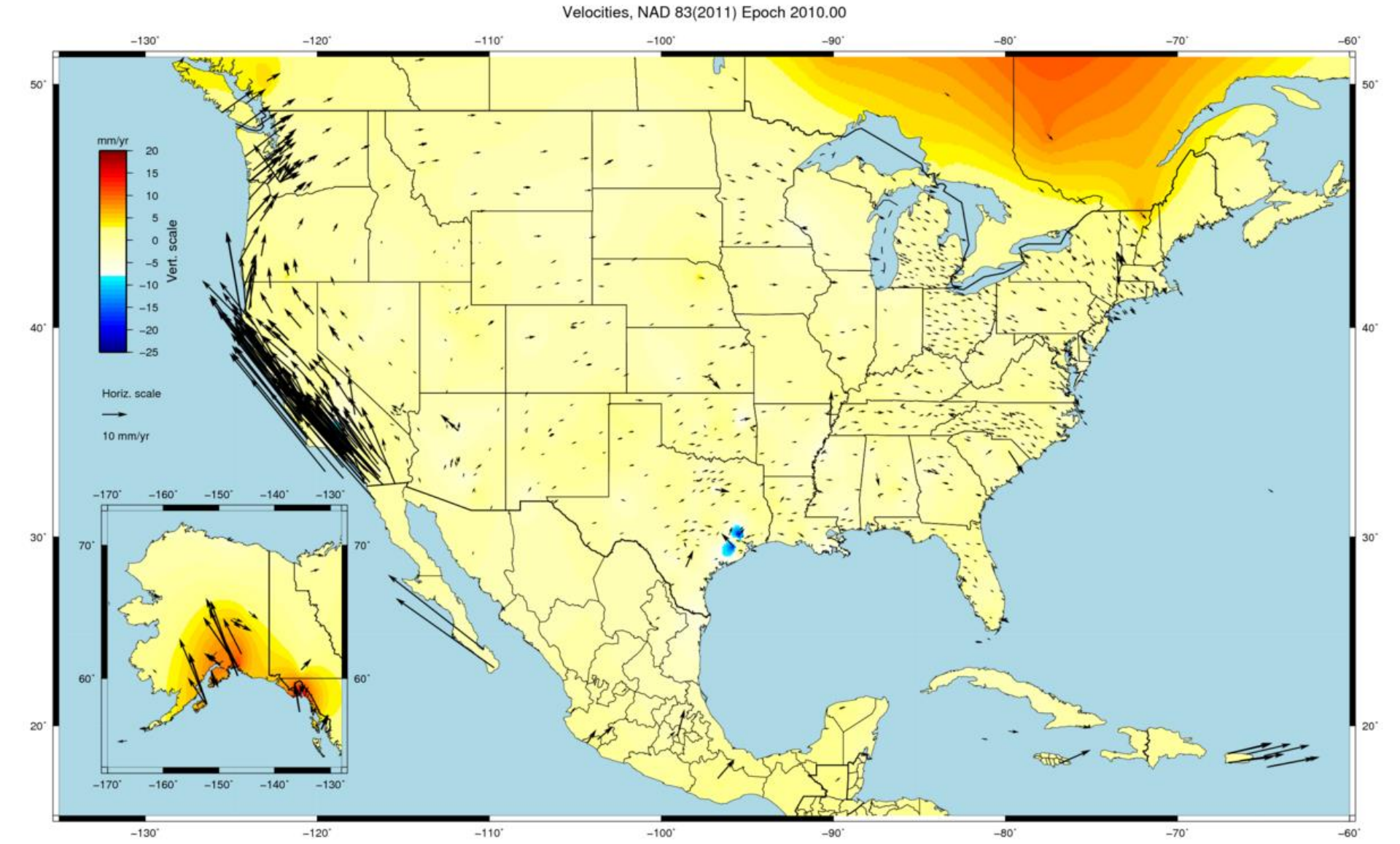
Testing PPP-RTK for RTN Integrity and Remote Projects

56th Meeting of the Civil GPS Service Interface Committee
Portland, Oregon - September 12-13, 2016

Gavin Schrock, PLS
Washington State Reference Network
Washington Geodetic Survey

Tectonically Active

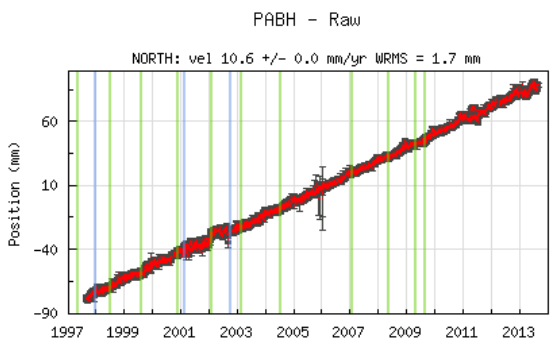


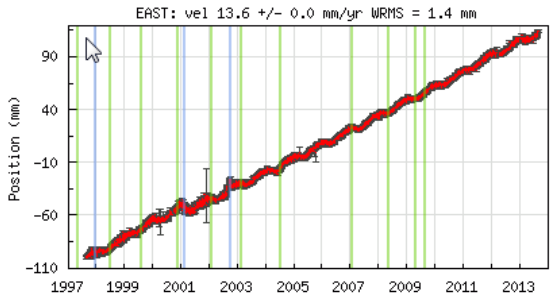
Velocity – Network Integrity Management

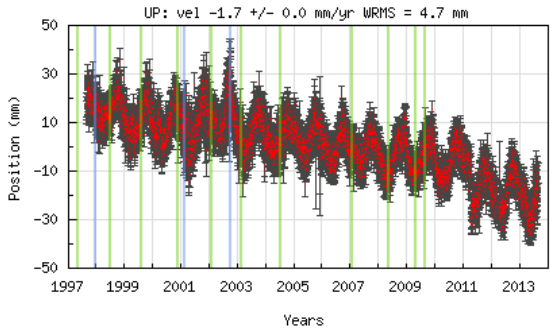
Costal

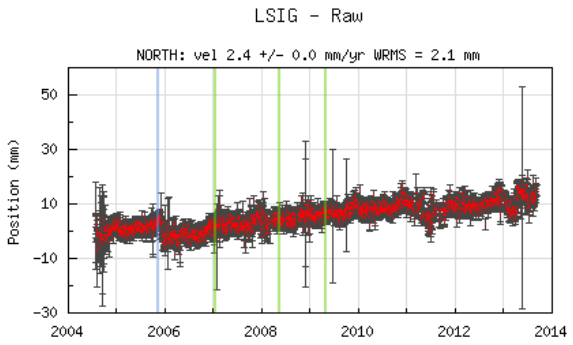
Central (Puget)

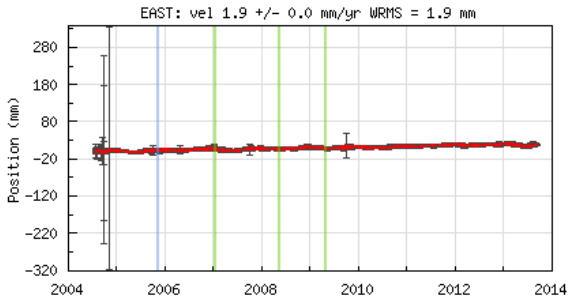
Eastern

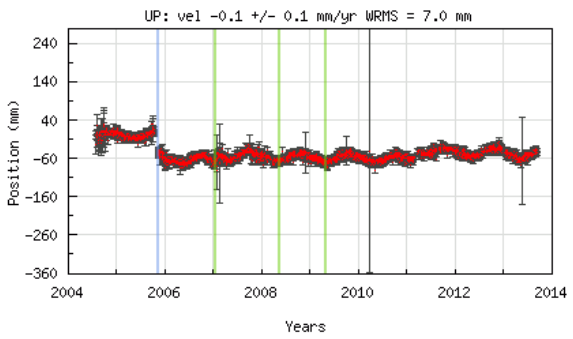


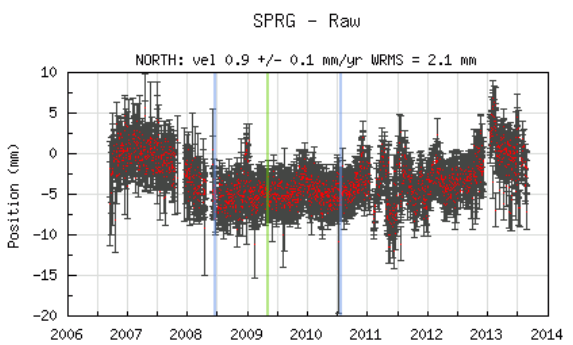


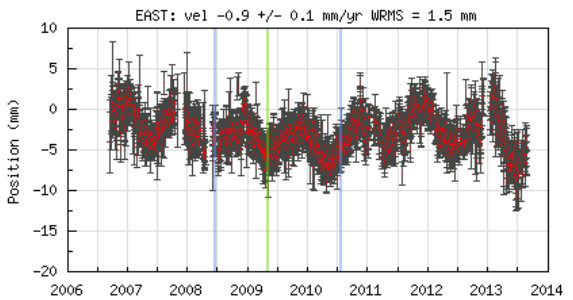


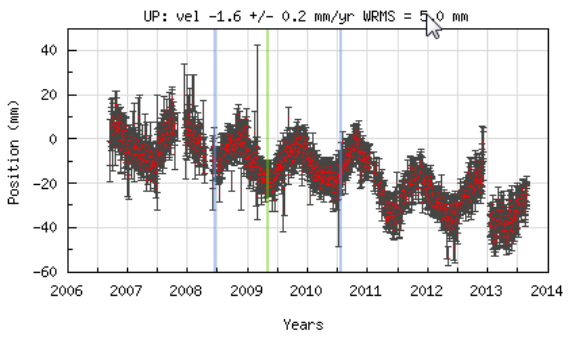




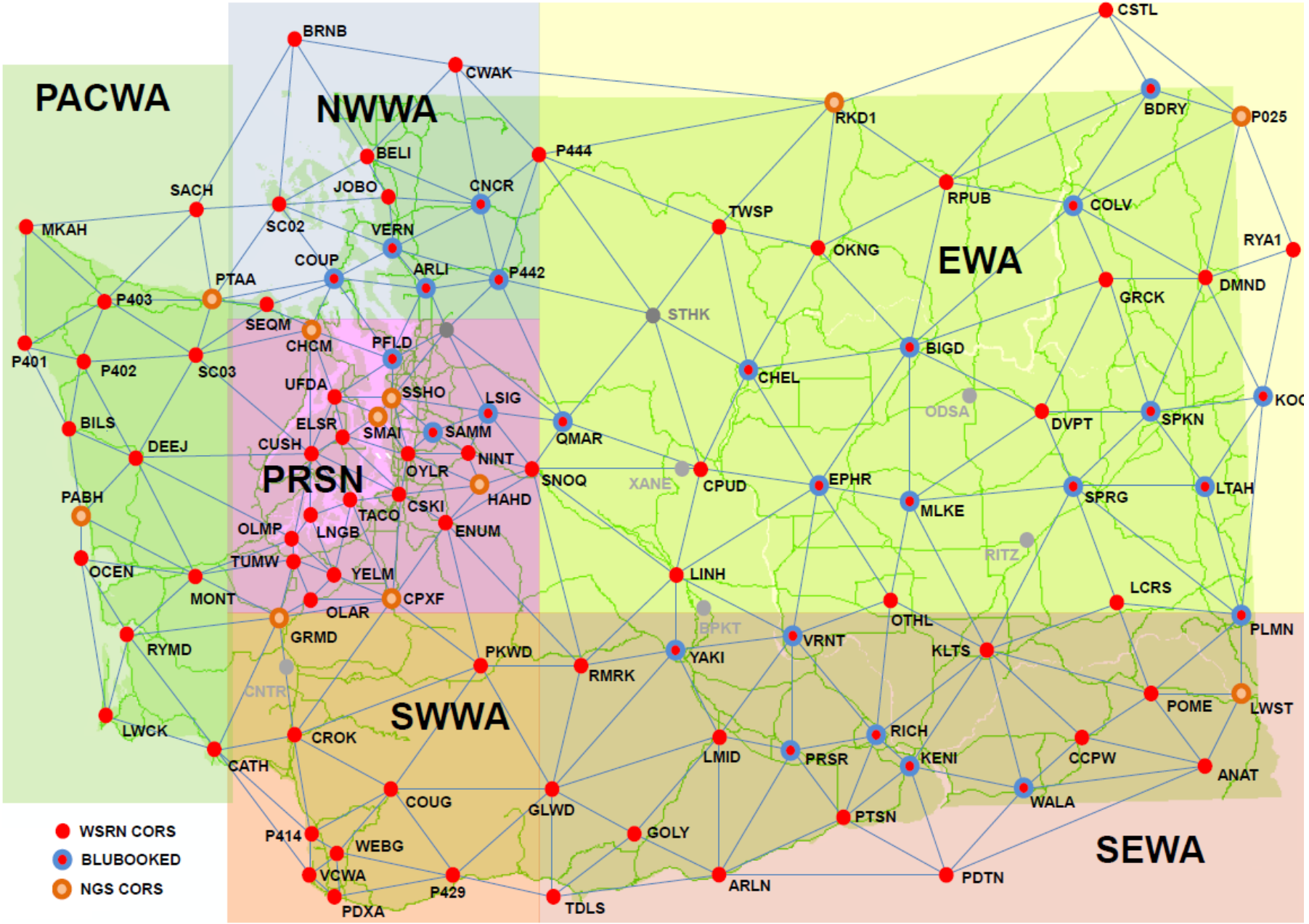


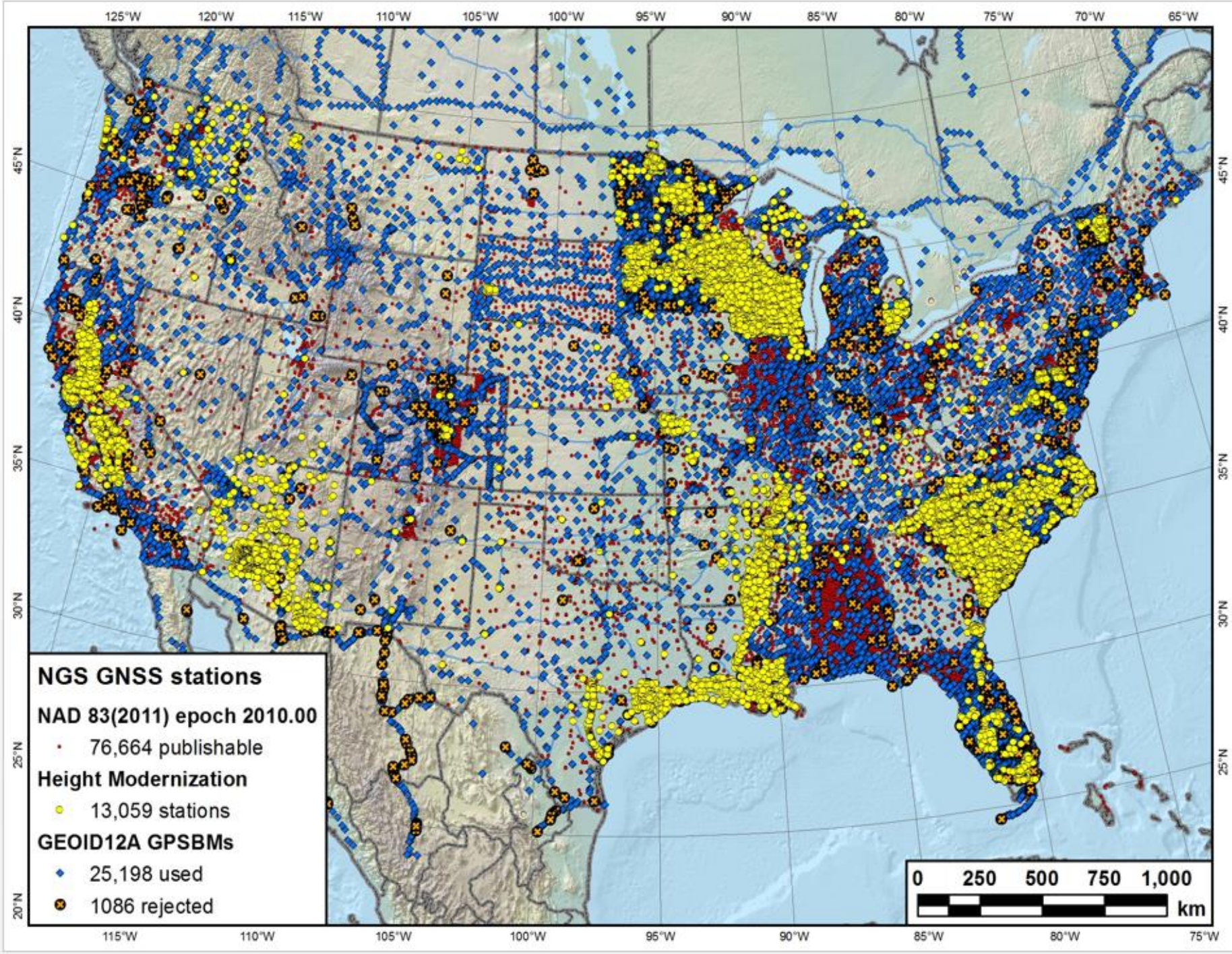






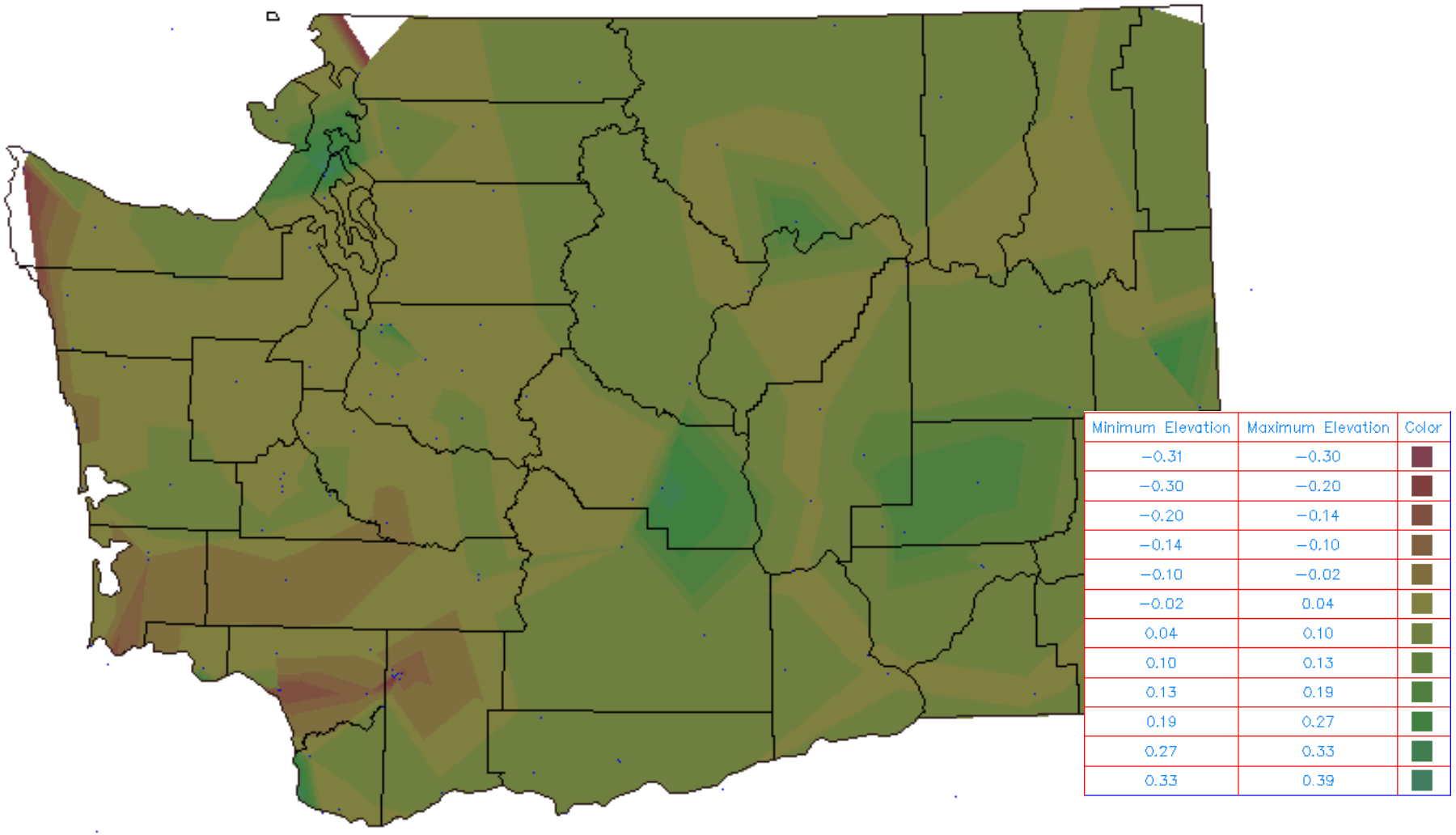
Velocity and Iono/Tropo Modeling Managed as Functional Subnets




125°W
120°W
115°W
110°W
105°W
100°W
95°W
90°W
85°W
80°W
75°W
70°W
65°W
45°N
40°N
35°N
30°N
25°N
20°N
NGS GNSS stations
NAD 83(2011) epoch 2010.00
76,664 publishable
Height Modernization
13,059 stations
GEOID12A GPSBMs
25,198 used
1086 rejected
0 250 500 750 1,000
km

