GETSI
GEodesy Tools for Societal Issues

High-Precision Positioning Unit 3 Student Exercise: Introduction to GNSS Time Series – Borah Peak, ID

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This is an introduction to GPS/GNSS time-series and vector graphs. GNSS data is often viewed in a time series to illustrate changes in position or velocity over time. These signals are analyzed and interpreted to understand what process is driving the motion recorded by the GNSS station. These skills are necessary for analyzing and interpreting data produced with static surveys.

Introduction

Static GNSS surveys are effective tools for capturing movement on the earth's surface. They record positions of fixed points over long periods of time. These positions can then be compared relative to other known positions, such as those from static GNSS stations like CORS (Continuously Operating Reference Stations) or the NOTA (Network of the Americas). A time series of points can be produced with this data, which allows us to determine movement magnitude and direction of the measured station relative to other locations or reference frames.

The time series of points is useful in illustrating patterns of movement that can describe various processes such as tectonics, volcanic inflation, hydrologic loading, and many others. The most common product today is the visualization of tectonic plate motion, such as in the data produced by the NOTA network. This assignment will familiarize you with reading and beginning to analyze signals found in time series, in this case derived from NOTA sites.

Collecting GNSS Data

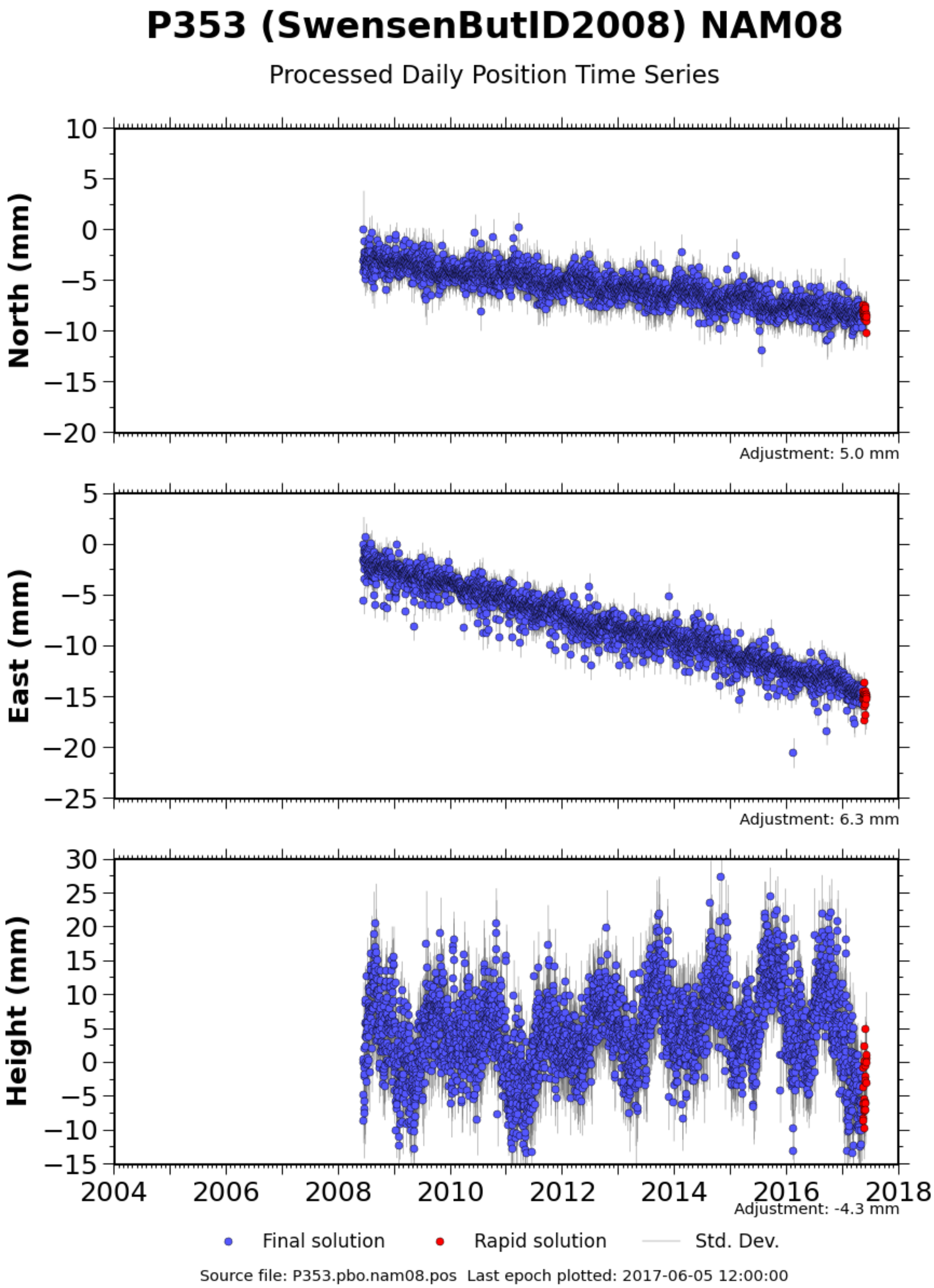
The GPS Velocity Viewer is an application hosted by EarthScope that visualizes GNSS data from NOTA and CORS sites. The viewer displays vectors of GNSS movement occurring in North America and a few other regions. Additionally, the viewer can be used to navigate to the time-series data used to produce the vector information displayed on the map. If your instructor provides you with time series you can skip this step, but you may wish to explore it on your own time.

