Aerial Lidar Report

2016 Kansas Lidar (South)

15164

atlantic

2223 Drake Ave SW
Suite 200
Huntsville, AL 35805
(256) 971-9991 – office
(256) 971-1154 – fax

May 2016

Table of Contents

Section 1: Lidar Acquisition

1.1 Acquisition

The Atlantic Group, LLC (Atlantic) has successfully completed lidar acquisition for the 2016 Kansas Lidar (South). Lidar for this AOI was acquired in seven (7) flight missions completed on November 24th, 2015. The project area encompasses 2,633 square miles or 6,819 square kilometers.

1.2 Acquisition Status Report

Upon notification to proceed, the flight crew loaded the flight plans and validated the flight parameters. The Acquisition Manager 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 PDOPs, and performed the first Q/C 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 immediately or at an optimal time.

1.3 Acquisition Details

Atlantic acquired ninety (90) passes of the AOI as a series of perpendicular and/or adjacent flight lines. The flight plan included zigzag flight line collection as a result of the inherent IMU drift associated with all IMU systems. Differential GPS unit in aircraft recorded sample positions at 2 Hz or more frequency. Lidar data was only acquired when GPS PDOP was ≤ 4 and at least 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 Flightline Orientation

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

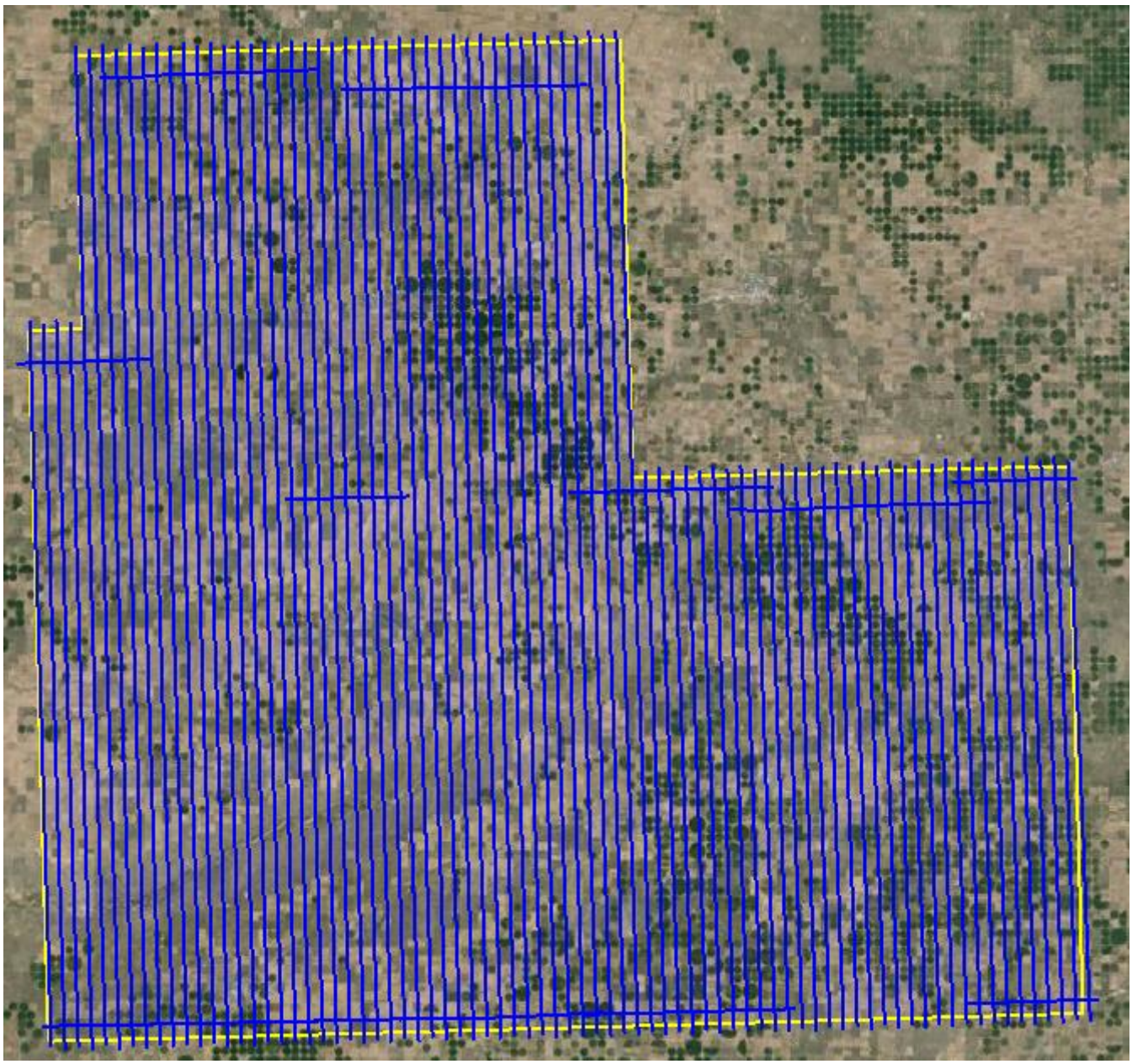


Figure 1: Trajectories as flown by Atlantic

1.6 Acquisition Equipment

Atlantic operated a Cessna T210L (N732JE) outfitted with a Leica ALS70-HP lidar system 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)	0.6
Nominal Pulse Density (pls/m²)	2.5
Nominal Flight Height (AGL meters)	2300
Nominal Flight Speed (kts)	120
Pass Heading (degree)	90
Sensor Scan Angle (degree)	45
Scan Frequency (Hz)	35.9
Pulse Rate of Scanner (kHz)	270.8
Line Spacing (m)	1265
Pulse Duration of Scanner (ns)	4
Pulse Width of Scanner (m)	0.46
Central Wavelength of Sensor Laser (nm)	1064
Sensor Operated with Multiple Pulses	Yes
Beam Divergence (mrad)	0.15
Nominal Swath Width (m)	1625
Nominal Swath Overlap (%)	20
Scan Pattern	Triangle

Table 2: Atlantic Lidar System Acquisition Parameters

1.8 Airborne GPS Kinematic

Differential GPS unit in aircraft collected positions at 2 Hz. Airborne GPS data was processed using the Inertial Explorer (version 8.60.5025) software. Flights were flown with a minimum of 6 satellites in view (10° above the horizon) and with a PDOP of ≤4 when the laser was online.

For all flights, the GPS data can be classified as good, with GPS 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 GPS, aircraft trajectory, mission information, and ground control files are reviewed and logged into a database.

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

Section 2: Lidar Processing

2.1 Generation of Laser Points

Atlantic used a combination of Waypoint and Leica software products to extract the lidar swath data from the raw flight records. Waypoint Inertial Explorer is used to extract the raw IPAS ABGPS/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 (*.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 (HARN)
Coordinate System: Universal Transverse Mercator Northern Zone 14
Vertical Datum: North American Vertical Datum of 1988
Geoid Model: Geoid12A
Units of Reference: Meters

2.3 Lidar Point Cloud Statistics

Table 3 illustrates the overall lidar point cloud statistics for this project.

Point Cloud Statistics	
Category	**Value**
Total Points	21,825,021,009
Nominal Pulse Spacing (m)	0.6442
Nominal Pulse Density (pls/m²)	2.41
Nominal Pulse Spacing (ft)	2.1134
Nominal Pulse Density (pls/ft²)	0.22
Total Aggregate Points	21,133,898,203
Aggregate Nominal Pulse Spacing (m)	0.5791
Aggregate Nominal Pulse Density (pls/m²)	2.98
Aggregate Nominal Pulse Spacing (ft)	1.9000
Aggregate Nominal Pulse Density (pls/ft²)	0.28

Table 3: Lidar Point Cloud Statistics

2.4 Lidar Classification

The calibrated point cloud data from the laser sensor was merged to produce processed (*.las) file(s) including but not limited to 3D position, intensity, and time-stamp. A filtering methodology was utilized to produce a multi-return surface elevation model dataset with bare-earth conditions. GeoCue, TerraScan, and TerraModel software was used for the initial batch processing and manual editing of the (*.las) point clouds. Atlantic utilized collected breakline data to preform classification for classes' 9-Water and 10-Rail (breakline buffer) in LP360. Outlined in Tables 4 and 5 are the classification codes utilized for this project.

LASv1.2 QC Delivery Classification Scheme	
Code	**Description**
0	Created, never classified
1	Unclassified[3]
2	Ground
7	Low Point (noise)
9	Water
10	Ignored Ground
11	Withheld
17	Bridge Deck
18	High Noise

Table 4: QC Classification Scheme

ASPRS Standard Lidar Point Classes	
Code	**Description**
0	Created, never classified
1	Unclassified[3]
2	Ground
7	Low Point (noise)
9	Water
10	Rail (breakline buffer)
17	Bridge Deck
18	High Noise

Table 5: Point Cloud Classification Scheme

Section 3: Relative Accuracy Assessment

3.1 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 5cm and the IMU error of 0.03492 degrees at an altitude of 2,300m; the expected radial horizontal positional error will be $RMSE_r$ = 12.99cm.

3.2 Calibration of Lidar Point Cloud

LiDAR ranging data were initially calibrated using previous best parameters for this instrument and aircraft. Using a combination of GeoCue, and TerraSolid's 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 2 cm or less. A final analysis of the calibrated LiDAR is preformed using a TerraMatch Tie Line report for an overall statistical model of the project area.

3.3 Relative Vertical Accuracy

Upon completion of the data calibration, Atlantic runs a complete set of Delta-Z (dZ) ortho images. 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 iterswath accuracy RMSDz requirement of the project. An amber color is assigned for offsets that fall between the RMSDz value and 2x of that value (essentially the 95% confidence level). Finally, red values are assigned to all values that fall beyond 2x 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

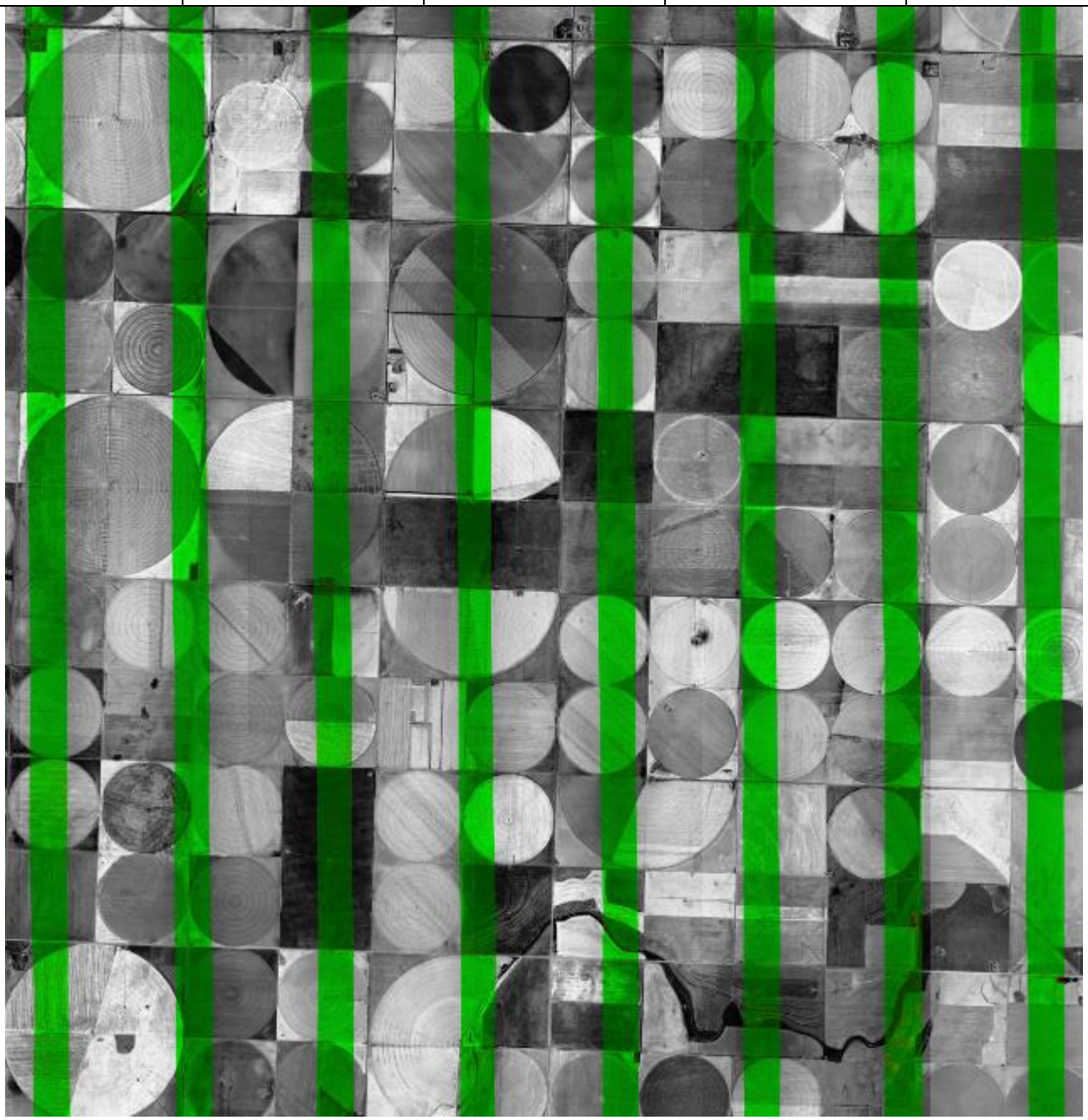


Figure 4: dZ ortho sub-sample

3.4 Interswath Accuracy Results

An overall statistical assessment of the relative accuracy using TerraMatch Tie Line Report between lidar swaths can be found in Tables 6, 7, 8, and 9 below. The values provided are in meters.

Average Magnitudes Per Line											
Line	X	Y	Z	Line	X	Y	Z	Line	X	Y	Z
1	0.023	0.016	0.012	30	0.088	0.068	0.014	62	0.004	0.015	0.012
2	0.02	0.018	0.015	31	0.024	0.03	0.014	63	0.013	0.014	0.015
3	0.012	0.018	0.013	32	0.016	0.019	0.011	64	0.014	0.012	0.014
4	0.011	0.016	0.013	33	0.022	0.019	0.013	65	0.023	0.039	0.015
5	0.018	0.01	0.012	34	0.029	0.019	0.011	66	0.004	0.019	0.013
6	0.023	0.014	0.013	35	-	-	0.014	69	0.012	0.04	0.018
7	0.032	0.021	0.012	36	0.014	0.056	0.011	70	0.024	0.027	0.015
9	0.032	0.014	0.011	37	0.007	0.048	0.013	71	0.014	0.01	0.017
11	0.03	0.015	0.013	38	0.002	0.032	0.012	72	0.014	0.01	0.017
12	0.032	0.018	0.015	39	0.009	0.019	0.011	73	0.017	0.014	0.017
13	0.033	0.018	0.013	40	0.023	0.021	0.013	74	0.022	0.013	0.017
14	0.047	0.013	0.016	44	0.017	0.034	0.014	75	0.023	0.017	0.019
15	0.019	0.016	0.013	45	0.011	0.018	0.018	76	0.041	0.068	0.018
16	0.016	0.015	0.014	46	0.012	0.013	0.012	77	0.004	0.015	0.016
17	0.024	0.012	0.014	47	0.025	0.014	0.014	79	0.001	0.041	0.017
18	0.026	0.027	0.015	48	0.032	0.021	0.011	80	0.005	0.018	0.017
19	0.034	0.02	0.013	49	0.011	0.015	0.014	81	0.011	0.014	0.018
20	0.043	0.022	0.015	50	0.012	0.018	0.011	83	0.018	0.007	0.021
21	0.021	0.012	0.014	51	0.011	0.023	0.014	84	0.025	0.019	0.014
22	0.023	0.009	0.014	52	0.004	0.037	0.011	85	0.047	0.026	0.013
23	0.02	0.019	0.015	55	0.041	0.056	0.011	86	0.03	0.035	0.013
24	0.028	0.017	0.014	56	0.005	0.013	0.012	87	0.033	0.03	0.014
25	0.016	0.021	0.013	57	0.008	0.011	0.012	88	0.063	0.018	0.013
27	0.014	0.018	0.014	59	0.021	0.021	0.013	89	0.048	0.037	0.014
28	0.013	0.013	0.016	60	0.022	0.013	0.015	91	0.047	0.035	0.011
29	0.053	0.061	0.014	61	0.019	0.012	0.015				

Table 6: Average Tie Line Magnitudes per Line

Internal Observation Statistics			
Category	X	Y	Z
Average Magnitude	0.016	0.017	0.014
RMS Values	0.028	0.029	0.019
Maximum Values	0.145	0.146	0.149
Observation Weight	3093.0	3093.0	1447151.0

Table 7: Tie Line Observation Statistics

Overall Relative Accuracy	
Category	**Mismatch**
Average 3D Mismatch	0.01413
Average XY Mismatch	0.03067
Average Z Mismatch	0.01408

Table 8: Relative Accuracy Results

TerraMatch Tie Lines	
Category	**Observations**
Section Lines	612,471
Roof Lines	1,546

Table 9: Total Tie Lines

Section 4: Vertical Accuracy Assessment

4.1 Ground Surveyed Check Points

Atlantic established a total of one hundred and forty six (146) checkpoints for this project (83 NVA + 63 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.

4.2 Vertical Accuracy

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).

4.3 Check Point Distribution

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

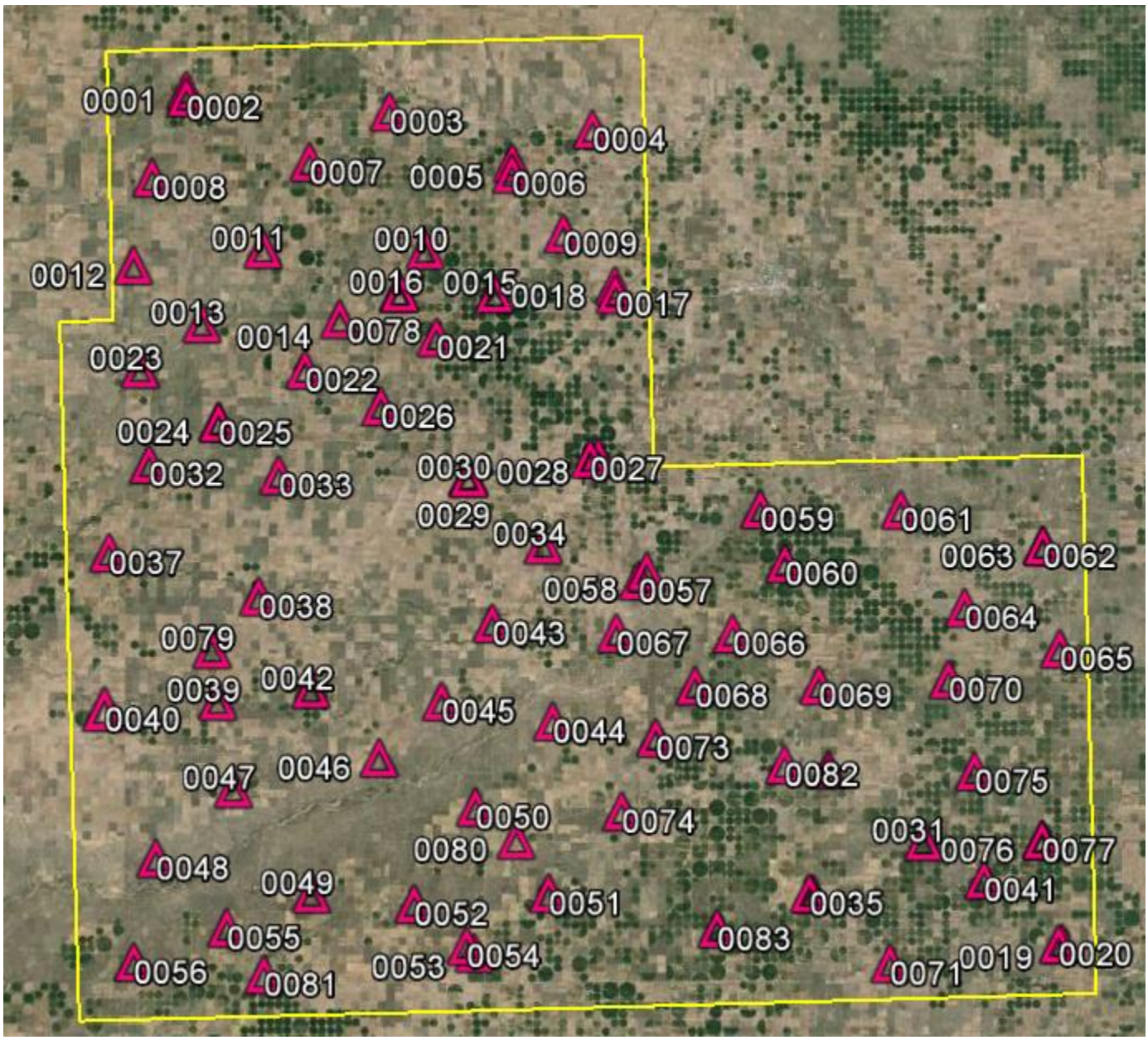


Figure 5: Non-vegetated Vertical Accuracy (NVA) Check Point Distribution

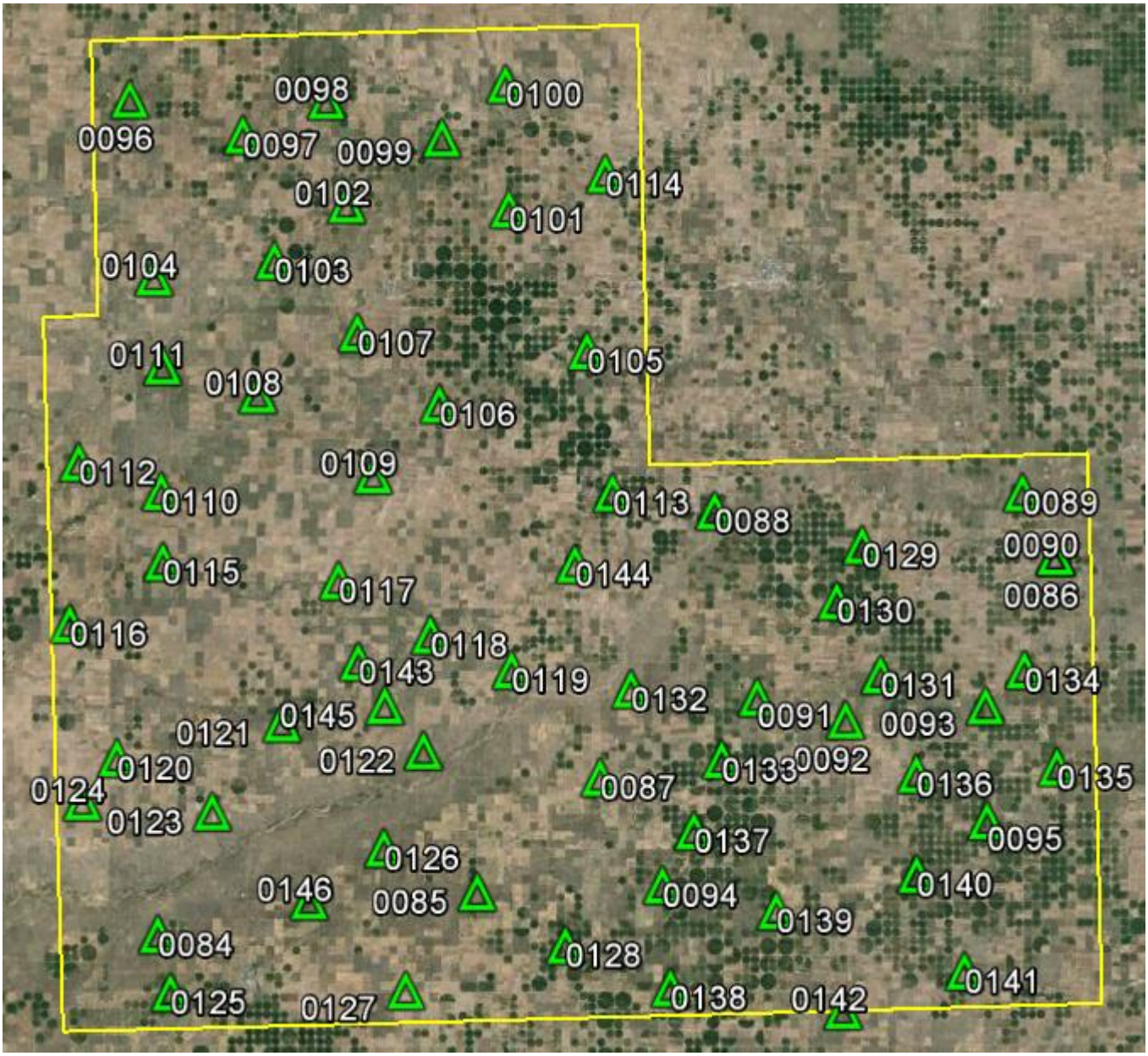


Figure 6: Vegetated Vertical Accuracy (VVA) Check Point Distribution

4.4 Check Point Assessment

A vertical accuracy assessment of the NVA & VVA check points against the lidar point cloud, bare-earth lidar, and derived bare-earth DEM's can be found in Tables 10, 11, 12, and 13 below. The coordinates provided are in NAD83 (HARN), UTM Zone 14N, NAVD88 (Geoid12A), Meters.

