Submitted 4 hours after the required deadline of 10 PM EST 22/02/22 *without using an extension*. Approved by Professor Singh.

EECE 5554 LAB 2 Analysis Report

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(Data borrowed from Mr. Chenghao Wang)

The region where the borrowed data was collected is *not clearly defined* and as such deviations from a self-estimated actual pose using pin drops on maps, cannot be ascertained.

Data samples are collected at the rate of 5 sample.s^{-1} using an RTK GPS puck[1]

4 scenarios are considered here- *Collection on a secluded open space (motion and static), and collection with lots of occlusions due to buildings (motion and static).*

Static data collection was done (reportedly)

- In an open space at ground level (sea level in this case) at the tennis courts on Carter Playground (with some metal fencing around the courts).
- In front of ISEC with a lot of buildings

Non-Static data collection was done (reportedly)

- In an open space at ground level (sea level in this case) at the tennis courts on Carter Playground (with some metal fencing around the courts), by walking alongside the courts' perimeter.
- In front of ISEC, by walking alongside the roads in a rectangular trajectory

It was determined that the UTM grid origin did not change for this experiment, and as such all the UTM values have been stripped to simply accommodate the offset from the UTM gridlines in meters, to improve the plot readability

The scatter plots have been color coded to show the data quality as encoded 'red' 'green' and 'blue' markers corresponding to the GNSS Fix, RTK Float and RTK Fix kind of solutions.

Data borrowed Quality stats:
S:\contEd\ee\LAB2\borrowed2\isec_moving.bag: Records: 3935, Float: 86.277% (3395)

S:\contEd\ee\LAB2\borrowed2\isec_static.bag: Records: 5084, Float: 85.8183% (4363)

S:\contEd\ee\LAB2\borrowed2\tennis_moving.bag: Records: 5419, Float: 44.4916% (2411), Fix: ~50%

S:\contEd\ee\LAB2\borrowed2\tennis_static.bag: Records: 5396, Float: 100% (5396)

Static Data collection (Open Space)

Table 1. Readouts for static case

Reference Data	**Latitude (Decimal degrees)**		**Longitude (Decimal degrees)**		**Altitude (m)**		**UTM Easting (m)**		**UTM Northing (m)**		**Zone**
	N/A		N/A		~0m (self-assessed)		N/A		N/A		19T
Collected Data	**Latitude (Decimal degrees)**		**Longitude (Decimal degrees)**		**Altitude (m)**		**UTM Easting (m)**		**UTM Northing (m)**		
	Mean	**Std. Dev**	**Mean**	**Std. Dev**	**Mean**	**Std. Dev**	**Mean**	**Std. Dev**	**Mean**	**Std. Dev**	
	42.3394	2.1380e-07	-71.0842	2.8557e-06	3.1576	0.1526	310.3247	0.2352	563.0719	0.0251	
	Variance										
	Latitude		**Longitude**		**Altitude**		**UTME**		**UTMN**		
	4.5710e-14		8.1552e-12		0.0233		0.0553		6.3107e-04		

Table 1 shows the readouts for the static data collection scenario on the Carter Playground Lawn-Tennis courts. Reference positions were not available from the data lending source. Data is collected at sea level. 100% of the published messages had RTK Float as the quality indicator and as a result a particularly good but not the best positioning accuracy.

Focusing on the UTM values after they have been pre-truncated to remove the redundant gridline numbers (328 and 4689), we record a variance of 0.0553 in the easting direction and 6.3107e-04 in the northing direction. In this case, there is a certain drift of the data points in a certain direction even though the recording device was held static. Most of the recorded data is concentrated at *three approximate UTM ordered pairs, with very minute variations not visible in this plot*. The altitude value shows a noticeable error at the 3-meter mark. The UTM Northing variation is noticeably less than that of the easting variance. (**Would like to know why)**

