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February 26, 2022

MECH 6970: Fundamentals of GPS
Lab 2

Static Class Data

Part A

Utilizing the data given in the assignment, the positions of each satellite in view were calculated. It was found that over the course of the data, satellite 1 came into view and satellite 14 faded out of view. This causes some issues with plotting, so the results were divided up into sections of consistent satellite view:

- From beginning of data until satellite 1 comes into view. (9 satellites from 0 to 235.7 seconds)
- After satellite 1 appears and until satellite 14 fades out of view (10 satellites from 236 seconds to 1178.9 seconds)
- Until the end of the data after satellite 14 is no longer visible (9 satellites from 1179 to 1182.4 seconds)

The satellite positions over these three time sections are summarized in the following skyplots.

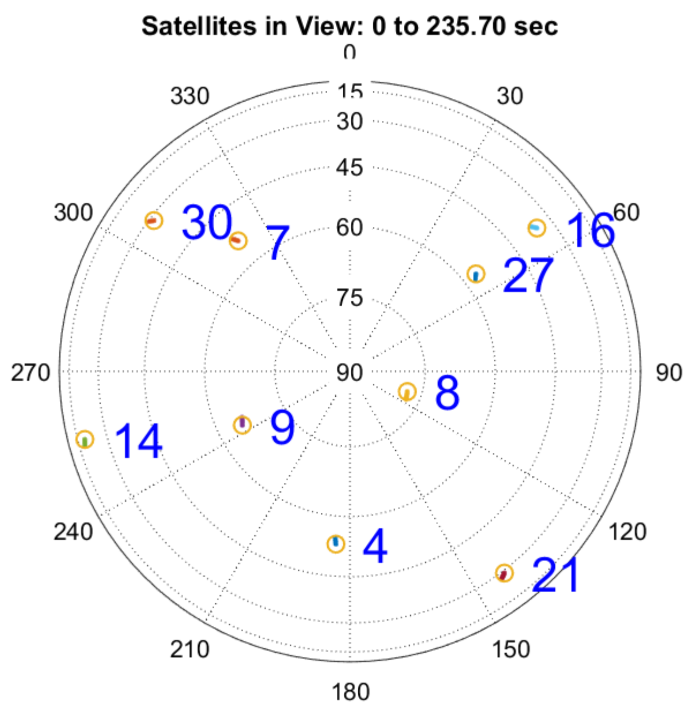


Figure 1: Skyplot from 0 to 235.7 seconds

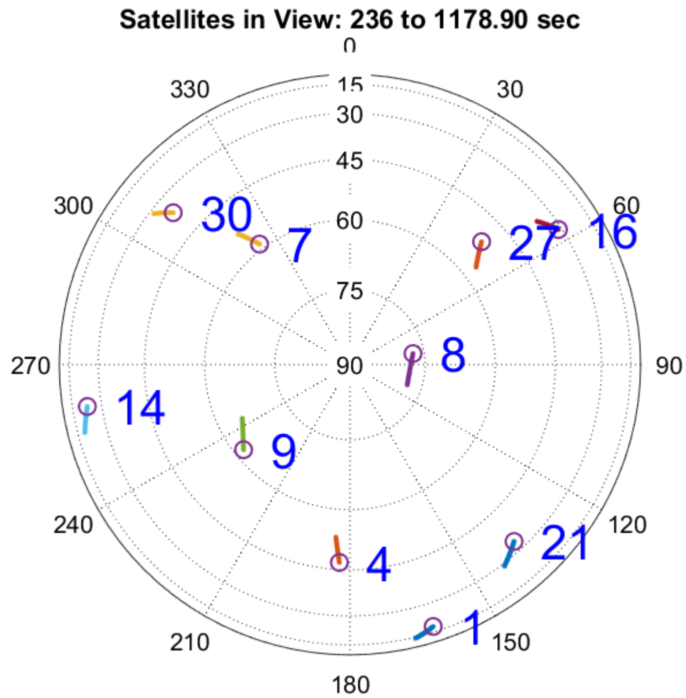


Figure 2: Skyplot from 238 to 1178.9 seconds

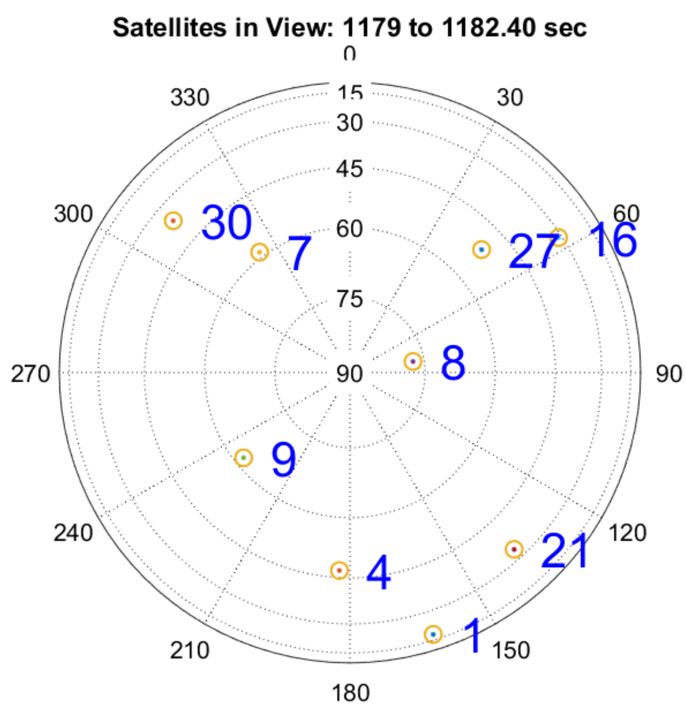


Figure 3: Skyplot from 1179 to 1182.4 seconds

Part B

Figure 4 shows our calculated initial position and the surveyed initial position of the antenna location. The initial error in ECEF is:

$$\text{Error}_{ECEF} = \begin{bmatrix} -3.269 \\ -1.6526 \\ 1.4851 \end{bmatrix} \text{ meters} \tag{1}$$

Figure 4: Initial Position Comparison

Part C

Figure 5 shows the position estimates over the time duration of the Trimble data set. The location of the antenna that received the data is on the roof of the Woltosz Laboratory building.

Figure 5: Static Data LLA Position

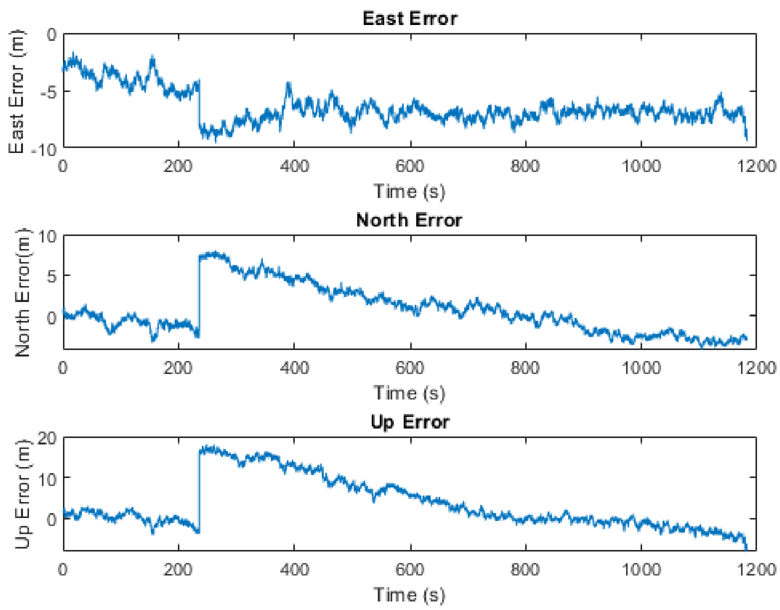
It is evident that there is wander of the position solution as satellites move throughout the sky. The wander can be quantified by finding the standard deviation of the norm of the ECEF position components. The standard deviation of the position solution was found to be approximately 5.5 meters.

Part D

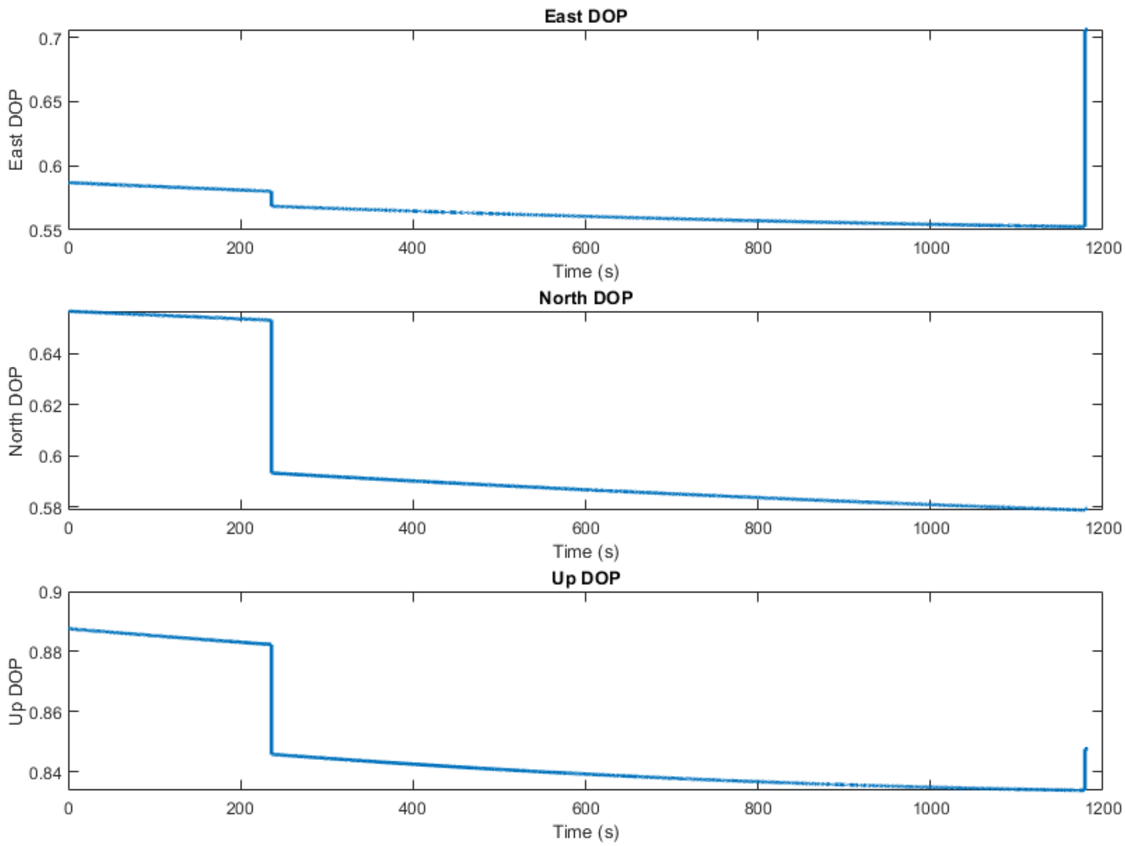
The position solutions wer mapped into the ENU frame with an origin at Toomer's Corner. The surveyed ENU position is found to be:

