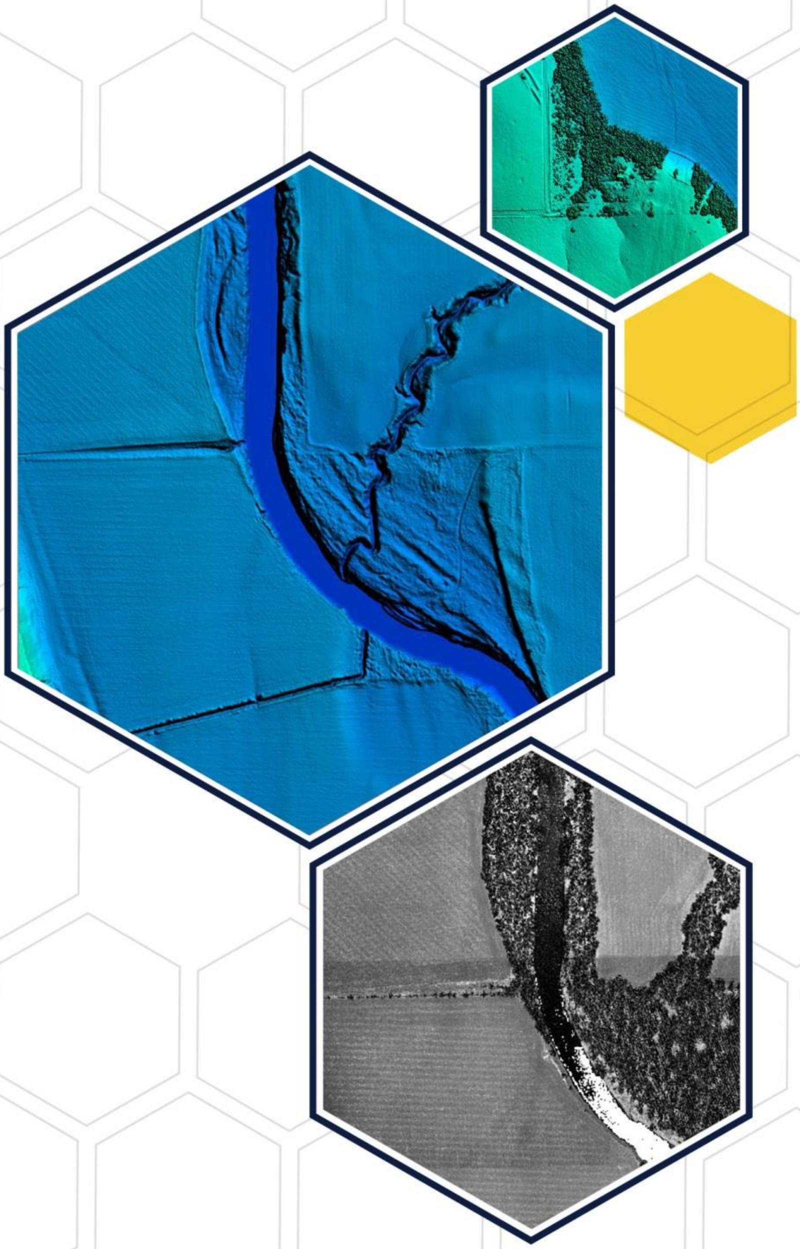


Aerial Lidar Report

16113

United States Geological Survey, 2017 Alabama 25 Counties Lidar (Block 1)

August 2017

Table of Contents

Section 1: Lidar Acquisition

1.1 Acquisition

The Atlantic Group, LLC (Atlantic) has successfully completed lidar acquisition for the 2017 Alabama 25 County Lidar (Block 1) Area of Interest (AOI). Lidar for this AOI was acquired in thirteen (13) flight missions completed on February 15th, 2017. The project area encompasses 1,182,395 acres, 4,785 square kilometers or 1,848 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 one hundred and thirty-eight (138) 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.

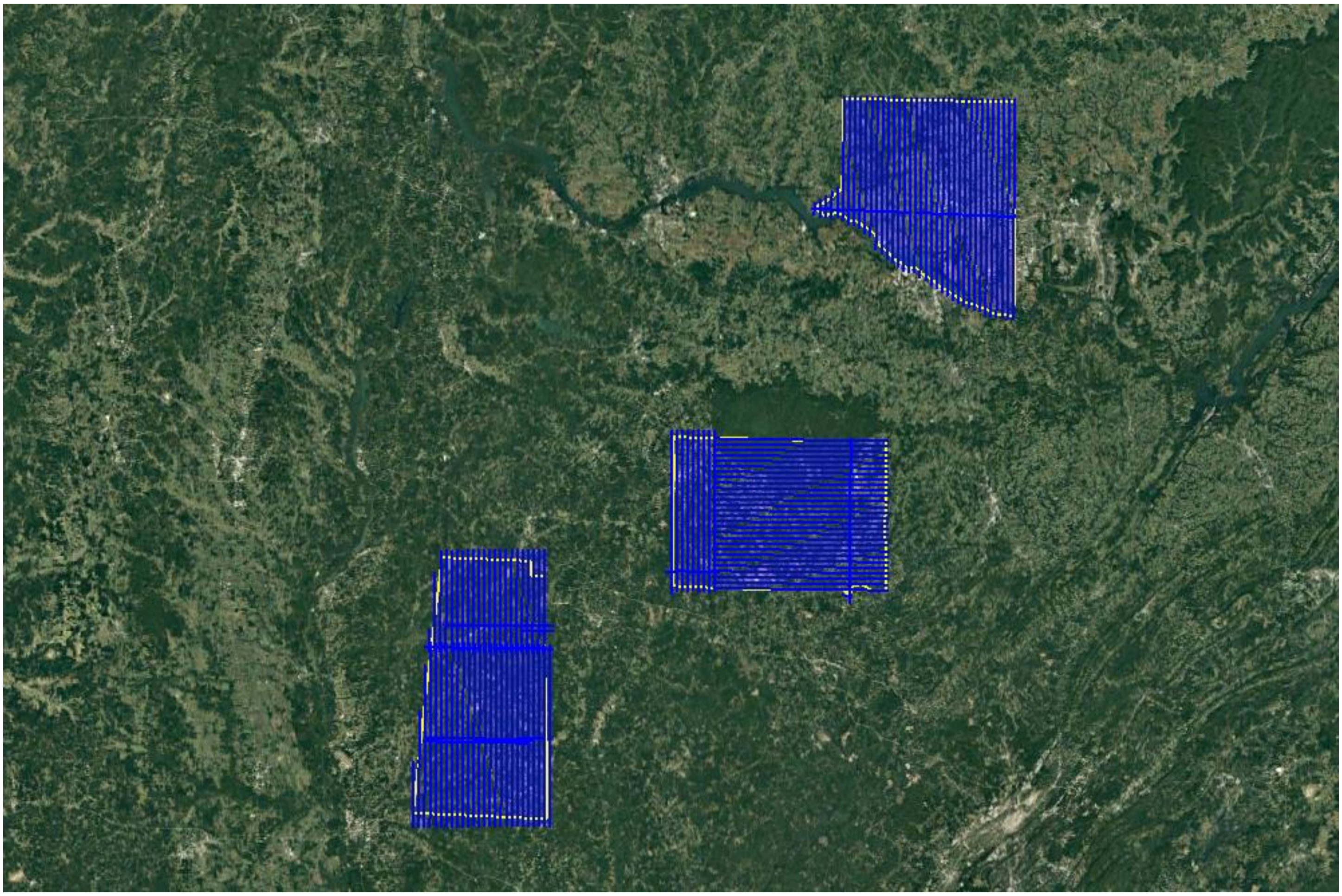


Figure 1: Trajectories as flown by Atlantic

1.6 Acquisition Equipment

Atlantic operated a Cessna T210L (N732JE) and Partenavia S.P.A. P-68 C/TC (N775MW) each 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)	0.7
Nominal Pulse Density (pls/m²)	2.4
Nominal Flight Height (AGL meters)	2,000
Nominal Flight Speed (kts)	130
Pass Heading (degree)	Varies
Sensor Scan Angle (degree)	45
Scan Frequency (Hz)	35.1
Pulse Rate of Scanner (kHz)	264.8
Line Spacing (m)	1,141
Pulse Duration of Scanner (ns)	4
Pulse Width of Scanner (m)	0.44
Central Wavelength of Sensor Laser (nm)	1064
Sensor Operated with Multiple Pulses	Yes
Beam Divergence (mrad)	0.22
Nominal Swath Width (m)	1,663
Nominal Swath Overlap (%)	20
Scan Pattern	Triangle

Table 2: Atlantic Lidar System Acquisition Parameters

1.8 GNSS Reference Station(s)

Eleven (11) Continuously Operating Reference Stations (CORS) and three (3) Alabama Department of Transportation (ALDOT) stations 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.

GPS Reference Station Coordinates					
Designation	**Type**	**PID**	**Latitude (N)**	**Longitude (W)**	**Elevation**
AL20	CORS	DI2224	34 42 37.12915	087 39 45.73609	133.182
AL23	ALDOT		34 08 54.84687	087 57 13.02166	142.491
ALBE	CORS	DM3487	34 28 31.49761	087 51 52.36634	227.761
ALC1	ALDOT		33 15 44.17849	088 05 43.40437	59.277
ALCU	CORS	DM3965	34 10 47.51409	086 50 41.52983	224.150
ALDS	CORS	DM5960	34 08 53.40799	087 24 17.49204	227.554
ALFA	CORS	DM3493	33 41 06.74504	087 49 45.50930	90.500
ALJA	CORS	DM3971	33 49 54.79664	087 16 39.26514	85.633
ALNC	CORS	DM2662	34 40 52.58348	087 18 33.99419	158.085
ALSP	ALDOT		34 25 05.08146	087 10 19.32663	175.120
GTAC	CORS	DG5771	34 42 39.82636	086 39 12.28466	194.331
HGIS	CORS	DK7412	34 43 41.17629	086 35 12.06178	177.731
MSPE	CORS	DO8516	33 47 52.33113	088 39 30.10859	76.640
TN39	CORS	DM4145	35 11 29.04675	087 00 26.74814	187.182

Table 3: GNSS Reference Station Coordinates

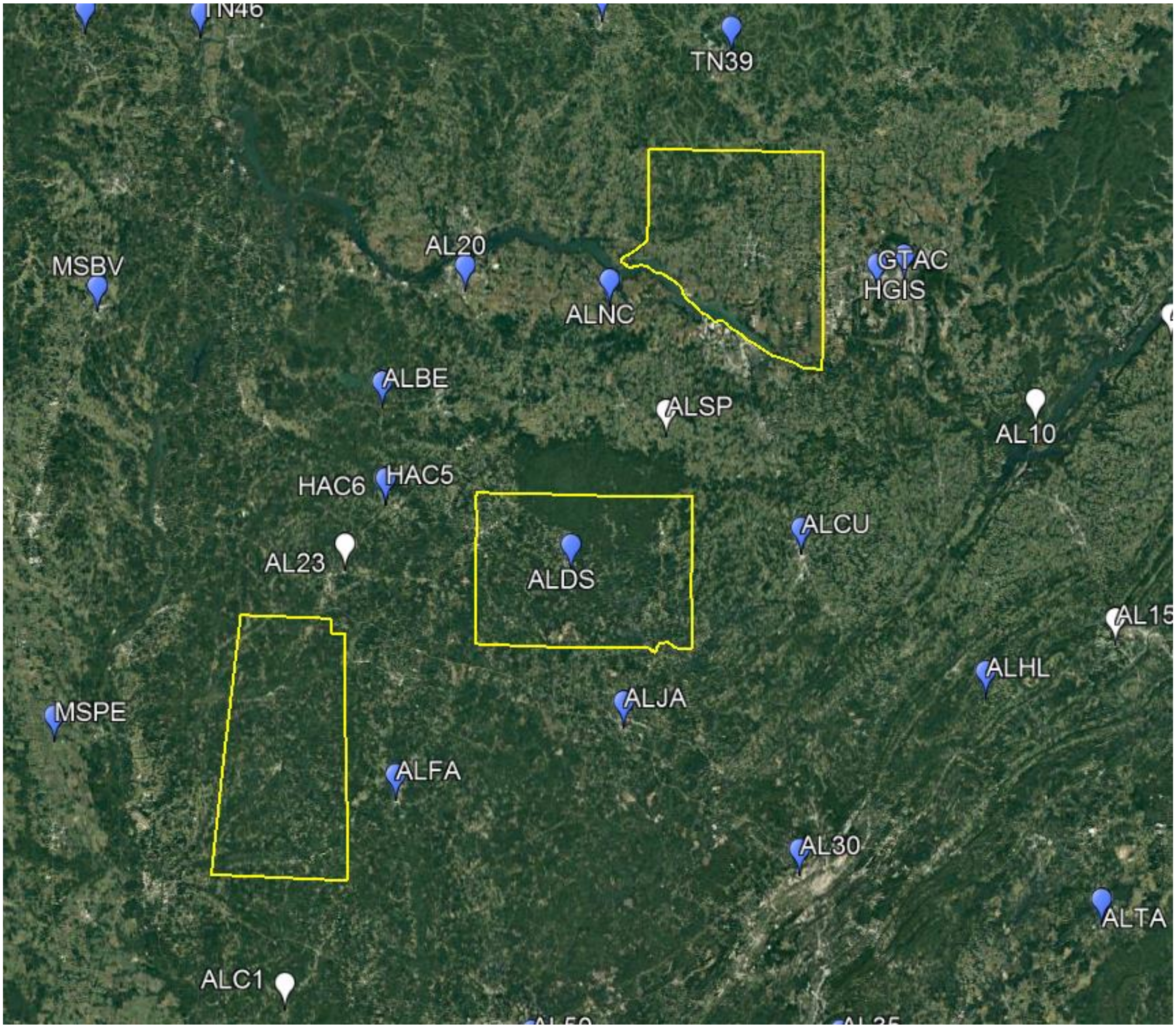


Figure 2: GNSS Reference Station(s)

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.

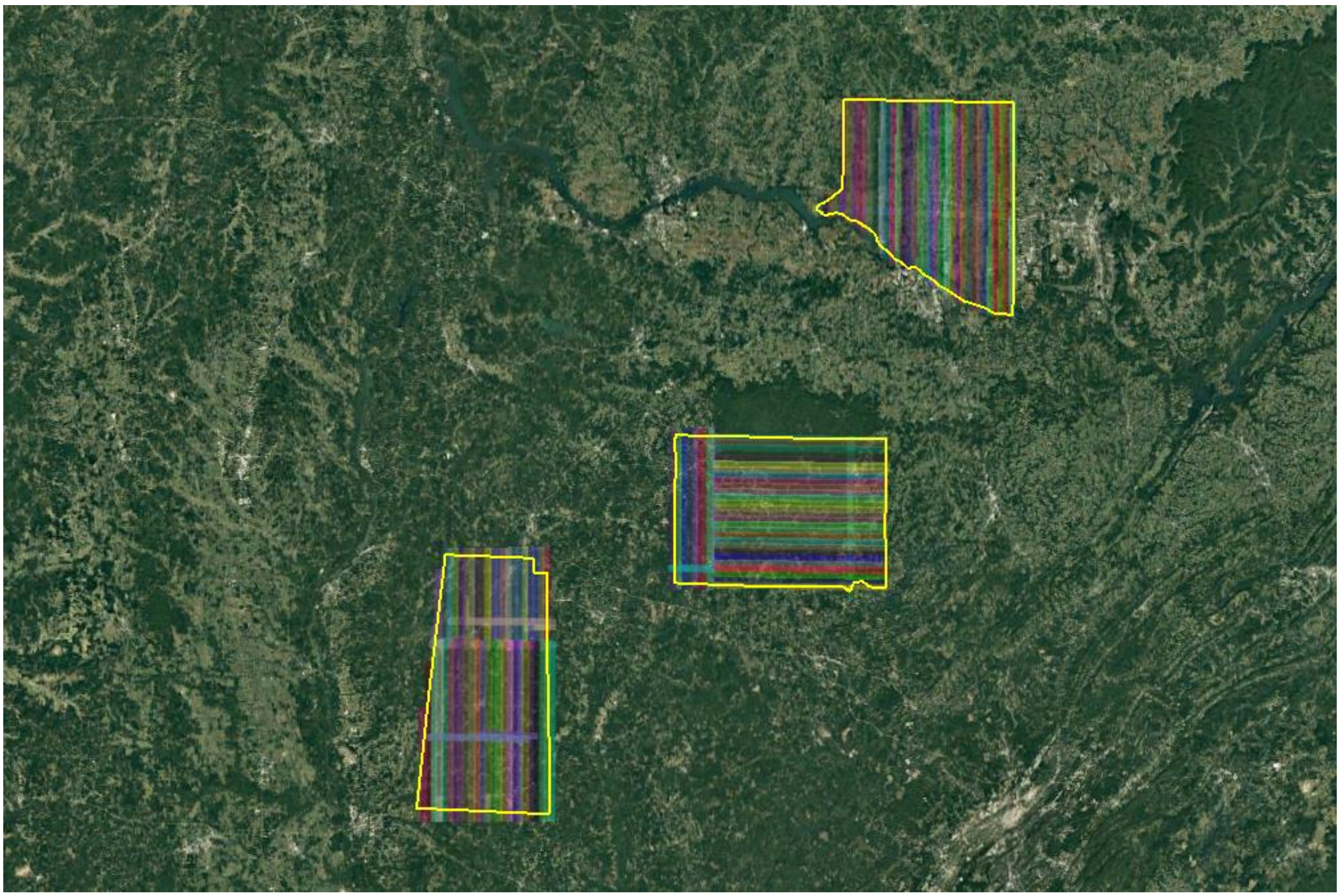


Figure 3: Lidar swath data showing complete coverage

2.2 Coordinate Reference System

Horizontal Datum:	North American Datum of 1983 (2011)
Coordinate System:	Universal Transverse Mercator Zone 16 North
Vertical Datum:	North American Vertical Datum of 1988
Geoid Model:	Geoid12B
Units of Reference:	Meters

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	30,393,615,336
Nominal Pulse Spacing (m)	0.6260
Nominal Pulse Density (pls/m²)	2.55
Nominal Pulse Spacing (ft)	2.0539
Nominal Pulse Density (pls/ft²)	0.24
Total Aggregate Points	26,333,693,413
Aggregate Nominal Pulse Spacing (m)	0.5463
Aggregate Nominal Pulse Density (pls/m²)	3.35
Aggregate Nominal Pulse Spacing (ft)	1.7923
Aggregate Nominal Pulse Density (pls/ft²)	0.31

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 2,000m; the expected radial horizontal positional error will be RMSEz = 29.0cm.

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.

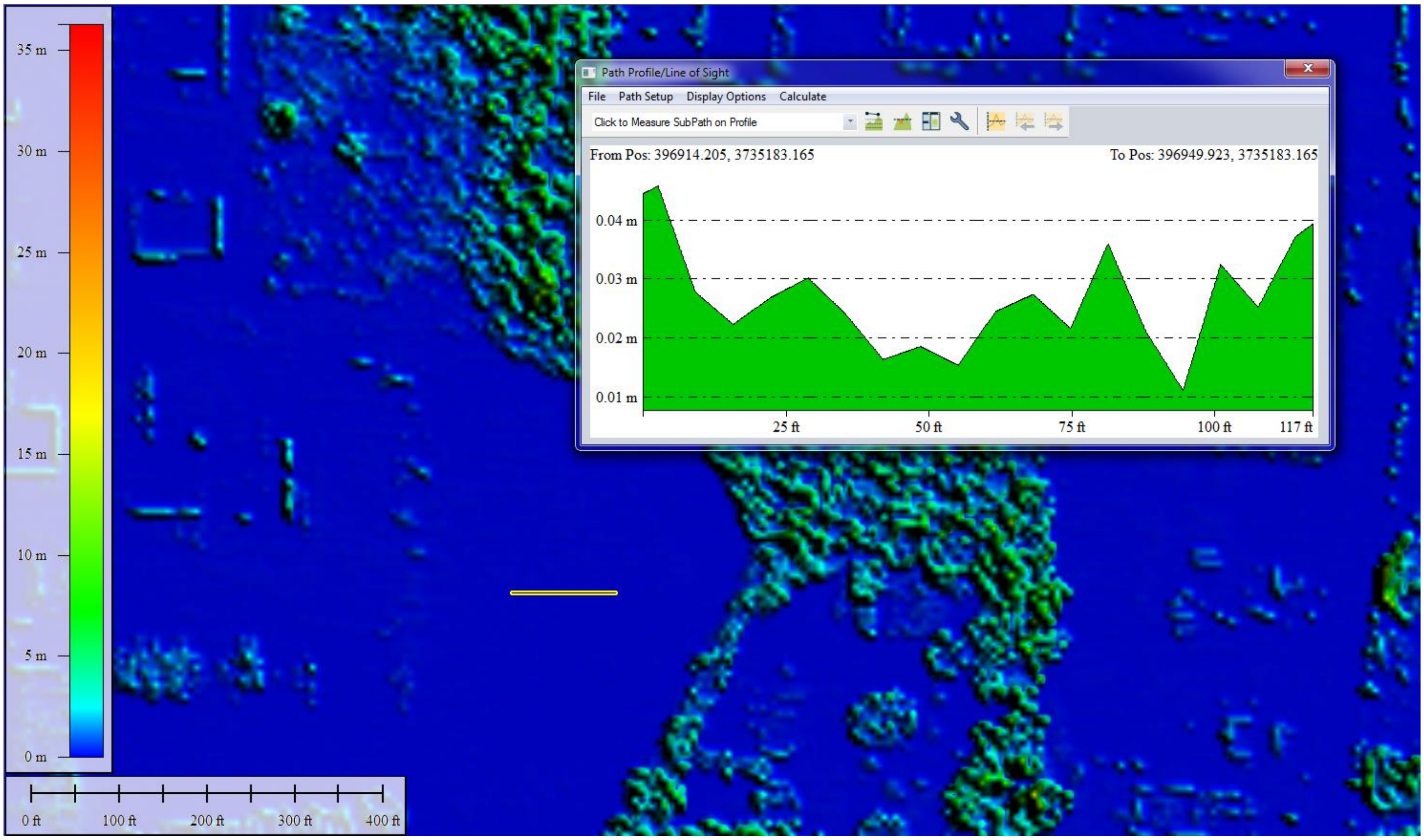


Figure 4: Smooth Surface Repeatability of ≤6cm

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

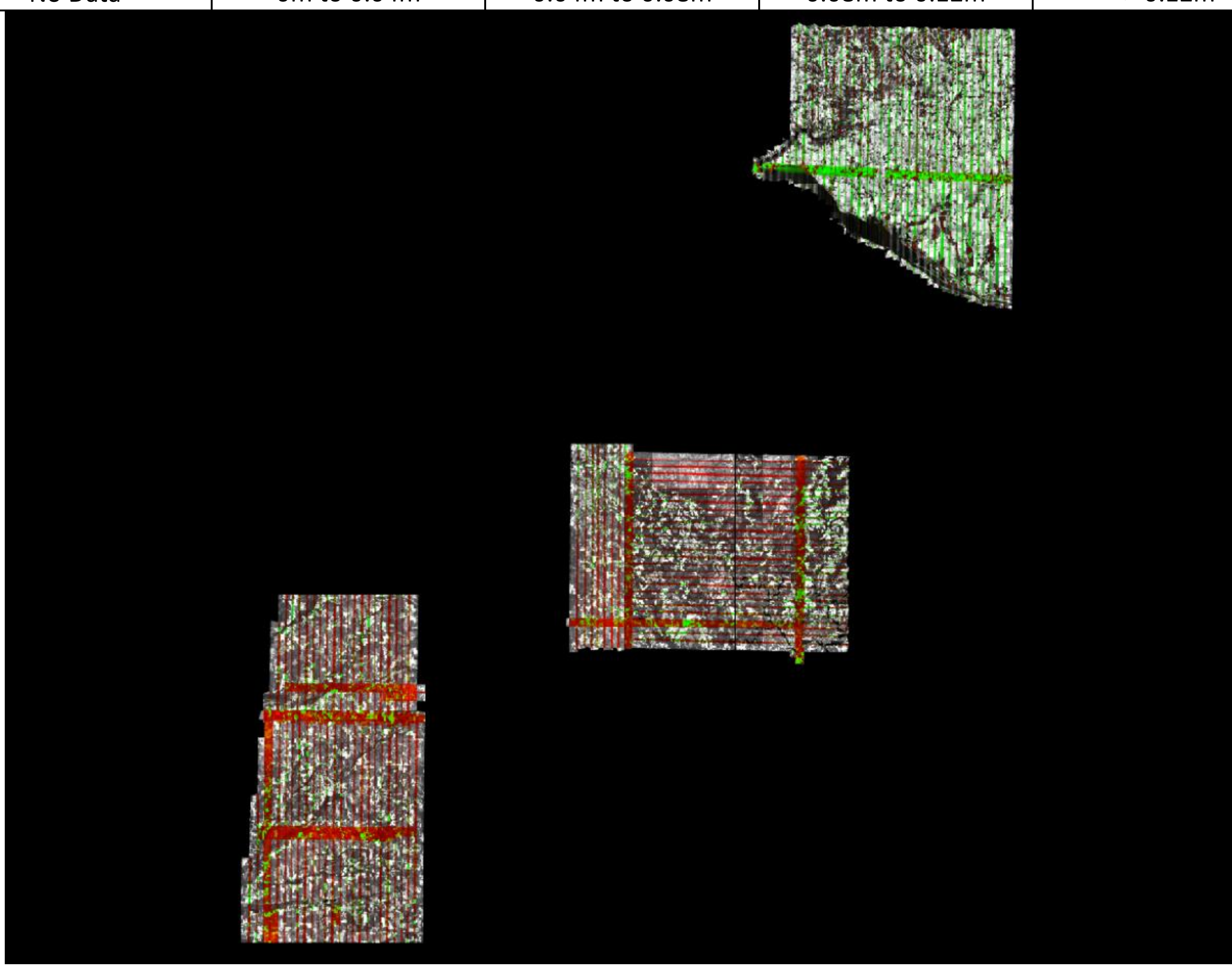


Figure 5: Swath Overlap Difference of ≤8cm, Maximum of ±16cm

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 meters.

Average Magnitudes Per Line											
Line	X	Y	Z	Line	X	Y	Z	Line	X	Y	Z
1002	0.011	0.013	0.017	1092	0.019	0.024	0.015	1175	0.008	0.070	0.016
1003	0.029	0.025	0.017	1093	0.016	0.023	0.017	1176	0.011	0.059	0.016
1004	0.030	0.027	0.016	1094	0.019	0.020	0.015	1177	0.009	0.059	0.016
1005	0.027	0.025	0.018	1095	0.018	0.025	0.015	1178	0.025	0.062	0.016
1006	0.023	0.021	0.018	1097	0.027	0.024	0.017	1179	0.013	0.071	0.016
1007	0.020	0.018	0.019	1098	0.028	0.030	0.017	1180	0.012	0.048	0.016
1008	0.019	0.017	0.020	1099	0.038	0.041	0.017	1181	0.008	0.069	0.017
1009	0.019	0.017	0.017	1100	0.036	0.033	0.018	1182	0.012	0.062	0.015
1010	0.020	0.019	0.017	1101	0.028	0.036	0.027	1183	0.008	0.058	0.016
1015	0.026	0.025	0.026	1102	0.029	0.018	0.019	1184	0.009	0.054	0.015
1023	0.033	0.046	0.019	1103	0.035	0.033	0.016	1185	0.007	0.073	0.016
1024	0.035	0.056	0.022	1104	0.028	0.023	0.016	1186	0.010	0.043	0.016
1025	0.038	0.052	0.021	1105	0.031	0.023	0.017	1187	0.009	0.045	0.016
1026	0.025	0.034	0.025	1106	0.030	0.022	0.017	1220	0.041	0.038	0.035
1027	0.049	0.051	0.020	1107	0.033	0.025	0.016	1221	0.024	0.045	0.014
1029	0.026	0.027	0.018	1108	0.027	0.027	0.016	1222	0.026	0.035	0.018
1030	0.020	0.026	0.016	1109	0.025	0.024	0.016	1223	0.029	0.080	0.018
1031	0.017	0.020	0.017	1110	0.018	0.014	0.016	1224	0.047	0.066	0.018
1032	0.021	0.023	0.017	1111	0.016	0.024	0.018	1225	0.058	0.044	0.017
1033	0.030	0.037	0.017	1112	0.022	0.023	0.020	1226	0.055	0.029	0.018
1034	0.026	0.035	0.017	1114	0.022	0.025	0.023	1227	0.047	0.033	0.017
1035	0.022	0.021	0.017	1140	0.026	0.030	0.023	1228	0.054	0.036	0.019
1036	0.024	0.022	0.017	1142	0.025	0.033	0.019	1229	0.050	0.037	0.018
1037	0.018	0.021	0.017	1143	0.031	0.032	0.015	1230	0.050	0.046	0.017
1038	0.018	0.021	0.017	1144	0.031	0.049	0.017	1231	0.049	0.044	0.017
1039	0.018	0.014	0.015	1145	0.040	0.039	0.015	1232	0.051	0.033	0.018
1040	0.019	0.020	0.018	1146	0.044	0.029	0.014	1233	0.058	0.042	0.017
1042	0.038	0.028	0.029	1147	0.044	0.036	0.013	1234	0.053	0.056	0.019
1043	0.026	0.022	0.019	1148	0.032	0.038	0.014	1235	0.051	0.050	0.017
1044	0.027	0.036	0.017	1149	0.043	0.046	0.014	1236	0.052	0.036	0.019
1045	0.022	0.035	0.018	1150	0.048	0.035	0.016	1237	0.054	0.040	0.017
1046	0.027	0.029	0.018	1151	0.049	0.036	0.015	1238	0.061	0.032	0.019
1047	0.020	0.021	0.017	1152	0.038	0.045	0.015	1239	0.055	0.041	0.019
1048	0.036	0.027	0.017	1153	0.037	0.046	0.015	1240	0.053	0.032	0.020

1049	0.020	0.039	0.019	**1154**	0.042	0.041	0.015	**1241**	0.021	0.016	0.014
1050	0.026	0.027	0.019	**1155**	0.038	0.051	0.016	**1242**	0.030	0.027	0.015
1051	0.019	0.021	0.017	**1156**	0.037	0.045	0.015	**1243**	0.029	0.033	0.016
1052	0.024	0.022	0.016	**1157**	0.045	0.042	0.015	**1244**	0.023	0.027	0.017
1058	0.033	0.029	0.023	**1158**	0.041	0.043	0.015	**1245**	0.020	0.020	0.024
1059	0.021	0.022	0.020	**1159**	0.040	0.039	0.014	**1261**	0.021	0.022	0.021
1060	0.013	0.021	0.019	**1160**	0.037	0.027	0.015	**1262**	0.025	0.021	0.017
1084	0.026	0.034	0.025	**1169**	0.020	0.029	0.028	**1263**	0.023	0.026	0.015
1087	0.015	0.028	0.014	**1170**	0.026	0.036	0.015	**1264**	0.020	0.022	0.015
1088	0.023	0.025	0.016	**1171**	0.019	0.052	0.015	**1265**	0.022	0.029	0.017
1089	0.027	0.022	0.016	**1172**	0.013	0.040	0.015	**1266**	0.031	0.035	0.022
1090	0.028	0.030	0.016	**1173**	0.011	0.041	0.015				
1091	0.027	0.030	0.018	**1174**	0.010	0.069	0.016				

Table 5: Average Tie Line Magnitudes per Line

Internal Observation Statistics			
Category	**X**	**Y**	**Z**
Average Magnitude	0.026	0.034	0.017
RMS Values	0.040	0.049	0.023
Maximum Values	0.157	0.157	0.160
Observation Weight	27807.0	27807.0	946113.0

Table 6: Tie Line Observation Statistics

Overall Relative Accuracy	
Category	**Mismatch**
Average 3D Mismatch	0.01822
Average XY Mismatch	0.05040
Average Z Mismatch	0.01699

Table 7: Relative Accuracy Results

TerraMatch Tie Lines	
Category	**Observations**
Section Lines	417,795
Roof Lines	13,325

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' 9-Water 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 fifty-two (52) check points for the block 1 project area (27 NVA + 25 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:

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

Vertical Accuracy Reporting Requirements in Feet:

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

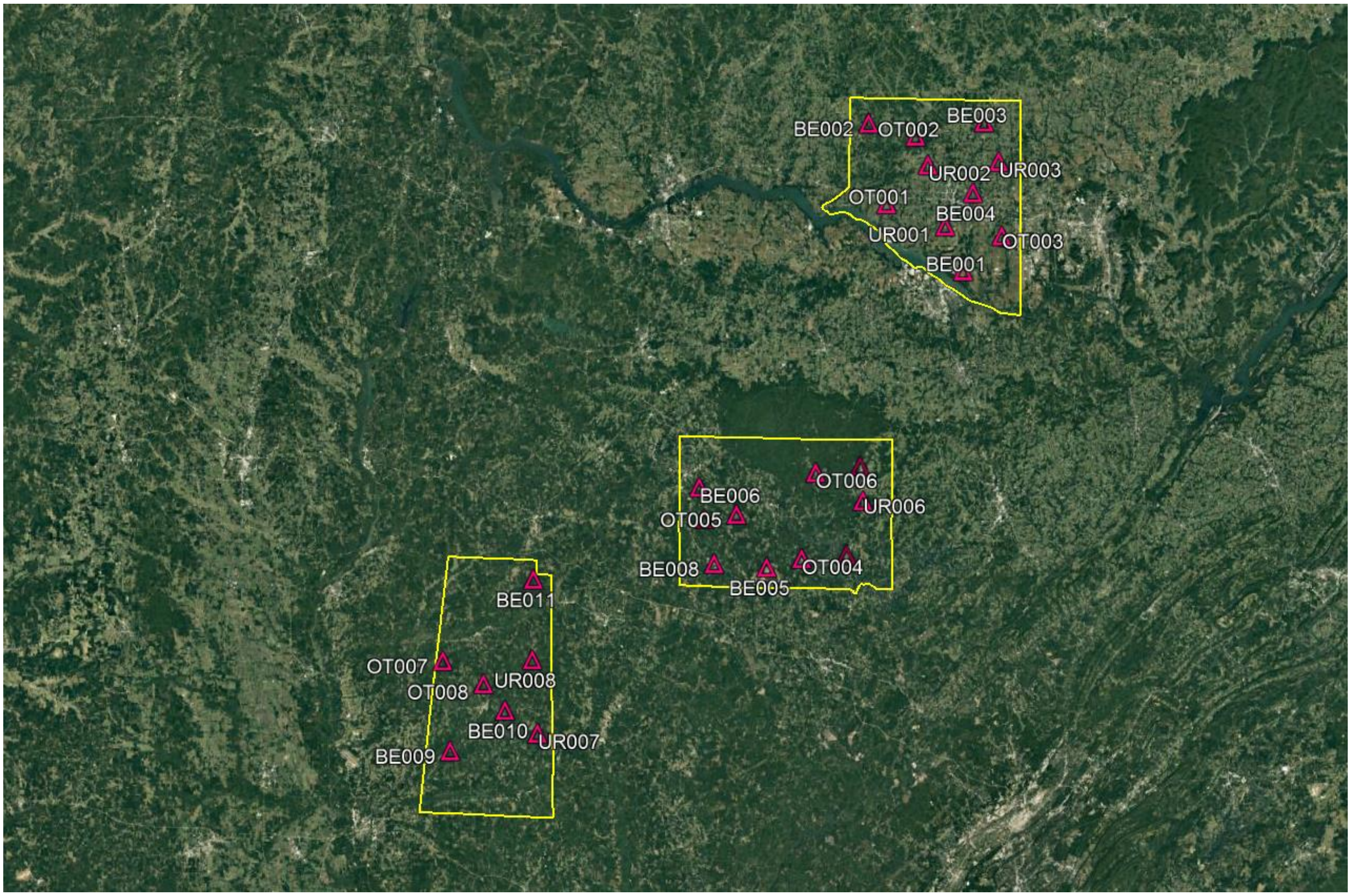


Figure 6: Non-vegetated Vertical Accuracy (NVA) Check Point Distribution

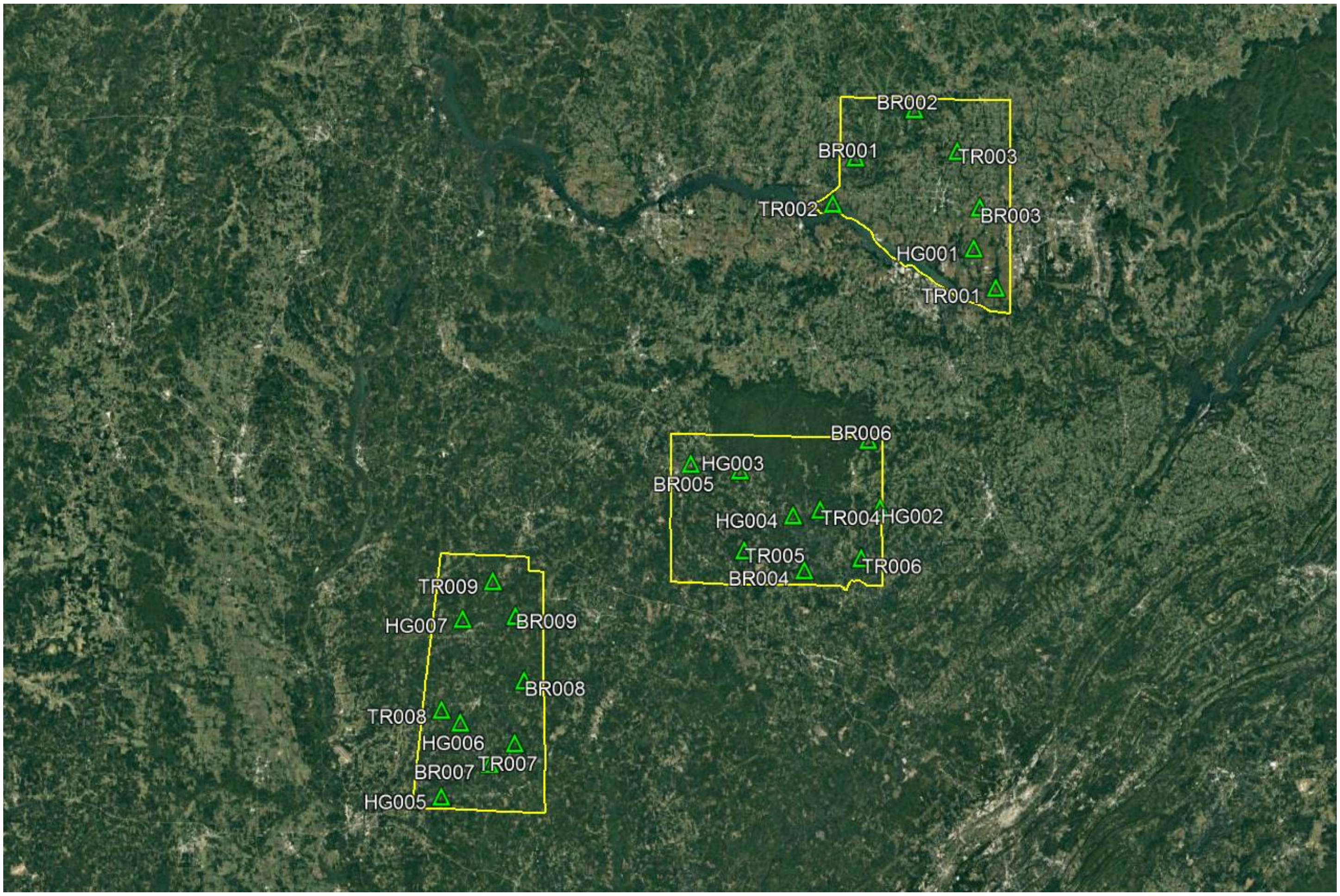


Figure 7: Vegetated Vertical Accuracy (VVA) Check Point Distribution

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 meters.

