Aerial Lidar Report

Colville National Forest

15137

atlantic

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Section 1: Lidar Acquisition

1.1 Acquisition

Atlantic Group, LLC (Atlantic) has successfully completed lidar acquisition for the Colville National Forest area of interest (AOI). Lidar for this project was acquired in sixteen (16) flight lifts completed on July 25^{h}, 2015. The project area encompasses 742 square miles or 1,922 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 five hundred and five (505) 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. At least two (2) GPS reference station(s) were in operation during all missions, sampling positions at 1 Hz or higher frequently. Differential GPS baseline lengths did not exceed 30 km, unless otherwise approved. Differential GPS unit in aircraft recorded sample positions at 2 Hz or more frequently. Lidar data was only acquired when GPS PDOP was ≤ 4 and at least 6 satellites were in view.

Atlantic monitored weather and atmospheric conditions and conducted lidar missions only when conditions existed that would not degrade sensor ability in the collection of data. These conditions included no snow, rain, fog, smoke, mist and/or low clouds. Lidar systems are active sensors, not requiring light, thus missions may be conducted during night hours when weather restrictions do not prevent collection. Atlantic accessed reliable weather sites and indicators (webcams) to establish the highest probability for successful collection in order to position our sensor to maximize successful data acquisition.

Within 72-hours prior to the planned day(s) of acquisition, Atlantic closely monitored the weather, checking all sources for forecasts at least twice daily. As soon as weather conditions were conducive to acquisition, our aircraft mobilized to the project site to begin data collection. Once on site, the acquisition team took responsibility for weather analysis. 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 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.

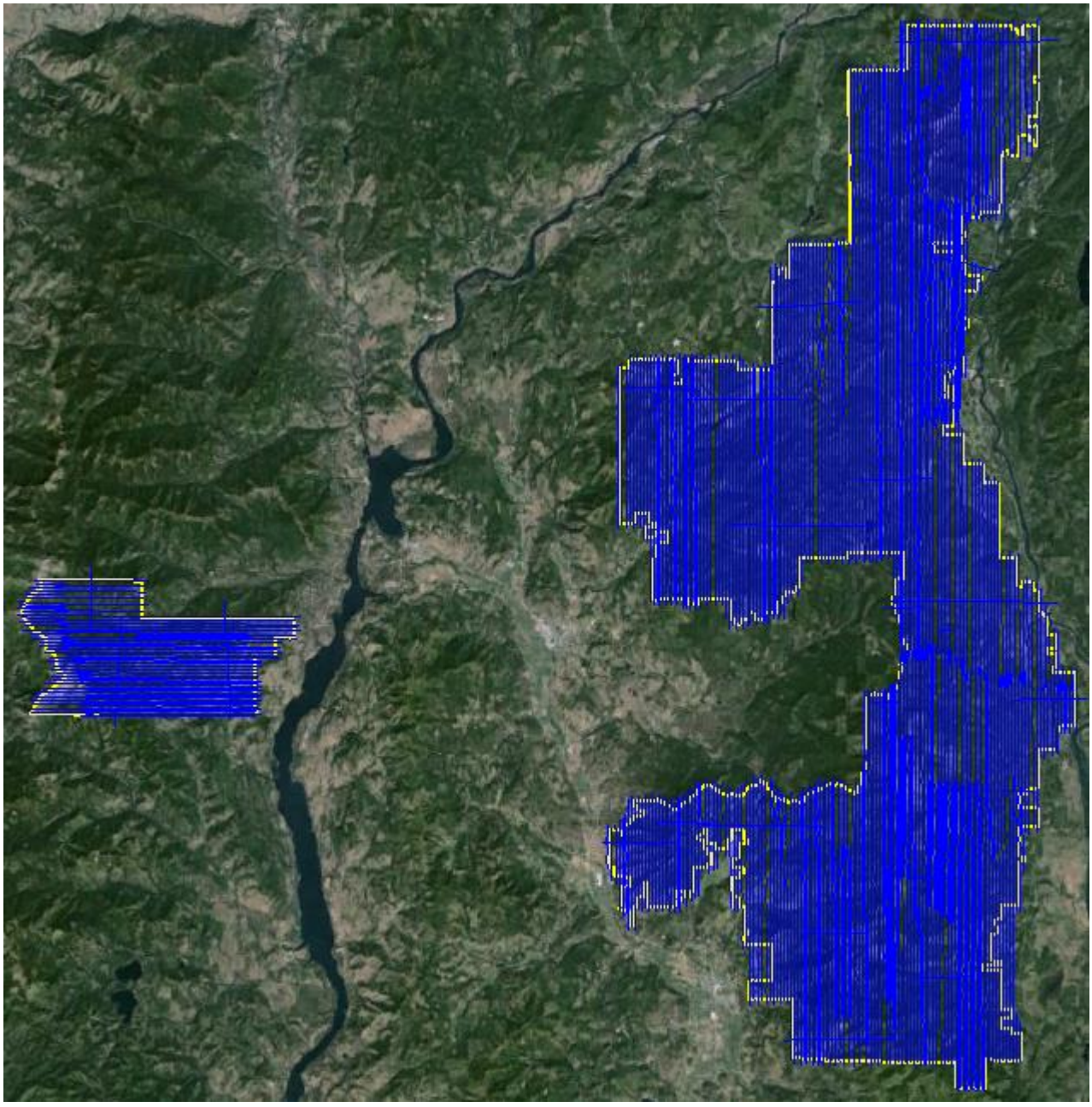


Figure 1: Trajectories as flown by Atlantic

1.5 Acquisition Lift Summary

Table 1 provides correlating dates and times for each acquisition mission reported in UTC Times.

Acquisition Lift Summary			
Lift ID	**Date**	**GPS Week**	**Time Range (HH:MM:SS)**
123_20150708_1	7/8/2015	1852	15:11:17 - 20:27:00
123_20150708_2	7/8/2015	1852	21:07:20 - 22:44:47
123_20150708_3	7/8/2015	1852	00:15:30 - 04:36:21
123_20150709_1	7/9/2015	1852	12:52:07 - 18:57:08
225_20150716_1	7/16/2015	1853	20:42:28 - 02:08:59
225_20150717_1	7/17/2015	1853	12:11:42 - 18:07:08
225_20150717_2	7/17/2015	1853	21:46:16 - 01:42:23
225_20150718_1	7/18/2015	1853	16:14:28 - 21:42:20
225_20150718_2	7/18/2015	1853	22:25:10 - 03:19:32
225_20150719_1	7/19/2015	1854	12:25:42 - 19:47:28
225_20150722_1	7/22/2015	1854	18:08:50 - 21:42:55
225_20150723_1	7/23/2015	1854	12:35:06 - 20:04:37
225_20150723_2	7/23/2015	1854	21:59:55 - 04:14:22
225_20150724_1	7/24/2015	1854	12:51:58 - 19:42:20
225_20150724_2	7/24/2015	1854	22:01:37 - 03:59:13
225_20150725_1	7/25/2015	1854	12:51:08 - 18:11:10

Table 1: Date and Time of Acquisition Missions

1.6 Acquisition Equipment

Atlantic operated a Partenavia S.P.A. P 68 C/TC (N775MW) and a Cessna T210L (N732JE) both outfitted with Leica ALS70-HP lidar systems during the collection of the project area. Table 1 represents a list of the features and characteristics for the Leica ALS70-HP lidar system:

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

Table 1: Atlantic Sensor Characteristics

1.7 Lidar System Parameters

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

Lidar System Acquisition Parameters	
Item	**Parameter**
System	Leica ALS-70 HP
Nominal Pulse Spacing (m)	0.5
Nominal Pulse Density (pls/m²)	4
Nominal Flight Height (MSL meters)	2926
Nominal Flight Speed (kts)	110
Pass Heading (degree)	0
Sensor Scan Angle (degree)	34
Scan Frequency (Hz)	38
Pulse Rate of Scanner (kHz)	209
Line Spacing (m)	680
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	No
Beam Divergence (mrad)	0.15
Nominal Swath With (m)	924
Nominal Swath Overlap (%)	50
Scan Pattern	Triangle

Table 2: Atlantic Lidar System Acquisition Parameters

1.8 GPS Reference Station(s)

Three (3) CORS stations, three (3) NGS monuments, and three (3) dedicated stations set by Atlantic was 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	**PID**	**Latitude (N)**	**Longitude (W)**	**Elevation**
G483	TO0750	48°52'22.90921"	117°21'09.55980"	751.156
K24	TO0445	48°12'27.50351"	117°43'53.77544"	488.499
SET1	n/a	48°34'42.52584"	118°16'03.94623"	687.248
SET2	n/a	48°38'52.87820"	117°30'40.16235"	965.905
SET3	n/a	48°12'27.72743"	117°43'53.36316"	488.402
P025	DL7722	48°43'51.63211"	116°17'14.98285"	695.892
RKD1	DN5852	48°57'51.64837"	119°24'46.83915"	313.547
SPN6	DK3593	47°31'06.10773"	117°25'24.00064"	720.987
Z264	TO0513	48°32'29.33445"	117°53'15.09442"	551.391

Table 3: GPS Reference Station Coordinates

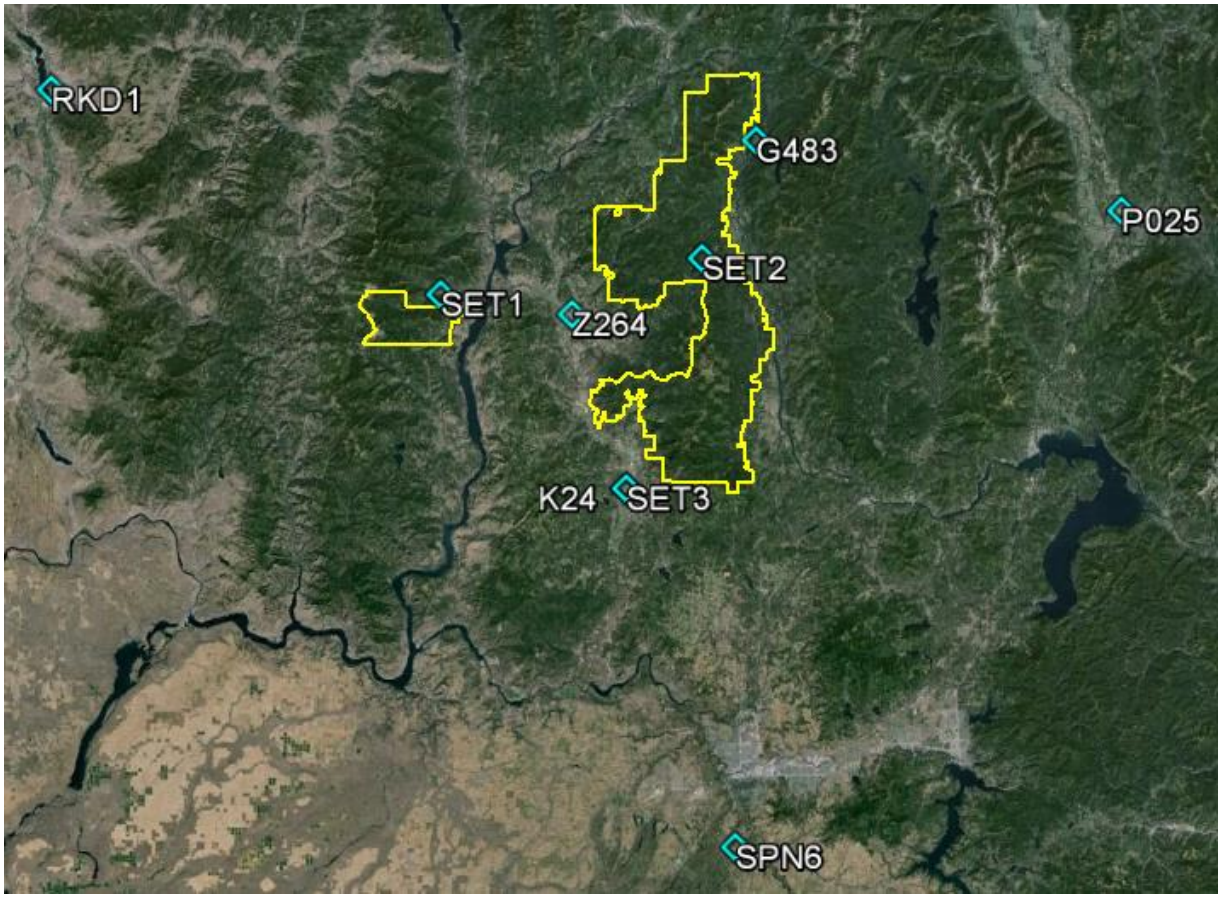


Figure 2: GPS Reference Station(s)

1.9 Airborne GPS Kinematic

Differential GPS unit in aircraft collected positions at 2 Hz. Airborne GPS data was processed using the Inertial Explorer (version 8.5.4320) software. Flights were flown with a minimum of 6 satellites in view (10° above the horizon) and with a PDOP of ≤4 when laser online. Distances from base station to aircraft were kept to a maximum of 30km.

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 and Calibration of Laser Points

The initial step of calibration is to verify availability and status of all needed GPS and Laser data against field notes and compile any data if not complete. Subsequently, the mission points are output using Leica's CloudPro post processor with the most recent boresight values. The initial point generation for each mission calibration is verified within TerraScan using distance colored points to identify errors. If a calibration error greater than specification is observed within the mission, the roll, pitch and scanner scale corrections that need to be applied are calculated. Once validated each output mission is imported into the GeoCue software package. Here a project level supplementary coverage check is carried out to ensure no data voids unreported by Field Operations are present.

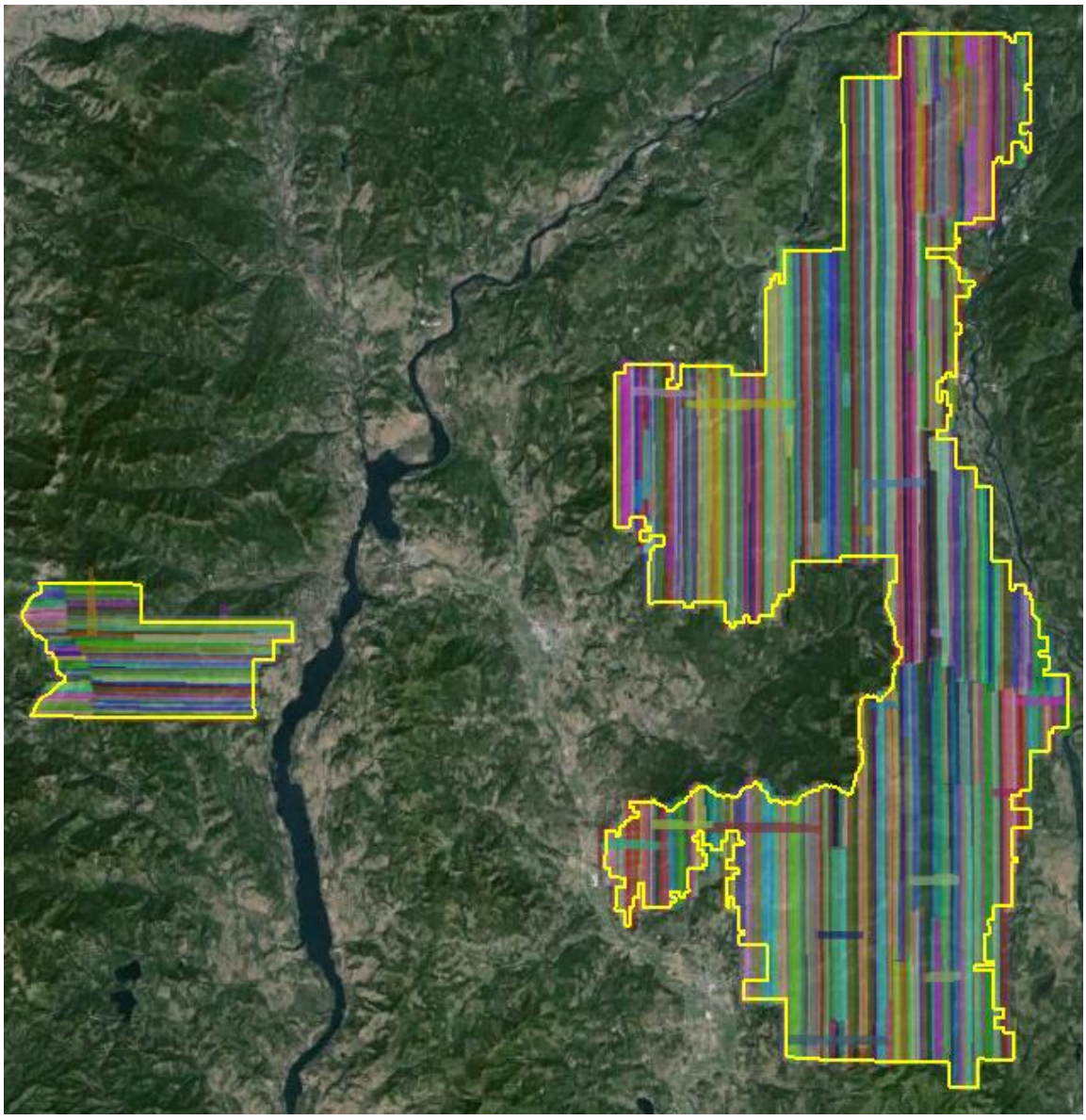


Figure 3: Lidar swath data showing complete coverage

2.2 Reference System

Horizontal Datum:	North American Datum of 1983
Coordinate System:	USFS R6 Albers
Vertical Datum:	North American Vertical Datum of 1988
Geoid Model:	Geoid12A
Units:	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	36,300,374,226
Aggregate Nominal Pulse Spacing (m)	0.2425
Aggregate Nominal Pulse Density (pls/m²)	18.3

Table 4: Lidar Point Cloud Statistics

2.4 Relative Accuracy

For effective data management, each imported mission is tiled out in GeoCue to a project specific tile scheme or index. Relative accuracy and internal quality are then checked using a number of carefully selected tiles in which points from all lines are loaded and inspected. Vertical differences between ground surfaces of each line are displayed by the generation of Z-Difference colored intensity orthos in GeoCue. The color scale of these orthos are adjusted so that errors greater than the specifications are flagged. Cross sections are visually inspected across each block to validate point to point, flight line to flight line and mission to mission alignment. When available, surveyed control points are used to supplement and verify the calibration of the data.

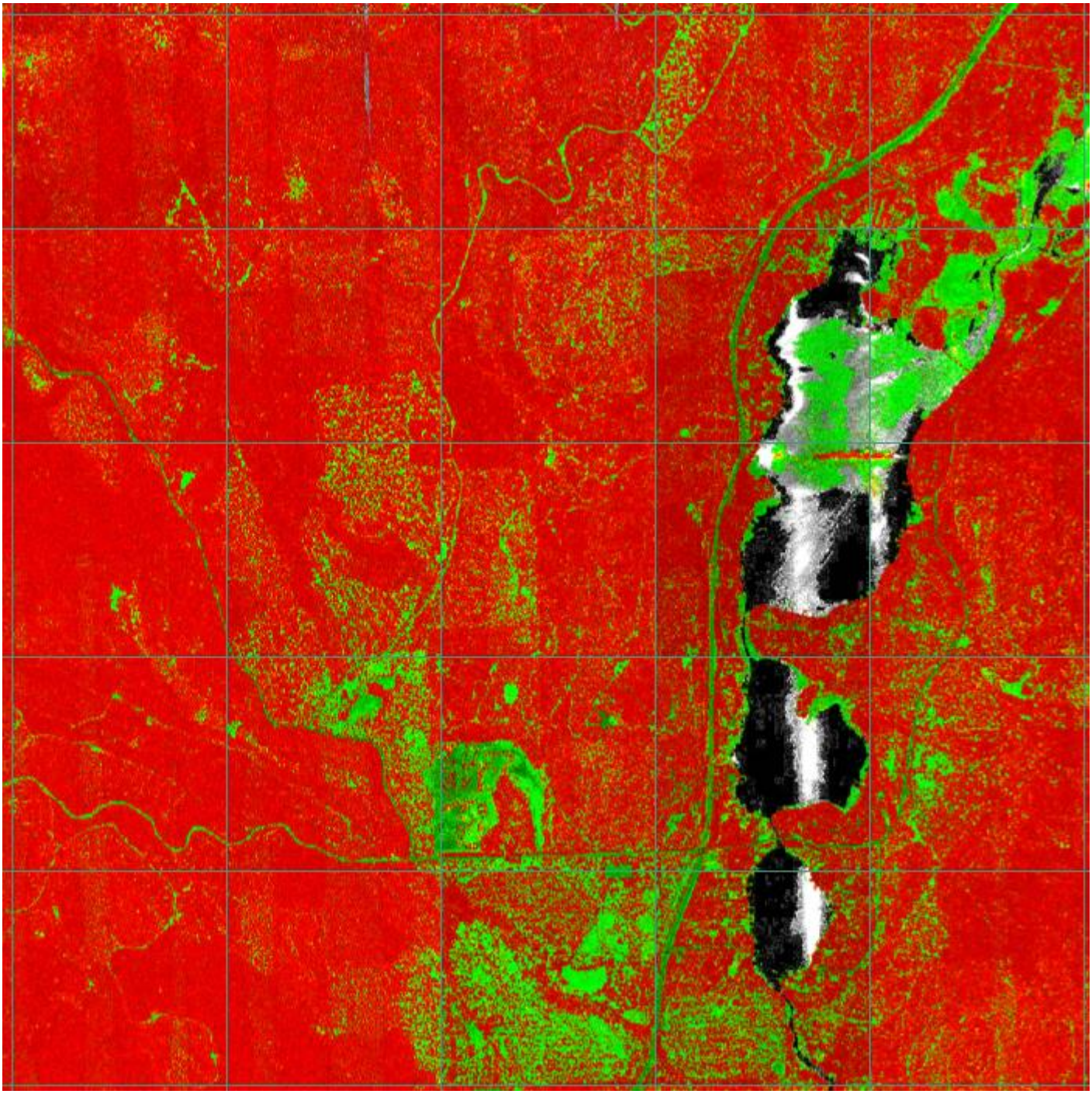


Figure 4: dZ ortho sub-sample

2.5 Relative Accuracy Results

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 U.S. Survey Feet.

Average Magnitudes Per Line											
Line	X	Y	Z	Line	X	Y	Z	Line	X	Y	Z
3	0.067	0.032	0.021	167	0.033	0.026	0.019	342	0.001	0.003	0.015
4	0.096	0.050	0.025	168	0.019	0.017	0.019	343	0.010	0.026	0.017
5	0.058	0.036	0.024	169	0.087	0.083	0.014	344	0.035	0.049	0.016
6	-	-	0.027	170	0.024	0.026	0.019	345	0.023	0.020	0.015
7	-	-	0.024	171	-	-	0.022	346	0.031	0.024	0.019
8	-	-	0.024	172	0.007	0.021	0.021	347	0.054	0.049	0.022
9	-	-	0.023	173	0.047	0.015	0.018	348	0.019	0.030	0.023
10	-	-	0.026	174	0.058	0.025	0.017	349	0.011	0.023	0.023
11	-	-	0.023	175	0.079	0.028	0.017	350	0.013	0.011	0.025
12	-	-	0.025	176	0.048	0.017	0.016	351	-	-	0.024
13	-	-	0.027	177	0.055	0.024	0.017	352	-	-	0.028
14	-	-	0.022	178	0.045	0.025	0.016	353	-	-	0.022
15	-	-	0.023	179	-	-	0.017	354	-	-	0.027
16	-	-	0.024	180	-	-	0.020	355	-	-	0.029
17	-	-	0.024	181	-	-	0.019	356	-	-	0.030
18	-	-	0.024	182	-	-	0.017	357	-	-	0.031
19	-	-	0.021	183	-	-	0.018	358	-	-	0.028
20	-	-	0.021	184	-	-	0.017	359	-	-	0.028
21	-	-	0.022	185	-	-	0.020	360	-	-	0.026
22	-	-	0.020	186	-	-	0.020	361	-	-	0.027
23	-	-	0.019	187	-	-	0.021	362	-	-	0.025
24	-	-	0.022	189	0.040	0.029	0.017	363	-	-	0.023
25	-	-	0.021	190	0.029	0.036	0.016	364	-	-	0.025
26	-	-	0.021	191	0.040	0.034	0.019	365	-	-	0.028
27	-	-	0.024	192	0.054	0.075	0.021	366	-	-	0.027
28	-	-	0.023	193	-	-	0.021	367	-	-	0.026
29	-	-	0.020	194	0.019	0.017	0.019	368	-	-	0.027
30	-	-	0.021	195	-	-	0.021	369	-	-	0.023
31	-	-	0.021	196	-	-	0.023	370	-	-	0.024
32	-	-	0.021	197	-	-	0.022	371	-	-	0.024
33	-	-	0.016	199	-	-	0.022	372	-	-	0.024
34	-	-	0.027	200	0.000	0.007	0.023	373	-	-	0.024
35	-	-	0.022	201	0.032	0.022	0.022	374	-	-	0.023
36	0.008	0.080	0.021	202	0.071	0.041	0.023	375	-	-	0.025
37	0.009	0.094	0.020	203	0.052	0.029	0.020	376	-	-	0.025
38	-	-	0.020	204	0.033	0.020	0.019	377	-	-	0.024
39	-	-	0.019	205	0.026	0.019	0.017	378	-	-	0.022

40	-	-	0.017	**206**	0.049	0.029	0.018	**379**	-	-	0.017
41	-	-	0.017	**207**	0.040	0.027	0.018	**380**	-	-	0.022
42	-	-	0.015	**208**	0.031	0.042	0.017	**381**	-	-	0.023
43	-	-	0.019	**209**	0.025	0.039	0.018	**382**	-	-	0.023
44	-	-	0.018	**210**	0.054	0.053	0.019	**383**	-	-	0.025
45	-	-	0.018	**211**	0.042	0.035	0.019	**384**	-	-	0.027
46	-	-	0.020	**212**	0.016	0.013	0.019	**385**	-	-	0.024
47	-	-	0.020	**213**	0.031	0.022	0.020	**386**	-	-	0.021
48	-	-	0.027	**214**	0.046	0.030	0.019	**387**	-	-	0.022
49	-	-	0.022	**215**	0.045	0.025	0.018	**388**	-	-	0.023
50	-	-	0.021	**216**	0.036	0.025	0.017	**389**	-	-	0.023
51	-	-	0.024	**217**	0.033	0.023	0.017	**390**	0.026	0.063	0.021
52	-	-	0.023	**218**	0.026	0.026	0.018	**391**	0.048	0.088	0.022
53	-	-	0.019	**219**	0.035	0.033	0.015	**392**	0.100	0.015	0.021
54	-	-	0.021	**220**	0.063	0.035	0.017	**393**	0.085	0.013	0.021
55	-	-	0.024	**221**	0.061	0.035	0.016	**394**	-	-	0.022
56	-	-	0.023	**222**	0.044	0.032	0.018	**395**	0.057	0.033	0.023
57	-	-	0.024	**223**	0.033	0.025	0.014	**396**	0.074	0.029	0.020
58	-	-	0.025	**224**	0.041	0.036	0.015	**397**	0.075	0.037	0.020
59	-	-	0.022	**225**	0.034	0.028	0.018	**398**	0.051	0.047	0.020
60	-	-	0.023	**226**	-	-	0.019	**399**	0.035	0.032	0.017
61	-	-	0.022	**227**	0.074	0.048	0.016	**400**	0.073	0.056	0.019
62	-	-	0.024	**228**	0.066	0.057	0.021	**401**	0.043	0.030	0.020
63	-	-	0.021	**229**	0.032	0.057	0.020	**402**	0.040	0.033	0.020
64	-	-	0.022	**230**	0.003	0.020	0.018	**403**	0.034	0.038	0.020
65	-	-	0.031	**233**	-	-	0.016	**404**	0.045	0.048	0.021
66	-	-	0.032	**235**	0.047	0.024	0.014	**405**	0.039	0.070	0.020
67	-	-	0.022	**236**	0.047	0.024	0.018	**406**	0.026	0.021	0.018
68	-	-	0.027	**237**	-	-	0.021	**407**	0.020	0.016	0.018
69	-	-	0.023	**238**	0.056	0.019	0.021	**408**	0.023	0.015	0.018
70	-	-	0.026	**239**	0.047	0.026	0.021	**411**	0.039	0.036	0.018
71	-	-	0.022	**240**	0.052	0.034	0.018	**413**	0.119	0.043	0.018
72	-	-	0.023	**241**	0.026	0.020	0.017	**414**	0.027	0.018	0.017
73	-	-	0.021	**242**	0.004	0.012	0.019	**415**	0.011	0.010	0.019
74	-	-	0.021	**243**	0.051	0.005	0.018	**416**	-	-	0.018
75	-	-	0.020	**244**	-	-	0.019	**417**	0.075	0.051	0.020
76	-	-	0.025	**245**	-	-	0.016	**418**	0.036	0.022	0.018
77	-	-	0.024	**246**	-	-	0.015	**419**	0.119	0.043	0.017
78	-	-	0.020	**247**	-	-	0.014	**420**	-	-	0.018
79	-	-	0.022	**248**	-	-	0.018	**421**	-	-	0.018
80	-	-	0.021	**249**	0.037	0.024	0.016	**422**	-	-	0.018
81	-	-	0.020	**250**	0.061	0.044	0.016	**423**	-	-	0.020
82	-	-	0.020	**251**	0.023	0.016	0.017	**424**	0.011	0.062	0.019

84	0.001	0.018	0.024	**253**	0.003	0.016	0.019	**425**	0.010	0.061	0.019
85	-	-	0.017	**254**	0.034	0.024	0.018	**426**	-	-	0.019
86	0.023	0.037	0.018	**255**	0.034	0.025	0.018	**427**	-	-	0.018
87	0.013	0.030	0.019	**256**	-	-	0.020	**428**	-	-	0.018
88	0.018	0.033	0.020	**257**	-	-	0.021	**429**	-	-	0.018
89	0.033	0.035	0.021	**258**	-	-	0.023	**430**	-	-	0.018
90	0.033	0.036	0.019	**259**	-	-	0.025	**431**	-	-	0.020
91	0.020	0.023	0.018	**260**	0.031	0.069	0.022	**432**	0.070	0.076	0.018
92	0.022	0.027	0.020	**261**	0.031	0.069	0.018	**433**	0.069	0.076	0.018
93	0.033	0.017	0.021	**262**	-	-	0.020	**434**	-	-	0.019
94	0.000	0.002	0.021	**263**	-	-	0.022	**435**	0.117	0.007	0.020
95	0.003	0.006	0.017	**264**	-	-	0.019	**436**	0.059	0.070	0.021
96	0.080	0.034	0.019	**266**	0.072	0.039	0.016	**437**	-	-	0.015
97	0.007	0.010	0.021	**267**	0.072	0.028	0.018	**438**	0.033	0.042	0.018
98	0.054	0.025	0.020	**270**	-	-	0.019	**439**	0.028	0.035	0.020
99	0.061	0.024	0.019	**271**	-	-	0.020	**440**	0.029	0.041	0.020
100	-	-	0.019	**272**	-	-	0.022	**441**	-	-	0.018
101	0.051	0.024	0.020	**273**	-	-	0.015	**442**	0.035	0.064	0.018
102	-	-	0.021	**274**	-	-	0.016	**443**	0.053	0.045	0.018
103	-	-	0.020	**275**	0.024	0.018	0.016	**444**	0.033	0.040	0.017
104	0.030	0.028	0.019	**276**	0.012	0.010	0.014	**445**	0.012	0.022	0.019
105	-	-	0.020	**277**	0.009	0.013	0.013	**446**	0.030	0.035	0.018
106	0.030	0.028	0.019	**278**	0.010	0.014	0.013	**447**	0.032	0.035	0.016
107	-	-	0.024	**279**	0.009	0.010	0.015	**448**	0.035	0.036	0.018
108	-	-	0.021	**280**	0.053	0.044	0.019	**449**	0.045	0.037	0.020
109	-	-	0.024	**281**	0.071	0.052	0.016	**450**	0.049	0.048	0.020
110	-	-	0.021	**282**	-	-	0.018	**451**	0.035	0.038	0.017
111	-	-	0.020	**283**	-	-	0.018	**452**	0.040	0.055	0.019
112	-	-	0.019	**284**	-	-	0.017	**453**	0.051	0.049	0.018
113	-	-	0.019	**285**	0.015	0.020	0.018	**454**	0.047	0.031	0.019
114	-	-	0.019	**286**	0.055	0.076	0.018	**455**	0.095	0.074	0.019
115	-	-	0.020	**287**	0.029	0.039	0.018	**456**	-	-	0.019
116	-	-	0.022	**288**	-	-	0.024	**457**	0.063	0.005	0.019
117	-	-	0.019	**289**	-	-	0.020	**458**	0.140	0.009	0.017
118	-	-	0.022	**290**	-	-	0.020	**459**	0.077	0.005	0.017
119	-	-	0.023	**291**	0.045	0.038	0.020	**460**	-	-	0.018
120	-	-	0.019	**292**	0.045	0.038	0.020	**461**	-	-	0.018
121	-	-	0.021	**293**	-	-	0.019	**462**	-	-	0.018
122	-	-	0.020	**294**	-	-	0.018	**463**	-	-	0.019
123	-	-	0.018	**295**	-	-	0.020	**464**	-	-	0.019
124	-	-	0.021	**296**	-	-	0.020	**465**	-	-	0.018
125	0.023	0.008	0.021	**297**	0.045	0.026	0.018	**466**	0.001	0.017	0.019
126	-	-	0.023	**298**	0.055	0.045	0.020	**467**	0.001	0.018	0.021

127	0.023	0.008	0.020	**299**	0.042	0.013	0.018	**468**	-	-	0.021
128	-	-	0.021	**300**	-	-	0.019	**469**	0.029	0.026	0.020
131	-	-	0.023	**301**	0.003	0.021	0.018	**470**	0.044	0.067	0.020
132	-	-	0.021	**302**	0.002	0.019	0.017	**471**	0.024	0.044	0.020
133	-	-	0.024	**303**	-	-	0.016	**472**	0.002	0.012	0.021
134	-	-	0.026	**304**	-	-	0.020	**474**	0.001	0.139	0.020
135	-	-	0.023	**305**	0.013	0.035	0.017	**475**	-	-	0.021
136	-	-	0.020	**306**	0.005	0.012	0.018	**476**	0.006	0.015	0.023
137	-	-	0.017	**308**	0.028	0.012	0.013	**477**	0.033	0.030	0.023
138	-	-	0.020	**309**	0.029	0.013	0.017	**478**	0.056	0.040	0.025
139	-	-	0.023	**310**	-	-	0.016	**479**	0.048	0.020	0.022
140	-	-	0.024	**311**	0.033	0.009	0.016	**480**	0.055	0.012	0.020
141	-	-	0.026	**312**	0.033	0.012	0.017	**481**	0.048	0.018	0.020
142	-	-	0.023	**313**	0.038	0.014	0.020	**482**	0.041	0.030	0.019
143	-	-	0.026	**314**	0.046	0.023	0.018	**483**	0.048	0.044	0.019
144	-	-	0.024	**315**	0.041	0.023	0.016	**484**	0.052	0.044	0.018
145	-	-	0.027	**316**	0.048	0.026	0.018	**485**	0.036	0.032	0.019
146	-	-	0.020	**317**	0.055	0.028	0.019	**486**	0.044	0.052	0.019
147	-	-	0.019	**319**	0.069	0.021	0.020	**487**	0.018	0.029	0.018
148	-	-	0.021	**321**	0.053	0.045	0.022	**488**	-	-	0.019
149	-	-	0.021	**322**	0.044	0.025	0.020	**489**	0.035	0.011	0.018
150	-	-	0.022	**323**	0.017	0.019	0.020	**490**	0.038	0.015	0.018
151	-	-	0.023	**324**	0.026	0.044	0.023	**491**	0.013	0.017	0.019
152	-	-	0.024	**325**	0.029	0.031	0.024	**492**	-	-	0.017
153	-	-	0.024	**326**	-	-	0.024	**493**	-	-	0.020
154	-	-	0.024	**327**	-	-	0.024	**494**	0.037	0.050	0.021
155	-	-	0.023	**328**	-	-	0.022	**495**	-	-	0.022
156	-	-	0.023	**329**	-	-	0.029	**496**	-	-	0.024
157	-	-	0.024	**330**	-	-	0.022	**497**	0.032	0.037	0.015
158	-	-	0.021	**331**	-	-	0.021	**498**	0.019	0.024	0.019
159	-	-	0.021	**332**	-	-	0.024	**499**	0.020	0.035	0.018
160	-	-	0.020	**333**	0.001	0.034	0.022	**501**	-	-	0.016
161	-	-	0.021	**334**	0.000	0.005	0.025	**502**	0.011	0.025	0.018
162	-	-	0.021	**336**	0.007	0.030	0.020	**503**	0.015	0.031	0.019
163	-	-	0.023	**338**	0.002	0.014	0.015	**504**	-	-	0.026
164	0.054	0.062	0.018	**339**	0.051	0.010	0.014	**505**	0.001	0.021	0.020
165	0.018	0.017	0.019	**340**	0.056	0.015	0.018				
166	0.029	0.024	0.018	**341**	0.035	0.003	0.016				

Table 5: Average Tie Line Magnitudes per Line

Internal Observation Statistics			
Category	**X**	**Y**	**Z**
Average Magnitude	0.034	0.026	0.020
RMS Values	0.049	0.036	0.027
Maximum Values	0.147	0.149	0.150
Observation Weight	3513.0	3513.0	409175.0

Table 6: Tie Line Observation Statistics

Overall Relative Accuracy	
Category	**Mismatch**
Average 3D Mismatch	0.02012
Average XY Mismatch	0.04898
Average Z Mismatch	0.01975

Table 7: Relative Accuracy Results

TerraMatch Tie Lines	
Category	**Observations**
Section Lines	150,802
Roof Lines	1,386

Table 8: Total Tie Lines

2.6 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.

2.7 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. Outlined in Table 9 are the classification codes utilized for this project.

ASPRS Standard Lidar Point Classes		
Code	**Description**	**Utilized**
0	Created, never classified	
1	Unclassified[3]	X
2	Ground	X
3	Low Vegetation	
4	Medium Vegetation	
5	High Vegetation	
6	Building	
7	Low Point (noise)	
8	Reserved	
9	Water	
10	Rail (breakline buffer)	
11	Road Surface	
12	Reserved	
13	Wire – Guard (Shield)	
14	Wire – Conductor (Phase)	
15	Transmission Tower	
16	Wire-structure Connector (e.g. Insulator)	
17	Bridge Deck	
18	High Noise	
19-63	Reserved	
64-255	User Definable	

Table 9: Point Cloud Classification Scheme

Section 3: Vertical Accuracy Assessment

3.1 Ground Surveyed Check Points

Atlantic established a total of one hundred and sixteen (116) checkpoints for this project (60 NVA + 56 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

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 95th 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 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 graphic(s) depicts the location and distribution of NVA and VVA Check Points established for this project.

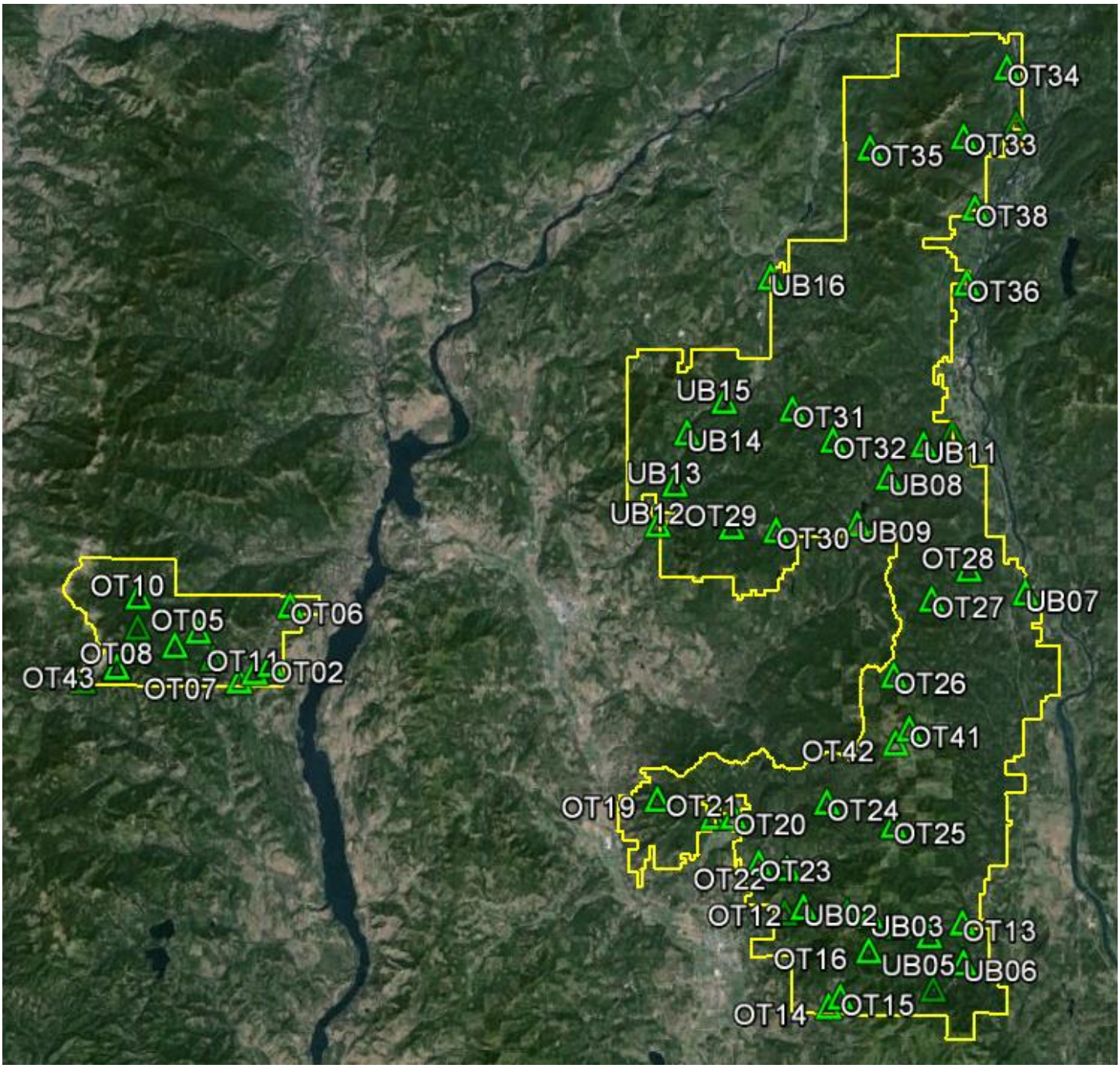


Figure 5: Non-vegetated Vertical Accuracy (NVA) Check Point Distribution

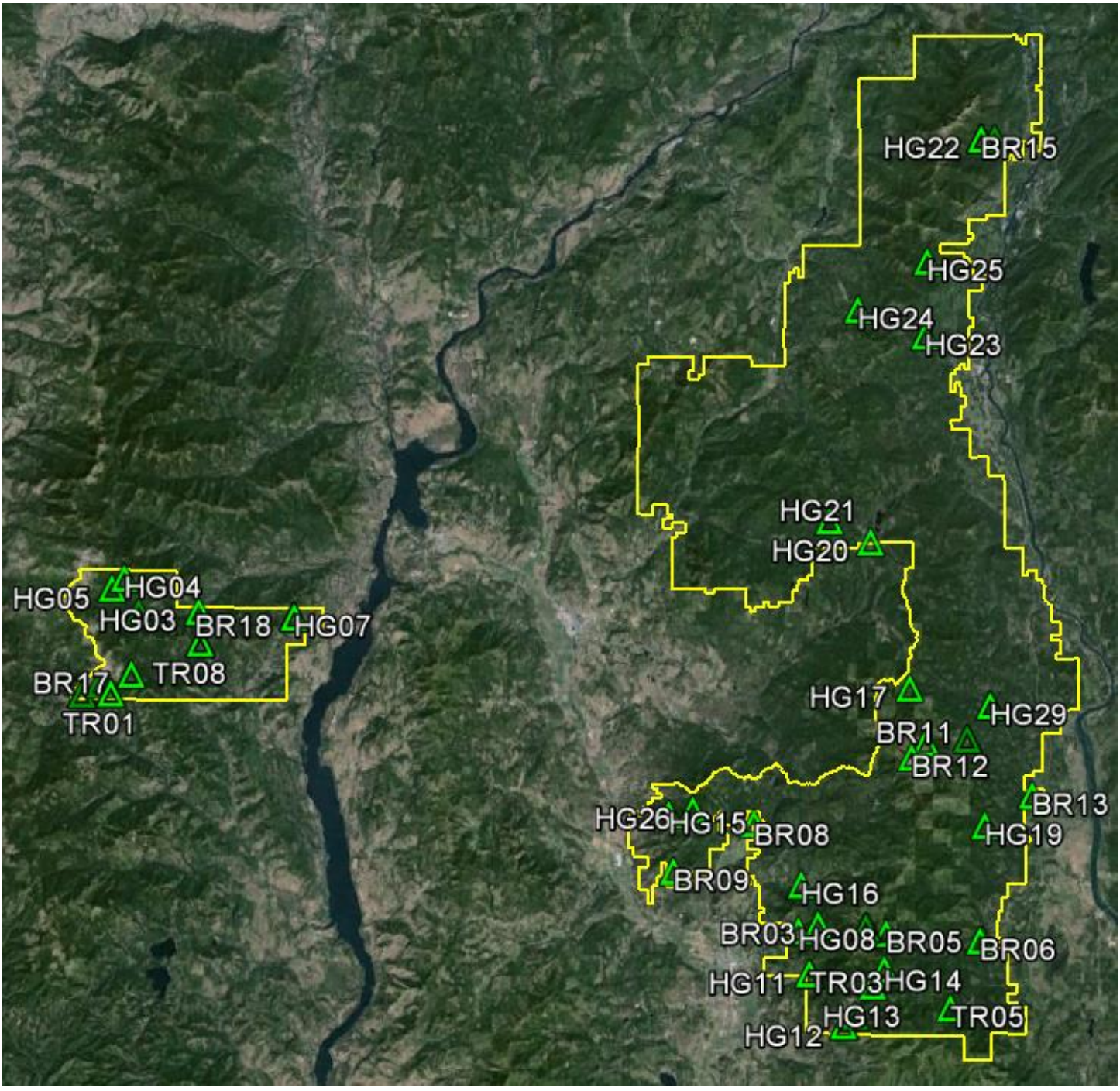


Figure 6: Vegetated Vertical Accuracy (VVA) Check Point Distribution

3.4 Check Point Assessment

A vertical accuracy assessment of the NVA & VVA checkpoints against the lidar point cloud swath data and bare-earth surface DEM's can be found in Tables 10, 11, and 12 below. The coordinates provided are in NAD83, USFS R6 Albers, NAVD88 (Geoid12A), Meters.

