

Block 3_IL_8_County_Lidar 2019 Final Report

Report Produced for U.S. Geological Survey

TASK ORDER: G17PC00007

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Overview

The original purpose of this project was to develop a consistent and accurate surface elevation dataset derived from high-accuracy Light Detection and Ranging (LiDAR) technology for the USGS IL_8County_PlusChampaign_2019_B19 project Area. The AOI covered approximately 6,337 square miles in total and include the counties of Champaign, Jo Daviess, Stephenson, Carroll, Ogle, Whiteside, Lee, Rock Island, and Henry. Block 3 allows for an increase in the quality level of the areas over Jo Daviess, Stephenson, Carroll, Ogle, Whiteside, Lee, Rock Island, and Henry County (~5318 sq. mi.) of an ANPS \leq 0.5m. Adverse ground conditions during the fall 2019 flight season limited Lidar acquisition to a small portion of the entire project area. Approximately 5318 square miles of Block 3 referred to as Block 3_IL_8_County_Lidar 2019 was acquired in the fall of 2019, spring and fall of 2020. During the times off collection the river level fluctuated.

The LiDAR data for Block 3 Illinois 8 County was processed and classified according to project specifications. Detailed breaklines, bare earth Digital Elevation Models (DEMs), and Intensity Images were produced for the Block 3 Project area. Data was formatted into tiles with each tile covering an area of 1000 meters by 1000 meters. A total of 14,482 LAS files, 14,482 DEMs, and 14,481 Intensity Images were produced for the project, encompassing the Block 3 AOI of approximately 5318 square miles and formatted into 14,482total tiles.

PROJECT TEAM

Aerial Services, Inc. (ASI) served as the prime contractor for the project. In addition to project management ASI was responsible for LiDAR acquisition and calibration, LAS classification, LiDAR products, Digital Elevation Model (DEM) production, Intensity Image production, and quality assurance. Subcontractor: SurvTech was responsible for LiDAR acquisition and calibration, LAS classification and hydro collection for 1264 square mile area of the Southwest section of the project area. SurvTech manually preformed bare earth cleanup, and collected hydro for 759 of square miles of the project. Subcontractor: Tetra Tech manually preformed bare earth cleanup, and collected hydro for 1732 of square miles of the project. Subcontractor Dewberry manually preformed bare earth cleanup, and collected hydro for 1533 of square miles of the project. All follow-on processing was completed by the prime contractor.

Surveying and Mapping, LLC (SAM) completed ground surveying for the project and delivered surveyed checkpoints. SAM was to acquire surveyed checkpoints for the project to use in independent testing of the vertical accuracy of the LiDAR-derived surface model. Please see SURVEY REPORT to view the separate Survey Report that was created for this portion of the project.

SURVEY AREA

The project area addressed by this report falls within the Block 3 Illinois 8 County, covering Jo Daviess, Stephenson, Carroll, Ogle, Whiteside, Lee, Rock Island, and Henry County, Illinois.

DATE OF SURVEY

LiDAR acquisition for Block 3 Illinois 8 County was conducted between the dates of November 23, to December 7, 2019, with missions flown on March 8, 2020 and November 12, 2020 to fill in a data void.

COORDINATE REFERENCE SYSTEM

Data produced for the project was delivered in the following reference system.

Horizontal Datum: The horizontal datum for the project is North American Datum of 1983 with the 2011 Adjustment (NAD 83 (2011)).

Vertical Datum: The Vertical datum for the project is North American Vertical Datum of 1988 (NAVD88).

Coordinate System: Albers Equal Area.

Units: Horizontal units are in meters, Vertical units are in meters.

Geoid Model: Geoid12B

LIDAR VERTICAL ACCURACY

For the Block 3 IL 8 County project, the tested RMSE_z of the classified LiDAR data for checkpoints in non-vegetated terrain equaled 0.055 meters compared with the 10 cm specification: The 95% confidence value of NVA of the classified LiDAR data computed using RMSE_z x 1.96 and was found to equal 0.108 meters compared with the 0.196 meter specification.

For the Block 3 IL 8 County project, the tested VVA of the classified LiDAR data computed using the 95th percentile was equal to 0.053 meters, compared with the 0.294 meter (0.96 ft) specification.

This project must meet Non-vegetated Vertical Accuracy (NVA) ≤ 0.0196 meters (19.6 cm) at the 95% confidence level based on RMSE_z ≤ 0.100 meters (10 cm) x 1.9600.

100 % of Totals	# of Points	RMSE _z NVA (m)	NVA- Non-vegetated Vertical Accuracy ((RMSE _z x 1.9600) m)	Mean (m)	Median (m)	Skew	Std Dev (m)	Min (m)	Max (m)	Kurtosis
NVA	127	0.055	0.108	-0.034	-0.030	-0.108	0.044	-0.160	0.110	1.073

Table 1: Non-vegetated Vertical Accuracy (NVA) results.

Additional accuracy information and statistics for the classified LiDAR data, raw swath data, and bare earth DEM data can be found in following sections of this report.

PROJECT DELIVERABLES

The deliverables for the project are listed below.

- Classified Point Cloud Data (Tiled)
- Bare Earth Surface (Raster DEM – IMG format)
- Intensity Images (8-bit gray scale, tiled, GeoTIFF format)
- Breakline Data (File GDB)
- Independent Survey Checkpoint Data (File GDB)
- Calibration Points (File GDB)
- Metadata
- Maximum surface height raster
- Swath separation Images
- Project Report (Acquisition, Processing, QC)
- Project Extent (Included in breakline GDB)

Swaths Extents (File GDB)
Tile Index (included in breakline GDB)

PROJECT TILING FOOTPRINT

14,482 tiles, 14,482 LAS files, 14,482 DEM tiles, and 14,481 Intensity Image tiles were delivered for the project. Each tile's extent is 1000 meter by 1000 meter. (See Appendix A for a complete listing of delivered tiles.)

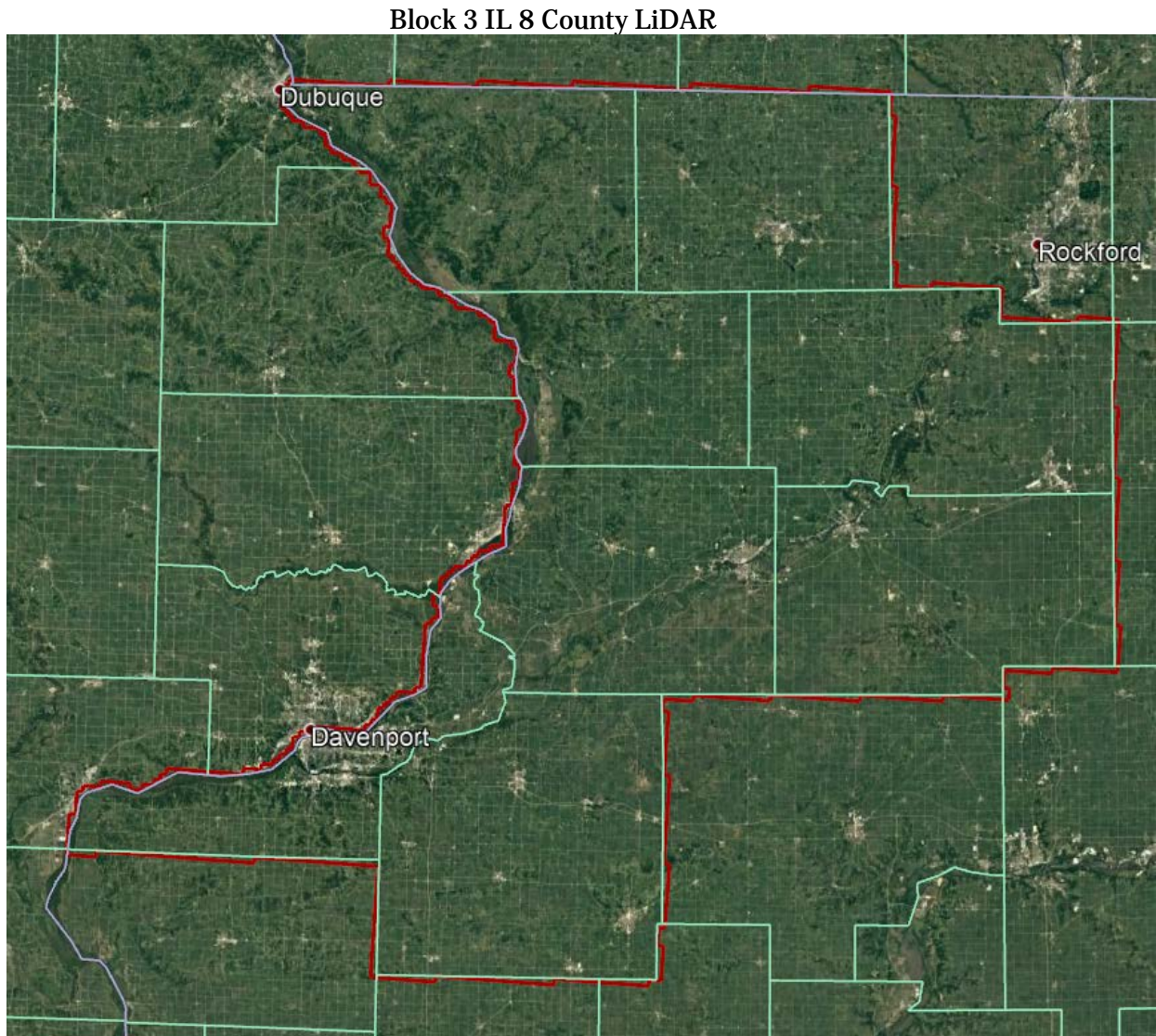


Figure 1: G17PC00007_Block 3 IL 8 County_2019_B19 Area of Interest

PROJECT AREA WITH ELEVATION MODEL

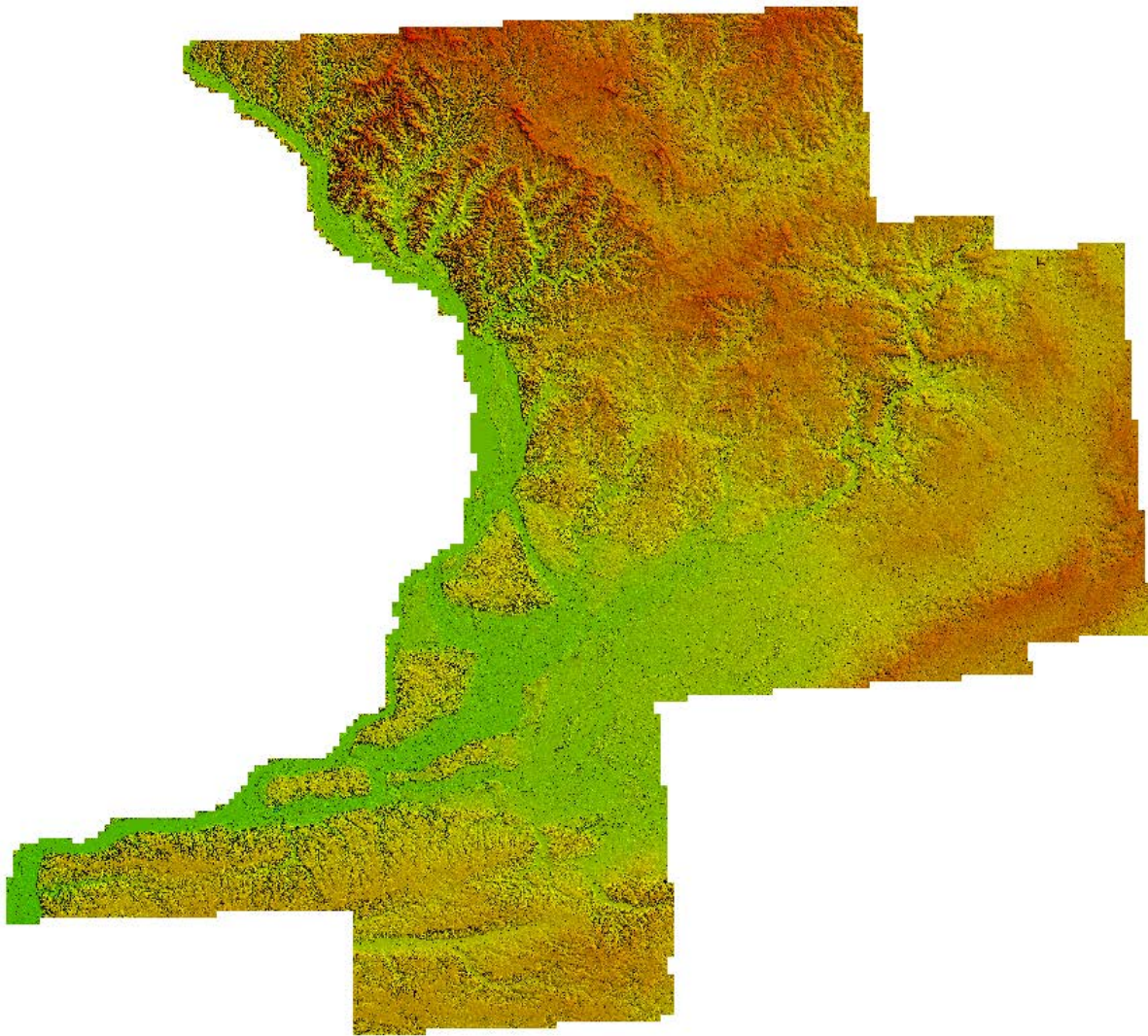


Figure 2: G17PC00007_Block 3 IL 8 County_2019_B19 Area of Interest Elevation DEM

Lidar Acquisition Details Aerial Services Inc.

Aerial Services, Inc. served as prime contractor for the Block 3 IL 8 County project and performed the LiDAR Acquisition and Calibration for Jo Daviess, Stephenson, Carroll, Ogle, Whiteside, Lee, and the northern 1/5 of Rock Island County.

Aerial Services, Inc. planned 142 passes for the project area as well as 11 additional cross flightlines for the purposes of quality control in our own processing which are not included in delivery. The flight plan included multiple flight directions to maximize county coverage while remaining short enough to avoid significant IMU drifting. In order to reduce any margin for error in the flight plan, Aerial Services, Inc. followed FEMA's Appendix A "guidelines" for flight planning and, at a minimum, includes the following criteria:

- A digital flight line layout using TrackAir Snapplan flight design software for direct integration into the aircraft flight navigation system.
- Planned flight lines; flight line numbers; and coverage area.
- Lidar coverage extended by a predetermined margin beyond all project borders to ensure necessary over-edge coverage appropriate for specific task order deliverables.
- Local restrictions related to air space and any controlled areas have been investigated so that required permissions can be obtained in a timely manner with respect to schedule. Additionally, Aerial Services, Inc. will file our flight plans as required by local Air Traffic Control (ATC) prior to each mission.

Aerial Services, Inc. monitored weather and atmospheric conditions and conducted lidar missions only when no conditions exist below the sensor that will affect the collection of data. These conditions include leaf-off for hardwoods, no snow, rain, fog, smoke, mist and 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. Aerial Services, Inc. accesses 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, Aerial Services, Inc. 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.

Aerial Services, Inc. lidar sensors are calibrated at designated sites located in Waverly and Hudson, IA and they are periodically checked and adjusted to minimize corrections at project sites.

LIDAR SYSTEM PARAMETERS

Aerial Services, Inc. operated a Cessna 210 (N5531A), Cessna 206 (N78AS), and Piper Navajo (N144AS) equipped with a Leica ALS70 LiDAR or a Riegl LMSQ-1560 system during the collection of this task order.

Item	Parameter	Parameter
System	Riegl LMS-Q1560	Leica ALS70
Maximum Number of Returns per Pulse	6	4
Nominal Pulse Spacing (single swath), (m)	0.5	0.5
Nominal Pulse Density (single swath) (ppsm), (m)	4	4
Altitude (AGL meters)	1500	1300
Approx. Flight Speed (knots)	130	125
Total Sensor Scan Angle (degree)	60	50
Scan Frequency (hz)	89	47
Scanner Pulse Rate (kHz)	400	393.6
Did the Sensor Operate with Multiple Pulses in The Air? (yes/no)	Yes	Yes
Nominal Swath Width on the Ground (m)	1725	1212
Swath Overlap (%)	30	30
Computed Down Track spacing (m) per beam	0.7	0.84
Computed Cross Track Spacing (m) per beam	0.72	1.37

Table 2: Aerial Services, Inc. Lidar System Parameters

ACQUISITION STATUS REPORT AND FLIGHTLINES

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.

Figure 3 shows the combined trajectory of the flightlines by mission.

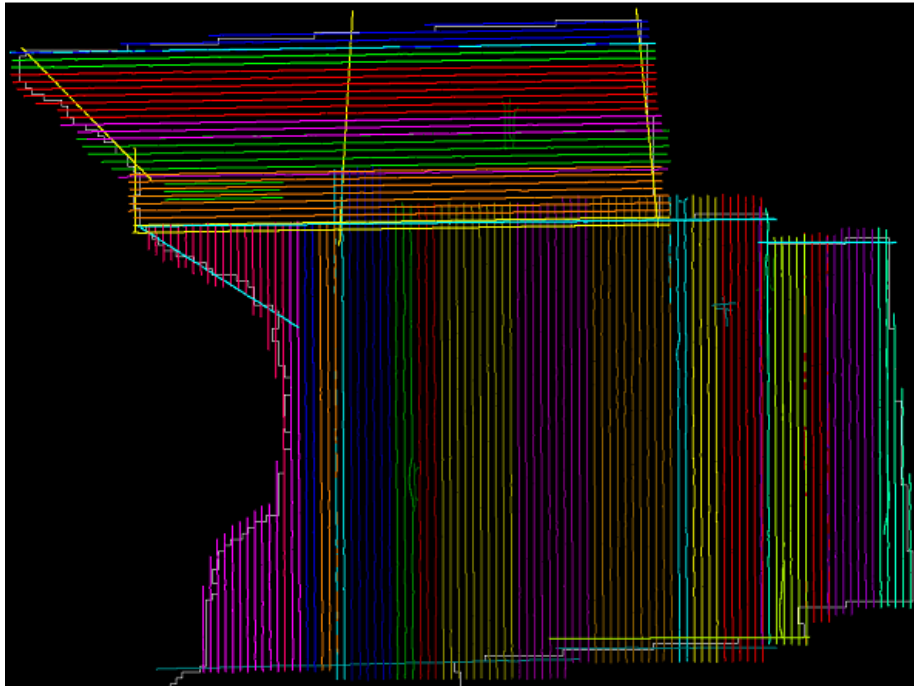


Figure 3: G17PC00007_Block 3 IL 8 County_2019_B19 trajectories by mission as flown by Aerial Services, Inc.

CALIBRATION REPORT

After processing the GNSS/GPS and IMU data in PosPac, LAS 1.4 point cloud data is then generated through Riegl software. RiProcess coordinates the activities of the following programs: RiAnalyze generates point records with timestamps, POF Import converts SBET trajectory information in to usable coordinates, and RiWorld combines the trajectory, calibration data, and point records into a 3-dimensional point cloud in the specified coordinate reference system and file format.

Relative accuracy and internal quality are checked using Terramatch, in which points from all lines are observed and compared. Vertical differences between ground surfaces of each line are displayed. Rasters are generated on filtered tiles to model Dz between adjacent lines. Inter-swath accuracy is tested to the <.08m standard specified in the base spec. Data are visually inspected across each block to validate point to point, flight line to flight line and mission to mission agreement.

A listing of Flightlines and corresponding, Lift_ID, Date, Point Source ID, Scanner, and adjusted GPS times are available in table 3.

Name	Lift_ID	Date	PT Source ID	Scanner	Start Time	End Time
201112_190310	20201112_F1_SN7215	11/12/2020	1189	ALS_70	289242979	289243085
201112_185952	20201112_F1_SN7215	11/12/2020	1188	ALS_70	289242781	289242901
201112_185620	20201112_F1_SN7215	11/12/2020	1187	ALS_70	289242569	289242661
201112_181114	20201112_F1_SN7215	11/12/2020	1180	ALS_70	289239863	289239964
201112_181434	20201112_F1_SN7215	11/12/2020	1181	ALS_70	289240062	289240155
201112_183016	20201112_F1_SN7215	11/12/2020	1182	ALS_70	289241005	289241120
201112_184158	20201112_F1_SN7215	11/12/2020	1186	ALS_70	289241707	289241818
201112_183848	20201112_F1_SN7215	11/12/2020	1185	ALS_70	289241516	289241622
201112_183541	20201112_F1_SN7215	11/12/2020	1184	ALS_70	289241329	289241440
201112_183237	20201112_F1_SN7215	11/12/2020	1183	ALS_70	289241146	289241247
191123_205503	20191123_F1_SN2221256	11/23/2019	3002	Riegl_LMS-Q1560	258577706	258579279
191123_212347	20191123_F1_SN2221256	11/23/2019	1002	Riegl_LMS-Q1560	258579430	258580817
191123_215139	20191123_F1_SN2221256	11/23/2019	1003	Riegl_LMS-Q1560	258581101	258582232
191123_221213	20191123_F1_SN2221256	11/23/2019	1004	Riegl_LMS-Q1560	258582336	258582883
191124_000047	20191123_F2_SN2221256	11/24/2019	1005	Riegl_LMS-Q1560	258588849	258590464
191124_002938	20191123_F2_SN2221256	11/24/2019	1006	Riegl_LMS-Q1560	258590581	258592285
191124_151821	20191124_F1_SN2221256	11/24/2019	1007	Riegl_LMS-Q1560	258643904	258645521
191124_154923	20191124_F1_SN2221256	11/24/2019	1008	Riegl_LMS-Q1560	258645766	258647331
191124_161817	20191124_F1_SN2221256	11/24/2019	1009	Riegl_LMS-Q1560	258647500	258649104
191124_164713	20191124_F1_SN2221256	11/24/2019	1010	Riegl_LMS-Q1560	258649236	258650845
191124_171640	20191124_F1_SN2221256	11/24/2019	1011	Riegl_LMS-Q1560	258651003	258652577
191124_174539	20191124_F1_SN2221256	11/24/2019	1012	Riegl_LMS-	258652742	258654337

				Q1560		
191124_181428	20191124_F1_SN2221256	11/24/2019	1013	Riegl_LMS-Q1560	258654471	258656018
191124_200618	20191124_F2_SN2221256	11/24/2019	1014	Riegl_LMS-Q1560	258661180	258661731
191124_202918	20191124_F2_SN2221256	11/24/2019	1015	Riegl_LMS-Q1560	258662560	258663118
191124_205332	20191124_F2_SN2221256	11/24/2019	1016	Riegl_LMS-Q1560	258664014	258664501
191124_210537	20191124_F2_SN2221256	11/24/2019	1017	Riegl_LMS-Q1560	258664740	258664982
191124_211207	20191124_F2_SN2221256	11/24/2019	1018	Riegl_LMS-Q1560	258665130	258666462
191124_213612	20191124_F2_SN2221256	11/24/2019	1019	Riegl_LMS-Q1560	258666575	258667971
191125_154041	20191125_F1_SN2221256	11/25/2019	1020	Riegl_LMS-Q1560	258731644	258733167
191125_160810	20191125_F1_SN2221256	11/25/2019	1021	Riegl_LMS-Q1560	258733292	258734802
191125_163527	20191125_F1_SN2221256	11/25/2019	1022	Riegl_LMS-Q1560	258734930	258736414
191125_202004	20191125_F2_SN2221256	11/25/2019	1023	Riegl_LMS-Q1560	258748407	258749816
191125_204547	20191125_F2_SN2221256	11/25/2019	1024	Riegl_LMS-Q1560	258749950	258751323
191125_211025	20191125_F2_SN2221256	11/25/2019	1025	Riegl_LMS-Q1560	258751428	258752835
191125_213558	20191125_F2_SN2221256	11/25/2019	1026	Riegl_LMS-Q1560	258752961	258754265
191125_215905	20191125_F2_SN2221256	11/25/2019	1027	Riegl_LMS-Q1560	258754347	258755761
191125_222416	20191125_F2_SN2221256	11/25/2019	1028	Riegl_LMS-Q1560	258755859	258757175
191125_224933	20191125_F2_SN2221256	11/25/2019	1029	Riegl_LMS-Q1560	258757376	258758769
191126_004518	20191125_F3_SN2221256	11/26/2019	1030	Riegl_LMS-Q1560	258764321	258765838
191126_012158	20191125_F3_SN2221256	11/26/2019	1031	Riegl_LMS-	258766521	258766875

				Q1560		
191126_013109	20191125_F3_SN2221256	11/26/2019	1032	Riegl_LMS-Q1560	258767072	258767577
191126_014251	20191125_F3_SN2221256	11/26/2019	1033	Riegl_LMS-Q1560	258767773	258768983
191203_153924	20191203_F1_SN2221256	12/3/2019	1034	Riegl_LMS-Q1560	259422766	259423168
191203_155010	20191203_F1_SN2221256	12/3/2019	1035	Riegl_LMS-Q1560	259423412	259423771
191203_155807	20191203_F1_SN2221256	12/3/2019	1036	Riegl_LMS-Q1560	259423889	259424130
191203_160318	20191203_F1_SN2221256	12/3/2019	1037	Riegl_LMS-Q1560	259424200	259424482
191203_160909	20191203_F1_SN2221256	12/3/2019	1038	Riegl_LMS-Q1560	259424551	259424724
191203_161324	20191203_F1_SN2221256	12/3/2019	1039	Riegl_LMS-Q1560	259424806	259425008
191203_161730	20191203_F1_SN2221256	12/3/2019	1040	Riegl_LMS-Q1560	259425052	259425202
191203_162110	20191203_F1_SN2221256	12/3/2019	1041	Riegl_LMS-Q1560	259425272	259425459
191203_162529	20191203_F1_SN2221256	12/3/2019	1042	Riegl_LMS-Q1560	259425531	259425680
191203_162919	20191203_F1_SN2221256	12/3/2019	1043	Riegl_LMS-Q1560	259425761	259425936
191203_163319	20191203_F1_SN2221256	12/3/2019	1044	Riegl_LMS-Q1560	259426001	259426121
191203_163631	20191203_F1_SN2221256	12/3/2019	1045	Riegl_LMS-Q1560	259426193	259426336
191203_163955	20191203_F1_SN2221256	12/3/2019	1046	Riegl_LMS-Q1560	259426398	259426497
191203_164300	20191203_F1_SN2221256	12/3/2019	1047	Riegl_LMS-Q1560	259426582	259426714
191203_164626	20191203_F1_SN2221256	12/3/2019	1048	Riegl_LMS-Q1560	259426788	259426875
191203_164935	20191203_F1_SN2221256	12/3/2019	1049	Riegl_LMS-Q1560	259426977	259427090
191203_165252	20191203_F1_SN2221256	12/3/2019	1050	Riegl_LMS-	259427174	259427247

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191203_165541	20191203_F1_SN2221256	12/3/2019	1051	Riegl_LMS-Q1560	259427343	259427419
191203_170221	20191203_F1_SN2221256	12/3/2019	1052	Riegl_LMS-Q1560	259427743	259428895
191203_190702	20191203_F2_SN2221256	12/3/2019	1053	Riegl_LMS-Q1560	259435225	259436308
191203_192621	20191203_F2_SN2221256	12/3/2019	1054	Riegl_LMS-Q1560	259436384	259437407
191203_194451	20191203_F2_SN2221256	12/3/2019	1055	Riegl_LMS-Q1560	259437494	259438552
191203_200422	20191203_F2_SN2221256	12/3/2019	1056	Riegl_LMS-Q1560	259438665	259438757
191203_201633	20191203_F2_SN2221256	12/3/2019	1057	Riegl_LMS-Q1560	259439396	259439436
191203_202231	20191203_F2_SN2221256	12/3/2019	1058	Riegl_LMS-Q1560	259439754	259440756
191203_204739	20191203_F2_SN2221256	12/3/2019	1059	Riegl_LMS-Q1560	259441261	259442293
191203_210618	20191203_F2_SN2221256	12/3/2019	1060	Riegl_LMS-Q1560	259442380	259443400
191203_212706	20191203_F2_SN2221256	12/3/2019	1061	Riegl_LMS-Q1560	259443628	259444296
191204_202331	20191203_F2_SN2221256	12/4/2019	1062	Riegl_LMS-Q1560	259526214	259526933
191204_211546	20191203_F2_SN2221256	12/4/2019	1063	Riegl_LMS-Q1560	259529348	259529713
191204_212809	20191203_F2_SN2221256	12/4/2019	1064	Riegl_LMS-Q1560	259530091	259530604
191204_214051	20191203_F2_SN2221256	12/4/2019	1065	Riegl_LMS-Q1560	259530853	259531652
191204_220041	20191203_F2_SN2221256	12/4/2019	1066	Riegl_LMS-Q1560	259532044	259532960
191204_221954	20191203_F2_SN2221256	12/4/2019	1067	Riegl_LMS-Q1560	259533196	259534243
191204_224411	20191203_F2_SN2221256	12/4/2019	1068	Riegl_LMS-Q1560	259534654	259535676
191205_154137	20191205_F1_SN2221256	12/5/2019	1069	Riegl_LMS-	259595699	259596670

				Q1560		
191205_160050	20191205_F1_SN2221256	12/5/2019	1070	Riegl_LMS-Q1560	259596852	259597811
191205_162001	20191205_F1_SN2221256	12/5/2019	1071	Riegl_LMS-Q1560	259598004	259599028
191205_163954	20191205_F1_SN2221256	12/5/2019	1072	Riegl_LMS-Q1560	259599197	259600154
191205_165926	20191205_F1_SN2221256	12/5/2019	1073	Riegl_LMS-Q1560	259600369	259601381
191205_172025	20191205_F1_SN2221256	12/5/2019	1074	Riegl_LMS-Q1560	259601627	259602548
191205_173905	20191205_F1_SN2221256	12/5/2019	1075	Riegl_LMS-Q1560	259602747	259603716
191205_180324	20191205_F1_SN2221256	12/5/2019	1076	Riegl_LMS-Q1560	259604206	259605298
191205_203056	20191205_F2_SN2221256	12/5/2019	1077	Riegl_LMS-Q1560	259613059	259614232
191205_205540	20191205_F2_SN2221256	12/5/2019	1078	Riegl_LMS-Q1560	259614542	259615094
191205_211120	20191205_F2_SN2221256	12/5/2019	1079	Riegl_LMS-Q1560	259615482	259615914
191205_212141	20191205_F2_SN2221256	12/5/2019	1080	Riegl_LMS-Q1560	259616104	259616533
191205_213217	20191205_F2_SN2221256	12/5/2019	1081	Riegl_LMS-Q1560	259616740	259617149
191205_214054	20191205_F2_SN2221256	12/5/2019	1082	Riegl_LMS-Q1560	259617257	259617621
191205_214924	20191205_F2_SN2221256	12/5/2019	1083	Riegl_LMS-Q1560	259617766	259618139
191205_215738	20191205_F2_SN2221256	12/5/2019	1084	Riegl_LMS-Q1560	259618261	259618627
191205_220725	20191205_F2_SN2221256	12/5/2019	1085	Riegl_LMS-Q1560	259618848	259619237
191205_221605	20191205_F2_SN2221256	12/5/2019	1086	Riegl_LMS-Q1560	259619368	259619725
191205_222527	20191205_F2_SN2221256	12/5/2019	1087	Riegl_LMS-Q1560	259619929	259620252
191205_223305	20191205_F2_SN2221256	12/5/2019	1088	Riegl_LMS-	259620388	259620623

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191205_224646	20191205_F2_SN2221256	12/5/2019	1089	Riegl_LMS-Q1560	259621209	259622379
191205_231434	20191205_F2_SN2221256	12/5/2019	1090	Riegl_LMS-Q1560	259622877	259623350
191206_005842	20191205_F3_SN2221256	12/6/2019	1091	Riegl_LMS-Q1560	259629125	259630273
191206_012103	20191205_F3_SN2221256	12/6/2019	1092	Riegl_LMS-Q1560	259630466	259631550
191210_175332	20191210_F1_SN2221256	12/10/2019	1095	Riegl_LMS-Q1560	260035614	260036657
191210_181406	20191210_F1_SN2221256	12/10/2019	1096	Riegl_LMS-Q1560	260036848	260037940
191210_183540	20191210_F1_SN2221256	12/10/2019	1097	Riegl_LMS-Q1560	260038142	260039210
200419_235056	20200419_F1_SN2221256	4/19/2020	1098	Riegl_LMS-Q1560	271375458	271376963
200420_001731	20200419_F1_SN2221256	4/20/2020	1099	Riegl_LMS-Q1560	271377053	271378503
200420_004318	20200419_F1_SN2221256	4/20/2020	1100	Riegl_LMS-Q1560	271378600	271380012
200420_010837	20200419_F1_SN2221256	4/20/2020	3003	Riegl_LMS-Q1560	271380120	271381521
200420_013545	20200419_F1_SN2221256	4/20/2020	1102	Riegl_LMS-Q1560	271381748	271382034
200420_014207	20200419_F1_SN2221256	4/20/2020	1103	Riegl_LMS-Q1560	271382130	271382422
200420_014832	20200419_F1_SN2221256	4/20/2020	1104	Riegl_LMS-Q1560	271382514	271382805
200420_020219	20200419_F1_SN2221256	4/20/2020	1105	Riegl_LMS-Q1560	271383342	271384719
200420_031737	20200419_F2_SN2221256	4/20/2020	1106	Riegl_LMS-Q1560	271387860	271388804
200420_033518	20200419_F2_SN2221256	4/20/2020	1107	Riegl_LMS-Q1560	271388921	271389866
200420_035234	20200419_F2_SN2221256	4/20/2020	1108	Riegl_LMS-Q1560	271389956	271390905
200420_041015	20200419_F2_SN2221256	4/20/2020	1109	Riegl_LMS-	271391018	271392002

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200420_042942	20200419_F2_SN2221256	4/20/2020	1110	Riegl_LMS-Q1560	271392185	271393321
200420_045021	20200419_F2_SN2221256	4/20/2020	1111	Riegl_LMS-Q1560	271393424	271394534
200420_051027	20200419_F2_SN2221256	4/20/2020	1112	Riegl_LMS-Q1560	271394630	271395770
200420_053054	20200419_F2_SN2221256	4/20/2020	1113	Riegl_LMS-Q1560	271395857	271396956
200420_055031	20200419_F2_SN2221256	4/20/2020	1114	Riegl_LMS-Q1560	271397034	271398145
200420_061011	20200419_F2_SN2221256	4/20/2020	1115	Riegl_LMS-Q1560	271398214	271399341
200420_080552	20200420_F1_SN2221256	4/20/2020	1116	Riegl_LMS-Q1560	271405155	271406263
200420_082618	20200420_F1_SN2221256	4/20/2020	1117	Riegl_LMS-Q1560	271406381	271407529
200420_084706	20200420_F1_SN2221256	4/20/2020	1118	Riegl_LMS-Q1560	271407629	271408715
200420_090718	20200420_F1_SN2221256	4/20/2020	1119	Riegl_LMS-Q1560	271408841	271409996
200420_120137	20200420_F2_SN2221256	4/20/2020	1120	Riegl_LMS-Q1560	271419299	271420831
200420_140709	20200420_F2_SN2221256	4/20/2020	1121	Riegl_LMS-Q1560	271426831	271428070
200420_143123	20200420_F2_SN2221256	4/20/2020	1122	Riegl_LMS-Q1560	271428286	271429662
200420_150949	20200420_F2_SN2221256	4/20/2020	1125	Riegl_LMS-Q1560	271430592	271431715
200420_153204	20200420_F2_SN2221256	4/20/2020	1126	Riegl_LMS-Q1560	271431927	271433194
200420_155902	20200420_F2_SN2221256	4/20/2020	1127	Riegl_LMS-Q1560	271433545	271433801
200426_142259	20200426_F1_SN2221256	4/26/2020	1128	Riegl_LMS-Q1560	271946181	271947206
200426_144328	20200426_F1_SN2221256	4/26/2020	1129	Riegl_LMS-Q1560	271947410	271948843
200426_150952	20200426_F1_SN2221256	4/26/2020	1130	Riegl_LMS-	271948994	271950019

				Q1560		
200426_152948	20200426_F1_SN2221256	4/26/2020	1131	Riegl_LMS-Q1560	271950190	271951611
200426_155539	20200426_F1_SN2221256	4/26/2020	1132	Riegl_LMS-Q1560	271951741	271952756
200426_161605	20200426_F1_SN2221256	4/26/2020	1133	Riegl_LMS-Q1560	271952967	271954299
200426_175417	20200426_F2_SN2221256	4/26/2020	1134	Riegl_LMS-Q1560	271958860	271959899
200426_181403	20200426_F2_SN2221256	4/26/2020	1135	Riegl_LMS-Q1560	271960046	271961345
200426_183751	20200426_F2_SN2221256	4/26/2020	1136	Riegl_LMS-Q1560	271961474	271962506
200426_202102	20200426_F3_SN2221256	4/26/2020	1137	Riegl_LMS-Q1560	271967665	271968913
200426_204350	20200426_F3_SN2221256	4/26/2020	1138	Riegl_LMS-Q1560	271969033	271970138
200426_210433	20200426_F3_SN2221256	4/26/2020	1139	Riegl_LMS-Q1560	271970275	271971460
200426_233308	20200426_F4_SN2221256	4/26/2020	1140	Riegl_LMS-Q1560	271979191	271980340
200426_235327	20200426_F4_SN2221256	4/26/2020	1141	Riegl_LMS-Q1560	271980409	271981569
200427_001411	20200426_F4_SN2221256	4/27/2020	1142	Riegl_LMS-Q1560	271981654	271982808
200427_003444	20200426_F4_SN2221256	4/27/2020	1143	Riegl_LMS-Q1560	271982886	271984052
200427_005540	20200426_F4_SN2221256	4/27/2020	1144	Riegl_LMS-Q1560	271984143	271985295
200427_011634	20200426_F4_SN2221256	4/27/2020	1145	Riegl_LMS-Q1560	271985397	271986565
200427_013732	20200426_F4_SN2221256	4/27/2020	1146	Riegl_LMS-Q1560	271986655	271987810
200427_015806	20200426_F4_SN2221256	4/27/2020	1147	Riegl_LMS-Q1560	271987888	271989050
200427_021905	20200426_F4_SN2221256	4/27/2020	1148	Riegl_LMS-Q1560	271989147	271990307
200427_023953	20200426_F4_SN2221256	4/27/2020	1149	Riegl_LMS-	271990395	271991568

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200427_041939	20200426_F5_SN2221256	4/27/2020	1150	Riegl_LMS-Q1560	271996381	271997503
200427_043955	20200426_F5_SN2221256	4/27/2020	1151	Riegl_LMS-Q1560	271997597	271998757
200427_050046	20200426_F5_SN2221256	4/27/2020	1152	Riegl_LMS-Q1560	271998848	272000002
200427_052202	20200426_F5_SN2221256	4/27/2020	1153	Riegl_LMS-Q1560	272000124	272001305
200427_054316	20200426_F5_SN2221256	4/27/2020	1154	Riegl_LMS-Q1560	272001398	272002558
200427_060359	20200426_F5_SN2221256	4/27/2020	1155	Riegl_LMS-Q1560	272002641	272003811
200427_062500	20200426_F5_SN2221256	4/27/2020	1156	Riegl_LMS-Q1560	272003902	272005068
200427_064606	20200426_F5_SN2221256	4/27/2020	1157	Riegl_LMS-Q1560	272005169	272006348
200427_070710	20200426_F5_SN2221256	4/27/2020	1158	Riegl_LMS-Q1560	272006432	272007605
200427_072812	20200426_F5_SN2221256	4/27/2020	1159	Riegl_LMS-Q1560	272007694	272008864
200427_092229	20200427_F1_SN2221256	4/27/2020	1160	Riegl_LMS-Q1560	272014551	272015696
200427_094315	20200427_F1_SN2221256	4/27/2020	1161	Riegl_LMS-Q1560	272015798	272016939
200427_100410	20200427_F1_SN2221256	4/27/2020	1162	Riegl_LMS-Q1560	272017053	272018222
200427_102502	20200427_F1_SN2221256	4/27/2020	1163	Riegl_LMS-Q1560	272018304	272019436
200427_104553	20200427_F1_SN2221256	4/27/2020	1164	Riegl_LMS-Q1560	272019555	272020712
200427_110629	20200427_F1_SN2221256	4/27/2020	1165	Riegl_LMS-Q1560	272020792	272021897
200427_112637	20200427_F1_SN2221256	4/27/2020	1166	Riegl_LMS-Q1560	272022000	272023195
200427_114746	20200427_F1_SN2221256	4/27/2020	1167	Riegl_LMS-Q1560	272023269	272024391
200427_120806	20200427_F1_SN2221256	4/27/2020	1168	Riegl_LMS-	272024489	272025677

				Q1560		
200427_122910	20200427_F1_SN2221256	4/27/2020	1169	Riegl_LMS-Q1560	272025752	272026889
200427_124933	20200427_F1_SN2221256	4/27/2020	1170	Riegl_LMS-Q1560	272026976	272028172
200427_142849	20200427_F2_SN2221256	4/27/2020	1171	Riegl_LMS-Q1560	272032932	272033963
200427_144857	20200427_F2_SN2221256	4/27/2020	1172	Riegl_LMS-Q1560	272034140	272034711
200427_151013	20200427_F2_SN2221256	4/27/2020	1173	Riegl_LMS-Q1560	272035416	272035489
200427_151305	20200427_F2_SN2221256	4/27/2020	1174	Riegl_LMS-Q1560	272035588	272035651
200427_151547	20200427_F2_SN2221256	4/27/2020	1175	Riegl_LMS-Q1560	272035750	272035797
200427_152123	20200427_F2_SN2221256	4/27/2020	1176	Riegl_LMS-Q1560	272036086	272037342

Table 3: G17PC00007_Block 3 IL 8 County_2019_B19 County ASI's Project flightline by Mission

ACQUISITION CONTROL

Aerial Services, Inc. conducted the survey which provided the established base stations used to control the lidar acquisition for the Block 3 IL 8 County project area. The coordinates of the base stations are provided in the table 4 below.

Name	NAD83(2011) Decimal Degrees		Ellipsoid Ht (WGS84, m)
	Easting X	Northing Y	
BLOM	88°59'59.49930"	40°29'44.30816"	204.83935
ZAU1	88°19'52.81628"	41°46'57.56804"	195.41349
RRW1	89°03'28.89821"	42°21'04.04290"	191.44371
JFWS	90°14'53.19156"	42°54'51.37589"	293.59778
IAEL	91°21'41.52963"	42°52'40.47667"	298.98058

IAWN	91°40'44.78882"	41°18'34.14516"	205.40784
IAMN	91°32'55.59727"	42°01'49.10896"	228.90442
NLIB	91°34'29.63309"	41°46'17.72574"	206.99284
IAMQ	90°38'42.19357"	42°04'25.22696"	187.57729
IADA	90°37'49.58792"	41°36'36.20858"	200.60856
WLNC	90°42'41.07282"	42°50'15.66940"	280.85510
IAAL	92°47'14.24701"	42°44'49.40421"	291.09259
IATA	92°33'05.07479"	41°58'01.67192"	247.33463
KA21	89°11'45.80479"	40°47'29.33859"	191.98074
DP3A	88°10'36.86735"	41°45'53.49315"	190.99026
DP6B	87°58'45.92656"	41°58'02.39623"	184.91448
LCDT	87°57'37.24233"	42°17'42.19411"	189.33510
WIPR	89°08'32.35189"	43°51'47.10985"	223.30746
DP5A	88°09'25.99644"	41°59'22.45397"	221.39973
IADE	91°49'53.52635"	43°16'15.83209"	316.51616
WIPR	89°08'32.35189"	43°51'47.10985"	223.30746
WINL	90°08'31.59781"	43°50'27.42794"	243.63394

Table 4: Base station used to control lidar acquisition for the Project.

AIRBORNE GPS KINEMATIC

Airborne GPS data was processed using Applanix PosPac 8.2 software. All flights were flown with PDOP less than or equal to 3.0 and with at least 6 satellites in common view of both a stationary reference receiver and the airborne GPS. Distances from base station to aircraft were kept to a maximum of 50 km.

For all flights, the GPS data can be classified as excellent, with GPS residuals no larger than 10 cm being recorded.

GPS processing reports for each mission are included in Appendix B.

GENERATION AND CALIBRATION OF LASER POINTS (RAW DATA)

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.

The initial points for each mission are inspected for flight line errors, flight line overlap, slivers or data holidays, point data minimums or issues with the LiDAR unit or GPS. Data collected by the LiDAR unit is reviewed for completeness, acceptable density and errors or corrupted values. Intra-swath repeatability is tested to meet the $<.06\text{m}$ standard specified in the base spec. In addition, all GPS data, aircraft trajectories, mission information and ground control files are reviewed. On a project level, a supplementary coverage check is carried out to ensure data voids unreported by Field Operations are not present.

Data collected by the lidar unit is reviewed for completeness, acceptable point 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

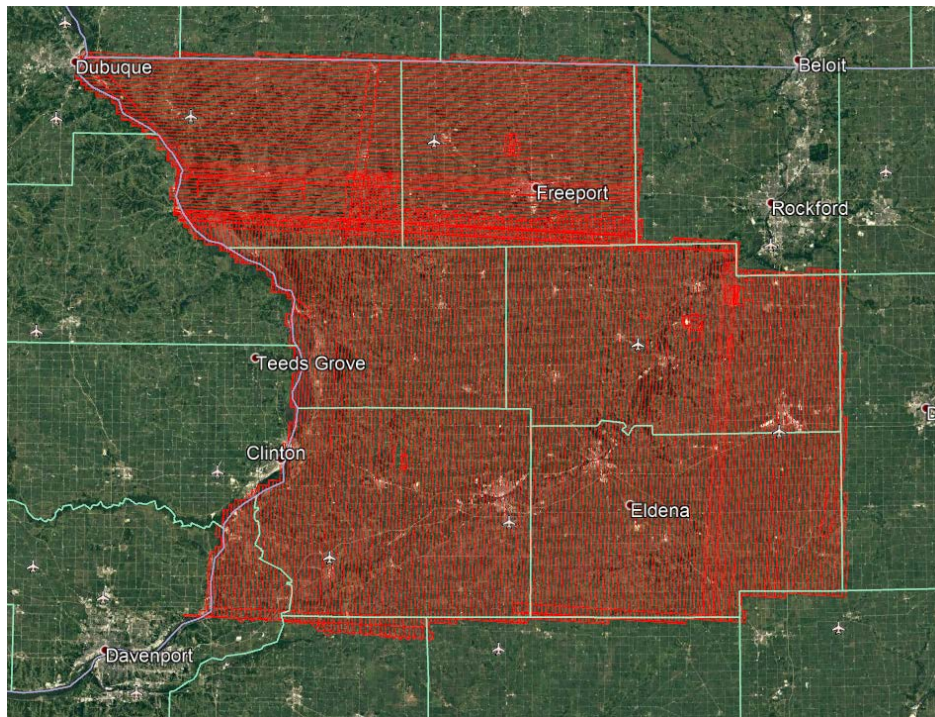


Figure 4: G17PC00007_Block 3 IL 8 County_2019_B19 Lidar swath coverage over AOI.

Boresight and Relative Accuracy

Subsequently, the project's data is then loaded into Microstation/TerraScan for viewing and post-processing of calibration errors. Small roll, pitch, heading, and elevation corrections are calculated using TerraMatch tie line methodology to produce the best relative accuracy that can be achieved to meet 8 cm RMSDz specification.

The relative accuracy of every swath is checked and QC'd at 3 different points along its length. Cross sections are visually inspected across each block to validate point to point, flight line to flight line and mission to mission agreement to verify that the project meet the specifications.

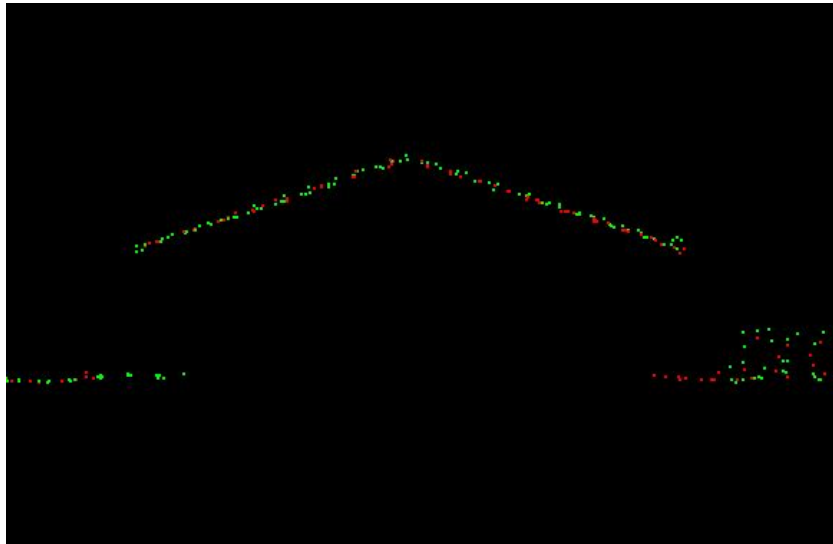


Figure 5: Profile view showing proper interswath calibration.

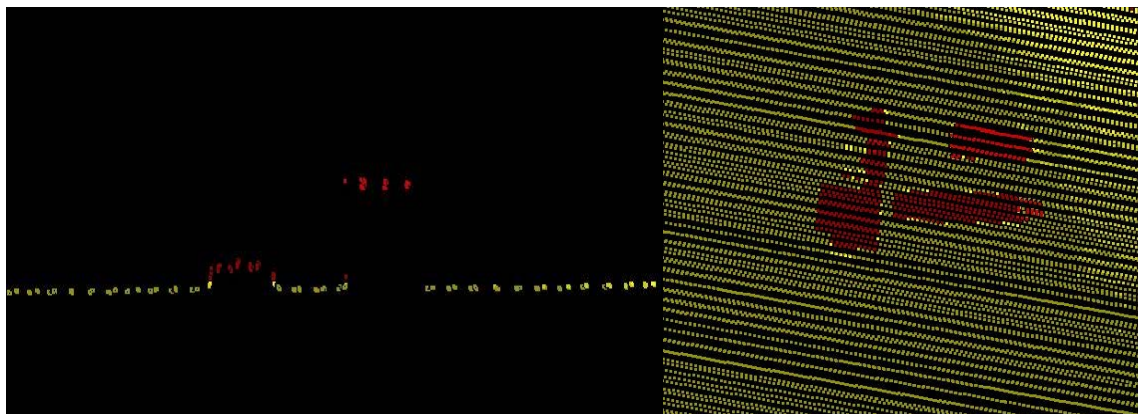


Figure 6: Top view showing a parking lot with a car and raised feature on a single swath demonstrating intraswath accuracy. Yellow color is scaled to a range of 6 cm in elevation. Points are within 6 cm of variation until the raised curb and car. Also shown is a profile view showing low variability of ranges within the swath.

DELTA-Z ACCURACY ASSESSMENT

Swath-to-swath relative accuracy is assessed by comparing the elevations of overlapping swaths. Delta-z is a raster file representing the differences in elevation of overlapping swaths and is generated from the subtraction of the two raster files created from each swath over the entire area of interest. It is then used to calculate the RMSDz, which in turn is displayed as a visual representation of error distribution.

The image below is a LIDAR “ortho” image created from the laser return intensity, Z (elevation) and swath number. The image is rendered as grayscale where there is no overlap between data from different flight lines (swath). Where two (or more) flight lines overlap, a color rendering is constructed base on the average maximum elevation difference between points in the overlapping swath. The distance (dZ) is indexed into a user-defined color. In the image below, four-color bands were separated into 8 cm increments. Thus green represents dZs from 0 to 8 cm, yellow from 8 cm to 16 cm, orange from 16 cm to 24 cm and red for dZ greater than 24 cm. The dZ image provides a quick method of quickly assessing the relative vertical accuracy of a LiDAR project.

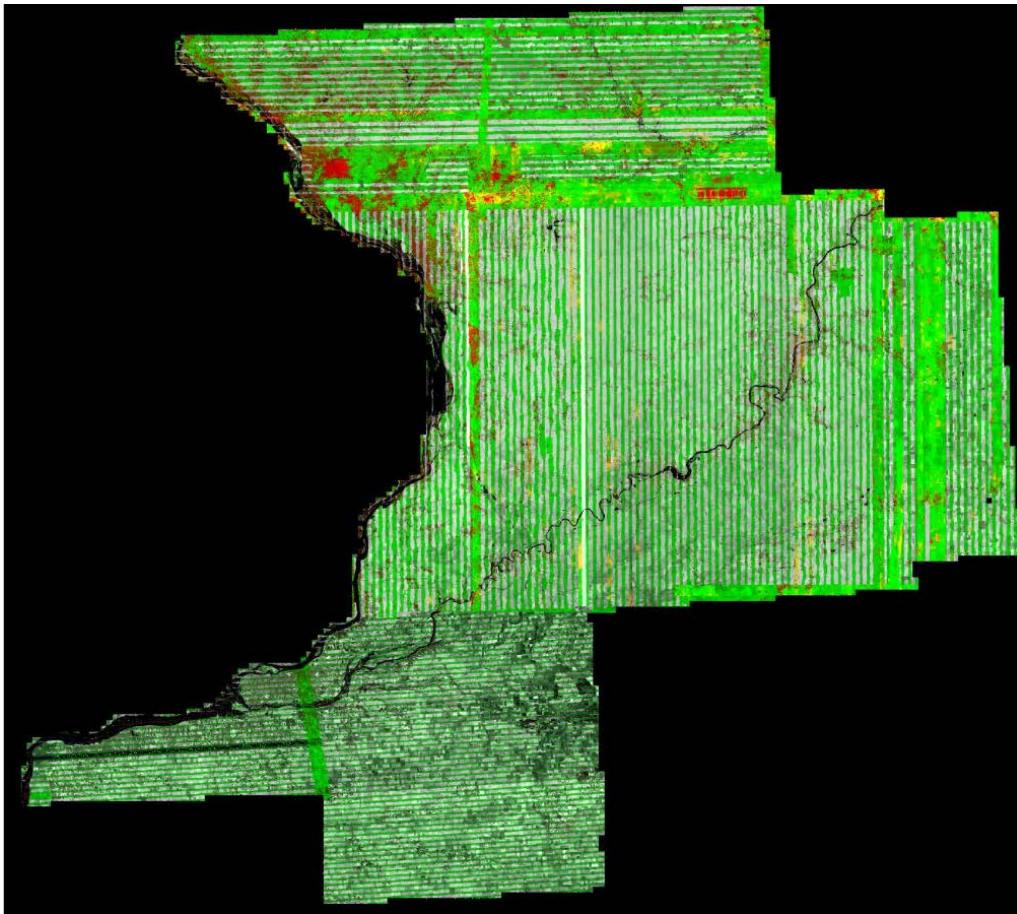


Figure 7: Block 3 IL 8 County Project Delta-z raster image.

Final Calibration Verification

Surveying and Mapping, LLC (SAM) conducted the survey for 76 ground control points (GCPs) which were used to test the accuracy of the calibrated swath data. These 76 GCPs were available to use as control in case the swath data exhibited any biases which would need to be adjusted or removed. The coordinates of all GCPs are provided in table 5 below. Accuracy results from testing the calibrated swath data against the GCPs is provided in table 6. The accuracy of the raw point cloud against GCP is 0.05 meters (5.0 cm) with a 95% confidence value of 0.098 meters (9.8 cm)

Point ID	NAD83 (2011 adj) Albers Equal Area		NAVD88 (Geoid 12B)		Dz (M)
	Easting X (M)	Northing Y (M)	Z-Survey (M)	Z-LiDAR (M)	
GCP01	437582.890	2178088.680	189.780	189.760	-0.020
GCP02	455625.350	2170904.740	184.060	184.050	-0.010
GCP03	469480.180	2178310.350	283.650	283.620	-0.030
GCP04	504976.900	2169627.720	294.090	294.000	-0.090
GCP05	538314.650	2177036.230	275.040	274.960	-0.080
GCP06	521332.480	2159312.430	238.590	238.540	-0.050
GCP07	472963.690	2160843.840	247.040	247.020	-0.020
GCP08	468129.320	2153793.440	192.060	192.060	+0.000
GCP09	494339.720	2137332.720	246.430	246.400	-0.030
GCP10	489434.750	2151574.860	201.960	201.960	+0.000
GCP11	485381.290	2121366.810	183.300	183.280	-0.020
GCP12	513778.660	2145162.370	277.570	277.570	+0.000
GCP13	527898.940	2127207.920	263.470	263.450	-0.020
GCP14	552188.500	2144967.430	219.340	219.250	-0.090
GCP15	547933.700	2131725.040	215.430	215.390	-0.040
GCP16	570240.810	2122414.900	237.800	237.720	-0.080
GCP17	581836.150	2109612.200	286.860	286.810	-0.050
GCP18	559321.510	2090911.730	281.010	280.930	-0.080
GCP19	536512.050	2112245.800	199.520	199.510	-0.010
GCP20	531861.920	2097879.380	206.470	206.450	-0.020
GCP22	512751.110	2119949.700	237.890	237.870	-0.020
GCP23	497549.850	2105398.710	205.900	205.950	+0.050
GCP24	481631.370	2110593.750	180.360	180.320	-0.040
GCP25	513867.970	2086056.370	196.610	196.620	+0.010
GCP26	489116.280	2087737.870	180.420	180.320	-0.100
GCP27	469486.040	2088917.470	181.840	181.720	-0.120
GCP28	454395.690	2068939.240	176.900	176.920	+0.020
GCP29	478298.290	2075897.760	177.250	177.340	+0.090
GCP30	503919.280	2073566.270	189.300	189.240	-0.060
GCP31	495925.170	2061578.150	201.060	201.040	-0.020
GCP32	467428.200	2052359.850	238.470	238.460	-0.010
GCP33	482059.910	2047596.970	247.550	247.530	-0.020
GCP34	504166.510	2041838.710	258.340	258.290	-0.050
GCP35	495840.380	2032342.490	252.610	252.590	-0.020
GCP36	467392.820	2034276.640	244.420	244.440	+0.020

GCP37	446184.530	2061352.930	172.180	172.190	+0.010
GCP38	434124.750	2054249.630	238.170	238.130	-0.040
GCP39	411214.880	2057187.730	167.760	167.740	-0.020
GCP40	414435.980	2047544.550	174.060	174.030	-0.030
GCP41	570647.480	2104826.170	239.980	239.910	-0.070
GCP42	574259.860	2143309.950	265.880	265.830	-0.050
GCP58	477791.100	2172638.720	267.420	267.420	+0.000
GCP59	491229.270	2181750.760	314.450	314.350	-0.100
GCP60	519244.150	2180611.640	264.800	264.700	-0.100
GCP61	528821.550	2172395.650	280.310	280.260	-0.050
GCP62	490080.090	2165683.330	312.200	312.130	-0.070
GCP63	456658.800	2164301.100	213.880	213.880	+0.000
GCP64	476175.450	2144095.420	192.500	192.520	+0.020
GCP65	534928.270	2151744.250	252.090	252.110	+0.020
GCP66	502043.810	2128696.280	245.480	245.460	-0.020
GCP67	526471.950	2138078.170	291.320	291.310	-0.010
GCP68	560669.270	2138141.160	239.040	238.910	-0.130
GCP69	551060.970	2124338.840	249.140	249.070	-0.070
GCP70	500595.930	2115040.580	227.320	227.310	-0.010
GCP71	557926.950	2116266.050	251.780	251.730	-0.050
GCP72	550321.690	2102387.930	244.270	244.210	-0.060
GCP73	540923.150	2083101.190	271.160	271.130	-0.030
GCP74	482532.640	2098561.670	213.160	213.110	-0.050
GCP75	510095.960	2094912.050	191.420	191.400	-0.020
GCP76	492418.360	2079787.090	185.910	186.000	+0.090
GCP77	470107.750	2064218.150	192.060	192.080	+0.020
GCP78	509628.050	2056316.360	197.740	197.720	-0.020
GCP79	477496.050	2038660.170	243.610	243.580	-0.030
GCP80	492233.680	2053026.270	206.880	206.880	+0.000
GCP81	484700.970	2064387.530	196.090	196.140	+0.050
GCP82	490055.780	2070776.040	185.640	185.580	-0.060
GCP83	474301.460	2057667.710	223.120	223.100	-0.020

Table 5: Block 3 IL 8 County Project surveyed ground control points (GCPs).

100 % of Totals	# of Points	RMSEz NVA (m)	NVA-Non-vegetated Vertical Accuracy ((RMSEz x 1.9600) m)	Mean (m)	Median (m)	Skew	Std Dev (m)	Min (m)	Max (m)	Kurtosis
GCP	76	0.050	0.098	-0.025	-0.020	0.126	0.044	-0.130	0.090	0.126

Table 6: Ground Control Vertical Accuracy (GCP) results.

SurvTech Solutions LiDAR Acquisition Details and System Parameters for USGS IL-8cty

SurvTech Solutions planned 82 passes for the project area as well as a series of cross flightlines for quality control. In order to reduce any margin for error in the flight plan, SurvTech Solutions followed FEMA’s Appendix A guidelines for flight planning and, at a minimum, includes the following criteria:

- A digital flight line layout using Optech’s AMM Software flight design software for direct integration into the aircraft flight navigation system.
- Planned flight lines; flight line numbers; and coverage area.
- Lidar coverage extended beyond all project borders to ensure necessary over-edge coverage appropriate for specific task order deliverables. A buffered AOI was provided by ASI.
- All airspace was coordinated and any controlled or restricted areas were pre coordinated and approval granted from the airspace owner.

SurvTech Solutions operated a Cessna 401 (Registration N41GD) equipped with a Teledyne Optech Galaxy Prime Lidar system during the collection of this task order. Data was acquired between April 26, 2020 and April 30, 2020.

Item	Parameter
System	Optech Galaxy Prime
Maximum Number of Returns per Pulse	8
Nominal Pulse Spacing (single swath), (m)	0.45
Nominal Pulse Density (single swath) (ppsm), (m)	5.84
Aggregate NPS (m) (if ANPS was designed to be met through single coverage, ANPS and NPS will be equal)	0.45
Aggregate NPD (m) (if ANPD was designed to be met through single coverage, ANPD and NPD will be equal)	4
Altitude (AGL meters)	1829
Approx. Flight Speed (knots)	150
Total Sensor Scan Angle (degree)	40
Scan Frequency (hz)	85
Scanner Pulse Rate (kHz)	400
Did the Sensor Operate with Multiple Pulses in The Air? (yes/no)	Yes
Nominal Swath Width on the Ground (m)	1331
Swath Overlap (%)	30
Computed Down Track spacing (m) per beam	0.46
Computed Cross Track Spacing (m) per beam	0.45

Table 7 - SURVTECH SOLUTIONS LiDAR system parameters

CALIBRATION REPORT

Point clouds are output using Optech's LMS. The initial point generation for each mission calibration is verified within LMS for calibration errors. If significant calibration errors are observed within the mission; the internal sensor misalignments are calculated. The data is then regenerated with the new solution and is validated internally once again to ensure quality.

Relative accuracy and internal quality are checked using Terramatch, as well as, BayesMap-StripAlign, in which points from all lines are observed and compared. Vertical differences between ground surfaces of each line are displayed. Rasters are generated on filtered tiles to model Dz between adjacent lines. Inter-swath accuracy is tested to the <.08m standard specified in the base spec. Data are visually inspected across each block to validate point to point, flight line to flight line and mission to mission agreement.

A listing of Flightlines and corresponding, Lift_ID, Date, Point Source ID, Scanner, and adjusted GPS times are available in table 8.

Name	Lift_ID	Date	PT Source ID	Scanner	Start Time	End Time
20200426_211628	20200426B	4/26/2020	101	Optech Galaxy Prime	271970988.2	271971830.4
20200426_210026	20200426B	4/26/2020	201	Optech Galaxy Prime	271970026	271970988.2
20200426_204502	20200426B	4/26/2020	301	Optech Galaxy Prime	271969101.8	271970026
20200426_201919	20200426B	4/26/2020	401	Optech Galaxy Prime	271967559.4	271968525.6
20200426_203958	20200426B	4/26/2020	411	Optech Galaxy Prime	271968797.7	271969101.8
20200426_200359	20200426B	4/26/2020	501	Optech Galaxy Prime	271966639.2	271967559.4
20200426_194743	20200426B	4/26/2020	601	Optech Galaxy Prime	271965663	271966639.2
20200426_193109	20200426B	4/26/2020	701	Optech Galaxy Prime	271964668.7	271965663
20200426_191501	20200426B	4/26/2020	801	Optech Galaxy Prime	271963700.5	271964668.7
20200426_185930	20200426B	4/26/2020	901	Optech Galaxy Prime	271962770.3	271963700.5
20200426_160528	20200426A	4/26/2020	1001	Optech Galaxy Prime	271952327.7	271953131.9
20200426_154960	20200426A	4/26/2020	1101	Optech Galaxy Prime	271951399.5	271952327.7
20200426_153519	20200426A	4/26/2020	1201	Optech Galaxy Prime	271950519.3	271951399.5
20200426_152015	20200426A	4/26/2020	1301	Optech Galaxy Prime	271949615.1	271950519.3
20200426_150513	20200426A	4/26/2020	1401	Optech Galaxy	271948712.9	271949615.1

				Prime		
20200426_145031	20200426A	4/26/2020	1501	Optech Galaxy Prime	271947830.7	271948712.9
20200426_143556	20200426A	4/26/2020	1601	Optech Galaxy Prime	271946956.5	271947830.7
20200426_142346	20200426A	4/26/2020	1701	Optech Galaxy Prime	271946226.3	271946956.5
20200426_141126	20200426A	4/26/2020	1801	Optech Galaxy Prime	271945486.1	271946226.3
20200426_140022	20200426A	4/26/2020	1901	Optech Galaxy Prime	271944822	271945486.1
20200426_134936	20200426A	4/26/2020	2001	Optech Galaxy Prime	271944175.8	271944822
20200426_134056	20200426A	4/26/2020	2101	Optech Galaxy Prime	27193655.7	271944175.8
20200426_133314	20200426A	4/26/2020	2201	Optech Galaxy Prime	271943193.6	271943655.7
20200426_132536	20200426A	4/26/2020	2301	Optech Galaxy Prime	271942735.5	271943193.6
20200426_131857	20200426A	4/26/2020	2401	Optech Galaxy Prime	271942337.4	271942735.5
20200426_131217	20200426A	4/26/2020	2501	Optech Galaxy Prime	271941937.3	271942337.4
20200426_130551	20200426A	4/26/2020	2601	Optech Galaxy Prime	271941551.2	271941937.3
20200426_125843	20200426A	4/26/2020	2701	Optech Galaxy Prime	271941123.1	271941551.2
20200426_213554	20200426B	4/26/2020	2901	Optech Galaxy Prime	271972154.5	271972972.6
20200426_214933	20200426B	4/26/2020	3001	Optech Galaxy Prime	271972972.6	271973858.8
20200426_220419	20200426B	4/26/2020	3101	Optech Galaxy Prime	271973858.8	271974687
20200426_221807	20200426B	4/26/2020	3201	Optech Galaxy Prime	271974687	271975573.2
20200426_223253	20200426B	4/26/2020	3301	Optech Galaxy Prime	271975573.2	271976393.4
20200426_224633	20200426B	4/26/2020	3401	Optech Galaxy Prime	271976393.4	271977929.8
20200427_121019	20200427A	4/27/2020	3501	Optech Galaxy Prime	272024618.5	272025588.8
20200427_122629	20200427A	4/27/2020	3601	Optech Galaxy Prime	272025588.8	272026441
20200427_124041	20200427A	4/27/2020	3701	Optech Galaxy Prime	272026441	272027329.2
20200427_125529	20200427A	4/27/2020	3801	Optech Galaxy	272027329.2	272028221.4

				Prime		
20200427_131021	20200427A	4/27/2020	3901	Optech Galaxy Prime	272028221.4	272029095.6
20200427_132456	20200427A	4/27/2020	4001	Optech Galaxy Prime	272029095.6	272029975.8
20200427_133936	20200427A	4/27/2020	4101	Optech Galaxy Prime	272029975.8	272030860
20200427_135420	20200427A	4/27/2020	4201	Optech Galaxy Prime	272030860	272031778.2
20200427_140938	20200427A	4/27/2020	4301	Optech Galaxy Prime	272031778.2	272032622.4
20200427_142342	20200427A	4/27/2020	4401	Optech Galaxy Prime	272032622.4	272033580.6
20200427_143941	20200427A	4/27/2020	4501	Optech Galaxy Prime	272033580.6	272034430.8
20200427_145351	20200427A	4/27/2020	4601	Optech Galaxy Prime	272034430.8	272035345
20200427_150905	20200427A	4/27/2020	4701	Optech Galaxy Prime	272035345	272036215.2
20200427_152335	20200427A	4/27/2020	4801	Optech Galaxy Prime	272036215.2	272037147.4
20200427_153907	20200427A	4/27/2020	4901	Optech Galaxy Prime	272037147.4	272037971.6
20200427_155252	20200427A	4/27/2020	5001	Optech Galaxy Prime	272037971.6	272039273.9
20200430_113108	20200430A	4/30/2020	5101	Optech Galaxy Prime	272281468.1	272282754.4
20200430_115234	20200430A	4/30/2020	5201	Optech Galaxy Prime	272282754.4	272283590.6
20200430_120631	20200430A	4/30/2020	5301	Optech Galaxy Prime	272283590.6	272284426.7
20200430_122027	20200430A	4/30/2020	5401	Optech Galaxy Prime	272284426.7	272285270.9
20200430_123431	20200430A	4/30/2020	5501	Optech Galaxy Prime	272285270.9	272286111.1
20200430_124831	20200430A	4/30/2020	5601	Optech Galaxy Prime	272286111.1	272286959.3
20200430_130239	20200430A	4/30/2020	5701	Optech Galaxy Prime	272286959.3	272287801.5
20200430_131642	20200430A	4/30/2020	5801	Optech Galaxy Prime	272287801.5	272288671.7
20200430_133112	20200430A	4/30/2020	5901	Optech Galaxy Prime	272288671.7	272289553.9
20200430_134554	20200430A	4/30/2020	6001	Optech Galaxy Prime	272289553.9	272290406.1
20200430_140006	20200430A	4/30/2020	6101	Optech Galaxy	272290406.1	272291282.3

				Prime		
20200430_141442	20200430A	4/30/2020	6201	Optech Galaxy Prime	272291282.3	272292116.5
20200430_142837	20200430A	4/30/2020	6301	Optech Galaxy Prime	272292116.5	272292946.7
20200430_144227	20200430A	4/30/2020	6401	Optech Galaxy Prime	272292946.7	272293816.9
20200430_145657	20200430A	4/30/2020	6501	Optech Galaxy Prime	272293816.9	272294665.1
20200430_151105	20200430A	4/30/2020	6601	Optech Galaxy Prime	272294665.1	272295859.4
20200430_182219	20200430B	4/30/2020	6701	Optech Galaxy Prime	2728306139	272307227.3
20200430_184027	20200430B	4/30/2020	6801	Optech Galaxy Prime	272307227.3	272308137.5
20200430_185538	20200430B	4/30/2020	6901	Optech Galaxy Prime	272308137.5	272308981.7
20200430_190942	20200430B	4/30/2020	7001	Optech Galaxy Prime	272308981.7	272309831.9
20200430_192352	20200430B	4/30/2020	7101	Optech Galaxy Prime	272309831.9	272310710.1
20200430_193830	20200430B	4/30/2020	7201	Optech Galaxy Prime	272310710.1	272311818.4
20200501_001730	20200430C	05/01/0200	7301	Optech Galaxy Prime	272327450	272328532.3
20200501_003532	20200430C	05/01/0200	7401	Optech Galaxy Prime	272328532.3	272329382.5
20200501_004942	20200430C	05/01/0200	7501	Optech Galaxy Prime	272329382.5	272330286.7
20200501_010447	20200430C	05/01/0200	7601	Optech Galaxy Prime	272330286.7	272331142.9
20200501_011903	20200430C	05/01/0200	7701	Optech Galaxy Prime	272331142.9	272332031.1
20200501_013351	20200430C	05/01/0200	7801	Optech Galaxy Prime	27332031.1	272332917.3
20200501_014837	20200430C	05/01/0200	7901	Optech Galaxy Prime	272332917.3	272333799.5
20200501_020320	20200430C	05/01/0200	8001	Optech Galaxy Prime	272333799.5	272334663.7
20200501_021744	20200430C	05/01/0200	8101	Optech Galaxy Prime	272334663.7	272335503.9
20200501_023144	20200430C	05/01/0200	8201	Optech Galaxy Prime	272335503.9	272336326.1
20200501_024526	20200430C	05/01/0200	8301	Optech Galaxy Prime	272336326.1	272336876.2

Table 8: G17PC00007_Block 3 IL 8 County_2019_B19 SurvTech's Project flightline by Mission

ACQUISITION CONTROL

SurvTech Solutions conducted the survey which provided the established base stations used to control the lidar acquisition for USGS IL-8cty project area. The coordinates of the base stations are provided in the table below.

Name	NAD83(2011) Decimal Degrees		Ellipsoid Ht (WGS84, m)
	Easting X	Northing Y	
IADA	-90.630429	41.610050	201.6822

Table 9: Base station used to control lidar acquisition for the Project.

AIRBORNE GPS KINEMATIC

Airborne GPS data was processed using PosPac MMS 8.0. Flights were flown with a minimum of 8 satellites in view (10° above the horizon) and with a PDOP of better than 4. Distances from base station to aircraft were kept to a maximum of 80km.

For all flights the GPS data can be classified as good with GPS residuals of 3cm average or better but no larger than 10cm being recorded. GPS processing reports for each mission are included in Appendix C.

GENERATION AND CALIBRATION OF LASER POINTS (RAW DATA)

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.

The initial points for each mission are inspected for flight line errors, flight line overlap, slivers or data holidays, point data minimums or issues with the LiDAR unit or GPS. Data collected by the LiDAR unit is reviewed for completeness, acceptable density and errors or corrupted values. Intra-swath repeatability is tested to meet the <.06m standard specified in the base spec. In addition, all GPS data, aircraft trajectories, mission information and ground control files are reviewed. On a project level, a supplementary coverage check is carried out to ensure data voids unreported by Field Operations are not present.

Data collected by the lidar unit is reviewed for completeness, acceptable point 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.

On a project level, a supplementary coverage check is carried out to ensure no data voids unreported by Field Operations are present.

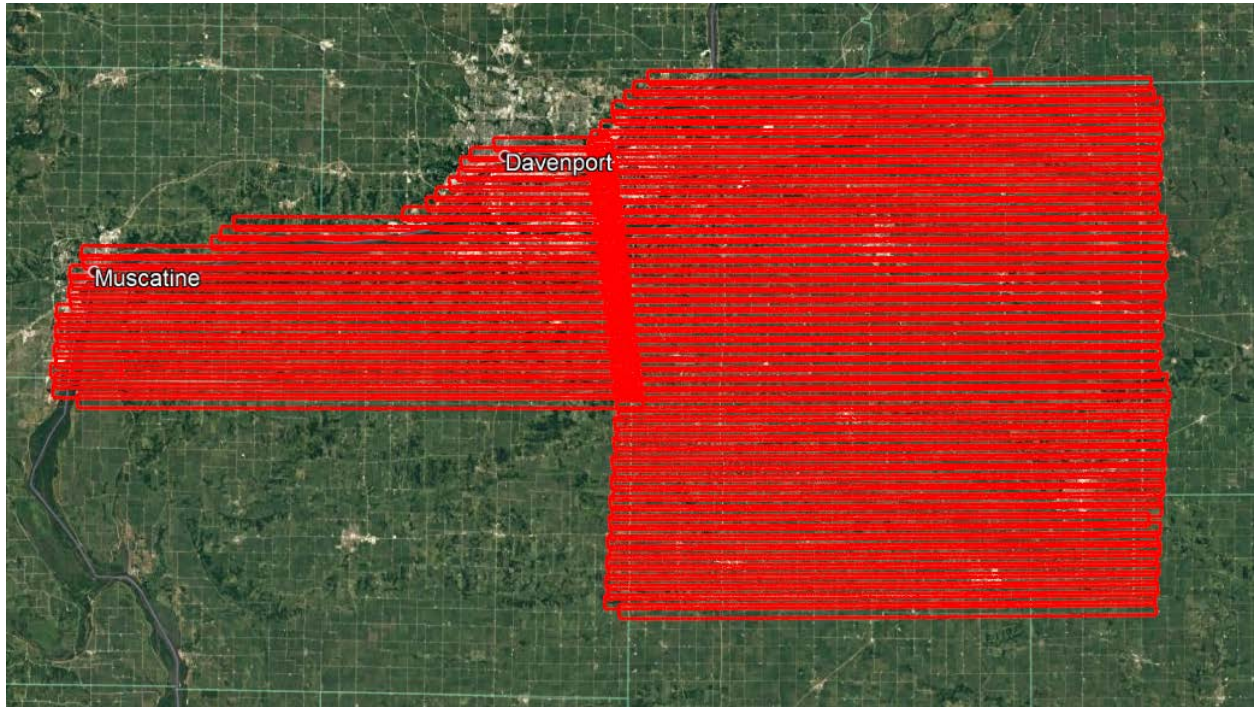


Figure 8: LiDAR swatch output showing complete coverage

Boresight and Relative Accuracy

The initial points for each mission calibration are inspected for flight line errors, flight line overlap, slivers, or gaps in the data, point data minimums, or issues with the lidar unit or GPS. Roll, pitch, and scanner scale are optimized during the calibration process until the relative accuracy is met.

Relative accuracy and internal quality are checked using at least 3 regularly spaced QC blocks in which points from all lines are loaded and inspected. Vertical differences between ground surfaces of each line are displayed. Color scale is 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 agreement.

For this project, the specifications used are as follows (derived from LiDAR base specification 2.1, QL2):

Relative accuracy (smooth surface repeatability) ≤ 6 cm maximum differences within individual swaths and ≤ 8 cm RMSDz between adjacent and overlapping swaths.

