

Aerial Lidar Report

Kansas Lidar

14135



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

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Section 1: Lidar Acquisition

1.1 Acquisition

Atlantic Group, LLC (Atlantic) has successfully completed lidar acquisition for the Kansas area(s) of interest. Lidar for this project was acquired in twenty seven (27) flight lifts completed on March 15th, 2015. The project area encompasses 3,944 square miles or 10,215 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 two hundred and sixty six (266) 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 40 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(s) of interest (AOI) and the flight-lines executed to provide AOI coverage.



Figure 1: Trajectories as flown by Atlantic

1.5 Acquisition Equipment

Atlantic operated a Partenavia S.P.A. P 68 C/TC (N775MW) and a Cessna T210L (N732JE) 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 systems:

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

1.6 Lidar System Acquisition Parameters

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

Lidar System Acquisition Parameters	
Item	Parameter
System	Leica ALS-70 HP
Nominal Pulse Spacing (m)	0.5
Nominal Pulse Density (pls/m ²)	4.7
Nominal Flight Height (AGL meters)	1600
Nominal Flight Speed (kts)	120
Pass Heading (degree)	90
Sensor Scan Angle (degree)	40
Scan Frequency (Hz)	44.9
Pulse Rate of Scanner (kHz)	335.2
Line Spacing (m)	863
Pulse Duration of Scanner (ns)	4
Pulse Width of Scanner (m)	0.46
Central Wavelength of Sensor Laser (nm)	1064
Sensor Operated with Multiple Pulses	Yes
Beam Divergence (mrad)	0.15
Nominal Swath Width (m)	1165
Nominal Swath Overlap (%)	20
Scan Pattern	Triangle

Table 2: Atlantic Lidar System Acquisition Parameters

1.7 GPS Reference Station(s)

Five (5) CORS stations, six (6) NGS monuments, eight (8) ITRF stations, and six (6) dedicated stations set by Atlantic 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				
Name	PID	Latitude (N)	Longitude (W)	Elevation
A267	HG0264	37°17'21.80110"	98°36'17.43271"	425.051
ANTHPORT	HG0758	37°09'14.95679"	98°04'43.09084"	378.134
BS01	n/a	36°46'33.90438"	98°40'04.05061"	419.886
BS02	n/a	37°19'29.85339"	97°23'10.27437"	358.767
CRANSTON RM 1	HF0236	37°15'29.59074"	96°51'39.25502"	369.531
CRANSTON RM 2	HF0238	37°15'30.14943"	96°51'39.23121"	369.818
FIELD	HF0774	37°15'55.05845"	97°31'56.64113"	364.579
FLIGHT01	n/a	37°02'43.73234"	97°23'59.29747"	311.156
FLIGHT02	n/a	37°09'46.03848"	98°04'43.00471"	380.056
FLIGHT03	n/a	37°04'30.30294"	98°34'03.96168"	416.629
ICT1	DK6487	37°35'15.77381"	97°18'31.95834"	364.408
ICT2	DK6489	37°45'06.45839"	97°22'05.23119"	382.979
ICT3	DK6491	37°45'09.31203"	97°12'58.38008"	402.315
ICT4	DK6493	37°37'08.55556"	97°37'56.95772"	393.233
OKBF	DG9774	36°49'40.88165"	99°38'28.84037"	539.827
RUTH	HF0661	37°11'16.18724"	97°24'06.94655"	348.284
SG04	n/a	37°07'54.87408"	97°15'57.84792"	360.530
SG09	n/a	36°25'50.68531"	98°17'03.64851"	391.960
SG10	n/a	36°52'53.11666"	98°17'10.84933"	332.442
SG11	n/a	37°19'53.63297"	99°18'31.90756"	636.322
SG41	n/a	37°09'03.58848"	98°21'43.53367"	391.597
SG42	n/a	36°49'09.61280"	97°49'11.66462"	308.742
SG43	n/a	36°55'31.90177"	97°04'54.39908"	322.754
SG44	n/a	37°04'10.73430"	96°45'38.20314"	389.370
Z42	n/a	37°10'20.40640"	97°02'58.05278"	324.864

Table 3: GPS Reference Station Coordinates

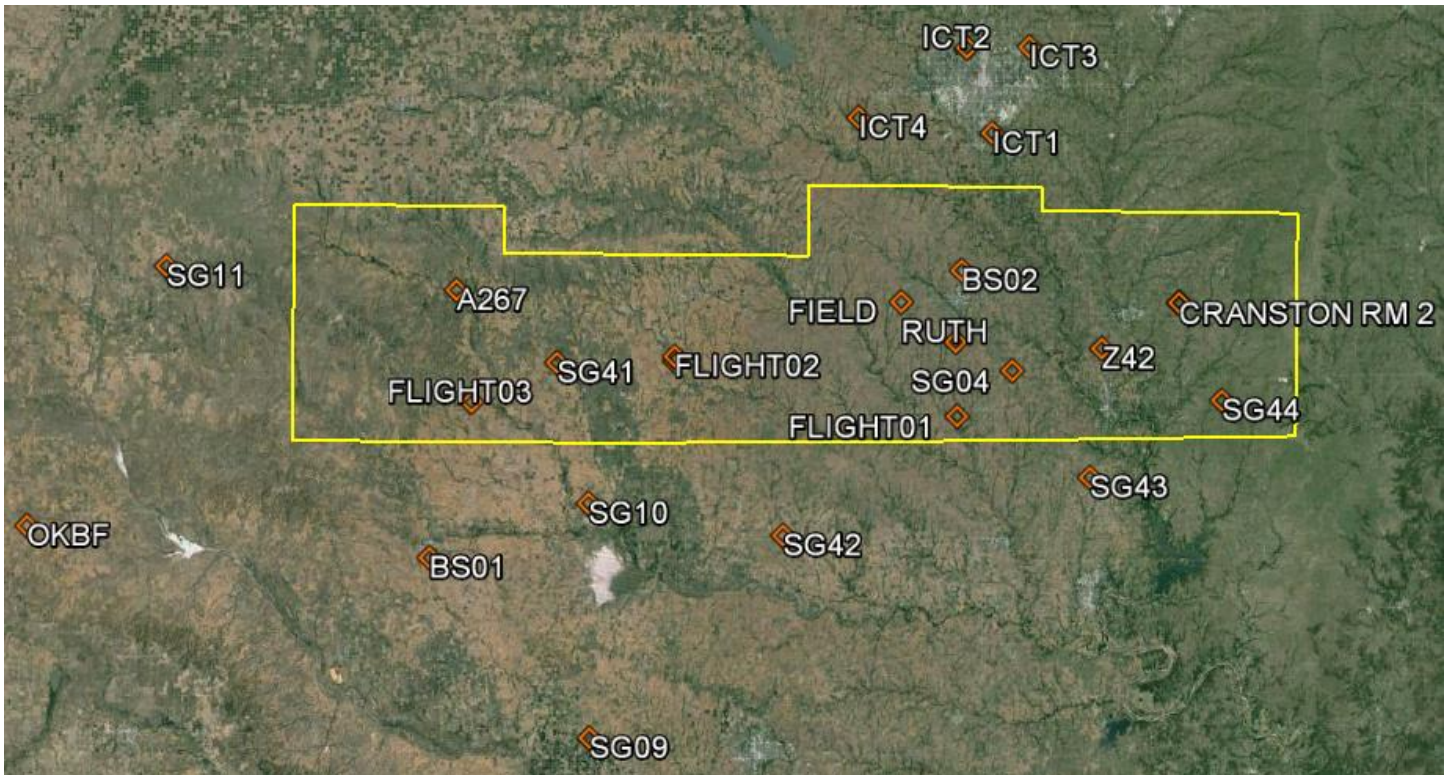


Figure 2: GPS Reference Station(s)

1.8 Airborne GPS Kinematic

Differential GPS unit in aircraft collected positions at 2 Hz. Airborne GPS data was processed using the Inertial Explorer (version 8.5.4320) 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 40km.

For all flights, the GPS data can be classified as good, with GPS residuals of 3cm average or better but none larger than 15cm 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 (HARN)
Coordinate System:	Universal Transverse Mercator Northern Zone 14
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	67,850,552,195
Aggregate Nominal Pulse Spacing (m)	0.3965
Aggregate Nominal Pulse Density (pls/m ²)	6.47

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.

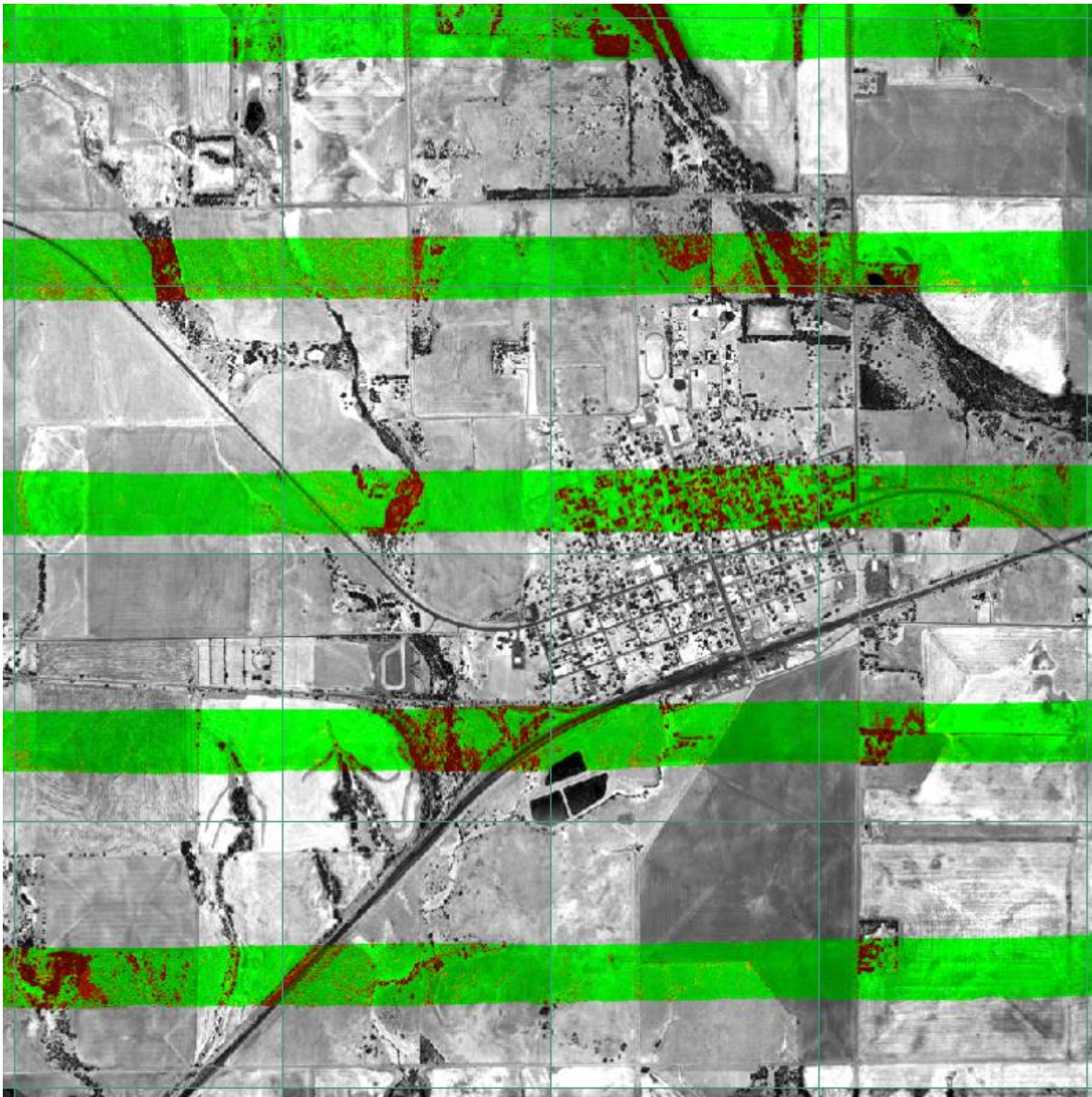


Figure 4: dZ Ortho Sub-Sample

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 Meters.

Average Magnitudes Per Line											
Line	X	Y	Z	Line	X	Y	Z	Line	X	Y	Z
11	0.020	0.001	0.011	102	0.031	0.091	0.013	222	0.009	0.013	0.011
12	0.022	0.036	0.015	103	0.020	0.045	0.014	223	0.011	0.022	0.013
13	0.027	0.041	0.012	104	0.027	0.003	0.014	224	0.017	0.029	0.011
14	0.028	0.038	0.015	105	0.025	0.041	0.013	227	0.006	0.016	0.013
15	0.013	0.020	0.012	106	0.020	0.004	0.013	228	0.008	0.014	0.012
16	0.009	0.015	0.014	107	0.019	0.028	0.014	229	0.010	0.017	0.011
18	0.009	0.027	0.013	108	0.018	0.070	0.012	230	0.008	0.022	0.011
19	0.014	0.027	0.012	109	0.023	0.036	0.012	231	0.007	0.012	0.010
20	0.019	0.027	0.014	110	0.028	0.022	0.012	232	0.008	0.009	0.010
23	0.012	0.019	0.012	111	0.012	0.030	0.012	233	0.009	0.009	0.011
24	0.018	0.028	0.011	112	0.016	0.032	0.012	234	0.010	0.010	0.011
25	0.024	0.029	0.012	114	0.013	0.011	0.012	235	0.012	0.018	0.011
26	0.025	0.029	0.012	115	0.013	0.013	0.011	238	0.049	0.031	0.014
27	0.028	0.040	0.011	116	0.024	0.049	0.011	239	0.028	0.027	0.011
28	0.019	0.035	0.012	117	0.019	0.048	0.012	240	0.010	0.031	0.012
29	0.020	0.032	0.011	118	0.022	0.040	0.012	241	0.010	0.010	0.010
30	0.024	0.038	0.013	119	0.013	0.011	0.012	242	0.013	0.022	0.012
31	0.022	0.043	0.013	120	0.013	0.013	0.012	243	0.012	0.020	0.011
32	0.019	0.041	0.013	121	0.014	0.052	0.012	244	0.011	0.022	0.011
33	0.020	0.055	0.011	122	0.049	0.022	0.012	248	0.032	0.025	0.015
35	0.025	0.049	0.012	124	0.007	0.013	0.012	249	0.027	0.025	0.013
36	0.032	0.043	0.013	125	0.008	0.016	0.014	250	0.034	0.031	0.013
37	0.019	0.042	0.011	126	0.021	0.006	0.013	251	0.025	0.052	0.011
38	0.017	0.044	0.011	127	0.031	0.006	0.014	252	0.014	0.020	0.012
39	0.010	0.018	0.012	128	0.036	0.039	0.012	253	0.013	0.023	0.012
40	0.013	0.057	0.013	129	0.011	0.019	0.013	254	0.009	0.013	0.012
41	0.009	0.014	0.012	130	0.009	0.024	0.012	255	0.007	0.010	0.011
42	0.013	0.017	0.013	131	0.017	0.042	0.014	258	0.016	0.023	0.013
43	0.023	0.028	0.013	132	0.017	0.025	0.012	259	0.010	0.013	0.012
44	0.030	0.029	0.013	133	0.006	0.032	0.013	260	0.007	0.015	0.014
47	0.010	0.031	0.012	134	0.002	0.044	0.012	261	0.009	0.029	0.012
49	0.014	0.014	0.012	135	0.035	0.017	0.013	262	0.019	0.021	0.013
50	0.023	0.007	0.011	136	0.034	0.025	0.012	263	0.023	0.009	0.012
51	0.017	0.010	0.012	137	0.001	0.048	0.014	264	0.034	0.034	0.010
52	0.026	0.037	0.011	139	0.035	0.066	0.011	265	0.015	0.038	0.013

54	0.020	0.032	0.011	140	0.038	0.049	0.014	266	0.014	0.035	0.012
55	0.047	0.017	0.015	141	0.030	0.043	0.013	267	0.018	0.031	0.013
57	0.017	0.068	0.012	142	0.025	0.052	0.013	268	0.037	0.000	0.011
58	0.020	0.036	0.012	143	0.031	0.057	0.012	269	0.038	0.000	0.013
59	0.022	0.024	0.011	144	0.036	0.044	0.014	271	-	-	0.016
60	0.020	0.039	0.012	145	0.032	0.041	0.013	276	0.027	0.039	0.015
61	0.015	0.046	0.011	146	0.013	0.048	0.014	277	0.015	0.041	0.012
62	0.007	0.071	0.012	147	0.008	0.042	0.013	278	0.013	0.025	0.011
63	0.008	0.077	0.012	148	0.002	0.038	0.013	279	0.021	0.023	0.012
64	0.029	0.036	0.012	149	0.004	0.043	0.012	280	0.013	0.036	0.012
65	0.016	0.020	0.012	150	0.034	0.063	0.013	281	0.032	0.020	0.013
67	0.017	0.018	0.012	151	0.034	0.061	0.012	282	0.022	0.032	0.011
68	0.014	0.013	0.010	152	-	-	0.014	283	0.000	0.033	0.012
69	0.010	0.014	0.011	155	0.013	0.075	0.017	284	0.013	0.015	0.012
70	0.021	0.028	0.010	156	0.012	0.068	0.014	285	0.034	0.031	0.015
71	0.019	0.032	0.011	157	0.022	0.035	0.014	287	0.009	0.043	0.022
72	0.010	0.020	0.010	158	-	-	0.015	289	0.084	0.002	0.017
73	0.014	0.017	0.012	159	0.046	0.031	0.015	291	0.017	0.023	0.013
74	0.013	0.020	0.011	160	0.053	0.040	0.015	292	0.006	0.025	0.014
75	0.084	0.003	0.013	161	0.031	0.039	0.014	293	0.035	0.040	0.013
77	0.016	0.041	0.012	162	0.014	0.028	0.014	294	0.025	0.031	0.014
78	0.016	0.035	0.014	163	0.009	0.024	0.013	295	0.030	0.018	0.013
79	0.010	0.010	0.012	164	0.010	0.025	0.013	296	0.038	0.031	0.013
80	0.015	0.039	0.013	165	0.014	0.036	0.014	297	0.003	0.050	0.013
81	0.016	0.034	0.012	166	0.029	0.054	0.015	298	0.012	0.039	0.013
82	0.015	0.024	0.013	167	0.027	0.020	0.015	299	0.028	0.011	0.013
83	0.012	0.031	0.012	168	0.026	0.018	0.014	300	0.036	0.009	0.019
84	0.023	0.043	0.013	200	0.008	0.009	0.012	302	0.044	0.001	0.018
85	0.019	0.062	0.012	201	0.009	0.011	0.013	303	0.009	0.038	0.017
86	0.013	0.035	0.012	202	0.010	0.014	0.013	306	0.019	0.005	0.024
87	0.014	0.026	0.015	203	0.011	0.013	0.014	307	0.013	0.015	0.012
88	0.002	0.003	0.010	204	0.013	0.011	0.013	308	0.009	0.027	0.014
89	0.006	0.008	0.012	205	0.016	0.026	0.017	309	0.015	0.029	0.012
90	0.012	0.011	0.019	207	0.031	0.029	0.014	400	0.001	0.002	0.016
92	0.012	0.012	0.017	208	0.017	0.018	0.012	401	0.004	0.000	0.015
93	0.047	0.035	0.012	209	0.018	0.017	0.012	402	-	-	0.015
94	0.035	0.033	0.013	213	0.017	0.044	0.016	403	0.001	0.002	0.015
95	0.016	0.044	0.012	214	0.020	0.040	0.016	404	0.016	0.000	0.013
96	0.016	0.040	0.012	217	0.008	0.026	0.015	405	0.078	0.001	0.014
97	0.026	0.040	0.011	218	0.008	0.011	0.012	406	0.002	0.002	0.015
98	0.026	0.046	0.011	219	0.007	0.010	0.013	407	0.012	0.017	0.012
99	0.024	0.037	0.011	220	0.007	0.009	0.012	408	0.012	0.016	0.010

100	0.021	0.047	0.011	221	0.009	0.011	0.012	409	0.004	0.001	0.014
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Table 5: Average Tie Line Magnitudes per Line

Internal Observation Statistics			
Category	X	Y	Z
Average Magnitude	0.013	0.020	0.013
RMS Values	0.023	0.035	0.017
Maximum Values	0.129	0.130	0.157
Observation Weight	23962.0	23962.0	2240654.0

Table 6: Tie Line Observation Statistics

Overall Relative Accuracy	
Category	Mismatch
Average 3D Mismatch	0.01306
Average XY Mismatch	0.03050
Average Z Mismatch	0.01279

Table 7: Relative Accuracy Results

TerraMatch Tie Lines	
Category	Observations
Section Lines	914,420
Roof Lines	11,962

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. Atlantic utilized collected breakline data to preform classification for classes' 9-Water and 10-Rail (breakline buffer). 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)	X
8	Reserved	
9	Water	X
10	Rail (breakline buffer)	X
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	X
18	High Noise	X
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 two hundred and twenty (220) checkpoints for this project (120 NVA + 100 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:

$RMSE_z \leq 10.0\text{cm}$ (Non-Vegetated Swath, DEM)

$NVA \leq 19.6\text{cm}$ 95% Confidence Level (Swath, DEM)

$VVA \leq 29.4\text{cm}$ 95th Percentile (DEM)

Vertical Accuracy Reporting Requirements in Feet:

$RMSE_z \leq 0.328\text{ft}$ (Non-Vegetated Swath, DEM)

$NVA \leq 0.643\text{ft}$ 95% Confidence Level (Swath, DEM)

$VVA \leq 0.965\text{ft}$ 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.

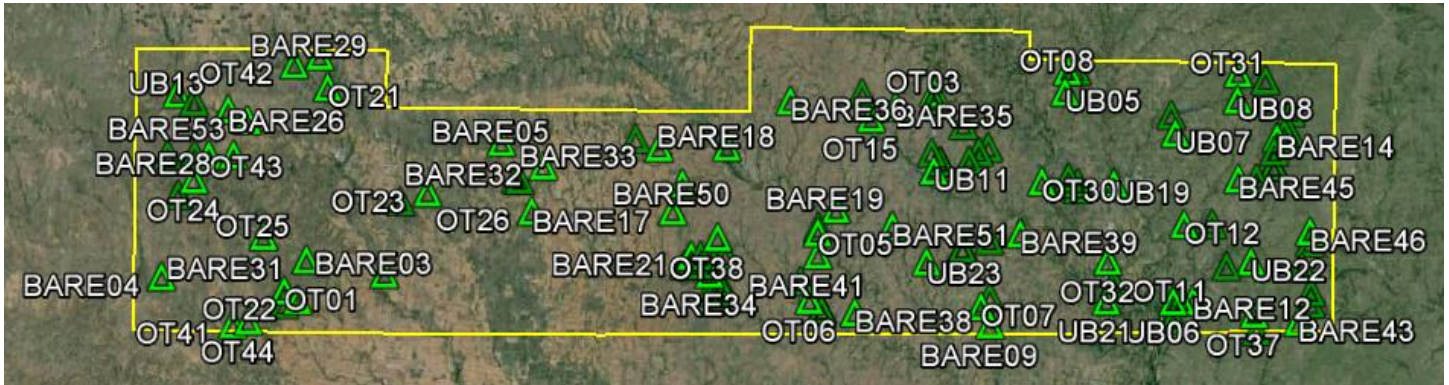


Figure 5: Non-vegetated Vertical Accuracy (NVA) Check Point Distribution

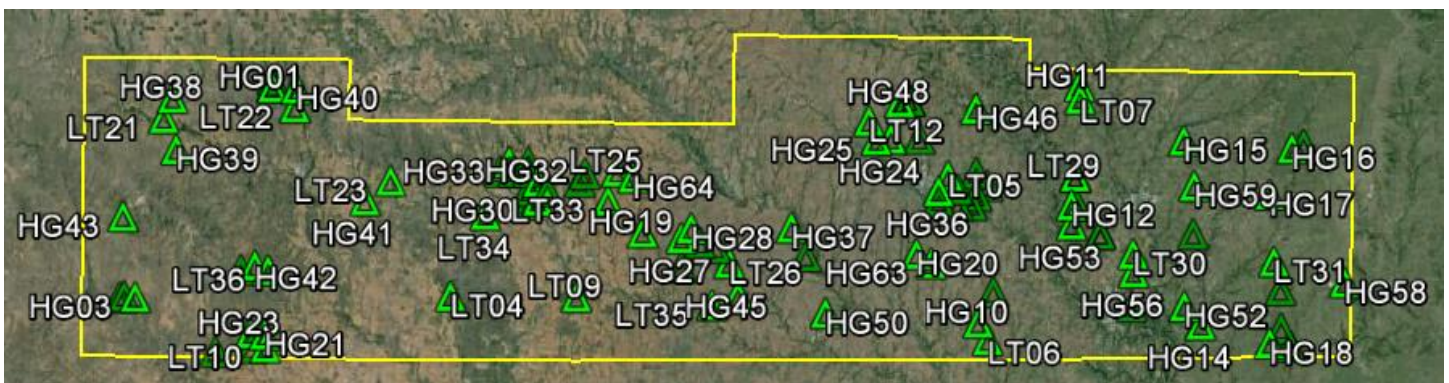


Figure 6: Vegetated Vertical Accuracy (VVA) Check Point Distribution

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 (HARN), UTM Zone 14N, NAVD88, Geoid12A, Meters.

Non-vegetated Vertical Accuracy (NVA) Check Point Assessment (Swath)						
PointID	Easting	Northing	KnownZ	LaserZ	Description	DeltaZ
BARE01	527174.176	4099742.604	442.765	442.870	Bare Earth	0.105
BARE02	507852.666	4118921.501	607.294	607.380	Bare Earth	0.086
BARE03	545069.885	4105392.451	417.943	418.040	Bare Earth	0.097
BARE04	505029.475	4104346.732	508.662	508.770	Bare Earth	0.108
BARE05	565769.586	4129061.127	476.794	476.930	Bare Earth	0.136
BARE06	651123.711	4128451.929	393.873	393.960	Bare Earth	0.087
BARE07	622496.625	4114627.221	353.113	353.240	Bare Earth	0.127
BARE08	619525.647	4105077.854	366.568	366.720	Bare Earth	0.152
BARE09	653552.862	4097759.286	344.458	344.580	Bare Earth	0.122
BARE10	668455.146	4143077.509	383.779	383.810	Bare Earth	0.031
BARE11	668932.996	4122146.063	355.266	355.300	Bare Earth	0.034
BARE12	689875.421	4102617.824	372.502	372.480	Bare Earth	-0.022
BARE13	685520.785	4135462.773	390.535	390.470	Bare Earth	-0.065
BARE14	704616.313	4131646.356	381.092	381.050	Bare Earth	-0.042
BARE15	704130.697	4126530.487	369.625	369.560	Bare Earth	-0.065
BARE16	704130.719	4126530.477	369.653	369.560	Bare Earth	-0.093
BARE17	596546.202	4117223.386	405.412	405.540	Bare Earth	0.128
BARE18	606079.678	4128727.728	389.440	389.540	Bare Earth	0.100
BARE19	625695.073	4117929.807	366.576	366.620	Bare Earth	0.044
BARE20	709404.781	4108577.202	410.347	410.390	Bare Earth	0.043
BARE21	599942.192	4109304.745	387.775	387.890	Bare Earth	0.115
BARE22	598770.782	4107641.595	381.743	381.850	Bare Earth	0.107
BARE23	604891.040	4101368.672	375.593	375.510	Bare Earth	-0.083
BARE24	603293.874	4102934.239	363.820	363.810	Bare Earth	-0.010
BARE25	604865.690	4104550.237	371.360	371.450	Bare Earth	0.090
BARE26	516671.080	4134238.877	501.793	501.780	Bare Earth	-0.013
BARE27	510722.868	4126137.168	563.685	563.640	Bare Earth	-0.045
BARE28	517746.835	4126167.100	503.136	503.110	Bare Earth	-0.026
BARE29	532990.729	4143956.944	555.073	555.110	Bare Earth	0.037
BARE30	547773.453	4118318.085	472.589	472.530	Bare Earth	-0.059
BARE31	531066.576	4107709.993	468.872	468.840	Bare Earth	-0.032
BARE32	573301.510	4124948.176	435.057	435.020	Bare Earth	-0.037
BARE33	593942.856	4128481.535	420.374	420.350	Bare Earth	-0.024
BARE34	603248.887	4106146.397	376.736	376.850	Bare Earth	0.114
BARE35	636103.612	4136211.677	391.809	391.780	Bare Earth	-0.029

BARE36	617285.013	4137065.669	432.547	432.420	Bare Earth	-0.127
BARE37	652780.214	4129246.434	380.660	380.610	Bare Earth	-0.050
BARE38	629293.100	4099623.741	345.359	345.380	Bare Earth	0.021
BARE39	658731.436	4114011.311	351.607	351.530	Bare Earth	-0.077
BARE40	693141.110	4116149.744	396.191	396.250	Bare Earth	0.059
BARE41	622599.174	4109781.534	354.447	354.480	Bare Earth	0.033
BARE42	702419.696	4141883.471	434.691	434.570	Bare Earth	-0.121
BARE43	708907.878	4098897.167	359.705	359.650	Bare Earth	-0.055
BARE44	707017.520	4136233.960	389.045	389.040	Bare Earth	-0.005
BARE45	697726.745	4124276.150	414.089	414.010	Bare Earth	-0.079
BARE46	710799.760	4115034.282	432.448	432.480	Bare Earth	0.032
BARE47	711146.433	4102204.104	376.954	377.090	Bare Earth	0.136
BARE48	686431.730	4099117.187	320.889	320.940	Bare Earth	0.051
BARE49	701402.494	4097176.960	399.118	399.210	Bare Earth	0.092
BARE50	598194.862	4122101.755	404.246	404.300	Bare Earth	0.054
BARE51	635819.326	4115029.138	367.468	367.350	Bare Earth	-0.118
BARE52	606030.867	4109414.751	382.486	382.450	Bare Earth	-0.036
BARE53	520147.140	4132371.517	483.179	483.150	Bare Earth	-0.029
OT01	527148.635	4102128.981	453.905	454.010	Open Terrain	0.105
OT02	569084.641	4122392.622	443.931	443.810	Open Terrain	-0.121
OT03	642966.233	4138932.134	391.962	392.000	Open Terrain	0.038
OT04	649400.590	4126845.812	368.556	368.570	Open Terrain	0.014
OT05	622510.080	4113727.966	359.012	359.100	Open Terrain	0.088
OT06	621167.920	4101720.749	360.131	360.300	Open Terrain	0.169
OT07	651876.176	4100954.382	345.912	346.010	Open Terrain	0.098
OT08	666869.797	4143023.395	381.074	381.140	Open Terrain	0.066
OT09	668902.001	4123085.415	357.130	357.170	Open Terrain	0.040
OT10	667236.818	4124086.720	355.009	355.160	Open Terrain	0.151
OT11	687786.665	4102328.486	326.794	326.850	Open Terrain	0.056
OT12	688090.248	4116026.590	383.349	383.360	Open Terrain	0.011
OT13	705922.875	4132537.753	395.773	395.670	Open Terrain	-0.103
OT14	648404.734	4111242.251	374.914	374.820	Open Terrain	-0.094
OT15	631766.432	4134191.168	385.766	385.650	Open Terrain	-0.116
OT16	600712.001	4107701.172	381.668	381.810	Open Terrain	0.142
OT17	606025.335	4102972.475	362.123	362.150	Open Terrain	0.027
OT18	604036.935	4107766.342	382.269	382.220	Open Terrain	-0.049
OT19	510522.860	4135537.627	503.049	503.050	Open Terrain	0.001
OT20	505902.690	4126085.804	613.310	613.250	Open Terrain	-0.060
OT21	534499.888	4138398.983	497.638	497.670	Open Terrain	0.032
OT22	529597.616	4100485.673	454.714	454.770	Open Terrain	0.056
OT23	552644.103	4119934.297	444.333	444.440	Open Terrain	0.107
OT24	510703.188	4121730.938	612.749	612.730	Open Terrain	-0.019

OT25	523298.471	4111788.785	491.708	491.730	Open Terrain	0.022
OT26	571327.886	4116874.079	436.034	435.960	Open Terrain	-0.074
OT27	601650.053	4109295.502	386.839	386.930	Open Terrain	0.091
OT28	630090.432	4138569.254	397.152	397.080	Open Terrain	-0.072
OT29	648325.257	4133201.112	396.739	396.700	Open Terrain	-0.039
OT30	662490.326	4123314.245	348.566	348.500	Open Terrain	-0.066
OT31	697522.580	4143058.962	430.694	430.640	Open Terrain	-0.054
OT32	674517.325	4109354.656	353.275	353.340	Open Terrain	0.065
OT33	704137.865	4129229.386	382.096	382.040	Open Terrain	-0.056
OT34	695828.245	4108683.825	369.952	369.990	Open Terrain	0.038
OT35	710817.118	4113130.643	412.902	412.910	Open Terrain	0.008
OT36	711110.522	4104288.987	383.470	383.540	Open Terrain	0.070
OT37	700935.089	4100228.557	402.949	402.970	Open Terrain	0.021
OT38	604625.804	4112645.453	388.937	388.990	Open Terrain	0.053
OT39	653227.548	4112771.047	368.477	368.430	Open Terrain	-0.047
OT40	648404.743	4111242.255	374.909	374.820	Open Terrain	-0.089
OT41	517961.300	4096022.617	482.344	482.360	Open Terrain	0.016
OT42	528461.990	4142408.492	529.914	529.960	Open Terrain	0.046
OT43	513300.617	4126066.108	568.191	568.130	Open Terrain	-0.061
OT44	520758.281	4096688.806	487.393	487.350	Open Terrain	-0.043
UB01	643013.845	4137438.764	395.865	395.960	Urban Terrain	0.095
UB02	644290.832	4126574.421	379.164	379.280	Urban Terrain	0.116
UB03	623353.052	4099986.476	349.020	349.200	Urban Terrain	0.180
UB04	653429.145	4102636.331	349.341	349.440	Urban Terrain	0.099
UB05	666418.347	4139310.891	391.879	391.920	Urban Terrain	0.041
UB06	686337.061	4102298.032	347.490	347.510	Urban Terrain	0.020
UB07	686304.608	4132258.617	386.505	386.370	Urban Terrain	-0.135
UB08	697418.294	4138331.331	422.778	422.720	Urban Terrain	-0.058
UB09	706827.798	4132632.316	386.298	386.260	Urban Terrain	-0.038
UB10	700988.461	4124382.502	394.265	394.200	Urban Terrain	-0.065
UB11	643104.548	4125004.561	366.263	366.230	Urban Terrain	-0.033
UB12	642687.395	4128192.016	381.614	381.540	Urban Terrain	-0.074
UB13	507460.096	4136939.796	511.862	511.850	Urban Terrain	-0.012
UB14	568427.977	4122459.721	444.076	444.010	Urban Terrain	-0.066
UB15	589746.522	4129998.600	432.429	432.370	Urban Terrain	-0.059
UB16	643005.871	4137433.303	396.475	396.390	Urban Terrain	-0.085
UB17	644262.003	4126587.649	379.686	379.590	Urban Terrain	-0.096
UB18	623364.545	4099968.235	348.784	348.850	Urban Terrain	0.066
UB19	675381.185	4123116.436	353.879	353.760	Urban Terrain	-0.119
UB20	675642.797	4105332.338	330.776	330.720	Urban Terrain	-0.056
UB21	674357.021	4102246.807	327.116	327.110	Urban Terrain	-0.006
UB22	700211.687	4109553.069	378.709	378.770	Urban Terrain	0.061

UB23	642016.674	4108817.265	356.644	356.580	Urban Terrain	-0.064
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Table 10: Lidar Point Cloud Swath Data Assessment

Non-vegetated Vertical Accuracy (NVA) Check Point Assessment (DEM)						
PointID	Easting	Northing	KnownZ	LaserZ	Description	DeltaZ
BARE01	527174.176	4099742.604	442.765	442.870	Bare Earth	0.105
BARE02	507852.666	4118921.501	607.294	607.380	Bare Earth	0.086
BARE03	545069.885	4105392.451	417.943	418.010	Bare Earth	0.067
BARE04	505029.475	4104346.732	508.662	508.770	Bare Earth	0.108
BARE05	565769.586	4129061.127	476.794	476.910	Bare Earth	0.116
BARE06	651123.711	4128451.929	393.873	393.940	Bare Earth	0.067
BARE07	622496.625	4114627.221	353.113	353.210	Bare Earth	0.097
BARE08	619525.647	4105077.854	366.568	366.700	Bare Earth	0.132
BARE09	653552.862	4097759.286	344.458	344.500	Bare Earth	0.042
BARE10	668455.146	4143077.509	383.779	383.800	Bare Earth	0.021
BARE11	668932.996	4122146.063	355.266	355.290	Bare Earth	0.024
BARE12	689875.421	4102617.824	372.502	372.480	Bare Earth	-0.022
BARE13	685520.785	4135462.773	390.535	390.420	Bare Earth	-0.115
BARE14	704616.313	4131646.356	381.092	380.990	Bare Earth	-0.102
BARE15	704130.697	4126530.487	369.625	369.540	Bare Earth	-0.085
BARE16	704130.719	4126530.477	369.653	369.540	Bare Earth	-0.113
BARE17	596546.202	4117223.386	405.412	405.520	Bare Earth	0.108
BARE18	606079.678	4128727.728	389.440	389.510	Bare Earth	0.070
BARE19	625695.073	4117929.807	366.576	366.610	Bare Earth	0.034
BARE20	709404.781	4108577.202	410.347	410.380	Bare Earth	0.033
BARE21	599942.192	4109304.745	387.775	387.890	Bare Earth	0.115
BARE22	598770.782	4107641.595	381.743	381.810	Bare Earth	0.067
BARE23	604891.040	4101368.672	375.593	375.500	Bare Earth	-0.093
BARE24	603293.874	4102934.239	363.820	363.770	Bare Earth	-0.050
BARE25	604865.690	4104550.237	371.360	371.430	Bare Earth	0.070
BARE26	516671.080	4134238.877	501.793	501.770	Bare Earth	-0.023
BARE27	510722.868	4126137.168	563.685	563.620	Bare Earth	-0.065
BARE28	517746.835	4126167.100	503.136	503.110	Bare Earth	-0.026
BARE29	532990.729	4143956.944	555.073	555.110	Bare Earth	0.037
BARE30	547773.453	4118318.085	472.589	472.530	Bare Earth	-0.059
BARE31	531066.576	4107709.993	468.872	468.820	Bare Earth	-0.052
BARE32	573301.510	4124948.176	435.057	435.020	Bare Earth	-0.037
BARE33	593942.856	4128481.535	420.374	420.310	Bare Earth	-0.064
BARE34	603248.887	4106146.397	376.736	376.810	Bare Earth	0.074
BARE35	636103.612	4136211.677	391.809	391.740	Bare Earth	-0.069
BARE36	617285.013	4137065.669	432.547	432.420	Bare Earth	-0.127
BARE37	652780.214	4129246.434	380.660	380.600	Bare Earth	-0.060
BARE38	629293.100	4099623.741	345.359	345.380	Bare Earth	0.021

BARE39	658731.436	4114011.311	351.607	351.530	Bare Earth	-0.077
BARE40	693141.110	4116149.744	396.191	396.250	Bare Earth	0.059
BARE41	622599.174	4109781.534	354.447	354.460	Bare Earth	0.013
BARE42	702419.696	4141883.471	434.691	434.570	Bare Earth	-0.121
BARE43	708907.878	4098897.167	359.705	359.600	Bare Earth	-0.105
BARE44	707017.520	4136233.960	389.045	389.030	Bare Earth	-0.015
BARE45	697726.745	4124276.150	414.089	414.010	Bare Earth	-0.079
BARE46	710799.760	4115034.282	432.448	432.460	Bare Earth	0.012
BARE47	711146.433	4102204.104	376.954	377.070	Bare Earth	0.116
BARE48	686431.730	4099117.187	320.889	320.940	Bare Earth	0.051
BARE49	701402.494	4097176.960	399.118	399.210	Bare Earth	0.092
BARE50	598194.862	4122101.755	404.246	404.290	Bare Earth	0.044
BARE51	635819.326	4115029.138	367.468	367.350	Bare Earth	-0.118
BARE52	606030.867	4109414.751	382.486	382.380	Bare Earth	-0.106
BARE53	520147.140	4132371.517	483.179	483.150	Bare Earth	-0.029
OT01	527148.635	4102128.981	453.905	454.010	Open Terrain	0.105
OT02	569084.641	4122392.622	443.931	443.800	Open Terrain	-0.131
OT03	642966.233	4138932.134	391.962	391.990	Open Terrain	0.028
OT04	649400.590	4126845.812	368.556	368.540	Open Terrain	-0.016
OT05	622510.080	4113727.966	359.012	359.080	Open Terrain	0.068
OT06	621167.920	4101720.749	360.131	360.260	Open Terrain	0.129
OT07	651876.176	4100954.382	345.912	345.980	Open Terrain	0.068
OT08	666869.797	4143023.395	381.074	381.140	Open Terrain	0.066
OT09	668902.001	4123085.415	357.130	357.160	Open Terrain	0.030
OT10	667236.818	4124086.720	355.009	355.120	Open Terrain	0.111
OT11	687786.665	4102328.486	326.794	326.760	Open Terrain	-0.034
OT12	688090.248	4116026.590	383.349	383.360	Open Terrain	0.011
OT13	705922.875	4132537.753	395.773	395.650	Open Terrain	-0.123
OT14	648404.734	4111242.251	374.914	374.810	Open Terrain	-0.104
OT15	631766.432	4134191.168	385.766	385.650	Open Terrain	-0.116
OT16	600712.001	4107701.172	381.668	381.770	Open Terrain	0.102
OT17	606025.335	4102972.475	362.123	362.070	Open Terrain	-0.053
OT18	604036.935	4107766.342	382.269	382.220	Open Terrain	-0.049
OT19	510522.860	4135537.627	503.049	503.050	Open Terrain	0.001
OT20	505902.690	4126085.804	613.310	613.250	Open Terrain	-0.060
OT21	534499.888	4138398.983	497.638	497.650	Open Terrain	0.012
OT22	529597.616	4100485.673	454.714	454.700	Open Terrain	-0.014
OT23	552644.103	4119934.297	444.333	444.340	Open Terrain	0.007
OT24	510703.188	4121730.938	612.749	612.730	Open Terrain	-0.019
OT25	523298.471	4111788.785	491.708	491.730	Open Terrain	0.022
OT26	571327.886	4116874.079	436.034	435.940	Open Terrain	-0.094
OT27	601650.053	4109295.502	386.839	386.930	Open Terrain	0.091

OT28	630090.432	4138569.254	397.152	397.080	Open Terrain	-0.072
OT29	648325.257	4133201.112	396.739	396.680	Open Terrain	-0.059
OT30	662490.326	4123314.245	348.566	348.500	Open Terrain	-0.066
OT31	697522.580	4143058.962	430.694	430.630	Open Terrain	-0.064
OT32	674517.325	4109354.656	353.275	353.300	Open Terrain	0.025
OT33	704137.865	4129229.386	382.096	382.040	Open Terrain	-0.056
OT34	695828.245	4108683.825	369.952	369.970	Open Terrain	0.018
OT35	710817.118	4113130.643	412.902	412.910	Open Terrain	0.008
OT36	711110.522	4104288.987	383.470	383.500	Open Terrain	0.030
OT37	700935.089	4100228.557	402.949	402.950	Open Terrain	0.001
OT38	604625.804	4112645.453	388.937	388.990	Open Terrain	0.053
OT39	653227.548	4112771.047	368.477	368.400	Open Terrain	-0.077
OT40	648404.743	4111242.255	374.909	374.810	Open Terrain	-0.099
OT41	517961.300	4096022.617	482.344	482.360	Open Terrain	0.016
OT42	528461.990	4142408.492	529.914	529.960	Open Terrain	0.046
OT43	513300.617	4126066.108	568.191	568.130	Open Terrain	-0.061
OT44	520758.281	4096688.806	487.393	487.350	Open Terrain	-0.043
UB01	643013.845	4137438.764	395.865	395.900	Urban Terrain	0.035
UB02	644290.832	4126574.421	379.164	379.270	Urban Terrain	0.106
UB03	623353.052	4099986.476	349.020	349.140	Urban Terrain	0.120
UB04	653429.145	4102636.331	349.341	349.440	Urban Terrain	0.099
UB05	666418.347	4139310.891	391.879	391.920	Urban Terrain	0.041
UB06	686337.061	4102298.032	347.490	347.480	Urban Terrain	-0.010
UB07	686304.608	4132258.617	386.505	386.370	Urban Terrain	-0.135
UB08	697418.294	4138331.331	422.778	422.690	Urban Terrain	-0.088
UB09	706827.798	4132632.316	386.298	386.240	Urban Terrain	-0.058
UB10	700988.461	4124382.502	394.265	394.160	Urban Terrain	-0.105
UB11	643104.548	4125004.561	366.263	366.150	Urban Terrain	-0.113
UB12	642687.395	4128192.016	381.614	381.490	Urban Terrain	-0.124
UB13	507460.096	4136939.796	511.862	511.840	Urban Terrain	-0.022
UB14	568427.977	4122459.721	444.076	443.990	Urban Terrain	-0.086
UB15	589746.522	4129998.600	432.429	432.370	Urban Terrain	-0.059
UB16	643005.871	4137433.303	396.475	396.350	Urban Terrain	-0.125
UB17	644262.003	4126587.649	379.686	379.560	Urban Terrain	-0.126
UB18	623364.545	4099968.235	348.784	348.850	Urban Terrain	0.066
UB19	675381.185	4123116.436	353.879	353.740	Urban Terrain	-0.139
UB20	675642.797	4105332.338	330.776	330.700	Urban Terrain	-0.076
UB21	674357.021	4102246.807	327.116	327.110	Urban Terrain	-0.006
UB22	700211.687	4109553.069	378.709	378.750	Urban Terrain	0.041
UB23	642016.674	4108817.265	356.644	356.540	Urban Terrain	-0.104

Table 11: Bare-Earth Surface NVA Assessment

Vegetated Vertical Accuracy (VVA) Check Point Assessment (DEM)						
PointID	Easting	Northing	KnownZ	LaserZ	Description	DeltaZ
HG01	532016.198	4140159.152	520.012	520.100	High Grass	0.088
HG02	531997.069	4141504.401	537.301	537.460	High Grass	0.159
HG03	509119.353	4104676.583	521.633	521.470	High Grass	-0.163
HG04	506530.211	4104608.217	510.686	510.790	High Grass	0.104
HG05	585097.192	4126410.999	435.084	435.070	High Grass	-0.014
HG06	639698.762	4139348.393	387.351	387.460	High Grass	0.109
HG07	639702.767	4139350.991	387.356	387.520	High Grass	0.164
HG08	651165.737	4127361.573	374.607	374.700	High Grass	0.093
HG09	622593.191	4113056.622	358.044	358.120	High Grass	0.076
HG10	651864.448	4102277.786	349.996	350.080	High Grass	0.084
HG11	668505.432	4142188.777	378.811	378.930	High Grass	0.119
HG12	667370.372	4122140.566	356.755	356.870	High Grass	0.115
HG13	668294.041	4122141.180	355.469	355.620	High Grass	0.151
HG14	689576.144	4102389.860	371.509	371.510	High Grass	0.001
HG15	686278.327	4133273.877	391.245	391.210	High Grass	-0.035
HG16	704699.559	4132230.630	378.679	378.640	High Grass	-0.039
HG17	701000.279	4124389.936	393.511	393.480	High Grass	-0.031
HG18	701353.306	4099432.307	401.914	402.080	High Grass	0.166
HG19	594954.548	4116666.004	401.339	401.280	High Grass	-0.059
HG20	641252.830	4113647.117	372.020	371.910	High Grass	-0.110
HG21	531186.049	4098668.547	451.055	450.980	High Grass	-0.075
HG22	529014.746	4096451.416	446.237	446.270	High Grass	0.033
HG23	528818.487	4098866.269	435.446	435.470	High Grass	0.024
HG24	636694.608	4132922.902	384.084	383.980	High Grass	-0.104
HG25	634233.313	4132655.477	386.151	386.100	High Grass	-0.051
HG26	601560.782	4110929.195	391.205	391.240	High Grass	0.035
HG27	601488.800	4115790.532	404.232	404.100	High Grass	-0.132
HG28	603124.514	4117454.287	402.762	402.780	High Grass	0.018
HG29	604674.915	4115073.545	393.829	393.830	High Grass	0.001
HG30	577174.703	4121734.814	427.597	427.600	High Grass	0.003
HG31	578759.449	4123350.381	435.112	435.030	High Grass	-0.082
HG32	577168.411	4124952.940	440.180	440.250	High Grass	0.070
HG33	572251.248	4128151.804	449.901	449.760	High Grass	-0.141
HG34	651279.048	4123593.640	353.994	353.960	High Grass	-0.034
HG35	648131.364	4121889.988	364.426	364.340	High Grass	-0.086
HG36	644866.171	4124228.147	373.851	373.850	High Grass	-0.001
HG37	620046.793	4117799.271	365.000	365.020	High Grass	0.020
HG38	515078.559	4138193.226	537.314	537.290	High Grass	-0.024
HG39	515806.004	4129565.882	508.521	508.580	High Grass	0.059
HG40	536061.297	4140013.370	527.405	527.400	High Grass	-0.005

HG41	547965.334	4121422.370	449.524	449.620	High Grass	0.096
HG42	529416.090	4110252.400	455.743	455.710	High Grass	-0.033
HG43	506906.263	4118222.470	612.805	612.710	High Grass	-0.095
HG44	575568.933	4121139.595	426.002	425.980	High Grass	-0.022
HG45	611172.678	4106317.532	368.330	368.250	High Grass	-0.080
HG46	651007.371	4138134.437	364.439	364.370	High Grass	-0.069
HG47	641539.927	4132988.031	386.489	386.420	High Grass	-0.069
HG48	638147.109	4139048.931	390.858	390.750	High Grass	-0.108
HG49	653109.226	4125256.653	362.692	362.680	High Grass	-0.012
HG50	626001.714	4103550.240	357.402	357.520	High Grass	0.118
HG51	654329.264	4107484.676	375.760	375.660	High Grass	-0.100
HG52	686739.150	4105457.496	375.751	375.830	High Grass	0.079
HG53	667437.919	4118917.414	344.971	345.020	High Grass	0.049
HG54	672337.417	4117396.078	354.682	354.660	High Grass	-0.022
HG55	688078.207	4117641.403	386.602	386.710	High Grass	0.108
HG56	678057.164	4111034.475	358.494	358.410	High Grass	-0.084
HG57	703063.204	4108389.013	396.196	396.230	High Grass	0.034
HG58	713964.785	4109784.766	337.931	338.010	High Grass	0.079
HG59	688137.086	4125687.325	405.871	405.810	High Grass	-0.061
HG60	672337.414	4117396.082	354.696	354.670	High Grass	-0.026
HG61	677847.905	4105342.306	346.746	346.740	High Grass	-0.006
HG62	703263.195	4101946.437	383.600	383.750	High Grass	0.150
HG63	643776.287	4112116.815	373.906	373.830	High Grass	-0.076
HG64	593199.820	4125829.064	413.065	413.090	High Grass	0.025
LT01	532002.678	4140326.052	523.973	524.130	Low Trees	0.157
LT02	507225.939	4104831.919	487.743	487.860	Low Trees	0.117
LT03	584252.307	4125056.824	432.776	432.930	Low Trees	0.154
LT04	562617.885	4105574.378	392.819	392.920	Low Trees	0.101
LT05	646424.845	4126782.390	378.618	378.700	Low Trees	0.082
LT06	653481.978	4099363.957	337.061	337.150	Low Trees	0.089
LT07	668622.415	4140039.313	369.827	369.700	Low Trees	-0.127
LT08	706669.599	4132883.276	399.745	399.730	Low Trees	-0.015
LT09	583912.891	4105730.208	405.812	405.960	Low Trees	0.148
LT10	531333.890	4096524.504	434.489	434.570	Low Trees	0.081
LT11	522854.314	4095713.887	483.035	483.170	Low Trees	0.135
LT12	632941.105	4135824.531	396.153	396.110	Low Trees	-0.043
LT13	607269.950	4114284.078	384.140	384.040	Low Trees	-0.100
LT14	575554.021	4123437.871	438.132	438.110	Low Trees	-0.022
LT15	575511.227	4126549.808	449.822	449.830	Low Trees	0.008
LT16	575480.251	4128149.290	457.982	457.920	Low Trees	-0.062
LT17	570687.453	4126525.498	443.069	443.040	Low Trees	-0.029
LT18	573017.838	4126571.063	448.581	448.560	Low Trees	-0.021

LT19	650498.760	4122015.096	354.113	354.010	Low Trees	-0.103
LT20	644902.381	4122630.088	365.665	365.690	Low Trees	0.025
LT21	513661.999	4134788.527	495.057	495.040	Low Trees	-0.017
LT22	535851.265	4136847.552	497.771	497.860	Low Trees	0.089
LT23	552230.398	4124767.957	453.004	452.970	Low Trees	-0.034
LT24	527057.921	4109501.741	466.350	466.310	Low Trees	-0.040
LT25	590513.464	4126809.379	422.156	422.130	Low Trees	-0.026
LT26	609628.311	4111735.112	371.818	371.950	Low Trees	0.132
LT27	648077.959	4124615.920	375.068	375.020	Low Trees	-0.048
LT28	667960.719	4126997.117	359.632	359.650	Low Trees	0.018
LT29	667960.719	4126997.117	359.633	359.650	Low Trees	0.017
LT30	677929.604	4114128.386	344.969	344.990	Low Trees	0.021
LT31	701862.934	4113155.045	366.966	366.990	Low Trees	0.024
LT32	704892.519	4098938.078	375.917	375.880	Low Trees	-0.037
LT33	589037.741	4121896.152	434.963	435.070	Low Trees	0.107
LT34	568343.577	4119262.151	425.068	425.160	Low Trees	0.092
LT35	606853.900	4104621.854	367.754	367.730	Low Trees	-0.024
LT36	531662.056	4109519.166	449.457	449.450	Low Trees	-0.007

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 (HARN), UTM Zone 14N, 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	44	-0.131	0.129	0.056	0.001	0.114	0.068	0.067
Urban Terrain	23	-0.139	0.120	0.082	-0.059	0.543	0.085	0.091
Bare Earth	53	-0.127	0.132	0.070	0.013	-0.063	0.079	0.078
High Grass	64	-0.163	0.166	0.070	-0.003	0.159	0.085	0.084
Low Trees	36	-0.127	0.157	0.065	0.013	0.154	0.078	0.081
Consolidated	220	-0.163	0.166	0.068	-0.006	0.130	0.080	0.080

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	44	0.132		
Urban Terrain	23			0.105
Bare Earth	53			0.115
High Grass	64			0.151
Low Trees	36			0.150
Consolidated	220		0.129	

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	120	0.078	0.154	
NVA of DEM	120	0.077	0.151	
VVA of DEM	100	0.083		0.151

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
Bare Earth/Open Terrain	0.132	0.105	FVA	0.151	NVA
Urban Terrain	0.179	0.105	SVA		
Brush	0.153	0.115	SVA		
High Grass	0.165	0.151	SVA	0.151	VVA
Low Trees	0.158	0.150	SVA		
Consolidated	0.156	0.129	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 the **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 Meters.