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	27	0.062	0.122	
NVA of Bare-Earth Lidar	27	0.059	0.115	
NVA of Bare-Earth DEM	27	0.057	0.112	
VVA of Bare-Earth Lidar	25	0.097		0.177

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

Vegetated Vertical Accuracy (VVA) 5% Outliers > 95th Percentile (0.177m)						
PointID	**Easting**	**Northing**	**KnownZ**	**LaserZ**	**Description**	**DeltaZ**
BR002	497730.910	3870126.461	180.103	180.287	Brush	0.184
HG003	457302.639	3787898.026	272.699	272.938	High Grass	0.239

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, and 15 below. The coordinates provided are in NAD83 (2011), UTM Zone 16 North, NAVD88 (Geoid12B), Meters.

Non-vegetated Vertical Accuracy (NVA) Check Point Assessment (Point Cloud)						
PointID	**Easting**	**Northing**	**KnownZ**	**LaserZ**	**Description**	**DeltaZ**
BE001	506382.505	3833447.026	181.632	181.682	Open Terrain/Bare Earth	0.050
BE002	485027.296	3867101.655	186.001	185.914	Open Terrain/Bare Earth	-0.087
BE003	511400.001	3867295.396	272.738	272.796	Open Terrain/Bare Earth	0.058
BE004	508745.927	3851174.300	224.042	224.026	Open Terrain/Bare Earth	-0.016
BE005	461213.118	3766497.115	224.483	224.461	Open Terrain/Bare Earth	-0.022
BE006	445976.213	3784703.414	231.354	231.339	Open Terrain/Bare Earth	-0.015
BE007	482618.214	3789300.113	266.554	266.658	Open Terrain/Bare Earth	0.104
BE008	449244.664	3767395.077	218.307	218.276	Open Terrain/Bare Earth	-0.031
BE009	388820.728	3725176.814	75.401	75.444	Open Terrain/Bare Earth	0.043
BE010	401407.481	3734347.081	138.738	138.797	Open Terrain/Bare Earth	0.059
BE011	408073.589	3764047.593	142.346	142.385	Open Terrain/Bare Earth	0.039
OT001	488987.147	3848777.121	214.031	214.028	Open Terrain/Bare Earth	-0.003
OT002	495754.941	3864102.881	191.764	191.797	Open Terrain/Bare Earth	0.033
OT003	515250.758	3841380.887	203.001	203.009	Open Terrain/Bare Earth	0.008
OT004	469195.952	3768423.941	246.688	246.714	Open Terrain/Bare Earth	0.026
OT005	454410.742	3778523.406	203.591	203.680	Open Terrain/Bare Earth	0.089
OT006	472500.634	3787911.161	261.029	261.090	Open Terrain/Bare Earth	0.061
OT007	387304.269	3745645.047	108.880	108.875	Open Terrain/Bare Earth	-0.005
OT008	396531.550	3740391.299	126.387	126.594	Open Terrain/Bare Earth	0.207

UR001	502332.187	3843631.158	206.214	206.219	Urban Terrain	0.005
UR002	498515.870	3857546.276	232.378	232.318	Urban Terrain	-0.060
UR003	514663.973	3858272.857	246.923	246.947	Urban Terrain	0.024
UR004	447088.776	3777577.429	254.801	254.783	Urban Terrain	-0.018
UR005	479409.021	3769236.899	226.592	226.516	Urban Terrain	-0.076
UR006	483206.190	3781435.050	253.167	253.165	Urban Terrain	-0.002
UR007	408796.479	3729096.075	143.262	143.201	Urban Terrain	-0.061
UR008	407705.217	3745799.660	109.150	109.116	Urban Terrain	-0.034

Table 12: Lidar Point Cloud NVA Assessment

Non-vegetated Vertical Accuracy (NVA) Check Point Assessment (Bare-Earth)						
PointID	Easting	Northing	KnownZ	LaserZ	Description	DeltaZ
BE001	506382.505	3833447.026	181.632	181.676	Open Terrain/Bare Earth	0.044
BE002	485027.296	3867101.655	186.001	185.914	Open Terrain/Bare Earth	-0.087
BE003	511400.001	3867295.396	272.738	272.791	Open Terrain/Bare Earth	0.053
BE004	508745.927	3851174.300	224.042	224.026	Open Terrain/Bare Earth	-0.016
BE005	461213.118	3766497.115	224.483	224.454	Open Terrain/Bare Earth	-0.029
BE006	445976.213	3784703.414	231.354	231.339	Open Terrain/Bare Earth	-0.015
BE007	482618.214	3789300.113	266.554	266.658	Open Terrain/Bare Earth	0.104
BE008	449244.664	3767395.077	218.307	218.268	Open Terrain/Bare Earth	-0.039
BE009	388820.728	3725176.814	75.401	75.405	Open Terrain/Bare Earth	0.004
BE010	401407.481	3734347.081	138.738	138.797	Open Terrain/Bare Earth	0.059
BE011	408073.589	3764047.593	142.346	142.385	Open Terrain/Bare Earth	0.039
OT001	488987.147	3848777.121	214.031	214.028	Open Terrain/Bare Earth	-0.003
OT002	495754.941	3864102.881	191.764	191.789	Open Terrain/Bare Earth	0.025
OT003	515250.758	3841380.887	203.001	202.981	Open Terrain/Bare Earth	-0.020
OT004	469195.952	3768423.941	246.688	246.714	Open Terrain/Bare Earth	0.026
OT005	454410.742	3778523.406	203.591	203.680	Open Terrain/Bare Earth	0.089
OT006	472500.634	3787911.161	261.029	261.090	Open Terrain/Bare Earth	0.061
OT007	387304.269	3745645.047	108.880	108.875	Open Terrain/Bare Earth	-0.005
OT008	396531.550	3740391.299	126.387	126.530	Open Terrain/Bare Earth	0.143
UR001	502332.187	3843631.158	206.214	206.219	Urban Terrain	0.005
UR002	498515.870	3857546.276	232.378	232.311	Urban Terrain	-0.067
UR003	514663.973	3858272.857	246.923	246.906	Urban Terrain	-0.017
UR004	447088.776	3777577.429	254.801	254.783	Urban Terrain	-0.018
UR005	479409.021	3769236.899	226.592	226.501	Urban Terrain	-0.091
UR006	483206.190	3781435.050	253.167	253.165	Urban Terrain	-0.002
UR007	408796.479	3729096.075	143.262	143.162	Urban Terrain	-0.100
UR008	407705.217	3745799.660	109.150	109.079	Urban Terrain	-0.071

Table 13: Bare-Earth Lidar NVA Assessment

Non-vegetated Vertical Accuracy (NVA) Check Point Assessment (DEM)						
PointID	**Easting**	**Northing**	**KnownZ**	**DEMZ**	**Description**	**DeltaZ**
BE001	506382.505	3833447.026	181.632	181.671	Open Terrain/Bare Earth	0.039
BE002	485027.296	3867101.655	186.001	185.893	Open Terrain/Bare Earth	-0.108
BE003	511400.001	3867295.396	272.738	272.789	Open Terrain/Bare Earth	0.051
BE004	508745.927	3851174.300	224.042	224.024	Open Terrain/Bare Earth	-0.018
BE005	461213.118	3766497.115	224.483	224.428	Open Terrain/Bare Earth	-0.055
BE006	445976.213	3784703.414	231.354	231.347	Open Terrain/Bare Earth	-0.007
BE007	482618.214	3789300.113	266.554	266.650	Open Terrain/Bare Earth	0.096
BE008	449244.664	3767395.077	218.307	218.264	Open Terrain/Bare Earth	-0.043
BE009	388820.728	3725176.814	75.401	75.436	Open Terrain/Bare Earth	0.035
BE010	401407.481	3734347.081	138.738	138.760	Open Terrain/Bare Earth	0.022
BE011	408073.589	3764047.593	142.346	142.376	Open Terrain/Bare Earth	0.030
OT001	488987.147	3848777.121	214.031	213.995	Open Terrain/Bare Earth	-0.036
OT002	495754.941	3864102.881	191.764	191.790	Open Terrain/Bare Earth	0.026
OT003	515250.758	3841380.887	203.001	203.008	Open Terrain/Bare Earth	0.006
OT004	469195.952	3768423.941	246.688	246.697	Open Terrain/Bare Earth	0.009
OT005	454410.742	3778523.406	203.591	203.663	Open Terrain/Bare Earth	0.072
OT006	472500.634	3787911.161	261.029	261.083	Open Terrain/Bare Earth	0.054
OT007	387304.269	3745645.047	108.880	108.892	Open Terrain/Bare Earth	0.012
OT008	396531.550	3740391.299	126.387	126.513	Open Terrain/Bare Earth	0.126
UR001	502332.187	3843631.158	206.214	206.229	Urban Terrain	0.015
UR002	498515.870	3857546.276	232.378	232.307	Urban Terrain	-0.071
UR003	514663.973	3858272.857	246.923	246.901	Urban Terrain	-0.022
UR004	447088.776	3777577.429	254.801	254.793	Urban Terrain	-0.008
UR005	479409.021	3769236.899	226.592	226.495	Urban Terrain	-0.097
UR006	483206.190	3781435.050	253.167	253.144	Urban Terrain	-0.023
UR007	408796.479	3729096.075	143.262	143.166	Urban Terrain	-0.096
UR008	407705.217	3745799.660	109.150	109.080	Urban Terrain	-0.070

Table 14: Bare=Earth DEM NVA Assessment

Vegetated Vertical Accuracy (VVA) Check Point Assessment (Bare Earth)						
PointID	**Easting**	**Northing**	**KnownZ**	**LaserZ**	**Description**	**DeltaZ**
BR001	484176.497	3859164.749	238.178	238.181	Brush	0.003
BR002	497730.910	3870126.461	180.103	180.287	Brush	0.184
BR003	512601.539	3847599.527	211.932	212.083	Brush	0.151
BR004	471913.156	3765053.980	225.738	225.771	Brush	0.033
BR005	446052.376	3789450.311	297.564	297.691	Brush	0.127
BR006	486698.835	3794682.681	285.958	285.959	Brush	0.001
BR007	399614.112	3721205.192	102.244	102.163	Brush	-0.081
BR008	407619.408	3740226.889	159.991	159.981	Brush	-0.010
BR009	405714.541	3754960.288	117.087	116.990	Brush	-0.097
HG001	511152.199	3838275.196	180.630	180.522	High Grass	-0.108

HG002	489347.004	3779134.206	265.702	265.723	High Grass	0.021
HG003	457302.639	3787898.026	272.699	272.938	High Grass	0.239
HG004	469389.432	3777566.455	226.319	226.449	High Grass	0.130
HG005	388440.622	3713754.116	76.157	76.085	High Grass	-0.072
HG006	392914.159	3730673.320	84.702	84.735	High Grass	0.033
HG007	393604.969	3754340.668	94.027	94.091	High Grass	0.064
TR001	516174.073	3829252.711	172.691	172.764	Trees	0.073
TR002	478888.594	3848619.680	181.704	181.718	Trees	0.014
TR003	507517.444	3860530.865	248.106	248.081	Trees	-0.025
TR004	475609.994	3778845.693	240.151	240.047	Trees	-0.104
TR005	458177.084	3769669.663	231.695	231.679	Trees	-0.016
TR006	484960.209	3767742.794	221.643	221.671	Trees	0.028
TR007	405377.576	3725898.158	125.304	125.432	Trees	0.128
TR008	388641.685	3733603.511	96.053	95.998	Trees	-0.055
TR009	400583.320	3762921.173	105.820	105.934	Trees	0.114

Table 15: Bare-Earth Lidar VVA Assessment

Section 4: Certification

4.1 Limitations of Use

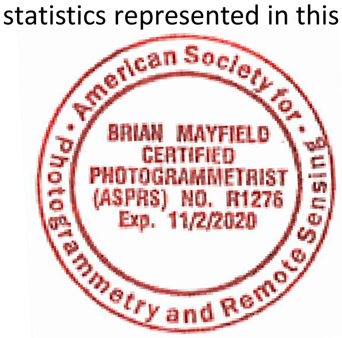
The accuracy assessment confirms that the data may be used for the intended applications stated in the **Project Purpose** section of this document. The dataset may also be used as a topographic input for other applications but the user should be aware that this lidar dataset was designed with a specific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

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.



B. Mayfield

Brian J. Mayfield, ASPRS Certified Photogrammetrist #R1276

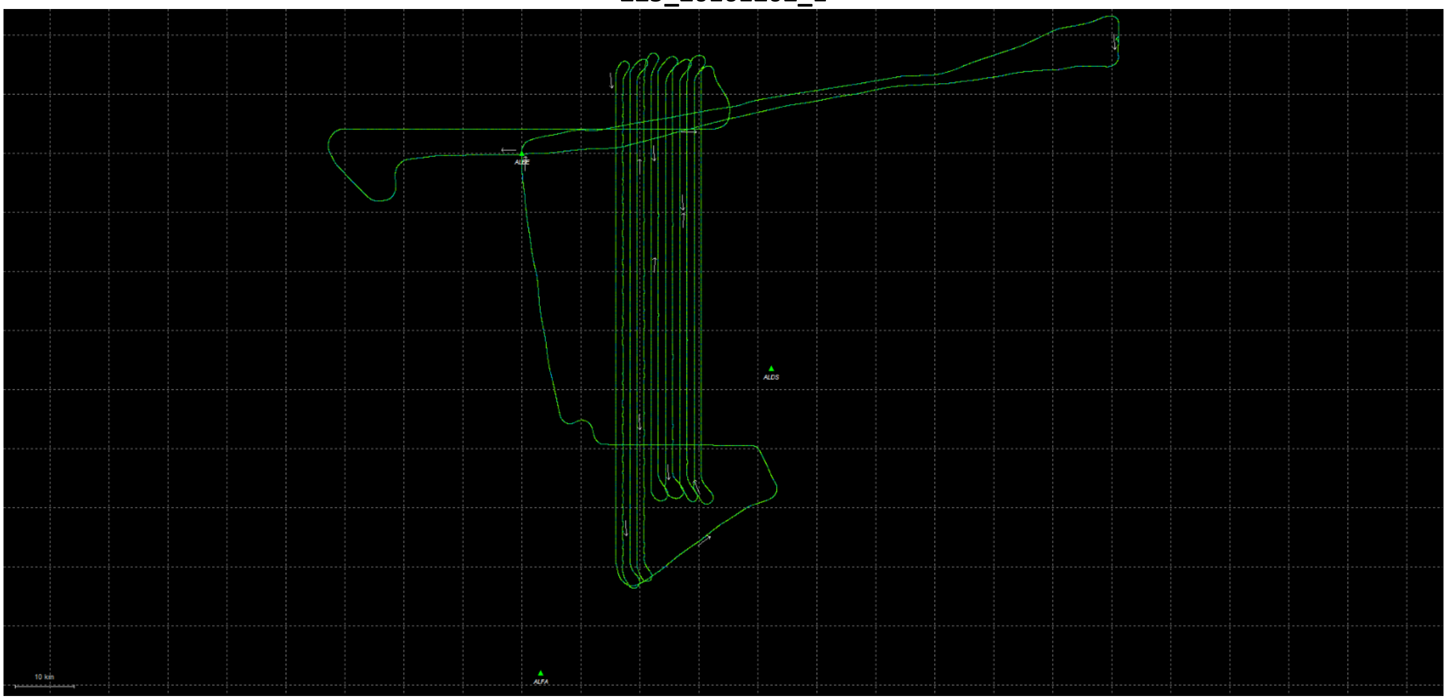
Section 5: GNSS Processing

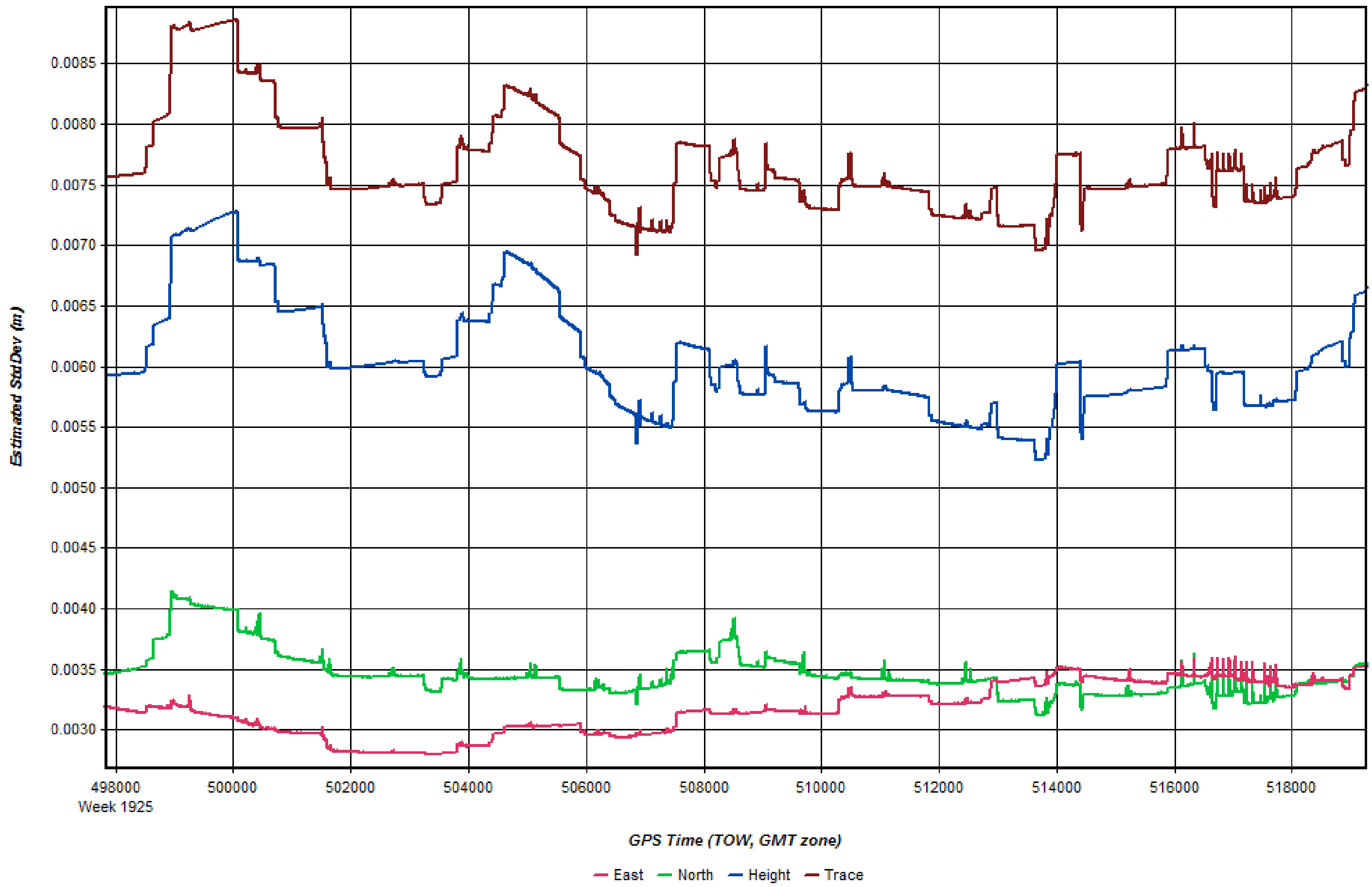
Inertial Explorer version 8.60.6717

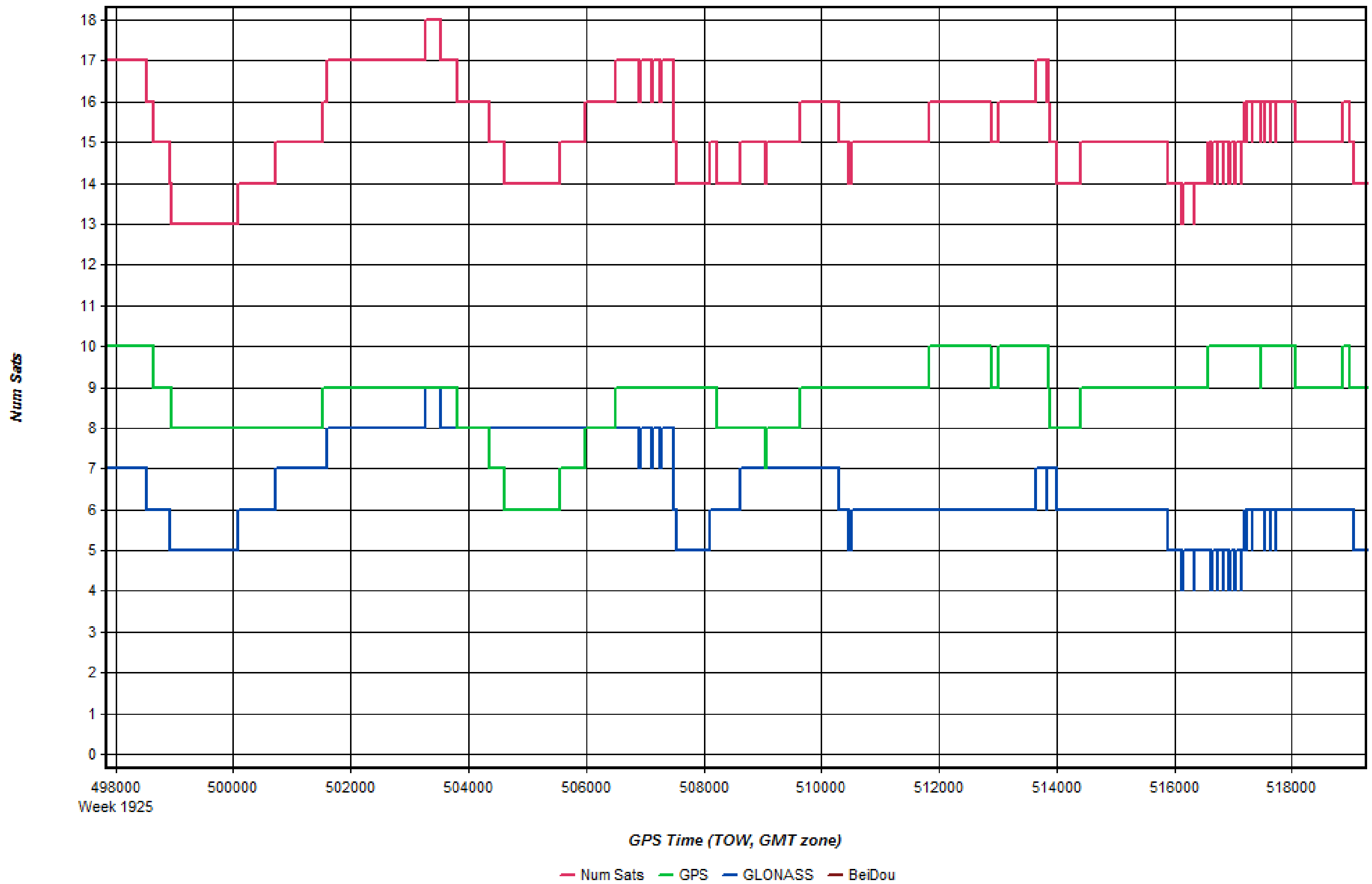
Plots by Mission: Coverage Map, Estimated Position Accuracy, Number of Satellites, Combined Separation, and PDOP.

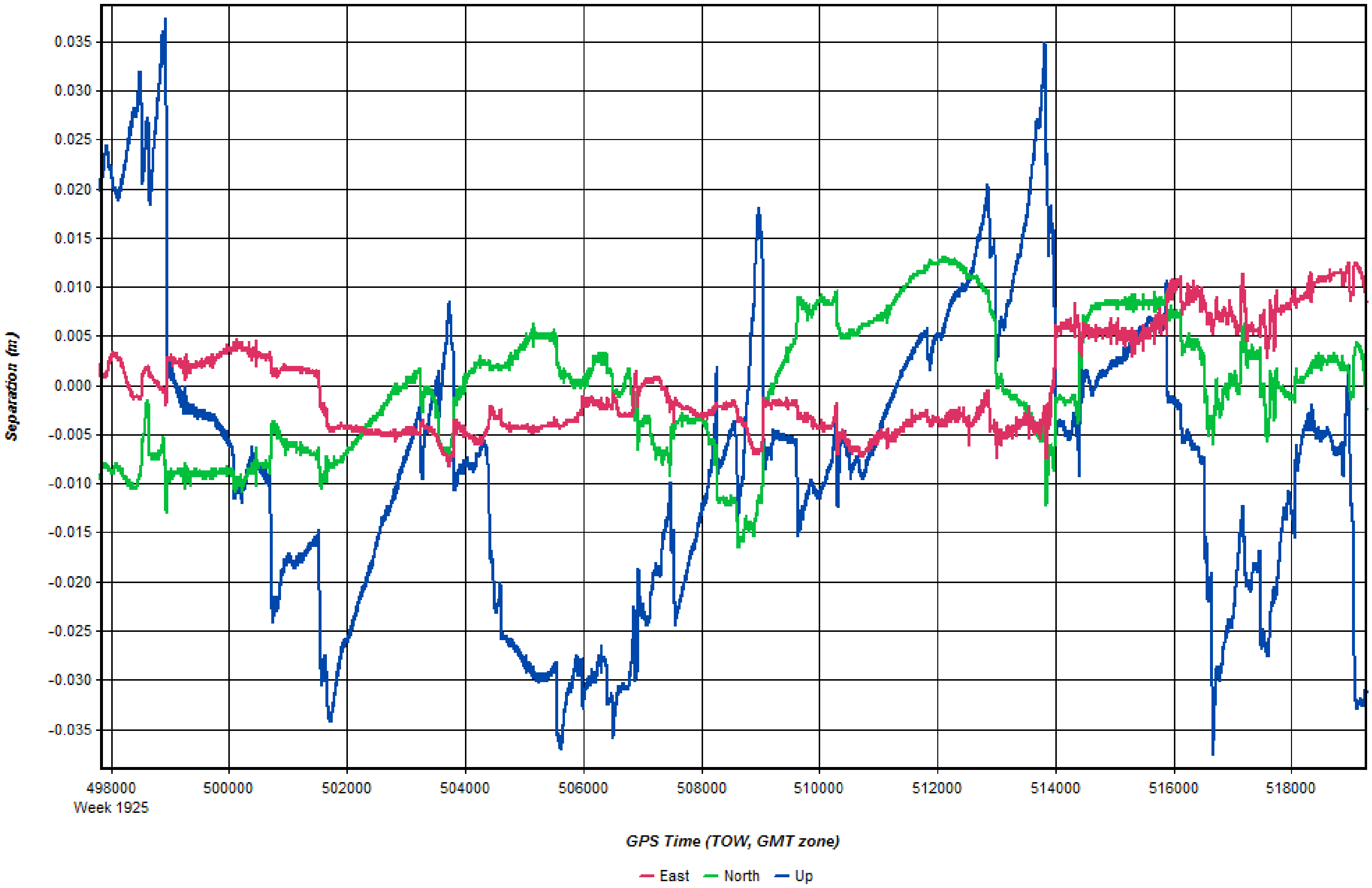
Coverage Map	The Coverage Map plot shows the Aircraft GNSS-IMU Trajectory in reference to localized GNSS Reference Stations.
Estimated Position Accuracy	The Estimated Position Accuracy plot shows the standard deviations of the east, north, and up directions versus time for the solution. The total standard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

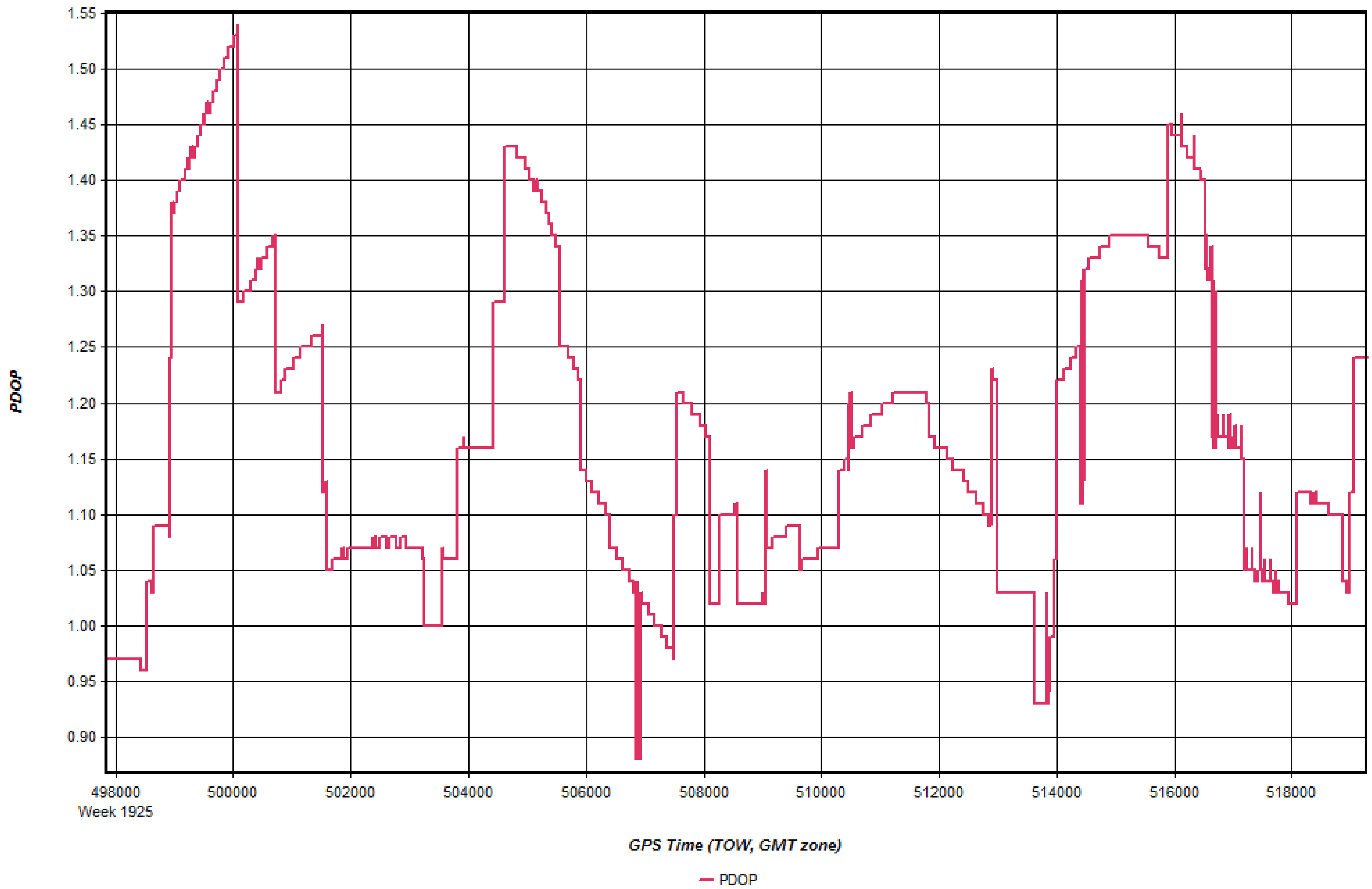
225_20161202_1



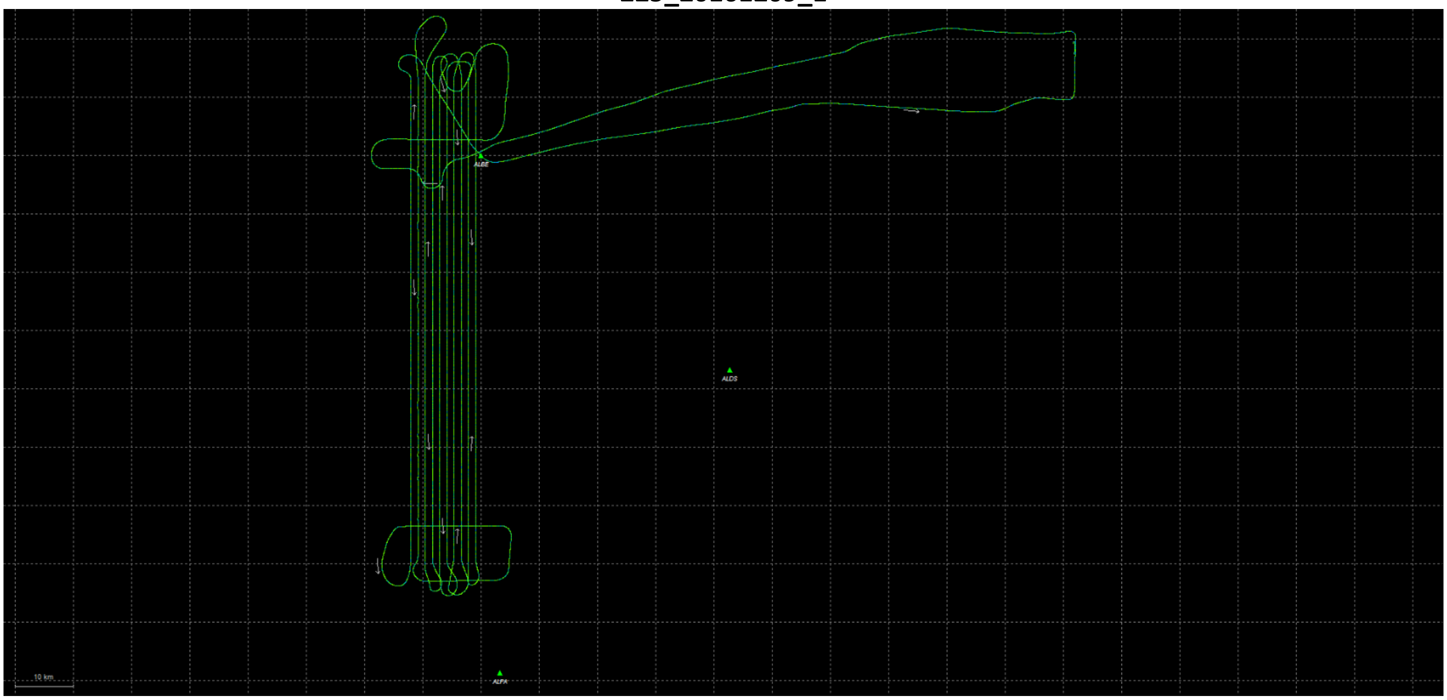

Estimated StdDev (m)
0.0085
0.0080
0.0075
0.0070
0.0065
0.0060
0.0055
0.0050
0.0045
0.0040
0.0035
0.0030
498000
Week 1925
500000
502000
504000
506000
508000
510000
512000
514000
516000
518000
GPS Time (TOW, GMT zone)
East
North
Height
Trace