Figure 1. shows the 2D distribution of UTM data, mean position highlighted by the black marker. The RMS error recorded between the true positions and the recorded data points were not calculated due to true position unavailability. Figure 2 shows the 3D distribution of the UTM data with the altitude information. The noise appears to be non- gaussian distributed in this case with a non-uniform spread biased towards a particular UTM value

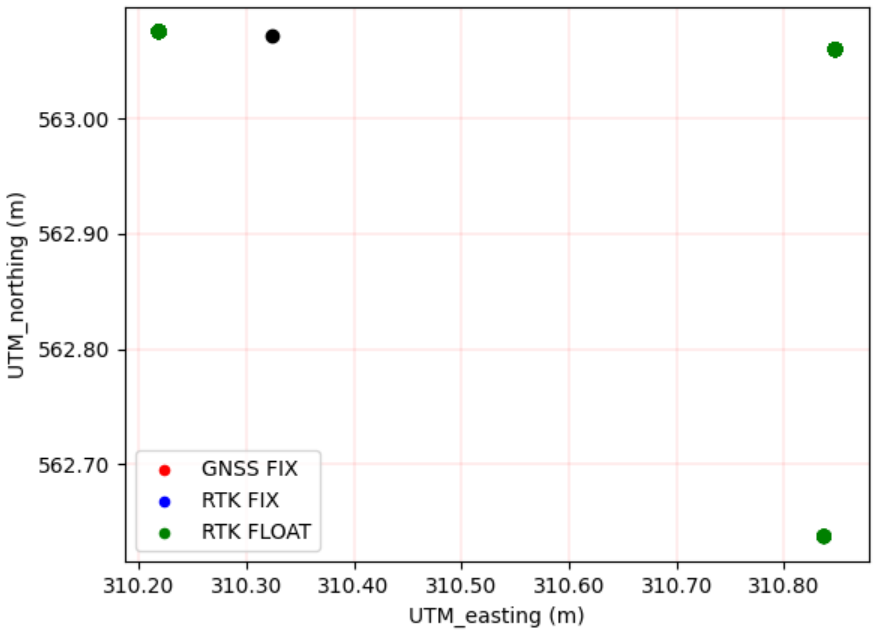

Figure 1. 2D distribution of the UTM easting and UTM northing (static case, Carter Tennis Courts)