Average Magnitudes Per Line											
Line	X	Y	Z	Line	X	Y	Z	Line	X	Y	Z
11	0.020	0.001	0.011	102	0.031	0.091	0.013	222	0.009	0.013	0.011
12	0.022	0.036	0.015	103	0.020	0.045	0.014	223	0.011	0.022	0.013
13	0.027	0.041	0.012	104	0.027	0.003	0.014	224	0.017	0.029	0.011
14	0.028	0.038	0.015	105	0.025	0.041	0.013	227	0.006	0.016	0.013
15	0.013	0.020	0.012	106	0.020	0.004	0.013	228	0.008	0.014	0.012
16	0.009	0.015	0.014	107	0.019	0.028	0.014	229	0.010	0.017	0.011
18	0.009	0.027	0.013	108	0.018	0.070	0.012	230	0.008	0.022	0.011
19	0.014	0.027	0.012	109	0.023	0.036	0.012	231	0.007	0.012	0.010
20	0.019	0.027	0.014	110	0.028	0.022	0.012	232	0.008	0.009	0.010
23	0.012	0.019	0.012	111	0.012	0.030	0.012	233	0.009	0.009	0.011
24	0.018	0.028	0.011	112	0.016	0.032	0.012	234	0.010	0.010	0.011
25	0.024	0.029	0.012	114	0.013	0.011	0.012	235	0.012	0.018	0.011
26	0.025	0.029	0.012	115	0.013	0.013	0.011	238	0.049	0.031	0.014
27	0.028	0.040	0.011	116	0.024	0.049	0.011	239	0.028	0.027	0.011
28	0.019	0.035	0.012	117	0.019	0.048	0.012	240	0.010	0.031	0.012
29	0.020	0.032	0.011	118	0.022	0.040	0.012	241	0.010	0.010	0.010
30	0.024	0.038	0.013	119	0.013	0.011	0.012	242	0.013	0.022	0.012
31	0.022	0.043	0.013	120	0.013	0.013	0.012	243	0.012	0.020	0.011
32	0.019	0.041	0.013	121	0.014	0.052	0.012	244	0.011	0.022	0.011
33	0.020	0.055	0.011	122	0.049	0.022	0.012	248	0.032	0.025	0.015
35	0.025	0.049	0.012	124	0.007	0.013	0.012	249	0.027	0.025	0.013
36	0.032	0.043	0.013	125	0.008	0.016	0.014	250	0.034	0.031	0.013
37	0.019	0.042	0.011	126	0.021	0.006	0.013	251	0.025	0.052	0.011
38	0.017	0.044	0.011	127	0.031	0.006	0.014	252	0.014	0.020	0.012
39	0.010	0.018	0.012	128	0.036	0.039	0.012	253	0.013	0.023	0.012
40	0.013	0.057	0.013	129	0.011	0.019	0.013	254	0.009	0.013	0.012
41	0.009	0.014	0.012	130	0.009	0.024	0.012	255	0.007	0.010	0.011
42	0.013	0.017	0.013	131	0.017	0.042	0.014	258	0.016	0.023	0.013
43	0.023	0.028	0.013	132	0.017	0.025	0.012	259	0.010	0.013	0.012
44	0.030	0.029	0.013	133	0.006	0.032	0.013	260	0.007	0.015	0.014
47	0.010	0.031	0.012	134	0.002	0.044	0.012	261	0.009	0.029	0.012
49	0.014	0.014	0.012	135	0.035	0.017	0.013	262	0.019	0.021	0.013
50	0.023	0.007	0.011	136	0.034	0.025	0.012	263	0.023	0.009	0.012
51	0.017	0.010	0.012	137	0.001	0.048	0.014	264	0.034	0.034	0.010

52	0.026	0.037	0.011	139	0.035	0.066	0.011	265	0.015	0.038	0.013
54	0.020	0.032	0.011	140	0.038	0.049	0.014	266	0.014	0.035	0.012
55	0.047	0.017	0.015	141	0.030	0.043	0.013	267	0.018	0.031	0.013
57	0.017	0.068	0.012	142	0.025	0.052	0.013	268	0.037	0.000	0.011
58	0.020	0.036	0.012	143	0.031	0.057	0.012	269	0.038	0.000	0.013
59	0.022	0.024	0.011	144	0.036	0.044	0.014	271	-	-	0.016
60	0.020	0.039	0.012	145	0.032	0.041	0.013	276	0.027	0.039	0.015
61	0.015	0.046	0.011	146	0.013	0.048	0.014	277	0.015	0.041	0.012
62	0.007	0.071	0.012	147	0.008	0.042	0.013	278	0.013	0.025	0.011
63	0.008	0.077	0.012	148	0.002	0.038	0.013	279	0.021	0.023	0.012
64	0.029	0.036	0.012	149	0.004	0.043	0.012	280	0.013	0.036	0.012
65	0.016	0.020	0.012	150	0.034	0.063	0.013	281	0.032	0.020	0.013
67	0.017	0.018	0.012	151	0.034	0.061	0.012	282	0.022	0.032	0.011
68	0.014	0.013	0.010	152	-	-	0.014	283	0.000	0.033	0.012
69	0.010	0.014	0.011	155	0.013	0.075	0.017	284	0.013	0.015	0.012
70	0.021	0.028	0.010	156	0.012	0.068	0.014	285	0.034	0.031	0.015
71	0.019	0.032	0.011	157	0.022	0.035	0.014	287	0.009	0.043	0.022
72	0.010	0.020	0.010	158	-	-	0.015	289	0.084	0.002	0.017
73	0.014	0.017	0.012	159	0.046	0.031	0.015	291	0.017	0.023	0.013
74	0.013	0.020	0.011	160	0.053	0.040	0.015	292	0.006	0.025	0.014
75	0.084	0.003	0.013	161	0.031	0.039	0.014	293	0.035	0.040	0.013
77	0.016	0.041	0.012	162	0.014	0.028	0.014	294	0.025	0.031	0.014
78	0.016	0.035	0.014	163	0.009	0.024	0.013	295	0.030	0.018	0.013
79	0.010	0.010	0.012	164	0.010	0.025	0.013	296	0.038	0.031	0.013
80	0.015	0.039	0.013	165	0.014	0.036	0.014	297	0.003	0.050	0.013
81	0.016	0.034	0.012	166	0.029	0.054	0.015	298	0.012	0.039	0.013
82	0.015	0.024	0.013	167	0.027	0.020	0.015	299	0.028	0.011	0.013
83	0.012	0.031	0.012	168	0.026	0.018	0.014	300	0.036	0.009	0.019
84	0.023	0.043	0.013	200	0.008	0.009	0.012	302	0.044	0.001	0.018
85	0.019	0.062	0.012	201	0.009	0.011	0.013	303	0.009	0.038	0.017
86	0.013	0.035	0.012	202	0.010	0.014	0.013	306	0.019	0.005	0.024
87	0.014	0.026	0.015	203	0.011	0.013	0.014	307	0.013	0.015	0.012
88	0.002	0.003	0.010	204	0.013	0.011	0.013	308	0.009	0.027	0.014
89	0.006	0.008	0.012	205	0.016	0.026	0.017	309	0.015	0.029	0.012
90	0.012	0.011	0.019	207	0.031	0.029	0.014	400	0.001	0.002	0.016
92	0.012	0.012	0.017	208	0.017	0.018	0.012	401	0.004	0.000	0.015
93	0.047	0.035	0.012	209	0.018	0.017	0.012	402	-	-	0.015
94	0.035	0.033	0.013	213	0.017	0.044	0.016	403	0.001	0.002	0.015
95	0.016	0.044	0.012	214	0.020	0.040	0.016	404	0.016	0.000	0.013
96	0.016	0.040	0.012	217	0.008	0.026	0.015	405	0.078	0.001	0.014
97	0.026	0.040	0.011	218	0.008	0.011	0.012	406	0.002	0.002	0.015
98	0.026	0.046	0.011	219	0.007	0.010	0.013	407	0.012	0.017	0.012

99	0.024	0.037	0.011	220	0.007	0.009	0.012	408	0.012	0.016	0.010
100	0.021	0.047	0.011	221	0.009	0.011	0.012	409	0.004	0.001	0.014

Table 5: Average Tie Line Magnitudes per Line

Internal Observation Statistics			
Category	X	Y	Z
Average Magnitude	0.013	0.020	0.013
RMS Values	0.023	0.035	0.017
Maximum Values	0.129	0.130	0.157
Observation Weight	23962.0	23962.0	2240654.0

Table 6: Tie Line Observation Statistics

Overall Relative Accuracy	
Category	Mismatch
Average 3D Mismatch	0.01306
Average XY Mismatch	0.03050
Average Z Mismatch	0.01279

Table 7: Relative Accuracy Results

TerraMatch Tie Lines	
Category	Observations
Section Lines	914,420
Roof Lines	11,962

Table 8: Total Tie Lines

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

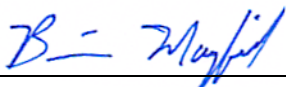
It should also be noted that lidar points do not represent a continuous surface model. Lidar points are discrete measurements of the surface and any values derived within a triangle of three lidar points are interpolated. As such, the user should not use the resultant lidar dataset for vertical placement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

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

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

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

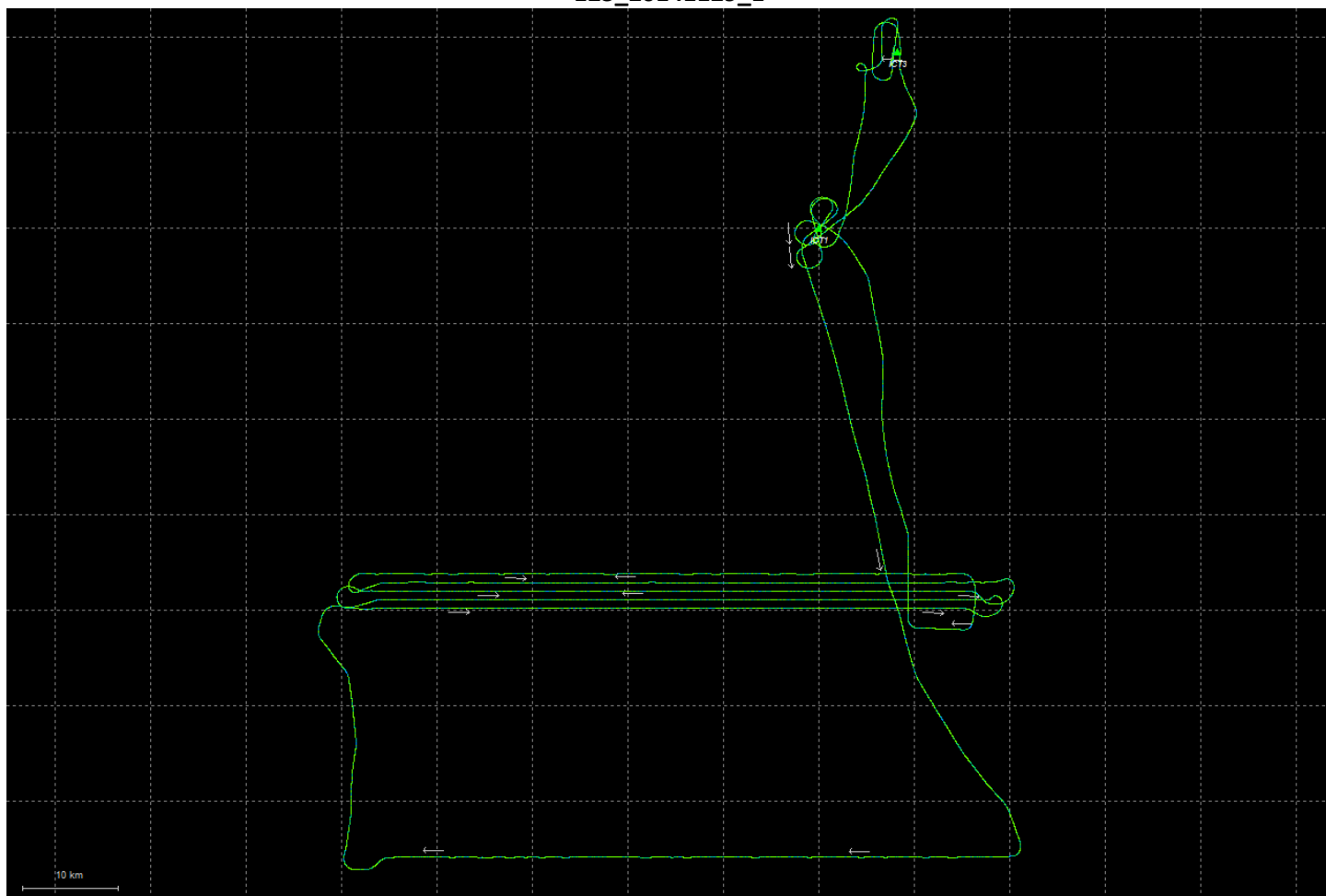


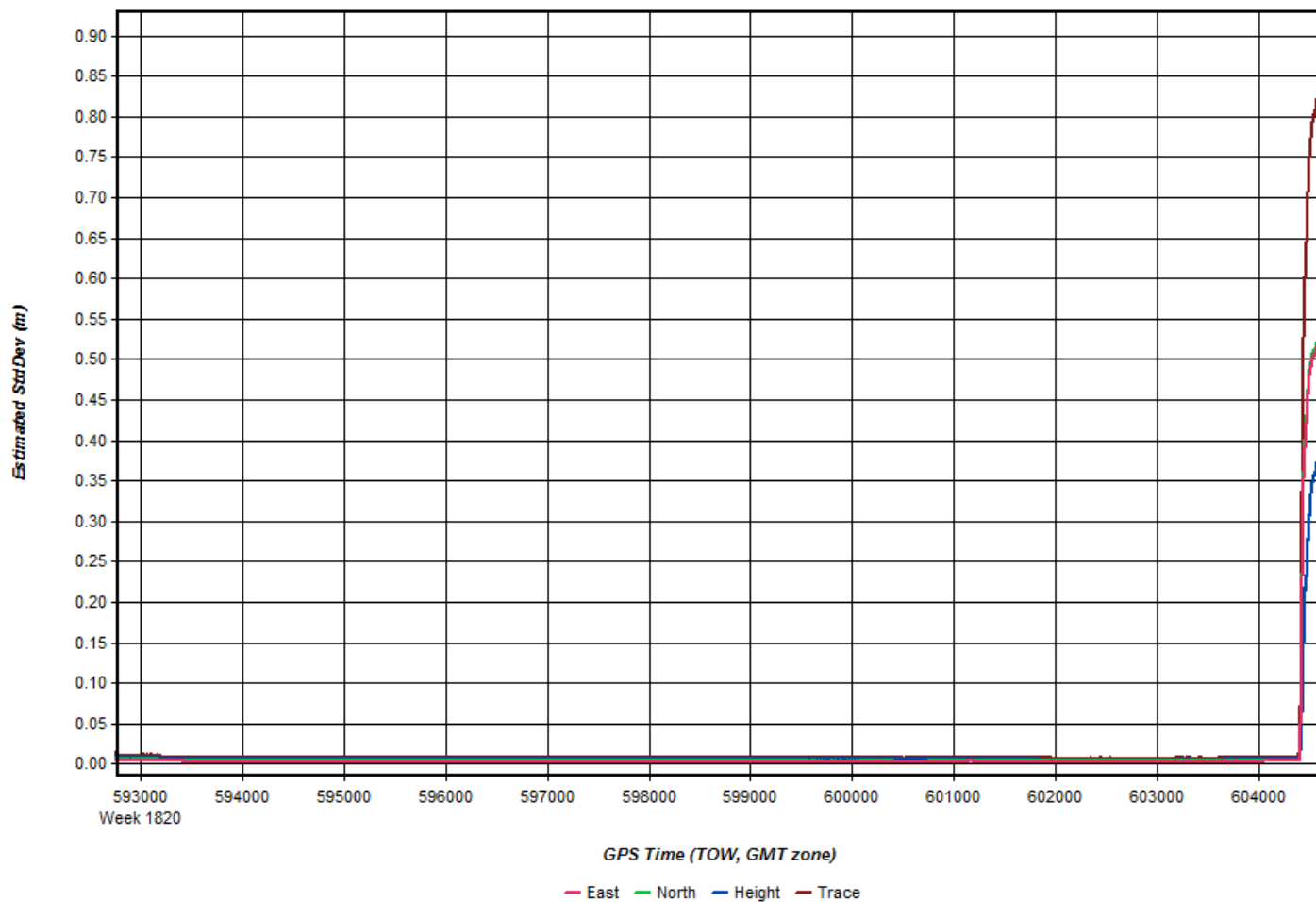
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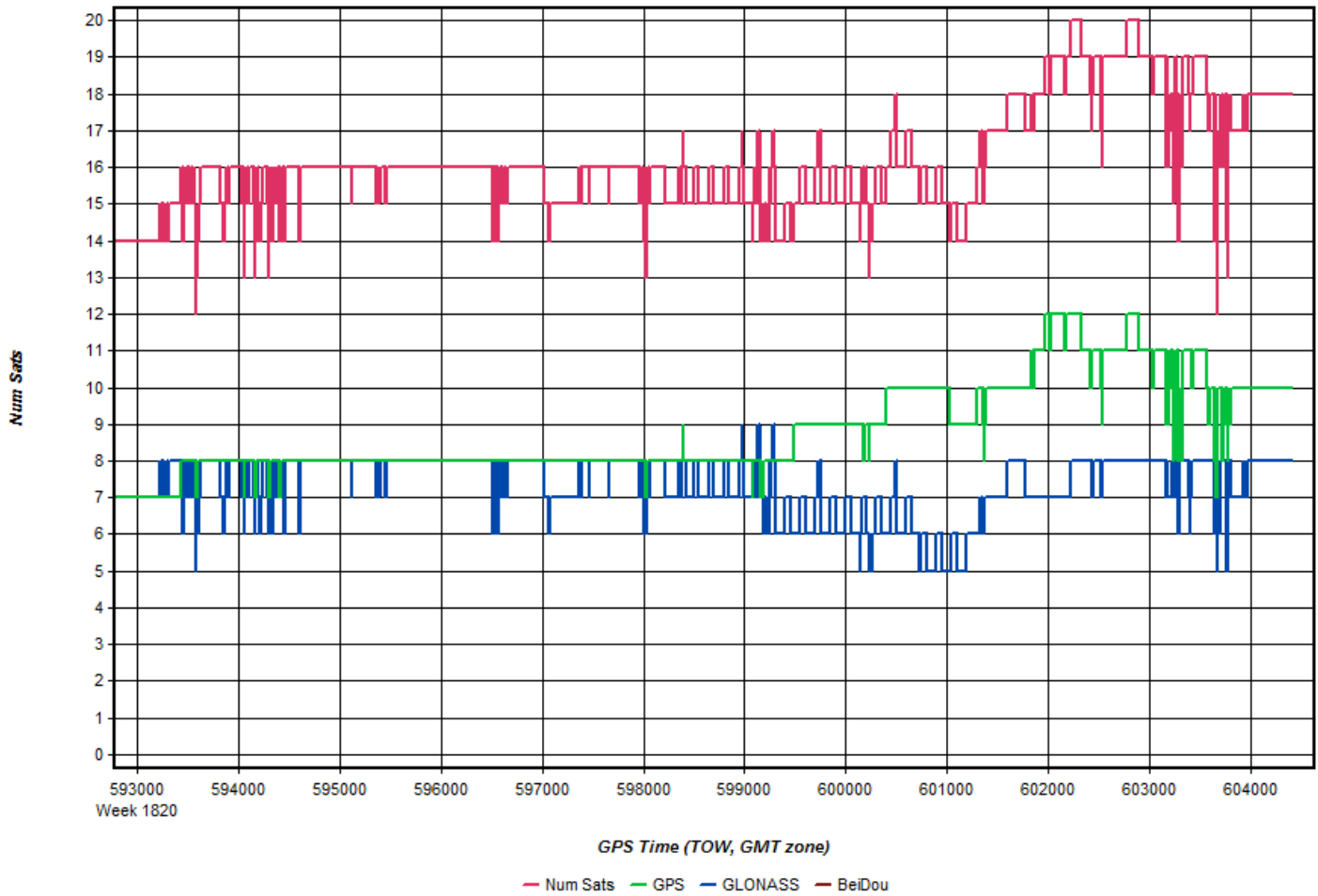
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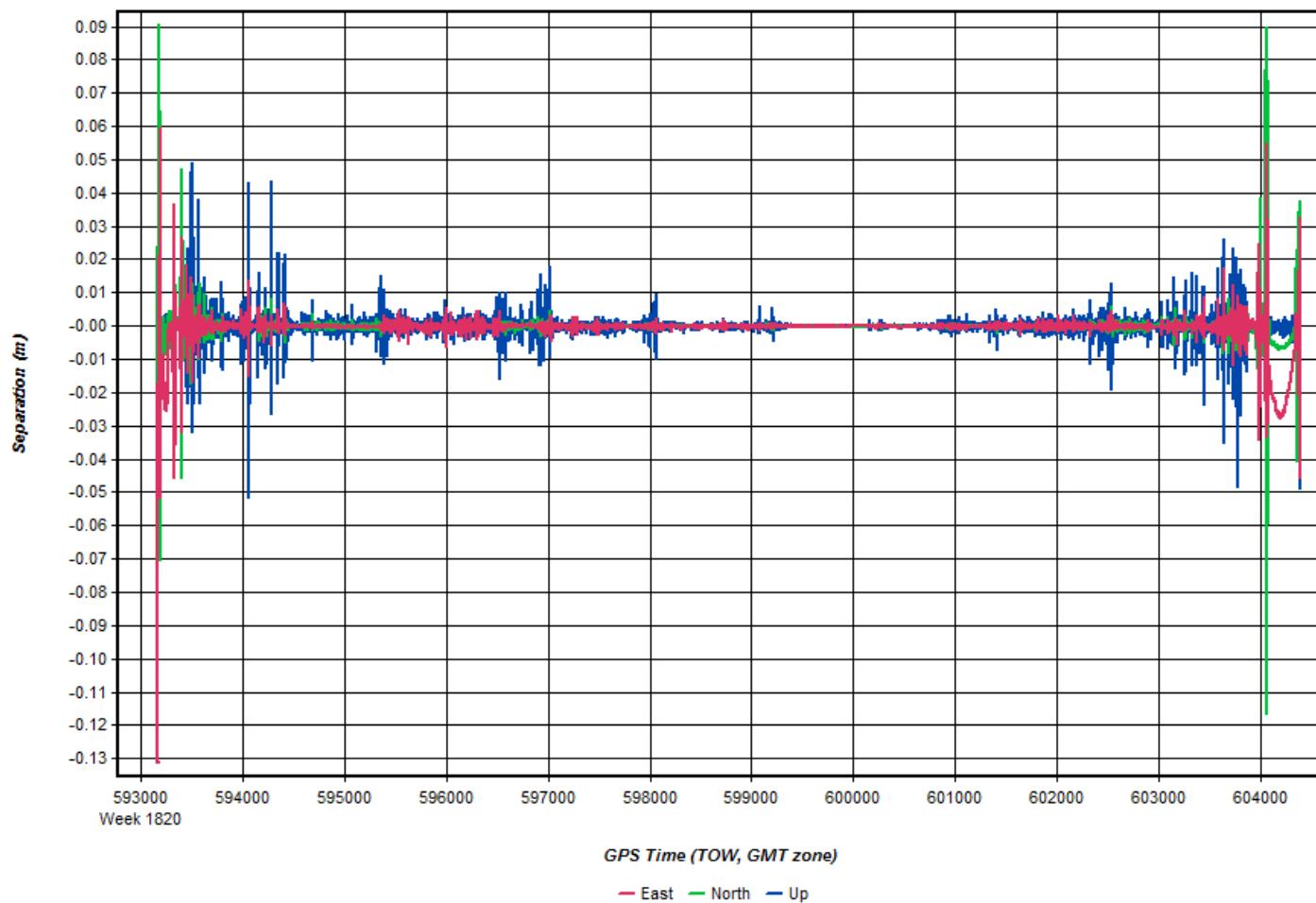
Plots by lift of the Coverage Map, Estimated Position Accuracy, Number of Satellites, Combined Separation, and PDOP.

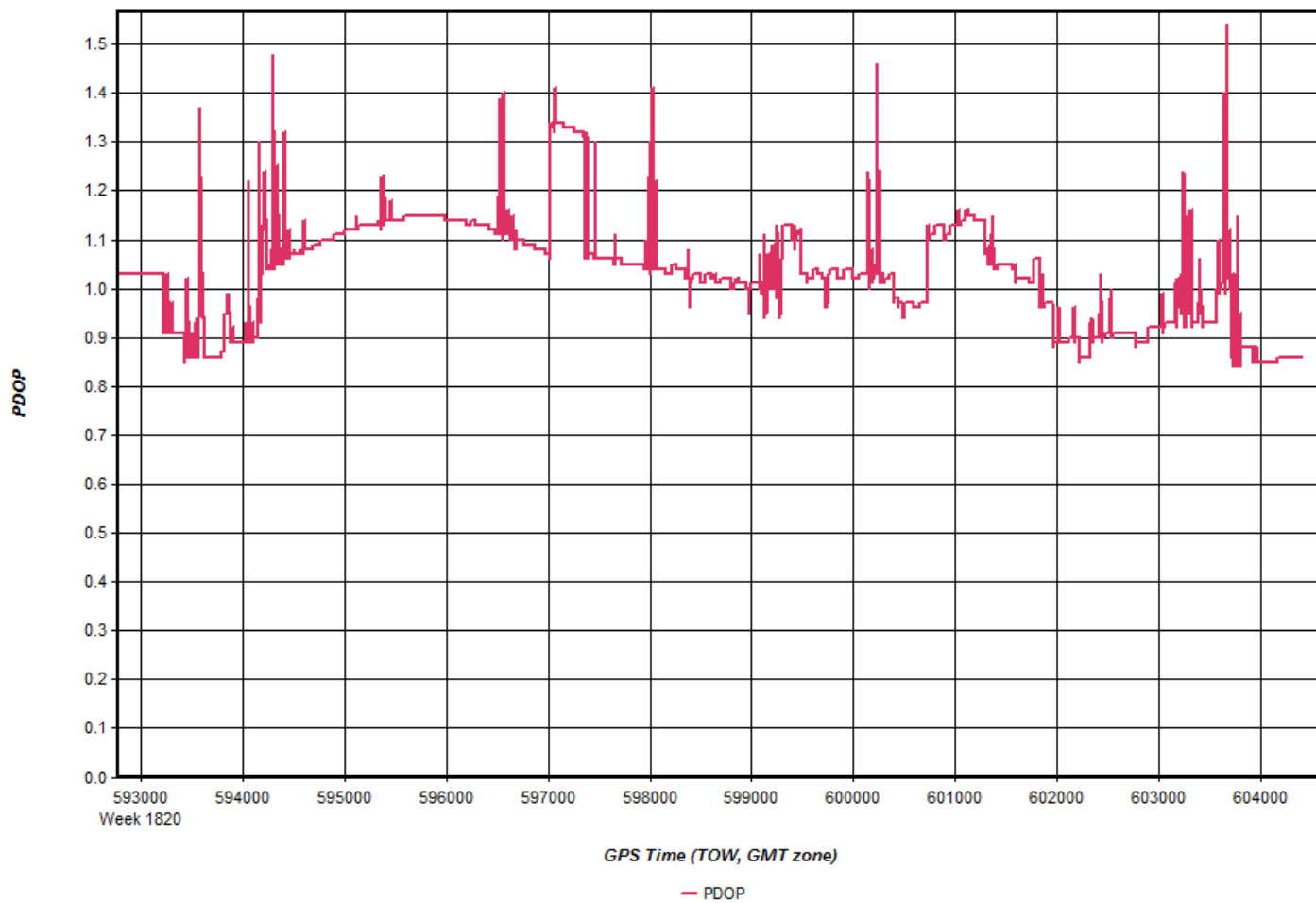
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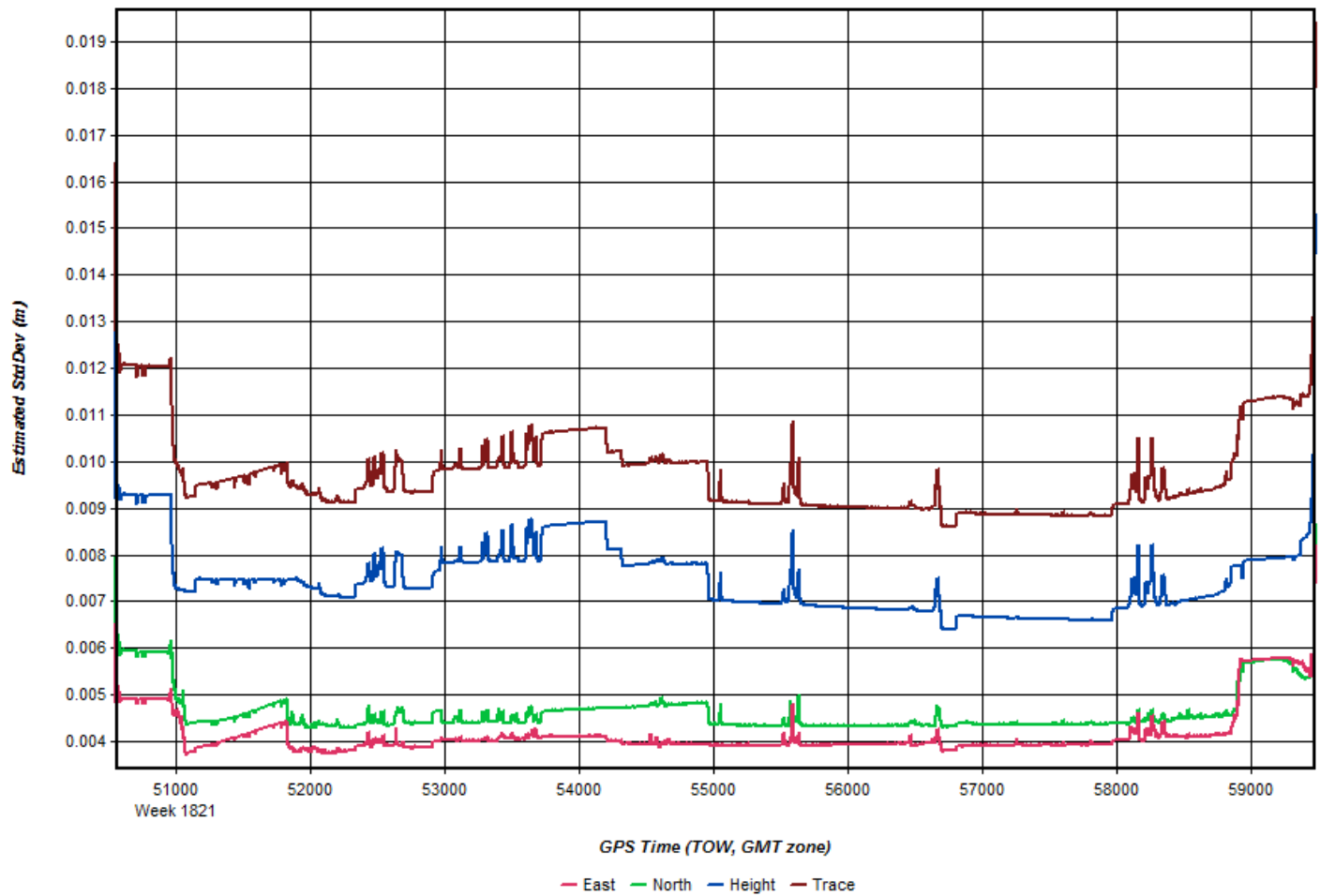


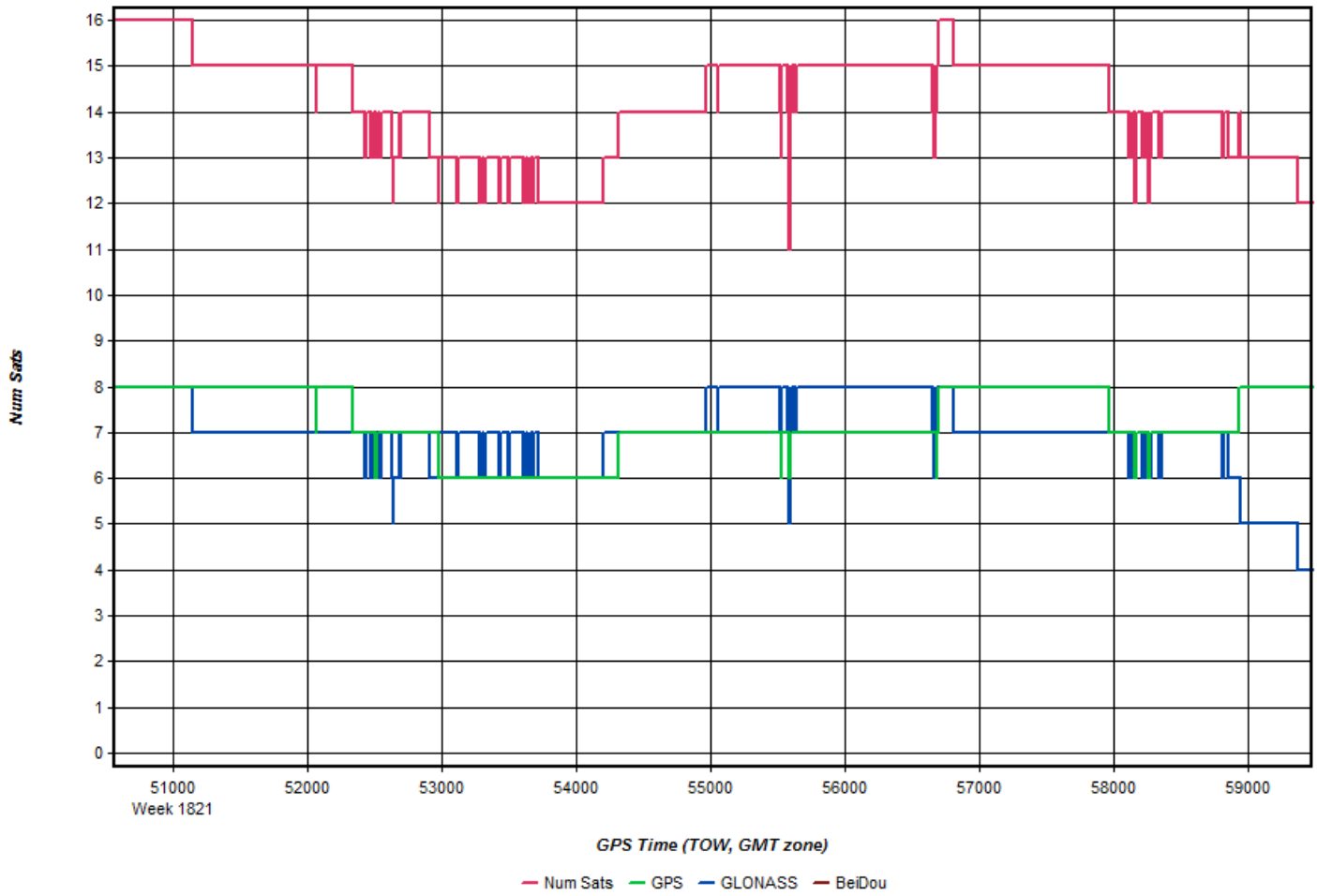


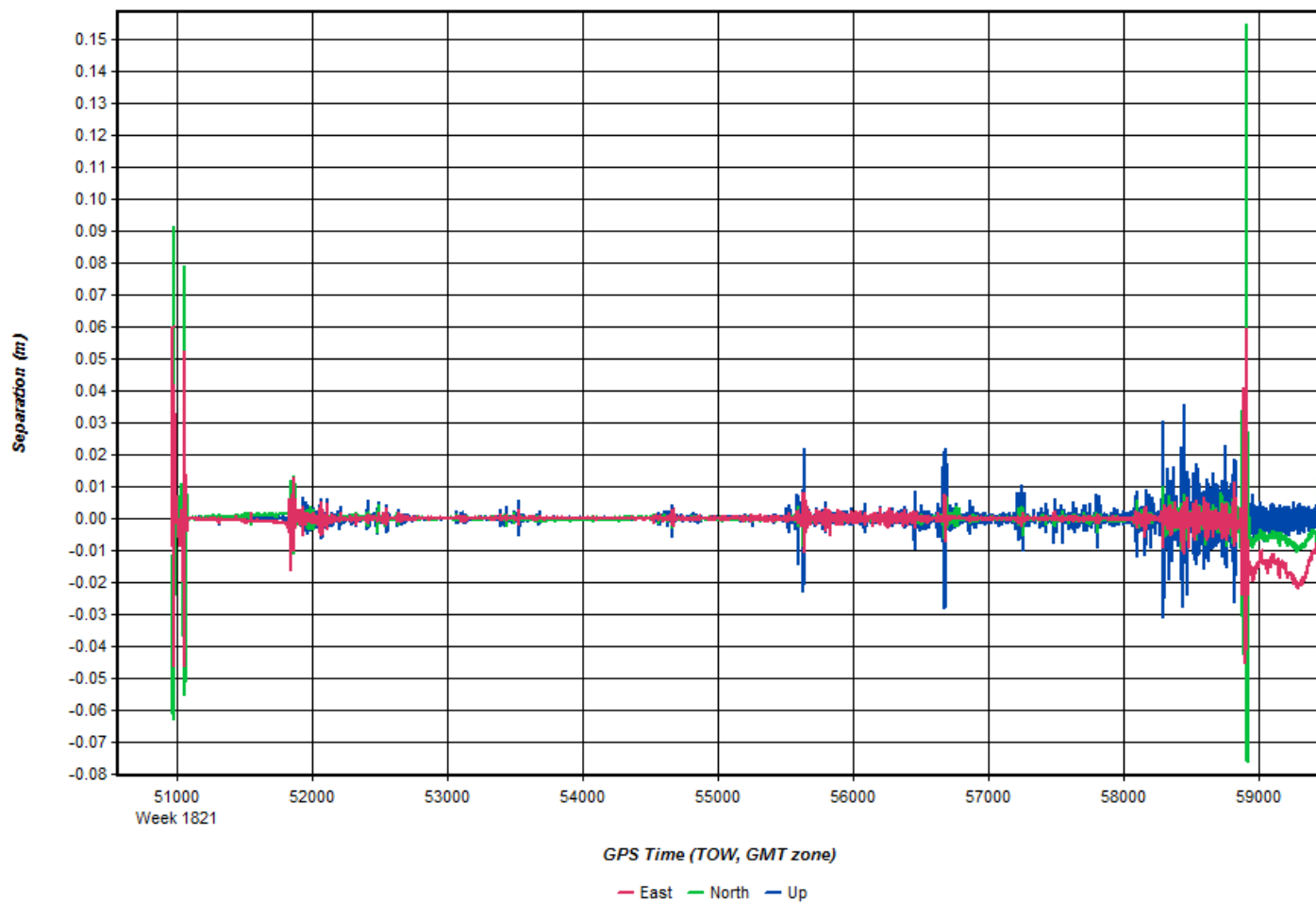


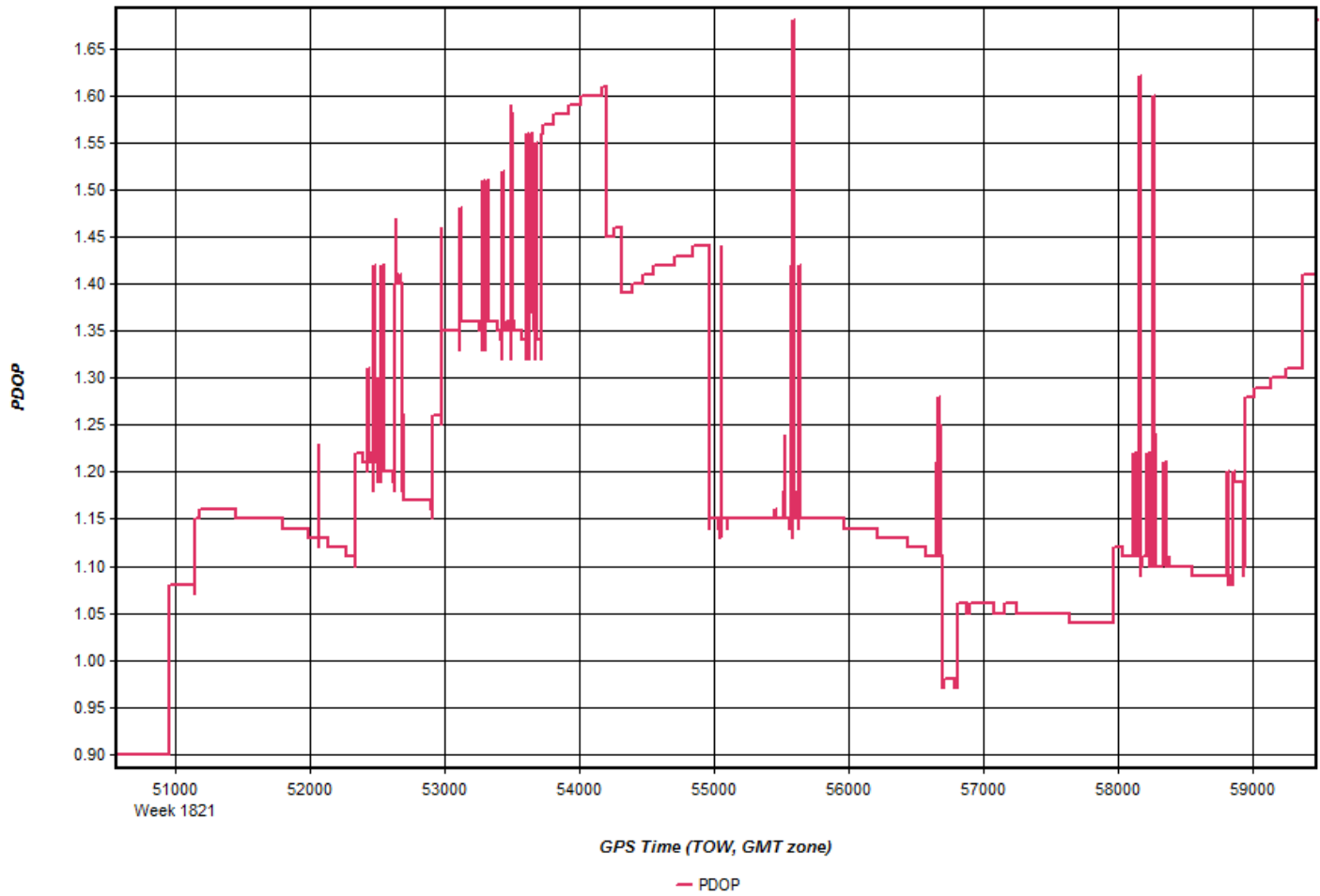
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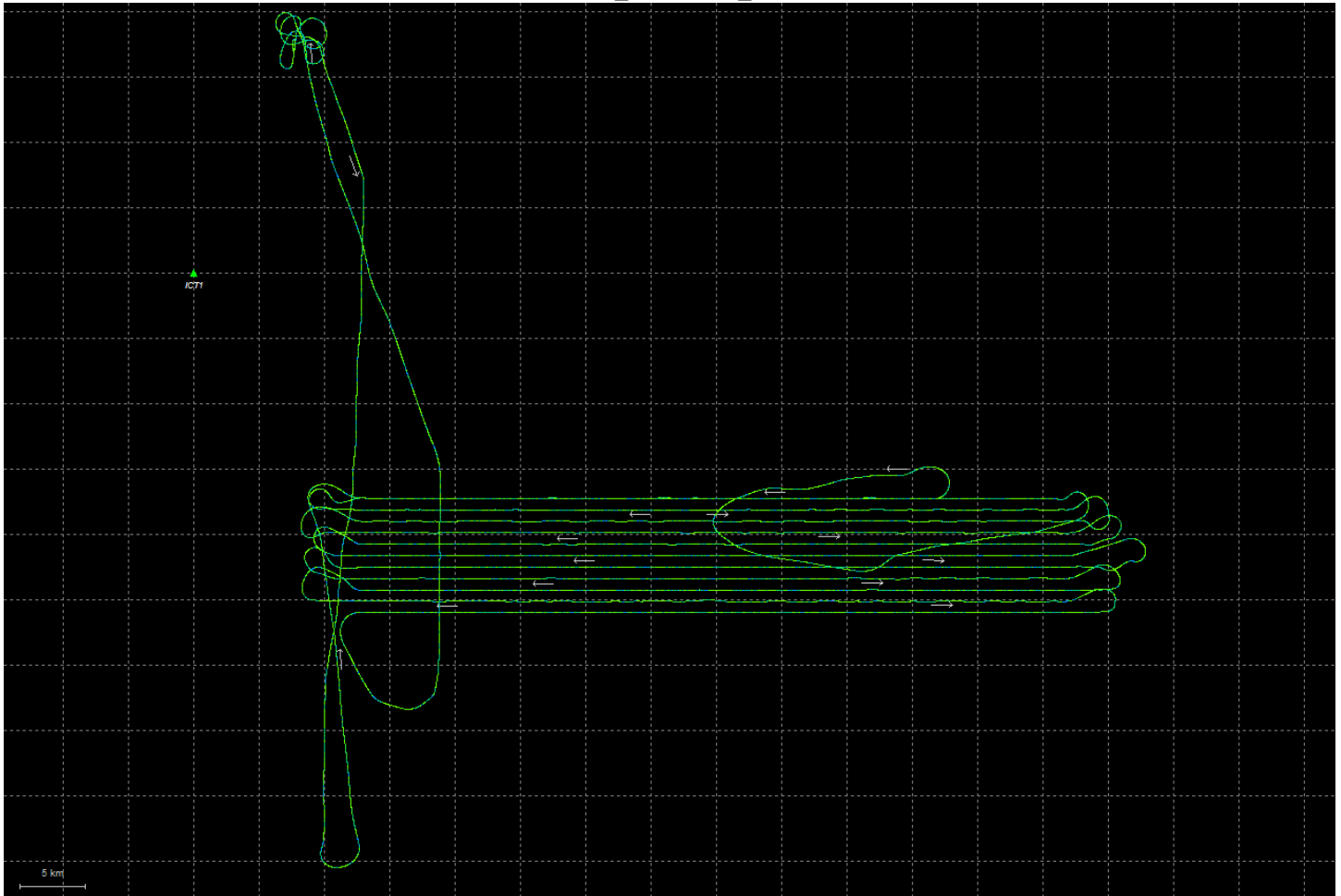


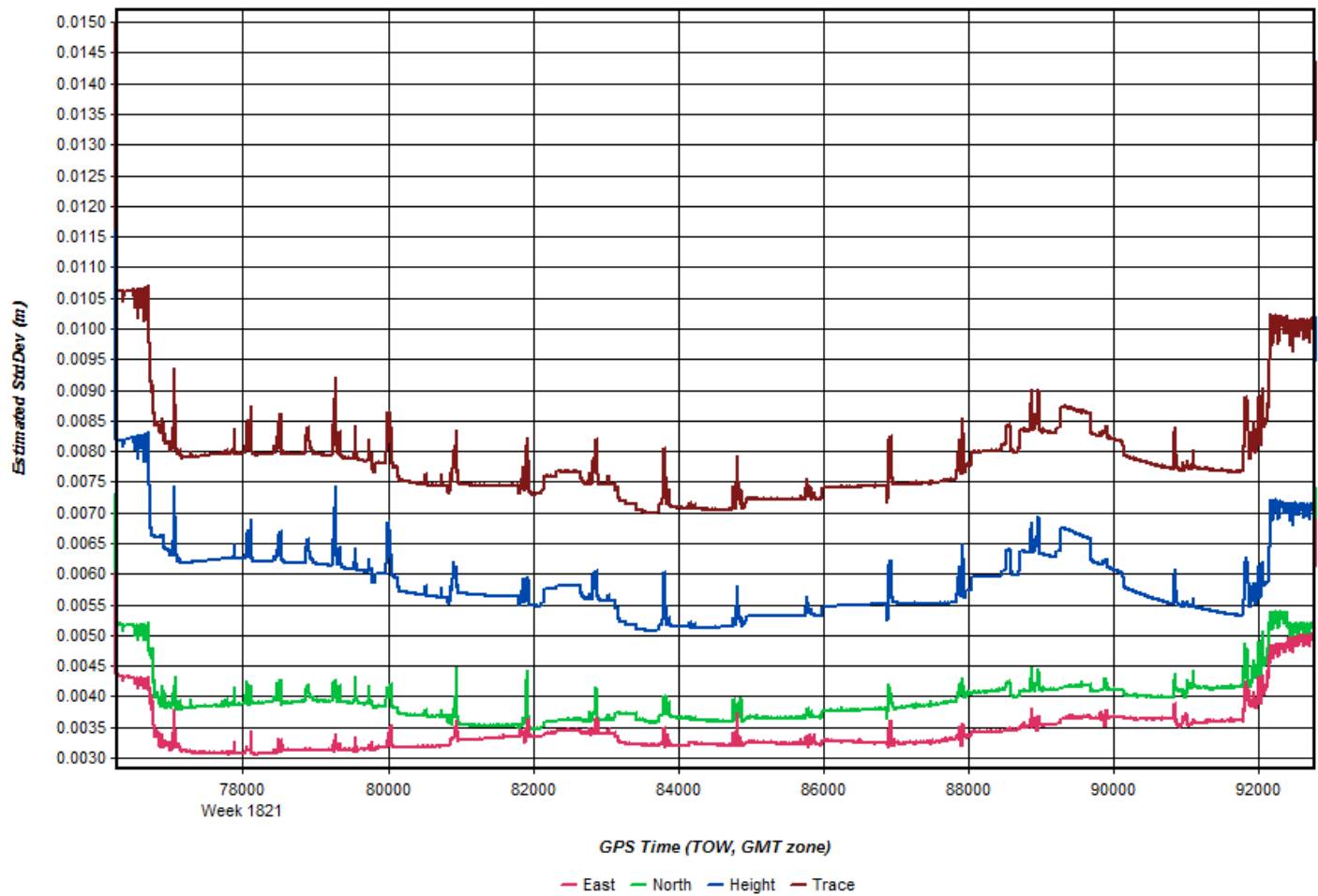


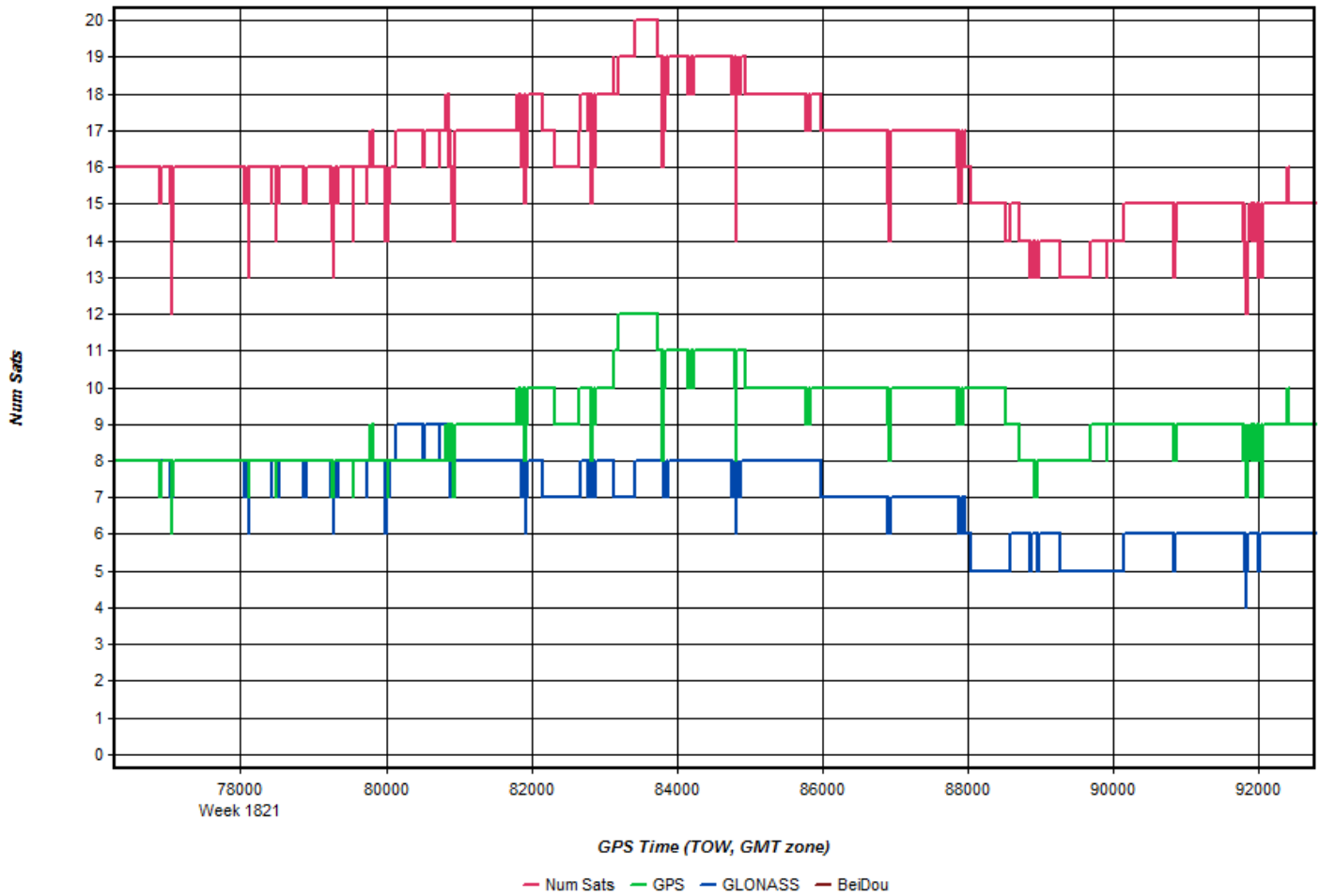


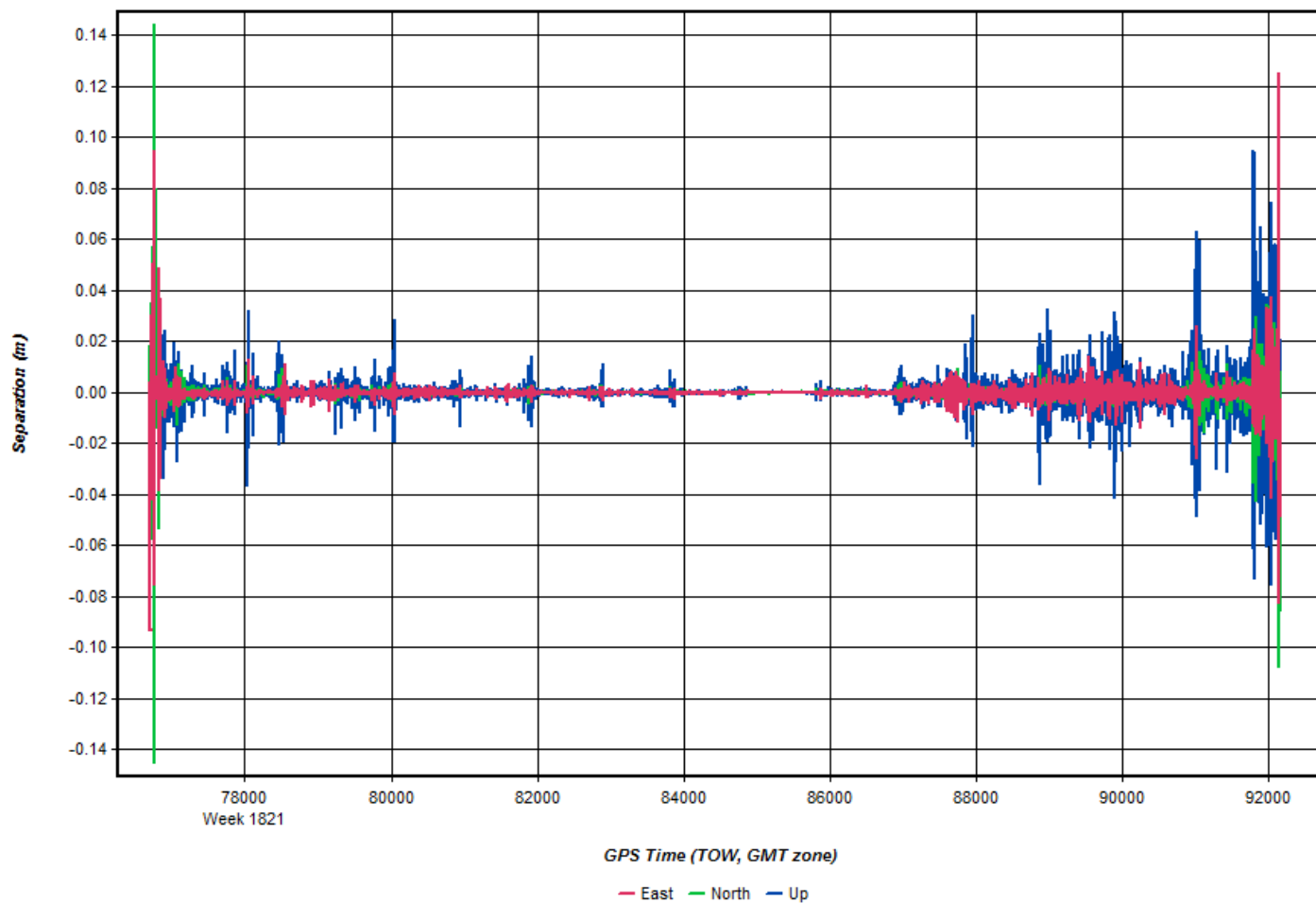


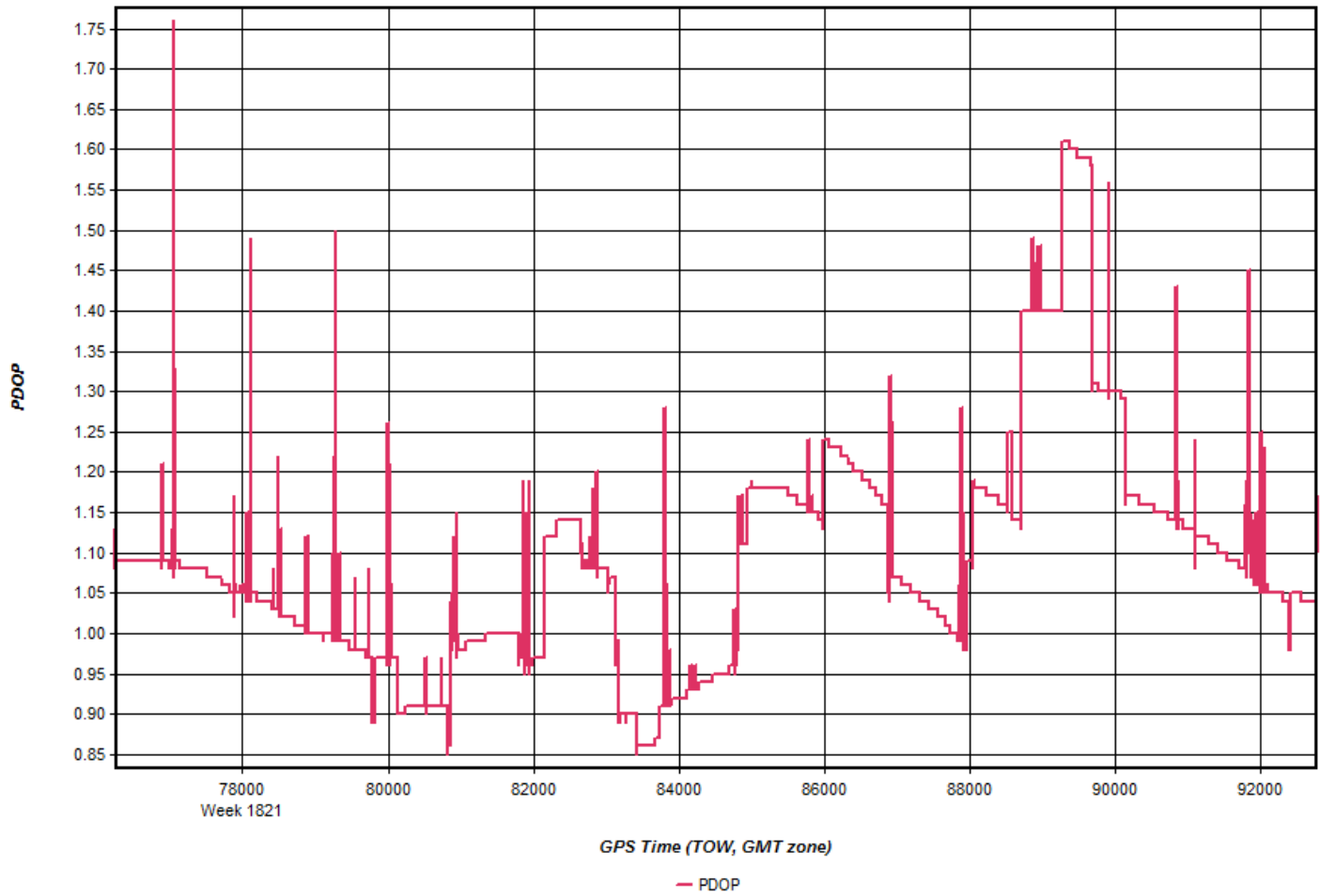
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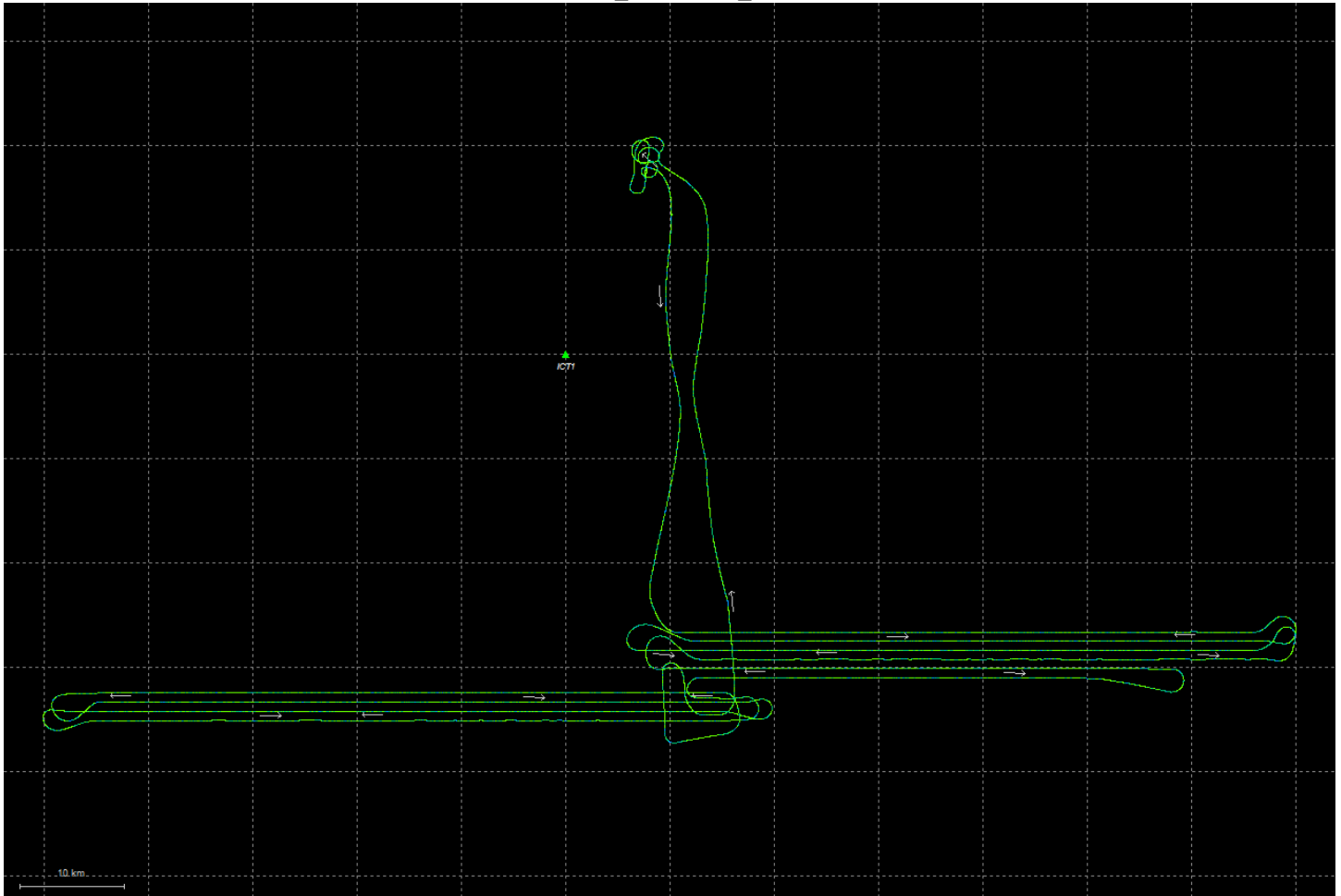


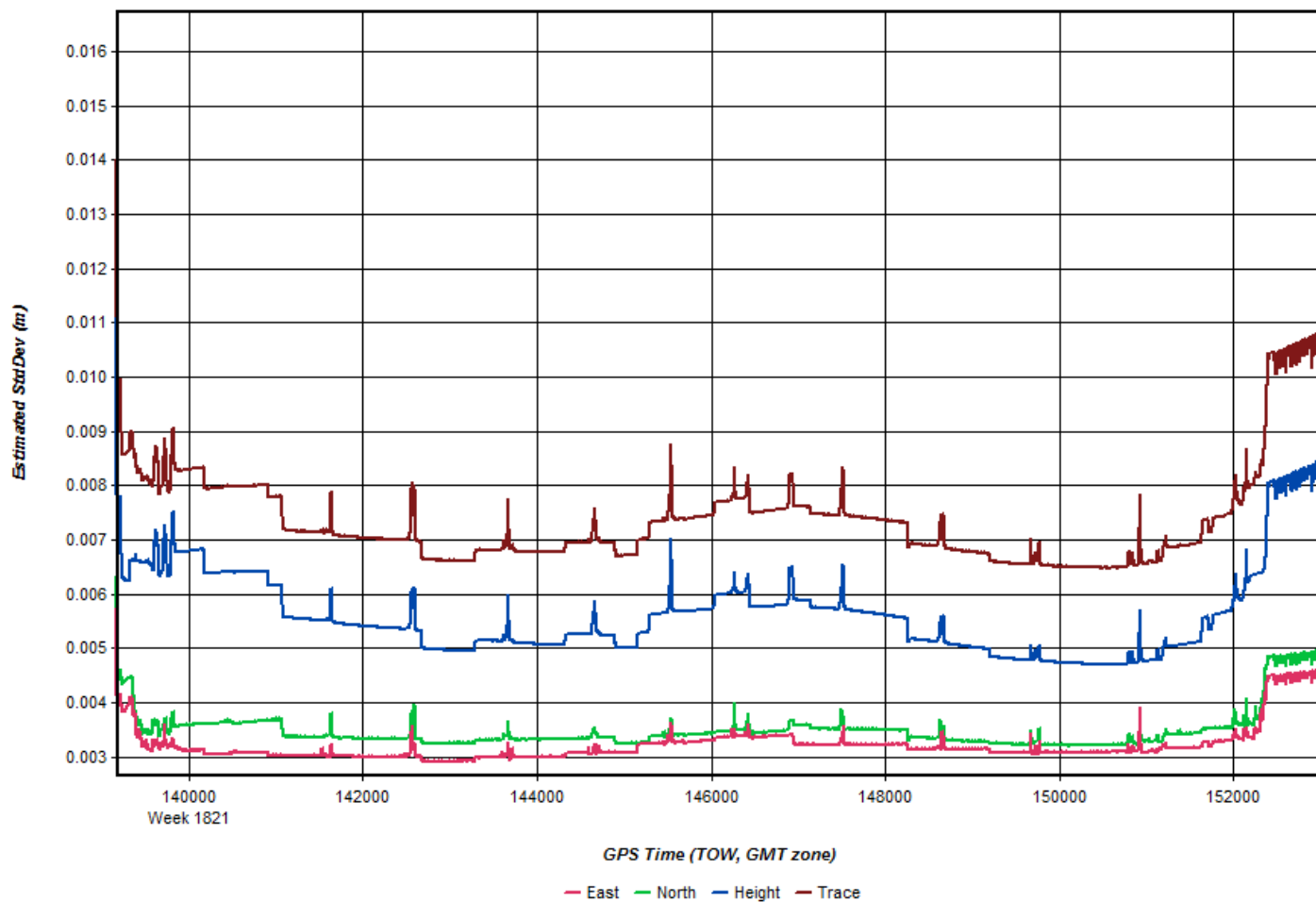


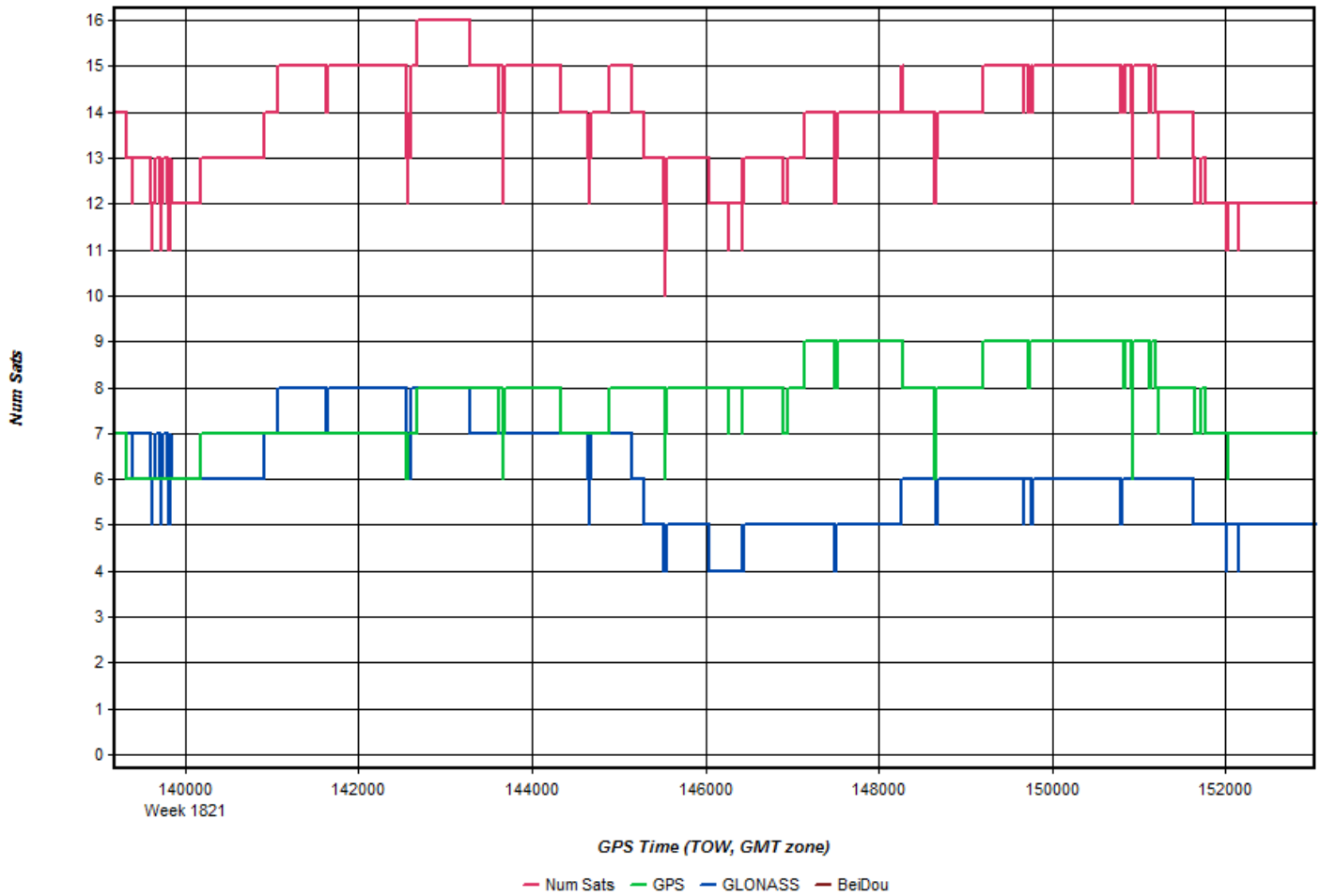


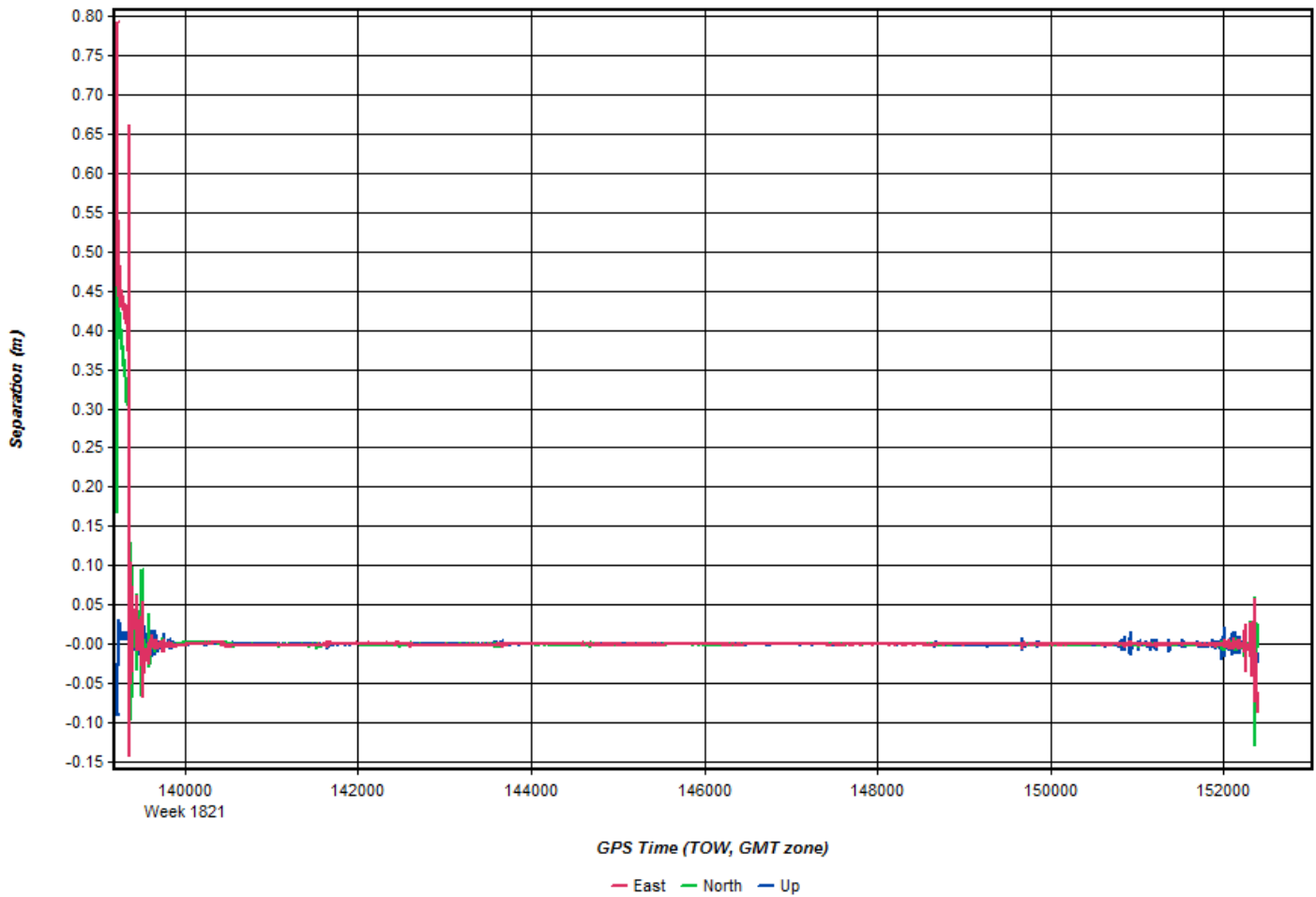


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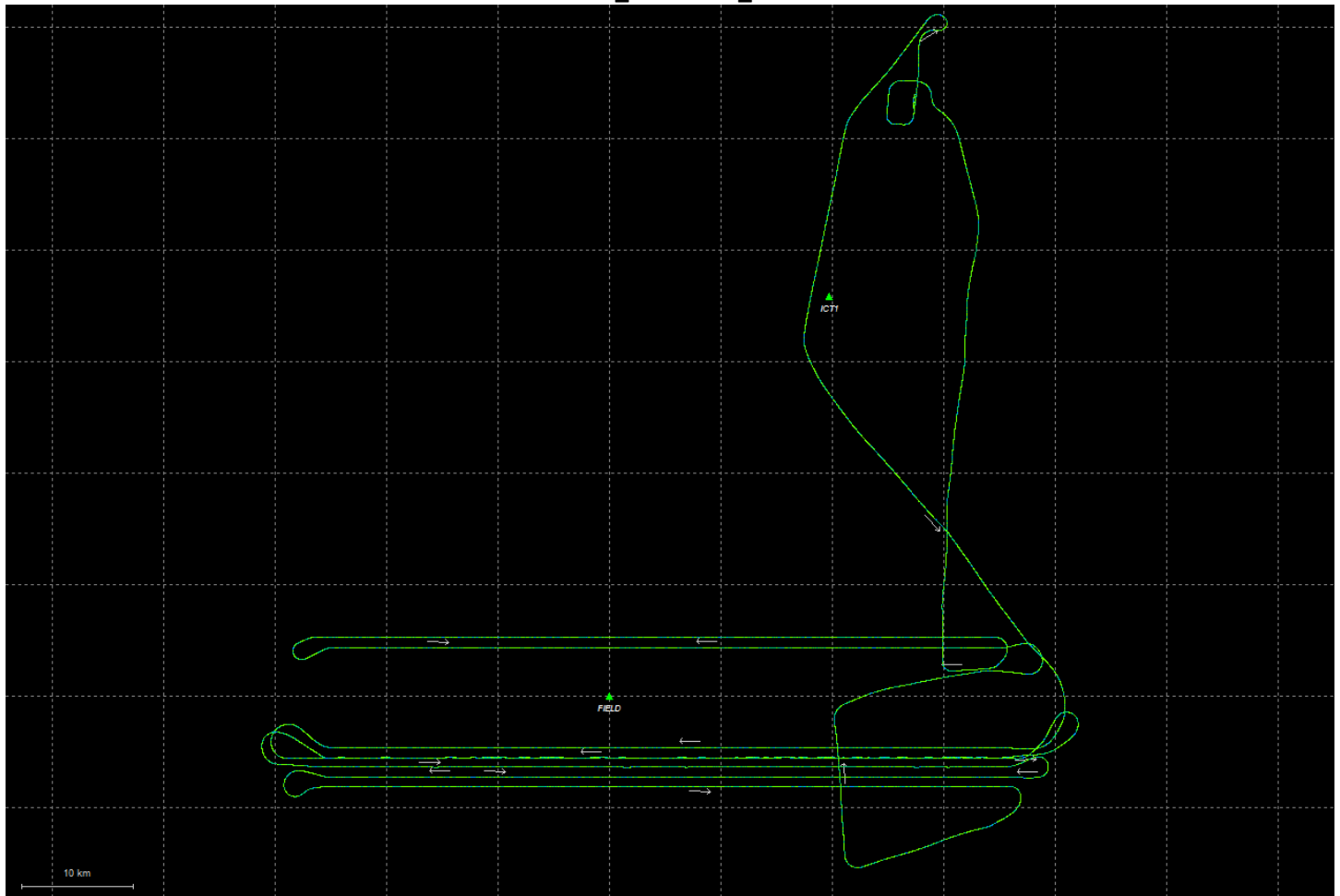


