New York State
Airborne LiDAR Acquisition Report

for

New York State Office of Information Technology Services
50 Wolf Road, 3-3
Albany, New York 12232

Project Number 15002-2

Lot 15, Madison-Otsego (Axis Acquisition)

by

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Section 1: Table of Contents

Section 2: Introduction

The New York State Office of Information Technology Services requested delivery of three dimensional classified point cloud and terrain data derived from LiDAR (Light Detection and Ranging) technology for the New York State LiDAR project area covering portions of Madison, Chenango, Oneida, Herkimer, Otsego and Delaware Counties. The data must meet Quality B standards as defined by the State. See Table 1.1 NYSOOITS LiDAR Quality Specification.

NYSDITS LiDAR Quality Specification		
	Quality A	Quality B
Nominal Point Spacing (m)	1.5	0.7
Vertical Accuracy (cm)	18.5	9.25
Final DEM Spacing (m)	2.0	1.0

Table 1 NYSOITS LiDAR Quality Specification

The point cloud is to include all returns from the sensor. Points are to be classified to differentiate between bare earth and other return sources using the following classes:

- 1 Processed, but unclassified
- 2 Bare-earth ground
- 7a Noise (low noise)
- 9 Water
- 11 Withheld (if the Withheld bit is not implemented in processing software)
- 12 Overlap
- 17 Bridges
- 18 High Noise

Data is to be stored in a non-proprietary format such as LAS and meet the requirements of "U.S. Geological Survey National Geospatial Program LiDAR Guidelines and Base Specifications, Techniques and Methods 11-B4 Version 1.2-Novermber 2014" except as specified by the governing contract.

The project area (Lot 15, Area 2) is located in central New York State, east of Syracuse, and covers approximately 1,841 square miles. The project area includes the includes the city of Oneida and the village of Cooperstown. (See Figure 1.1 Location of Project Area) The project area measures roughly 64 miles from the eastern boundary to the western boundary and approximately 48 miles from the northern boundary to the southern boundary. (See Figure 2 Project Area)

LiDAR data was processed and projected to UTM Zone 18 North, referenced to the North American Datum 1983 (NAD83) (2011), in units of meters. The vertical datum used for the project is the North American Vertical Datum 1988 (NAVD88) in meters. Orthometric heights are to be determined using Geoid 12A.

The planning task took into account the various terrain changes and land surface configurations within the project area and created an overall plan that was efficient and complete.

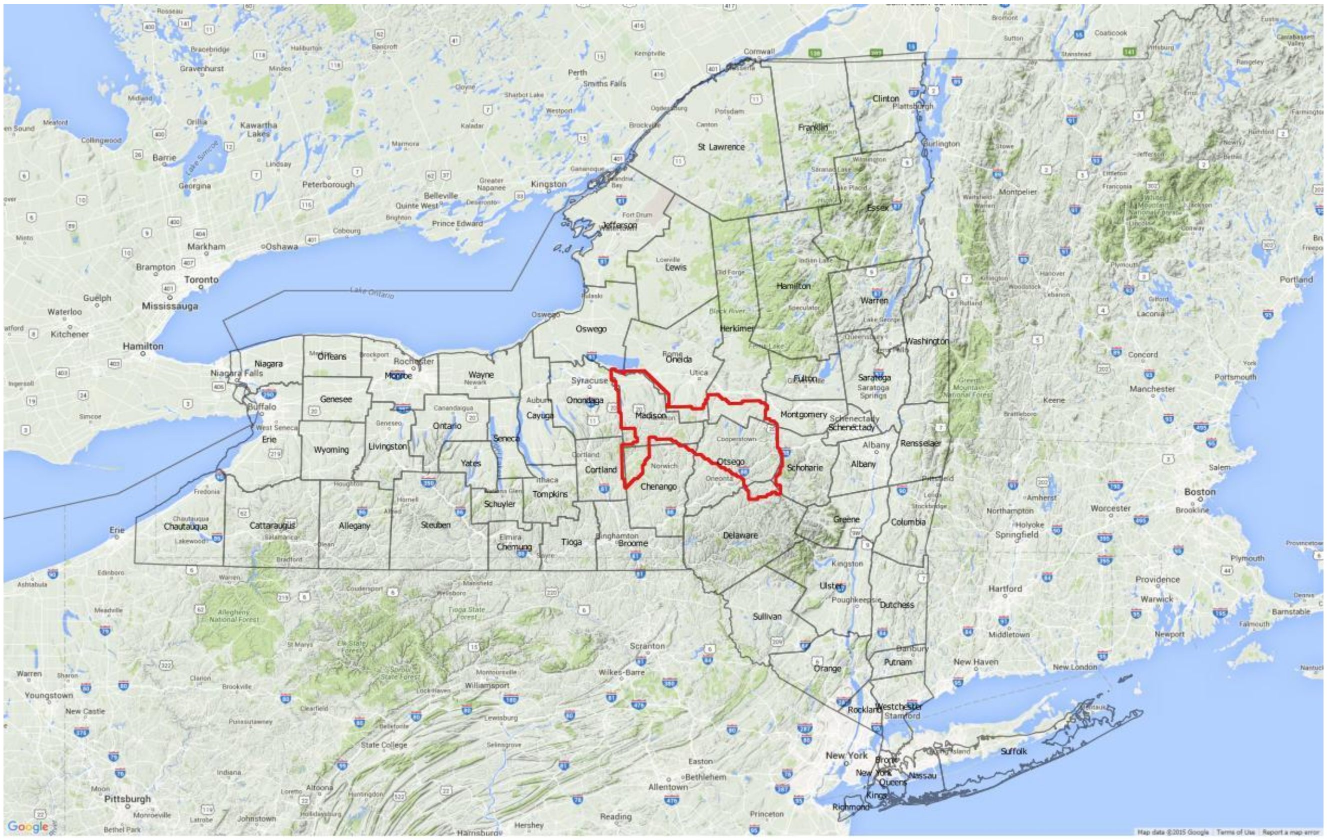


Figure 1: Location of Project Area

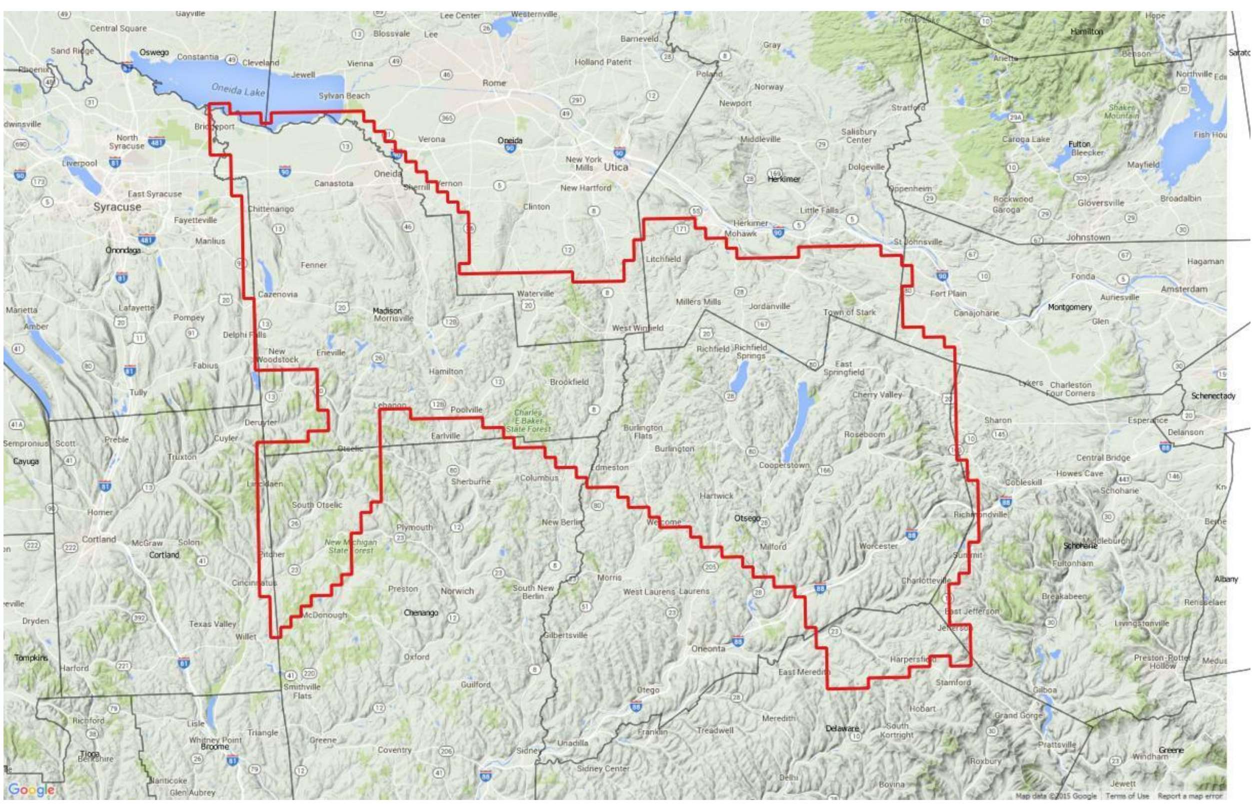


Figure 2: Project Area

Section 3: LiDAR Acquisition

3.1 Acquisition

The Madison-Otsego LiDAR project Airborne LiDAR was acquired by both Axis GeoAviation and Keystone Aerial Surveys. The LiDAR coverage is approximately 1,844 square miles or 4,776 square kilometers. This report focuses on the portion of the project flown by Axis GeoAviation. Axis GeoAviation flew an area of approximately 272 square miles or 704 square kilometers in seven (7) flight missions. The aircraft used was a Cessna 206 N223TC and was outfitted with a Trimble-Harrier 68i LiDAR system. The LiDAR sensor is a Riegl LMS-680i Airborne LiDAR scanner, which operates at up to 400,000 pulses per second, and fires a near infrared single frequency laser, which is aimed by a rotating polygonal mirror. The primary advantage of this system is it is able to collect data on parallel scan lines, and maintain geometrically consistent scan spacing throughout its full 60° operating window. The third component of the sensor rack is the Applanix 510 POS AV System, which combines highly precise pitch, roll and yaw sensors, with accelerometers and a precision GPS/GLONASS satellite positioning system. This critical unit measures all of the changes in attitude of the aircraft and using precise timing data from the GPS signal, allows use of a time stamp for every measurement of the system, including the LiDAR, the camera and the IMU inputs, which in turn provides the processing backbone for applying corrections to images, knowing where the LiDAR unit was when it received a return pulse. The system also serves as a means of augmenting the navigational solutions provided by the Global Navigation Satellite System (GNSS) unit, since its gyroscope and accelerometer data are used as part of the input dataset for the Smoothed Best Estimated Trajectory (SBET) solution for the mission.

Figure 3 represents a list of the features and characteristics for the Harrier 68i system:

SPECIFICATIONS

Sensor Head Specifications

Beam deflection	Rotating polygon
Pulse repetition rate	80 kHz–400 kHz
Field of view	45 degrees to 60 degrees (max)
Measurement rate	266 kHz @ 60 degree 200 kHz @ 40 degree
Operating altitude	30 m AGL–1 600 m AGL
Beam divergence	≤ 0.5 mrad
Range capture	Full waveform digitization
Intensity capture	16 bit dynamic range for each echo
Scan frequency	10 Hz to 200 Hz
Eye safety class	Class 3R
Swath width	83% of op. altitude (45 degrees)
Range resolution	0.020 m
Vertical accuracy	<0.15 m (absolute)
Horizontal accuracy	<0.25 m (absolute)
Scan pattern	Parallel lines
Temperature	0 °C to +40 °C (operation) –10 °C to +50 °C (storage)
Humidity	0% to 85% non-condensing
Weight	42 kg
Dimensions	30 W × 64 L × 48 H cm

Figure 3 Harrier 68i Sensor Characteristics

3.2 Acquisition Details

One hundred-three (103) adjacent flight lines plus five (5) calibration strips were acquired to cover of the project area during seven (7) flight missions. See Figure 3.3.1 Flight line Orientation and Table 2 Acquisition Dates. The majority of the flight missions were flown in a northeast-southwest pattern in the north section. Two missions flown on 4-18-2015 and 4-19-2015 southern section was flown with east-west flight lines. The flight plan included cross strip flight line collection to compensate for IMU drift associated with all IMU systems. At least two (5) GPS CORS reference station(s) were in operation during all missions, sampling positions at 5 Hz or higher frequency. Differential GPS baseline lengths did not exceed 50km, unless otherwise approved. Differential GPS unit in the aircraft recorded sample positions at 2Hz or more frequently. LiDAR data was only acquired when GPS PDOP was ≤3 and at least 6 satellites were in view.

Weather and atmospheric conditions were monitored and LiDAR missions conducted only when conditions existed that would not degrade sensor ability in the collection of data. The LiDAR sensors were calibrated at a designated site located at the Easton/Newman Field Airport MD (ESN) and checked and adjusted to minimize corrections at project sites.

3.3 LiDAR Flight Line Orientation

Figure 4 represents the alignment of the flight-lines executed to provide coverage.

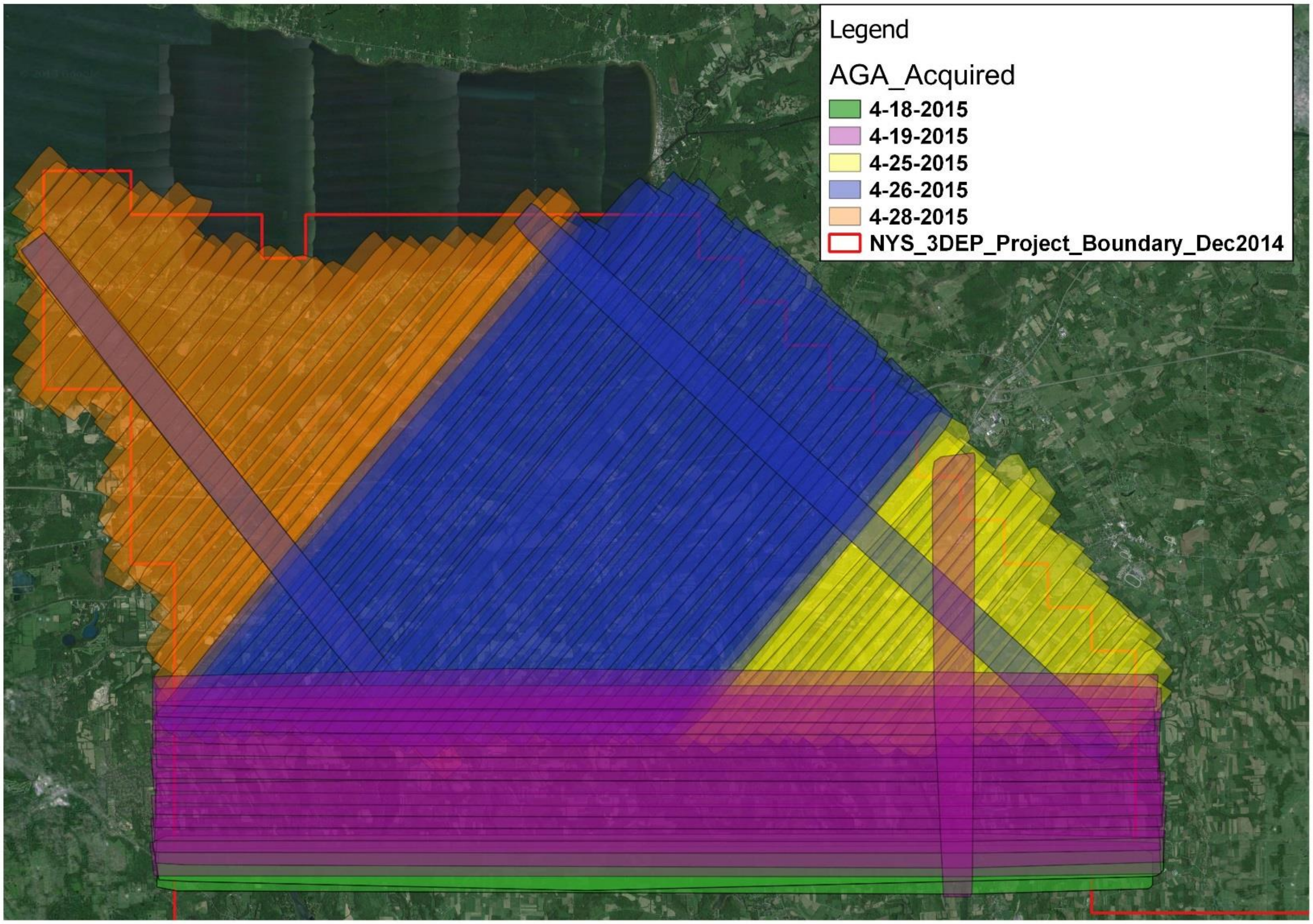


Figure 4: Flight line alignment

3.4 Acquisition Flight Summary

LiDAR acquisition missions were flown between April 18th, 2015 and April 28th, 2015. Flights were planned at various flying heights above 700 m AGL.

Date of Mission(s)	Lift Number	# of Lines Acquired (Including Cross Strips)	Mission Times (UTM)	Aircraft Tail Number
***April 18, 2015**	1	2	15:25-16:02	N223TC
April 19, 2015	1	16	11:10-14:43	N223TC
April 25, 2015	1	25	21:27-23:48	N223TC
April 26, 2015	1	22	15:37-18:32	N223TC
April 26, 2015	2	11	22:01-23:54	N223TC
***April 28, 2015**	1	21	12:09-13:59	N223TC
April 28, 2015	2	11	16:44-17:33	N223TC

Table 2: Acquisition Dates

***Indicates Mission Errors-See Section 3.6 for corrective measures taken**

Flight Logs for each acquisition mission are provided in Section 4 Flight Logs. Calibration lines were run at the beginning or end of the day and a cross strip running Southeast or Northwest was obtained at the end of each successful lift.

3.5 LiDAR System Acquisition Limitations

There are several limiting factors to LiDAR data acquisition which include weather, ground conditions, satellite configuration and equipment malfunctions.

During a LiDAR acquisition mission, there can be no clouds, rain, fog or excessive humidity between the sensor and the ground. Excessive, heavy winds, engaging the aircraft perpendicular to the line of flight, can result in "crab" of the aircraft which results in "gaps" or "slivers' in the data between flight lines. Ground conditions which include pools of standing water and ditches filled with moving water affect the accuracy of LiDAR returns. The number of satellites "visible" to the aircraft during acquisition is an important factor and a poor Global Positioning System (GPS) configuration will contribute to less than desired accuracy. Therefore, satellite configuration, measured by PDOP (Positional Dilution of Precision) is checked each morning to ensure acquisition occurs during the most favorable geometric configuration of the satellites. Finally, despite the best maintenance routines and practices, systems malfunction and fail. Operator awareness is key to identifying the exact moment when a system malfunctions. This enables the crew to stop acquisition and correct the issue before continuing. At times, lines acquired with anomalies will need to be re-acquired.

3.6 Acquisition Issues and Resolutions

Unfortunately, there were missions that experienced some minor unexpected equipment malfunctions and weather delays. The following identifies the missions, the type of issue and the actions taken to overcome the problem. The mission that was aborted on April 18th was re-flown on April 19th.

- April 18th 2015, Lift 1: Two (2) lines were flown. This mission was aborted early because of high wind.
- April 28th 2015, Lift 1: Twenty (20) lines were flown and one (1) cross tie was flown. During line 75 an Automatic start/stop took place and manual control was taken over.

3.7 LiDAR System Acquisition Parameters

LiDAR acquisition was planned to meet the following specifications:

Item	Parameter
System	Harrier 68i
Nominal Pulse Spacing (m)	0.69
Nominal Pulse Density (pls/m²)	2.07
Nominal Flight Height (MSL meters)	884
Nominal Flight Speed (kts)	120-125
Pass Heading (degree)	50,228
Sensor Scan Angle (degree)	60
Scan Frequency (Hz)	90.7
Pulse Rate of Scanner (kHz)	200
Line Spacing (m)	273.25
Pulse Duration of Scanner (ns)	4
Pulse Width of Scanner (m)	0.44
Central Wavelength of Sensor Laser (nm)	1047
Sensor Operated with Multiple Pulses	Yes
Beam Divergence (mrad)	<0.5
Nominal Swath Width (m)	1020.76
Nominal Swath Overlap (%)	30
Scan Pattern	Parallel Lines

Table 3 System Parameters for LiDAR Acquisition

3.8 CORS Reference Stations

The presence of a strong CORS (Continuously Operating Reference Station) configuration allowed for the LiDAR to be acquired with Global Navigation Satellite System (GNSS) techniques and procedures. Table 4 and Figure 5 below contains a listing and graphic of the CORS stations that were used during the processing, their calculated latitude, longitude and ellipsoid height. Minor variations in position, due to changes in satellite availability, geometry and varying availability of the CORS stations, were observed, and are of millimeter level magnitude. These variations had no impact on system positioning and are unavoidable.

NAME	LATITUDE (N)	LONGITUDE (W)	ELEVATION (M)
NYBH	42 06 35.12975	-75 49 38.72404	311.868
NYCL	42 35 03.73985	-76 12 40.81440	329.695
NYCS	42 40 02.86998	-74 29 10.96749	269.475
NYFV	42 56 21.03156	-74 21 12.03355	103.483
NYHC	41 57 30.01437	-75 17 33.89641	259.484
NYLV	43 47 47.27688	-75 29 07.57632	240.401

NAME	LATITUDE (N)	LONGITUDE (W)	ELEVATION (M)
NYMX	43 28 12.41226	-76 13 54.90897	89.977
NYON	42 26 24.84807	-75 06 42.52864	305.853
NYRM	43 10 40.06175	-75 29 13.90348	127.363
NYSB	42 40 45.06563	-75 30 47.49781	295.895
NYWG	42 21 03.82838	-76 52 33.32269	282.37
NYWL	42 53 55.25987	-76 51 07.32507	108.78
NYWT	44 01 41.69175	-75 55 15.97088	117.113
NYWV	42 00 44.63247	-76 31 17.69049	220.959
OSPA	43 27 53.55754	-76 30 41.49734	51.146

Table 4: GPS Reference Station Coordinates

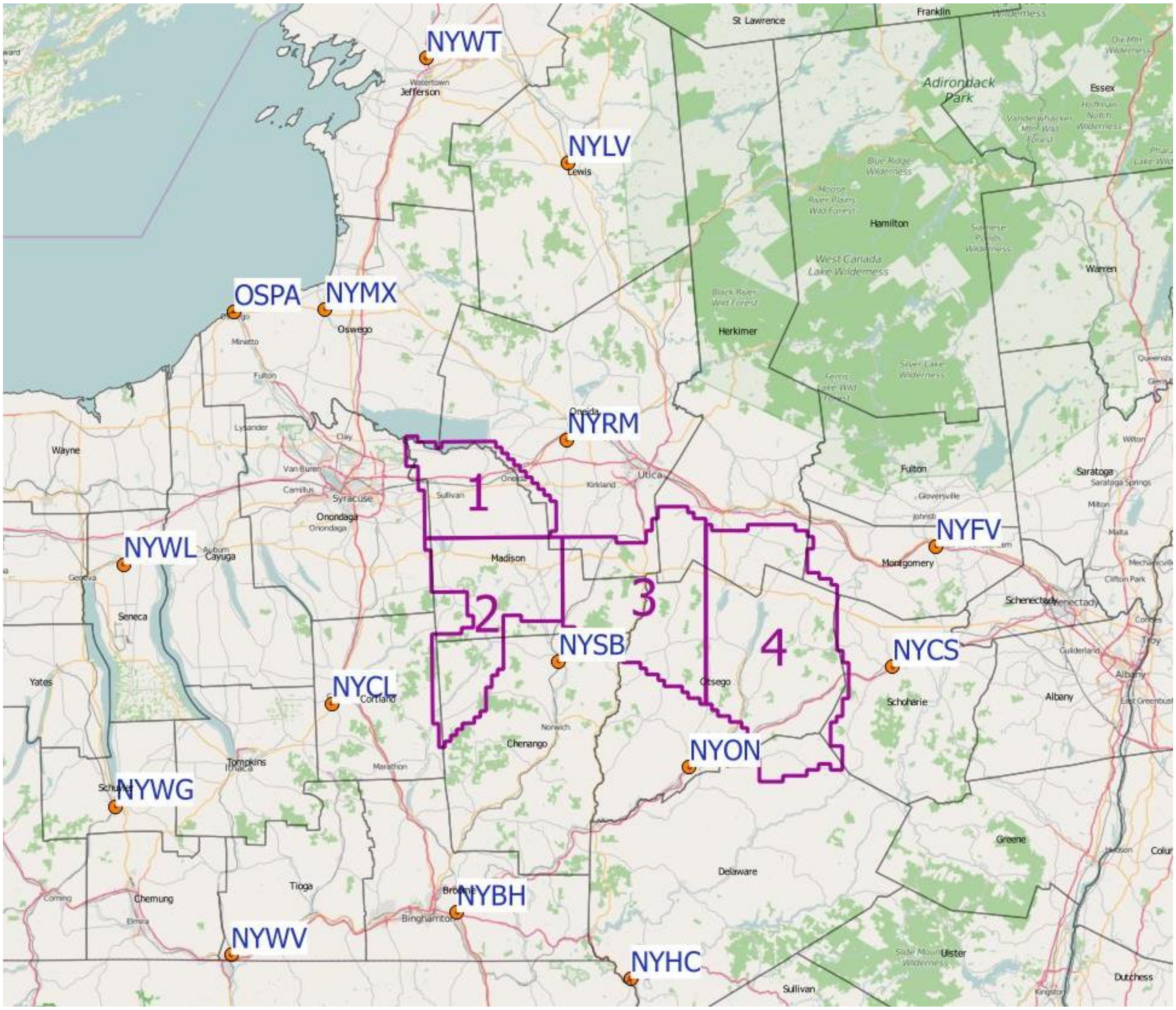


Figure 5: GPS Reference Stations

3.9 Airborne GPS Kinematic and Processing

The Differential GPS unit in the aircraft collected positions at 2Hz. Airborne GPS data was processed using the Inertial Explorer (version 8.5.4320) software. Flights were flown with a minimum of 6 satellites in view (10° above the horizon) and with a PDOP of ≤3 when laser online. Distances from base station to aircraft were kept to a maximum of 50km.

For all flights, the GPS data can be classified as good, with GPS residuals of 3cm average or better but none larger than 15cm being recorded when laser online.

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

AXIS makes use of the latest in Airborne-GPS (AGPS) and Inertial Measurement Unit (IMU) systems to determine the precise three-dimensional trajectory of its aircraft in flight. These state of the art sensor systems use the global navigation satellite system (GNSS), pitch-roll-yaw sensors, accelerometers and gyrocompasses to measure and record every change in the attitude, speed and direction of the aircraft during its data collection mission.

These measurements are linked together according to a precise time baseline that is collected as part of the GNSS message stream, allowing corrections for attitude variations to be known at the exact time the digital sensor records an image.

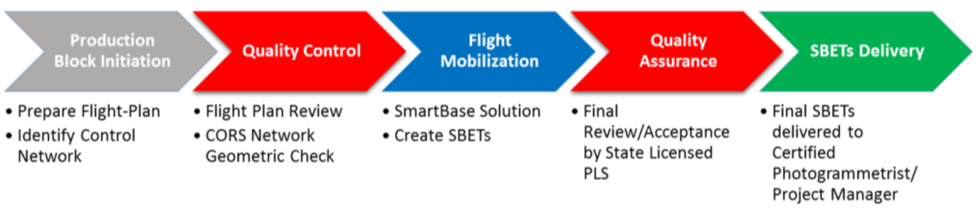
AGPS/IMU Processing

AXIS uses Applanix POS Pac MMS v.7.1 to process Airborne GNSS/IMU datasets and compute Smoothed Best Estimated Trajectory (SBET) files for our LiDAR and Photogrammetry missions. This state-of-the-art GNSS/IMU processing technology uses a combination of GNSS data collected onboard the aerial platform during the mission, twenty-four (24) hours of satellite geometry and ephemeris data from the National CORS network that surrounds the flight mission footprint, and data from the onboard IMU that tracks the heading, acceleration/deceleration, pitch, roll and yaw of the aircraft during the flight.

The processing software uses all of the data inputs to determine the precise three dimensional trajectory of the aircraft during the mission. The process includes operator managed and software driven QA/QC checks, and a professional land surveyor monitors the entire process, focusing on the geometry and spacing of the CORS network control points around the project area, data integrity and software are properly configured to account for the system hardware locations in relation to the IMU reference location.

The workflow for each production block will follow a structured path, modified as needed to make adjustments for buy ups or other optional tasks:

SBET Processing Workflow Chart



First, a flight plan and project are reviewed prior to mobilization to confirm CORS network geometry, station availability and data observation rates. Once approved for flight, the mission is executed by the flight operations team within the parameters of the flight plan, STATE requirements, applicable mapping guidelines, industry standards and our own in-house protocols. These requirements include collection of data on the ground before and after the flight, proper manipulation of the IMU during flight to avoid heading drift and careful navigation of the aircraft to avoid loss of satellite lock during the entire mission such as unduly steep banking turns, flight line deviations, or operation during turbulent conditions. Upon return to the airfield, the IMU and other data are downloaded and posted to our computer network for post processing. Post processing involves assembling flight data from the onboard GNSS and IMU, downloaded CORS vector data for a time balanced observation period centered on the takeoff to touchdown flight window of the data collection mission, published and vetted positional data for the CORS control stations, broadcast and precise ephemeris data documenting the projected and actual positions of the satellites during the mission.

GNSS Base Stations for the SmartBase processing are selected based on conformance with requirements of the software, including distance from the center of the flight mission, network station spacing, observation rates of the network base stations, and availability of both broadcast and precise ephemeris data for the satellites included in the GNSS dataset.

All of these datasets are linked to the project database, checked for accuracy and readied for processing. The software uses a proprietary process to compute GNSS based forward and backward trajectories, IMU based forward and backward trajectories based on accelerometer and gyrocompass data, pitch, roll and yaw sensors, and then combine all of the independent solutions into a precisely computed string of plane and sensor positions during the mission. Due to the speed of travel of the aircraft, positioning is determined at the rate of fifty (50) times per second, based on actual observed data from equipment operating at that recording interval, not from interpolated data from equipment operating at slower data rates. This method yields truer positioning from direct observation rather than estimated positions between true fixes. The IMU system operates at very high speed, typically at two hundred measurements (200) per second, which allows the system to maintain a precise track on changes in aircraft attitude during acquisition. The GNSS data is combined with the IMU data to bridge the separations in position fixes and refine the precision of the planes trajectory down to nearly centimeter level three-dimensional precision.

The software downloads GNSS data from the CORS stations around the project area, and performs a dataset integrity check of the GNSS RINEX files to find errors in the data such as gaps, incompatible collection rates or missing antenna information. The Applanix SmartBase software includes a SmartBase Quality Check module that performs an extremely accurate network analysis and adjustment on all the base-lines and reference stations in the network. The Quality Check module uses 18 to 24 hours of reference station data to accurately compute the base-lines between one station set as the control and the rest of the stations. The long duration of data is used to ensure that all multipath variations due to changes in satellite positions are averaged out as much as possible.

The output of the Quality Check module is a table indicating the estimated error for each set of reference station coordinates. If the estimated error is larger than 5 cm, the coordinates are flagged as unacceptable, indicating the input coordinate cannot be trusted. The user has the option of using the adjusted coordinates instead of the input coordinates, or not using the reference station at all in the Applanix SmartBase computations.

Additional quality checks are made on the individual reference station observation files before the Applanix SmartBase is computed. The final result of this process ensures the integrity of the computed reference station data and coordinates are known and trusted before the airborne data set is even processed.

Once the network framework is approved, the software establishes a Virtual Reference Station in close proximity to the project area. This technology is known as the Applanix SmartBase Solution, and allows the software to minimize vector length from the primary base station to the aircraft, minimizing the effect of atmospheric and other systematic errors. Once the Virtual Reference Station is established, forward and backward processing of the GNSS and IMU datasets is executed to determine the exact path, known as the Smoothed Best Estimated Trajectory (SBET), of the airborne platform and its associated equipment.

AGPS/IMU QA Review & Analysis

Once the SBET file is created, reports and output files of the data are automatically generated for review by the system operator. The primary analysis tool are the charts showing differences in values for aircraft roll-pitch and yaw values, positional quality information, satellite health and geometry, signal to noise ratios, and variances in direction or velocity vectors between forward and backward processed data that indicate some environmental variable has affected the data. The primary means of mitigating these errors is proper positioning support by the surrounding base station network, management of flight path length to eliminate IMU drift, and flight procedures that avoid interruption of satellite data reception.

AGPS/IMU Data Finalization and Preparation for LiDAR Production

The SBET QA/QC review is finalized by independent assessment of the output charts and reports showing deviations between processing directions, spikes in aircraft attitude variations and quality of GNSS data and positional fixes. IMU data is put to further use in the next step of the data processing workflow, when Exterior Orientations of the digital sensor systems are determined and corrections are applied to the images based on changes in aircraft orientation at the time of exposure.

GPS processing results for each lift are included in Section5: GPS Processing.

