GPS Strain Analysis

Also known as…

Average-Crustal-Strain Analysis for Instantaneous/Infinitesimal Horizontal Strain Using GPS Velocity/ Dispacement Data

The Plan…

Give students an overview of the process

Teacher Leads

Student Leads

The Plan…

Teacher Leads

Give students an overview of the process

Tell them how to find and interpret the input data for the process

Student Leads

The Plan…

Teacher Leads

- Give students an overview of the process
- Tell them how to find and interpret the input data for the process
- Show them how to perform the analytical process

Student Leads

The Plan…

Teacher Leads

Give students an overview of the process

Tell them how to find and interpret the input data for the process

Show them how to perform the analytical process

Explain the meaning of the results of the analytical process

Student Leads

The Plan…

Teacher Leads

- Give students an overview of the process
- Tell them how to find and interpret the input data for the process
- Show them how to perform the analytical process
- Explain the meaning of the results of the analytical process
- Apply the results in a useful manner

Student Leads

The Plan…

Teacher Leads

Give students an overview of the process

Tell them how to find and interpret the input data for the process

Show them how to perform the analytical process

Explain the meaning of the results of the analytical process

Apply the results in a useful manner

Student Leads

Have students execute the process using pre-selected data that you (the teacher) have worked through.

The Plan…

Teacher Leads

Give students an overview of the process

Tell them how to find and interpret the input data for the process

Show them how to perform the analytical process

Explain the meaning of the results of the analytical process

Apply the results in a useful manner

Student Leads

Have students execute the process using pre-selected data that you (the teacher) have worked through.

Finally, have them select their own data based on personal interest and execute the process.

The Plan…

An example of the analysis

How to find PBO GPS data
— Notice which reference frame is used
— Acquire data for 3 sites

Using one of the strain calculators

What the output means

Interpreting the results in the context of local/regional geology

UNAVCO

GPS Strain & Earthquakes Unit 3: Finding location and velocity data for PBO GPS stations

Original activity by Vince Cronin (Baylor University). Revisions by Beth Pratt-Sitaula (UNAVCO).

Analyzing the velocities recorded at different GPS stations can give significant insights into plate tectonic motion, earthquake hazards, volcanic hazards, groundwater removal, and more.

GPS data can be acquired from a variety of different research groups around the world, but some the most accessible and easy to use GPS data comes from the EarthScope Plate Boundary Observatory (PBO), which is managed by UNAVCO. The data are available online for free at https://www.unavco.org/instrumentation/networks/status/pbo/gps. In this exercise you will learn one method for downloading GPS station location and velocity data.

Worked Example: Finding PBO GPS data in the Oregon Coast Ranges

Finding station locations in latitude-longitude coordinates

We will search for data generated by one of the PBO's permanent GPS stations above the Cascadia subduction zone in northwest Oregon. If we do not know which station we want to learn about, we can go to the interactive PBO map and zoom-in on our area of interest (https://www.unavco.org/instrumentation/networks/status/pbo/gps). We find several green marker dots along the coastline. Clicking on any of the dots will provide some initial information. The dot we chose (Figure 1) is associated with station P395 (Rose_LodgeOR2006) located west of Salem in northwest Oregon. Clicking on the dot gives us a box that provides the

www.unavco.org/instrumentation/networks/status/pbo/gps

PBO GPS Stations Network Monitoring | UNAVCO

HOME | ABOUT | CONTACT | HELP   Search

UNAVCO

Community Projects **Instrumentation** Data Software Science Education

home › instrumentation › networks › pbo

Instrumentation

- Help with Instrumentation
- **Network Monitoring**
  - All Networks & Stations
    - All Real-time GNSS/GPS Networks
  - PBO Networks
    - PBO GNSS/GPS Network
      - PBO GNSS/GPS Real-time
    - PBO Strainmeter Network
    - PBO Seismic Network
  - Polar GNSS/GPS Networks
    - ANET
    - GNET
    - Polar Networks State of Health
  - NASA-GGN GNSS/GPS Network
  - COCONet GNSS/GPS Network
    - COCONet GNSS/GPS Real-time
  - TLALOCNet GNSS/GPS Network
    - TLALOCNet GNSS/GPS Real-time
  - Principal Investigator GNSS/GPS Stations

Related Links

- *PBO Project Overview*

PBO GPS Stations Network Monitoring

This section of our web site provides network monitoring (instrument state of health) information for the PBO network of GNSS/GPS instruments to our engineers, principal investigators, and the public at large. See the PBO project page for more information about the PBO network.

Please note: This area is not for data access, please see the Data section of our website to access data acquired from these instruments.

See also:
Show only PBO Real-time GNSS/GPS Stations

PBO GPS NETWORK MAP - 1129 STATIONS DISPLAYED   Full Screen Views : Map Table

https://www.unavco.org/instrumentation/networks/status/pbo/gps

www.unavco.org/instrumentation/networks/status/pbo/gps

PBO GPS Stations Network Monitoring | UNAVCO

HOME | ABOUT | CONTACT | HELP

Search

UNAVCO

Community Projects Instrumentation Data Software Science Education

home › instrumentation › networks › pbo

Instrumentation
- Help with Instrumentation
- **Network Monitoring**
  - All Networks & Stations
    - All Real-time GNSS/GPS Networks
  - PBO Networks
    - PBO GNSS/GPS Network
      - PBO GNSS/GPS Real-time
    - PBO Strainmeter Network
    - PBO Seismic Network
  - Polar GNSS/GPS Networks
    - ANET
    - GNET
    - Polar Networks State of Health
  - NASA-GGN GNSS/GPS Network
  - COCONet GNSS/GPS Network
    - COCONet GNSS/GPS Real-time
  - TLALOCNet GNSS/GPS Network
    - TLALOCNet GNSS/GPS Real-time
  - Principal Investigator GNSS/GPS Stations

Related Links
- *PBO Project Overview*

PBO GPS Stations Network Monitoring

This section of our web site provides network monitoring (instrument state of health) information for the PBO network of GNSS/GPS instruments to our engineers, principal investigators, and the public at large. See the PBO project page for more information about the PBO network.

Please note: This area is not for data access, please see the Data section of our website to access data acquired from these instruments.

See also:
Show only PBO Real-time GNSS/GPS Stations

PBO GPS NETWORK MAP - 1129 STATIONS DISPLAYED

Full Screen Views : Map Table

https://www.unavco.org/instrumentation/networks/status/pbo/gps

www.unavco.org/instrumentation/networks/status/pbo/gps

PBO GPS Stations Network Monitoring | UNAVCO

HOME | ABOUT | CONTACT | HELP

Search

UNAVCO

Community Projects **Instrumentation** Data Software Science Education

home › instrumentation › networks › pbo

Instrumentation

- Help with Instrumentation
- **Network Monitoring**
  - All Networks & Stations
    - All Real-time GNSS/GPS Networks
  - PBO Networks
    - PBO GNSS/GPS Network
      - PBO GNSS/GPS Real-time
    - PBO Strainmeter Network
    - PBO Seismic Network
  - Polar GNSS/GPS Networks
    - ANET
    - GNET
    - Polar Networks State of Health
  - NASA-GGN GNSS/GPS Network
  - COCONet GNSS/GPS Network
    - COCONet GNSS/GPS Real-time
  - TLALOCNet GNSS/GPS Network
    - TLALOCNet GNSS/GPS Real-time
  - Principal Investigator GNSS/GPS Stations

Related Links

- *PBO Project Overview*

PBO GPS Stations Network Monitoring

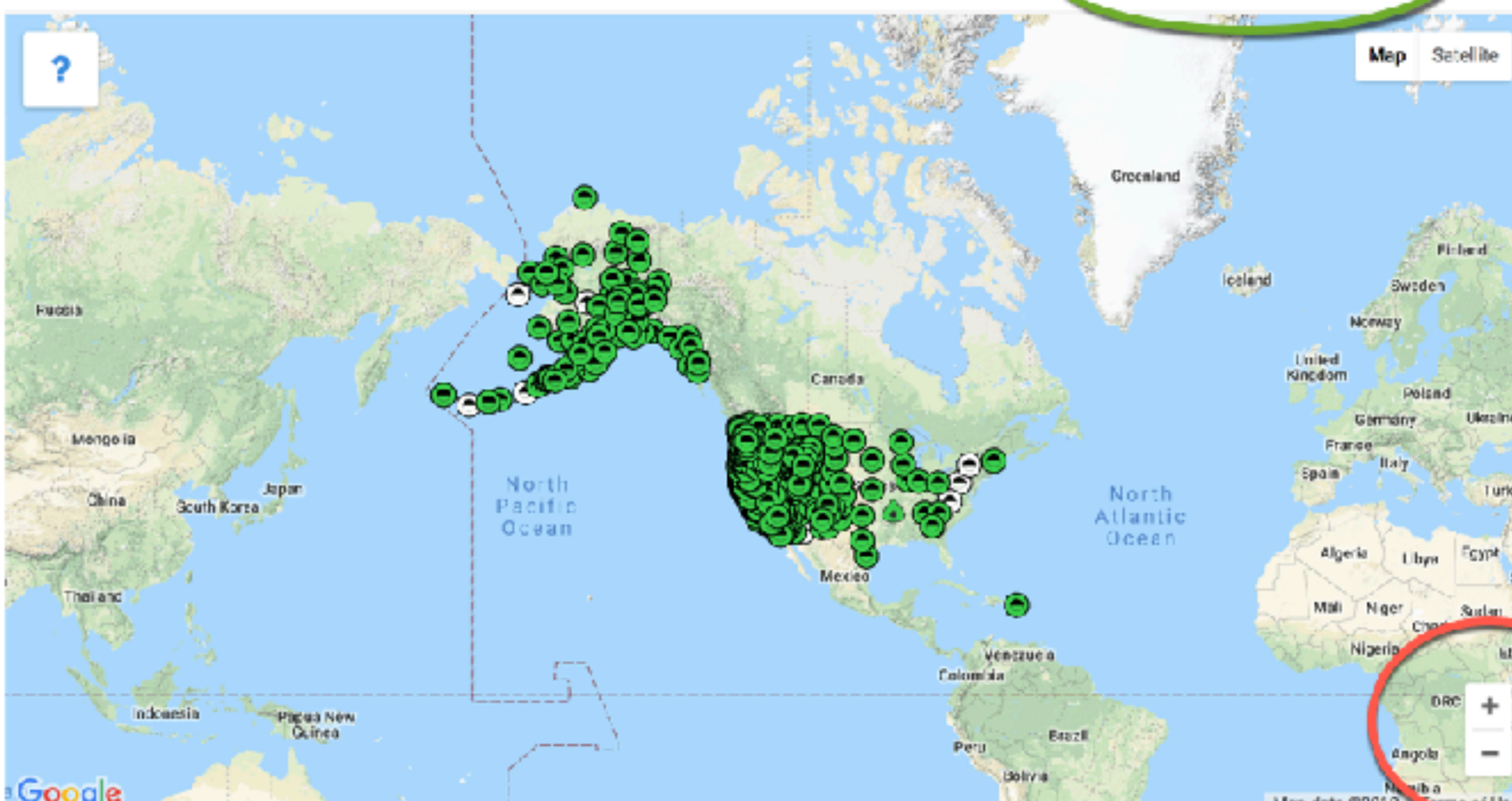
This section of our web site provides network monitoring (instrument state of health) information for the PBO network of GNSS/GPS instruments to our engineers, principal investigators, and the public at large. See the PBO project page for more information about the PBO network.

Please note: This area is not for data access, please see the Data section of our website to access data acquired from these instruments.

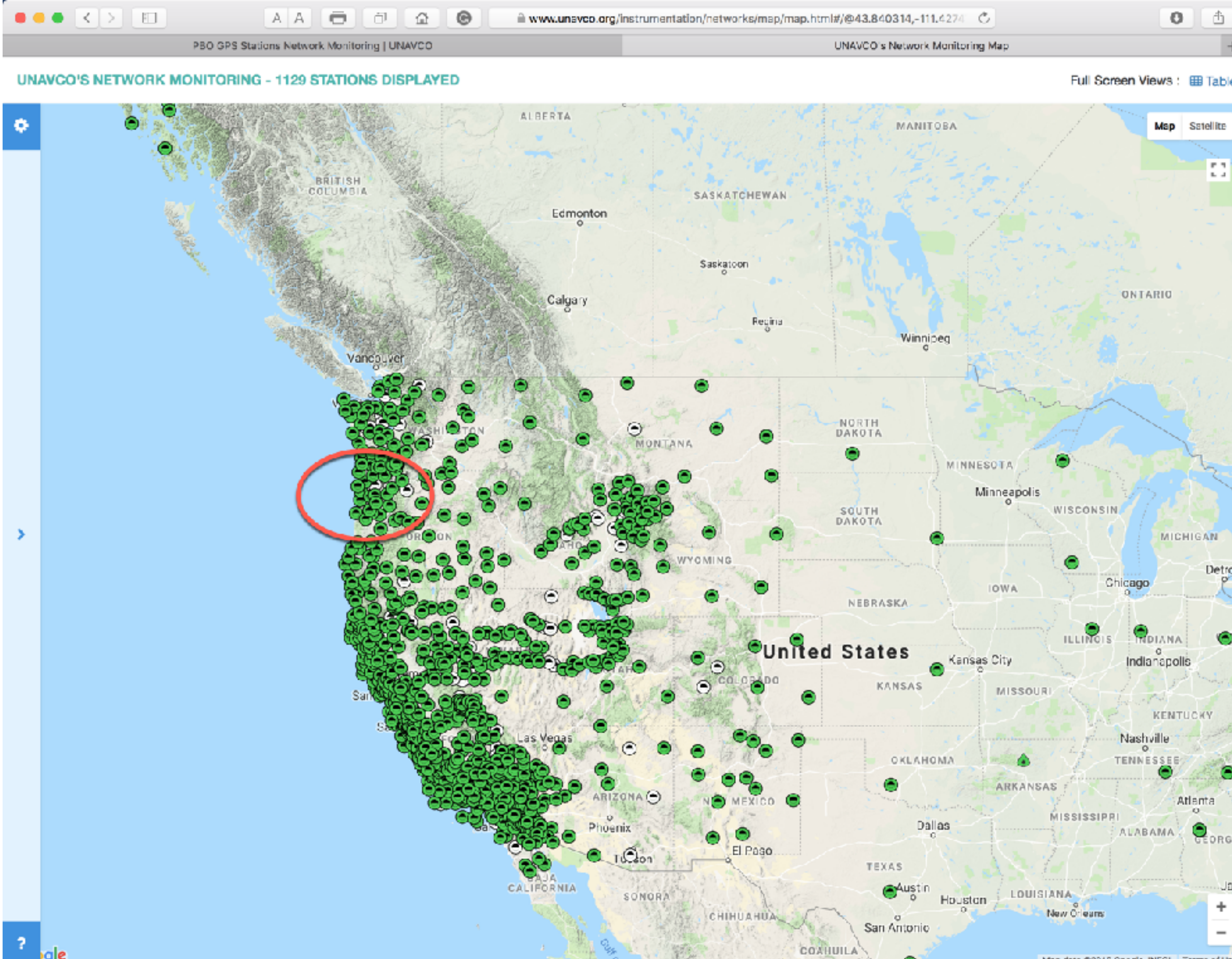
See also:
Show only PBO Real-time GNSS/GPS Stations