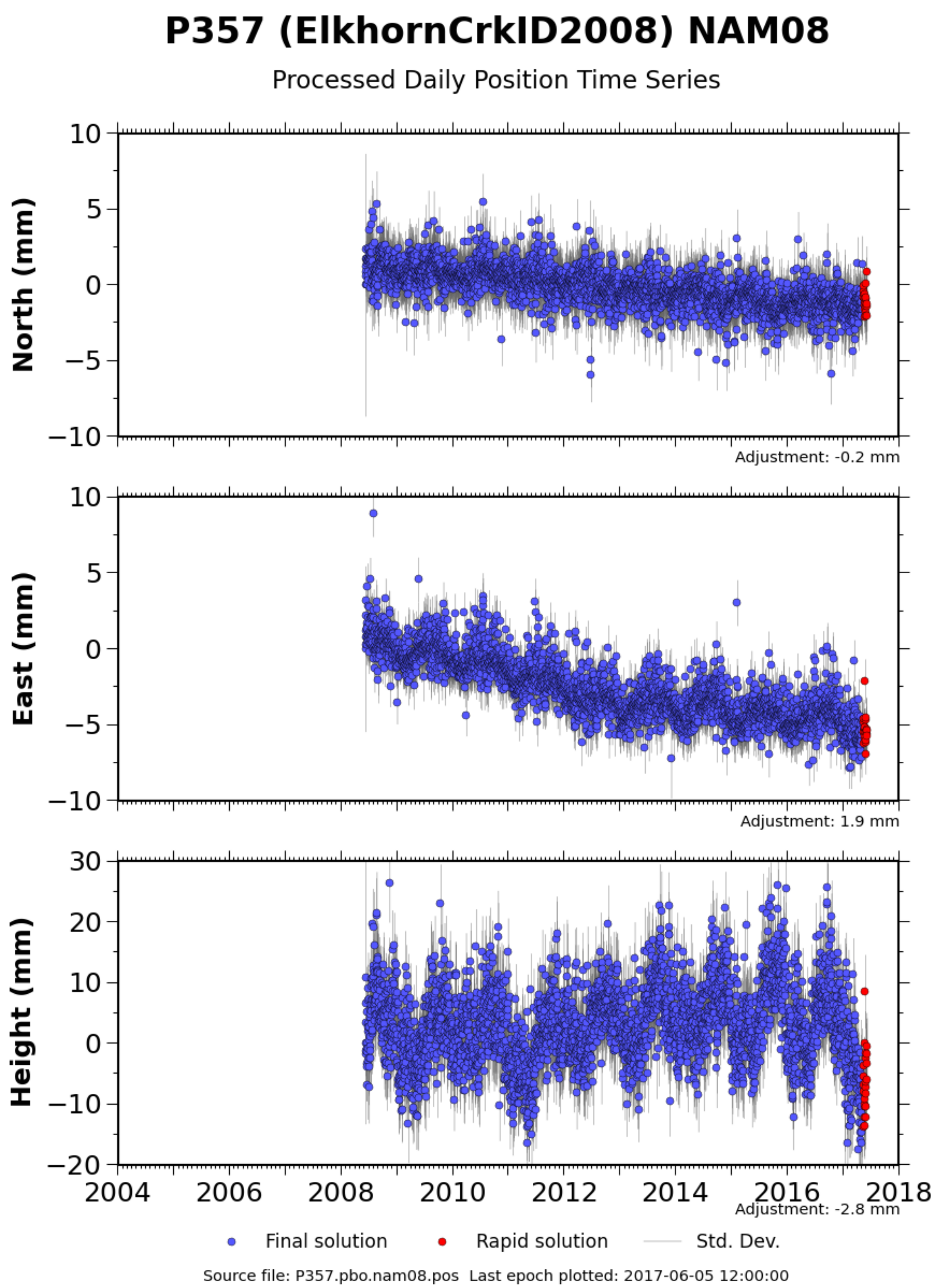
1. Explore the GAGE GPS Velocity Viewer. The site may take a few minutes to load: http://www.unavco.org/software/visualization/GPS-Velocity-Viewer/GPS-Velocity-Viewer.html.
2. Change the options in the menu to show "Station labels and data download."
3. Press the "Draw Map" button. This is necessary after every options change.
4. Click on a station name to view the statistics and time series for that station. You can select "View larger plot" for an expanded graph.
5. Look at the various statistics such as speed, direction, and speed components.