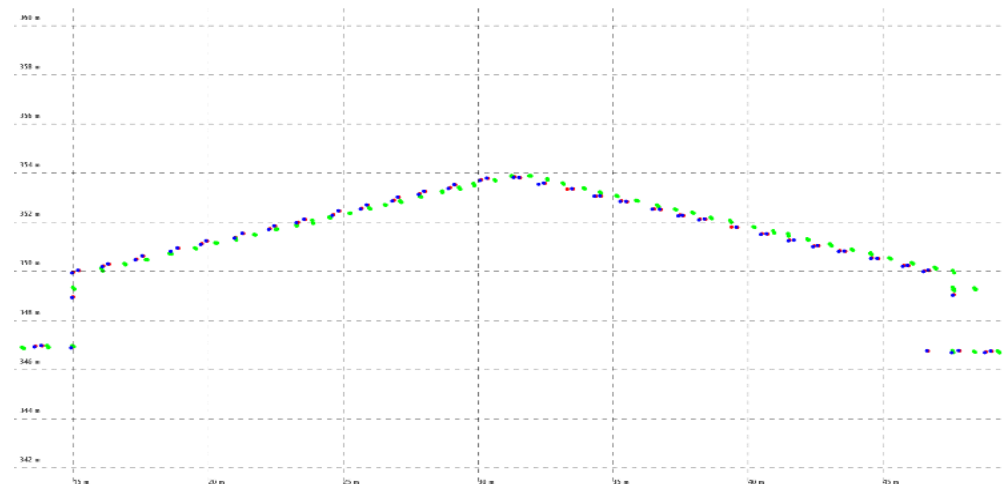
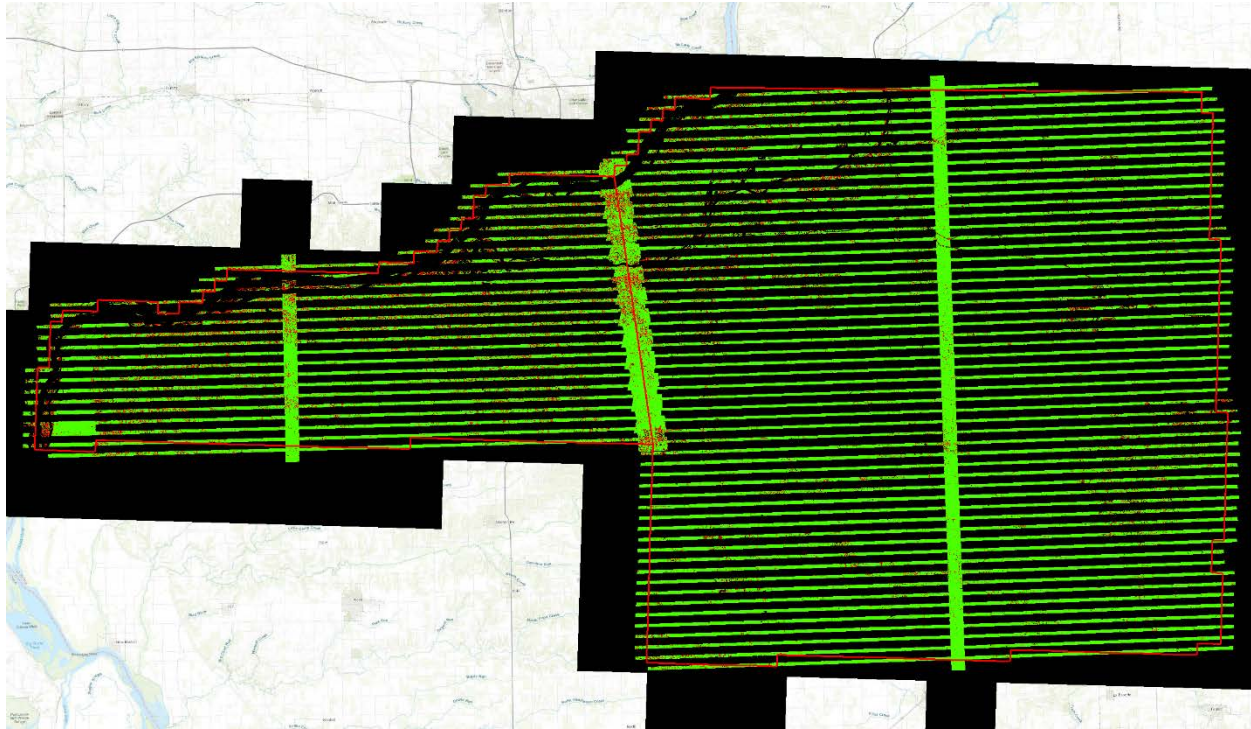


Figure 2- Profile views showing correct roll and pitch adjustments

Final Calibration Verification



Surveying & Mapping, LLC (SAM) conducted the survey throughout the area of interest. 25 ground control points (GCPs) were used to test the accuracy of the calibrated swath data. These 25 GCPs were available to use as control in case the swath data exhibited any biases which would need to be adjusted or removed. The coordinates of all GCPs are provided in Figure 3- Surveyed ground control points (GCPs) and the accuracy results from testing the calibrated swath data against the GCPs is provided in the following Tables. Ground control points (GCPs) vertical accuracy results (vegetated and non-vegetated); no further adjustments to the swath data were required based on the accuracy results of the GCPs.

Table 10 - Surveyed ground control points (GCPs)

Point ID	(Projection of GCP) Meter					
	Control X	Control Y	Control Z	Surface Z	Z Location	Delta Z
GCP28	454395.686	2068939.237	176.901	176.920	Control	+0.019
GCP29	478298.290	2075897.759	177.250	177.344	Control	+0.094
GCP30	503919.280	2073566.267	189.296	189.238	Control	-0.058
GCP31	495925.169	2061578.148	201.059	201.041	Control	-0.018
GCP32	467428.198	2052359.850	238.471	238.462	Control	-0.009
GCP33	482059.908	2047596.967	247.553	247.538	Control	-0.015
GCP34	504166.515	2041838.707	258.340	258.292	Control	-0.048
GCP35	495840.381	2032342.494	252.615	252.625	Control	+0.010
GCP36	467392.819	2034276.641	244.419	244.450	Control	+0.031
GCP37	446184.532	2061352.926	172.184	172.192	Control	+0.008
GCP38	434124.748	2054249.629	238.169	238.136	Control	-0.033

GCP39	411214.876	2057187.733	167.756	167.745	Control	-0.011
GCP40	414435.983	2047544.548	174.061	174.045	Control	-0.016
GCP76	492418.365	2079787.095	185.907	186.005	Control	+0.098
GCP77	470107.753	2064218.147	192.064	192.085	Control	+0.021
GCP78	509628.046	2056316.365	197.742	197.723	Control	-0.019
GCP79	477496.049	2038660.168	243.610	243.593	Control	-0.017
GCP80	492233.681	2053026.268	206.883	206.917	Control	+0.034
GCP81	484700.972	2064387.528	196.086	196.146	Control	+0.060
GCP82	490055.784	2070776.041	185.642	185.580	Control	-0.062
GCP83	474301.459	2057667.707	223.117	223.113	Control	-0.004
GCP84	449984.729	2049192.016	236.707	236.783	Control	+0.076
GCP85	421588.779	2052328.174	188.164	188.171	Control	+0.007
GCP86	430174.290	2059051.448	220.648	220.606	Control	-0.042
GCP87	440035.926	2051335.131	235.419	235.459	Control	+0.040

This project meets Non-vegetated Vertical Accuracy (NVA) ≤ 19.6 cm at the 95% confidence level based on $RMSEz \leq 10 \text{ cm} \times 1.9600$.

Table 11- Ground control points (GCPs) vertical accuracy results - NVA

100 % of Totals	# of Points	RMSEz (m) NVA Spec=0.1 m	NVA-Non-vegetated Vertical Accuracy ((RMSEz x 1.9600) Spec = .196m	Mean (m)	Median (m)	Skew	Std Dev (m)	Min (m)	Max (m)	Kurtosis
GCP	25	0.043	0.085	0.006	-0.004	0.594	0.044	-0.062	0.098	-0.126

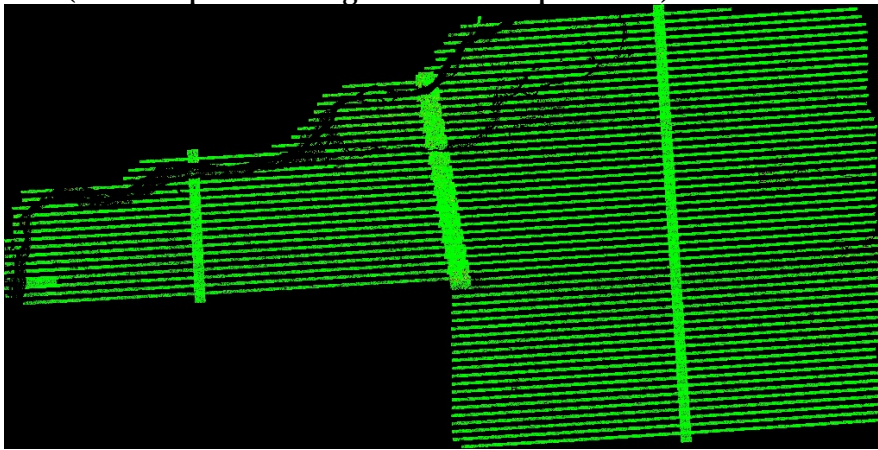
LiDAR Quality Control Reporting

OVERVIEW

SurvTech Solutions conducted the evaluation of calibrated data for USGS IL-8cty to ensure that the swath lidar has been calibrated and produced to meet the required specifications in the Scope of Work (SOW). This review includes verifying the calibration and final formatting of the swath data. Between swath relative accuracy, horizontal alignment, and LAS statistics were reviewed. Results of this review are provided below.

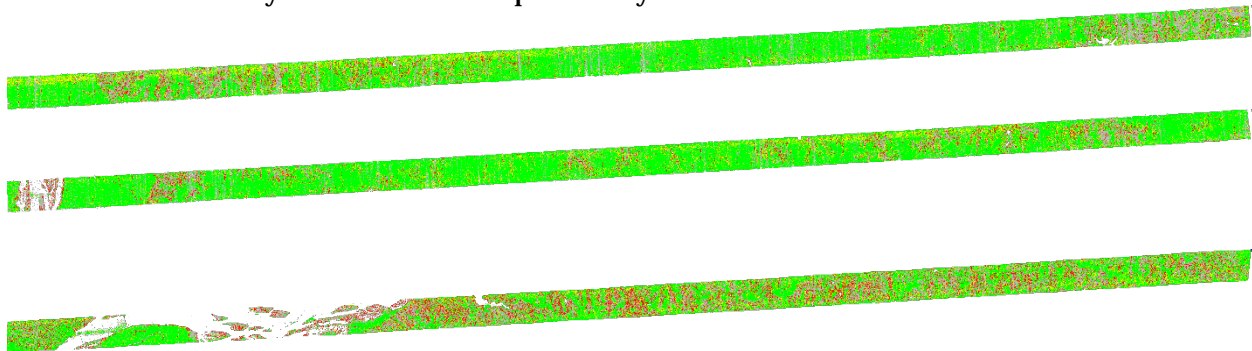
BETWEEN SWATH RELATIVE ACCURACY (DZ ORTHOS):

Inter-swath relative accuracy passes specification. All pixels colored green are areas where overlapping flight lines are within 8 cm of each other. Areas colored red are where differences greater than 8 cm exist (this is expected in vegetated and sloped areas).



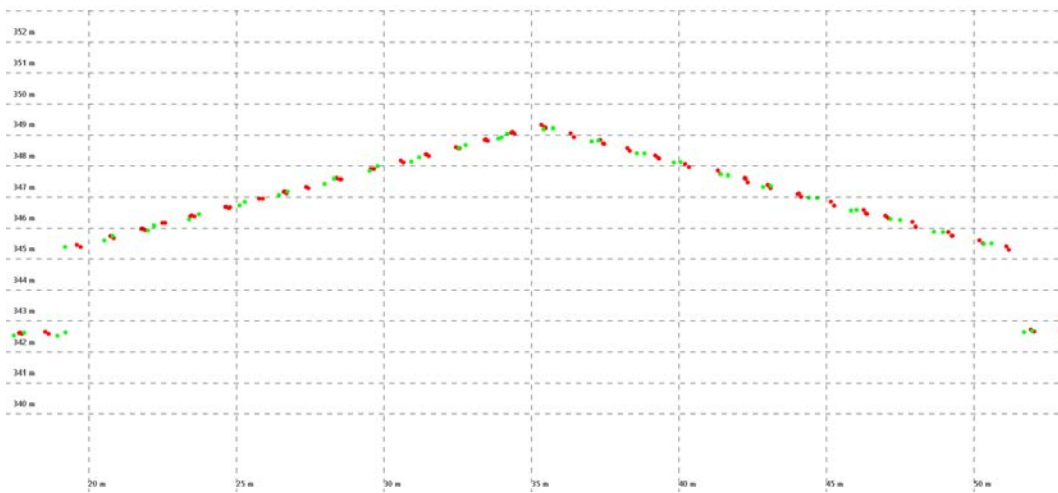
WITHIN SWATH RELATIVE ACCURACY (INTRASWATH):

Intra-swath relative accuracy was reviewed and passes specification. All flight lines were reviewed to confirm intra-swath within 8 cm (green) of each it on flat plainer surfaces. Areas colored red are where differences greater than 8 cm exist. Red areas are expected in vegetated and sloped areas as this is an assessment only of hard surface repeatability.

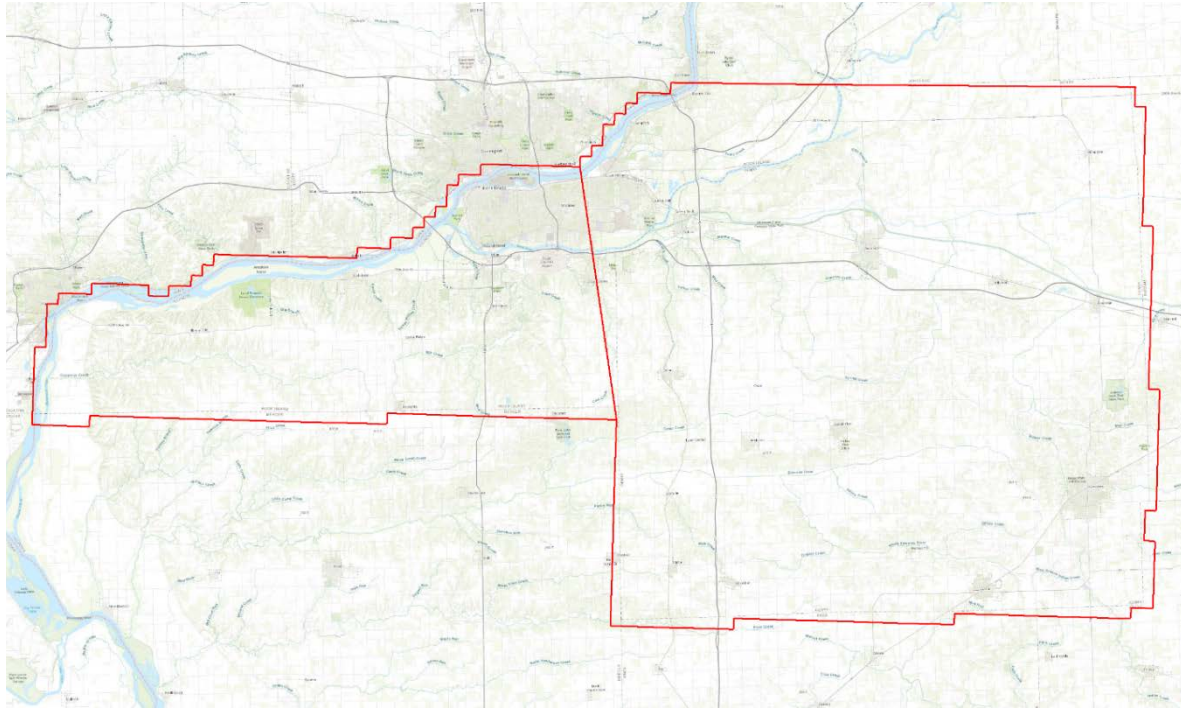


HORIZONTAL ALIGNMENT/CALIBRATION CHECK (ROOFTOPS/PLANAR SURFACE PROFILES):

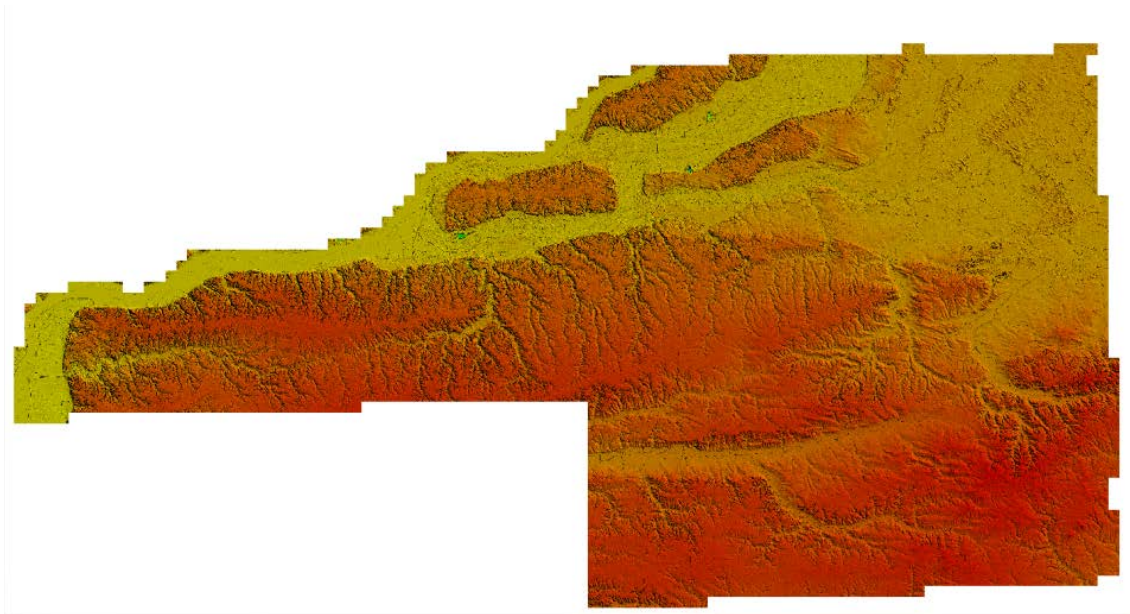
The profiles show lidar points colored by flight line. The overlapping flight lines match and there is no horizontal (or vertical) offset between the flight lines.



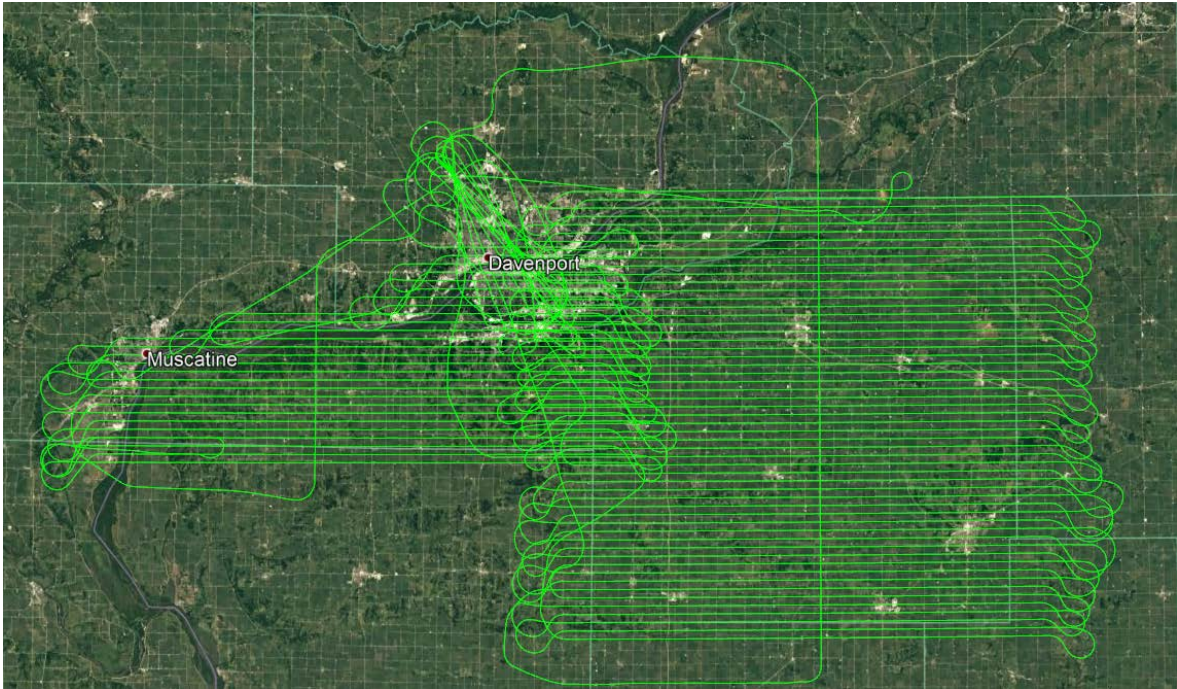
PROJECT OVERVIEW



PROJECT AREA WITH ELEVATION MODEL

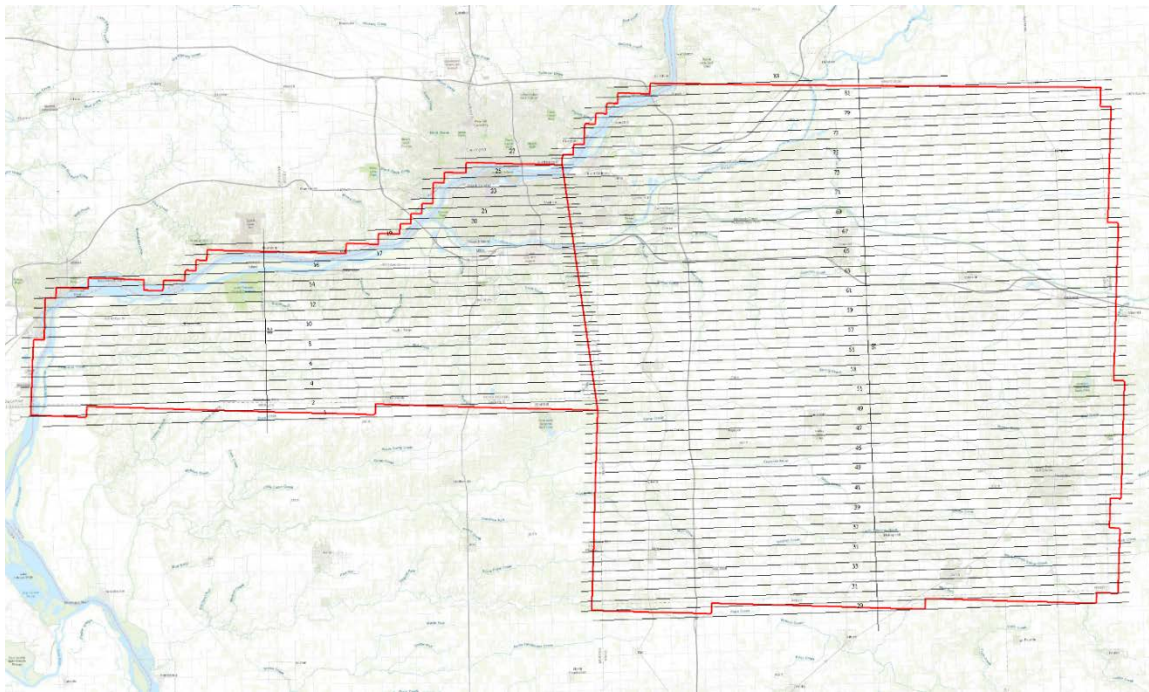


PROJECT COMBINED SMOOTHED TRAJECTORIES



Combined project SBET

PLANNED FLIGHT LINE OVERVIEW



Project planned flight line overview

See Appendix C: For SurvTech GPS and IMU Processing Reports

DATA CLASSIFICATION AND EDITING

Once the calibration, absolute swath vertical accuracy, and relative accuracy of the data were confirmed, ASI utilized TerraScan software for data processing. The acquired 3D laser point clouds, in LAS binary format, were imported into the project and tiled according to the project tile grid. Once tiled, the laser points were classified using a proprietary routine in TerraScan. This routine classifies any obvious low outliers in the dataset to class 7 and high outliers in the dataset to class 18. After points that could negatively affect the ground are removed from class 1, the ground layer is extracted from this remaining point cloud. The ground extraction process encompassed in this routine takes place by building an iterative surface model. This surface model is generated using three main parameters: building size, iteration angle and iteration distance. The initial model is based on low points being selected by a "roaming window" with the assumption that these are the ground points. The size of this roaming window is determined by the building size parameter. The low points are triangulated and the remaining points are evaluated and subsequently added to the model if they meet the iteration angle and distance constraints. This process is repeated until no additional points are added within iterations. A second critical parameter is the maximum terrain angle constraint, which determines the maximum terrain angle allowed within the classification model.

Once the ground surface had been deduced through the filtering process a vegetation class was then extracted by distance from ground from the remaining class 1. Vegetation points were filtered by distance into Low Vegetation is 0.5-5 feet, Medium Vegetation is 5-20 feet, High Vegetation is >20 feet from the ground. Classes 3, 4, and 5 define low, medium, and high vegetation points respectively and were classified using an automated method. These vegetation classes represent all non-noise points that fall into the distances above the ground surface, and will likely include buildings, utility poles, powerlines, and other infrastructure.

In TerraScan surface models for each tile was created to examine the ground classification. ASI analysts visually reviewed the ground surface model for artifacts left in the ground classification. These artifacts consist of vegetation, buildings, and bridges that were still present in the ground after initial processing. ASI analysts employ 3D visualization techniques to view the point cloud at multiple angles and in profile to ensure that errant points are removed from the ground classification. Bridge decks are manually classified to class 17. After the ground classification had been completed, the dataset was processed through a water classification routine that utilized breaklines compiled by the Prime and Subcontractor to automatically classify hydro features. The water classification routine selects ground points within the breakline polygons and automatically classifies them as class 9, water. During this water classification routine, ground points that are within 2x NPS or less of the hydrographic features are moved to class 20 ignored ground, due to breakline proximity. Overage points are then identified in TerraScan and used to set the overlap bit for those points. The withheld points identified during the classification routine are used to set the withheld bit. The LiDAR tiles were classified to the following classification schema:

- o Class 1 – Default, Processed, but unclassified
- o Class 2 – Ground, Bare-earth
- o Class 3 – Low Vegetation is 0.5-5 feet
- o Class 4 – Medium Vegetation is 5-20 feet
- o Class 5 – High Vegetation is >20 feet

- o Class 7 – Low Noise (low and manually identified)
- o Class 9 – Water
- o Class 17 – Bridge Decks
- o Class 18 – High Noise (high, manually identified)
- o Class 20 – Ignored Ground (Breakline Proximity)

After manual classification, the LAS tiles were peer reviewed and then underwent a final QA/QC. After the final QA/QC and corrections, the LAS files were then converted from LAS v1.2 to LAS v1.4 using TerraScan software to flag the overlap bit and withheld bit. An LP360 64 bit was used to deduce the Well Known Text (WKT) and ASI proprietary software was used to format the LAS to the final LAS v1.4 Format 6 version. LAStools by rapidlasso GmbH, open source, lasInfo (open source LGPL) and ASI proprietary software was used to perform final analysis to checks on LAS header information, LAS point classes, and LAS timestamps.

This project consists of 119,347,163,080 lidar points the table below shows the total number of points for every class.

Project Count by Class		
Class 1	Processed, unclassified	21361829926
Class 2	Bare-earth ground	38718958422
Class 3	Low vegetation (0.5-5 ft)	1599404165
Class 4	Medium vegetation (5-20 ft)	3493724918
Class 5	High vegetation (>20 ft)	7596791141
Class 7	Low Noise	68532366
Class 9	Water	134226386
Class 17	Bridge Decks	5088690
Class 18	High Noise	217996338
Class 20	Ignored_Ground	4492192
Class Overlap 1	Overlap Processed, unclassified	15470110973
Class Overlap 2	Overlap Bare-earth ground	14730437957
Class Overlap 3	Overlap Low vegetation (0.5-5 ft)	978716001

Class Overlap 4	Overlap Medium vegetation (5-20 ft)	1706745310
Class Overlap 5	Overlap High vegetation (>20 ft)	3465034698
Class Overlap 7	Overlap Low Noise	3107641
Class Overlap 9	Overlap Water	8315335
Class Overlap 17	Overlap Bridge Decks	2736413
Class Overlap 18	Overlap High Noise	59918671
Class Overlap 20	Overlap Ignored_Ground	1503301
Class Withheld 1	Withheld Processed, unclassified	1736488666
Class Withheld 2	Withheld Bare-earth ground	860580366
Class Withheld 3	Withheld Low vegetation (0.5-5 ft)	89017532
Class Withheld 4	Withheld Medium vegetation (5-20 ft)	144776079
Class Withheld 5	Withheld High vegetation (>20 ft)	296589660
Class Withheld 7	Withheld Low Noise	1796187
Class Withheld 9	Withheld Water	621984
Class Withheld 17	Withheld Bridge Decks	50512
Class Withheld 18	Withheld High Noise	14079281
Class Withheld 20	Withheld Ignored_Ground	33752
Class Overlap Withheld 1	Overlap Withheld Processed, unclassified	3669582271
Class Overlap Withheld 2	Overlap Withheld Bare-earth ground	1752286049
Class Overlap Withheld 3	Overlap Withheld Low vegetation (0.5-5 ft)	240507852
Class Overlap Withheld 4	Overlap Withheld Medium vegetation (5-20 ft)	322287289

Class Overlap Withheld 5	Overlap Withheld High vegetation (>20 ft)	568935740
Class Overlap Withheld 7	Overlap Withheld Low Noise	1993044
Class Overlap Withheld 9	Overlap Withheld Water	185122
Class Overlap Withheld 17	Overlap Withheld Bridge Decks	91463
Class Overlap Withheld 18	Overlap Withheld High Noise	19536898
Class Overlap Withheld 20	Overlap Withheld Ignored_Ground	52489
Project Total Count		119347163080

Table 12: By Class Point Count.

LiDAR QUALITATIVE ASSESSMENT

ASI’s qualitative assessment utilizes a combination of statistical analysis and interpretative methodology or visualization to assess the quality of the data for a bare-earth digital terrain model (DTM). This includes creating pseudo image products such as LiDAR orthos produced from the intensity returns, Triangular Irregular Network (TIN)’s, Digital Elevation Models (DEM) and 3-dimensional models as well as reviewing the actual point cloud data. This process looks for anomalies in the data, areas where man-made structures or vegetation points may not have been classified properly to produce a bare-earth model, and other classification errors. This report will present representative examples where the LiDAR and post processing had issues as well as examples of where the LiDAR performed well.

VISUAL REVIEW

The following sections describe common types of issues identified in LiDAR data and the results of the visual review for Block 3 IL 8 County project.

Data Voids

Acceptable voids (areas with no LiDAR returns in the LAS files) that are present in the majority of LiDAR projects include voids caused by bodies of water. No unacceptable voids are present in the Block 3 IL 8 County project.

Bridge Removal Artifacts

The DEM surface models are created from TINs or Terrains. TIN and Terrain models create continuous surfaces from the inputs. Because a continuous surface is being created, the TIN or Terrain will use interpolation to continue the surface beneath the bridge where no LiDAR data was acquired. Locations where bridges were removed will generally contain less detail in the bare-earth surface because these areas are interpolated. The DEM in the bottom view shows an area where a bridge has been removed from ground. The surface model must make a continuous model and in order to do so, points are connected through interpolation. This results in less detail where the surface must be interpolated. The profile in the top view shows the LiDAR points of this particular feature colored by class. All bridge points have been removed from ground (orange) and are bridge deck (blue).

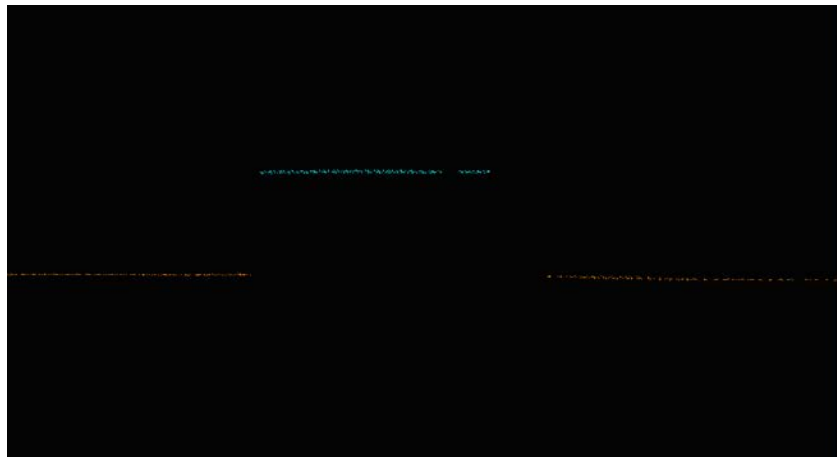


Figure 9: Profile view of a classified bridge deck (blue) and ground (orange).

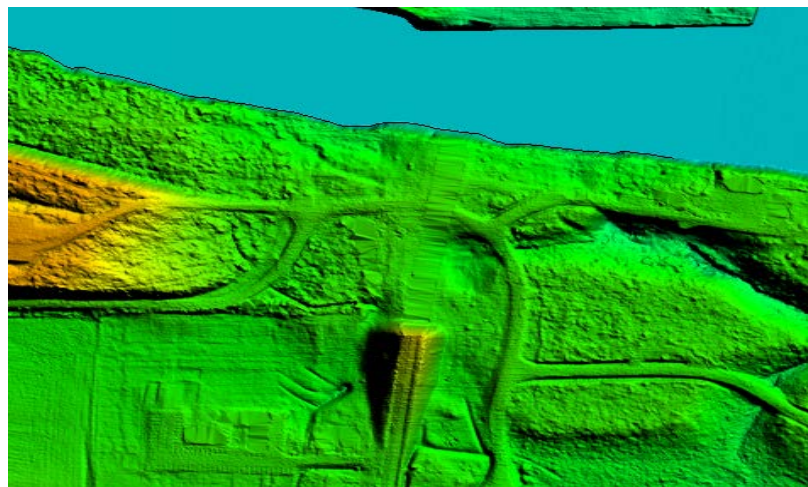


Figure 10: DEM with bridge removed from surface model.

Culverts

Bridges have been removed from the bare earth surface while culverts remain in the bare earth surface. In instances where it is difficult to determine if the feature is a culvert or bridge, such as with some small bridges, ASI erred on assuming they would be culverts especially if they are on secondary or tertiary roads. Below is an example of a culvert that has been left in the ground surface.

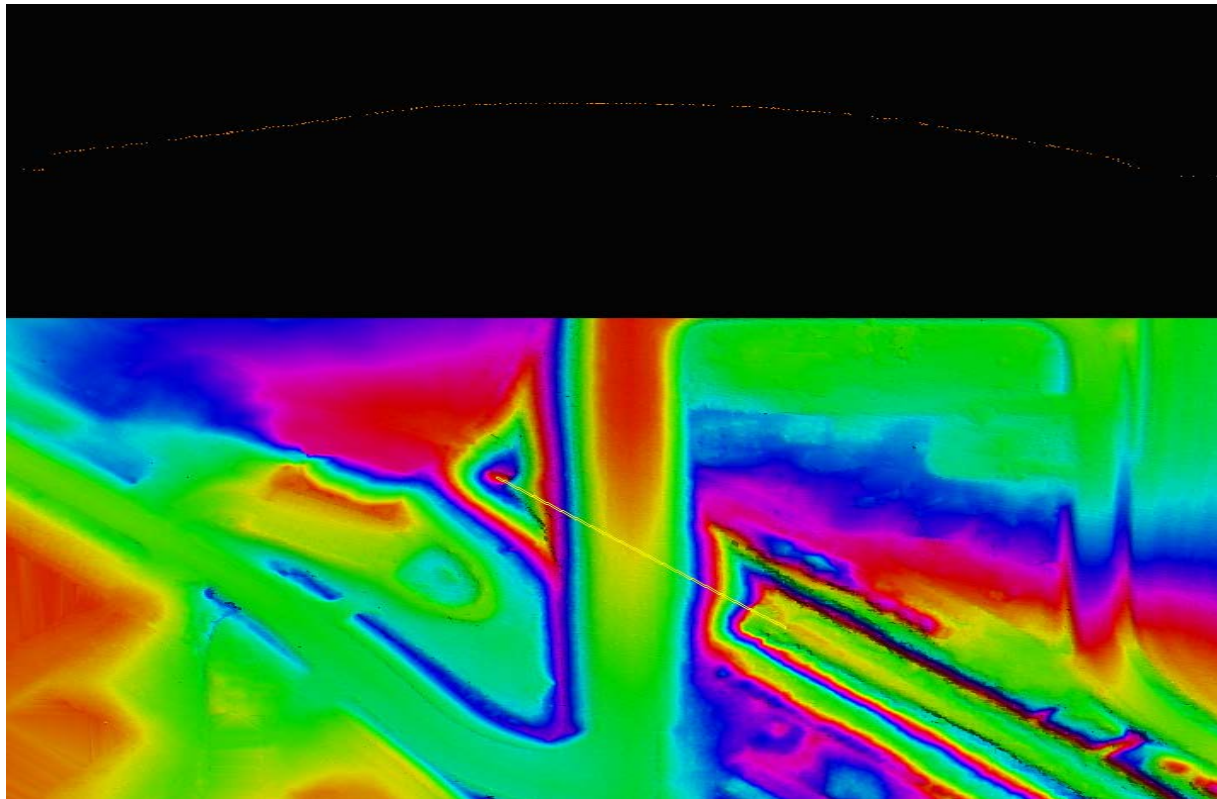


Figure 11: Profile with points colored by class (class 1=white, class 2=orange) is shown in the top view and the DEM is shown in the bottom view. This culvert remains in the bare earth surface. Bridges have been removed from the bare earth surface and classified to class 17.

Dirt Mounds

Irregularities in the natural ground exist and may be misinterpreted as artifacts that should be removed. Hills and dirt mounds are present throughout the project area. These features are correctly included in the ground.

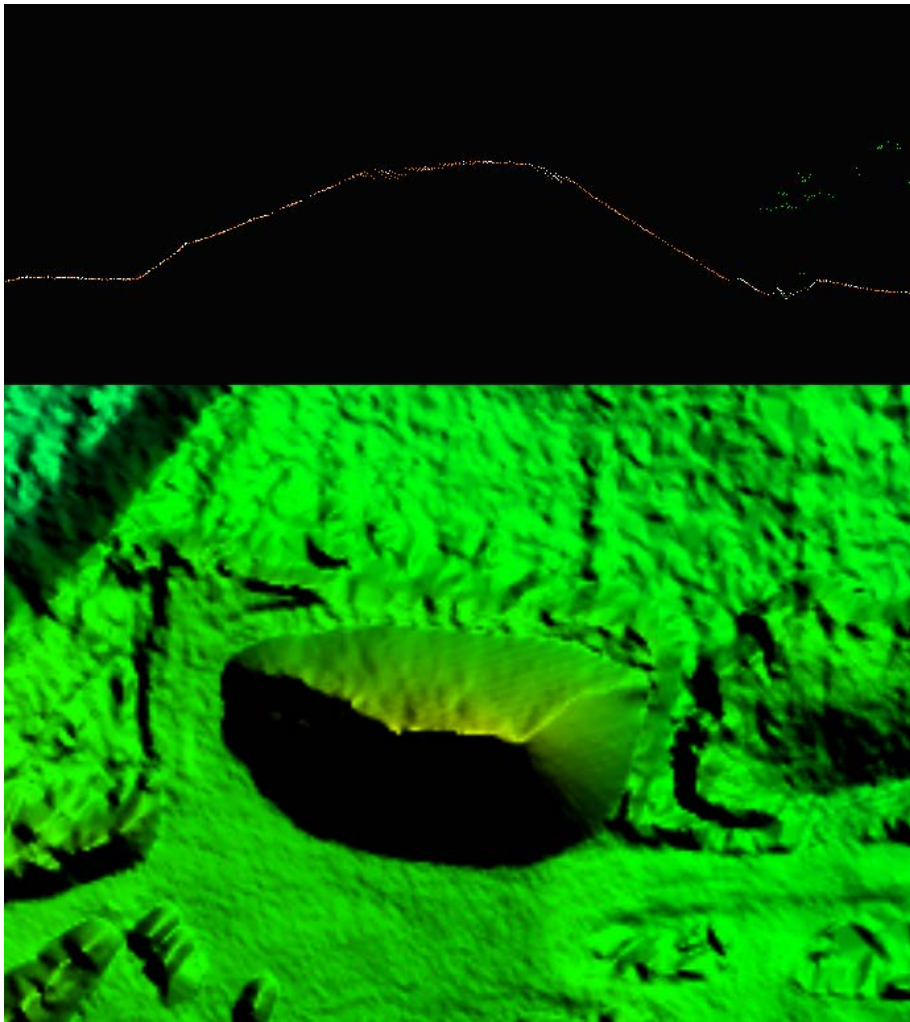


Figure 12: Profile with the points colored by class (unclassified points are white, ground points are orange) is shown on the right and a DEM of the surface is shown to the left. These features are correctly included in the ground classification.

Flightline Ridges

Ridges occur when there is a difference between the elevations of adjoining flight lines or swaths. Some flightline ridges are visible in the final DEMs but they do not exceed the project specifications and the overall relative accuracy requirements for the project area have been met. An example of a visible flightline ridge that is within tolerance is shown below.

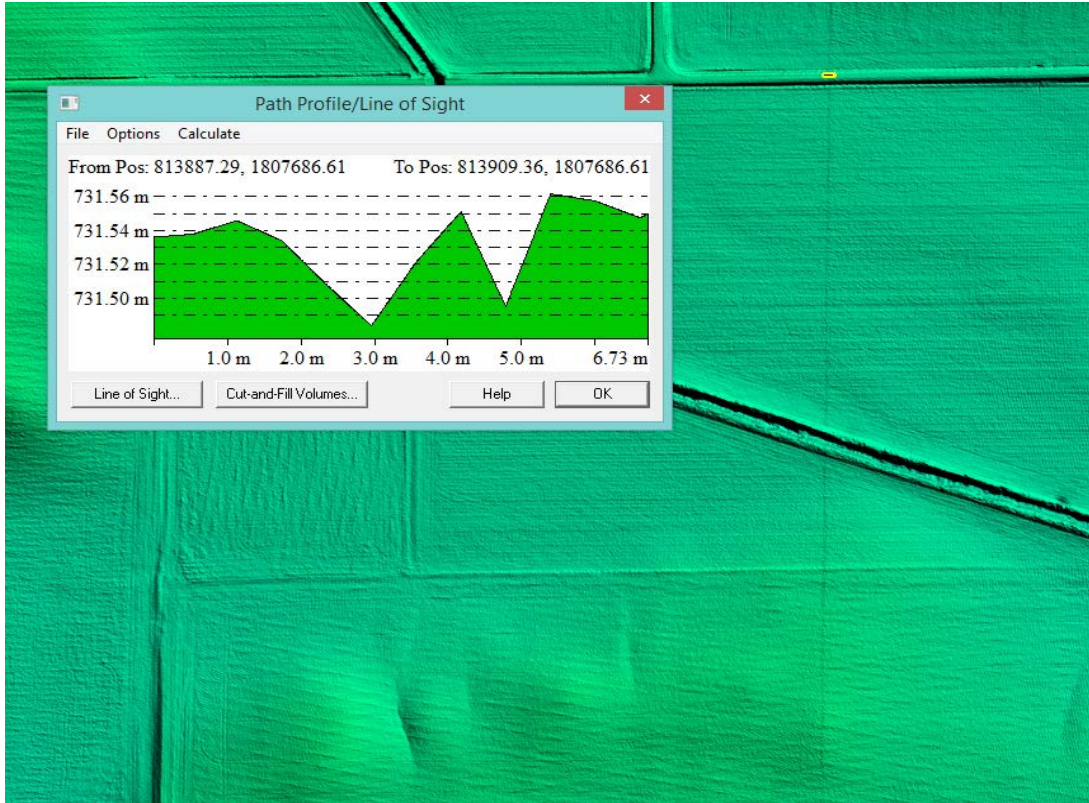


Figure 13: The flight line ridge is less than 8 cm. Overall, the Block 3 IL 8 County project data meets the project specifications for 8 cm RMSDz relative accuracy requirement.

Dam and Lock system

Irregularities in the natural water flow exist in sections of river affected by Lock and Dam systems. Series of locks enable vessels to “step” up or down a river or canal from one water level to another. There are Lock systems in the Block 3 IL 8 County Lidar project area.

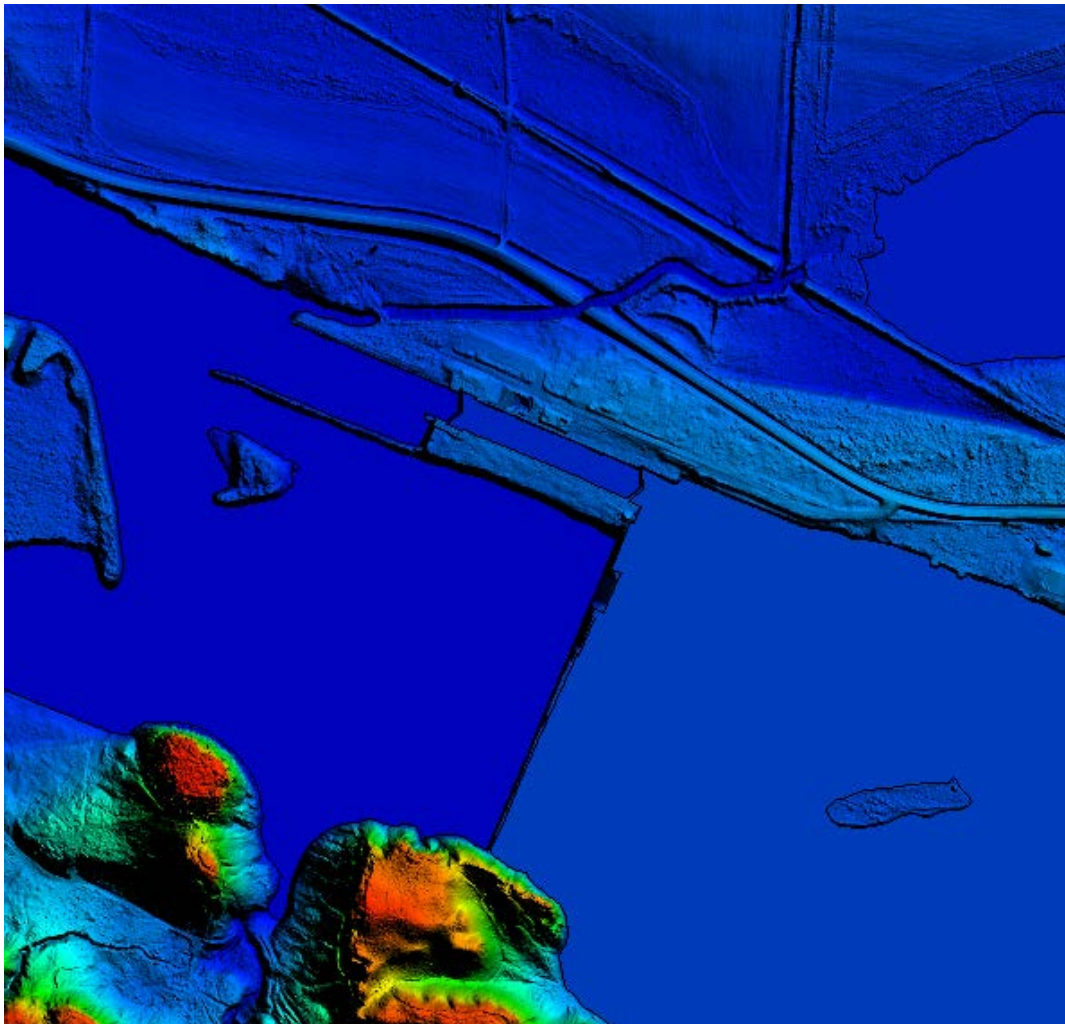


Figure 14: DEM shows Large Dam structure that disrupts natural monotonic river flow, coupled with a lock system.

FORMATTING

After the final QA/QC is performed and all corrections have been applied to the dataset, all LiDAR files are updated to the final format requirements and the final formatting, header information, point data records, and variable length records are verified using ASI proprietary tools. ASI routinely reviews for: proper LAS versions, Coordinate Reference System, Global Encoder Bit, Time Stamp, System ID, Multiple Returns, Intensity, Classification, Overlap and Withheld Points, Scan angle, XYZ Coordinates.

LiDAR Positional Accuracy

BACKGROUND

ASI quantitatively tested the dataset by testing the vertical accuracy of the LiDAR. The vertical accuracy is tested by comparing the discreet measurement of the survey checkpoints to that of the interpolated value within the three closest LiDAR points that constitute the vertices of a three-dimensional triangular face of the TIN. Therefore, the end result is that only a small sample of the LiDAR data is actually tested. However there is an increased level of confidence with LiDAR data due to the relative accuracy. This relative accuracy in turn is based on how well one LiDAR point "fits" in comparison to the next contiguous LiDAR measurement, and is verified as part of the initial processing. If the relative accuracy of a dataset is within specifications and the dataset passes vertical accuracy requirements at the location of survey checkpoints, the vertical accuracy results can be applied to the whole dataset with high confidence due to the passing relative accuracy. The nature of lidar data makes it difficult to assess absolute horizontal accuracy as one would with imagery or compiled planimetric data. Guidance on how absolute horizontal accuracy can be estimated and reported based on the error budget of the instrumentation and operational parameters can be found in ASPRS (2014). The horizontal accuracy of each lidar project shall be reported using the form specified by the ASPRS (2014).

SURVEY VERTICAL ACCURACY CHECKPOINTS

For the vertical accuracy assessment of Block 3 IL 8 County project, one hundred twenty seven checkpoints were surveyed. All of those checkpoints are located within bare earth/open terrain (127 NVA points). Please see provided survey report which details and validates how the survey was completed for this project. Checkpoints were evenly distributed throughout the project area so as to cover as many flight lines as possible using the "dispersed method" of placement. All checkpoints surveyed for vertical accuracy testing purposes are listed in the following table.

Point ID	NAD83 (2011) Albers Equal Area	NAD83 (2011) Albers Equal Area	NAVD88 (Geoid12B)
	Easting (M)	Northing (M)	Elevation (M)
NVA01	437928.170	2178798.030	202.350
NVA02	454346.440	2171733.710	240.700
NVA03	469428.980	2178221.220	287.410
NVA04	505670.210	2169645.840	290.360
NVA05	538164.310	2176719.760	272.810
NVA06	522263.200	2162161.360	234.430
NVA07	472923.450	2160845.000	247.780
NVA08	469233.110	2153052.640	197.440
NVA09	494511.930	2136119.970	242.170
NVA10	487999.070	2154736.680	211.670
NVA11	485293.120	2121153.550	184.740
NVA12	513566.760	2144432.170	290.060
NVA13	528852.030	2127036.260	263.630
NVA14	553218.410	2144649.270	221.360
NVA15	549215.610	2131962.040	223.370
NVA16	570024.120	2124311.420	248.800
NVA17	574725.740	2114946.730	248.350
NVA18	559719.590	2090924.420	282.220
NVA19	537892.470	2110735.780	221.960
NVA20	531813.940	2097503.010	206.800
NVA21	519882.860	2106191.110	205.290
NVA22	512041.070	2123585.930	232.430
NVA23	497124.080	2104046.490	193.680
NVA24	480595.680	2110719.070	180.600
NVA25	521660.520	2084424.630	197.570
NVA26	489409.930	2086917.580	179.500
NVA27	468725.570	2088016.180	178.790
NVA28	462660.970	2069342.290	208.820
NVA29	475461.160	2075653.610	177.330
NVA30	503661.100	2073716.750	188.390
NVA31	496206.400	2060867.050	202.870
NVA32	465844.160	2052115.150	235.800
NVA33	481488.400	2047703.000	244.350
NVA34	505032.580	2043805.130	253.820
NVA35	495372.230	2034067.360	255.780

NVA36	473087.120	2033358.910	248.930
NVA37	448727.890	2063845.150	182.160
NVA38	442319.890	2048436.330	245.270
NVA39	422948.960	2055356.150	232.070
NVA40	413552.350	2050480.270	169.420
NVA41	579684.480	2097814.300	283.650
NVA53	440869.600	2176480.620	225.790
NVA54	446347.250	2178428.760	249.870
NVA55	457693.430	2168729.310	261.170
NVA56	460761.670	2178948.750	278.790
NVA57	465693.120	2171654.480	231.100
NVA58	481805.950	2182287.020	306.090
NVA59	477945.680	2171731.230	263.090
NVA60	519010.280	2181206.110	261.230
NVA61	505305.350	2156526.340	262.800
NVA62	478244.580	2141577.000	181.640
NVA63	533229.270	2152709.240	274.010
NVA64	526629.640	2141813.280	288.770
NVA65	566874.030	2143420.920	241.070
NVA66	502248.970	2128657.980	240.880
NVA67	542279.270	2104914.580	239.810
NVA68	570399.470	2104825.330	238.800
NVA69	557561.710	2115624.600	246.520
NVA70	572159.500	2138098.260	234.430
NVA71	550433.630	2099322.290	230.410
NVA72	494356.690	2123720.670	260.900
NVA73	547596.410	2088477.870	266.540
NVA74	501921.420	2089835.490	189.260
NVA75	477783.580	2102107.140	190.390
NVA76	488062.31	2093624.15	210.94
NVA77	534204.76	2087517.11	203.76
NVA78	483811.03	2062814.49	205.59
NVA79	504838.02	2060161.07	189.69
NVA80	492661.47	2070999.7	187.74
NVA81	495676.81	2048092.98	218.98
NVA82	504735.42	2033839	239.38
NVA83	489030.09	2036722.38	239.47
NVA84	467508.08	2036237.05	237.45
NVA85	474635.23	2052009.44	234.38
NVA86	473465.81	2045866.31	239.67
NVA87	483210.86	2039787.41	232.79

NVA88	495189.66	2056398.62	206.64
NVA89	469869.59	2064677.97	194.44
NVA90	453902.89	2056203.14	226.81
NVA91	438229.47	2059963.5	182.62
NVA92	433938.94	2053652.08	231.91
NVA93	427109.91	2048118.14	224.08
NVA94	414108.63	2055300.01	168.88
NVA95	420092.34	2050602.68	211.65
NVA96	454150.17	2050335.9	237.85
NVA97	446531.23	2057421.95	224.28
NVA98	514801.78	2102198.83	193.41
NVA99	510258.67	2116627.36	249.46
NVA100	545037.18	2120085.46	224.42
NVA101	540661.69	2134963.4	280.57
NVA102	506492.42	2183075.77	237.68
NVA103	490789.29	2165608.75	298.01
NVA104	494525.55	2177905.22	307.86
NVA105	519827.35	2170423.43	246.15
NVA106	537036.59	2184375.68	282.41
NVA107	529079.41	2173071.42	286.44
NVA108	538973.58	2161027.76	235.93
NVA109	510404.32	2164673.15	279.39
NVA110	501123.63	2147823.64	238.38
NVA111	459135.16	2161827.38	204.23
NVA112	513809.95	2085987.43	195.59
NVA113	531239.29	2118531.89	251.48
NVA114	472485.4	2062730.54	209.65
NVA115	481743.75	2082303.04	178.26
NVA116	559907.54	2108733.84	239.37
NVA117	565974.21	2096871.49	290.83
NVA118	557262.49	2128054.04	236.57
NVA119	578268.56	2123898.69	279.44
NVA120	495051.26	2115623.92	218
NVA121	489465.27	2145767.12	196.63
NVA122	479827.87	2150555.74	291.83
NVA124	506288.2	2138379.61	254.17
NVA125	518832.99	2133869.45	241.03
NVA126	521268.34	2117302.32	223.7
NVA127	486906.66	2076202.43	188.3
NVA128	476940.5	2092657.27	177.91
NVA129	485708.52	2100436.82	224.95

NVA130	520546.8	2159202.89	238.5
NVA131	450006.8	2069319.74	172.69
NVA132	503390.85	2041099.33	261.27
NVA133	540879.69	2143583.12	222.27
NVA134	559543.08	2153337.95	244.93
NVA135	483452.99	2132444.89	185.99
NVA136	523607.37	2103307.9	197.02
NVA137	574650	2090740.45	256.43
NVA138	502666.96	2081548.42	191.41
NVA139	519639.27	2152217.82	262.92
VVA01	437159.920	2178167.990	184.630
VVA02	455501.640	2170437.920	186.170
VVA03	489858.010	2182002.980	310.440
VVA04	520031.450	2159258.430	237.250
VVA05	468754.830	2153576.140	193.060
VVA06	536421.510	2184329.460	281.130
VVA07	505334.440	2169810.730	289.230
VVA08	489836.580	2166273.670	302.660
VVA09	559016.390	2151180.680	210.400
VVA11	541278.690	2143216.120	234.020
VVA12	527412.690	2127568.460	259.260
VVA13	513889.800	2144572.930	281.360
VVA14	505189.620	2157033.880	253.230
VVA15	490013.380	2145216.440	191.850
VVA16	479782.330	2150568.370	293.190
VVA17	476733.010	2172564.150	259.190
VVA18	512524.300	2123045.400	227.280
VVA19	506627.890	2138084.930	263.180
VVA20	479612.060	2136682.270	180.960
VVA21	502746.240	2128189.660	237.230
VVA22	485176.630	2121069.330	183.580
VVA23	491607.100	2126545.300	199.230
VVA24	494077.690	2137471.650	215.890
VVA25	569519.770	2123462.530	250.020
VVA26	572898.770	2144048.790	241.950
VVA27	541940.750	2118404.790	203.720
VVA28	520956.030	2102210.560	195.250
VVA29	551569.890	2098650.270	226.130
VVA30	579668.340	2097799.260	283.750
VVA31	513051.540	2086170.290	194.180
VVA32	535739.870	2112773.340	226.360

VVA33	498115.530	2105285.590	205.180
VVA34	481583.930	2110224.830	179.710
VVA35	498668.600	2115068.190	225.120
VVA36	519782.180	2165251.460	255.740
VVA37	528675.810	2172378.130	274.700
VVA38	512368.520	2176709.680	244.330
VVA39	506844.240	2182612.180	236.620
VVA40	547542.990	2088429.300	266.110
VVA41	477638.890	2102346.920	180.790
VVA42	518403.620	2111222.490	222.670
VVA43	500557.350	2090485.570	185.010
VVA44	489298.650	2087029.920	180.040
VVA45	488185.820	2097396.450	215.280
VVA46	469989.220	2093013.840	184.480
VVA47	478628.180	2094428.920	186.400
VVA48	481058.100	2099113.030	205.250
VVA49	487957.110	2103770.180	190.020
VVA50	502513.640	2081607.500	190.220
VVA51	481431.070	2082549.520	176.710
VVA52	468463.050	2081573.230	191.850
VVA53	495406.630	2076514.410	187.270
VVA54	504980.150	2060382.990	189.380
VVA55	483260.070	2062952.090	207.220
VVA56	484445.230	2067325.140	193.390
VVA57	503951.380	2040451.520	256.070
VVA58	505026.770	2043848.320	252.250
VVA59	482337.760	2047748.580	246.380
VVA60	491960.790	2057329.690	205.280
VVA61	496002.620	2032496.370	255.070
VVA62	497711.060	2047504.990	235.020
VVA63	488876.080	2036642.110	236.230
VVA64	473138.570	2033377.970	248.930
VVA65	467397.660	2034837.390	244.820
VVA66	468583.51	2046032.33	230.41
VVA67	467692.15	2052226.63	237.06
VVA68	462978.33	2075604.01	178.86
VVA69	462888.84	2067286.94	208.57
VVA70	455835.88	2069310.64	180.03
VVA71	449064.38	2066452.92	209.67
VVA72	459332.94	2064176.38	173.44
VVA73	449869.78	2060416.42	202.71

VVA74	451072.71	2051802.81	233.7
VVA75	441894.27	2048515.29	245.61
VVA76	437779.15	2060069.63	187.8
VVA77	441922.49	2054761.1	237.8
VVA78	427087.03	2048242.14	227.96
VVA79	434246.04	2054188.12	238.03
VVA80	426315.26	2058973.6	169.49
VVA81	422819.45	2054944.83	233.61
VVA82	429706.33	2052554.61	219.32
VVA83	414382.78	2055281.61	200.09
VVA84	411398.93	2056137.69	169.28
VVA85	413591.2	2057333.52	171.02
VVA86	410795.5	2048609.73	164.24
VVA87	413591.83	2052386.68	175.28
VVA88	416641.81	2047761.63	226.34
VVA89	419615.11	2056057.09	181.52
VVA90	574617.81	2115061.1	249.54
VVA91	540312.71	2091749.41	214.07
VVA92	557916.16	2115100.73	247.27
VVA110	547245.72	2131572.84	217.46

Table 13: Block 3 IL 8 County project LiDAR Validation Checkpoints.

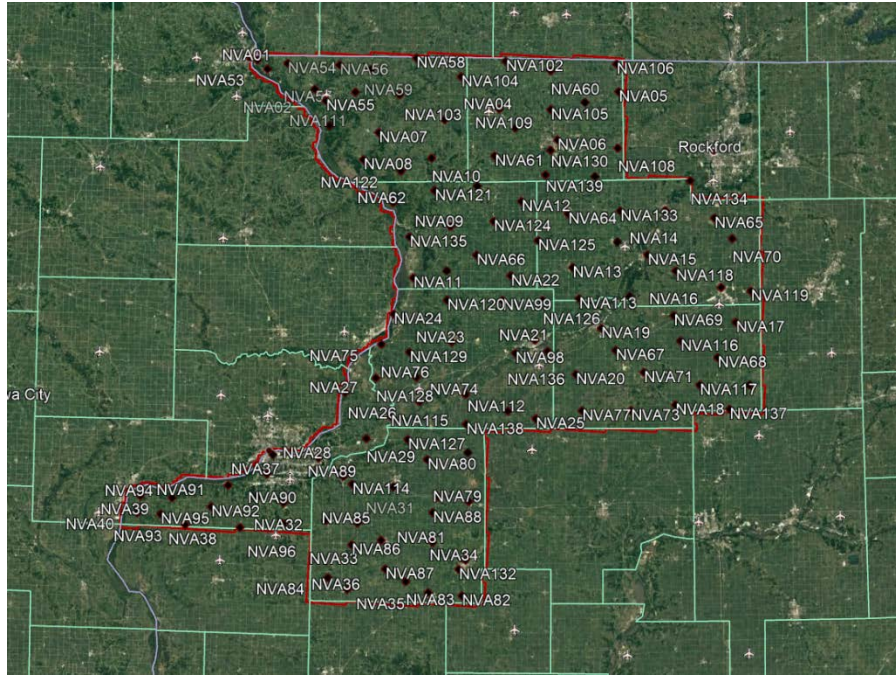


Figure 15: Location of Block 3 IL 8 County LiDAR NVA Checkpoints

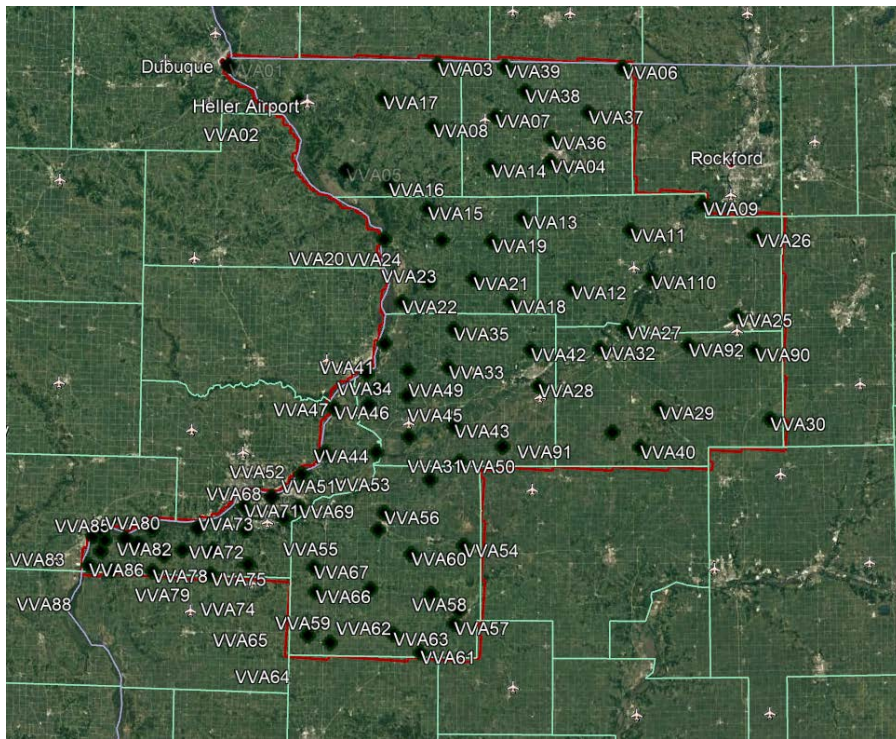


Figure 16: No VVA Checkpoints were located in Block 3 IL 8 County

VERTICAL ACCURACY TEST PROCEDURES

NVA (Non-vegetated Vertical Accuracy) is determined with check points located only in nonvegetated terrain, including open terrain (grass, dirt, sand, and/or rocks) and urban areas, where there is a very high probability that the LiDAR sensor will have detected the bare-earth ground surface and where random errors are expected to follow a normal error distribution. The NVA determines how well the calibrated LiDAR sensor performed. With a normal error distribution, the vertical accuracy at the 95% confidence level is computed as the vertical root mean square error (RMSEz) of the checkpoints x 1.9600. For the Block 3 IL 8 County project, vertical accuracy must be 19.6 cm (0.64 ft) or less based on an RMSEz of 10 cm (0.33 ft) x 1.9600. VVA (Vegetated Vertical Accuracy) is determined with all checkpoints in vegetated land cover categories, including tall grass, weeds, crops, brush and low trees, and fully forested areas, where there is a possibility that the LiDAR sensor and post-processing may yield elevation errors that do not follow a normal error distribution. VVA at the 95% confidence level equals the 95th percentile error for all checkpoints in all vegetated land cover categories combined. The Block 3 IL 8 County Lidar project VVA standard is 29.4 cm (0.96 ft) based on the 95th percentile.

Quantitative Criteria	Measure of Acceptability
Non-Vegetated Vertical Accuracy (NVA) in open terrain and urban land cover categories using RMSEz *1.96	19.6 cm (based on RMSEz (10 cm)*1.96)
Vegetated Vertical Accuracy (VVA) in all vegetated land cover categories combined and at the 95 th Percentile error	29.4 cm (based on combined 95th percentile)

Table 14: Acceptance Criteria.

The primary QA/QC vertical accuracy testing steps used by ASI are summarized as follows:

1. SAM surveyed QA/QC vertical checkpoints in accordance with the project's specifications.
2. Next, ASI interpolated the bare-earth LiDAR DTM to provide the z-value for every checkpoint.
3. ASI then computed the associated z-value differences between the interpolated z-value from the LiDAR data and the ground truth survey checkpoints and computed NVA, VVA, and other statistics.
4. The data were analyzed by ASI to assess the accuracy of the data. The review process examined the various accuracy parameters as defined by the scope of work. The overall descriptive statistics of each dataset were computed to assess any trends or anomalies. This report provides tables, graphs and figures to summarize and illustrate data quality.

VERTICAL ACCURACY RESULTS

The table below summarizes the tested vertical accuracy resulting from a comparison of the surveyed checkpoints to the elevation values present within the fully classified LiDAR LAS files.

Land Cover Category	# of Points	NVA – Non-vegetated Vertical Accuracy (95% confidence) Spec = 0.196 m	VVA – Vegetated Vertical Accuracy (95 th Percentile) spec = 0.294 m
NVA	127	0.108	
VVA	92		0.053

Table 15: Tested NVA and VVA.

HORIZONTAL ACCURACY TEST PROCEDURES

The Riegl LMS-Q1560 data set was produced to meet ASPRS “Positional Accuracy Standards for Digital Geospatial Data” (2014) for a 23 (cm) RMSE_x / RMSE_y Horizontal Accuracy Class which equates to Positional Horizontal Accuracy = +/- 45.08 cm at a 95% confidence level.

The Leica ALS70 data set was produced to meet ASPRS “Positional Accuracy Standards for Digital Geospatial Data” (2014) for a 19.8 (cm) RMSE_x / RMSE_y Horizontal Accuracy Class which equates to Positional Horizontal Accuracy = +/- 38.88 cm at a 95% confidence level.

The Optech Galaxy Prime data set was produced to meet ASPRS “Positional Accuracy Standards for Digital Geospatial Data” (2014) for a 26.6 (cm) RMSE_x / RMSE_y Horizontal Accuracy Class which equates to Positional Horizontal Accuracy = +/- 52.21 cm at a 95% confidence level.

Breakline Production Methodology

MicroStation, in conjunction with TerraSolid's TerraScan and TerraModeler was utilized for the collection of hydrologic breaklines, which occurred independently of manual edit. Collection was done using 2D information in the LAS format, intensity format, and ground surface. Breaklines are developed to the limit of the project boundary. Breaklines are in the same coordinate reference system and unit of measure as the LiDAR point delivery. Hydrologic water-surface edges are set at or just below the immediately surrounding terrain. Breaklines are developed to the limit of the project boundary.

BREAKLINE QUALITATIVE ASSESSMENT

Completeness and horizontal placement is verified through visual review against LiDAR intensity imagery, and bare earth surface. Breakline features are checked for connectivity of features, enforced monotonicity on linear hydrographic breaklines, and flatness on water bodies.

After all corrections and edits to the breakline features, the breaklines are imported into the final GDB and verified for correct formatting.

FEATURE DEFINITION

Inland Streams and Rivers

Streams and Rivers with a nominal width of 30 meters (100 feet), were collected to best fit the shoreline by using information in the LAS format; intensity format, ground surface TIN, and sometimes "quick guide" contours. Streams and rivers do not break at bridges, but they are closed ended breaks at culvert locations. Streams and Rivers breaklines have been delivered in PolylineZ format in the final GDB.

Inland Ponds and Lakes

Inland ponds and lakes of 2 acres (86,111 square feet/ ~350'/~106 meter diameter for a round pond) or greater were collected. Inland pond and Lakes were collected to best fit the shoreline by using information in the LAS format; intensity format, ground surface TIN, and sometimes "quick guide" contours. Inland pond and Lakes Breaklines have been delivered in PolygonZ format in the final GDB.

Islands

Permanent island 4046m² (1 acre) or larger were delineated within all water bodies. Breaklines have been delivered in PolygonZ format in the final GDB

Bridge Breaklines

Breaklines were placed across the bottom of the bridge embankment when triangulation occurred due to bridge deck classification. Breaklines have been delivered in PolylineZ format in the final GDB.

Intensity Imagery Production & Qualitative Assessment

INTENSITY PRODUCTION METHODOLOGY

ASI utilized MicroStation in conjunction with TerraSolid's TerraScan for Intensity production. Global Mapper was used to QC the products. ArcGIS was used to finalize the Intensity's projection.

Intensity Images are created for each tile in the tiling schema. The Intensities are reviewed for any issues requiring corrections. Tiles are verified for final formatting and loaded into Global Mapper to ensure there are no missing, or corrupt tiles, and to check for seamlessness across tile boundaries.

INTENSITY QUALITATIVE ASSESSMENT

ASI performed a qualitative assessment of the Intensity deliverables to ensure that all tiled Intensity products were delivered with the proper extents, and contained proper referencing information. Intensity bounding values were manually set in RiProcess to utilize the full range of values available. Subcontractor intensities were linearly scaled to match the intensity of ASI's collection. During some reprocessing to improve the calibration, some points received maximum value intensity; however these were corrected to the original output values prior to delivery.



Figure 17: Intensity Image example.

DEM Production & Qualitative Assessment

DEM PRODUCTION METHODOLOGY

ASI utilized MicroStation Connect in conjunction with TerraSolid's TerraScan and TerraModeler for DEM production. Global Mapper version 21.0 was used to format and QC the products. GDAL version 2.4.0 was used to finalize the DEMs projection.

The final bare earth LiDAR points are used to create a terrain. The final 3D breaklines collected for the project are enforced in the terrain. The terrain is then converted to raster format using linear interpolation. DEMs are created for each tile in the tiling schema. The DEMs are reviewed for any issues requiring corrections, including remaining LiDAR ground misclassification, erroneous breakline elevations, poor hydro flattening, and processing artifacts. Tiles are verified for final formatting and loaded into Global Mapper to ensure there are no missing, or corrupt tiles, and to check for seamlessness across tile boundaries.

DEM QUALITATIVE ASSESSMENT

ASI performed a qualitative assessment of the bare earth DEM deliverables to ensure that all tiled DEM products were delivered with the proper extents, were free of processing artifacts, and contained proper referencing information.

The image below shows an example of a bare earth DEM.

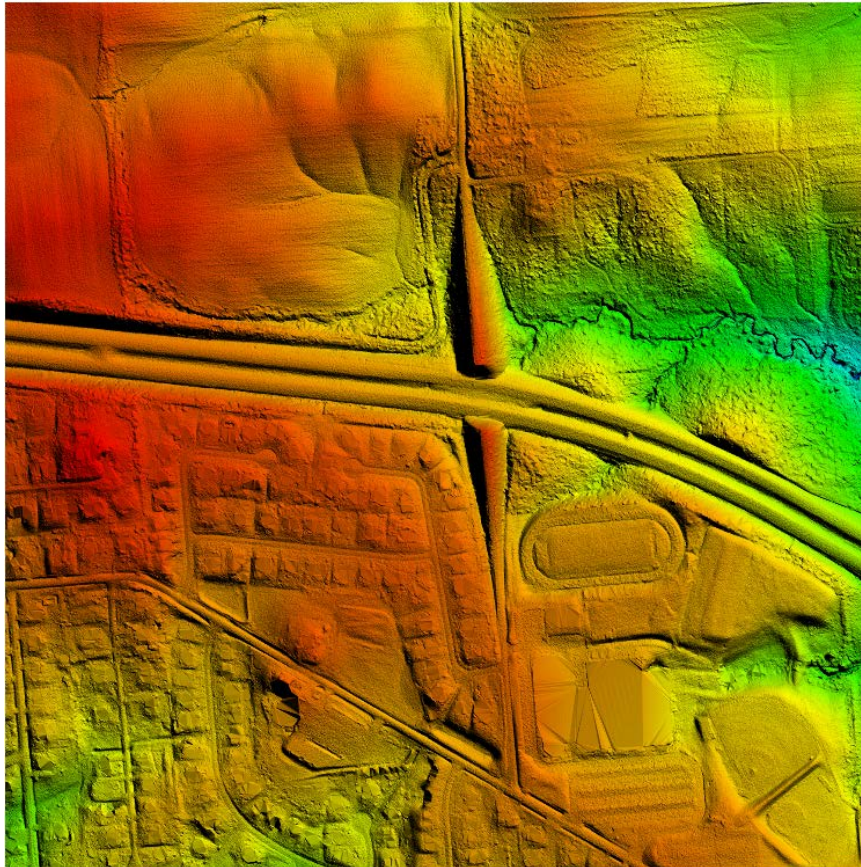


Figure 18: Block 3 IL 8 County project bare earth DEM

DEM VERTICAL ACCURACY RESULTS

The same 127 checkpoints that were used to test the vertical accuracy of the LIDAR were used to validate the vertical accuracy of the final DEM products as well. Accuracy results may vary between the source LiDAR and final DEM deliverable. DEMs are created by averaging several LiDAR points within each pixel which may result in slightly different elevation values at each survey checkpoint when compared to the source LAS. The DEM pixel does not average several LiDAR point's together, it interpolates (linearly) between two or three points to derive an elevation value. The vertical accuracy of the DEM is tested by extracting the elevation of the pixel that contains the x/y coordinates of the checkpoint and comparing these DEM elevations to the survey elevations.

Table 16; summarizes the tested vertical accuracy result from a comparison of surveyed checkpoint to the elevation values present within the final DEM dataset.

Land Cover Category	# of Points	NVA – Non-vegetated Vertical Accuracy (RMSEz x 1.960)	VVA – Vegetated Vertical Accuracy (95 th percentile)
NVA	127	0.096	
VVA	92		0.060

Table 16: DEM vertical accuracy summary

DEM datasets were tested to meet ASPRS Positional Accuracy Standards for Digital Geospatial Data (2014) for a 10 cm RMSEz Vertical Accuracy Class. Actual NVA accuracy was found to be RMSEz = 0.049 meters with a 0.096 meters accuracy at 95 % confidence level. Actual VVA accuracy tested 0.060 meters using checkpoints located in forested land cover categories at the 95th percentile, derived according to ASPRS guidelines, tested against the DEM. Based on the vertical accuracy testing conducted by ASI, the DEM dataset for the Block 3 IL 8 County project satisfies the project's pre-defined vertical accuracy criteria.

