GPS accuracy part 2: RTK float versus RTK fixed

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ABSTRACT

During the University of Calgary's 2010 geophysics field school, geophone and source point locations for a 3C-2D seismic line were GPS surveyed by student crews over a period of many days. In the course of the RTK GPS (real time kinematic global positioning system) survey, some geophones were surveyed up to three times, particularly in problem areas on the line. In this case, the problem areas had thick bushes and trees, such that the GPS rover was not able to achieve a good GPS solution due to signal attenuation by the vegetation. Comparisons of the repeated data points show that RTK fixed solutions have the best repeatability (accuracy better than one decimeter). RTK float solutions can be as repeatable as fixed solutions, but can also be out by up to five meters, with no way to tell unless surveying a known point. The authors recommend RTK fixed solutions for small station/receiver spacings.

FIG. 1. Typical daily GPS base station setup, looking roughly southwest. The part of the seismic line that is visible in this picture is high-lighted with a red line.

INTRODUCTION

A 2.5 km long east-west 3C-2D seismic line was acquired during the University of Calgary's 2010 geophysics field school. The students in attendance were split into eight groups, and each group was given a different task for the day, one of which was a differential real time kinematic global positioning system (RTK GPS) survey. The system used was a Sokkia GSR2700 ISX RTK system in RTCA GNSS mode (see also Hall et al., 2008). The GPS base station, with a high-power radio to broadcast correction terms, was consistently setup over the southwest corner of a cement patio at the Rothney Astrophysical Observatory (Figure 1). Setup was done daily, by the students. The base station location was determined by averaging five minutes of GPS readings on the first day, and using this information as a 'known point' on subsequent days. GPS data were corrected to a nearby survey monument (ASCM 176727) after the survey was completed. The survey monument was surveyed with the GPS rover on the last day of field school. This post-survey correction was less than 1.5 m.

Geophone and source point locations were acquired using the GPS rover with no averaging (i.e., the location is taken to be the result of a single GPS calculation), which should give decimeter accuracy for RTK fixed solutions. The GPS system typically returns results in three different modes. In order of increasing accuracy, these are; 1) autonomous, 2) RTK float and 3) RTK fixed. Autonomous means the GPS rover is not receiving corrections from the base station radio, due to problems at the base station, distance from the base station, or topography (radio doesn't go through hills). RTK Float is similar to autonomous, in that it is a stand-alone mode. While the rover is receiving corrections from the base station in this mode, it either cannot see enough satellites to make an accurate calculation, or does not have enough satellites in common with the base station for the correction term to be valid. RTK fixed means that the GPS rover and base station can see at least five satellites in common, and the rover is receiving corrections from the base station.

The seismic line started half a section (~800 m) south of the Rothney Astrophysical Observatory (station 101), and followed an east-west road allowance to the west, crossed highway 22 using a microwave link, and proceeded another section (~1600 m) to the west. The topography of the seismic line generally trends downhill to the west (towards higher station numbers) with a steep hill half-way along the section west of the highway (Figure 2). An east-dipping sandstone outcrop was observed near the top of the west side of this hill, opposite to the overall trend. Before starting the GPS survey, it was assumed that the base station would have to be moved from the patio to a rover-surveyed point at the top of the hill, in order for the GPS rover to receive corrections in the radio shadow west of the hill. Interestingly, this turned out to be untrue. The rover was able to receive corrections from the base station at the Rothney Observatory at all points on the line.

Of more concern was the thick brush and trees at the base of the hill (both sides), which made obtaining a RTK fixed solution difficult or impossible, as signals from the satellites are attenuated by the vegetation. Due to the nature of field school, we were able to send different crews of students into the bushes on different days, and at different times of day, in order to try to improve our survey. This report shows comparisons of repeated measurements of geophone locations by three different crews: Aug 31, September 1 and September 4. A total of 137 geophone locations were re-surveyed, with varying degrees of success.

The question is: What are the consequences in terms of accuracy, if RTK float is the best that can be obtained for a given location?

