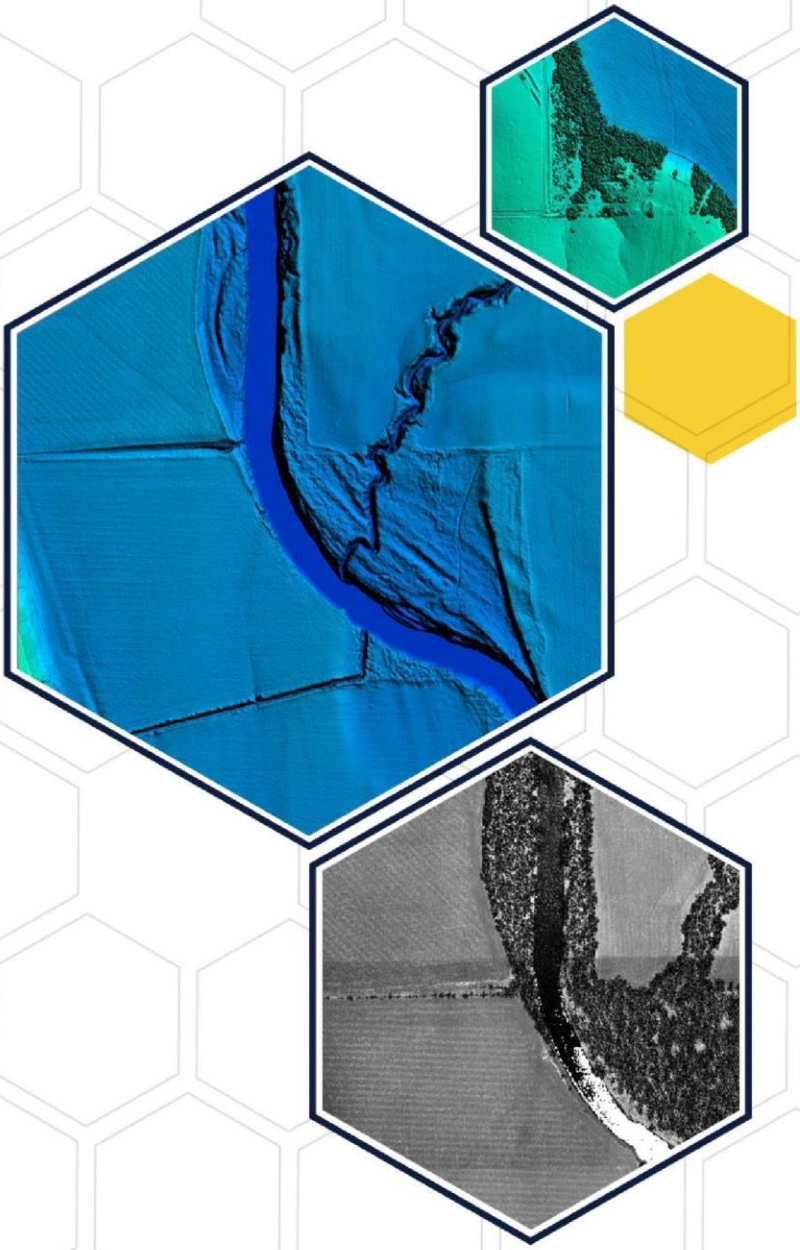

atlantic

Aerial Lidar Report

17004
Shelby County Tennessee, Shelby County, TN
June 2017

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Section 1: Lidar Acquisition

1.1 Acquisition

The Atlantic Group, LLC (Atlantic) has successfully completed lidar acquisition for the Shelby County, TN Area of Interest (AOI). Lidar for this AOI was acquired in four (4) flight mission completed on March 4th, 2017. The project area encompasses 503,019 acres, 2,036 square kilometers or 786 square miles.

1.2 Acquisition Status Report

Upon notification to proceed, the flight crew loaded the flight plans and validated the flight parameters. Atlantic's Director of Flight Operations contacted air traffic control and coordinated flight pattern requirements. Lidar acquisition began immediately upon notification that control base stations were in place. During flight operations, the flight crew monitored weather and atmospheric conditions. Lidar missions were flown only when no condition existed below the sensor that would affect the collection of data. The pilot constantly monitored the aircraft course, position, pitch, roll, and yaw of the aircraft. The sensor operator monitored the sensor, the status of the GNSS constellations, and performed the first QC review during acquisition. The flight crew constantly reviewed weather and cloud locations. Any flight lines impacted by unfavorable conditions were marked as invalid and re-flown at an optimal time.

1.3 Acquisition Details

Atlantic acquired fifty-nine (59) passes of the AOI as a series of perpendicular and/or adjacent flight-lines. Differential GNSS unit in aircraft recorded sample positions at 2 Hz or more frequency. Lidar data was only acquired when a minimum of 6 satellites were in view.

Atlantic lidar sensors are calibrated at a designated site located at the Fayetteville Municipal Airport (FYM) in Fayetteville, TN and are periodically checked and adjusted to minimize corrections at project sites.

1.4 Project Purpose

The primary purpose of the lidar survey was to establish measurements of the bare earth surface, as well as top surface feature data for providing geometric inputs for modeling, other numerical modeling and economic related assessments.

1.5 Lidar Flight-line Orientation

The following graphic represents the alignment of the project area of interest (AOI) and the flight-lines executed to provide AOI coverage.

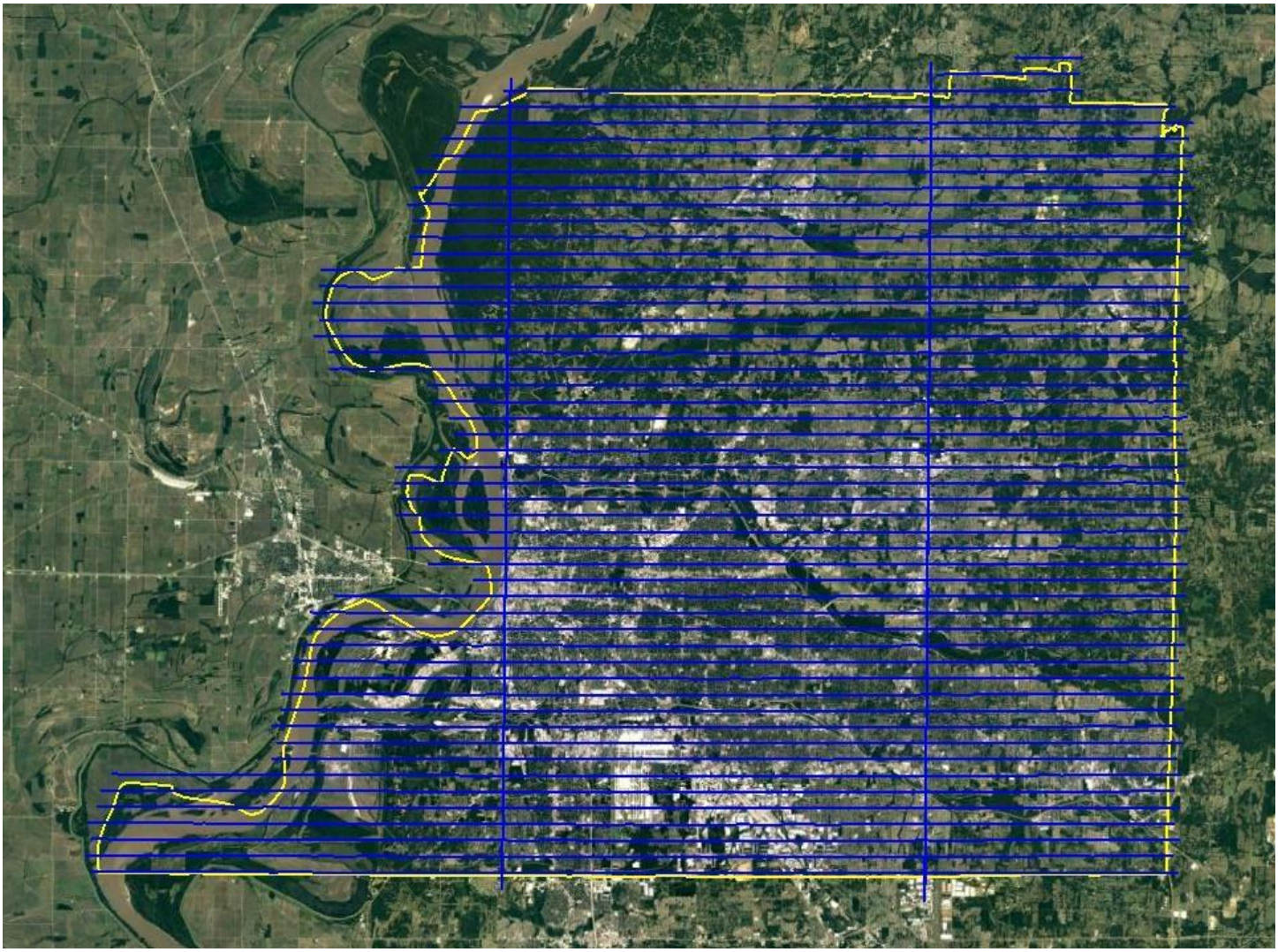


Figure 1: Trajectories as flown by Atlantic

1.6 Acquisition Equipment

Atlantic operated a Partenavia S.P.A P 68 C/TC (N775MW) and a Piper PA-31-350 Chieftain (N1872H) outfitted with Leica ALS70-HP lidar systems during the collection of the project area. Table 1 represents a list of the features and characteristics for the Leica ALS70-HP lidar system:

Atlantic's Sensor Characteristics		
Leica ALS70-HP		
Manufacturer	Leica	
Model	ALS70 - HP	
Platform	Fixed-Wing	
Scan Pattern	Sine, Triangle, Raster	
Maximum Scan Rate (Hz)	Sine	200
	Triangle	158
	Raster	120
Field of View (°)	0 - 75 (Full Angle, User Adjustable)	
Maximum Pulse rate (kHz)	500	
Maximum Flying height (m AGL)	3500	
Number of returns	Unlimited	
Number of Intensity Measurements	3 (First, Second, Third)	
Roll Stabilization (Automatic Adaptive, °)	75 - Active FOV	
Storage Media	Removable 500 GB SSD	
Storage Capacity (Hours @ Max Pulse Rate)	6	
Size (cm)	Scanner	37 W x 68 L x 26 H
	Control Electronics	45 W x 47 D x 36 H
Weight (kg)	Scanner	43
	Control Electronics	45
Operating Temperature	0 - 40 °C	
Flight Management	FCMS	
Power Consumption	927 @ 22.0 - 30.3 VDC	

Table 1: Atlantic Sensor Characteristics

1.7 Lidar System Acquisition Parameters

Table 2 illustrates Atlantic's system parameters for lidar acquisition on this project.

Lidar System Acquisition Parameters	
Item	**Parameter**
System	Leica ALS-70 HP
Nominal Pulse Spacing (m)	0.5
Nominal Pulse Density (pls/m²)	4.3
Nominal Flight Height (AGL meters)	1,600
Nominal Flight Speed (kts)	130
Pass Heading (degree)	90
Sensor Scan Angle (degree)	45
Scan Frequency (Hz)	47.3
Pulse Rate of Scanner (kHz)	356.6
Line Spacing (m)	922
Pulse Duration of Scanner (ns)	4
Pulse Width of Scanner (m)	0.35
Central Wavelength of Sensor Laser (nm)	1064
Sensor Operated with Multiple Pulses	Yes
Beam Divergence (mrad)	0.22
Nominal Swath Width (m)	1,220
Nominal Swath Overlap (%)	20
Scan Pattern	Triangle

Table 2: Atlantic Lidar System Acquisition Parameters

1.8 GNSS Reference Station(s)

Two (2) Continuously Operating Reference Stations (CORS) were used to control the lidar acquisition for the project area. The coordinates provided in Table 3 below are in NAD83 (2011), Geographic Coordinate System, Ellipsoid, Meters.

GNSS Reference Station Coordinates					
Designation	**Type**	**PID**	**Latitude (N)**	**Longitude (W)**	**Elevation**
TN45	CORS	DJ9572	35 17 57.37247	089 39 34.60010	64.142
ZME1	CORS	DF8976	35 04 02.59573	089 57 19.30088	69.412

Table 3: GNSS Reference Station Coordinates

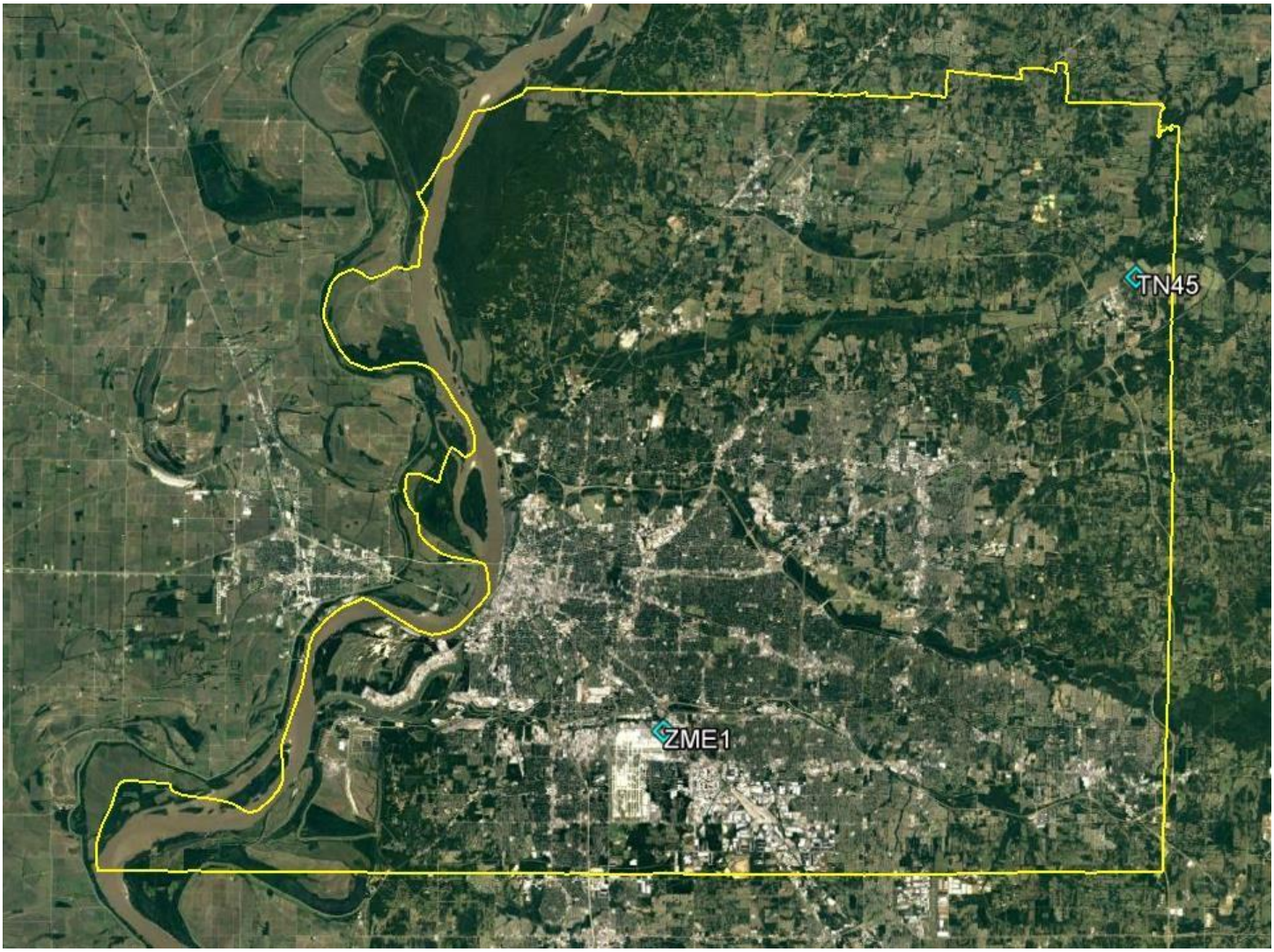


Figure 2: GNSS Reference Station(s)

1.9 Airborne GNSS Kinematic

Differential GNSS unit in aircraft collected positions at 2 Hz. Airborne GNSS data was processed using the Inertial Explorer (version 8.60.6717) software. Flights were flown with a minimum of 6 satellites in view (10° above the horizon).

For all flights, the GNSS data can be classified as good, with residuals of 3cm average or better but none larger than 10cm being recorded.

Data collected by the lidar unit is reviewed for completeness, acceptable density and to make sure all data is captured without errors or corrupted values. In addition, all GNSS, aircraft trajectory, mission information, and ground control files are reviewed and logged into a database.

GNSS processing results for each lift are included in **Section 5: GNSS Processing**.

Section 2: **Lidar Processing**

2.1 Lidar Point Cloud Generation

Atlantic used Leica software products to download the IPAS ABGNSS/IMU data and raw laser scan files from the airborne system. Waypoint Inertial Explorer is used to extract the raw IPAS ABGNSS/IMU data, which is further processed in combination with controlled base stations to provide the final Smoothed Best Estimate Trajectory (SBET) for each mission. The SBET's are combined with the raw laser scan files to export the Lidar ASCII Standard (*.las) formatted swath point clouds.