$$\text{ENU}_T = \begin{bmatrix} -477.0506 \\ -121.5705 \\ -12.2735 \end{bmatrix} \text{ meters} \tag{2}$$

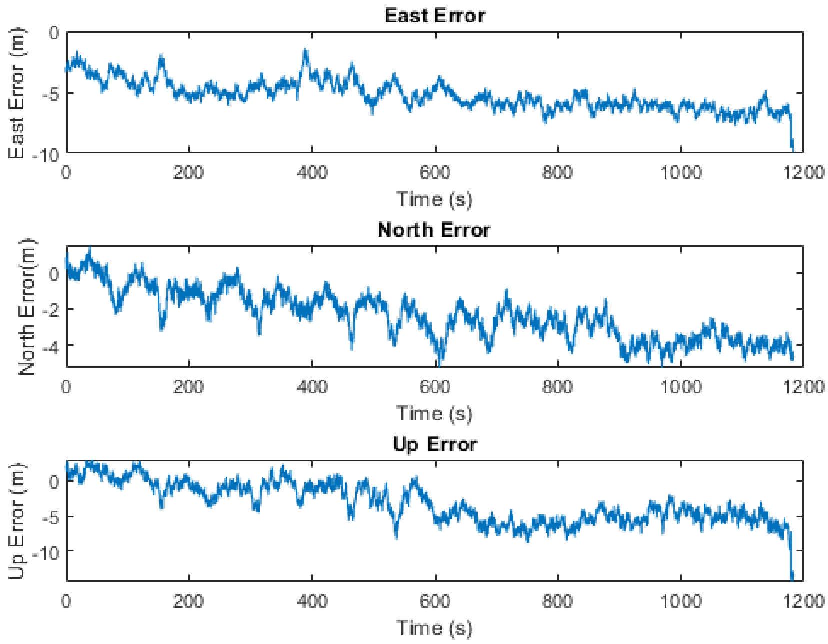
The converted position solution error in each direction is shown here in the figure below.



What is interesting is the shift in the solution around 250 seconds — exactly when satellite 1 comes into view and the solution begins being calculated with 10 satellites instead of 9. A synchronous drop can be seen in the DOP figure due to the addition of another satellite (note the DOP was rotated into the ENU frame estimate with a rotation matrix relating the two frames). A spike in the DOP is also seen at the end of the run when satellite 14 is no longer visible.