PBO GPS NETWORK MAP - 1129 STATIONS DISPLAYED

Full Screen Views : Map Table



https://www.unavco.org/instrumentation/networks/status/pbo/gps

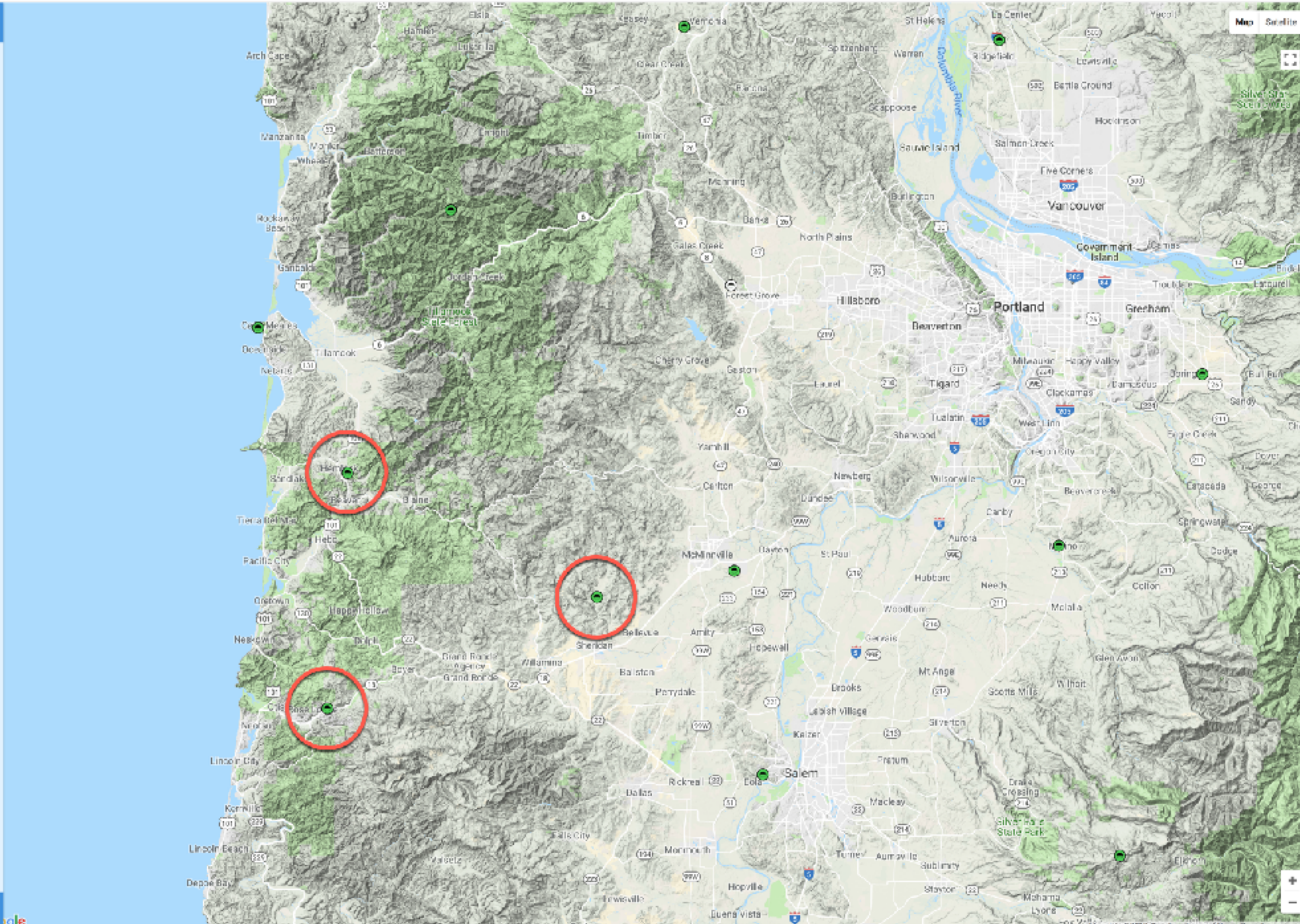

www.unavco.org/instrumentation/networks/map/map.html#/@43.840314,-111.4274
PBO GPS Stations Network Monitoring | UNAVCO
UNAVCO's Network Monitoring Map
UNAVCO'S NETWORK MONITORING - 1129 STATIONS DISPLAYED
Full Screen Views :
Table
Map
Satellite
ALBERTA
MANITOBA
BRITISH COLUMBIA
SASKATCHEWAN
Edmonton
Saskatoon
Calgary
Regina
Winnipeg
ONTARIO
Vancouver
NORTH DAKOTA
MONTANA
MINNESOTA
Minneapolis
SOUTH DAKOTA
WISCONSIN
MICHIGAN
WYOMING
Detroit
Chicago
IOWA
NEBRASKA
United States
ILLINOIS
INDIANA
Indianapolis
Kansas City
KANSAS
MISSOURI
KENTUCKY
Las Vegas
Nashville
OKLAHOMA
TENNESSEE
ARKANSAS
ARIZONA
NEW MEXICO
Atlanta
Phoenix
Dallas
MISSISSIPPI
ALABAMA
GEORGIA
El Paso
Tucson
TEXAS
BAJA CALIFORNIA
Austin
LOUISIANA
SONORA
Houston
New Orleans
CHIHUAHUA
San Antonio
COAHUILA
Map data ©2018 Google, INEGI
Terms of Use

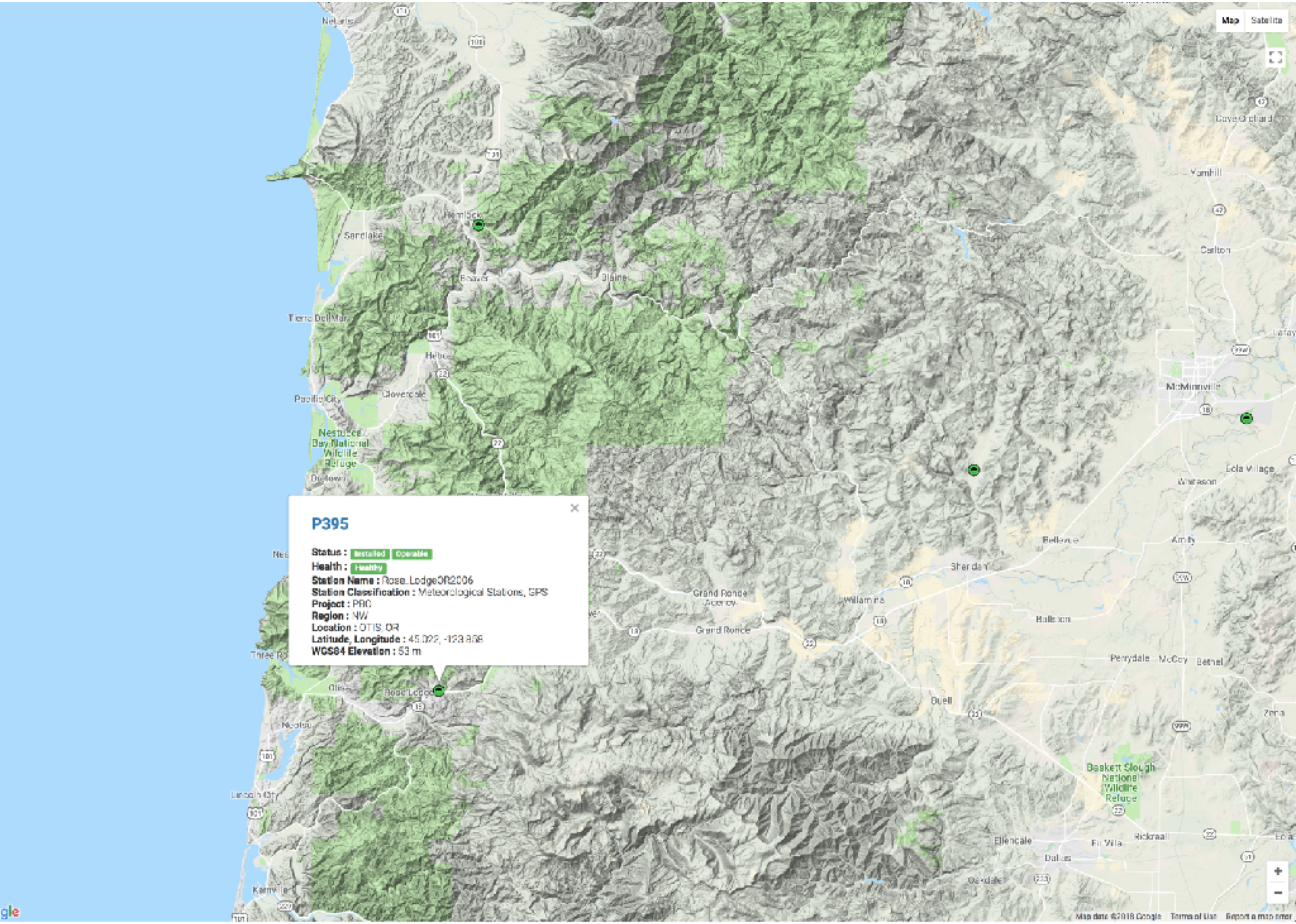
PBO GPS Stations Network Monitoring | UNAVCO

UNAVCO's Network Monitoring Map

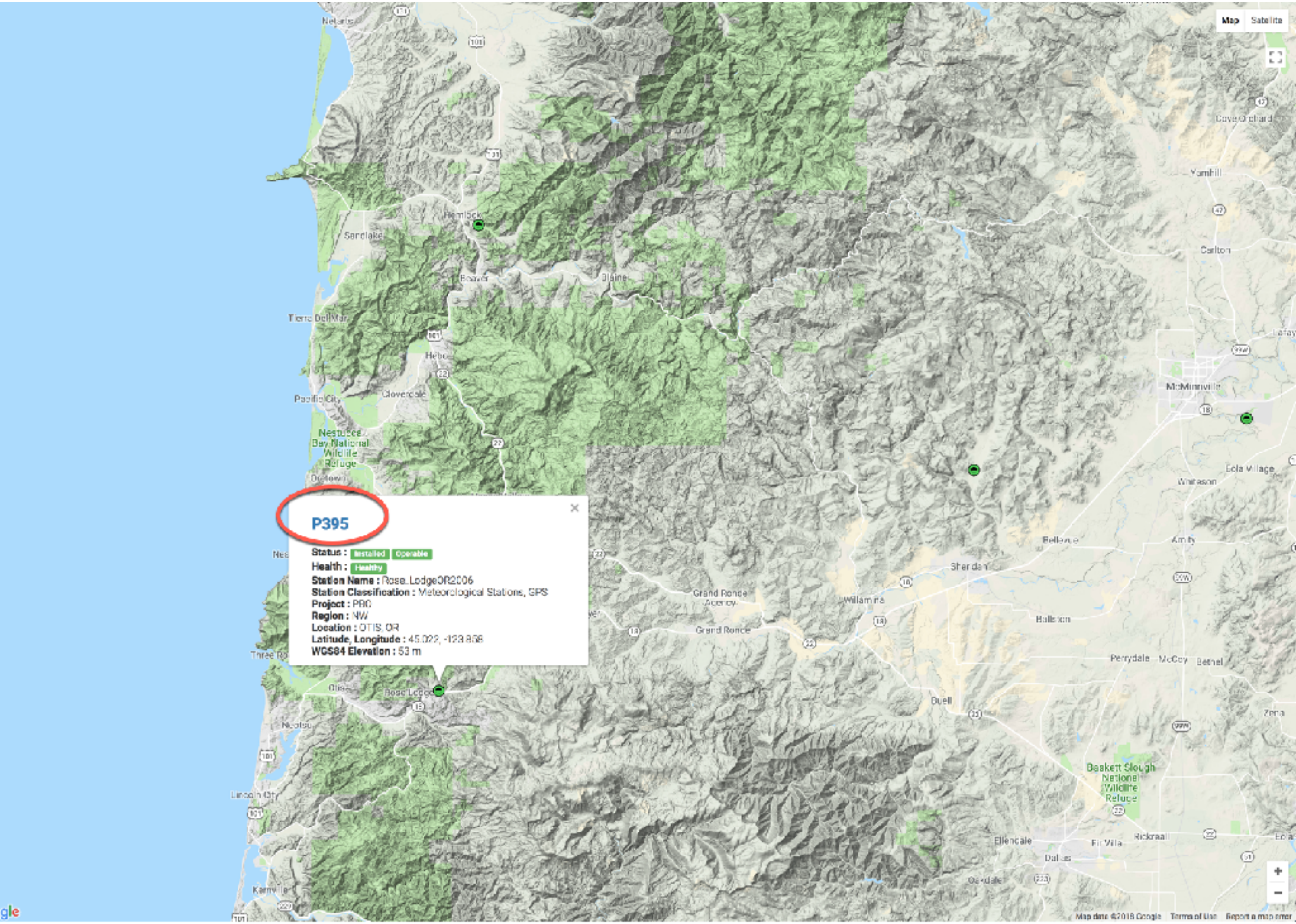
UNAVCO'S NETWORK MONITORING - 1129 STATIONS DISPLAYED

Full Screen Views : Table

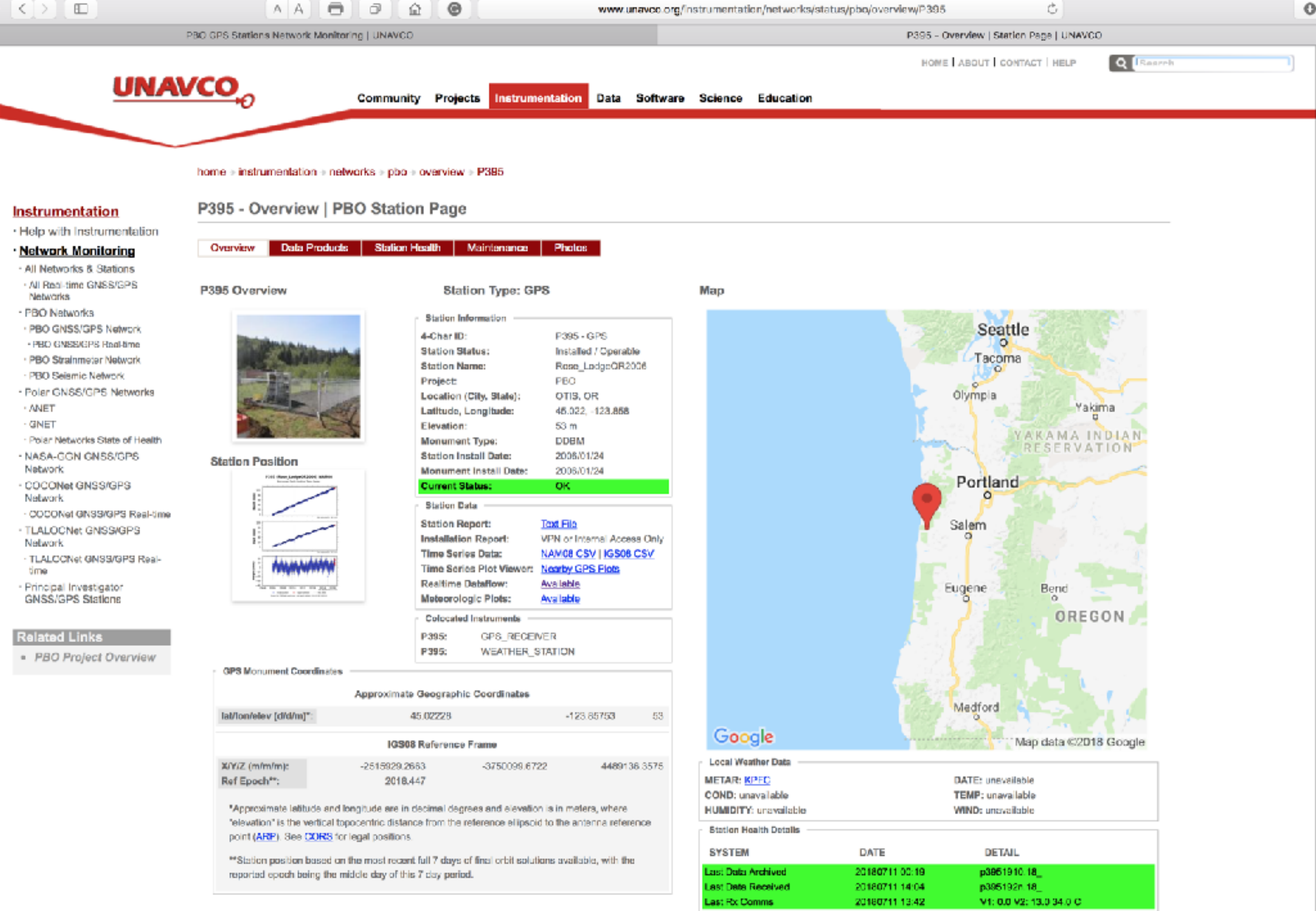




P395
Status : Installed Operable
Health : Healthy
Station Name : Rose_LodgeOR2006
Station Classification : Meteorological Stations, GPS
Project : PBO
Region : NW
Location : OTIS, OR
Latitude, Longitude : 45.022, -123.858
WGS84 Elevation : 53 m
Map
Satellite
Hemlock
Sandlake
Beaver
Blaine
Tierra Del Mar
Hebo
Pacific City
Cloverdale
Nestucca Bay National Wildlife Refuge
Grand Ronde Agency
Grand Ronde
Willamina
Sheridan
Bellevue
Amity
Ballston
Perrydale
McCoy
Bethel
Buell
Otis
Rose Lodge
Neotsu
Yamhill
Carlton
McMinnville
Eola Village
Whiteson
Cove Orchard
Baskett Slough National Wildlife Refuge
Ellendale
Dallas
Rickreall
Zena
Map data ©2018 Google
Terms of Use
Report a map error



P395
Status : Installed Operable
Health : Healthy
Station Name : Rose_LodgeOR2006
Station Classification : Meteorological Stations, GPS
Project : PBO
Region : NW
Location : OTIS, OR
Latitude, Longitude : 45.022, -123.958
WGS84 Elevation : 53 m
Map
Satellite
Hemlock
Sandlake
Beaver
Blaine
Tierra Del Mar
Hebo
Pacific City
Cloverdale
Nestucca Bay National Wildlife Refuge
Grand Ronde Agency
Grand Ronde
Willamina
Sheridan
Bellevue
Amity
Ballston
Perrydale
McCoy
Bethel
Buell
McMinnville
Yamhill
Carlton
Cove Orchard
Eola Village
Whiteson
Baskett Slough National Wildlife Refuge
Ellendale
Dallas
Rickreall
Fir Villa
Oakdale
Otis
Rose Lodge
Neotsu
Lincoln City
Kernville
Zena
Map data ©2018 Google
Terms of Use
Report a map error



www.unavco.org/instrumentation/networks/status/pbo/overview/P395

PBO GPS Stations Network Monitoring | UNAVCO — P395 - Overview | Station Page | UNAVCO

HOME | ABOUT | CONTACT | HELP

UNAVCO

Community Projects Instrumentation Data Software Science Education

home » instrumentation » networks » pbo » overview » P395

Instrumentation

- Help with Instrumentation
- **Network Monitoring**
  - All Networks & Stations
    - All Real-time GNSS/GPS Networks
  - PBO Networks
    - PBO GNSS/GPS Network
      - PBO GNSS/GPS Real-time
    - PBO Strainmeter Network
    - PBO Seismic Network
  - Polar GNSS/GPS Networks
    - ANET
    - GNET
    - Polar Networks State of Health
  - NASA-GGN GNSS/GPS Network
  - COCONet GNSS/GPS Network
    - COCONet GNSS/GPS Real-time
  - TLALOCNet GNSS/GPS Network
    - TLALOCNet GNSS/GPS Real-time
  - Principal Investigator GNSS/GPS Stations

Related Links

- *PBO Project Overview*

P395 - Overview | PBO Station Page

Overview | Data Products | Station Health | Maintenance | Photos

P395 Overview

Station Position

Station Type: GPS

Station Information

4-Char ID:	P395 - GPS
Station Status:	Installed / Operable
Station Name:	Rose_LodgeOR2006
Project:	PBO
Location (City, State):	OTIS, OR
Latitude, Longitude:	45.022, -123.858
Elevation:	53 m
Monument Type:	DDBM
Station Install Date:	2006/01/24
Monument Install Date:	2006/01/24
Current Status:	OK

Station Data

Station Report:	Text File
Installation Report:	VPN or Internal Access Only
Time Series Data:	NAM08 CSV | IGS08 CSV
Time Series Plot Viewer:	Nearby GPS Plots
Realtime Dataflow:	Available
Meteorologic Plots:	Available

Colocated Instruments

P395:	GPS_RECEIVER
P395:	WEATHER_STATION

GPS Monument Coordinates

Approximate Geographic Coordinates

lat/lon/elev [d/d/m]*:	45.02228	-123.85753	53

IGS08 Reference Frame

X/Y/Z (m/m/m):	-2515929.2663	-3750099.6722	4489136.3575
Ref Epoch**:	2018.447		

*Approximate latitude and longitude are in decimal degrees and elevation is in meters, where "elevation" is the vertical topocentric distance from the reference ellipsoid to the antenna reference point (ARP). See CORS for legal positions.

