EECE 5554 Lab 2
Standalone and RTK GNSS Analysis

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1 Discussion

1. What are three major sources of error in GPS measurements?

The three major sources of GPS error are:

- Multipath reflections from buildings, trees, or ground surfaces.
- Satellite geometry (HDOP), which amplifies ranging errors.
- Atmospheric delay in the ionosphere and troposphere.

2. How was error calculated for each dataset?

Error was calculated differently for stationary and walking datasets. In all cases, altitude was ignored and only 2D UTM position was used.

Stationary Datasets:

For stationary data, position error was defined as the Euclidean distance from each measured point (E_i, N_i) to the centroid $(\bar{E}, \bar{N})$:

$$r_i = \sqrt{(E_i - \bar{E})^2 + (N_i - \bar{N})^2} \tag{1}$$

where:

- E_i, N_i are the measured UTM easting and northing values
- $\bar{E}, \bar{N}$ are the centroid (mean) easting and northing values
- r_i is the radial position error for each sample

The dataset error was summarized using the root-mean-square (RMS) value:

$$\mathrm{RMS}_{\text{stationary}} = \sqrt{\frac{1}{n}\sum_{i=1}^{n} r_i^2} \tag{2}$$

This provides a single scalar value representing overall 2D position error.

Walking Datasets:

For walking data, a line of best fit was computed using least squares regression:

$$N = mE + b \tag{3}$$

where m is the slope and b is the intercept.

Cross-track error was defined as the perpendicular distance from each measured point to the fitted line:

$$d_i = \frac{|mE_i - N_i + b|}{\sqrt{m^2 + 1}} \tag{4}$$

The walking dataset error was summarized using RMS cross-track error:

$$\text{RMS}_{\text{walk}} = \sqrt{\frac{1}{n}\sum_{i=1}^{n} d_i^2} \tag{5}$$

This produces a single scalar value representing deviation from the ideal straight-line trajectory.