Non-vegetated Vertical Accuracy (NVA) Check Point Assessment (Point Cloud)						
PointID	**Easting**	**Northing**	**KnownZ**	**LaserZ**	**Description**	**DeltaZ**
1	237397.83	4181095.89	1073.07	1073.2	Open Terrain	0.091
2	237396.42	4180454.43	1073.86	1073.9	Open Terrain	-0.005
3	256326.66	4178617	1003.67	1003.8	Open Terrain	0.089
4	275205.7	4176425.83	976.657	976.69	Open Terrain	0.03
5	267646.04	4173507.39	980.884	980.91	Open Terrain	0.025
6	267595.29	4172523.33	974.442	974.51	Open Terrain	0.064
7	248733.93	4174117.37	1036.7	1036.8	Open Terrain	0.087
8	234007.24	4173101.71	1093.31	1093.3	Open Terrain	0.018
9	272235.95	4166831.09	957.159	957.16	Open Terrain	0
10	259331.9	4165661.27	1009.95	1009.9	Open Terrain	-0.013
11	244207.79	4166156.56	1070.61	1070.6	Open Terrain	0.028
12	232057.74	4165011.33	1119.14	1119.1	Open Terrain	-0.004
13	238308.05	4159433.65	1076.13	1076.2	Open Terrain	0.078
14	251176.67	4159459.85	1043.12	1043.2	Open Terrain	0.048
15	265664.59	4161425.06	991.139	991.12	Open Terrain	-0.023
16	256860.38	4161760.04	1017.53	1017.6	Open Terrain	0.101
17	276931.85	4161062.33	955.009	955.07	Open Terrain	0.065
18	276882.6	4161825.56	956.588	956.59	Open Terrain	0.002
19	316942.89	4099676.14	903.299	903.27	Open Terrain	-0.029
20	316614.78	4099629.03	902.423	902.43	Open Terrain	0.01
21	260130.35	4157535.2	1005.85	1005.9	Open Terrain	0.023
22	247811.97	4154857.32	1053.83	1053.9	Open Terrain	0.05
23	232432.86	4155360.82	1095.23	1095.4	Open Terrain	0.173
24	239616.16	4150265.15	1082.74	1082.8	Open Terrain	0.032
25	239616.48	4150168.38	1082.56	1082.7	Open Terrain	0.127
26	254778.39	4151266.46	1025.2	1025.4	Open Terrain	0.148
27	274153.1	4145865.78	965.062	965.02	Open Terrain	-0.046
28	274930.3	4145891.58	964.122	964.17	Open Terrain	0.047
29	262751.29	4144522.3	999.508	999.48	Open Terrain	-0.029
30	262786.41	4144397.21	999.695	999.71	Open Terrain	0.016
31	304261.64	4109553.11	927.162	927.19	Open Terrain	0.023
32	233024.86	4146509.24	1106.38	1106.5	Open Terrain	0.086
33	245096.4	4145133.73	1060.11	1060.2	Open Terrain	0.084
34	269582	4138031.38	982.252	982.21	Open Terrain	-0.045

35	293499.2	4105002.44	951.559	951.65	Open Terrain	0.094
36	293810.06	4104961.24	950.598	950.59	Open Terrain	-0.007
37	229045.15	4138397.51	1123.63	1123.7	Open Terrain	0.068
38	242915.51	4133946.22	1065.54	1065.6	Open Terrain	0.101
39	238834.37	4124375.52	1079.85	1080	Open Terrain	0.107
40	228237.64	4123890.69	1122.95	1123	Open Terrain	0.043
41	309794.72	4105822.57	917.881	917.87	Open Terrain	-0.01
42	247573.37	4125221.68	1060.67	1060.7	Open Terrain	0.048
43	264612.95	4130874.93	997.571	997.59	Open Terrain	0.015
44	269998.52	4121639.71	991.445	991.47	Open Terrain	0.028
45	259699.78	4123774.05	1027.05	1027.2	Open Terrain	0.133
46	253736.72	4118679.75	1051.32	1051.4	Open Terrain	0.09
47	240072.05	4116203.86	1084.65	1084.7	Open Terrain	0.008
48	232650.18	4109906.83	1090.29	1090.5	Open Terrain	0.171
49	247081.29	4106247.18	1065.29	1065.4	Open Terrain	0.085
50	262594.66	4113872.05	1013.82	1013.9	Open Terrain	0.047
51	269184.72	4105686.94	1020.76	1020.7	Open Terrain	-0.01
52	256627.25	4105044.07	1040.98	1041.1	Open Terrain	0.093
53	262114.95	4100333.92	1034.83	1034.8	Open Terrain	-0.003
54	261404.27	4101018.78	1041.18	1041.2	Open Terrain	0.022
55	239083.15	4103276.02	1083.3	1083.3	Open Terrain	0.006
56	230301.25	4100307.04	1100.69	1100.8	Open Terrain	0.121
57	278347.11	4134448.01	970.403	970.41	Open Terrain	0.006
58	279123.31	4135268.52	968.798	968.8	Open Terrain	0.005
59	289853.79	4140770.95	917.186	917.2	Open Terrain	0.014
60	292023.71	4135679.67	946.602	946.54	Open Terrain	-0.058
61	302951.23	4140370.87	915.147	915.15	Open Terrain	0.002
62	316131.11	4136646.86	899.29	899.28	Open Terrain	-0.011
63	316130.76	4136636.96	899.088	899.13	Open Terrain	0.042
64	308665.99	4131112.85	922.722	922.64	Open Terrain	-0.081
65	317441.26	4127067.59	903.81	903.79	Open Terrain	-0.024
66	286975.6	4129319.6	960.794	960.79	Open Terrain	-0.005
67	276153.59	4129642.01	975.368	975.42	Open Terrain	0.05
68	283346.69	4124573.83	972.907	972.92	Open Terrain	0.011
69	294871.4	4124302.43	950.112	950.15	Open Terrain	0.041
70	306977.89	4124510.71	924.722	924.66	Open Terrain	-0.061
71	300831.96	4098315.51	930.684	930.59	Open Terrain	-0.097
72	295557.34	4116440.4	938.624	938.64	Open Terrain	0.013
73	279566.59	4119840.94	972.349	972.35	Open Terrain	0.003
74	276197.08	4113110.54	985.108	985.15	Open Terrain	0.04
75	309195.26	4115925.9	912.07	912.07	Open Terrain	0.003
76	315362.42	4109340.71	905.163	905.22	Open Terrain	0.059

77	315315.25	4109335.06	905.58	905.55	Open Terrain	-0.033
78	256734.34	4161778.09	1017.36	1017.4	Open Terrain	0.076
79	238428.61	4129179.95	1088.03	1088.2	Urban Terrain	0.182
80	266315.1	4110743	1010.32	1010.3	Urban Terrain	0.004
81	242424.75	4098856.21	1098.33	1098.3	Urban Terrain	-0.029
82	291478.43	4117029.96	948.23	948.22	Urban Terrain	-0.006
83	284791.62	4101973.06	969.785	969.74	Urban Terrain	-0.043

Table 10: Lidar Point Cloud NVA Assessment

Non-vegetated Vertical Accuracy (NVA) Check Point Assessment (Bare-Earth)						
PointID	**Easting**	**Northing**	**KnownZ**	**LaserZ**	**Description**	**DeltaZ**
1	237397.830	4181095.885	1073.065	1073.124	Open Terrain	0.059
2	237396.416	4180454.430	1073.856	1073.851	Open Terrain	-0.005
3	256326.655	4178616.996	1003.670	1003.759	Open Terrain	0.089
4	275205.704	4176425.833	976.657	976.667	Open Terrain	0.010
5	267646.038	4173507.394	980.884	980.900	Open Terrain	0.016
6	267595.293	4172523.330	974.442	974.470	Open Terrain	0.028
7	248733.925	4174117.369	1036.700	1036.772	Open Terrain	0.072
8	234007.235	4173101.712	1093.305	1093.323	Open Terrain	0.018
9	272235.945	4166831.086	957.159	957.149	Open Terrain	-0.010
10	259331.896	4165661.266	1009.945	1009.884	Open Terrain	-0.061
11	244207.787	4166156.564	1070.607	1070.613	Open Terrain	0.006
12	232057.740	4165011.330	1119.139	1119.141	Open Terrain	0.002
13	238308.047	4159433.650	1076.132	1076.210	Open Terrain	0.078
14	251176.674	4159459.847	1043.119	1043.167	Open Terrain	0.048
15	265664.587	4161425.062	991.139	991.116	Open Terrain	-0.023
16	256860.380	4161760.039	1017.528	1017.622	Open Terrain	0.094
17	276931.853	4161062.325	955.009	955.074	Open Terrain	0.065
18	276882.603	4161825.562	956.588	956.591	Open Terrain	0.003
19	316942.889	4099676.136	903.299	903.270	Open Terrain	-0.029
20	316614.780	4099629.034	902.423	902.433	Open Terrain	0.010
21	260130.345	4157535.197	1005.846	1005.869	Open Terrain	0.023
22	247811.972	4154857.320	1053.831	1053.842	Open Terrain	0.011
23	232432.863	4155360.815	1095.234	1095.399	Open Terrain	0.165
24	239616.158	4150265.152	1082.741	1082.773	Open Terrain	0.032
25	239616.484	4150168.383	1082.555	1082.649	Open Terrain	0.094
26	254778.386	4151266.462	1025.204	1025.287	Open Terrain	0.083
27	274153.100	4145865.782	965.062	965.016	Open Terrain	-0.046
28	274930.295	4145891.579	964.122	964.146	Open Terrain	0.024
29	262751.294	4144522.296	999.508	999.479	Open Terrain	-0.029
30	262786.413	4144397.206	999.695	999.689	Open Terrain	-0.006
31	304261.637	4109553.111	927.162	927.185	Open Terrain	0.023

32	233024.856	4146509.243	1106.382	1106.468	Open Terrain	0.086
33	245096.404	4145133.730	1060.112	1060.196	Open Terrain	0.084
34	269582.000	4138031.376	982.252	982.207	Open Terrain	-0.045
35	293499.196	4105002.439	951.559	951.644	Open Terrain	0.085
36	293810.063	4104961.243	950.598	950.578	Open Terrain	-0.020
37	229045.147	4138397.506	1123.634	1123.698	Open Terrain	0.064
38	242915.510	4133946.222	1065.542	1065.643	Open Terrain	0.101
39	238834.369	4124375.524	1079.845	1079.928	Open Terrain	0.083
40	228237.640	4123890.691	1122.952	1122.995	Open Terrain	0.043
41	309794.717	4105822.572	917.881	917.869	Open Terrain	-0.012
42	247573.369	4125221.676	1060.667	1060.715	Open Terrain	0.048
43	264612.949	4130874.934	997.571	997.571	Open Terrain	0.000
44	269998.517	4121639.710	991.445	991.462	Open Terrain	0.017
45	259699.784	4123774.045	1027.051	1027.129	Open Terrain	0.078
46	253736.716	4118679.745	1051.316	1051.406	Open Terrain	0.090
47	240072.051	4116203.863	1084.649	1084.632	Open Terrain	-0.017
48	232650.178	4109906.829	1090.288	1090.394	Open Terrain	0.106
49	247081.291	4106247.182	1065.294	1065.379	Open Terrain	0.085
50	262594.662	4113872.050	1013.823	1013.870	Open Terrain	0.047
51	269184.715	4105686.941	1020.756	1020.746	Open Terrain	-0.010
52	256627.250	4105044.067	1040.984	1041.027	Open Terrain	0.043
53	262114.952	4100333.924	1034.832	1034.826	Open Terrain	-0.006
54	261404.268	4101018.784	1041.184	1041.206	Open Terrain	0.022
55	239083.149	4103276.024	1083.298	1083.302	Open Terrain	0.004
56	230301.246	4100307.038	1100.685	1100.775	Open Terrain	0.090
57	278347.109	4134448.012	970.403	970.375	Open Terrain	-0.028
58	279123.311	4135268.523	968.798	968.803	Open Terrain	0.005
59	289853.791	4140770.948	917.186	917.194	Open Terrain	0.008
60	292023.707	4135679.668	946.602	946.504	Open Terrain	-0.098
61	302951.230	4140370.869	915.147	915.102	Open Terrain	-0.045
62	316131.110	4136646.861	899.290	899.271	Open Terrain	-0.019
63	316130.762	4136636.962	899.088	899.074	Open Terrain	-0.014
64	308665.992	4131112.846	922.722	922.594	Open Terrain	-0.128
65	317441.262	4127067.594	903.810	903.786	Open Terrain	-0.024
66	286975.601	4129319.595	960.794	960.730	Open Terrain	-0.064
67	276153.587	4129642.007	975.368	975.408	Open Terrain	0.040
68	283346.686	4124573.825	972.907	972.902	Open Terrain	-0.005
69	294871.402	4124302.427	950.112	950.133	Open Terrain	0.021
70	306977.892	4124510.705	924.722	924.620	Open Terrain	-0.102
71	300831.962	4098315.505	930.684	930.587	Open Terrain	-0.097
72	295557.338	4116440.402	938.624	938.637	Open Terrain	0.013
73	279566.591	4119840.937	972.349	972.298	Open Terrain	-0.051

74	276197.084	4113110.544	985.108	985.148	Open Terrain	0.040
75	309195.258	4115925.898	912.070	912.050	Open Terrain	-0.020
76	315362.419	4109340.708	905.163	905.222	Open Terrain	0.059
77	315315.252	4109335.059	905.580	905.545	Open Terrain	-0.035
78	256734.336	4161778.090	1017.357	1017.375	Open Terrain	0.018
79	238428.607	4129179.950	1088.033	1088.215	Urban Terrain	0.182
80	266315.101	4110742.996	1010.317	1010.306	Urban Terrain	-0.011
81	242424.747	4098856.212	1098.333	1098.304	Urban Terrain	-0.029
82	291478.431	4117029.960	948.230	948.212	Urban Terrain	-0.018
83	284791.616	4101973.062	969.785	969.742	Urban Terrain	-0.043

Table 11: Lidar Bare-Earth NVA Assessment

Non-vegetated Vertical Accuracy (NVA) Check Point Assessment (DEM)						
PointID	**Easting**	**Northing**	**KnownZ**	**DEMZ**	**Description**	**DeltaZ**
1	237397.830	4181095.885	1073.065	1073.129	Open Terrain	0.064
2	237396.416	4180454.430	1073.856	1073.859	Open Terrain	0.003
3	256326.655	4178616.996	1003.670	1003.768	Open Terrain	0.098
4	275205.704	4176425.833	976.657	976.677	Open Terrain	0.020
5	267646.038	4173507.394	980.884	980.896	Open Terrain	0.012
6	267595.293	4172523.330	974.442	974.449	Open Terrain	0.007
7	248733.925	4174117.369	1036.700	1036.781	Open Terrain	0.081
8	234007.235	4173101.712	1093.305	1093.322	Open Terrain	0.017
9	272235.945	4166831.086	957.159	957.130	Open Terrain	-0.029
10	259331.896	4165661.266	1009.945	1009.908	Open Terrain	-0.037
11	244207.787	4166156.564	1070.607	1070.614	Open Terrain	0.007
12	232057.740	4165011.330	1119.139	1119.130	Open Terrain	-0.009
13	238308.047	4159433.650	1076.132	1076.219	Open Terrain	0.087
14	251176.674	4159459.847	1043.119	1043.184	Open Terrain	0.065
15	265664.587	4161425.062	991.139	991.112	Open Terrain	-0.027
16	256860.380	4161760.039	1017.528	1017.623	Open Terrain	0.095
17	276931.853	4161062.325	955.009	955.051	Open Terrain	0.042
18	276882.603	4161825.562	956.588	956.599	Open Terrain	0.011
19	316942.889	4099676.136	903.299	903.251	Open Terrain	-0.048
20	316614.780	4099629.034	902.423	902.426	Open Terrain	0.003
21	260130.345	4157535.197	1005.846	1005.867	Open Terrain	0.021
22	247811.972	4154857.320	1053.831	1053.857	Open Terrain	0.026
23	232432.863	4155360.815	1095.234	1095.398	Open Terrain	0.164
24	239616.158	4150265.152	1082.741	1082.764	Open Terrain	0.023
25	239616.484	4150168.383	1082.555	1082.644	Open Terrain	0.089
26	254778.386	4151266.462	1025.204	1025.286	Open Terrain	0.082
27	274153.100	4145865.782	965.062	965.035	Open Terrain	-0.027
28	274930.295	4145891.579	964.122	964.143	Open Terrain	0.021

29	262751.294	4144522.296	999.508	999.485	Open Terrain	-0.023
30	262786.413	4144397.206	999.695	999.691	Open Terrain	-0.004
31	304261.637	4109553.111	927.162	927.189	Open Terrain	0.027
32	233024.856	4146509.243	1106.382	1106.469	Open Terrain	0.087
33	245096.404	4145133.730	1060.112	1060.215	Open Terrain	0.103
34	269582.000	4138031.376	982.252	982.225	Open Terrain	-0.027
35	293499.196	4105002.439	951.559	951.650	Open Terrain	0.091
36	293810.063	4104961.243	950.598	950.588	Open Terrain	-0.010
37	229045.147	4138397.506	1123.634	1123.702	Open Terrain	0.068
38	242915.510	4133946.222	1065.542	1065.647	Open Terrain	0.105
39	238834.369	4124375.524	1079.845	1079.925	Open Terrain	0.080
40	228237.640	4123890.691	1122.952	1122.991	Open Terrain	0.039
41	309794.717	4105822.572	917.881	917.878	Open Terrain	-0.003
42	247573.369	4125221.676	1060.667	1060.685	Open Terrain	0.018
43	264612.949	4130874.934	997.571	997.607	Open Terrain	0.036
44	269998.517	4121639.710	991.445	991.462	Open Terrain	0.017
45	259699.784	4123774.045	1027.051	1027.127	Open Terrain	0.076
46	253736.716	4118679.745	1051.316	1051.424	Open Terrain	0.108
47	240072.051	4116203.863	1084.649	1084.643	Open Terrain	-0.006
48	232650.178	4109906.829	1090.288	1090.394	Open Terrain	0.106
49	247081.291	4106247.182	1065.294	1065.361	Open Terrain	0.067
50	262594.662	4113872.050	1013.823	1013.861	Open Terrain	0.038
51	269184.715	4105686.941	1020.756	1020.746	Open Terrain	-0.010
52	256627.250	4105044.067	1040.984	1041.030	Open Terrain	0.046
53	262114.952	4100333.924	1034.832	1034.850	Open Terrain	0.018
54	261404.268	4101018.784	1041.184	1041.195	Open Terrain	0.011
55	239083.149	4103276.024	1083.298	1083.307	Open Terrain	0.009
56	230301.246	4100307.038	1100.685	1100.769	Open Terrain	0.084
57	278347.109	4134448.012	970.403	970.396	Open Terrain	-0.007
58	279123.311	4135268.523	968.798	968.800	Open Terrain	0.002
59	289853.791	4140770.948	917.186	917.202	Open Terrain	0.016
60	292023.707	4135679.668	946.602	946.510	Open Terrain	-0.092
61	302951.230	4140370.869	915.147	915.108	Open Terrain	-0.039
62	316131.110	4136646.861	899.290	899.281	Open Terrain	-0.009
63	316130.762	4136636.962	899.088	899.080	Open Terrain	-0.008
64	308665.992	4131112.846	922.722	922.599	Open Terrain	-0.123
65	317441.262	4127067.594	903.810	903.789	Open Terrain	-0.021
66	286975.601	4129319.595	960.794	960.727	Open Terrain	-0.067
67	276153.587	4129642.007	975.368	975.410	Open Terrain	0.042
68	283346.686	4124573.825	972.907	972.897	Open Terrain	-0.010
69	294871.402	4124302.427	950.112	950.131	Open Terrain	0.019
70	306977.892	4124510.705	924.722	924.617	Open Terrain	-0.105

71	300831.962	4098315.505	930.684	930.584	Open Terrain	-0.100
72	295557.338	4116440.402	938.624	938.622	Open Terrain	-0.002
73	279566.591	4119840.937	972.349	972.296	Open Terrain	-0.053
74	276197.084	4113110.544	985.108	985.149	Open Terrain	0.041
75	309195.258	4115925.898	912.070	912.034	Open Terrain	-0.036
76	315362.419	4109340.708	905.163	905.221	Open Terrain	0.058
77	315315.252	4109335.059	905.580	905.558	Open Terrain	-0.022
78	256734.336	4161778.090	1017.357	1017.370	Open Terrain	0.013
79	238428.607	4129179.950	1088.033	1088.230	Urban Terrain	0.197
80	266315.101	4110742.996	1010.317	1010.304	Urban Terrain	-0.013
81	242424.747	4098856.212	1098.333	1098.313	Urban Terrain	-0.020
82	291478.431	4117029.960	948.230	948.208	Urban Terrain	-0.022
83	284791.616	4101973.062	969.785	969.740	Urban Terrain	-0.045