**Station position based on the most recent full 7 days of final orbit solutions available, with the reported epoch being the middle day of this 7 day period.

Map

Seattle, Tacoma, Olympia, Yakima, YAKAMA INDIAN RESERVATION, Portland, Salem, Eugene, Bend, OREGON, Medford

Google Map data ©2018 Google

Local Weather Data

METAR: KPFC	DATE: unavailable
COND: unavailable	TEMP: unavailable
HUMIDITY: unavailable	WIND: unavailable

Station Health Details

SYSTEM	DATE	DETAIL
Last Data Archived	20180711 00:19	p3951910.18_
Last Data Received	20180711 14:04	p395192n.18_
Last Rx Comms	20180711 13:42	V1: 0.0 V2: 13.0 34.0 C

Last modified: Saturday, 24-May-2014 01:18:38 UTC

https://www.unavco.org/instrumentation/networks/status/pbo/overview/P395

Instrumentation
- Help with Instrumentation
- **Network Monitoring**
  - All Networks & Stations
    - All Real-time GNSS/GPS Networks
  - PBO Networks
    - PBO GNSS/GPS Network
    - PBO GNSS/GPS Real-time
    - PBO Strainmeter Network
    - PBO Seismic Network
  - Polar GNSS/GPS Networks
    - ANET
    - GNET
    - Polar Networks State of Health
  - NASA-GGN GNSS/GPS Network
  - COCONet GNSS/GPS Network
    - COCONet GNSS/GPS Real-time
  - TLALOCNet GNSS/GPS Network
    - TLALOCNet GNSS/GPS Real-time
  - Principal Investigator GNSS/GPS Stations

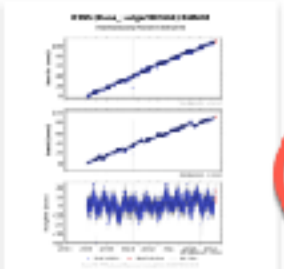
Related Links
- PBO Project Overview

P395 - Overview | PBO Station Page

Overview | Data Products | Station Health | Maintenance | Photos

P395 Overview

Station Position



Station Type: GPS

Station Information

4-Char ID:	P395 - GPS
Station Status:	Installed / Operable
Station Name:	Rose_LodgeOR2006
Project:	PBO
Location (City, State):	OTIS, OR
Latitude, Longitude:	45.022, -123.858
Elevation:	53 m
Monument Type:	DDBM
Station Install Date:	2006/01/24
Monument Install Date:	2006/01/24
Current Status:	OK

Station Data

Station Report:	Text File
Installation Report:	VPN or Internal Access Only
Time Series Data:	NAM08 CSV | IGS08 CSV
Time Series Plot Viewer:	Nearby GPS Plots
Realtime Dataflow:	Available
Meteorologic Plots:	Available

Collocated Instruments

P395:	GPS_RECEIVER
P395:	WEATHER_STATION

GPS Monument Coordinates

Approximate Geographic Coordinates

lat/lon/elev (d/d/m)*:	45.02228	-123.85753	53

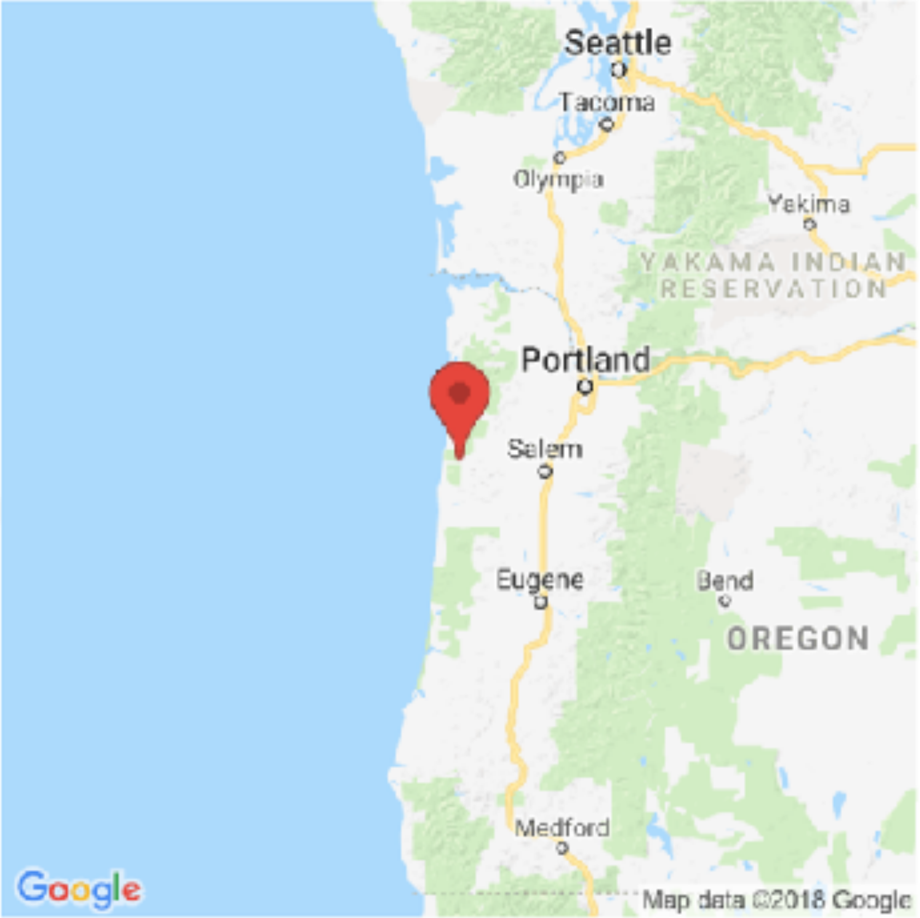
IGS08 Reference Frame

X/Y/Z (m/m/m):	-2515929.2663	-3750099.6722	4489136.3575
Ref Epoch**:	2018.447		

*Approximate latitude and longitude are in decimal degrees and elevation is in meters, where "elevation" is the vertical topocentric distance from the reference ellipsoid to the antenna reference point (ARP). See CORS for legal positions.

**Station position based on the most recent full 7 days of final orbit solutions available, with the reported epoch being the middle day of this 7 day period.

Map



Local Weather Data

METAR: KPFC
COND: unavailable
HUMIDITY: unavailable
DATE: unavailable
TEMP: unavailable
WIND: unavailable

Station Health Details

SYSTEM	DATE	DETAIL
Last Data Archived	20180711 00:19	p3951910.18_
Last Data Received	20180711 14:04	p3951920.18_
Last Rx Comms	20180711 13:42	V1: 0.0 V2: 13.0 34.0 C

https://www.unavco.org/instrumentation/networks/status/pbo/overview/P395

Current Status: OK

Station Data

Station Report:	Text File
Installation Report:	VPN or Internal Access Only
Time Series Data:	NAM08 CSV | IGS08 CSV
Time Series Plot Viewer:	Nearby GPS Plots
Realtime Dataflow:	Available
Meteorologic Plots:	Available

Colocated Instruments

www.unavco.org/instrumentation/networks/status/pbo/overview/P395

PBO GPS Stations Network Monitoring | UNAVCO | P395 – Overview | Station Page | UNAVCO

HOME | ABOUT | CONTACT | HELP

UNAVCO

Community | Projects | Instrumentation | Data | Software | Science | Education

home › instrumentation › networks › pbo › overview › P395

Instrumentation
- Help with Instrumentation
- **Network Monitoring**
  - All Networks & Stations
    - All Real-time GNSS/GPS Networks
  - PBO Networks
    - PBO GNSS/GPS Network
    - PBO GNSS/GPS Real-time
    - PBO Strainmeter Network
    - PBO Seismic Network
  - Polar GNSS/GPS Networks
    - ANET
    - GNET
    - Polar Networks State of Health
  - NASA-GGN GNSS/GPS Network
  - COCONet GNSS/GPS Network
    - COCONet GNSS/GPS Real-time
  - TLALOCNet GNSS/GPS Network
    - TLALOCNet GNSS/GPS Real-time
  - Principal Investigator GNSS/GPS Stations

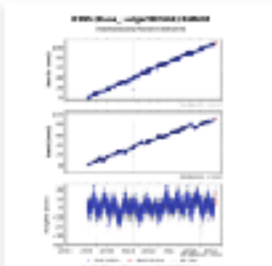
Related Links
- *PBO Project Overview*

P395 - Overview | PBO Station Page

Overview | Data Products | Station Health | Maintenance | Photos

P395 Overview

Station Position



Station Type: GPS

Station Information

4-Char ID:	P395 - GPS
Station Status:	Installed / Operable
Station Name:	Rose_LodgeOR2006
Project:	PBO
Location (City, State):	OTIS, OR
Latitude, Longitude:	45.022, -123.858
Elevation:	53 m
Monument Type:	DDBM
Station Install Date:	2006/01/24
Monument Install Date:	2006/01/24
Current Status:	OK

Station Data

Station Report:	Text File
Installation Report:	VPN or Internal Access Only
Time Series Data:	NAM08 CSV | IGS08 CSV
Time Series Plot Viewer:	Nearby GPS Plots
Realtime Dataflow:	Available
Meteorologic Plots:	Available

Colocated Instruments

P395:	GPS_RECEIVER
P395:	WEATHER_STATION

GPS Monument Coordinates

Approximate Geographic Coordinates

lat/lon/elev (d/d/m)*:	45.02228	-123.85753	53

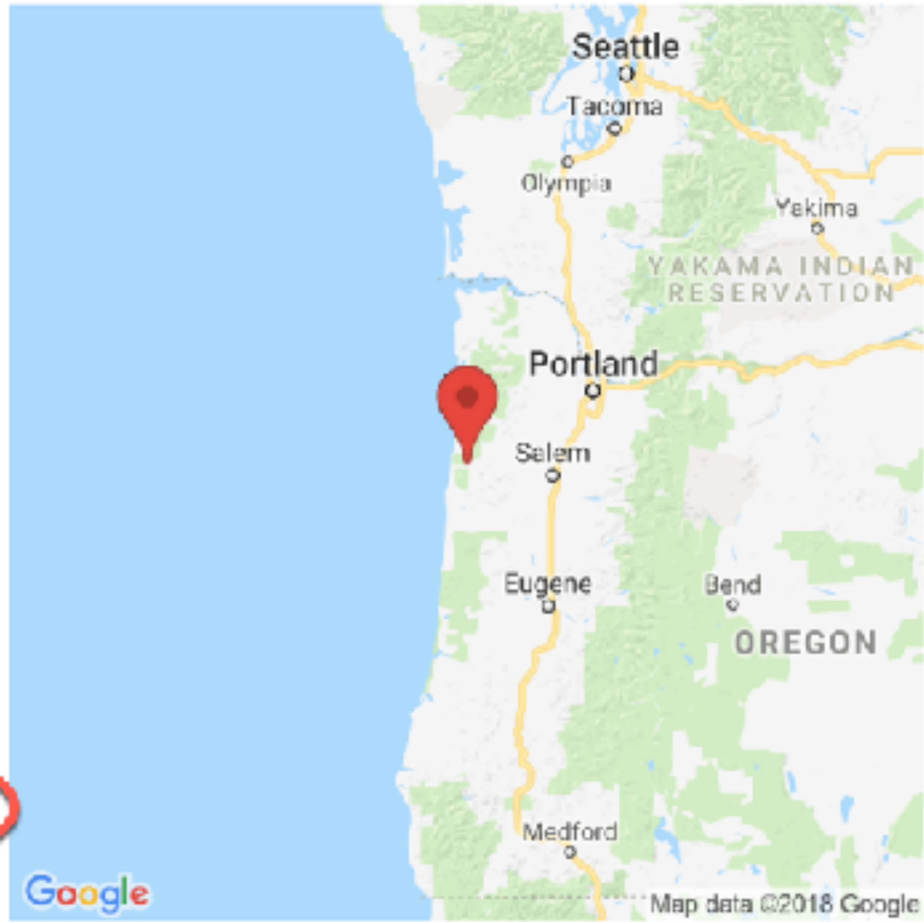
IGS08 Reference Frame

X/Y/Z (m/m/m):	-2515929.2663	-3750099.5722	4489136.3575
Ref Epoch**:	2018.447		

*Approximate latitude and longitude are in decimal degrees and elevation is in meters, where "elevation" is the vertical topocentric distance from the reference ellipsoid to the antenna reference point (ARP). See CORS for legal positions.

**Station position based on the most recent full 7 days of final orbit solutions available, with the reported epoch being the middle day of this 7 day period.

Map



Local Weather Data

METAR: KPFC	DATE: unavailable
COND: unavailable	TEMP: unavailable
HUMIDITY: unavailable	WIND: unavailable

Station Health Details

SYSTEM	DATE	DETAIL
Last Data Archived	20180711 00:19	p3951910.18_
Last Data Received	20180711 14:04	p3951920.18_
Last Rx Comms	20180711 13:42	V1: 0.0 V2: 13.0 34.0 C

https://www.unavco.org/instrumentation/networks/status/pbo/overview/P395

Last modified: Saturday, 24-May-2014 01:18:38 UTC

GPS Monument Coordinates

Approximate Geographic Coordinates

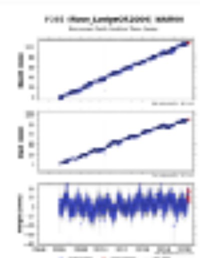
lat/lon/elev (d/d/m)*:	45.02228	-123.85753	53

P395 - Overview | PBO Station Page

Overview | Data Products | Station Health | Maintenance | Photos

P395 Overview

Station Position



Station Type: GPS

Station Information

4-Char ID:	P395 - GPS
Station Status:	Installed / Operable
Station Name:	Rose_LodgeOR2006
Project:	PBO
Location (City, State):	OTIS, OR
Latitude, Longitude:	45.022, -123.858
Elevation:	53 m
Monument Type:	DDBM
Station Install Date:	2006/01/24
Monument Install Date:	2006/01/24
Current Status:	OK

Station Data

Station Report:	Text File
Installation Report:	VPN or Internal Access Only
Time Series Data:	NAM08 CSV | IGS08 CSV
Time Series Plot Viewer:	Nearby GPS Plots
Realtime Dataflow:	Available
Meteorologic Plots:	Available

Colocated Instruments

P395:	GPS_RECEIVER
P395:	WEATHER_STATION

GPS Monument Coordinates

Approximate Geographic Coordinates

lat/lon/elev [d/d/m]*:	45.02228	-123.85753	53

IGS08 Reference Frame

X/Y/Z (m/m/m):	-2515929.2683	-3750099.6722	4489136.3575
Ref Epoch**:	2018.447		

*Approximate latitude and longitude are in decimal degrees and elevation is in meters, where "elevation" is the vertical topocentric distance from the reference ellipsoid to the antenna reference point (ARP). See CORS for legal positions.

**Station position based on the most recent full 7 days of final orbit solutions available, with the reported epoch being the middle day of this 7 day period.