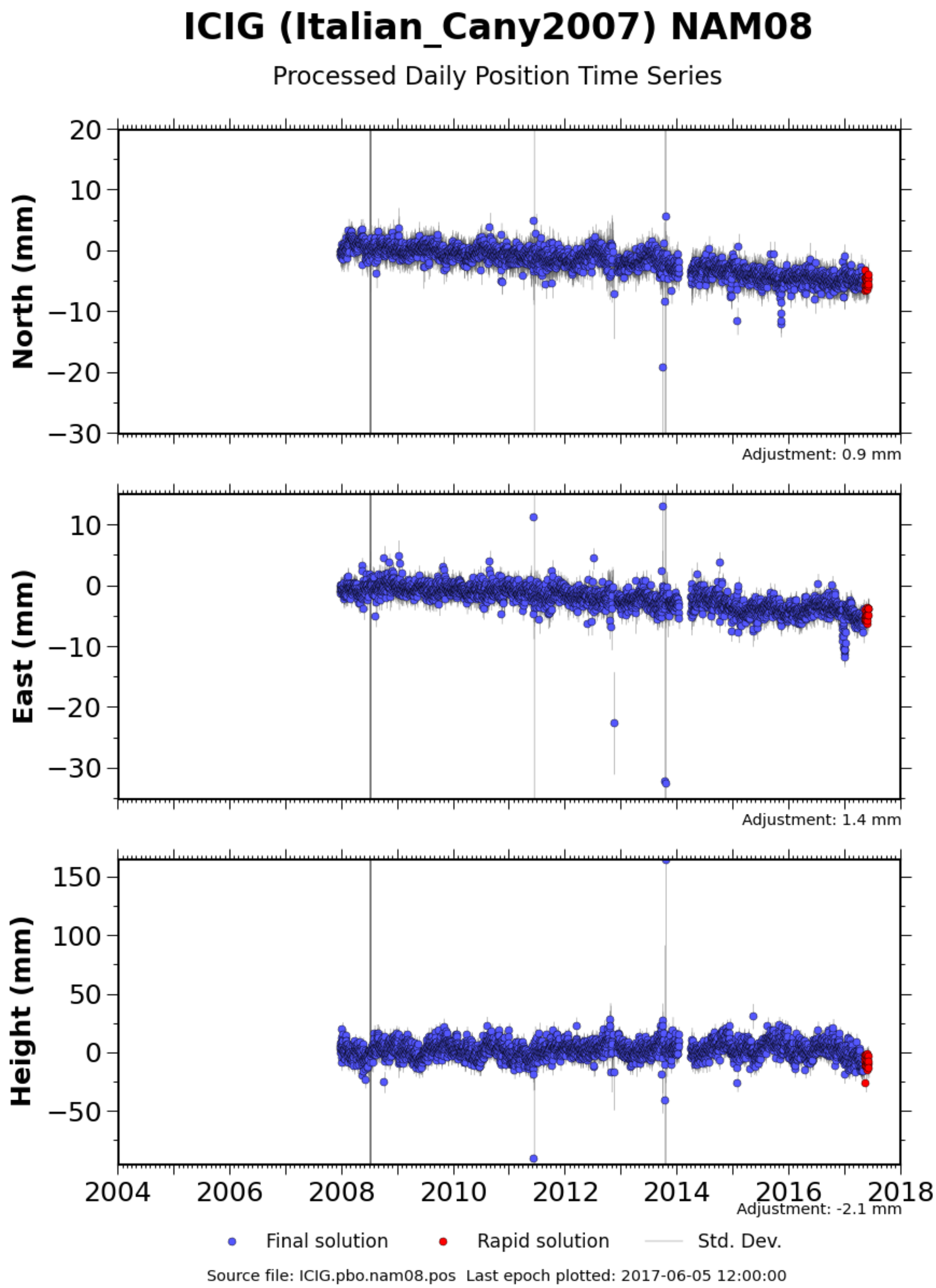
Time Series and Calculating Velocity

Time series display many observations over a length of time. Time series of GNSS stations are divided into three graphs that individually describe the North, East, and Upward components of station motion. Note that a negative y-value on the plot indicates movement in the opposite direction indicated by the plot, which is the South, West, or Down components respectively.