Appendix A: List of Delivered LAS File

w4080n2045	w4110n2057	w4150n2048	w4180n2054
w4080n2046	w4110n2058	w4150n2049	w4180n2055
w4080n2047	w4120n2045	w4150n2050	w4180n2056
w4080n2048	w4120n2046	w4150n2051	w4180n2057
w4080n2049	w4120n2047	w4150n2052	w4180n2058
w4080n2050	w4120n2048	w4150n2053	w4180n2059
w4080n2051	w4120n2049	w4150n2054	w4190n2046
w4080n2052	w4120n2050	w4150n2055	w4190n2047
w4080n2053	w4120n2051	w4150n2056	w4190n2048
w4090n2045	w4120n2052	w4150n2057	w4190n2049
w4090n2046	w4120n2053	w4150n2058	w4190n2050
w4090n2047	w4120n2054	w4150n2059	w4190n2051
w4090n2048	w4120n2055	w4160n2046	w4190n2052
w4090n2049	w4120n2056	w4160n2047	w4190n2053
w4090n2050	w4120n2057	w4160n2048	w4190n2054
w4090n2051	w4120n2058	w4160n2049	w4190n2055
w4090n2052	w4130n2045	w4160n2050	w4190n2056
w4090n2053	w4130n2046	w4160n2051	w4190n2057
w4090n2054	w4130n2047	w4160n2052	w4190n2058
w4090n2055	w4130n2048	w4160n2053	w4190n2059
w4090n2056	w4130n2049	w4160n2054	w4200n2046
w4090n2057	w4130n2050	w4160n2055	w4200n2047
w4100n2045	w4130n2051	w4160n2056	w4200n2048
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w4100n2047	w4130n2053	w4160n2058	w4200n2050
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w4100n2053	w4130n2059	w4170n2050	w4200n2056
w4100n2054	w4140n2045	w4170n2051	w4200n2057
w4100n2055	w4140n2046	w4170n2052	w4200n2058
w4100n2056	w4140n2047	w4170n2053	w4200n2059
w4100n2057	w4140n2048	w4170n2054	w4210n2046
w4100n2058	w4140n2049	w4170n2055	w4210n2047
w4110n2045	w4140n2050	w4170n2056	w4210n2048
w4110n2046	w4140n2051	w4170n2057	w4210n2049
w4110n2047	w4140n2052	w4170n2058	w4210n2050
w4110n2048	w4140n2053	w4170n2059	w4210n2051
w4110n2049	w4140n2054	w4180n2046	w4210n2052
w4110n2050	w4140n2055	w4180n2047	w4210n2053
w4110n2051	w4140n2056	w4180n2048	w4210n2054
w4110n2052	w4140n2057	w4180n2049	w4210n2055
w4110n2053	w4140n2058	w4180n2050	w4210n2056
w4110n2054	w4140n2059	w4180n2051	w4210n2057
w4110n2055	w4150n2046	w4180n2052	w4210n2058
w4110n2056	w4150n2047	w4180n2053	w4210n2059

w4220n2046	w4250n2049	w4280n2049	w4310n2049
w4220n2047	w4250n2050	w4280n2050	w4310n2050
w4220n2048	w4250n2051	w4280n2051	w4310n2051
w4220n2049	w4250n2052	w4280n2052	w4310n2052
w4220n2050	w4250n2053	w4280n2053	w4310n2053
w4220n2051	w4250n2054	w4280n2054	w4310n2054
w4220n2052	w4250n2055	w4280n2055	w4310n2055
w4220n2053	w4250n2056	w4280n2056	w4310n2056
w4220n2054	w4250n2057	w4280n2057	w4310n2057
w4220n2055	w4250n2058	w4280n2058	w4310n2058
w4220n2056	w4250n2059	w4280n2059	w4310n2059
w4220n2057	w4250n2060	w4280n2060	w4310n2060
w4220n2058	w4250n2061	w4280n2061	w4310n2061
w4220n2059	w4250n2062	w4280n2062	w4310n2062
w4220n2060	w4260n2046	w4290n2046	w4320n2046
w4230n2046	w4260n2047	w4290n2047	w4320n2047
w4230n2047	w4260n2048	w4290n2048	w4320n2048
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w4250n2046	w4280n2046	w4310n2046	w4340n2046
w4250n2047	w4280n2047	w4310n2047	w4340n2047
w4250n2048	w4280n2048	w4310n2048	w4340n2048

w4340n2049	w4360n2060	w4380n2059	w4400n2055
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w4350n2176	w4370n2176	w4390n2172	w4410n2058
w4350n2177	w4370n2177	w4390n2173	w4410n2059
w4350n2178	w4370n2178	w4390n2174	w4410n2060
w4350n2179	w4370n2179	w4390n2175	w4410n2061
w4350n2180	w4370n2180	w4390n2176	w4410n2062
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w4360n2047	w4380n2046	w4390n2178	w4410n2064
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w4360n2049	w4380n2048	w4390n2180	w4410n2173
w4360n2050	w4380n2049	w4390n2181	w4410n2174
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w4360n2054	w4380n2053	w4400n2049	w4410n2178
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w4360n2057	w4380n2056	w4400n2052	w4410n2181
w4360n2058	w4380n2057	w4400n2053	w4420n2047
w4360n2059	w4380n2058	w4400n2054	w4420n2048

w4420n2049	w4430n2172	w4450n2053	w4460n2067
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w4420n2051	w4430n2174	w4450n2055	w4460n2069
w4420n2052	w4430n2175	w4450n2056	w4460n2070
w4420n2053	w4430n2176	w4450n2057	w4460n2167
w4420n2054	w4430n2177	w4450n2058	w4460n2168
w4420n2055	w4430n2178	w4450n2059	w4460n2169
w4420n2056	w4430n2179	w4450n2060	w4460n2170
w4420n2057	w4430n2180	w4450n2061	w4460n2171
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w5760n2110	w5770n2099	w5770n2150	w5780n2139
w5760n2111	w5770n2100	w5780n2089	w5780n2140
w5760n2112	w5770n2101	w5780n2090	w5780n2141
w5760n2113	w5770n2102	w5780n2091	w5780n2142
w5760n2114	w5770n2103	w5780n2092	w5780n2143
w5760n2115	w5770n2104	w5780n2093	w5780n2144
w5760n2116	w5770n2105	w5780n2094	w5780n2145
w5760n2117	w5770n2106	w5780n2095	w5780n2146
w5760n2118	w5770n2107	w5780n2096	w5780n2147
w5760n2119	w5770n2108	w5780n2097	w5780n2148
w5760n2120	w5770n2109	w5780n2098	w5780n2149
w5760n2121	w5770n2110	w5780n2099	w5780n2150
w5760n2122	w5770n2111	w5780n2100	w5790n2089
w5760n2123	w5770n2112	w5780n2101	w5790n2090
w5760n2124	w5770n2113	w5780n2102	w5790n2091
w5760n2125	w5770n2114	w5780n2103	w5790n2092
w5760n2126	w5770n2115	w5780n2104	w5790n2093
w5760n2127	w5770n2116	w5780n2105	w5790n2094
w5760n2128	w5770n2117	w5780n2106	w5790n2095
w5760n2129	w5770n2118	w5780n2107	w5790n2096
w5760n2130	w5770n2119	w5780n2108	w5790n2097
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w5760n2132	w5770n2121	w5780n2110	w5790n2099
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w5760n2139	w5770n2128	w5780n2117	w5790n2106
w5760n2140	w5770n2129	w5780n2118	w5790n2107
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w5760n2142	w5770n2131	w5780n2120	w5790n2109
w5760n2143	w5770n2132	w5780n2121	w5790n2110
w5760n2144	w5770n2133	w5780n2122	w5790n2111

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w5790n2117	w5800n2106	w5810n2095	w5820n2099
w5790n2118	w5800n2107	w5810n2096	w5820n2100
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w5790n2142	w5800n2131	w5810n2120	w5830n2089
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w5790n2144	w5800n2133	w5810n2122	w5830n2091
w5790n2145	w5800n2134	w5810n2123	w5830n2092
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w5800n2093	w5800n2144	w5810n2133	w5830n2102
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w5800n2100	w5810n2089	w5820n2093	w5830n2109

w5840n2089
w5840n2090
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w5840n2097

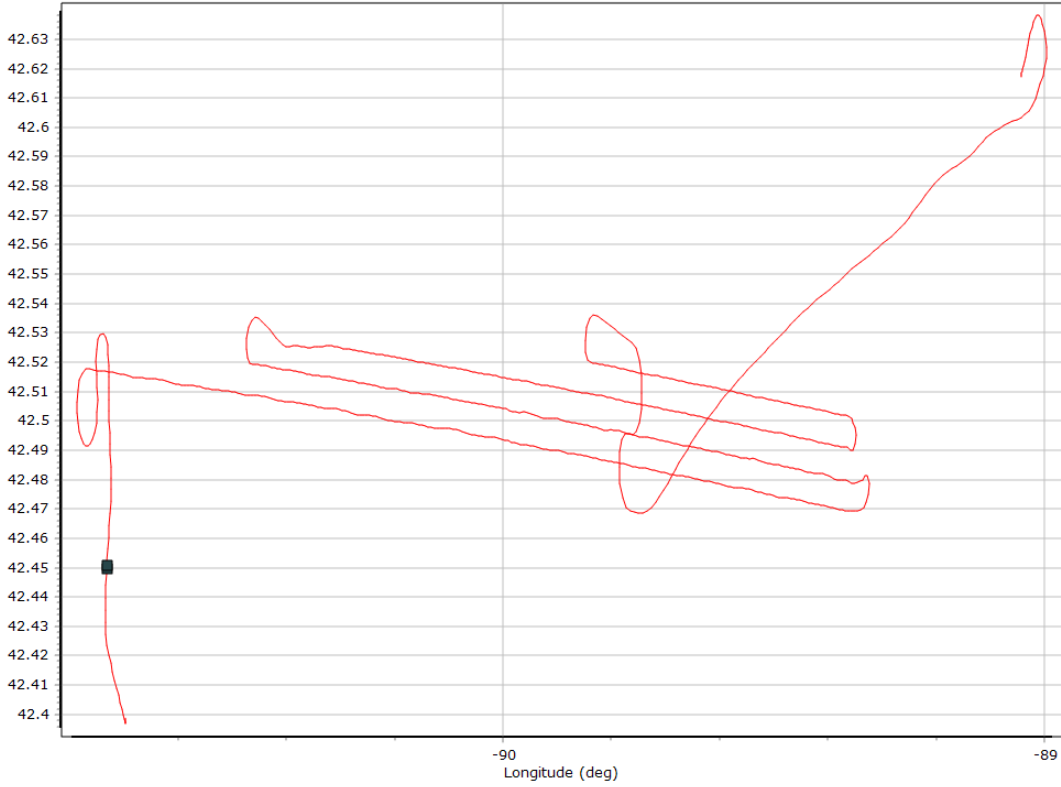
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Appendix B: ASI Mission GPS and IMU Processing Report

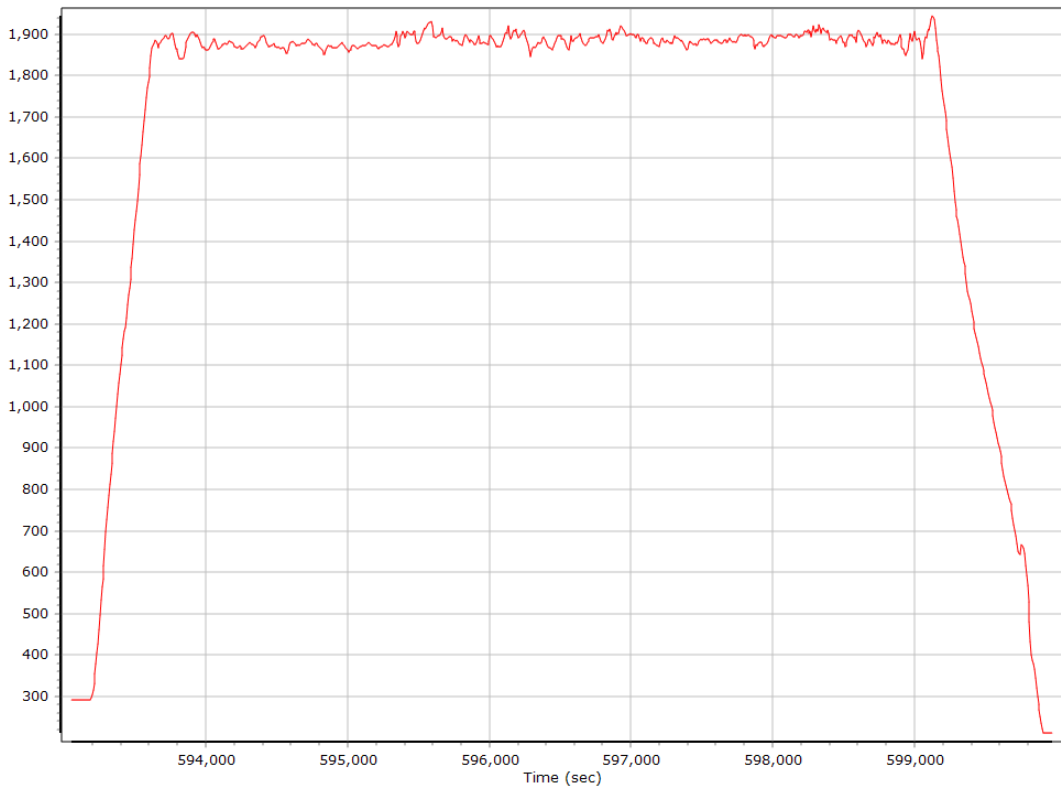
POSPac MMS 8.4 Diagnostic QC Report - report_Mission 1.pdf - 11/02/2020 14:15:35

Smoothed Trajectory Information

Top View



Altitude

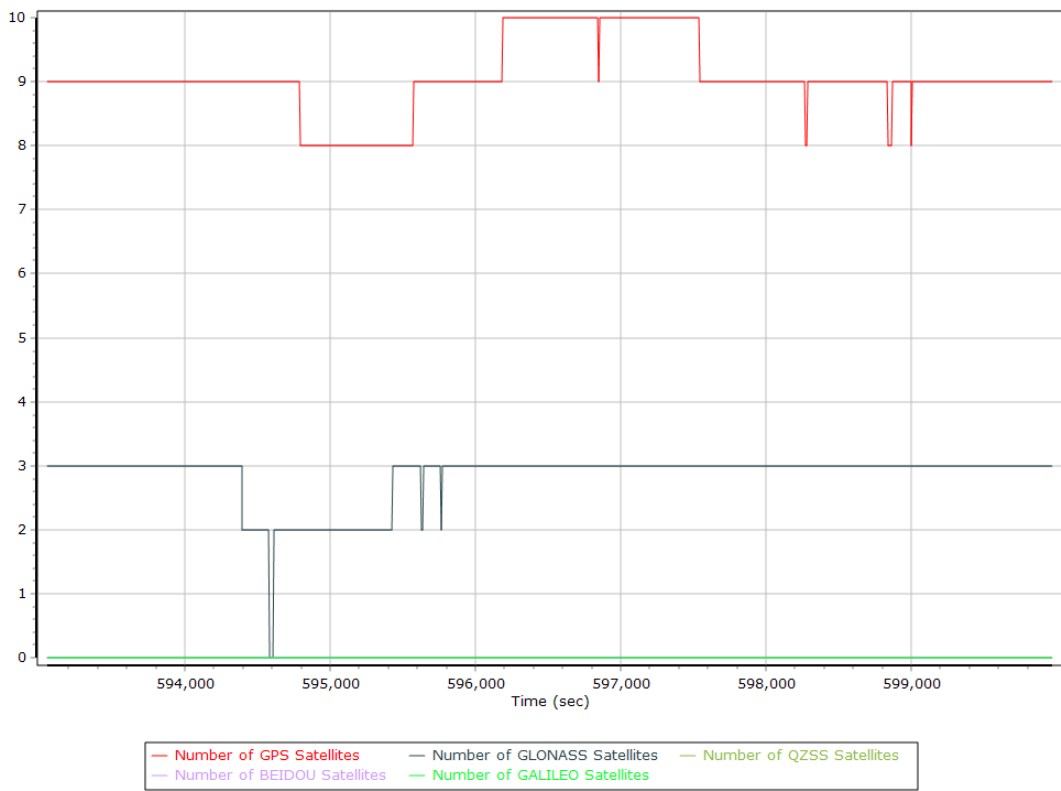


GNSS QC

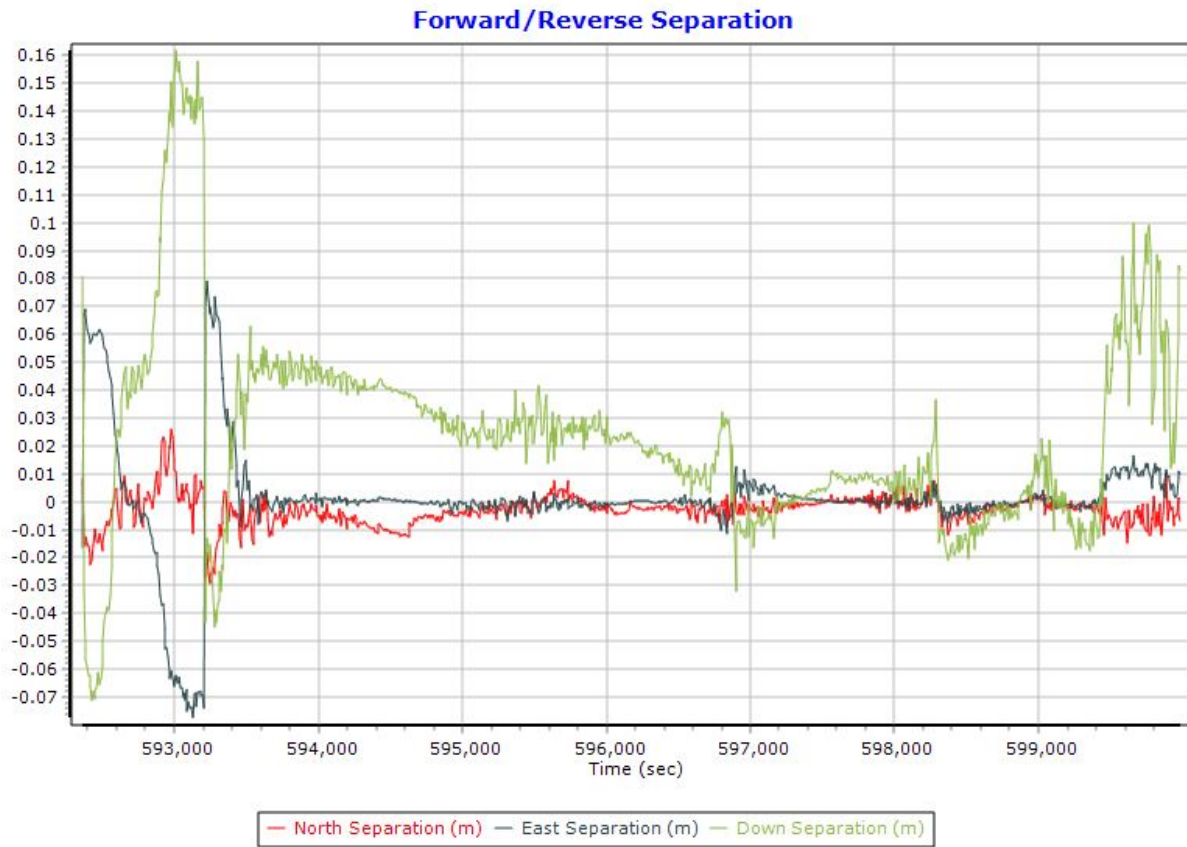
GNSS QC Statistics

Statistics	Min	Max	Mean
Baseline length (km)	0.58	81.77	
Number of GPS SV	5	10	9
Number of GLONASS SV	0	3	3
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Number of GALILEO SV	0	0	0
Total number of SV	5	13	12
PDOP	1.35	6.70	1.61
QC Solution Gaps	1.00	2.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	7618.00	1.00	3.00
Percentage	99.95	0.01	0.04

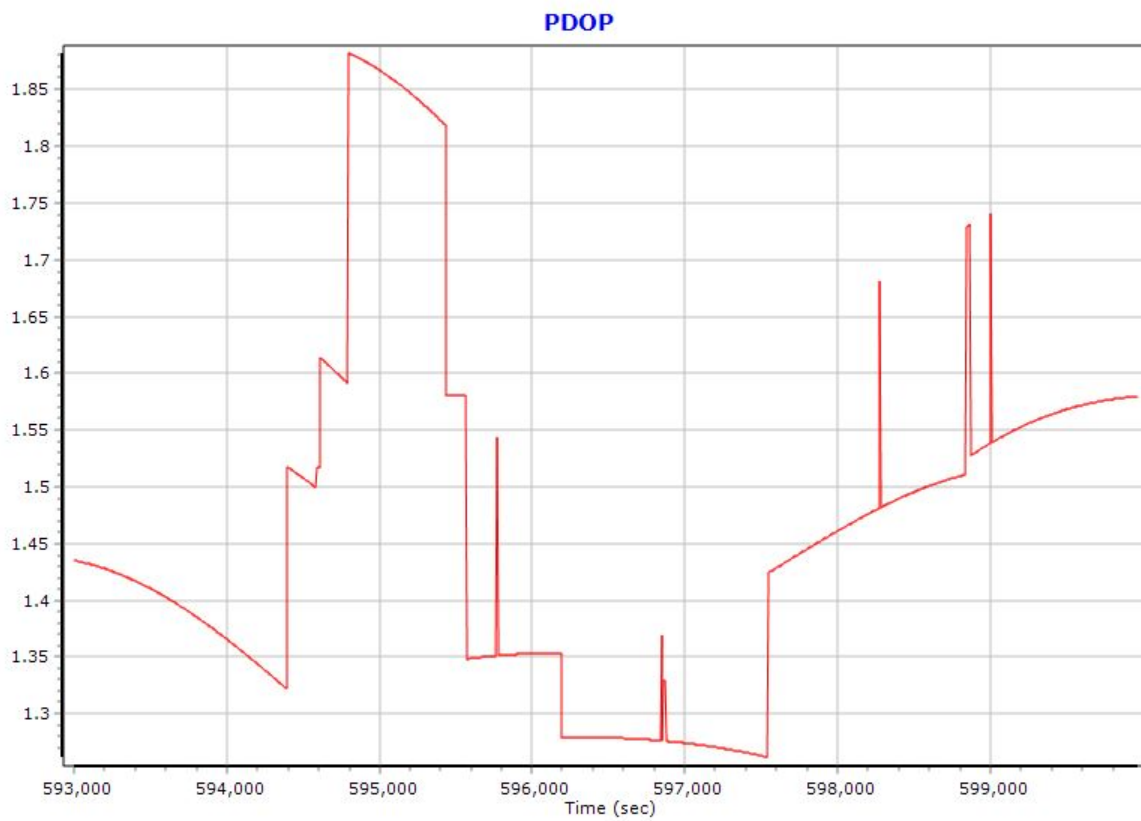
Number of Satellites



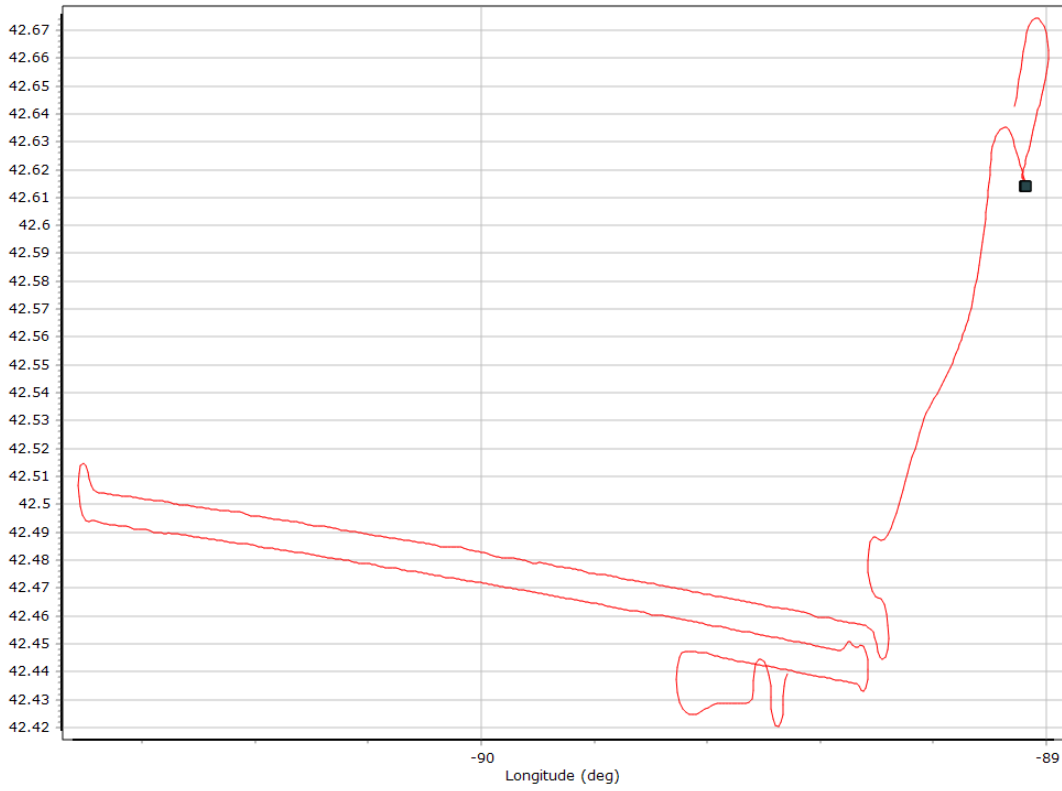
Forward/Reverse Separation



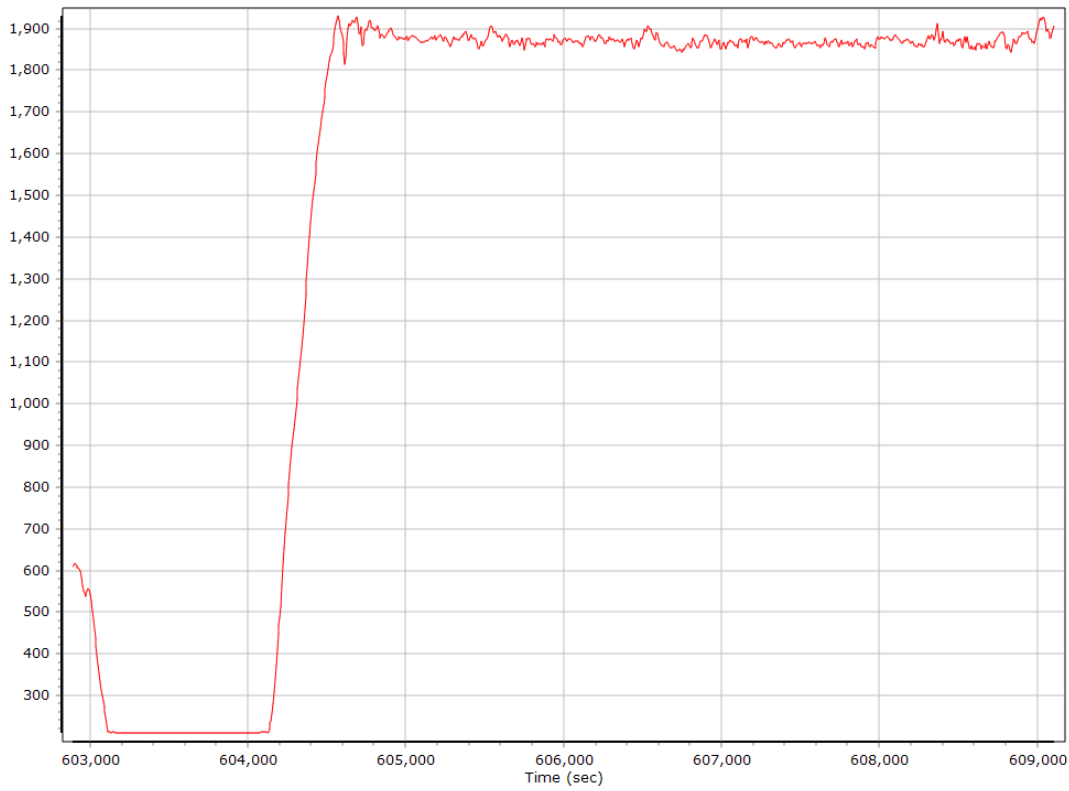
PDOP



Top View



Altitude

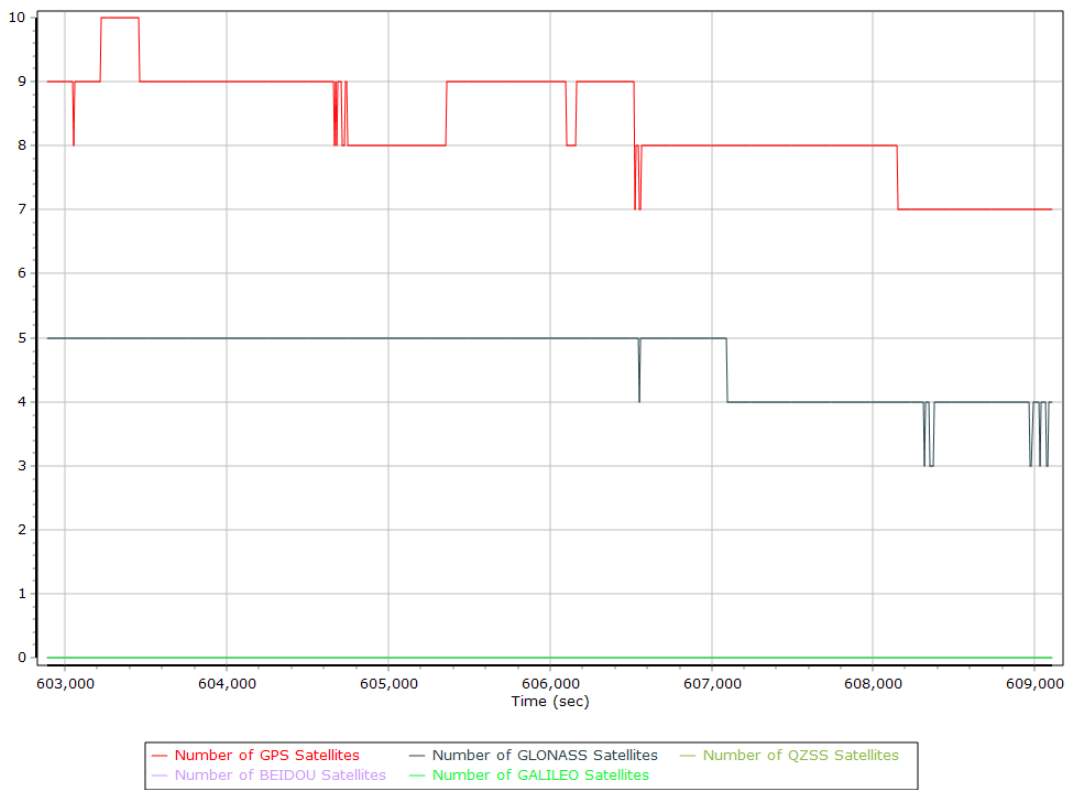


GNSS QC

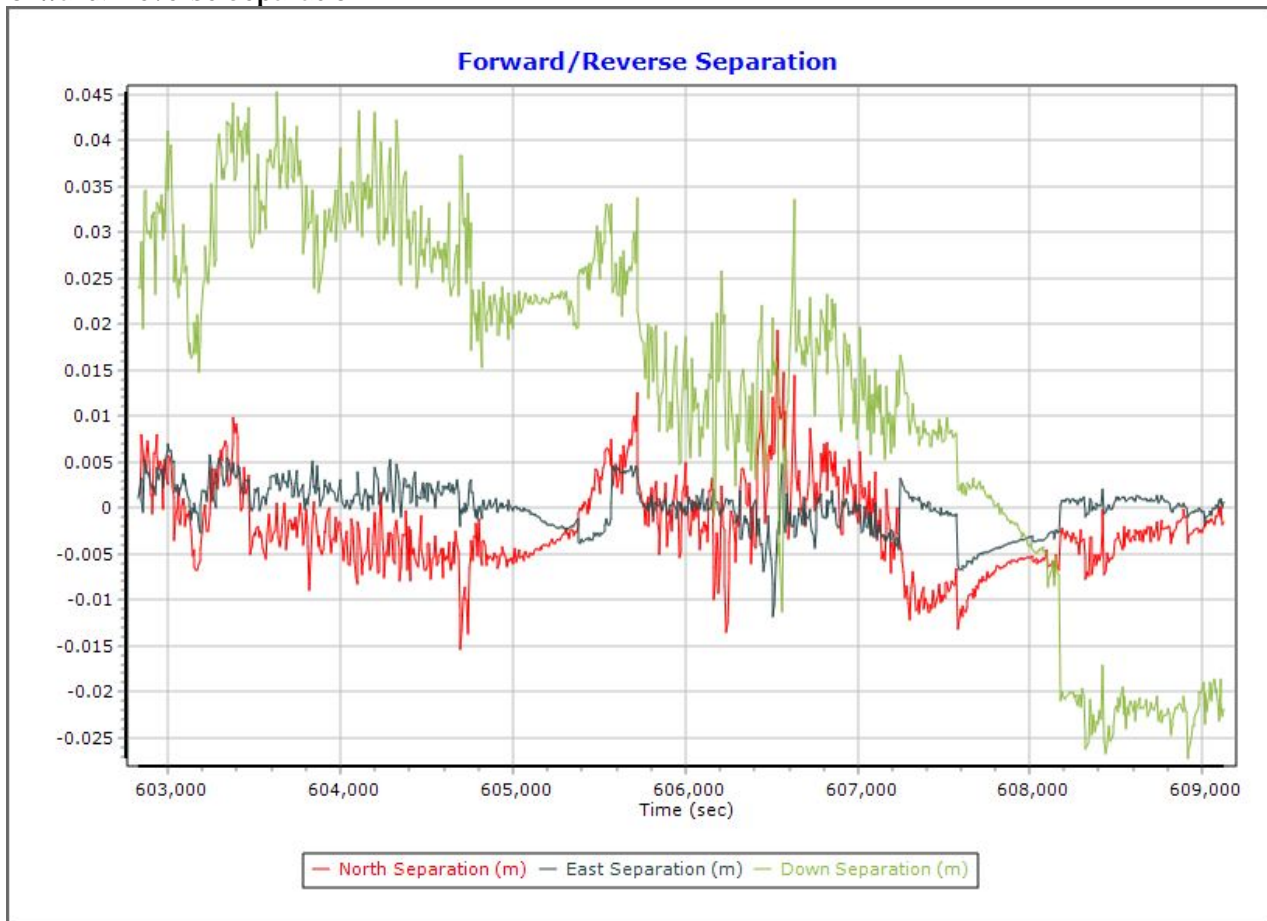
GNSS QC Statistics

Statistics	Min	Max	Mean
Baseline length (km)	4.38	86.07	
Number of GPS SV	7	10	8
Number of GLONASS SV	0	7	6
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Number of GALILEO SV	0	0	0
Total number of SV	9	16	14
PDOP	1.25	1.94	1.49
QC Solution Gaps	0.00	0.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	6256.00	0.00	0.00
Percentage	100.00	0.00	0.00

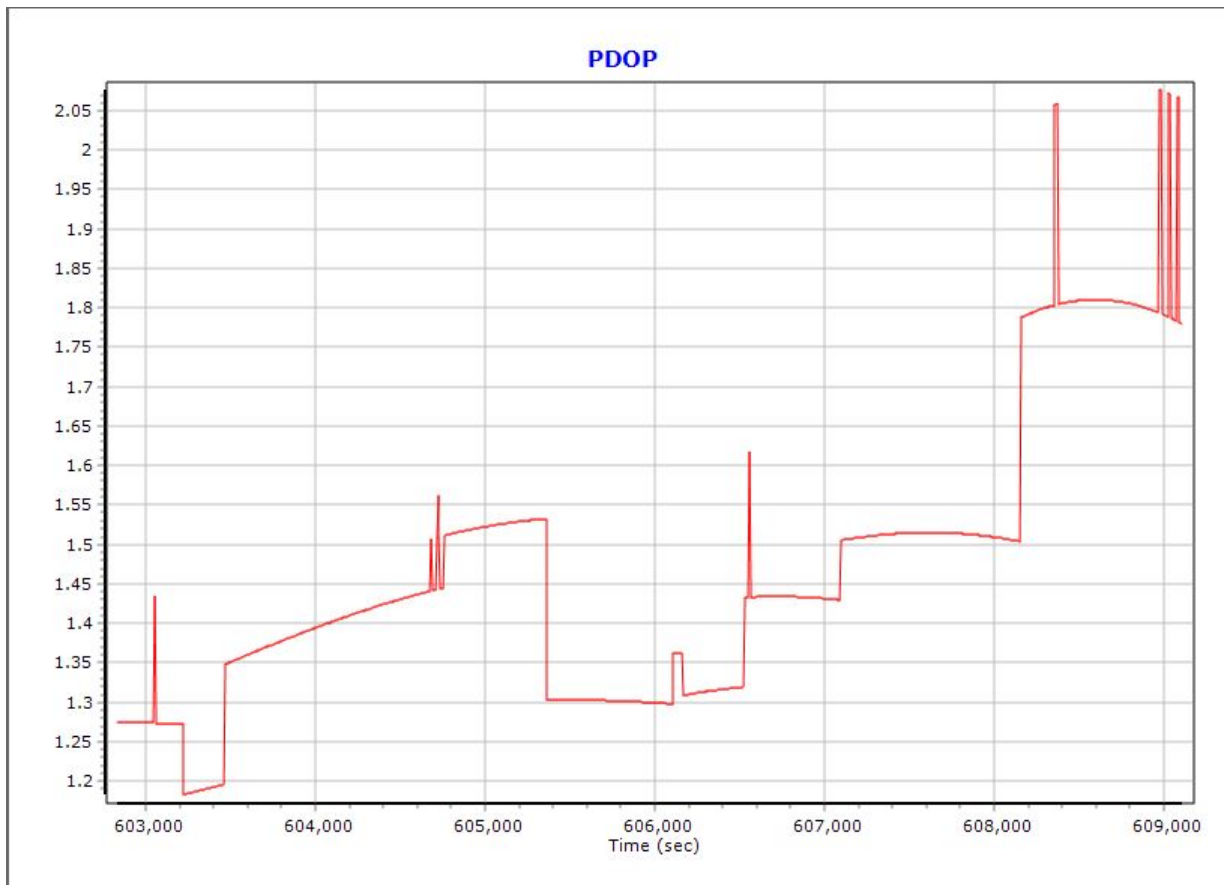
Number of Satellites



Forward/Reverse Separation

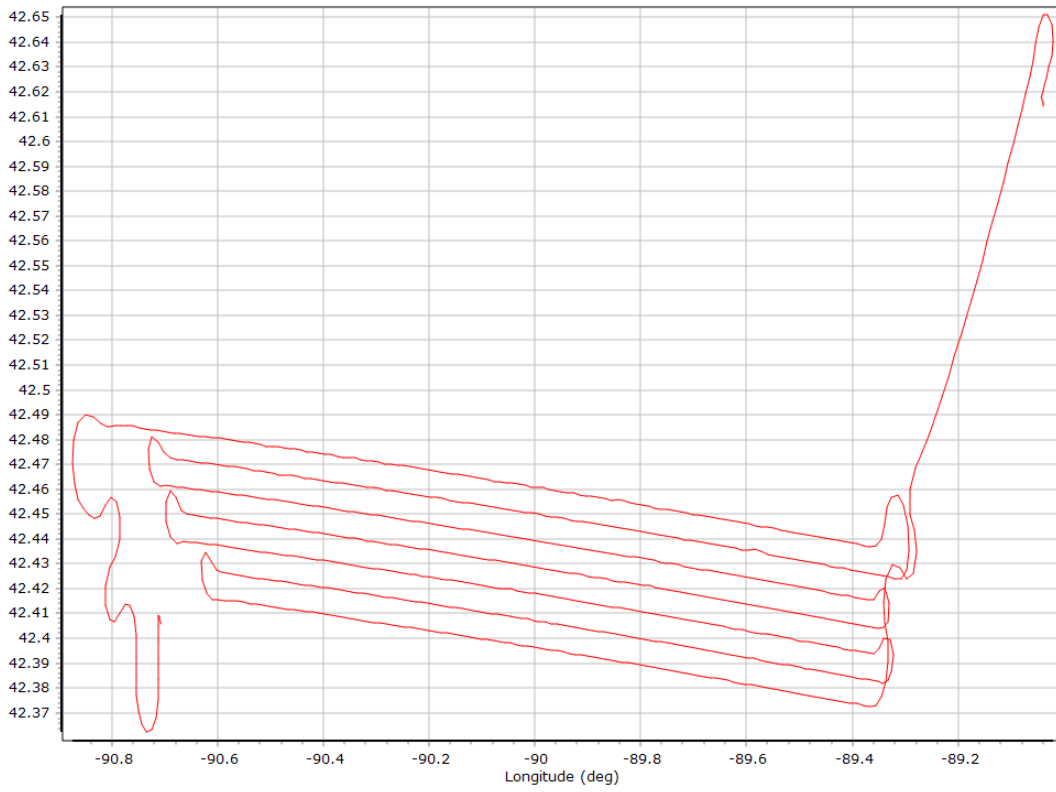


PDOP

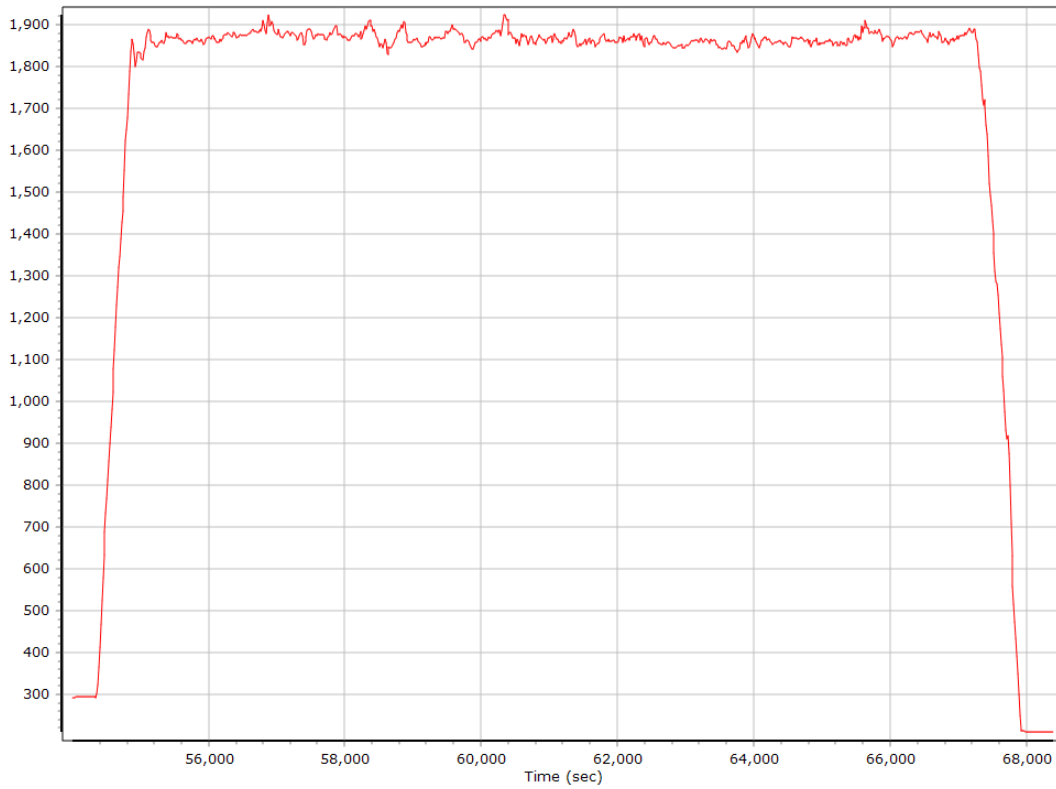


Smoothed Trajectory Information

Top View



Altitude

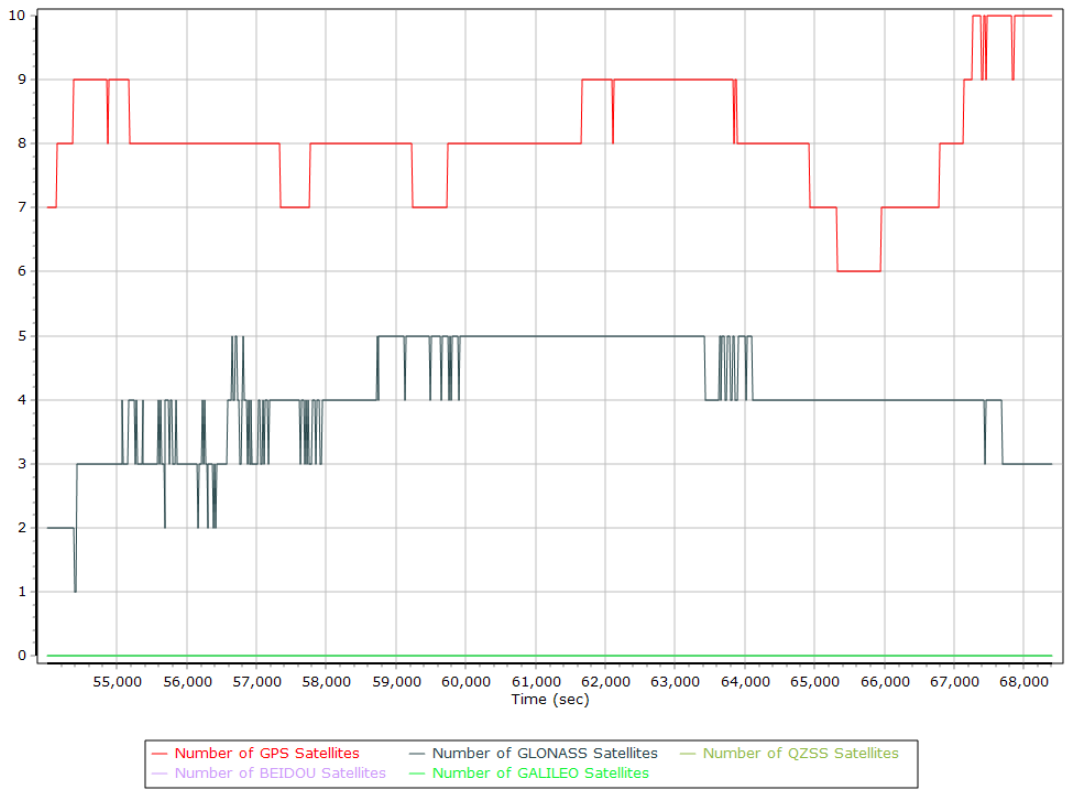


GNSS QC

GNSS QC Statistics

Statistics	Min	Max	Mean
Baseline length (km)	0.35	85.16	
Number of GPS SV	5	10	8
Number of GLONASS SV	0	6	5
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Number of GALILEO SV	0	0	0
Total number of SV	7	15	13
PDOP	1.20	2.46	1.55
QC Solution Gaps	1.00	1.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	15015.00	0.00	1.00
Percentage	99.99	0.00	0.01

Number of Satellites



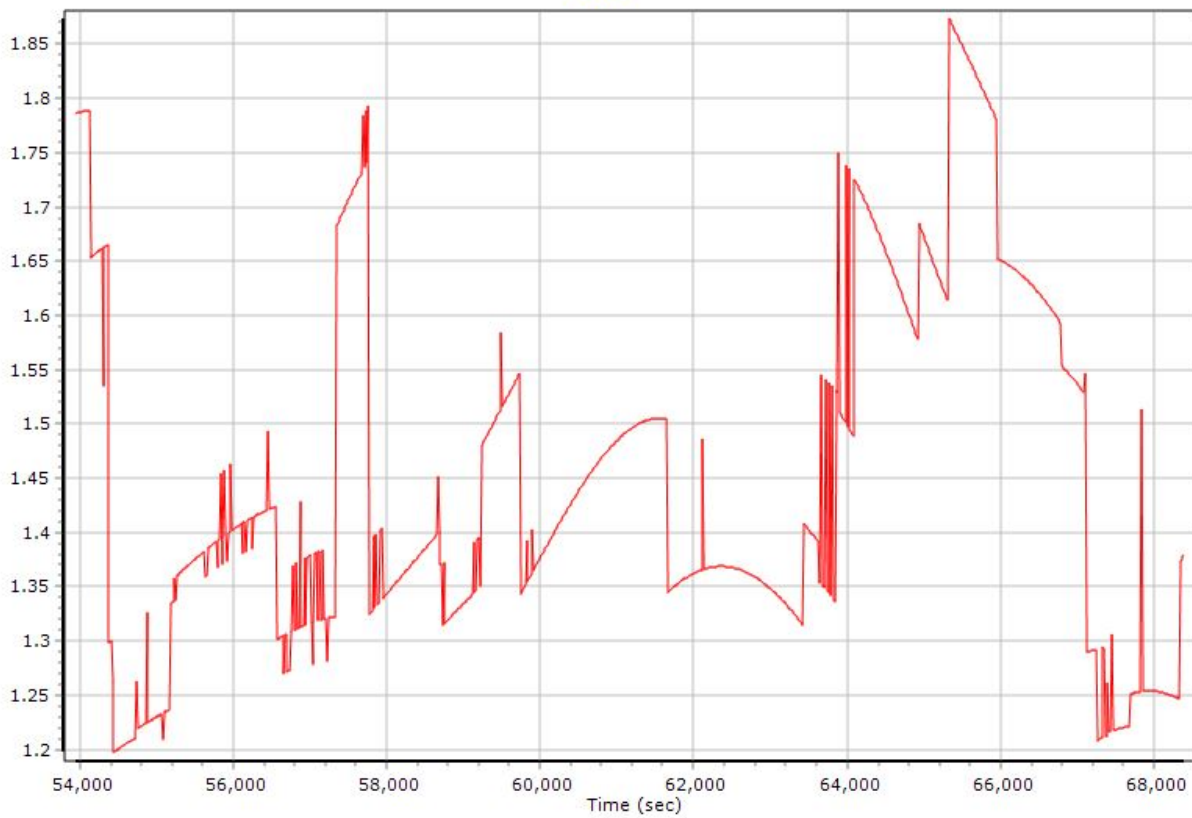
Forward/Reverse Separation

Forward/Reverse Separation



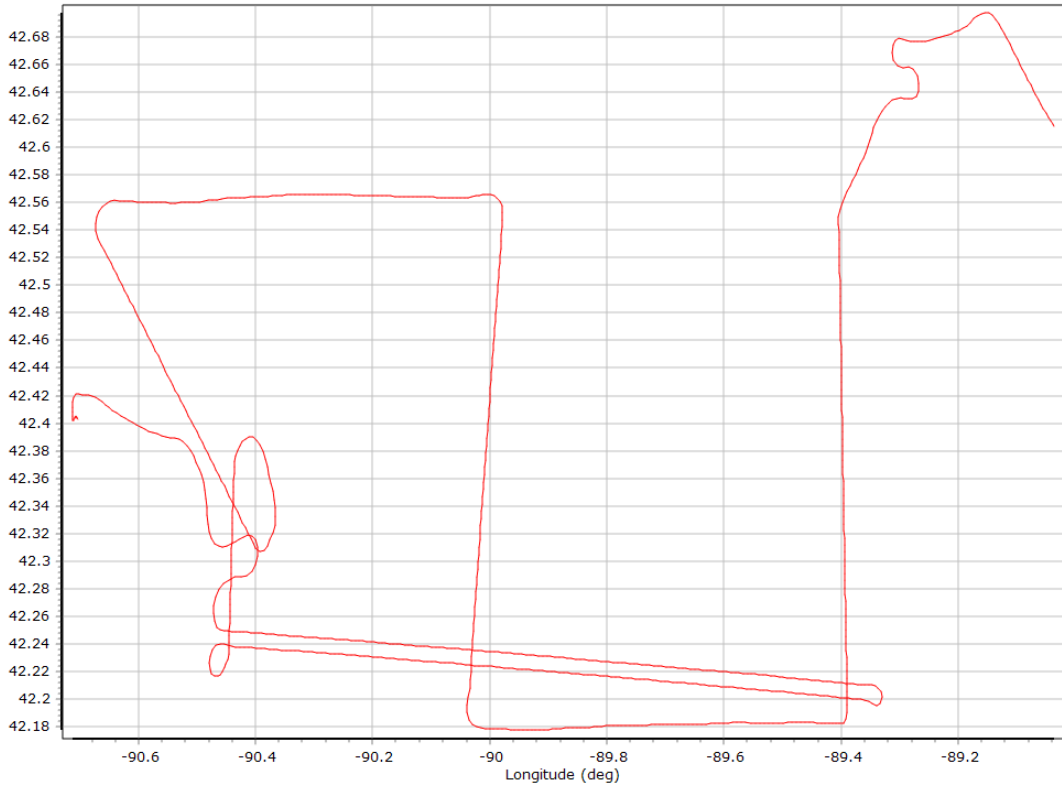
PDOP

PDOP

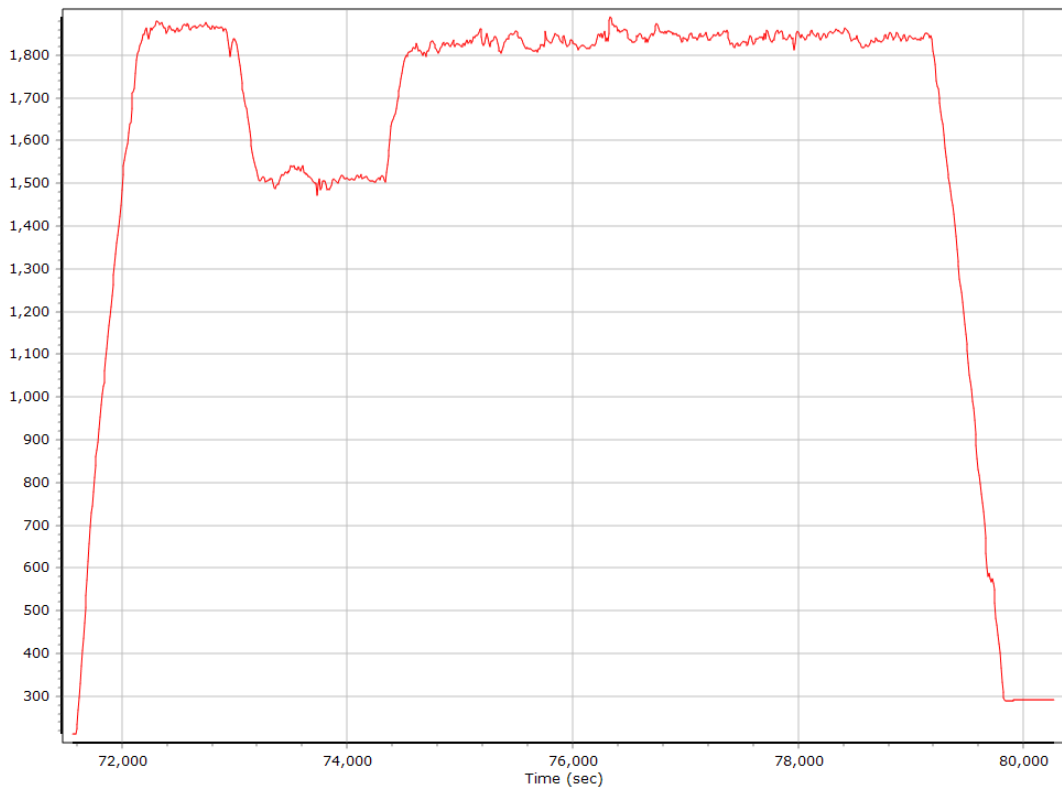


Smoothed Trajectory Information

Top View



Altitude

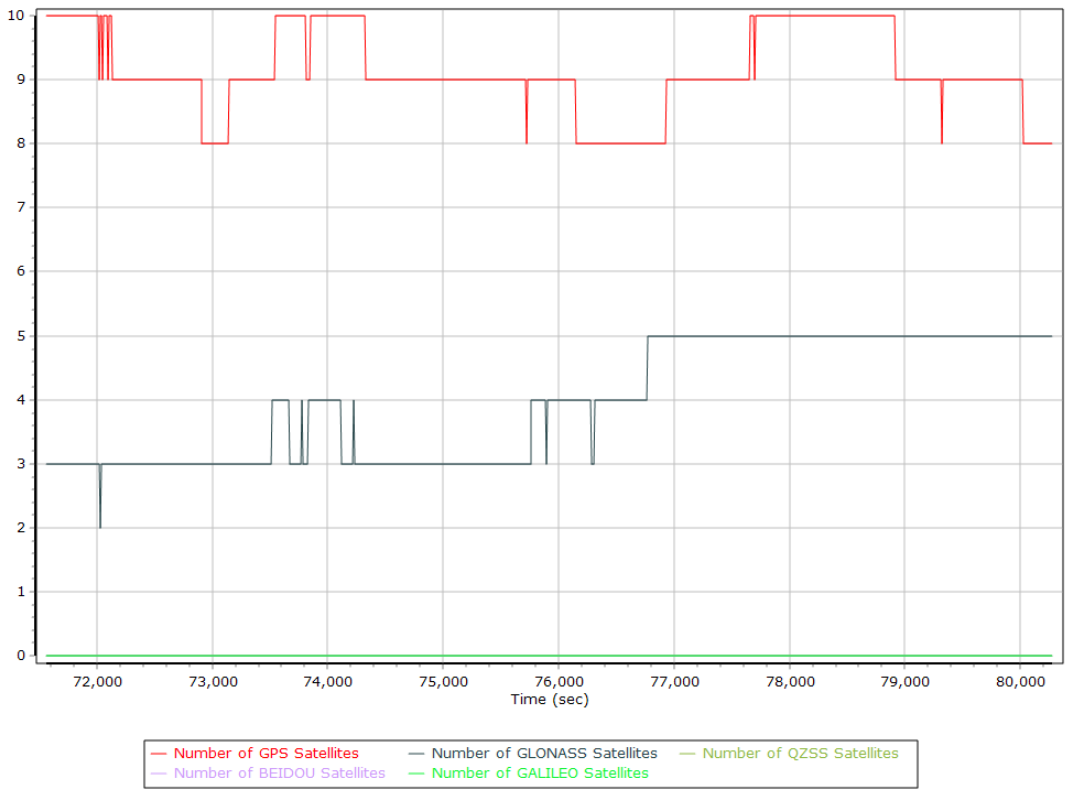


GNSS QC

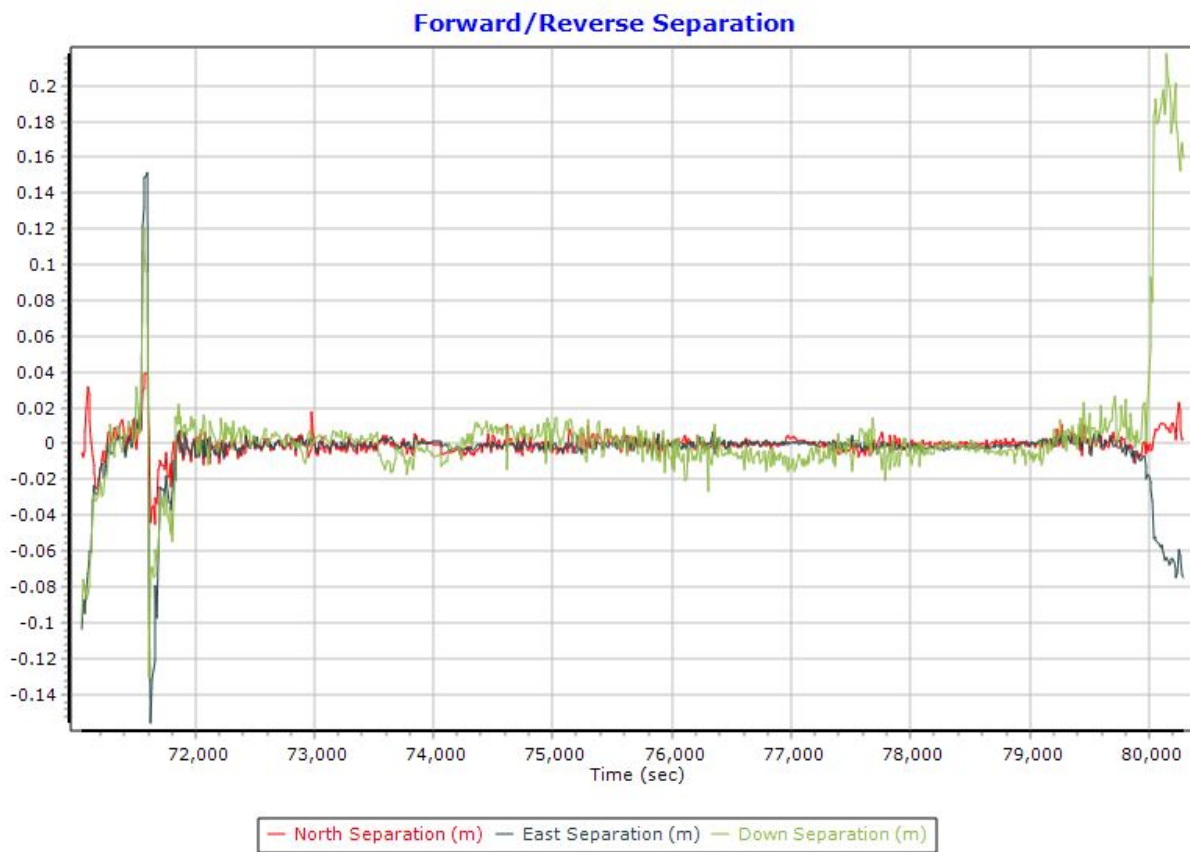
GNSS QC Statistics

Statistics	Min	Max	Mean
Baseline length (km)	5.71	79.33	
Number of GPS SV	8	10	9
Number of GLONASS SV	0	5	4
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Number of GALILEO SV	0	0	0
Total number of SV	9	15	13
PDOP	1.26	2.04	1.56
QC Solution Gaps	1.00	1.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	9213.00	0.00	1.00
Percentage	99.99	0.00	0.01

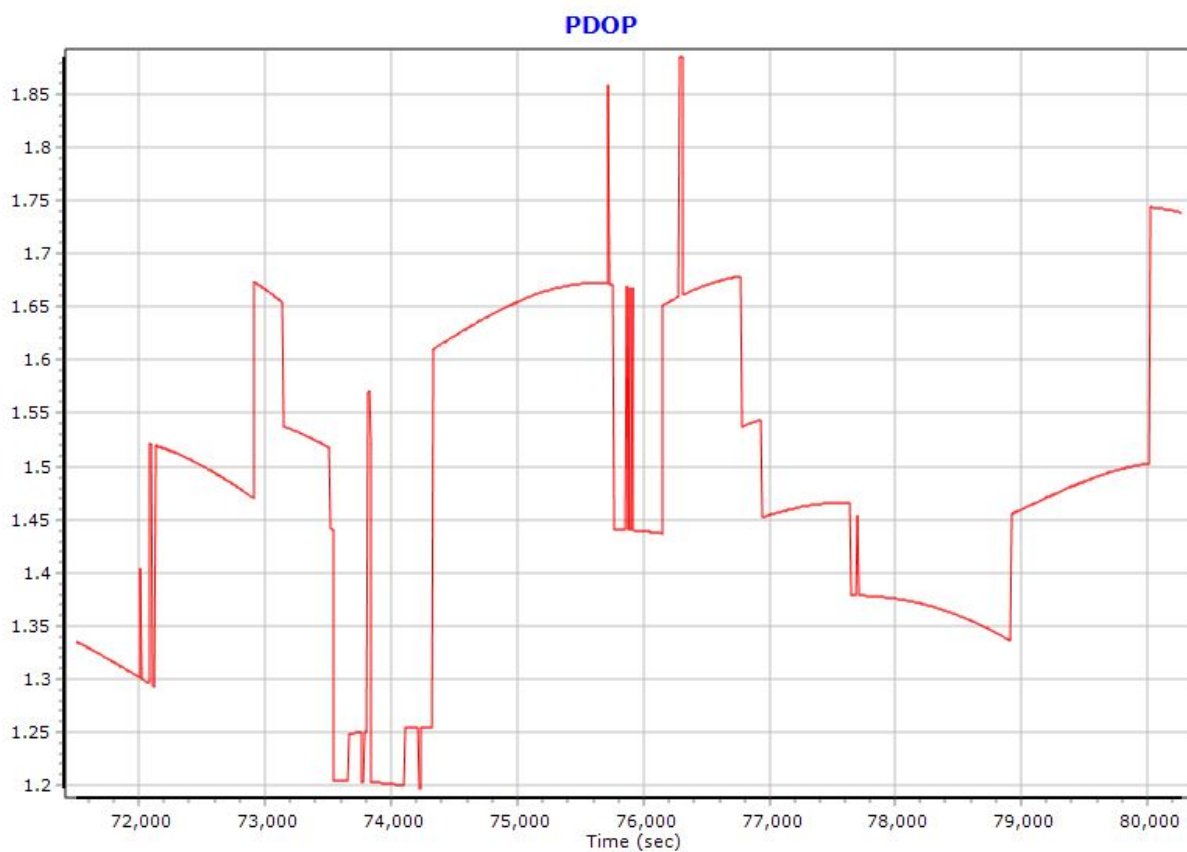
Number of Satellites



Forward/Reverse Separation

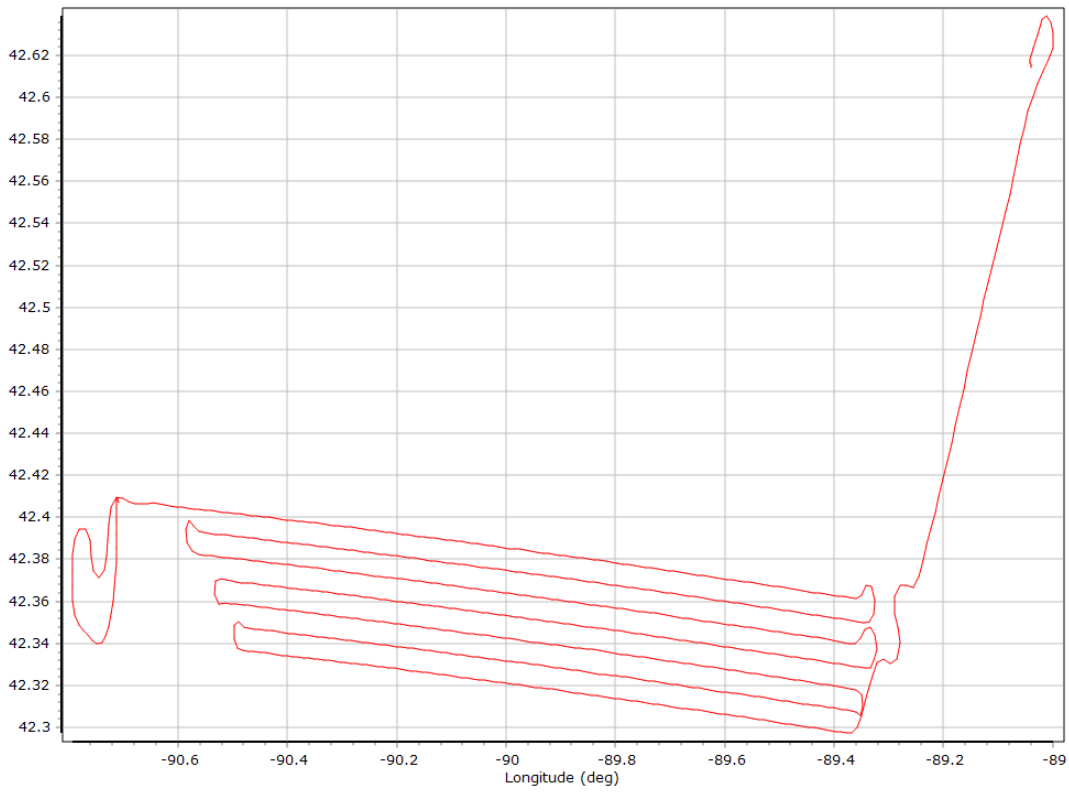


PDOP

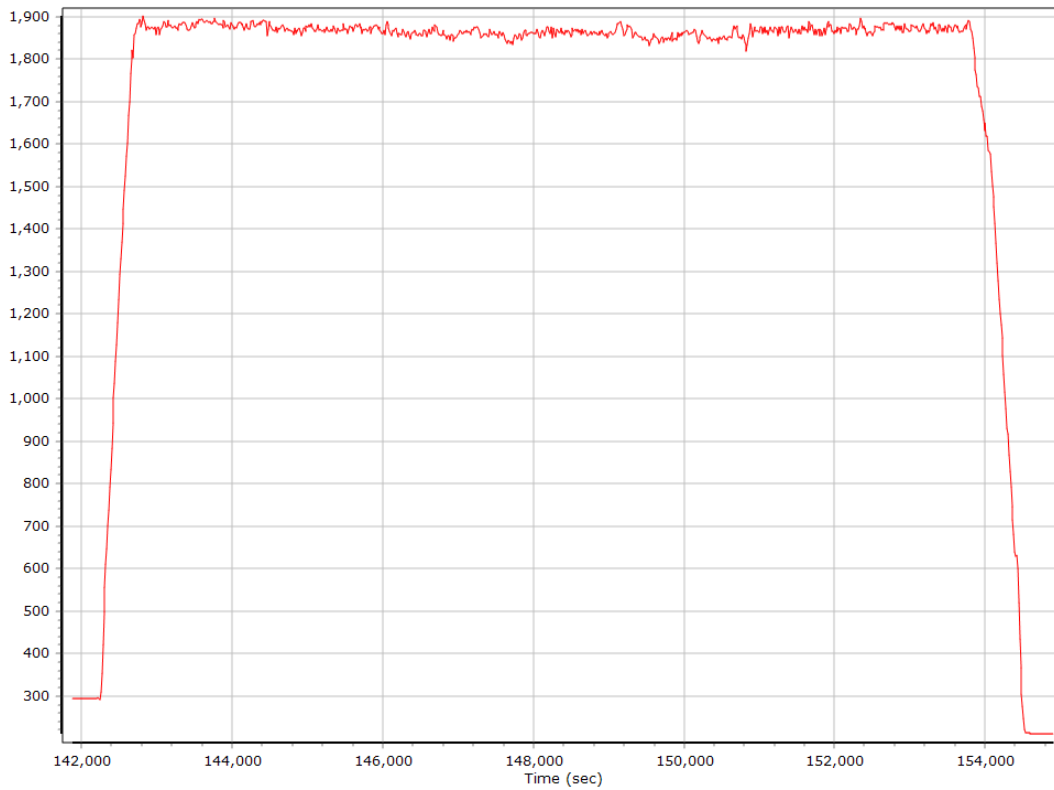


Smoothed Trajectory Information

Top View



Altitude

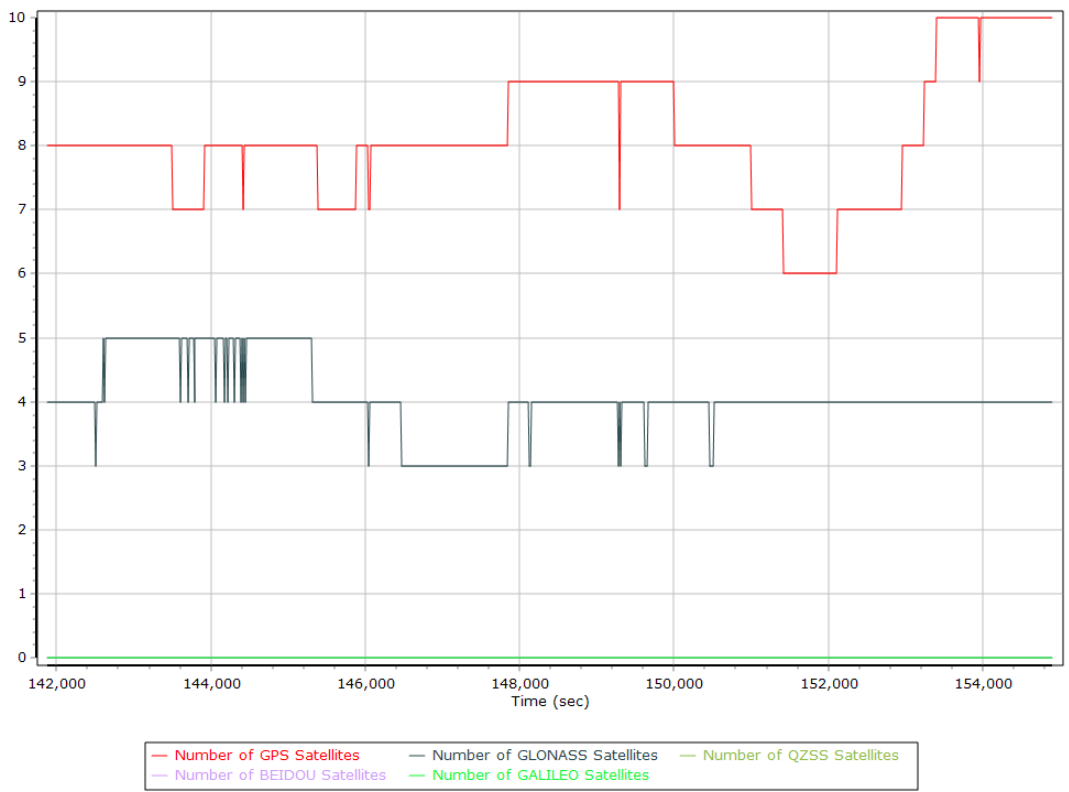


GNSS QC

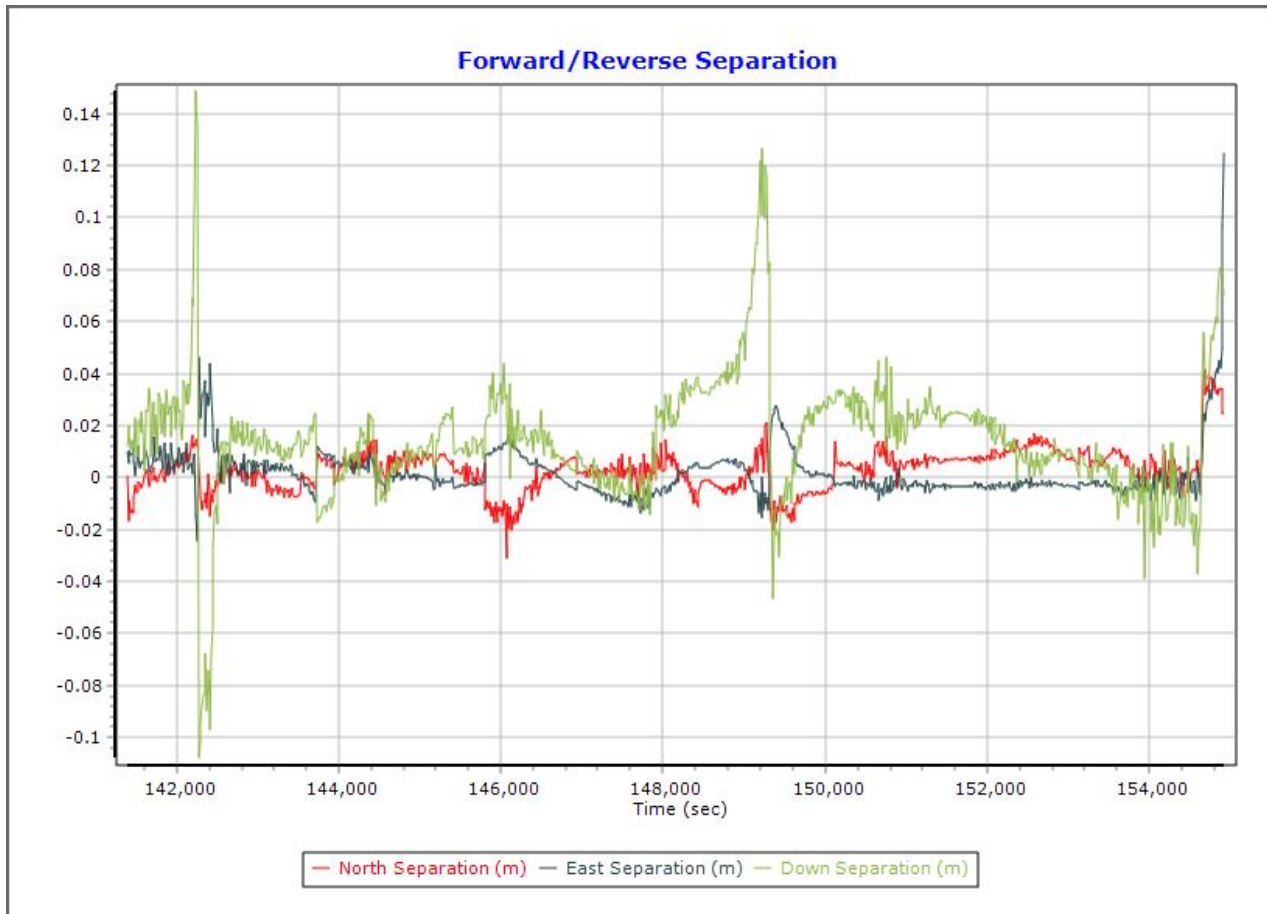
GNSS QC Statistics

Statistics	Min	Max	Mean
Baseline length (km)	0.44	83.89	
Number of GPS SV	6	10	8
Number of GLONASS SV	0	6	4
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Number of GALILEO SV	0	0	0
Total number of SV	8	15	12
PDOP	1.22	2.27	1.57
QC Solution Gaps	1.00	1.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	13536.00	0.00	1.00
Percentage	99.99	0.00	0.01

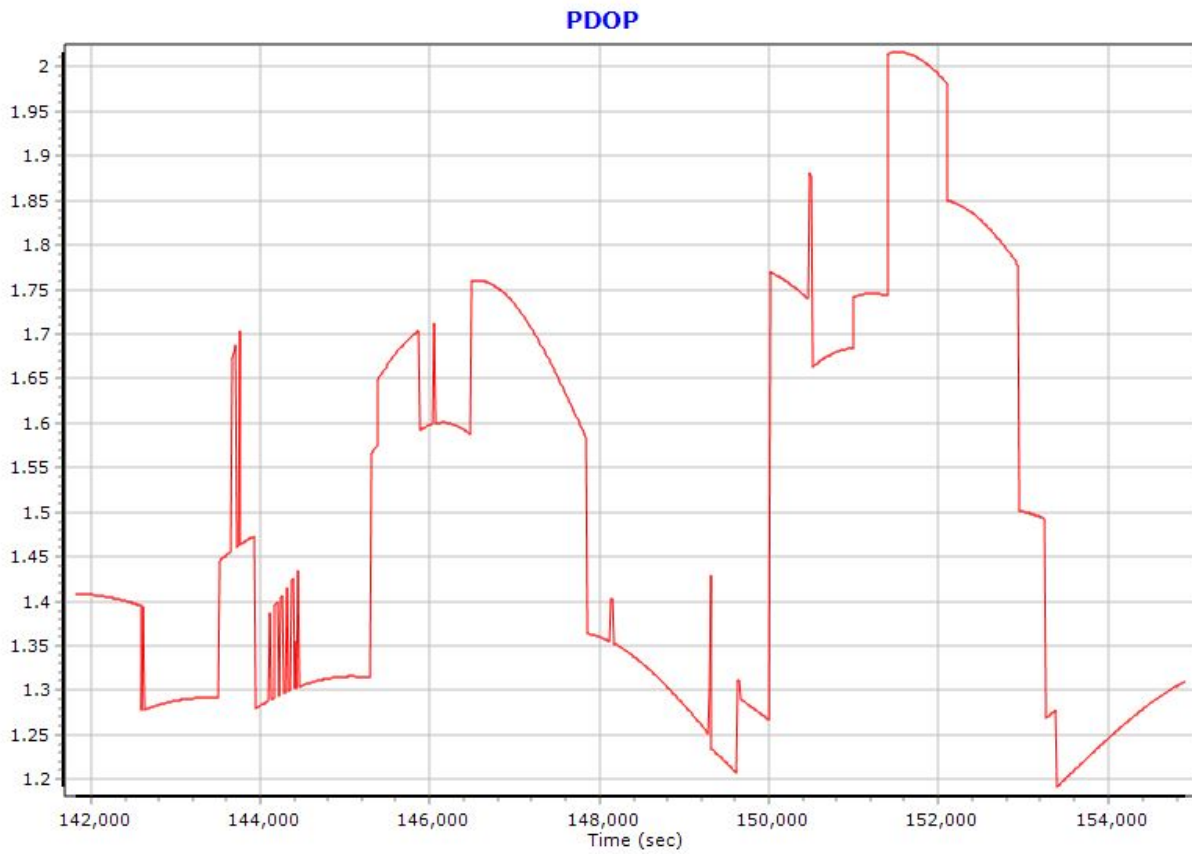
Number of Satellites



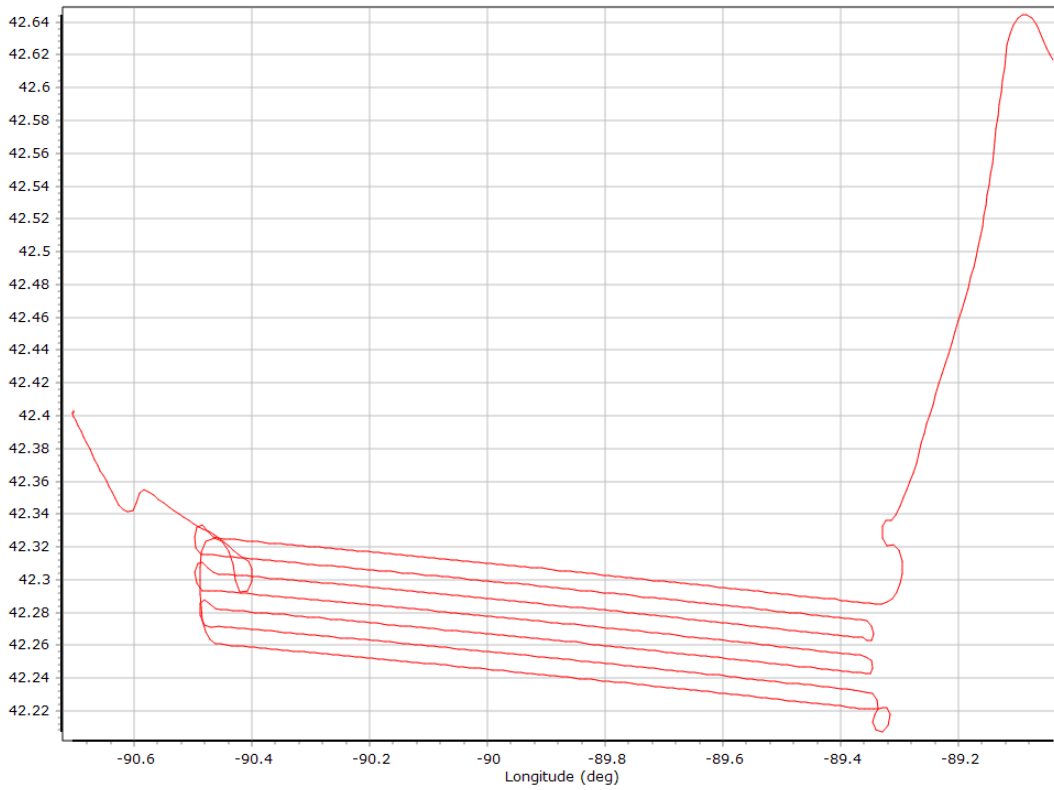
Forward/Reverse Separation



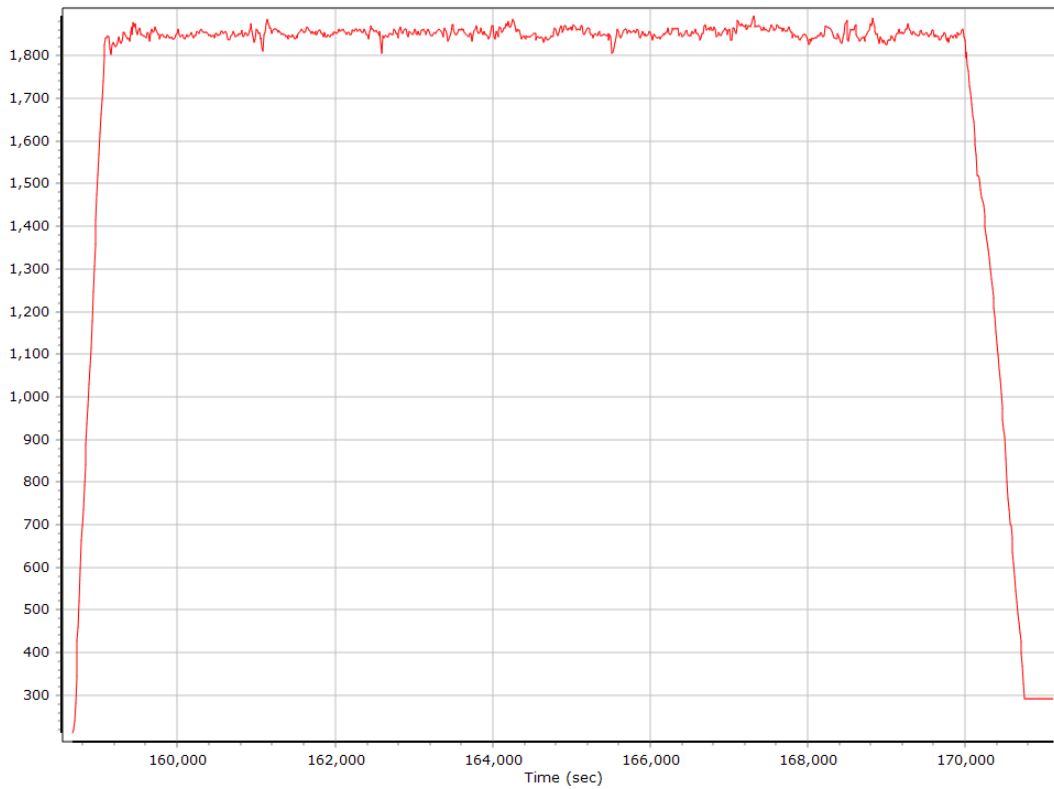
PDOP



Top View



Altitude

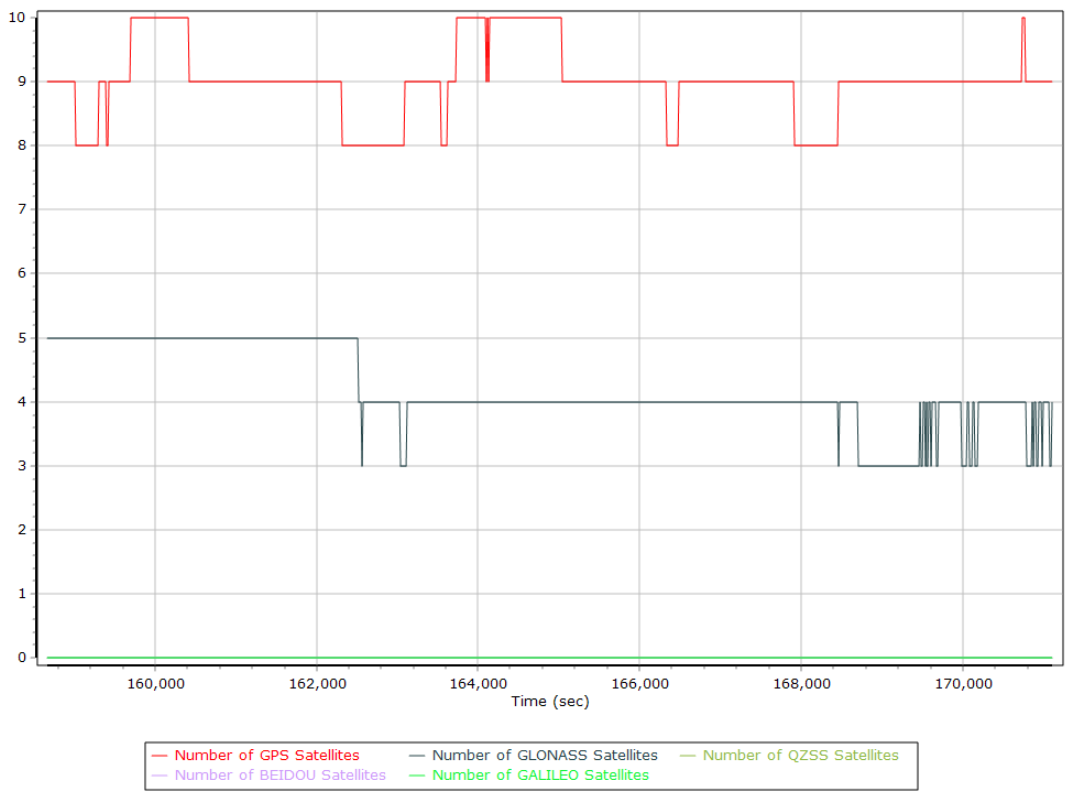


GNSS QC

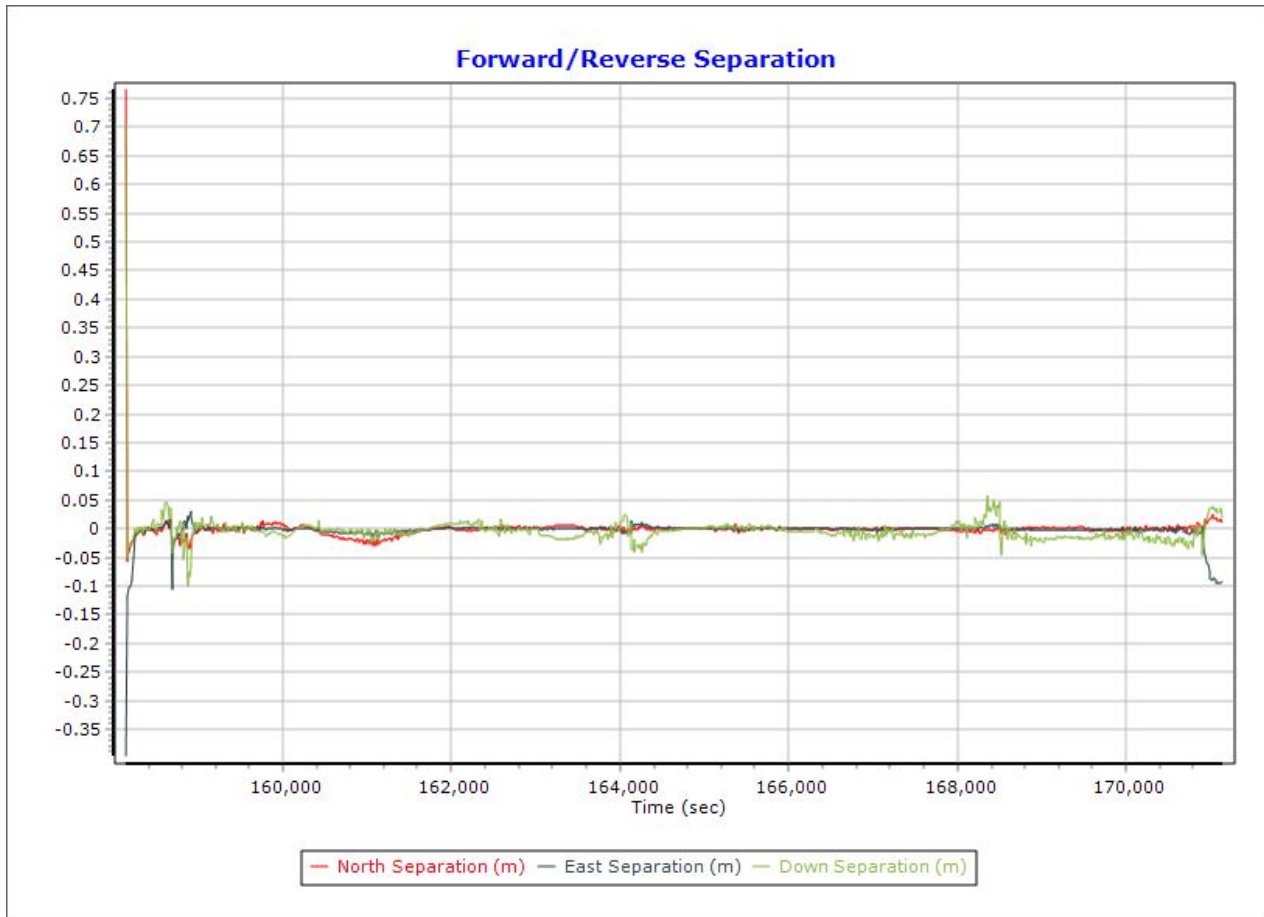
GNSS QC Statistics

Statistics	Min	Max	Mean
Baseline length (km)	0.37	77.14	
Number of GPS SV	5	10	9
Number of GLONASS SV	0	6	4
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Number of GALILEO SV	0	0	0
Total number of SV	5	16	13
PDOP	1.23	2.98	1.45
QC Solution Gaps	1.00	1.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	12968.00	0.00	1.00
Percentage	99.99	0.00	0.01

