# C-CLEAR Western Canada Glaciers LiDAR data acquisition and processing report


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## *Introduction*

Airborne LiDAR data collections were conducted over Glaciers in western Canada between August 22nd and 30th of 2006. The LiDAR survey was conducted with an Optech ALTM 3100 sensor. The Data set was processed in Optech’s Realm software and saved in LAS binary format. The ‘all hits’ data were classified into ground and non ground returns. The LiDAR Data sets are relatively large and need to be broken down into more manageable sections. Each survey was broken down into 1 km tiles. The bridge glacier was the exception as this survey needed to broken down into two kilometer tiles due to the large area covered. The tiles were processed in a number of different software environments before reaching the final output. This Report outlines the data acquisitions specifications and the steps taken to convert the raw LAS output files into raster grids in Surfer and Arc formats.

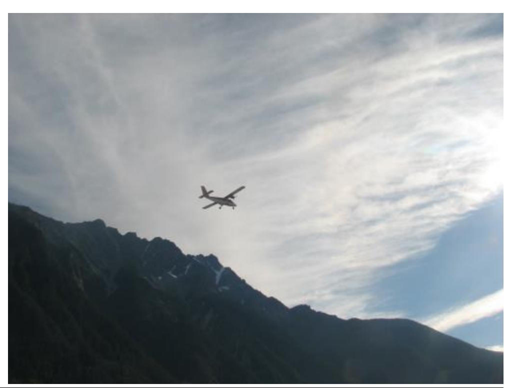
## ***ALTM 3100 survey specifications:***

GSC Survey– J Day238, August 25th to J Day August 29th

| Location | Laser Frequency (kHz) | Scanner Rate (Hz) | Scan Angle (± degrees) | Beam divergence | Strip overlap (%) | Flying Speed (knots) | Flying height (m a.g.l) |
|---|---|---|---|---|---|---|---|
| Peyto | 33 | 25 | 20/21 | Narrow | 50 | 160 | 1000-2000 |
| Helm | 33 | 23 | 21 | Narrow | 50 | 140 | 1500-2500 |
| Weart | 33 | 18.5 | 23 | Narrow | 50 | 140 | 2500-2500 |
| Whistler | 33 | 16.5 | 23 | Narrow | 50 | 140 | 1500-2500 |
| Bridge | 33 | 17 | 23 | Narrow | 50 | 140 | 2000-3000 |
| Sentinal & Garibaldi | 33 | 24 | 22 | Narrow | 50 | 138 | 1500-2500 |
| Place | 33 | 22 | 22 | Narrow | 50 | 140 | 1500-2500 |

Table 1: ALTM 3100 survey specifications for the GSC survey.

Installation of ALTM into Twin Otter Aircraft from Ken Bork Air Ltd:

*Photos by Dr. Christopher Hopkinson and Peter Horne*

Peyto Glacier – This survey was conducted on August 25th. The survey had 10 flight lines. The survey took approximately two hours to fly. There were some light clouds when the survey was conducted but did not prove to be an issue. The Air temperature at ground was 20 degrees Celsius. The ground conditions were dry. This survey was flown by Doctor Christopher Hopkinson. The image below shows the area that this survey covered.

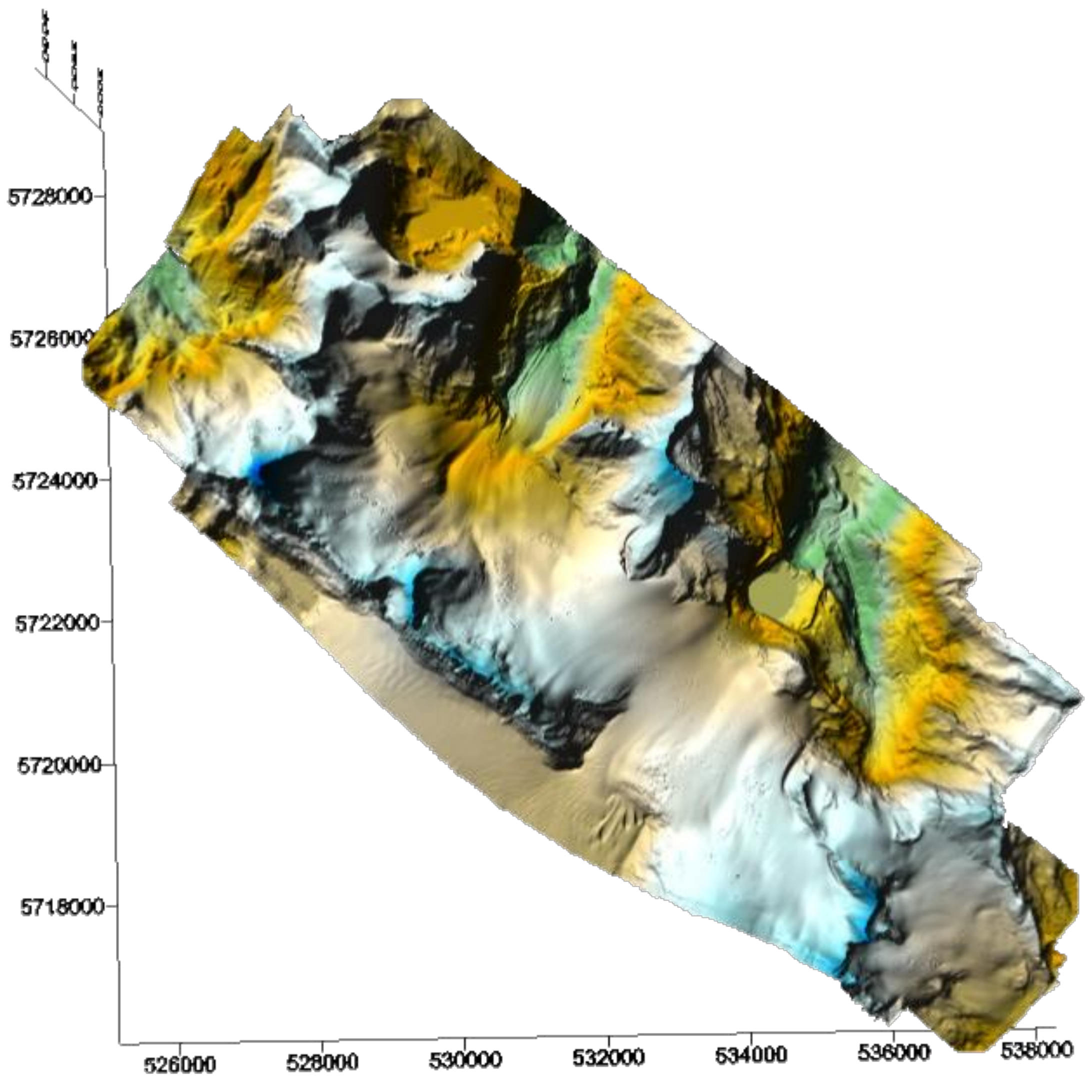



*Figure 1: Peyto Glacier 10m grid*

Helm Glacier - This survey was conducted on August 26th. The survey had 7 flight lines. The survey took approximately 1 hour to fly. There were no clouds when the survey was conducted. The Air temperature at ground was 30 degrees Celsius. The ground conditions were dry. This survey was flown by Laura Chasmer and Peter Horne. The image below shows the area that this survey covered.

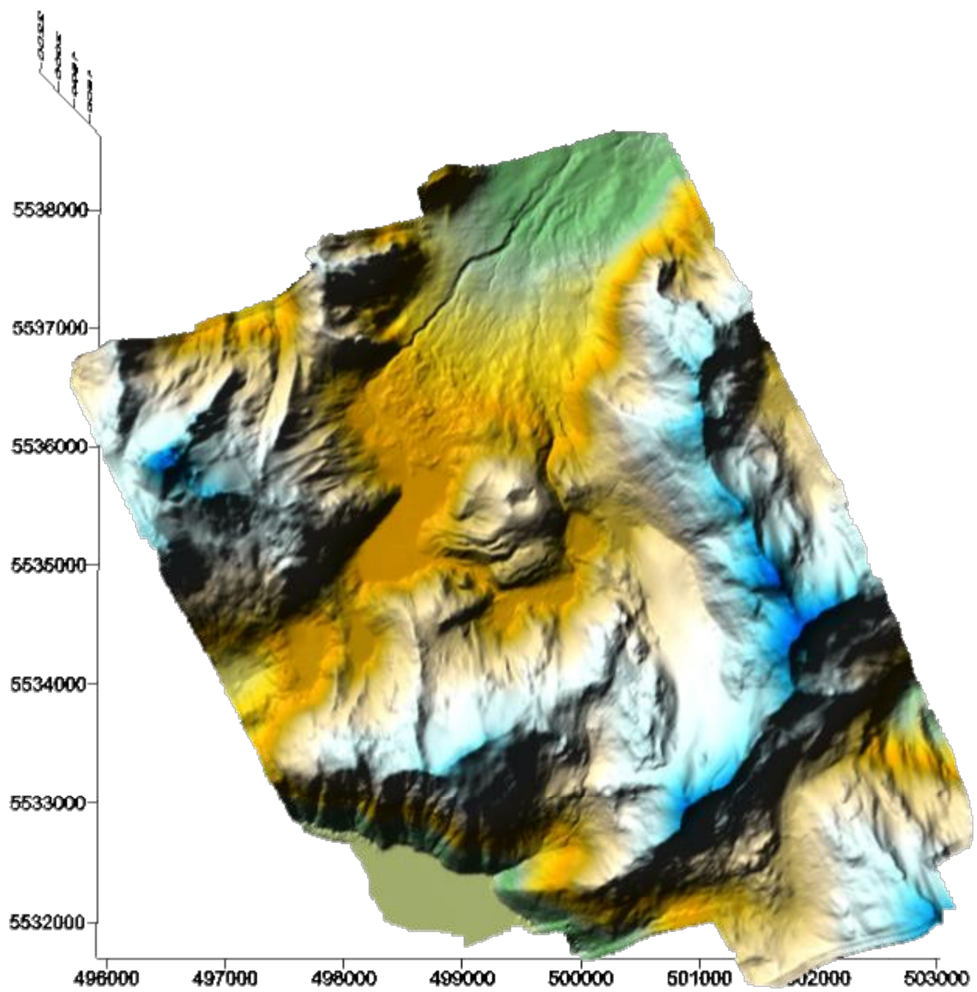



*Figure 2: Helm Glacier 10m grid*

Weart Glacier- This survey was conducted on August 26th. The survey had 5 flight lines. The survey took approximately 1 hour to fly. There were no clouds when the survey was conducted. The Air temperature at ground was 30 degrees Celsius. The ground conditions were dry. This survey was flown by Laura Chasmer and Peter Horne. The image below shows the area that this survey covered.

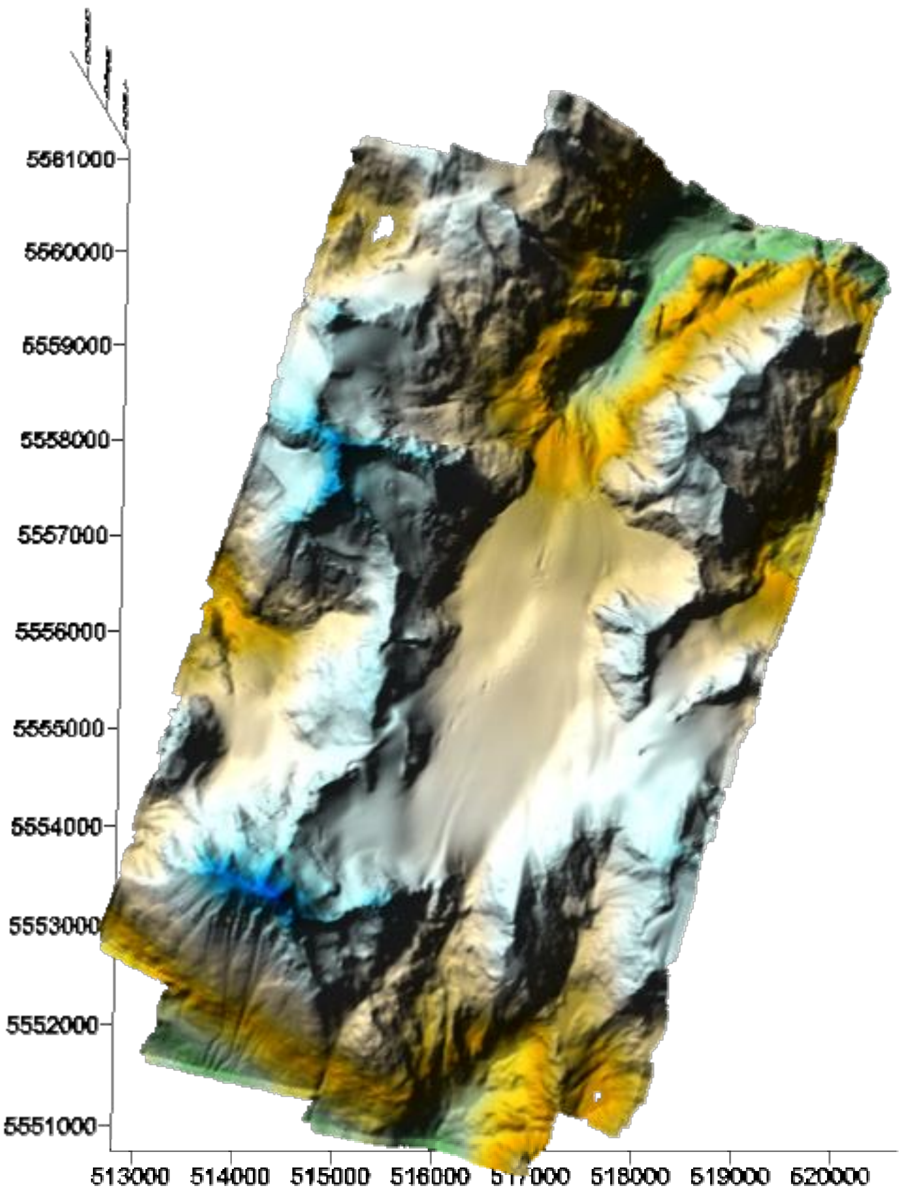



*Figure 3: Weart Glacier 10m grid*

Whistler- This survey was conducted on August 26th. The survey had 7 flight lines. The survey took approximately 1 hour to fly. There were no clouds when the survey was conducted. The Air temperature at ground was 30 degrees Celsius. The ground conditions were dry. This survey was flown by Laura Chasmer and Peter Horne. The image below shows the area that this survey covered. This area was not on the list of survey objectives but was flown because it was on the transit between two other surveys and it 'seemed like a good idea at the time', given the 2010 Olympics are to be located at this site.

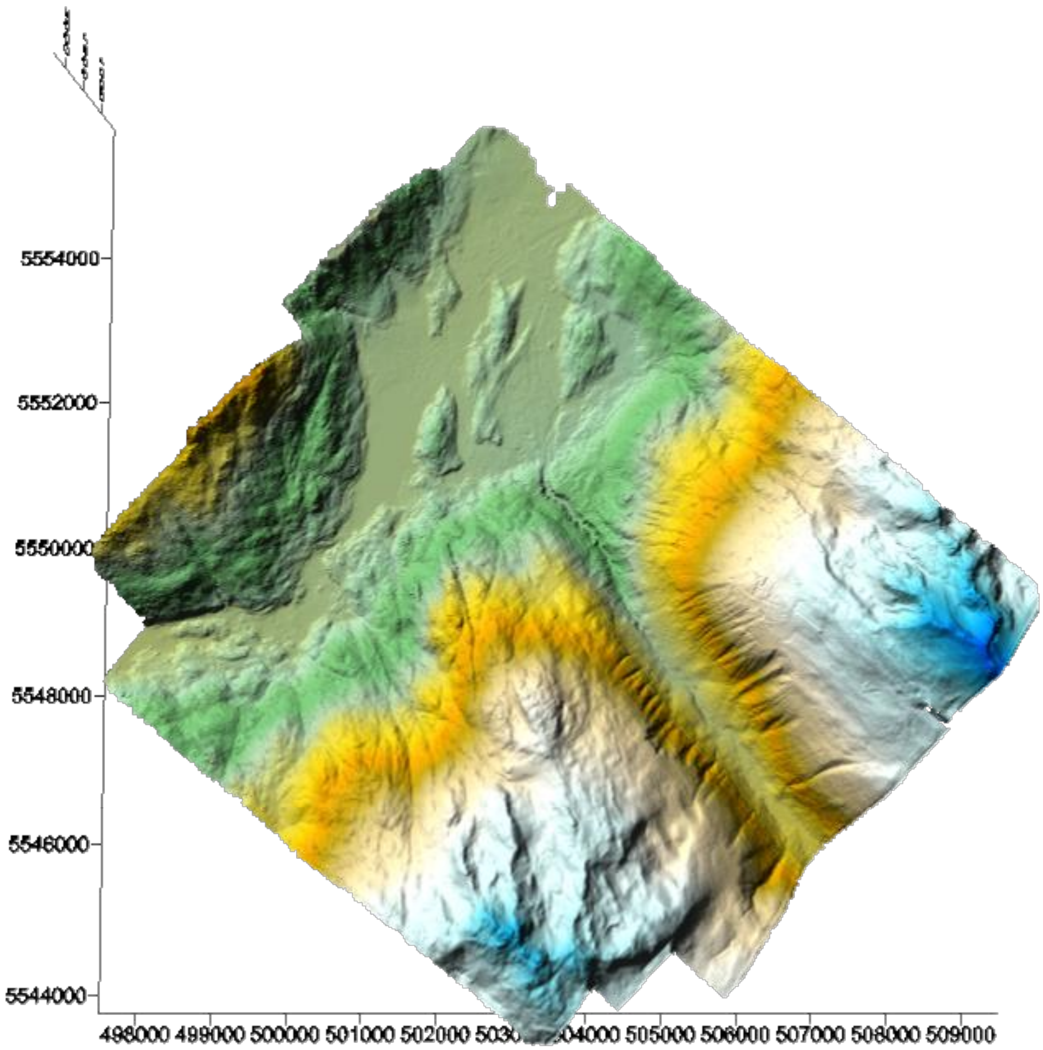



*Figure 4: Whisler 10m grid*

Sentinel Glacier- This survey was conducted on August 27th. The survey had 14 flight lines. The survey took approximately 2 hours to fly. There was no cloud cover when the survey was conducted. The Air temperature at ground was 15 degrees Celsius. The ground conditions were dry. This survey was flown by Laura Chasmer and Peter Horne. The image below shows the area that this survey covered.