Table 12: DEM Bare-Earth NVA Assessment

Vegetated Vertical Accuracy (VVA) Check Point Assessment (Bare Earth)						
PointID	**Easting**	**Northing**	**KnownZ**	**LaserZ**	**Description**	**DeltaZ**
84	233960.207	4103577.143	1078.533	1078.631	Brush	0.098
85	263250.102	4106695.534	1023.073	1023.144	Brush	0.071
86	316848.862	4135689.381	897.185	897.174	Brush	-0.011
87	274739.245	4116779.860	982.414	982.587	Brush	0.173
88	285838.330	4140681.043	938.864	938.862	Brush	-0.002
89	313978.153	4141561.914	882.751	882.756	Brush	0.005
90	316848.862	4135689.382	897.185	897.173	Brush	-0.012
91	289266.583	4123635.505	960.172	960.343	Brush	0.171
92	297280.183	4121373.345	941.522	941.549	Brush	0.027
93	310084.048	4122303.318	922.142	922.252	Brush	0.110
94	280165.730	4106855.522	999.660	999.686	Brush	0.026
95	309943.943	4111876.932	913.500	913.513	Brush	0.013
96	233457.320	4179552.117	1093.926	1093.970	Crops	0.044
97	243719.101	4175986.153	1053.290	1053.318	Crops	0.028
98	251453.704	4178909.329	1023.353	1023.493	Crops	0.140
99	261891.017	4175191.156	991.246	991.334	Crops	0.088
100	267828.263	4179934.453	1007.822	1007.789	Crops	-0.033
101	267825.182	4168569.763	977.163	977.128	Crops	-0.035
102	253042.169	4169430.987	1024.084	1024.153	Crops	0.069
103	246289.812	4164491.916	1053.841	1053.996	Crops	0.155
104	235262.372	4163318.079	1105.024	1105.161	Crops	0.137
105	274594.472	4155503.220	968.401	968.393	Crops	-0.008
106	260995.611	4151045.043	1006.982	1007.018	Crops	0.036
107	253696.222	4157723.632	1030.902	1030.973	Crops	0.071
108	244467.022	4152403.950	1064.503	1064.615	Crops	0.112

109	254810.247	4144797.217	1025.863	1025.951	Crops	0.088
110	235402.424	4143808.701	1096.901	1097.135	Crops	0.234
111	235845.221	4155209.273	1092.247	1092.341	Crops	0.094
112	227918.668	4146677.290	1125.745	1125.812	Crops	0.067
113	276575.870	4142570.610	966.523	966.526	Crops	0.003
114	276712.496	4171526.060	956.903	956.968	Crops	0.065
115	235368.472	4137417.057	1095.584	1095.799	Crops	0.215
116	226704.766	4132032.323	1128.868	1129.035	Crops	0.167
117	251353.656	4135273.002	1036.617	1036.721	Crops	0.104
118	259613.596	4130120.240	1016.752	1016.916	Crops	0.164
119	266923.077	4126746.298	1007.455	1007.474	Crops	0.019
120	230673.298	4119711.964	1117.027	1117.052	Crops	0.025
121	245846.205	4122510.133	1060.092	1060.329	Crops	0.237
122	258688.679	4119640.434	1037.984	1038.051	Crops	0.067
123	239259.762	4114615.244	1088.692	1088.697	Crops	0.005
124	227412.093	4115850.148	1132.144	1132.213	Crops	0.069
125	234969.238	4098301.476	1109.249	1109.335	Crops	0.086
126	254838.569	4110888.534	1030.794	1030.935	Crops	0.141
127	256472.352	4097915.807	1056.798	1057.022	Crops	0.224
128	271160.818	4101633.456	1010.616	1010.686	Crops	0.070
129	299204.308	4137190.507	928.517	928.654	Crops	0.137
130	296754.136	4132209.495	941.205	941.126	Crops	-0.079
131	300563.271	4125390.665	937.608	937.631	Crops	0.023
132	277767.480	4124721.428	978.261	978.443	Crops	0.182
133	285867.753	4118088.652	959.169	959.324	Crops	0.155
134	313724.709	4125461.144	912.062	912.039	Crops	-0.023
135	316467.328	4116556.713	895.180	895.220	Crops	0.040
136	303600.309	4116280.623	923.062	923.203	Crops	0.141
137	283166.540	4111708.167	976.388	976.331	Crops	-0.057
138	280633.020	4097498.759	983.158	982.851	Crops	-0.307
139	290483.698	4104238.344	957.382	957.432	Crops	0.050
140	303385.045	4107173.721	930.837	930.867	Crops	0.030
141	307529.783	4098259.270	915.892	915.569	Crops	-0.323
142	296356.367	4095006.718	940.806	940.664	Crops	-0.142
143	252970.245	4127878.805	1035.521	1035.506	Tree	-0.015
144	272973.990	4136195.581	982.054	982.162	Tree	0.108
145	255289.765	4123848.799	1036.440	1036.618	Tree	0.178
146	247873.750	4106300.161	1061.512	1061.638	Tree	0.126

Table 13: Lidar Bare-Earth VVA Assessment

4.5 Vertical Accuracy Results

An overall statistical assessment of the check points can be found in Tables 14, 15, 16, 17, and 18 below. The values provided are in meters.

Check Points Error Statistics								
Land Cover Category	**# of points**	**Min**	**Max**	**Mean**	**Median**	**Skew**	**Std Dev**	**$RMSE_Z$**
Open Terrain	78	-0.128	0.165	0.018	0.015	-0.133	0.055	0.057
Urban Terrain	5	-0.043	0.182	0.016	-0.018	2.142	0.093	0.085
Brush	12	-0.012	0.173	0.056	0.027	0.814	0.068	0.086
Crops	47	-0.323	0.237	0.059	0.069	-1.381	0.115	0.128
Trees	4	-0.015	0.178	0.099	0.117	-1.200	0.082	0.122
Consolidated	146	-0.323	0.237	0.036	0.027	-0.643	0.084	0.091

Table 14: Check Points Error Statistics

Check Points Vertical Accuracy Assessment				
Land Cover Category	**# of Points**	**FVA — Fundamental Vertical Accuracy ($RMSE_Z$ x 1.9600)**	**CVA — Consolidated Vertical Accuracy (95th Percentile)**	**SVA — Supplemental Vertical Accuracy (95th Percentile)**
Open Terrain	78	0.112		
Urban Terrain	5			0.154
Brush	12			0.172
Crops	47			0.236
Trees	4			0.170
Consolidated	146		0.181	

Table 15: Check Points Vertical Accuracy Assessment

Non-vegetated Vertical Accuracy (NVA) and Vegetated Vertical Accuracy (VVA)				
Broad Land Cover Type	**# of Points**	**$RMSE_Z$**	**95% Confidence Level**	**95th Percentile**
NVA of Lidar Point Cloud	83	0.066	0.128	
NVA of Bare-Earth Lidar	83	0.059	0.116	
NVA of DEM	83	0.060	0.117	
VVA of Bare-Earth Lidar	63	0.121		0.233

Table 16: Non-vegetated Vertical Accuracy (NVA) and Vegetated Vertical Accuracy (VVA)

Comparison of NSSDA, NDEP, and ASPRS Statistics					
Land Cover Category	**NSSDA Accuracy$_z$ at 95% confidence level based on RMSE$_z$ * 1.9600**	**NDEP FVA, plus SVAs and CVA based on 95th Percentile**	**NDEP Accuracy Term**	**ASPRS Vertical Accuracy**	**ASPRS Accuracy Term**
Open Terrain	0.112	0.101	FVA	0.116	NVA
Urban Terrain	0.167	0.154	SVA		
Brush	0.168	0.172	SVA	0.233	VVA
Crops	0.251	0.236	SVA		
Trees	0.239	0.170	SVA		
Consolidated	0.178	0.181	CVA	n/a	n/a

Table 17: Comparison of NSSDA, NDEP, and ASPRS Statistics

5% Outliers > 95th Percentile (0.181 m)						
PointID	**Easting**	**Northing**	**KnownZ**	**LaserZ**	**Description**	**DeltaZ**
79	238428.607	4129179.950	1088.033	1088.215	Urban Terrain	0.182
110	235402.424	4143808.701	1096.901	1097.135	Crops	0.234
115	235368.472	4137417.057	1095.584	1095.799	Crops	0.215
121	245846.205	4122510.133	1060.092	1060.329	Crops	0.237
127	256472.352	4097915.807	1056.798	1057.022	Crops	0.224
132	277767.480	4124721.428	978.261	978.443	Crops	0.182
138	280633.020	4097498.759	983.158	982.851	Crops	-0.307
141	307529.783	4098259.270	915.892	915.569	Crops	-0.323

Table 18: 5% Outlier Check Points

Section 5: Certification

5.1 Limitations of Use

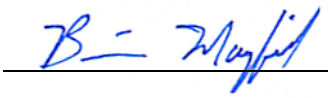
The accuracy assessment confirms that the data may be used for the intended applications stated in the **Project Purpose** section of this document. The dataset may also be used as a topographic input for other applications but the user should be aware that this lidar dataset was designed with a specific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

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

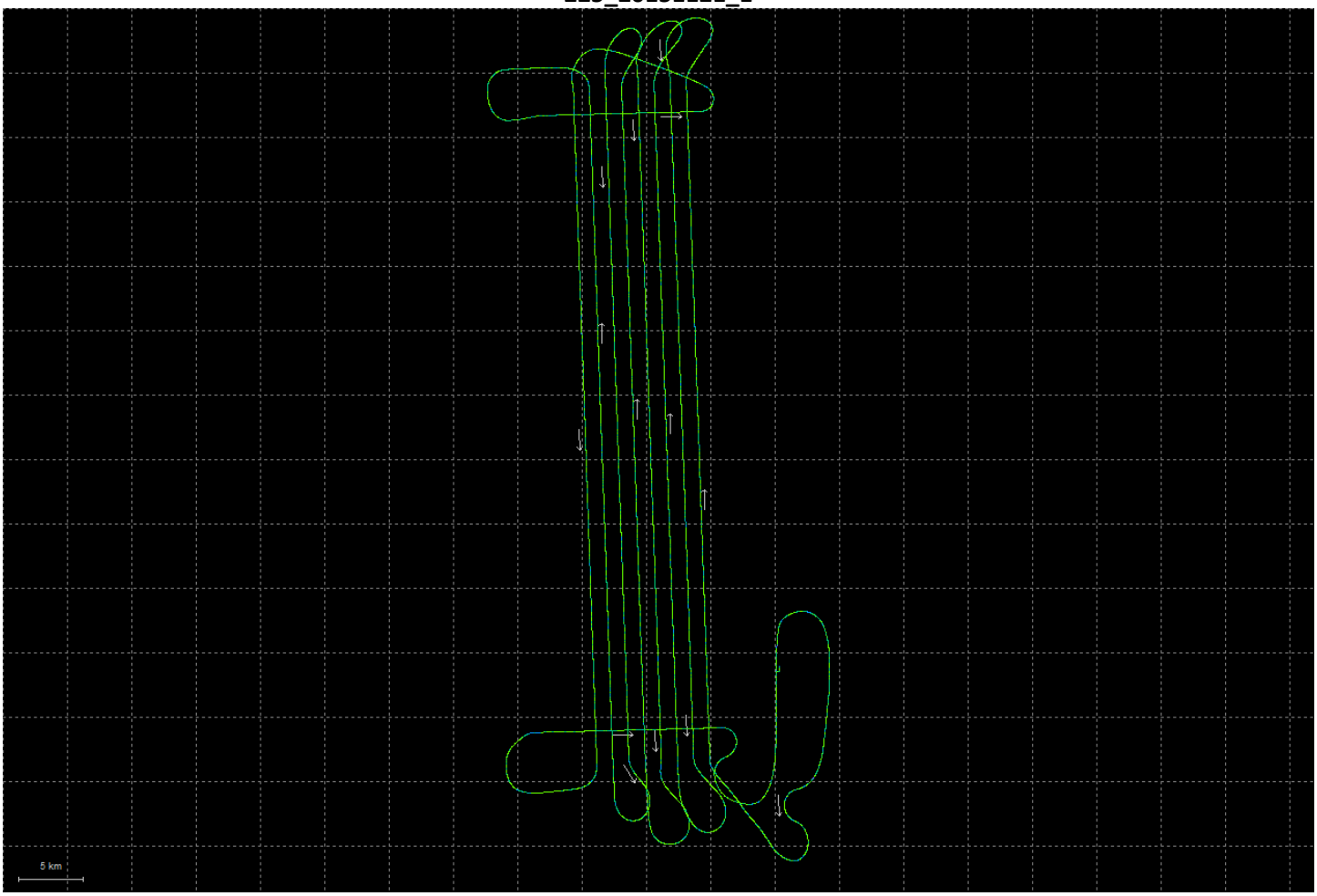
Section 6: GPS Processing

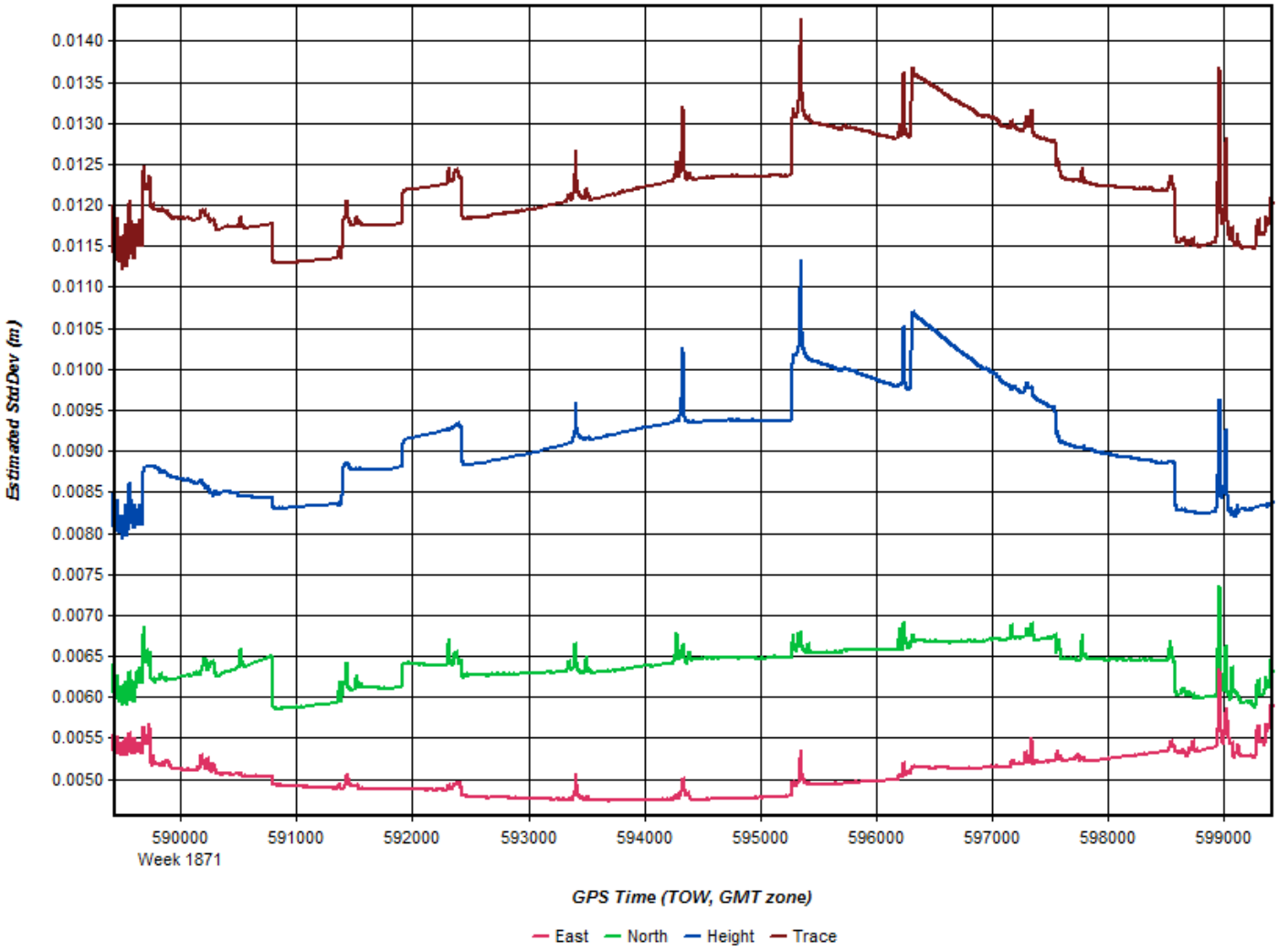
Inertial Explorer Version 8.60.5025

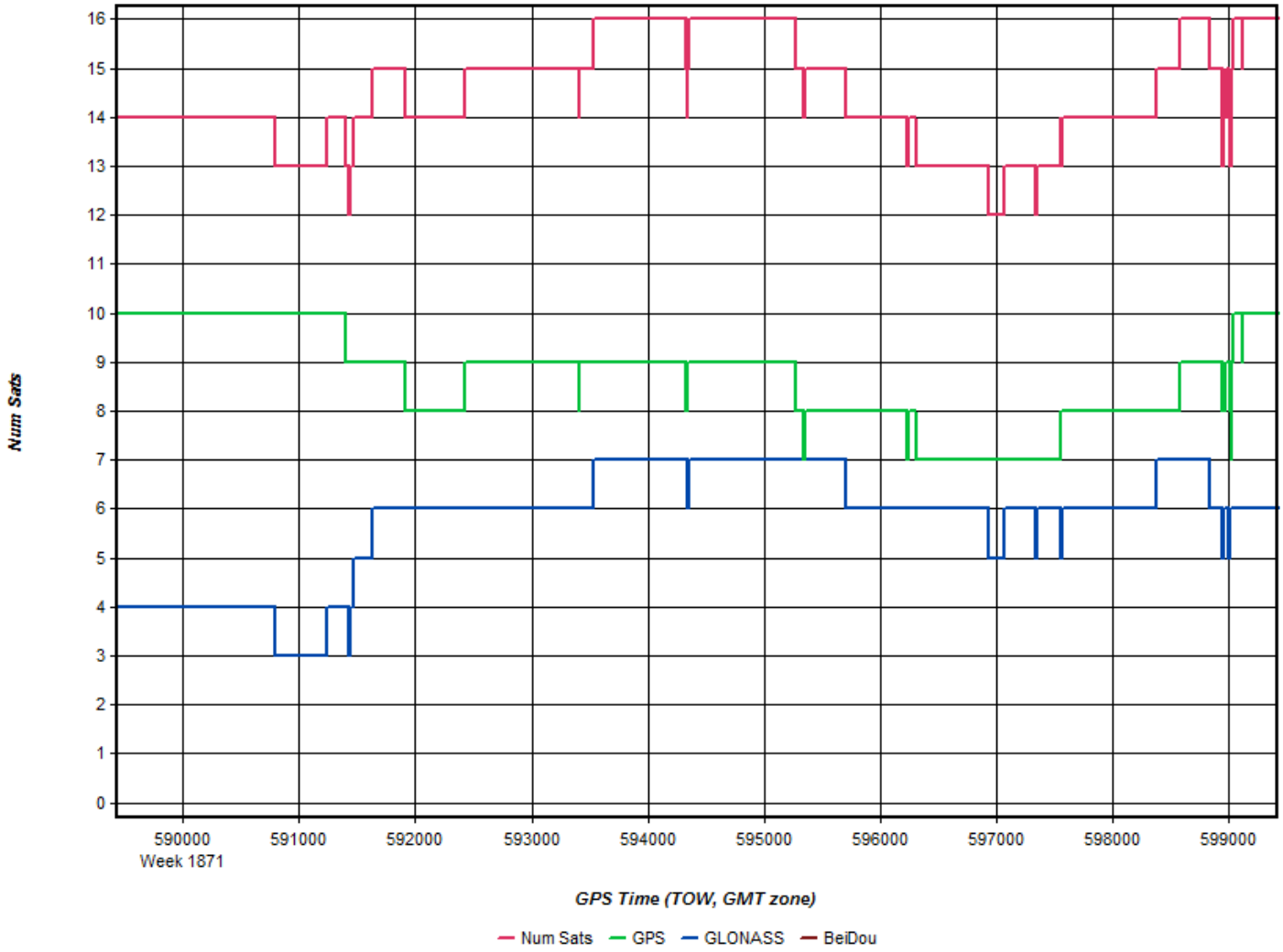
Plots by Mission: Coverage Map, Estimated Position Accuracy, Number of Satellites, Combined Separation, and PDOP.

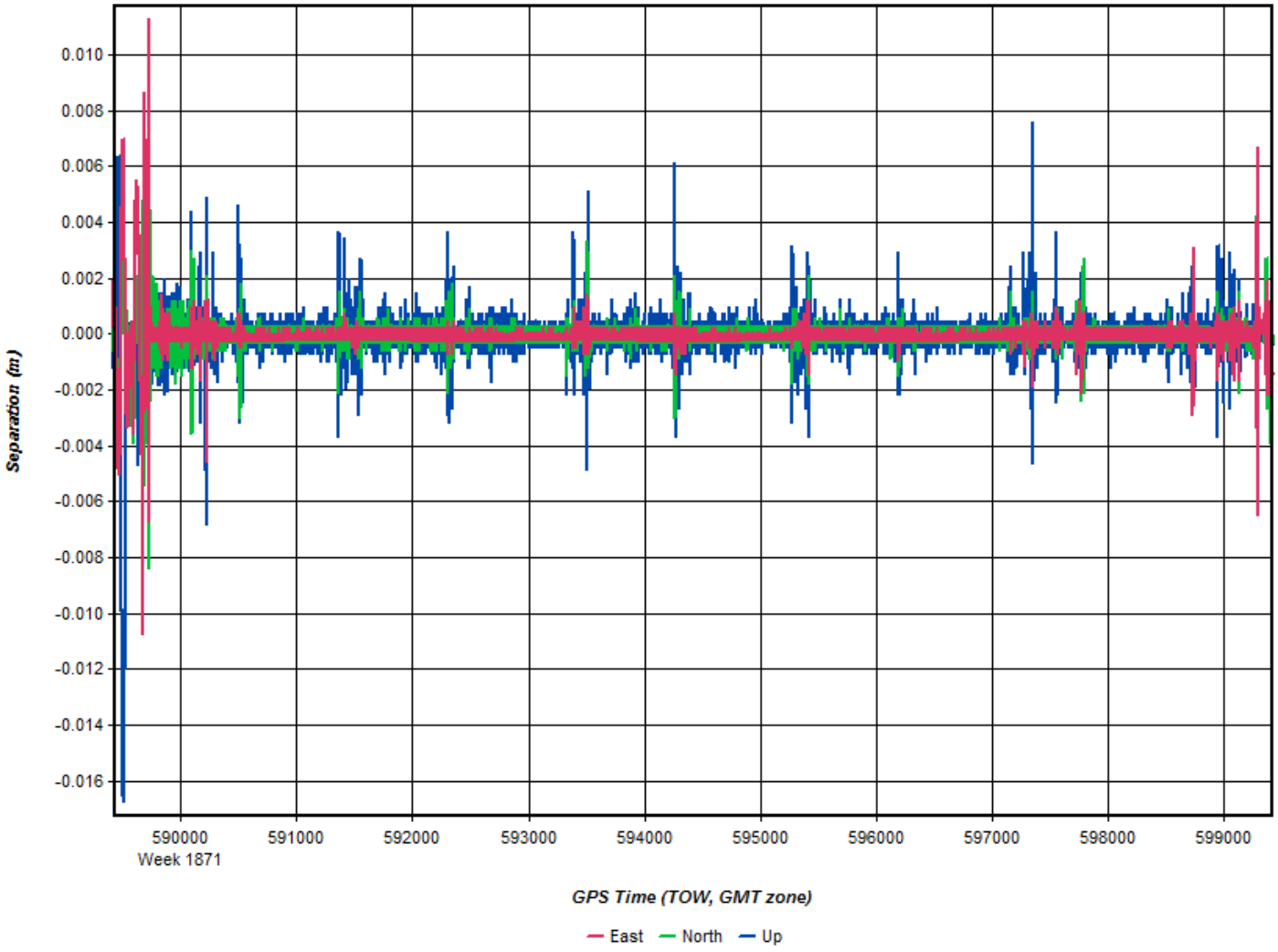
Coverage Map	The Coverage Map plot shows the Aircraft GPS-IMU Trajectory in reference to localized GPS Reference Stations.
Estimated Position Accuracy	The Estimated Position Accuracy plot shows the standard deviations of the east, north, and up directions versus time for the solution. The total standard 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.

