PROJECT BULLSEYE

GNSS RTK Satellite Receiver Testing

Taryn Roby[1], Kyle Albrecht[2], Marianne Okal[3]
Red Rocks Community College, Front Range Community College, UNAVCO

Motivation and Background

Background

GNSS (Global Navigation Satellite Systems) are all of the positioning satellites in outer space, and are composed of three main segments:

- Satellites in space
- Control - worldwide stations monitoring the condition and orbit of satellites
- User - any satellite receiver

Figure 1.
StoneX S900A in use at Boulder Reservoir

Objective

To test the accuracy and precision of four receivers that UNAVCO distributes to members of its community who require them for scientific research - the StoneX S900A, the Emlid Reach RS2, the Septentrio Altus APS3G, and the Trimble R7 and compare each unit's performance at different distances over 3 miles.

- Accuracy - how close RTK data is to true value
- Precision - repeatability of RTK data

Significance

The goal of Project Bullseye is to create a reference guide for the four satellite receivers. Aid scientists in selecting equipment best suited for their scientific research.

An in depth evaluation of each instrument will be provided for UNAVCO's reference.

GNSS Receivers

StoneX S900A	Emlid Reach RS2	Trimble R7	Septentrio Altus APS3G
			

Figure 2.
Chart of the GNSS receivers used in experiment

Methods

1. 10 stationary points identified at intervals of ~0.2 miles with the addition of mile 1.5 and 3.0. Stationary base point collected data for 2+ hours to obtain accurate position. Collected using the StoneX S900A.
2. Interval points underwent static surveys lasting 30 minutes to get accurate solution. Static solutions -due to their high accuracy- served as control data to compare with experimental data.
3. Magnail markers placed at all points for reference when conducting tests.
4. Ten RTK measurements were acquired over each Central and Cluster Point.
5. Precision of RTK equipment was tested to determine if points created within a distance of centimeters can be detected. Three points were placed 2 cm apart next to each other 46 cm away from the Central Point.

Figure 3.
Locations designated for research project at Boulder Reservoir, Coot Lake, N 55th St., and Lookout Rd. Image courtesy of Google Earth.

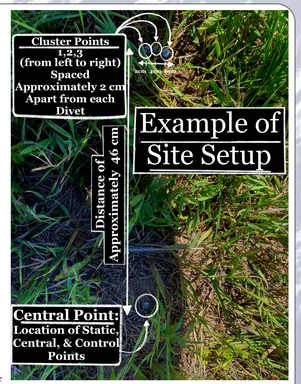
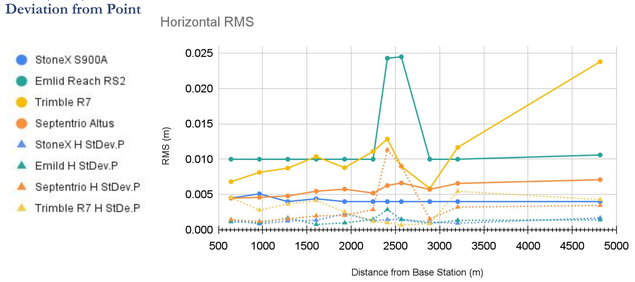


Figure 4.
Diagram of how each site was set up and how the Static Central, Control Cluster Points were taken and where.

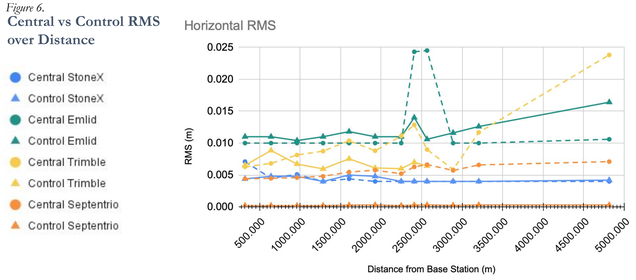
Results

Figure 5.
Instrument Reported Error (RMS) vs Standard Deviation from Point



- The Trimble R7 is the only device that behaved how we initially expected by increasing in error as the rover moved further from the base.
- The error values given by the GNSS receivers seem to be conservative. When comparing the instrument recorded RMS to our standard deviations from the Static Point, the true error seems to be significantly smaller.

Figure 6.
Central vs Control RMS over Distance



- Control Points generally were far more accurate than Central Points which was expected. The exceptions to this observation relate to the Emlid Reach RS2.
- Data points collected near 2,500 meters from the base station see an increase in error both horizontally and vertically. The source of interference with the receivers seems to be caused by density of flora and fauna near Coot Lake.

