ACCURACIES OF VARIOUS GPS ANTENNAS UNDER FORESTED CONDITIONS

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ABSTRACT

GPS accuracy is much more variable in forested settings than in open conditions. Even with current technology, forest canopy provides a difficult environment for GPS data collection. Foresters often struggle with productivity using high-end equipment and question the accuracy of lesser grade units. Few realize or can quantify the actual precision of the data they collect. This preliminary study was conducted to compare five different models of mapping grade and professional grade GPS antennas to determine realistic accuracy expectations under canopy. The study was conducted at the University of Georgia's new GPS test course at Whitehall Forest.

KEYWORDS. GPS, accuracy, tree canopy, multi-path, velocity filtering, WAAS, static accuracy, dynamic accuracy.

INTRODUCTION

GPS has become a very common and useful tool for foresters and other natural resource managers over the past few years. New antenna technologies coupled with affordable data collection hardware and software has contributed to the growing popularity of GPS.

Types of GPS Equipment

Excluding survey grade, GPS systems can be classified into three categories. The first is professional grade, which can provide sub-meter or better horizontal accuracy. These are generally more expensive but do allow greater control over data collection parameters. Professional grade GPS units often require more signal strength to lock on to satellites and therefore are usually associated with good precision and sometimes less than desirable productivity. Mapping grade units are the next step down. They can provide accuracy in the 1-5 meter range and tend to track better under forest canopy. The third are consumer/recreational grade units geared toward sportsmen who need many features in a low cost all-in-one unit. Ease of use and available basemaps are more important than accuracy. These units often have stated accuracies similar to mapping grade units but are designed for navigation purposes rather than data collection.

In Prisley, S., P. Bettinger, I-K. Hung, and J. Kushla, eds. 2006. Proceedings of the 5th Southern Forestry and Natural Resources GIS Conference, June 12-14, 2006, Asheville, NC. Warnell School of Forestry and Natural Resources, University of Georgia, Athens, GA.

Recent GPS Technology

The most recent units benefit from new technologies such as velocity filtering and WAAS real-time correction. Each can increase positional accuracy by manipulating or adjusting the GPS data. Velocity filtering uses algorithms that monitor direction and speed and remove positions that are outside of a predicted "bubble" of possibilities. This cancels out erroneous data commonly seen as "flyer" points with older GPS units. This filtering process produces much "smoother" data as a result (see figure 1). Due to its nature, velocity filtering only works when the antenna is in motion (dynamic mode).

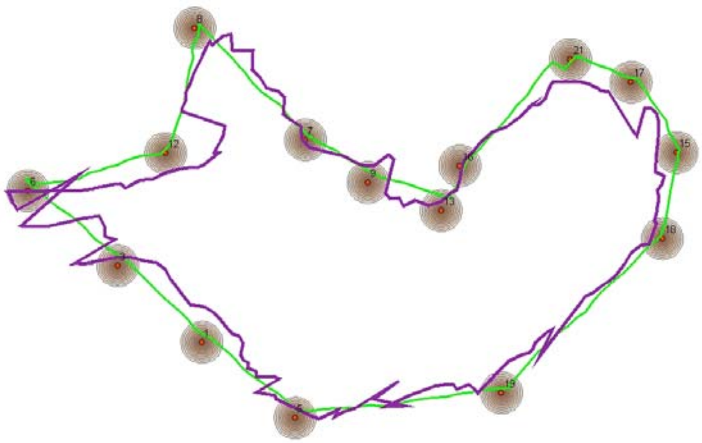


Figure 1 – The effects of velocity filtering under tree canopy at the Whitehall GPS test course. This figure shows data collected with and without velocity filtering.

WAAS (Wide Area Augmentation System) is a real-time differential correction system developed by the Federal Aviation Administration (FAA). This system currently uses two satellites to rebroadcast differential correction information from ground base stations on a GPS frequency rather than from ground-based beacons. This gives users with WAAS-capable antennas the benefit of better positional accuracy in the field for better verification. WAAS correction can also eliminate the hassles of post-processing back in the office. Because it is satellite-based, it has advantages over beacons because of its location above the horizon. Obstructions can block this signal, but most manufacturers allow the use of recent or predicted correction data to be applied to GPS positions for a short period of time when this occurs. The current WAAS system is improving to provide better coverage throughout the US through the use of additional satellites.