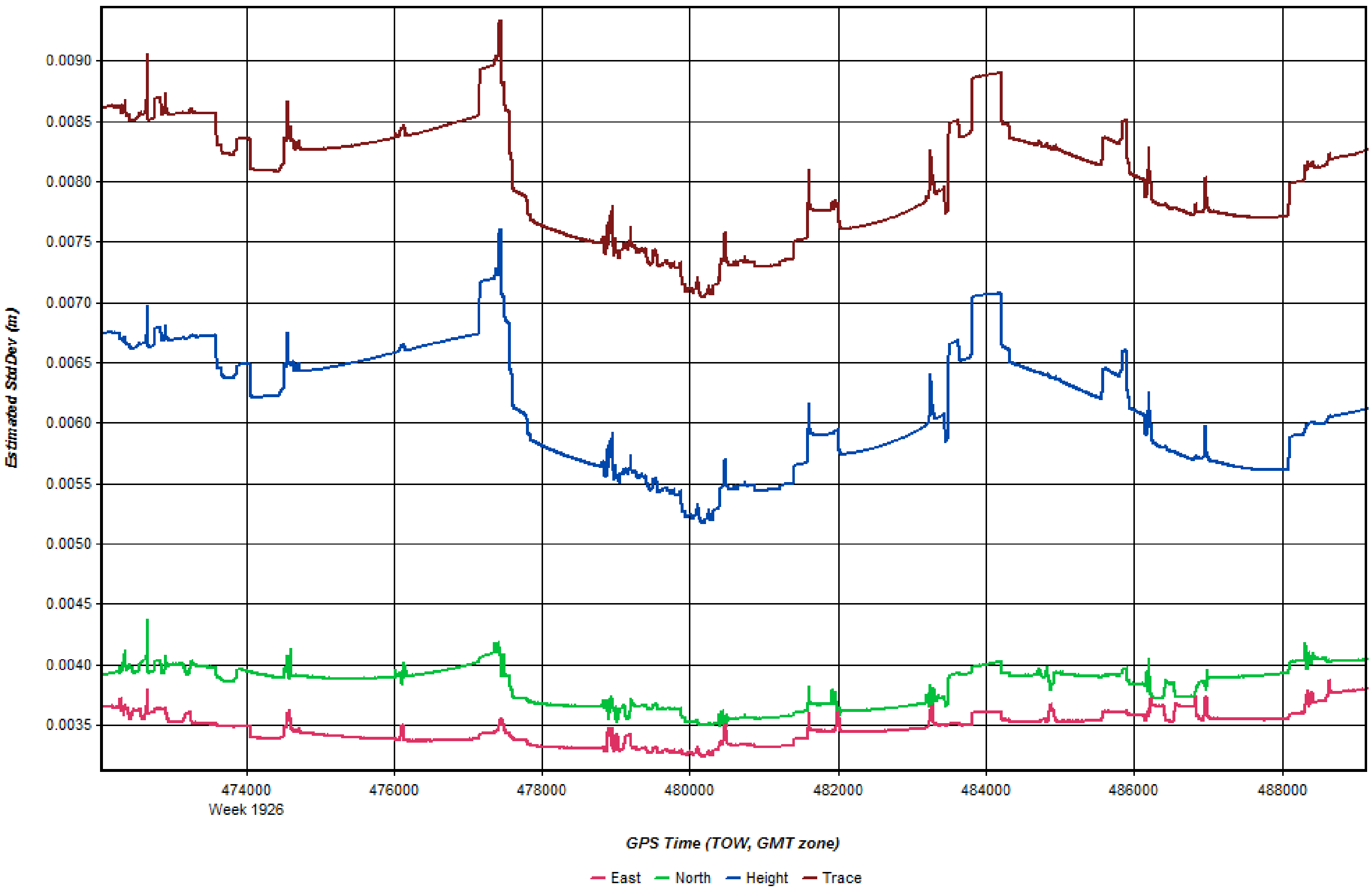

Num Sats
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
498000
Week 1925
500000
502000
504000
506000
508000
510000
512000
514000
516000
518000
GPS Time (TOW, GMT zone)
Num Sats
GPS
GLONASS
BeiDou

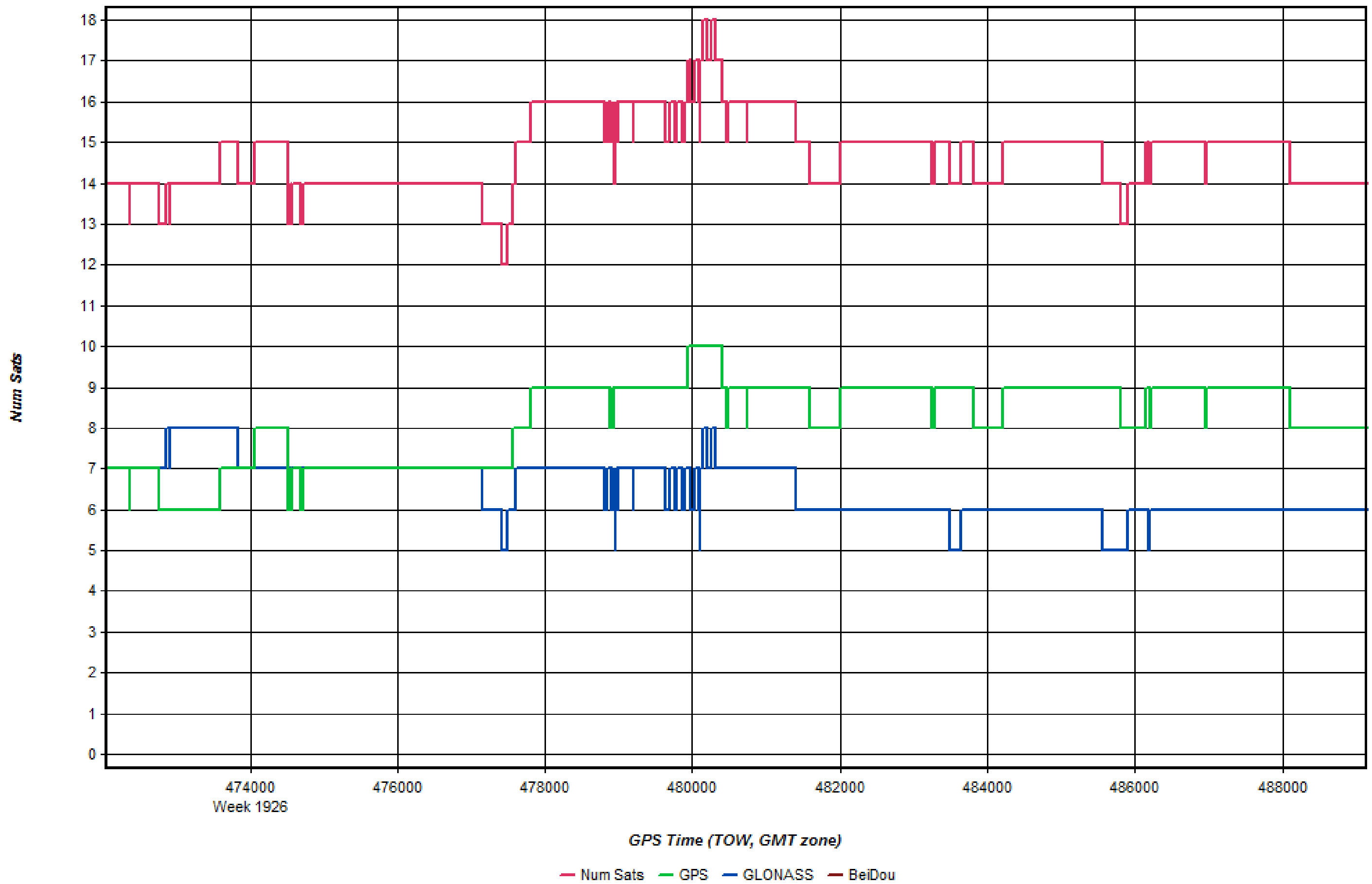

0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
-0.005
-0.010
-0.015
-0.020
-0.025
-0.030
-0.035
Separation (m)
498000
Week 1925
500000
502000
504000
506000
508000
510000
512000
514000
516000
518000
GPS Time (TOW, GMT zone)
East
North
Up

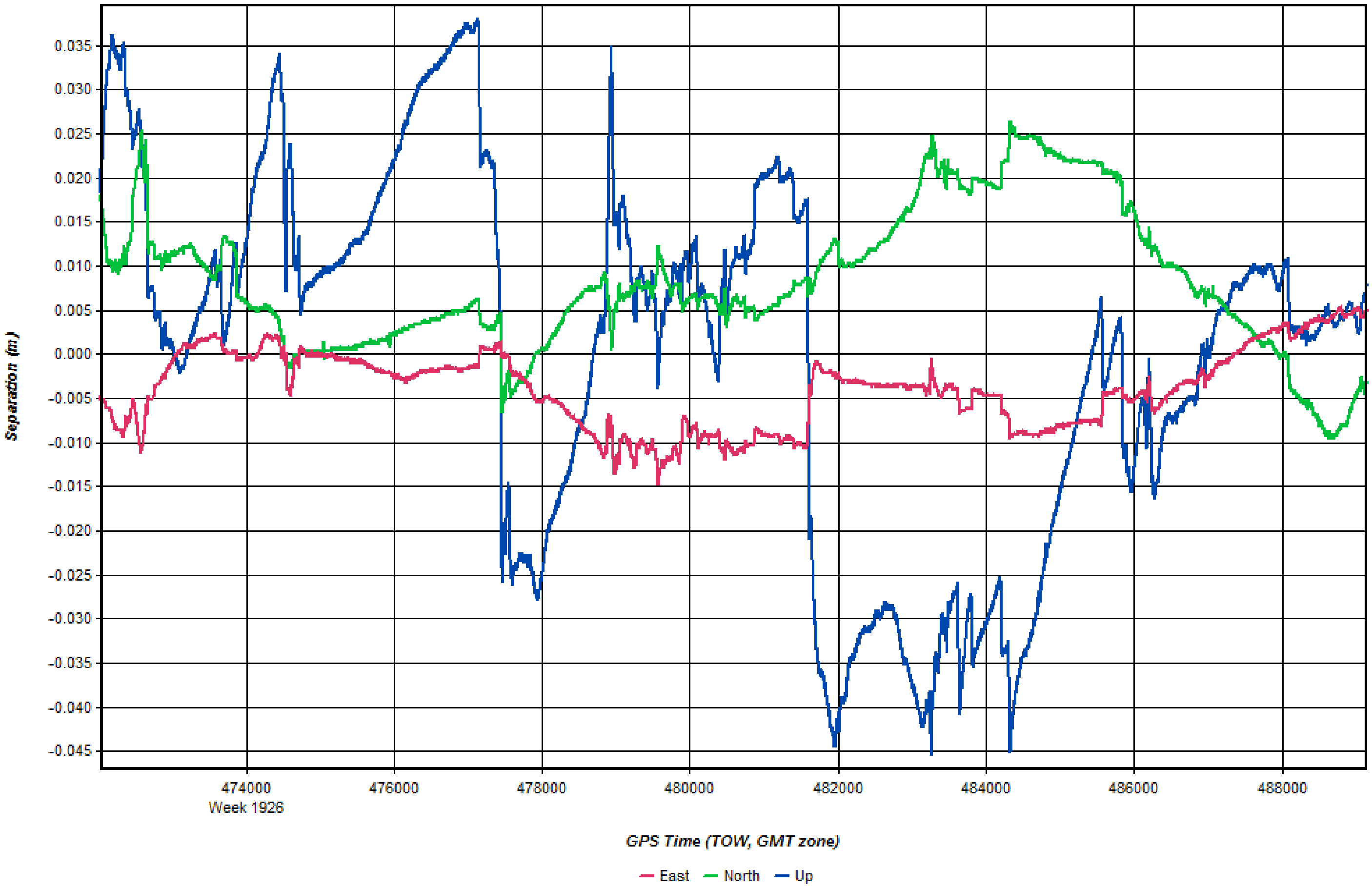

PDOP
1.55
1.50
1.45
1.40
1.35
1.30
1.25
1.20
1.15
1.10
1.05
1.00
0.95
0.90
498000
Week 1925
500000
502000
504000
506000
508000
510000
512000
514000
516000
518000
GPS Time (TOW, GMT zone)
PDOP

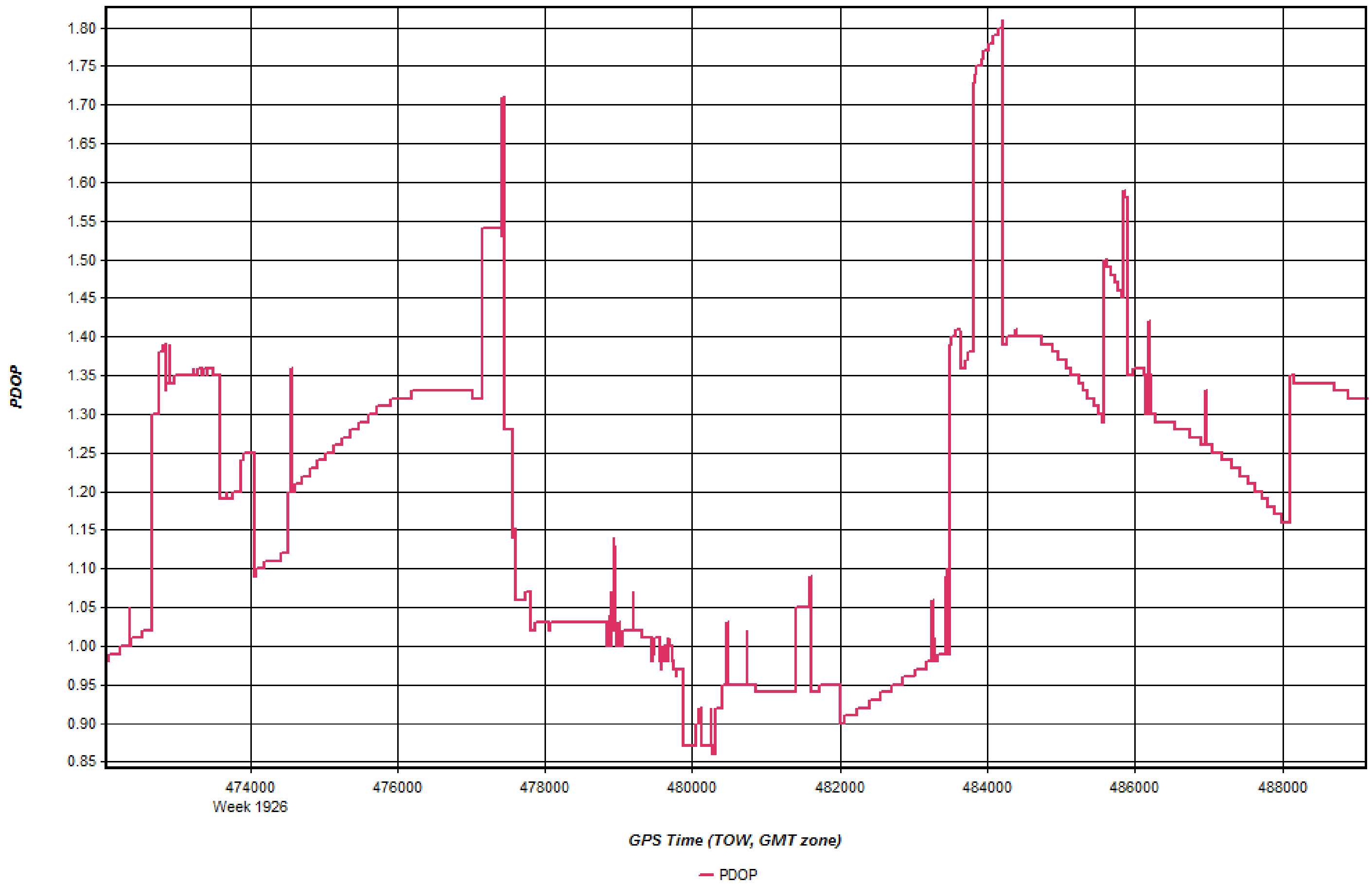
225_20161209_1



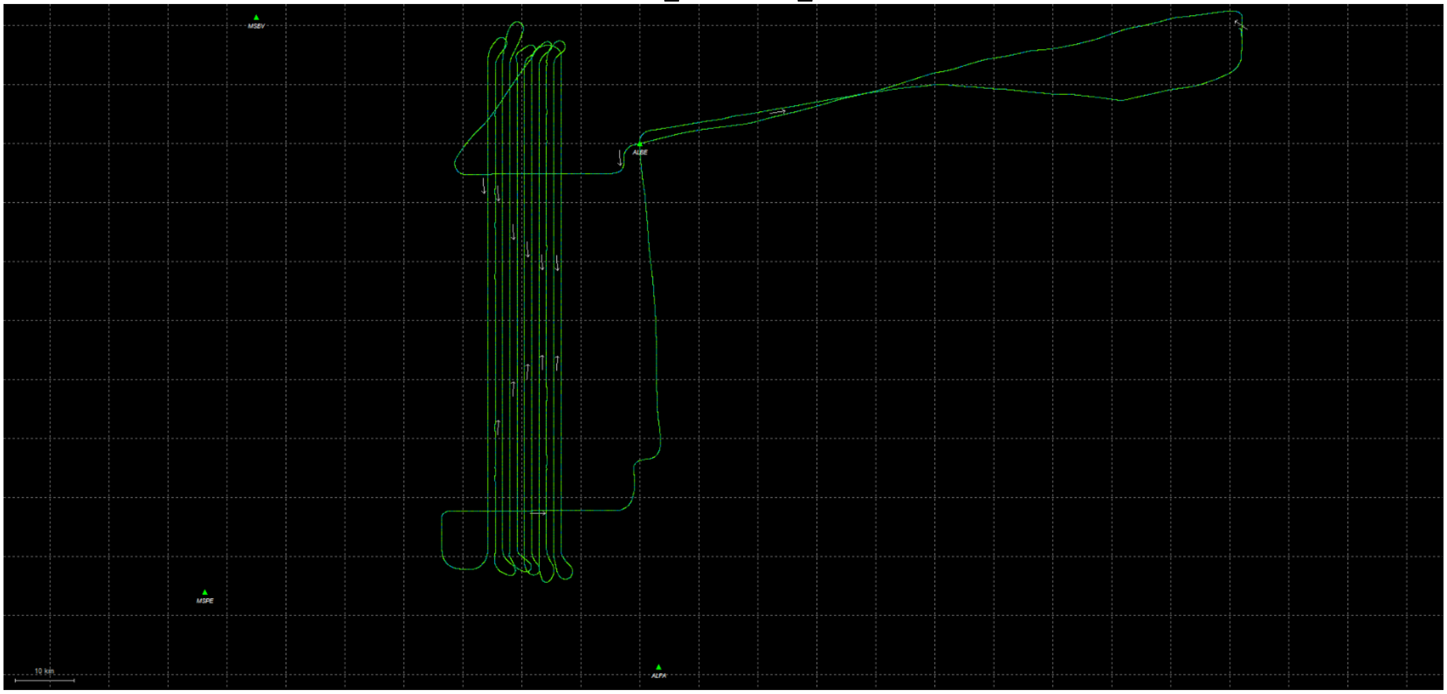

Estimated Std Dev (m)
0.0090
0.0085
0.0080
0.0075
0.0070
0.0065
0.0060
0.0055
0.0050
0.0045
0.0040
0.0035
474000
Week 1926
476000
478000
480000
482000
484000
486000
488000
GPS Time (TOW, GMT zone)
East
North
Height
Trace

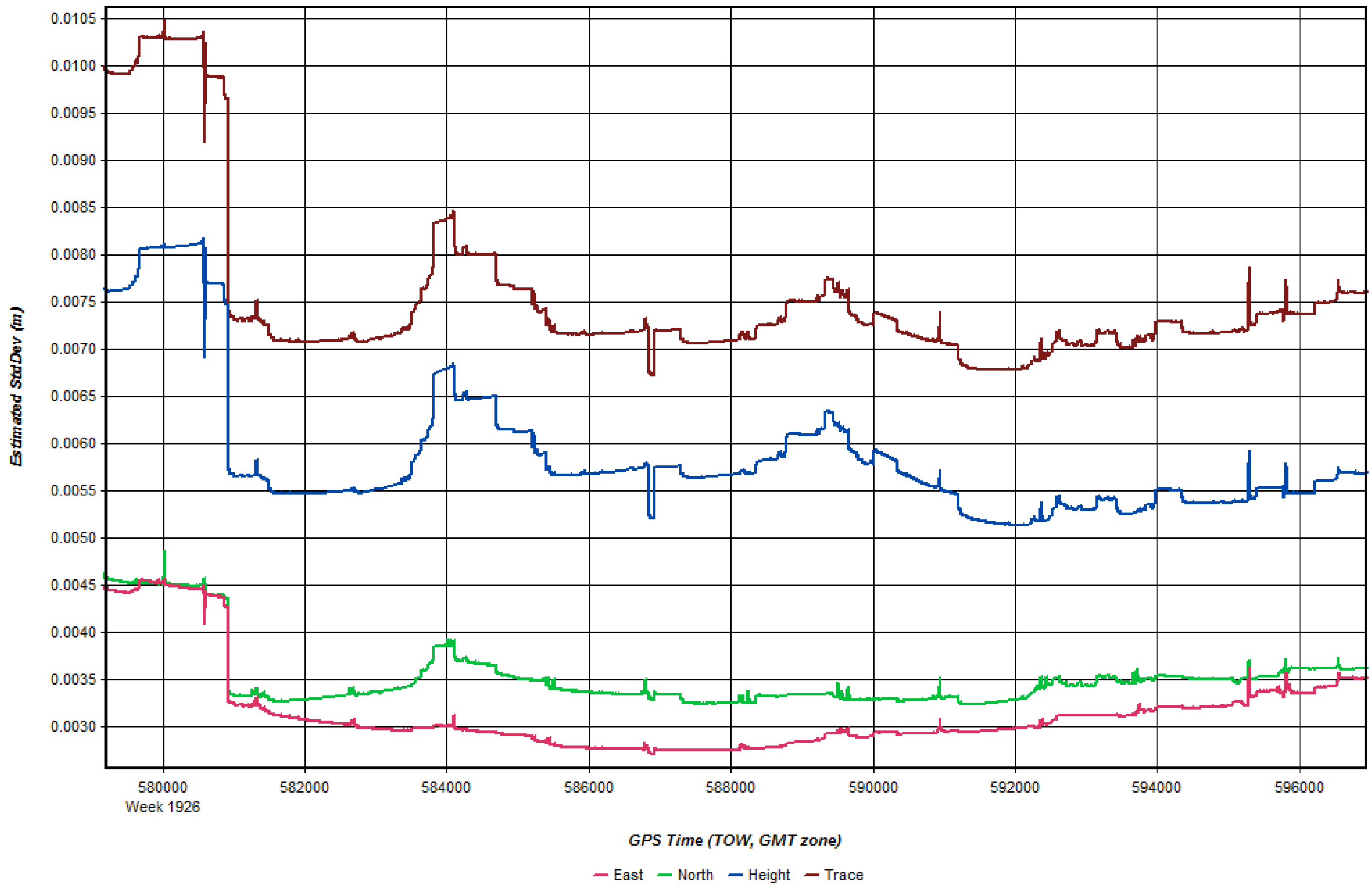

Num Sats
GPS Time (TOW, GMT zone)
474000
Week 1926
476000
478000
480000
482000
484000
486000
488000
Num Sats
GPS
GLONASS
BeiDou

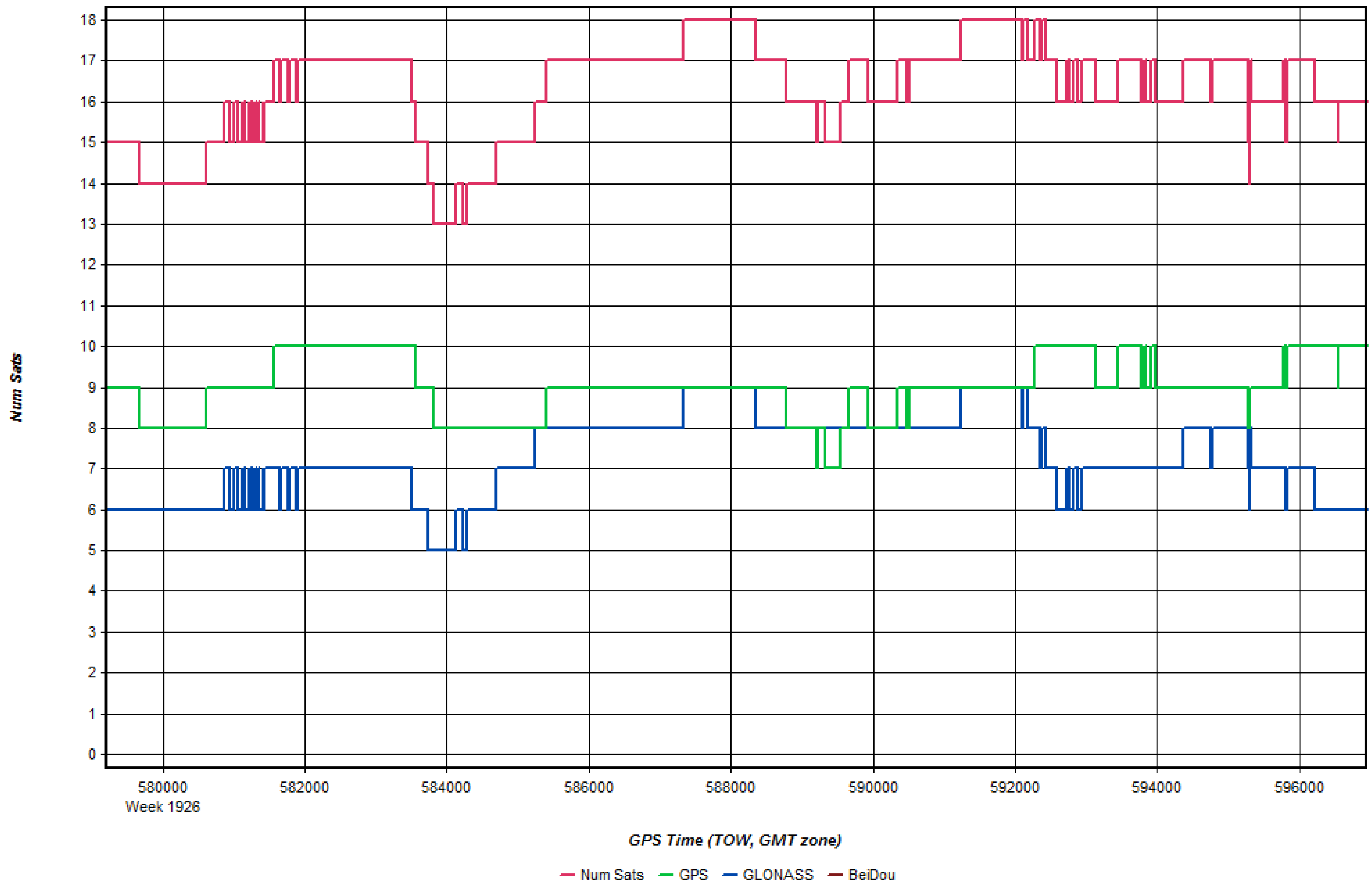

Separation (m)
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
-0.005
-0.010
-0.015
-0.020
-0.025
-0.030
-0.035
-0.040
-0.045
474000
Week 1926
476000
478000
480000
482000
484000
486000
488000
GPS Time (TOW, GMT zone)
East
North
Up

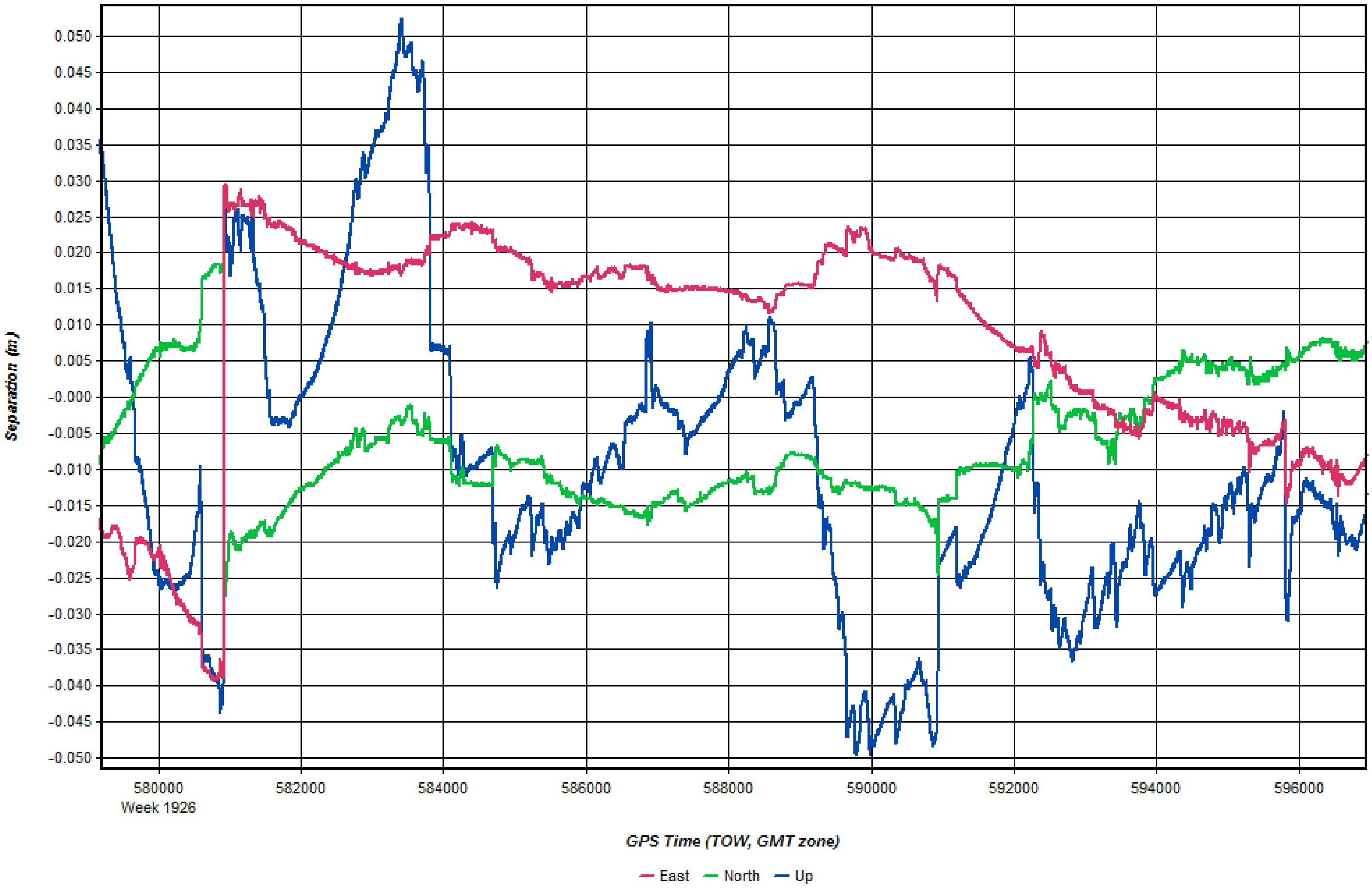

1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1.25
1.20
1.15
1.10
1.05
1.00
0.95
0.90
0.85
PDOP
474000
Week 1926
476000
478000
480000
482000
484000
486000
488000
GPS Time (TOW, GMT zone)
PDOP

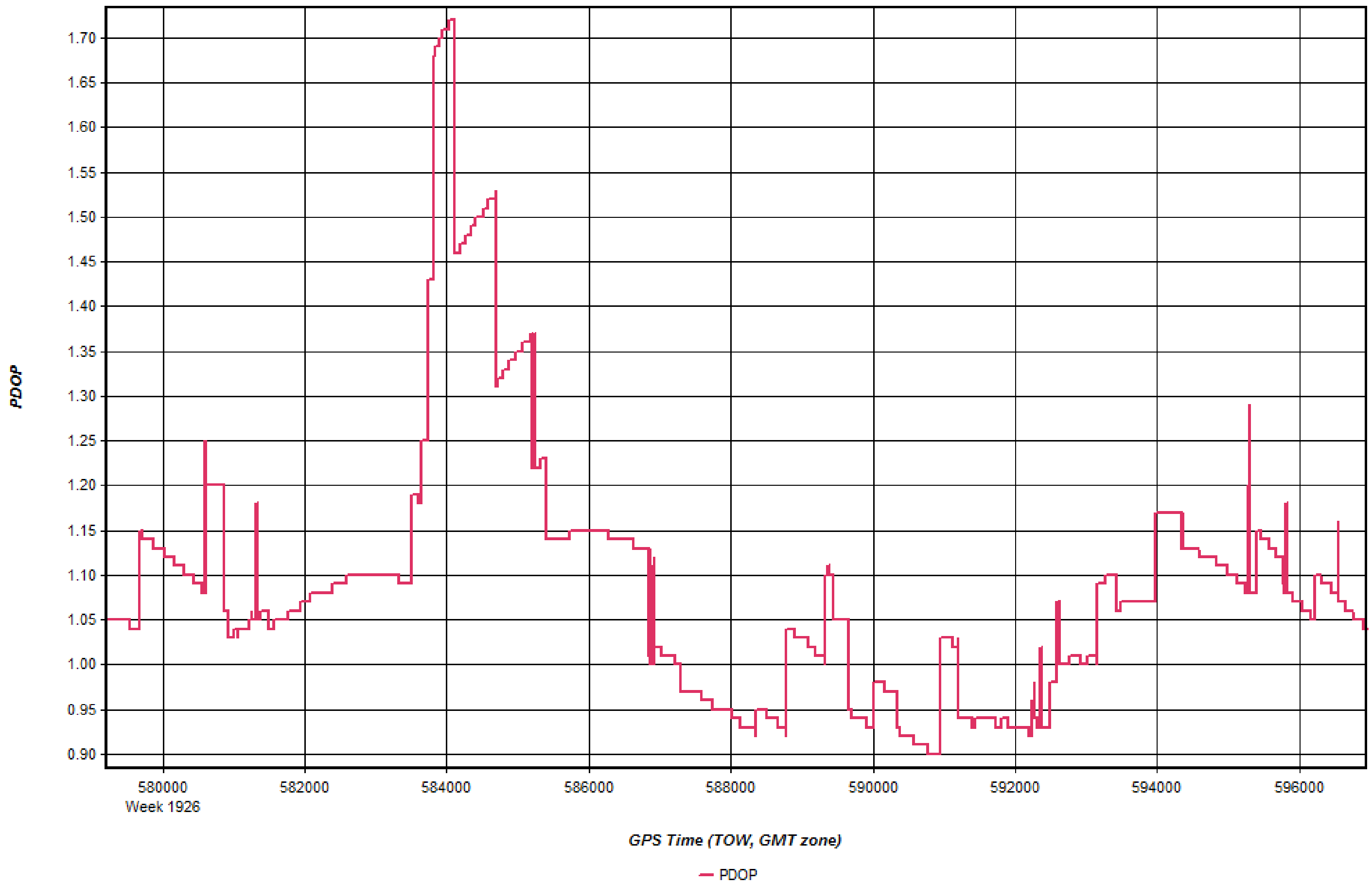
225_20161210_1



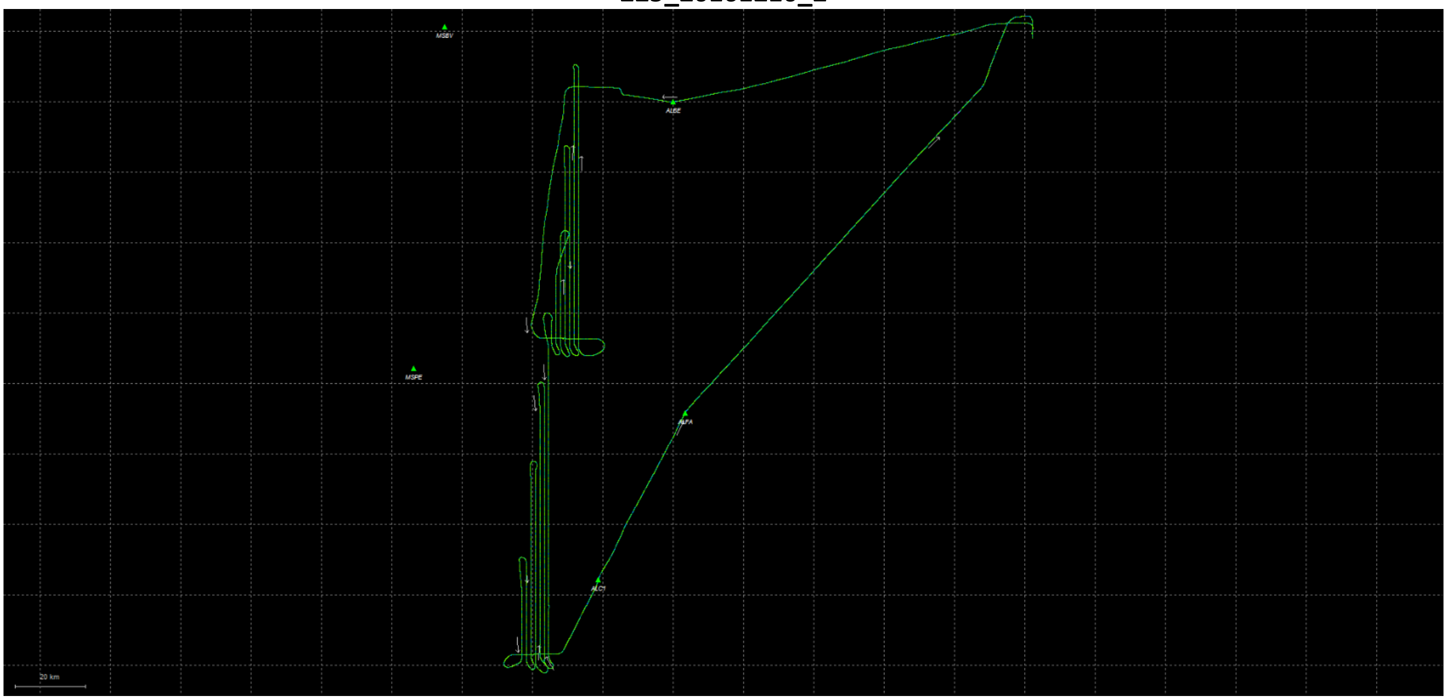

Estimated StdDev (m)
0.0105
0.0100
0.0095
0.0090
0.0085
0.0080
0.0075
0.0070
0.0065
0.0060
0.0055
0.0050
0.0045
0.0040
0.0035
0.0030
580000
Week 1926
582000
584000
586000
588000
590000
592000
594000
596000
GPS Time (TOW, GMT zone)
East
North
Height
Trace