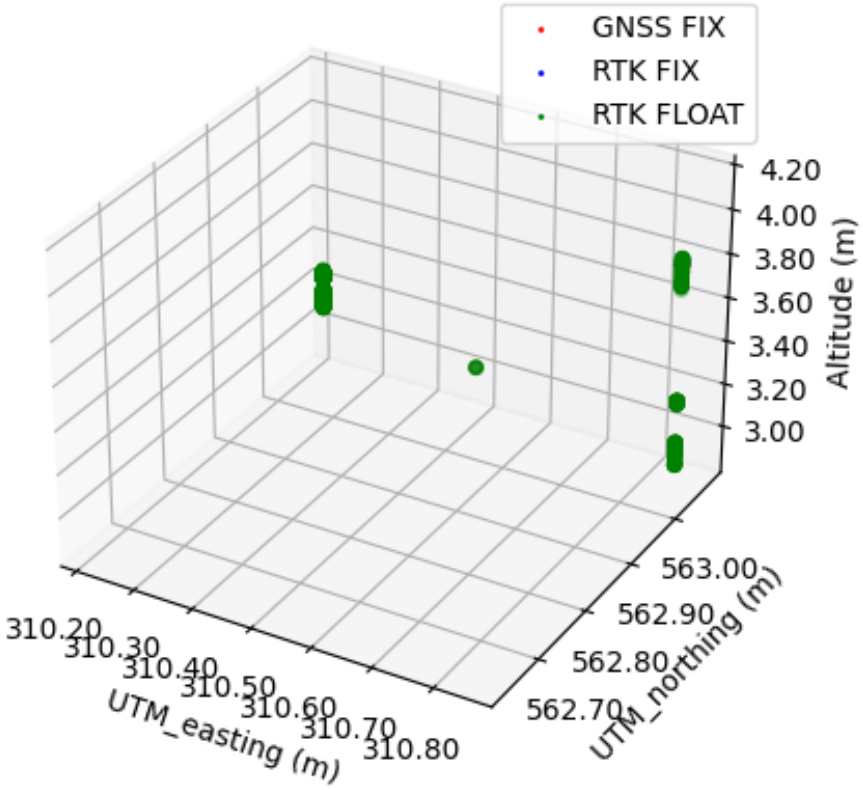

Figure 2. 3D distribution of static data (Carter Tennis Courts)

Static Data collection (Building Proximity- ISEC)

Table 2. Readouts for static case (ISEC)

Reference Data	**Reference Latitude (Decimal degrees)**		**Reference Longitude (Decimal degrees)**		**Reference Altitude (m)**		**Reference UTM Easting (m)**		**Reference UTM Northing (m)**		**Zone**
	N/A		N/A		~0m (self-assessed)		N/A		N/A		19T
Collected Data	**Latitude (Decimal degrees)**		**Longitude (Decimal degrees)**		**Altitude (m)**		**UTM Easting (m)**		**UTM Northing (m)**		
	Mean	**Std. Dev**	**Mean**	**Std. Dev**	**Mean**	**Std. Dev**	**Mean**	**Std. Dev**	**Mean**	**Std. Dev**	
	42.3372	5.7391e-06	85.0999	2.0508e-05	4.1886	4.2821	85.0999	1.6831	327.0432	0.6557	
	Variance										
	Latitude		**Longitude**		**Altitude**		**UTME**		**UTMN**		
	3.2937e-11		4.2059e-10		18.3363		2.8328		0.4299		

Table 2 shows the readouts for static data collection scenario when near ISEC. Reference positions were not available from the data lending source. Data is collected at sea level. 85% of the published messages had RTK Float as the quality indicator.

Even with RTK Float as the quality metric for most of the recording, the data was inaccurate as compared to the first case. An easting variance of 2.8328 and 0.4299 for the northing direction is observed. In this case, there is a certain drift of the data points around a central location. The altitude value shows a much larger variance of 18.3363. The UTM Northing variation is again noticeably less than that of the easting variance. *(Would like to know why)*

Figure 3. shows the 2D distribution of UTM data, mean position highlighted by the black marker. The RMS error between the true positions and the recorded data points were not calculated due to true position unavailability The noise characteristics appear to be gaussian in this case, centered around a true central position (unknown)