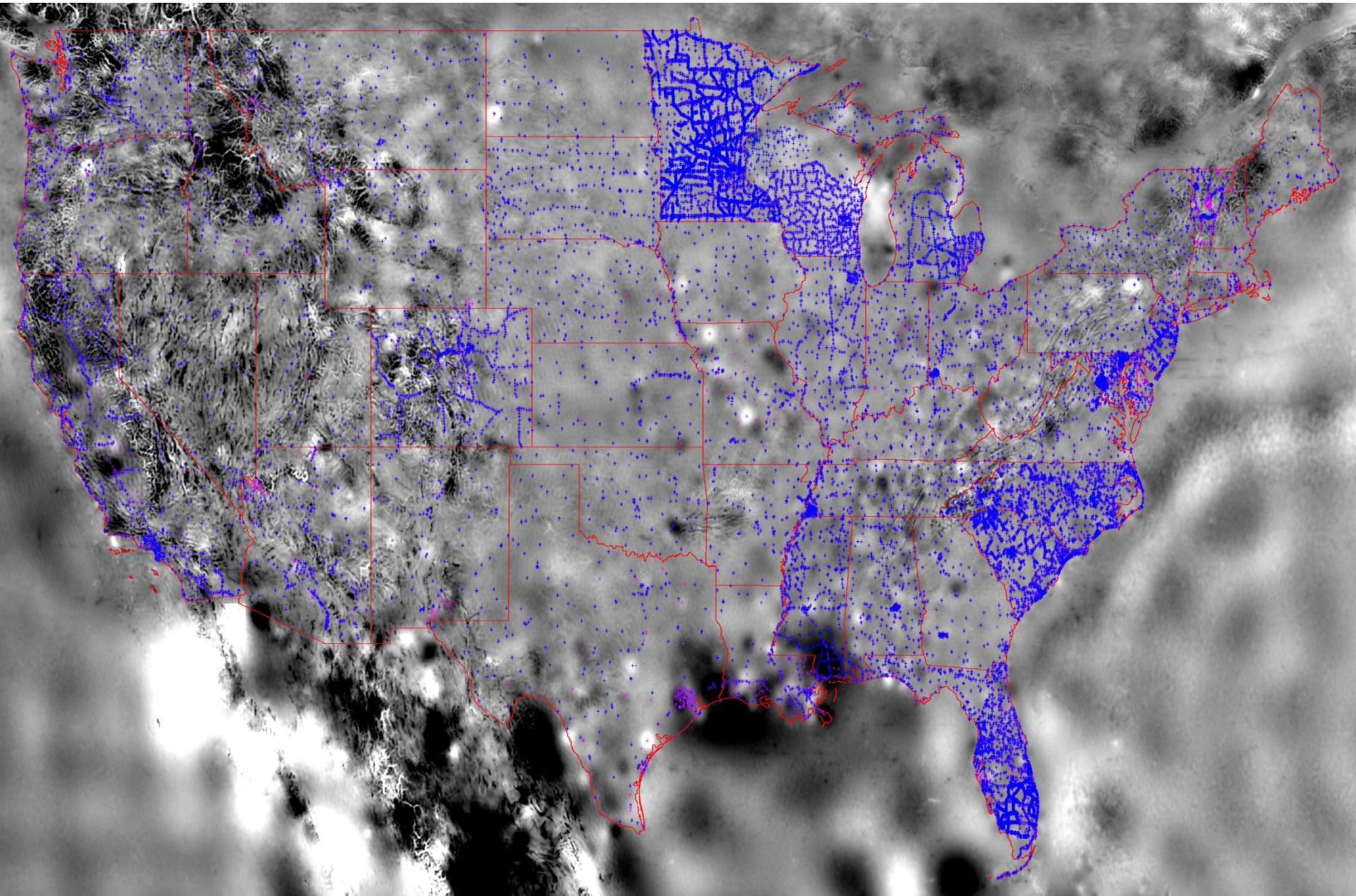

Estimated Distance Moved
0 - 0.05 meters
0.05 - 0.10 meter
0.1 - 0.2 meters
0.2 - 0.3 meters
0.3 - 0.5 meters
0.5 - 0.75 meters
0.75 - 1.0 meters
Estimated Point Displacement from 2012 - 2062

NAD83-CORS96 to NAD83(2011) Ellipsoid Height Differences - Feet

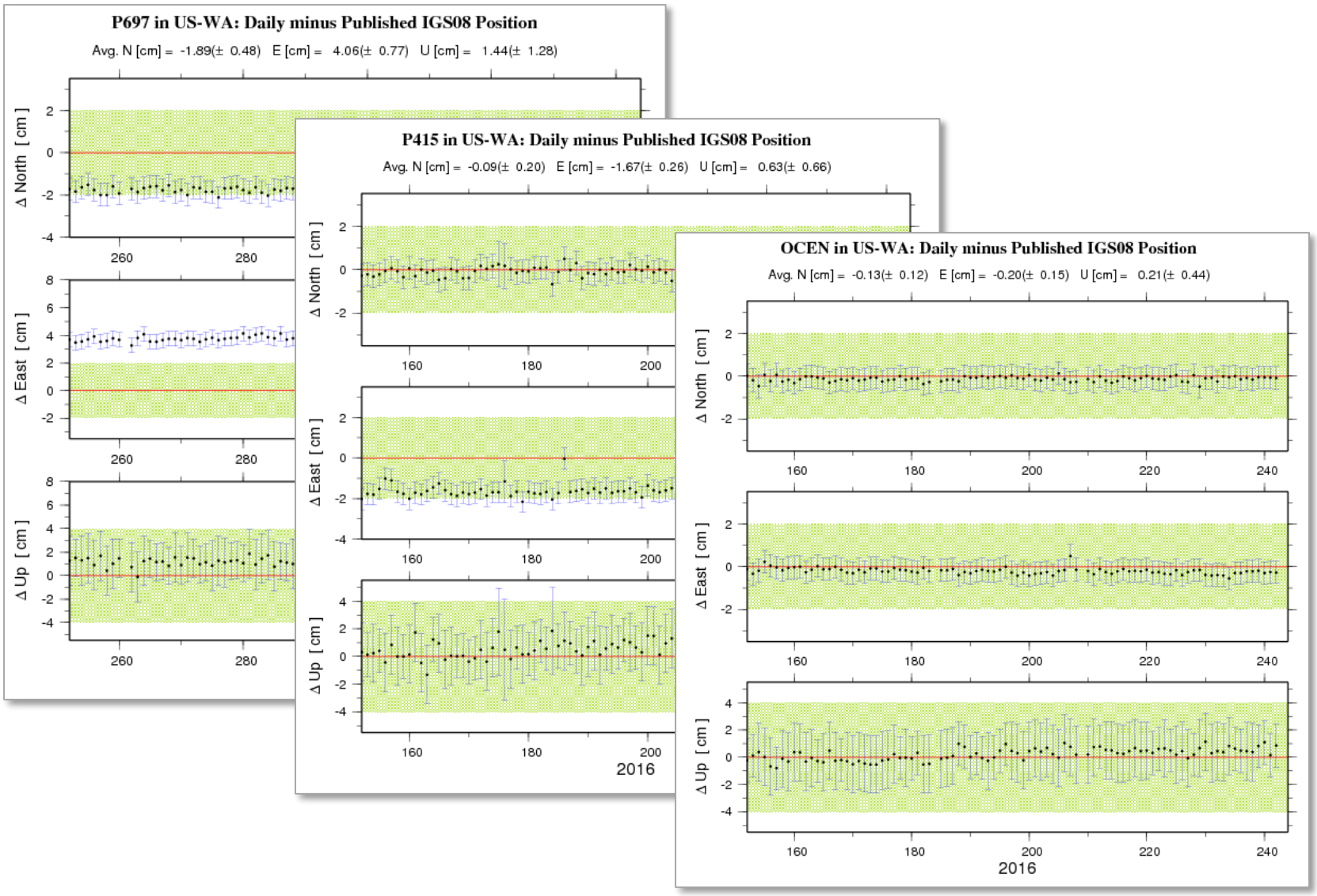


Minimum Elevation	Maximum Elevation	Color
−0.31	−0.30	
−0.30	−0.20	
−0.20	−0.14	
−0.14	−0.10	
−0.10	−0.02	
−0.02	0.04	
0.04	0.10	
0.10	0.13	
0.13	0.19	
0.19	0.27	
0.27	0.33	
0.33	0.39	

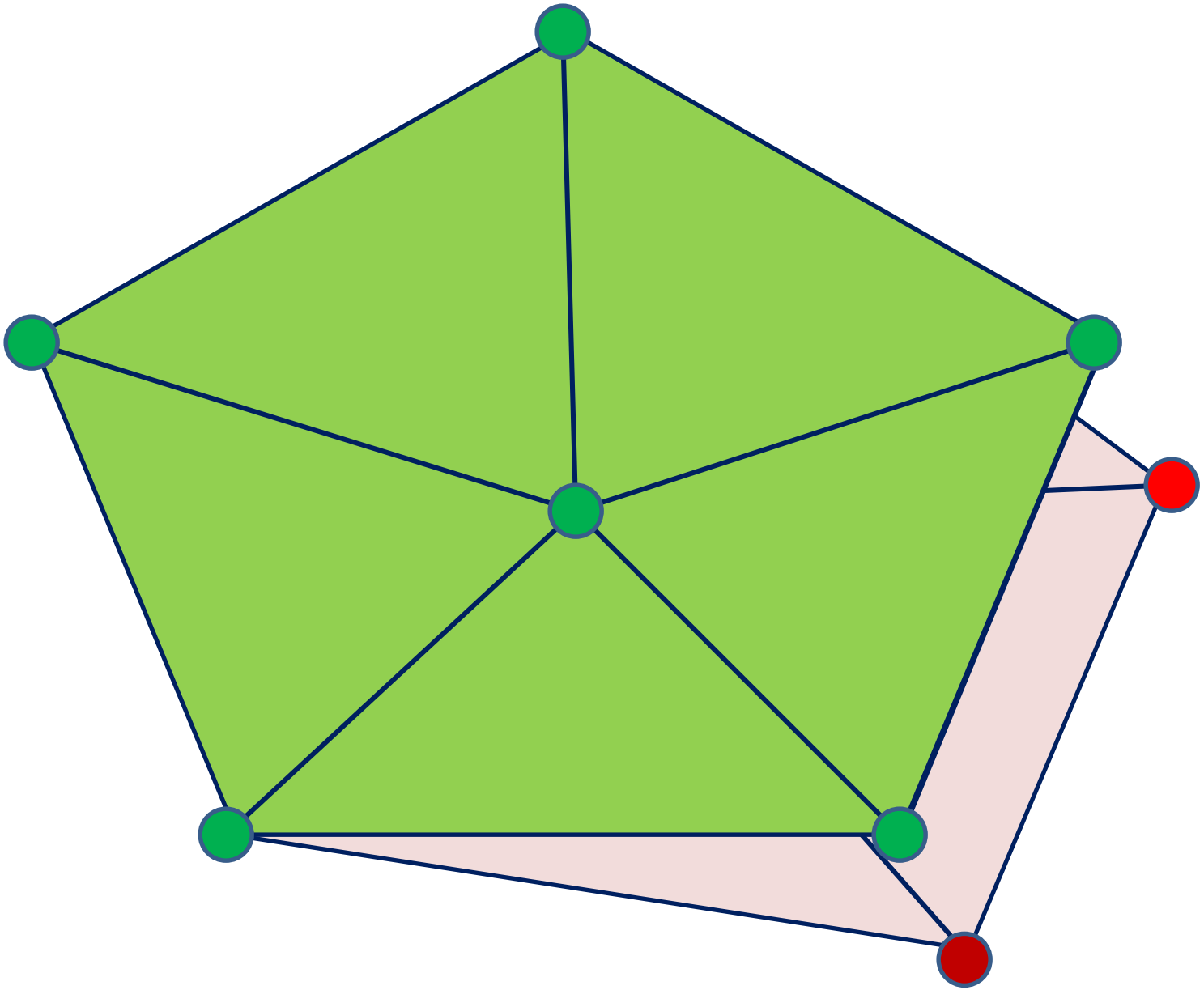
Residuals + Control for 2009-2012A Geoid



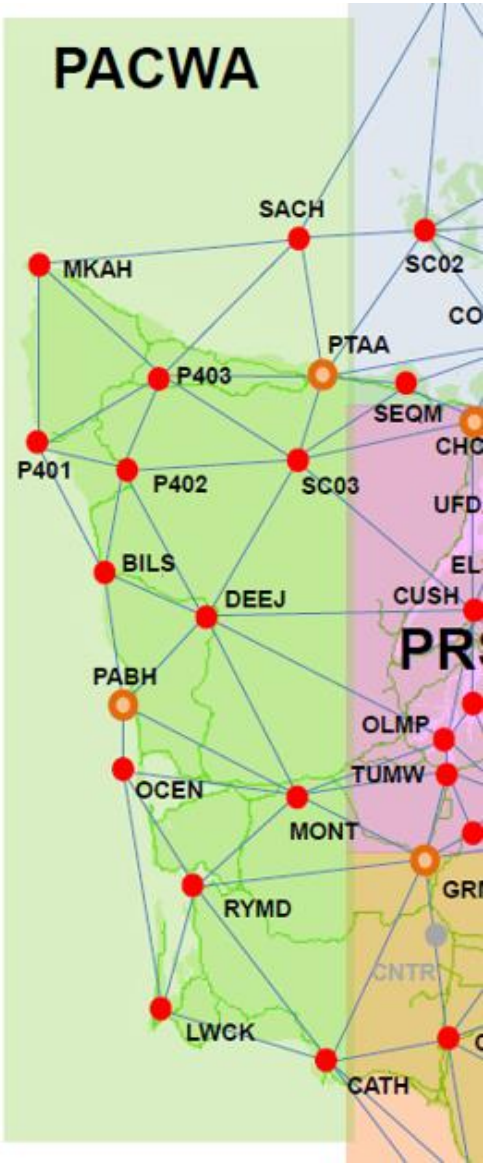
Published vs. Current Positions



Published vs. Current Positions

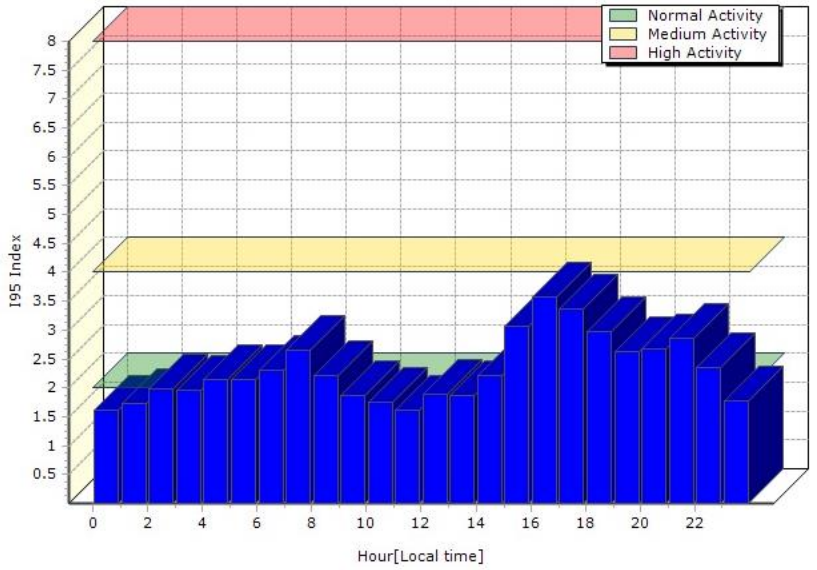


Published vs. Current Positions



Map 2D | Current Displacements | Adjustment | Displacement Chart | Scatter Plot | Axis Rotations | NMEA Output

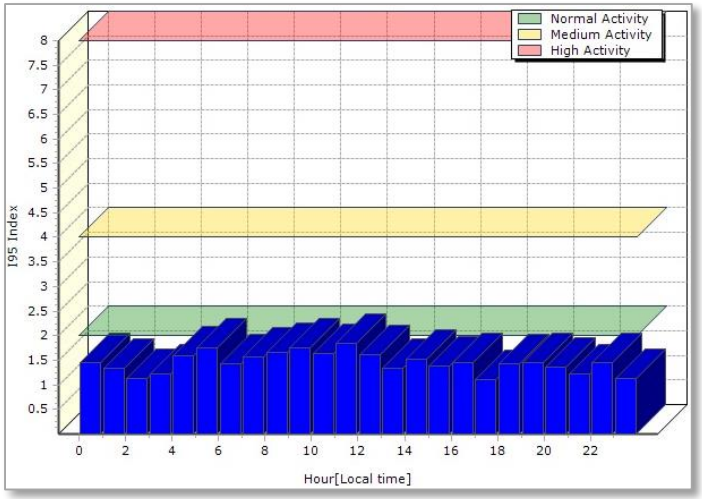
Status	Station Name	Station Cod	Ax	Δ Northing [m]	Δ Easting [m]	Δ Height [m]	Δ 2D [m]	Δ 3D [m]
	P401	P401		0.031	0.064	-0.004	0.071	0.071
	OCEN	OCEN		0.041	0.055	0.013	0.068	0.069
	P402	P402		0.027	0.055	0.001	0.061	0.061
	BILS	BILS		0.030	0.046	-0.022	0.055	0.059
	MKAH	MKAH		0.009	0.036	0.001	0.037	0.037
	P403	P403		0.012	0.032	-0.003	0.034	0.034
	OLAR	OLAR		0.005	-0.006	0.024	0.008	0.026
	MONT	MONT		0.009	0.022	0.009	0.024	0.025
	RYMD	RYMD		0.015	0.013	0.010	0.020	0.023
	CATH	CATH		0.007	-0.002	0.017	0.007	0.019
	CROK	CROK		0.000	-0.015	0.000	0.015	0.015
	CUSH	CUSH		-0.003	0.010	0.005	0.010	0.011
	OLMP	OLMP		-0.001	0.004	0.003	0.004	0.005
	PTAA	PTAA		0.000	0.000	0.000	0.000	0.000
	GRMD	GRMD		0.000	0.000	0.000	0.000	0.000



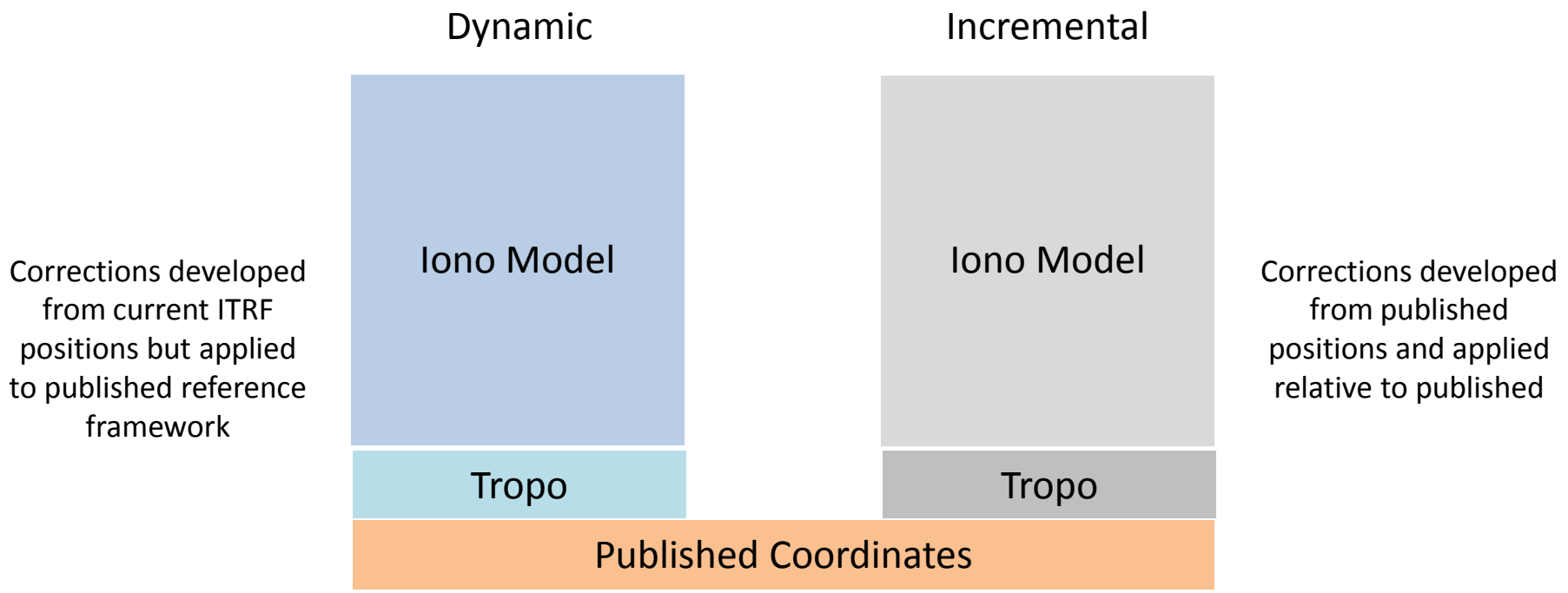
Published vs. Current Positions

Map 2D | Current Displacements | Adjustment | Displacement Chart | Scatter Plot | Axis Rotations | NMEA Output

