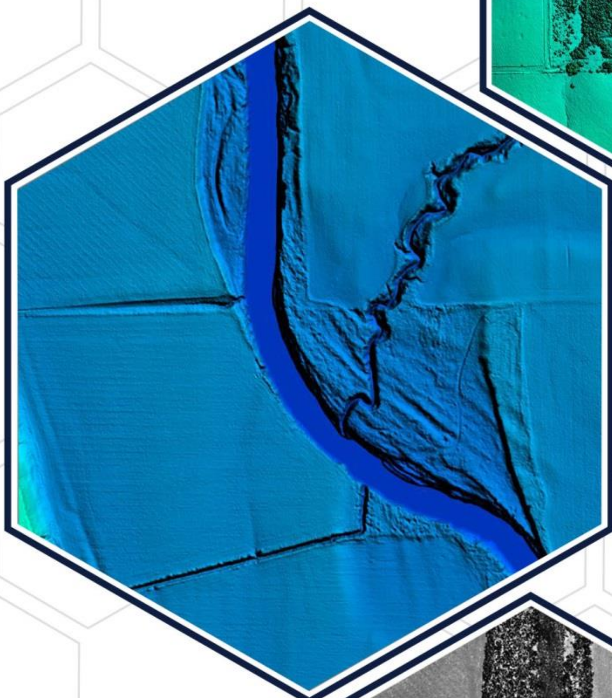

Aerial Lidar Report

17080
Washington Resource Conservation and Development Council (WRCD),
Upper Wenatchee Restoration Project
April 2018

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Section 1: Lidar Acquisition

1.1 Acquisition

The Atlantic Group, LLC (Atlantic) has successfully completed lidar acquisition for the Upper Wenatchee Restoration Project Area of Interest (AOI). Lidar for this AOI was acquired in five (5) flight missions completed on October 5th, 2017-October 15th, 2017. The project area encompasses 78,590 acres, 318 square kilometers or 128 square miles.

1.2 Acquisition Status Report

Upon notification to proceed, the flight crew loaded the flight plans and validated the flight parameters. Atlantic's Director of Flight Operations contacted air traffic control and coordinated flight pattern requirements. Lidar acquisition began immediately upon notification that control base stations were in place. During flight operations, the flight crew monitored weather and atmospheric conditions. Lidar missions were flown only when no condition existed below the sensor that would affect the collection of data. The pilot constantly monitored the aircraft course, position, pitch, roll, and yaw of the aircraft. The sensor operator monitored the sensor, the status of the GNSS constellations, and performed the first QC review during acquisition. The flight crew constantly reviewed weather and cloud locations. Any flight lines impacted by unfavorable conditions were marked as invalid and re-flown at an optimal time.

1.3 Acquisition Details

Atlantic acquired one hundred and sixty-seven (167) passes of the AOI as a series of perpendicular and/or adjacent flight-lines. Differential GNSS unit in aircraft recorded sample positions at 2 Hz or more frequency. Lidar data was only acquired when a minimum of 6 satellites were in view.

Atlantic lidar sensors are calibrated at a designated site located at the Fayetteville Municipal Airport (FYM) in Fayetteville, TN and are periodically checked and adjusted to minimize corrections at project sites.

1.4 Project Purpose

The primary purpose of the lidar survey was to establish measurements of the bare earth surface, as well as top surface feature data for providing geometric inputs for modeling, other numerical modeling and economic related assessments.

1.5 Lidar Flight-line Orientation

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

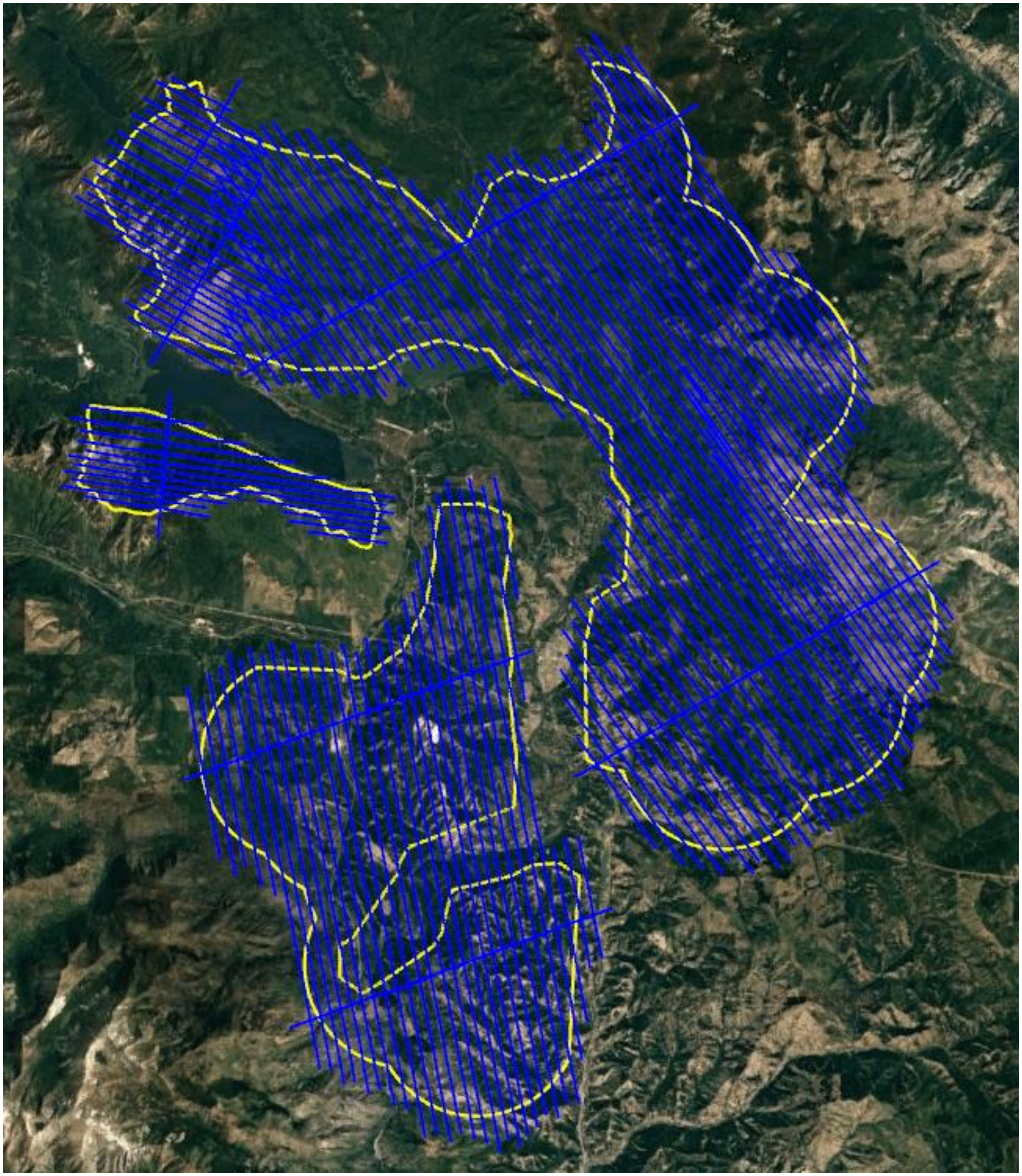


Figure 1: Trajectories as flown by Atlantic

1.6 Acquisition Equipment

Atlantic operated a Cessna T210L (N732JE) outfitted with a Leica ALS70-HP lidar system during the collection of the project area. Table 1 represents a list of the features and characteristics for the Leica ALS70-HP lidar system:

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

Table 1: Atlantic Sensor Characteristics

1.7 Lidar System Acquisition Parameters

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

Lidar System Acquisition Parameters	
Item	**Parameter**
System	Leica ALS-70 HP
Nominal Pulse Spacing (m)	0.5
Nominal Pulse Density (pls/m²)	4.5
Nominal Flight Height (AGL meters)	2900
Nominal Flight Speed (kts)	110
Pass Heading (degree)	Varies
Sensor Scan Angle (degree)	22
Scan Frequency (Hz)	40.5
Pulse Rate of Scanner (kHz)	239.8
Line Spacing (m)	368
Pulse Duration of Scanner (ns)	4
Pulse Width of Scanner (m)	0.64
Central Wavelength of Sensor Laser (nm)	1064
Sensor Operated with Multiple Pulses	Yes
Beam Divergence (mrad)	0.22
Nominal Swath Width (m)	933
Nominal Swath Overlap (%)	50
Scan Pattern	Triangle

Table 2: Atlantic Lidar System Acquisition Parameters

1.8 GNSS Reference Station(s)

Six (6) UNAVCO Reference Stations and one (1) Continuously Operating Reference Station (CORS) was used to control the lidar acquisition for the project area. The coordinates provided in Table 3 below are in NAD83 (2011), Geographic Coordinate System, Ellipsoid, Meters.

GNSS Reference Station Coordinates					
Designation	**Type**	**PID**	**Latitude (N)**	**Longitude (W)**	**Elevation**
P442	UNAVCO		48 15 37.71323	121 36 55.91475	147.207
P413	UNAVCO		48 25 35.42653	120 08 58.43864	501.611
P434	UNAVCO		47 44 24.71402	121 04 32.12801	1698.384
SC00	UNAVCO		46 57 03.31340	120 43 28.53321	1178.761
P416	UNAVCO		47 02 23.77742	121 35 48.87882	1576.869
P065	UNAVCO		46 50 38.2410	120 55 59.06932	1017.498
BREW	CORS	DK4088	48 07 53.46856	119 40 57.42174	238.992

Table 3: GNSS Reference Station Coordinates

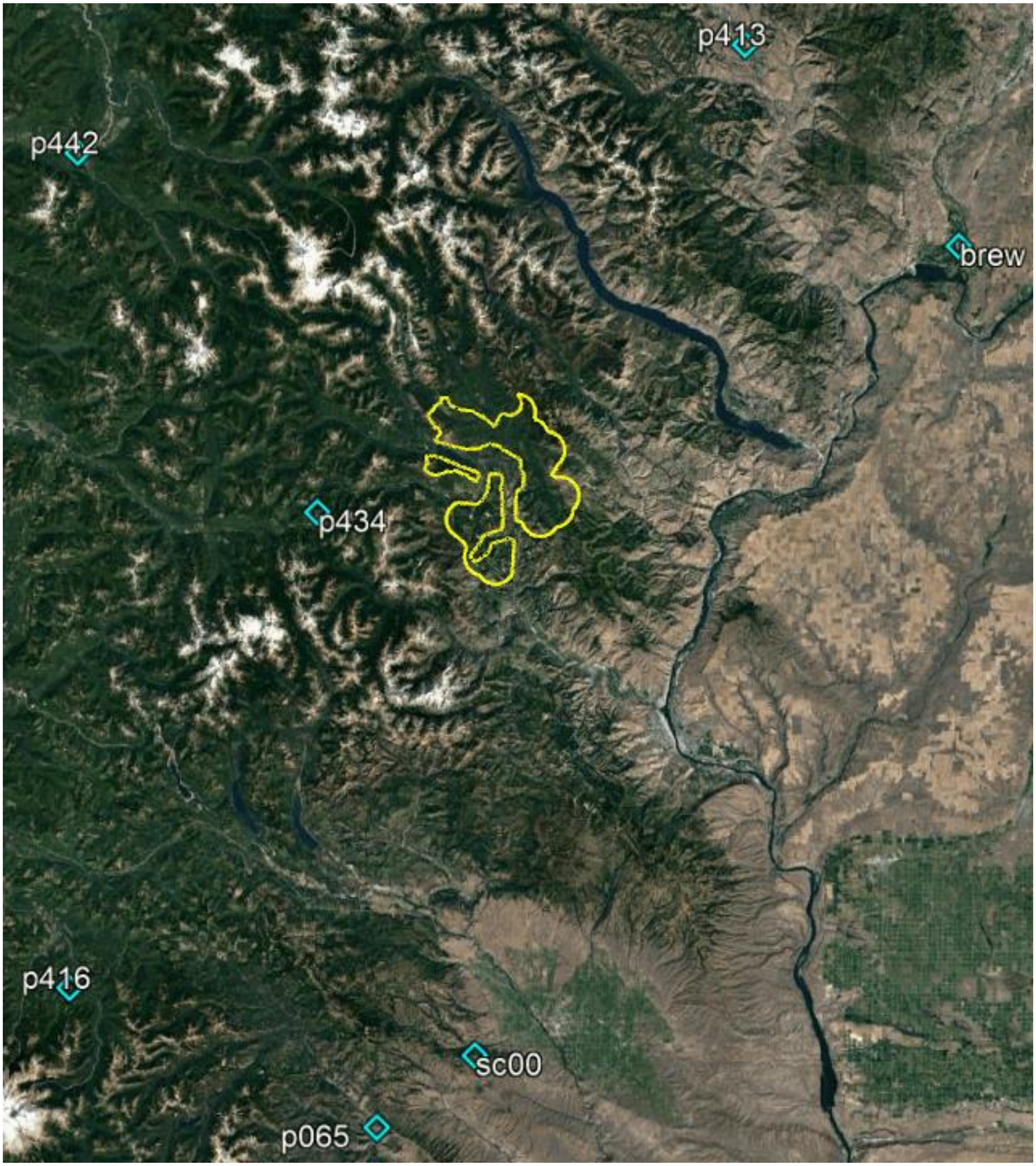


Figure 2: GNSS Reference Station(s)

1.9 Airborne GNSS Kinematic

Differential GNSS unit in aircraft collected positions at 2 Hz. Airborne GNSS data was processed using the Inertial Explorer (version 8.60.6717) software. Flights were flown with a minimum of 6 satellites in view (10° above the horizon).

For all flights, the GNSS data can be classified as good, with residuals of 3cm average or better but none larger than 10cm being recorded.

Data collected by the lidar unit is reviewed for completeness, acceptable density and to make sure all data is captured without errors or corrupted values. In addition, all GNSS, aircraft trajectory, mission information, and ground control files are reviewed and logged into a database.

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

Section 2: **Lidar Processing**

2.1 Lidar Point Cloud Generation

Atlantic used Leica software products to download the IPAS ABGNSS/IMU data and raw laser scan files from the airborne system. Waypoint Inertial Explorer is used to extract the raw IPAS ABGNSS/IMU data, which is further processed in combination with controlled base stations to provide the final Smoothed Best Estimate Trajectory (SBET) for each mission. The SBET's are combined with the raw laser scan files to export the Lidar ASCII Standard (*.las) formatted swath point clouds.