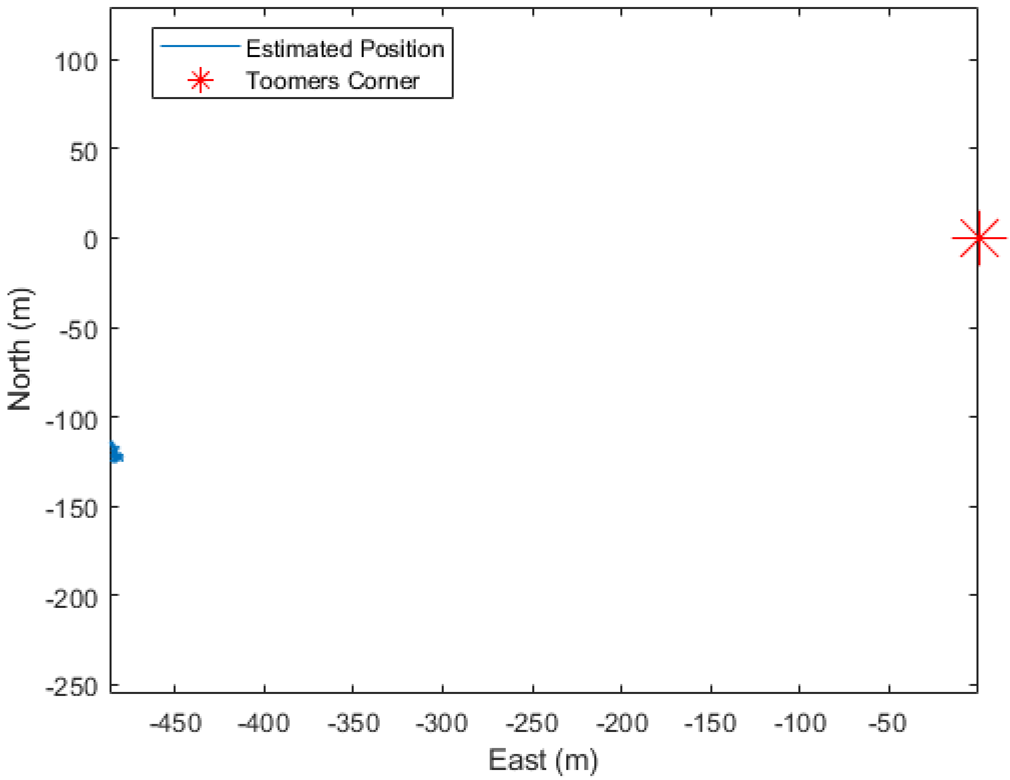


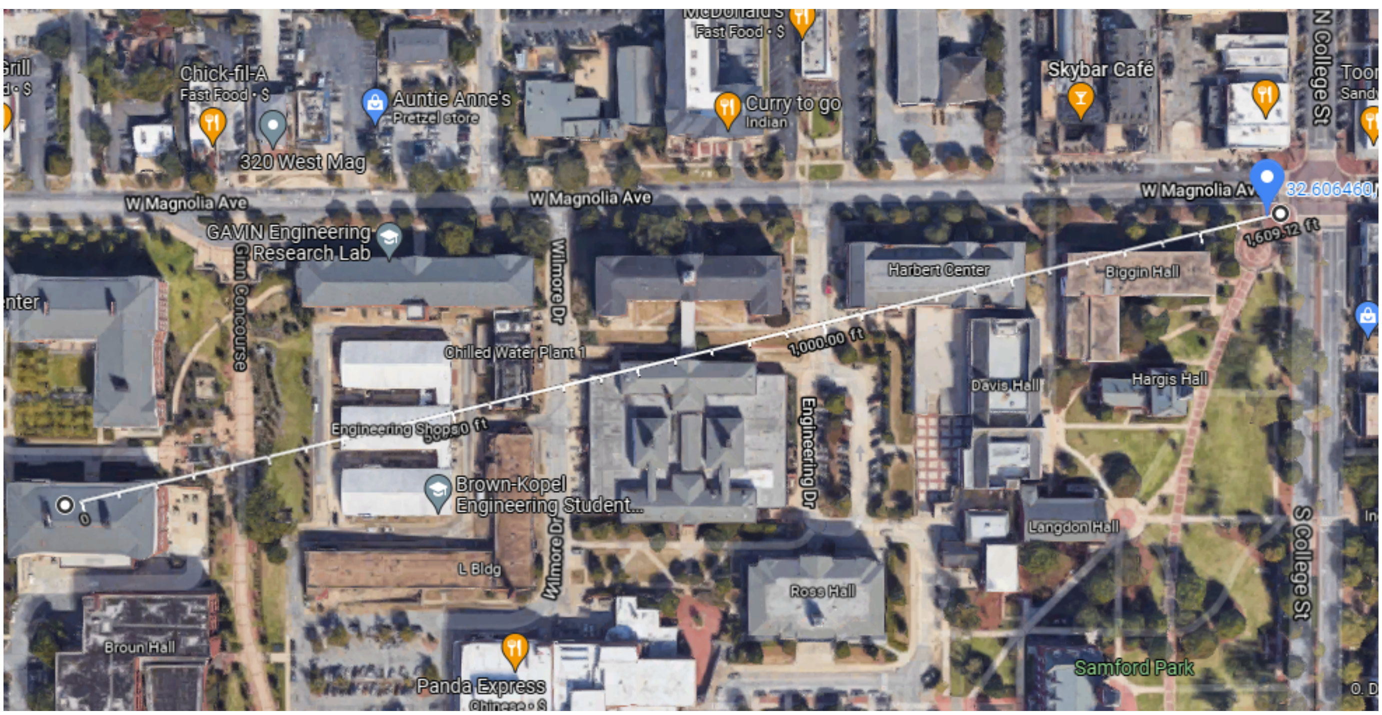
The drop in DOP creates an expectation for a lower error, but it can be seen that the addition of satellite one spikes the error significantly. The skyplot figure in part A shows that satellite 1 is quite low on the horizon. As was explored in homework 2, there is some usefulness to ignoring satellites with low elevation angles due to increased atmospheric error. Exploring this option, new solutions were computed ignoring satellite 1 in the following figure.



The resulting error was reduced throughout the run, so in this case the decrease in DOP from an additional satellite is outweighed by the error introduced from a satellite low in the sky - so a mask angle is beneficial here.

A 2D (East, North) plot of this result shows the estimation of the position with respect to Toomer's Corner. A Google Maps image is provided for visual comparison. The relative position of the solution with respect to Toomer's matches the lla/ECEF solutions: Woltosz lies southwest of Toomer's Corner.