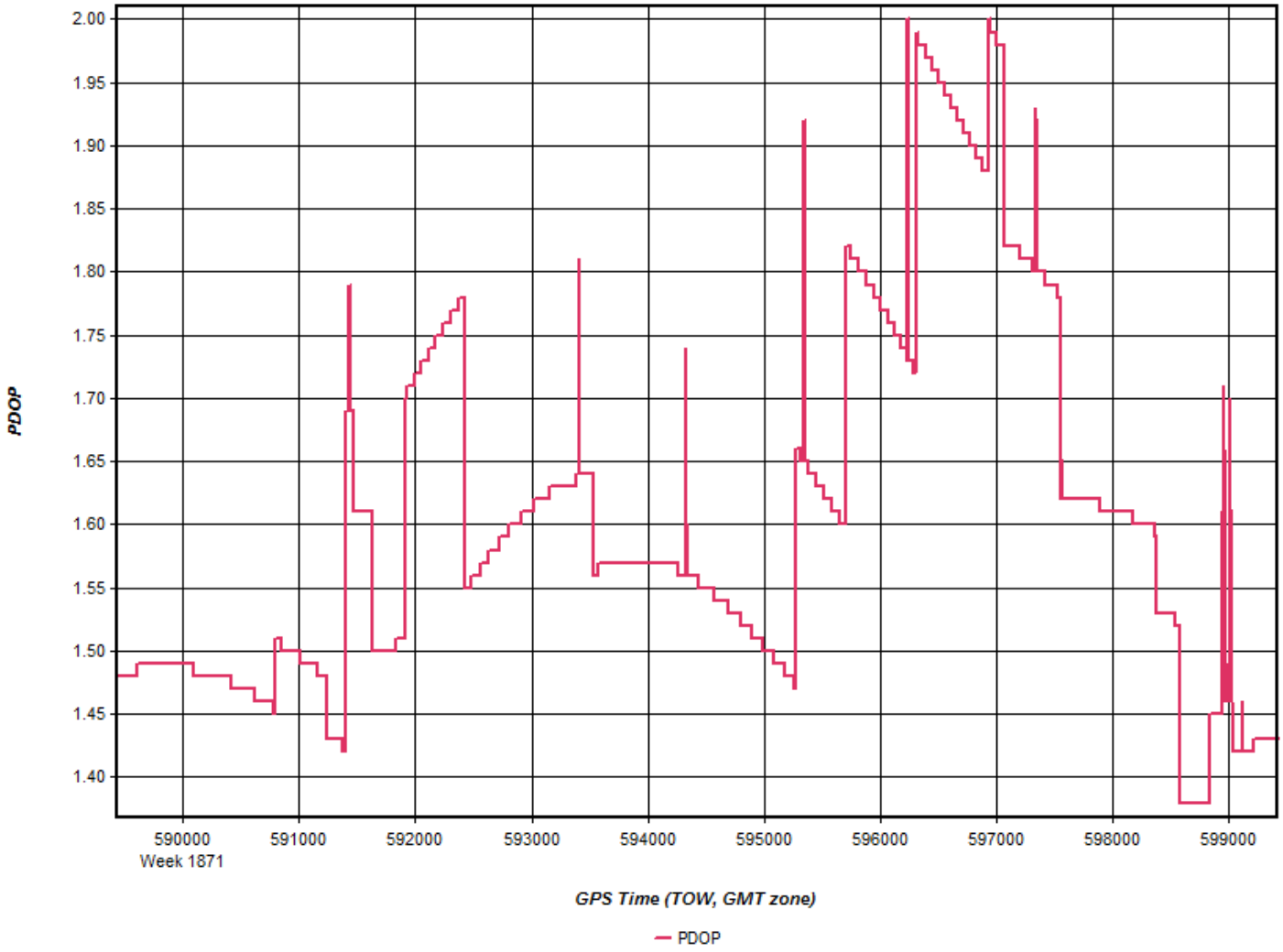
225_20151121_1



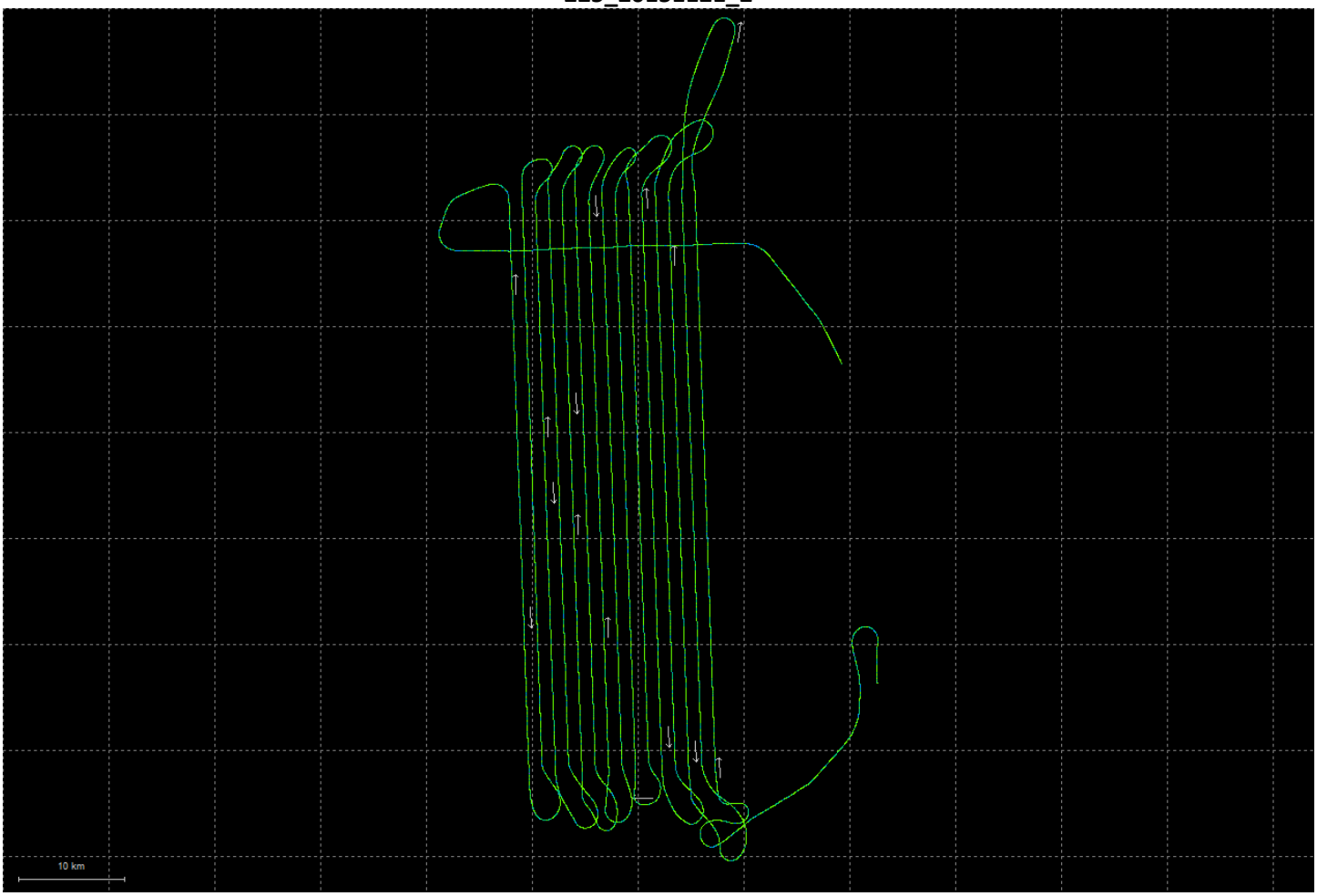

Estimated StdDev (m)
0.0140
0.0135
0.0130
0.0125
0.0120
0.0115
0.0110
0.0105
0.0100
0.0095
0.0090
0.0085
0.0080
0.0075
0.0070
0.0065
0.0060
0.0055
0.0050
590000
Week 1871
591000
592000
593000
594000
595000
596000
597000
598000
599000
GPS Time (TOW, GMT zone)
East
North
Height
Trace

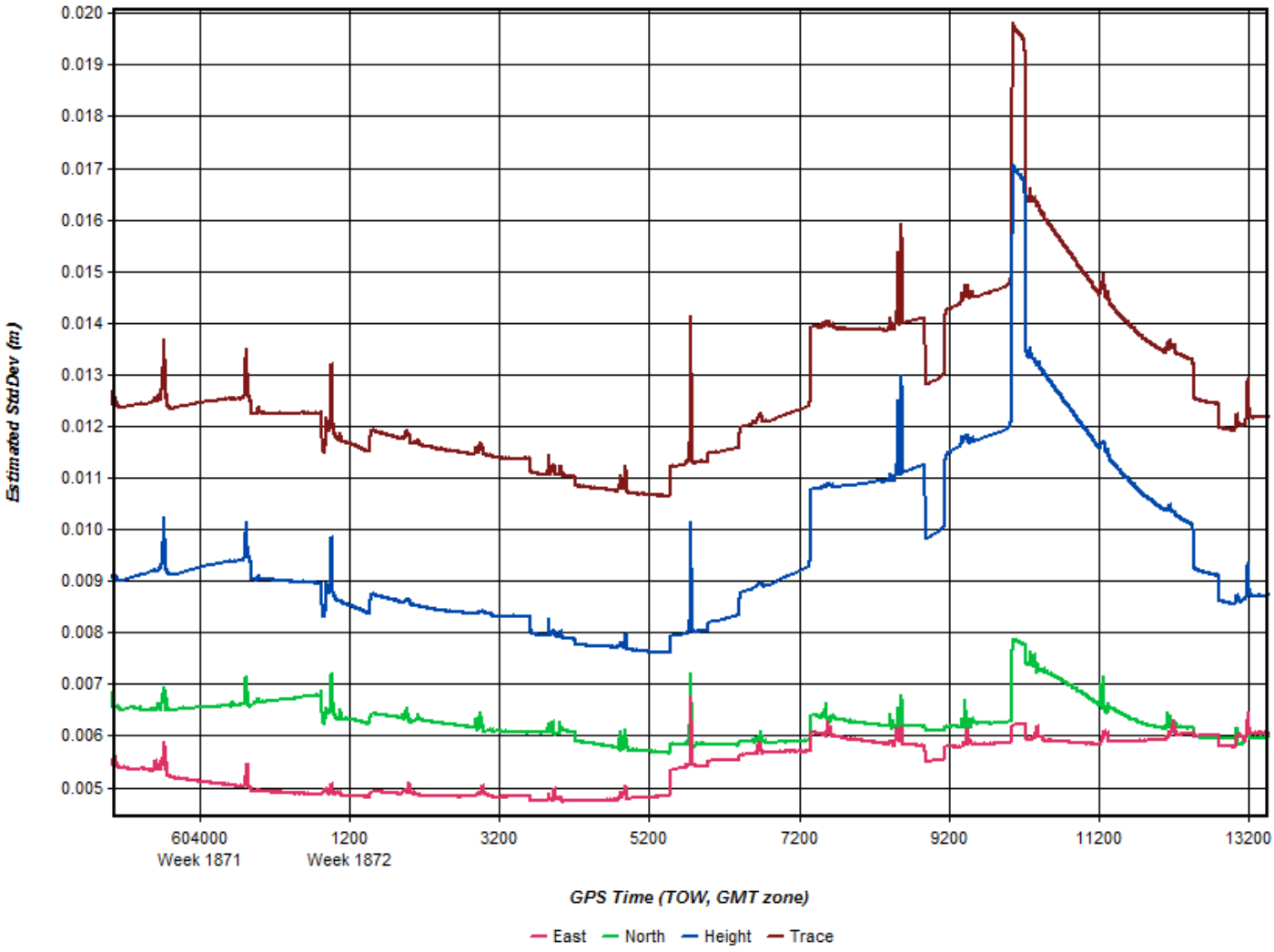

Num Sats
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
590000
Week 1871
591000
592000
593000
594000
595000
596000
597000
598000
599000
GPS Time (TOW, GMT zone)
Num Sats
GPS
GLONASS
BeiDou

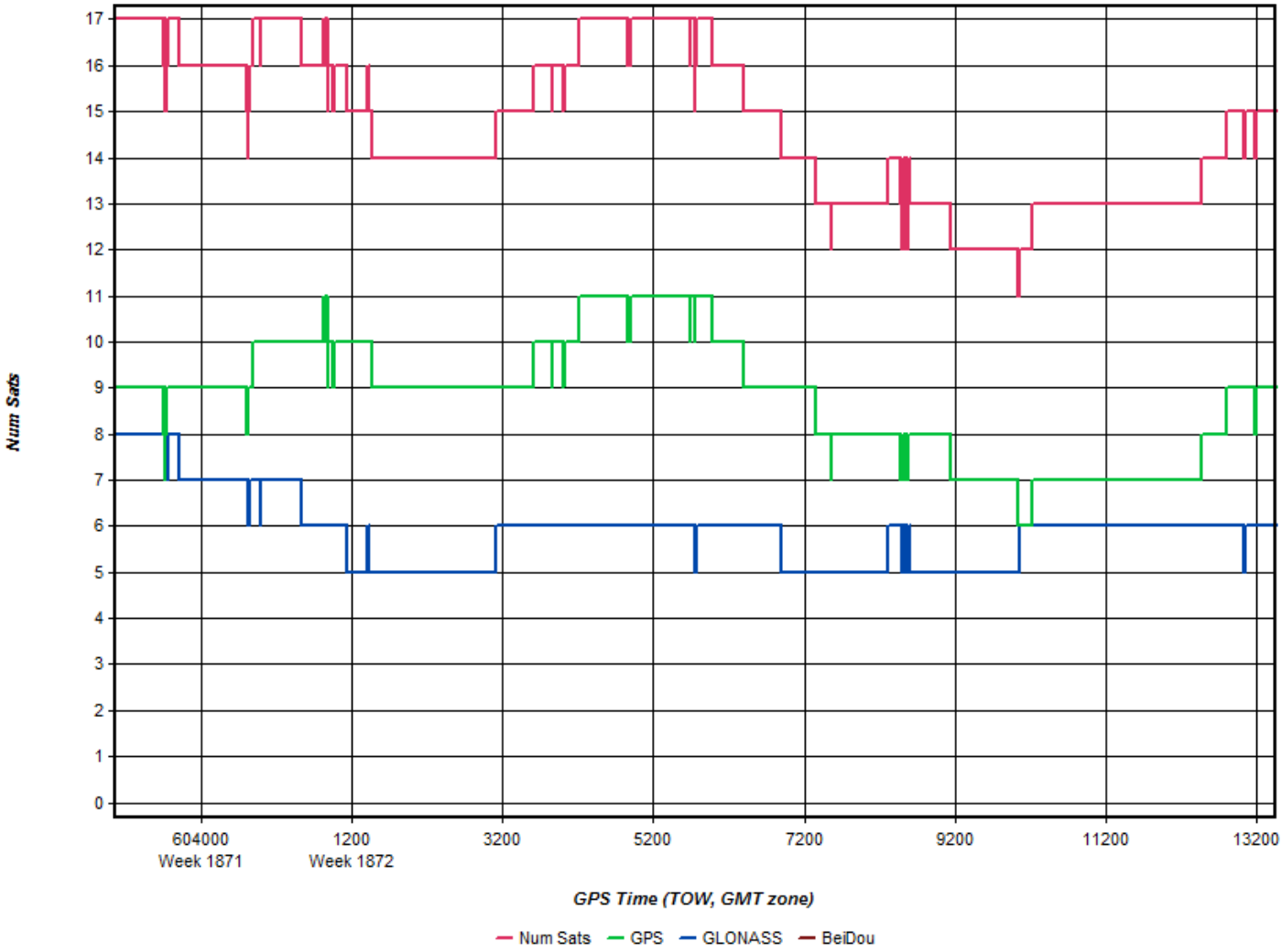

0.010
0.008
0.006
0.004
0.002
0.000
-0.002
-0.004
-0.006
-0.008
-0.010
-0.012
-0.014
-0.016
Separation (m)
590000
Week 1871
591000
592000
593000
594000
595000
596000
597000
598000
599000
GPS Time (TOW, GMT zone)
East
North
Up

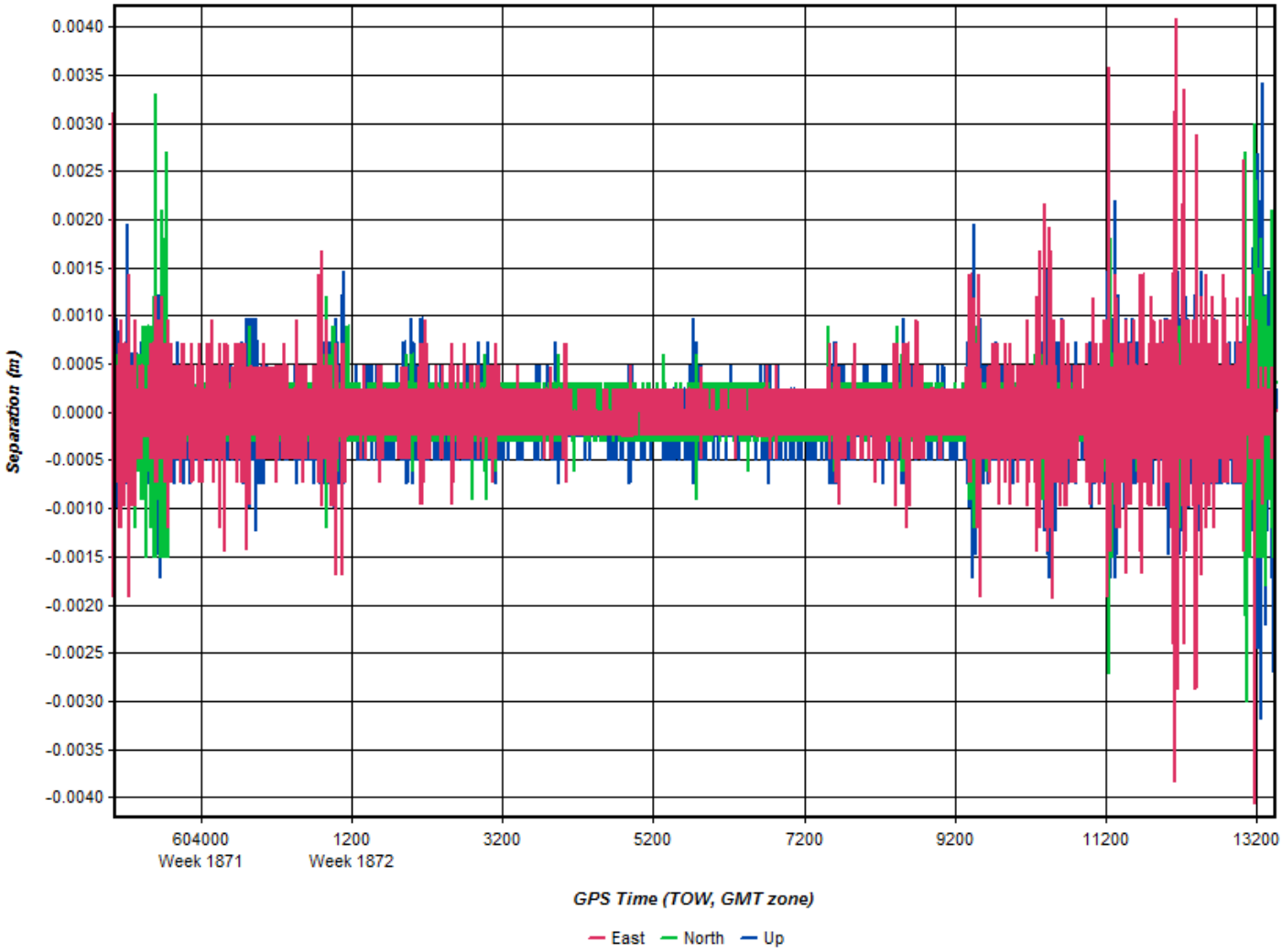

PDOP
2.00
1.95
1.90
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
590000
Week 1871
591000
592000
593000
594000
595000
596000
597000
598000
599000
GPS Time (TOW, GMT zone)
PDOP

