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

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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 name and location of the site, as well as a clickable link to more information at https://www.unavco.org/instrumentation/networks/status/pbo/overview/P395

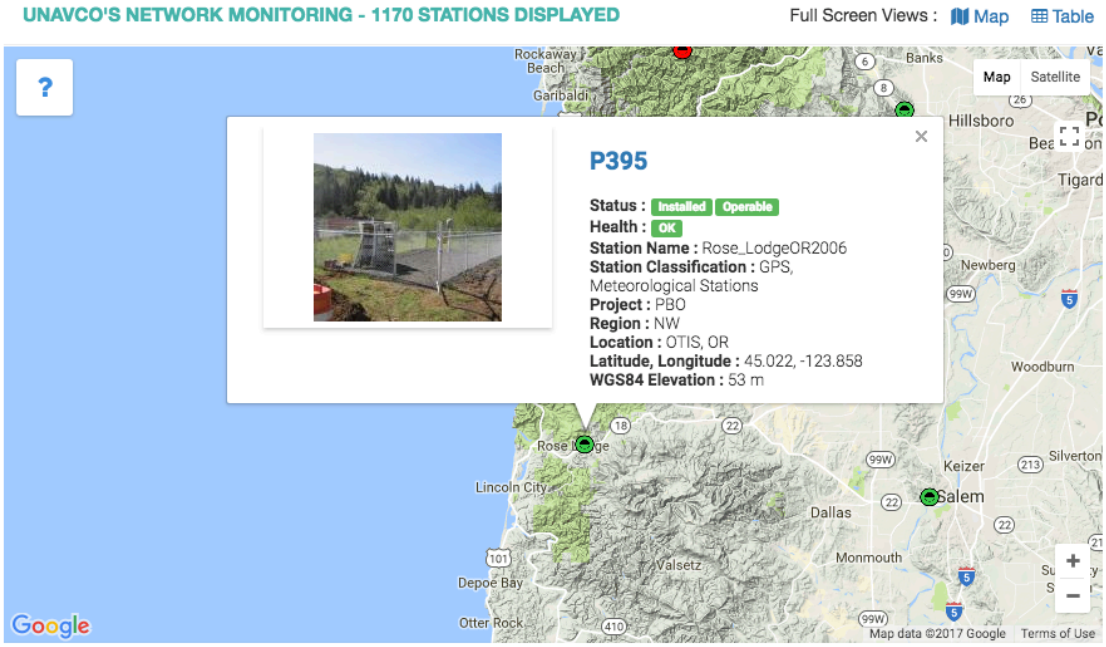


Figure 1. Interactive Plate Boundary Observatory station viewer – zoomed to the area around station P395 in northwest Oregon (west of Salem). Inset window provides some data and a clickable link for more data about site P395. From https://www.unavco.org/instrumentation/networks/status/pbo/gps.

The overview page provides us with some information that we will need, and even some resources we might not need (such as a picture of the station) but is nice to have (Figure 2).

Figure 2. Plate Boundary Observatory Station P395 just northeast of Lincoln City, Oregon. From https://www.unavco.org/instrumentation/networks/status/pbo/photos/P395

Near the bottom on the left side of the P395 overview page is a box titled "GPS Monument Coordinates." The station location is listed on the line that begins "lat/log/elev (d/d/m)." The first number is the site latitude with positive values indicating north latitude (geographic coordinate system in the WGS84 datum). The second number is the longitude, with negative indicating west longitude. The third number is the elevation in meters relative to the WGS84 ellipsoid – that is, it is not the elevation relative to mean sea level, as might be indicated on a USGS topographic map. On September 16, 2015, those data for site P404 were

Latitude 45.02228° (positive is north latitude)
Longitude -123.85753° (negative is west longitude)
Elevation of 53 meters above the WGS84 datum

Carefully record* the latitude and longitude, with all of the decimal places. The sign of the longitude is important. These data will be part of the input for the strain calculator that we will use later in this process.

*Recording sheets are at the end of this document.