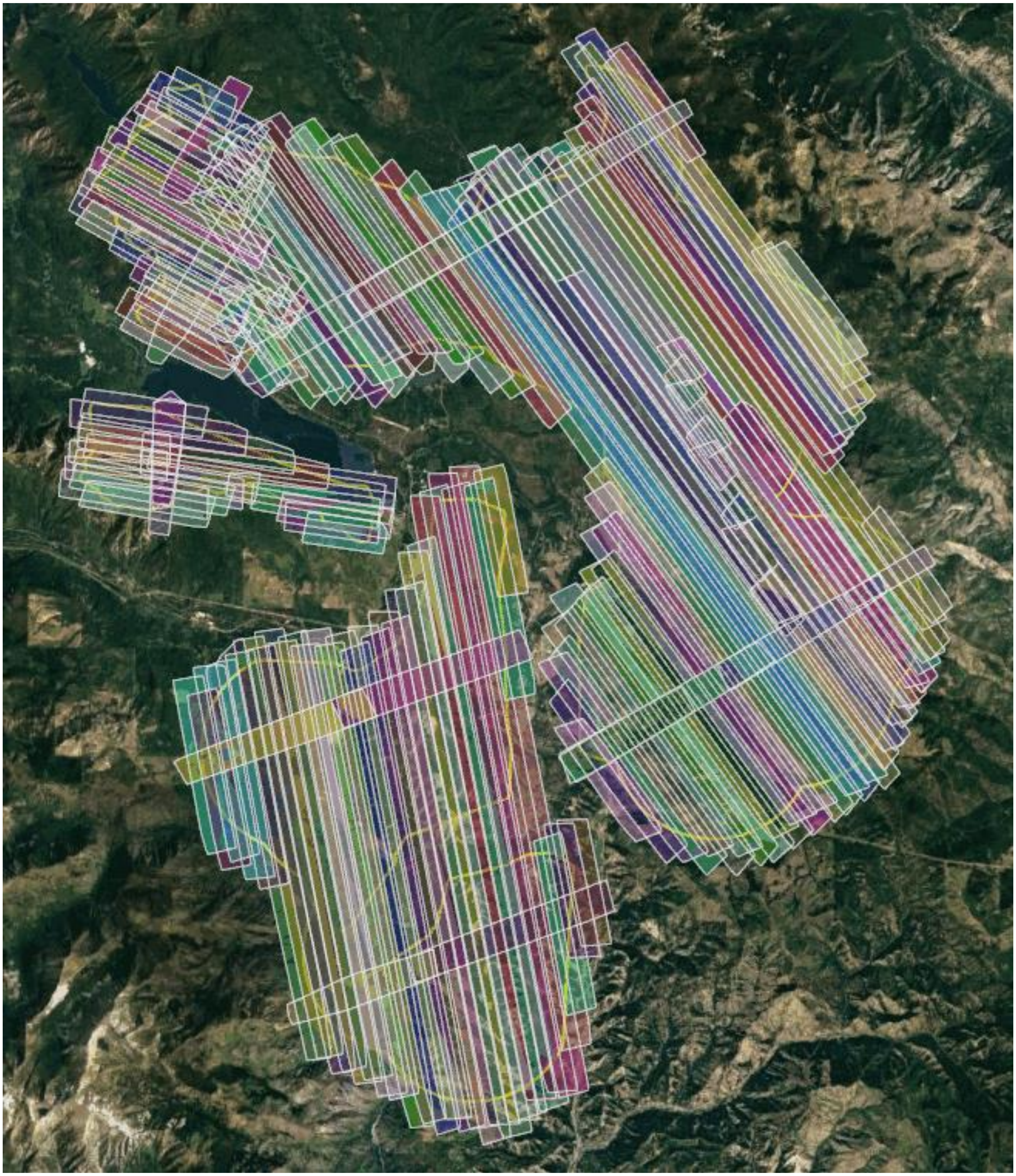


Figure 3: Lidar swath data showing complete coverage

2.2 Coordinate Reference System

Horizontal Datum: North American Datum of 1983
Coordinate System: USFS R6 Albers
Vertical Datum: North American Vertical Datum of 1988
Geoid Model: Geoid12B
Units of Reference: Meters

2.3 Lidar Point Cloud Statistics

Table 4 illustrates the overall lidar point cloud statistics for this project.

Point Cloud Statistics	
Category	**Value**
Total Points	8,123,753,631
Nominal Pulse Spacing (m)	0.3904
Nominal Pulse Density (pls/m²)	6.56
Nominal Pulse Spacing (ft)	1.2809
Nominal Pulse Density (pls/ft²)	0.61
Aggregate Total Points	6,248,545,243
Aggregate Nominal Pulse Spacing (m)	0.2391
Aggregate Nominal Pulse Density (pls/m²)	17.49
Aggregate Nominal Pulse Spacing (ft)	0.7845
Aggregate Nominal Pulse Density (pls/ft²)	1.62

Table 4: Lidar Point Cloud Statistics

2.4 Expected Horizontal Positional Error

As described in Section 7.5 of the ASPRS Positional Accuracy Standards for Digital Geospatial Data the horizontal errors in lidar data are largely a function of GNSS positional error, INS angular error, and flying altitude. Therefore, lidar data collected with GNSS error of 8cm and the IMU error of 0.00427 degrees at an altitude of 2,900m; the expected radial horizontal positional error will be RMSEr = 40.0cm.

2.5 Lidar Calibration

Lidar ranging data were initially calibrated using previous best parameters for this instrument and aircraft. Using a combination of GeoCue, TerraScan and TerraMatch; the overlapping swath point clouds are corrected for any orientation or linear deviations to obtain the best fit swath-to-swath calibration. Relative calibration was evaluated using advanced plane-matching analysis and parameter corrections derived. This process was repeated interactively until residual errors between overlapping swaths, across all project missions, was reduced to ≤2cm. A final analysis of the calibrated lidar is preformed using a TerraMatch Tie Line report for an overall statistical model of the project area.

Upon completion of the data calibration, Atlantic runs a complete set of elevation difference intensity rasters (dZ Orthos). A user-defined color ramp is applied depicting the offsets between overlapping swaths based on project specifications. The dZ orthos provide an opportunity to review the data calibration in a qualitative manner. Atlantic assigns green to all offset values that fall below the required RMSDz requirement of the project. A yellow color is assigned for offsets that fall between the RMSDz value and 1.5x of that value. Finally, red values are assigned to all values that fall beyond 1.5x of the RMSDz requirements of the project.

No Data	0m to 0.04m	0.04m to 0.08m	0.08m to 0.12m	> 0.12m

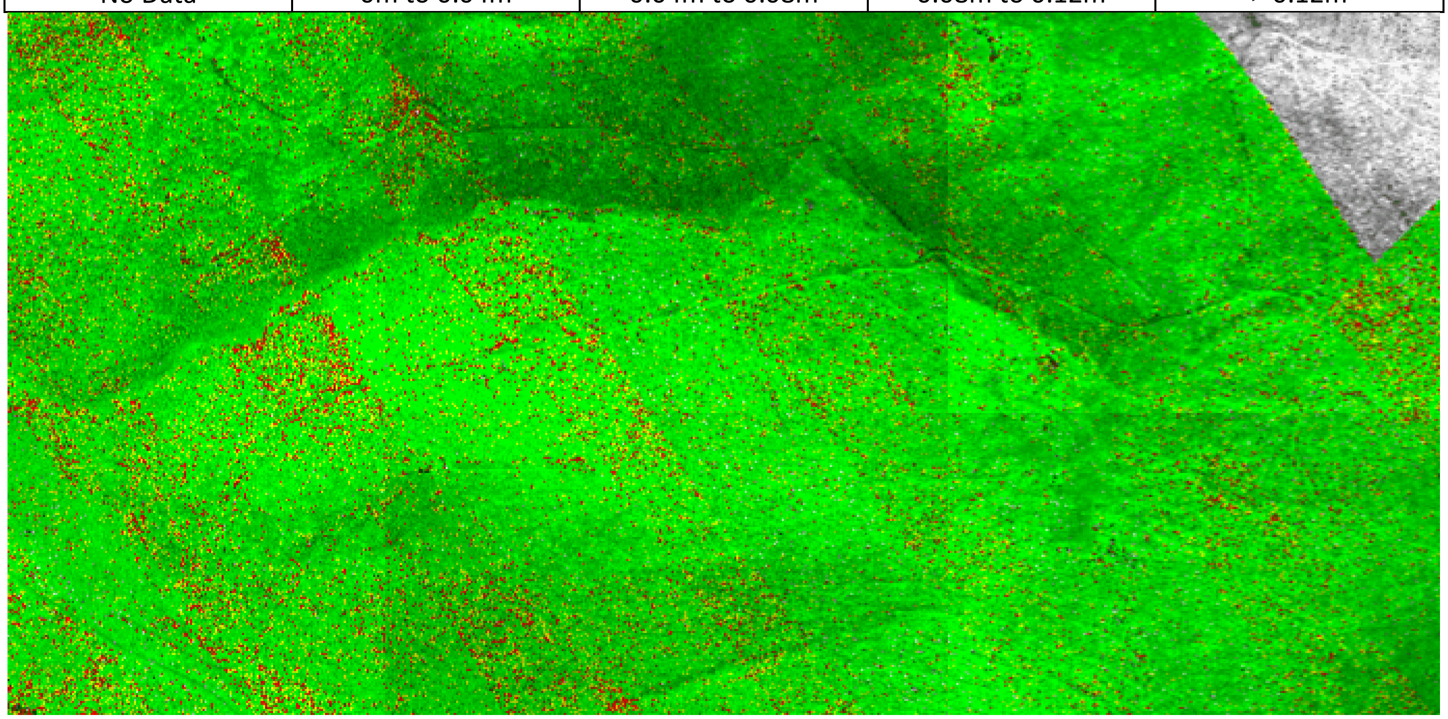


Figure 5: Swath Overlap Difference of ≤8cm, Maximum of ±16cm

2.6 Overlap Consistency (Interswath)

An overall statistical assessment of the relative accuracy using TerraMatch Tie Line Report between lidar swaths can be found in Tables 5, 6, 7, and 8 below. The values provided are in meters.

Average Magnitudes Per Line											
Line	**X**	**Y**	**Z**	**Line**	**X**	**Y**	**Z**	**Line**	**X**	**Y**	**Z**
142	0.005	0.011	0.025	**210**	-	-	0.023	**266**	0.023	0.026	0.027
143	0.012	0.026	0.025	**211**	0.015	0.011	0.019	**267**	0.027	0.018	0.031
144	-	-	0.025	**212**	0.02	0.014	0.026	**268**	0.021	0.019	0.022
145	-	-	0.025	**213**	0.023	0.014	0.025	**269**	0.003	0.017	0.022
146	-	-	0.023	**214**	-	-	0.039	**270**	-	-	0.023
147	-	-	0.027	**215**	-	-	0.03	**271**	0.021	0.019	0.023
148	-	-	0.023	**216**	-	-	0.031	**272**	0.022	0.013	0.021
149	-	-	0.023	**217**	-	-	0.03	**273**	-	-	0.022
150	-	-	0.024	**218**	-	-	0.022	**274**	-	-	0.022
151	-	-	0.022	**219**	-	-	0.023	**275**	0.021	0.017	0.021
152	-	-	0.022	**220**	-	-	0.024	**276**	0.02	0.014	0.021
153	0.008	0.034	0.022	**221**	-	-	0.024	**277**	-	-	0.021
154	0.018	0.07	0.022	**222**	-	-	0.026	**278**	0.047	0.002	0.023
155	-	-	0.023	**223**	-	-	0.029	**279**	0.019	0.015	0.021
156	-	-	0.022	**224**	-	-	0.036	**280**	0.019	0.016	0.021
157	-	-	0.021	**225**	-	-	0.04	**281**	0.046	0.003	0.022
158	-	-	0.02	**226**	-	-	0.043	**282**	-	-	0.038
159	-	-	0.02	**227**	-	-	0.028	**283**	0.036	0.023	0.033
160	-	-	0.019	**228**	0.022	0.019	0.022	**284**	0.015	0.012	0.021
161	-	-	0.019	**229**	-	-	0.024	**285**	0.015	0.014	0.021
162	-	-	0.019	**230**	-	-	0.025	**286**	0.012	0.012	0.021
163	-	-	0.023	**231**	-	-	0.022	**287**	0.013	0.017	0.02
164	-	-	0.026	**232**	-	-	0.022	**288**	0.012	0.015	0.017
165	0.015	0.031	0.024	**233**	-	-	0.028	**289**	0.016	0.016	0.02
166	-	-	0.028	**234**	0.033	0.016	0.024	**290**	0.037	0.01	0.02
167	-	-	0.024	**235**	0.028	0.004	0.026	**291**	0.014	0.016	0.017
168	-	-	0.021	**236**	0.032	0.006	0.024	**292**	0.019	0.017	0.018
169	-	-	0.025	**237**	0.03	0.018	0.023	**293**	0.039	0.004	0.023
170	-	-	0.026	**238**	0.015	0.027	0.024	**294**	-	-	0.022
171	-	-	0.032	**239**	0.01	0.023	0.023	**295**	0.019	0.014	0.019
172	-	-	0.027	**240**	0.004	0.039	0.023	**296**	0.016	0.016	0.018
173	-	-	0.028	**241**	0.018	0.028	0.022	**297**	-	-	0.026
174	-	-	0.031	**242**	0.021	0.016	0.022	**298**	-	-	0.027
175	-	-	0.032	**243**	0.017	0.013	0.022	**299**	0.02	0.018	0.02
176	-	-	0.03	**244**	-	-	0.039	**300**	0.017	0.019	0.021
177	0.015	0.045	0.025	**245**	0.027	0.01	0.029	**301**	0.017	0.028	0.023
189	-	-	0.036	**246**	0.027	0.006	0.022	**302**	-	-	0.025
191	-	-	0.022	**247**	0.02	0.017	0.025	**303**	0.022	0.018	0.027

192	-	-	0.021	**248**	0.016	0.014	0.021	**304**	0.023	0.025	0.023
193	0.004	0.023	0.027	**249**	0.014	0.016	0.02	**305**	0.015	0.017	0.022
194	0.021	0.019	0.027	**250**	0.016	0.014	0.019	**306**	0.023	0.012	0.021
195	-	-	0.038	**251**	0.018	0.015	0.019	**307**	0.034	0.023	0.029
196	-	-	0.025	**252**	0.015	0.016	0.019	**308**	-	-	0.024
197	-	-	0.022	**253**	0.02	0.018	0.02	**309**	-	-	0.025
198	-	-	0.025	**254**	0.021	0.016	0.021	**310**	0.006	0.013	0.023
199	-	-	0.023	**255**	0.013	0.014	0.02	**311**	0.007	0.014	0.024
200	-	-	0.024	**256**	0.016	0.015	0.02	**312**	-	-	0.021
201	-	-	0.024	**257**	0.016	0.016	0.021	**313**	-	-	0.027
202	-	-	0.021	**258**	0.019	0.02	0.023	**314**	-	-	0.034
203	0.022	0.025	0.024	**259**	-	-	0.025	**315**	-	-	0.037
204	0.02	0.016	0.022	**260**	-	-	0.023	**316**	-	-	0.027
205	0.019	0.015	0.022	**261**	-	-	0.024	**317**	-	-	0.023
206	0.018	0.015	0.021	**262**	0.018	0.02	0.022	**318**	-	-	0.021
207	0.021	0.026	0.024	**263**	0.013	0.013	0.022	**319**	-	-	0.023
208	0.024	0.02	0.027	**264**	0.027	0.009	0.026	**320**	-	-	0.036
209	-	-	0.024	**265**	0.02	0.017	0.022				

Table 5: Average Tie Line Magnitudes per Line

Internal Observation Statistics			
Category	**X**	**Y**	**Z**
Average Magnitude	0.018	0.016	0.023
RMS Values	0.026	0.024	0.030
Maximum Values	0.099	0.094	0.100
Observation Weight	5709.0	5709.0	253308.0

Table 6: Tie Line Observation Statistics

Overall Relative Accuracy	
Category	**Mismatch**
Average 3D Mismatch	0.02326
Average XY Mismatch	0.02830
Average Z Mismatch	0.02280

Table 7: Relative Accuracy Results

TerraMatch Tie Lines	
Category	**Observations**
Section Lines	103,113
Roof Lines	1,767

Table 8: Total Tie Lines

2.7 Lidar Classification

Atlantic uses multiple automated filtering routines on the calibrated lidar point cloud identifying and extracting bare-earth and above ground features. GeoCue, TerraScan, and TerraModeler software was used for the initial batch processing and manual editing of the lidar point clouds. Outlined in Table 9 are the classification codes utilized for this project.