Map

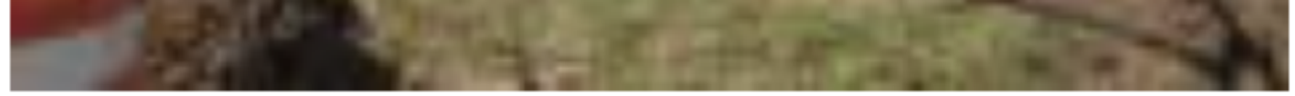
Local Weather Data

METAR: KPFC	**DATE:** unavailable
COND: unavailable	**TEMP:** unavailable
HUMIDITY: unavailable	**WIND:** unavailable

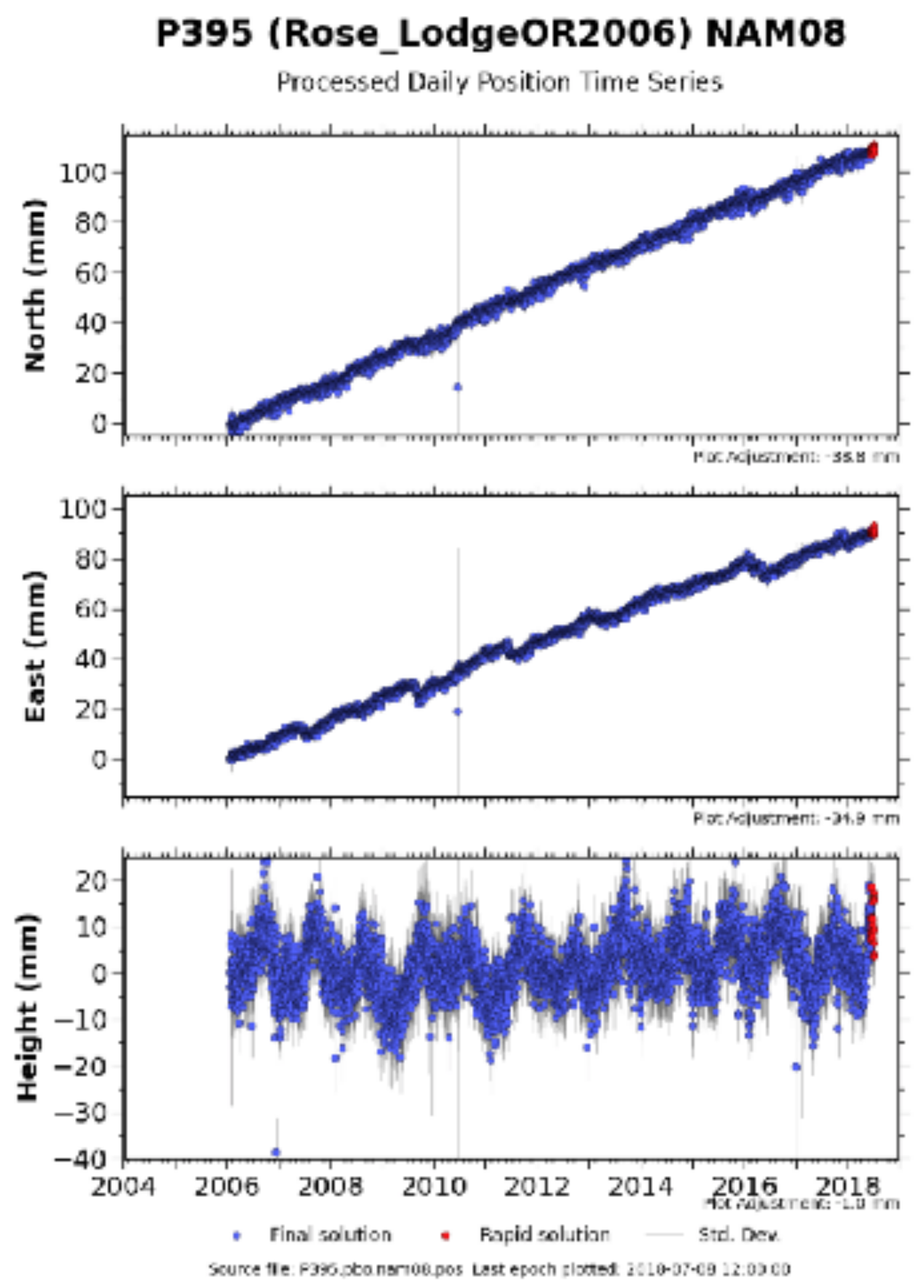
Station Health Details

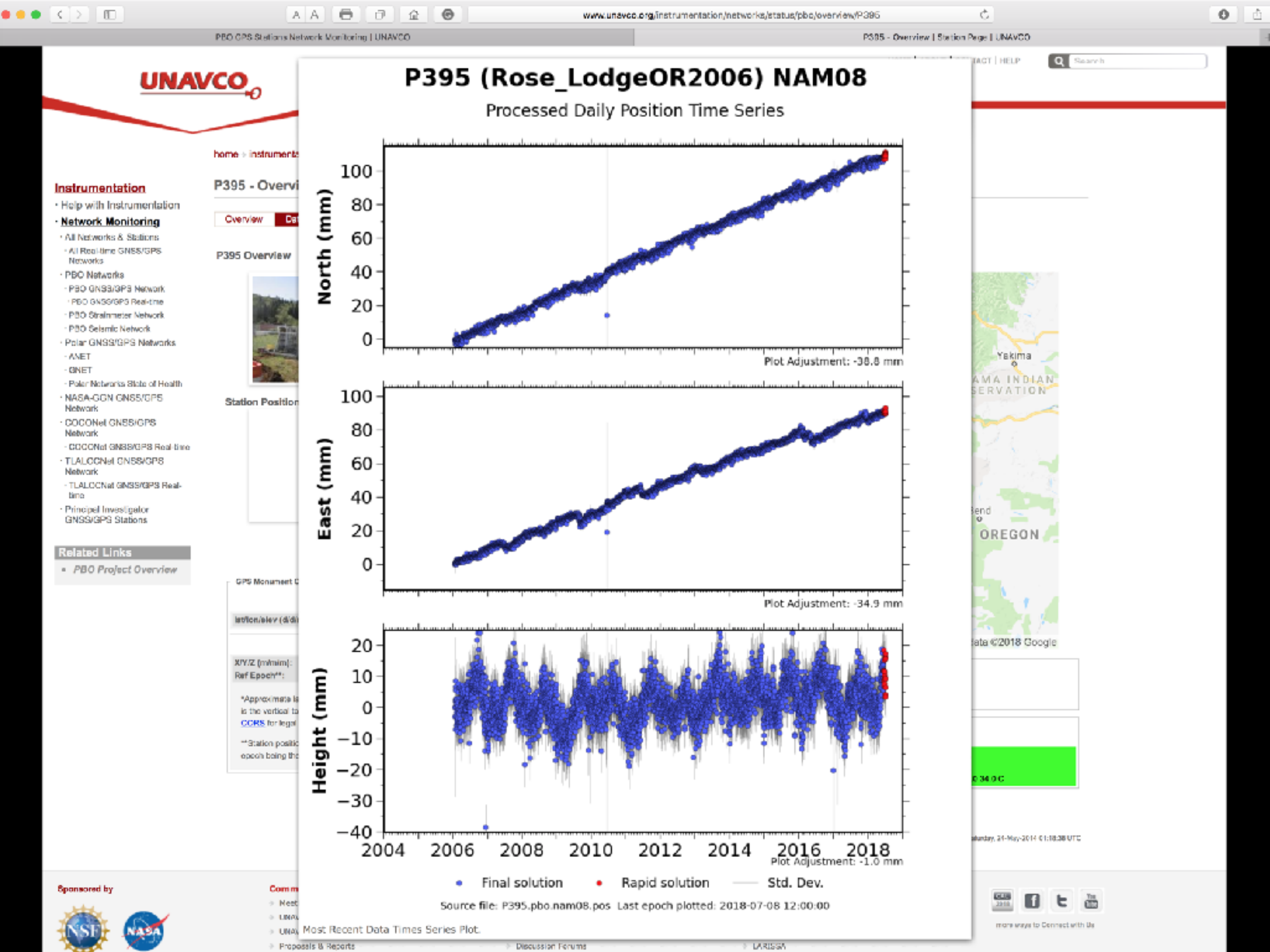
SYSTEM	DATE	DETAIL
Last Data Archived	20180711 00:19	p3951910.18_
Last Data Received	20180711 14:04	p395192n.18_
Last Rx Comms	20180711 13:42	V1: 0.0 V2: 13.0 34.0 C

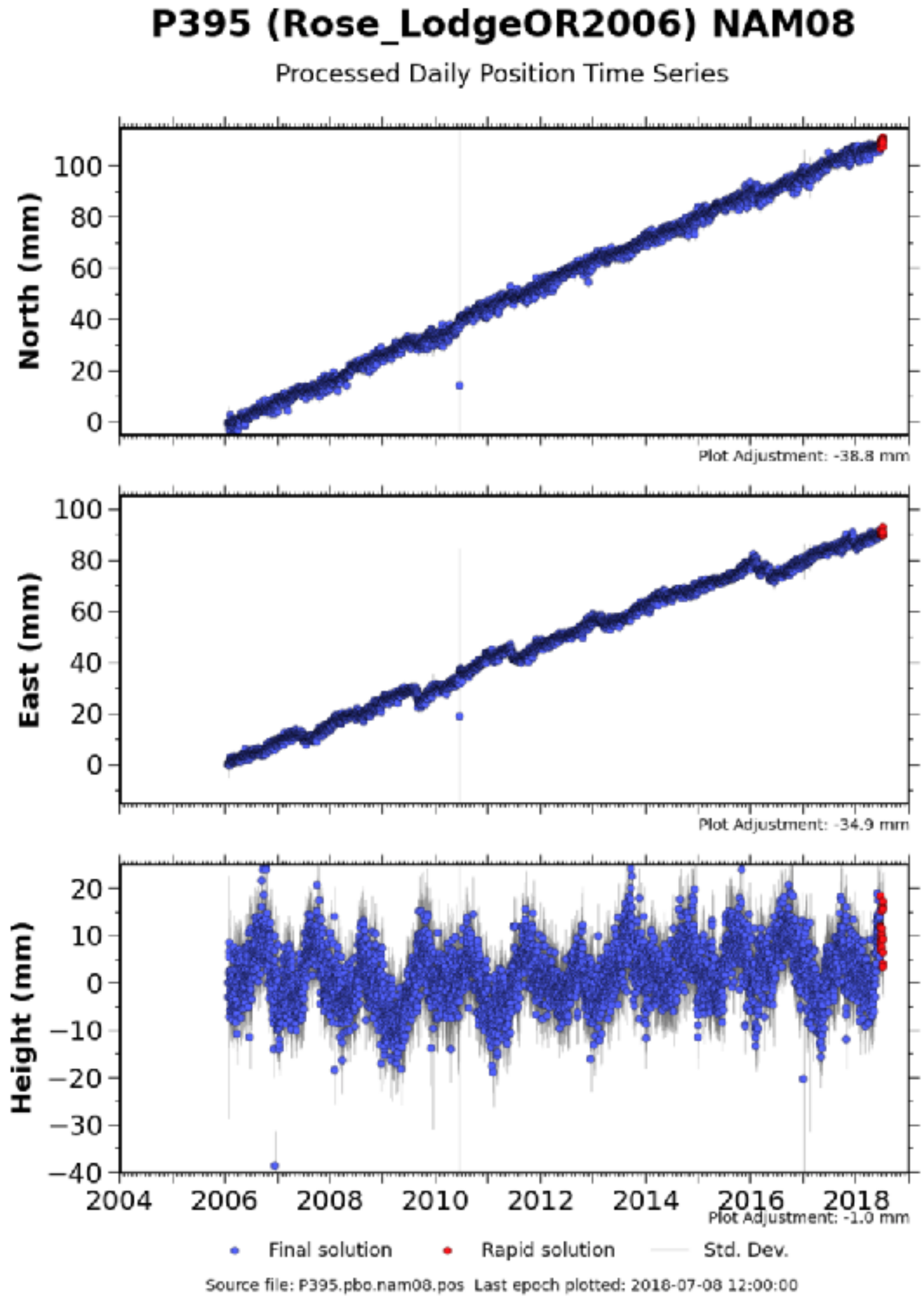
https://www.unavco.org/instrumentation/networks/status/pbo/overview/P395