Finding station velocities

Now we need to acquire the velocity data for the site. Returning to the overview page for site P395, mid-way along the left side of the page there is a box labeled "Station Position" with three graphs. Clicking on the box causes the window to expand. The three plots show the change in position as a function of time – that is, they are *time-series plots*. The upper plot shows change in a north or south direction, the middle plot shows motion in an east or west direction, and the lowest plot shows motion in the up or down direction. These changes are measured relative to a reference frame that is computed relative to a set of GPS sites established in the stable interior of North America (called NAM14 for "North America 2014). Read more about references frames at http://www.unavco.org/software/visualization/GPS-Velocity-Viewer/GPS-Velocity-Viewer-frames.html

You can switch from the raw data view to a "cleaned" view to a "detrended" view using either the navigation arrows on your keyboard or by using the small control bar that should appear near the bottom of the plot window. Both the cleaned and detrended plots provide a numerical estimate of the mean velocity in each of the three directions along with the corresponding uncertainty (Figure 3). These velocities are frequently updated as new data are collected. We can also access the daily position data in a CSV spreadsheet file, and compute our own velocities and uncertainties.

On December 5, 2017, the posted velocities were:

North 8.66 ± 0.08 mm/yr (positive value indicates motion toward north)

East 6.92 ± 0.18 mm/yr (positive value indicates motion toward east)

Height 0.46 ± 0.30 mm/yr (negative value indicates motion down)

We can use these data and the Pythagorean Theorem to find the total site velocity

$$v_{site3D} = \sqrt{8.66^2 + 6.92^2 + (0.46)^2} = 11.095 \text{ mm/yr}$$

and the site mean horizontal velocity

$$v_{site2D} = \sqrt{8.66^2 + 6.92^2} = 11.085 \text{ mm/yr.}$$

Carefully record the velocities and their associated uncertainties. The signs of the velocities are important because they indicate the direction of the velocity vector. These data will be used along with the site latitude and longitude as input for the strain calculator we will use later in this process.

