Demonstrating the Accuracy of Differential Corrections for Agricultural GPS in Louisiana

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Introduction

Global positioning systems (GPS) and GPS receivers allow users to estimate their position at various locations anywhere on earth. GPS was originally developed by the United States Department of Defense (DoD) for military application but has since entered the civilian market and been used for such applications as precision navigation, surveying, and mapping. GPS and Geographical Information Systems (GIS) also have made site-specific technologies a viable agricultural practice for producers to utilize on farm, field, and intra-field levels. Precision agricultural applications with GPS receivers include field mapping, site-specific sampling (soil and pests), yield monitoring, parallel tracking, and variable rate application of production inputs. The agricultural industries in the Mid-South have been slow to adopt precision agricultural technologies compared to producers in the Mid-Western U. S. Louisiana's producers and consultants are starting to adopt precision agricultural technologies, but the adoption rates of these technologies is still low (< 15%).

Differential Corrections

Uncorrected GPS receivers currently have an accuracy of <15 meters. Inaccuracies in uncorrected GPS signal can be attributed to satellite and receiver timing errors, ionosphere interference, multipath, and system errors (Lewis 2003). Differential GPS (DGPS) is a method of improving GPS receiver accuracy with data from local reference station, differential satellite, or chipset configuration to augment the information available from satellites. DGPS improves the integrity of the complete GPS system by identifying certain errors and offering correction factors (DePriest 2004).

Real-Time Kinematic (RTK) is the process of transmitting GPS correction signals in real time from a reference receiver at a known location to one or more remote rover receivers (Thales 2005). RTK has become the industry standard for GPS differential correction with reported accuracy ±1 cm (Trimble 2000). RTK capable receivers compensate for atmospheric delay, orbital errors, and other variables in GPS geometry (Thales 2005). RTK receivers are currently being used in precision agriculture for field area and topography (elevation) mapping and automated steering applications of field equipment (Trimble 2000).

Two U. S. government agencies provide differential correction signals at no cost to GPS users. These include the Coast Guard Beacon DGPS service and the Wide Area Augmentation System (WAAS) provided by the Federal Aviation Administration (FAA) (Nowatski 2004). The Beacon service consists of two ground control centers and 60 remote broadcast sites scattered across the continental United States that provide correction signals with a reported accuracy of <3 meters when in range of a broadcast site (Nowatski 2004). A limitation of the Beacon signal is that it is broadcast in amplitude modulated (AM) radio frequency. AM signals are prone to degradation by weather events and atmospheric conditions which could decrease GPS accuracy (Nowatski 2004). Most of Louisiana except for the Northwestern and Southwestern portions is in a dual coverage area that receives correction signals from Vicksburg, MS, and English Turn, LA (USCG 2005).

Wide Area Augmentation System (WAAS) consists of approximately 25 ground reference stations and two master stations that monitor GPS satellite data. Data is analyzed and converted to correction data that is uploaded to one of the two geostationary satellites in fixed position over the equator (De Priest 2004). The geostationary satellites then transmit that data to WAAS enabled GPS receivers to increase accuracy levels. WAAS enabled receivers have a reported accuracy of <3 meters (Nowatski 2004, FAA 2005).

Several companies offer subscription-based differential correction services; some of these include OmniSTAR (OmniSTAR Inc, Houston, TX), John Deere (Moline, IL), Case IH (Racine, WI), and AGCO (Duluth, GA). These differential corrections have advertised accuracies of ≤1 meter and are available for approximately $800 per year (Nowatski 2004). The OmniSTAR correction service advertises sub-meter accuracy across the continental U. S. and Canada. OmniSTAR correction is similar to WAAS in that it employs ten base stations in the continental U. S. and one in Mexico. These base stations transmit GPS correction data to the network control center in Houston, TX where it is then uploaded to the OmniSTAR stationary satellite and broadcast to remote GPS receivers (OmniSTAR 2005).