Data Collection Methods

There are two basic modes of logging GPS data; dynamic and static. Dynamic data collection refers to using a specific time or distance interval to log positions while the antenna is in motion. This is commonly used for collecting line and area features that have meandering segments. The user can control the stream of logging by pausing and restarting. Static mode, on the other hand, refers to collecting positions while keeping the antenna stationary above the feature being mapped for a period of time and those positions are then averaged. Theoretically this method will dilute bad positions if enough observations are taken. Static data is often collected on point features and for positions on lines and areas between straight segments.

Assessing GPS Needs and Expectations

Foresters have different needs and uses for GPS. Procurement foresters primarily tend to use GPS for precise acreage determination. Many feel that the extra cost of a professional grade GPS can be justified on just a few bid sales. Management foresters also use GPS for acreage determination, but also for updating a GIS database where spatial integrity is more important. They are often more conservative and look for more cost-effective units.

Foresters, like many GPS users, falsely assume that they can realize the manufacturers' stated accuracies under tree canopy. They don't realize that these stated accuracies apply to low multi-path or open conditions, not under tree canopy. Multi-path occurs when signals are reflected off of objects such as trees or buildings. These reflections delay the signal before it reaches the antenna and throw off the range calculations. Since accurate timing is necessary for accurate positioning, this can cause significant error. Multi-path is the greatest source of error in forestry settings and the most difficult to combat.

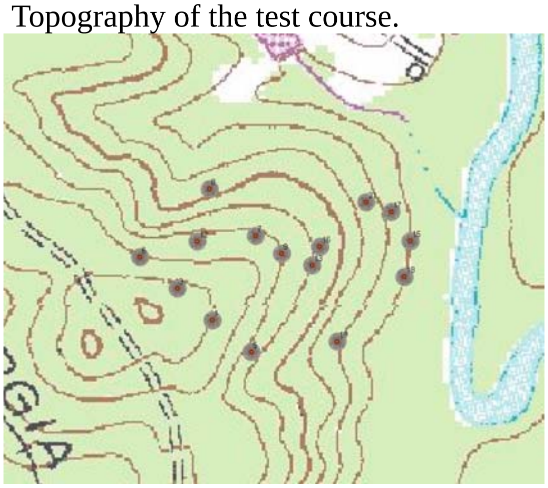
Until recently, there have been few if any surveyed courses under heavy tree canopy to perform real world accuracy tests in the Southeast. The goal of this study is to provide foresters with realistic expectations of GPS accuracy under canopy using several different antennas and data collection methods.

METHODS

Test Course

All testing was conducted at the University of Georgia GPS test course at Whitehall Forest in Athens, GA. This facility is situated primarily under heavy hardwood canopy on rolling terrain in the Georgia Piedmont. The course varies from a hilltop down to the edge of the Oconee River bottom. This area could be classified as at least a challenging course during leaf-on. For this test a subset of the stations were selected that represents about eight acres, all of which were under full canopy.

Topography of the test course.



Leaf-off aerial shot of the test course.

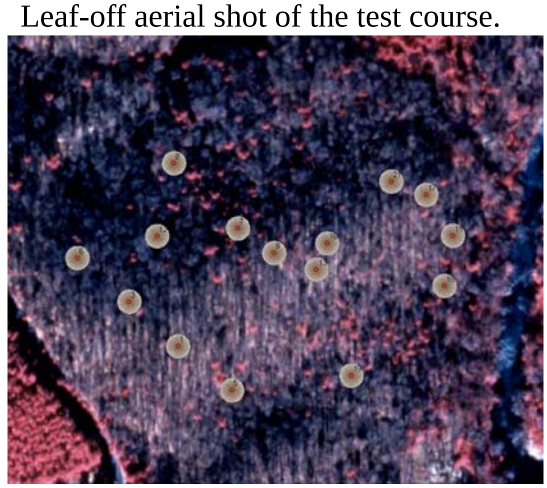


Figure 2 – GPS test stations used for the test.

Units tested

Three professional grade units were tested along with two mapping grade units. All were real-time WAAS capable DGPS receivers. An additional Garmin 17HVS mapping grade unit was included that had WAAS disabled so no correction was applied.

CSI Seres | Trimble GeoXH | Geneq SX-Blue

Figure 3 - Professional grade units (sub-meter accuracy).

Garmin GPS 17HVS | Garmin GPS 10

Figure 4 - Mapping grade units (1-3 meter accuracy).