Non-vegetated Vertical Accuracy (NVA) Check Point Assessment (Swath)						
PointID	**Easting**	**Northing**	**KnownZ**	**LaserZ**	**Description**	**DeltaZ**
OT01	712493.386	1603649.924	1417.717	1417.581	Open Terrain/Bare Earth	-0.136
OT02	729131.124	1605569.907	704.701	704.688	Open Terrain/Bare Earth	-0.013
OT03	716884.102	1606506.796	1504.753	1504.604	Open Terrain/Bare Earth	-0.149
OT04	724037.025	1605951.515	949.401	949.408	Open Terrain/Bare Earth	0.007
OT05	722662.608	1608323.814	1343.097	1343.218	Open Terrain/Bare Earth	0.121
OT06	730749.314	1610788.092	903.734	903.604	Open Terrain/Bare Earth	-0.130
OT07	726404.169	1604023.646	685.982	685.985	Open Terrain/Bare Earth	0.003
OT08	720608.354	1606988.858	1066.606	1066.558	Open Terrain/Bare Earth	-0.048
OT09	717264.390	1608502.125	1326.143	1326.355	Open Terrain/Bare Earth	0.212
OT10	717239.892	1611234.389	1082.704	1082.745	Open Terrain/Bare Earth	0.041
OT11	727765.344	1604852.777	668.366	668.489	Open Terrain/Bare Earth	0.123
OT12	776974.420	1585286.816	1097.952	1098.129	Open Terrain/Bare Earth	0.177
OT13	791189.738	1584269.908	910.319	910.208	Open Terrain/Bare Earth	-0.111
OT14	779492.979	1576577.071	852.296	852.332	Open Terrain/Bare Earth	0.036
OT15	780507.753	1577440.971	875.303	875.254	Open Terrain/Bare Earth	-0.049
OT16	782920.402	1581591.229	1143.846	1143.788	Open Terrain/Bare Earth	-0.058
OT17	788752.488	1578333.945	911.129	911.030	Open Terrain/Bare Earth	-0.099
OT18	791371.363	1580732.109	794.593	794.446	Open Terrain/Bare Earth	-0.147
OT19	763792.839	1594530.720	1191.858	1191.788	Open Terrain/Bare Earth	-0.070
OT20	770585.288	1593187.959	668.417	668.443	Open Terrain/Bare Earth	0.026
OT21	768796.095	1593116.886	745.119	745.267	Open Terrain/Bare Earth	0.148
OT22	775470.338	1588714.357	818.562	818.613	Open Terrain/Bare Earth	0.051
OT23	772941.773	1589120.709	747.362	747.375	Open Terrain/Bare Earth	0.013
OT24	778841.655	1594653.759	951.385	951.416	Open Terrain/Bare Earth	0.031
OT25	784821.501	1592746.244	1497.692	1497.686	Open Terrain/Bare Earth	-0.006
OT26	784496.544	1606010.595	1273.037	1272.964	Open Terrain/Bare Earth	-0.073
OT27	787691.439	1612815.531	1114.163	1114.137	Open Terrain/Bare Earth	-0.026
OT28	790933.495	1615566.526	870.168	870.170	Open Terrain/Bare Earth	0.002
OT29	769761.800	1618779.574	897.850	897.879	Open Terrain/Bare Earth	0.029
OT30	773714.684	1618551.638	947.237	947.300	Open Terrain/Bare Earth	0.063
OT31	774883.529	1629301.217	847.630	847.607	Open Terrain/Bare Earth	-0.023
OT32	778561.137	1626655.011	1158.943	1159.038	Open Terrain/Bare Earth	0.095
OT33	789517.354	1653799.066	1564.949	1565.008	Open Terrain/Bare Earth	0.059
OT34	793228.147	1660026.689	749.746	749.736	Open Terrain/Bare Earth	-0.010
OT35	781204.578	1652580.549	919.034	918.971	Open Terrain/Bare Earth	-0.063
OT36	790108.334	1640824.750	629.733	629.770	Open Terrain/Bare Earth	0.037

OT37	794180.030	1655059.647	808.056	808.005	Open Terrain/Bare Earth	-0.051
OT38	790673.708	1647498.189	763.142	763.173	Open Terrain/Bare Earth	0.031
OT39	715461.306	1604943.688	1491.683	1491.684	Open Terrain/Bare Earth	0.001
OT40	780890.116	1584953.180	1186.435	1186.451	Open Terrain/Bare Earth	0.016
OT41	786002.288	1601310.901	1592.203	1592.192	Open Terrain/Bare Earth	-0.011
OT42	784815.370	1600028.186	2084.926	2084.891	Open Terrain/Bare Earth	-0.035
OT43	715477.471	1604949.329	1492.514	1492.458	Open Terrain/Bare Earth	-0.056
OT44	715485.556	1604950.841	1492.858	1492.822	Open Terrain/Bare Earth	-0.036
UB01	775352.670	1584768.828	892.823	892.976	Urban Terrain	0.153
UB02	777013.843	1585311.337	1095.067	1095.244	Urban Terrain	0.177
UB03	782936.908	1584718.241	1050.721	1050.743	Urban Terrain	0.022
UB04	785557.796	1583842.546	961.810	961.851	Urban Terrain	0.041
UB05	788272.845	1583063.981	904.157	904.245	Urban Terrain	0.088
UB06	791372.150	1580731.176	794.502	794.415	Urban Terrain	-0.087
UB07	796014.842	1613588.930	629.250	629.160	Urban Terrain	-0.090
UB08	783575.676	1623528.805	984.020	984.118	Urban Terrain	0.098
UB09	780908.484	1619313.097	968.313	968.407	Urban Terrain	0.094
UB10	789153.056	1627466.437	787.184	787.183	Urban Terrain	-0.001
UB11	786621.181	1626473.854	986.771	986.798	Urban Terrain	0.027
UB12	763210.438	1618808.836	671.742	671.801	Urban Terrain	0.059
UB13	764635.785	1622409.019	729.879	729.928	Urban Terrain	0.049
UB14	765585.488	1626969.220	807.904	807.842	Urban Terrain	-0.062
UB15	768823.824	1629837.085	805.427	805.473	Urban Terrain	0.046
UB16	772648.867	1640898.410	620.619	620.645	Urban Terrain	0.026

Table 10: Lidar Point Cloud Swath Data Assessment

Non-vegetated Vertical Accuracy (NVA) Check Point Assessment (DEM)						
PointID	**Easting**	**Northing**	**KnownZ**	**LaserZ**	**Description**	**DeltaZ**
OT01	712493.386	1603649.924	1417.717	1417.581	Open Terrain/Bare Earth	-0.136
OT02	729131.124	1605569.907	704.701	704.681	Open Terrain/Bare Earth	-0.020
OT03	716884.102	1606506.796	1504.753	1504.590	Open Terrain/Bare Earth	-0.163
OT04	724037.025	1605951.515	949.401	949.389	Open Terrain/Bare Earth	-0.012
OT05	722662.608	1608323.814	1343.097	1343.181	Open Terrain/Bare Earth	0.084
OT06	730749.314	1610788.092	903.734	903.599	Open Terrain/Bare Earth	-0.135
OT07	726404.169	1604023.646	685.982	685.935	Open Terrain/Bare Earth	-0.047
OT08	720608.354	1606988.858	1066.606	1066.500	Open Terrain/Bare Earth	-0.106
OT09	717264.390	1608502.125	1326.143	1326.331	Open Terrain/Bare Earth	0.188
OT10	717239.892	1611234.389	1082.704	1082.745	Open Terrain/Bare Earth	0.041
OT11	727765.344	1604852.777	668.366	668.429	Open Terrain/Bare Earth	0.063
OT12	776974.420	1585286.816	1097.952	1098.113	Open Terrain/Bare Earth	0.161
OT13	791189.738	1584269.908	910.319	910.207	Open Terrain/Bare Earth	-0.112
OT14	779492.979	1576577.071	852.296	852.302	Open Terrain/Bare Earth	0.006

OT15	780507.753	1577440.971	875.303	875.224	Open Terrain/Bare Earth	-0.079
OT16	782920.402	1581591.229	1143.846	1143.788	Open Terrain/Bare Earth	-0.058
OT17	788752.488	1578333.945	911.129	911.019	Open Terrain/Bare Earth	-0.110
OT18	791371.363	1580732.109	794.593	794.416	Open Terrain/Bare Earth	-0.177
OT19	763792.839	1594530.720	1191.858	1191.757	Open Terrain/Bare Earth	-0.101
OT20	770585.288	1593187.959	668.417	668.443	Open Terrain/Bare Earth	0.026
OT21	768796.095	1593116.886	745.119	745.240	Open Terrain/Bare Earth	0.121
OT22	775470.338	1588714.357	818.562	818.613	Open Terrain/Bare Earth	0.051
OT23	772941.773	1589120.709	747.362	747.368	Open Terrain/Bare Earth	0.006
OT24	778841.655	1594653.759	951.385	951.395	Open Terrain/Bare Earth	0.010
OT25	784821.501	1592746.244	1497.692	1497.674	Open Terrain/Bare Earth	-0.018
OT26	784496.544	1606010.595	1273.037	1272.917	Open Terrain/Bare Earth	-0.120
OT27	787691.439	1612815.531	1114.163	1114.133	Open Terrain/Bare Earth	-0.030
OT28	790933.495	1615566.526	870.168	870.169	Open Terrain/Bare Earth	0.001
OT29	769761.800	1618779.574	897.850	897.860	Open Terrain/Bare Earth	0.010
OT30	773714.684	1618551.638	947.237	947.300	Open Terrain/Bare Earth	0.063
OT31	774883.529	1629301.217	847.630	847.607	Open Terrain/Bare Earth	-0.023
OT32	778561.137	1626655.011	1158.943	1159.029	Open Terrain/Bare Earth	0.086
OT33	789517.354	1653799.066	1564.949	1564.981	Open Terrain/Bare Earth	0.032
OT34	793228.147	1660026.689	749.746	749.732	Open Terrain/Bare Earth	-0.014
OT35	781204.578	1652580.549	919.034	918.938	Open Terrain/Bare Earth	-0.096
OT36	790108.334	1640824.750	629.733	629.764	Open Terrain/Bare Earth	0.031
OT37	794180.030	1655059.647	808.056	808.002	Open Terrain/Bare Earth	-0.054
OT38	790673.708	1647498.189	763.142	763.140	Open Terrain/Bare Earth	-0.002
OT39	715461.306	1604943.688	1491.683	1491.684	Open Terrain/Bare Earth	0.001
OT40	780890.116	1584953.180	1186.435	1186.447	Open Terrain/Bare Earth	0.012
OT41	786002.288	1601310.901	1592.203	1592.178	Open Terrain/Bare Earth	-0.025
OT42	784815.370	1600028.186	2084.926	2084.872	Open Terrain/Bare Earth	-0.054
OT43	715477.471	1604949.329	1492.514	1492.458	Open Terrain/Bare Earth	-0.056
OT44	715485.556	1604950.841	1492.858	1492.806	Open Terrain/Bare Earth	-0.052
UB01	775352.670	1584768.828	892.823	892.939	Urban Terrain	0.116
UB02	777013.843	1585311.337	1095.067	1095.225	Urban Terrain	0.158
UB03	782936.908	1584718.241	1050.721	1050.7	Urban Terrain	-0.021
UB04	785557.796	1583842.546	961.81	961.818	Urban Terrain	0.008
UB05	788272.845	1583063.981	904.157	904.209	Urban Terrain	0.052
UB06	791372.15	1580731.176	794.502	794.406	Urban Terrain	-0.096
UB07	796014.842	1613588.93	629.25	629.113	Urban Terrain	-0.137
UB08	783575.676	1623528.805	984.02	984.082	Urban Terrain	0.062
UB09	780908.484	1619313.097	968.313	968.392	Urban Terrain	0.079
UB10	789153.056	1627466.437	787.184	787.162	Urban Terrain	-0.022
UB11	786621.181	1626473.854	986.771	986.784	Urban Terrain	0.013
UB12	763210.438	1618808.836	671.742	671.762	Urban Terrain	0.02
UB13	764635.785	1622409.019	729.879	729.797	Urban Terrain	-0.082

UB14	765585.488	1626969.22	807.904	807.828	Urban Terrain	-0.076
UB15	768823.824	1629837.085	805.427	805.387	Urban Terrain	-0.04
UB16	772648.867	1640898.41	620.619	620.645	Urban Terrain	0.026

Table 11: Bare-Earth Surface NVA Assessment

Vegetated Vertical Accuracy (VVA) Check Point Assessment (DEM)						
PointID	**Easting**	**Northing**	**KnownZ**	**LaserZ**	**Description**	**DeltaZ**
BR01	712459.247	1603645.355	1415.574	1415.570	Brush	-0.004
BR02	717237.584	1610839.141	1122.894	1122.922	Brush	0.028
BR03	777030.953	1585313.676	1096.505	1096.669	Brush	0.164
BR04	781286.886	1585198.539	1160.192	1160.149	Brush	-0.043
BR05	782972.606	1584704.474	1054.521	1054.597	Brush	0.076
BR06	791167.125	1584258.893	910.830	910.711	Brush	-0.119
BR07	780472.019	1577471.008	879.796	879.886	Brush	0.090
BR08	771222.585	1593957.918	671.854	671.850	Brush	-0.004
BR09	764321.426	1589619.260	851.707	851.742	Brush	0.035
BR10	789619.769	1601734.144	1103.882	1103.787	Brush	-0.095
BR11	785997.525	1601327.451	1590.481	1590.432	Brush	-0.049
BR12	784794.655	1600020.691	2082.787	2082.736	Brush	-0.051
BR13	795385.554	1596992.491	735.919	736.045	Brush	0.126
BR14	790694.013	1653845.660	1180.857	1180.850	Brush	-0.007
BR15	789511.407	1653782.856	1563.440	1563.488	Brush	0.048
BR16	722674.914	1608340.690	1343.842	1343.934	Brush	0.092
BR17	716739.371	1605465.387	1586.727	1586.881	Brush	0.154
BR18	730744.600	1610781.069	903.091	903.086	Brush	-0.005
HG01	714981.701	1603788.154	1512.653	1512.529	High Grass	-0.124
HG02	712483.826	1603646.239	1416.544	1416.620	High Grass	0.076
HG03	722464.421	1611052.788	850.111	850.249	High Grass	0.138
HG04	715903.115	1613765.844	1327.112	1327.054	High Grass	-0.058
HG05	714853.828	1612878.581	1306.648	1306.674	High Grass	0.026
HG06	722668.497	1608330.368	1343.607	1343.640	High Grass	0.033
HG07	730783.252	1610774.032	899.022	899.126	High Grass	0.104
HG08	775341.566	1584739.885	889.780	889.823	High Grass	0.043
HG09	781177.915	1585107.921	1172.327	1172.224	High Grass	-0.103
HG10	791382.789	1584239.988	899.608	899.596	High Grass	-0.012
HG11	776416.573	1580980.427	944.693	944.776	High Grass	0.083
HG12	779502.369	1576592.837	852.136	852.148	High Grass	0.012
HG13	781933.083	1580113.977	1411.033	1410.931	High Grass	-0.102
HG14	782900.725	1581574.095	1146.082	1145.966	High Grass	-0.116
HG15	763788.192	1594549.350	1190.621	1190.785	High Grass	0.164
HG16	775476.644	1588737.780	817.971	818.047	High Grass	0.076
HG17	784477.239	1606011.661	1274.868	1274.691	High Grass	-0.177

HG18	789588.693	1601740.040	1105.347	1105.321	High Grass	-0.026
HG19	791328.831	1594269.549	1070.918	1070.834	High Grass	-0.084
HG20	780744.685	1618582.070	963.311	963.440	High Grass	0.129
HG21	777110.693	1620340.233	1177.611	1177.643	High Grass	0.032
HG22	789553.744	1653795.239	1563.980	1563.892	High Grass	-0.088
HG23	785034.283	1636568.326	964.972	964.939	High Grass	-0.033
HG24	779130.159	1638683.086	967.807	967.851	High Grass	0.044
HG25	785072.539	1643024.824	1276.134	1276.139	High Grass	0.005
HG26	765878.555	1595013.434	1281.855	1281.886	High Grass	0.031
HG27	713992.176	1604570.766	1363.422	1363.379	High Grass	-0.043
HG28	716674.169	1605476.350	1584.703	1584.718	High Grass	0.015
HG29	791527.234	1604676.189	853.718	853.714	High Grass	-0.004
TR01	714981.611	1603779.429	1512.170	1511.990	Trees	-0.180
TR02	781201.360	1585145.250	1168.084	1168.035	Trees	-0.049
TR03	776387.007	1581033.202	949.546	949.482	Trees	-0.064
TR04	779519.347	1576568.283	852.075	852.035	Trees	-0.040
TR05	788751.082	1578359.273	912.179	912.033	Trees	-0.146
TR06	791552.352	1604683.879	853.424	853.336	Trees	-0.088
TR07	789551.651	1653789.382	1564.406	1564.343	Trees	-0.063
TR08	722657.416	1608338.654	1342.957	1342.964	Trees	0.007
TR09	730733.079	1610791.387	904.750	904.744	Trees	-0.006

Table 12: Bare-Earth Surface VVA Assessment

3.5 Vertical Accuracy Results

An overall statistical assessment of the check points can be found in Tables 13, 14, 15, and 16 below. The coordinates provided are in NAD83, USFS R6 Albers, NAVD88 (Geoid12A), Meters.

Check Points Error Statistics								
Category	**# of Points**	**Min (m)**	**Max (m)**	**Mean (m)**	**Median (m)**	**Skew**	**Std Dev (m)**	**$RMSE_Z$ (m)**
Open Terrain/Bare Earth	44	-0.177	0.188	-0.018	-0.016	0.297	0.081	0.082
Urban Terrain	16	-0.137	0.158	0.004	0.011	0.121	0.080	0.077
Brush	18	-0.119	0.164	0.024	0.012	0.106	0.081	0.083
High Grass	29	-0.177	0.164	0.001	0.012	-0.099	0.085	0.084
Trees	9	-0.180	0.007	-0.070	-0.063	-0.734	0.061	0.090
Consolidated	116	-0.180	0.188	-0.008	-0.005	0.143	0.083	0.083

Table 13: 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/Bare Earth	44	0.161		
Urban Terrain	16			0.127
Brush	18			0.156
High Grass	29			0.134
Trees	9			0.002
Consolidated	116		0.142	

Table 14: Check Points Vertical Accuracy Assessment in Meters

Non-vegetated Vertical Accuracy (NVA) and Vegetated Vertical Accuracy (VVA)				
Broad Land Cover Type	**# of Points**	**$RMSE_Z$ (m)**	**95% Confidence Level (m)**	**95th Percentile (m)**
NVA of Point Cloud	60	0.082	0.160	
NVA of DEM	60	0.081	0.158	
VVA of DEM	56	0.084		0.142

Table 15: 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 (m)**	**NDEP FVA, plus SVAs and CVA based on 95th Percentile (m)**	**NDEP Accuracy Term**	**ASPRS Vertical Accuracy (m)**	**ASPRS Accuracy Term**
Open Terrain/Bare Earth	0.161	0.116	FVA	0.158	NVA
Urban Terrain	0.151	0.127	SVA		
Brush	0.162	0.156	SVA		
High Grass	0.164	0.134	SVA	0.142	VVA
Trees	0.177	0.002	SVA		
Consolidated	0.162	0.142	CVA	N/A	N/A

Table 16: Comparison of NSSDA, NDEP, and ASPRS Statistics

3.6 Limitations of Use

The accuracy assessment confirms that the data may be used for the intended applications stated in **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 USFS.

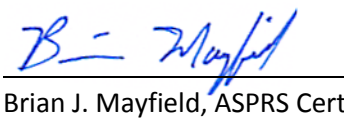
It should also be noted that lidar points do not represent a continuous surface model. Lidar points are discrete measurements of the surface and any values derived within a triangle of three lidar points are interpolated. As such, the user should not use the resultant lidar dataset for vertical placement 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.

Section 4: Certification

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



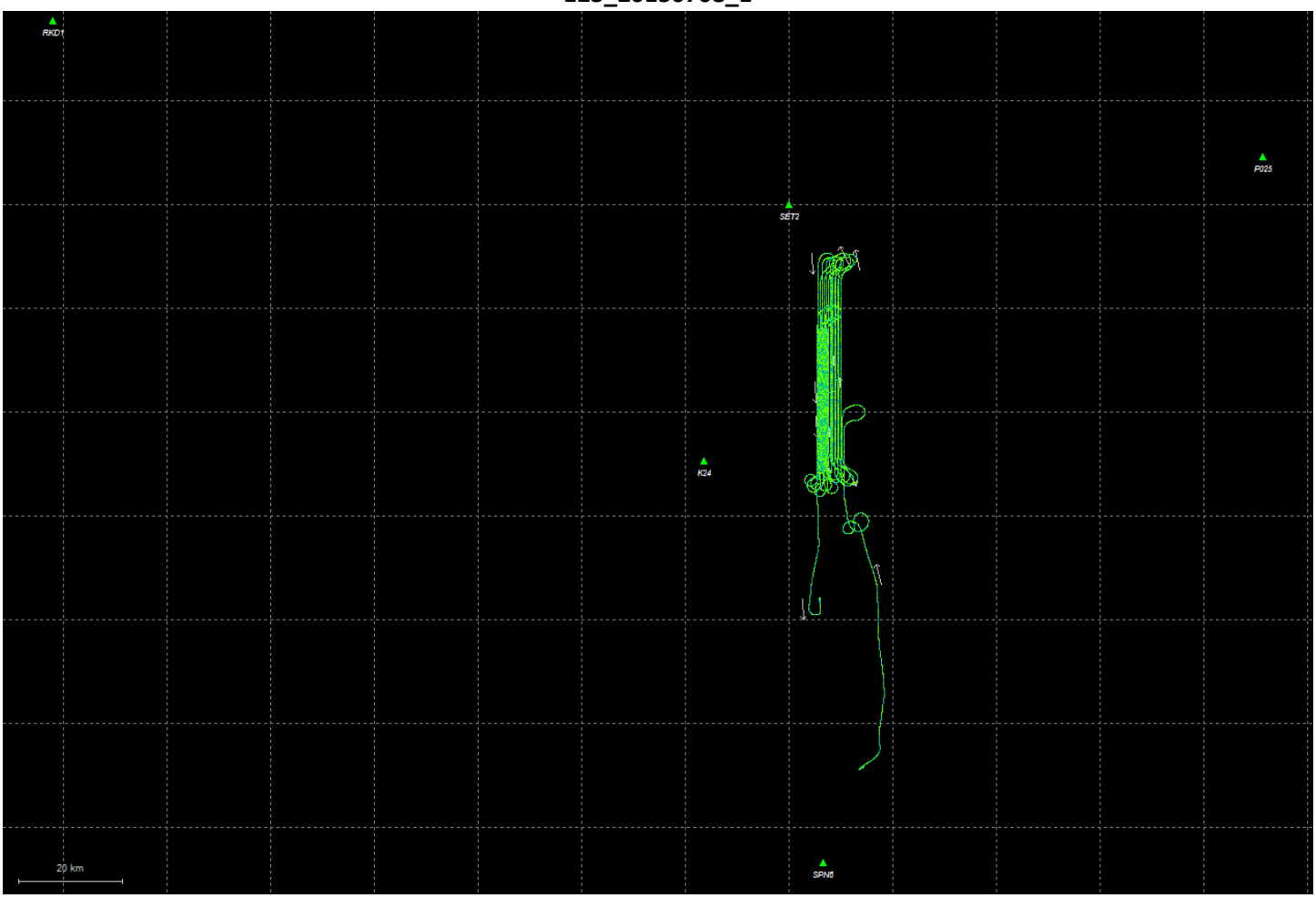
Brian J. Mayfield, ASPRS Certified Photogrammetrist #R1276

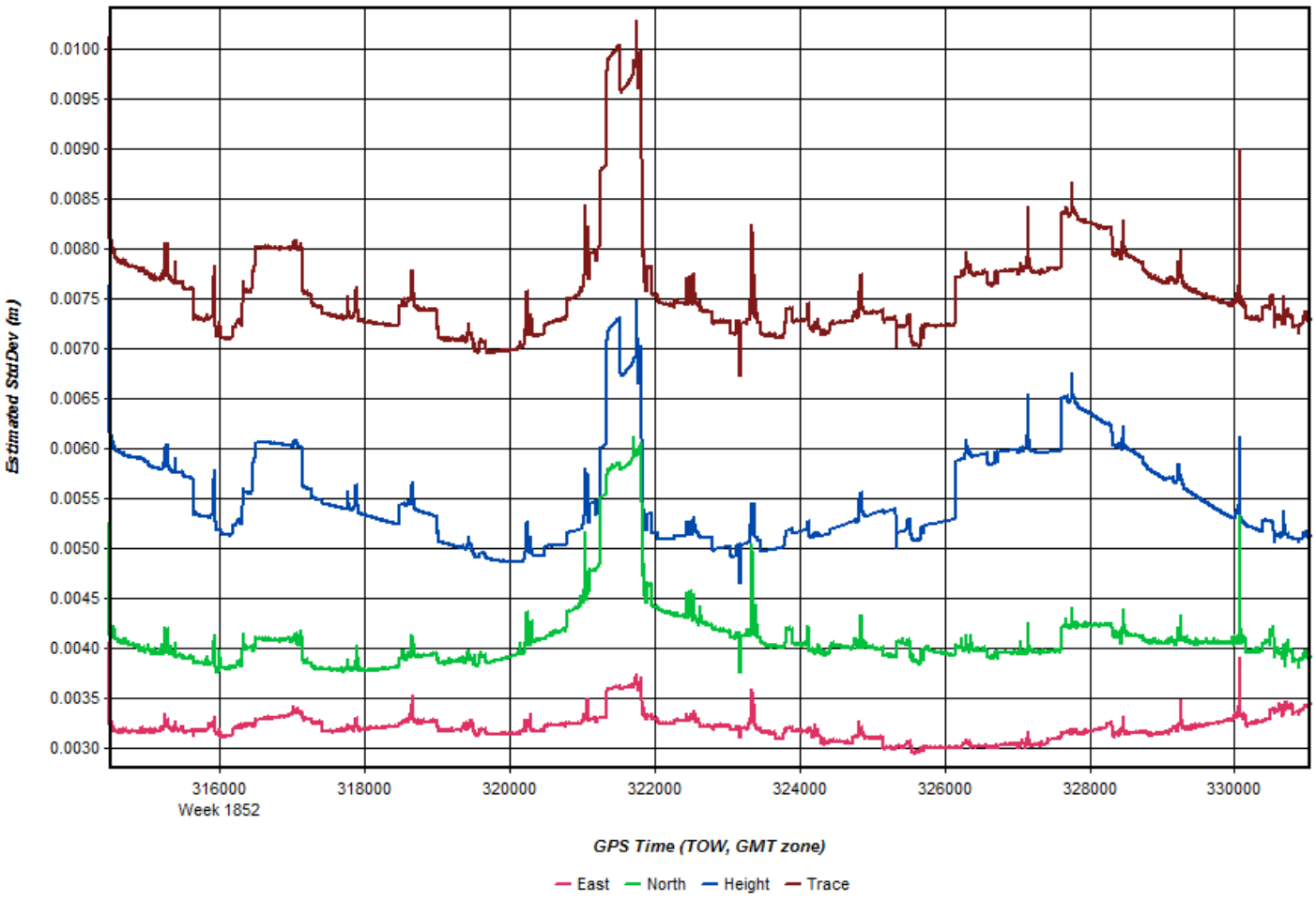
Section 5: GPS Processing

Inertial Explorer Version 8.50.4320

Plots by lift of the Coverage Map, Estimated Position Accuracy, Number of Satellites, Height Profile, Combined Separation, and PDOP.

123_20150708_1

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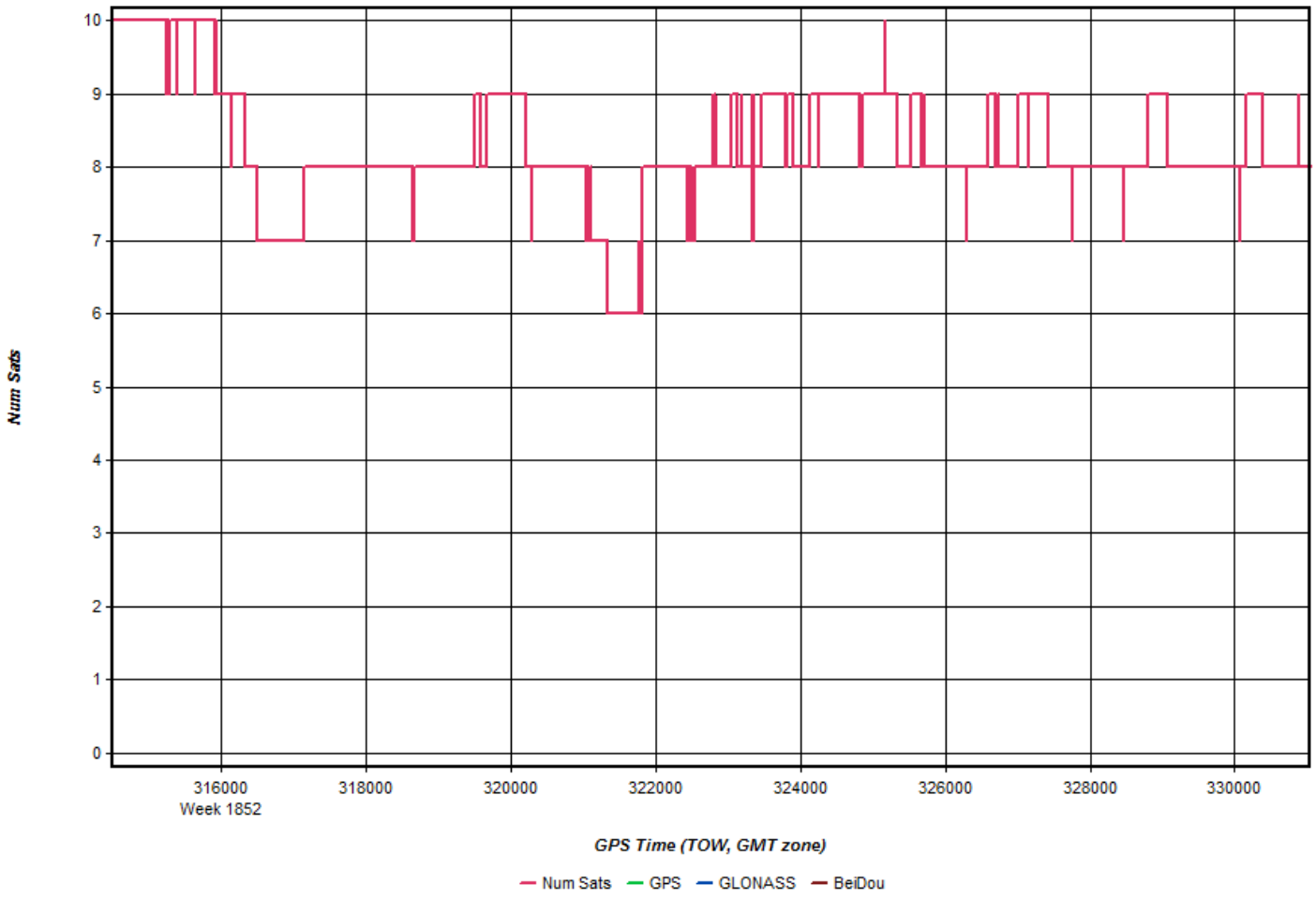
GPS Time (TOW, GMT zone)
East
North
Height
Trace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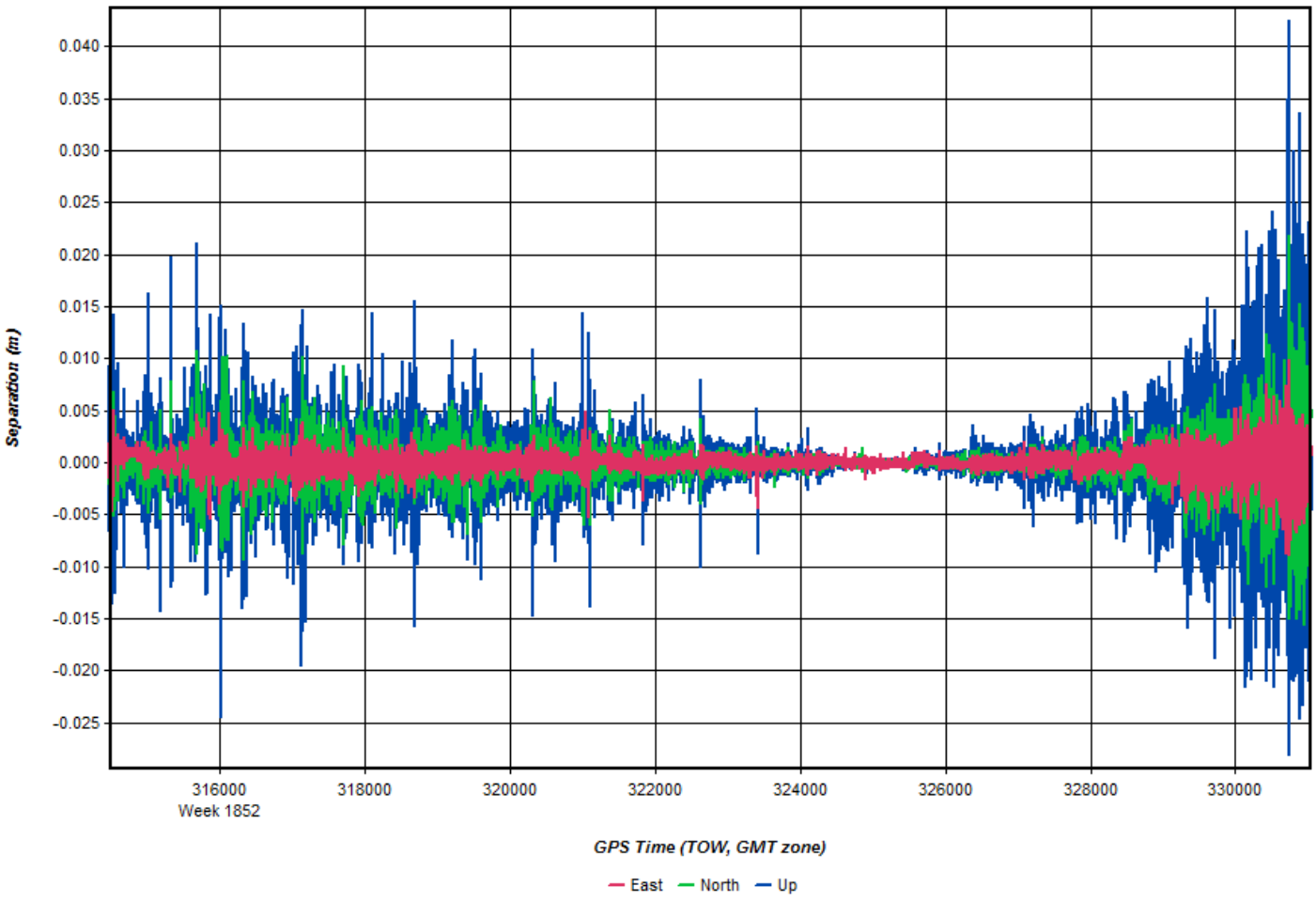
GPS
GLONASS
BeiDou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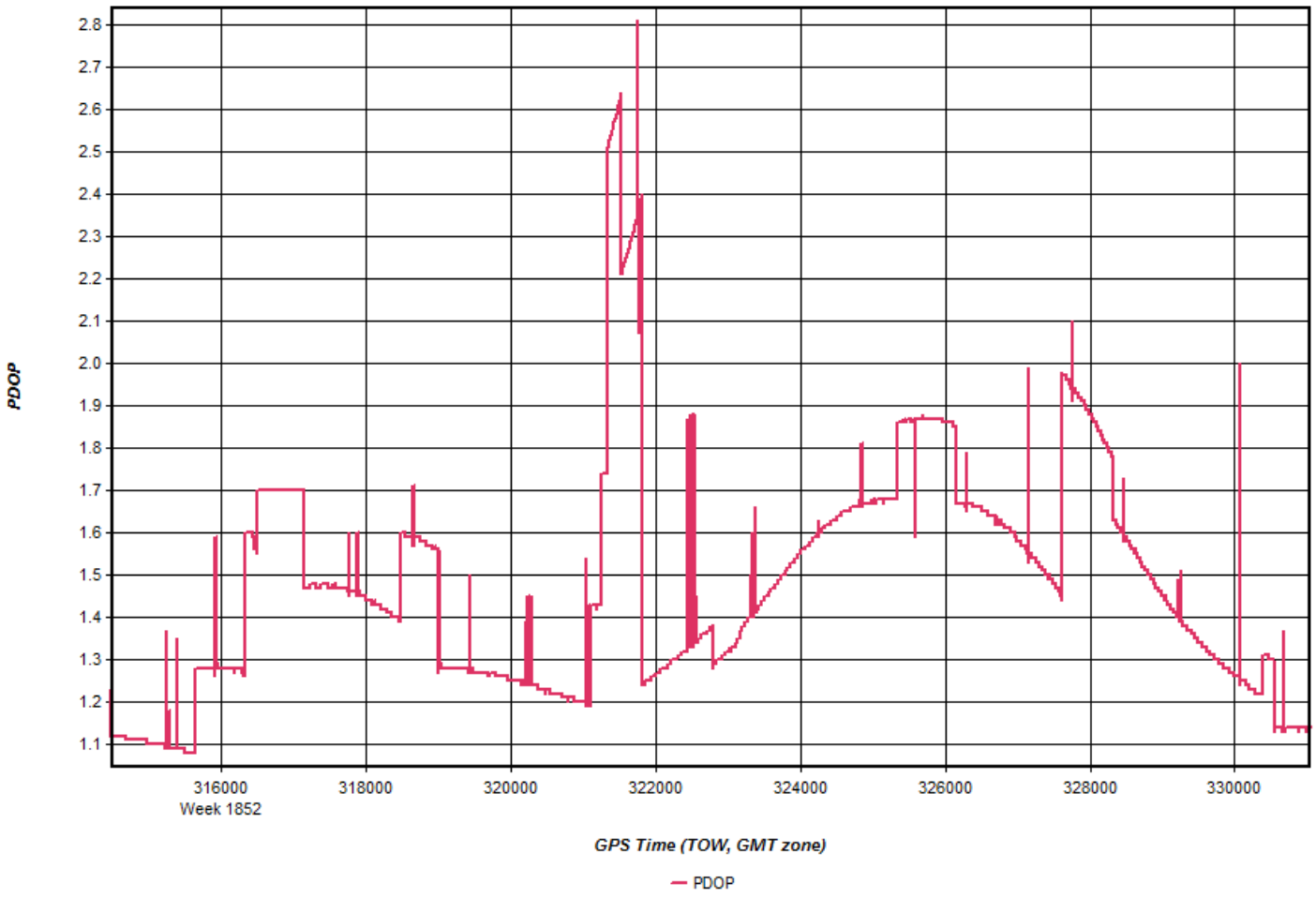
GPS Time (TOW, GMT zone)
East
North
Up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1.3
1.2
1.1
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324000
326000
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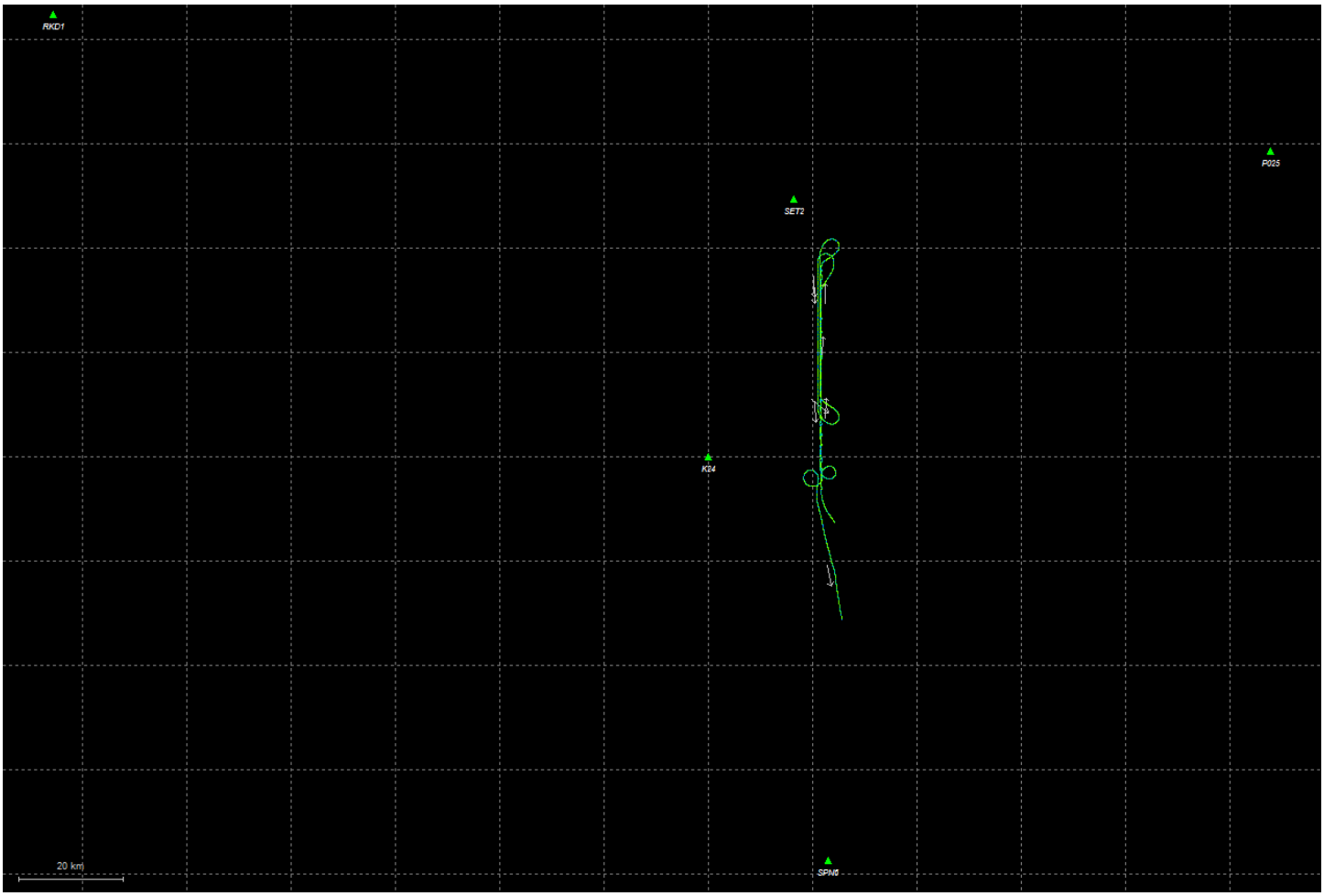
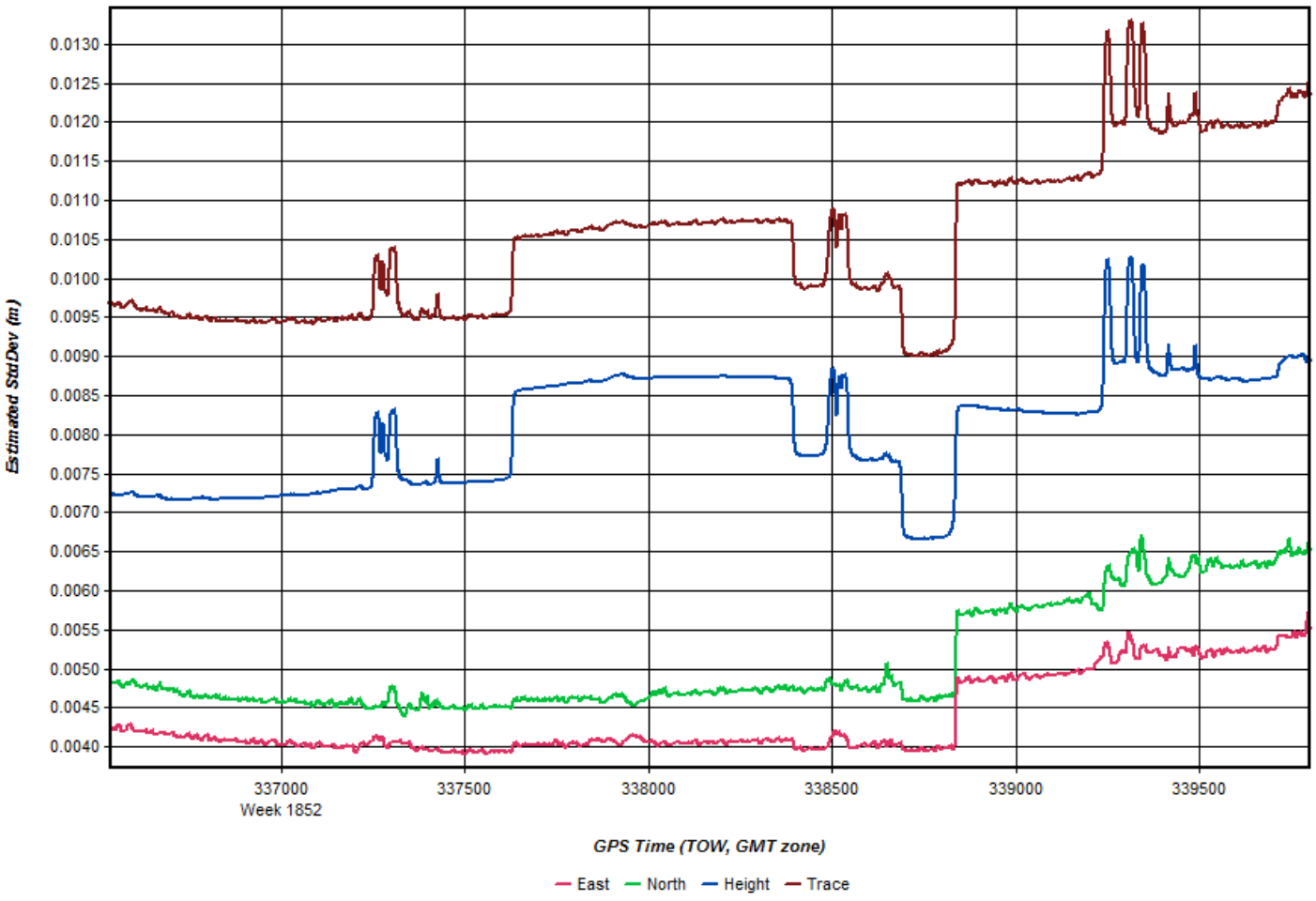
GPS Time (TOW, GMT zone)
PDOP