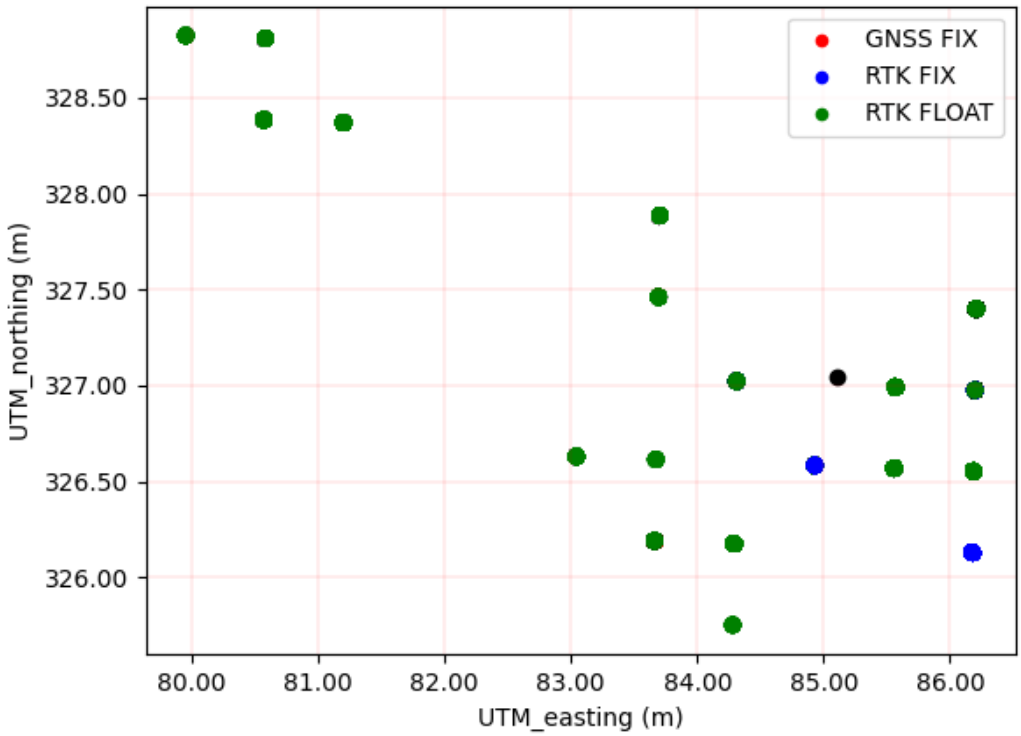

Figure 3. 2D distribution of the UTM easting and UTM northing (static case- ISEC)

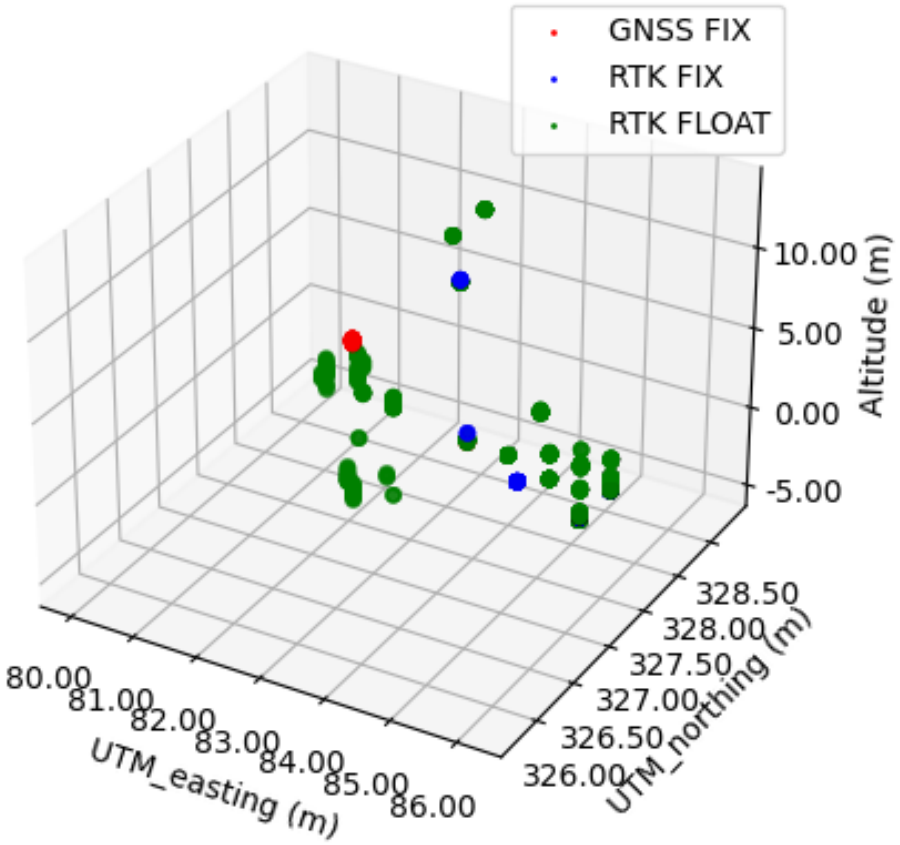

Figure 4. 3D distribution of static data (ISEC)

Non-Static Data collection (Open Space)