Section 4: Flight Logs

4/18/2015: Lift 1

LiDAR and Imagery Flight Report				Project(s): NY State 215019	
Pilot: Jerry Lewis			Project Number(s): 215019		
Operator: Jameson Harrington			Project Name(s): NY State LiDAR		
Aircraft: Cessna 206 N223TC			Block Number:		
LiDAR Unit: Harrier 68i	View Angle (deg): 60		Camera Unit: Tac P65 50mm	Date: 4/18	
MTA Zone: 2	Ground Speed Start (kts): 122		Pulses per Scanline: 1470	Sun Angle: > 30 Degrees	
Log Mode: 3	Altitude(feet AMT): 2900		Endlap (%): 60%	Lens: LiDAR Only	
Pulse Rate: 200khz	Point Spacing (m): 0 .69		Side-Lap(%): 30%	Point Density (ppms): 4.7	

Direction	Line #	From	To	Start Time	Altitude(AMSL)	Remarks	Clouds	Turbulance
W	56			11:25	4180	156 KTS downwind	⊕	Mod - Severe
W	55			11:50	4180		⊕	Mod - Severe

Cloud Cover Codes	⊕ = High Thin	●= Solid Overcast	O = Clear

Remarks:

4/19/2015: Lift 1

LiDAR and Imagery Flight Report		Project(s): NY State 215019	
Pilot: Jerry Lewis		Project Number(s):	215019
Operator: Jameson Harrington		Project Name(s):	NY State LiDAR
Aircraft: Cessna 206 N223TC		Block Number:	
LiDAR Unit: Harrier 68i	View Angle (deg): 60	Camera Unit: Tac P65 50mm	Date: 4/19
MTA Zone: 2	Ground Speed Start (kts): 122	Pulses per Scanline: 1470	Sun Angle: > 30 Degrees
Log Mode: 3	Altitude(feet AMT): 2900	Endlap (%): 60%	Lens: LiDAR Only
Pulse Rate: 200khz	Point Spacing (m): 0 .69	Side-Lap(%): 30%	Point Density (ppms): 4.7

Direction	Line #	From	To	Start Time	Altitude(AMSL)	Remarks	Clouds	Turbulance
E	55			7:10	4180		O	
W	54			7:25	4180		O	
E	53			7:40	4160'		O	
W	52			7:54	4160'		O	
E	51			8:07	4160'		⊕	
W	49			8:20	4140'		⊕	
E	48			8:34	4120'		⊕	
W	50			8:48	4100'		⊕	
E	47			9:01	4080'		⊕	
W	46			9:14	4040'		⊕	
E	45			9:27	4000'		⊕	
W	44			9:41	3960'		⊕	
E	43			9:54	3920'		⊕	
W	42			10:09	3880'		⊕	
E	41			10:22	3840'		⊕	
N	58			10:39	3480'	Cross Flight	O	

Cloud Cover Codes: ⊕ = High Thin; ●= Solid Overcast; O = Clear

Remarks: Abort due to high winds and turbulance

4/25/2015: Lift 1

LiDAR and Imagery Flight Report

Project(s): NY State 215019

Pilot: Jerry Lewis		Project Number(s):	215019
Operator: Jameson Harrington		Project Name(s):	NY State LiDAR
Aircraft: Cessna 206 N223TC		Block Number:	

LiDAR Unit: Harrier 68i	View Angle (deg): 60	Camera Unit: Tac P65 50mm	Date: 4/25
MTA Zone: 2	Ground Speed Start (kts): 122	Pulses per Scanline: 1470	Sun Angle: > 30 Degrees
Log Mode: 3	Altitude(feet AMT): 2900	Endlap (%): 60%	Lens: LiDAR Only
Pulse Rate: 200khz	Point Spacing (m): 0 .69	Side-Lap(%): 30%	Point Density (ppms): 4.7

Direction	Line #	From	To	Start Time	Altitude(AMSL)	Remarks	Clouds	Turbulance
SW	81			17:27	4000'		⊕	
NE	82			17:32	4000'		⊕	
SW	83			17:37	3980'		⊕	
NE	84			17:42	3920'		⊕	
SW	85			17:47	3860'		⊕	
NE	86			17:52	3780'		⊕	Light Chop
SW	80			17:57	3900'		⊕	
NE	79			18:02	3800'		⊕	
SW	78			18:07	3700'		⊕	
NE	77			18:13	3640'		⊕	Light Chop
SW	76			18:19	3580'		⊕	
NE	75			18:27	3540'	Auto Start/Stop failure - switch to manual	⊕	
SW	74			18:30	3540'		⊕	
NE	73			18:36	3540'		⊕	
SW	72			18:42	3600'		⊕	Light Chop
NE	71			18:48	3600'		⊕	
SW	70			18:54	3640'		⊕	
NE	69			19:00	3640'		⊕	
SW	68			19:06	3660'		⊕	

Cloud Cover Codes: ⊕ = High Thin ●= Solid Overcast O = Clear

Remarks:

axis geospatial / AXIS GeoAviation		LiDAR and Imagery Flight Report	Project(s): NY State 215019
Pilot: Jerry Lewis		Project Number(s):	215019
Operator: Jameson Harrington		Project Name(s):	NY State LiDAR
Aircraft: Cessna 206 N223TC		Block Number:	
LiDAR Unit: Harrier 68i	View Angle (deg): 60	Camera Unit: Tac P65 50mm	Date: 4/25
MTA Zone: 2	Ground Speed Start (kts): 122	Pulses per Scanline: 1470	Sun Angle: > 30 Degrees
Log Mode: 3	Altitude(feet AMT): 2900	Endlap (%): 60%	Lens: LiDAR Only
Pulse Rate: 200khz	Point Spacing (m): 0 .69	Side-Lap(%): 30%	Point Density (ppms): 4.7

Direction	Line #	From	To	Start Time	Altitude(AMSL)	Remarks	Clouds	Turbulance
NE	67			19:11	3660'		⊕	
SW	66			19:17	3660'		⊕	Light Chop
NE	65			19:24	3660'		⊕	
SW	64			19:30	3660'		⊕	
NE	63			19:37	3660'		⊕	
SW	62			19:44	3660'		⊕	

4/26/2015: Lift 1

axis geospatial / AXIS GeoAviation	LiDAR and Imagery Flight Report	Project(s): NY State 215019	
Pilot: Jerry Lewis		Project Number(s): 215019	
Operator: Jameson Harrington		Project Name(s): NY State LiDAR	
Aircraft: Cessna 206 N223TC		Block Number:	
LiDAR Unit: Harrier 68i	View Angle (deg): 60	Camera Unit: Tac P65 50mm	Date: 4/26 Flight 1
MTA Zone: 2	Ground Speed Start (kts): 122	Pulses per Scanline: 1470	Sun Angle: > 30 Degrees
Log Mode: 3	Altitude(feet AMT): 2900	Endlap (%): 60%	Lens: LiDAR Only
Pulse Rate: 200khz	Point Spacing (m): 0 .69	Side-Lap(%): 30%	Point Density (ppms): 4.7

Direction	Line #	From	To	Start Time	Altitude(AMSL)	Remarks	Clouds	Turbulance
SW	61			11:37	3260'		OVC	
NE	60			11:44	3600'		OVC	
SW	59			11:51	3600'		OVC	
NE	58			11:59	3580'		OVC	
SW	57			12:05	3560'		OVC	
NE	56			12:13	3540'		BKN	
SW	55			12:20	3540'		BKN	
NE	54			12:28	3540'		BKN	
SW	53			12:35	3540'		BKN	
NE	52			12:43	3520'		OVC	
SW	51			12:51	3500'		OVC	
NE	50			12:59	3500'		OVC	
SW	49			13:08	3500'		OVC	
NE	48			13:16	3480'		OVC	
SW	47			13:24	3460'		OVC	
NE	46			13:32	3460'		OVC	
SW	45			13:41	3440'		OVC	
NE	44			13:50	3420'		OVC	
SW	43			13:59	3380'		OVC	

Cloud Cover Codes: ⊕ = High Thin ●= Solid Overcast O = Clear

Remarks: Abort due to high winds and turbulance

		LiDAR and Imagery Flight Report	Project(s): NY State 215019

Pilot: Jerry Lewis		Project Number(s): 215019
Operator: Jameson Harrington		Project Name(s): NY State LiDAR
Aircraft: Cessna 206 N223TC		Block Number:

LiDAR Unit: Harrier 68i	View Angle (deg): 60	Camera Unit: Tac P65 50mm	Date: 4/26 Flight 1
MTA Zone: 2	Ground Speed Start (kts): 122	Pulses per Scanline: 1470	Sun Angle: > 30 Degrees
Log Mode: 3	Altitude(feet AMT): 2900	Endlap (%): 60%	Lens: LiDAR Only
Pulse Rate: 200khz	Point Spacing (m): 0 .69	Side-Lap(%): 30%	Point Density (ppms): 4.7

Direction	Line #	From	To	Start Time	Altitude(AMSL)	Remarks	Clouds	Turbulance
NE	42			14:08	3380'		OVC	
NW	87			14:24	3460'	Cross Flight	OVC	

4/26/2015: Lift 2

axis geospatial	AXIS GEOAVIATION	LiDAR and Imagery Flight Report	Project(s): NY State 215019
Pilot: Jerry Lewis		Project Number(s): 215019	
Operator: Jameson Harrington		Project Name(s): NY State LiDAR	
Aircraft: Cessna 206 N223TC		Block Number:	

LiDAR Unit: Harrier 68i	View Angle (deg): 60	Camera Unit: Tac P65 50mm	Date: 4/26 Flight 2
MTA Zone: 2	Ground Speed Start (kts): 122	Pulses per Scanline: 1470	Sun Angle: > 30 Degrees
Log Mode: 3	Altitude(feet AMT): 2900	Endlap (%): 60%	Lens: LiDAR Only
Pulse Rate: 200khz	Point Spacing (m): 0 .69	Side-Lap(%): 30%	Point Density (ppms): 4.7

Direction	Line #	From	To	Start Time	Altitude(AMSL)	Remarks	Clouds	Turbulance
SW	41			18:01	3380'		BKN	
NE	40			18:10	3380'		BKN	
SW	39			18:19	3380'		BKN	
NE	38			18:28	3380'		BKN	
SW	37			18:37	3400'		BKN	
NE	36			18:46	3400'		BKN	
SW	35			18:56	3400'		BKN	
NE	34			19:05	3420'		BKN	
SW	33			19:15	3420'		BKN	
NE	32			19:24	3420'		OVC	
SW	31			19:33	3420'		OVC	
NW	90			19:46	3400'	Cross Flight	OVC	

Cloud Cover Codes — ⊕ = High Thin — ●= Solid Overcast — O = Clear

Remarks: Abort due to high winds and turbulance

4/28/2015: Lift 1

LiDAR and Imagery Flight Report		Project(s): NY State 215019
Pilot: Jerry Lewis	Project Number(s):	215019
Operator: Jameson Harrington	Project Name(s):	NY State LiDAR
Aircraft: Cessna 206 N223TC	Block Number:	

LiDAR Unit: Harrier 68i	View Angle (deg): 60	Camera Unit: Tac P65 50mm	Date: 4/28 Flight 1
MTA Zone: 2	Ground Speed Start (kts): 122	Pulses per Scanline: 1470	Sun Angle: > 30 Degrees
Log Mode: 3	Altitude(feet AMT): 2900	Endlap (%): 60%	Lens: LiDAR Only
Pulse Rate: 200khz	Point Spacing (m): 0 .69	Side-Lap(%): 30%	Point Density (ppms): 4.7

Direction	Line #	From	To	Start Time	Altitude(AMSL)	Remarks	Clouds	Turbulance
SW	1			8:09	3260'		OVC	
NE	2			8:12	3260'		OVC	
SW	3			8:16	3260'		OVC	
NE	4			8:19	3260'		OVC	
SW	5			8:23	3280'		OVC	
NE	6			8:27	3280'		BKN	
SW	7			8:31	3280'		BKN	
NE	8			8:35	3300'		BKN	
SW	9			8:41	3300'		BKN	
NE	10			8:51	3300'	Automatic Start/Stop failure - switch to manual	OVC	
SW	11			8:56	3300'		OVC	
NE	12			9:02	3300'		OVC	
SW	13			9:07	3300'		OVC	
NE	14			9:12	3300'		OVC	
SW	15			9:17	3300'		OVC	
NE	16			9:22	3300'		OVC	
SW	17			9:28	3300'		OVC	
NE	18			9:34	3300'		OVC	
SW	19			9:38	3300'		OVC	

Cloud Cover Codes	⊕ = High Thin	●= Solid Overcast	O = Clear

Remarks:

LiDAR and Imagery Flight Report		Project(s): NY State 215019	
Pilot: Jerry Lewis		Project Number(s):	215019
Operator: Jameson Harrington		Project Name(s):	NY State LiDAR
Aircraft: Cessna 206 N223TC		Block Number:	

LiDAR Unit: Harrier 68i	View Angle (deg): 60	Camera Unit: Tac P65 50mm	Date: 4/28 Flight 1
MTA Zone: 2	Ground Speed Start (kts): 122	Pulses per Scanline: 1470	Sun Angle: > 30 Degrees
Log Mode: 3	Altitude(feet AMT): 2900	Endlap (%): 60%	Lens: LiDAR Only
Pulse Rate: 200khz	Point Spacing (m): 0 .69	Side-Lap(%): 30%	Point Density (ppms): 4.7

Direction	Line #	From	To	Start Time	Altitude(AMSL)	Remarks	Clouds	Turbulance
NE	20			9:44	3300'		SCK	
SE	89			9:56	3400'	Cross Flight	SCK	

4/28/2015: Lift 2

axis geospatial	AXIS GeoAviation	LiDAR and Imagery Flight Report	Project(s): NY State 215019

Pilot: Jerry Lewis		Project Number(s): 215019
Operator: Jameson Harrington		Project Name(s): NY State LiDAR
Aircraft: Cessna 206 N223TC		Block Number:

LiDAR Unit: Harrier 68i	View Angle (deg): 60	Camera Unit: Tac P65 50mm	Date: 4/28 Flight 2
MTA Zone: 2	Ground Speed Start (kts): 122	Pulses per Scanline: 1470	Sun Angle: > 30 Degrees
Log Mode: 3	Altitude(feet AMT): 2900	Endlap (%): 60%	Lens: LiDAR Only
Pulse Rate: 200khz	Point Spacing (m): 0 .69	Side-Lap(%): 30%	Point Density (ppms): 4.7

Direction	Line #	From	To	Start Time	Altitude(AMSL)	Remarks	Clouds	Turbulance
SW	21			11:59	3300'		BKN	
NE	22			12:05	3300'		BKN	Moderate
SW	23			12:13	3300'		BKN	
NE	24			12:20	3300'		BKN	
SW	25			12:27	3300'		BKN	
NE	26			12:35	3320'		BKN	
SW	27			12:44	3340'		BKN	
NE	28			12:52	3380'		BKN	
SW	29			13:01	3380'		BKN	
NE	30			13:10	3400'		BKN	
SW	90			13:26	3300'		BKN	

Cloud Cover Codes		⊕ = High Thin	●= Solid Overcast	O = Clear

Remarks:

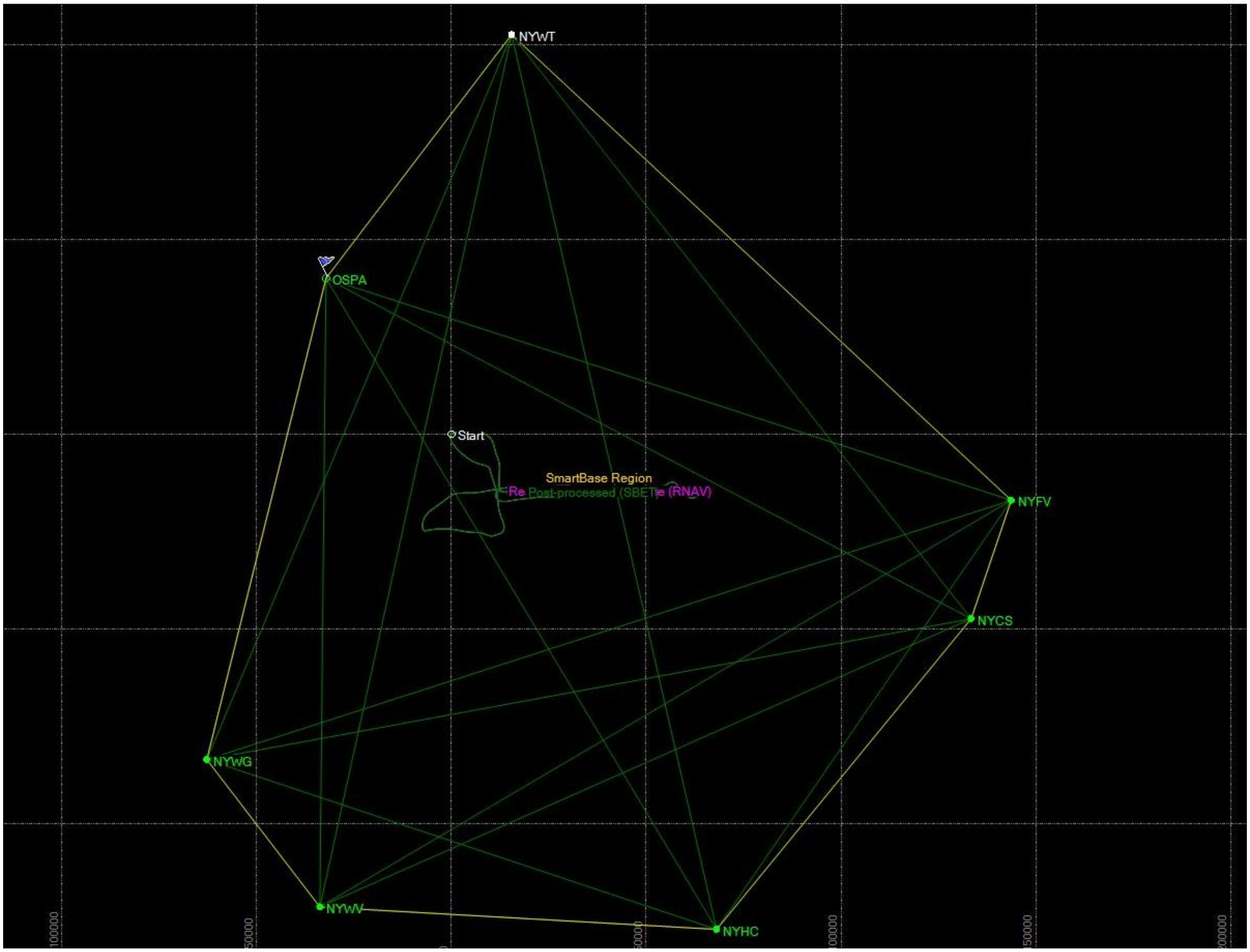
Section 5: GPS Processing Plots

POSPac MMS Version 7.1

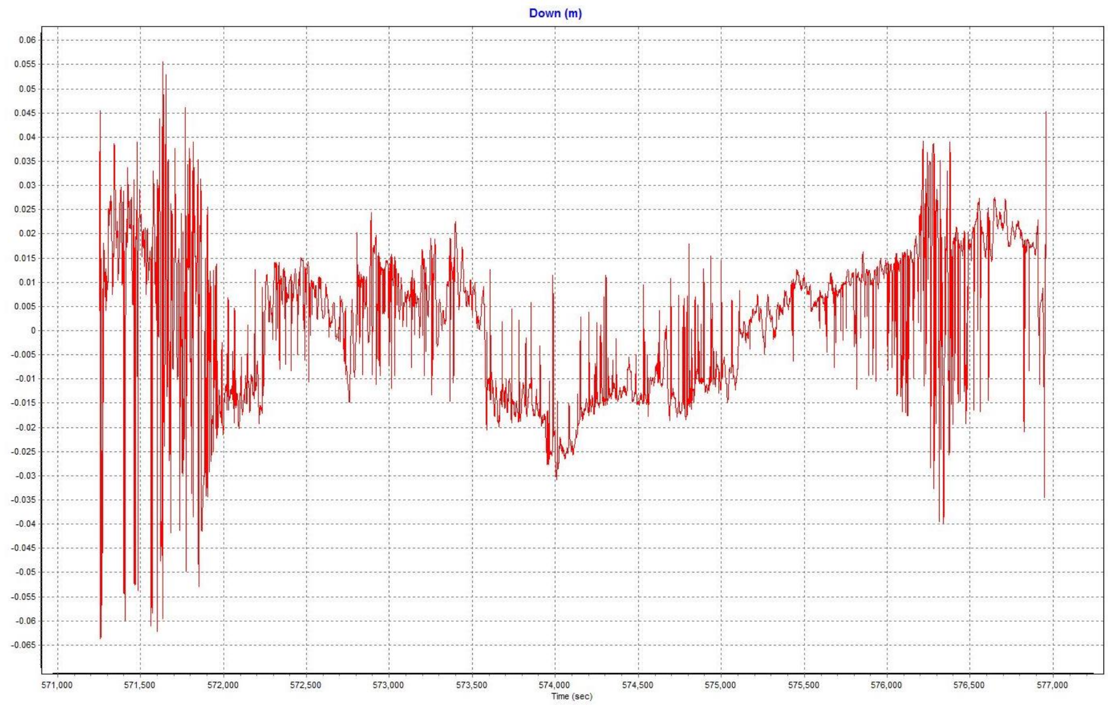
Plots by lift of the Coverage Map, Estimated Position Accuracy (Down Standard Deviation), Estimated Position Accuracy (Down Separation), Estimated Position Accuracy (East Standard Deviation), Estimated Position Accuracy (East Separation), GLONASS Statics, GNSS Solution Quality, GPS Statistics, Estimated Position Accuracy (North Standard Deviation), Estimated Position Accuracy (North Separation), and PDOP.

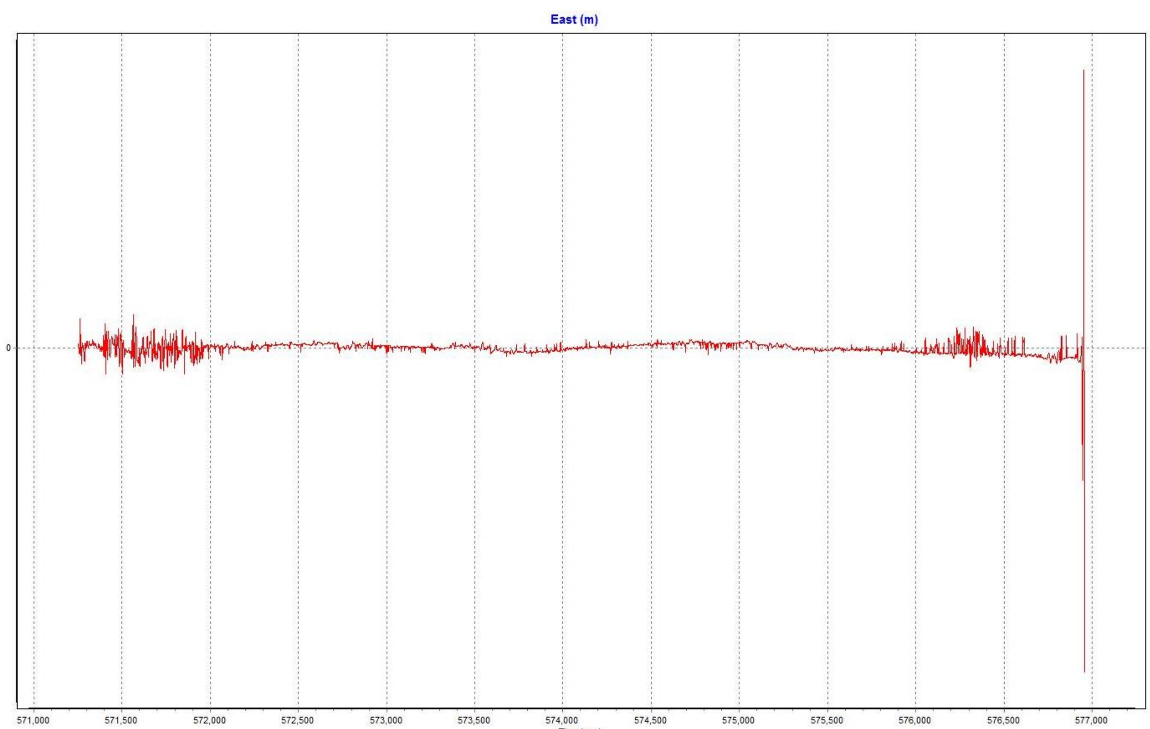
04/18/2015

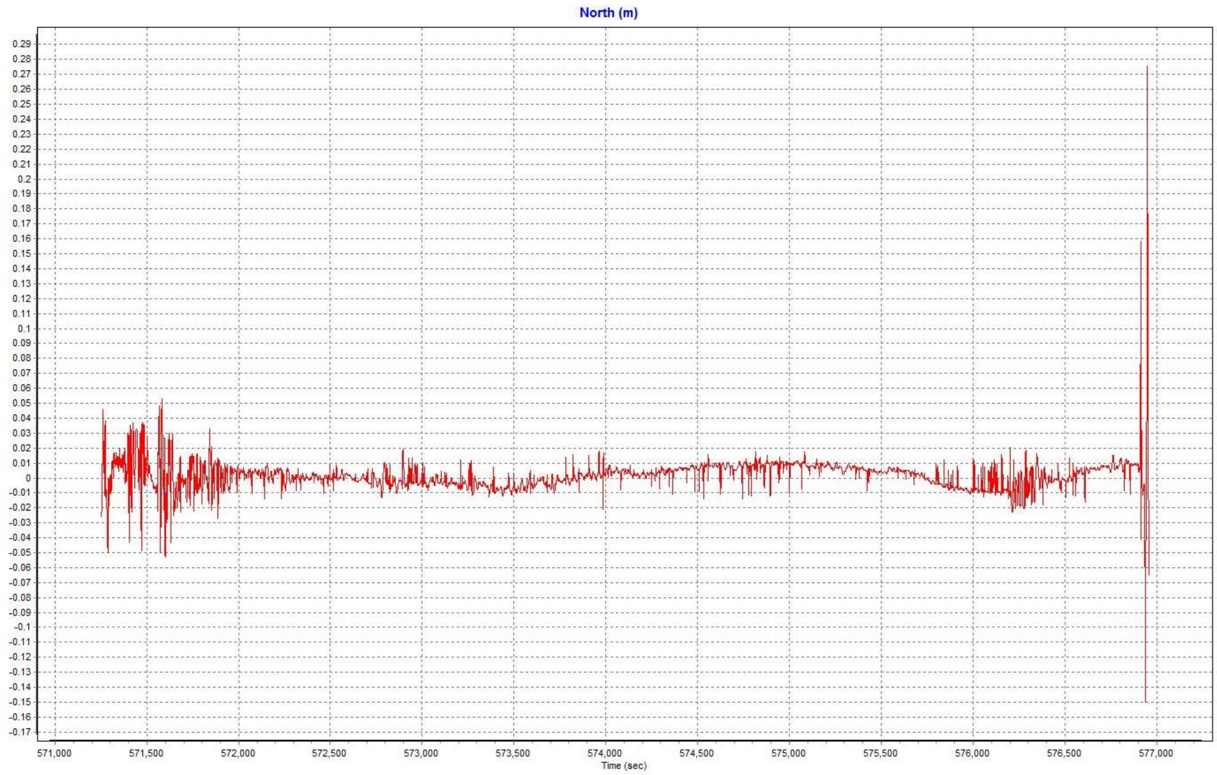
Coverage Map: The Coverage Map plot shows the Aircraft GPS-IMU Trajectory in reference to localized GPS Reference Stations.



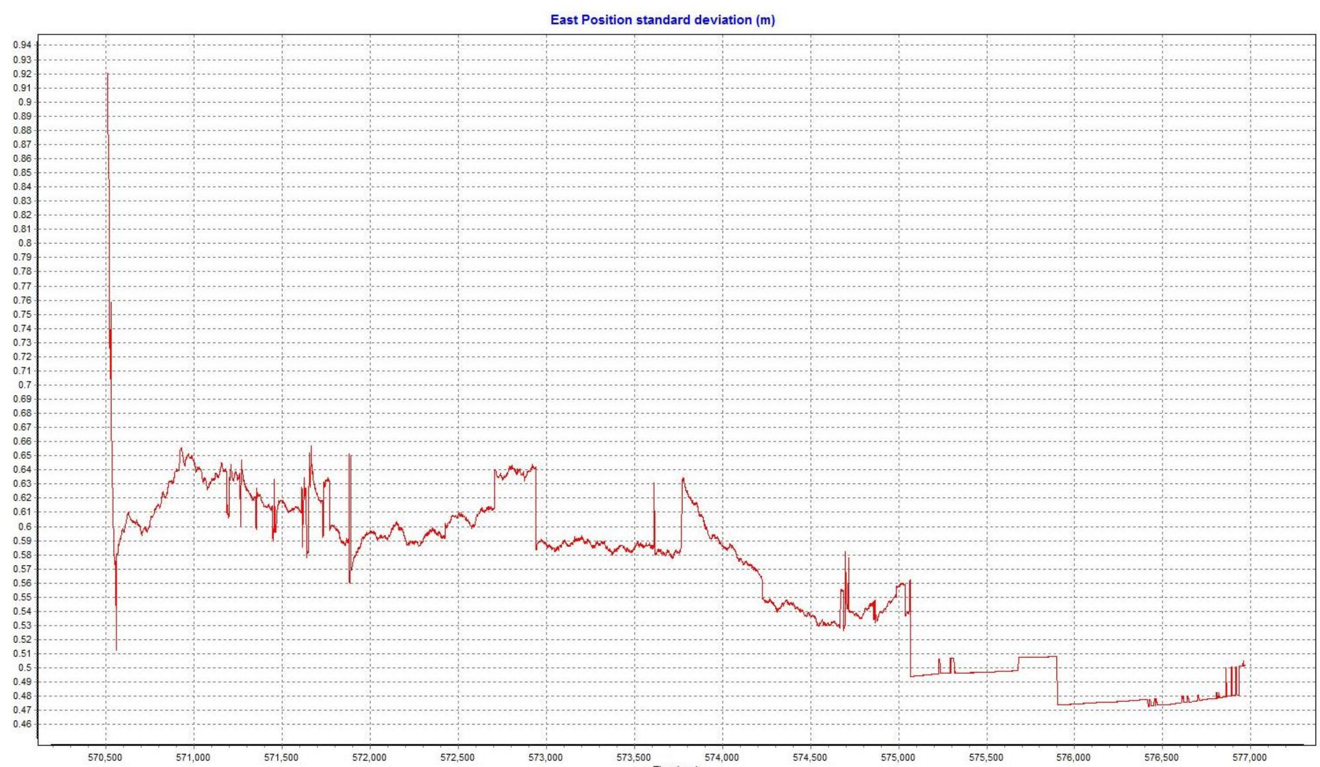
Combined Separation: Plots the north, east, and height position difference between any two solutions loaded into the project. This is most often the forward and reverse processing results, unless other solutions have been loaded from the Combine Solutions dialog. Plotting the difference between forward 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.

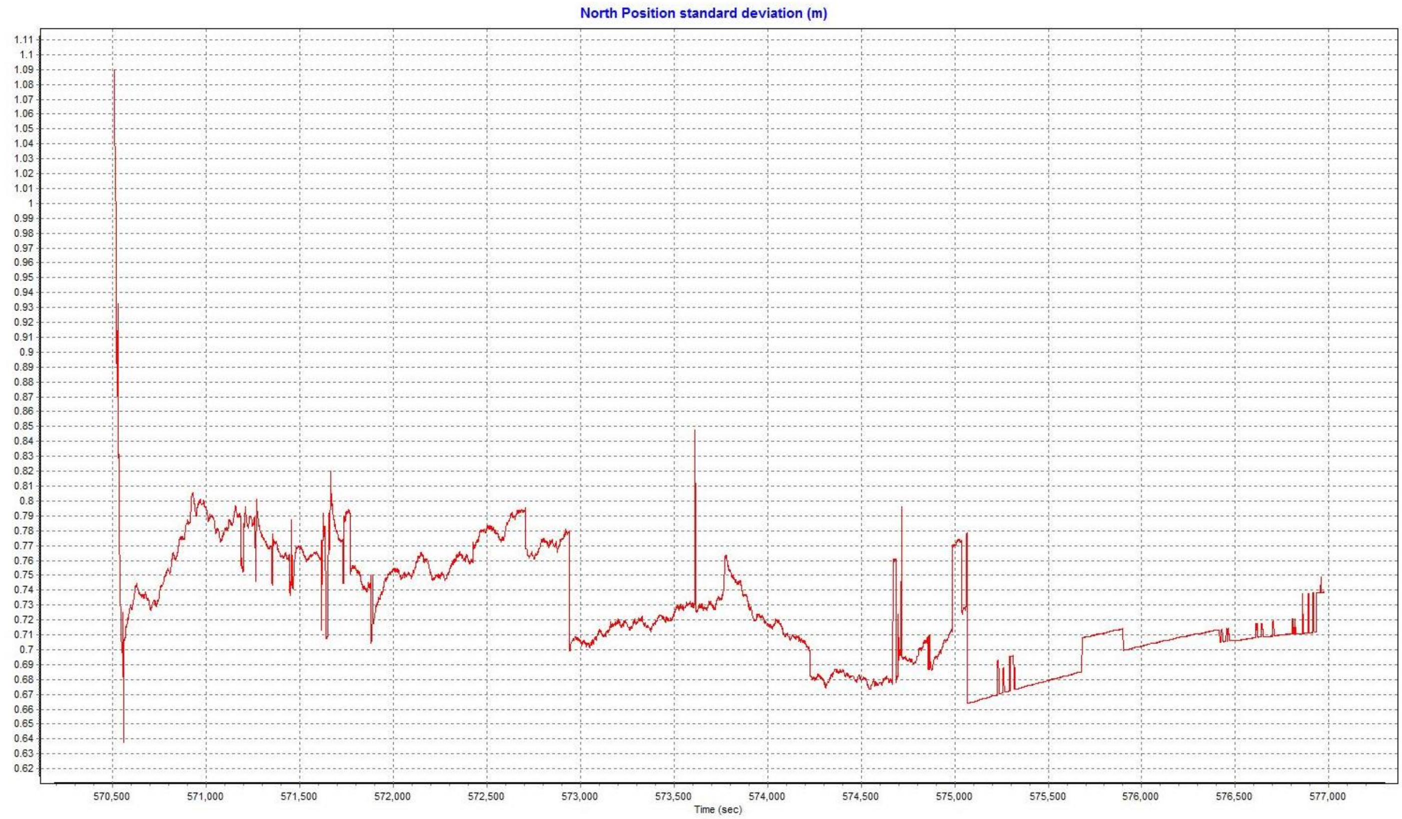


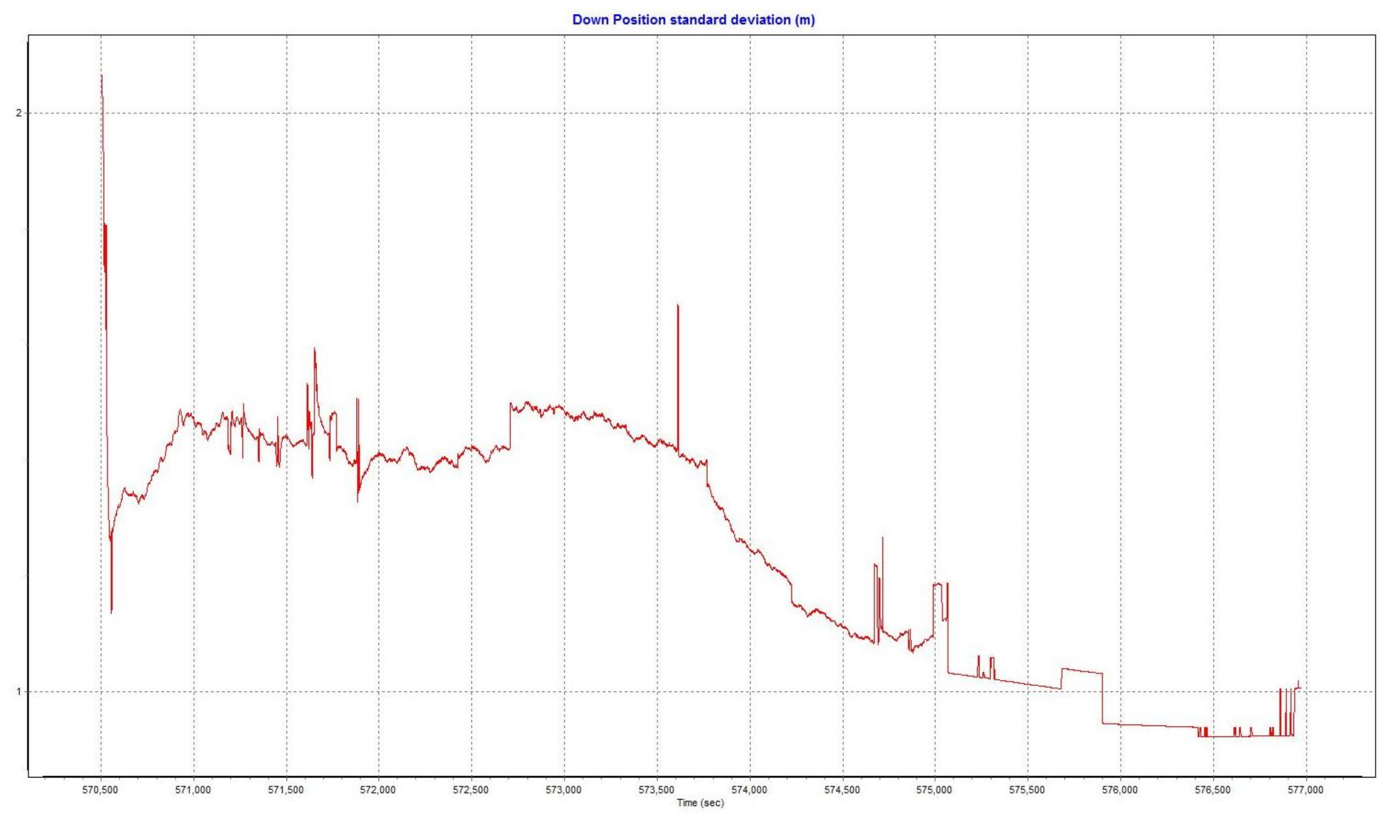




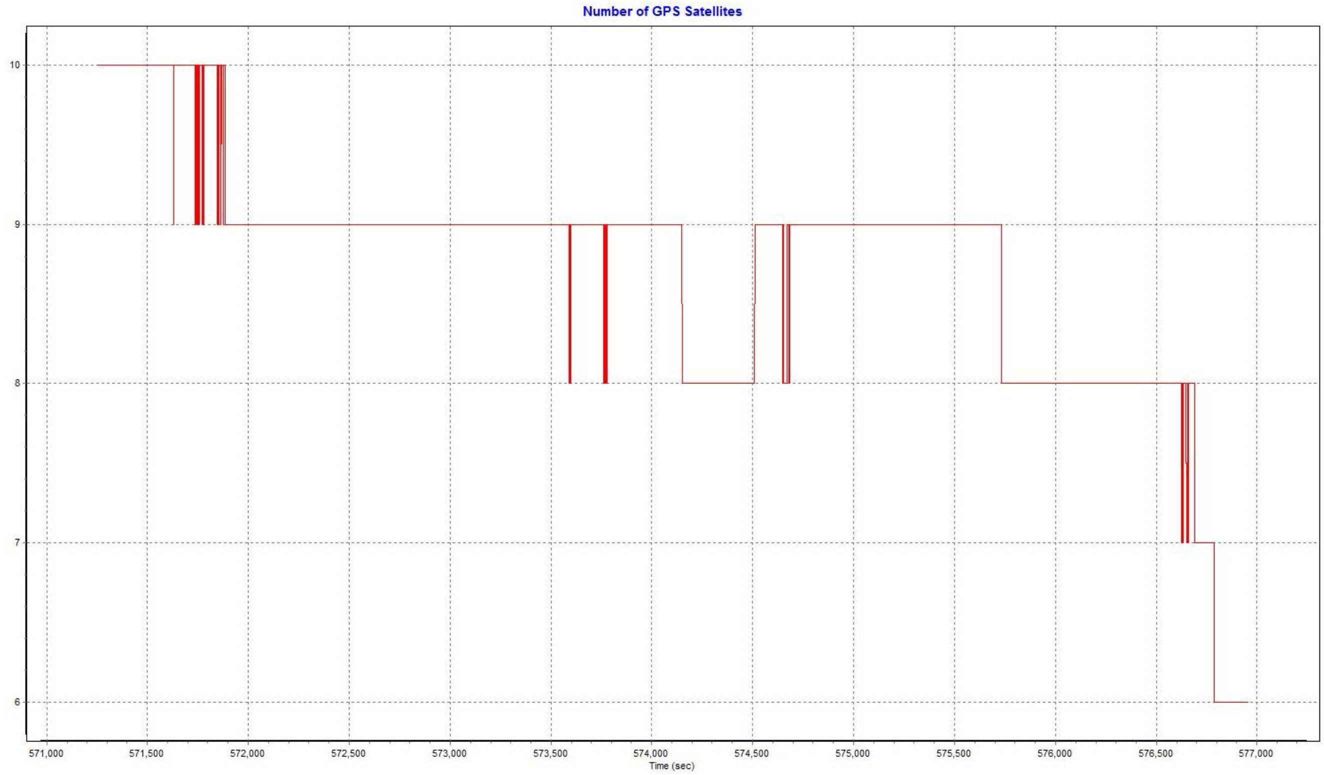
Estimated Position Accuracy: The Estimated Position Accuracy plot shows the standard deviations of the east, north, and up directions versus time for the solution.