ASPRS Standard Lidar Point Classes	
Code	**Description**
1	Unclassified
2	Ground
7	Low Noise
18	High Noise

Table 9: Point Cloud Classification Scheme

Section 3: Lidar Accuracy

3.1 Ground Surveyed Control Points

Atlantic established a total of twenty-eight (28) control points for this project. Point cloud data accuracy was tested against a Triangulated Irregular Network (TIN) constructed from lidar points in clear and open areas. A clear and open area can be characterized with respect to topographic and ground cover variation such that a minimum of 5 times the NPS exists with less than 1/3 of the $RMSE_Z$ deviation from a low-slope plane. Slopes that exceed 10 percent were avoided.

3.2 Vertical Accuracy Requirements

Below are the vertical accuracy reporting requirements for this project:

Vertical Accuracy Reporting Requirements in Meters:

$RMSE_Z \leq$ 10.0cm (Non-Vegetated Swath, DEM)
FVA ≤ 19.6cm 95% Confidence Level (Swath, DEM)
CVA ≤ 29.4cm 95^{th} Percentile (DEM)

*The terms FVA (Fundamental Vertical Accuracy), SVA (Supplemental Vertical Accuracy) and CVA (Consolidated Vertical Accuracy) are from the National Digital Elevation Program (NDEP) Guidelines for Digital Elevation Data (2004). The term FVA refers to open terrain, urban and levee classes; the term SVA refers to classes tested that are in addition or supplemental to the open terrain; the term CVA refers to the consolidated accuracy of the data from all classes (FVA + SVA).

3.3 Control Point Distribution

The following graphics depict the location and distribution of the control points established for this project.

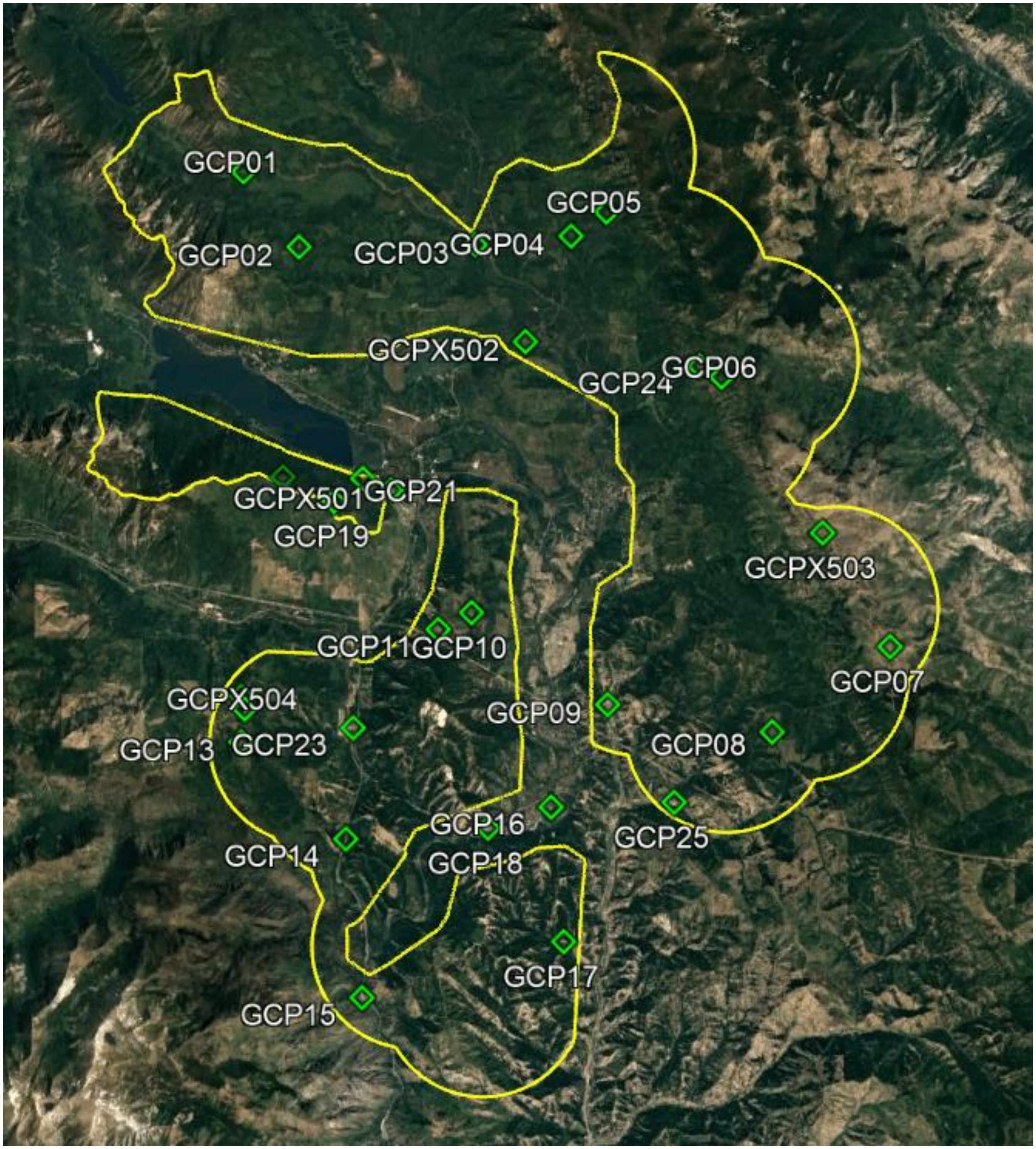


Figure 6: Lidar Control Point Distribution

3.4 Vertical Accuracy Results

An overall statistical assessment of the control points can be found in Tables 10 and 11 below. The values provided are in meters.

Vertical Accuracy Assessment of Control Points			
Category	# of Points	FVA — Fundamental Vertical Accuracy (RMSEz x 1.9600)	CVA — Consolidated Vertical Accuracy (95th Percentile)
Control Points	28	0.145	0.135

Table 10: Fundamental Vertical Accuracy (FVA) and Consolidate Vertical Accuracy (CVA)

Control Point Error Statistics								
Category	# of Points	Min	Max	Mean	Median	Skew	Std Dev	RMSEz
Control Points	28	-0.143	0.139	0.011	0.006	0.099	0.074	0.074

Table 11: Control Point Error Statistics

3.5 Control Point Assessment

A vertical accuracy assessment of the control points against the bare-earth lidar can be found in Tables 12 below. The coordinates provided are in NAD83, USFS R6 Albers, NAVD88 (Geoid12B), Meters.

Fundamental Vertical Accuracy (FVA) Contorl Point Assessment (Bare-Earth)						
PointID	Easting	Northing	KnownZ	LaserZ	Description	DeltaZ
GCP01	541406.861	1535939.859	806.893	806.910	Lidar Control Point	0.017
GCP02	543031.052	1533710.473	1044.696	1044.750	Lidar Control Point	0.054
GCP03	548241.042	1533734.951	703.897	703.820	Lidar Control Point	-0.077
GCP04	551076.965	1533967.048	858.992	859.090	Lidar Control Point	0.098
GCP05	552125.551	1534667.256	1106.063	1106.080	Lidar Control Point	0.017
GCP06	555490.454	1529774.374	1443.576	1443.540	Lidar Control Point	-0.036
GCP07	560406.613	1521790.864	1766.949	1766.930	Lidar Control Point	-0.019
GCP08	556904.427	1519301.819	789.711	789.680	Lidar Control Point	-0.031
GCP09	552047.082	1520148.663	591.034	591.160	Lidar Control Point	0.126
GCP10	548048.795	1522887.627	919.649	919.610	Lidar Control Point	-0.039
GCP11	547058.322	1522403.183	894.488	894.470	Lidar Control Point	-0.018
GCP12	541221.429	1520482.313	1089.915	1089.970	Lidar Control Point	0.055
GCP13	541203.377	1519133.529	1190.803	1190.820	Lidar Control Point	0.017
GCP14	544282.755	1516245.503	581.674	581.570	Lidar Control Point	-0.104
GCP15	544722.459	1511560.901	508.505	508.470	Lidar Control Point	-0.035
GCP16	550354.550	1517139.065	536.065	536.060	Lidar Control Point	-0.005
GCP17	550695.210	1513167.563	483.301	483.340	Lidar Control Point	0.039
GCP18	548484.298	1516530.596	530.363	530.220	Lidar Control Point	-0.143
GCP19	544004.629	1526203.496	970.542	970.670	Lidar Control Point	0.128

GCP20	542503.997	1526932.324	997.152	997.250	Lidar Control Point	0.098
GCP21	544865.240	1526870.141	609.223	609.350	Lidar Control Point	0.127
GCP23	544524.755	1519521.776	633.679	633.610	Lidar Control Point	-0.069
GCP24	554841.705	1530105.671	1222.857	1222.810	Lidar Control Point	-0.047
GCP25	553990.092	1517252.128	551.661	551.800	Lidar Control Point	0.139
GCPX501	545702.658	1526521.355	605.993	605.980	Lidar Control Point	-0.013
GCPX502	549700.459	1530865.000	656.047	656.120	Lidar Control Point	0.073
GCPX503	558438.966	1525159.223	1576.939	1576.890	Lidar Control Point	-0.049
GCPX504	541321.116	1520101.006	1136.713	1136.730	Lidar Control Point	0.017

Table 12: Lidar Point Cloud FVA Assessment

Section 4: **Certification**

4.1 Limitations of Use

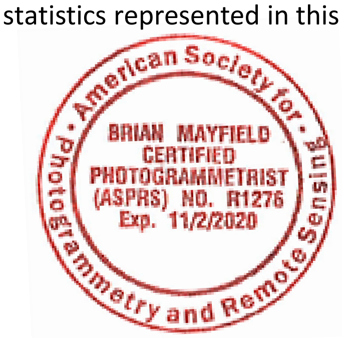
The accuracy assessment confirms that the data may be used for the intended applications stated in the **Project Purpose** section of this document. The dataset may also be used as a topographic input for other applications, but the user should be aware that this lidar dataset was designed with a specific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

