



## High-Precision Positioning Unit 3 Student Exercise: Introduction to GNSS Time Series – Cook Inlet, AK

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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 UNACO 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.

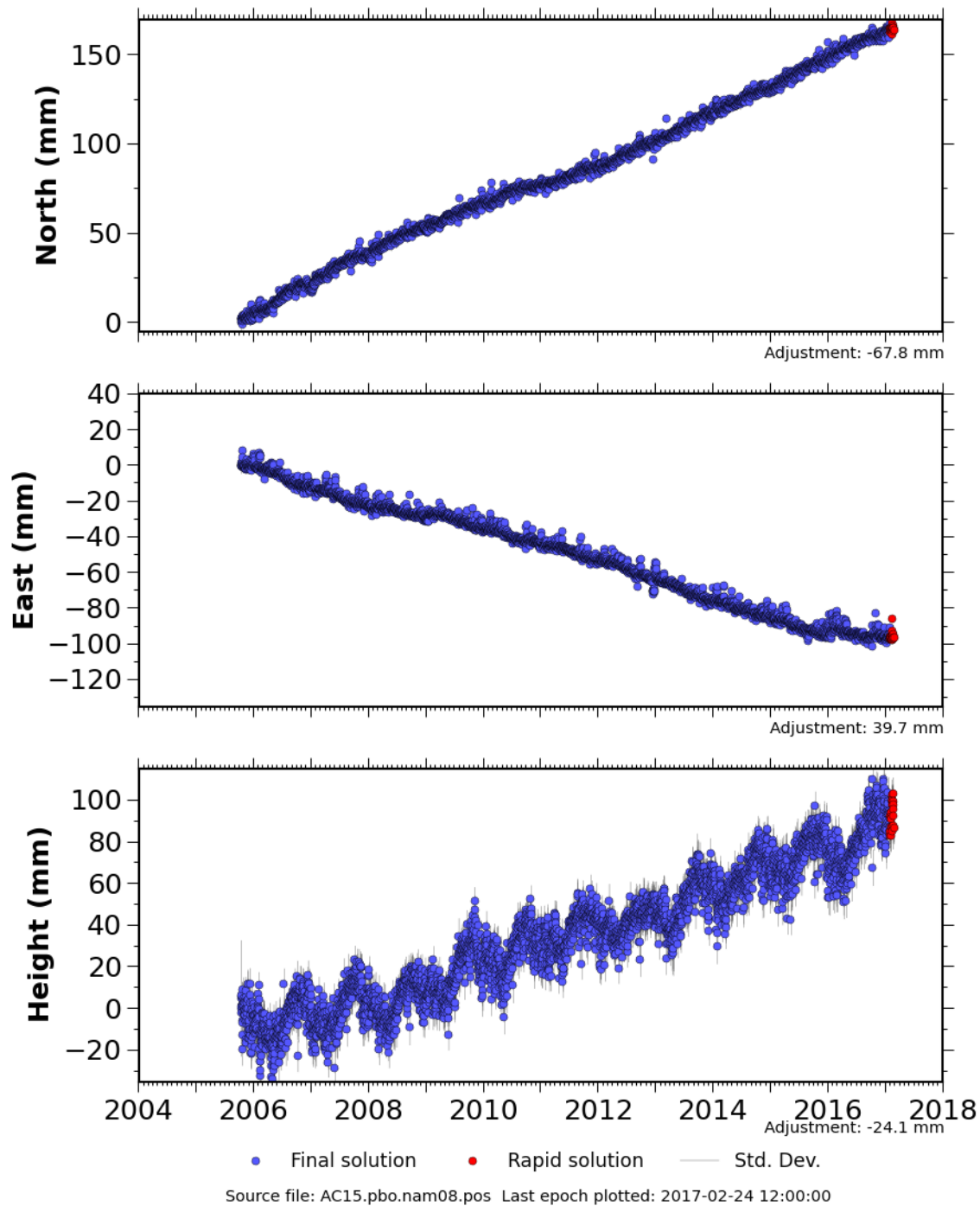
### Time Series and Calculating Velocity