3. What are the four calculated error values for the stationary datasets?

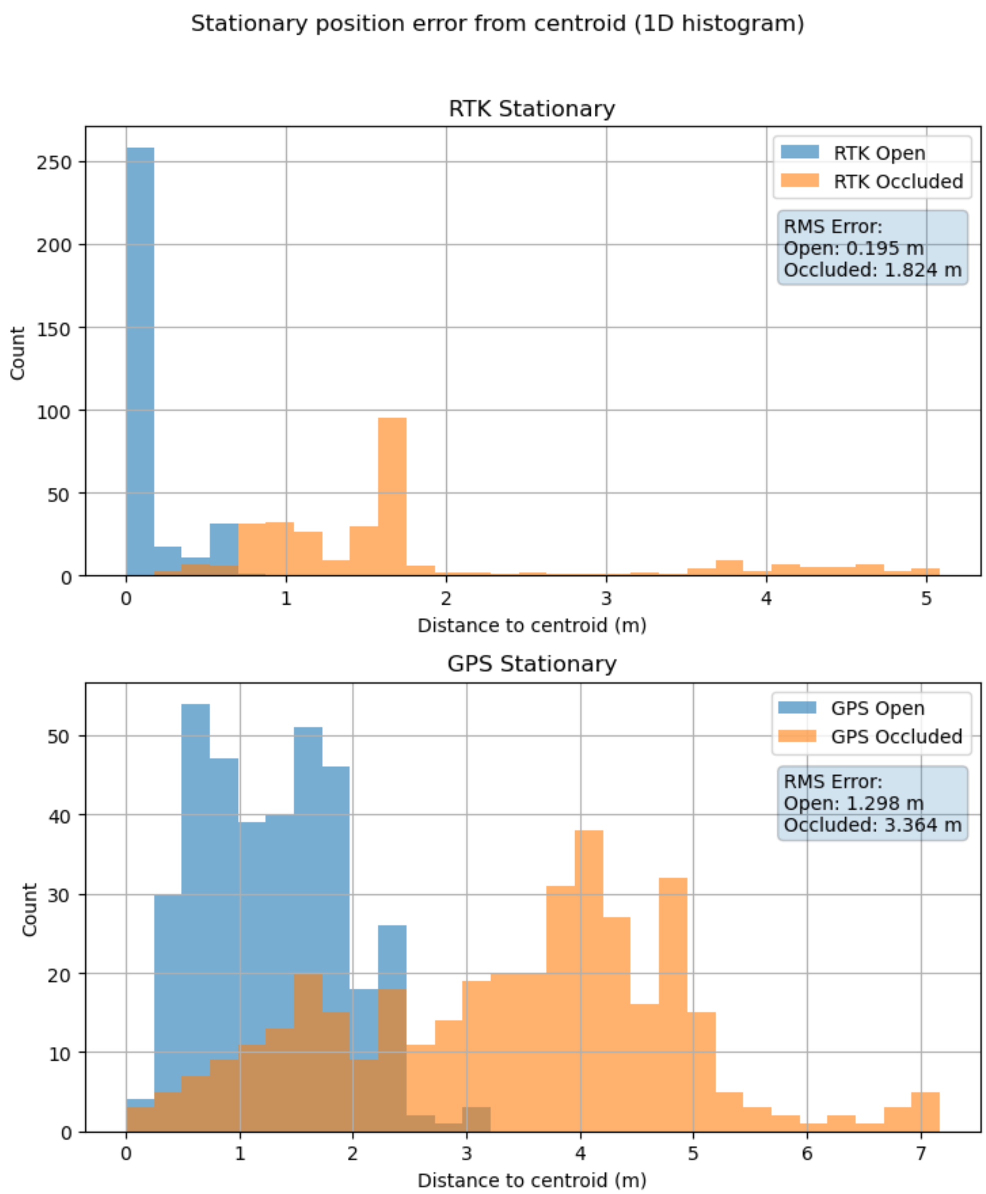

Figure 1: Stationary position error from centroid (1D histogram)

In the histogram we can see all the RMS error values and the distribution of point distances to the centroid.

4. How do RTK open and occluded errors differ? Does this relate to fix quality?

The RTK stationary open dataset produced an RMS error of approximately 0.195 m, while the occluded dataset produced an RMS error of approximately 1.824 m. This represents roughly a tenfold increase in position error under occluded conditions.

Fix quality refers to whether integer carrier phase ambiguities are successfully resolved. In open conditions, the strong satellite connects and minimal multi-path allow the receiver to find a fixed solution leading to high accuracy, with over 250 samples falling within the smallest error bin of .175 meters. Under occlusion, degraded carrier phase measurements likely prevented consistent ambiguity resolution, causing the receiver to fall back to a float or mixed-quality solution, which explains the increased positional variance.

5. Do these results align with known GPS vs RTK performance?

The stationary open-sky GPS RMS errors were on the order of 1.298 meters, and the occluded errors were on the order of 3.364 m. These results are consistent with expected standalone GPS performance.The RTK open-sky RMS error was 0.195 m, a significant improvement from GPS although higher than the expected centimeter level accuracy suggesting that the receiver didn't maintain a fixed solution the whole time. In the occluded situation, the RMS error increased 1.824, this degradation is consistent with known RTK behavior when satellite visibility is reduced and ambiguity resolution becomes unstable.

6. What are the top two likely physical sources of error in your standalone data?

The two most significant physical sources of error in the standalone GPS datasets are multipath reflections and poor satellite geometry.

Multipath occurs when GNSS signals reflect off nearby surfaces such as buildings, trees, or the ground before reaching the receiver. These reflected signals travel longer paths and introduce pseudorange bias, which shifts the estimated position. This effect is particularly pronounced in occluded environments and likely contributed to the increased RMS error observed in the occluded standalone dataset.

Poor satellite geometry, quantified by HDOP, also amplifies ranging errors. When satellites are clustered in a limited region of the sky, small measurement errors translate into larger horizontal position errors. In occluded environments, reduced satellite visibility worsens geometry, further degrading accuracy. Because standalone GPS does not apply differential or carrier-phase corrections, these geometric and multipath effects directly impact the final position estimate.