Table 3. Setup for motional data collection

Landmark type	Reference Latitude (Decimal degrees)	Reference Longitude (Decimal degrees)	Reference Altitude (m)	Reference UTM Easting Value	Reference UTM Northing Value	Zone
Start Position (approx.)	N/A	N/A	0.0 (ground level)	N/A	N/A	19T
Stop Position (approx.)	N/A	N/A		N/A	N/A	19T

Table 3 shows the readouts for non-static data collection scenario at the Carter tennis courts. Reference positions are indeterminate in this case as well. Data is collected at a base elevation of 0-meters by walking along the sides of a tennis court. About half of the data is categorized as RTK Fix while the other half is RTK float. This RTK Float condition can be attributed to the border metallic fencing causing some multipath effect interference while walking alongside them, while the rest was in a more open space.

The trajectory of recording has been taken to be rectangular, and as such to determine the spread of data, piecewise best fit lines have been added for each segment as shown in Figure 5. For each segment (L1 through the L4), the residual error values were obtained as: 115.3823, 164.0944, 385.2139, 178.0686. Noise characteristics are equivalent to the static open field case with the improvement of kalman estimation even while moving.

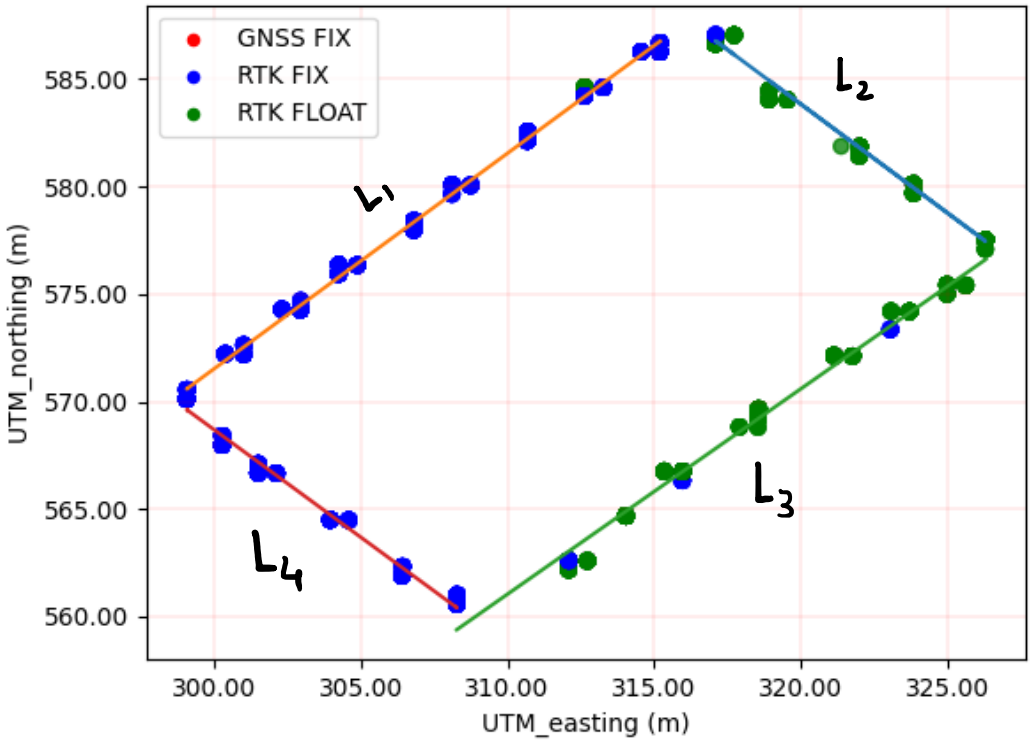

Figure 5. 2D distribution of the UTM easting and UTM northing (non-static case-Carter Tennis Courts)