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

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

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

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



Brian J. Mayfield, ASPRS Certified Photogrammetrist #R1276

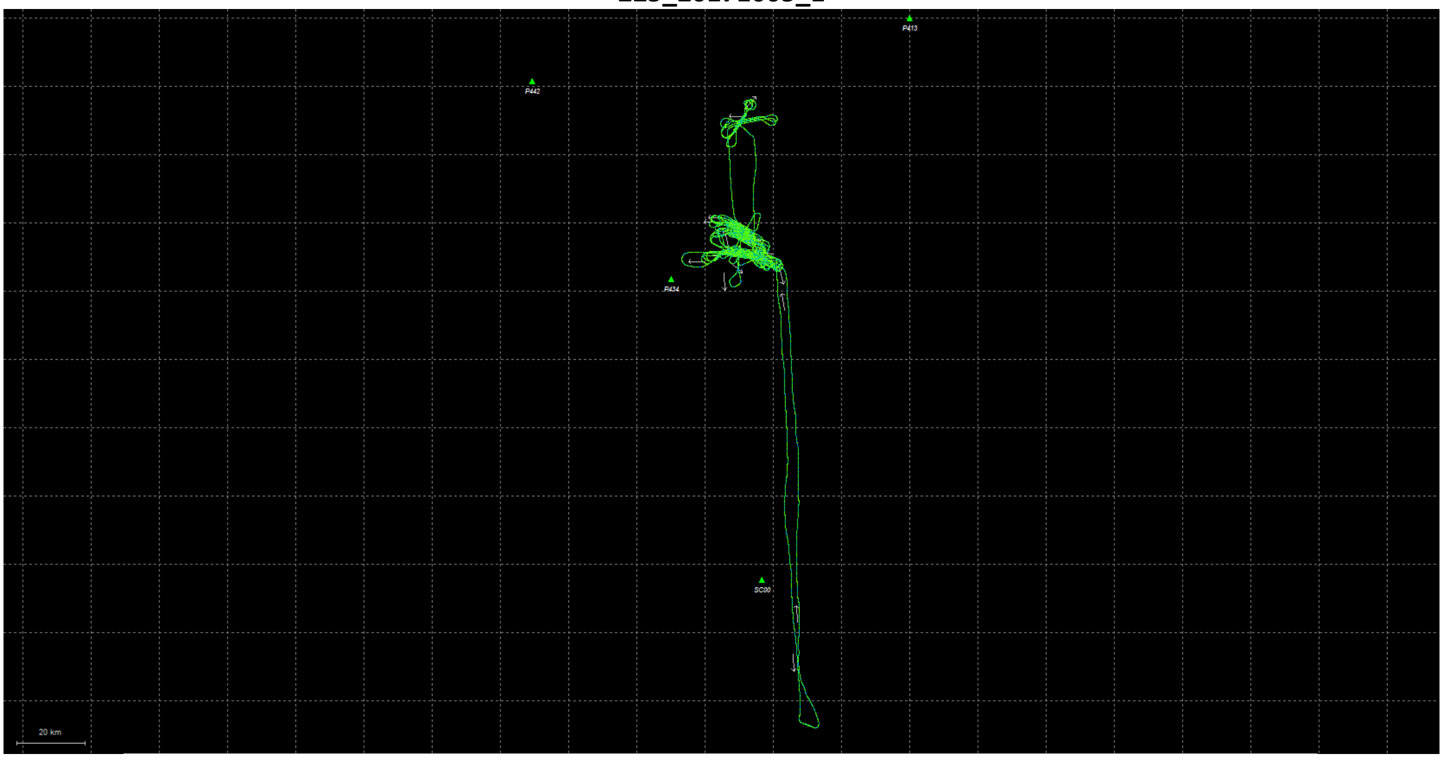
Section 5: GNSS Processing

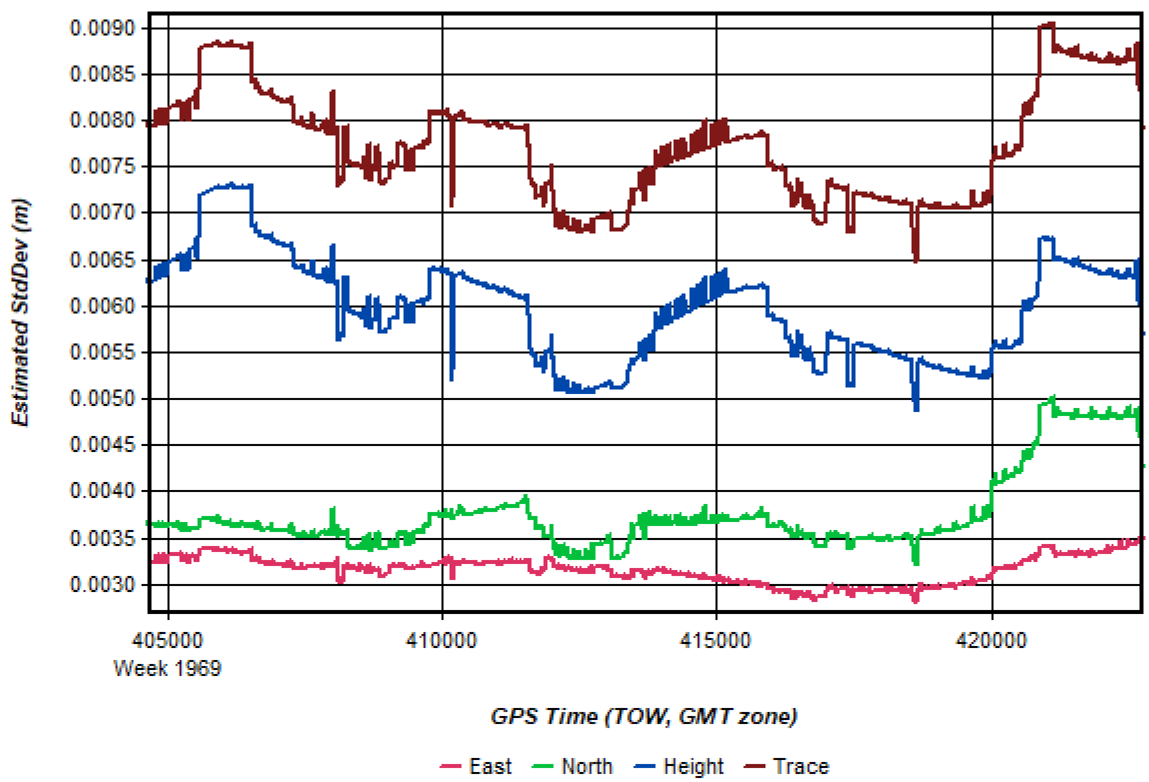
Inertial Explorer version 8.60.6717

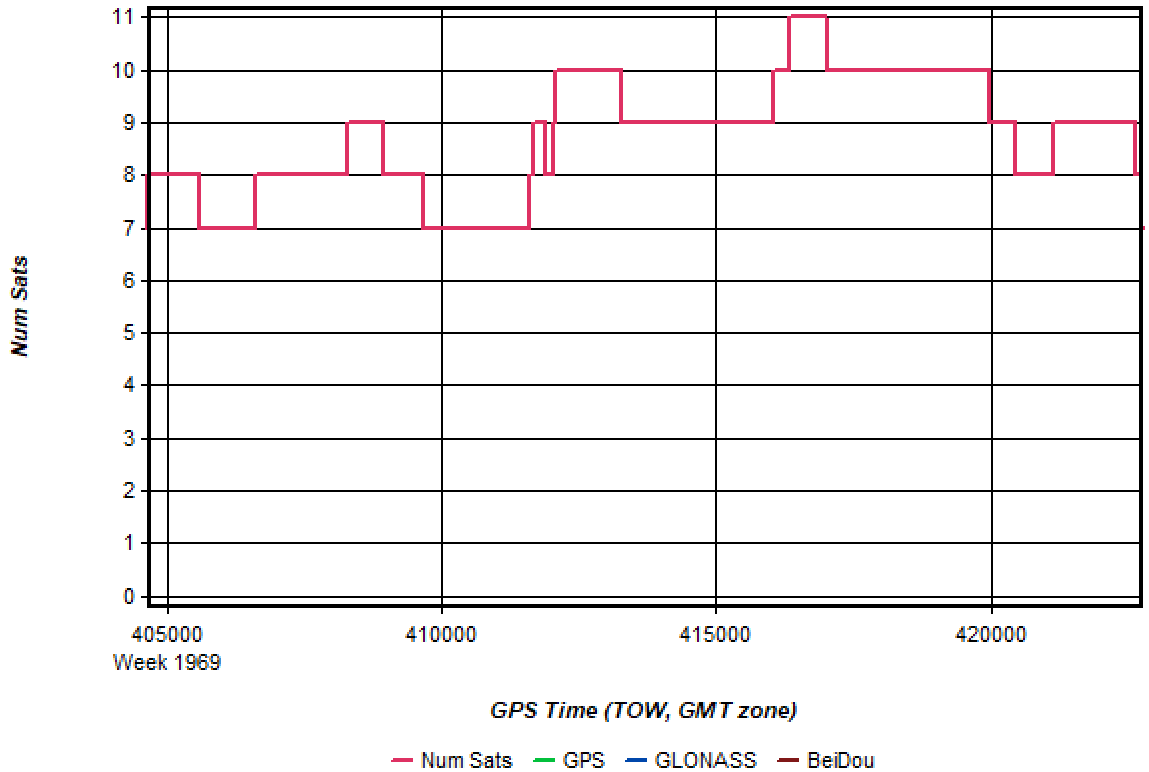
Plots by Mission: Coverage Map, Estimated Position Accuracy, Number of Satellites, Combined Separation, and PDOP.

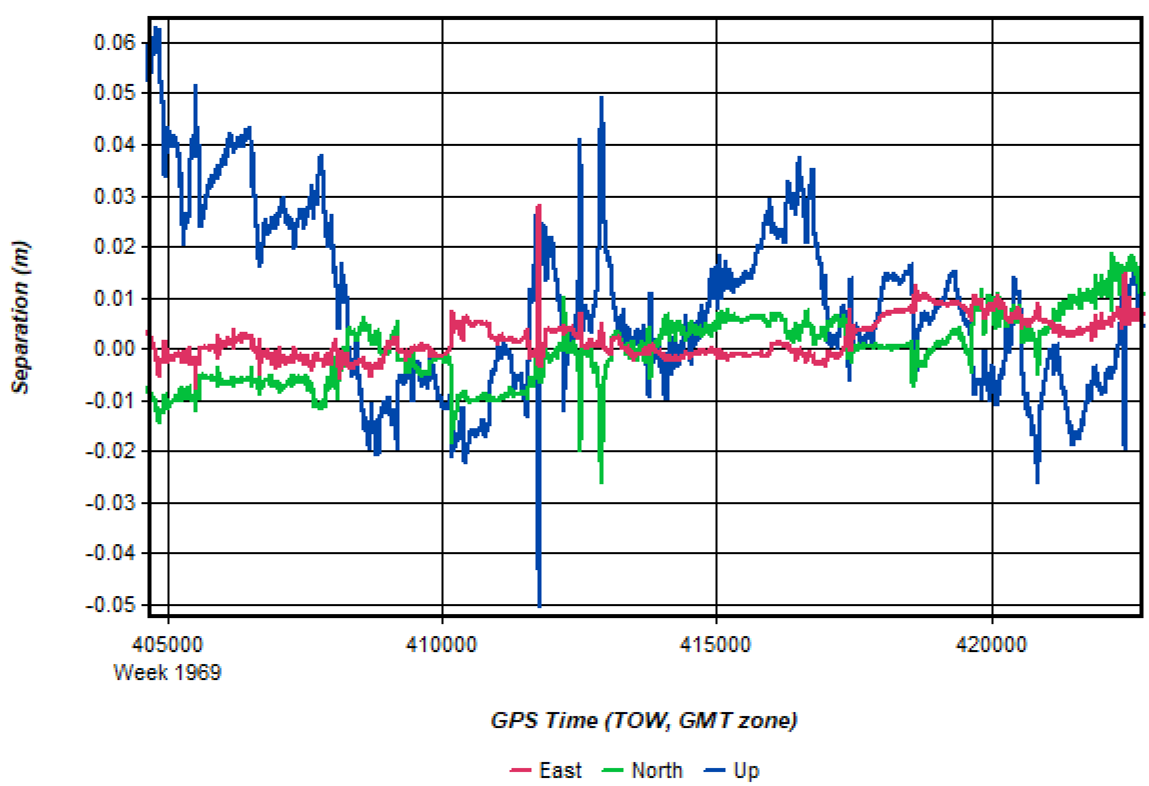
Coverage Map	The Coverage Map plot shows the Aircraft GNSS-IMU Trajectory in reference to localized GNSS Reference Stations.
Estimated Position Accuracy	The Estimated Position Accuracy plot shows the standard deviations of the east, north, and up directions versus time for the solution. The total standard deviation with a distance dependent component is also plotted.
Number of Satellites	Plots the number of satellites used in the solution as a function of time. The number of GPS satellites, GLONASS satellites, and the total number of satellites are distinguished with separate lines.
Combined Separation	Plots the north, east, and height position difference between any two solutions loaded into the project. This is most often the forward and reverse processing results, unless other solutions have been loaded from the Combine Solutions dialog. Plotting the difference between forward and reverse solutions can be very helpful in quality checking. When processing both directions, no information is shared between forward and reverse processing. Thus both directions are processed independently of each other. When forward and reverse solutions agree closely, it helps provide confidence in the solution. To a lesser extent, this plot can also help gauge solution accuracy.
PDOP	PDOP is a unit less number which indicates how favorable the satellite geometry is to 3D positioning accuracy. A strong satellite geometry, where the PDOP is low, occurs when satellites are well distributed in each direction (north, south, east and west) as well as directly overhead. Values in the range of 1-2 indicate very good satellite geometry, 2-3 are adequate in the sense that they do not generally, by themselves, limit positioning accuracy. Values between 3 and 4 are considered marginal, and values approaching or exceeding 5 can be considered poor. PDOP spikes can occur on aircraft turns were the antenna angle is unfavorable, these spikes while aesthetically unfavorable do not generally reduce the accuracy of the acquired data.

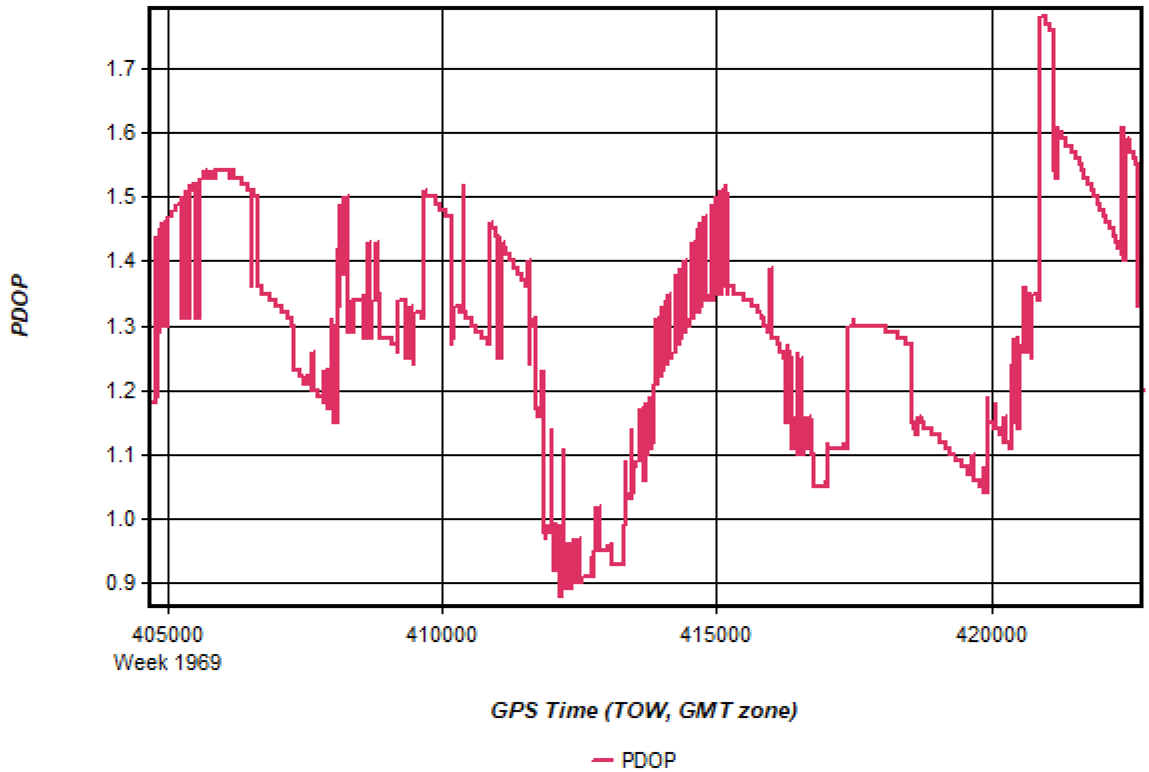
225_20171005_1






Num Sats
11
10
9
8
7
6
5
4
3
2
1
0
405000
Week 1969
410000
415000
420000
GPS Time (TOW, GMT zone)
Num Sats
GPS
GLONASS
BeiDou


Separation (m)
0.06
0.05
0.04
0.03
0.02
0.01
0.00
-0.01
-0.02
-0.03
-0.04
-0.05
405000
Week 1969
410000
415000
420000
GPS Time (TOW, GMT zone)
East
North
Up



