

GETSI module on GPS, Strain, and Earthquakes

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Phil Resor, Wesleyan University
Beth Pratt-Sitaula, UNAVCO

Vince Cronin

Phil Resor

Bill Hammond

Nancy West

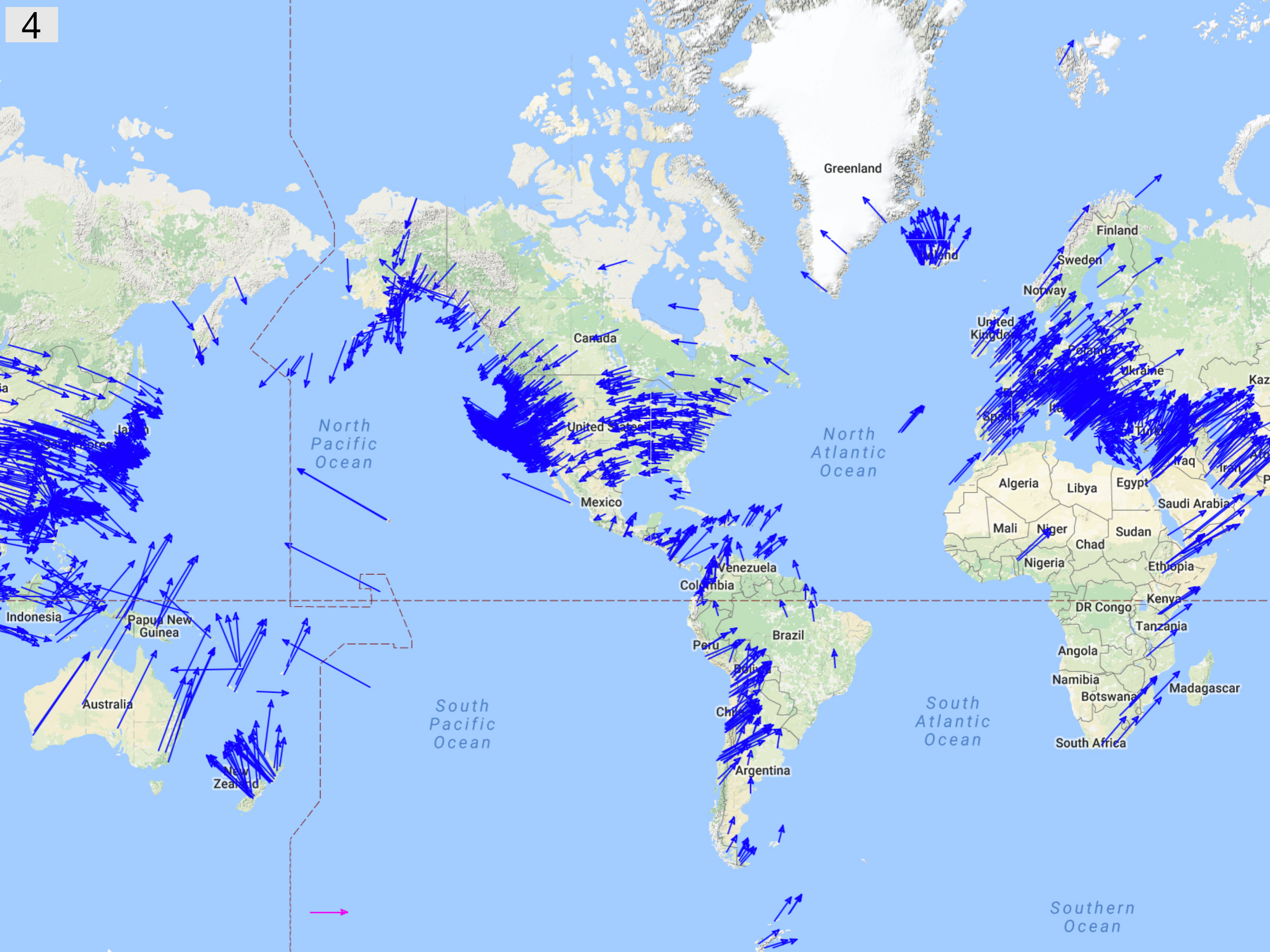
Shelly Olds

Corné Kreemer

Beth Pratt-Sitaula



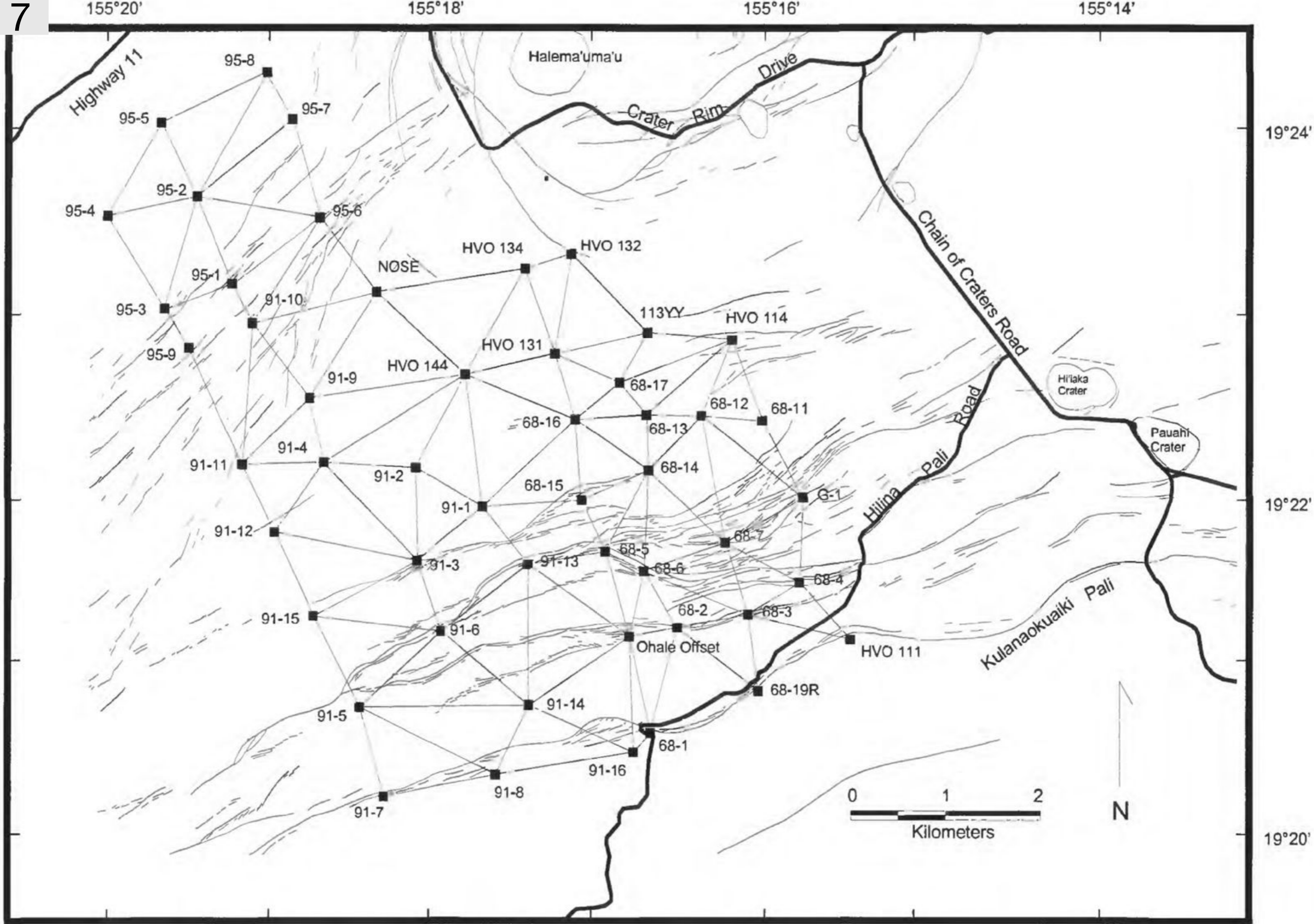








US Geological Survey benchmark, installed October 1, 1906

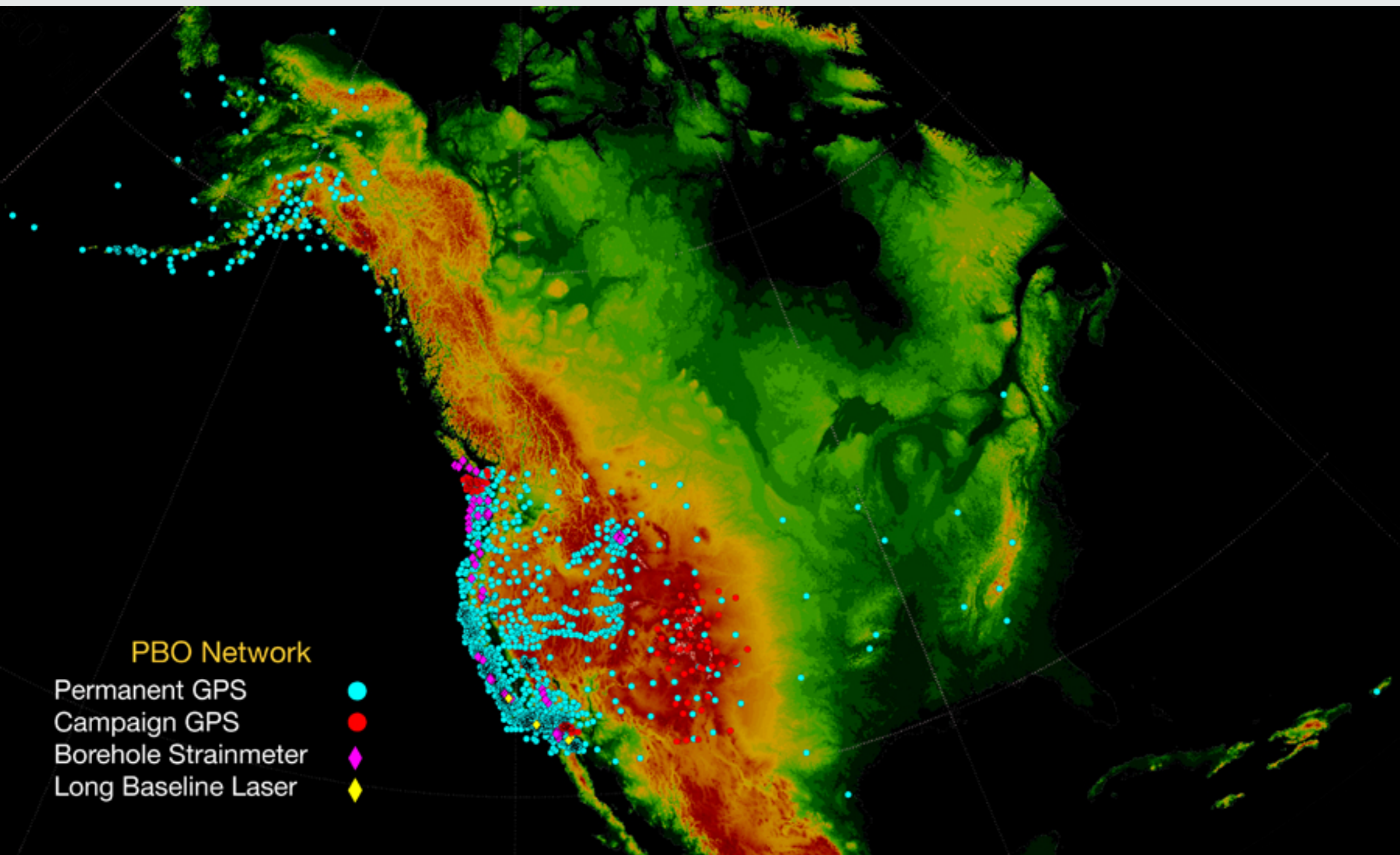


EDM trilateration array, Kilauea, Hawaii, from Avery et al., 2002



Using a geodimeter for repeat geodetic surveys of Mt. St. Helens, circa 1970s

EarthScope Plate Boundary Observatory





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Instrumentation

- Help with Instrumentation
- **Network Monitoring**
 - PBO Networks
 - PBO GPS Network
 - PBO Strainmeter Network
 - PBO Seismic Network
 - PBO Network State of Health
 - PBO Network Maintenance
 - Polar Networks
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 - NASA-GGN
 - COCONet
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 - Real-Time GPS Subnets
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 - Principal Investigator Stations

Related Links

- [PBO Project Overview](#)

PBO Network Monitoring

[PBO](#) is a network of ~1100 continuous Global Positioning System (cGPS) and meteorology stations in the western U.S. PBO provides raw GPS data, GPS-PWV, surface meteorology measurements, time series of daily positions, as well as a station velocity field to support a broad range of geoscience investigations.