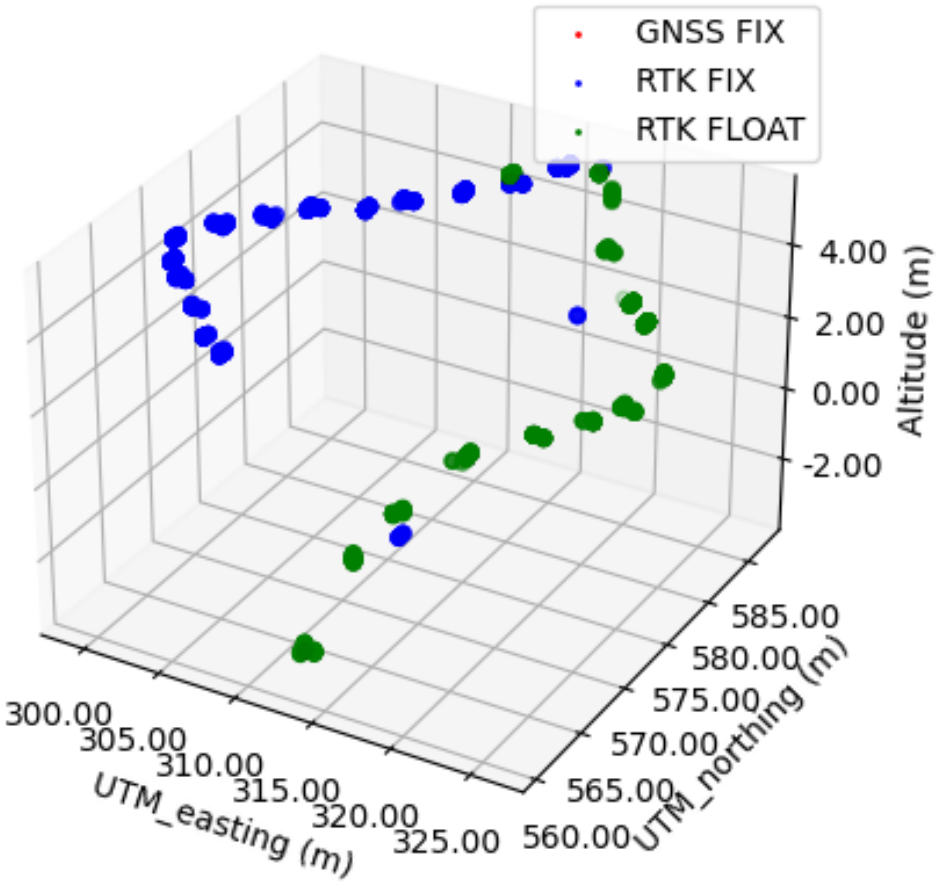

Figure 6. 3D representation of non-static data (Carter Tennis Courts)

Non-Static Data collection (Building Proximity- ISEC)

Table 4 4. Setup for motional data collection

Landmark type	Reference Latitude (Decimal degrees)	Reference Longitude (Decimal degrees)	Reference Altitude (m)	Reference UTM Easting Value	Reference UTM Northing Value	Zone
Start Position (approx.)	N/A	N/A	0.0 (ground level)	N/A	N/A	19T
Stop Position (approx.)	N/A	N/A		N/A	N/A	19T

Table 4 shows the readouts for non-static data collection scenario near ISEC. Reference positions are indeterminate in this case as well. Data is collected at a base elevation of 0-meters by walking along the sidewalks in front of the ISEC building. About 86% of the data is categorized as RTK Float while the rest is a mix of GNSS Fix and RTK Fix. This RTK Float condition can be attributed to the buildings reflecting GPS signals.

The trajectory of recording has been taken to be rectangular, and as such to determine the spread of data, piecewise best fit lines have been added here as well for each segment as shown in Figure 7. For each segment (L1 through the L4), the residual error values were obtained as: 62.0168, 436.664, 216.454, *48709.6708*

L4 is the outlier in this case with the best fit line not being able to approximate the segment properly due to the very high spread of position data. It could be due to the ISEC building itself as it is near the start point of the dataset. The approximate position of ISEC has been marked in Figure 7 as well. The noise characteristics are poor, with a likely non-gaussian spread of the position information in this scenario.