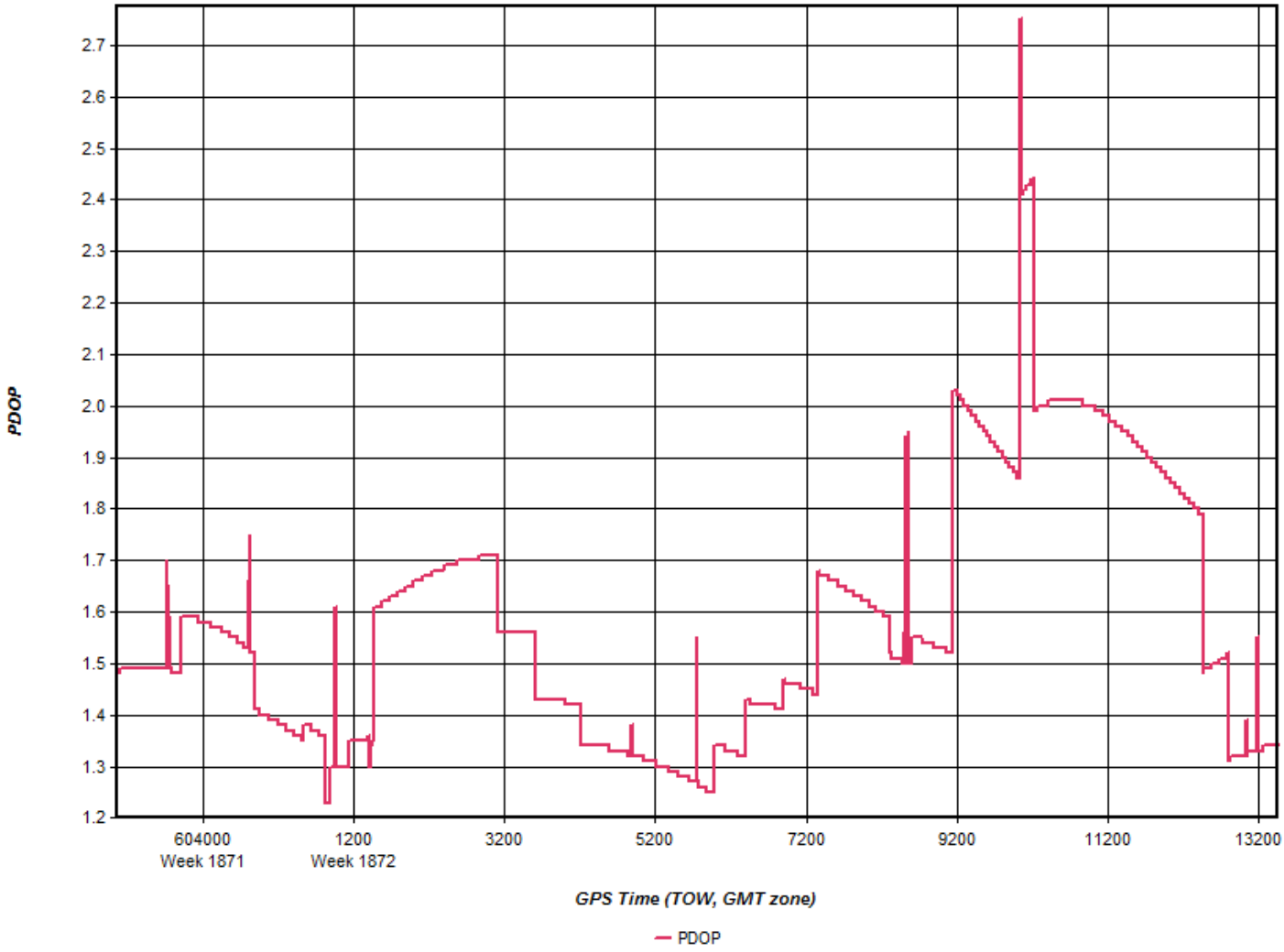
225_20151121_2



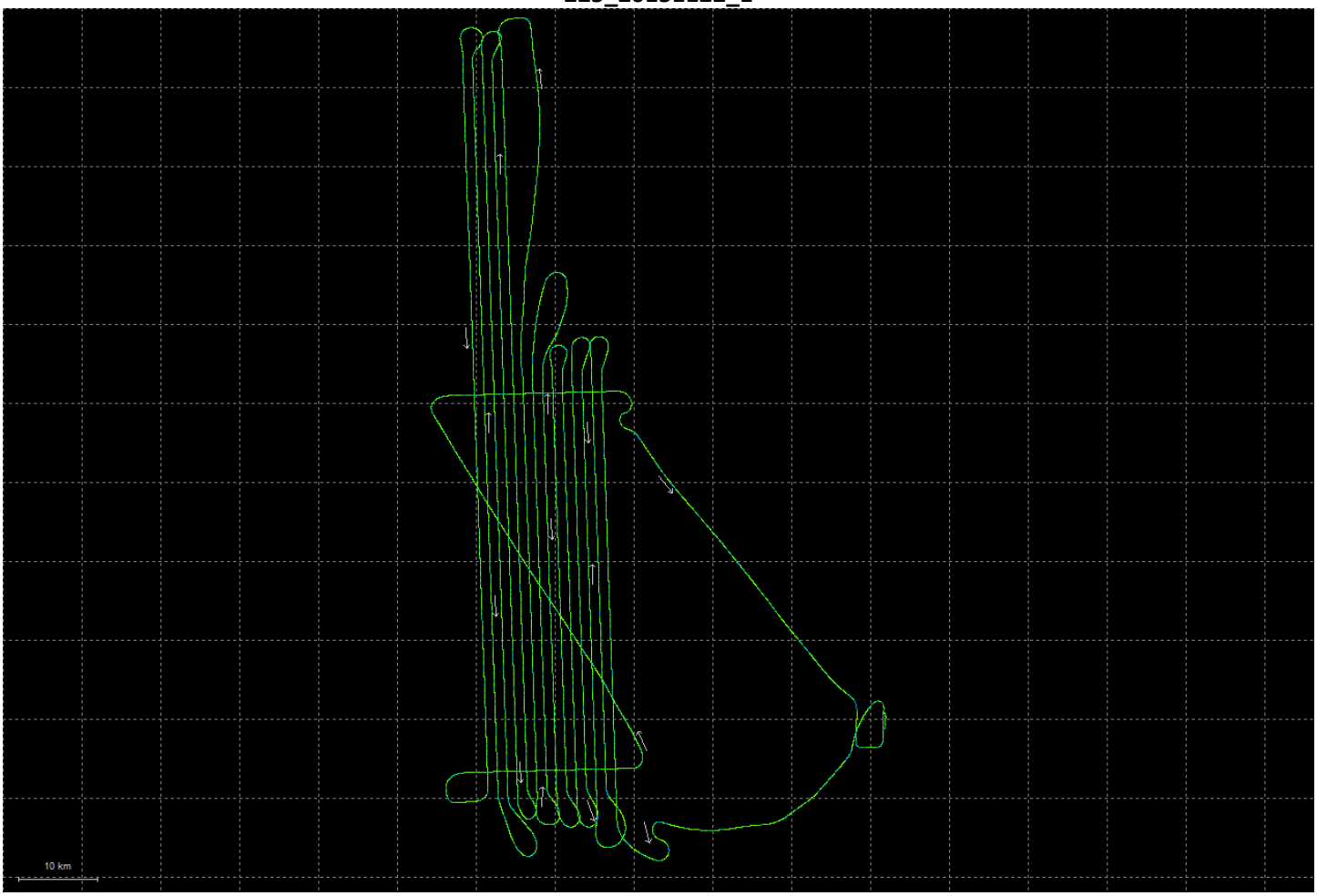

0.020
0.019
0.018
0.017
0.016
0.015
0.014
0.013
0.012
0.011
0.010
0.009
0.008
0.007
0.006
0.005
Estimated StdDev (m)
604000
Week 1871
1200
Week 1872
3200
5200
7200
9200
11200
13200
GPS Time (TOW, GMT zone)
East
North
Height
Trace

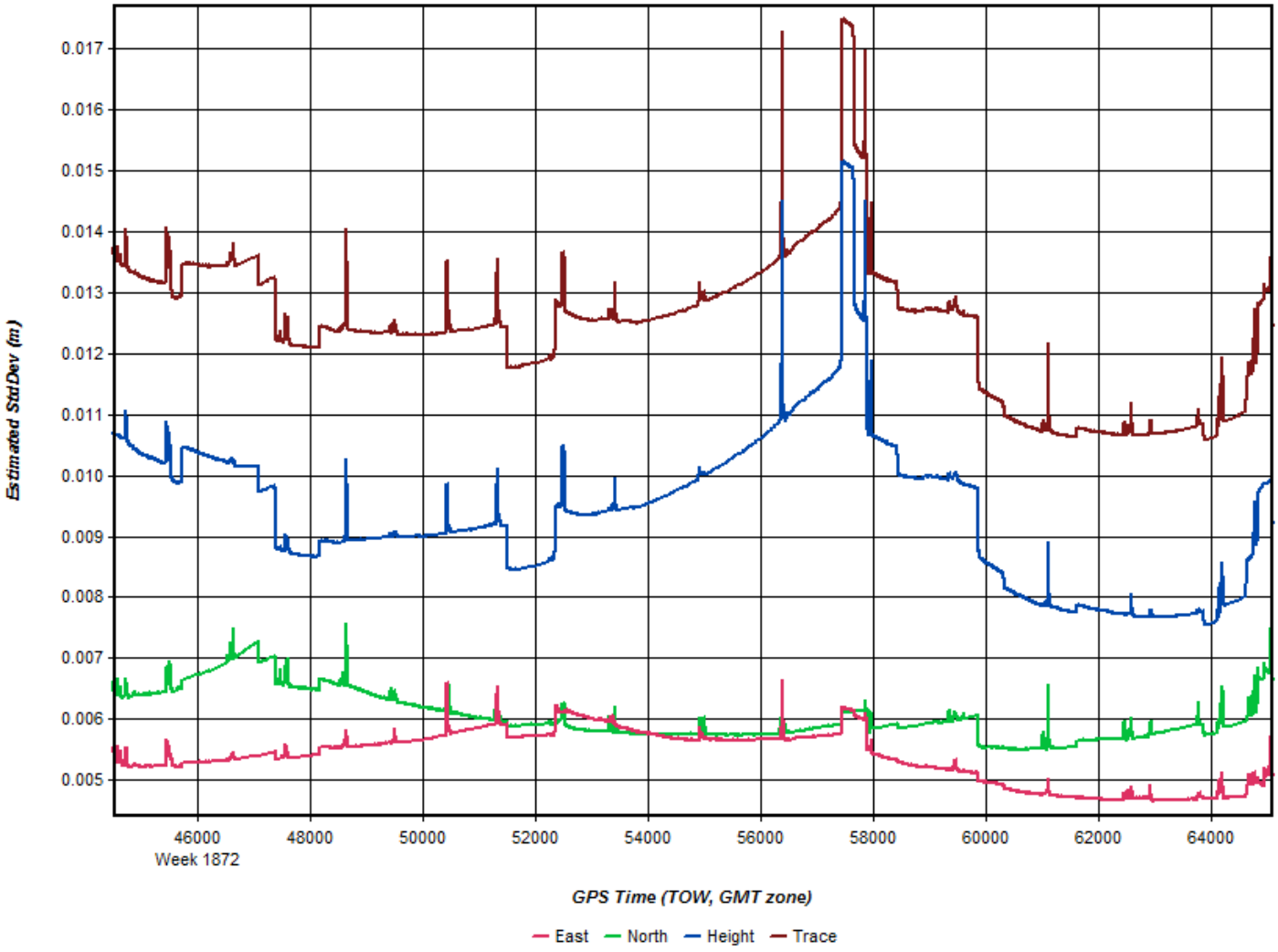

Num Sats
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
604000
Week 1871
1200
Week 1872
3200
5200
7200
9200
11200
13200
GPS Time (TOW, GMT zone)
Num Sats
GPS
GLONASS
BeiDou

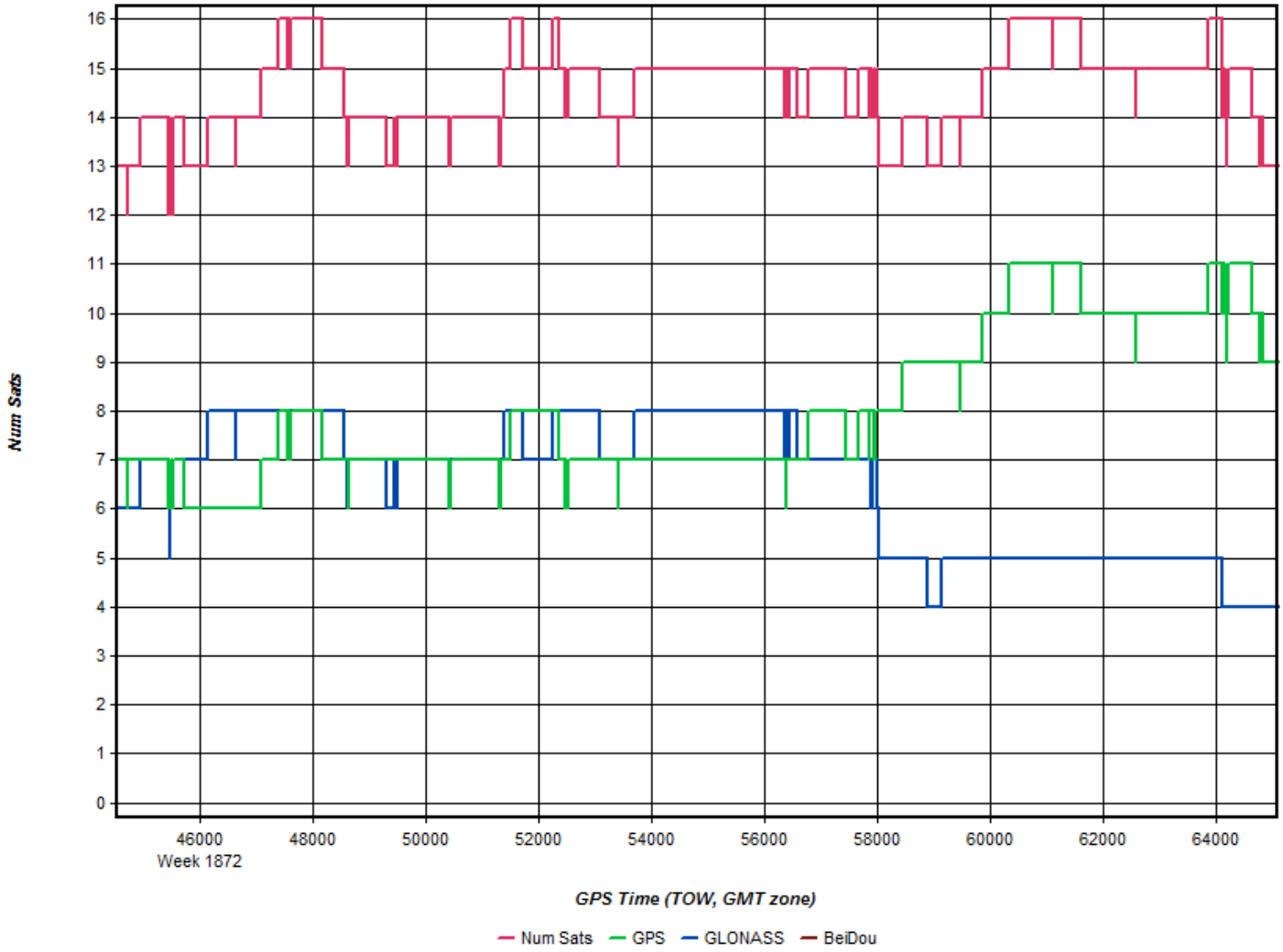

0.0040
0.0035
0.0030
0.0025
0.0020
0.0015
0.0010
0.0005
0.0000
-0.0005
-0.0010
-0.0015
-0.0020
-0.0025
-0.0030
-0.0035
-0.0040
Separation (m)
604000
Week 1871
1200
Week 1872
3200
5200
7200
9200
11200
13200
GPS Time (TOW, GMT zone)
East
North
Up

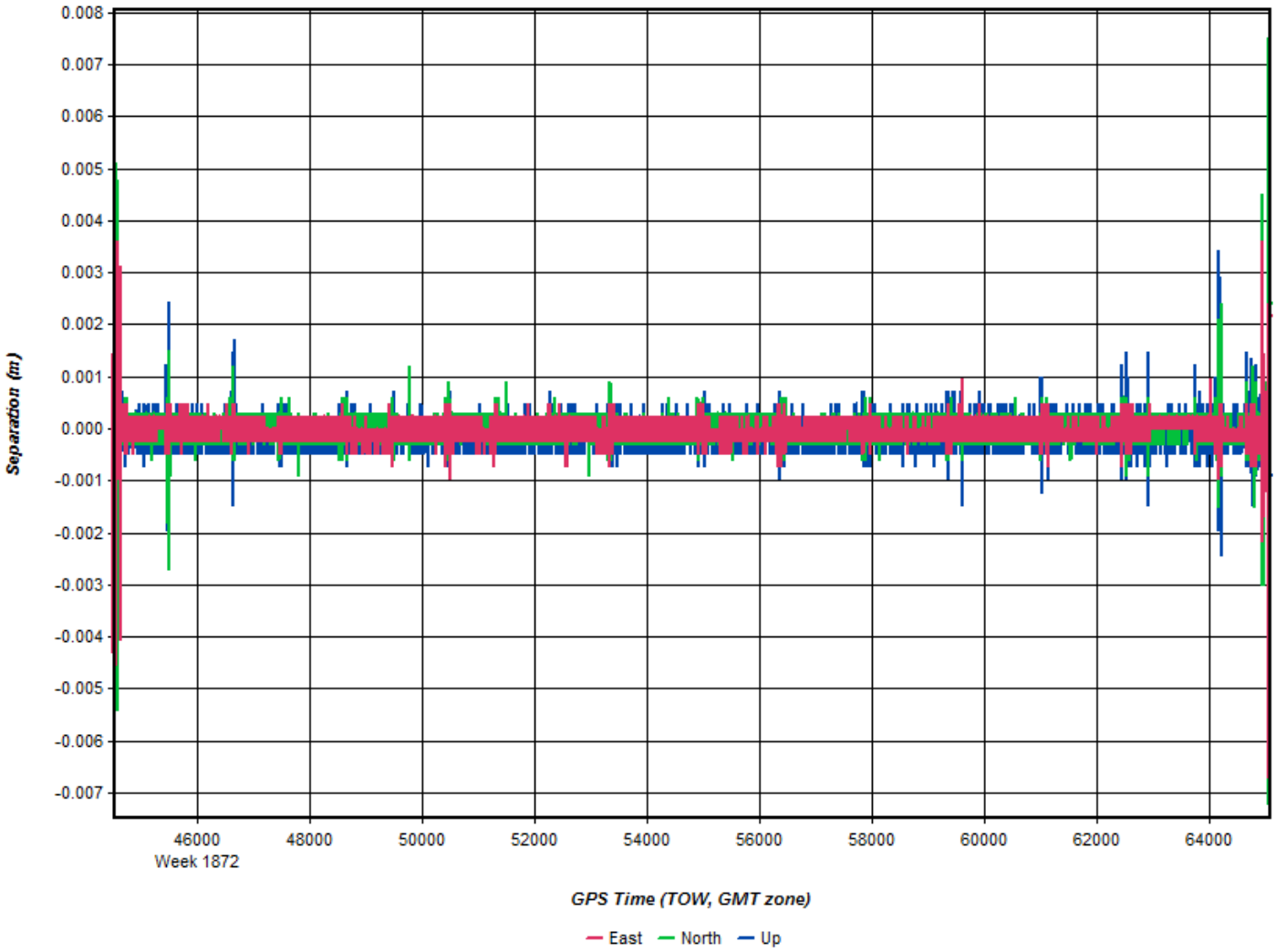

PDOP
2.7
2.6
2.5
2.4
2.3
2.2
2.1
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
604000
Week 1871
1200
Week 1872
3200
5200
7200
9200
11200
13200
GPS Time (TOW, GMT zone)
PDOP

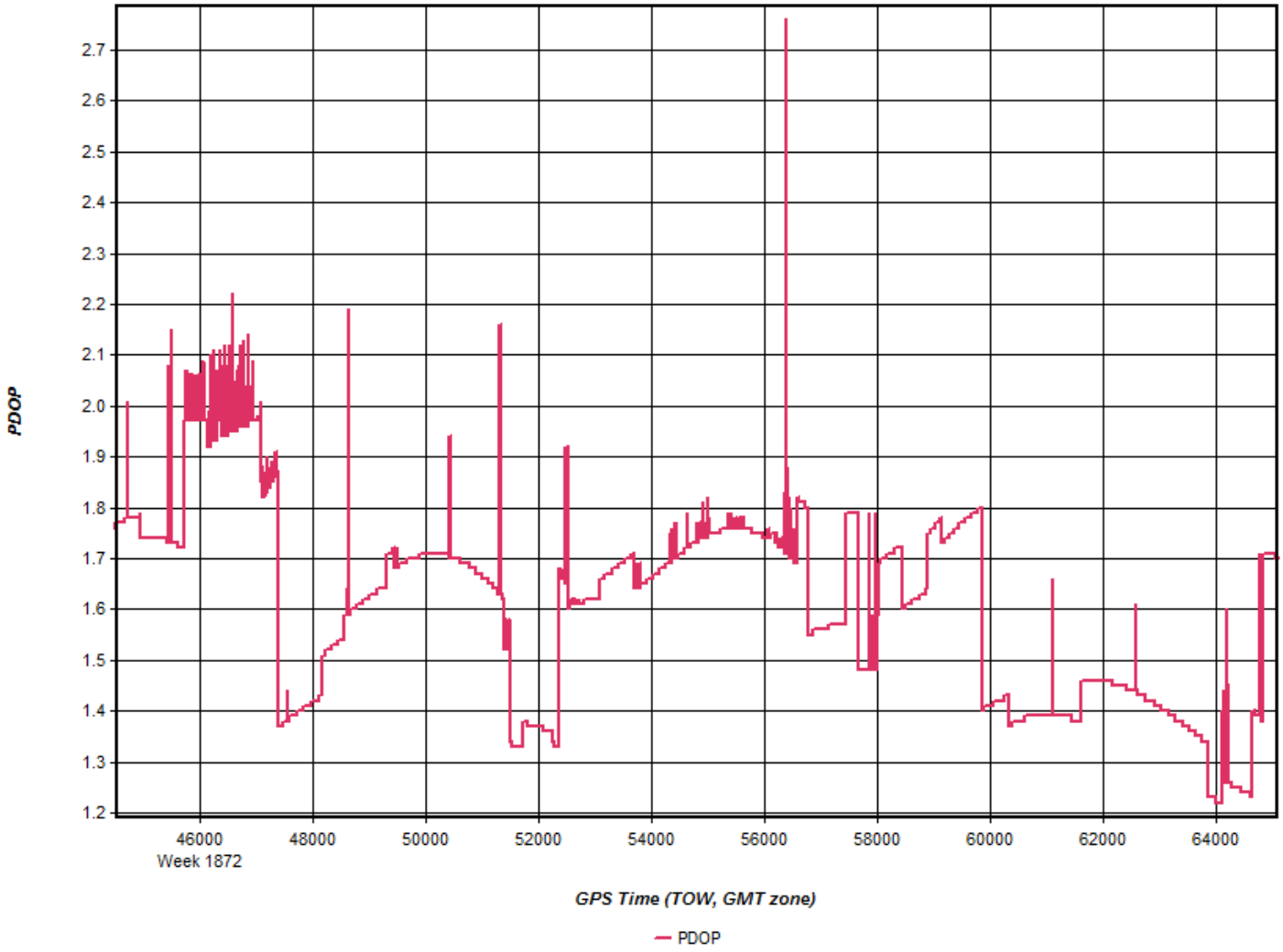
225_20151122_1



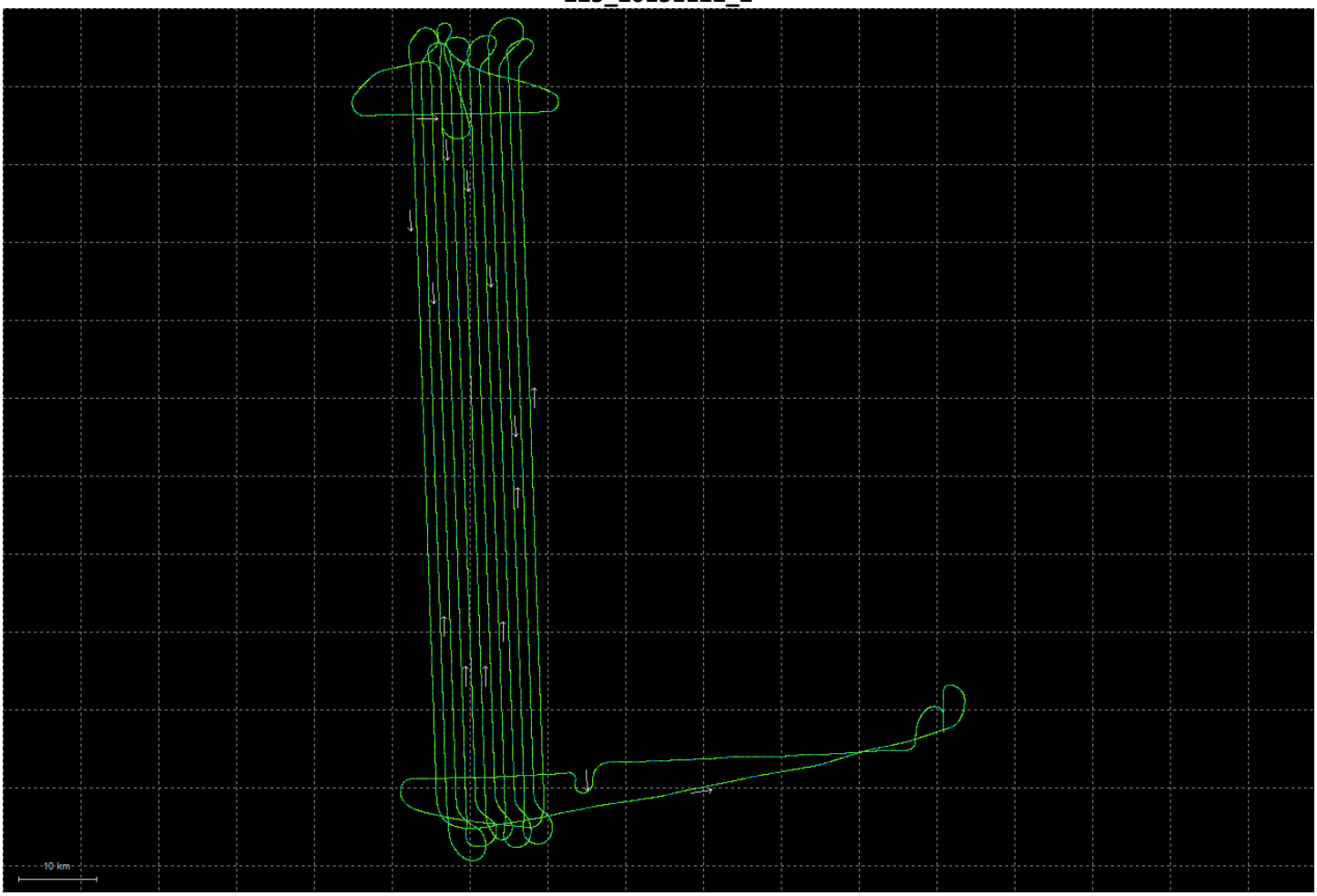

Estimated StdDev (m)
0.017
0.016
0.015
0.014
0.013
0.012
0.011
0.010
0.009
0.008
0.007
0.006
0.005
46000
Week 1872
48000
50000
52000
54000
56000
58000
60000
62000
64000
GPS Time (TOW, GMT zone)
East
North
Height
Trace

