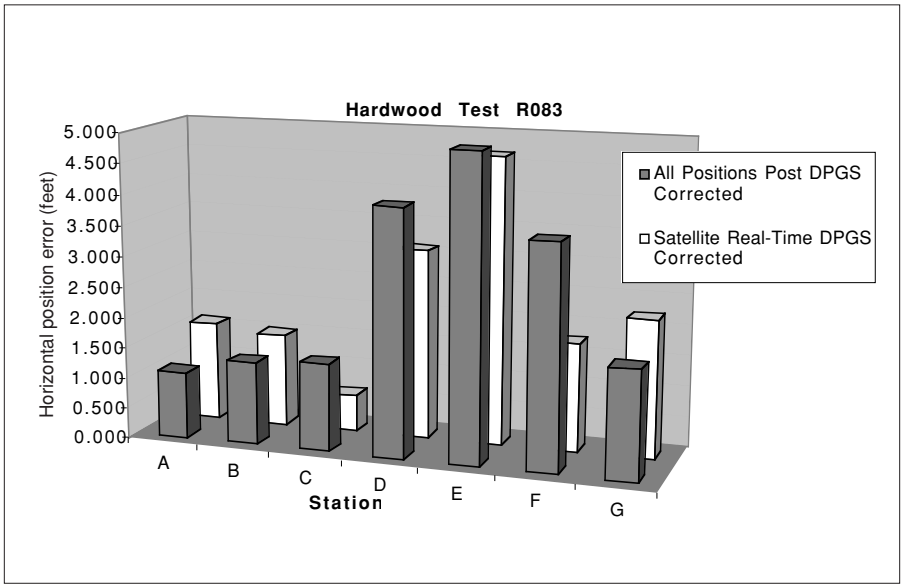

Figure 2—Horizontal position error (ft) for DGPS positions corrected in real time compared to postprocessed positions for file R083118a.

visited that morning were revisited. The point features were collected in a short period of time. No more than 14 minutes was required to collect 150 positions. A walk file, R090120a, was collected around the course from station F back to station F. That file contained 250 positions. Table 2 shows that all the positions were real-time corrected at each station (A through G) for the R090118a data collection file. Figure 3 shows the horizontal position error for that file.

Figure 4 shows the walk file that includes 26 positions that were not real-time corrected. Figure 5 shows the walk file with those 26 positions removed. The area after the positions were removed was 3.203 acres, for an error of 0.969 percent. After that file was postprocessed, it had an area of 3.219 acres, or an error of 0.963 percent.

The Data Collector's Observations and Data—September 8

Observations for files R090818a and R090821a: On September 8, positions at stations A and G were easily collected. However, because of the topography and the position of the satellites, it took 1½ hours to collect 171 points at station B. At stations C, D, and E, positions were collected in 12 to 20 minutes. The DPGS signal was lost at station F for a short period of time. Table 3 shows that most positions at stations A through E were real-time corrected for the R090818a data collection file. However, at stations F and G many positions were not real-time corrected. Figure 6 shows the horizontal position error for that file.

Table 2—Number of DGPS positions collected in real time (file R090118a).

Station	A	B	C	D	E	F	G
Total number of positions recorded	157	158	155	158	158	160	157
Number of positions real-time DGPS corrected	157	158	155	158	158	160	157
Number of positions **not** real-time DGPS corrected	0	0	0	0	0	0	0