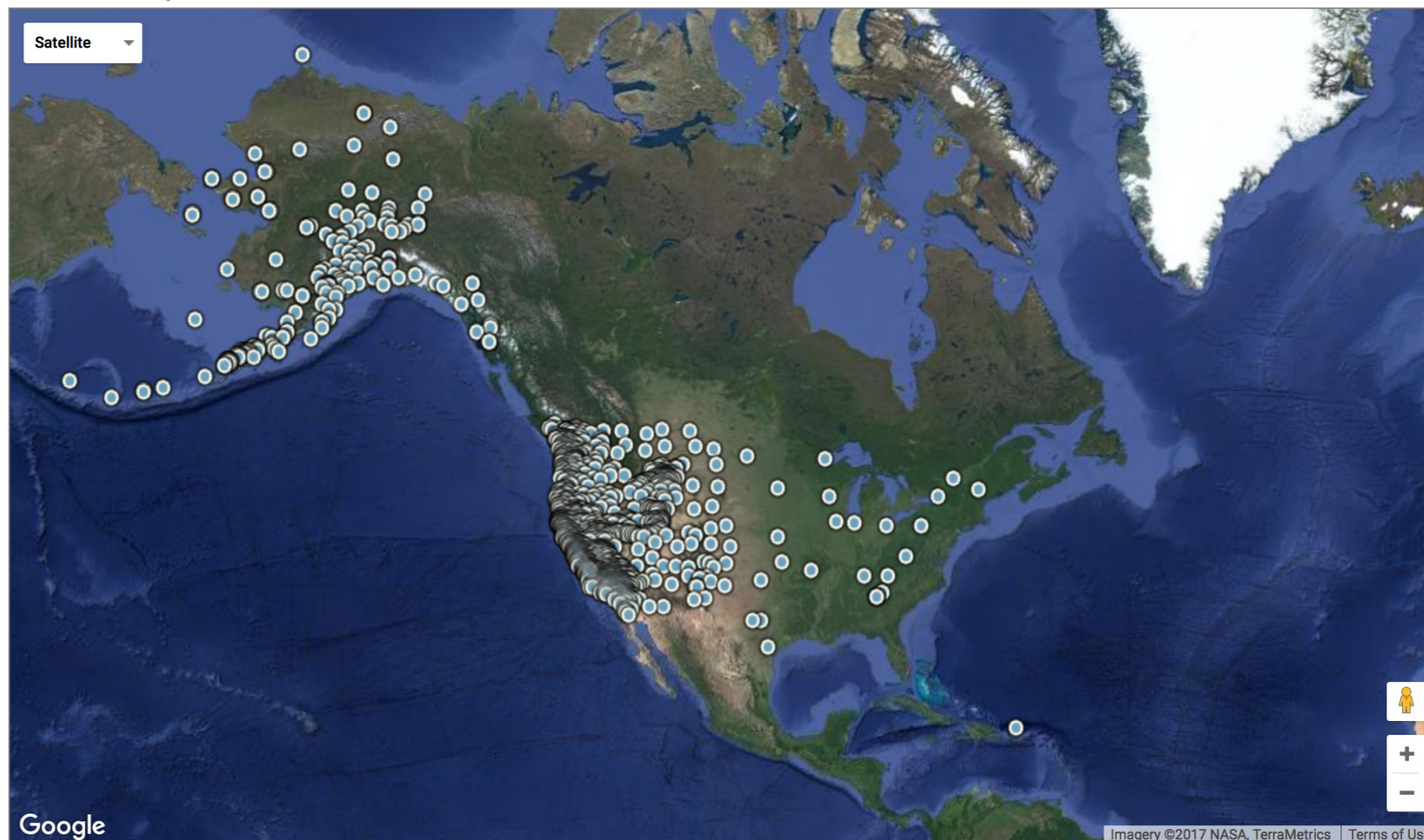
- [PBO Project Page](#)
- [PBO Network State of Health Map](#)
- [Realtime Stations](#)

Station Meta Data

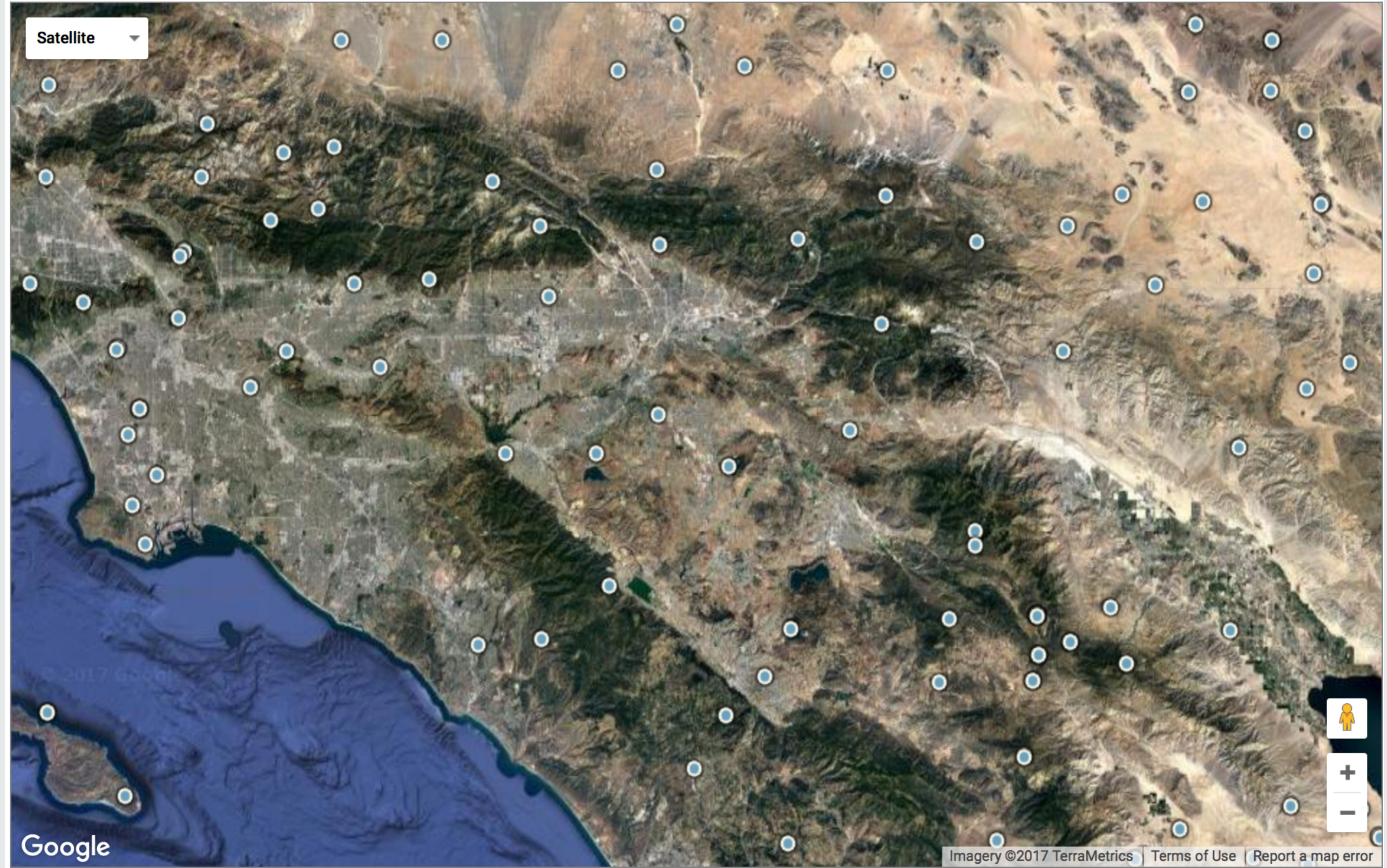
Station meta data for PBO stations are maintained by UNAVCO engineers and stored within a UNAVCO production database through the internal tool known as MDM. Additionally, some meta data is extracted from files generated by equipment located at the station. All meta data displayed within the station pages for PBO is retrieved from this production database.

Select a Station Page (1313 Stations):

PBO Network Map



PBO Network Map



PBO Network Map

The image shows a satellite map of a mountainous region with numerous blue circular markers representing PBO network stations. A popup window is open over one of the stations, displaying its details. The popup includes a title, a close button, a photograph of the station, and a list of technical specifications. The map interface includes a 'Satellite' dropdown menu in the top left, a person icon, zoom in (+) and zoom out (-) buttons in the bottom right, and the Google logo in the bottom left corner. The footer contains copyright and legal information.

Satellite

ID: [BEMT](#)

Name: BEMT_SCGN_CS2001

Location: Twentynine Palms, CA

Target: Transform

Latitude: 34.000534

Longitude: -115.99819

Elevation: 1373.6489

Install Type: DDBM

PBO GPS STATION [Close]

Google

Imagery ©2017 TerraMetrics | Terms of Use | Report a map error

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BEMT - Overview | PBO Station Page

- Overview**
- Data Products
- Station Health
- Maintenance
- Photos

BEMT Station Overview

Station Type: GPS

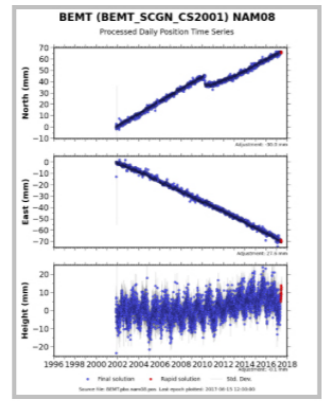


Station Information	
Station Status:	Installed/Operable
Station ID:	BEMT
Station Name:	BEMT_SCGN_CS2001
Location (City, State):	Twentynine Palms, CA
Monument Type:	DDBM
Station Install Date:	2001-11-15

Station Data	
IGS Site Log:	Text File
Installation Report:	BIRT Report
Time Series Data:	NAM08 CSV IGS08 CSV
Time Series Plot Viewer:	Nearby GPS Plots
Realtime Dataflow:	Available
Meteorologic Plots:	Not Available

Colocated Instruments	
None	

Station Position



GPS Monument Coordinates

Approximate Geographic Coordinates

lat/lon/elev (d/d/m)*:	34.00053	-115.99819	1374
------------------------	----------	------------	------

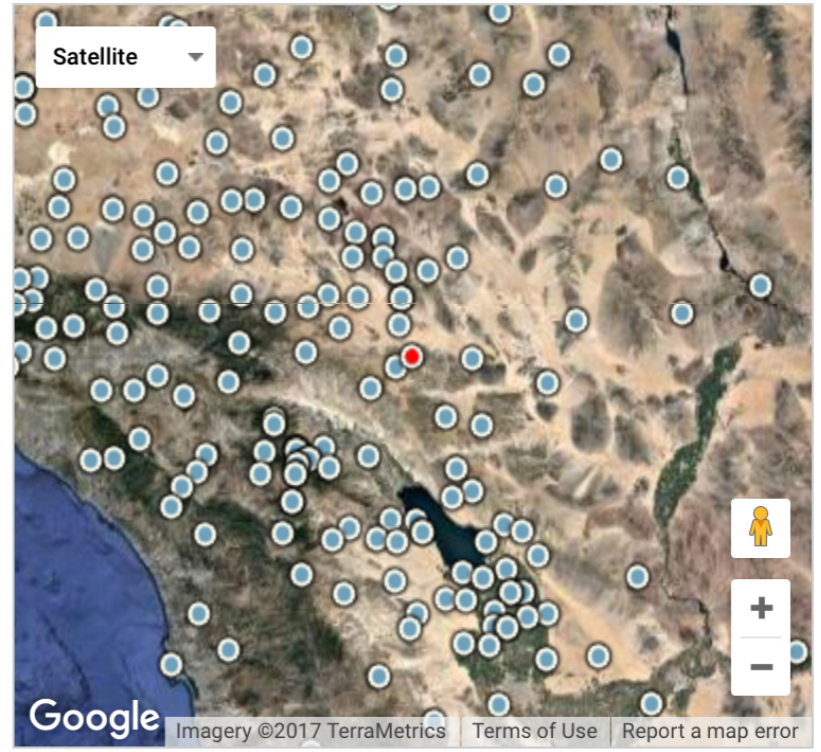
IGS08 Reference Frame

X/Y/Z (m/m/m):	-2320746.2798	-4758616.0859	3547263.8166
Ref Epoch**:	2016.434		

*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.