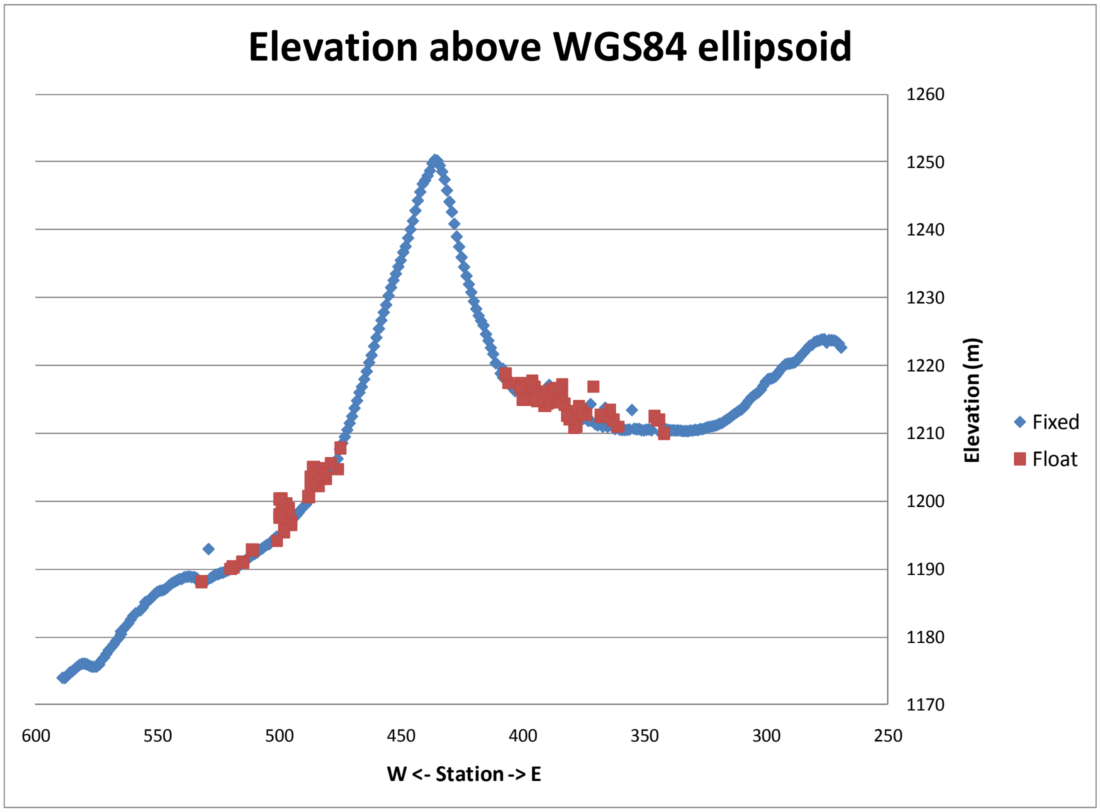

FIG. 2. Elevation profile for the western end of the line (west of highway 22).

DATA PREPARATION

Survey flags were placed every 10 m by the chaining crews; every eighth station was labeled with a station number and was given a different colour (red flag every eight stations). This means that the chaining crew had to be able to add by eight, and the GPS survey crew had to be able to add by one, and assume the chaining crew was correct. All of which was mostly true – but there was some trouble in the bushes. So, after combining the daily data, some attention had to be paid to confirming, or fixing, station numbers recorded by the GPS crew. This was done in two ways: 1) by calculating station to station distances and looking for numbers significantly different than the known station spacing (10 m), and 2) by plotting the data on a map with the station numbers and visually inspecting the result.

After the station numbers were reconciled, the data were sorted by station number, and geophones that had been surveyed more than once were identified. Triplicates were converted to duplicates such that while one data point might appear in more than one comparison, each comparison is unique. Finally, the duplicates were separated by type, Fixed-Fixed (both fixed solutions), Float-Fixed (one float, one fixed), and Float-Float (both float solutions). Finally, the comparisons were made by subtracting eastings (*x*), northings (*y*) and elevations (*z*) for repeated measurements.