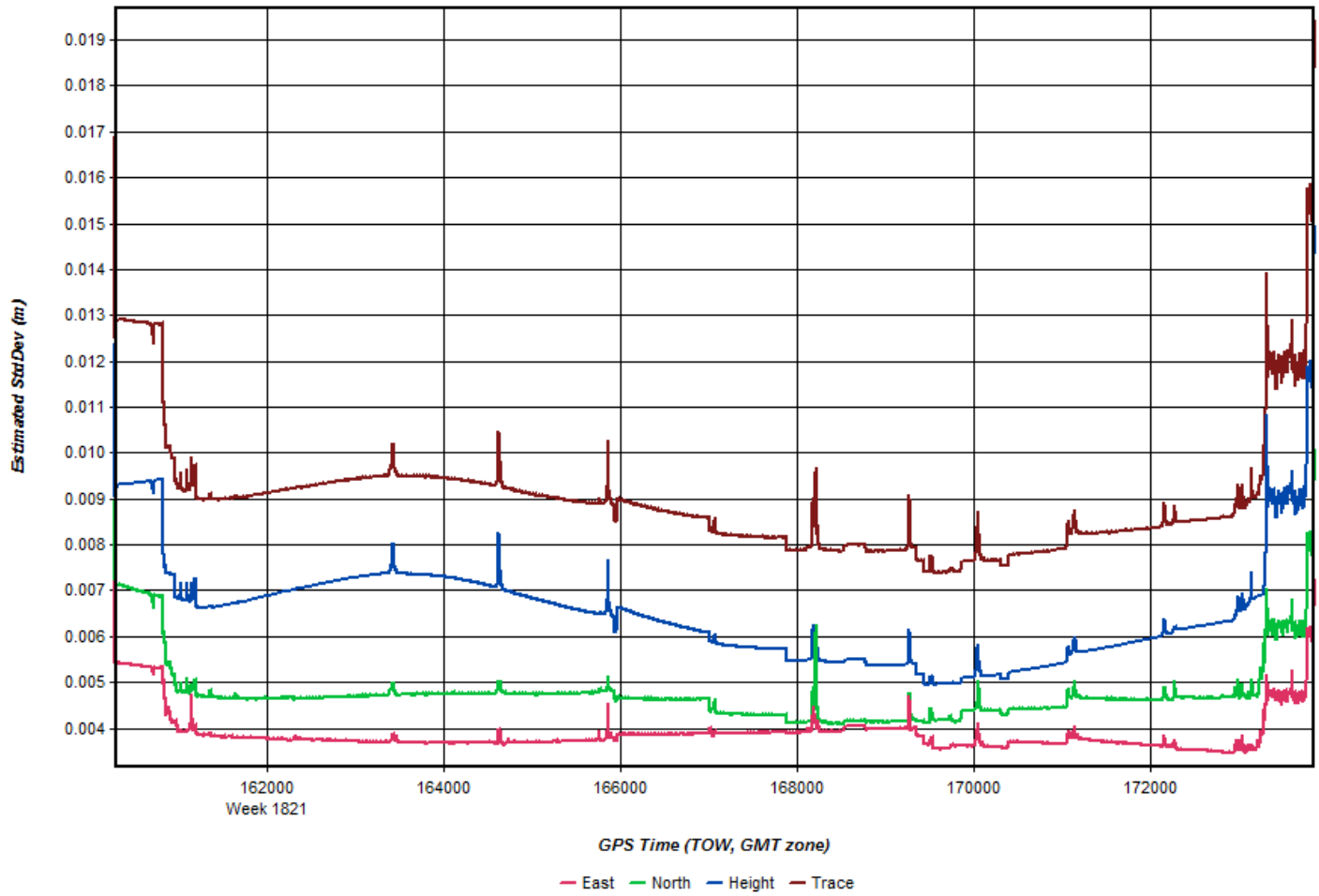


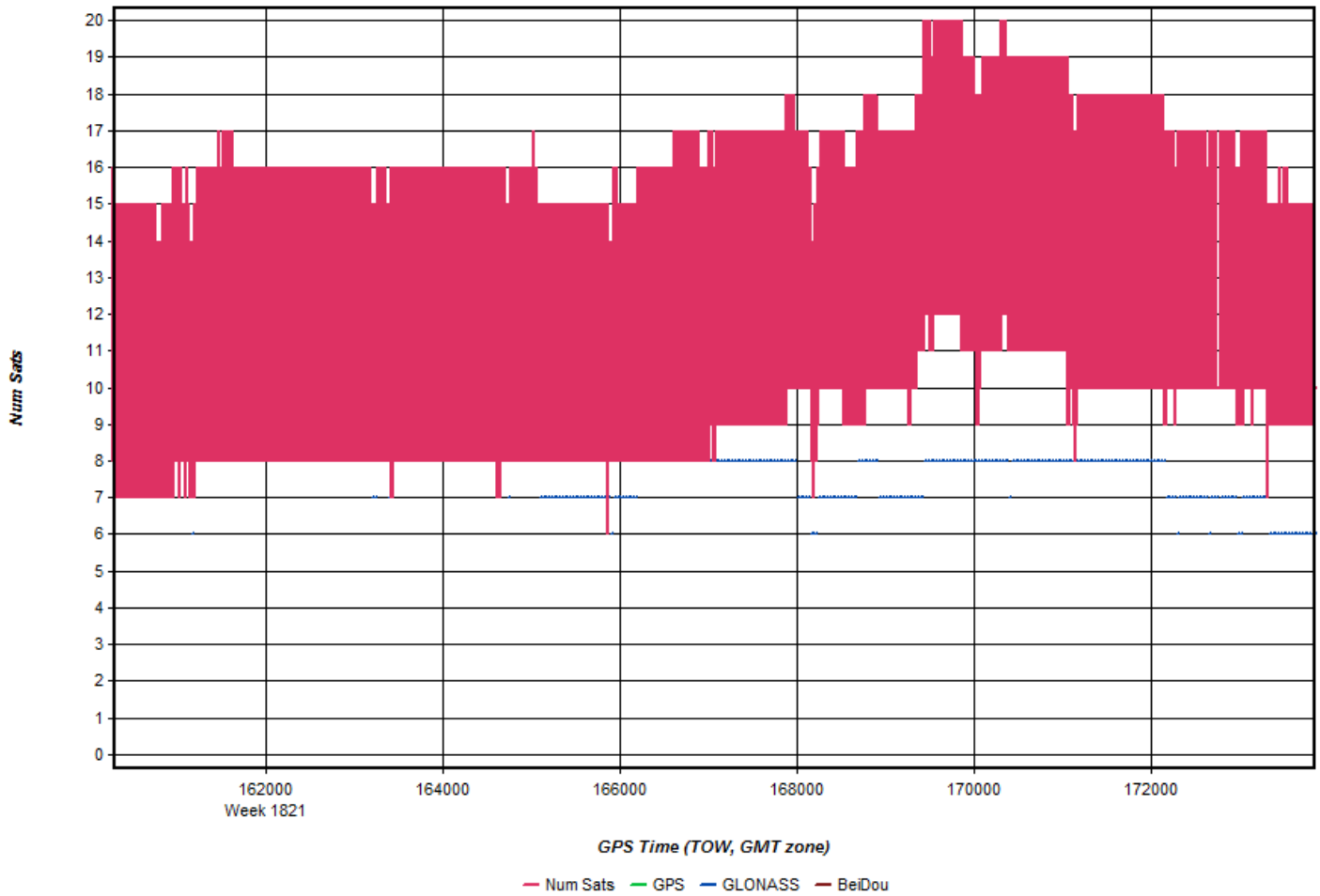


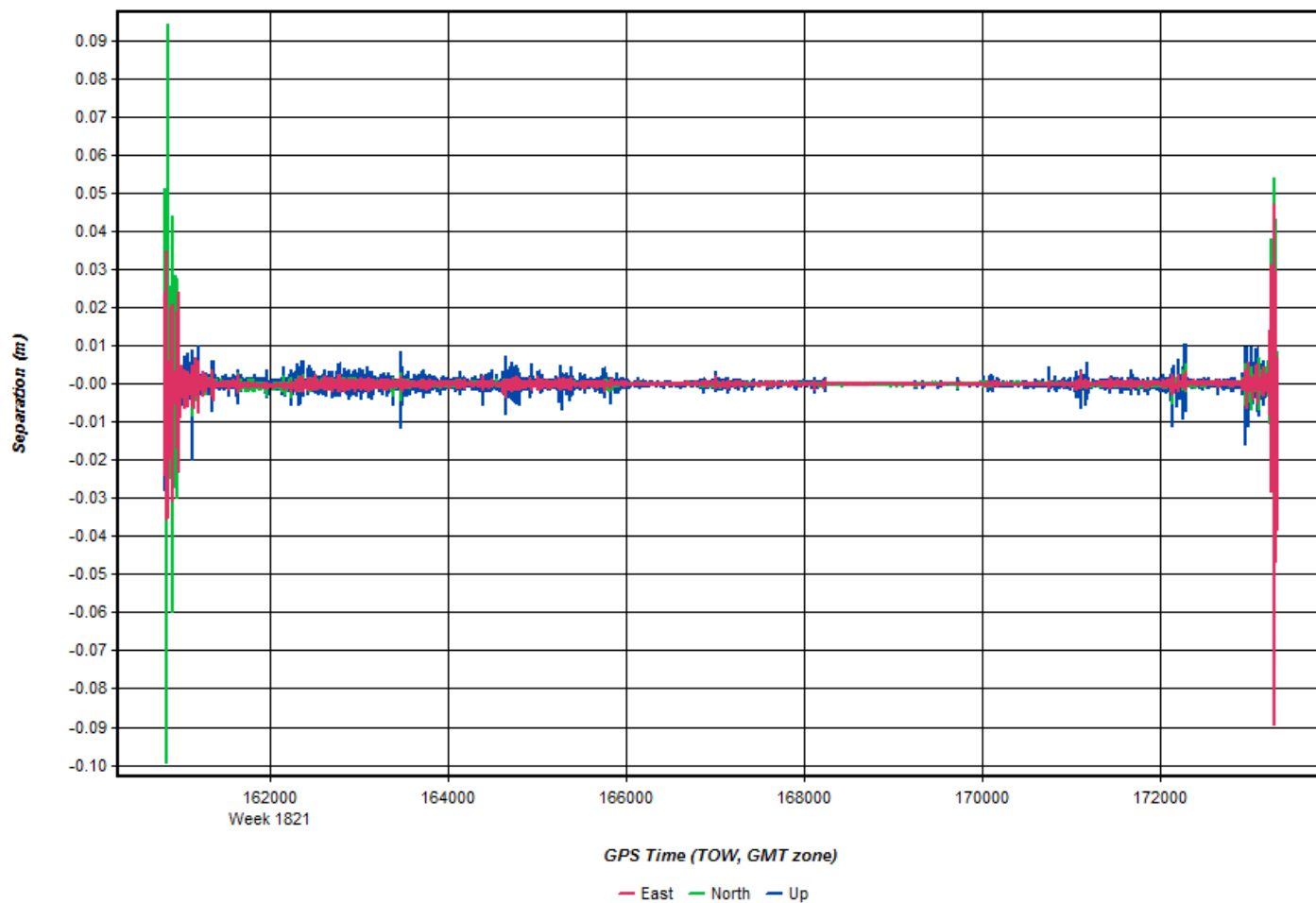


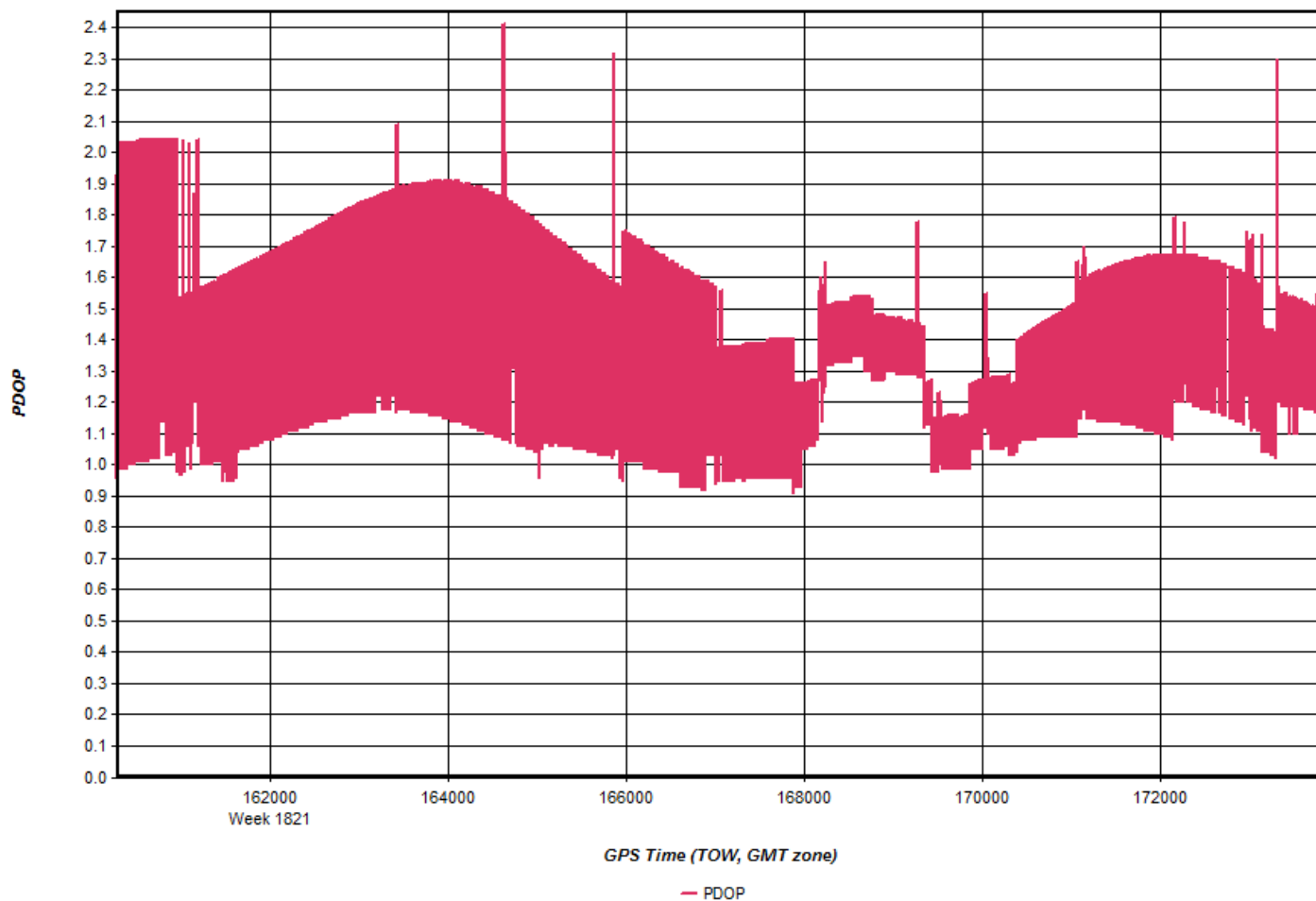
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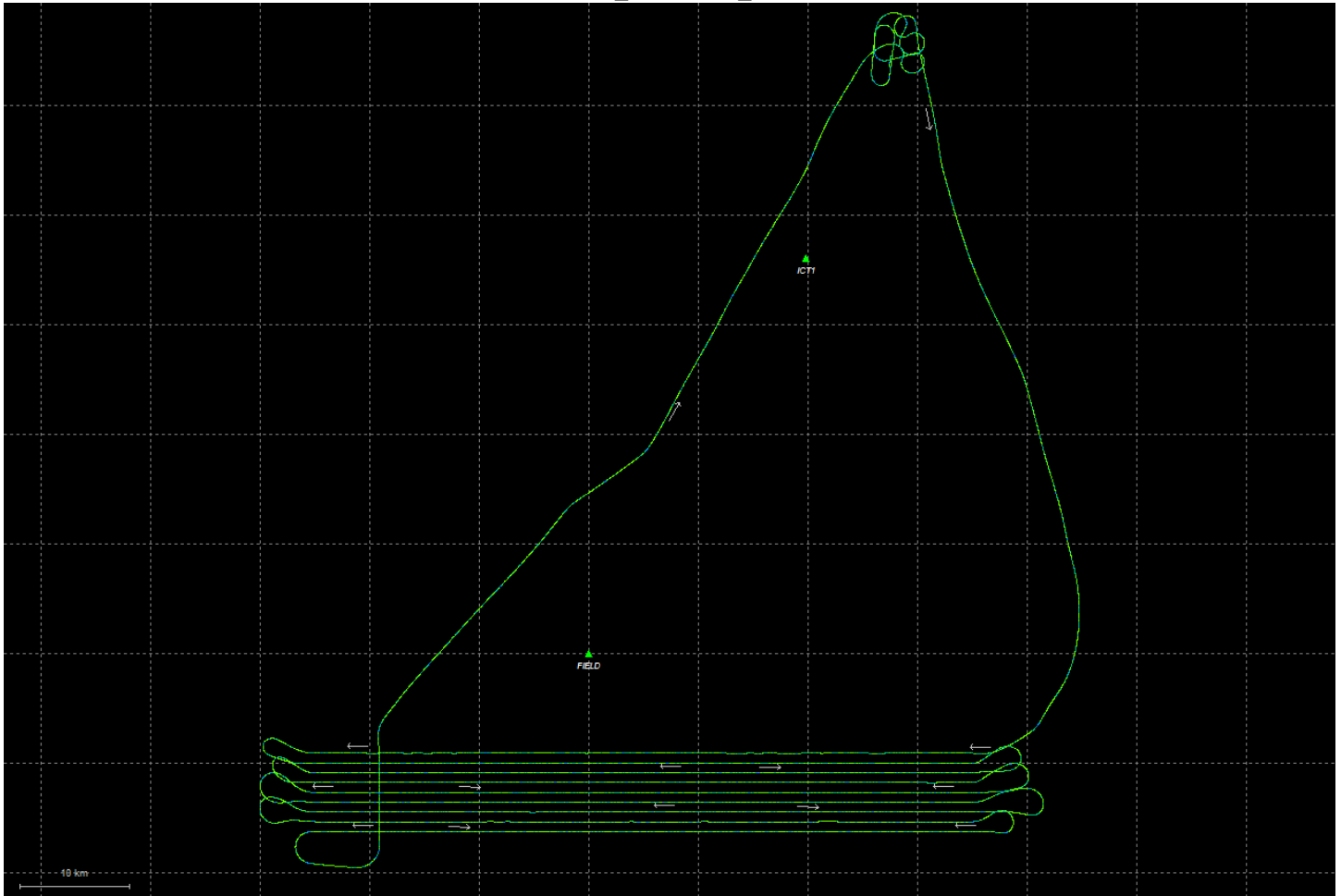


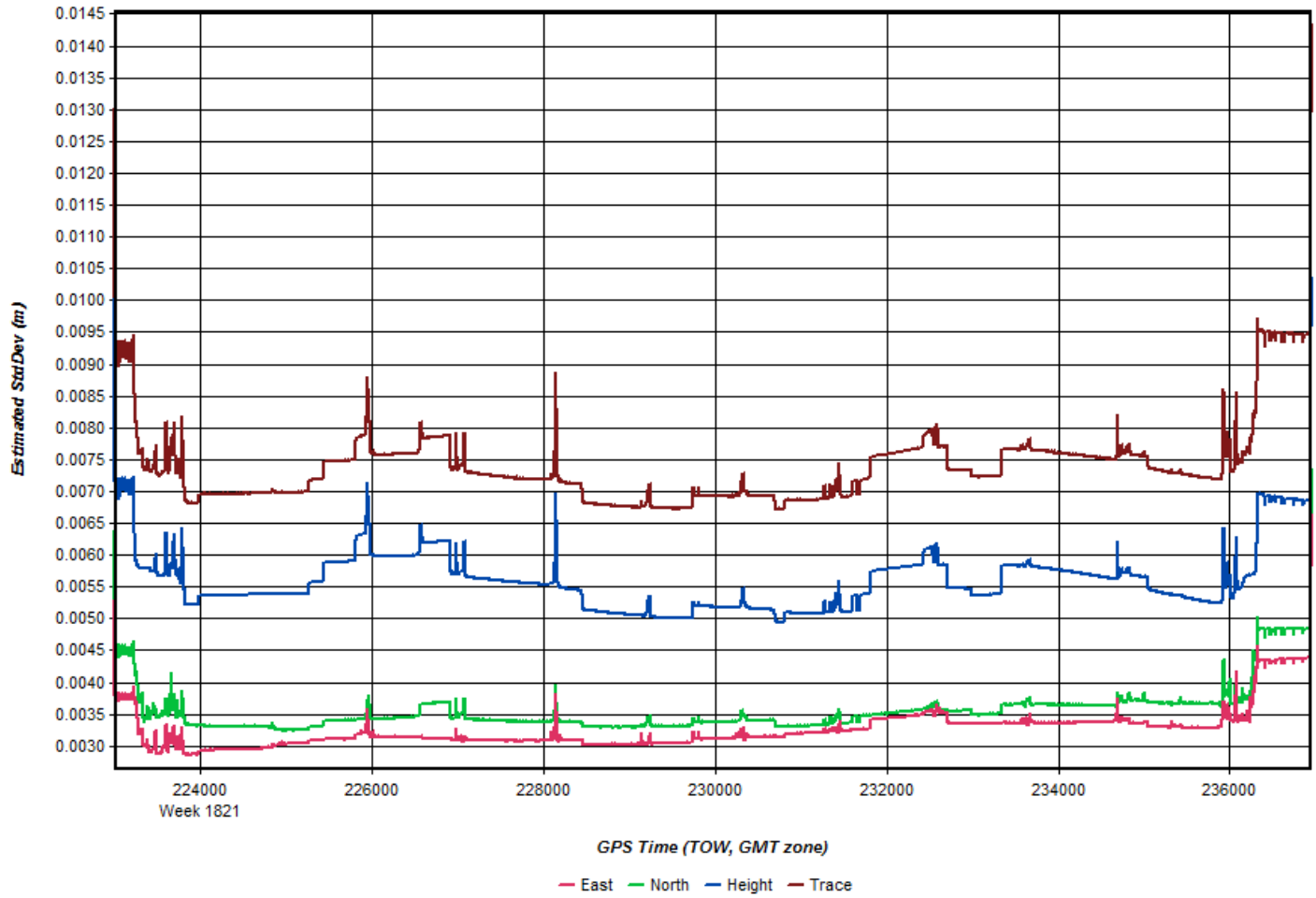


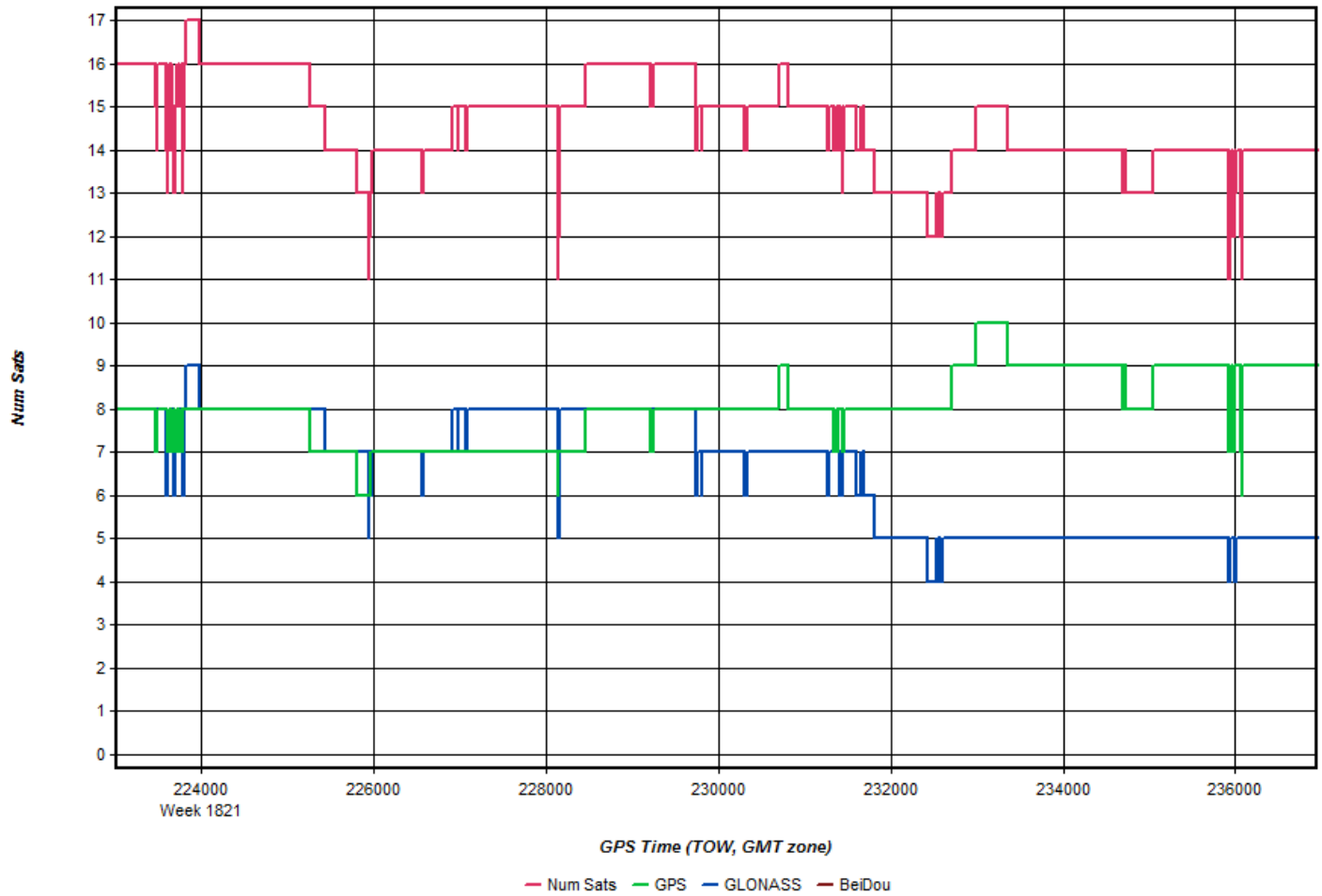


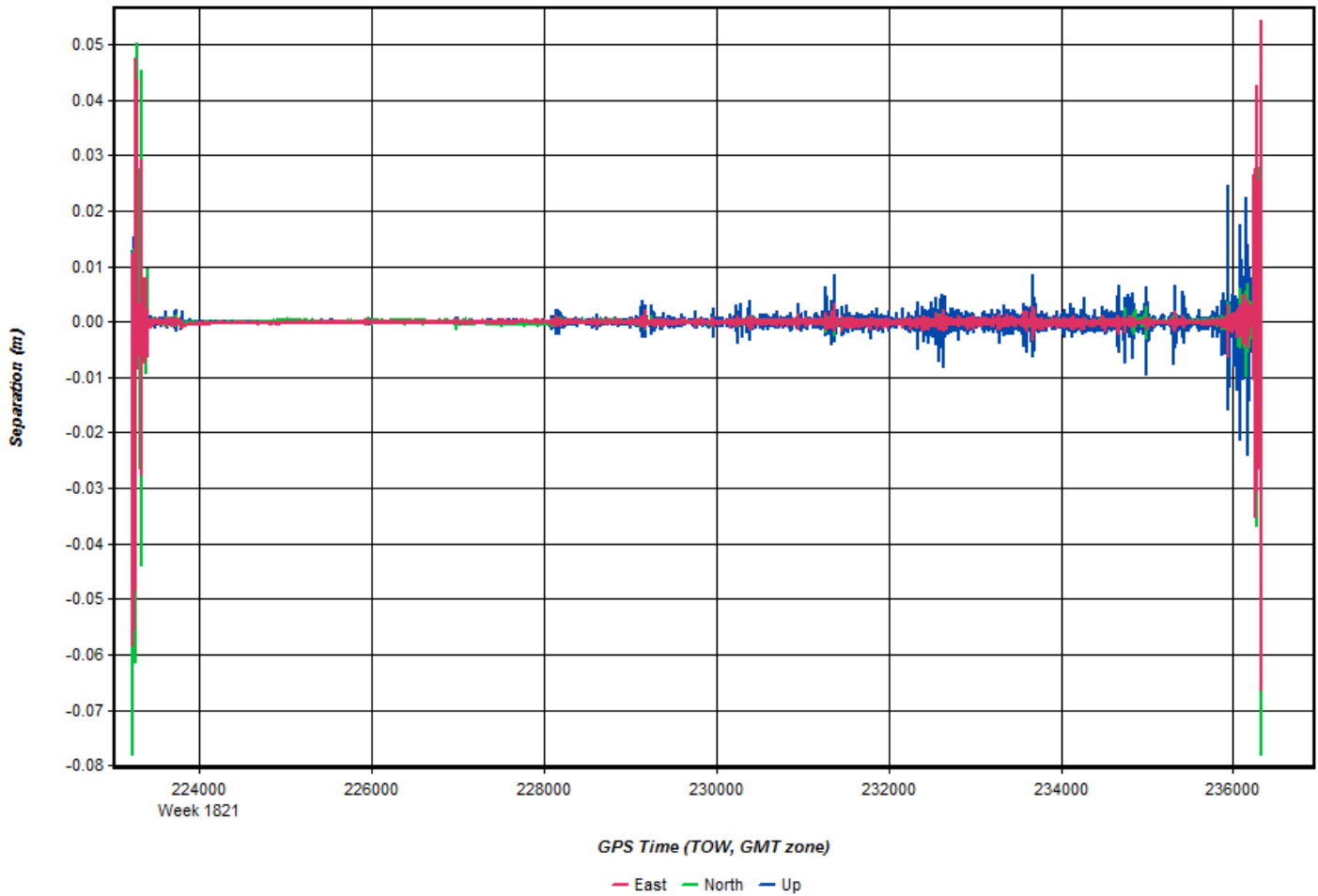


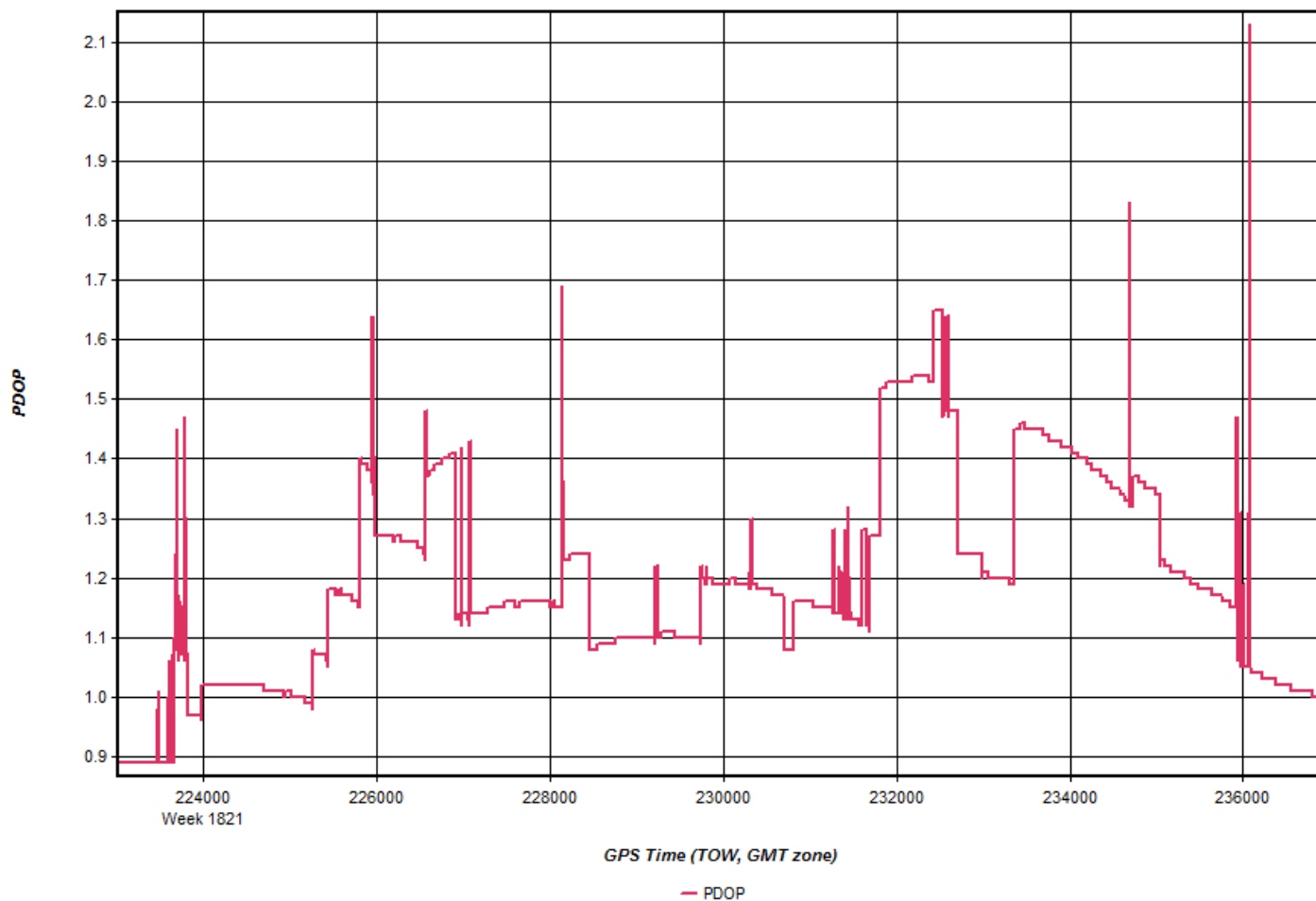
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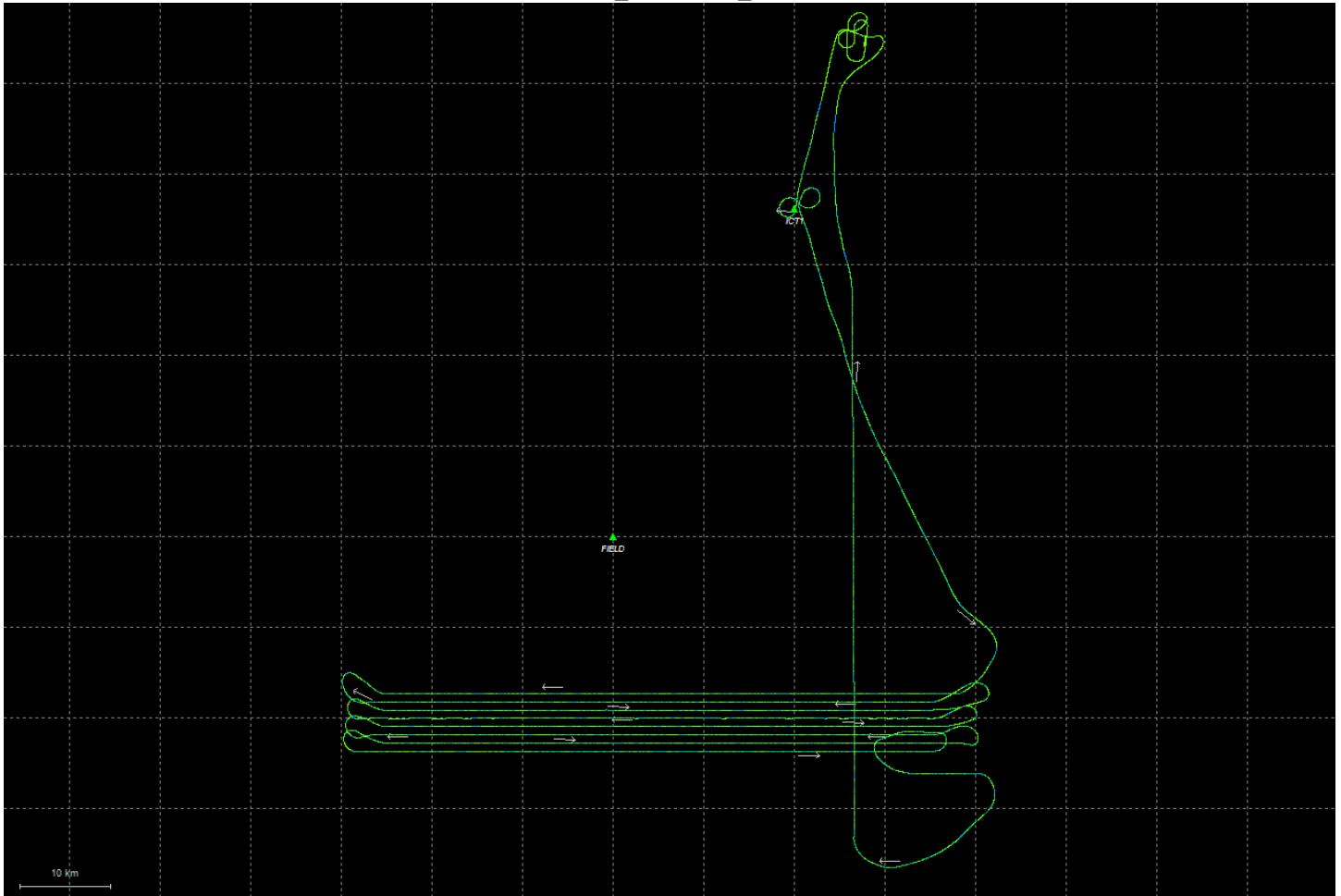


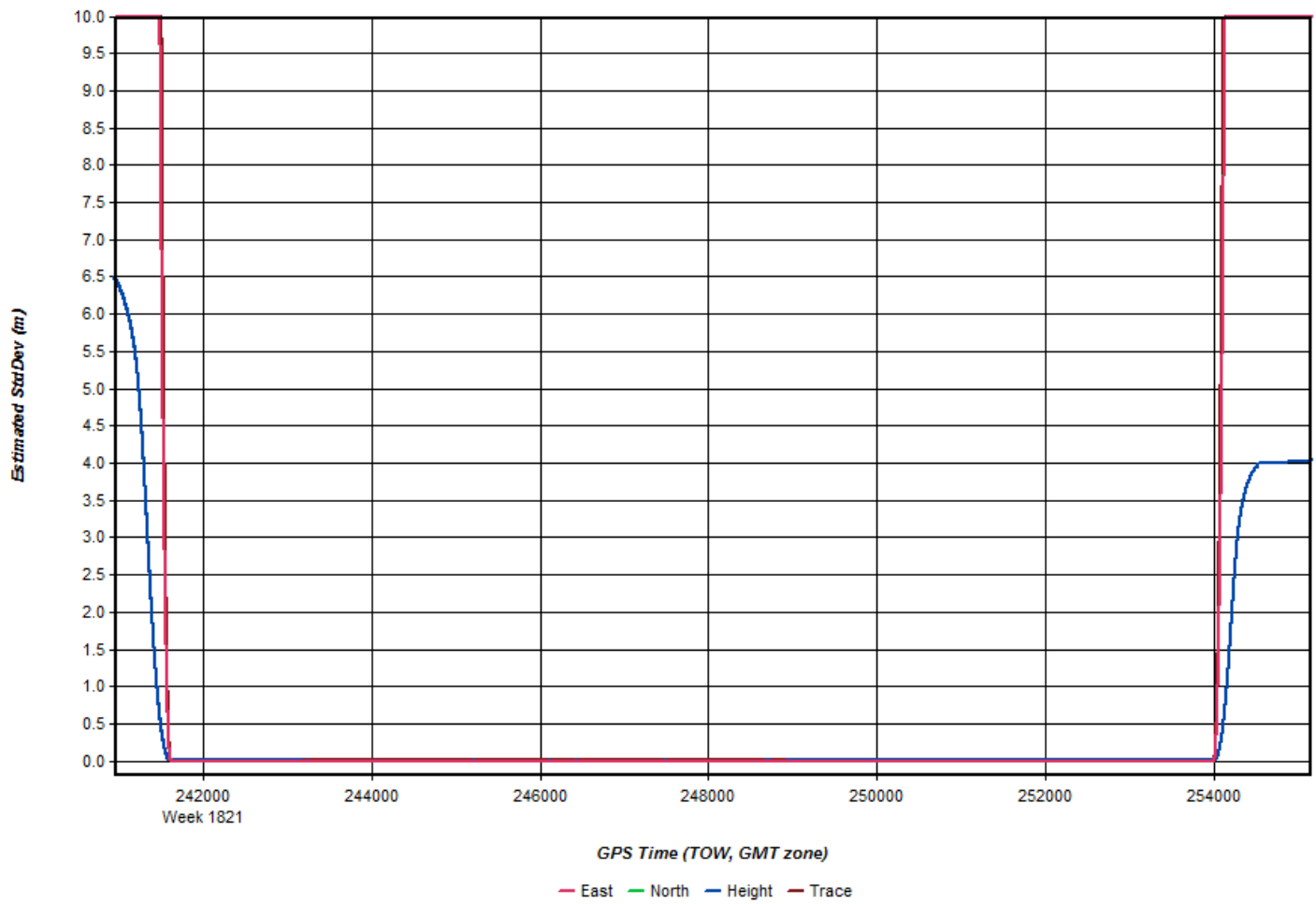


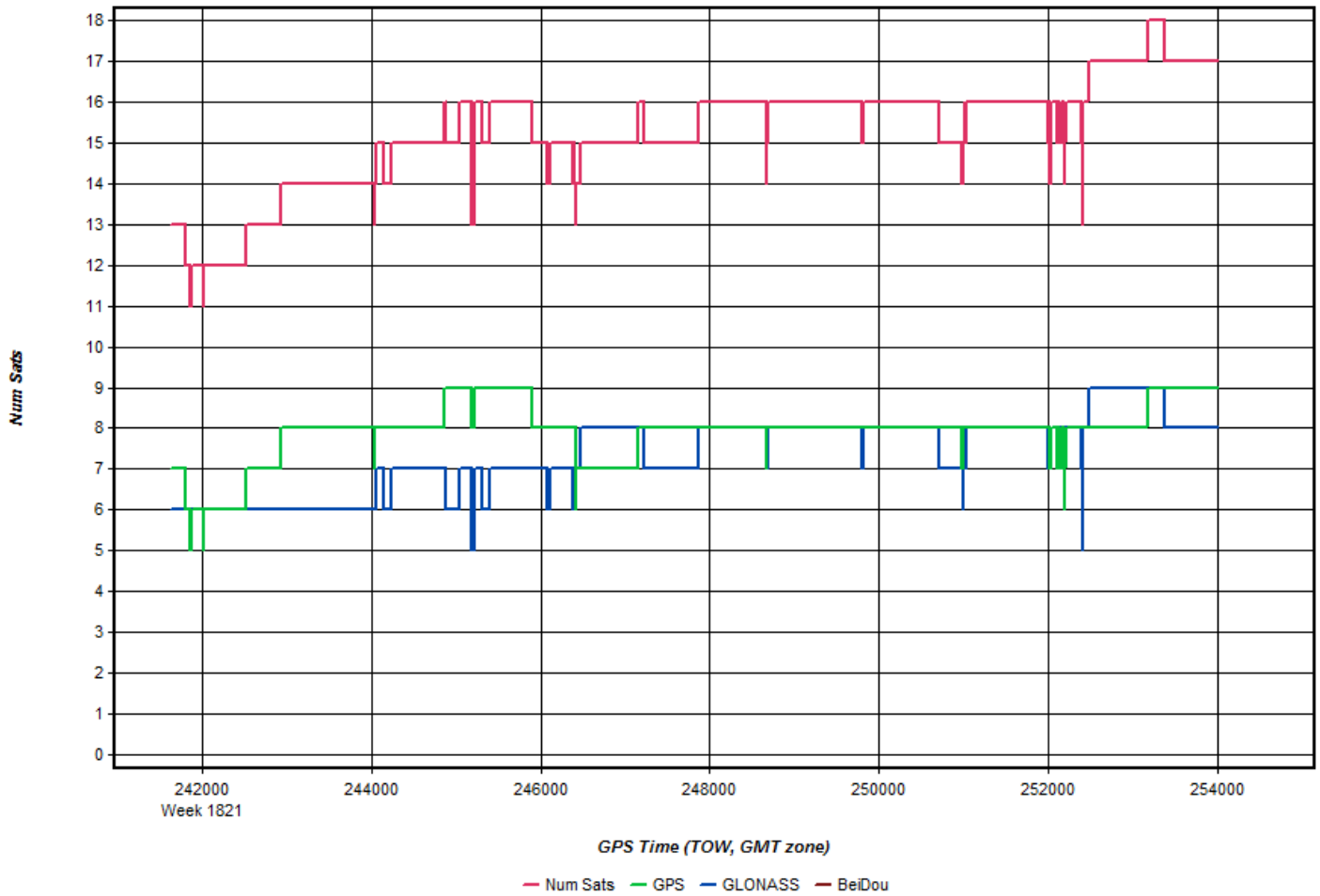


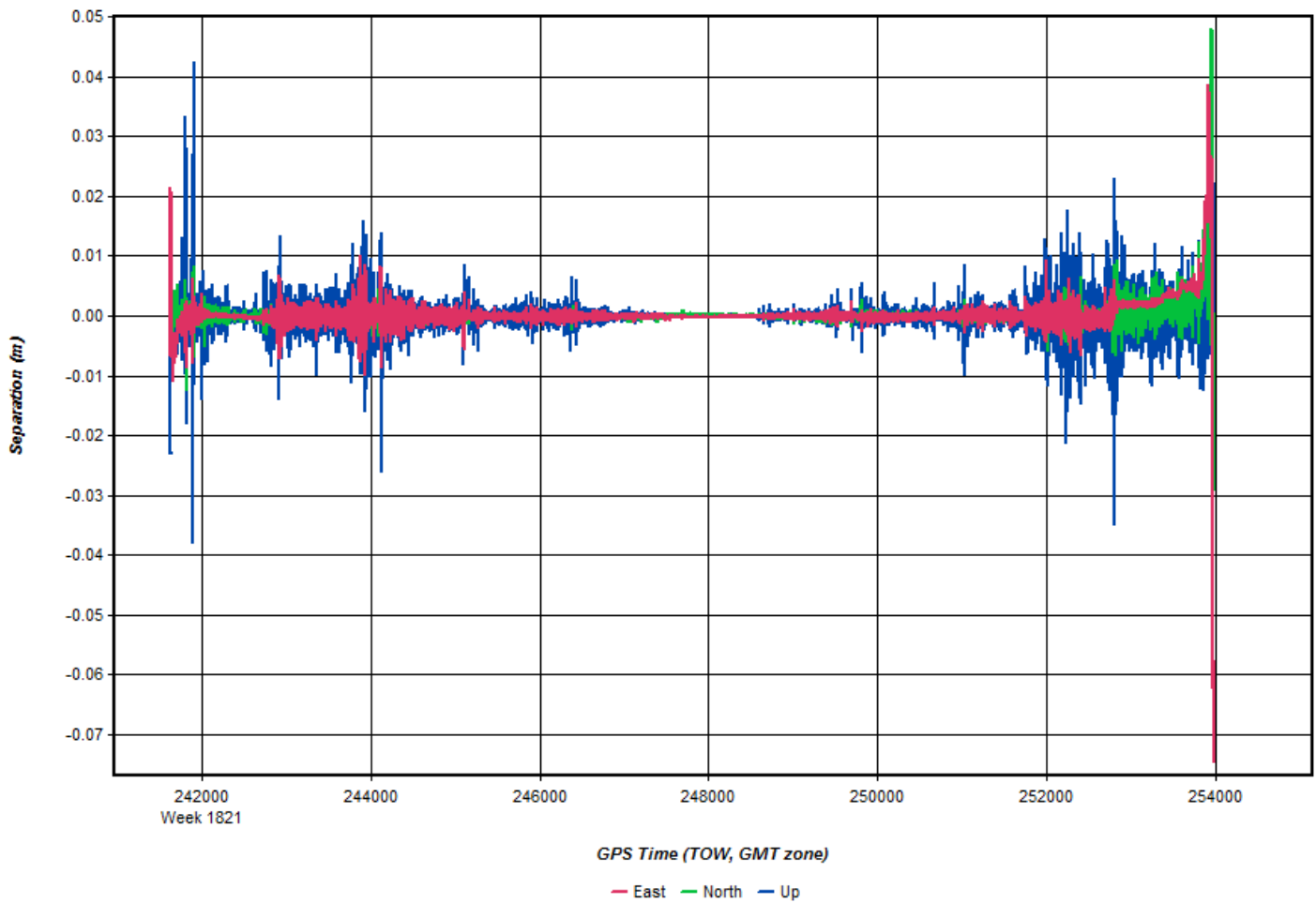


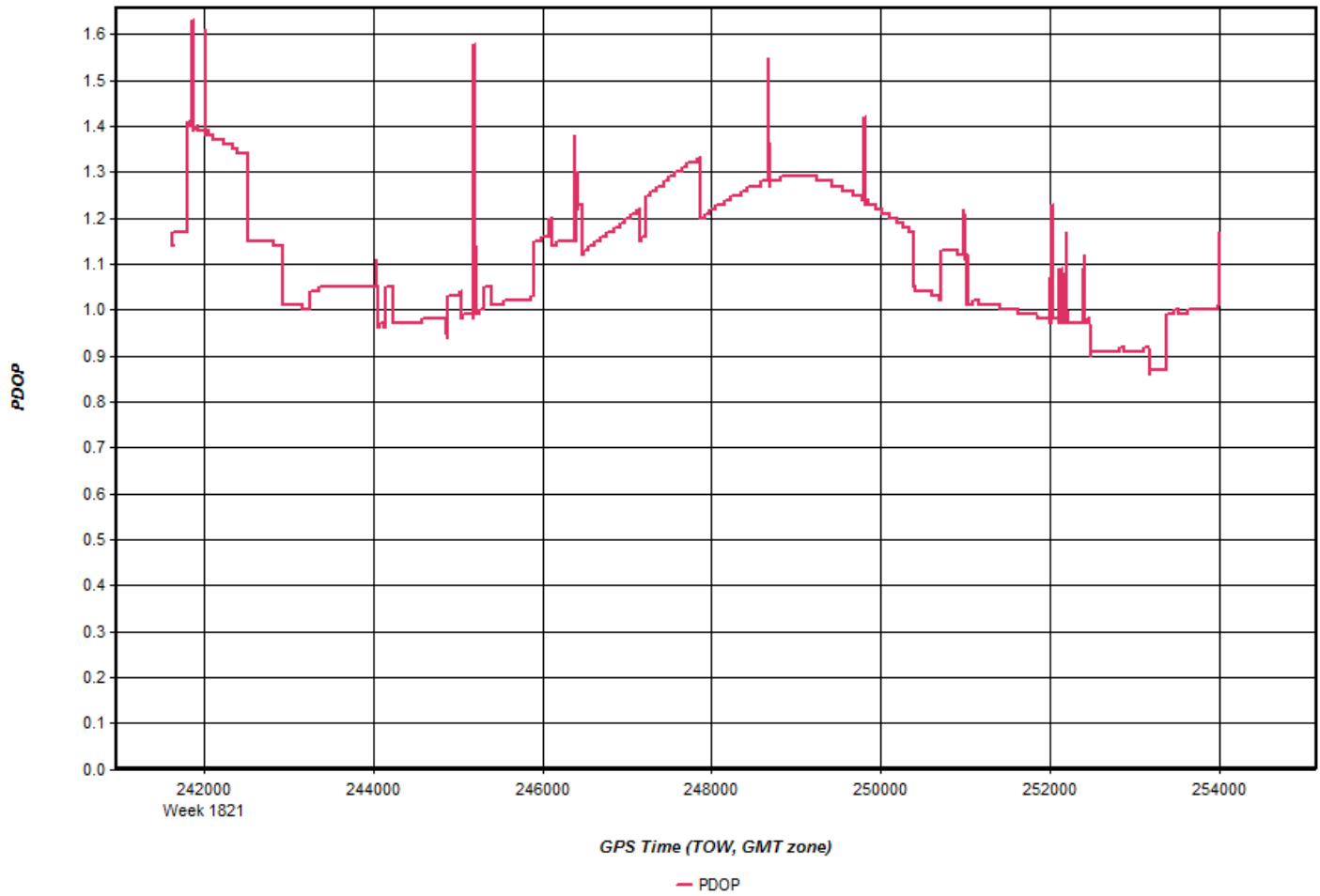
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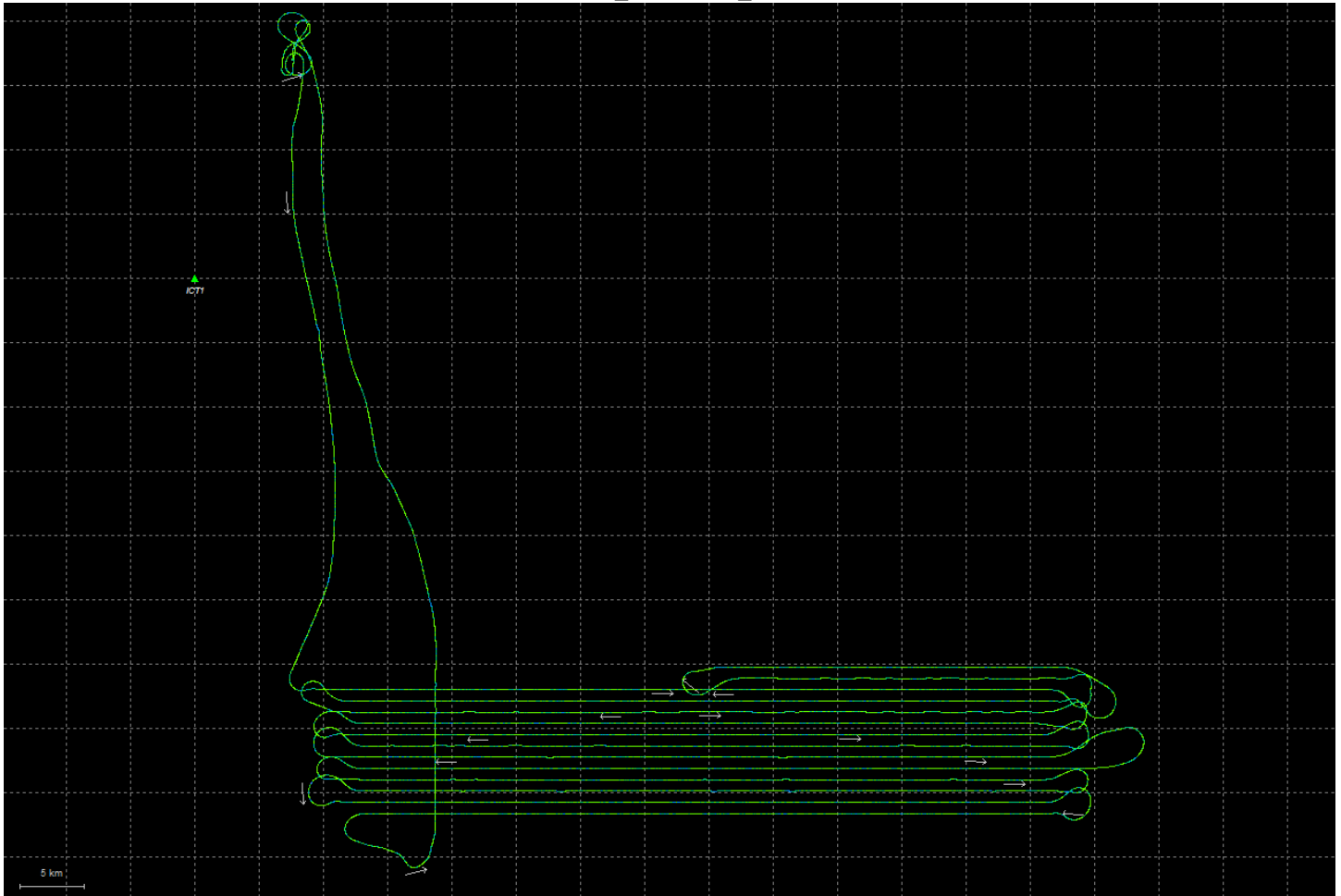