Nearby Stations Map



Local Weather Data

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

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Related Links

- [PBO Project Overview](#)

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BEMT - Overview | PBO Station Page

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- Maintenance
- Photos

BEMT Station Overview



Station Type: GPS

Station Information

Station Status: Installed/Operable
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Station Name: BEMT_SCGN_CS2001
Location (City, State): Twentynine Palms, CA
Monument Type: DDBM
Station Install Date: 2001-11-15

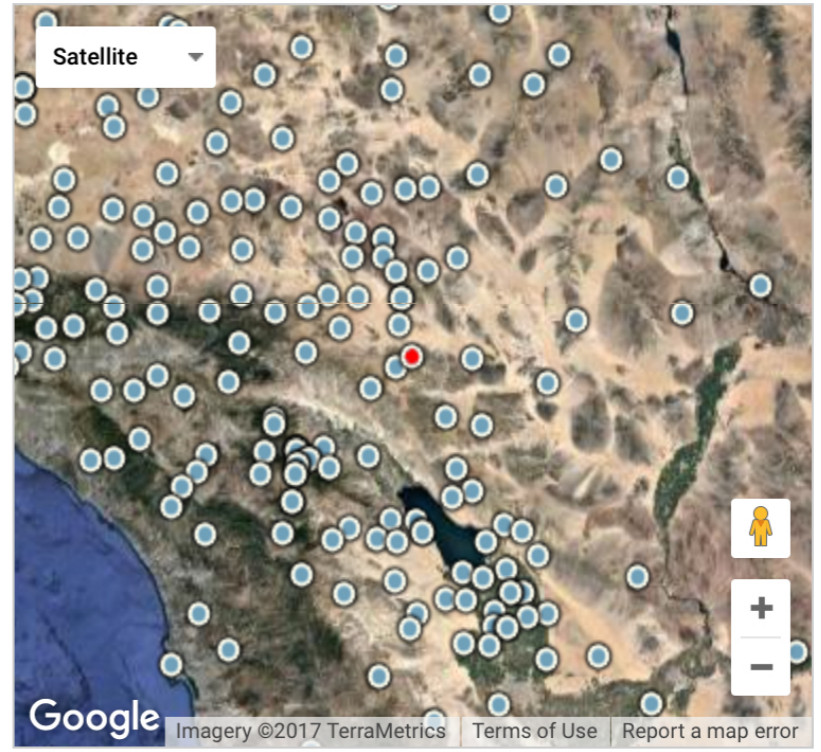
Station Data

IGS Site Log: [Text File](#)
Installation Report: [BIRT Report](#)
Time Series Data: [NAM08 CSV](#) | [IGS08 CSV](#)
Time Series Plot Viewer: [Nearby GPS Plots](#)
Realtime Dataflow: [Available](#)
Meteorologic Plots: Not Available

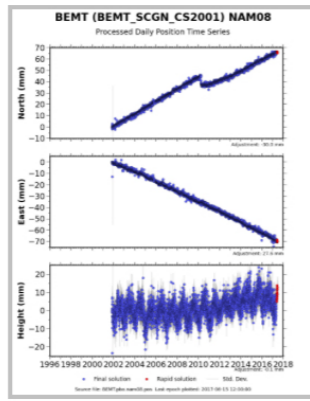
Colocated Instruments

None

Nearby Stations Map



Station Position



GPS Monument Coordinates

Approximate Geographic Coordinates

lat/lon/elev (d/d/m)*: 34.00053 -115.99819 1374

IGS08 Reference Frame

X/Y/Z (m/m/m): -2320746.2798 -4758616.0859 3547263.8166
Ref Epoch:** 2016.434

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 ** 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.

Local Weather Data

METAR: [KNXP](#) **DATE:** unavailable
COND: unavailable **TEMP:** unavailable
HUMIDITY: unavailable **WIND:** unavailable

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PBO station BEMT in
Twentynine Palms,
California

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BEMT - Overview | PBO Station Page

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BEMT Station Overview

Station Type: GPS

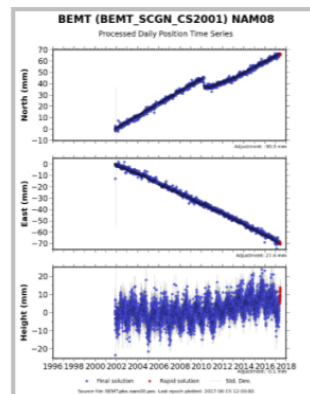


Station Information	
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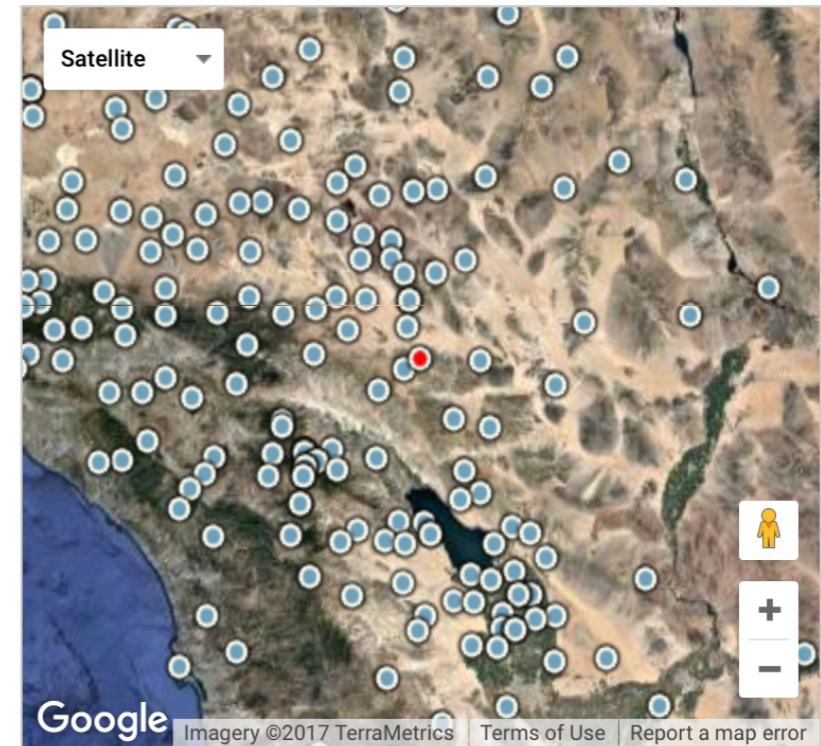
Station Data	
IGS Site Log:	Text File
Installation Report:	BIRT Report
Time Series Data:	NAM08 CSV IGS08 CSV
Time Series Plot Viewer:	Nearby GPS Plots
Realtime Dataflow:	Available
Meteorologic Plots:	Not Available

Colocated Instruments	
None	

Station Position



Nearby Stations Map



Local Weather Data	
METAR:	KNXP
COND:	unavailable
HUMIDITY:	unavailable
DATE:	unavailable
TEMP:	unavailable
WIND:	unavailable

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GPS Monument Coordinates

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BEMT - Overview | PBO Station Page

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BEMT Station Overview

Station Type: GPS



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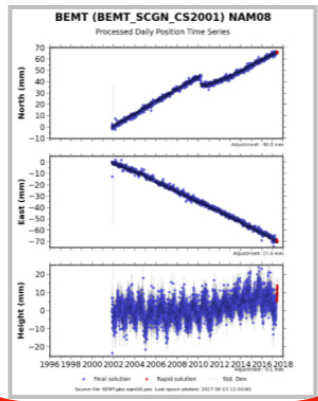
Station Data

IGS Site Log:	Text File
Installation Report:	BIRT Report
Time Series Data:	NAM08 CSV IGS08 CSV
Time Series Plot Viewer:	Nearby GPS Plots
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Colocated Instruments

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GPS Monument Coordinates

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------------------------	----------	------------	------

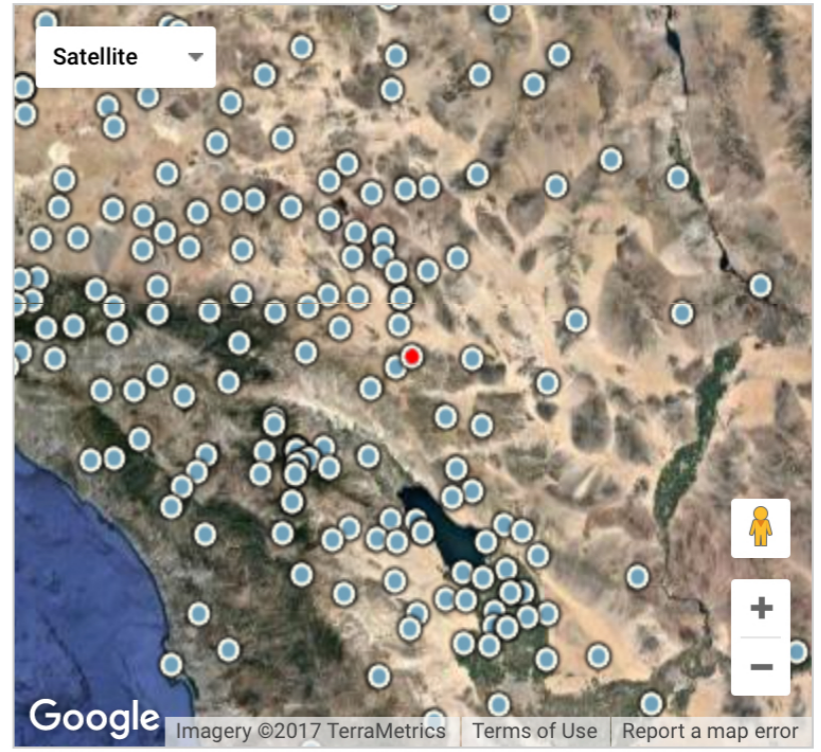
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Nearby Stations Map