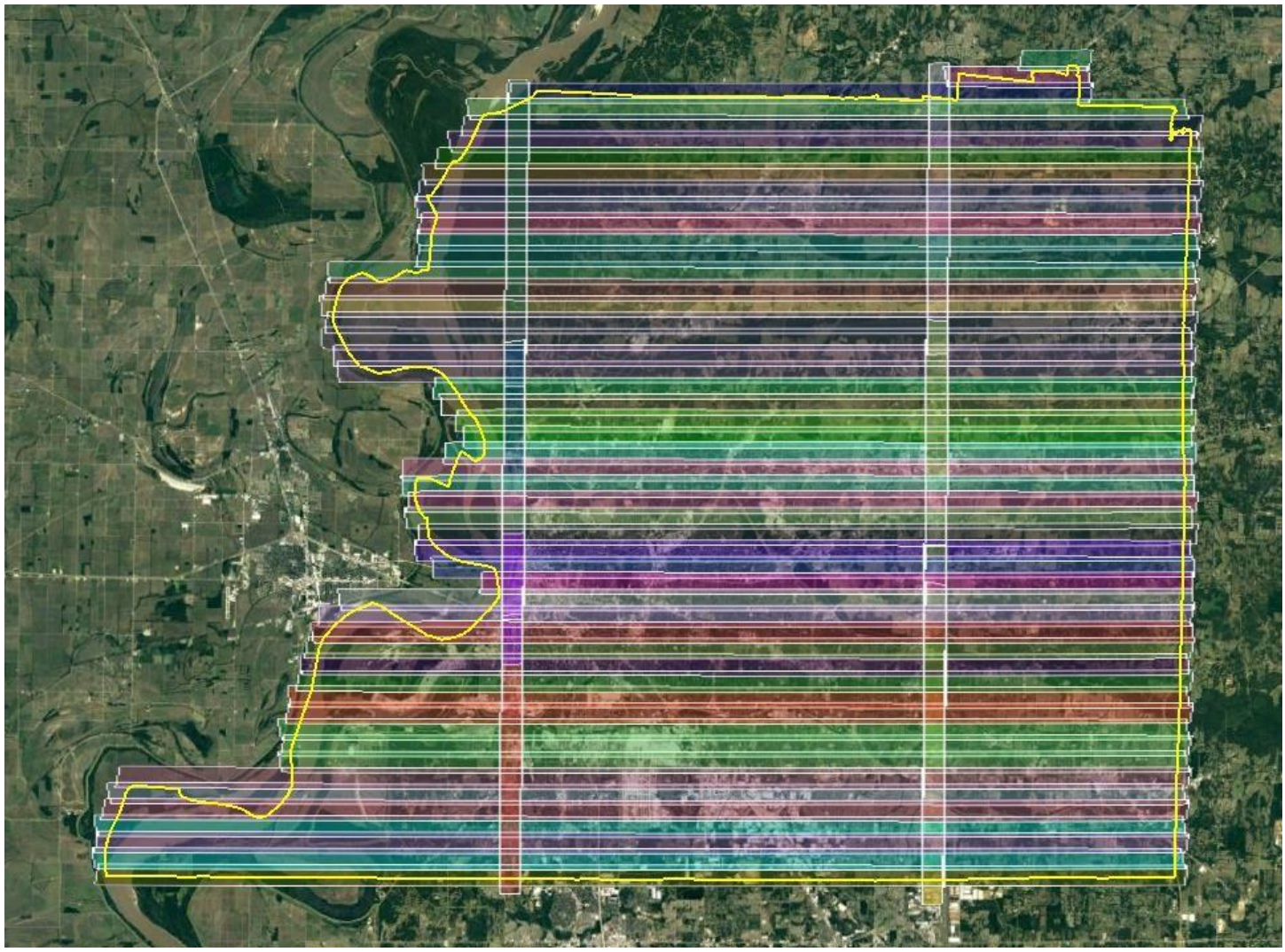


Figure 3: Lidar swath data showing complete coverage

2.2 Coordinate Reference System

Horizontal Datum:	North American Datum of 1983
Coordinate System:	State Plane Tennessee (FIPS 4100)
Vertical Datum:	North American Vertical Datum of 1988

Geoid Model: Geoid12B
Units of Reference: U.S. Survey Feet

2.3 Lidar Point Cloud Statistics

Table 4 illustrates the overall lidar point cloud statistics for this project.

Point Cloud Statistics	
Category	**Value**
Total Points	18,653,045,653
Nominal Pulse Spacing (m)	0.4414
Nominal Pulse Density (pls/m²)	5.13
Nominal Pulse Spacing (ft)	1.4481
Nominal Pulse Density (pls/ft²)	0.48
Total Aggregate Points	16,676,964,391
Aggregate Nominal Pulse Spacing (m)	0.4087
Aggregate Nominal Pulse Density (pls/m²)	5.99
Aggregate Nominal Pulse Spacing (ft)	1.3410
Aggregate Nominal Pulse Density (pls/ft²)	0.56

Table 4: Lidar Point Cloud Statistics

2.4 Expected Horizontal Positional Error

As described in Section 7.5 of the ASPRS Positional Accuracy Standards for Digital Geospatial Data the horizontal errors in lidar data are largely a function of GNSS positional error, INS angular error, and flying altitude. Therefore, lidar data collected with GNSS error of 8cm and the IMU error of 0.00427 degrees at an altitude of 1,600m; the expected radial horizontal positional error will be RMSEz = 24.1cm.

2.5 Smooth Surface Repeatability (Intraswath)

Departures from planarity of first returns within single swaths in non-vegetated areas were assessed at multiple locations with hard surface areas (parking lots or large rooftops) inside the project area. Each area was evaluated using signed difference rasters (maximum elevation – minimum elevation) at a cell size equal to 2 x ANPS, rounded to the next integer. The following graphic depicts a sample of the assessment.

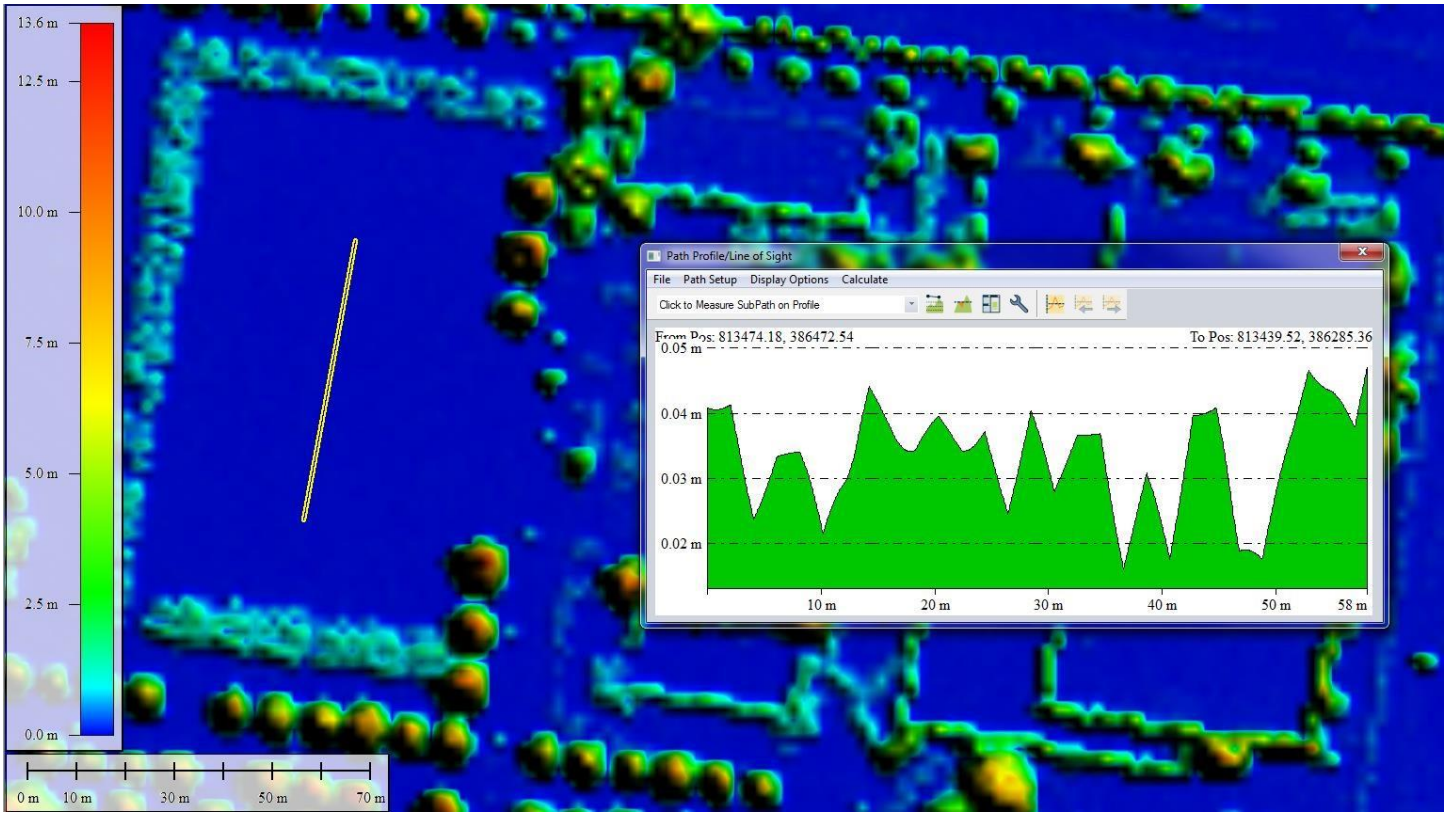


Figure 4: Smooth Surface Repeatability of ≤6cm

2.6 Lidar Calibration

Lidar ranging data were initially calibrated using previous best parameters for this instrument and aircraft. Using a combination of GeoCue, TerraScan and TerraMatch; the overlapping swath point clouds are corrected for any orientation or linear deviations to obtain the best fit swath-to-swath calibration. Relative calibration was evaluated using advanced plane-matching analysis and parameter corrections derived. This process was repeated interactively until residual errors between overlapping swaths, across all project missions, was reduced to ≤2cm. A final analysis of the calibrated lidar is preformed using a TerraMatch Tie Line report for an overall statistical model of the project area.

Upon completion of the data calibration, Atlantic runs a complete set of elevation difference intensity rasters (dZ Orthos). A user-defined color ramp is applied depicting the offsets between overlapping swaths based on project specifications.

The dZ orthos provide an opportunity to review the data calibration in a qualitative manner. Atlantic assigns green to all offset values that fall below the required RMSDz requirement of the project. A yellow color is assigned for offsets that fall between the RMSDz value and 1.5x of that value. Finally, red values are assigned to all values that fall beyond 1.5x of the RMSDz requirements of the project.

No Data	0m to 0.04m	0.04m to 0.08m	0.08m to 0.12m	> 0.12m

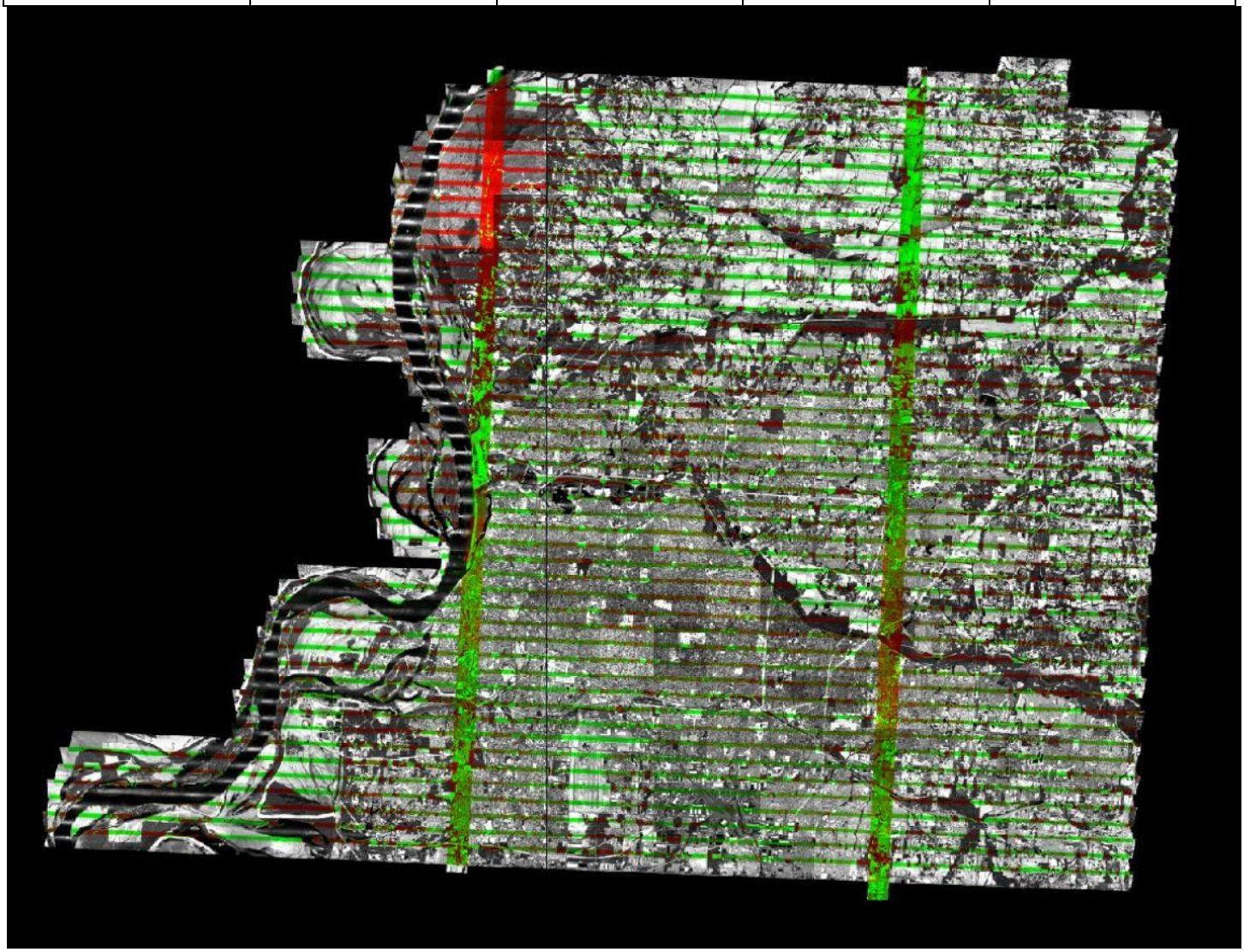


Figure 5: Swath Overlap Difference of ≤8cm, Maximum of ±16cm

2.7 Overlap Consistency (Interswath)

An overall statistical assessment of the relative accuracy using TerraMatch Tie Line Report between lidar swaths can be found in Tables 5, 6, 7, and 8 below. The values provided are in feet.

Average Magnitudes Per Line											
Line	X	Y	Z	Line	X	Y	Z	Line	X	Y	Z
2	0.042	0.062	0.036	20	0.049	0.049	0.050	49	0.047	0.046	0.040
3	0.026	0.026	0.030	21	0.044	0.042	0.041	50	0.042	0.042	0.042
4	0.046	0.051	0.037	22	0.045	0.052	0.041	51	0.044	0.052	0.041
5	0.054	0.053	0.037	23	0.043	0.050	0.047	52	0.045	0.044	0.040
6	0.044	0.048	0.040	24	0.047	0.048	0.050	53	0.051	0.049	0.038
7	0.042	0.055	0.038	25	0.049	0.043	0.044	54	0.048	0.045	0.038
8	0.036	0.047	0.040	26	0.045	0.040	0.042	55	0.046	0.047	0.044
9	0.042	0.045	0.039	27	0.064	0.063	0.044	56	0.048	0.058	0.042
10	0.062	0.065	0.039	28	0.047	0.048	0.041	57	0.053	0.052	0.040
11	0.056	0.069	0.041	40	0.047	0.057	0.039	58	0.049	0.049	0.039
12	0.057	0.076	0.045	41	0.049	0.065	0.043	59	0.045	0.054	0.044
13	0.042	0.046	0.039	42	0.053	0.048	0.038	60	0.054	0.058	0.045
14	0.053	0.059	0.042	43	0.075	0.066	0.052	63	0.074	0.114	0.041
15	0.079	0.085	0.041	44	0.062	0.057	0.051	64	0.081	0.164	0.040
16	0.053	0.055	0.042	46	0.036	0.034	0.038	65	0.085	0.150	0.043
17	0.059	0.072	0.046	47	0.045	0.046	0.039	66	0.086	0.144	0.043
18	0.050	0.067	0.043	48	0.040	0.038	0.040	67	0.100	0.138	0.047

Table 5: Average Tie Line Magnitudes per Line

Internal Observation Statistics			
Category	X	Y	Z
Average Magnitude	0.054	0.060	0.044
RMS Values	0.087	0.100	0.062
Maximum Values	0.561	0.499	0.499
Observation Weight	176294.0	176294.0	1465579.0

Table 6: Tie Line Observation Statistics

Overall Relative Accuracy	
Category	**Mismatch**
Average 3D Mismatch	0.05202
Average XY Mismatch	0.09917
Average Z Mismatch	0.04368

Table 7: Relative Accuracy Results

TerraMatch Tie Lines	
Category	**Observations**
Section Lines	549,260
Roof Lines	80,859

Table 8: Total Tie Lines

2.8 Lidar Classification

Atlantic uses multiple automated filtering routines on the calibrated lidar point cloud identifying and extracting bare-earth and above ground features. GeoCue, TerraScan, and TerraModeler software was used for the initial batch processing and manual editing of the lidar point clouds. Atlantic utilized collected breakline data to preform classification for classes' 9Water and 10-Ignored Ground in LP360. Outlined in Table 9 are the classification codes utilized for this project.

ASPRS Standard Lidar Point Classes	
Code	**Description**
1	Unclassified
2	Ground
7	Low Noise
9	Water
10	Ignored Ground
17	Bridges
18	High Noise
Flags	Overlap & Withheld

Table 9: Point Cloud Classification Scheme

Section 3: Lidar Accuracy

3.1 Ground Surveyed Check Points

Atlantic established a total of ninety-two (92) check points for this project (52 NVA + 40 VVA). Point cloud data accuracy was tested against a Triangulated Irregular Network (TIN) constructed from lidar points in clear and open areas. A clear and open area can be characterized with respect to topographic and ground cover variation such that a minimum of 5 times the NPS exists with less than 1/3 of the $RMSE_Z$ deviation from a low-slope plane. Slopes that exceed 10 percent were avoided. Each land cover type representing 10 percent or more of the total project area were tested and reported with a VVA. In land cover categories other than dense urban areas, the tested points did not have obstructions 45 degrees above the horizon to ensure a sufficient TIN surface. The VVA value is provided as a target. It is understood that in areas of dense vegetation, swamps, or extremely difficult terrain, this value may be exceeded. The NVA value is a requirement that must be met, regardless of any allowed "busts" in the VVA(s) for individual land cover types within the project. Checkpoints for each assessment (NVA & VVA) are required to be well-distributed throughout the land cover type, for the entire project area.

3.2 Vertical Accuracy Requirements

Below are the vertical accuracy reporting requirements for this project:

Vertical Accuracy Reporting Requirements in Meters:

$RMSE_Z \leq 10.0$cm (Non-Vegetated Swath, DEM)
NVA ≤ 19.6cm 95% Confidence Level (Swath, DEM)
VVA ≤ 29.4cm 95^{th} Percentile (DEM)

Vertical Accuracy Reporting Requirements in Feet:

$RMSE_Z \leq 0.328$ft (Non-Vegetated Swath, DEM)
NVA ≤ 0.643ft 95% Confidence Level (Swath, DEM)
VVA ≤ 0.965ft 95^{th} Percentile (DEM)

*The terms FVA (Fundamental Vertical Accuracy), SVA (Supplemental Vertical Accuracy) and CVA (Consolidated Vertical Accuracy) are from the National Digital Elevation Program (NDEP) Guidelines for Digital Elevation Data (2004). The term FVA refers to open terrain, urban and levee classes; the term SVA refers to classes tested that are in addition or supplemental to the open terrain; the term CVA refers to the consolidated accuracy of the data from all classes (FVA + SVA).