123_20150708_2

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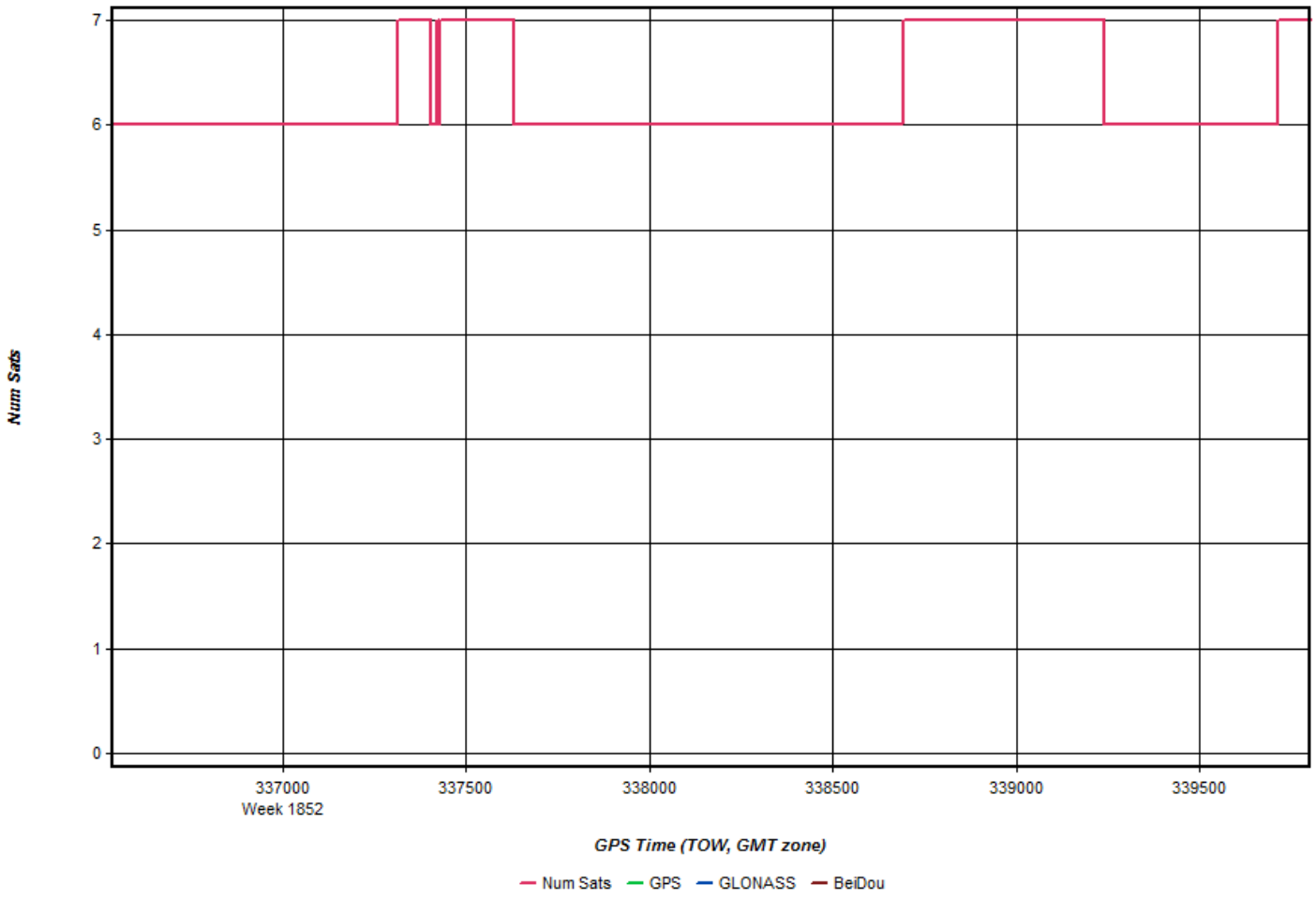
East
North
Height
Trace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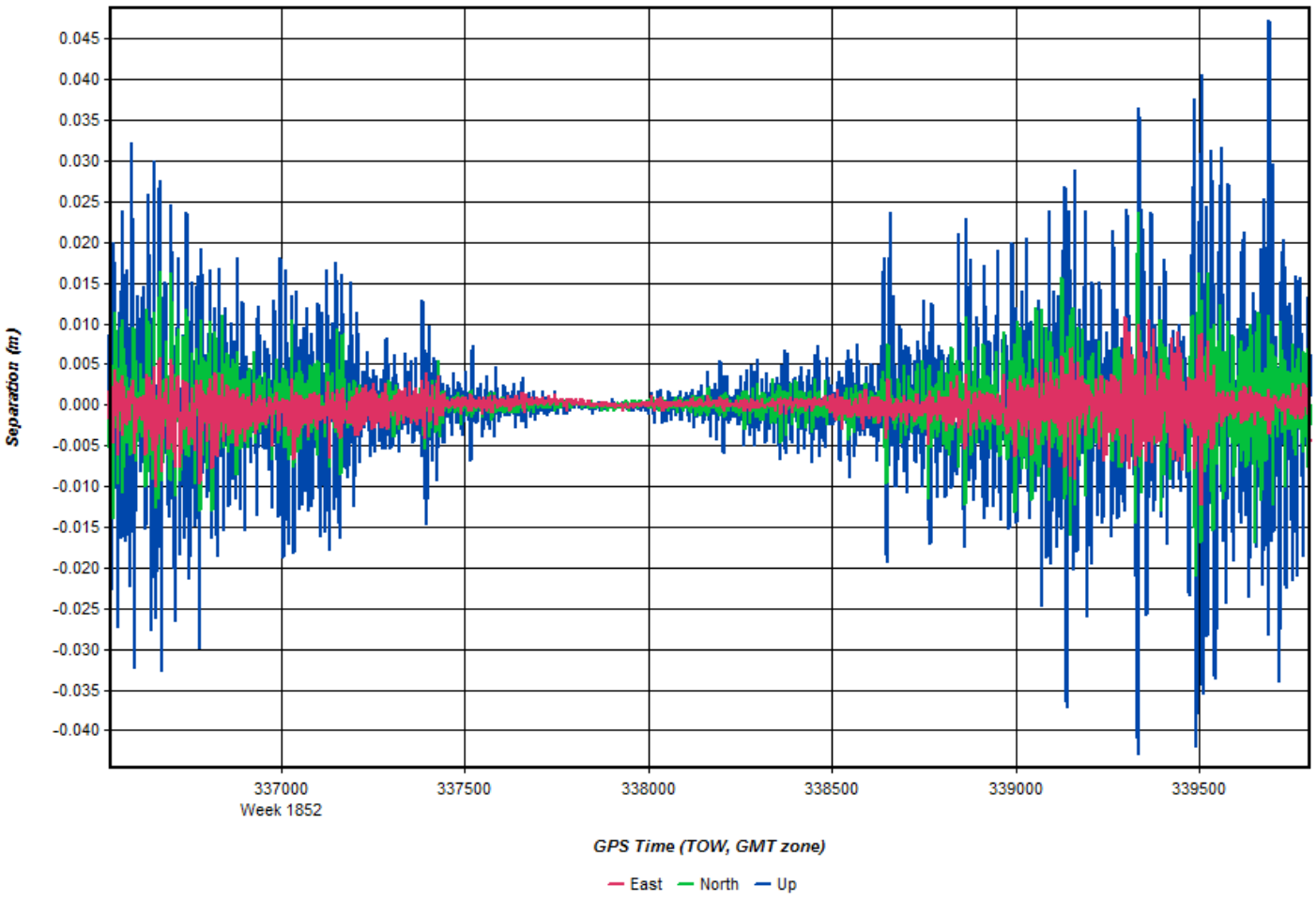
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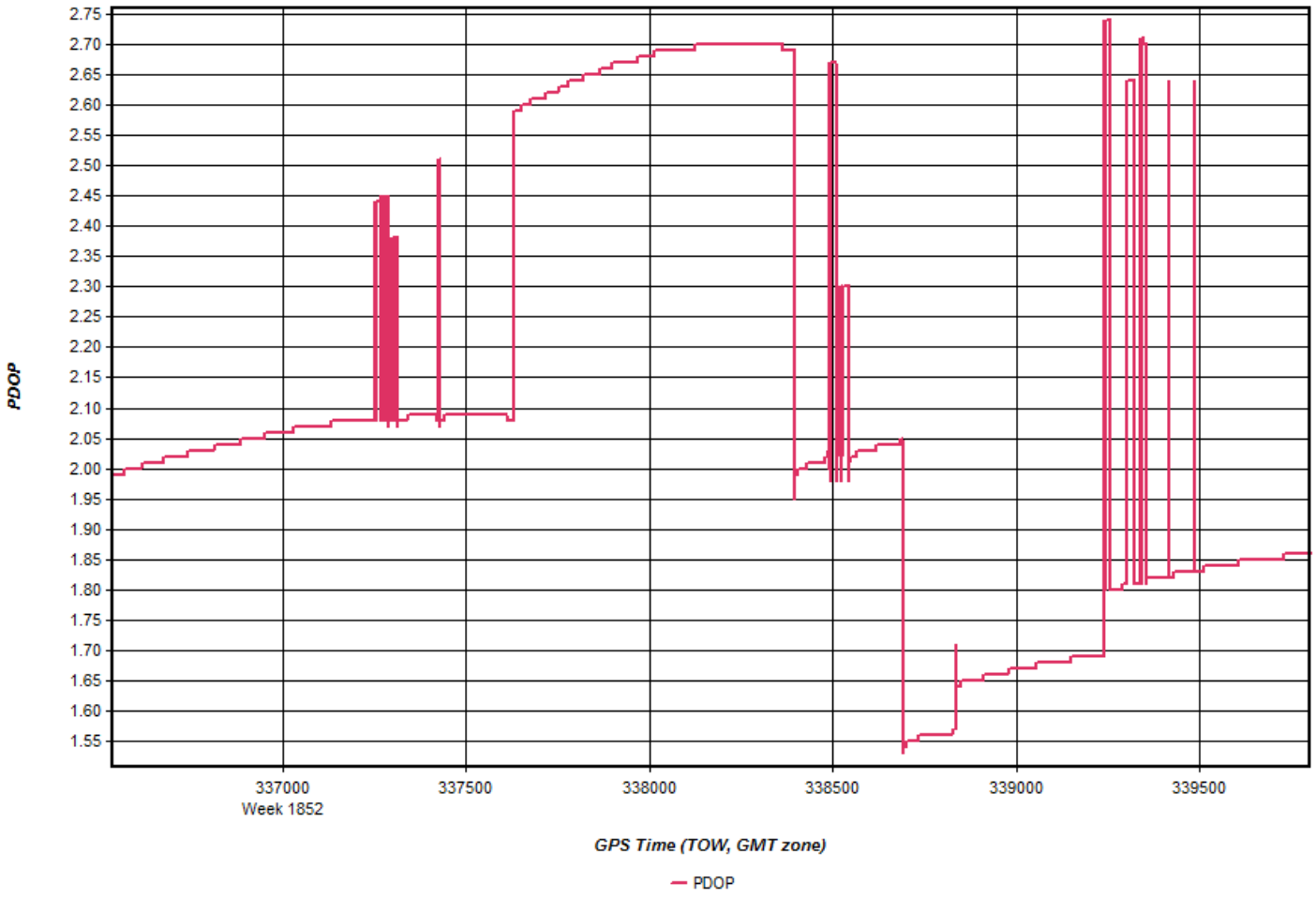
East
North
Up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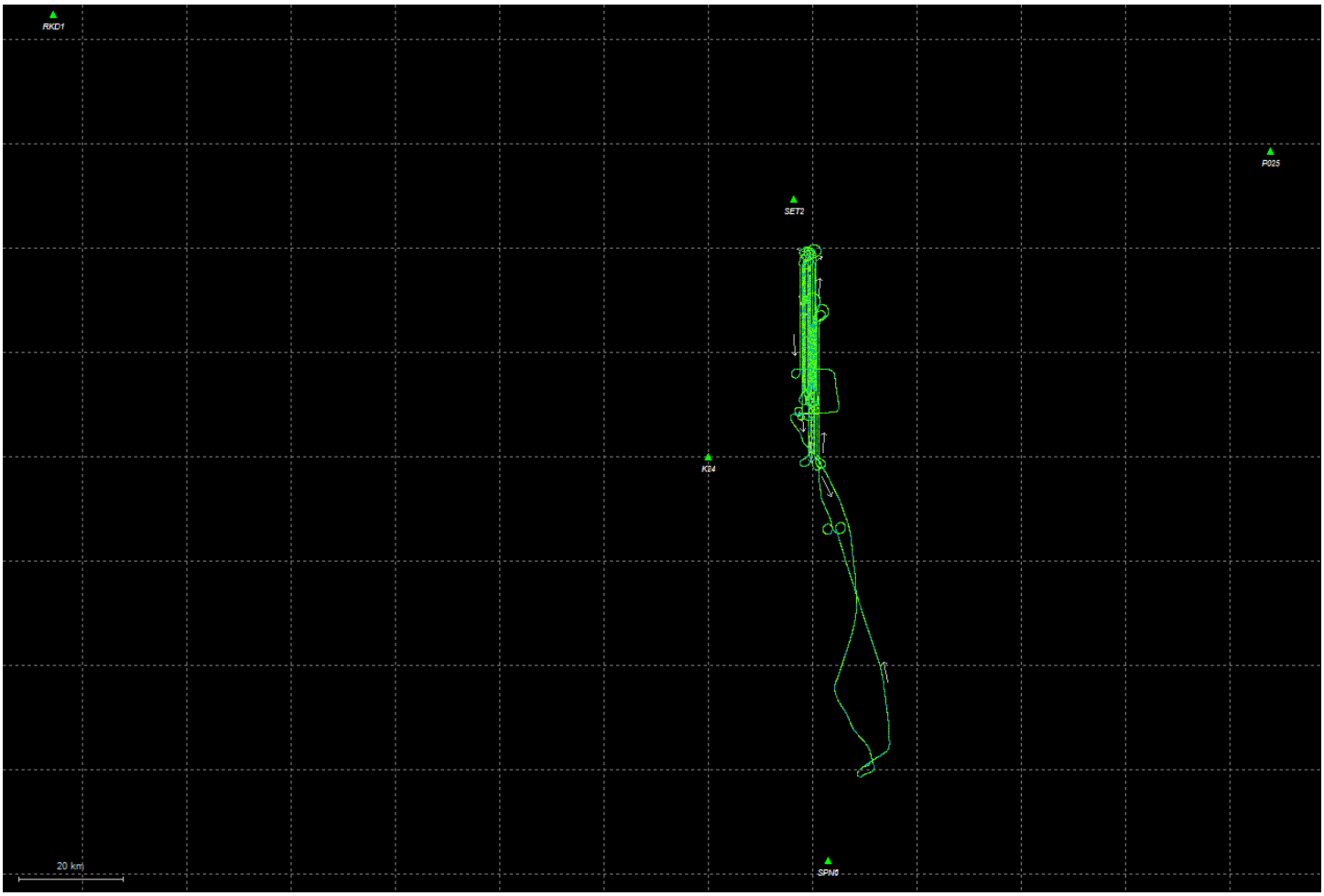

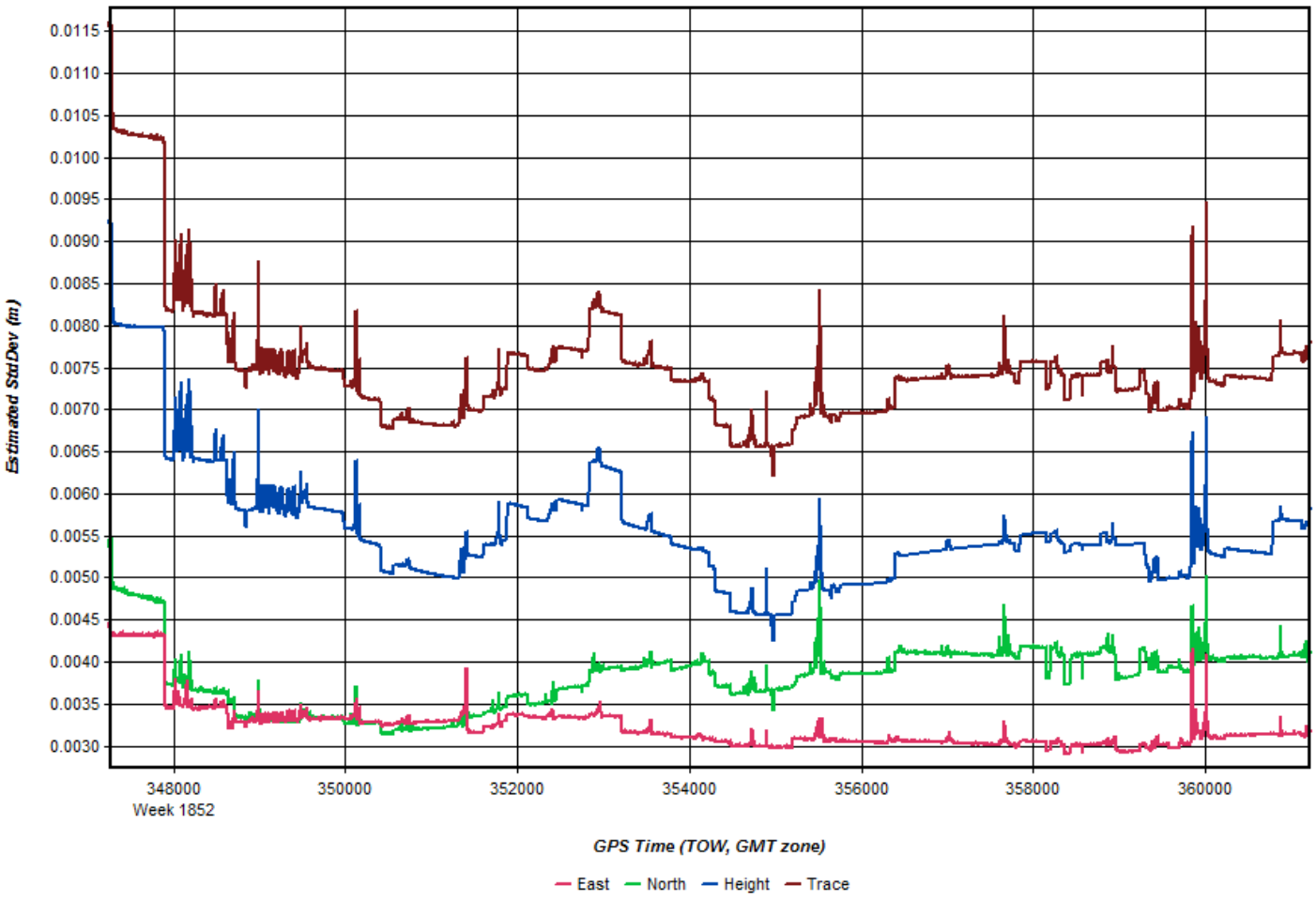
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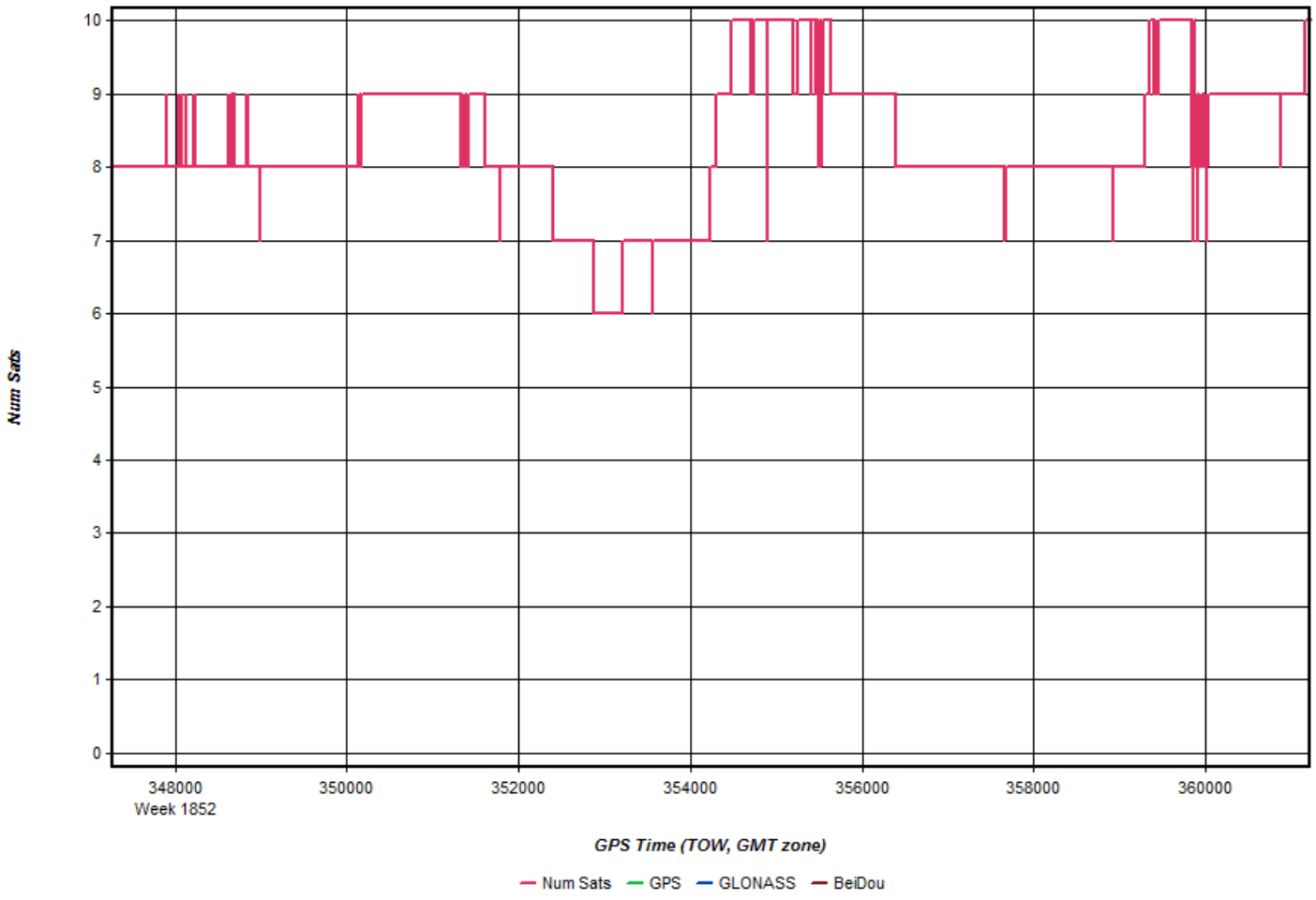
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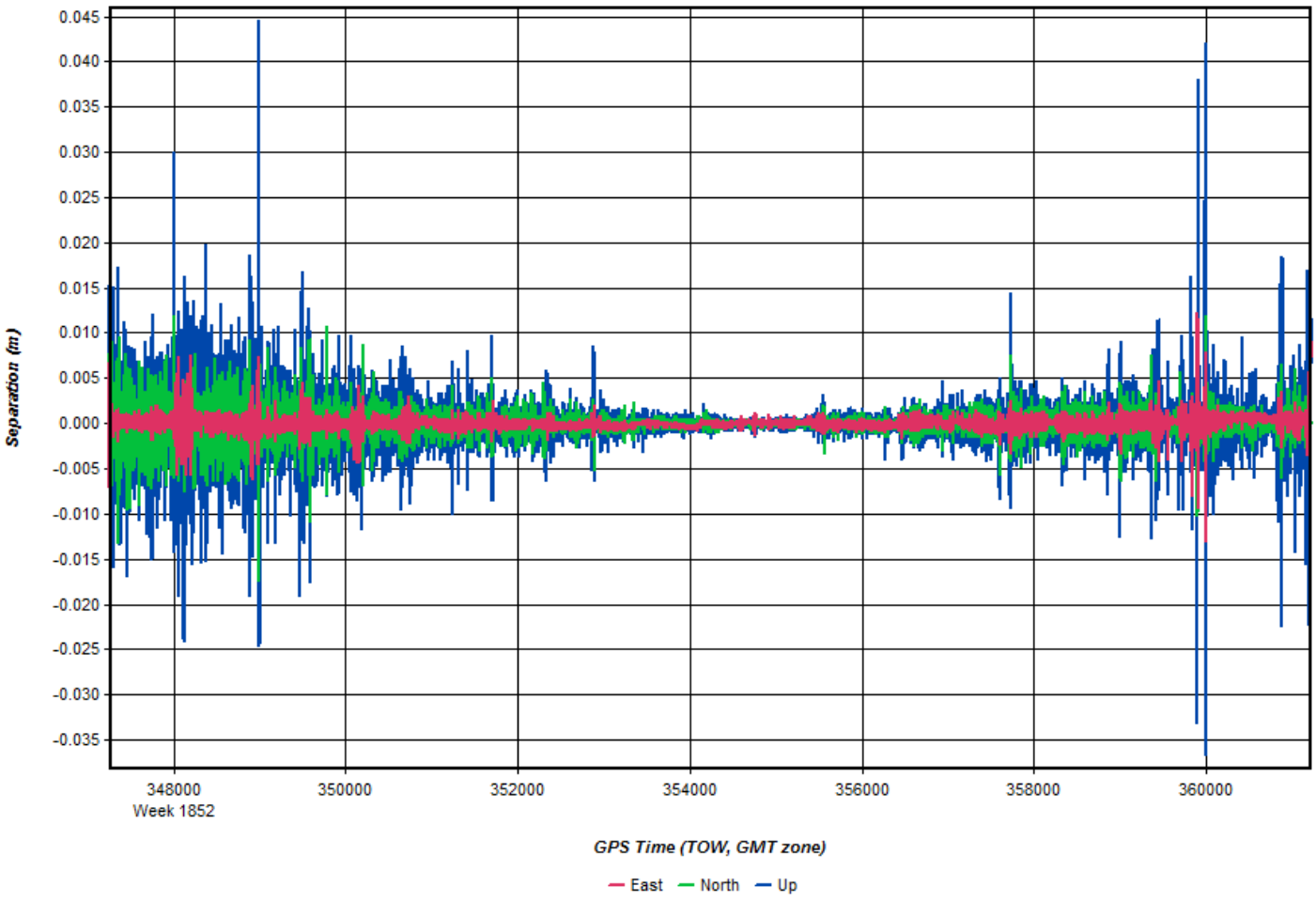
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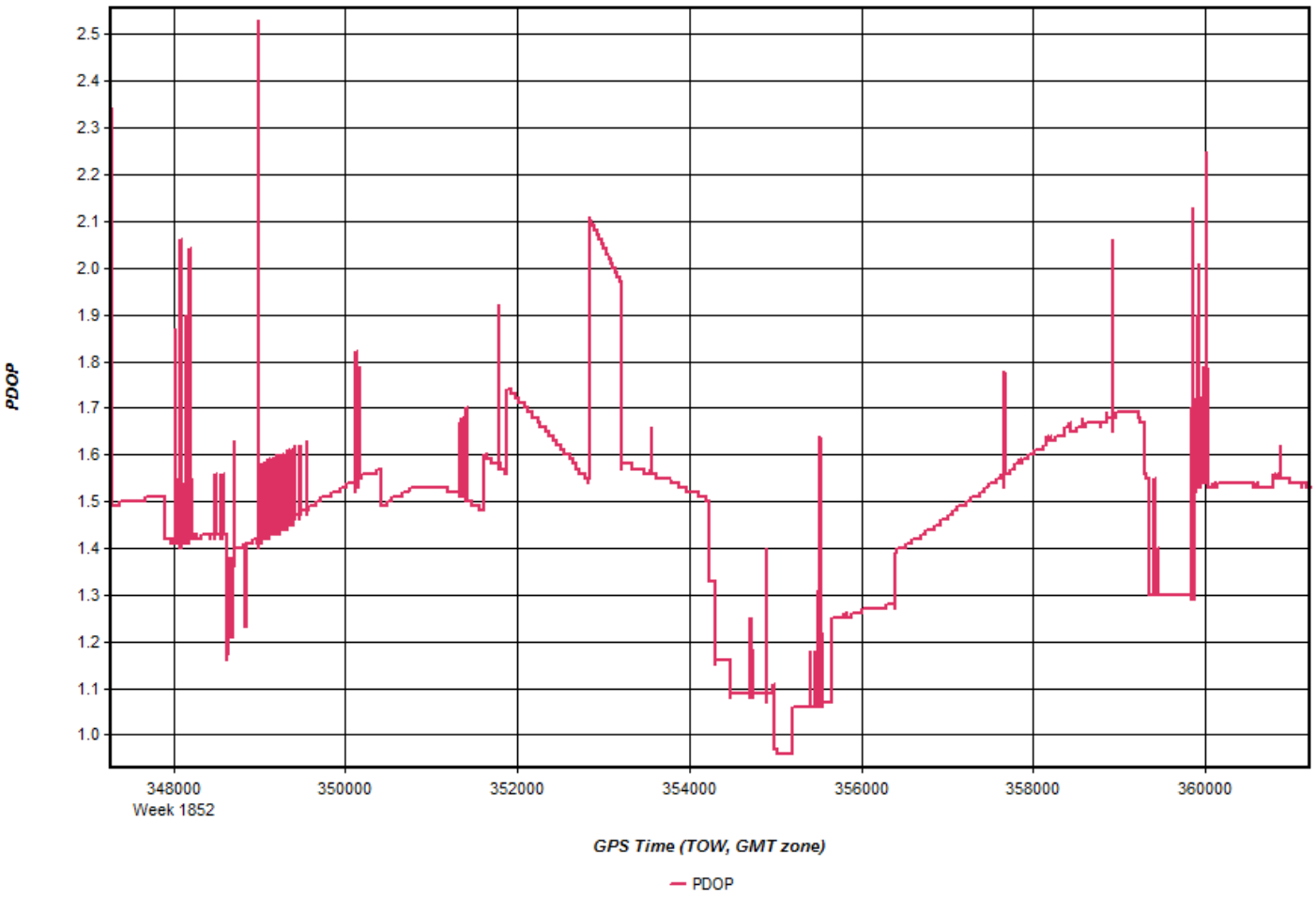
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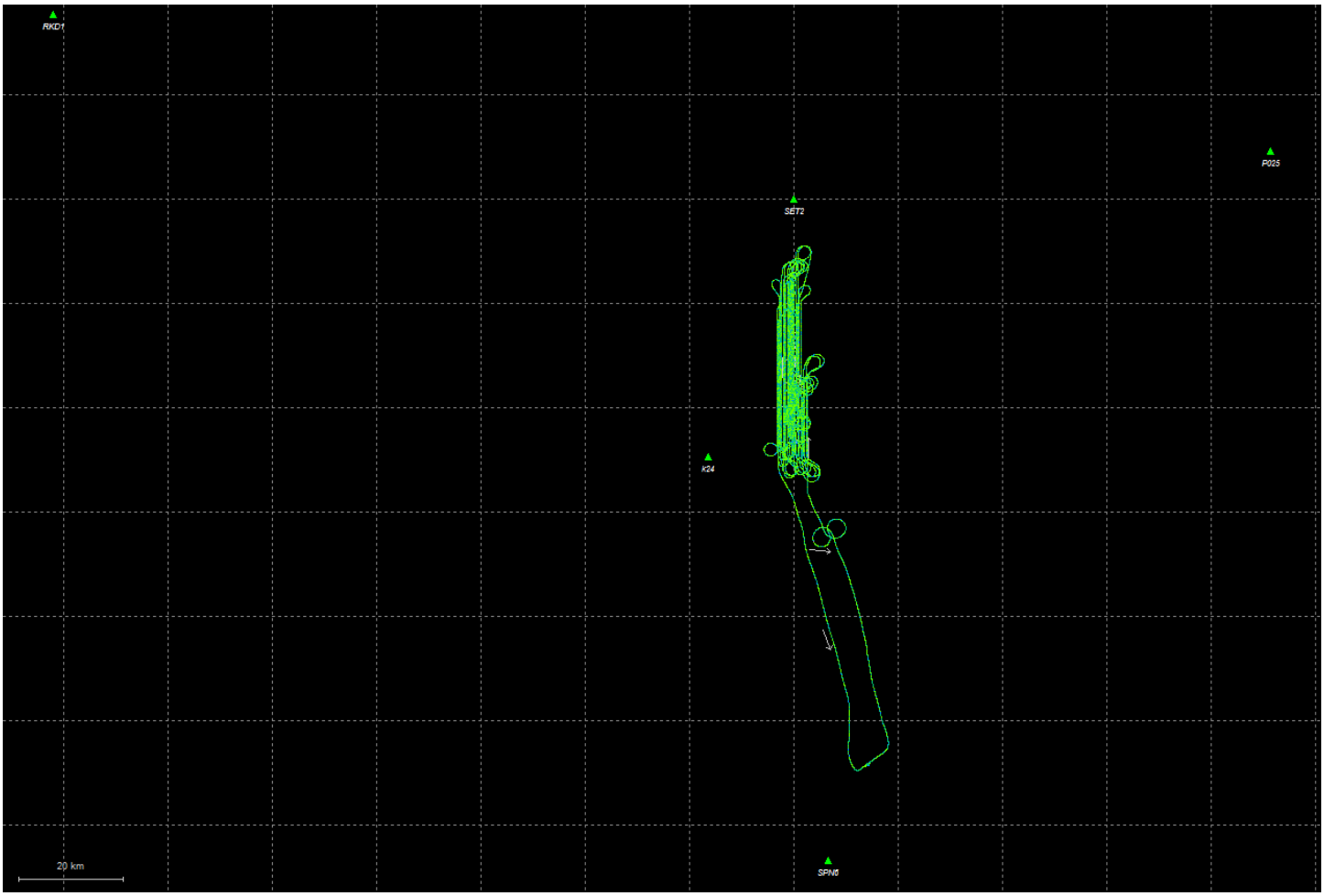

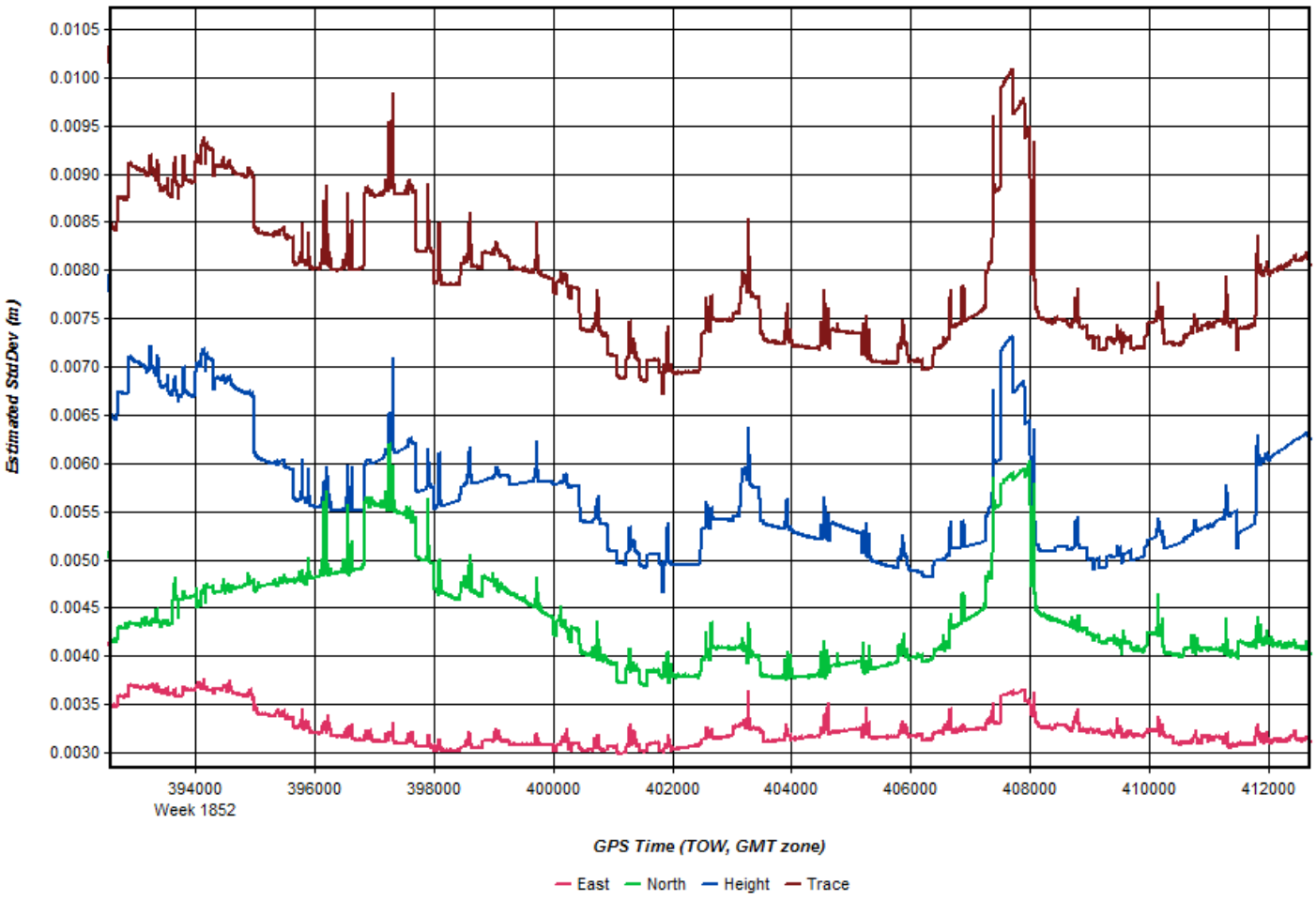
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North
Height
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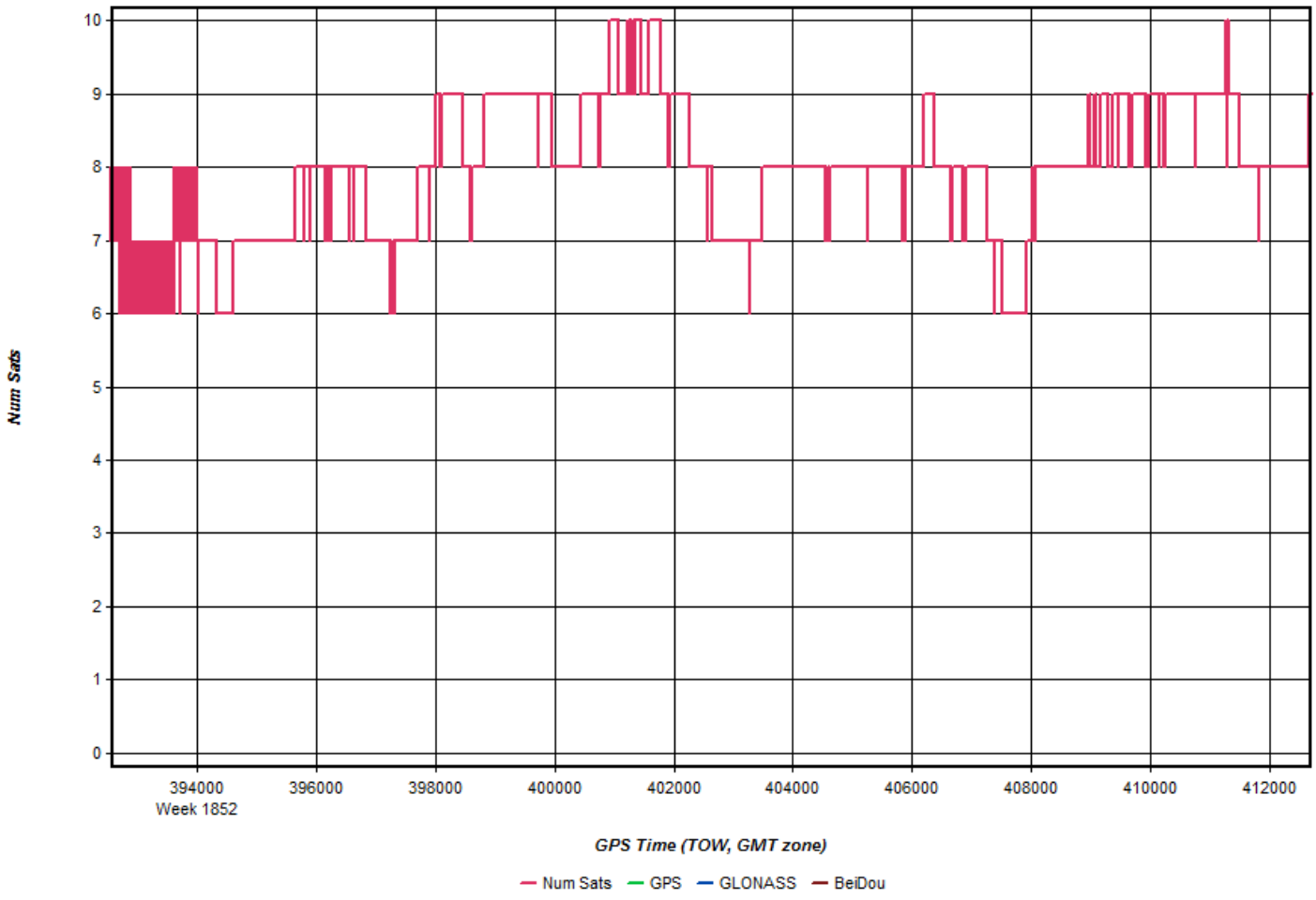
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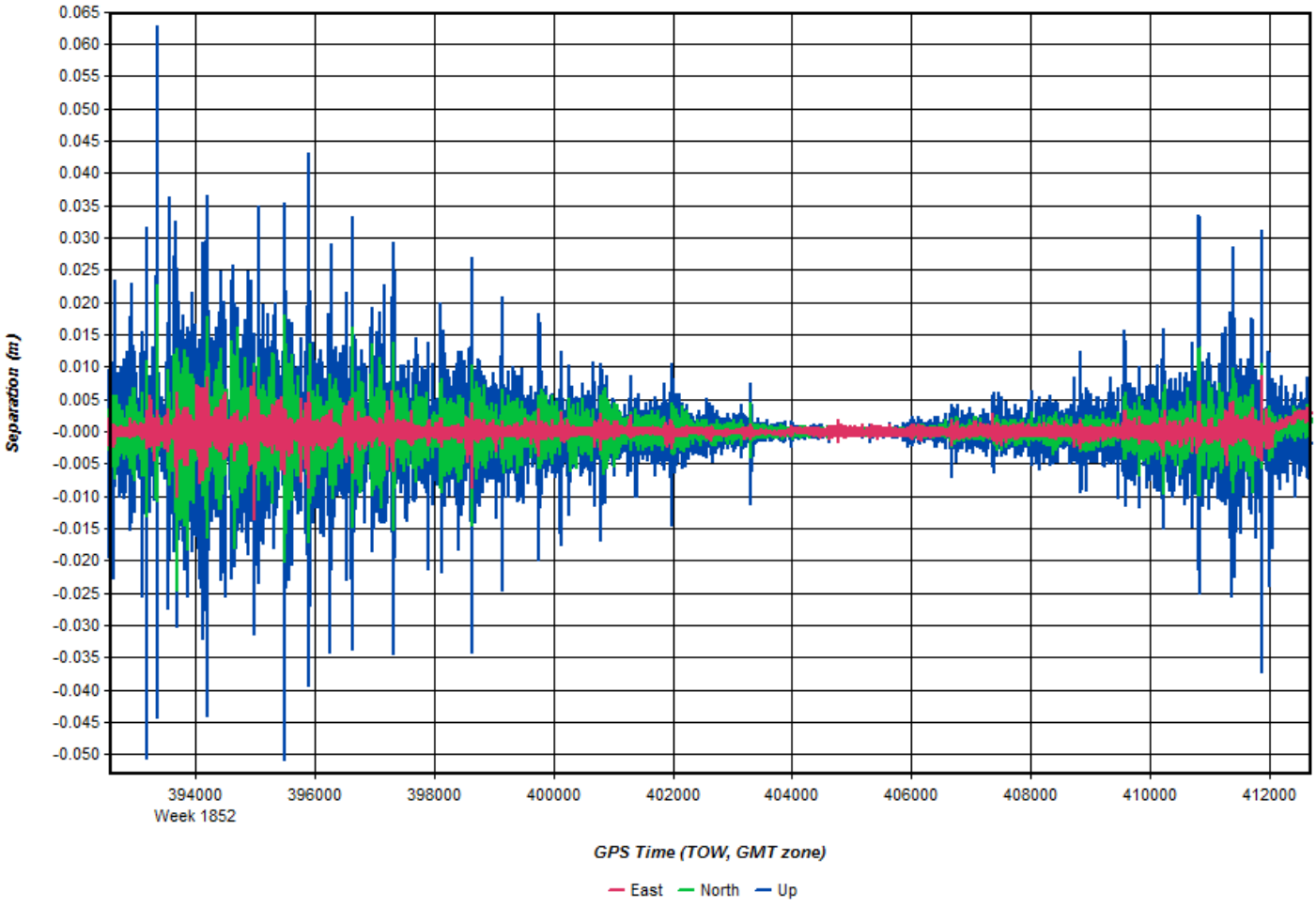
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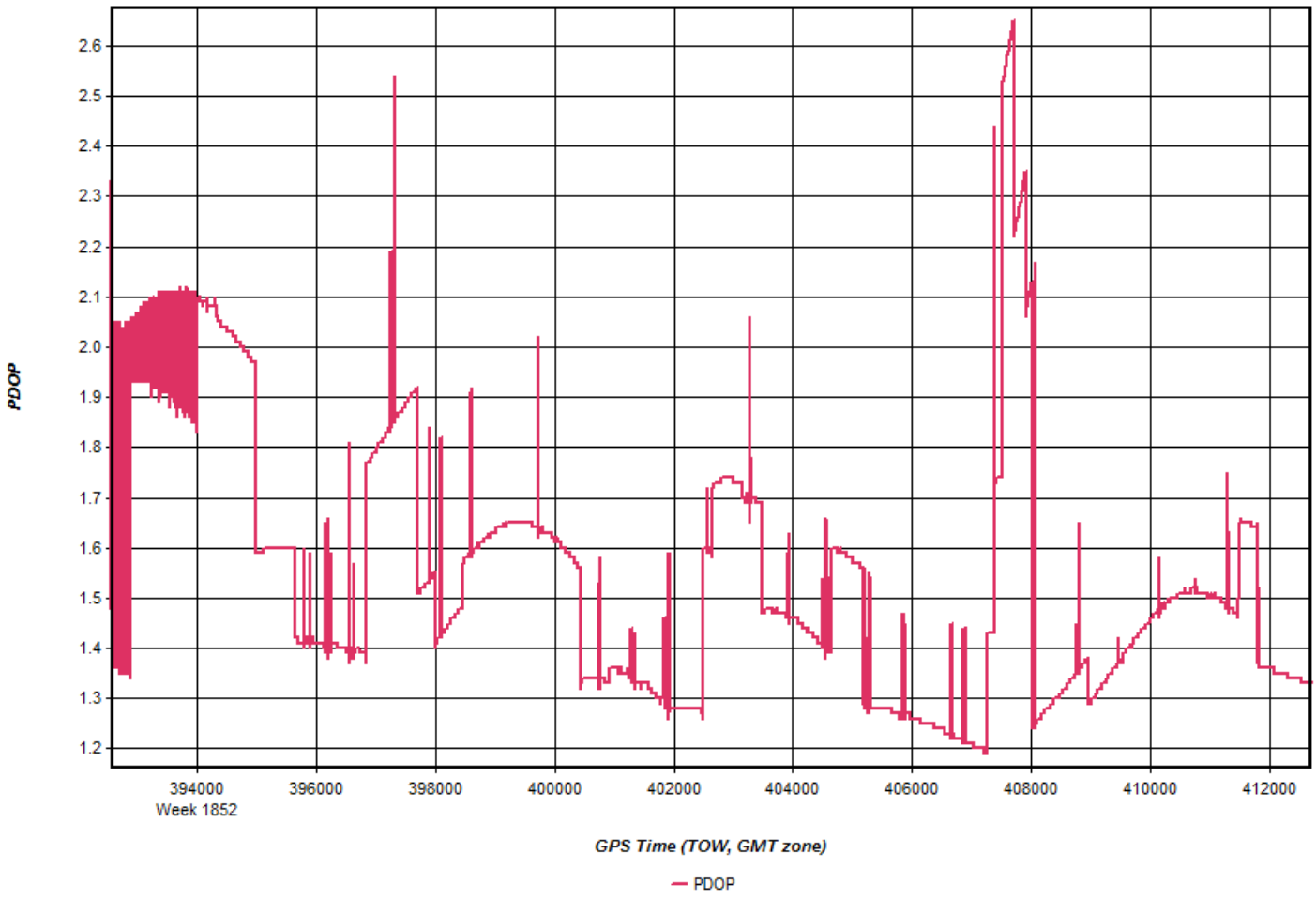
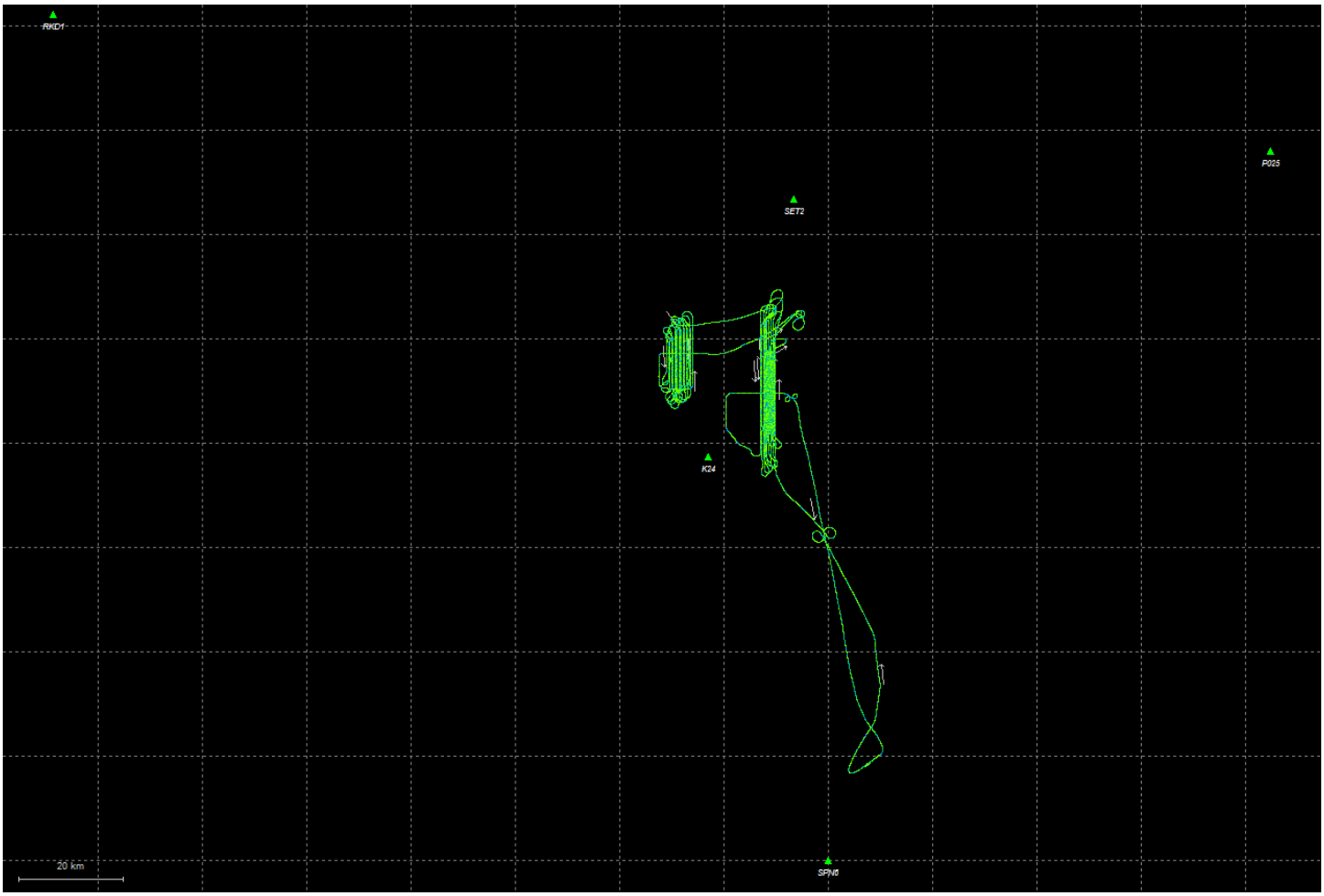
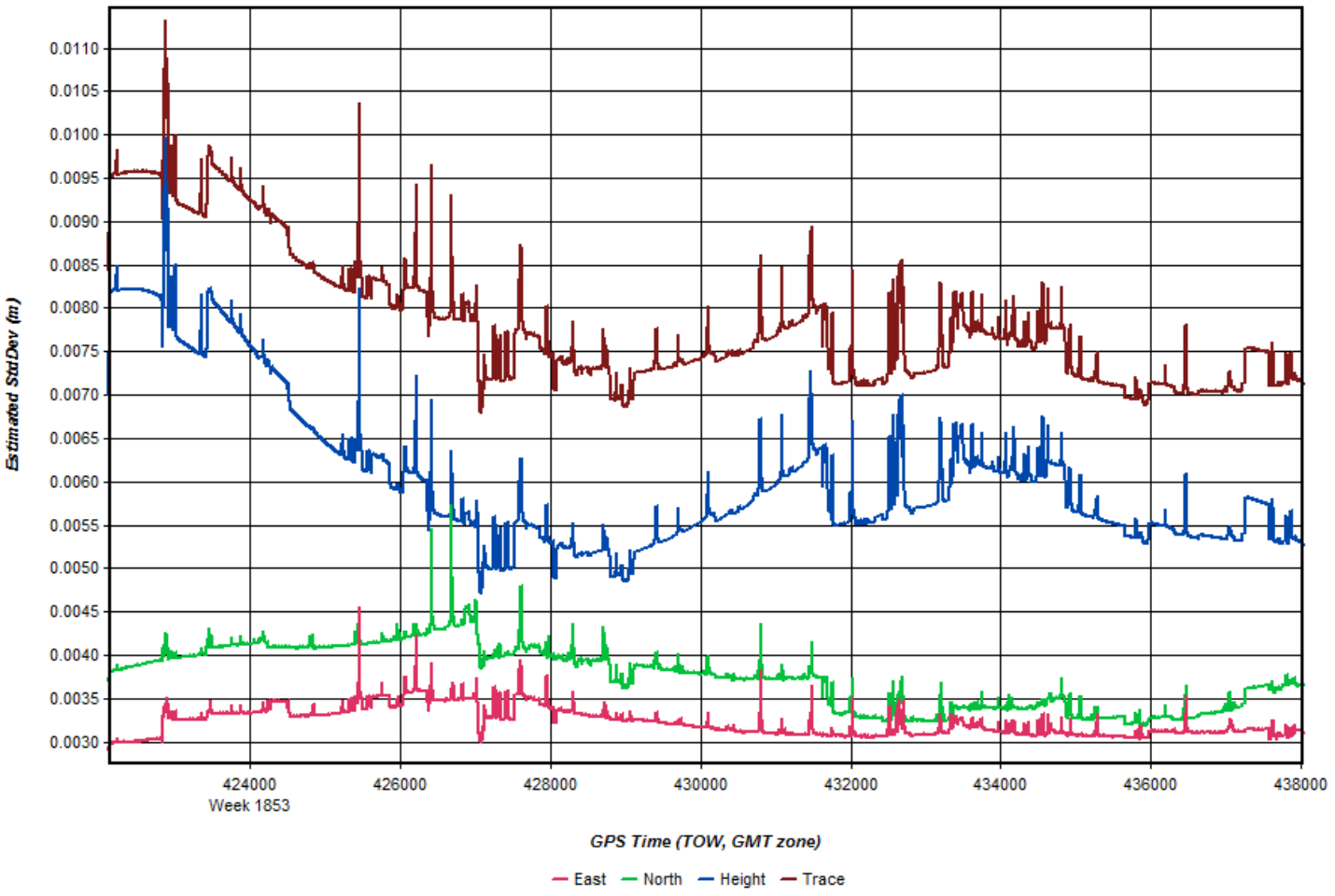
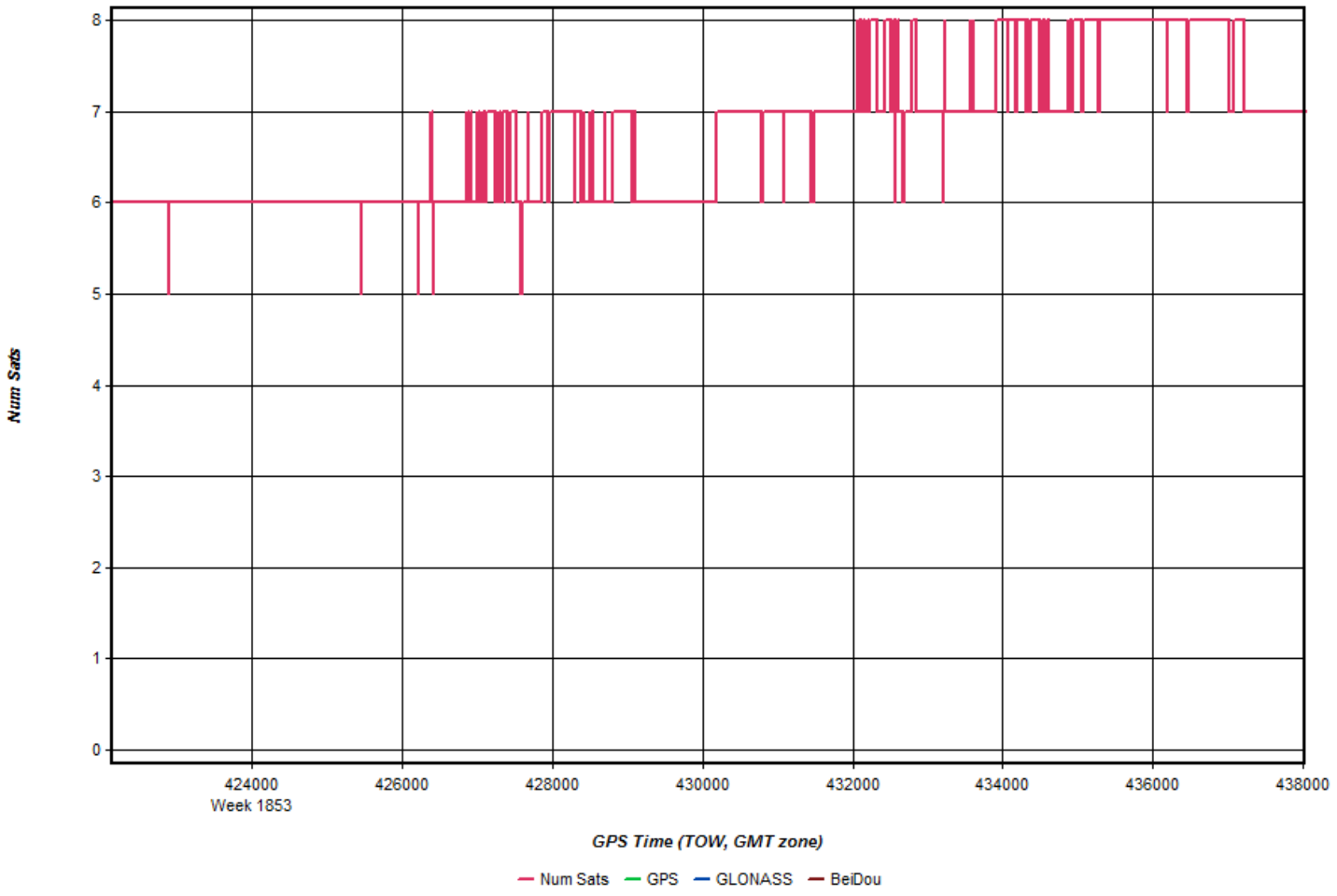
402000
404000
406000
408000
410000
412000
GPS Time (TOW, GMT zone)
East
North
Up