Figure 7.
Static vs Central vs Control Point Horizontal Error Over Distance

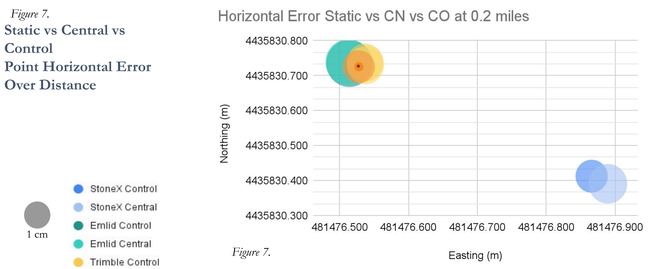


Figure 7.

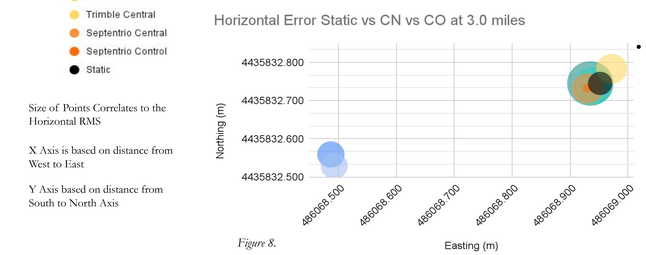


Figure 8.

- Overall all the data represents, these GNSS receivers preformed far better than expected over distance even at 4,000 meters
- Throughout all the data, the StoneX S900A has a consistent offset in accuracy due to the miscalibration of internal leveling mechanism in the device.

Size of Points Correlates to the Horizontal RMS

X Axis is based on distance from West to East

Y Axis based on distance from South to North Axis

Discussion

Data Analysis:

- **Overall as all the data represents, these GNSS receivers performed far better than expected even at distances over 4,000 meters**
- **Error seems far more correlated to obstruction of radio communication and satellite skyview than distance.**

Qualitative Analysis of Devices (Ranked):

1. **This particular Septentrio kit had a highly precise instrument (PolaRx5) used for the base in place of another Altus.** As a result, the Septentrio Altus had a complex set up process, however, once set up, **it worked extremely well**. The tablet is not very user friendly with its touch-screen keyboard.
2. The StoneX S900A was fairly easy to use with the accompanying tablet and the **data was precise. Accuracy errors were caused by a miscalibration of the internal leveling mechanism of the device.**
3. Emlid Reach RS2 is extremely easy to use with a friendly user interface and set-up process. **The data collected by this device has slightly larger errors in comparison to the other devices. Given the errors, it is recommended for scientific work that does not requiring precise measurements.**
4. The Trimble R7 was difficult to set up and had many external devices such as transmitters, batteries, antennas that must all be carried. **On the data end, the Trimble R7 was also more inaccurate than the others due to only seeing GPS satellites. Given the age of these units, difficulty in use, and inaccuracy, we believe the Trimble R7 could be phased out of UNAVCO's equipment pool.**

Conclusion

Future Work:

As seen in the graphs, we believed that the error of these devices would increase over distance far more than it did. Researchers in the future could investigate as to how far these devices can record accurately. Researchers could investigate and create a quantitative analysis of further how obstacles blocking the skyview and radio link between the receivers impact the quality of data.

Implications:

As stated in our purpose, all the data we collected will be uploaded onto UNAVCO's website for free distribution for scientists funded by the NSF to use in order to pick a GNSS receiver that suits their scientific needs. This data may also be used at the discretion of UNAVCO to determine the value of possessing each brand of receiver.

Figure 9.
Taryn Roby (left) & Kyle Albrecht (right) operating StoneX S900A at Boulder Reservoir Photographed by their mentor: Marianne Okal

Personal Acknowledgements:
Thank you to Marianne Okal who was an excellent mentor and Project Bullseye would not be possible without her guidance.
Thank you to the City of Boulder and Joy Master for allowing us access to the Boulder Reservoir which provided an optimal and safe location to conduct our research.
Thank you to Kelsey Russo-Nixon and the Geo-Launchpad program for providing us this amazing opportunity to develop our scientific careers.

"This material is based upon work supported by the National Science Foundation under Grant Nos. 1724794 and 2117397. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation."

Land Acknowledgement:
Front Range Community College & UNAVCO acknowledge that, with respect, the lands that our campuses occupy are the unceded ancestral and traditional homelands of the **Arapaho** (uh-RAH-pah-HO)**, Cheyenne** (shy-AN)**, and Ute**(oo-tee) nations. We further recognize that this workshop is held on the unceded land of **Dakhóta** (DAH-koh-TAH) nation.

We honor the land, the water, all peoples both living and past, and we are grateful to be here - recognizing that the original stewards of this land were those ancestors who have lived here for thousands of years, prior to written histories, as well as the many diverse and vibrant Native communities who are still connected to this land on which we gather today. We ask you to join me in acknowledging their community, their elders both past and present, as well as future generations. This acknowledgement is one small part of our commitment to dismantling the ongoing legacies of settler colonialism.