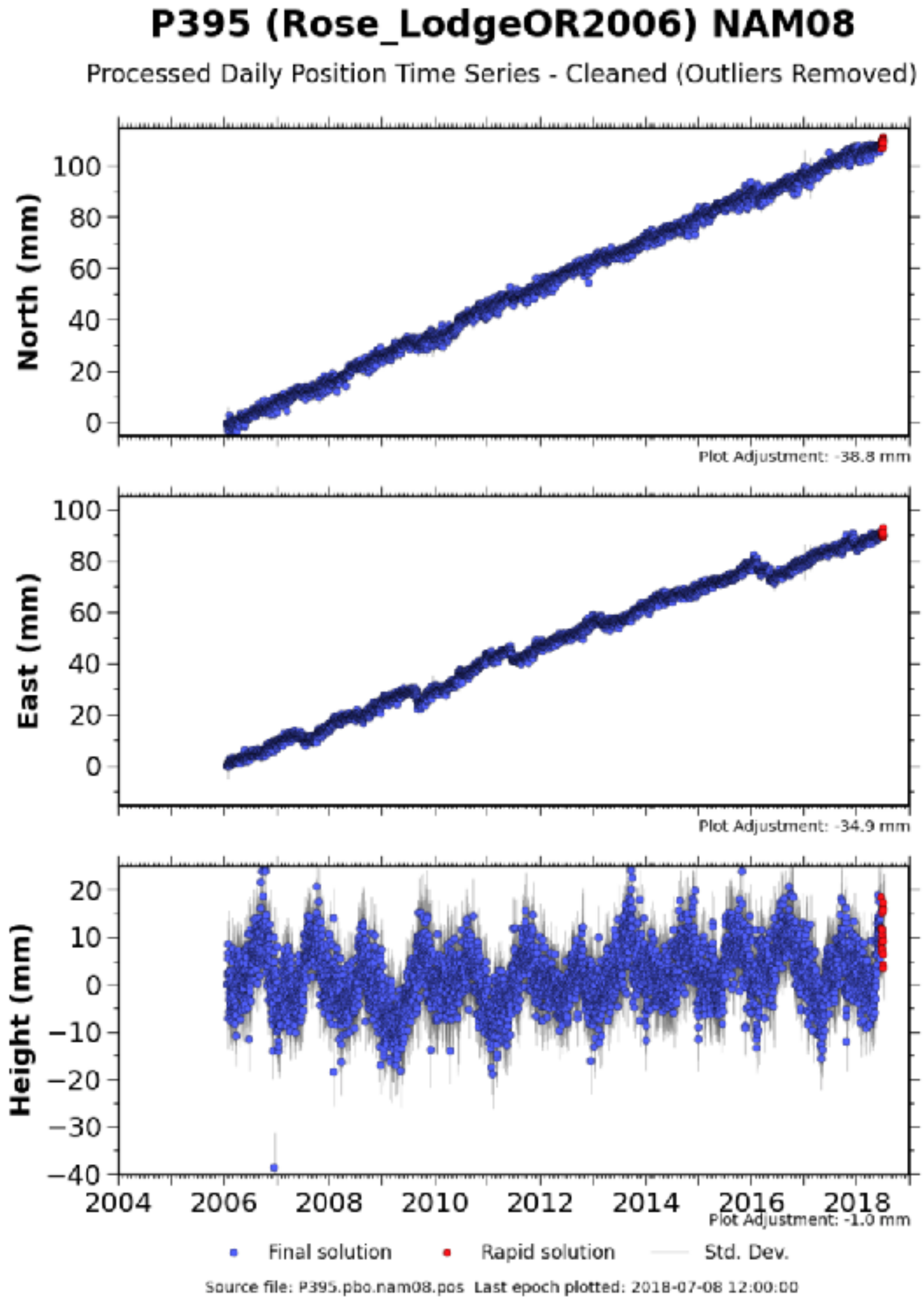
Station Position



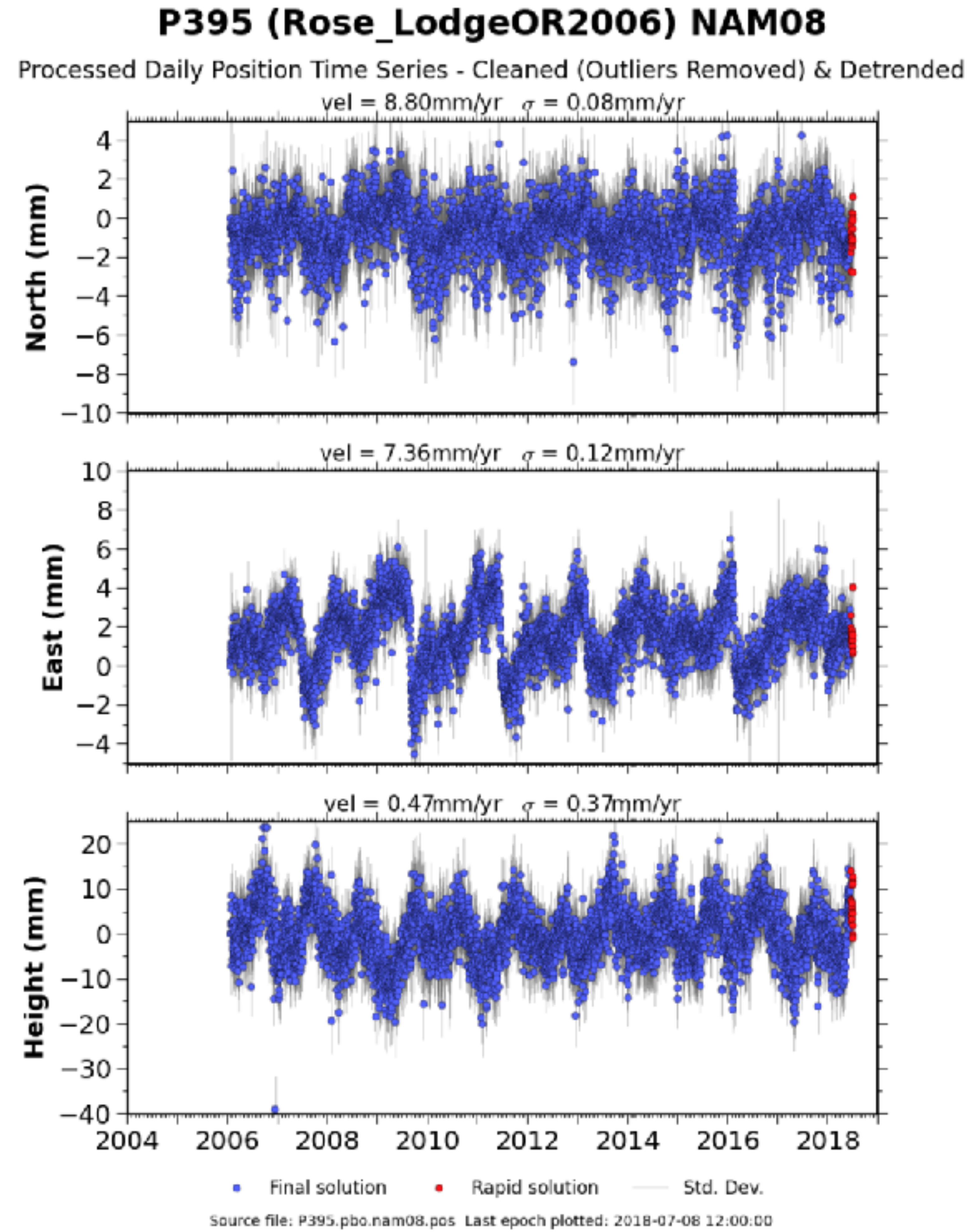

www.unavco.org/instrumentation/networks/status/pbo/overview/P395
PBO GPS Stations Network Monitoring | UNAVCO
P395 - Overview | Station Page | UNAVCO
UNAVCO
Instrumentation
Help with Instrumentation
Network Monitoring
All Networks & Stations
PBO Networks
Polar GNSS/GPS Networks
Related Links
PBO Project Overview
P395 Overview
Station Position
P395 (Rose_LodgeOR2006) NAM08
Processed Daily Position Time Series
North (mm)
Plot Adjustment: -38.8 mm
East (mm)
Plot Adjustment: -34.9 mm
Height (mm)
Plot Adjustment: -1.0 mm
2004
2006
2008
2010
2012
2014
2016
2018
Final solution
Rapid solution
Std. Dev.
Source file: P395.pbo.nam08.pos Last epoch plotted: 2018-07-08 12:00:00
Most Recent Data Times Series Plot.
Yakima
OREGON
Map data ©2018 Google
Sponsored by
NSF
NASA
Proposals & Reports
Discussion Forums
LARISSA



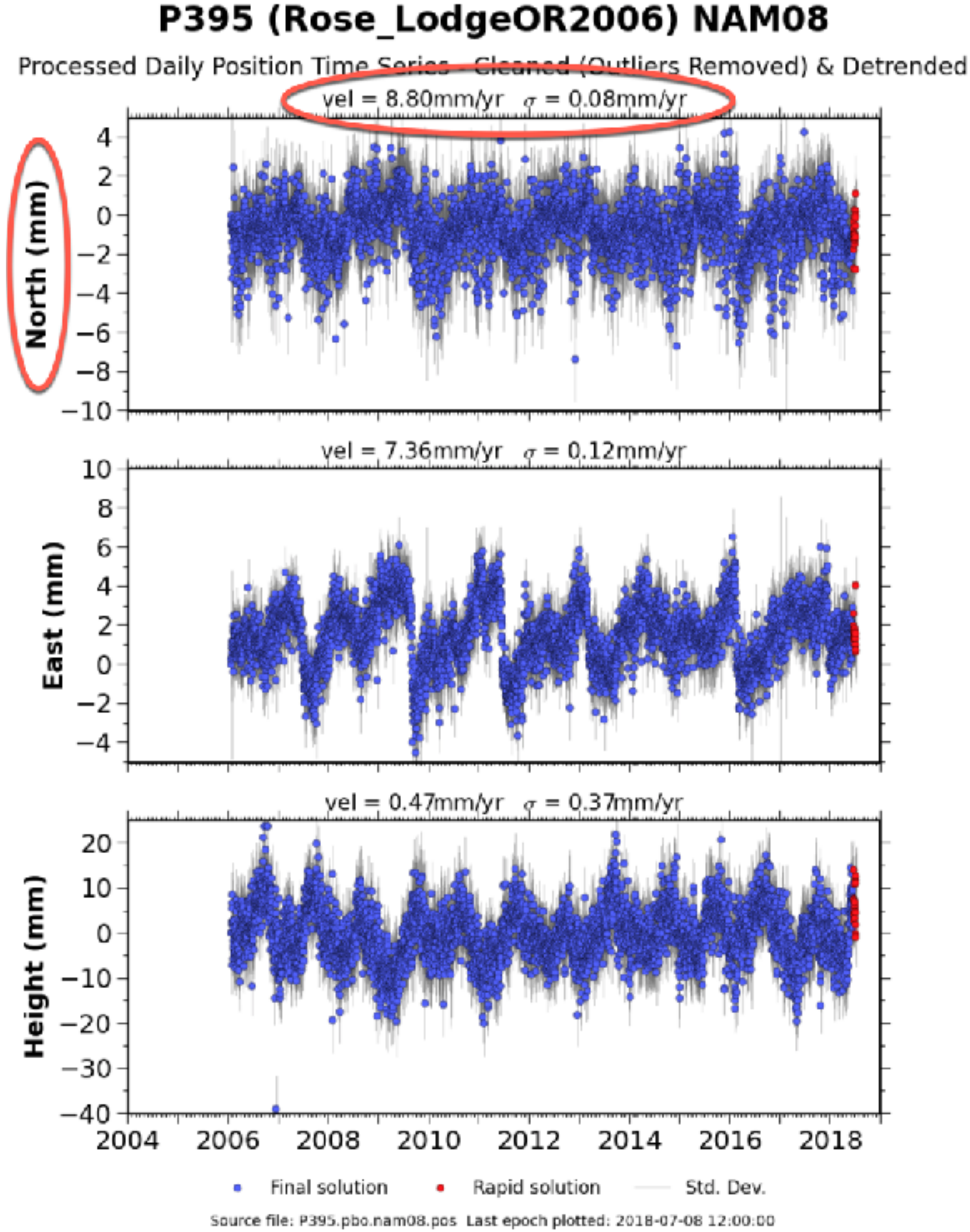
Most Recent Data Times Series Plot.



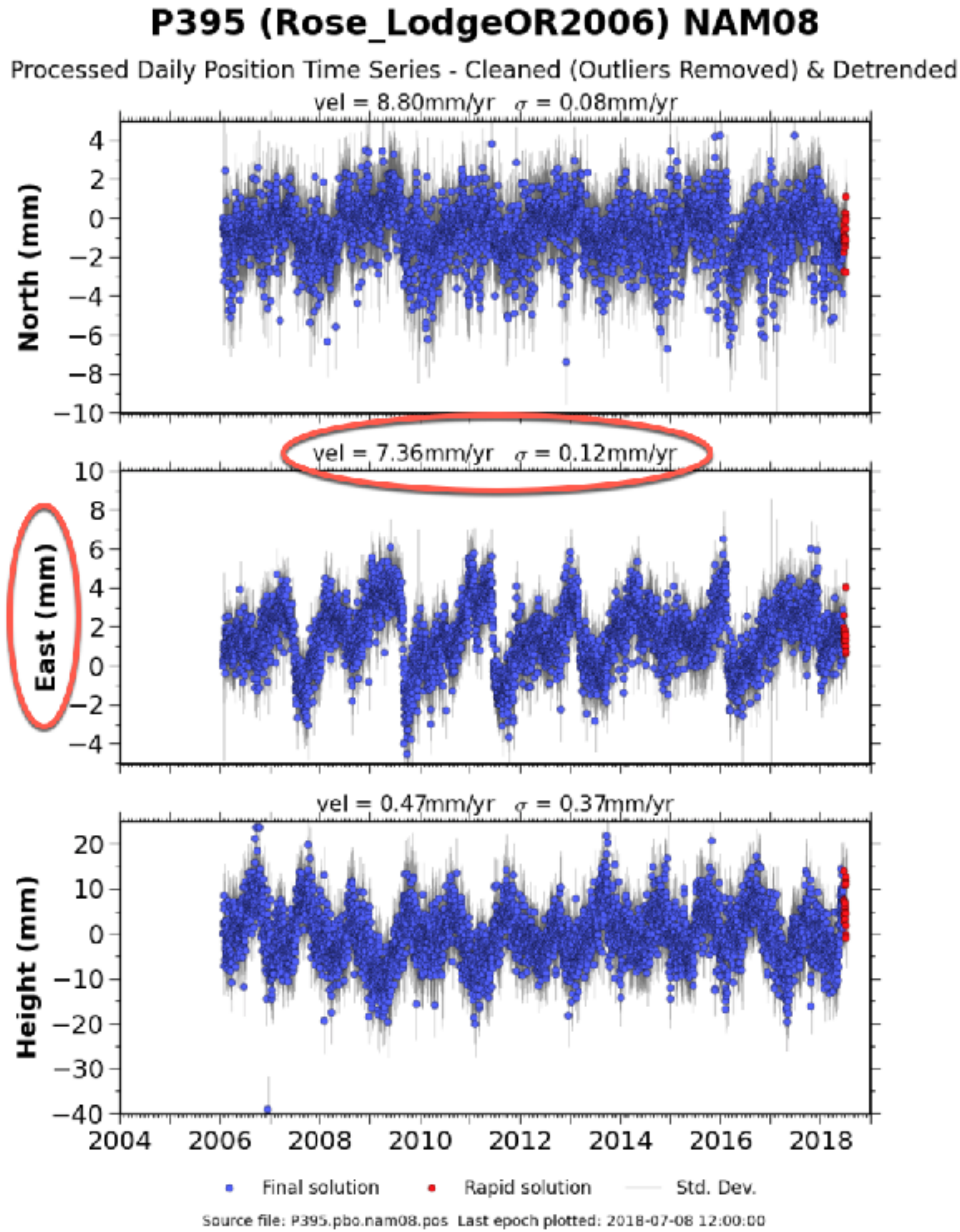
Most Recent Cleaned Data Times Series Plot.



Most Recent Detrended Data Times Series Plot.

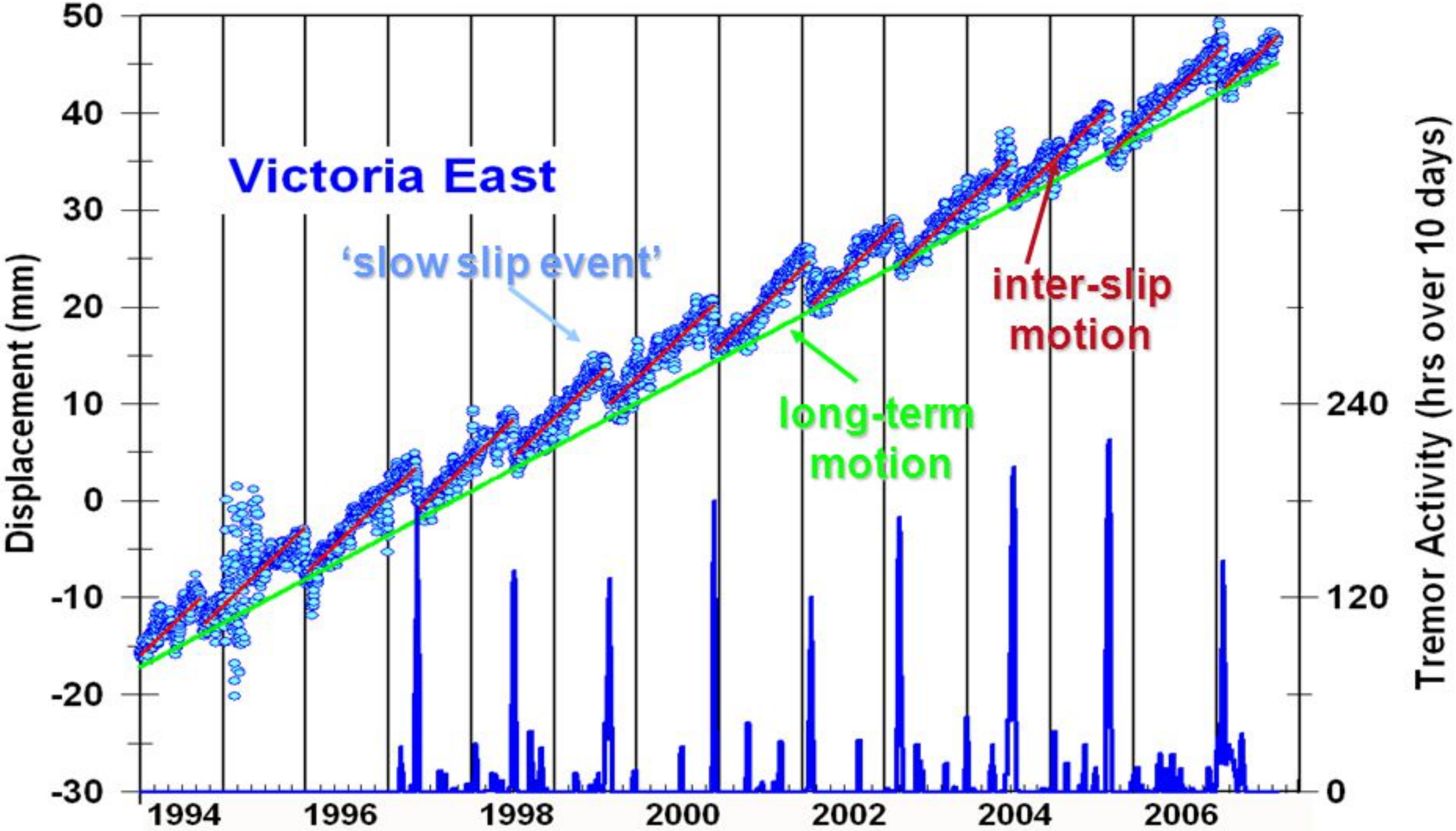


Most Recent Detrended Data Times Series Plot.

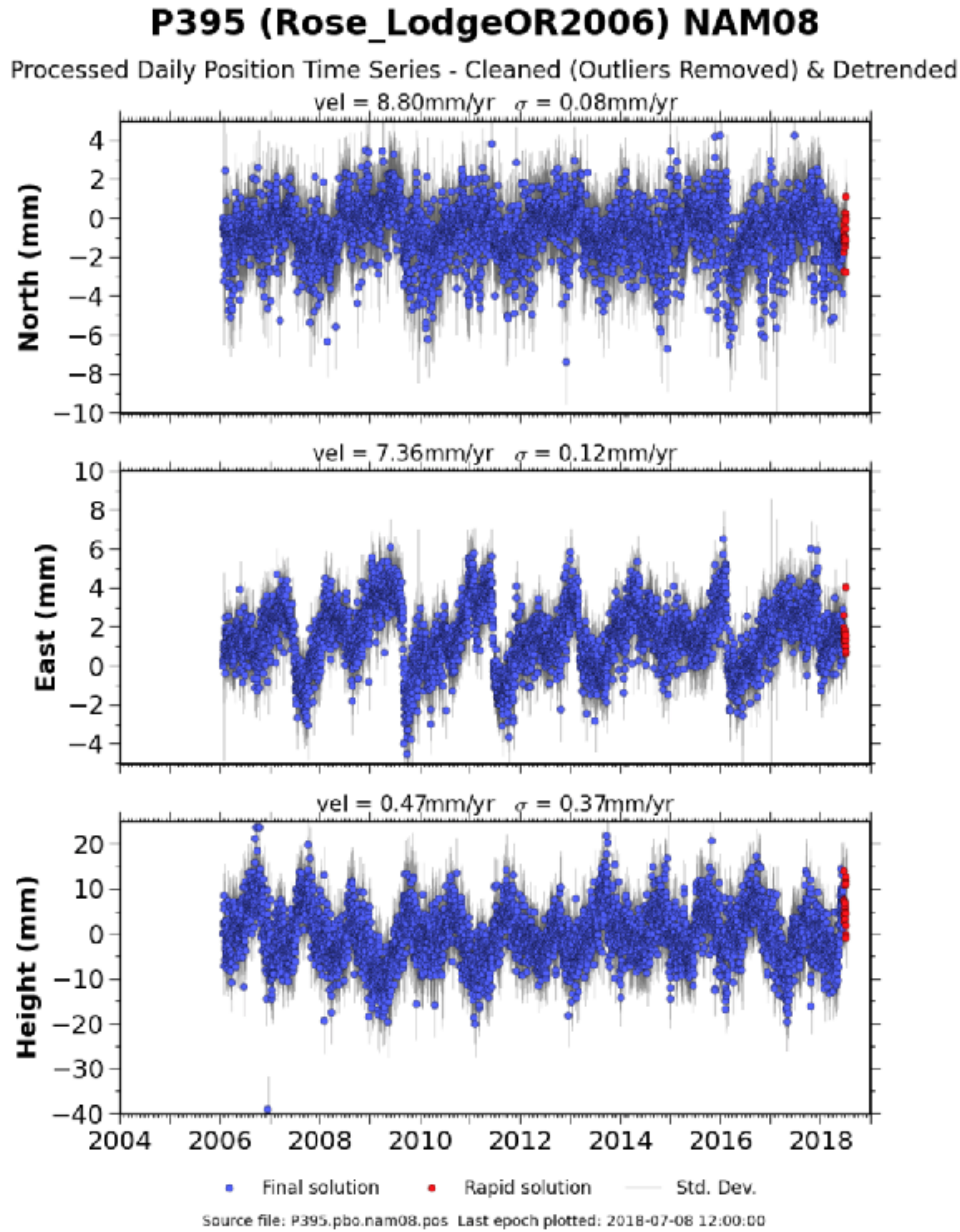


Most Recent Detrended Data Times Series Plot.