The goal of newer chipset and software technologies is to provide better accuracy without differential correction even in low signal conditions. These include SiRF technology and SiRF XTrac (SiRF Technology Inc., San Jose, CA). SiRF technology GPS's include multipath mitigation, patented foliage lock which tracks weaker satellite signals and single sat which allows for tracking if only one satellite is in view (SiRF Technology 2005). These technologies are promoted as superior products for vehicle navigation and in urban canyon environments. XTrac is built on previous SiRF technology and tracks GPS signals at far lower signal levels than currently possible with other autonomous GPS's. XTrac advertises use in low signal conditions such as urban canyons, parking garages, dense foliage, under bridges and overpasses, and indoors (SiRF Technology 2005).

Objective

The objective of this study was to demonstrate the accuracy of commercially available DGPS signals used in precision agriculture in Louisiana.

Materials and Methods

This demonstration was done at the Northeast Research Station (Latitude 31.949836, Longitude -91.233717) located near St. Joseph, LA in Tensas Parish (Figure 1). Five commercial GPS correction technologies and one uncorrected were tested during this study including: RTK (standard), WAAS, Beacon, OmniSTAR, SiRF, XTrac, and uncorrected (Table 1). Two separate fields were mapped in the morning and afternoon simultaneously with each GPS unit. The first field (Open Field) was an open area with no visible obstruction to satellites. This field was approximately 7.78 acres in size and was located adjacent to a RTK base station. The second field (Trees Field) was completely surrounded by trees and had approximate area of 17.38 acres. The second field was approximately 3,200 ft (0.6 miles) north of field one. All data except that for the RTK was recorded on handheld computers (Dell, HP, and Trimble) and Site Mate version 10.1 software. Data collected in Site Mate was in the UTM coordinate system; zone 15 N, datum NAD 83. The RTK data was recorded using a Trimble Ag GPS 170 computer in the Geographic Latitude/Longitude coordinate system, datum WGS 84. The RTK data was projected to the UTM system using ArcView 3.3 and the projection utility extension. All GPS receivers were mounted to a Kawasaki Mule ATV (Figure 2). Antennas were mounted as close as possible to the vehicle's midpoint between the front and rear axles. All data was imported into ArcView 3.3 GIS for display and analysis. Acreage calculations and percent change from RTK values for each individual field boundary was processed using ArcView 3.3 Area tools extension. All field boundaries were compared to the corresponding RTK field boundary as a standard. GPS drift from standard was also calculated for each field boundary. These data were obtained using the measuring tool in ArcView 3.3 to measure the distance between RTK values and other correction boundaries at the points where the boundary was farthest away from the known RTK boundary.

Results

The Beacon and OmniSTAR correction signals consistently outperformed the other corrections in ranges for acreage error and drift (Table 2 and Figures 3-6). The Beacon receiver demonstrated an acreage error range of ±1.1% when compared to the standard (RTK). The drift from boundary for the Beacon receiver ranged from 0-10 ft. but was in the 0-4 ft. range for three of the four boundaries. The OmniSTAR receiver had an acreage error range of ±2.2% and drift of 0-11 ft. The OmniSTAR drift was 0-4 ft or less for three of the four boundaries though. Surprisingly, the WAAS receiver performed poorly when compared to the Beacon and OmniSTAR and did not separate itself from the uncorrected signals. The WAAS signal had an acreage error range of ±5.8% and a drift range of 0-25 ft. The WAAS drift range was only less than 8 ft. for two of the four boundaries. The uncorrected GPS performed better than the newer technology, XTrac GPS and SiRF GPS. The uncorrected signal had an acreage error range of ±3% and a drift range of 0-12 ft but was less than 7 ft. for three of the four boundaries. The SiRF receiver had an acreage error range of ±8.6% and a drift range 0-25 ft. but was less than 8 ft. for three of the four boundaries. The XTrac receiver had an acreage error range of ±7.8% and a drift range of 0-47 ft. but was less than 12 ft. for three of the four boundaries.