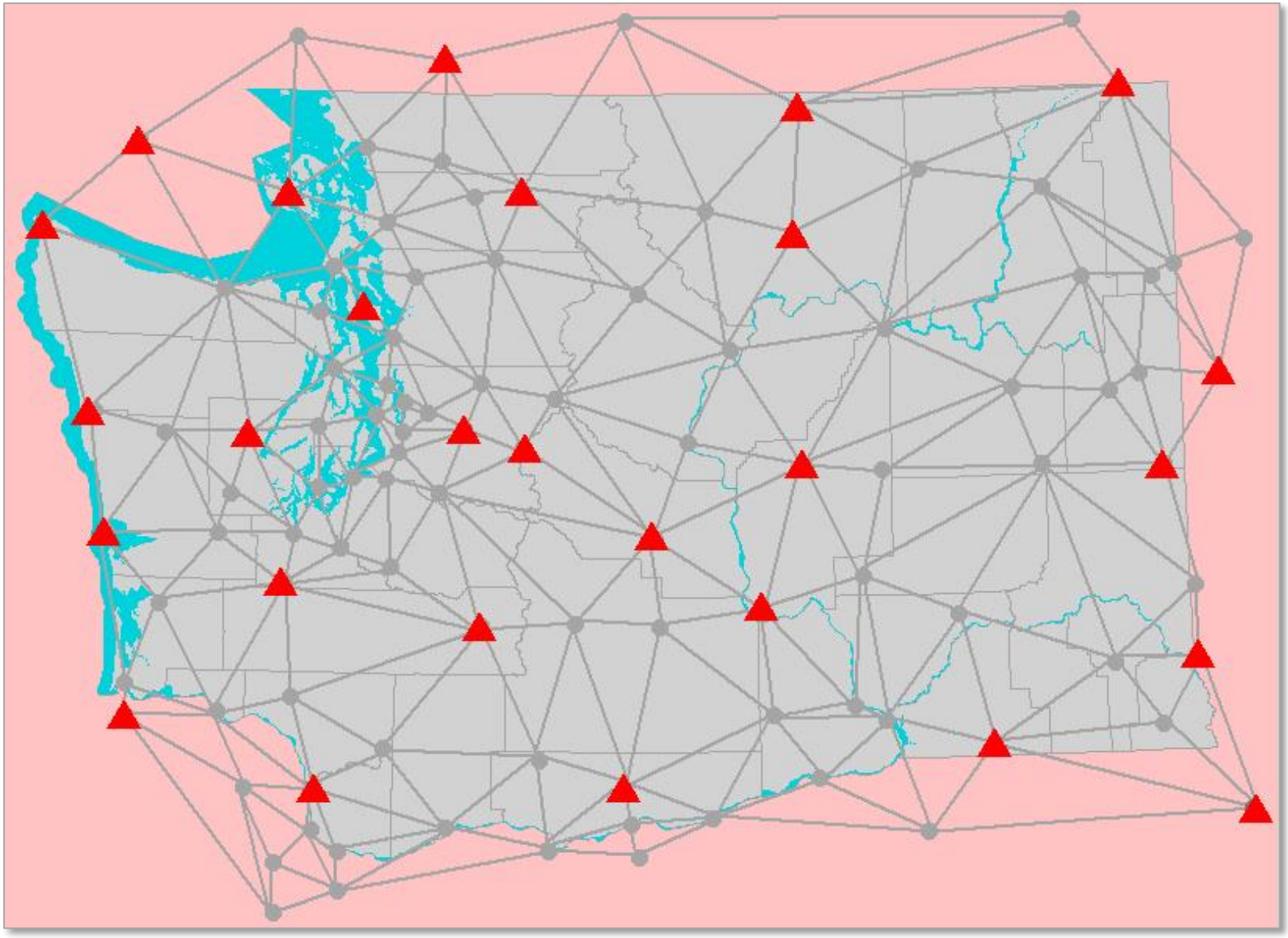
Status	Station Name	Station Cod	Ax	Δ Northing [m]	Δ Easting [m]	Δ Height [m]	Δ 2D [m]	Δ 3D [m]
●	HAHD	HAHD	☐	-0.006	-0.011	0.042	0.013	0.044
●	COUP	COUP	☐	-0.003	0.003	0.032	0.004	0.032
●	ENUM	ENUM	☐	0.010	-0.011	-0.025	0.015	0.029
●	OLAR	OLAR	☐	0.017	0.000	0.022	0.017	0.027
●	NINT	NINT	☐	-0.002	-0.015	-0.021	0.015	0.026
●	QMAR	QMAR	☐	-0.017	-0.013	-0.003	0.021	0.021
●	CPXF	CPXF	☐	0.004	-0.008	-0.017	0.009	0.019
●	PFLD	PFLD	☐	-0.009	-0.001	0.016	0.009	0.019
●	LSIG	LSIG	☐	-0.013	-0.013	0.002	0.018	0.018
●	CUSH	CUSH	☐	0.010	0.014	0.004	0.017	0.018
●	ELSR	ELSR	☐	0.006	0.005	0.016	0.007	0.017
●	LNGB	LNGB	☐	0.002	-0.004	-0.016	0.005	0.017
●	OLMP	OLMP	☐	0.010	0.010	0.000	0.014	0.014
●	SNOQ	SNOQ	☐	-0.007	0.000	-0.013	0.007	0.014
●	ARLI	ARLI	☐	-0.009	-0.002	0.008	0.010	0.012
●	P442	P442	☐	-0.009	0.005	-0.004	0.011	0.011
●	UFDA	UFDA	☐	-0.005	0.006	0.005	0.008	0.009
●	TACO	TACO	☐	0.000	-0.007	-0.004	0.007	0.008
●	SAMM	SAMM	☐	-0.006	-0.004	0.000	0.008	0.008
●	CSKI	CSKI	☐	-0.003	-0.003	-0.005	0.004	0.006
●	OYLR	OYLR	☐	-0.002	0.001	-0.003	0.002	0.004
▲	SMAI	SMAI		0.000	0.000	0.000	0.000	0.000
▲	CHCM	CHCM		0.000	0.000	0.000	0.000	0.000
▲	GRMD	GRMD		0.000	0.000	0.000	0.000	0.000
▲	SSHO	SSHO		0.000	0.000	0.000	0.000	0.000



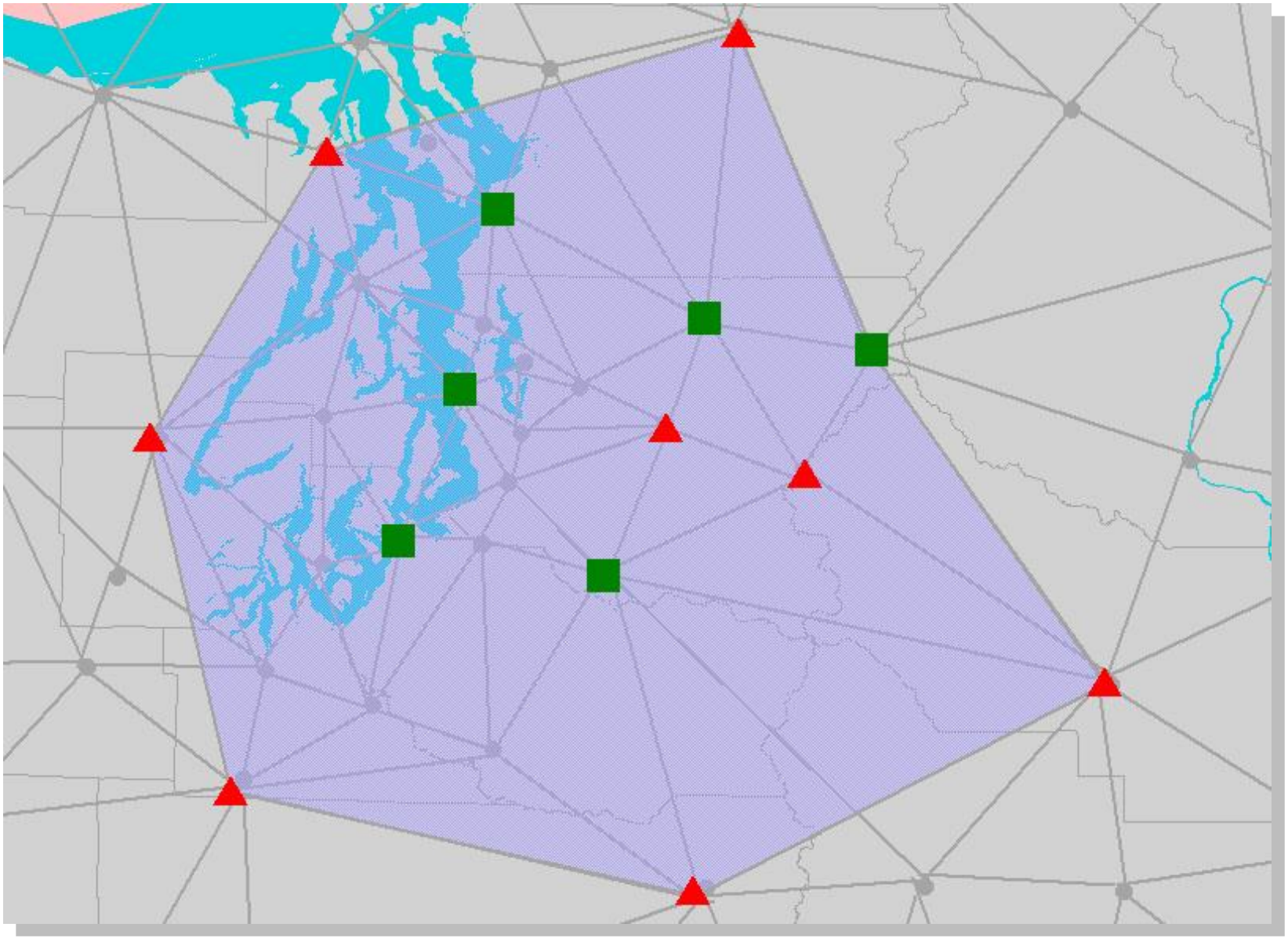
Dynamic Control



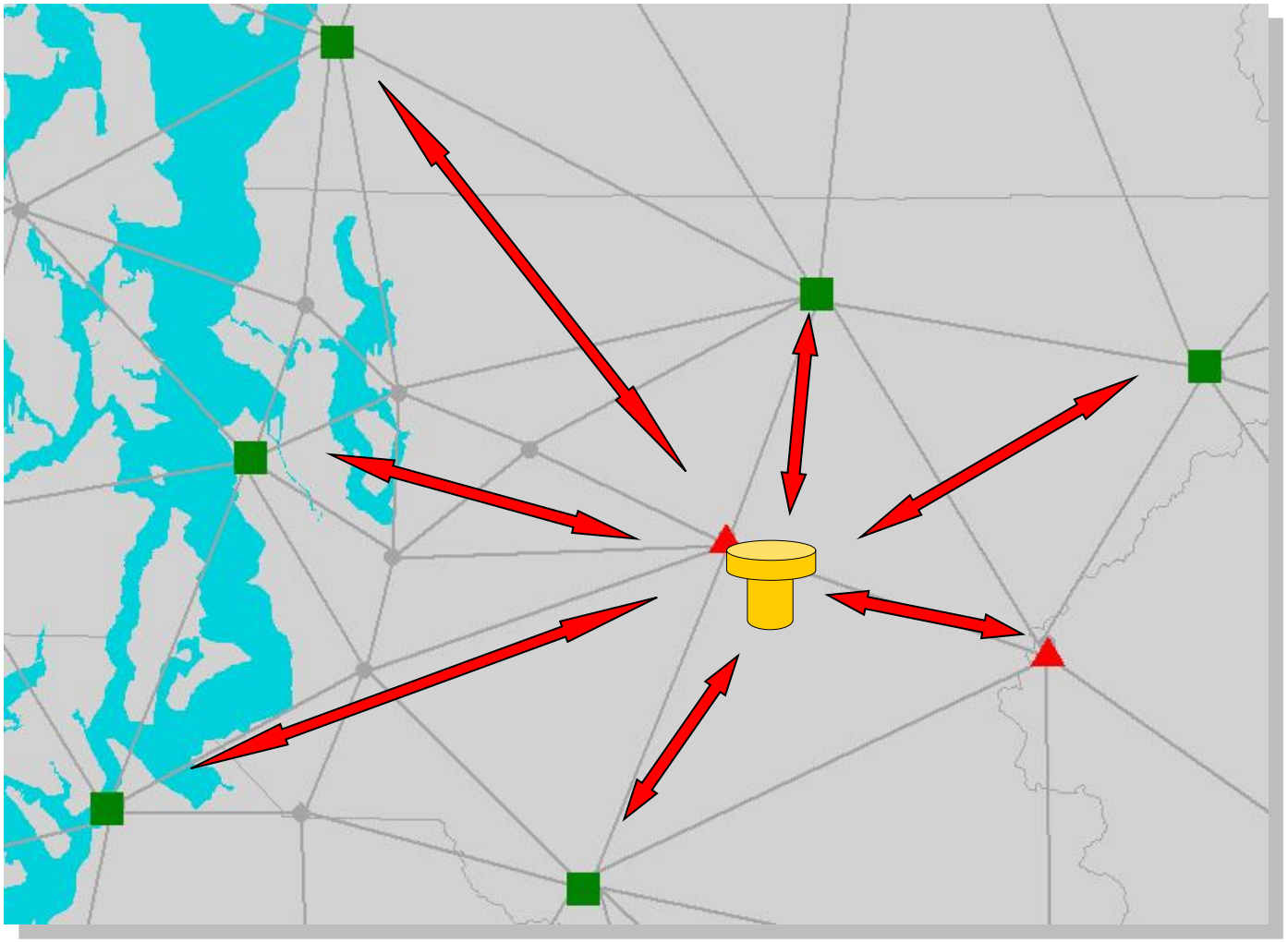
Integrity Monitoring



Integrity Monitoring

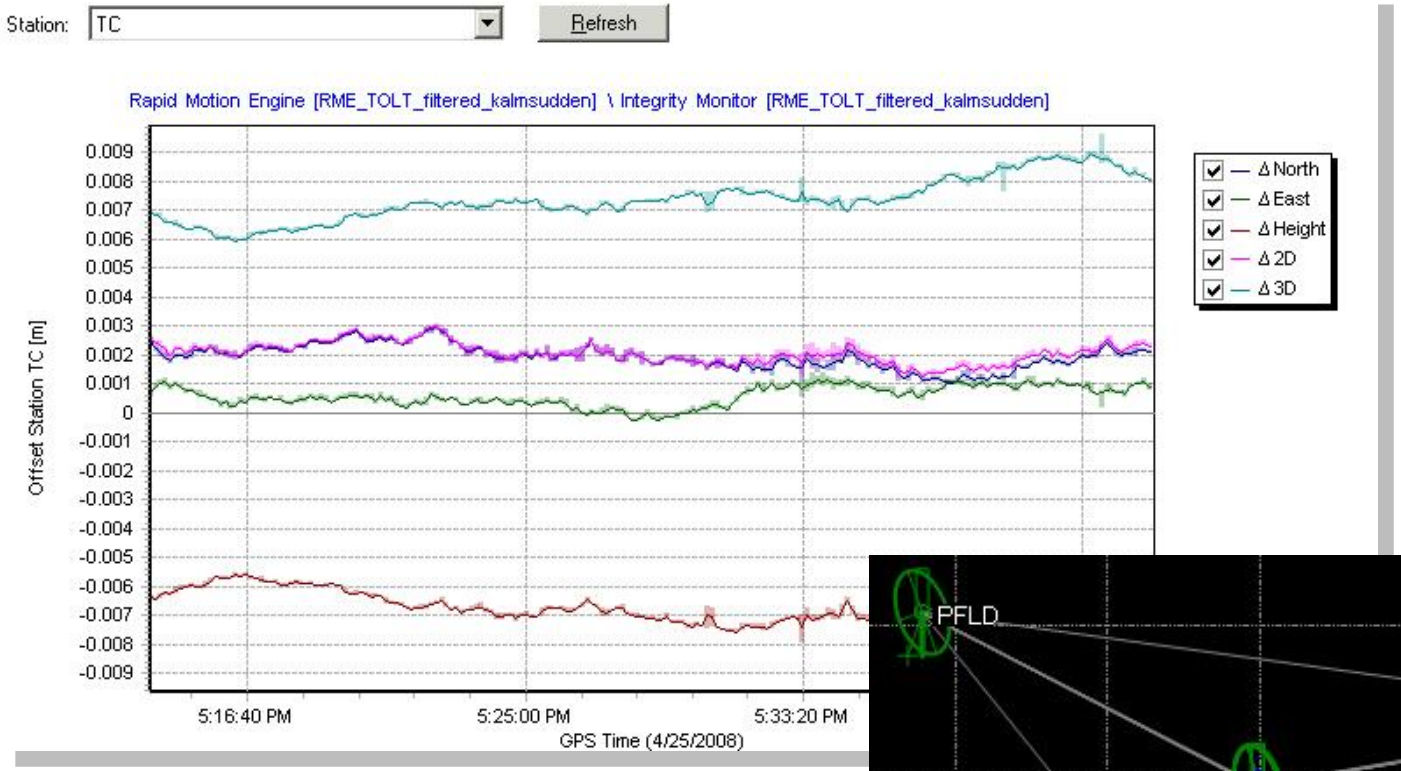


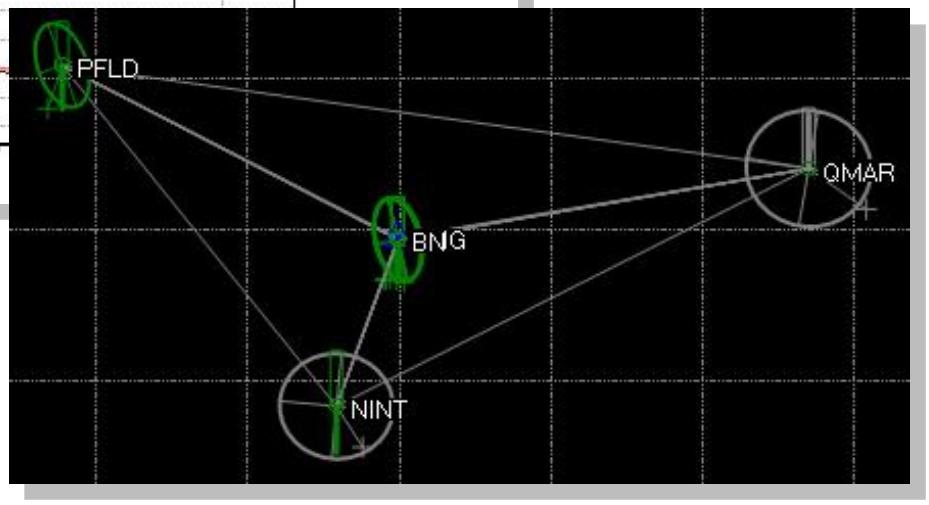
Integrity Monitoring



Integrity Monitoring

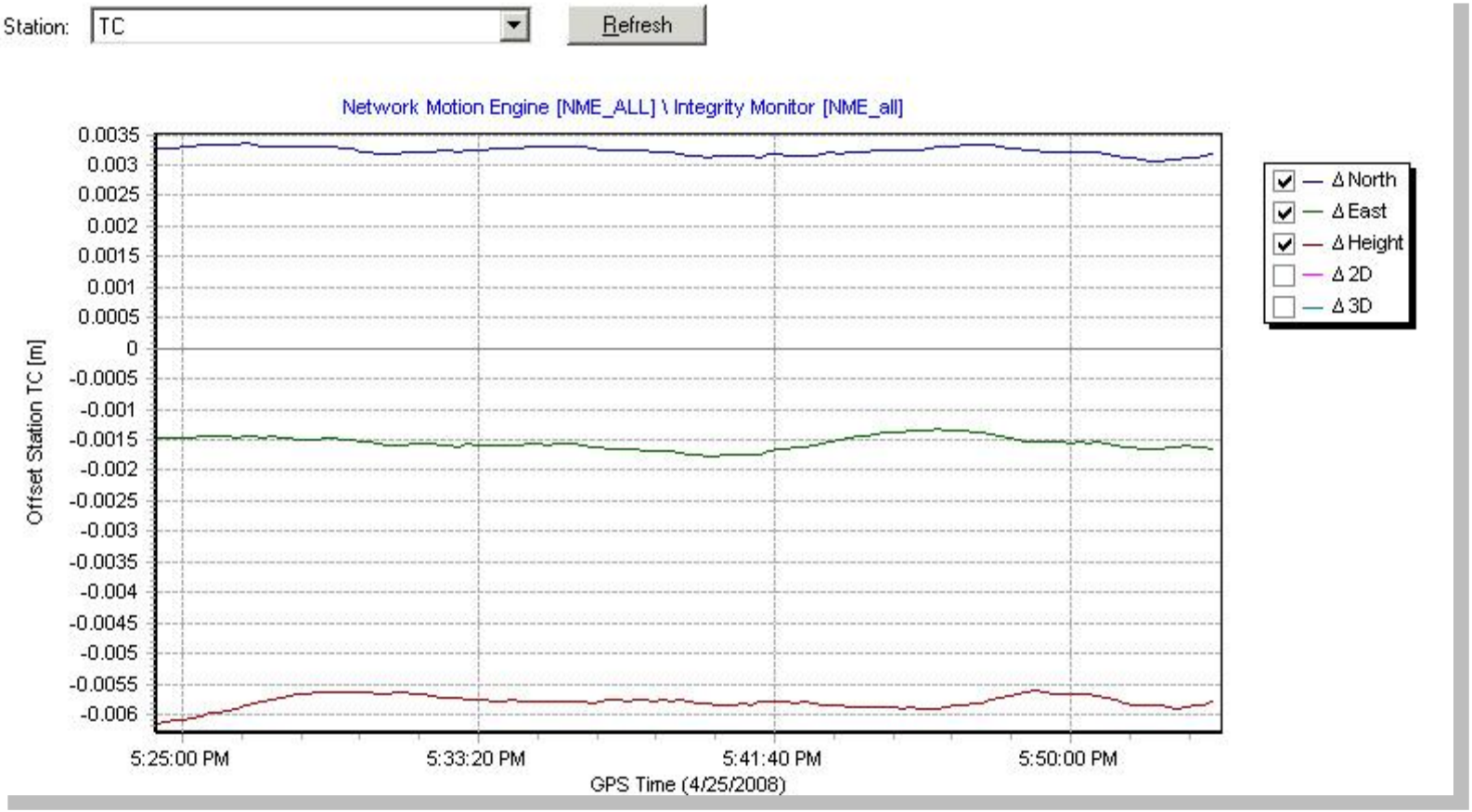
Rapid Motion – Motion Trends





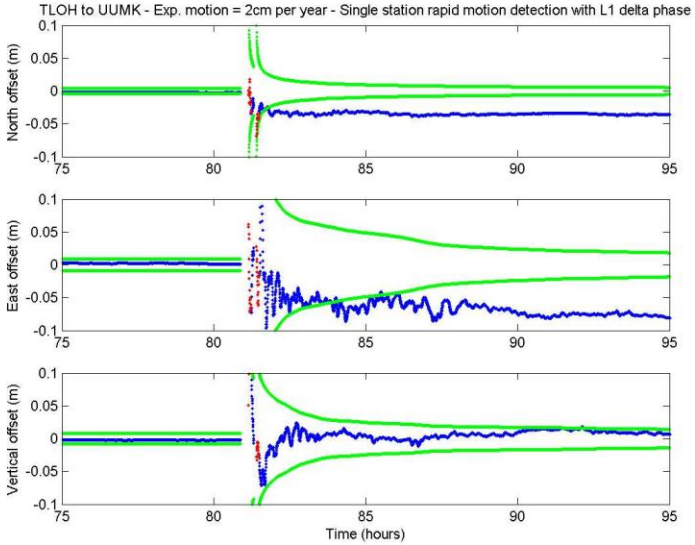
Integrity Monitoring

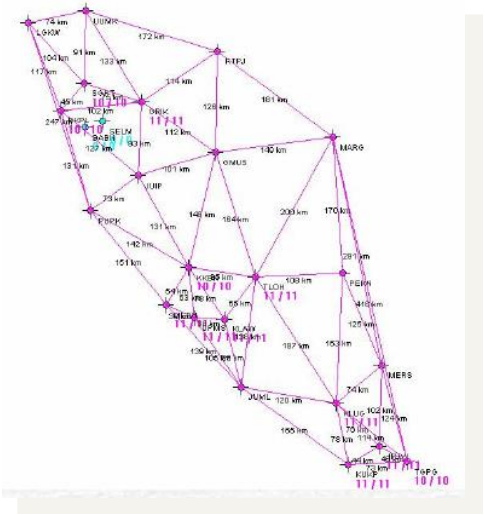
Network Integrity – Constant Loop Closures