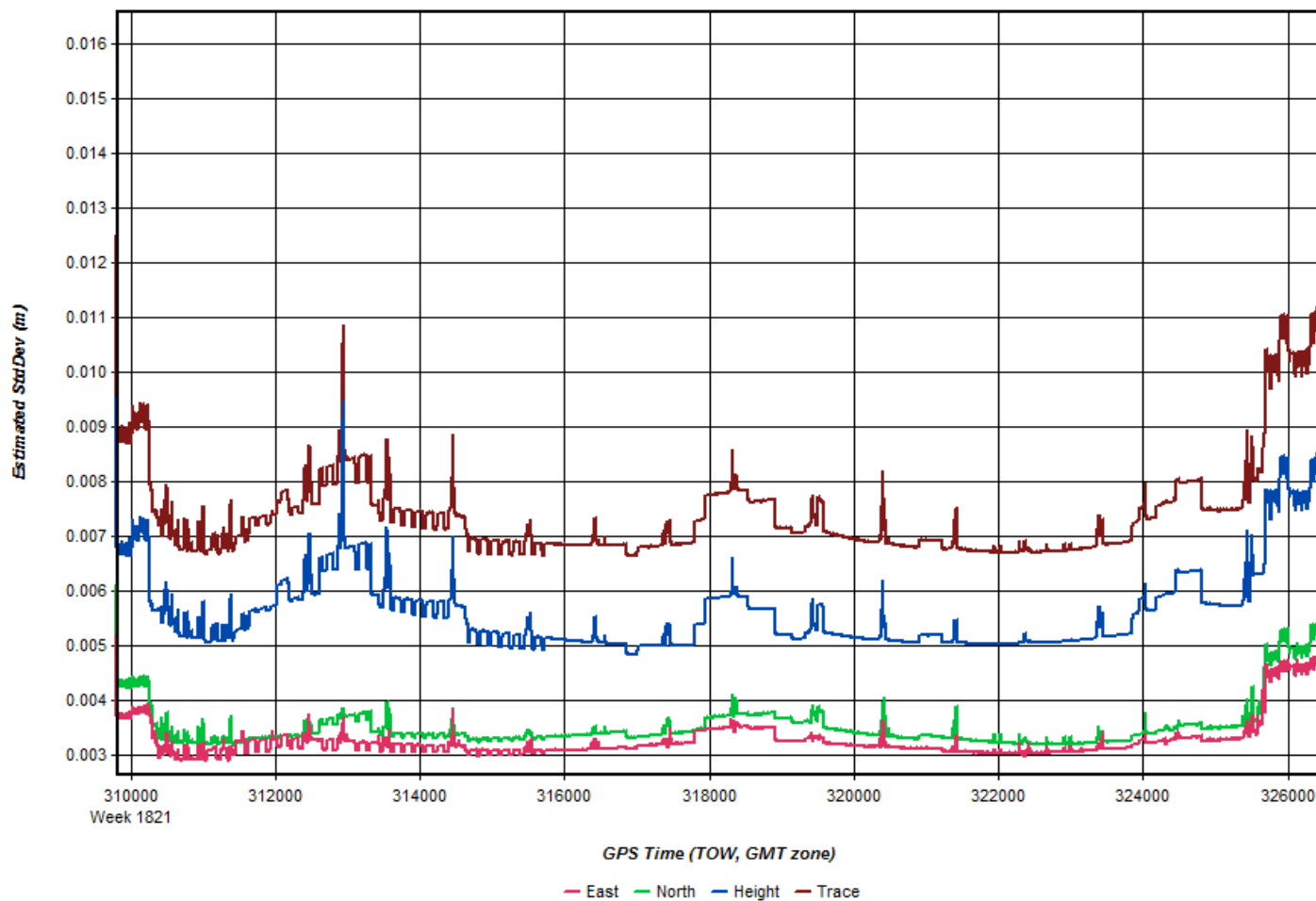


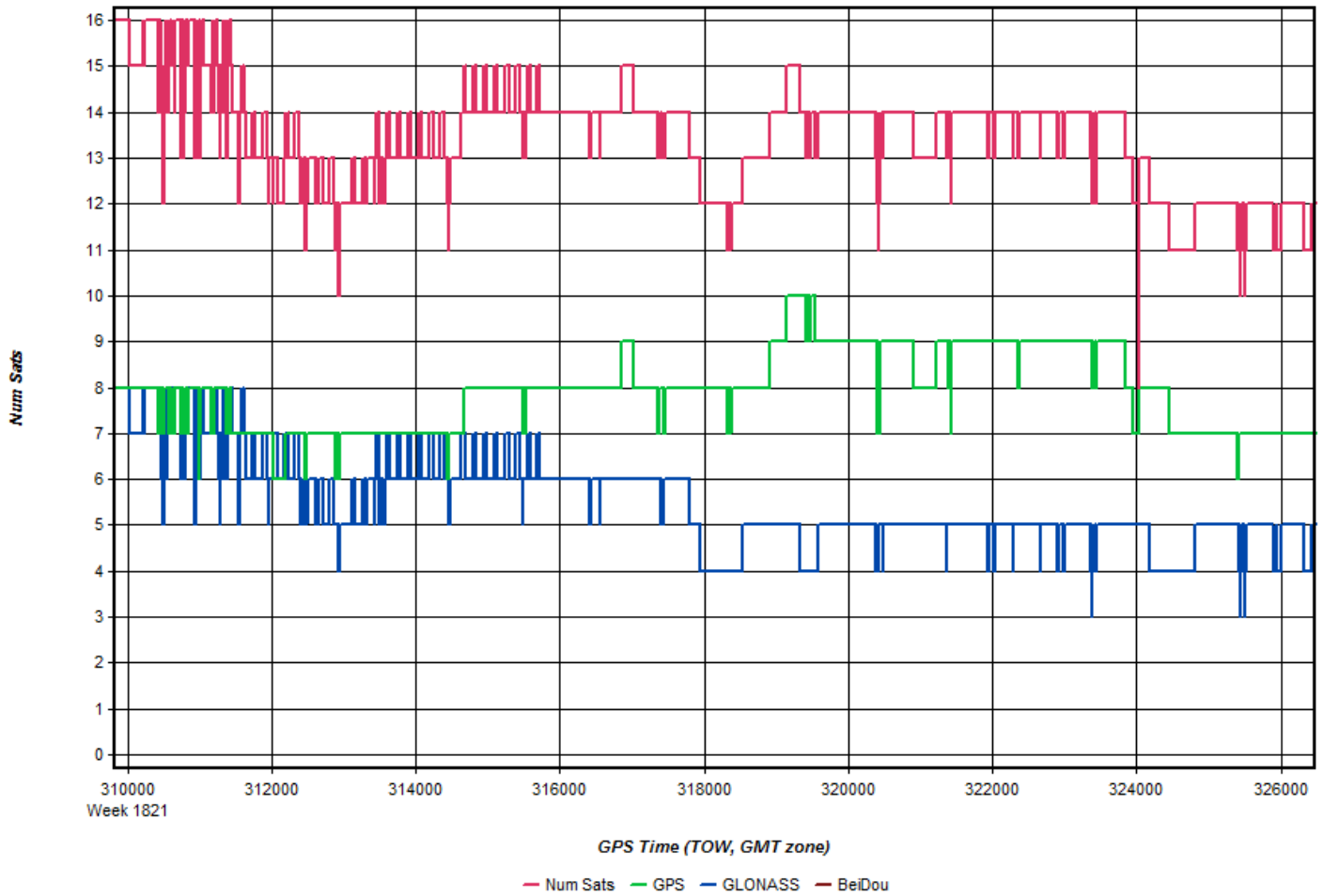


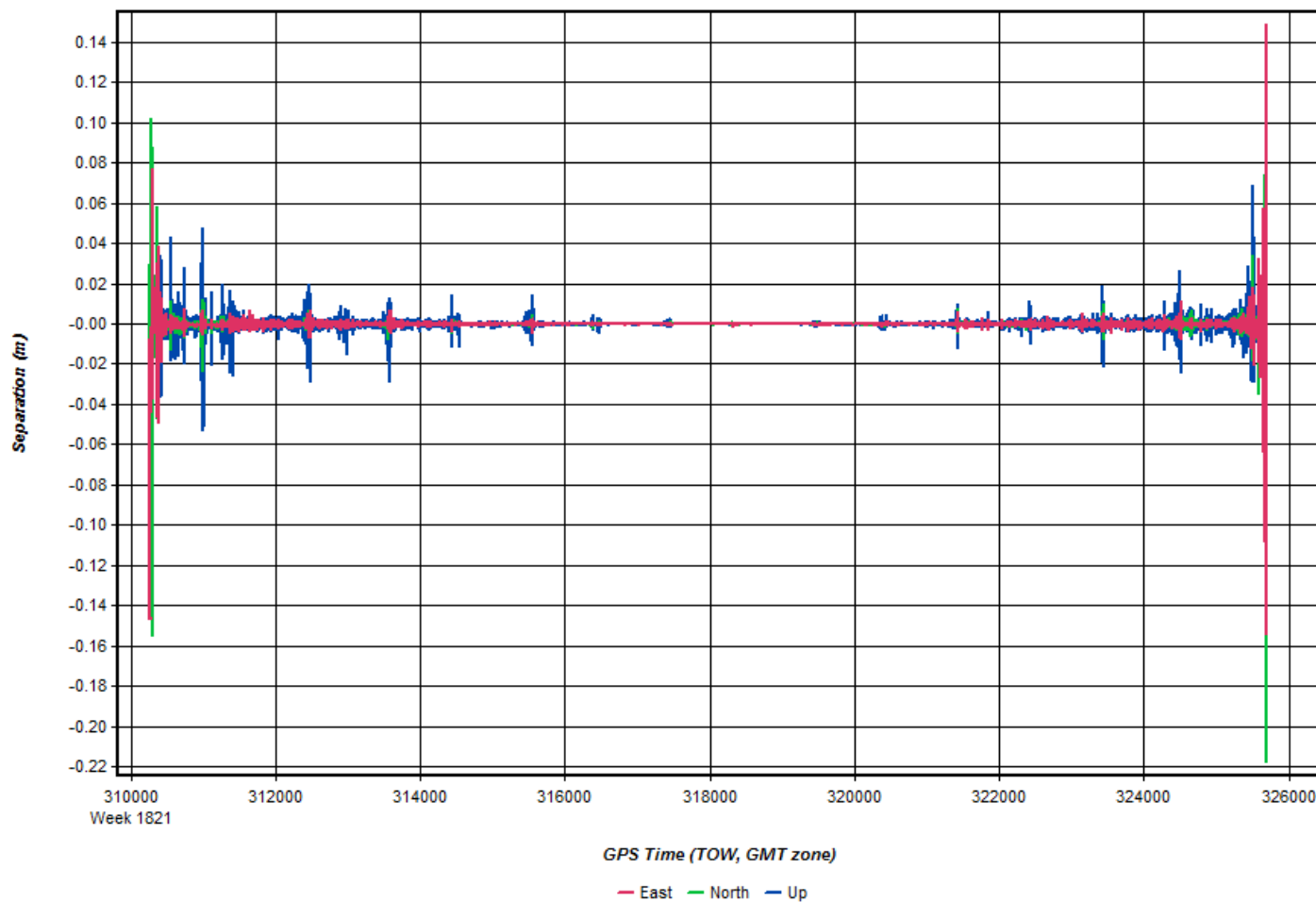


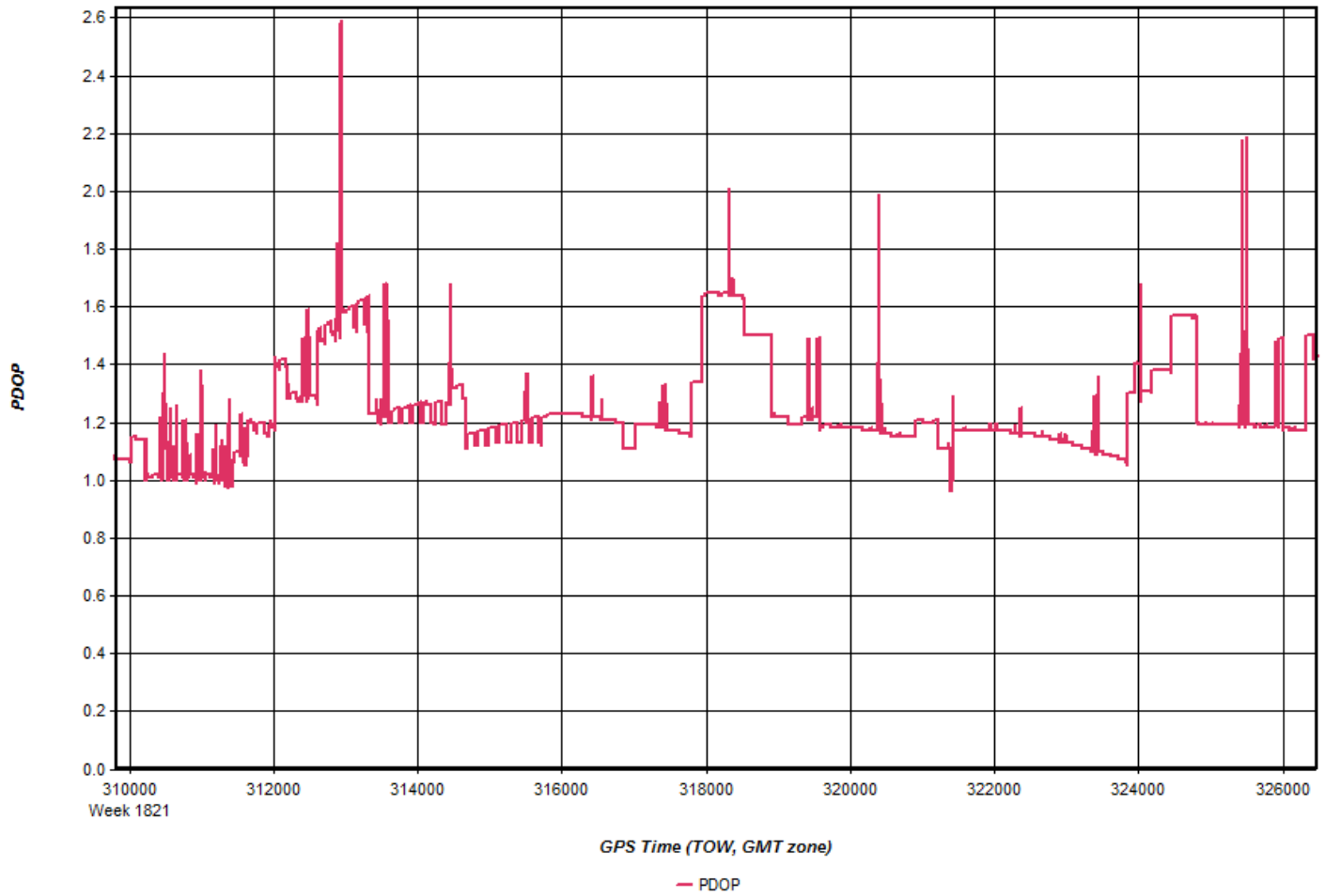
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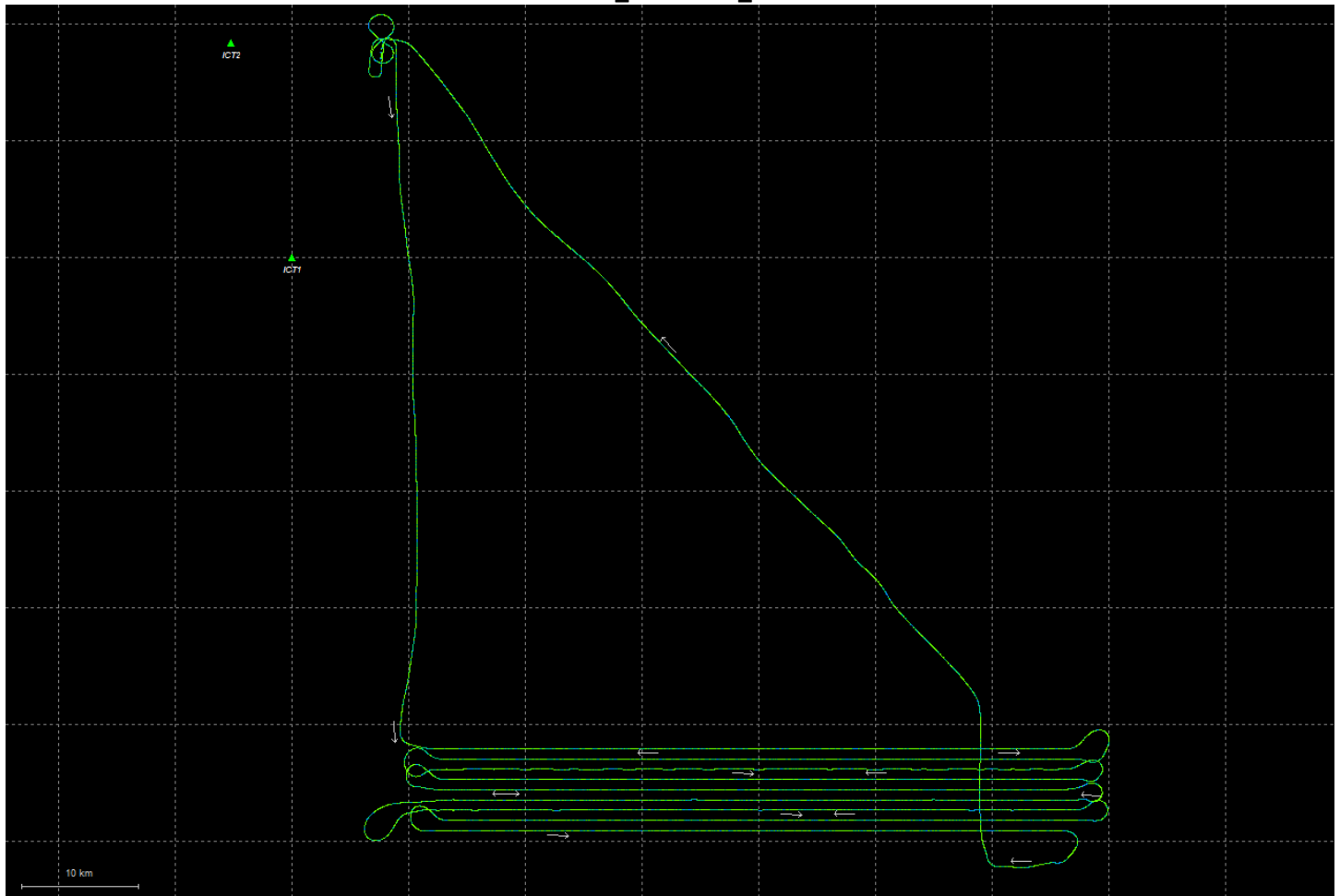


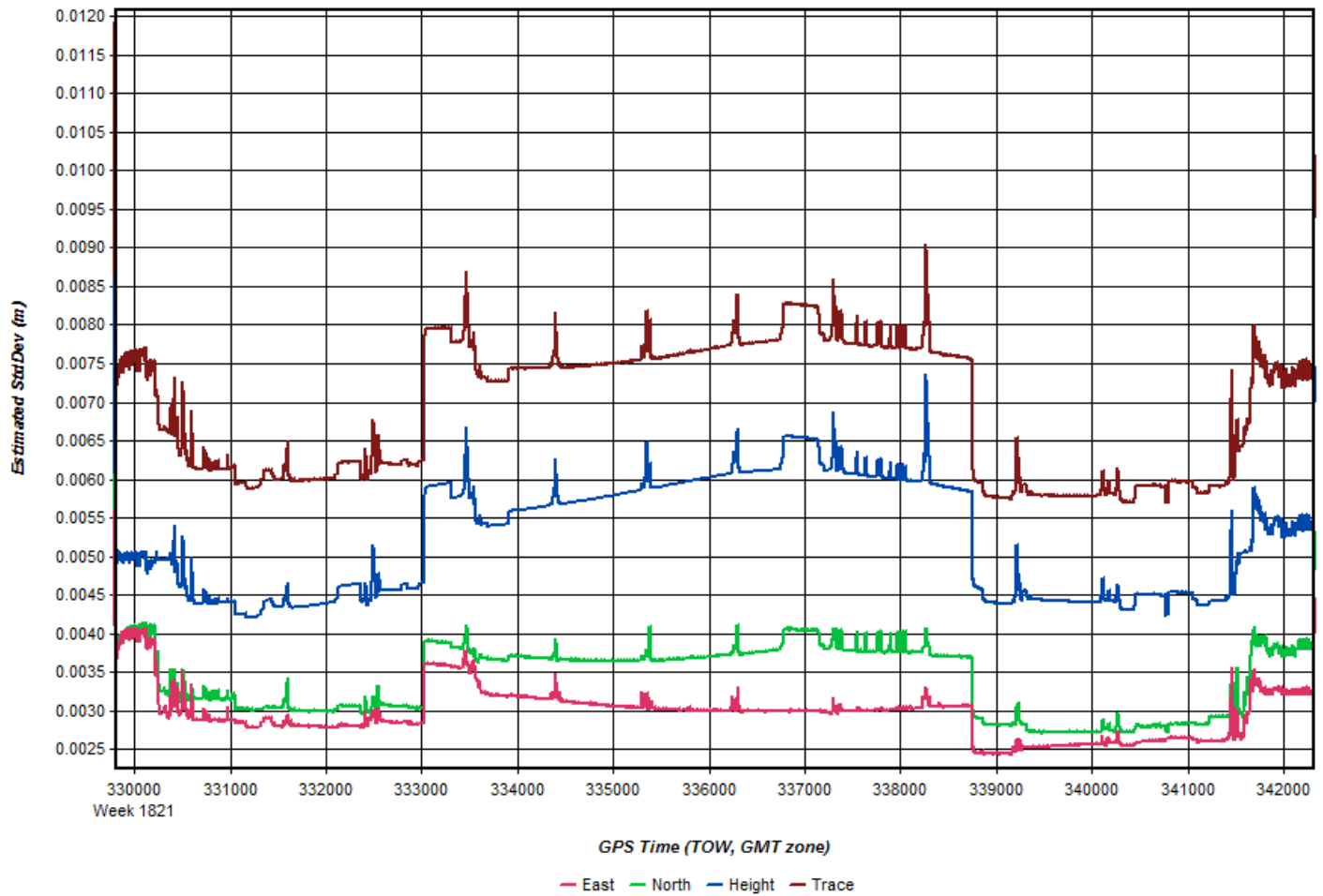


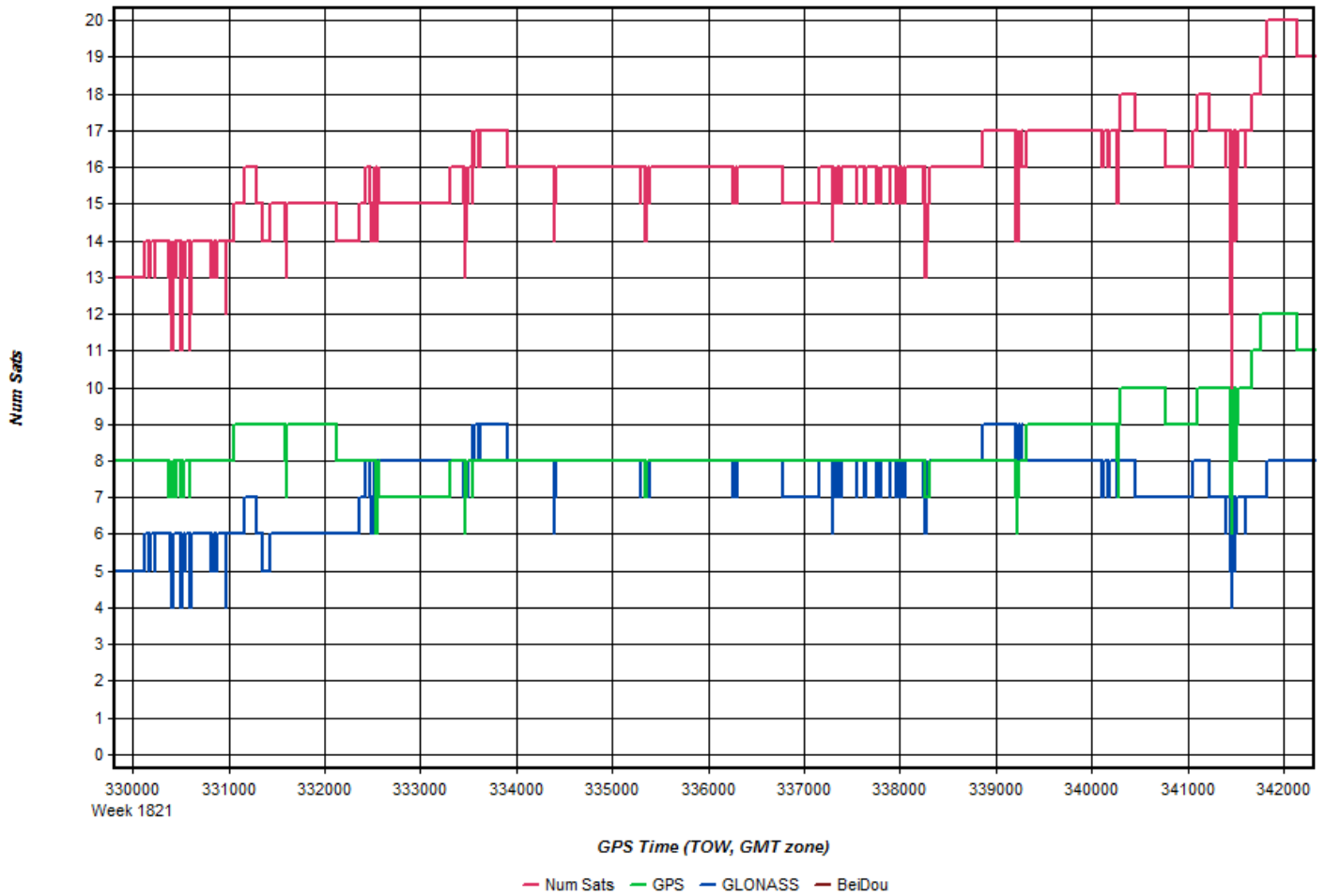


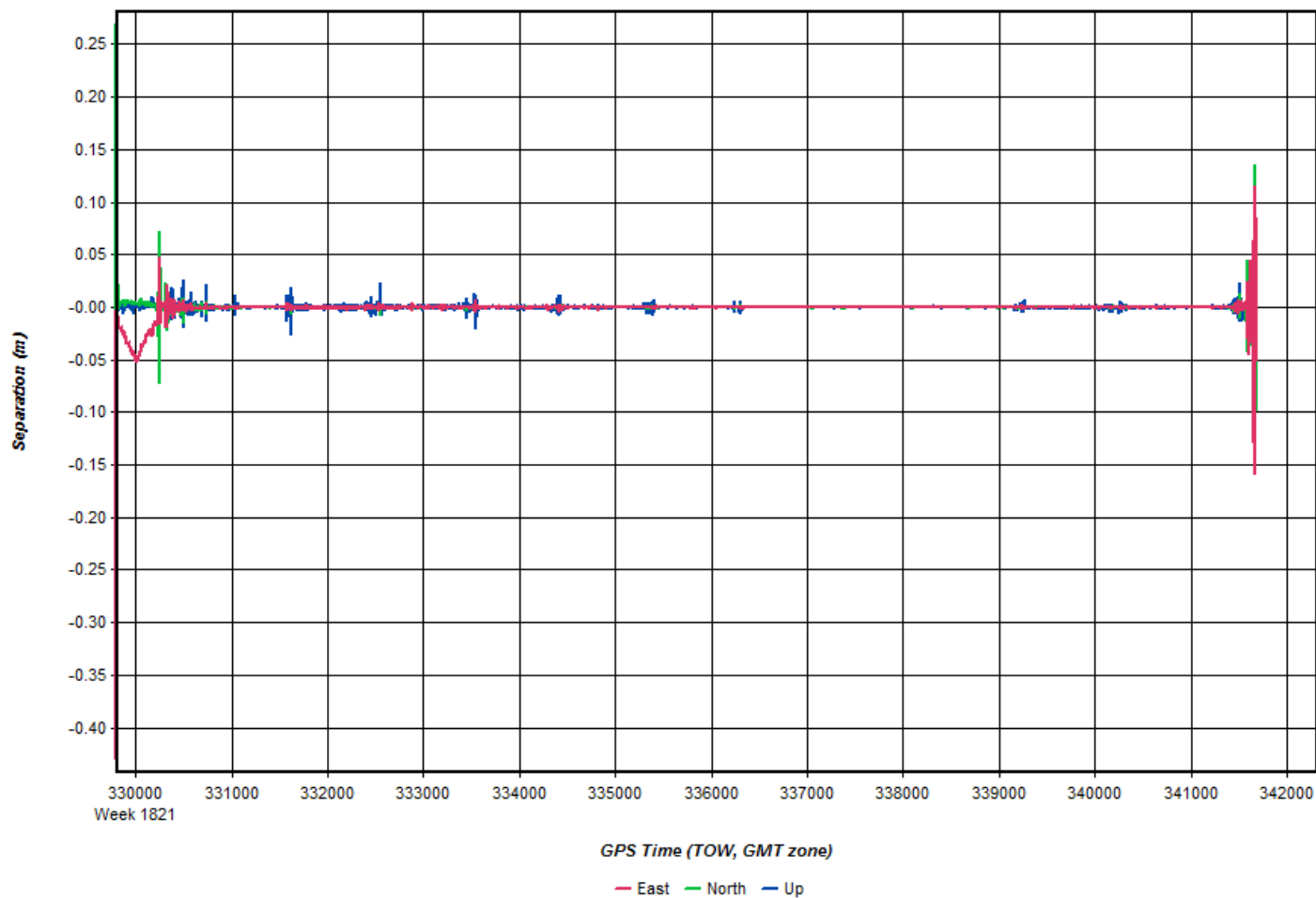


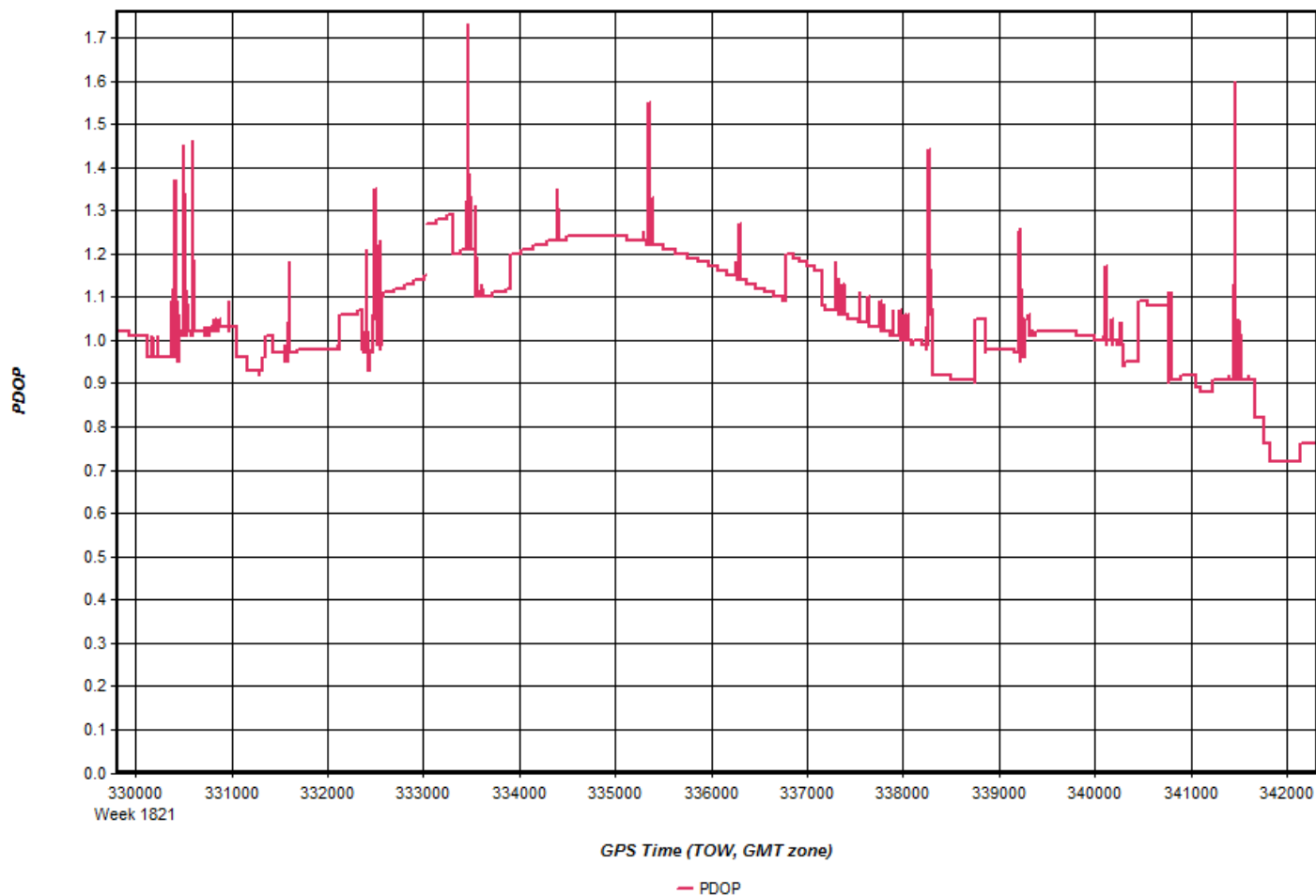
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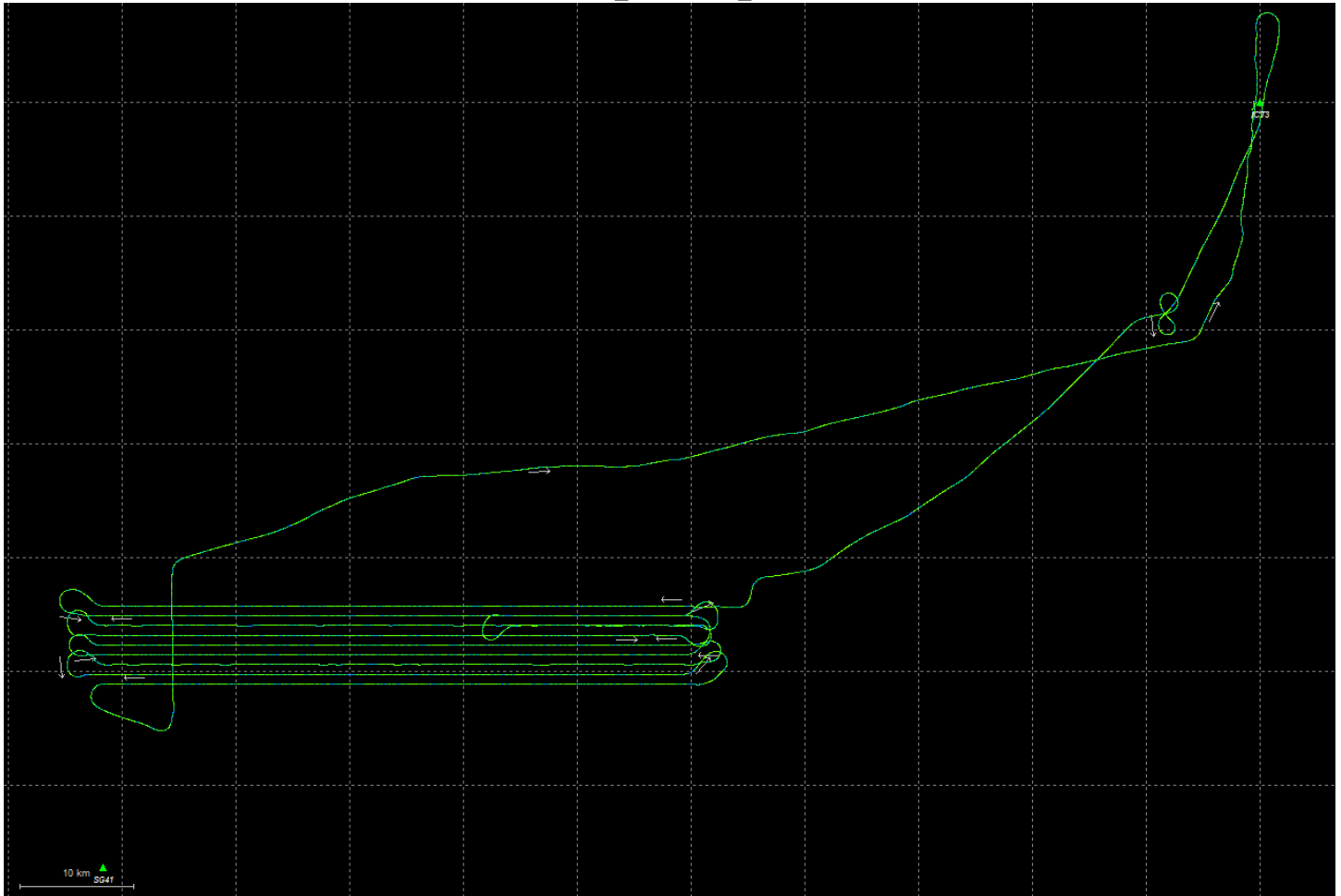


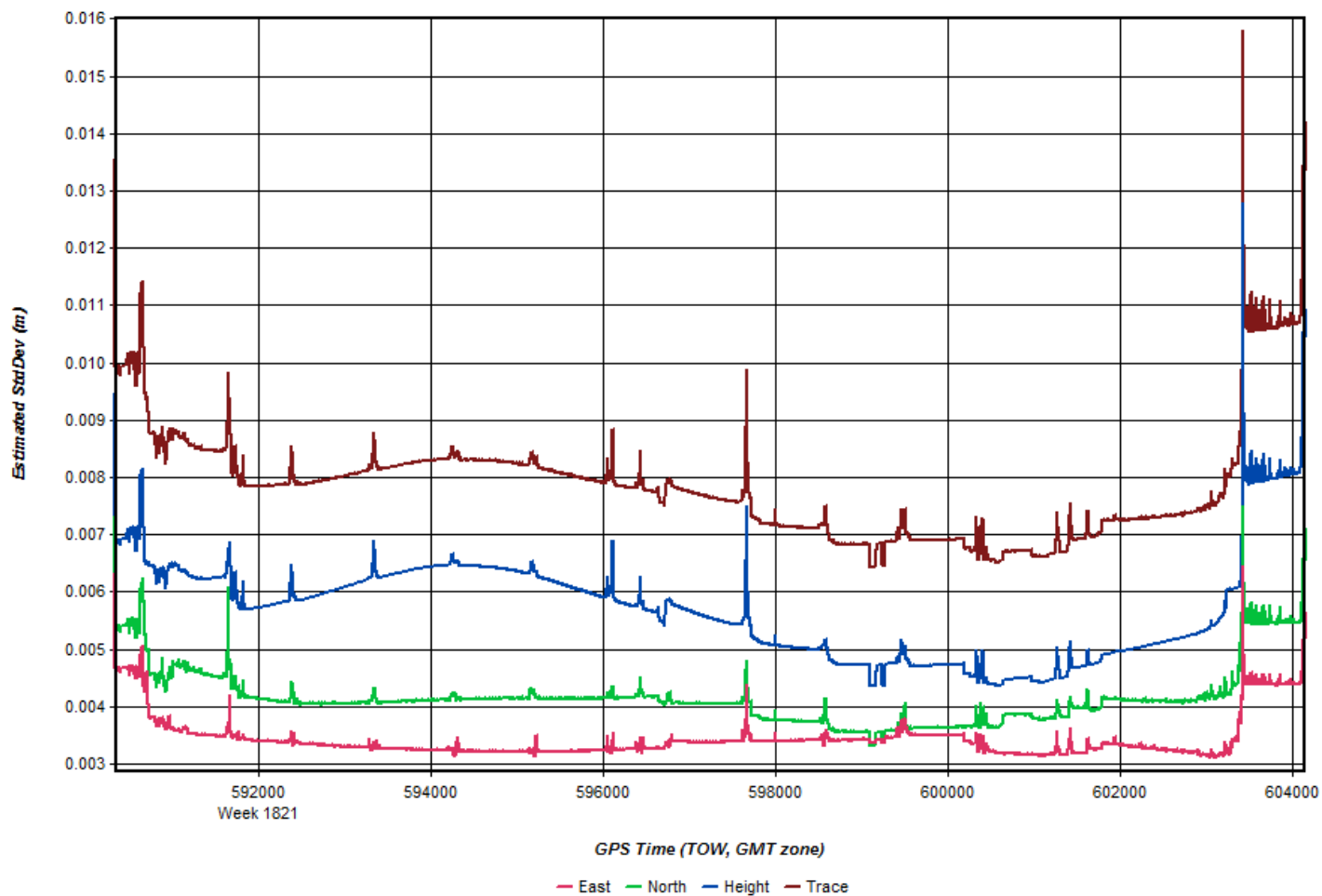


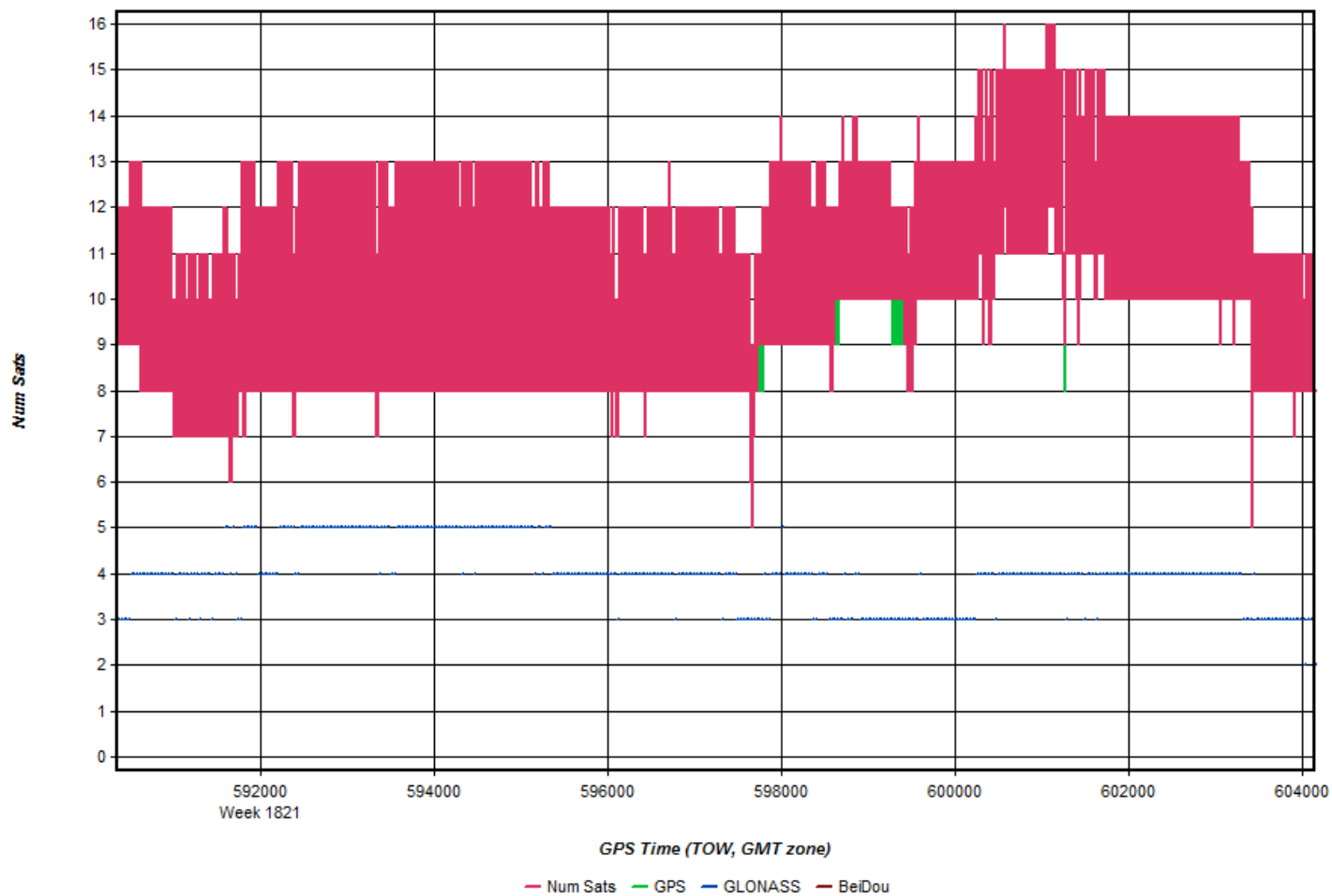


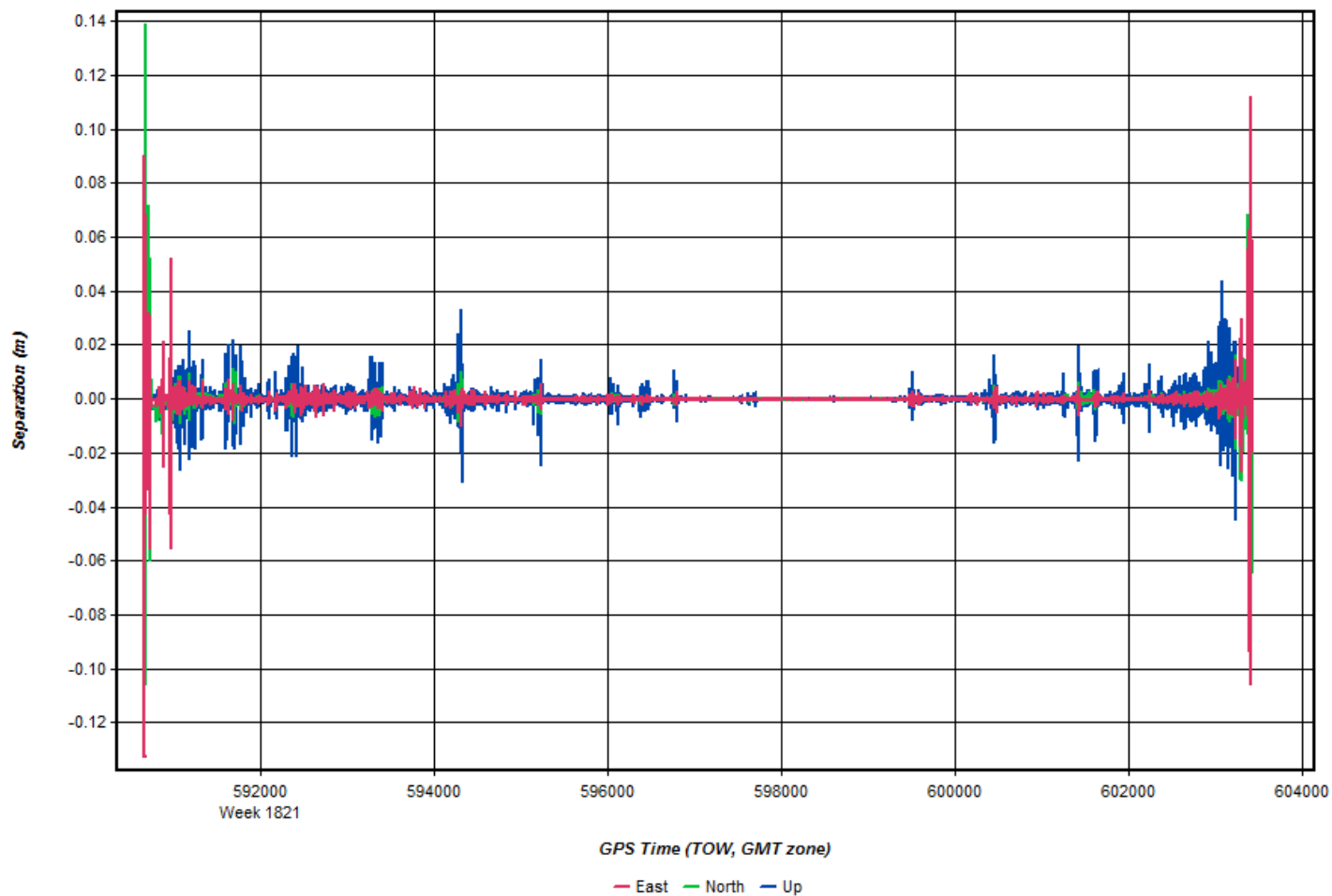


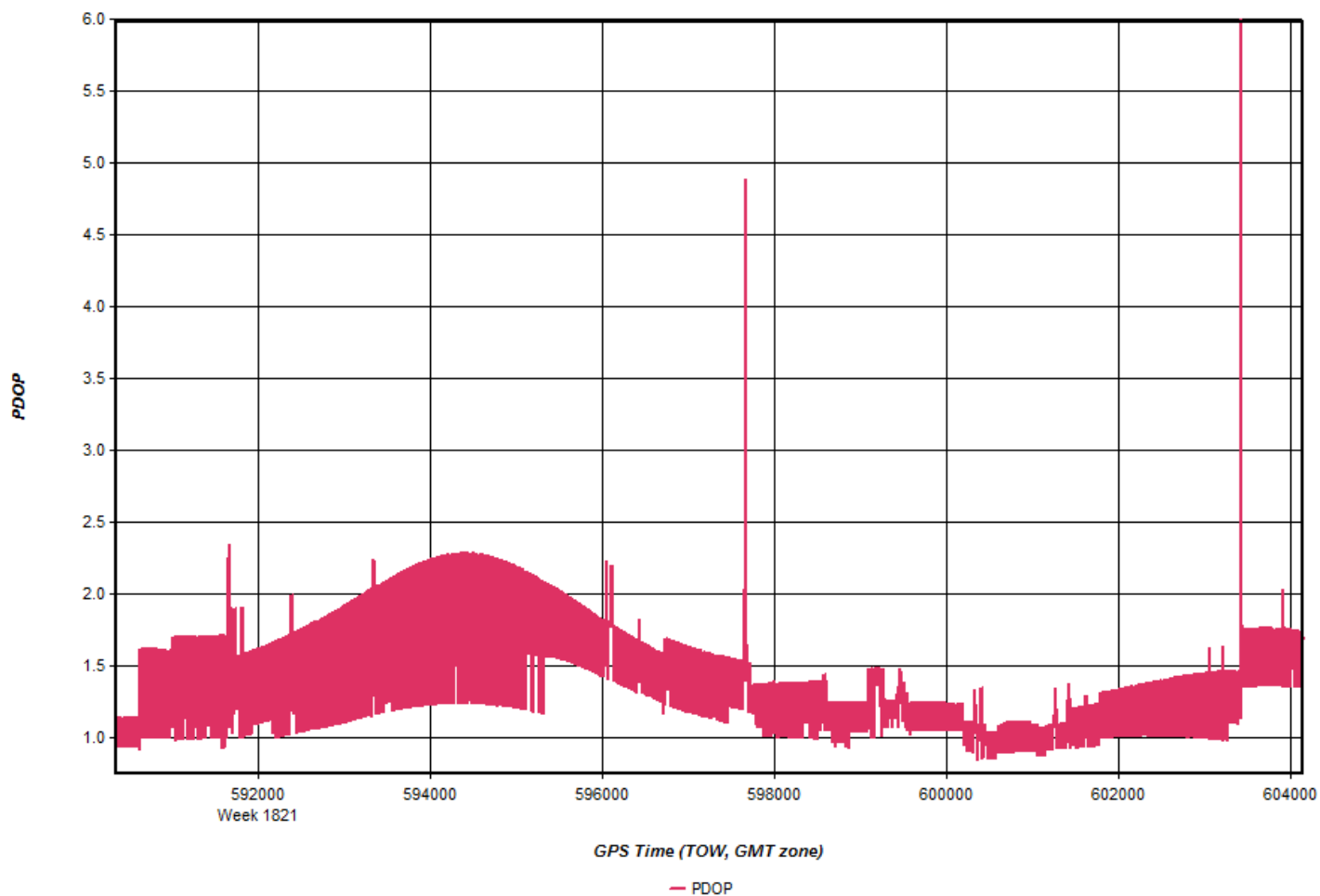
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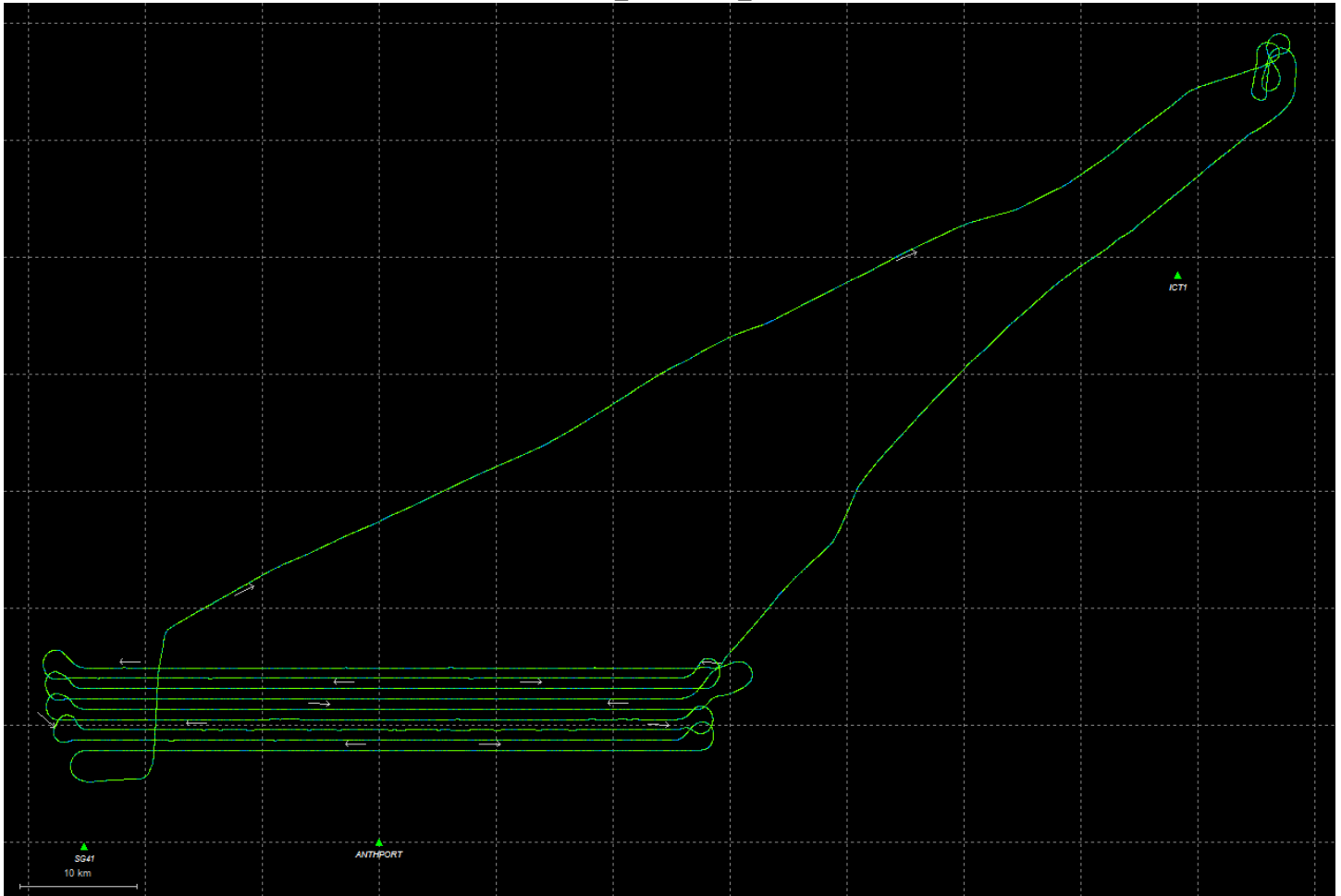


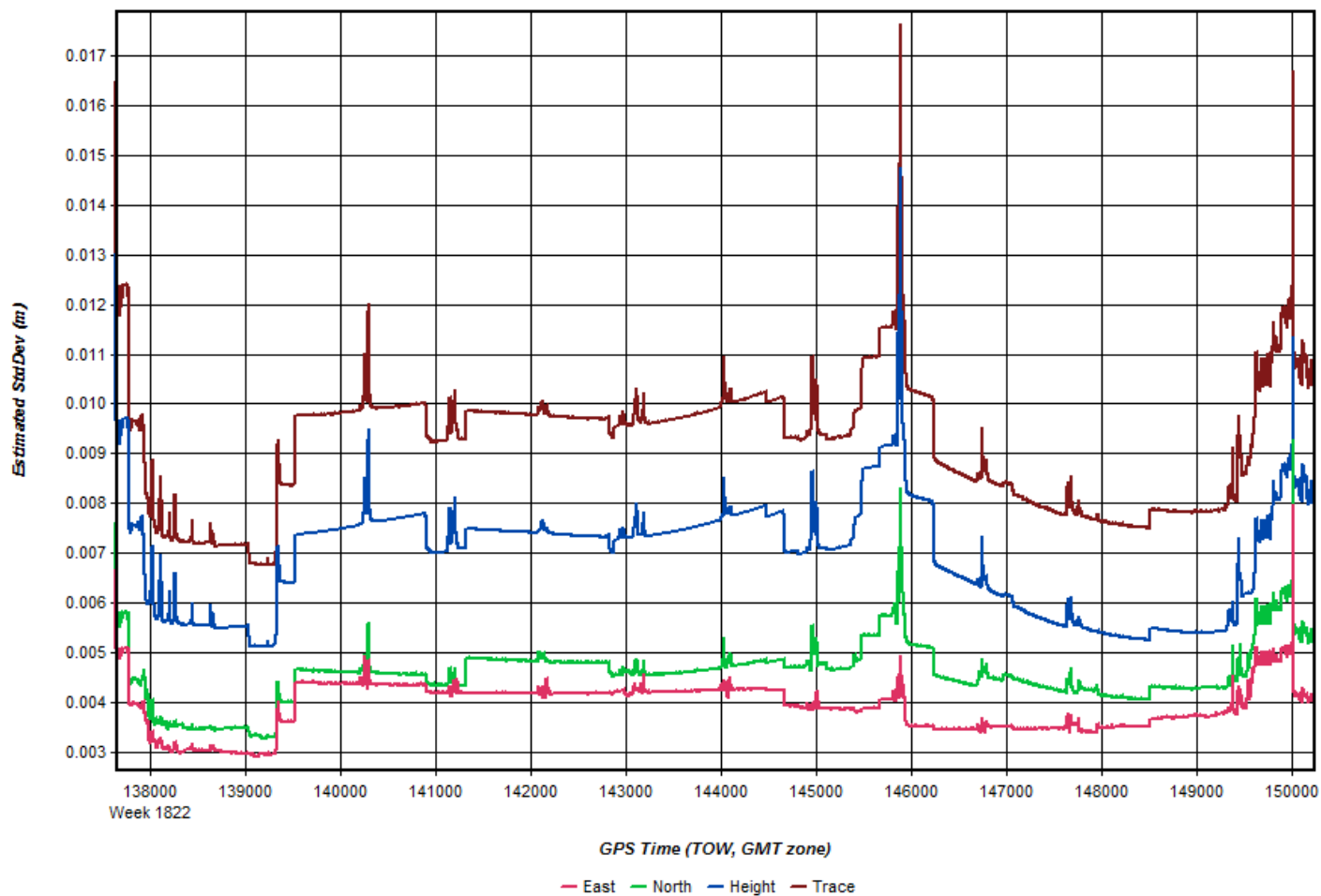


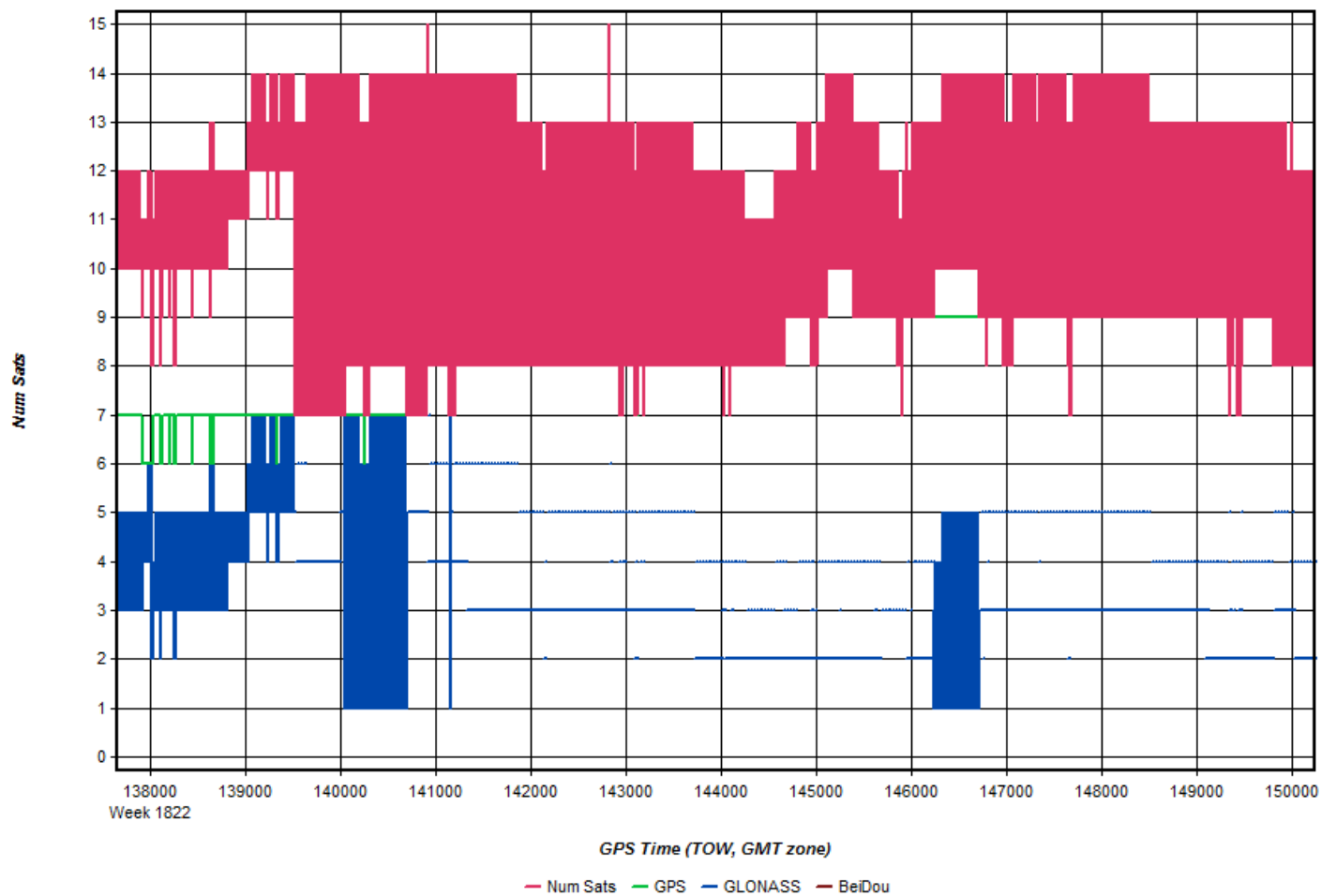


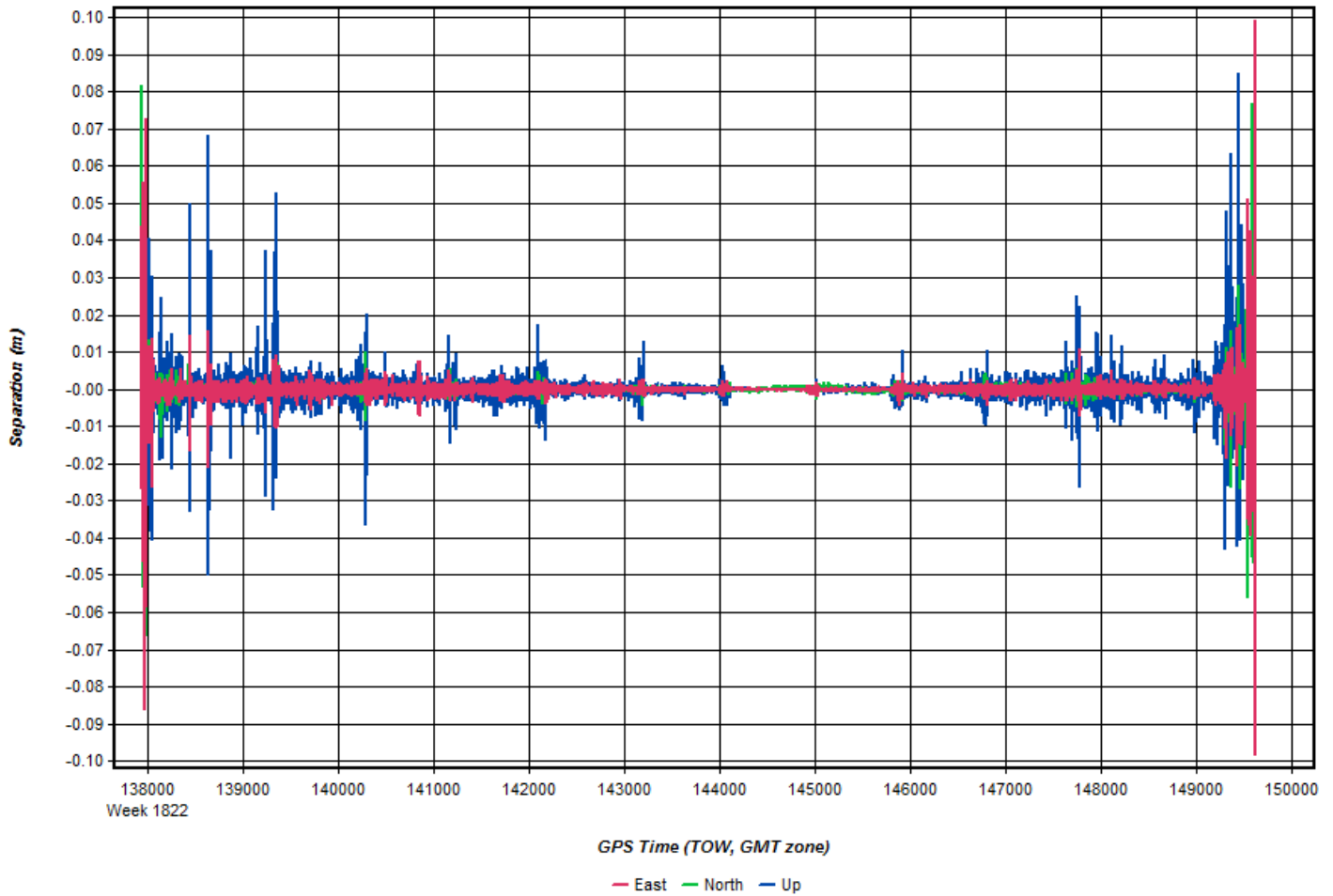


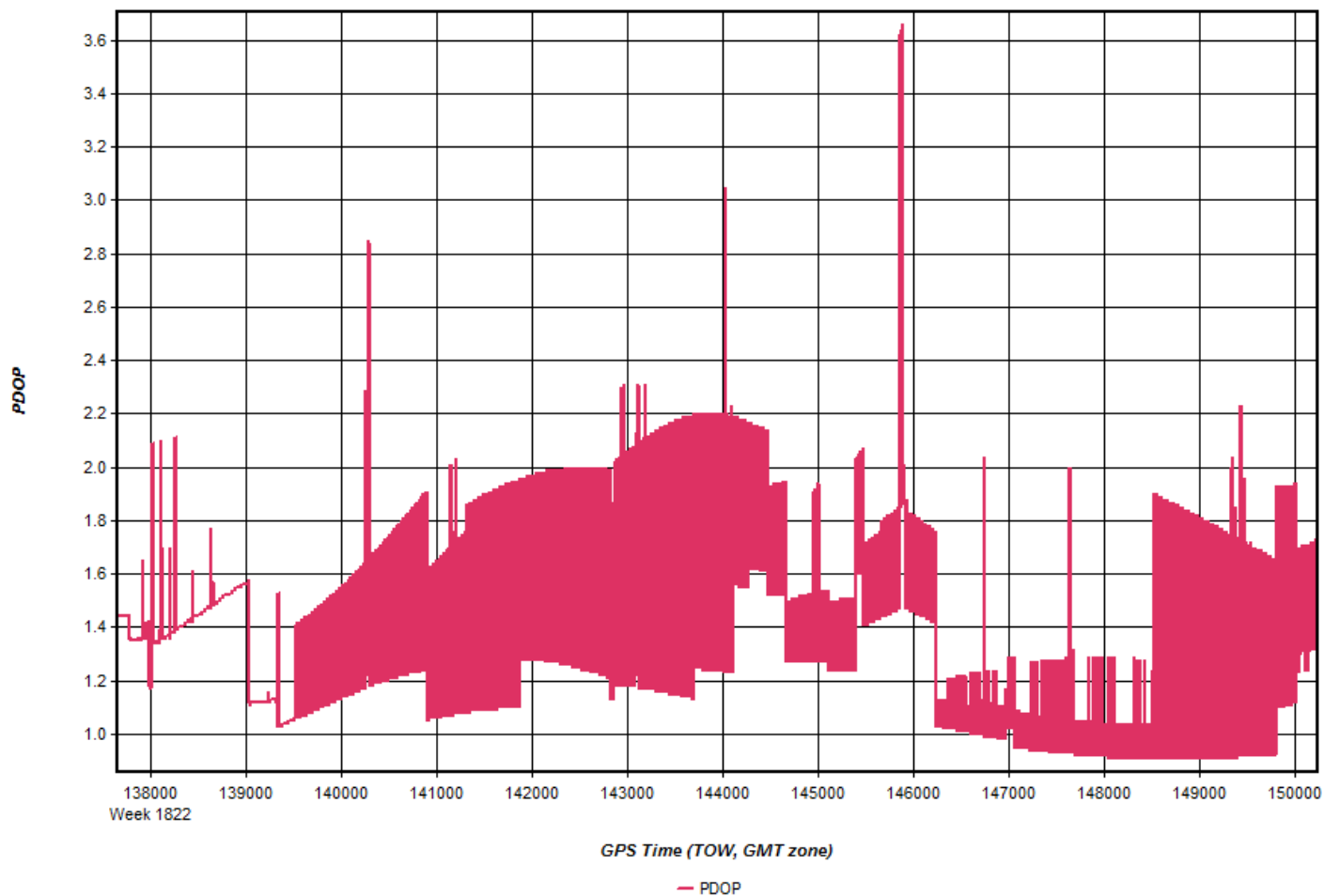
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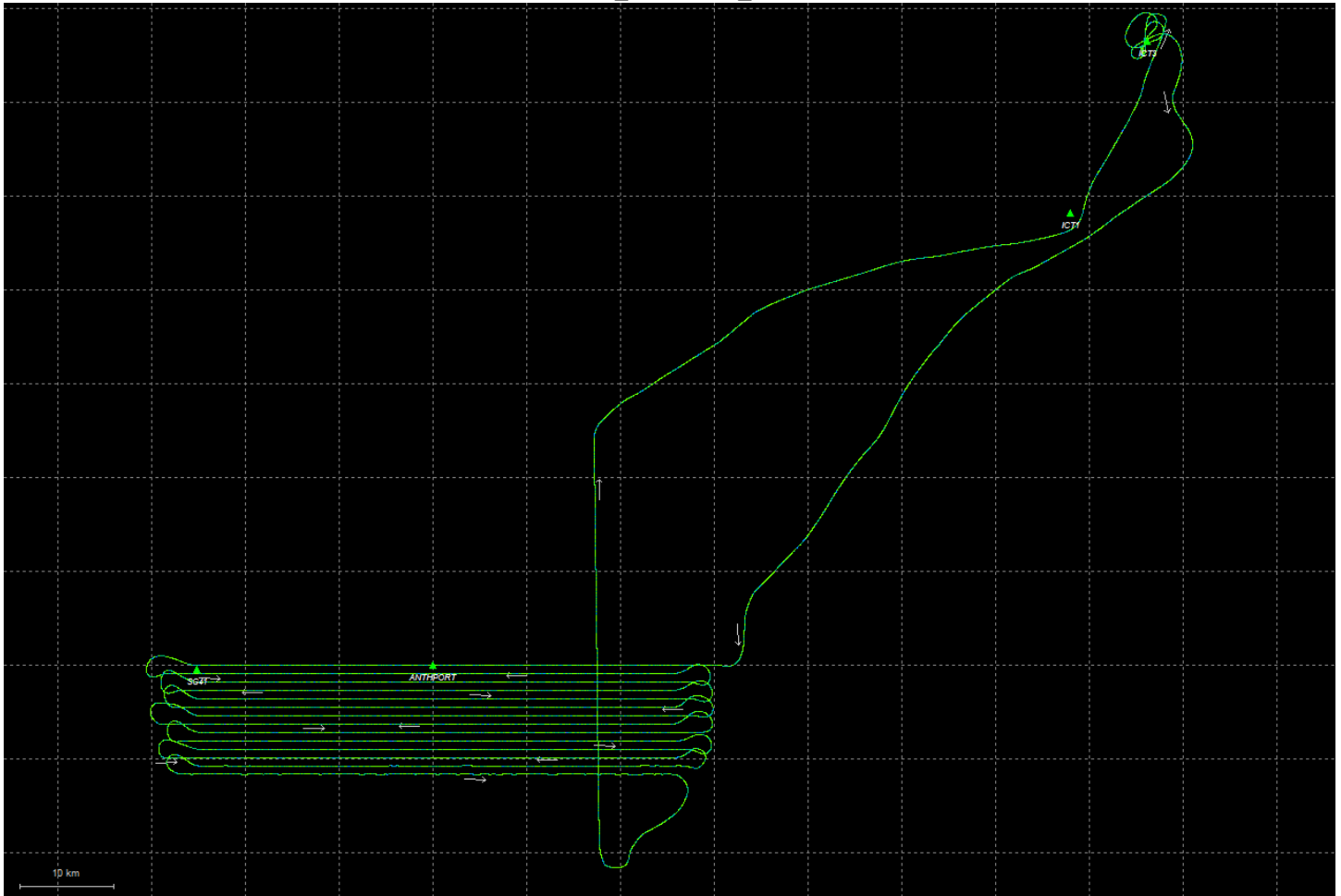