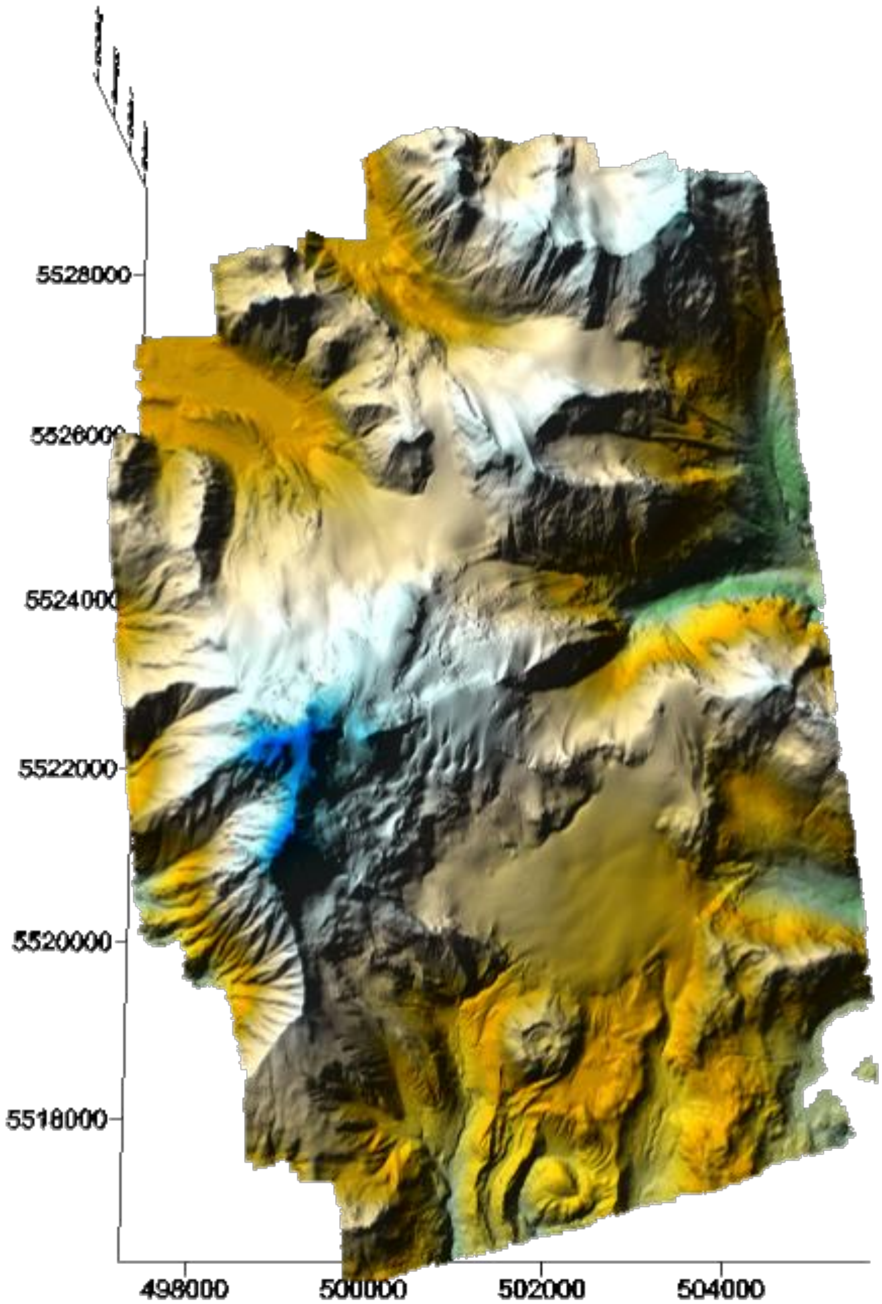



*Figure 5: Sentinal Glacier 10m grid*

Bridge Glacier- This survey was conducted on August 27th. The survey had 14 flight lines. The survey took approximately 4 hours to fly. There was no cloud cover when the survey was conducted. The Air temperature at ground was 15 degrees Celsius. The ground conditions were dry. This survey was flown by Laura Chasmer and Peter Horne. The image below shows the area that this survey covered.

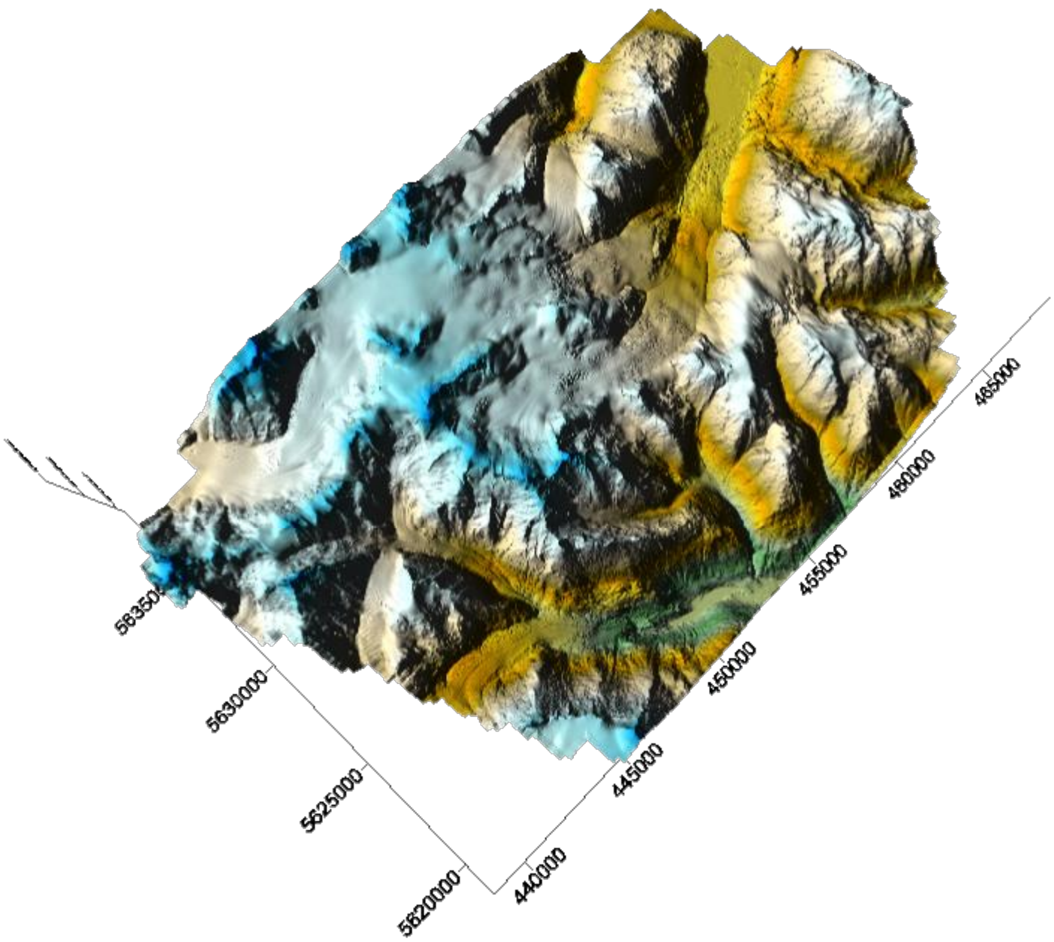



*Figure 6: Bridge Glacier 10m grid*

Place Glacier- This survey was conducted on August 29th. This survey was originally flown on August 26th but had to be flown again due to effects caused by GPS roll over on the GPS data. The survey had 8 flight lines. The survey took approximately 1 hour to fly. There was 5% cloud cover when the survey was conducted. The Air temperature at ground was 20 degrees Celsius. The ground conditions were dry. This survey was flown by Dr. Chris Hopkinson. The image below shows the area that this survey covered.

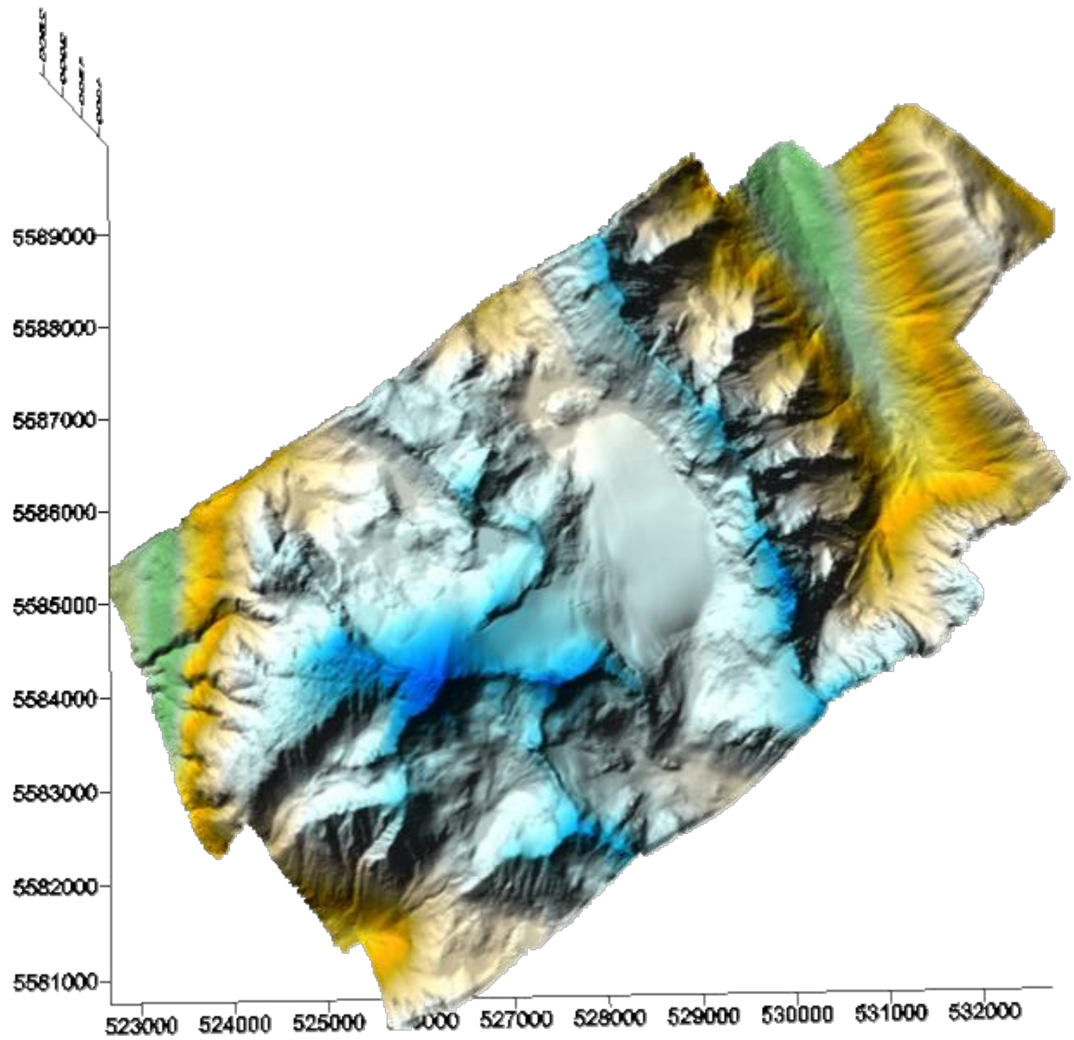



*Figure 7: Place Glacier 10m gird*

### ***Data processing summary:***

GPS trajectory and inertial measurement unit data were integrated and processed with the Applanix proprietary 'PosPac' software environment.

The IMU, GPS, Return Intensity data were integrated Optech's proprietary 'REALM' software. The data output was processed by flight line and saved in the binary 'LAS' format. The data were then imported into Terrascan and classified into ground returns before being exported to an ASCII XYZ format. The data were gridded in surfer and saved in GRD and ASC format. The ASC files were imported into ArcGIS and saved as a raster. See description below describing the tiling, classification and gridding procedures.

All data have been outputted relative to the GPS base station location coordinates relative to the NAD83 CSRS datum. All elevations are ellipsoidal and all coordinates have been outputted in the UTM projection. Apart from Peyto, all GPS base stations were set up as close to the survey locations as was convenient at the time of the data acquisitions. It was not possible to locate over known monuments due to timing and sky view factors. Therefore, all base station positions were calculated using the NRCAN online *Precise Point Positioning* (PPP) service.

### ***GPS base stations:***

*Peyto Glacier Base Station Info*

The GPS base station that was used for validation was located at:
Name: P - Joanna
NAD83 coordinates provided by the Geological Survey of Canada:

531559.327
5726322.137
2215.825

*Helm, Weart and Whisler Glacier Base Station Info*

## CSRS-PPP

**(Processing Software Version: 1.04 246 )**

### Processing Summary for Pemberton_2380.06o

| Data Start | | Data End |
|---|---|---|
| 2006-08-26 22:56:20.00 | | 2006-08-27 03:19:54.00 |
| **Apri / Aposteriori Phase Std** | | **Apri / Aposteriori Code Std** |
| 0.015m / 0.011m | | 2.0m / 1.042m |
| **Observations** | **Frequency** | **Mode** |
| Phase and Code | L1 and L2 | Static |
| **Elevation Cut-Off** | **Rejected Epochs** | **Estimation Step** |
| 10.000 degrees | 0.02 % | Same as Input RINEX File |
| **Antenna Model** | **APC to ARP** | **ARP to Marker** |
| | 0.000 m | 0.000 m |

(APC = antenna phase center; ARP = antenna reference point)

### Estimated Position for Pemberton_2380.06o

| | Latitude (+n) (dms) | Longitude (+e) (dms) | Ell. Height (m) |
|---|---|---|---|
| **NAD83-CSRS** | 50 18 11.0210 | -122 44 19.2431 | 192.124 |
| **Sigmas** | 0.004 | 0.010 | 0.016 |
| **Apriori** | 50 18 11.053 | -122 44 19.318 | 193.807 |
| **Estimated - Apriori** | -0.975 m | 1.473 m | -1.682 m |

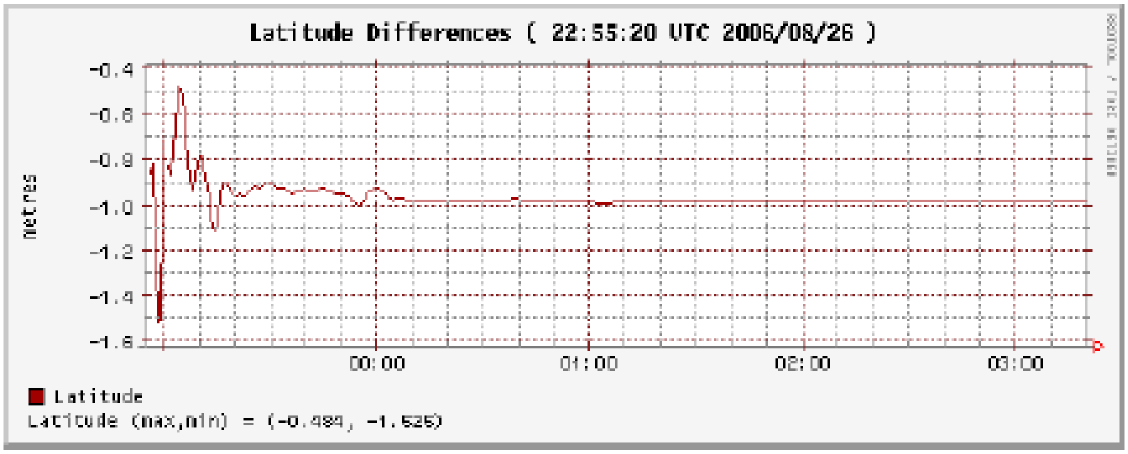
(Coordinates from RINEX file used as apriori position)