Look at the data from these NOTA GPS stations.
(https://www.unavco.org/instrumentation/networks/status/pbo/gps)




P357 (ElkhornCrkID2008) NAM08
Processed Daily Position Time Series
North (mm)
Adjustment: -0.2 mm
East (mm)
Adjustment: 1.9 mm
Height (mm)
Adjustment: -2.8 mm
2004
2006
2008
2010
2012
2014
2016
2018
Final solution
Rapid solution
Std. Dev.
Source file: P357.pbo.nam08.pos Last epoch plotted: 2017-06-05 12:00:00


ICIG (Italian_Cany2007) NAM08
Processed Daily Position Time Series
North (mm)
20
10
0
−10
−20
−30
Adjustment: 0.9 mm
East (mm)
10
0
−10
−20
−30
Adjustment: 1.4 mm
Height (mm)
150
100
50
0
−50
2004
2006
2008
2010
2012
2014
2016
2018
Adjustment: -2.1 mm
Final solution
Rapid solution
Std. Dev.
Source file: ICIG.pbo.nam08.pos Last epoch plotted: 2017-06-05 12:00:00

Calculating Velocity for Eastern Idaho

Answer the following questions for the time series.

1. What cardinal directions are the stations moving (N, E, S, W, SW, etc.)?

   Swenson Butte (P353): ________________ Elkhorn Creek (P357): ________________
   Italian Canyon (ICIG): ________________

2. How are the stations moving relative to each other?

3. Draw a trend line or otherwise calculate the average velocity (per year) of each station. Make sure to include units and direction (circle one).

   Swenson Butte (P353):

   ____________ (north / south) ____________ (east / west) ____________ (up / down)

   Elkhorn Creek (P357):

   ____________ (north / south) ____________ (east / west) ____________ (up / down)

   Italian Canyon (ICIG):

   ____________ (north / south) ____________ (east / west) ____________ (up / down)

4. What pattern is displayed in the vertical time-series? What is this a signal of? (Hint: look at the time-period associated with the patterns) You can discuss this with a partner.

Mapping Vectors

A vector is an object that has direction and magnitude that is often visualized using an arrow. The orientation of the arrow refers to the direction and the length of the arrow is scaled for its magnitude. Vectors are useful for displaying two-dimensional data, such as motion of the earth when viewed on a map. It is important to remember that the third dimension, vertical motion, is not represented in these vectors, and one must use care to consider it as necessary.

Symbolizing GNSS station movement as a vector is as simple as plotting the east and north movements on a grid, and then connecting them with a line to the origin (0,0). The resulting line is a length of the total magnitude of the stations east and north movement combined. The orientation of the line, measured with a protractor clockwise from north, is the bearing or compass direction of the movement. Using the grids provided on the following page and your measurements from question 3 above, draw a vector for each of the GNSS stations. Pay attention to the axis values.

5. Using a ruler to measure or calculate by hand the total length of the vector (red line in Step 3 below). This is the total horizontal velocity of the station.

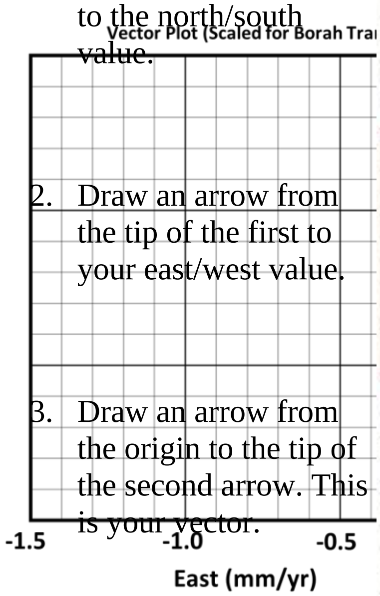
   Swenson Butte (P353): ________________

   Elkhorn Creek (P357): ________________ Italian Canyon (ICIG): ________________

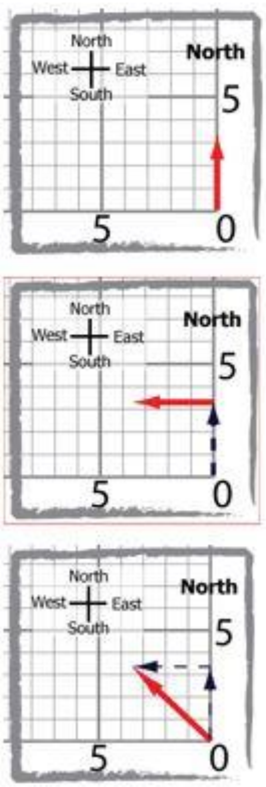
To Draw a Vector:

1. Draw an arrow from 0 to the north/south value.

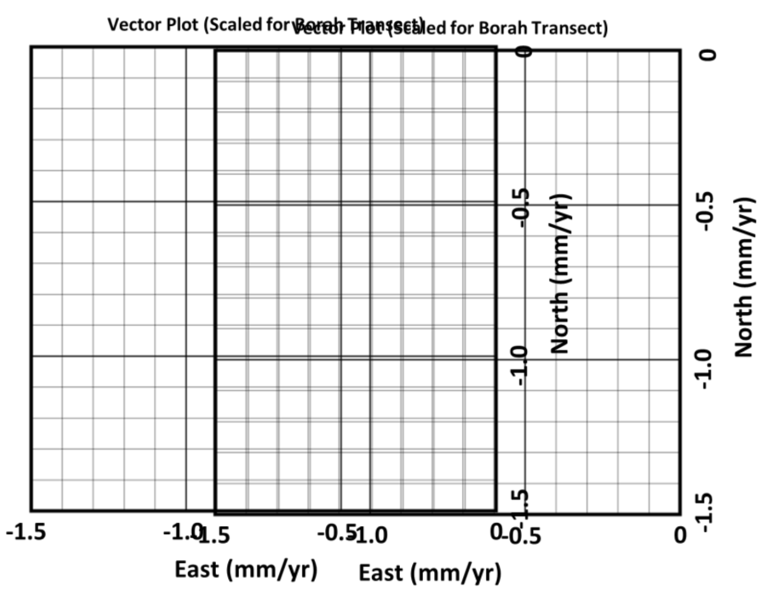
Swenson Butte (P353):



2. Draw an arrow from the tip of the first to your east/west value.
3. Draw an arrow from the origin to the tip of the second arrow. This is your vector.



Elkhorn Creek (P357): Italian Canyon (ICIG):



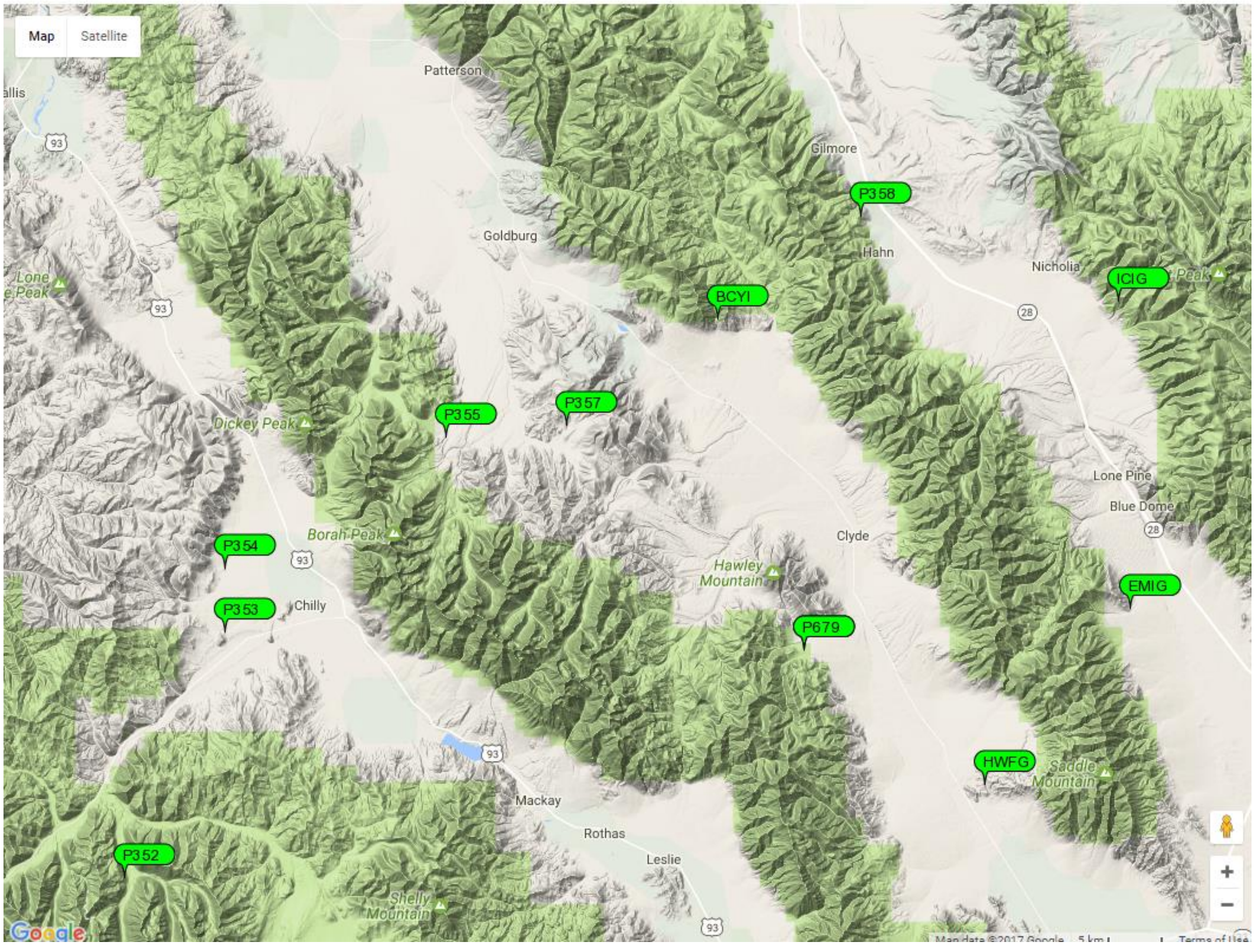


Figure 1: Map of Network of the Americas GPS stations in central Idaho rendered using the GAGE Velocity Viewer (http://www.unavco.org/software/visualization/GPS-Velocity-Viewer/GPS-Velocity-Viewer.html). Base image from Google Maps.