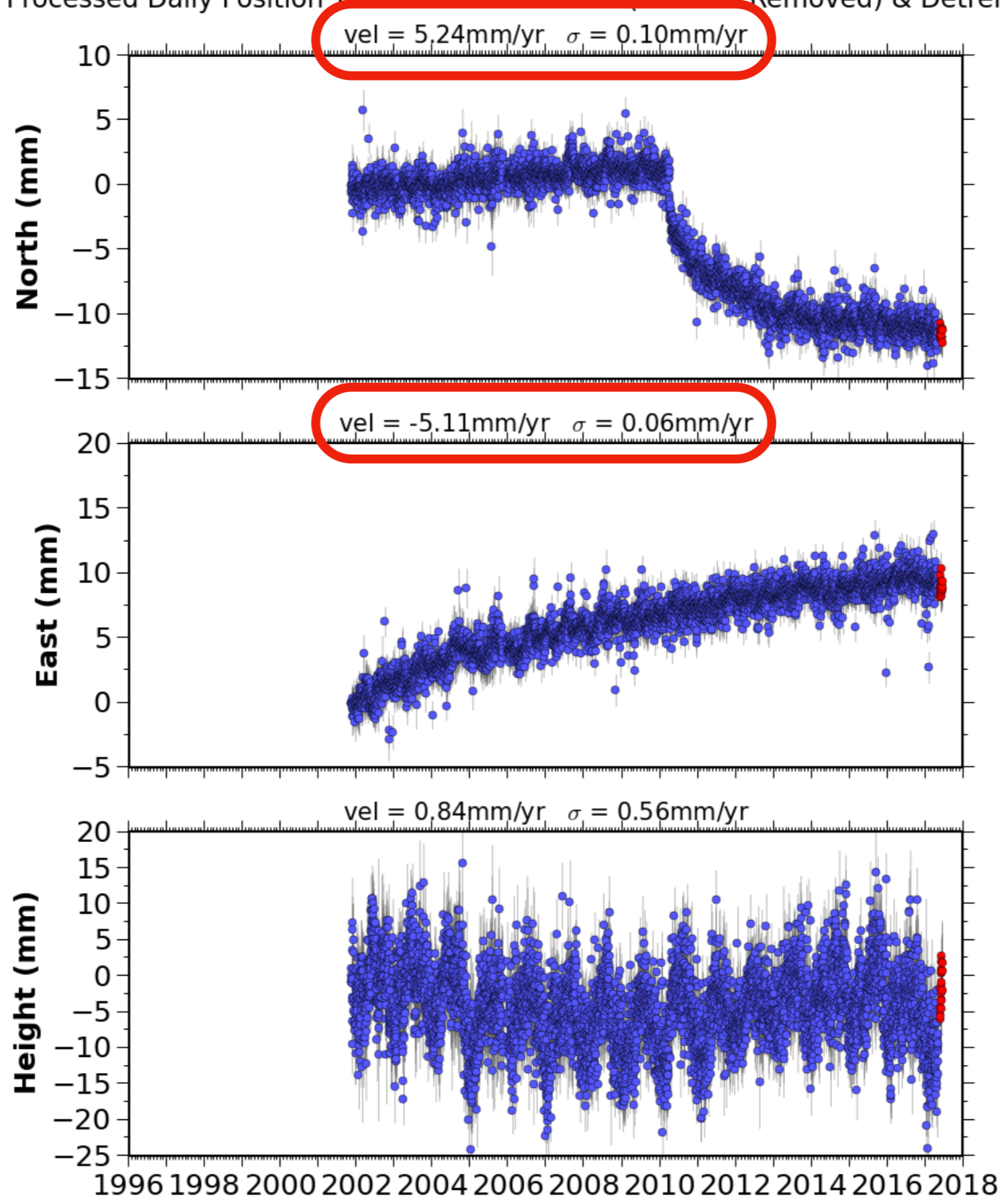


Local Weather Data

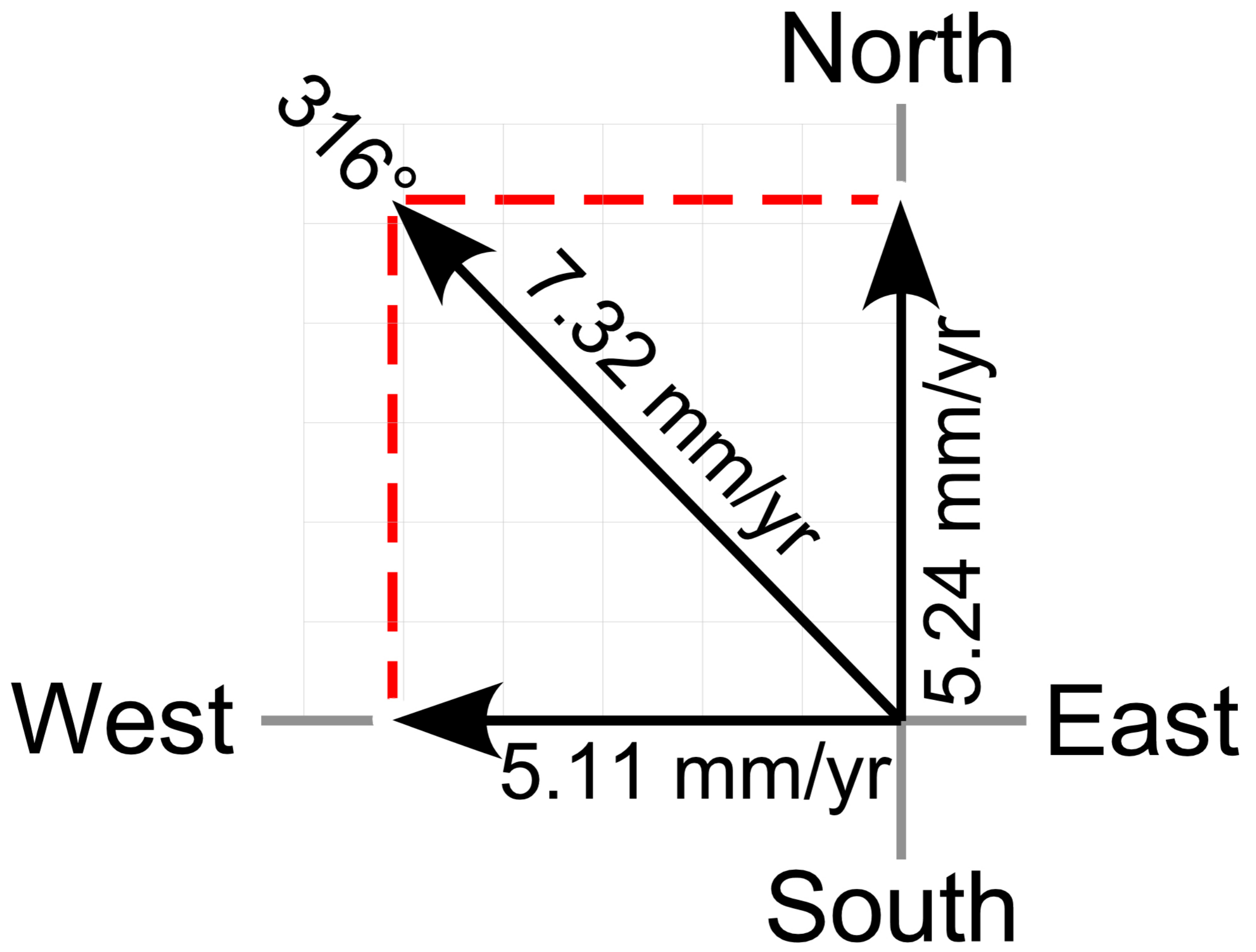
METAR: KNXP	DATE: unavailable
COND: unavailable	TEMP: unavailable
HUMIDITY: unavailable	WIND: unavailable

BEMT (BEMT_SCGN_CS2001) NAM08

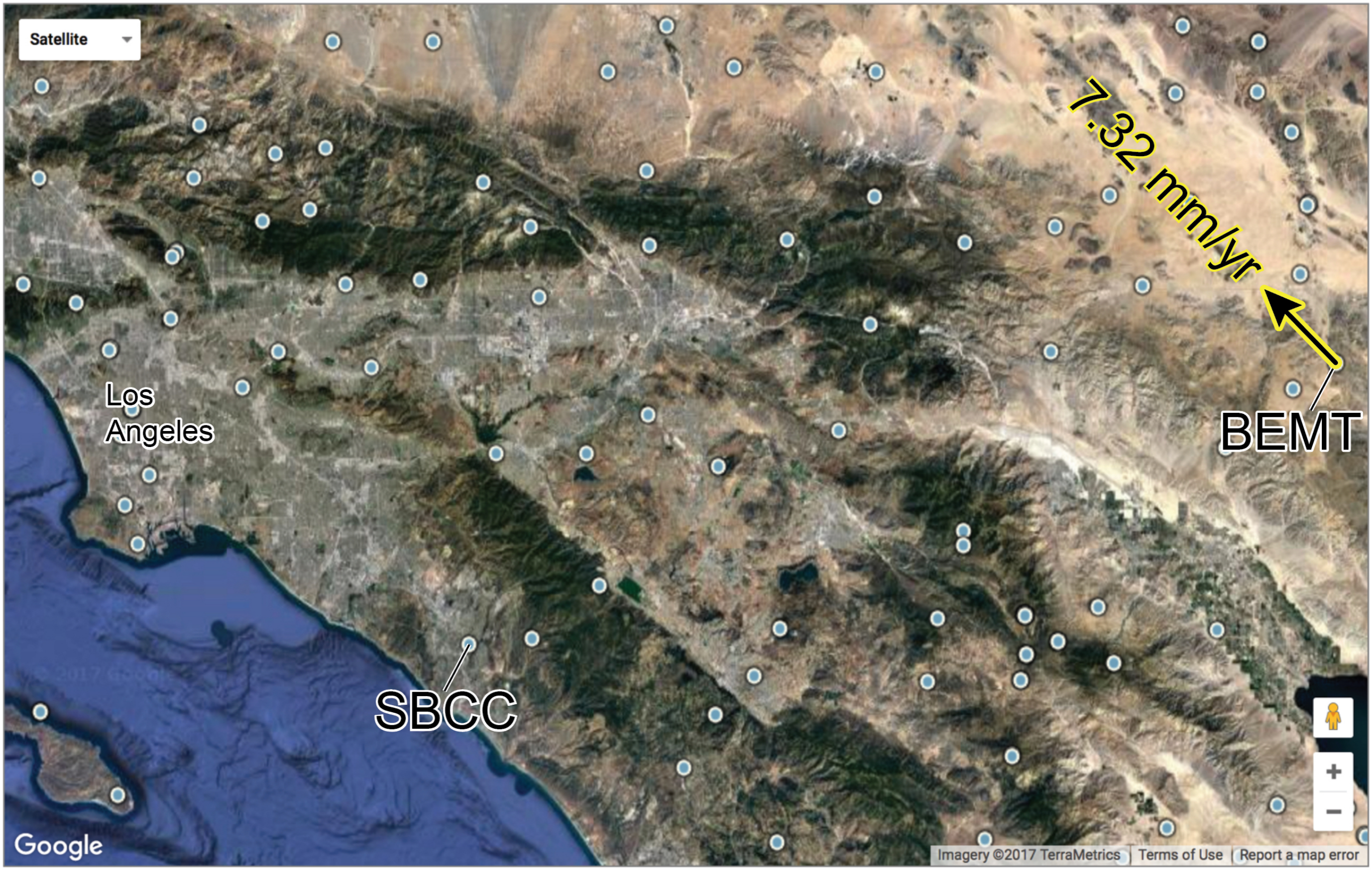
Processed Daily Position Time Series - Cleaned (Outliers Removed) & Detrended



• Final solution • Rapid solution — Std. Dev.



PBO Network Map



PBO Network Map



Satellite

Los Angeles

38.35 mm/yr

SBCC

7.32 mm/yr

BEMT

Google

Imagery ©2017 TerraMetrics Terms of Use Report a map error

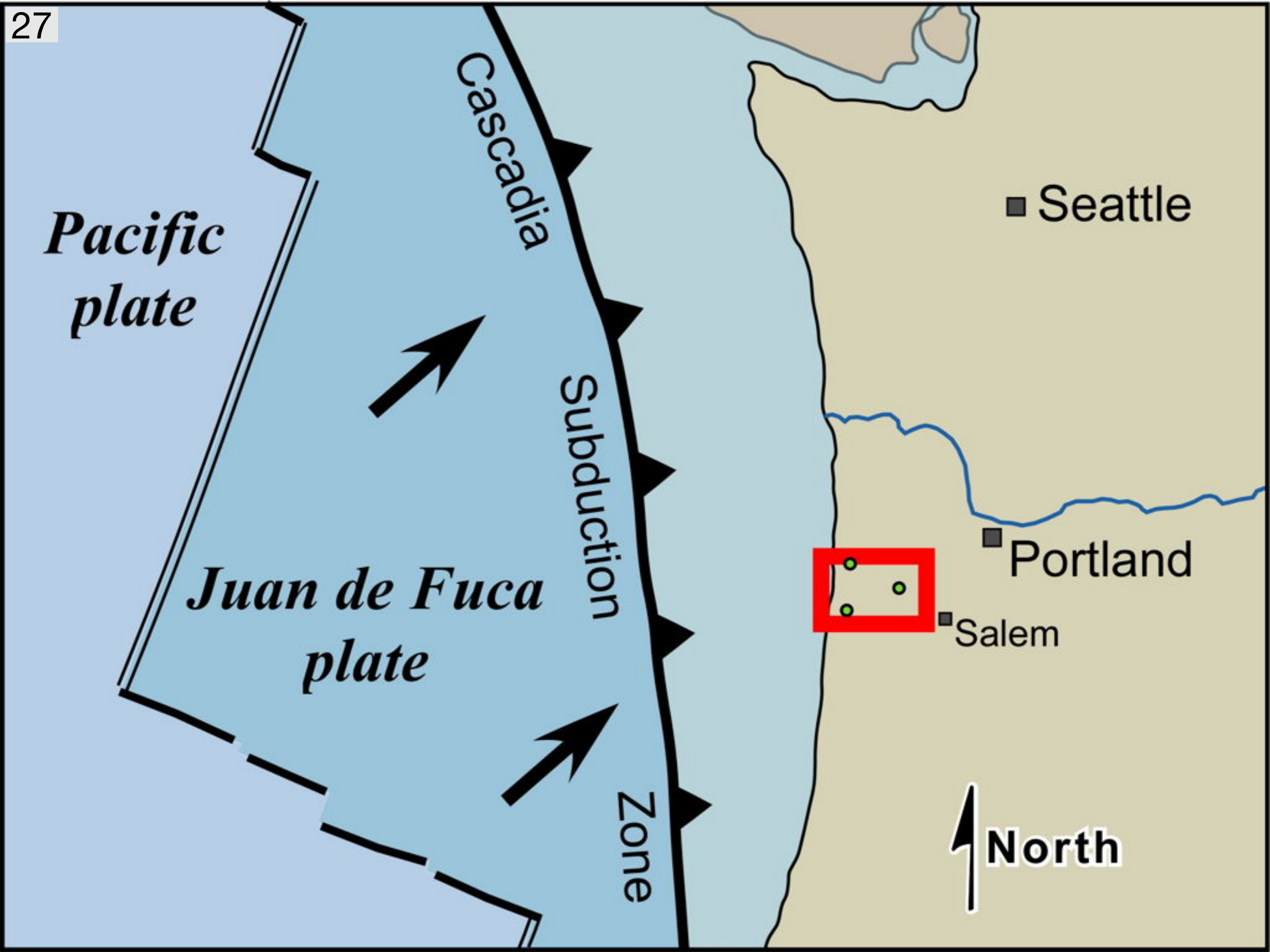


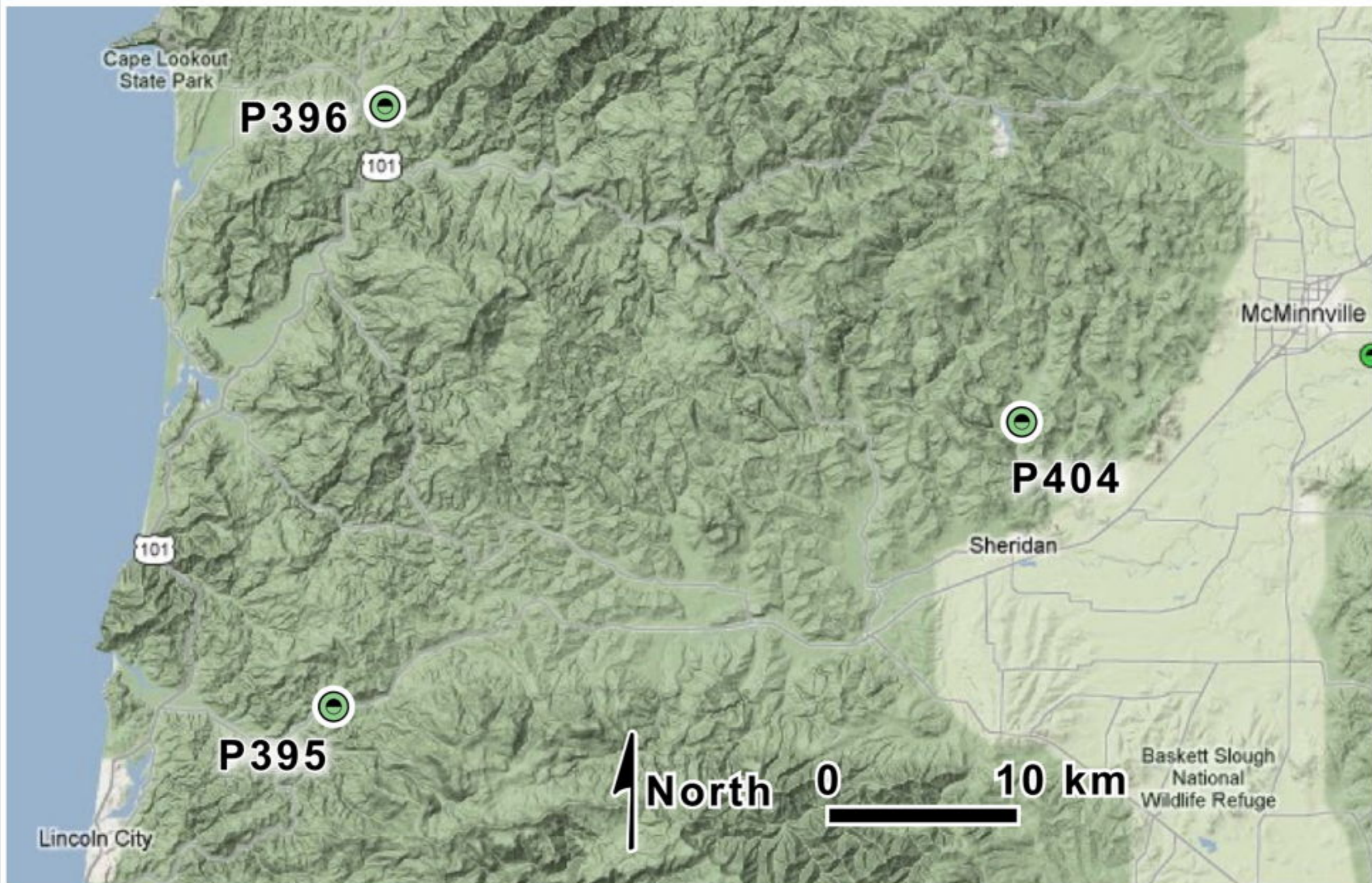
USGS Quaternary Fault and Fold Database of the United States