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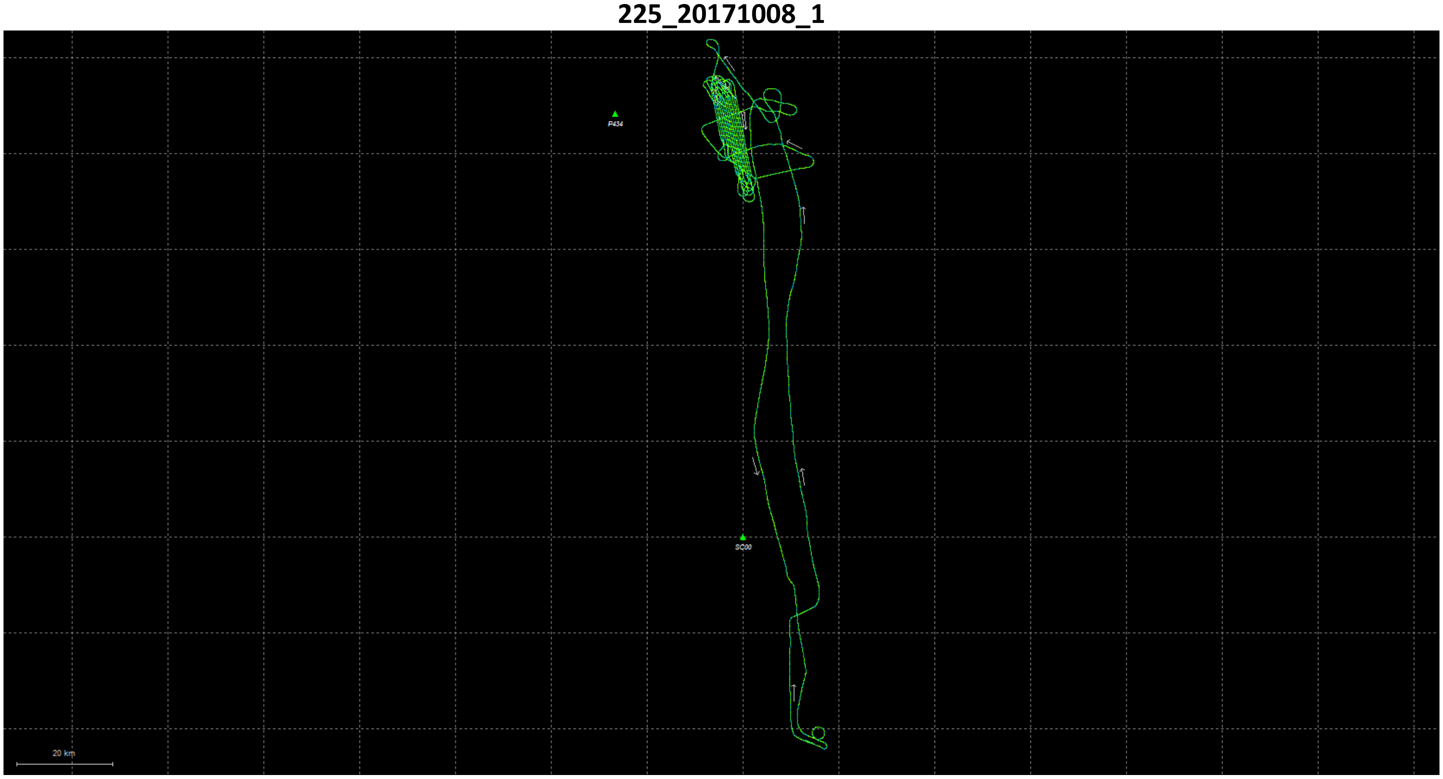
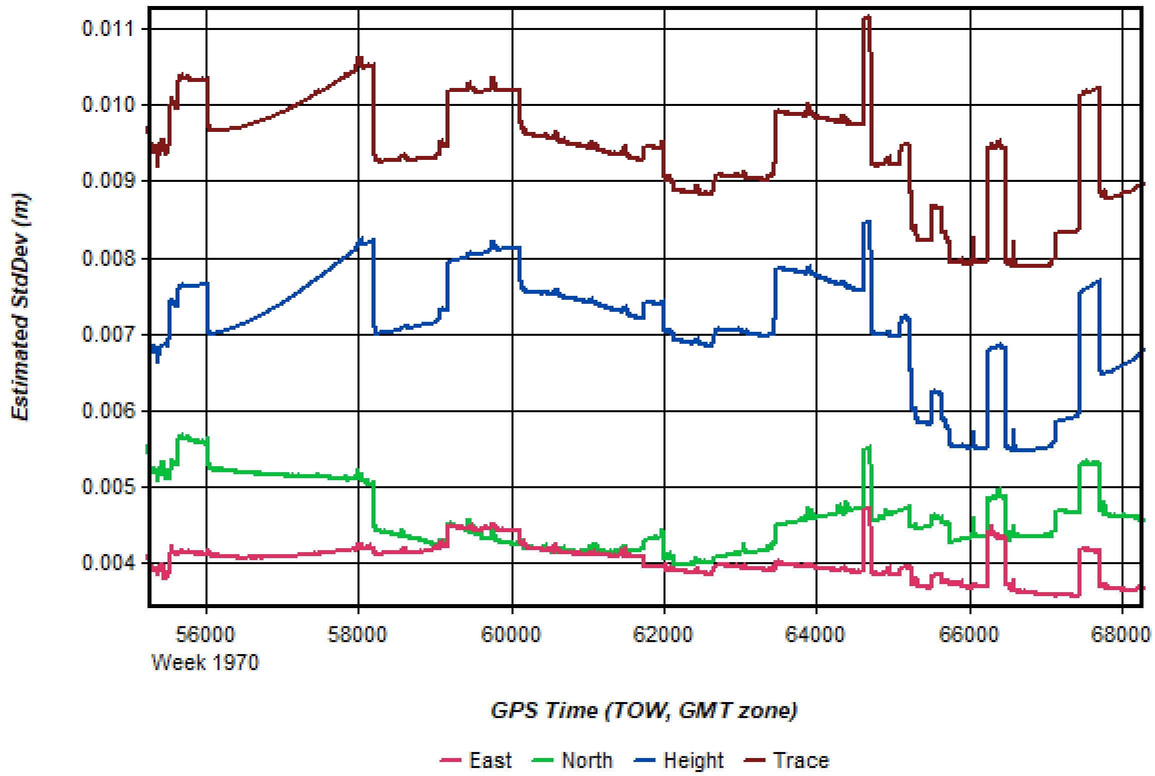
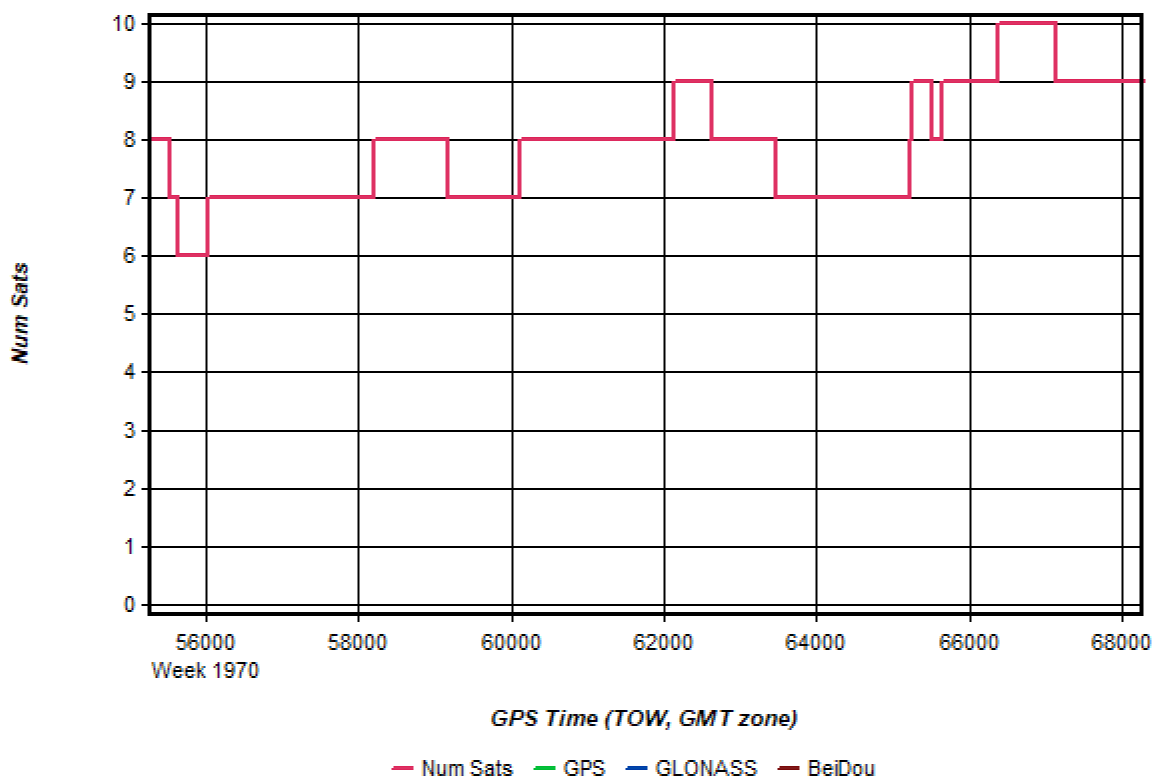
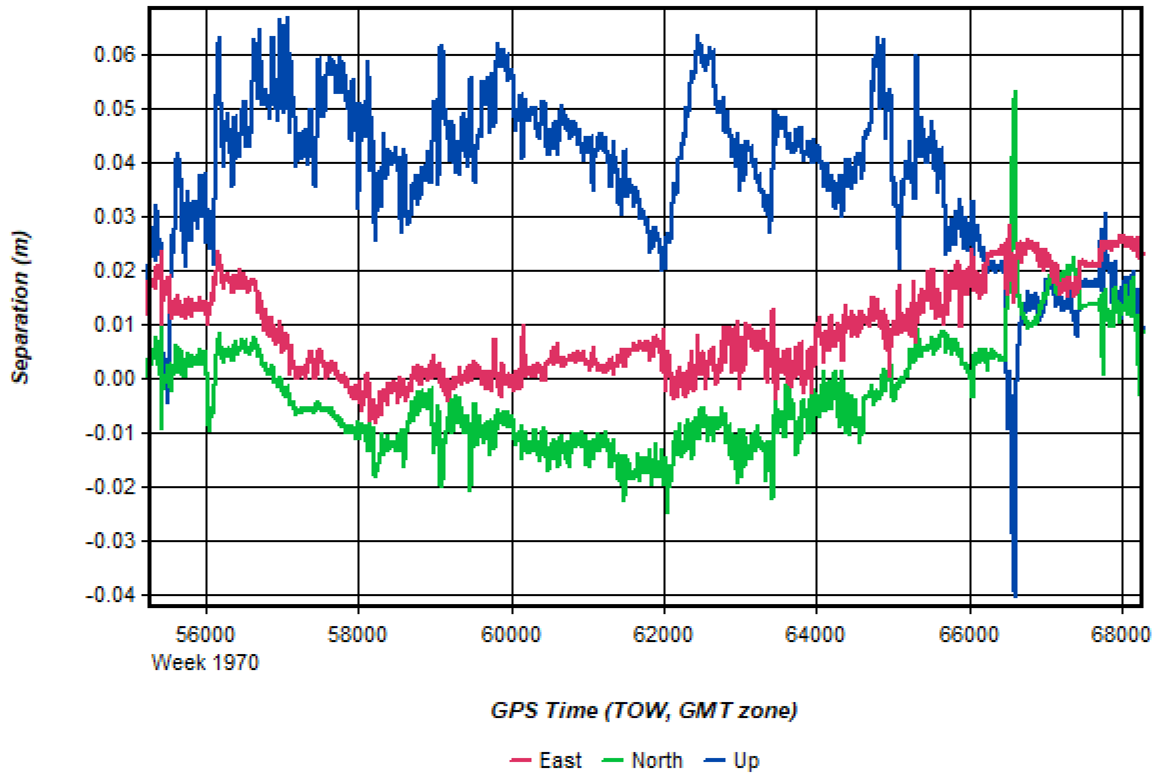
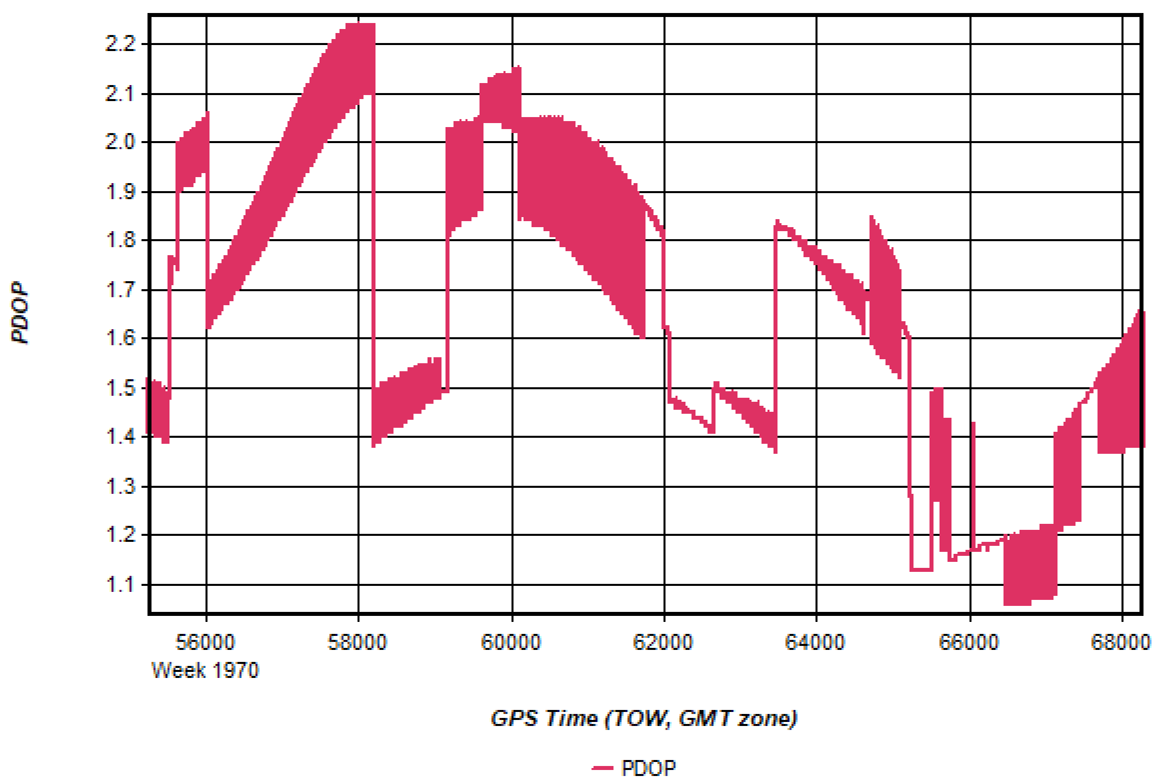


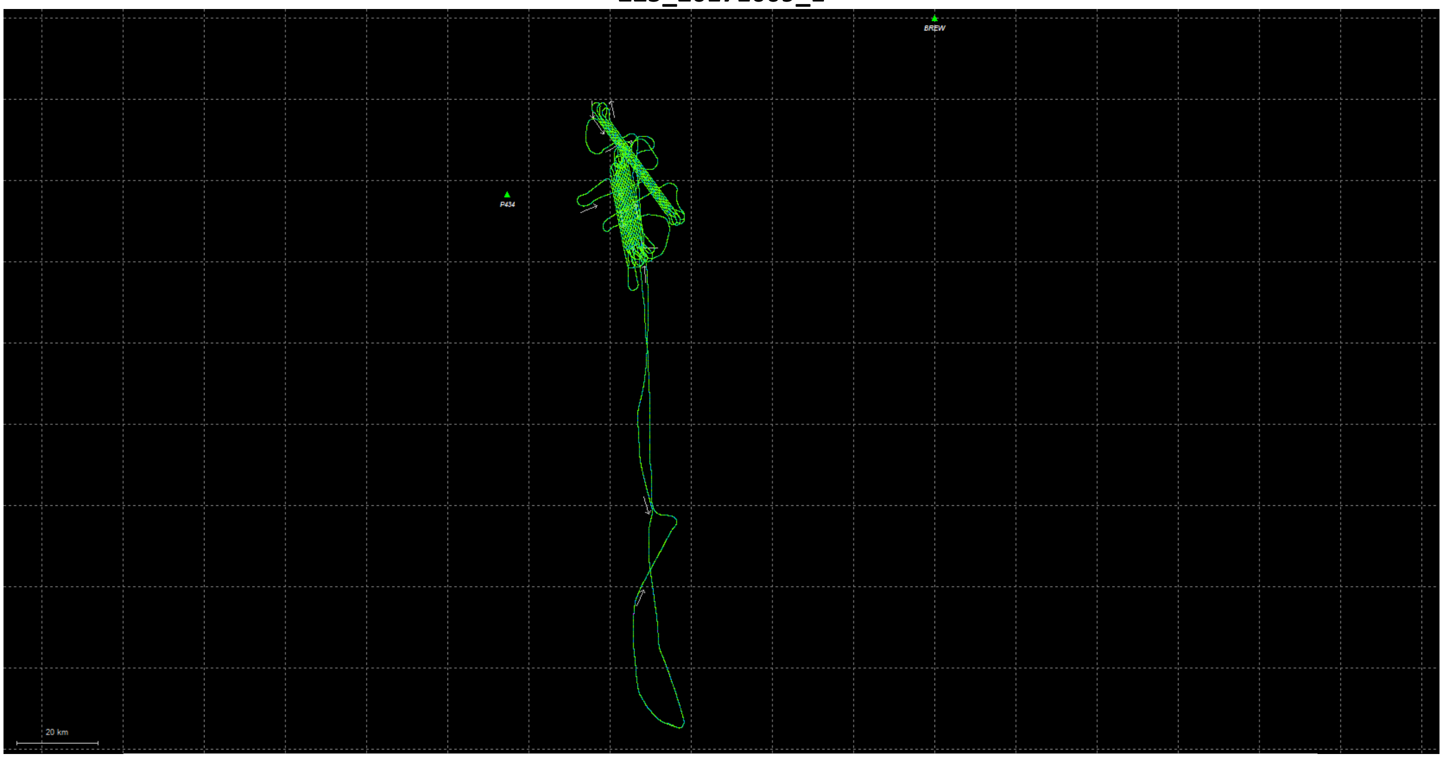

Estimated StdDev (m)
0.011
0.010
0.009
0.008
0.007
0.006
0.005
0.004
56000
Week 1970
58000
60000
62000
64000
66000
68000
GPS Time (TOW, GMT zone)
East
North
Height
Trace