Discussion

All GPS receivers performed well enough to be used for field scouting of management zones and soil sampling of management zones when sub-meter accuracy is not necessary. The RTK, Beacon, WAAS, and subscription corrections should be used for field boundary mapping, variable rate applications, yield monitoring, and soil EC mapping. For topography/elevation mapping and auto-steer the RTK will provide the highest degree of accuracy. This demonstration was done on a particular day and timeframe. Other similar test may yield different results depending on location, weather, receiver quality, time of day, etc. However, one must keep in mind that as accuracy increases so does receiver price.

Table 1. DGPS receivers used in correction testing.

Correction	Published Accuracy
RTK	< 2 cm
OmniSTAR	< 1 meter
Beacon	1-3 meter
WAAS	1-3 meters
Uncorrected	< 10 meters
SiRF	< 15 meters
SiRF/XTrac	1-5 meters

Table 2. Field boundaries acreage, % error, and drift range results.

Open Field AM GPS	Acreage	% Acreage	% error	# Satellites	HDOP	Drift (Ft.)
RTK	7.787	100	0	6	2.6	0
WAAS	7.838	100.6	0.6	5	2	0-25
Beacon	7.85	100.8	0.8	7	1.4	0-10
OmniSTAR	7.929	101.8	1.8	6	1.5	0-11
Uncorrected	7.646	98.2	-1.8	5	2.3	0-12
XTrac	8.146	104.6	4.6	7	1.5	0-47
SiRF	8.463	108.6	8.6	6	1.5	0-25

Trees Field AM						
RTK	17.38	100	0	N/A	N/A	0
WAAS	16.374	94.2	-5.8	N/A	N/A	0-18
Beacon	17.192	98.9	-1.1	N/A	N/A	0-4
OmniSTAR	16.995	97.8	-2.2	N/A	N/A	0-4
Uncorrected	17.798	102.4	2.4	N/A	N/A	0-7
XTrac	17.724	102	2	N/A	N/A	0-11
SiRF	16.916	97.3	-2.7	N/A	N/A	0-8

GPS	Acreage	% Acreage	% error	# Satellites	HDOP	Drift (Ft.)
Open Field PM						
RTK	7.779	100	0	6	4.1	0
WAAS	7.932	102	2	6	2	0-5
Beacon	7.832	100.7	0.7	6	2	0-3
OmniSTAR	7.94	102.1	2.1	6	2	0-3
Uncorrected	7.548	97	-3	6	2	0-6
XTrac	7.872	101.2	1.2	6	2	0-7
SiRF	8.016	103	3	6	2	0-7
Trees Field PM						
RTK	17.321	100	0	6	2.6	0
WAAS	16.86	97.4	-2.6	7	1.3	0-8
Beacon	17.191	99.2	-0.8	7	1.3	0-3
OmniSTAR	17.031	98.3	-1.7	8	1	0-3
Uncorrected	17.769	102.6	2.6	6	1.5	0-6
XTrac	18.664	107.8	7.8	8	1	0-12
SiRF	16.909	97.6	-2.4	8	1	0-8