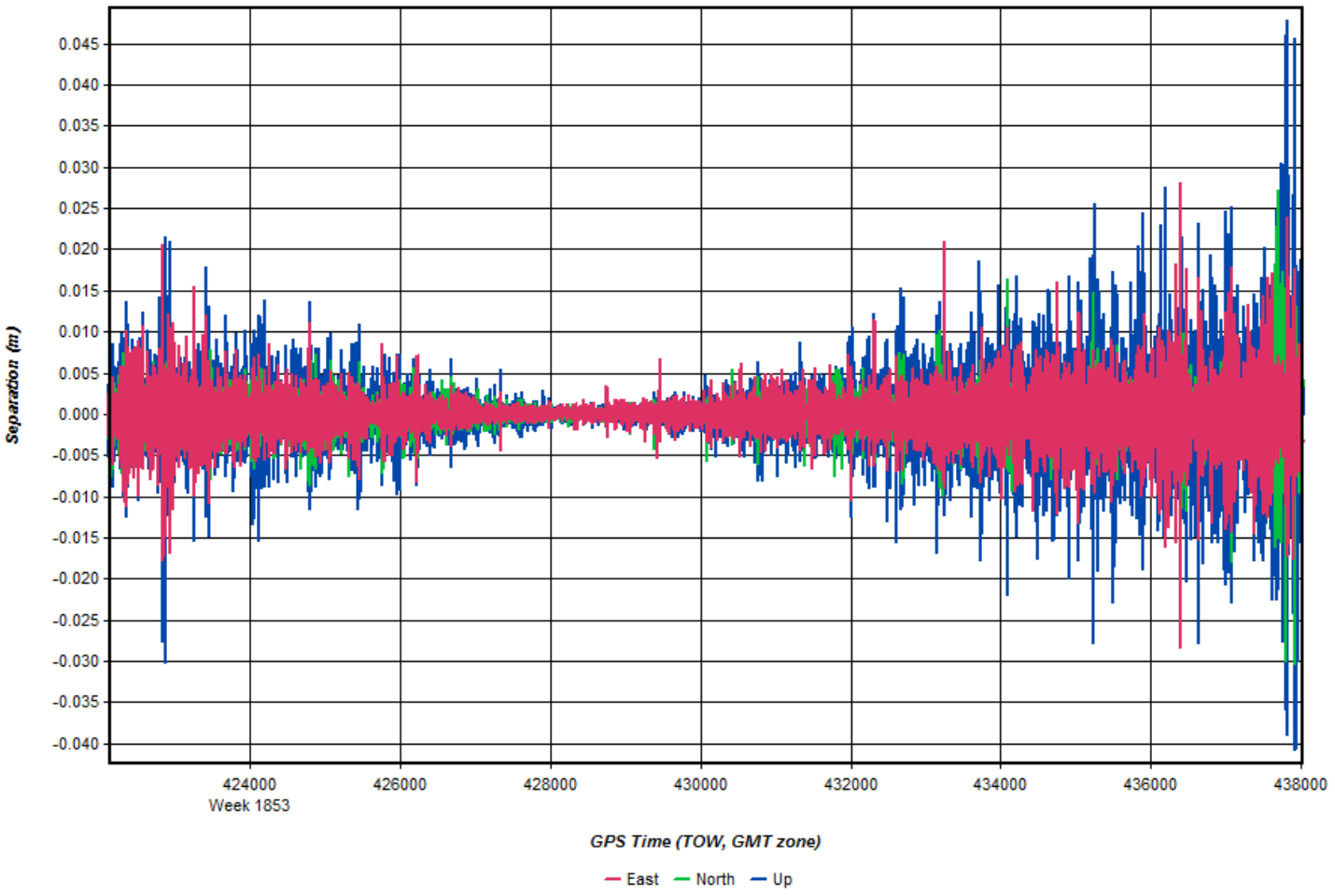

PDOP
2.6
2.5
2.4
2.3
2.2
2.1
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
394000
Week 1852
396000
398000
400000
402000
404000
406000
408000
410000
412000
GPS Time (TOW, GMT zone)
PDOP

225_20150716_1



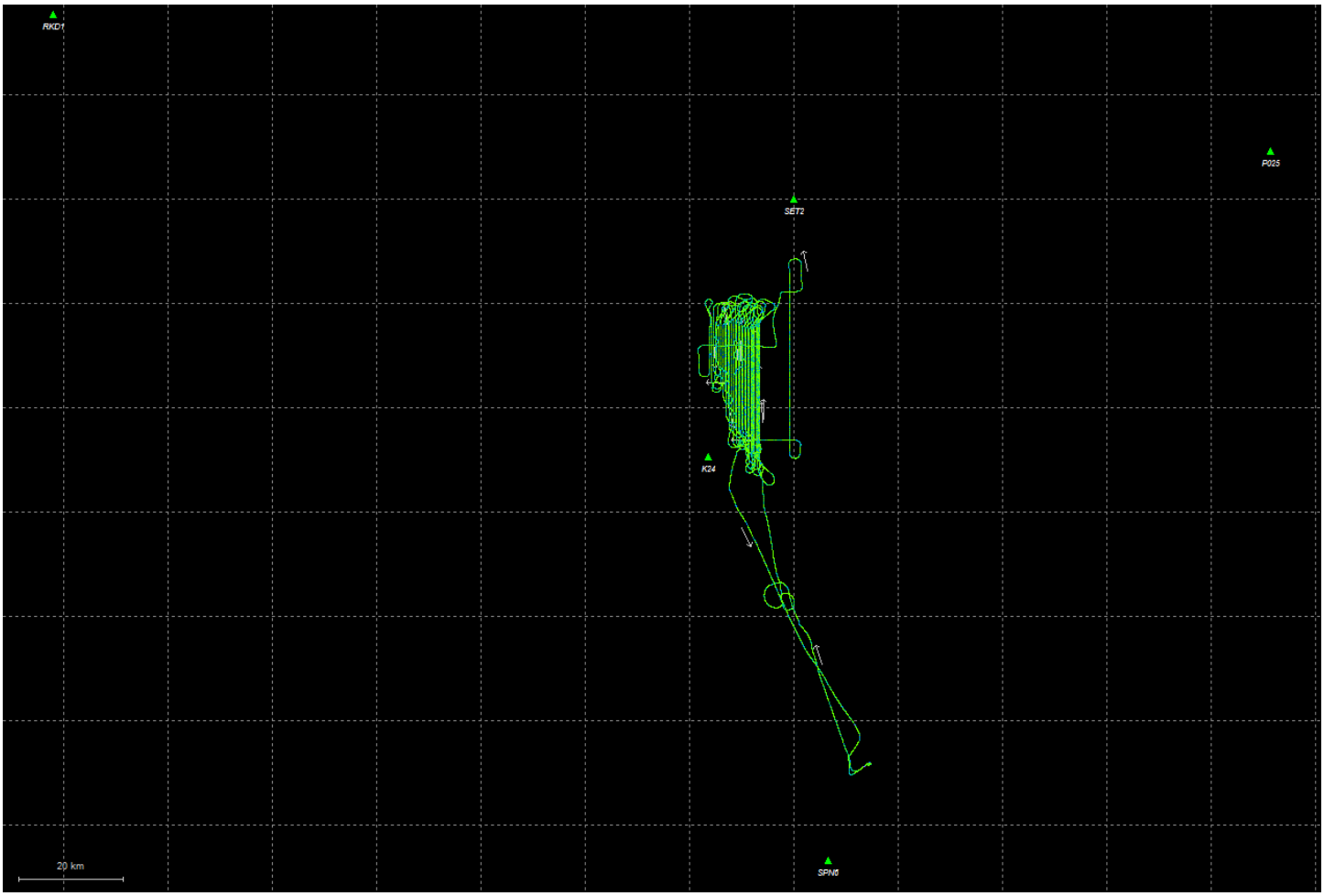

Estimated StdDev (m)
0.0110
0.0105
0.0100
0.0095
0.0090
0.0085
0.0080
0.0075
0.0070
0.0065
0.0060
0.0055
0.0050
0.0045
0.0040
0.0035
0.0030
424000
Week 1853
426000
428000
430000
432000
434000
436000
438000
GPS Time (TOW, GMT zone)
East
North
Height
Trace

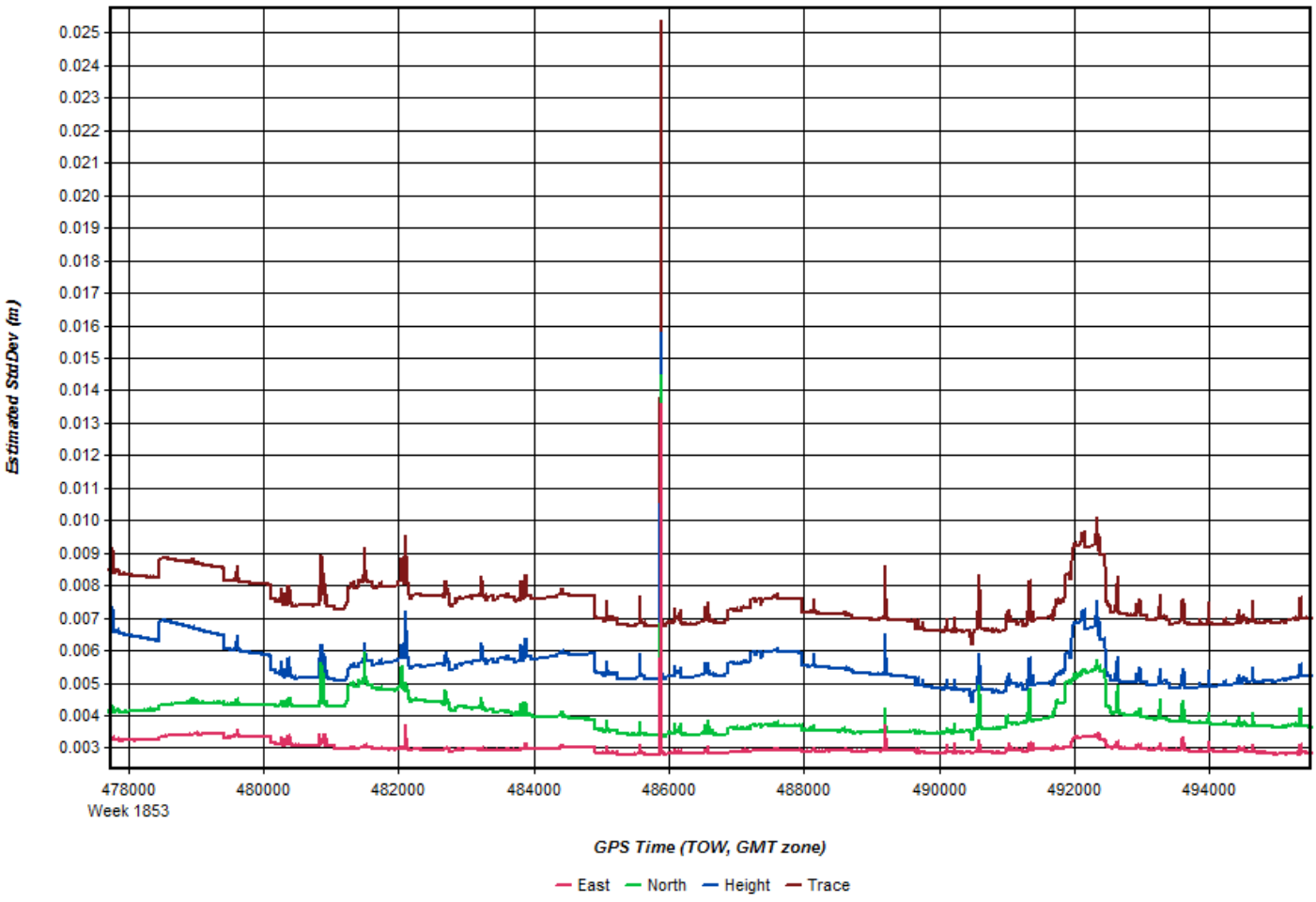

Num Sats
8
7
6
5
4
3
2
1
0
424000
Week 1853
426000
428000
430000
432000
434000
436000
438000
GPS Time (TOW, GMT zone)
Num Sats
GPS
GLONASS
BeiDou

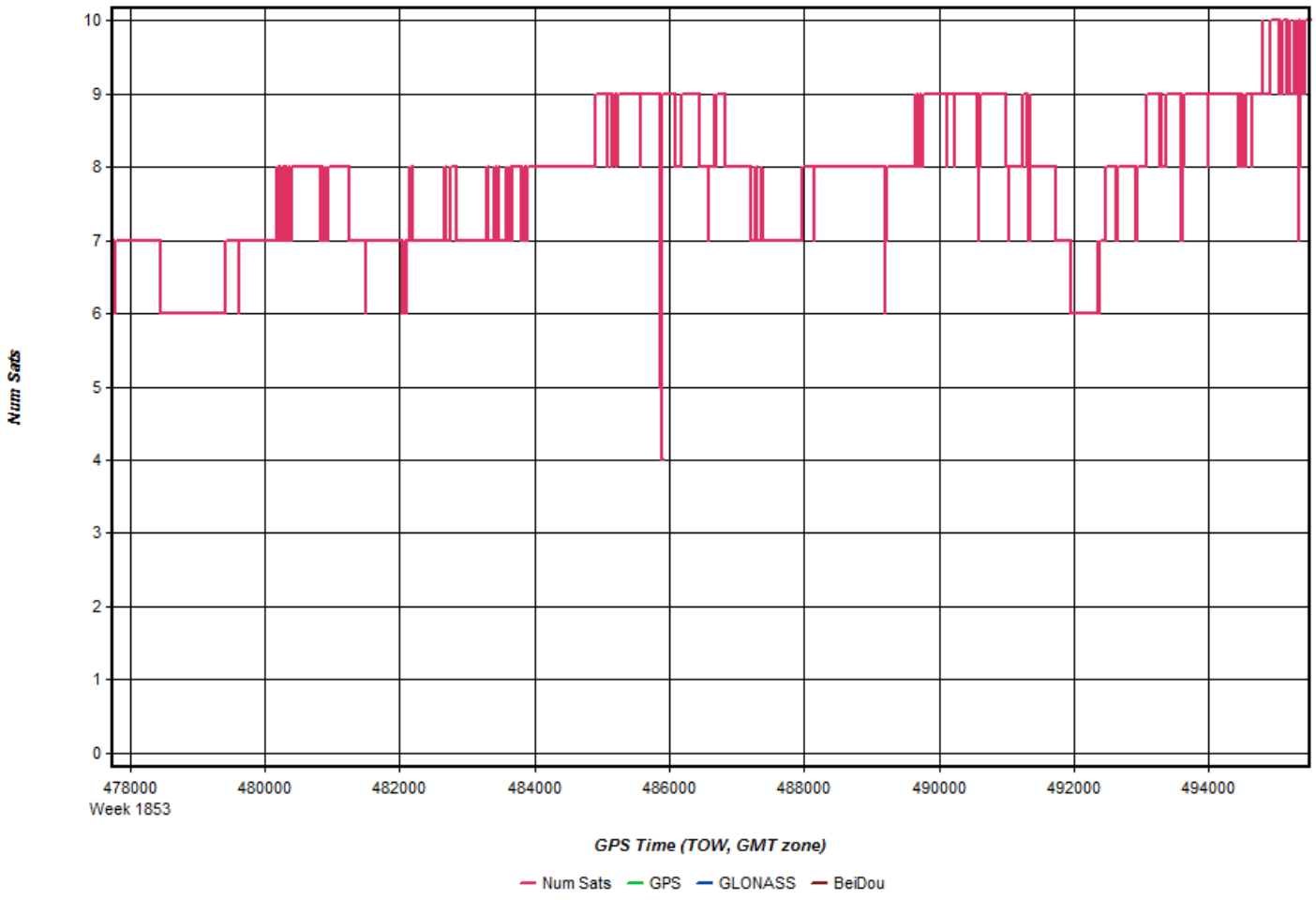

Separation (m)
0.045
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
-0.005
-0.010
-0.015
-0.020
-0.025
-0.030
-0.035
-0.040
424000
Week 1853
426000
428000
430000
432000
434000
436000
438000
GPS Time (TOW, GMT zone)
East
North
Up

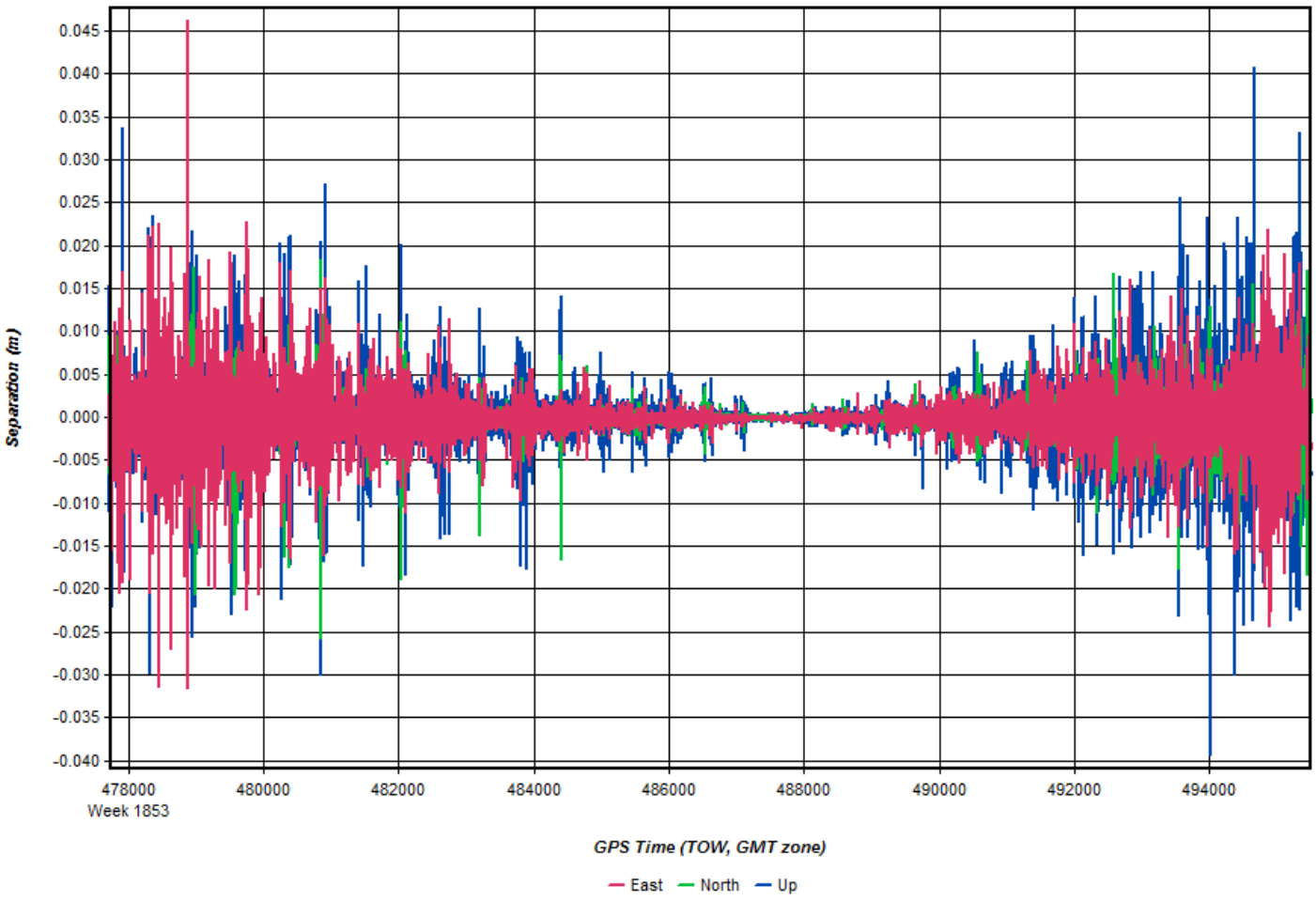

PDOP
3.8
3.6
3.4
3.2
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
424000
Week 1853
426000
428000
430000
432000
434000
436000
438000
GPS Time (TOW, GMT zone)
PDOP

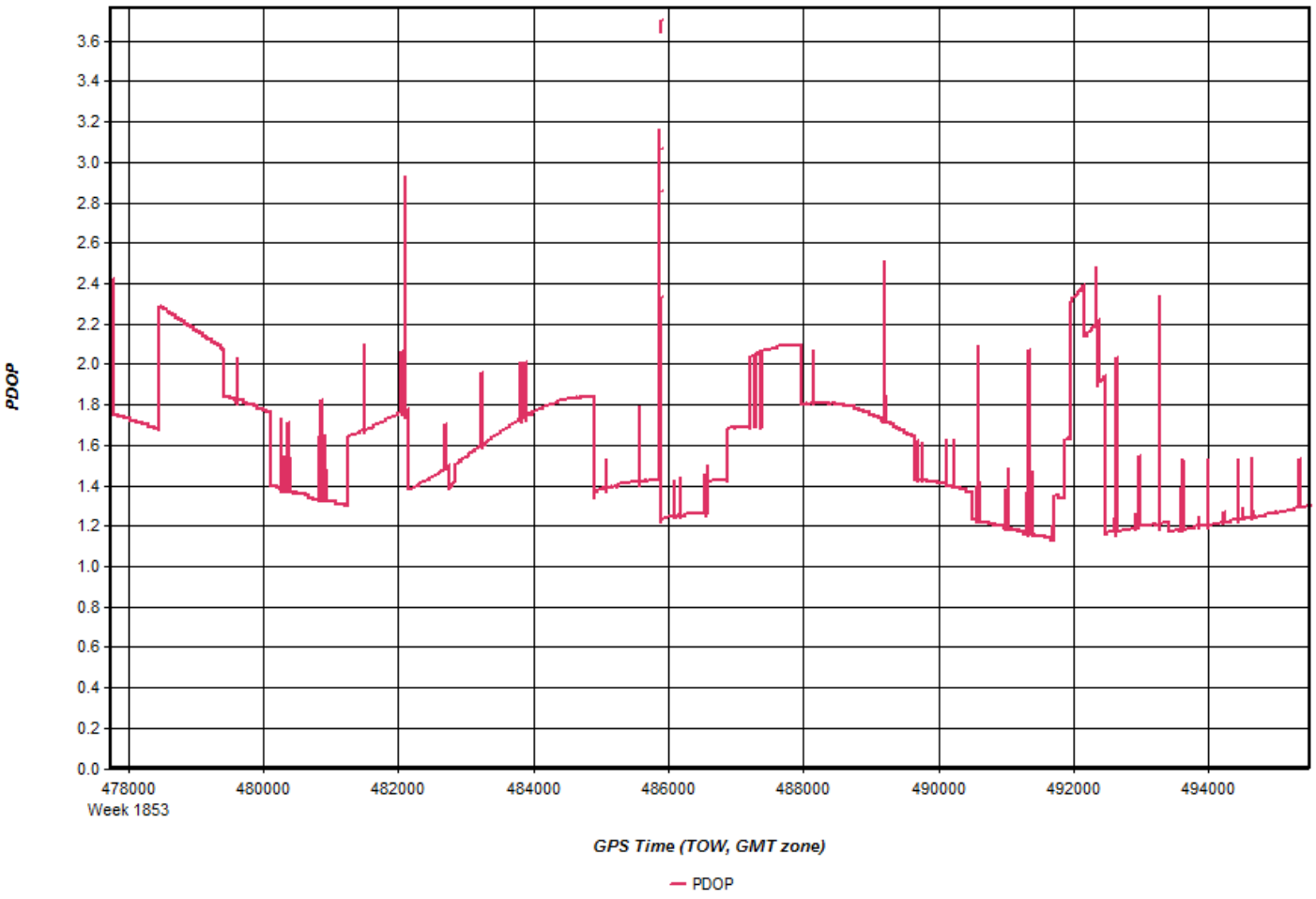
225_20150717_1



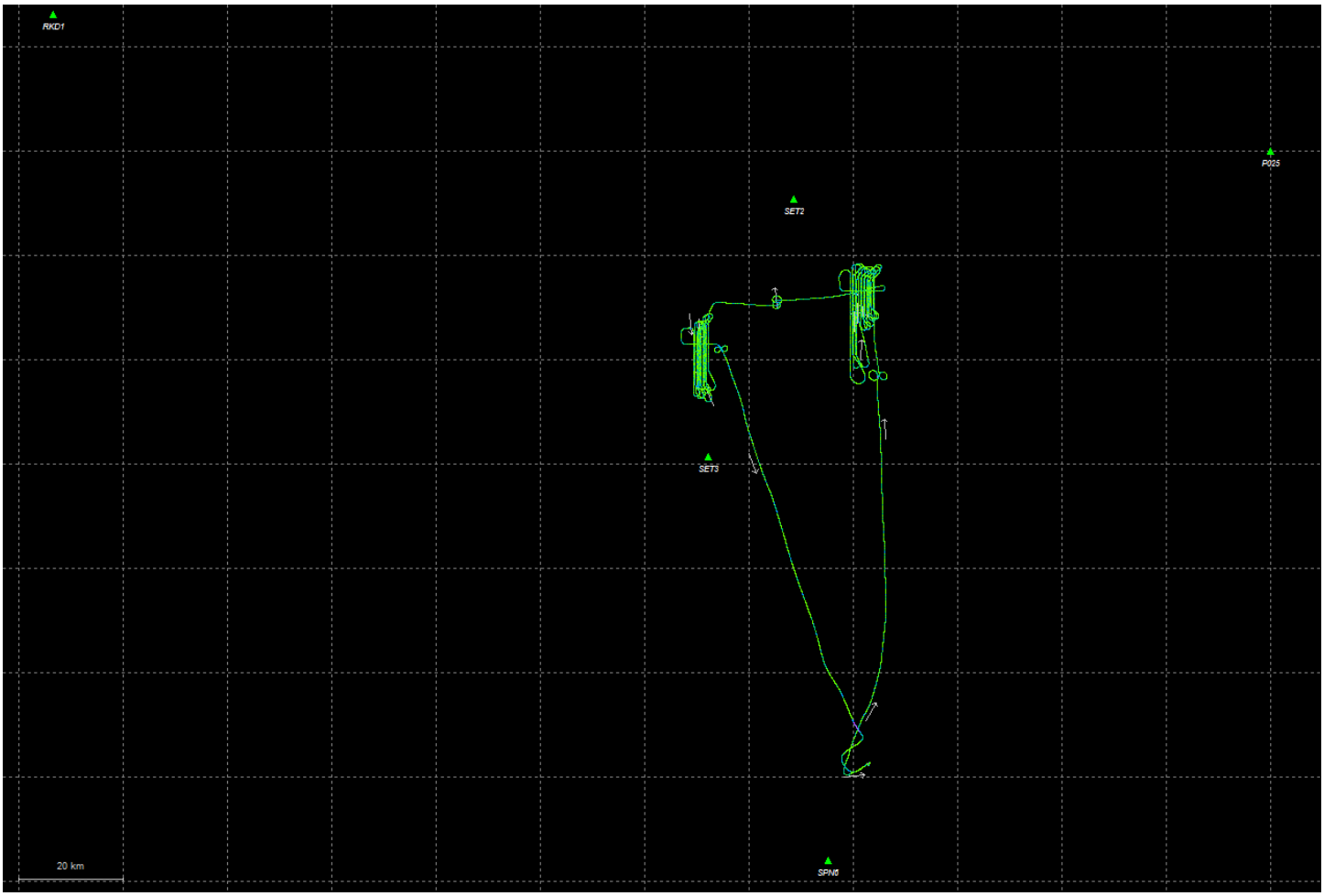

Estimated StdDev (m)
0.025
0.024
0.023
0.022
0.021
0.020
0.019
0.018
0.017
0.016
0.015
0.014
0.013
0.012
0.011
0.010
0.009
0.008
0.007
0.006
0.005
0.004
0.003
478000
Week 1853
480000
482000
484000
486000
488000
490000
492000
494000
GPS Time (TOW, GMT zone)
East
North
Height
Trace

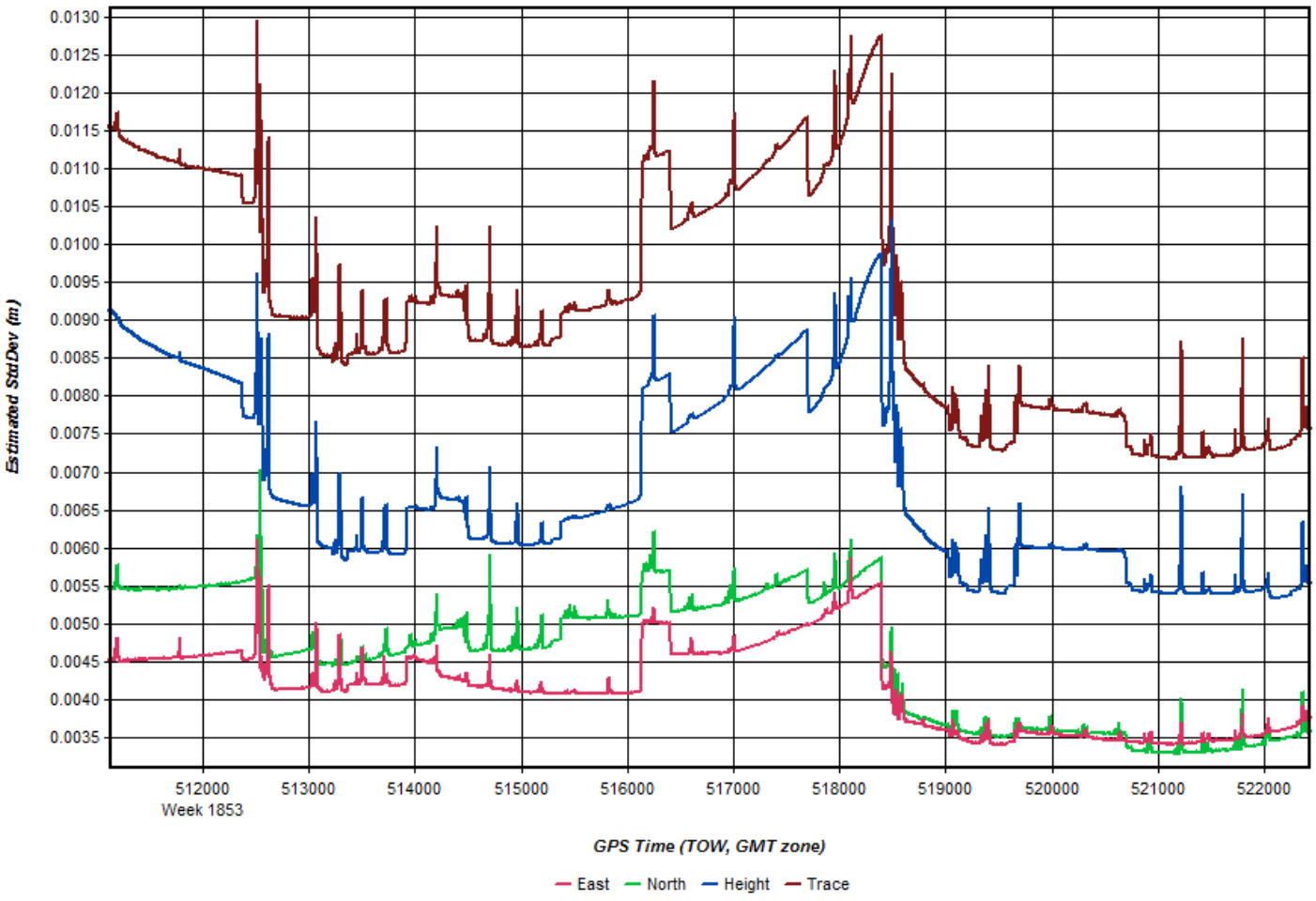

Num Sats
10
9
8
7
6
5
4
3
2
1
0
478000
Week 1853
480000
482000
484000
486000
488000
490000
492000
494000
GPS Time (TOW, GMT zone)
Num Sats
GPS
GLONASS
BeiDou

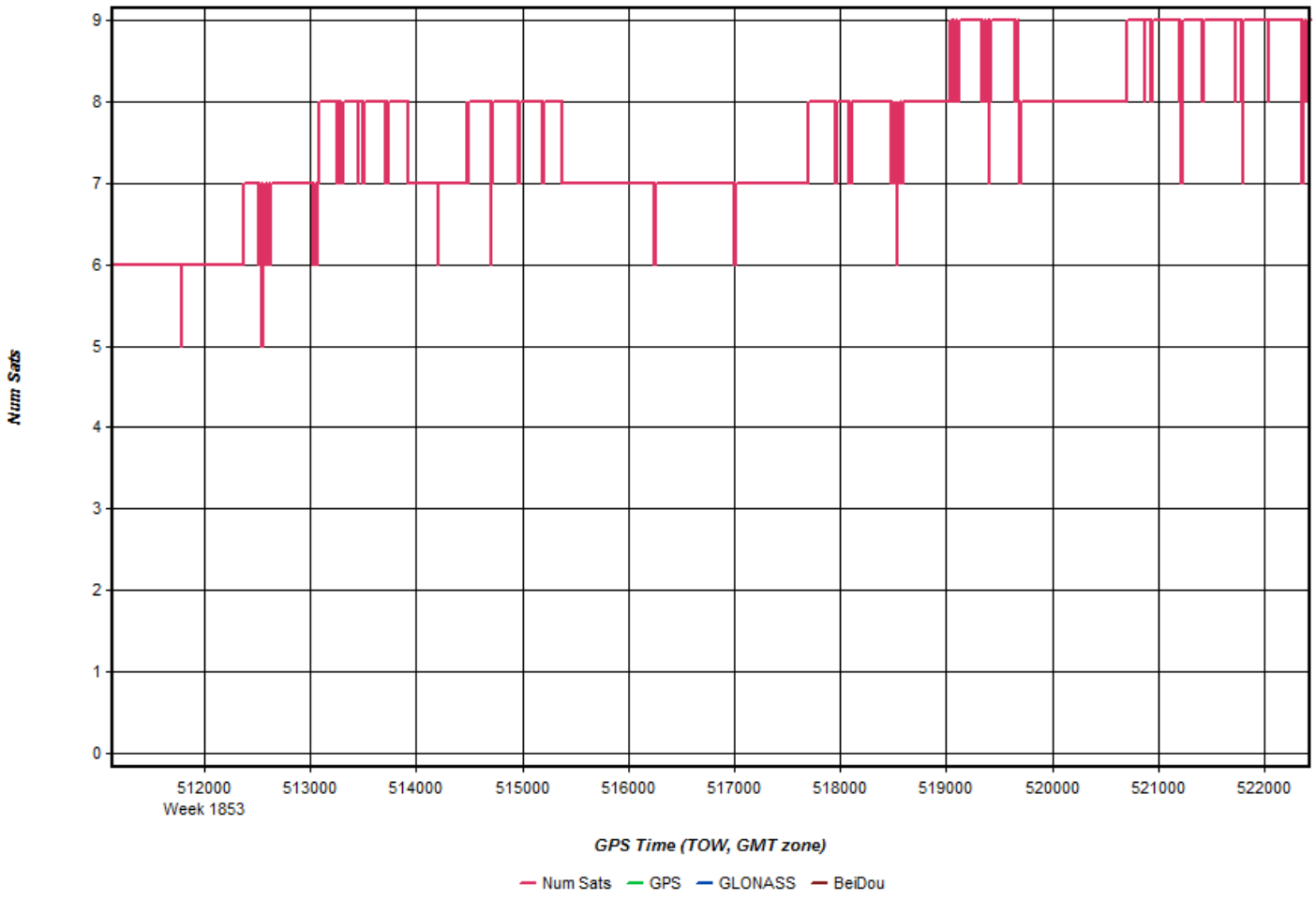

Separation (m)
0.045
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
-0.005
-0.010
-0.015
-0.020
-0.025
-0.030
-0.035
-0.040
478000
Week 1853
480000
482000
484000
486000
488000
490000
492000
494000
GPS Time (TOW, GMT zone)
East
North
Up