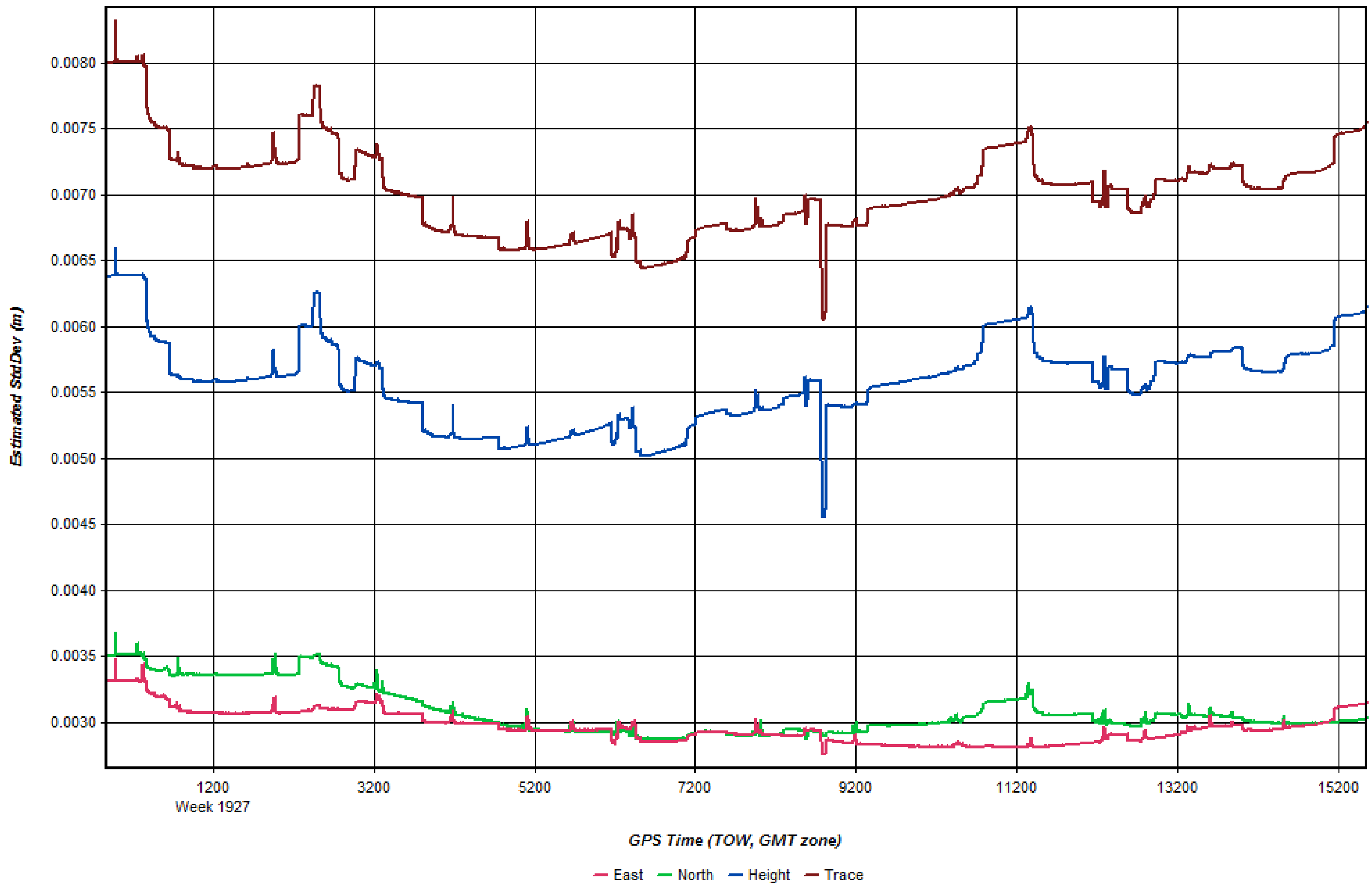

Num Sats
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
580000
Week 1926
582000
584000
586000
588000
590000
592000
594000
596000
GPS Time (TOW, GMT zone)
Num Sats
GPS
GLONASS
BeiDou

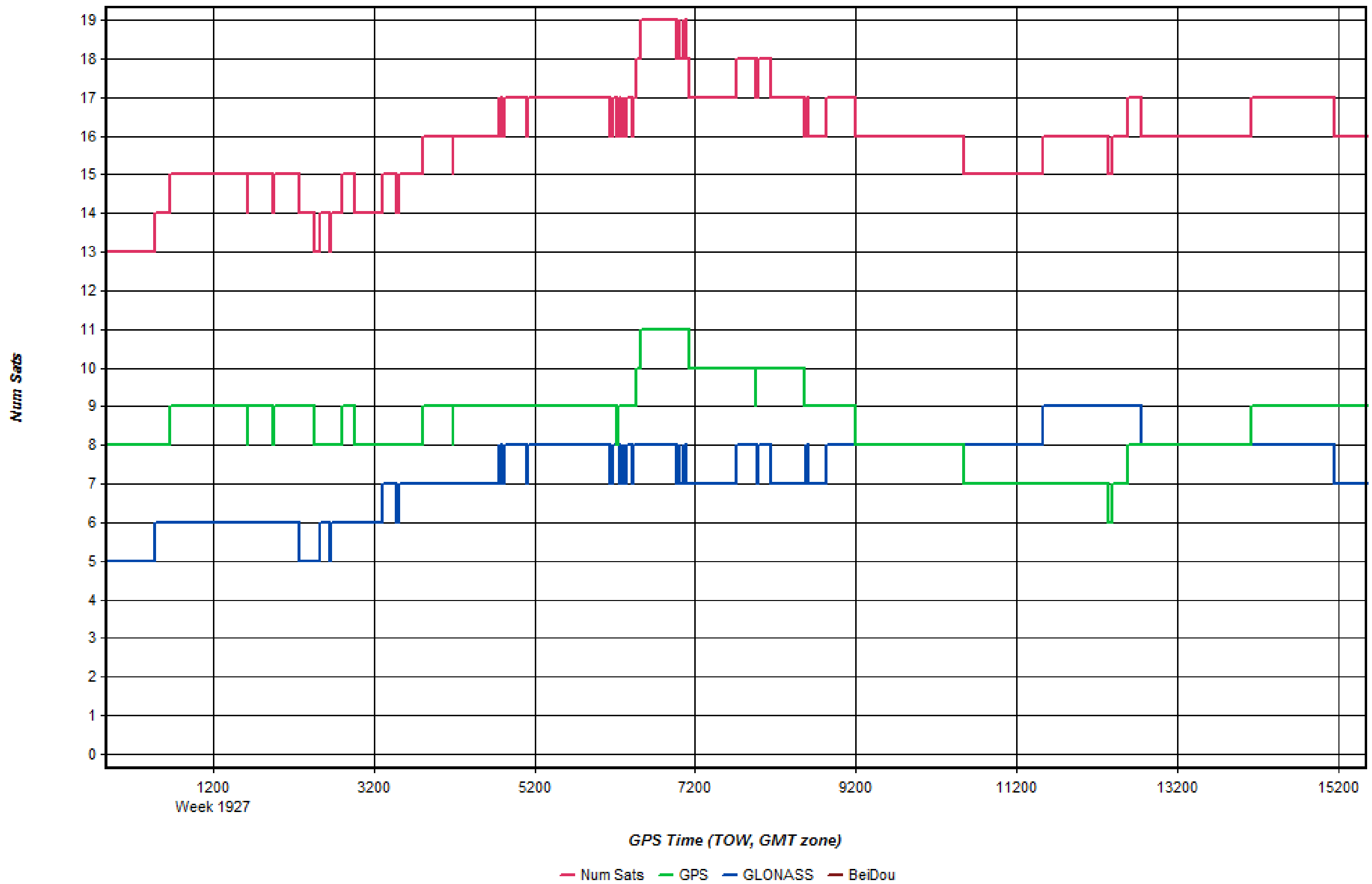

Separation (m)
0.050
0.045
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
-0.000
-0.005
-0.010
-0.015
-0.020
-0.025
-0.030
-0.035
-0.040
-0.045
-0.050
580000
Week 1926
582000
584000
586000
588000
590000
592000
594000
596000
GPS Time (TOW, GMT zone)
East
North
Up

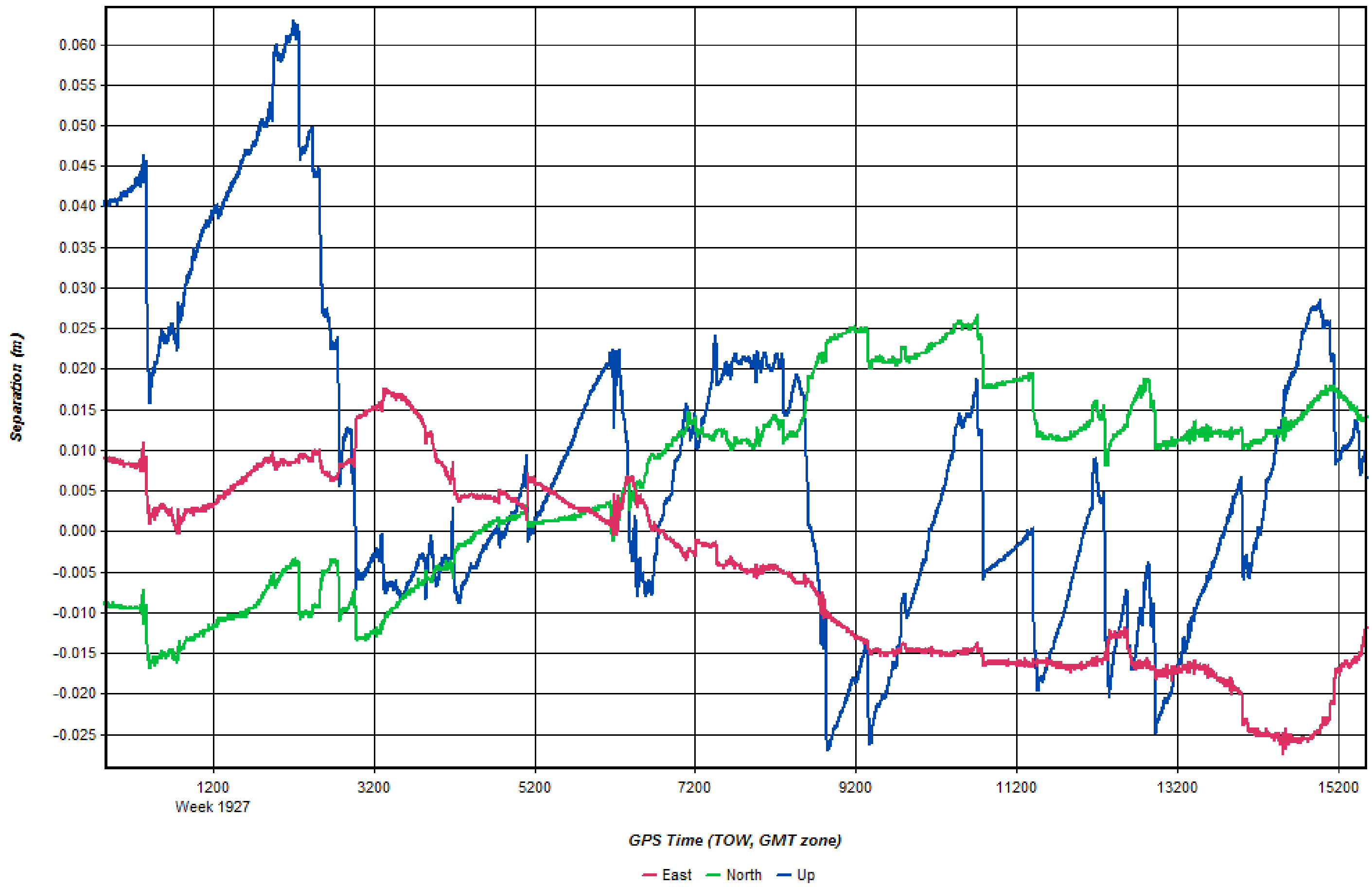

PDOP
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1.25
1.20
1.15
1.10
1.05
1.00
0.95
0.90
580000
Week 1926
582000
584000
586000
588000
590000
592000
594000
596000
GPS Time (TOW, GMT zone)
PDOP

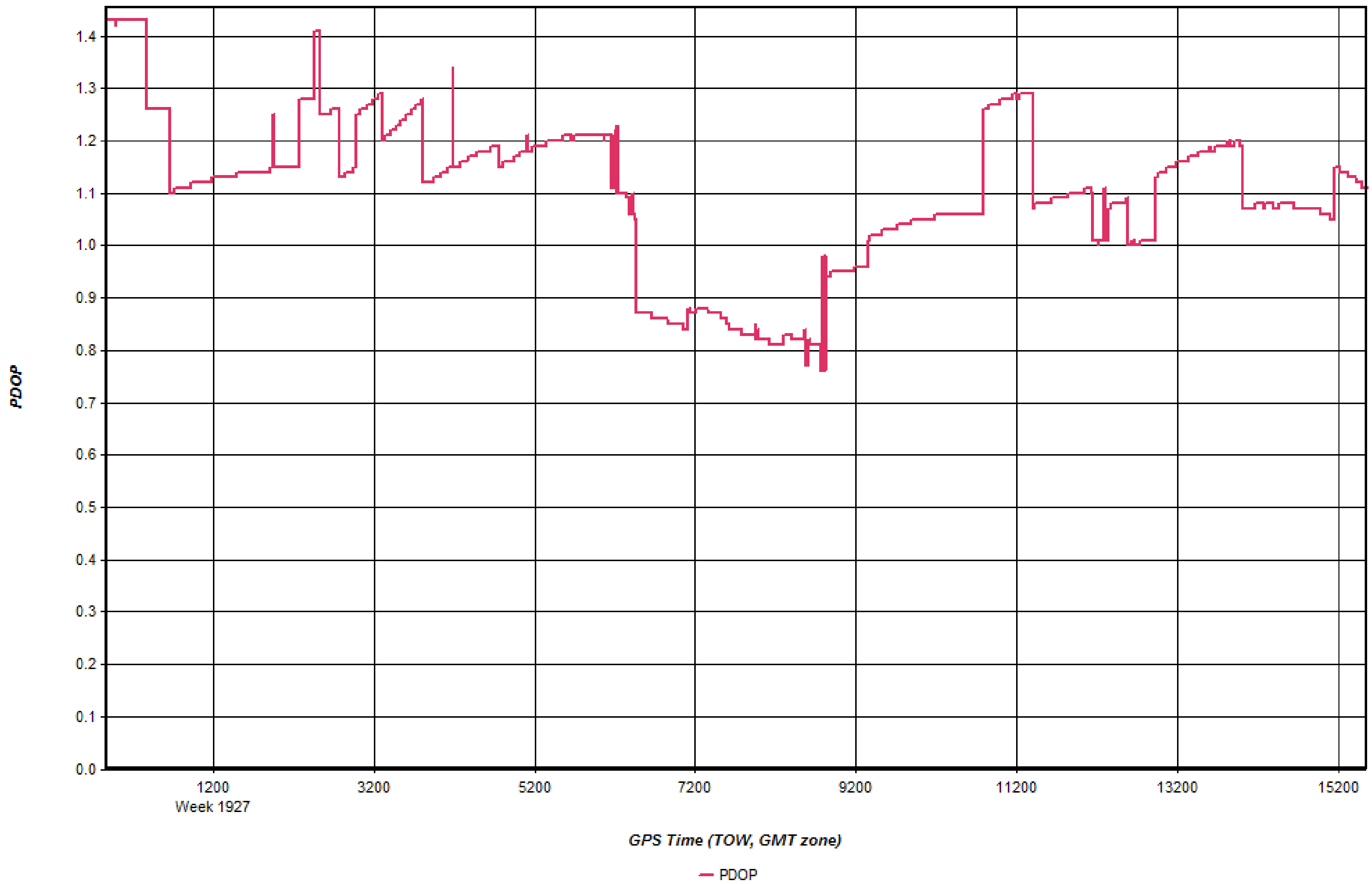
225_20161210_2



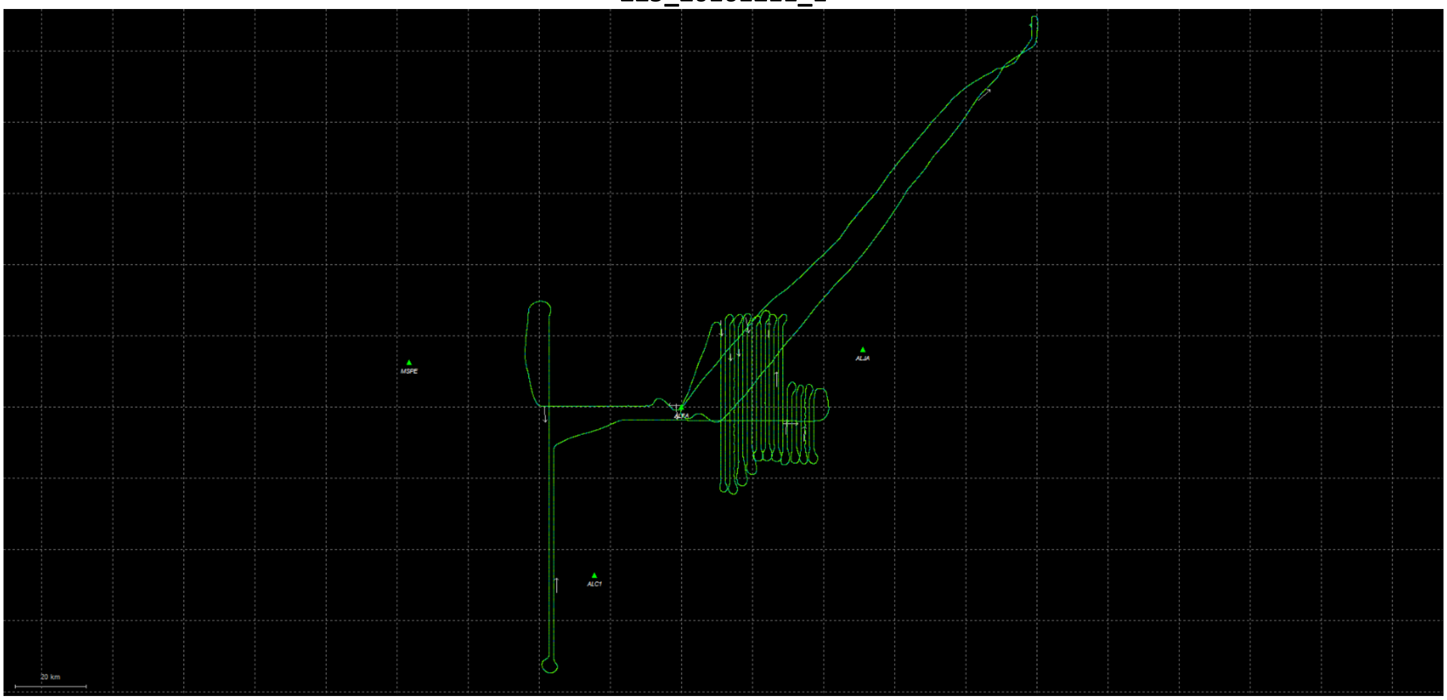

Estimated StdDev (m)
0.0080
0.0075
0.0070
0.0065
0.0060
0.0055
0.0050
0.0045
0.0040
0.0035
0.0030
1200
Week 1927
3200
5200
7200
9200
11200
13200
15200
GPS Time (TOW, GMT zone)
East
North
Height
Trace

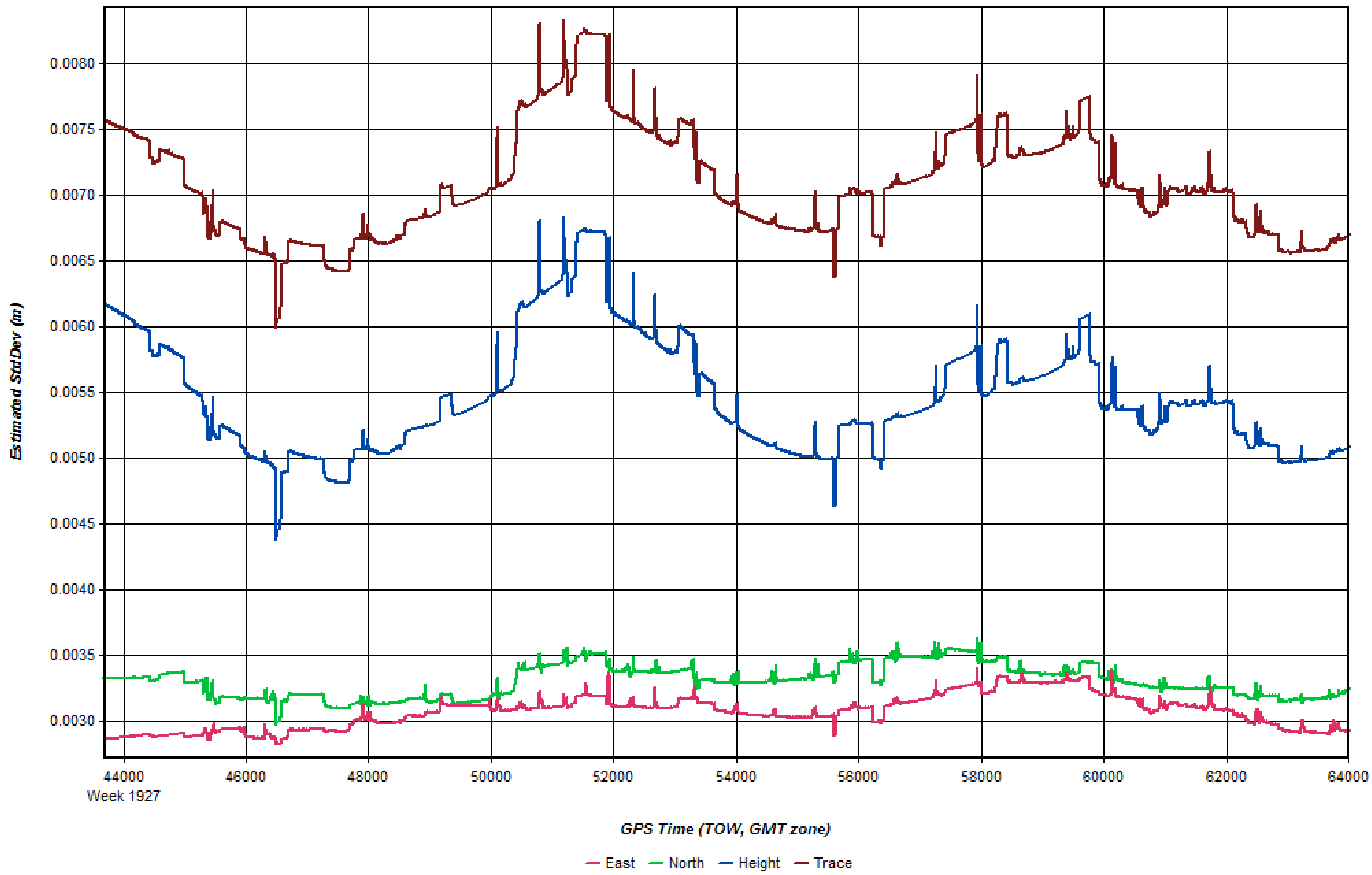

Num Sats
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
1200
Week 1927
3200
5200
7200
9200
11200
13200
15200
GPS Time (TOW, GMT zone)
Num Sats
GPS
GLONASS
BeiDou

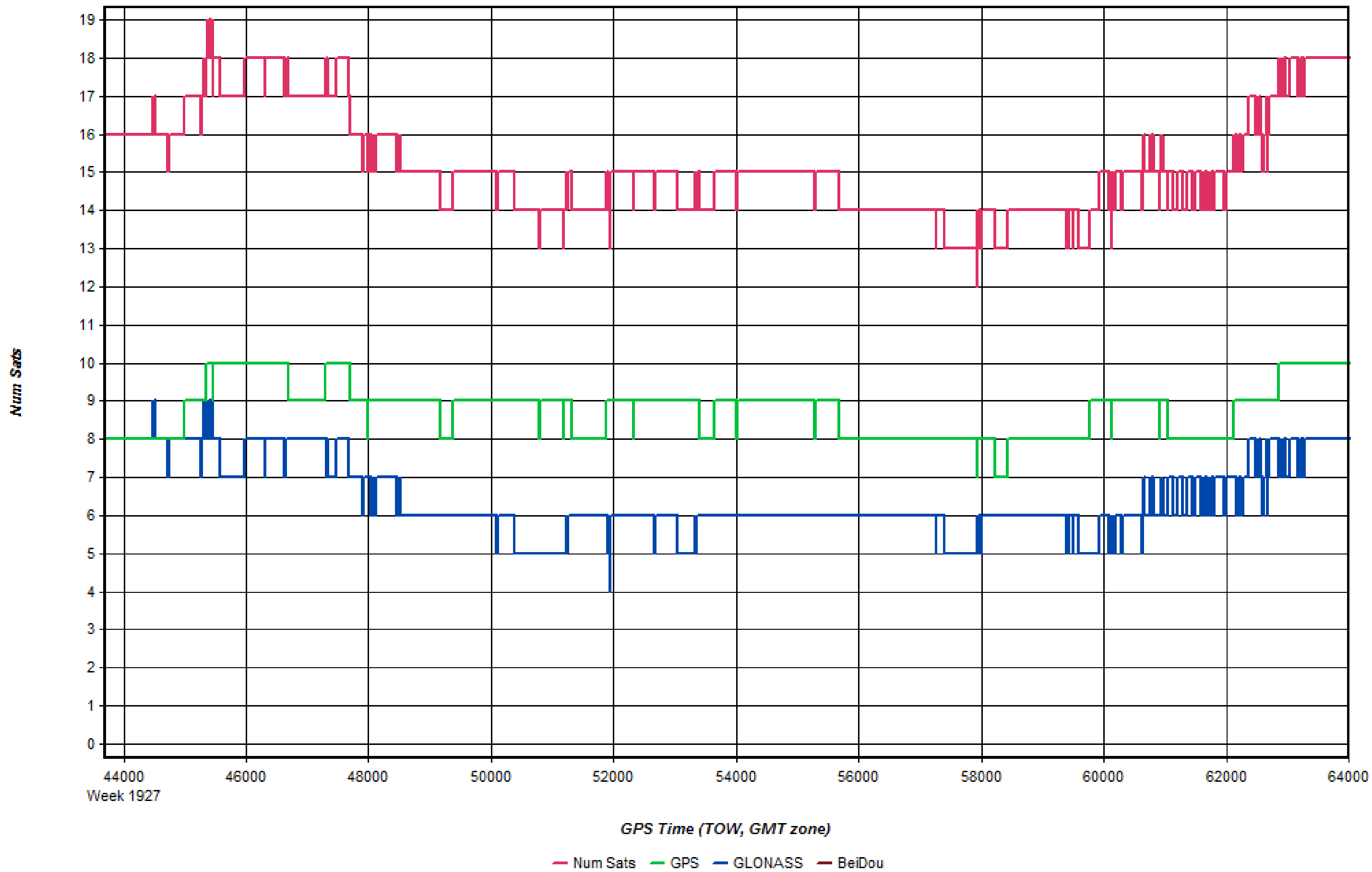

0.060
0.055
0.050
0.045
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
-0.005
-0.010
-0.015
-0.020
-0.025
Separation (m)
1200
Week 1927
3200
5200
7200
9200
11200
13200
15200
GPS Time (TOW, GMT zone)
East
North
Up

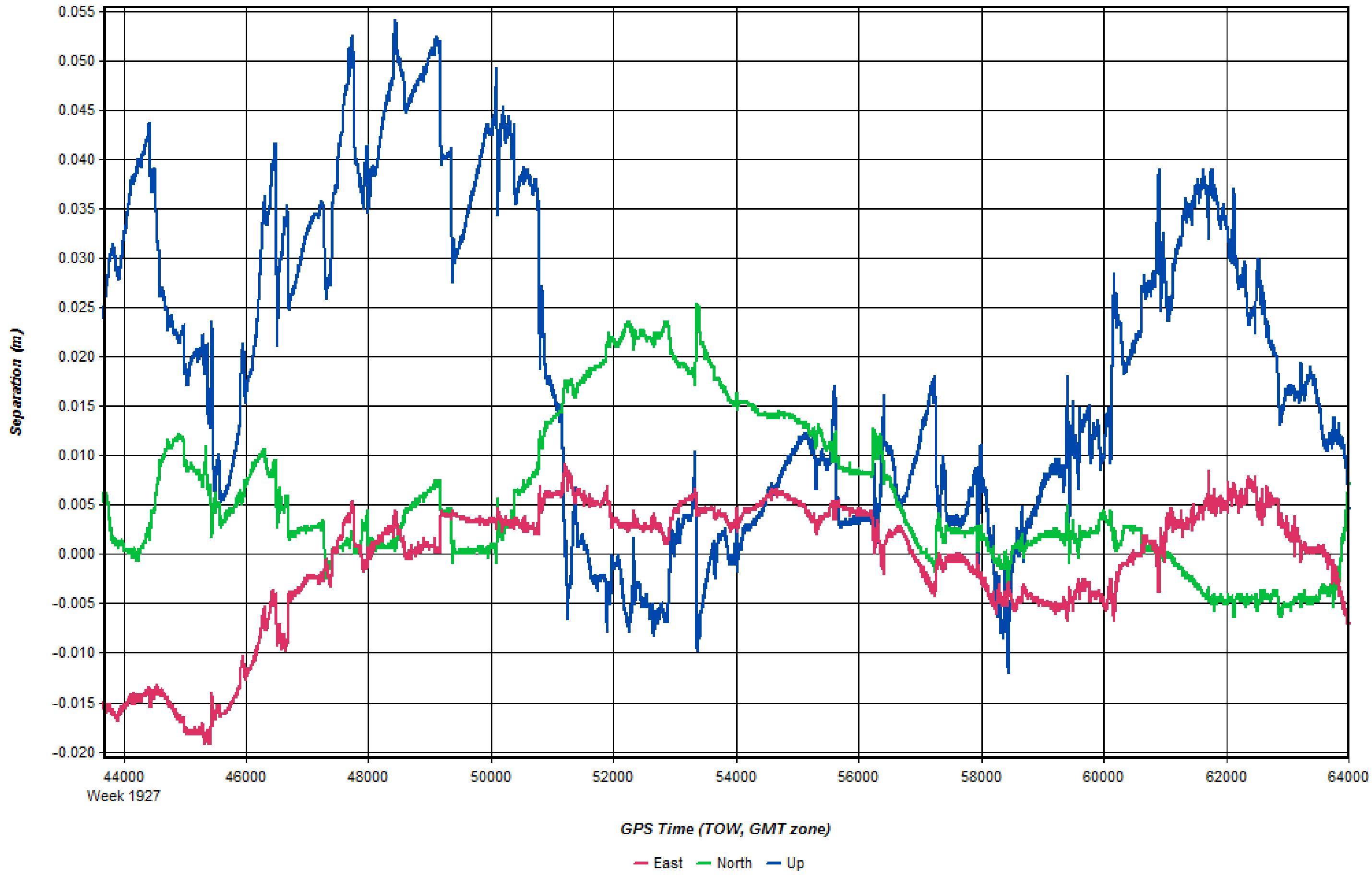

PDOP
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
1200
Week 1927
3200
5200
7200
9200
11200
13200
15200
GPS Time (TOW, GMT zone)
PDOP

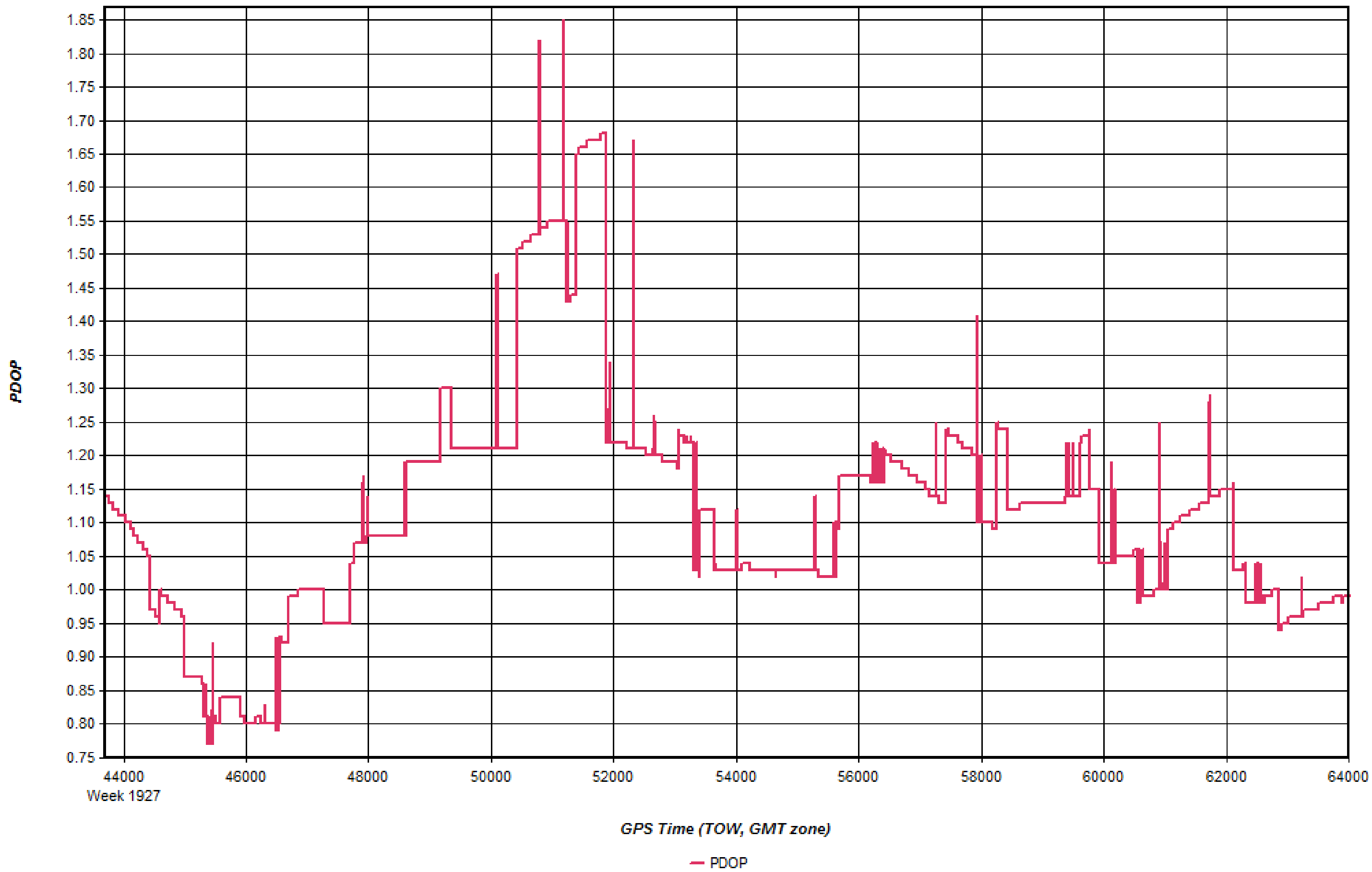
225_20161211_1



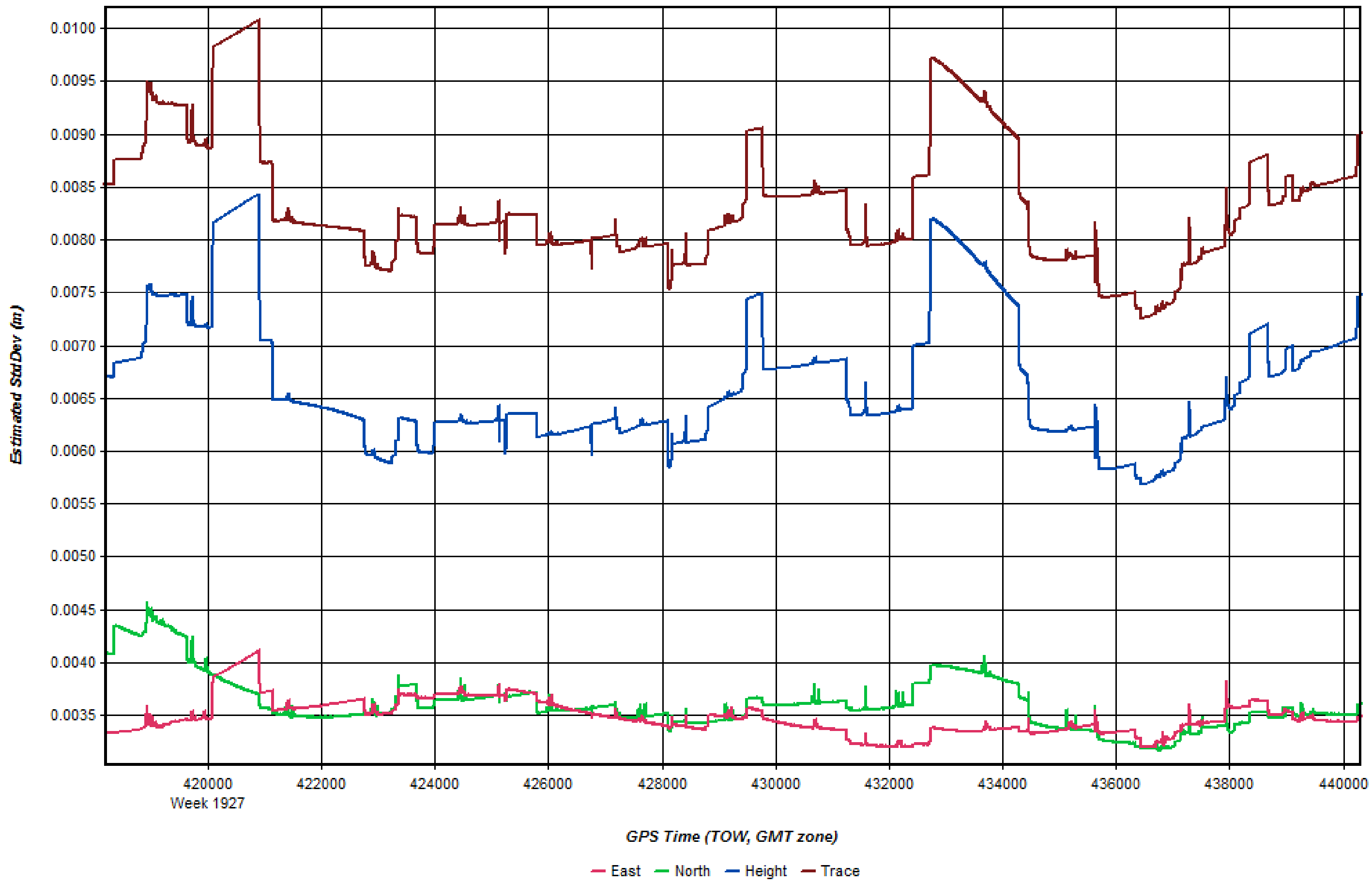

Estimated StdDev (m)
0.0080
0.0075
0.0070
0.0065
0.0060
0.0055
0.0050
0.0045
0.0040
0.0035
0.0030
44000
Week 1927
46000
48000
50000
52000
54000
56000
58000
60000
62000
64000
GPS Time (TOW, GMT zone)
East
North
Height
Trace