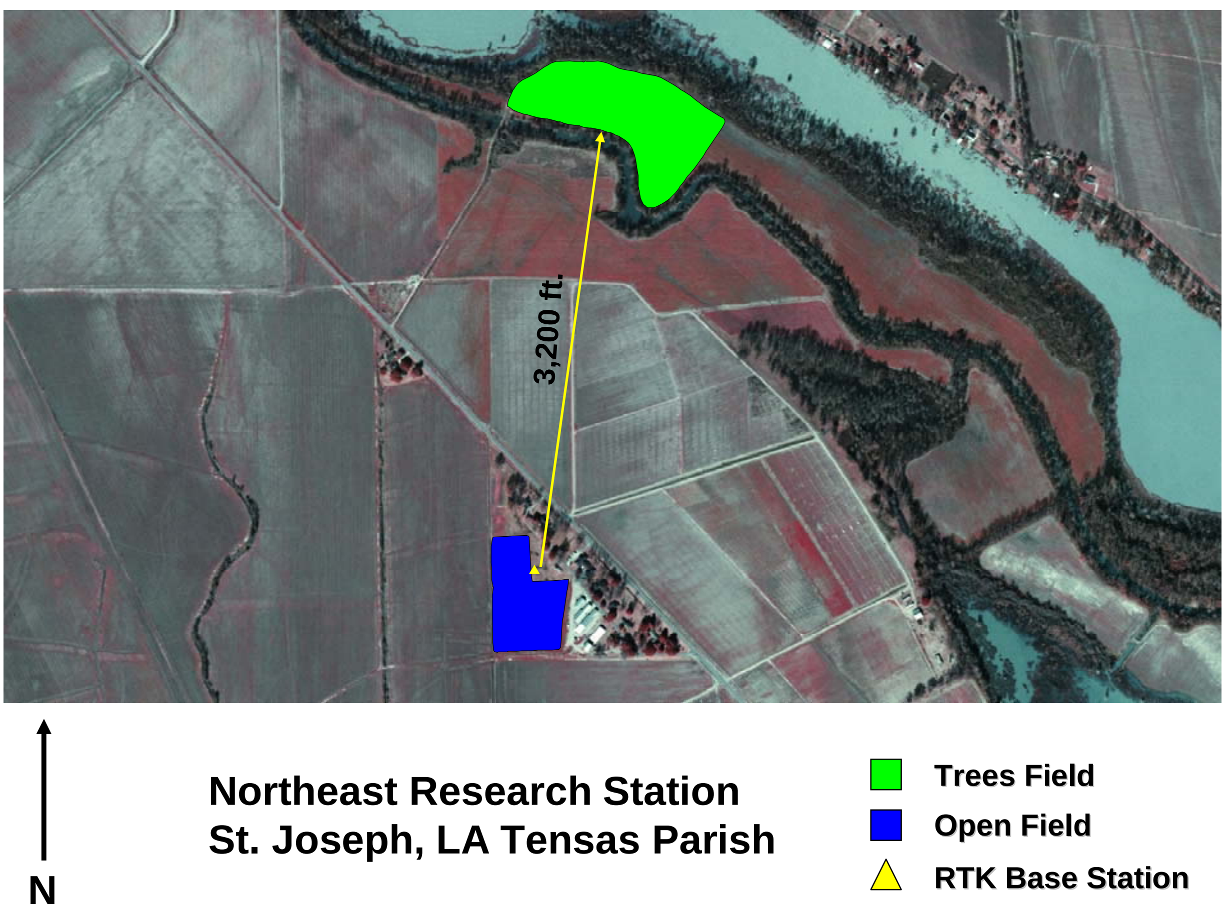

Figure 1. Aerial imagery of test site location and fields.

Figure 2. ATV mounted with GPS receivers.