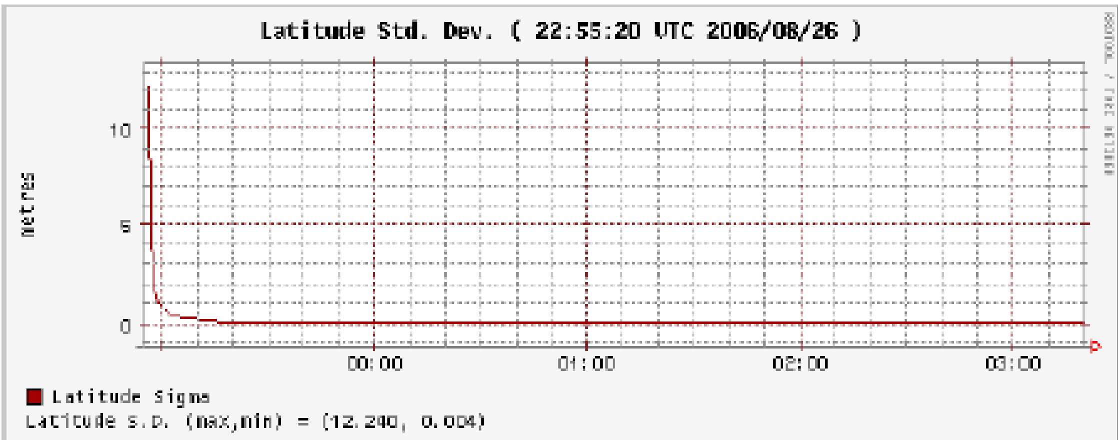
19:19:17 UTC 2006/09/28 1 Pemberton_2380.06o

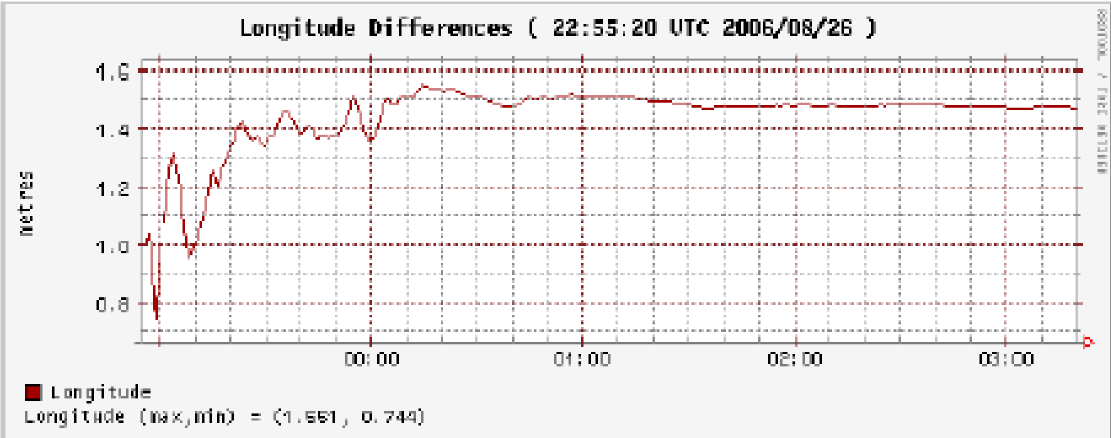
## Estimated Parameters & Observations Statistics

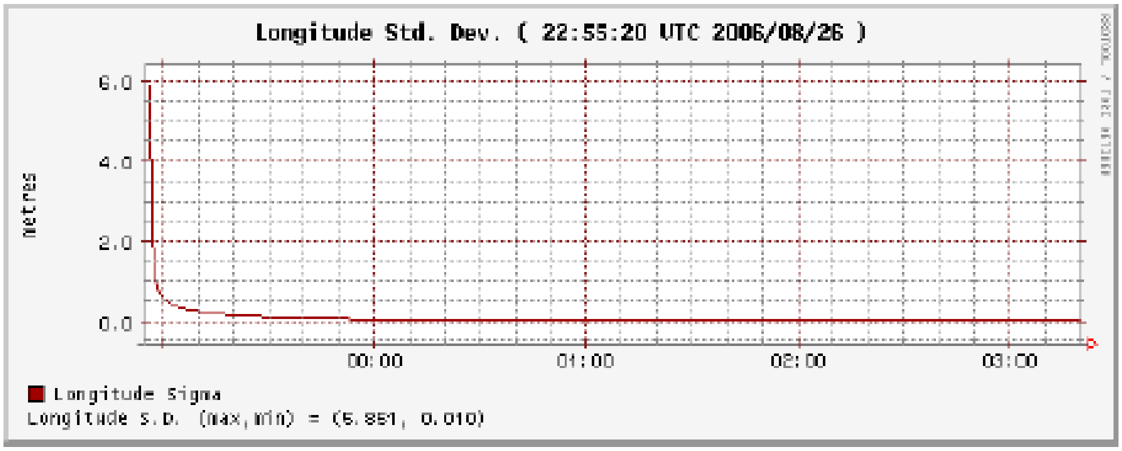
(Note 1: 1 plotted point = average of 32 estimated points)

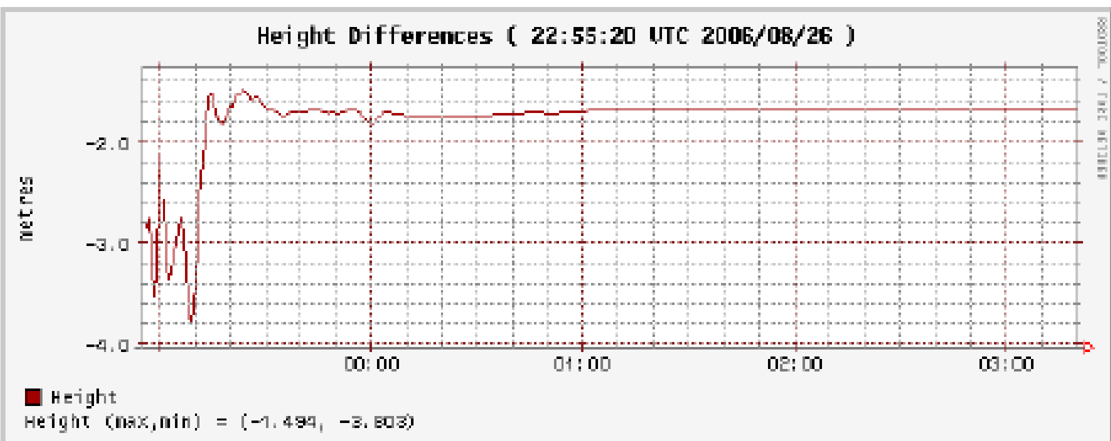
(Note 2: Estimated Tropospheric Zenith Delay Plotted)

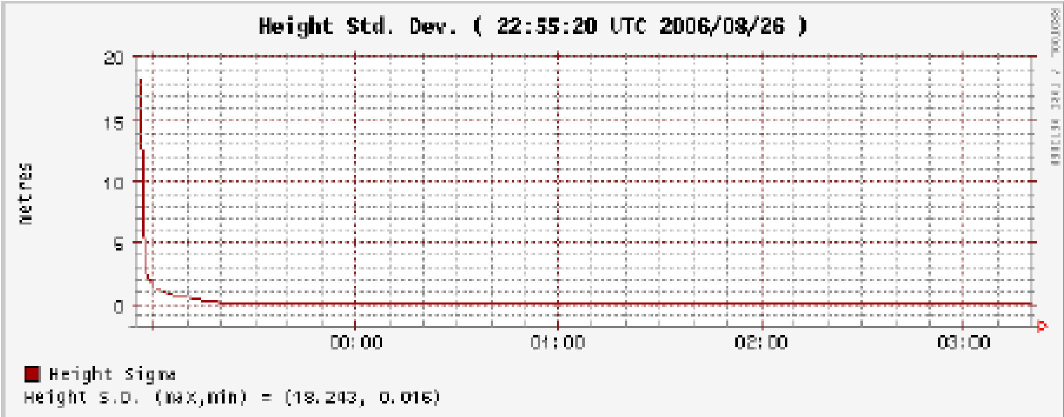


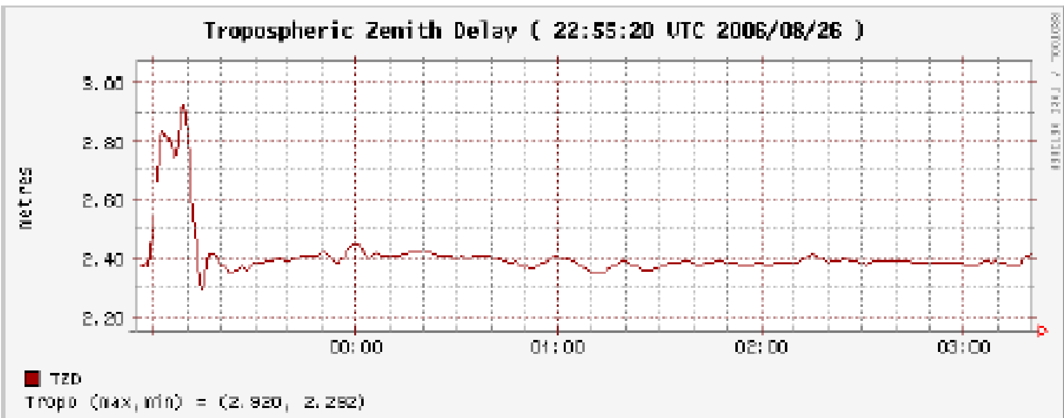



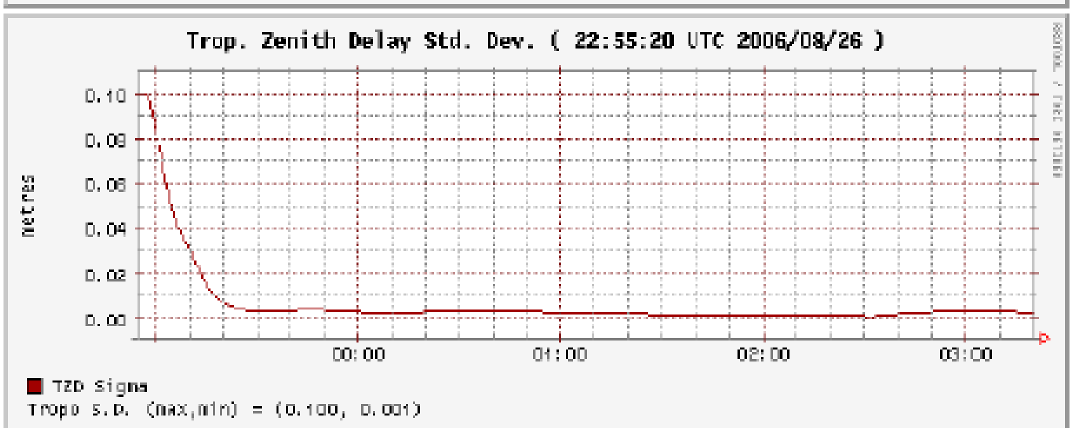

Longitude Differences ( 22:55:20 UTC 2006/08/26 )
metres
1.6
1.4
1.2
1.0
0.8
00:00
01:00
02:00
03:00
Longitude
Longitude (max,min) = (1.551, 0.744)

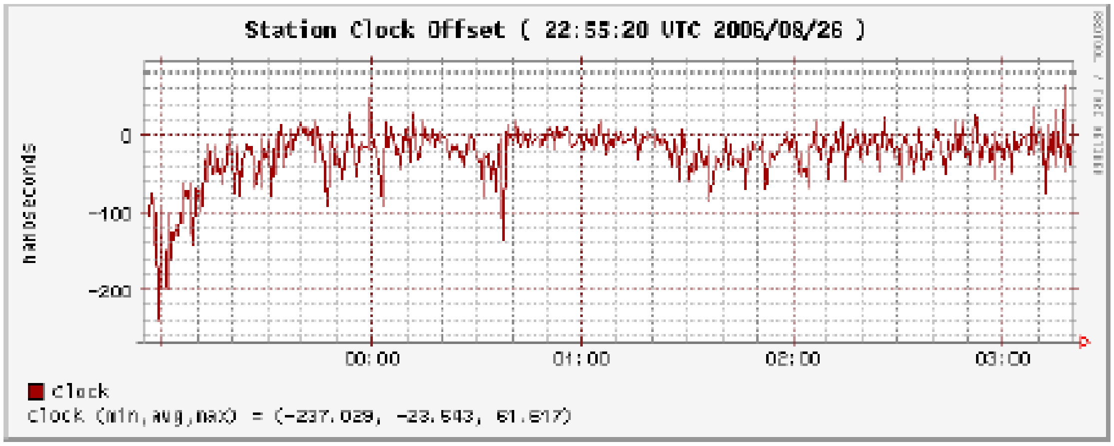

Longitude Std. Dev. ( 22:55:20 UTC 2006/08/26 )
metres
6.0
4.0
2.0
0.0
00:00
01:00
02:00
03:00
Longitude Sigma
Longitude S.D. (max,min) = (5.851, 0.010)

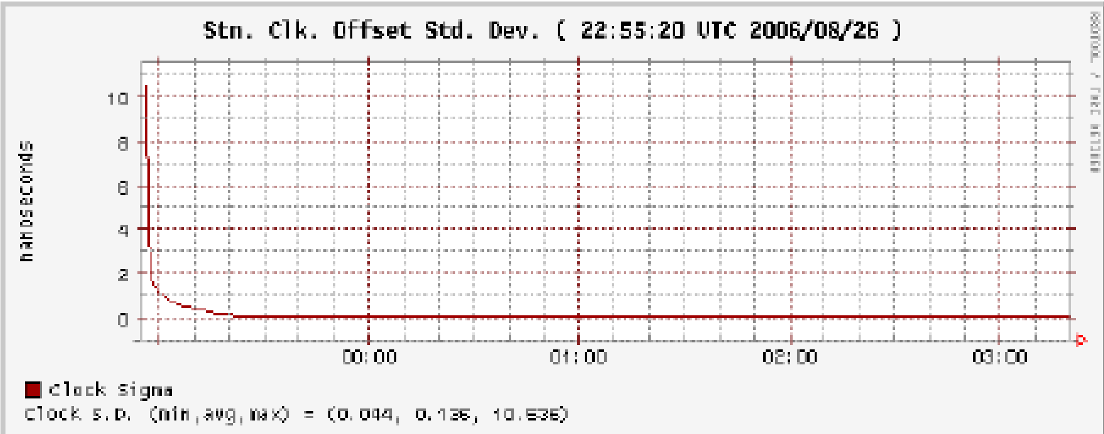

Height Differences ( 22:55:20 UTC 2006/08/26 )
metres
-2.0
-3.0
-4.0
00:00
01:00
02:00
03:00
Height
Height (max,min) = (-1.494, -3.803)

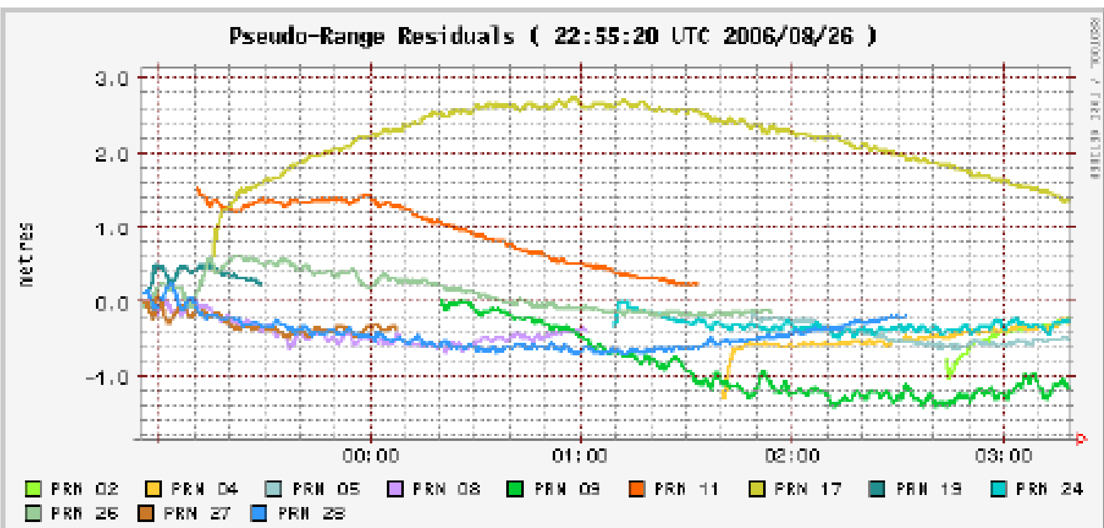

Height Std. Dev. ( 22:55:20 UTC 2006/08/26 )
metres
20
15
10
5
0
00:00
01:00
02:00
03:00
Height Sigma
Height S.D. (max,min) = (18.243, 0.016)