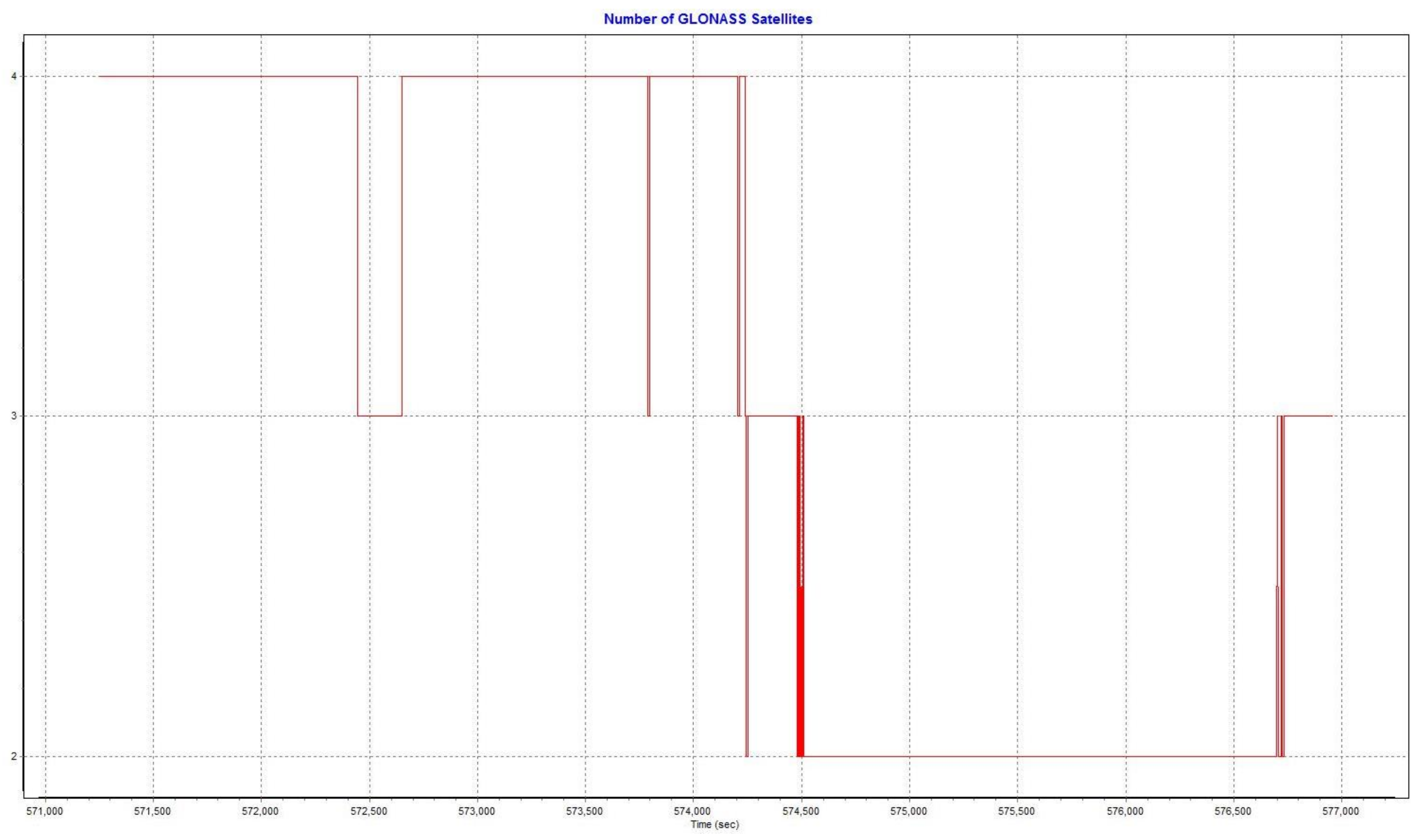



North Position standard deviation (m)
Time (sec)
570,500
571,000
571,500
572,000
572,500
573,000
573,500
574,000
574,500
575,000
575,500
576,000
576,500
577,000


Down Position standard deviation (m)
2
1
Time (sec)
570,500
571,000
571,500
572,000
572,500
573,000
573,500
574,000
574,500
575,000
575,500
576,000
576,500
577,000

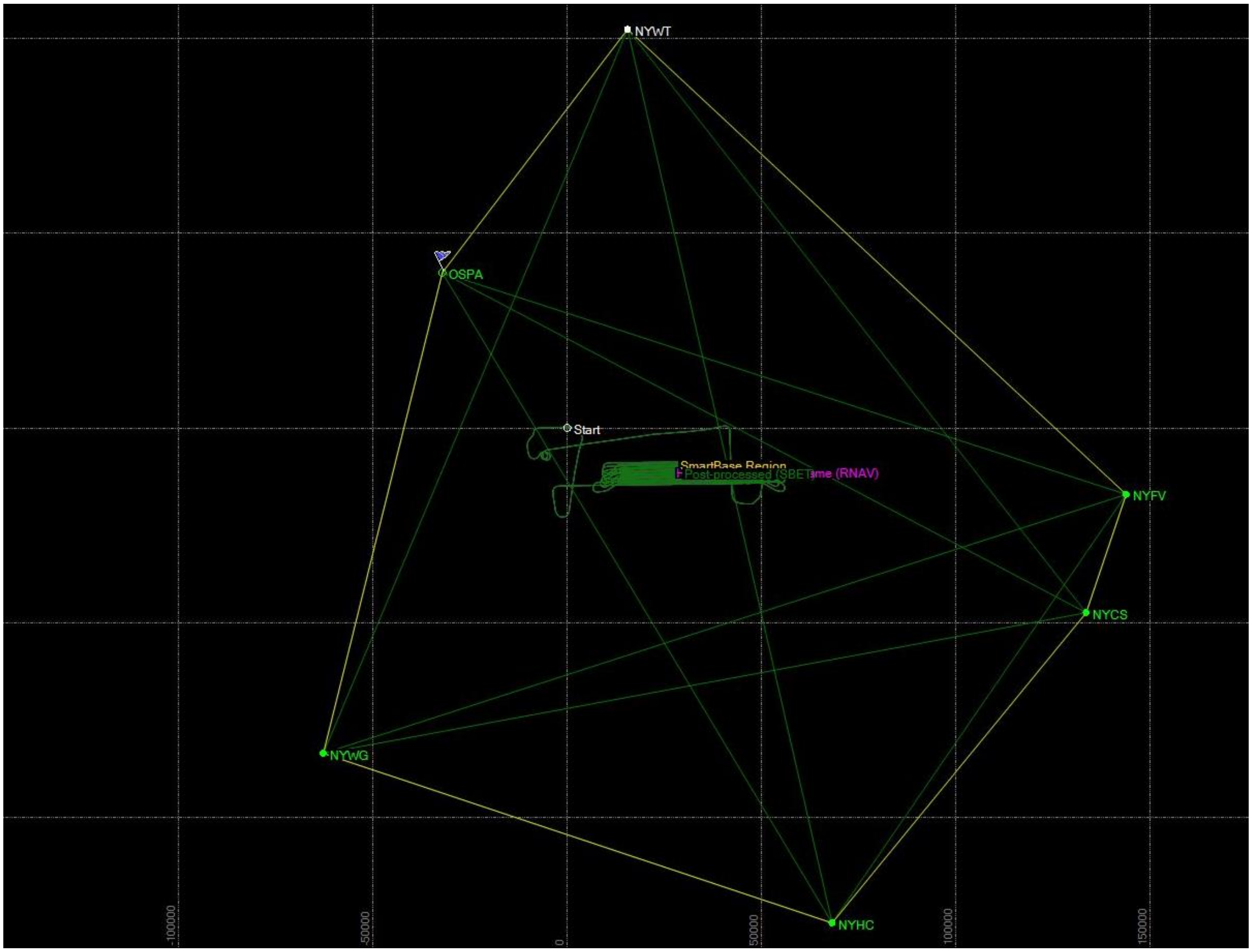
Number of Satellites: Plots the number of satellites used in the solution as a function of time. The number of GPS satellites, GLONASS satellites and the total number of satellites are distinguished with separate lines.

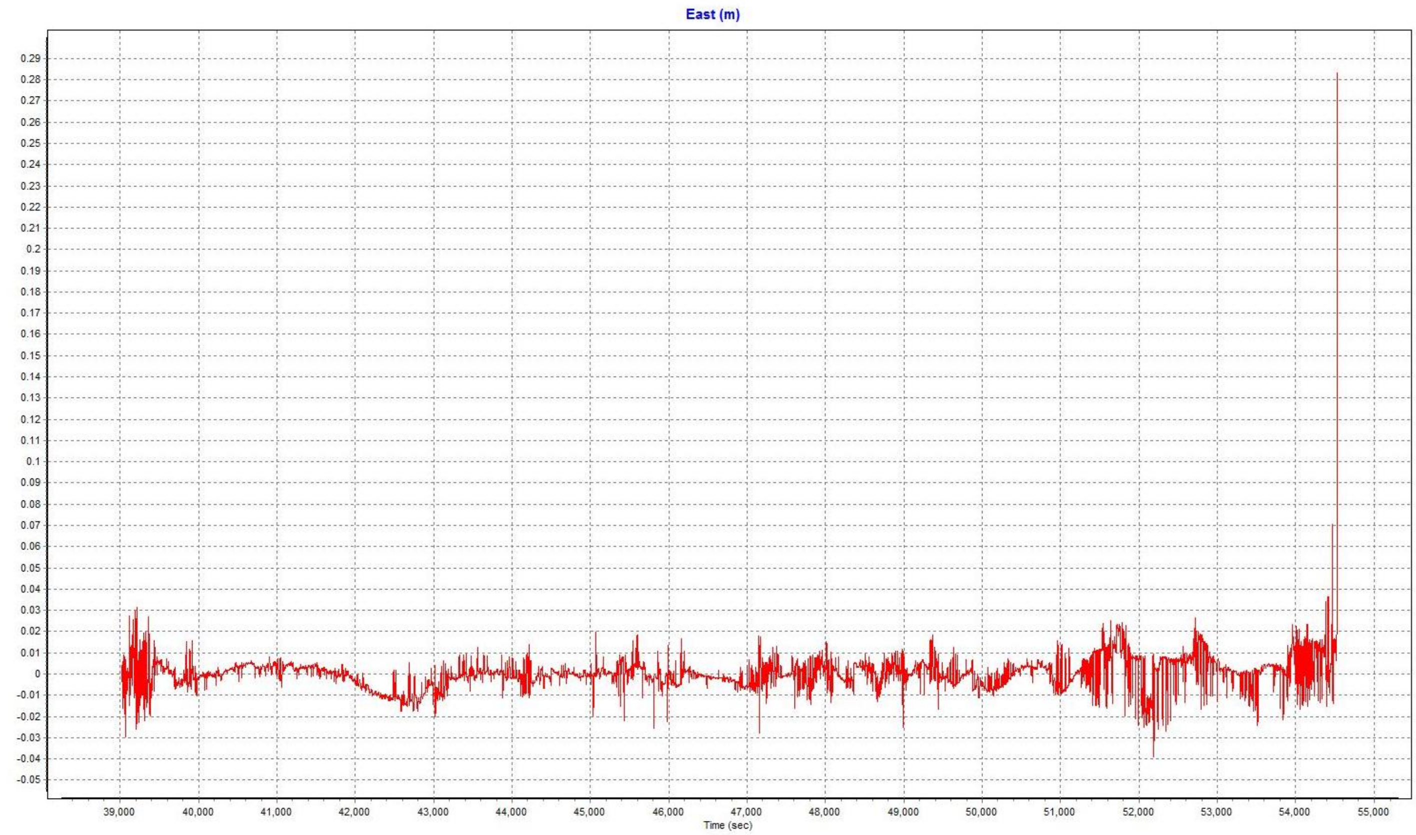


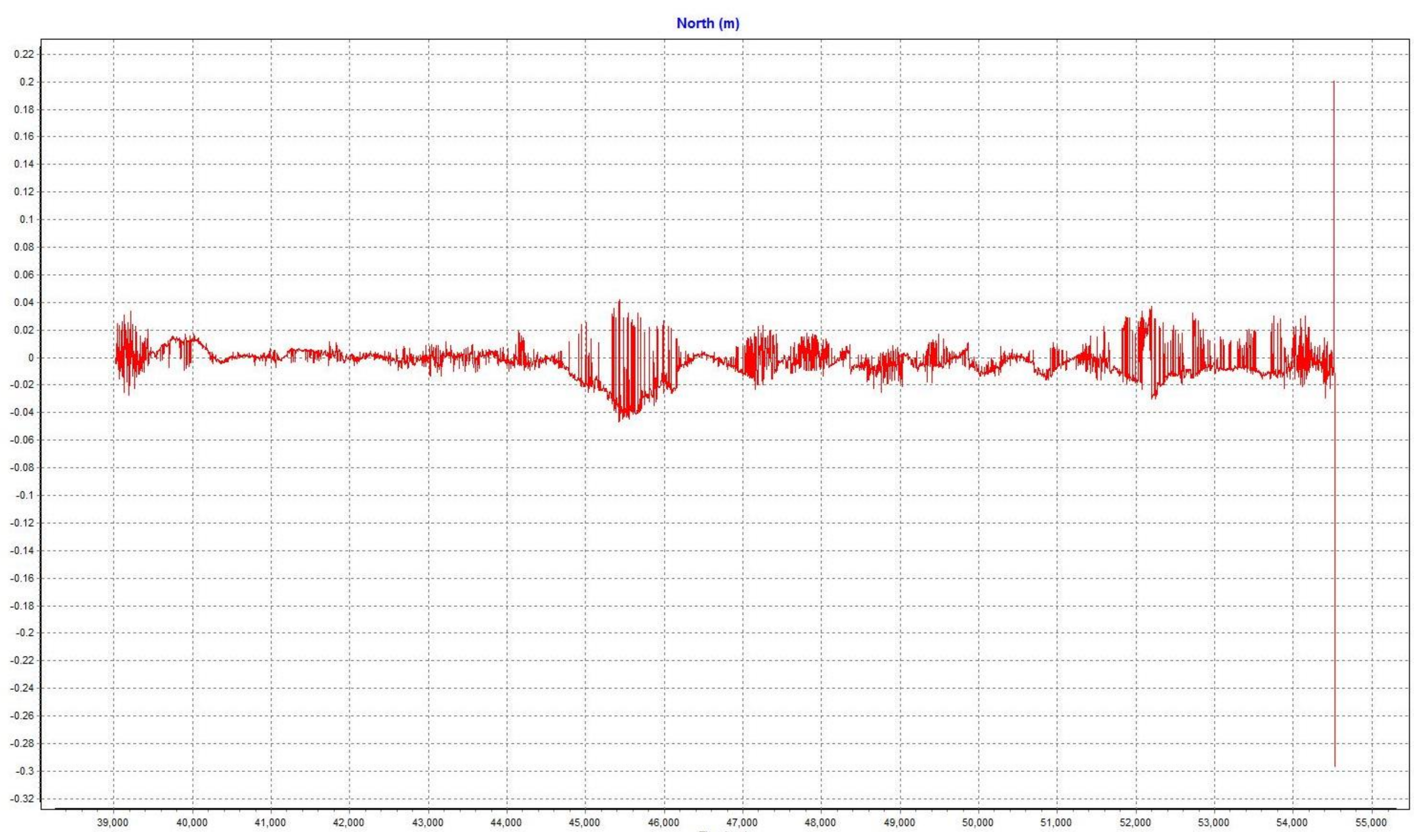


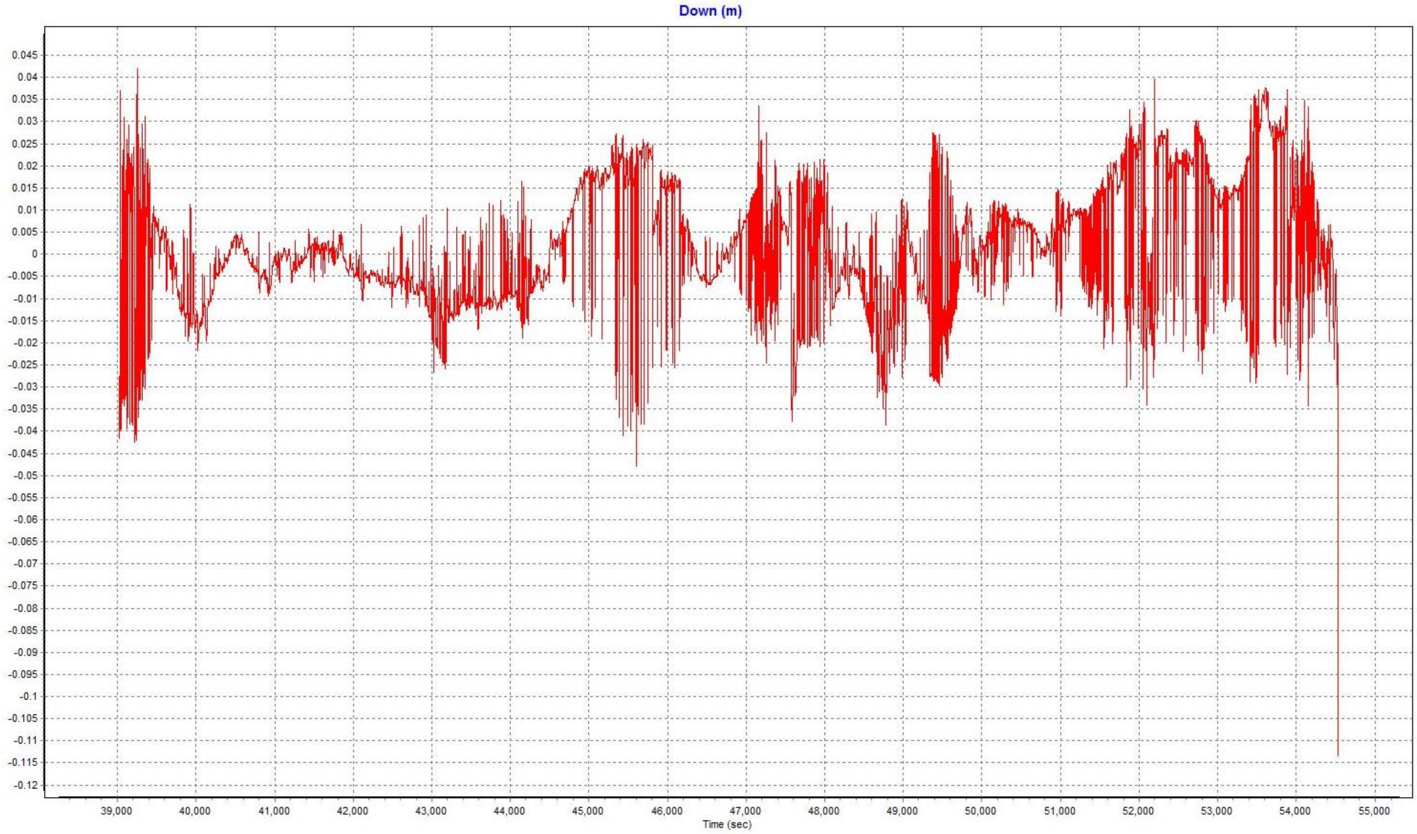
PDOP: PDOP is a unit less number which indicates how favorable the satellite geometry is to 3D positioning accuracy. A strong satellite geometry, where the PDOP is low, occurs when satellites are well distributed in each direction (north, south, east and west) as well as directly overhead. Values in 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.

04/19/2015

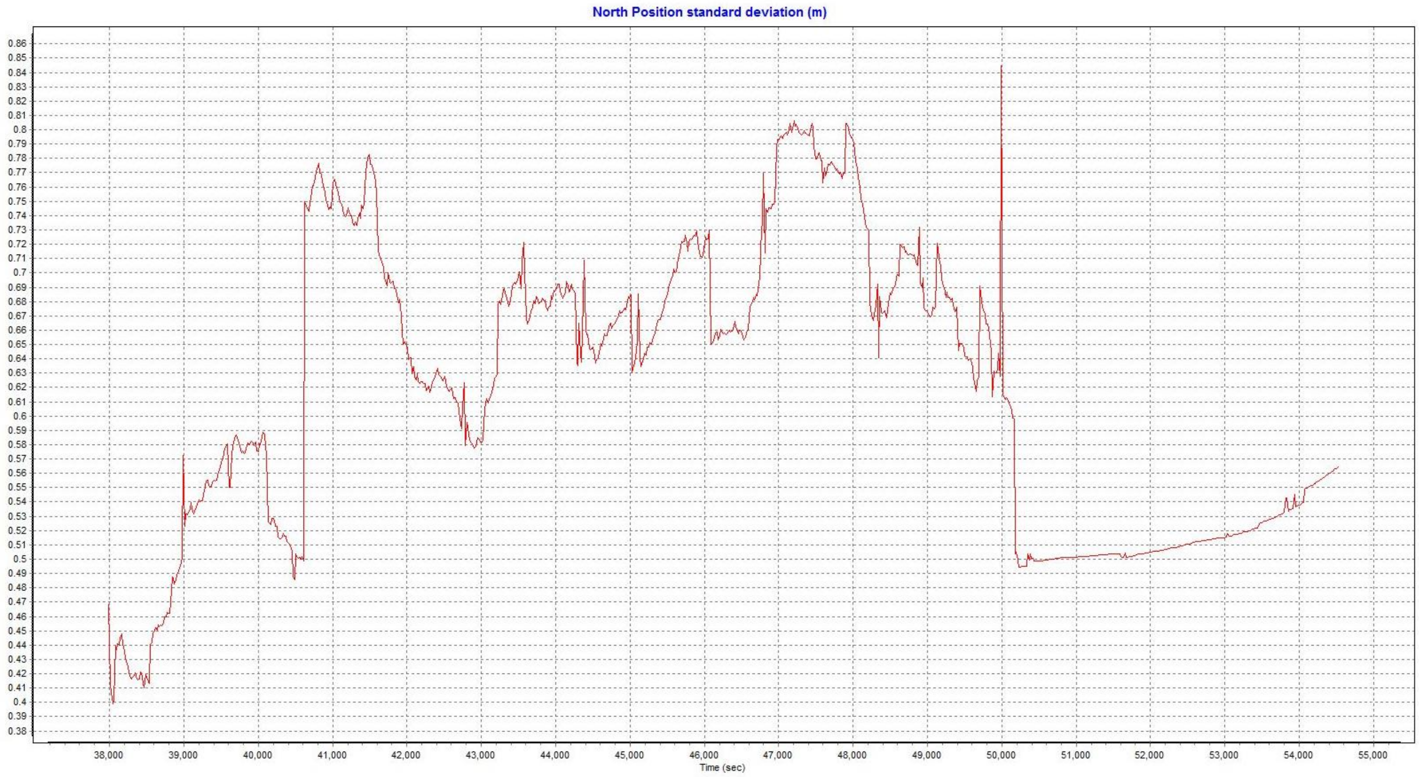

NYWT
OSPA
Start
SmartBase Region
Post-processed (SBET)
(RNAV)
NYFV
NYCS
NYWG
NYHC
-100000
-50000
0
50000
100000
150000

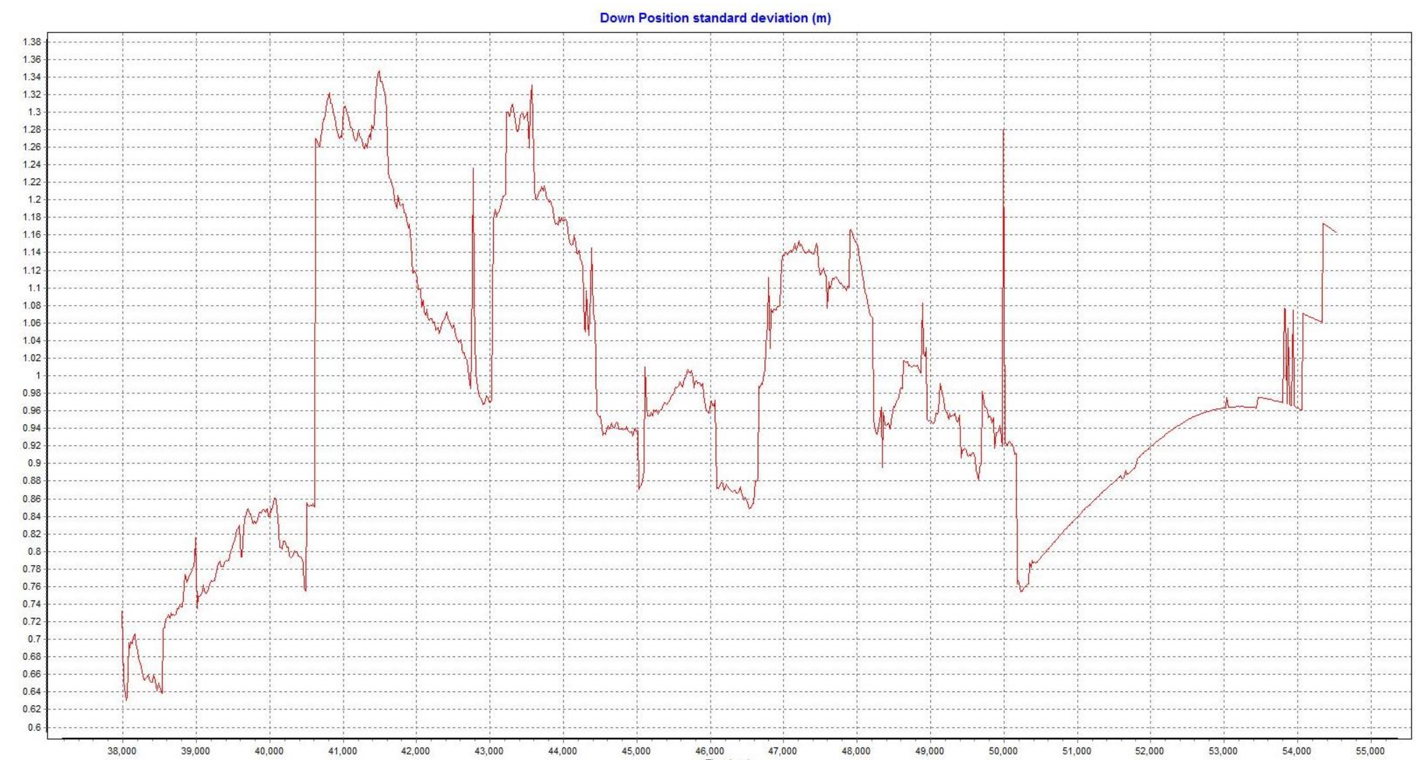

East (m)
Time (sec)

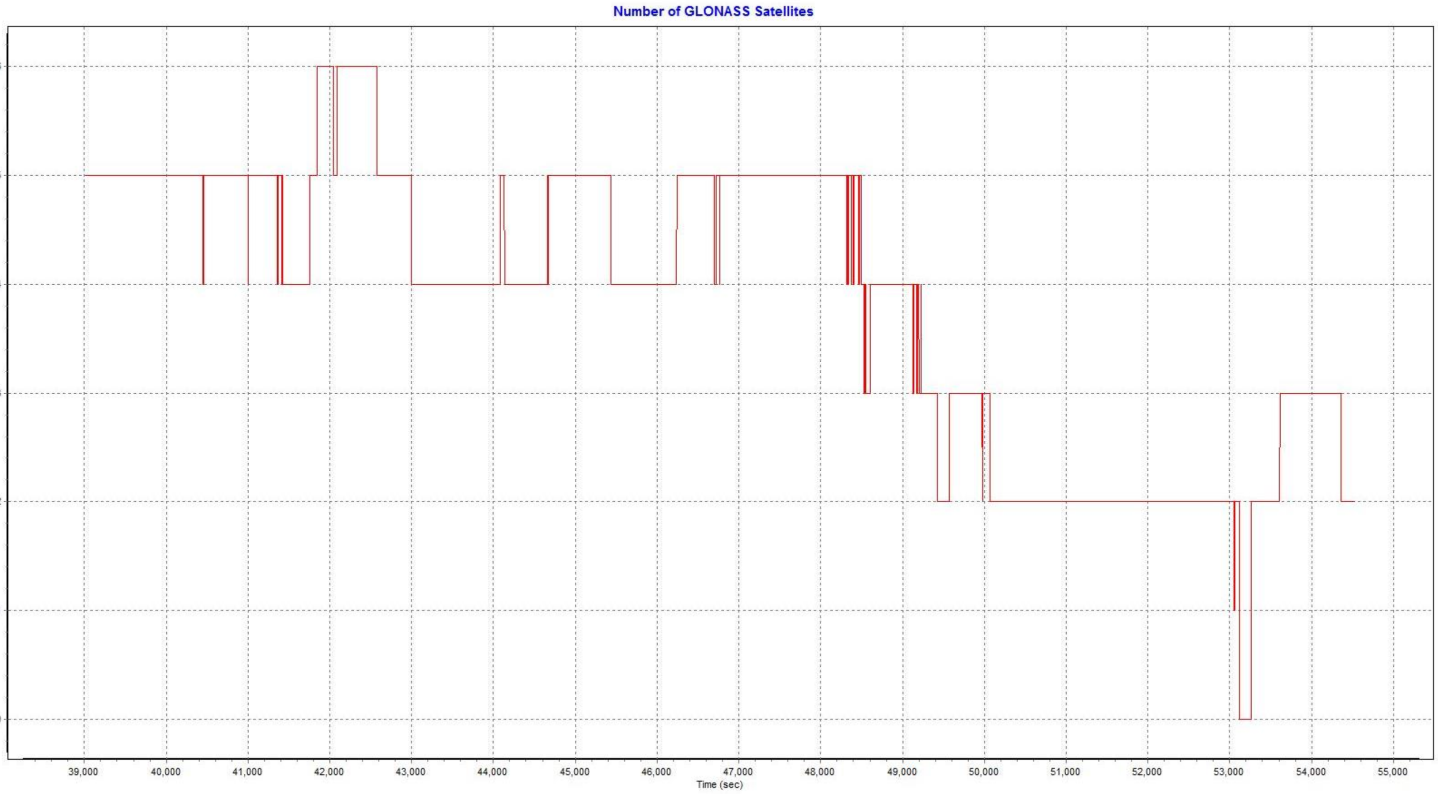

North (m)
Time (sec)

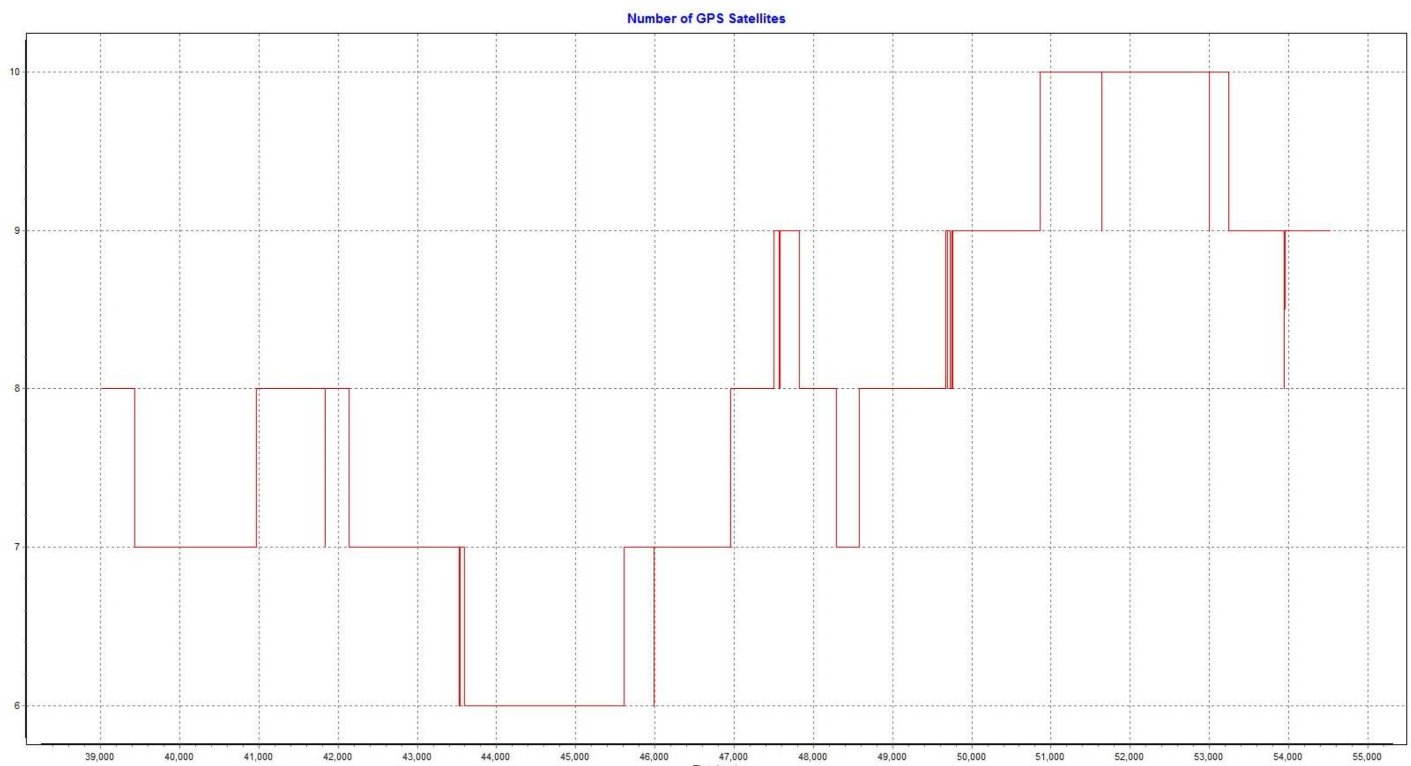

Down (m)
Time (sec)