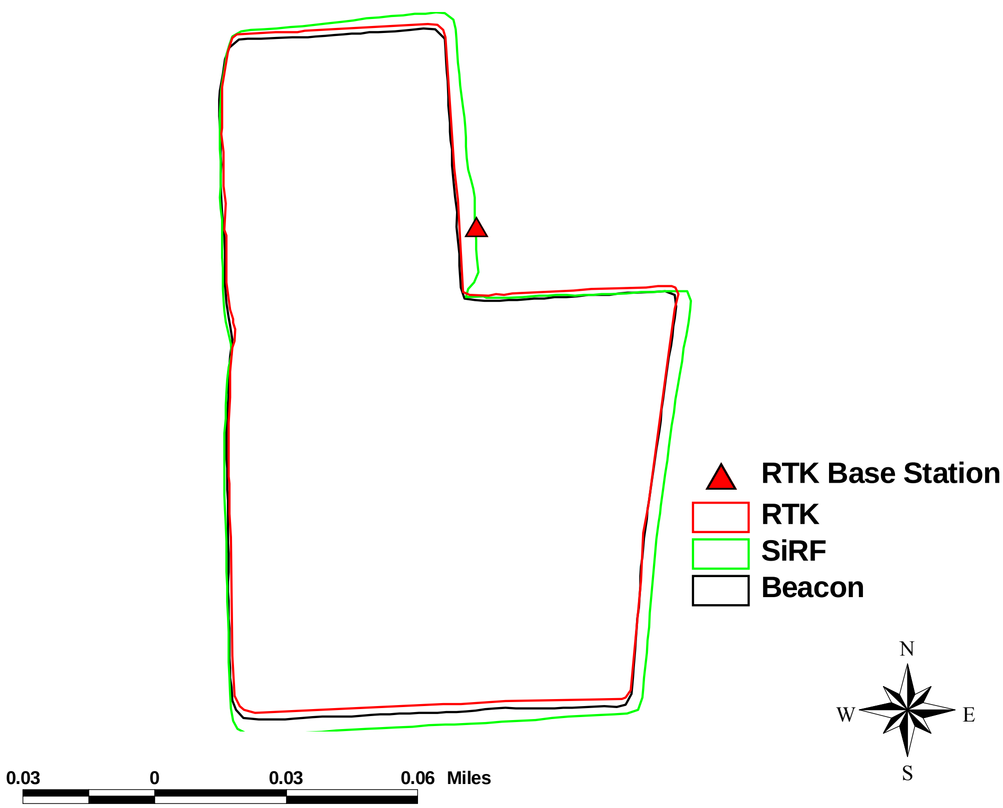

Figure 3. Open field (AM) illustrating the most and least accurate corrections.

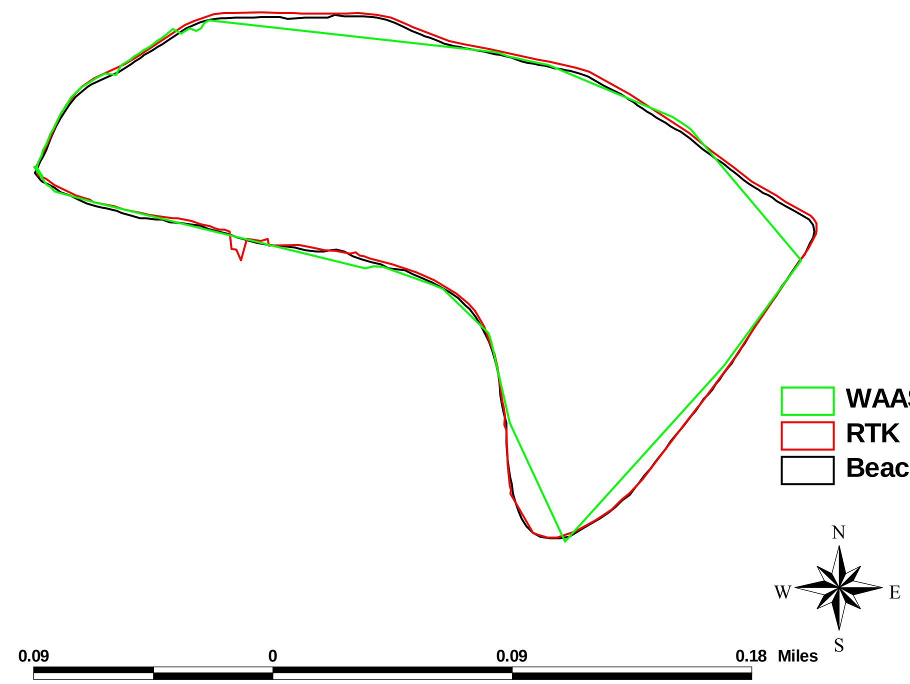

Figure 4. Trees field (AM) illustrating the most and least accurate corrections.