7. How does error change between stationary and moving datasets?

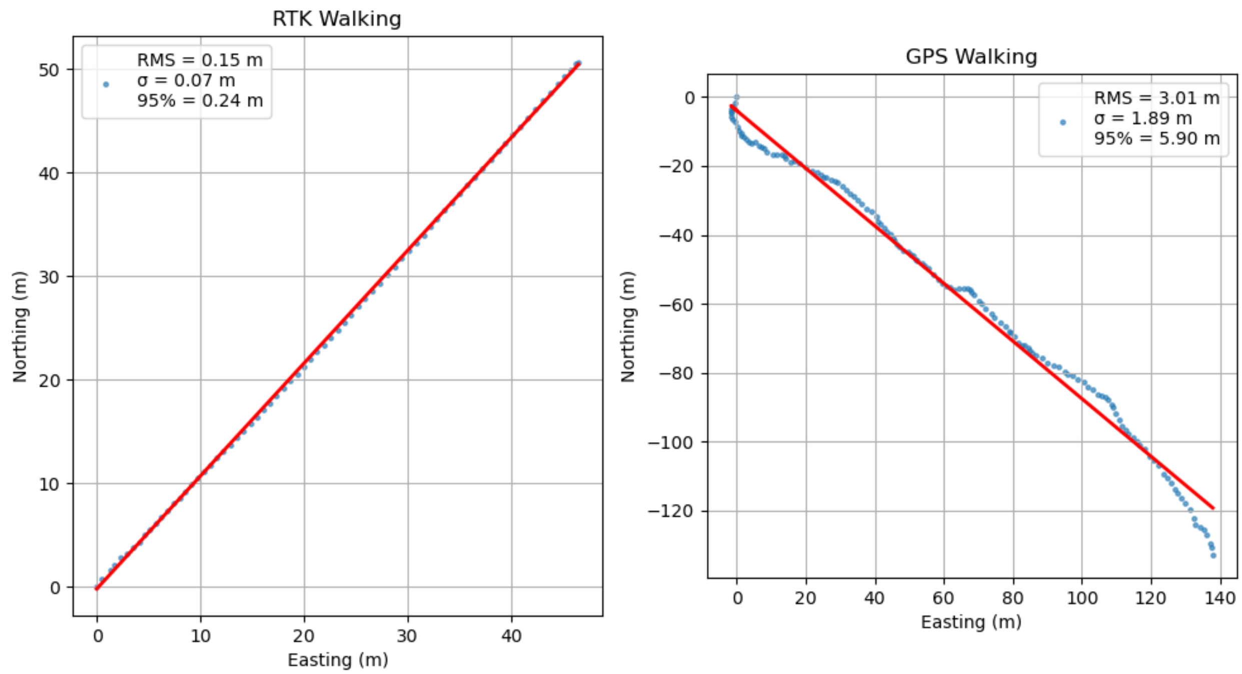

Figure 2: RTK vs GPS Walking Error

For standalone GPS, moving RMS error was 3.01 m compared to 1.298 m when stationary (open-sky). For RTK, moving RMS error was 0.15 m compared to 0.195 m when stationary. The decrease in error while walking could be due to the cross-track deviation metric not penalizing along-track drift. Additionally, motion can reduce persistent multi-path effects because the receiver continuously changes relative geometry with reflecting surfaces.

