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Mechanized Irrigation System Positioning Using Two Inexpensive GPS Receivers

R. Troy Peters, Ph.D.

USDA-ARS, Bushland, Texas

Steven R. Evett, Ph.D.

USDA-ARS, Bushland, Texas

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Abstract. *Precision irrigation or chemigation using mechanized irrigation systems such as center pivots or lateral moves requires accurate and real-time knowledge of the irrigation system's field location. A GPS receiver mounted on a center pivot or lateral move has the potential to increase the accuracy of these position estimates. Differentially corrected GPS receivers have become more affordable (less than $200 US) and it has become more feasible to use them for reporting field position of mechanized irrigation systems. Although these low-cost differentially corrected receivers have been shown to have accuracies of 95% less than 2.1 meters in previous experiments in the panhandle of Texas, the remaining 5% of the reported points gave errors greater than 6 meters. These errors are large enough to present problems for site-specific irrigation. It was hypothesized that the errors from an additional GPS receiver in a known, stationary location could be used to correct the positioning estimates of the receiver mounted on a moving irrigation system and thereby improve the accuracy sufficiently for use with precision irrigation or chemigation. This was tested by placing two similar low-cost receivers in stationary locations and correlating the errors in the North-South and East-West directions. The* r^2 *values of the linear regression lines were very small, showing that almost no correlation existed between the errors of these two receivers. This demonstrated that the integration of an additional, stationary low-cost GPS receiver will not significantly improve positioning estimates of GPS receivers mounted on moving irrigation systems.*

Keywords. *Precision irrigation, Site-specific irrigation, Center pivot, Lateral move*

Introduction

Along with increased accuracy, the cost of differentially corrected GPS receivers has been decreasing, making possible their use in many additional applications. One such application includes precision farming where GPS systems are used to guide tractors, and to create yield maps. There has been additional interest in using GPS technology for center-pivot or lateral-move positioning for precision or site-specific irrigation or chemigation.

Most modern center pivots use a small instrument called a resolver to report angular position. However, these are often subject to errors. A major limitation of using resolvers for site-specific irrigation work is that they only report the position of the first tower from the center point. The resolver-reported angular position of the first tower may not translate into an accurate representation of the position of the end tower. Other site-specific irrigation research has found errors in the reported resolver angle and identified correction algorithms to get accurate field positions (e.g. Sadler et al., 2002; Peters and Evett, 2005). Though these errors are not a cause for concern for most irrigators, accurate pivot position is required for site-specific irrigation. A low cost GPS receiver mounted near the end of the pivot could provide a more accurate representation of the pivot's position; (Peters and Evett, 2005) and the GPS receiver could also be used as a safeguard for the resolver-reported angular position.

Site specific irrigation with lateral-move irrigation systems requires accurate reporting of the real-time position in the field. This is difficult to obtain on lateral-move systems since most lateral-move control systems do not have a mechanism for reporting field position. Heermann et al. (1997) discussed the position reporting alternatives and concluded that GPS was the most viable method for determining field position for lateral-move systems. Applying GPS positioning to lateral-move systems could provide significant cost savings over buried cable, or other alignment and control systems in use.

Heermann et al. (1997) investigated non-differentially corrected GPS positioning on a lateral-move irrigation system for site-specific irrigation work. They determined potential position with dead reckoning based on travel speed and known initial position. This was then corrected with an averaging algorithm applied to the GPS receiver reported positions. The demonstrated accuracy was within plus or minus 7 m. Kostrzewski et al. (2002) briefly described a lateral-move system with a differentially corrected GPS unit mounted on one end for reporting system position. In this experiment the position accuracy was described by fitting a regression curve to the measured points from a moving system and the variance from the regression was discussed. Reinke Manufacturing Inc. (Deshler, Nebraska) has applied for a patent (Barker, 2004) for a GPS control system for mechanized irrigation systems; and GPS units are being tested on cornering systems (Robinson, 2003). Peters and Evett (2005) investigated the accuracy of low-cost GPS units as applied to center pivots or lateral-move irrigation systems and found that significant improvement of angular position reporting was possible. The tested low-cost receiver was accurate to within 2.1 m 95% of the time. However, the remaining 5% of points had errors as large as 6.6 m.

