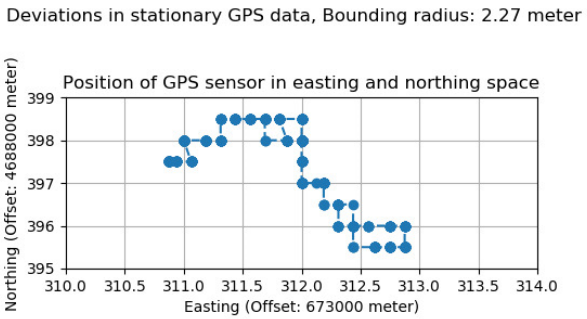
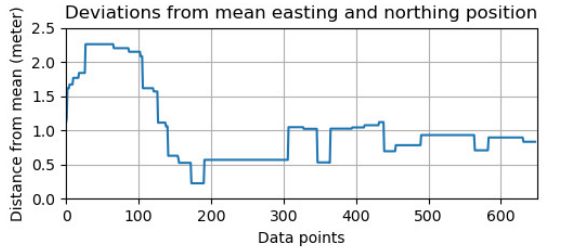
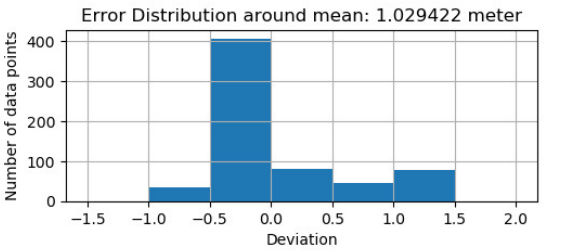
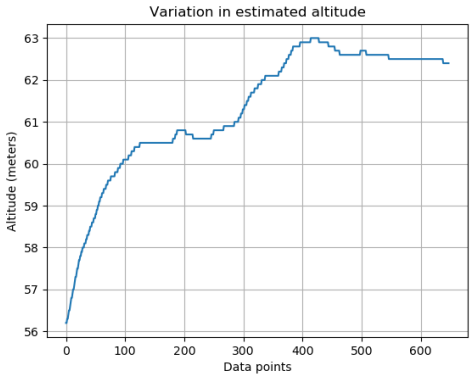
Observations in case of stationary data:





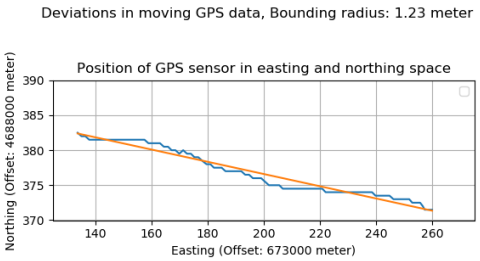


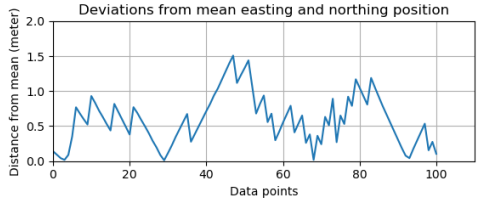


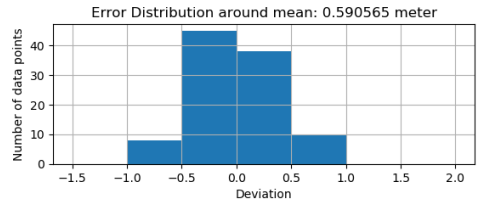
1. **Accuracy comparison in horizontal vs vertical:** GPS navigation has better accuracy along horizontal compared to vertical when estimating position of the receiver, the reason for more error in vertical is justified as in case of horizontal we have satellites in all direction – along North-South, East-West, however in case of vertical we have satellites in only one direction - top.
2. **Trends in positioning of GPS sensor in horizontal –** GPS receiver starts at around (311, 398) position on graph and slowly drifts towards (312.5, 395.5) and circles around that position.
3. **Trends in error for stationary data-** As per the observation in graph for "Deviations from mean" in stationary GPS data the error is large for initial data points and then stabilizes at around 1m from calculated mean position.
4. **Error distribution**- The error distribution for the given data does not follow the normal distribution or gaussian distribution trend and seems to stabilize within 1st standard deviation after initial estimate of position.
5. **Sources of error-** I collected the data at two places, one on the street where there were buildings on both side of the street and other in an open baseball field. Observed data establishes that the variations in position was much larger for data on the street when compared to open field. Other parameters like the time of day, weather, positioning of sensor, etc. were similar. This reflects that the major source of errors when using GPS receiver is due to – multipath effects.
6. **Bounding Error-** According to me, the error could not be bounded as it depends largely on number of factors and can have large deviations when in situations like urban canyon, fewer observable satellites, etc.

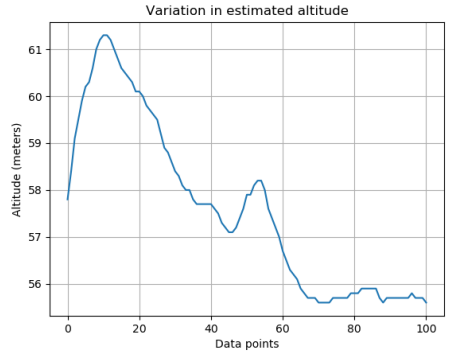
Note – Trends in error and positioning reflects sensor post-processing method for estimating position which takes into account prior estimates– the sensor reaches to final mean position by slowly drifting towards it and staying within that region rather than abruptly jumping across random points.

Observations in case of moving data:









1. **Selecting the mean trajectory –** Mean trajectory is estimated using regression over simple slope method as regression takes into consideration all the points on the data set which may have random errors with them and can establish a more close-to-real trajectory.
2. **Trends in positioning of GPS sensor in horizontal –** GPS receiver positioning data seems to oscillate around the mean trajectory (mean + error → mean – error → mean + error) which seems to reflect GPS receiver post-processing behaviour of slowly reaching to mean position and then overshooting and then trying to move back close to the mean position.
3. **Trends in error for moving data –** The error data in this case do not seems to move to a stable value and is random. This makes sense as the previous estimate of position and new measurement taken after 1 second will have implied variation of around 2-3 meters (walking speed * time) + receirver errors, therefore the GPS receiver do not zero down to any fixed position. Thus, random error pattern is observed though moving towards mean and then overshooting.
4. **Error distribution –** The error seems to be distributed majorly within +1 and -1 standard deviation equally, reflecting its oscillatory behaviour around mean, however it also reflects it does not follow general error distribution trends like normal distribution or gaussian distribution.

Note- When comparing the max error in case of moving data vs stationary data – stationary data seems to have more maximum deviation from the mean position. This might be due to the fact that in case of stationary, the GPS receiver is able to zero down on the accurate position after initial few points which shifts the collective mean of all data points farther from initial measurements and closer to true mean. Thus, higher maximum error when comparing it to the calculated mean. While in case of moving data the GPS receiver is not able to zero down on any fixed value; the error distribution remains random and thus the calculated mean does not shift far from the measurements.