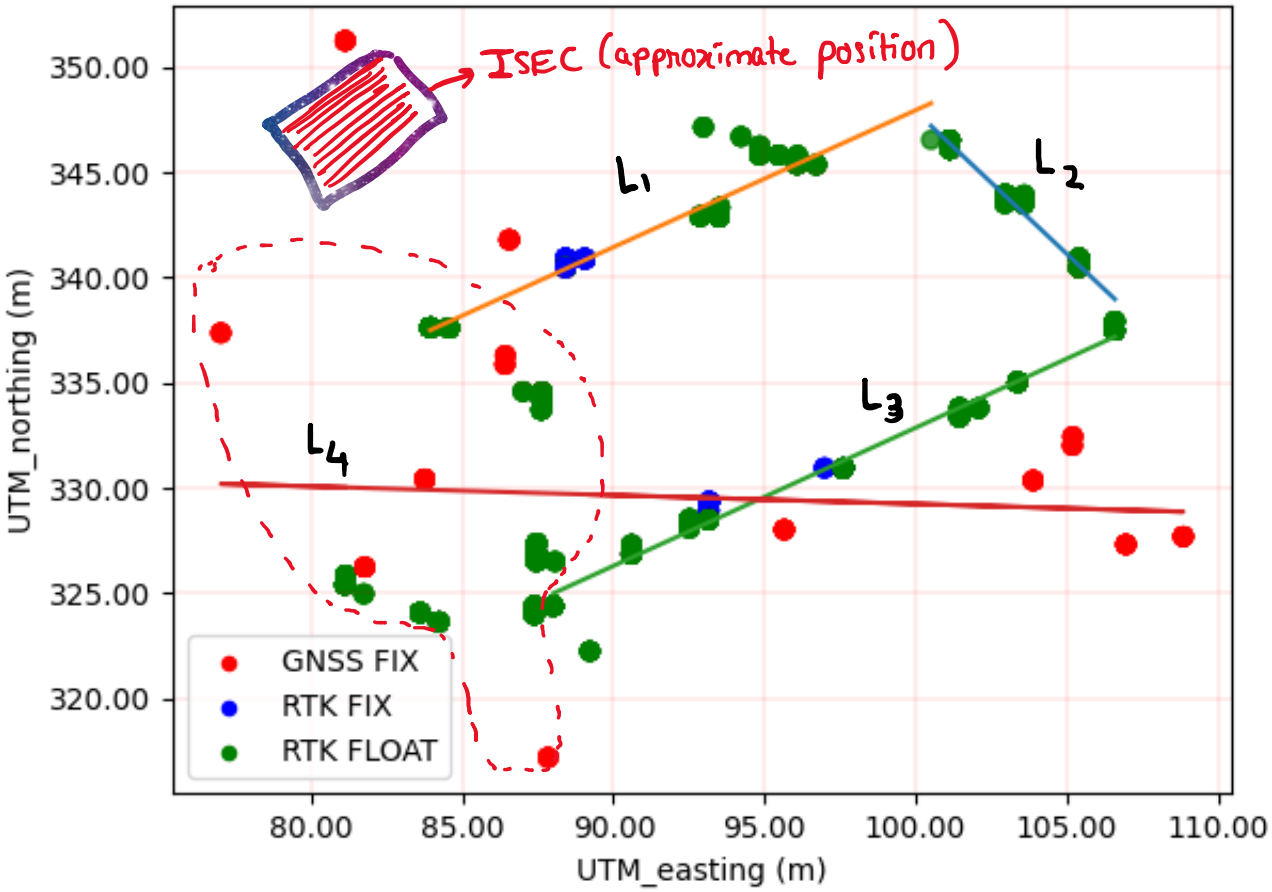

Figure 7. 2D distribution of the UTM easting and UTM northing (non-static case- ISEC)