SoloFieldCE software was used to collect the GPS data and ArcGIS was used for the analysis. Reciever settings for the professional grade units were set for the following:

Unit	**Elev. Angle**	**Age of Data**
Trimble GeoXH	10	4 min (maximum setting)
CSI Seres	10	800 sec
Generq SX-Blue	10	800 sec

All units used an HDOP filter of 4.

Procedures
The GPS course was traversed twice with each unit. The first pass tested static accuracy by collecting 120 positions (2 minutes) at each station. These positions were later plotted and the following calculated:

- The average position at each station and standard deviation
- The positional spread at each station
- Distance of the average position from the actual
- Acreage of the polygon created from the average positions.

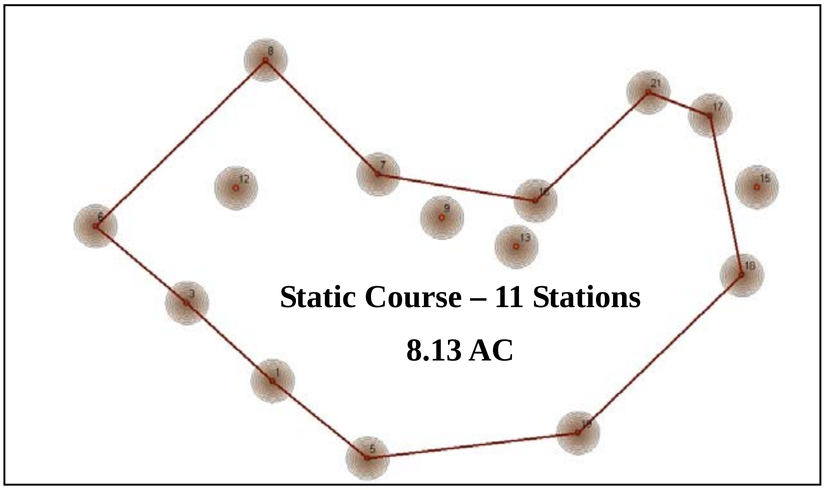


Figure 5 – Static test course.

The second pass tested dynamic accuracy by walking the course and logging positions at a five second interval. An additional four stations were added for this test. The area of each polygon was compared with the actual. Instantaneous accuracy was also measured by logging two quick points and over-riding the five second interval while approaching each station. This allowed the effects of velocity filtering to be applied.

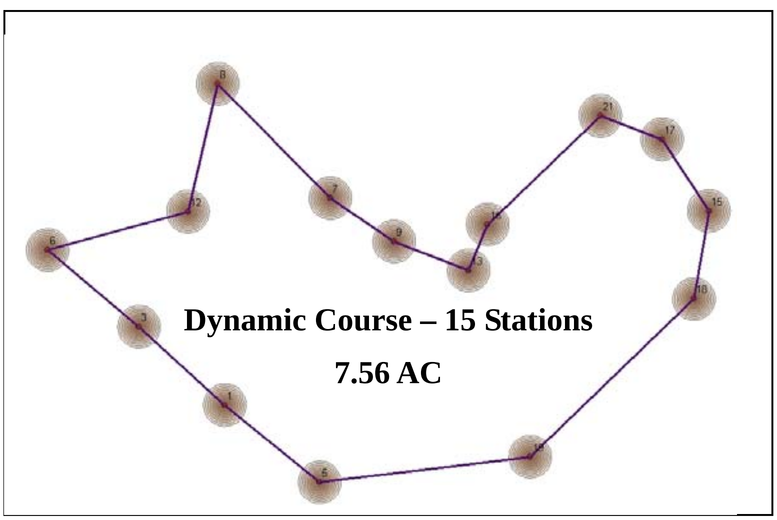


Figure 6 – Dynamic test course.

The testing was conducted on May 30, 2006. The professional grade units were run simultaneously in the morning from 9am until noon and mapping grade units in the afternoon from 1pm-4pm. There was good satellite coverage during the entire test (Figure 7).