RESULTS

Figure 3 shows the total number of comparisons made, colour-coded by type of comparison, plotted against the average number of satellites used in the comparison (i.e. number of satellites for the first GPS calculation plus the number of satellites for the second, all divided by 2). As might be expected, the average number of satellites for Fixed-Fixed is higher than for Float-Fixed or Float-Float, with some overlap. Note that none of the comparisons has fewer than five satellites on average.

Figure 4 is a bar graph showing all of the absolute values of *dx*, *dy* and *dz* for all comparisons. Other than two anomalous results for Fixed-Fixed, it is clear that we need to get a fixed solution for repeatability with accuracy in the decimeter or less range. If a fixed solution can be obtained, accuracy is not improved by having more satellites available. Visually, the Float-Fixed and Float-Float results (decimeter to five meter accuracy for repeated points) appear to be equally poor relative to the Fixed-Fixed results.

Figure 5 shows cross-plots of *dx* vs. *dy*, *dx* vs. *dz* and *dy* vs. *dz*. Again, repeatability is clearly the best for RTK fixed solutions, with the exception of two anomalous points. The best repeatability is in the *x* direction, followed by *y* and *z*.

Table 1 and Figure 6 show the statistical results (minimum value, maximum value, median value, mean value and standard deviation) of the absolute value of the distances calculated for this study, to the nearest decimeter, where 'Count' is the total number of comparisons for that row of the table. The rows labeled 'Fixed-Fixed (edited)' are the Fixed-Fixed results with the two anomalous values removed from the data. Note that these anomalous values, while clearly visible on Figures 2, 4 and 5, are within the range of results for Float-Fixed, and Float-Float – meaning that it would not be possible to identify these points if RTK float were the best available solution.

DISCUSSION

It is clear from Table 1 and Figure 6 that an RTK float solution can be as repeatable as a fixed solution (one decimeter or less), but, it could also be out by up to 5 m. The problem is that we have no way to tell how close a given measurement is to the actual location, without repeating the survey more accurately. As usual, the question that needs to be asked is, how accurate to we need to be? RTK float would likely be good enough for a 100 m station spacing, but not for 1 m or even 10 m station spacing.

The two anomalous points in the Fixed-Fixed data may be explained by the observation that one group of students was holding the range-pole up as high as they could to try and get a fixed solution, then quickly dropping the range pole to the ground beside a geophone and collecting a data point before the unit flipped to RTK float. It is possible that survey points were accidentally acquired while the pole was in the air.