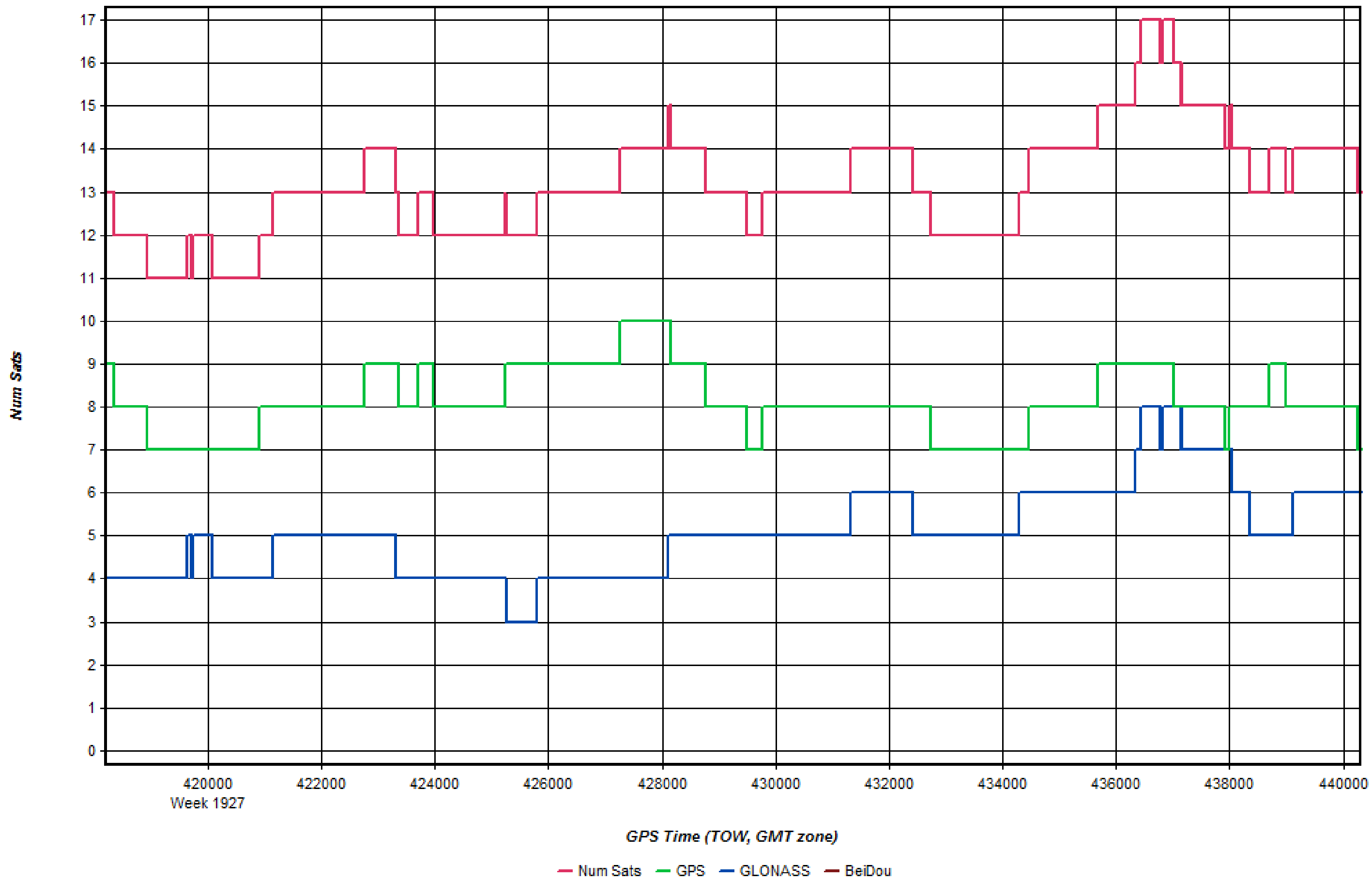

Num Sats
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
44000
Week 1927
46000
48000
50000
52000
54000
56000
58000
60000
62000
64000
GPS Time (TOW, GMT zone)
Num Sats
GPS
GLONASS
BeiDou

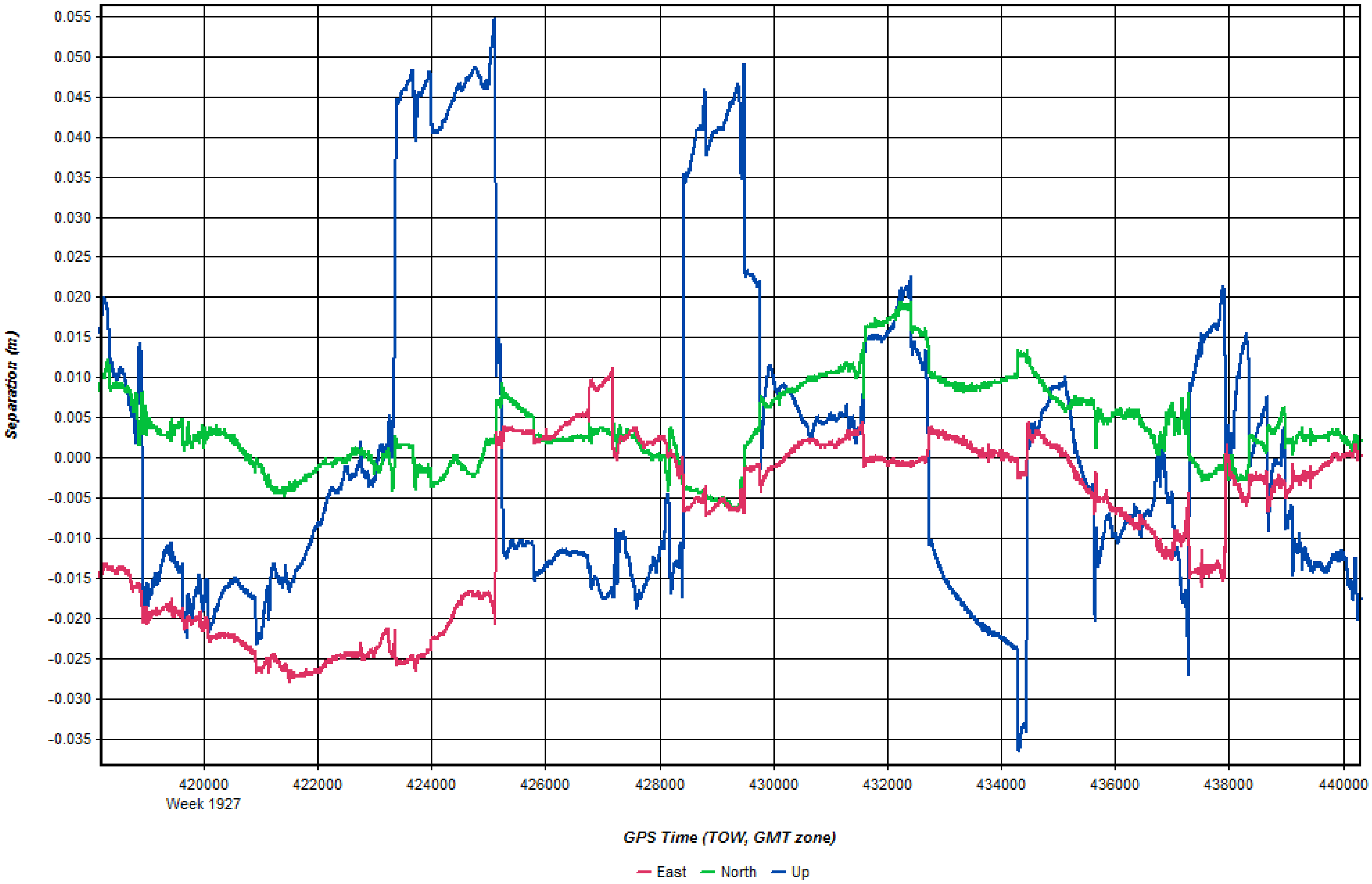

Separation (m)
0.055
0.050
0.045
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
-0.005
-0.010
-0.015
-0.020
44000
Week 1927
46000
48000
50000
52000
54000
56000
58000
60000
62000
64000
GPS Time (TOW, GMT zone)
East
North
Up

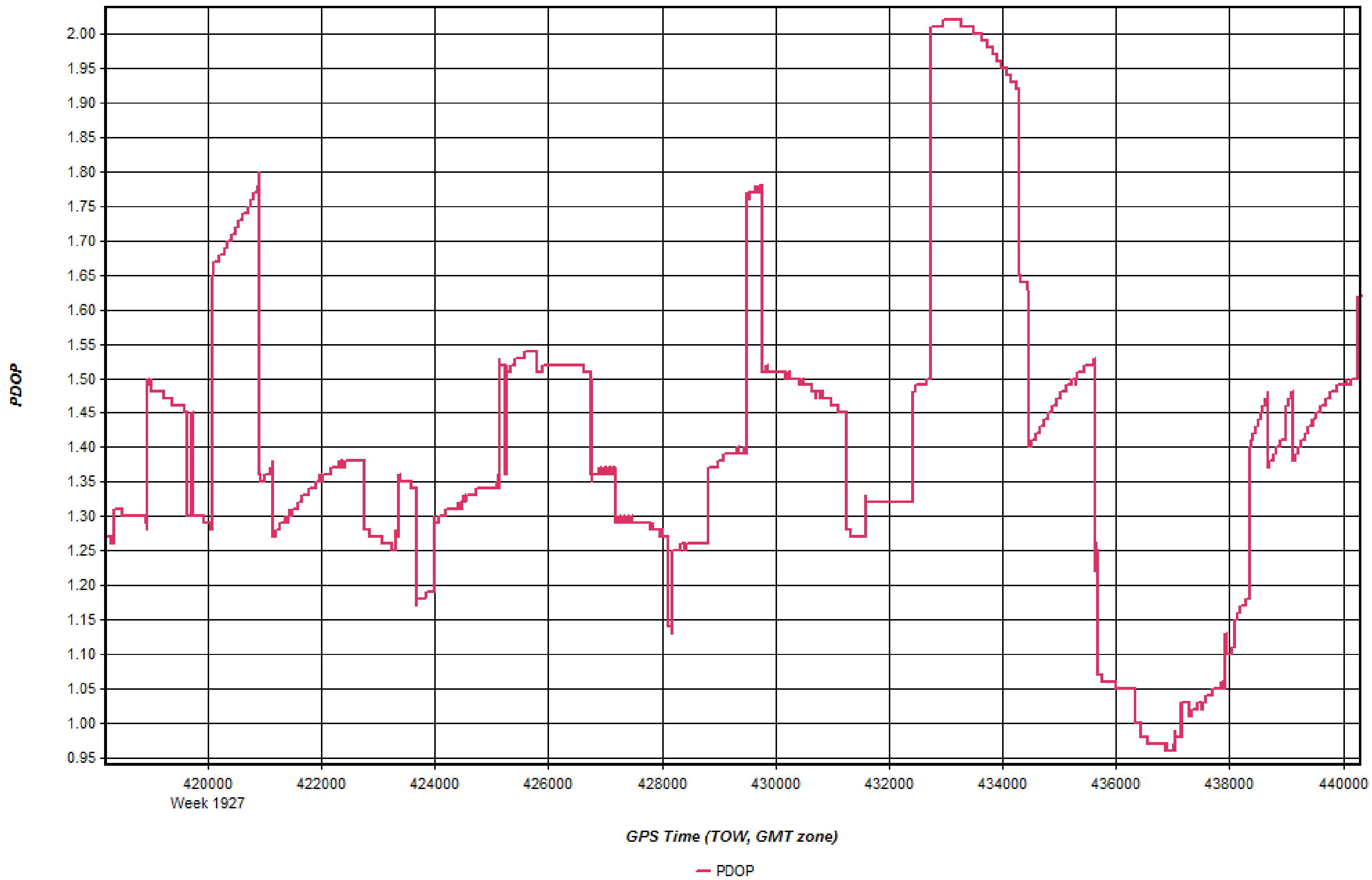

PDOP
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1.25
1.20
1.15
1.10
1.05
1.00
0.95
0.90
0.85
0.80
0.75
44000
Week 1927
46000
48000
50000
52000
54000
56000
58000
60000
62000
64000
GPS Time (TOW, GMT zone)
PDOP

225_20161215_2

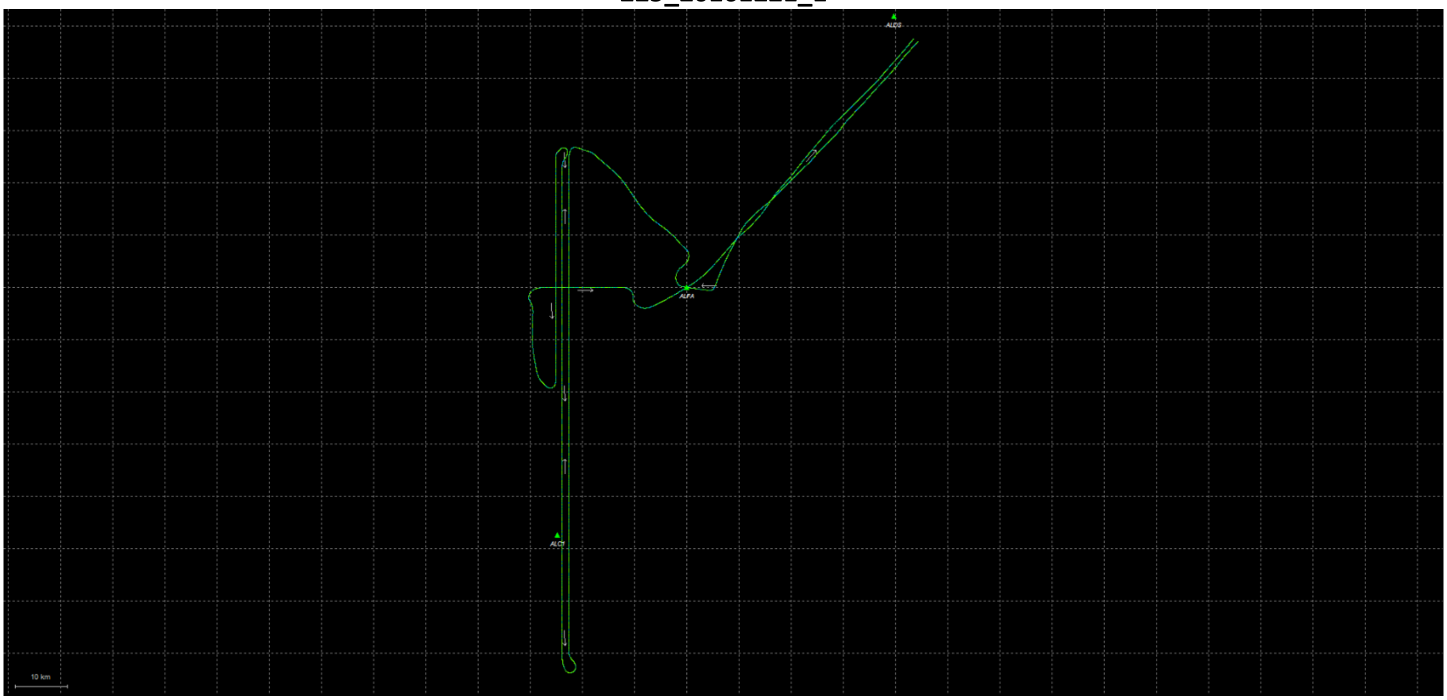

Estimated StdDev (m)
0.0100
0.0095
0.0090
0.0085
0.0080
0.0075
0.0070
0.0065
0.0060
0.0055
0.0050
0.0045
0.0040
0.0035
420000
Week 1927
422000
424000
426000
428000
430000
432000
434000
436000
438000
440000
GPS Time (TOW, GMT zone)
East
North
Height
Trace

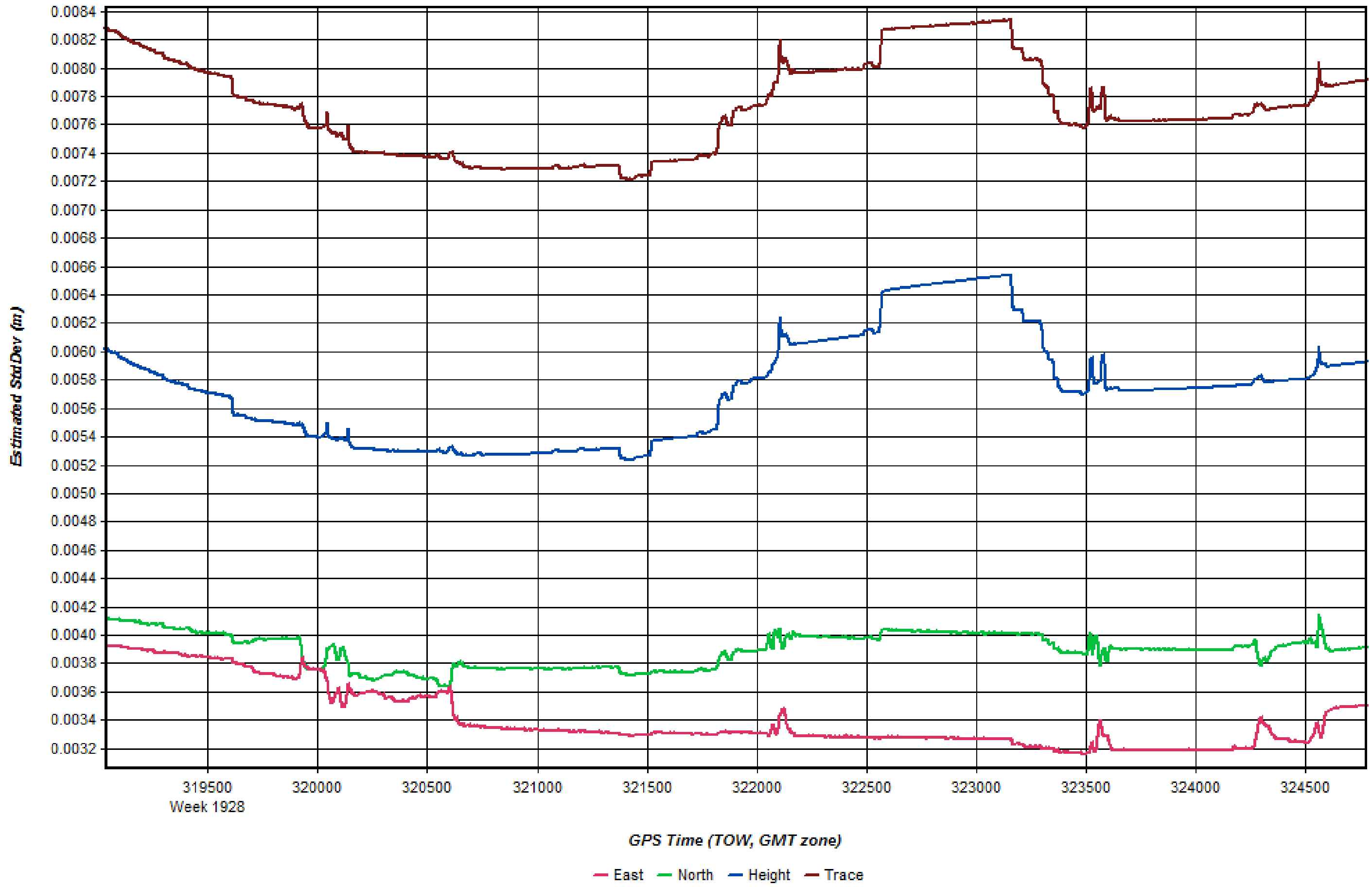

Num Sats
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
420000
Week 1927
422000
424000
426000
428000
430000
432000
434000
436000
438000
440000
GPS Time (TOW, GMT zone)
Num Sats
GPS
GLONASS
BeiDou

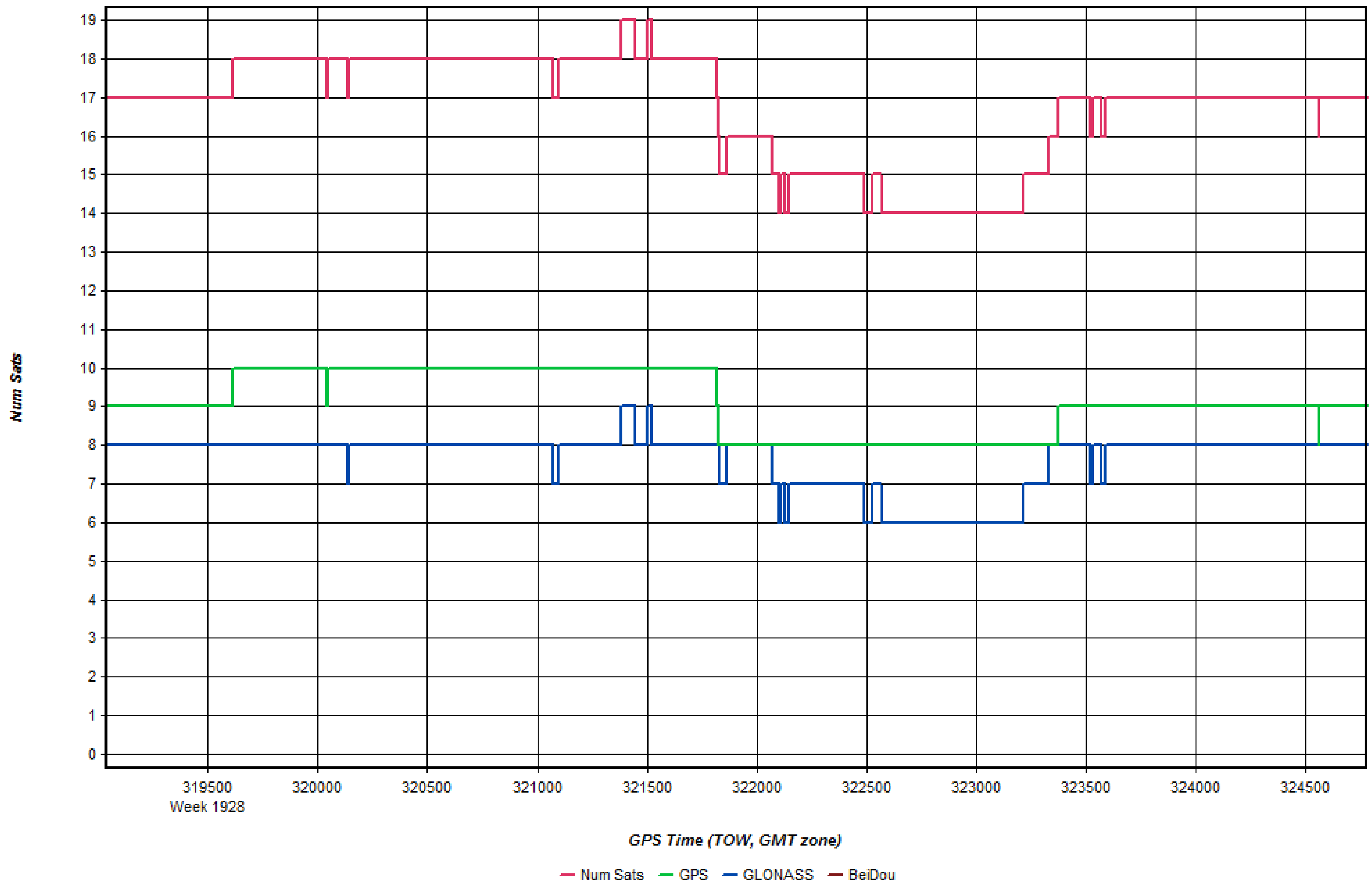

Separation (m)
0.055
0.050
0.045
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
-0.005
-0.010
-0.015
-0.020
-0.025
-0.030
-0.035
420000
Week 1927
422000
424000
426000
428000
430000
432000
434000
436000
438000
440000
GPS Time (TOW, GMT zone)
East
North
Up

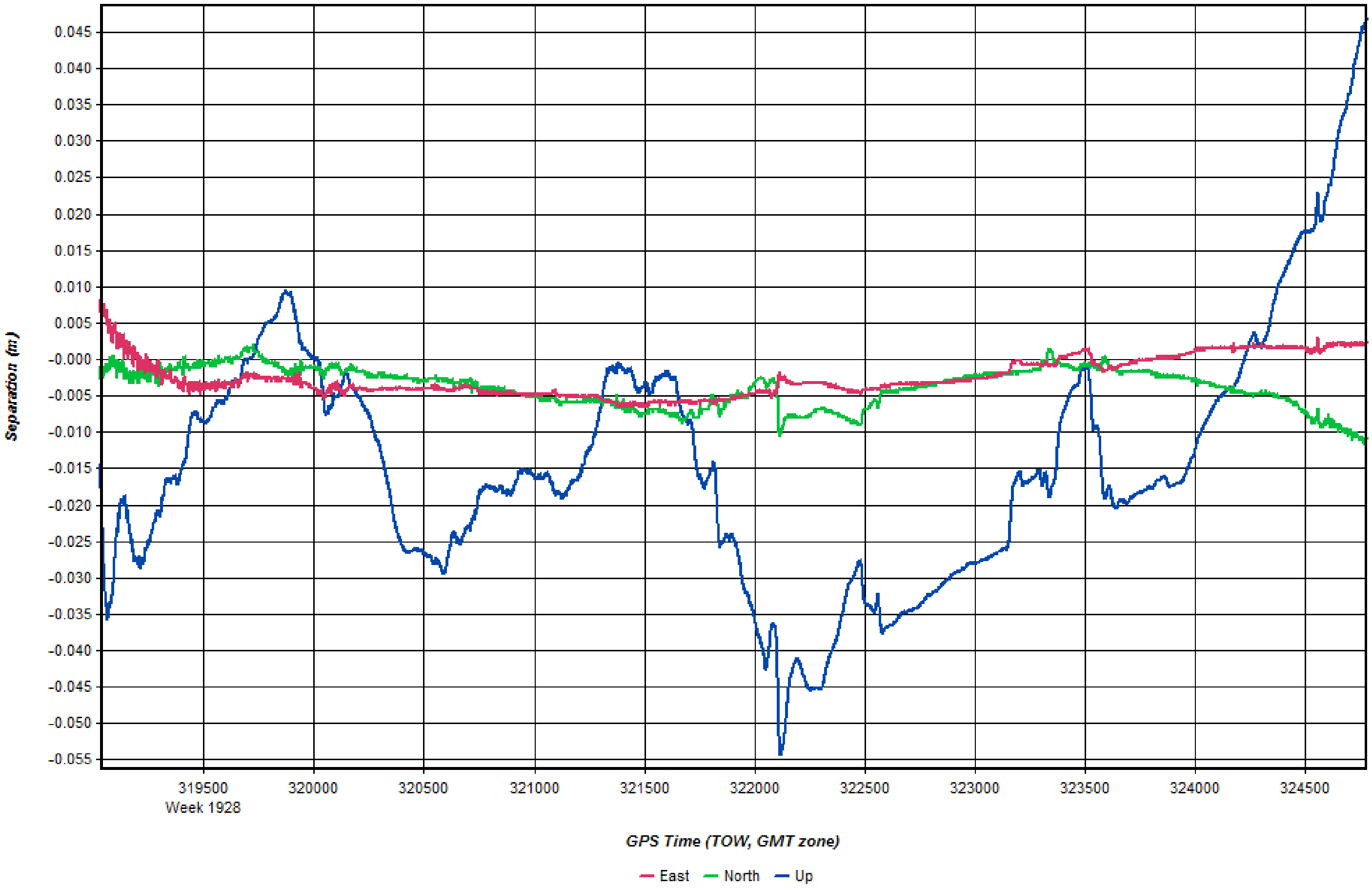

PDOP
2.00
1.95
1.90
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1.25
1.20
1.15
1.10
1.05
1.00
0.95
420000
Week 1927
422000
424000
426000
428000
430000
432000
434000
436000
438000
440000
GPS Time (TOW, GMT zone)
PDOP

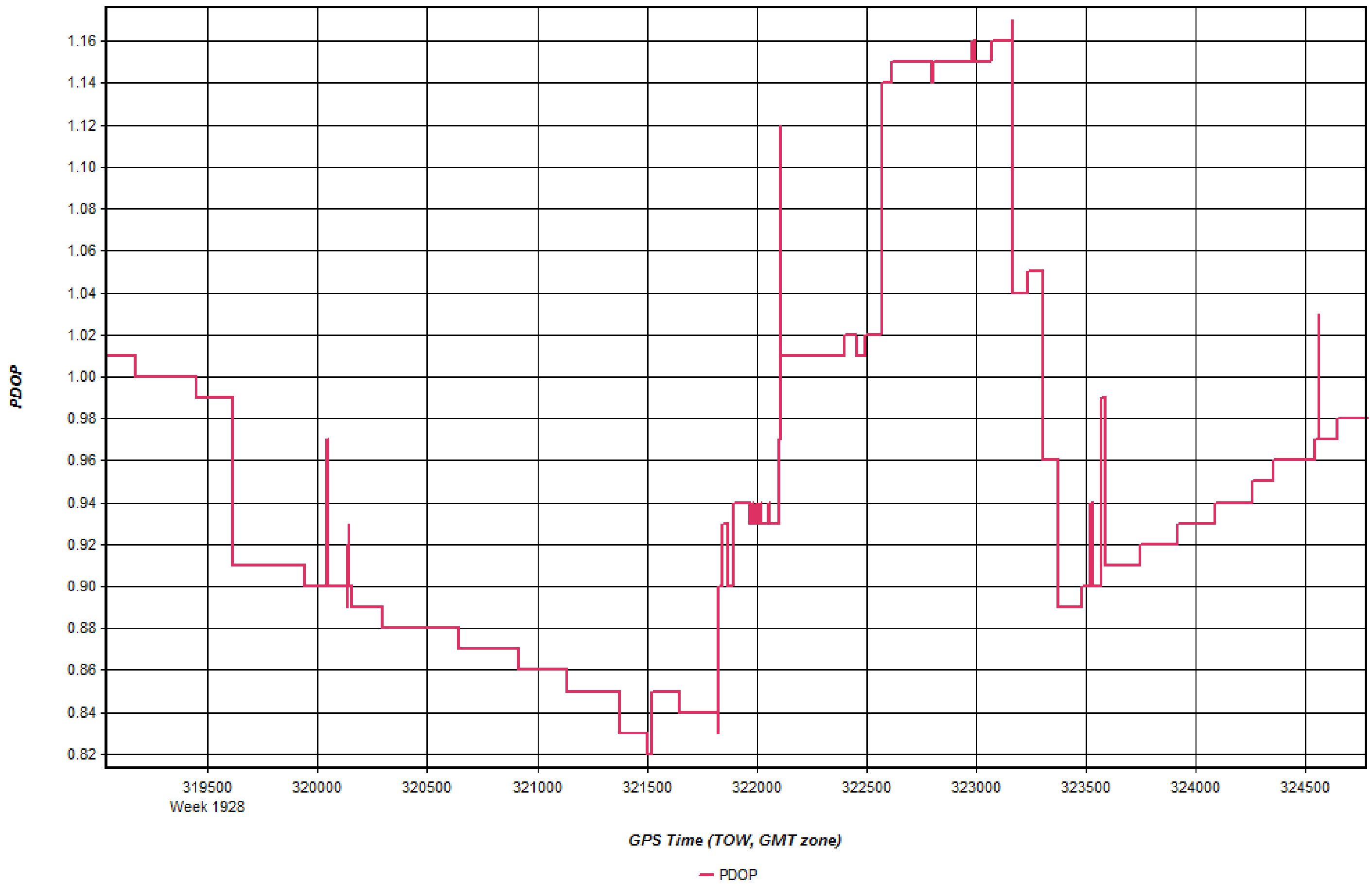
225_20161221_1



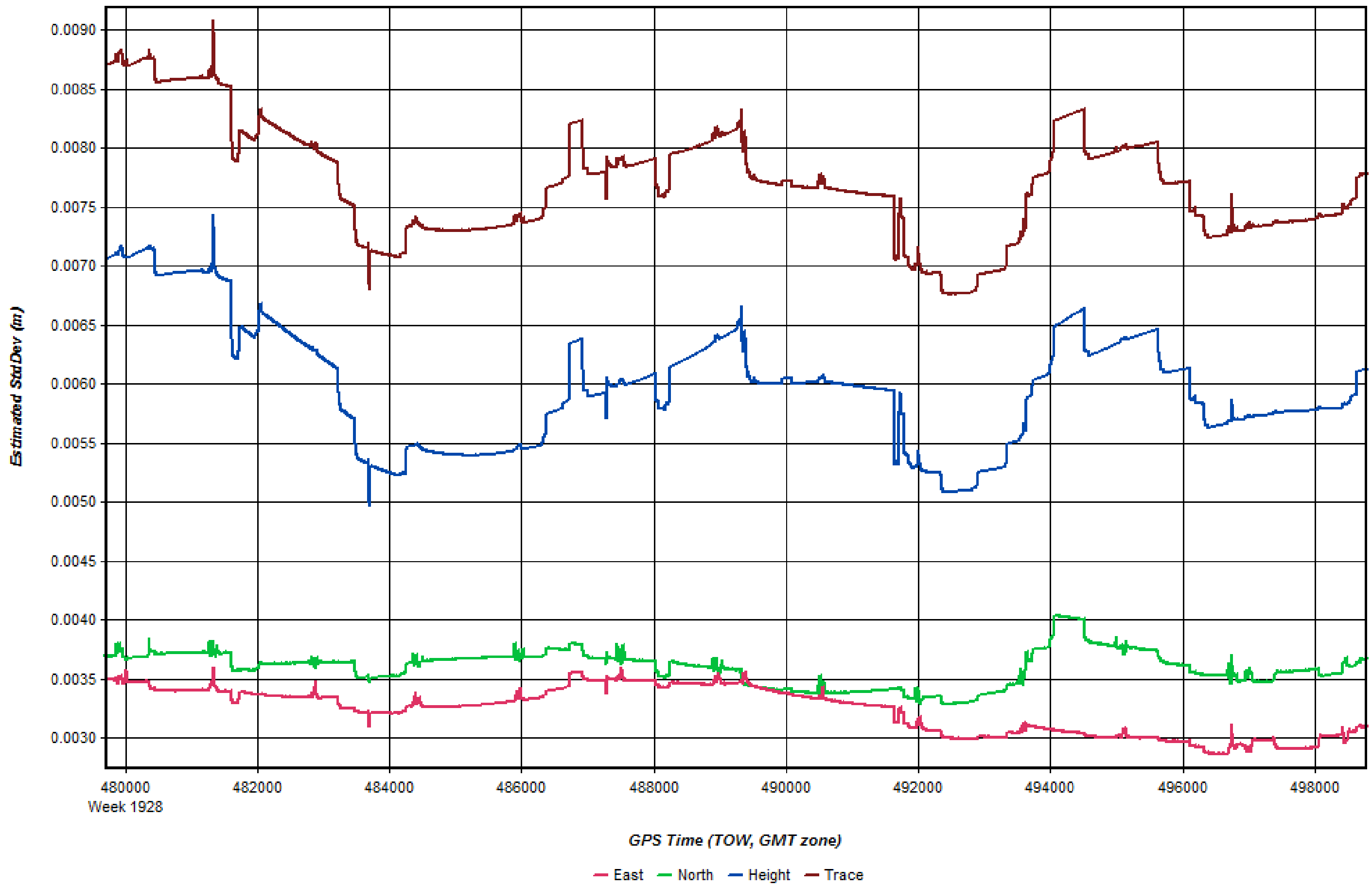

0.0084
0.0082
0.0080
0.0078
0.0076
0.0074
0.0072
0.0070
0.0068
0.0066
0.0064
0.0062
0.0060
0.0058
0.0056
0.0054
0.0052
0.0050
0.0048
0.0046
0.0044
0.0042
0.0040
0.0038
0.0036
0.0034
0.0032
Estimated Std Dev (m)
319500
Week 1928
320000
320500
321000
321500
322000
322500
323000
323500
324000
324500
GPS Time (TOW, GMT zone)
East
North
Height
Trace