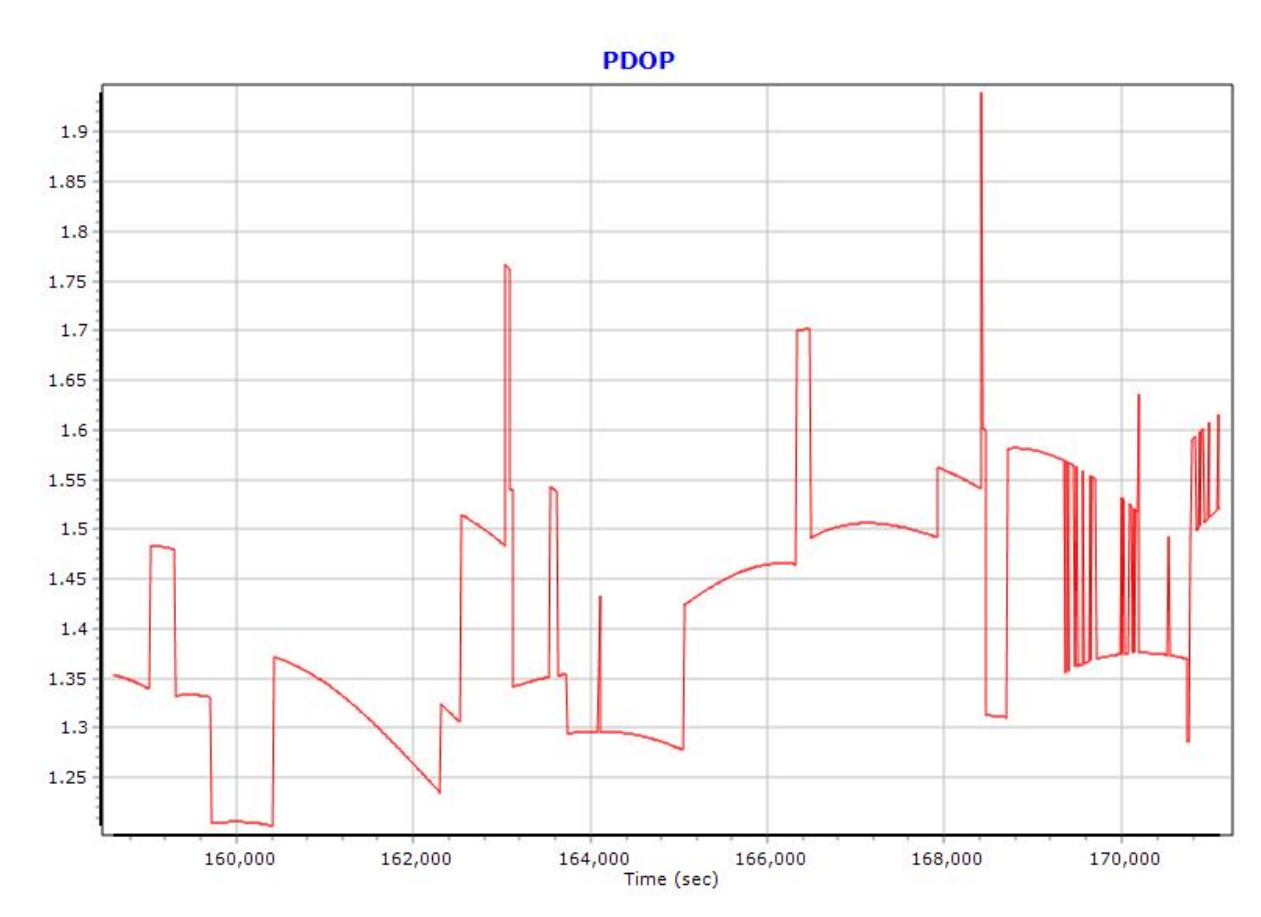
Number of Satellites



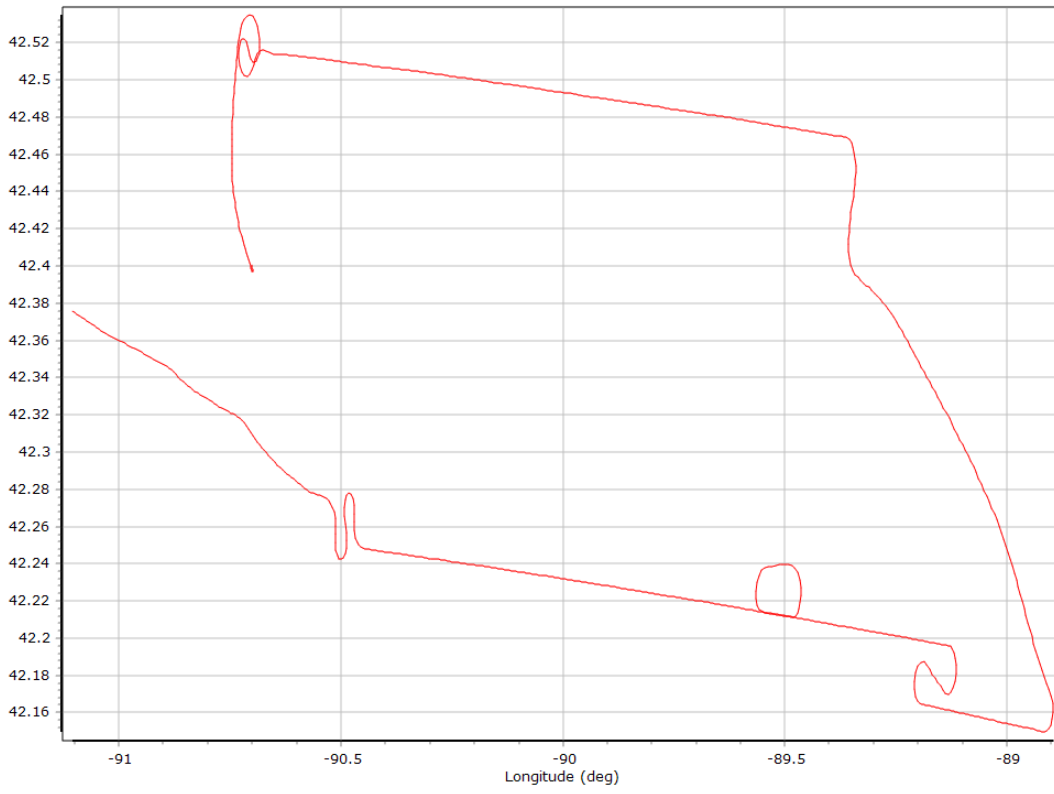
Forward/Reverse Separation



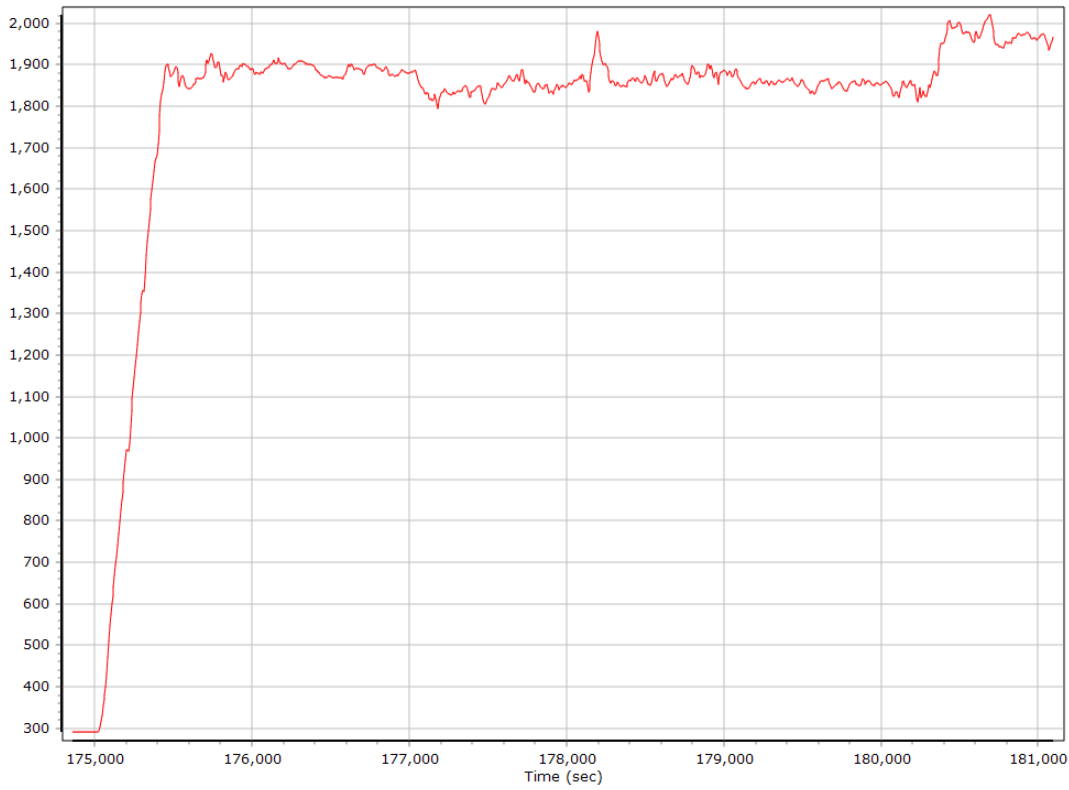
PDOP



Top View



Altitude

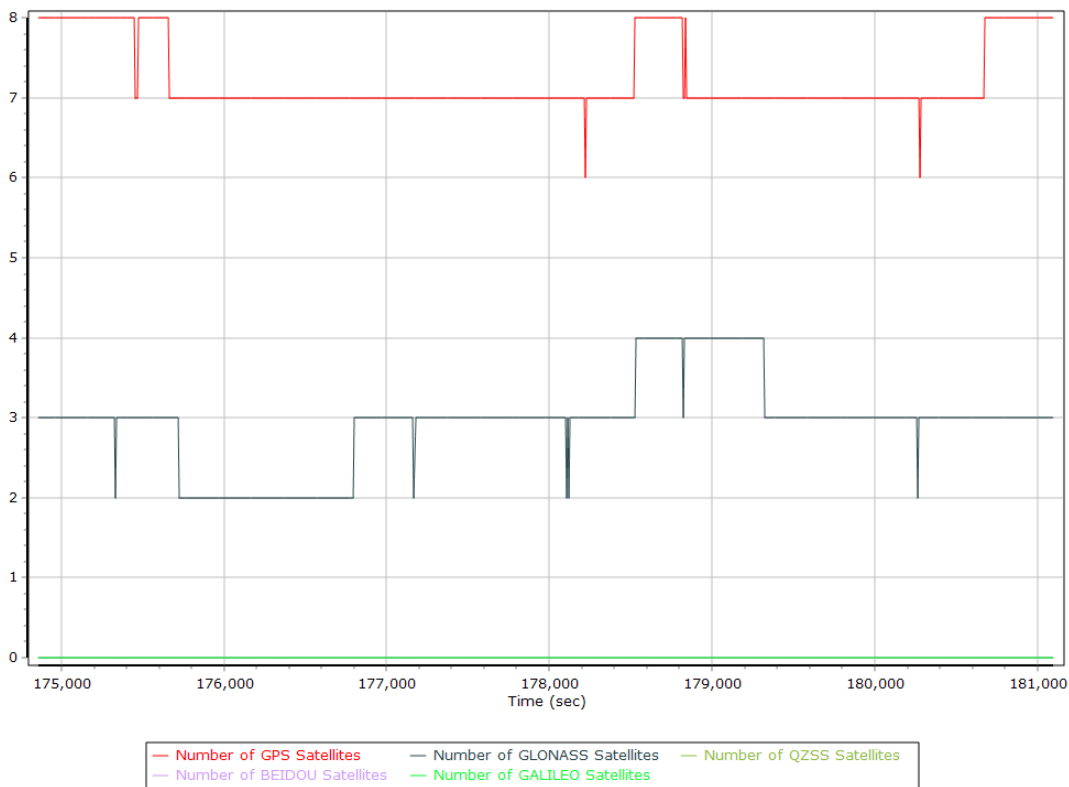


GNSS QC

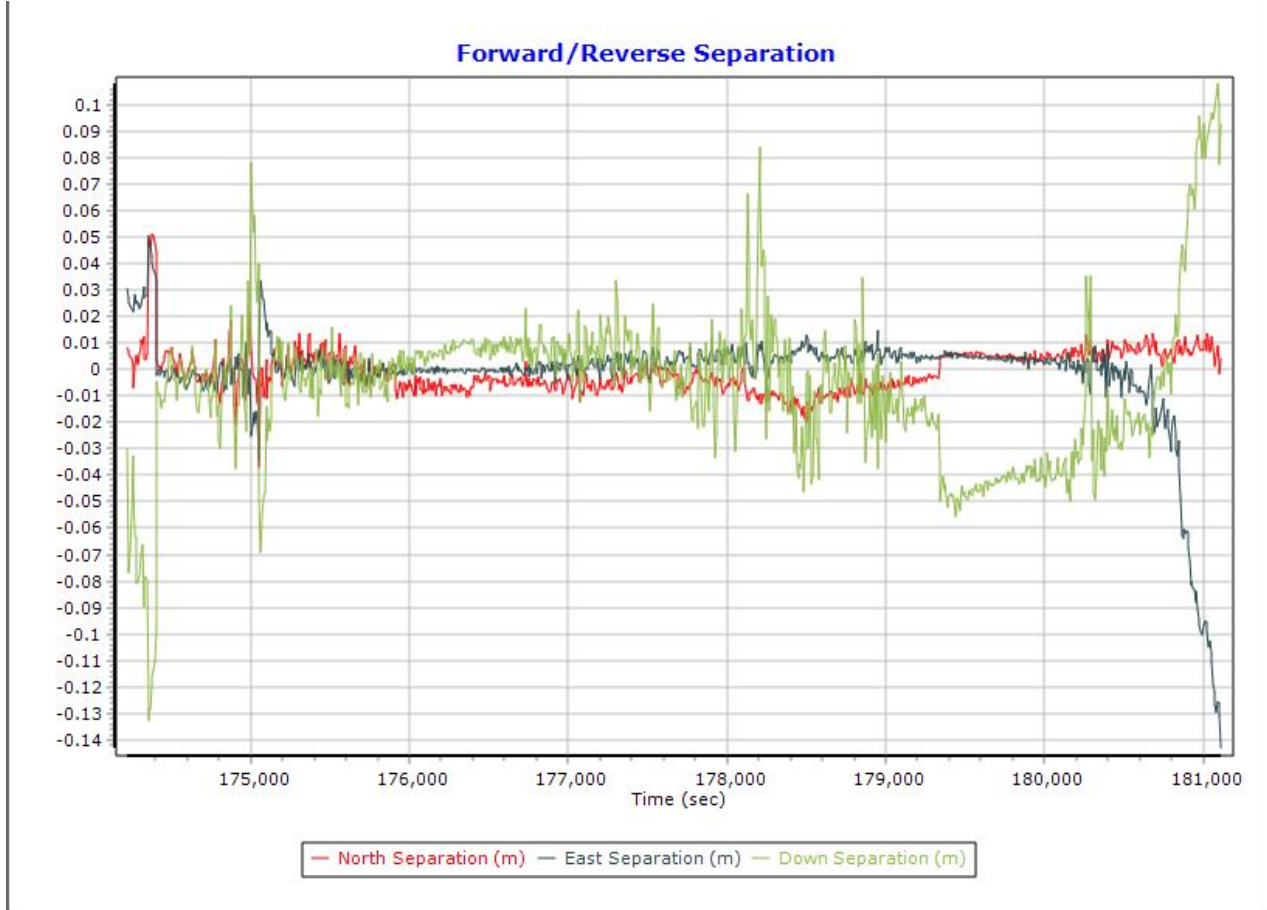
GNSS QC Statistics

Statistics	Min	Max	Mean
Baseline length (km)	11.90	94.19	
Number of GPS SV	6	8	7
Number of GLONASS SV	0	4	3
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Number of GALILEO SV	0	0	0
Total number of SV	7	12	10
PDOP	1.40	2.51	1.85
QC Solution Gaps	1.00	1.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	6880.00	0.00	1.00
Percentage	99.99	0.00	0.01

Number of Satellites



Forward/Reverse Separation

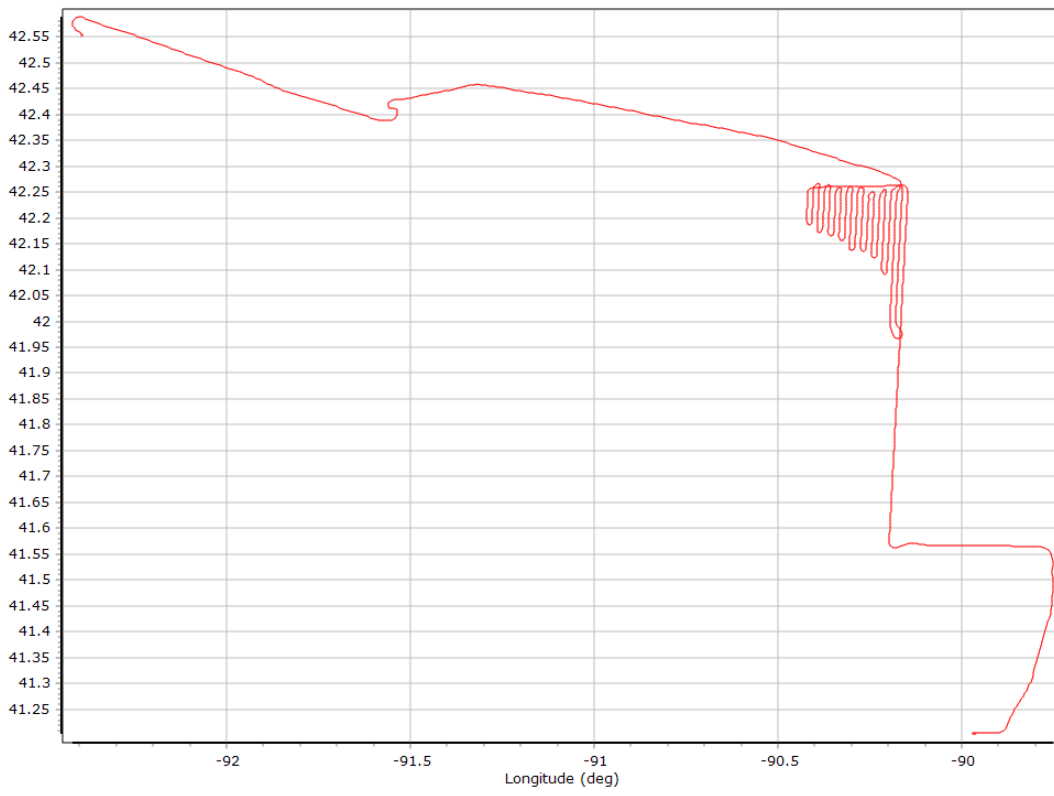


PDOP

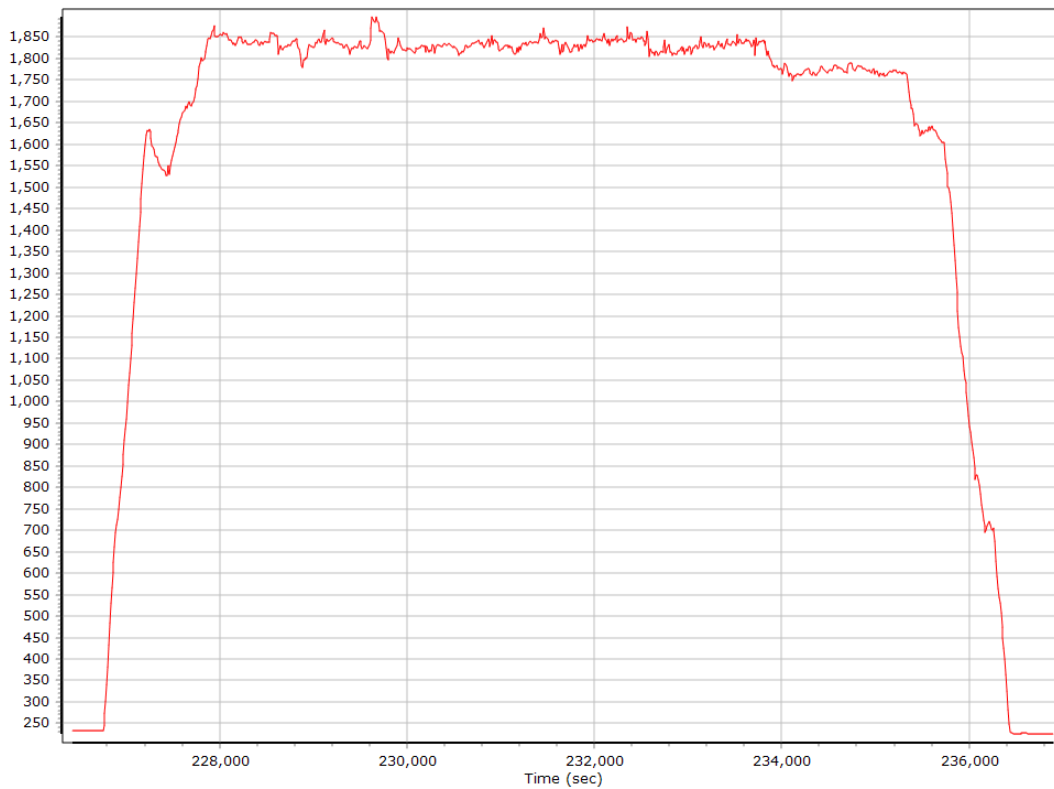


Smoothed Trajectory Information

Top View



Altitude

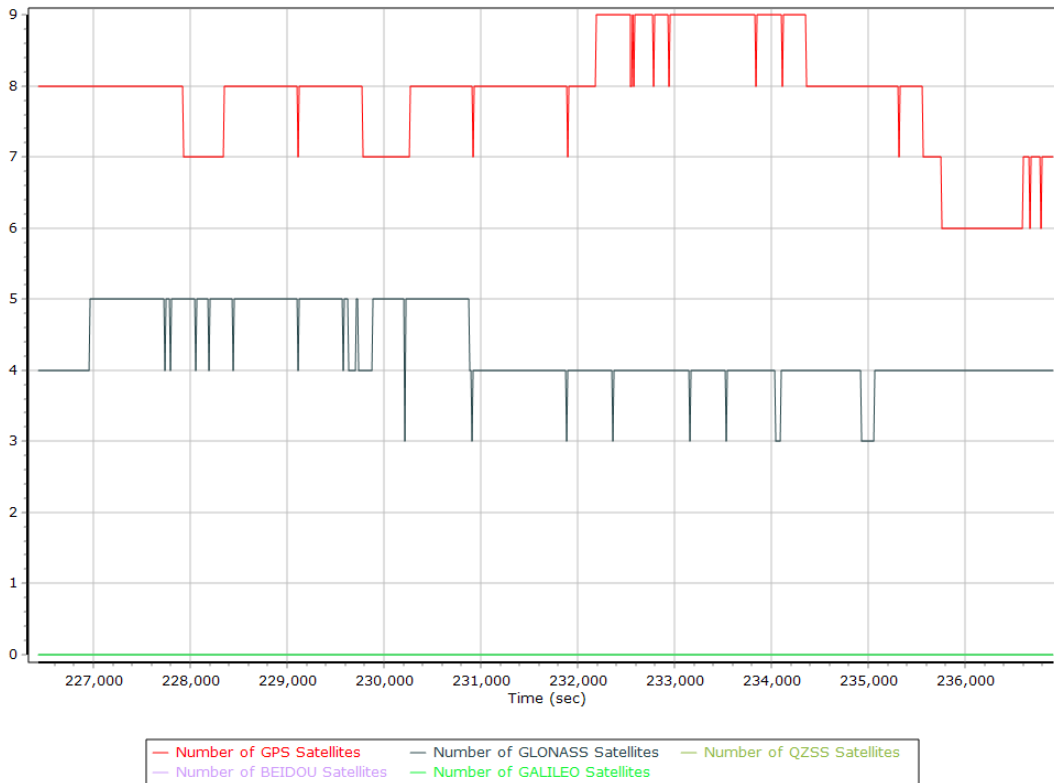


GNSS QC

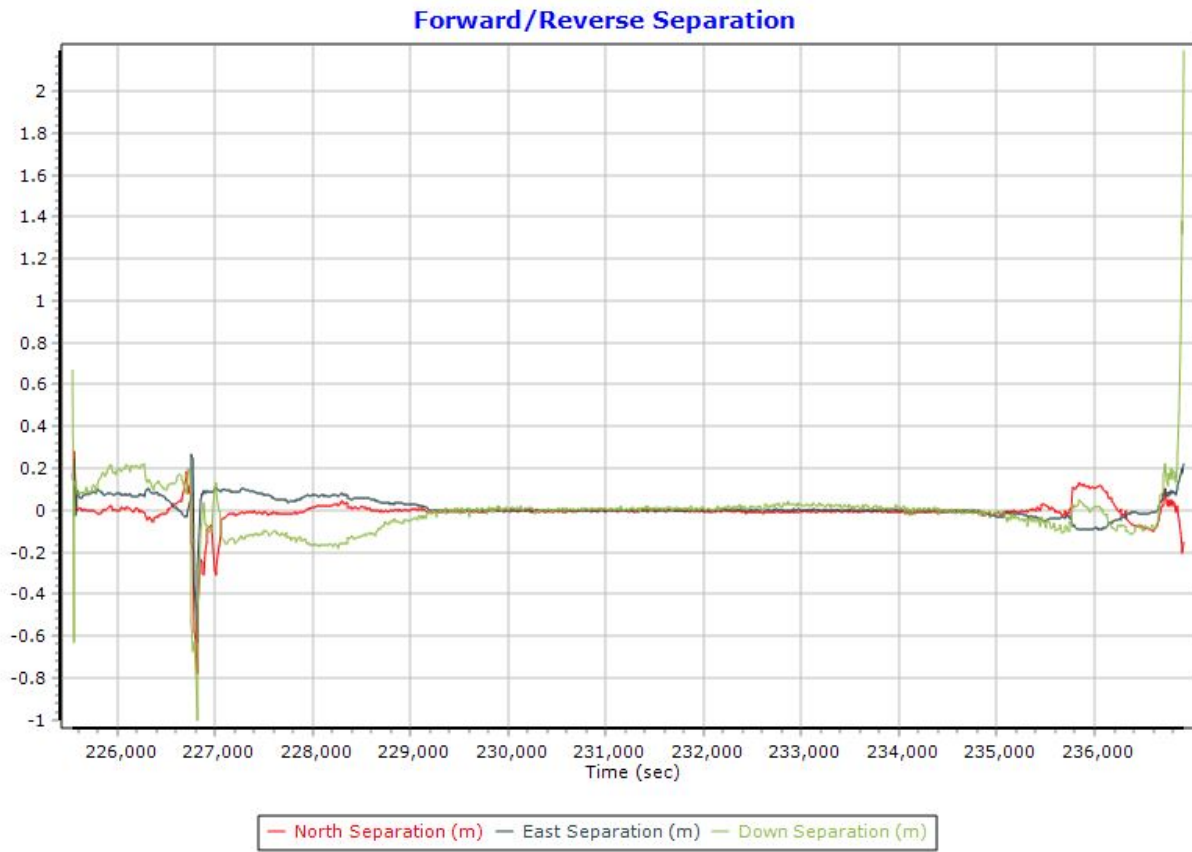
GNSS QC Statistics

Statistics	Min	Max	Mean
Baseline length (km)	21.31	152.71	
Number of GPS SV	6	9	8
Number of GLONASS SV	0	7	5
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Number of GALILEO SV	0	0	0
Total number of SV	6	16	13
PDOP	1.17	3.19	1.52
QC Solution Gaps	1.00	1.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	11368.00	0.00	1.00
Percentage	99.99	0.00	0.01

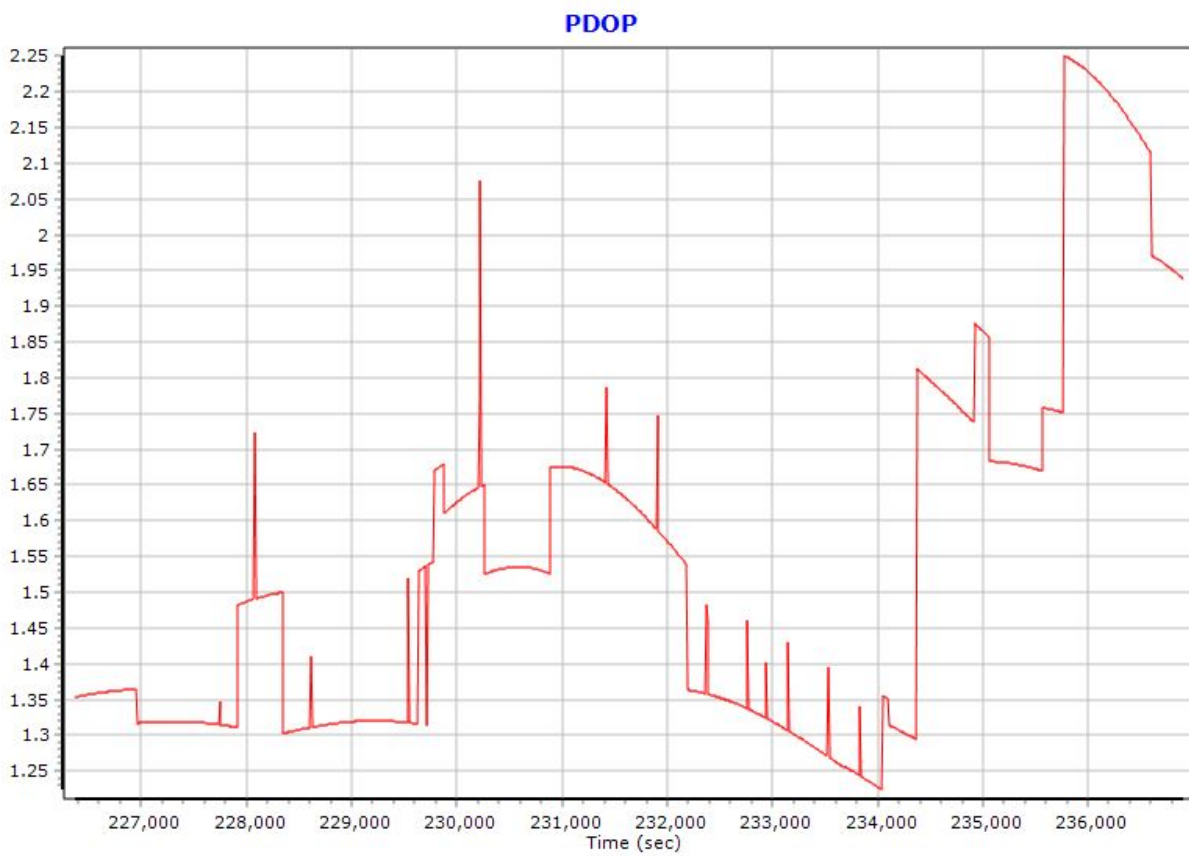
Number of Satellites



Forward/Reverse Separation

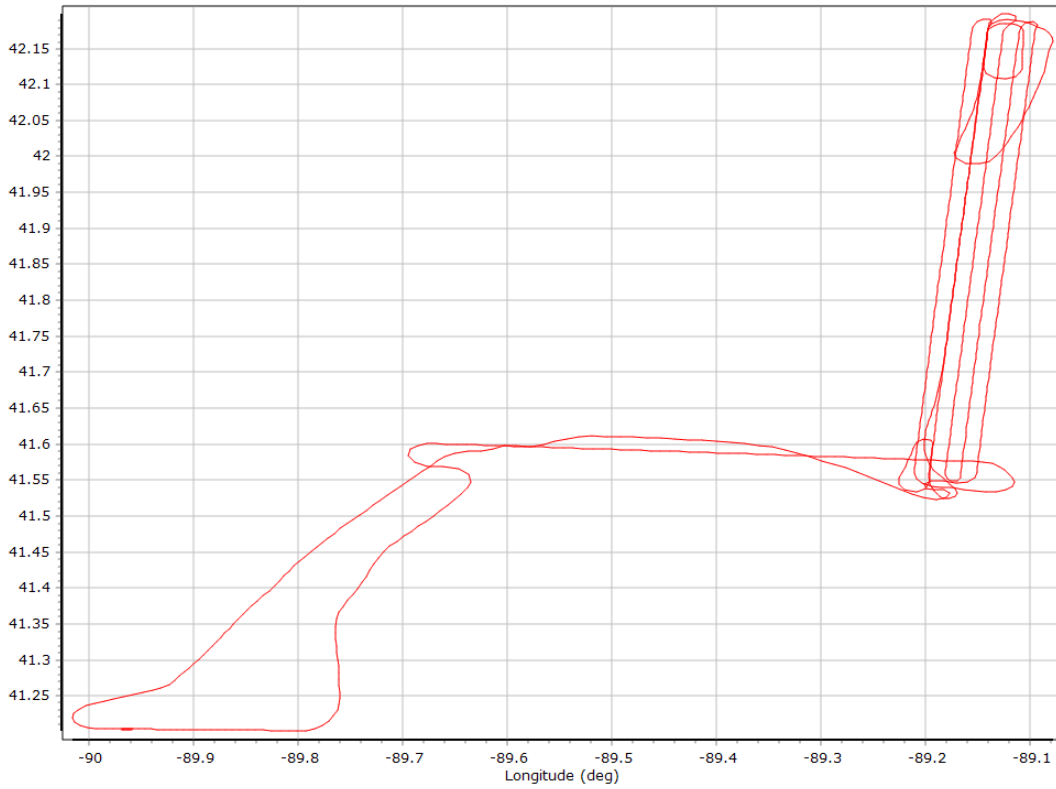


PDOP

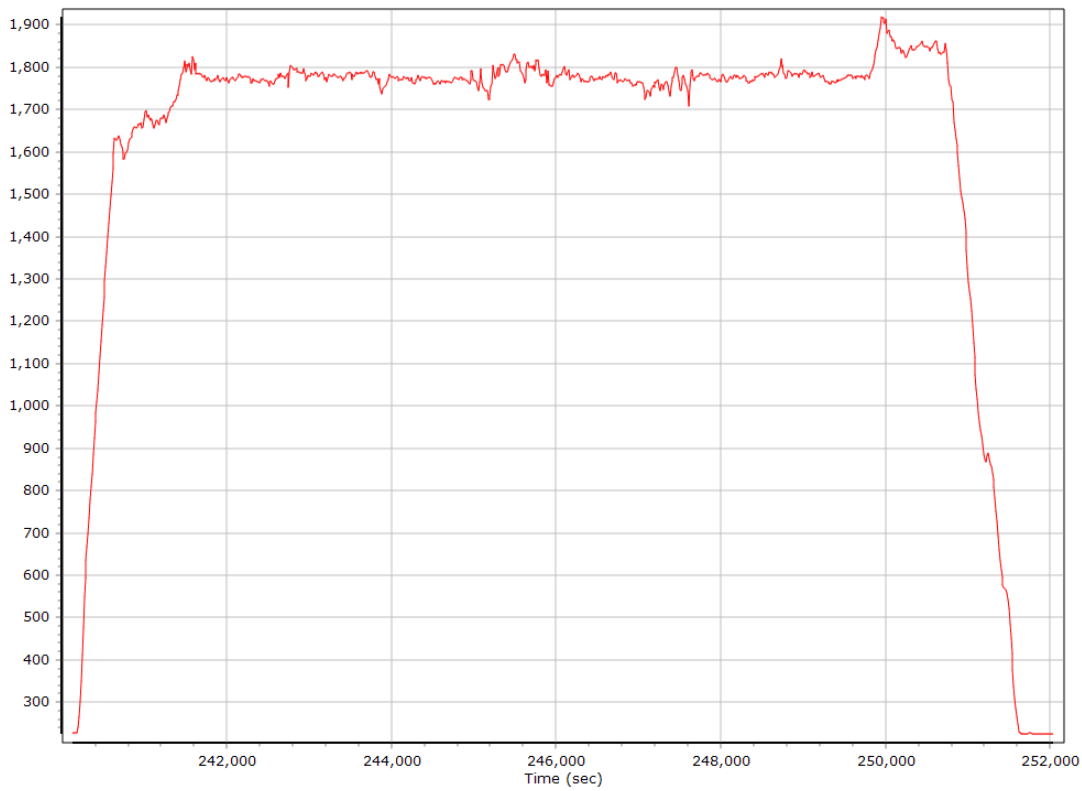


Smoothed Trajectory Information

Top View



Altitude

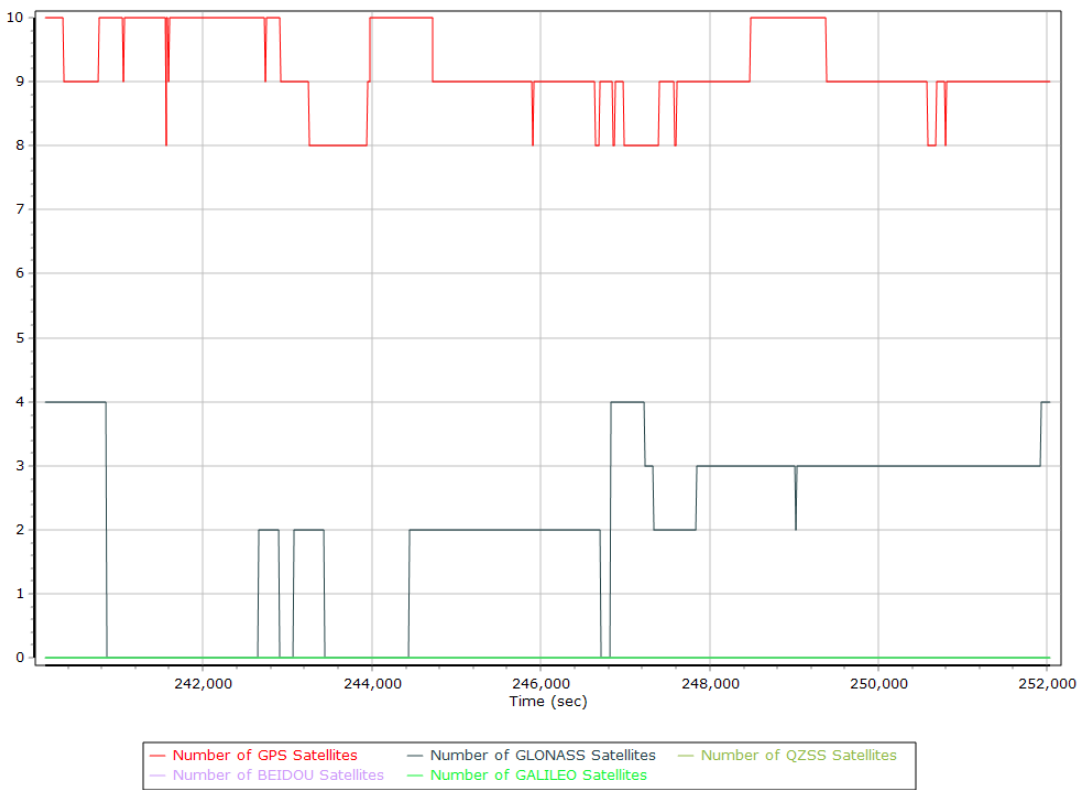


GNSS QC

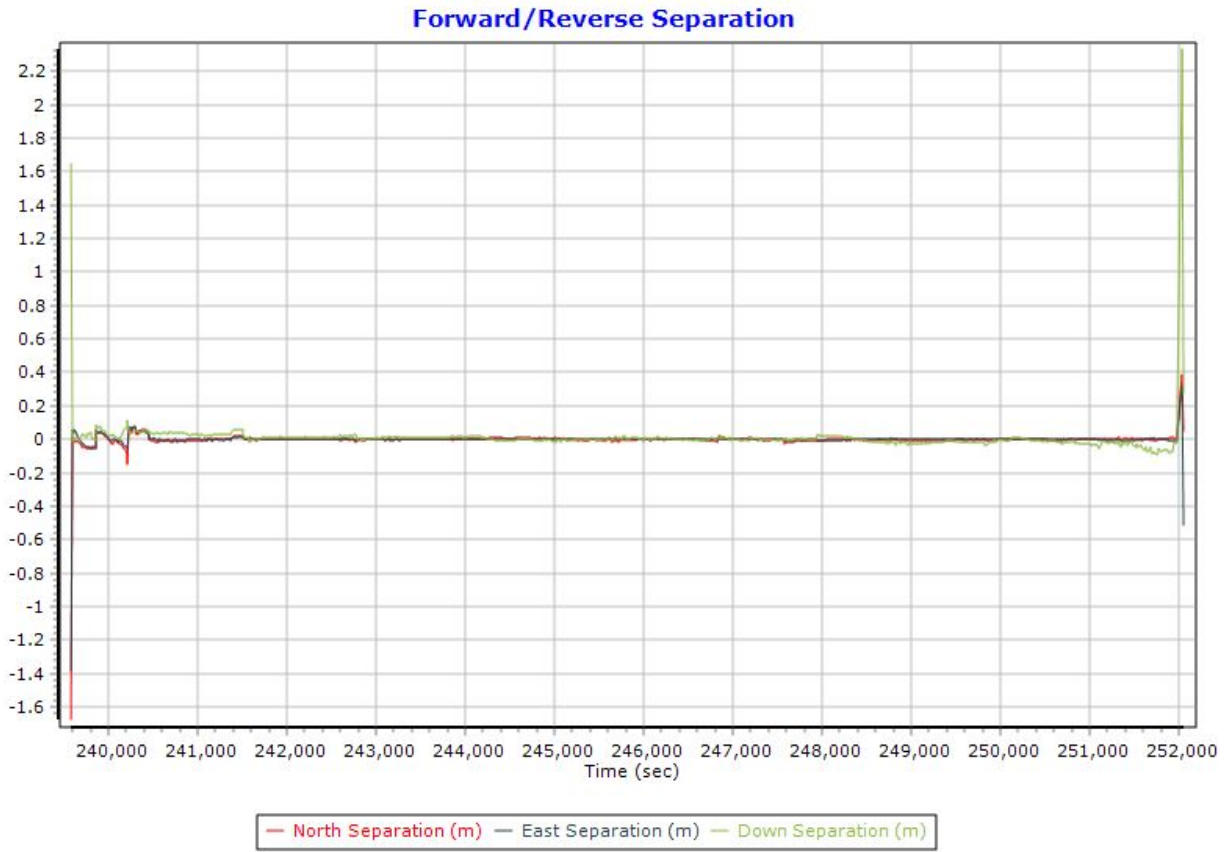
GNSS QC Statistics

Statistics	Min	Max	Mean
Baseline length (km)	11.61	79.83	
Number of GPS SV	5	10	9
Number of GLONASS SV	0	4	2
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Number of GALILEO SV	0	0	0
Total number of SV	5	14	11
PDOP	1.31	3.57	1.65
QC Solution Gaps	1.00	1.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	12453.00	2.00	2.00
Percentage	99.97	0.02	0.02

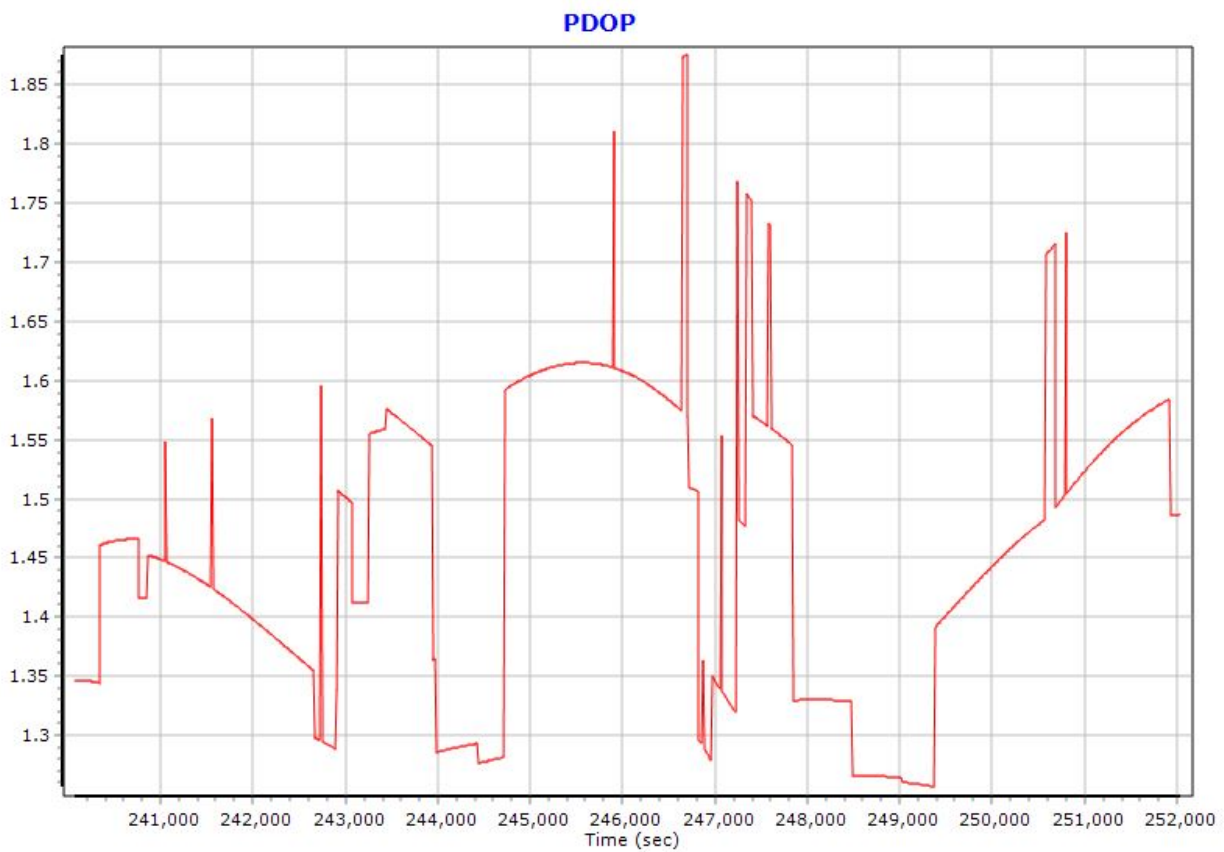
Number of Satellites



Forward/Reverse Separation

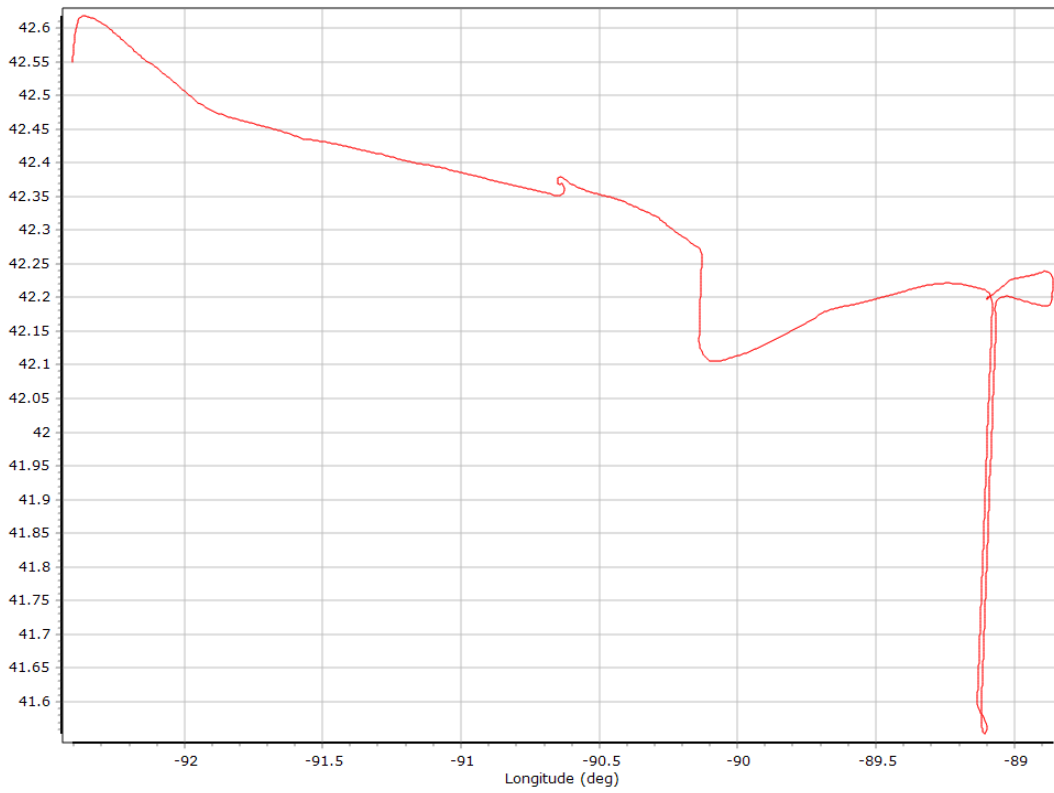


PDOP

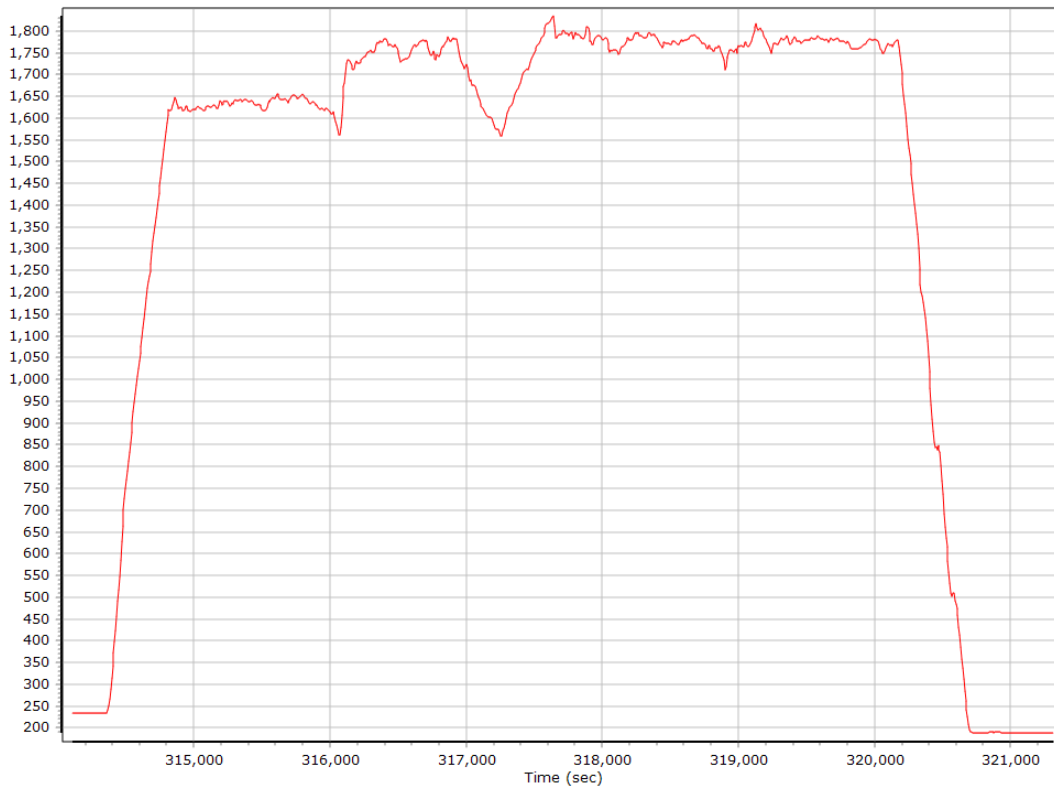


Smoothed Trajectory Information

Top View



Altitude

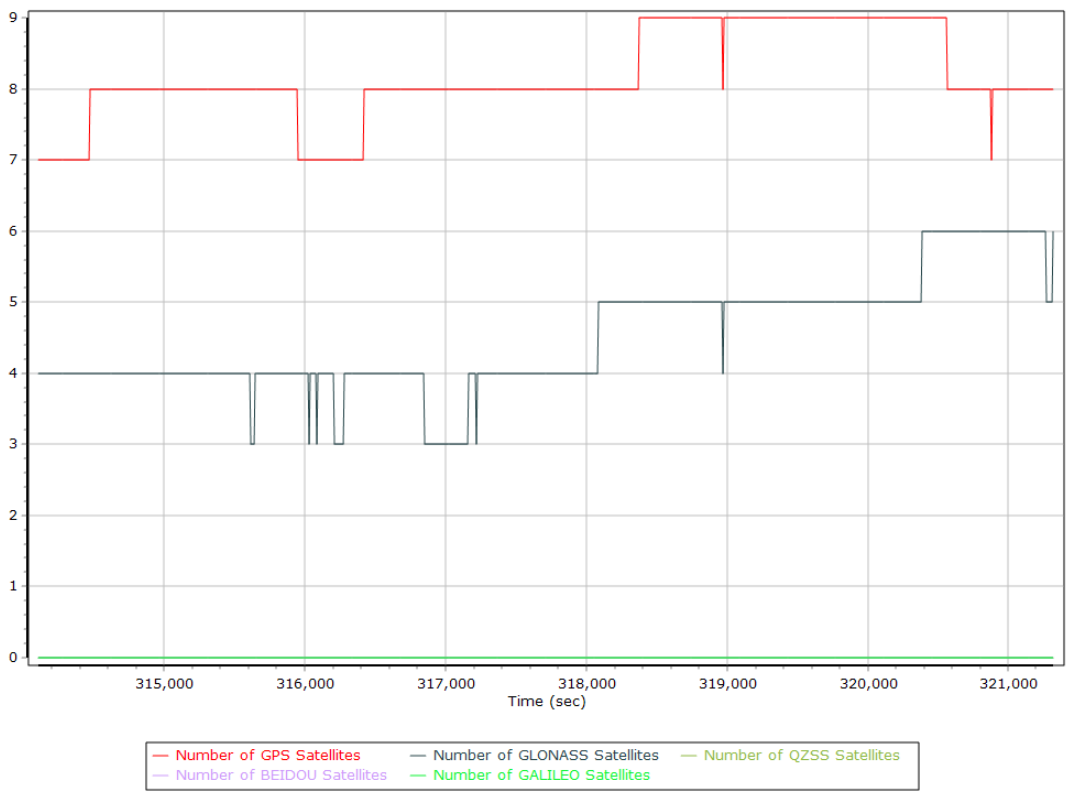


GNSS QC

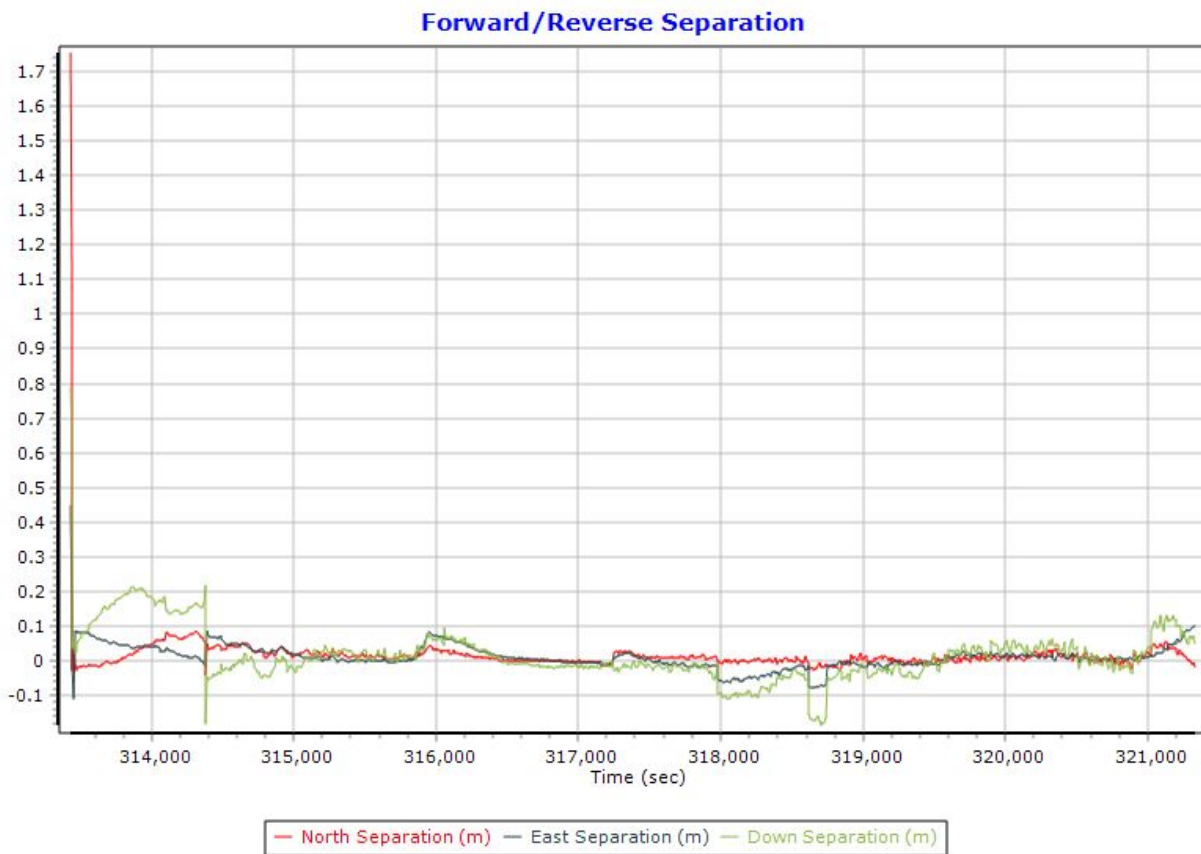
GNSS QC Statistics

Statistics	Min	Max	Mean
Baseline length (km)	7.61	183.51	
Number of GPS SV	6	9	8
Number of GLONASS SV	0	6	5
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Number of GALILEO SV	0	0	0
Total number of SV	6	15	14
PDOP	1.30	3.28	1.44
QC Solution Gaps	1.00	1.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	7904.00	0.00	1.00
Percentage	99.99	0.00	0.01

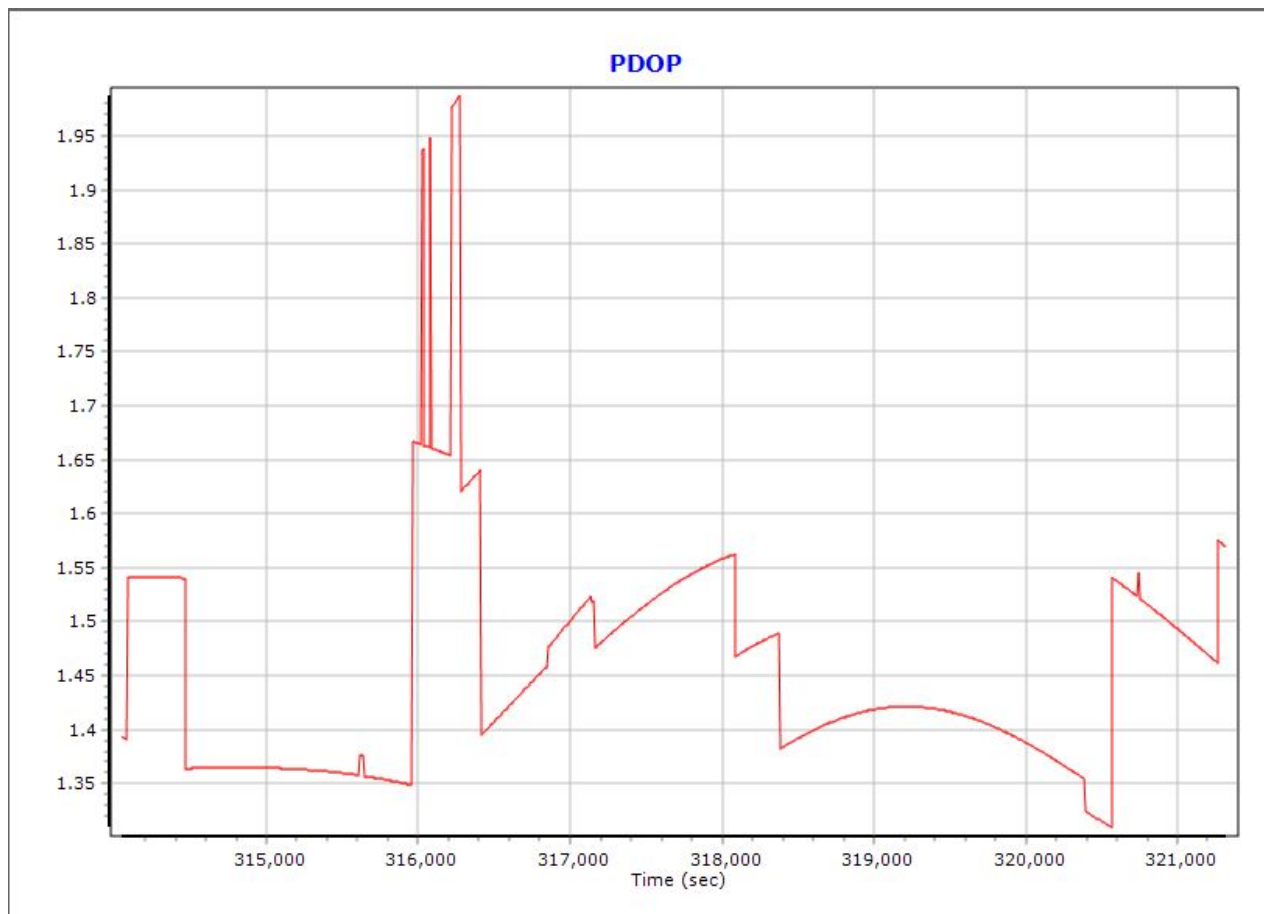
Number of Satellites



Forward/Reverse Separation



PDOP



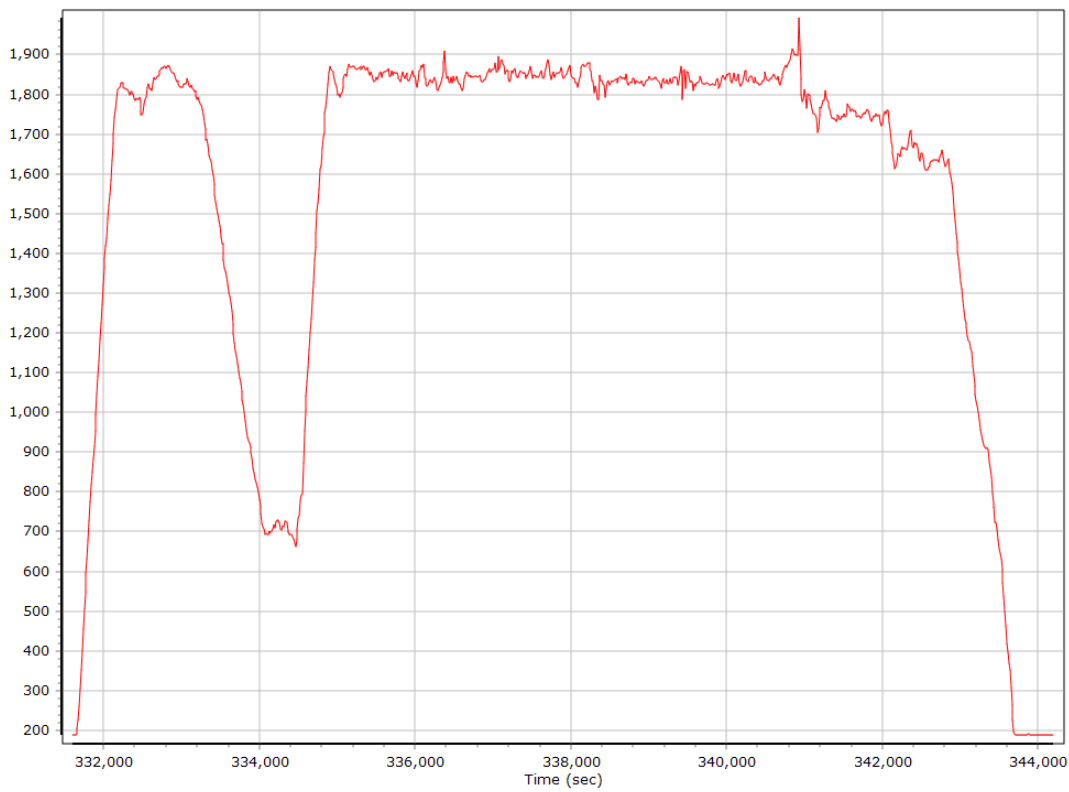
13:57:29

Smoothed Trajectory Information

Top View



Altitude

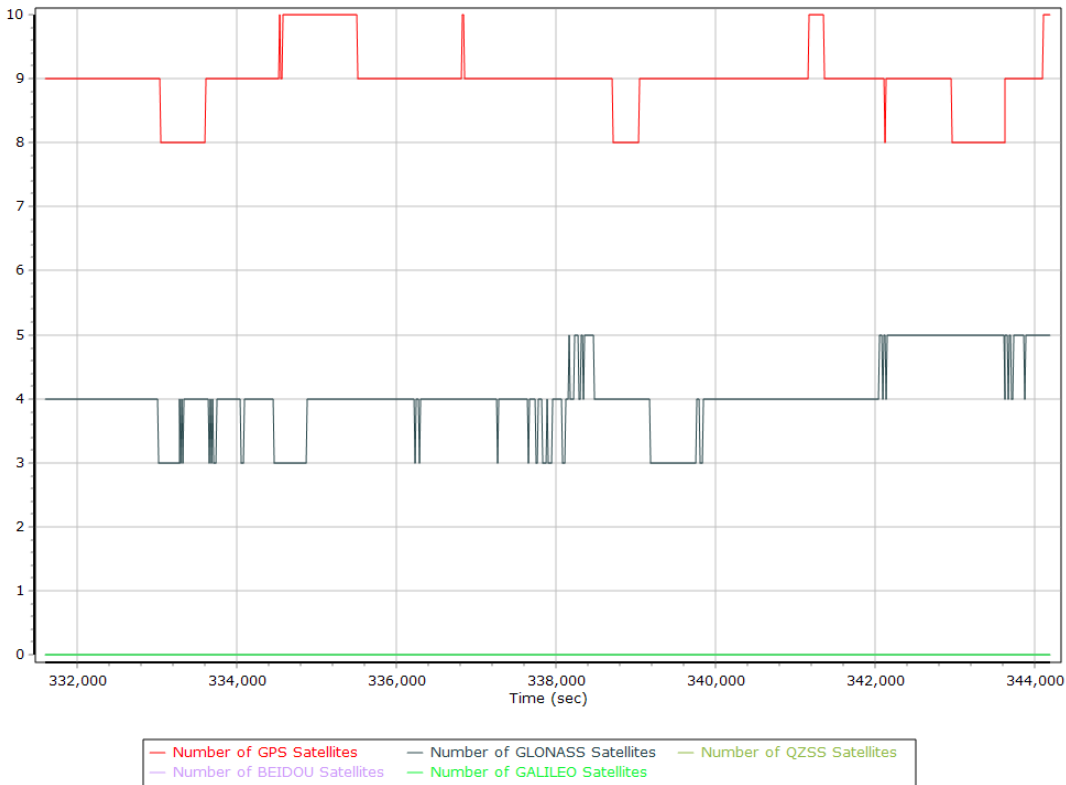


GNSS QC

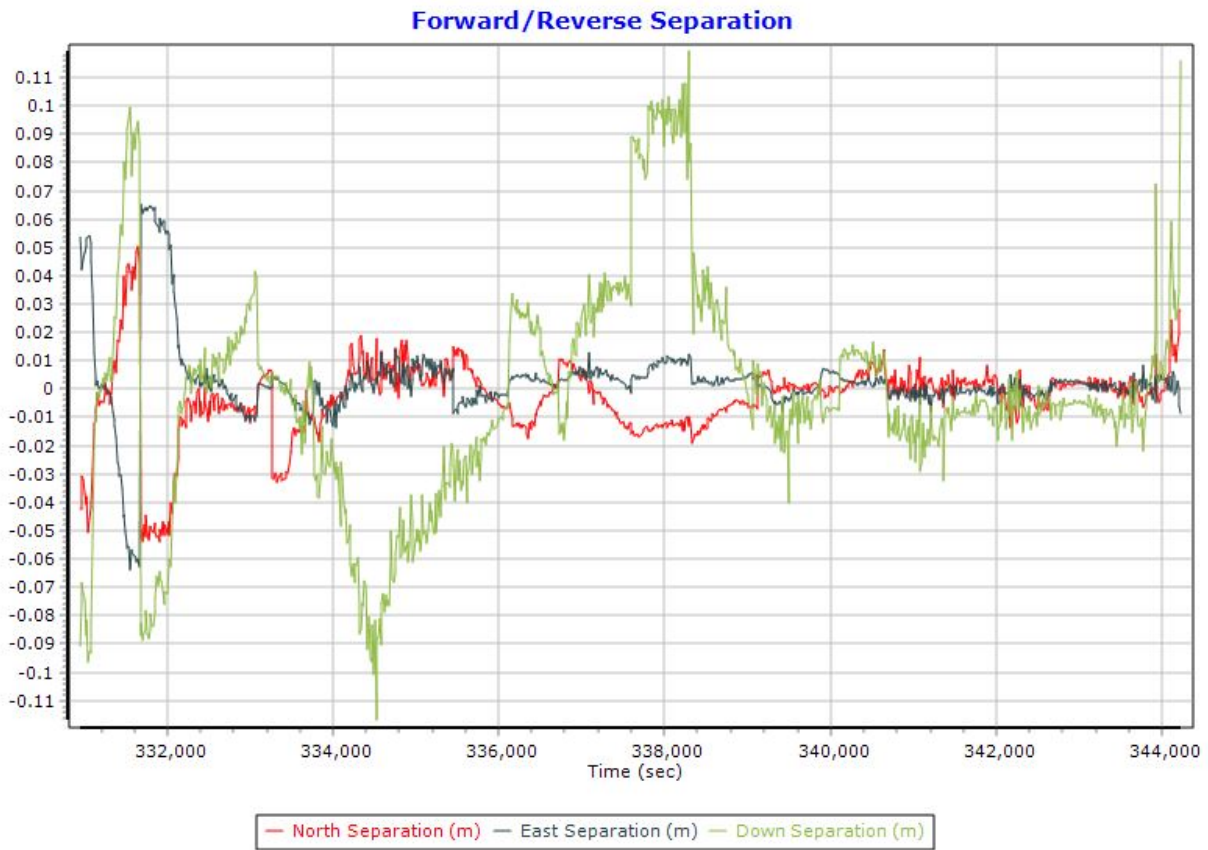
GNSS QC Statistics

Statistics	Min	Max	Mean
Baseline length (km)	3.42	90.34	
Number of GPS SV	7	10	9
Number of GLONASS SV	0	5	4
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Number of GALILEO SV	0	0	0
Total number of SV	9	15	13
PDOP	1.30	2.24	1.56
QC Solution Gaps	1.00	1.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	13253.00	0.00	1.00
Percentage	99.99	0.00	0.01