2 All other plots not mentioned in the Discussion but in the Rubric

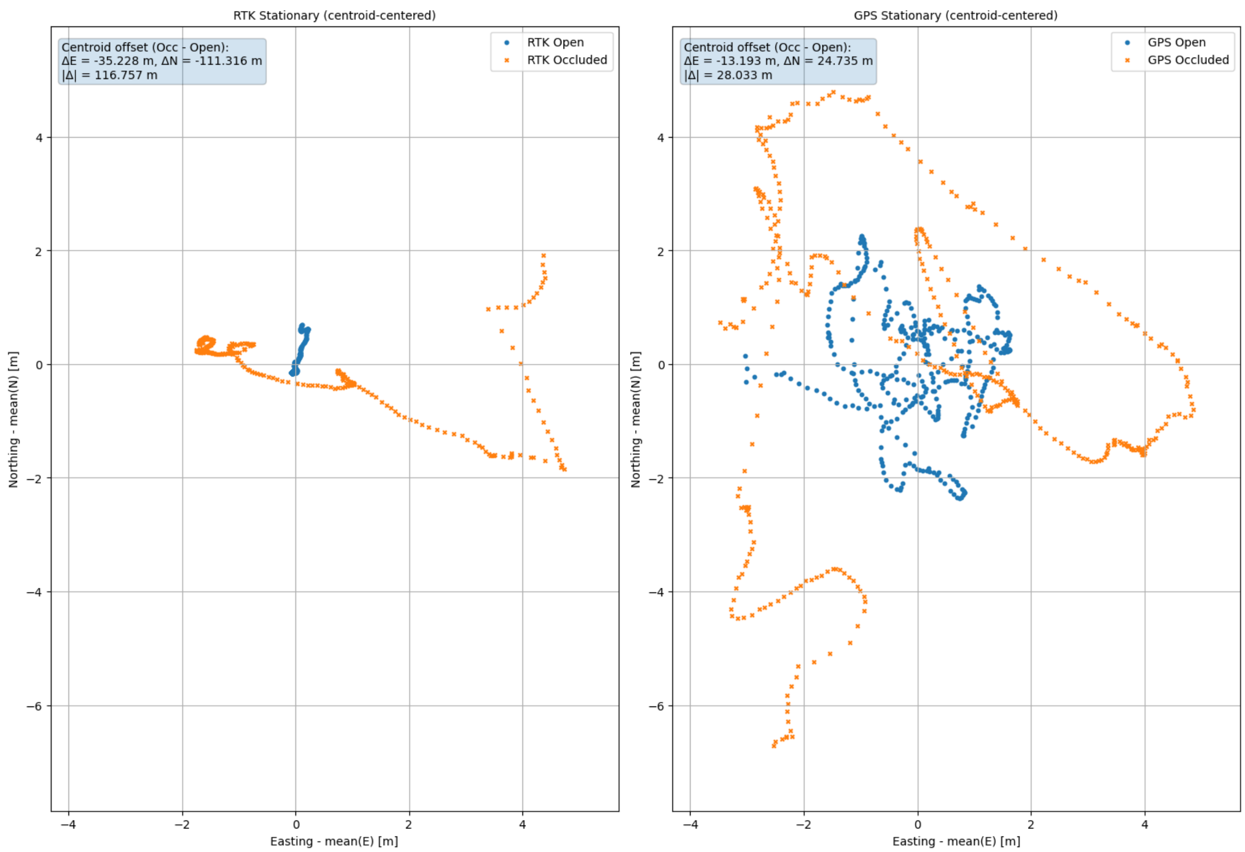

Figure 3: Stationary Northing vs Easting (centroid-centered)