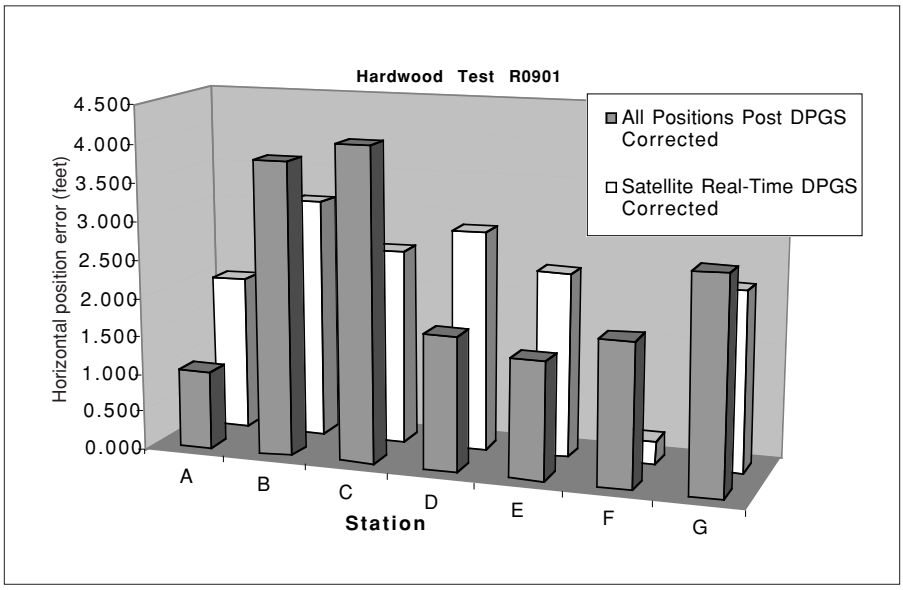

Figure 3—Position error (feet) for DPGS positions corrected in real time compared to all post-processed positions for file R090118a.

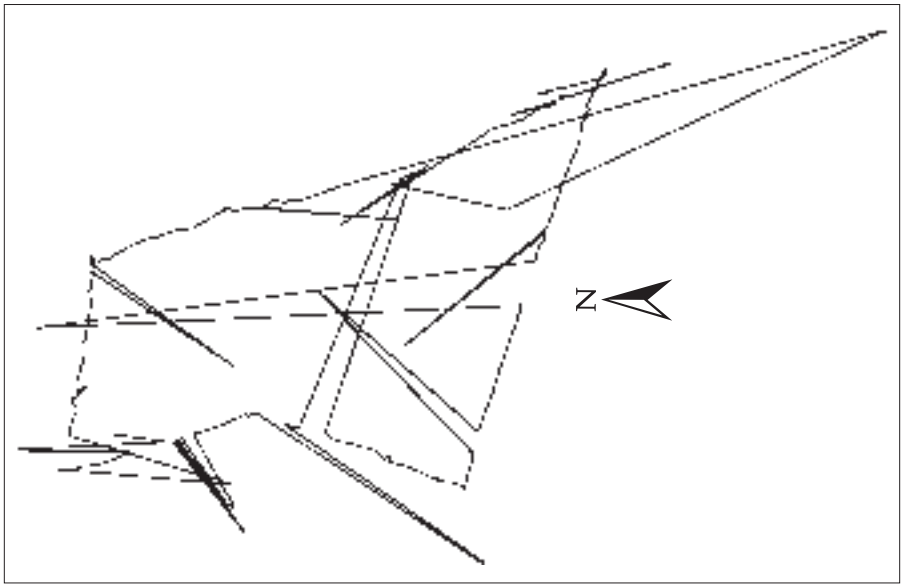

Figure 4—Walk file R090120a, corrected in real time with 26 uncorrected positions (250 total).

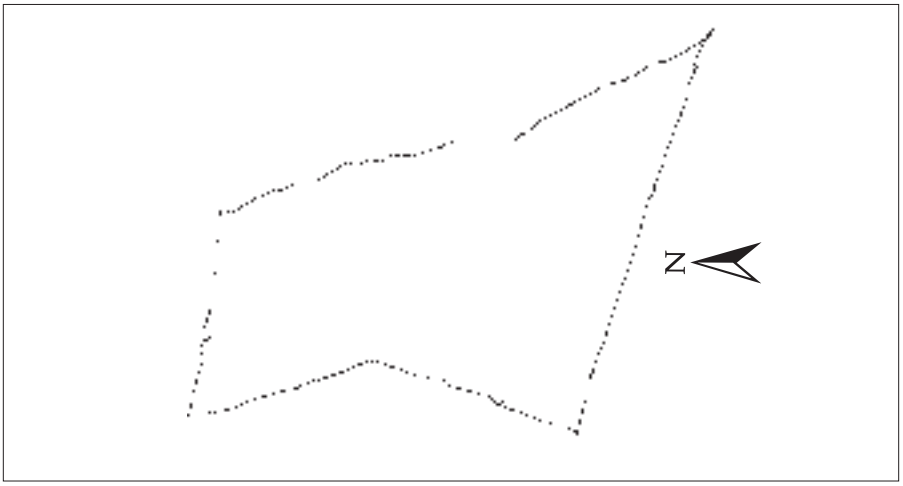

Figure 5—Walk File R090120a corrected in real time with the 26 uncorrected positions removed.

Table 3—Number of positions corrected by DGPS in real time compared to those that were not for file R090818a, September 8, 1999.