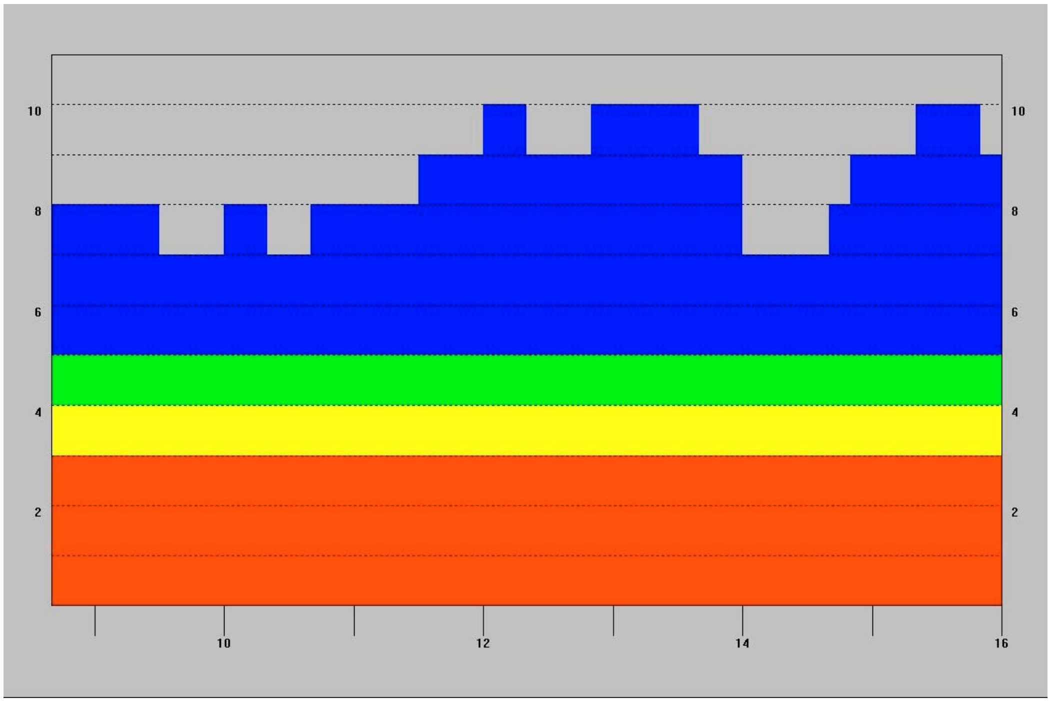


Figure 7. Mission plan for May 30, 2006, UGA Whitehall Forest, Athens, GA. Numbers of satellites are displayed on the vertical axis and time along the horizontal axis.

RESULTS

Table 1 reports the static accuracy calculated for each unit using 120 positions at each of the 11 stations. The average spread and standard deviation estimate the relative precision of each unit. Average positions were very good considering the large spreads. Accuracy was less than 10 meters on all but five occasions. These large spreads would not inspire confidence if this was what was seen every time. The Trimble GeoXH showed the smallest error probably due to its advanced multi-path rejection technology. The Garmin units yielded spreads nearly as good as the Trimble and had average errors less than six meters. The SX-Blue and CSI Seres suffered from several stations with large spreads which adversely affected their averages.

Table 1. Static accuracy test.

Unit	Avg Error (meters)	Avg Spread (meters)	Avg SD (meters)
Trimble GeoXH	2.82	8.68	1.25558860
CSI Seres	6.45	23.72	3.71593500
Geneq SX-Blue	8.21	24.33	3.42165364
Garmin GPS 10	4.56	10.43	1.31687172
Garmin 17 HVS	4.80	5.35	2.48592633
Garmin 17 HVS (Uncorrected)	5.61	10.12	2.64241380

Table 2 reports the difference in acreage using the average positions from each station. Surprisingly, the uncorrected Garmin 17 was closest to the actual acreage here even though the Trimble's spatial geometry was most like the test course.

Table 2. Static areas vs. actual. Actual = 8.13 ac (3.29 Ha).

	Area		% Difference
Unit	Acres	Hectares	from actual
Trimble GeoXH	8.24	3.34	-1.35%
CSI Seres	7.85	3.18	3.44%
SX-Blue	8.60	3.48	-5.78%
Garmin 10	7.90	3.20	2.83%
Garmin 17HVS	8.00	3.24	1.60%
Garmin 17 HVS (Uncorrected)	8.23	3.33	-1.23%

The dynamic test was run on a slightly different course that used four extra stations. There was no editing done to any of the data to remove any flyers. Dynamic results are not quite as impressive on the surface, but considering the risk of using the static spread the results are quite good. Based on the geometry of each unit's traverse, the Garmin units showed the smoothest data. Table 3 below summarizes these findings.