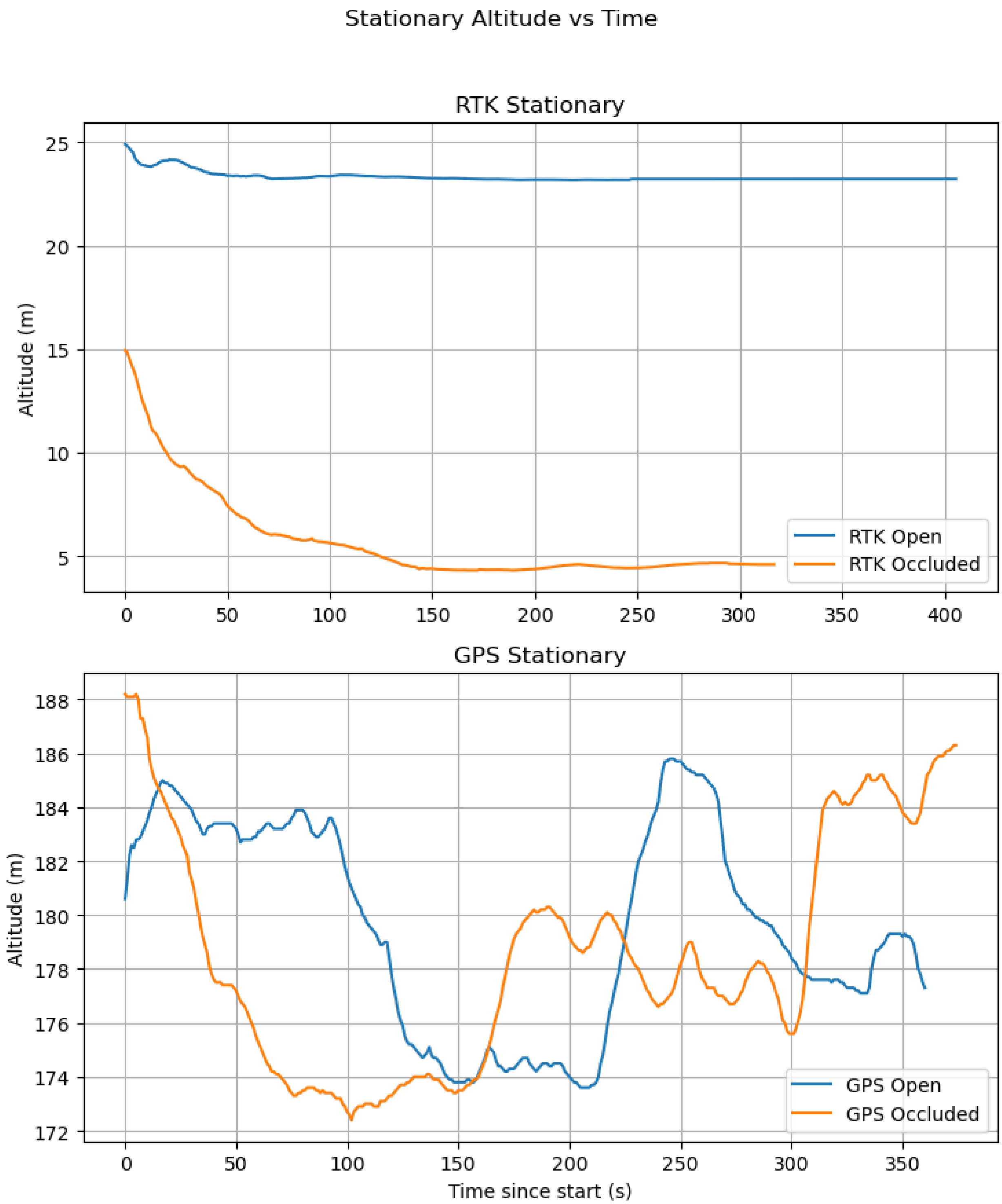

Figure 4: Stationary Altitude vs Time

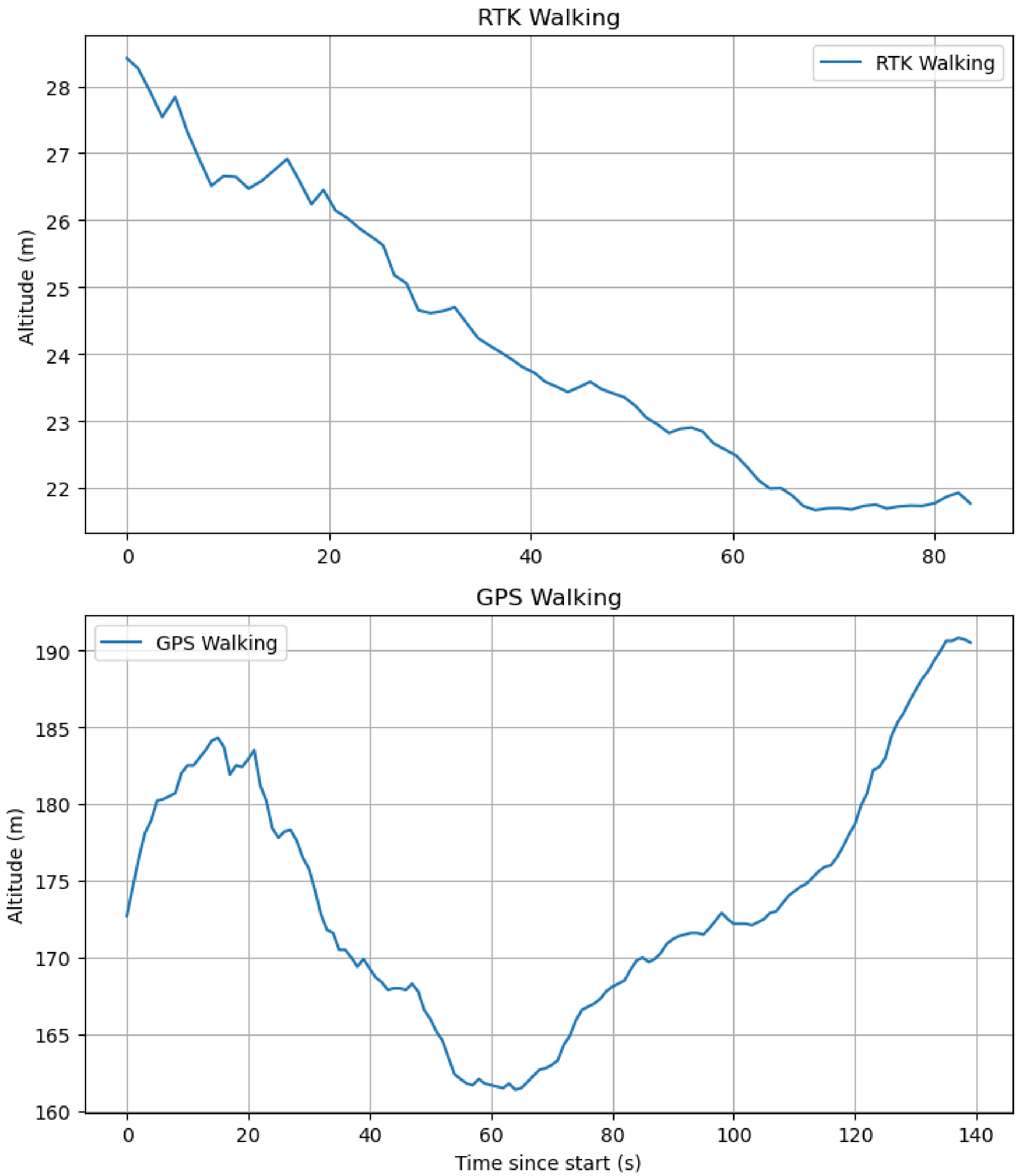

Figure 5: Walking Altitude vs Time