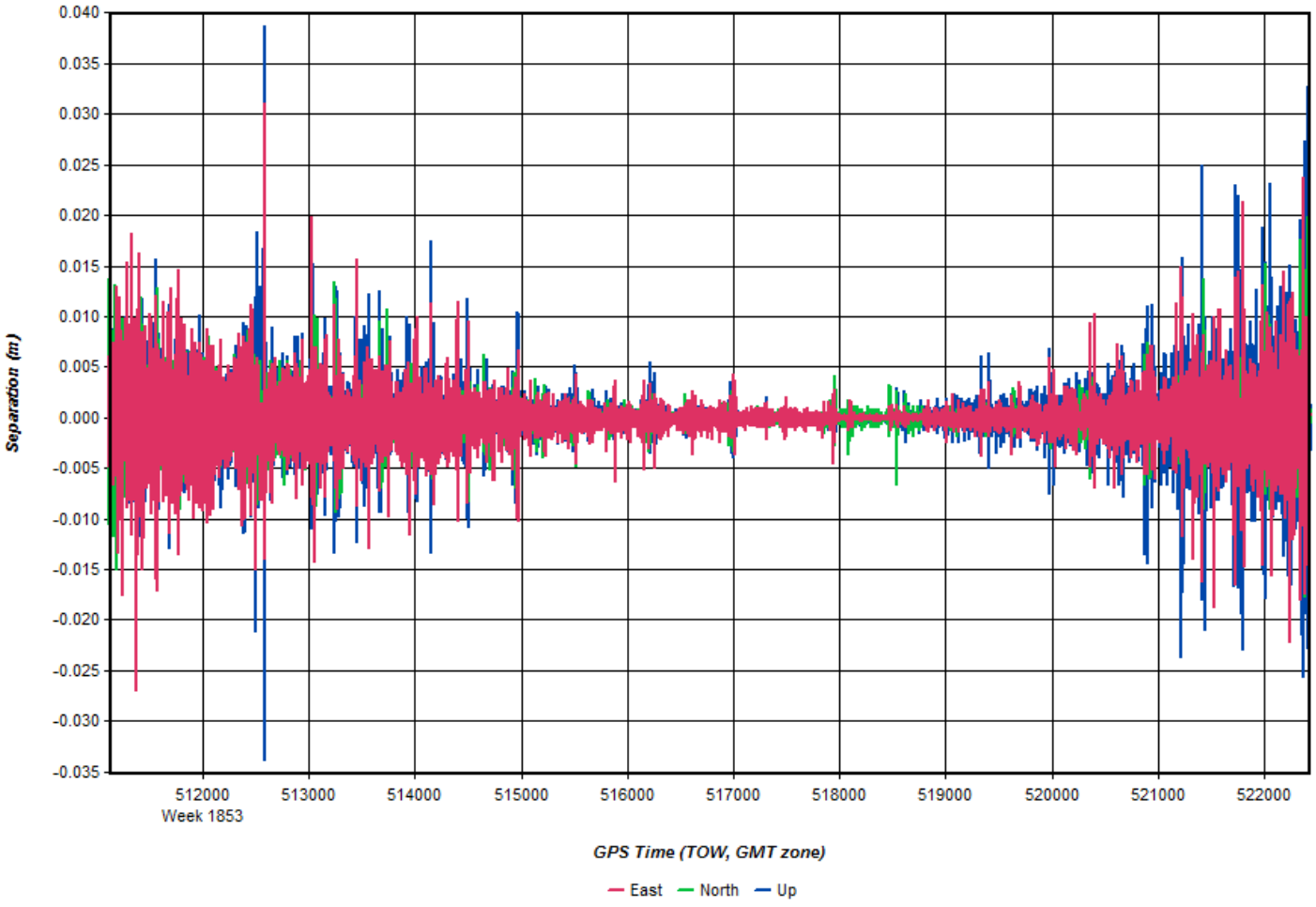

PDOP
3.6
3.4
3.2
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
478000
480000
482000
484000
486000
488000
490000
492000
494000
Week 1853
GPS Time (TOW, GMT zone)
PDOP

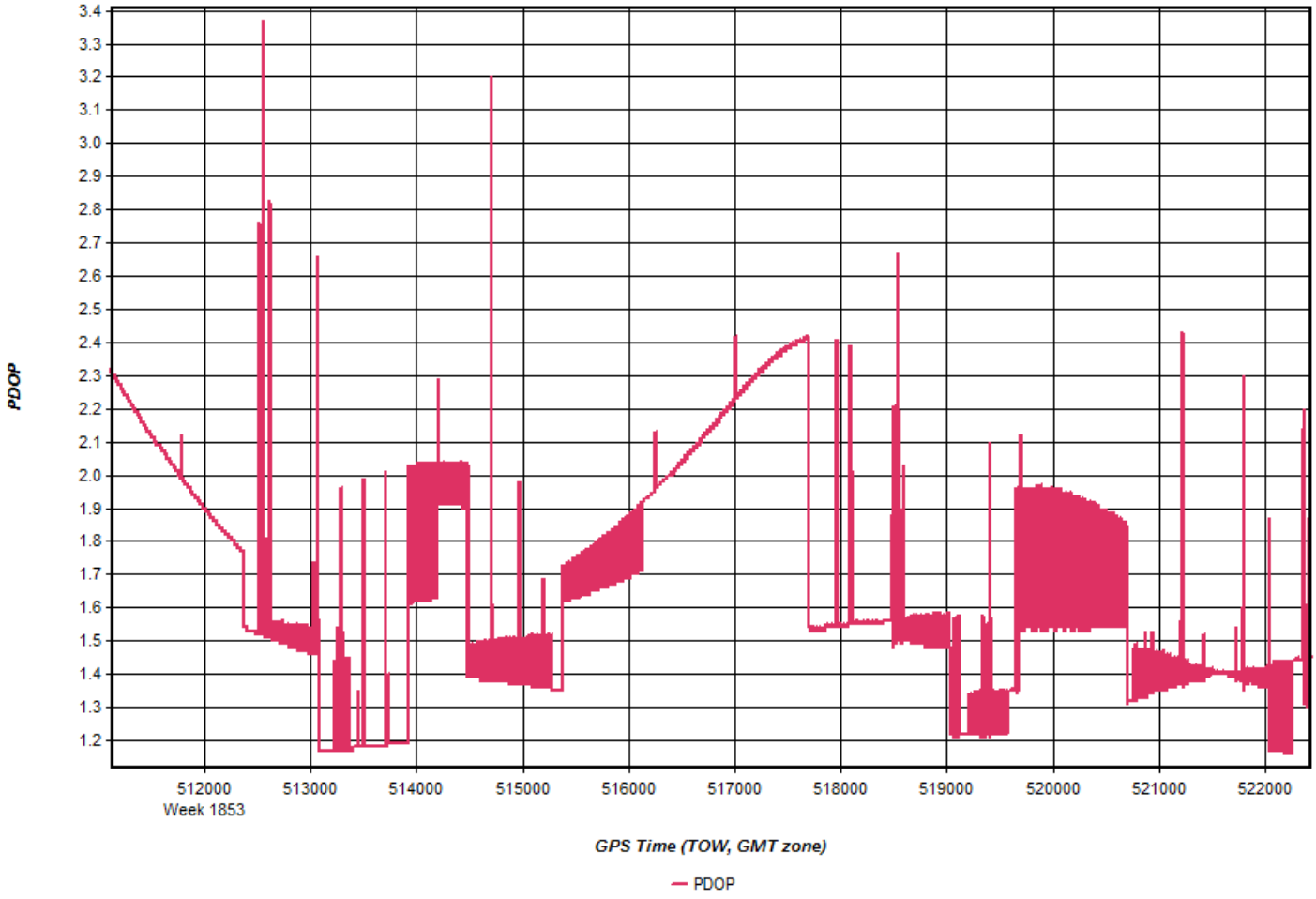
225_20150717_2



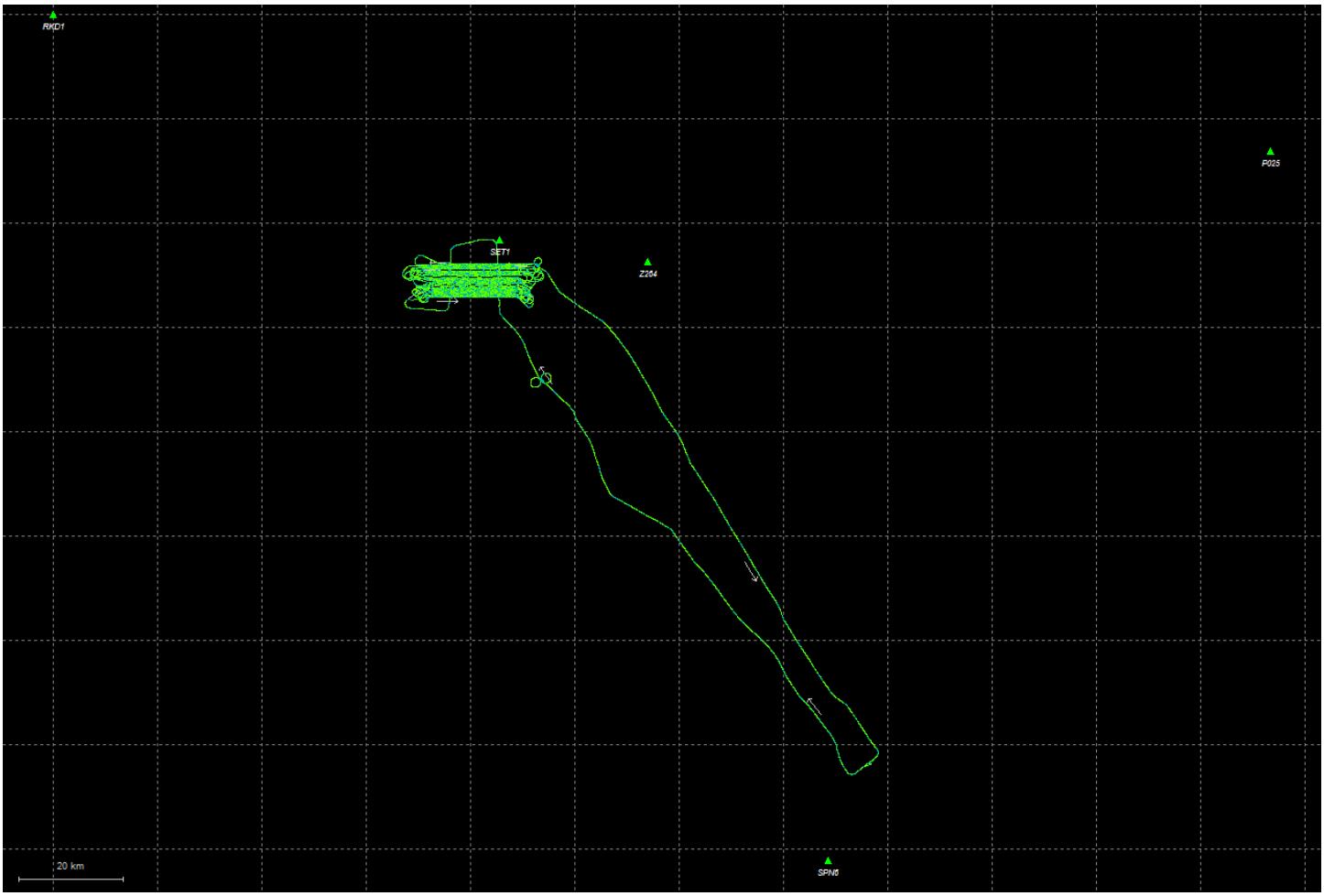

Estimated StdDev (m)
0.0130
0.0125
0.0120
0.0115
0.0110
0.0105
0.0100
0.0095
0.0090
0.0085
0.0080
0.0075
0.0070
0.0065
0.0060
0.0055
0.0050
0.0045
0.0040
0.0035
512000
Week 1853
513000
514000
515000
516000
517000
518000
519000
520000
521000
522000
GPS Time (TOW, GMT zone)
East
North
Height
Trace

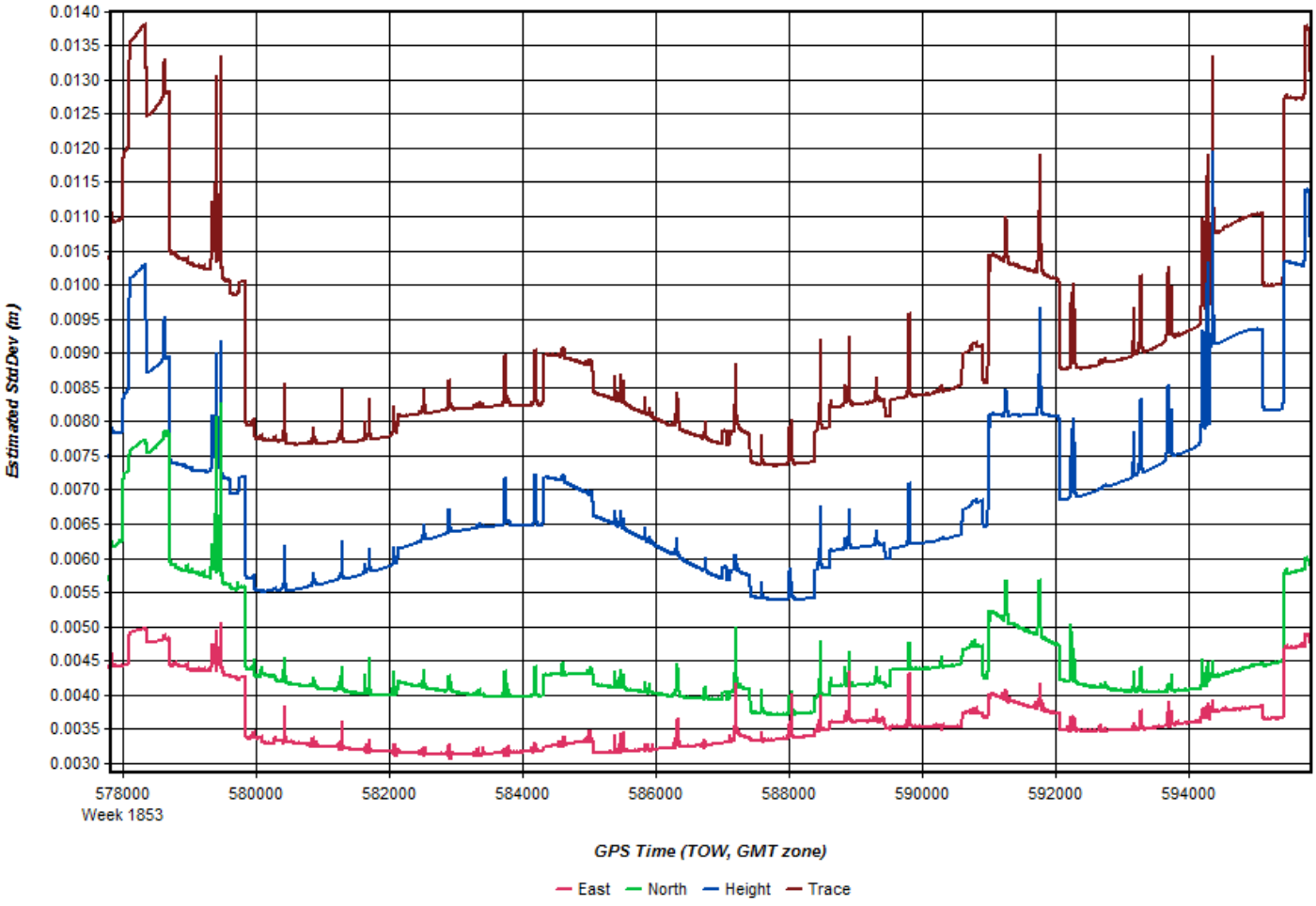

Num Sats
9
8
7
6
5
4
3
2
1
0
512000
Week 1853
513000
514000
515000
516000
517000
518000
519000
520000
521000
522000
GPS Time (TOW, GMT zone)
Num Sats
GPS
GLONASS
BeiDou

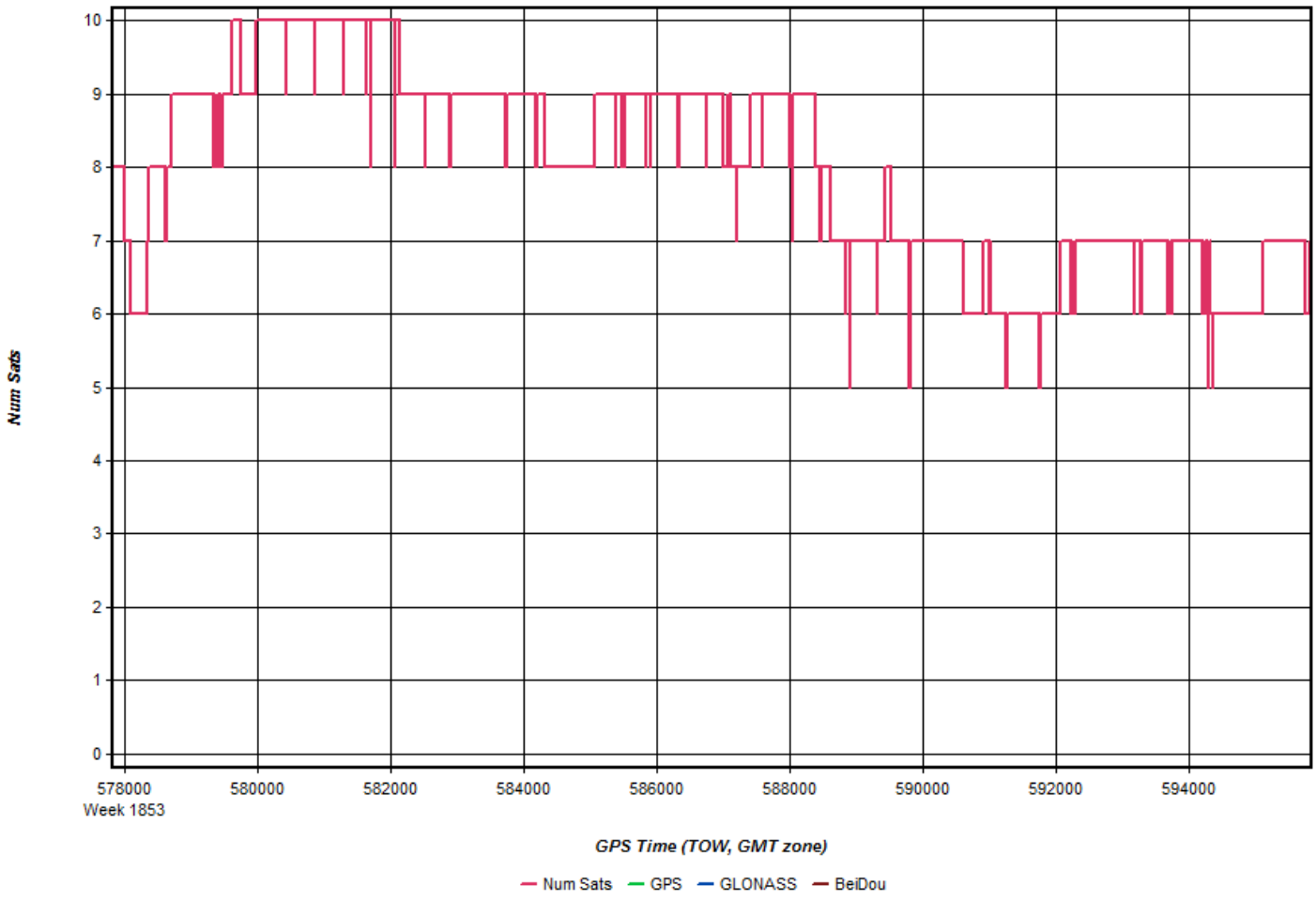

0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
-0.005
-0.010
-0.015
-0.020
-0.025
-0.030
-0.035
Separation (m)
512000
Week 1853
513000
514000
515000
516000
517000
518000
519000
520000
521000
522000
GPS Time (TOW, GMT zone)
East
North
Up

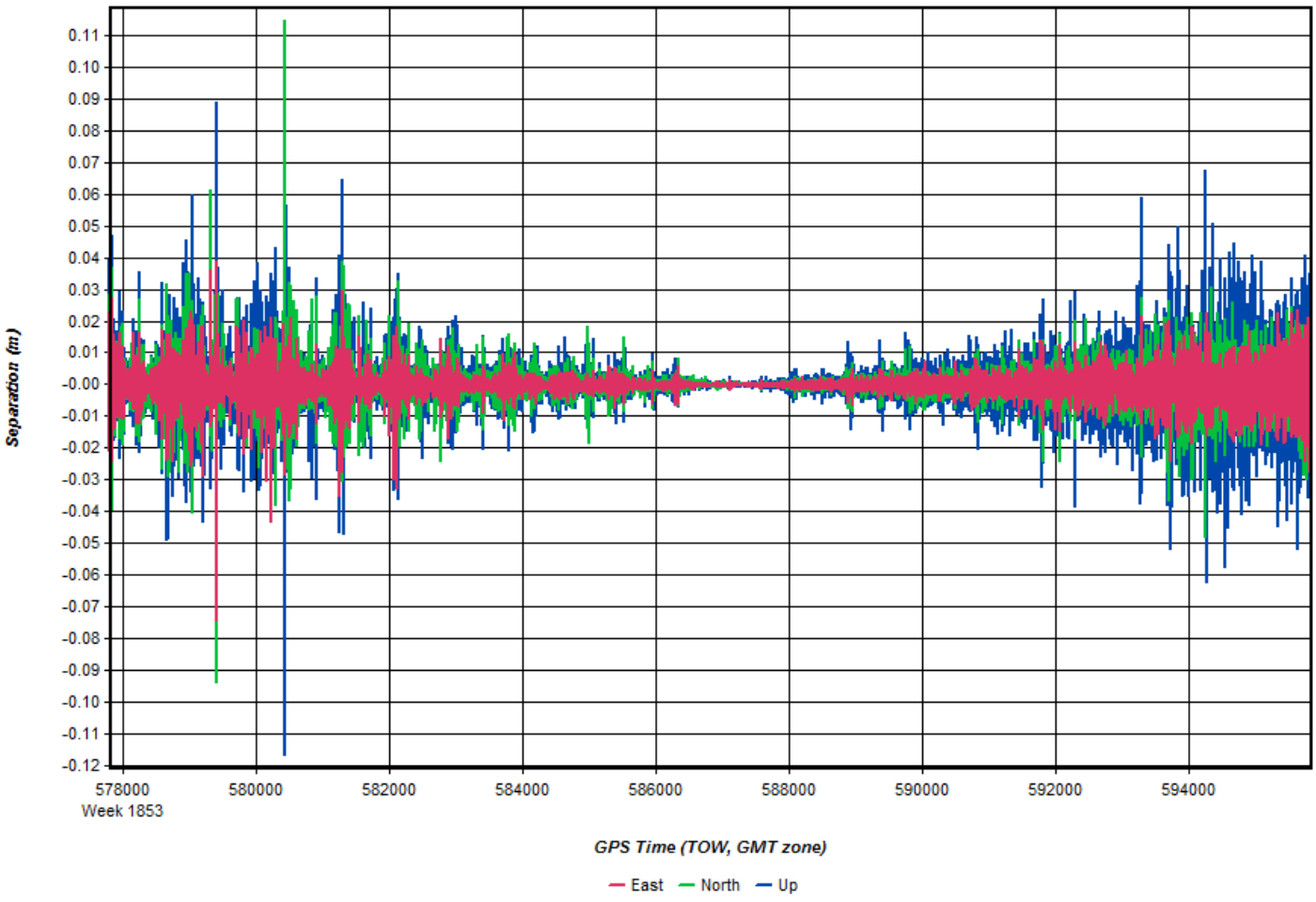

PDOP
3.4
3.3
3.2
3.1
3.0
2.9
2.8
2.7
2.6
2.5
2.4
2.3
2.2
2.1
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
512000
Week 1853
513000
514000
515000
516000
517000
518000
519000
520000
521000
522000
GPS Time (TOW, GMT zone)
PDOP

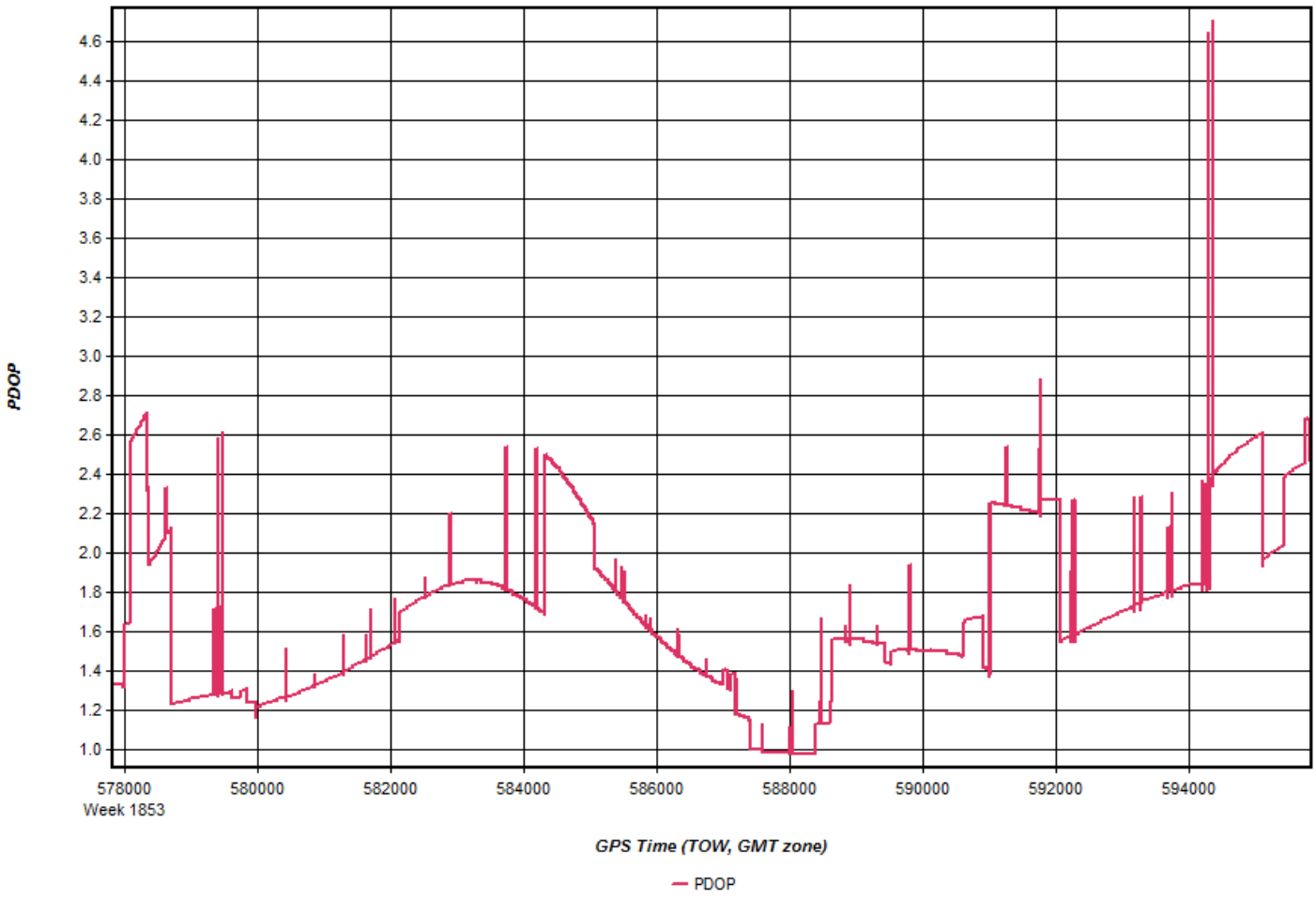
225_20150718_1



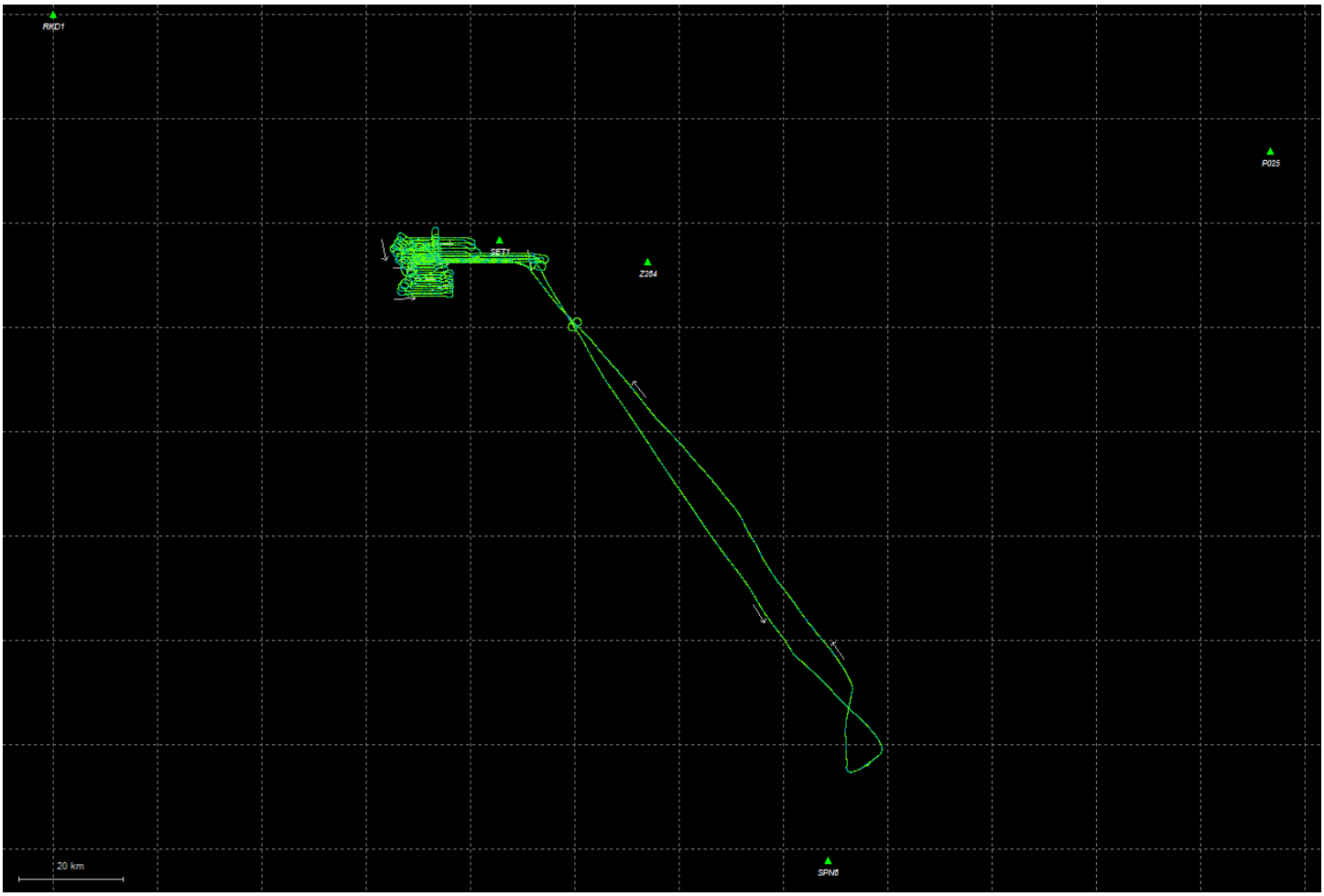

Estimated StdDev (m)
0.0140
0.0135
0.0130
0.0125
0.0120
0.0115
0.0110
0.0105
0.0100
0.0095
0.0090
0.0085
0.0080
0.0075
0.0070
0.0065
0.0060
0.0055
0.0050
0.0045
0.0040
0.0035
0.0030
578000
Week 1853
580000
582000
584000
586000
588000
590000
592000
594000
GPS Time (TOW, GMT zone)
East
North
Height
Trace

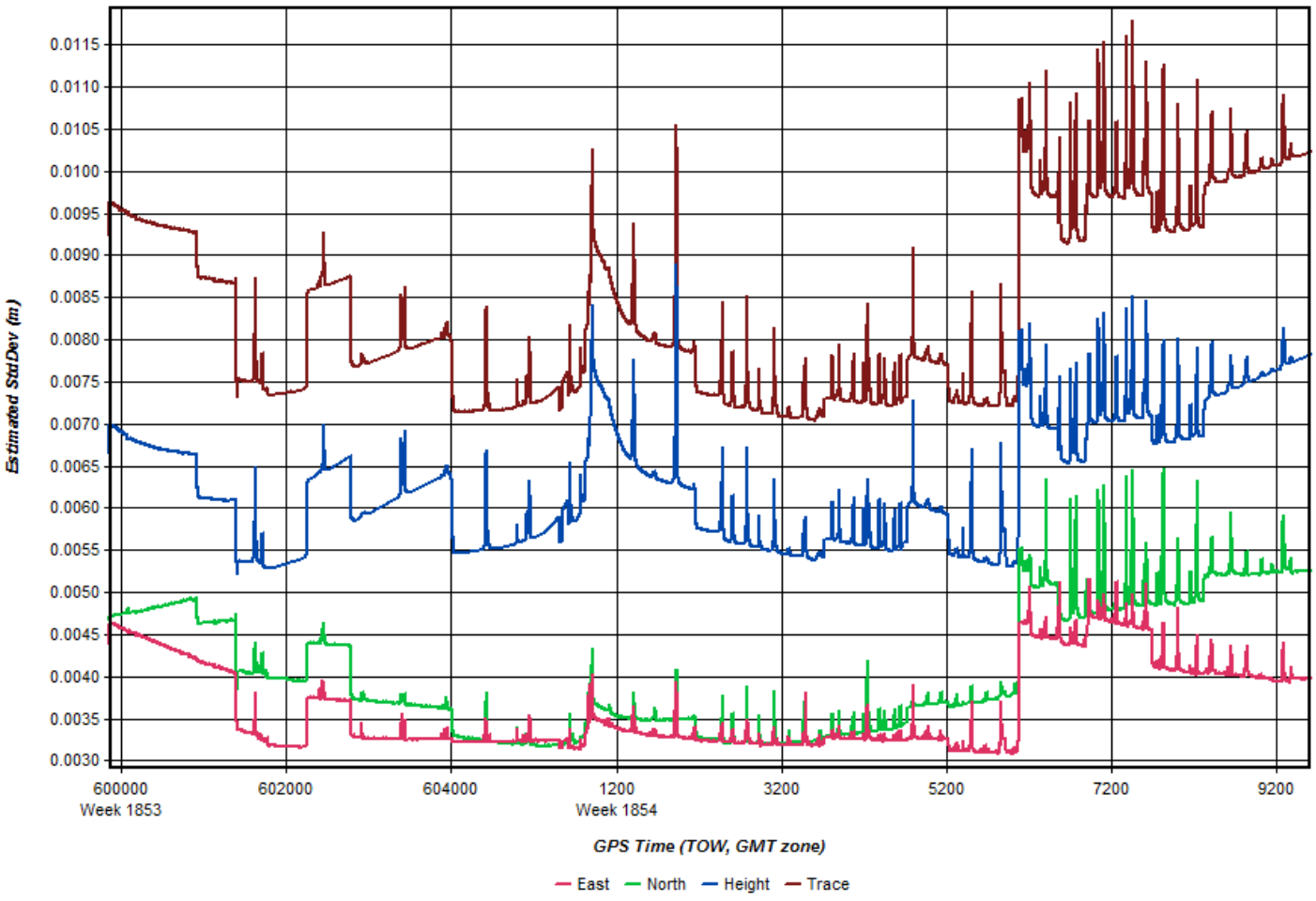

Num Sats
10
9
8
7
6
5
4
3
2
1
0
578000
Week 1853
580000
582000
584000
586000
588000
590000
592000
594000
GPS Time (TOW, GMT zone)
Num Sats
GPS
GLONASS
BeiDou

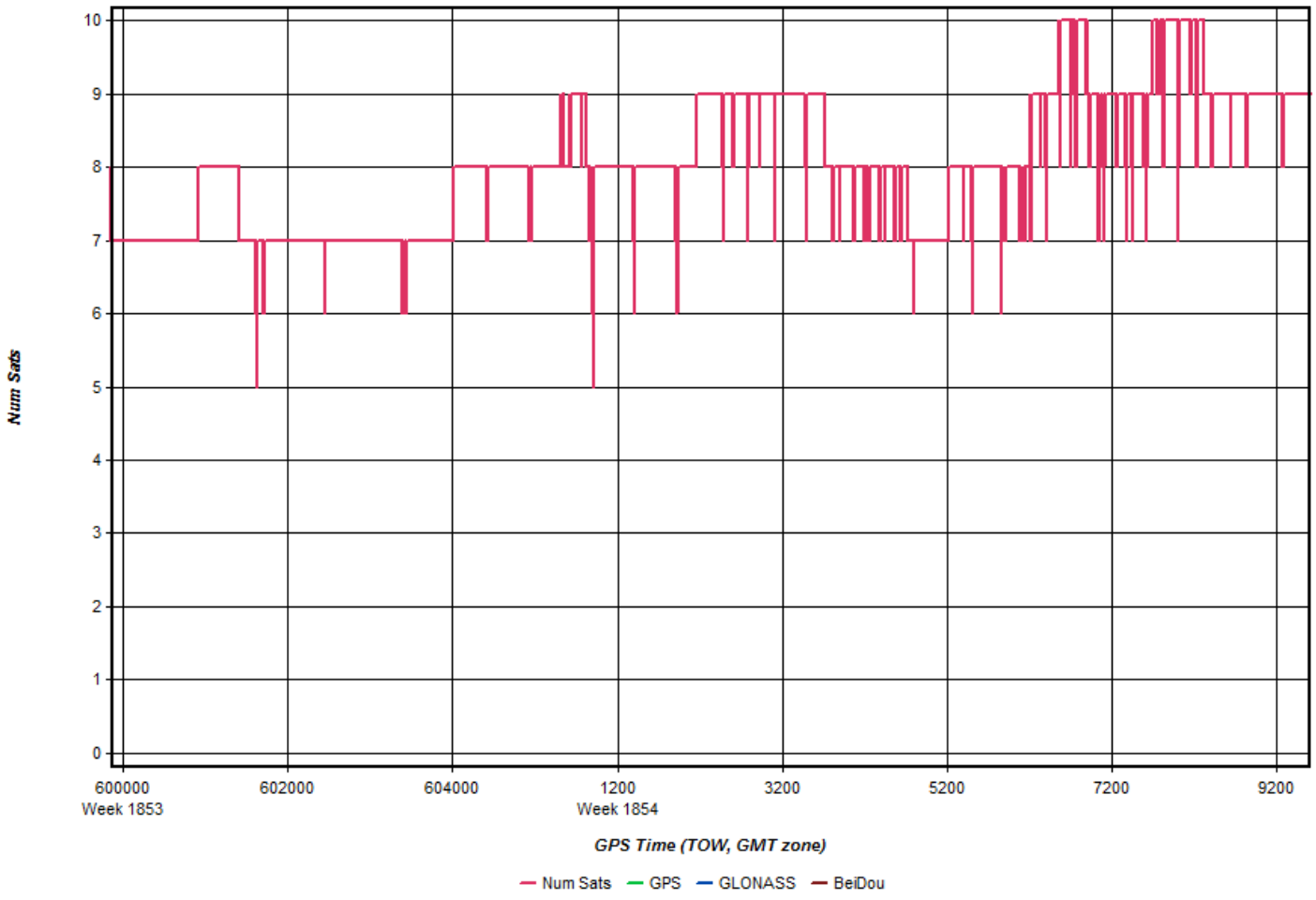

Separation (m)
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
-0.00
-0.01
-0.02
-0.03
-0.04
-0.05
-0.06
-0.07
-0.08
-0.09
-0.10
-0.11
-0.12
578000
Week 1853
580000
582000
584000
586000
588000
590000
592000
594000
GPS Time (TOW, GMT zone)
East
North
Up

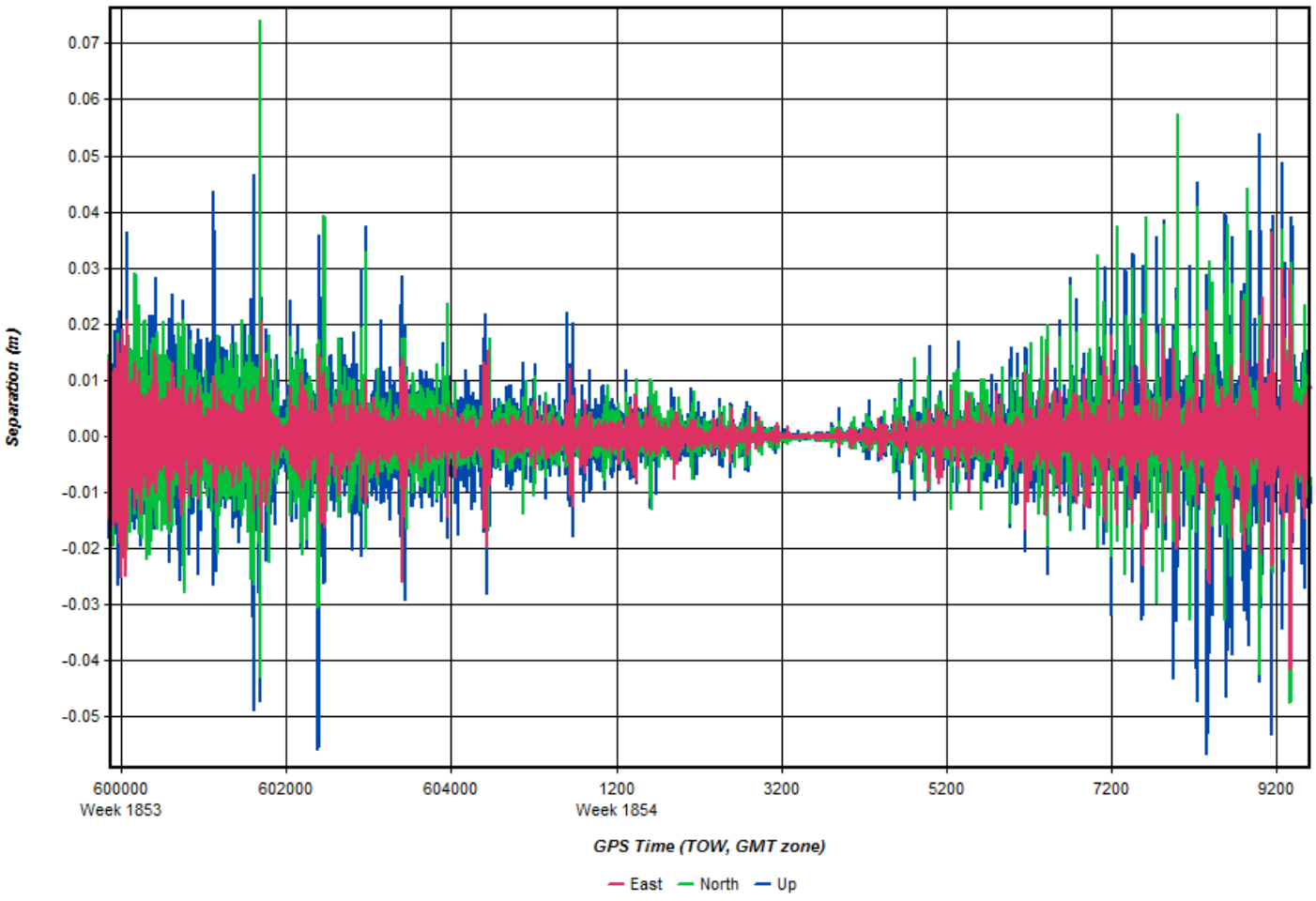

PDOP
4.6
4.4
4.2
4.0
3.8
3.6
3.4
3.2
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
578000
Week 1853
580000
582000
584000
586000
588000
590000
592000
594000
GPS Time (TOW, GMT zone)
PDOP