6. Copy the vectors from the previous page onto the map. Vectors should start at the base of the station label. They may need to scaled down by ½ to not overlap. If so, note it.

7. Think about the regional geologic history and potential context for the movements seen in these stations. Discuss as a group, then answer the following questions: How are the movements of these stations related? How are these movements related to tectonic processes in this area?

8. Considering the movements you have found, explain what the implications of this deformation would be on a piece infrastructure, such as a road or building, in the area.

S.J. *Payne* et al.

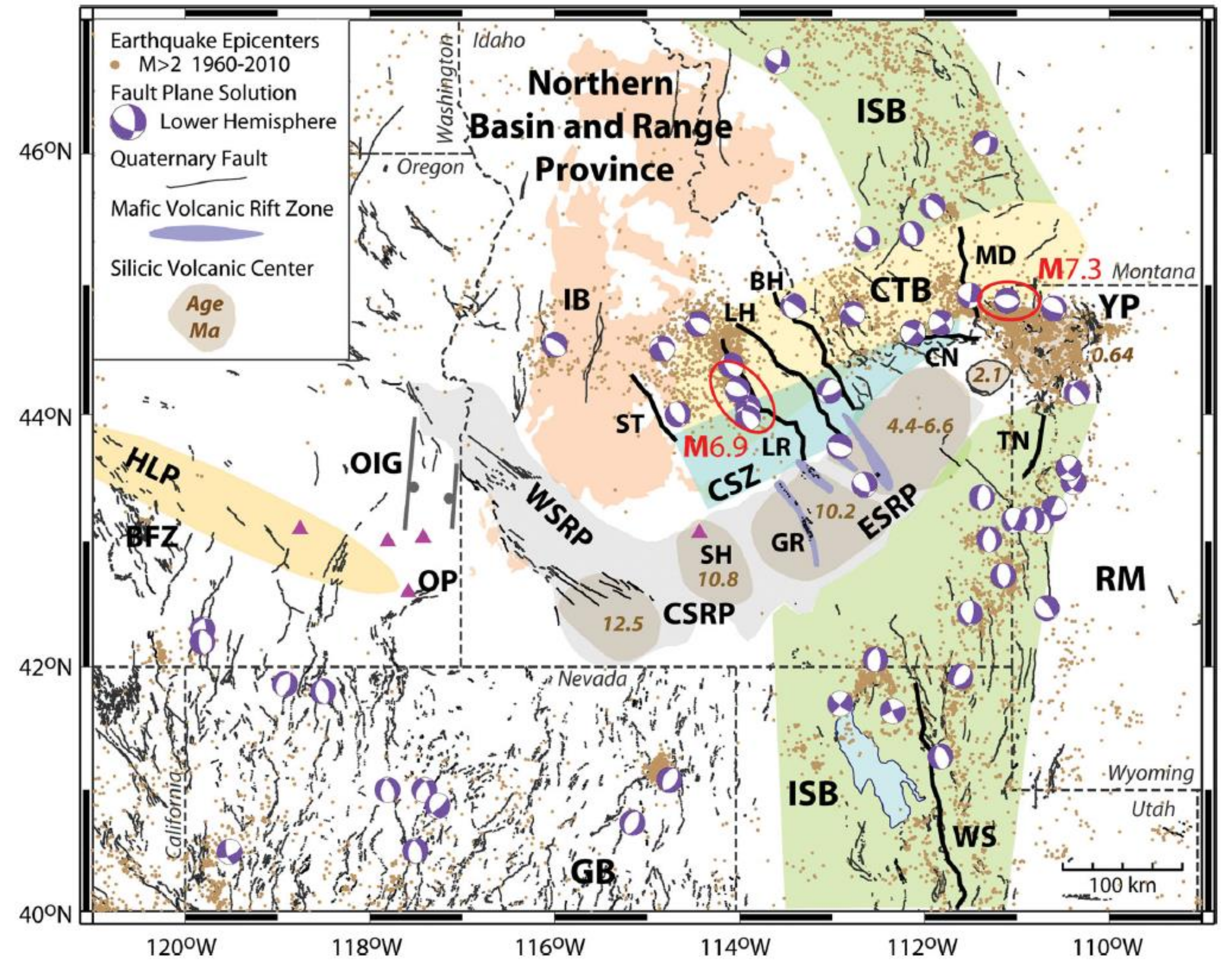
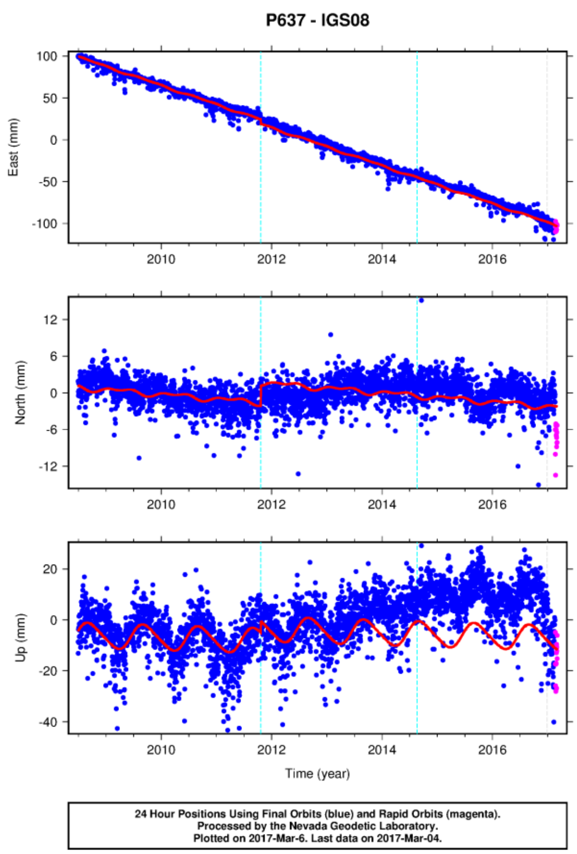