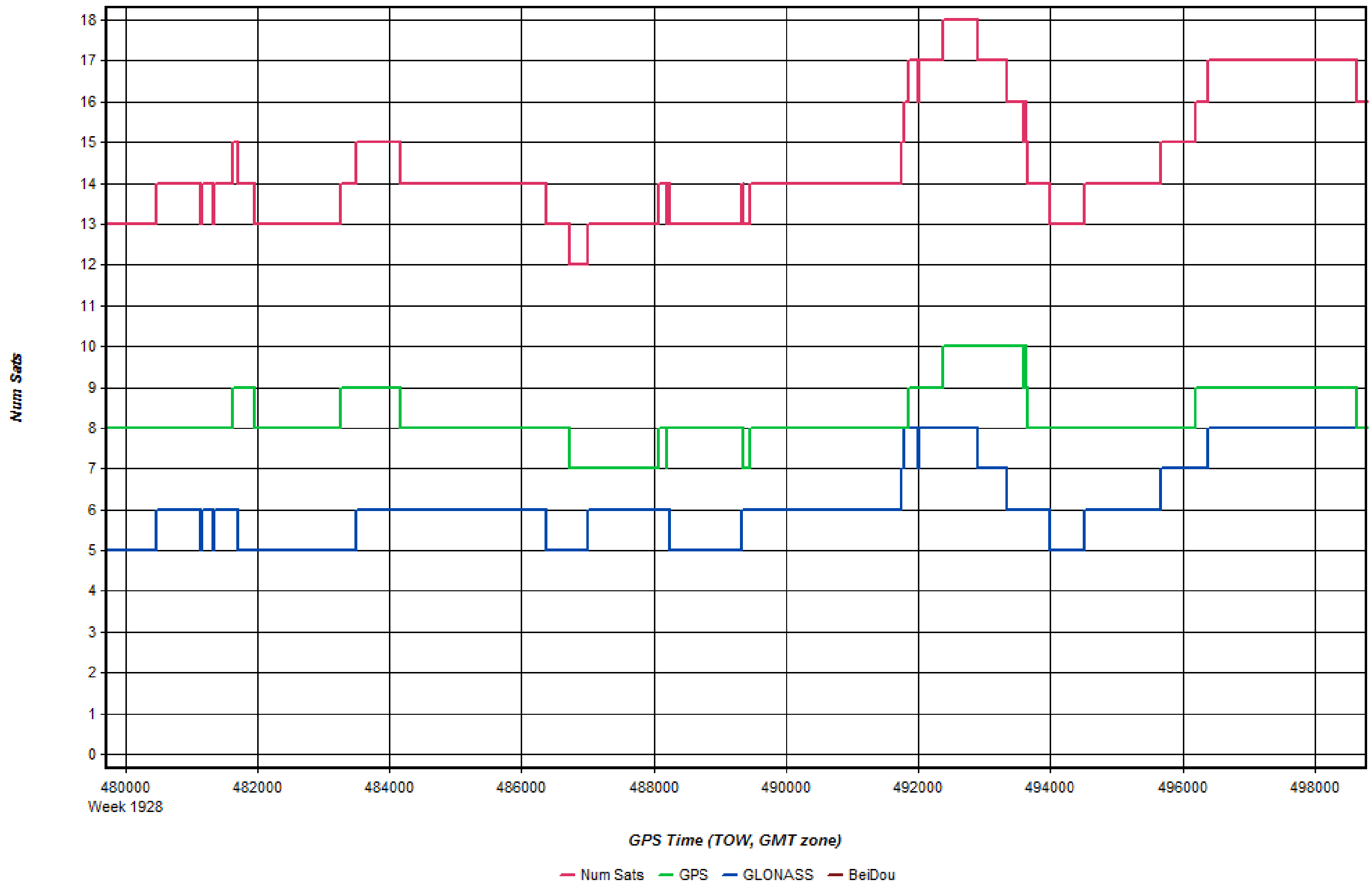

Num Sats
GPS Time (TOW, GMT zone)
Week 1928
Num Sats
GPS
GLONASS
BeiDou

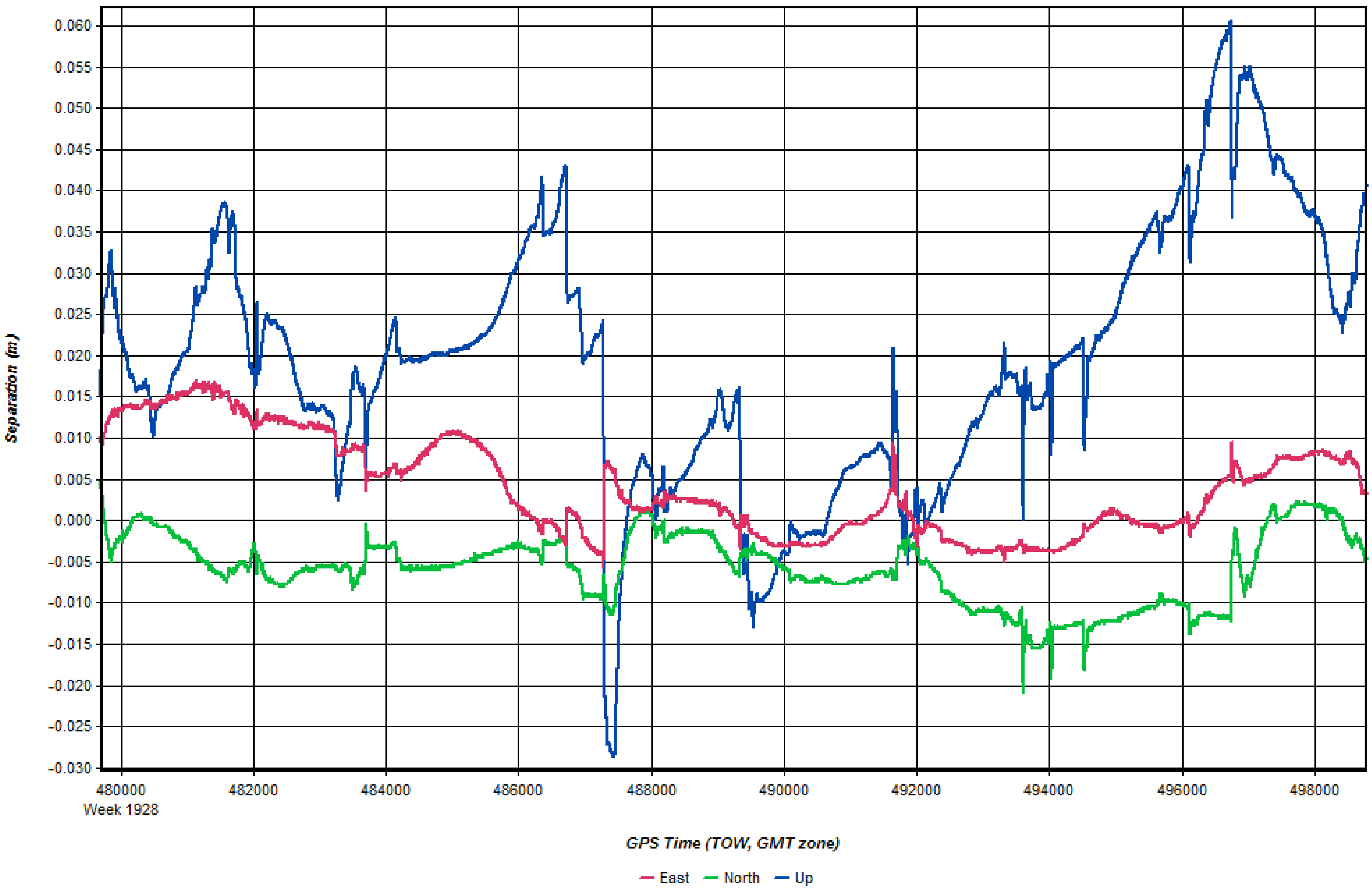

Separation (m)
0.045
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
-0.000
-0.005
-0.010
-0.015
-0.020
-0.025
-0.030
-0.035
-0.040
-0.045
-0.050
-0.055
319500
Week 1928
320000
320500
321000
321500
322000
322500
323000
323500
324000
324500
GPS Time (TOW, GMT zone)
East
North
Up

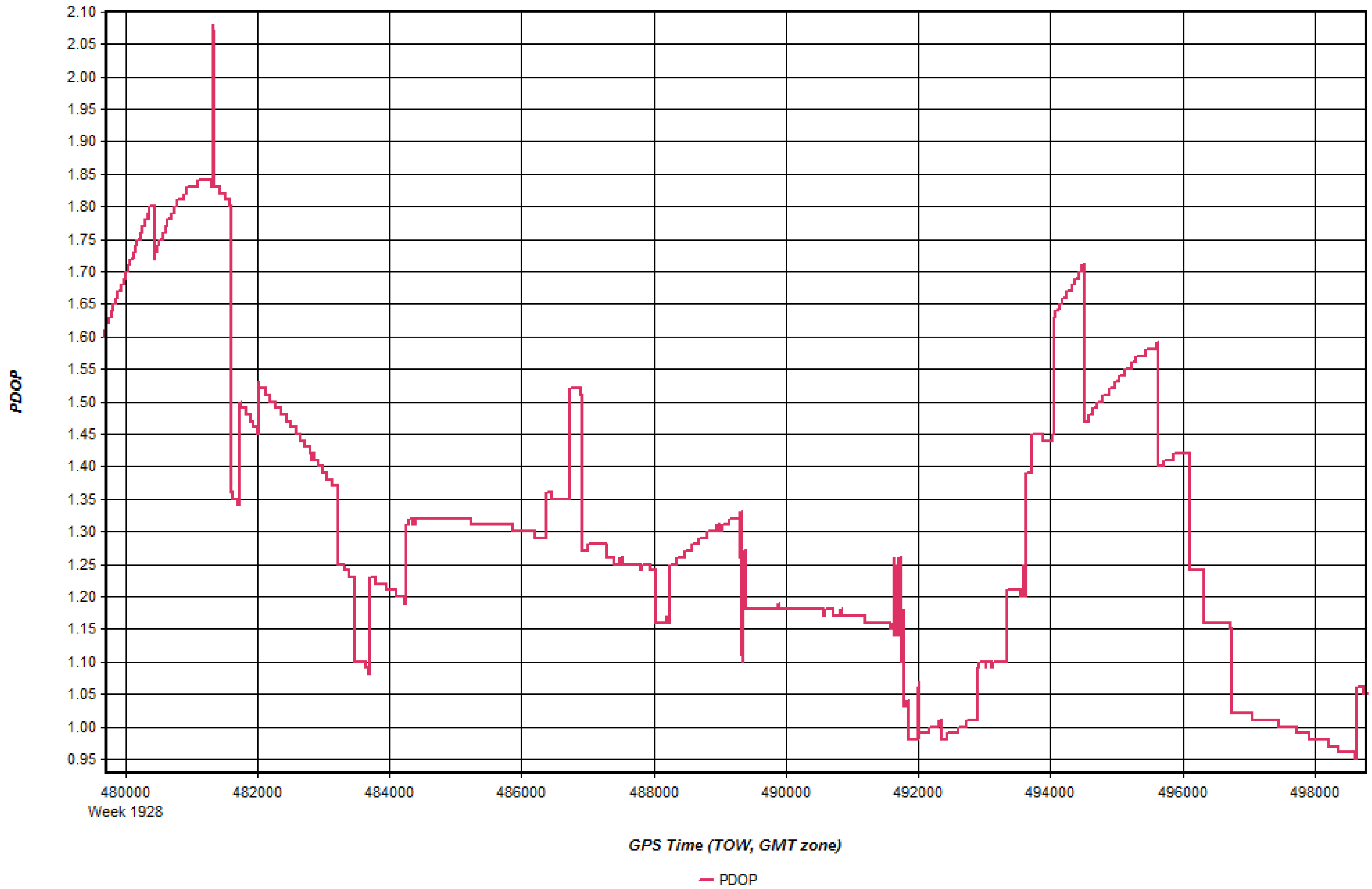

PDOP
1.16
1.14
1.12
1.10
1.08
1.06
1.04
1.02
1.00
0.98
0.96
0.94
0.92
0.90
0.88
0.86
0.84
0.82
319500
Week 1928
320000
320500
321000
321500
322000
322500
323000
323500
324000
324500
GPS Time (TOW, GMT zone)
PDOP

225_20161223_1

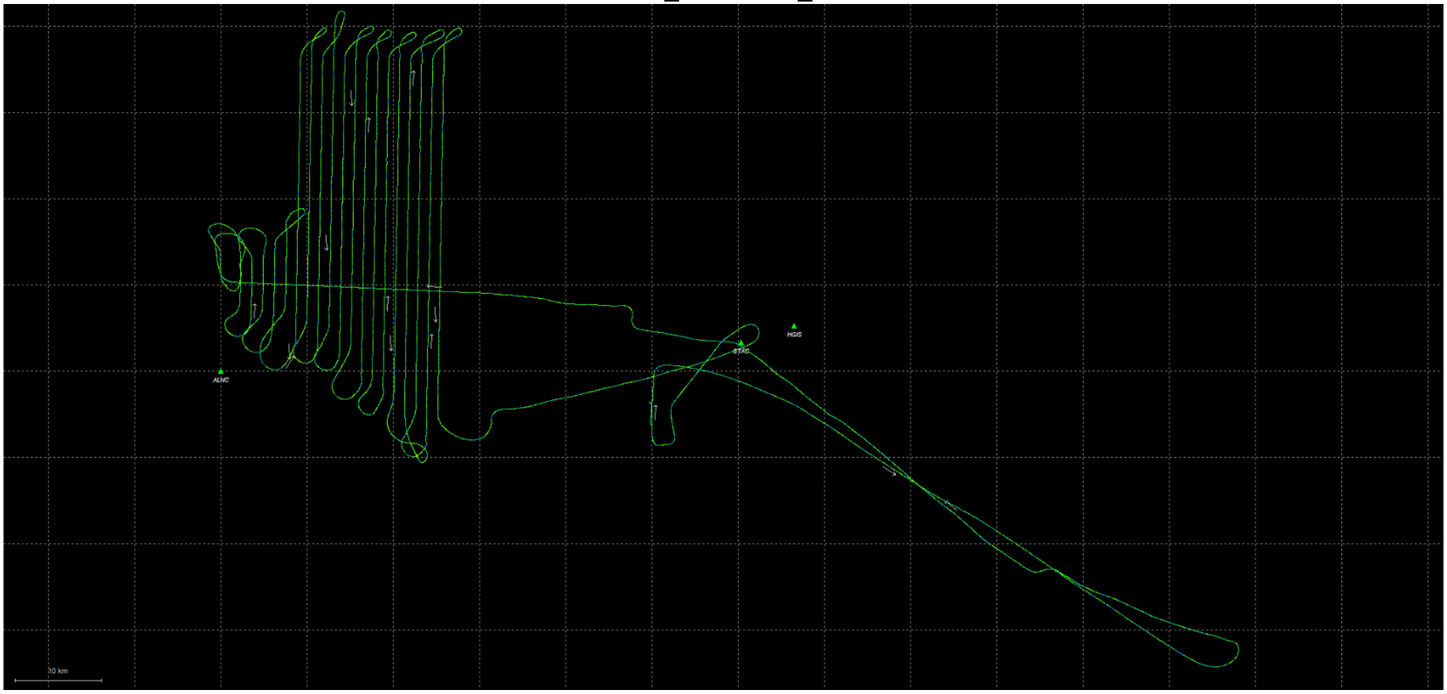

0.0090
0.0085
0.0080
0.0075
0.0070
0.0065
0.0060
0.0055
0.0050
0.0045
0.0040
0.0035
0.0030
Estimated StdDev (m)
480000
Week 1928
482000
484000
486000
488000
490000
492000
494000
496000
498000
GPS Time (TOW, GMT zone)
East
North
Height
Trace

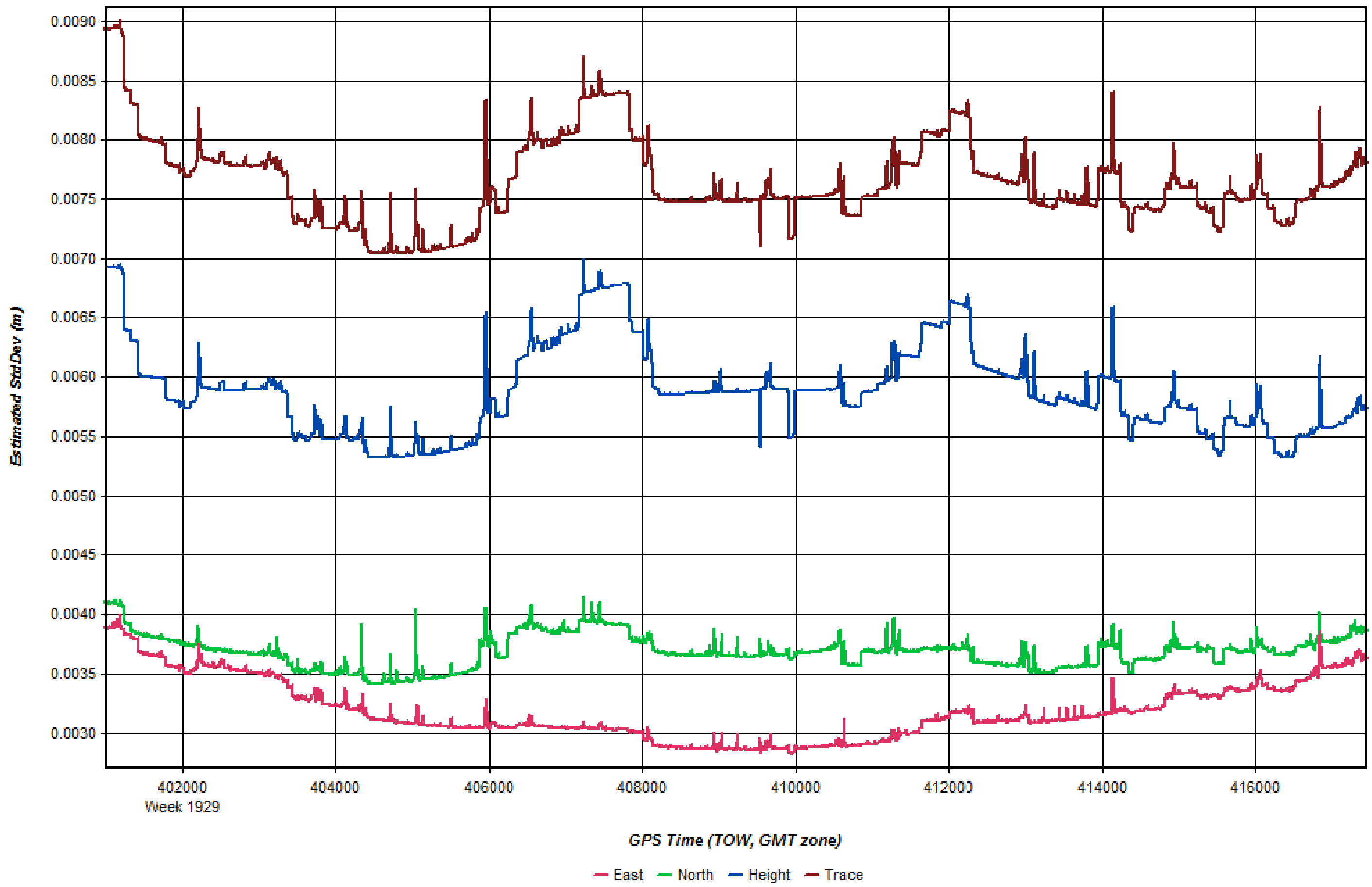

Num Sats
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
480000
Week 1928
482000
484000
486000
488000
490000
492000
494000
496000
498000
GPS Time (TOW, GMT zone)
Num Sats
GPS
GLONASS
BeiDou

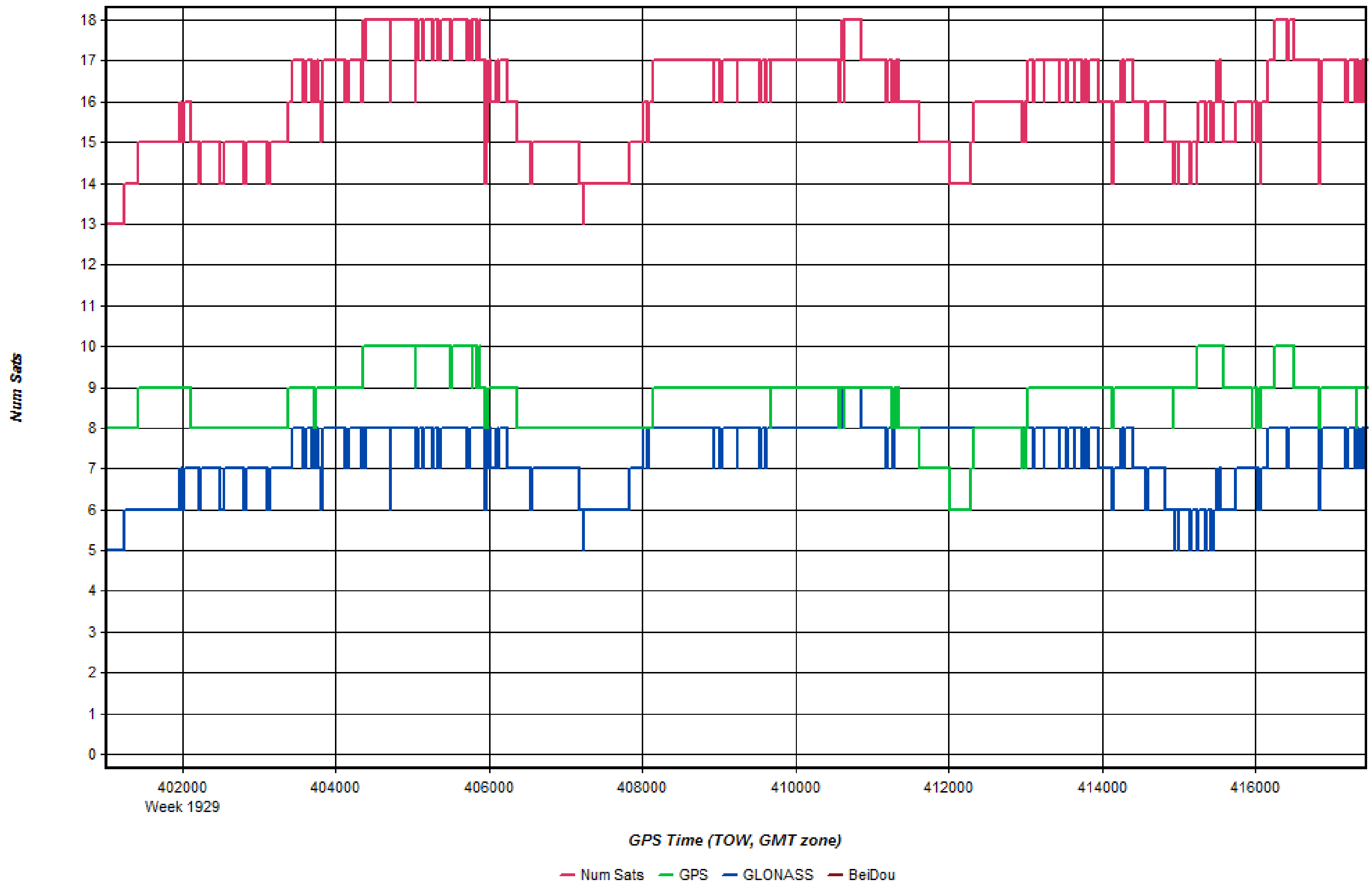

0.060
0.055
0.050
0.045
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
-0.005
-0.010
-0.015
-0.020
-0.025
-0.030
Separation (m)
480000
Week 1928
482000
484000
486000
488000
490000
492000
494000
496000
498000
GPS Time (TOW, GMT zone)
East
North
Up

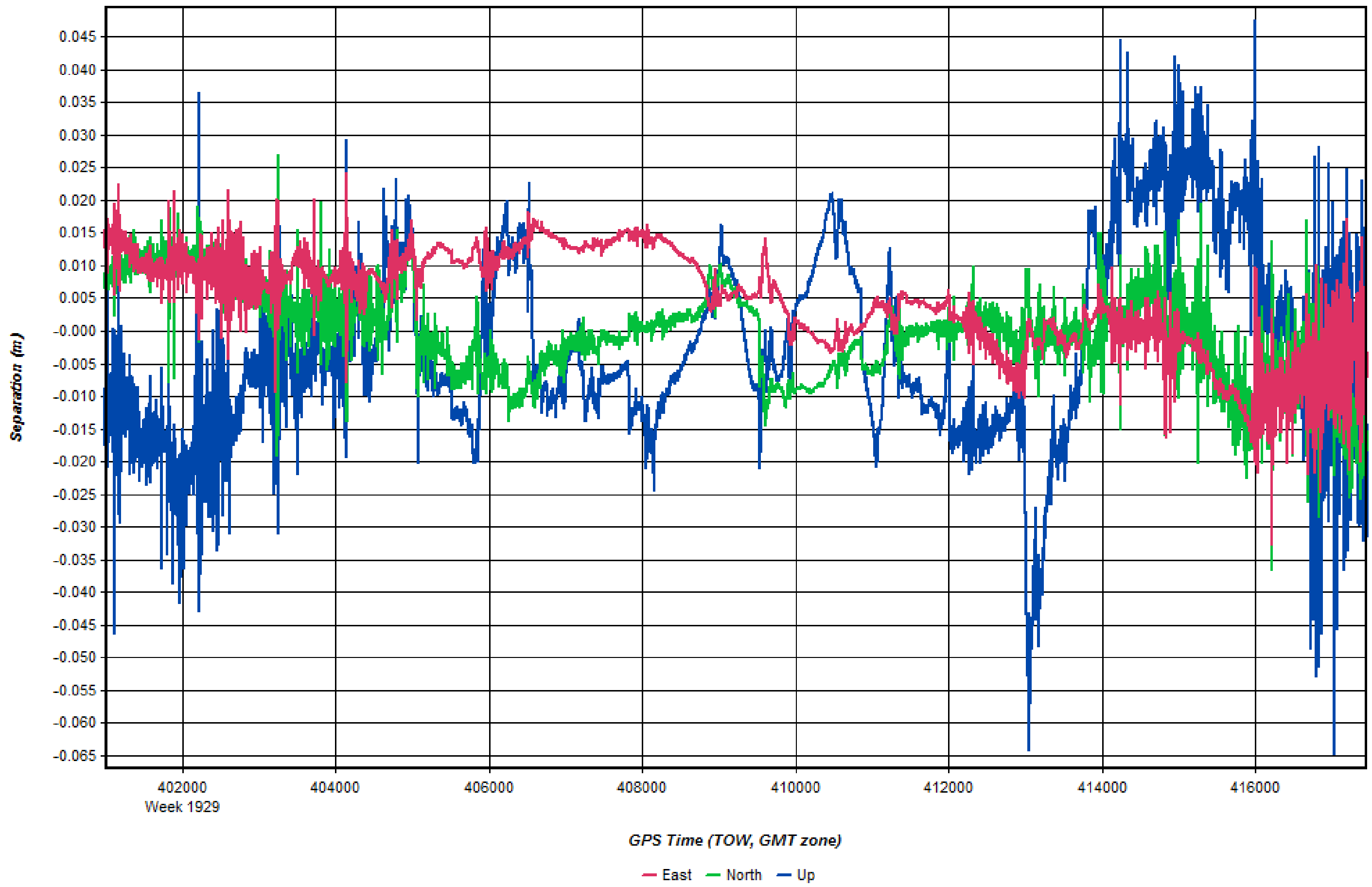

2.10
2.05
2.00
1.95
1.90
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1.25
1.20
1.15
1.10
1.05
1.00
0.95
PDOP
480000
Week 1928
482000
484000
486000
488000
490000
492000
494000
496000
498000
GPS Time (TOW, GMT zone)
PDOP

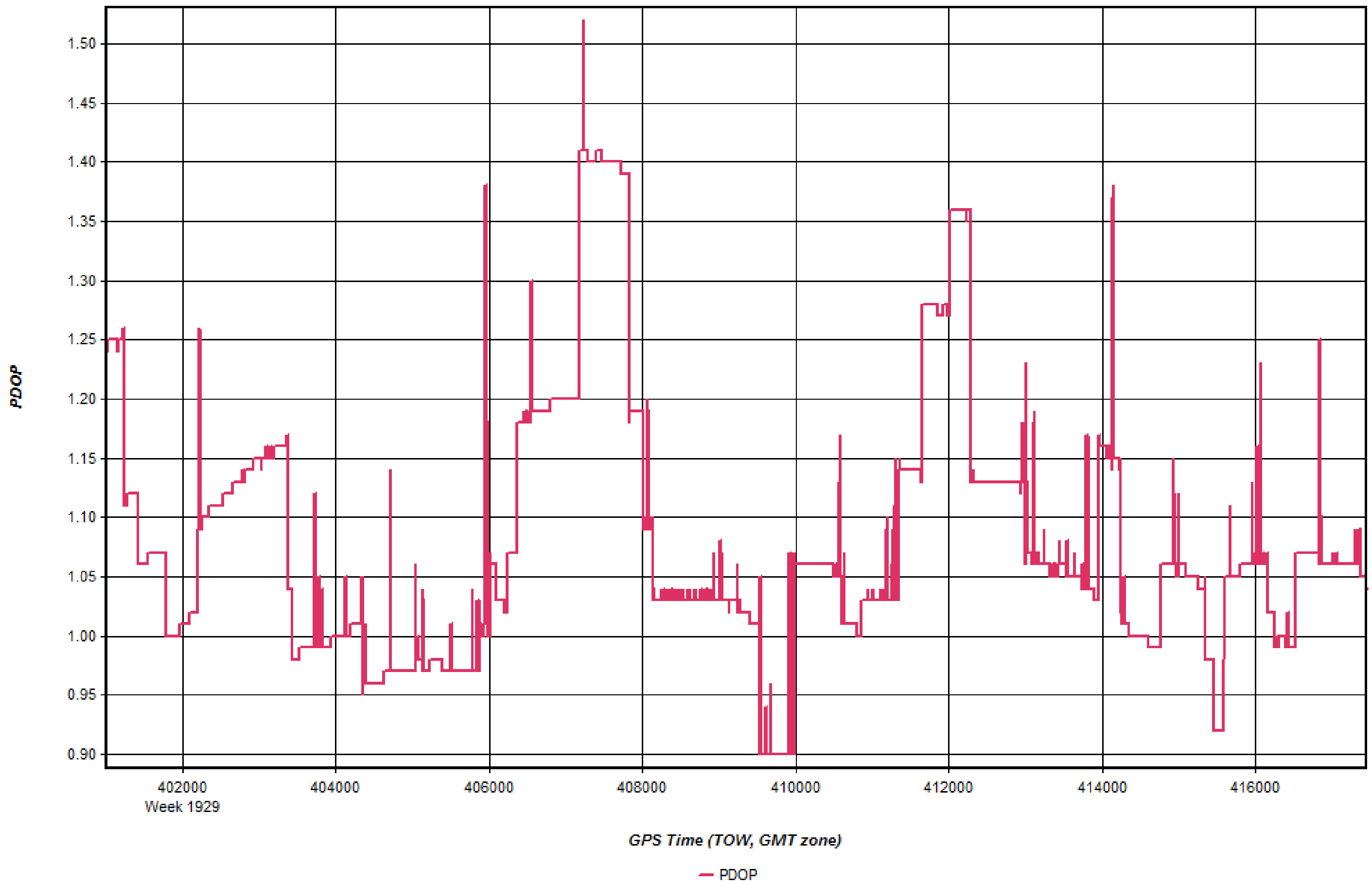
123_20161229_1



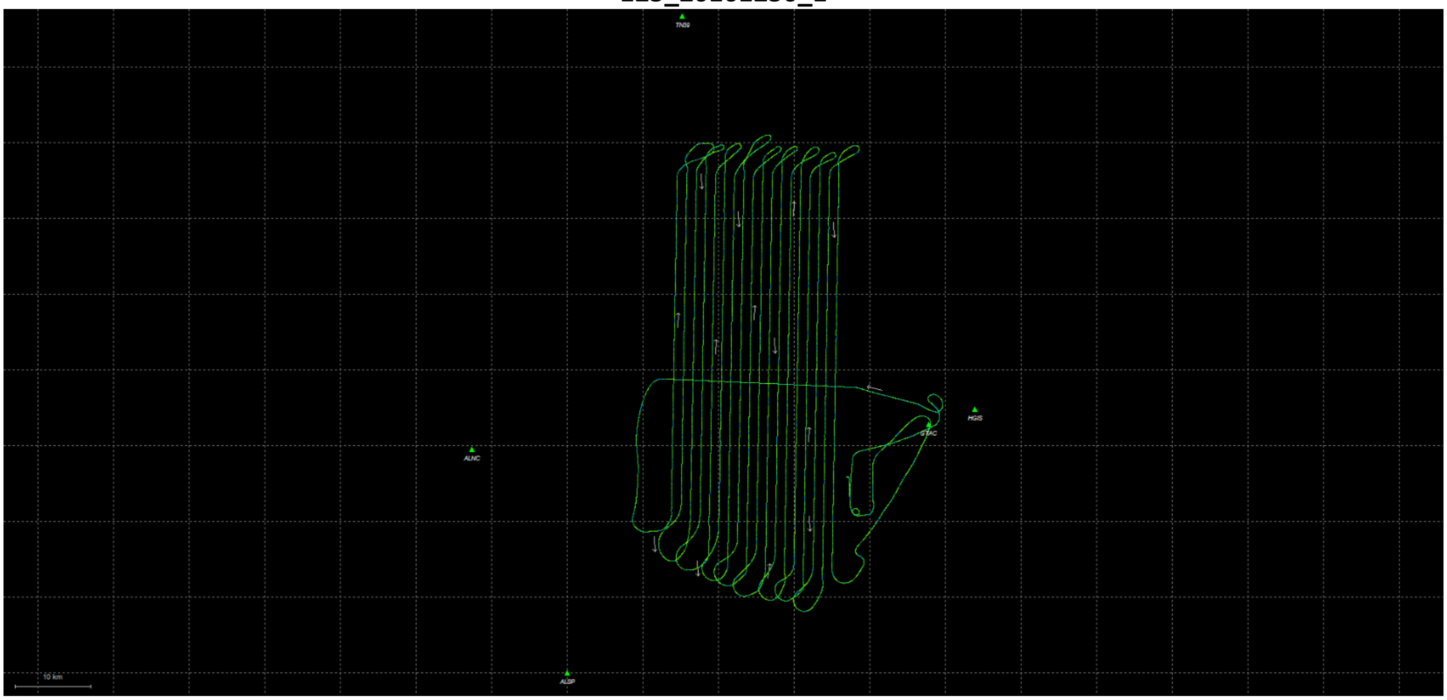

Estimated StdDev (m)
0.0090
0.0085
0.0080
0.0075
0.0070
0.0065
0.0060
0.0055
0.0050
0.0045
0.0040
0.0035
0.0030
402000
Week 1929
404000
406000
408000
410000
412000
414000
416000
GPS Time (TOW, GMT zone)
East
North
Height
Trace