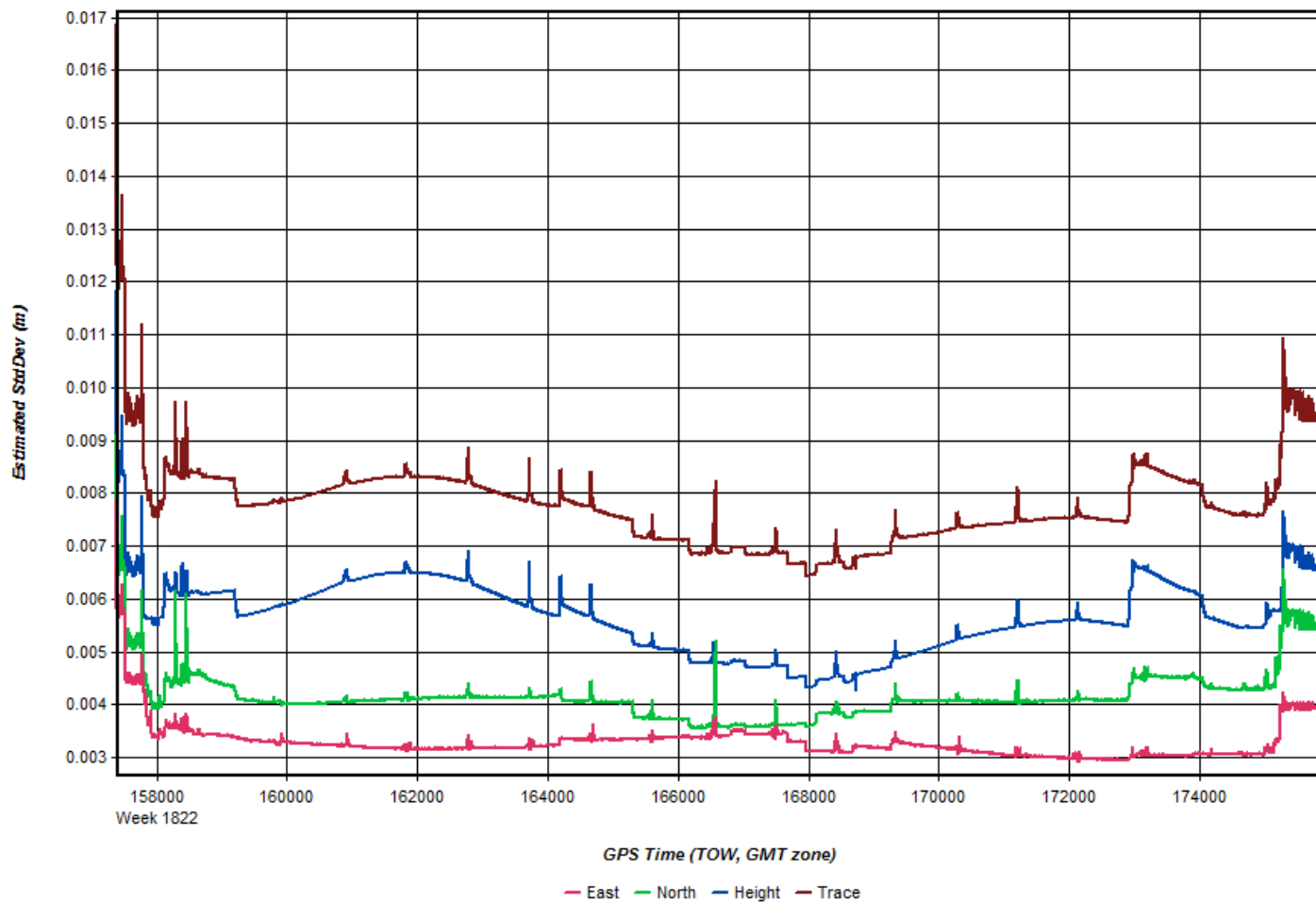


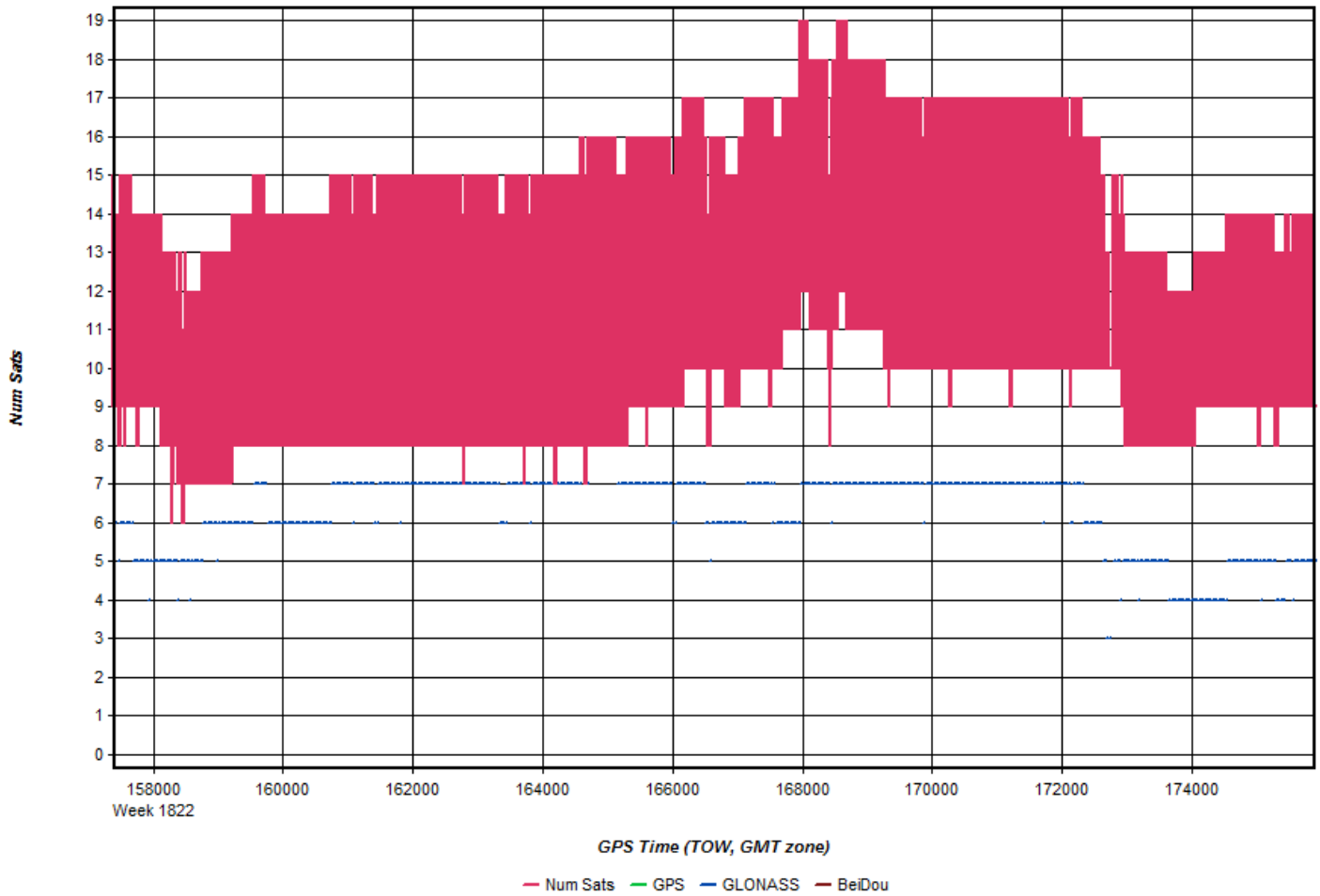


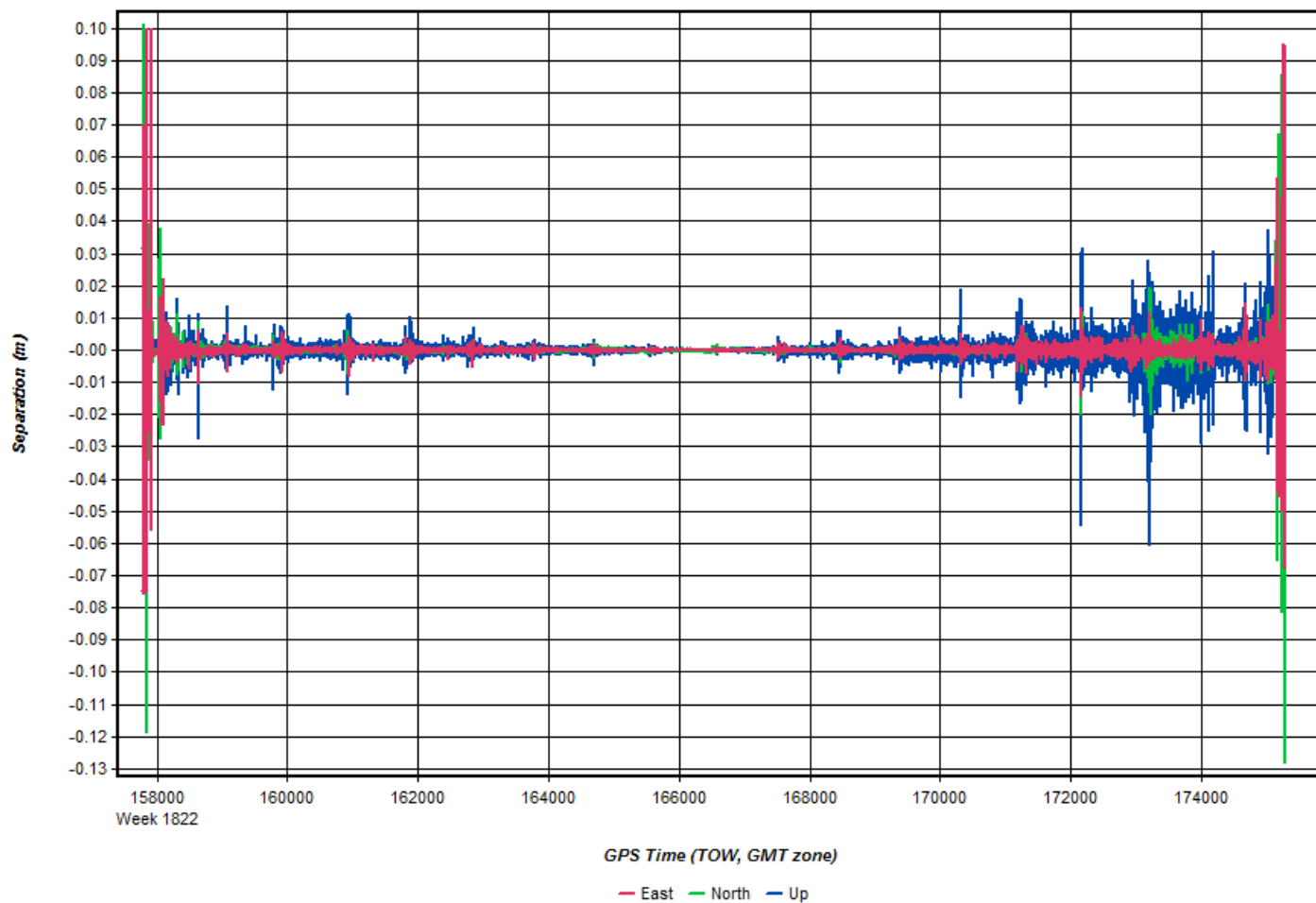


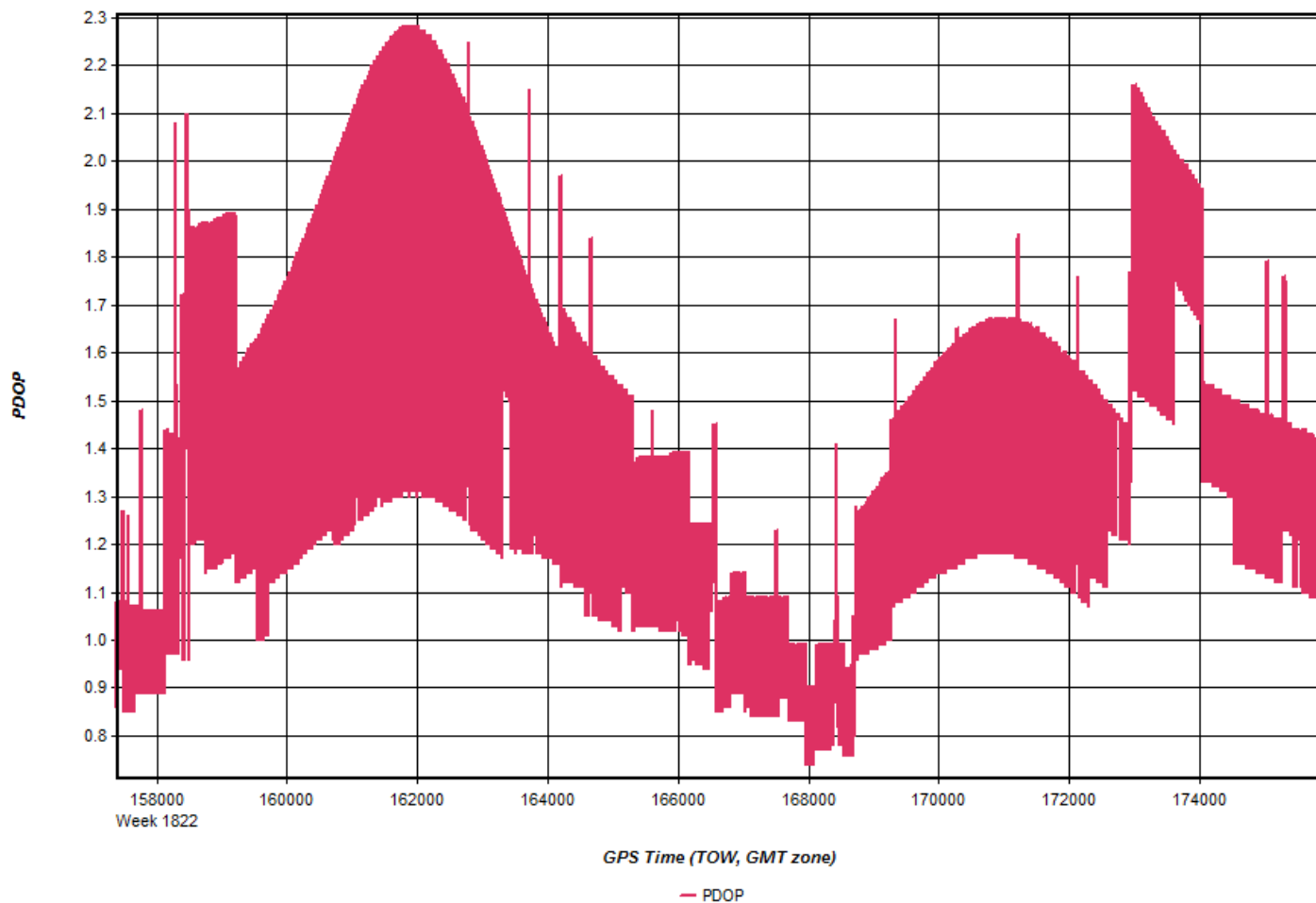
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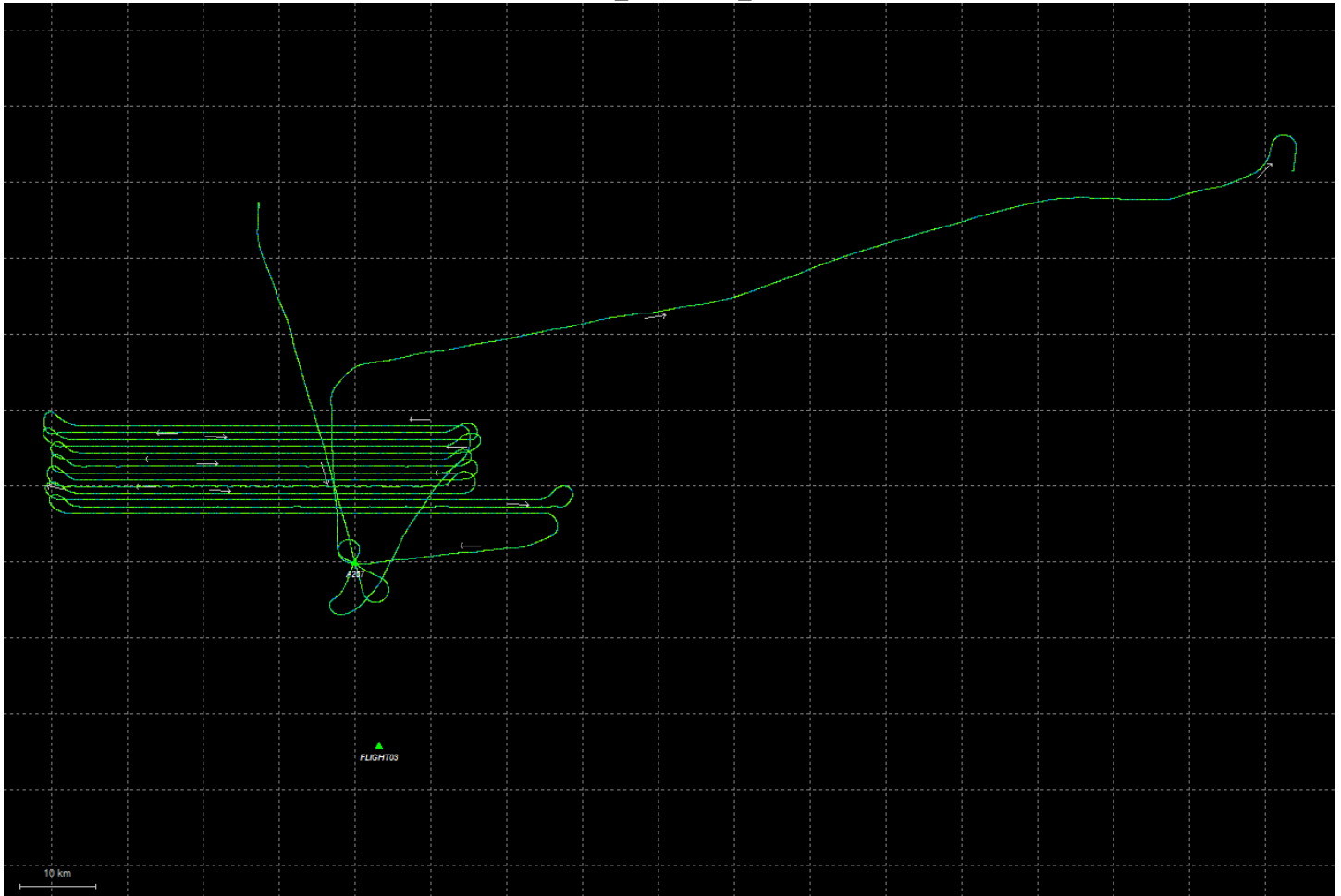


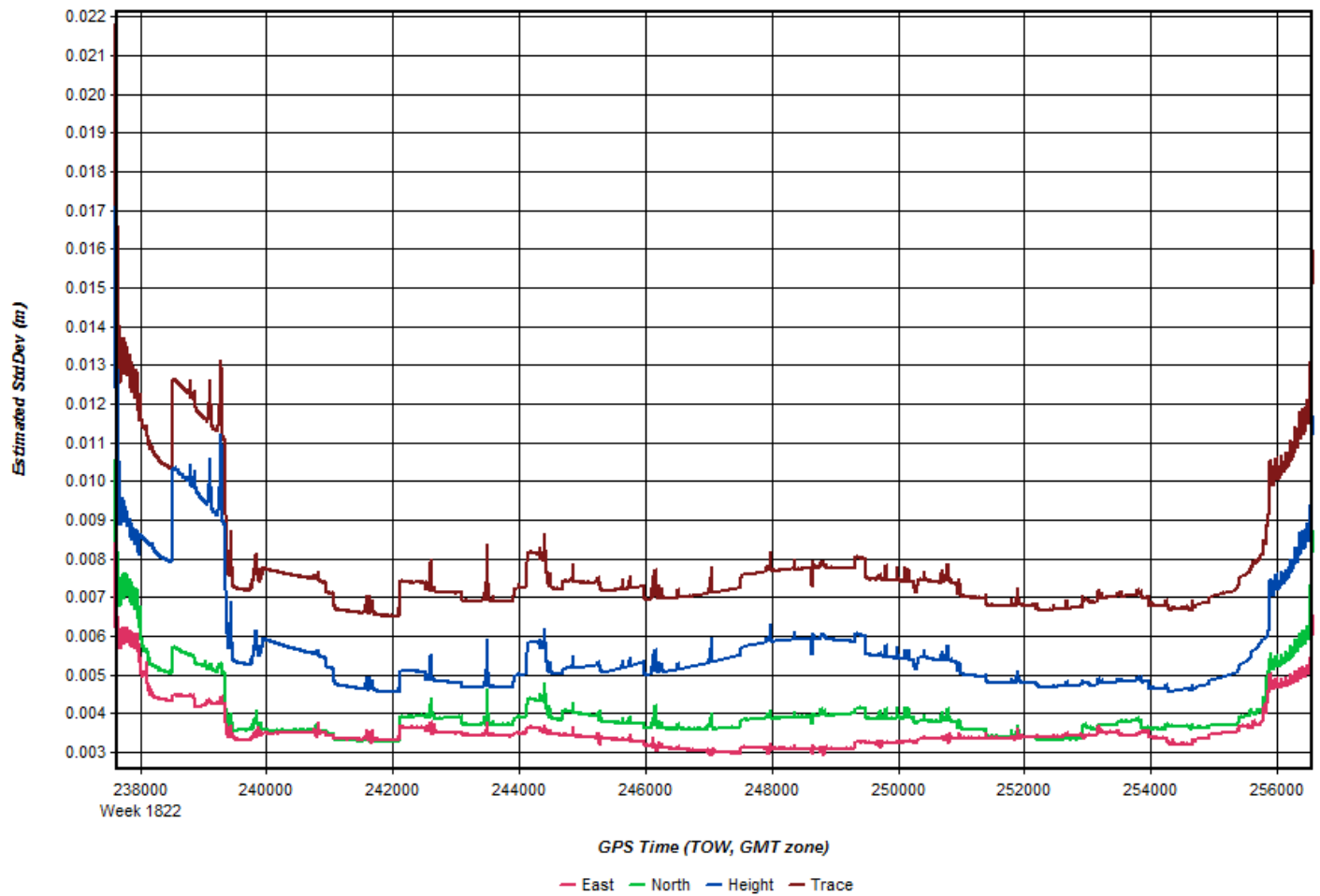


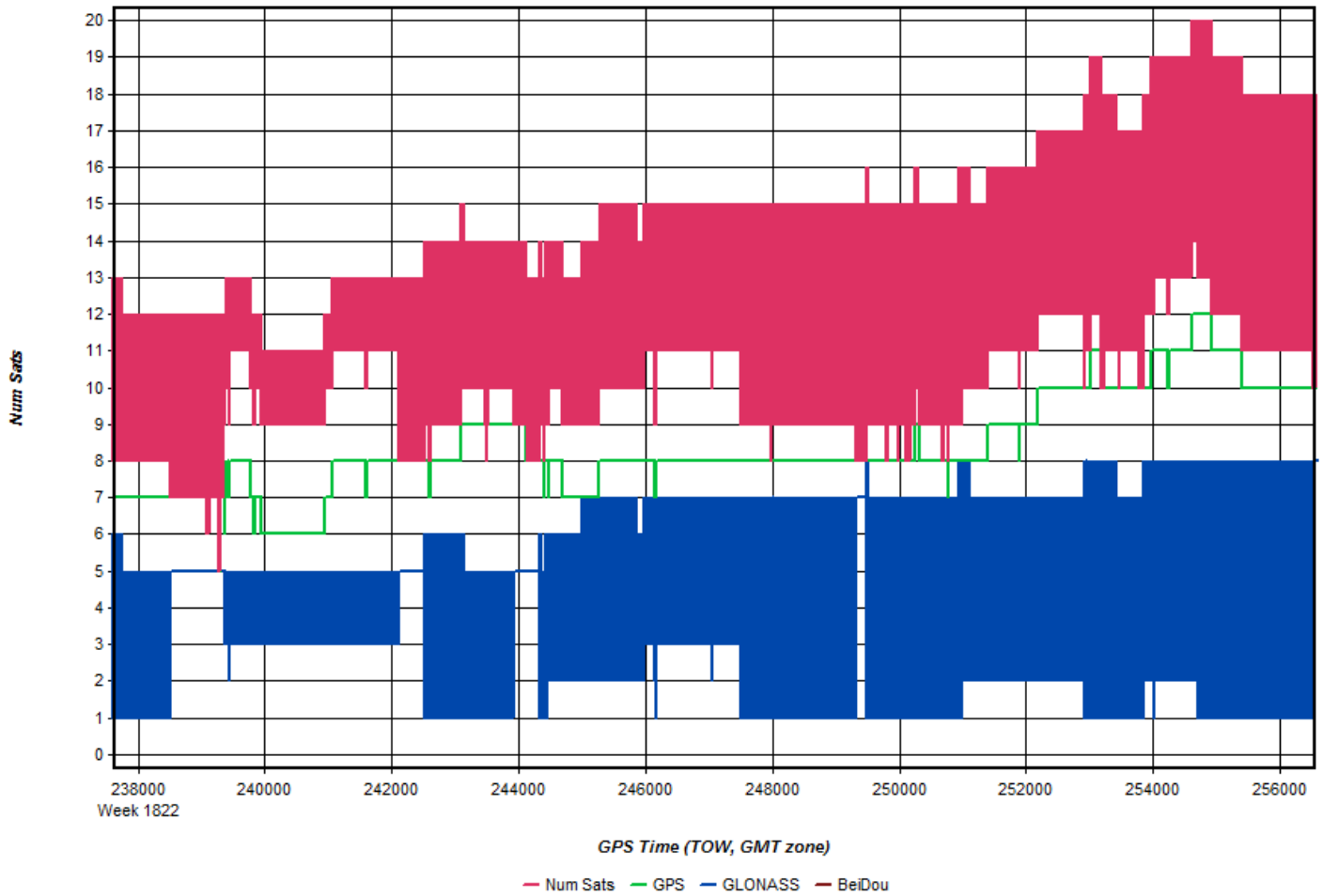


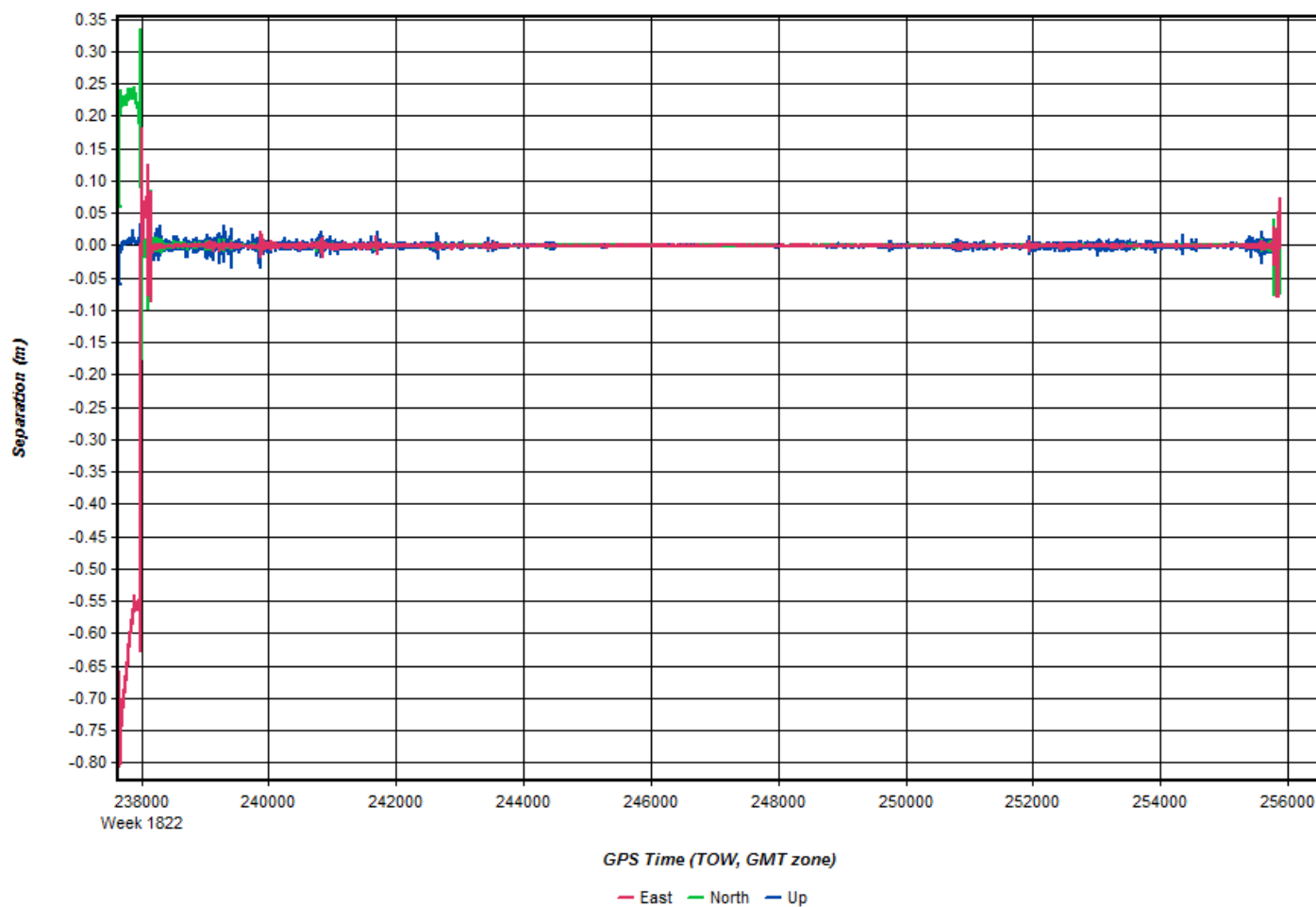


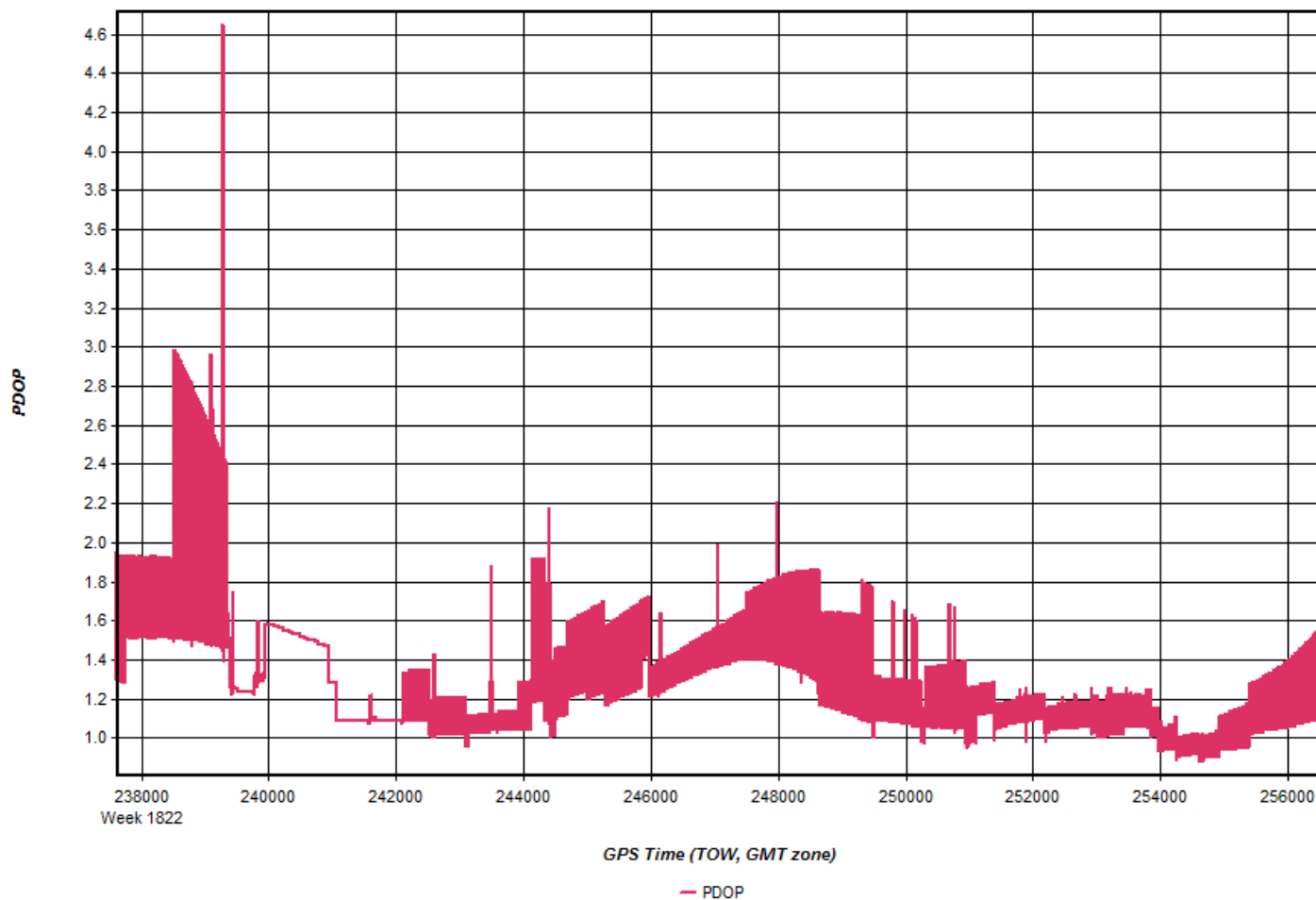
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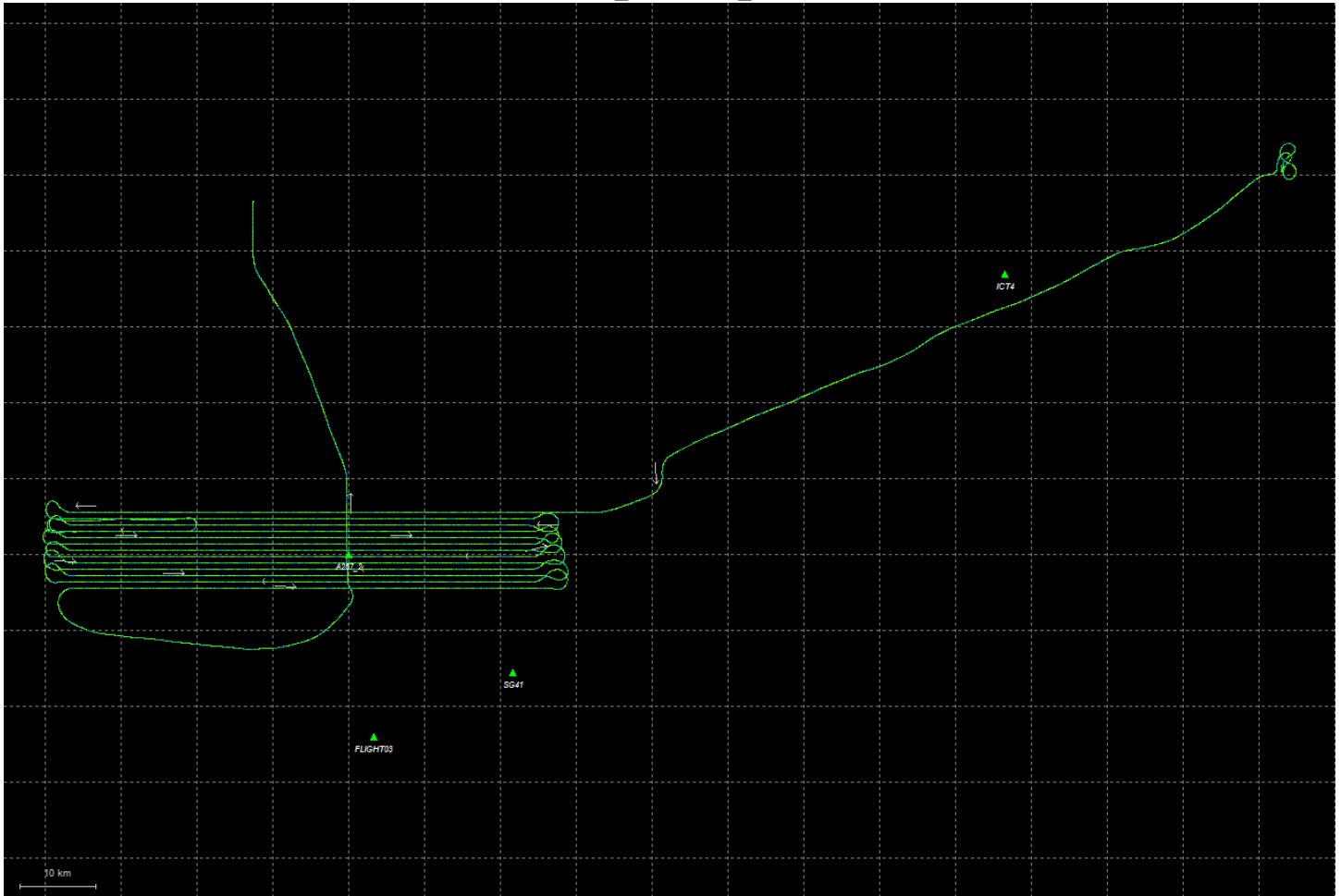


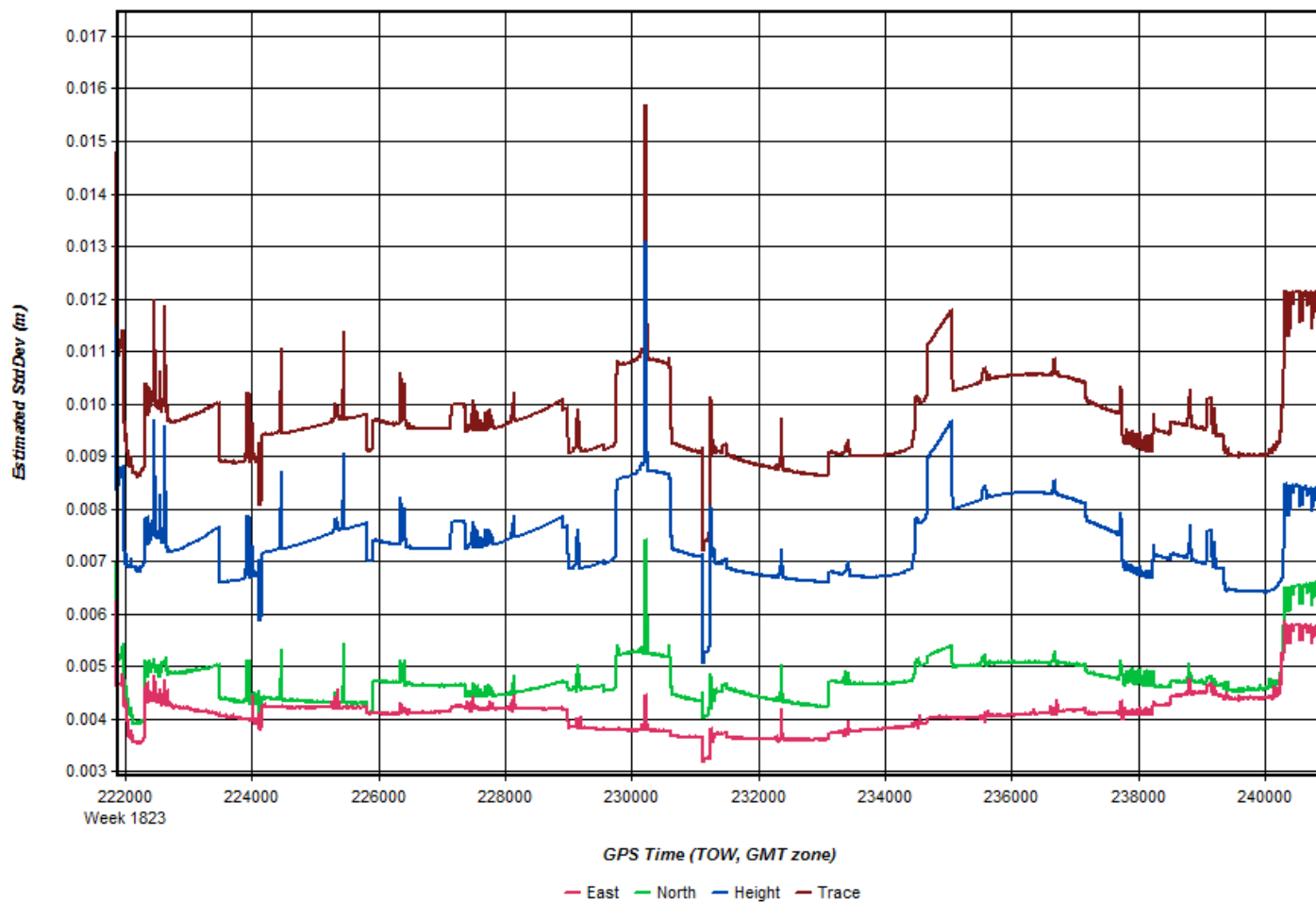


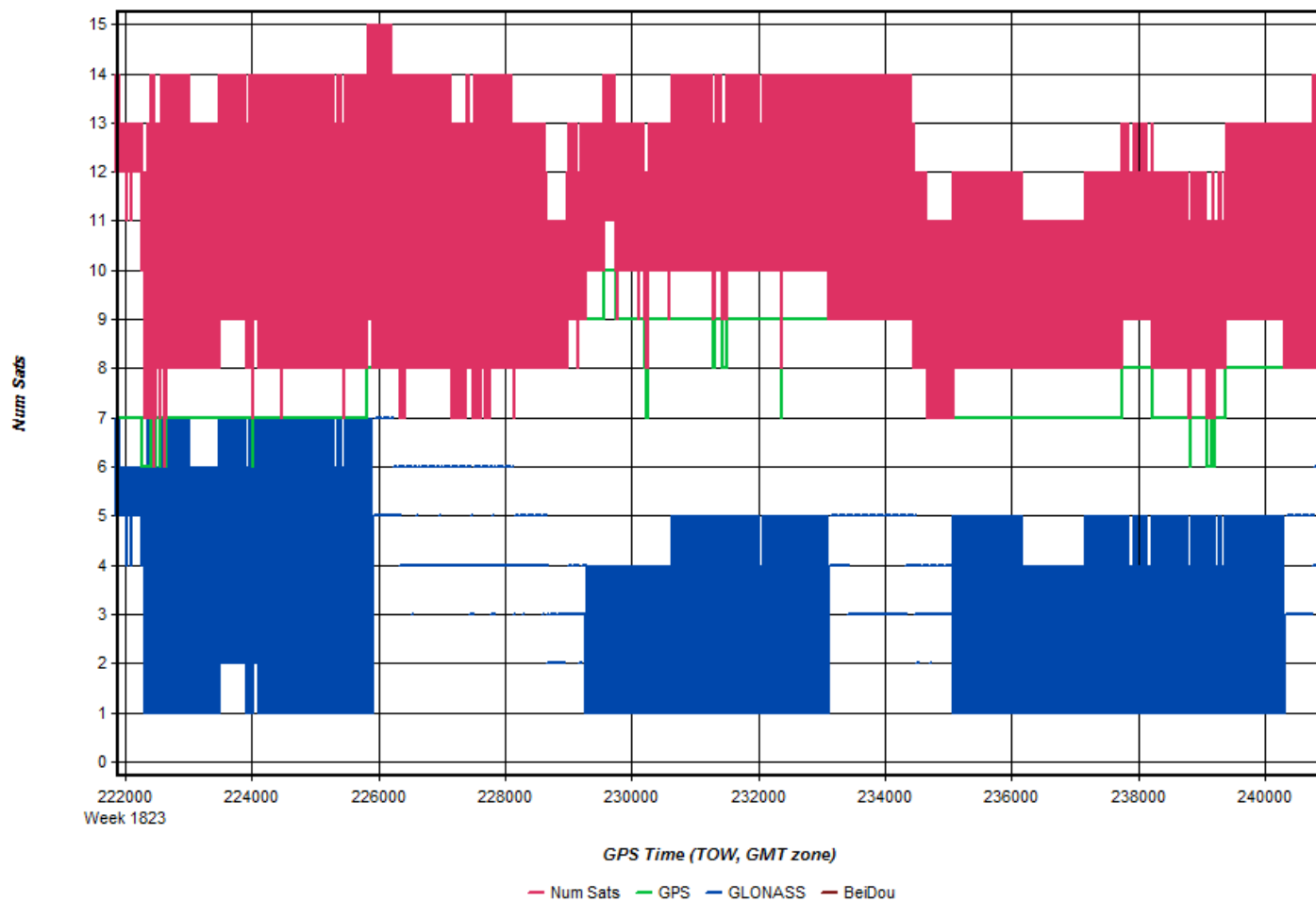


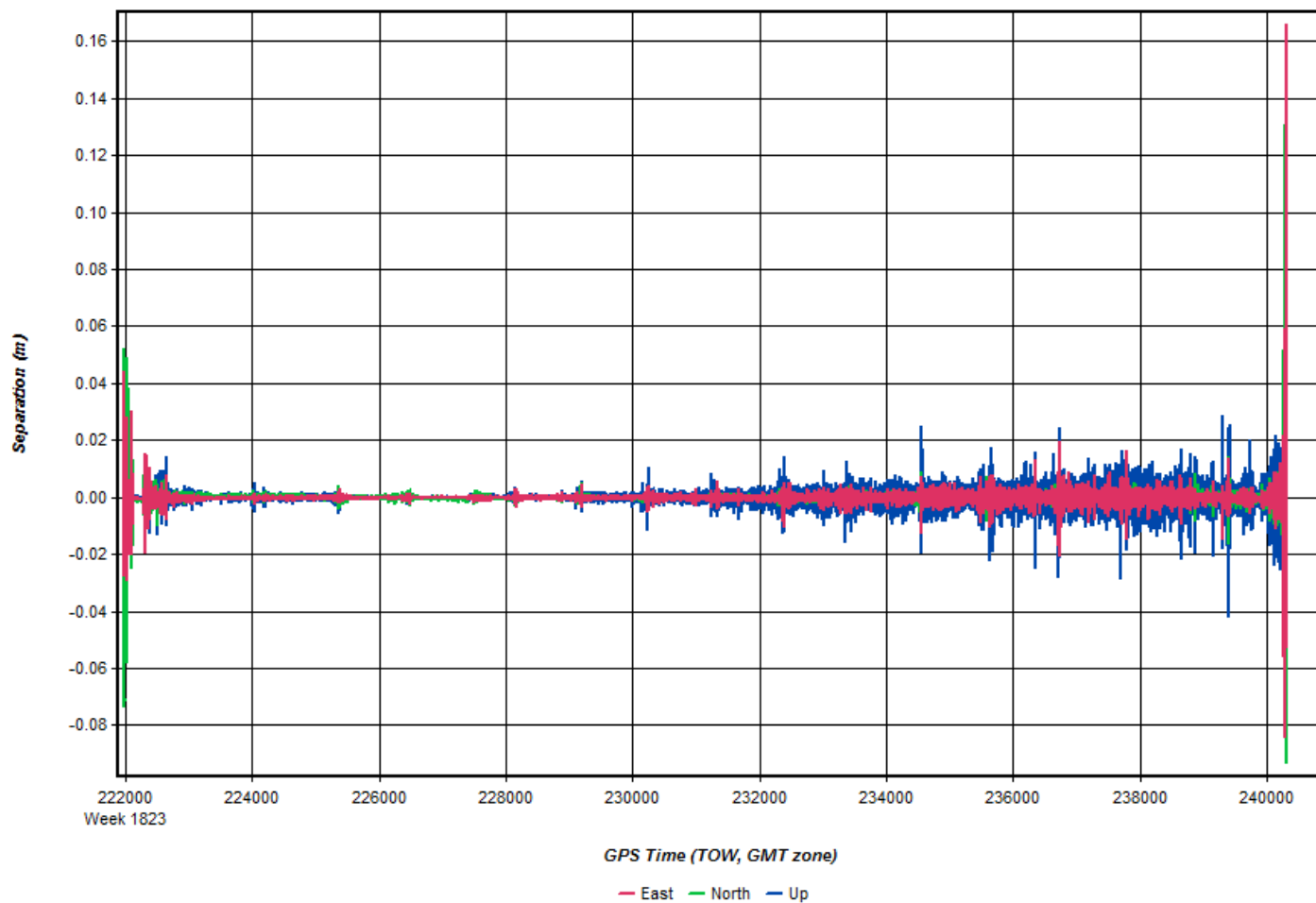


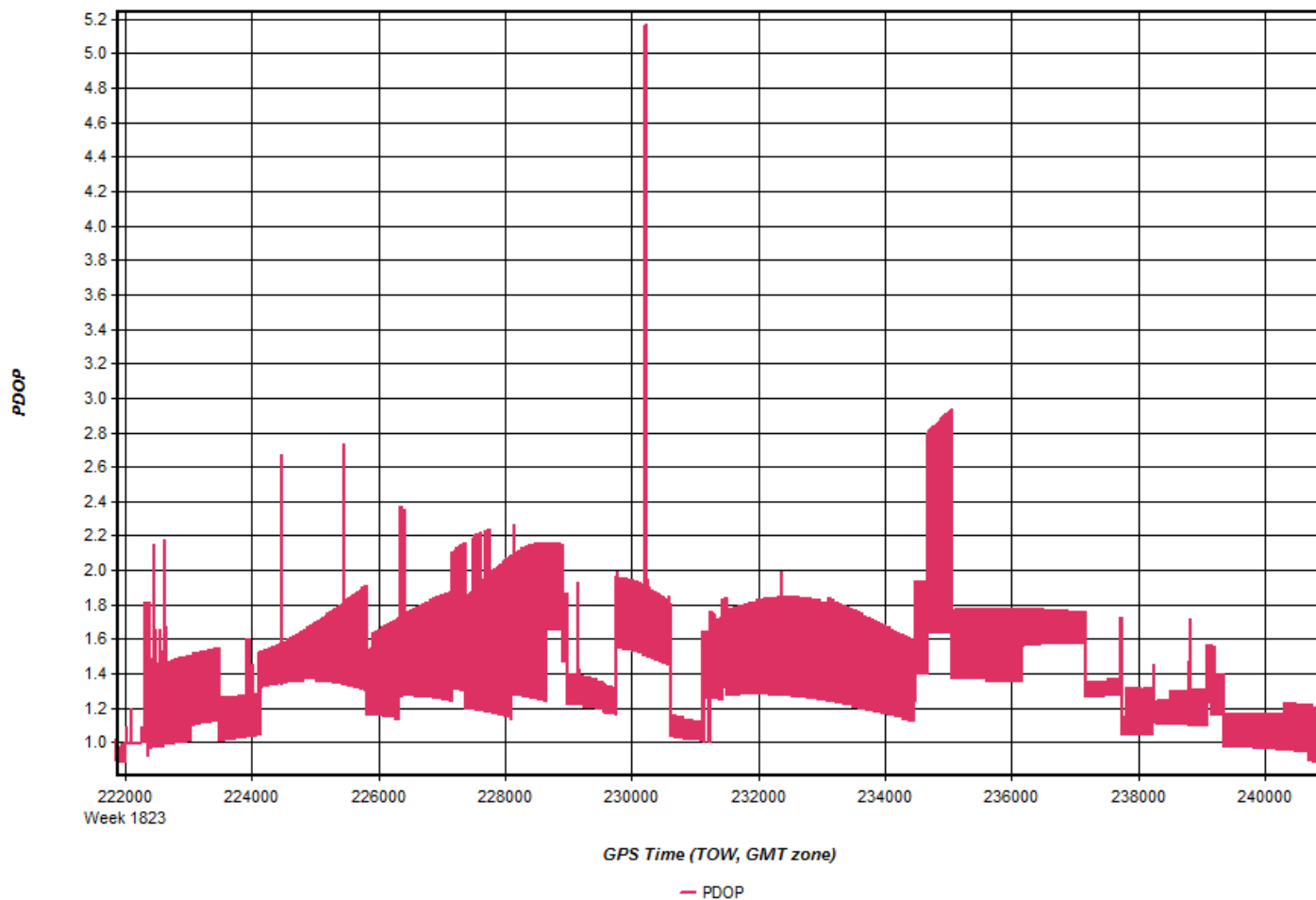
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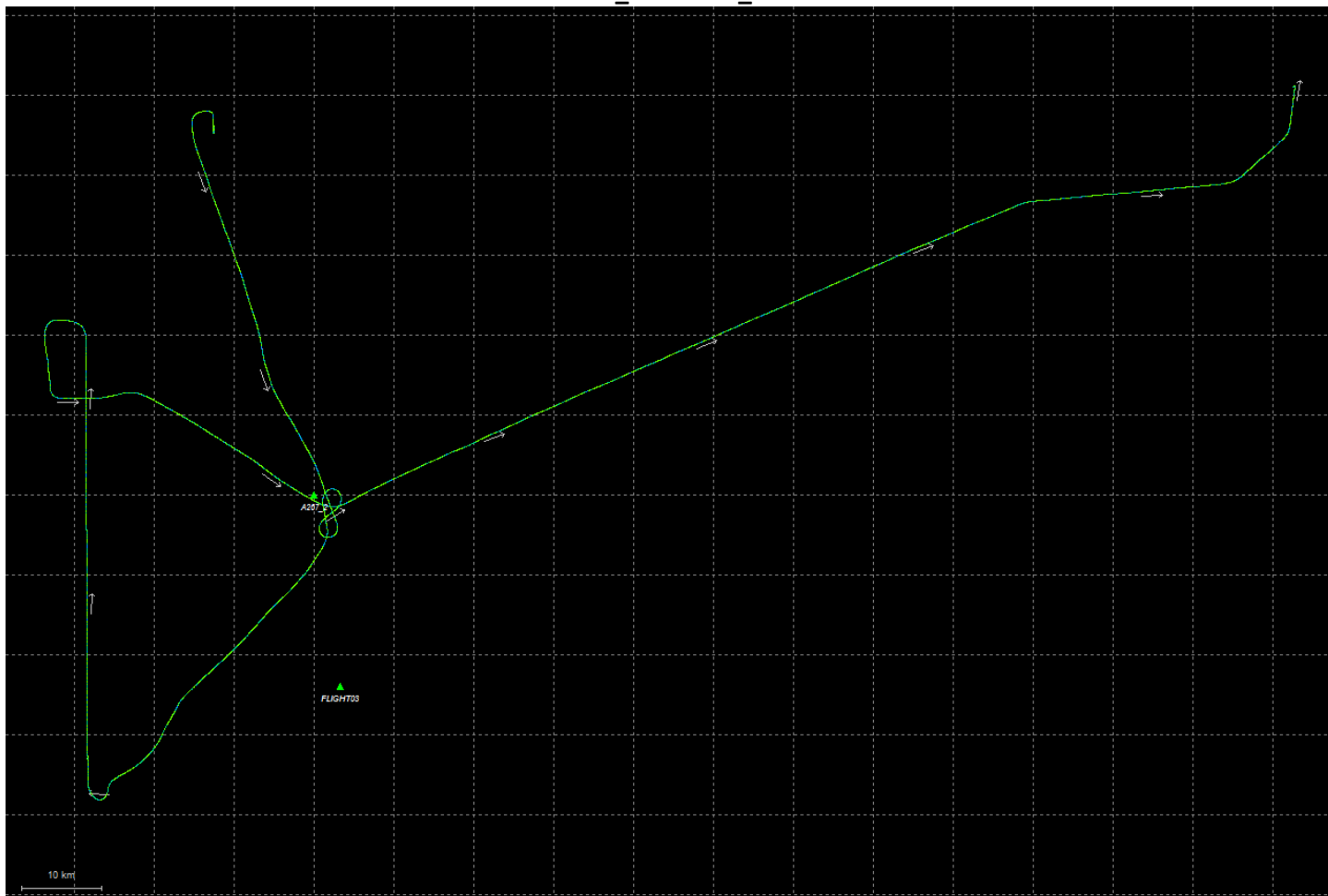