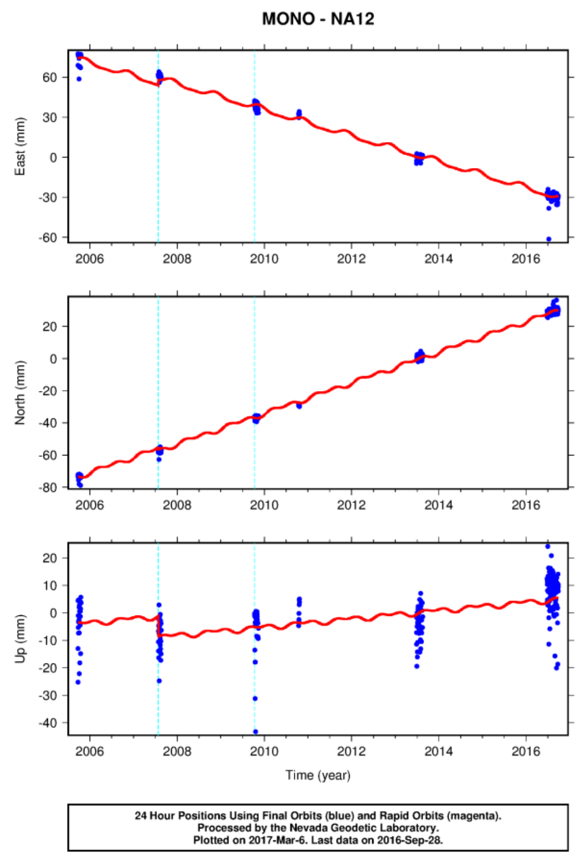
Figure 2: (Figure 1 from Payne et al., 2012, in *Oxford Academic Geophysical Journal International*) Map of seismic deformation and quaternary geologic structures in Idaho and surrounding areas. The Lost River Fault is labeled LR on the map. Note the two major earthquakes on the map in red. (Oxford International allows reuse of figures for educational purposes: https://academic.oup.com/gji/pages/rights_and_new_business_development).

Periodicity of Measurements

Static GNSS stations can be measured with a range of occupation lengths and formats that each result in different data sets. These types include campaign or rapid-static, static, and permanent or continuous surveys. GNSS positions are always averaged over some length of time, often the occupation time, and may have gaps in the data. This must be considered when designing a survey and when interpreting data so you do not fail to capture and event or misinterpret the results.

Look at the following graphs, MONO and P637, of stations by Mono Lake, California, about 4 km apart. The blue dots are station positions, and the red lines are estimates of a model that fits the data. These data are from Nevada Geodetic Laboratory (http://geodesy.unr.edu/NGLStationPages/GlobalStationList).

