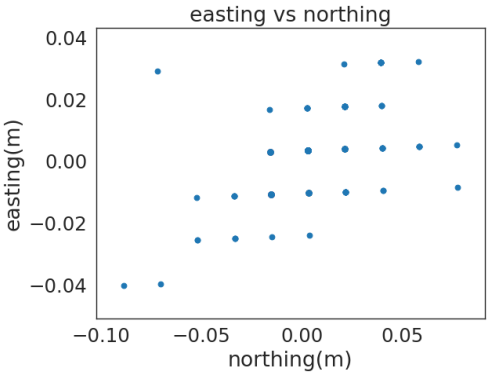
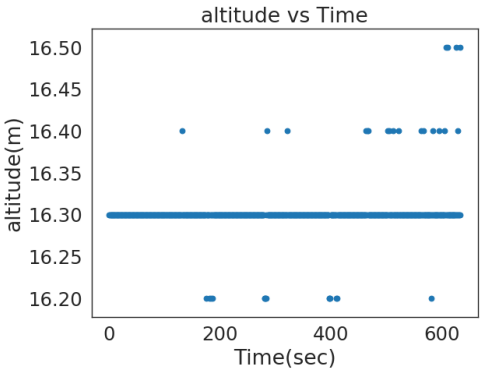
My previous version of the report I pushed to GitLab was corrupted and not viewable for some reason. But, It was veiwable on Canvas. I mentioned this issue to Asjad and he asked me to push a new version to GitLab.

good stationary data analysis:





I plotted utm easting vs utm northing graph to see how the location of the gnss puck is changing. I also plotted altitude vs time to see the variation in altitude. Ideally, there should not be any deviation in UTM and altitude values. But, they do vary because of various reasons such as satellite and signal propogation errors. From the easting vs northin graph, we can conclude that the GPS is accurate upto 0.088 meters. This is the maximum deviation from the ground truth we got in the data collected. I subtracted UTM values from their mean for better visualization. Error is defined as true value subtracted from measured value, here the true value is the origin. RMSE values for both northing and easting are as shown below:

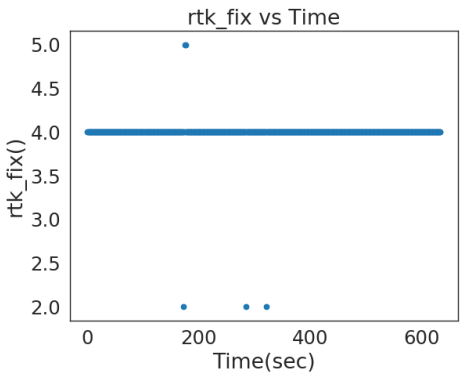
```
get_rsme('easting')
```

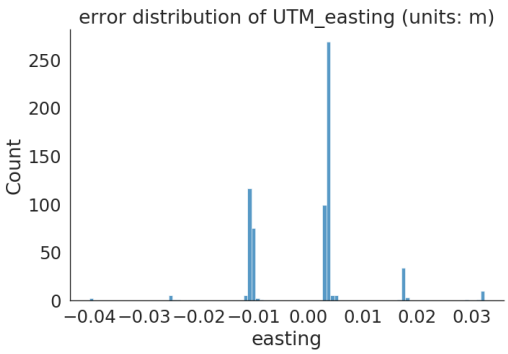
```
0.009542013898217787
```

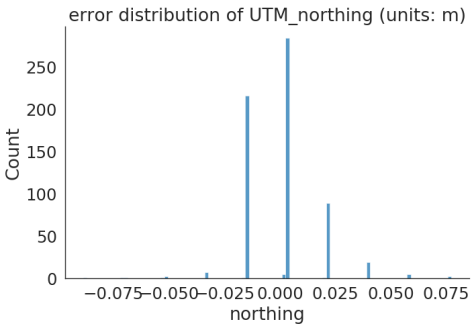
```
get_rsme('northing')
```

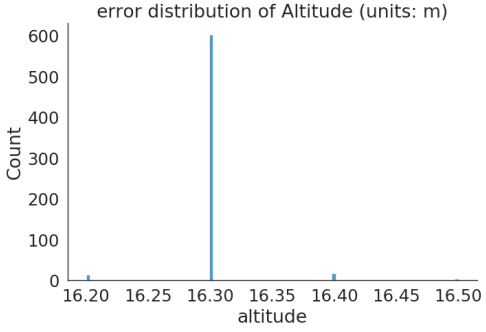
```
0.01719372022940543
```

The RMSE is much smaller than what we got from lab1 since we are using corrections from the base to improve the accuracy of the rover readings. Also, if we look at the quality stayed ‘4’ for most of the time while collecting this dataset. The below figures show the error distribution of utm easting, utm northing and altitude:









The error distribution do not seem to be a normal distribution but a random distribution. I have also calculated upper bound, lower bound and mean of the data:

```
get_bounds('easting')
```

```
upper bound : 0.032291725219693035
mean: -1.2374857044595434e-11
lower bound : -0.0399952296866104
```

```
get_bounds('northing')
```

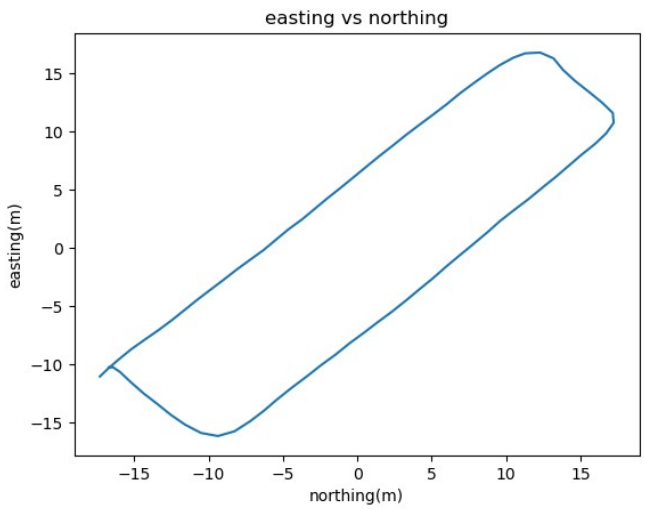
```
upper bound : 0.07725469674915075
mean: -4.502614652077983e-10
lower bound : -0.08863489236682653
```

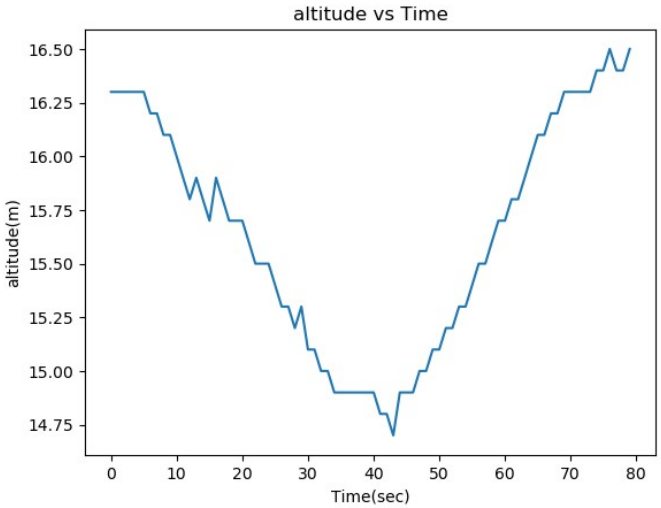
```
get_bounds('altitude')
```

```
upper bound : 16.5
mean: 16.301574803149613
lower bound : 16.2
```

Although there is some noise in the data, we can understand that the puck is sitting still by looking at the graphs.

good moving data analysis:





We walked in a rectangular path on top of the columbus garage. The fluctuation from the ground truth seems to be at a minimum compared to stationary data as the GPS puck uses kalman filter to get more accurate values. The path we took had a small slope so there's a small change in the altitude. I also calcluated the upper bound, lower bound and mean of utm and altitude values below:

```
get_bounds('easting')
```

```
upper bound : 16.806451915530488
mean: 6.5483618527650835e-12
lower bound : -16.176643996383063
```