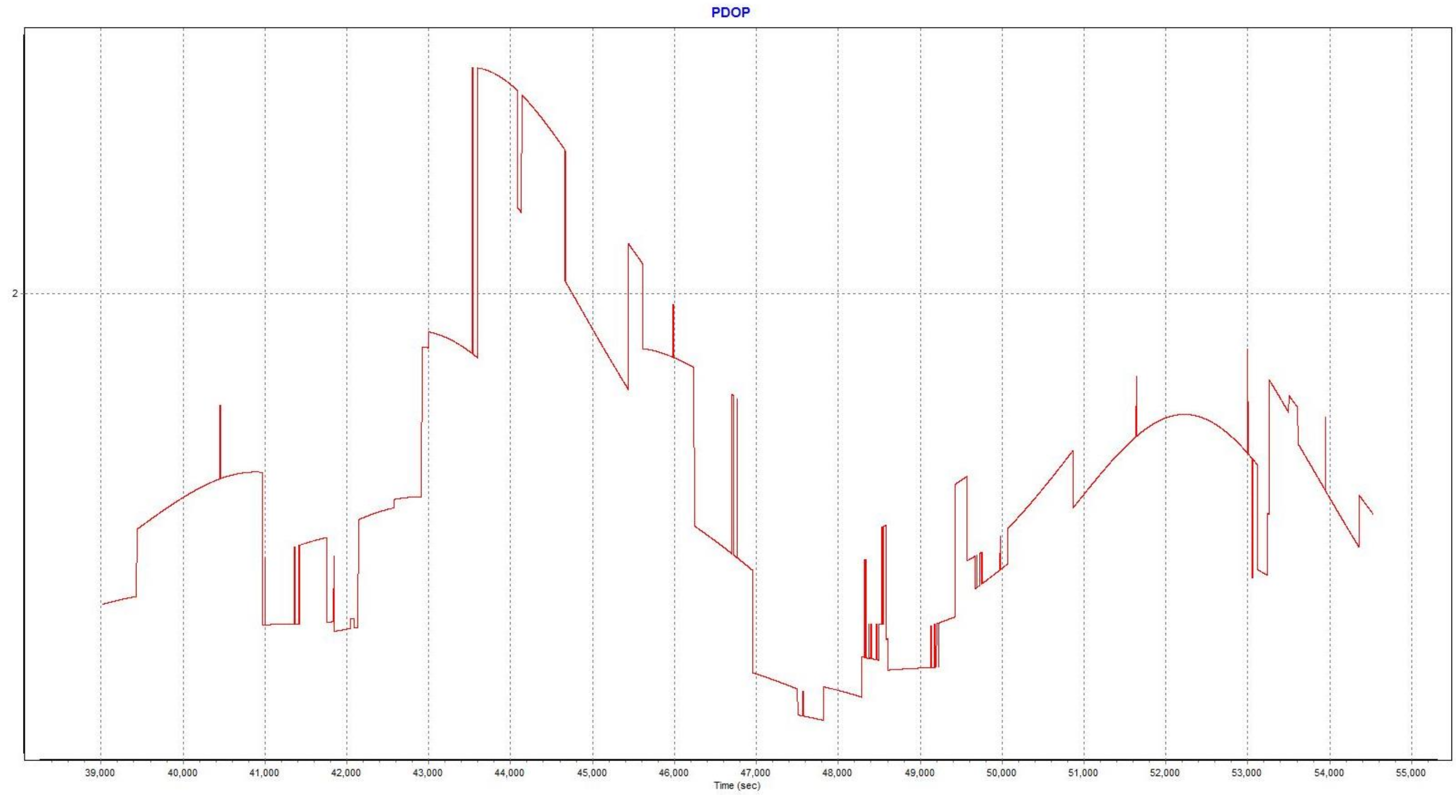

East Position standard deviation (m)
Time (sec)


North Position standard deviation (m)
Time (sec)
38,000
39,000
40,000
41,000
42,000
43,000
44,000
45,000
46,000
47,000
48,000
49,000
50,000
51,000
52,000
53,000
54,000
55,000

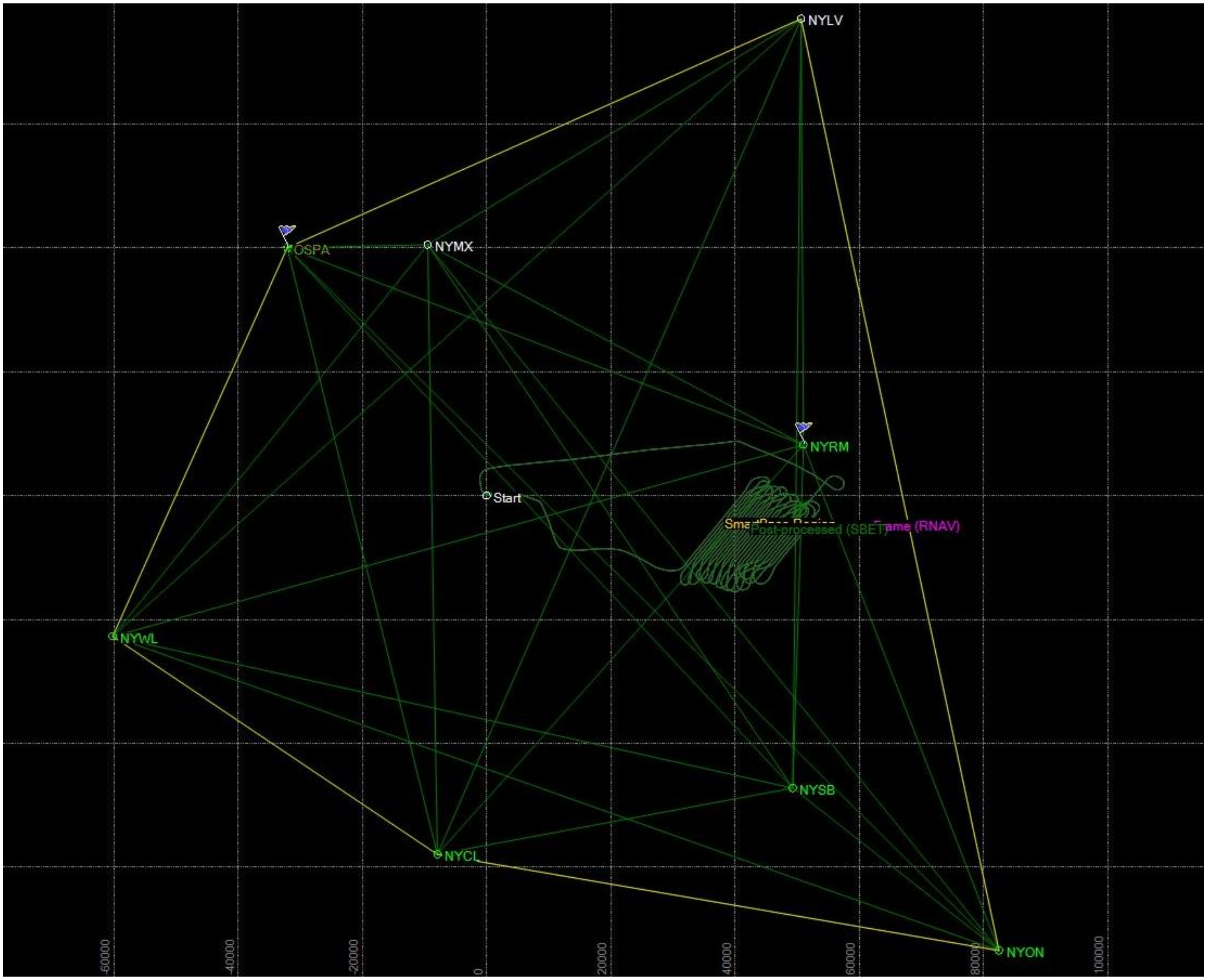

Down Position standard deviation (m)
Time (sec)
38,000
39,000
40,000
41,000
42,000
43,000
44,000
45,000
46,000
47,000
48,000
49,000
50,000
51,000
52,000
53,000
54,000
55,000

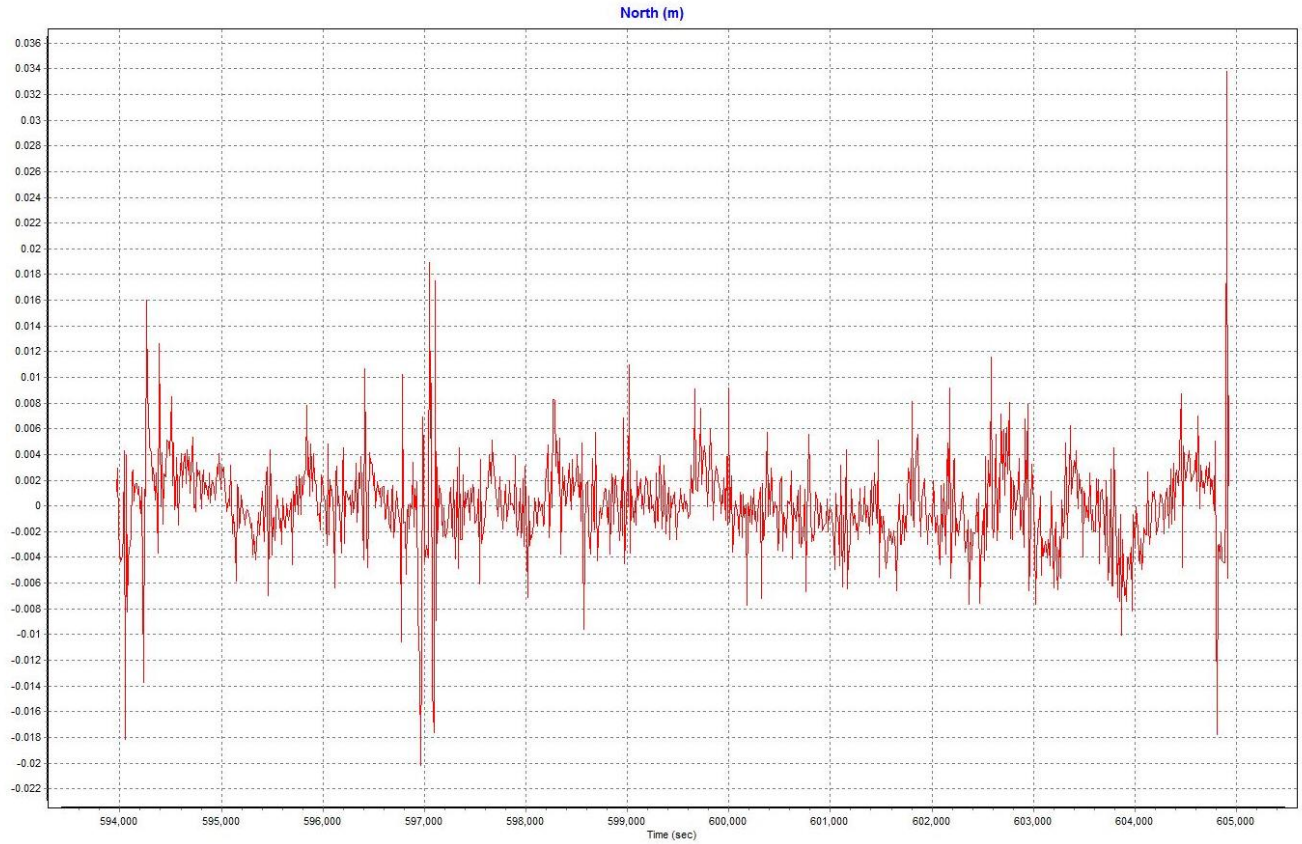

Number of GLONASS Satellites
6
5
4
3
2
1
0
39,000
40,000
41,000
42,000
43,000
44,000
45,000
46,000
47,000
48,000
49,000
50,000
51,000
52,000
53,000
54,000
55,000
Time (sec)

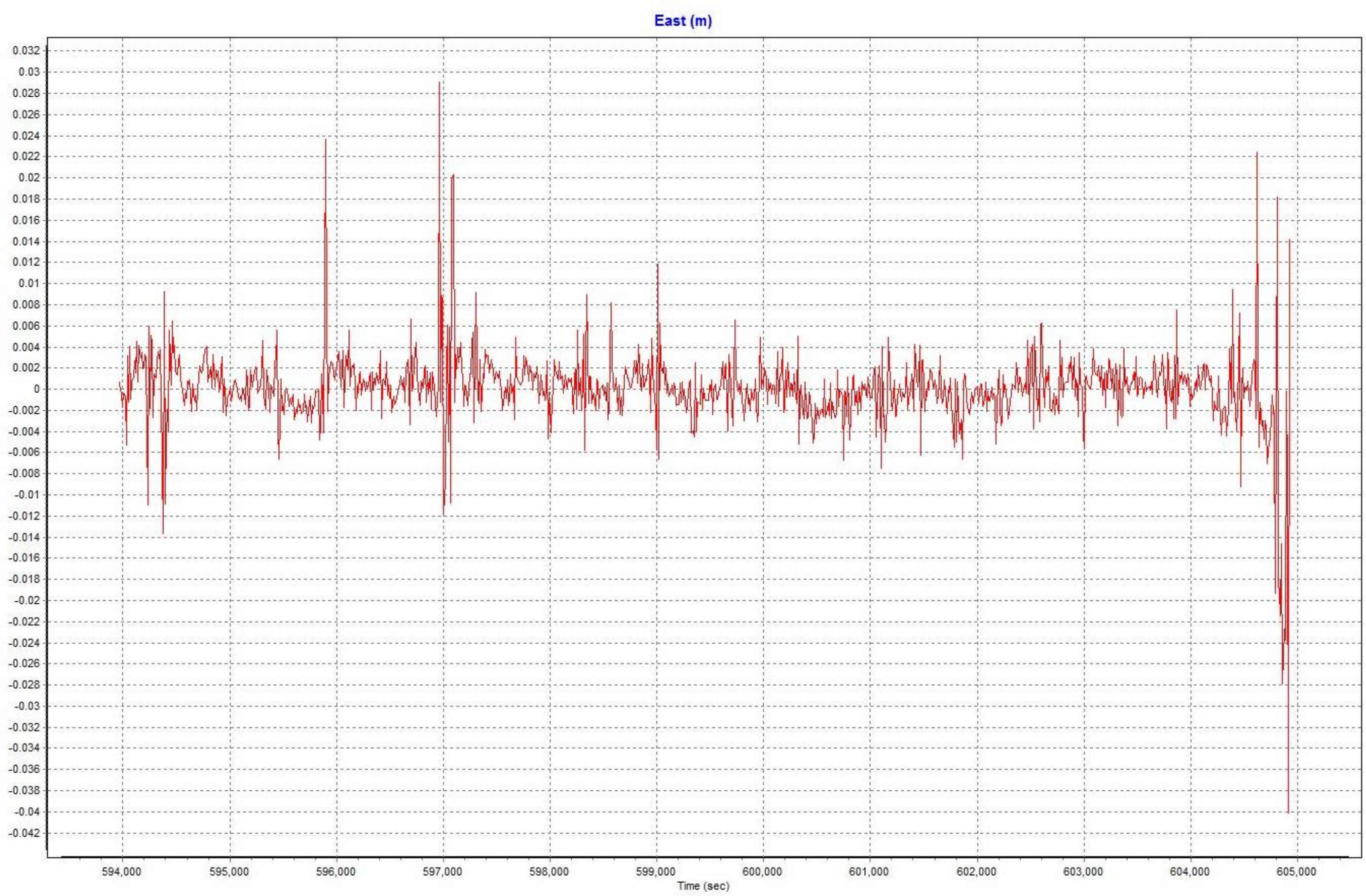

Number of GPS Satellites
10
9
8
7
6
39,000
40,000
41,000
42,000
43,000
44,000
45,000
46,000
47,000
48,000
49,000
50,000
51,000
52,000
53,000
54,000
55,000
Time (sec)

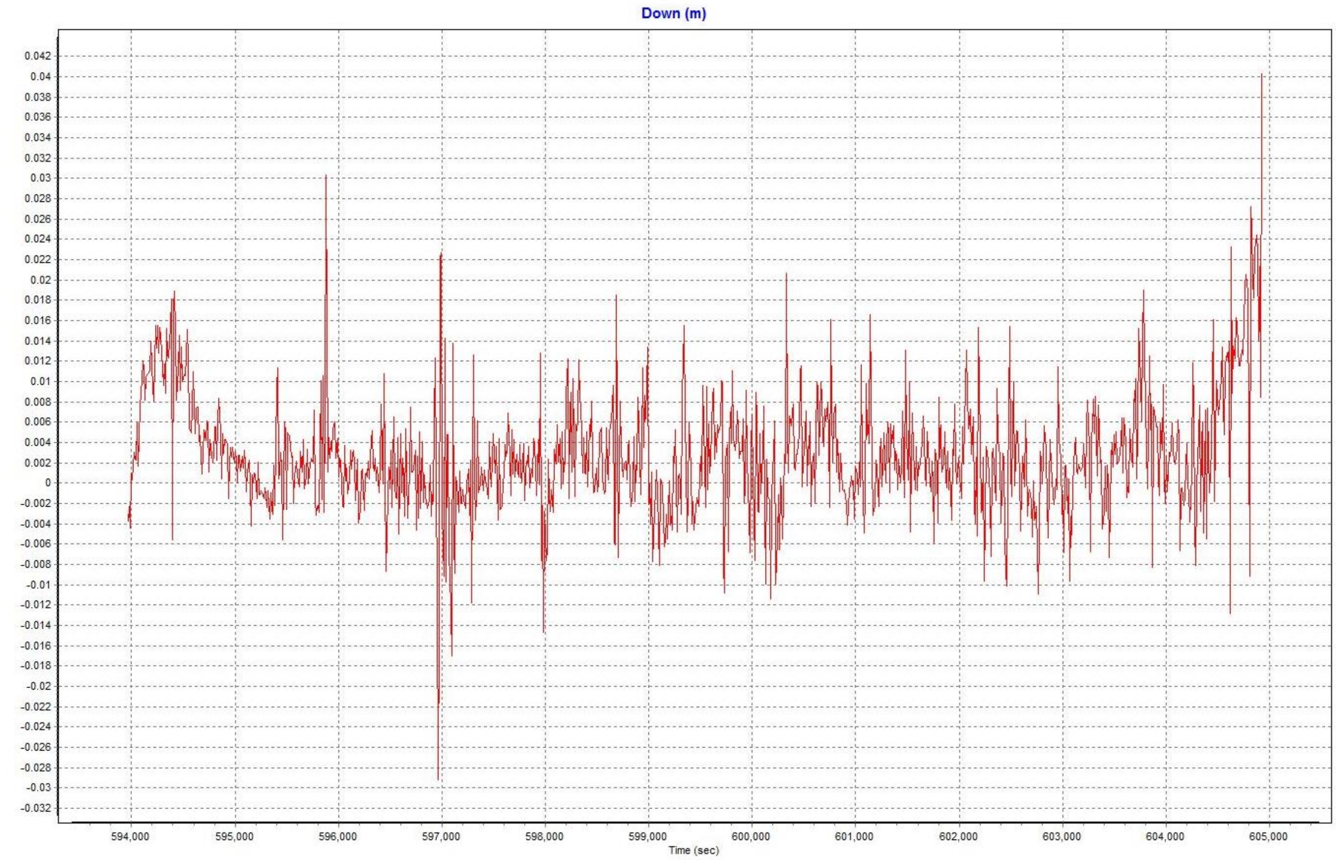

PDOP
2
39,000
40,000
41,000
42,000
43,000
44,000
45,000
46,000
47,000
48,000
49,000
50,000
51,000
52,000
53,000
54,000
55,000
Time (sec)

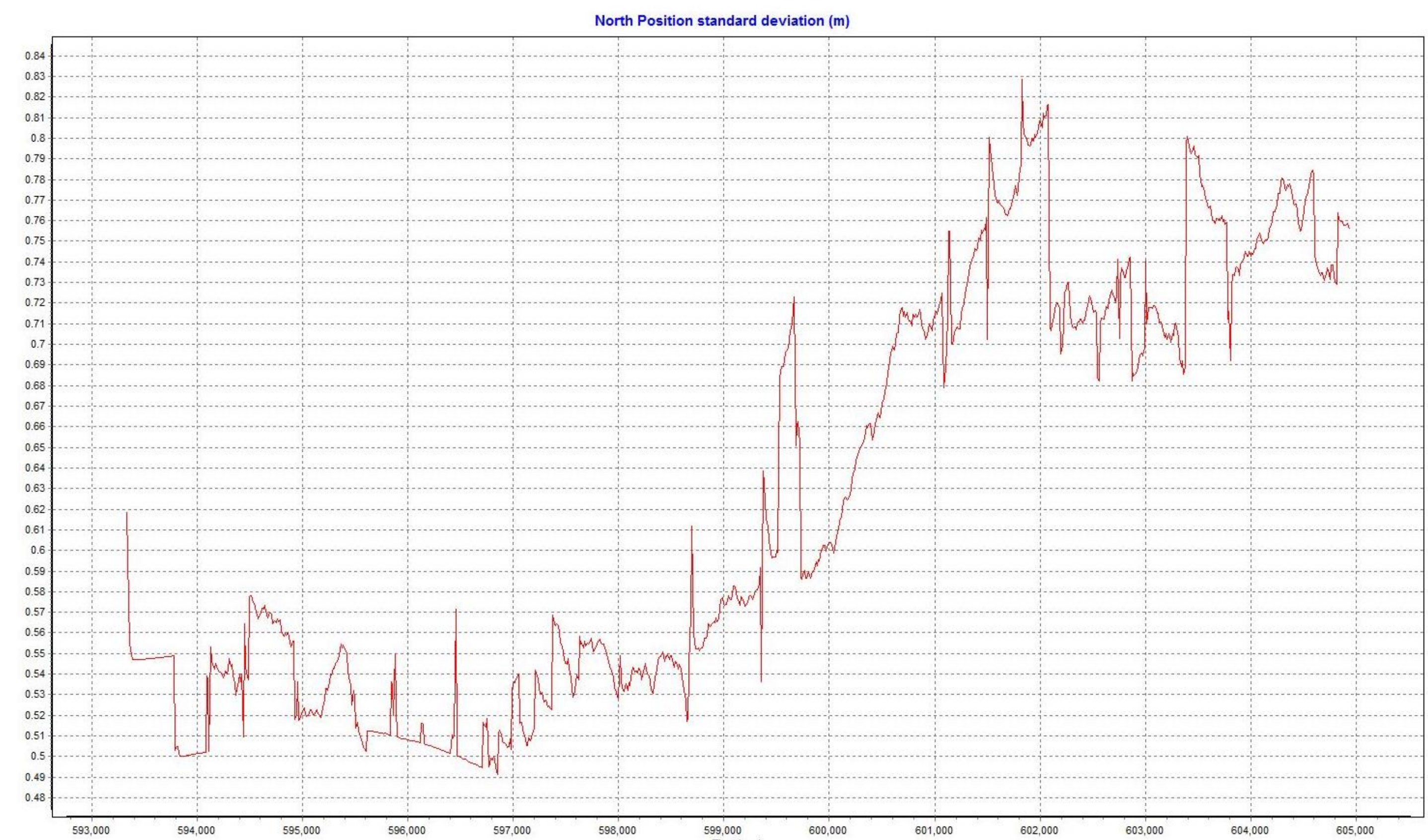
04/25/2015

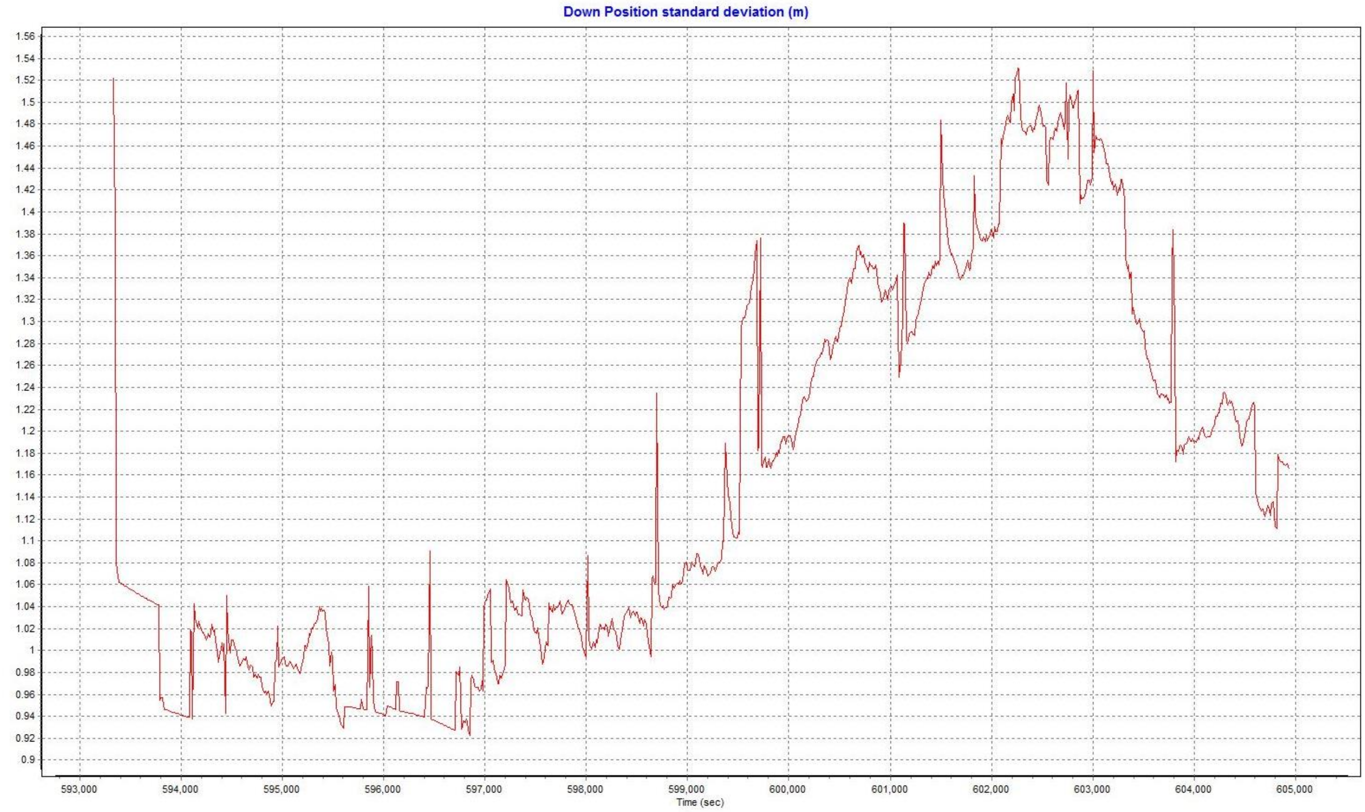

NYLV
OSPA
NYMX
NYRM
Start
Post-processed (SBET)
(RNAV)
NYWL
NYSB
NYCL
NYON
-60000
-40000
-20000
0
20000
40000
60000
80000
100000

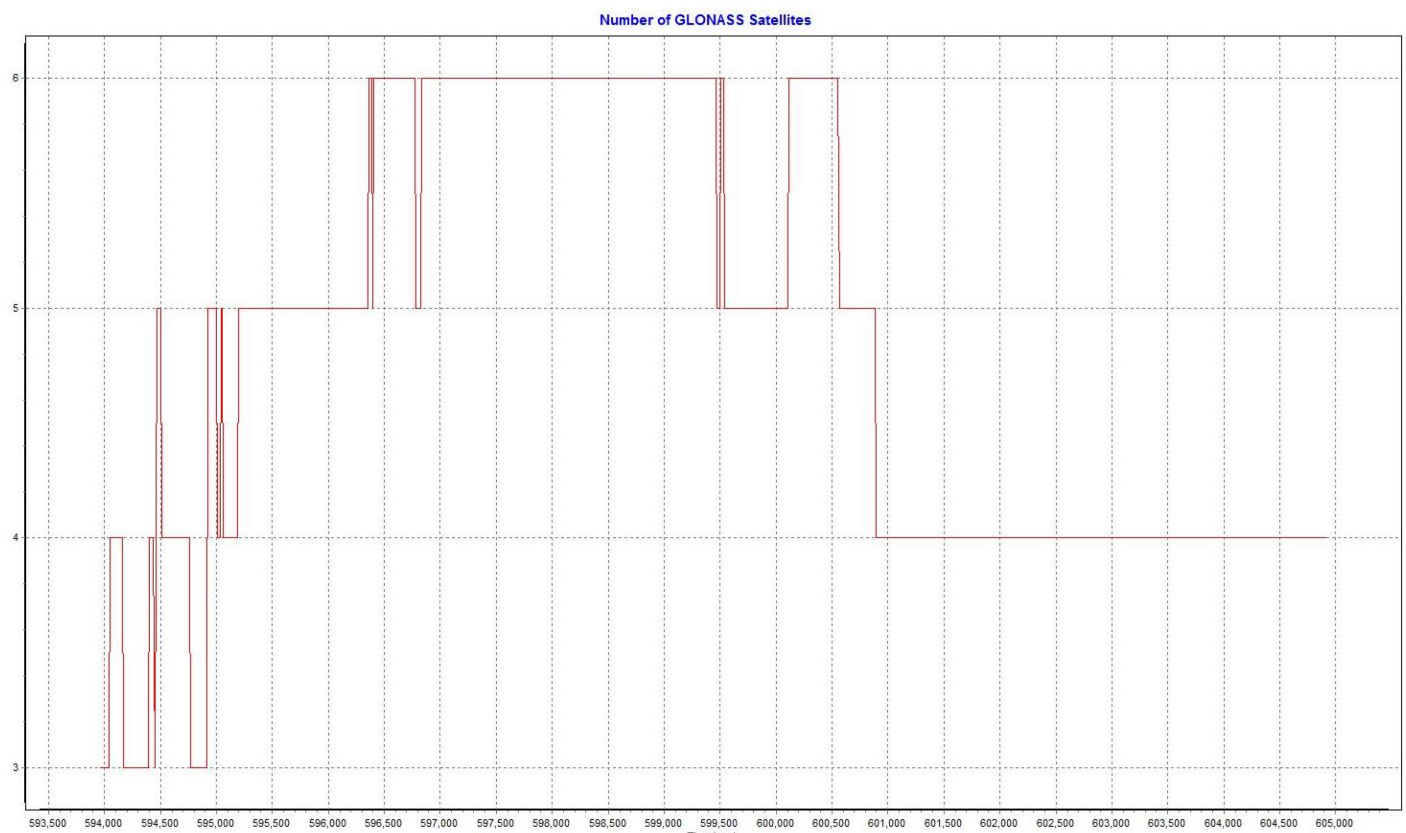

North (m)
Time (sec)

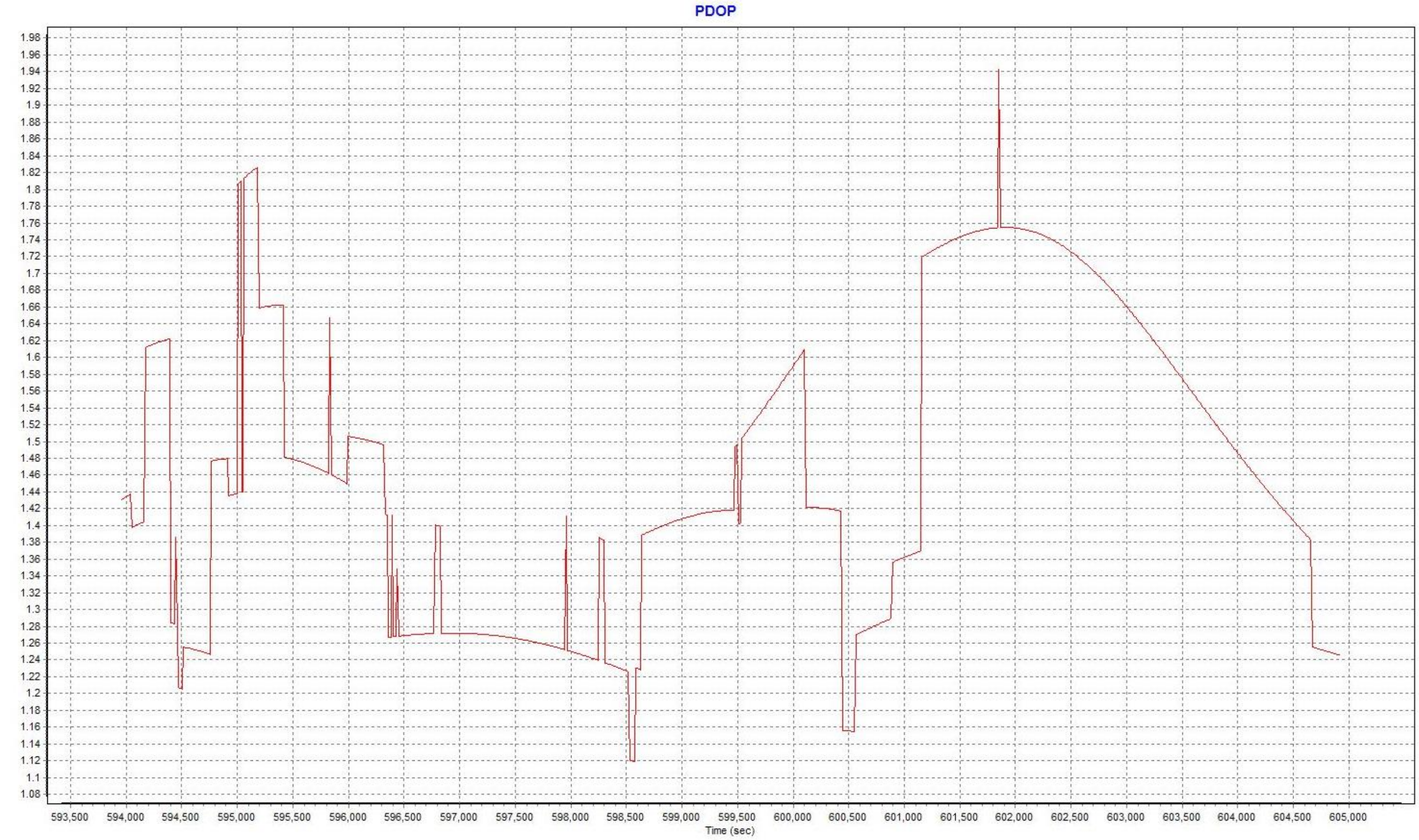

East (m)
Time (sec)


Down (m)
Time (sec)

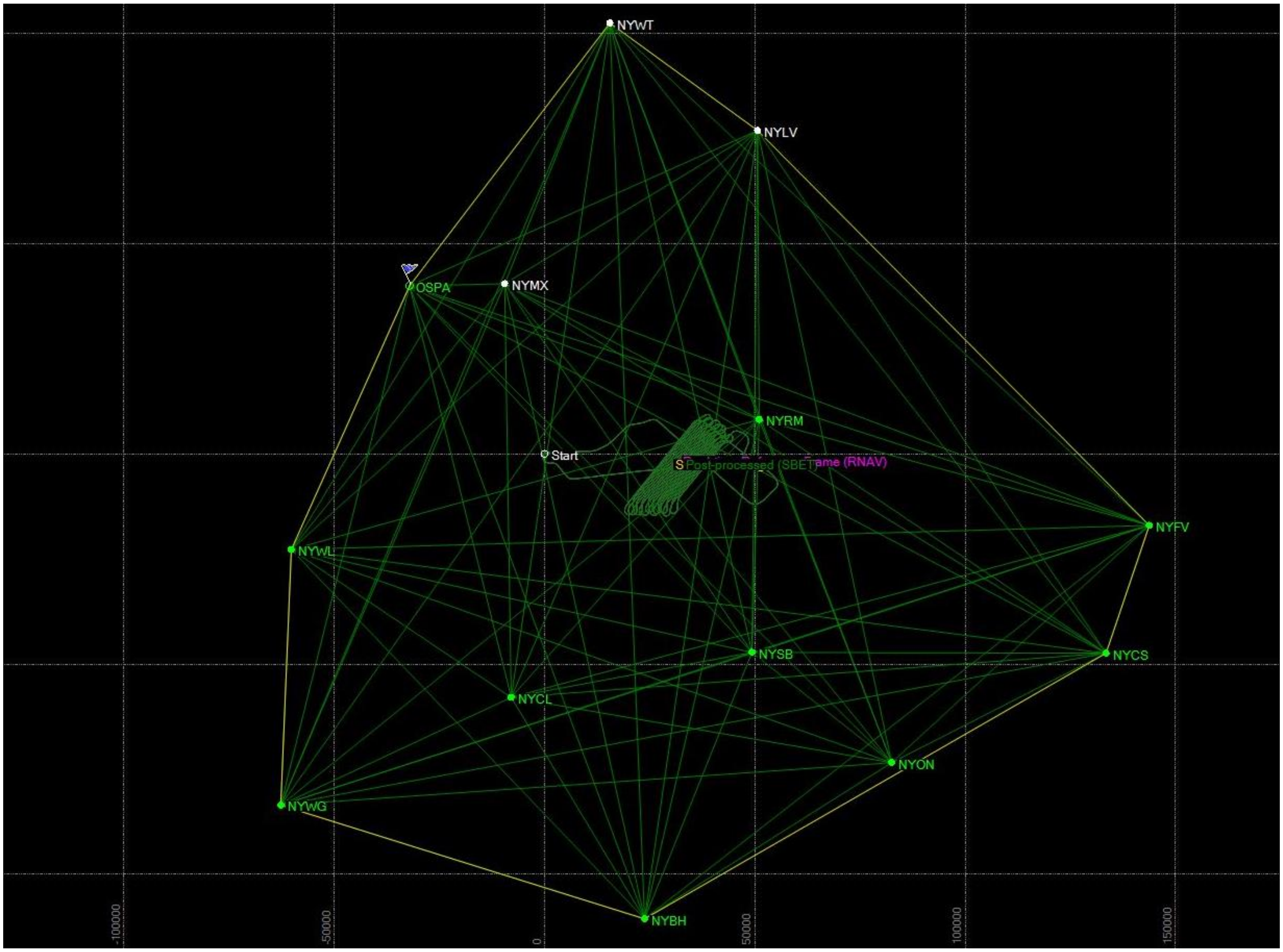

North Position standard deviation (m)
Time (sec)