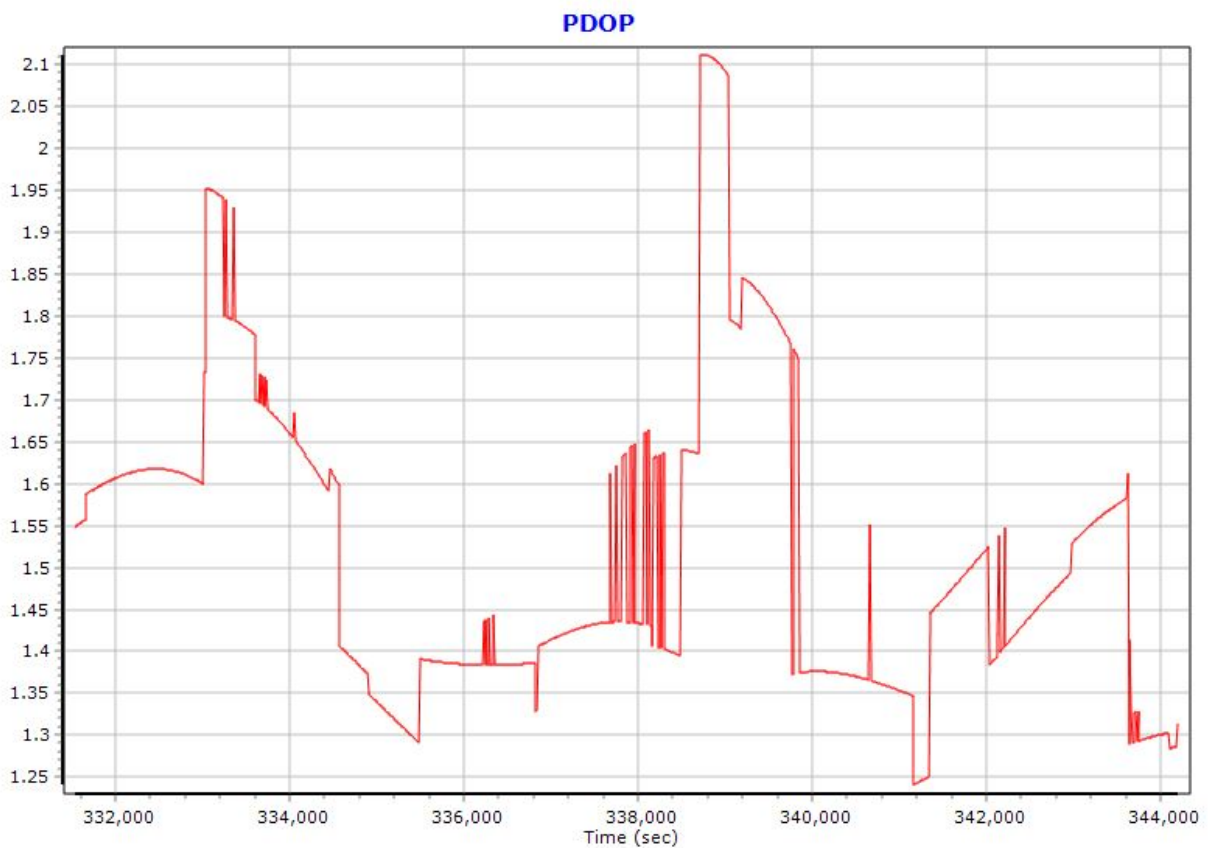
Number of Satellites



Forward/Reverse Separation

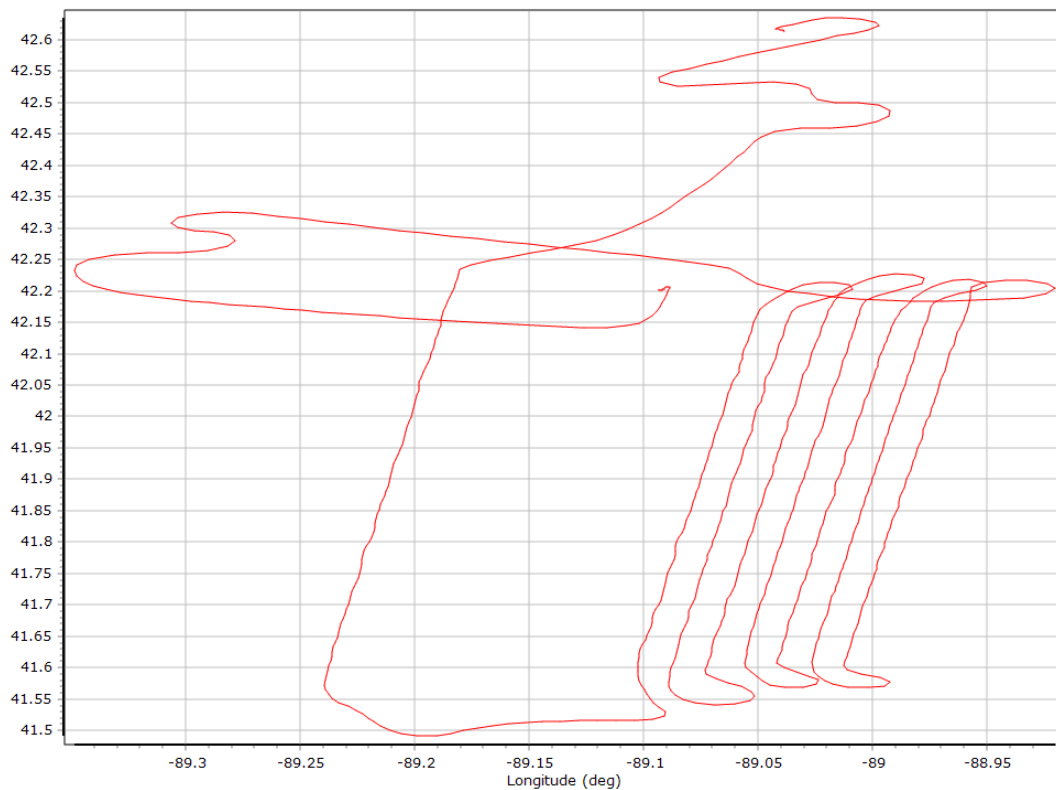


PDOP

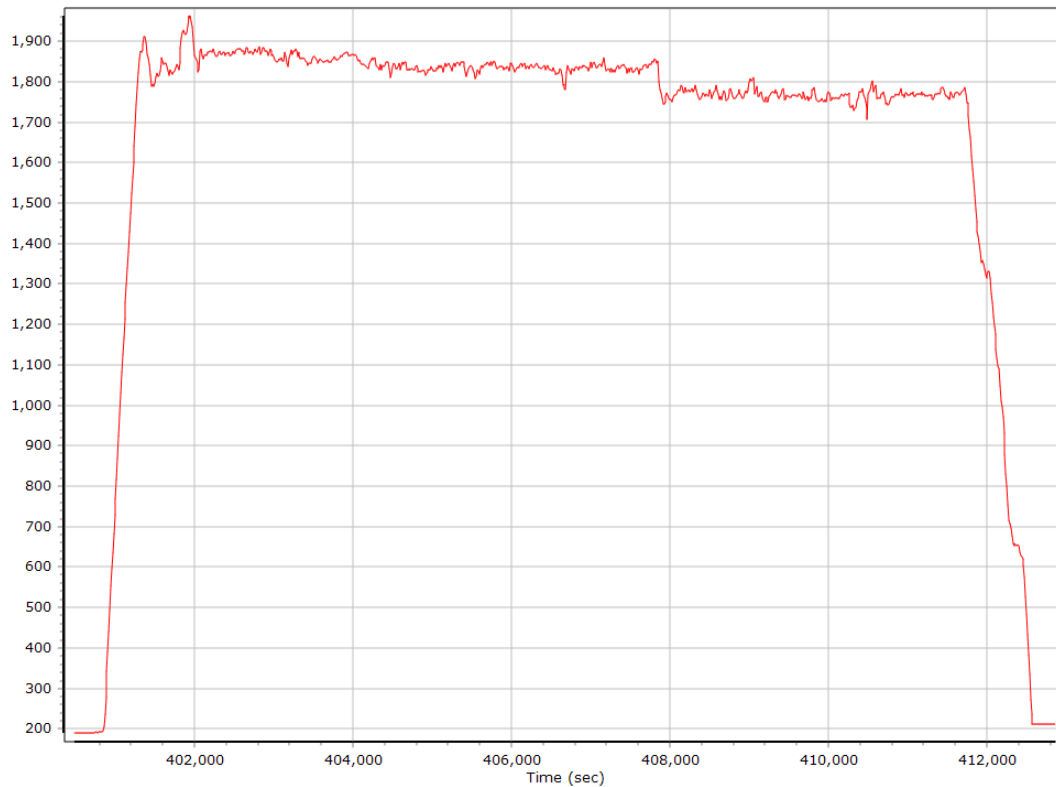


Smoothed Trajectory Information

Top View



Altitude

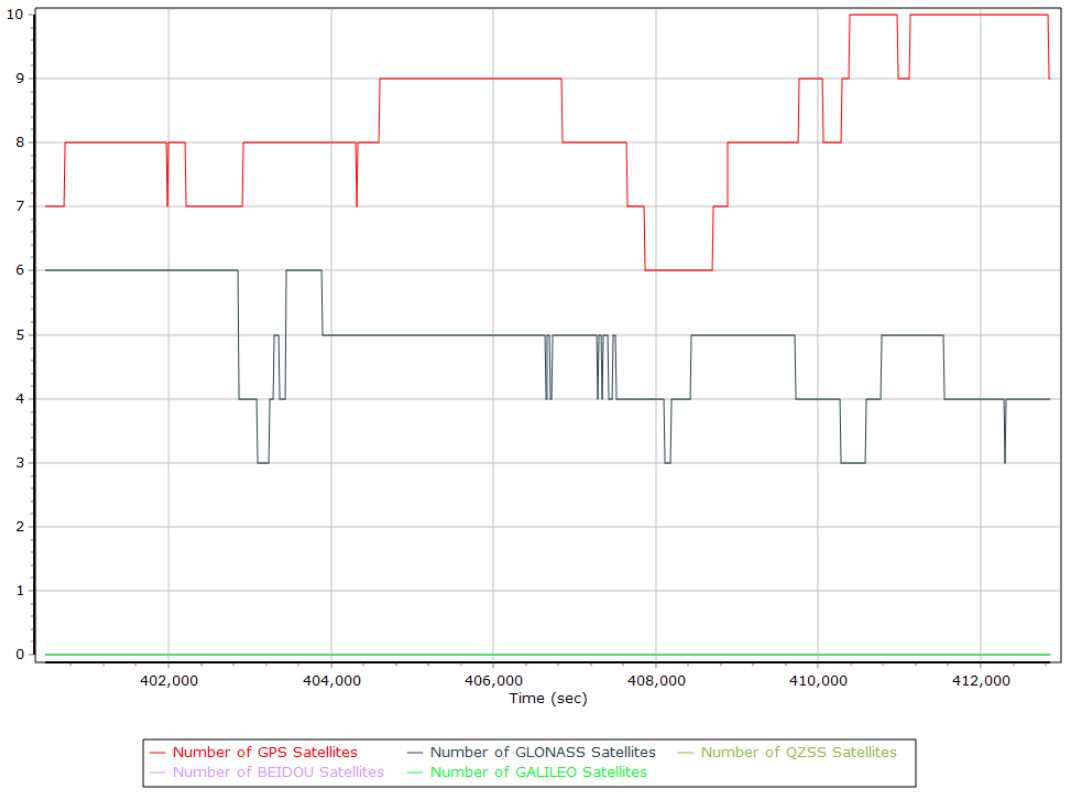


GNSS QC

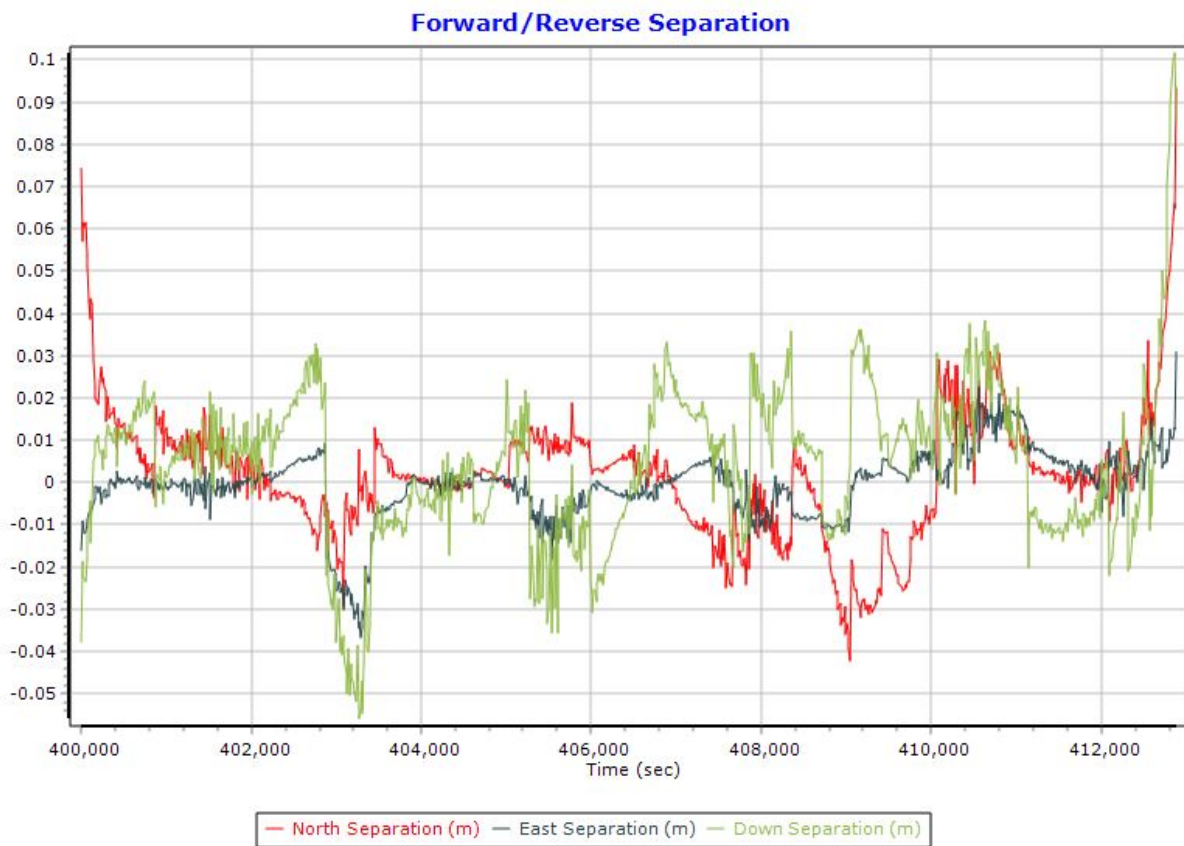
GNSS QC Statistics

Statistics	Min	Max	Mean
Baseline length (km)	0.22	72.31	
Number of GPS SV	6	10	8
Number of GLONASS SV	0	7	6
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Number of GALILEO SV	0	0	0
Total number of SV	8	16	14
PDOP	1.21	2.47	1.45
QC Solution Gaps	1.00	1.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	12880.00	0.00	1.00
Percentage	99.99	0.00	0.01

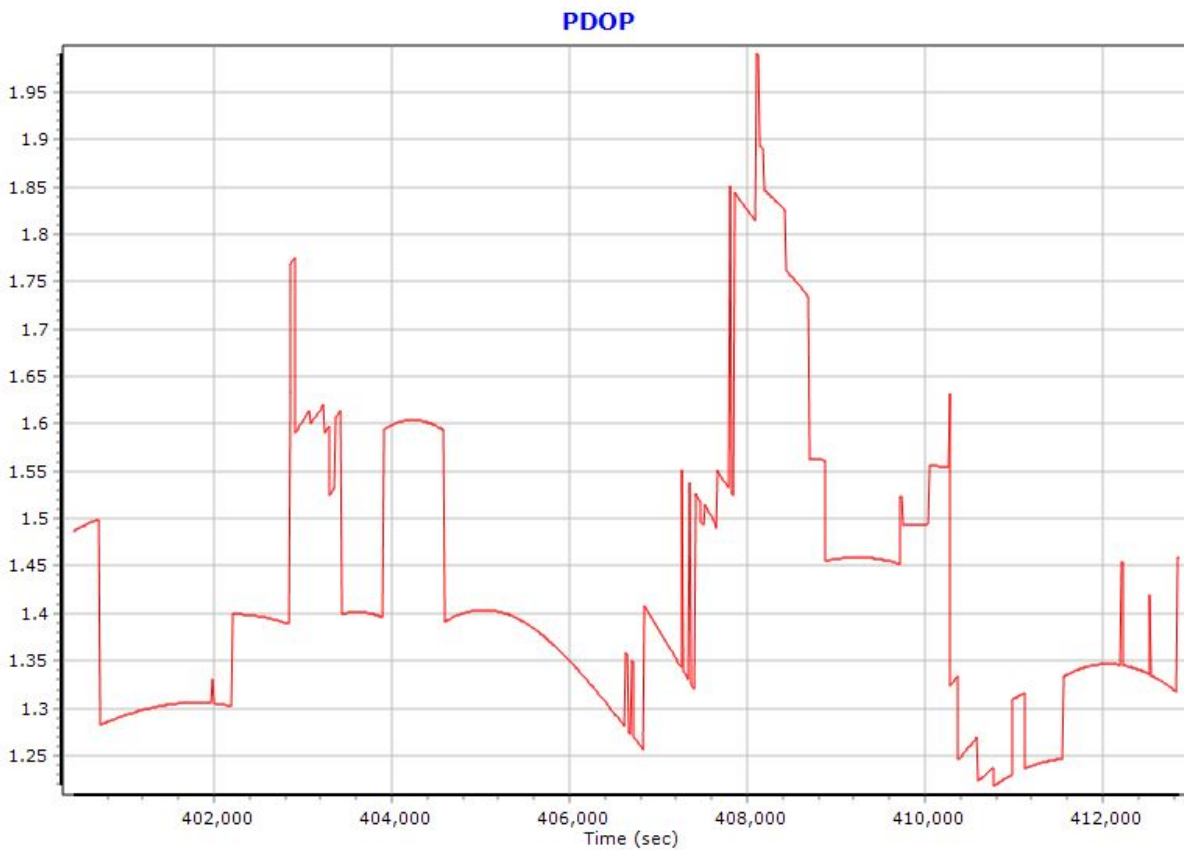
Number of Satellites



Forward/Reverse Separation

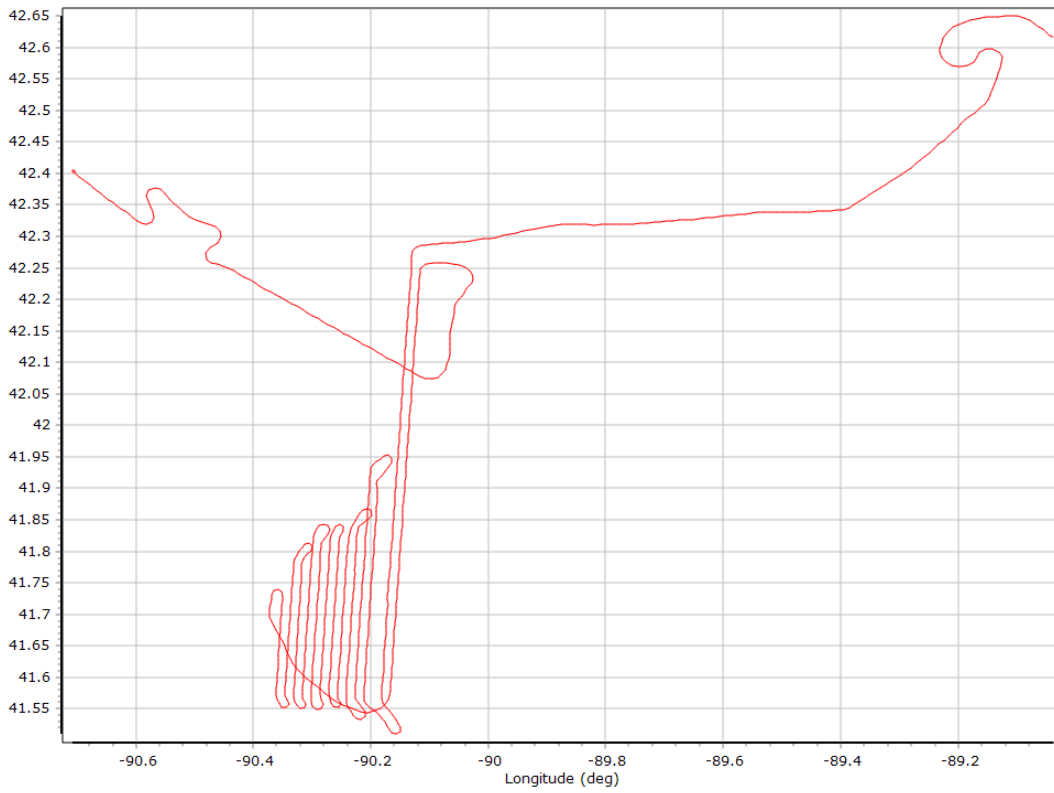


PDOP

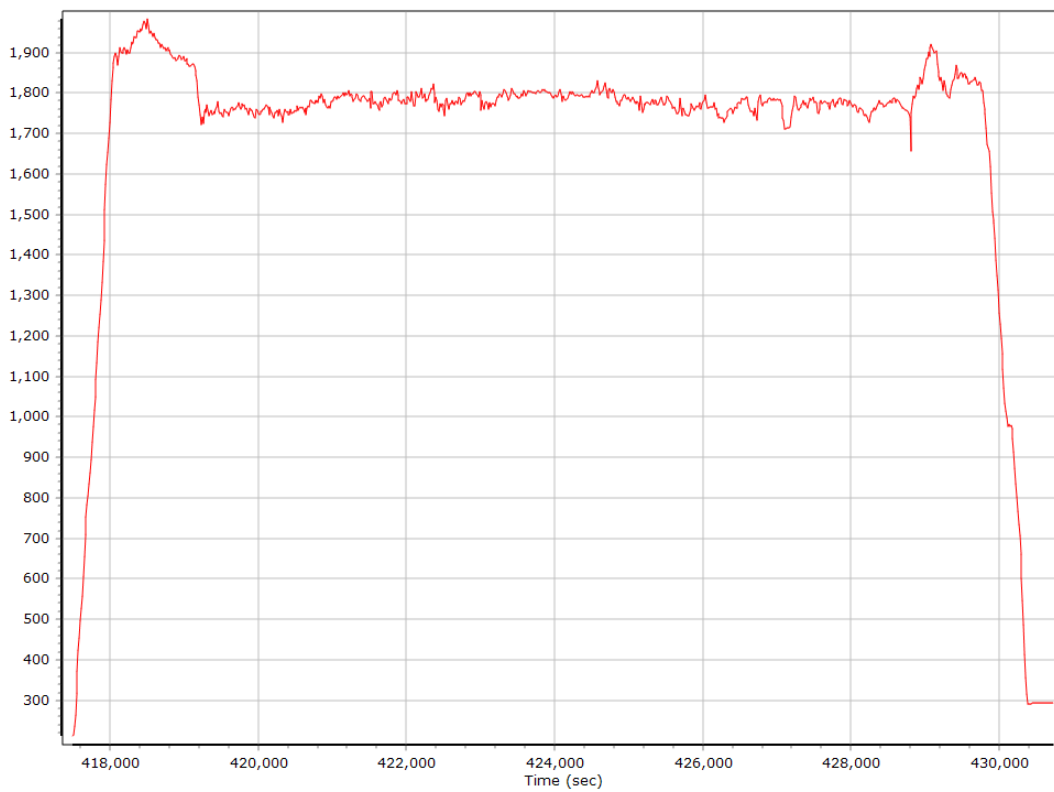


Smoothed Trajectory Information

Top View



Altitude

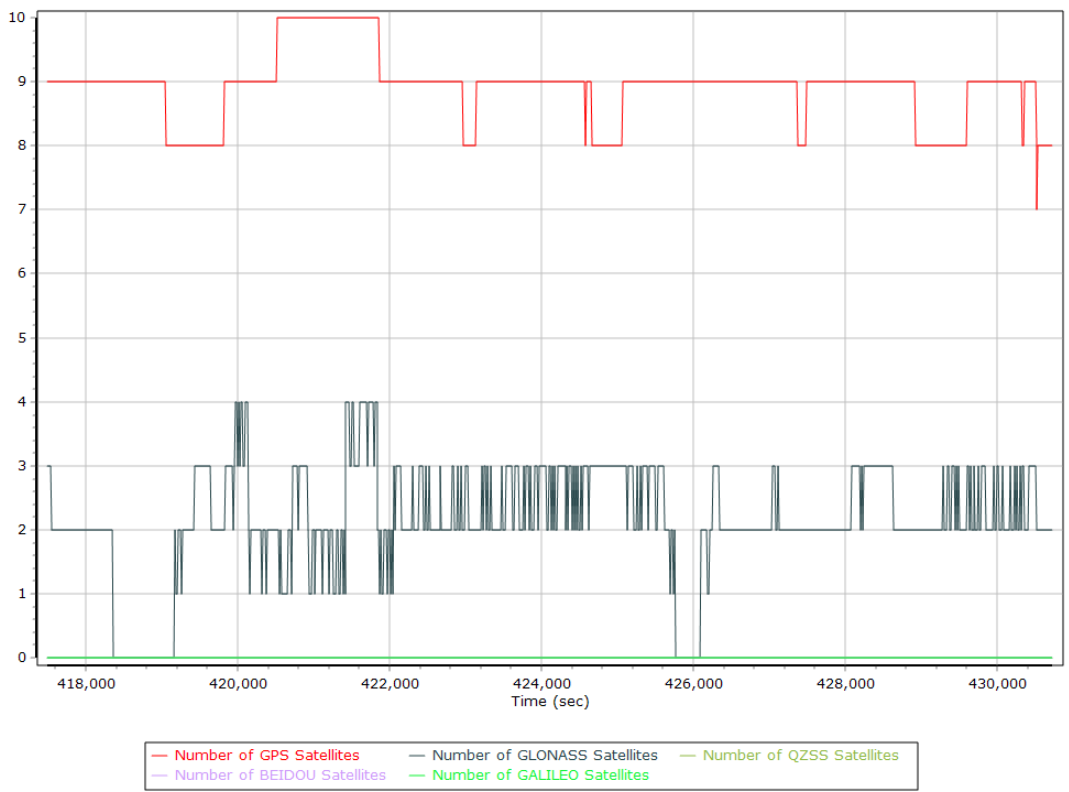


GNSS QC

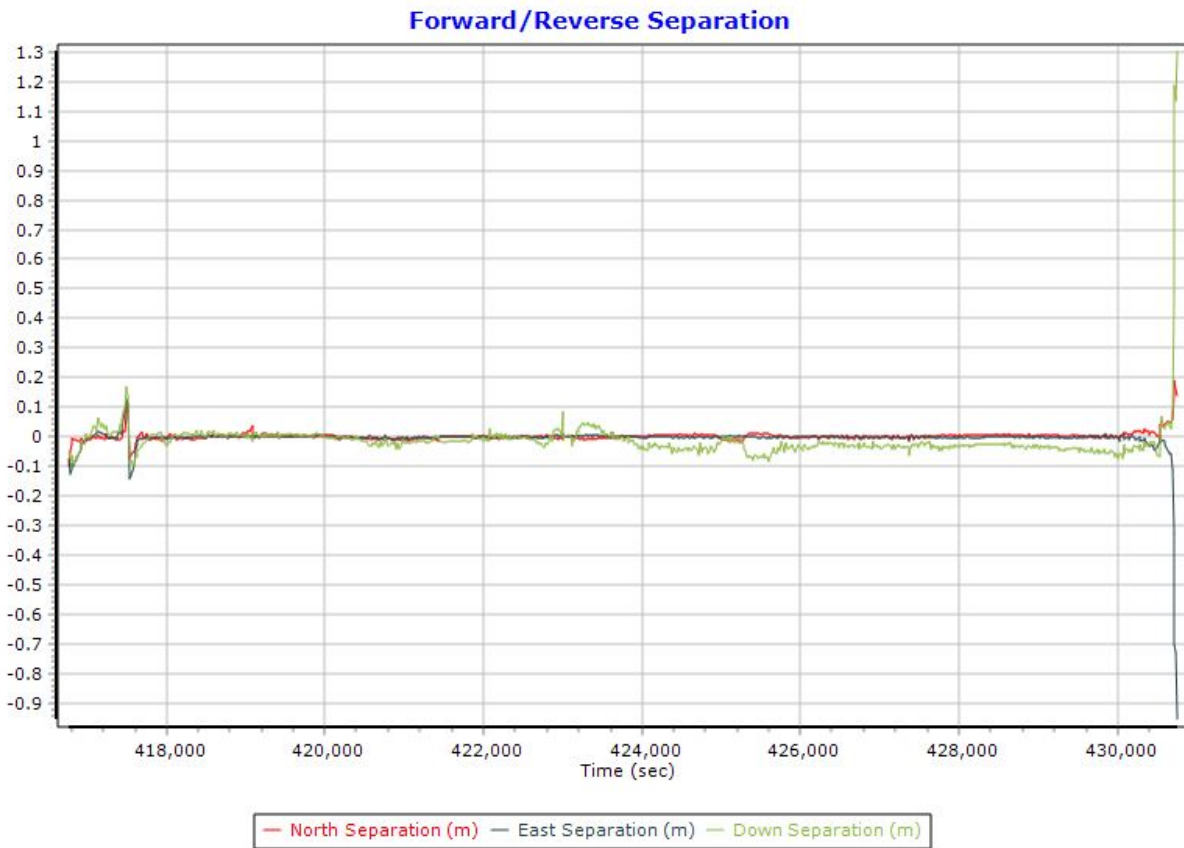
GNSS QC Statistics

Statistics	Min	Max	Mean
Baseline length (km)	3.99	113.20	
Number of GPS SV	5	10	9
Number of GLONASS SV	0	4	2
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Number of GALILEO SV	0	0	0
Total number of SV	7	14	11
PDOP	1.28	3.16	1.66
QC Solution Gaps	1.00	1.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	13934.00	0.00	1.00
Percentage	99.99	0.00	0.01

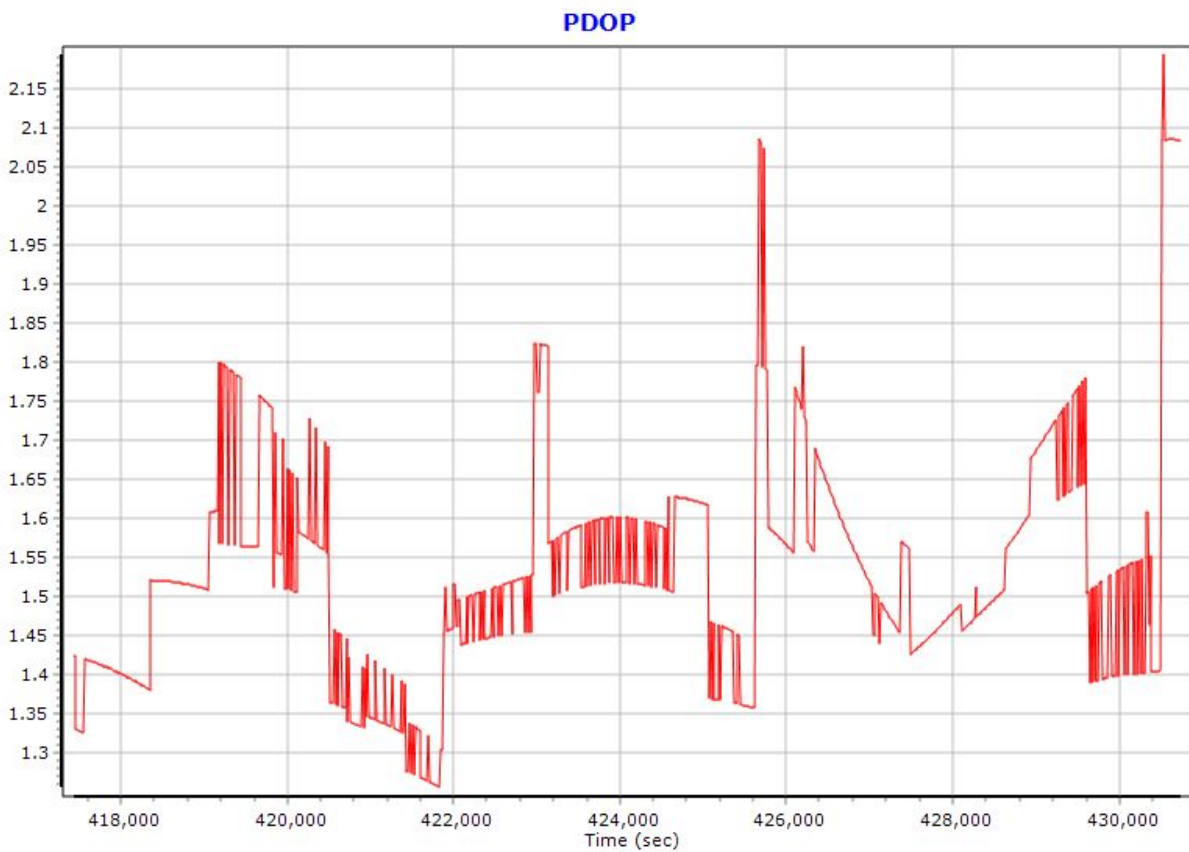
Number of Satellites



Forward/Reverse Separation

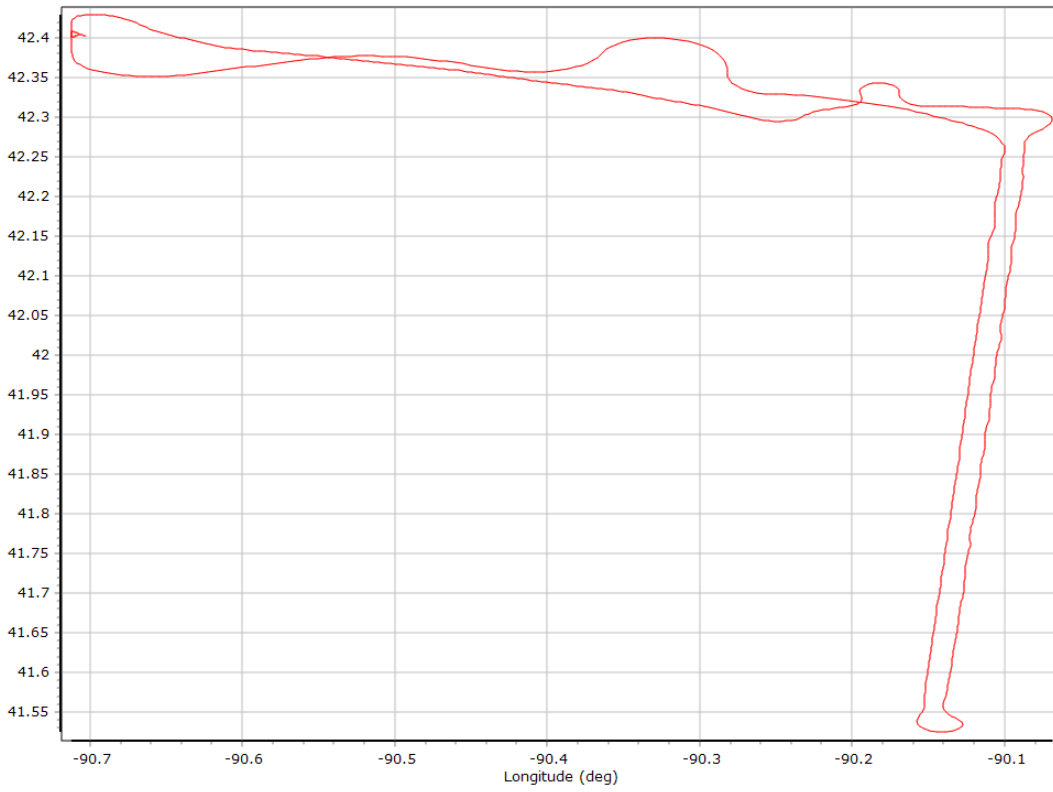


PDOP

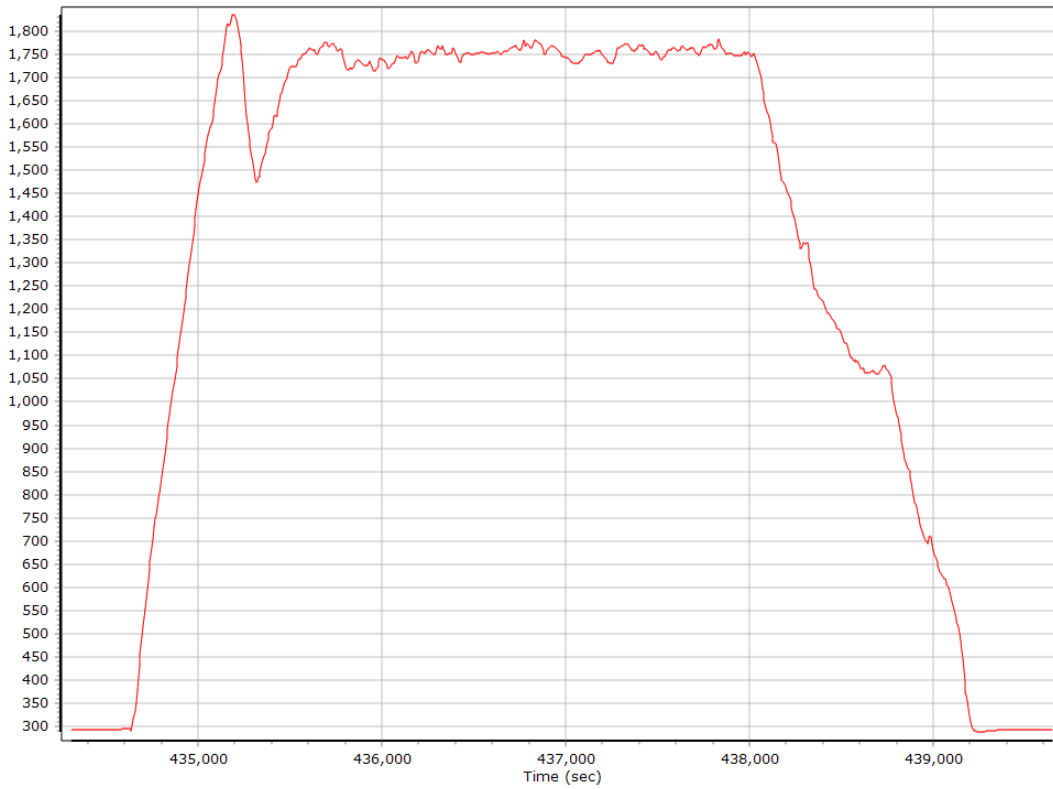


Smoothed Trajectory Information

Top View



Altitude

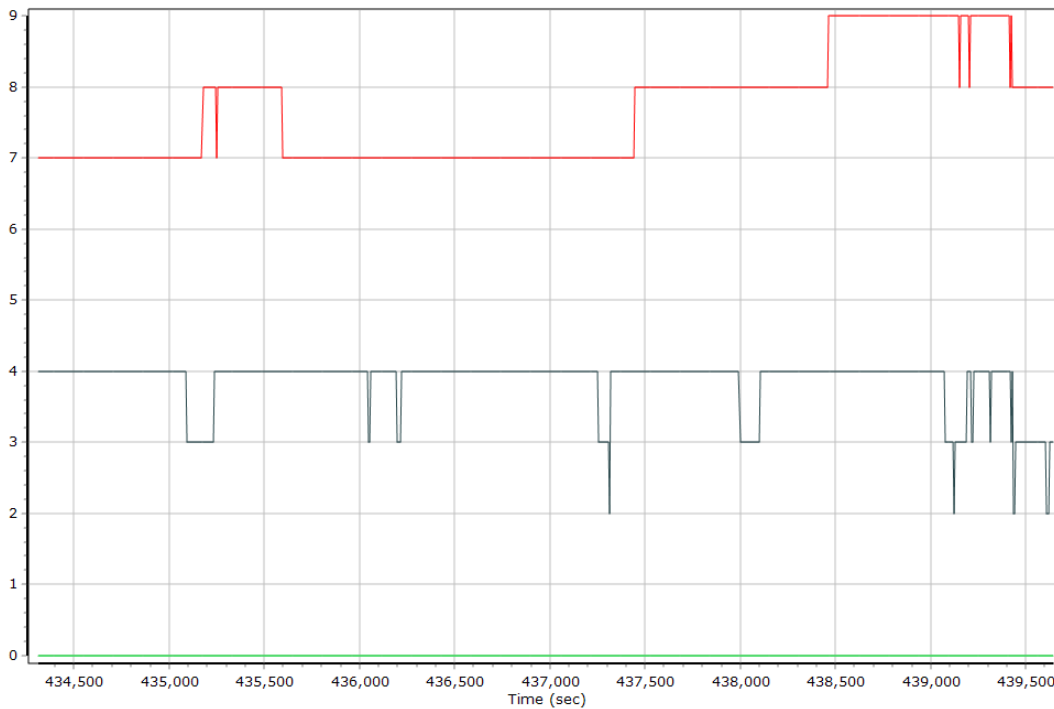


GNSS QC

GNSS QC Statistics

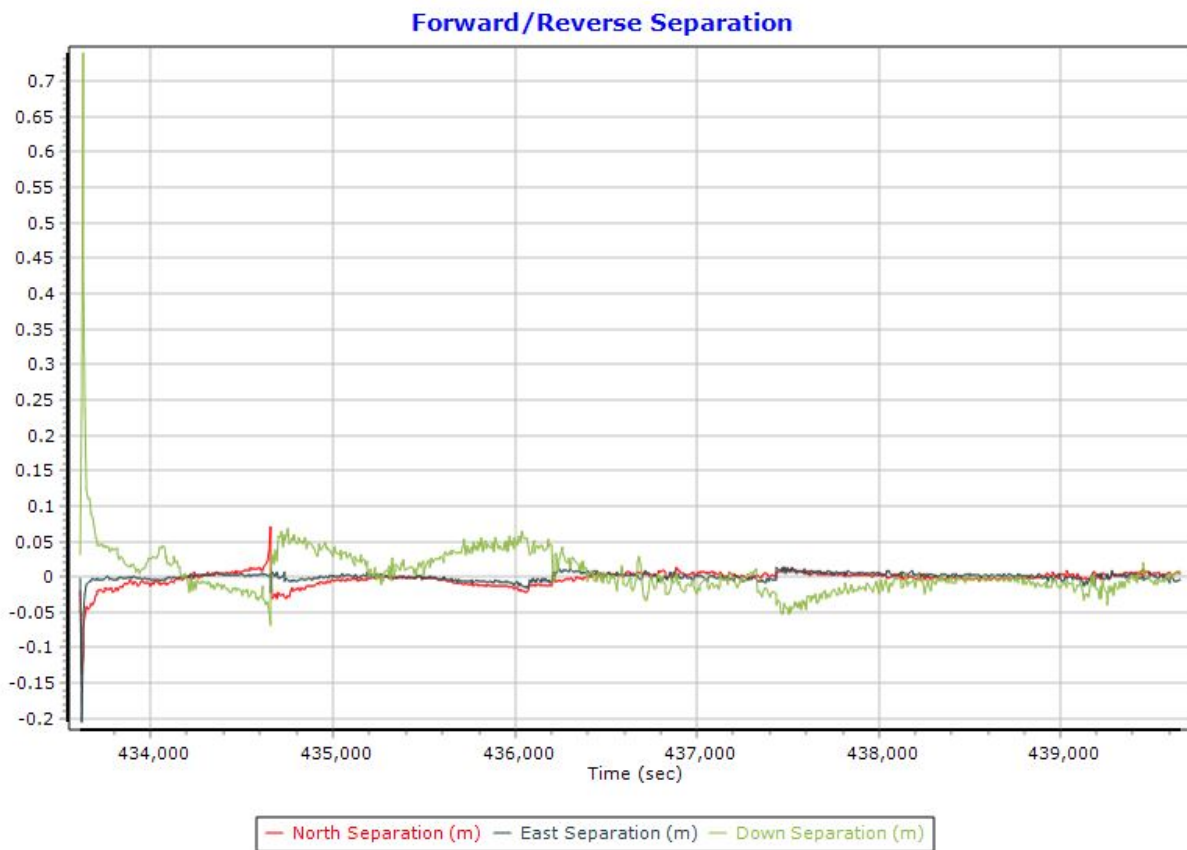
Statistics	Min	Max	Mean
Baseline length (km)	16.06	74.25	
Number of GPS SV	6	9	8
Number of GLONASS SV	0	6	5
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Number of GALILEO SV	0	0	0
Total number of SV	7	15	12
PDOP	1.23	3.09	1.76
QC Solution Gaps	1.00	1.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	6027.00	0.00	1.00
Percentage	99.98	0.00	0.02

Number of Satellites

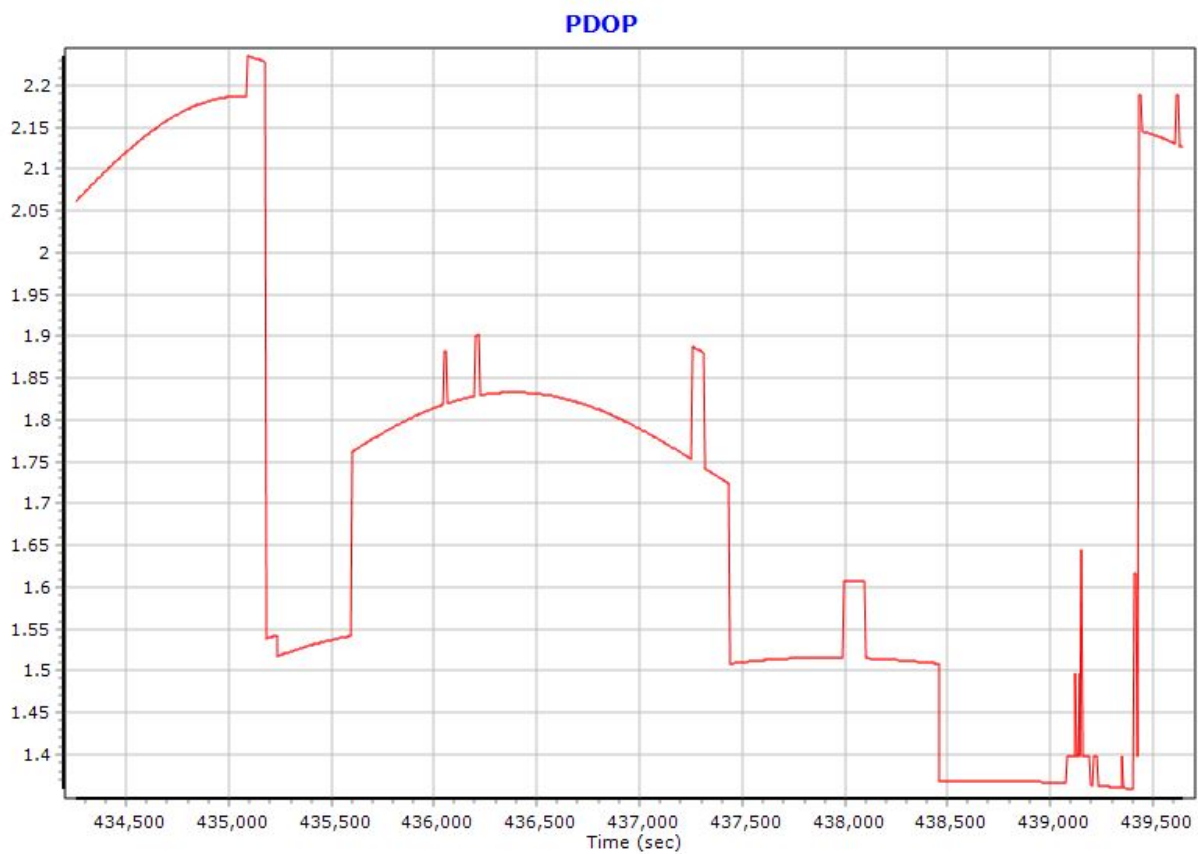


— Number of GPS Satellites
 — Number of GLONASS Satellites
 — Number of QZSS Satellites
— Number of BEIDOU Satellites
 — Number of GALILEO Satellites

Forward/Reverse Separation

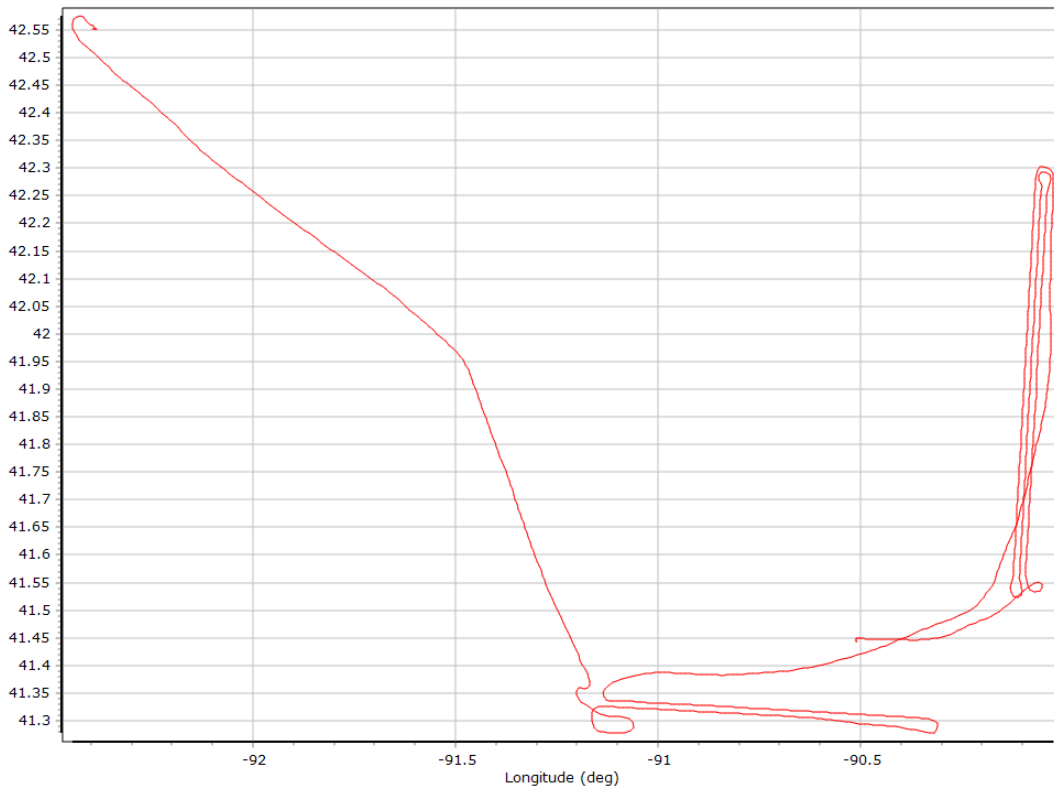


PDOP

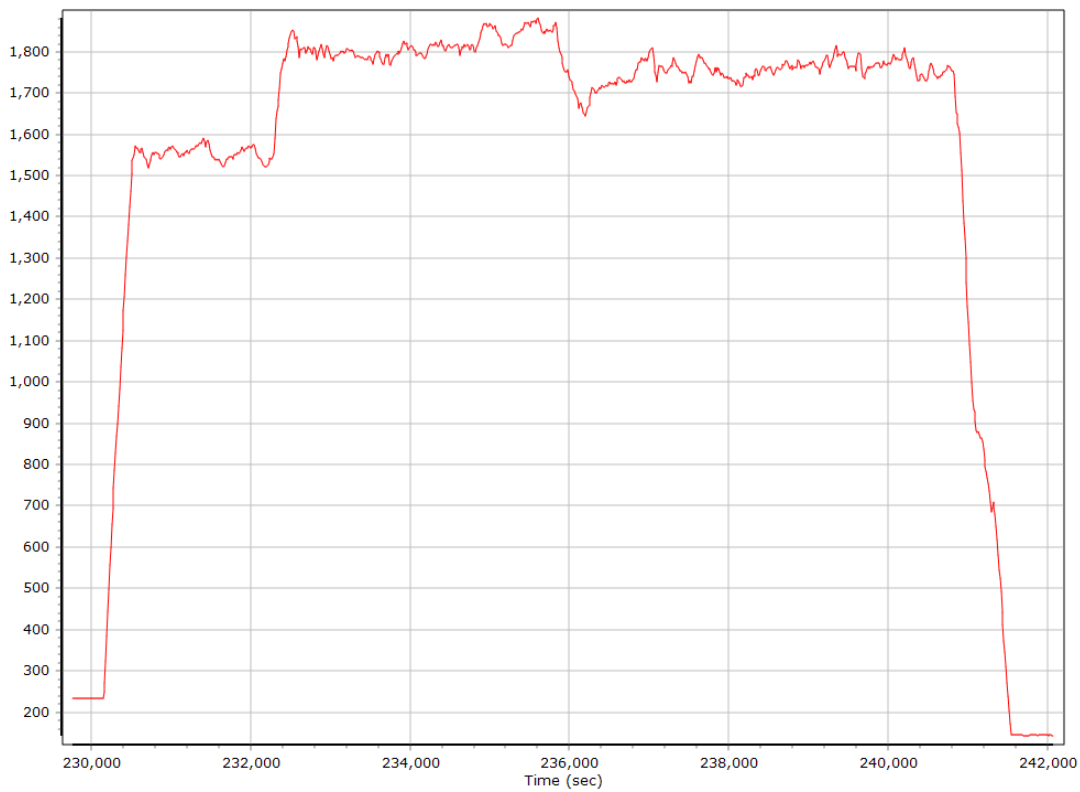


Smoothed Trajectory Information

Top View



Altitude

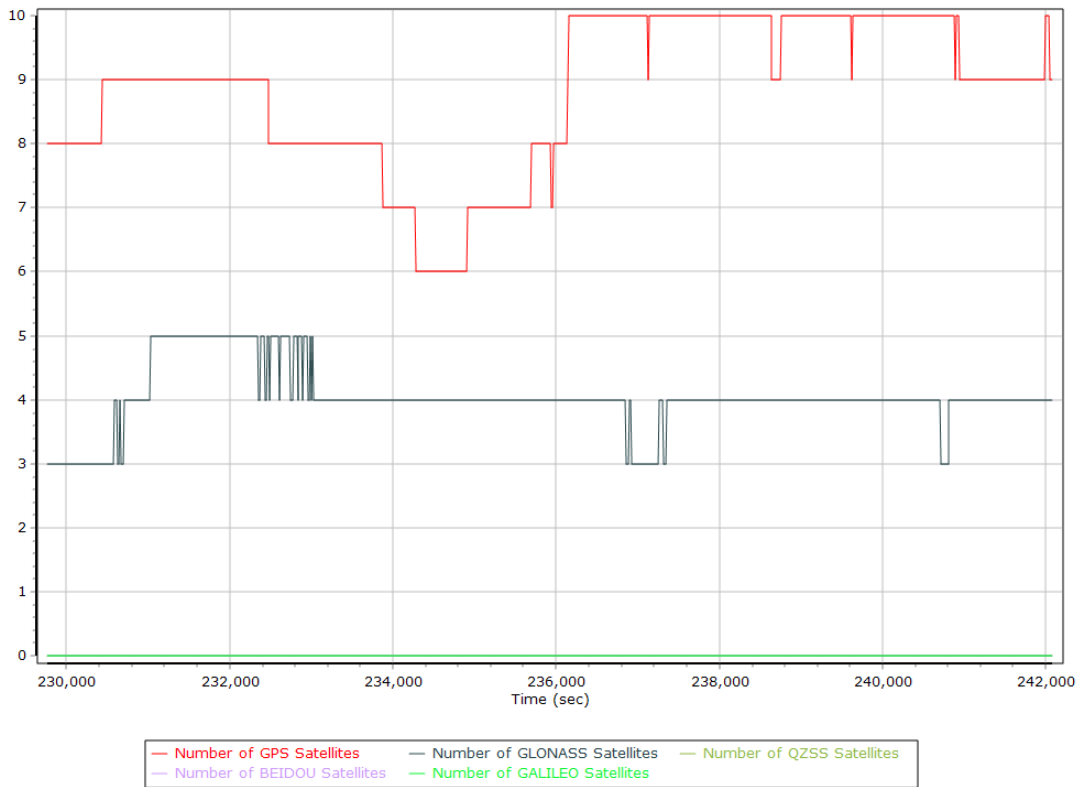


GNSS QC

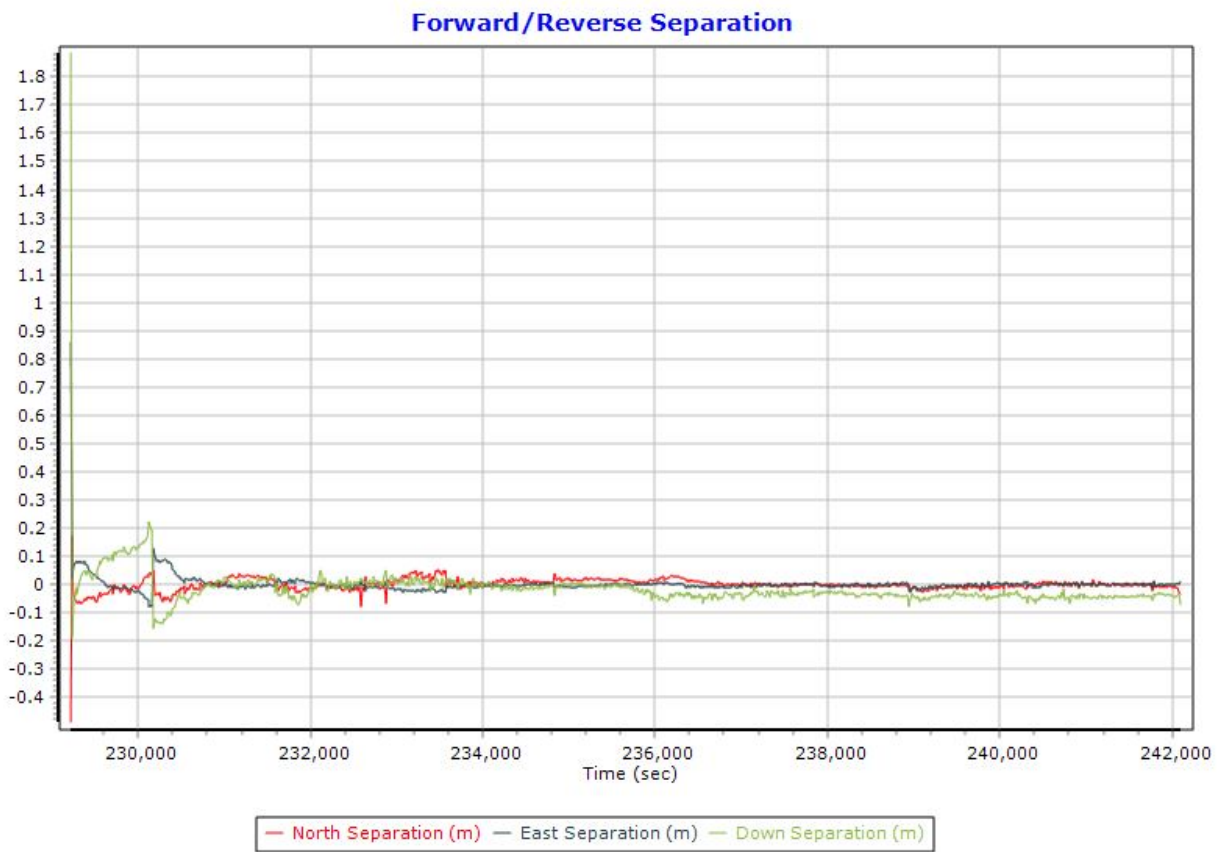
GNSS QC Statistics

Statistics	Min	Max	Mean
Baseline length (km)	42.04	165.07	
Number of GPS SV	5	10	9
Number of GLONASS SV	0	7	5
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Number of GALILEO SV	0	0	0
Total number of SV	7	17	14
PDOP	1.19	2.94	1.55
QC Solution Gaps	1.00	1.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	12853.00	0.00	1.00
Percentage	99.99	0.00	0.01

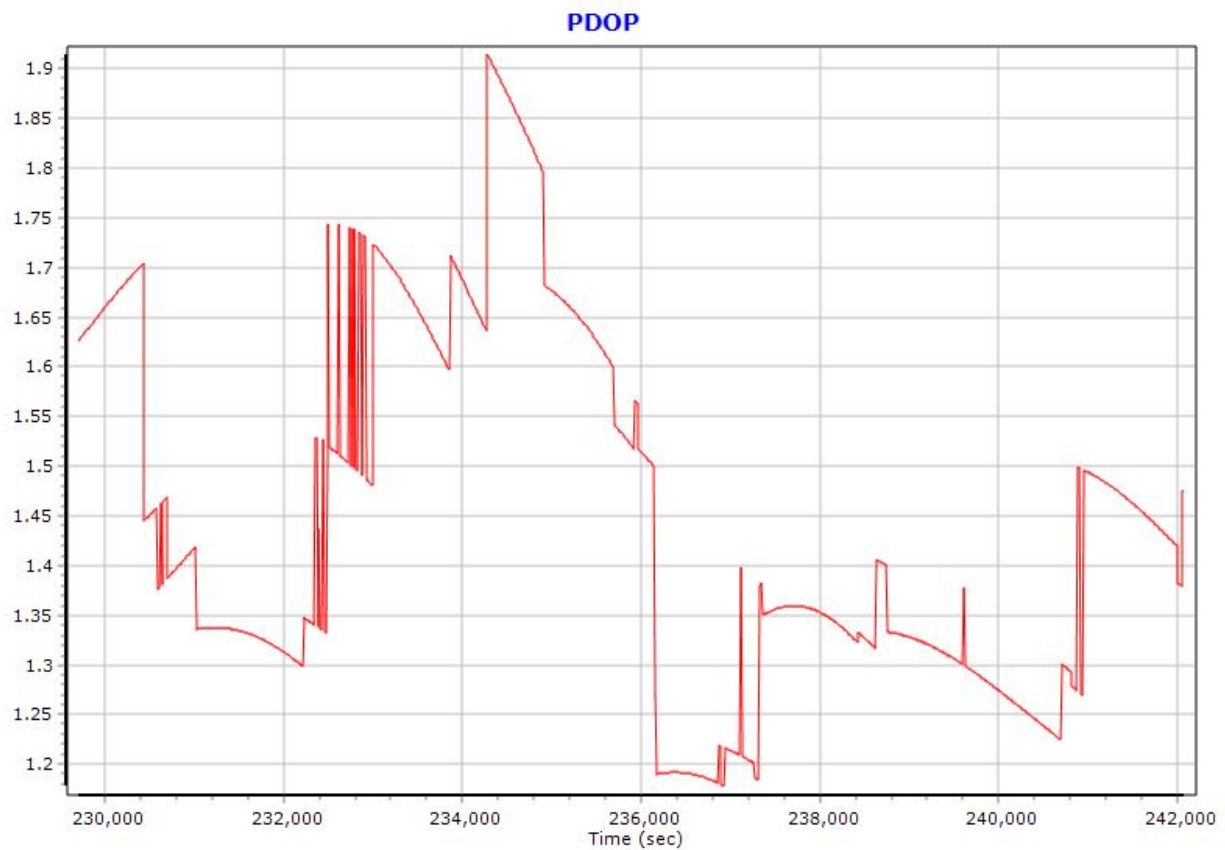
Number of Satellites



Forward/Reverse Separation

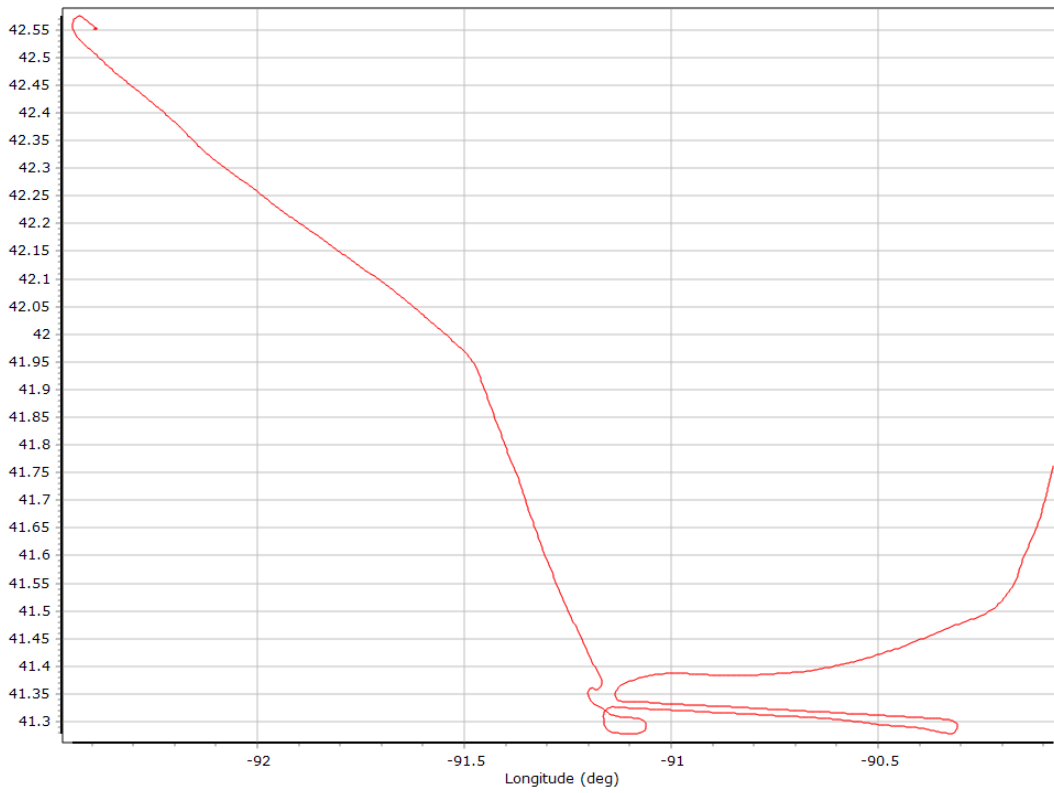


PDOP

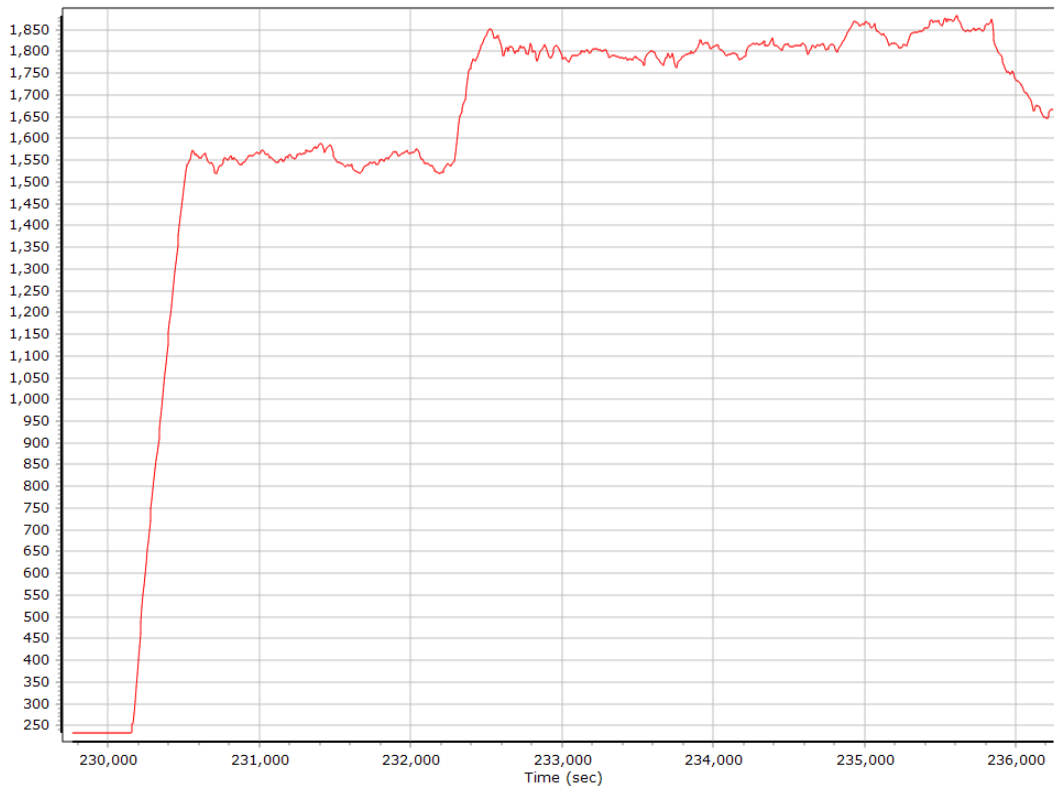


Smoothed Trajectory Information

Top View



Altitude

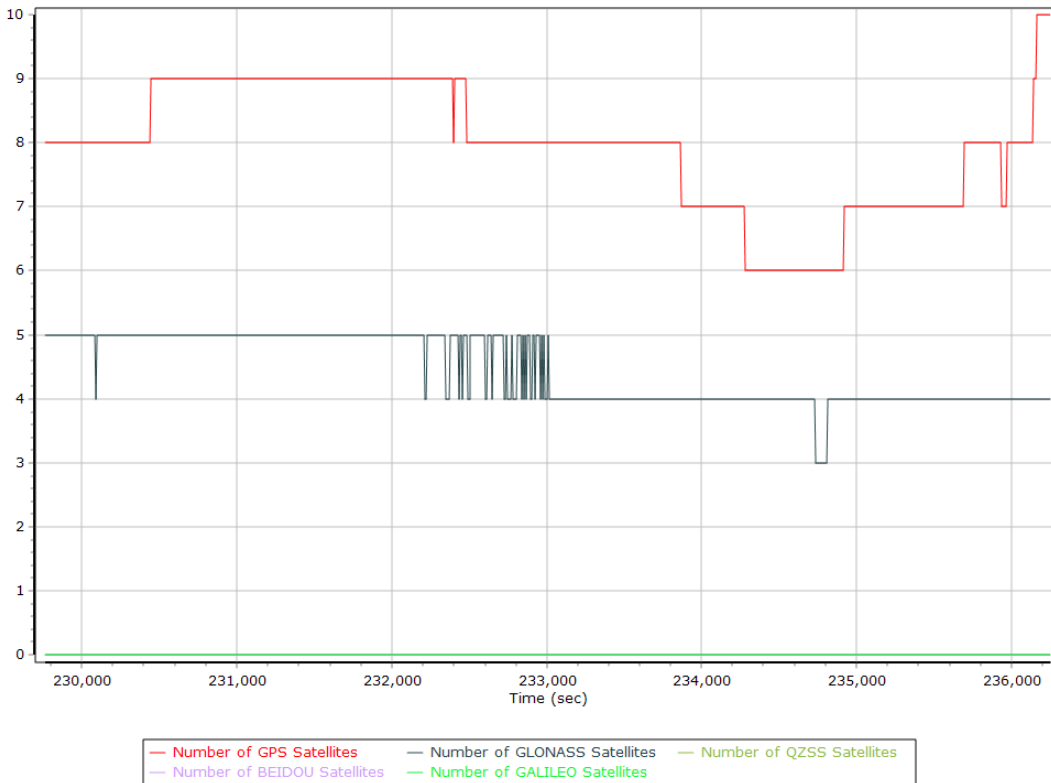


GNSS QC

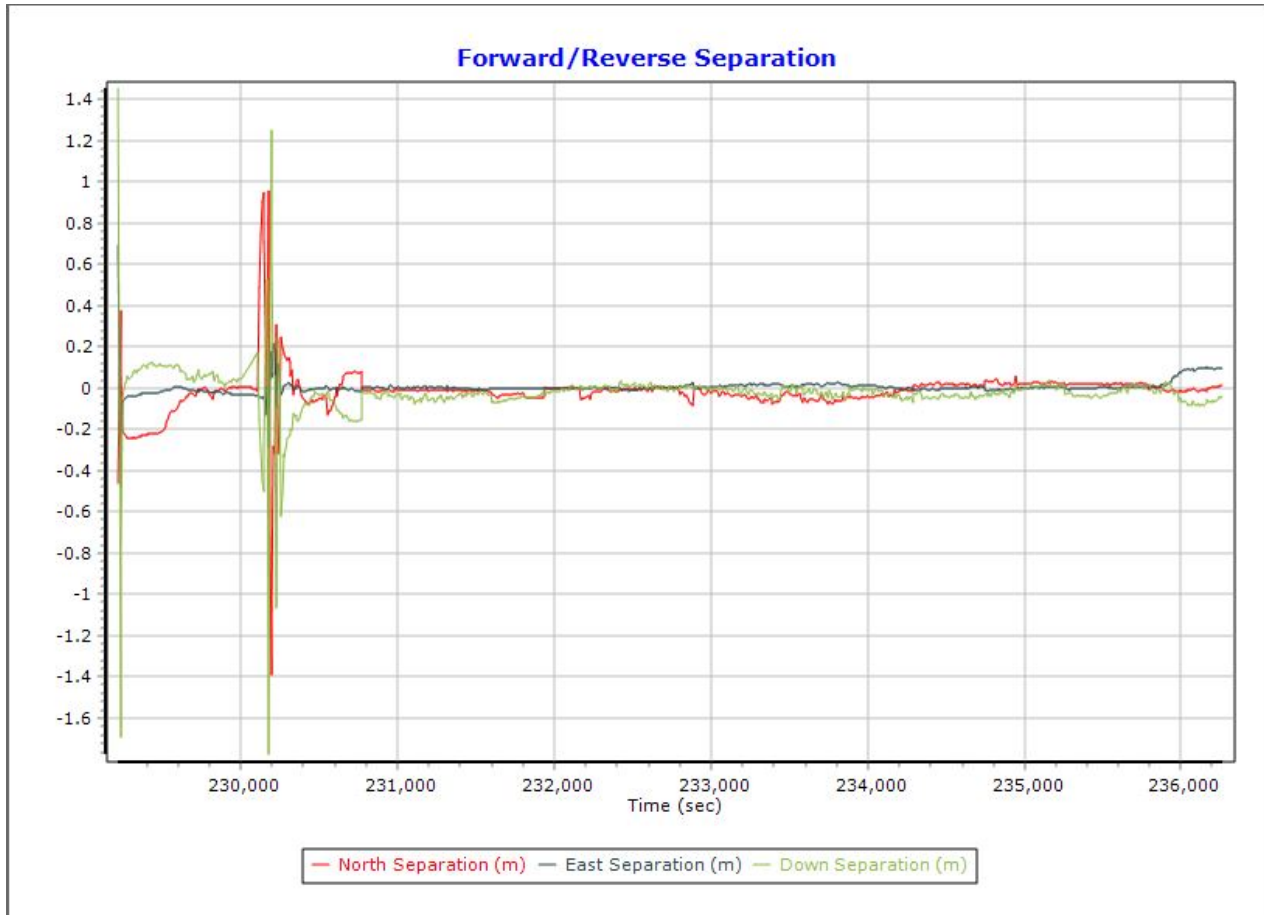
GNSS QC Statistics

Statistics	Min	Max	Mean
Baseline length (km)	8.95	134.79	
Number of GPS SV	6	10	8
Number of GLONASS SV	0	7	6
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Number of GALILEO SV	0	0	0
Total number of SV	7	16	14
PDOP	1.19	2.80	1.65
QC Solution Gaps	1.00	1.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	7051.00	0.00	1.00
Percentage	99.99	0.00	0.01