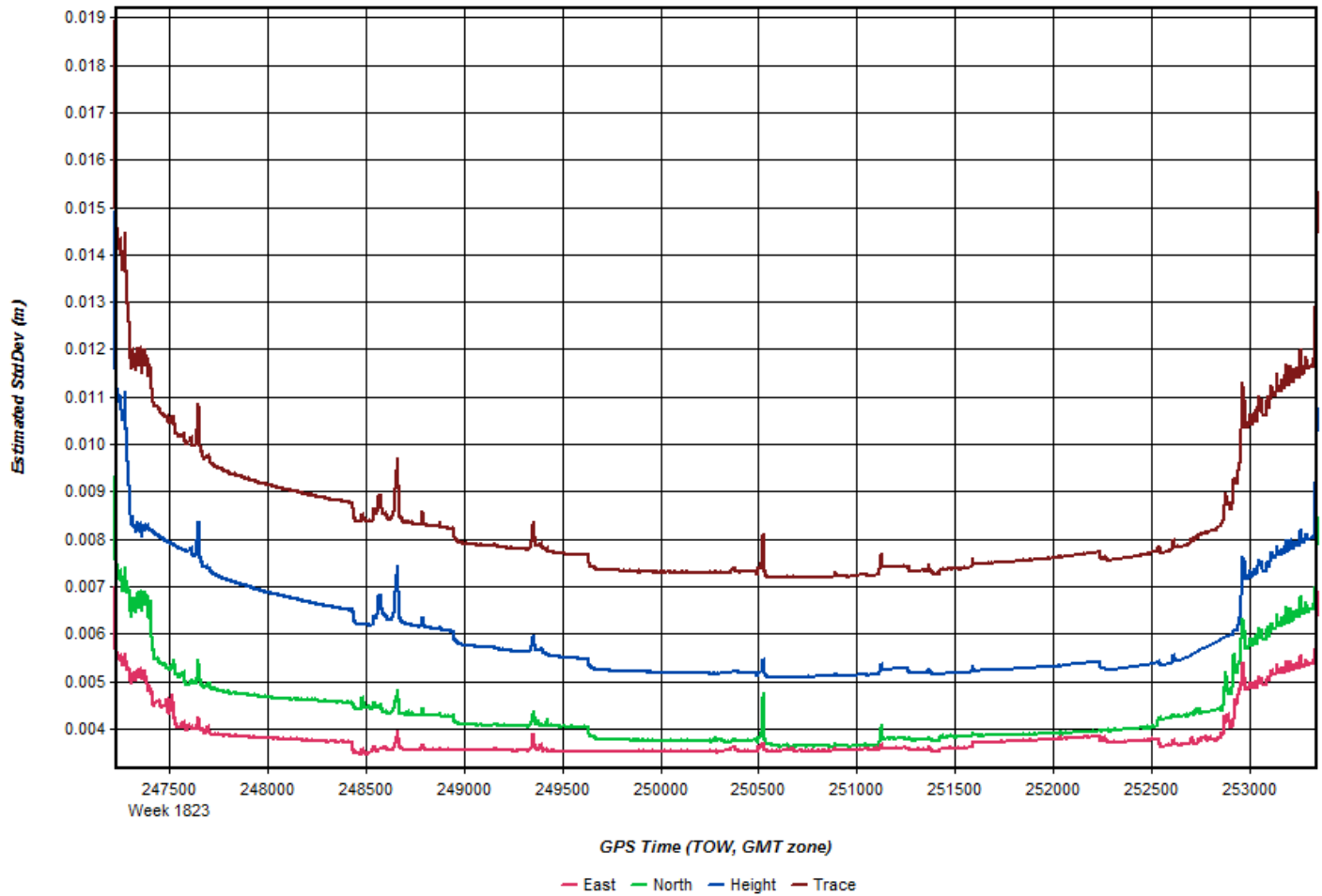


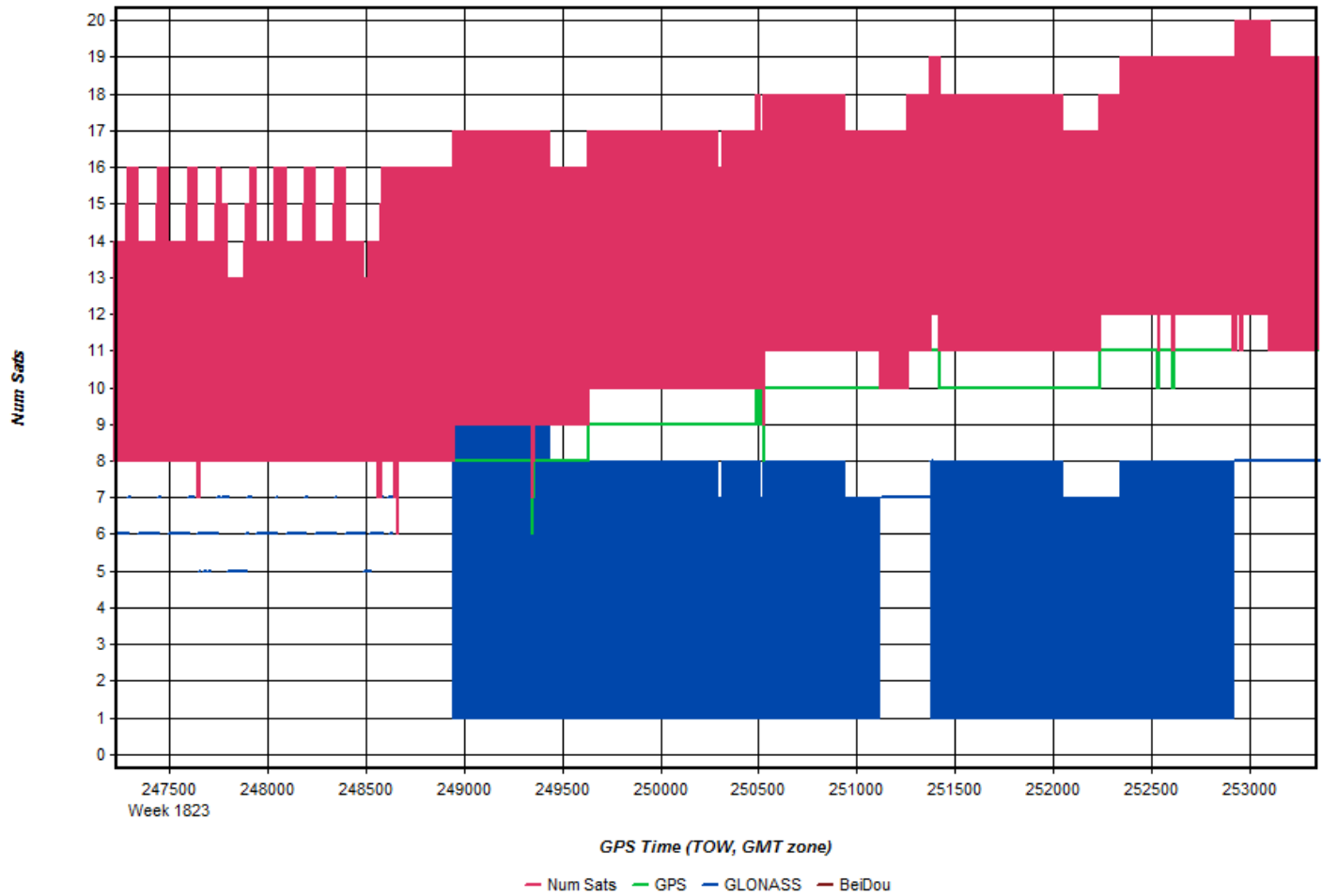


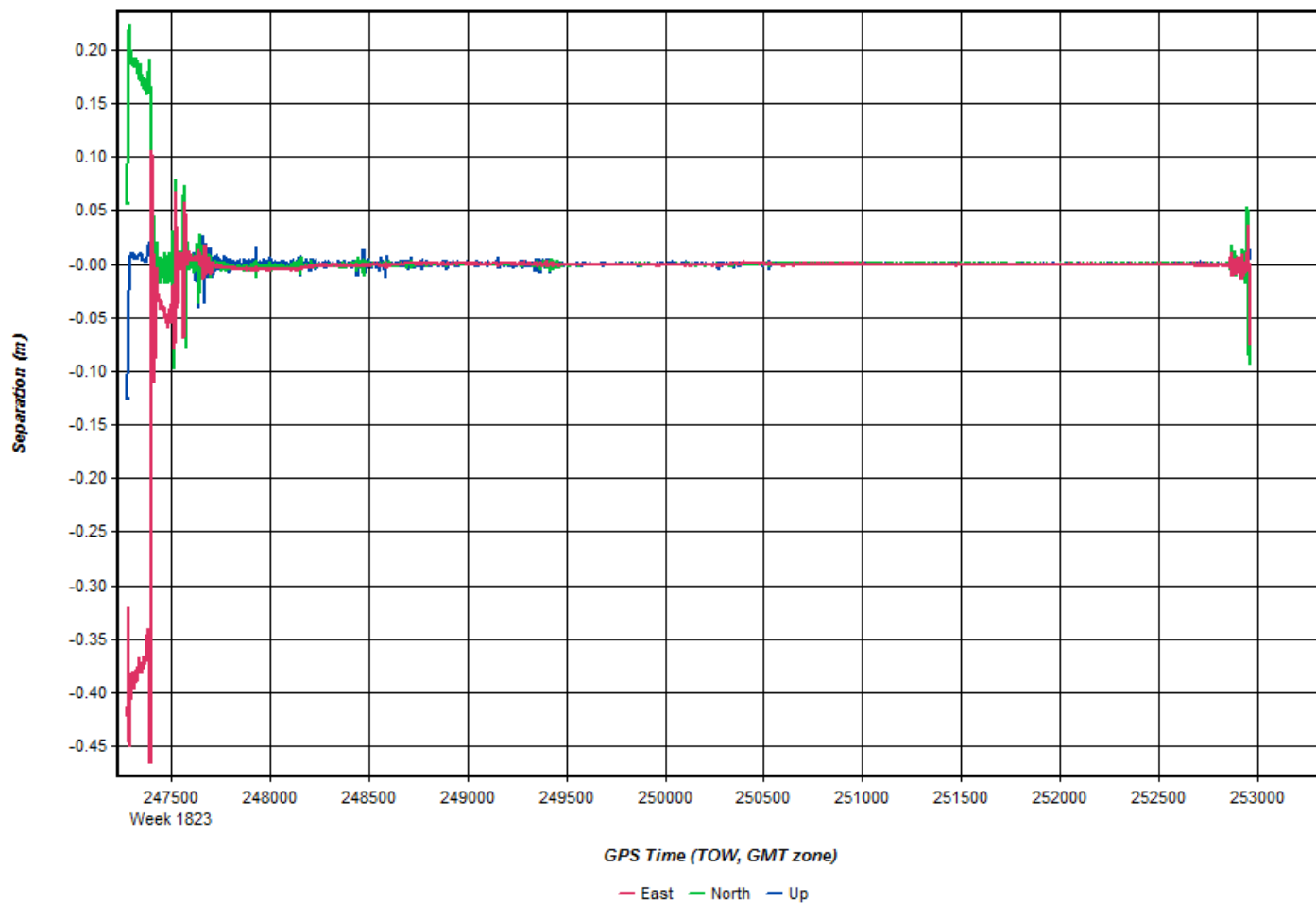


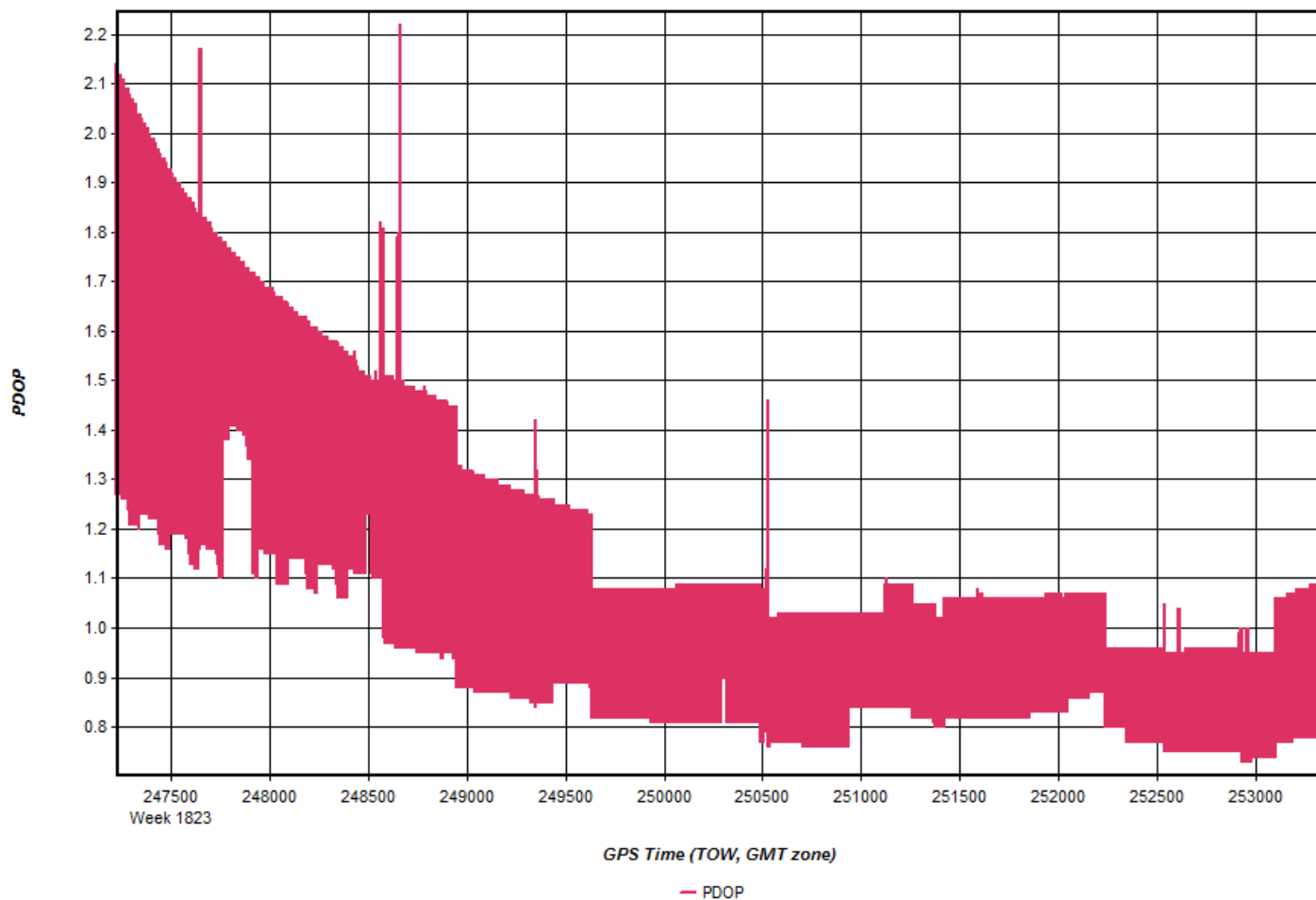
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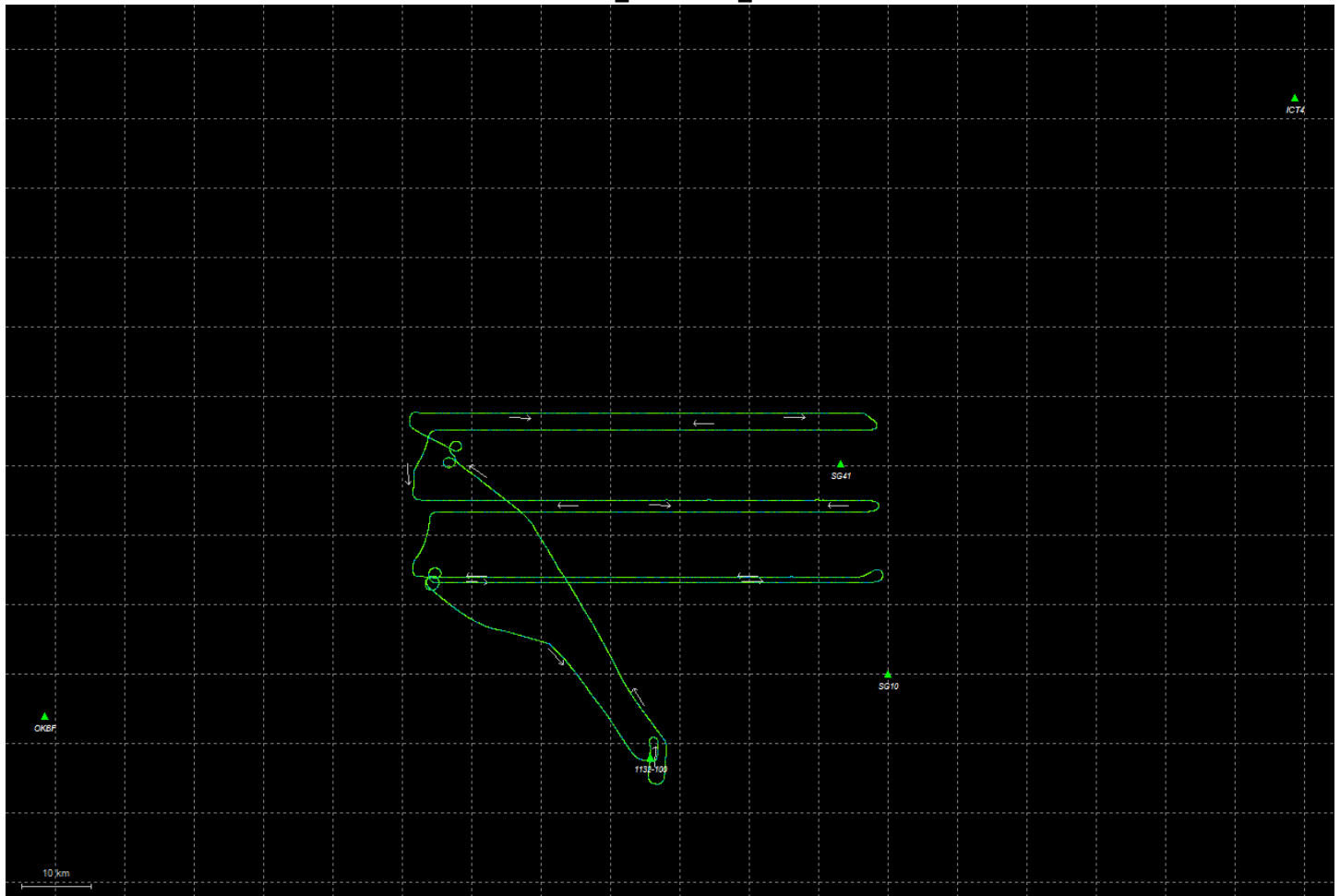


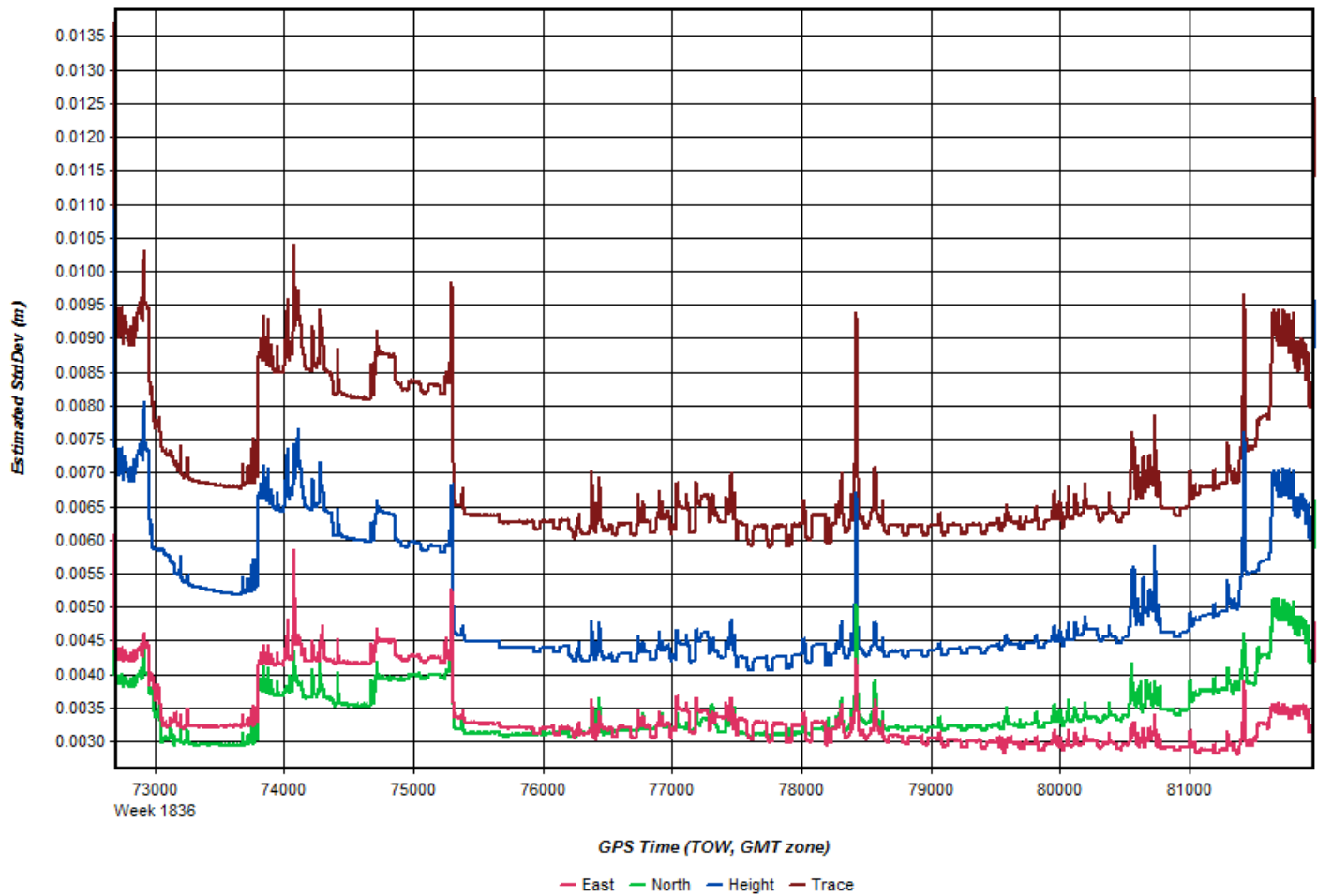


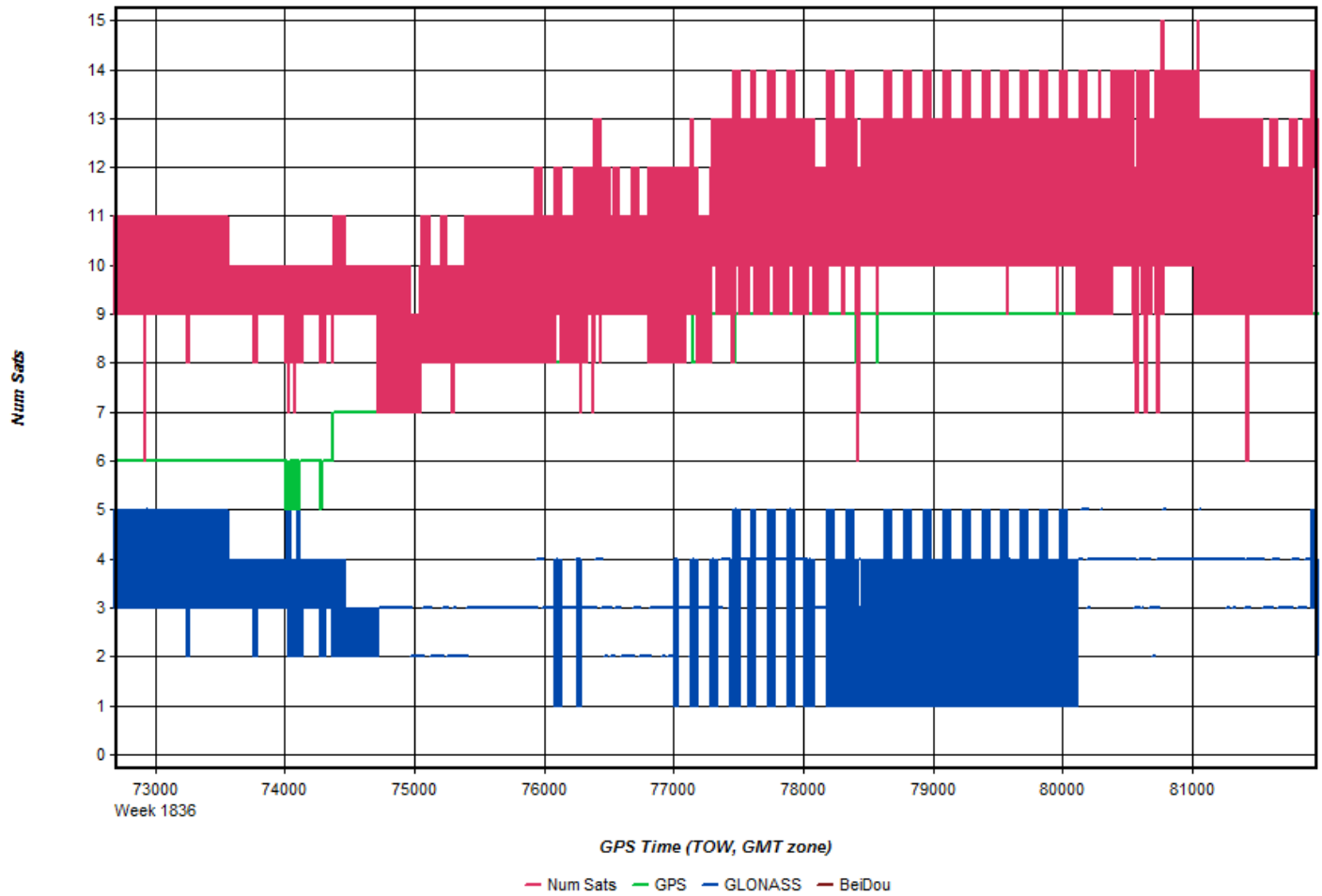


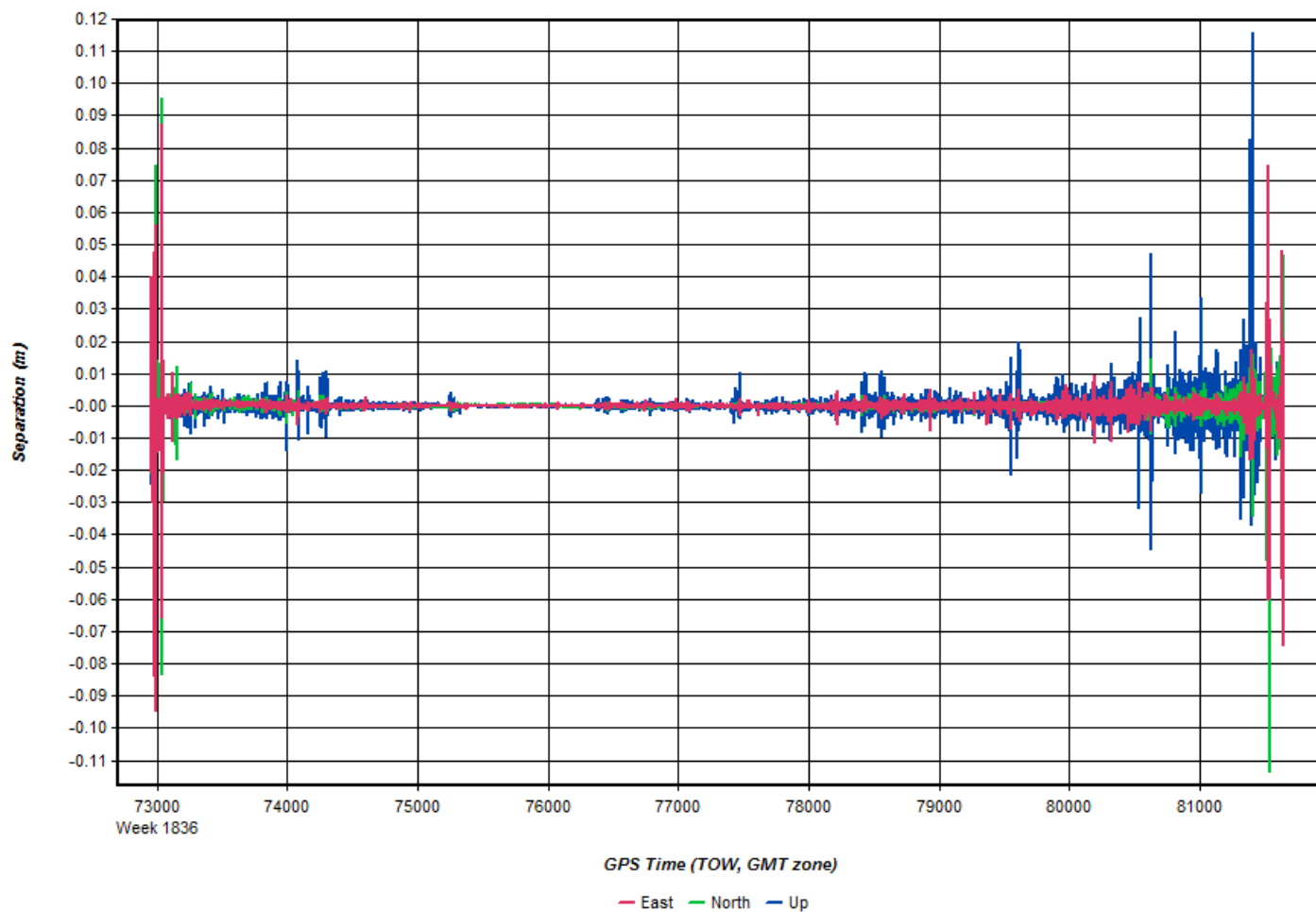


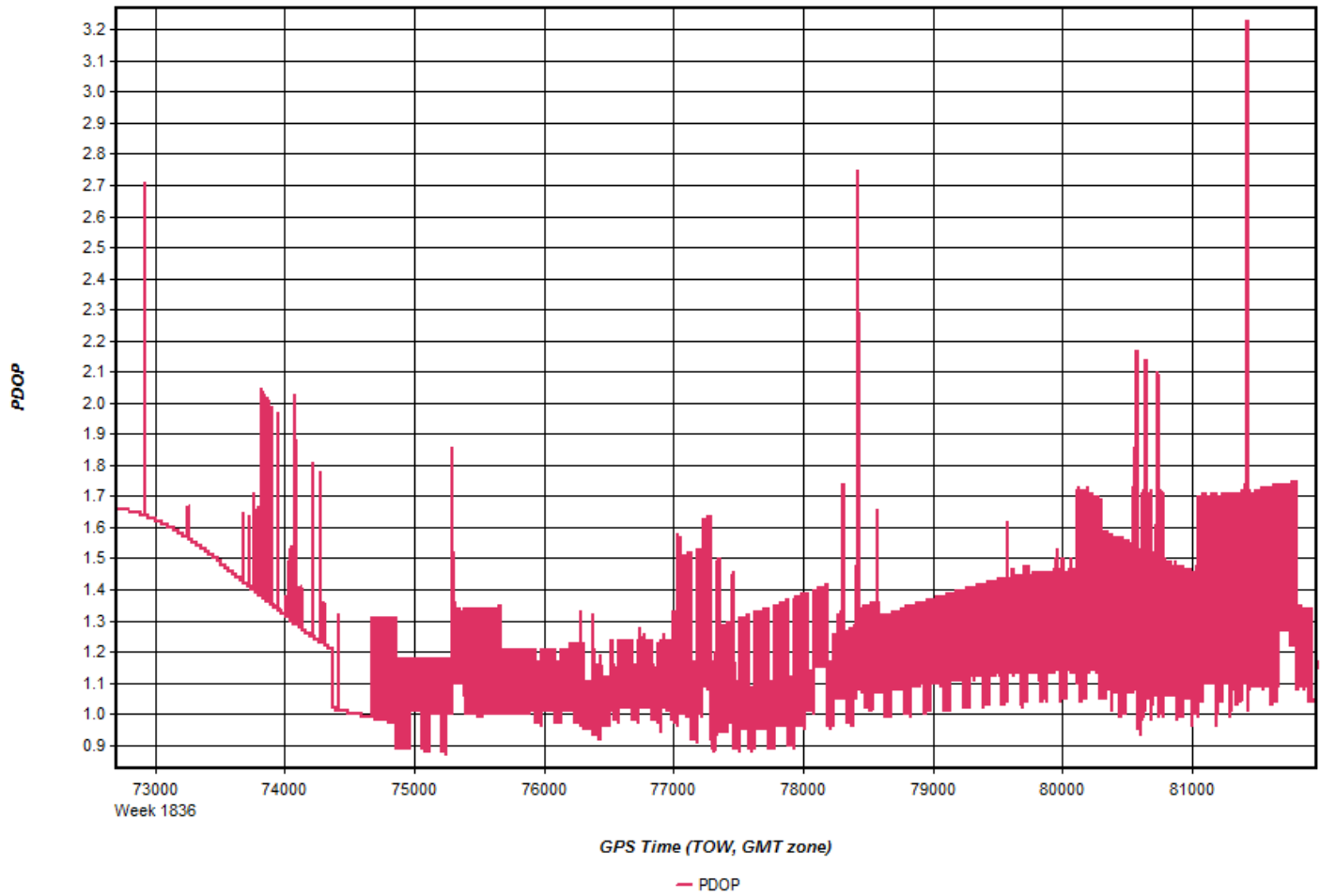
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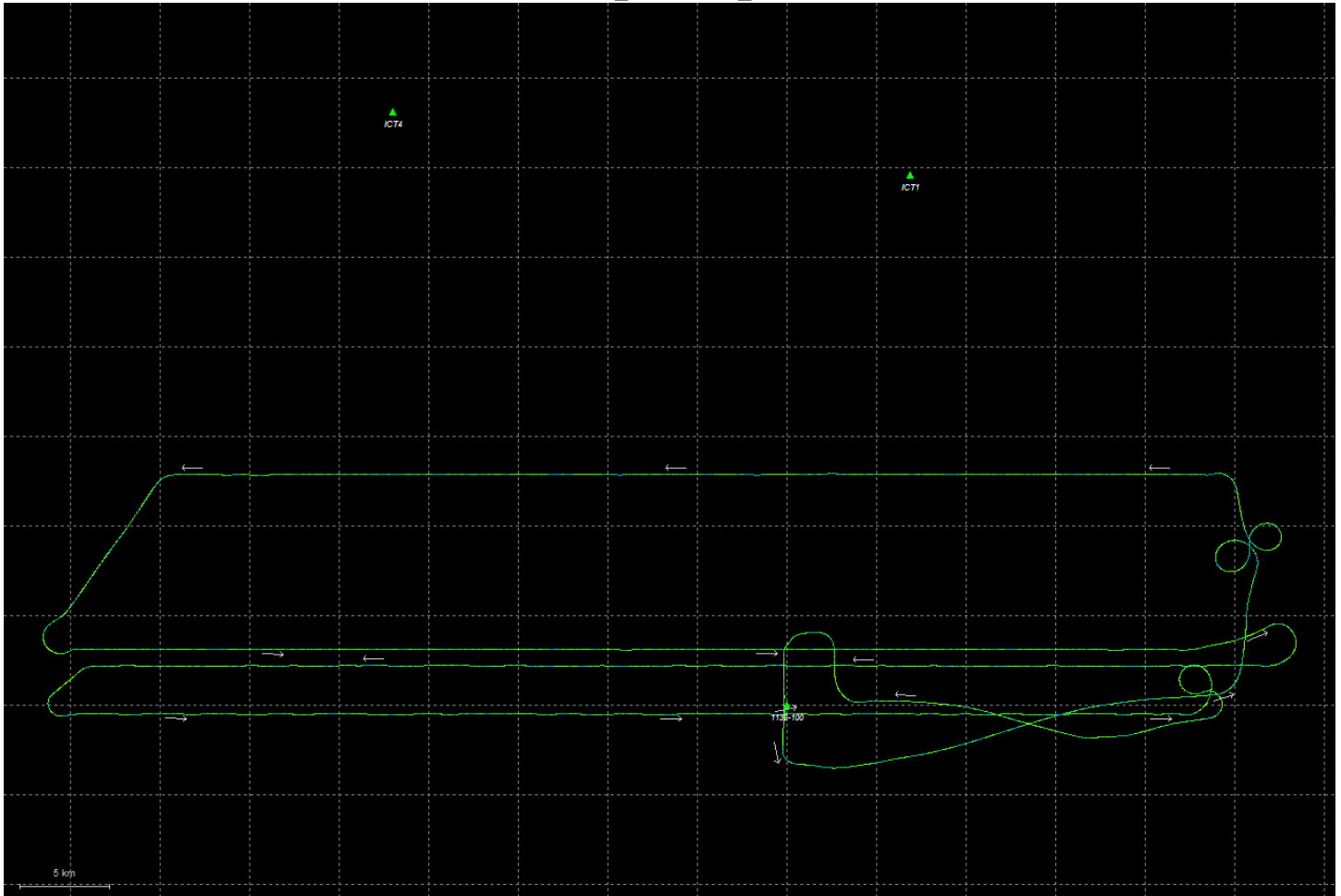


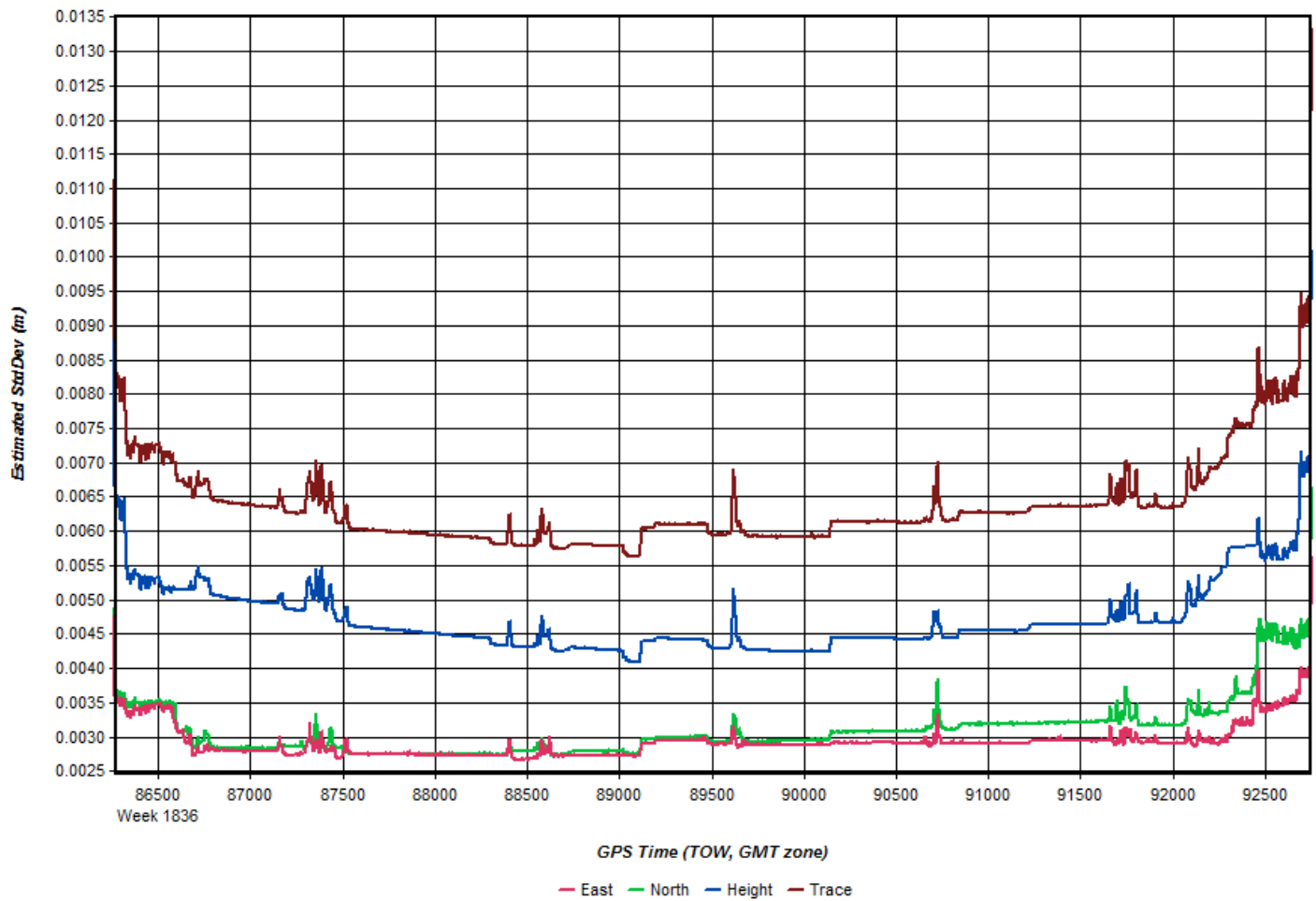


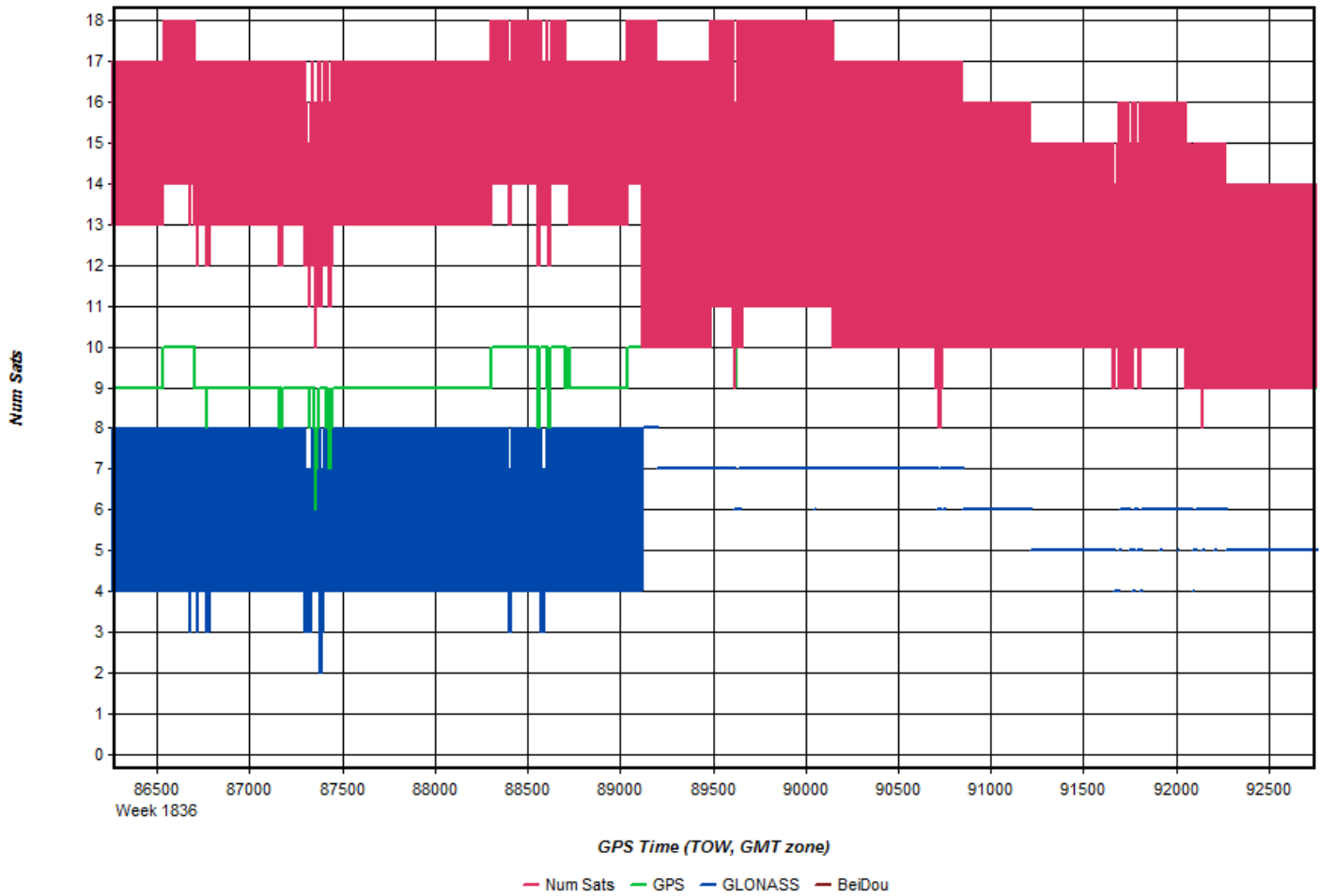


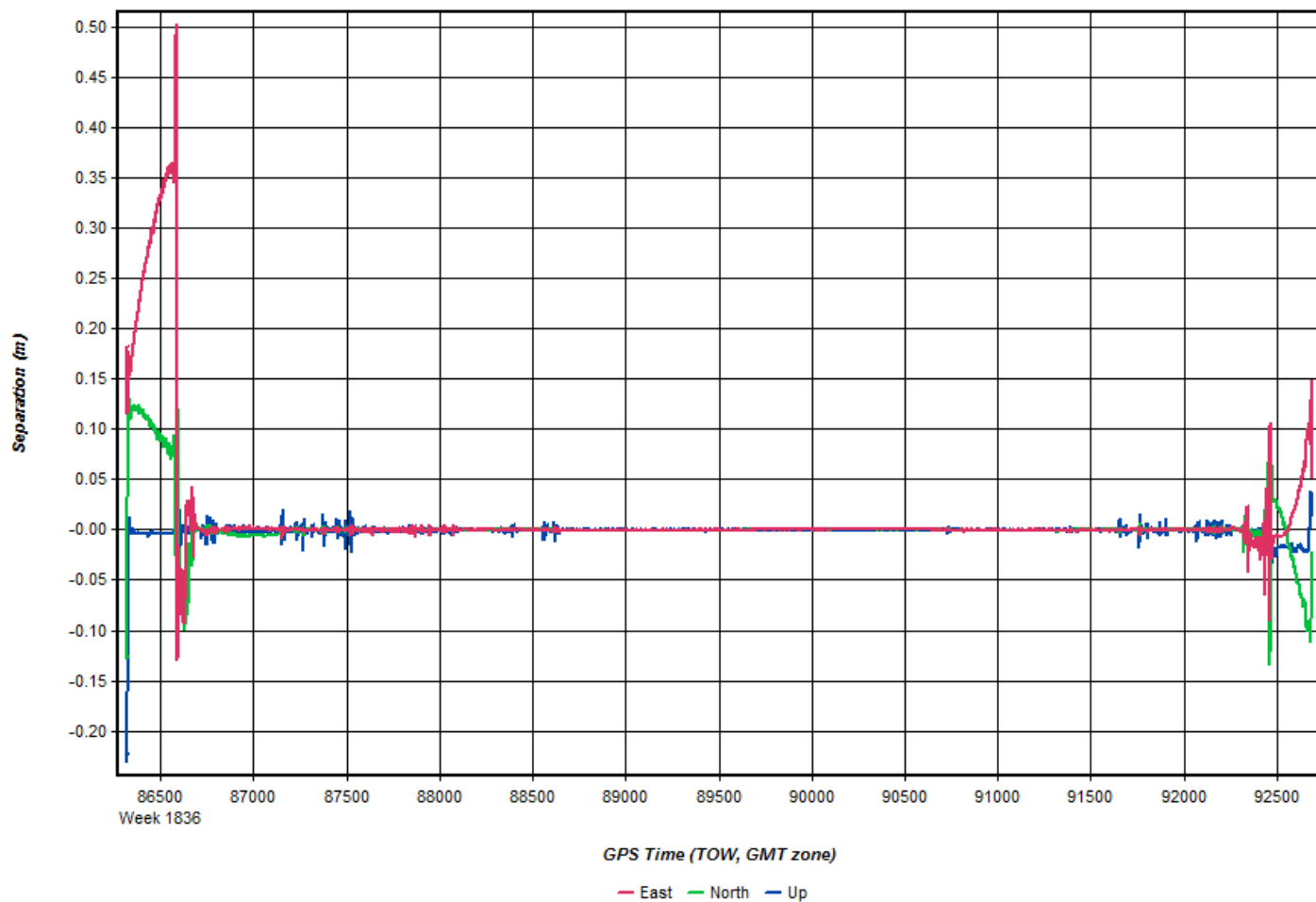


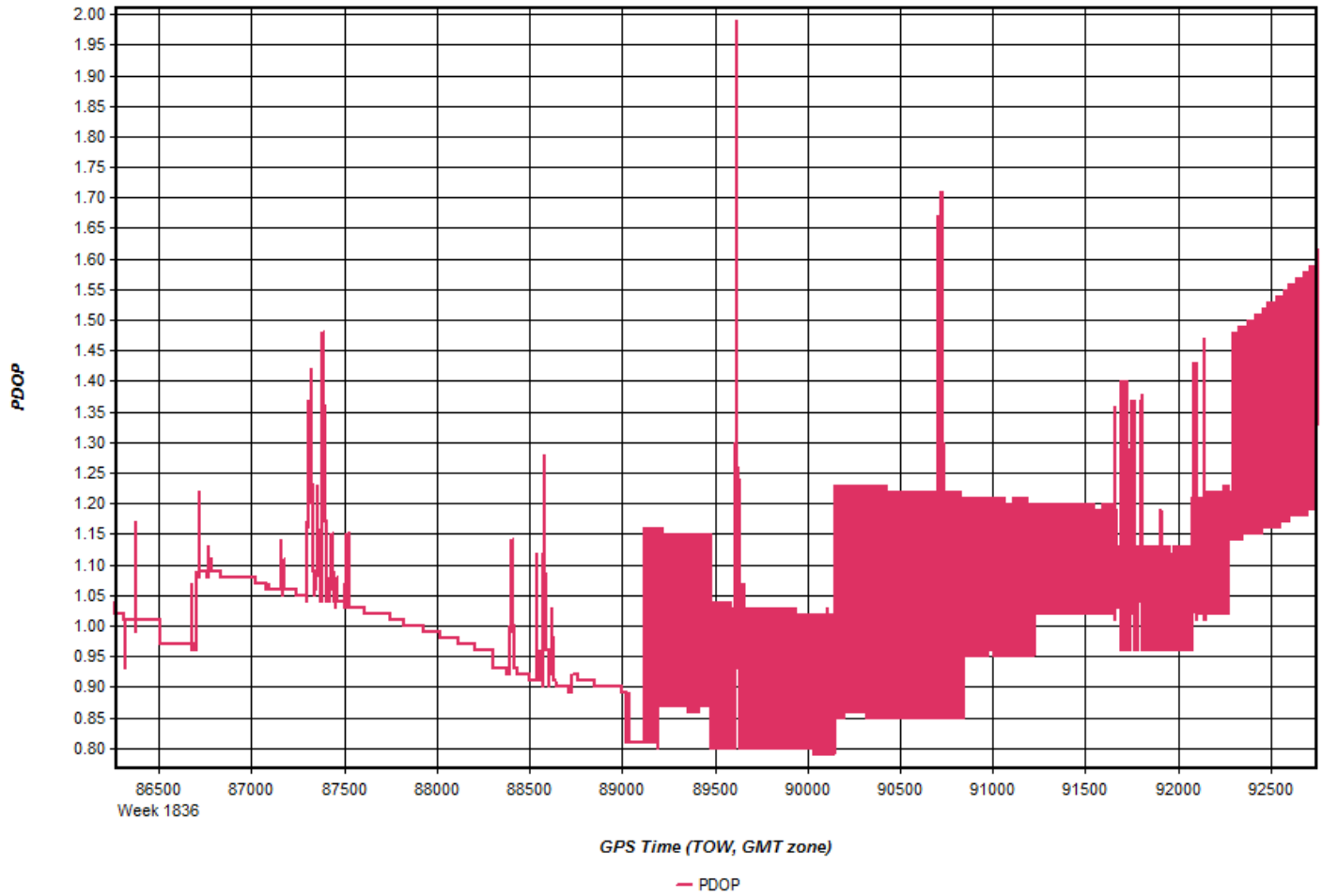
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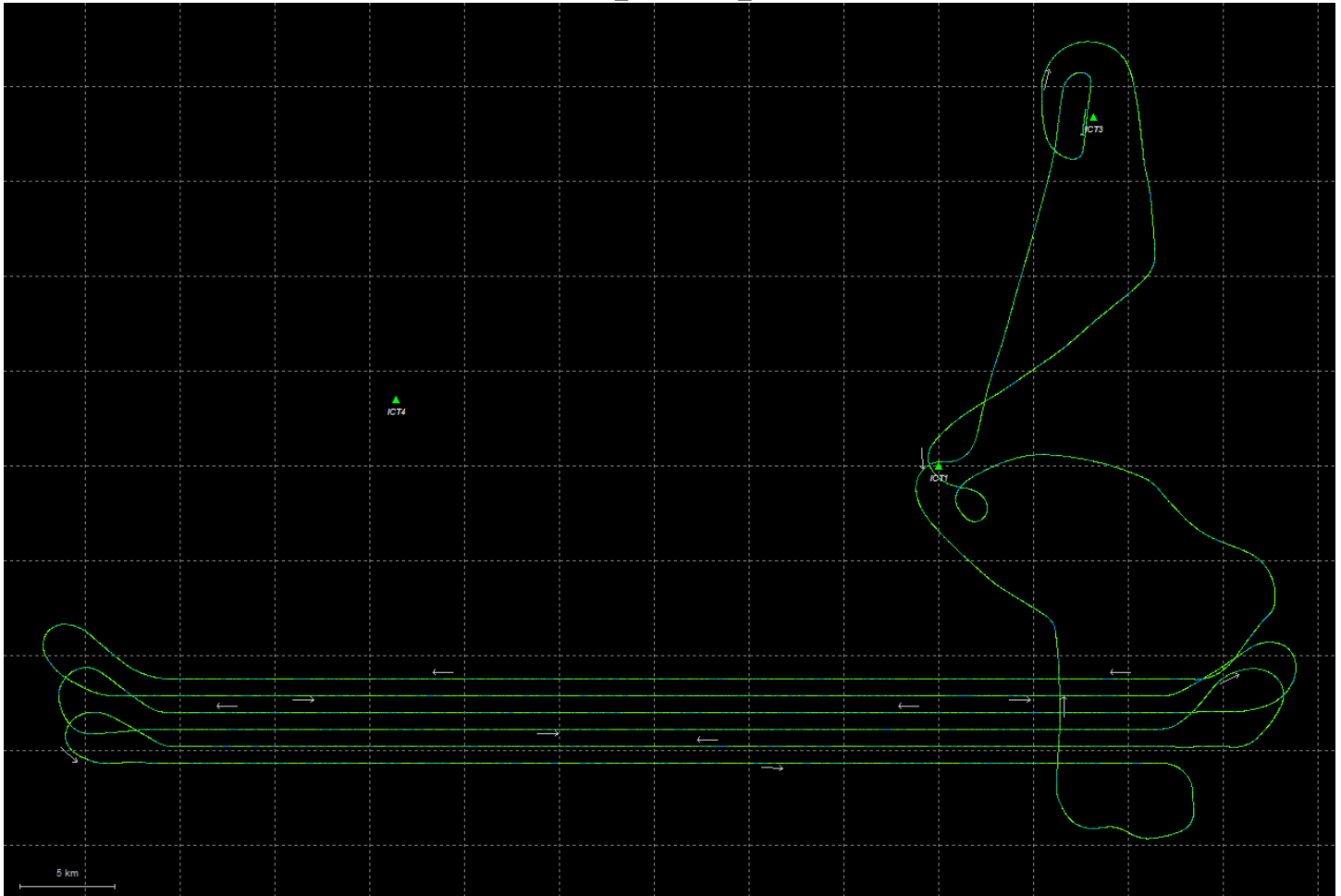