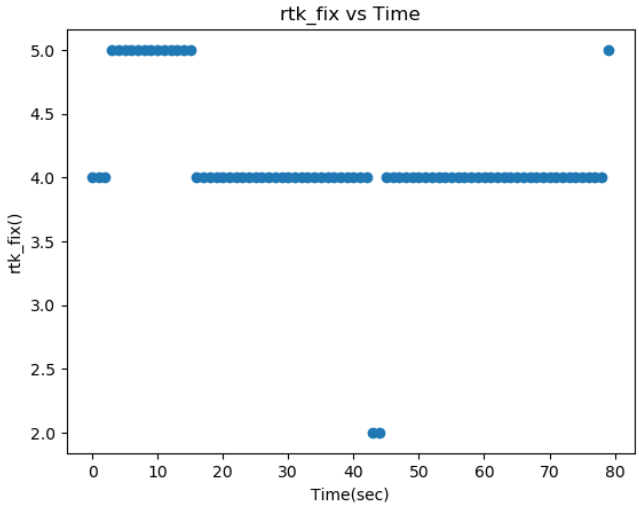
```
get_bounds('northing')
```

```
upper bound : 17.241238871589303
mean: -3.9581209421157836e-10
lower bound : -17.315465713851154
```

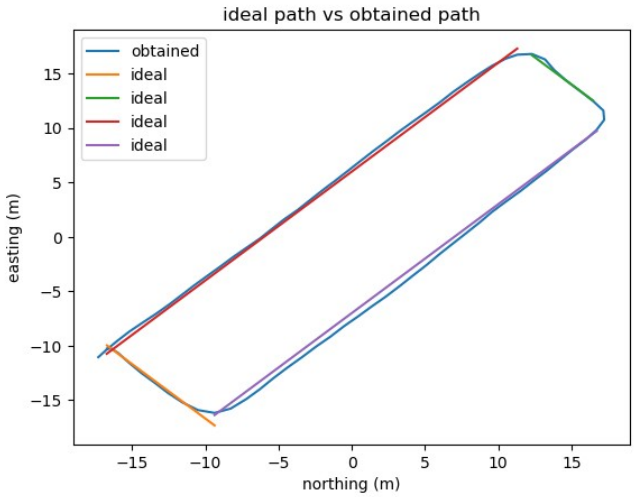
```
get_bounds('altitude')
```

```
upper bound : 16.5
mean: 15.640000000000004
lower bound : 14.7
```

while we were walking, the quality of data jumped from 4 to 5 for a brief moment. So, at this moment, we did not receive any correction for the rover readings.