*The terms NVA (Non-vegetated Vertical Accuracy) and VVA (Vegetated Vertical Accuracy) are from the ASPRS Positional Accuracy Standards for Digital Geospatial Data v1.0 (2014). The term NVA refers to assessments in clear, open areas (which typically produce only single lidar returns); the term VVA refers to assessments in vegetated areas (typically characterized by multiple return lidar).

3.3 Check Point Distribution

The following graphics depict the location and distribution of NVA and VVA check points established for this project.

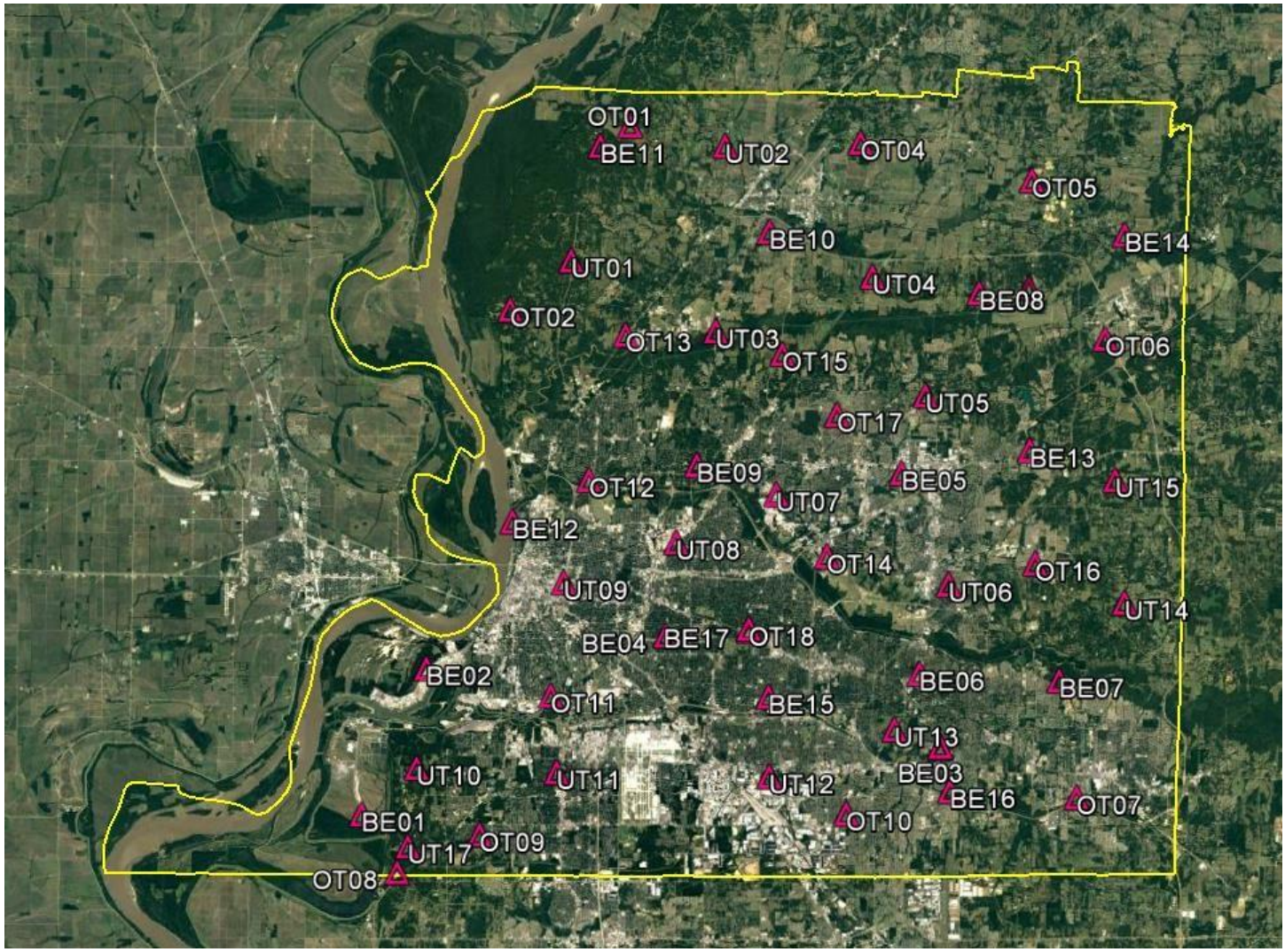


Figure 6: Non-vegetated Vertical Accuracy (NVA) Check Point Distribution

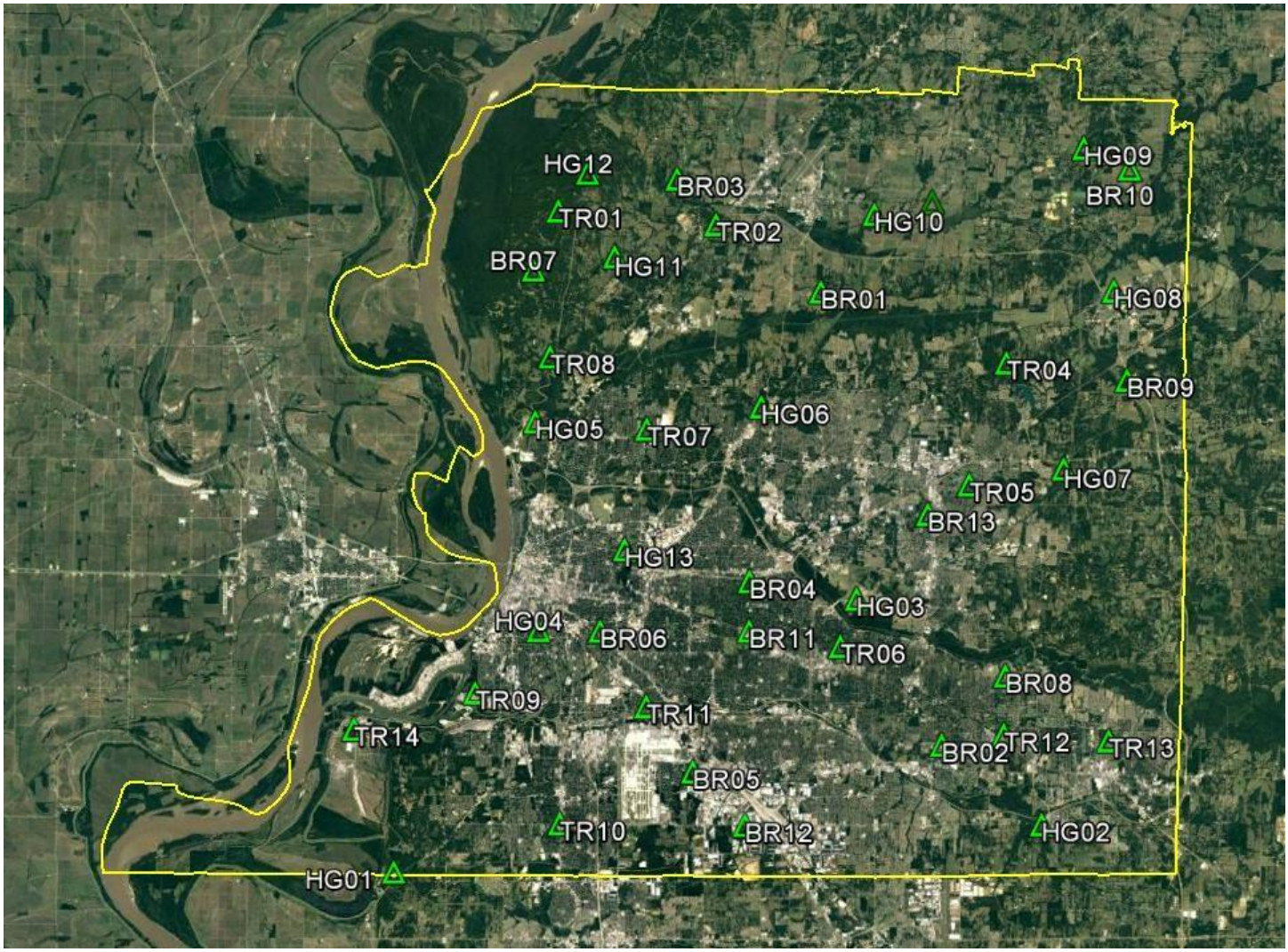


Figure 7: Vegetated Vertical Accuracy (VVA) Check Point Distribution

3.4 Vertical Accuracy Results

An overall statistical assessment of the check points can be found in Tables 10 and 11 below. The values provided are in feet.

Non-vegetated Vertical Accuracy (NVA) and Vegetated Vertical Accuracy (VVA)				
Broad Land Cover Type	**# of Points**	**RMSEz**	**95% Confidence Level**	**95th Percentile**
NVA of Lidar Point Cloud	52	0.209	0.410	
NVA of Bare-Earth Lidar	52	0.212	0.415	
NVA of Bare-Earth DEM	52	0.220	0.431	
VVA of Bare-Earth DEM	40	0.221		0.419
VVA of Bare-Earth Lidar	40	0.224		0.404

Table 10: Non-vegetated Vertical Accuracy (NVA) and Vegetated Vertical Accuracy (VVA)

Vegetated Vertical Accuracy (VVA) 5% Outliers > 95th Percentile (0.404ft)						
PointID	**Easting**	**Northing**	**KnownZ**	**LaserZ**	**Description**	**DeltaZ**
HG03	820043.978	314399.561	254.784	255.363	High Grass	0.579
HG04	760866.744	310993.545	314.020	314.518	High Grass	0.498

Table 11: 5% Outlier Check Points

3.5 Check Point Assessment

A vertical accuracy assessment of the NVA & VVA check points against the lidar point cloud and bare-earth lidar can be found in Tables 12, 13, 14, 15, and 16 below. The coordinates provided are in NAD83, Tennessee (FIPS 4100) NAVD88 (Geoid12B), U.S. Survey Feet.

Non-vegetated Vertical Accuracy (NVA) Check Point Assessment (Point Cloud)						
PointID	**Easting**	**Northing**	**KnownZ**	**LaserZ**	**Description**	**DeltaZ**
BE01	726472.782	278367.218	210.370	210.657	Open Terrain/Bare Earth	0.287
BE02	739613.515	304975.837	235.536	235.570	Open Terrain/Bare Earth	0.034
BE03	834620.053	286644.712	342.353	342.980	Open Terrain/Bare Earth	0.627
BE04	784382.598	309201.301	304.013	303.892	Open Terrain/Bare Earth	-0.121
BE05	829443.468	337535.129	290.691	290.791	Open Terrain/Bare Earth	0.100
BE06	831265.812	300278.510	304.957	305.074	Open Terrain/Bare Earth	0.117
BE07	857210.456	297990.492	281.970	282.236	Open Terrain/Bare Earth	0.266
BE08	845200.714	370294.533	279.135	279.360	Open Terrain/Bare Earth	0.225
BE09	791426.260	340544.559	292.488	292.699	Open Terrain/Bare Earth	0.211
BE10	806662.196	383169.923	268.837	269.060	Open Terrain/Bare Earth	0.223

BE11	775854.109	400348.651	393.880	393.768	Open Terrain/Bare Earth	-0.112
BE12	756748.024	331470.710	237.054	236.896	Open Terrain/Bare Earth	-0.158
BE13	853429.930	340778.118	385.600	385.776	Open Terrain/Bare Earth	0.176
BE14	872730.435	379994.323	267.699	267.750	Open Terrain/Bare Earth	0.051
BE15	803037.797	297127.542	270.049	270.056	Open Terrain/Bare Earth	0.007
BE16	836081.992	278315.012	304.742	304.878	Open Terrain/Bare Earth	0.136
BE17	799910.473	309487.738	302.189	302.492	Open Terrain/Bare Earth	0.303
OT01	781545.498	403909.233	301.881	301.941	Open Terrain/Bare Earth	0.060
OT02	757875.284	370709.810	254.609	254.643	Open Terrain/Bare Earth	0.034
OT03	834614.266	286343.008	343.541	344.005	Open Terrain/Bare Earth	0.464
OT04	824272.973	399006.762	355.155	355.127	Open Terrain/Bare Earth	-0.028
OT05	855850.881	390779.499	341.005	340.925	Open Terrain/Bare Earth	-0.080
OT06	868307.287	360869.662	316.890	316.686	Open Terrain/Bare Earth	-0.204
OT07	859604.168	276197.736	331.979	331.803	Open Terrain/Bare Earth	-0.176
OT08	732651.950	267385.330	260.951	260.814	Open Terrain/Bare Earth	-0.137
OT09	748274.110	273764.036	298.178	298.039	Open Terrain/Bare Earth	-0.139
OT10	816615.805	274909.130	362.000	361.991	Open Terrain/Bare Earth	-0.009
OT11	762582.119	298943.402	240.455	240.558	Open Terrain/Bare Earth	0.103
OT12	771278.474	338589.972	236.787	236.992	Open Terrain/Bare Earth	0.205
OT13	779175.536	365198.434	234.586	234.905	Open Terrain/Bare Earth	0.319
OT14	814933.610	322656.712	270.315	270.244	Open Terrain/Bare Earth	-0.071
OT15	808152.112	360461.031	257.784	257.935	Open Terrain/Bare Earth	0.151
OT16	853614.339	319779.711	313.763	313.784	Open Terrain/Bare Earth	0.021
OT17	817862.997	348802.152	331.197	331.151	Open Terrain/Bare Earth	-0.046
OT18	799898.947	309851.513	302.885	303.031	Open Terrain/Bare Earth	0.146
UT01	769594.080	379357.728	283.901	283.644	Urban Terrain	-0.257
UT02	799053.621	399424.631	305.728	305.326	Urban Terrain	-0.402
UT03	795944.421	365174.227	239.634	239.837	Urban Terrain	0.203
UT04	825483.319	374099.565	289.247	289.012	Urban Terrain	-0.235
UT05	834462.618	351734.283	300.892	300.880	Urban Terrain	-0.012
UT06	837357.171	316544.686	343.162	343.099	Urban Terrain	-0.063
UT07	805990.767	334543.163	254.614	254.204	Urban Terrain	-0.410

UT08	787014.470	326387.897	248.349	248.402	Urban Terrain	0.053
UT09	765813.705	319802.551	272.816	272.637	Urban Terrain	-0.179
UT10	737063.983	286567.553	303.218	302.966	Urban Terrain	-0.252
UT11	763075.058	284737.200	254.686	254.534	Urban Terrain	-0.152
UT12	802576.195	282356.891	304.818	304.761	Urban Terrain	-0.057
UT13	826199.292	290149.146	340.385	340.161	Urban Terrain	-0.224
UT14	869942.836	311858.201	317.555	317.522	Urban Terrain	-0.033
UT15	869117.089	334652.615	336.767	336.591	Urban Terrain	-0.176
UT16	854512.121	370869.125	270.989	270.782	Urban Terrain	-0.207
UT17	734825.607	272115.689	234.937	235.209	Urban Terrain	0.272

Table 12: Lidar Point Cloud NVA Assessment

Non-vegetated Vertical Accuracy (NVA) Check Point Assessment (Bare-Earth)						
PointID	**Easting**	**Northing**	**KnownZ**	**LaserZ**	**Description**	**DeltaZ**
BE01	726472.782	278367.218	210.370	210.602	Open Terrain/Bare Earth	0.232
BE02	739613.515	304975.837	235.536	235.464	Open Terrain/Bare Earth	-0.072
BE03	834620.053	286644.712	342.353	342.963	Open Terrain/Bare Earth	0.610
BE04	784382.598	309201.301	304.013	303.800	Open Terrain/Bare Earth	-0.213
BE05	829443.468	337535.129	290.691	290.733	Open Terrain/Bare Earth	0.042
BE06	831265.812	300278.510	304.957	305.052	Open Terrain/Bare Earth	0.095
BE07	857210.456	297990.492	281.970	282.008	Open Terrain/Bare Earth	0.038
BE08	845200.714	370294.533	279.135	279.260	Open Terrain/Bare Earth	0.125
BE09	791426.260	340544.559	292.488	292.699	Open Terrain/Bare Earth	0.211
BE10	806662.196	383169.923	268.837	269.040	Open Terrain/Bare Earth	0.203
BE11	775854.109	400348.651	393.880	393.722	Open Terrain/Bare Earth	-0.158
BE12	756748.024	331470.710	237.054	236.896	Open Terrain/Bare Earth	-0.158
BE13	853429.930	340778.118	385.600	385.658	Open Terrain/Bare Earth	0.058
BE14	872730.435	379994.323	267.699	267.750	Open Terrain/Bare Earth	0.051
BE15	803037.797	297127.542	270.049	270.048	Open Terrain/Bare Earth	-0.001
BE16	836081.992	278315.012	304.742	304.822	Open Terrain/Bare Earth	0.080
BE17	799910.473	309487.738	302.189	302.437	Open Terrain/Bare Earth	0.248

OT01	781545.498	403909.233	301.881	301.907	Open Terrain/Bare Earth	0.026
OT02	757875.284	370709.810	254.609	254.643	Open Terrain/Bare Earth	0.034
OT03	834614.266	286343.008	343.541	343.860	Open Terrain/Bare Earth	0.319
OT04	824272.973	399006.762	355.155	355.074	Open Terrain/Bare Earth	-0.081
OT05	855850.881	390779.499	341.005	340.925	Open Terrain/Bare Earth	-0.080
OT06	868307.287	360869.662	316.890	316.686	Open Terrain/Bare Earth	-0.204
OT07	859604.168	276197.736	331.979	331.803	Open Terrain/Bare Earth	-0.176
OT08	732651.950	267385.330	260.951	260.782	Open Terrain/Bare Earth	-0.169
OT09	748274.110	273764.036	298.178	298.039	Open Terrain/Bare Earth	-0.139
OT10	816615.805	274909.130	362.000	361.991	Open Terrain/Bare Earth	-0.009
OT11	762582.119	298943.402	240.455	240.558	Open Terrain/Bare Earth	0.103
OT12	771278.474	338589.972	236.787	236.992	Open Terrain/Bare Earth	0.205
OT13	779175.536	365198.434	234.586	234.796	Open Terrain/Bare Earth	0.210
OT14	814933.610	322656.712	270.315	270.244	Open Terrain/Bare Earth	-0.071
OT15	808152.112	360461.031	257.784	257.886	Open Terrain/Bare Earth	0.102
OT16	853614.339	319779.711	313.763	313.698	Open Terrain/Bare Earth	-0.065
OT17	817862.997	348802.152	331.197	331.151	Open Terrain/Bare Earth	-0.046
OT18	799898.947	309851.513	302.885	303.031	Open Terrain/Bare Earth	0.146
UT01	769594.080	379357.728	283.901	283.573	Urban Terrain	-0.328
UT02	799053.621	399424.631	305.728	305.326	Urban Terrain	-0.402
UT03	795944.421	365174.227	239.634	239.804	Urban Terrain	0.170
UT04	825483.319	374099.565	289.247	289.012	Urban Terrain	-0.235
UT05	834462.618	351734.283	300.892	300.880	Urban Terrain	-0.012
UT06	837357.171	316544.686	343.162	343.099	Urban Terrain	-0.063
UT07	805990.767	334543.163	254.614	254.084	Urban Terrain	-0.530
UT08	787014.470	326387.897	248.349	248.308	Urban Terrain	-0.041
UT09	765813.705	319802.551	272.816	272.494	Urban Terrain	-0.322
UT10	737063.983	286567.553	303.218	302.857	Urban Terrain	-0.361
UT11	763075.058	284737.200	254.686	254.386	Urban Terrain	-0.300
UT12	802576.195	282356.891	304.818	304.761	Urban Terrain	-0.057
UT13	826199.292	290149.146	340.385	340.138	Urban Terrain	-0.247
UT14	869942.836	311858.201	317.555	317.218	Urban Terrain	-0.337
UT15	869117.089	334652.615	336.767	336.554	Urban Terrain	-0.213