Estimated Position
Toomers Corner
100
50
0
-50
-100
-150
-200
-250
North (m)
-450
-400
-350
-300
-250
-200
-150
-100
-50
East (m)


Chick-fil-A
Fast Food · $
Auntie Anne's
Pretzel store
320 West Mag
McDonald's
Fast Food · $
Curry to go
Indian
Skybar Café
N College St
W Magnolia Ave
W Magnolia Ave
W Magnolia Ave
32.606460
1,609.12 ft
GAVIN Engineering
Research Lab
Gim Concourse
Wilmore Dr
Harbert Center
Biggin Hall
Chilled Water Plant 1
1,000.00 ft
Davis Hall
Hargis Hall
Engineering Shops
500.0 ft
Brown-Kopel
Engineering Student...
Engineering Dr
Langdon Hall
S College St
L Bldg
Ross Hall
Broun Hall
Panda Express
Samford Park

Part E

Figure 6 shows the East, North, and Up components of velocity in an ENU frame whose reference is Toomer's Corner. The velocity was calculated using the Doppler measurements from the Trimble data set.

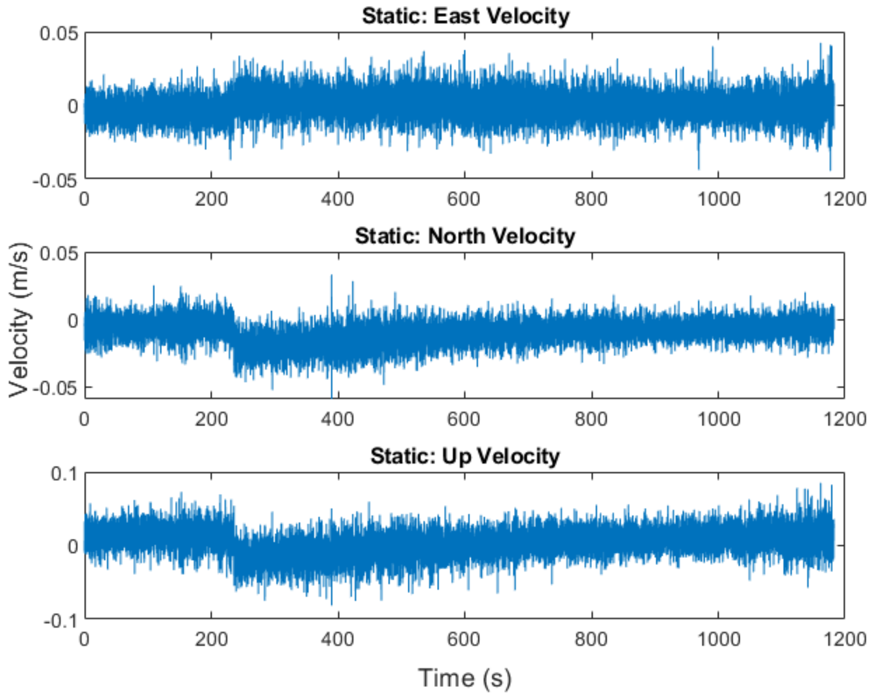


Figure 6: Static Data ENU Velocity

Knowing the antenna used to collect this data was static, it is evident there is noise in our measurement as our velocity components are non-zero. The accuracy of these components were evaluated by finding the standard deviation of each component's data set using the `std()` function in MATLAB.

$$\sigma_{East} = 0.0098\,\mathrm{m/s}$$
$$\sigma_{North} = 0.0094\,\mathrm{m/s}$$
$$\sigma_{Up} = 0.0197\,\mathrm{m/s}$$

Dynamic Class Data

Part A

The expected position error can be found by multiplying the calculated DOP by the given sigma of the pseudo-range error. For this lab, an expected pseudorange error of 0.5 meters. The DOP varies substantially more than in the static case since now the vehicle's motion has an effect on the visible satellites as well. The DOP was converted into ENU coordinates and is shown in figure 7. The vertical solution has a higher DOP as expected. The resulting error estimates are shown in the figure 8 by incorporating the expected pseudorange errors. Over the course of the run the mean error for the 3 local navigation axes are:

$$\mu_{E_{err}} = 0.3736\text{m} \tag{3}$$
$$\mu_{N_{err}} = 0.3813\text{m} \tag{4}$$
$$\mu_{U_{err}} = 0.5021\text{m} \tag{5}$$