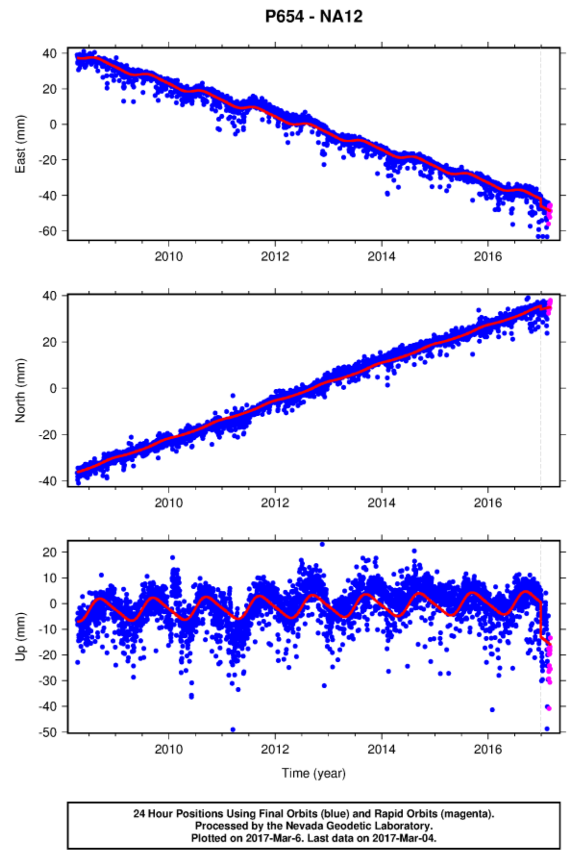




9. Which site is a campaign-style measurement and which is the continuous station?

10. Note the vertical cyan lines in each of the graphs. These represent potential disturbances in the normal signal. How does the expression of the change differ between campaign versus continuous stations?

11. Are the disturbances mirrored in both the fit line and the data? Why or why not?



Now consider the event shown in the P654 site. This site is also on Mono Lake, on the north shore, opposite the other two stations.

Does the event shown here look similar to the events shown in the previous graphs?

Careful, this can be deceiving. The disturbance shown on P637 and MONO in cyan are changes in equipment, but the event in grey on P654 and P637 was an earthquake. Changes in antenna models or other equipment can have significant impact on position measurements.

12. In light of this, why would users need to maintain good records of equipment changes or any modification to a station? Think about how this could apply to the measurements across the Lost River Range Fault.

Review and Discussion

In small groups, discuss how you could apply a time-series analysis of a static survey to record some other type of movement not discussed here. What kind of accuracy and precision is needed for the application, and why is a static survey the right tool for the job? What are the social implications or benefits of understanding the research problem you propose? Would it be possible for you to measure this with another tool? If so, what? And, why is a GNSS survey a better solution?

References

S. J. Payne, R. McCaffrey, R. W. King, and S. A. Kattenhorn. 2012. A new interpretation of deformation rates in the Snake River Plain and adjacent basin and range regions based on

GPS measurements, Geophysical Journal International, Volume 189, Issue 1, p 101–122, https://doi.org/10.1111/j.1365-246X.2012.05370.x

Component	Exemplary	Basic	Nonperformance
General Considerations	Exemplary work will not just answer all components of the given question but also answer correctly, completely, and thoughtfully. Attention to detail—as well as answers that are logical and make sense—is an important piece of this.	Basic work may answer all components of the given question, but some answers are incorrect, ill-considered, or difficult to interpret given the context of the question. Basic work may also be missing components of a given question.	Nonperformance occurs when students are missing large portions of the assignment, or when the answers simply do not make sense and are incorrect.
10 pts **Questions 1–8 and Vector Plots**	**9–10** points: Student actively participated in discussion and answers questions correctly. And Students correctly plot the vectors on page 6. And Students recognized that the stations were moving toward each other.	**5–8** points: Missed minor details on: Student participated in discussion and answers questions correctly. And/Or Students correctly plot the vectors on page 6. And/Or Students recognized that the stations were moving toward each other.	**0–4** points: Student did not participate in discussion and/or answers questions correctly. And/or Students failed to correctly plot the vectors on page 6. And/Or Students failed to recognize that the stations were moving toward each other.
5 pts **Question 9**	**5** points: Students recognize that the movements in the area may have an impact on building, but are relatively small and not likely a large concern. It is important to discuss here the significance of the measurements Students discuss the differences between vertical and horizontal movement.	**3–4** points: Students recognize 2 of the 3 previous points. And/Or Are missing a critical aspect from one or more points.	**0–2** points: Students recognize 1 of the 3 previous points. And/Or Are missing a critical aspect from one or more points.

5 pts **Questions 10–13**	**9–10** points: Students answer all questions and correctly identify: Campaign vs continuous measurements Different sources of signals can look similar on a time series Equipment changes or changes in technique can cause significant error.	**3–4** points: Students recognize 2 of the 3 previous points. And/Or Are missing a critical aspect from one or more points.	**0–2** points: Students recognize 1 of the 3 previous points. And/Or Are missing a critical aspect from one or more points.
10 pts **Write-up or Discussion**	**9–10** points: The discussion is well written and includes all of the following components: • Justification of survey type • Social implication • Discussion of accuracy and precision of results	**5–8** points: The discussion is moderately well written and includes all of the components OR The discussion is well written but missing 1–2 components or fails to answer some of the questions.	**0–4** points: The discussion is poorly written discussion and is missing several components AND/OR The discussion fails to discuss more than 2 critical components or fails to answer questions.