Integrity Monitoring

Network Integrity – Constant Loop Closures



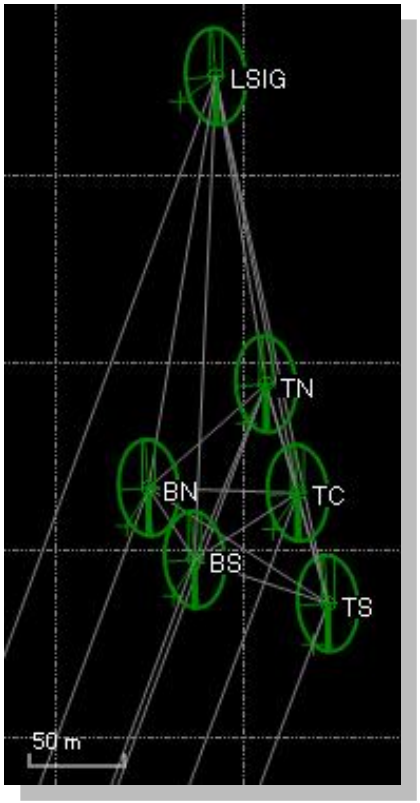


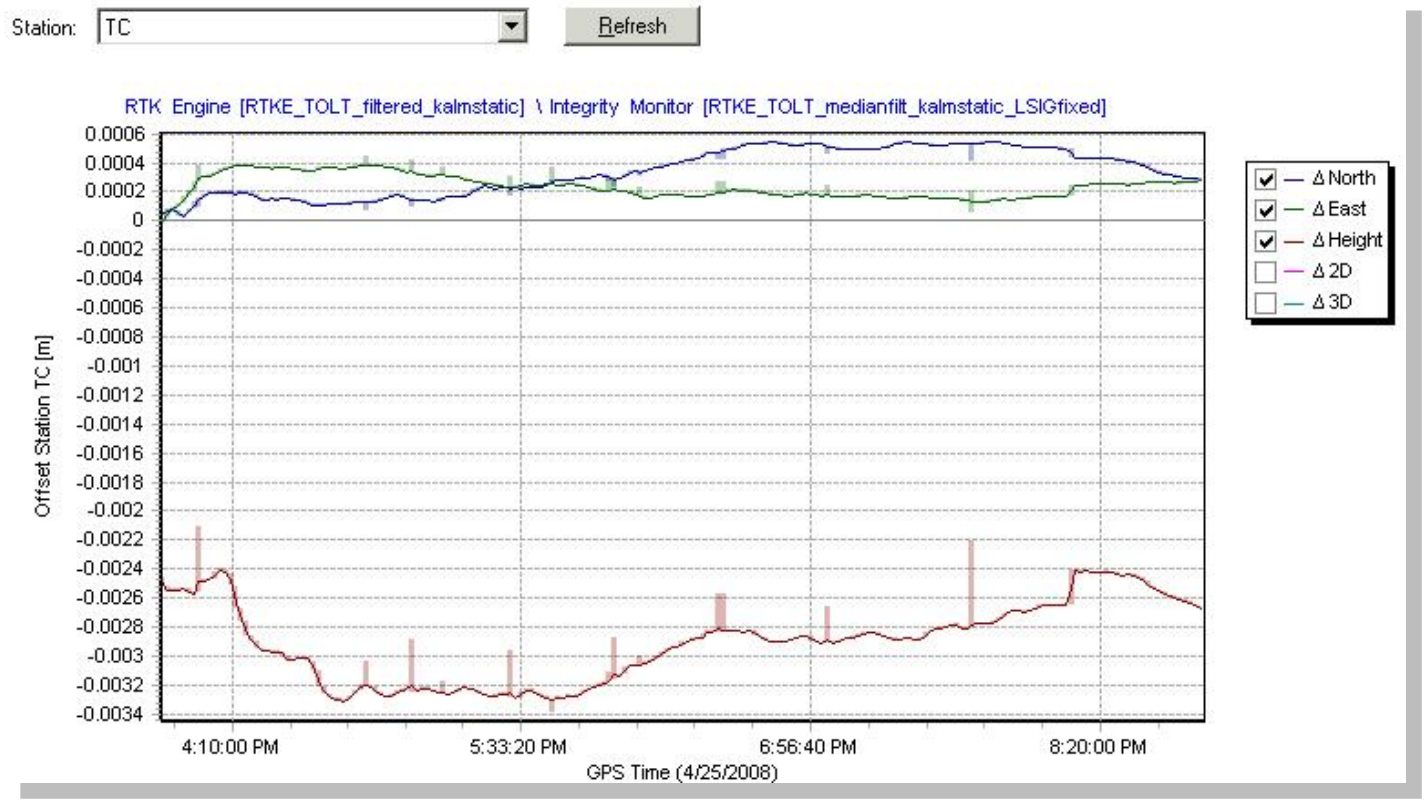
JUPEM – Real-Time Network

Department of Surveying and Mapping, Malaysia

Integrity Monitoring

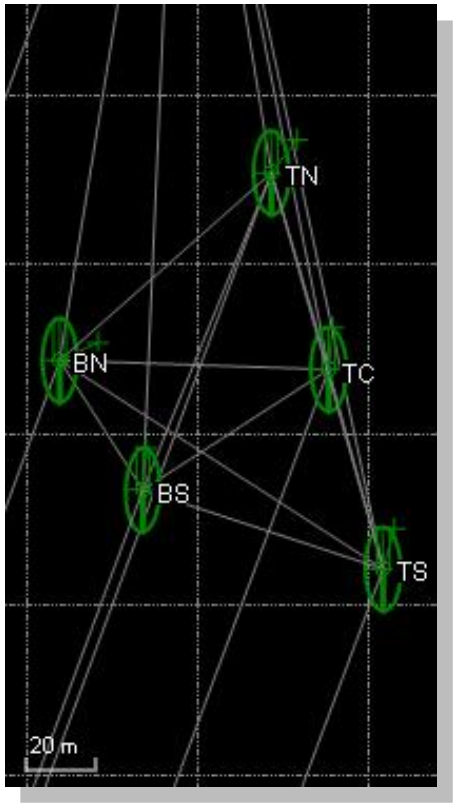
Server-Side Multiple RTK

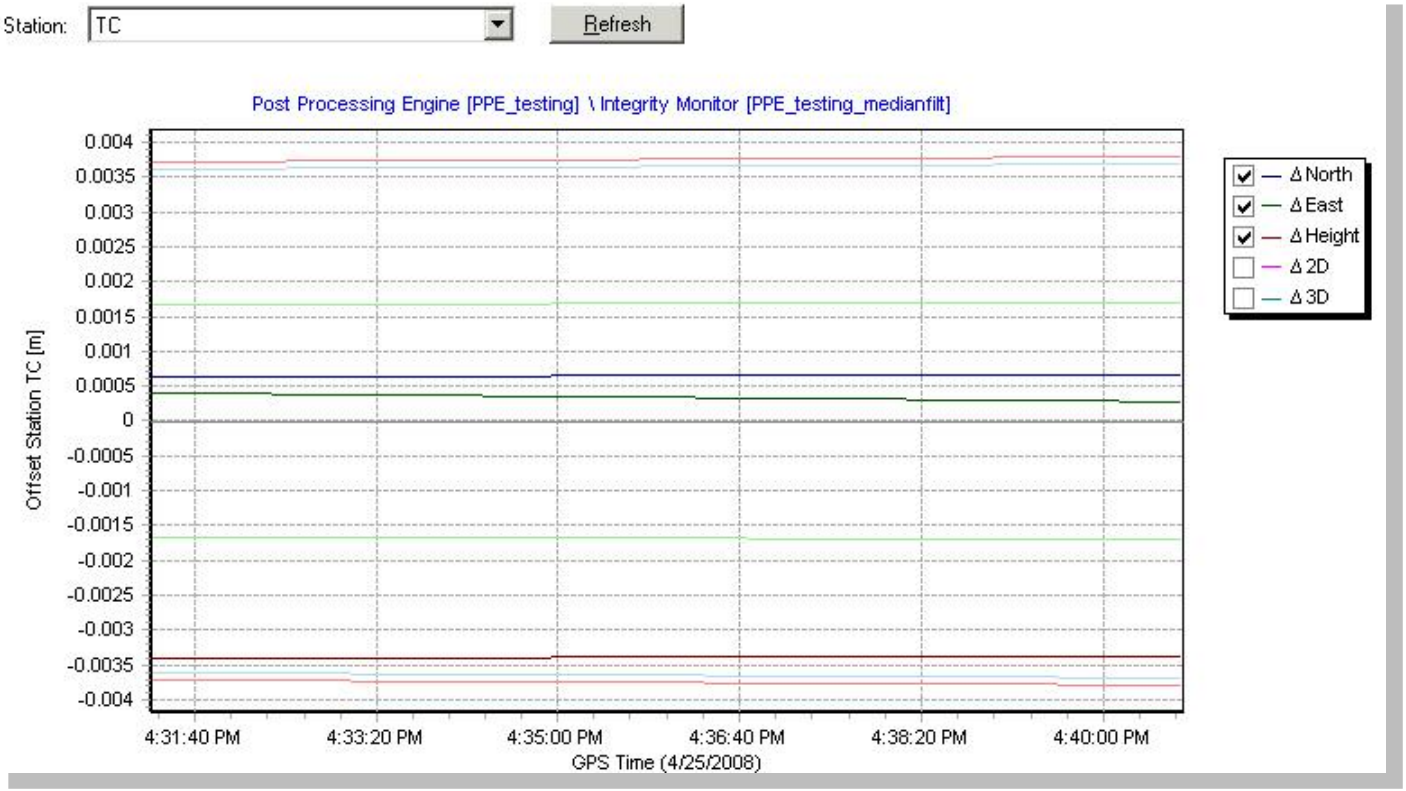




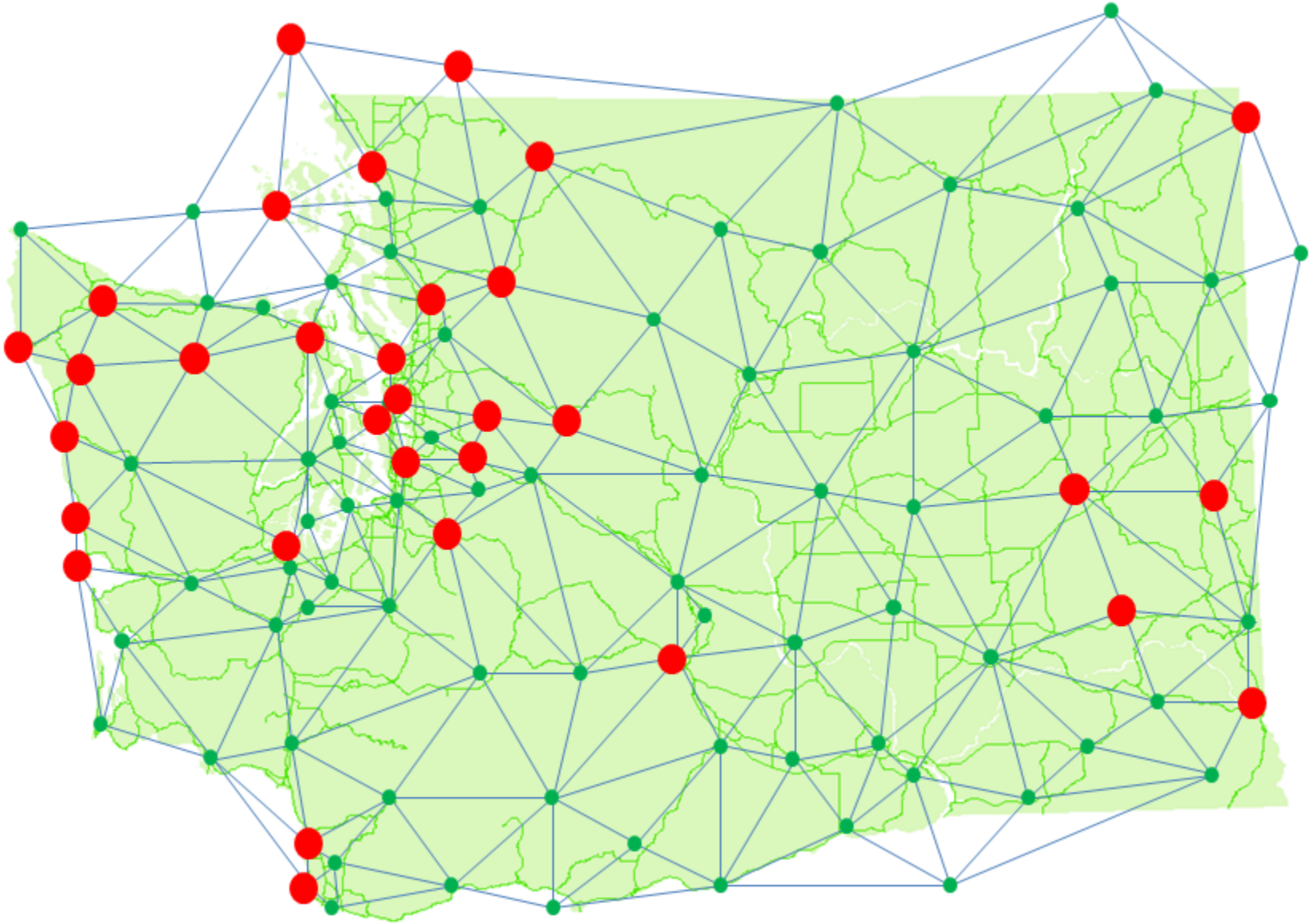
Integrity Monitoring

Automated Post-Processing

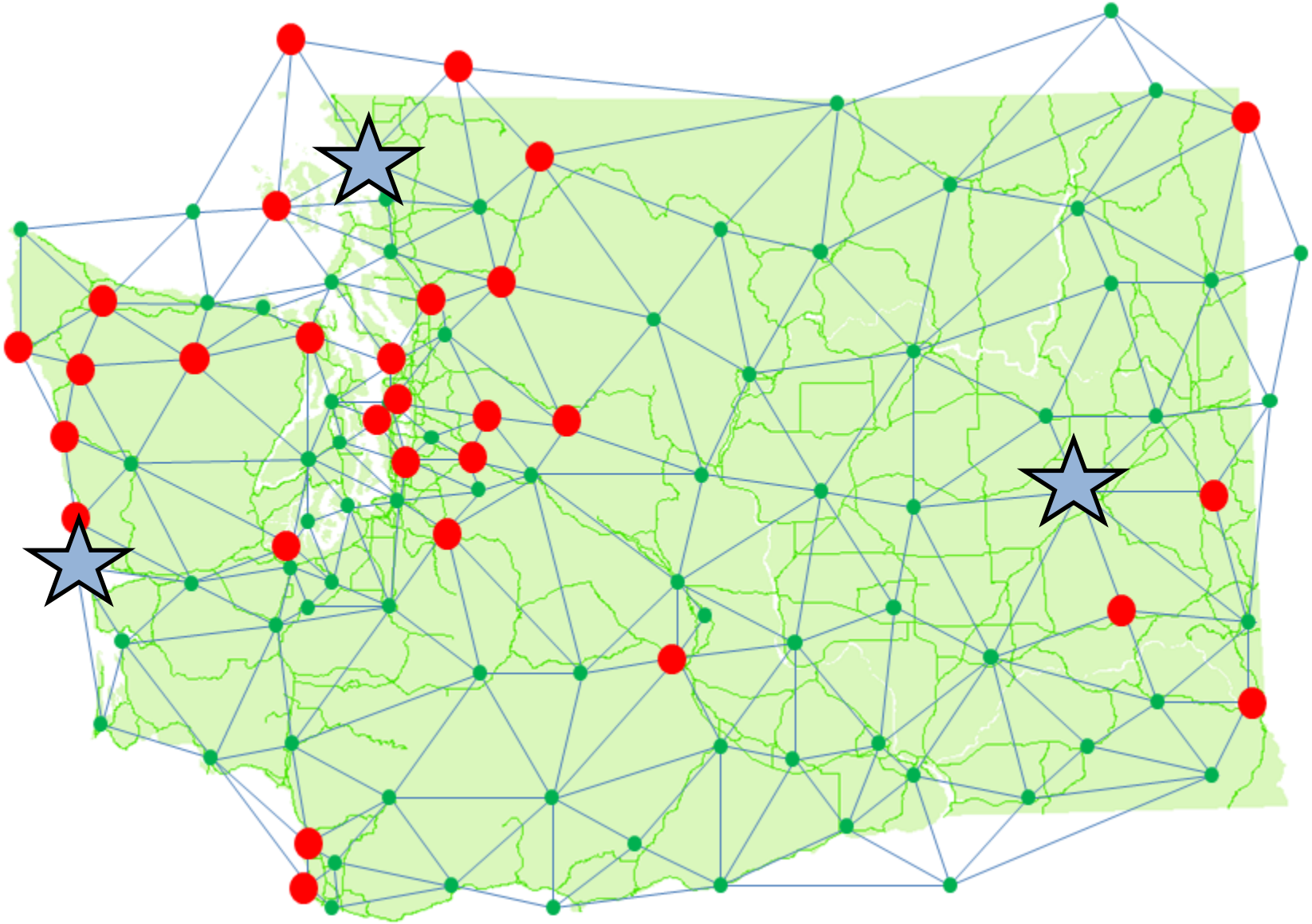




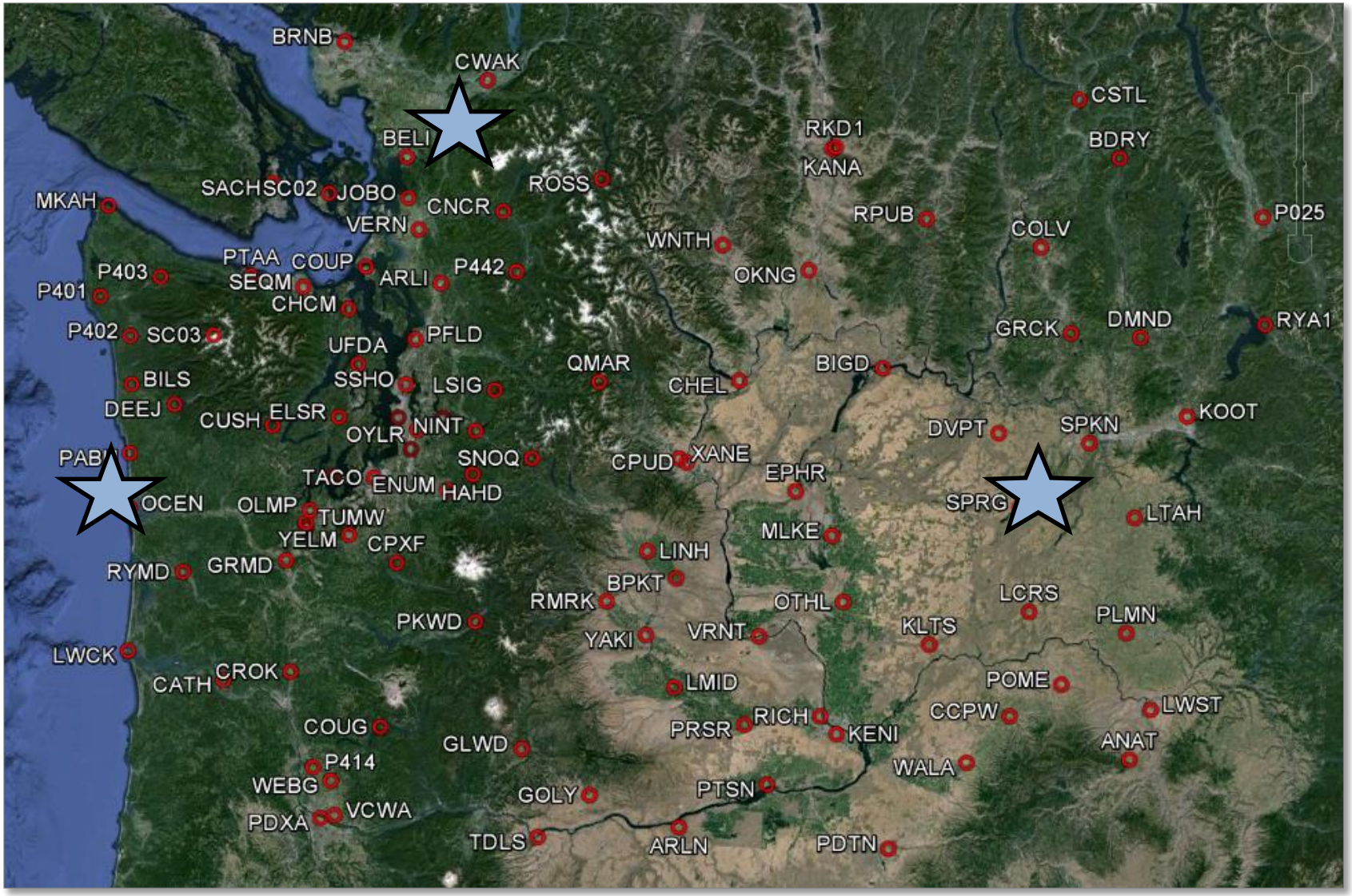