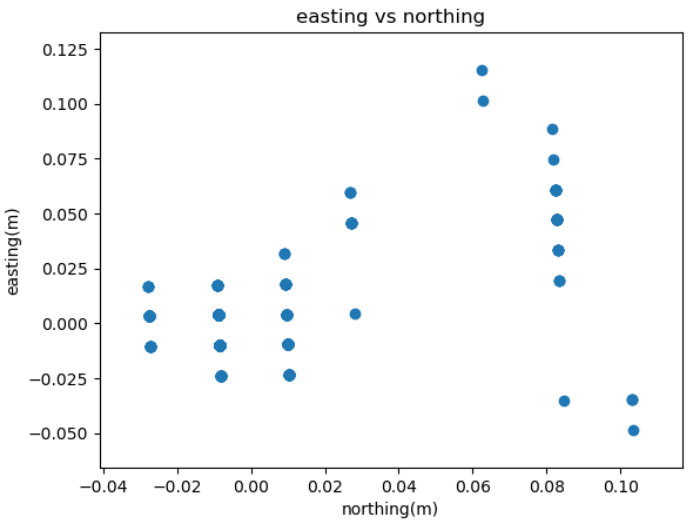


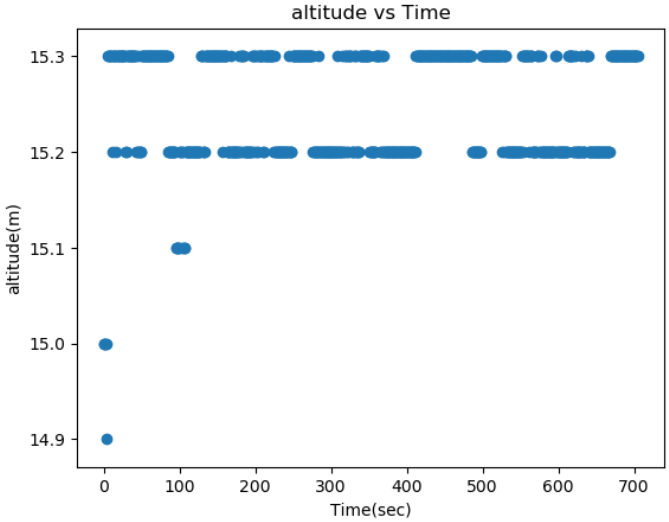
I fit a best line to all four sides of the rectangle and calculated RMSE on all four sides and averaged all four RMSEs to get final RMSE



The final RMSE value is 0.375

bad stationary data analysis:





We collected our bad data outside of ISEC. From the northing vs easting graph (also, from the calculations done in the analysis scripts), we can say that the GPS is accurate upto 0.115 meters, which is worse than that of the good data. Because of the multi-path errors

encountered while collecting the data, GPS is less accurate. UTM values were subtracted from their mean values for better visualizations. RMSE for both northing and easting values are shown below:

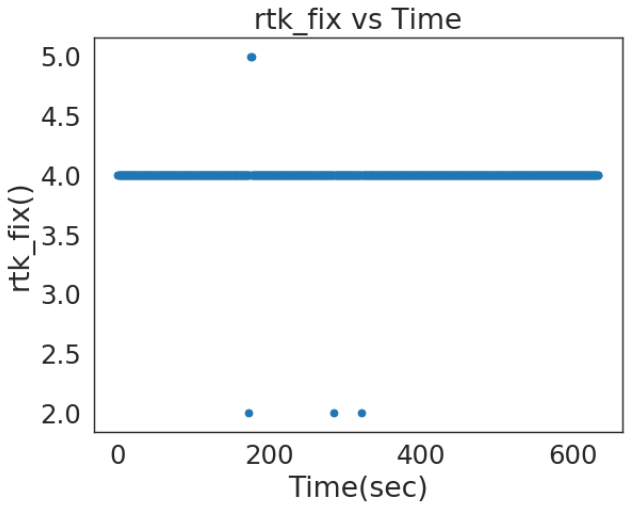
```
get_rsme('easting')
```

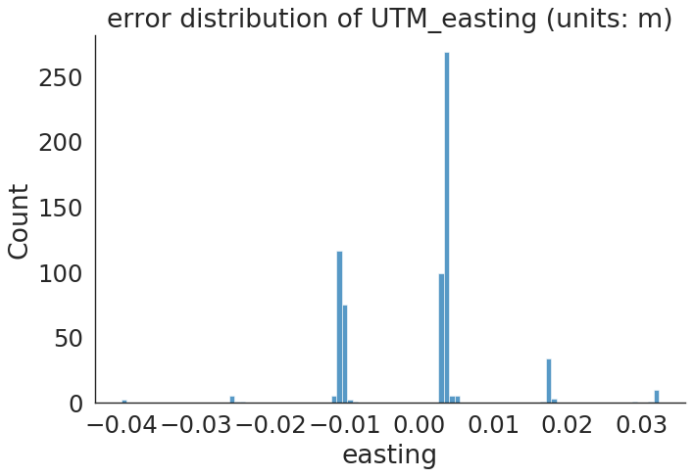
```
0.018582037806649902
```

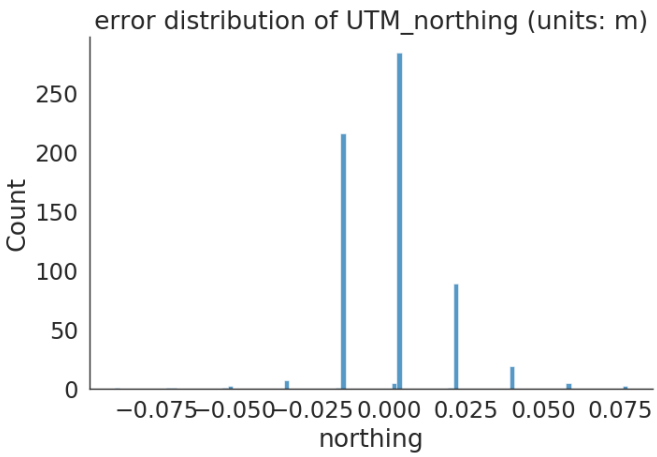
```
get_rsme('northing')
```

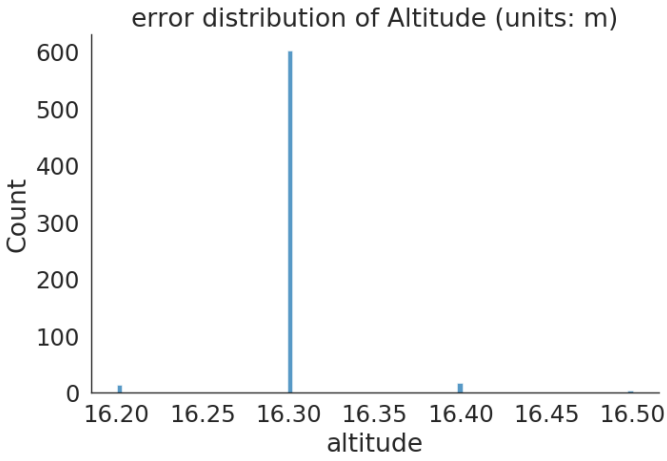
```
0.0246772360429117
```

The RMSE values for this data are worse than that of that dataset collected on top of the garage, as expected. The quality was '4' for most of the time. The error distributions of utm northing, utm easting and altitude are random in this dataset too:





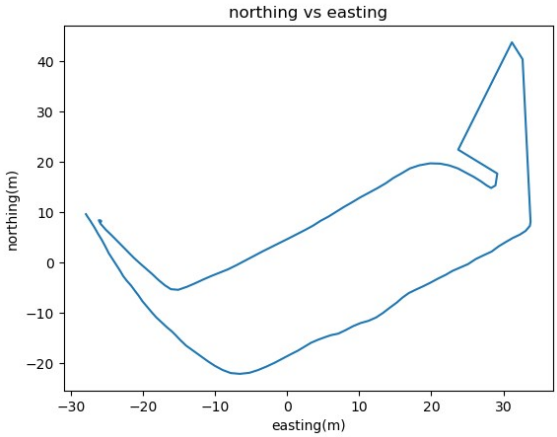


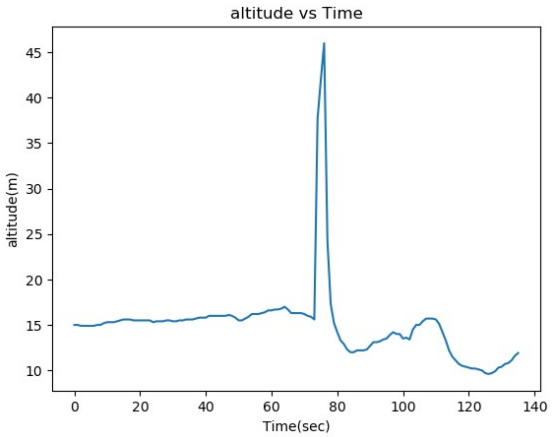


Finally, the upper bound, lower bound and mean of the error in this dataset are:

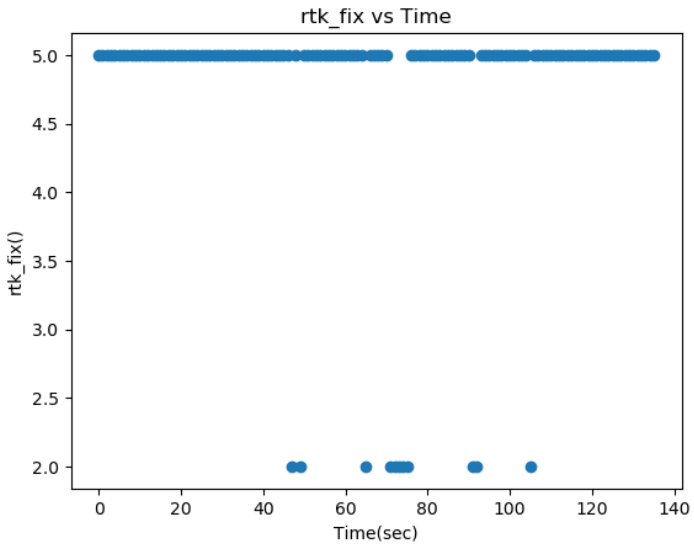
```
: get_bounds('easting')

upper bound : 0.032291725219693035
mean: -1.2374857044595434e-11
lower bound : -0.0399952296866104

: get_bounds('northing')

upper bound : 0.07725469674915075
mean: -4.502614652077983e-10
lower bound : -0.08863489236682653

: get_bounds('altitude')

upper bound : 16.5
mean: 16.301574803149613
lower bound : 16.2
```

bad moving data analysis:





We walked in a rectangular path infront of ISEC. In the UTM northing vs easting plot, we can see that there is a lot of fluctuation in the right top part and also a sudden jump in altitude. This is happening around 70 secs and if we look at the rtk quality graph below:

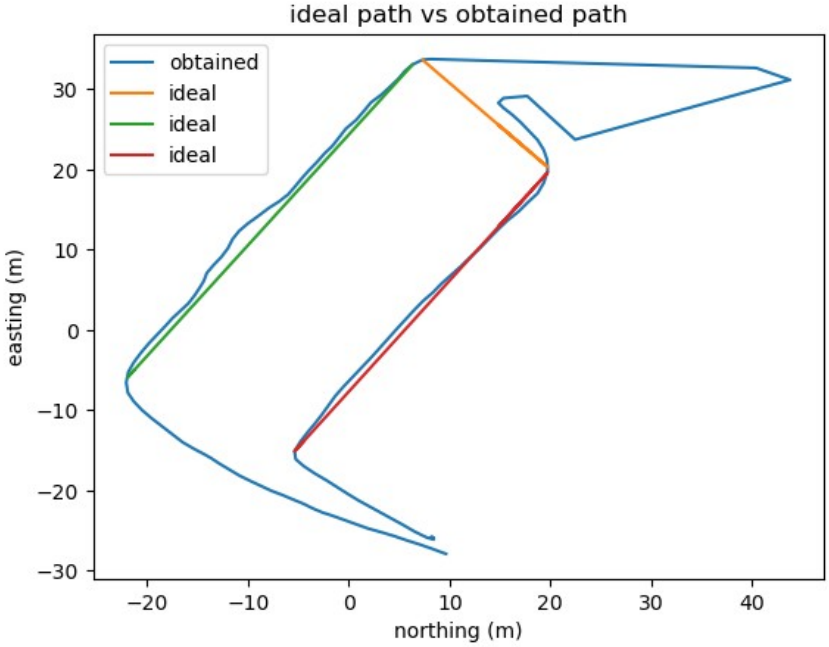


We understand that the quality of the data is ‘5’ for most of the time and it changed to a quality of ‘2’ around the 70th second. It was at this same moment, we observe a weird jump in altitude and utm values. Take a look at the utm northing values in the time interval of 60 – 80 secs.

```
df_gps['northing'][60: 80]
```

```
60    -2.420884
61    -1.629481
62    -0.970322
63    -0.293330
64     0.735297
65     1.504151
66     2.200325
67     3.250154
68     4.114576
69     4.905980
70     5.567162
71     6.306750
72     7.310491
73     8.104610
74    40.390396
75    43.760069
76    22.443152
77    17.699136
78    15.334948
79    14.831236
Name: northing, dtype: float64
```

There's a sudden jump in the value from 8.1 to 40.3 at 74th second. It is quite clear this happened because of the drop in the quality of the data. I also calculated the RMSE for only 3 sides of the rectangle because we could not close the loop properly on the fourth side as you can see from the plot above. Look at the below plot for the three best fit lines:



RMSE value for the given three sides is 6.937. But, in reality, it would be more because I have not included the fourth side into calculations.