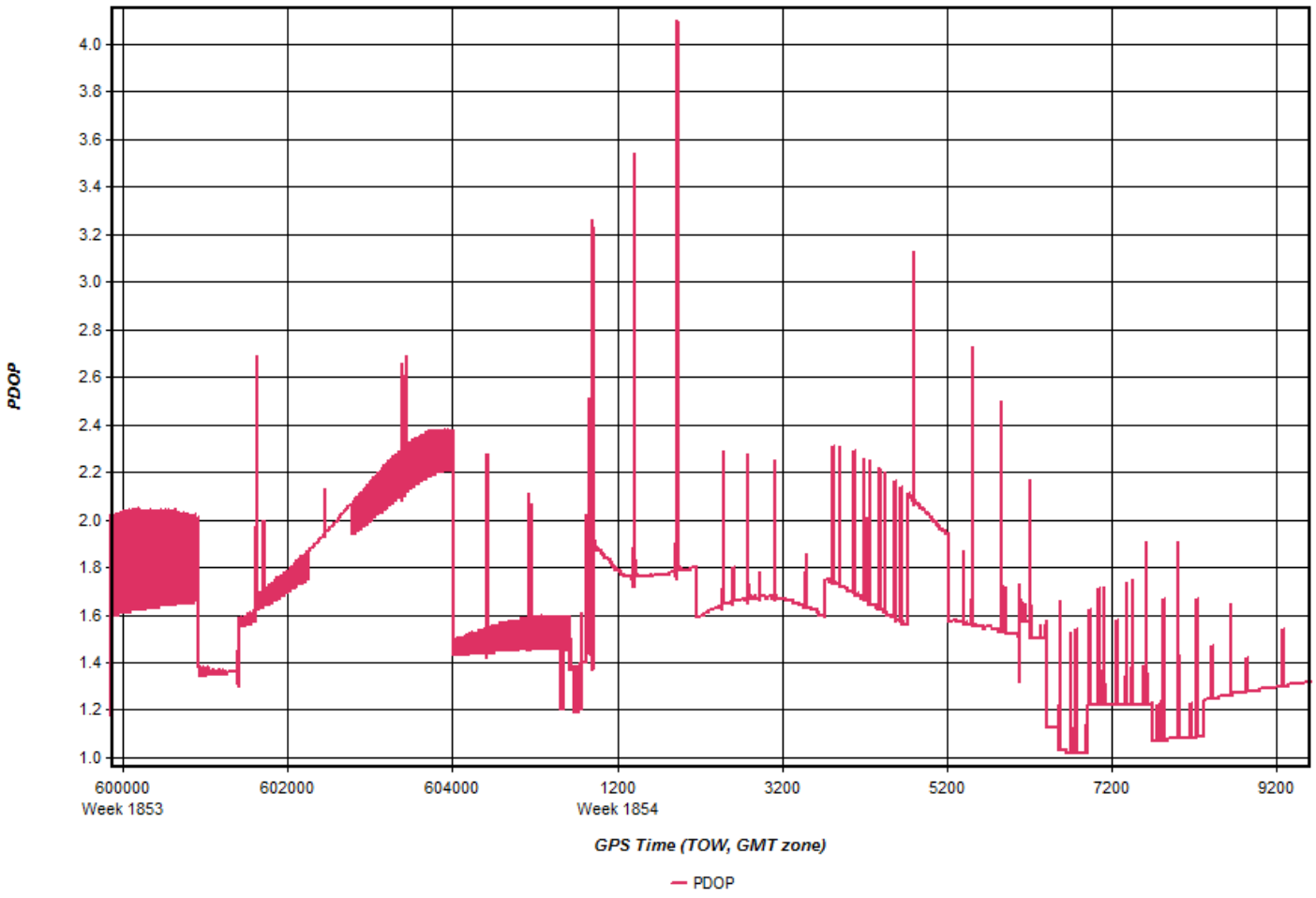
225_20150718_2



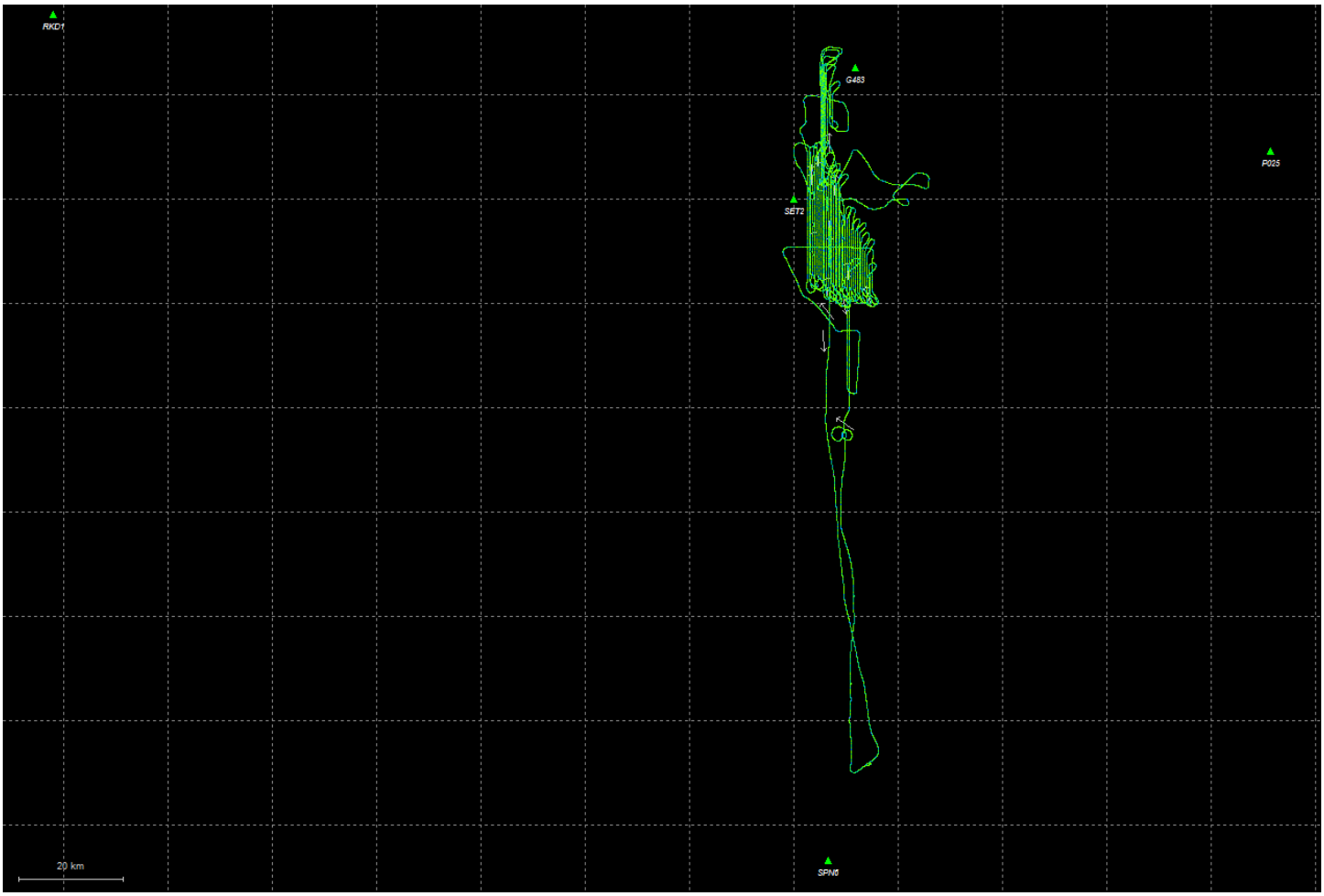

Estimated StdDev (m)
0.0115
0.0110
0.0105
0.0100
0.0095
0.0090
0.0085
0.0080
0.0075
0.0070
0.0065
0.0060
0.0055
0.0050
0.0045
0.0040
0.0035
0.0030
600000
Week 1853
602000
604000
1200
Week 1854
3200
5200
7200
9200
GPS Time (TOW, GMT zone)
East
North
Height
Trace

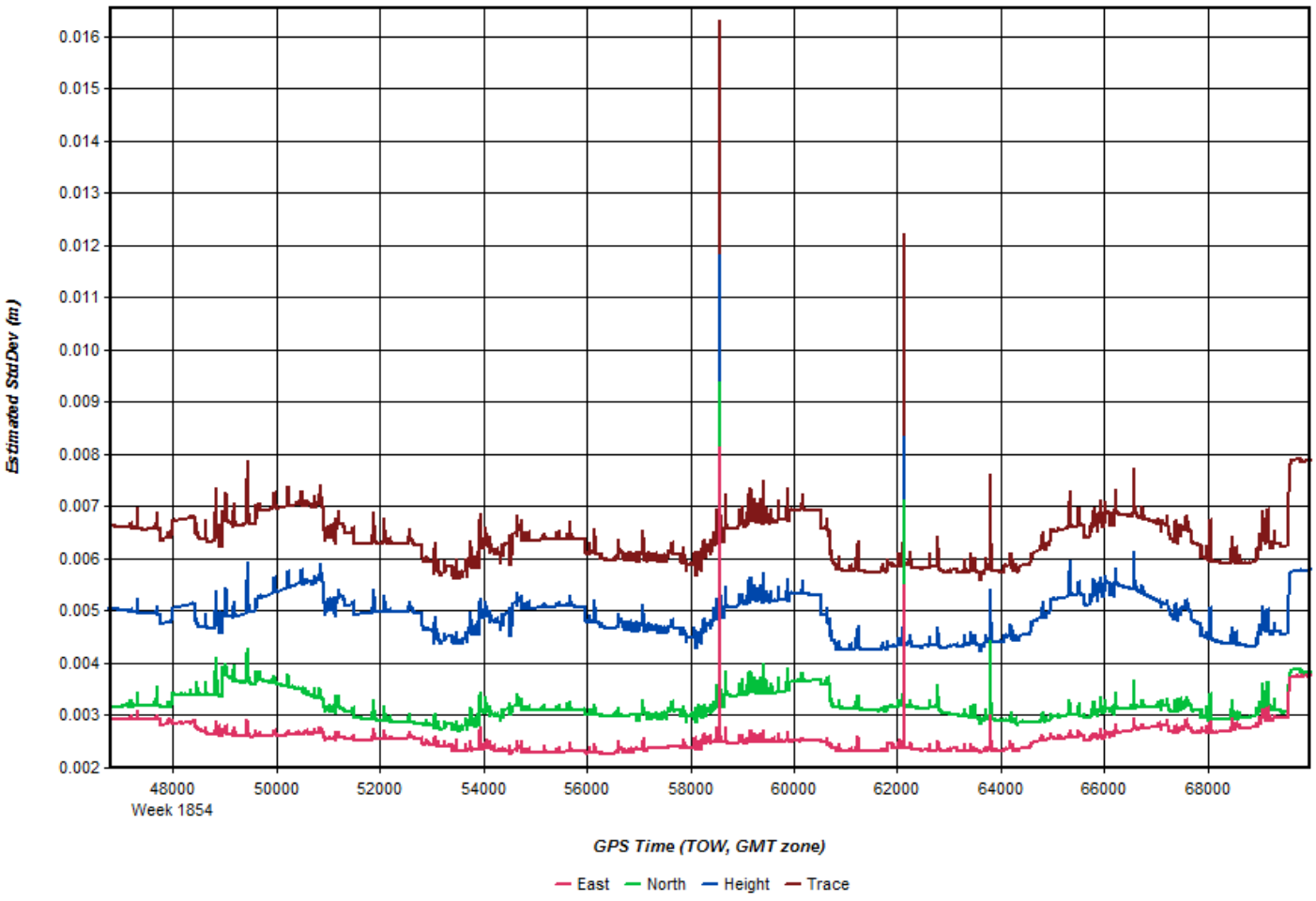

Num Sats
10
9
8
7
6
5
4
3
2
1
0
600000
Week 1853
602000
604000
1200
Week 1854
3200
5200
7200
9200
GPS Time (TOW, GMT zone)
Num Sats
GPS
GLONASS
BeiDou

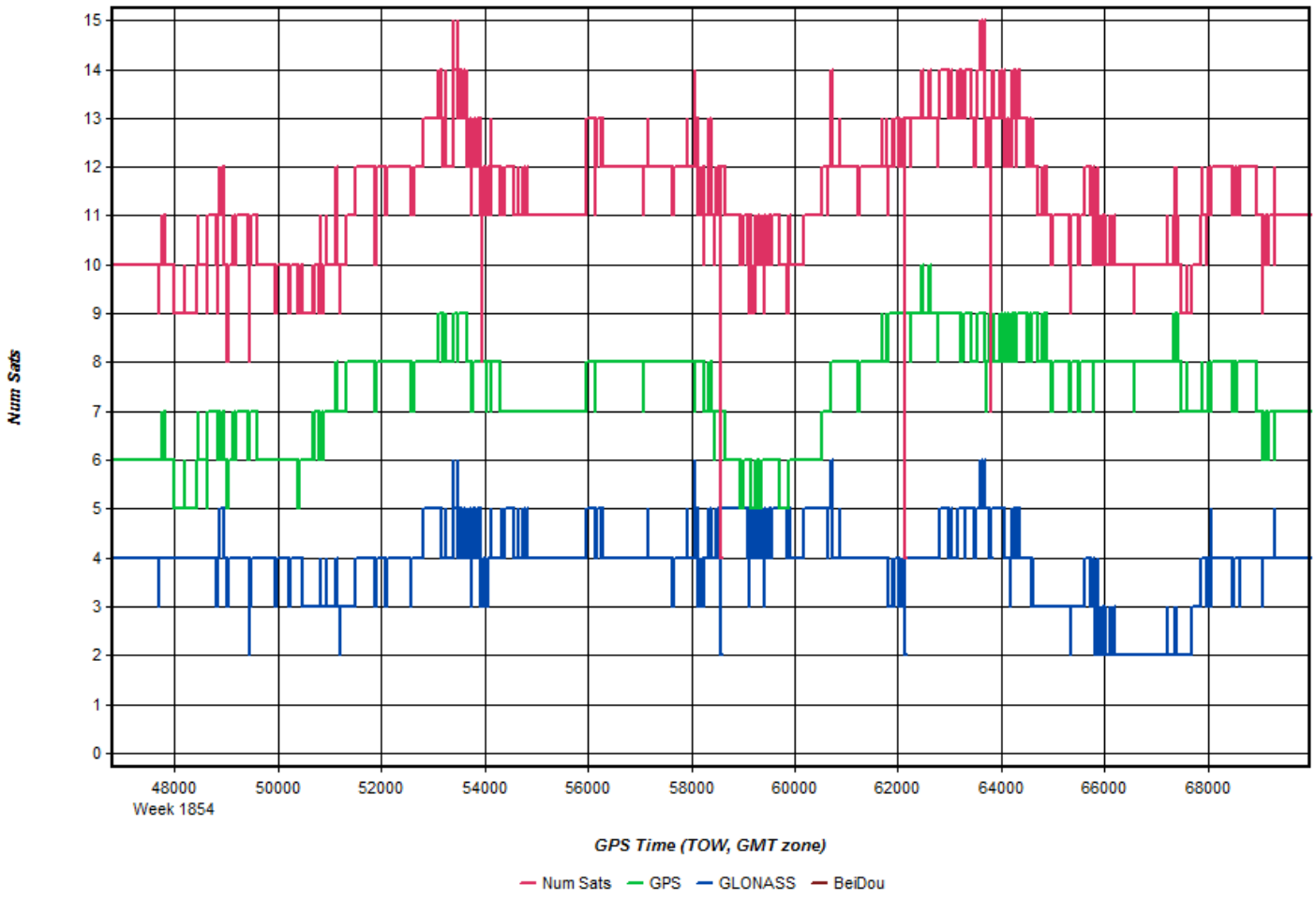

Separation (m)
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
-0.01
-0.02
-0.03
-0.04
-0.05
600000
Week 1853
602000
604000
1200
Week 1854
3200
5200
7200
9200
GPS Time (TOW, GMT zone)
East
North
Up

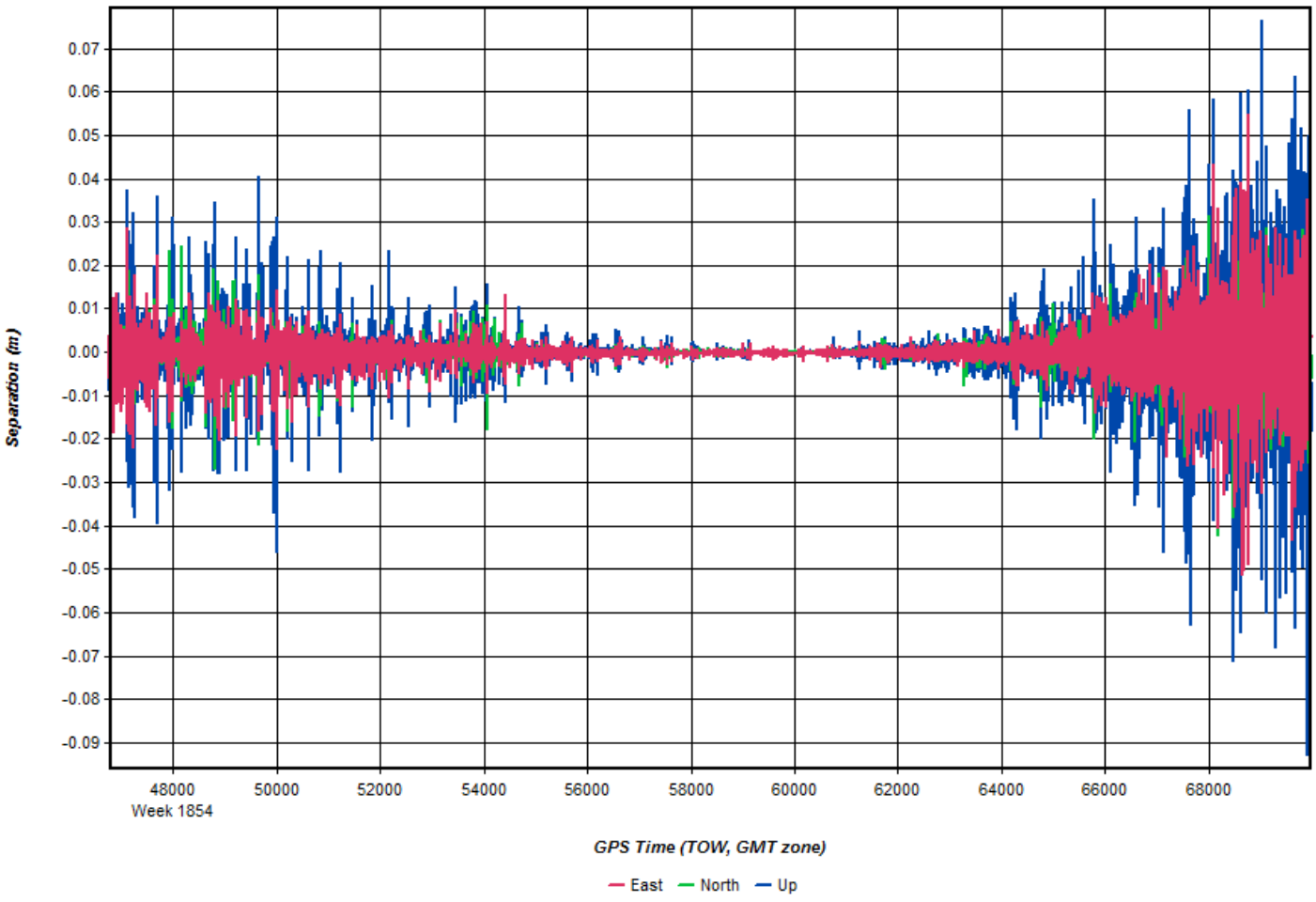

PDOP
4.0
3.8
3.6
3.4
3.2
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
600000
Week 1853
602000
604000
1200
Week 1854
3200
5200
7200
9200
GPS Time (TOW, GMT zone)
PDOP

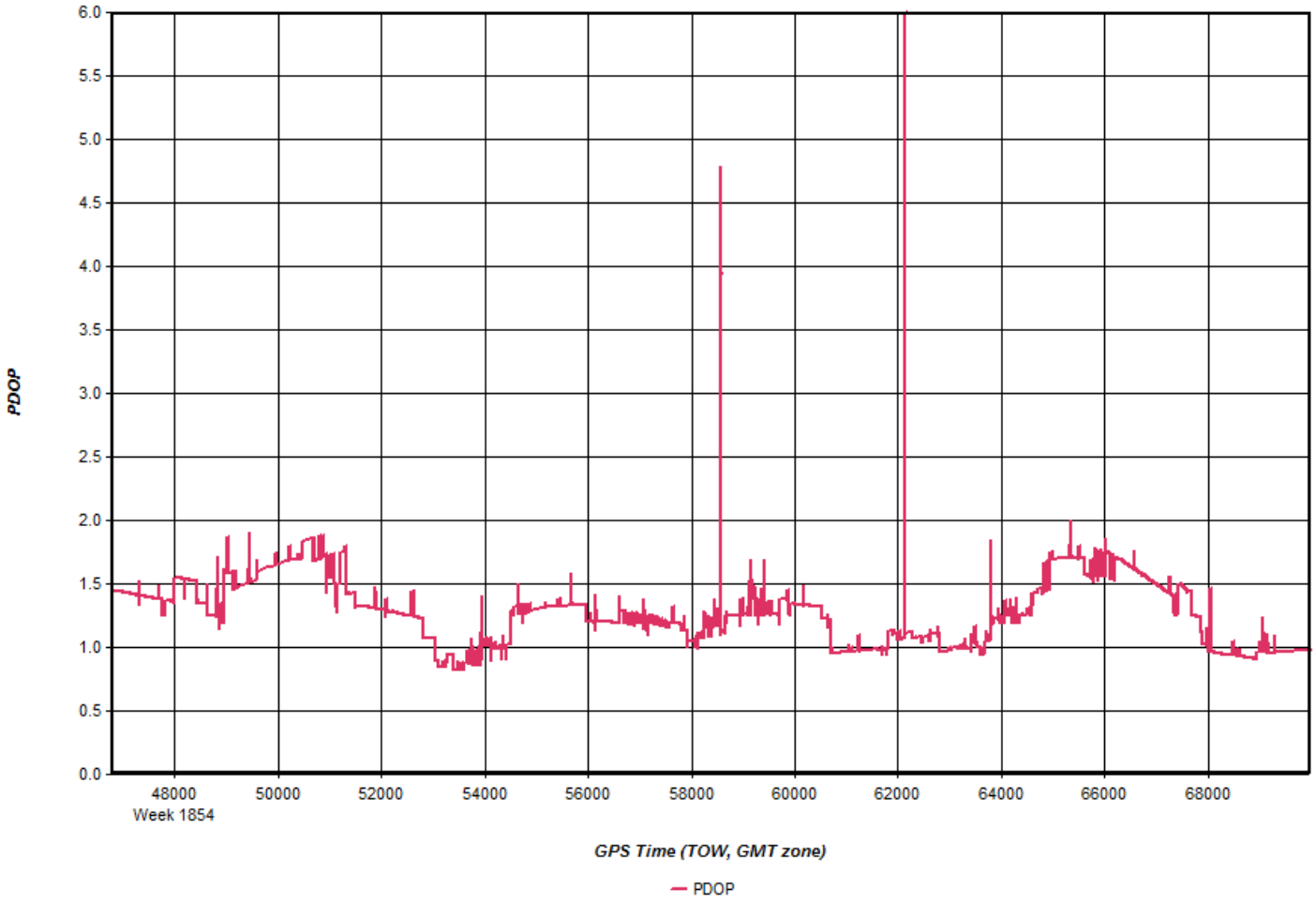
225_20150719_1



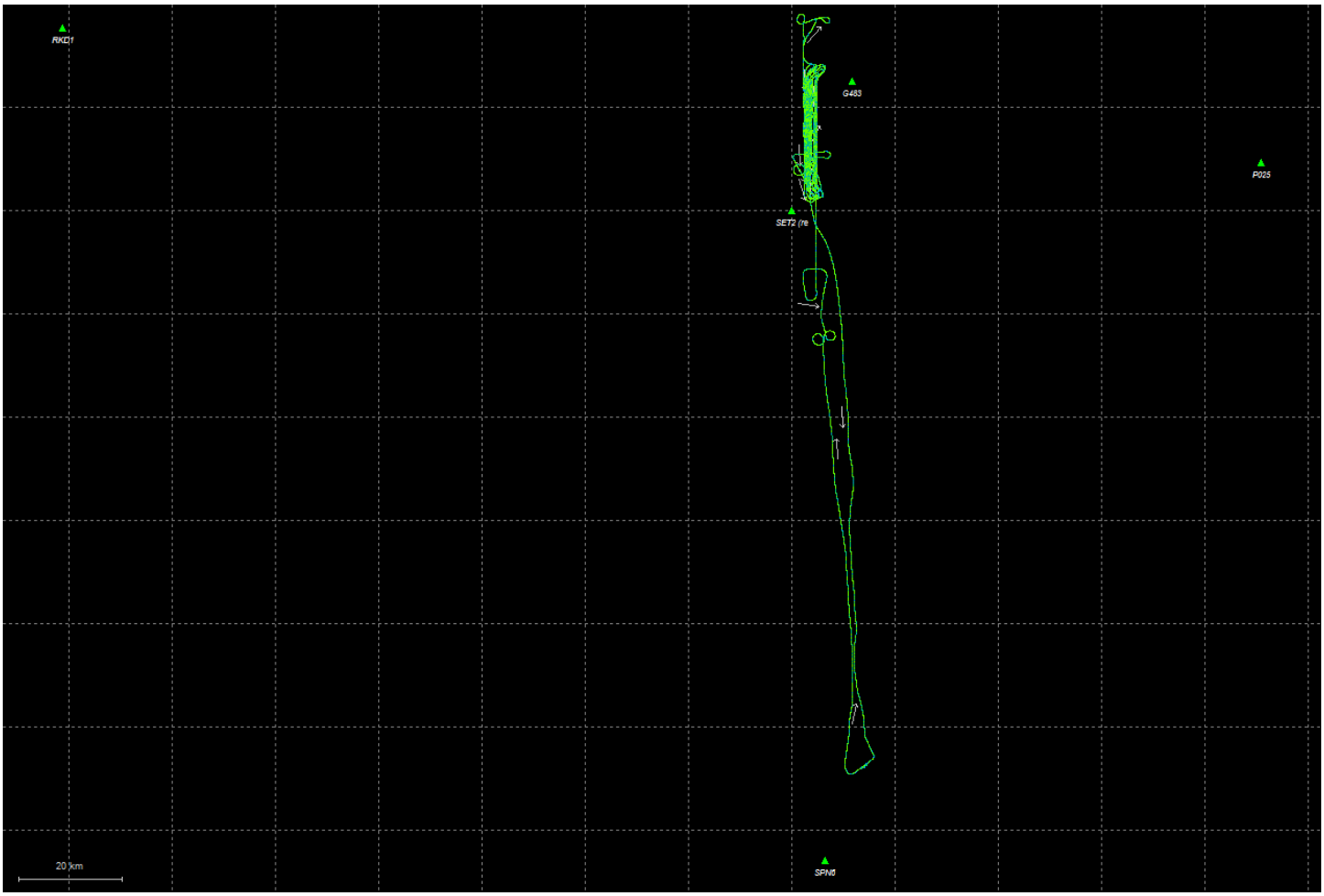

Estimated StdDev (m)
0.016
0.015
0.014
0.013
0.012
0.011
0.010
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
48000
Week 1854
50000
52000
54000
56000
58000
60000
62000
64000
66000
68000
GPS Time (TOW, GMT zone)
East
North
Height
Trace

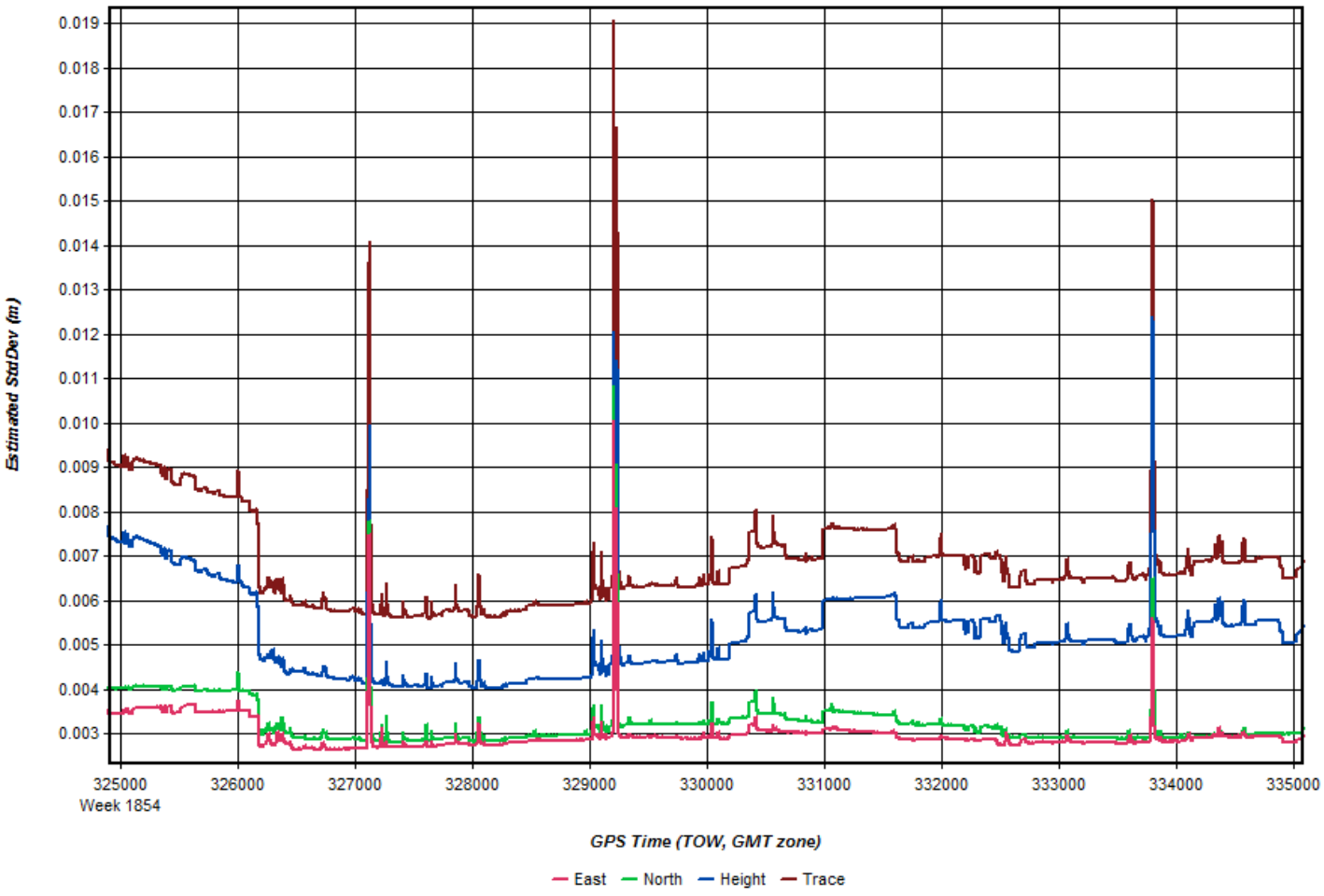

Num Sats
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
48000
Week 1854
50000
52000
54000
56000
58000
60000
62000
64000
66000
68000
GPS Time (TOW, GMT zone)
Num Sats
GPS
GLONASS
BeiDou

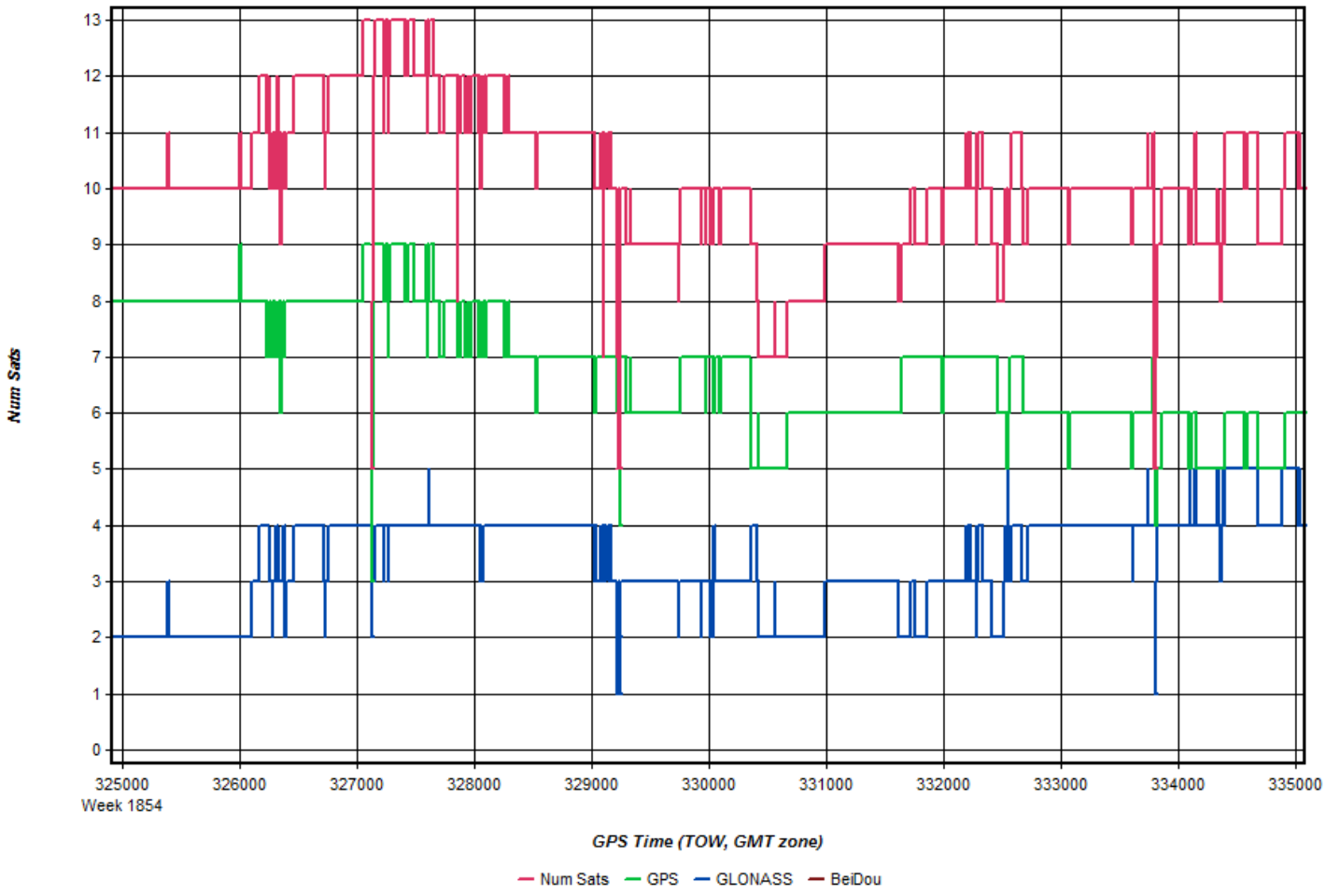

Separation (m)
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
-0.01
-0.02
-0.03
-0.04
-0.05
-0.06
-0.07
-0.08
-0.09
48000
Week 1854
50000
52000
54000
56000
58000
60000
62000
64000
66000
68000
GPS Time (TOW, GMT zone)
East
North
Up

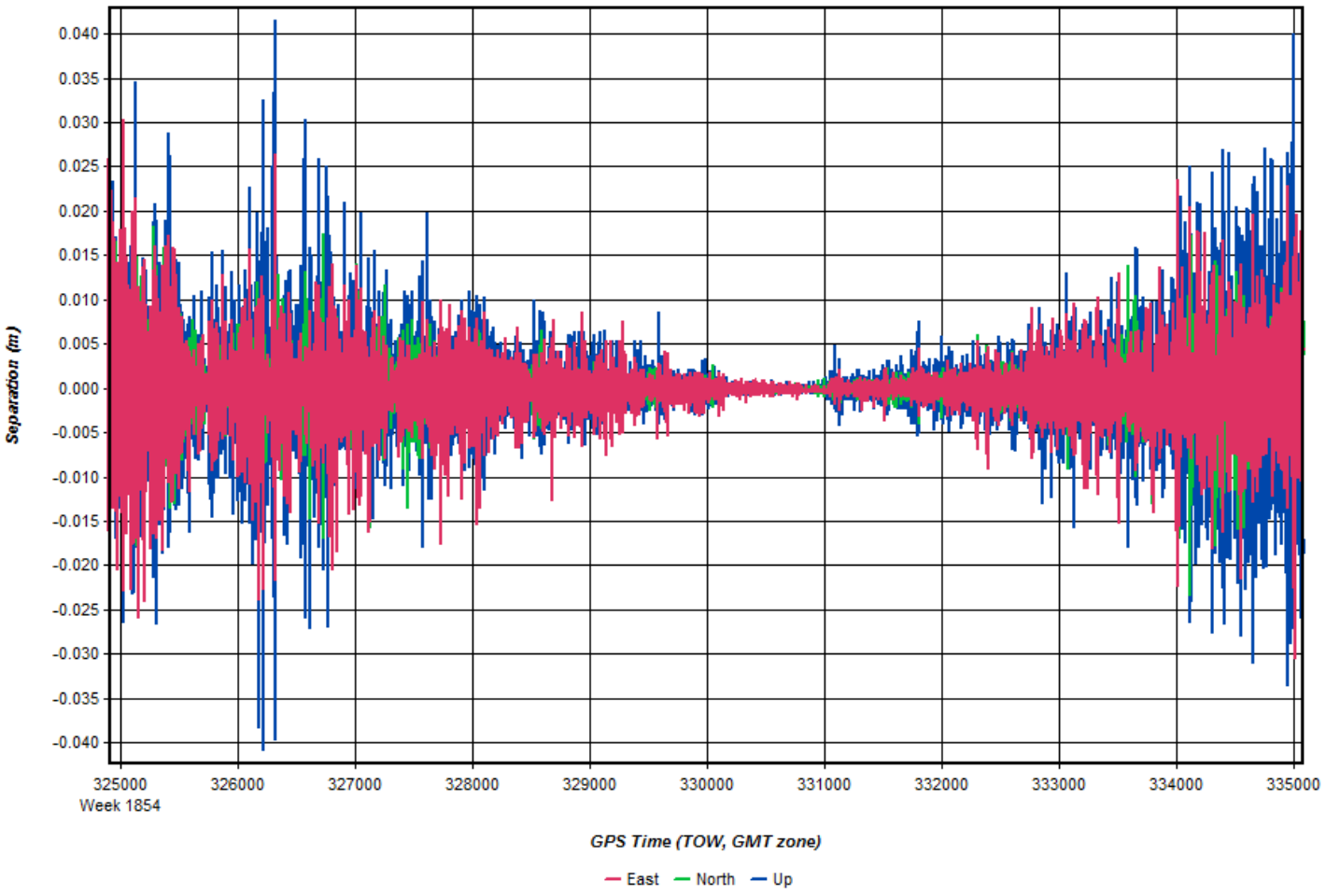

PDOP
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
48000
Week 1854
50000
52000
54000
56000
58000
60000
62000
64000
66000
68000
GPS Time (TOW, GMT zone)
PDOP

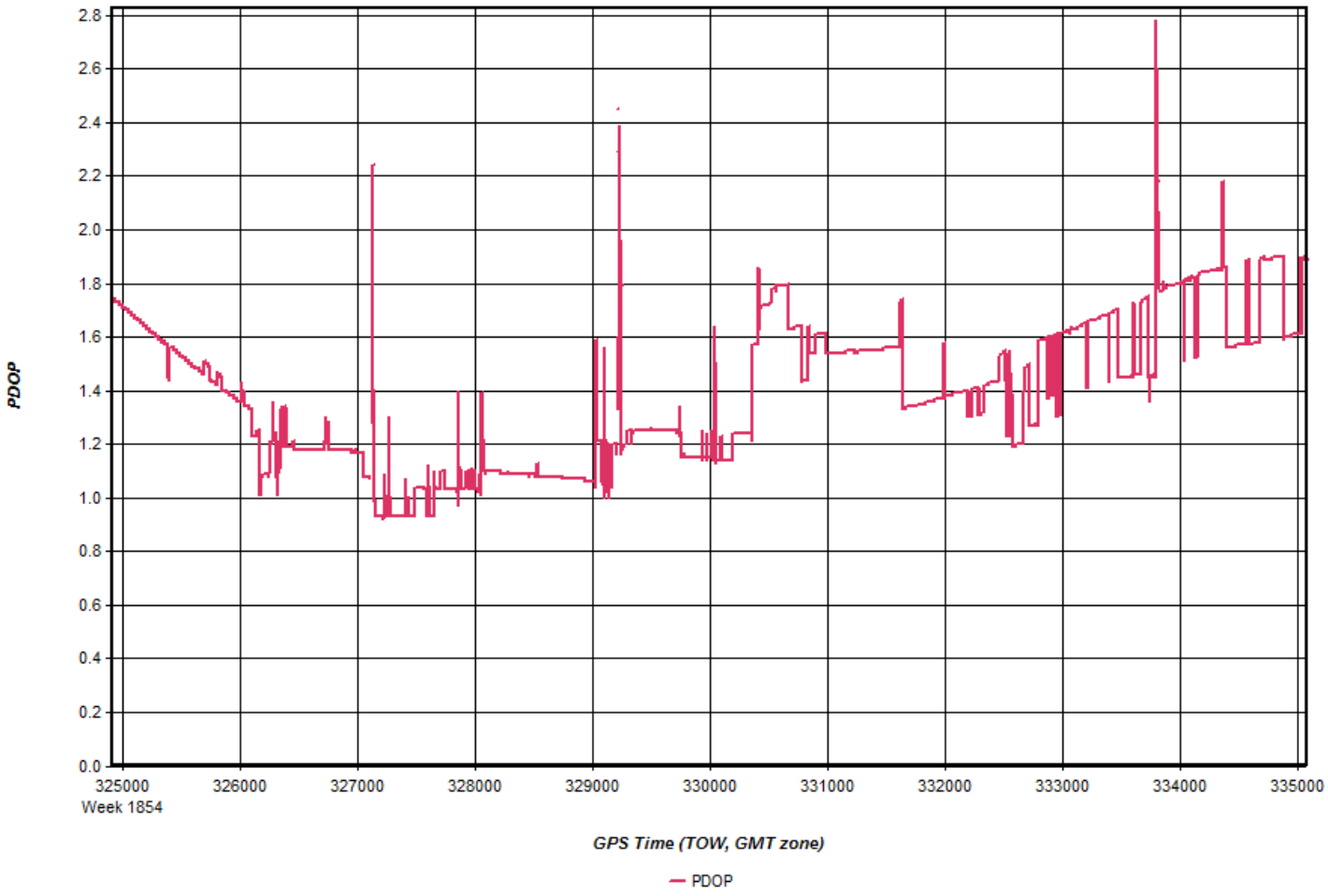
225_20150722_1



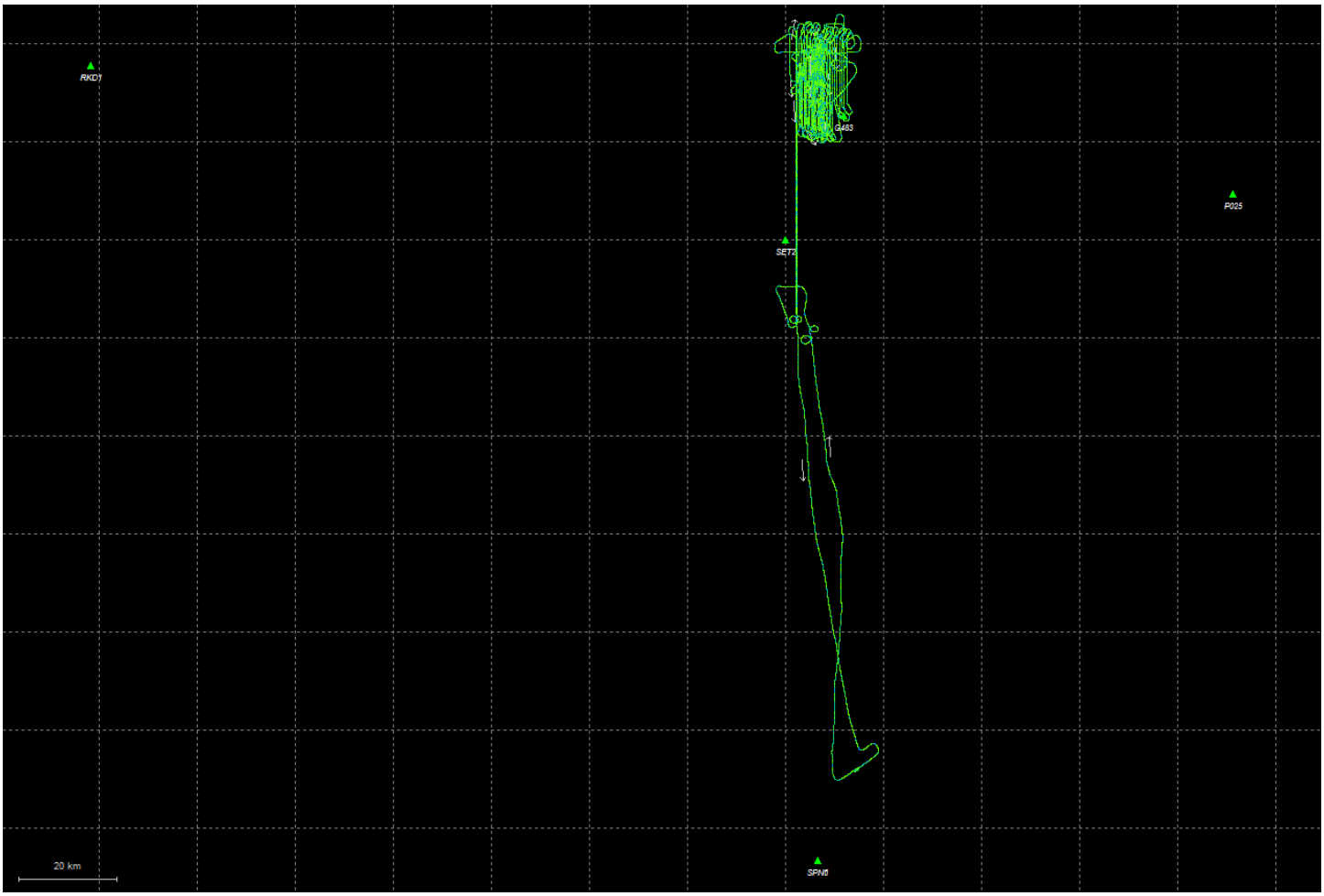

Estimated StdDev (m)
0.019
0.018
0.017
0.016
0.015
0.014
0.013
0.012
0.011
0.010
0.009
0.008
0.007
0.006
0.005
0.004
0.003
325000
Week 1854
326000
327000
328000
329000
330000
331000
332000
333000
334000
335000
GPS Time (TOW, GMT zone)
East
North
Height
Trace