Stations in (server side) PPP Test



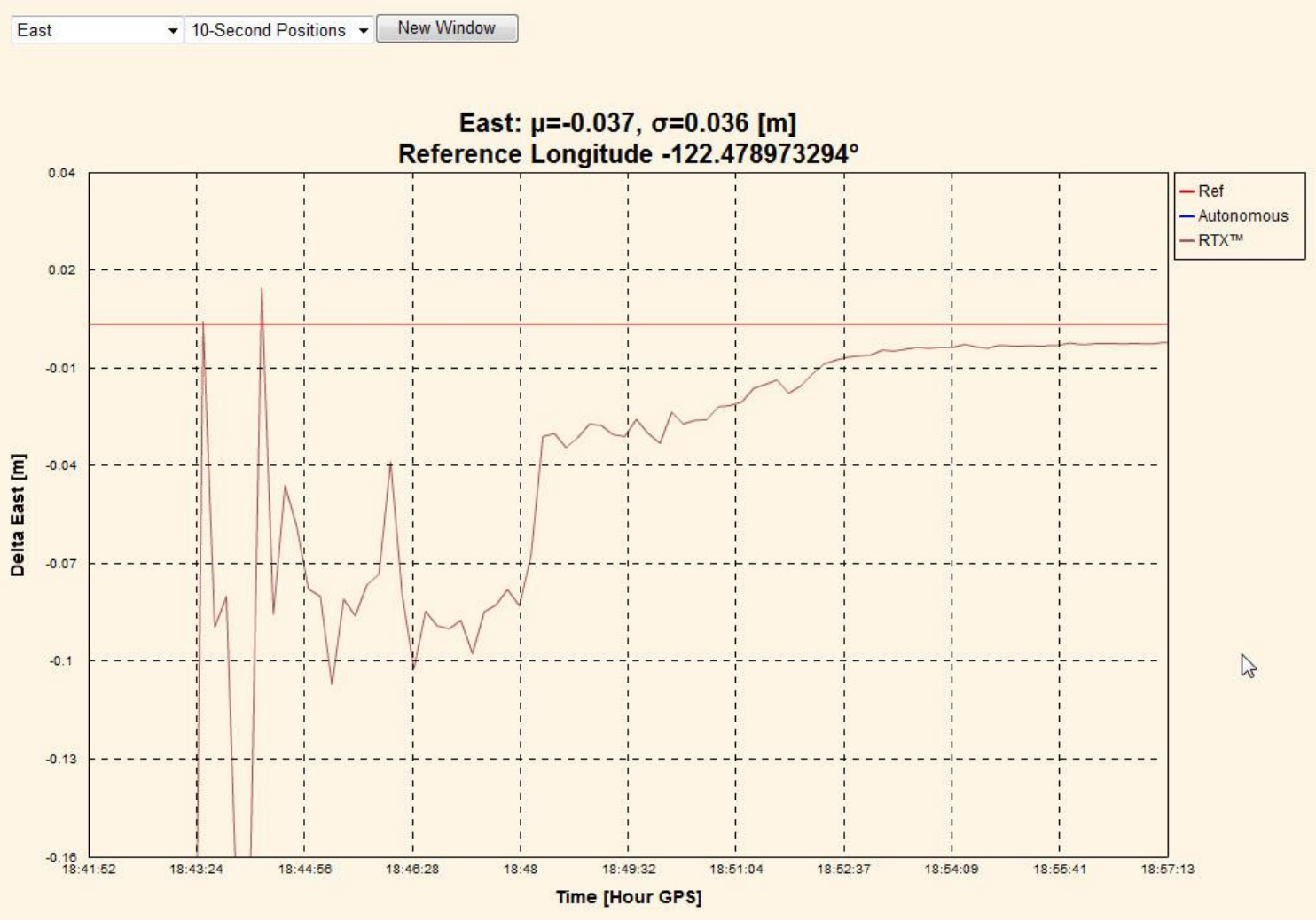
Stations in Onboard (sat based) PPP Test



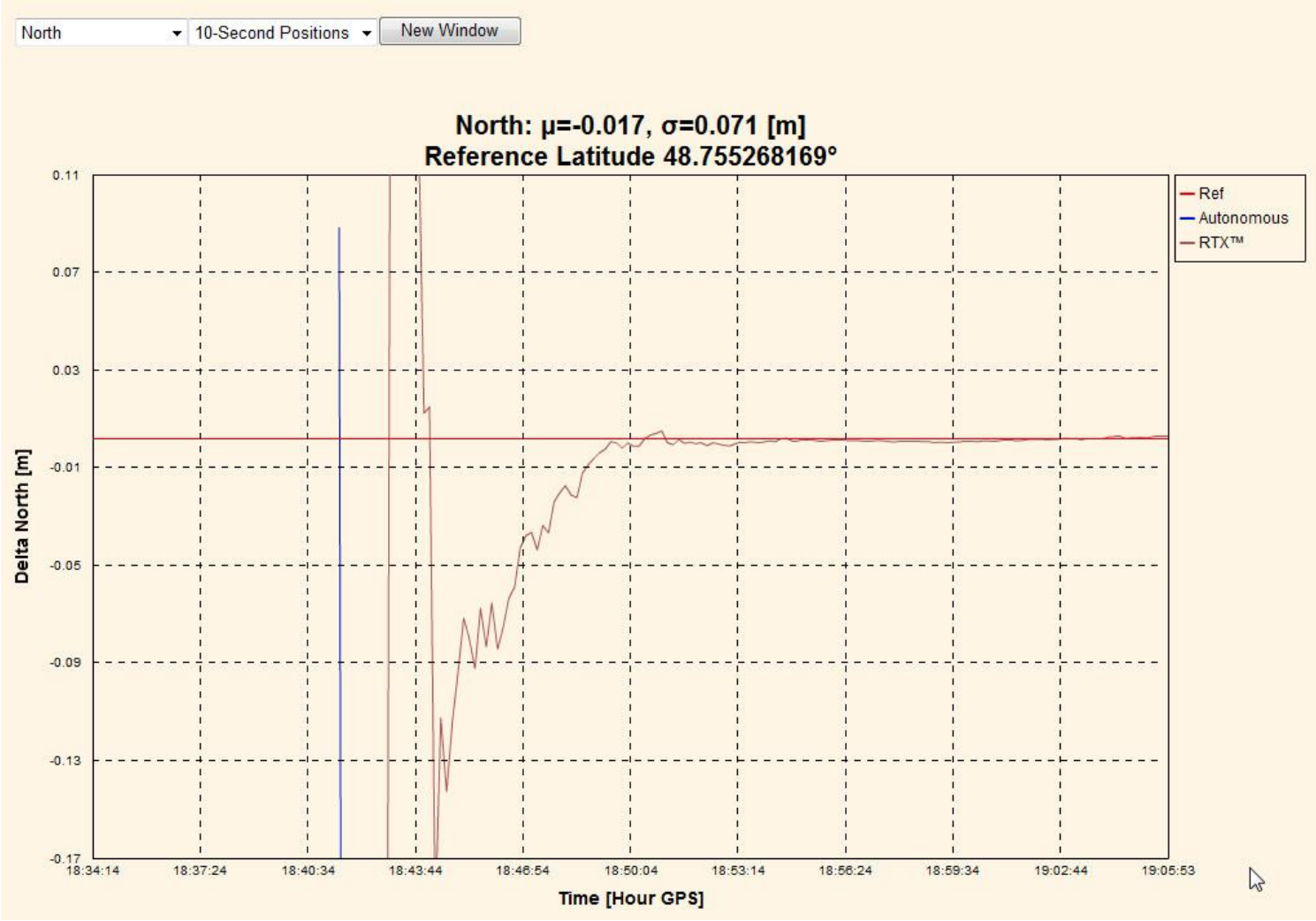
Stations in Onboard (sat based) PPP Test



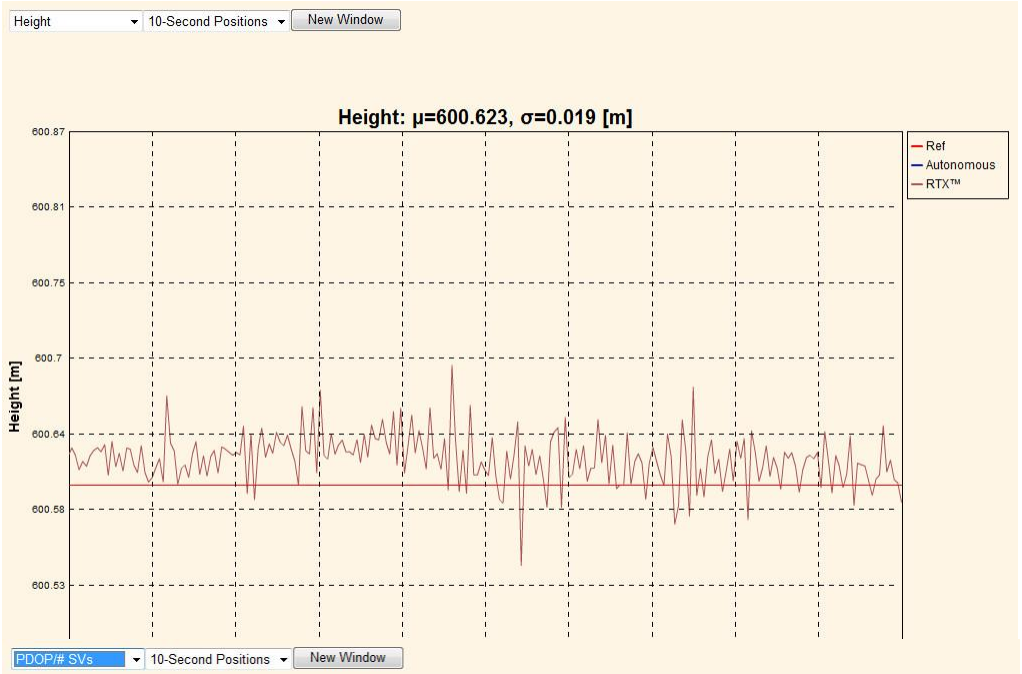
Onboard [Central] - East



Onboard [Central] - North



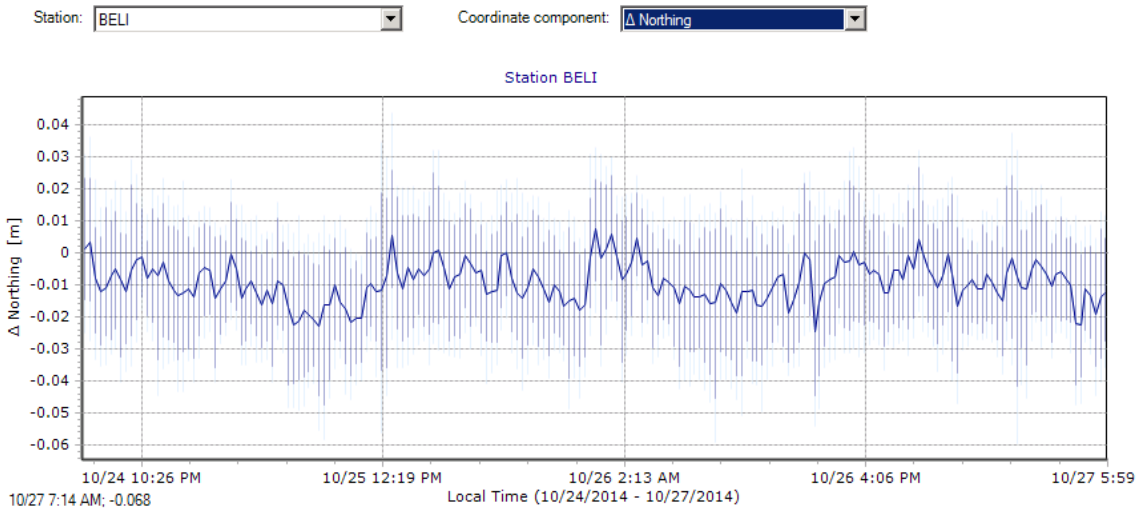
Onboard [Central] - Height

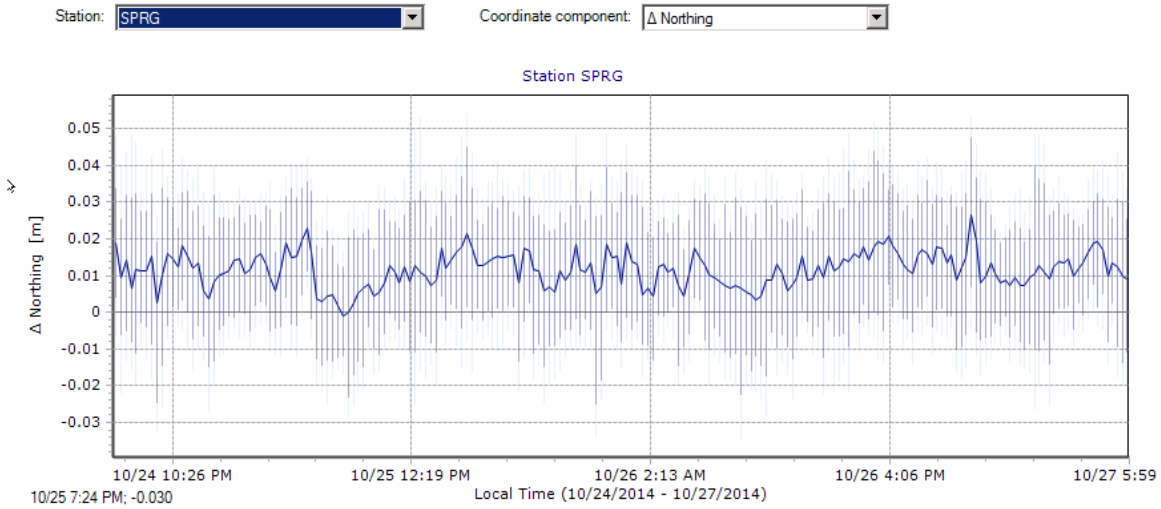


Onboard [Coastal] Height

PDOP & #Sats

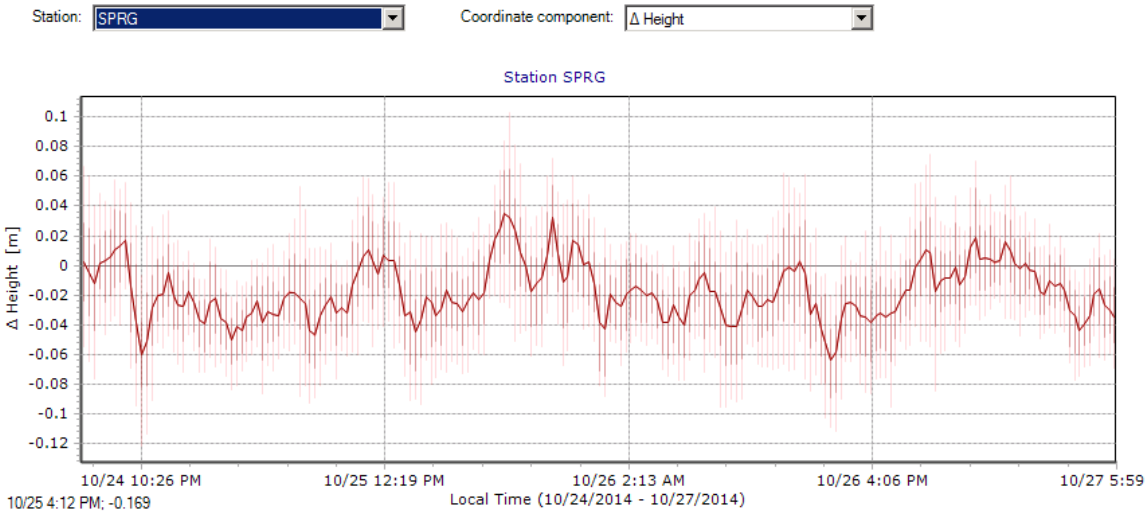
PPP [Central & East] – North
Bellingham and Sprague, WA