UT16	854512.121	370869.125	270.989	270.782	Urban Terrain	-0.207
UT17	734825.607	272115.689	234.937	235.029	Urban Terrain	0.092

Table 13: Bare-Earth Lidar NVA Assessment

Non-vegetated Vertical Accuracy (NVA) Check Point Assessment (DEM)						
PointID	**Easting**	**Northing**	**KnownZ**	**DEMZ**	**Description**	**DeltaZ**
BE01	726472.782	278367.218	210.370	210.583	Open Terrain/Bare Earth	-0.212
BE02	739613.515	304975.837	235.536	235.474	Open Terrain/Bare Earth	0.062
BE03	834620.053	286644.712	342.354	342.918	Open Terrain/Bare Earth	-0.564
BE04	784382.598	309201.301	304.014	303.804	Open Terrain/Bare Earth	0.210
BE05	829443.468	337535.129	290.692	290.772	Open Terrain/Bare Earth	-0.081
BE06	831265.812	300278.510	304.958	305.079	Open Terrain/Bare Earth	-0.121
BE07	857210.456	297990.492	281.971	282.018	Open Terrain/Bare Earth	-0.048
BE08	845200.714	370294.533	279.136	279.244	Open Terrain/Bare Earth	-0.109
BE09	791426.260	340544.559	292.489	292.757	Open Terrain/Bare Earth	-0.269
BE10	806662.196	383169.923	268.838	269.051	Open Terrain/Bare Earth	-0.213
BE11	775854.109	400348.651	393.881	393.709	Open Terrain/Bare Earth	0.172
BE12	756748.024	331470.710	237.054	236.915	Open Terrain/Bare Earth	0.140
BE13	853429.930	340778.118	385.601	385.654	Open Terrain/Bare Earth	-0.053
BE14	872730.435	379994.323	267.700	267.761	Open Terrain/Bare Earth	-0.061
BE15	803037.797	297127.542	270.050	270.044	Open Terrain/Bare Earth	0.006
BE16	836081.992	278315.012	304.743	304.768	Open Terrain/Bare Earth	-0.026
BE17	799910.473	309487.738	302.190	302.510	Open Terrain/Bare Earth	-0.321
OT01	781545.498	403909.233	301.882	301.930	Open Terrain/Bare Earth	-0.049
OT02	757875.284	370709.810	254.609	254.637	Open Terrain/Bare Earth	-0.028
OT03	834614.266	286343.008	343.542	343.849	Open Terrain/Bare Earth	-0.308
OT04	824272.973	399006.762	355.156	355.098	Open Terrain/Bare Earth	0.057
OT05	855850.881	390779.499	341.006	340.877	Open Terrain/Bare Earth	0.129
OT06	868307.287	360869.662	316.891	316.761	Open Terrain/Bare Earth	0.129
OT07	859604.168	276197.736	331.980	331.796	Open Terrain/Bare Earth	0.184
OT08	732651.950	267385.330	260.952	260.800	Open Terrain/Bare Earth	0.152
OT09	748274.110	273764.036	298.179	298.005	Open Terrain/Bare Earth	0.173
OT10	816615.805	274909.130	362.001	361.984	Open Terrain/Bare Earth	0.017
OT11	762582.119	298943.402	240.455	240.565	Open Terrain/Bare Earth	-0.109
OT12	771278.474	338589.972	236.787	236.945	Open Terrain/Bare Earth	-0.158
OT13	779175.536	365198.434	234.586	234.895	Open Terrain/Bare Earth	-0.309
OT14	814933.610	322656.712	270.316	270.190	Open Terrain/Bare Earth	0.126
OT15	808152.112	360461.031	257.785	257.934	Open Terrain/Bare Earth	-0.149

OT16	853614.339	319779.711	313.764	313.739	Open Terrain/Bare Earth	0.025
OT17	817862.997	348802.152	331.198	331.088	Open Terrain/Bare Earth	0.110
OT18	799898.947	309851.513	302.886	303.089	Open Terrain/Bare Earth	-0.203
UT01	769594.080	379357.728	283.902	283.574	Urban Terrain	0.327
UT02	799053.621	399424.631	305.729	305.293	Urban Terrain	0.435
UT03	795944.421	365174.227	239.634	239.830	Urban Terrain	-0.195
UT04	825483.319	374099.565	289.248	288.954	Urban Terrain	0.294
UT05	834462.618	351734.283	300.893	300.824	Urban Terrain	0.069
UT06	837357.171	316544.686	343.163	343.056	Urban Terrain	0.107
UT07	805990.767	334543.163	254.615	254.097	Urban Terrain	0.517
UT08	787014.470	326387.897	248.350	248.308	Urban Terrain	0.042
UT09	765813.705	319802.551	272.817	272.527	Urban Terrain	0.289
UT10	737063.983	286567.553	303.219	302.828	Urban Terrain	0.391
UT11	763075.058	284737.200	254.687	254.365	Urban Terrain	0.321
UT12	802576.195	282356.891	304.819	304.693	Urban Terrain	0.126
UT13	826199.292	290149.146	340.386	340.138	Urban Terrain	0.248
UT14	869942.836	311858.201	317.556	317.236	Urban Terrain	0.319
UT15	869117.089	334652.615	336.768	336.587	Urban Terrain	0.181
UT16	854512.121	370869.125	270.990	270.749	Urban Terrain	0.240
UT17	734825.607	272115.689	234.937	235.089	Urban Terrain	-0.152

Table 14: Bare=Earth DEM NVA Assessment

Vegetated Vertical Accuracy (VVA) Check Point Assessment (Bare Earth)						
PointID	**Easting**	**Northing**	**KnownZ**	**LaserZ**	**Description**	**DeltaZ**
BR01	815714.374	371367.280	250.990	251.038	Brush	0.048
BR02	834757.788	286832.013	347.389	347.707	Brush	0.318
BR03	789890.696	393281.116	261.349	261.357	Brush	0.008
BR04	800346.829	318429.776	282.564	282.718	Brush	0.154
BR05	788421.394	283719.342	291.828	292.013	Brush	0.185
BR06	772277.988	310406.938	299.454	299.330	Brush	-0.124
BR07	762589.603	377576.811	342.459	342.741	Brush	0.282
BR08	847066.787	299134.154	277.065	276.927	Brush	-0.138
BR09	871798.248	352807.831	290.412	290.785	Brush	0.373
BR10	873891.971	391799.137	283.704	284.103	Brush	0.399
BR11	799911.621	309326.775	304.042	303.945	Brush	-0.097
BR12	797694.520	273486.542	337.275	337.003	Brush	-0.272
BR13	833887.501	329504.071	316.902	317.129	Brush	0.227

HG01	732230.037	267439.832	259.812	259.945	High Grass	0.133
HG02	852714.369	271399.728	322.482	322.473	High Grass	-0.009
HG03	820043.978	314399.561	254.784	255.363	High Grass	0.579
HG04	760866.744	310993.545	314.020	314.518	High Grass	0.498
HG05	761828.793	349512.095	237.913	238.072	High Grass	0.159
HG06	803815.816	350602.019	311.058	311.104	High Grass	0.046
HG07	859421.450	336902.073	321.515	321.607	High Grass	0.092
HG08	870041.793	369362.326	261.348	261.575	High Grass	0.227
HG09	865552.198	395977.557	295.960	296.166	High Grass	0.206
HG10	826211.575	385288.917	289.678	289.777	High Grass	0.099
HG11	777753.794	379400.283	248.594	248.803	High Grass	0.209
HG12	773342.487	395039.548	381.396	381.652	High Grass	0.256
HG13	777433.274	325252.151	248.581	248.881	High Grass	0.300
TR01	767630.907	388279.390	391.388	391.252	Trees	-0.136
TR02	796771.923	384596.775	299.862	299.919	Trees	0.057
TR03	837002.810	387096.106	294.508	294.565	Trees	0.057
TR04	849593.643	356907.958	354.141	354.141	Trees	0.000
TR05	841790.346	334666.767	342.482	342.461	Trees	-0.021
TR06	816721.495	305812.764	335.657	335.517	Trees	-0.140
TR07	782427.605	347350.110	329.633	329.851	Trees	0.218
TR08	765040.421	361399.218	237.418	237.525	Trees	0.107
TR09	748669.135	299943.723	234.019	234.244	Trees	0.225
TR10	763363.009	275153.506	309.749	309.873	Trees	0.124
TR11	780277.910	296150.721	256.790	256.921	Trees	0.131
TR12	846364.924	288303.212	355.152	354.972	Trees	-0.180
TR13	865763.582	286383.552	350.455	350.449	Trees	-0.006
TR14	725885.141	294134.481	216.321	216.686	Trees	0.365

Table 15: Bare-Earth Lidar VVA Assessment

Vegetated Vertical Accuracy (VVA) Check Point Assessment (DEM)						
PointID	**Easting**	**Northing**	**KnownZ**	**DEMZ**	**Description**	**DeltaZ**
BR01	815714.374	371367.280	250.991	251.045	Brush	-0.055
BR02	834757.788	286832.013	347.390	347.704	Brush	-0.314

BR03	789890.696	393281.116	261.350	261.329	Brush	0.020
BR04	800346.829	318429.776	282.565	282.689	Brush	-0.125
BR05	788421.394	283719.342	291.829	291.999	Brush	-0.170
BR06	772277.988	310406.938	299.455	299.351	Brush	0.104
BR07	762589.603	377576.811	342.460	342.706	Brush	-0.246
BR08	847066.787	299134.154	277.066	276.963	Brush	0.102
BR09	871798.248	352807.831	290.413	290.725	Brush	-0.313
BR10	873891.971	391799.137	283.705	284.118	Brush	-0.413
BR11	799911.621	309326.775	304.043	303.994	Brush	0.049
BR12	797694.520	273486.542	337.276	337.014	Brush	0.262
BR13	833887.501	329504.071	316.903	317.143	Brush	-0.241
HG01	732230.037	267439.832	259.813	259.994	High Grass	-0.182
HG02	852714.369	271399.728	322.483	322.493	High Grass	-0.010
HG03	820043.978	314399.561	254.785	255.388	High Grass	-0.603
HG04	760866.744	310993.545	314.021	314.553	High Grass	-0.532
HG05	761828.793	349512.095	237.913	238.025	High Grass	-0.112
HG06	803815.816	350602.019	311.059	311.064	High Grass	-0.005
HG07	859421.450	336902.073	321.516	321.673	High Grass	-0.157
HG08	870041.793	369362.326	261.349	261.591	High Grass	-0.242
HG09	865552.198	395977.557	295.961	296.174	High Grass	-0.214
HG10	826211.575	385288.917	289.679	289.758	High Grass	-0.080
HG11	777753.794	379400.283	248.594	248.787	High Grass	-0.192
HG12	773342.487	395039.548	381.397	381.601	High Grass	-0.205
HG13	777433.274	325252.151	248.581	248.803	High Grass	-0.221
TR01	767630.907	388279.390	391.389	391.206	Trees	0.183
TR02	796771.923	384596.775	299.863	299.999	Trees	-0.136
TR03	837002.810	387096.106	294.509	294.583	Trees	-0.074
TR04	849593.643	356907.958	354.142	354.174	Trees	-0.032
TR05	841790.346	334666.767	342.483	342.470	Trees	0.013
TR06	816721.495	305812.764	335.658	335.541	Trees	0.117
TR07	782427.605	347350.110	329.634	329.830	Trees	-0.196
TR08	765040.421	361399.218	237.418	237.575	Trees	-0.157
TR09	748669.135	299943.723	234.019	234.245	Trees	-0.225
TR10	763363.009	275153.506	309.750	309.829	Trees	-0.079
TR11	780277.910	296150.721	256.791	256.911	Trees	-0.120
TR12	846364.924	288303.212	355.153	354.981	Trees	0.172
TR13	865763.582	286383.552	350.456	350.448	Trees	0.008
TR14	725885.141	294134.481	216.321	216.680	Trees	-0.359

Table 16: Bare-Earth Lidar VVA Assessment

Section 4: **Certification**

4.1 Limitations of Use

The accuracy assessment confirms that the data may be used for the intended applications stated in the **Project Purpose** section of this document. The dataset may also be used as a topographic input for other applications but the user should be aware that this lidar dataset was designed with a specific purpose and was not intended to meet specifications and/or requirements of users outside of Shelby County Tennessee.

It should also be noted that lidar points do not represent a continuous surface model. Lidar points are discrete measurements of the surface and any values derived within a triangle of three lidar points are interpolated. As such, the user should not use the resultant lidar dataset for vertical placement of a planimetric feature such as a headwall, building footprint or any other planimetric feature unless there is an associated lidar point that can be reasonably located on this structure.

Consideration should be given by the end user of this dataset to the fact that this lidar dataset was developed differently and that previous lidar datasets that may be available for this geographic location. It is likely that the data in this project was created using different geodetic control, a different Geoid, newer lidar technology and more up-to-date processing techniques. As such, any direct comparative analysis performed between this dataset and previous datasets could result in misleading or inaccurate results. Users are encouraged to proceed with caution while performing this type of comparative analysis and to completely understand the variables that make each of these datasets unique and not corollary.

It is encouraged that the user refers to the full FGDC Metadata and project reports for a complete understanding on the content of this dataset.

I, hereby, certify to the extent of my knowledge that the statements and statistics represented in this document are true and factual.