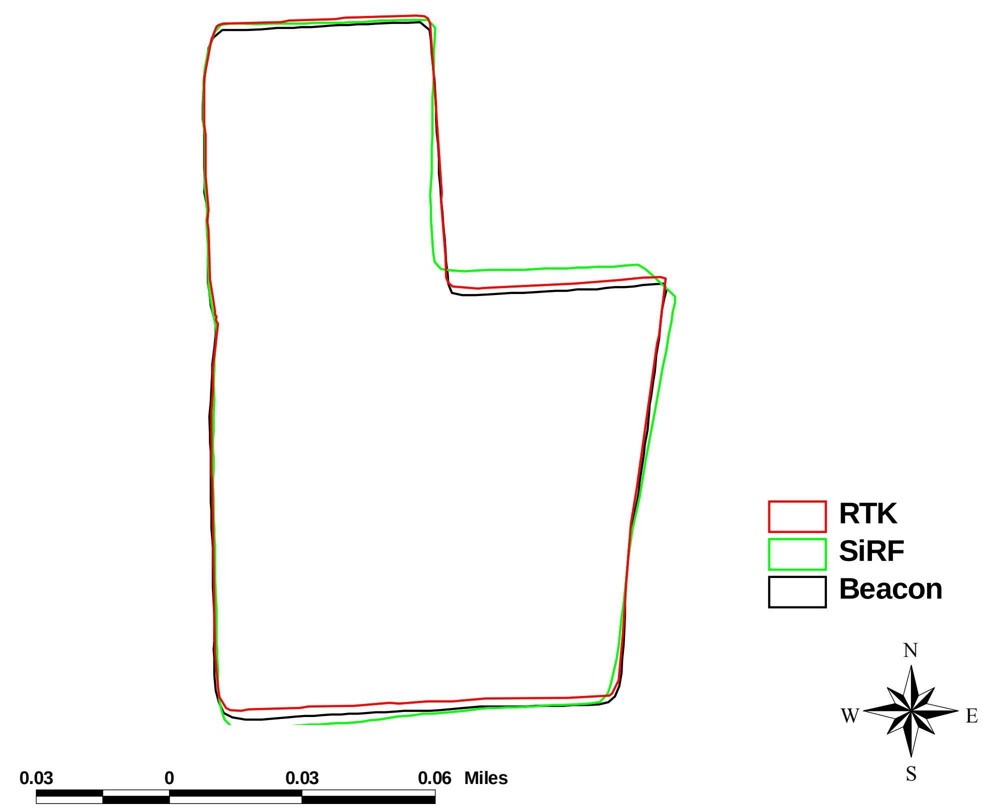

Figure 5. Open field (PM) illustrating the most and least accurate corrections.

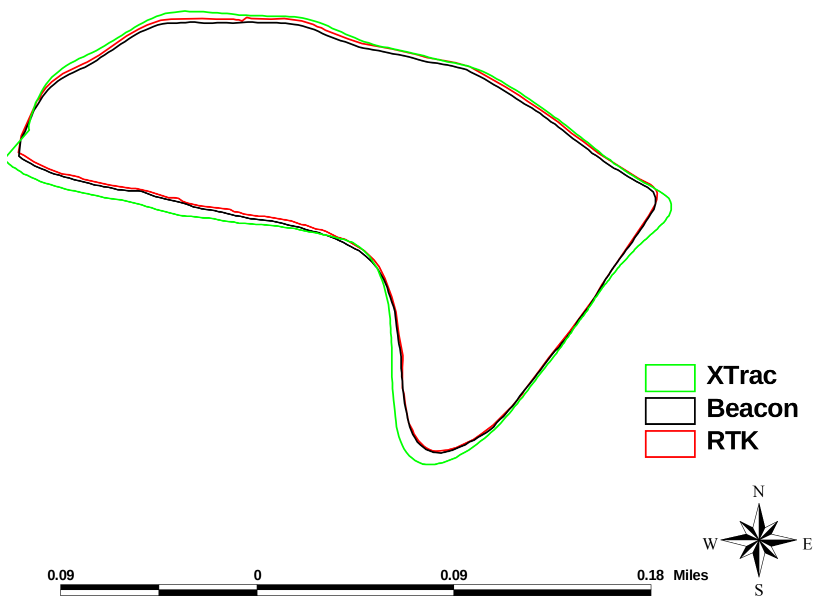

Figure 6. Trees field (PM) illustrating the most and least accurate corrections.

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