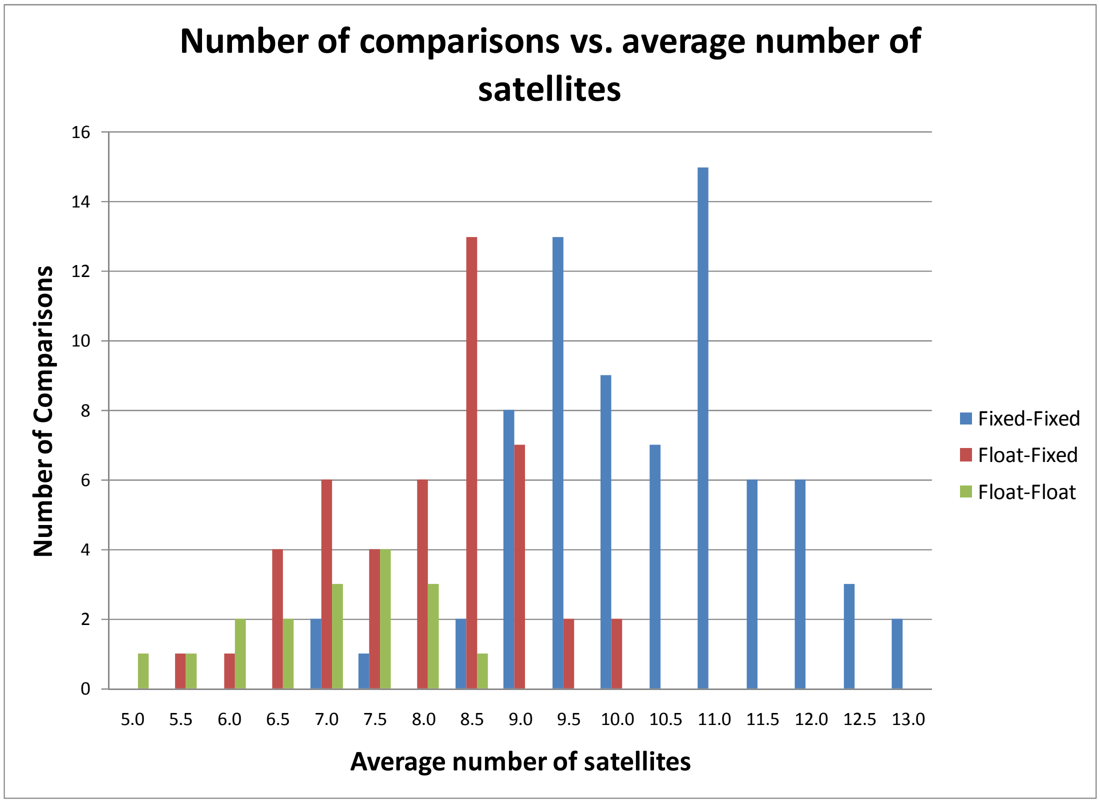

FIG. 3. Number of comparisons versus average number of satellites.