Brian J. Mayfield, ASPRS Certified Photogrammetrist #R1276

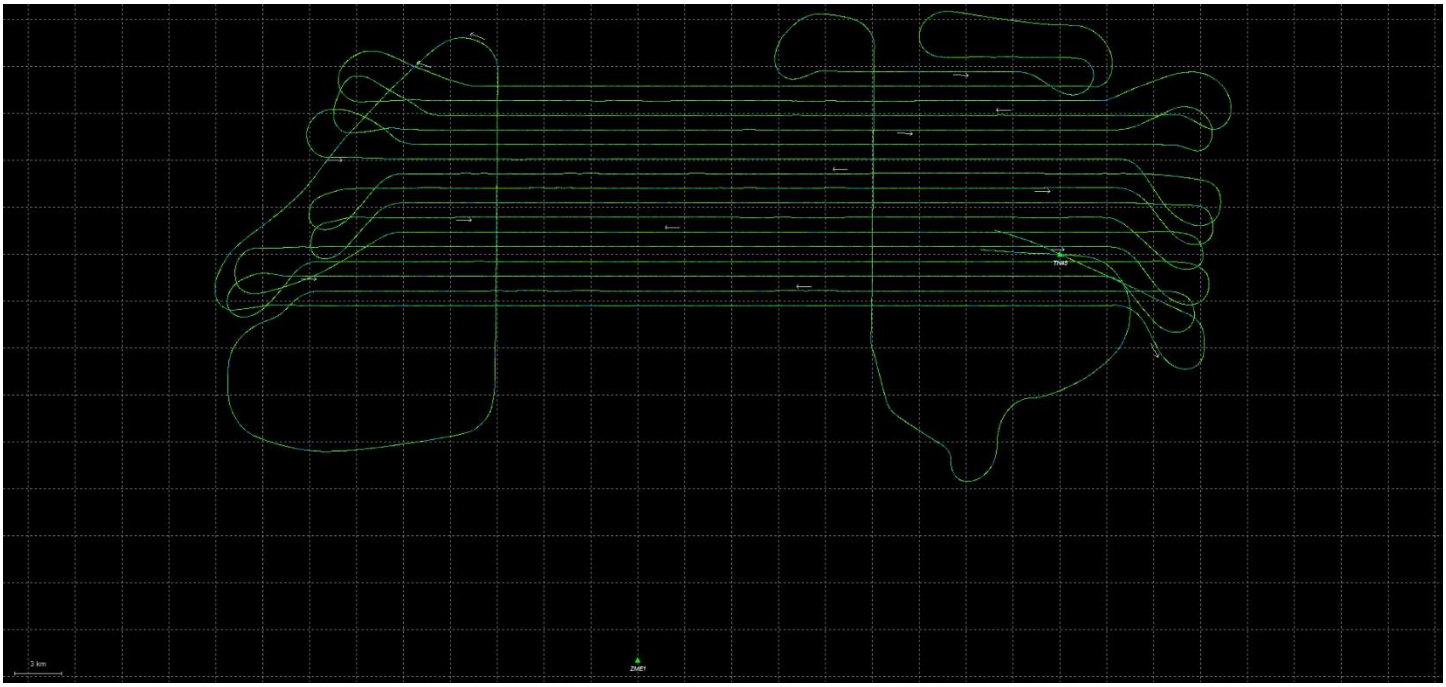
Section 5: **GNSS Processing**

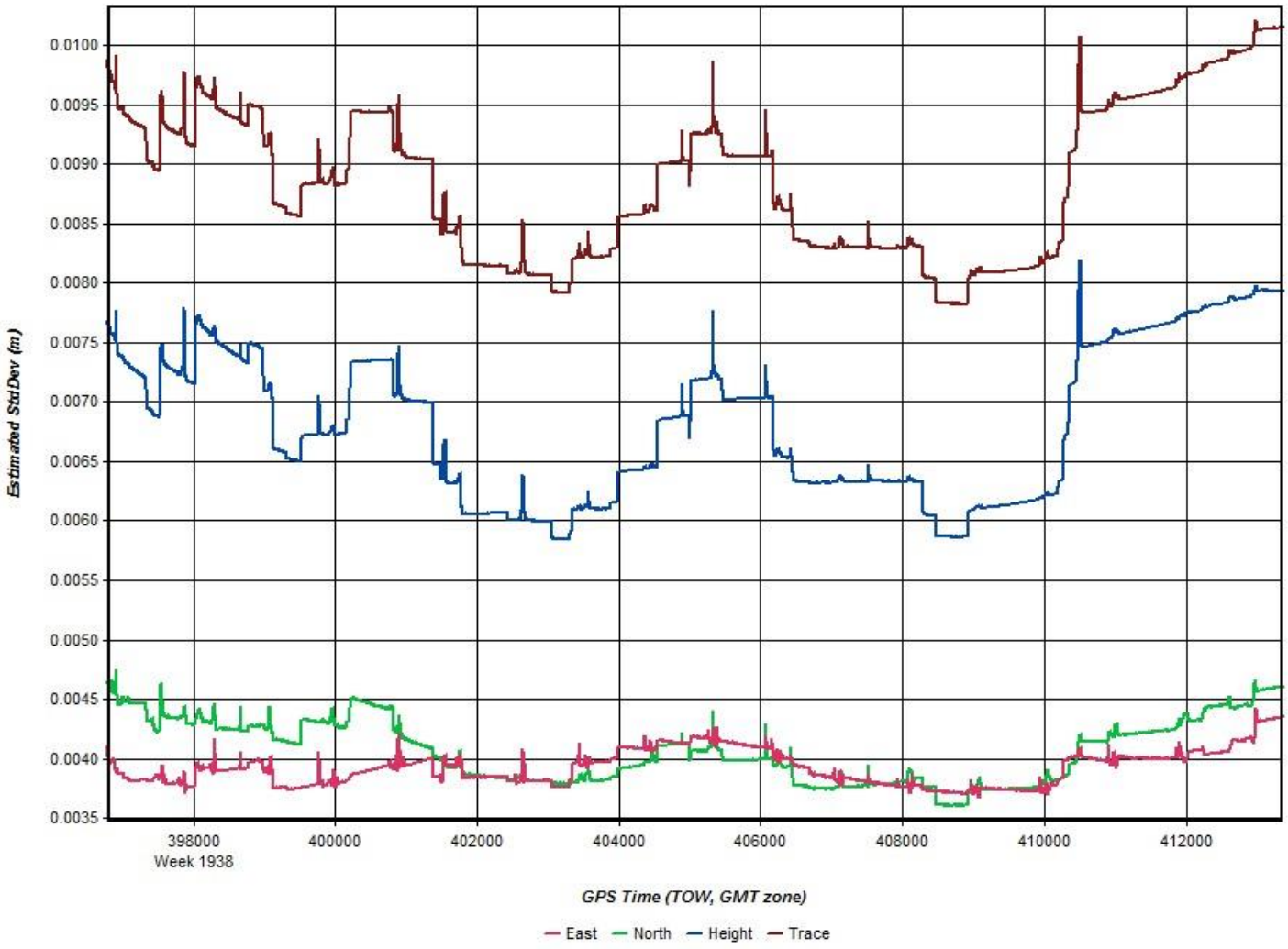
Inertial Explorer version 8.60.6717

Plots by Mission: Coverage Map, Estimated Position Accuracy, Number of Satellites, Combined Separation, and PDOP.

Coverage Map	The Coverage Map plot shows the Aircraft GNSS-IMU Trajectory in reference to localized GNSS Reference Stations.
Estimated Position Accuracy	The Estimated Position Accuracy plot shows the standard deviations of the east, north, and up directions versus time for the solution. The total standard deviation with a distance dependent component is also plotted.
Number of Satellites	Plots the number of satellites used in the solution as a function of time. The number of GPS satellites, GLONASS satellites, and the total number of satellites are distinguished with separate lines.
Combined Separation	Plots the north, east, and height position difference between any two solutions loaded into the project. This is most often the forward and reverse processing results, unless other solutions have been loaded from the Combine Solutions dialog. Plotting the difference between forward and reverse solutions can be very helpful in quality checking. When processing both directions, no information is shared between forward and reverse processing. Thus both directions are processed independently of each other. When forward and reverse solutions agree closely, it helps provide confidence in the solution. To a lesser extent, this plot can also help gauge solution accuracy.
PDOP	PDOP is a unit less number which indicates how favorable the satellite geometry is to 3D positioning accuracy. A strong satellite geometry, where the PDOP is low, occurs when satellites are well distributed in each direction (north, south, east and west) as well as directly overhead. Values in the range of 1-2 indicate very good satellite geometry, 2-3 are adequate in the sense that they do not generally, by themselves, limit positioning accuracy. Values between 3 and 4 are considered marginal, and values approaching or exceeding 5 can be considered poor. PDOP spikes can occur on aircraft turns were the antenna angle is unfavorable, these spikes while aesthetically unfavorable do not generally reduce the accuracy of the acquired data.

225_20170302_1

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0.0040
0.0035
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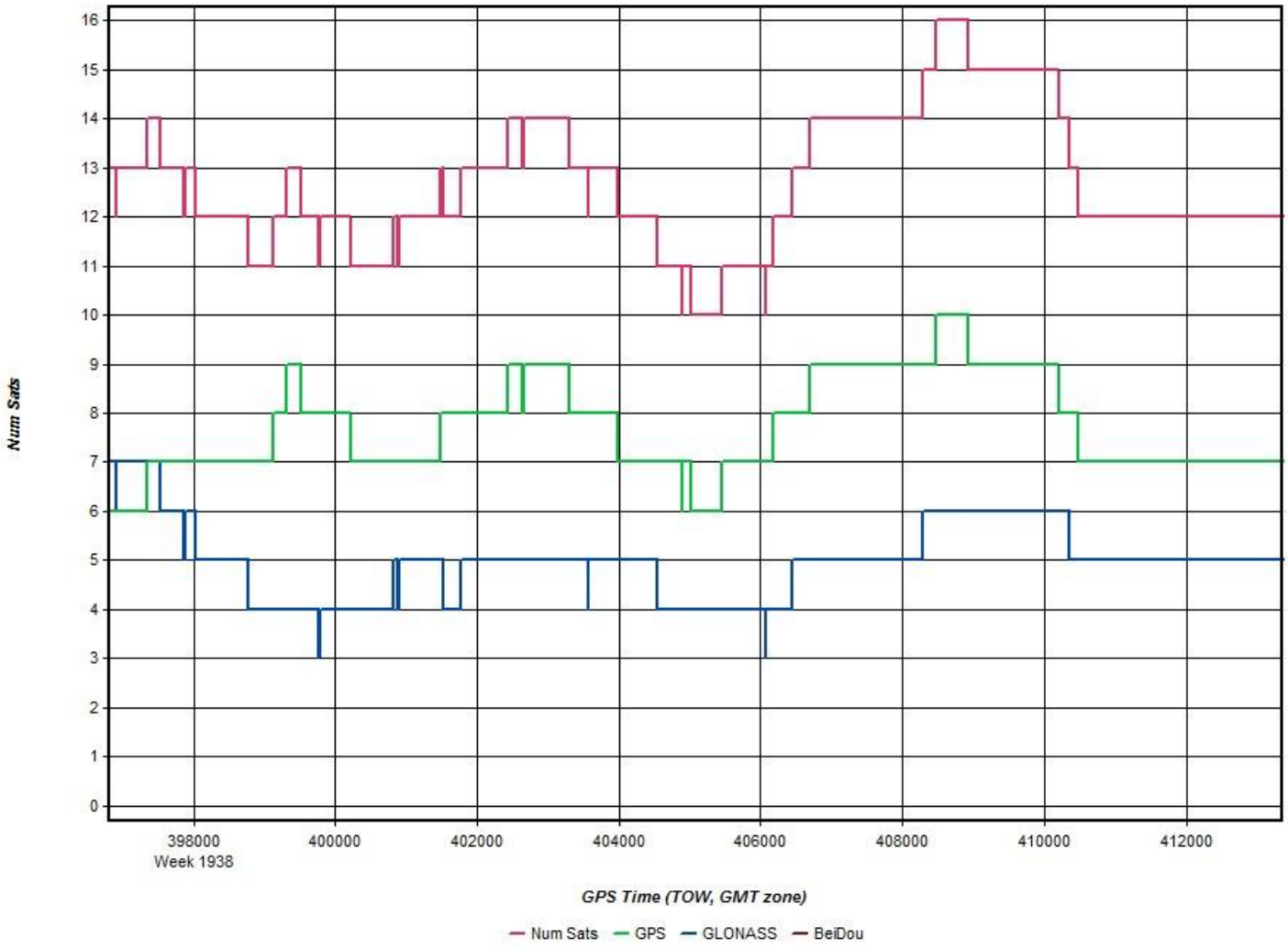
GPS Time (TOW, GMT zone)
East
North
Height
Trace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Week 1938
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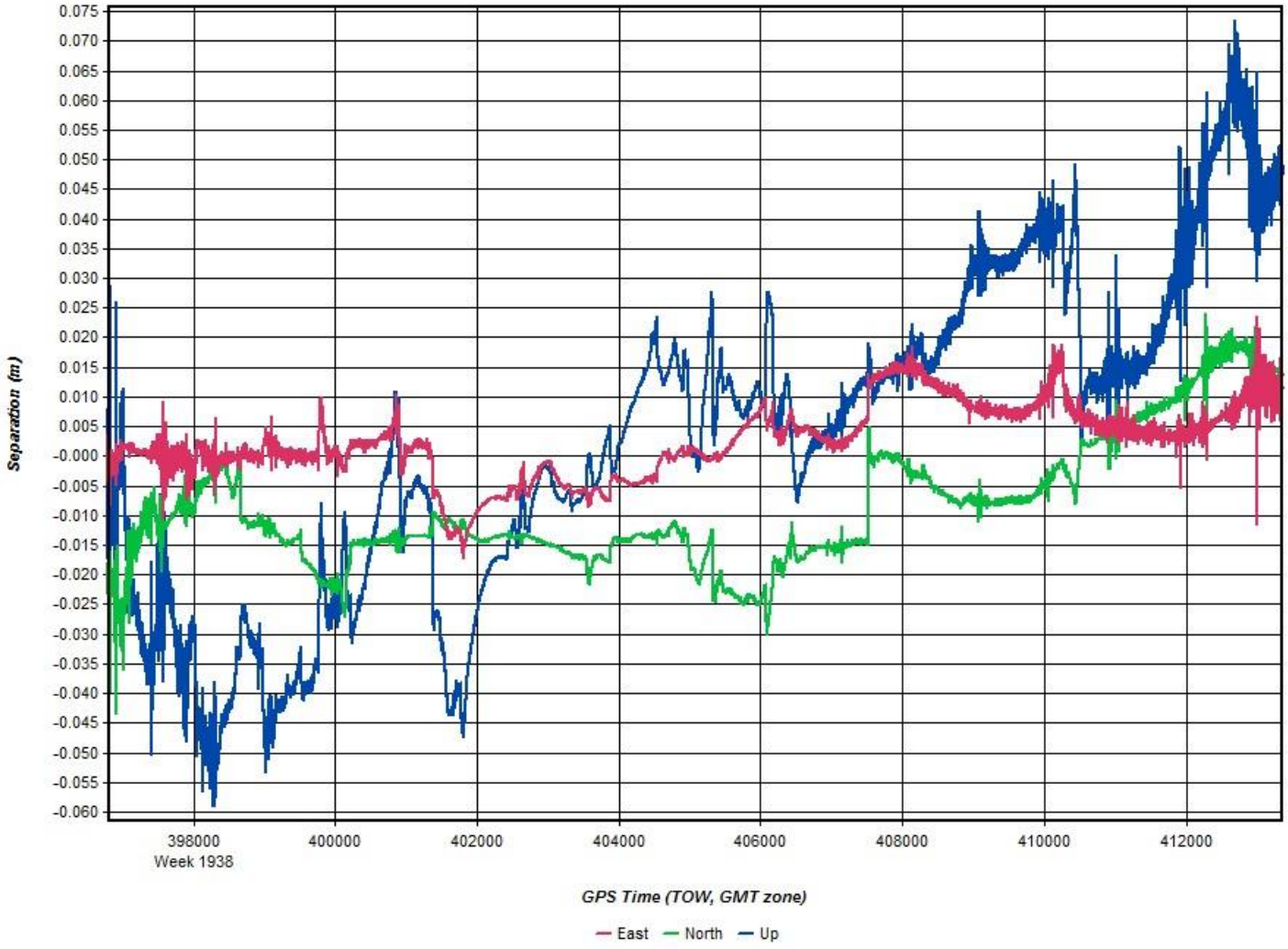
GPS
GLONASS
BeiDou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0.020
0.015
0.010
0.005
-0.000
-0.005
-0.010
-0.015
-0.020
-0.025
-0.030
-0.035
-0.040
-0.045
-0.050
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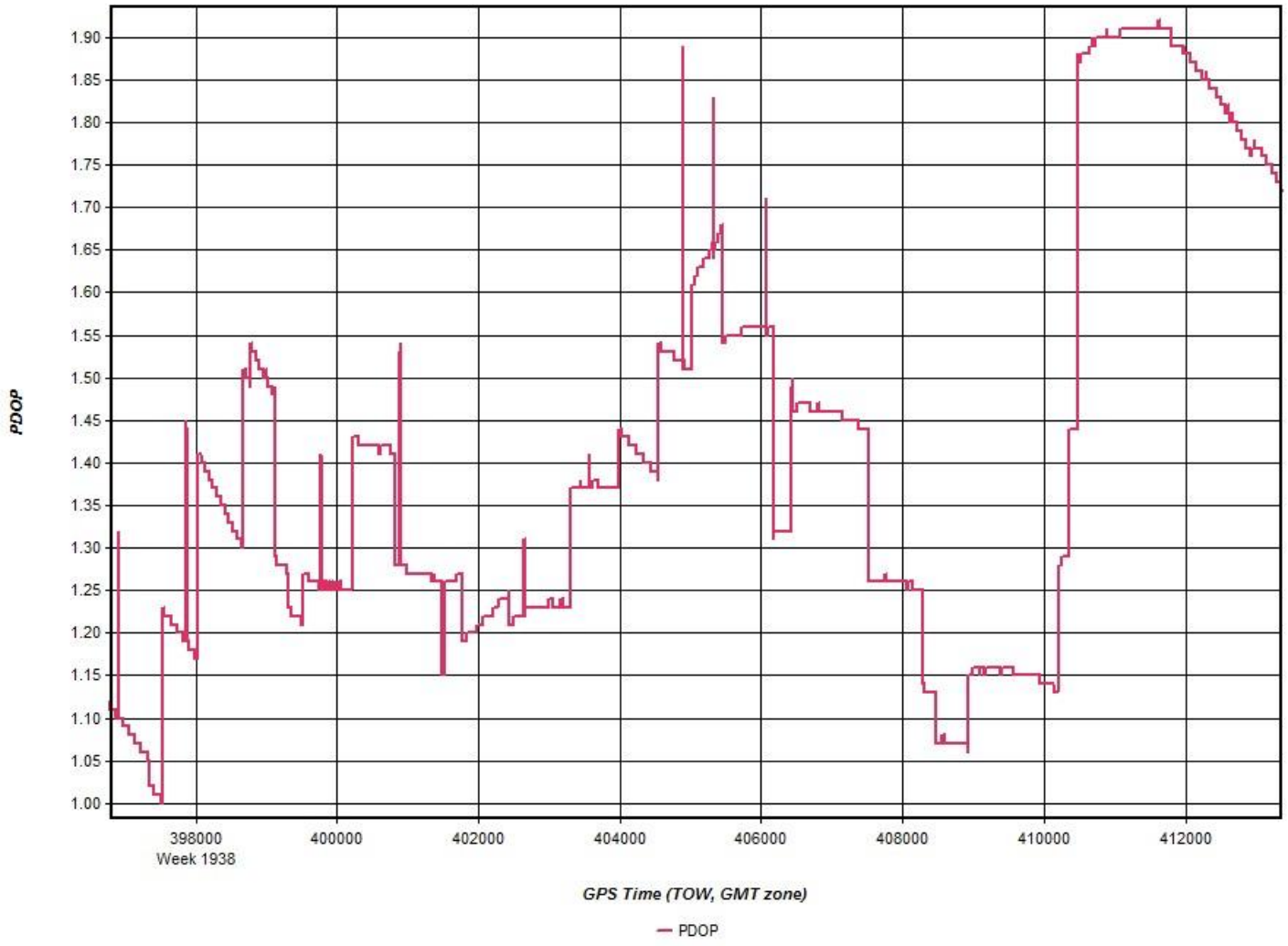
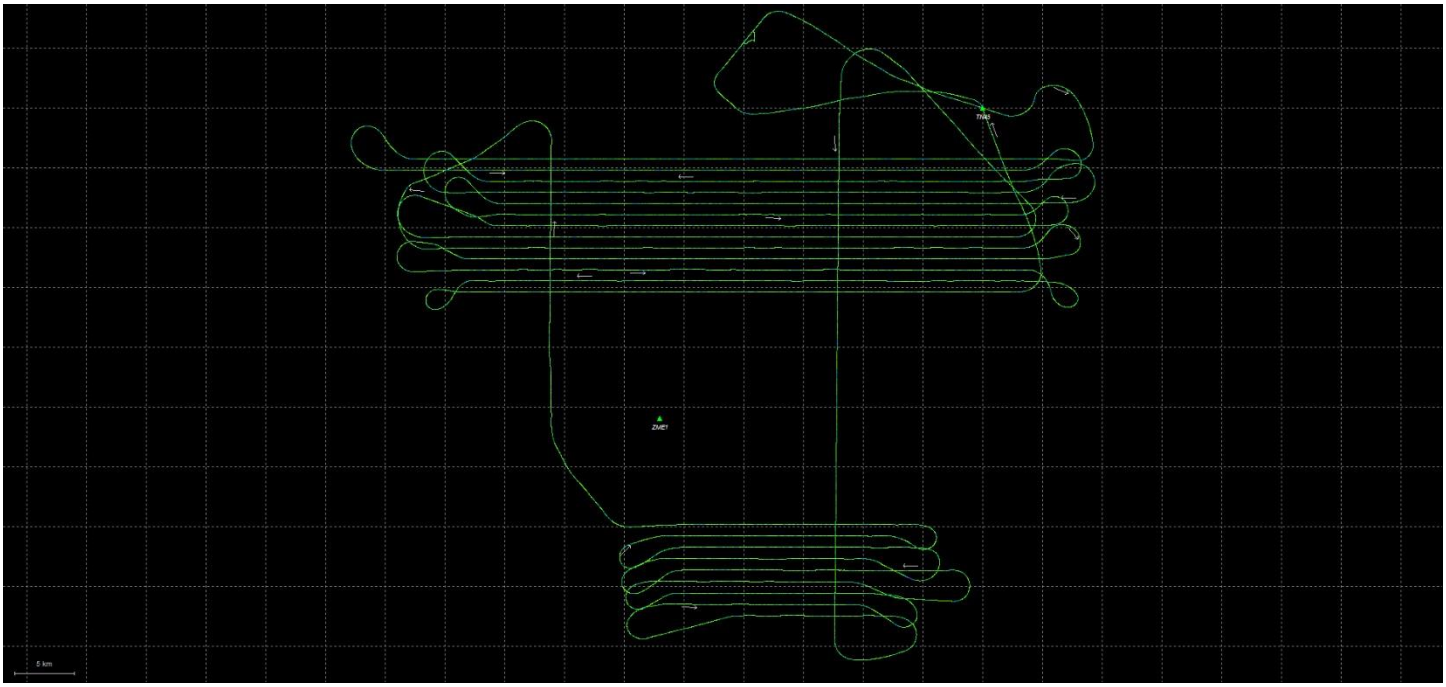
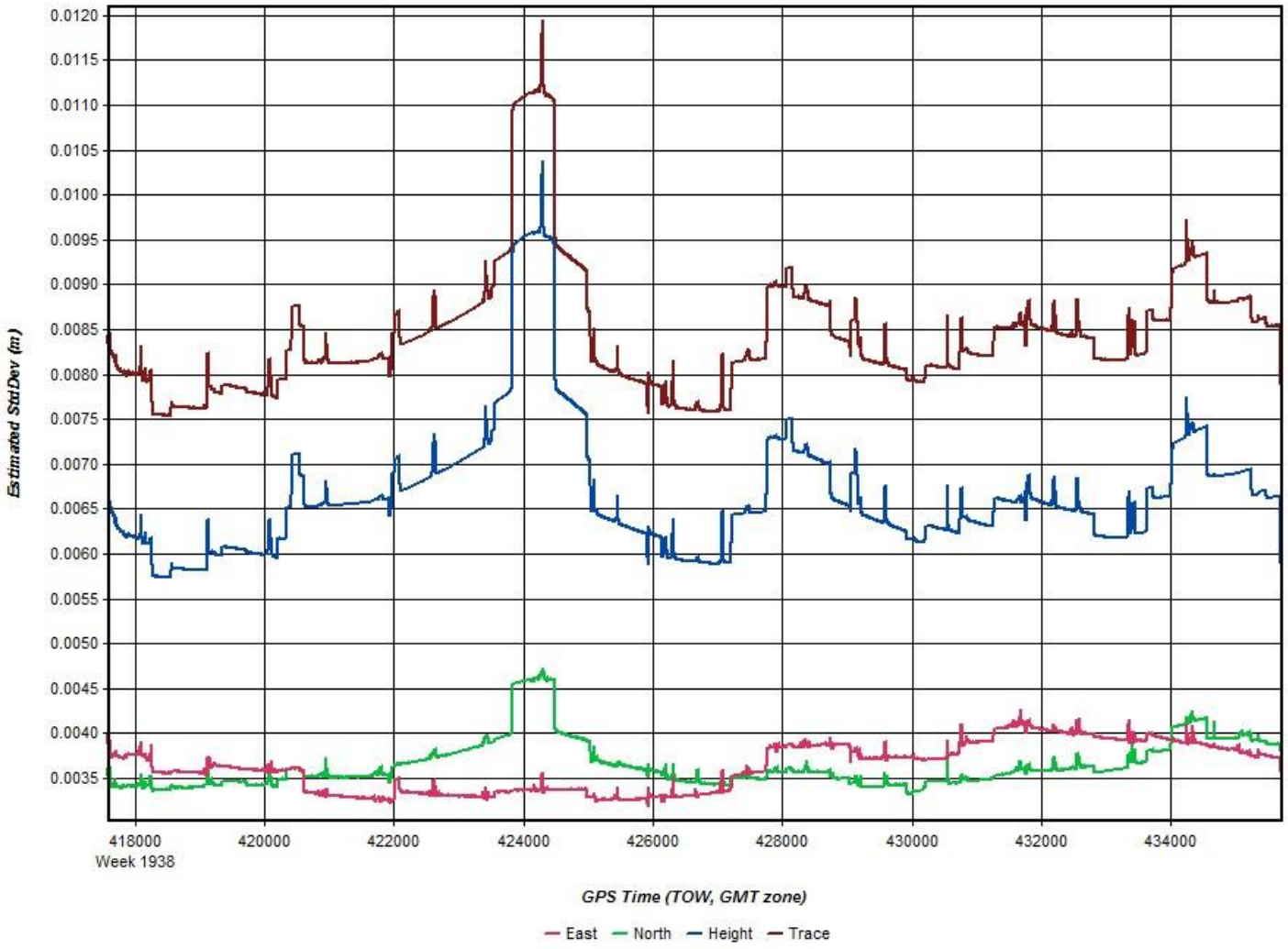
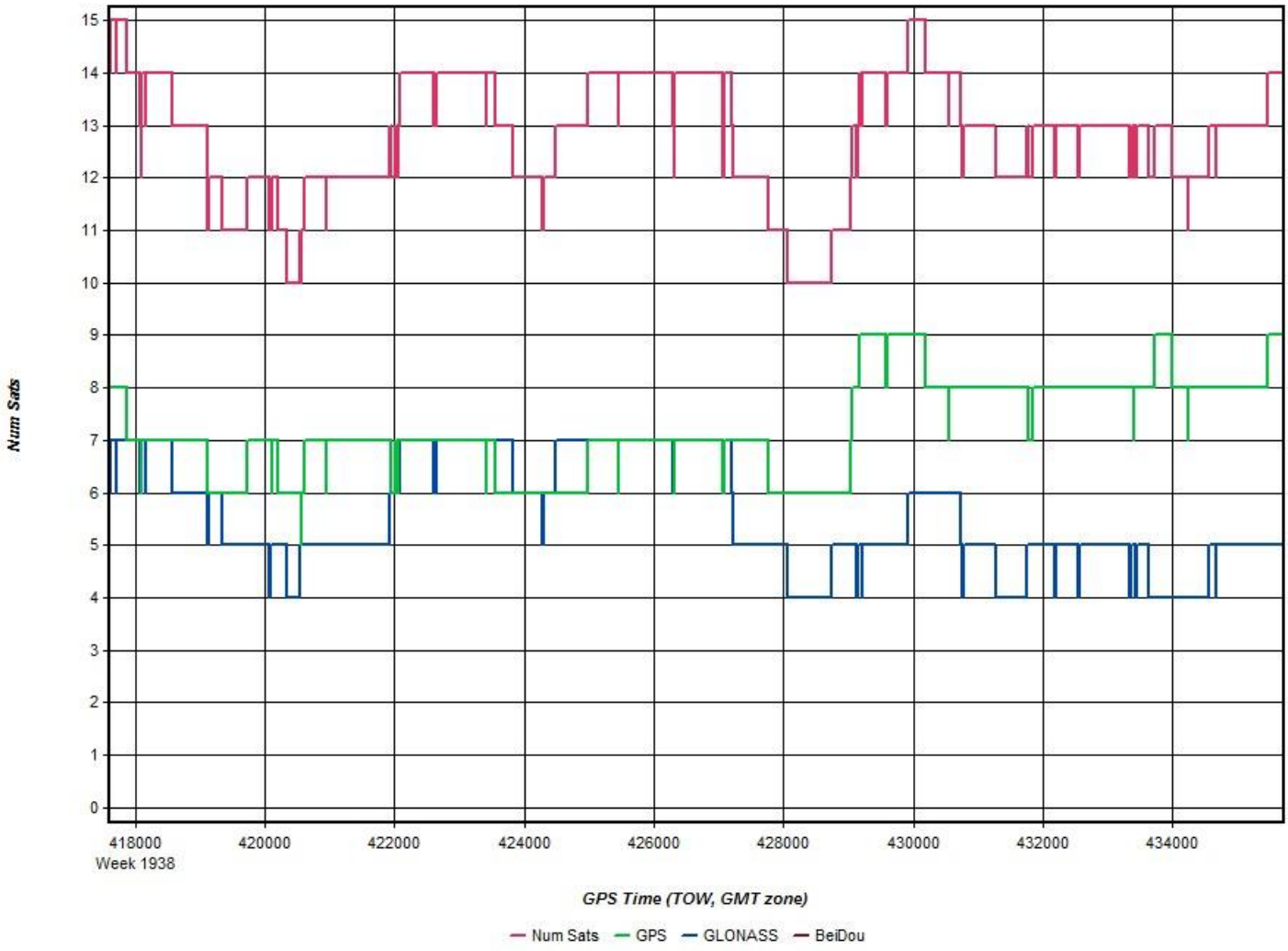
398000
Week 1938
400000
402000
404000
406000
408000
410000
412000
GPS Time (TOW, GMT zone)
East
North
Up