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 near Anchorage, AK.  
 (<https://www.unavco.org/instrumentation/networks/status/pbo/gps>)

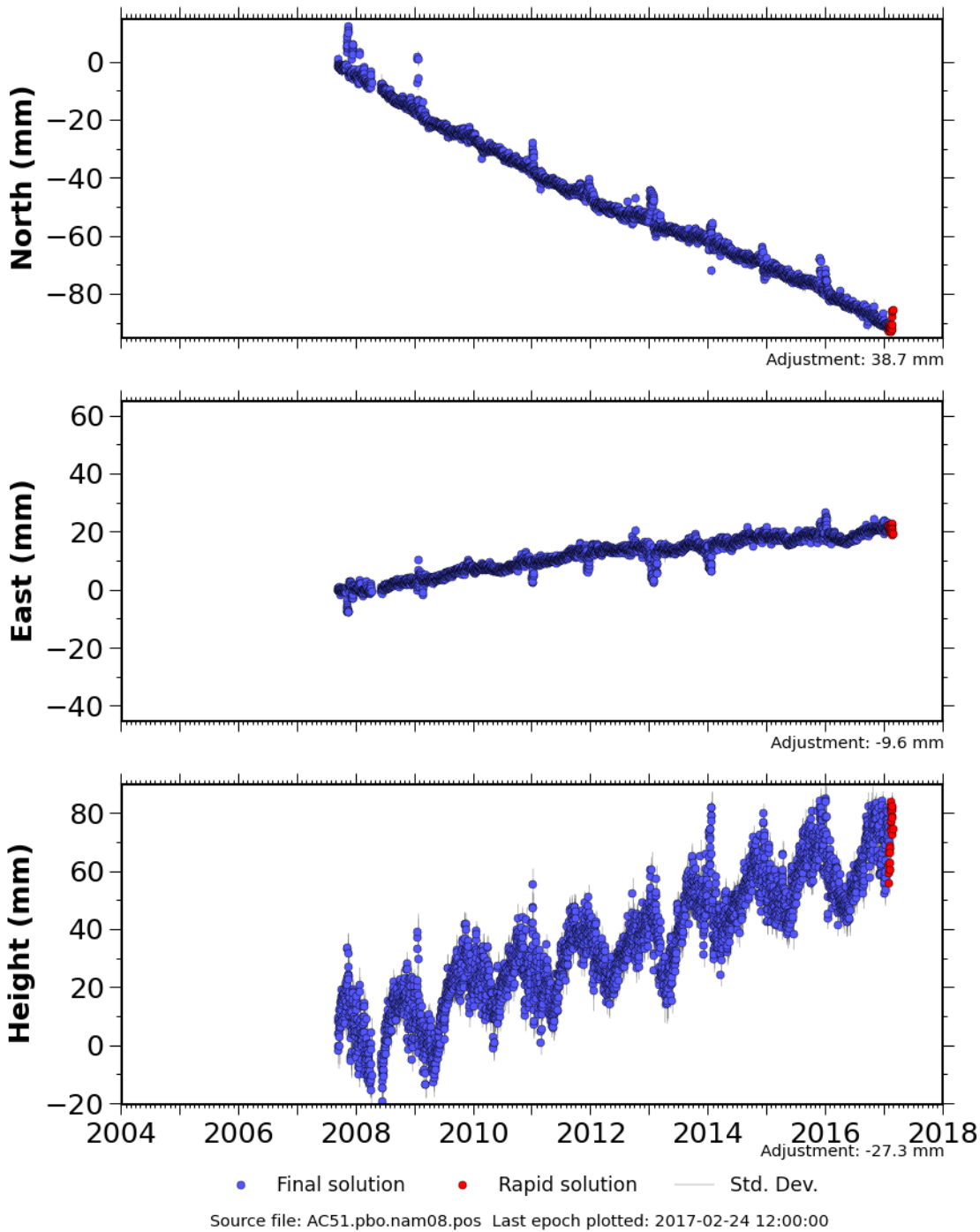