Station	A	B	C	D	E	F	G
Total number of positions recorded	188	172	166	159	159	155	180
No. of positions real-time DGPS corrected	188	144	153	159	152	0	107
No. of positions **not** real-time DGPS corrected	0	28	13	0	7	155	73
Percent positions **not** real-time DGPS corrected	0.00	16.28	7.83	0.00	4.40	100.00	40.56

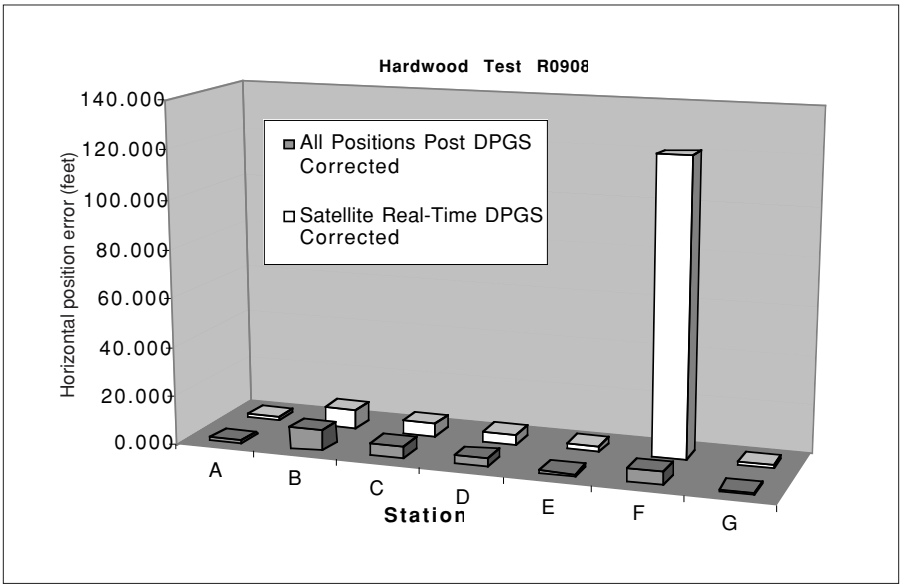

Figure 6—Horizontal position errors from file R090818a corrected in real time and the file with postprocessed positions.

The Data Collector's Observations and Data—September 24

Conditions were dry when a walk file, R092418a, was made around the course and 210 positions were collected. Some were collected without the DGPS real-time beacon signal. A point file, R092419a, was started. Stations A, B, and C were collected in about 13 minutes per station. At station D, located in a small draw, only 61 positions were collected. The satellites were obscured by vegetation to the west. At station E, on a ridge, 88 positions were recorded. The station was abandoned because of a poor satellite constellation (four satellites with a PDOP of 9.7). Because of the poor satellite constellation and time constraints, positions were not collected at stations F and G.

Table 4 shows that most positions at stations A through D were real-time corrected for the R092419a data collection file. At station E, just 15 percent of the points were real-time corrected. No positions were collected at stations F and G. Figure 7 shows the horizontal position error for that file.

Walk Files

Walk files were collected on September 1, 8, and 24. Table 5 shows the results.

Table 4—Number of DGPS positions corrected in real time compared to those that were not for file R092419a.

Station	A	B	C	D	E	F	G
Total number of positions recorded	154	157	152	61	88	0	0
No. of positions real-time DGPS corrected	154	141	95	61	13	0	0
No. of positions **not** real-time DGPS corrected	0	16	57	0	75	0	0
% of positions **not** real-time DGPS corrected	0	10.19	37.50	0	85.23	0	0

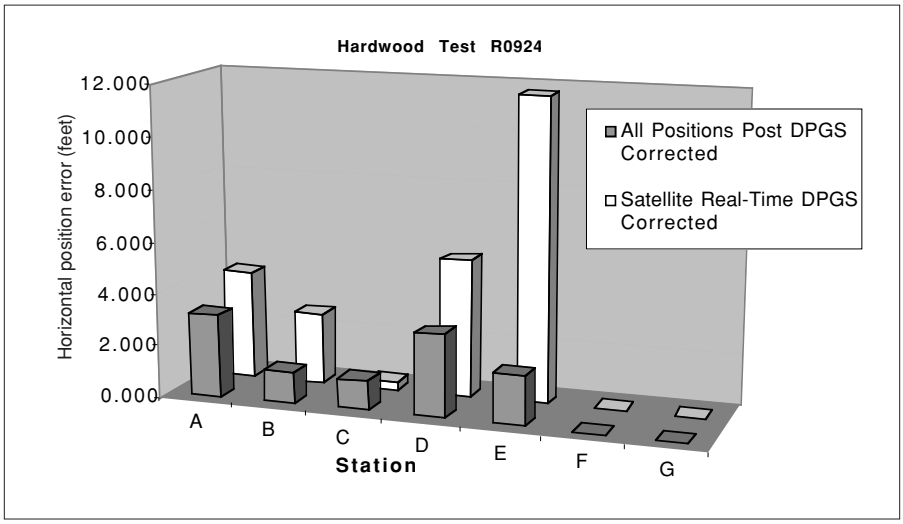

Figure 7—Horizontal position error from file R090924a for DPGS positions collected in real time compared with postprocessed positions.