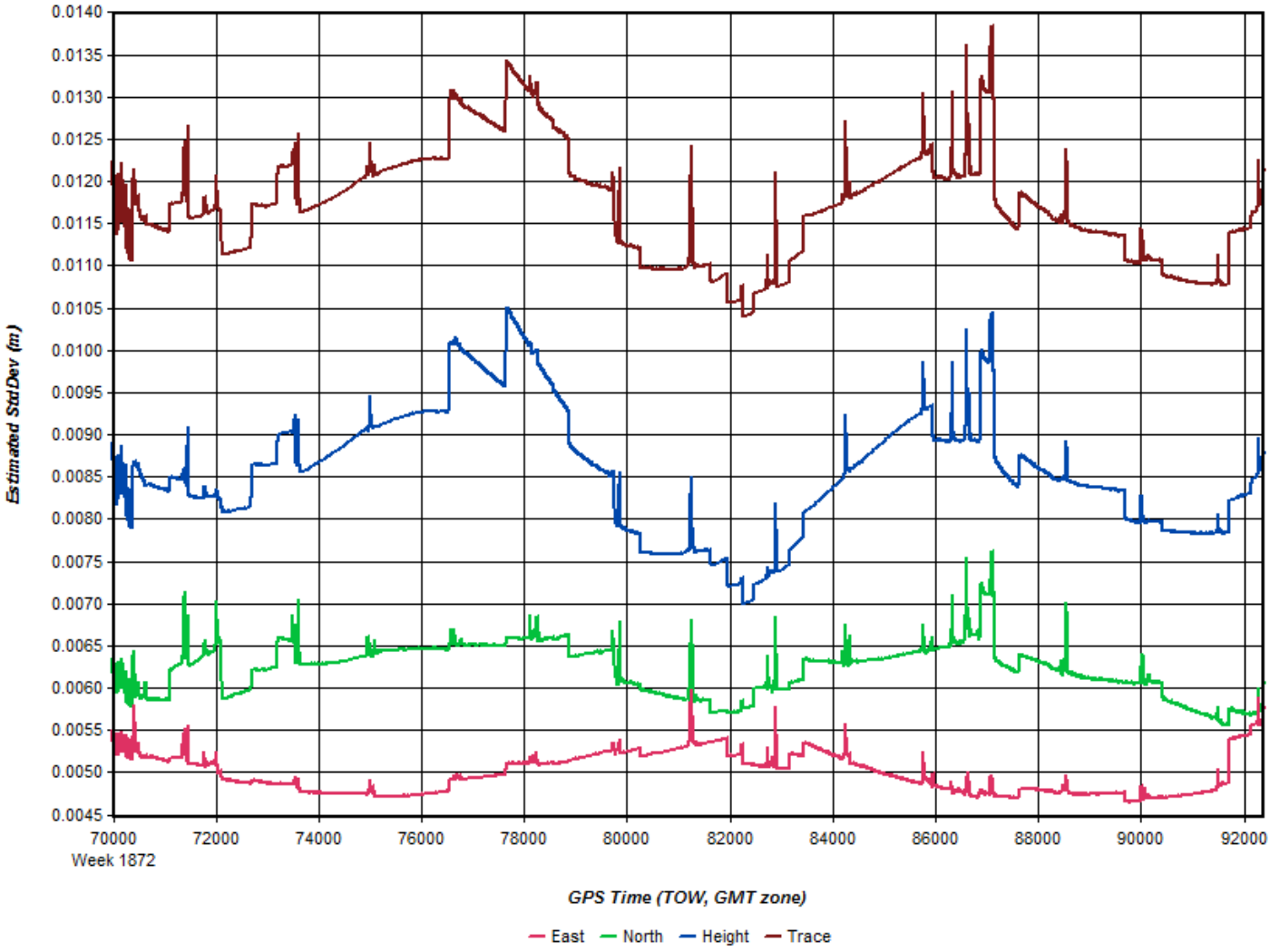

Num Sats
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
46000
Week 1872
48000
50000
52000
54000
56000
58000
60000
62000
64000
GPS Time (TOW, GMT zone)
Num Sats
GPS
GLONASS
BeiDou

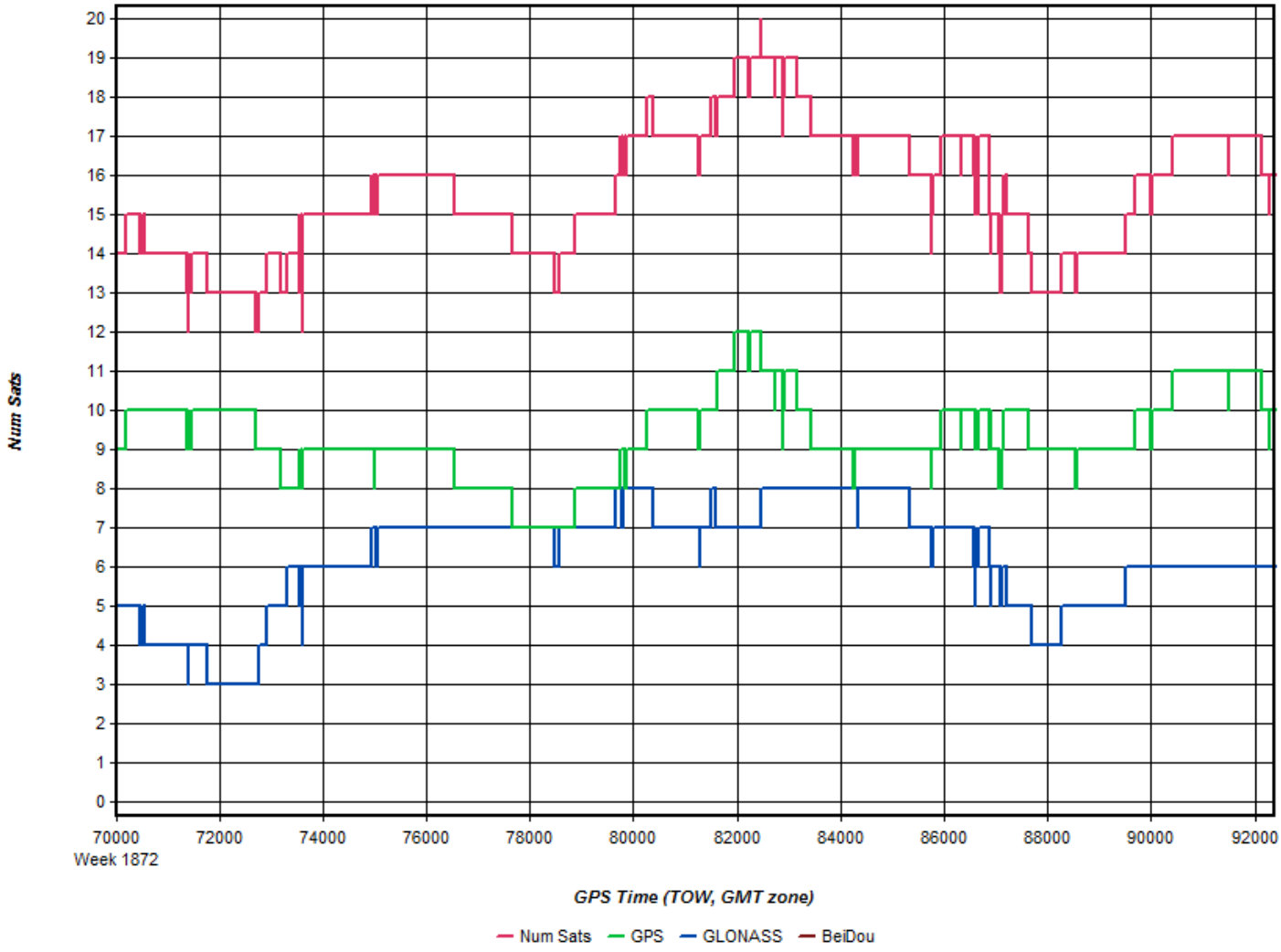

0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0.000
-0.001
-0.002
-0.003
-0.004
-0.005
-0.006
-0.007
Separation (m)
46000
Week 1872
48000
50000
52000
54000
56000
58000
60000
62000
64000
GPS Time (TOW, GMT zone)
East
North
Up

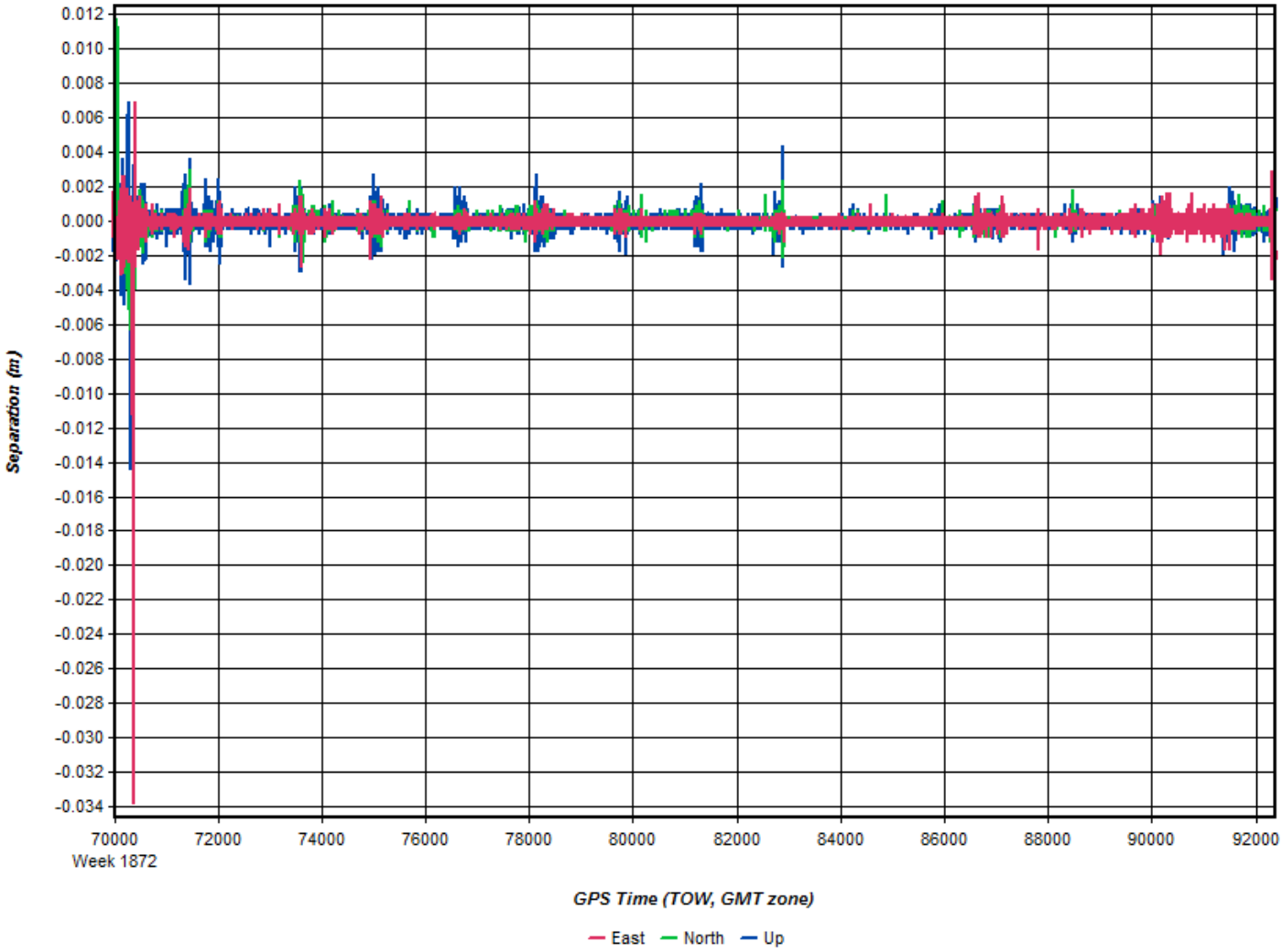

PDOP
2.7
2.6
2.5
2.4
2.3
2.2
2.1
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
46000
Week 1872
48000
50000
52000
54000
56000
58000
60000
62000
64000
GPS Time (TOW, GMT zone)
PDOP

225_20151122_2



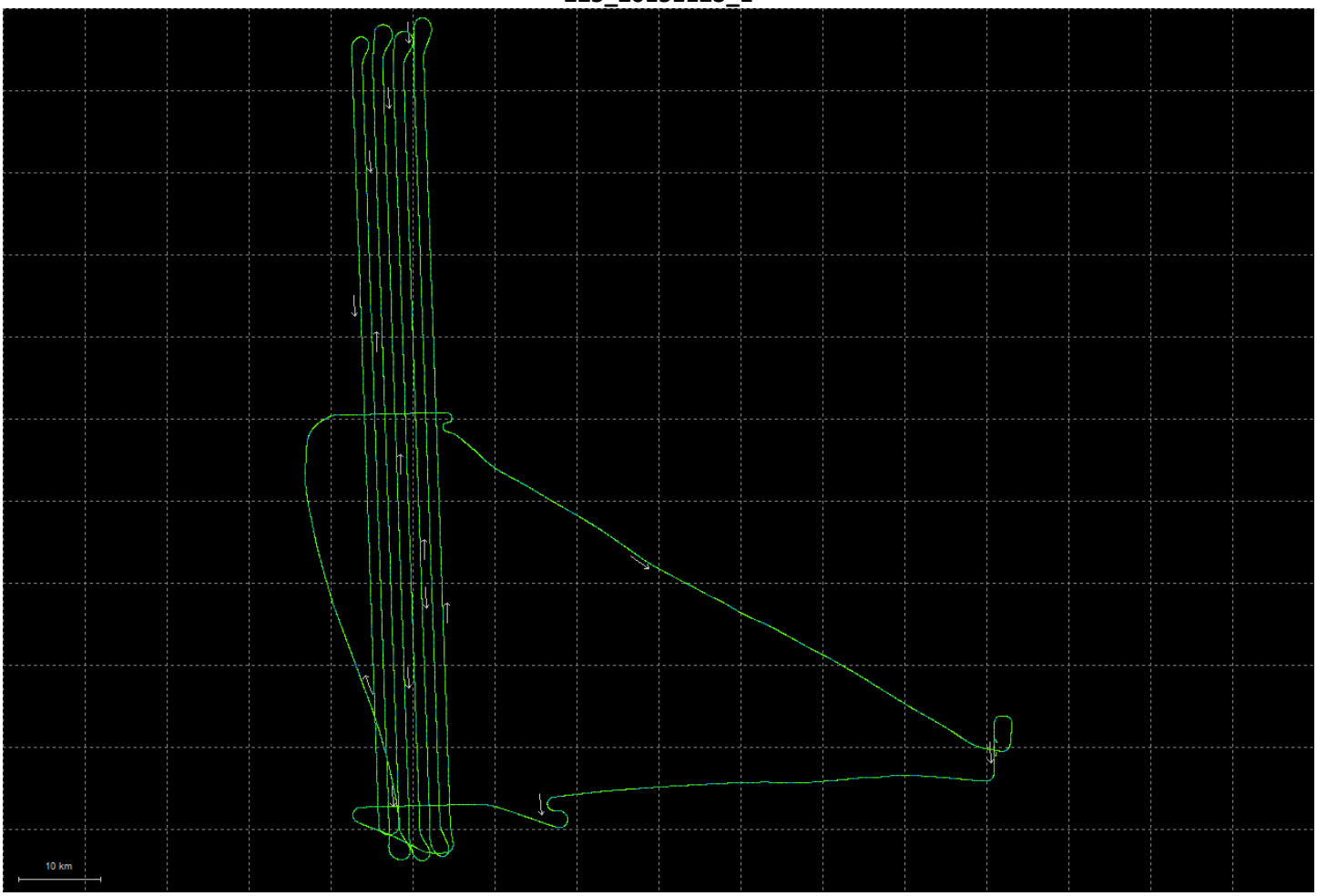

Estimated StdDev (m)
0.0140
0.0135
0.0130
0.0125
0.0120
0.0115
0.0110
0.0105
0.0100
0.0095
0.0090
0.0085
0.0080
0.0075
0.0070
0.0065
0.0060
0.0055
0.0050
0.0045
70000
72000
74000
76000
78000
80000
82000
84000
86000
88000
90000
92000
Week 1872
GPS Time (TOW, GMT zone)
East
North
Height
Trace

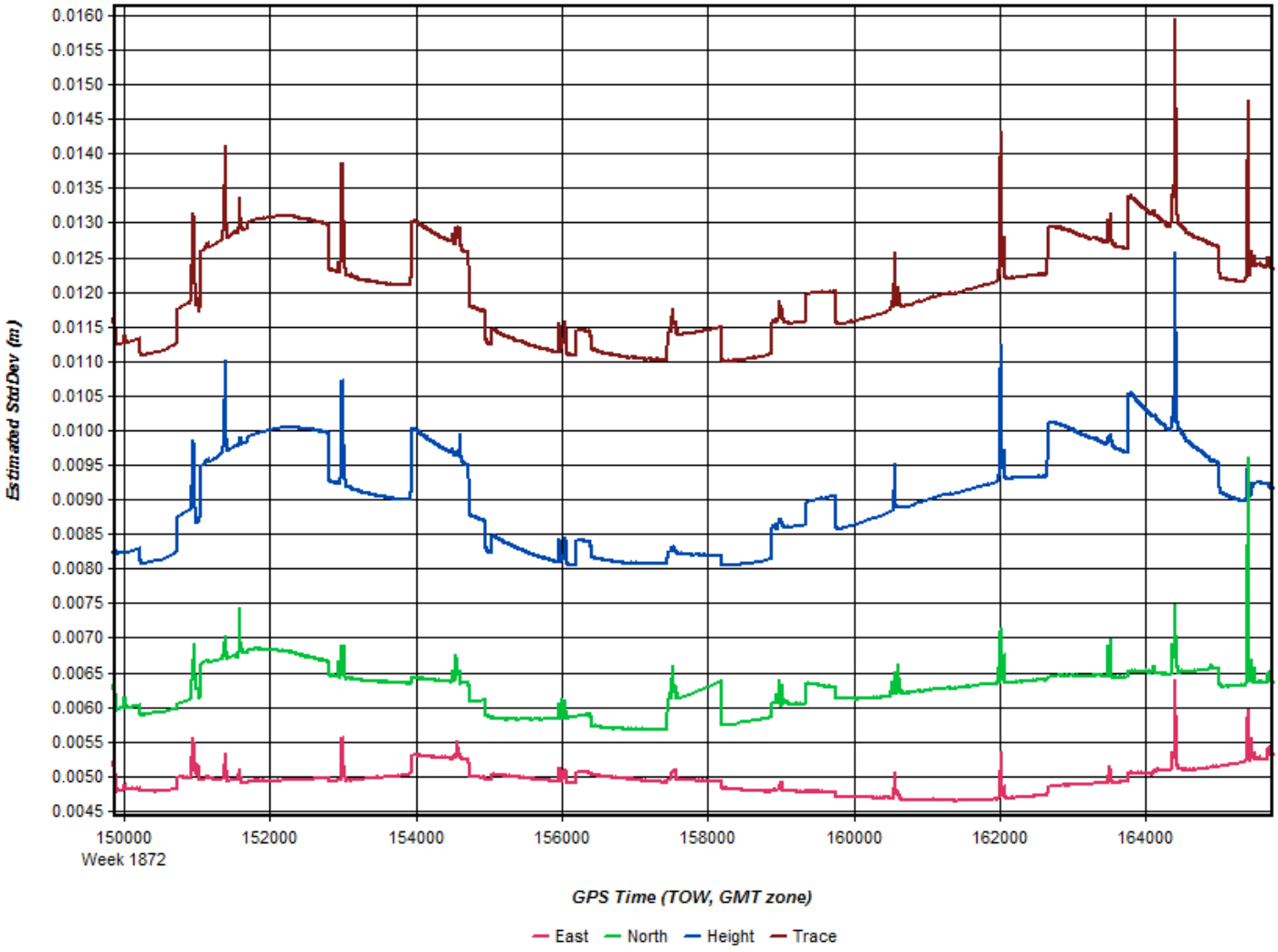

Num Sats
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
70000
Week 1872
72000
74000
76000
78000
80000
82000
84000
86000
88000
90000
92000
GPS Time (TOW, GMT zone)
Num Sats
GPS
GLONASS
BeiDou

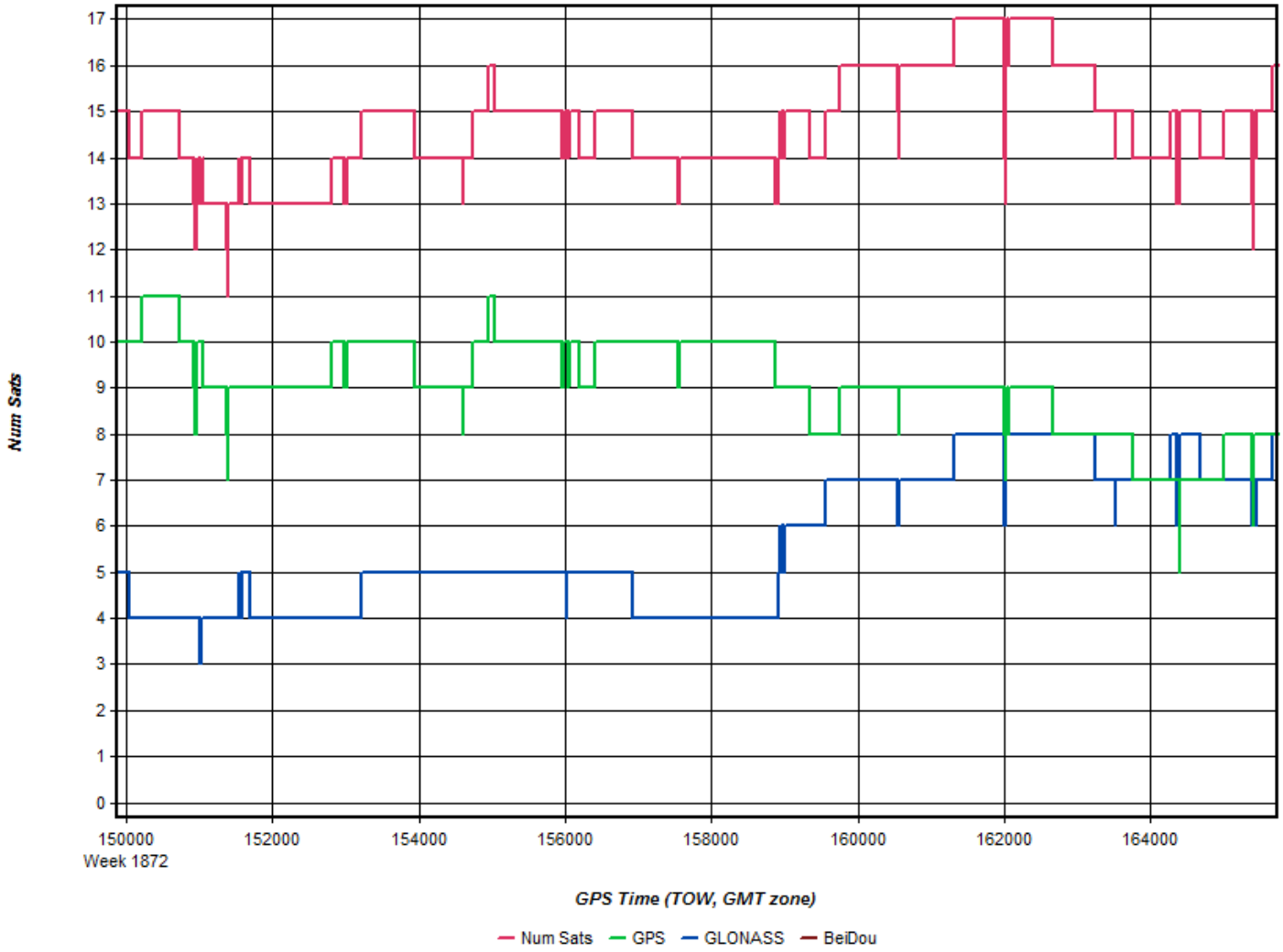

0.012
0.010
0.008
0.006
0.004
0.002
0.000
-0.002
-0.004
-0.006
-0.008
-0.010
-0.012
-0.014
-0.016
-0.018
-0.020
-0.022
-0.024
-0.026
-0.028
-0.030
-0.032
-0.034
Separation (m)
70000
Week 1872
72000
74000
76000
78000
80000
82000
84000
86000
88000
90000
92000
GPS Time (TOW, GMT zone)
East
North
Up