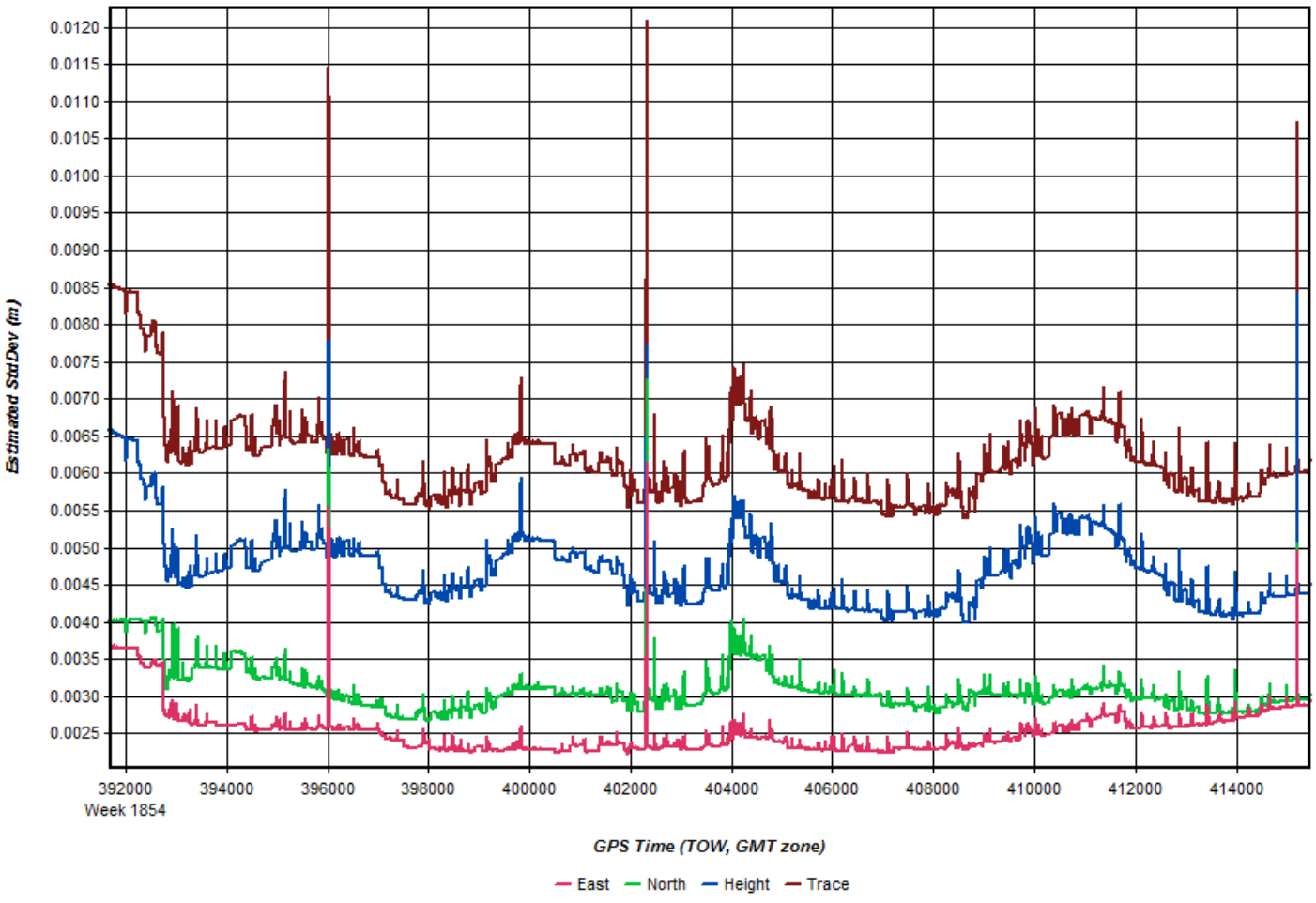

Num Sats
13
12
11
10
9
8
7
6
5
4
3
2
1
0
325000
Week 1854
326000
327000
328000
329000
330000
331000
332000
333000
334000
335000
GPS Time (TOW, GMT zone)
Num Sats
GPS
GLONASS
BeiDou

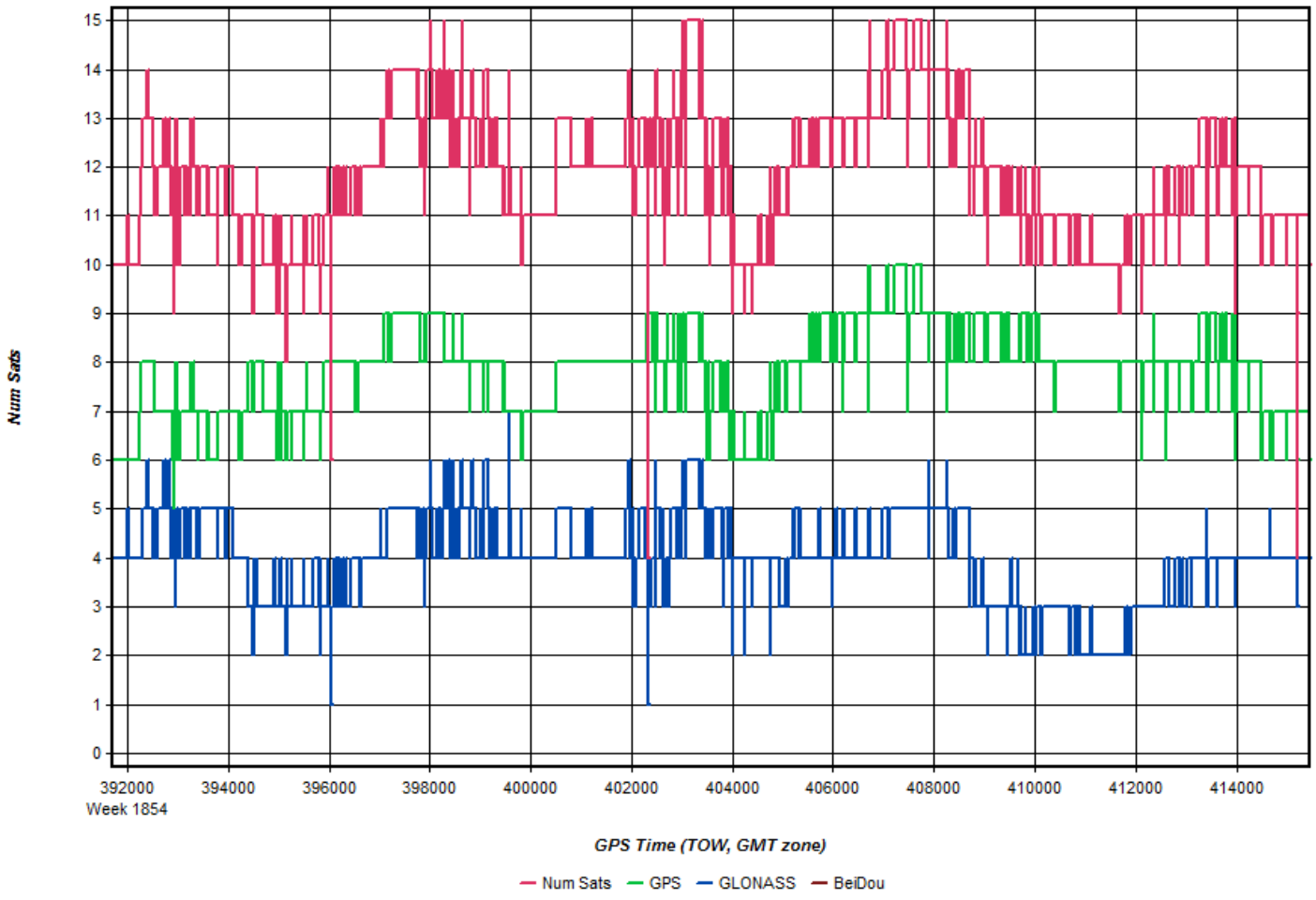

0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
-0.005
-0.010
-0.015
-0.020
-0.025
-0.030
-0.035
-0.040
Separation (m)
325000
Week 1854
326000
327000
328000
329000
330000
331000
332000
333000
334000
335000
GPS Time (TOW, GMT zone)
East
North
Up

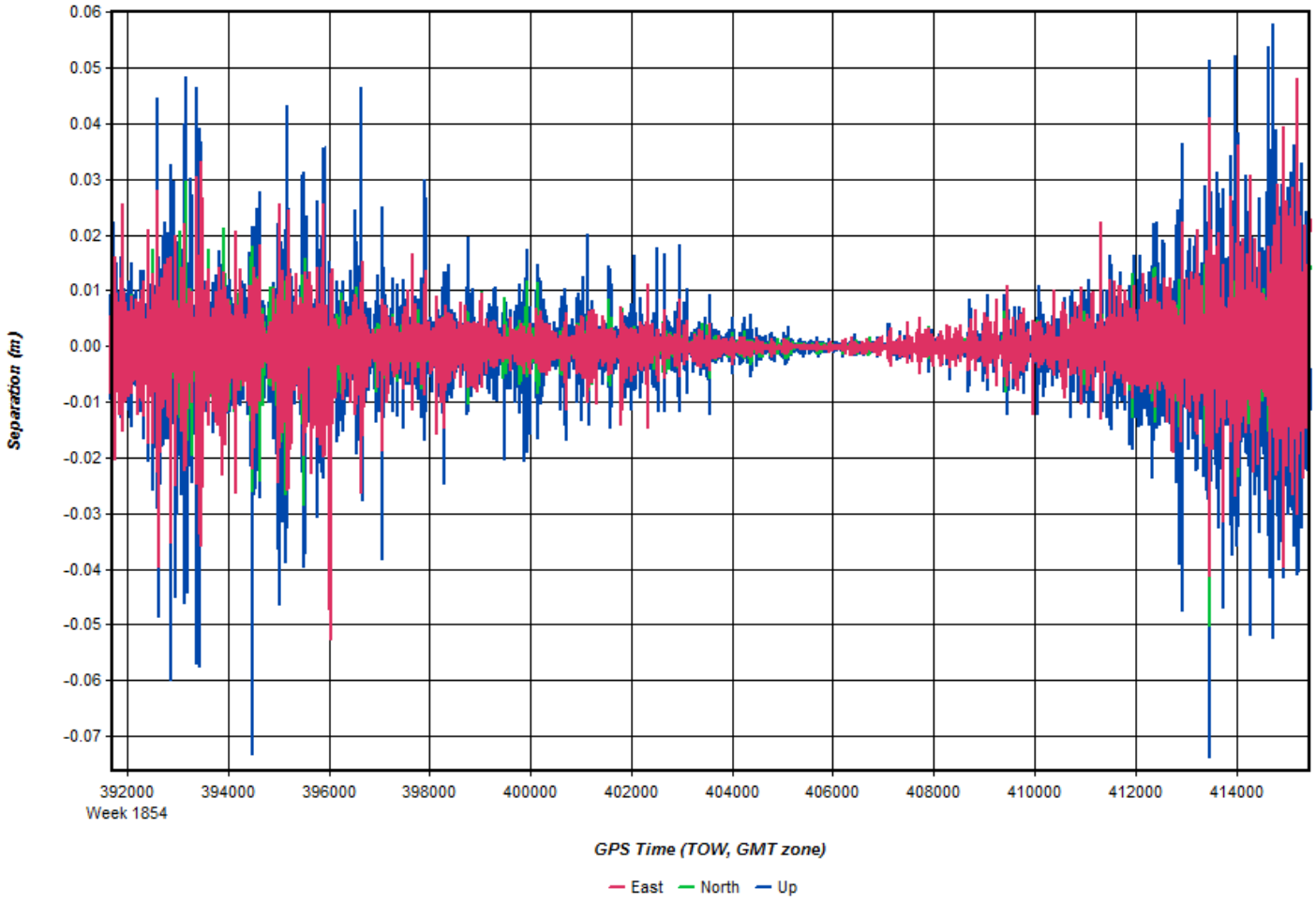

PDOP
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
325000
326000
327000
328000
329000
330000
331000
332000
333000
334000
335000
Week 1854
GPS Time (TOW, GMT zone)
PDOP

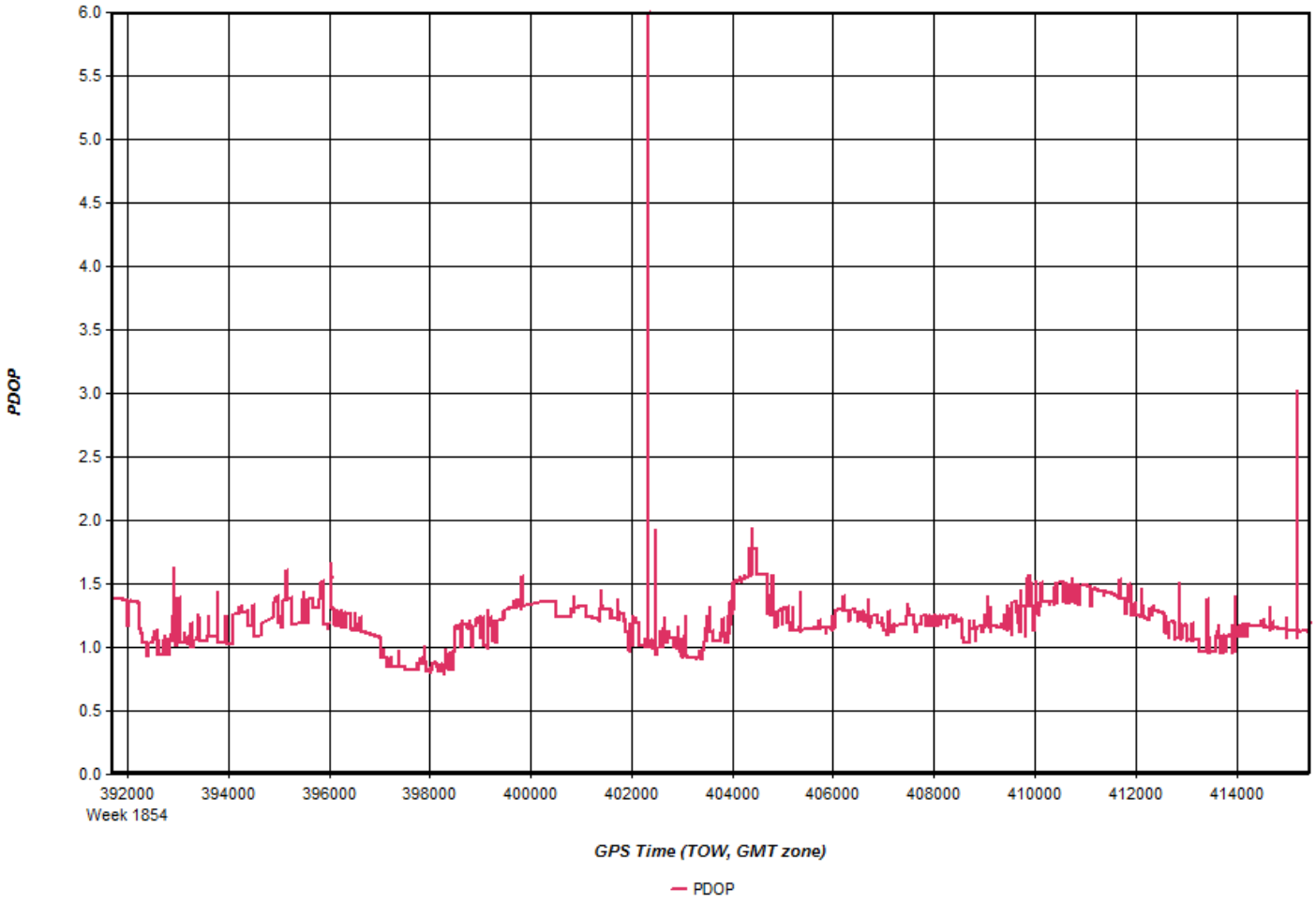
225_20150723_1



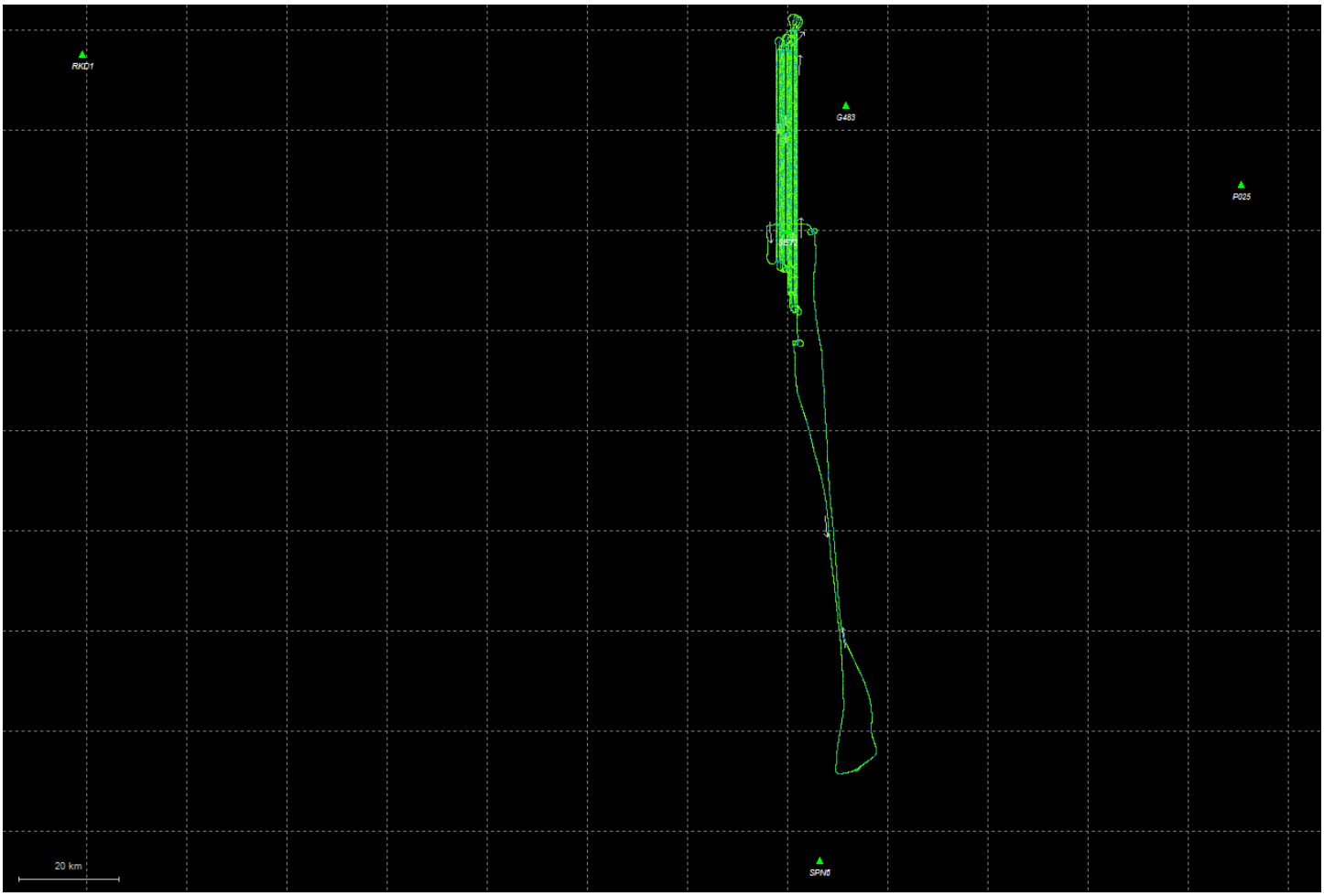

Estimated StdDev (m)
0.0120
0.0115
0.0110
0.0105
0.0100
0.0095
0.0090
0.0085
0.0080
0.0075
0.0070
0.0065
0.0060
0.0055
0.0050
0.0045
0.0040
0.0035
0.0030
0.0025
392000
Week 1854
394000
396000
398000
400000
402000
404000
406000
408000
410000
412000
414000
GPS Time (TOW, GMT zone)
East
North
Height
Trace

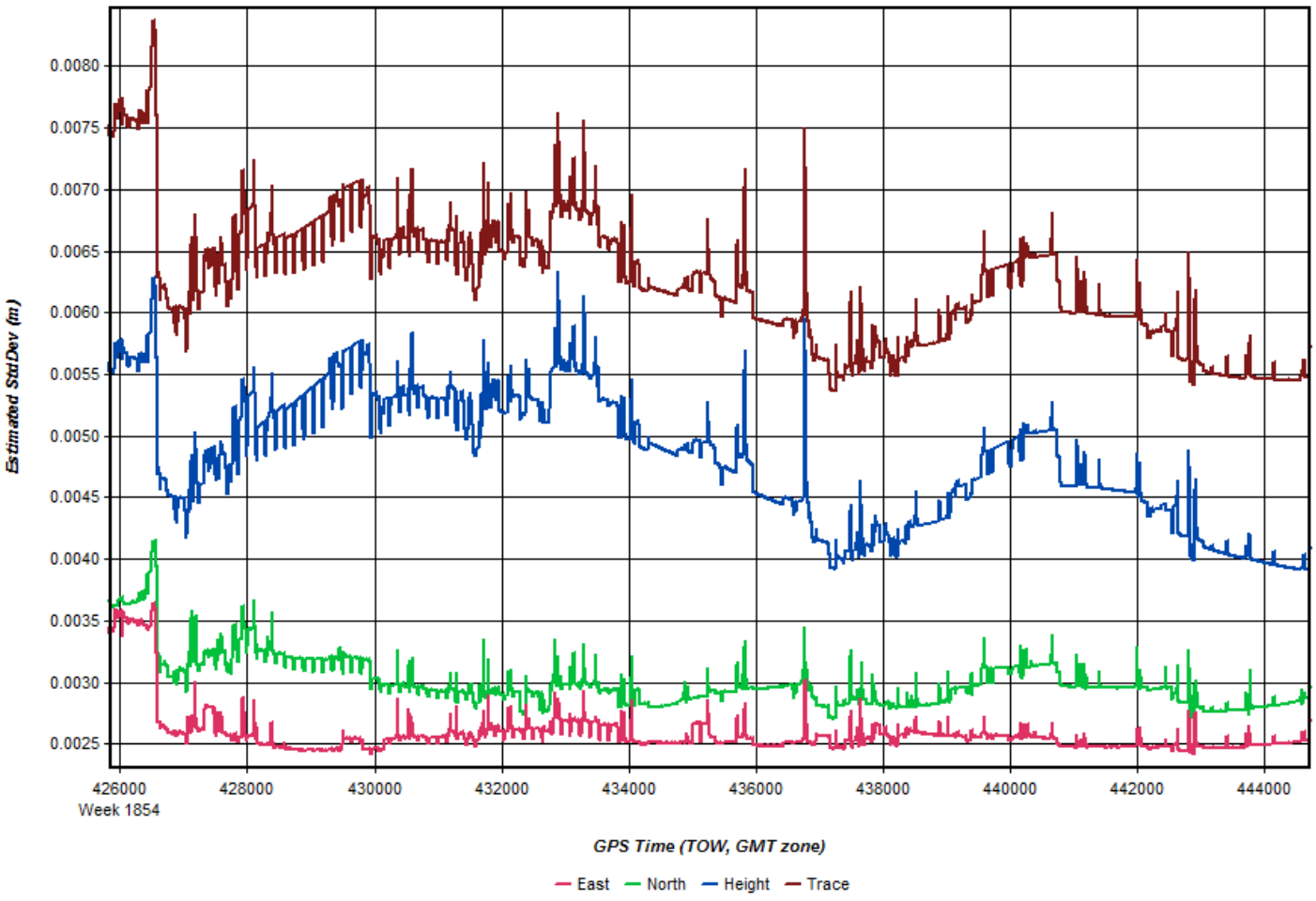

Num Sats
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
392000
394000
396000
398000
400000
402000
404000
406000
408000
410000
412000
414000
Week 1854
GPS Time (TOW, GMT zone)
Num Sats
GPS
GLONASS
BeiDou

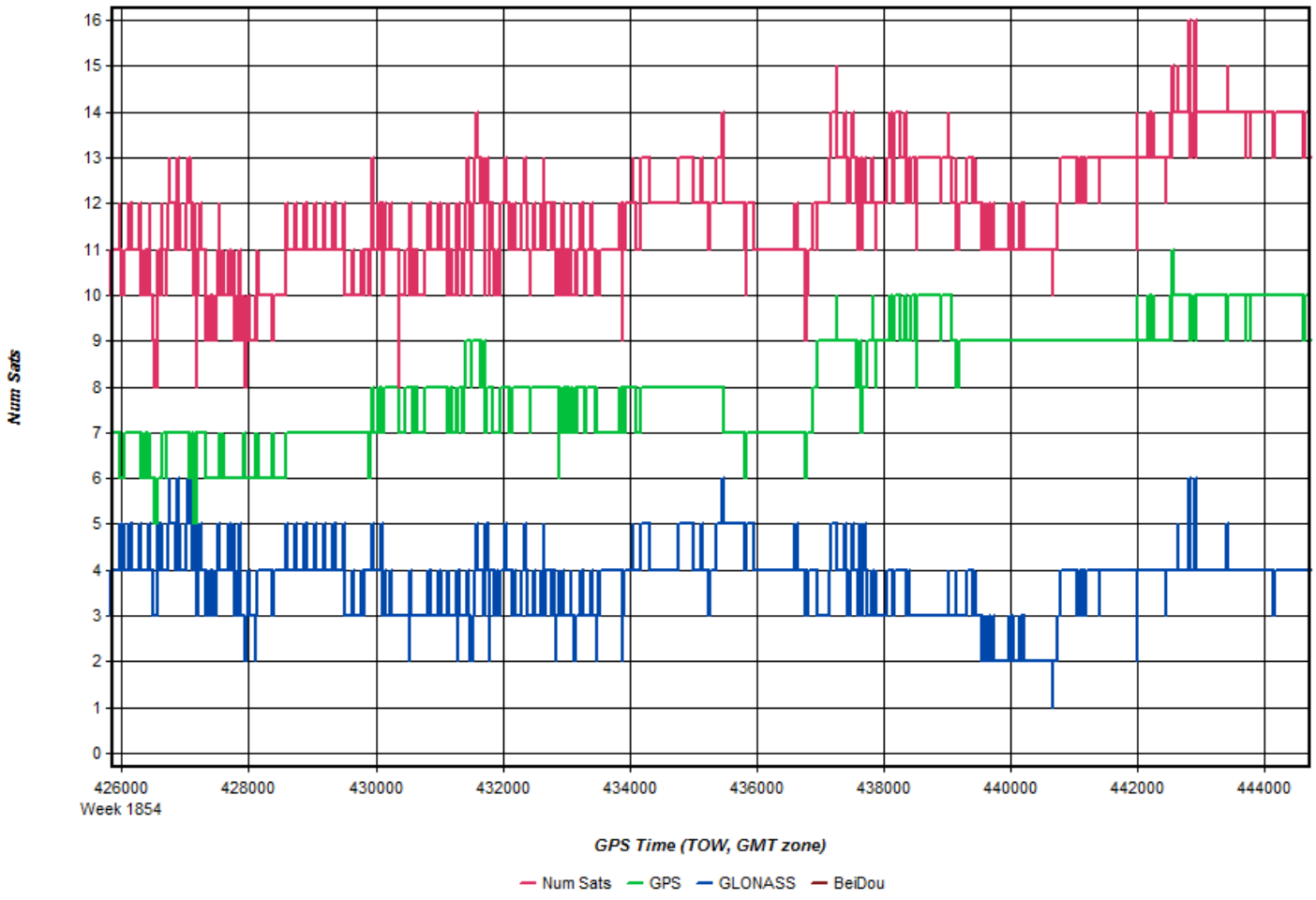

0.06
0.05
0.04
0.03
0.02
0.01
0.00
-0.01
-0.02
-0.03
-0.04
-0.05
-0.06
-0.07
Separation (m)
392000
Week 1854
394000
396000
398000
400000
402000
404000
406000
408000
410000
412000
414000
GPS Time (TOW, GMT zone)
East
North
Up

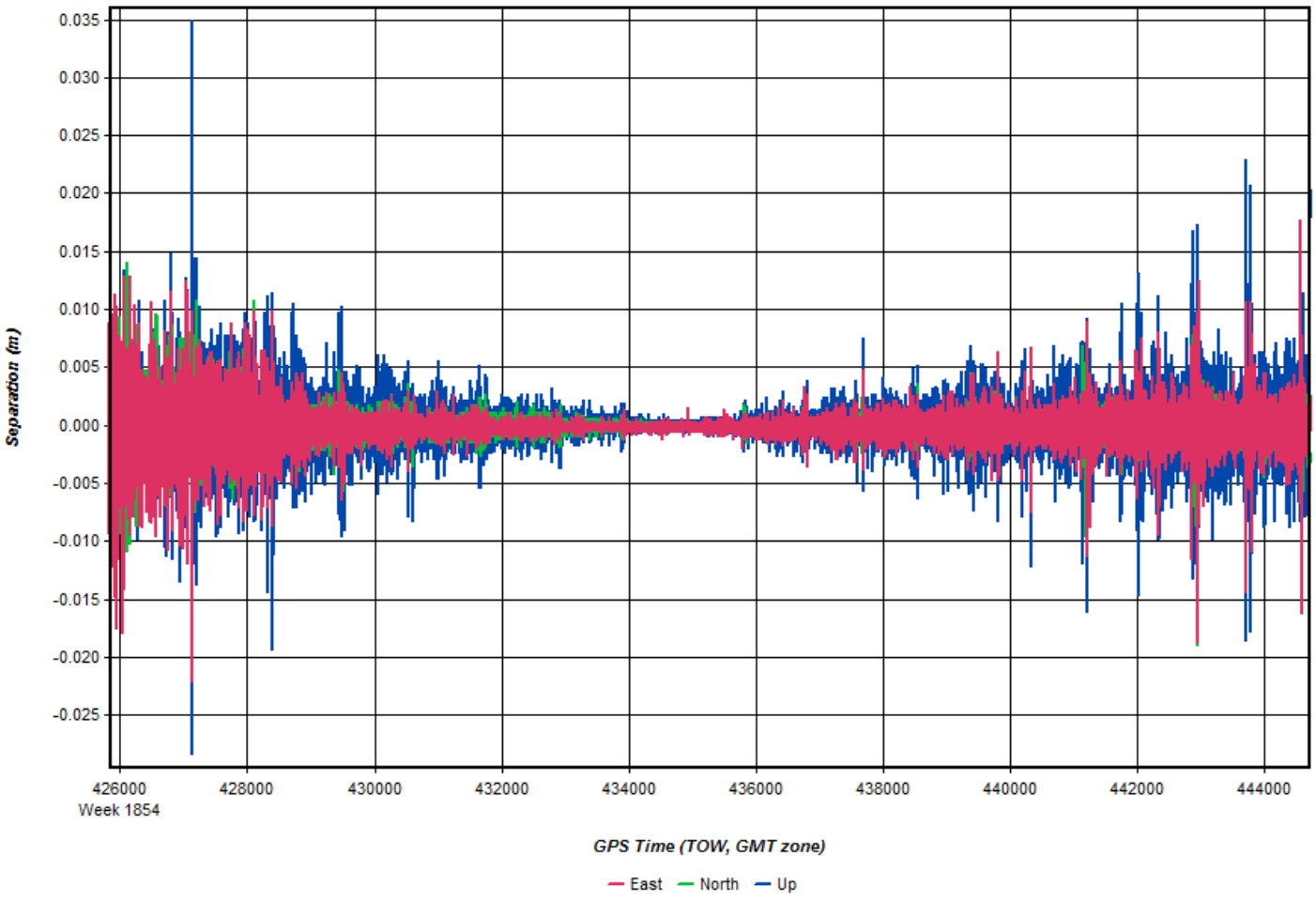

PDOP
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
392000
394000
396000
398000
400000
402000
404000
406000
408000
410000
412000
414000
Week 1854
GPS Time (TOW, GMT zone)
PDOP

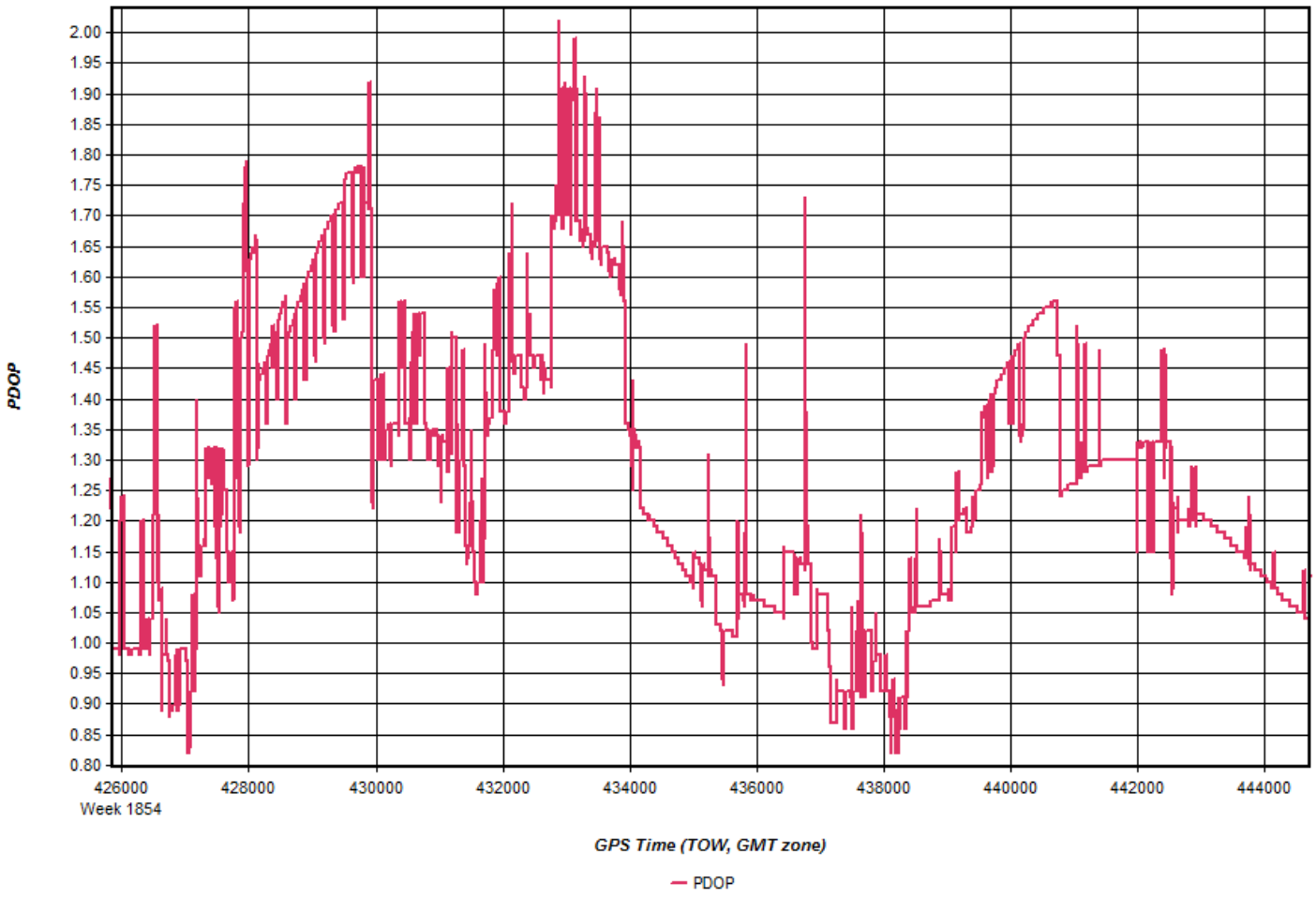
225_20150723_2



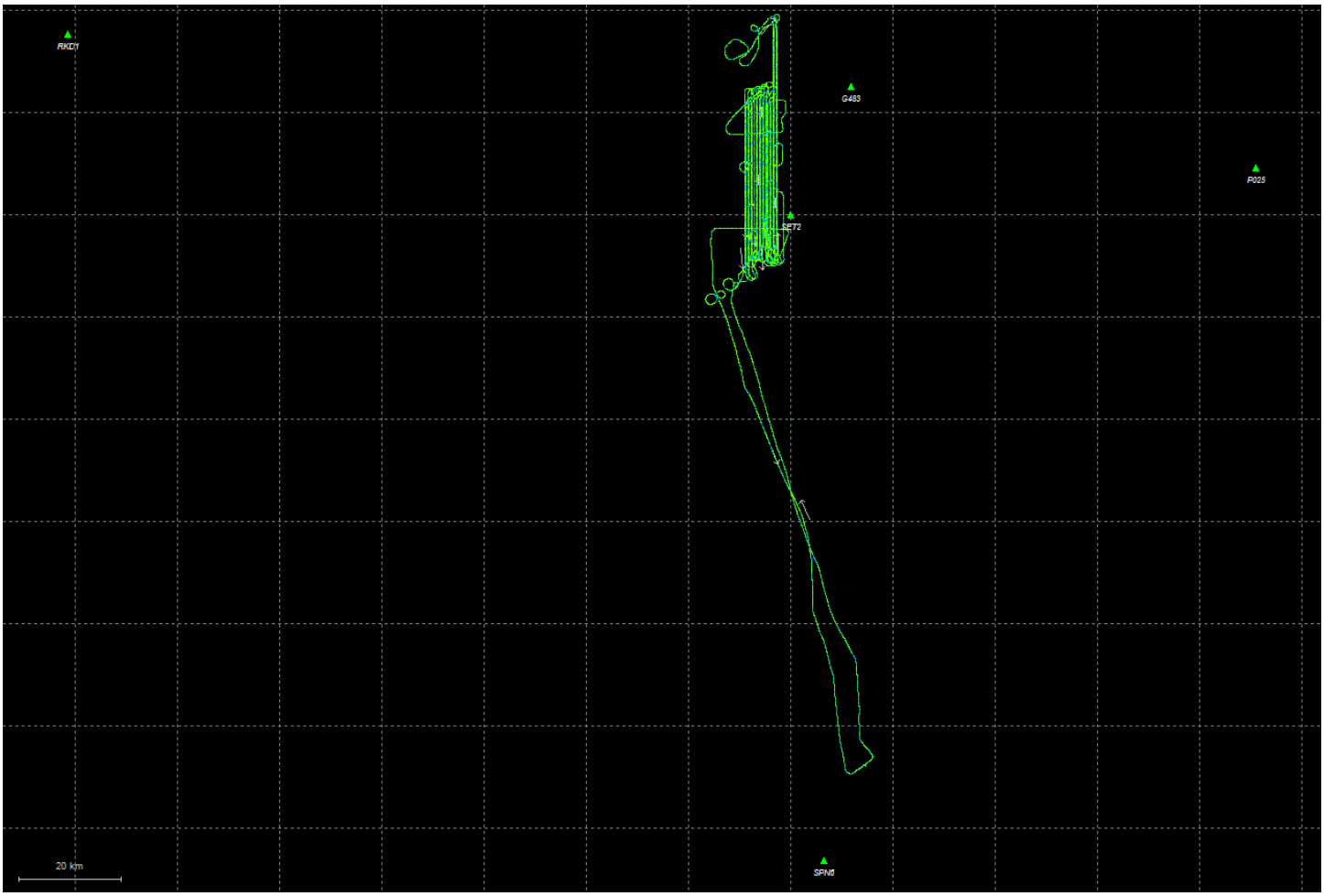

Estimated StdDev (m)
0.0080
0.0075
0.0070
0.0065
0.0060
0.0055
0.0050
0.0045
0.0040
0.0035
0.0030
0.0025
426000
Week 1854
428000
430000
432000
434000
436000
438000
440000
442000
444000
GPS Time (TOW, GMT zone)
East
North
Height
Trace

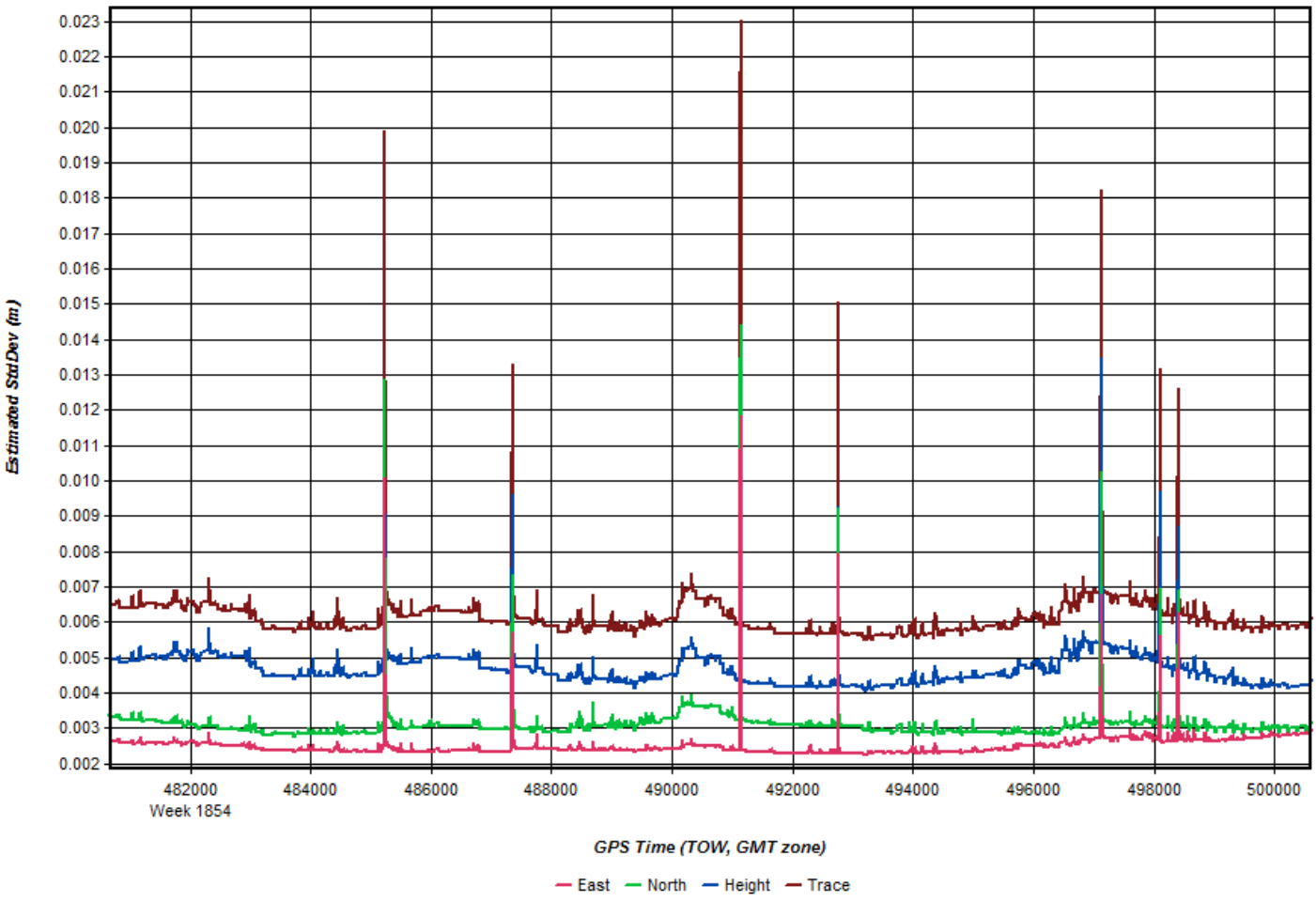

Num Sats
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
426000
Week 1854
428000
430000
432000
434000
436000
438000
440000
442000
444000
GPS Time (TOW, GMT zone)
Num Sats
GPS
GLONASS
BeiDou

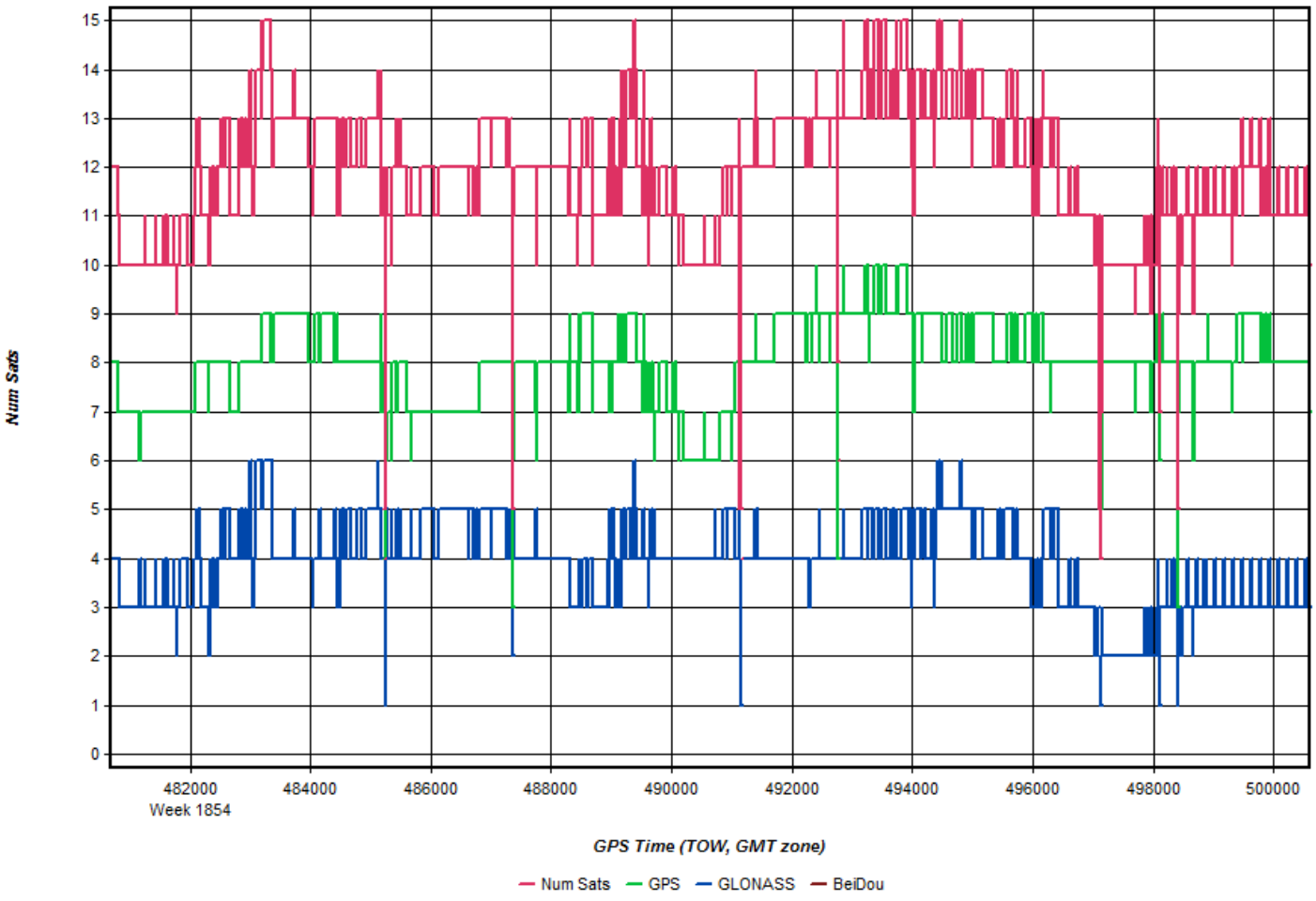

0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
-0.005
-0.010
-0.015
-0.020
-0.025
Separation (m)
426000
Week 1854
428000
430000
432000
434000
436000
438000
440000
442000
444000
GPS Time (TOW, GMT zone)
East
North
Up