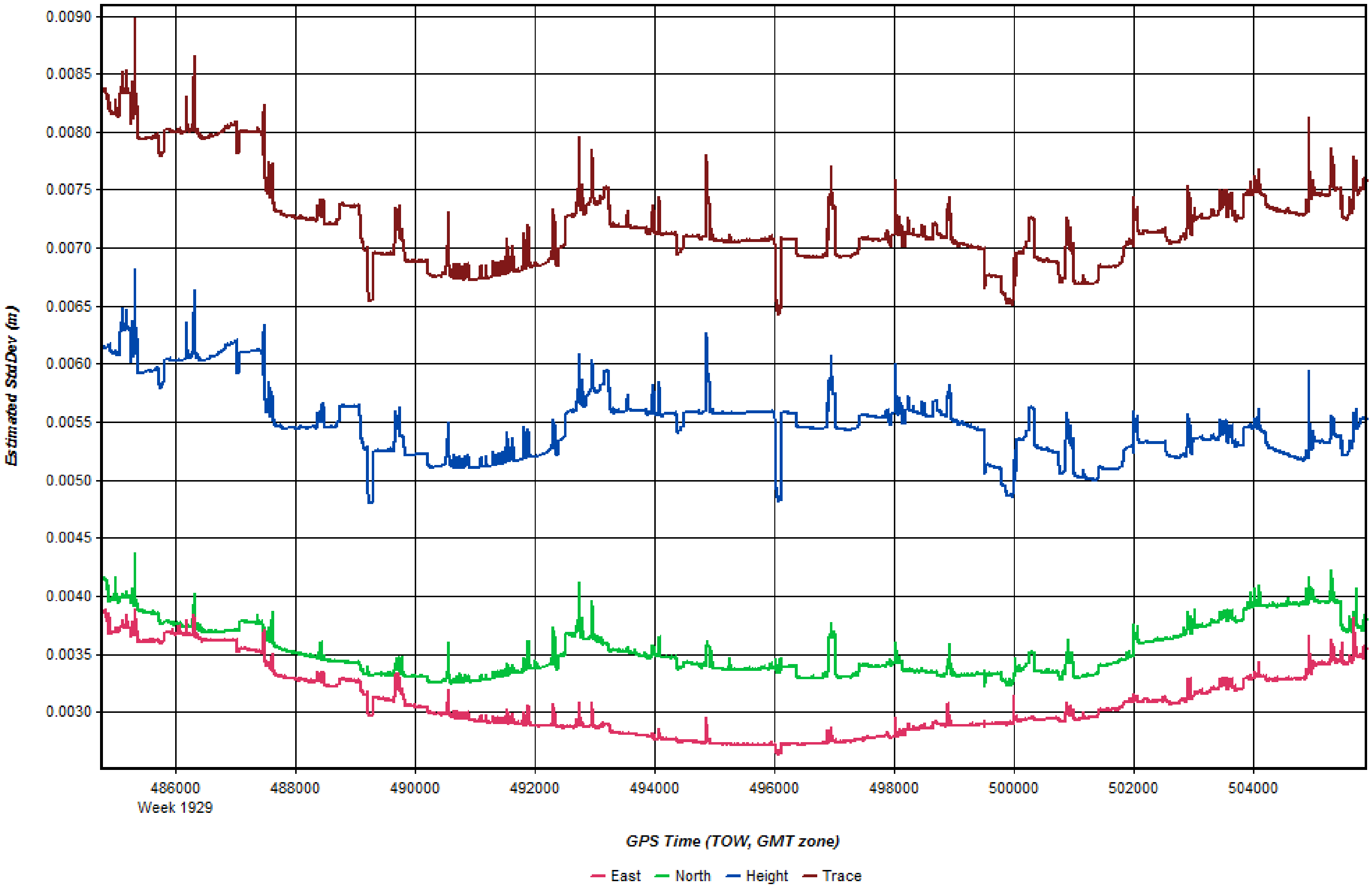

Num Sats
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
402000
Week 1929
404000
406000
408000
410000
412000
414000
416000
GPS Time (TOW, GMT zone)
Num Sats
GPS
GLONASS
BeiDou

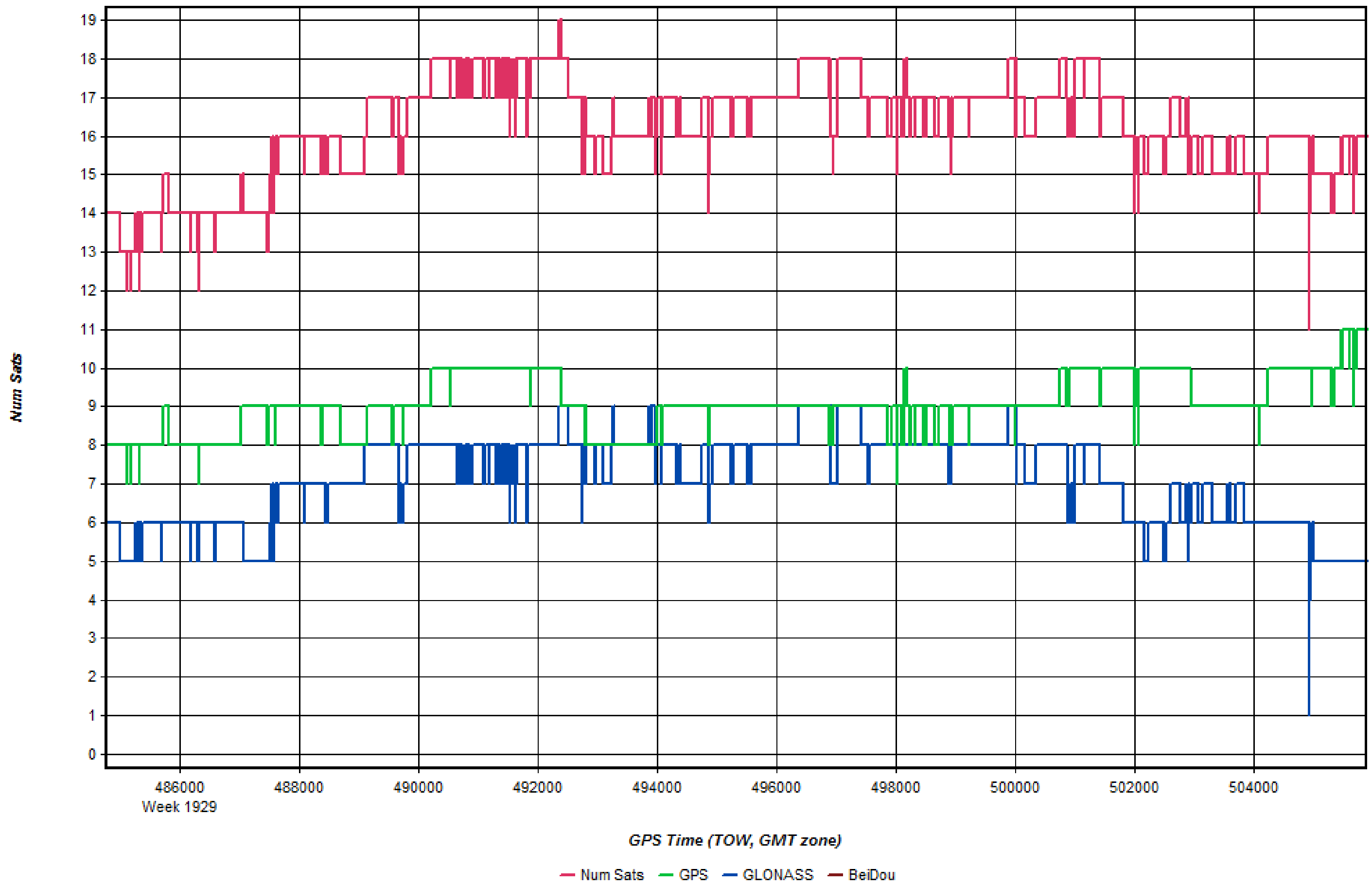

0.045
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
-0.000
-0.005
-0.010
-0.015
-0.020
-0.025
-0.030
-0.035
-0.040
-0.045
-0.050
-0.055
-0.060
-0.065
Separation (m)
402000
Week 1929
404000
406000
408000
410000
412000
414000
416000
GPS Time (TOW, GMT zone)
East
North
Up

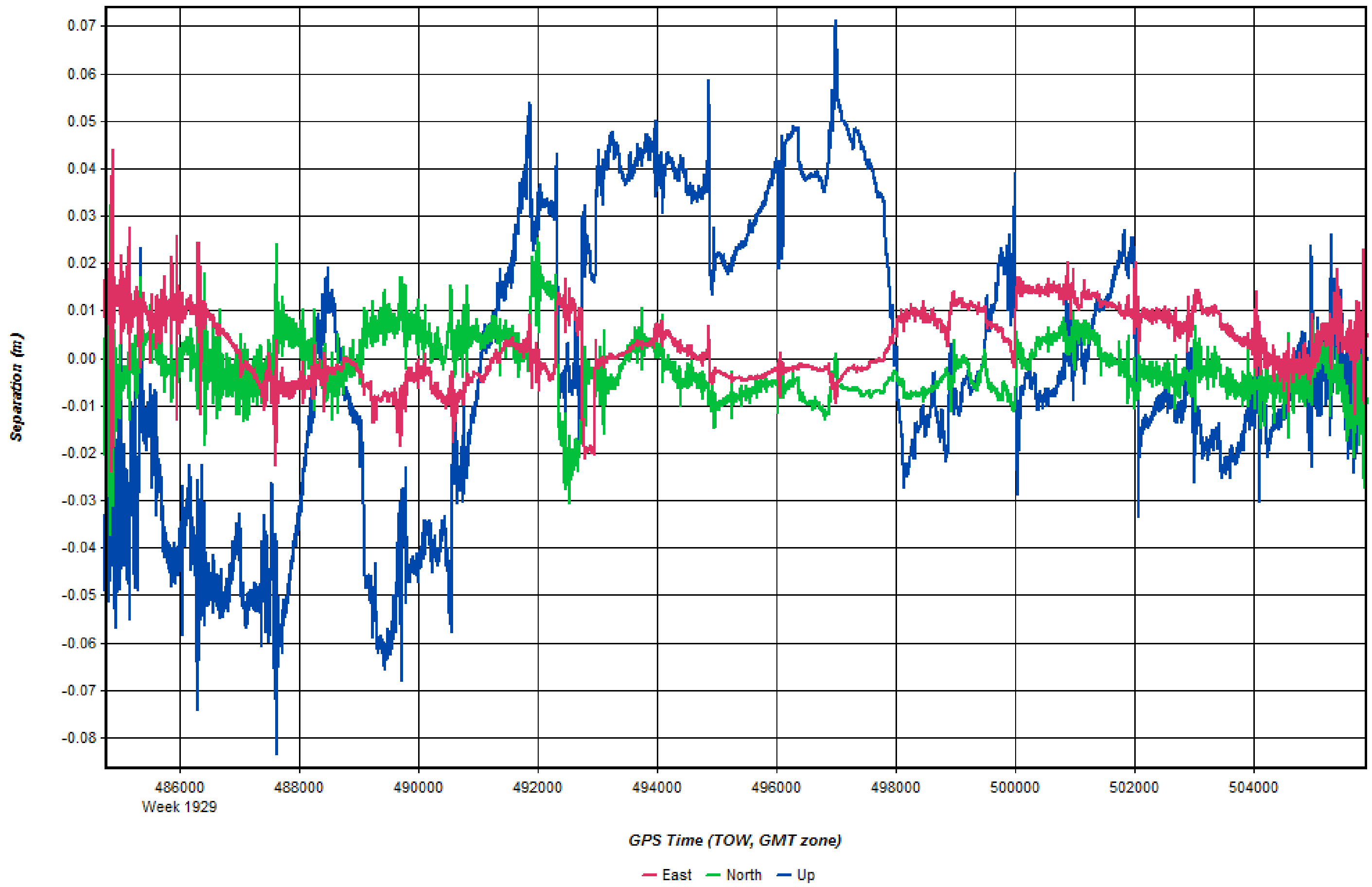

PDOP
1.50
1.45
1.40
1.35
1.30
1.25
1.20
1.15
1.10
1.05
1.00
0.95
0.90
402000
Week 1929
404000
406000
408000
410000
412000
414000
416000
GPS Time (TOW, GMT zone)
PDOP

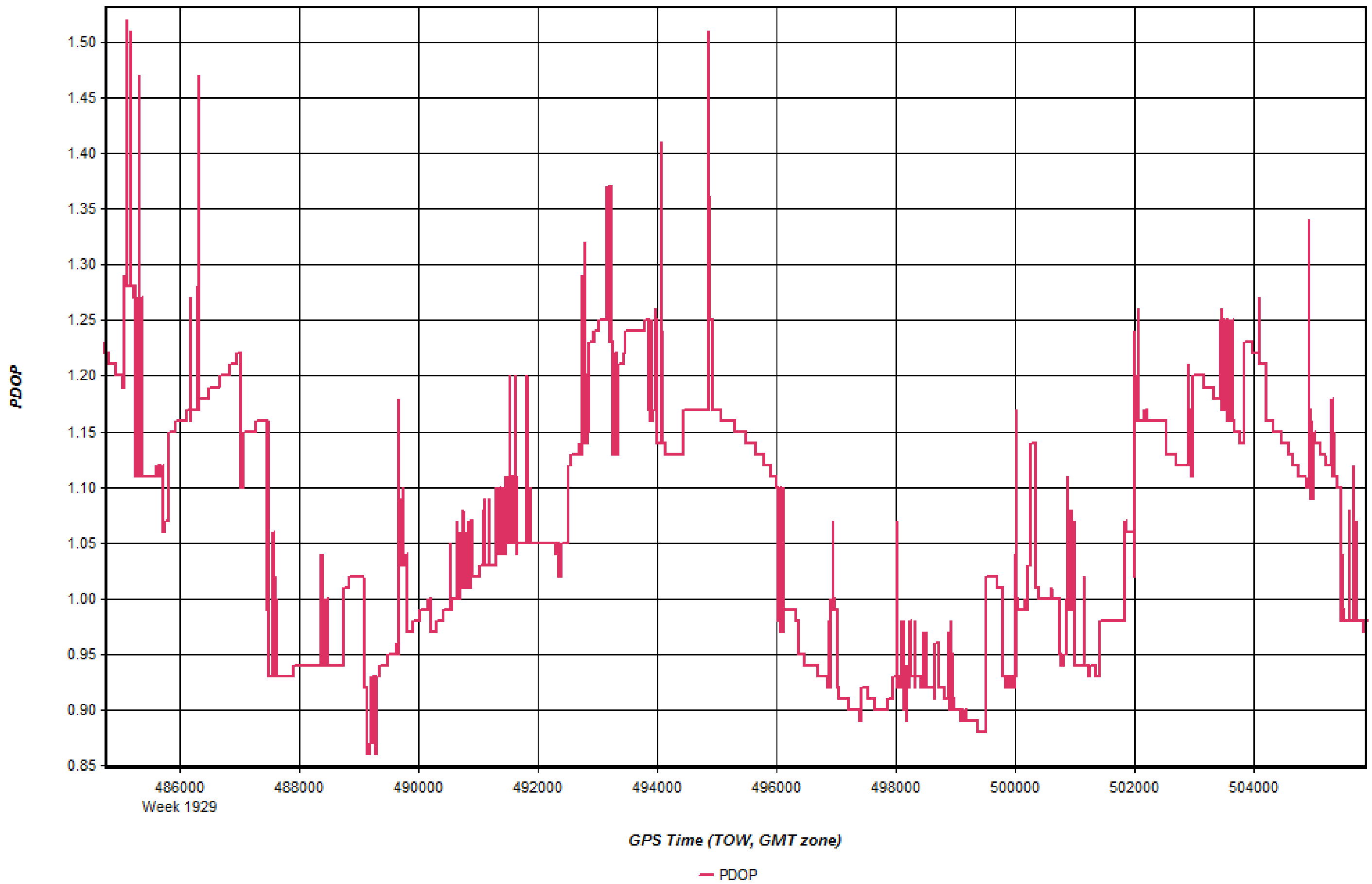
123_20161230_1



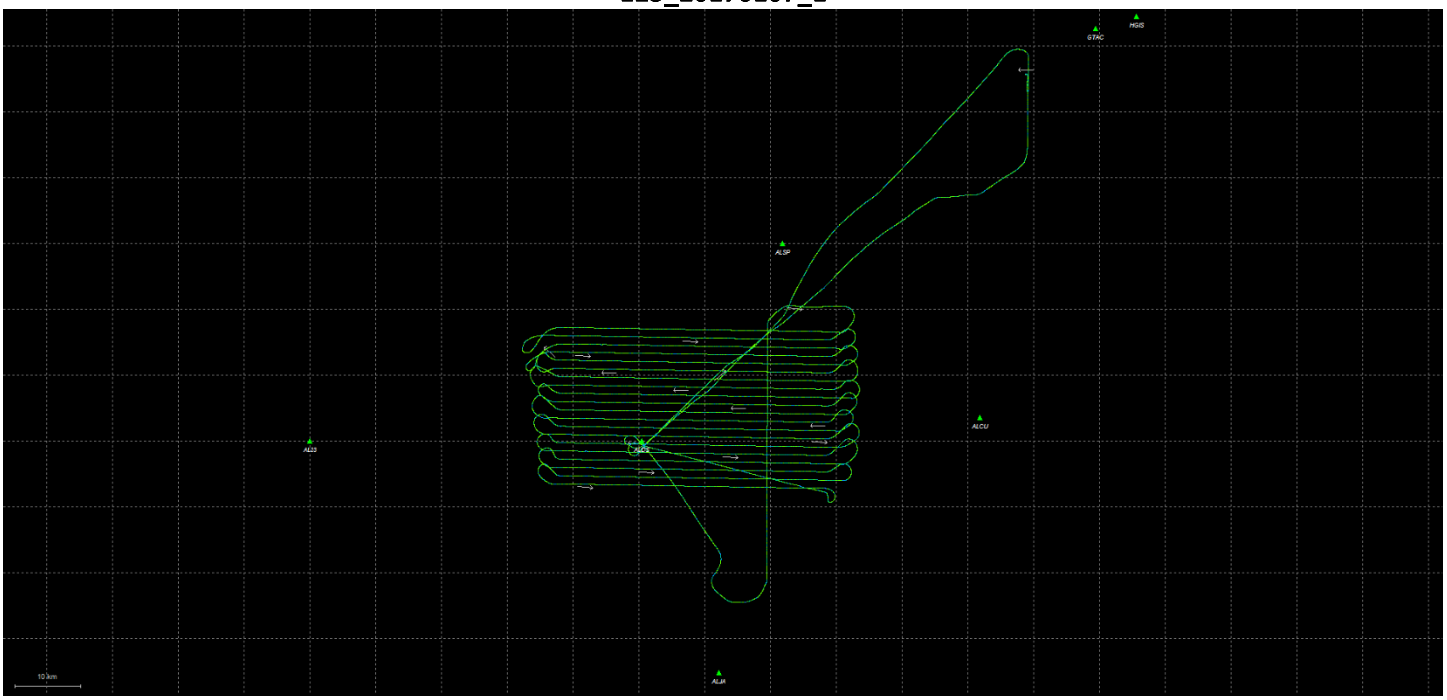

0.0090
0.0085
0.0080
0.0075
0.0070
0.0065
0.0060
0.0055
0.0050
0.0045
0.0040
0.0035
0.0030
Estimated Std Dev (m)
486000
Week 1929
488000
490000
492000
494000
496000
498000
500000
502000
504000
GPS Time (TOW, GMT zone)
East
North
Height
Trace

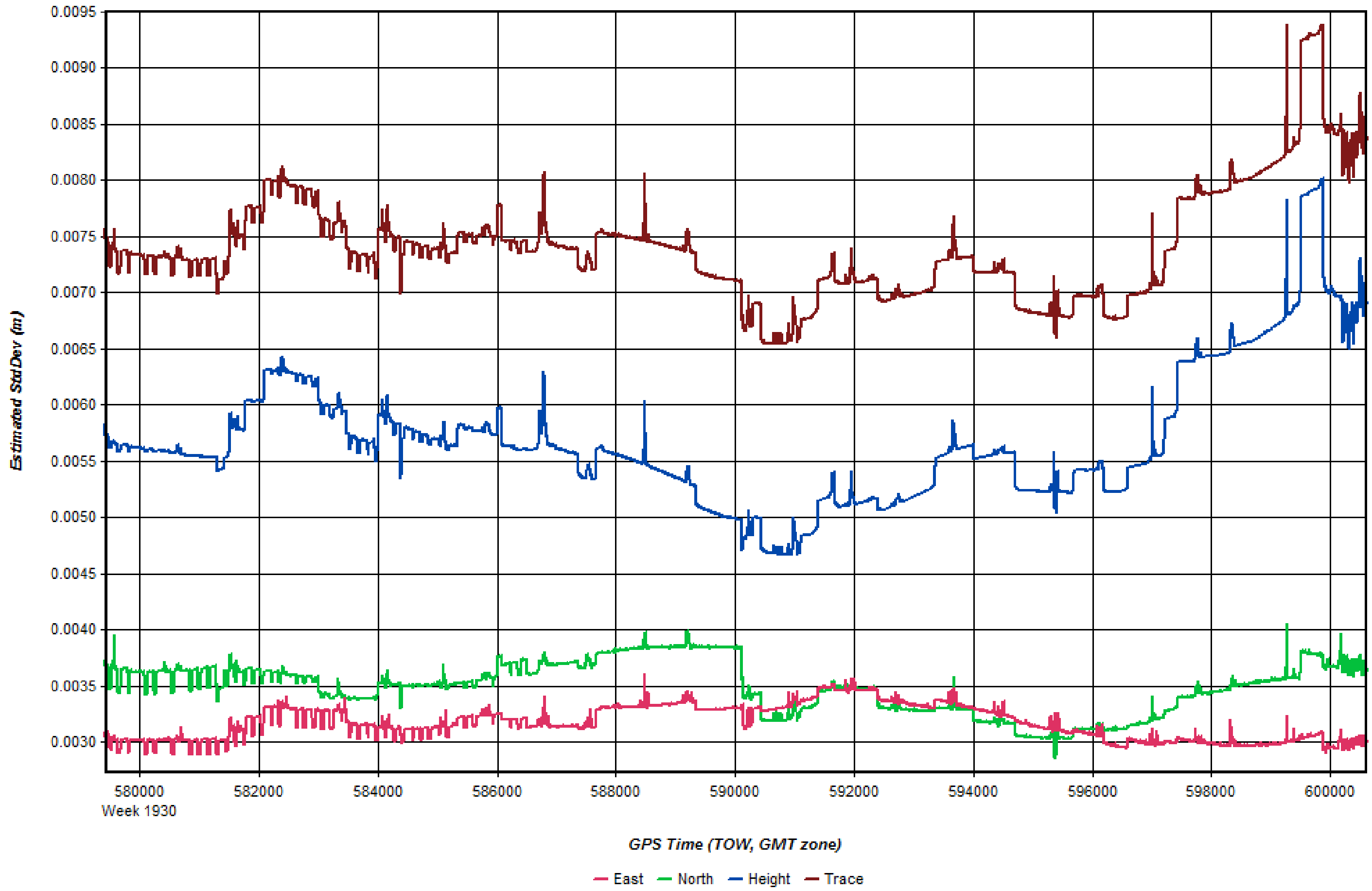

Num Sats
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
486000
Week 1929
488000
490000
492000
494000
496000
498000
500000
502000
504000
GPS Time (TOW, GMT zone)
Num Sats
GPS
GLONASS
BeiDou

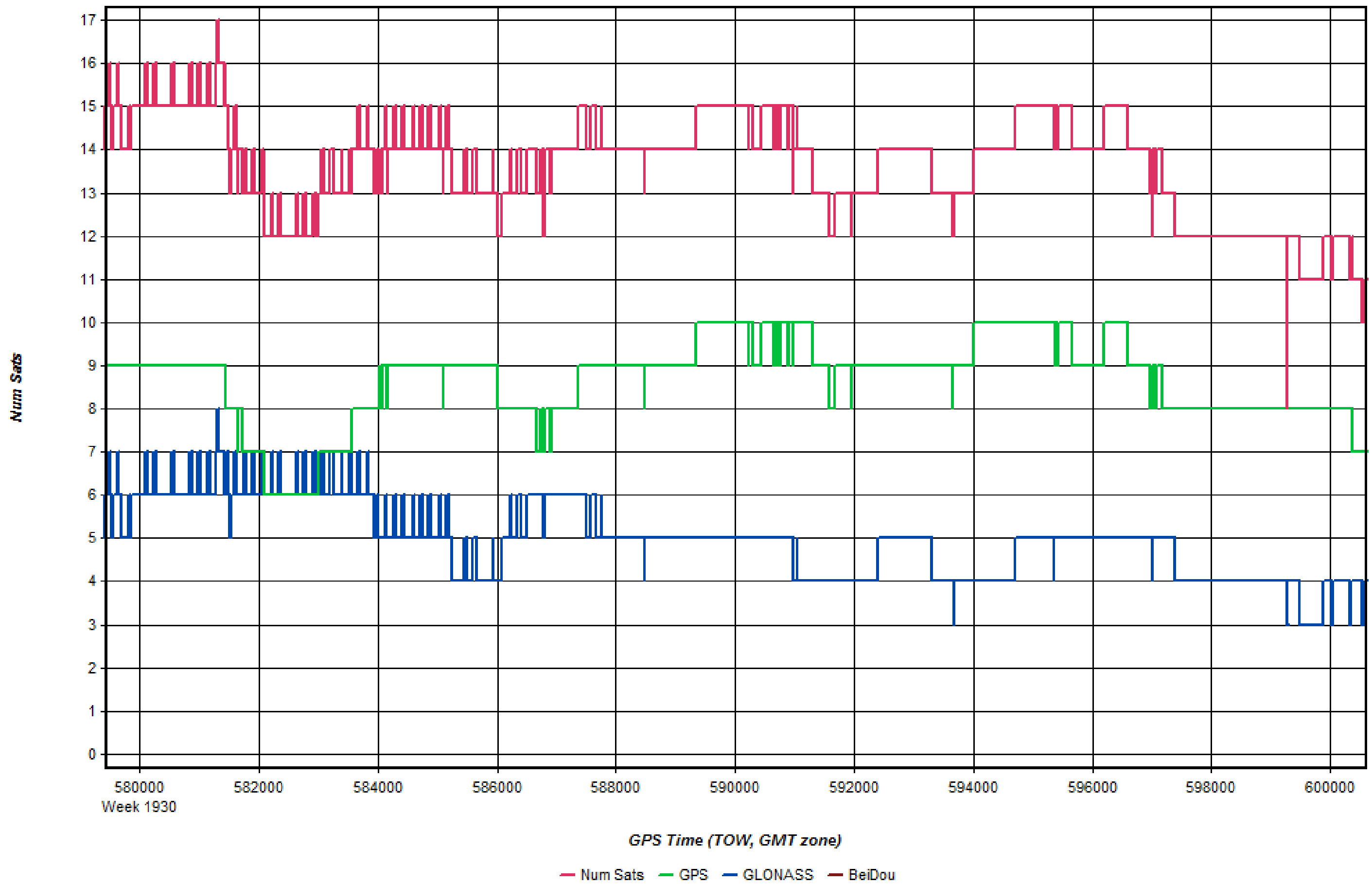

Separation (m)
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
-0.01
-0.02
-0.03
-0.04
-0.05
-0.06
-0.07
-0.08
486000
Week 1929
488000
490000
492000
494000
496000
498000
500000
502000
504000
GPS Time (TOW, GMT zone)
East
North
Up

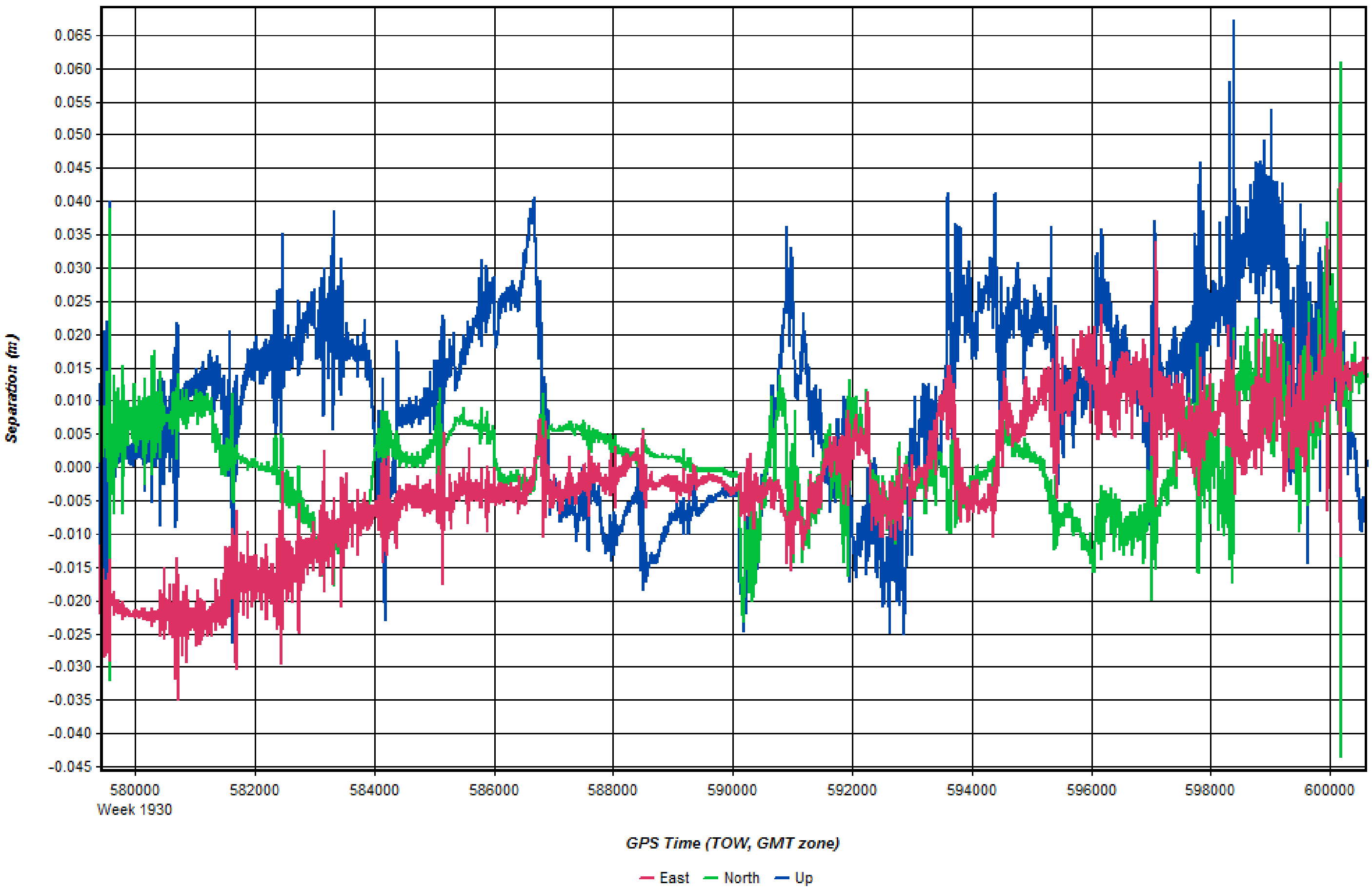

PDOP
1.50
1.45
1.40
1.35
1.30
1.25
1.20
1.15
1.10
1.05
1.00
0.95
0.90
0.85
486000
Week 1929
488000
490000
492000
494000
496000
498000
500000
502000
504000
GPS Time (TOW, GMT zone)
PDOP

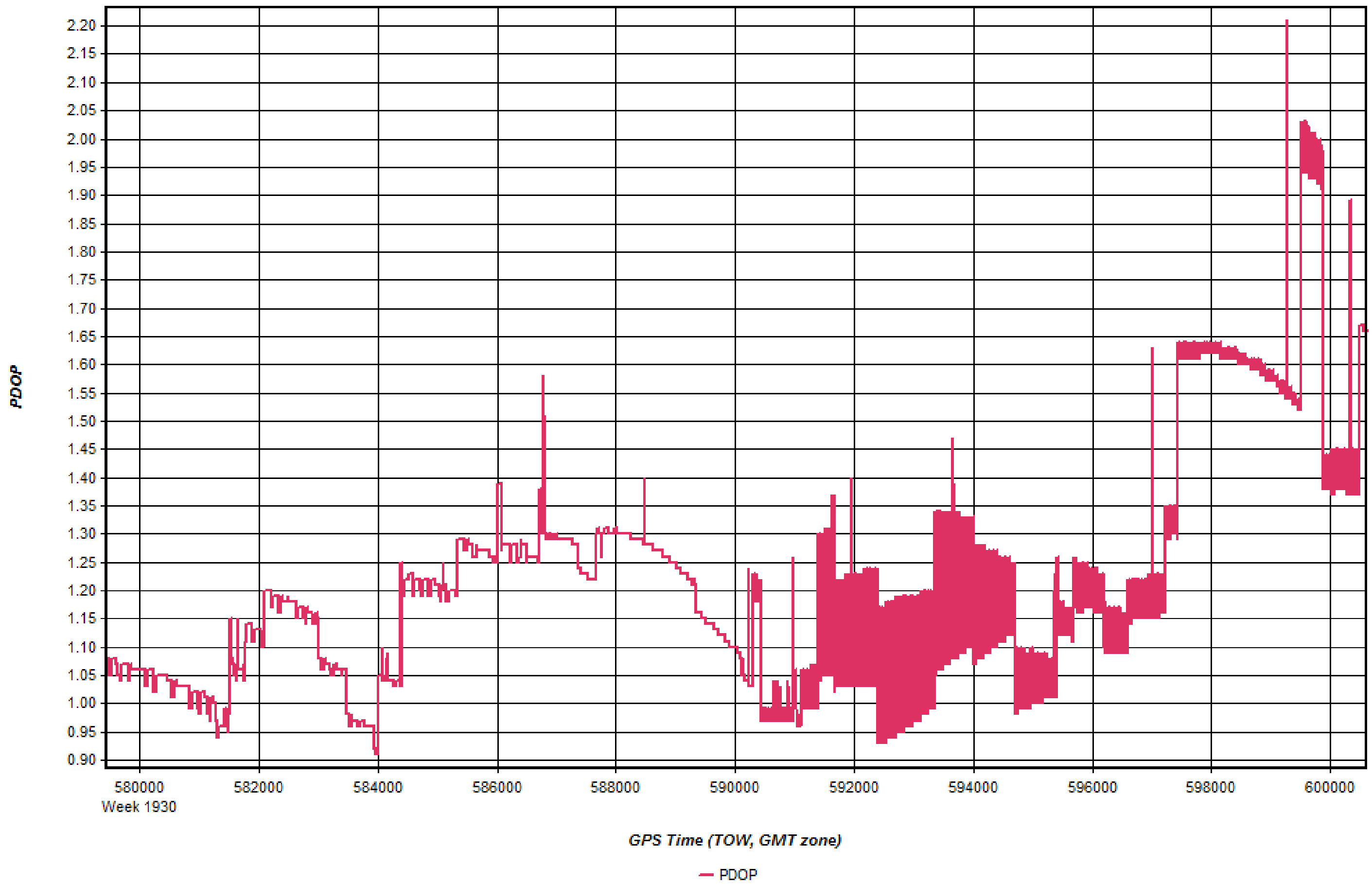
123_20170107_1



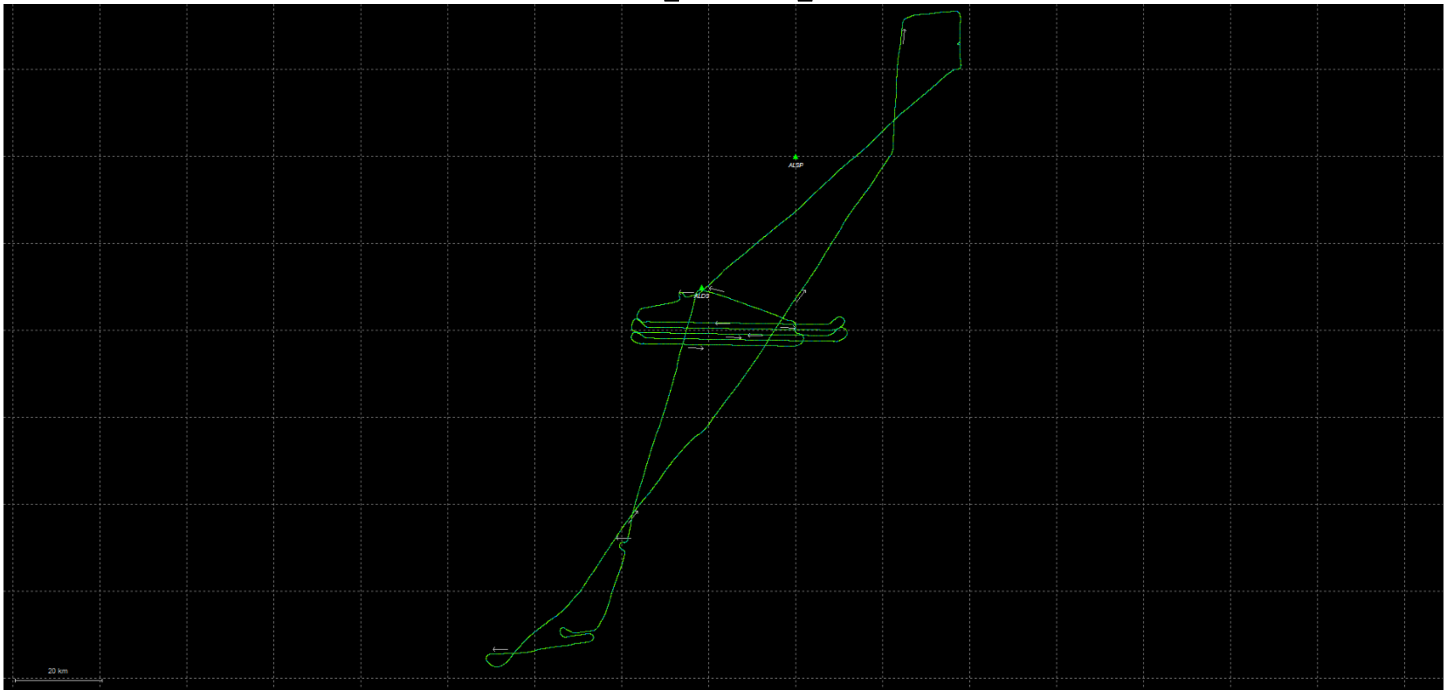

Estimated StdDev (m)
0.0095
0.0090
0.0085
0.0080
0.0075
0.0070
0.0065
0.0060
0.0055
0.0050
0.0045
0.0040
0.0035
0.0030
580000
Week 1930
582000
584000
586000
588000
590000
592000
594000
596000
598000
600000
GPS Time (TOW, GMT zone)
East
North
Height
Trace