Table 3. Dynamic accuracy. Actual = 7.56 ac (3.06 Ha).

	Area		% Difference
Unit	Acres	Hectares	from actual
Trimble GeoXH	7.54	3.05	0.26%
CSI Seres	7.94	2.97	-5.03%
SX-Blue	7.35	3.21	2.78%
Garmin 10	7.39	2.99	2.25%
Garmin 17HVS	7.51	3.04	0.66%
Garmin 17 HVS (Uncorrected)	7.32	2.96	3.17%

Instantaneous accuracy was measured in conjunction with the dynamic area tests. The findings are presented in Table 4 and Figure 8.

Table 4. Instantaneous accuracy test results.

Unit	Avg Error (meters)
Trimble GeoXH	4.53
CSI Seres	7.64
SX-Blue	3.67
Garmin 10	4.24
Garmin 17HVS	4.08
Garmin 17 HVS (Uncorrected)	9.22

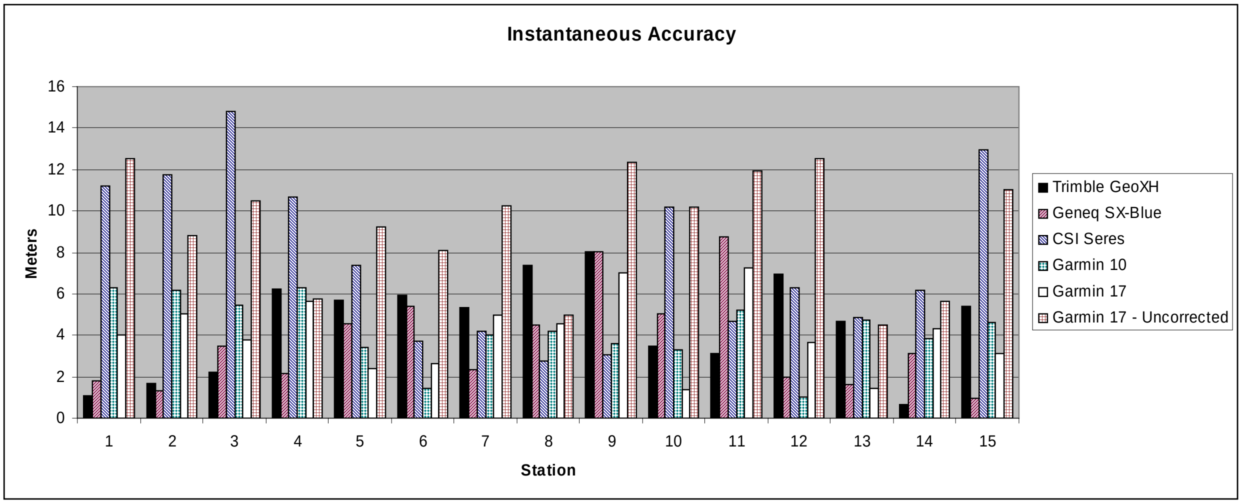


Figure 8. Instantaneous accuracy spread.

DISCUSSION

Most foresters may not benefit from a professional grade unit compared to mapping grade under canopy. If acreage calculation is most important, dynamic data collection will probably give more confidence in the end. For point data, one must be especially careful to monitor spread and deviation as forest canopy can produce large errors. Because of the error that is possible, users should strive to verify their data against basemaps such as high-precision DOQQ's whenever possible.

CONCLUSIONS

From the results, the Trimble GeoXH was the front-runner in most tests. From a cost standpoint it is several thousand dollars more expensive than the least expensive unit in the test (Garmin 10). Only the end user can decide if the additional cost for marginally more accurate data is justified. The Trimble unit also requires more time to complete each test due to frequent signal loss, so productivity must also factor into the decision. High-end units like this can also require more technical support. The CSI and Geneq units suffered from large spreads that increased error. Most data collection software allows the user to view statistics or a measure of data quality, which allows for some degree of on-the-fly data quality control. Since the data was collected as-is, there was no editing and actual error should be decreased by educated users. The CSI and Geneq units were very productive, in fact seldom did either lose signal or WAAS correction. An antenna configuration utility could be used to increase quality control settings over the factory defaults and possibly yield better results. This data definitely shows that the manufacturers' stated accuracies are not realistic in forested conditions. The results here also show that further study is warranted using the measures listed above.