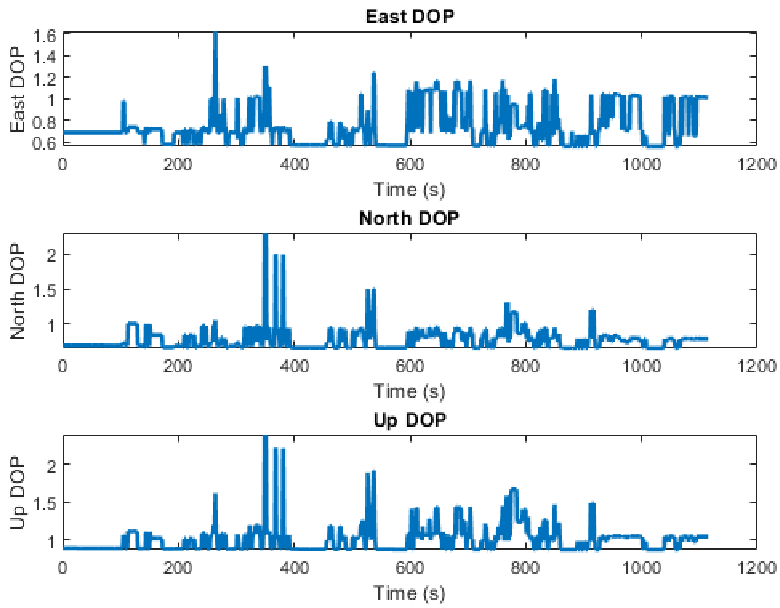


Figure 7: Dynamic Data ENU Position DOP

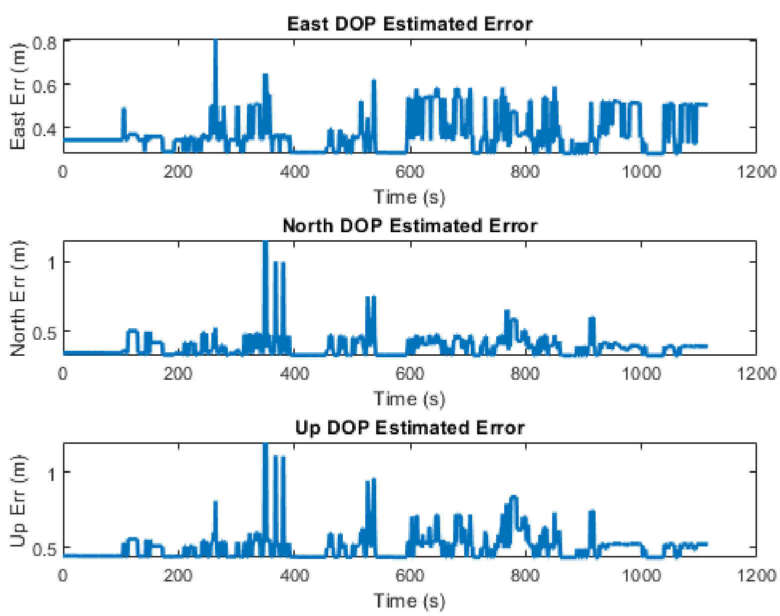


Figure 8: Dynamic Data ENU Position Error

Part B

The converted ECEF positions are expressed in geodetic coordinates shown in figure 9. The path solution shown starts and ends near the rear of Woltosz and takes a path down Magnolia and around the outer rim of campus.

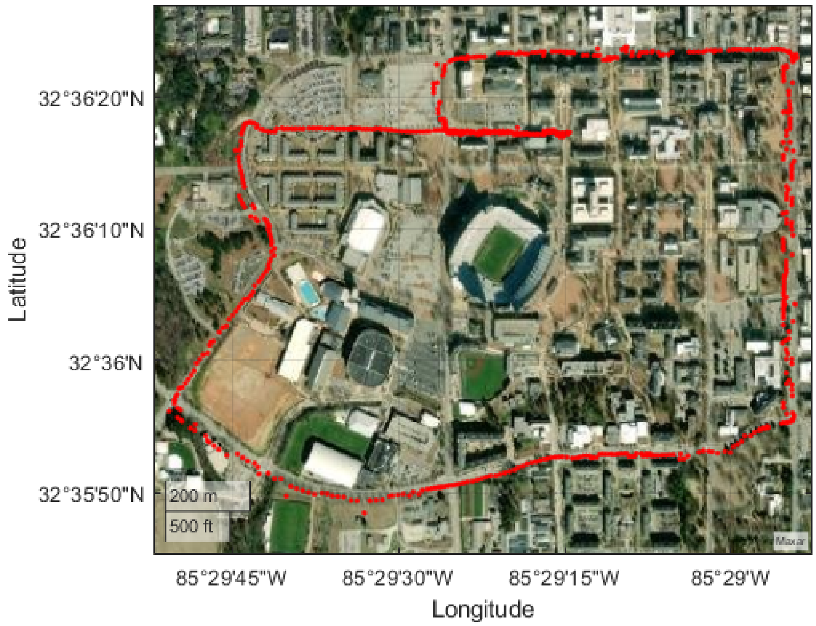


Figure 9: Dynamic Data ENU Position Error

Part C

The speed and course were plotted against time in Figure 10. The speed was calculated by taking the norm of the velocity and the course was calculated by taking the inverse tangent of the East velocity divided by the North velocity. The course calculations at zero speed were adjusted to maintain the previously calculated course because when the car is static the velocity estimates are extremely noisy. Without adjusting the course calculations, the noise in the velocity estimates produce sporadic and false course calculations. The course was initialized to North.