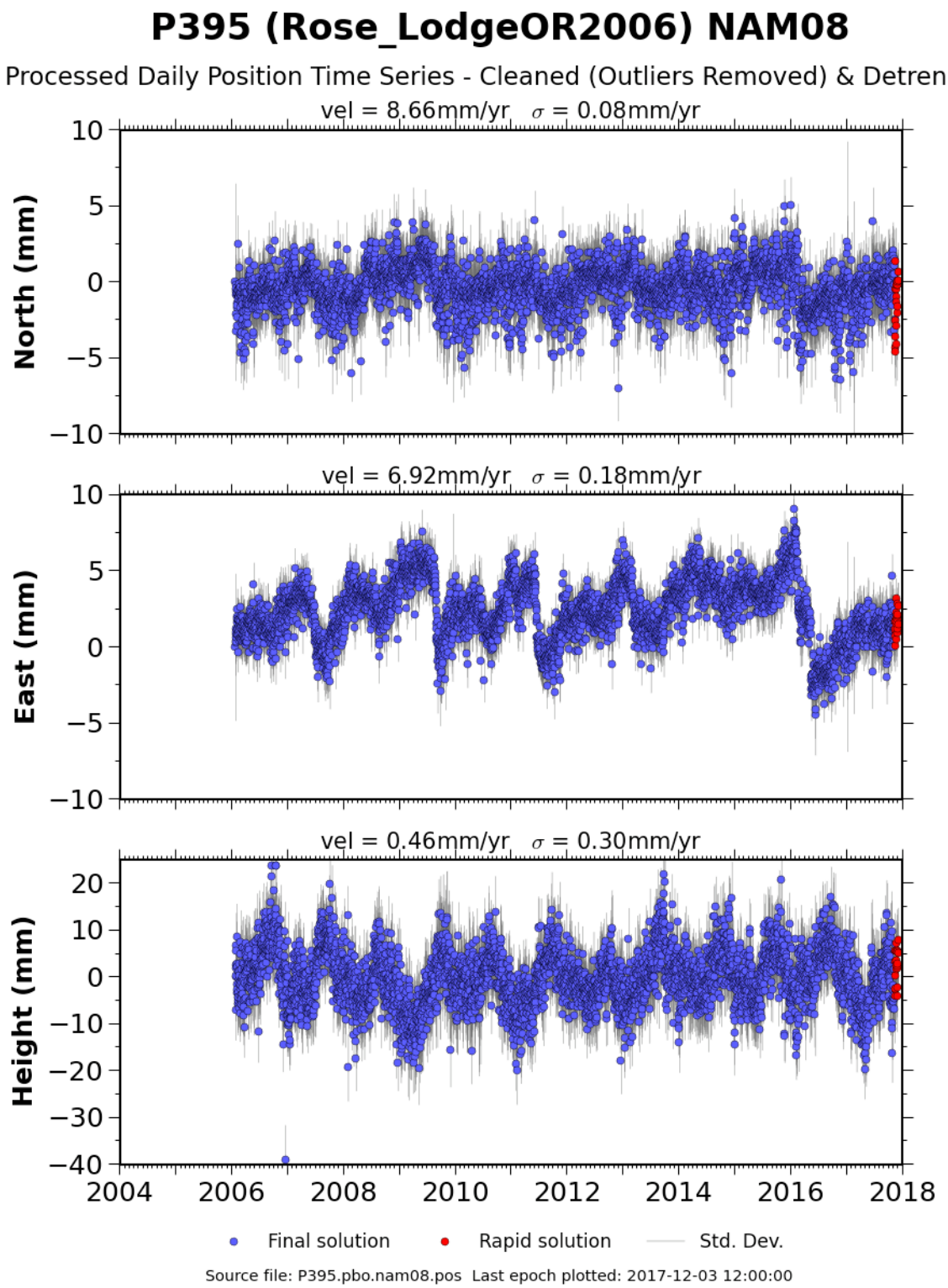


Figure 3. Static plot of cleaned and detrended time-series plots with interpreted velocities relative to the stable North American reference frame (NAM14) from PBO GPS station P395. Accessed 5 December 2017 via https://www.unavco.org/instrumentation/networks/status/pbo/overview/P395.

Resources

- Information about the EarthScope Plate Boundary Observatory is available online via https://www.unavco.org/instrumentation/networks/status/pbo
- Information about the reference frames can be found at http://www.unavco.org/software/visualization/GPS-Velocity-Viewer/GPS-Velocity-Viewer-frames.html
- Information about UNAVCO is available online via http://www.unavco.org/
- The full public data holdings of UNAVCO are available via their "Data Archive Interface Version 2" at https://www.unavco.org/data/gps-gnss/data-access-methods/dai2/app/dai2.html#.

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 2014 Reference Frame (NAM14)

Site	Decimal Lat	Decimal Long
P395	_____	_____
P396	_____	_____
P404	_____	_____

GPS site velocities relative to NAM14, 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.