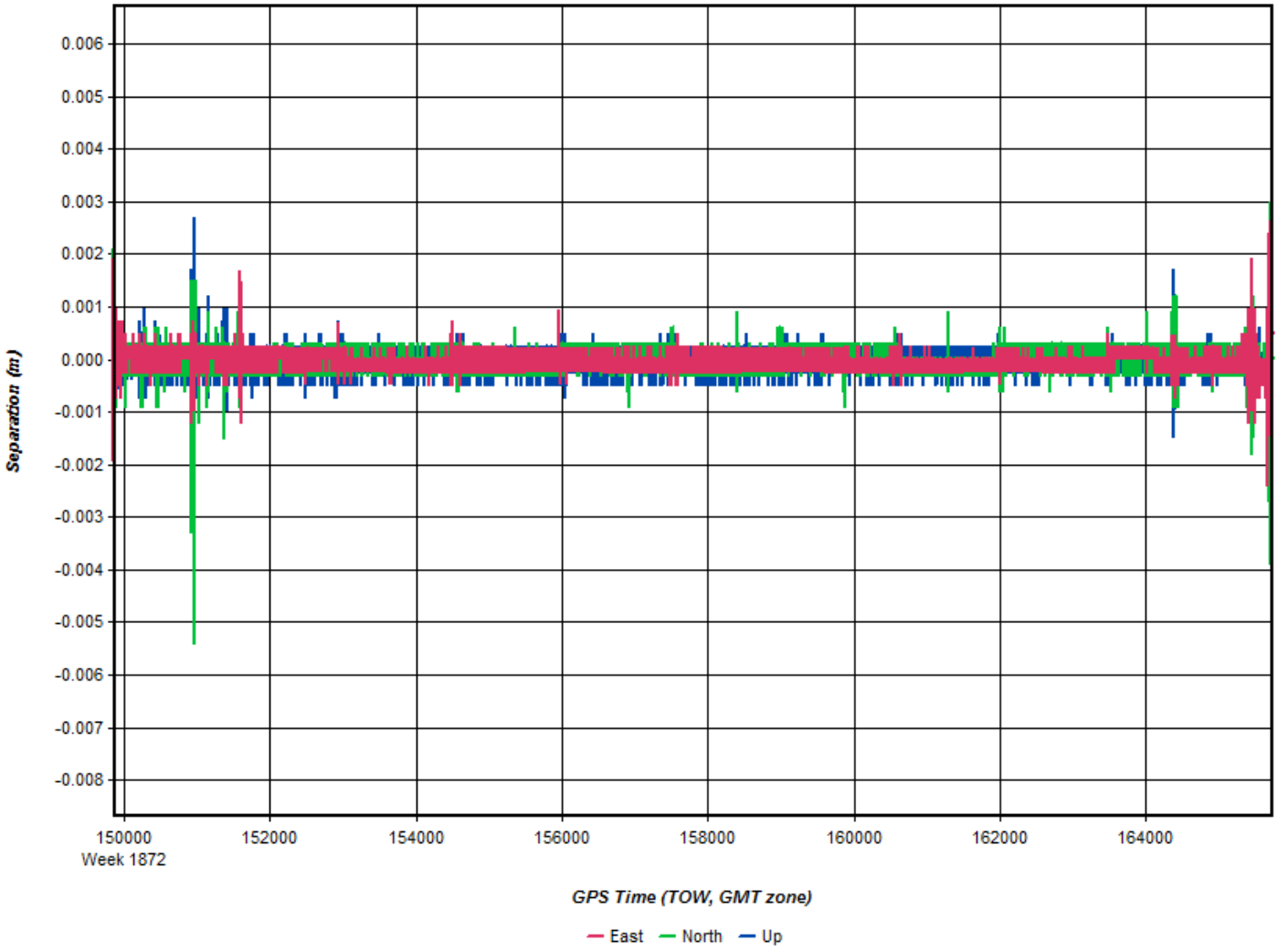

PDOP
1.95
1.90
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1.25
1.20
1.15
70000
72000
74000
76000
78000
80000
82000
84000
86000
88000
90000
92000
Week 1872
GPS Time (TOW, GMT zone)
PDOP

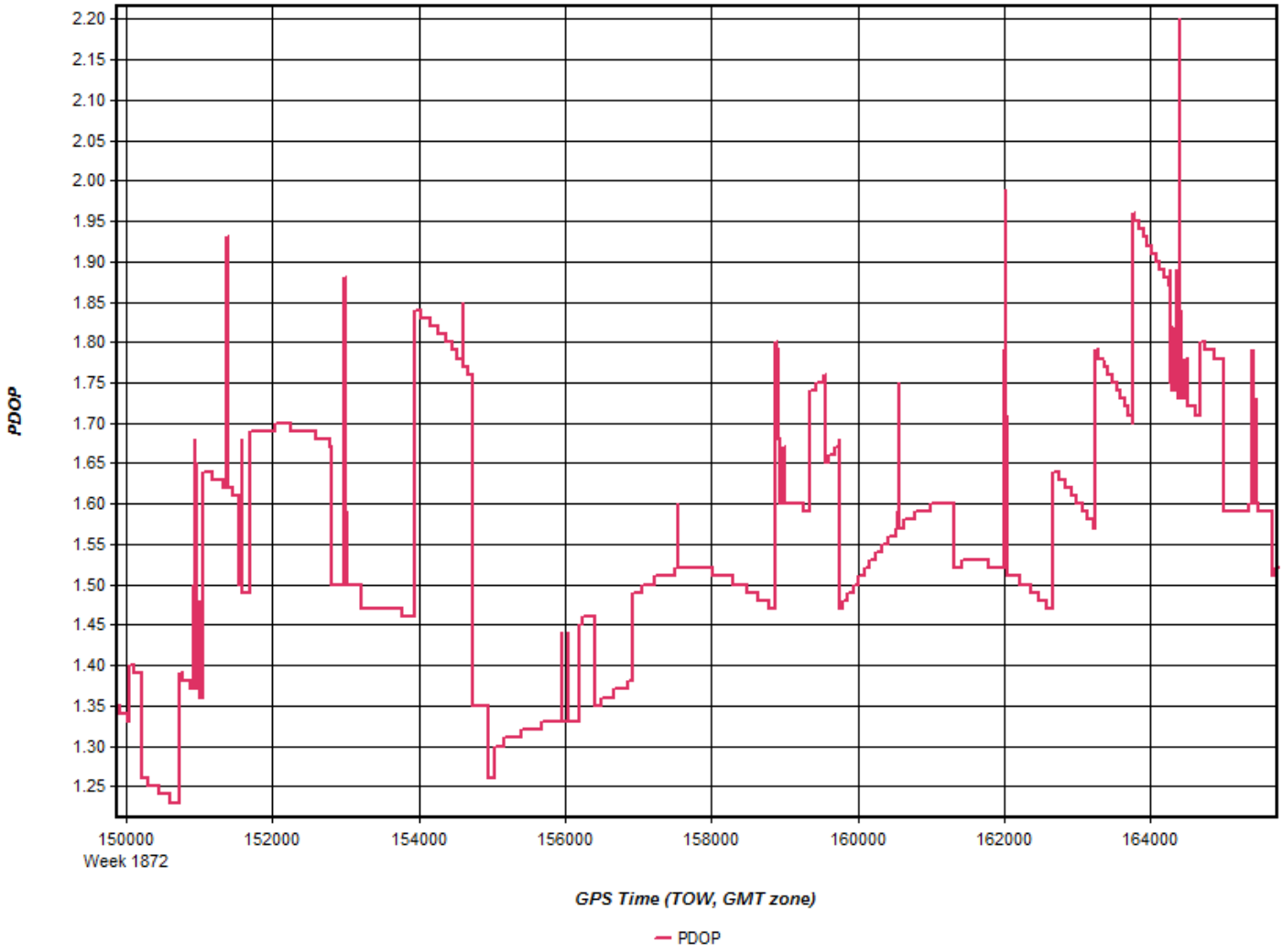
225_20151123_1



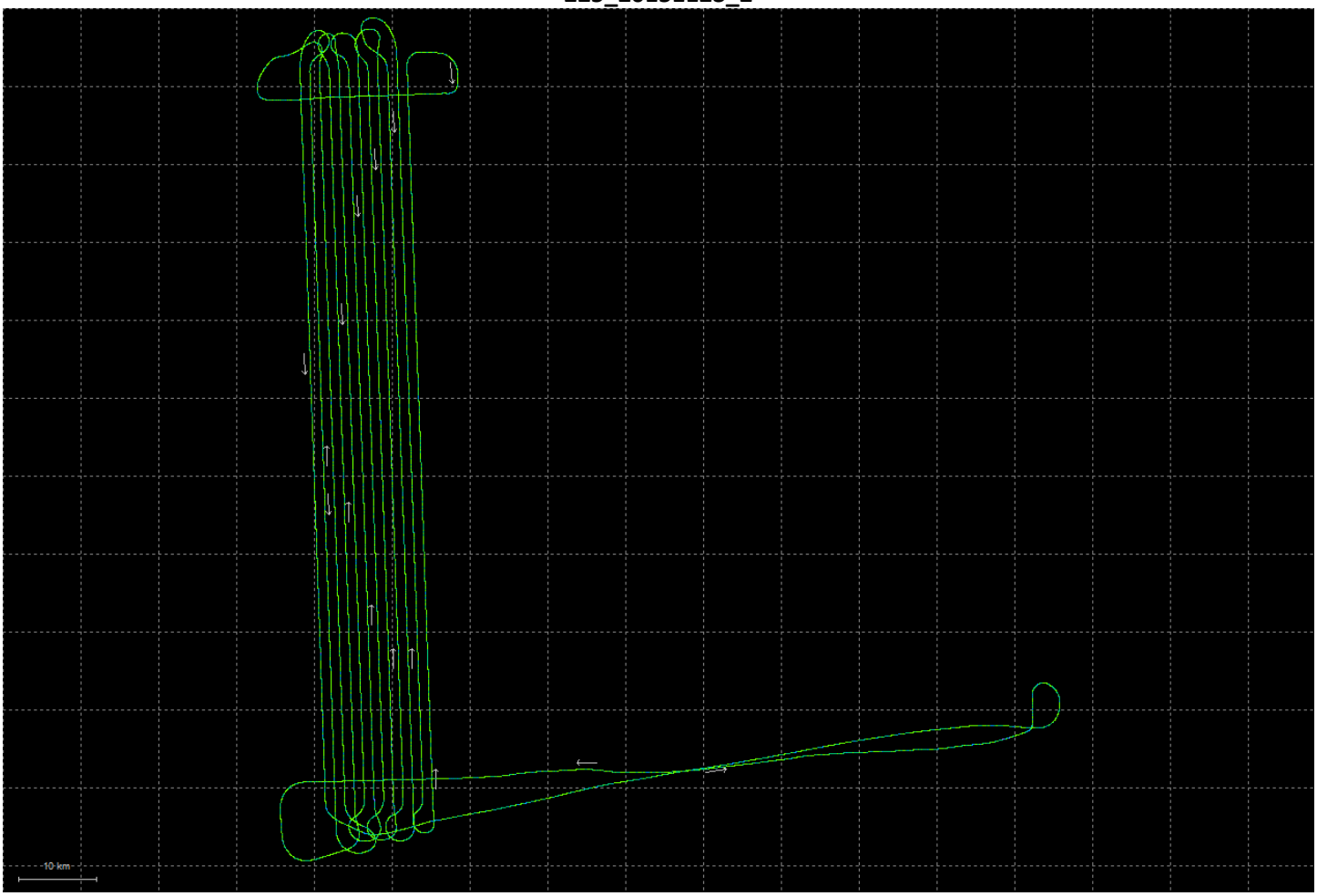

Estimated StdDev (m)
0.0160
0.0155
0.0150
0.0145
0.0140
0.0135
0.0130
0.0125
0.0120
0.0115
0.0110
0.0105
0.0100
0.0095
0.0090
0.0085
0.0080
0.0075
0.0070
0.0065
0.0060
0.0055
0.0050
0.0045
150000
Week 1872
152000
154000
156000
158000
160000
162000
164000
GPS Time (TOW, GMT zone)
East
North
Height
Trace

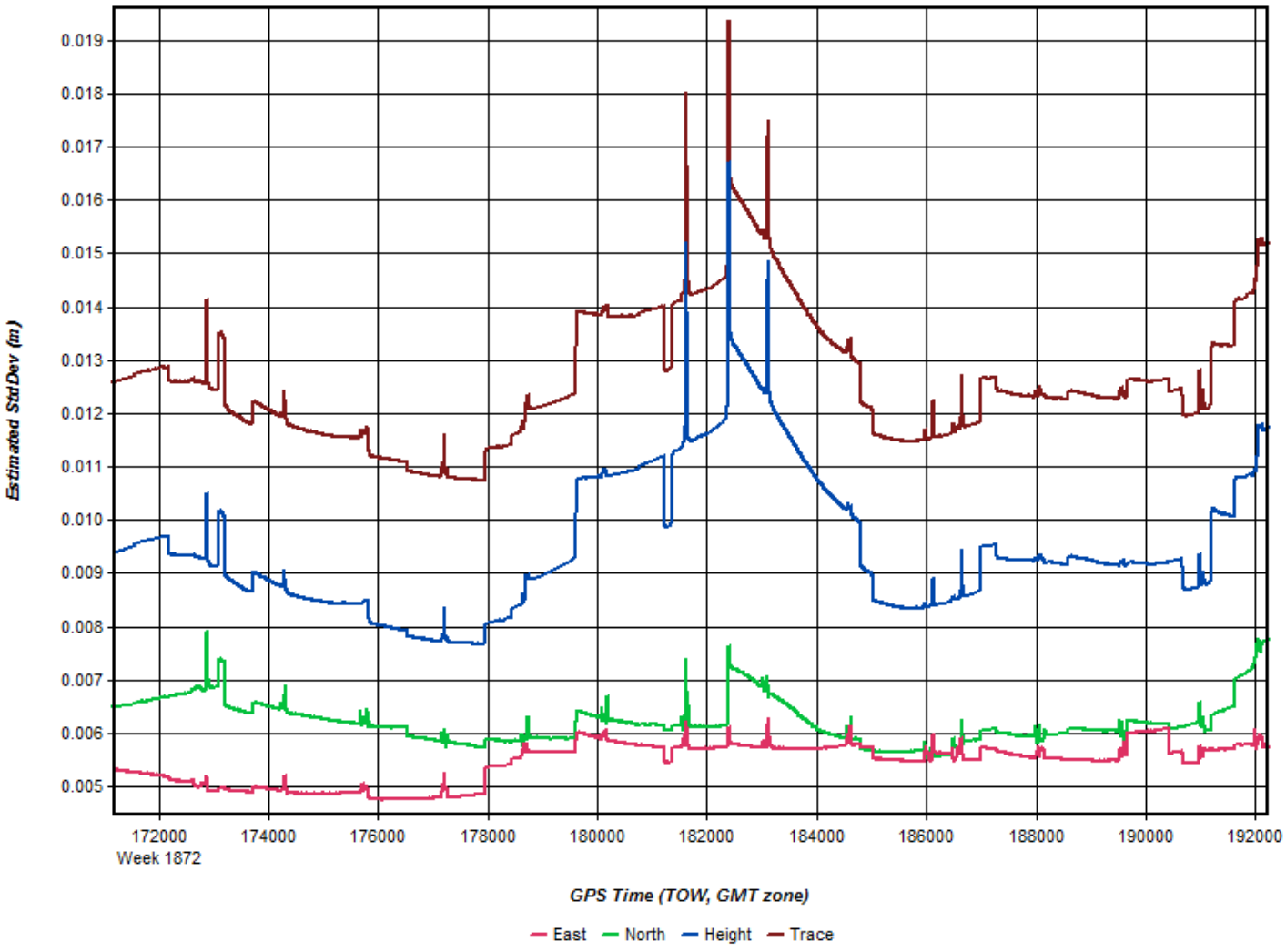

Num Sats
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
150000
Week 1872
152000
154000
156000
158000
160000
162000
164000
GPS Time (TOW, GMT zone)
Num Sats
GPS
GLONASS
BeiDou


0.006
0.005
0.004
0.003
0.002
0.001
0.000
-0.001
-0.002
-0.003
-0.004
-0.005
-0.006
-0.007
-0.008
Separation (m)
150000
Week 1872
152000
154000
156000
158000
160000
162000
164000
GPS Time (TOW, GMT zone)
East
North
Up

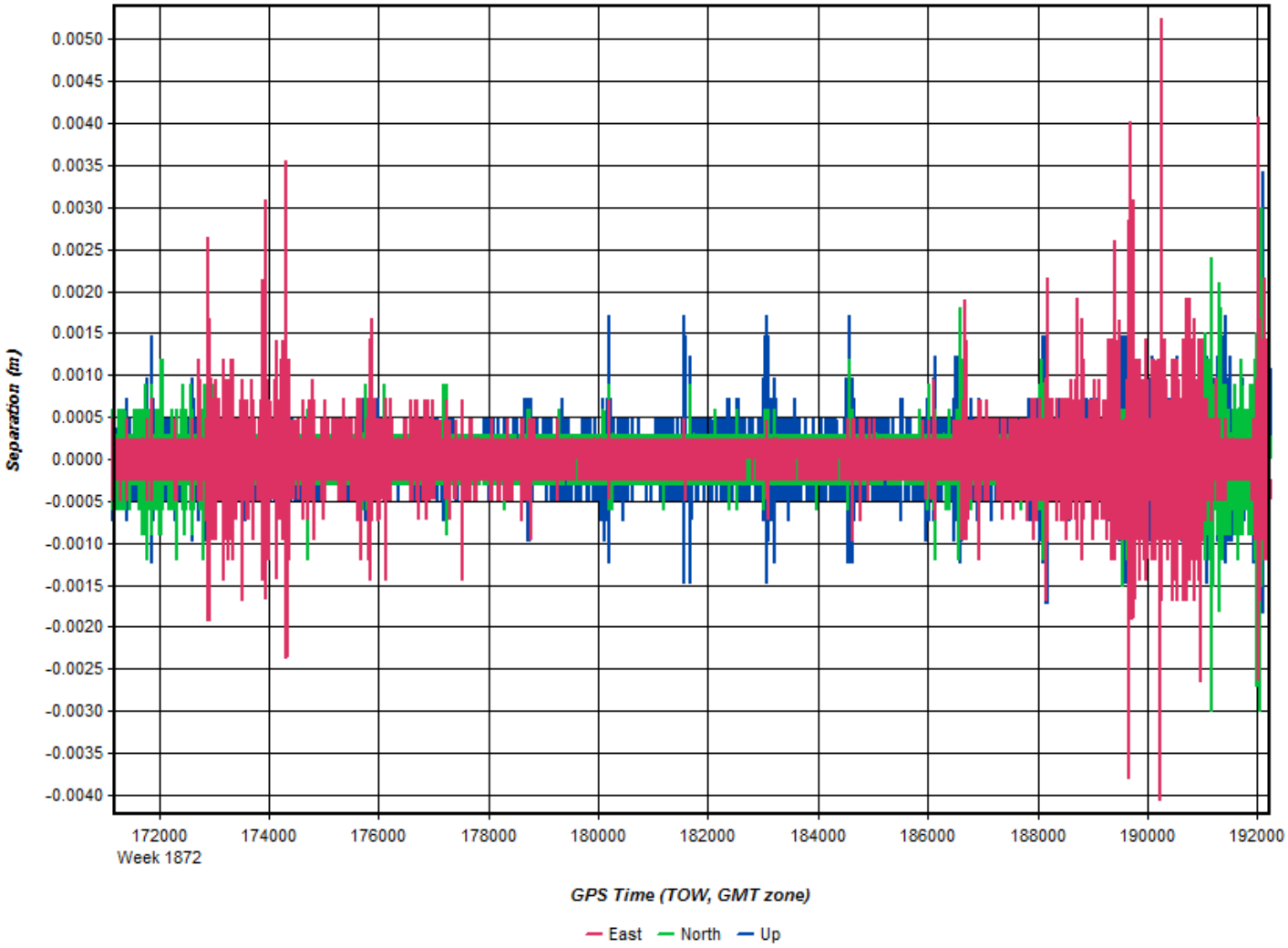

PDOP
2.20
2.15
2.10
2.05
2.00
1.95
1.90
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1.25
150000
Week 1872
152000
154000
156000
158000
160000
162000
164000
GPS Time (TOW, GMT zone)
PDOP