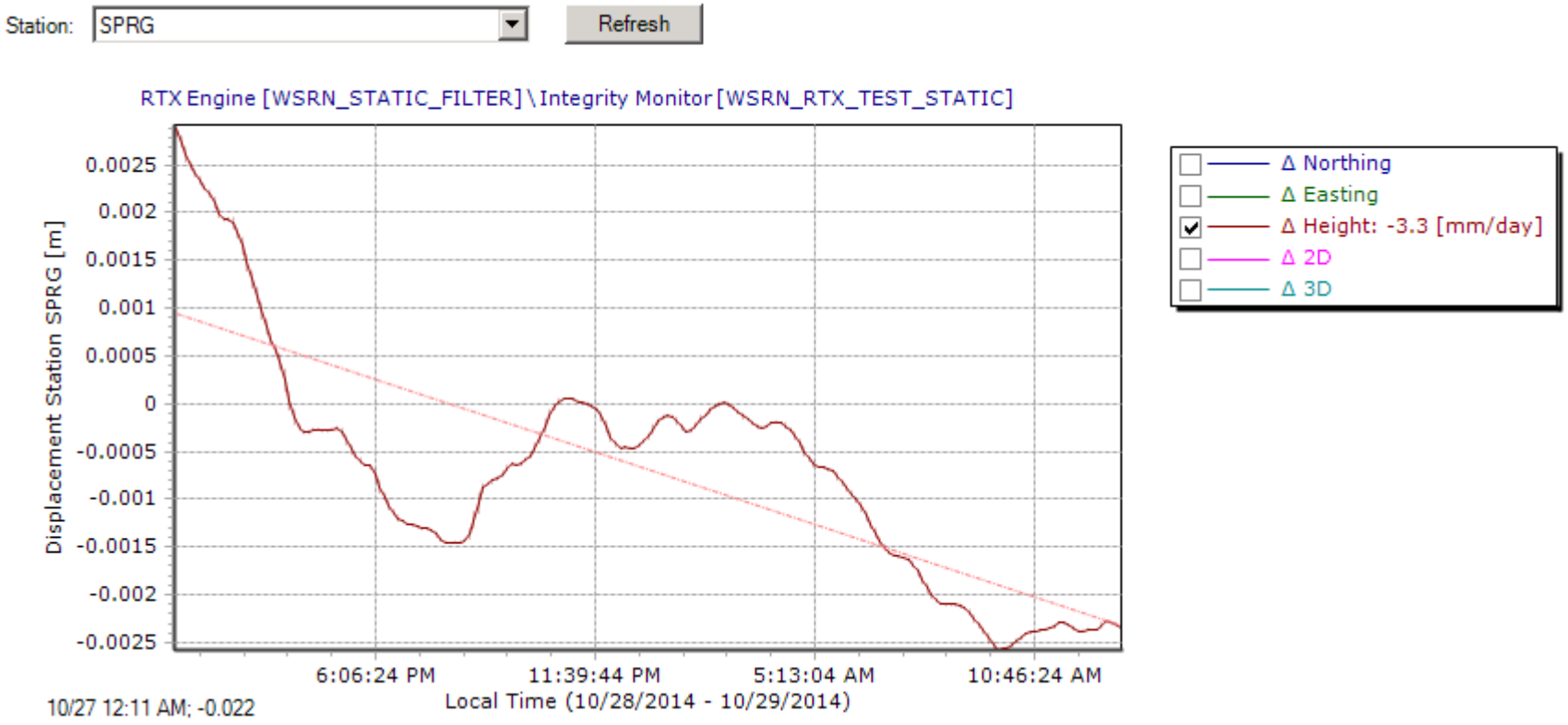


PPP [Central & East] – East

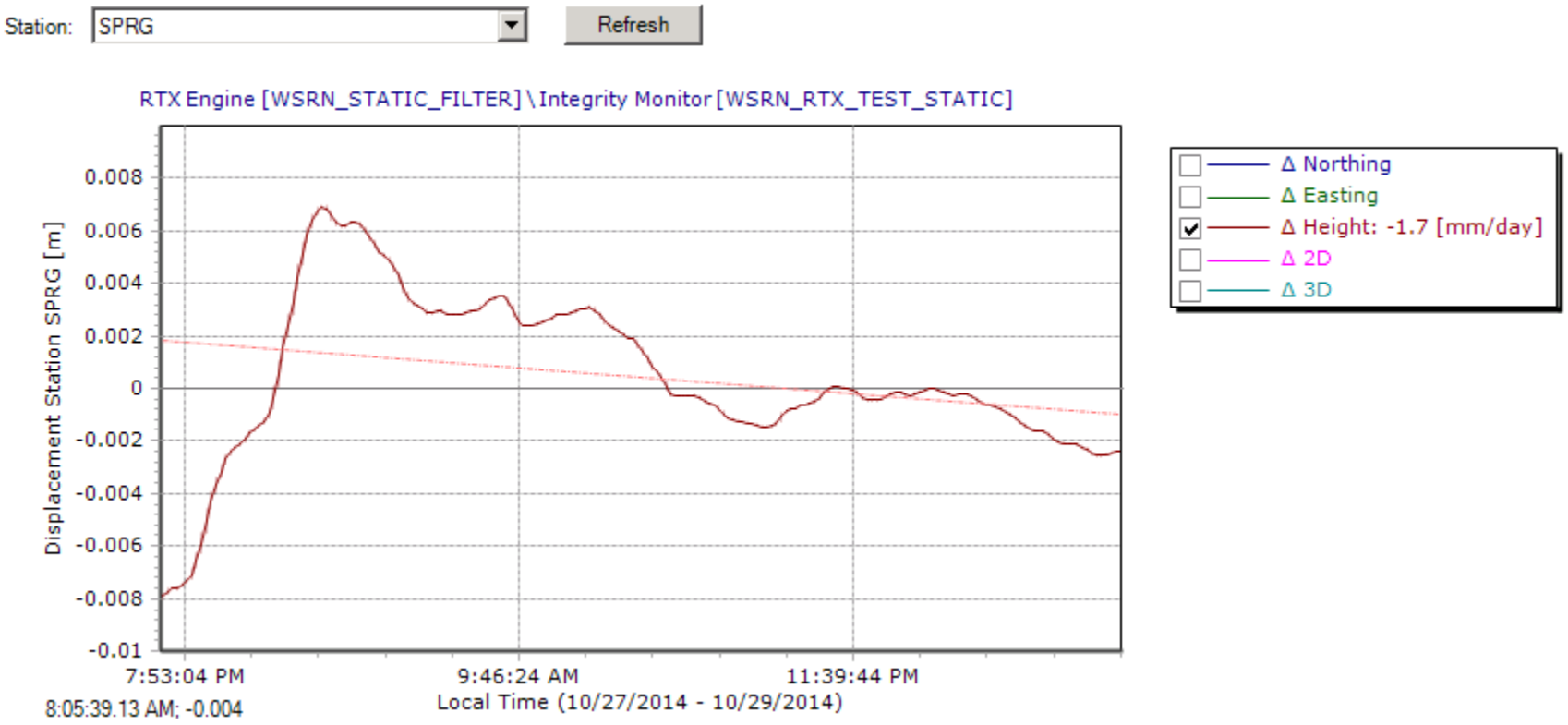
PPP [East] – Height



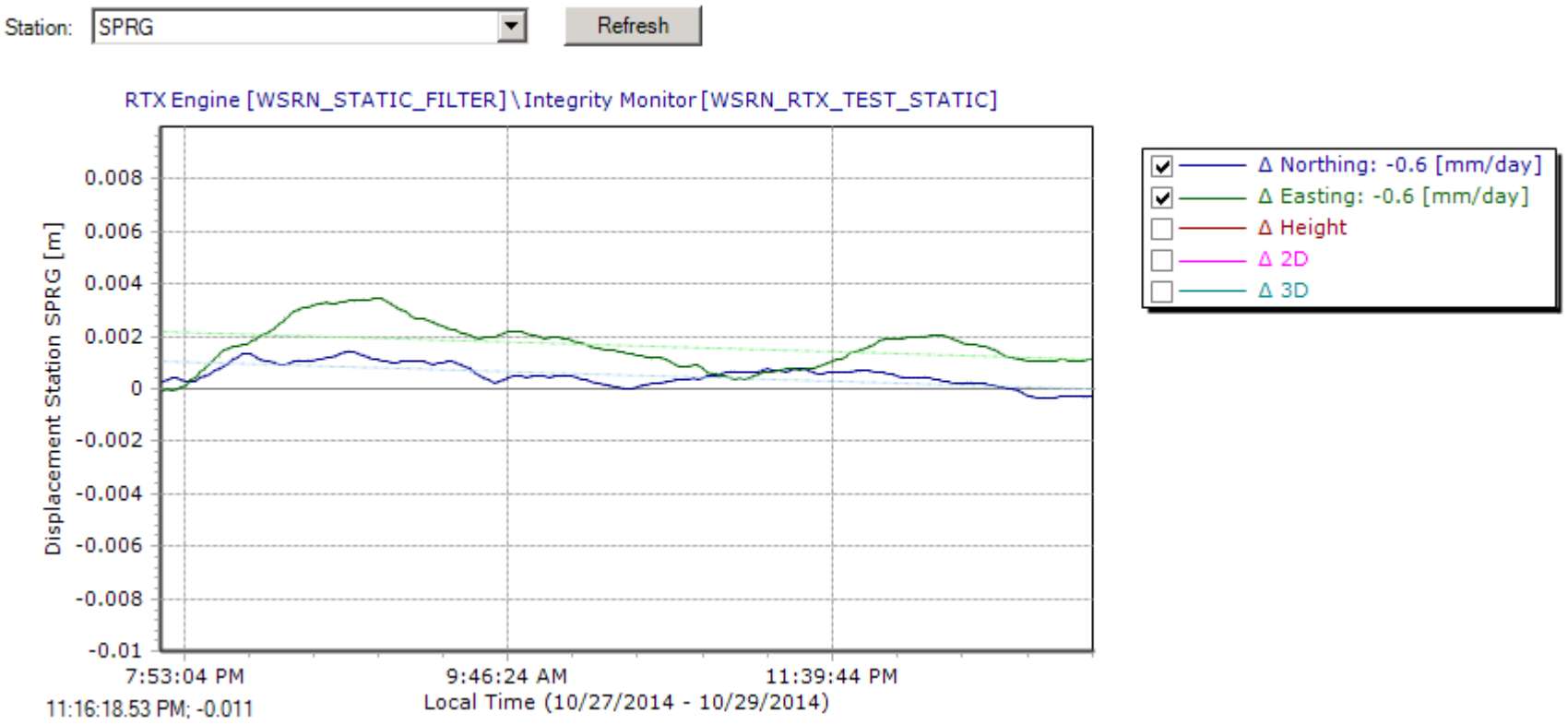
PPP – Static 24hr - Height



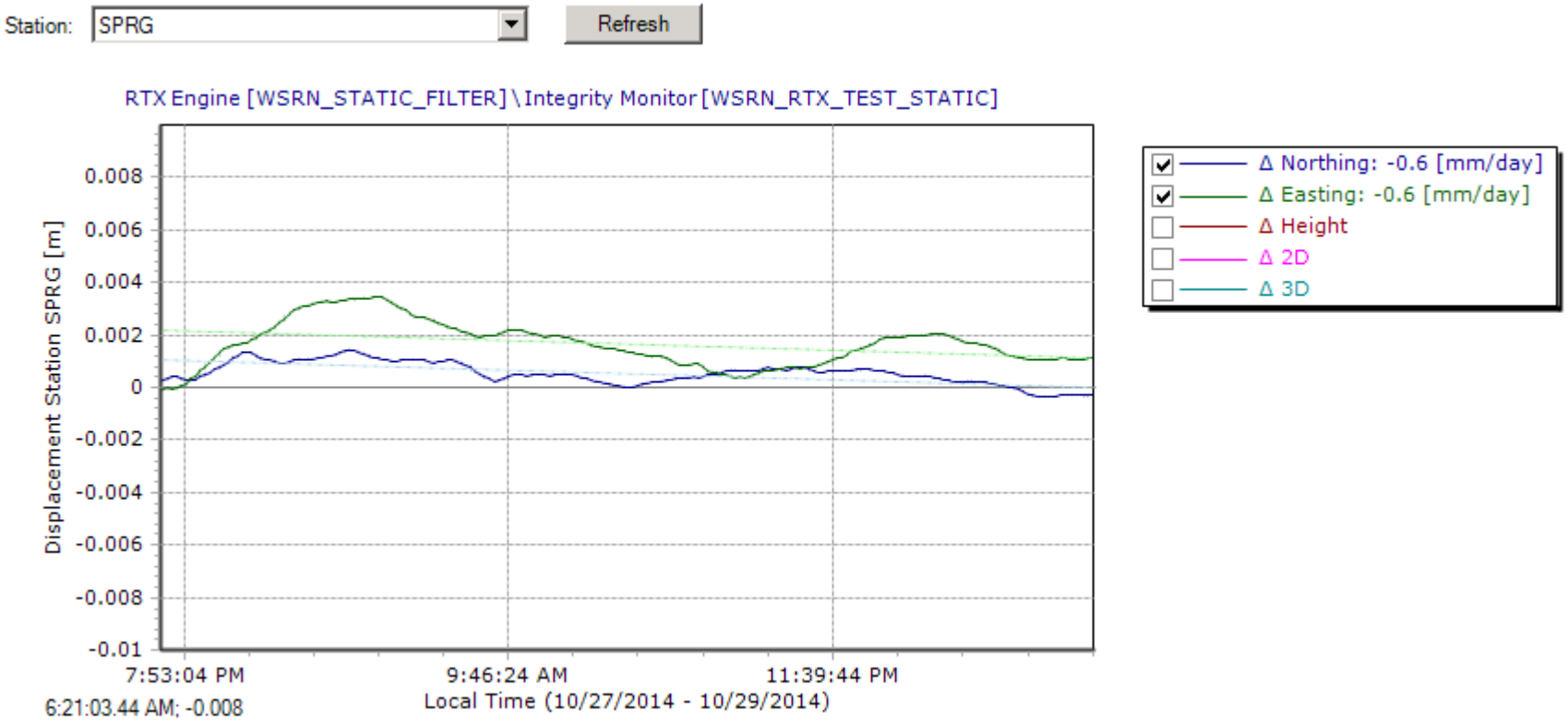
PPP – Static 72hr - Height



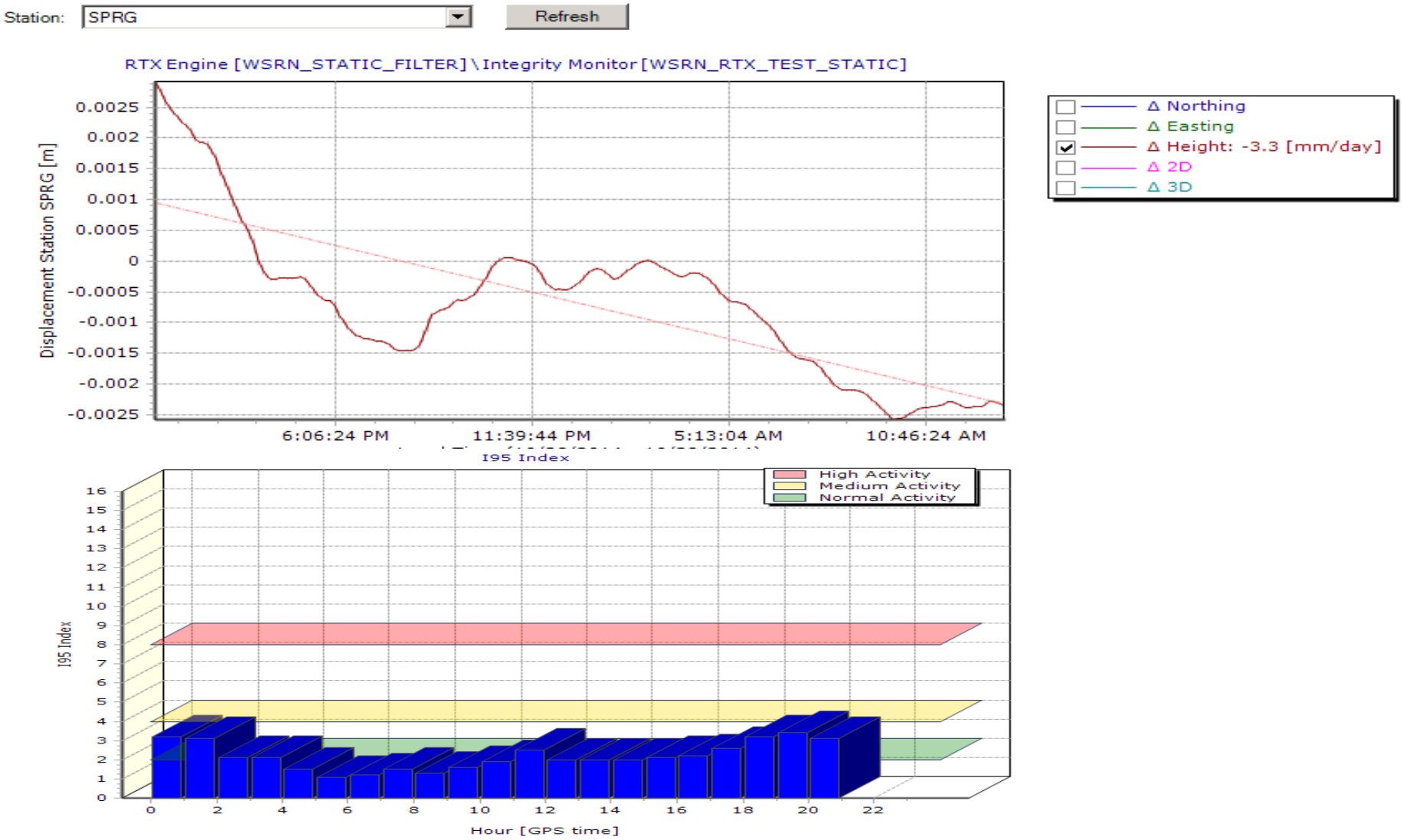
PPP – Static 24hr - Height



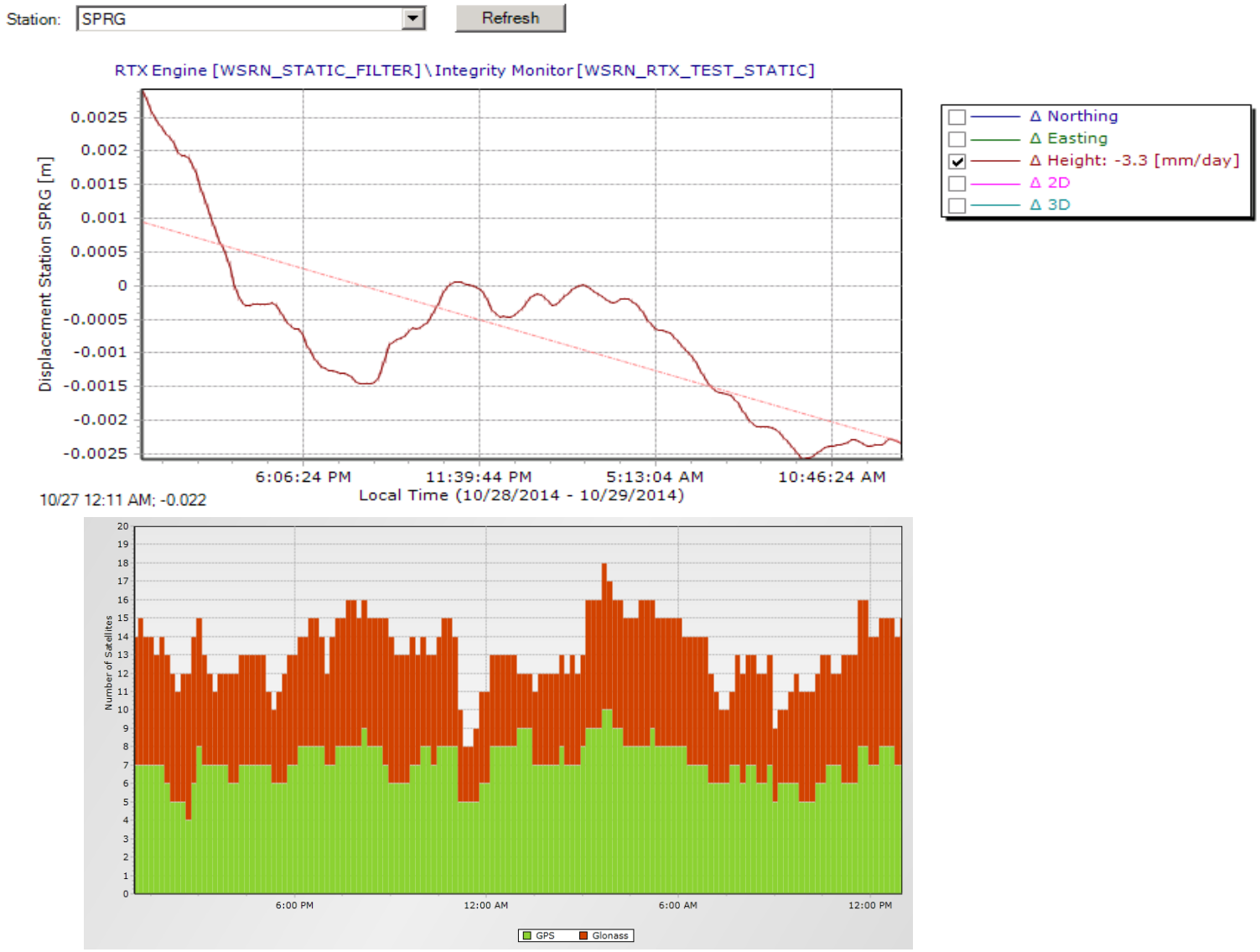
PPP – Static 72hr - Height



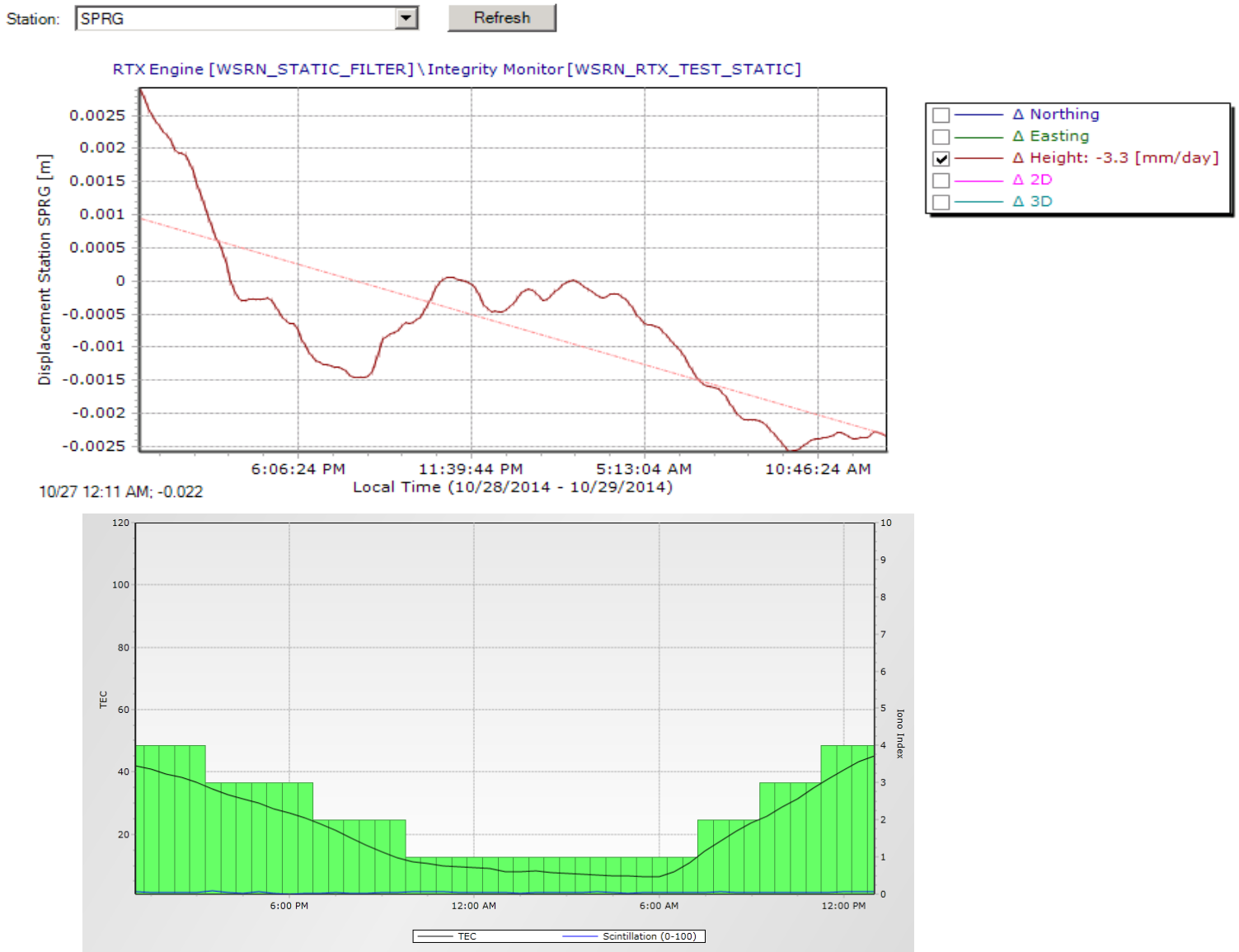
PPP – Height Drift



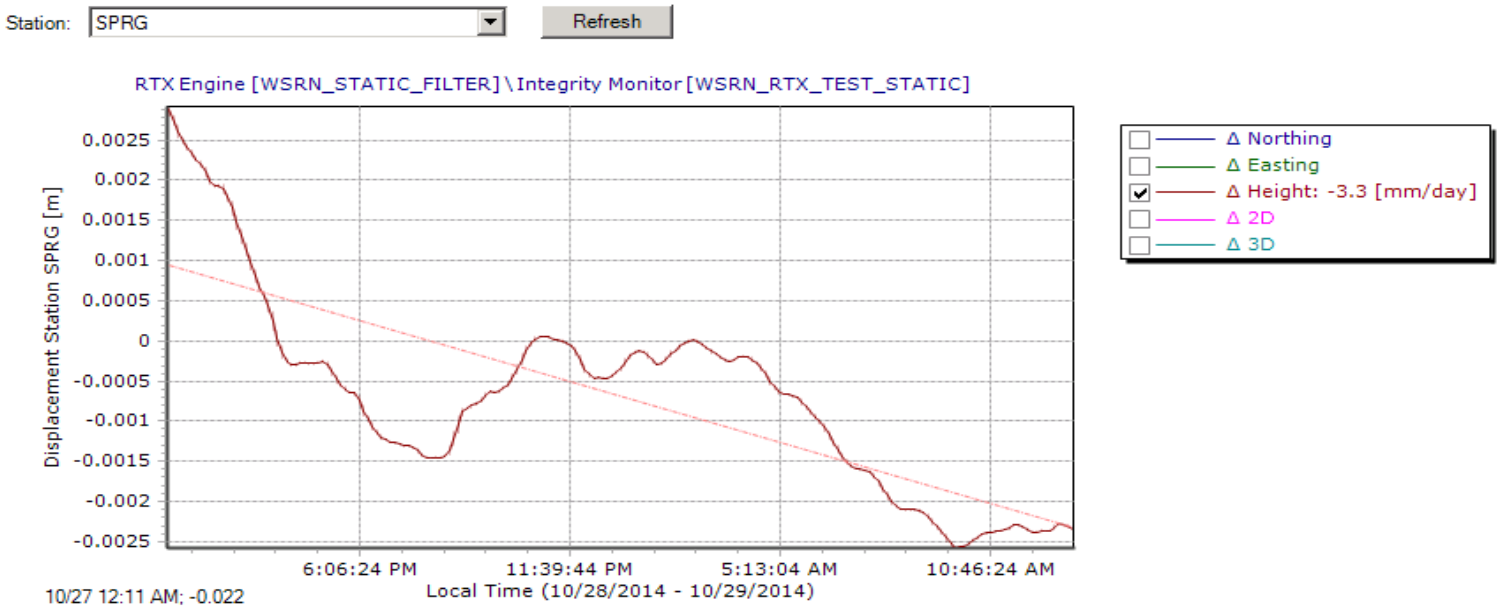
PPP – Height Drift

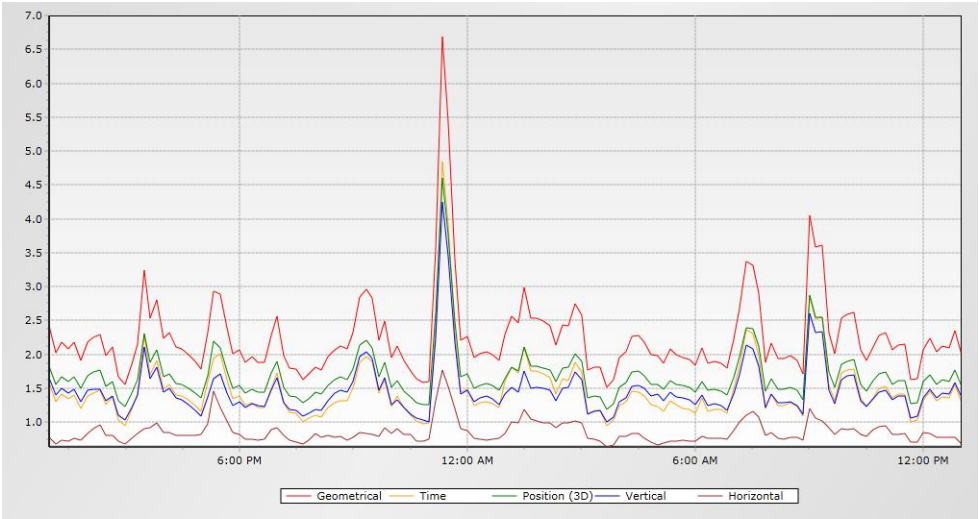


PPP – Height Drift

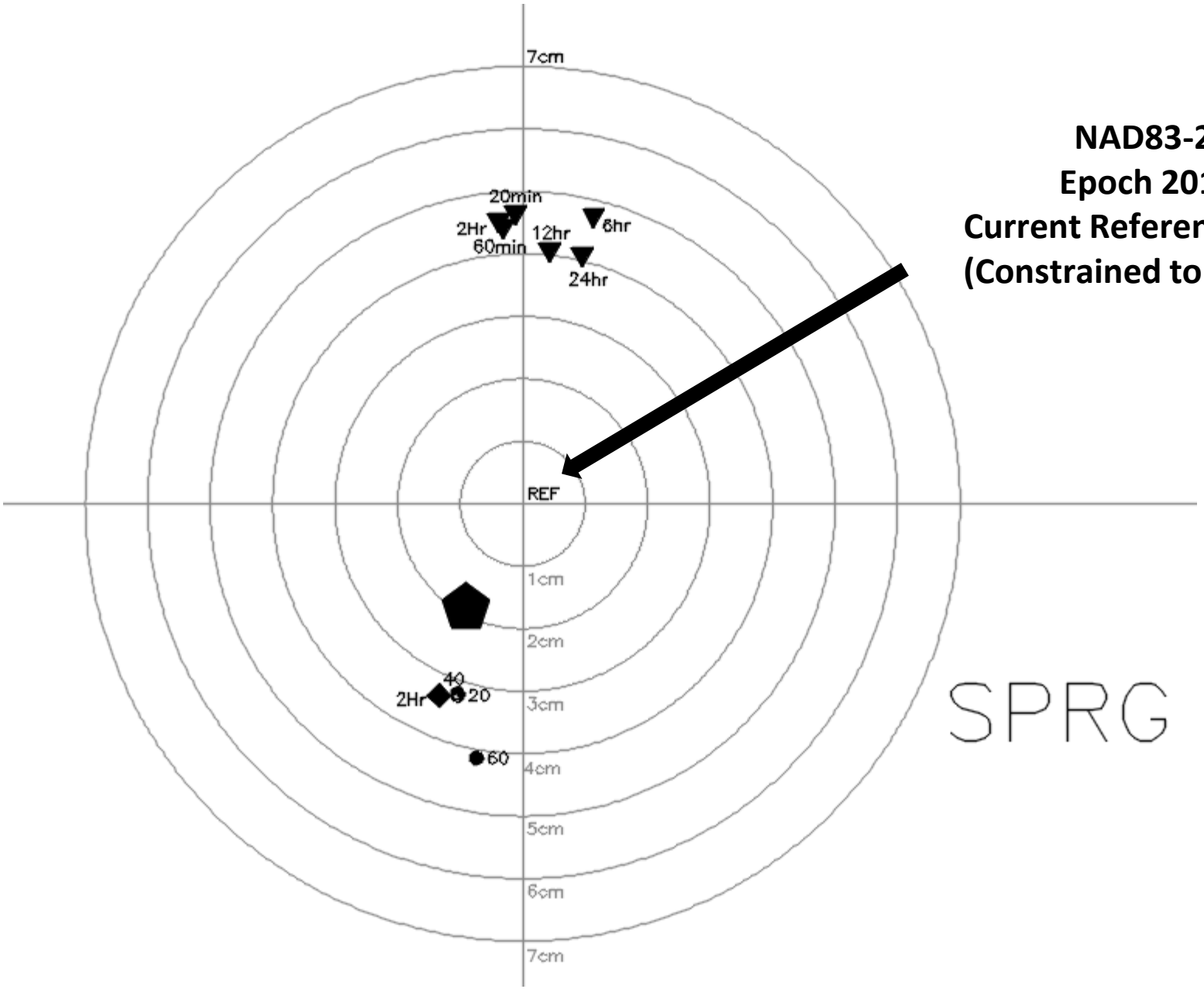


PPP – Height Drift





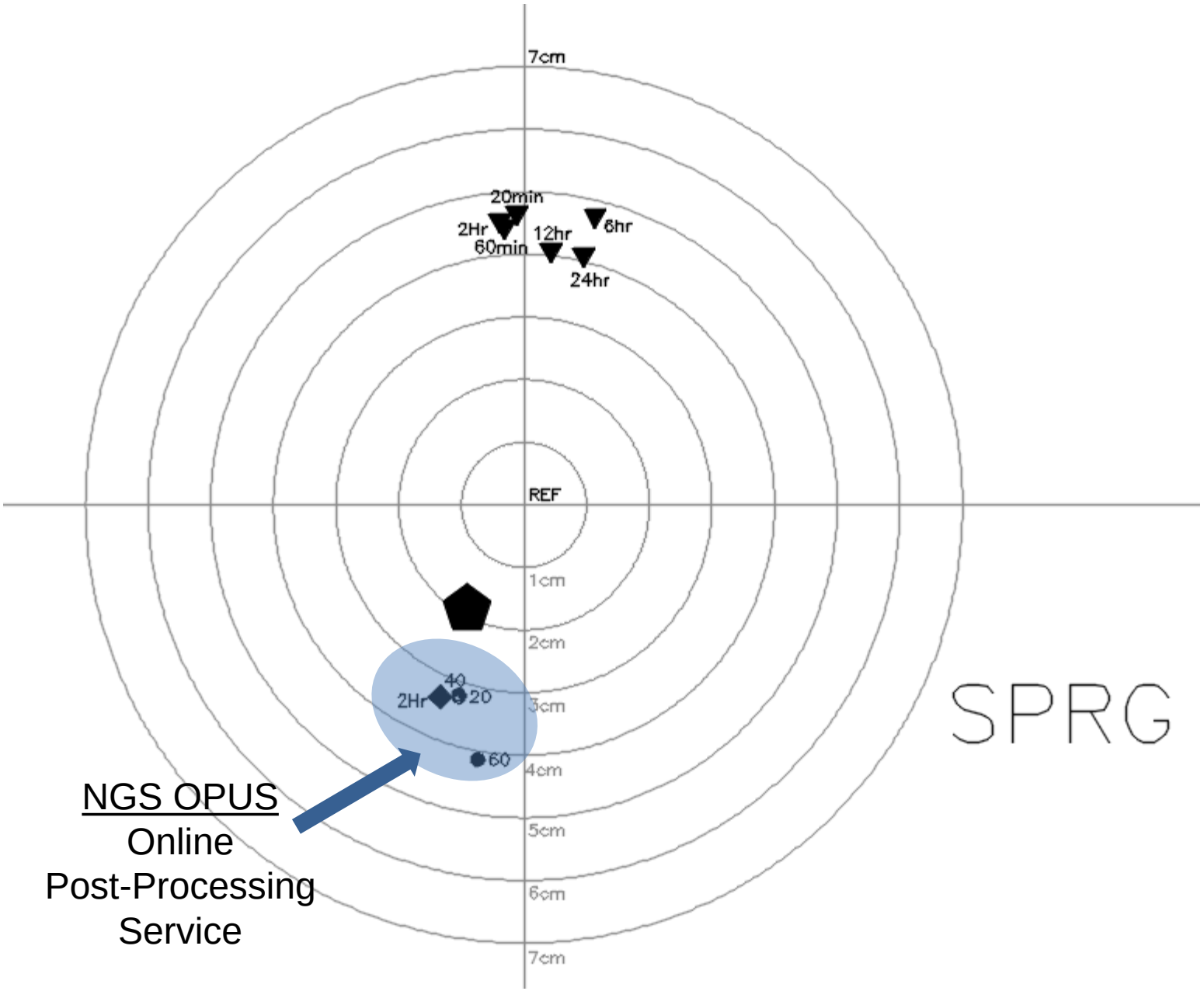
PPP Testing



NAD83-2011
Epoch 2010.00
Current Reference Position
(Constrained to NGS CORS)

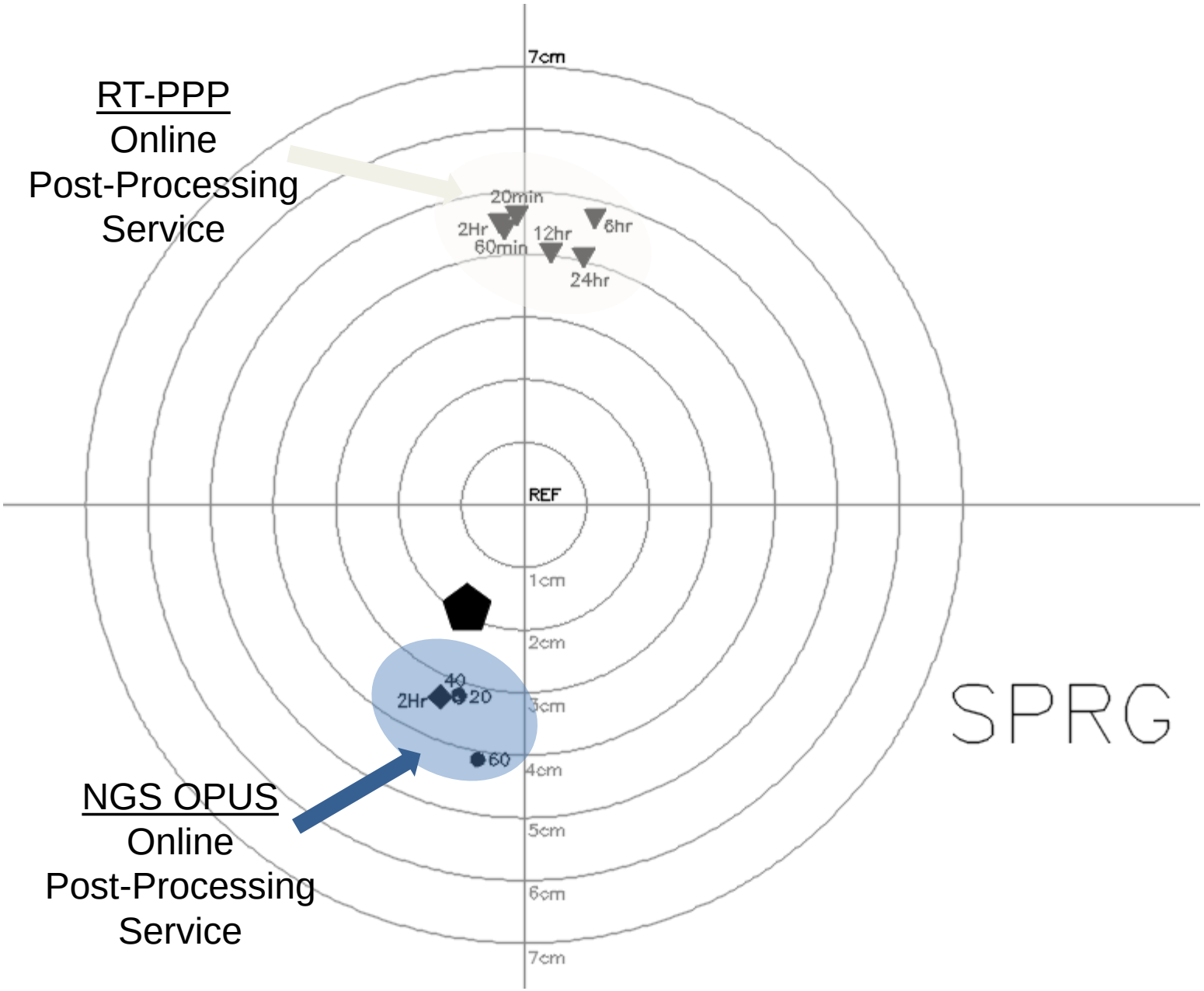
SPRG

PPP Testing

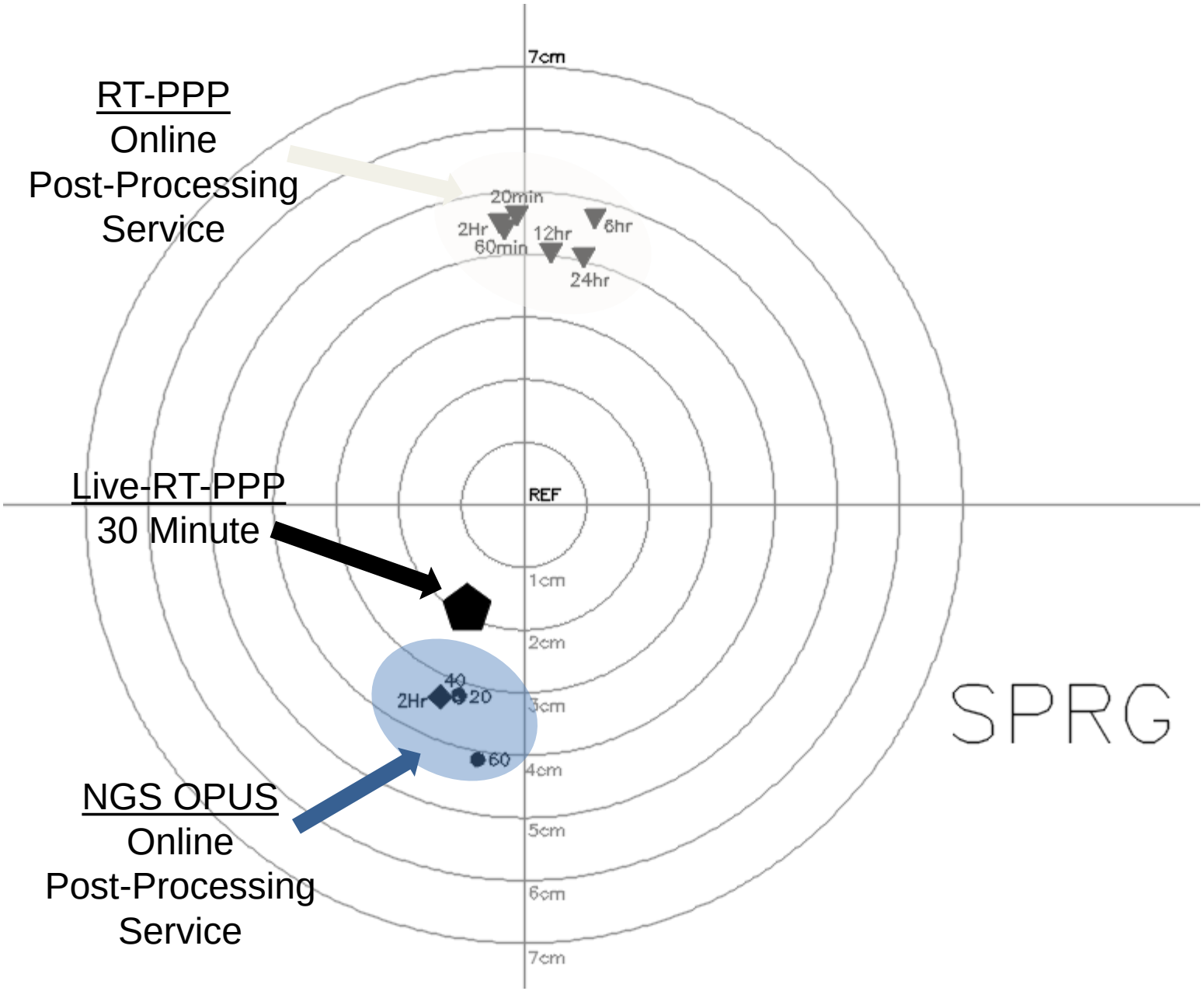


NGS OPUS
Online
Post-Processing
Service

Reference Framework - Horizontal