Table 5—Number of DGPS positions that were corrected in real time compared to those that were not for walk files R090120a, RO90821a, and R092418a. Acreage errors are included.

Walk file number	R090120a	R090821a	R092418a
Total number of positions recorded	252	77	215
Number of positions real-time DGPS corrected	226	50	197
Number of positions **not** real-time DGPS corrected	26	27	18
Percent positions **not** real-time DGPS corrected	10.32	35.06	8.37
		Acreage error	
Acreage of file, real-time and DGPS corrected	3.219	*1.867	3.248
Percent error from actual	3.13	43.82	2.26
Acreage of file real-time, and **not** DGPS corrected	3.183	2.017	3.135
Percent error from actual	4.21	39.30	5.66
Actual acreage of walk course	3.323	3.323	3.323

*Incomplete course. Some points were not included in the acreage.

Discussion

This test indicates that a heavy hardwood canopy can attenuate satellite GPS and real-time CORS DGPS correction signals, preventing them from being picked up by the receiver. No real-time corrections were received for Stations F in Table 3 and Stations F and G in Table 4. In some cases, only a portion of the positions were real-time corrected: stations B, C, E, F, and G in Table 3, stations B, C, E, F, and G in Table 4, and a small number of positions in Table 5. File R090821a was an incomplete walk file: stations D, E, and F were abandoned because of weather. The 35-percent error reflects the incompleteness of the file.

A heavy canopy can attenuate the broadcast DPGS signal. The radio link between the DGPS broadcast station in Louisville, KY, was lost only occasionally when collecting the individual files. Table 2 shows 100-percent acquisition of the CORS DGPS real-time signal. If you are planning a DGPS real-time operation under the canopy, allow extra time to get the data. You should use satellite visibility software to predict the times when enough satellites are at higher elevations with good PDOP.

This test indicated that when the Trimble ProXR GPS receiver was used under the hardwood canopy and the positions were real-time corrected with the CORS DGPS broadcast signal, the receiver provided nearly 1-m (1.02 to 5.29 ft) average horizontal-position accuracy. If the data are postprocessed, the ProXR will produce better (1.204 to 3.194 ft) average horizontal accuracy.

Summary

The Trimble ProXR will work under a hardwood canopy in conditions when a GPS constellation is high above the horizon. There were many times when four to five satellites were tracked but with a PDOP of 7 or higher (particularly in the morning sessions). The satellites needed to provide an acceptable PDOP typically are low in the horizon and not accessible through the heavy canopy and tree trunks. The radio link with the CORS station in Louisville 150 km (90 mi) away did not present much of a problem. Although the link was lost on occasion, the loss was infrequent.

About the Authors

Ross Taylor is a lands program manager for the Hoosier National Forest.

Tony Jasumback retired in the spring of 2000 as the GPS coordinator at MTDC. He has been involved in the development and evaluation of GPS equipment for Forest Service use since 1984.

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Describes the results of tests of the Trimble ProXR global positioning system (GPS) receiver conducted under a hardwood canopy at the U.S. Department of Agriculture, Forest Service GPS hardwoods test site in the Hoosier National Forest near Bedford, IN. The test evaluated the receiver's real-time accuracy using signal corrections broadcast from a continuously operating reference station (CORS) differential GPS (DGPS) station 150 km from the test site. The test indicated that a heavy hardwood canopy can attenuate satellite GPS and real-time CORS DGPS correction signals, preventing them from being picked up by the receiver. No real-time corrections were received at several stations on the test course. Only a portion of of the positions were corrected at a number of stations. When the Trimble ProXR GPS receiver was used under the hardwood canopy and real-time corrected with the CORS DGPS signal, it provided nearly 1-m (1.02 to 5.29 ft) horizontal-position accuracy. If the data are postprocessed, the ProXR will produce better (1.204 to 3.194 ft) average horizontal accuracy.

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