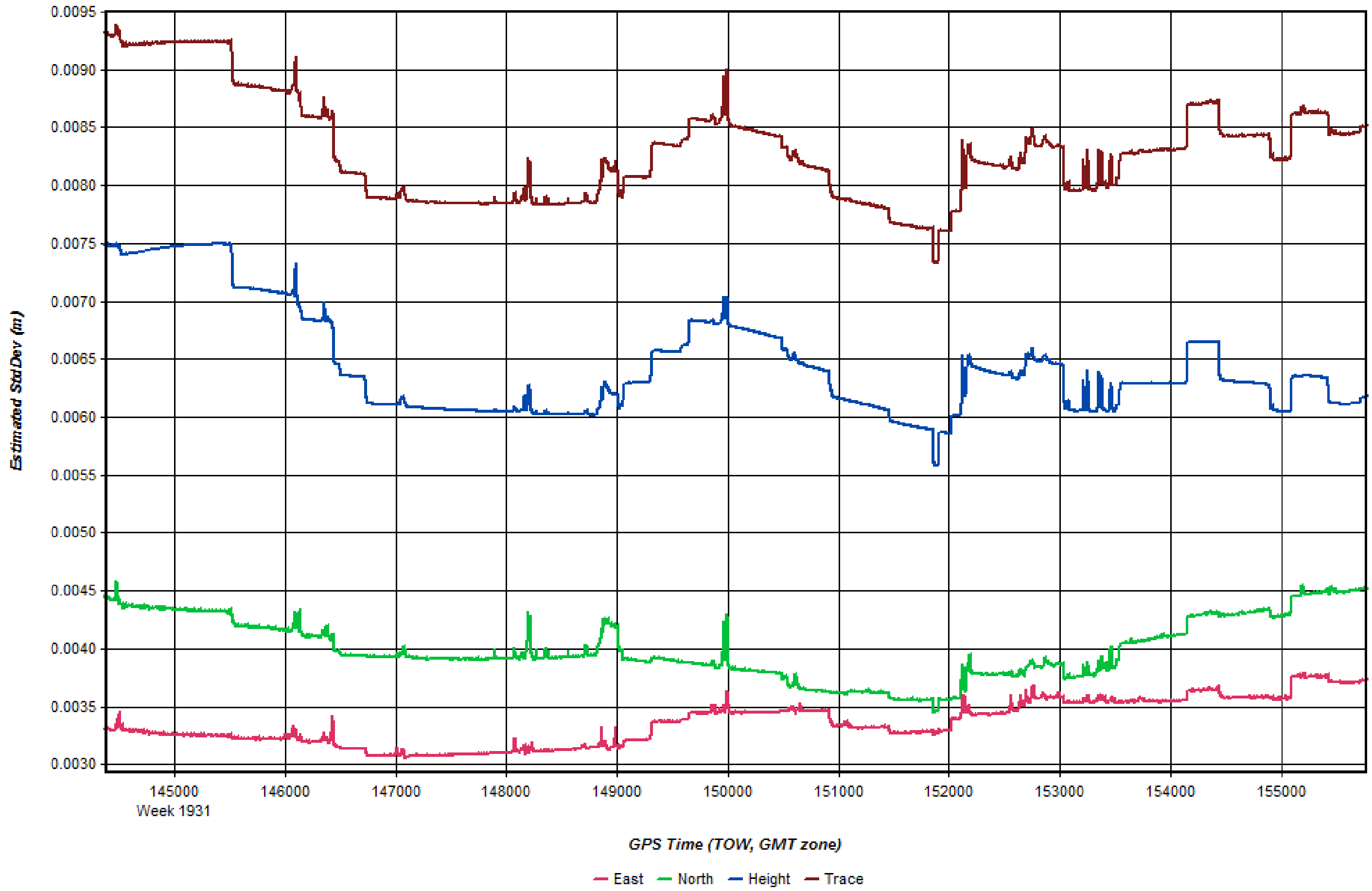

Num Sats
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
580000
Week 1930
582000
584000
586000
588000
590000
592000
594000
596000
598000
600000
GPS Time (TOW, GMT zone)
Num Sats
GPS
GLONASS
BeiDou

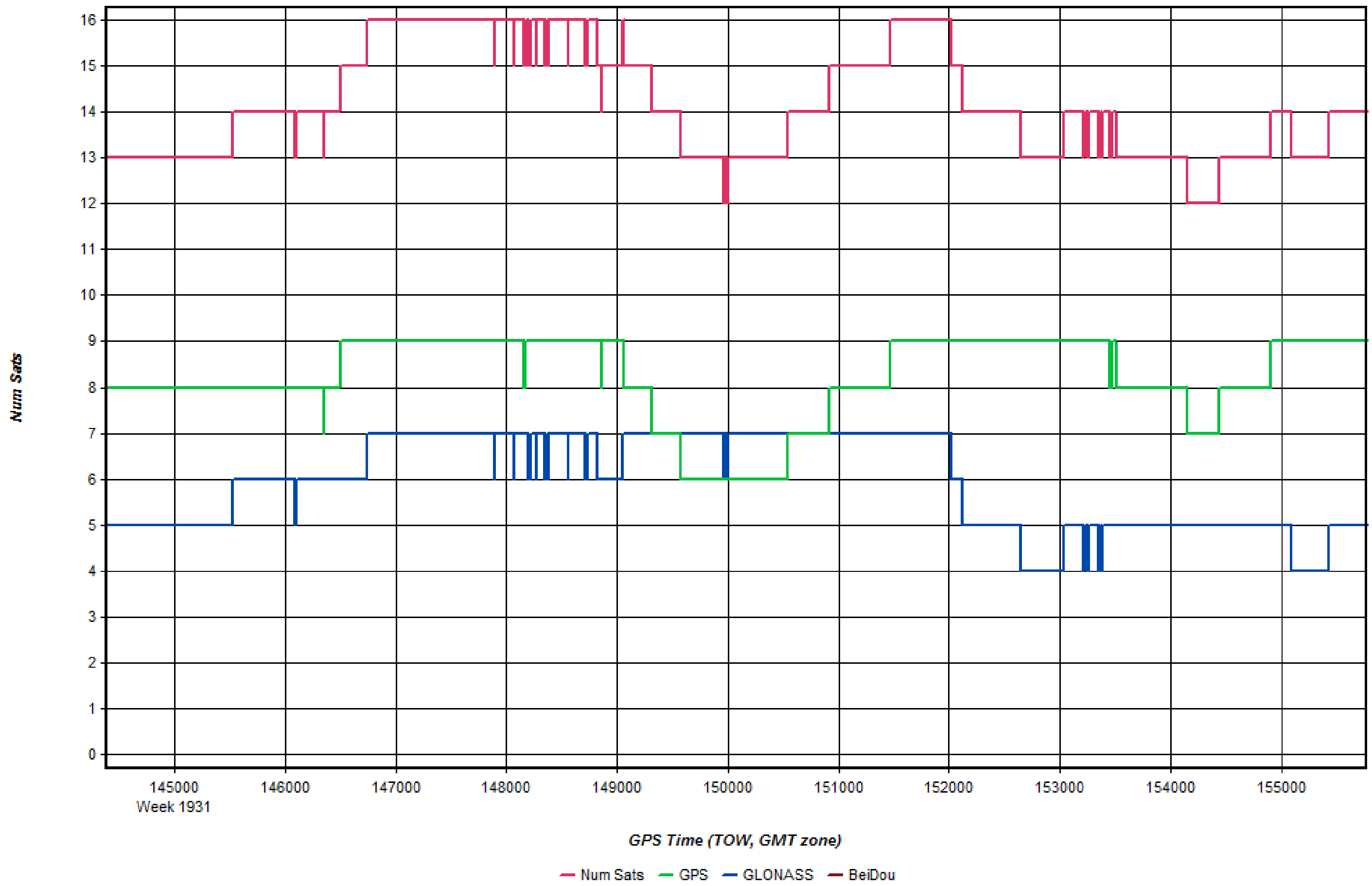

Separation (m)
0.065
0.060
0.055
0.050
0.045
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
-0.005
-0.010
-0.015
-0.020
-0.025
-0.030
-0.035
-0.040
-0.045
580000
Week 1930
582000
584000
586000
588000
590000
592000
594000
596000
598000
600000
GPS Time (TOW, GMT zone)
East
North
Up

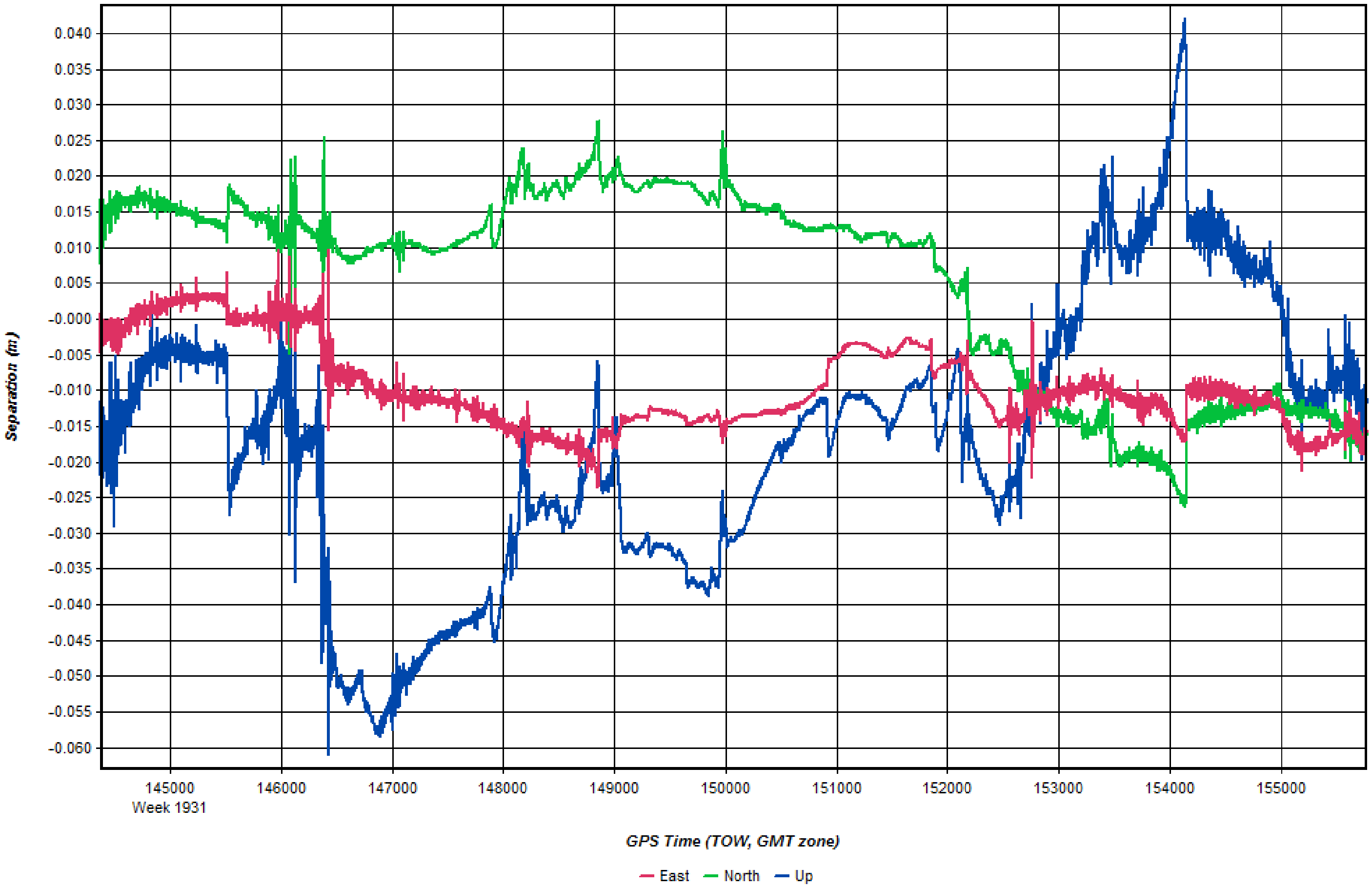

PDOP
2.20
2.15
2.10
2.05
2.00
1.95
1.90
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1.25
1.20
1.15
1.10
1.05
1.00
0.95
0.90
580000
Week 1930
582000
584000
586000
588000
590000
592000
594000
596000
598000
600000
GPS Time (TOW, GMT zone)
PDOP

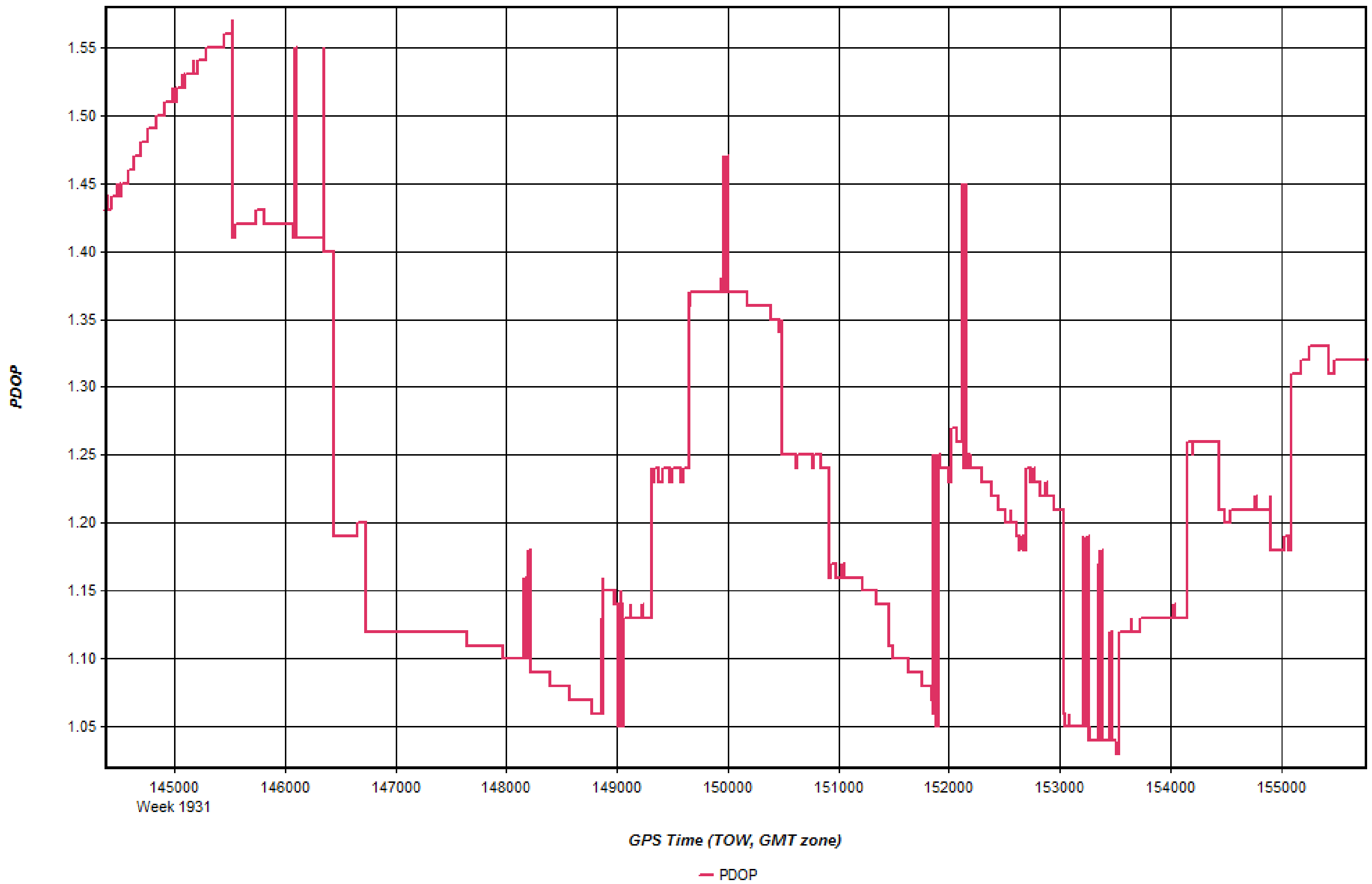
123_20170109_1



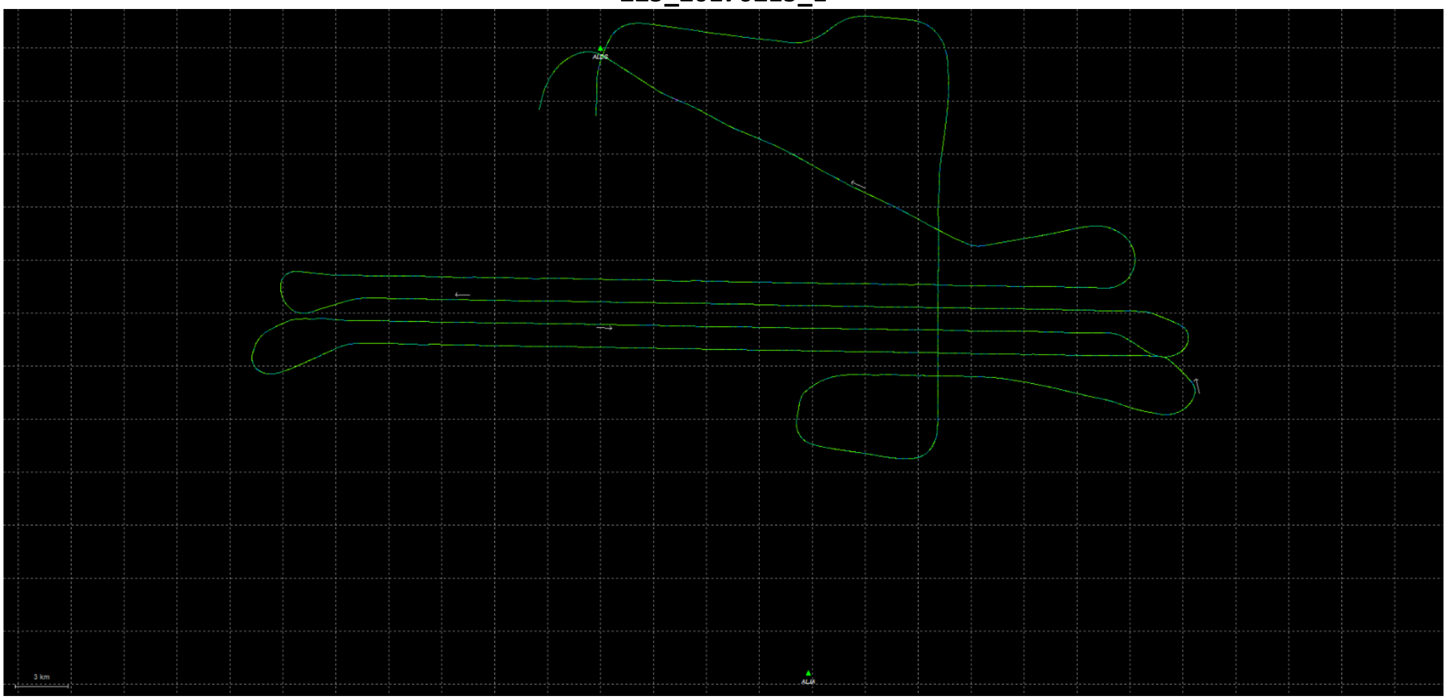

0.0095
0.0090
0.0085
0.0080
0.0075
0.0070
0.0065
0.0060
0.0055
0.0050
0.0045
0.0040
0.0035
0.0030
Estimated StdDev (m)
145000
Week 1931
146000
147000
148000
149000
150000
151000
152000
153000
154000
155000
GPS Time (TOW, GMT zone)
East
North
Height
Trace

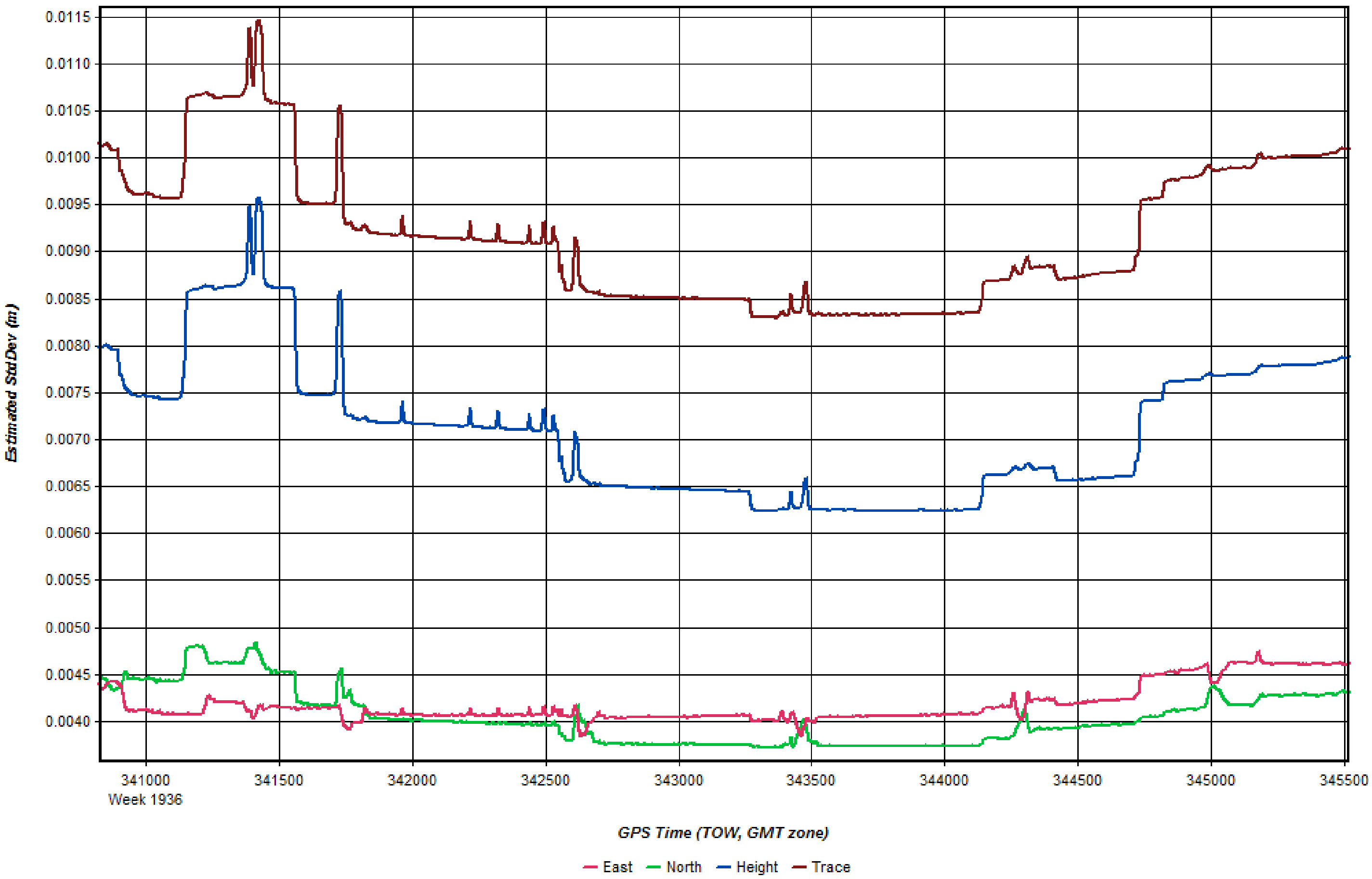

16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
Num Sats
145000
Week 1931
146000
147000
148000
149000
150000
151000
152000
153000
154000
155000
GPS Time (TOW, GMT zone)
Num Sats
GPS
GLONASS
BeiDou

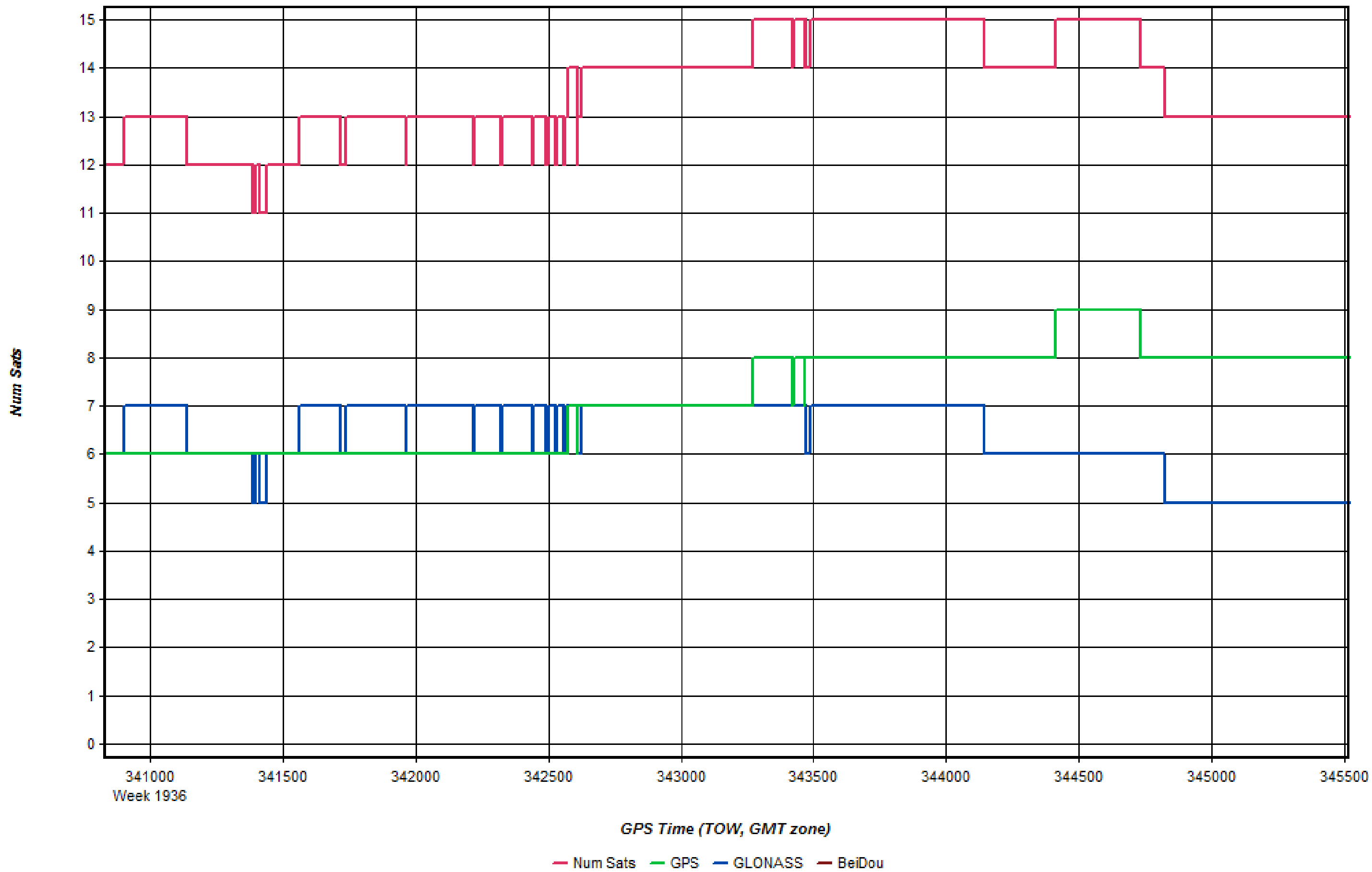

0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
-0.000
-0.005
-0.010
-0.015
-0.020
-0.025
-0.030
-0.035
-0.040
-0.045
-0.050
-0.055
-0.060
Separation (m)
145000
Week 1931
146000
147000
148000
149000
150000
151000
152000
153000
154000
155000
GPS Time (TOW, GMT zone)
East
North
Up

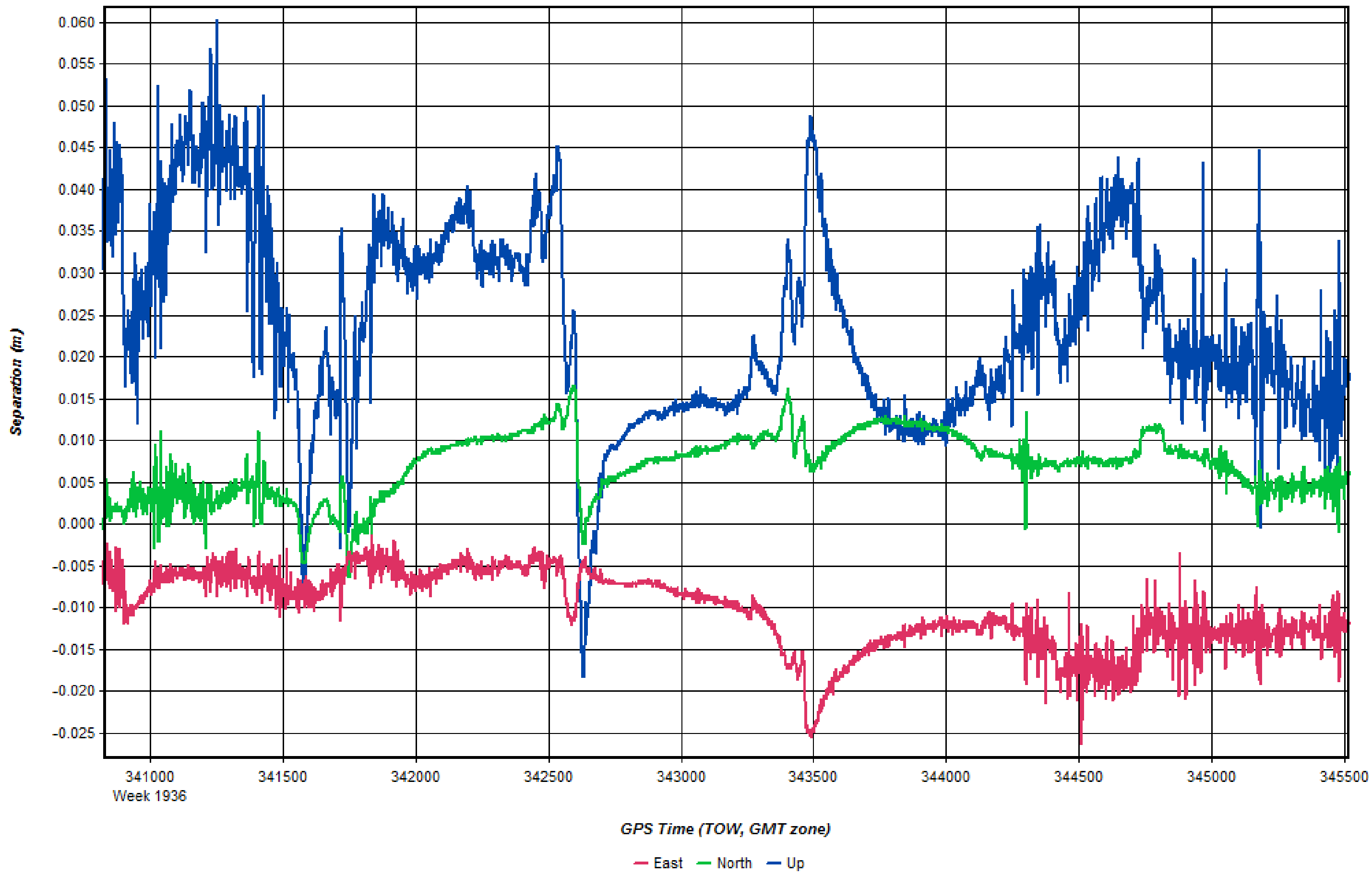

1.55
1.50
1.45
1.40
1.35
1.30
1.25
1.20
1.15
1.10
1.05
PDOP
145000
Week 1931
146000
147000
148000
149000
150000
151000
152000
153000
154000
155000
GPS Time (TOW, GMT zone)
PDOP

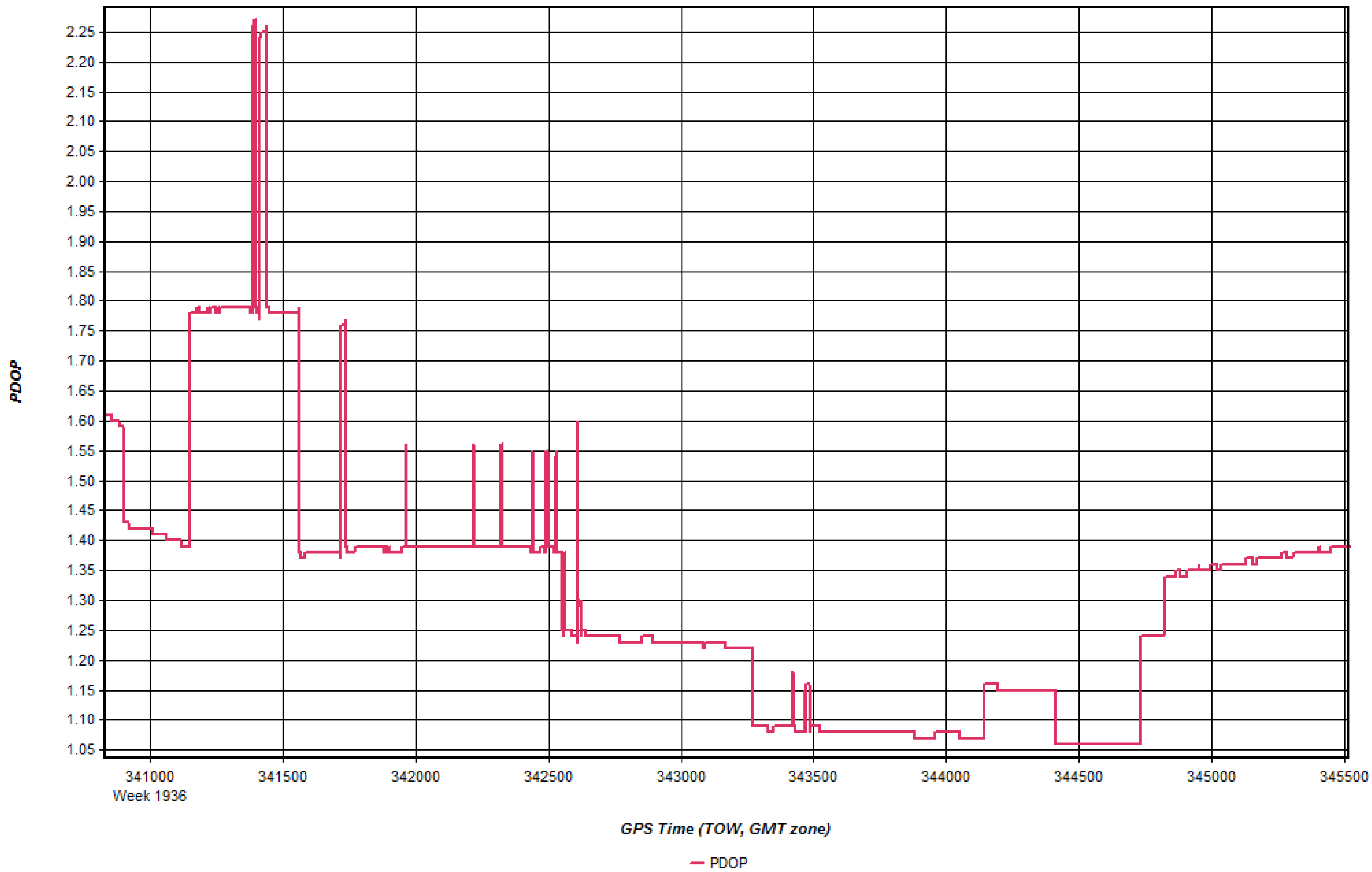
225_20170215_1




Estimated Std Dev (m)
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
341000
Week 1936
341500
342000
342500
343000
343500
344000
344500
345000
345500
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
341000
Week 1936
341500
342000
342500
343000
343500
344000
344500
345000
345500
GPS Time (TOW, GMT zone)
Num Sats
GPS
GLONASS
BeiDou


0.060
0.055
0.050
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
-0.020
-0.025
Separation (m)
341000
Week 1936
341500
342000
342500
343000
343500
344000
344500
345000
345500
GPS Time (TOW, GMT zone)
East
North
Up


PDOP
2.25
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
1.20
1.15
1.10
1.05
341000
Week 1936
341500
342000
342500
343000
343500
344000
344500
345000
345500
GPS Time (TOW, GMT zone)
PDOP