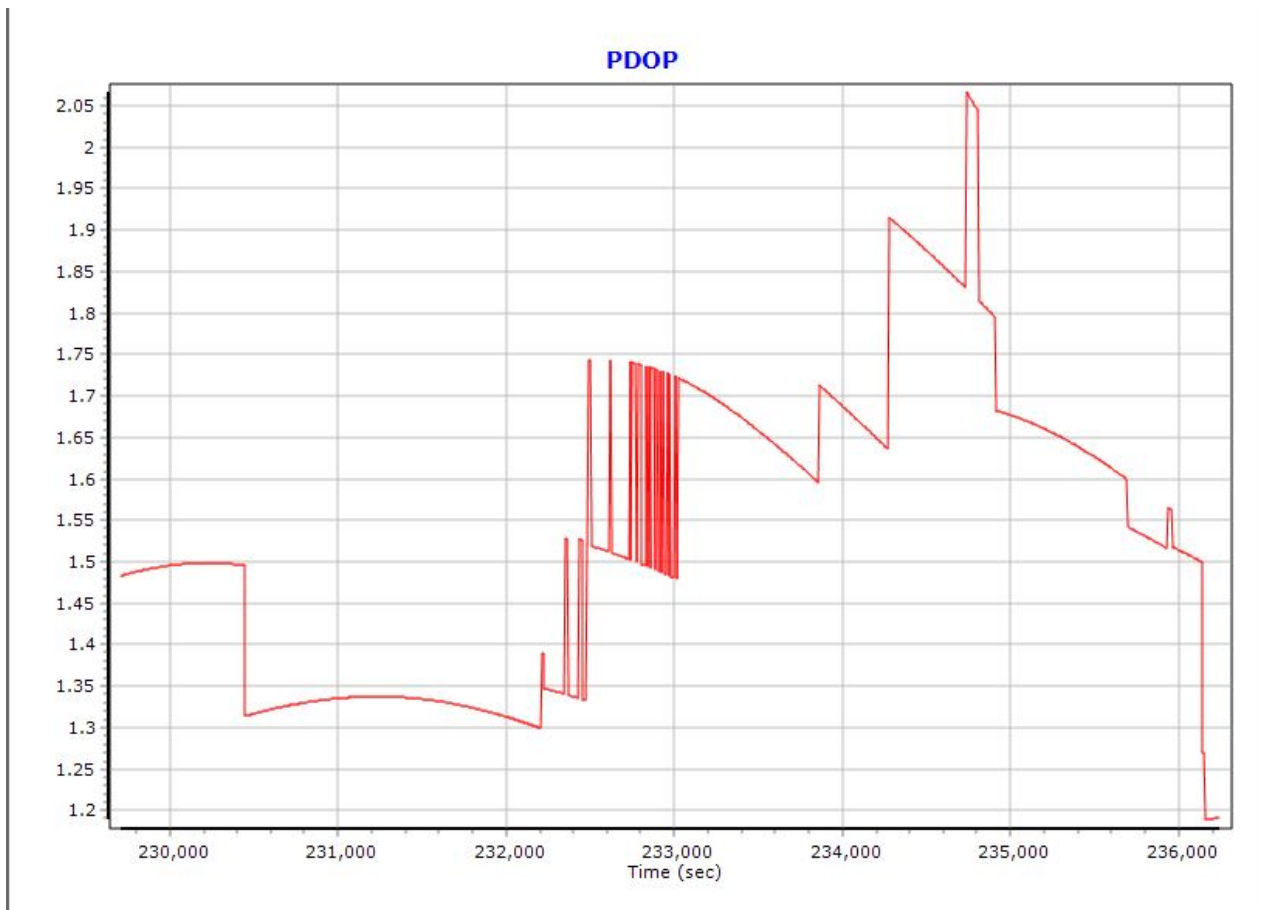
Number of Satellites



Forward/Reverse Separation

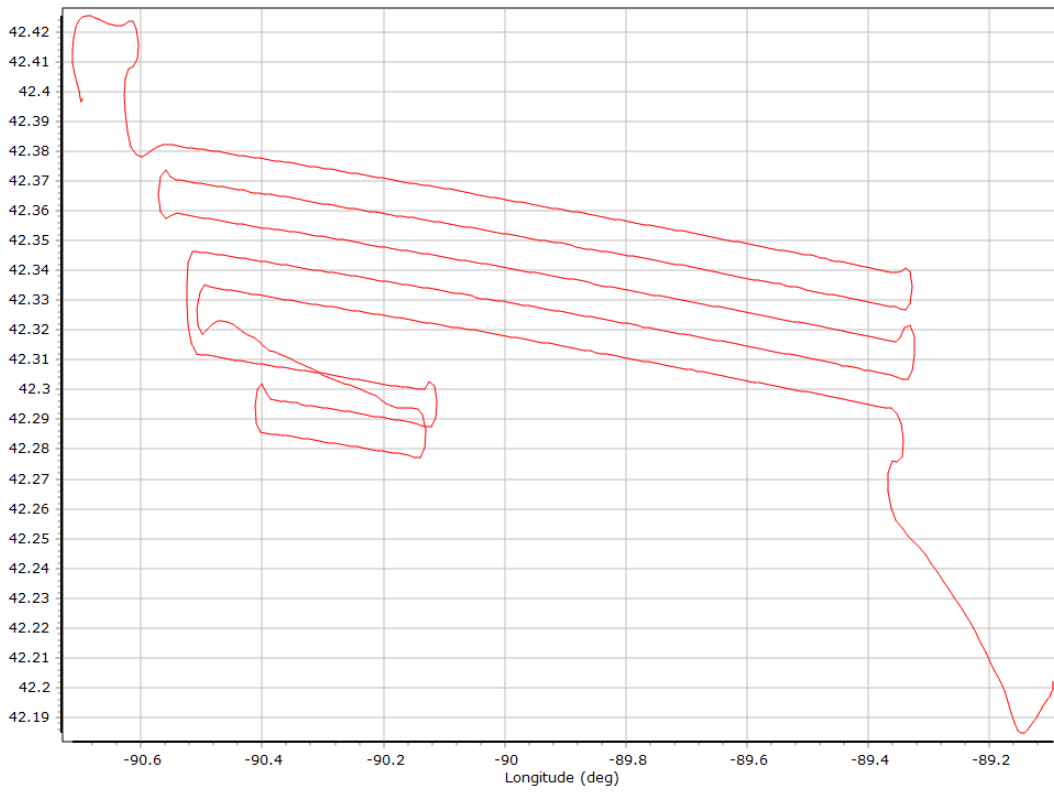


PDOP

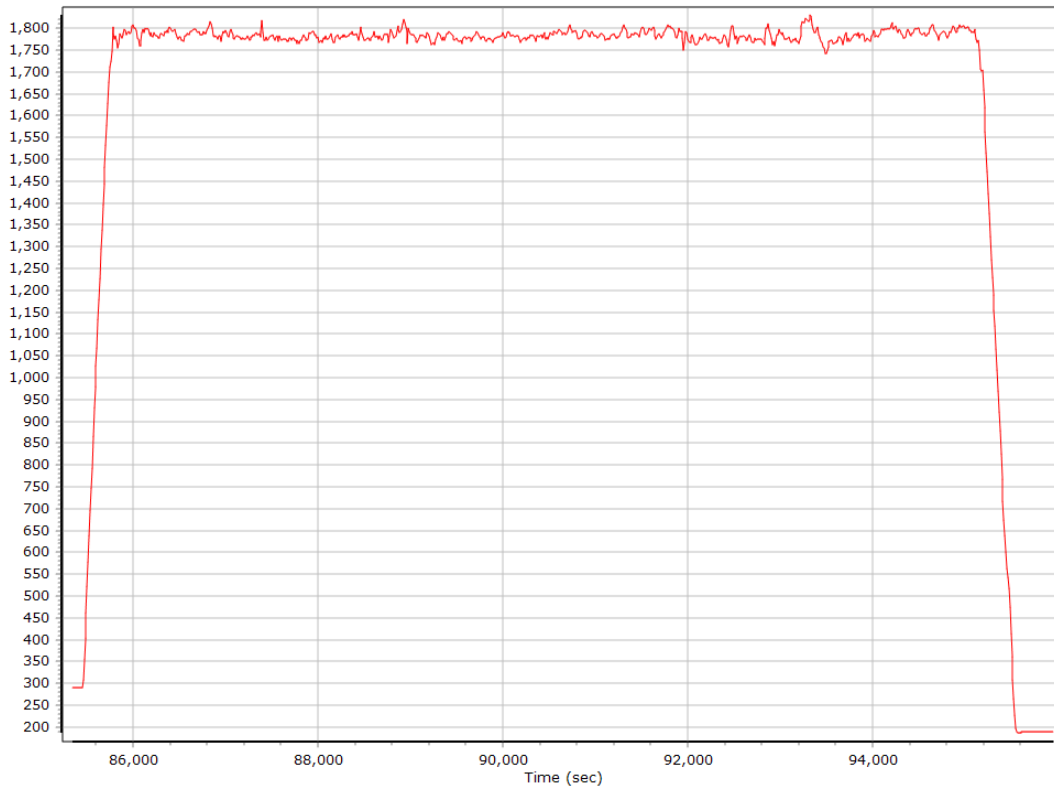


Smoothed Trajectory Information

Top View



Altitude

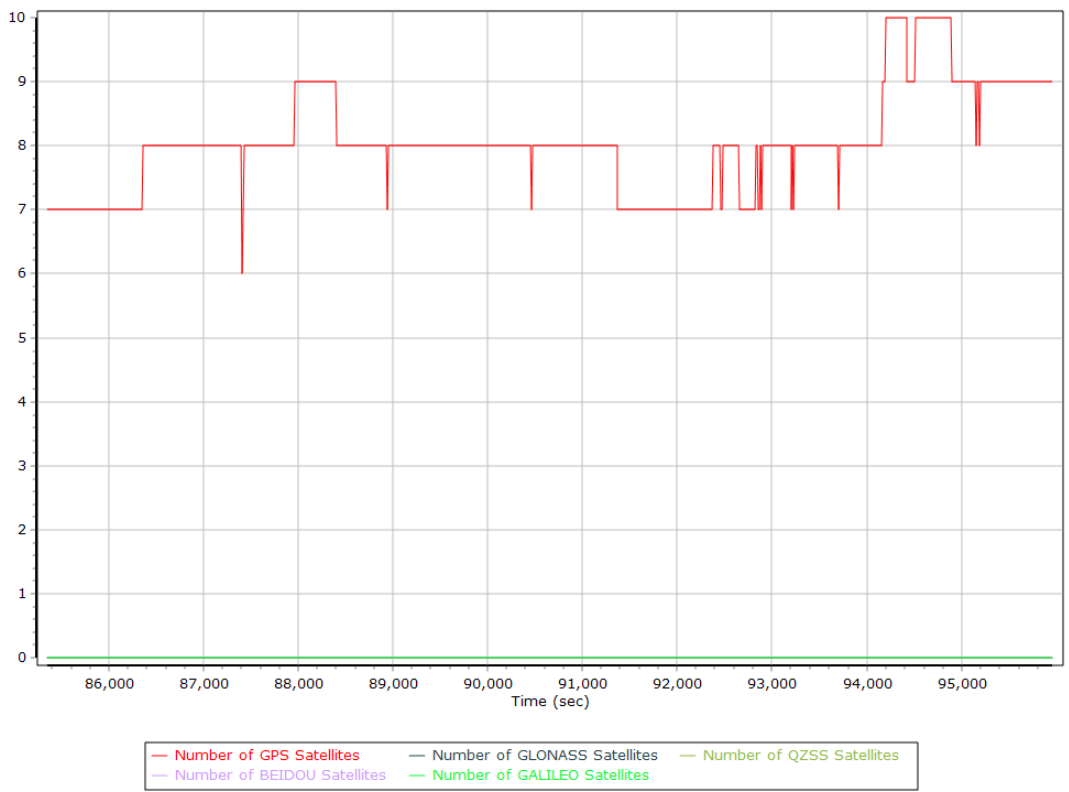


GNSS QC

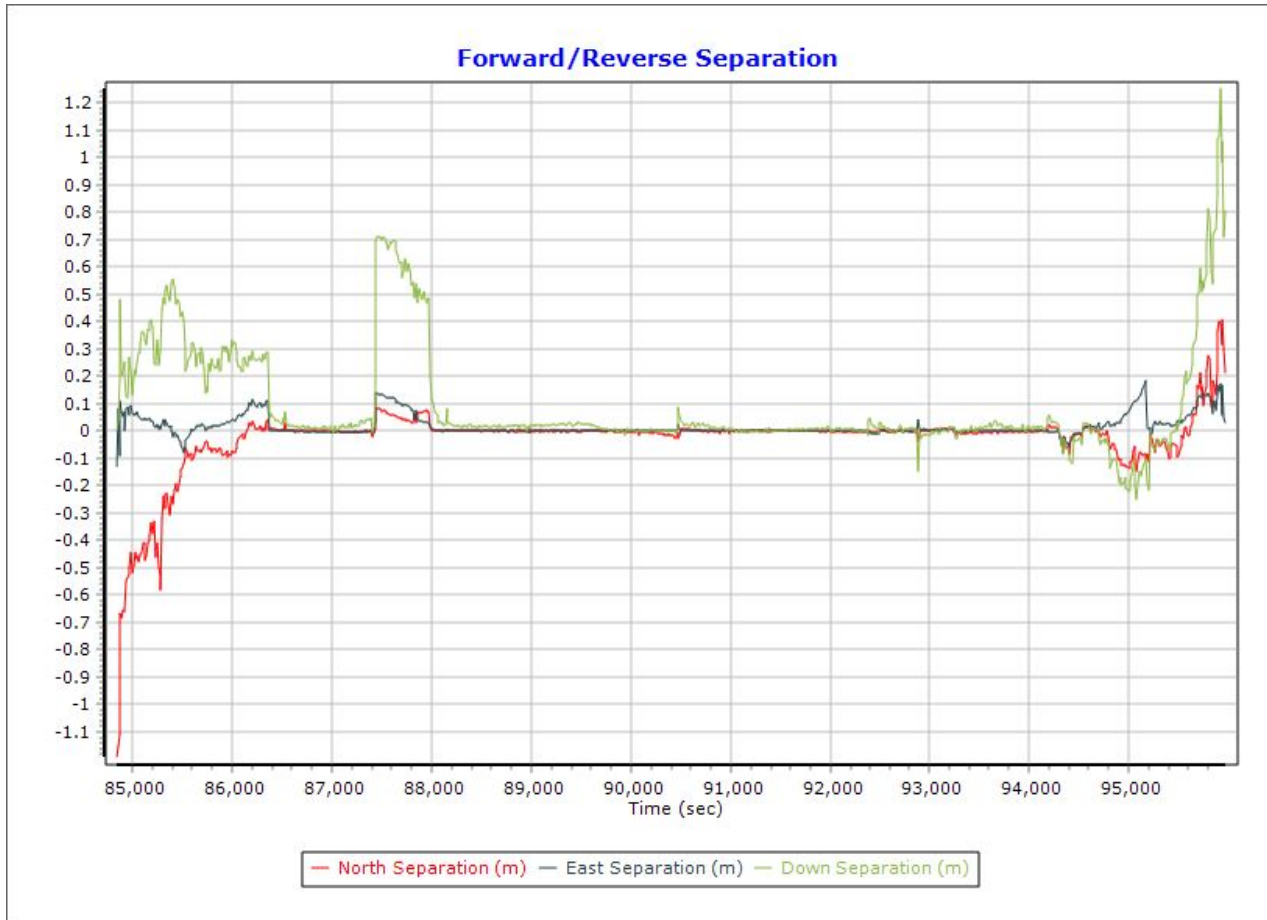
GNSS QC Statistics

Statistics	Min	Max	Mean
Baseline length (km)	0.21	76.70	
Number of GPS SV	6	10	8
Number of GLONASS SV	0	0	0
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Number of GALILEO SV	0	0	0
Total number of SV	6	10	8
PDOP	1.62	3.70	2.08
QC Solution Gaps	0.00	0.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	10956.00	135.00	0.00
Percentage	98.78	1.22	0.00

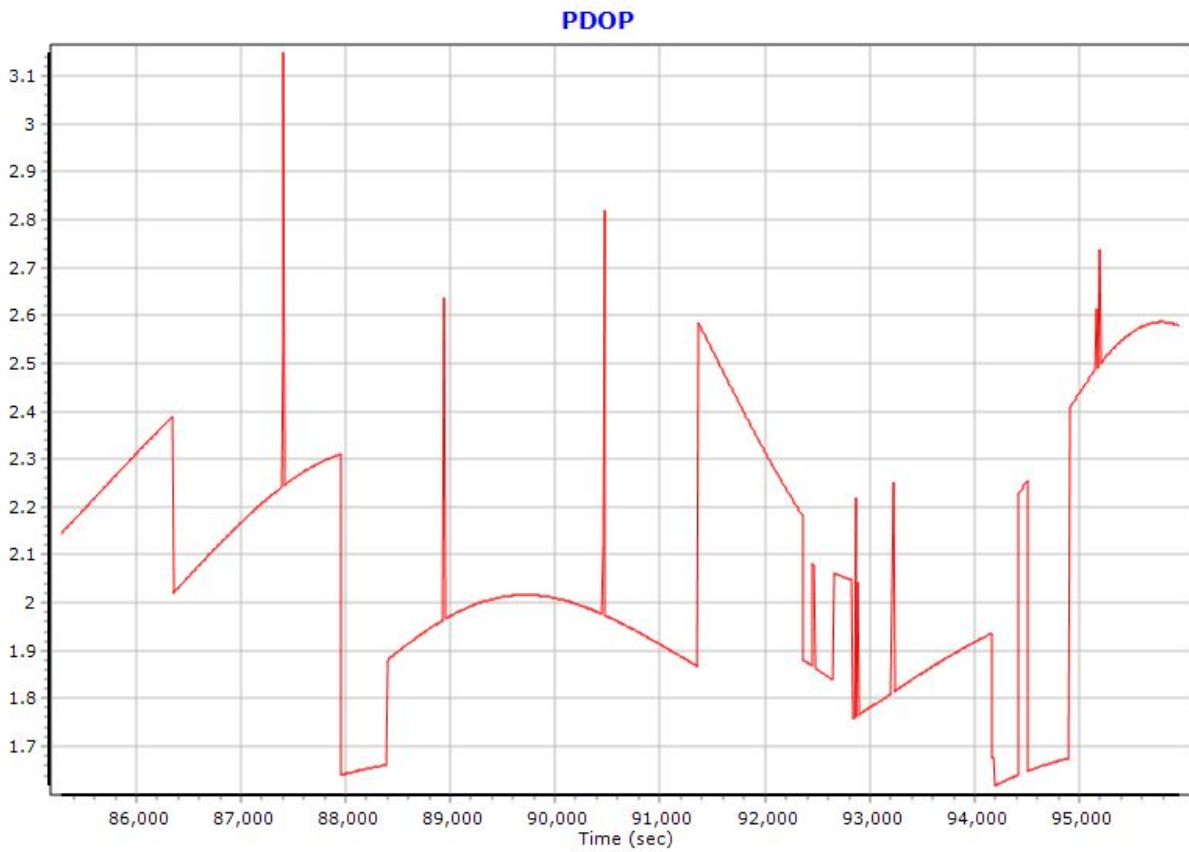
Number of Satellites



Forward/Reverse Separation

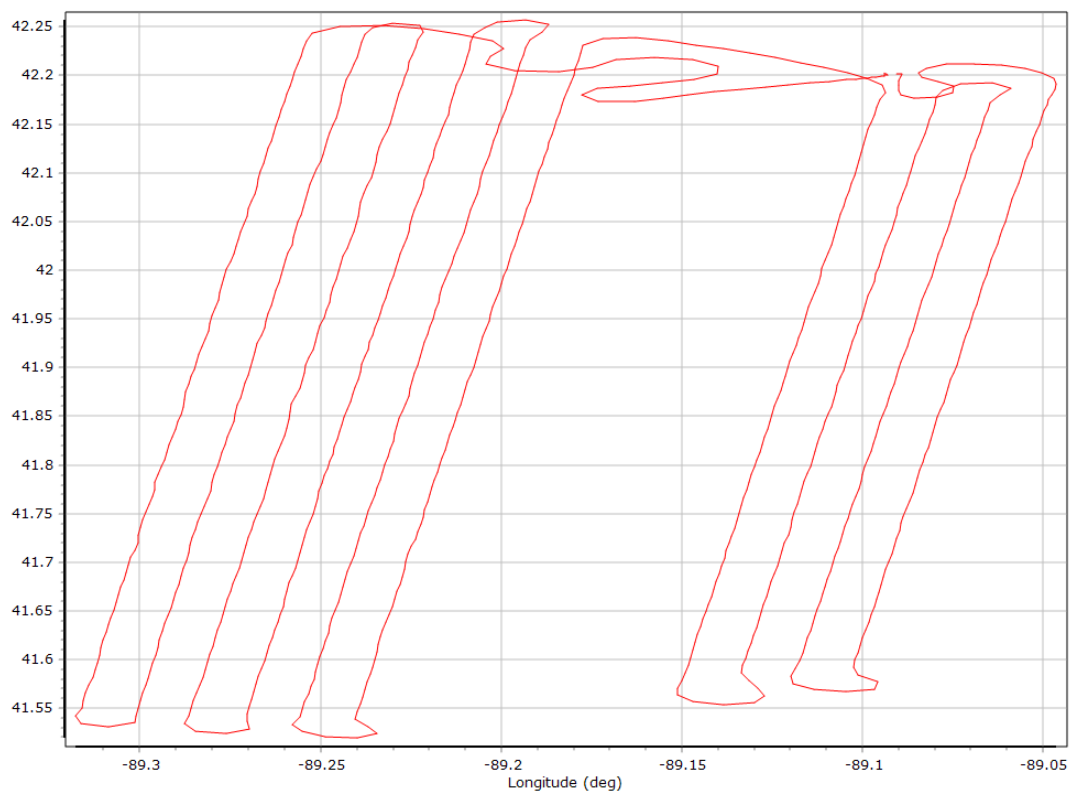


PDOP

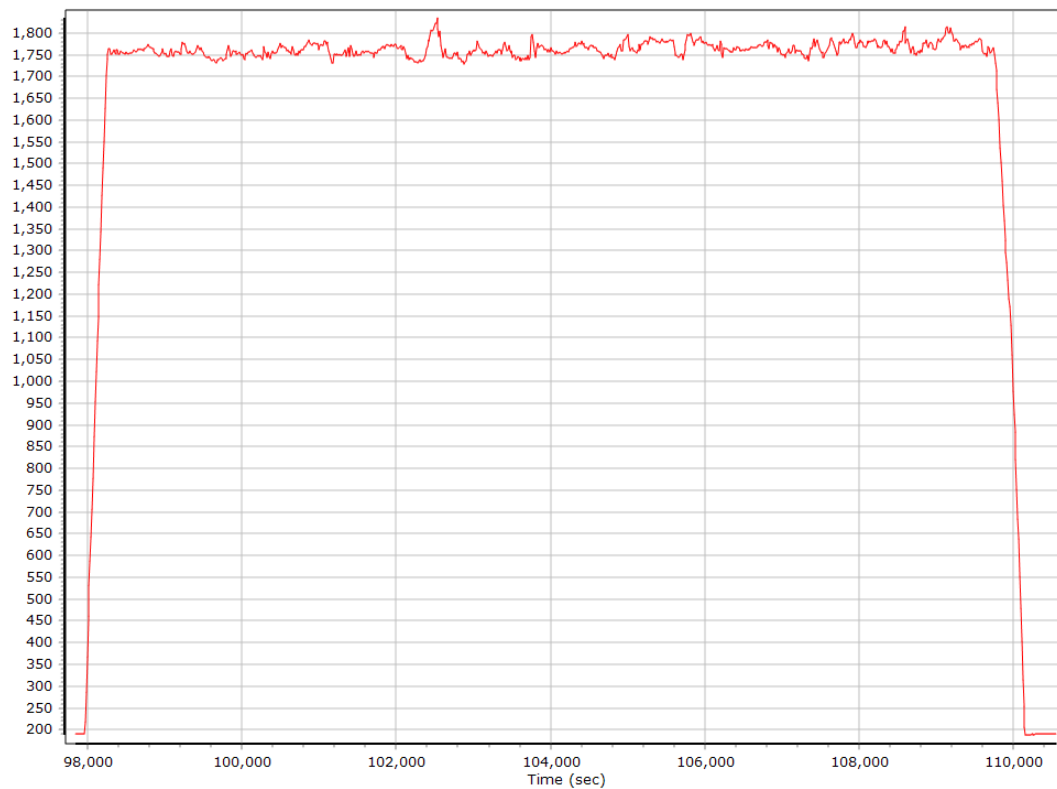


Smoothed Trajectory Information

Top View



Altitude

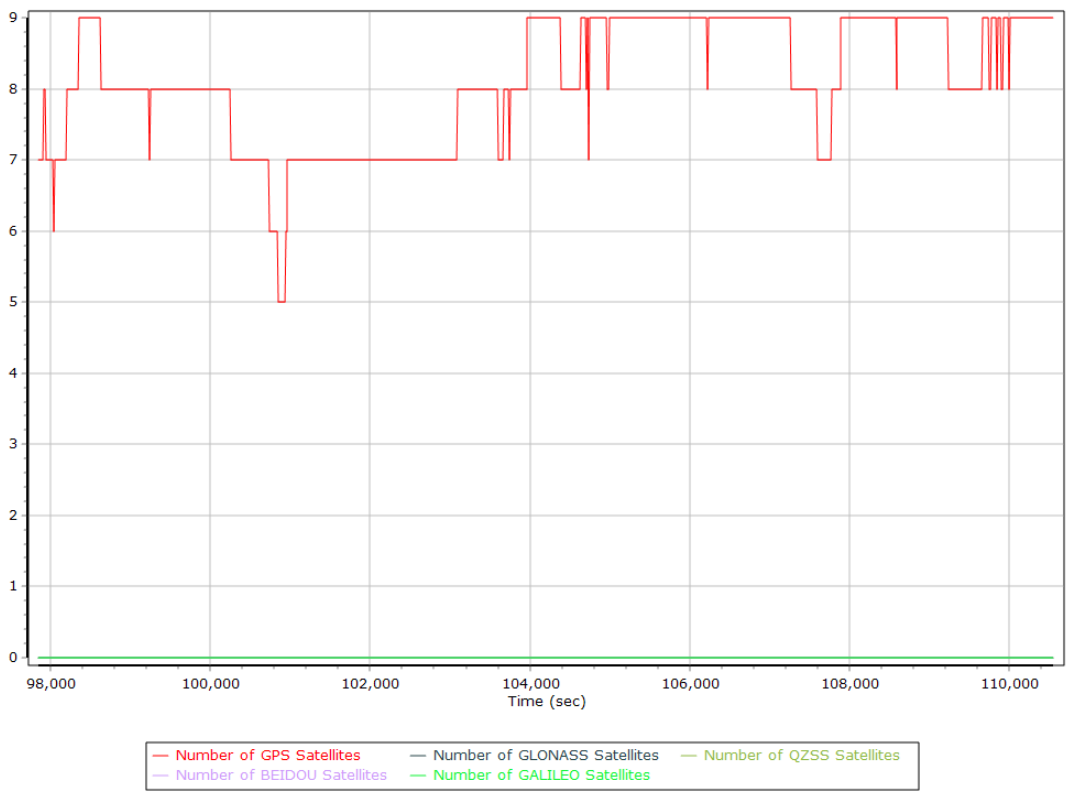


GNSS QC

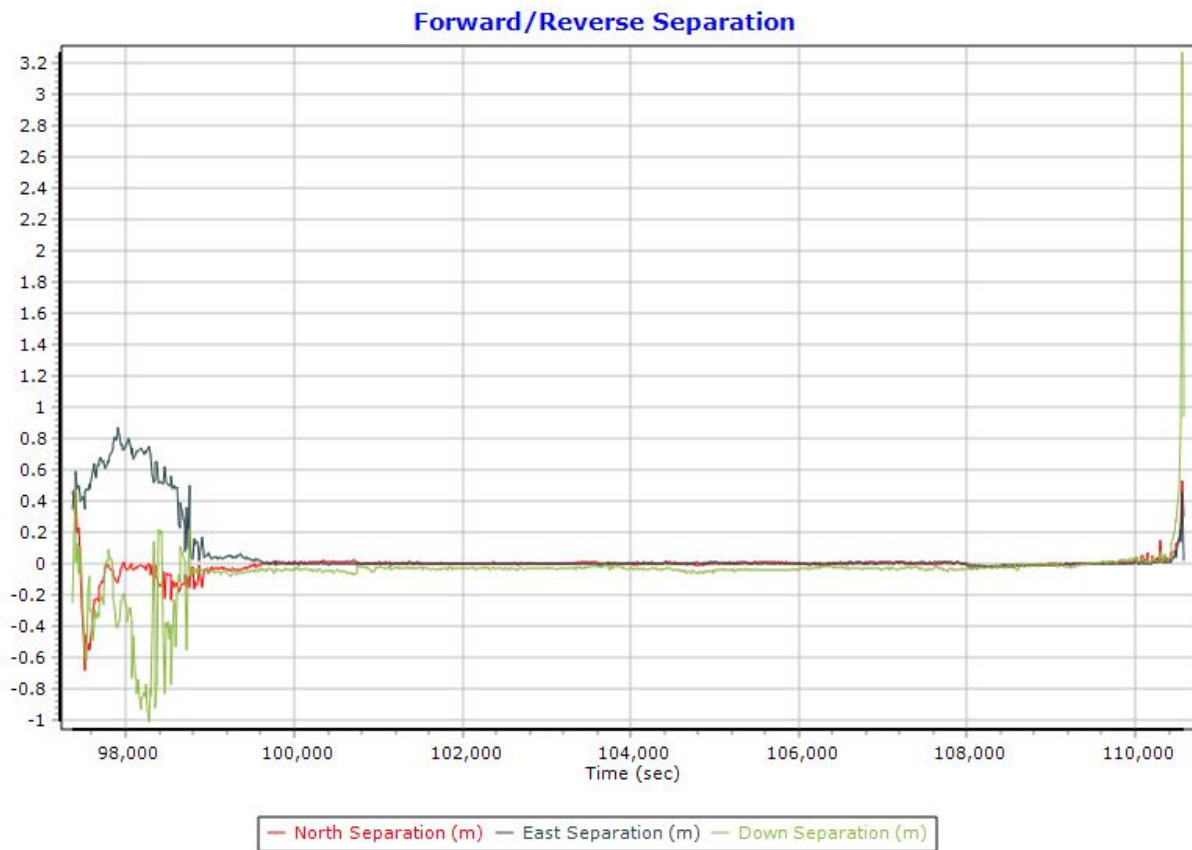
GNSS QC Statistics

Statistics	Min	Max	Mean
Baseline length (km)	2.02	45.60	
Number of GPS SV	5	9	8
Number of GLONASS SV	0	0	0
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Number of GALILEO SV	0	0	0
Total number of SV	5	9	8
PDOP	1.53	4.59	2.02
QC Solution Gaps	0.00	0.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	13194.00	1.00	0.00
Percentage	99.99	0.01	0.00

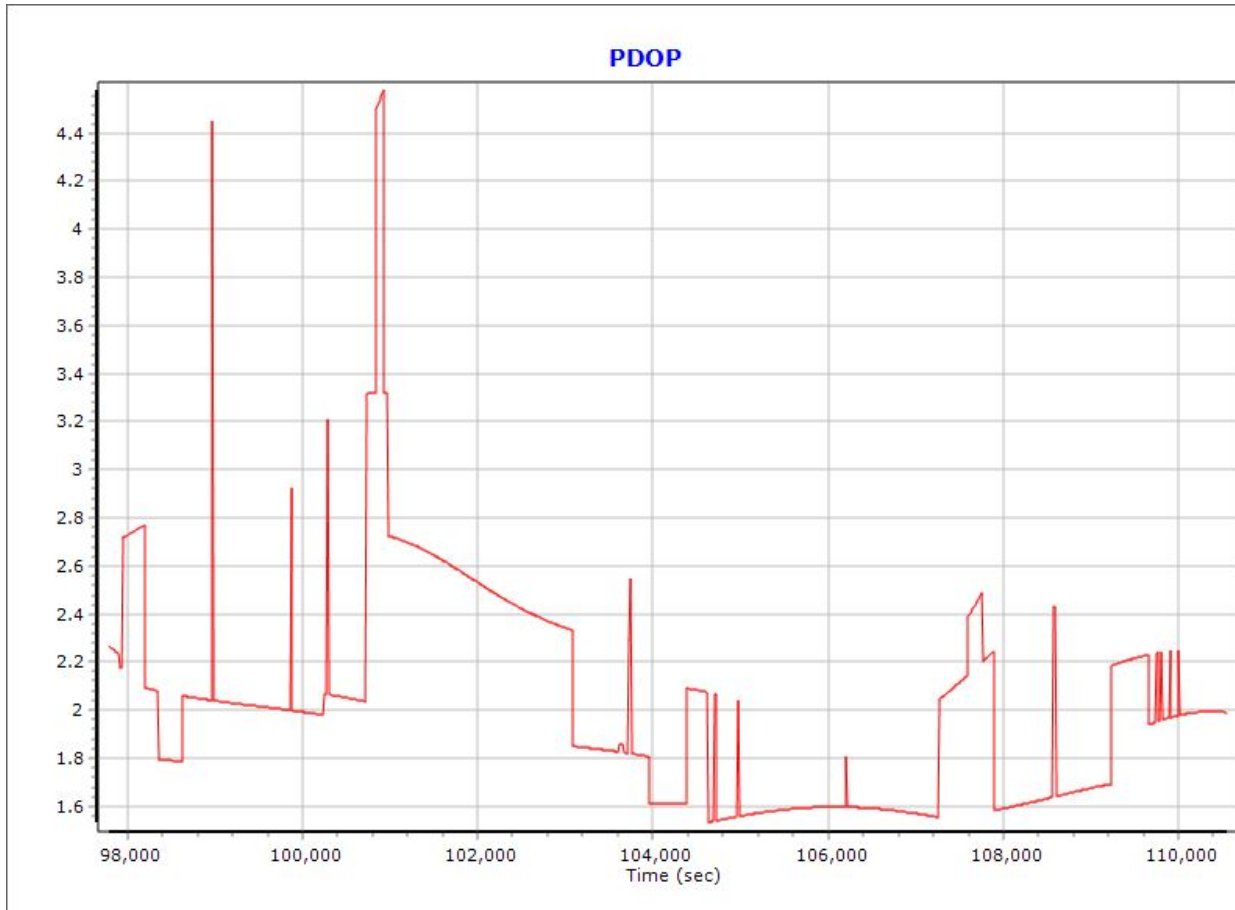
Number of Satellites



Forward/Reverse Separation

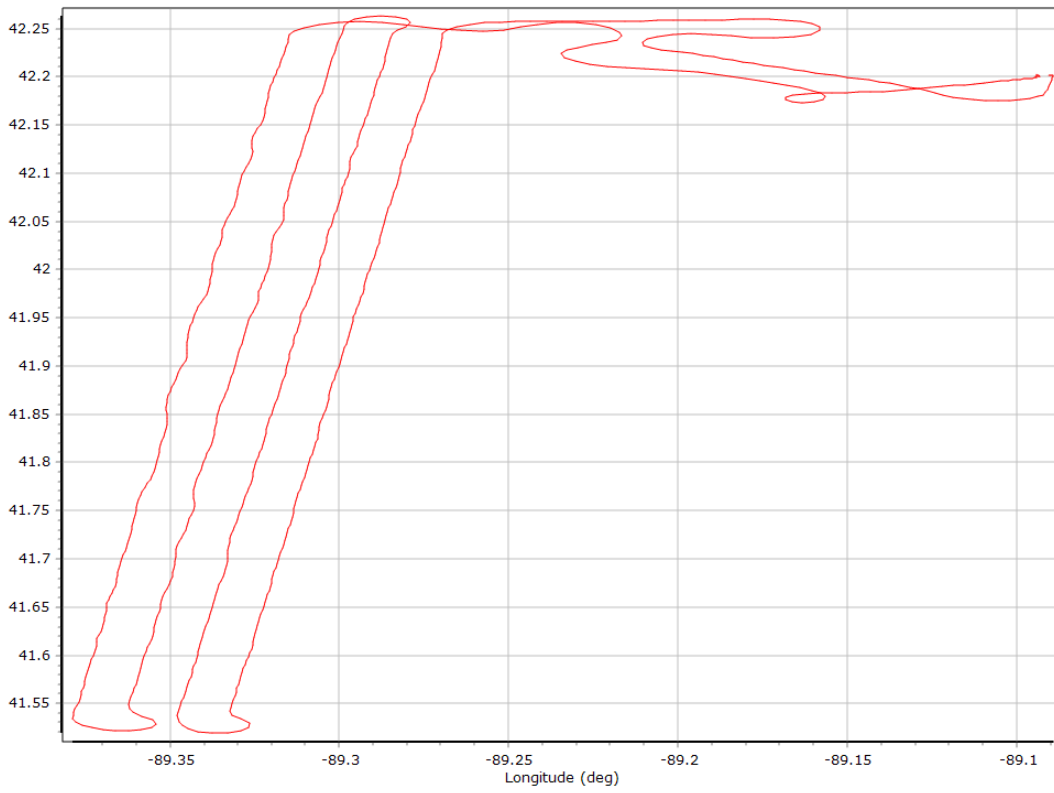


PDOP

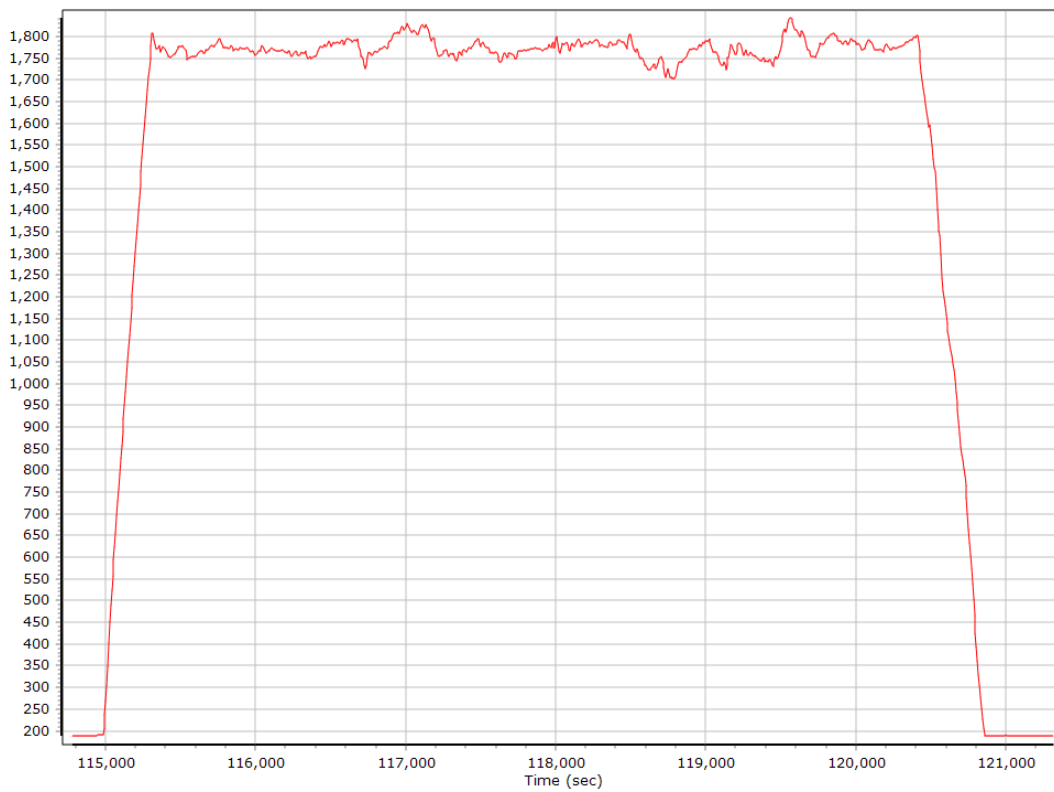


Smoothed Trajectory Information

Top View



Altitude

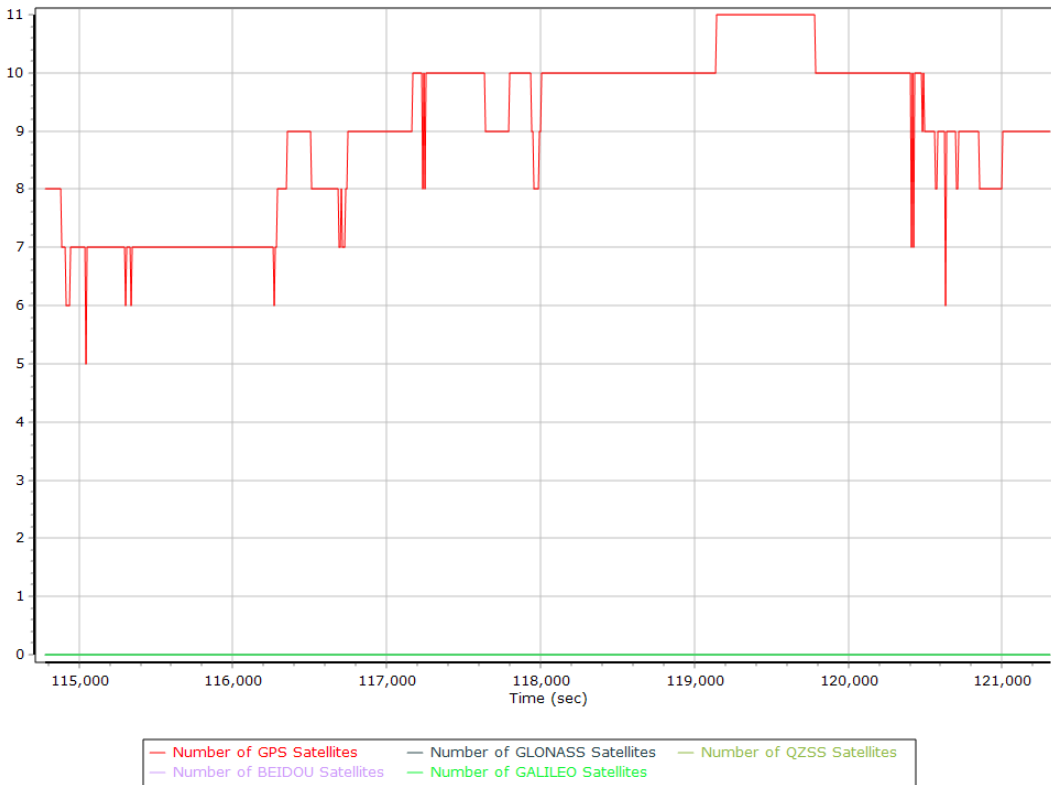


GNSS QC

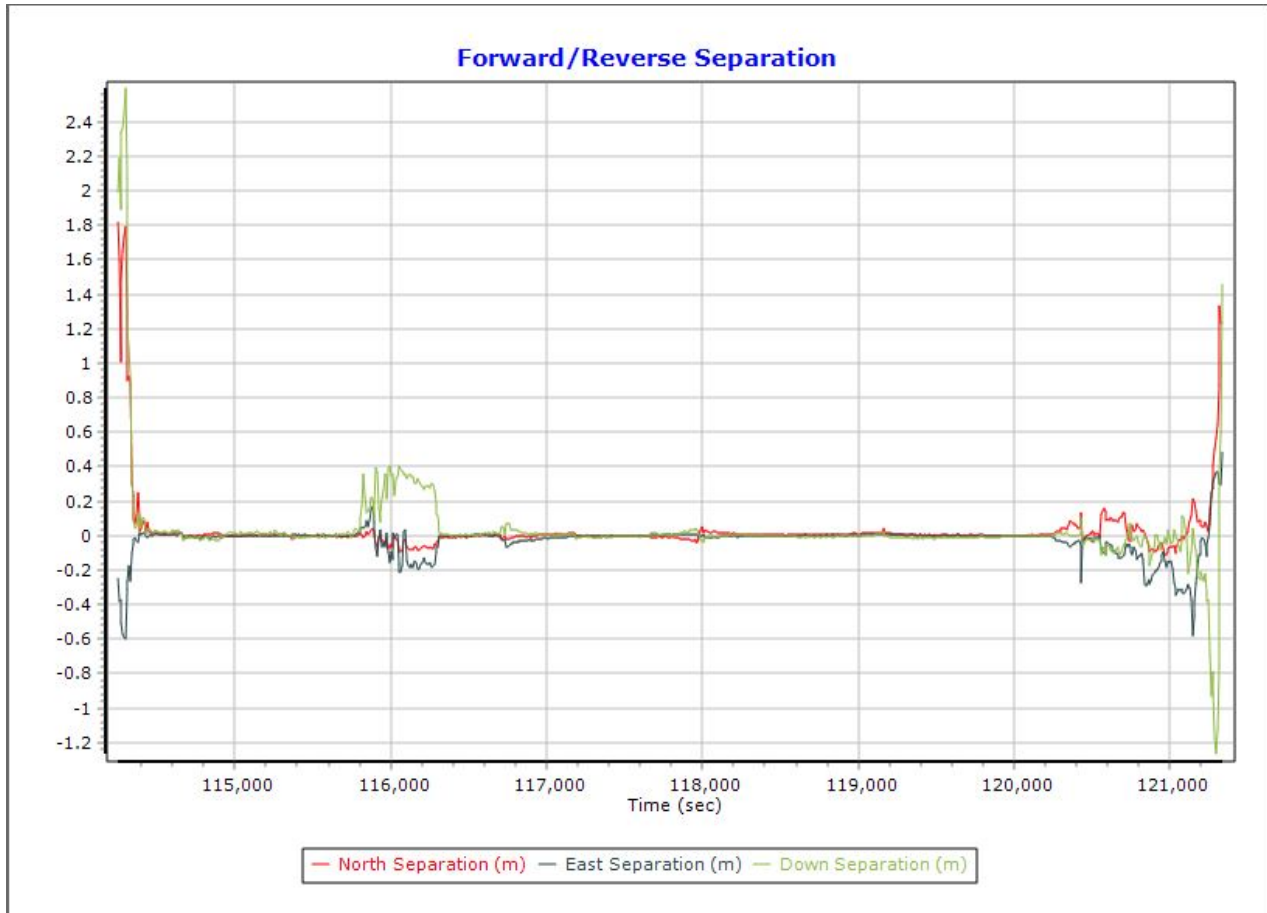
GNSS QC Statistics

Statistics	Min	Max	Mean
Baseline length (km)	2.29	52.11	
Number of GPS SV	6	11	9
Number of GLONASS SV	0	0	0
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Total number of SV	6	11	9
PDOP	1.40	3.08	1.68
QC Solution Gaps	0.00	0.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	7049.00	0.00	0.00
Percentage	100.00	0.00	0.00

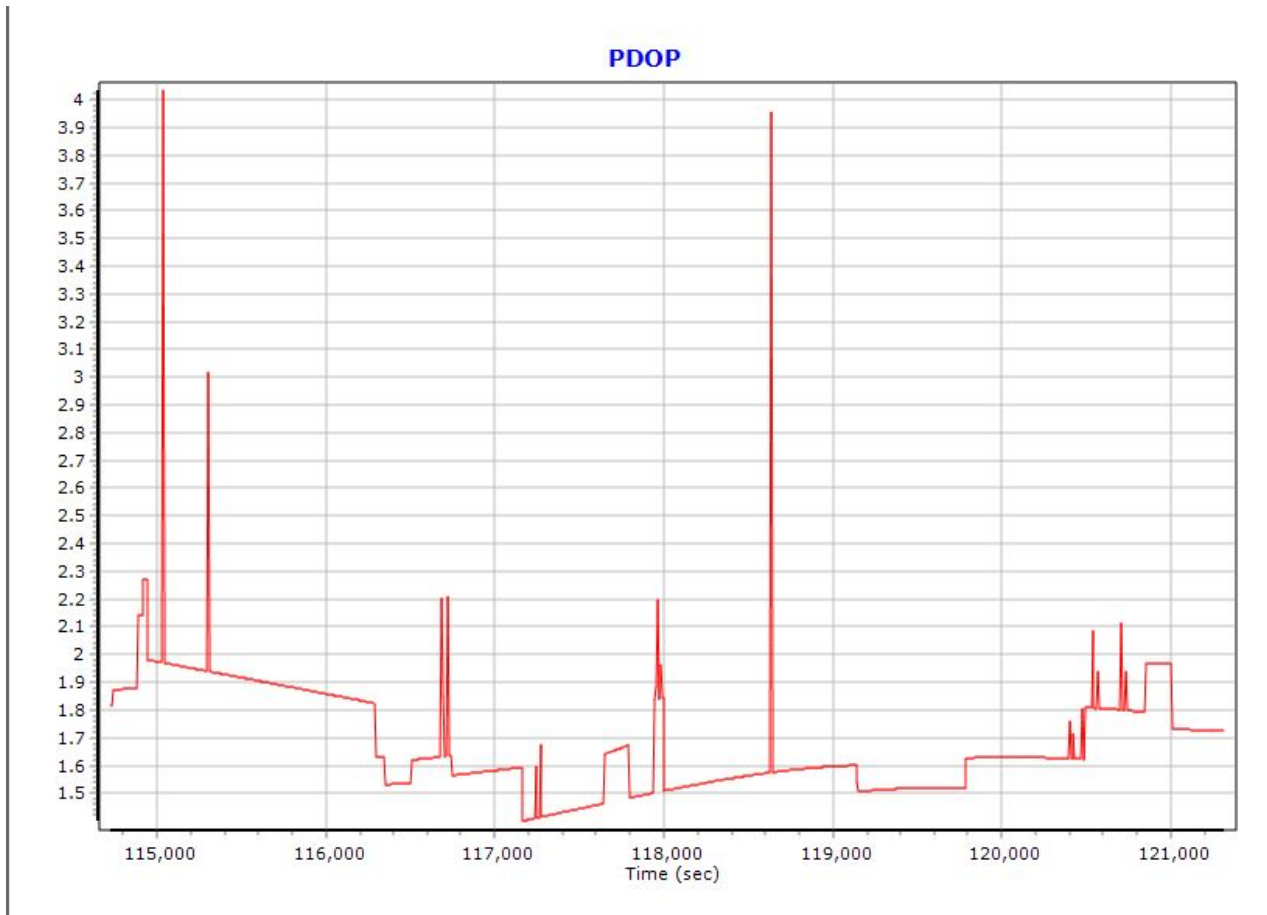
Number of Satellites



Forward/Reverse Separation

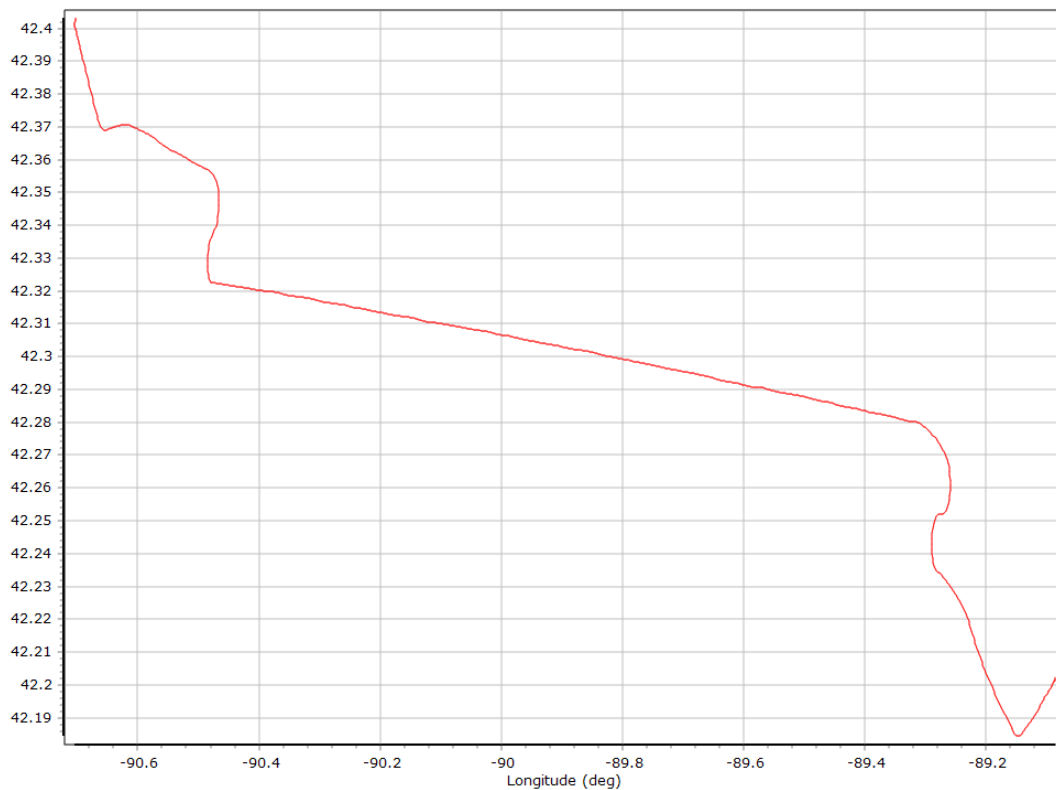


PDOP

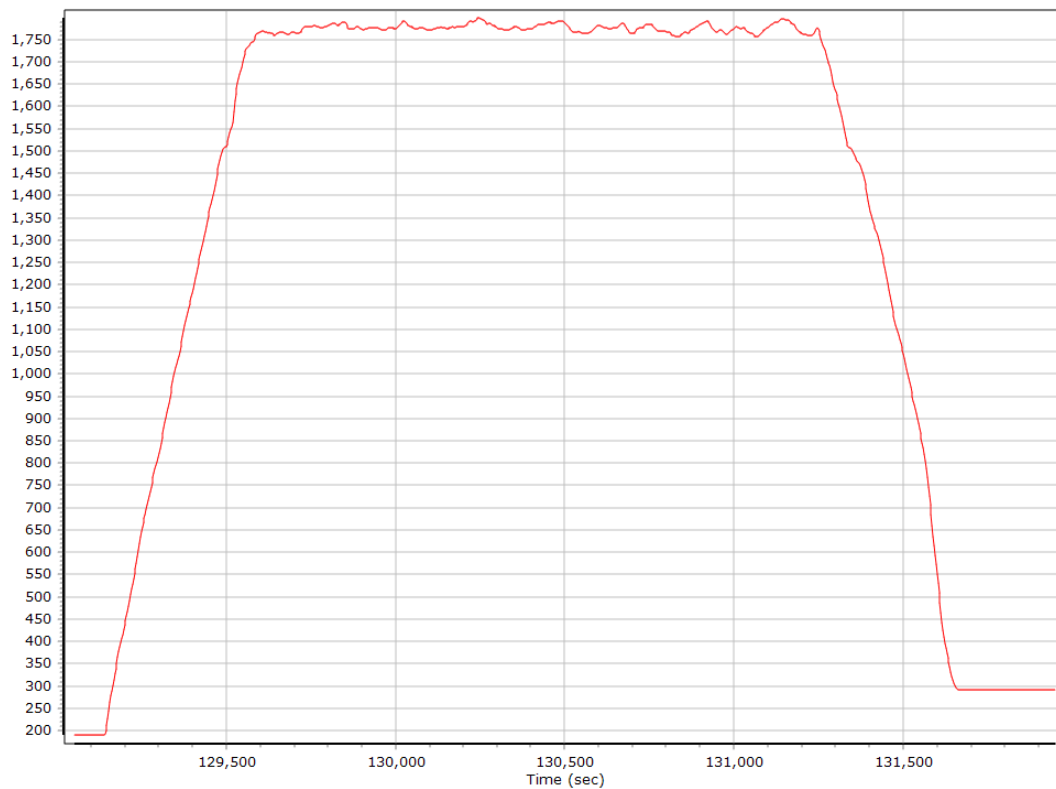


Smoothed Trajectory Information

Top View



Altitude

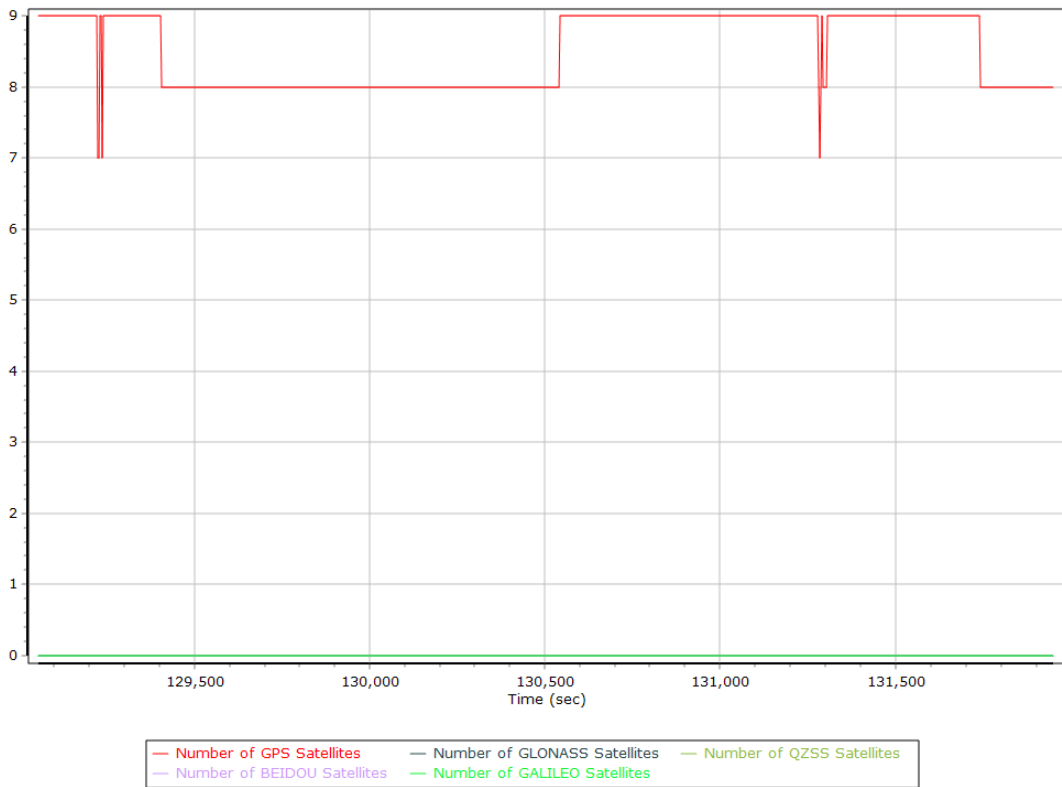


GNSS QC

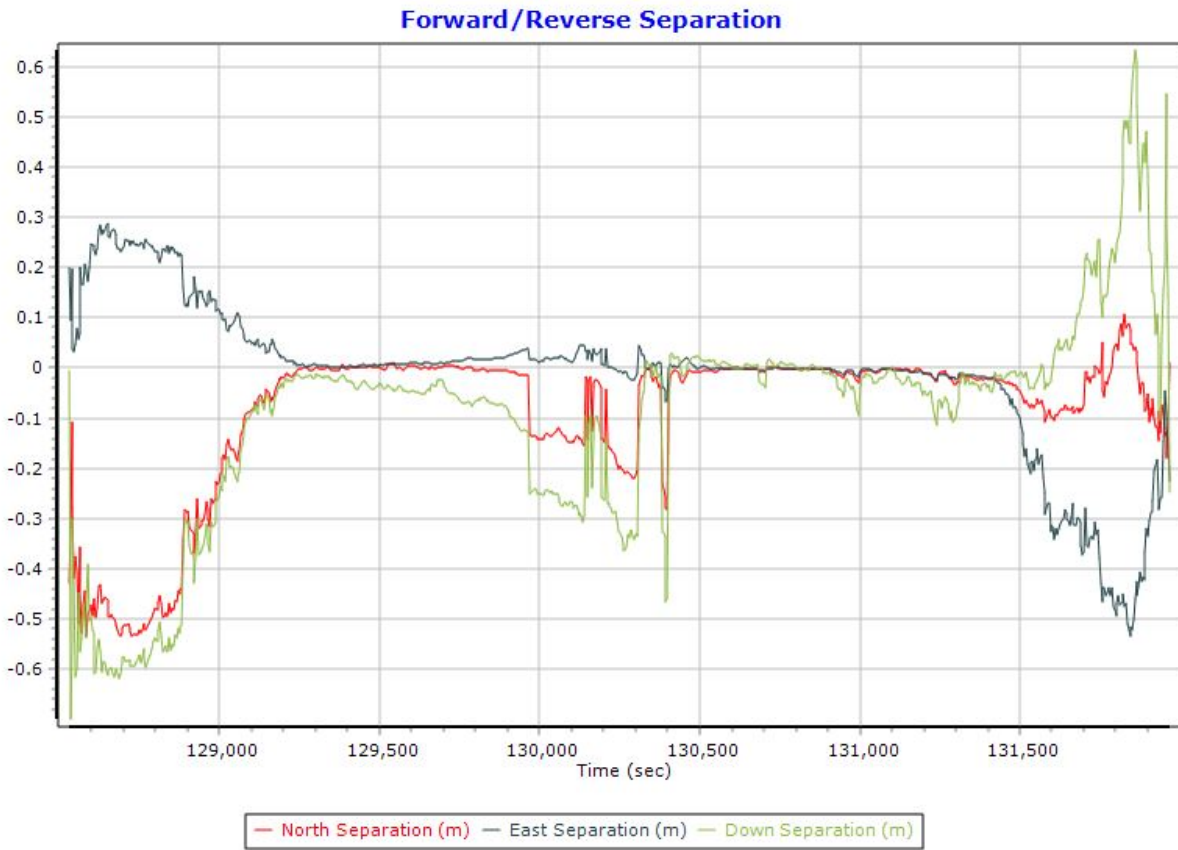
GNSS QC Statistics

Statistics	Min	Max	Mean
Baseline length (km)	1.36	75.46	
Number of GPS SV	6	10	9
Number of GLONASS SV	0	0	0
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Number of GALILEO SV	0	0	0
Total number of SV	6	10	9
PDOP	1.48	2.45	2.01
QC Solution Gaps	0.00	0.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	3182.00	230.00	0.00
Percentage	93.26	6.74	0.00

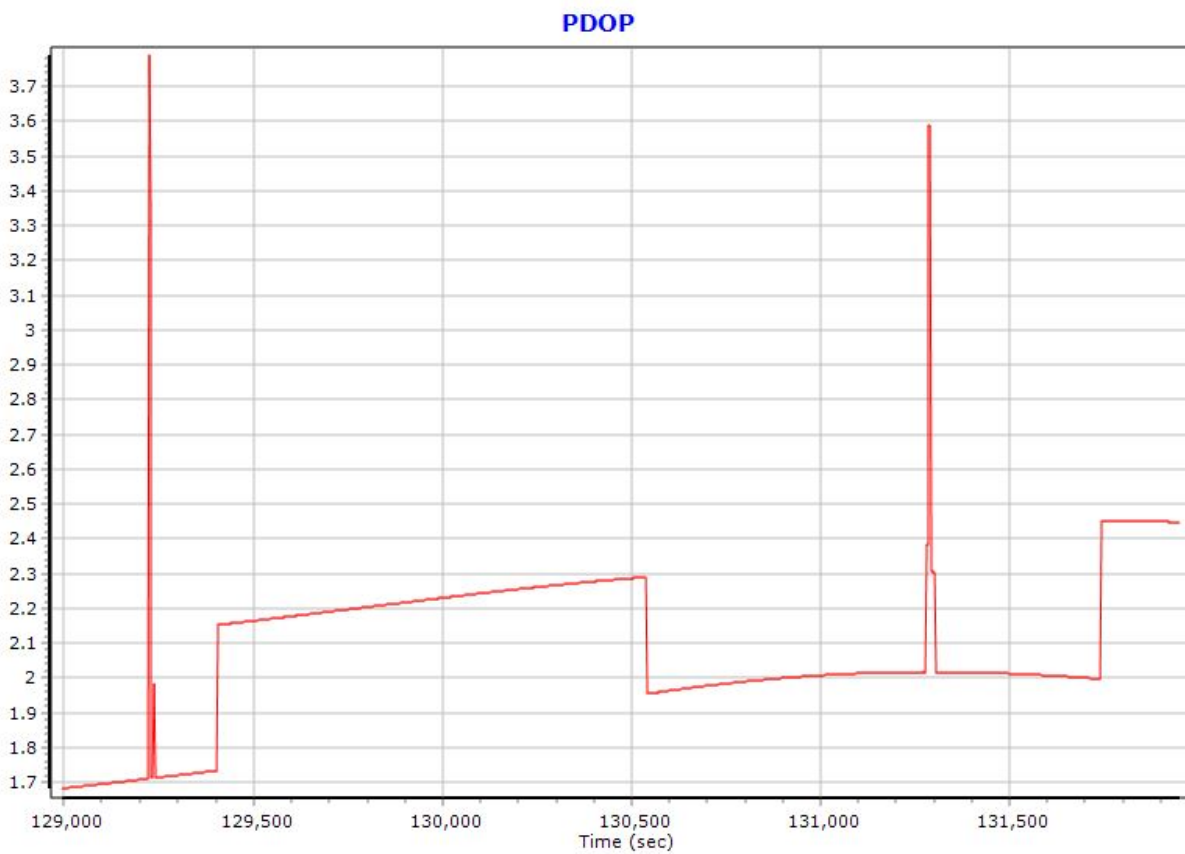
Number of Satellites



Forward/Reverse Separation

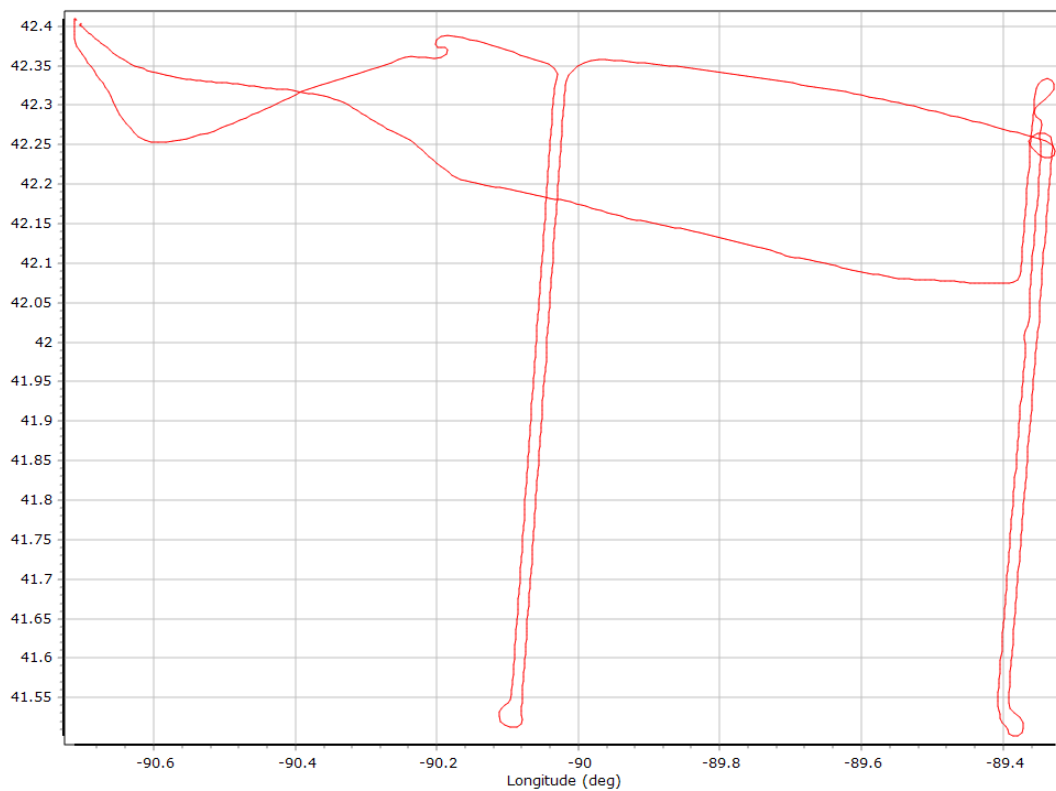


PDOP

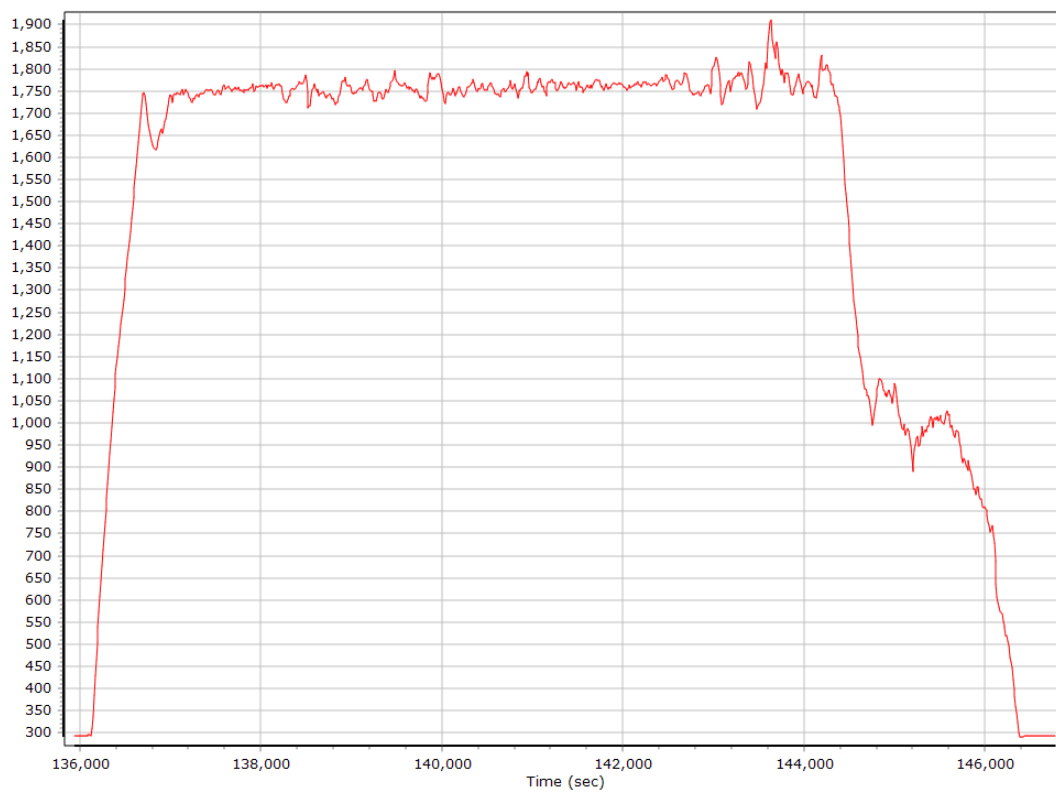


Smoothed Trajectory Information

Top View



Altitude

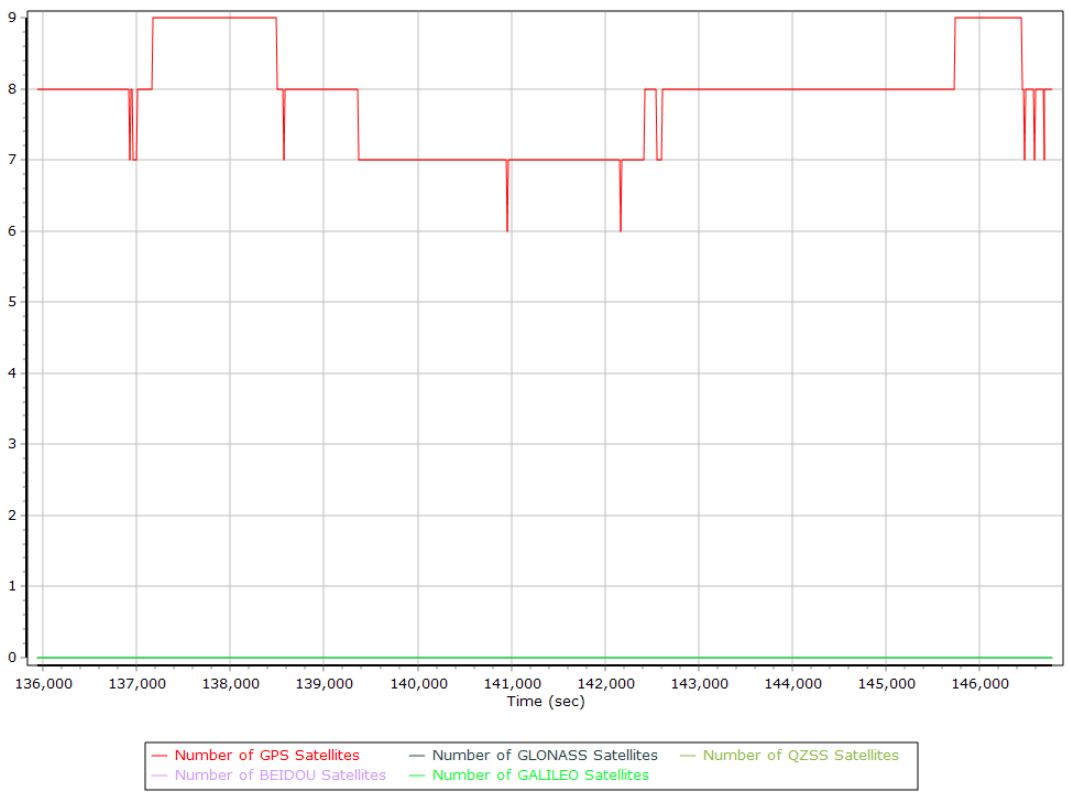


GNSS QC

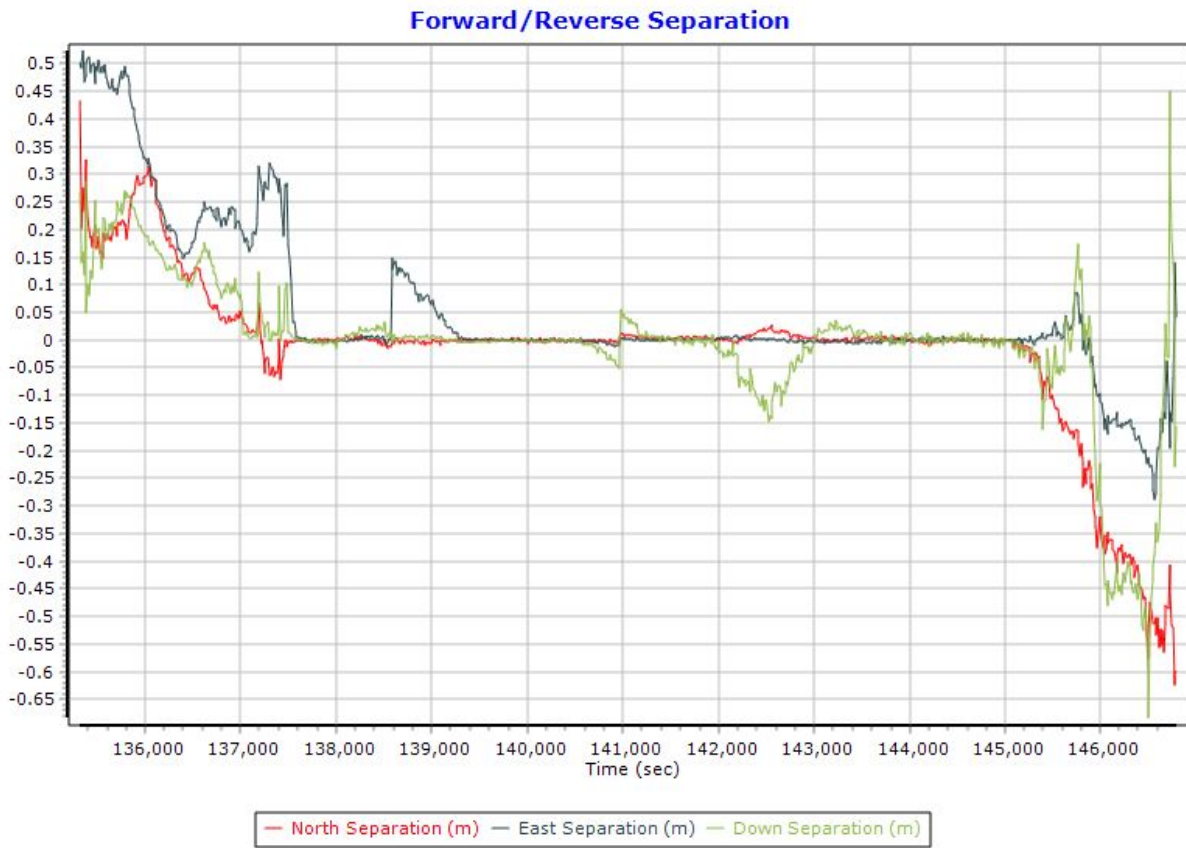
GNSS QC Statistics

Statistics	Min	Max	Mean
Baseline length (km)	6.56	80.47	
Number of GPS SV	6	9	8
Number of GLONASS SV	0	0	0
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Number of GALILEO SV	0	0	0
Total number of SV	6	9	8
PDOP	1.59	5.35	2.06
QC Solution Gaps	0.00	0.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	11433.00	0.00	0.00
Percentage	100.00	0.00	0.00

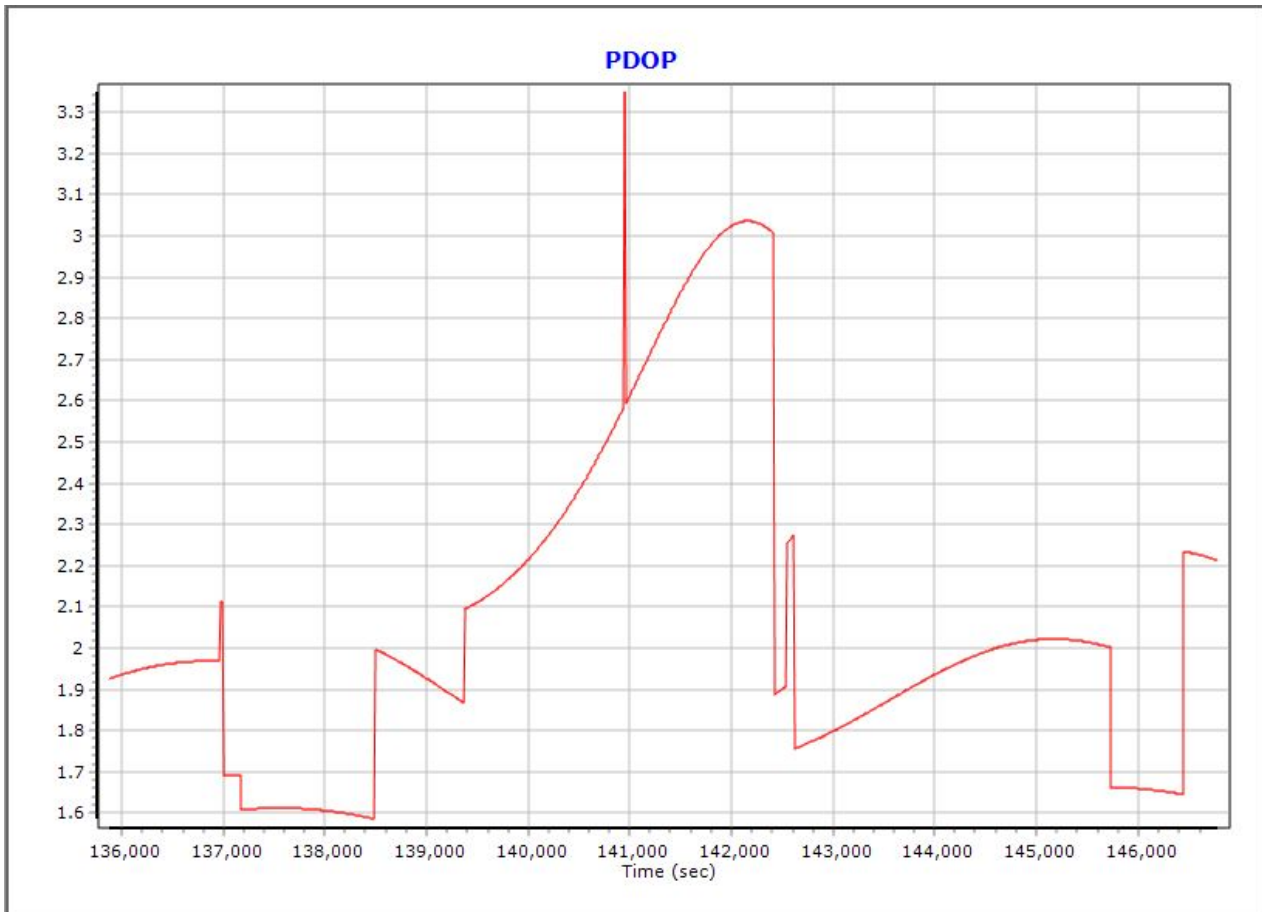
Number of Satellites



Forward/Reverse Separation

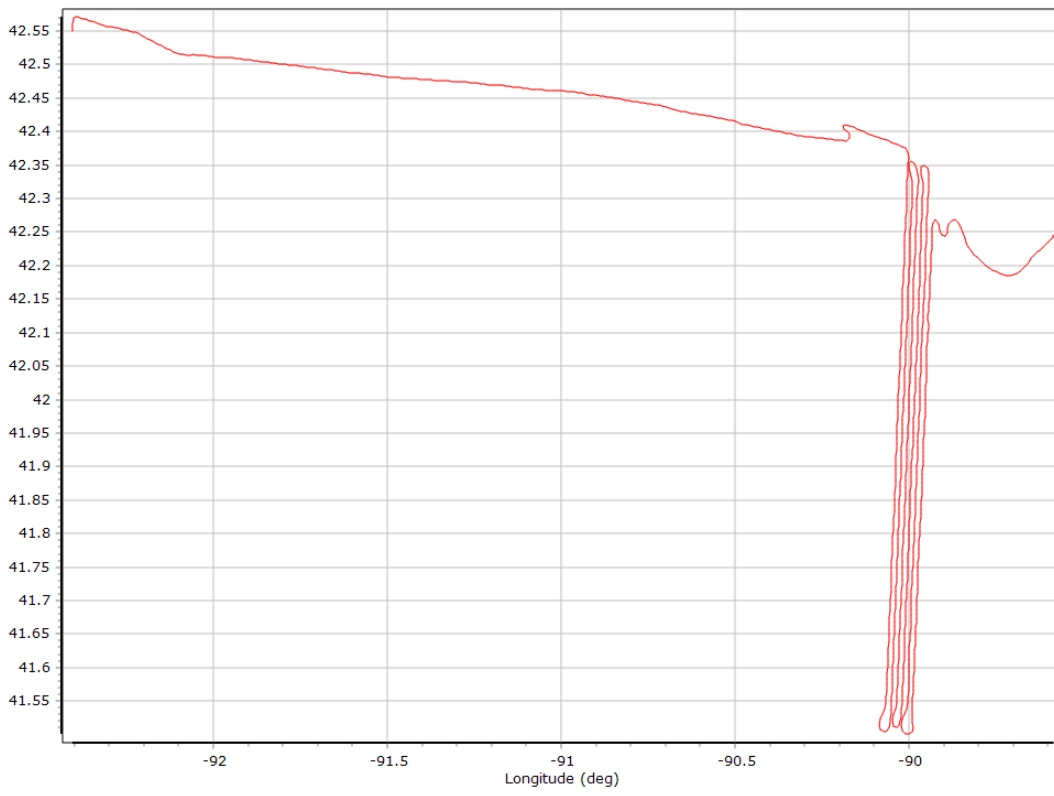


PDOP

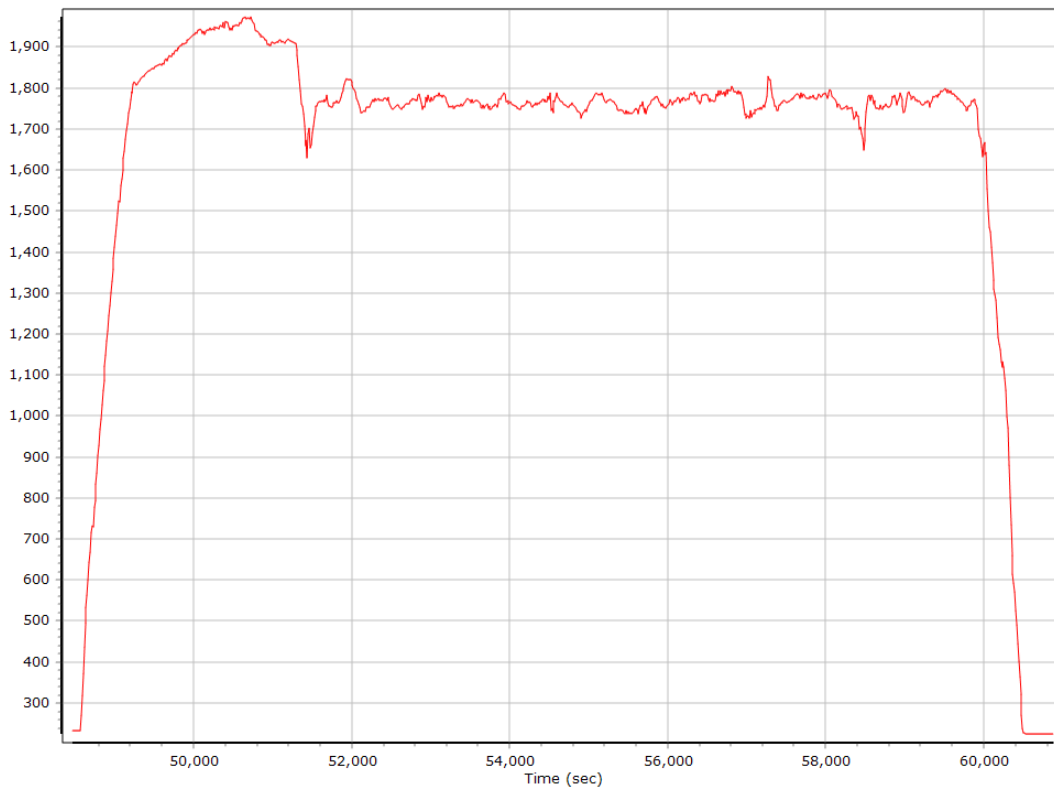


Smoothed Trajectory Information

Top View



Altitude

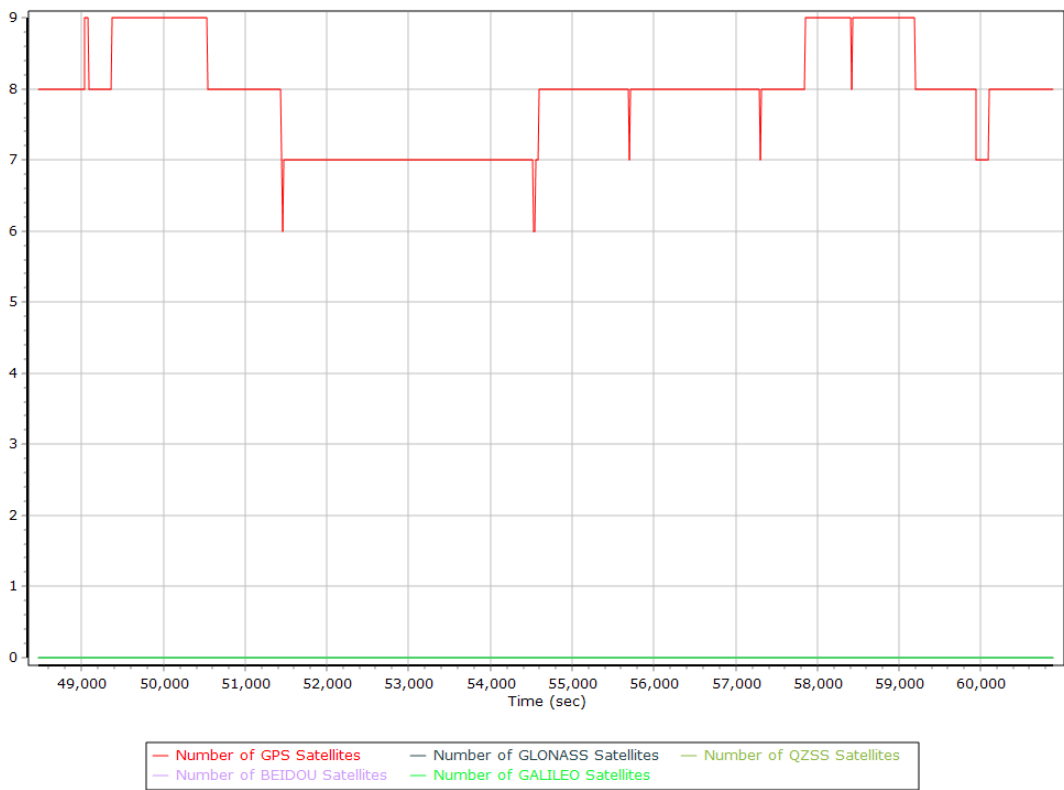


GNSS QC

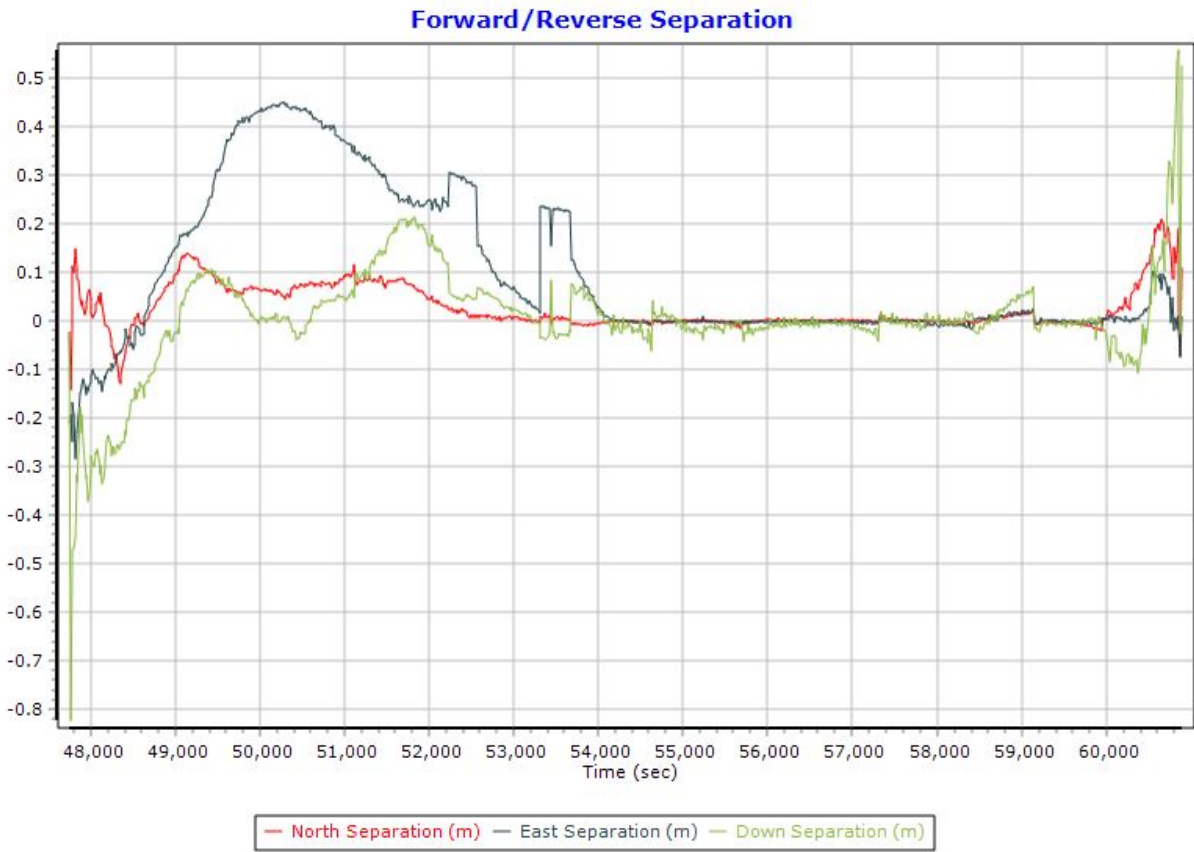
GNSS QC Statistics

Statistics	Min	Max	Mean
Baseline length (km)	32.02	170.63	
Number of GPS SV	5	9	8
Number of GLONASS SV	0	0	0
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Number of GALILEO SV	0	0	0
Total number of SV	5	9	8
PDOP	1.59	5.75	2.04
QC Solution Gaps	0.00	0.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	13140.00	0.00	0.00
Percentage	100.00	0.00	0.00