The probable causes for GPS position error include interferences in the ionosphere, the ephemeris and the troposphere, as well as multi-path errors and problems with the GPS clock and receiver. It was hypothesized that incorporating the use of a second GPS receiver positioned in a known stationary location might be used to compensate for the errors caused by atmospheric differences. This could either be at the pivot point, or at a nearby location for lateral-move systems. Atmospheric conditions that would cause errors in one receiver might also cause similar errors in the other receiver. Therefore the position as reported by a mobile receiver mounted on the irrigation platform might be corrected by subtracting the error between the position as reported by the second receiver from its known location. The objective of this research was to test the hypothesis that the accuracy of a low-cost GPS receiver mounted on a moving irrigation platform could be significantly improved by using a second receiver in a known location and correcting the errors of the mobile receiver based on the errors of the stationary receiver.

Materials and Methods

To be able to correct the position of one receiver based on the other, the errors of both receivers would have to track together. In other words, if one receiver gave an error of one meter to the south of the true position, then the other receiver should give a similar error. Ideally a regression line of the errors plotted against each other in one direction would have a slope near to unity and an r^2 term also close to one. To test this two different low-cost (US $170), OEM (original equipment manufacturer) GPS receivers (Garmin 16 HVS and 17 HVS)[1] were set out in a field in stationary locations away from possible interferences and left for an extended period of time. These receivers were wired into Campbell Scientific dataloggers (CR10X and CR23X). The dataloggers read and recorded the output NMEA (National Marine Electronics Association) sentence ($GPGGA), which used the RS-232 protocol, on one minute intervals. The data from each receiver was later aligned with data from the other based on the highly accurate time stamp associated with each reading.

The reported positions in longitude and latitude were translated into X-Y positions on a theoretical grid using a series of equations described by Carlson (1999). These equations used the WGS-84 (World Geodetic Survey 1984) reference datum to determine the earth's spheroid model. The average position of the receiver was set as the axis origin and the variations of the individual measurements were calculated as points on that grid. These same receivers were later tested separately with the WAAS differential correction disabled.

Results and Discussion

The low-cost, OEM Garmin receivers were compared against each other in the North-South (Figure 1) and in the East-West (Figure 2) directions. The equation of the linear regression line and the r^2 coefficient of the fit are also shown in each figure. These receivers were only capable of outputting the latitude and longitude with four decimal places, causing the limited location precision shown. It can be seen that there is virtually no correlation between the errors of the two receivers as indicated by an r^2 value of 0.0193 in the N-S direction and 0.0306 in the E-W direction. This shows that the WAAS differential correction is already correcting for the positioning errors caused by the atmosphere. Even though the WAAS ground station is far away, this is apparently close enough for accurate estimation of the atmospheric influences on GPS position accuracy. The remaining errors are likely due to the GPS clock and receiver inaccuracies. The performance of the two low-cost GPS receivers is summarized in Figure 3. The Garmin 16 HVS performed slightly better than the Garmin 17 HVS with both having a 95% error rate less than one meter over the course of the trial.

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[1] The mention of trade or manufacturer names is for information only and does not imply an endorsement, recommendation or exclusion by USDA-Agricultural Research Service.

The two low-cost, OEM Garmin receivers were again tested with the WAAS differential correction disabled. The errors without WAAS correction of the Garmin 16 HVS were plotted against the errors of the Garmin 17 HVS in the North-South direction (Figure 4). The linear regression line with its equation and r^2 value are also shown. The same was done in the East-West direction (Figure 5). Although the r^2 term in the North-South direction was very small (0.0211), the r^2 of the errors in the East-West direction was 0.4324 showing a slight correlation between the errors of the two receivers in that direction. This supports the premises that although there are errors caused by the atmosphere that could be corrected with a stationary GPS receiver in a known location, these errors are effectively dealt with by the WAAS differential correction. Therefore, using an additional low-cost GPS receiver will not significantly improve the accuracy of GPS units mounted on moving irrigation systems at least in the high plains region of Texas. The performance of the two low-cost GPS receivers without differential correction is summarized in Figure 6. In this case the Garmin 17 HVS receiver performed slightly better than the Garmin 16 HVS receiver. The error statistics for the non-differentially corrected signals are more than twice those of the differentially corrected signals showing the clear advantage of differential correction.