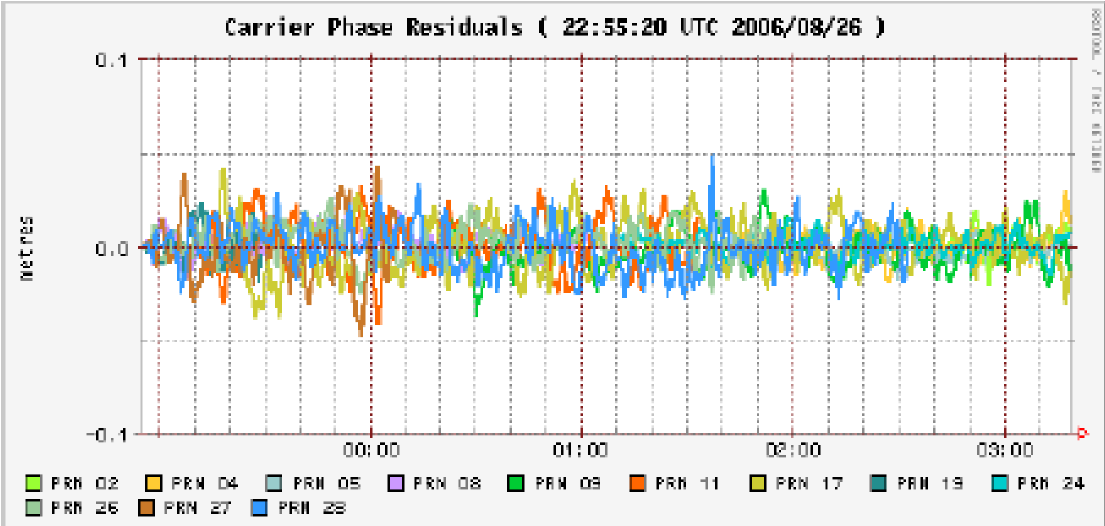

Tropospheric Zenith Delay ( 22:55:20 UTC 2006/08/26 )
metres
3.00
2.80
2.60
2.40
2.20
00:00
01:00
02:00
03:00
TZD
Tropo (max,min) = (2.920, 2.292)

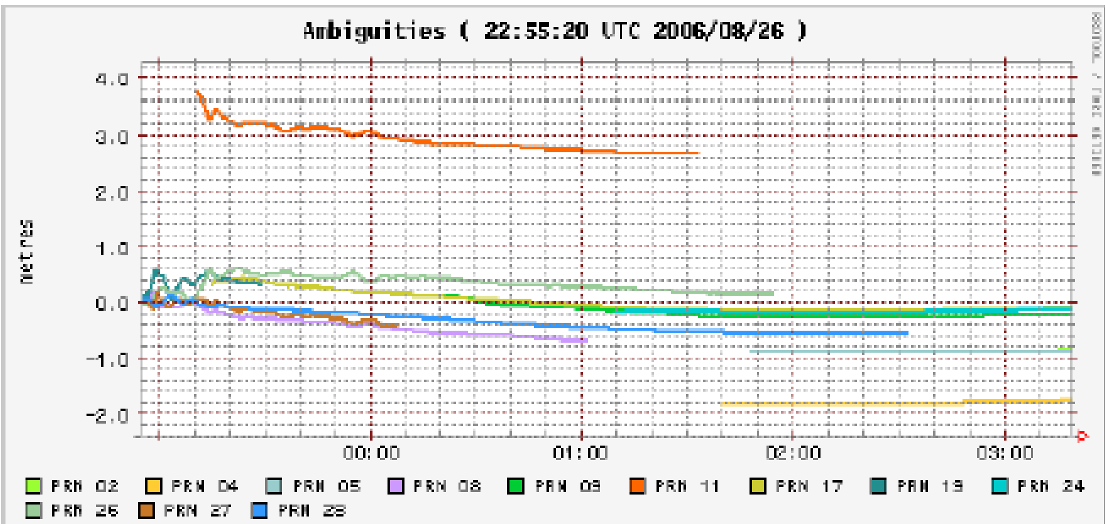

Trop. Zenith Delay Std. Dev. ( 22:55:20 UTC 2006/08/26 )
metres
0.10
0.08
0.06
0.04
0.02
0.00
00:00
01:00
02:00
03:00
TZD Sigma
Tropo S.D. (max,min) = (0.100, 0.001)


Station Clock Offset ( 22:55:20 UTC 2006/08/26 )
nanoseconds
0
-100
-200
00:00
01:00
02:00
03:00
Clock
Clock (min,avg,max) = (-237.029, -23.543, 61.617)


Stn. Clk. Offset Std. Dev. ( 22:55:20 UTC 2006/08/26 )
nanoseconds
10
8
6
4
2
0
00:00
01:00
02:00
03:00
Clock Sigma
Clock S.D. (min,avg,max) = (0.044, 0.136, 10.536)


Pseudo-Range Residuals ( 22:55:20 UTC 2006/08/26 )
metres
3.0
2.0
1.0
0.0
-1.0
00:00
01:00
02:00
03:00
PRN 02
PRN 04
PRN 05
PRN 08
PRN 09
PRN 11
PRN 17
PRN 19
PRN 24
PRN 26
PRN 27
PRN 28




<u>**CSRS-PPP Duplicate RINEX Data Block**</u>

A duplicate data block has been removed from your RINEX observation file.

**Your RINEX observation file contains duplicate time tags.**

**First duplicate epoch (time: 20060826230037.0000000) was removed.**

**--- Disclaimer ---**

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# CSRS-PPP

**(Processing Software Version: 1.04 246 )**

## Processing Summary for CAM_2390_sentinel.06o

| | | |
|---|---|---|
| **Data Start** | | **Data End** |
| 2006-08-27 16:40:26.00 | | 2006-08-27 19:03:21.00 |
| **Apri / Aposteriori Phase Std** | | **Apri / Aposteriori Code Std** |
| 0.015m / 0.013m | | 2.0m / 0.734m |
| **Observations** | **Frequency** | **Mode** |
| Phase and Code | L1 and L2 | Static |
| **Elevation Cut-Off** | **Rejected Epochs** | **Estimation Step** |
| 10.000 degrees | 0.01 % | Same as Input RINEX File |
| **Antenna Model** | **APC to ARP** | **ARP to Marker** |
| | 0.000 m | 0.000 m |

(APC = antenna phase center; ARP = antenna reference point)

## Estimated Position for CAM_2390_sentinel.06o

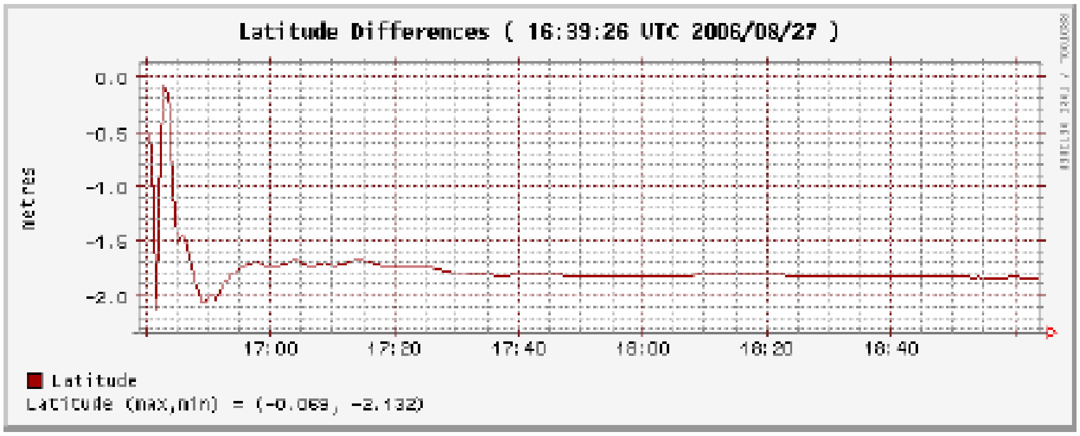
| | **Latitude (+n) (dms)** | **Longitude (+e) (dms)** | **Ell. Height (m)** |
|---|---|---|---|
| **NAD83-CSRS** | 50 03 38.1320 | -123 06 31.5428 | 495.106 |
| **Sigmas** | 0.005 | 0.008 | 0.015 |
| **Apriori** | 50 03 38.191 | -123 06 31.620 | 503.906 |
| **Estimated - Apriori** | -1.837 m | 1.539 m | -8.800 m |

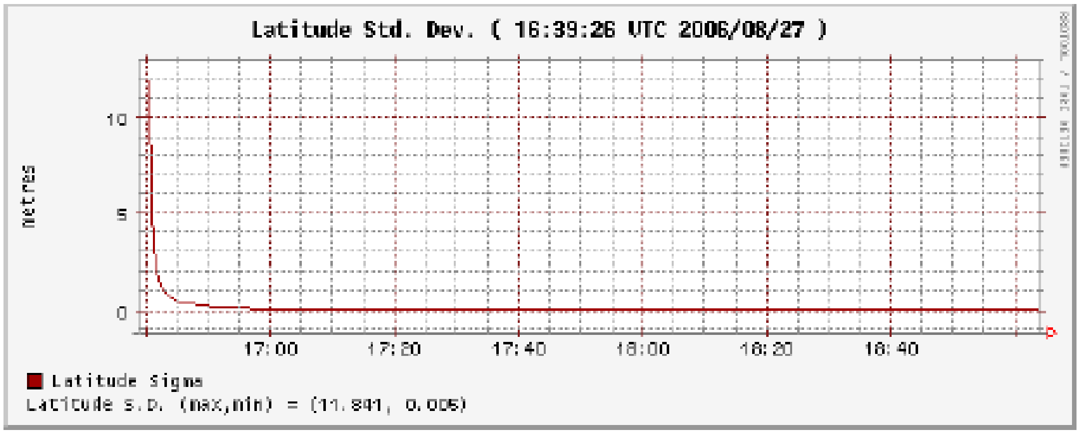
(Coordinates from RINEX file used as apriori position)

## Estimated Parameters & Observations Statistics

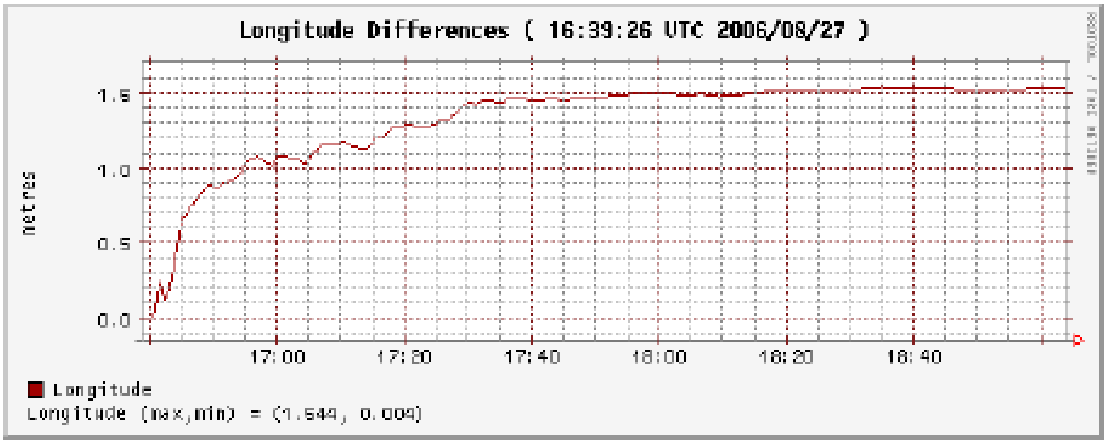
(Note 1: 1 plotted point = average of 17 estimated points)

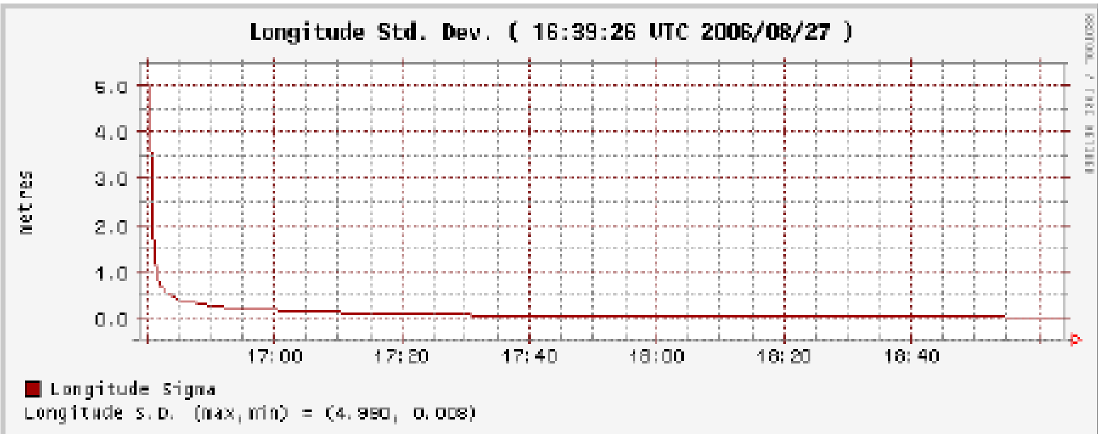
(Note 2: Estimated Tropospheric Zenith Delay Plotted)