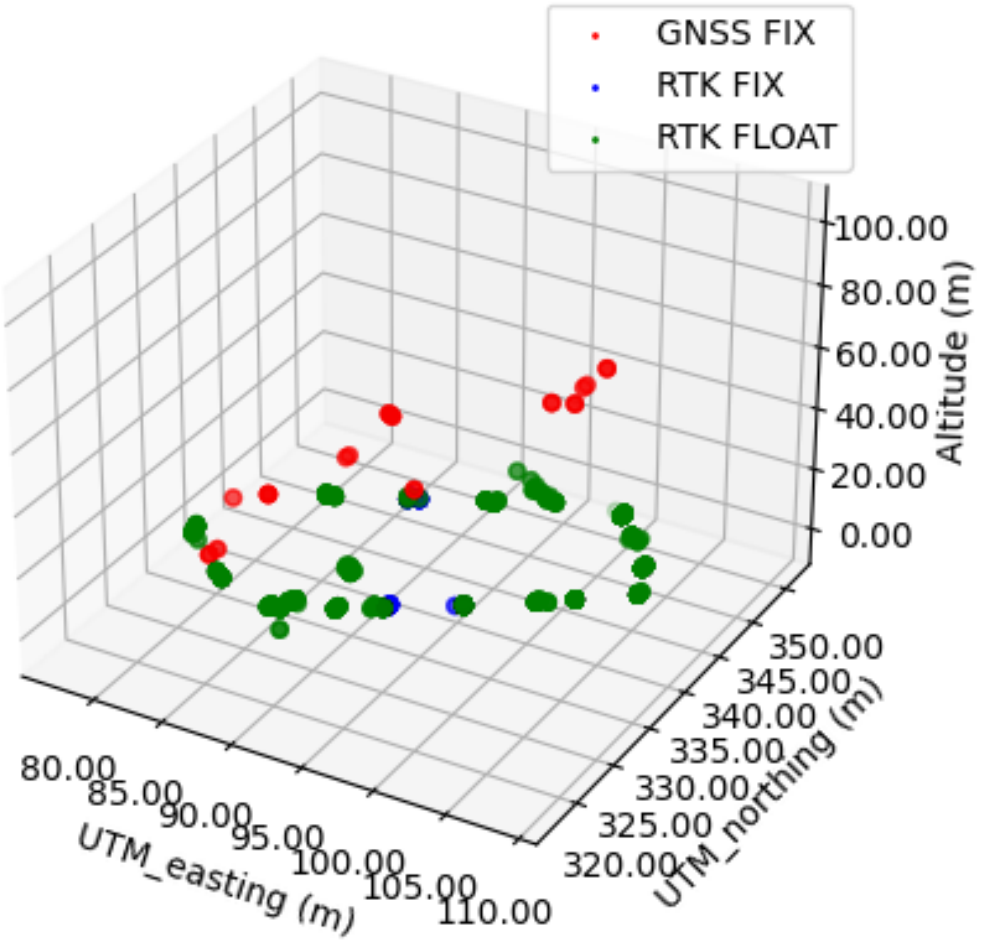

Figure 8. 3D representation of non-static data (ISEC)

Concluding remarks:

A lot could not be said about the data due to indirect sourcing from a third party. However, a couple of key observations were made with the available information. For the static case, UTM Northing showed lower variations (standard deviation and hence the variance) than UTM Easting. It is a reasonable assumption that there were reflective objects on the east side of the recoding zones. Centimeter level precision was observed with this device as compared to a standard GNSS puck. RTK Float ambiguities dominated the quality indicator metrics and demonstrated a wider spread than when the ambiguities were RTK Fixed. As expected, being in an open space drastically reduced the error spread for both the static and non-static cases by at least an order of magnitude on average (which is cross verified by the fact that RTK Float ambiguities reported errors as large as a meter, while RTK Fixed ambiguities could go to a centimeter level precision).