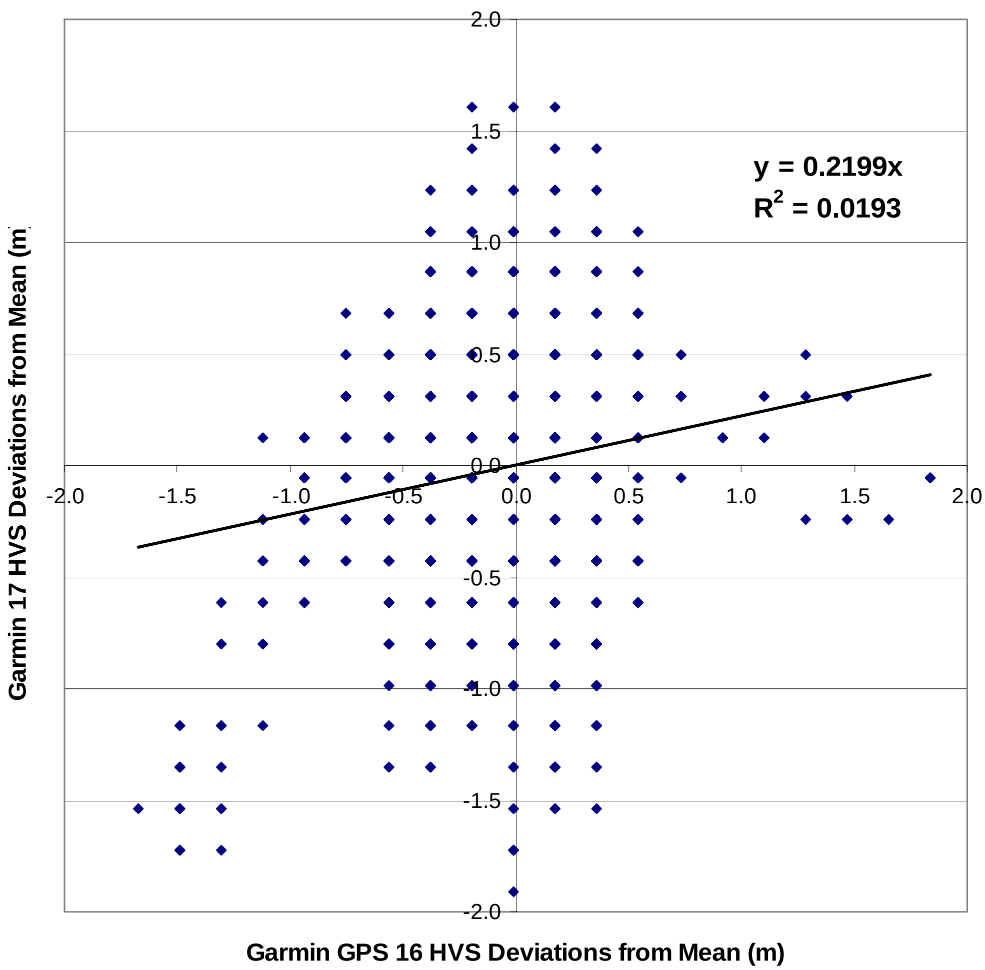

Figure 1. Comparison of the two Garmin GPS receivers (both differentially corrected) in the North-South direction. The equation of the regression line and the r^2 value is also shown.