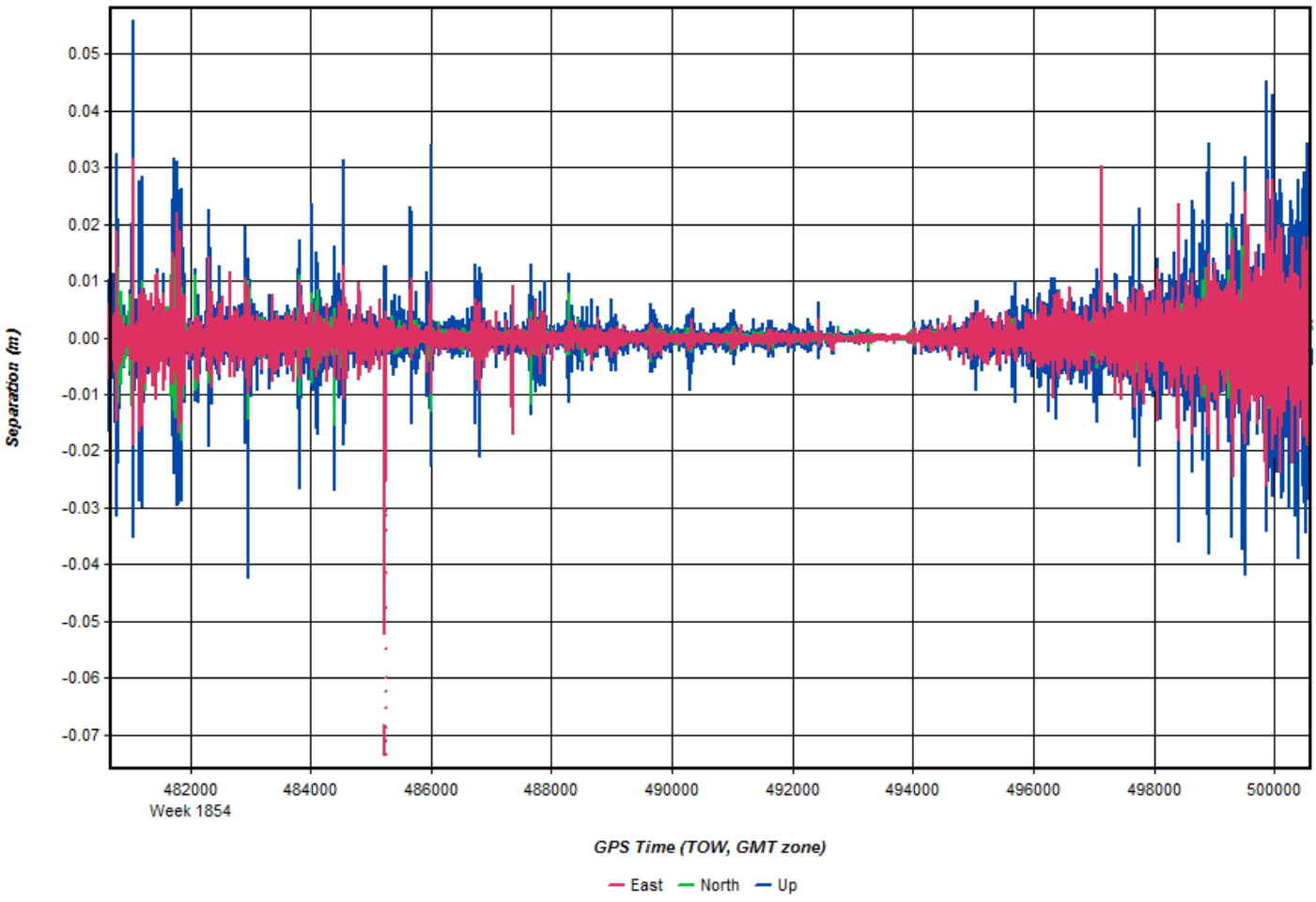

PDOP
2.00
1.95
1.90
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1.25
1.20
1.15
1.10
1.05
1.00
0.95
0.90
0.85
0.80
426000
Week 1854
428000
430000
432000
434000
436000
438000
440000
442000
444000
GPS Time (TOW, GMT zone)
PDOP

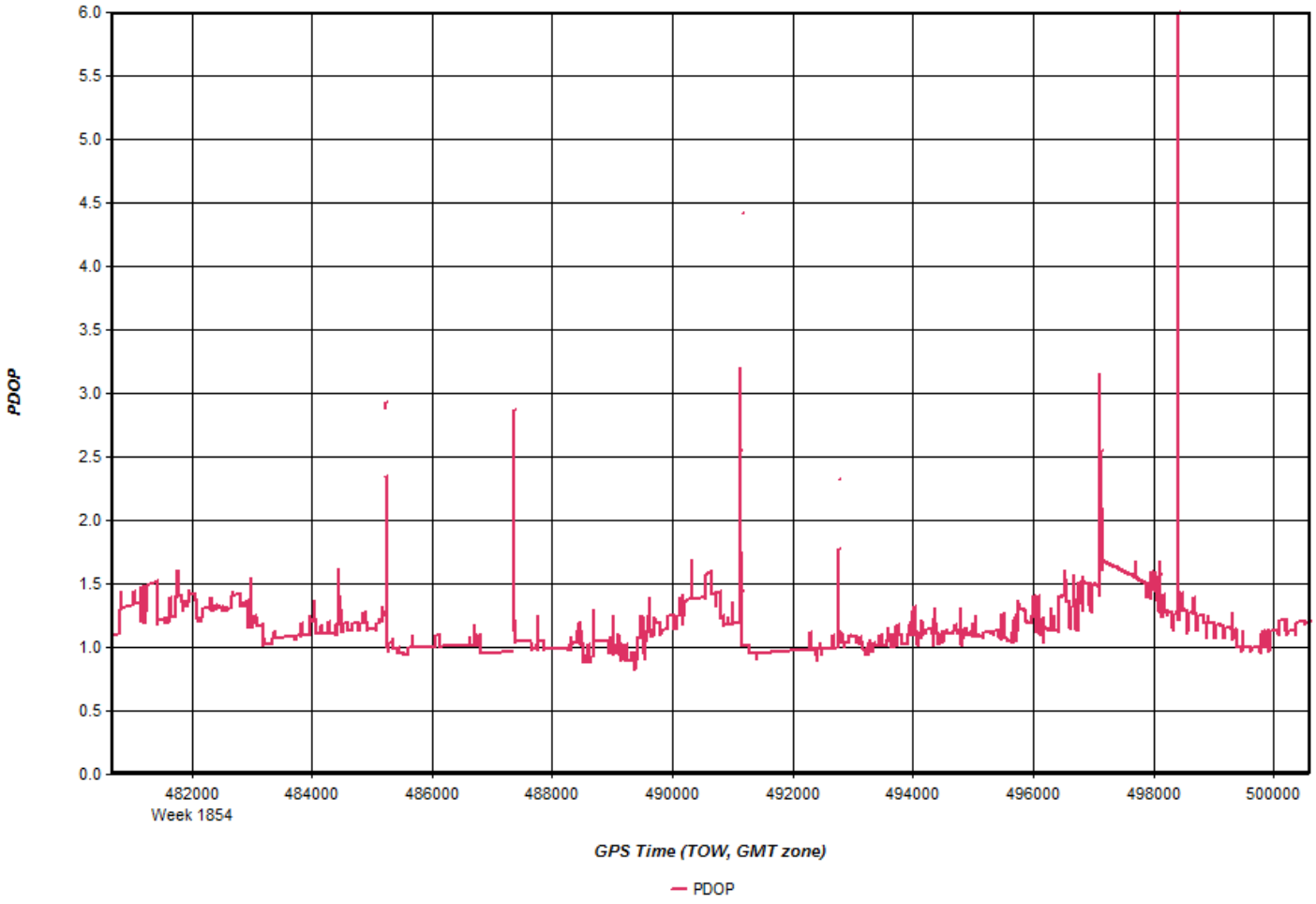
225_20150724_1



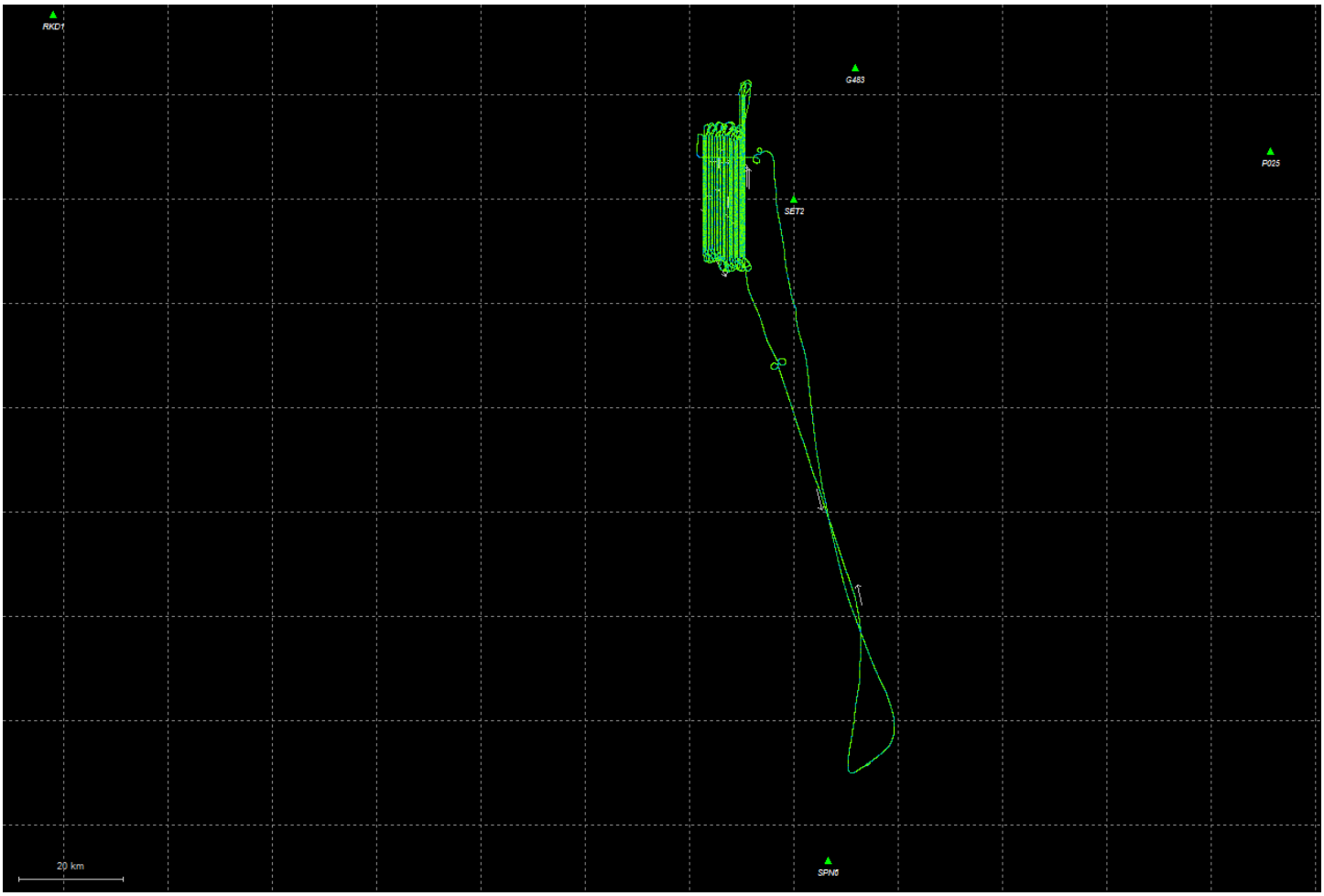

Estimated StdDev (m)
0.023
0.022
0.021
0.020
0.019
0.018
0.017
0.016
0.015
0.014
0.013
0.012
0.011
0.010
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
482000
Week 1854
484000
486000
488000
490000
492000
494000
496000
498000
500000
GPS Time (TOW, GMT zone)
East
North
Height
Trace

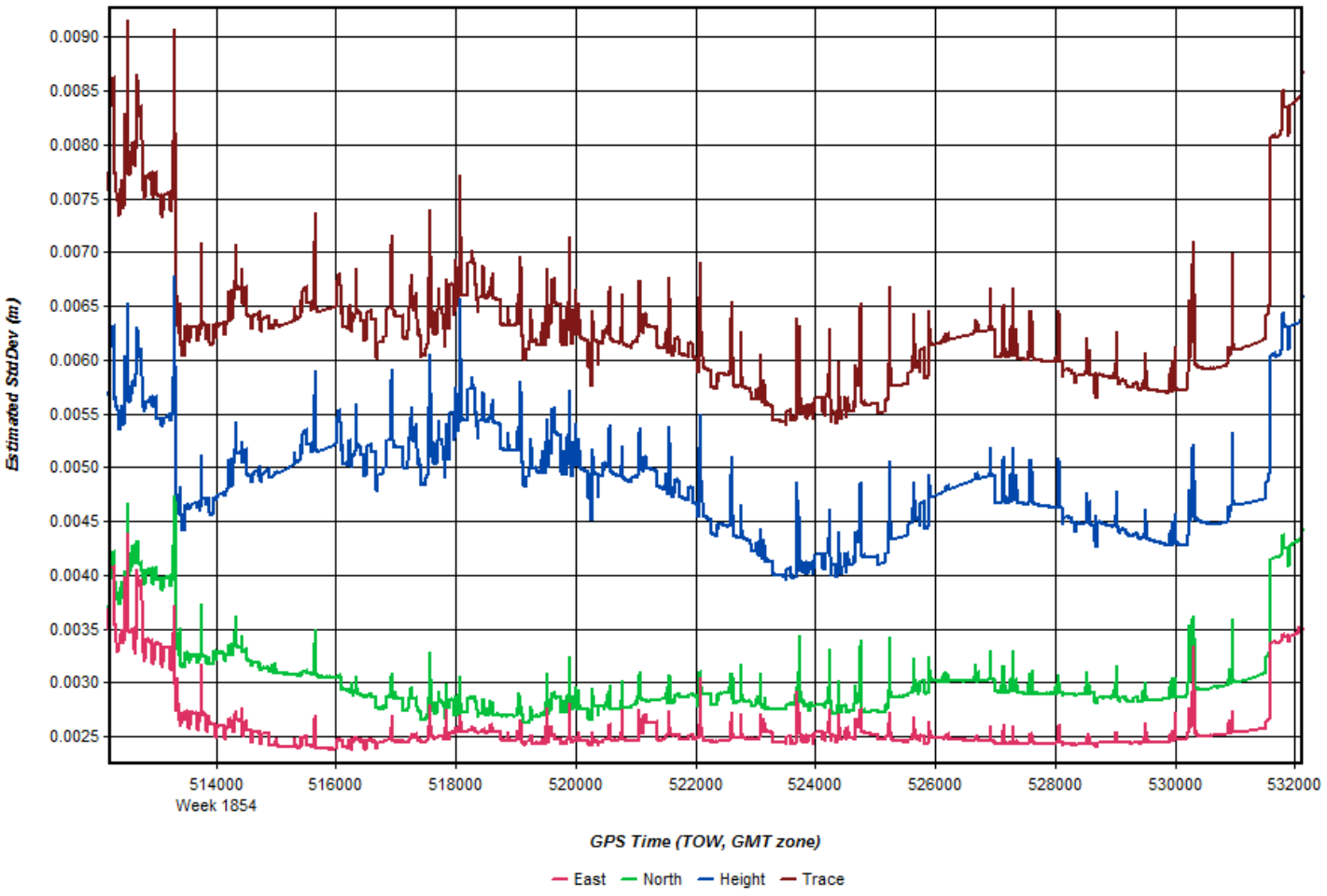

Num Sats
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
482000
Week 1854
484000
486000
488000
490000
492000
494000
496000
498000
500000
GPS Time (TOW, GMT zone)
Num Sats
GPS
GLONASS
BeiDou

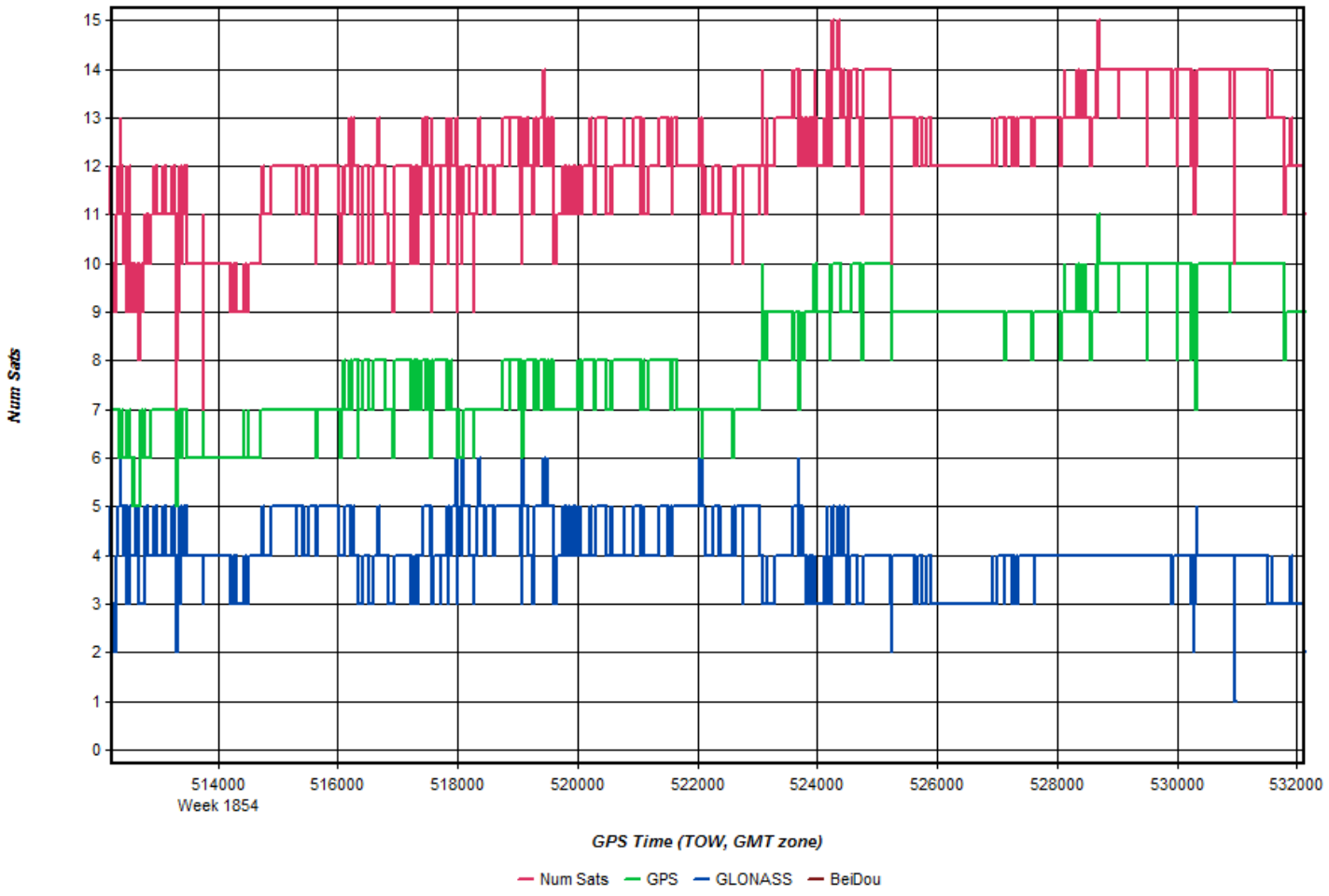

0.05
0.04
0.03
0.02
0.01
0.00
-0.01
-0.02
-0.03
-0.04
-0.05
-0.06
-0.07
Separation (m)
482000
Week 1854
484000
486000
488000
490000
492000
494000
496000
498000
500000
GPS Time (TOW, GMT zone)
East
North
Up

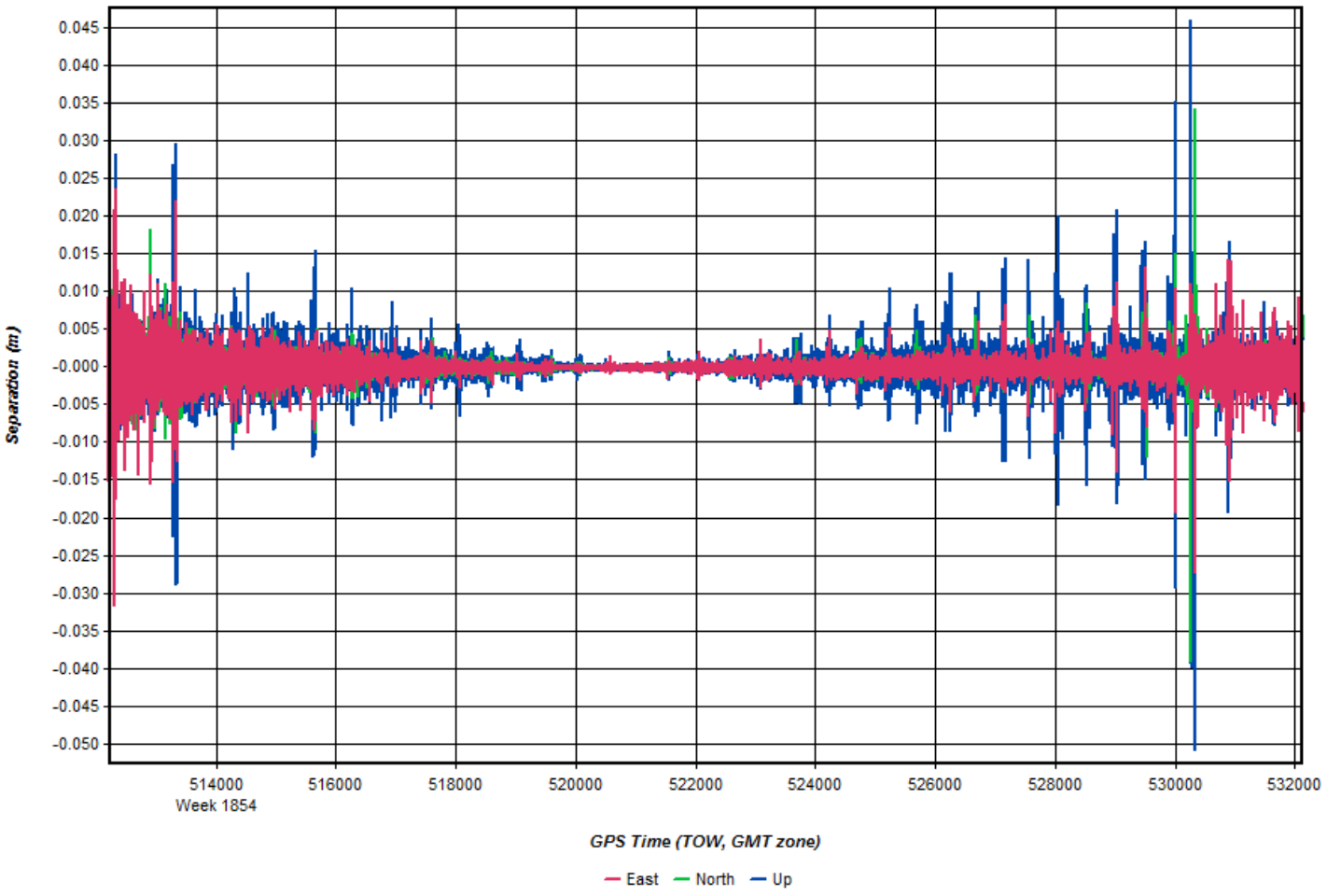

PDOP
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
482000
Week 1854
484000
486000
488000
490000
492000
494000
496000
498000
500000
GPS Time (TOW, GMT zone)
PDOP

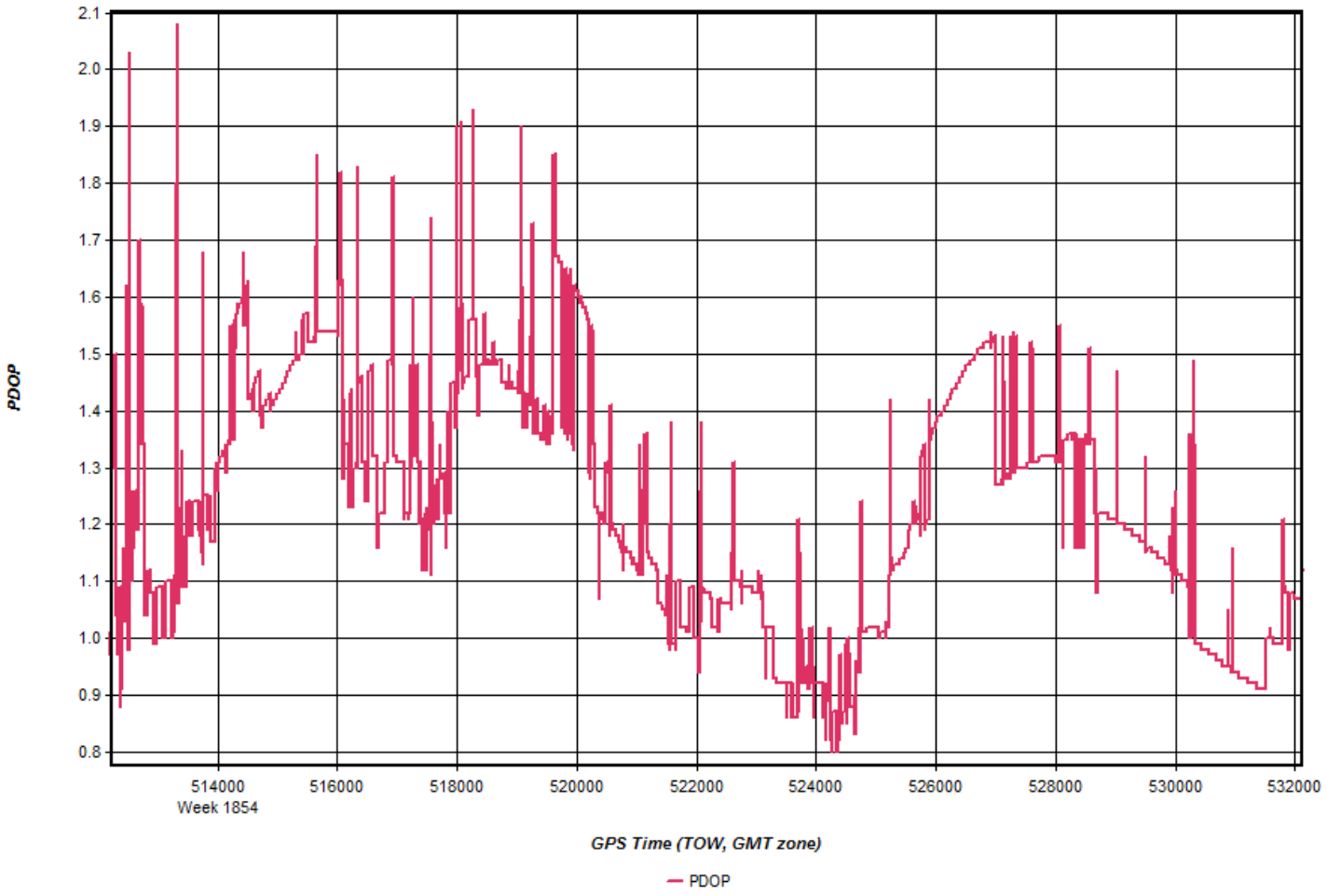
225_20150724_2



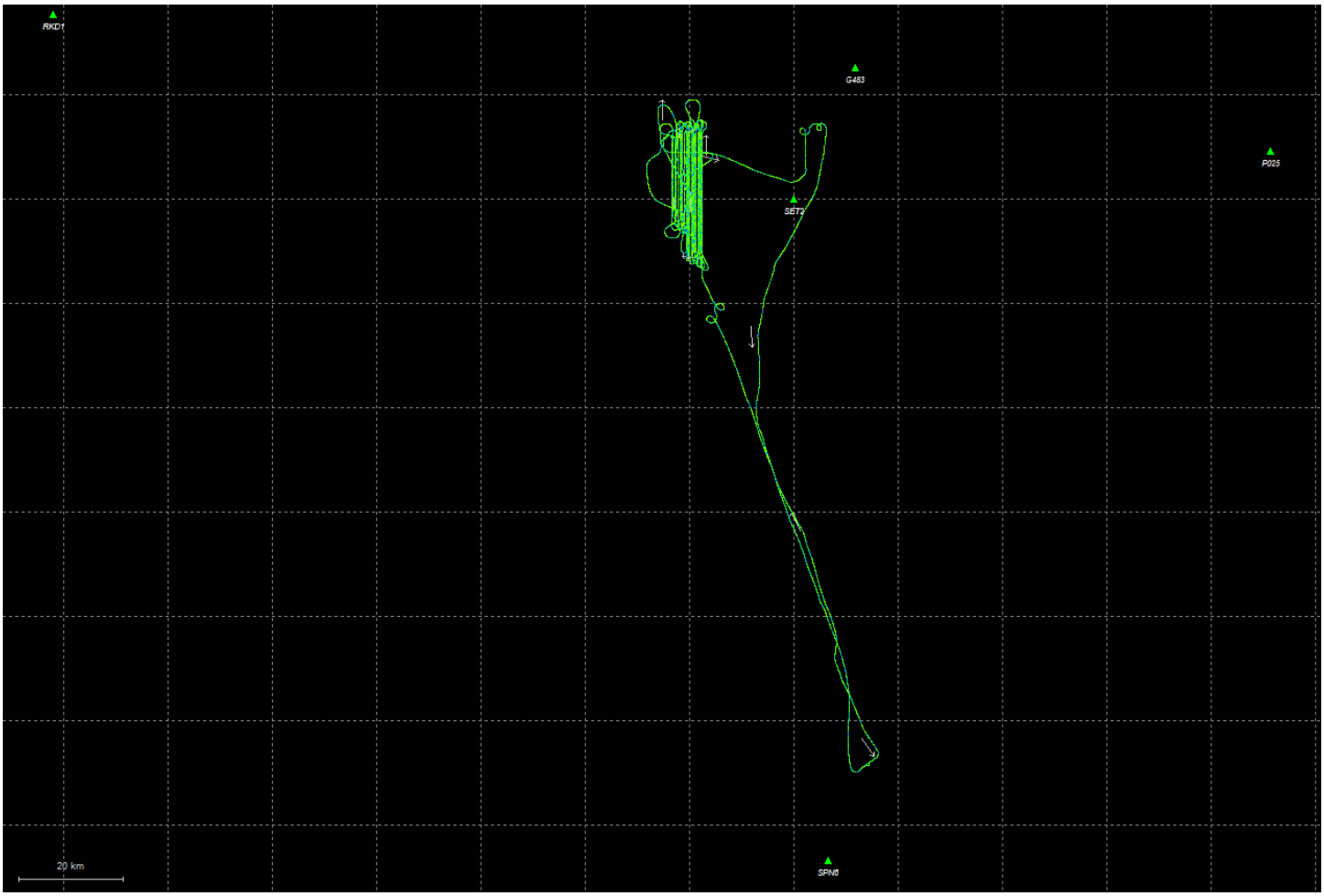

Estimated StdDev (m)
0.0090
0.0085
0.0080
0.0075
0.0070
0.0065
0.0060
0.0055
0.0050
0.0045
0.0040
0.0035
0.0030
0.0025
514000
Week 1854
516000
518000
520000
522000
524000
526000
528000
530000
532000
GPS Time (TOW, GMT zone)
East
North
Height
Trace

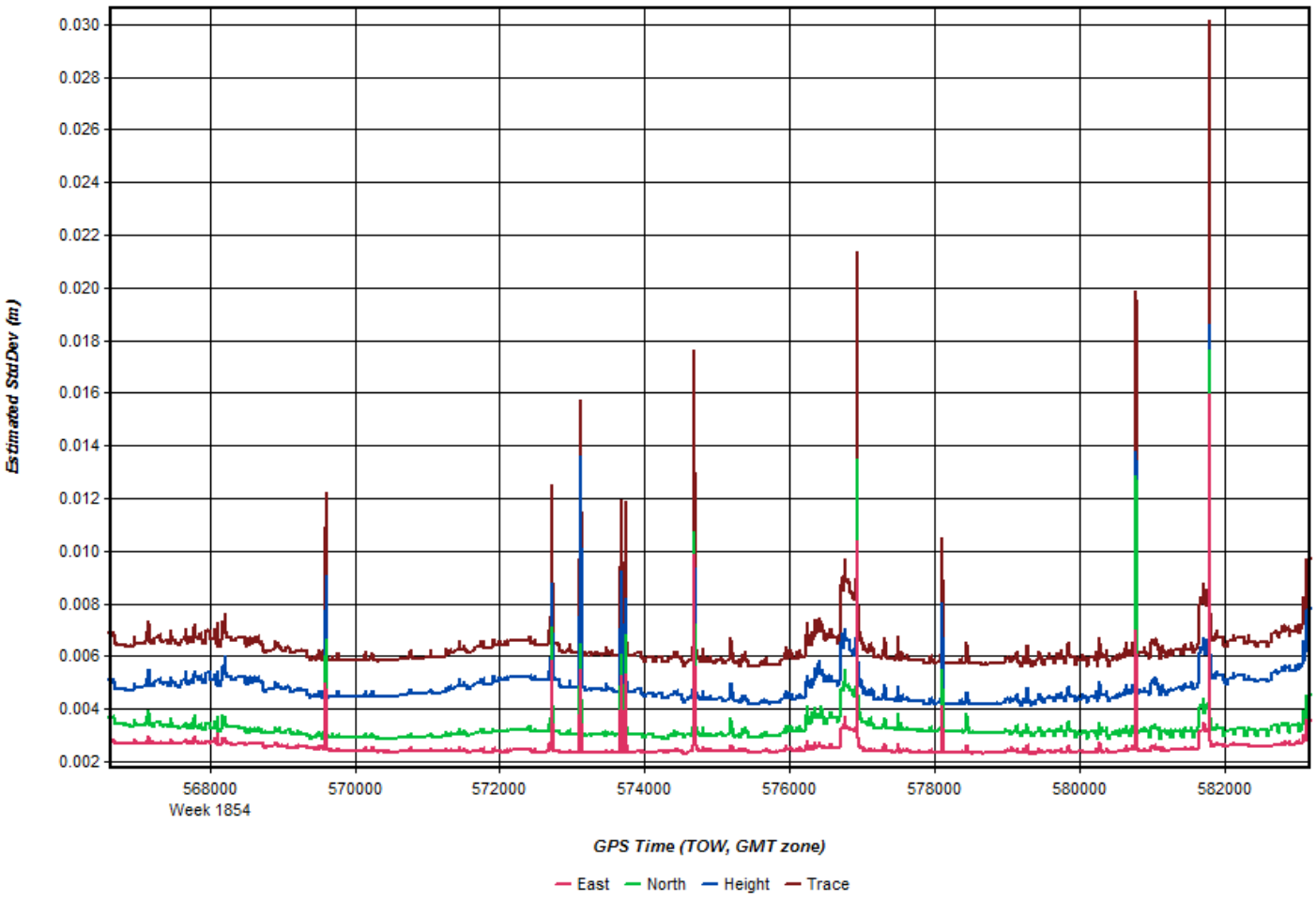

Num Sats
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
514000
Week 1854
516000
518000
520000
522000
524000
526000
528000
530000
532000
GPS Time (TOW, GMT zone)
Num Sats
GPS
GLONASS
BeiDou

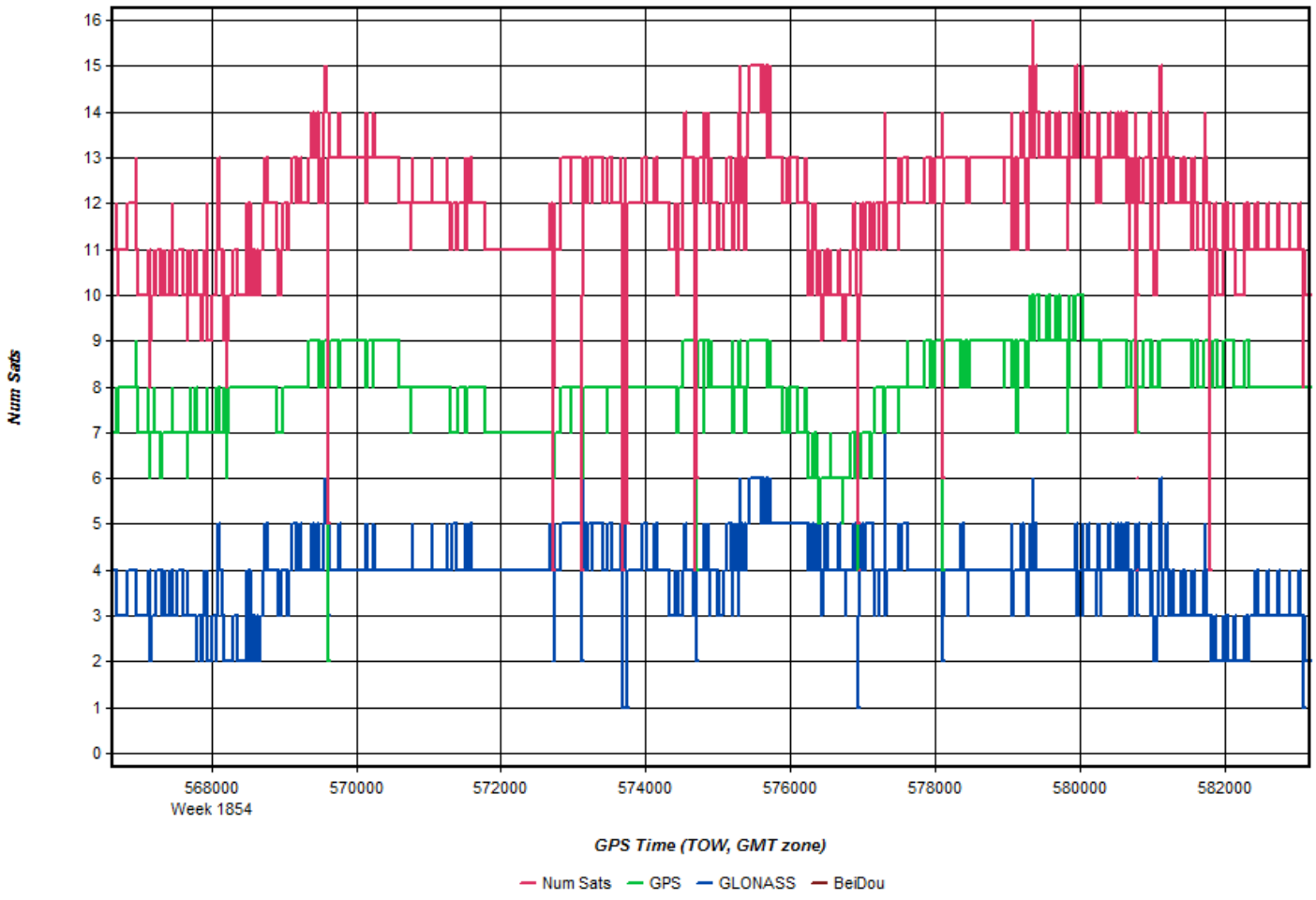

0.045
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
-0.000
-0.005
-0.010
-0.015
-0.020
-0.025
-0.030
-0.035
-0.040
-0.045
-0.050
Separation (m)
514000
Week 1854
516000
518000
520000
522000
524000
526000
528000
530000
532000
GPS Time (TOW, GMT zone)
East
North
Up

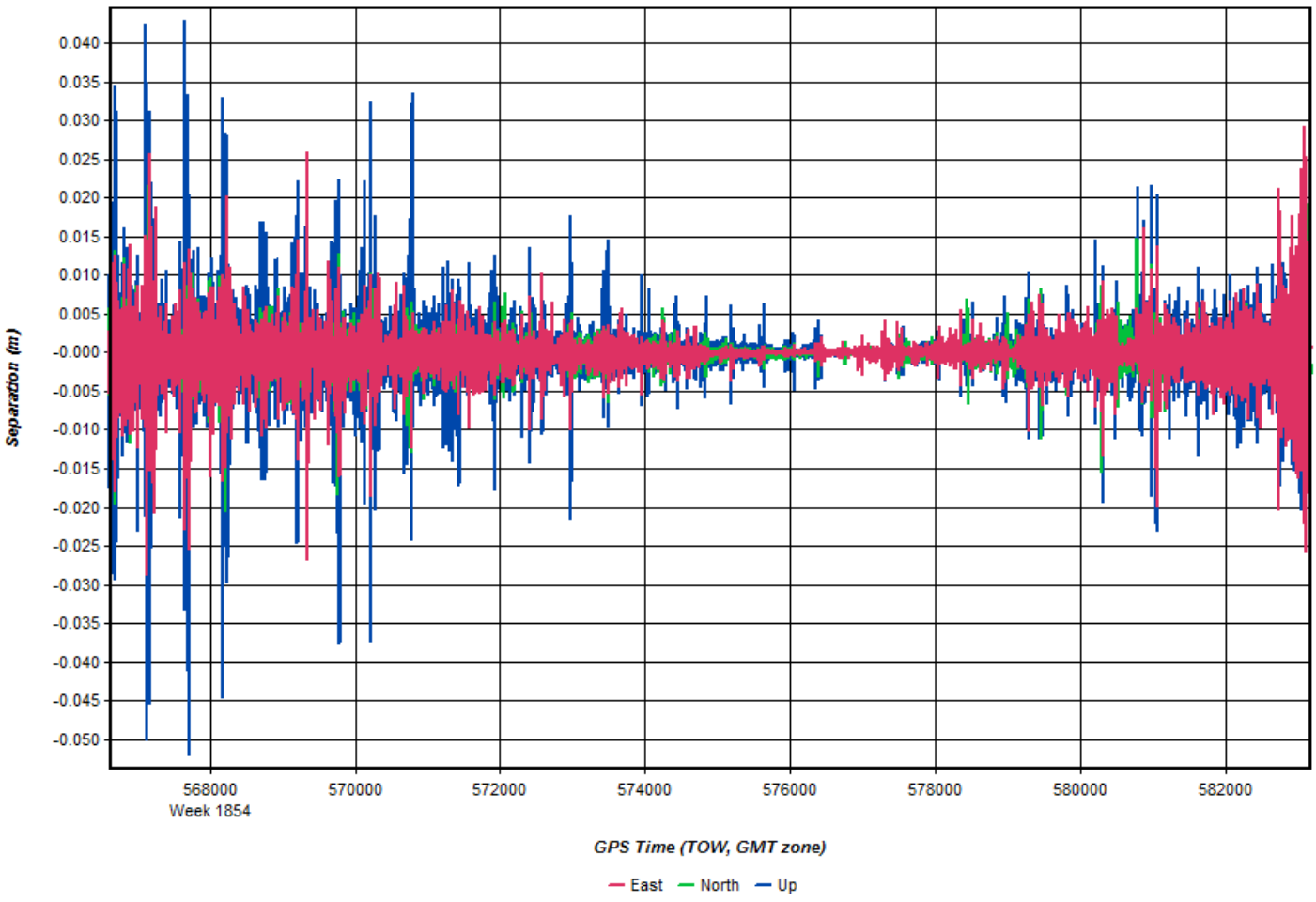

PDOP
2.1
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
514000
Week 1854
516000
518000
520000
522000
524000
526000
528000
530000
532000
GPS Time (TOW, GMT zone)
PDOP

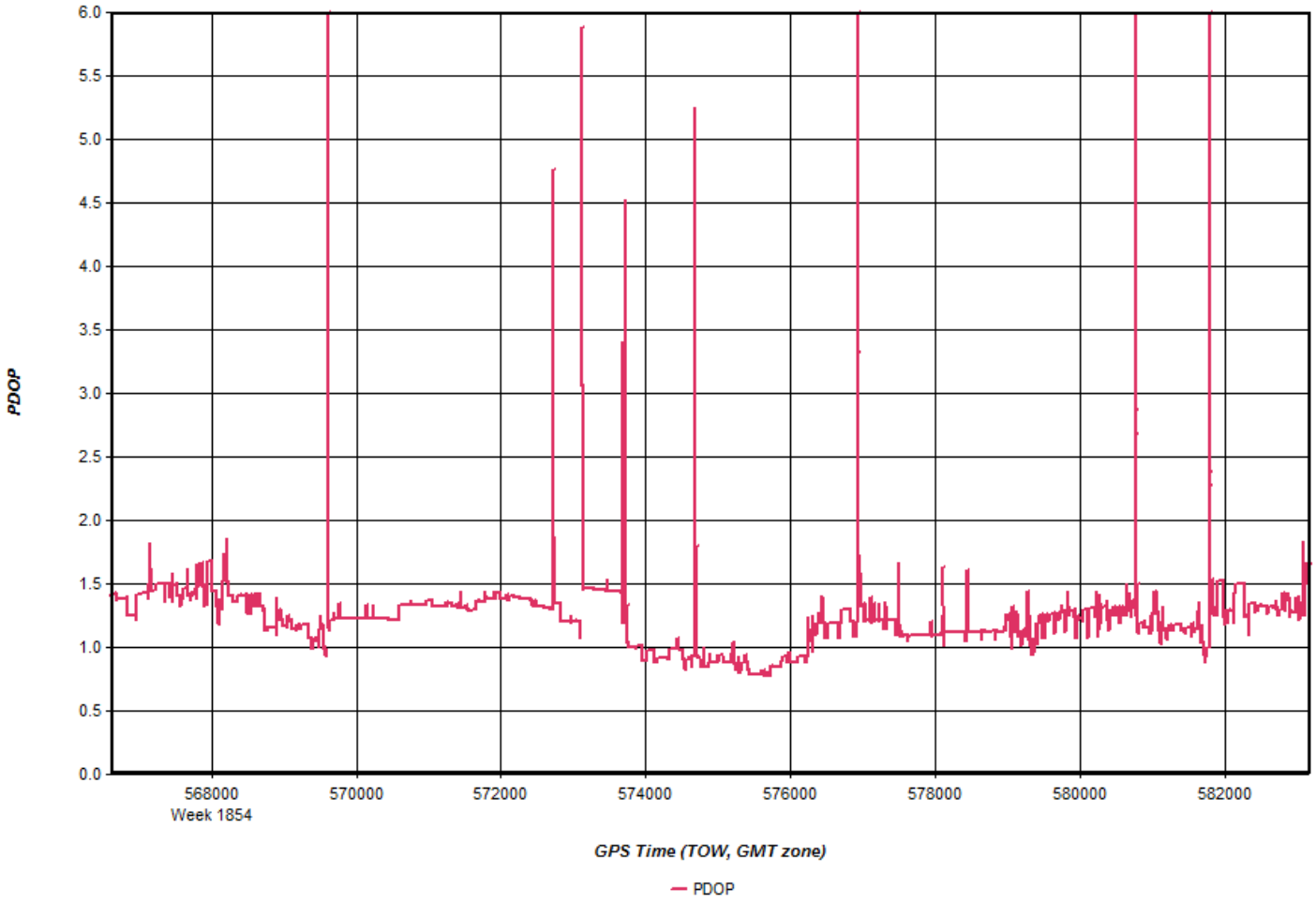
225_20150725_1




Estimated StdDev (m)
0.030
0.028
0.026
0.024
0.022
0.020
0.018
0.016
0.014
0.012
0.010
0.008
0.006
0.004
0.002
568000
Week 1854
570000
572000
574000
576000
578000
580000
582000
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
568000
Week 1854
570000
572000
574000
576000
578000
580000
582000
GPS Time (TOW, GMT zone)
Num Sats
GPS
GLONASS
BeiDou


Separation (m)
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
568000
Week 1854
570000
572000
574000
576000
578000
580000
582000
GPS Time (TOW, GMT zone)
East
North
Up


PDOP
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
568000
Week 1854
570000
572000
574000
576000
578000
580000
582000
GPS Time (TOW, GMT zone)
PDOP