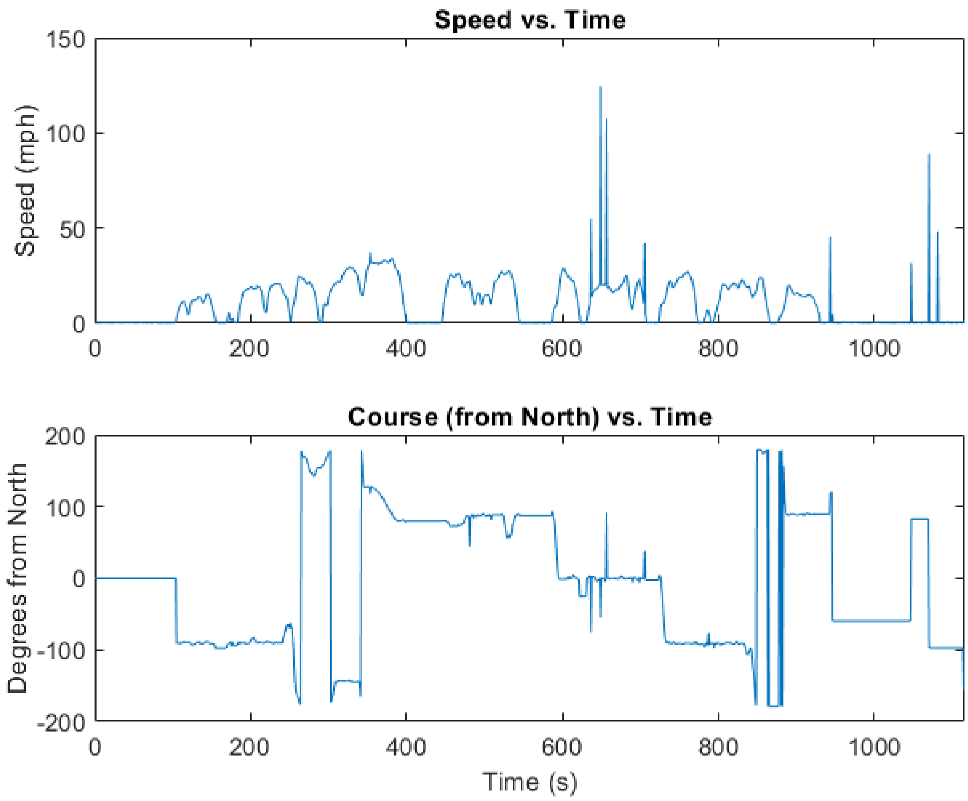


Figure 10: Dynamic Data Speed and Course

Looking at Figure 10 it is evident there are some spikes in speed and course that aren't realistic given the surrounding data and route followed. These are likely because of measurement noise or dropouts.

Part D

The clock bias and drift estimates are plotted versus time in figure 11.

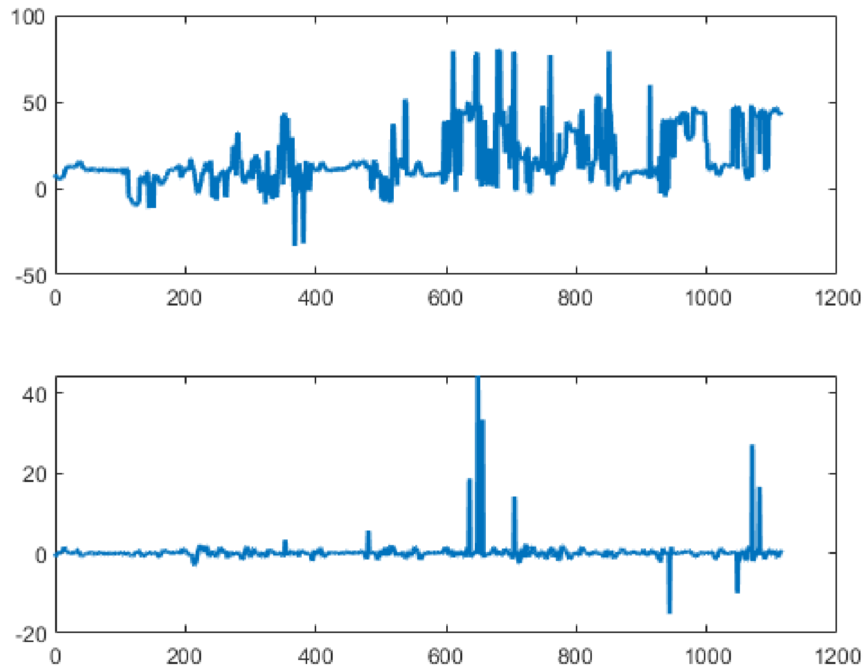


Figure 11: Dynamic Data ENU Position Error

Geocaching Data: RINEX files

Part A

The RINEX file was downloaded from NASA's Crustal Dynamics Data Information System (CDDIS) website: https://cddis.nasa.gov/About/Background.html. This site has many files of satellite-derived data including GPS Navigation Data. The file downloaded from the website is:

USN700USA_R_20220260000_01D_GN.rnx

This file was found under the site directory: 2022/027/22n. According to the CDDIS website, the file can be decoded.