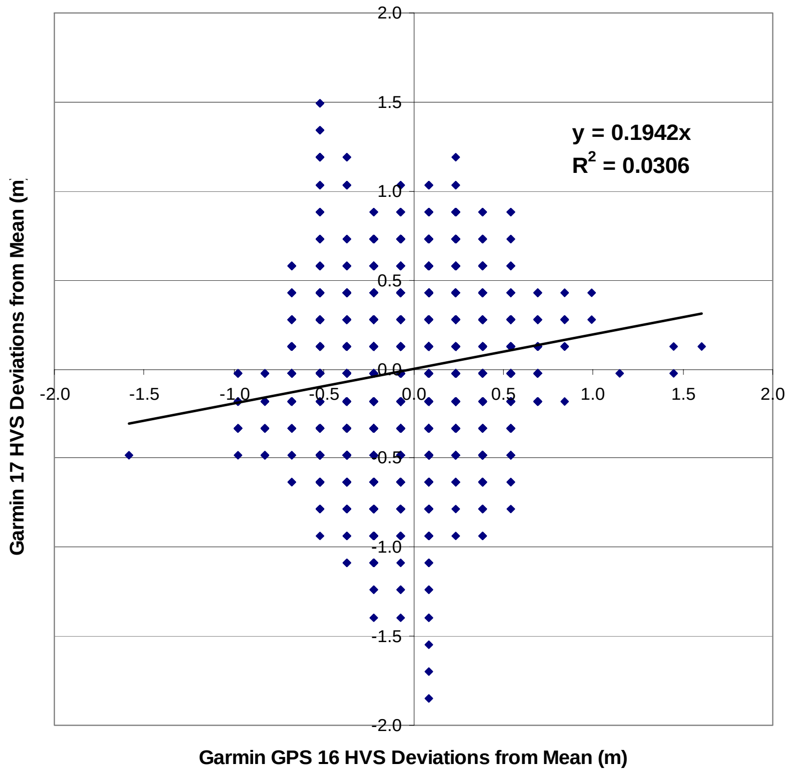

Figure 2. Comparison of the two Garmin GPS receivers (both differentially corrected) in the East-West direction. The equation of the regression line and the r^2 value is also shown.

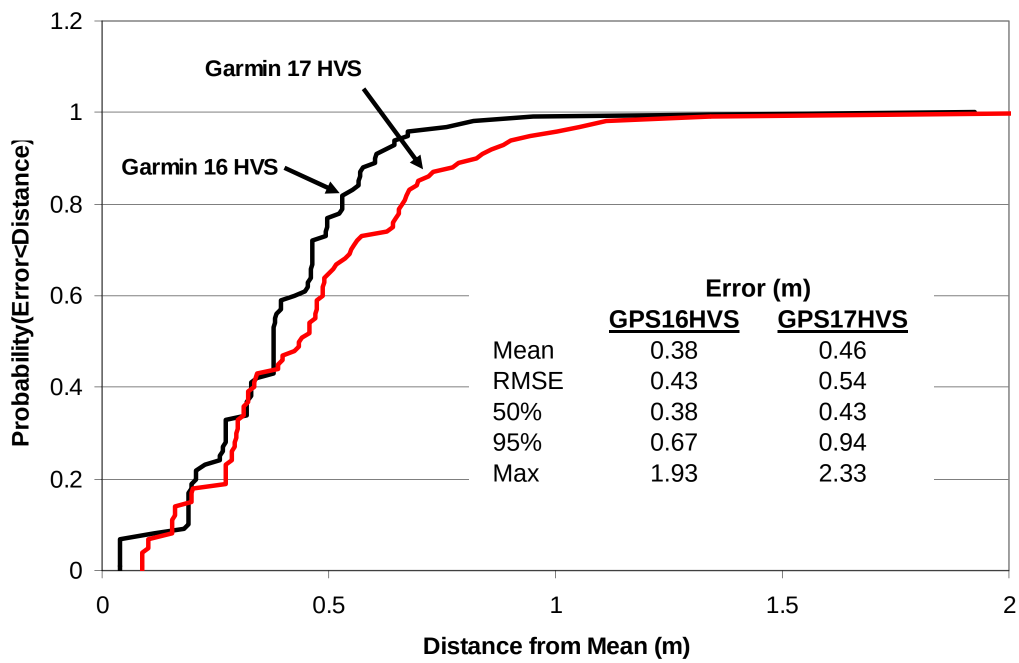

Figure 3. Cumulative probability plot that the GPS error will be less than the given distance for the two low cost GPS receivers with differential correction (WAAS enabled).