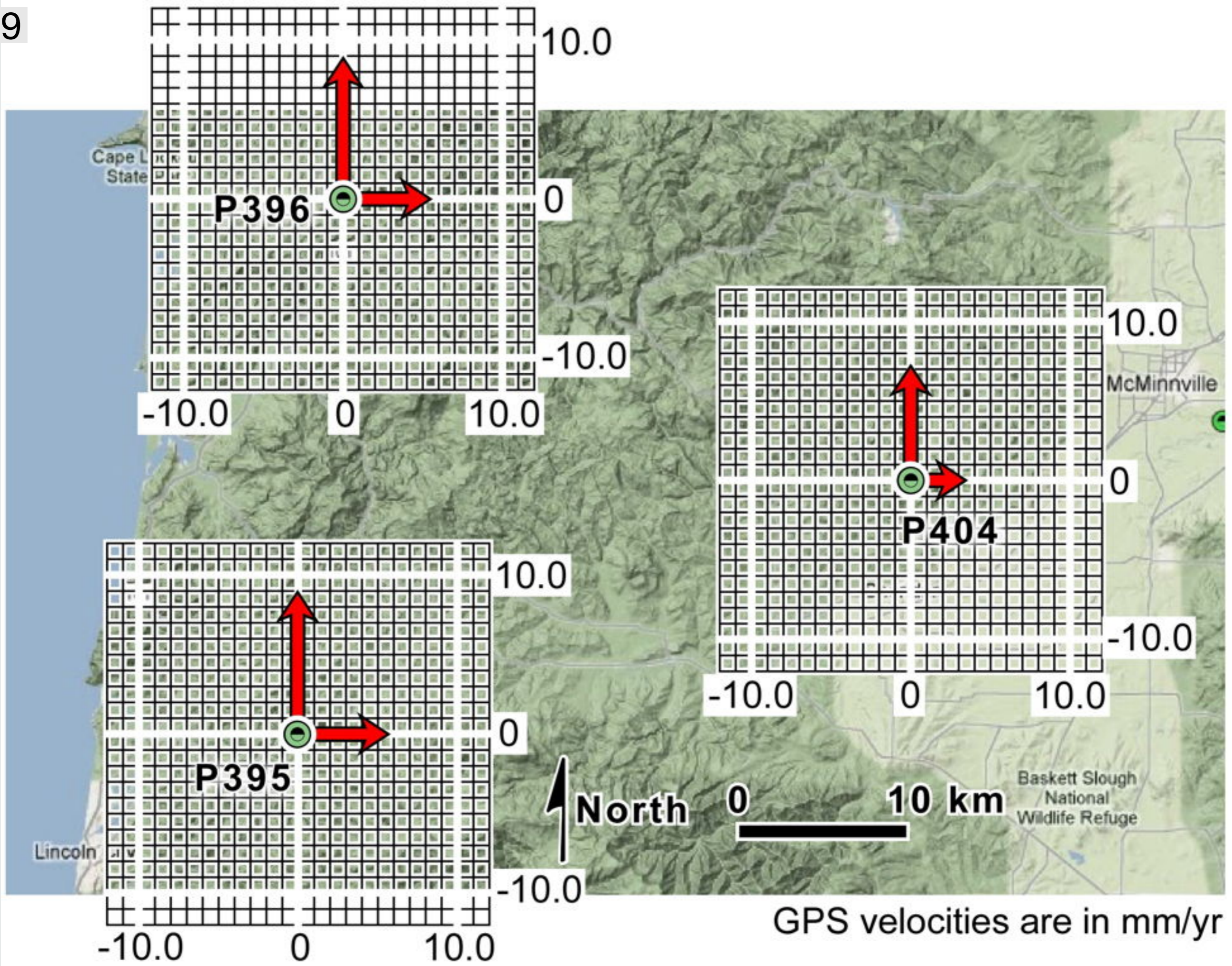
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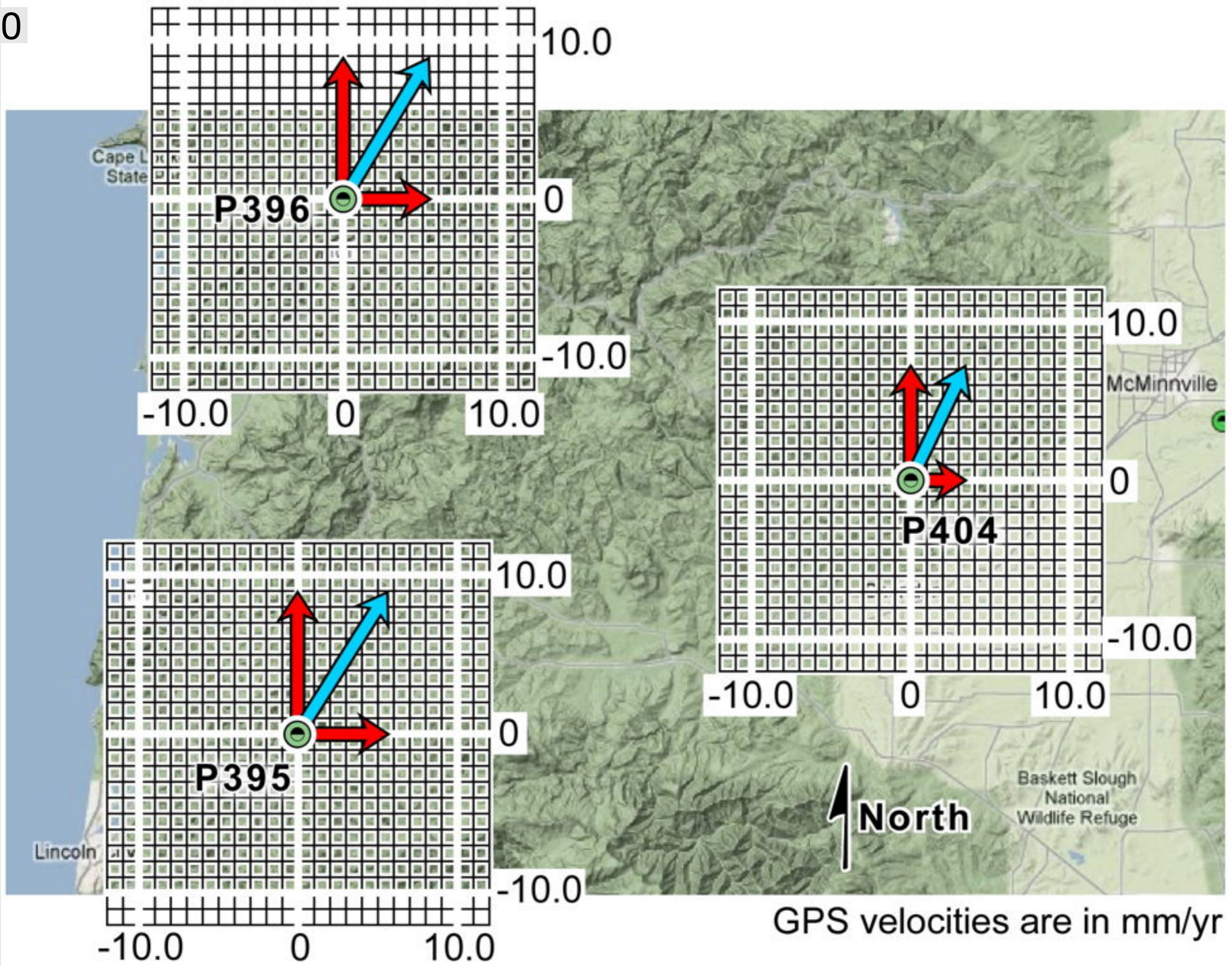


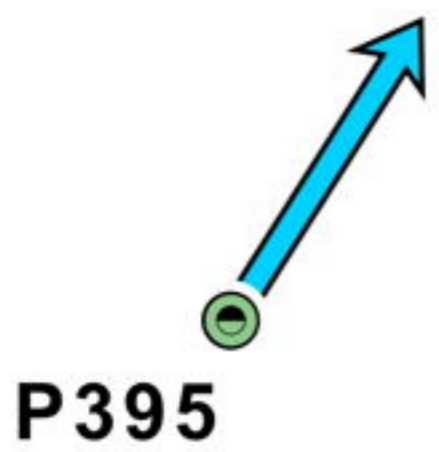
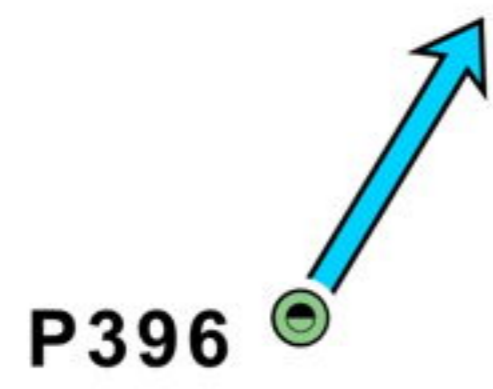