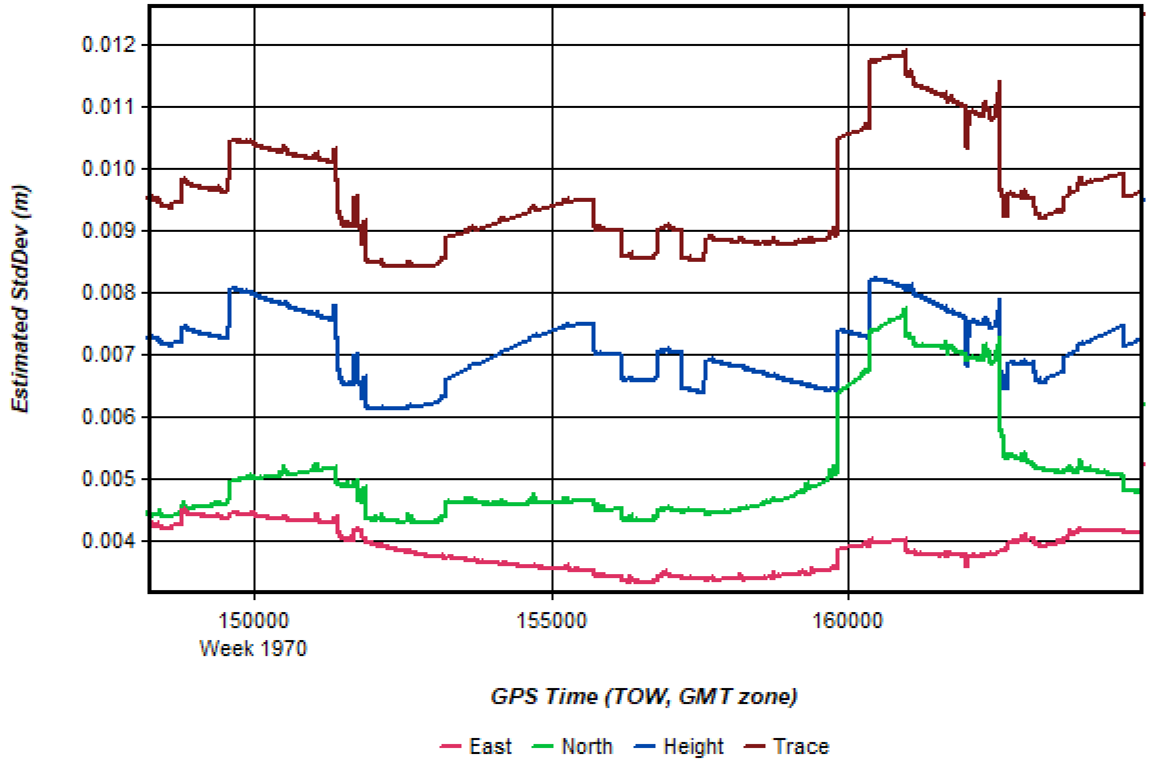

Num Sats
10
9
8
7
6
5
4
3
2
1
0
56000
Week 1970
58000
60000
62000
64000
66000
68000
GPS Time (TOW, GMT zone)
Num Sats
GPS
GLONASS
BeiDou

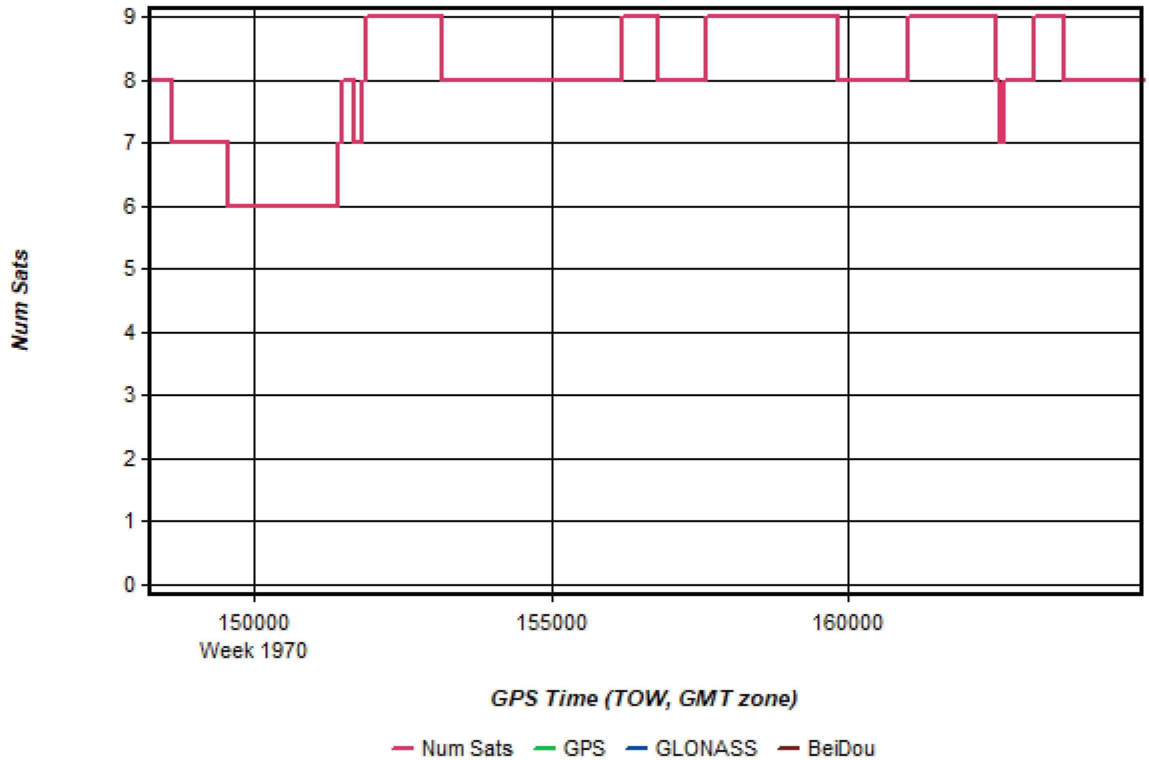

Separation (m)
0.06
0.05
0.04
0.03
0.02
0.01
0.00
-0.01
-0.02
-0.03
-0.04
56000
Week 1970
58000
60000
62000
64000
66000
68000
GPS Time (TOW, GMT zone)
East
North
Up

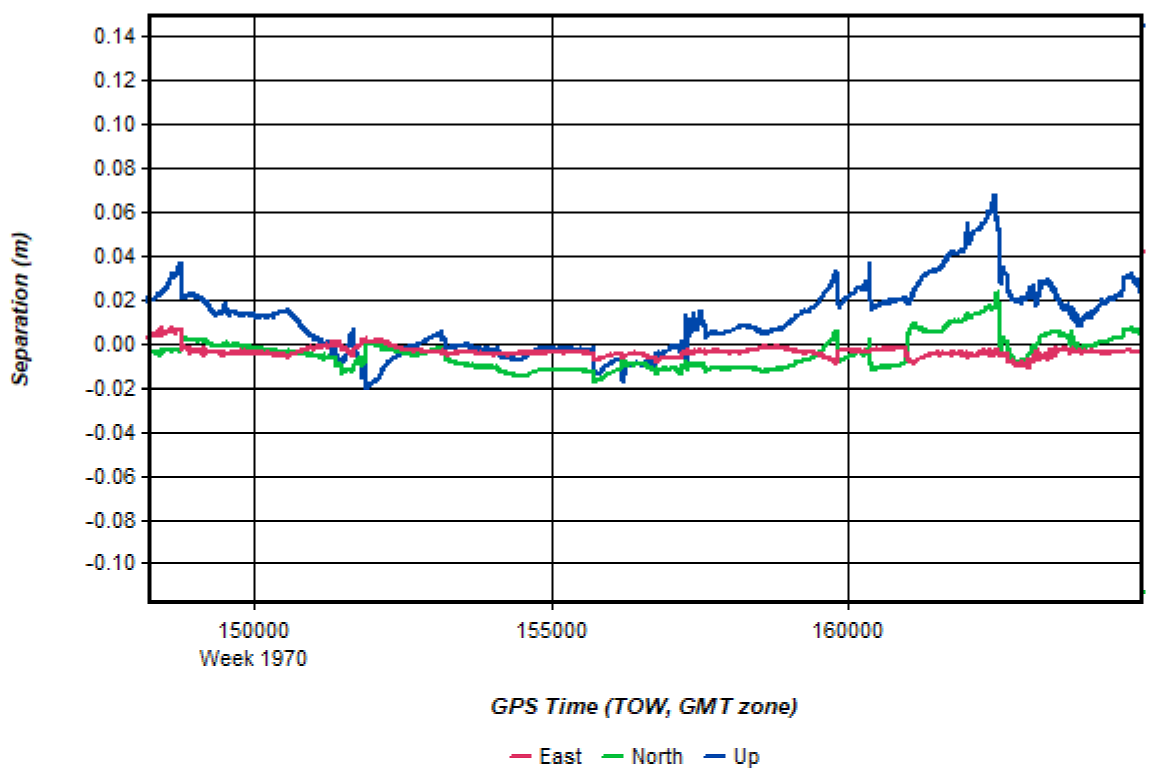

PDOP
2.2
2.1
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
56000
Week 1970
58000
60000
62000
64000
66000
68000
GPS Time (TOW, GMT zone)
PDOP

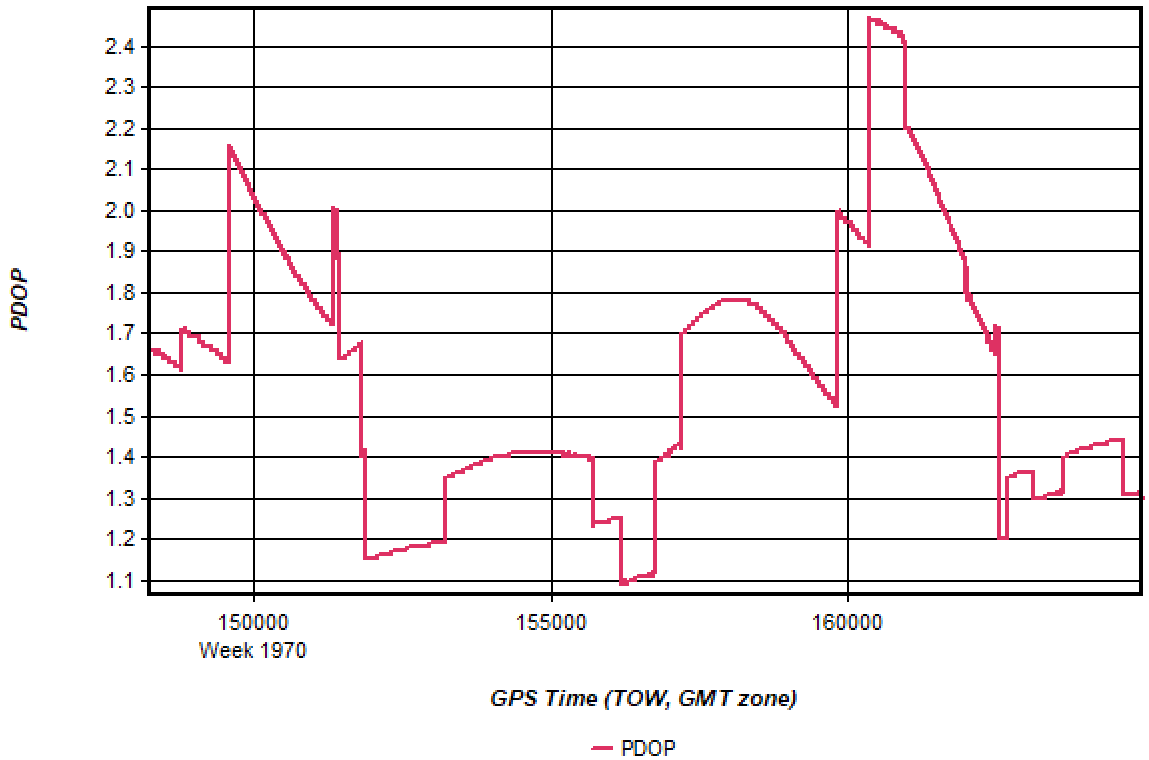
225_20171009_1






Num Sats
9
8
7
6
5
4
3
2
1
0
150000
Week 1970
155000
160000
GPS Time (TOW, GMT zone)
Num Sats
GPS
GLONASS
BeiDou


Separation (m)
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
-0.02
-0.04
-0.06
-0.08
-0.10
150000
Week 1970
155000
160000
GPS Time (TOW, GMT zone)
East
North
Up