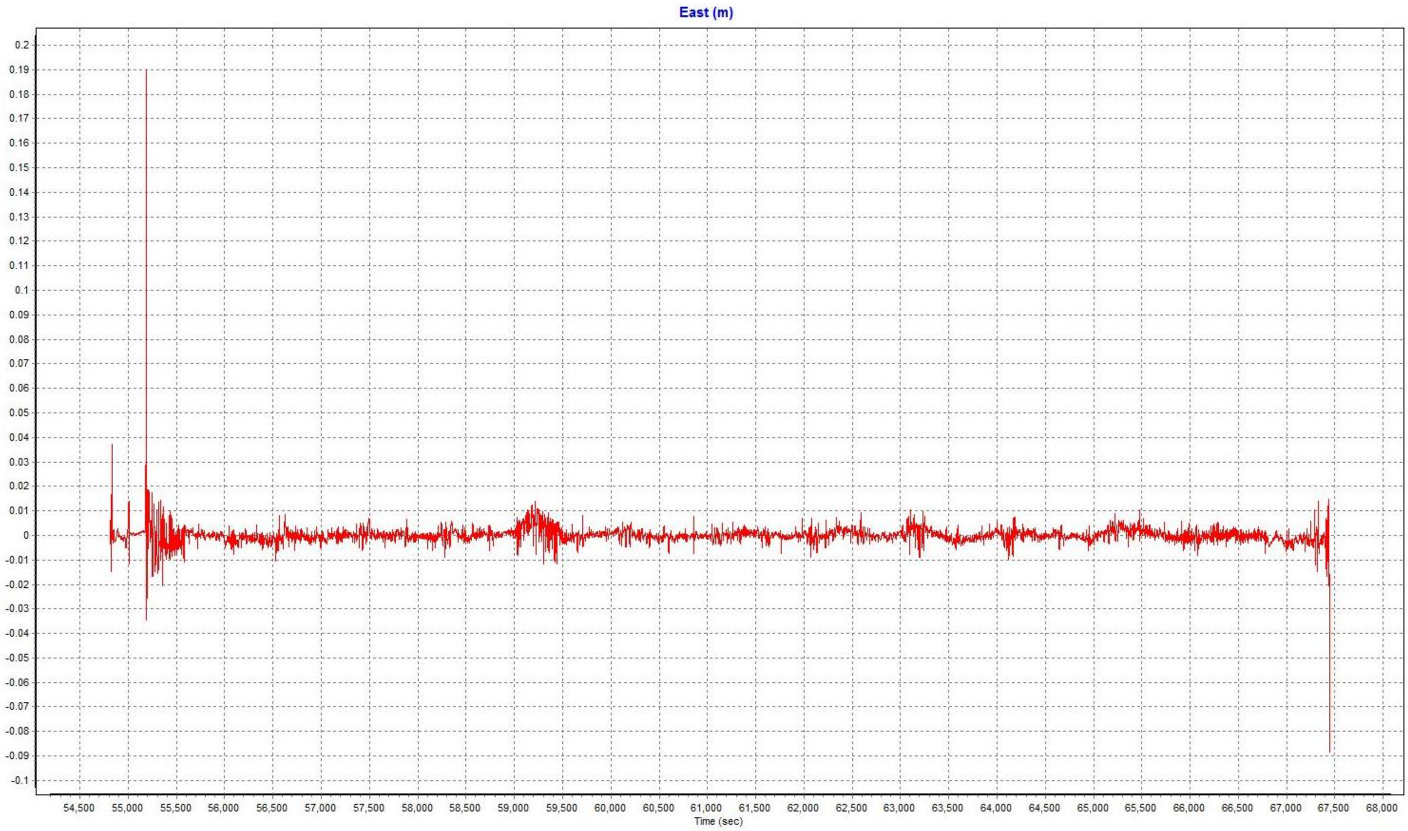

Down Position standard deviation (m)
Time (sec)

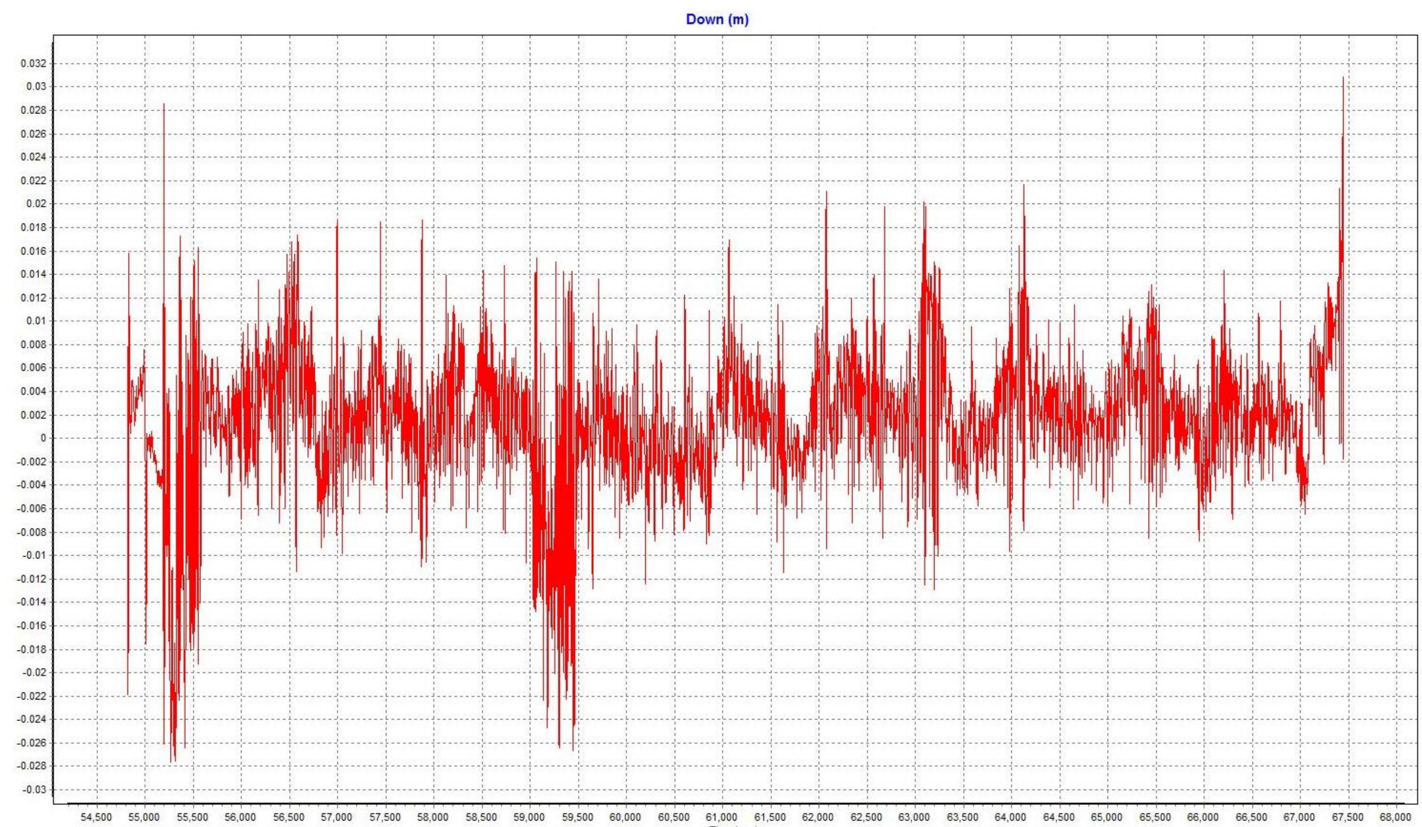

Number of GLONASS Satellites
Time (sec)

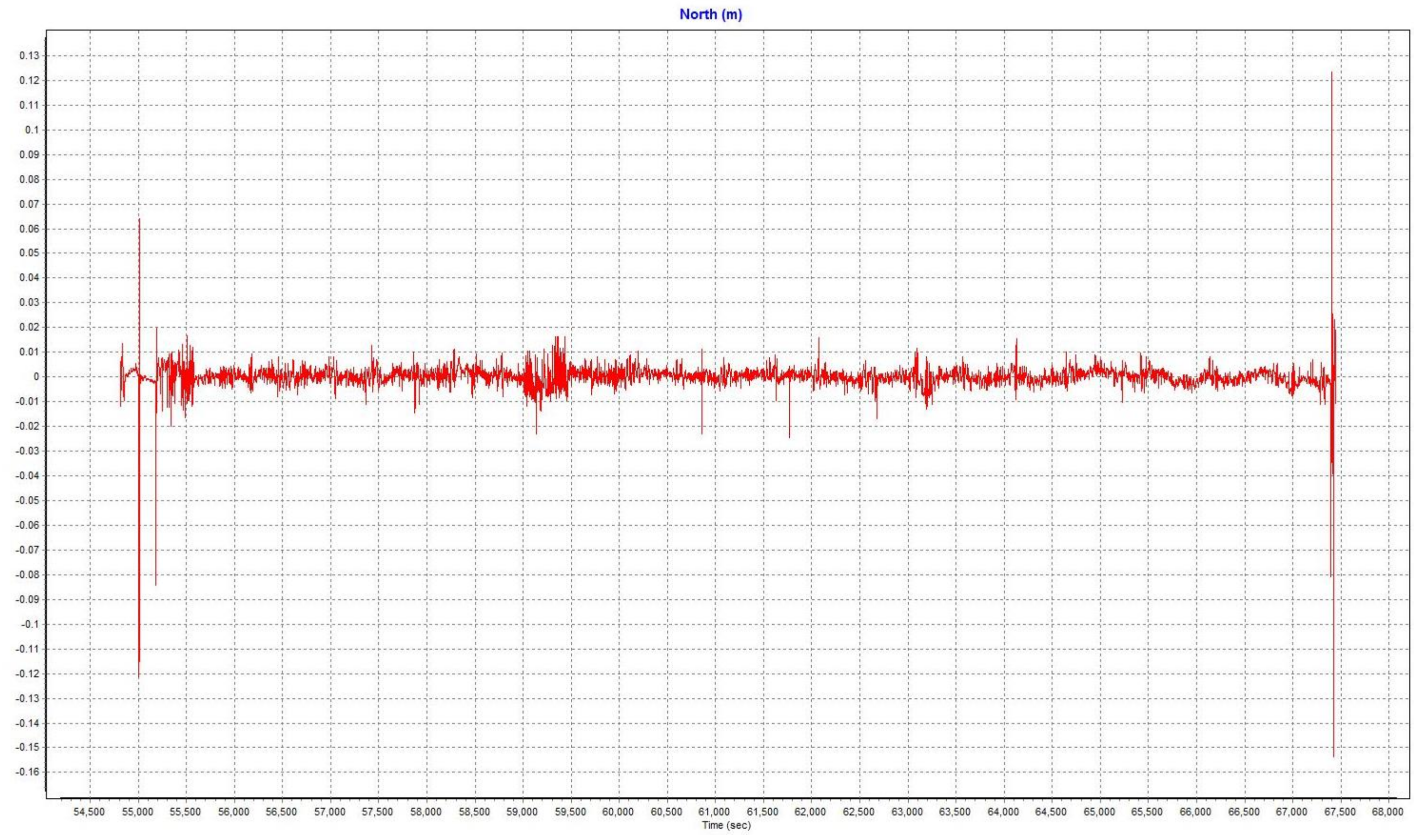

PDOP
1.98
1.96
1.94
1.92
1.9
1.88
1.86
1.84
1.82
1.8
1.78
1.76
1.74
1.72
1.7
1.68
1.66
1.64
1.62
1.6
1.58
1.56
1.54
1.52
1.5
1.48
1.46
1.44
1.42
1.4
1.38
1.36
1.34
1.32
1.3
1.28
1.26
1.24
1.22
1.2
1.18
1.16
1.14
1.12
1.1
1.08
593,500
594,000
594,500
595,000
595,500
596,000
596,500
597,000
597,500
598,000
598,500
599,000
599,500
600,000
600,500
601,000
601,500
602,000
602,500
603,000
603,500
604,000
604,500
605,000
Time (sec)

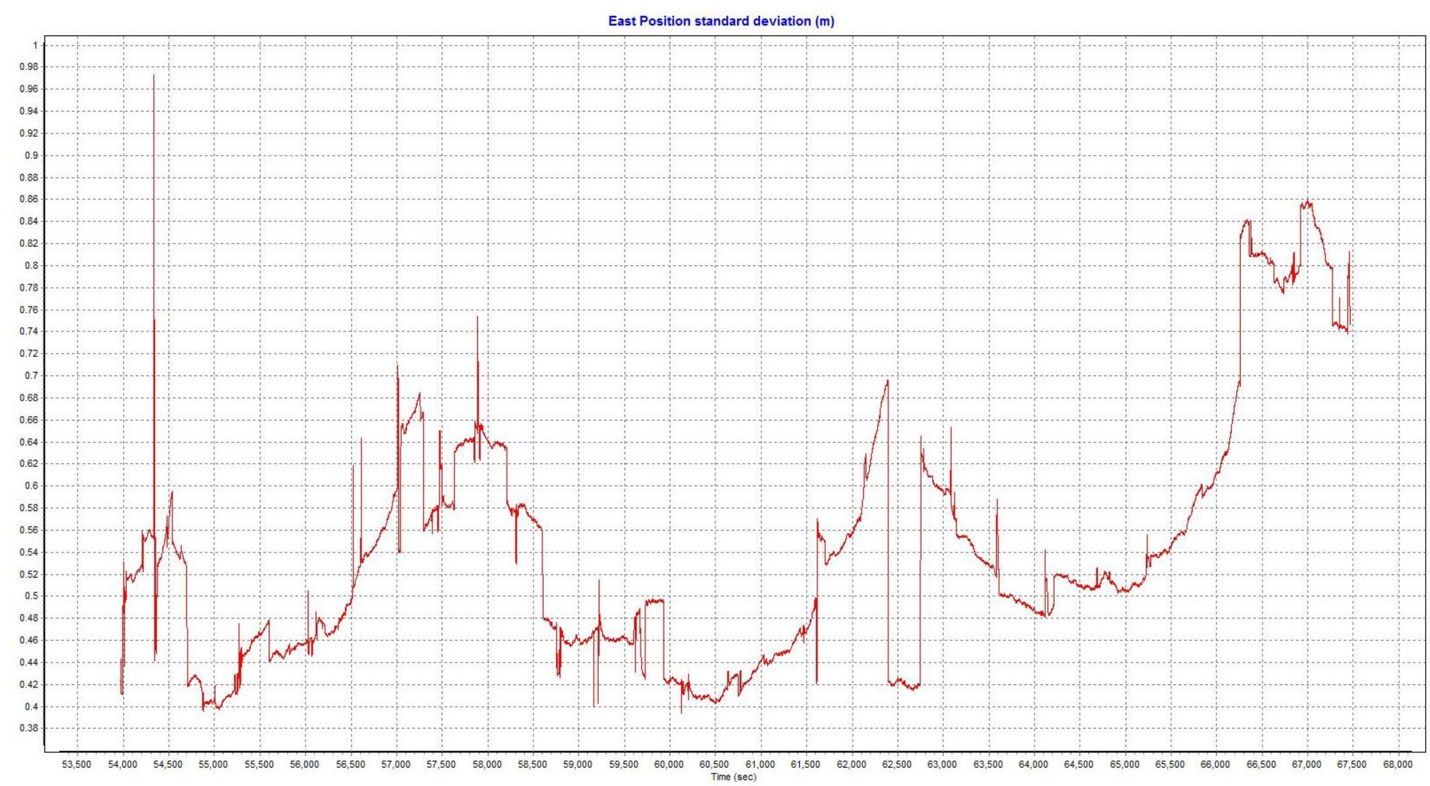
4-26-2015 Lift 1



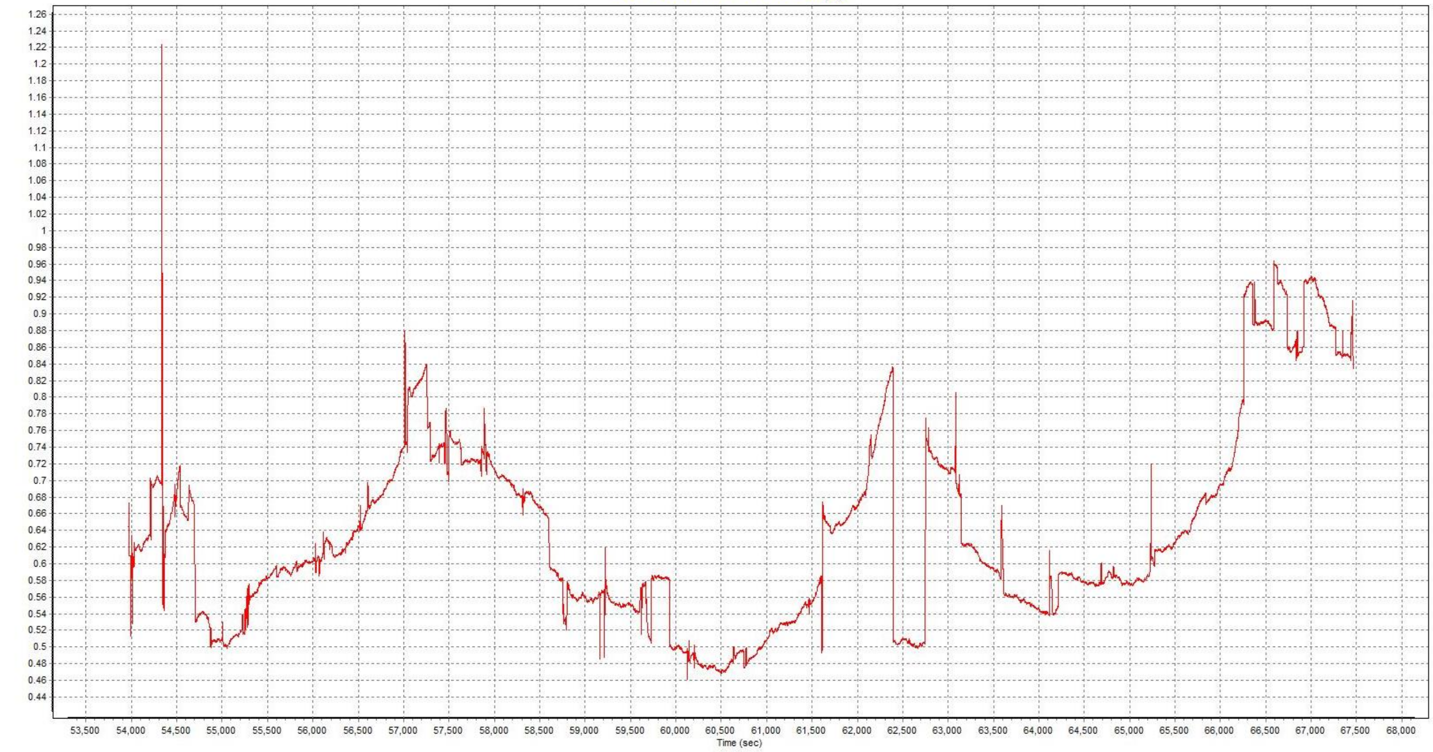

East (m)
0.2
0.19
0.18
0.17
0.16
0.15
0.14
0.13
0.12
0.11
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
-0.05
-0.06
-0.07
-0.08
-0.09
-0.1
54,500 55,000 55,500 56,000 56,500 57,000 57,500 58,000 58,500 59,000 59,500 60,000 60,500 61,000 61,500 62,000 62,500 63,000 63,500 64,000 64,500 65,000 65,500 66,000 66,500 67,000 67,500 68,000
Time (sec)


Down (m)
0.032
0.03
0.028
0.026
0.024
0.022
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
-0.002
-0.004
-0.006
-0.008
-0.01
-0.012
-0.014
-0.016
-0.018
-0.02
-0.022
-0.024
-0.026
-0.028
-0.03
54,500 55,000 55,500 56,000 56,500 57,000 57,500 58,000 58,500 59,000 59,500 60,000 60,500 61,000 61,500 62,000 62,500 63,000 63,500 64,000 64,500 65,000 65,500 66,000 66,500 67,000 67,500 68,000
Time (sec)

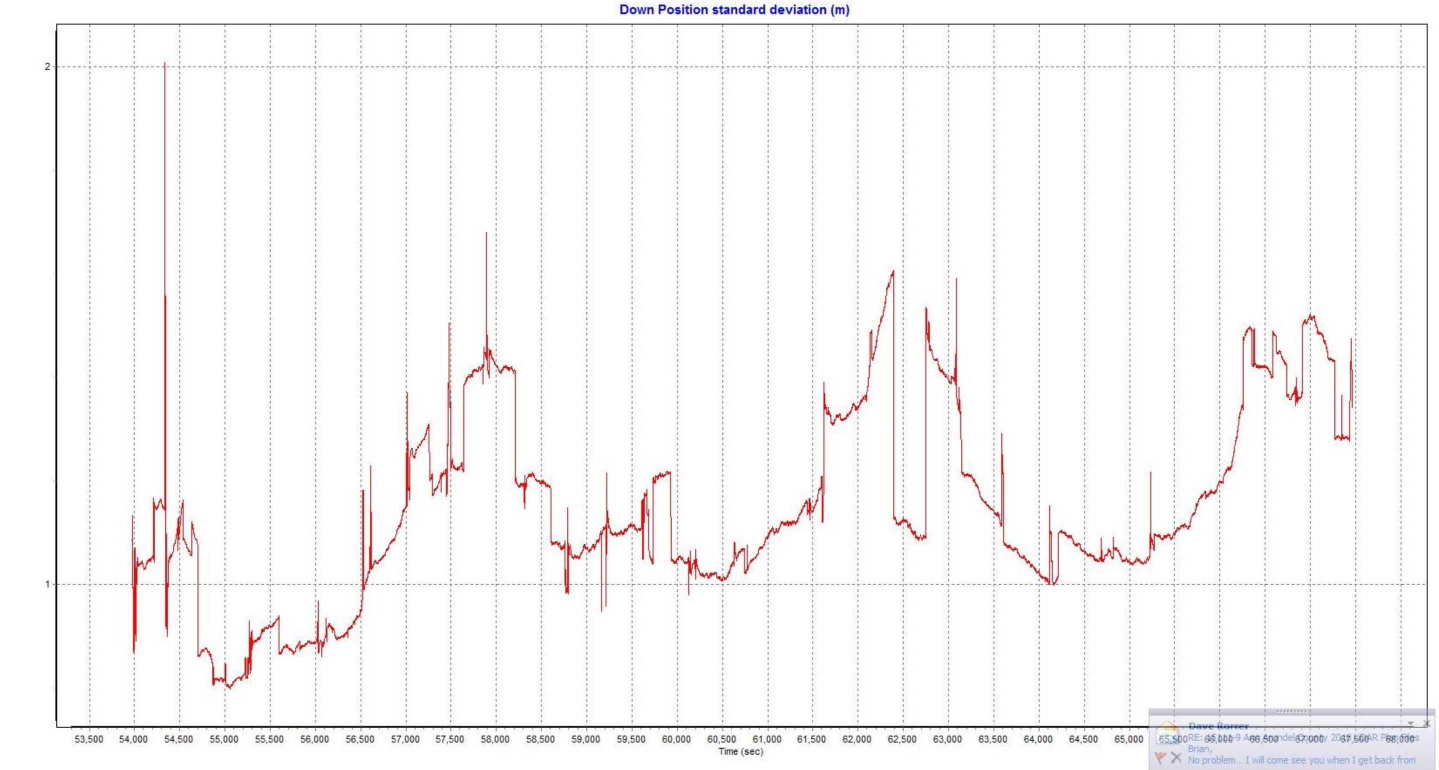

North (m)
Time (sec)

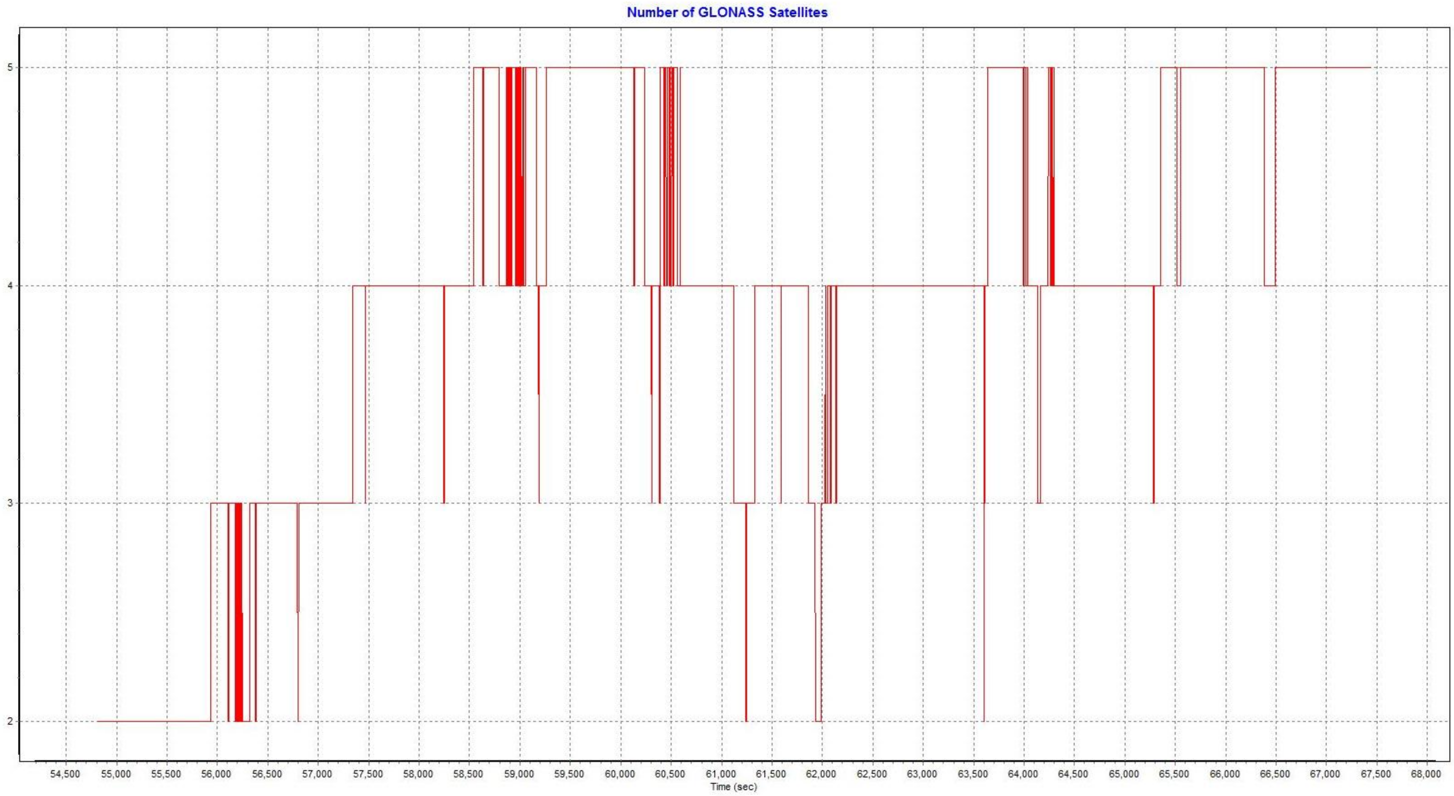

East Position standard deviation (m)
Time (sec)

North Position standard deviation (m)



Down Position standard deviation (m)




Number of GLONASS Satellites
5
4
3
2
54,500
55,000
55,500
56,000
56,500
57,000
57,500
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58,500
59,000
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62,000
62,500
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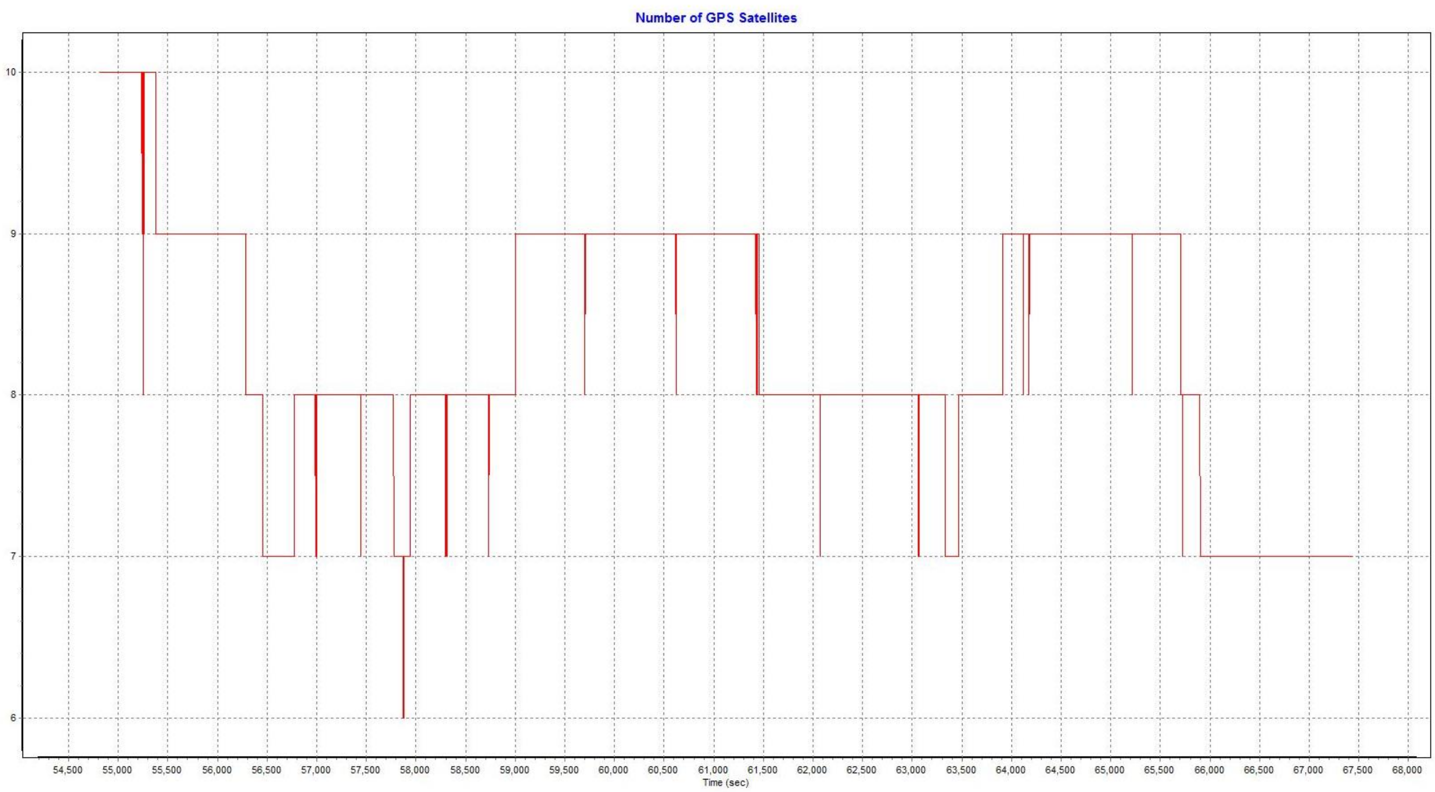
65,500
66,000
66,500
67,000
67,500
68,000
Time (sec)


Number of GPS Satellites
10
9
8
7
6
54,500
55,000
55,500
56,000
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57,000
57,500
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58,500
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62,000
62,500
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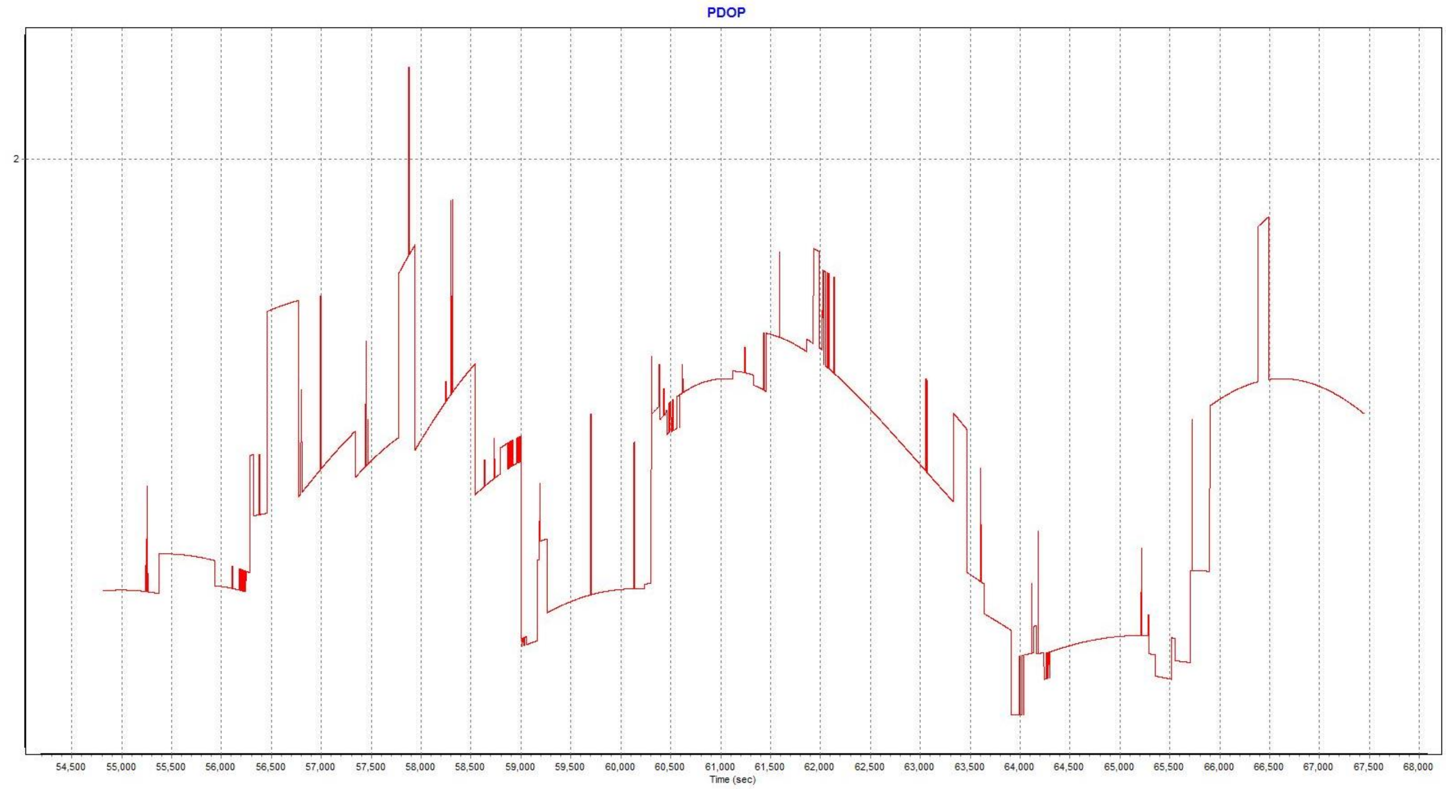
65,500
66,000
66,500
67,000
67,500
68,000
Time (sec)