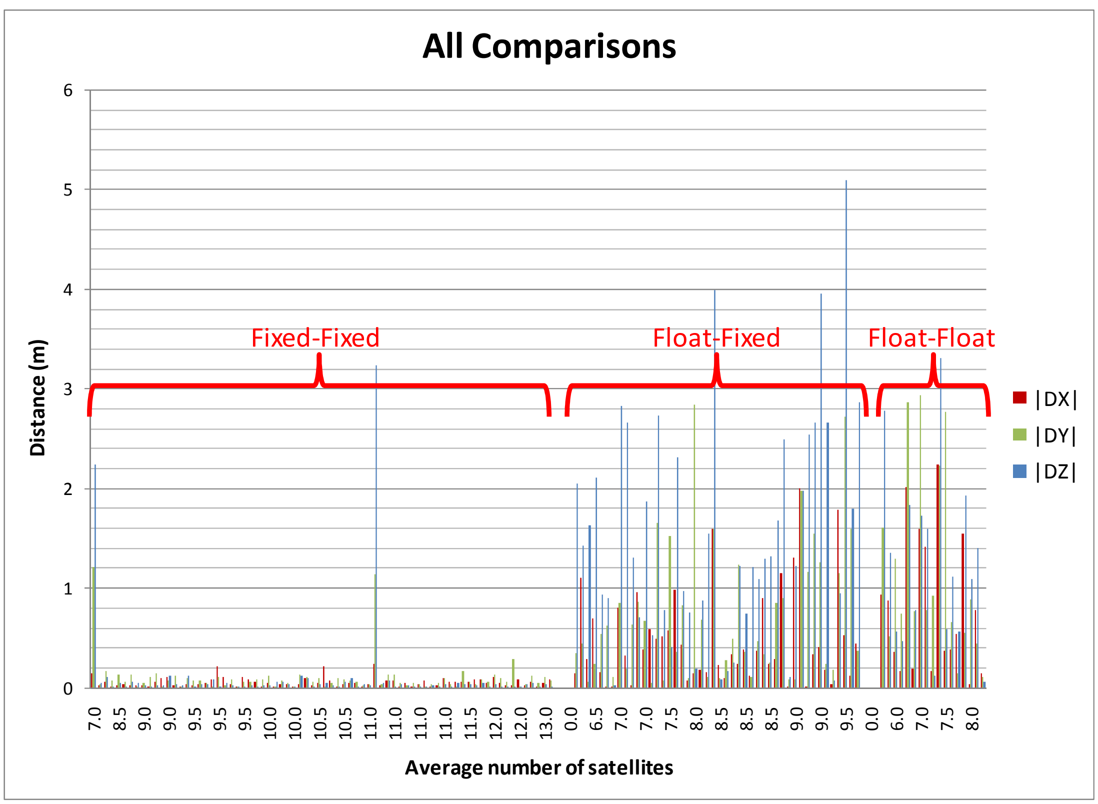

FIG. 4. All results.

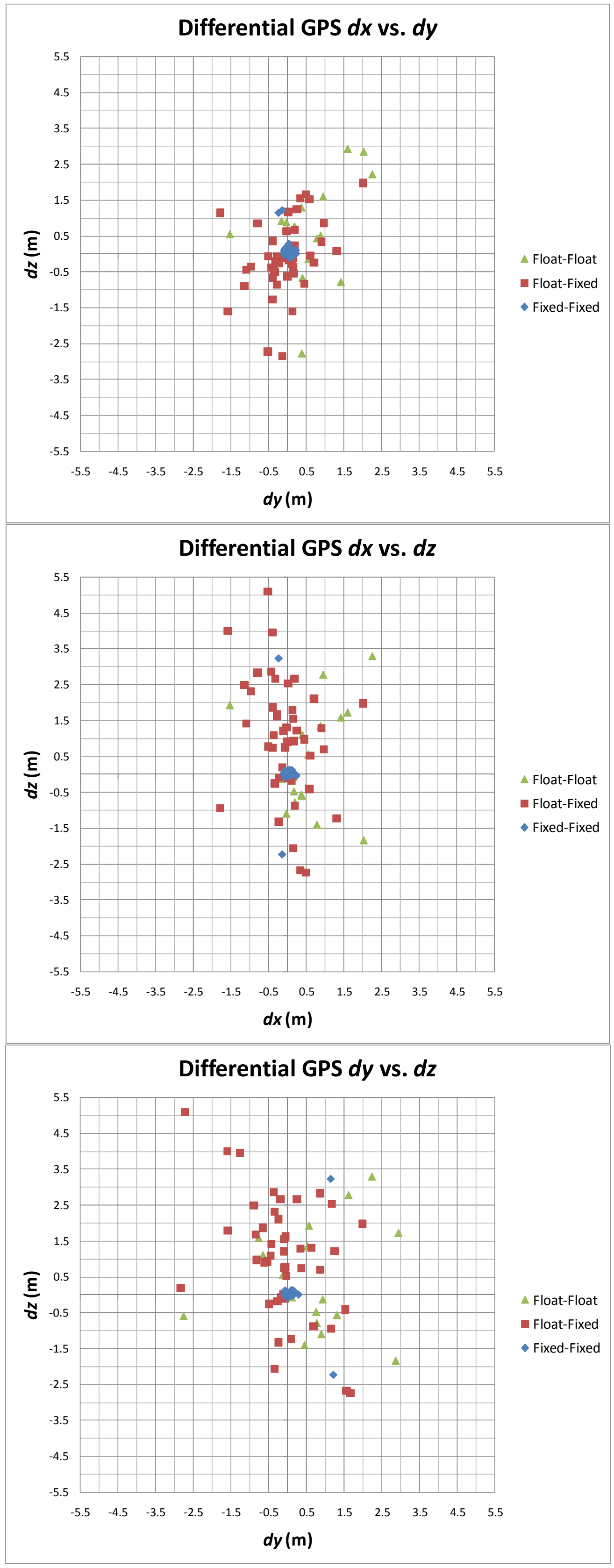

FIG. 5. Cross-plots.

Table 1. Statistics summary.