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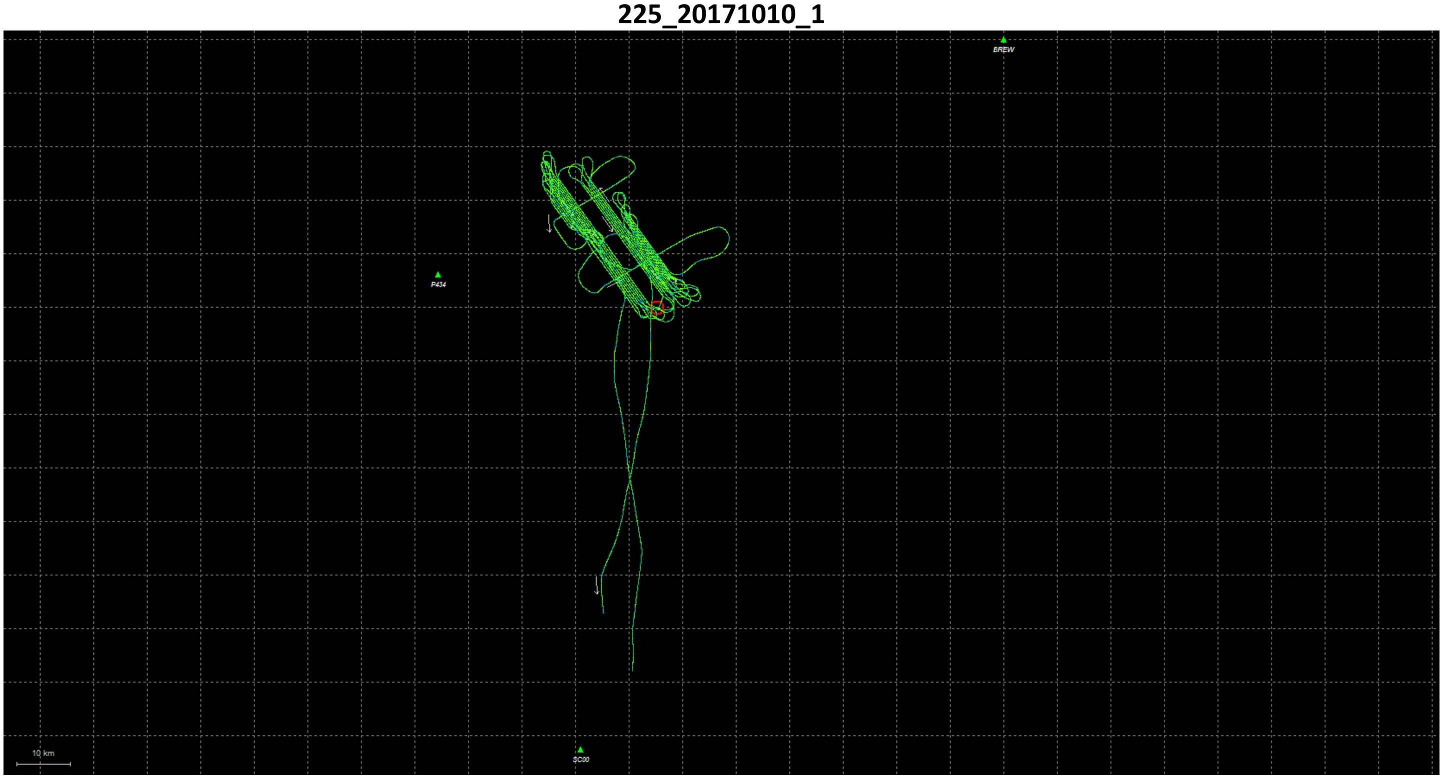
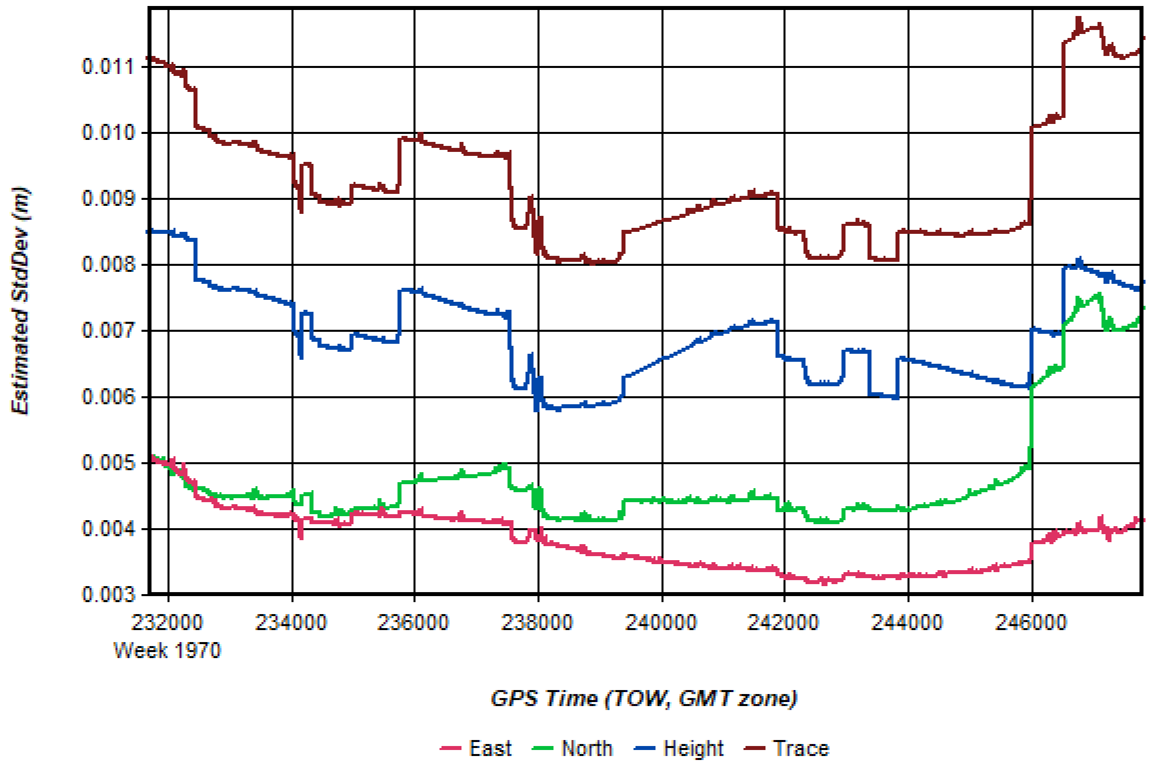
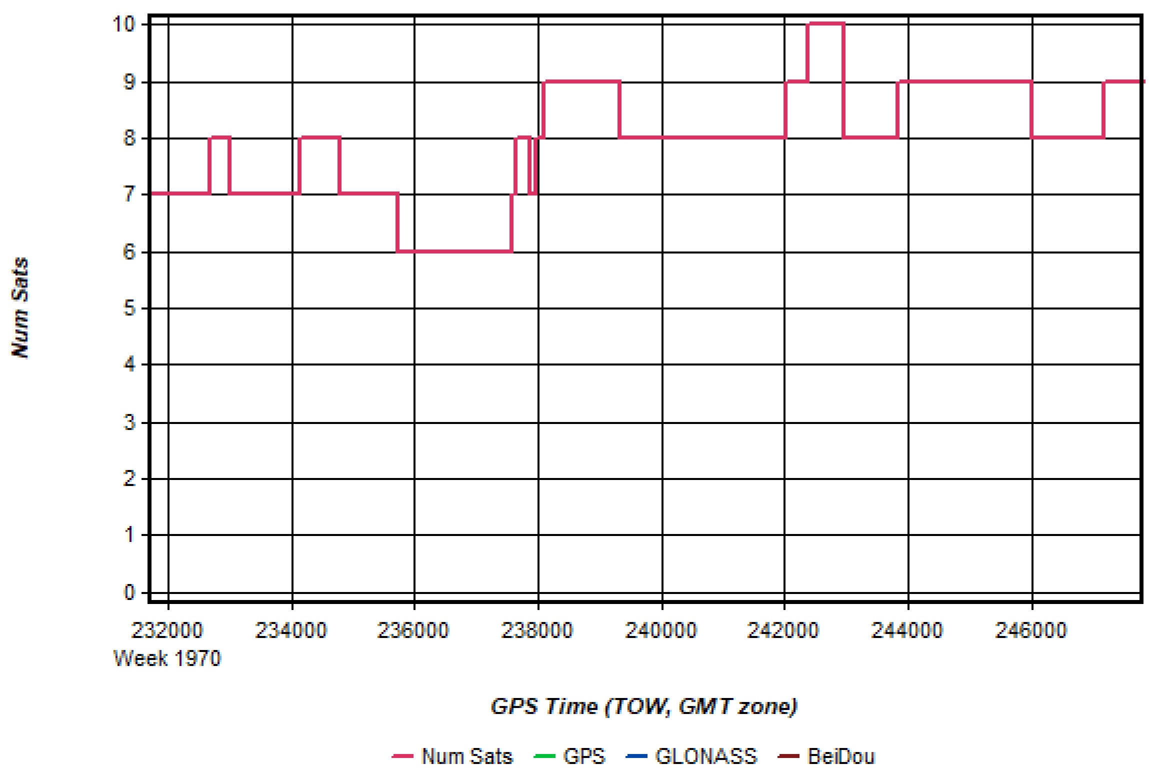
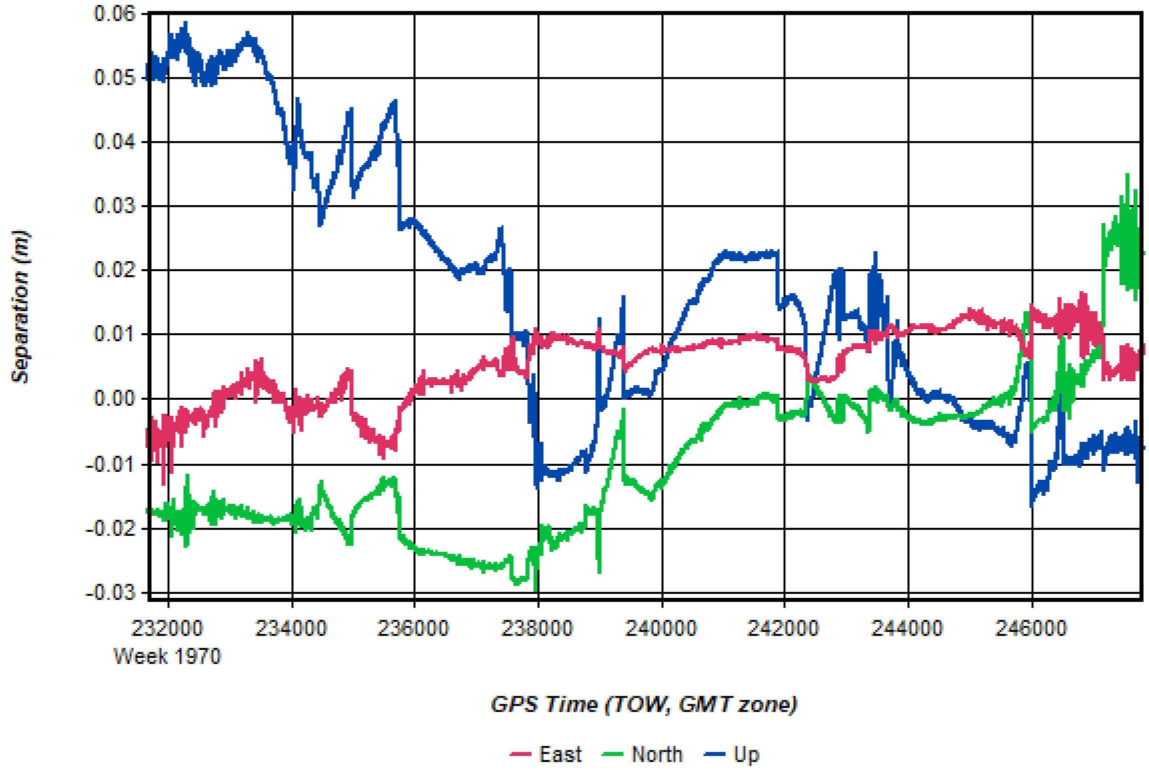
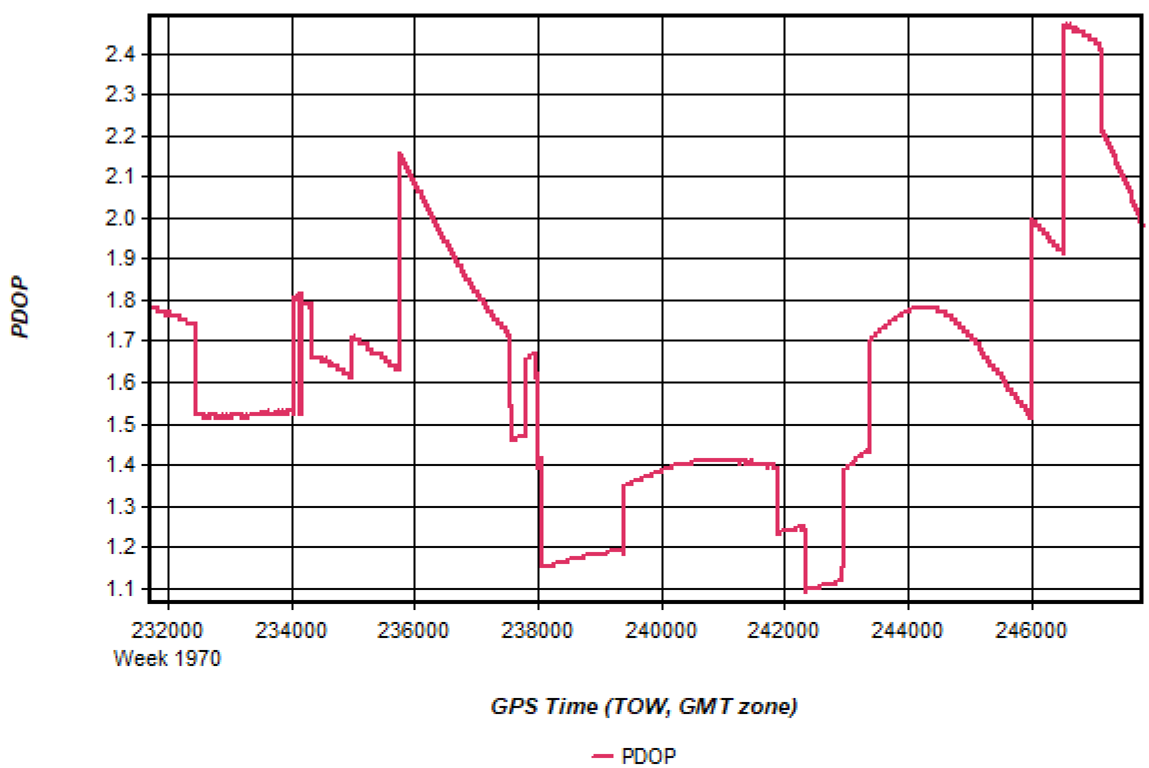