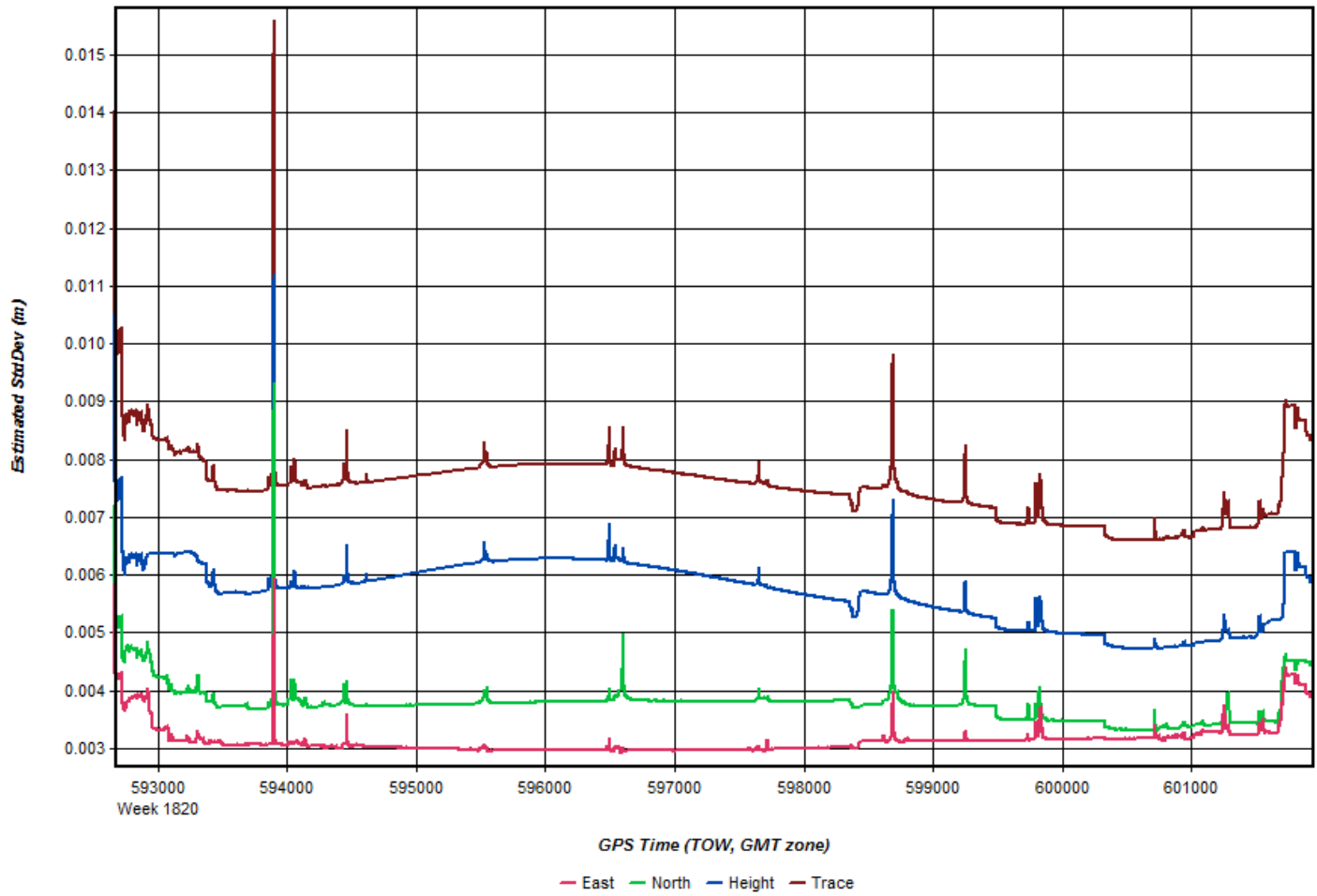


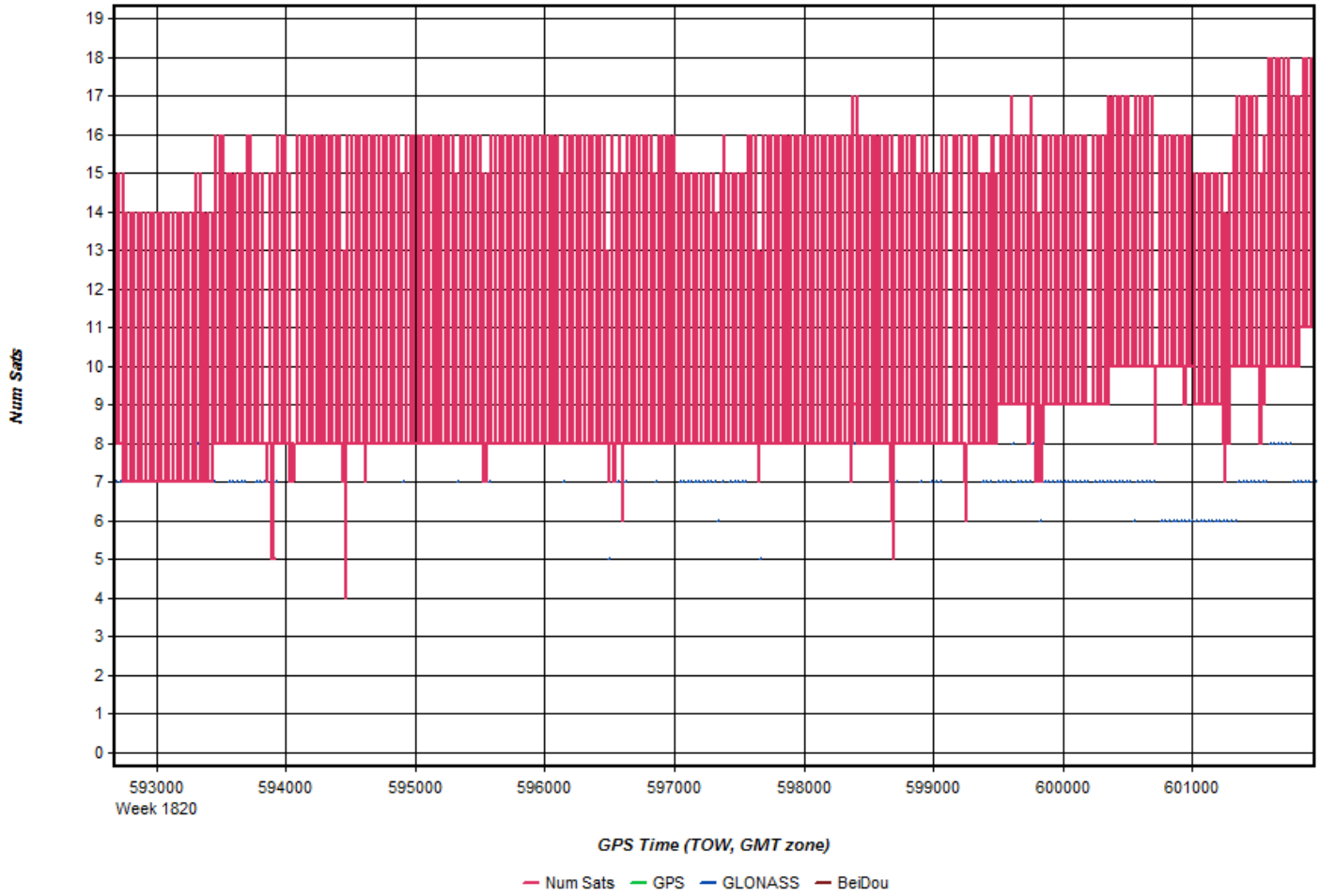


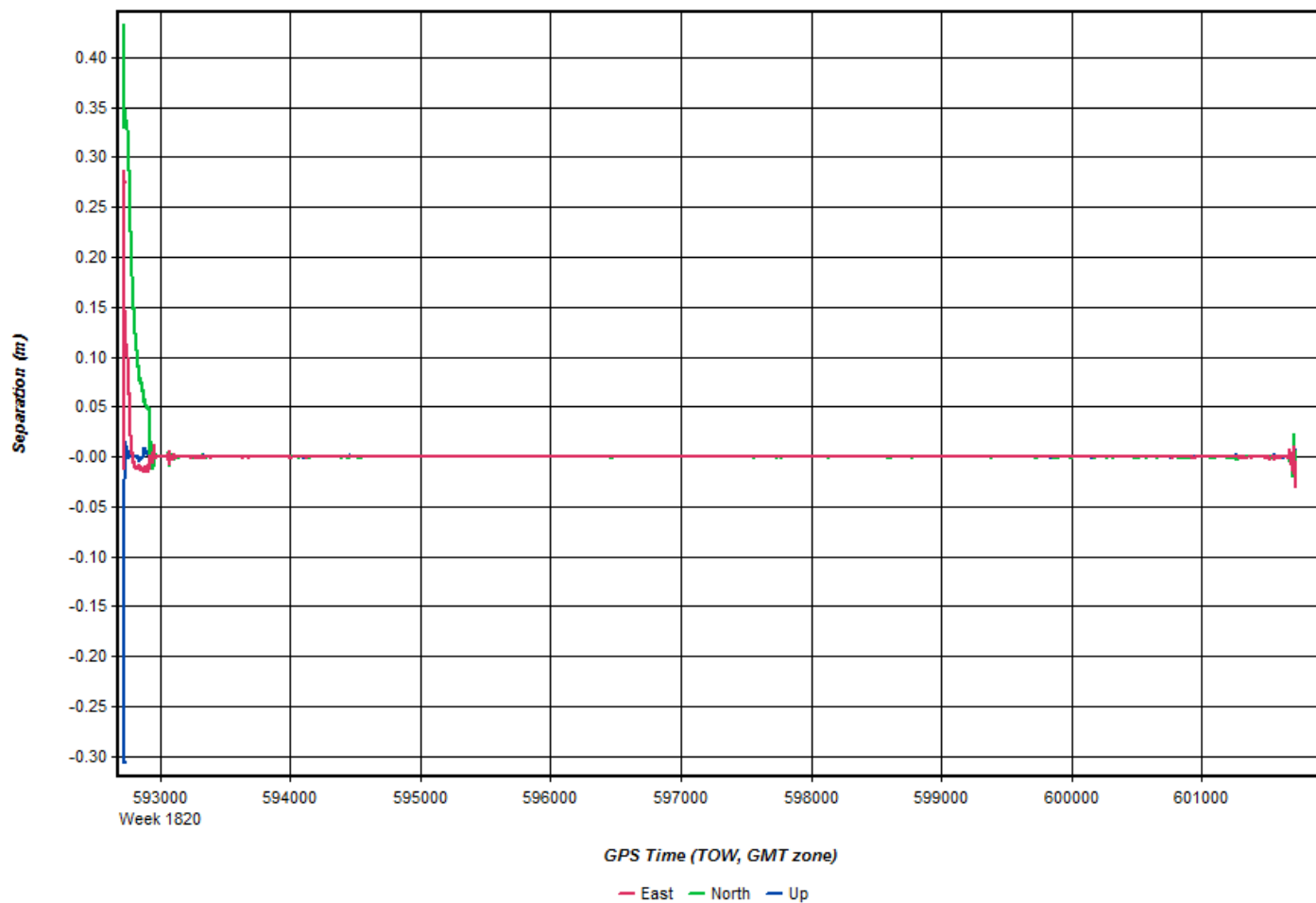


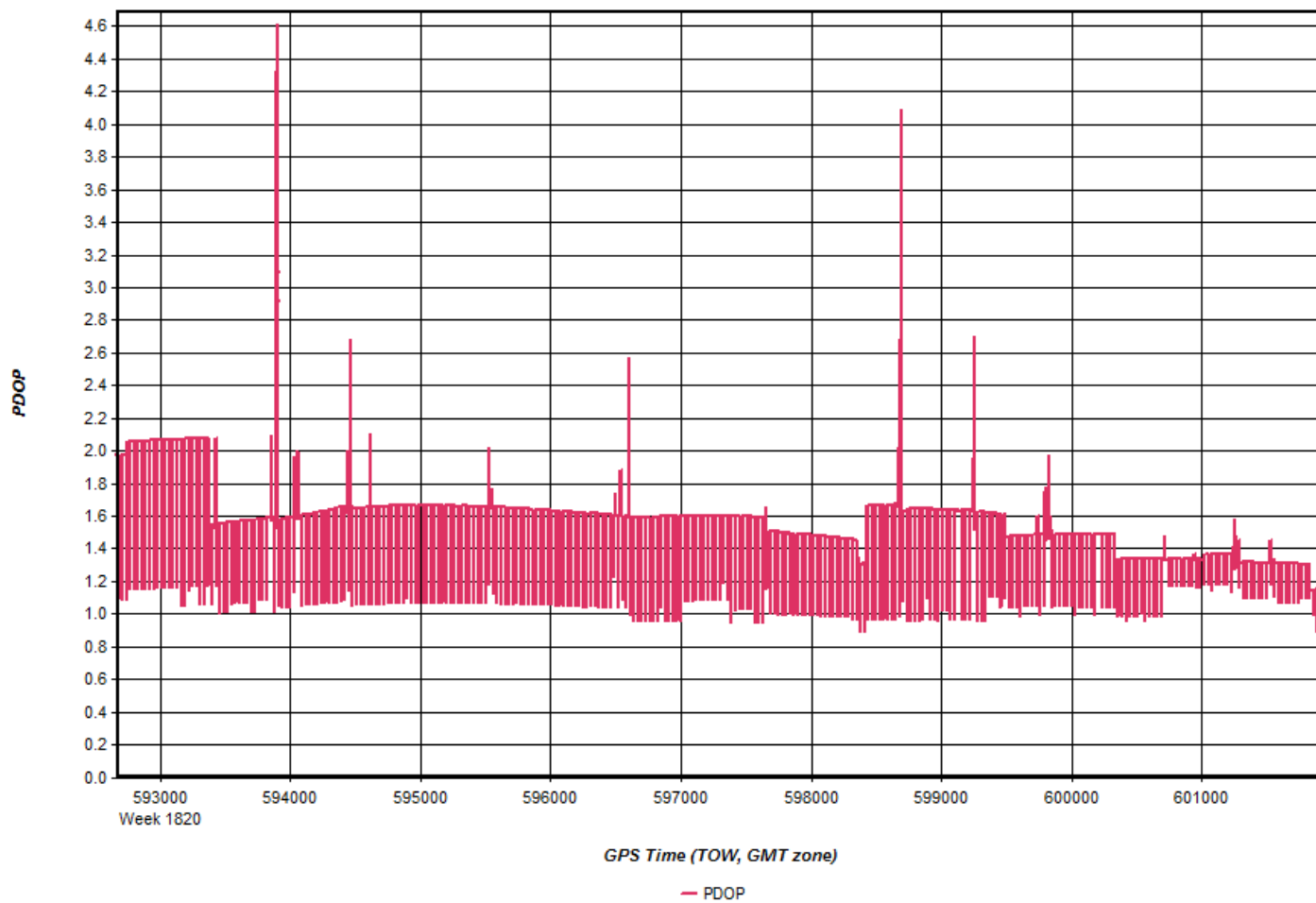
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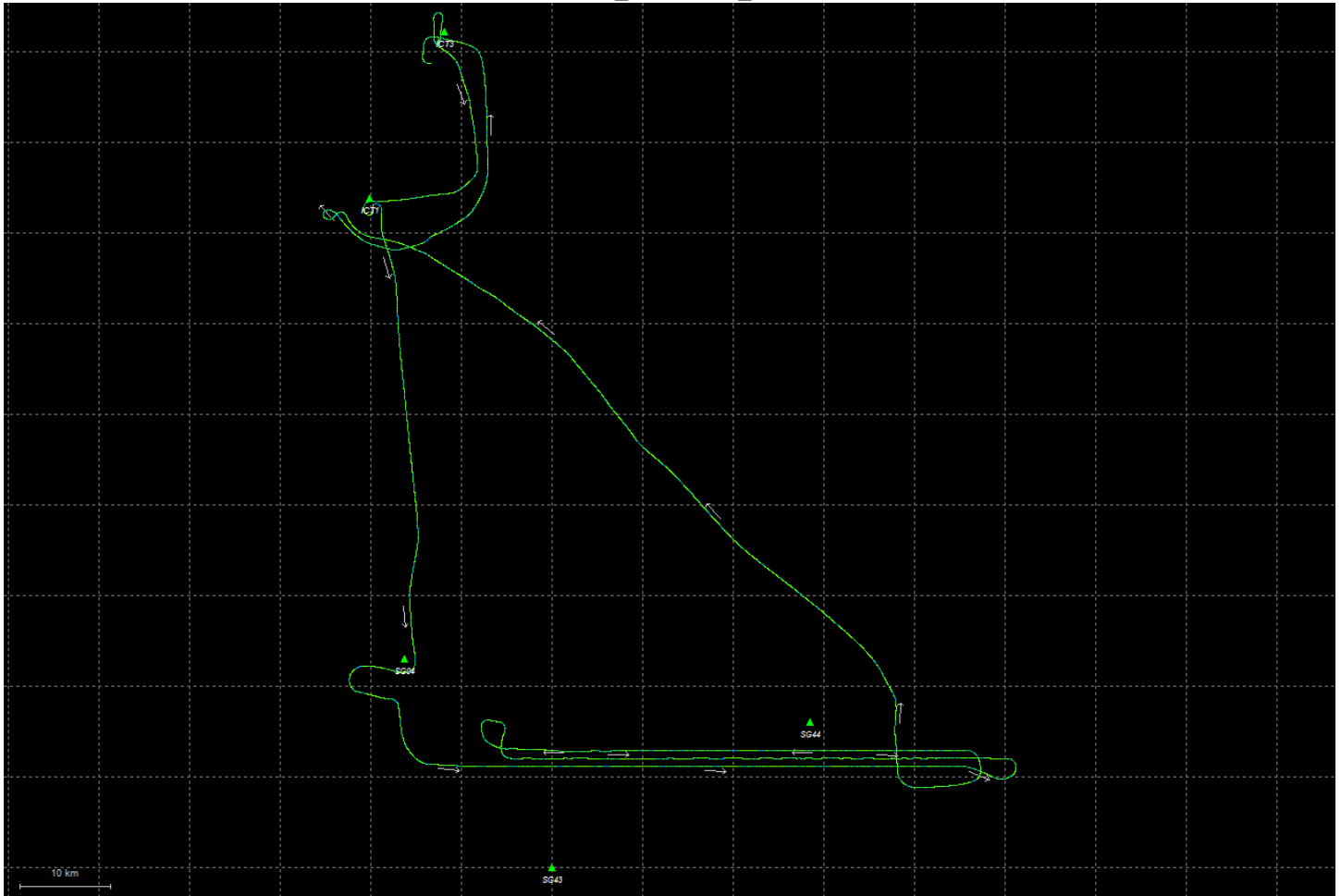


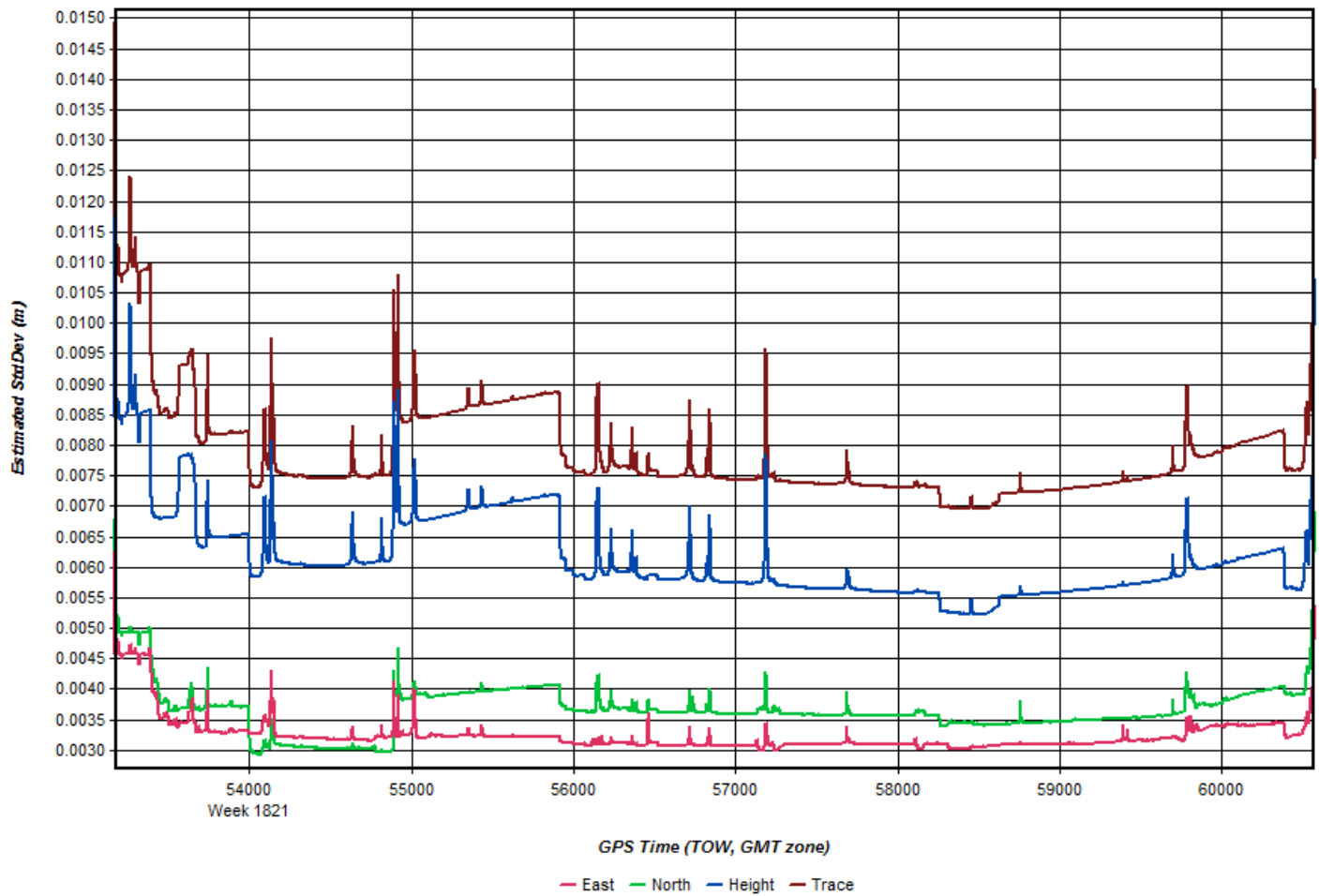


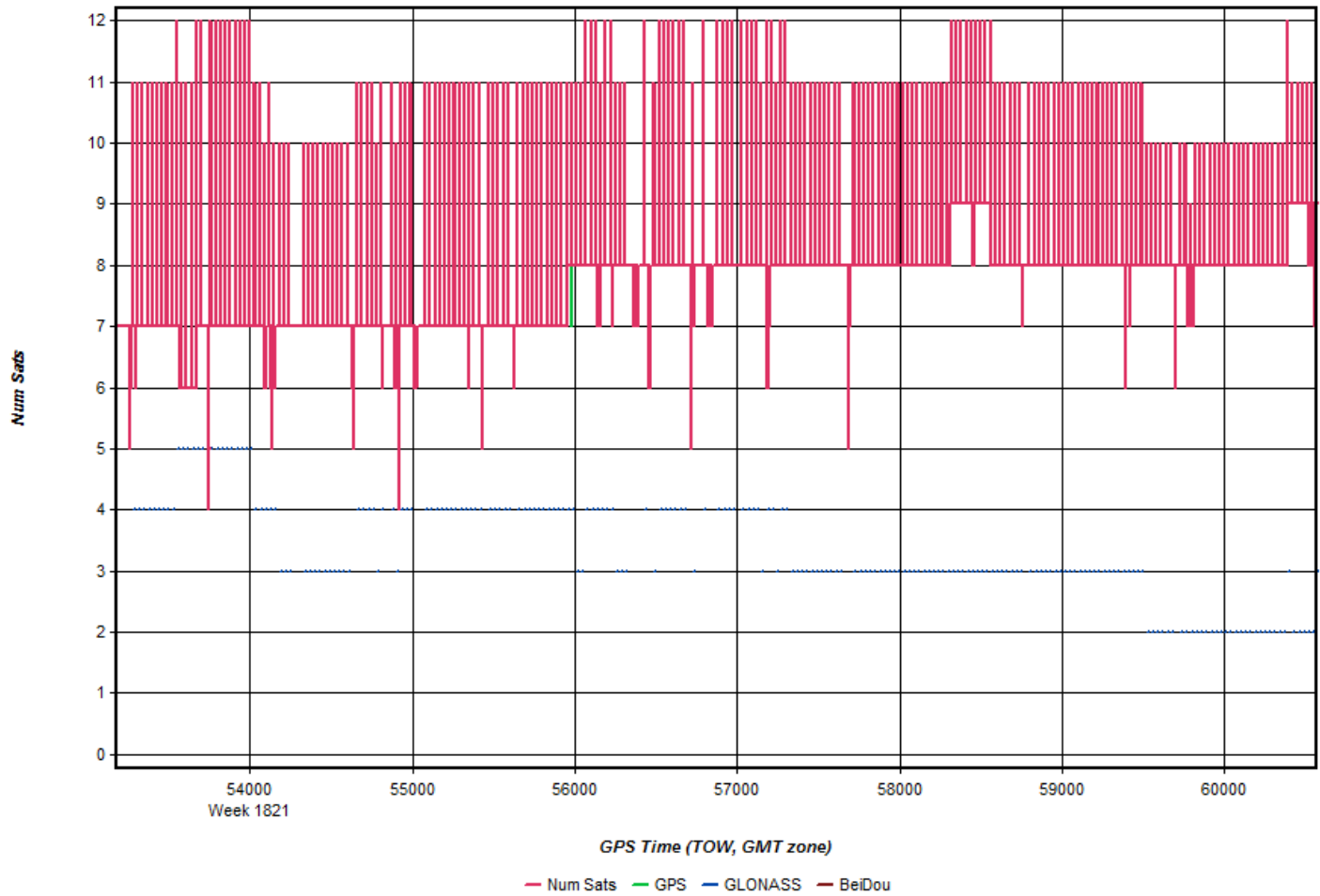


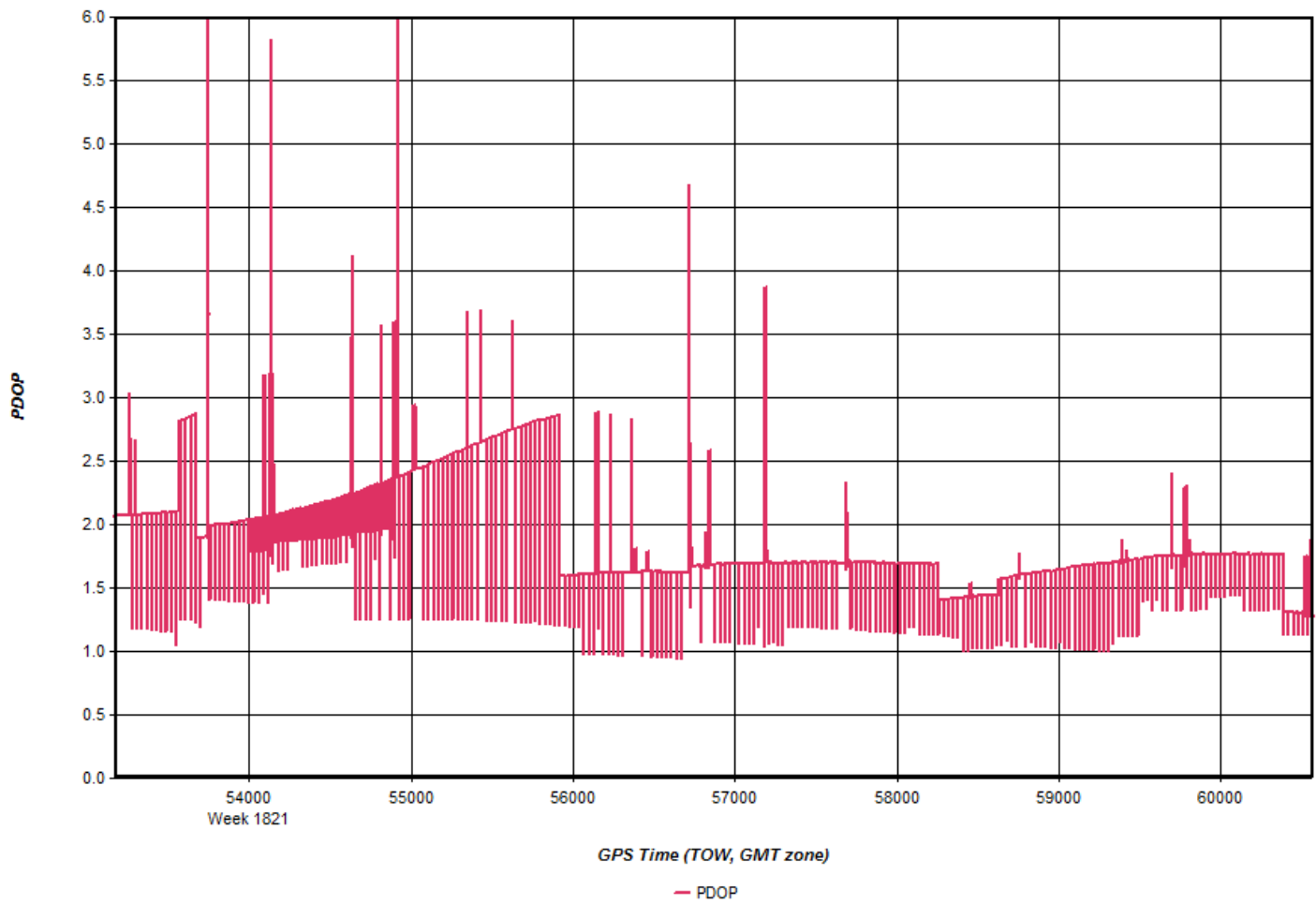


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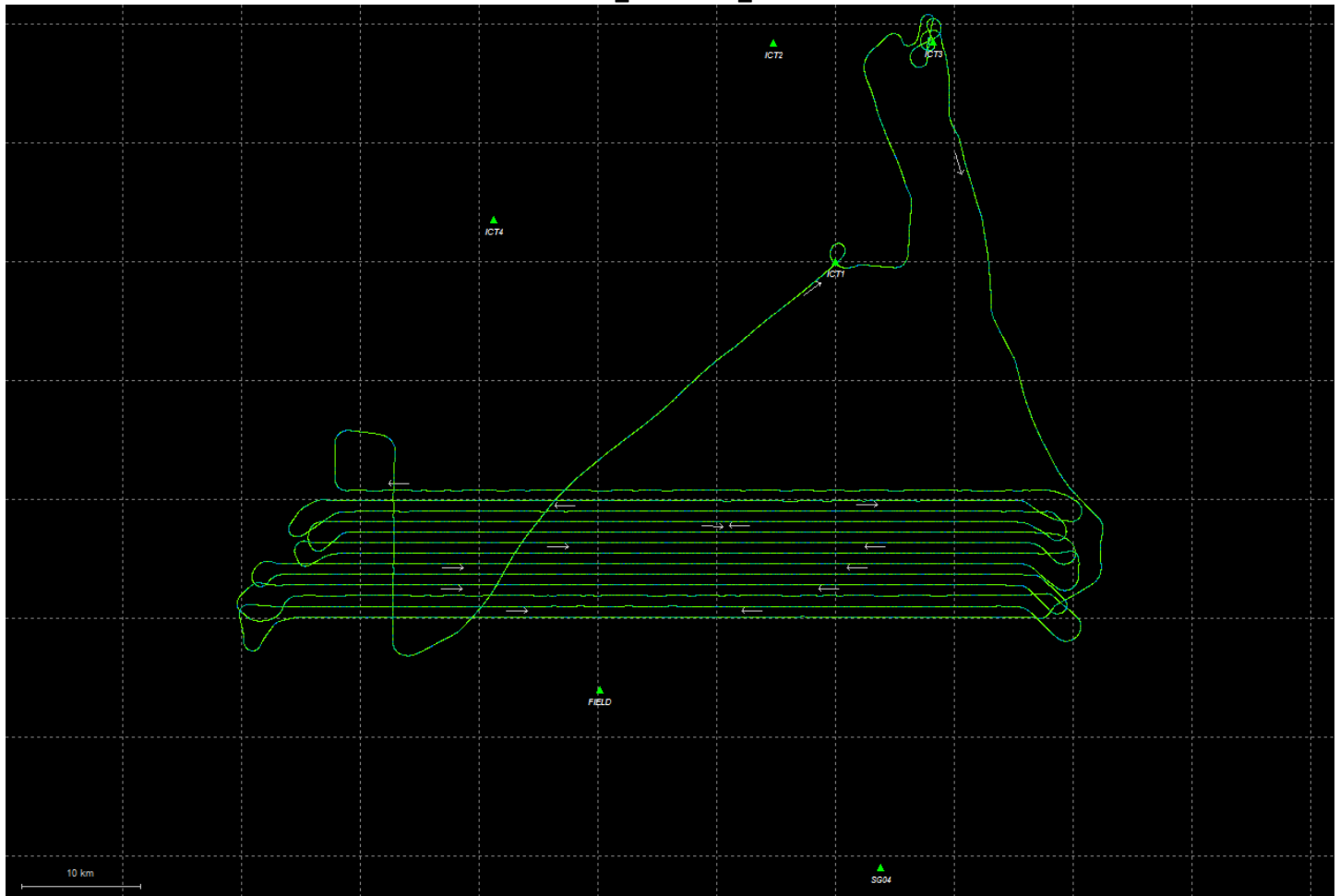


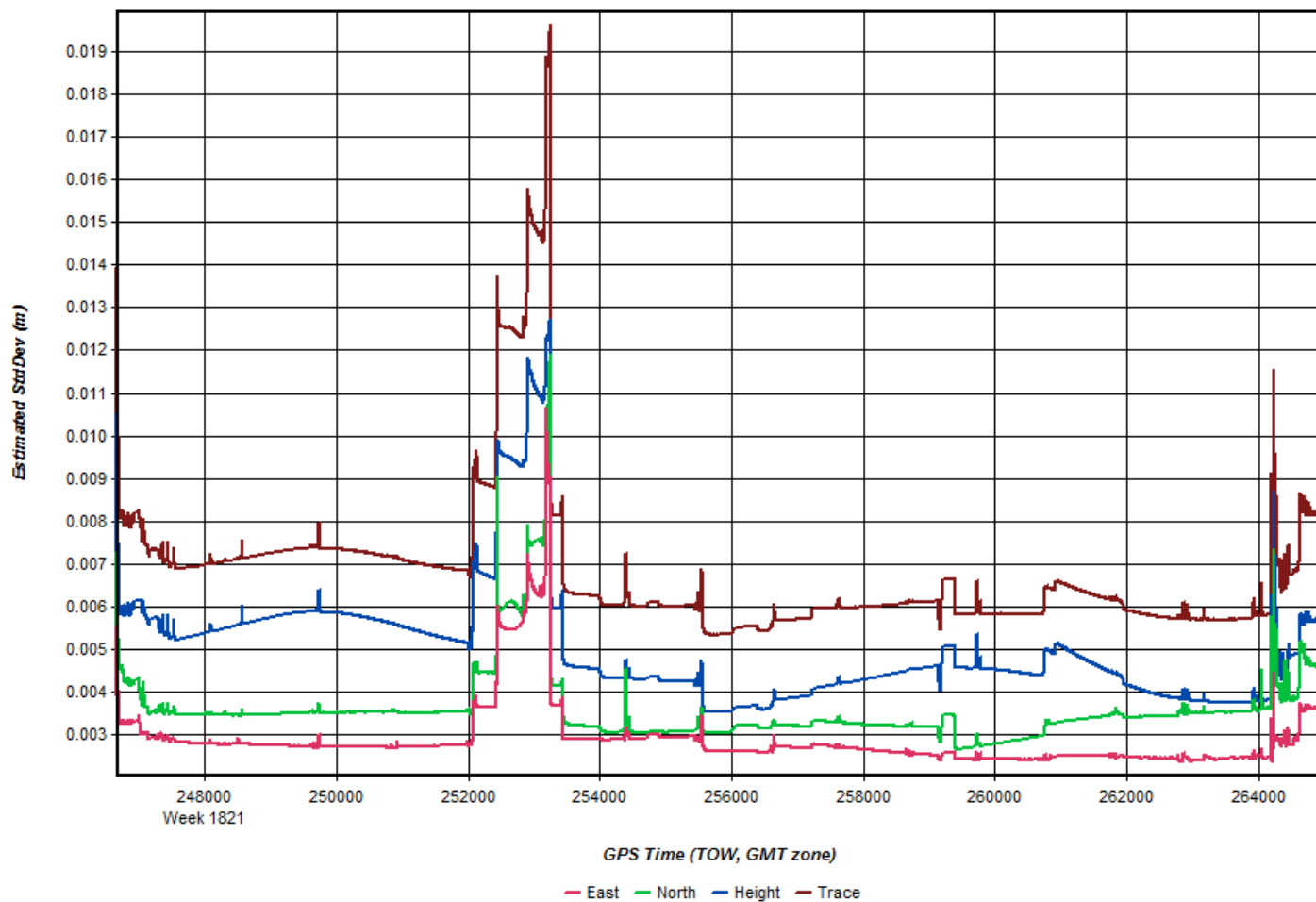


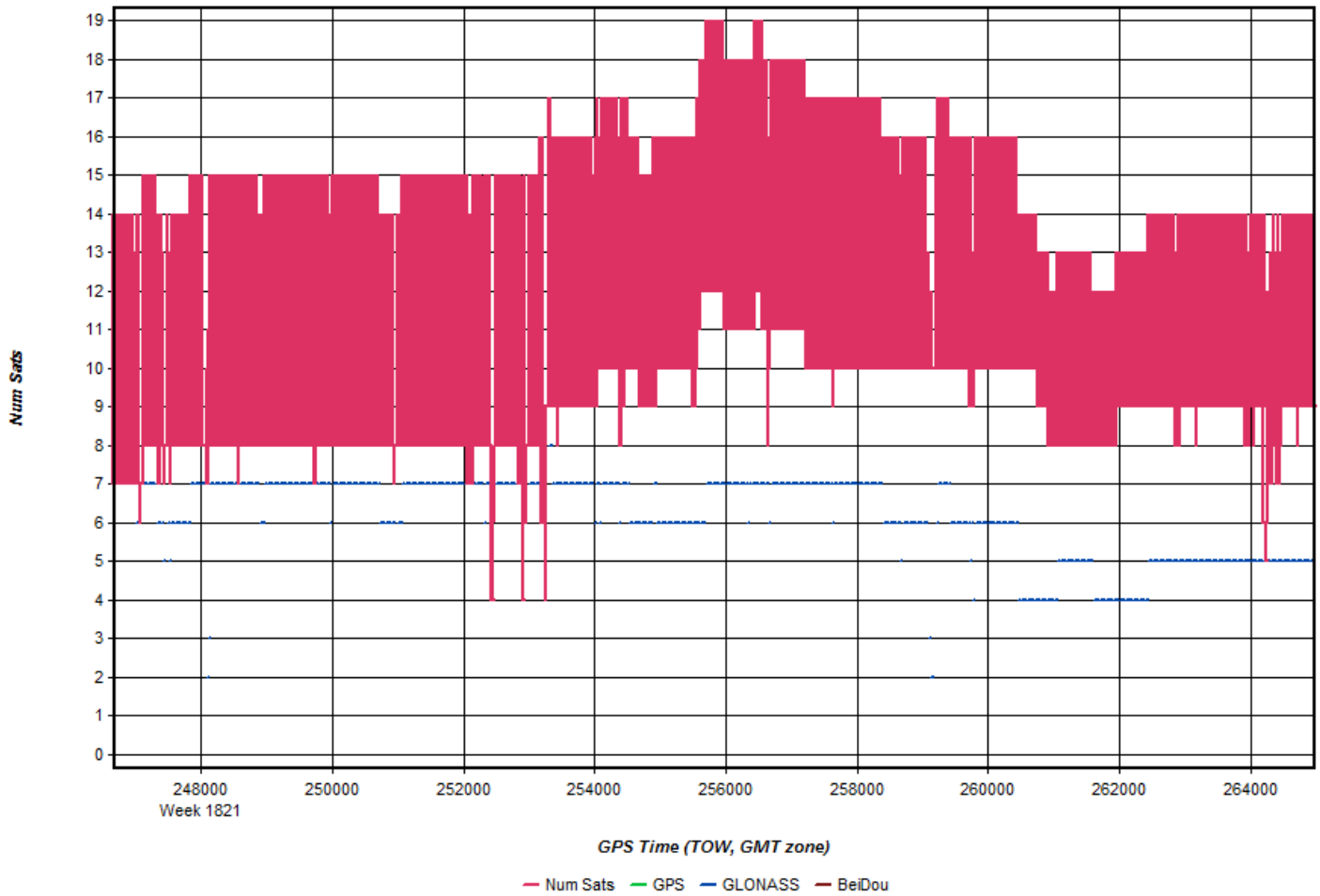


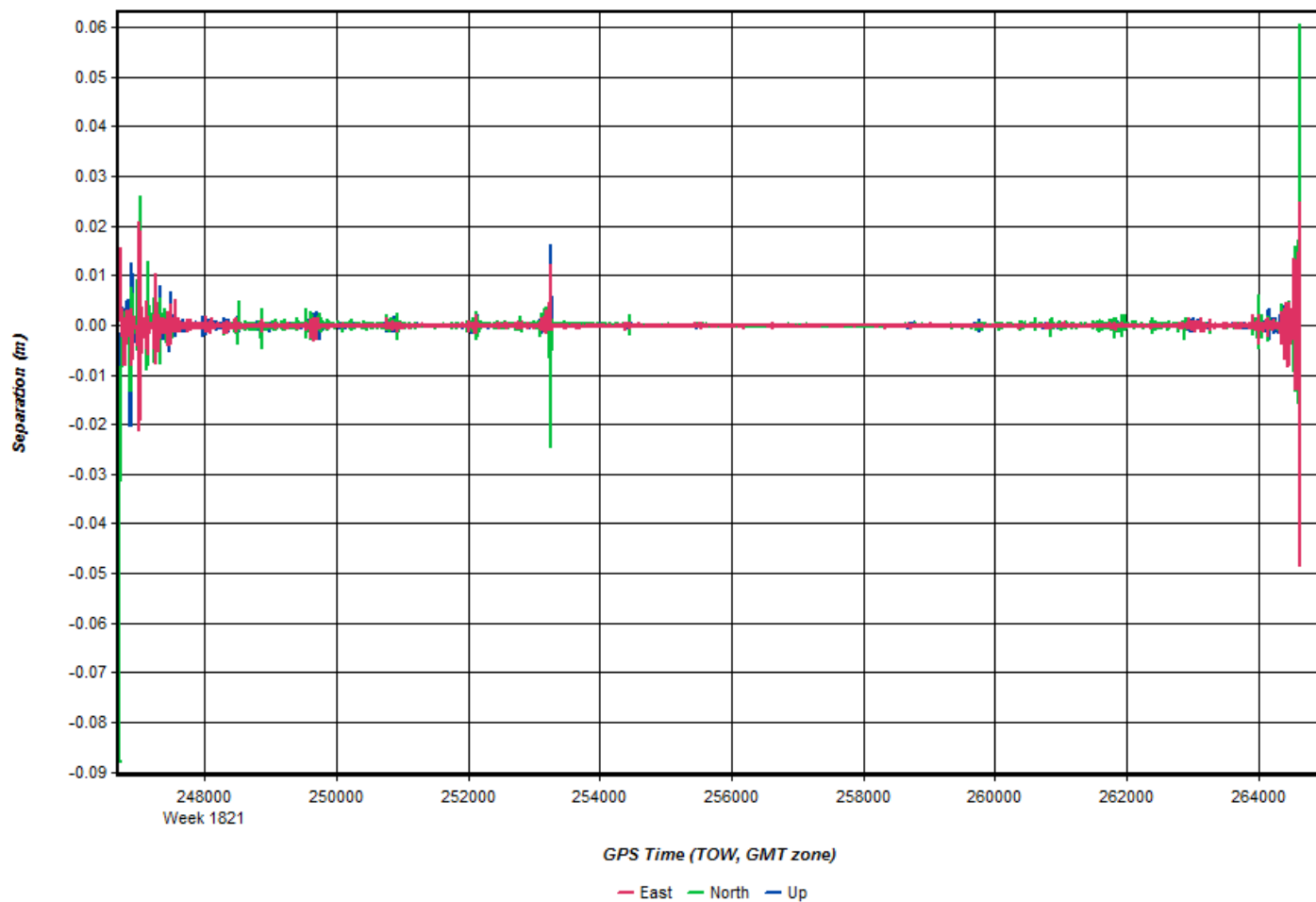


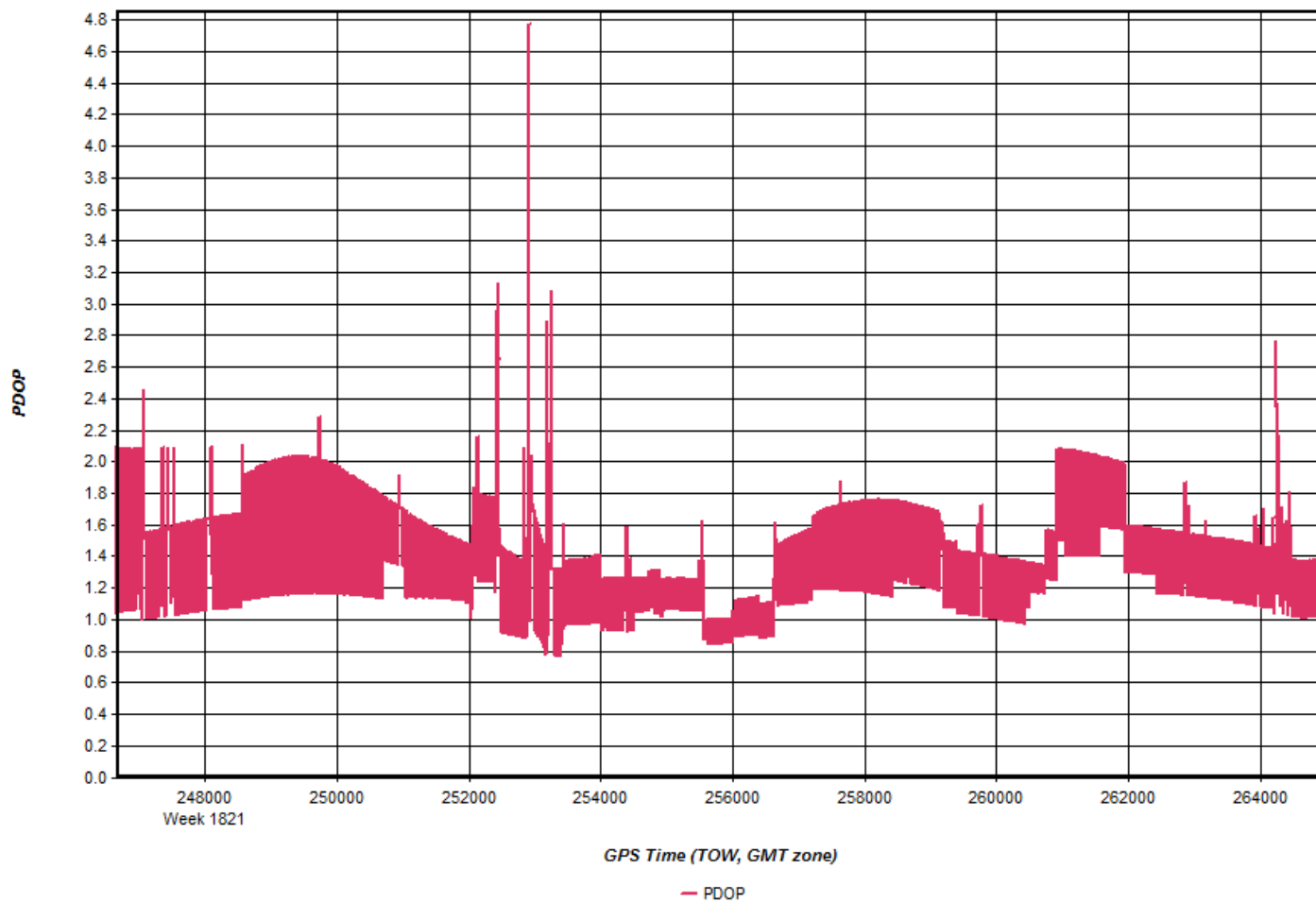
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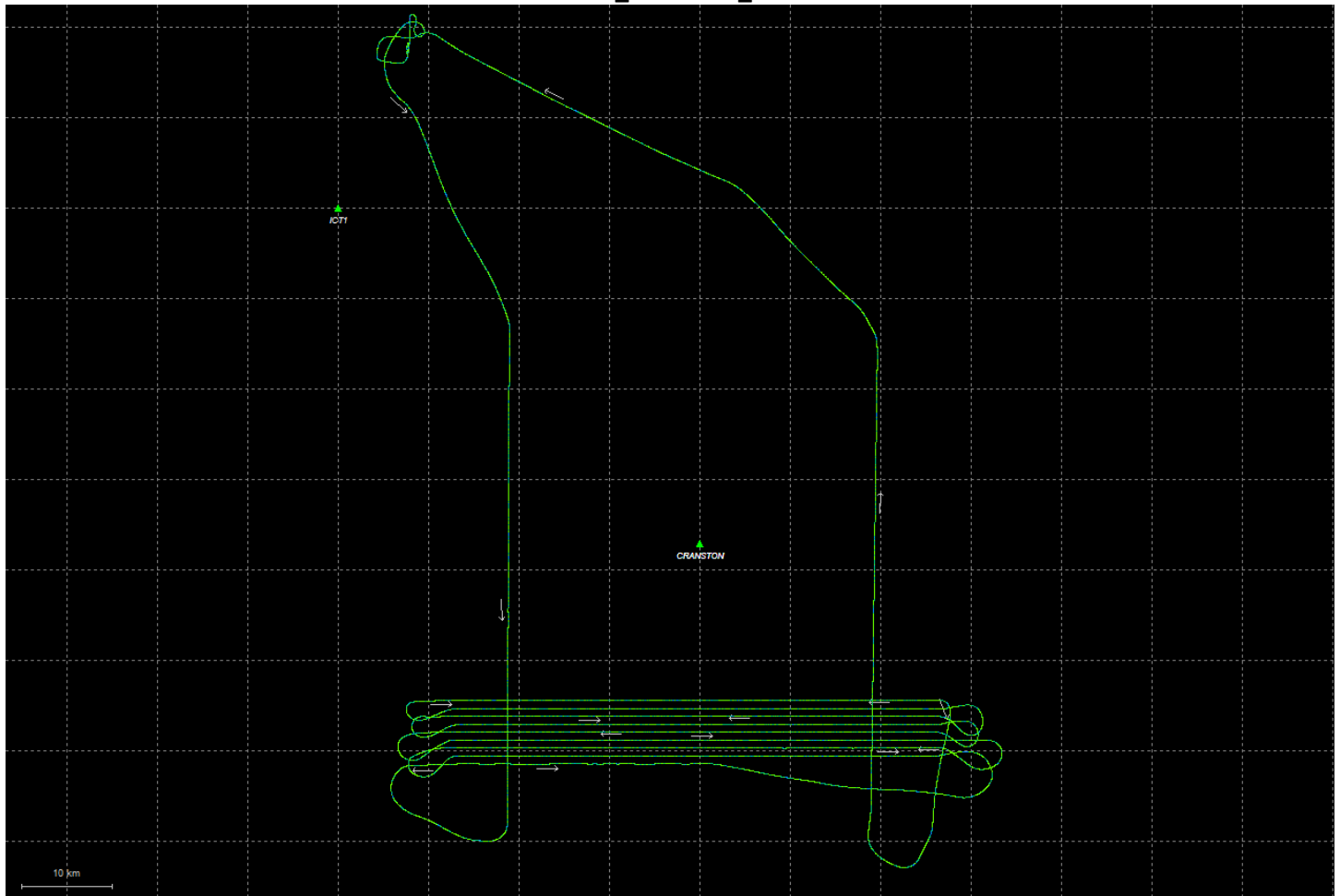


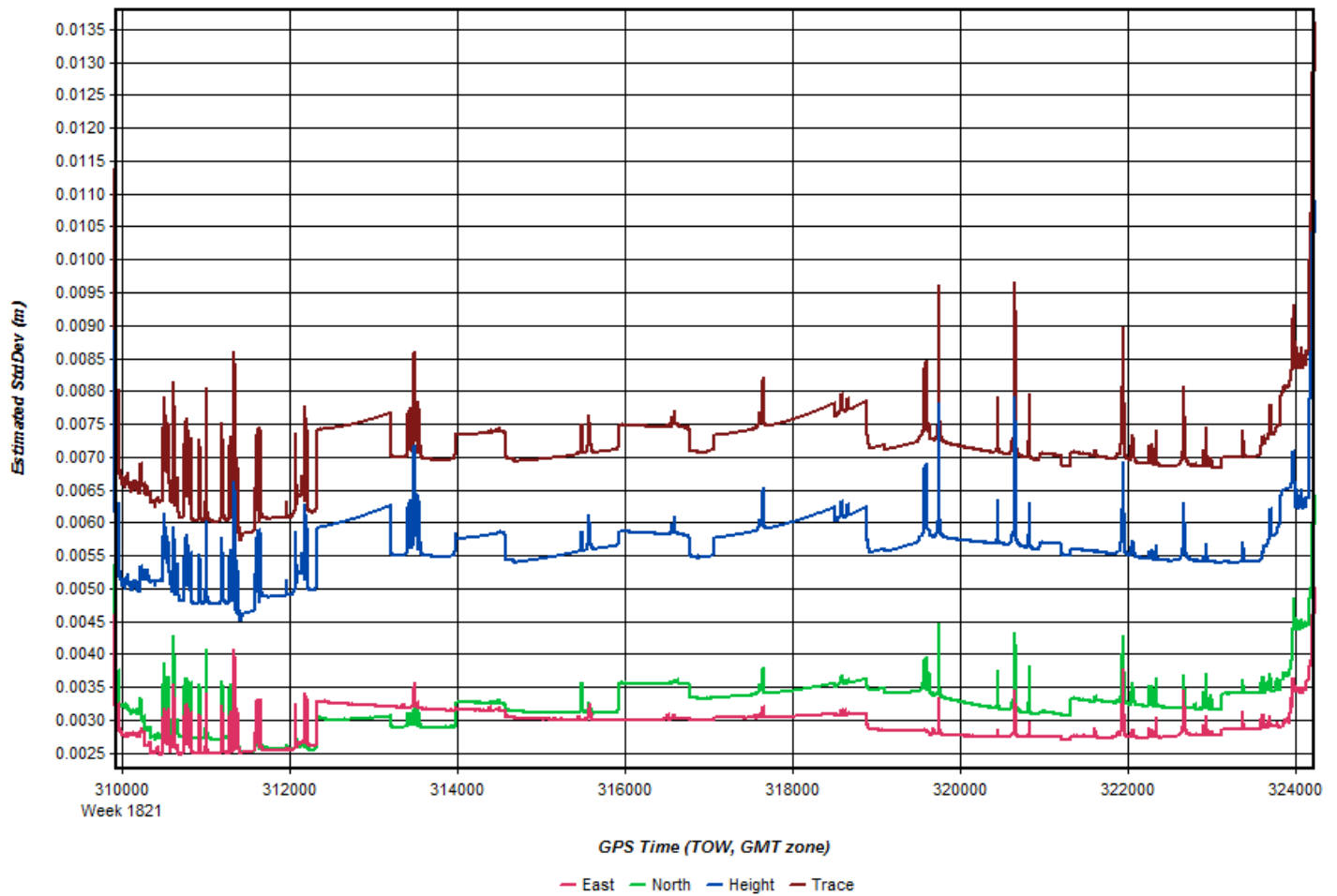


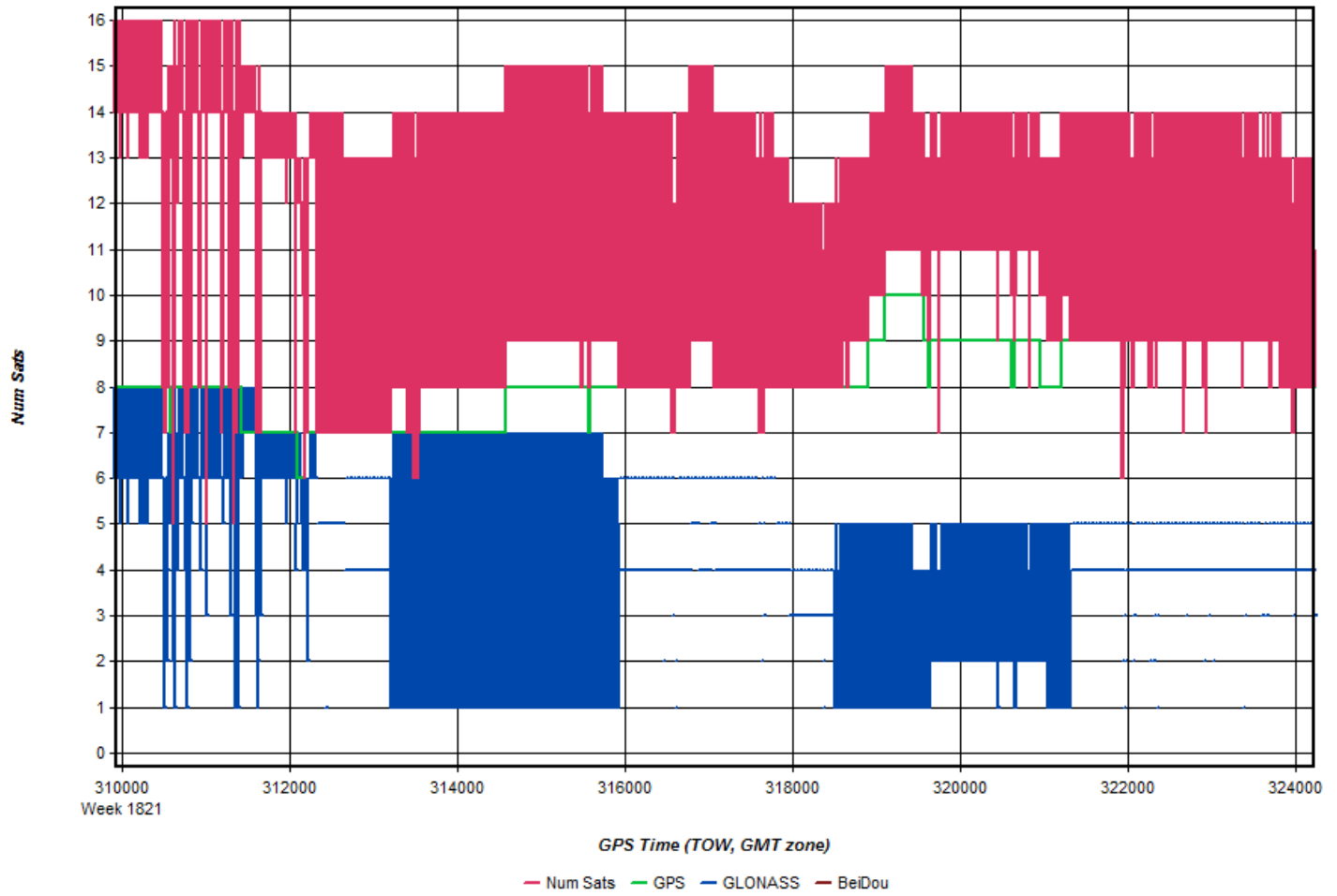




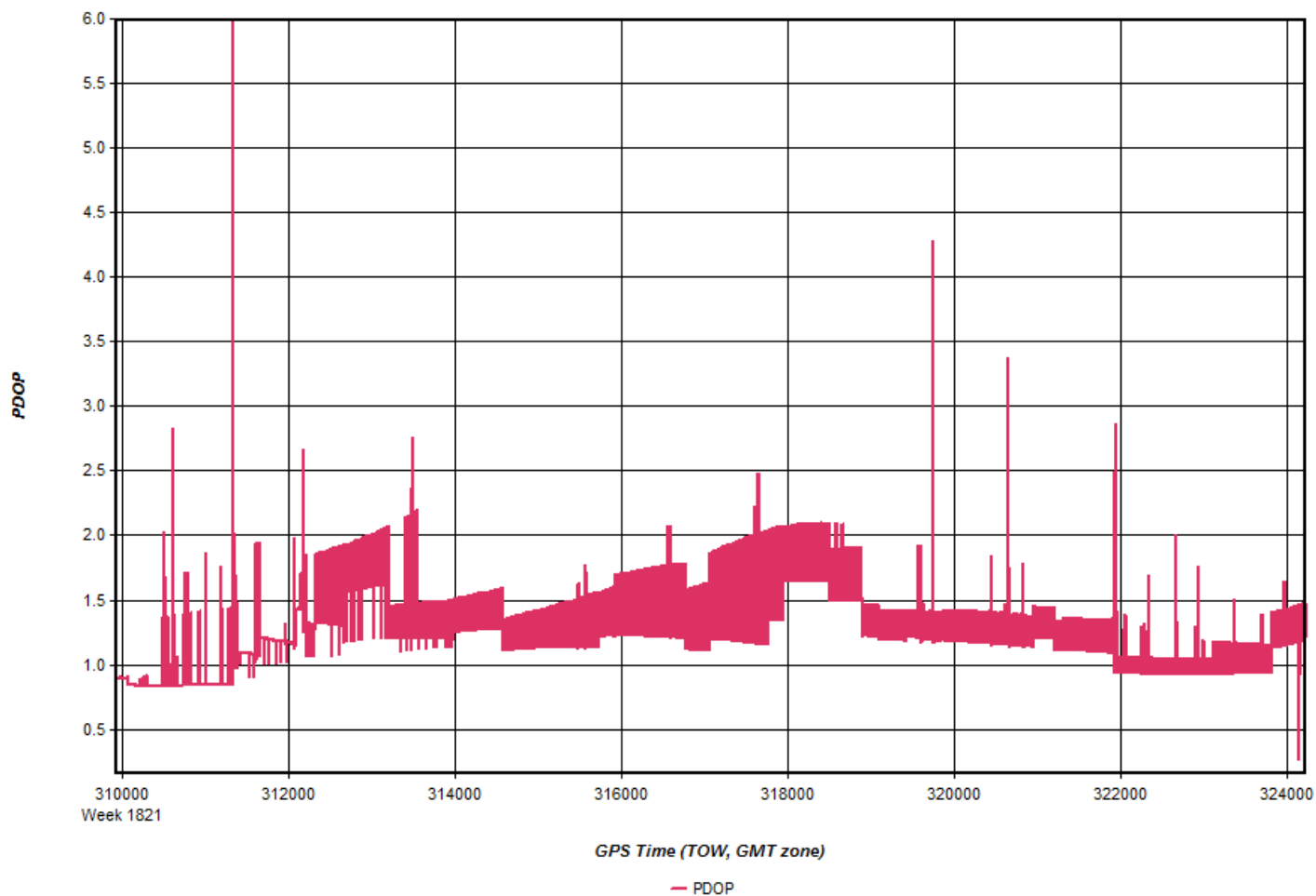
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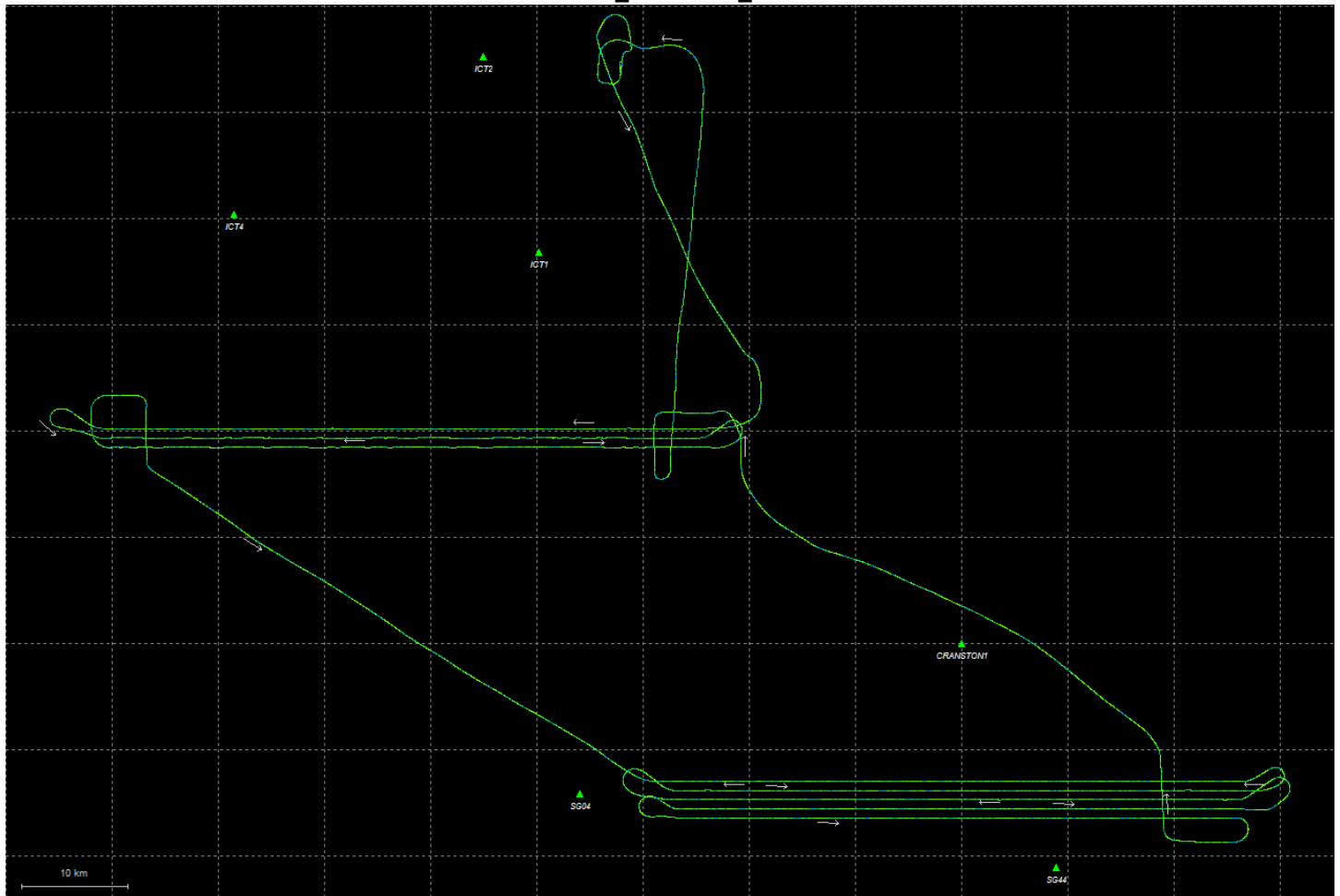