Episodic Tremor and Slip



Rogers and Dragert, 2003



Most Recent Detrended Data Times Series Plot.

Datasheet for finding GPS location and velocity data from the EarthScope Plate Boundary Observatory website for sites P395, P396 and P404 (https://www.unavco.org/instrumentation/networks/status/pbo/overview/P395 and so on)

Name: ____

Date on which the data were acquired from the PBO website: __________________

Geographic coordinates using WGS 1984 datum, North American 2008 Reference Frame (NAM08)

Site	**Decimal Lat**	**Decimal Long**
P395	________________	________________
P396	________________	________________
P404	________________	________________

GPS site velocities relative to NAM08, expressed in mm/year

Site	**N Velocity ± Uncert**		**E Velocity ± Uncert**		**Height Velocity ± Uncert**	
P395	________	________	________	________	________	________
P396	________	________	________	________	________	________
P404	________	________	________	________	________	________

Now plot the horizontal velocities on the map on the following page and then answer the following questions.

Use your group's map of the velocity field to hypothesize (infer) the instantaneous deformation for this set of stations.

	Approximate Magnitude (mm/yr)	**Approximate Azimuth (ex. "north" or "southwest")**
Translation:	____________	____________
Rotation direction (+ = counter clockwise, - = clockwise):		____________

Strain:

	Sign (+ = extension, - = contraction)	**Approximate Azimuth**
Max horizontal extension	____________	____________
Min horizontal extension	____________	____________

Look For Your Paper Handout

Site Locations

P395

GPS Monument Coordinates

Approximate Geographic Coordinates			
lat/lon/elev (d/d/m)*:	45.02228	-123.85753	53

P396

GPS Monument Coordinates

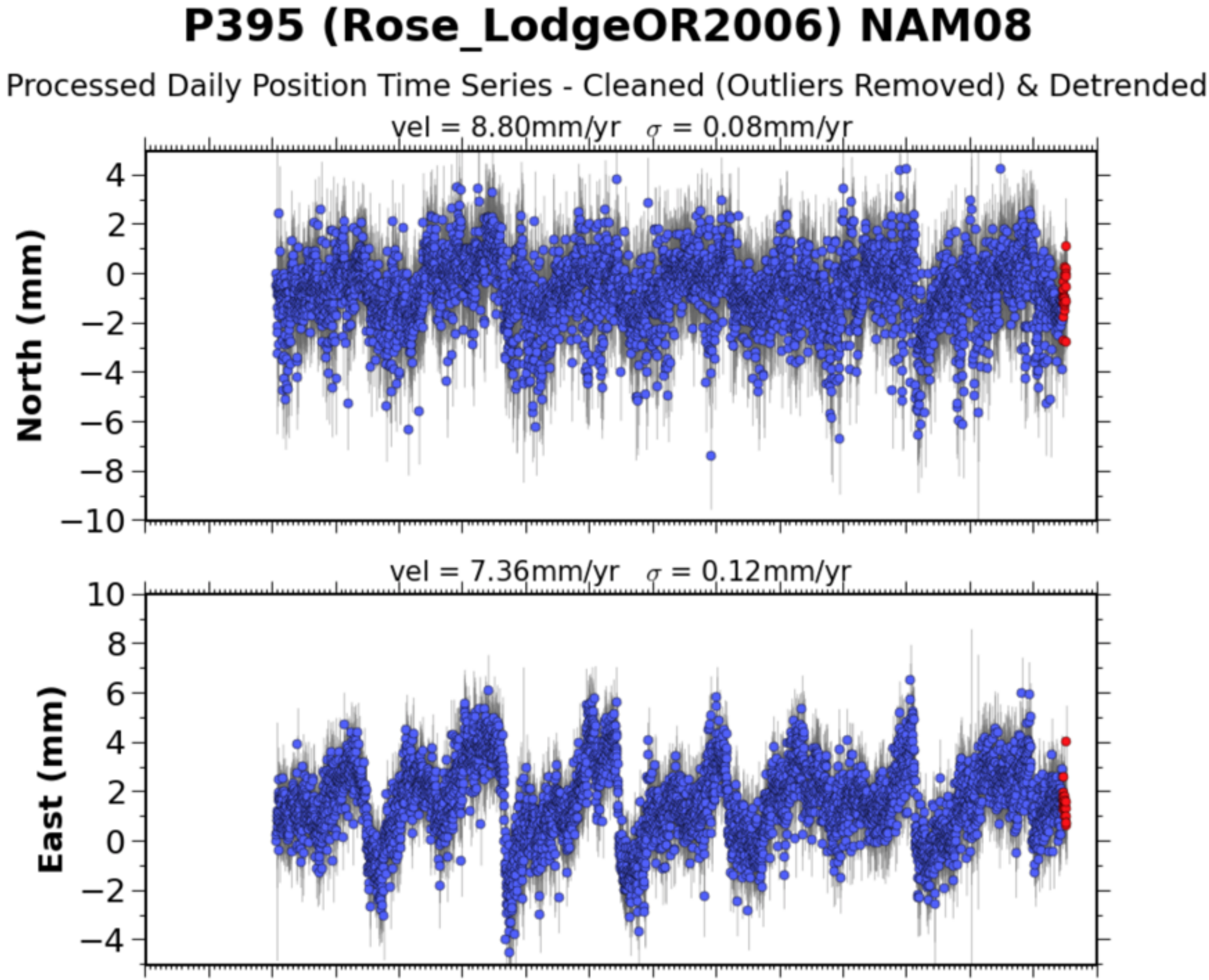
Approximate Geographic Coordinates			
lat/lon/elev (d/d/m)*:	45.30951	-123.82289	55

P404

GPS Monument Coordinates

Approximate Geographic Coordinates			
lat/lon/elev (d/d/m)*:	45.15853	-123.39033	79

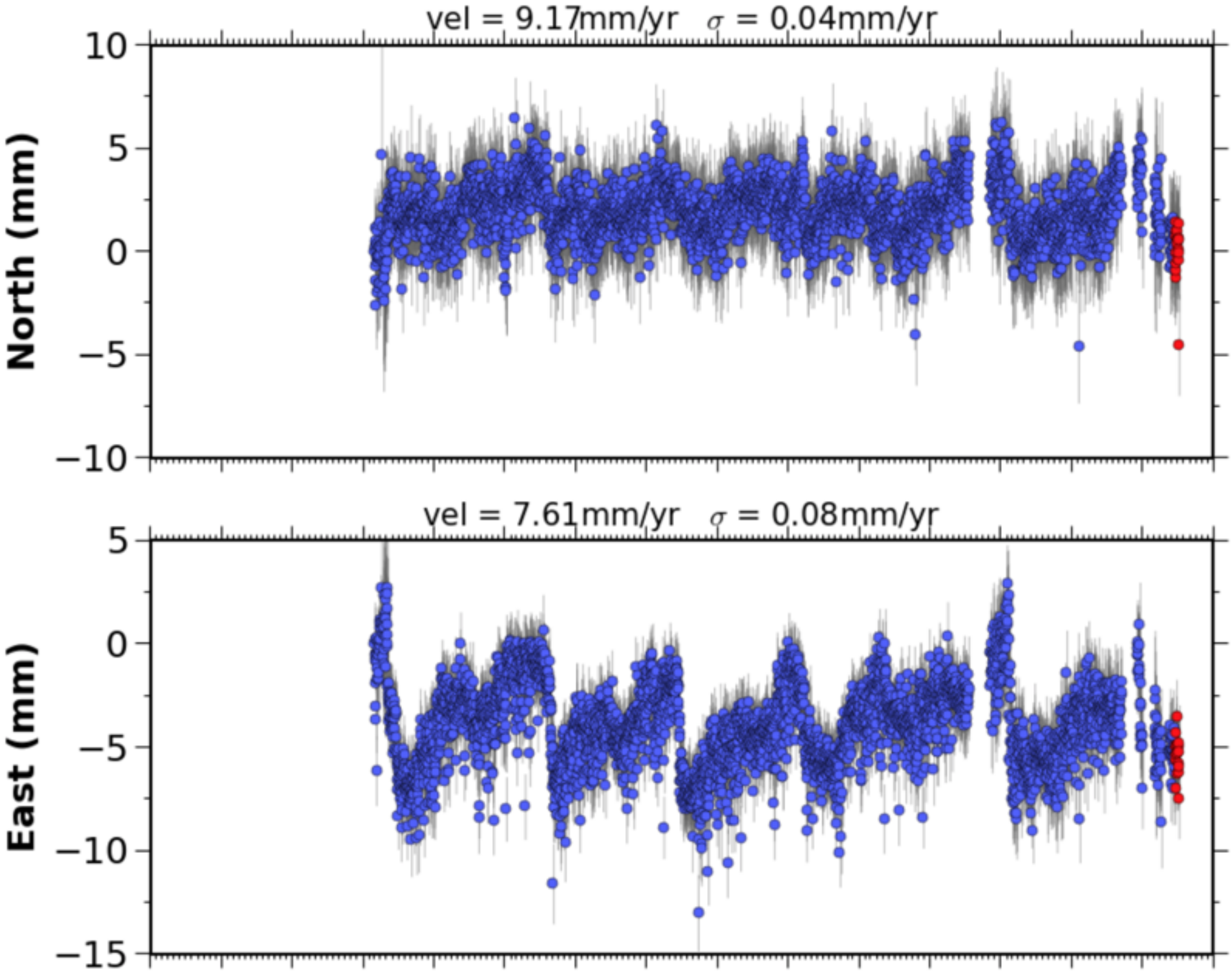
Data accessed on 11 July 2018 via https://www.unavco.org/instrumentation/networks/status/pbo/gps



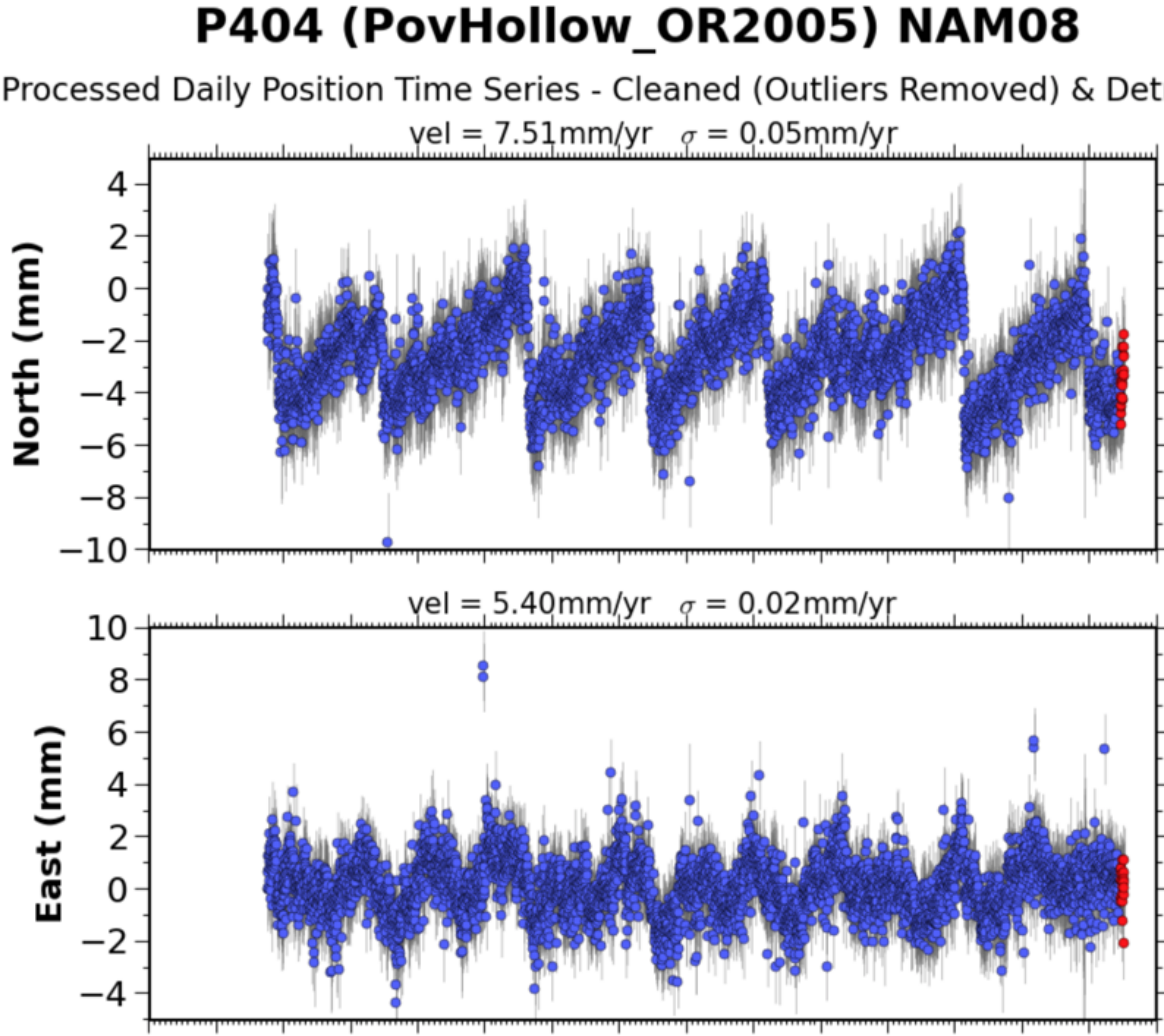
Data accessed on 11 July 2018 via https://www.unavco.org/instrumentation/networks/status/pbo/gps

P396 (RoosBC026GOR2007) NAM08

Processed Daily Position Time Series - Cleaned (Outliers Removed) & Detrended



Data accessed on 11 July 2018 via https://www.unavco.org/instrumentation/networks/status/pbo/gps



Data accessed on 11 July 2018 via https://www.unavco.org/instrumentation/networks/status/pbo/gps

Datasheet for finding GPS location and velocity data from the EarthScope Plate Boundary Observatory website for sites P395, P396 and P404 (https://www.unavco.org/instrumentation/networks/status/pbo/overview/P395 and so on)

Name: ____________________

Date on which the data were acquired from the PBO website: July 11, 2018

Geographic coordinates using WGS 1984 datum, North American 2008 Reference Frame (NAM08)

Site	Decimal Lat	Decimal Long
P395	45.02228	-123.85753
P396	45.30951	-123.82289
P404	45.15853	-123.39033

GPS site velocities relative to NAM08, expressed in mm/year

Site	N Velocity	± Uncert	E Velocity	± Uncert	Height Velocity	± Uncert
P395	8.80	0.08	7.36	0.12	——	——
P396	9.17	0.04	7.61	0.08	——	——
P404	7.51	0.05	5.40	0.02	——	——

Now plot the horizontal velocities on the map on the following page and then answer the following questions.