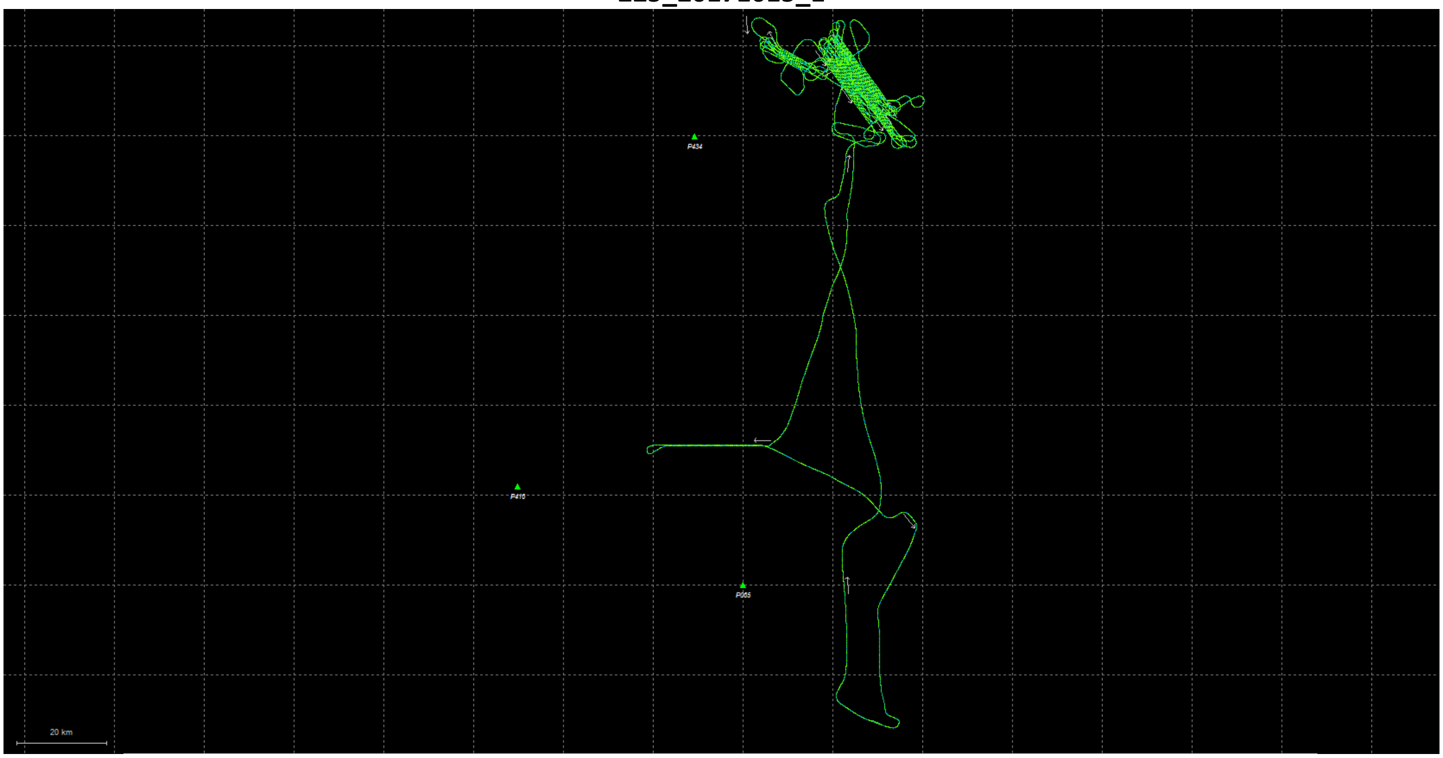

Estimated StdDev (m)
0.011
0.010
0.009
0.008
0.007
0.006
0.005
0.004
0.003
232000
Week 1970
234000
236000
238000
240000
242000
244000
246000
GPS Time (TOW, GMT zone)
East
North
Height
Trace

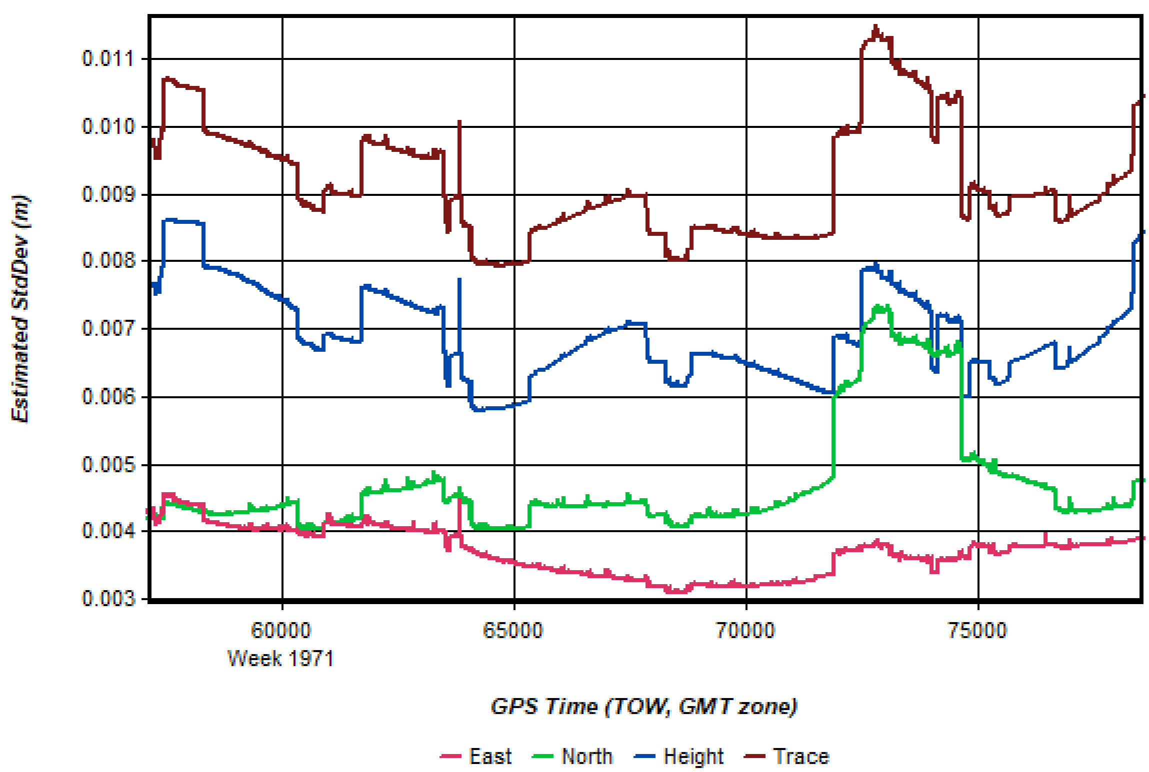

Num Sats
10
9
8
7
6
5
4
3
2
1
0
232000
Week 1970
234000
236000
238000
240000
242000
244000
246000
GPS Time (TOW, GMT zone)
Num Sats
GPS
GLONASS
BeiDou

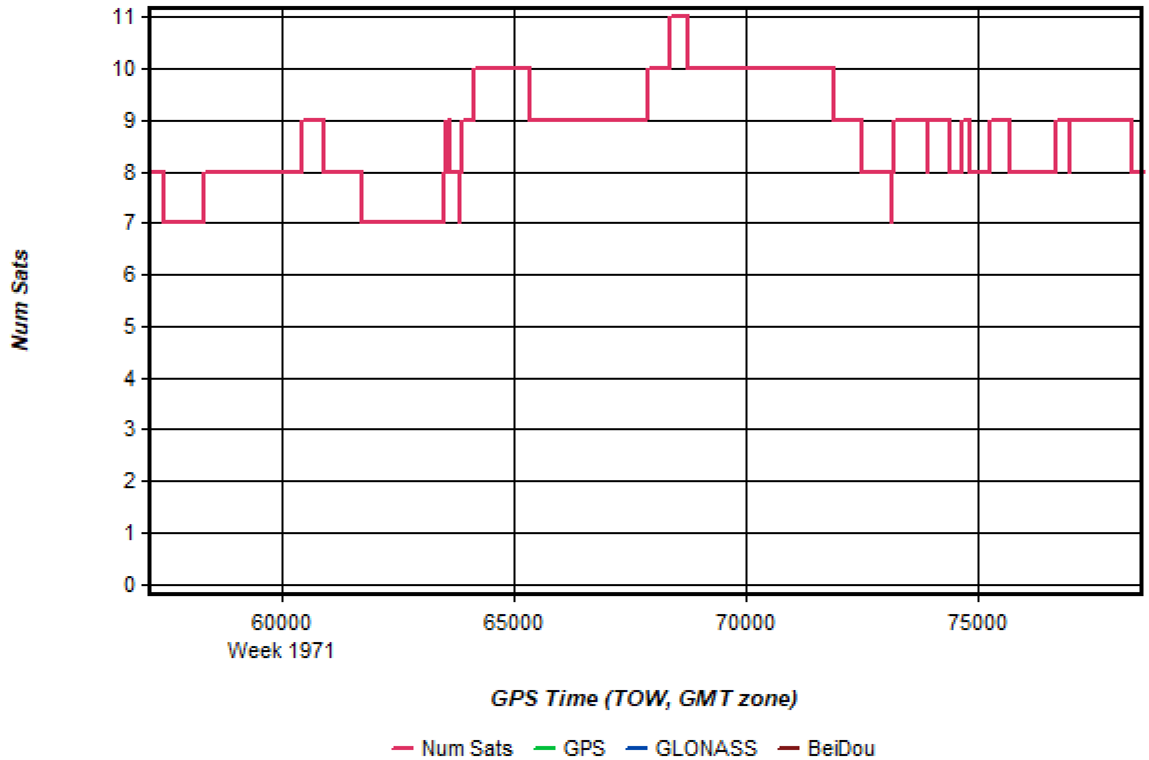

Separation (m)
0.06
0.05
0.04
0.03
0.02
0.01
0.00
-0.01
-0.02
-0.03
232000
Week 1970
234000
236000
238000
240000
242000
244000
246000
GPS Time (TOW, GMT zone)
East
North
Up

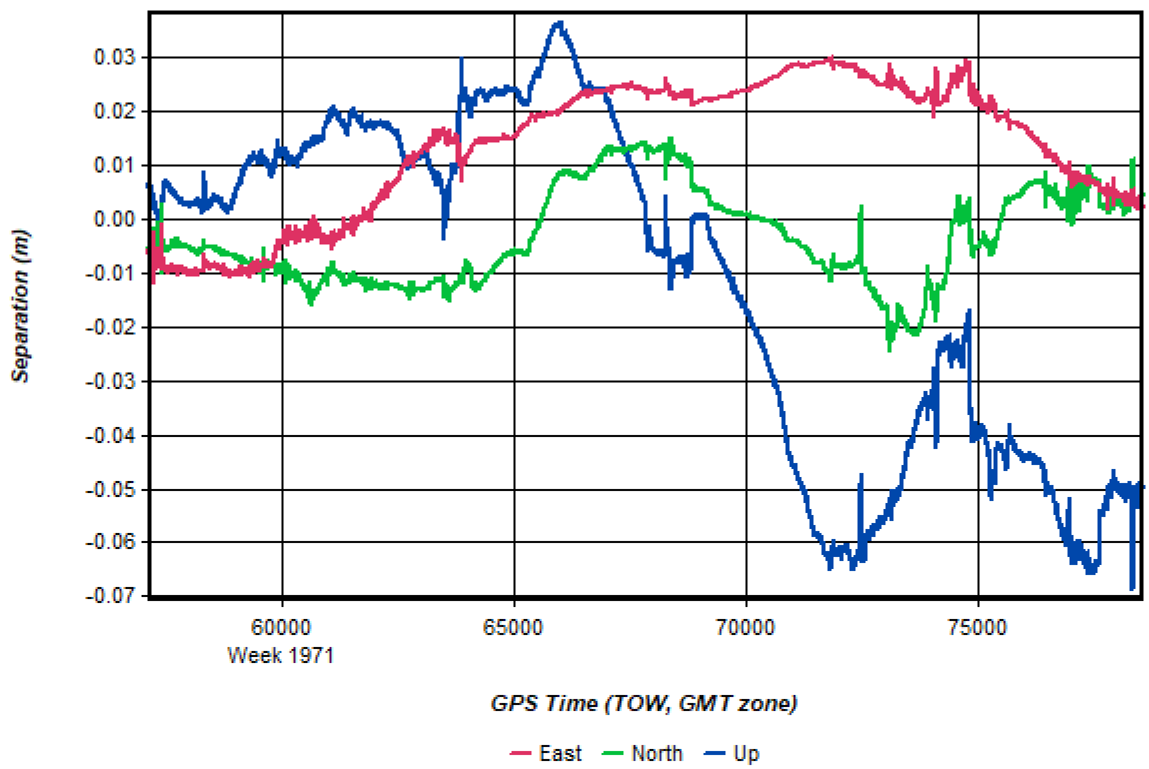

PDOP
2.4
2.3
2.2
2.1
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
232000
Week 1970
234000
236000
238000
240000
242000
244000
246000
GPS Time (TOW, GMT zone)
PDOP

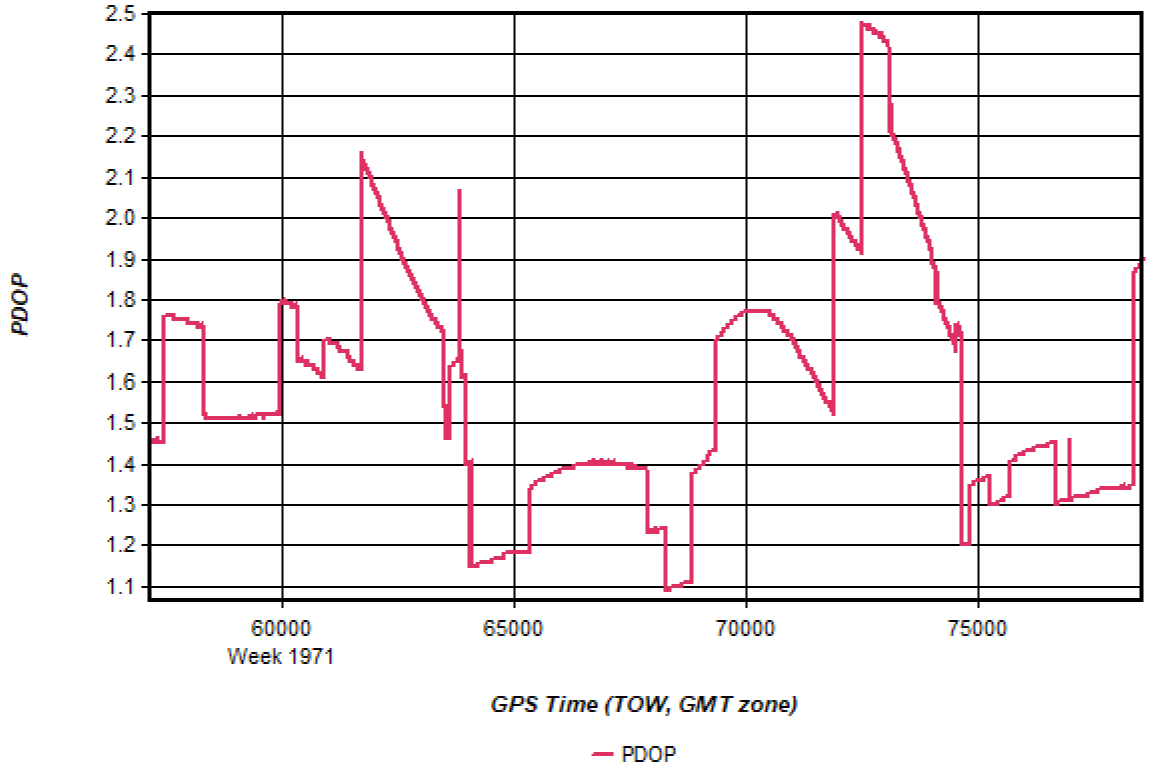
225_20171015_1






Num Sats
60000
Week 1971
65000
70000
75000
GPS Time (TOW, GMT zone)
Num Sats
GPS
GLONASS
BeiDou


Separation (m)
60000
Week 1971
65000
70000
75000
GPS Time (TOW, GMT zone)
East
North
Up


PDOP
2.5
2.4
2.3
2.2
2.1
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
60000
Week 1971
65000
70000
75000
GPS Time (TOW, GMT zone)
PDOP