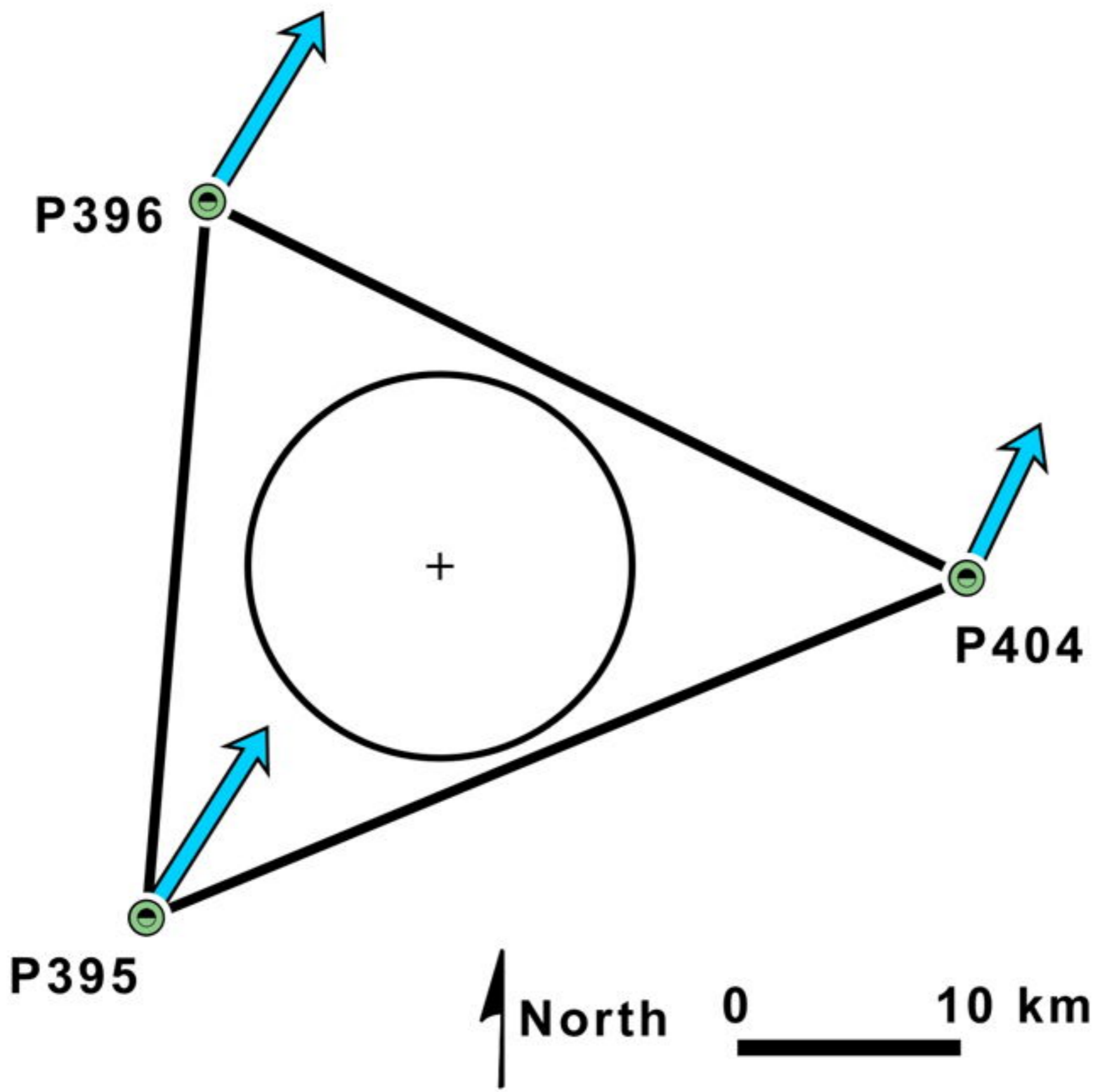


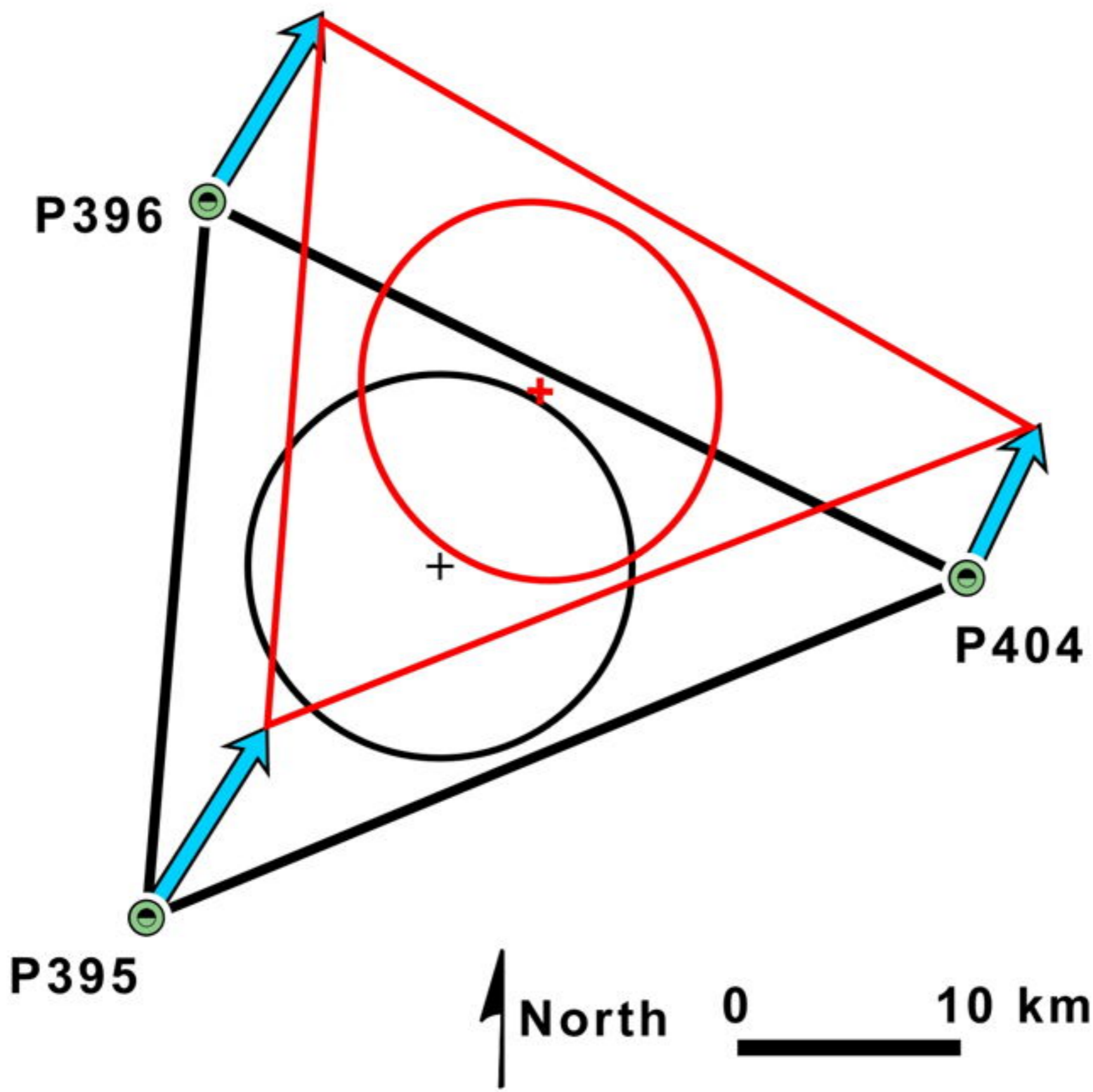


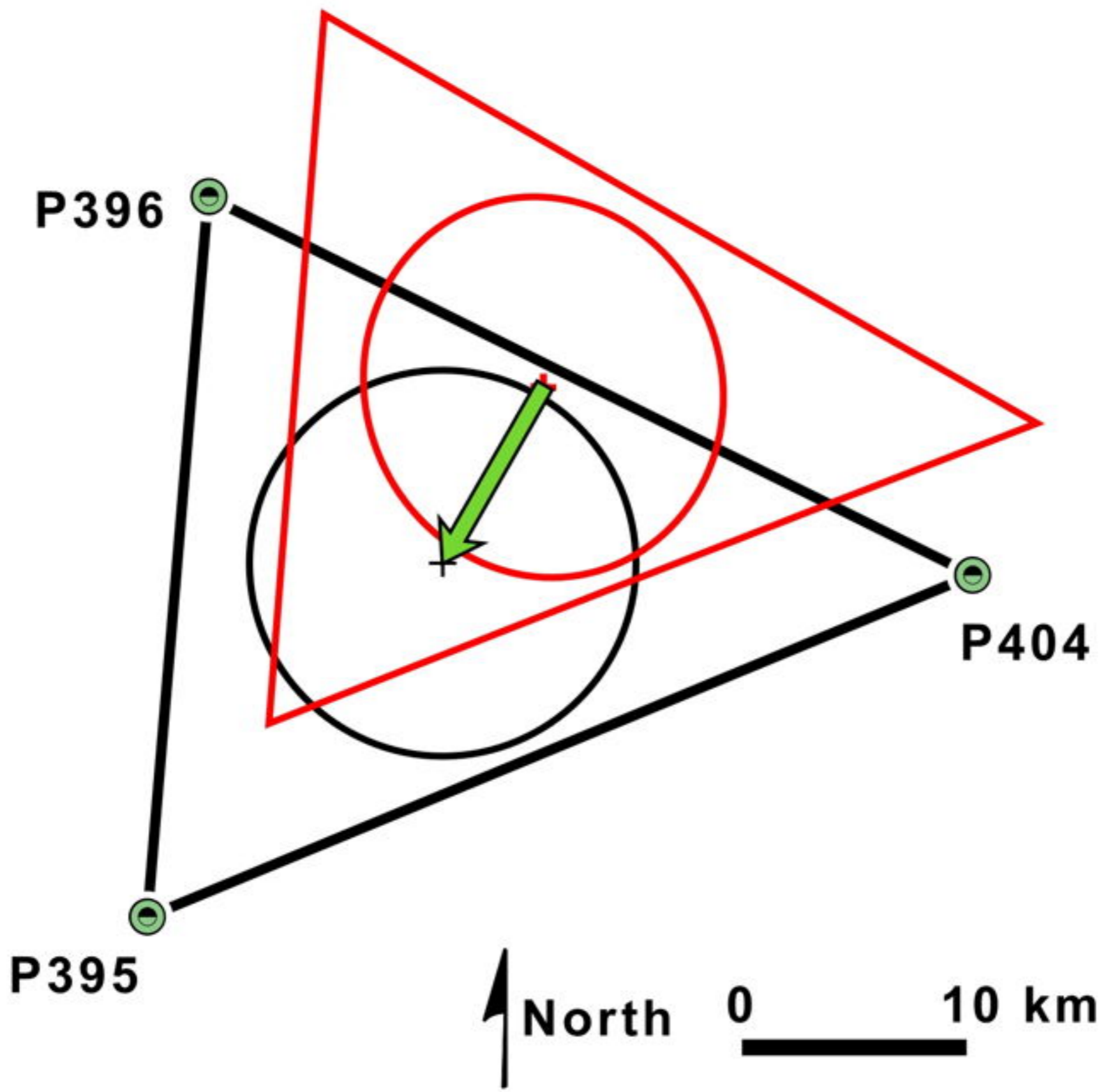


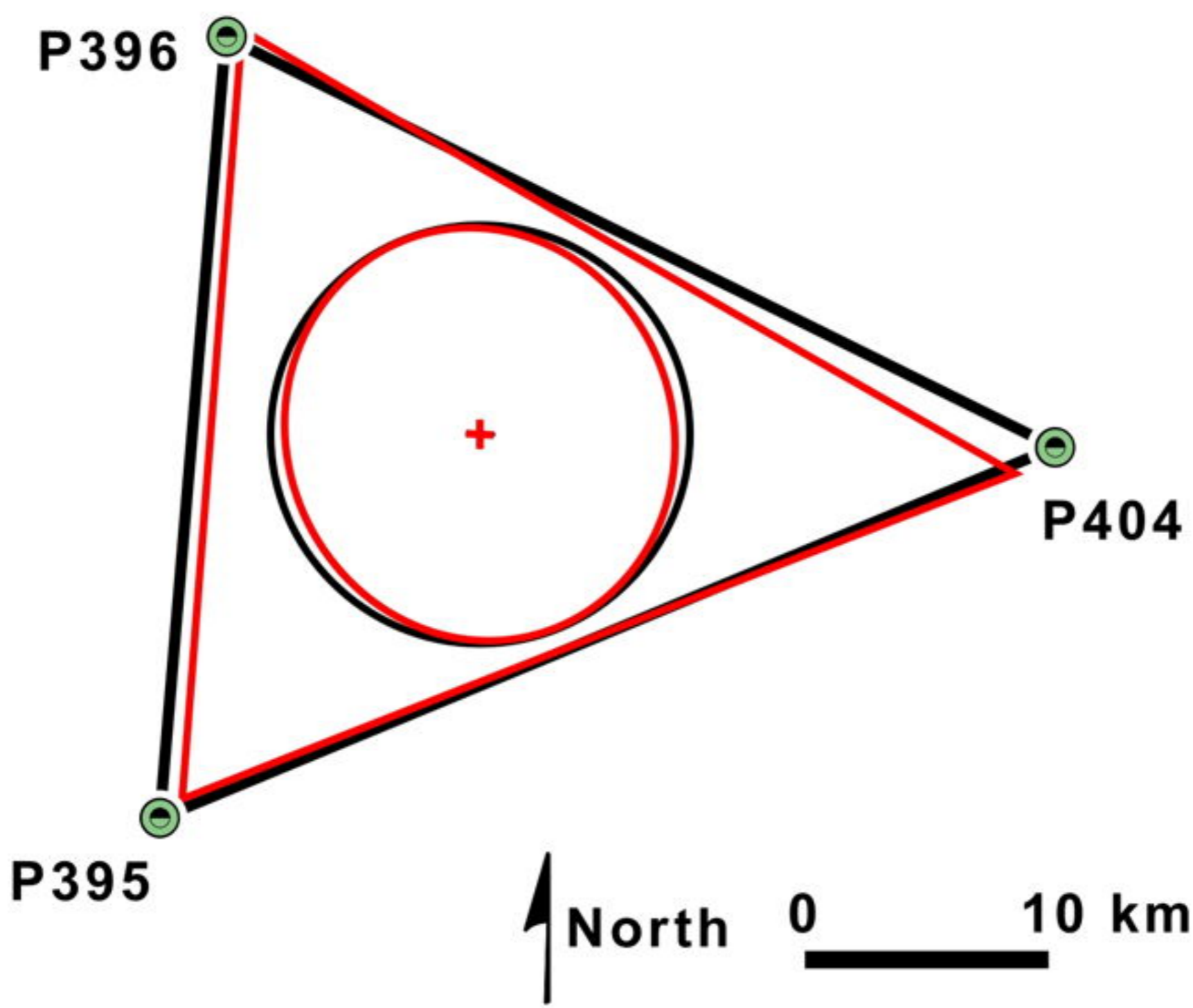




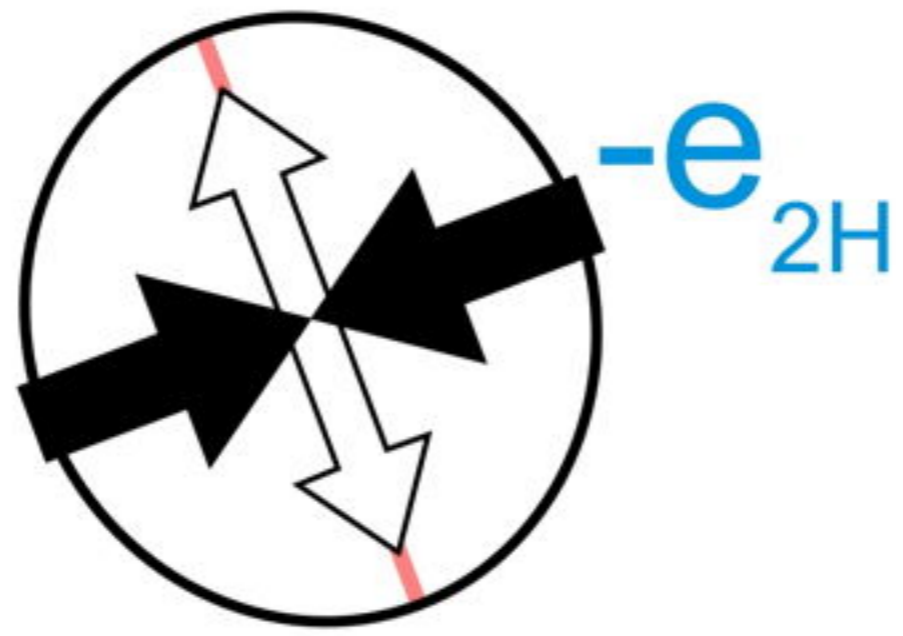








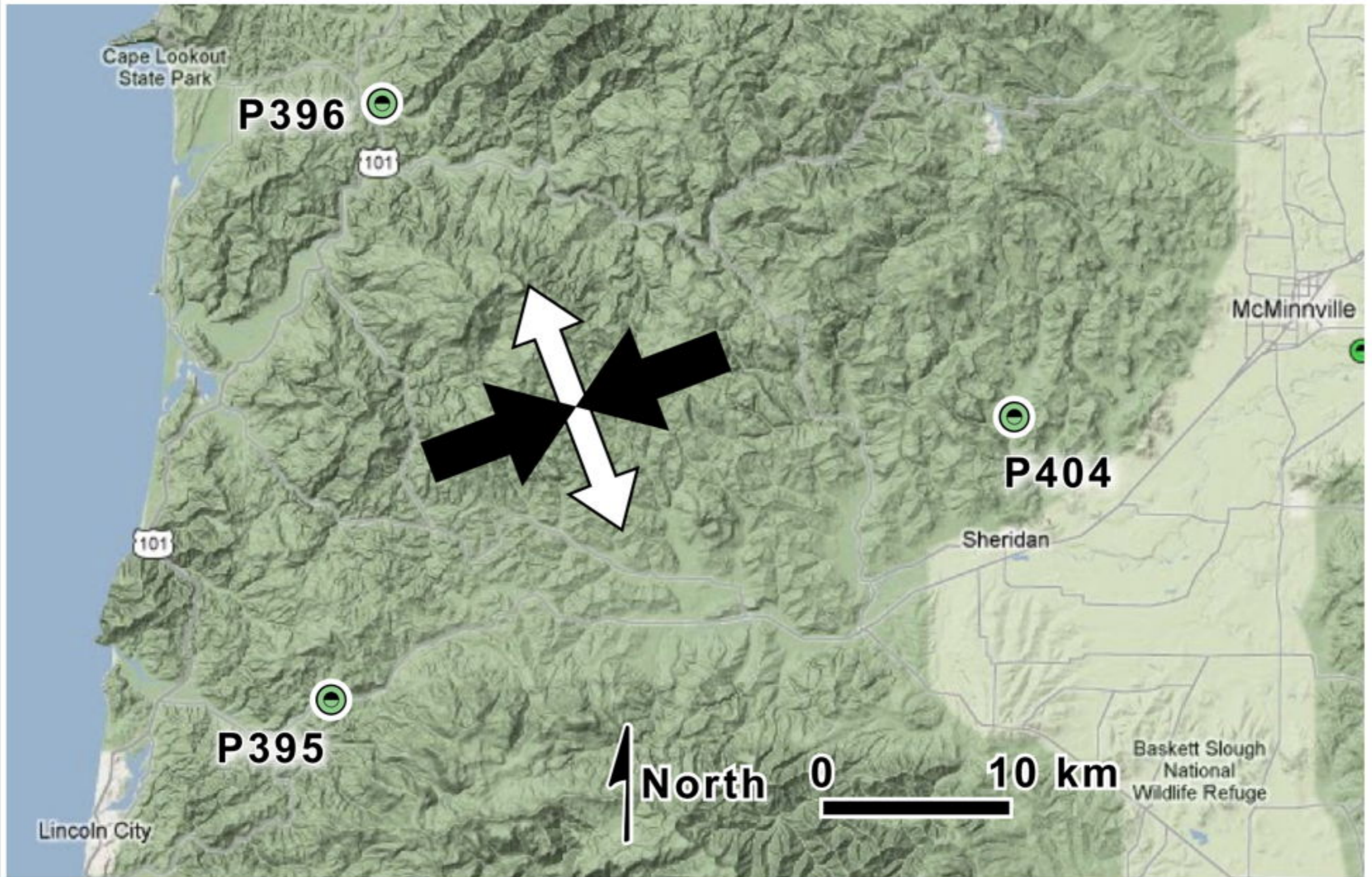
P396 

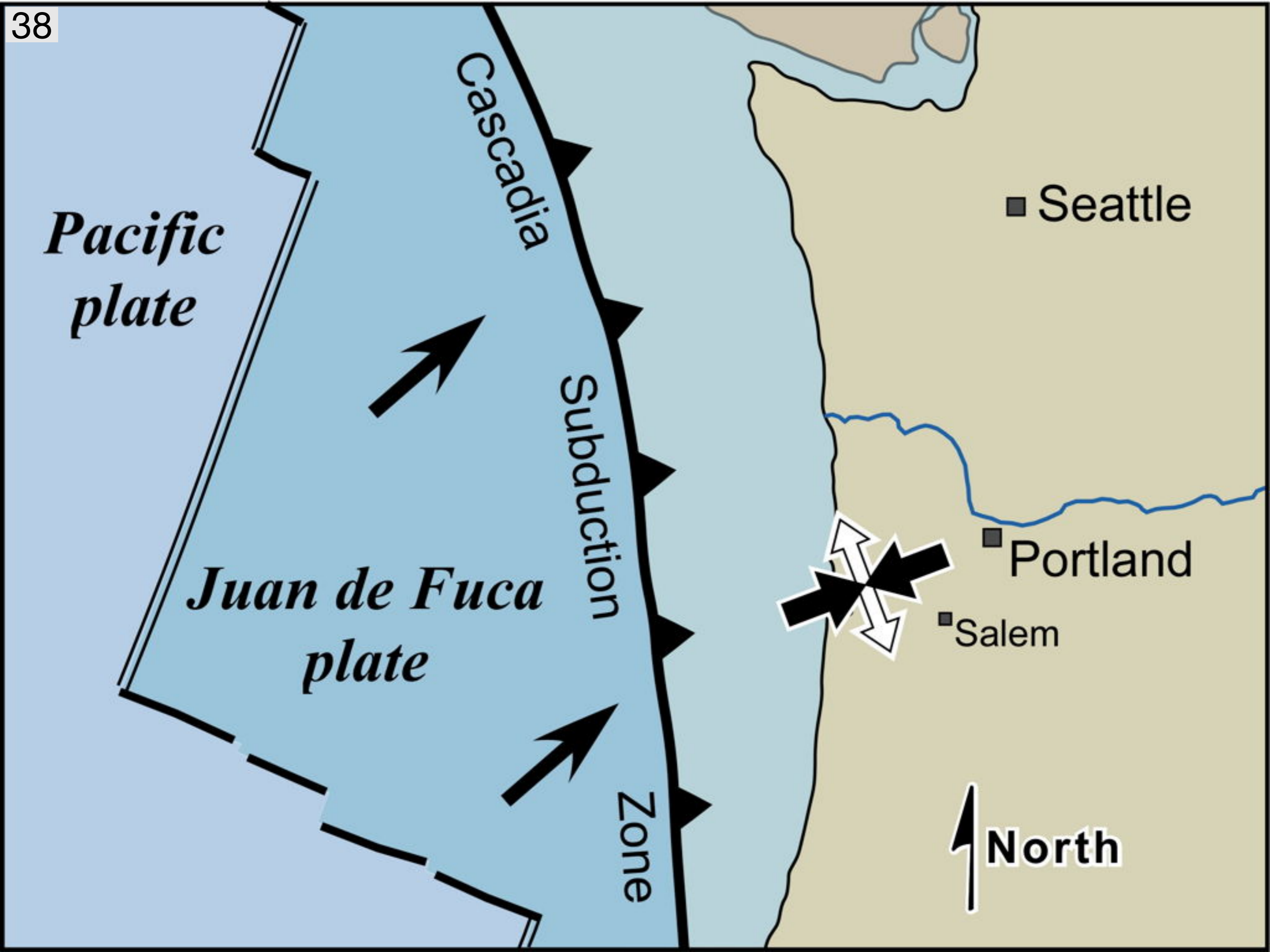



P404

P395 







Pacific plate

Juan de Fuca plate

Cascadia

Subduction

Zone

■ Seattle

■ Portland

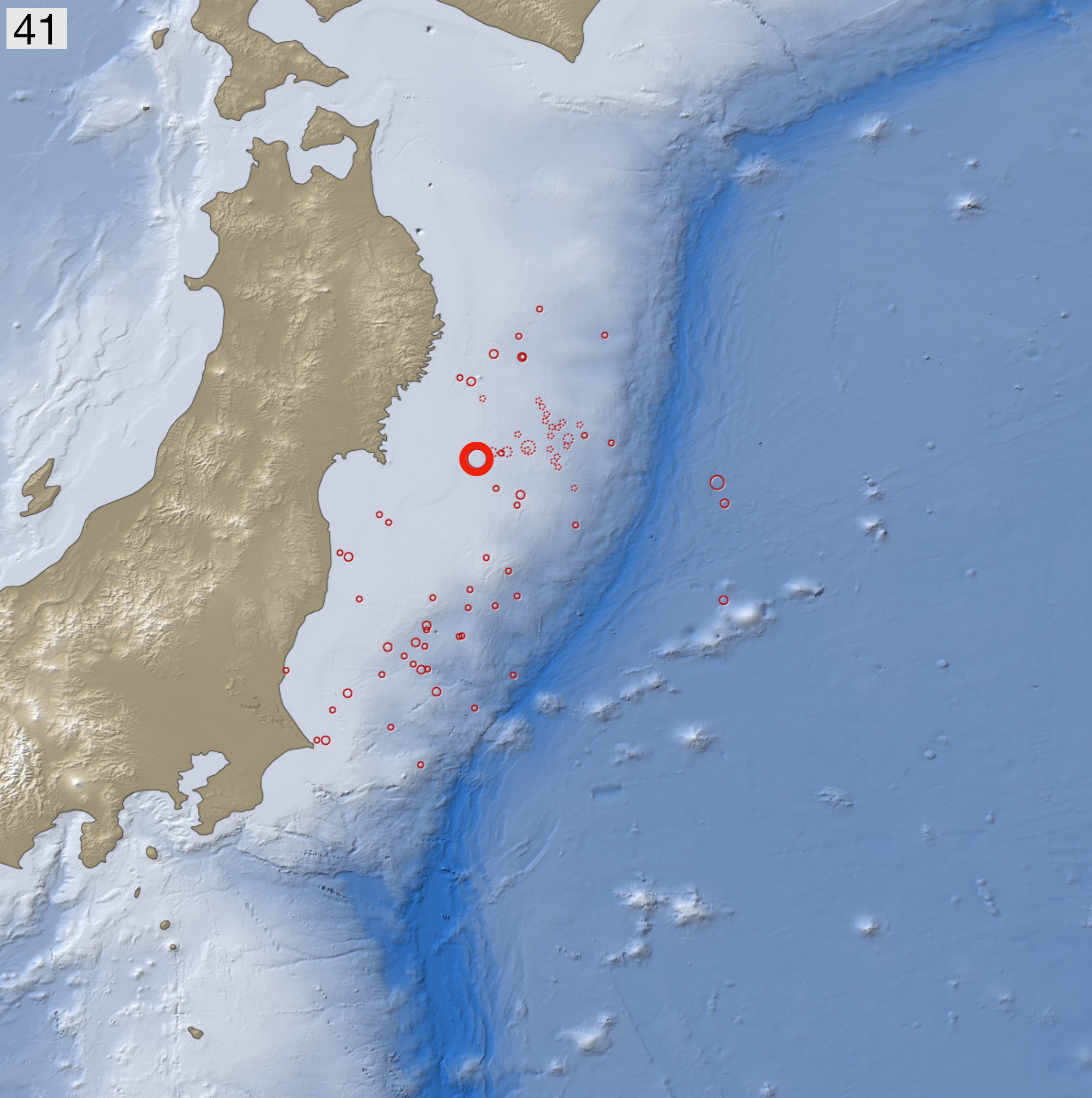
■ Salem

↑ North

	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)	(m/yr)
11		P395	-123.857526308	45.022279723	5.57	0.01	8.80	0.01
12		P396	-123.822895924	45.309513198	5.30	0.02	8.75	0.02
13		P404	-123.390327353	45.158534252	3.36	0.01	7.05	0.01
14								
15	Primary Output Data							
16	Translation Vector							
17		E component \pm uncert (m/yr)	0.0047	\pm	8.16497E-06			
18		N component \pm uncert (m/yr)	0.0082	\pm	8.16497E-06			
19		Azimuth (degrees)	30.0					
20		Speed (m/yr)	0.0095					
21		Rotation \pm uncertainty (degrees/yr)	-0.00000131	\pm	0.00000002			
22		Rotation \pm uncertainty (nano-rad/yr)	-22.9284	\pm	0.4145			
23		Direction of rotation	clockwise					
24		Max horizontal extension (e1H) (nano-strain)	12.4212					
25		Azimuth of S1H (degrees)	160.1043	or	340.1042865			
26		Min horizontal extension (e2H) (nano-strain)	-68.1043					
27		Azimuth of S2H (degrees)	70.1043	or	250.1042865			
28		Max shear strain (nano-strain)	80.5255					
29		Area strain (nano-strain)	-55.6831					



View of Miho and the snowy cone of Mount Fuji, 1687. From Atwater and others, 2015.