	Count	|DX| (m)	|DY| (m)	|DZ| (m)
MIN, Fixed-Fixed	74	0.0	0.0	0.0
MIN, Fixed-Fixed (edited)	72	0.0	0.0	0.0
MIN, Float-Fixed	46	0.0	0.0	0.0
MIN, Float-Float	17	0.0	0.1	0.1
MAX, Fixed-Fixed	74	0.2	1.2	3.2
MAX, Fixed-Fixed (edited)	72	0.2	0.3	0.1
MAX, Float-Fixed	46	2.0	2.8	5.1
MAX, Float-Float	17	2.2	2.9	3.3
MEDIAN, Fixed-Fixed	74	0.0	0.1	0.0
MEDIAN, Fixed-Fixed (edited)	72	0.0	0.1	0.0
MEDIAN, Float-Fixed	46	0.3	0.5	1.3
MEDIAN, Float-Float	17	0.5	0.8	1.1
MEAN, Fixed-Fixed	74	0.1	0.1	0.1
MEAN, Fixed-Fixed (edited)	72	0.1	0.1	0.0
MEAN, Float-Fixed	46	0.5	0.7	1.5
MEAN, Float-Float	17	0.8	1.2	1.3
STDDEV, Fixed-Fixed	74	0.0	0.2	0.4
STDDEV, Fixed-Fixed (edited)	72	0.0	0.0	0.0
STDDEV, Float-Fixed	46	0.5	0.7	1.1
STDDEV, Float-Float	17	0.7	0.9	0.9

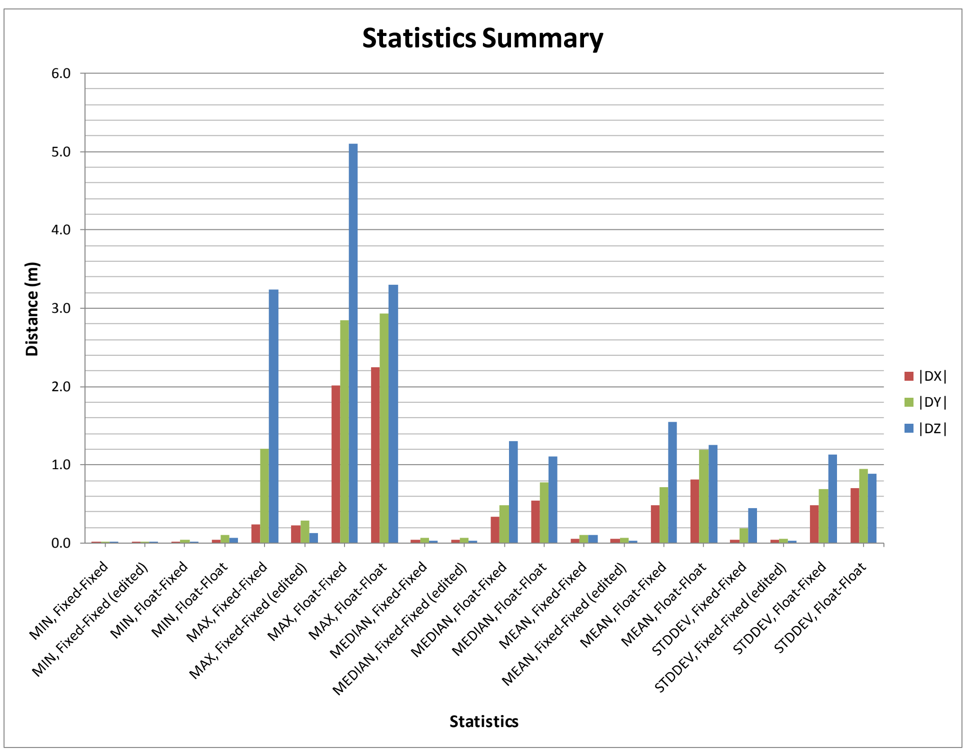

FIG. 6. Statistics summary.

ACKNOWLEDGEMENTS

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REFERENCES

Kevin W. Hall, K.W., Cooper, J.K., and Lawton, D.C., 2008, GPS accuracy: Hand-held versus RTK: CREWES Research Report, **20**.