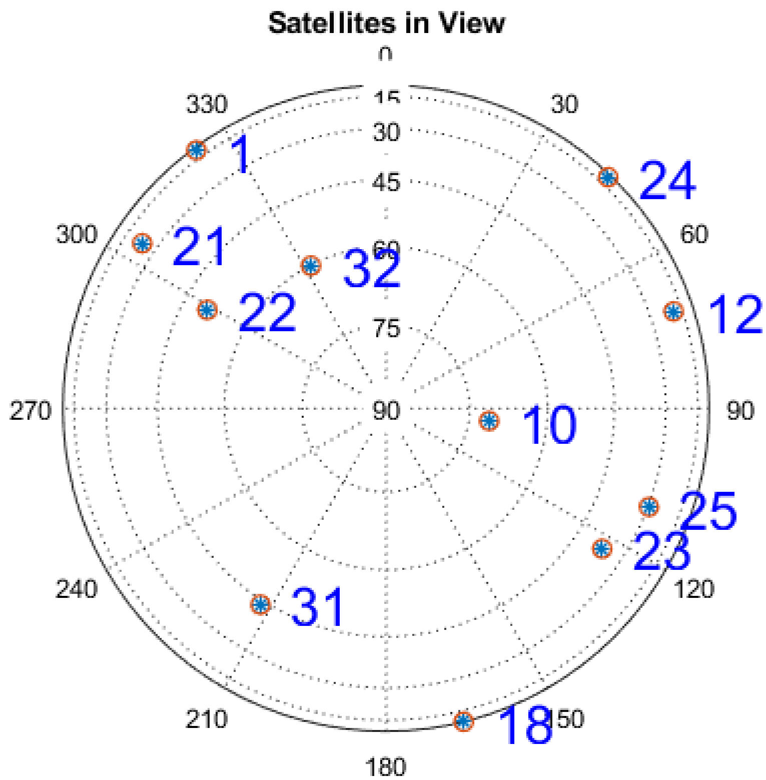
- The directory denotes data from Jan 27, 2022. 22n is the notation for "GPS broadcast ephemeris data."
- USN7 denotes the IGS station name: this one is near Washington, D.C
- 00 is the monument/marker number and receiver number
- USA is the ISO country code for the United States
- R denotes the data source is from a GPS receiver
- 20220260000 is the Gregorian year, day of the year, hour, and minute. This was collected at midnight January 26th, 2022
- 01D_30S means this is a 30-second sampling rate for 24 hours of data

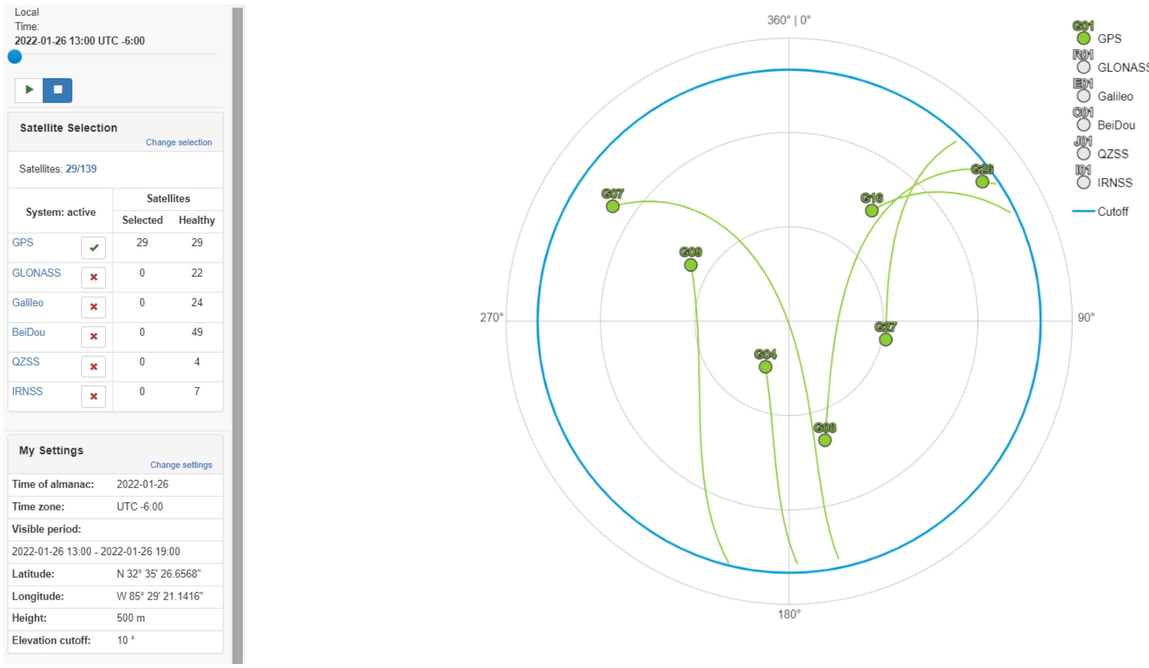
Part B

The data for Lab 1 was collected on January 26, 2022 around 12:55pm. The GPS Week and seconds for this time period are:

$$GPS_{week} = 2194$$
$$GPS_{sec} = 305718$$

Calculating the azimuth and elevation angles yields a sky plot which does not make sense. We must have a bug, but here is what we have. The second figure contains the actual satellite positions for the day.




Local
Time:
2022-01-26 13:00 UTC -6:00
Satellite Selection
Change selection
Satellites: 29/139
System: active
Satellites
Selected
Healthy
GPS 29 29
GLONASS 0 22
Galileo 0 24
BeiDou 0 49
QZSS 0 4
IRNSS 0 7
My Settings
Change settings
Time of almanac: 2022-01-26
Time zone: UTC -6:00
Visible period:
2022-01-26 13:00 - 2022-01-26 19:00
Latitude: N 32° 35' 26.6568"
Longitude: W 85° 29' 21.1416"
Height: 500 m
Elevation cutoff: 10 °
360° | 0°
90°
180°
270°
G07
G09
G16
G27
G04
G08
GPS
GLONASS
Galileo
BeiDou
QZSS
IRNSS
Cutoff