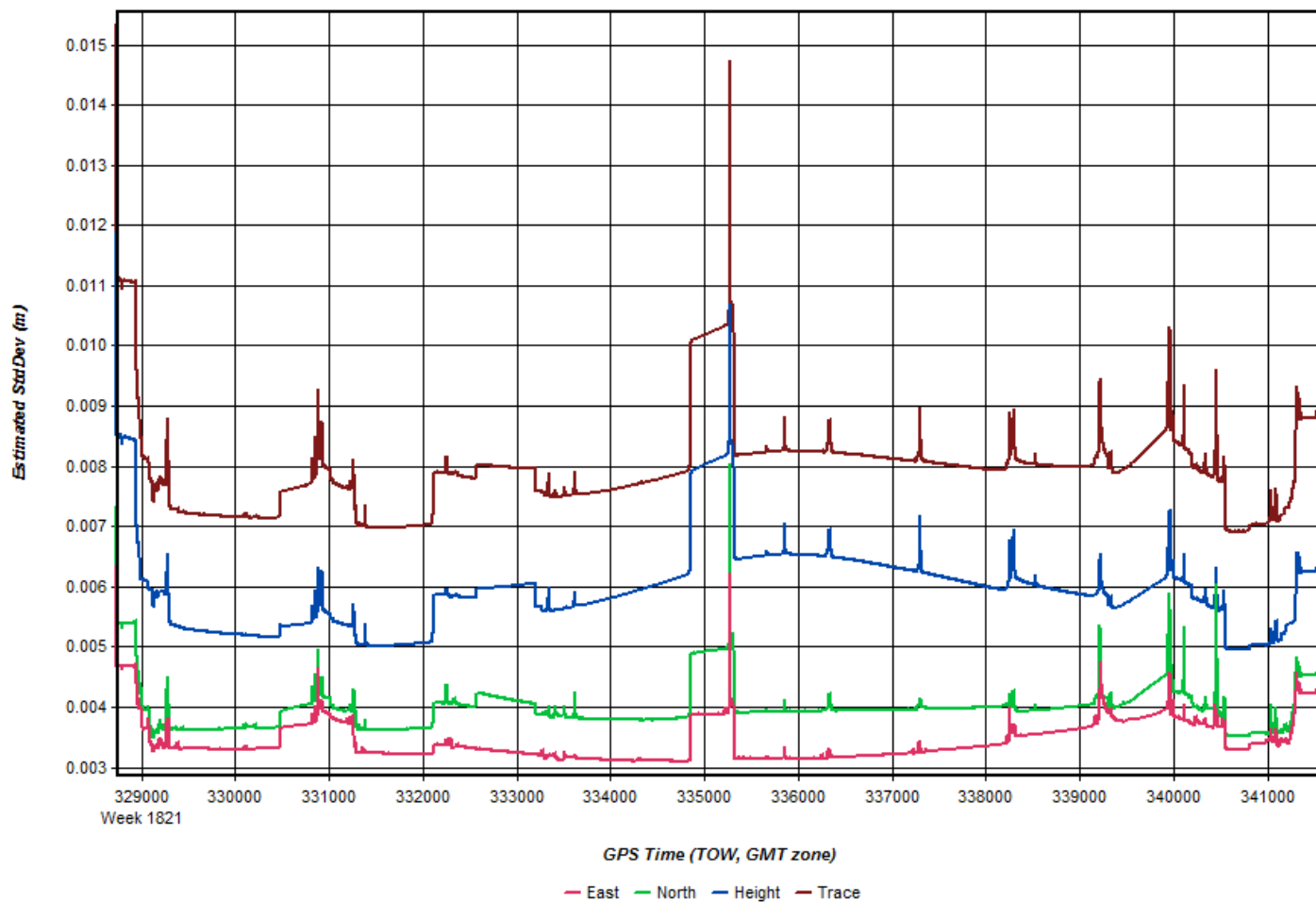


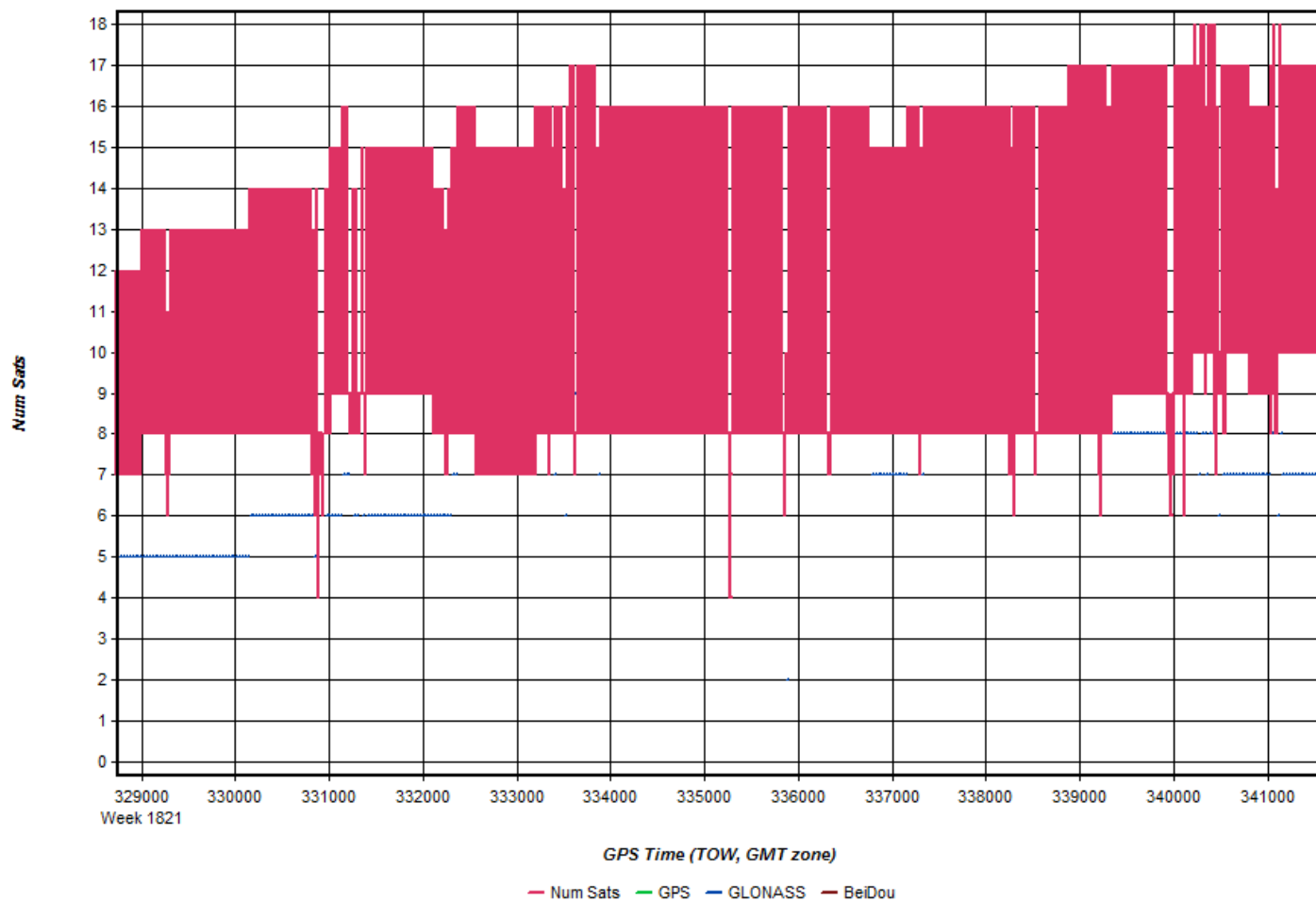


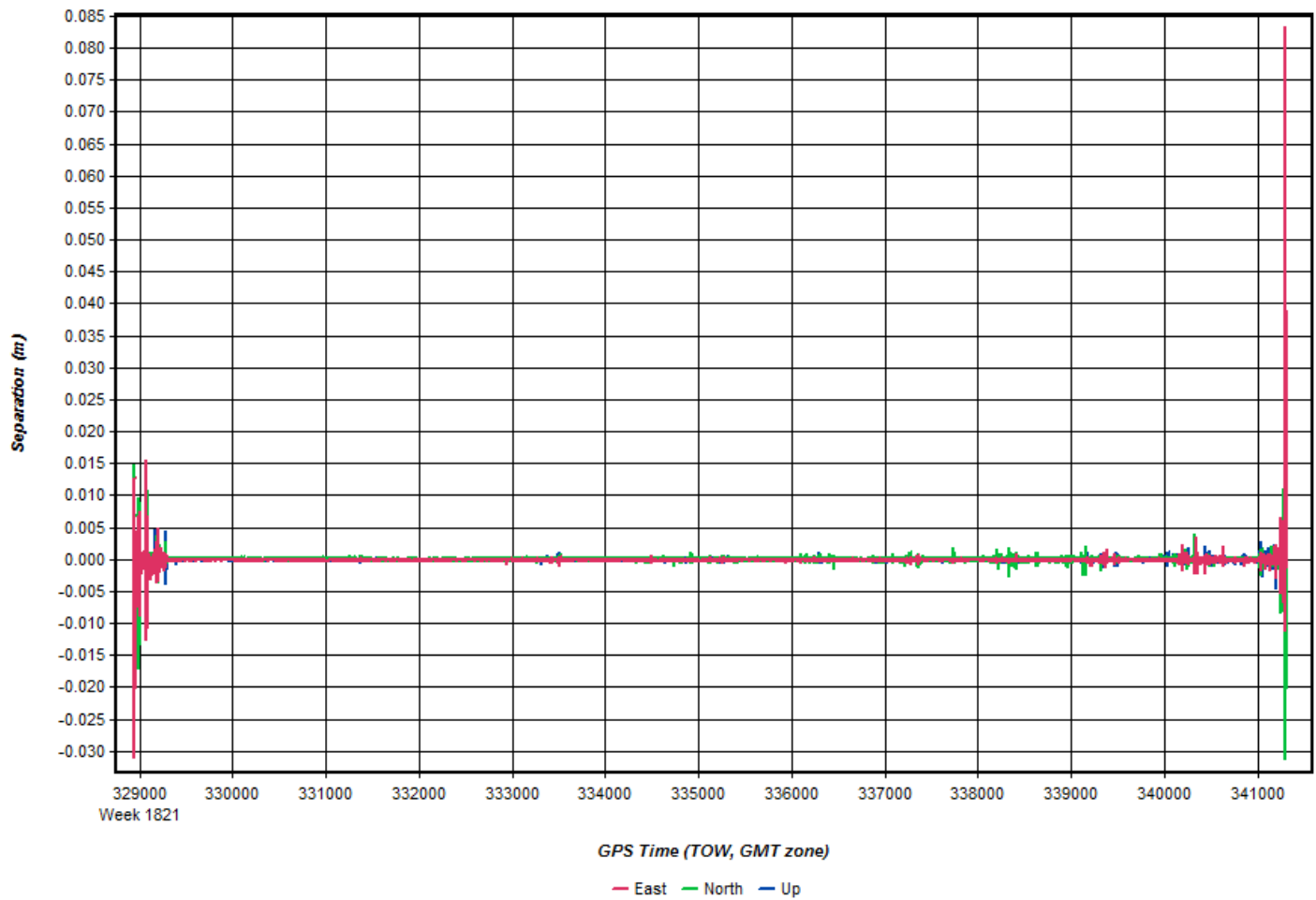


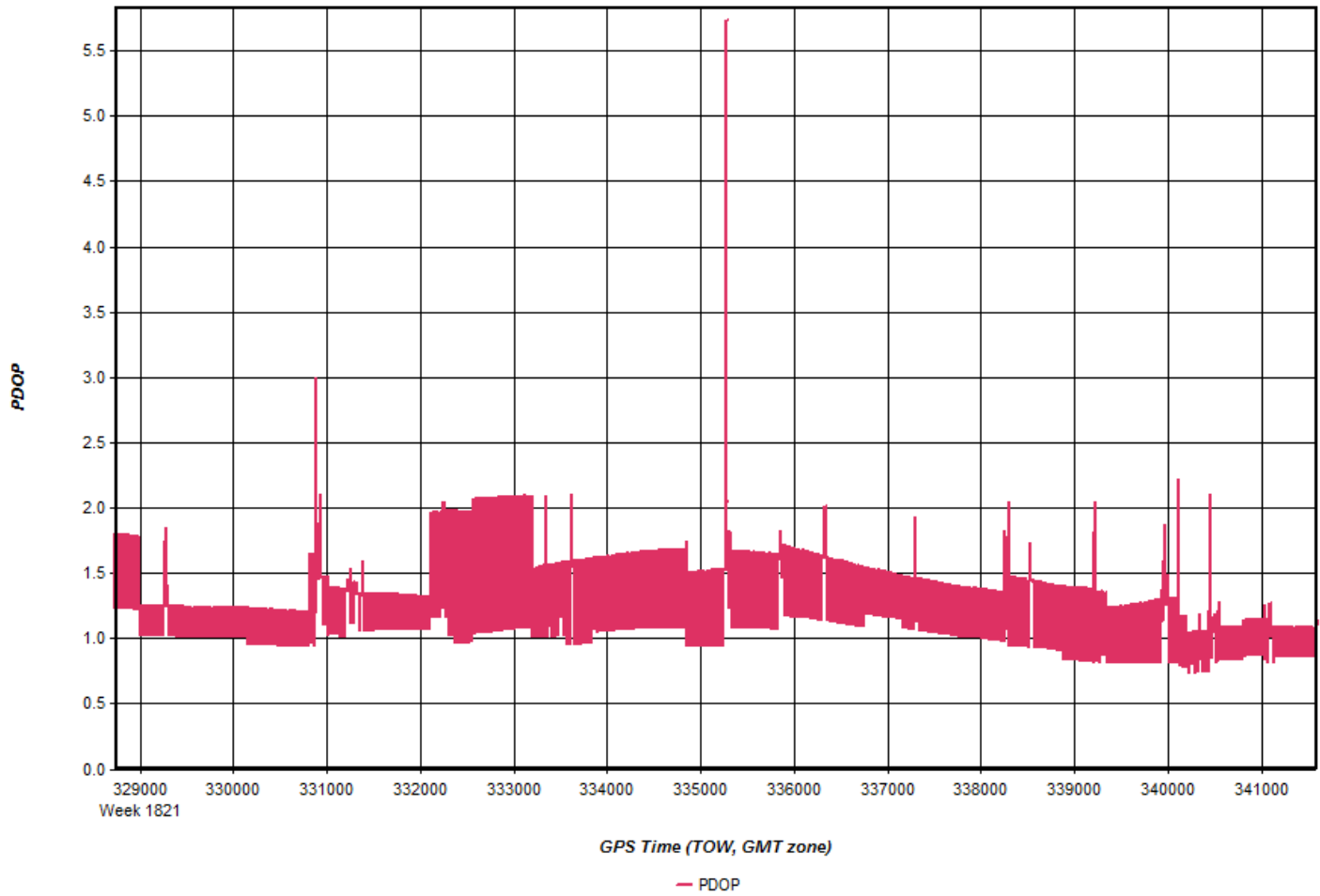
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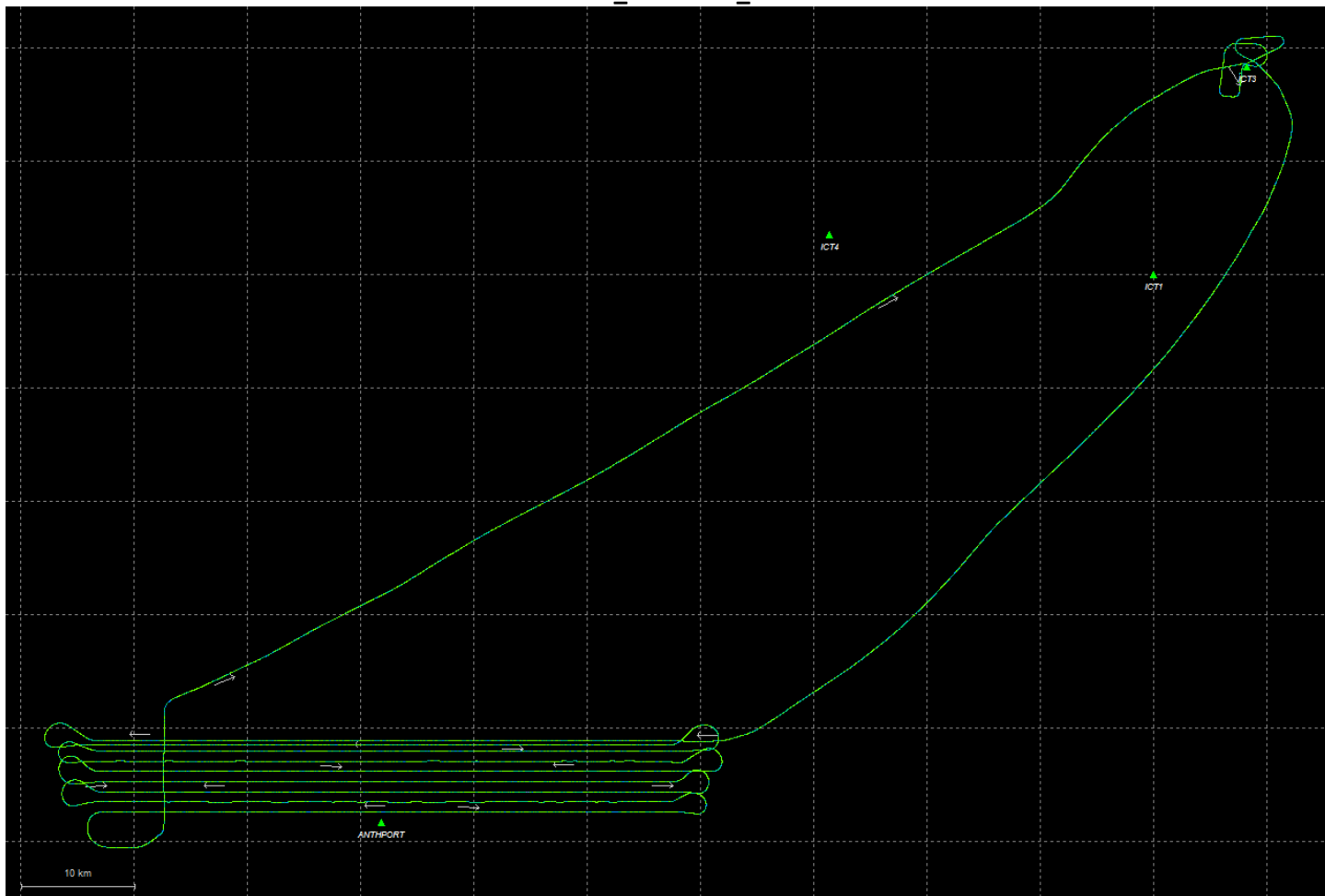


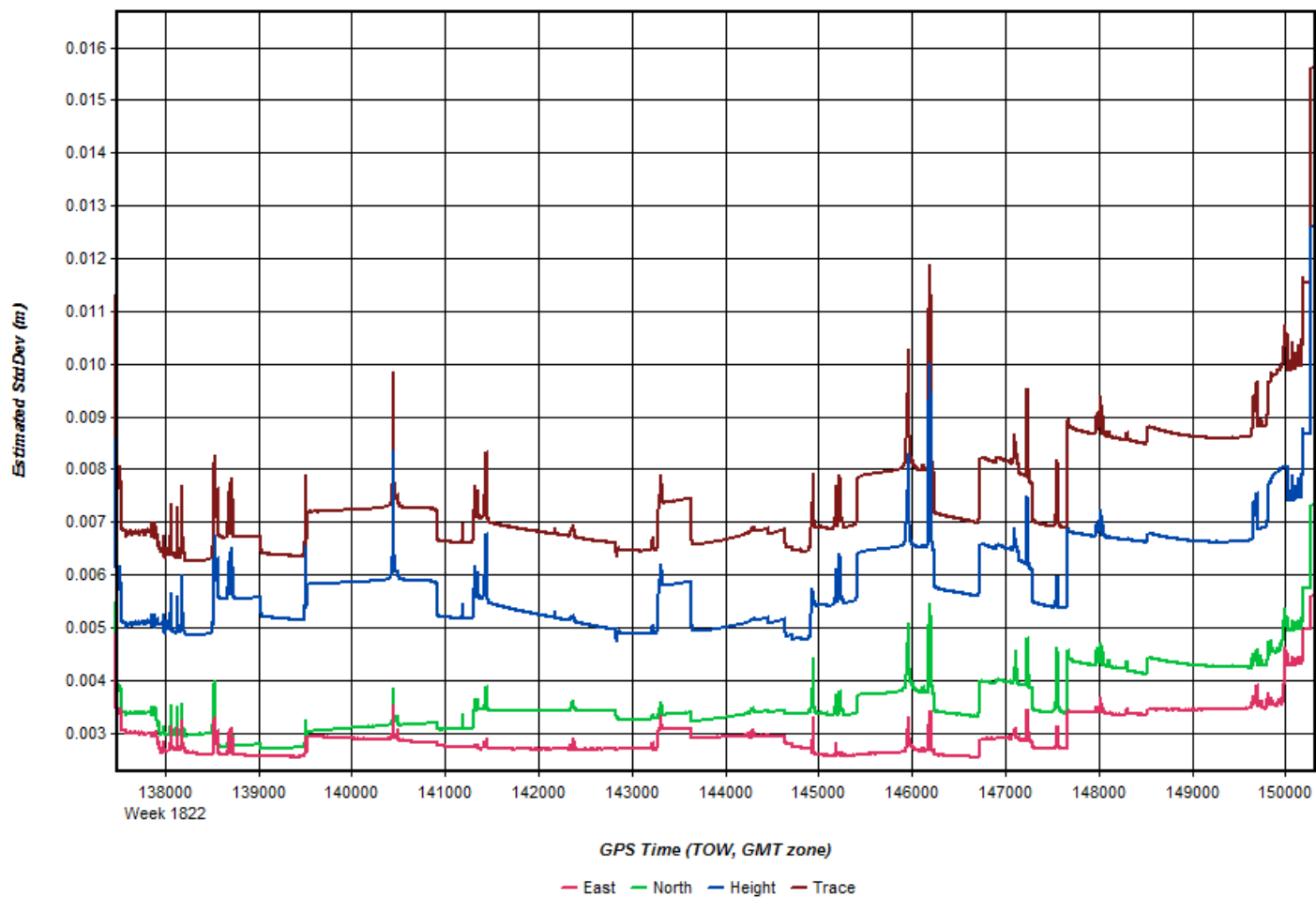


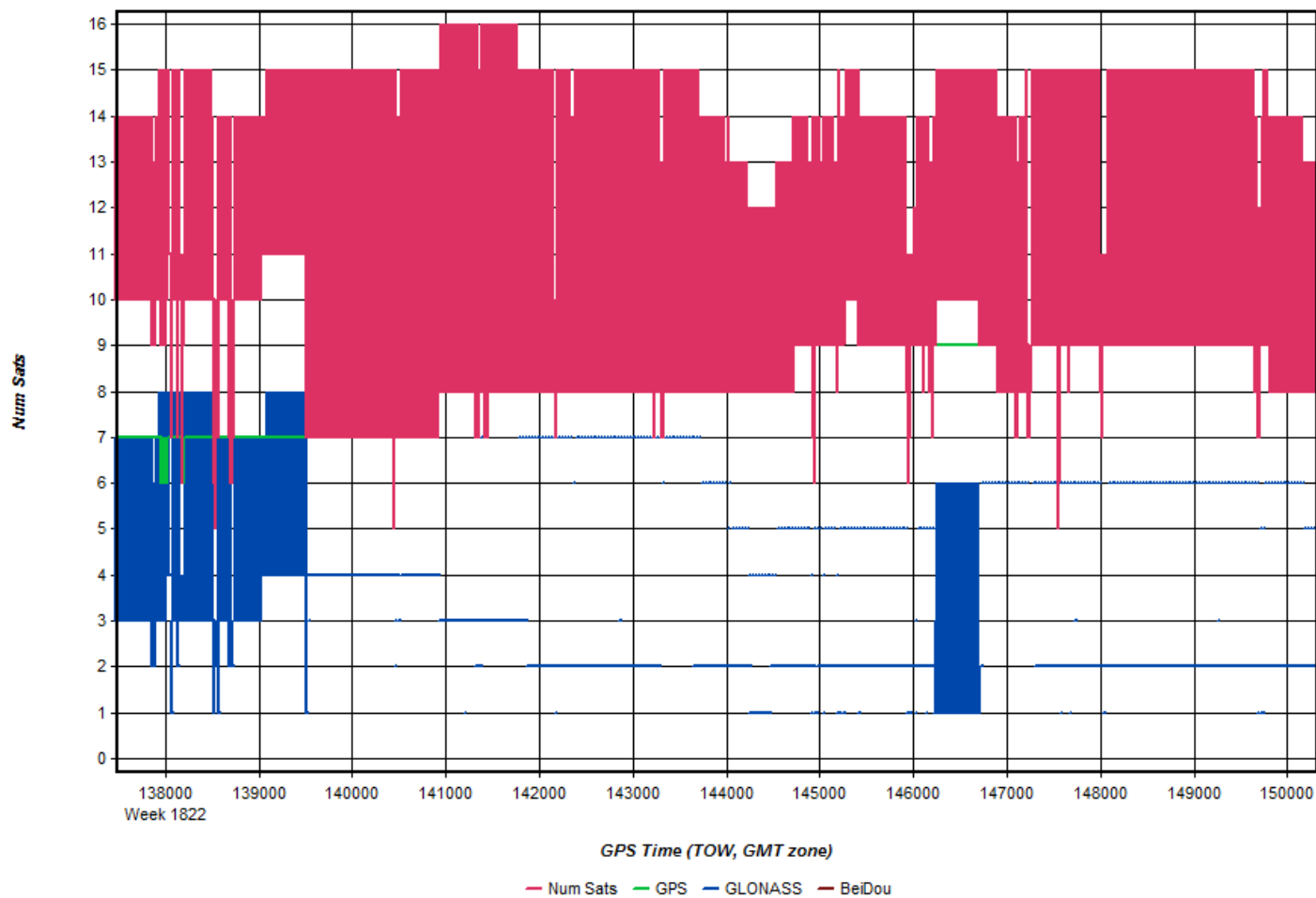


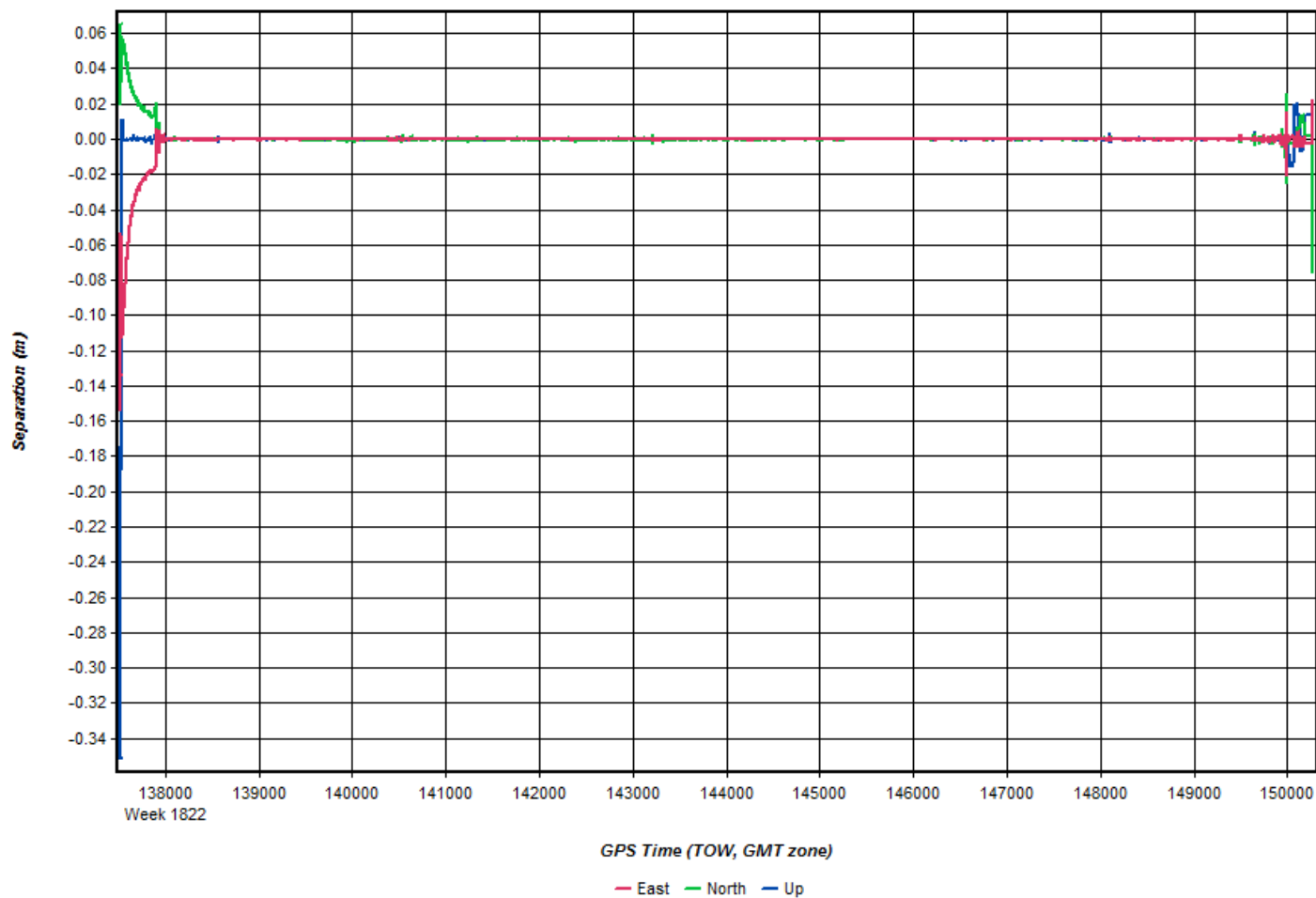


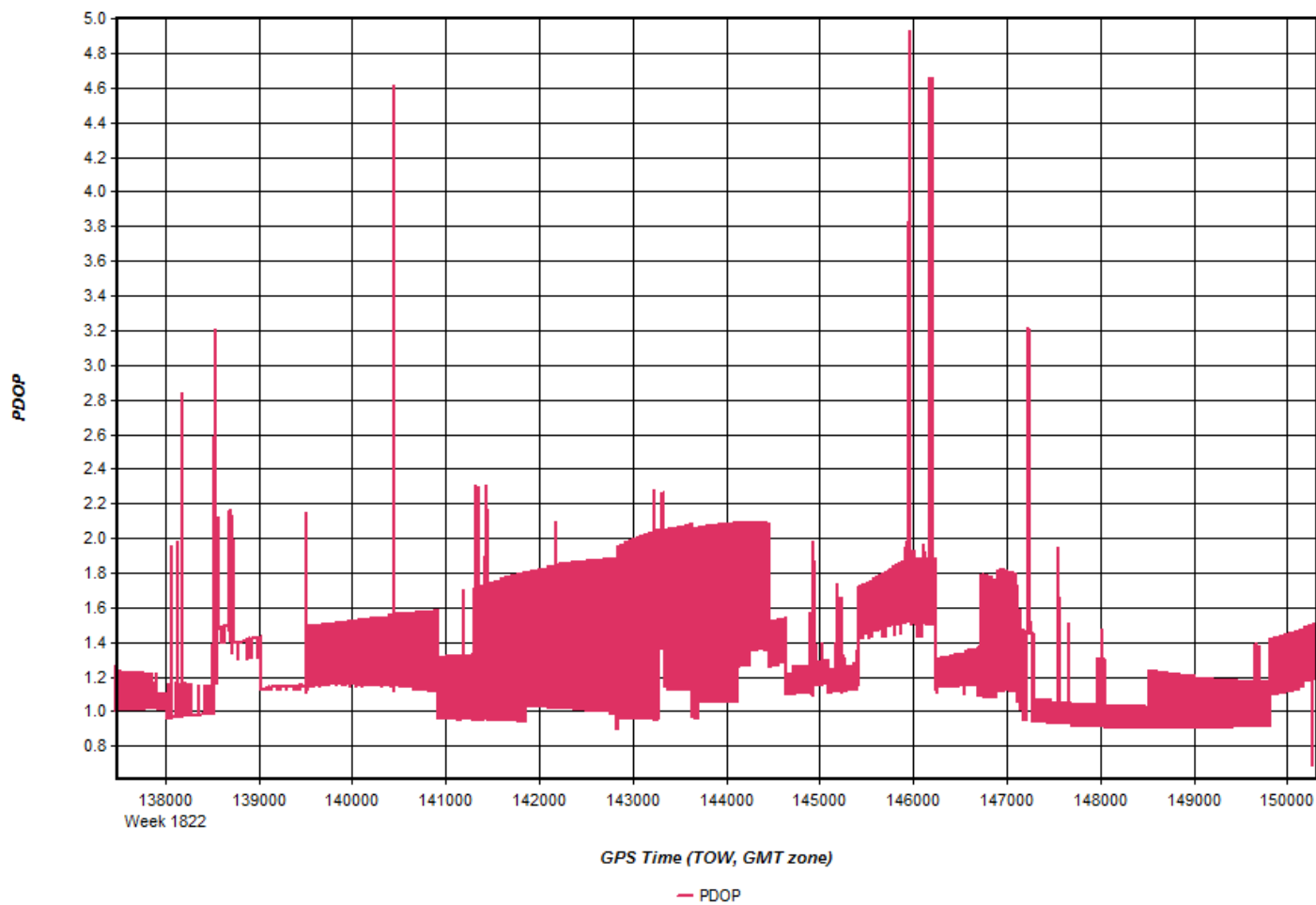
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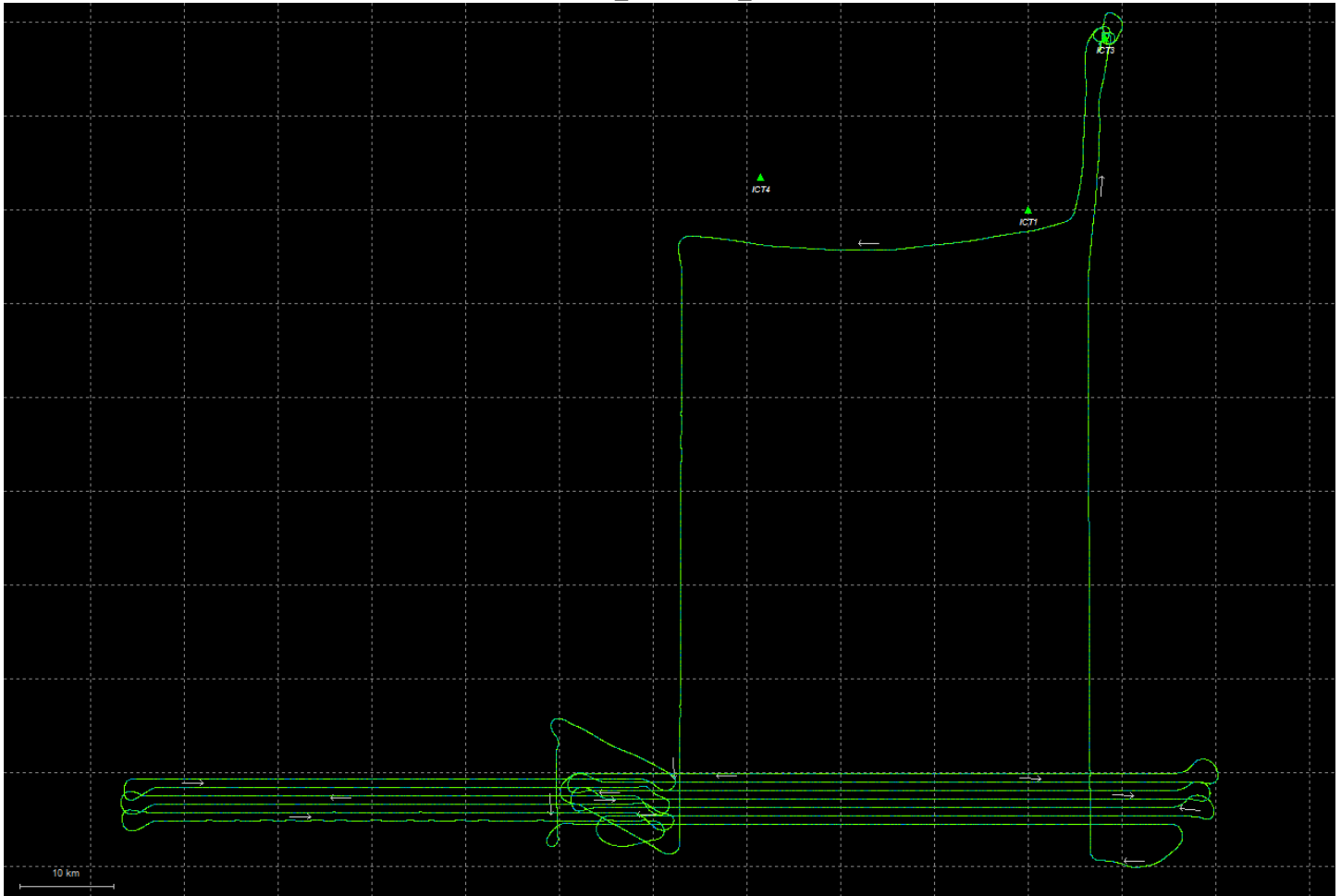


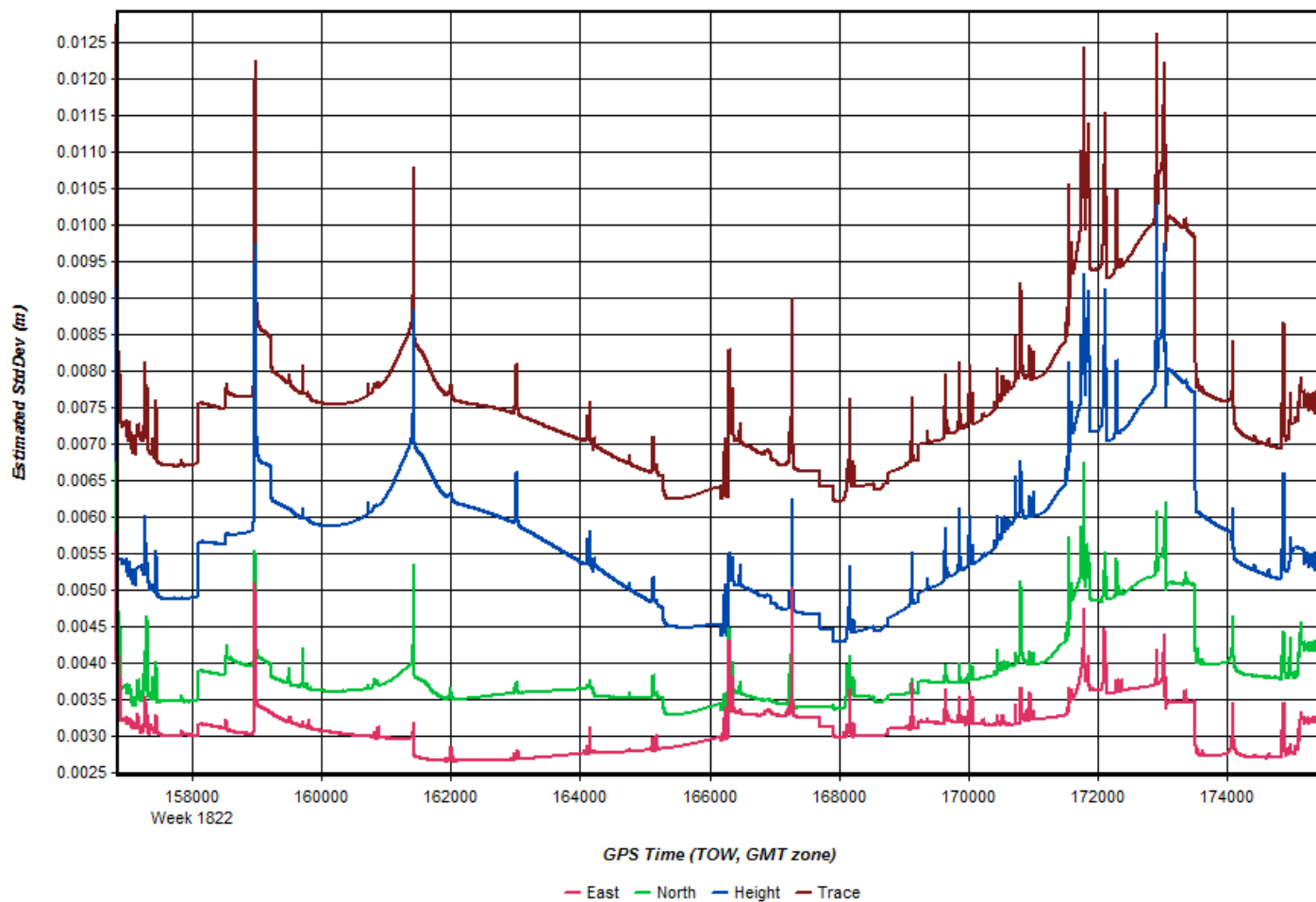


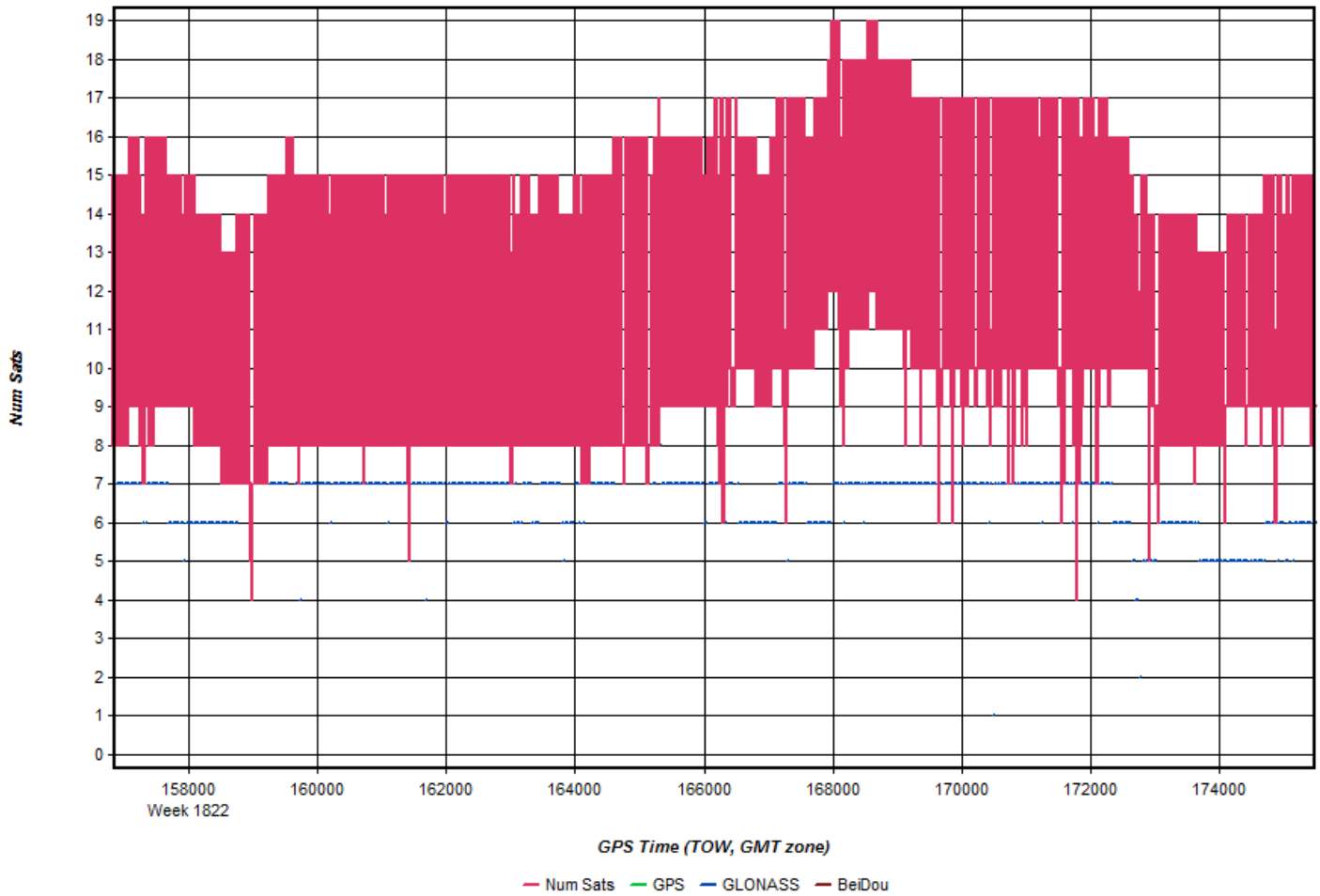


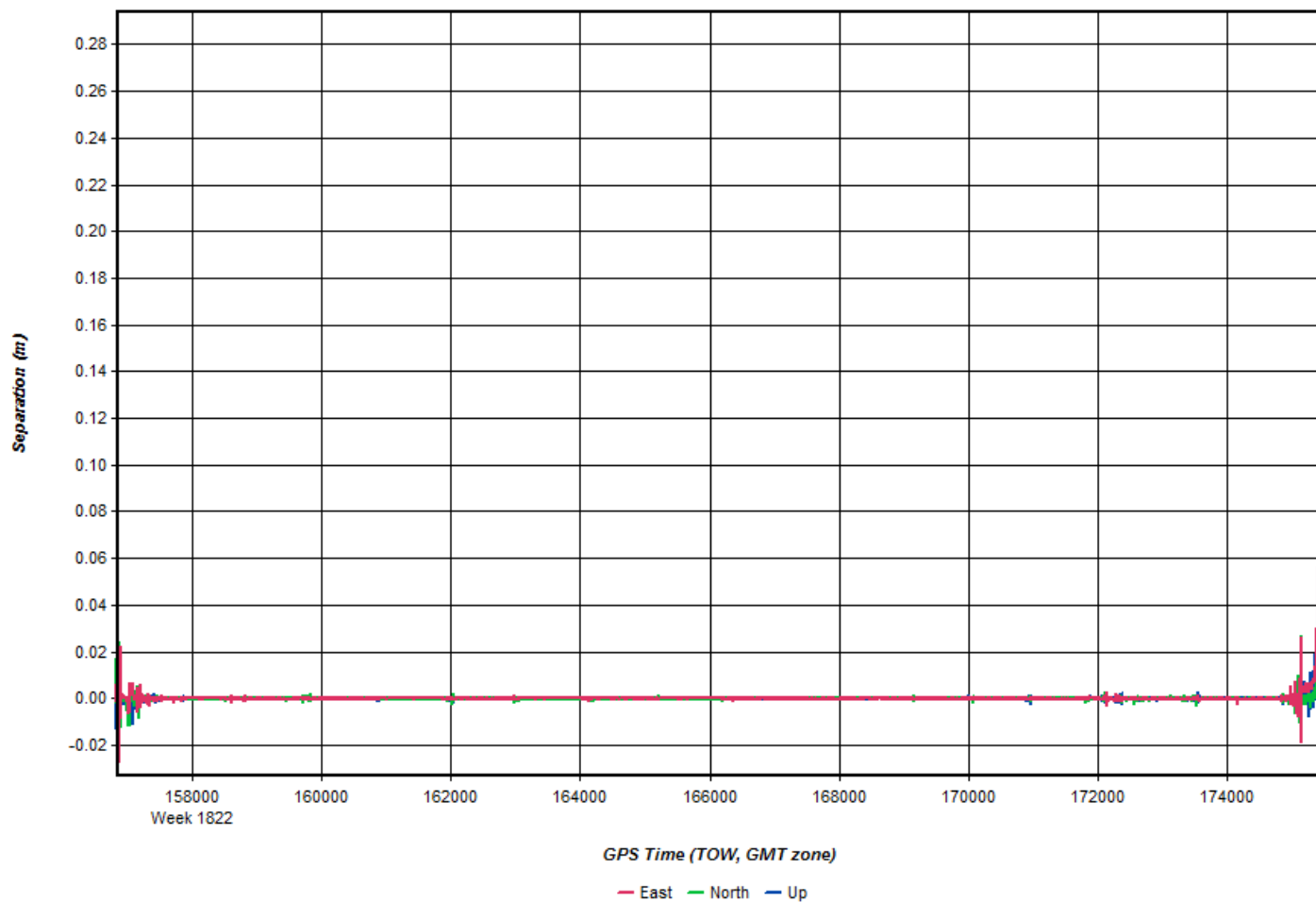


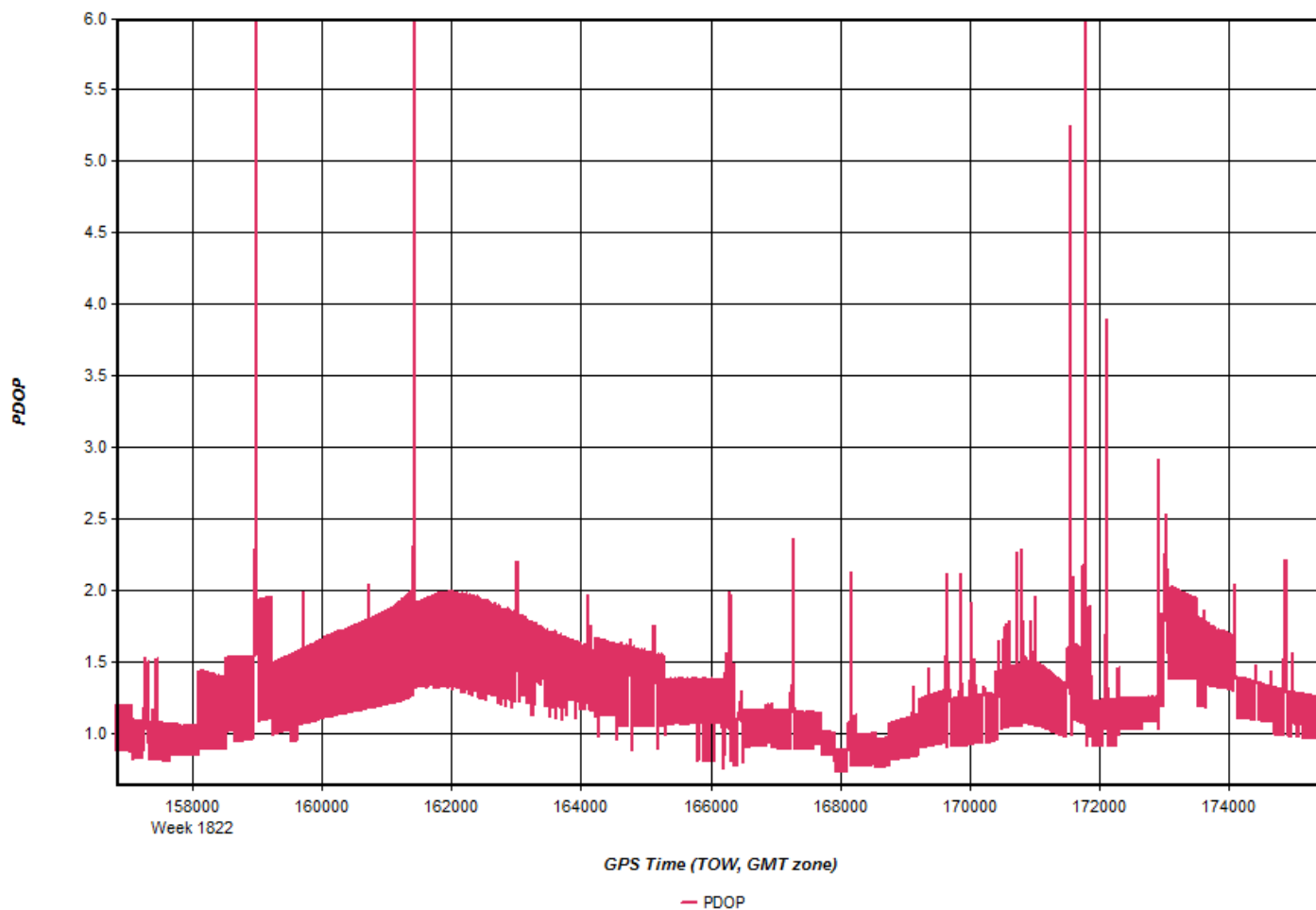
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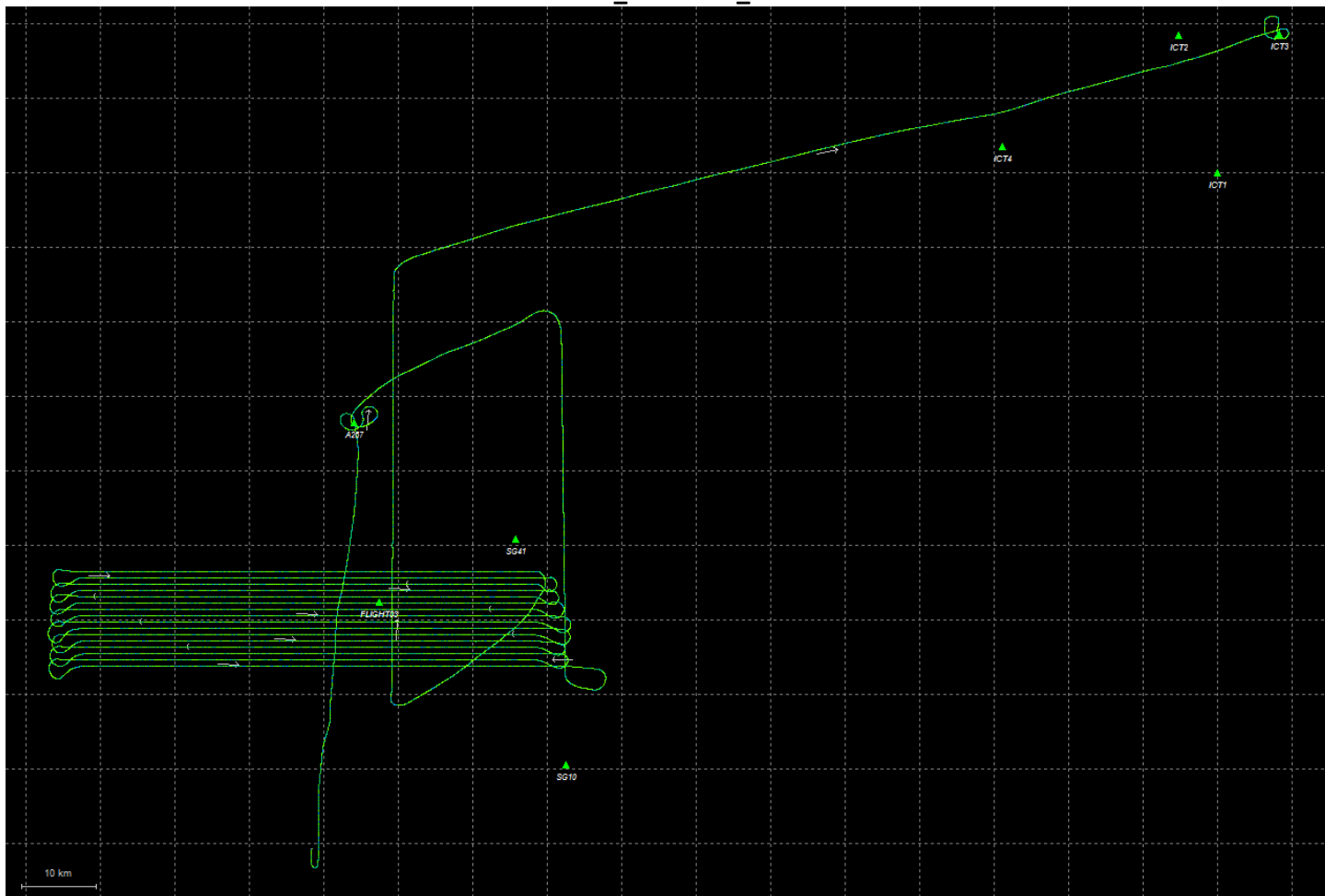


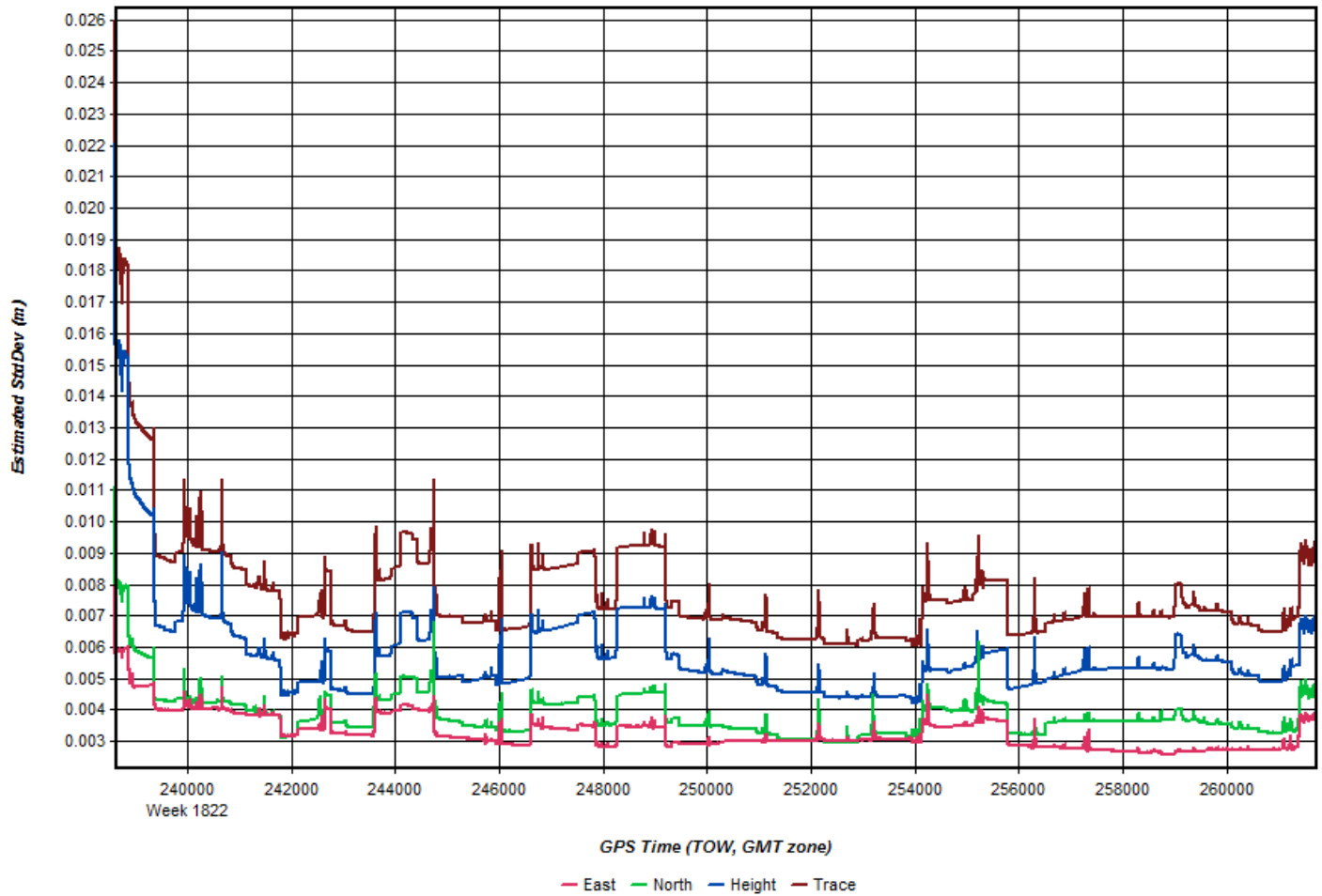


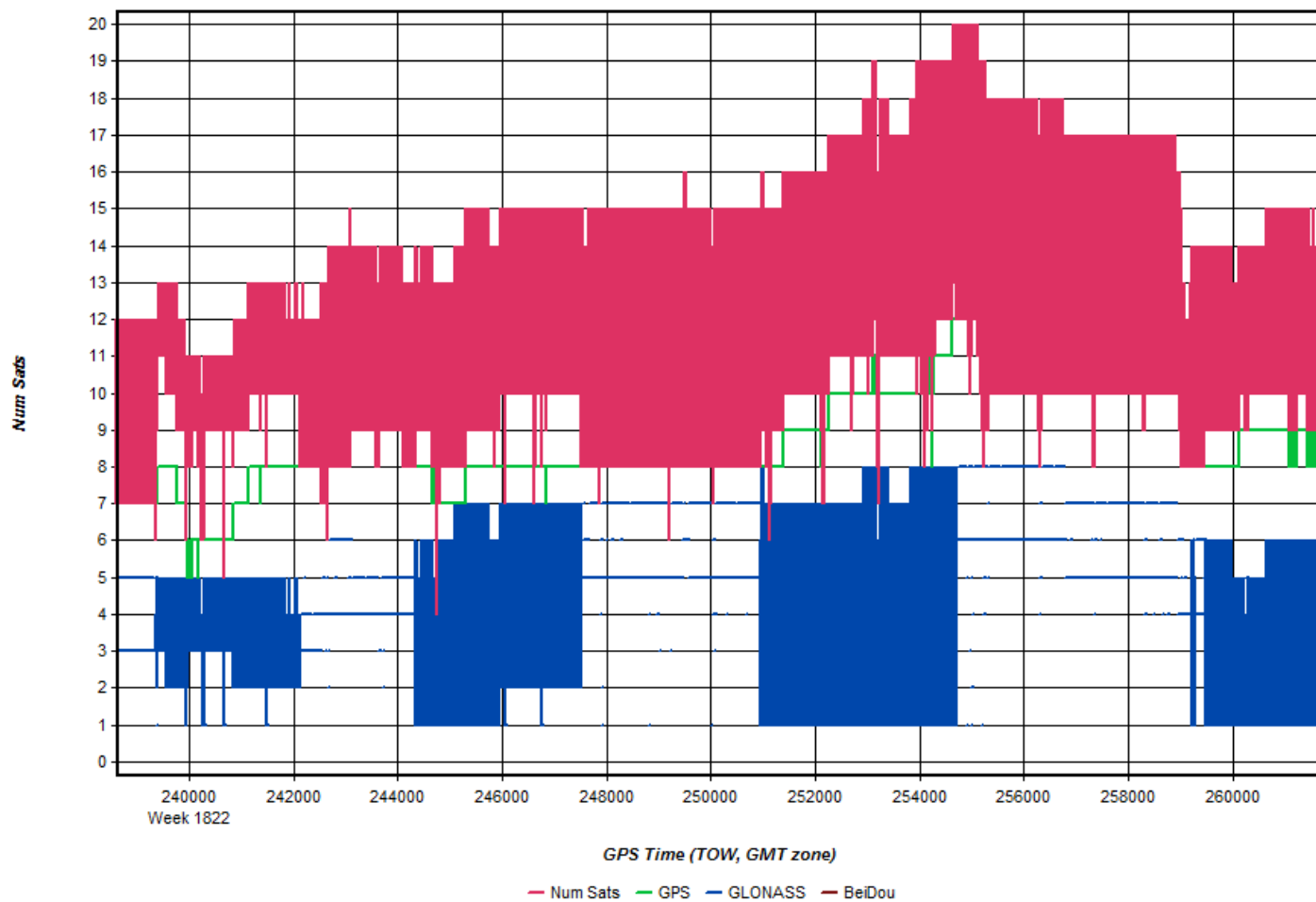


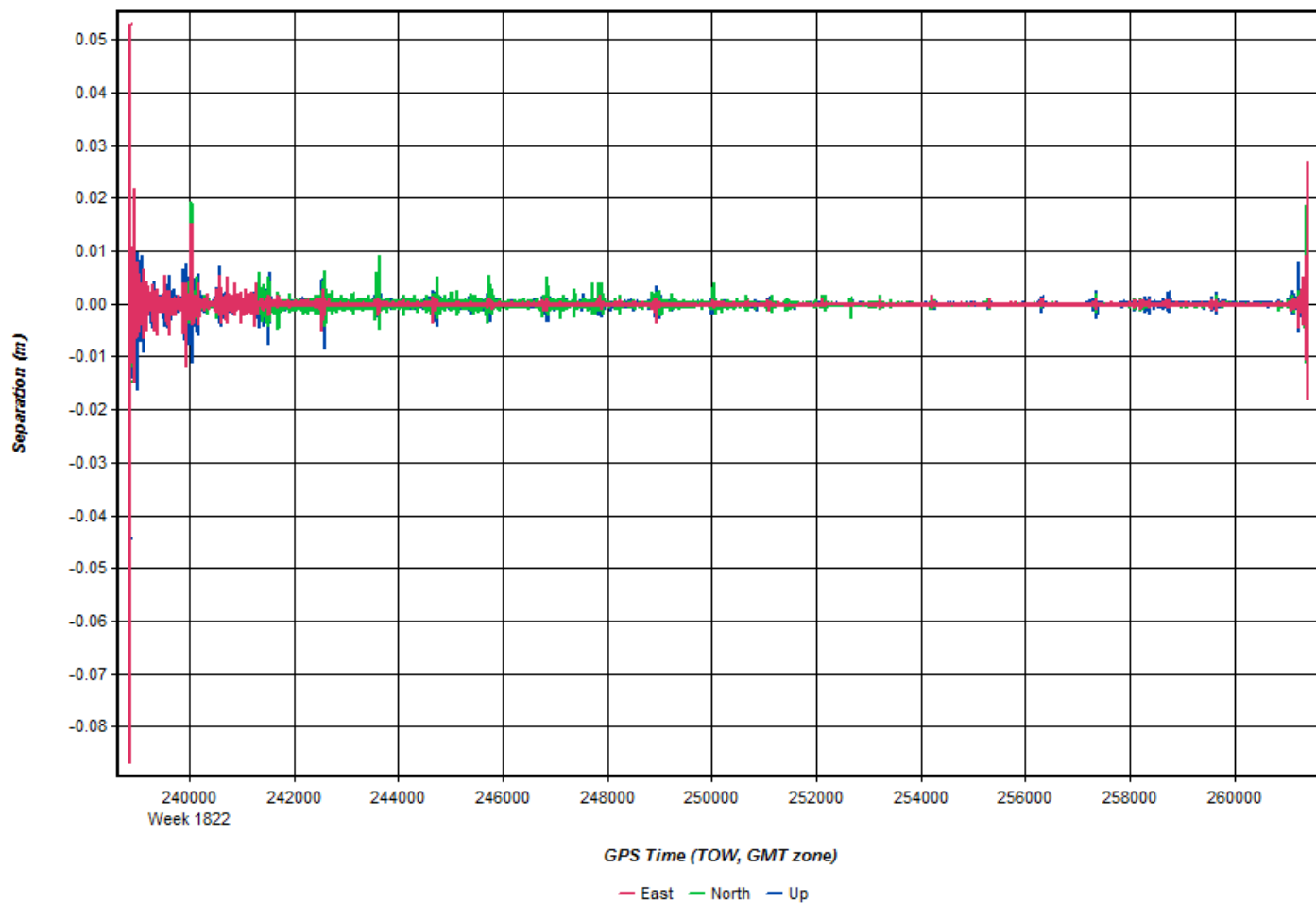


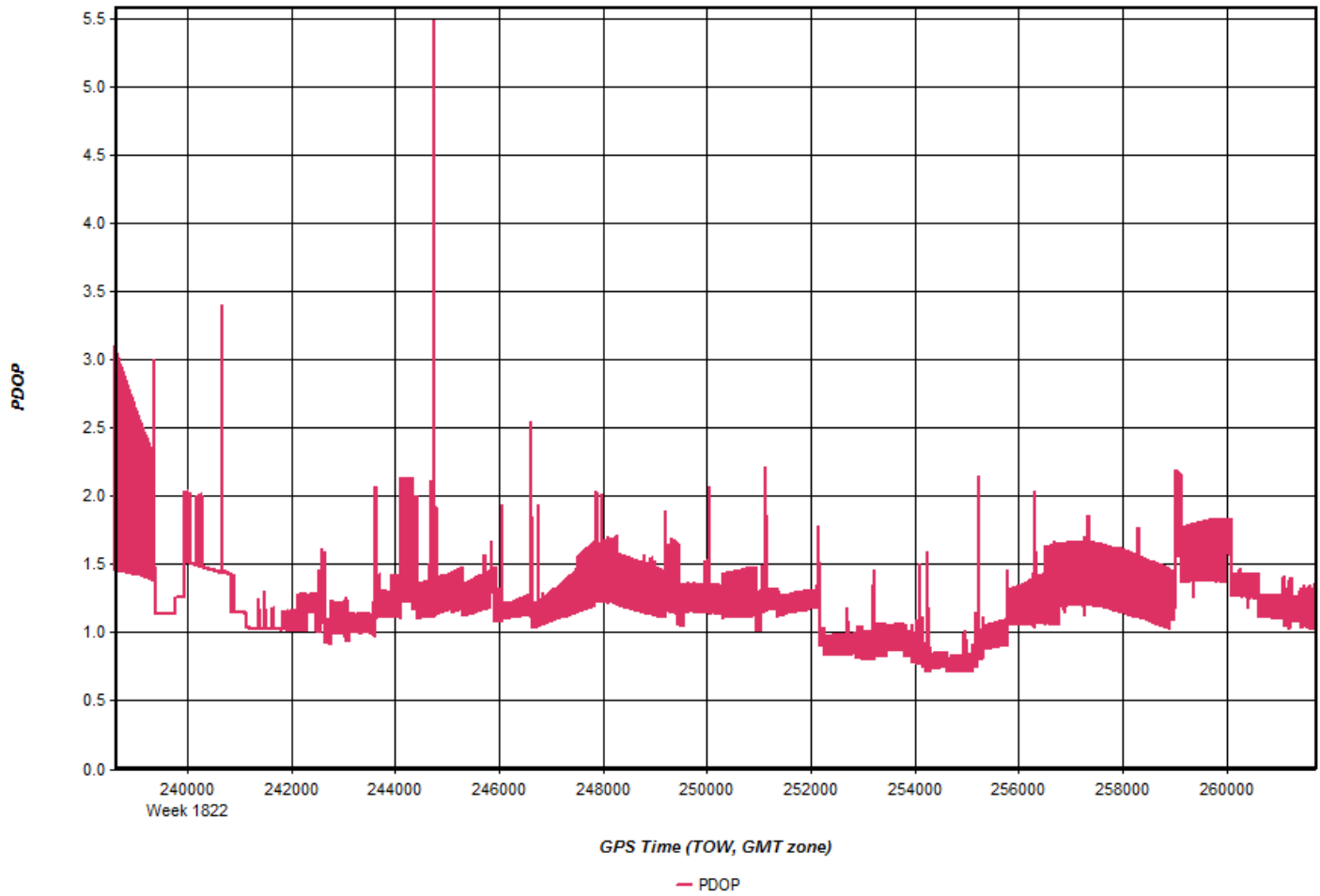
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225_20141216_1