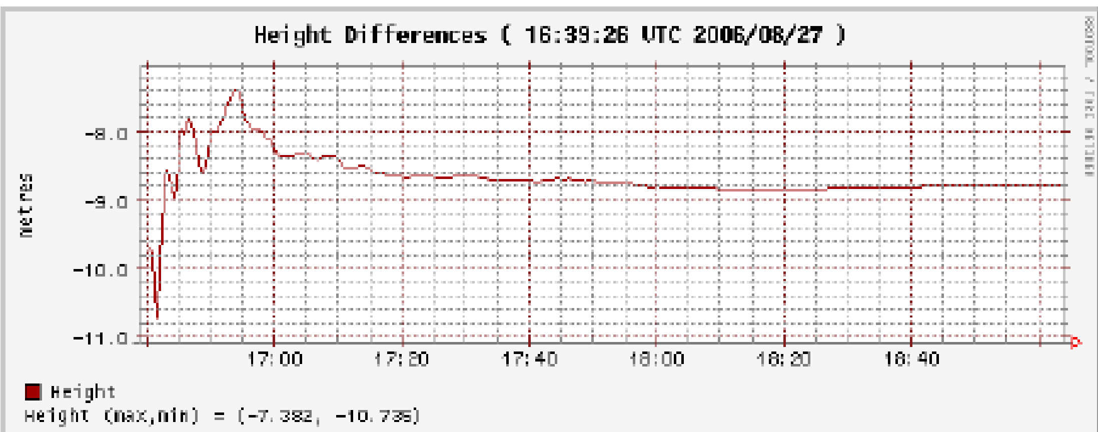


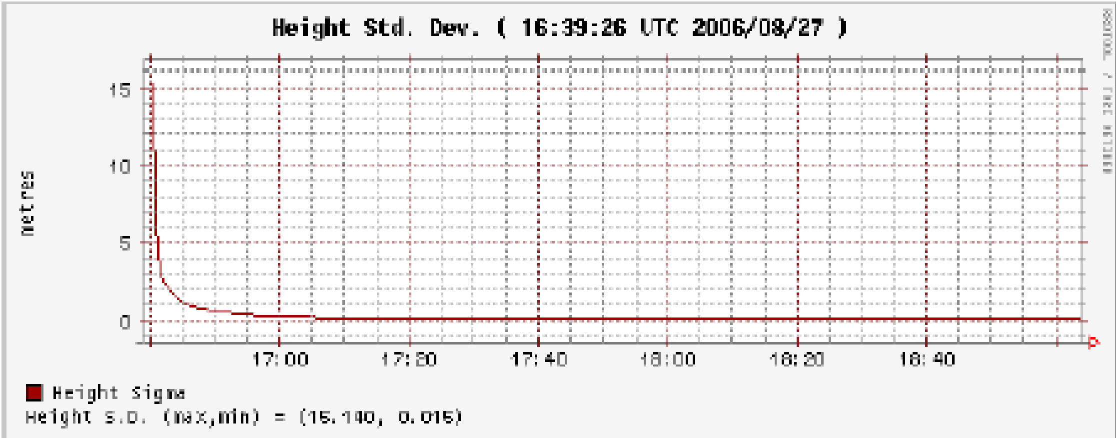

CAM_2390_sentinel.06o 2 19:30:33 UTC 2006/09/28

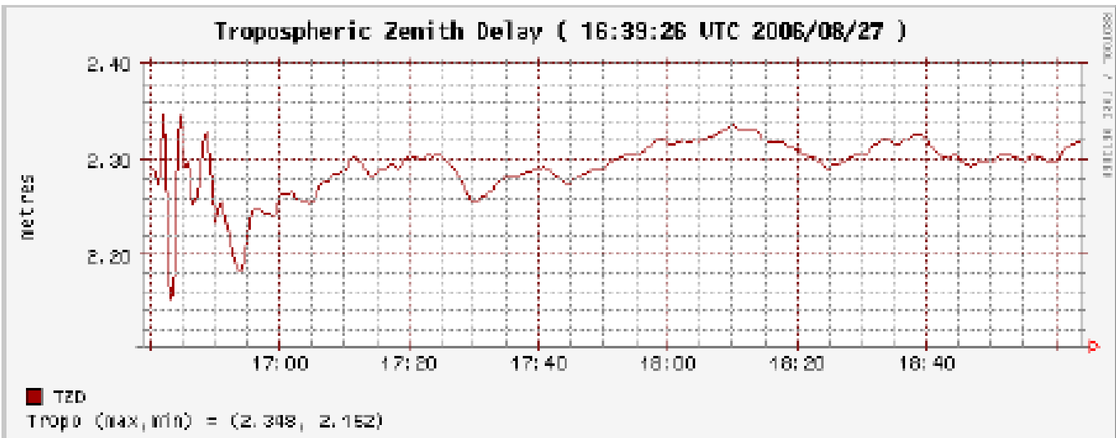


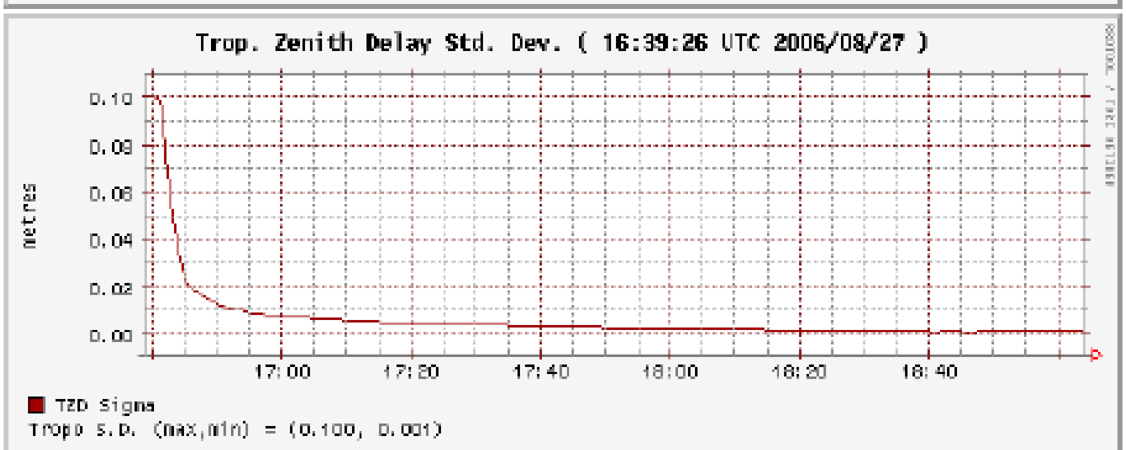



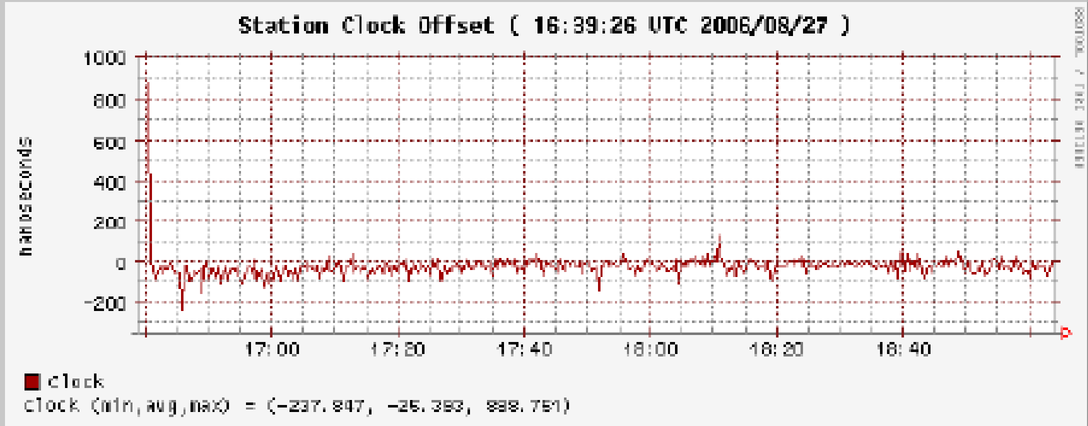

19:30:33 UTC 2006/09/28 3 CAM_2390_sentinel.06o

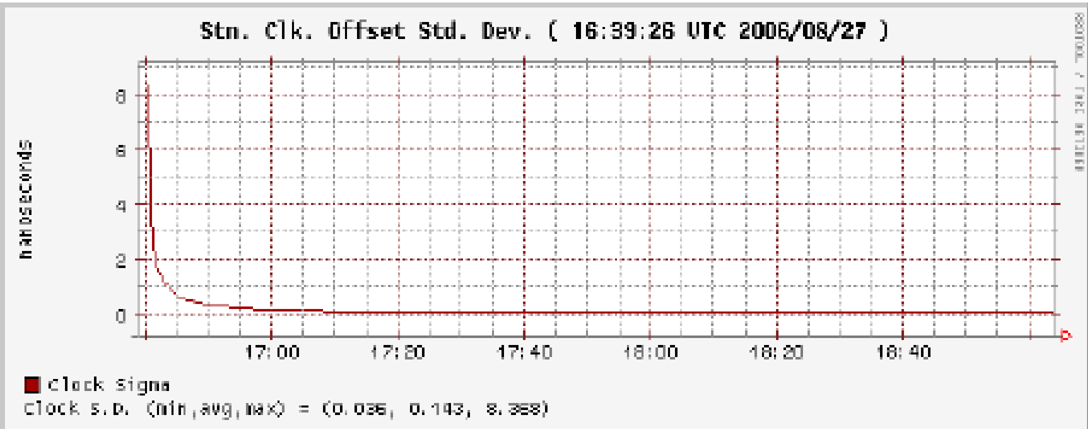


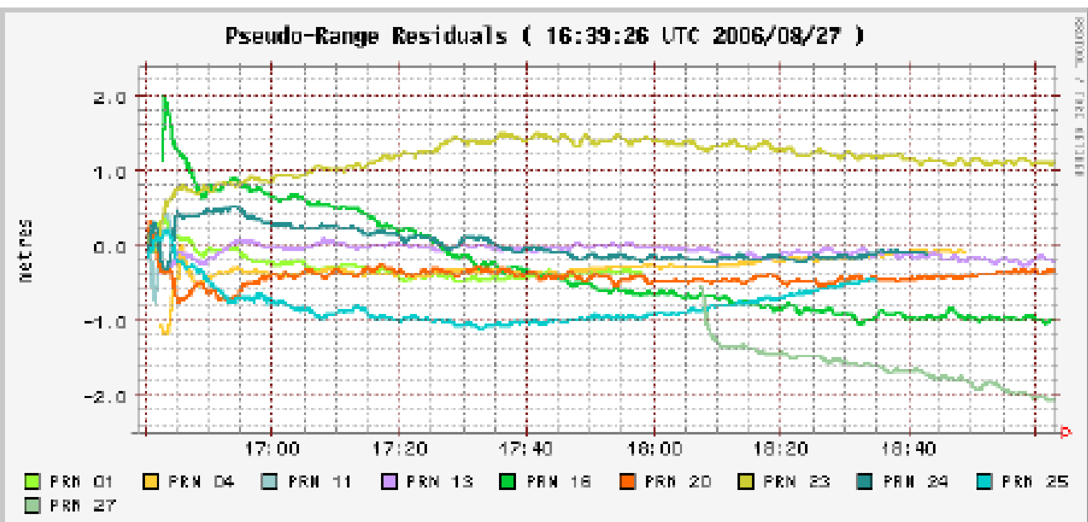



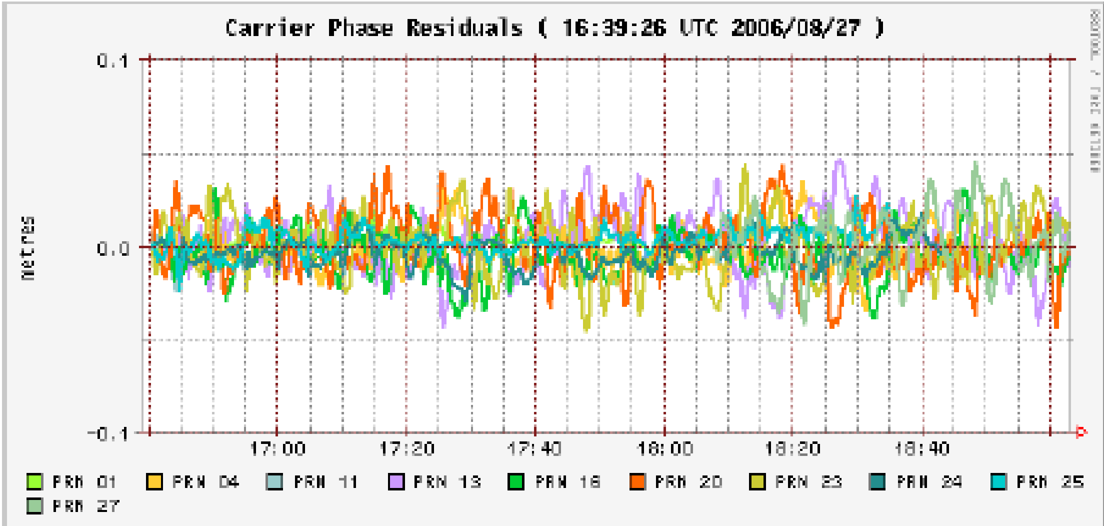

CAM_2390_sentinel.06o 4 19:30:33 UTC 2006/09/28

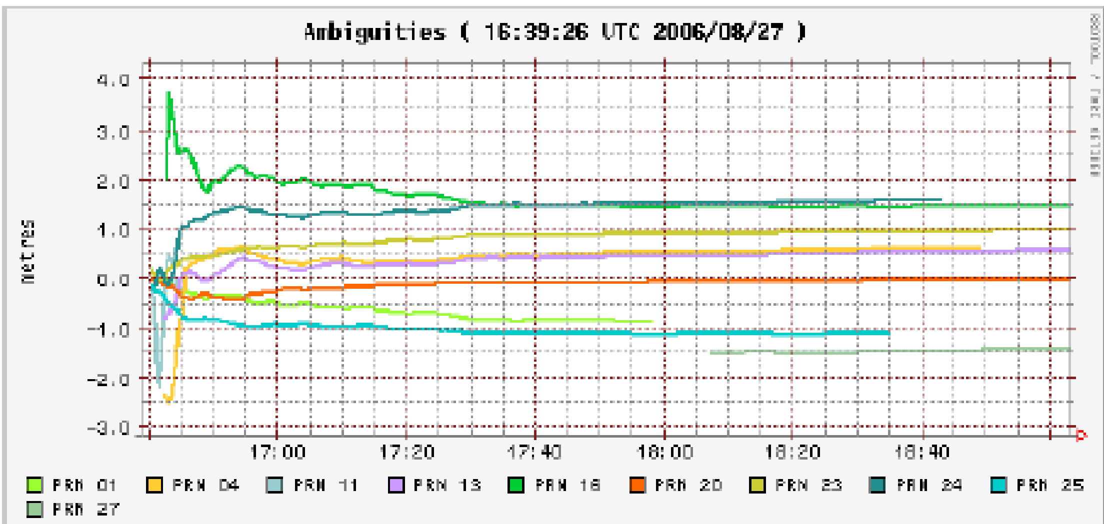



19:30:33 UTC 2006/09/28 5 CAM_2390_sentinel.06o




**--- Disclaimer ---**

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*Bridge Glacier Base Station Info*

# CSRS-PPP

**(Processing Software Version: 1.04 246 )**

## Processing Summary for CAM_2390_bridge.06o

| Data Start | | Data End |
|---|---|---|
| 2006-08-27 22:18:04.00 | | 2006-08-28 02:00:14.00 |
| **Apri / Aposteriori Phase Std** | | **Apri / Aposteriori Code Std** |
| 0.015m / 0.012m | | 2.0m / 1.048m |
| **Observations** | **Frequency** | **Mode** |
| Phase and Code | L1 and L2 | Static |
| **Elevation Cut-Off** | **Rejected Epochs** | **Estimation Step** |
| 10.000 degrees | 0.01 % | Same as Input RINEX File |
| **Antenna Model** | **APC to ARP** | **ARP to Marker** |
| | 0.000 m | 0.000 m |

(APC = antenna phase center; ARP = antenna reference point)

## Estimated Position for CAM_2390_bridge.06o

| | Latitude (+n) (dms) | Longitude (+e) (dms) | Ell. Height (m) |
|---|---|---|---|
| **NAD83-CSRS** | 50 34 12.9951 | -123 16 22.8401 | 302.221 |
| **Sigmas** | 0.004 | 0.008 | 0.014 |
| **Apriori** | 50 34 13.037 | -123 16 22.882 | 302.242 |
| **Estimated - Apriori** | -1.282 m | 0.829 m | -0.021 m |

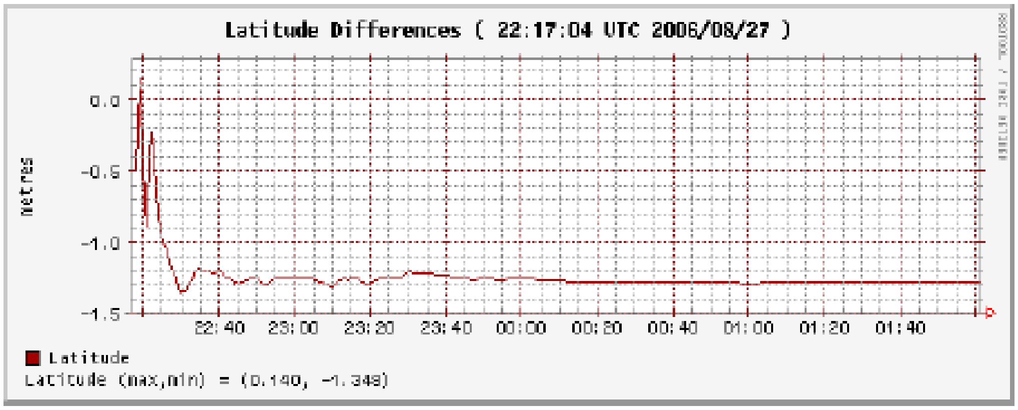
(Coordinates from RINEX file used as apriori position)

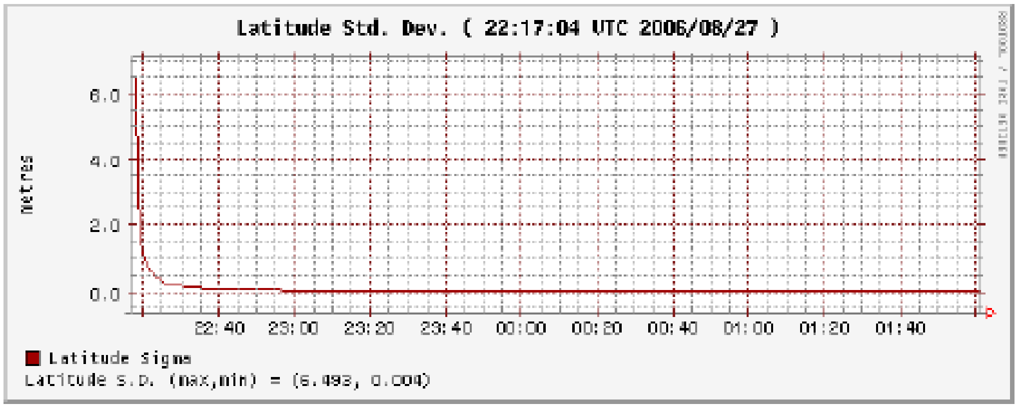
19:38:10 UTC 2006/09/28 1 CAM_2390_bridge.06o

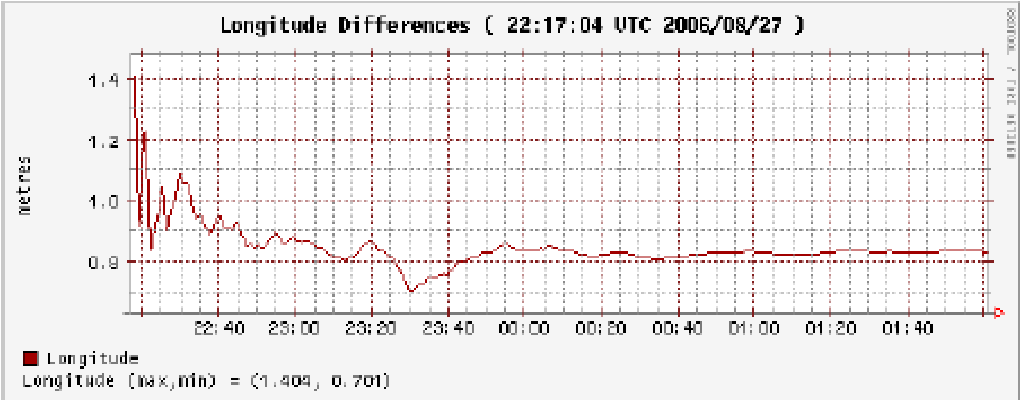
## Estimated Parameters & Observations Statistics

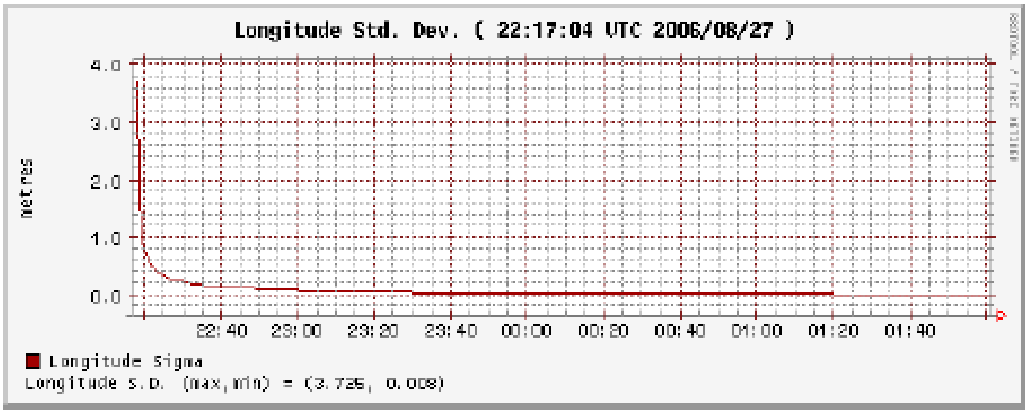
(Note 1: 1 plotted point = average of 27 estimated points)