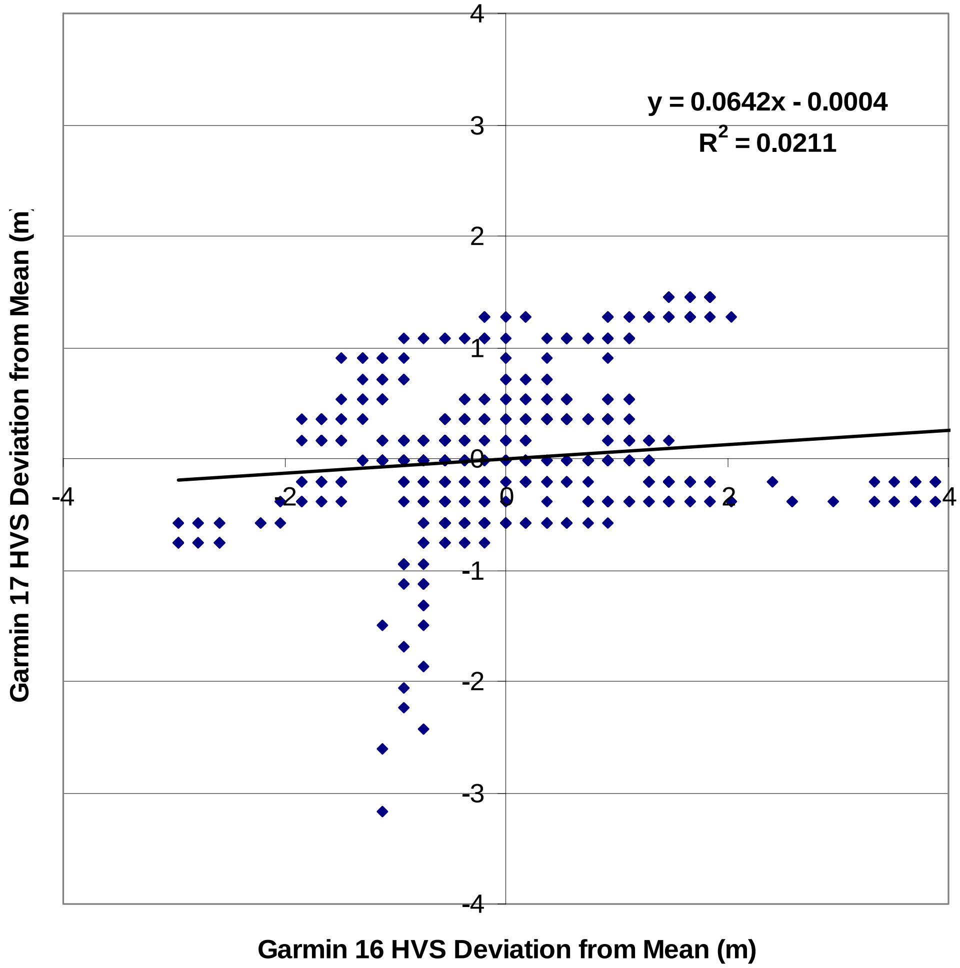

Figure 4. Comparison of the two Garmin GPS receivers without differential correction in the North-South direction. The equation of the regression line and the r^2 value is also shown.