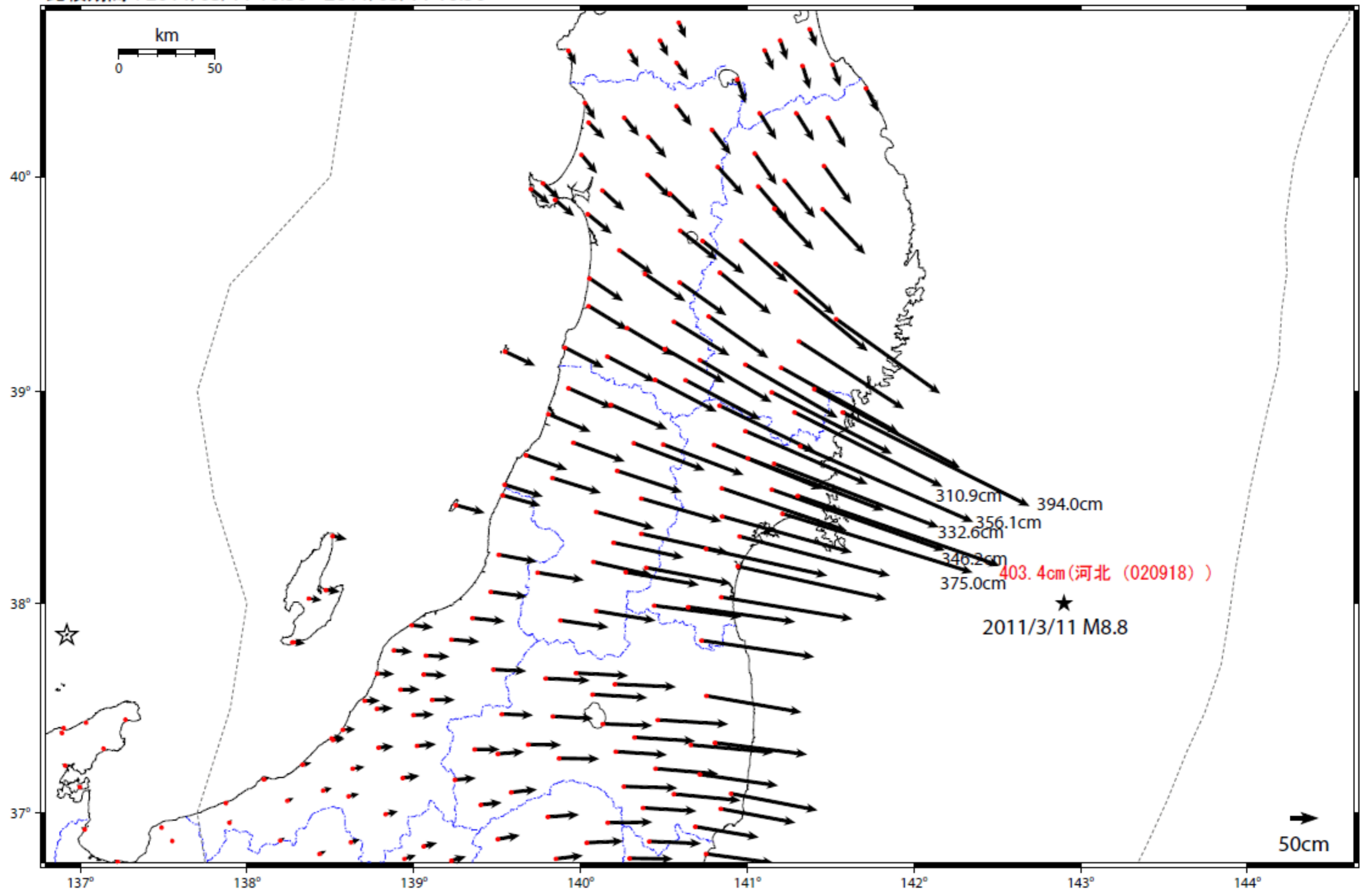
M9–9.1
Tohoku
earthquake of
7 April 2011,
along with
the
epicenters of
some of its
major
aftershocks



**Aftermath of M9
earthquake and tsunami,
Tohoku, northeastern
Honshu, Japan, 2011**

変動ベクトル図 (水平)

基準期間 : 2011/03/01 21:00 - 2011/03/08 21:00
比較期間 : 2011/03/11 16:30 - 2011/03/11 16:30



[基準 : R3速報解 比較 : S3迅速解]

☆固定局 : 船倉島 (950252)



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www.nvcr.com

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MAIN ST
CLINTON ST

ROAD
CLOSED

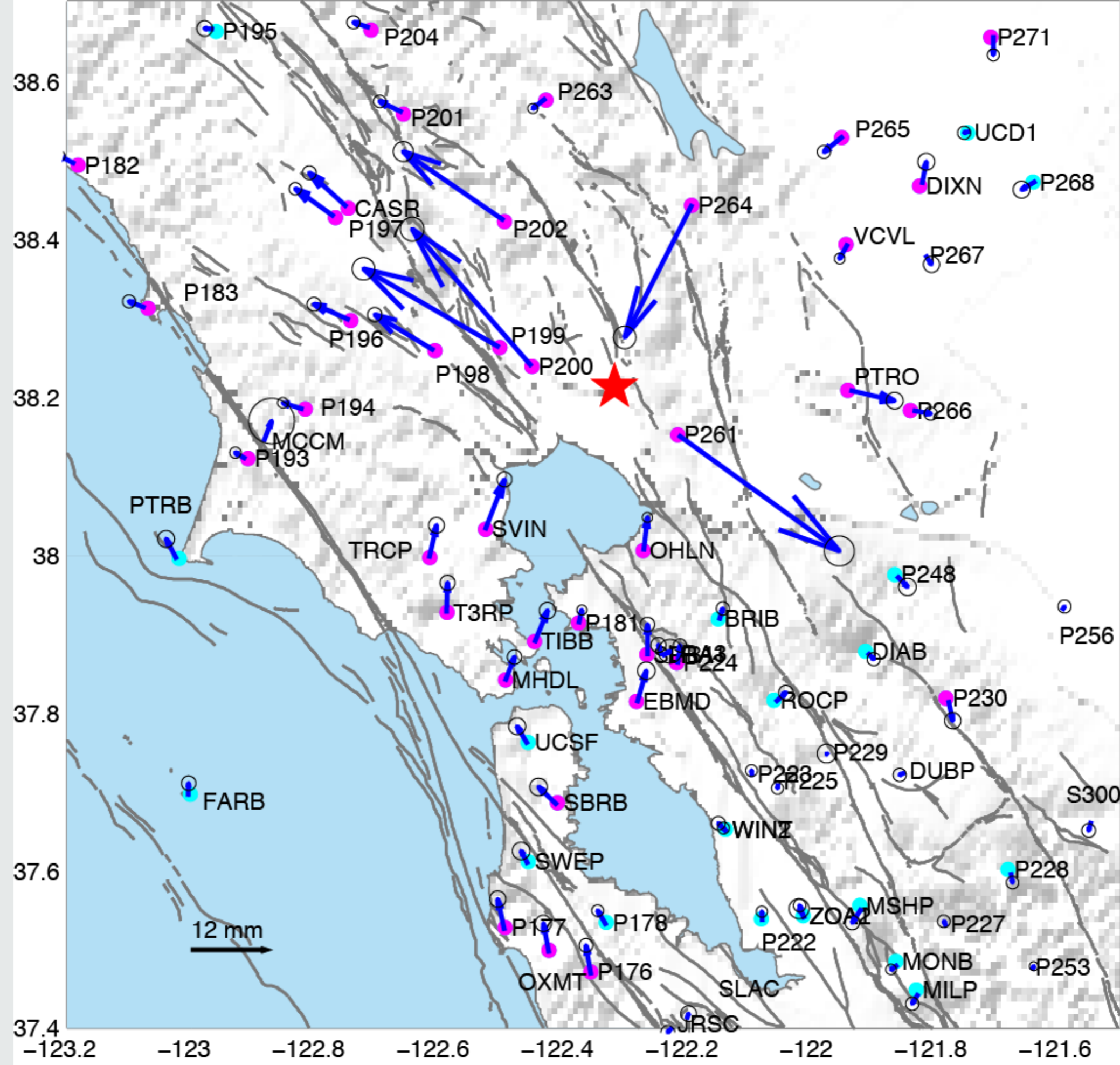
ROAD
CLOSED

CITY OF NAPA
WATER DIVISION

ROAD
CLOSED

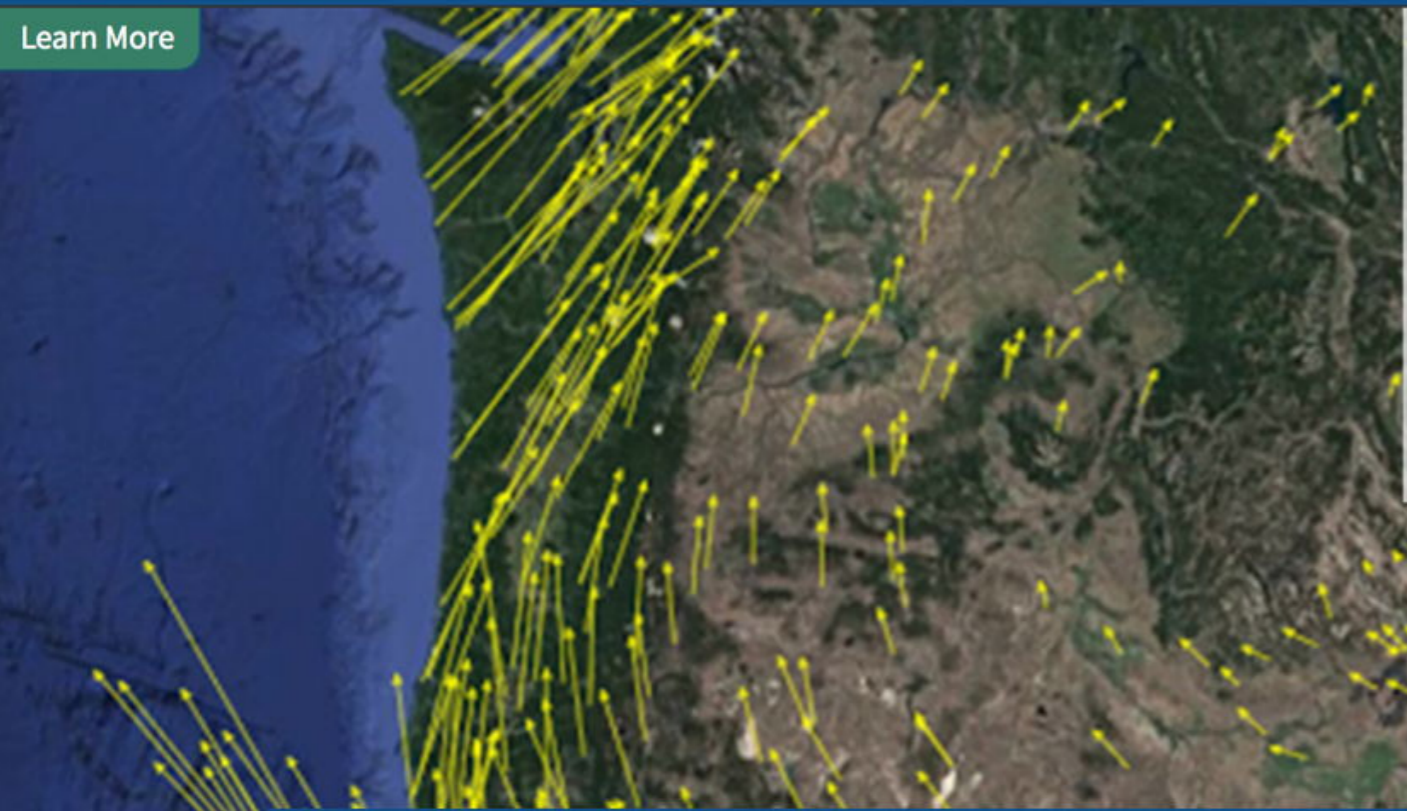
CITY OF NAPA





Cyan = over 1 sigma, Magenta = over 2 sigma

[Learn More](#)



GPS, Strain, and Earthquakes



Vince Cronin (Baylor University)
Phillip Resor (Wesleyan University)
 Technical Advisors: Bill Hammond and Corné Kreemer (University of Nevada Reno)
 Editor: Beth Pratt-Sitaula (UNAVCO)

Summary

Understanding how the Earth's crust deforms is crucial in a variety of geoscience disciplines, including structural geology, tectonics, and hazards assessment (earthquake, volcano, landslide). With the installation of numerous high precision Global Positioning System (GPS) stations, our ability to measure this deformation (strain) has increased dramatically, but GPS data are still only rarely included in undergraduate courses, even for geoscience majors. In this module students analyze GPS velocity data from triangles of adjacent GPS stations to determine the local strain. Students learn about strain, strain ellipses, GPS, and how to tie these to regional geology and ongoing societal hazards. A case study from the 2014 South Napa earthquake helps students make connections between interseismic strain and earthquake displacements.