PDOP
2
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62,500
63,000
63,500
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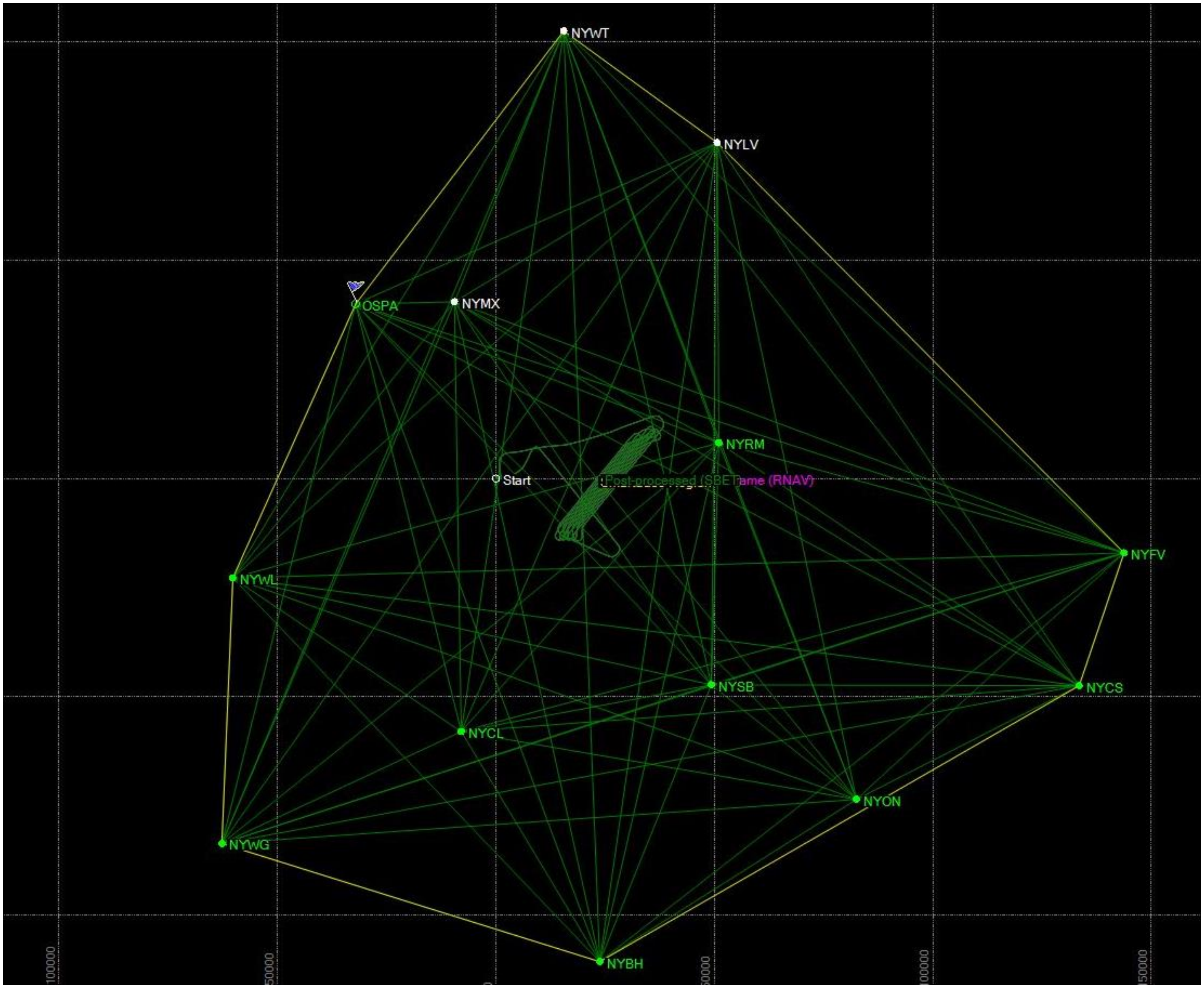
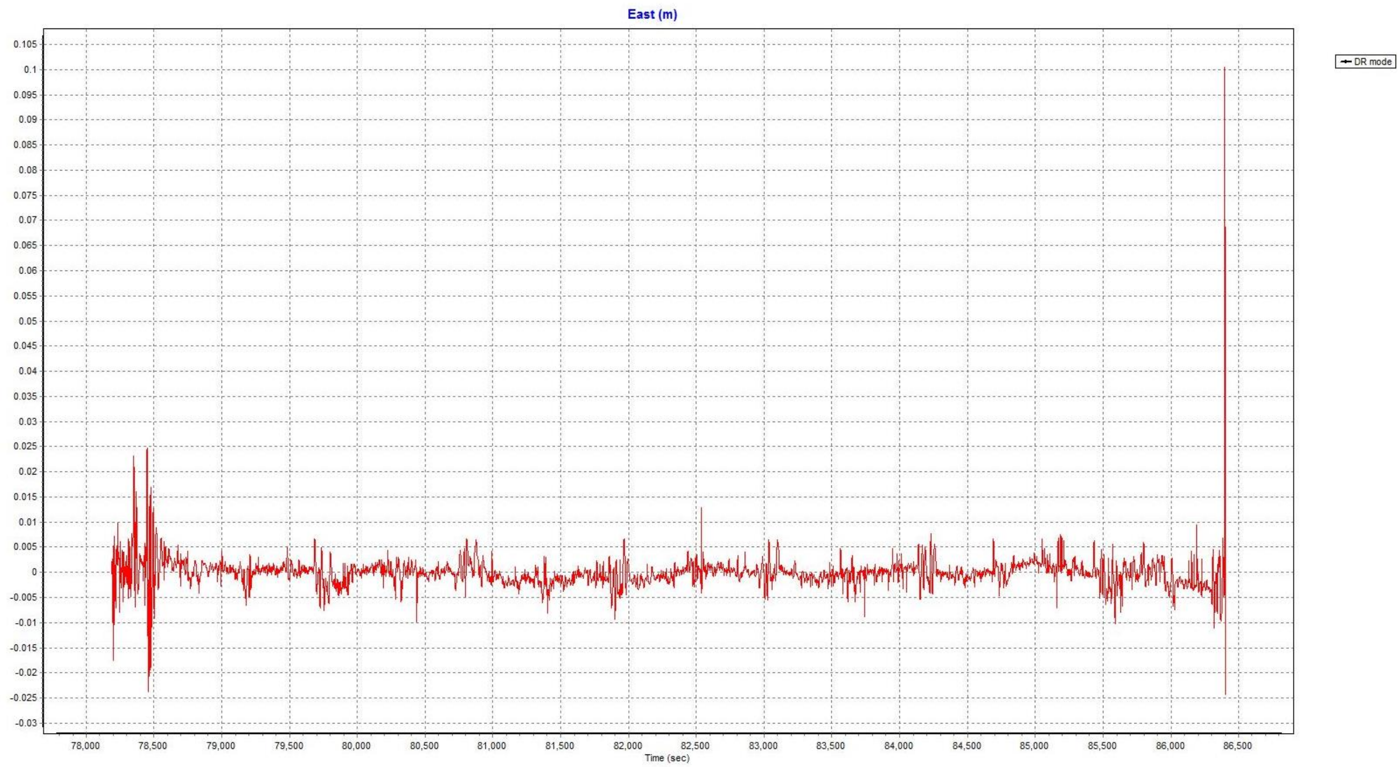
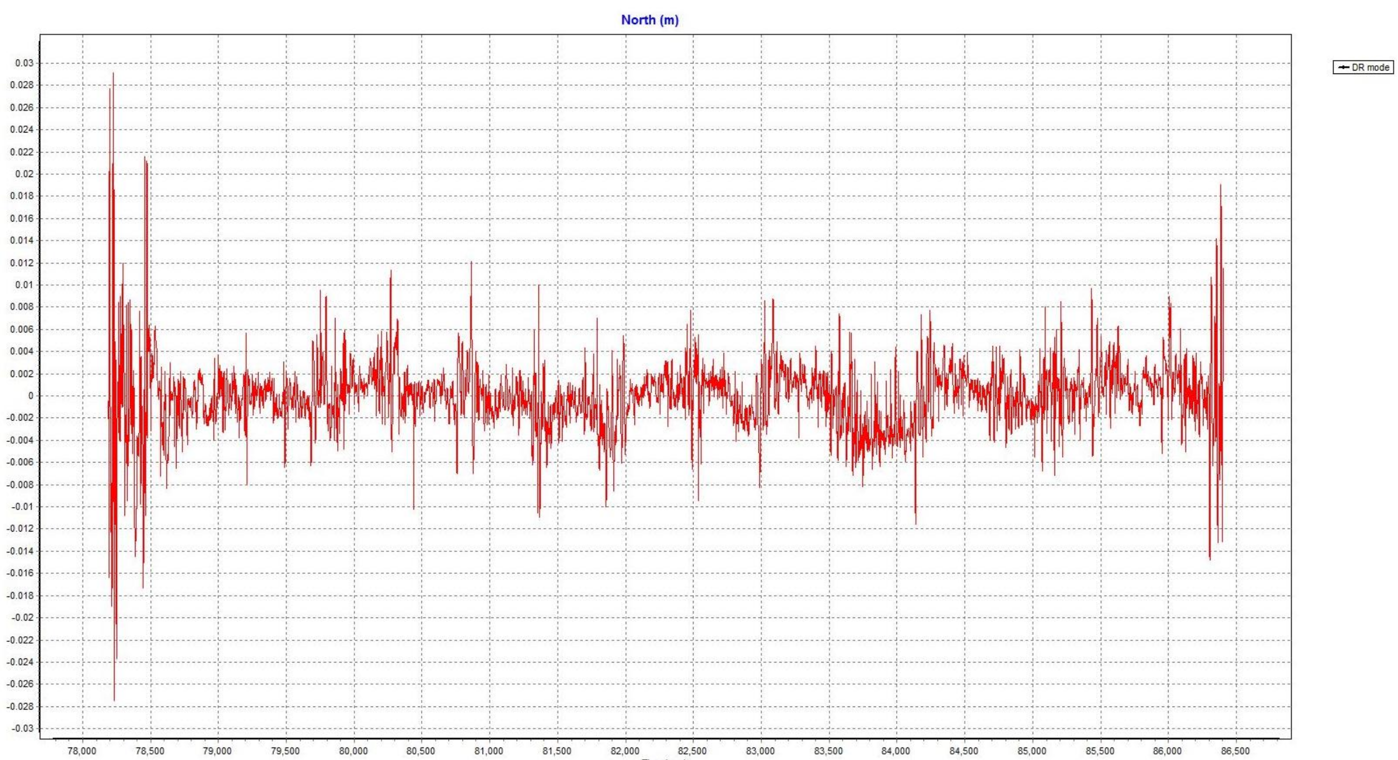
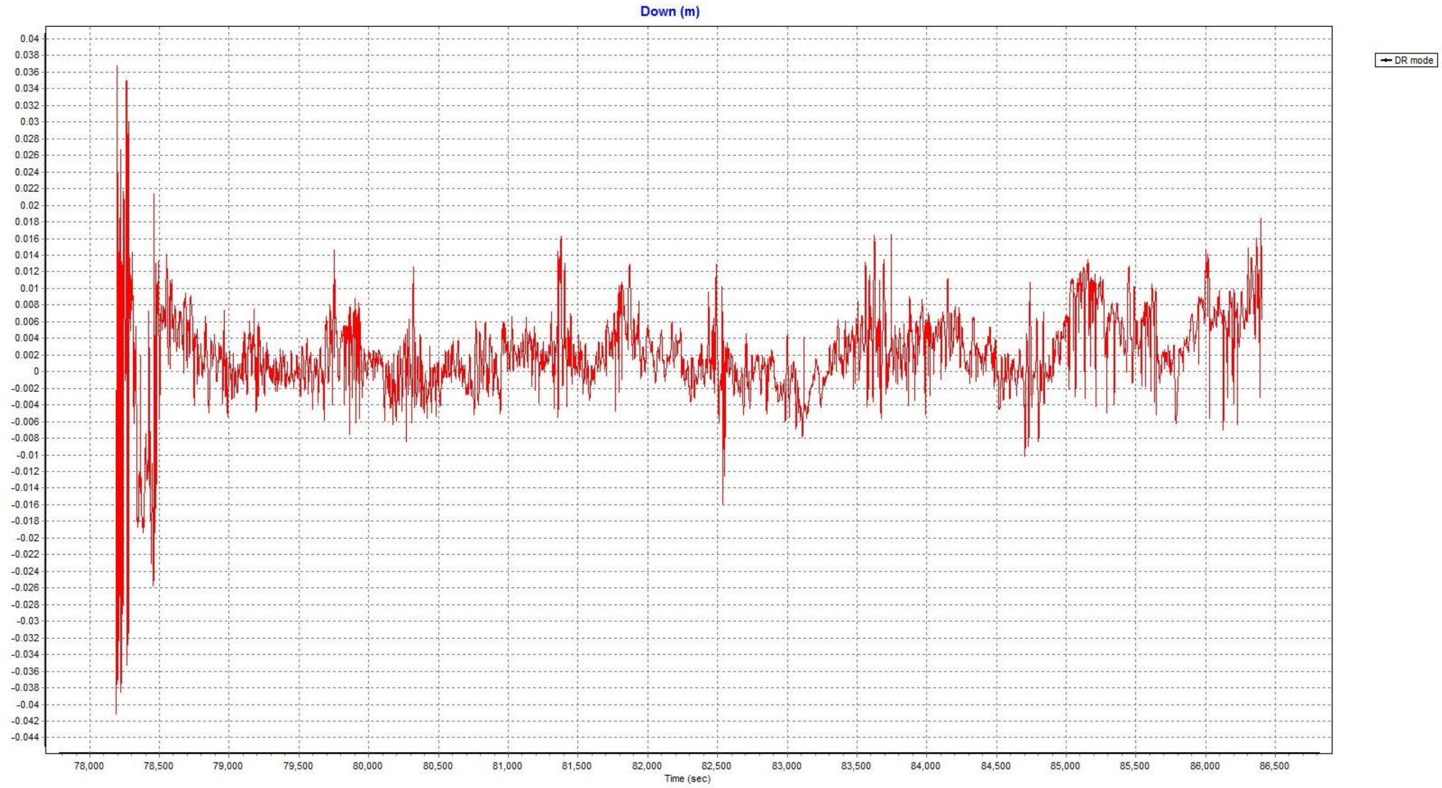
65,500
66,000
66,500
67,000
67,500
68,000
Time (sec)

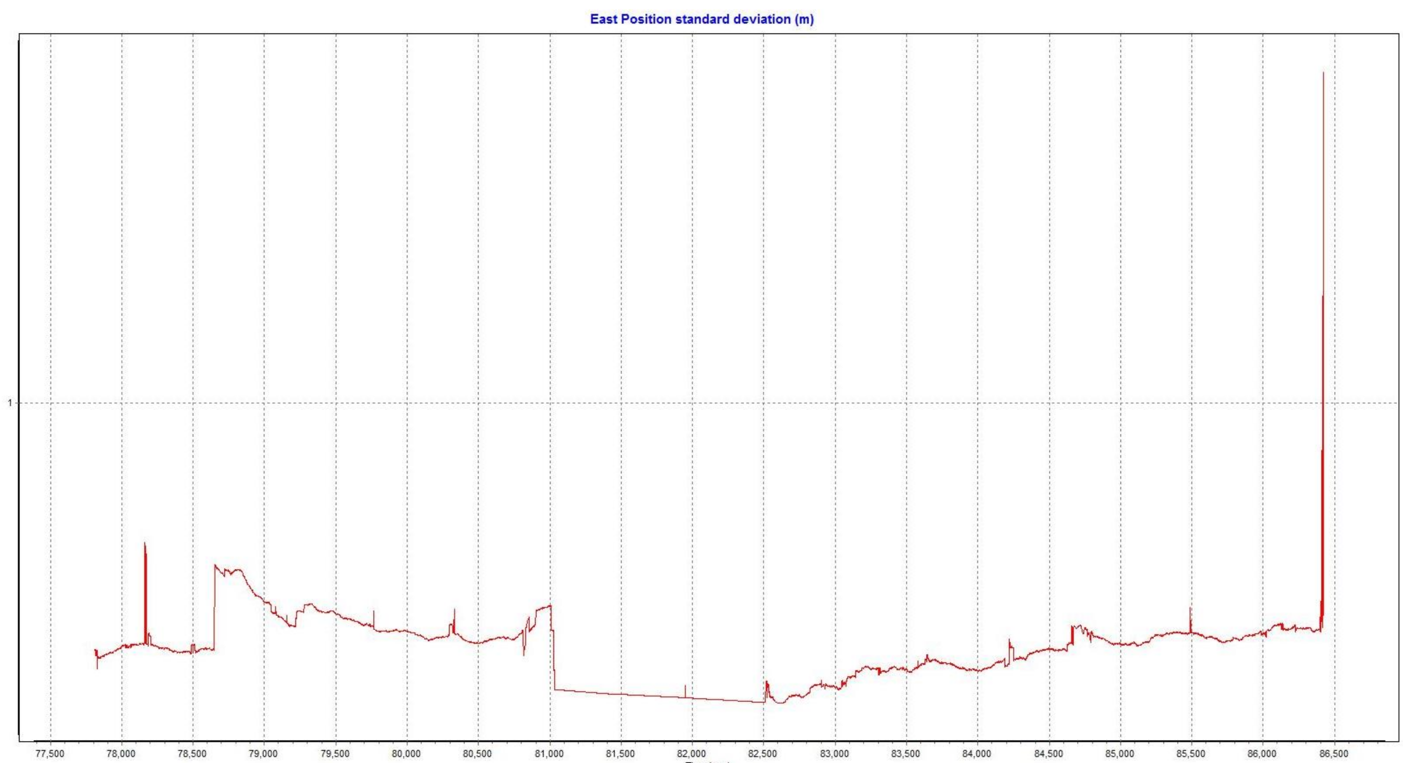
04/26/2015 Lift 2

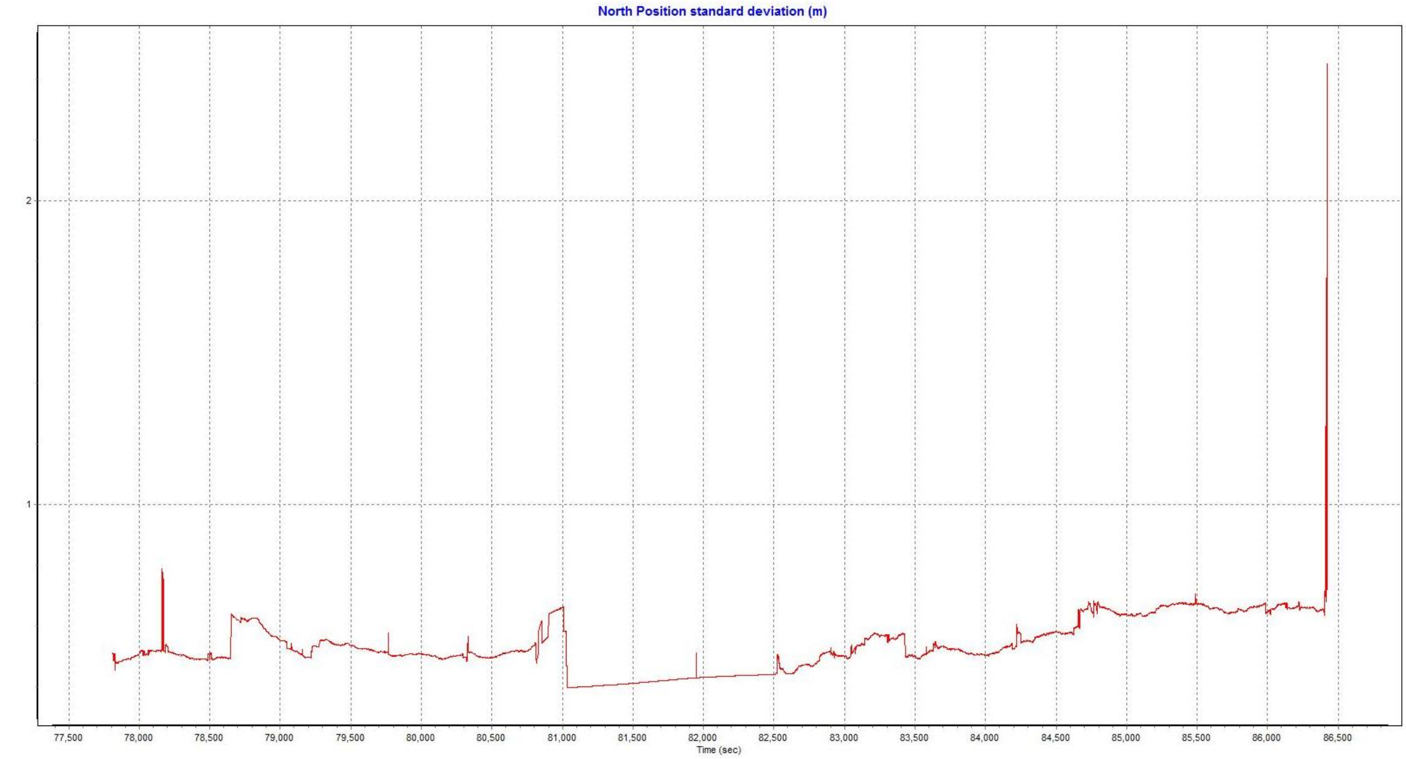



East (m)
DR mode
Time (sec)


North (m)
DR mode
Time (sec)


Down (m)
DR mode
Time (sec)


East Position standard deviation (m)
Time (sec)


North Position standard deviation (m)
2
1
77,500
78,000
78,500
79,000
79,500
80,000
80,500
81,000
81,500
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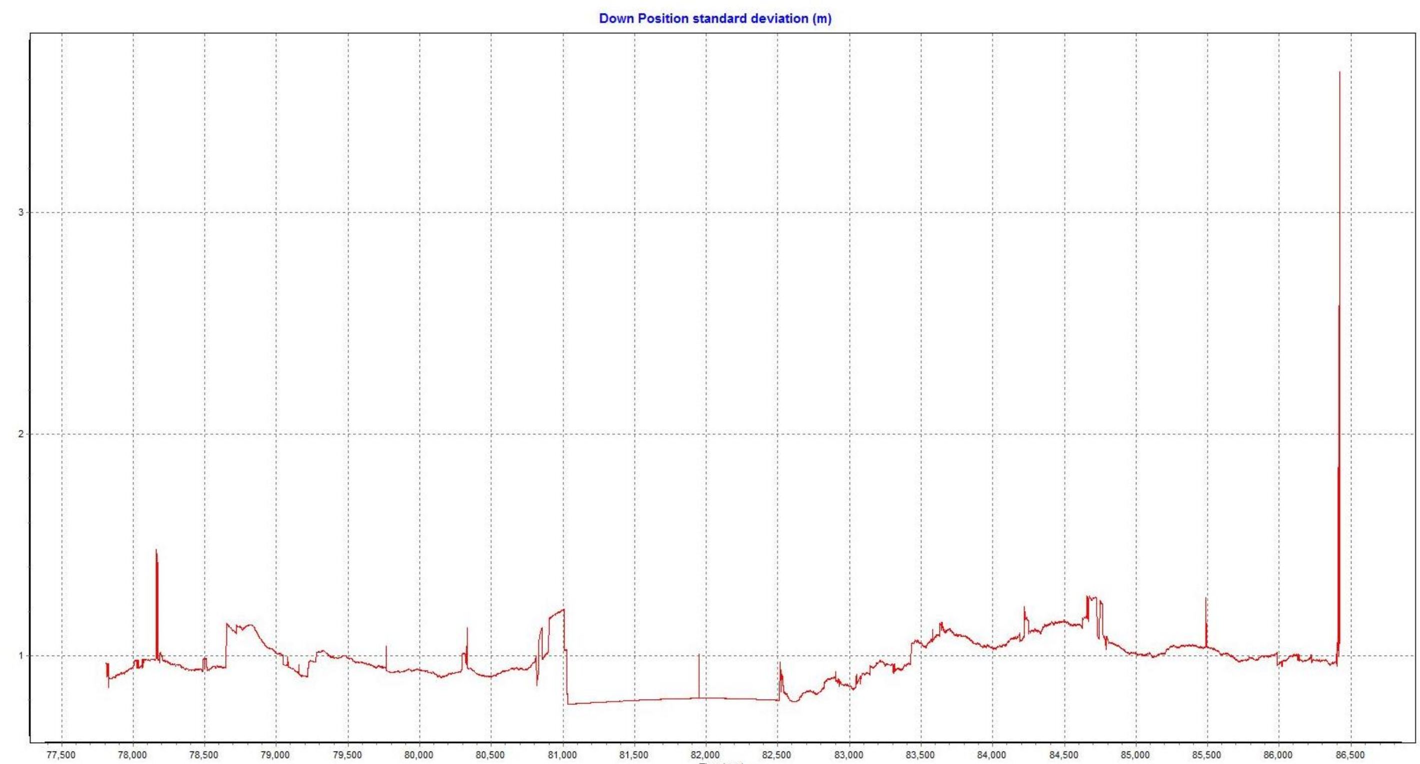
86,000
86,500
Time (sec)


Down Position standard deviation (m)
3
2
1
77,500
78,000
78,500
79,000
79,500
80,000
80,500
81,000
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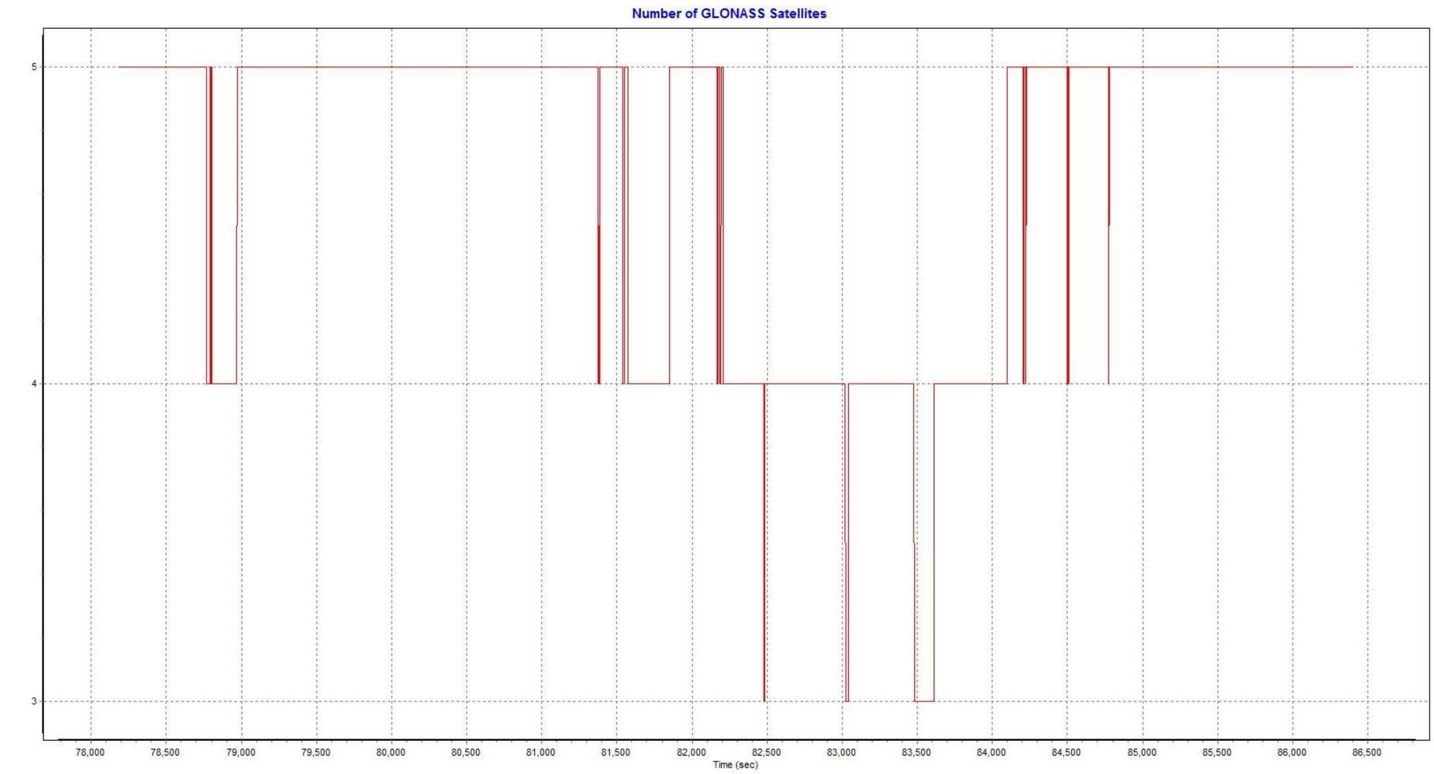
86,000
86,500
Time (sec)


Number of GLONASS Satellites
5
4
3
78,000
78,500
79,000
79,500
80,000
80,500
81,000
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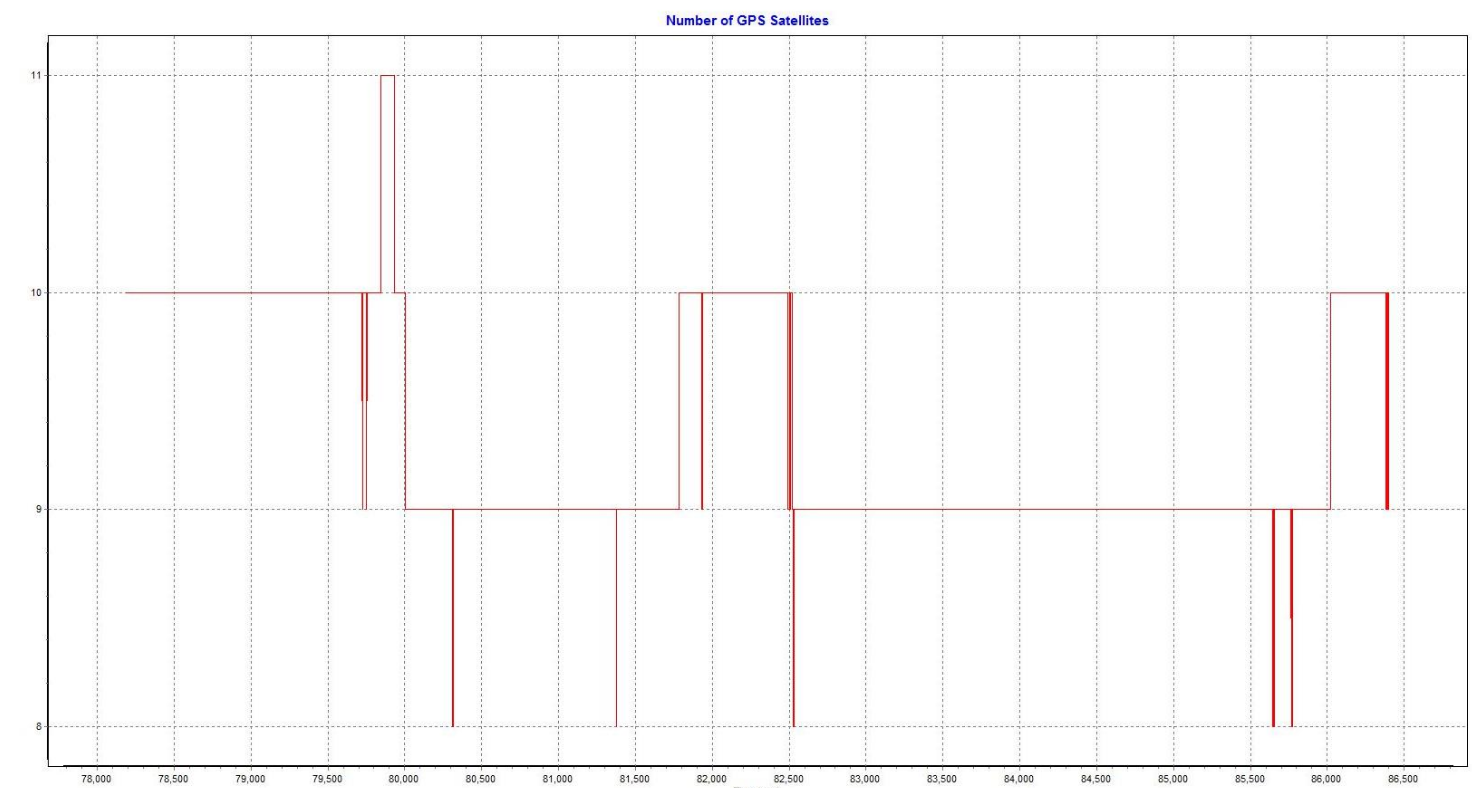
86,000
86,500
Time (sec)