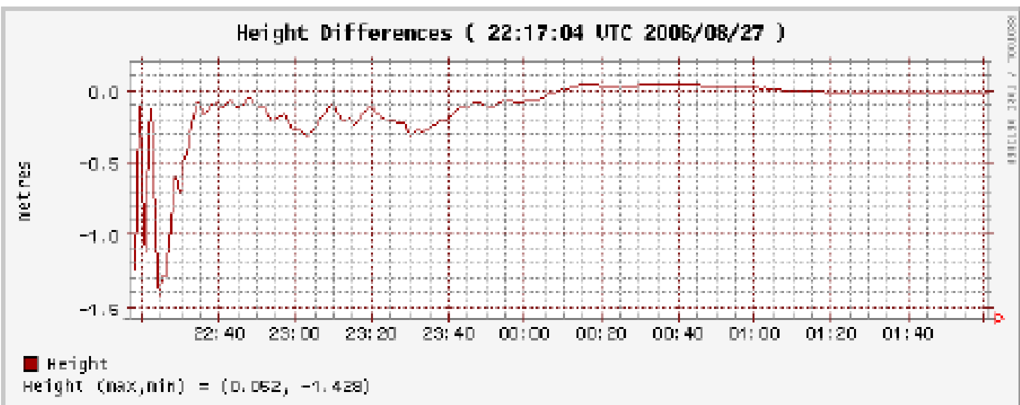
(Note 2: Estimated Tropospheric Zenith Delay Plotted)

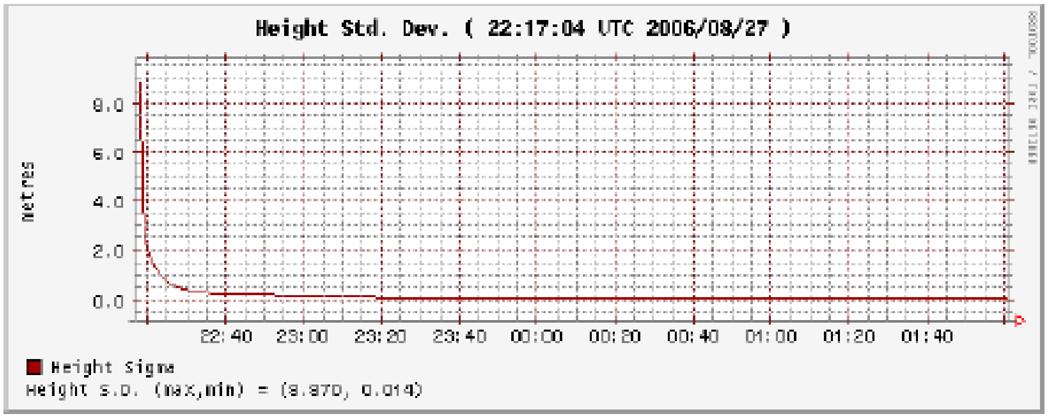


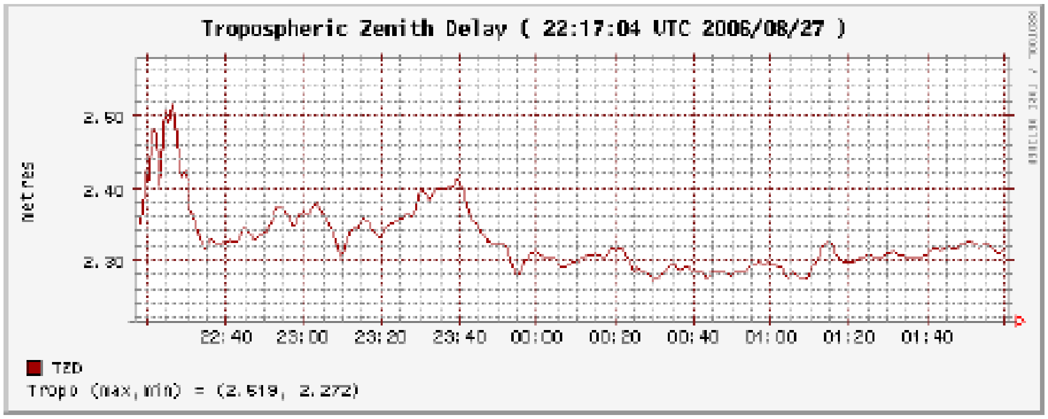



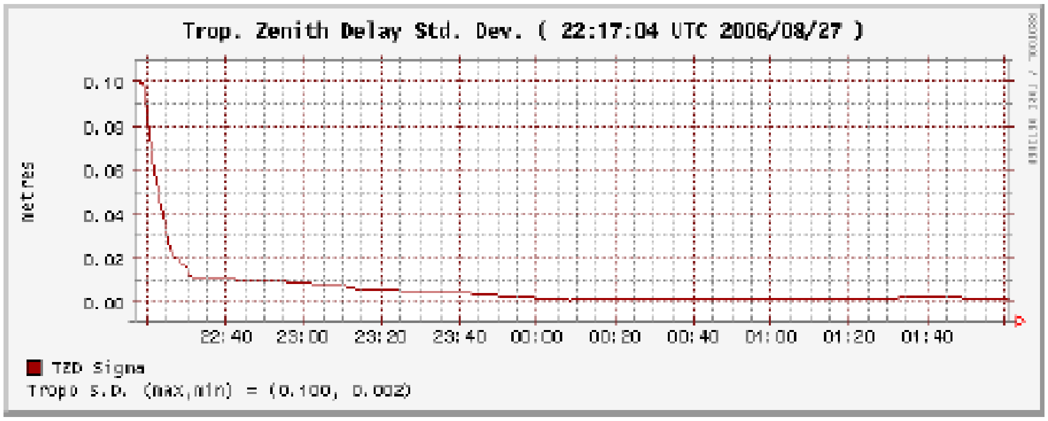

Longitude Differences ( 22:17:04 UTC 2006/08/27 )
metres
1.4
1.2
1.0
0.8
22:40
23:00
23:20
23:40
00:00
00:20
00:40
01:00
01:20
01:40
Longitude
Longitude (max,min) = (1.409, 0.701)

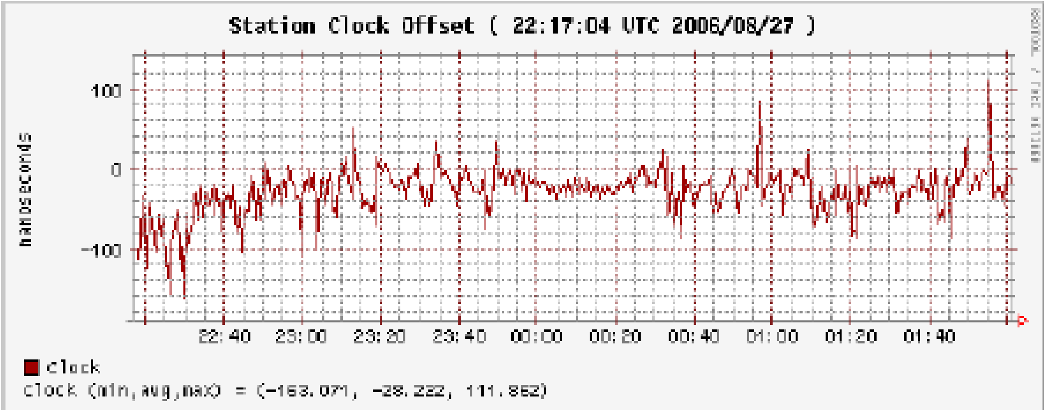

Longitude Std. Dev. ( 22:17:04 UTC 2006/08/27 )
metres
4.0
3.0
2.0
1.0
0.0
22:40
23:00
23:20
23:40
00:00
00:20
00:40
01:00
01:20
01:40
Longitude Sigma
Longitude S.D. (max,min) = (3.725, 0.008)

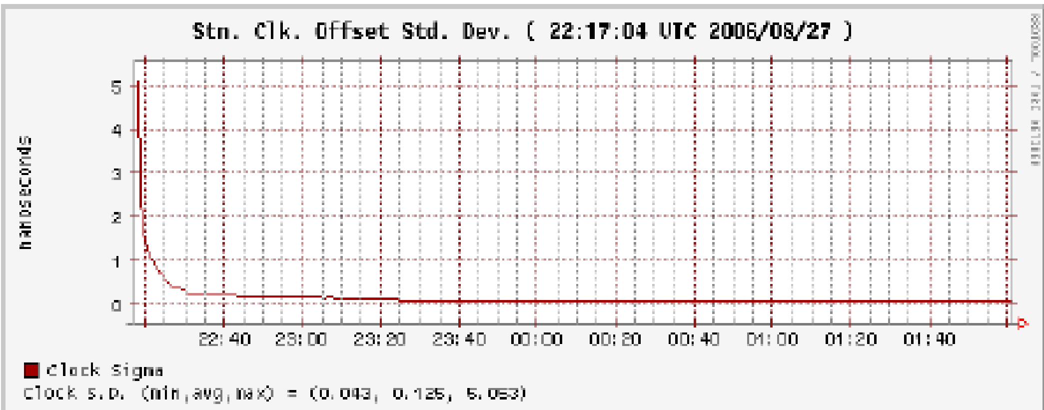

Height Differences ( 22:17:04 UTC 2006/08/27 )
metres
0.0
-0.5
-1.0
-1.5
22:40
23:00
23:20
23:40
00:00
00:20
00:40
01:00
01:20
01:40
Height
Height (max,min) = (0.052, -1.428)

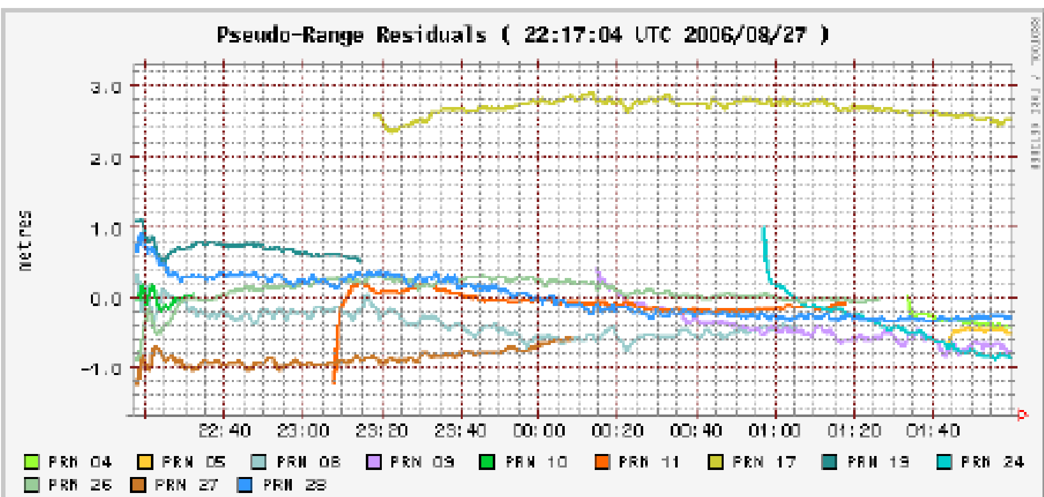

Height Std. Dev. ( 22:17:04 UTC 2006/08/27 )
metres
8.0
6.0
4.0
2.0
0.0
22:40 23:00 23:20 23:40 00:00 00:20 00:40 01:00 01:20 01:40
Height Sigma
Height S.D. (max,min) = (8.870, 0.014)

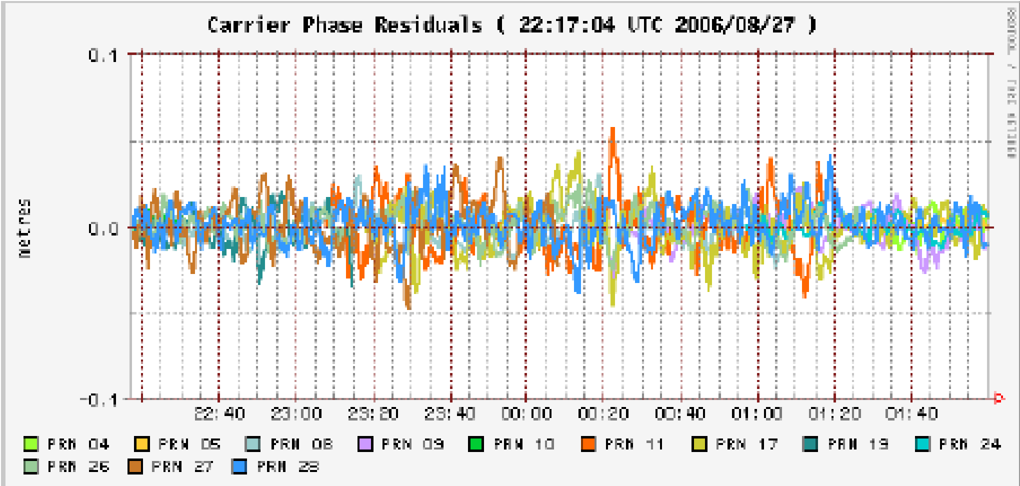

Tropospheric Zenith Delay ( 22:17:04 UTC 2006/08/27 )
metres
2.50
2.40
2.30
22:40 23:00 23:20 23:40 00:00 00:20 00:40 01:00 01:20 01:40
TZD
Tropo (max,min) = (2.519, 2.272)

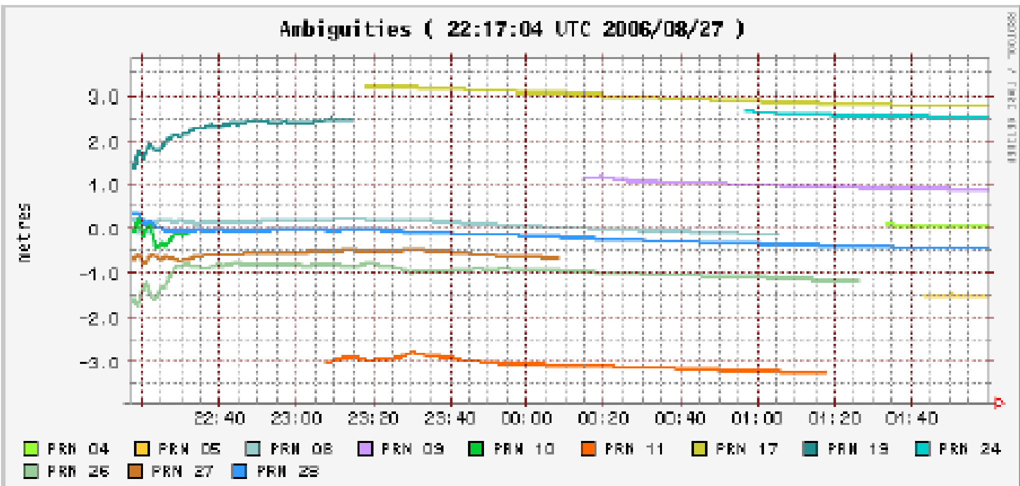

Trop. Zenith Delay Std. Dev. ( 22:17:04 UTC 2006/08/27 )
metres
0.10
0.08
0.06
0.04
0.02
0.00
22:40 23:00 23:20 23:40 00:00 00:20 00:40 01:00 01:20 01:40
TZD Sigma
Tropo S.D. (max,min) = (0.100, 0.002)


Station Clock Offset ( 22:17:04 UTC 2006/08/27 )
nanoseconds
100
0
-100
22:40 23:00 23:20 23:40 00:00 00:20 00:40 01:00 01:20 01:40
Clock
Clock (min,avg,max) = (-163.071, -28.222, 111.862)


Stn. Clk. Offset Std. Dev. ( 22:17:04 UTC 2006/08/27 )
nanoseconds
5
4
3
2
1
0
22:40 23:00 23:20 23:40 00:00 00:20 00:40 01:00 01:20 01:40
Clock Sigma
Clock S.D. (min,avg,max) = (0.043, 0.125, 5.063)


Pseudo-Range Residuals ( 22:17:04 UTC 2006/08/27 )
metres
3.0
2.0
1.0
0.0
-1.0
22:40 23:00 23:20 23:40 00:00 00:20 00:40 01:00 01:20 01:40
PRN 04 PRN 05 PRN 08 PRN 09 PRN 10 PRN 11 PRN 17 PRN 19 PRN 24
PRN 26 PRN 27 PRN 28

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*Place Glacier Base Station Info*

# CSRS-PPP

**(Processing Software Version: 1.04 246 )**

## Processing Summary for CAM_2410_Place2.06o

| **Data Start** | | **Data End** |
|---|---|---|
| 2006-08-28 23:32:28.00 | | 2006-08-29 01:20:26.00 |
| **Apri / Aposteriori Phase Std** | | **Apri / Aposteriori Code Std** |
| 0.015m / 0.012m | | 2.0m / 1.211m |
| **Observations** | **Frequency** | **Mode** |
| Phase and Code | L1 and L2 | Static |
| **Elevation Cut-Off** | **Rejected Epochs** | **Estimation Step** |
| 10.000 degrees | 0.02 % | Same as Input RINEX File |
| **Antenna Model** | **APC to ARP** | **ARP to Marker** |
| | 0.000 m | 0.000 m |

(APC = antenna phase center; ARP = antenna reference point)