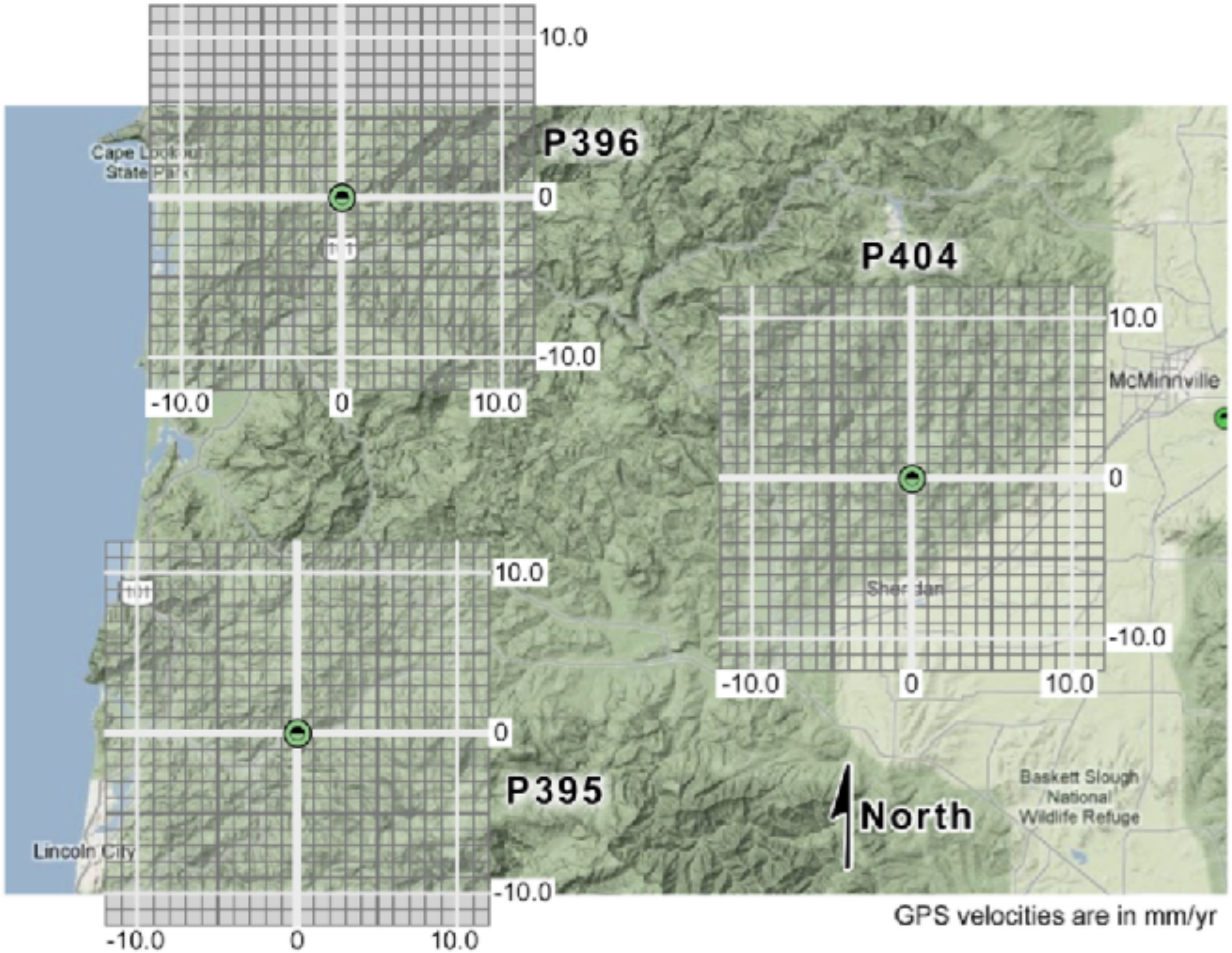
Use your group's map of the velocity field to hypothesize (infer) the instantaneous deformation for this set of stations.

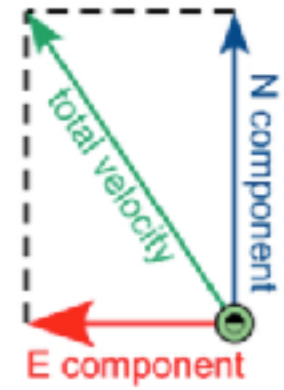
	Approximate Magnitude (mm/yr)	Approximate Azimuth (ex. "north" or "southwest")
Translation:	____________	____________
Rotation direction (+ = counter clockwise, - = clockwise):		____________

Strain:

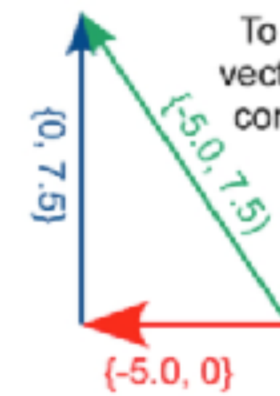
	Sign (+ = extension, - = contraction)	Approximate Azimuth
Max horizontal extension	____________	____________
Min horizontal extension	____________	____________

Carefully draw the E-W and N-S velocity vectors associated with the three PBO GPS sites shown as green dots in the map below. A negative east component is a vector pointing west, and a negative north component is a vector pointing south. The graphs are scaled in units of millimeters per year. Then draw the total horizontal velocity vector for each site, and determine the horizontal speed (that is, the length of the total horizontal velocity vector) of each site. You can determine the total horizontal speed by one of the methods shown at right below.



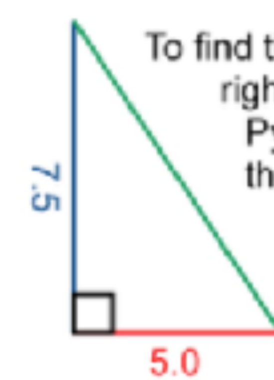


To find the total speed graphically, use a ruler and the scale shown on the graph to measure the length of the total velocity vector.



To find the total speed using vector math, add the E and N component vectors together, and find the length of the resulting total velocity vector using the Pythagorean theorem.

total speed = $\sqrt{(-5.0^2)+(7.5^2)}$



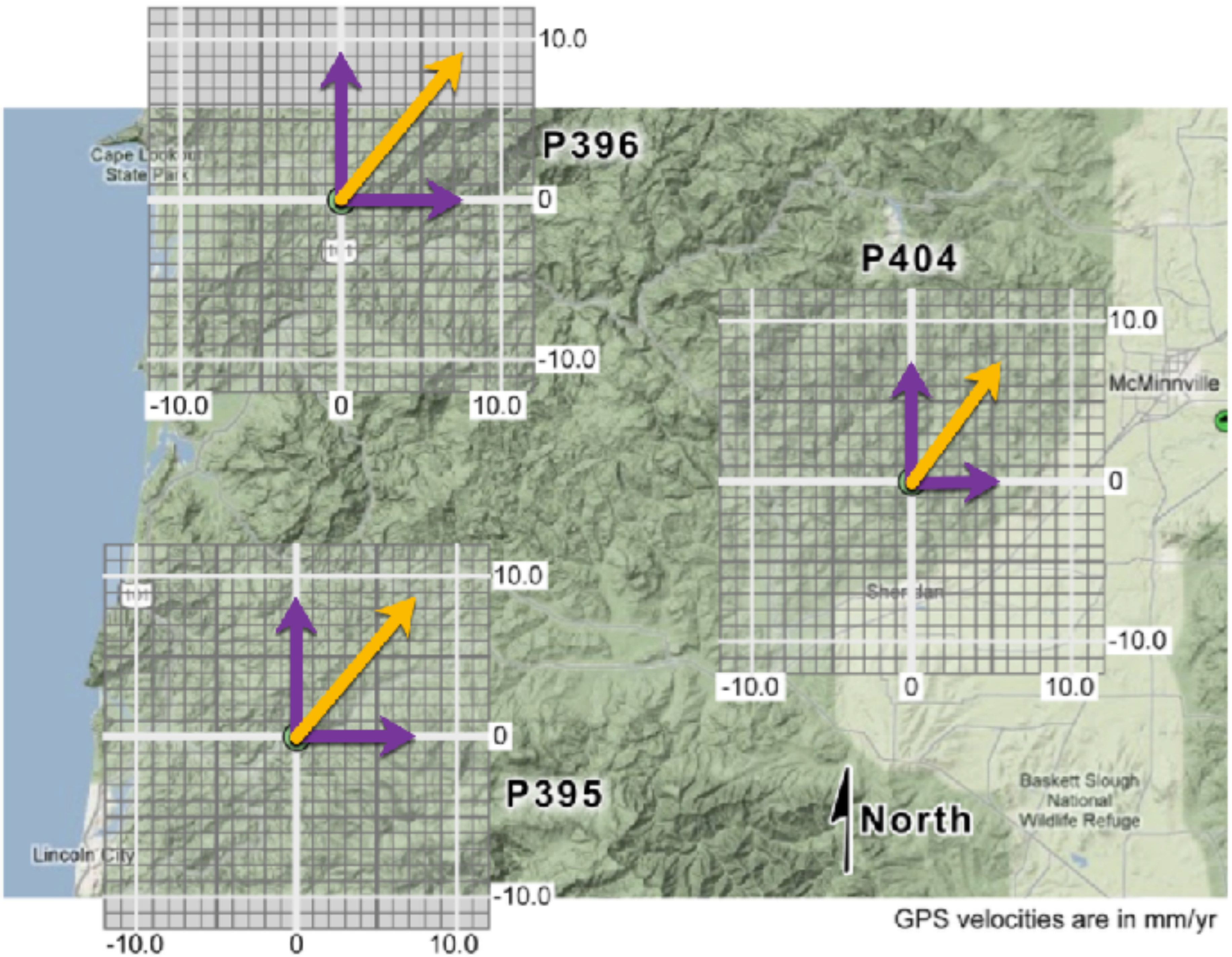
To find the total speed by solving a right-triangle problem, use the Pythagorean theorem to find the length of the hypotenuse of a triangle whose sides are the lengths of the E and N components.

total speed = $\sqrt{(5.0^2)+(7.5^2)}$

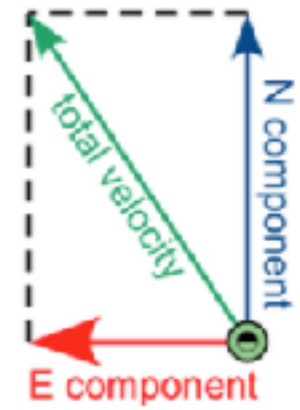
Total horizontal speeds: P395 ______________ mm/yr; P396 ______________ mm/yr; P404 ______________ mm/yr

Look For Your Paper Handout

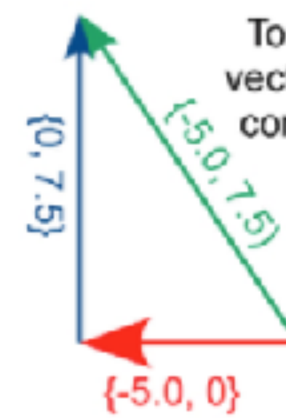
Carefully draw the E-W and N-S velocity vectors associated with the three PBO GPS sites shown as green dots in the map below. A negative east component is a vector pointing west, and a negative north component is a vector pointing south. The graphs are scaled in units of millimeters per year. Then draw the total horizontal velocity vector for each site, and determine the horizontal speed (that is, the length of the total horizontal velocity vector) of each site. You can determine the total horizontal speed by one of the methods shown at right below.



GPS velocities are in mm/yr

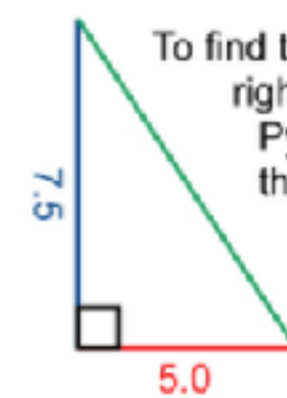


To find the total speed graphically, use a ruler and the scale shown on the graph to measure the length of the total velocity vector.



To find the total speed using vector math, add the E and N component vectors together, and find the length of the resulting total velocity vector using the Pythagorean theorem.

total speed = $\sqrt{(-5.0^2)+(7.5^2)}$



To find the total speed by solving a right-triangle problem, use the Pythagorean theorem to find the length of the hypotenuse of a triangle whose sides are the lengths of the E and N components.

total speed = $\sqrt{(5.0^2)+(7.5^2)}$

Total horizontal speeds: P395 ~11.5 mm/yr; P396 ~11.9 mm/yr; P404 ~9.2 mm/yr

Datasheet for finding GPS location and velocity data from the EarthScope Plate Boundary Observatory website for sites P395, P396 and P404 (https://www.unavco.org/instrumentation/networks/status/pbo/overview/P395 and so on)

Name: ______________________________

Date on which the data were acquired from the PBO website: July 11, 2018

Geographic coordinates using WGS 1984 datum, North American 2008 Reference Frame (NAM08)

Site	Decimal Lat	Decimal Long
P395	45.02228	-123.85753
P396	45.30951	-123.82289
P404	45.15853	-123.39033

GPS site velocities relative to NAM08, expressed in mm/year

Site	N Velocity	± Uncert	E Velocity	± Uncert	Height Velocity	± Uncert
P395	8.80	0.08	7.36	0.12	——	——
P396	9.17	0.04	7.61	0.08	——	——
P404	7.51	0.05	5.40	0.02	——	——

Now plot the horizontal velocities on the map on the following page and then answer the following questions.

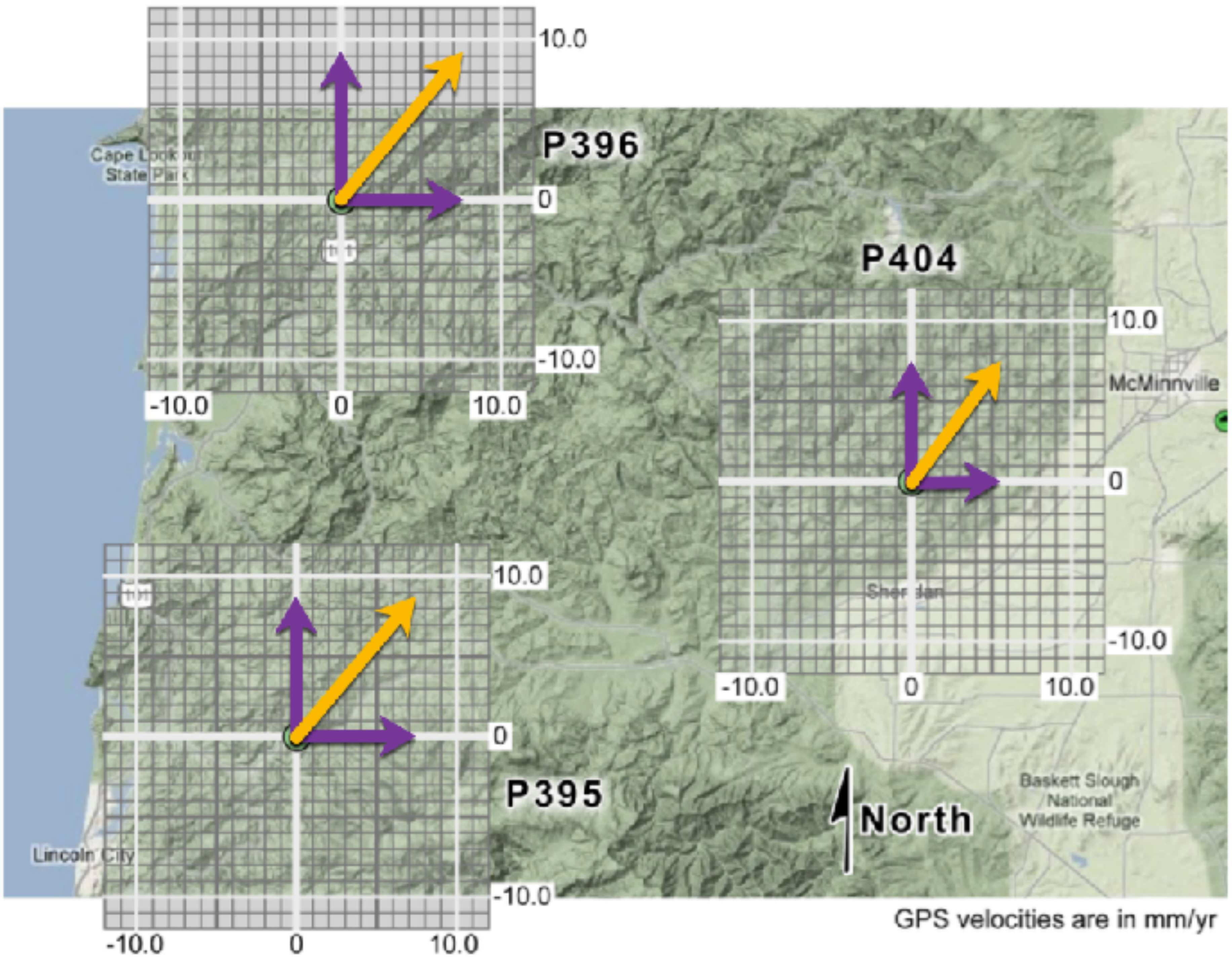
Use your group's map of the velocity field to hypothesize (infer) the instantaneous deformation for this set of stations.