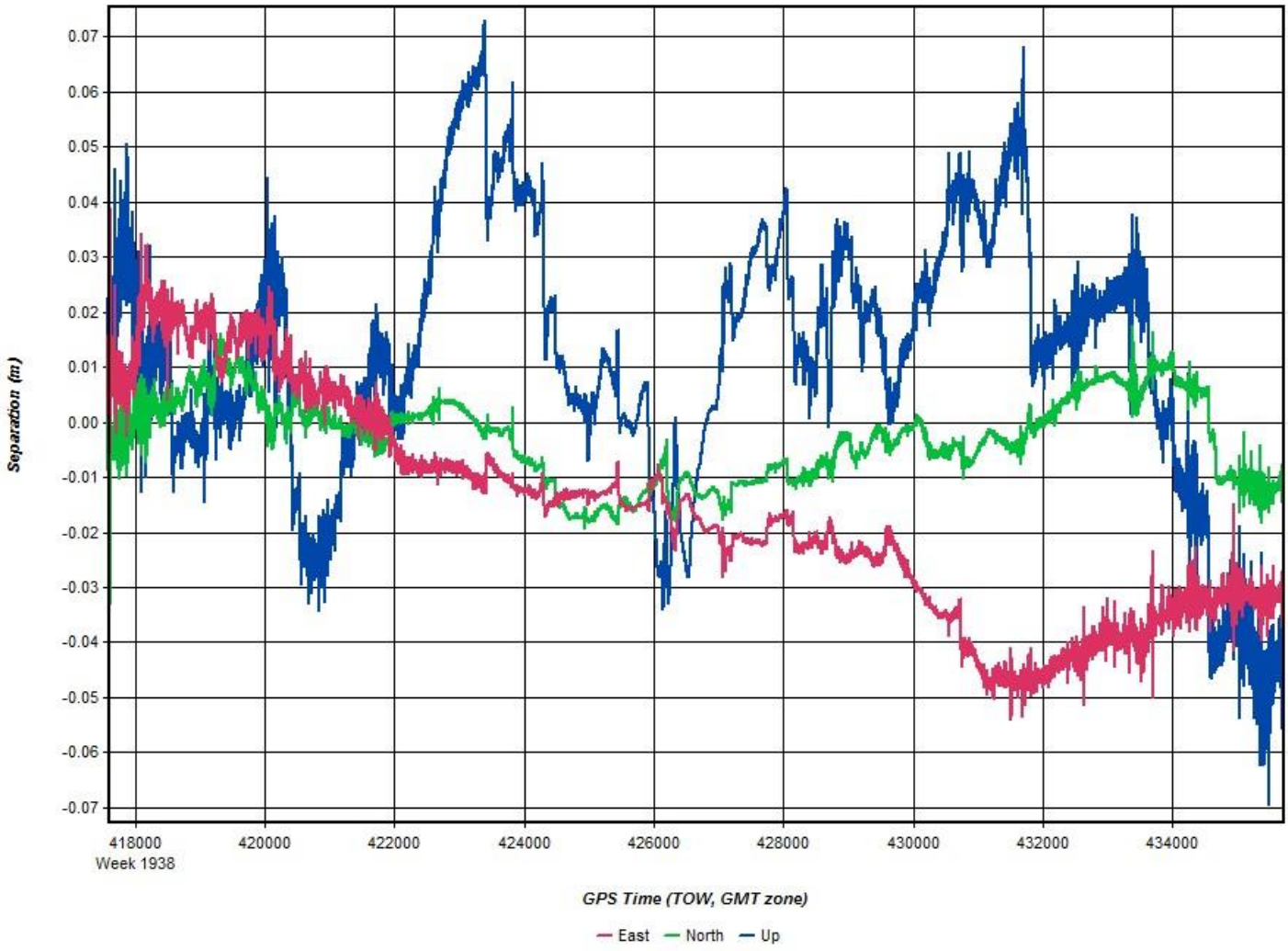


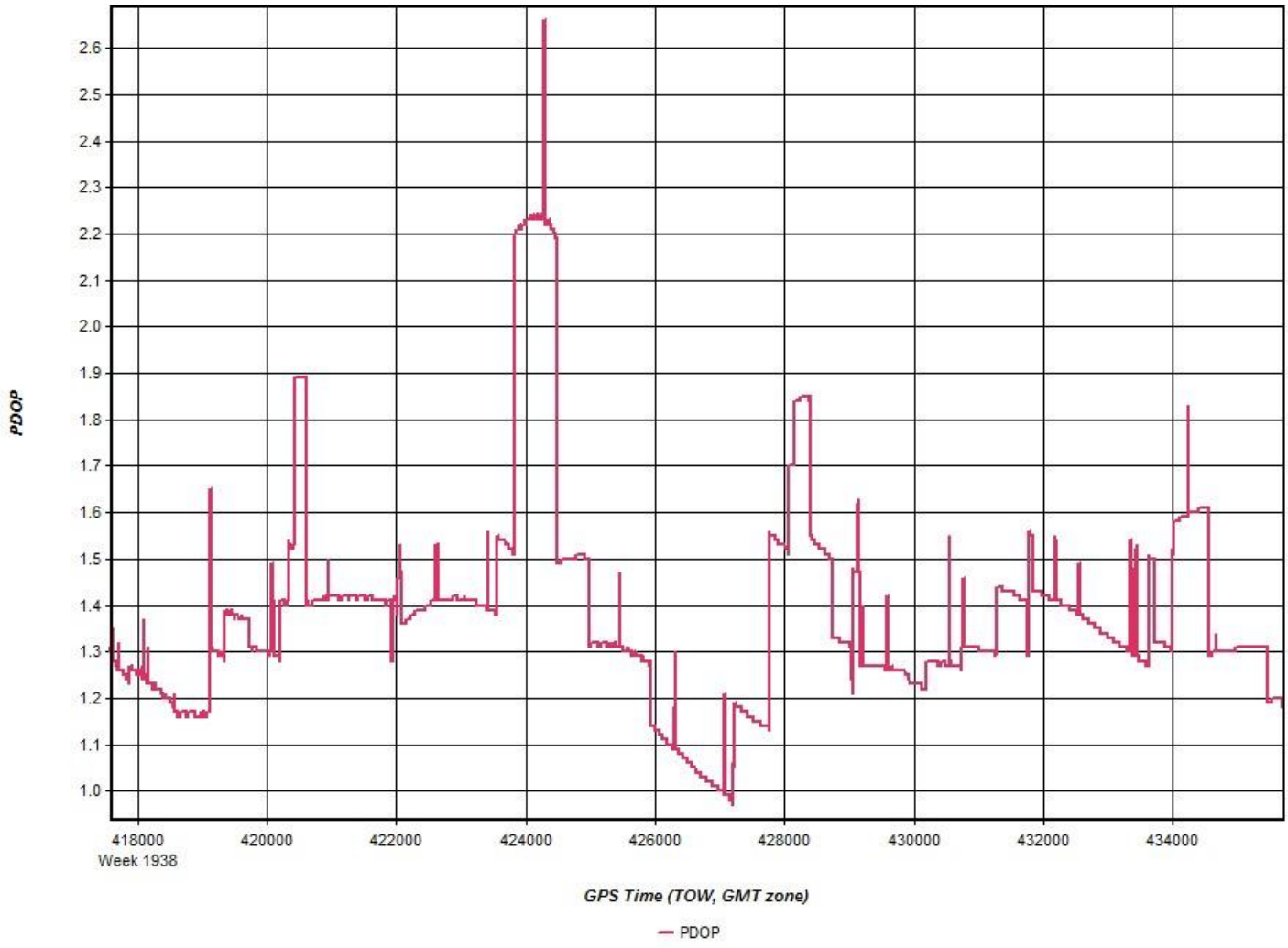
225_20170302_2



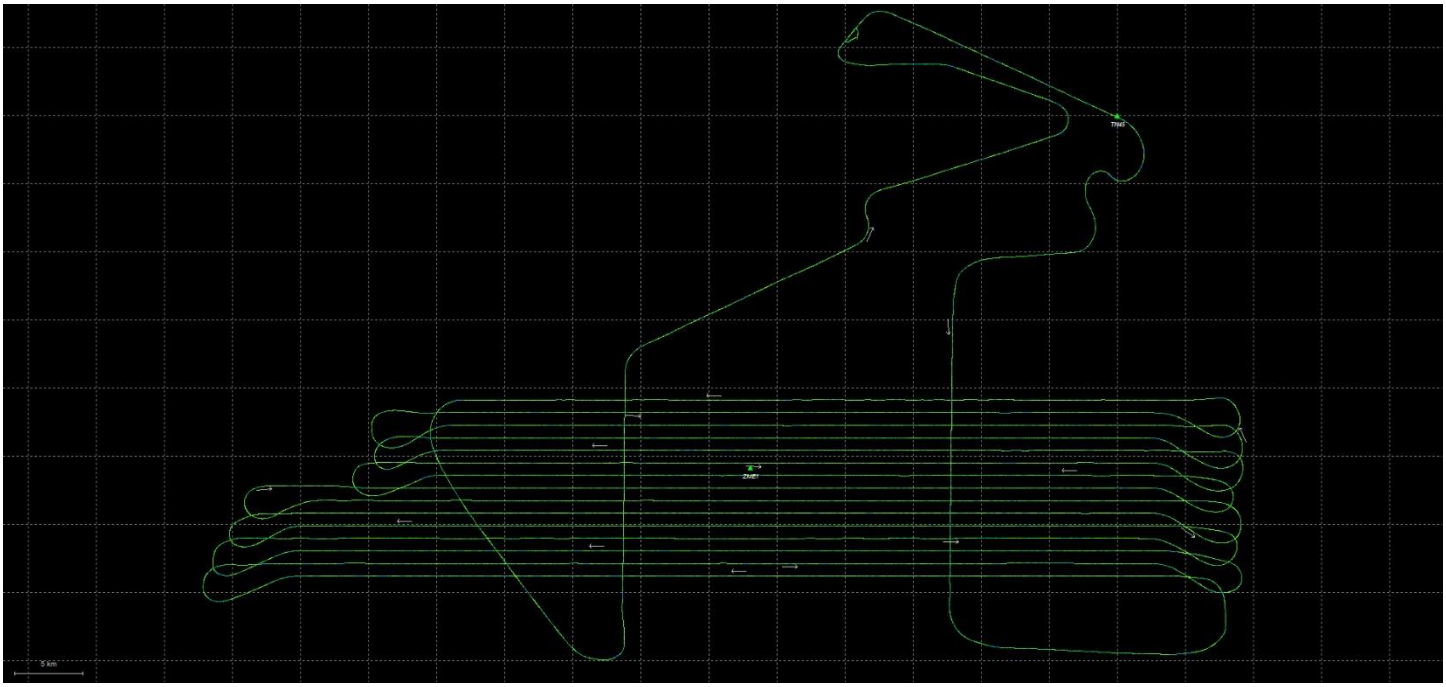

Estimated StdDev (m)
0.0120
0.0115
0.0110
0.0105
0.0100
0.0095
0.0090
0.0085
0.0080
0.0075
0.0070
0.0065
0.0060
0.0055
0.0050
0.0045
0.0040
0.0035
418000
Week 1938
420000
422000
424000
426000
428000
430000
432000
434000
GPS Time (TOW, GMT zone)
East
North
Height
Trace