Number of GPS Satellites
11
10
9
8
78,000
78,500
79,000
79,500
80,000
80,500
81,000
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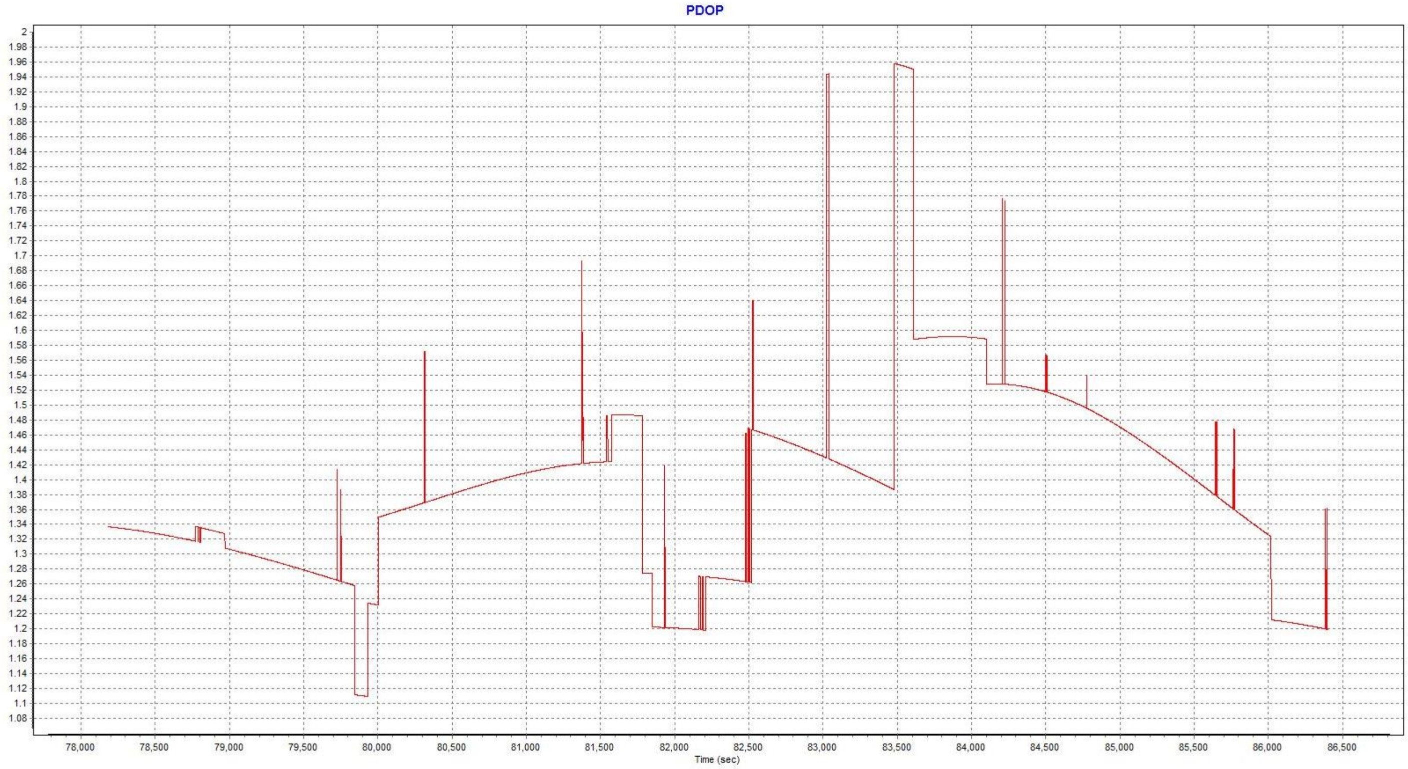
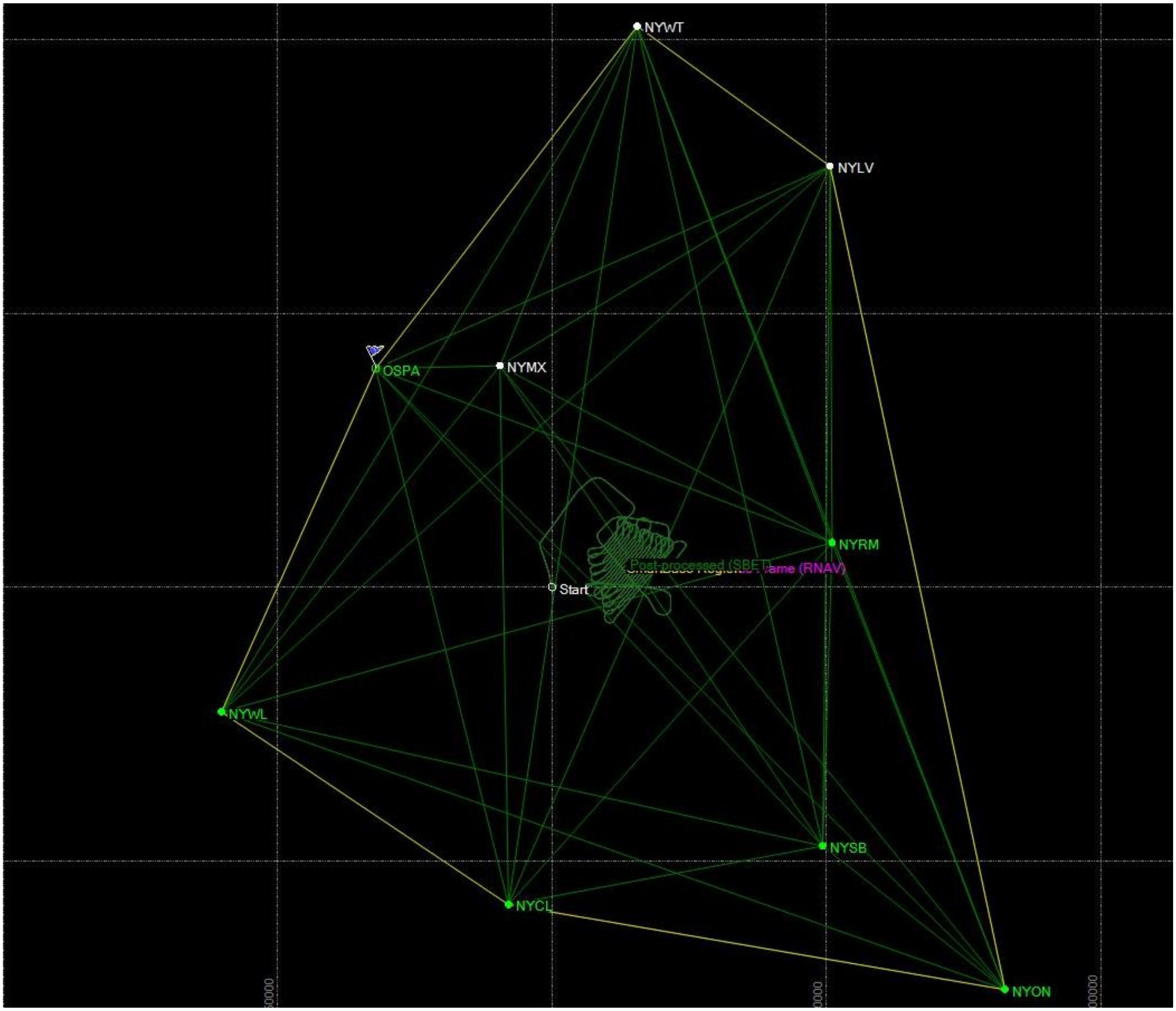
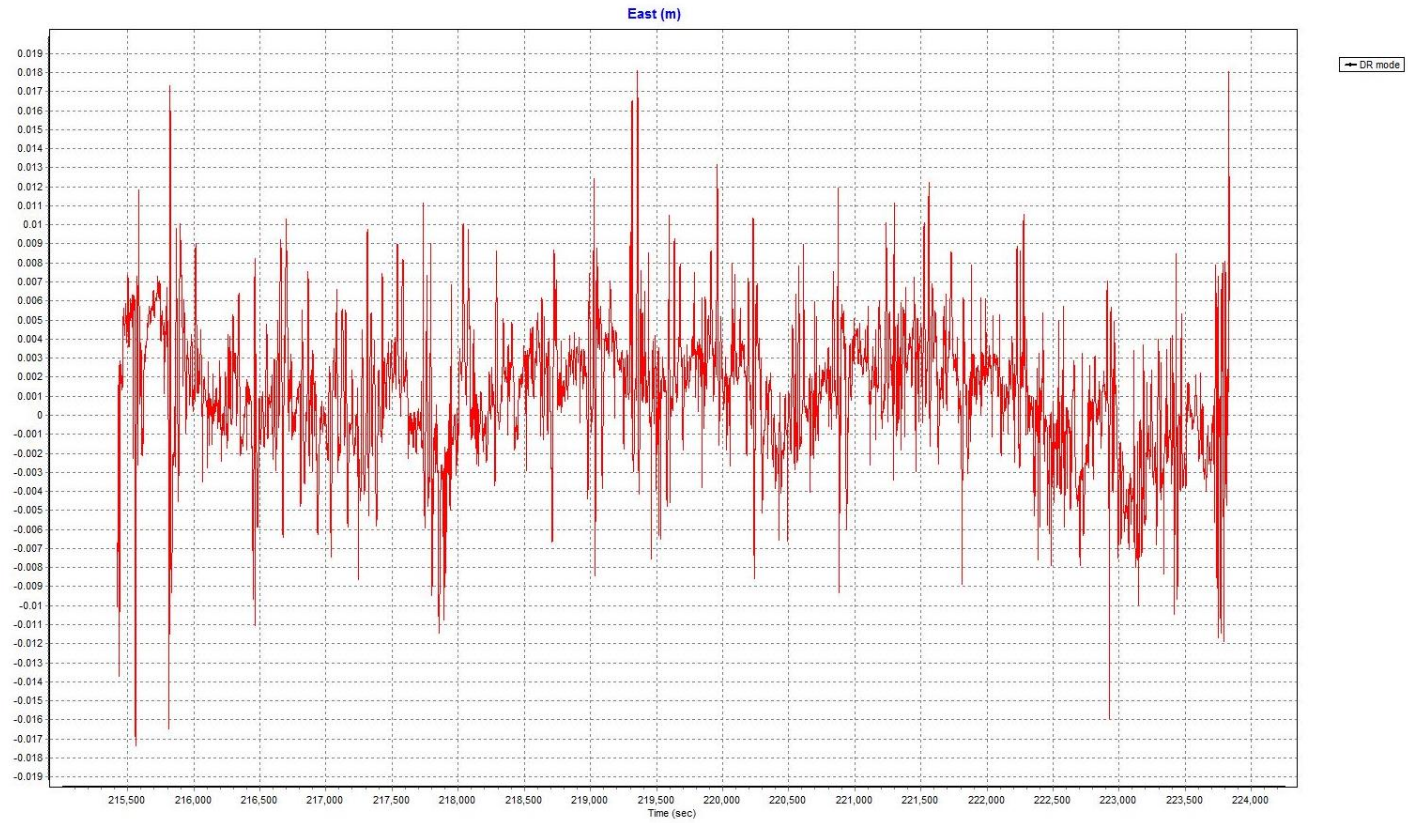
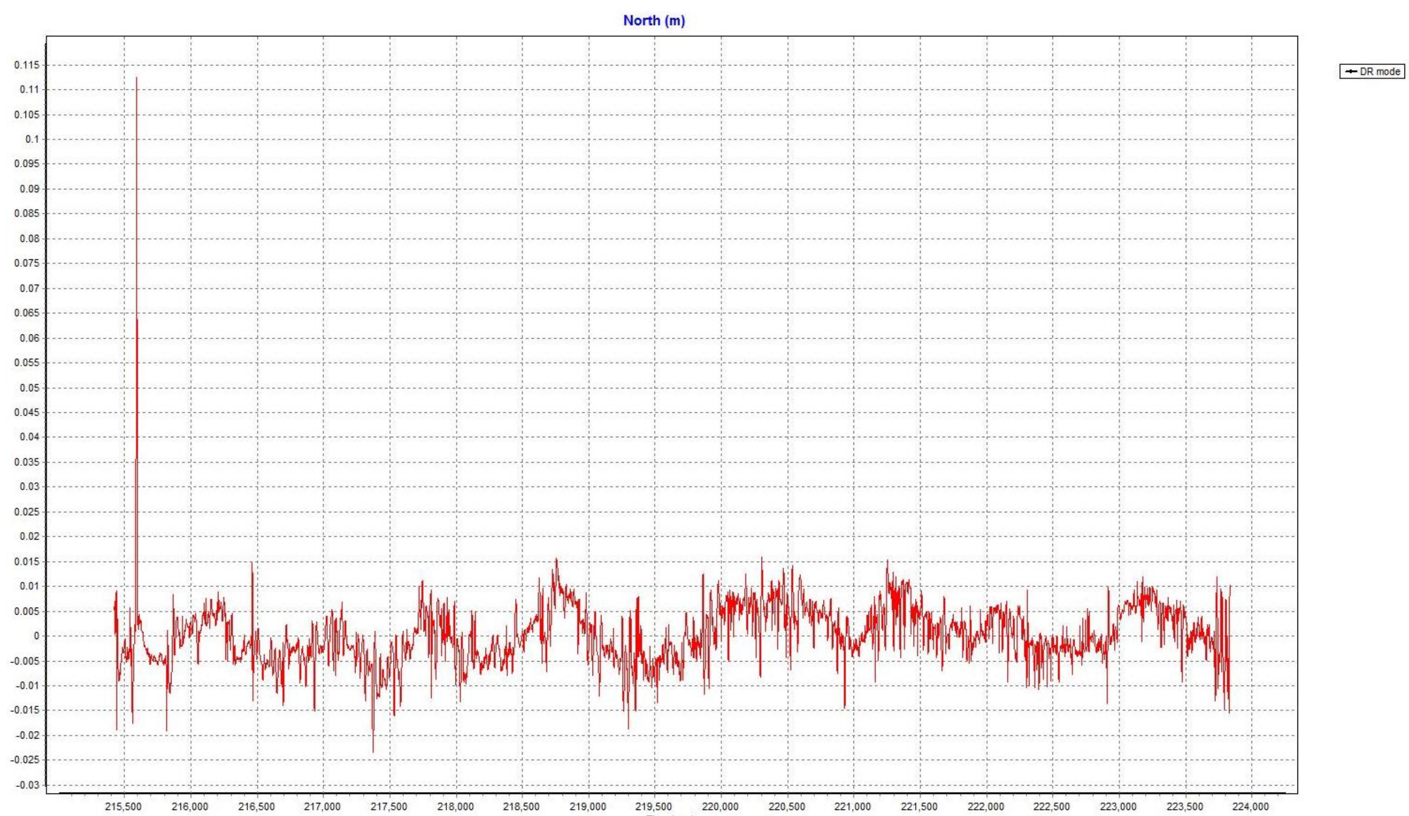
86,000
86,500
Time (sec)

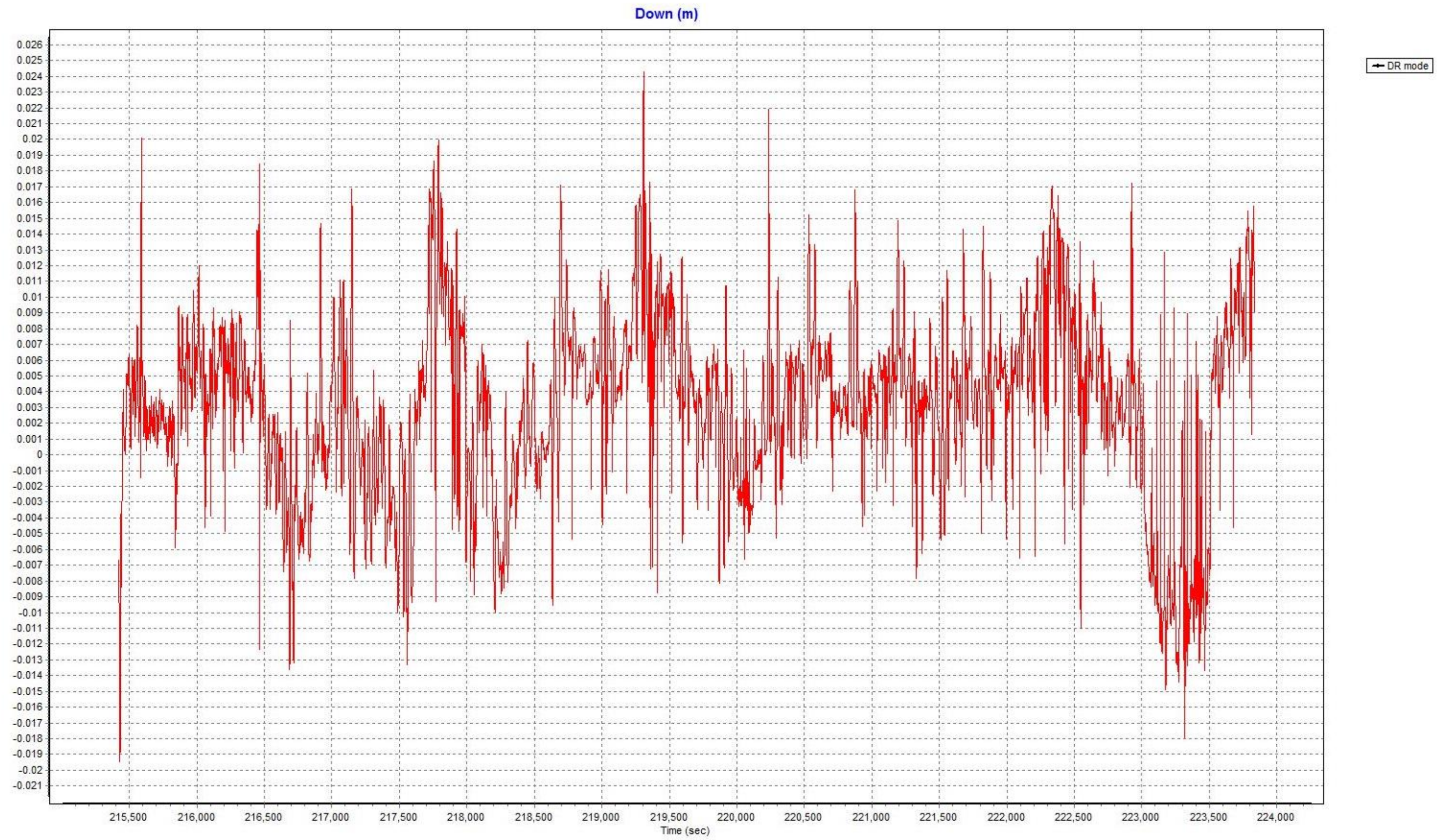

PDOP
Time (sec)

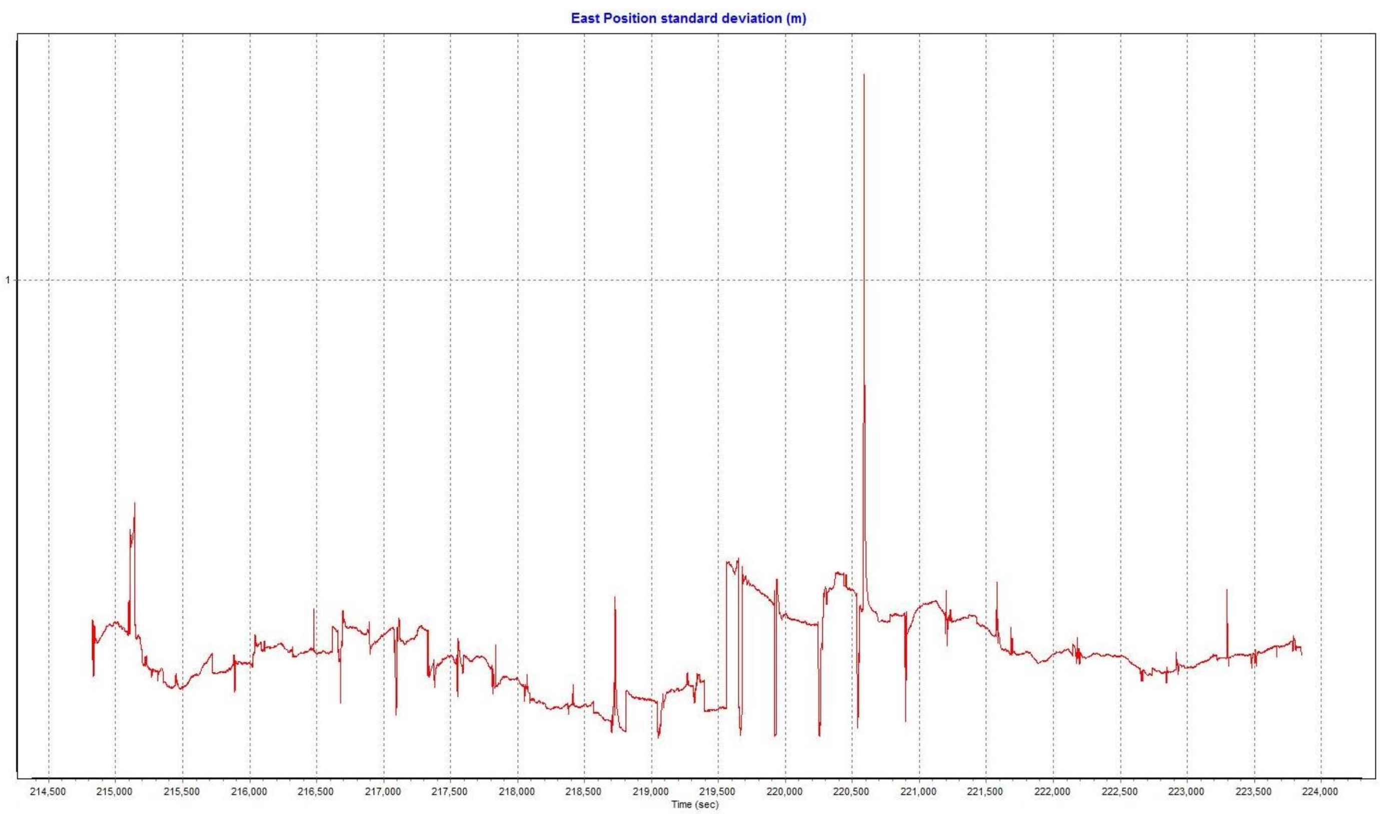
04/28/2015 lift 1

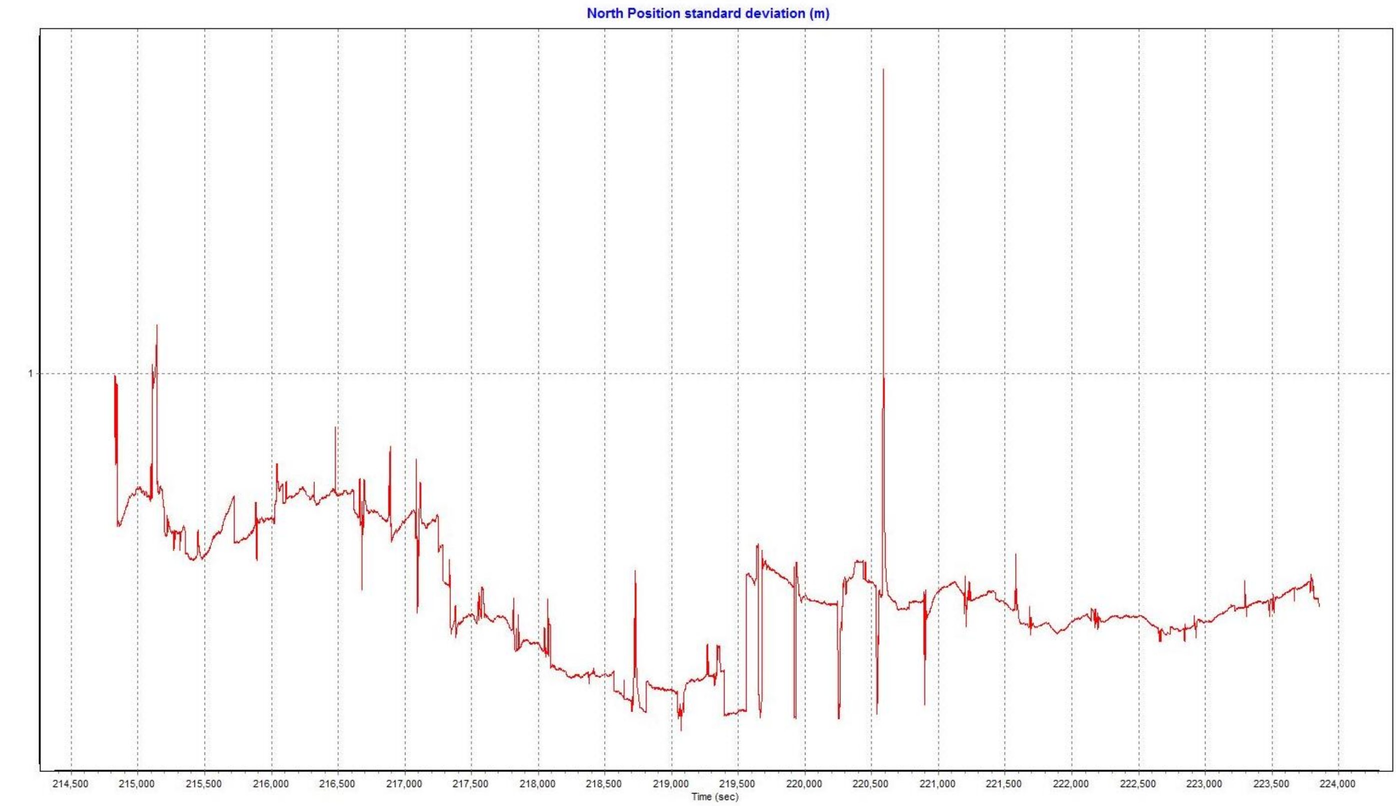



East (m)
DR mode
Time (sec)


North (m)
DR mode
Time (sec)


Down (m)
DR mode
Time (sec)


East Position standard deviation (m)
Time (sec)


North Position standard deviation (m)
1
214,500
215,000
215,500
216,000
216,500
217,000
217,500
218,000
218,500
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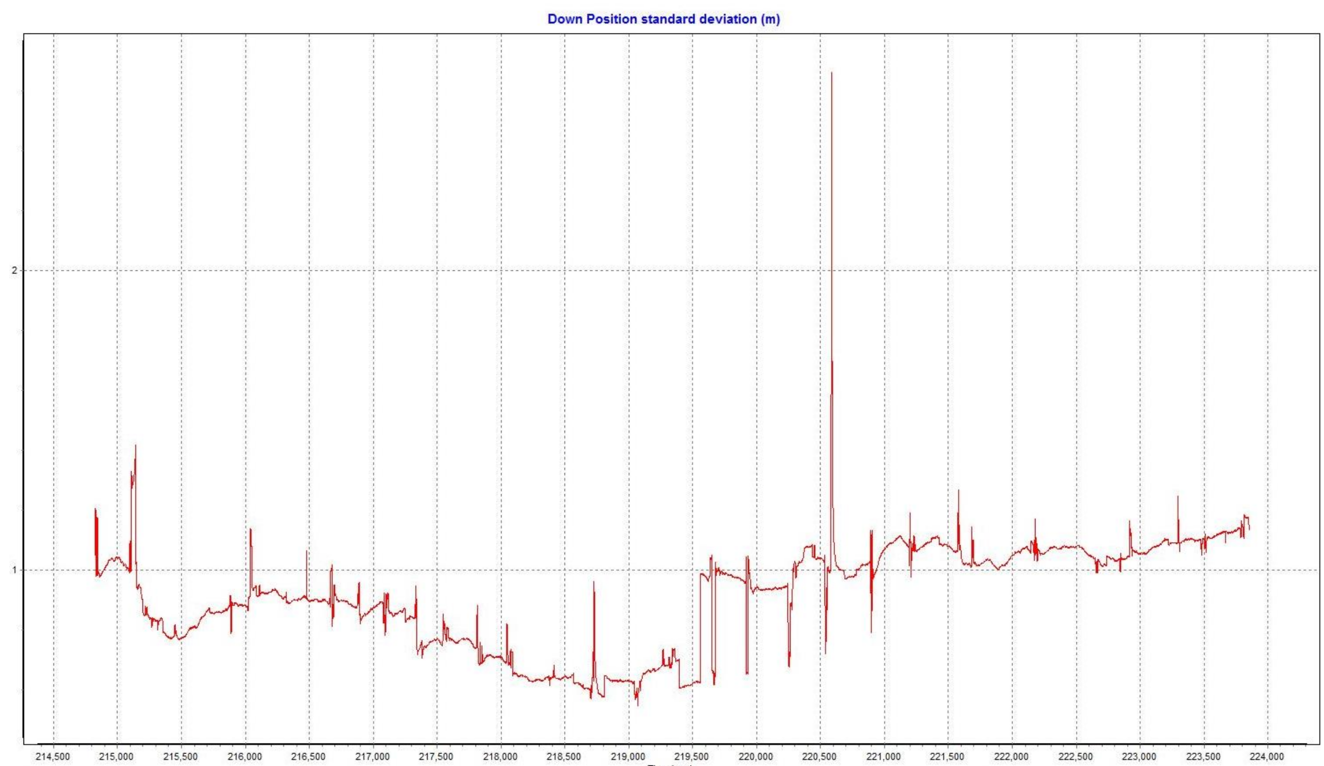
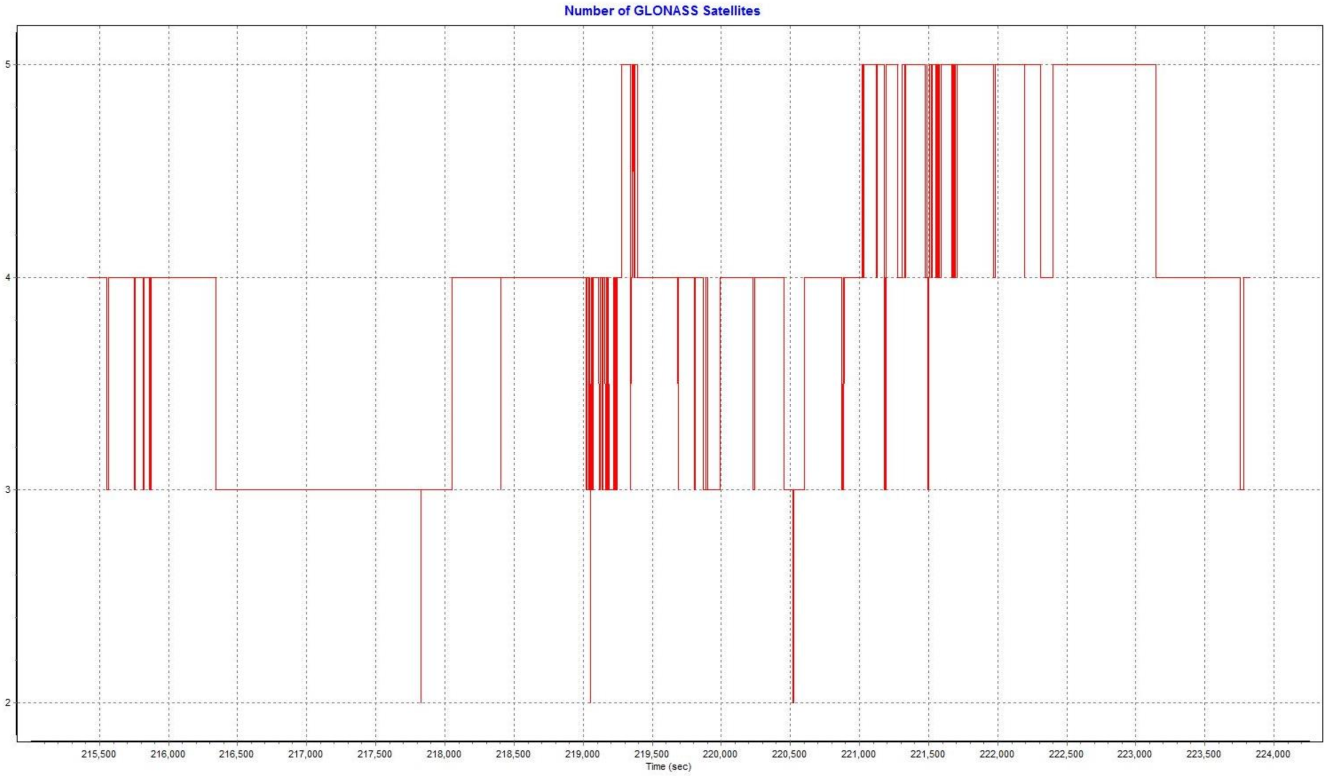
219,500
220,000
220,500
221,000
221,500
222,000
222,500
223,000
223,500
224,000
Time (sec)


Down Position standard deviation (m)
2
1
214,500
215,000
215,500
216,000
216,500
217,000
217,500
218,000
218,500
219,000
219,500
220,000
220,500
221,000
221,500
222,000
222,500
223,000
223,500
224,000
Time (sec)


Number of GLONASS Satellites
5
4
3
2
215,500
216,000
216,500
217,000
217,500
218,000
218,500
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220,500
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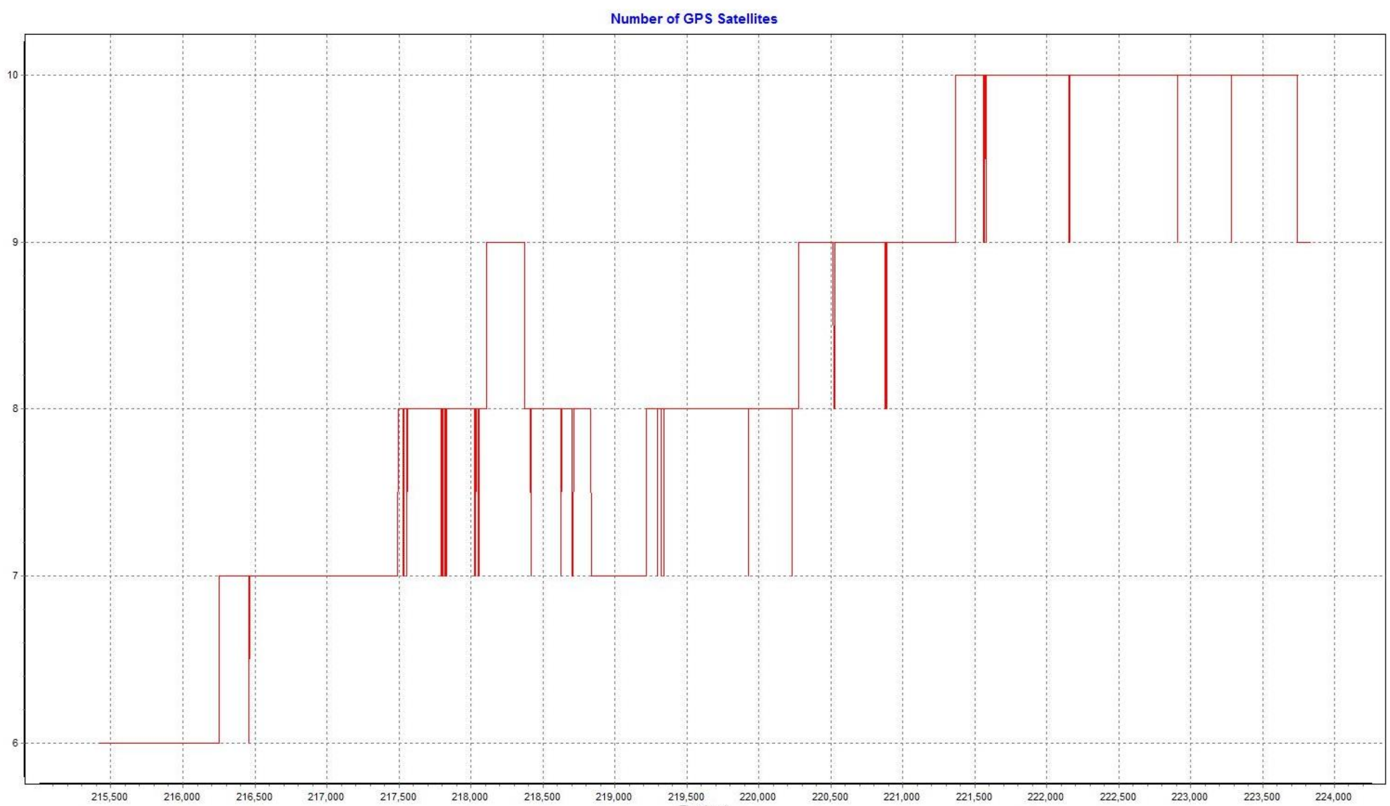
223,000
223,500
224,000
Time (sec)