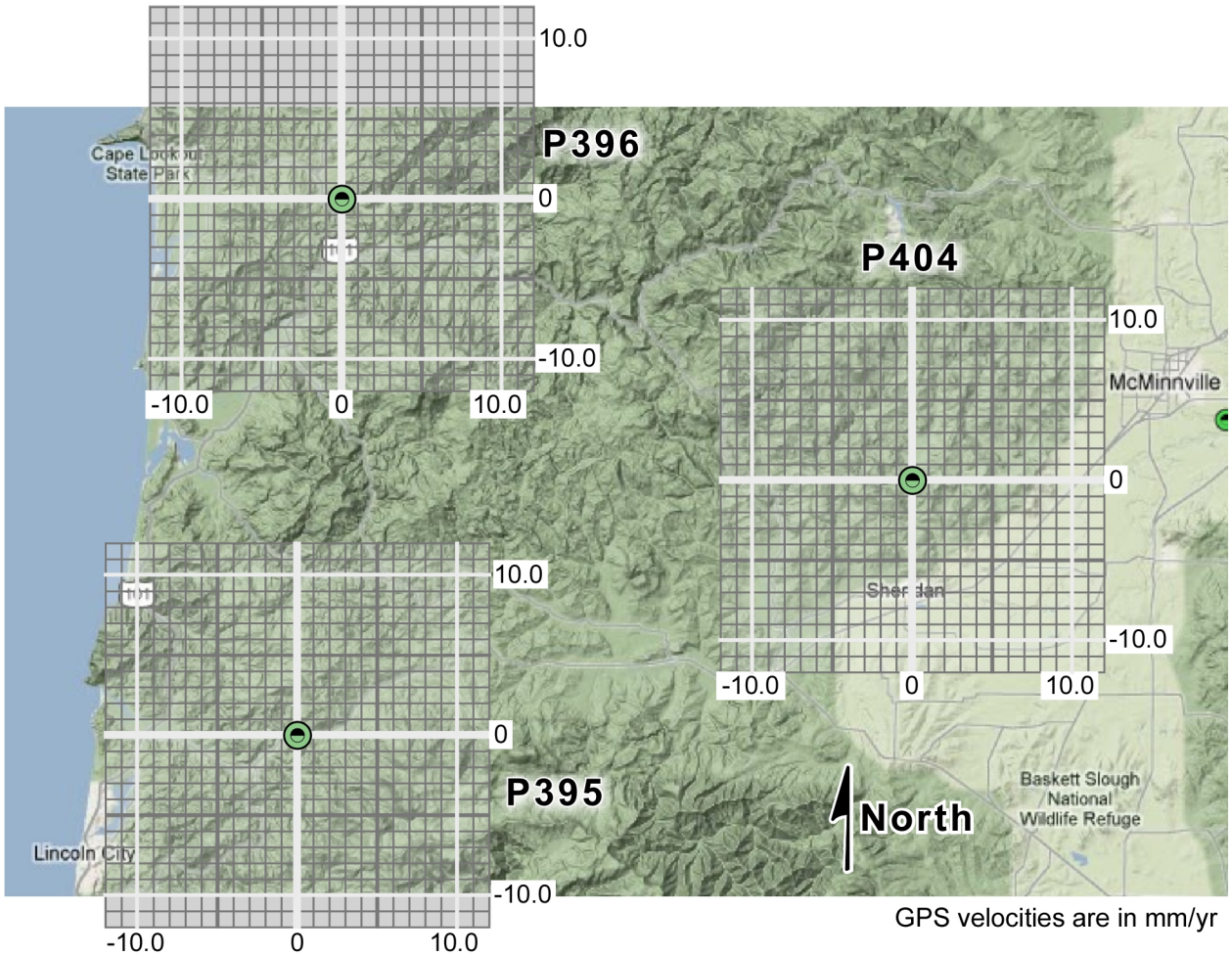
Use your group's map of the velocity field to hypothesize (infer) the instantaneous deformation for this set of stations.

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

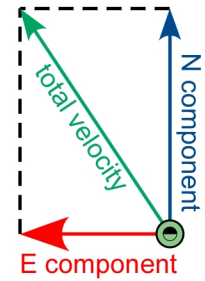
Strain:

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

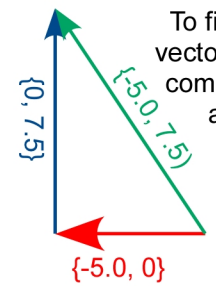
Carefully draw the E-W and N-S velocity vectors associated with the three PBO GPS sites shown as green dots in the map below. A negative east component is a vector pointing west, and a negative north component is a vector pointing south. The graphs are scaled in units of millimeters per year. Then draw 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

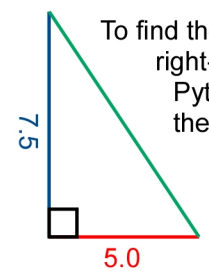


To find the total speed graphically, use a ruler and the scale shown on the graph to measure the length of the total velocity vector.



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 _____mm/yr; P396 _____mm/yr; P404 _____mm/yr