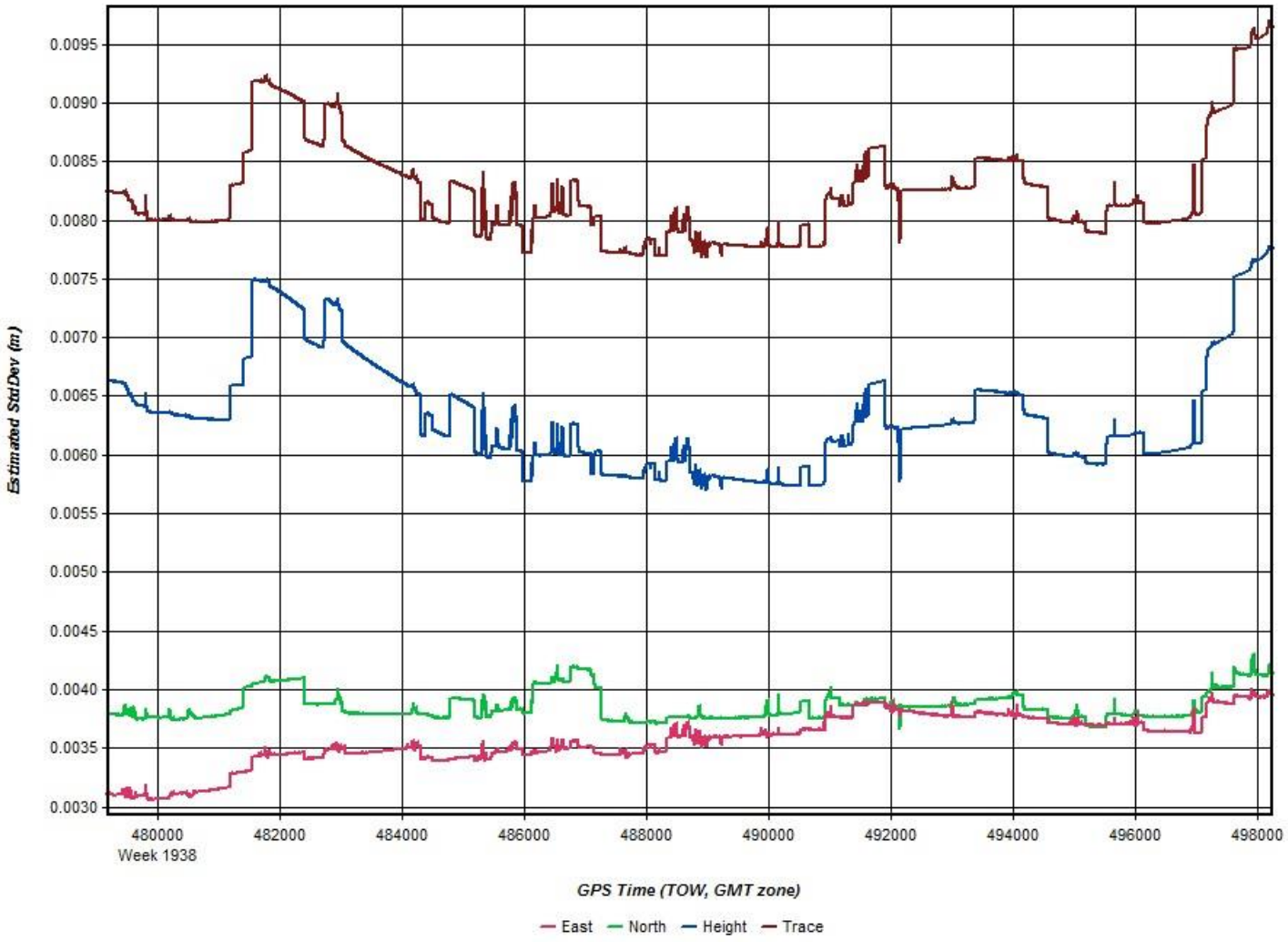

Num Sats
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
418000
Week 1938
420000
422000
424000
426000
428000
430000
432000
434000
GPS Time (TOW, GMT zone)
Num Sats
GPS
GLONASS
BeiDou

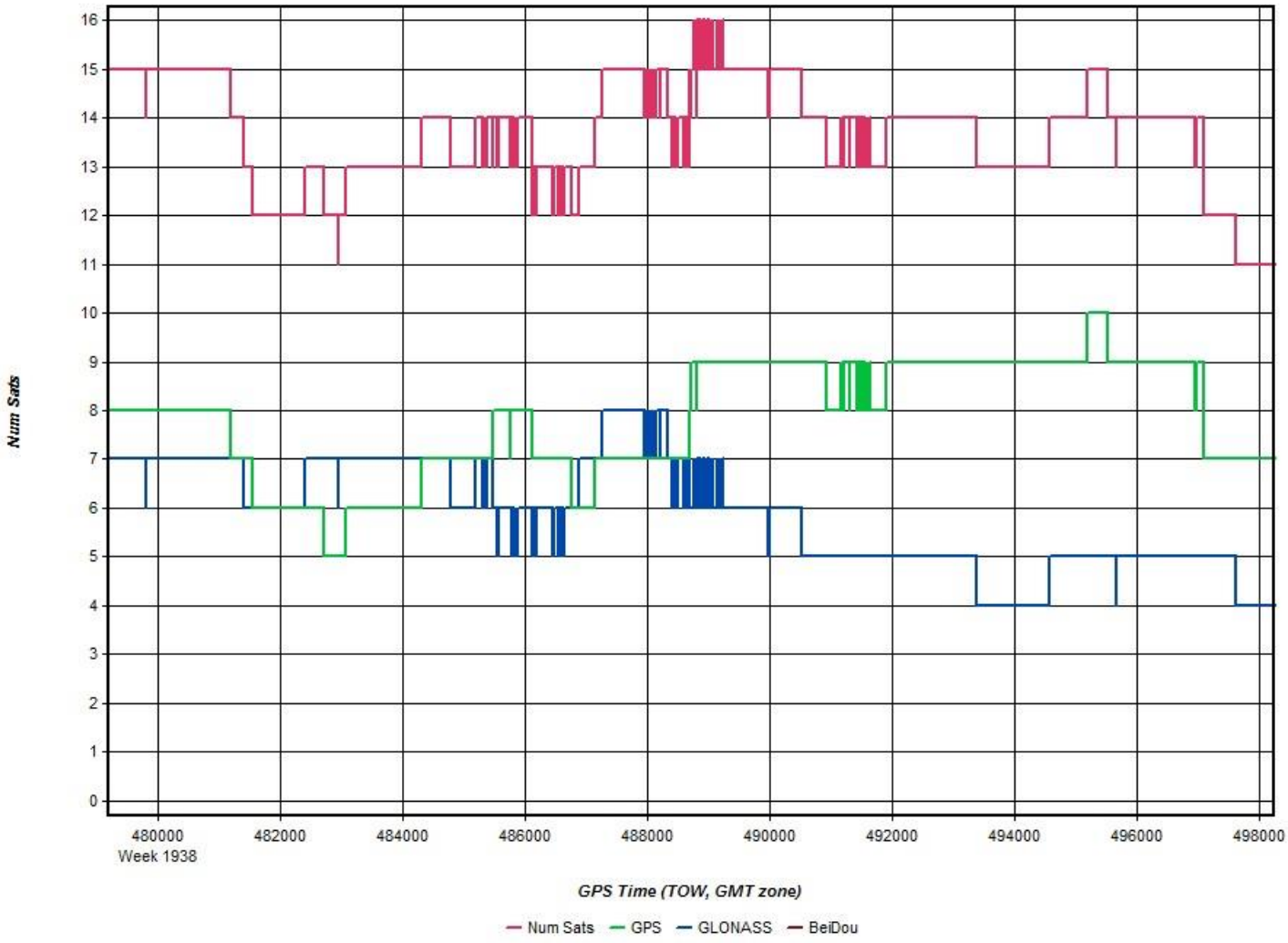

Separation (m)
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
-0.01
-0.02
-0.03
-0.04
-0.05
-0.06
-0.07
418000
Week 1938
420000
422000
424000
426000
428000
430000
432000
434000
GPS Time (TOW, GMT zone)
East
North
Up

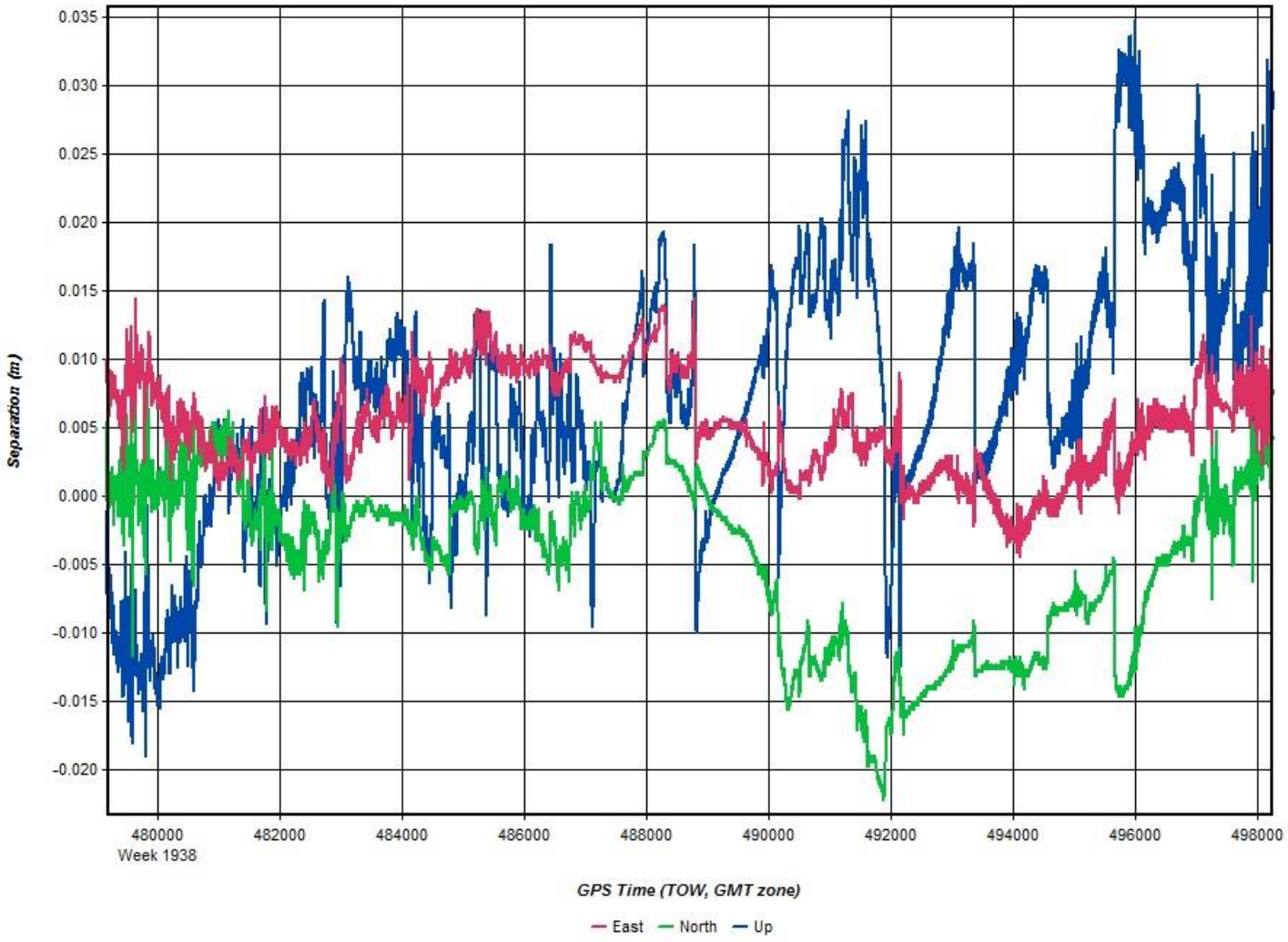


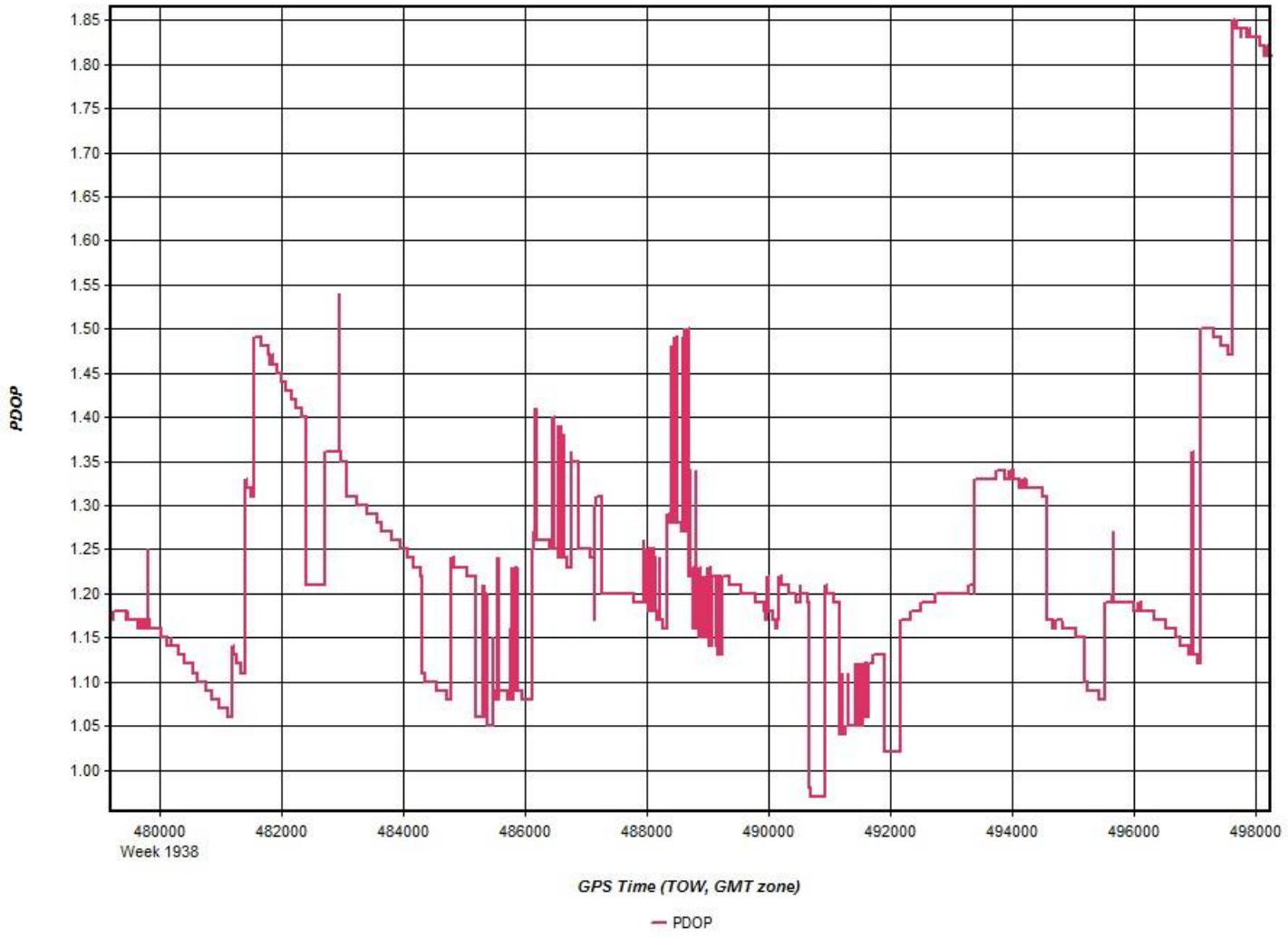
225_20170303_1



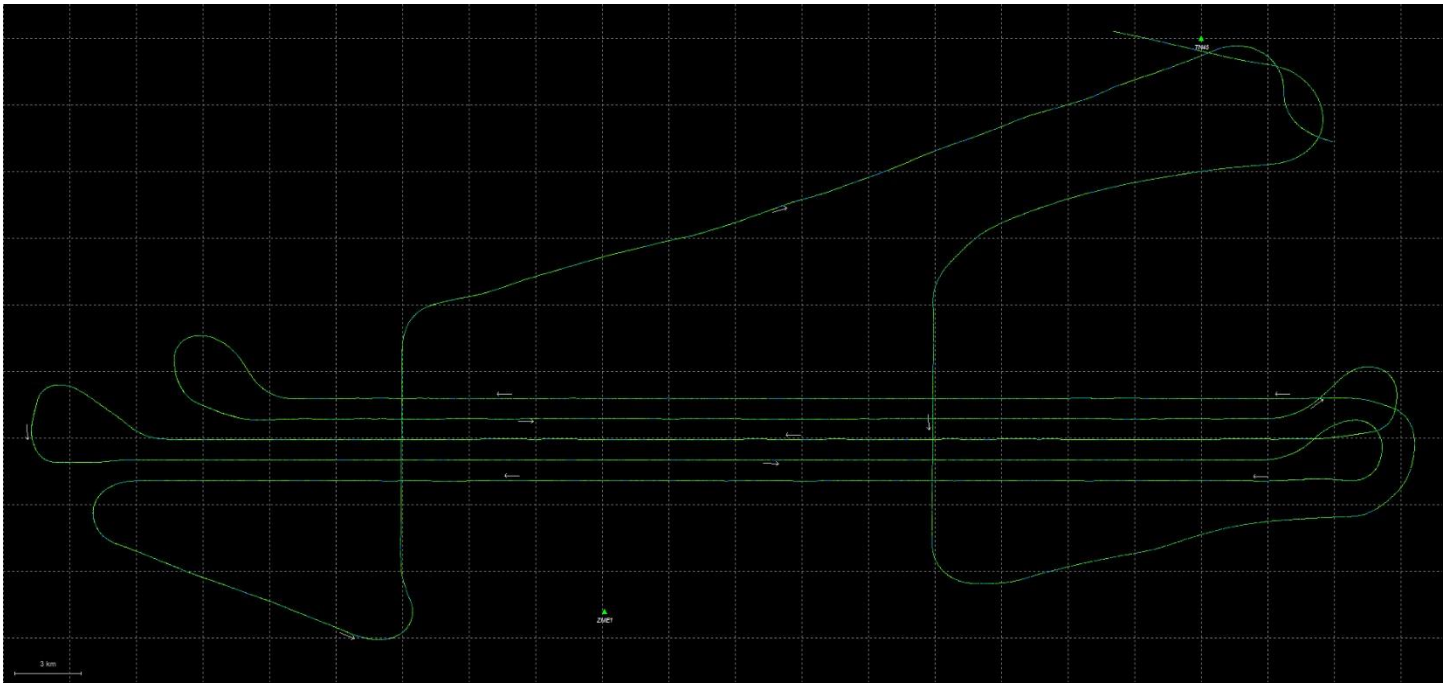

Estimated StdDev (m)
0.0095
0.0090
0.0085
0.0080
0.0075
0.0070
0.0065
0.0060
0.0055
0.0050
0.0045
0.0040
0.0035
0.0030
480000
Week 1938
482000
484000
486000
488000
490000
492000
494000
496000
498000
GPS Time (TOW, GMT zone)
East
North
Height
Trace