Number of GPS Satellites
10
9
8
7
6
215,500
216,000
216,500
217,000
217,500
218,000
218,500
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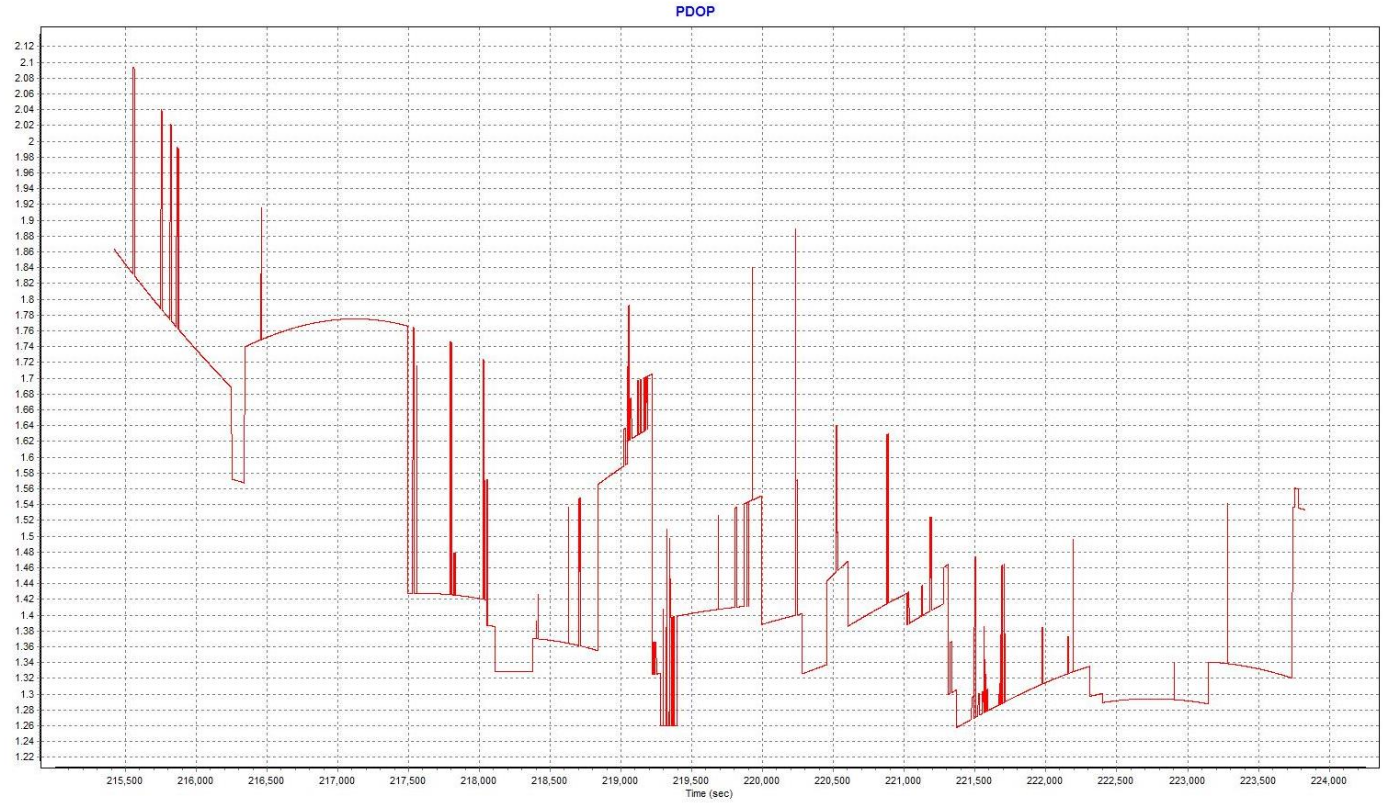
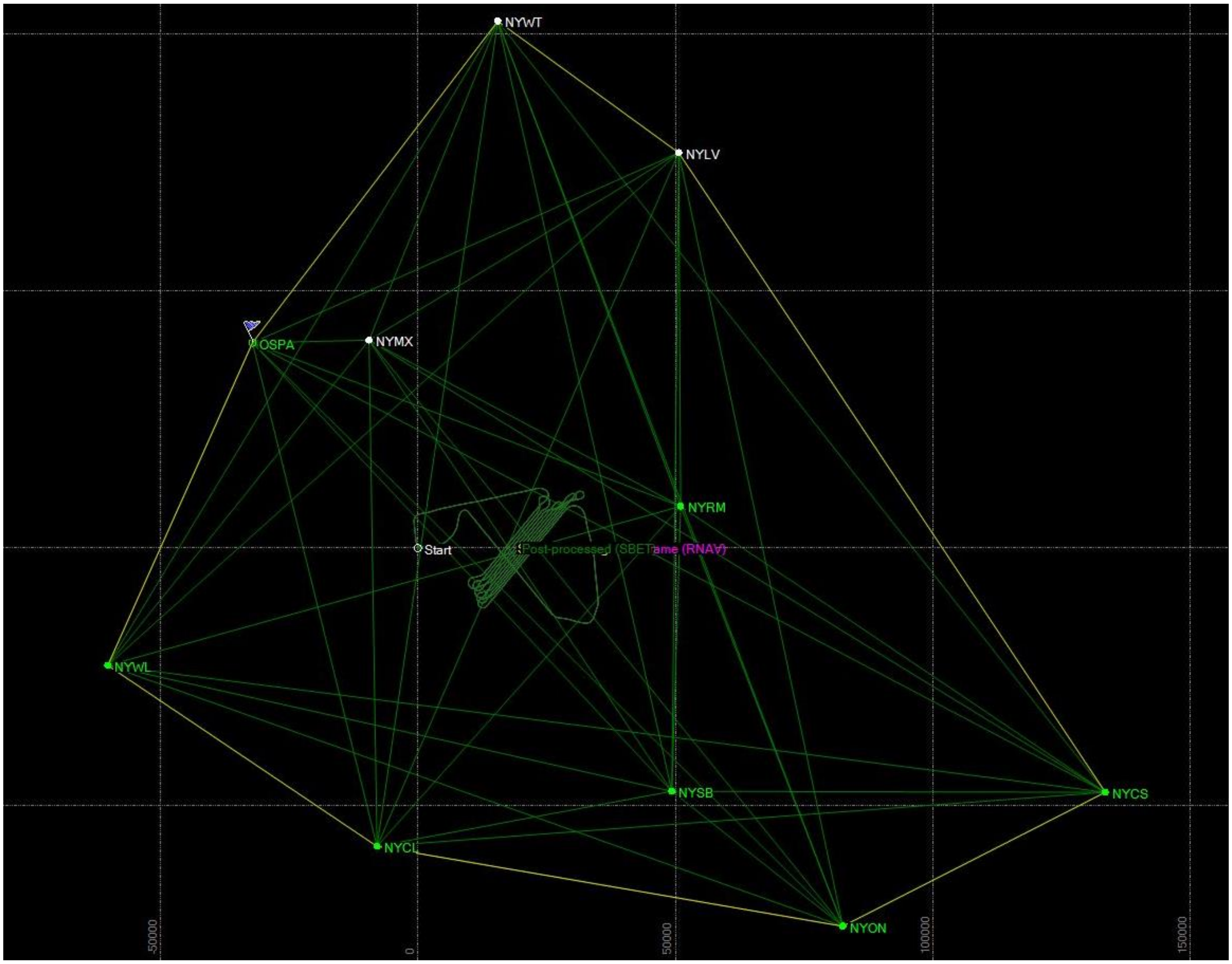
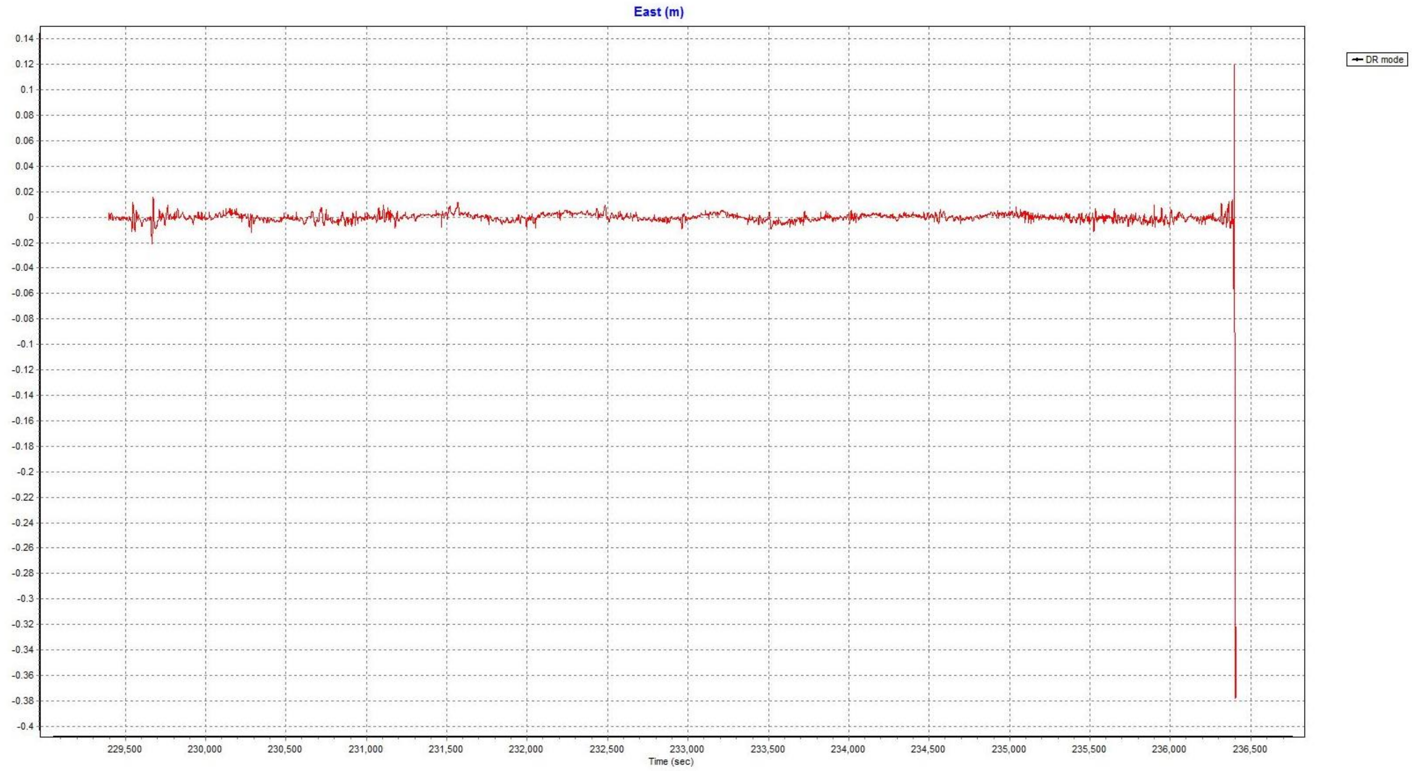
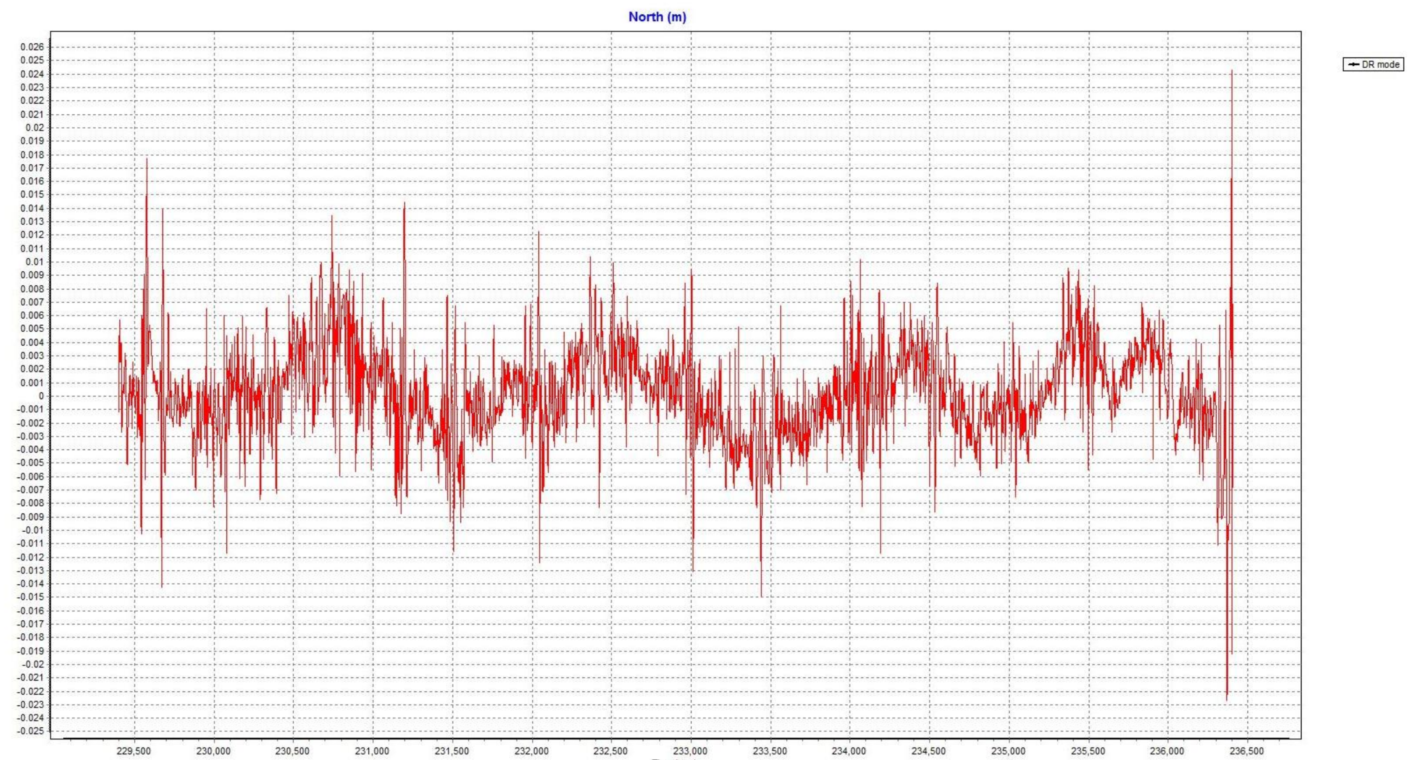
223,000
223,500
224,000
Time (sec)

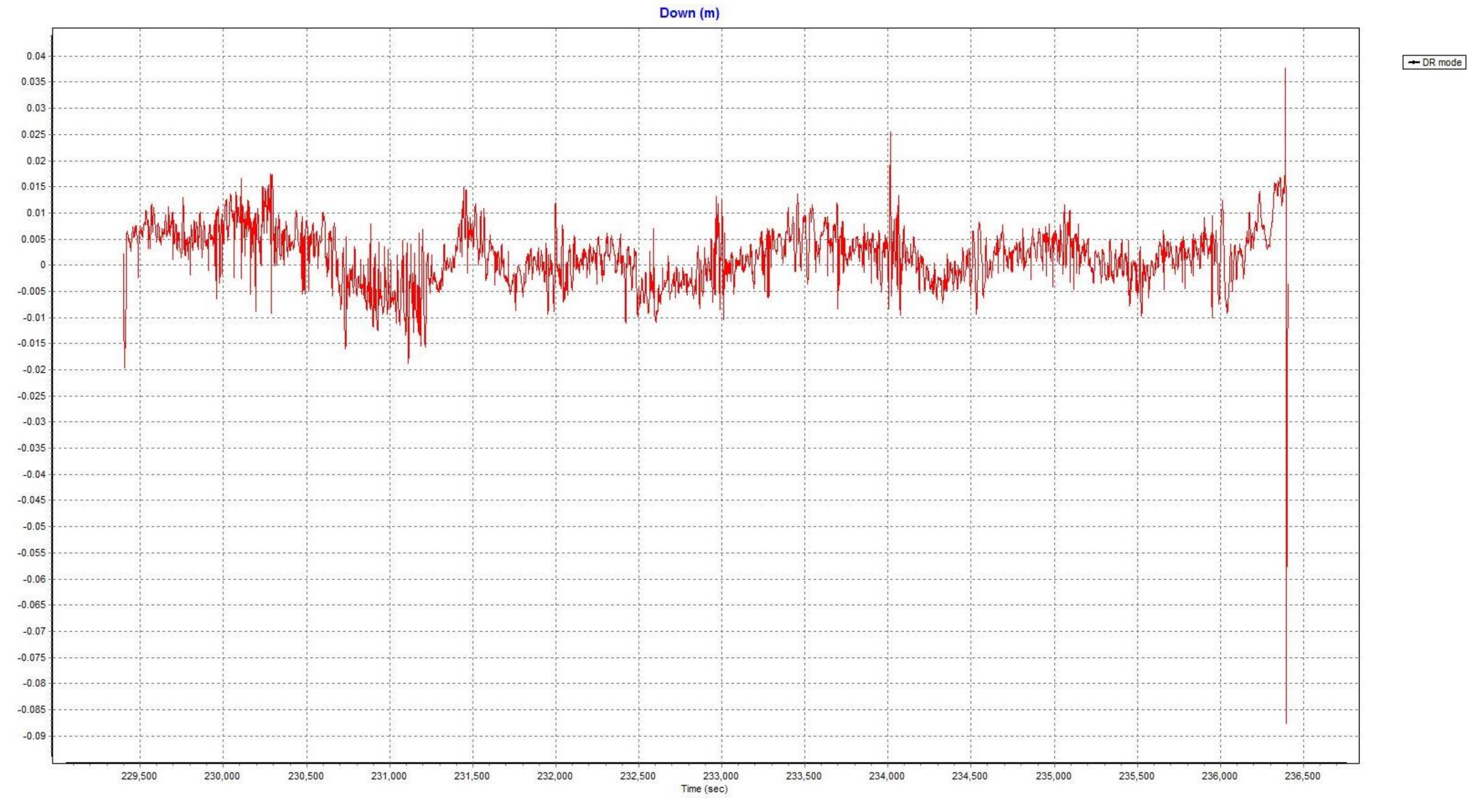

PDOP
Time (sec)

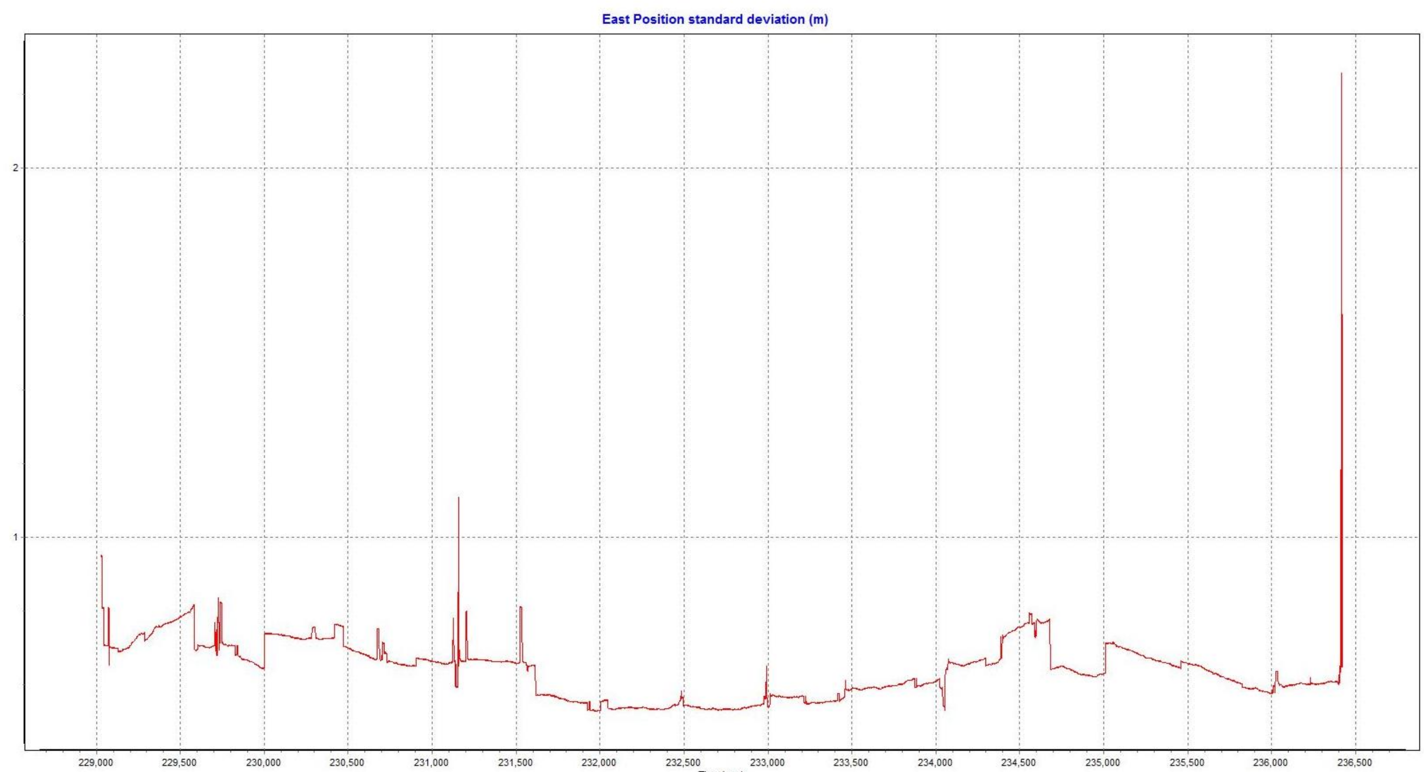
04/28/2015-Lift 2

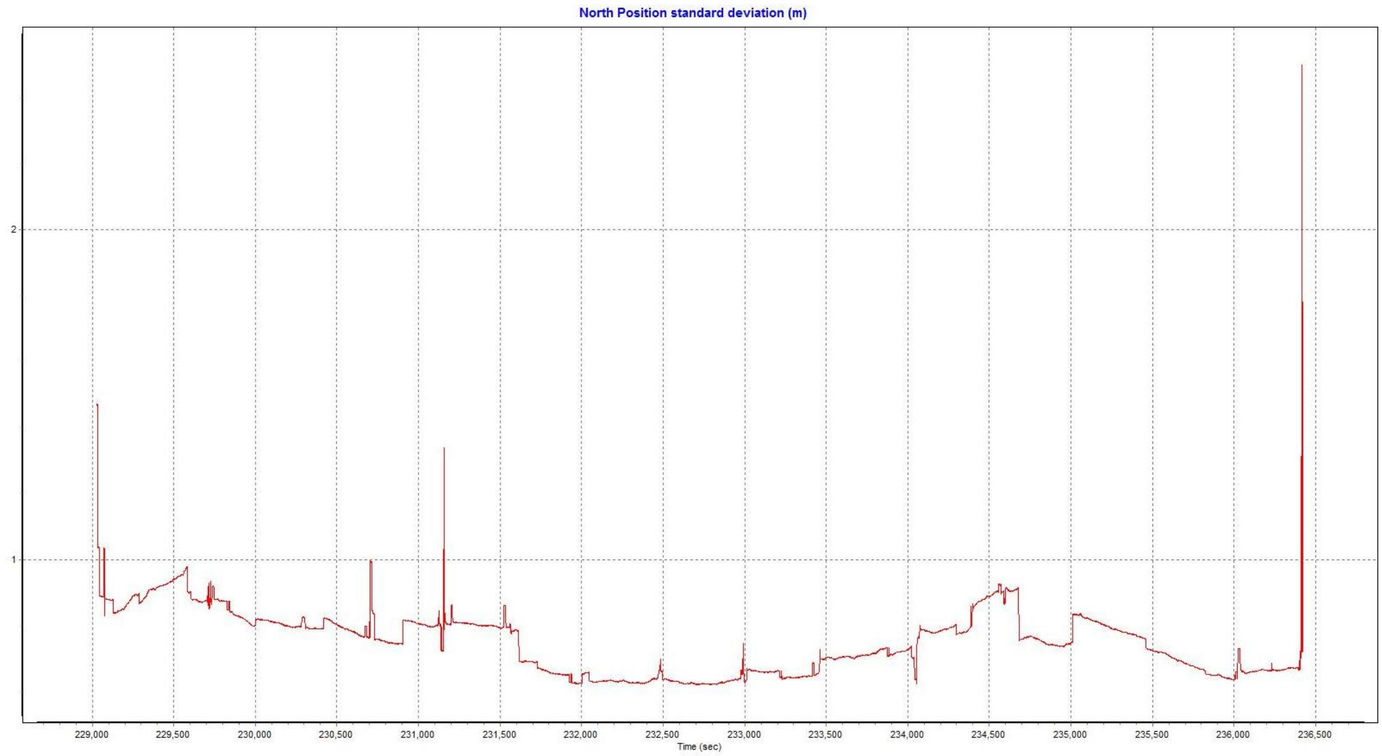


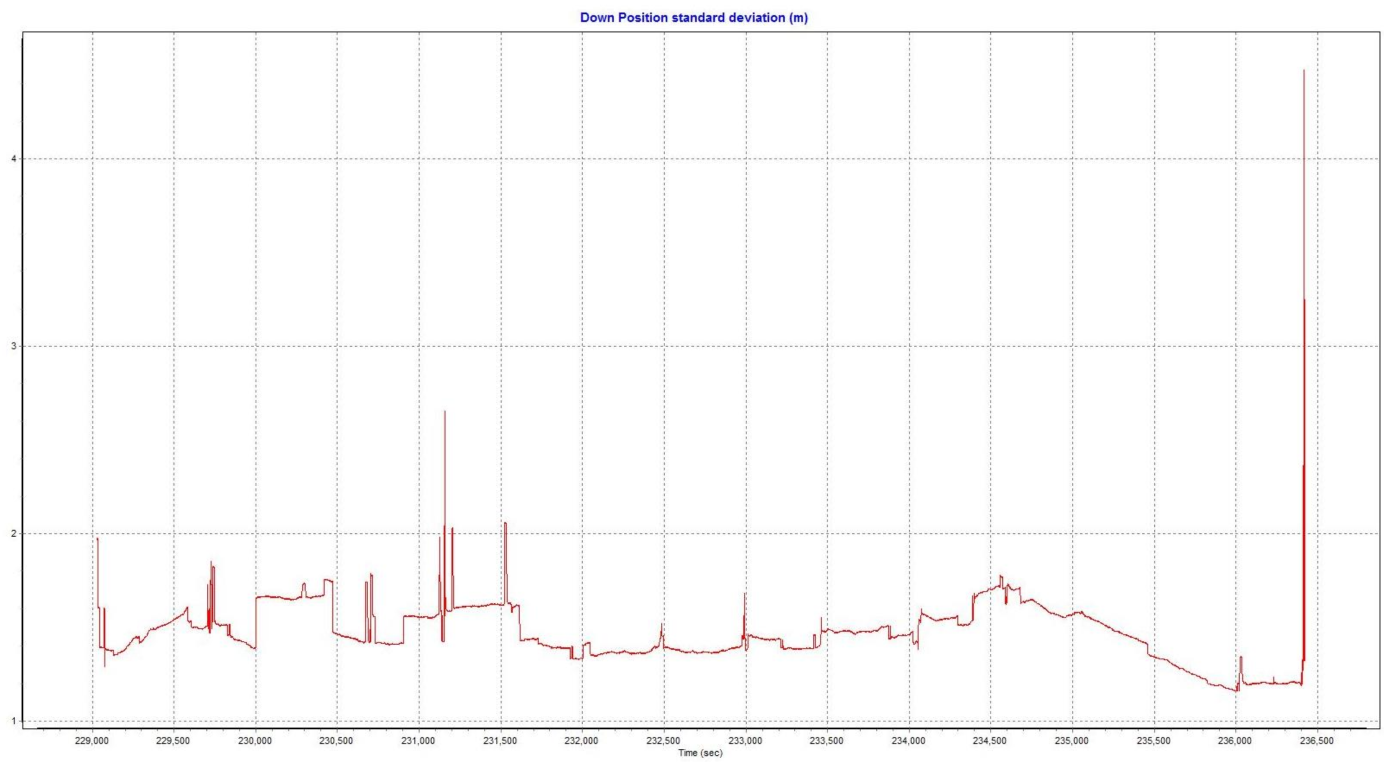

East (m)
DR mode
Time (sec)


North (m)
DR mode
Time (sec)


Down (m)
DR mode
Time (sec)


East Position standard deviation (m)
Time (sec)


North Position standard deviation (m)
2
1
229,000
229,500
230,000
230,500
231,000
231,500
232,000
232,500
233,000
233,500
234,000
234,500
235,000
235,500
236,000
236,500
Time (sec)


Down Position standard deviation (m)
4
3
2
1
229,000
229,500
230,000
230,500
231,000
231,500
232,000
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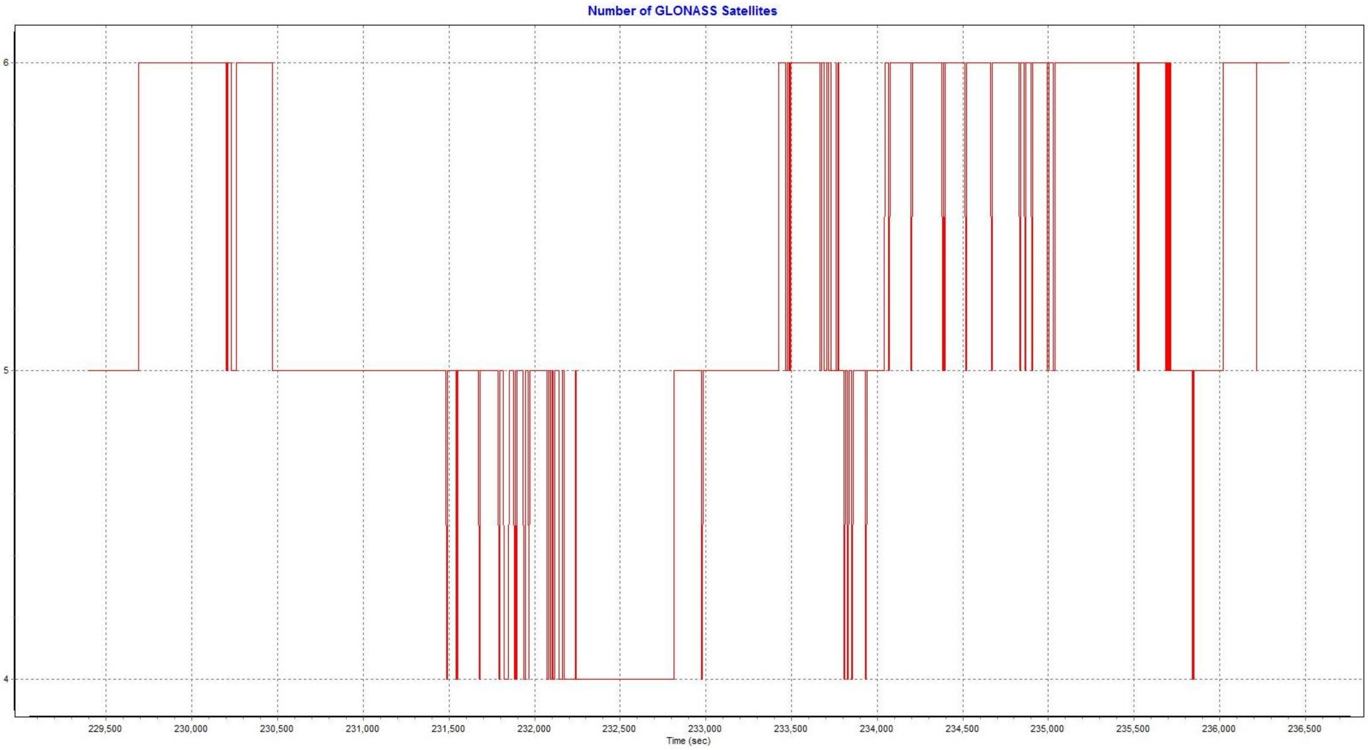
236,000
236,500
Time (sec)


Number of GLONASS Satellites
6
5
4
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231,000
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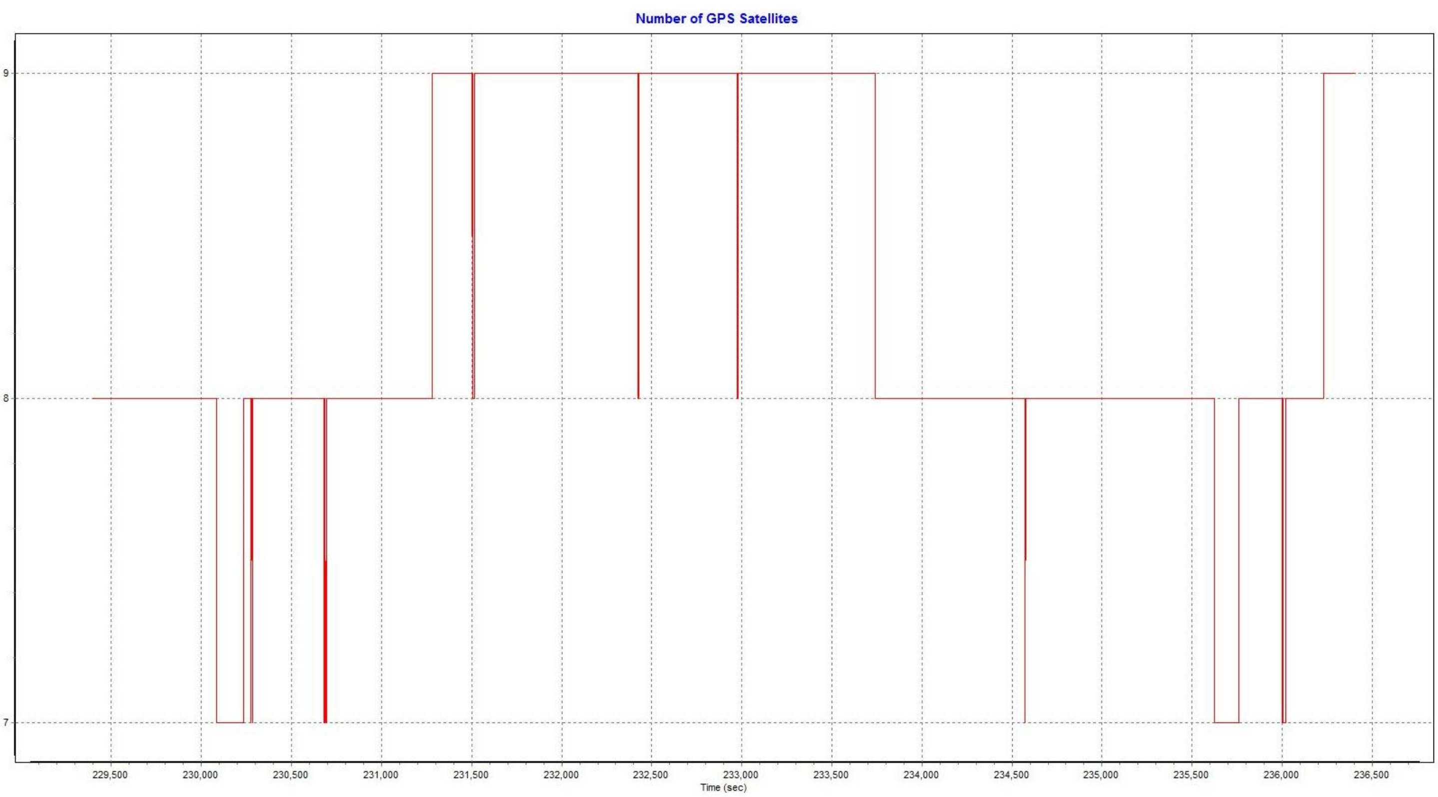
236,500
Time (sec)


Number of GPS Satellites
9
8
7
229,500
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230,500
231,000
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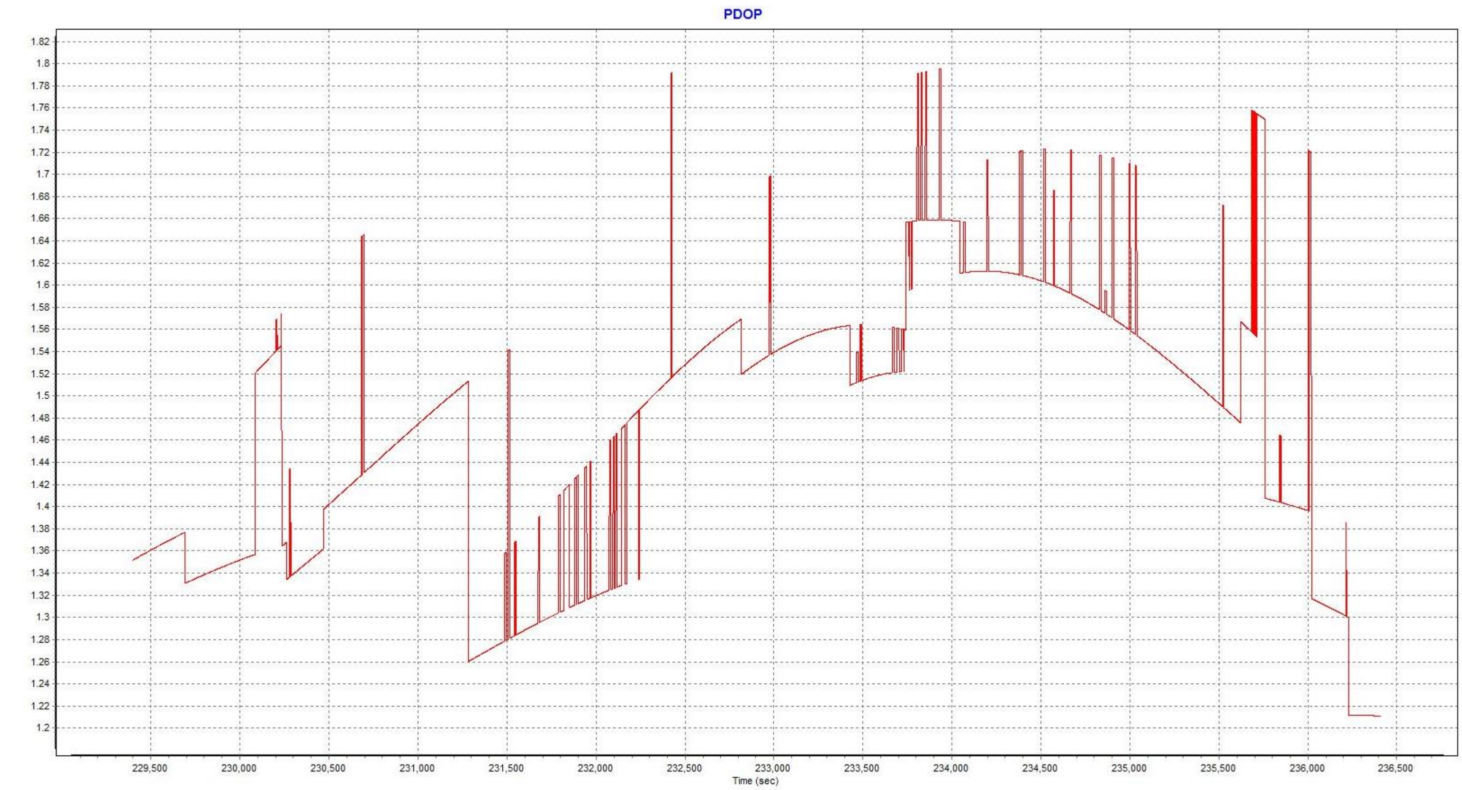
Time (sec)


PDOP
1.82
1.8
1.78
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1.74
1.72
1.7
1.68
1.66
1.64
1.62
1.6
1.58
1.56
1.54
1.52
1.5
1.48
1.46
1.44
1.42
1.4
1.38
1.36
1.34
1.32
1.3
1.28
1.26
1.24
1.22
1.2
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234,500
235,000
235,500
236,000
236,500
Time (sec)