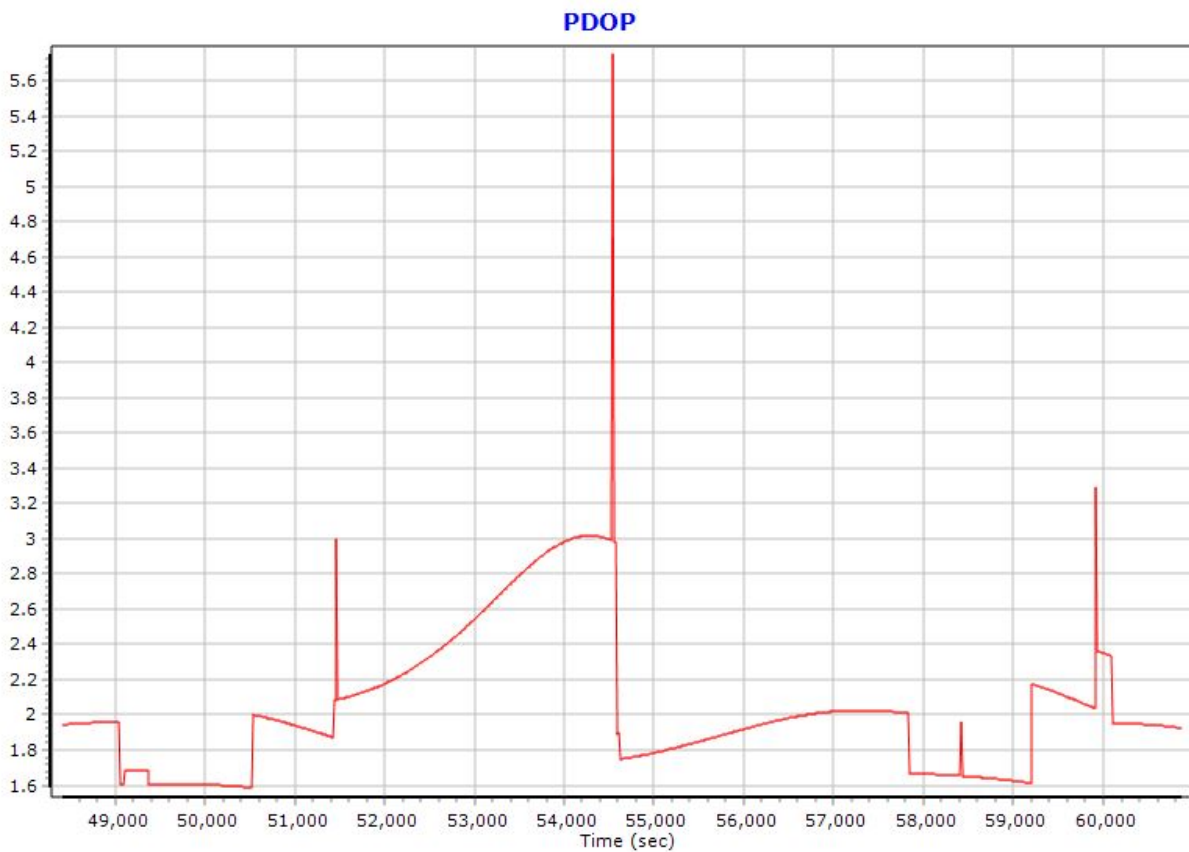
Number of Satellites



Forward/Reverse Separation

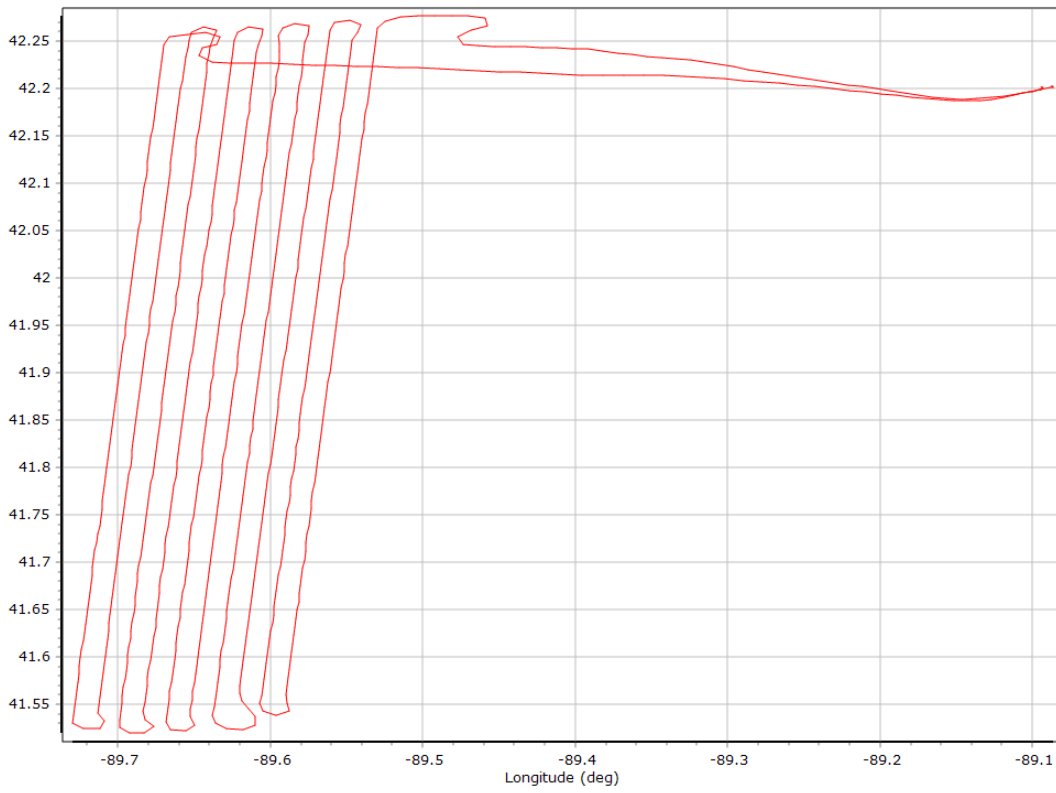


PDOP

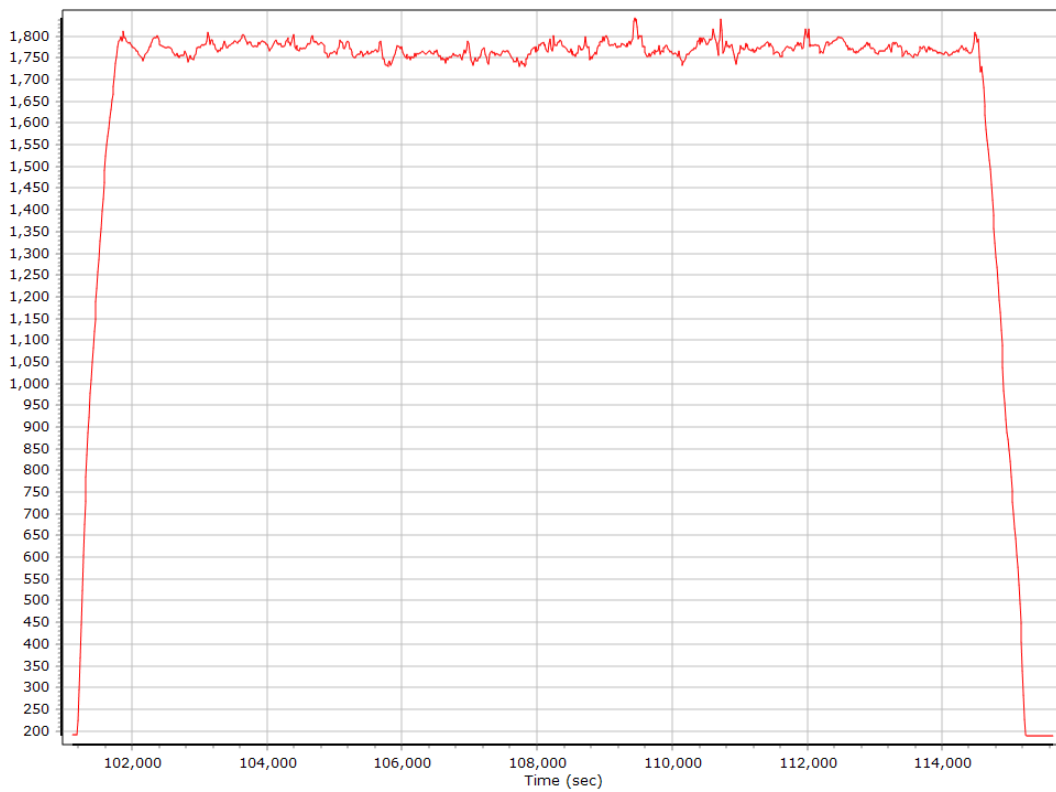


Smoothed Trajectory Information

Top View



Altitude

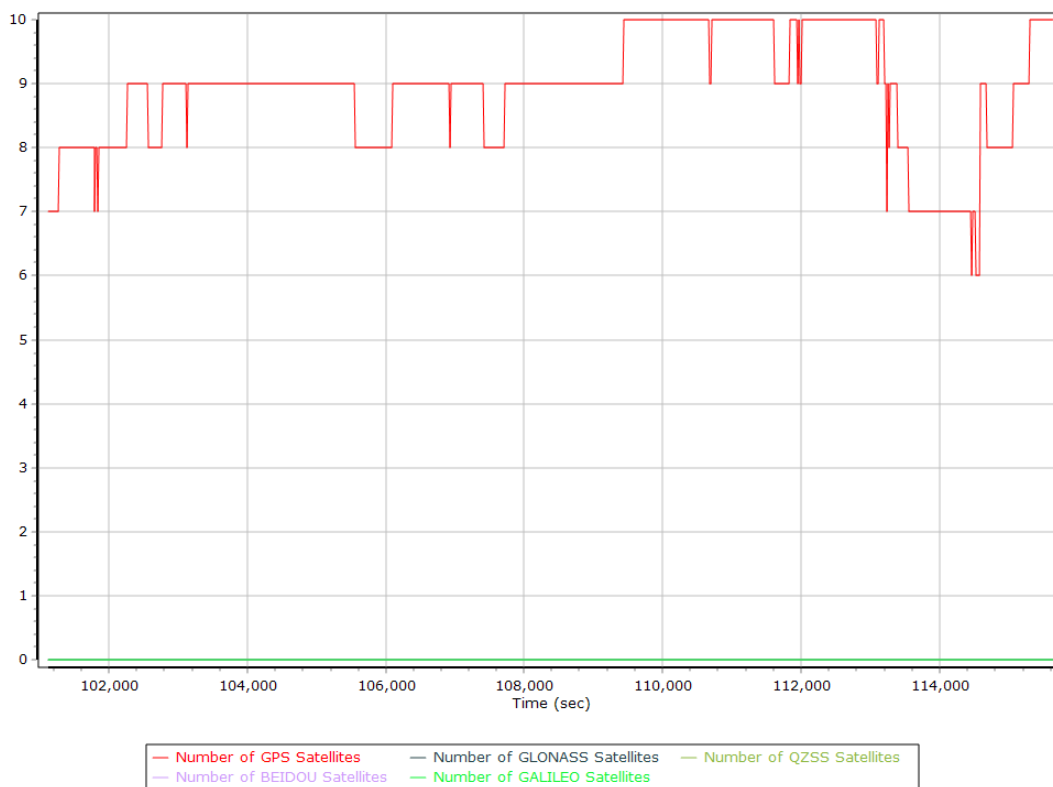


GNSS QC

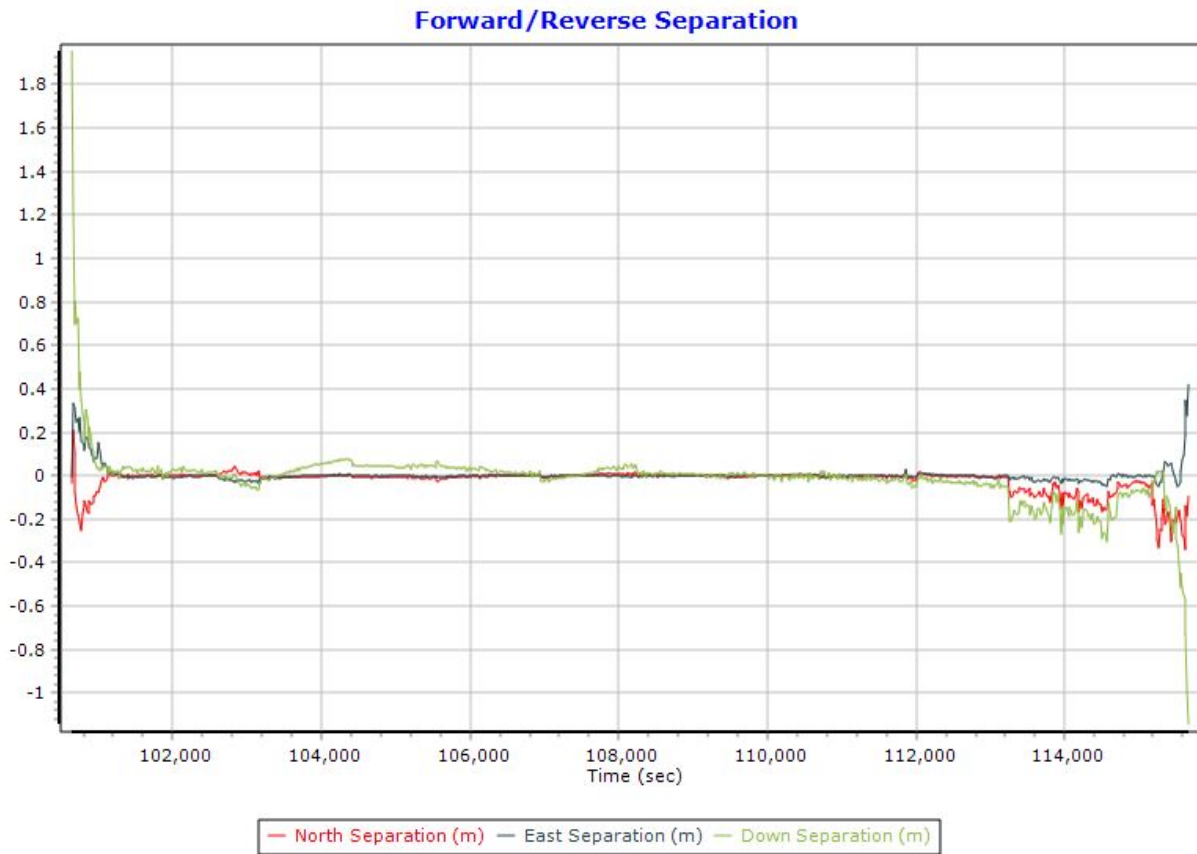
GNSS QC Statistics

Statistics	Min	Max	Mean
Baseline length (km)	0.42	48.88	
Number of GPS SV	6	10	9
Number of GLONASS SV	0	0	0
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Number of GALILEO SV	0	0	0
Total number of SV	6	10	9
PDOP	1.39	3.01	1.77
QC Solution Gaps	0.00	0.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	15015.00	1.00	0.00
Percentage	99.99	0.01	0.00

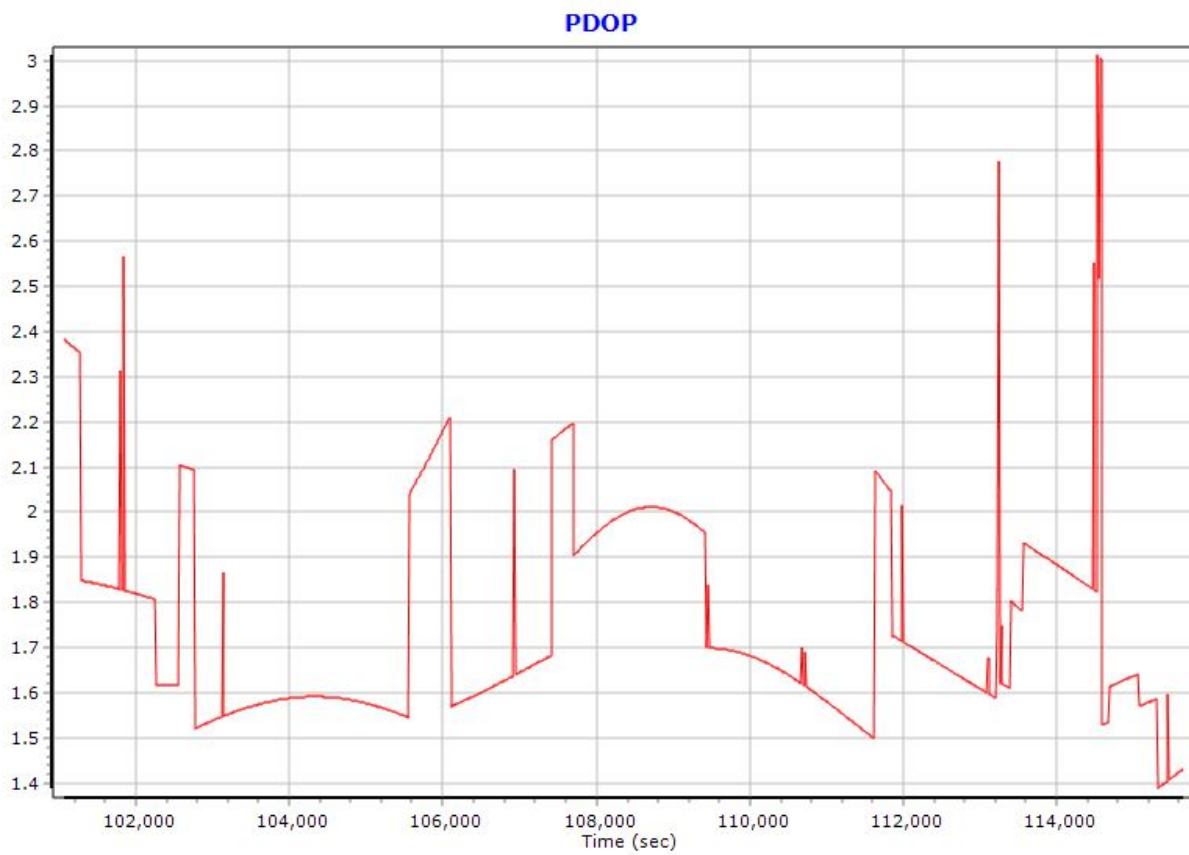
Number of Satellites



Forward/Reverse Separation

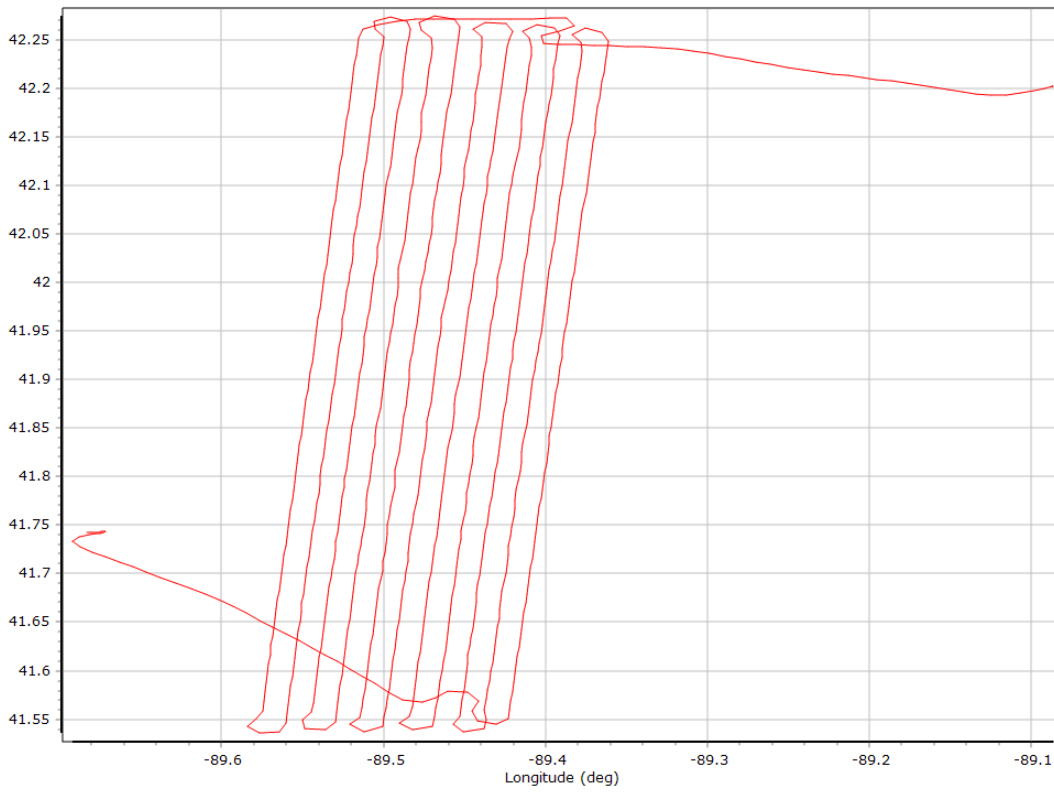


PDOP

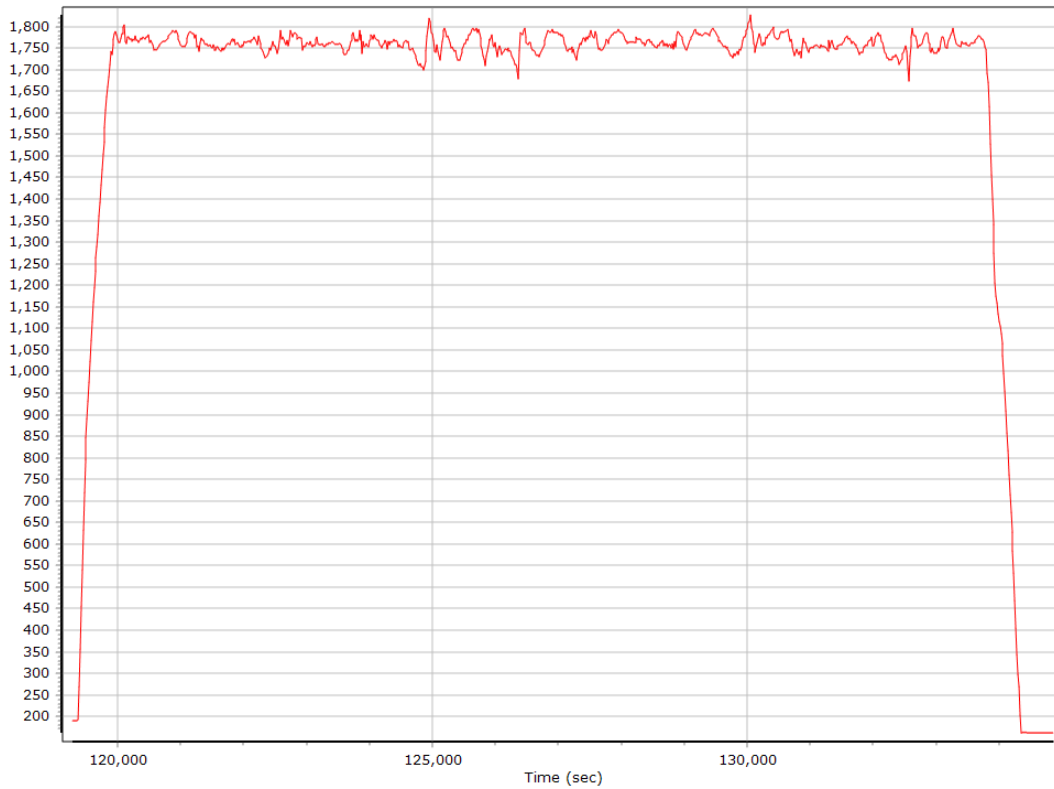


Smoothed Trajectory Information

Top View



Altitude

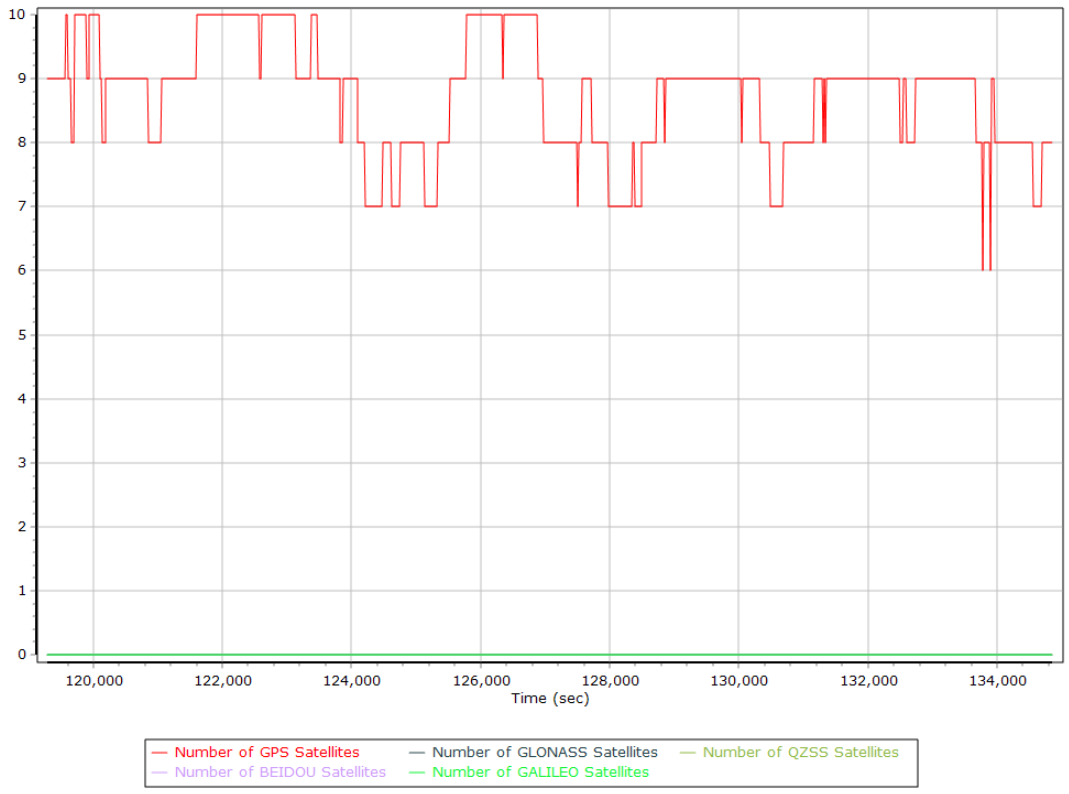


GNSS QC

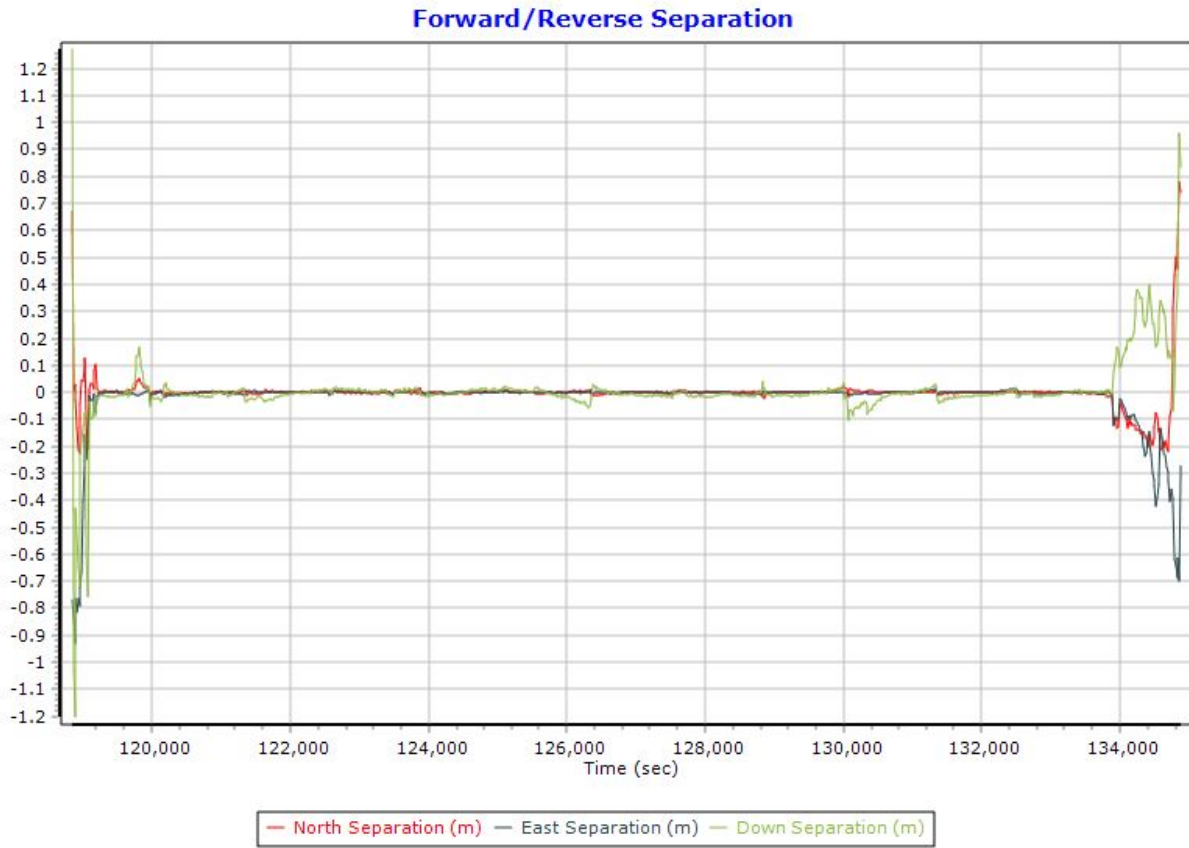
GNSS QC Statistics

Statistics	Min	Max	Mean
Baseline length (km)	0.51	44.11	
Number of GPS SV	6	10	9
Number of GLONASS SV	0	0	0
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Number of GALILEO SV	0	0	0
Total number of SV	6	10	9
PDOP	1.46	3.33	1.85
QC Solution Gaps	0.00	0.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	15983.00	0.00	0.00
Percentage	100.00	0.00	0.00

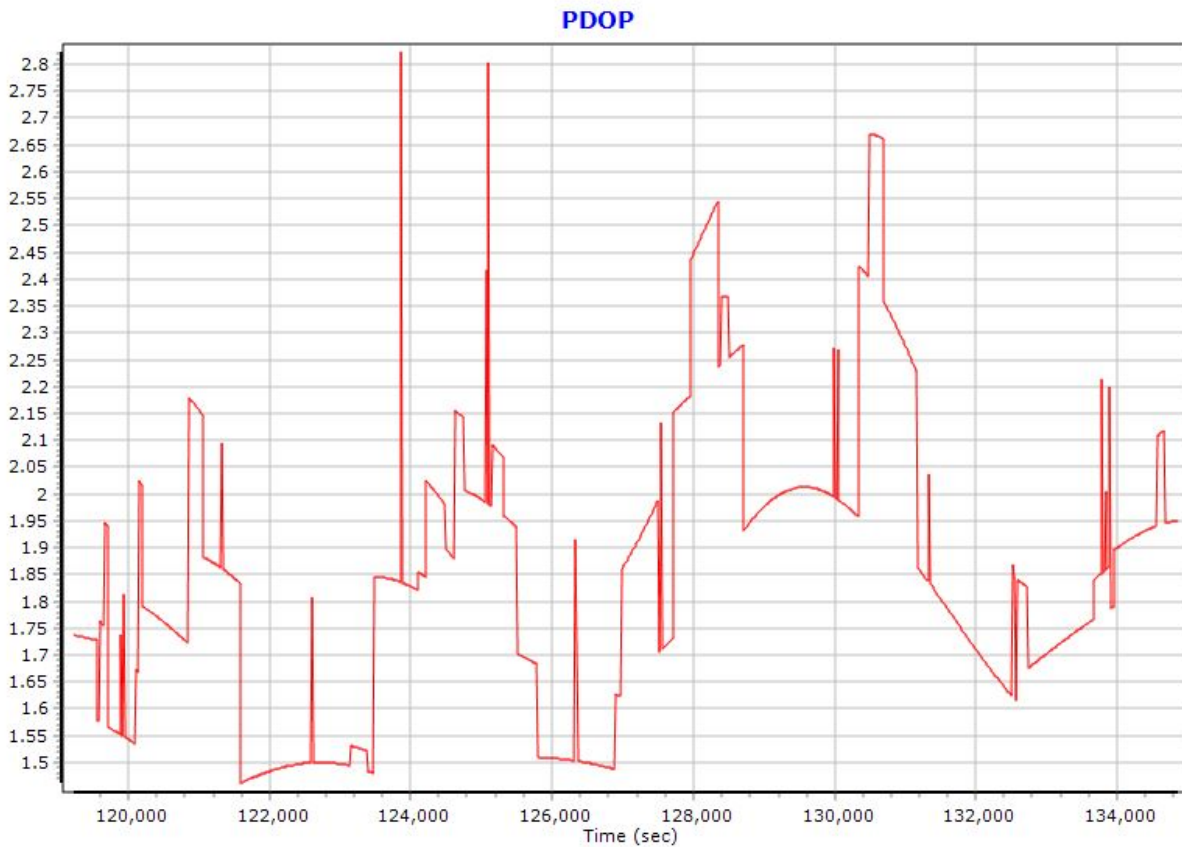
Number of Satellites



Forward/Reverse Separation

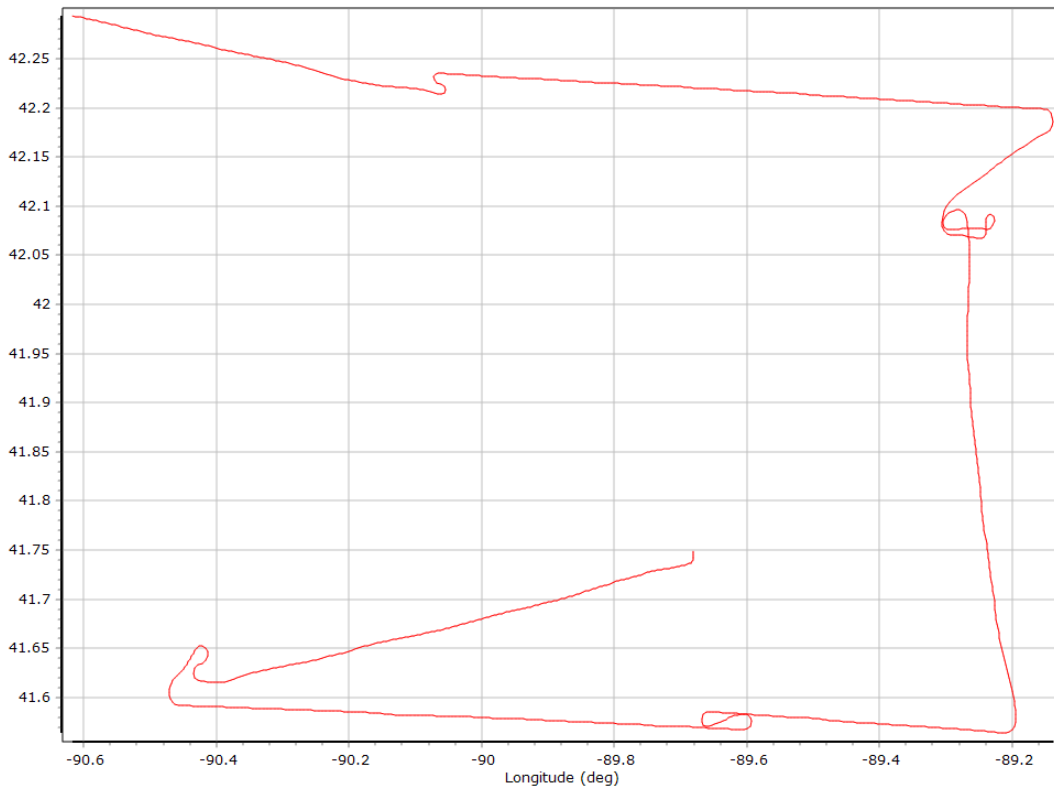


PDOP

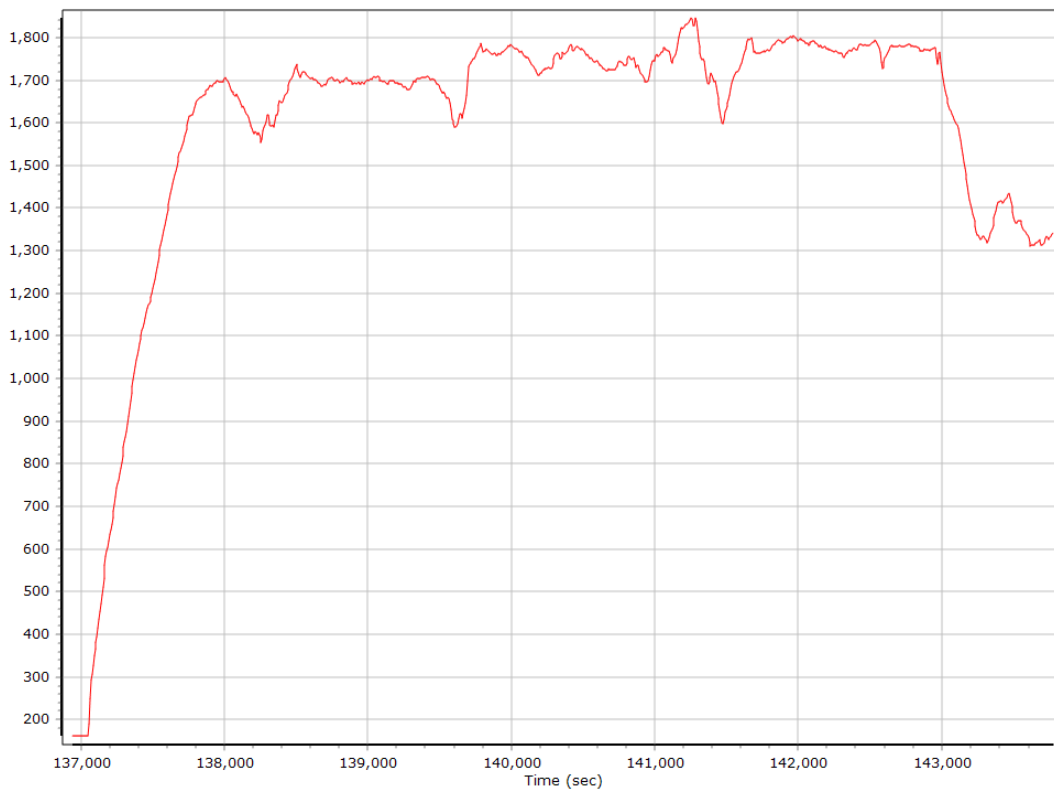


Smoothed Trajectory Information

Top View



Altitude

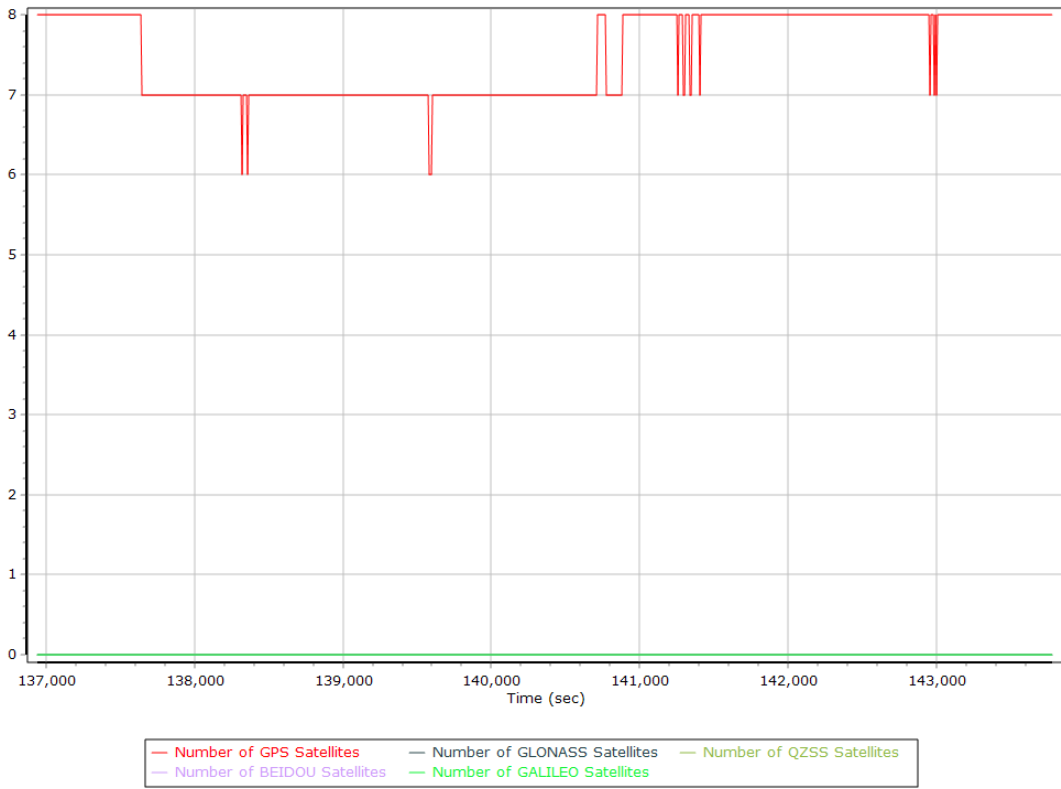


GNSS QC

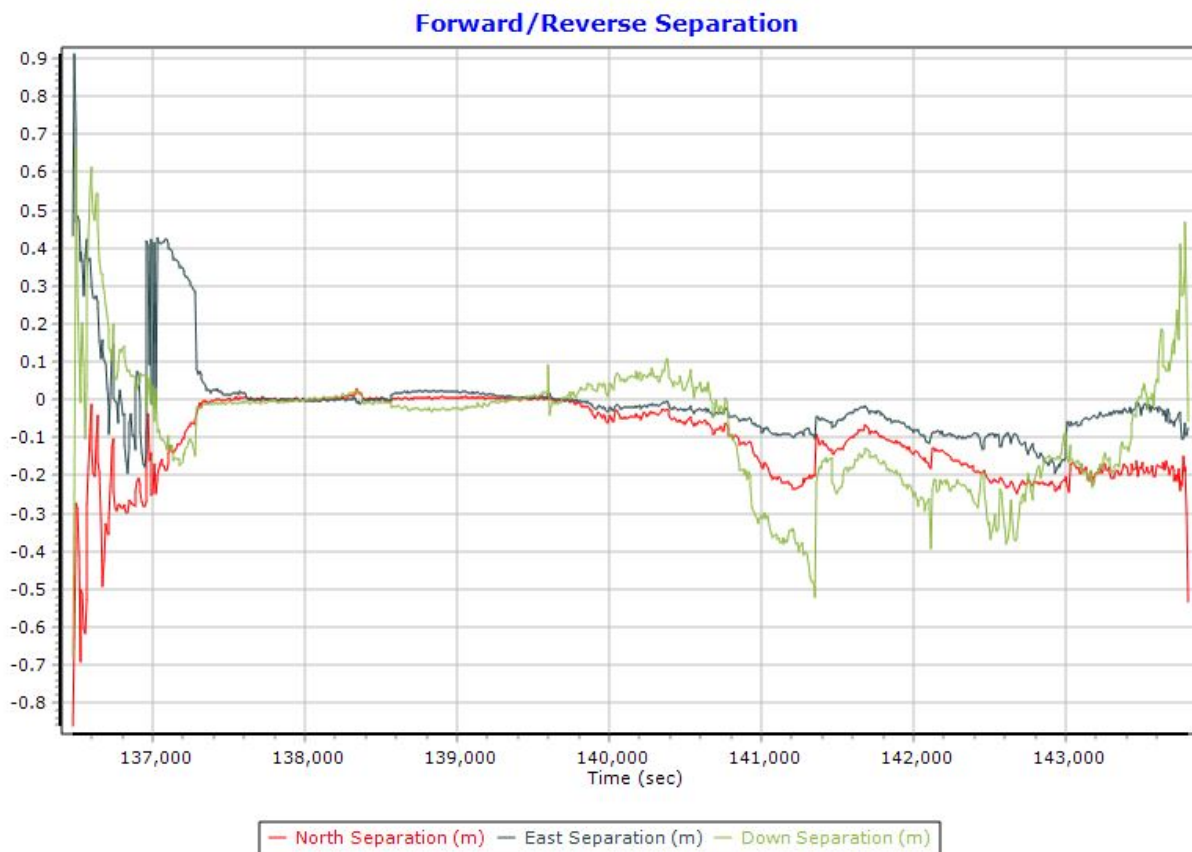
GNSS QC Statistics

Statistics	Min	Max	Mean
Baseline length (km)	14.89	82.17	
Number of GPS SV	6	9	8
Number of GLONASS SV	0	0	0
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Number of GALILEO SV	0	0	0
Total number of SV	6	9	8
PDOP	1.58	3.76	2.20
QC Solution Gaps	0.00	0.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	7273.00	0.00	0.00
Percentage	100.00	0.00	0.00

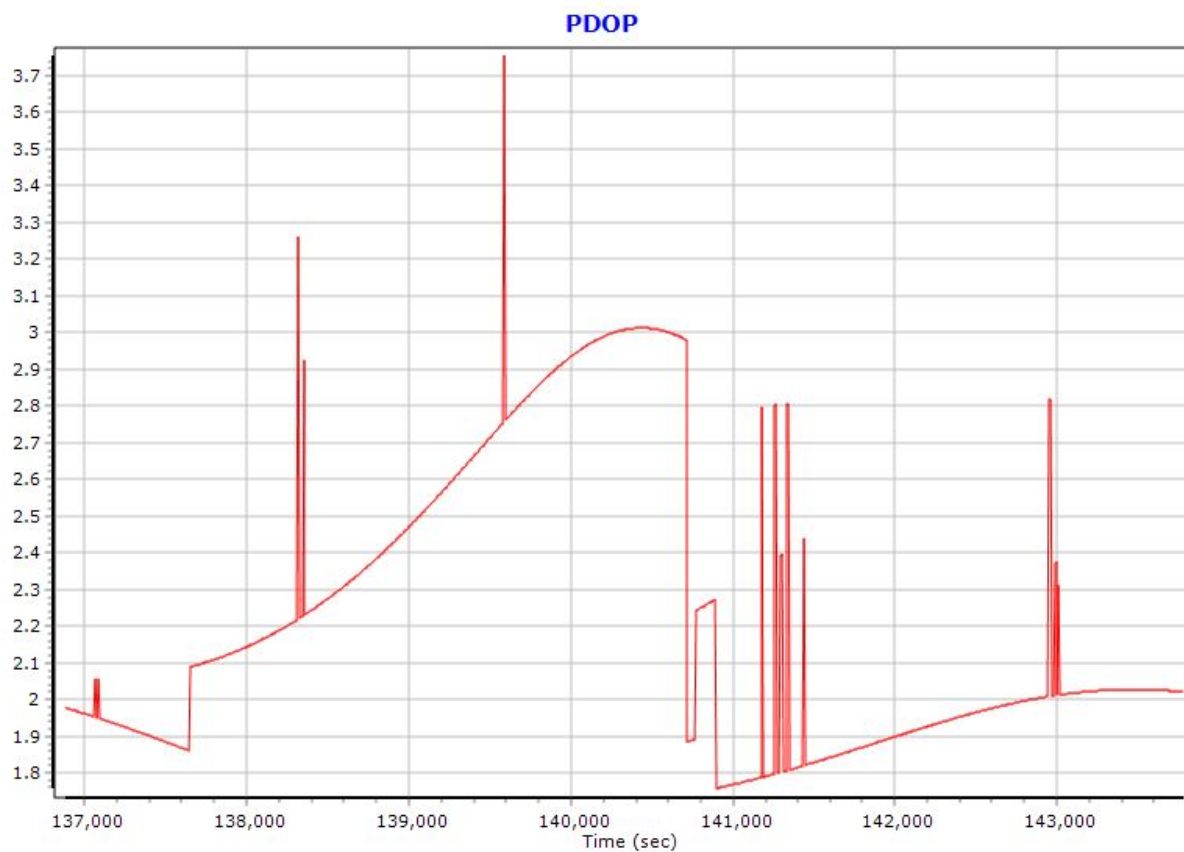
Number of Satellites



Forward/Reverse Separation

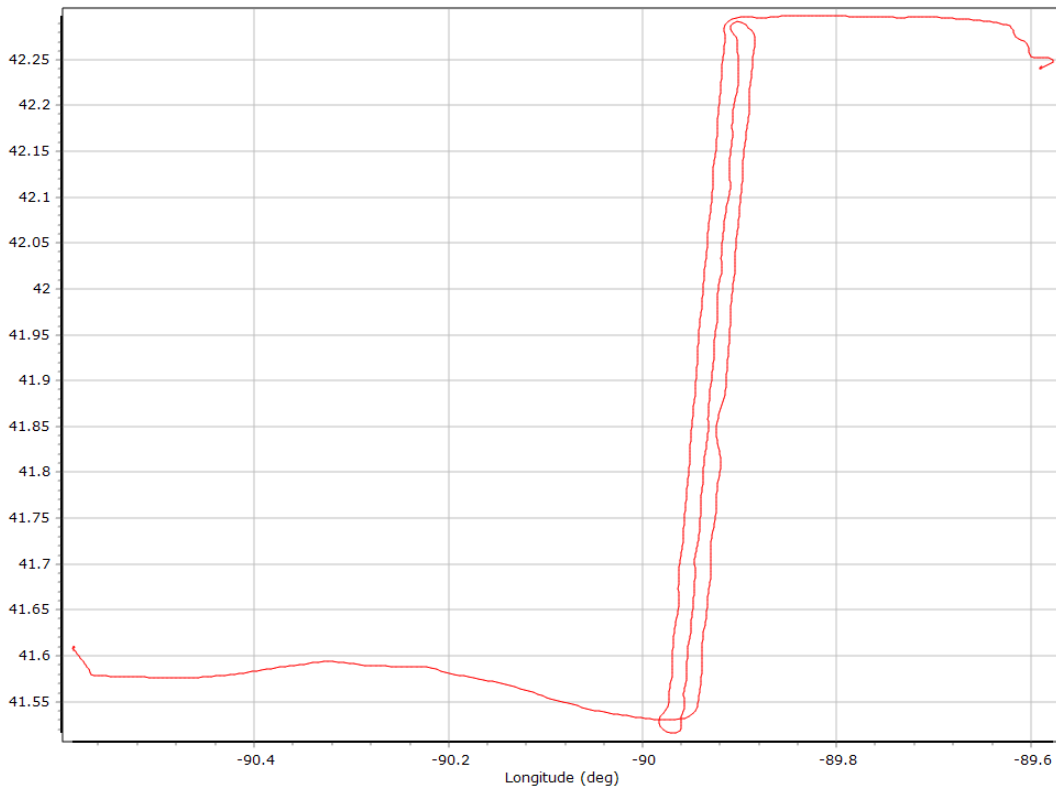


PDOP

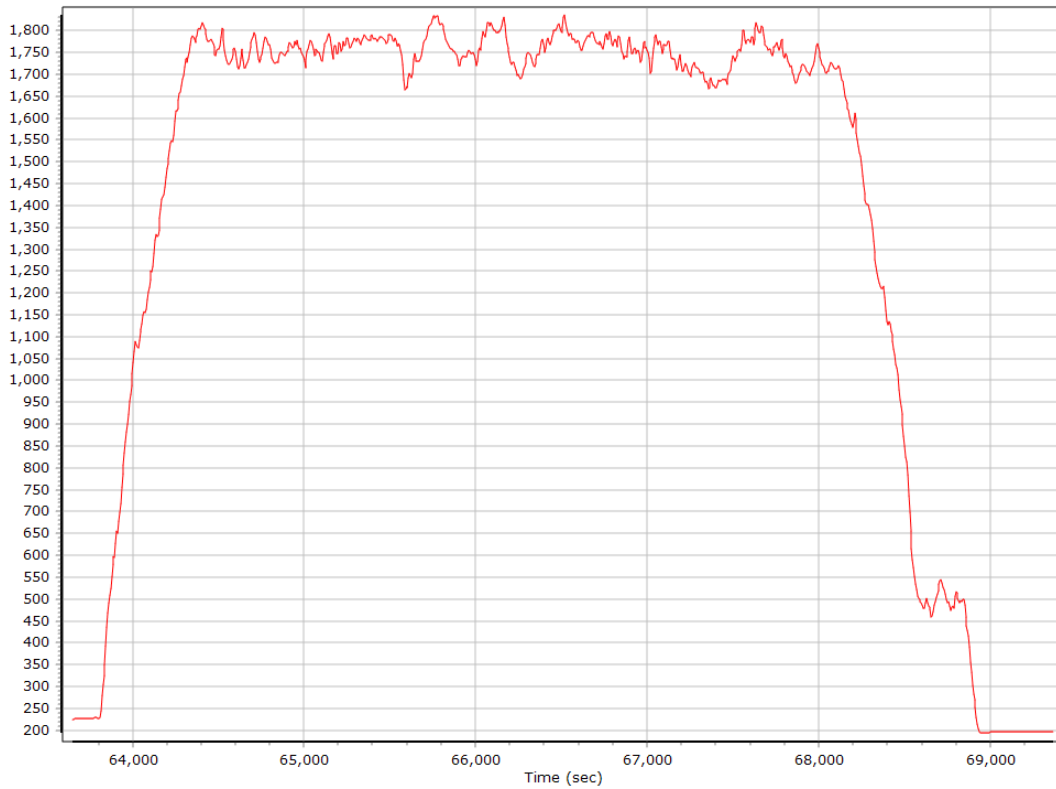


Smoothed Trajectory Information

Top View



Altitude

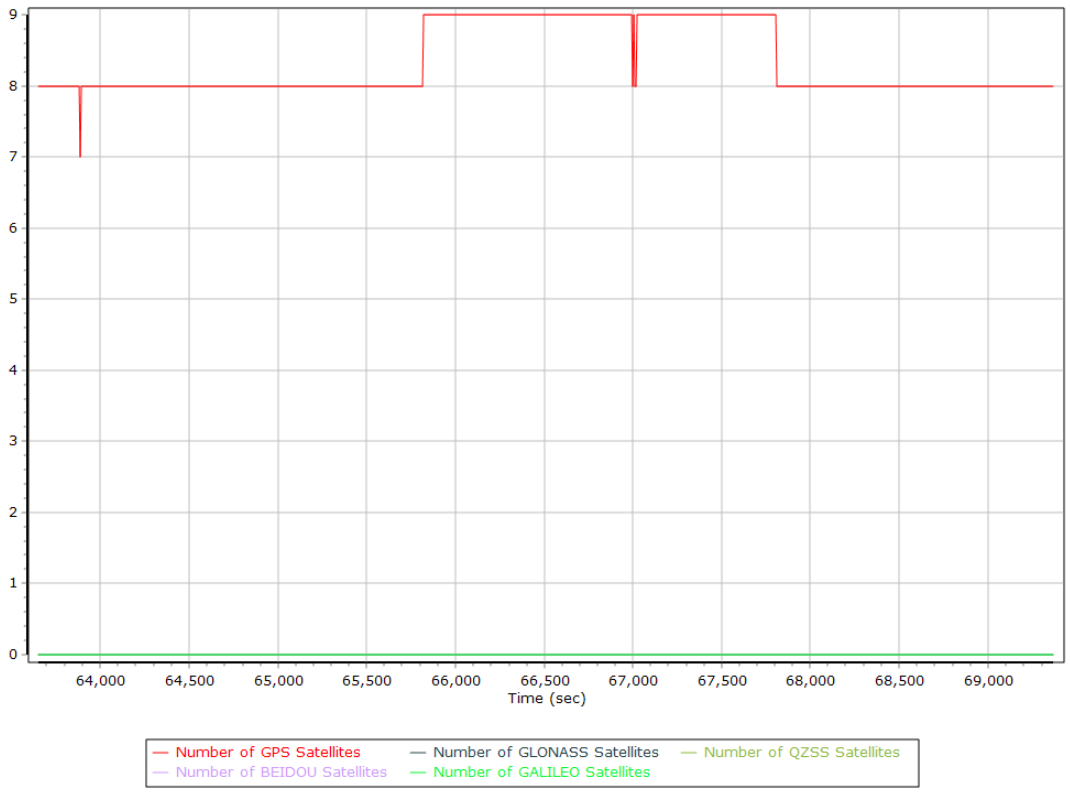


GNSS QC

GNSS QC Statistics

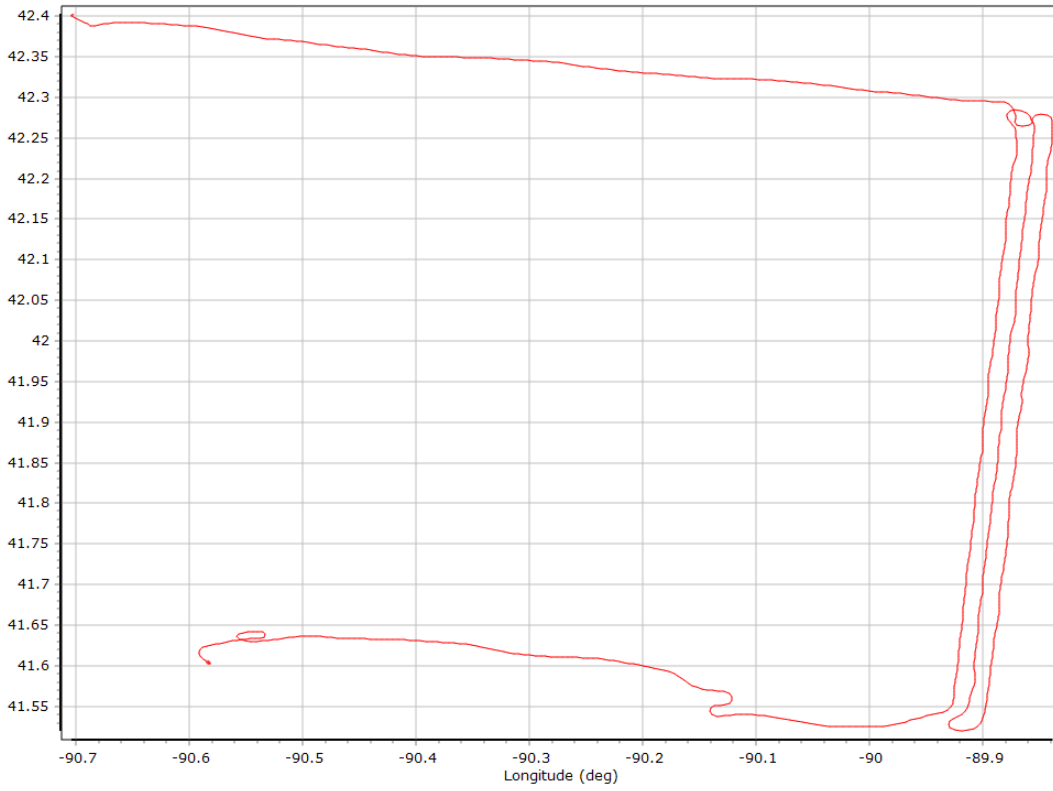
Statistics	Min	Max	Mean
Baseline length (km)	1.41	62.94	
Number of GPS SV	7	9	8
Number of GLONASS SV	0	0	0
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Total number of SV	7	9	8
PDOP	1.77	2.65	2.04
QC Solution Gaps	0.00	0.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	6255.00	0.00	0.00
Percentage	100.00	0.00	0.00

Number of Satellites

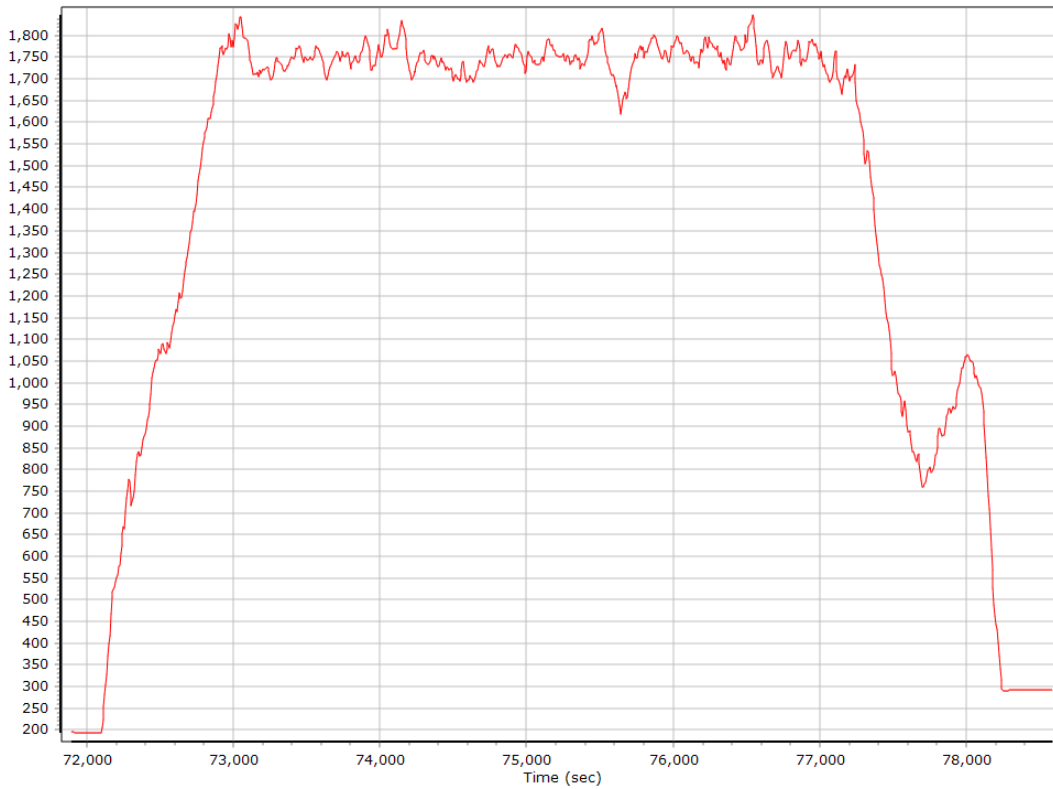


Smoothed Trajectory Information

Top View



Altitude

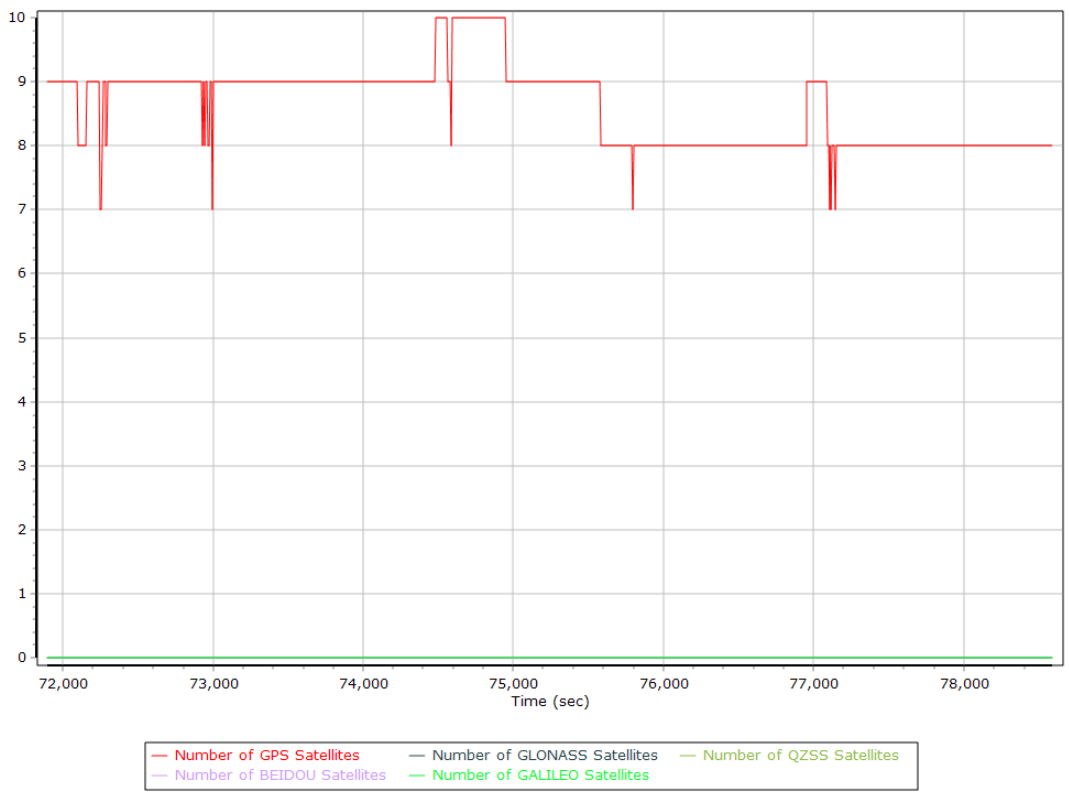


GNSS QC

GNSS QC Statistics

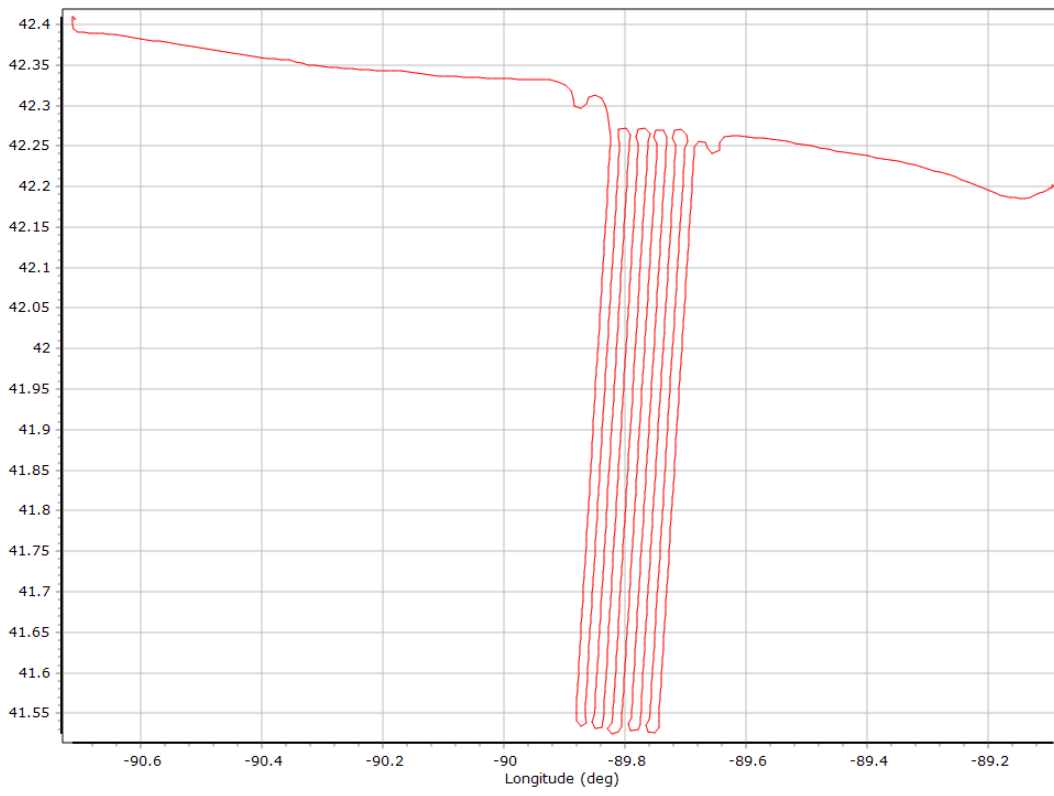
Statistics	Min	Max	Mean
Baseline length (km)	18.45	72.56	
Number of GPS SV	6	10	9
Number of GLONASS SV	0	0	0
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Number of GALILEO SV	0	0	0
Total number of SV	6	10	9
PDOP	1.35	2.77	1.71
QC Solution Gaps	0.00	0.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	6593.00	629.00	0.00
Percentage	91.29	8.71	0.00

Number of Satellites

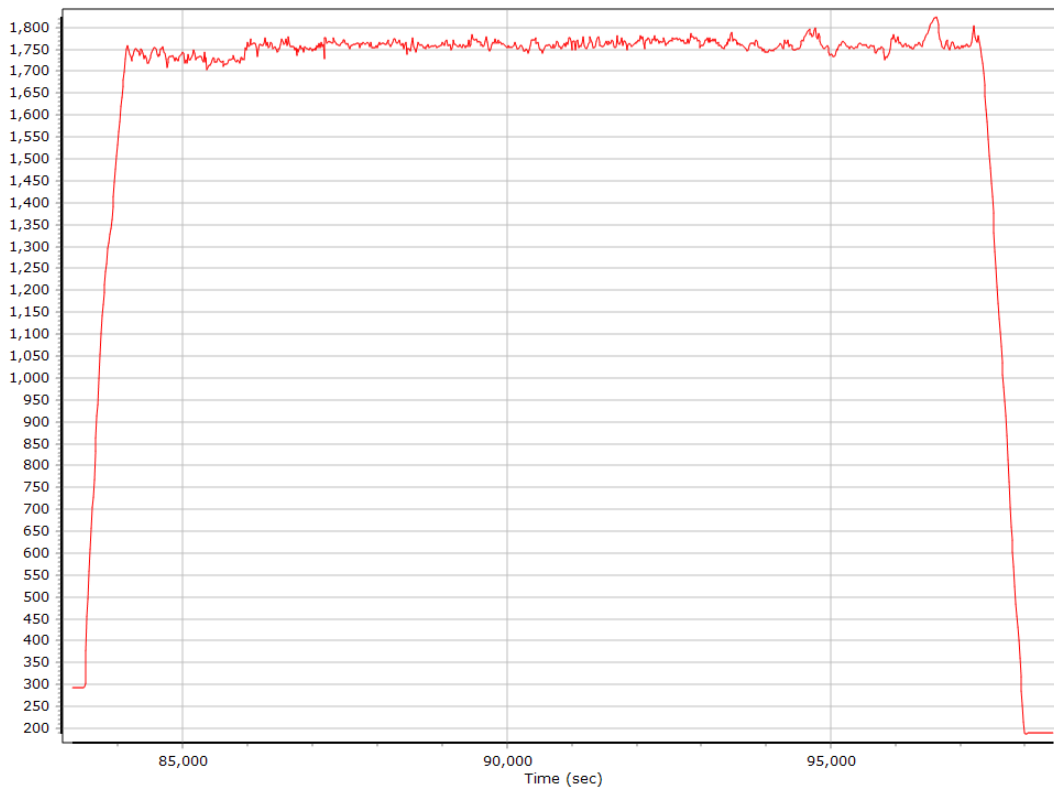


Smoothed Trajectory Information

Top View



Altitude

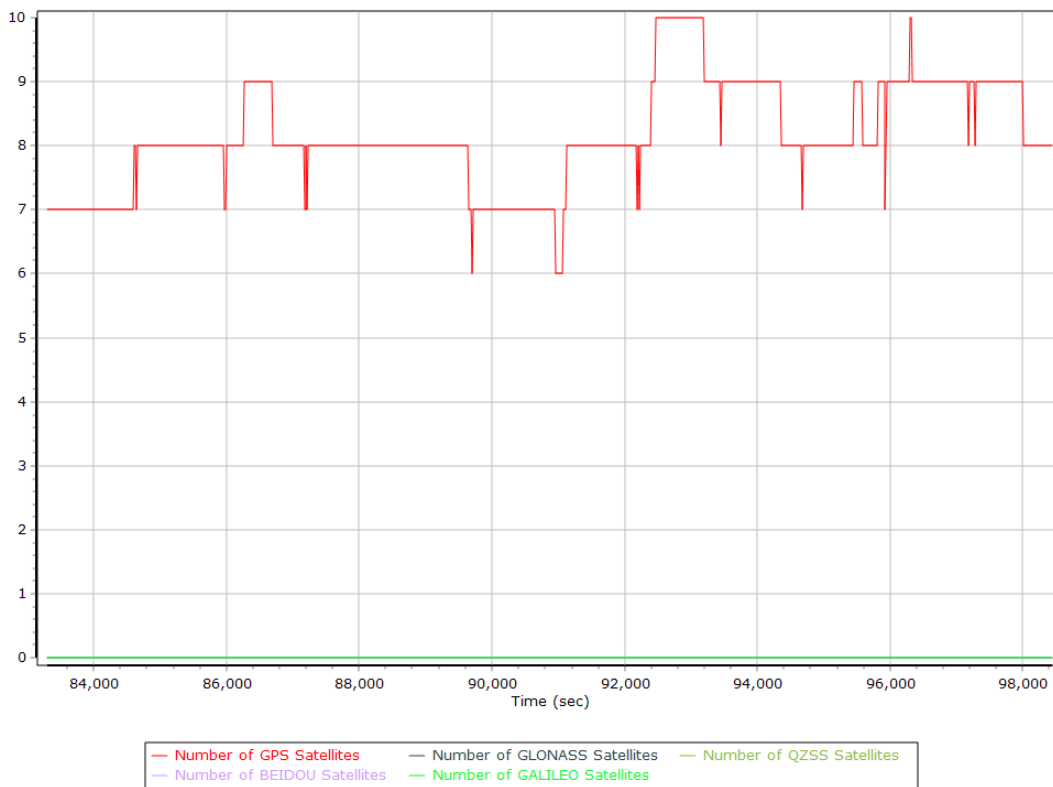


GNSS QC

GNSS QC Statistics

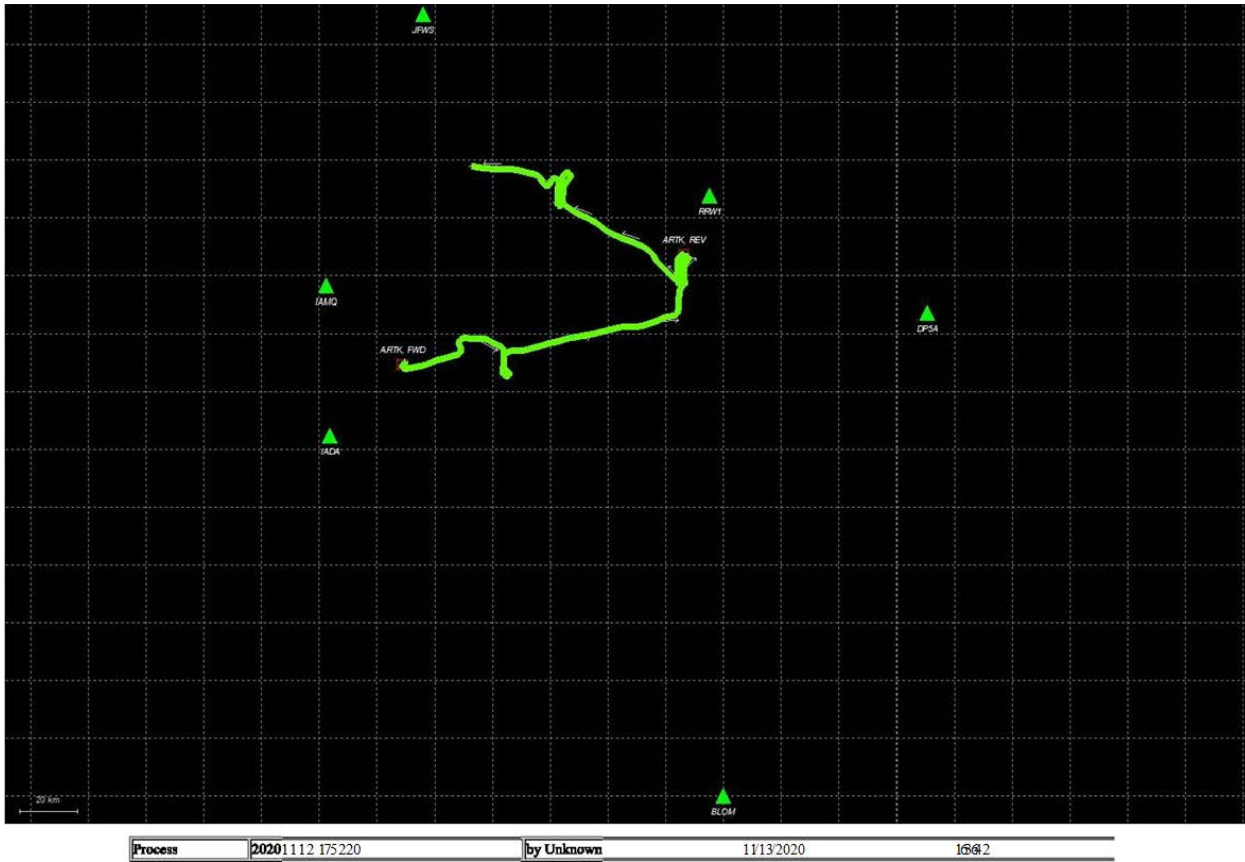
Statistics	Min	Max	Mean
Baseline length (km)	0.62	87.52	
Number of GPS SV	6	10	8
Number of GLONASS SV	0	0	0
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Number of GALILEO SV	0	0	0
Total number of SV	6	10	8
PDOP	1.61	3.26	2.08
QC Solution Gaps	0.00	0.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	15112.00	472.00	0.00
Percentage	96.97	3.03	0.00