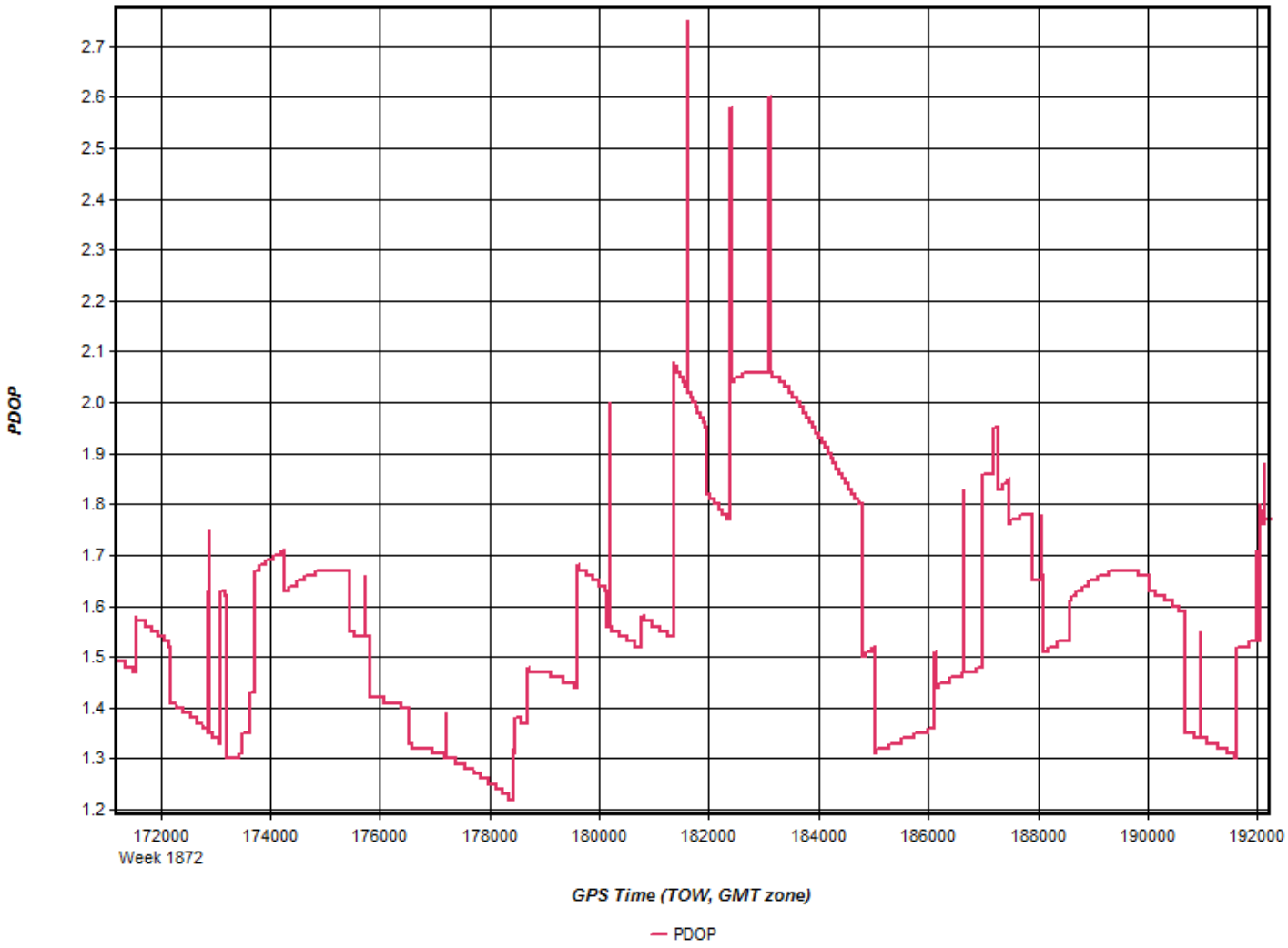
225_20151123_2



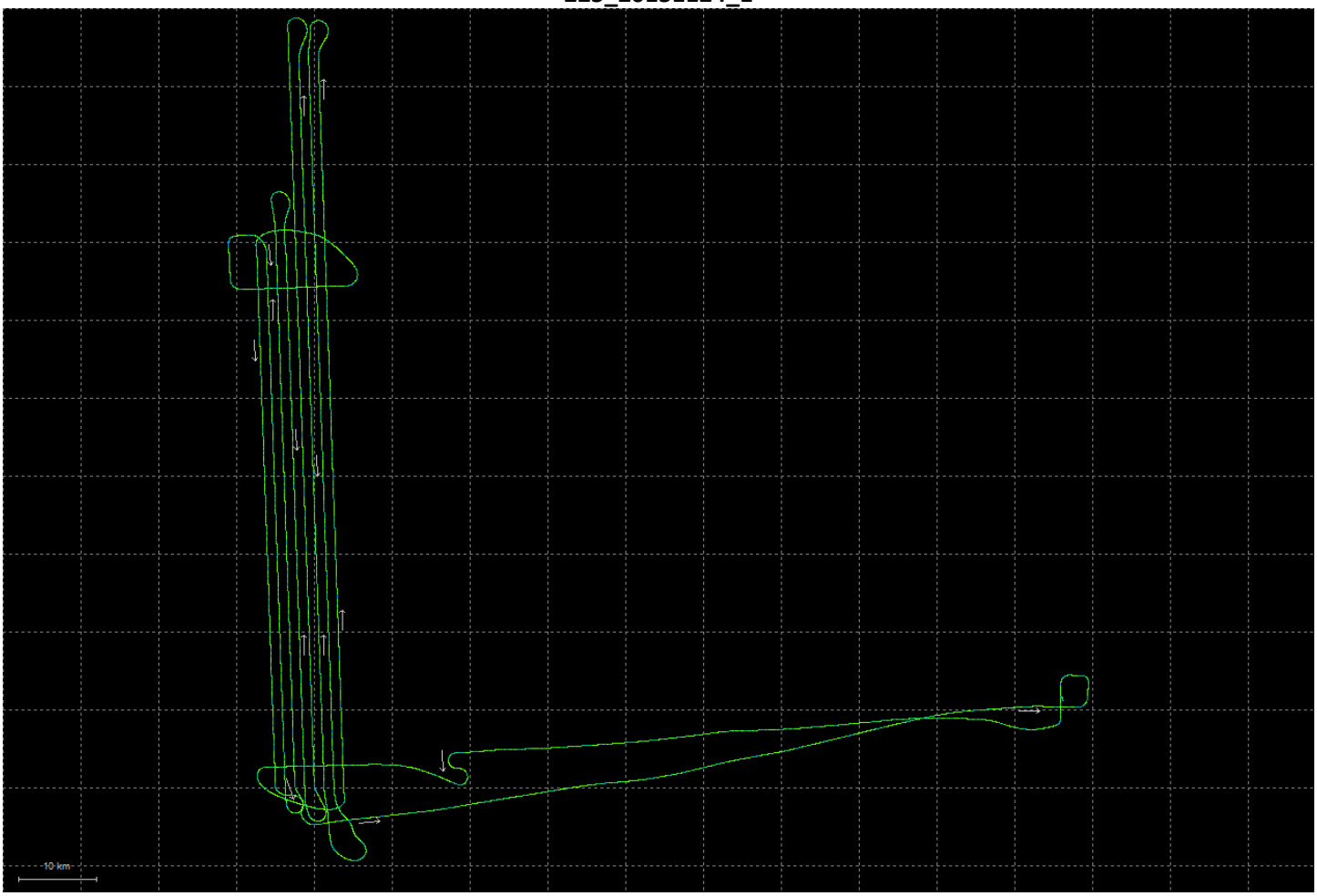

Estimated StdDev (m)
0.019
0.018
0.017
0.016
0.015
0.014
0.013
0.012
0.011
0.010
0.009
0.008
0.007
0.006
0.005
172000
Week 1872
174000
176000
178000
180000
182000
184000
186000
188000
190000
192000
GPS Time (TOW, GMT zone)
East
North
Height
Trace

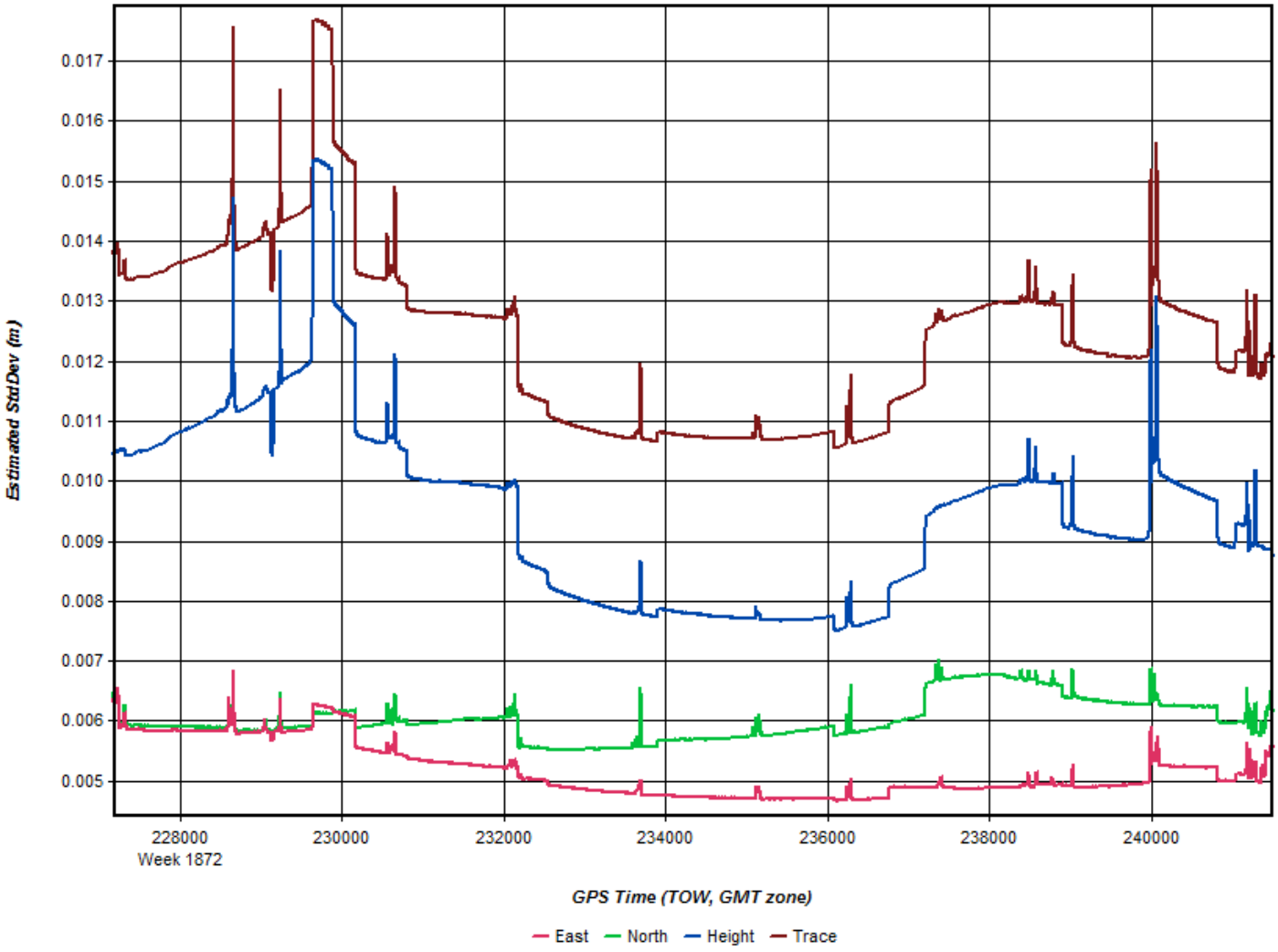

Num Sats
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
172000
Week 1872
174000
176000
178000
180000
182000
184000
186000
188000
190000
192000
GPS Time (TOW, GMT zone)
Num Sats
GPS
GLONASS
BeiDou

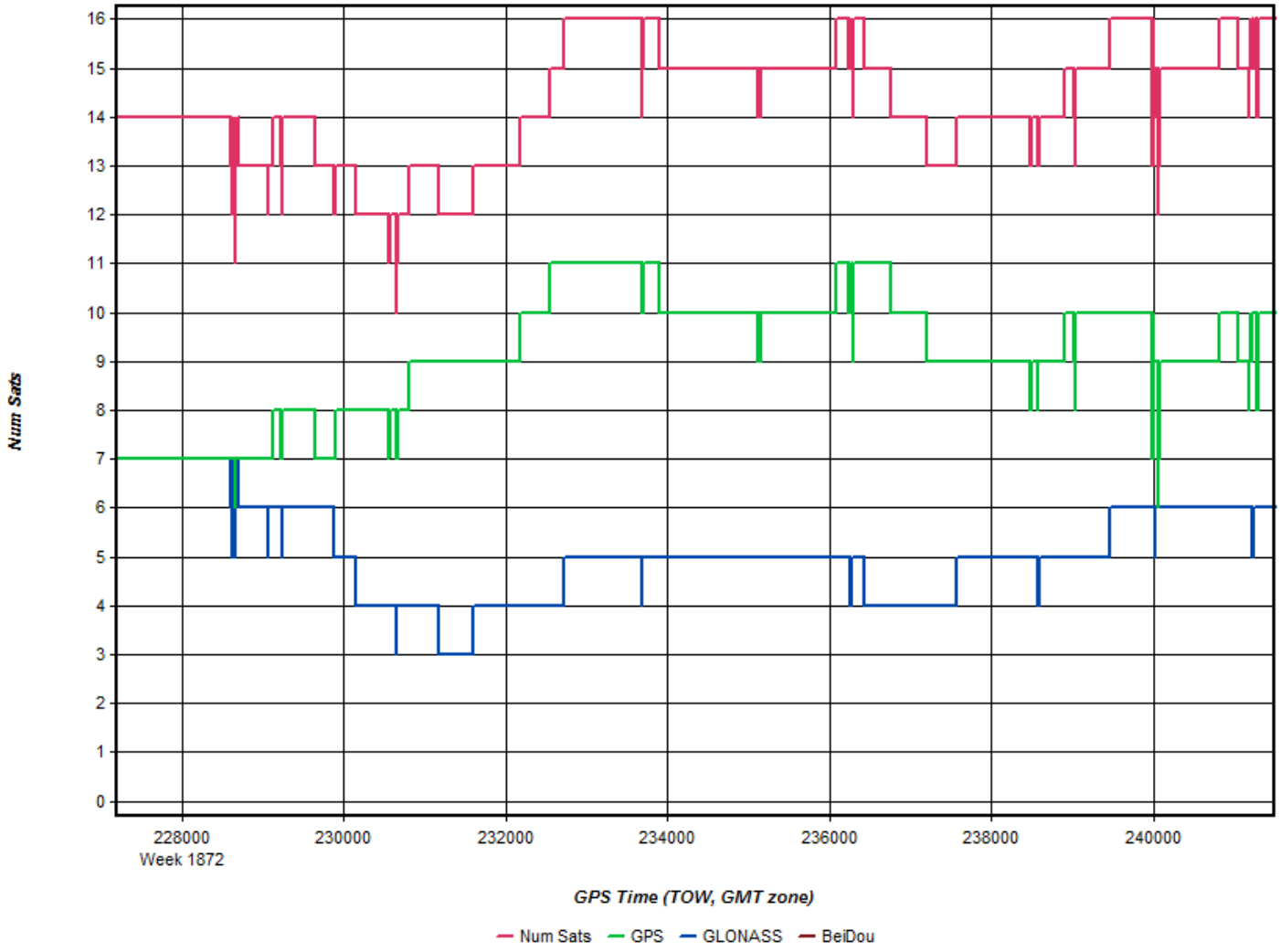

Separation (m)
0.0050
0.0045
0.0040
0.0035
0.0030
0.0025
0.0020
0.0015
0.0010
0.0005
0.0000
-0.0005
-0.0010
-0.0015
-0.0020
-0.0025
-0.0030
-0.0035
-0.0040
172000
Week 1872
174000
176000
178000
180000
182000
184000
186000
188000
190000
192000
GPS Time (TOW, GMT zone)
East
North
Up

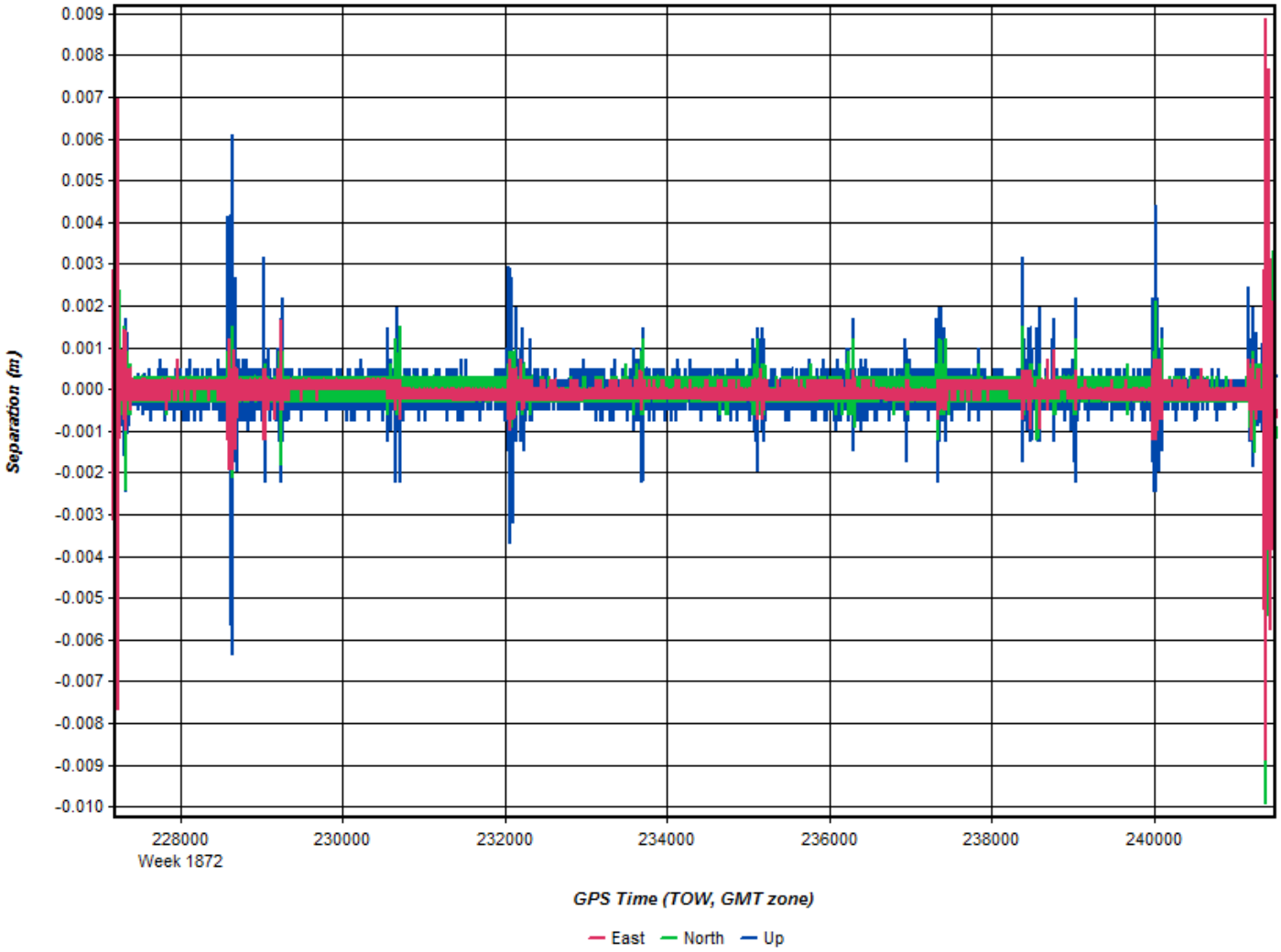

PDOP
2.7
2.6
2.5
2.4
2.3
2.2
2.1
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
172000
Week 1872
174000
176000
178000
180000
182000
184000
186000
188000
190000
192000
GPS Time (TOW, GMT zone)
PDOP

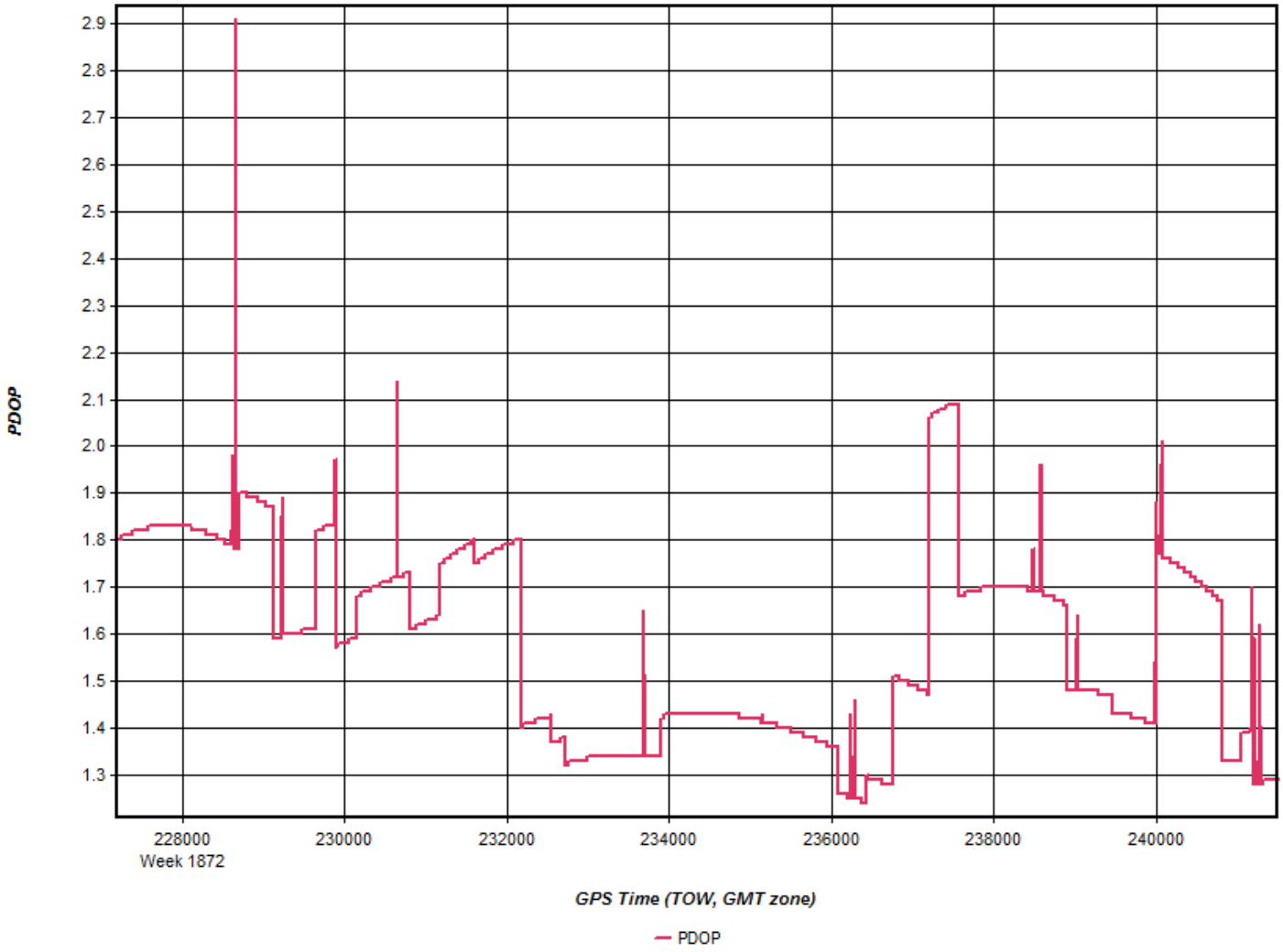
225_20151124_1




Estimated StdDev (m)
0.017
0.016
0.015
0.014
0.013
0.012
0.011
0.010
0.009
0.008
0.007
0.006
0.005
228000
Week 1872
230000
232000
234000
236000
238000
240000
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
228000
Week 1872
230000
232000
234000
236000
238000
240000
GPS Time (TOW, GMT zone)
Num Sats
GPS
GLONASS
BeiDou


0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0.000
-0.001
-0.002
-0.003
-0.004
-0.005
-0.006
-0.007
-0.008
-0.009
-0.010
Separation (m)
228000
Week 1872
230000
232000
234000
236000
238000
240000
GPS Time (TOW, GMT zone)
East
North
Up


PDOP
2.9
2.8
2.7
2.6
2.5
2.4
2.3
2.2
2.1
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
228000
Week 1872
230000
232000
234000
236000
238000
240000
GPS Time (TOW, GMT zone)
PDOP