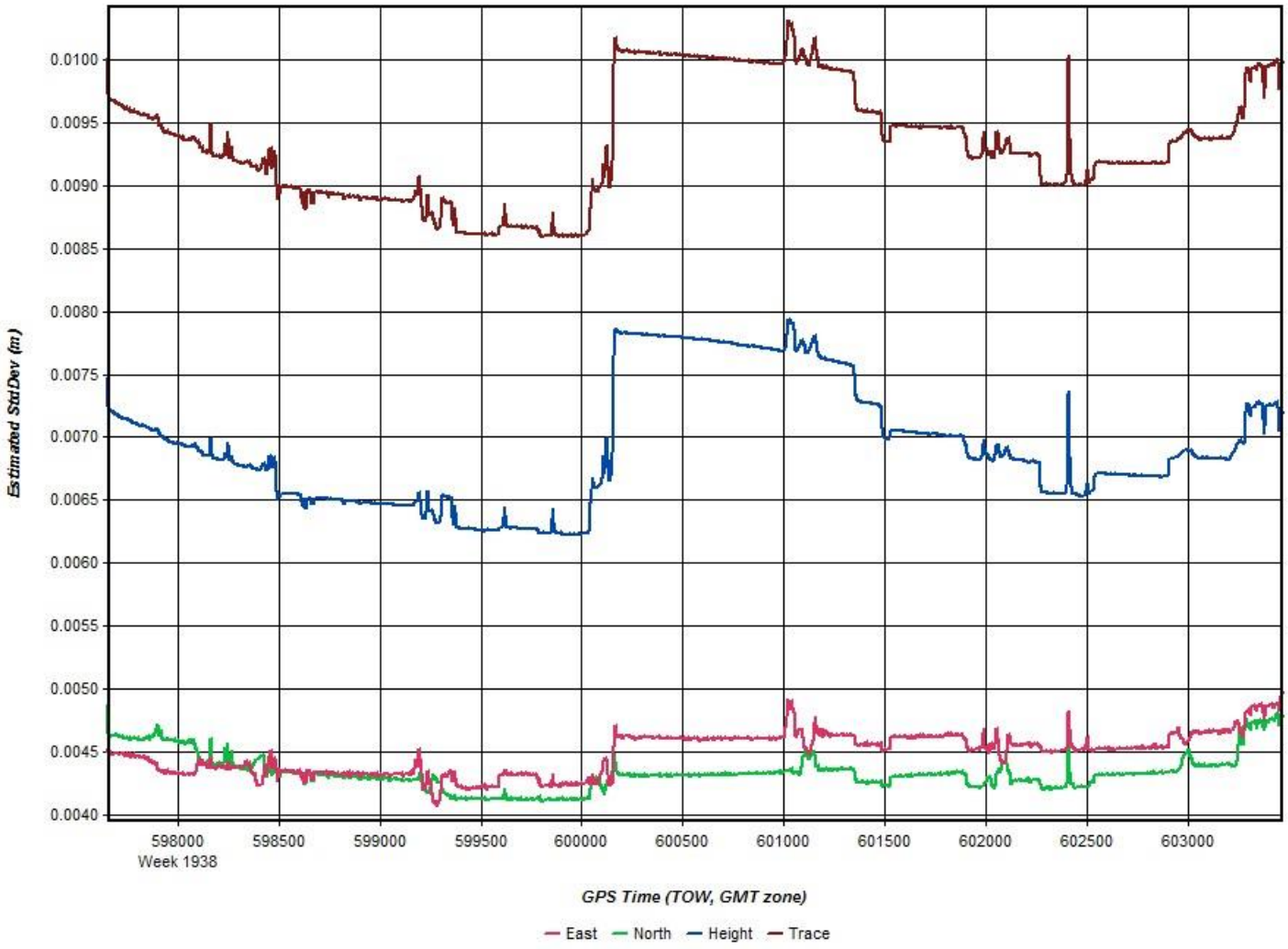

Num Sats
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
480000
Week 1938
482000
484000
486000
488000
490000
492000
494000
496000
498000
GPS Time (TOW, GMT zone)
Num Sats
GPS
GLONASS
BeiDou

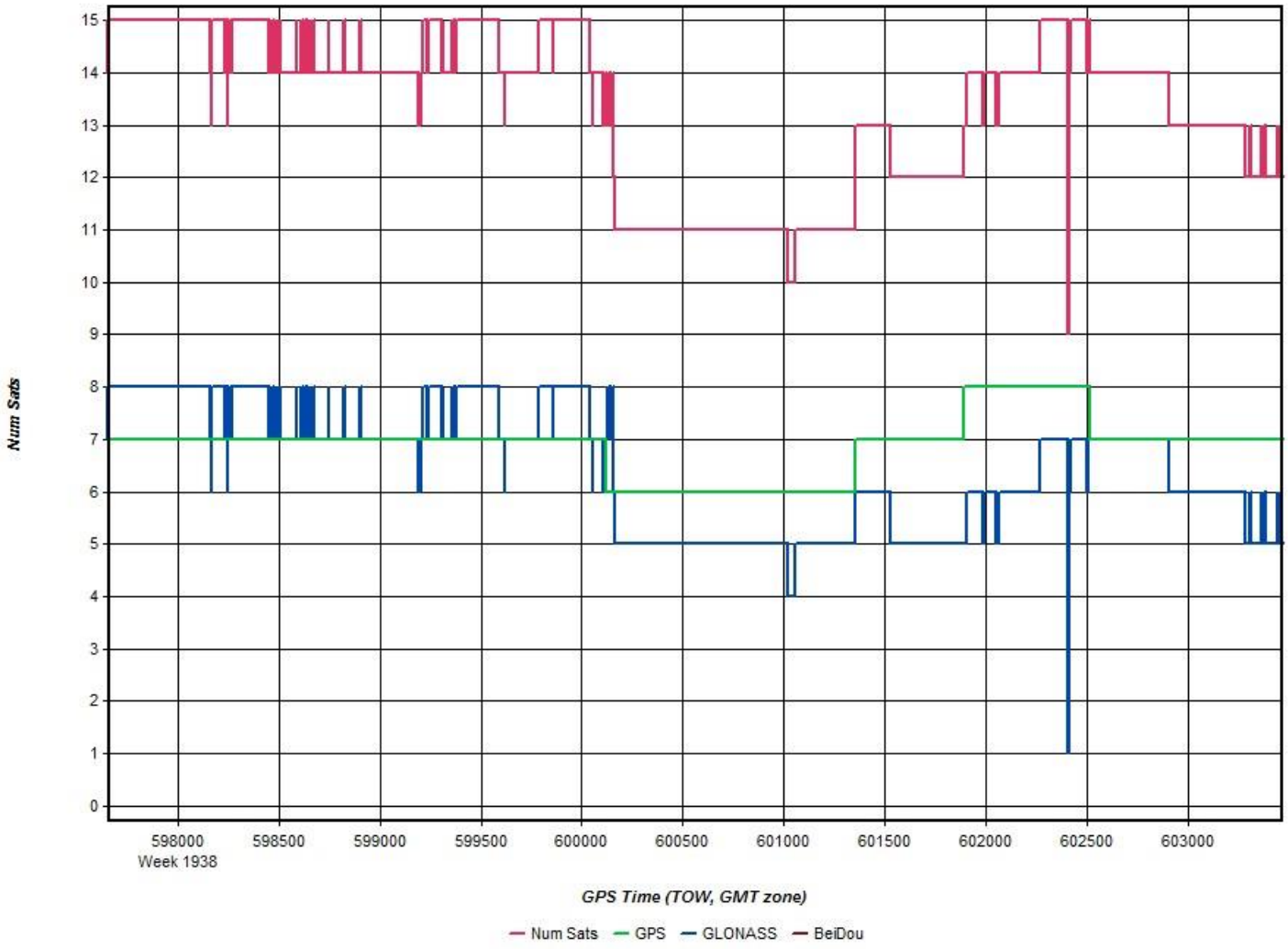

0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
-0.005
-0.010
-0.015
-0.020
Separation (m)
480000
Week 1938
482000
484000
486000
488000
490000
492000
494000
496000
498000
GPS Time (TOW, GMT zone)
East
North
Up

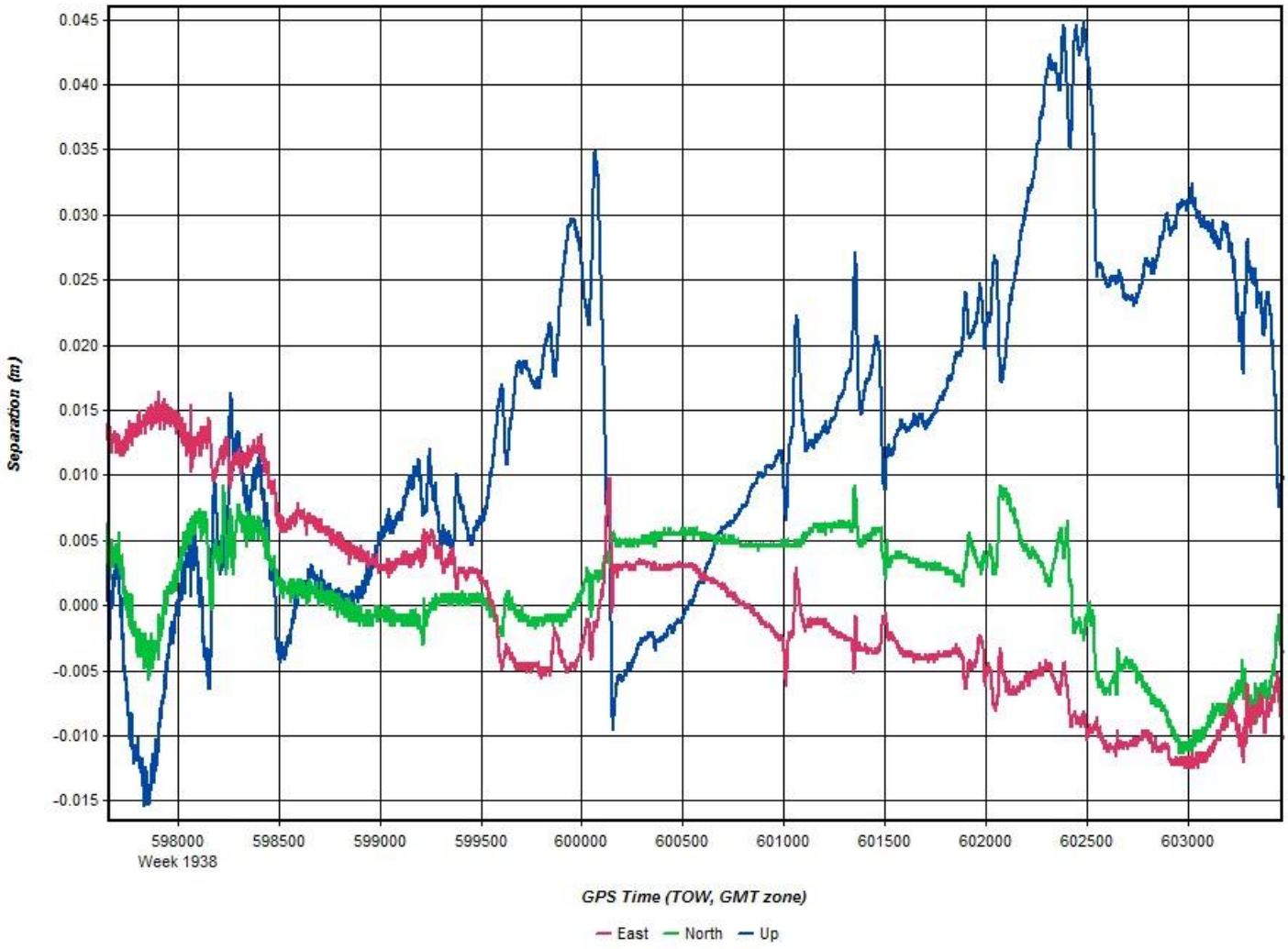


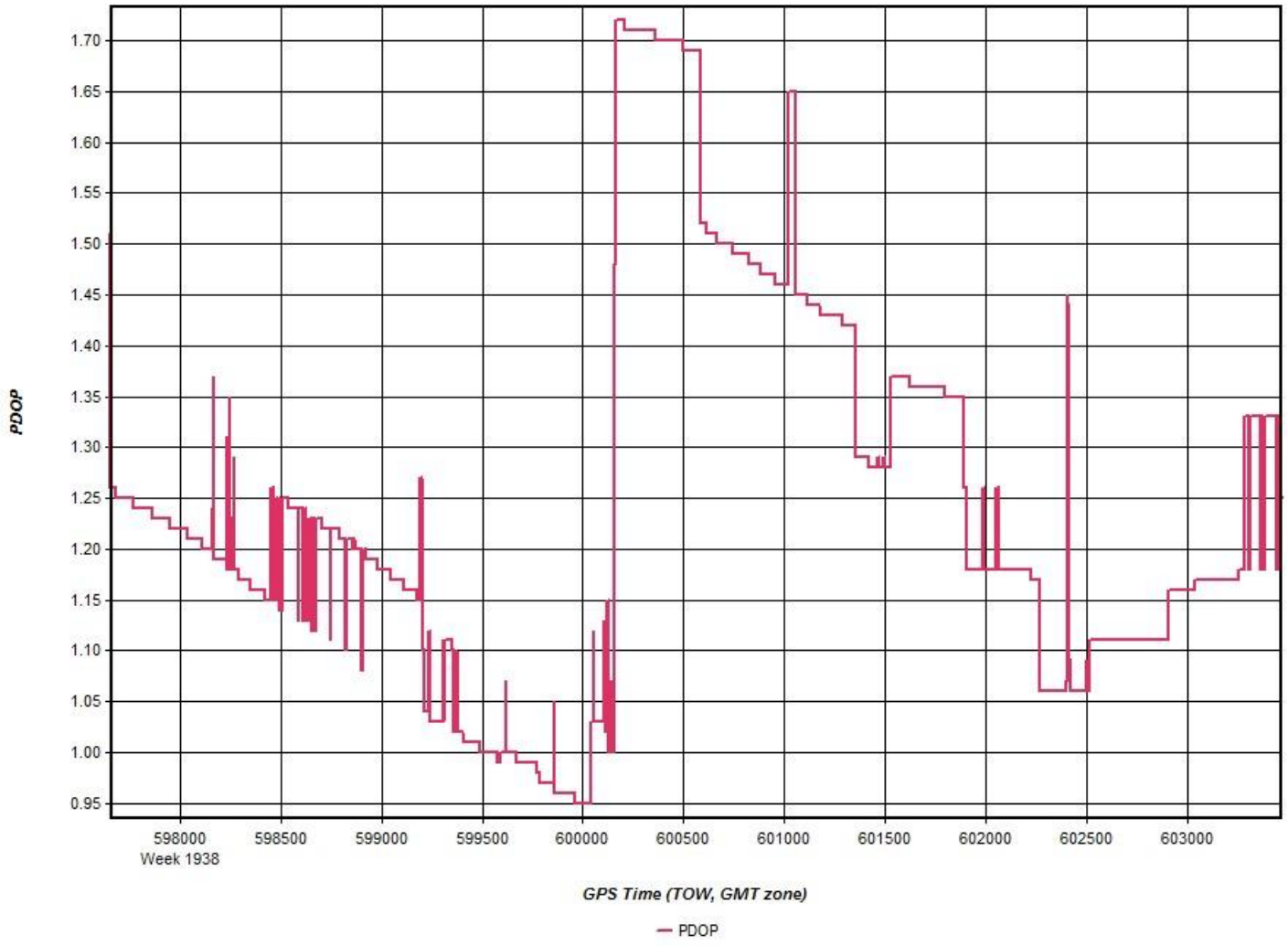
123_20170304_1




Estimated StdDev (m)
0.0100
0.0095
0.0090
0.0085
0.0080
0.0075
0.0070
0.0065
0.0060
0.0055
0.0050
0.0045
0.0040
598000
Week 1938
598500
599000
599500
600000
600500
601000
601500
602000
602500
603000
GPS Time (TOW, GMT zone)
East
North
Height
Trace


Num Sats
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
598000
Week 1938
598500
599000
599500
600000
600500
601000
601500
602000
602500
603000
GPS Time (TOW, GMT zone)
Num Sats
GPS
GLONASS
BeiDou


0.045
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
-0.005
-0.010
-0.015
Separation (m)
598000
Week 1938
598500
599000
599500
600000
600500
601000
601500
602000
602500
603000
GPS Time (TOW, GMT zone)
East
North
Up


PDOP
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1.25
1.20
1.15
1.10
1.05
1.00
0.95
598000
Week 1938
598500
599000
599500
600000
600500
601000
601500
602000
602500
603000
GPS Time (TOW, GMT zone)
PDOP