Number of Satellites

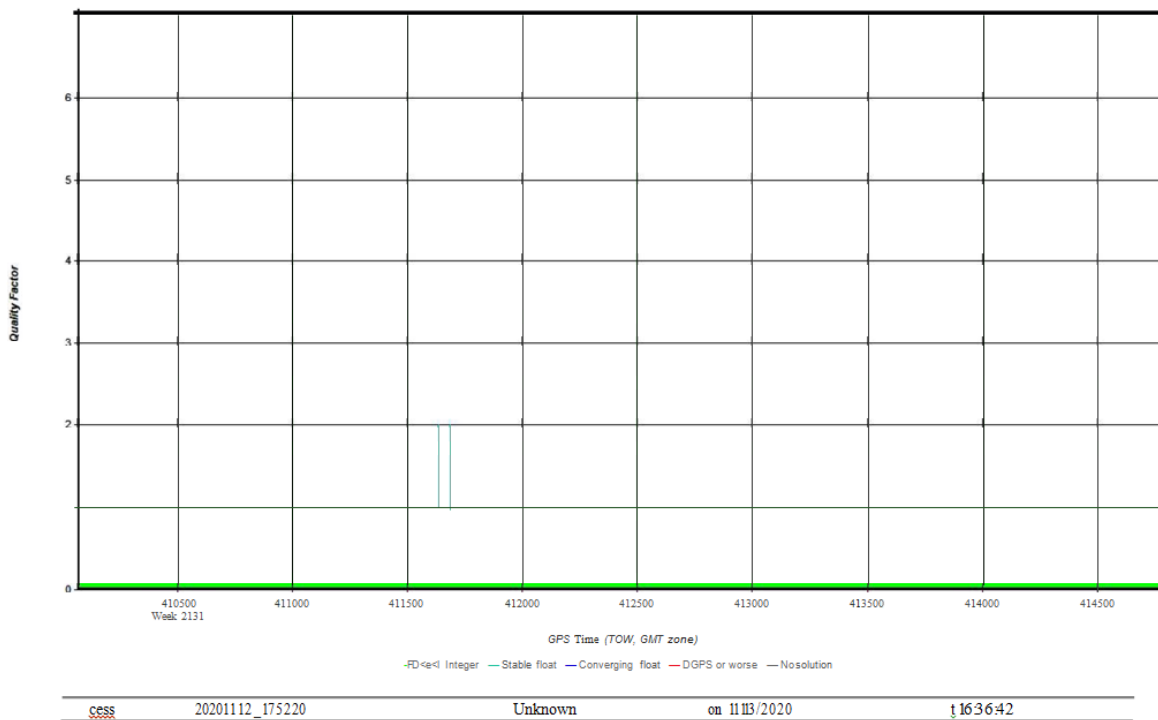


Smoothed Trajectory Information

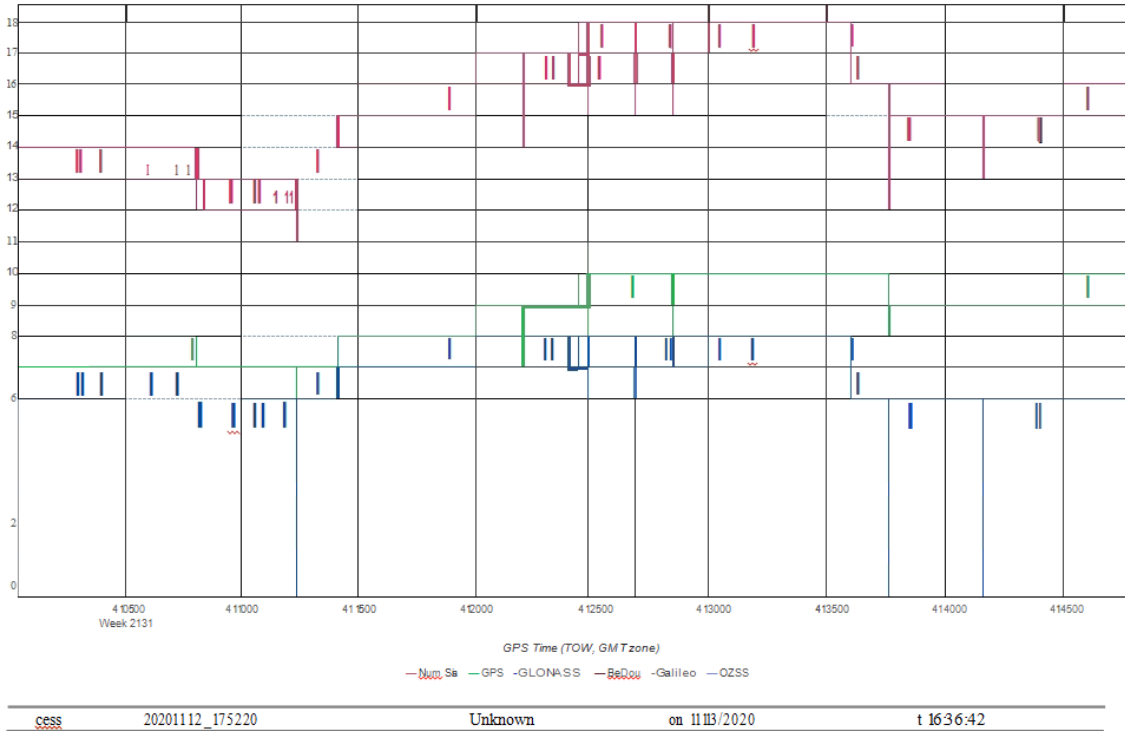
Top View



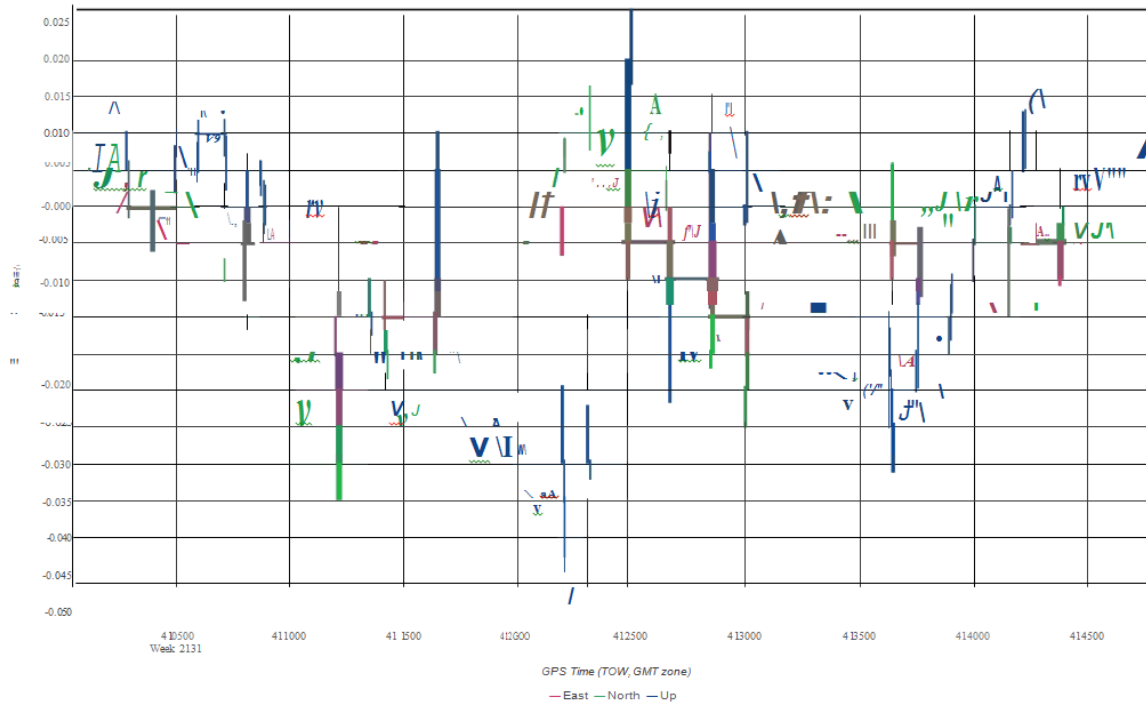
Quality Factor Plot



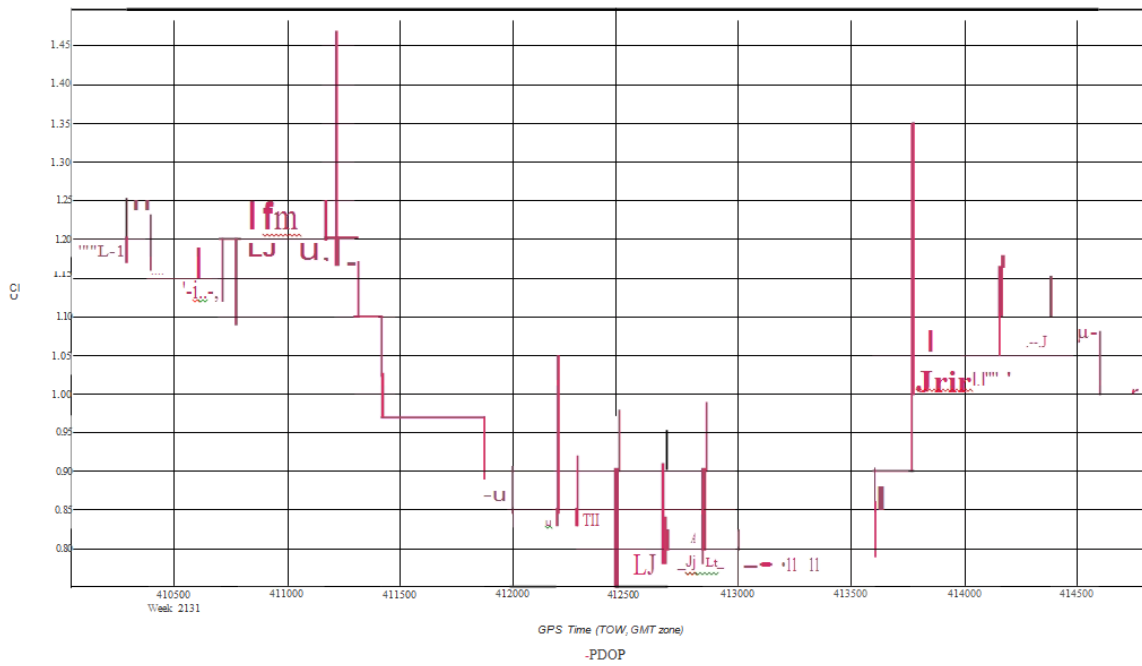
Number of Satellite Line Plot



Forward/Reverse Combined Separation Plot



PDOP



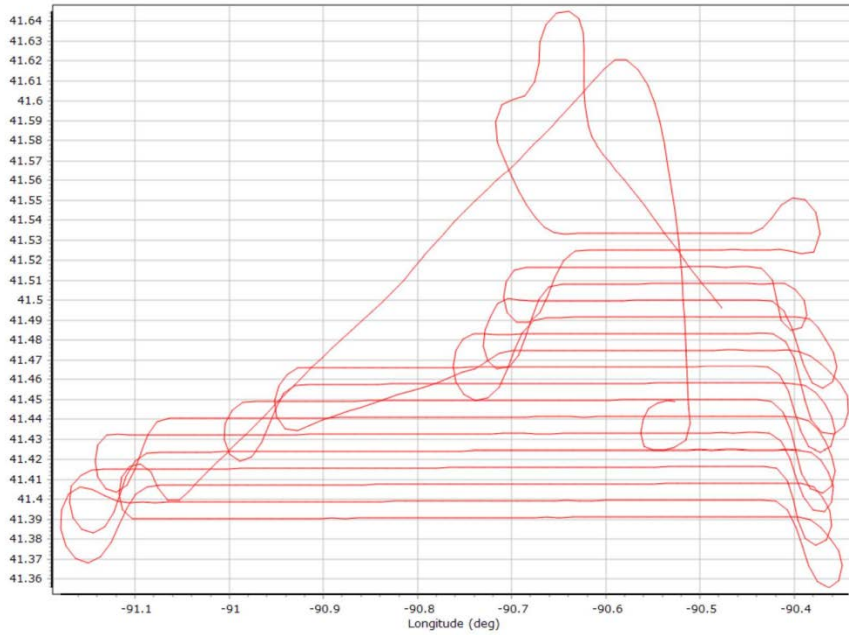
Proc11	2020112_175220	Unknown	Jan 11 13/2020	1	63642
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Appendix C: SurvTech GPS and IMU Processing Reports

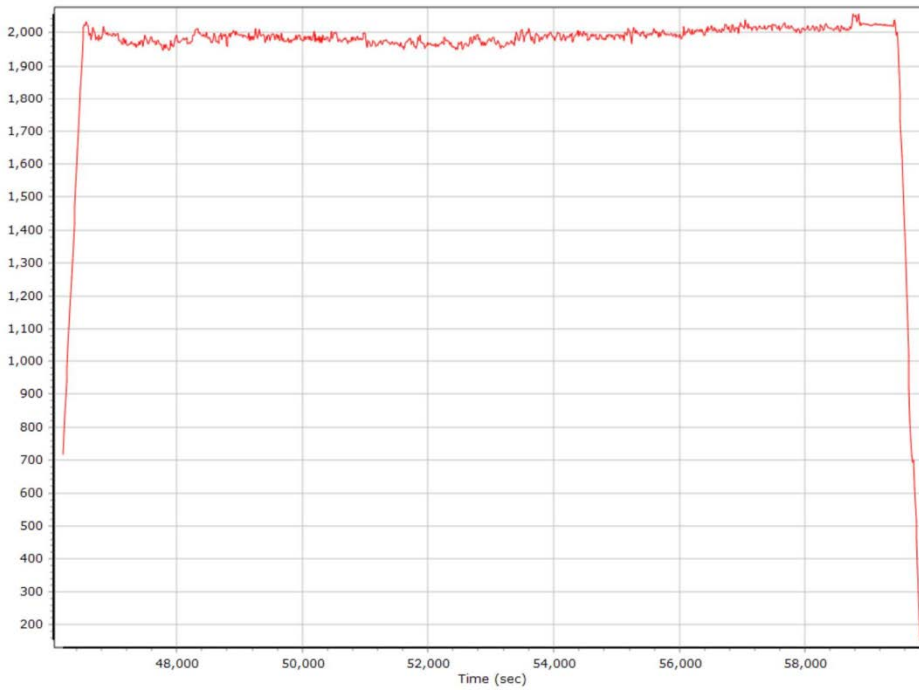
POSPac MMS 8.4 table- 200426A.pdf - 04/28/2020 08:13:04

Smoothed Trajectory Information

Top View



Altitude

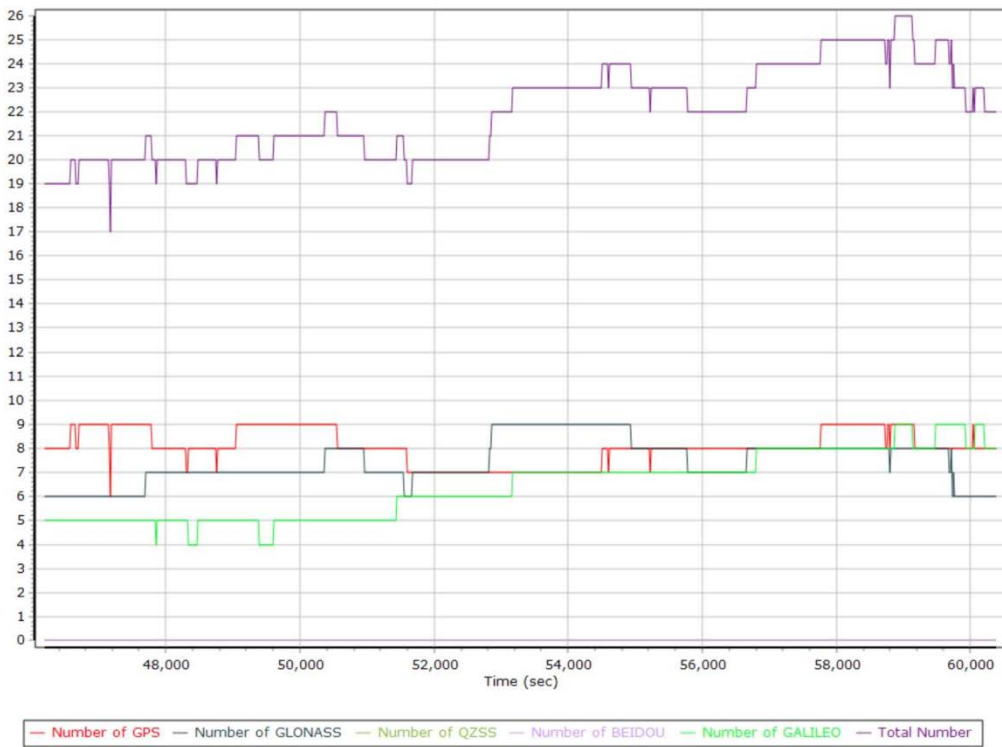


GNSS QC

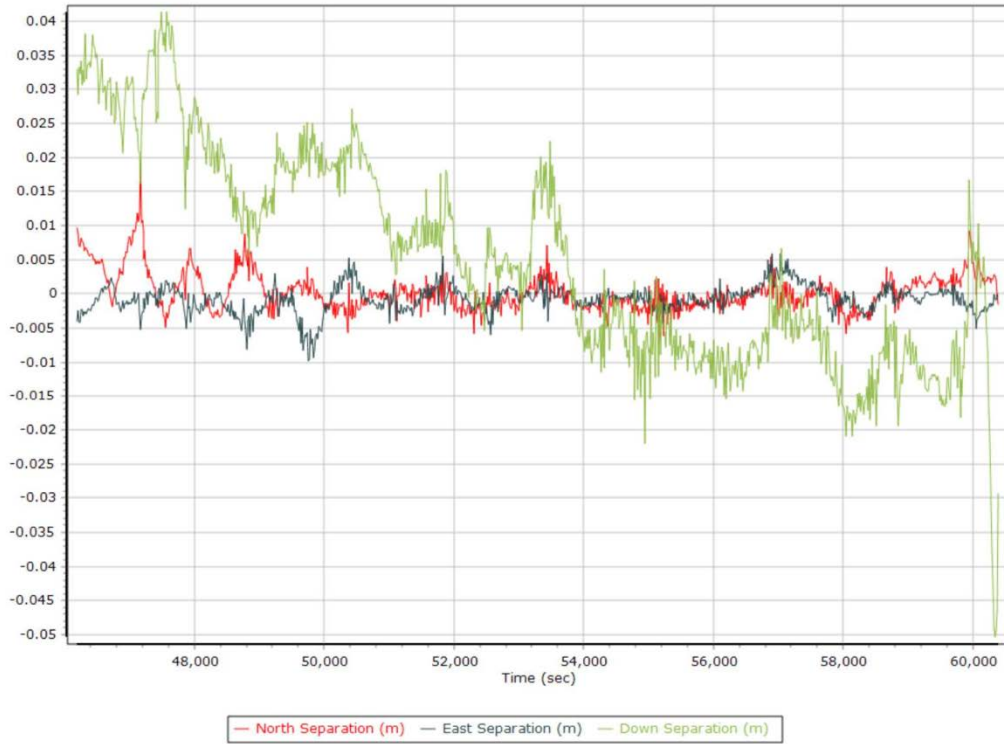
GNSS QC Statistics

Statistics	1 91	Ma	
Number of GLONASS SV	0 99		
	1		
	ed		No solution
	14902		
	9		

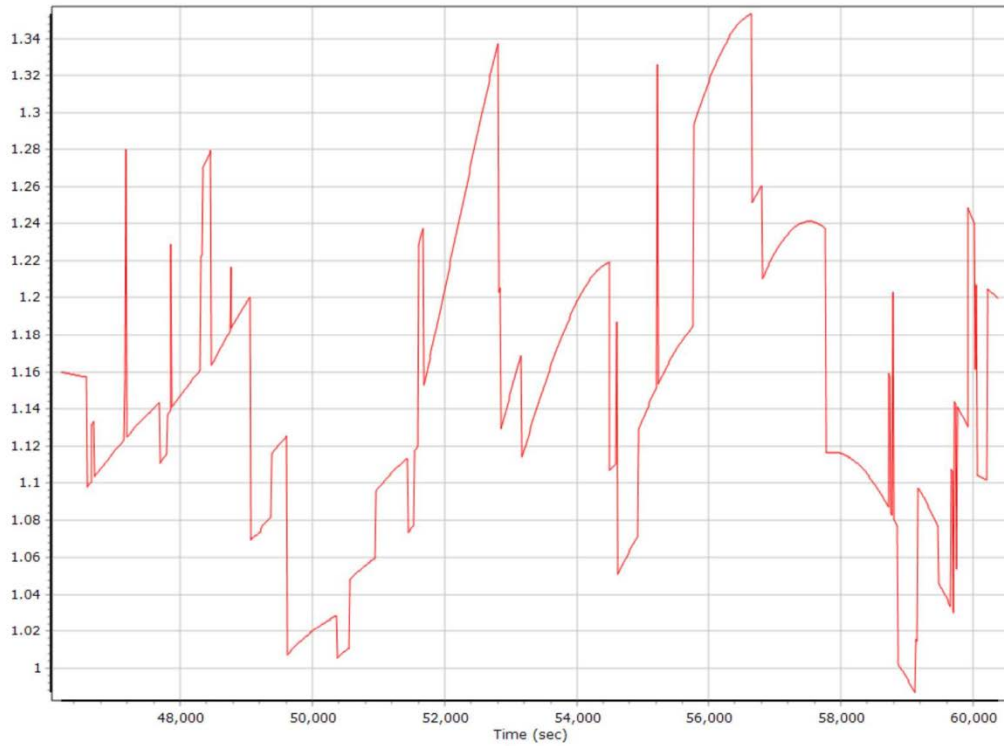
Num SVs in solution



Forward/Reverse Separation

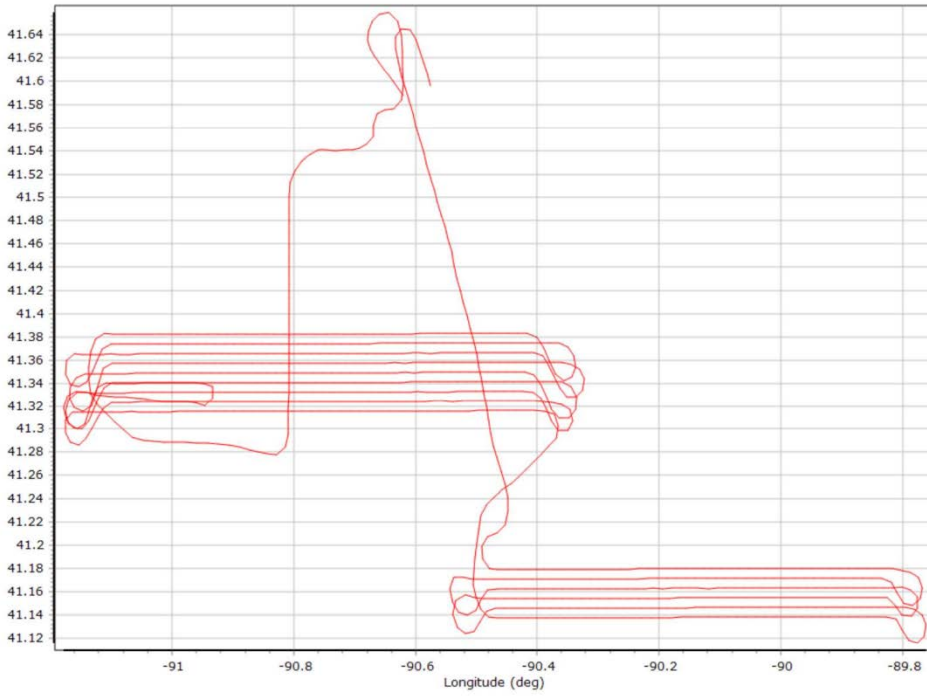


PDOP

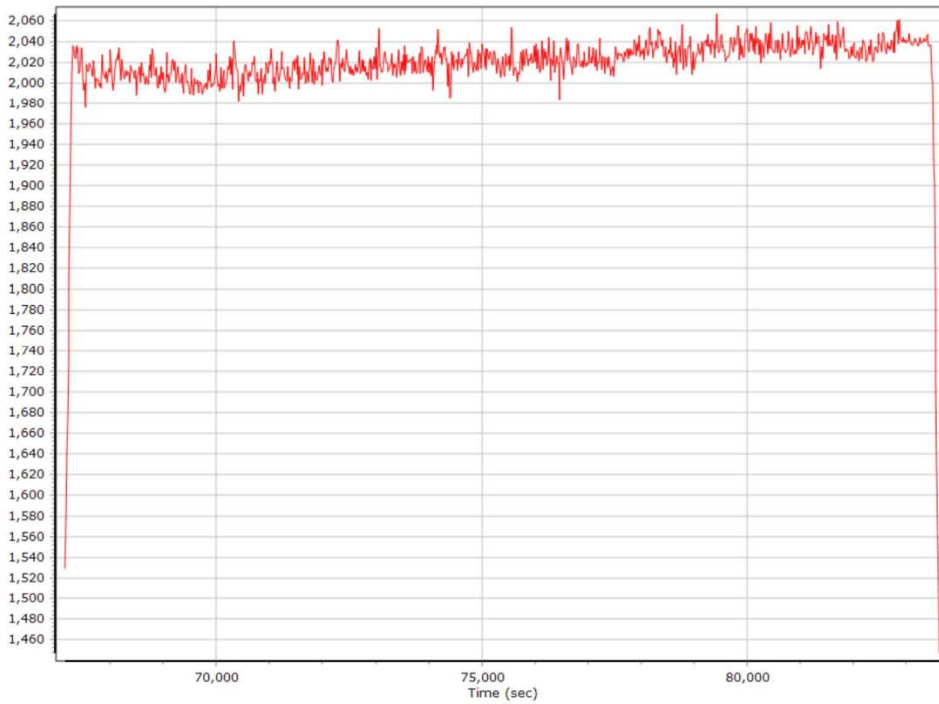


Smoothed Trajectory Information

Top View



Altitude

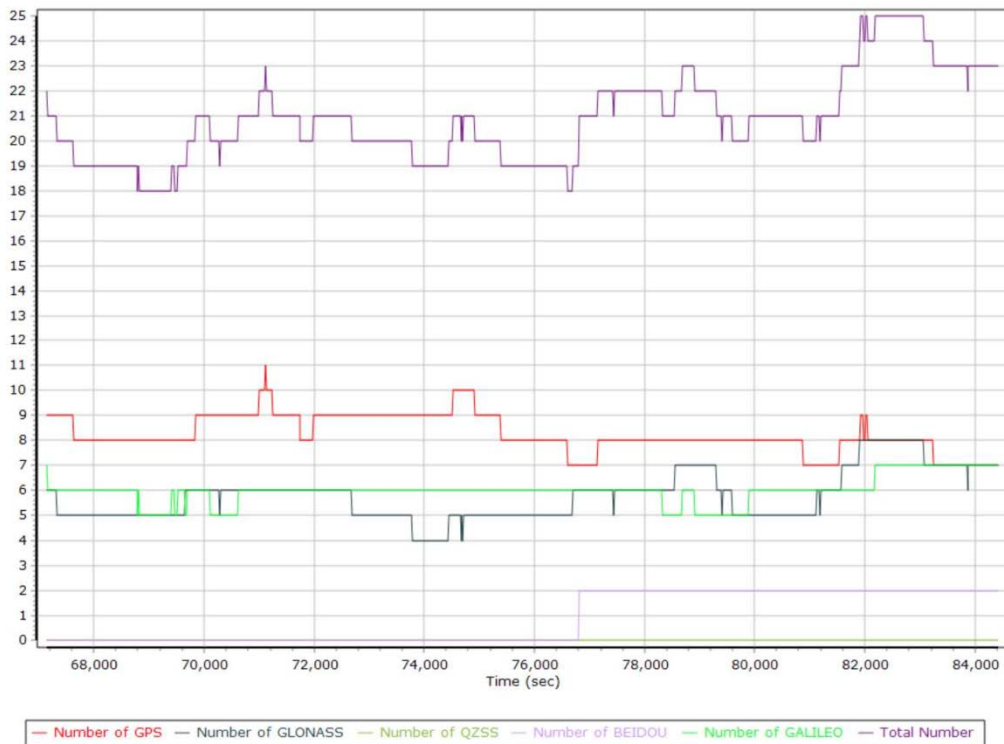


GNSS QC

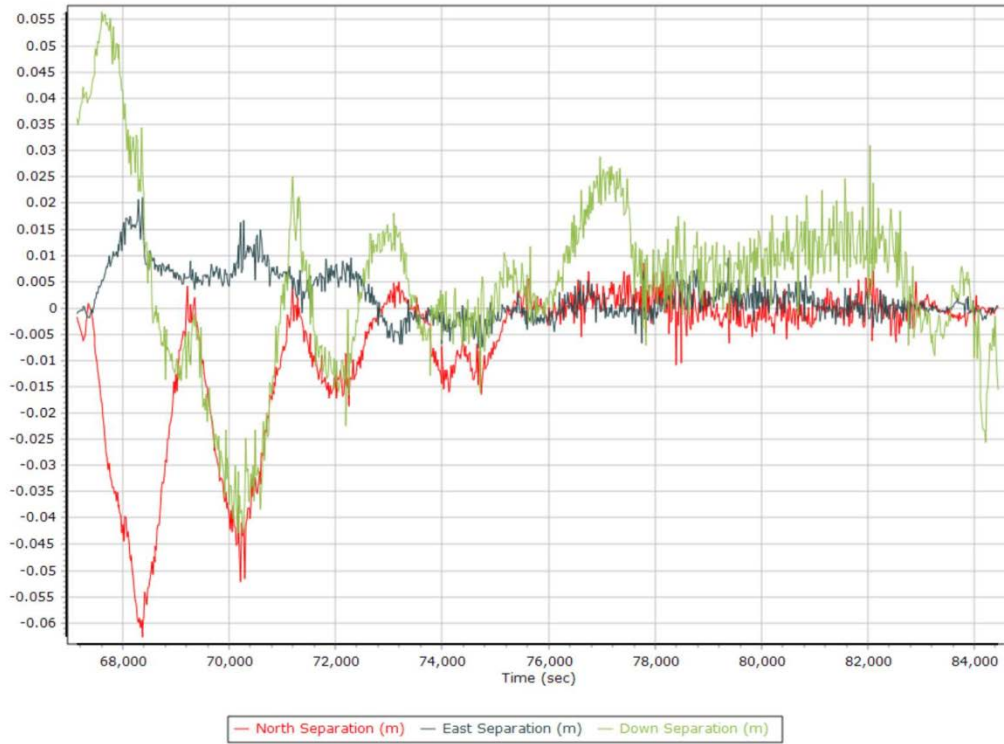
GNSS QC Statistics

Statistics	1 85	Ma	
	7	9	
Number of GLONASS SV	0 94		
	1		
	ed		No solution
	18202		
	9		

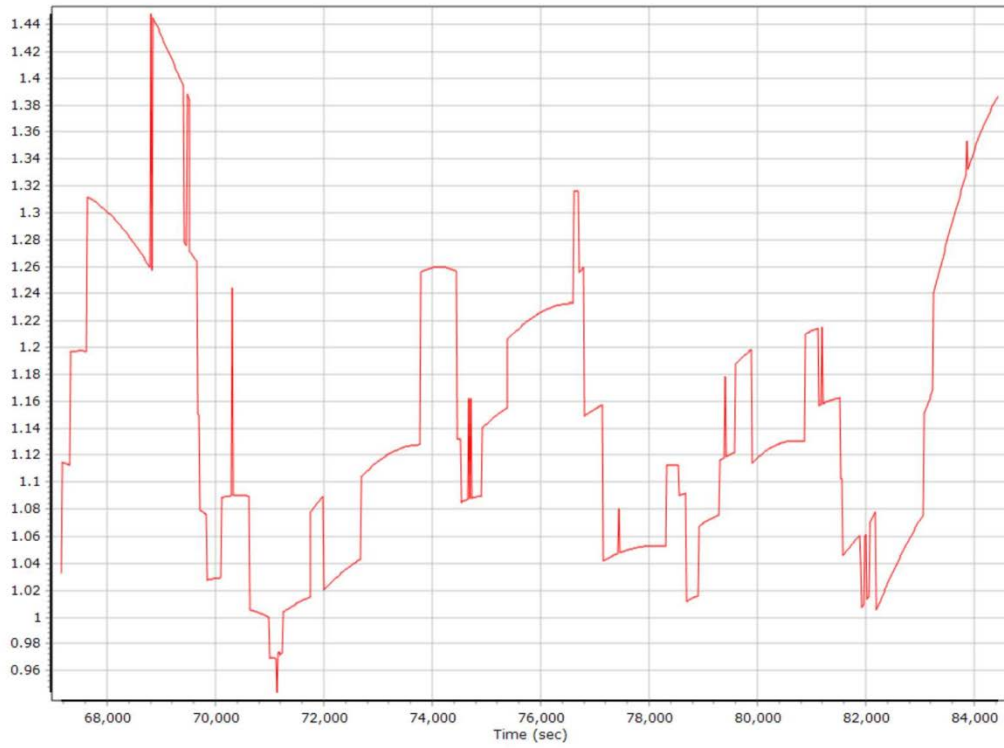
Num SVs in solution



Forward/Reverse Separation

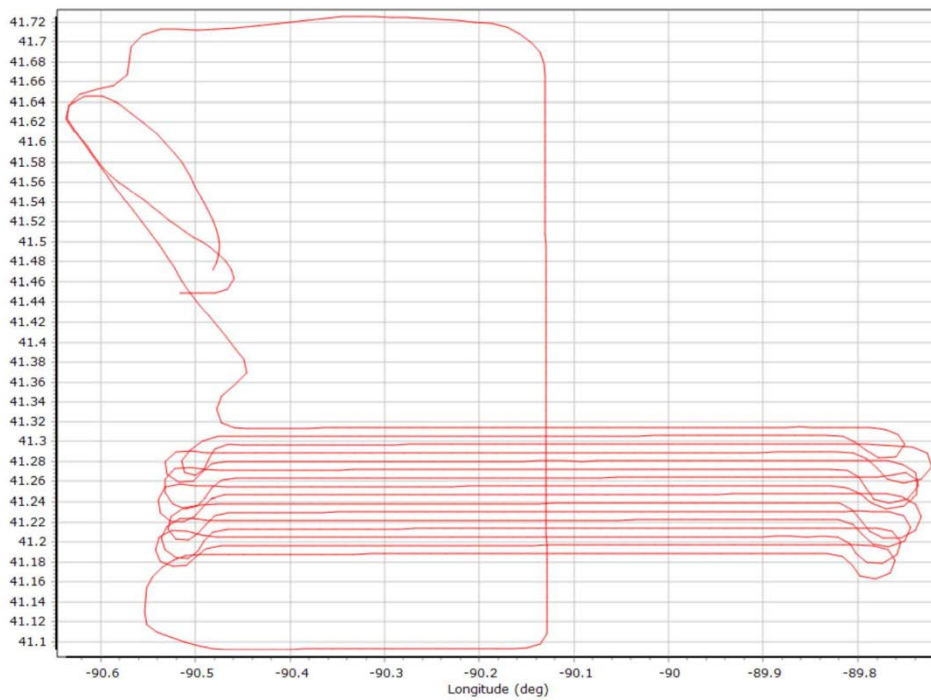


PDOP

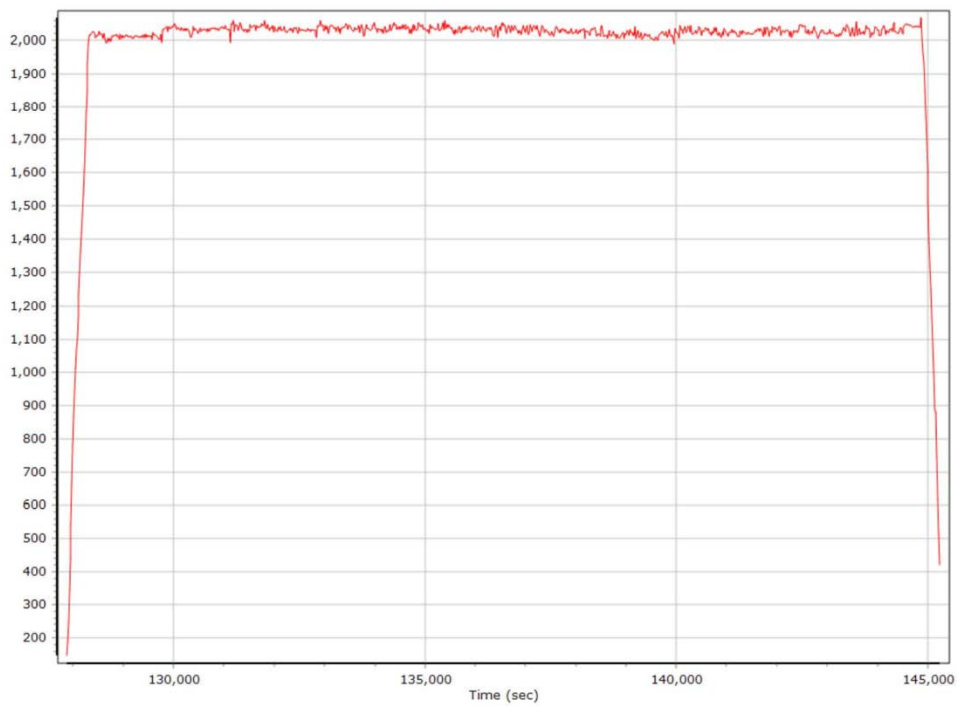


Smoothed Trajectory Information

Top View



Altitude

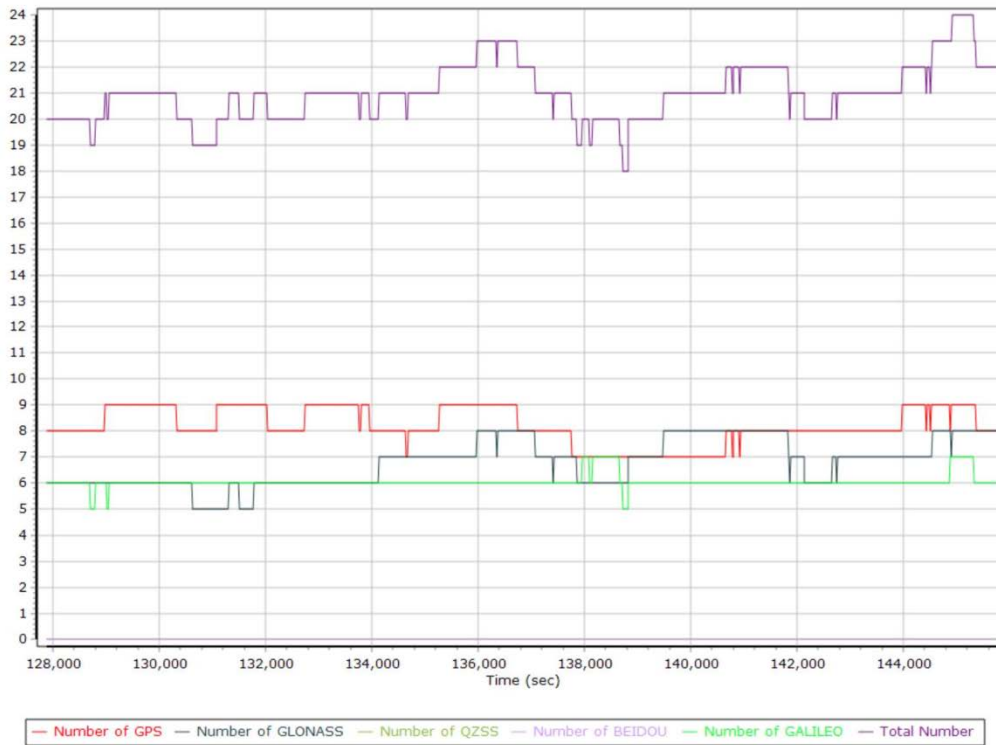


GNSS QC

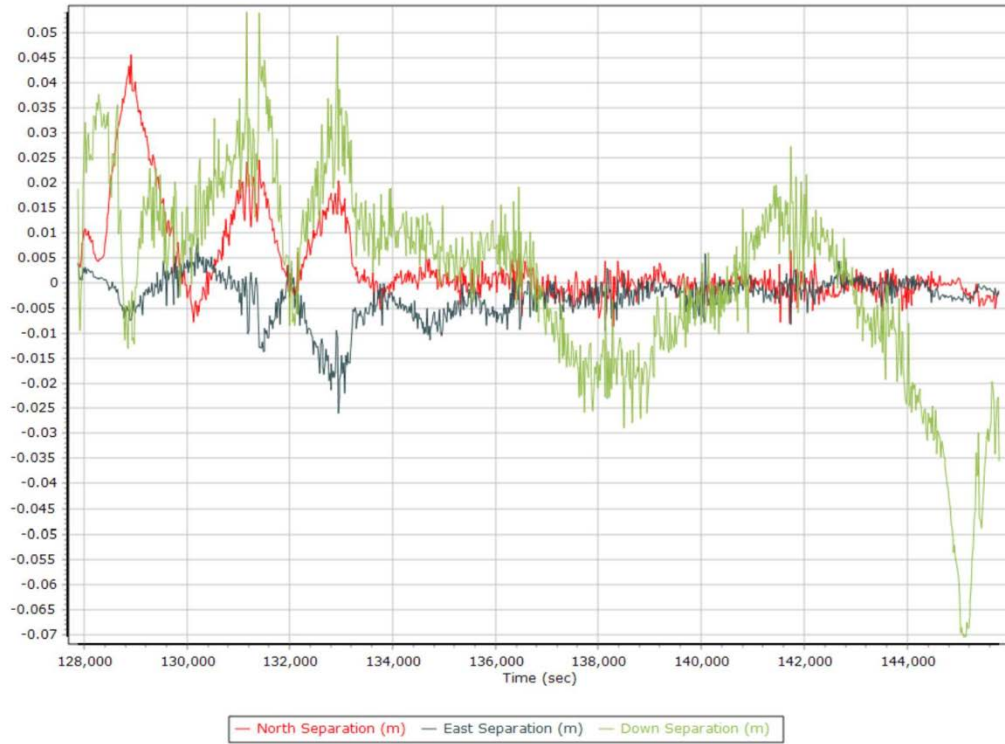
GNSS QC Statistics

Statistics	1 84	Ma	
	7		
Number of GLONASS SV	00		
	1		
	ed		
			No solution
	18600		

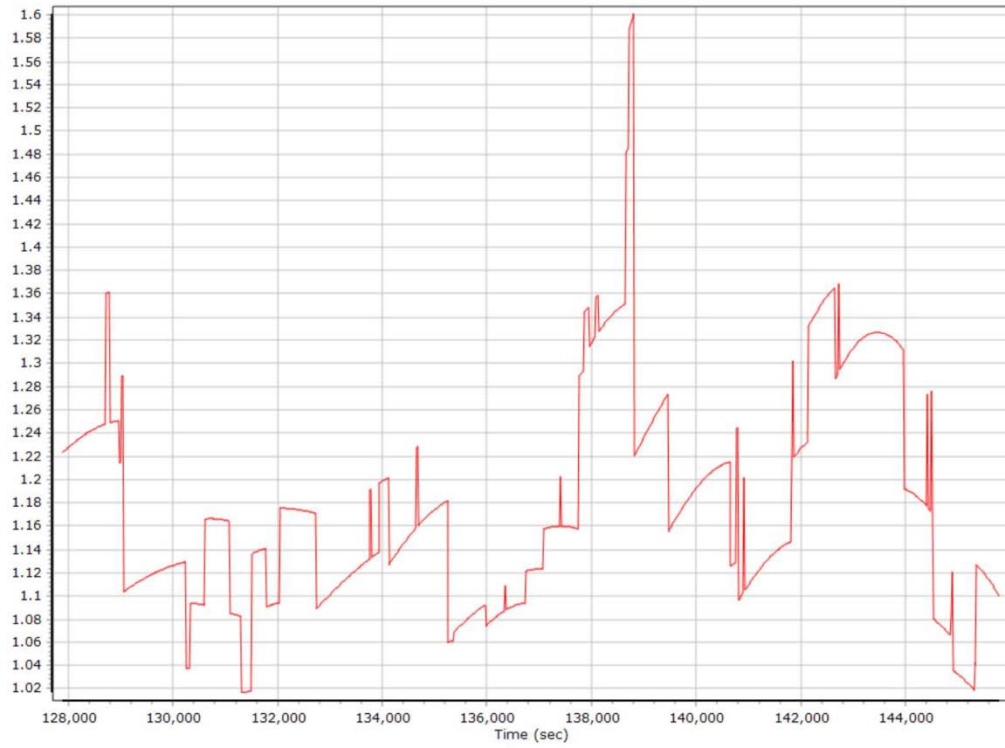
Num SVs in solution



Forward/Reverse Separation

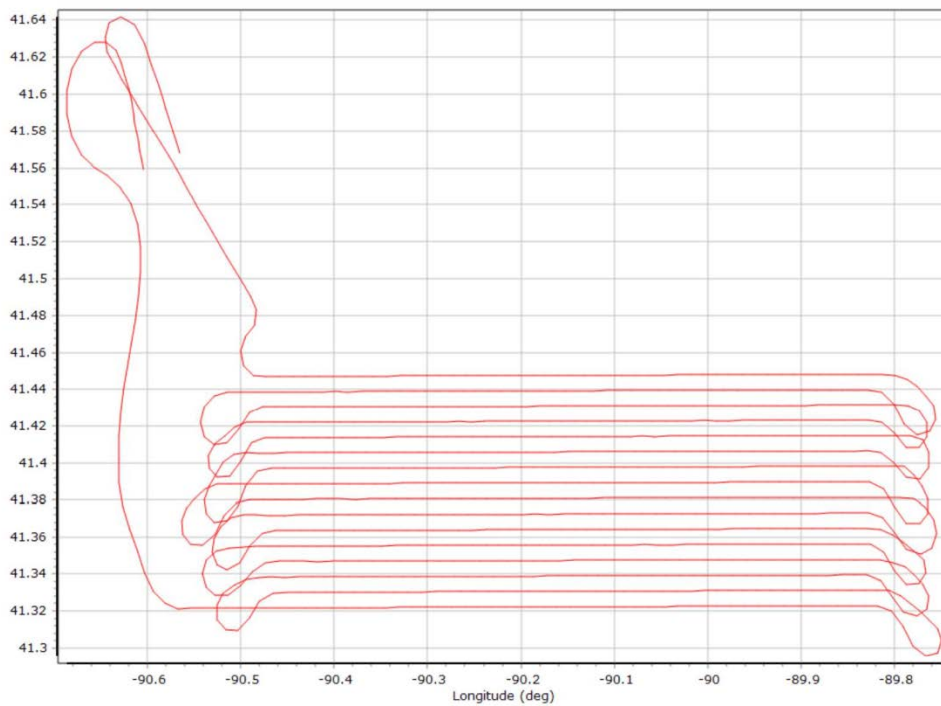


PDOP

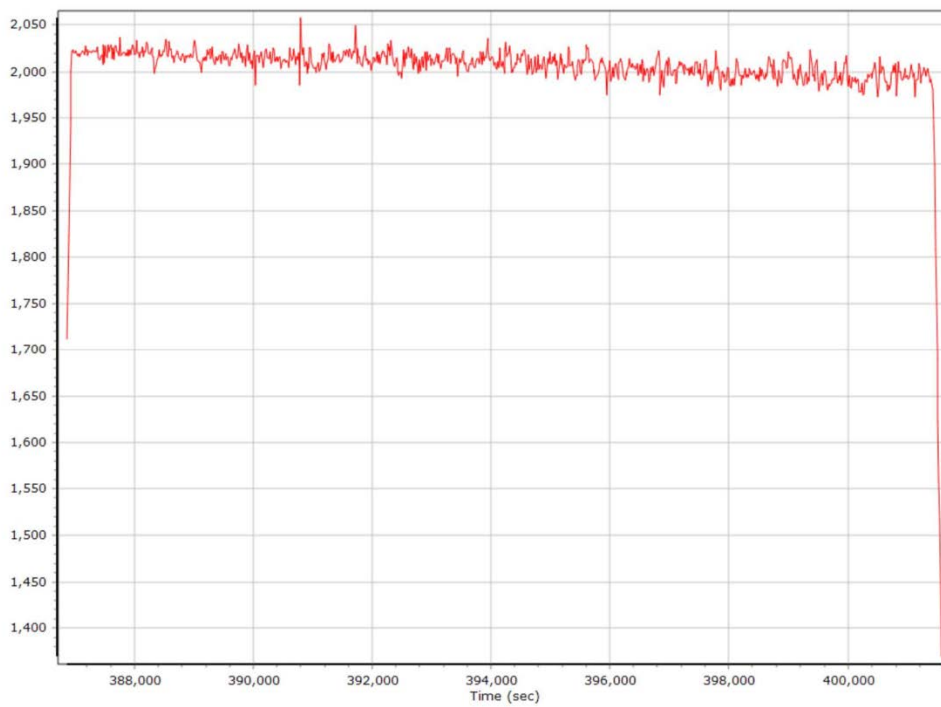


Smoothed Trajectory Information

Top View



Altitude

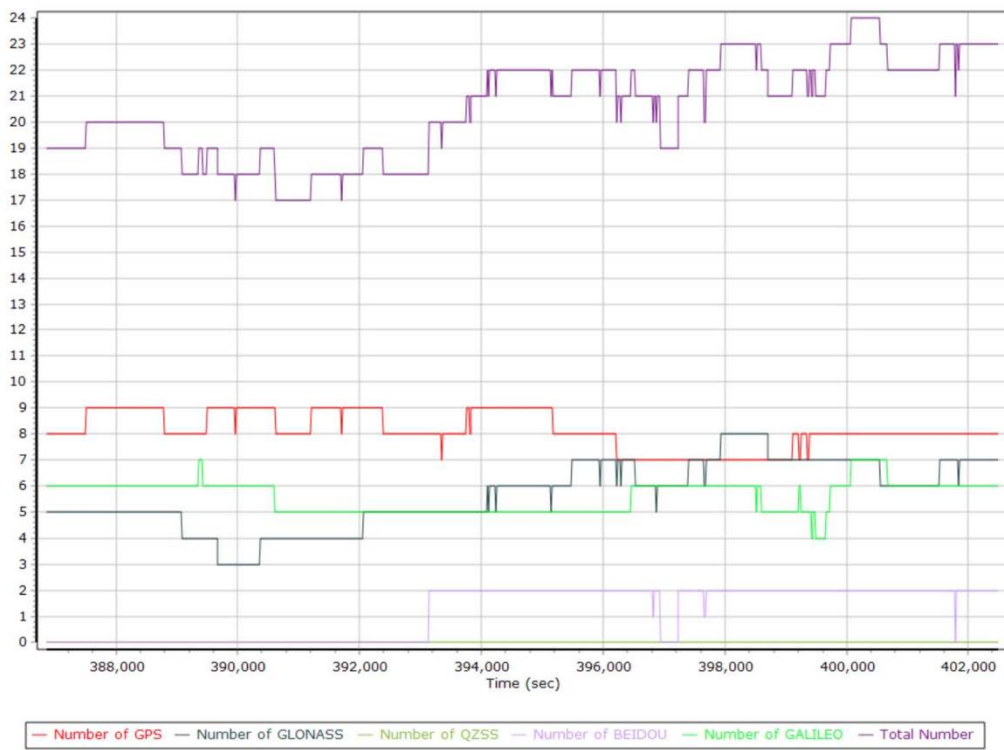


GNSS QC

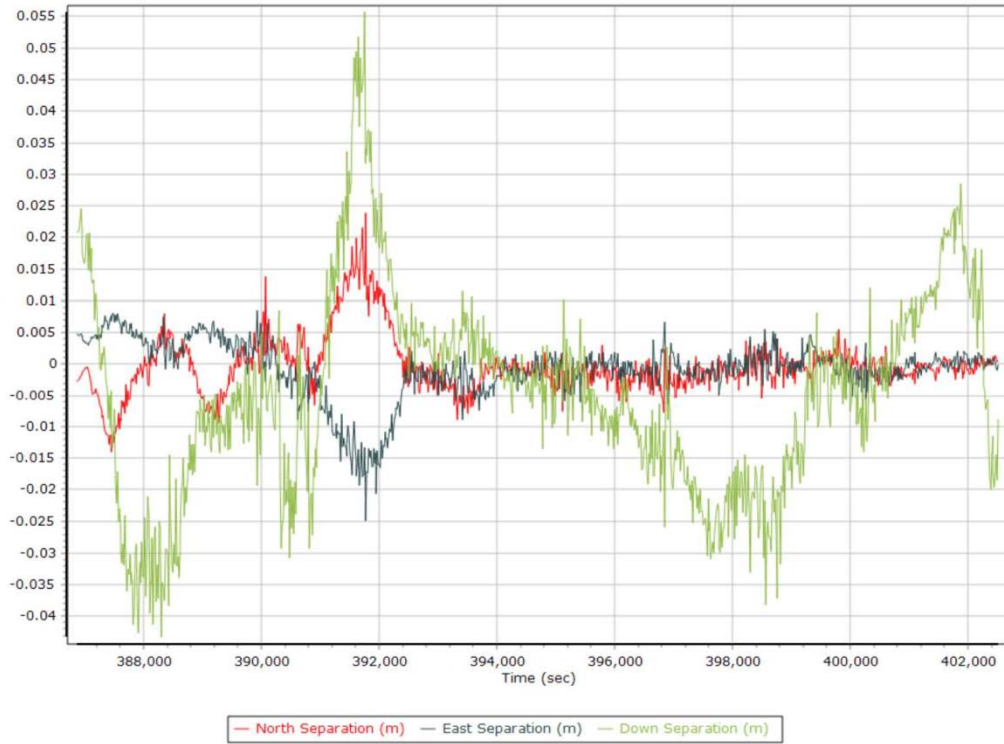
GNSS QC Statistics

Statistics	1 79	Ma	
	7		
Number of GLONASS SV	1 04		
	1		
	ed		No solution
	1666		
	9		

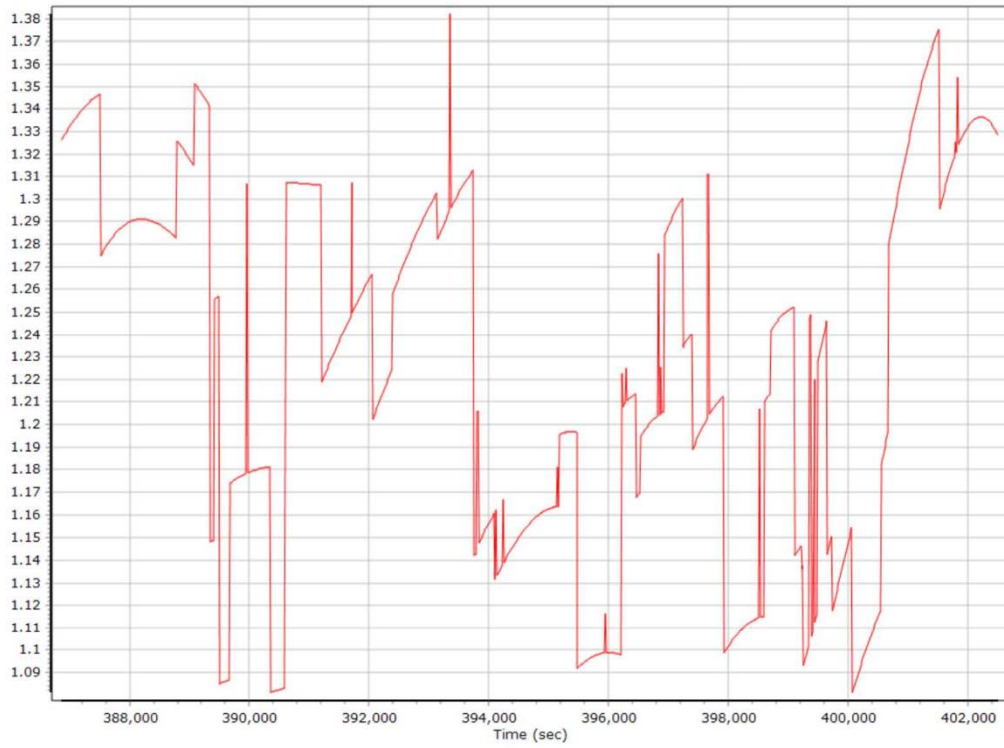
Num SVs in solution



Forward/Reverse Separation

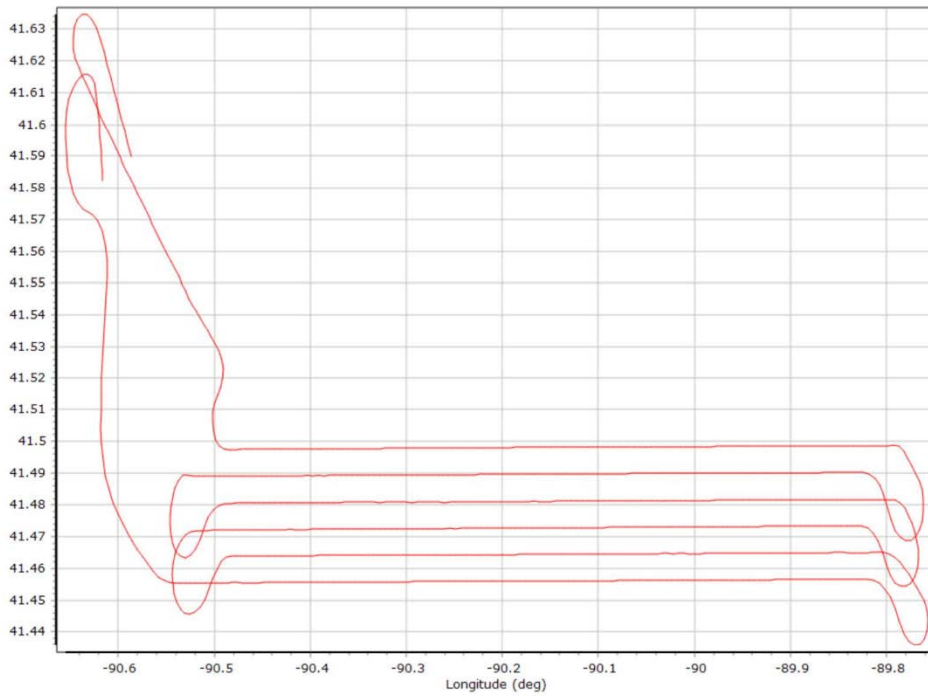


PDOP

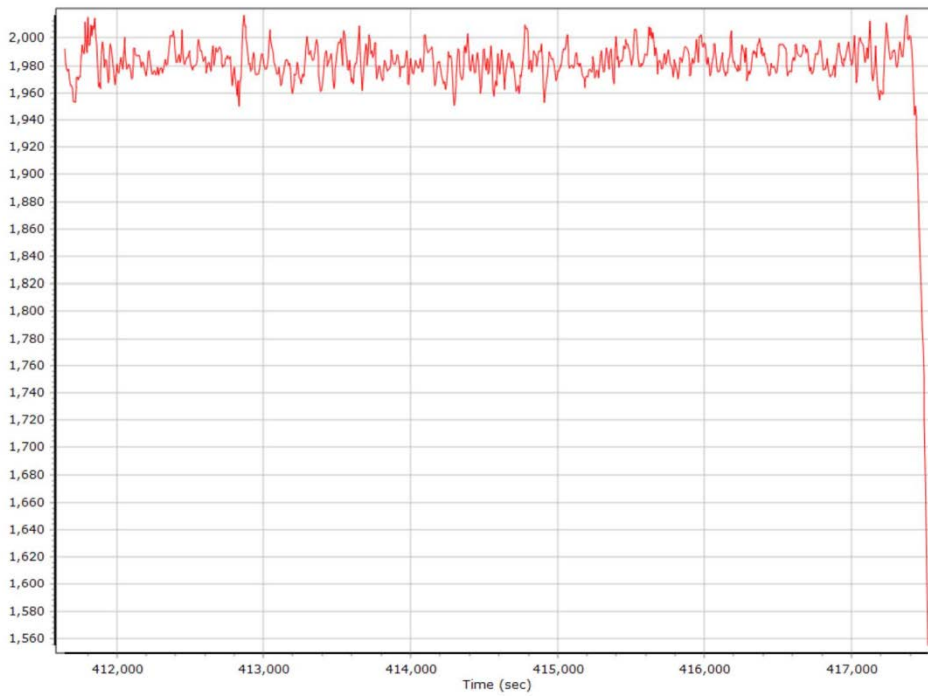


Smoothed Trajectory Information

Top View



Altitude

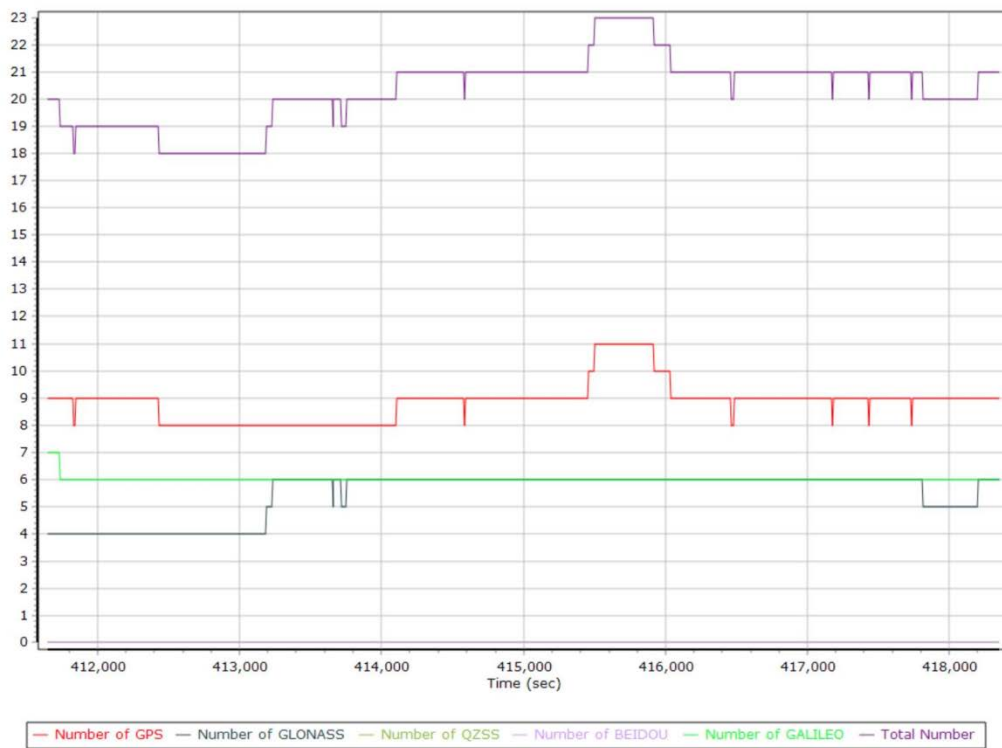


GNSS QC

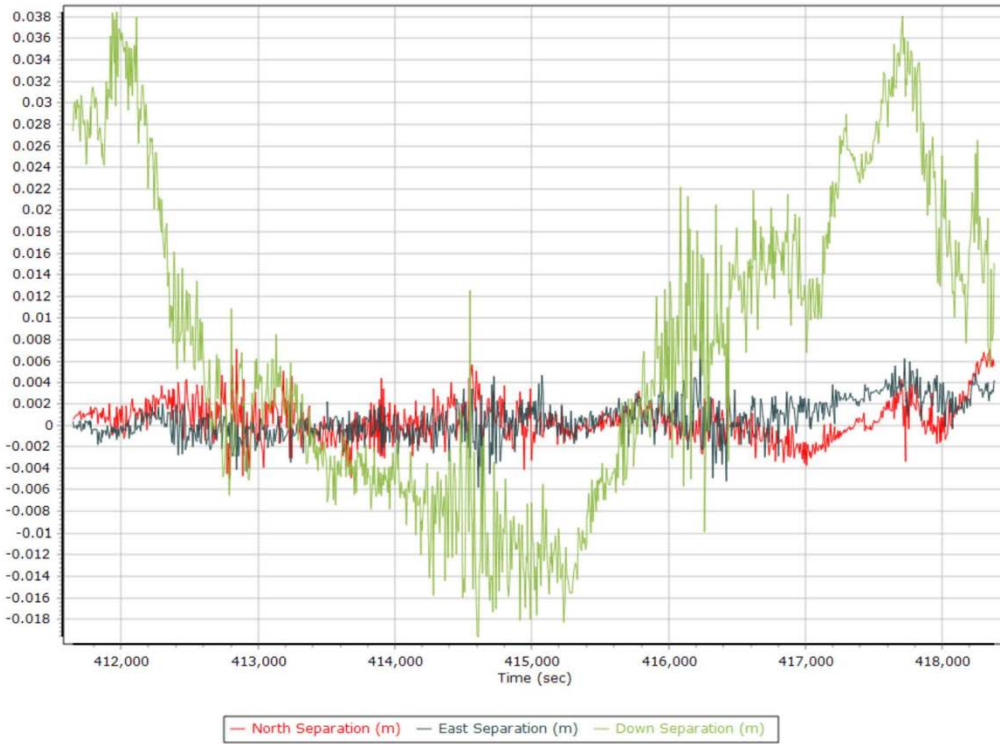
GNSS QC Statistics

Statistics	1 80	Ma	
	8		
	1 02		
Number of GLONASS SV	1		
	ed		No solution
	7791		
	9		

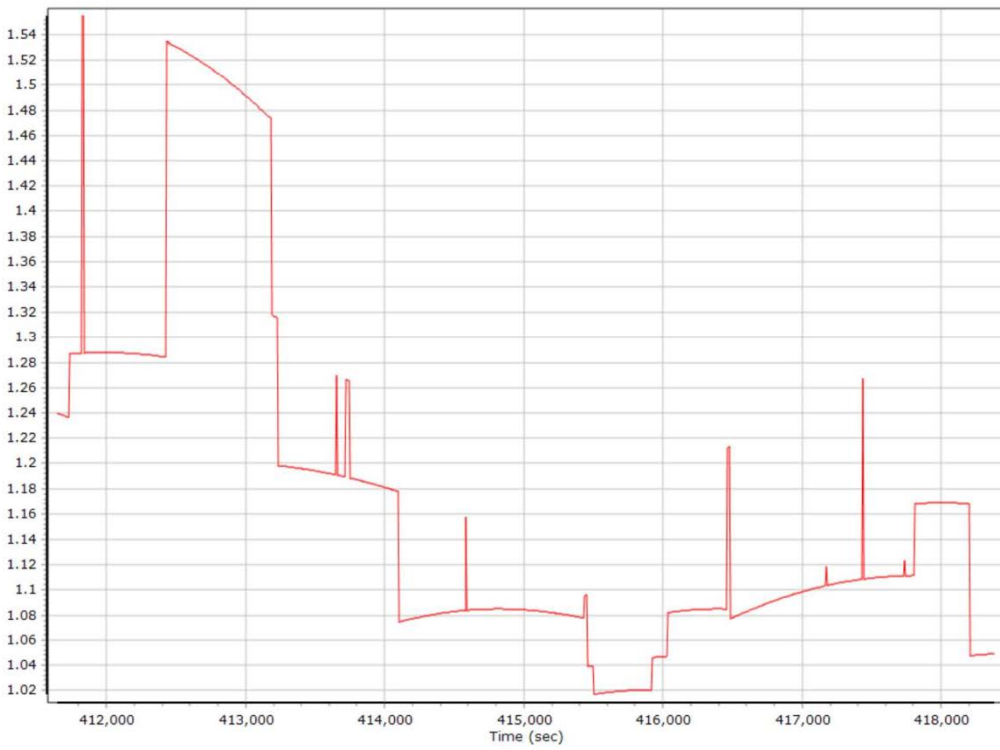
Num SVs in solution



Forward/Reverse Separation

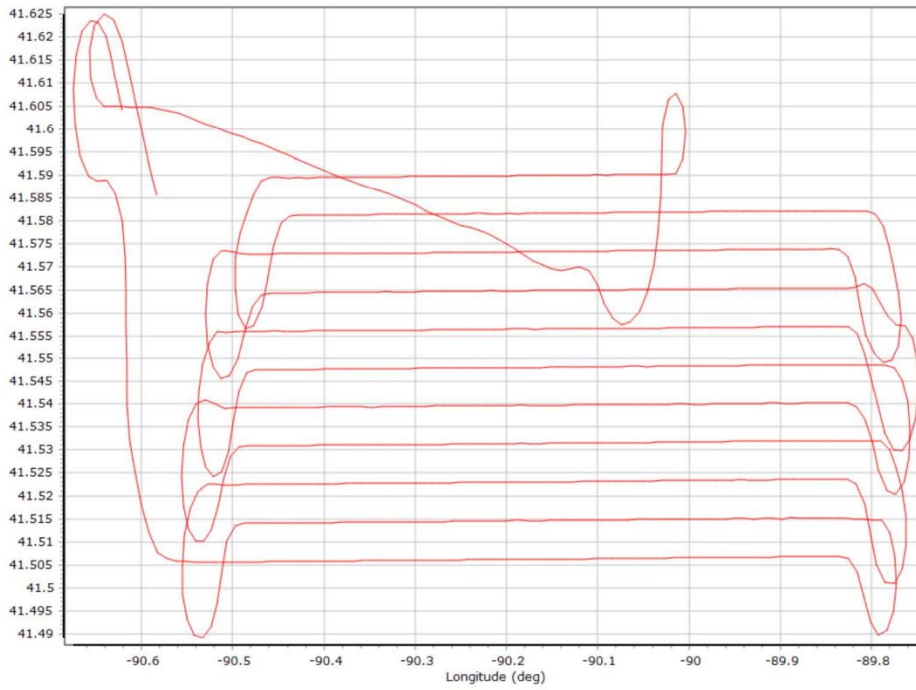


PDOP

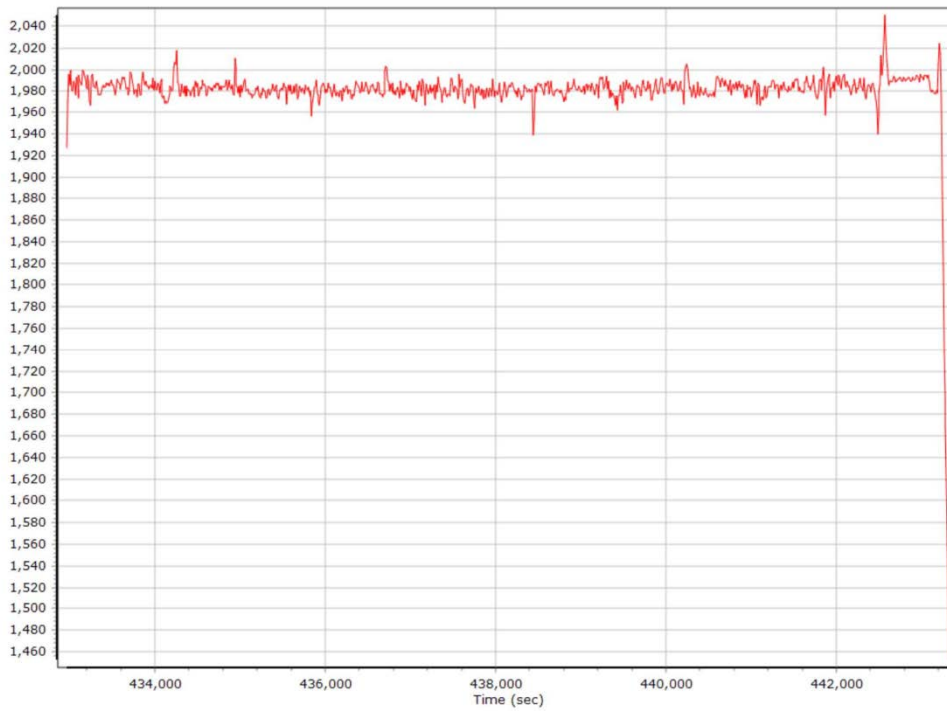


Smoothed Trajectory Information

Top View



Altitude

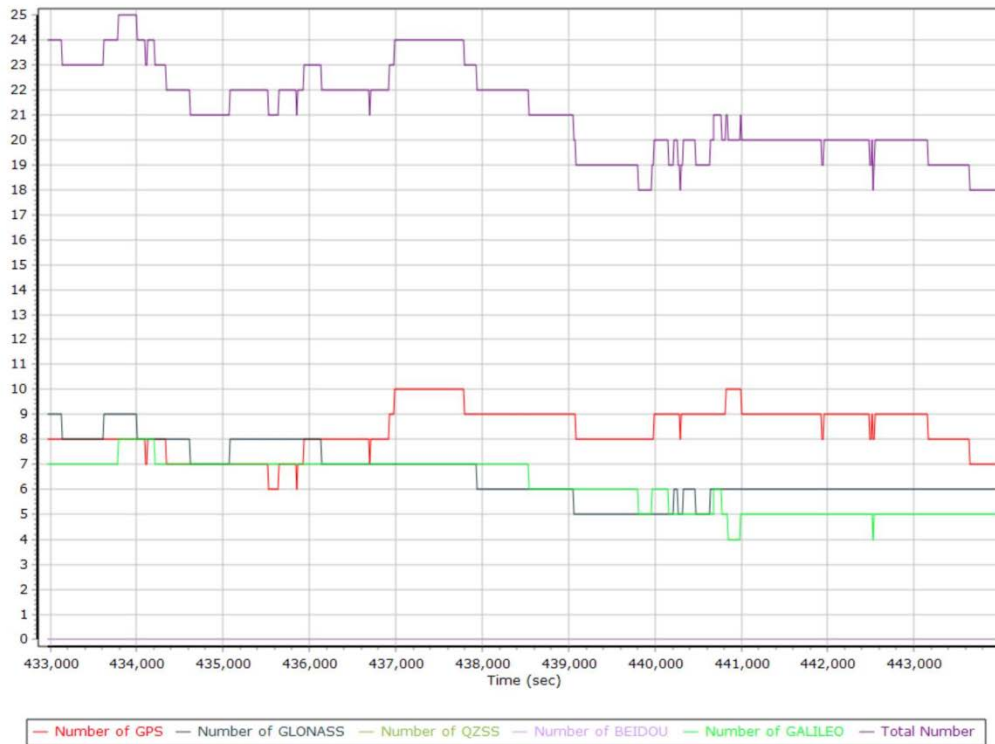


GNSS QC

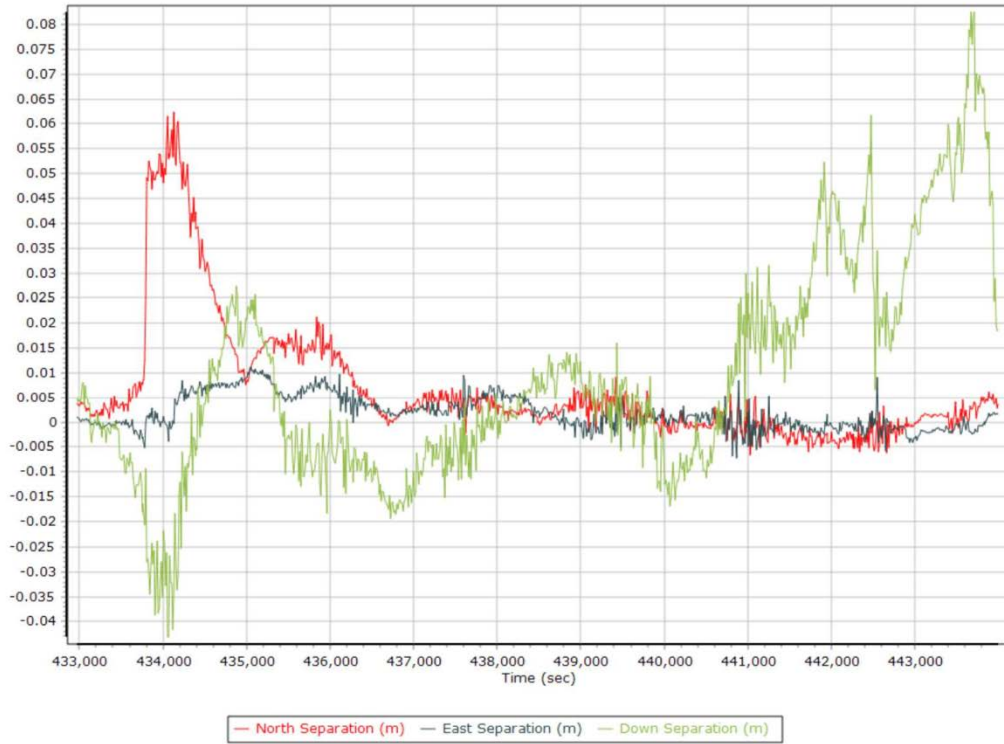
GNSS QC Statistics

Statistics	1 81	Ma	
Number of GLONASS SV	0 99		
	1		
	ed		No solution
	12001		
	9		

Num SVs in solution



Forward/Reverse Separation



PDOP