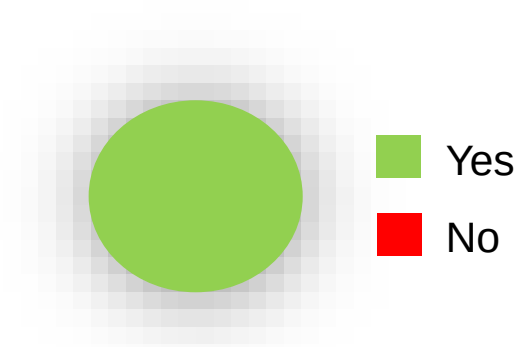


PPP Testing

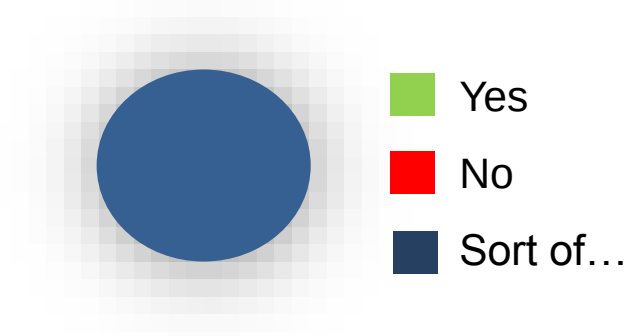

RT-PPP
Online
Post-Processing
Service
Live-RT-PPP
30 Minute
NGS OPUS
Online
Post-Processing
Service
7cm
20min
2Hr
60min
12hr
6hr
24hr
REF
1cm
2cm
3cm
4cm
5cm
6cm
7cm
40
2Hr
20
60
SPRG

CONCLUSIONS

- Onboard vs. [Net] RT-PPP
  - No substantial differences in convergence times or noise
- Horizontal ([Net] RT-PPP)
  - 20 minutes convergence
  - Slightly better North vs. East
  - 2-3cm accuracy
  - No significant drift



- Vertical ([Net] RT-PPP)
  - 20 minutes convergence
  - 8-10cm accuracy
  - Random drift



PPP-RTK

Current High Precision Real-Time Capabilities

	RTK / RTN	PPP	PPP-RTK
GOOD Centimeter Precision	Centimeter Precision	Decimeter Precision	Centimeter Precision
FAST Within a Few Seconds	Fast Initialization	Long Convergence + Continuous Sky	Quick Convergence
CHEAP No Network or Base	Dense Network	No Network or Base	Sparse Network

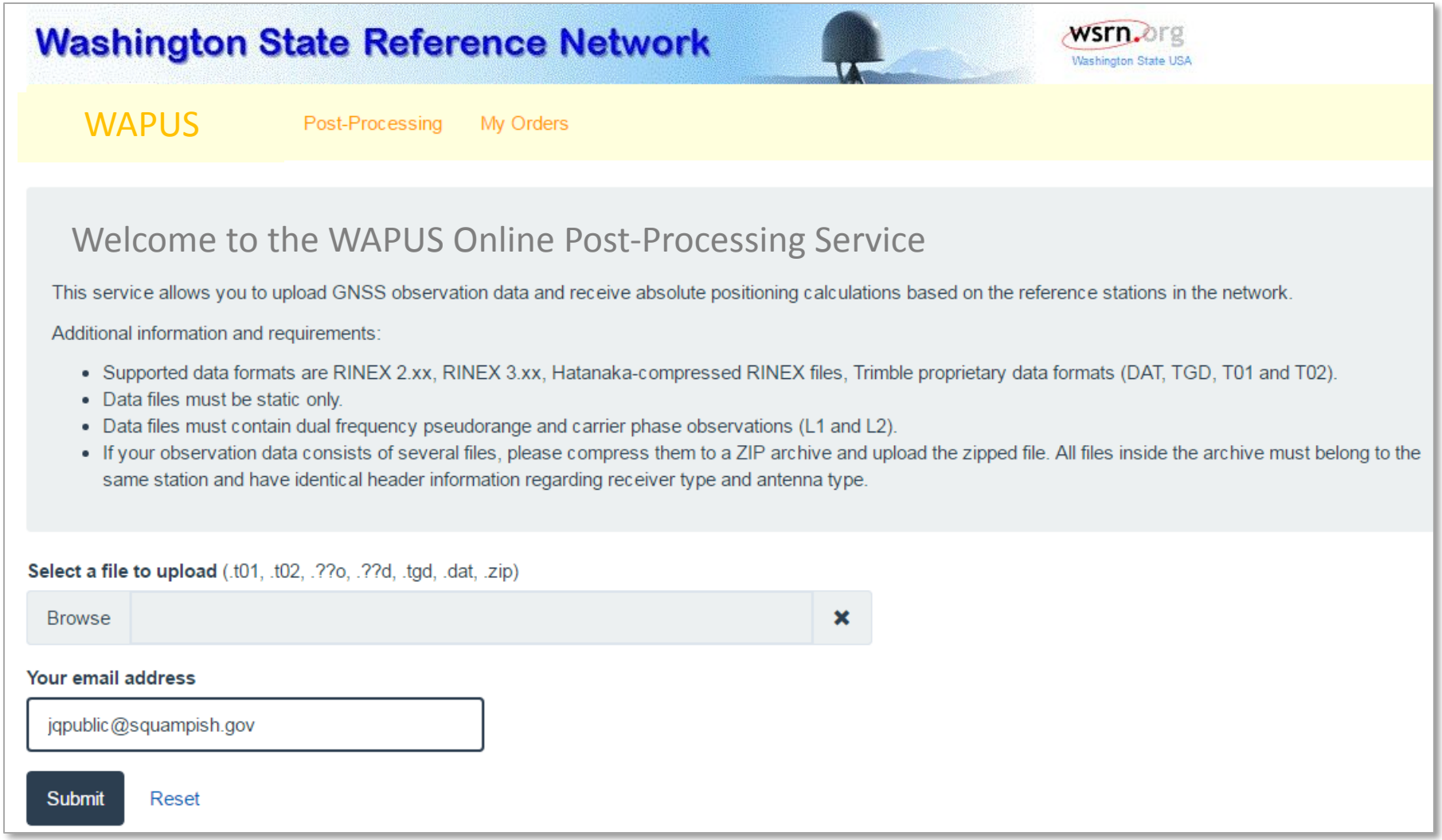
Choose Two:

GOOD service CHEAP won't be FAST

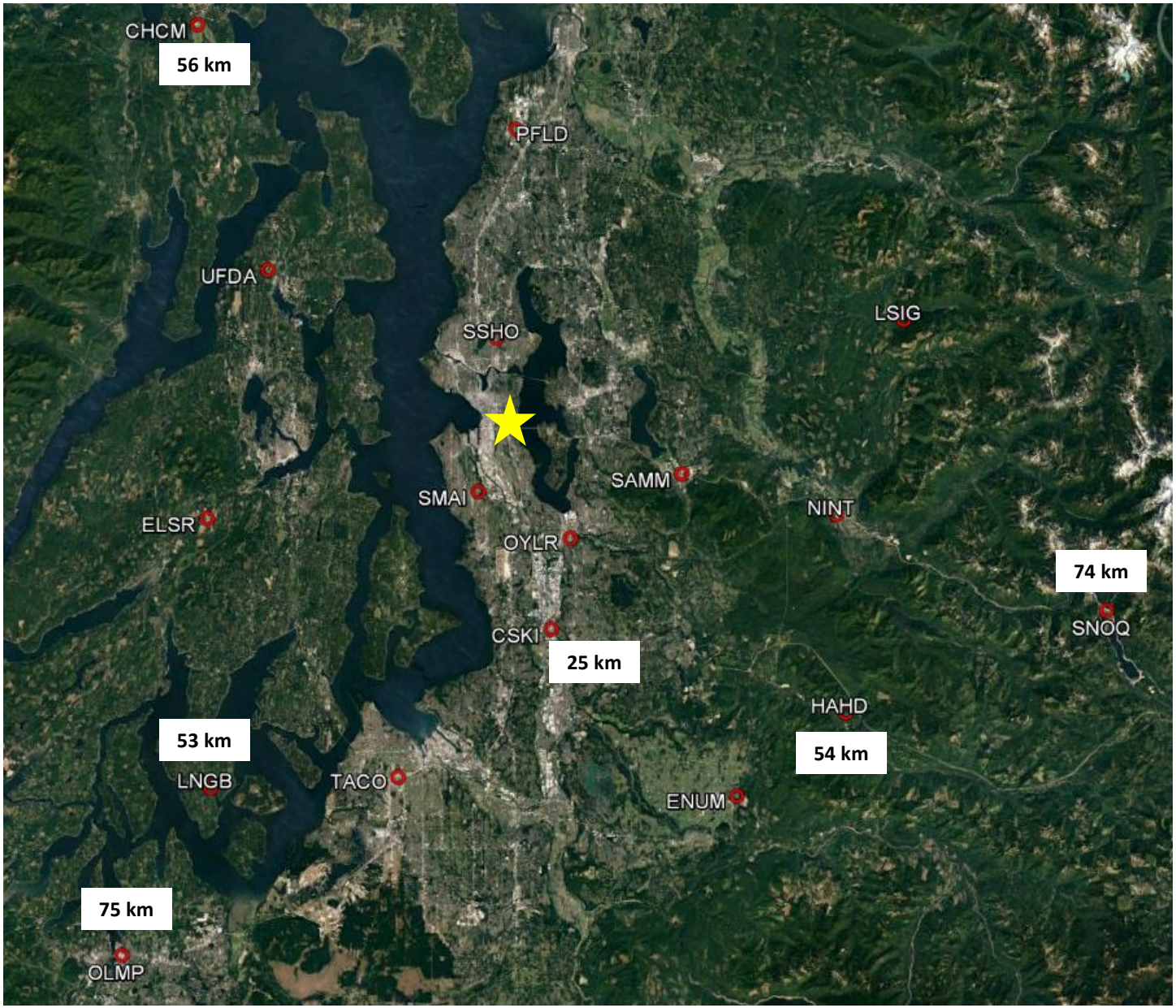
GOOD service FAST won't be CHEAP

FAST service CHEAP won't be good

WAPUS


Washington State Reference Network
wsrn.org
Washington State USA
WAPUS
Post-Processing
My Orders
Welcome to the WAPUS Online Post-Processing Service
This service allows you to upload GNSS observation data and receive absolute positioning calculations based on the reference stations in the network.
Additional information and requirements:
Supported data formats are RINEX 2.xx, RINEX 3.xx, Hatanaka-compressed RINEX files, Trimble proprietary data formats (DAT, TGD, T01 and T02).
Data files must be static only.
Data files must contain dual frequency pseudorange and carrier phase observations (L1 and L2).
If your observation data consists of several files, please compress them to a ZIP archive and upload the zipped file. All files inside the archive must belong to the same station and have identical header information regarding receiver type and antenna type.
Select a file to upload (.t01, .t02, .??o, .??d, .tgd, .dat, .zip)
Browse
Your email address
jqpublic@squampish.gov
Submit
Reset

WAPUS


CHCM
56 km
PFLD
UFDA
SSHO
LSIG
SAMM
SMAI
NINT
ELSR
OYLR
74 km
SNOQ
CSKI
25 km
HAHD
53 km
54 km
LNGB
TACO
ENUM
75 km
OLMP

WAPUS

wsrn

WAPUS Online Post-processing Report

Order Information

Order ID: 20
Uploaded file(s): OCCI252E.T02
Upload date: 09/08/2016 21:54:03 UTC

Antenna:
- Name: TRM57971.00 NONE
- Height: 0.000
- Reference: Bottom of antenna mount

Processing Information

Session:
- Start time: 09/08/2016 04:00:00 UTC
- End time: 09/08/2016 04:59:59 UTC

Solution type: Static
Processing interval: 30 s
Ephemeris type: Broadcast
Reference frame: ITRF2008
Tectonic plate: North America

Baselines

Station Code	Distance [km]	Observations (# total / # usable / # used / %)	Used satellites
CSKI	25.56	3600 / 120 / 113 / 94%	8 GPS / 7 GLN
LNGB	53.28	3600 / 120 / 113 / 94%	8 GPS / 7 GLN
HAHD	53.62	3600 / 120 / 113 / 94%	8 GPS / 7 GLN
CHCM	56.37	3525 / 118 / 111 / 94%	8 GPS / 7 GLN
SNOQ	74.87	3600 / 120 / 113 / 94%	8 GPS / 7 GLN
OLMP	75.05	3600 / 120 / 113 / 94%	8 GPS / 7 GLN

WAPUS

Final Results for: OCCI

ITRF2008 @ epoch 2005.00 Measurement method: Antenna Ground Point (AGP)		
Coordinate	**Value**	**σ [m]**
X [m]	-2304357.900	0.005
Y [m]	-3640573.957	0.007
Z [m]	4687063.632	0.008
Latitude	47° 36' 3.42174" N	0.004
Longitude	122° 19' 56.64442" W	0.003
El. height	-12.908	0.011

Report Information

Software version: 3.8.4
Creation date: 09/08/2016 21:54:27 UTC

OPUS, WAPUS, PPP

Baselines

Station Code	Distance [km]	Observations (# total / # usable / # used / %)	Used satellites
CHCM	0.00	3392 / 113 / 112 / 99%	11 GPS / 9 GLN
VERN	55.80	3392 / 113 / 112 / 99%	11 GPS / 9 GLN
CSKI	80.93	3392 / 113 / 112 / 99%	11 GPS / 9 GLN
LNGB	88.05	3392 / 113 / 112 / 99%	11 GPS / 9 GLN
OLMP	107.75	3392 / 113 / 112 / 99%	11 GPS / 9 GLN
HAHD	109.15	3392 / 113 / 112 / 99%	11 GPS / 9 GLN

Final Results for: CHCM

ITRF2008 @ epoch 2005.00 Measurement method: Antenna Ground Point (AGP)		
Coordinate	**Value**	**σ [m]**
X [m]	-2314209.028	0.002
Y [m]	-3594275.753	0.003
Z [m]	4717681.293	0.003
Latitude	48° 00' 38.20885" N	0.003
Longitude	122° 46' 33.05883" W	0.002
El. height	20.699	0.004

Report Information

Software version: 3.8.4
Creation date: 09/08/2016 21:36:21 UTC

WAPUS
1 hour

OPUS 4 hour

REF FRAME: NAD_83(2011)(EPOCH:2010.0000) IGS08 (EPOCH:2016.6866)

X:	-2314209.030(m)	0.007(m)	-2314209.920(m)	0.007(m)
Y:	-3594275.762(m)	0.007(m)	-3594274.586(m)	0.007(m)
Z:	4717681.296(m)	0.008(m)	4717681.333(m)	0.008(m)
LAT:	48 0 38.20872	0.003(m)	48 0 38.22172	0.003(m)
E LON:	237 13 26.94134	0.004(m)	237 13 26.87452	0.004(m)
W LON:	122 46 33.05866	0.004(m)	122 46 33.12548	0.004(m)
EL HGT:	20.707(m)	0.011(m)	20.395(m)	0.011(m)
ORTHO HGT:	42.441(m)	0.025(m)	[NAVD88 (Computed using GEOID12B)]	

Used Satellites

# Total Satellites:	31
GPS:	G01 G03 G06 G07 G09 G11 G14 G16 G22 G23 G25 G26 G27 G30 G31 G32
GLONASS:	R01 R02 R03 R07 R08 R09 R10 R11 R12 R13 R17 R18 R20 R23 R24

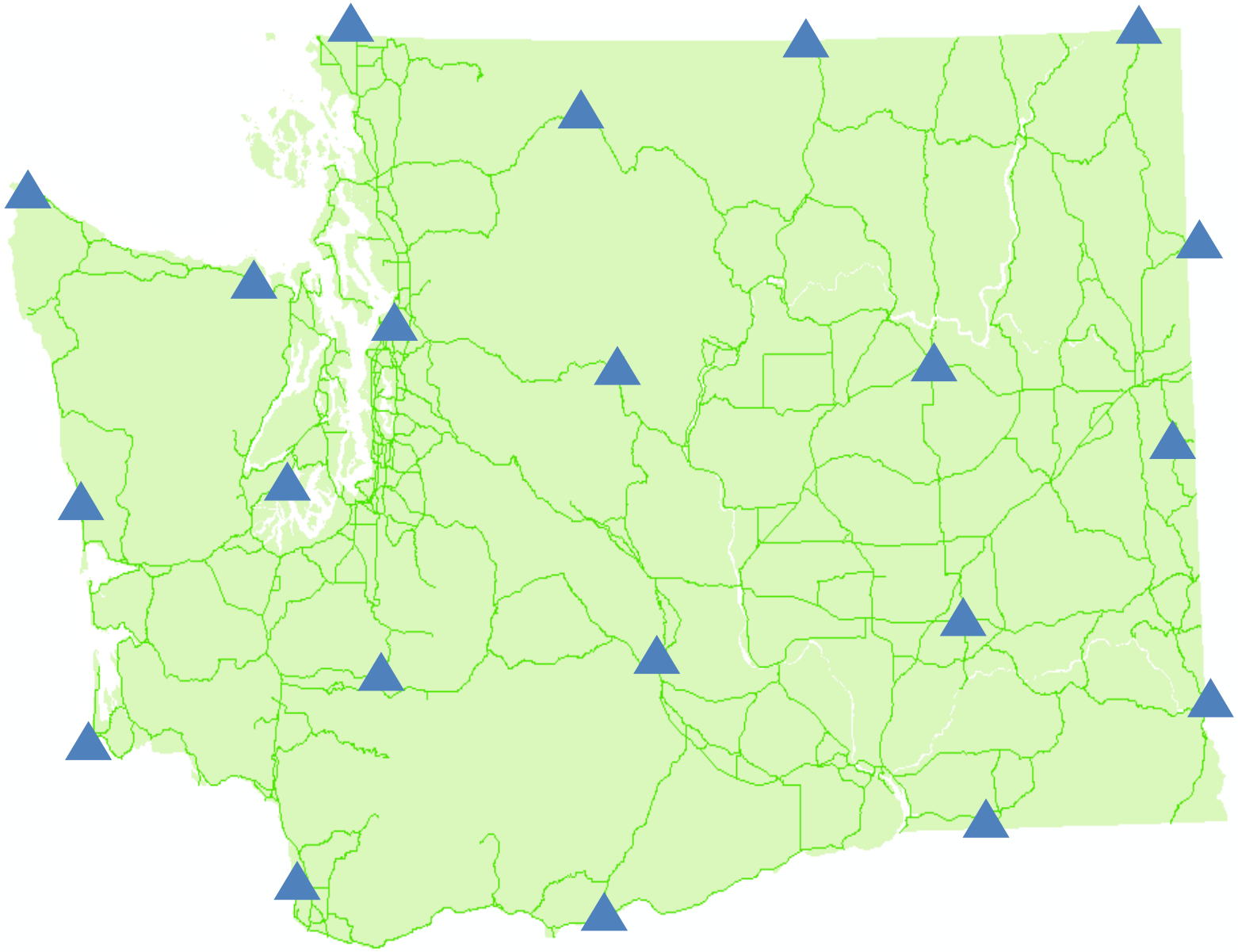
Processing Results

ITRF2008 at Epoch 2005.0		
Coordinate	**Value**	**σ**
X	-2314209.708 m	0.014 m
Y	-3594274.561 m	0.008 m
Z	4717681.455 m	0.008 m
Latitude	48° 00' 38.22763" N	0.005 m
Longitude	122° 46' 33.11756" W	0.013 m
El. Height	20.395 m	0.011 m

ITRF2008 at Epoch 2016.69		
Coordinate	**Value**	**σ**
X	-2314209.919 m	0.014 m
Y	-3594274.585 m	0.008 m
Z	4717681.333 m	0.008 m
Latitude	48° 00' 38.22175" N	0.005 m
Longitude	122° 46' 33.12547" W	0.013 m
El. Height	20.394 m	0.011 m

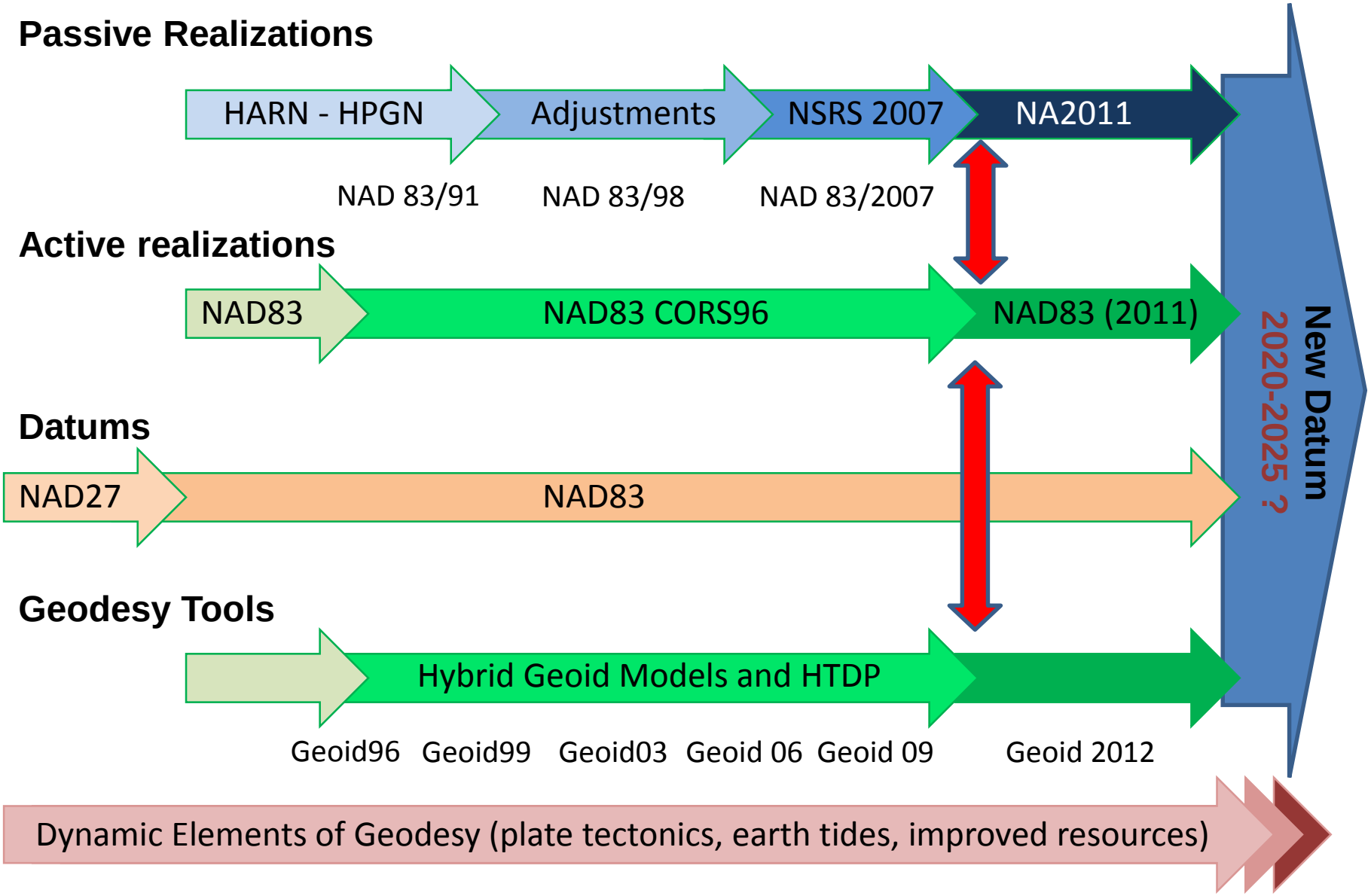
PPP
4 hour

Future PPP-RTK(af) Network?



Active and Passive Realizations

Published References and Resources @ Epochs



Reference Framework Planning

Washington Geodetic Survey

presents the
One-Day Seminar:

DATUM MATTERS

with

Dave Doyle

Geodesy Editor- Professional Surveyor Magazine
NGS Chief Geodetic Surveyor (Ret.)

Modernization of the National Spatial Reference System - Keeping Pace with Changes in Positioning Technology and User Expectations in a Dynamic World + WSRN Updates

8:30am – 4:00pm October 25th, 2013
Blencoe Auditorium
Renton Technical College, WA
$90 – Lunch Provided

Page 1 of 3

ar:

"2022"

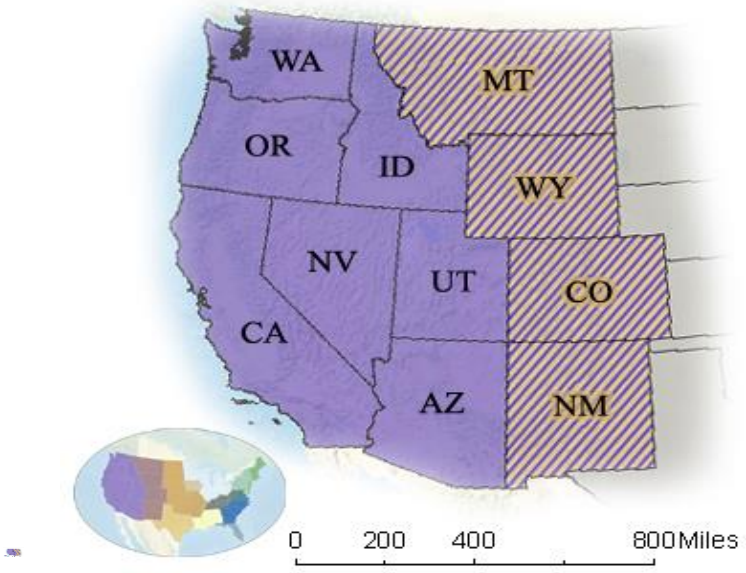
Preparing for Reference Framework Updates

Featured Presenter
Dr. Dru Smith
National Spatial Reference System (NSRS)
Modernization Manager
National Geodetic Survey

- *An overview of the planned NSRS update*
- *What to expect – vertical – horizontal – temporal*
- *Actions Washington can take to prepare*
- *Updates from the LSAW & WGS 2022 teams*

Save the date:
8:30am – 4:00pm February 12th, 2016
Blencoe Auditorium
Renton Technical College
$65* – Lunch Provided
Admission includes optional WGS membership. *Students free
Register at: http://www.gsow.org/wgs-2016-seminar-2022/
Questions? Email: wgs.seminars@gmail.com

Western Region Height Modernization Consortium



Thank You

schrockg@gmail.com