## Estimated Position for CAM_2410_Place2.06o

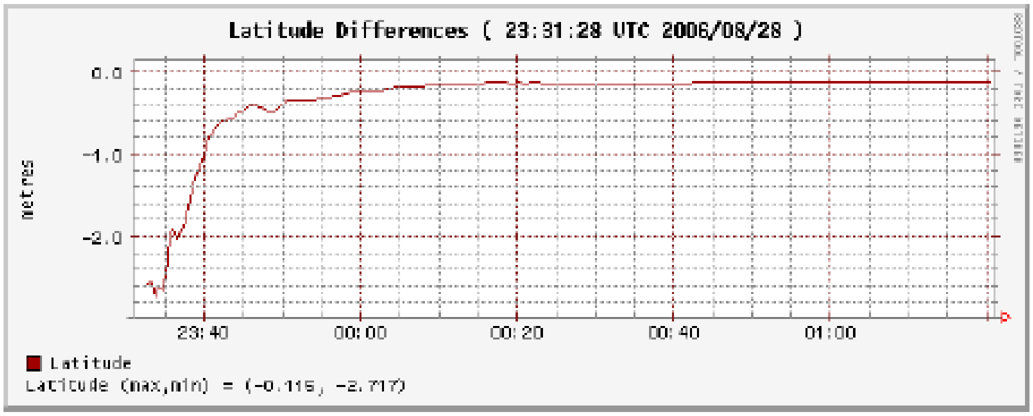
| | **Latitude (+n)** (dms) | **Longitude (+e)** (dms) | **Ell. Height** (m) |
|---|---|---|---|
| **NAD83-CSRS** | 50 18 11.0954 | -122 44 19.0377 | 191.903 |
| **Sigmas** | 0.012 | 0.027 | 0.043 |
| **Apriori** | 50 18 11.100 | -122 44 19.095 | 191.588 |
| **Estimated - Apriori** | -0.134 m | 1.131 m | 0.314 m |

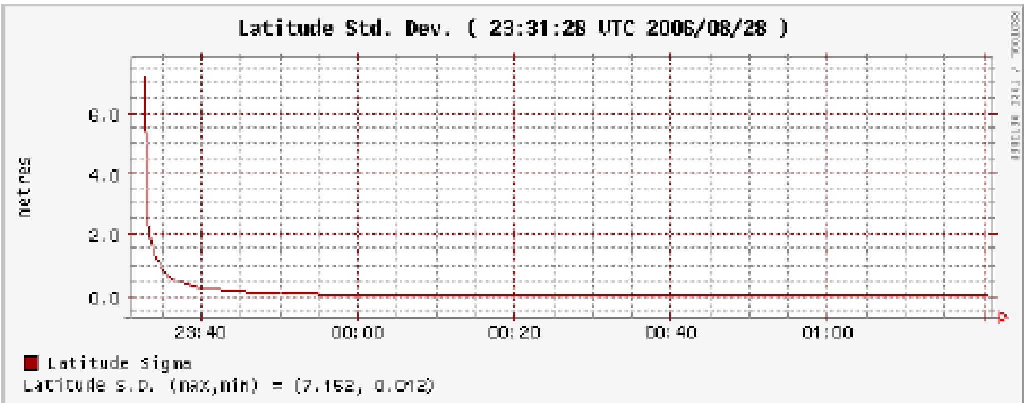
(Coordinates from RINEX file used as apriori position)

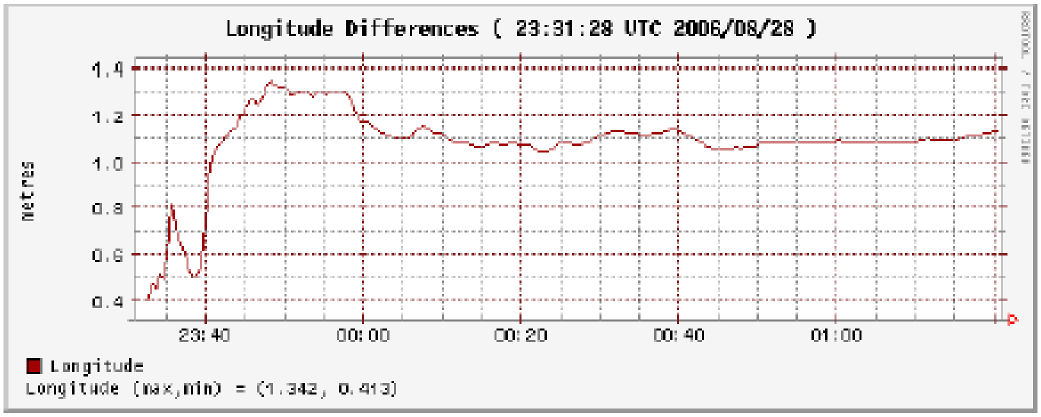
## Estimated Parameters & Observations Statistics

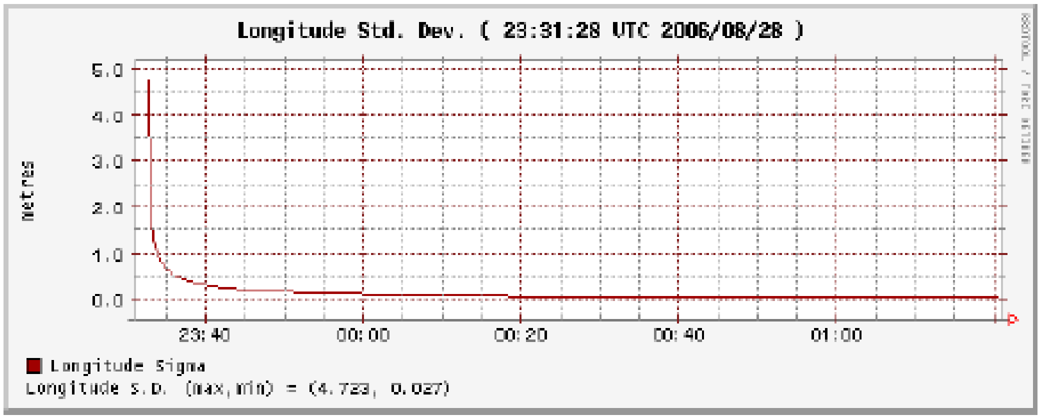
(Note 1: 1 plotted point = average of 13 estimated points)

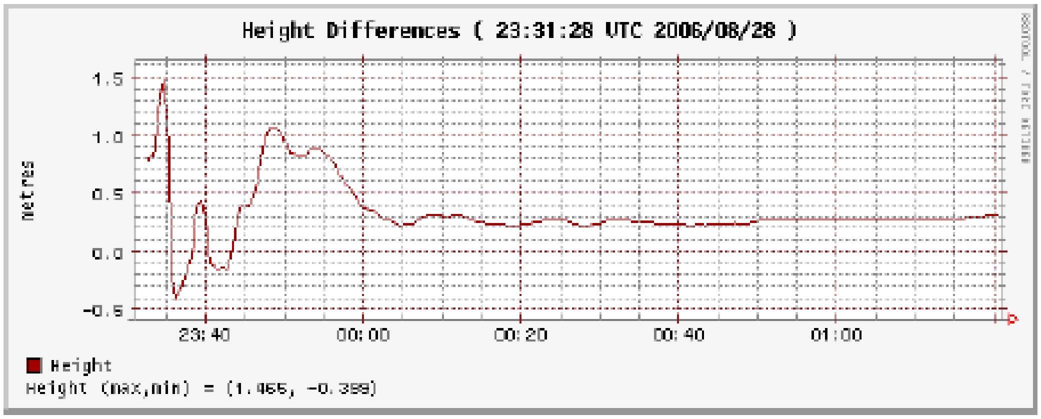
(Note 2: Estimated Tropospheric Zenith Delay Plotted)

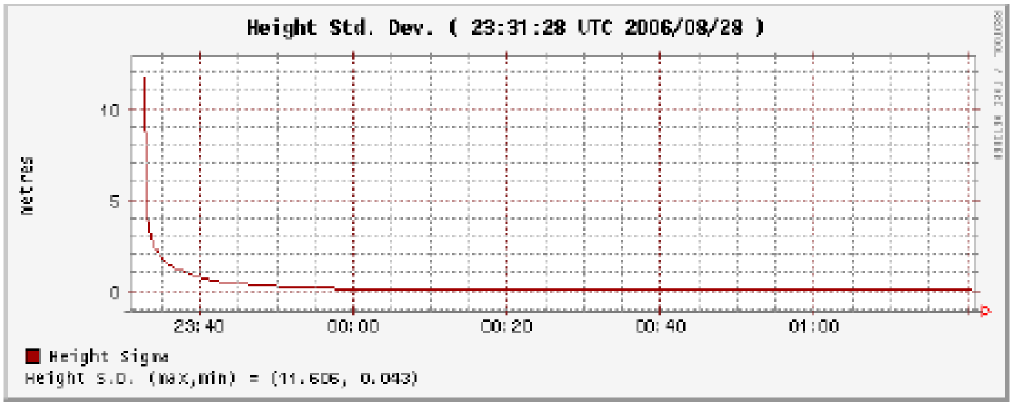


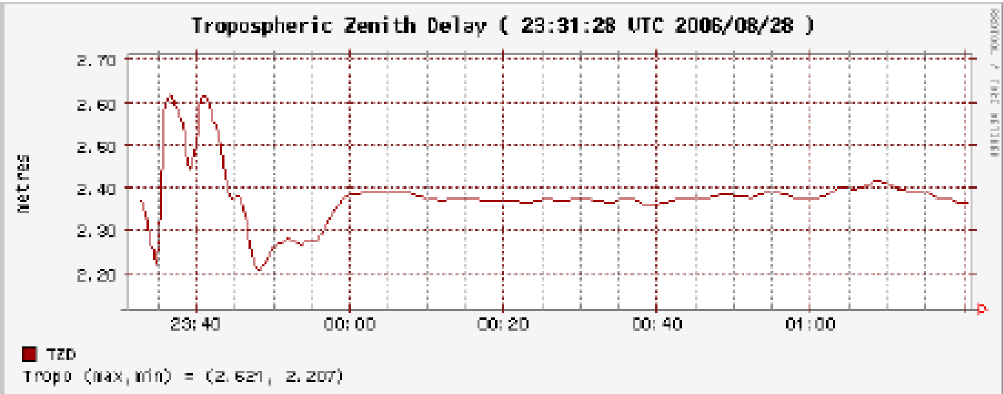



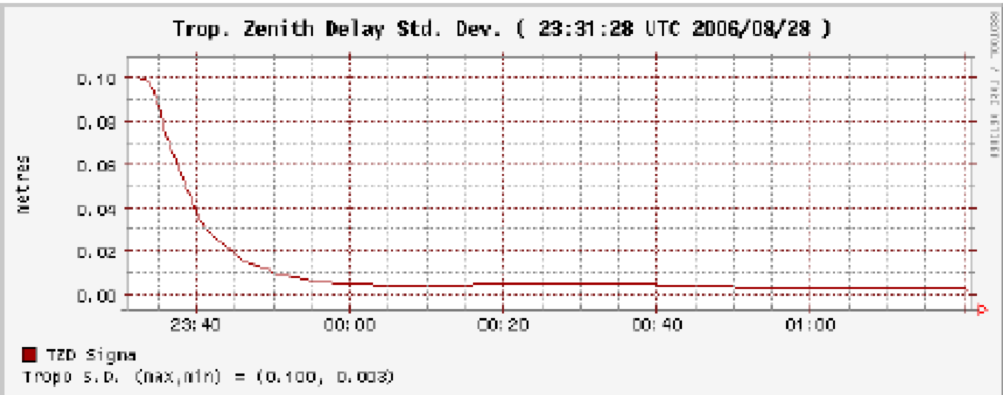

Longitude Differences ( 23:31:28 UTC 2006/08/28 )
metres
1.4
1.2
1.0
0.8
0.6
0.4
23:40
00:00
00:20
00:40
01:00
Longitude
Longitude (max,min) = (1.342, 0.413)


Longitude Std. Dev. ( 23:31:28 UTC 2006/08/28 )
metres
5.0
4.0
3.0
2.0
1.0
0.0
23:40
00:00
00:20
00:40
01:00
Longitude Sigma
Longitude S.D. (max,min) = (4.723, 0.027)

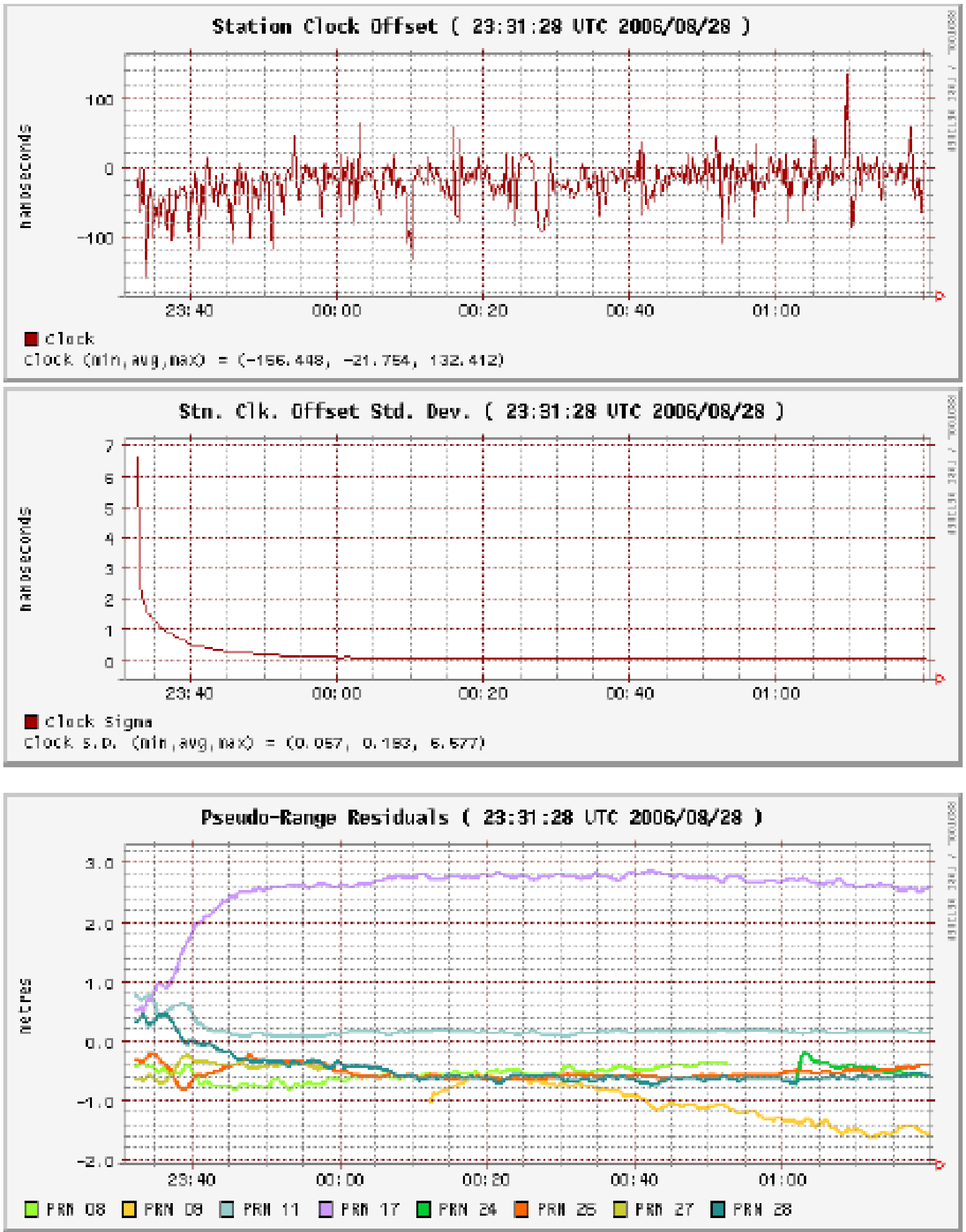

Height Differences ( 23:31:28 UTC 2006/08/28 )
metres
1.5
1.0
0.5
0.0
-0.5
23:40
00:00
00:20
00:40
01:00
Height
Height (max,min) = (1.465, -0.399)