	Approximate Magnitude (mm/yr)	**Approximate Azimuth (ex. "north" or "southwest")**
Translation:	____________	____________
Rotation direction (+ = counter clockwise, - = clockwise):		____________

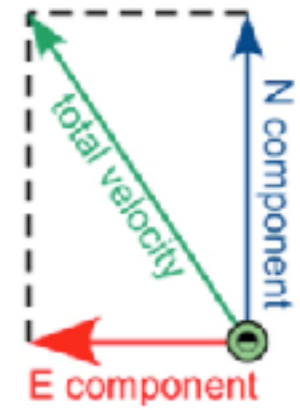
Strain:

	Sign (+ = extension, - = contraction)	**Approximate Azimuth**
Max horizontal extension	____________	____________
Min horizontal extension	____________	____________

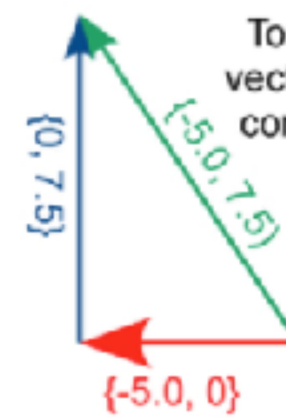
Carefully draw the E-W and N-S velocity vectors associated with the three PBO GPS sites shown as green dots in the map below. A negative east component is a vector pointing west, and a negative north component is a vector pointing south. The graphs are scaled in units of millimeters per year. Then draw the total horizontal velocity vector for each site, and determine the horizontal speed (that is, the length of the total horizontal velocity vector) of each site. You can determine the total horizontal speed by one of the methods shown at right below.



GPS velocities are in mm/yr

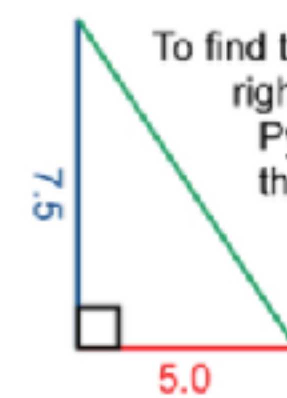


To find the total speed graphically, use a ruler and the scale shown on the graph to measure the length of the total velocity vector.



To find the total speed using vector math, add the E and N component vectors together, and find the length of the resulting total velocity vector using the Pythagorean theorem.

total speed = $\sqrt{(-5.0^2)+(7.5^2)}$



To find the total speed by solving a right-triangle problem, use the Pythagorean theorem to find the length of the hypotenuse of a triangle whose sides are the lengths of the E and N components.

total speed = $\sqrt{(5.0^2)+(7.5^2)}$

Total horizontal speeds: P395 ~11.5 mm/yr; P396 ~11.9 mm/yr; P404 ~9.2 mm/yr

Graphic solutions are OK for initial visualization, but we need an analytical or numerical solution to improve the reliability of our result.

The GPS module includes “calculators” written in three forms (Excel, MatLab, and Mathematica) as well as documents that would allow students to write their own code:

Primer on Infinitesimal Strain Analysis in 1, 2 and 3-D

and

Algorithm for Triangle Strain

Fire-up the Excel version of
the strain calculator

Infinitesimal strain from GPS velocity data from sites in a triangular array

October 18, 2012

Send corrections, suggestions, comments to Vince_Cronin@baylor.edu

Instructions

(1) Input the name. location, and velocity data from three GPS sites in the yellow cells.
(2) When the required data have been input, the answers will appear in the Output Data section (blue cells).

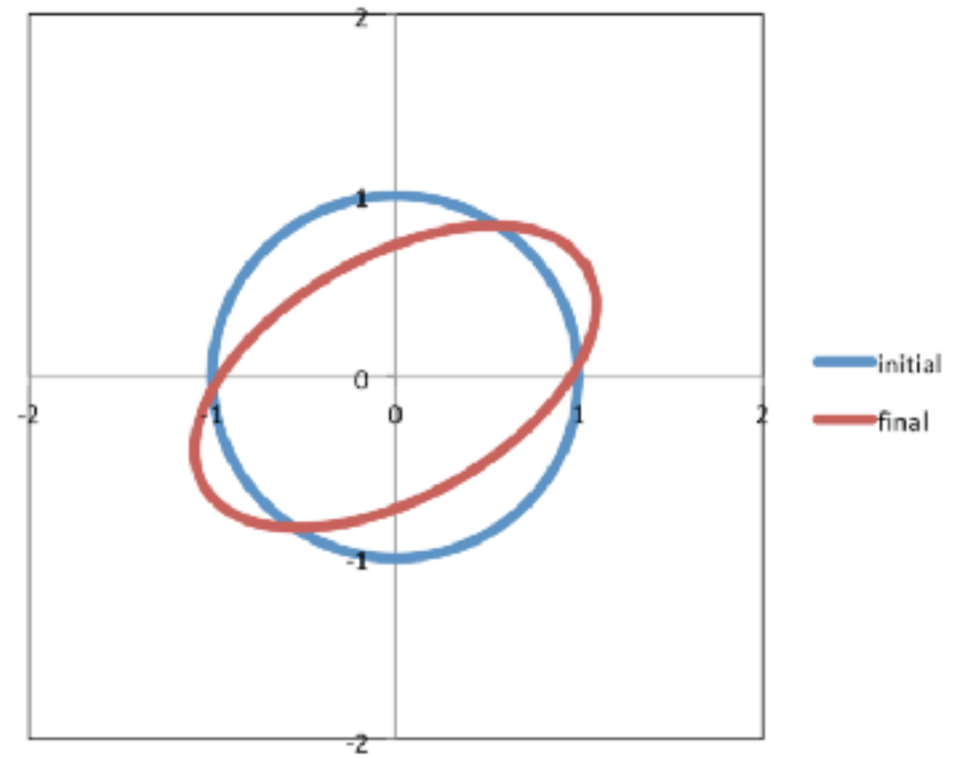
Initial Input Data

Site Name	Longitude west is negative	Latitude south is negative	E velocity (mm/yr)	E vel uncert (mm/yr)	N velocity (mm/yr)	N vel uncert (mm/yr)
AC63	-145.847244751	63.502426437	1.79	0.01	-2.76	0.01
AC62	-146.312697002	63.083606996	-19.51	0.01	5.43	0.01
AB37	-145.451879261	62.967323566	-21.6	0.01	10.3	0.01

Primary Output Data

Translation Vector			
E component ± uncert (m/yr)	-0.0131	±	5.7735E-06
N component ± uncert (m/yr)	0.0043	±	5.7735E-06
Azimuth (degrees)	288.3		
Speed (m/yr)	0.0138		
Rotation ± uncertainty (degrees/yr)	-0.00001044	±	0.00000001
Rotation ± uncertainty (nano-rad/yr)	-182.2906	±	0.2002
Direction of rotation	clockwise		
Max horizontal extension (e1H) (nano-strain)	207.4117		
Azimuth of S1H (degrees)	59.8113	or	239.8113245
Min horizontal extension (e2H) (nano-strain)	-339.1133		
Azimuth of S2H (degrees)	149.8113	or	329.8113245
Max shear strain (nano-strain)	546.5250		
Area strain (nano-strain)	-131.7015		

Strain ellipse (exaggerated by 1e6)

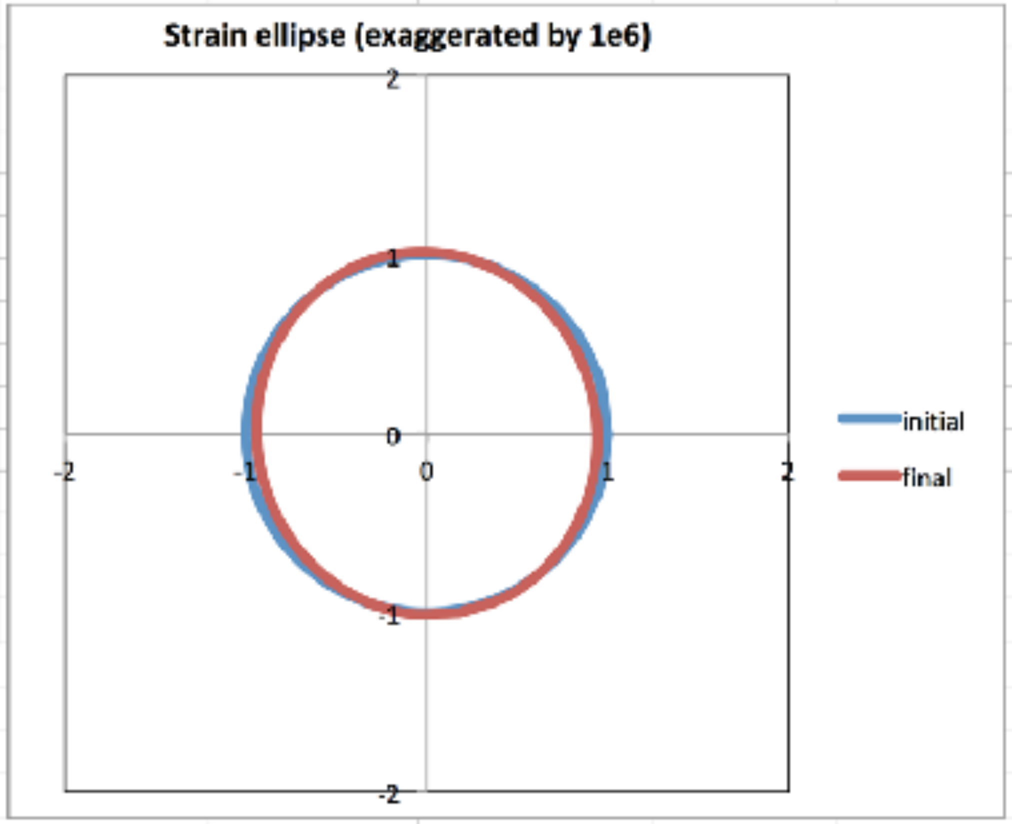


Other Output

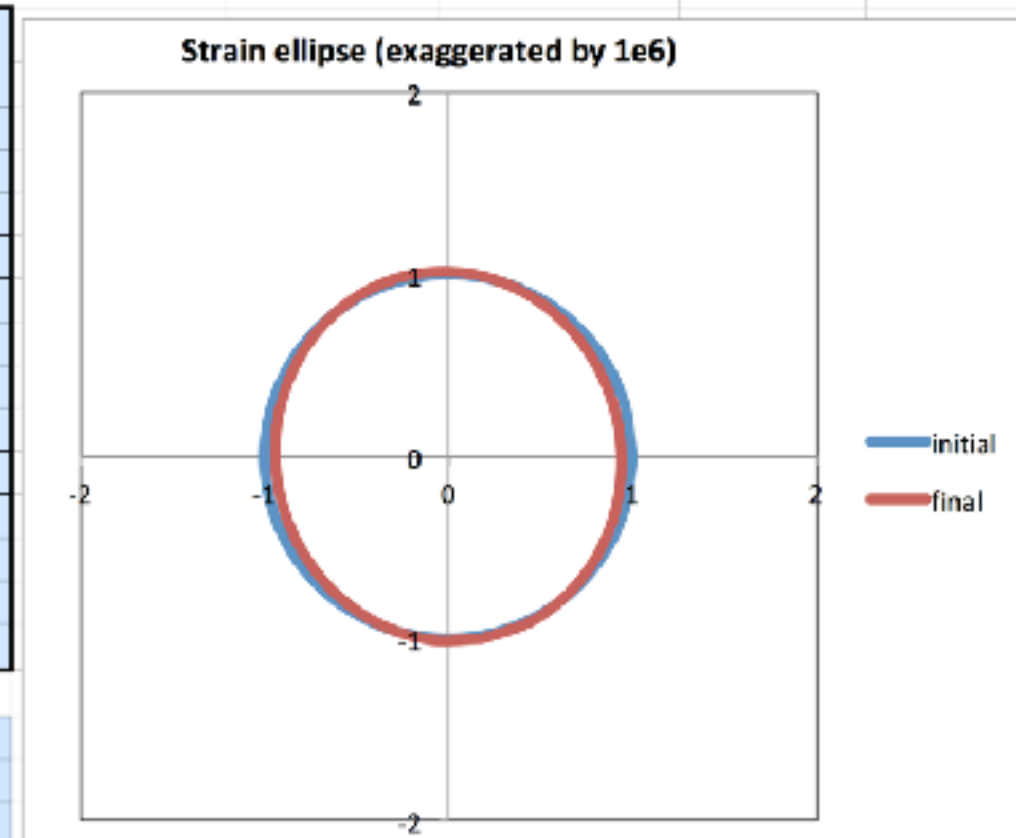
Lagrangian strain-rate tensor			
εxx ± uncert (nano-strain)	69.2189	±	0.3280
εxy ± uncert (nano-strain)	237.5470	±	0.2002
εyy ± uncert (nano-strain)	-200.9205	±	0.2298
First invariant of strain-rate tensor	-131.7015		

	A	B	C	D	E	F	G	H
1	**Infinitesimal strain from GPS velocity data from sites in a triangular array**							October 18, 2012
2		Send corrections, suggestions, comments to Vince_Cronin@baylor.edu						
3								
4	**Instructions**							
5		(1) Input the name. location, and velocity data from three GPS sites in the yellow cells.						
6		(2) When the required data have been input, the answers will appear in the Output Data section (blue cells).						
7								
8	**Initial Input Data**							
9		Site	Longitude	Latitude	E velocity	E vel uncert	N velocity	N vel uncert
10		Name	west is negative	south is negative	(mm/yr)	(mm/yr)	(mm/yr)	(mm/yr)
11		P395	-123.857530000	45.022280000	7.36	0.02	8.8	0.08
12		P396	-123.822890000	45.309510000	7.61	0.08	9.17	0.04
13		P404	-123.390330000	45.158530000	5.4	0.02	7.51	0.05
14								

	A	B	C	D	E
15	**Primary Output Data**				
16		Translation Vector			
17		E component ± uncert (m/yr)	0.0068	±	2.82843E-05
18		N component ± uncert (m/yr)	0.0085	±	3.41565E-05
19		Azimuth (degrees)	38.6		
20		Speed (m/yr)	0.0109		
21		Rotation ± uncertainty (degrees/yr)	-0.00000157	±	0.00000009
22		Rotation ± uncertainty (nano-rad/yr)	-27.3470	±	1.6500
23		Direction of rotation	clockwise		
24		Max horizontal extension (e1H) (nano-strain)	18.0762		
25		Azimuth of S1H (degrees)	169.7234	or	349.723356
26		Min horizontal extension (e2H) (nano-strain)	-61.0800		
27		Azimuth of S2H (degrees)	79.7234	or	259.723356
28		Max shear strain (nano-strain)	79.1562		
29		Area strain (nano-strain)	-43.0038		
30					
31	**Other Output**				
32		Lagrangian strain-rate tensor			
33		εxx ± uncert (nano-strain)	-58.5607	±	1.2303
34		εxy ± uncert (nano-strain)	-13.8950	±	1.6500
35		εyy ± uncert (nano-strain)	15.5569	±	2.7299
36		First invariant of strain-rate tensor (nano-strain)	-43.0038		



15	**Primary Output Data**			
16	Translation Vector			
17	E component ± uncert (m/yr)	0.0068	±	2.82843E-05
18	N component ± uncert (m/yr)	0.0085	±	3.41565E-05
19	Azimuth (degrees)	38.6		
20	Speed (m/yr)	0.0109		
21	Rotation ± uncertainty (degrees/yr)	-0.00000157	±	0.00000009
22	Rotation ± uncertainty (nano-rad/yr)	-27.3470	±	1.6500
23	Direction of rotation	clockwise		
24	Max horizontal extension (e1H) (nano-strain)	18.0762		
25	Azimuth of S1H (degrees)	169.7234	or	349.723356
26	Min horizontal extension (e2H) (nano-strain)	-61.0800		
27	Azimuth of S2H (degrees)	79.7234	or	259.723356
28	Max shear strain (nano-strain)	79.1562		
29	Area strain (nano-strain)	-43.0038		
30				
31	**Other Output**			
32	Lagrangian strain-rate tensor			
33	εxx ± uncert (nano-strain)	-58.5607	±	1.2303
34	εxy ± uncert (nano-strain)	-13.8950	±	1.6500
35	εyy ± uncert (nano-strain)	15.5569	±	2.7299
36	First invariant of strain-rate tensor (nano-strain)	-43.0038		
37	Second invariant of strain-rate tensor (nano-strain)	-1.1041E-06		
38	Third invariant of strain-rate tensor (nano-strain)	-1.1041E-06		
39				
40	**Computation**			
41	Site name	P395	P396	P404
42	latitude in radians	0.785787023	0.790800132	0.788165034
43	longitude in radians	-2.161721702	-2.16111712	-2.153567524



UNAVCO

GPS Strain & Earthquakes: Explanation of Strain Calculator Output

Original document by Vince Cronin (Baylor University). Revisions by Beth Pratt-Sitaula (UNAVCO).

The "GPS Triangle Strain Calculator" (Excel and Matlab versions) takes the velocity at each of the three GPS stations, and determines what types of transformations the region between them is undergoing. It breaks the total measured GPS velocities into components of the different types of transformations—translation, rotation, extension, and strain.

Figure 1. Translation.

- The ***Translation Vector*** can be visualized as the vector from one specific point to another -- from the original position of the center of the triangle formed by the three GPS sites to the displaced position of the center of the triangle.
    - The ***East component*** of the translation vector is computed by taking the average of the three E (east-west) velocity vectors, expressed in meters per year (1 m/yr = 1000 mm/yr; 1 mm/yr = 0.001 m/yr). A negative value signifies westward movement.
    - In a similar way, the ***N component*** of the translation vector is the average of the N (north-south) velocity vectors, also expressed in meters per year; negative value is southward movement.
    - The ***Azimuth*** of the translation is the average direction that the GPS sites are moving. The azimuth is measured in a horizontal plane, starting at north (0° azimuth) and

Cascadia