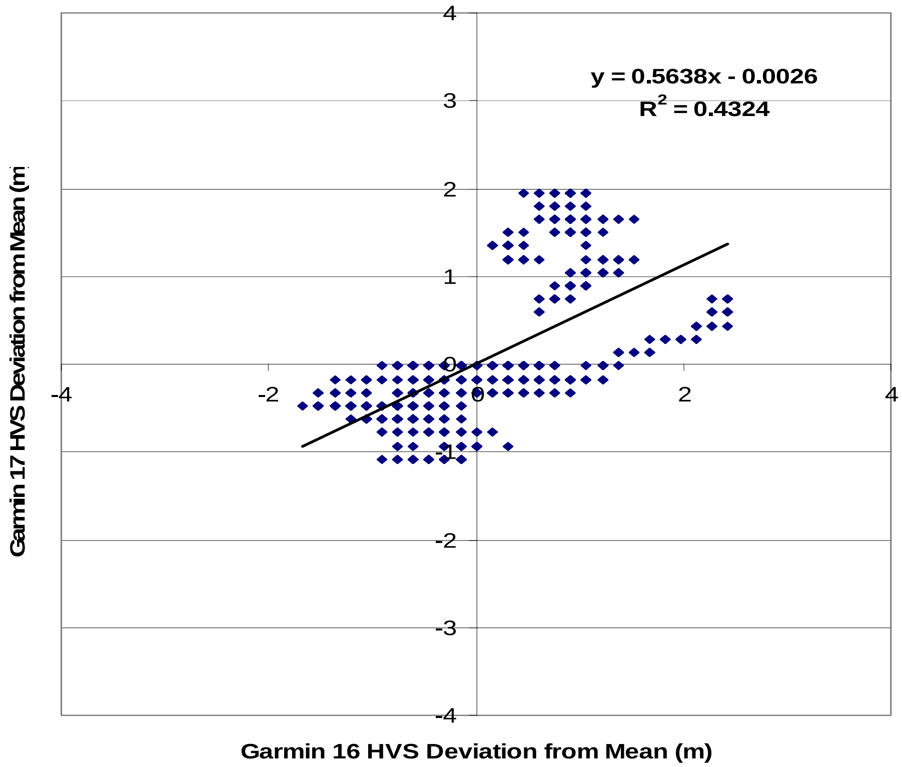

Figure 5. Comparison of the two Garmin GPS receivers without differential correction in the East-West direction. The equation of the regression line and the r^2 value is also shown.

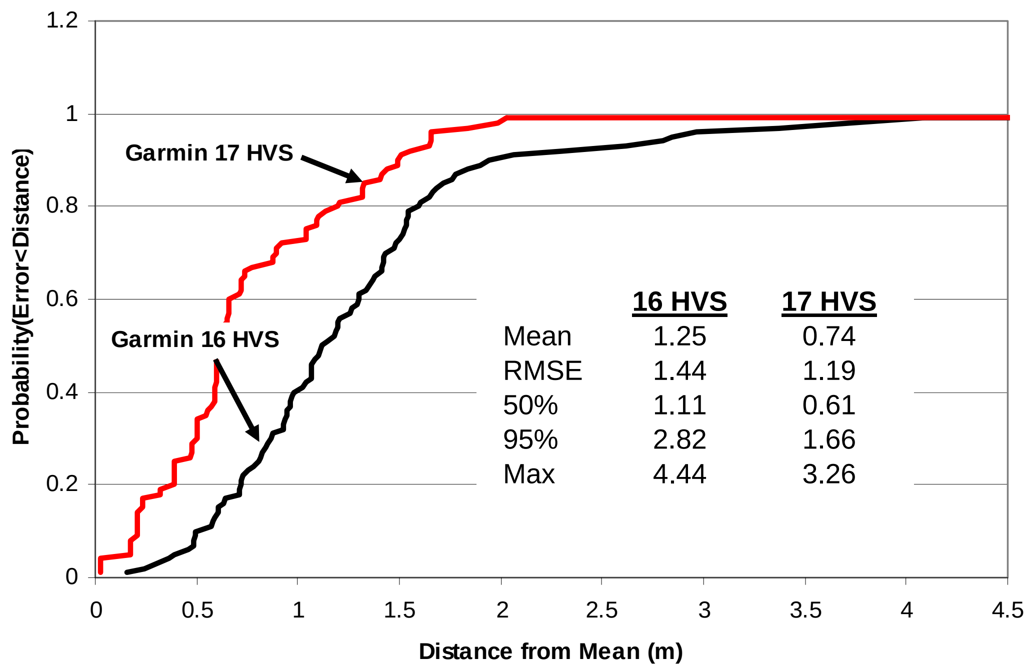

Figure 6. Cumulative probability plot that the GPS error will be less than the given distance for the two low cost GPS receivers *without* differential correction (WAAS disabled).

Summary and Conclusion

Low-cost, differentially corrected GPS receivers can improve the accuracy of position estimates of moving self-propelled irrigation platforms over traditionally used methods for determining the platform's position. This is needed for site-specific or precision irrigation or chemigation. Relatively large outlying GPS positioning errors remain a problem. It was hypothesized that the positioning accuracy could be improved by using the errors of one receiver located in a known position to correct the position estimates of a second receiver mounted on the moving irrigation platform. This hypothesis was tested by placing two different, similar, differentially (WAAS) corrected receivers in stationary locations for extended periods of time. The errors in the North-South and the East-West directions were plotted and a linear regression was run. The r^2 terms were very small (less than 0.05). A similar test was run with the differential correction disabled on both low-cost receivers and a much higher r^2 term was found in the East-West direction. This demonstrates that the differential correction adequately accounted for atmospheric errors even though the WAAS ground station was far away. The integration of an additional, stationary low-cost GPS receiver will not significantly improve positioning estimates of GPS receivers mounted on moving irrigation systems under our test conditions.

Acknowledgements

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