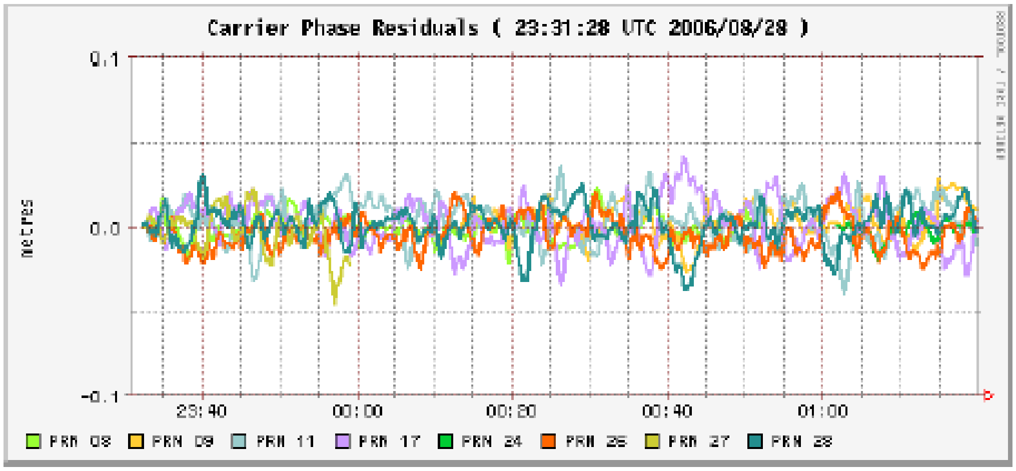



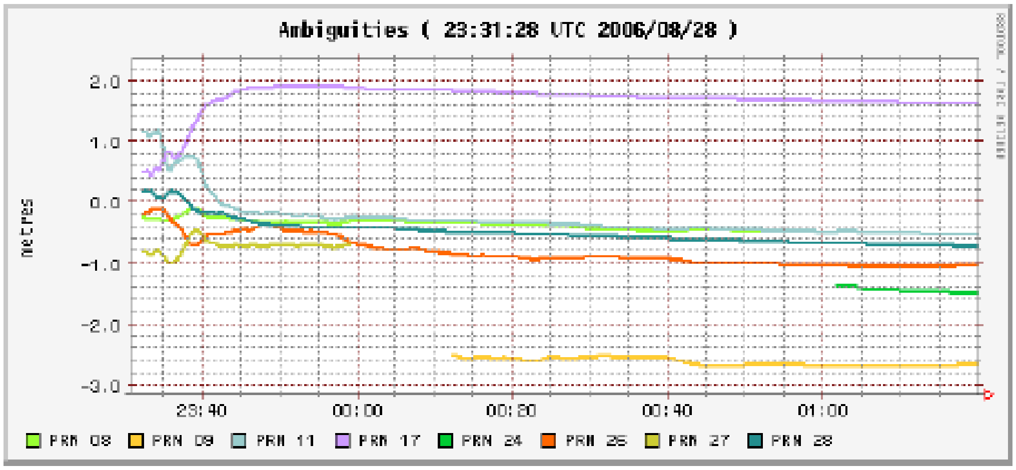




CAM_2410_Place2.06o 4 19:57:03 UTC 2006/09/28




19:57:03 UTC 2006/09/28 5 CAM_2410_Place2.06o

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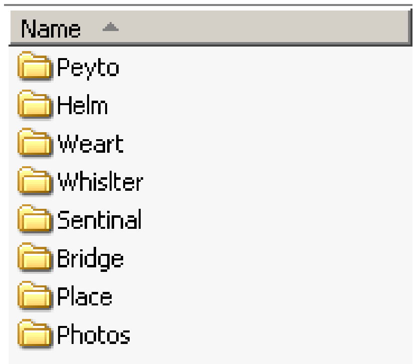
CAM_2410_Place2.06o 6 19:57:03 UTC 2006/09/28

### ***Output file locations:***

All laser pulse output data are organized into one main directory on the GSC lidar hard drive and named according to the individual survey site:

- Peyto
- Helm
- Weart
- Whistler
- Sentinal
- Bridge
- Place




Within This directory are three sub directories:

- Non Ground (XYZ)
- LAS Binary
- Ground (XYZ, GRD, ASC)
- Overview


The 'Non Ground' directory contain all return data; i.e. first, second, third and last returns saved in tiles. This data was then classified extracting all non ground the data. The data is divided into 1 km x 1 km patch files. These files are saved in a .xyz file format.

The 'LAS Binary' directory contains the raw flight line data. This data is stored in a .las file format. Must of the LAS files do correspond to the flight lines but not in all cases.

The 'Ground' directory contains ground return data. This is generally the last return. The data is divided into 1 km x 1 km patch files. These files are saved in a .xyz, .grd and .asc file formats. The xyz files additionally contain the intensity for each return.

The 'Overview' Directory contains a decimated grid of the area. It is stored in both .grd and .xyz formats

The DGN file that is included in the main folder this for processing within Terrascan. This is the fence that the tiles were generated from. The tiles are also number according to this fence starting in the upper left as tile 1 and reading across then down.

## XYZ file data formats:

Each xyz file is named with a numerical identifier showing the tile number. The ASC, GRD and XYZ files for the ground classification also contains tile number plus the upper left (north western) corner coordinate of the square patch. For example: the upper left coordinate for file named ‘T01_5440000_5694000.xyz’ is:

Easting 544000

Northing 5694000

## Data tiling and ground classification

Terrascan is a component of Bentley Microstation. This software was used to separate the LiDAR Data set into more manageable One kilometer squared tiles, and to classify the data into ground returns. Bridge Glaciers was the exception. This survey was broken into two kilometer tiles due to the large size of the survey. The output from Terrascan is xyz text files. Terrascan is found under the “MDL Applications” within the utilities menu. This toolbar needs to be loaded into Microstation every time a new session is started. After Terrascan has been launched the LiDAR data sets can be loaded. This is done by selecting read points from the files tab within Terrascan. The Different flights lines are shown under the files section of the “Read Points” window. The user selects the appropriate flight lines and then clicks “ADD” and “DONE” to load the data

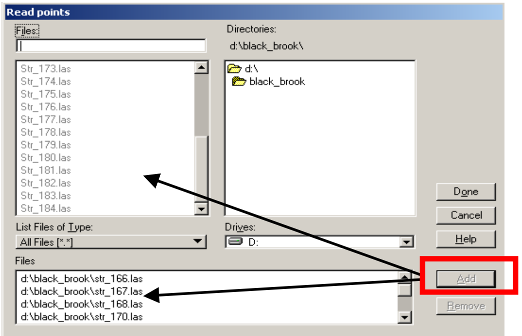



**Figure 1: Read Points Dialog**

The Load Points dialog will be displayed next. This display allows the user to choose the appropriate settings to load the data into Terrascan. For the initial viewing of the data it is recommended to load every 100th point. The data sets are too large to load every point and by selecting a higher filtering the load time will be decreased. The lidar data is in a .las format. The “Flightline Numbering” should be set to “Increase by File” The figure below shows the above steps.

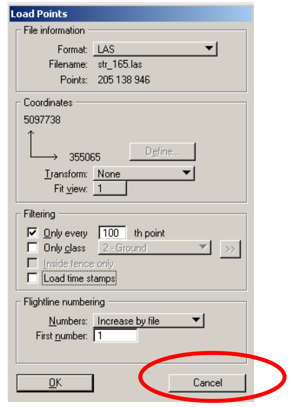



**Figure 2: Load Points Dialog**

After the data is loaded the "place shape" tool is used to draw a fence around the desired study area. By creating a fence, the data can be limited to only loading in points that fall within the study area. This will help to limit the number of points providing faster load times. After the fence is created the points were cleared by selecting (File, clear points). The new fence was selected and the same data points were reloaded (file, read points) the only difference from before is that the "inside fence only" option was selected.

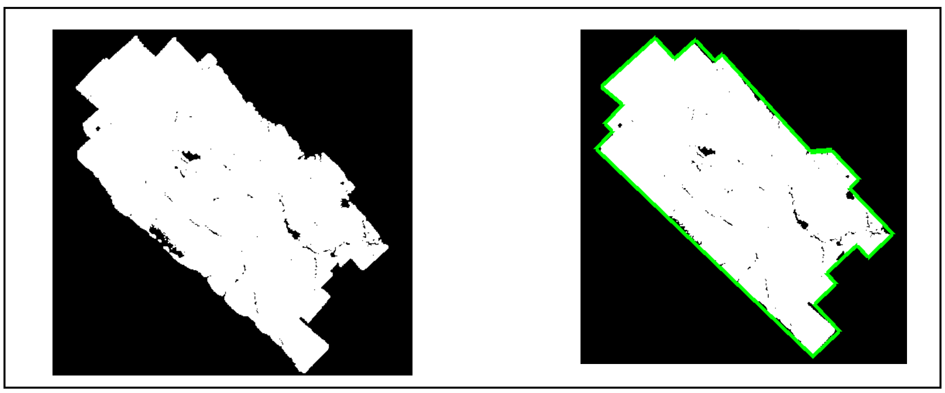


**Figure 3: The first image is of the loaded flight lines with out using the fence. The second image shows the load flight lines restricted to only points within the fence.**

The tiles were 2040 by 2040 m in size. The grid was set to line up with the UTM grid using the ACCUDRAW feature of Microstation. By zooming in the tile was lined up to the UTM grid at 588980E, 5220980N. The tiles were generated with a 20 m buffer so that the array of tiles would overlap. The grid was also set to a 20m off set in the East and North. This was done to compensate for the buffer. Having the 20m overlap in the grid is done to ensure that there will not be data gaps. The tile grid was created by using the "Construct Array" tool. The Array that was created was 15x15 over the study area with 2000m spacing. Any blocks that were not within the study area were deleted. The tiles were numbered by starting at the upper left corner.

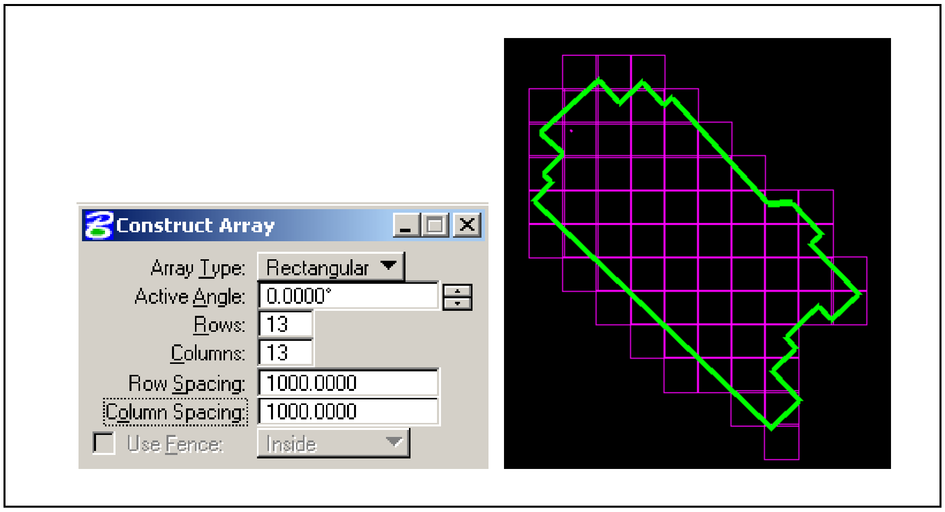



**Figure 4: Construct Array Dialog and the resulting Array image to the left.**

Starting at tile 1 the flight line data was loaded for that tile only. The data was first classified by class into the Default field; this moves all of the data into one class. This classification is done by selecting “Classify” on the Terrascan toolbar, then “Routine”, then “By Class…”. The data is then classified again using the Ground Routine (i.e. Classify, Routine, Ground), this separates the data into two classes ground and non-ground. The All hits data is contained within the default class and must be saved in a .xyz file format before classifying the ground data. The ground data sets are then exported into *.XYZ format.

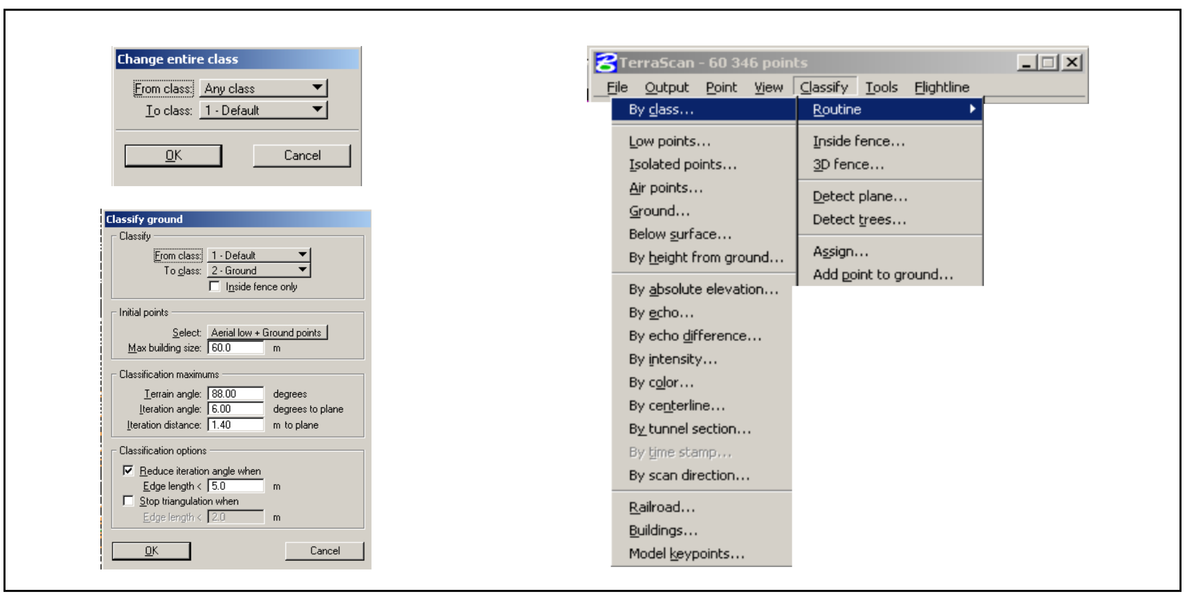



**Figure 5: The Image to the upper right shows the classifying of all class into one class. The Bottom image is of the “ground classify” dialog the default setting were used in this classification. As shown to the left both these dialog are accessed under “classify”.**

The ground and all hits data for each tile contained the Easting, Northing, Elevation, and Intensity saved in *.xyz format. The naming convention for each tile identifies the "Julian Day, Tile#, Easting, Northing, and Class" This is an example of the naming convention: 145t01_590980_5222980_G.xyz. There were a total of 73 tiles classified.

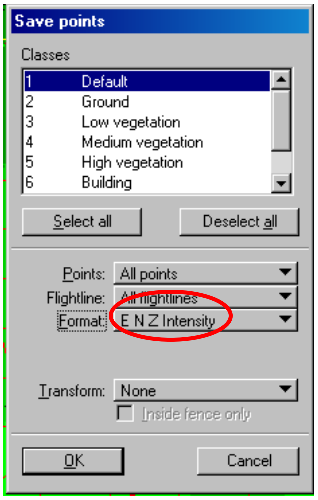



**Figure 6: Image showing the saving of All Hits data setting xyz format.**

### *Data gridding and output*

The *.xyz files that were created within Terrascan need were rsaterized into *.grd files. This is a necessary step in order to generate *.asc files which can be created from *.grd files. This process is completed within Golden Software Surfer. This software is useful for viewing lidar derived digital elevation models. The figure below is an example of one of the tiles represented within Surfer.

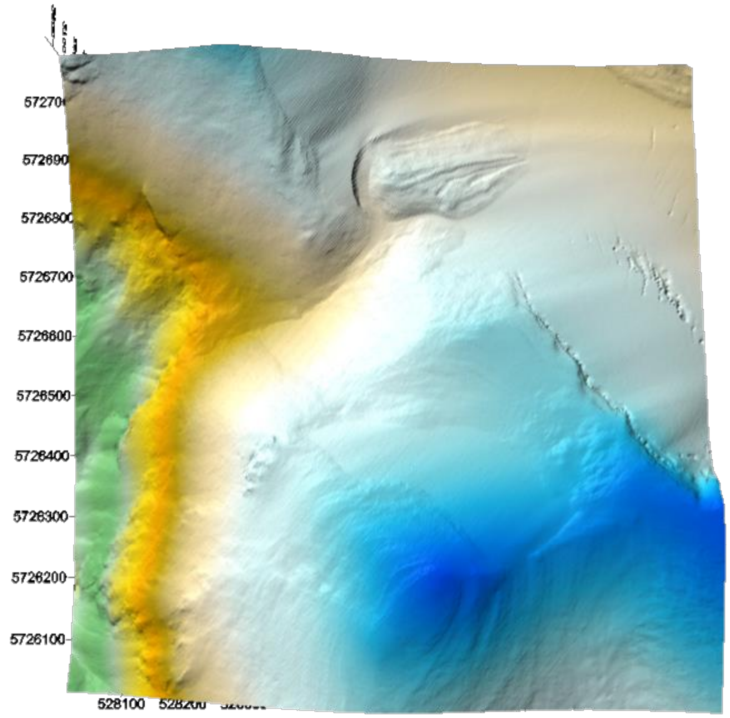



**Figure 7: This image shows a Surfer Grid of a tile within the Peyto survey**

Surfer Software comes with an automation program called Scripter. This program allows the user to setup parameters and run processes on a number of files automatically. The process was automated using a script that Douglas Stiff and Jon Kwong (AGRG Researchers) created. The script reads *.xyz files from a folder, determines the X, Y extents, compensates for the 20m buffer that was created in the Terrascan process, converts the files to *.grd files, produces a report with the process parameters and specifics about each file and then converts the file to *.ASC format. *.ASC files are ESRI 3D ASCII files, which can be used to generate ARC rasters and feature classes.

The following parameters were used in the surfer scripting process:

| | | | |
|---|---|---|---|
| *Ground Classification Parameters* | | Search Ellipse Angle: | 0 |
| X Spacing: | 1 | | |
| Y Spacing: | 1 | | |
| Grid Size: | 2001 rows x | Number of Search Sectors: | 4 |
| 2001 columns | | Maximum Data Per Sector: | 64 |
| Gridding Method: | IDW | Maximum Empty Sectors: | 3 |
| **Search Parameters** | | Minimum Data: | 2 |
| Search Ellipse Radius #1: | 20 | Maximum Data: | 6 |
| Search Ellipse Radius #2: | 20 | | |