## AC15 (CooperLndgAK2005) NAM08

Processed Daily Position Time Series



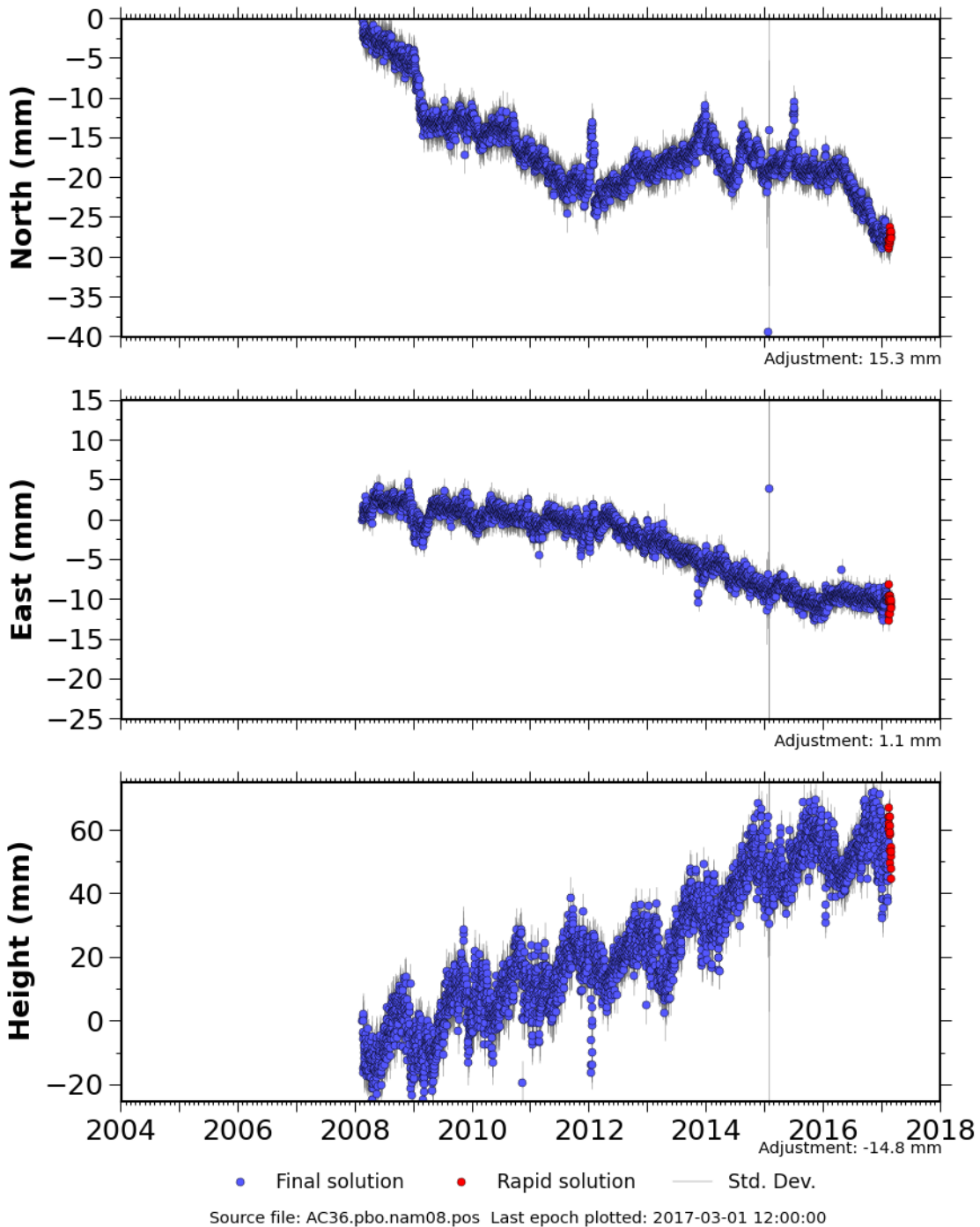
# AC51 (StrandlineAK2007) NAM08

Processed Daily Position Time Series



# AC36 (MoosePointAK2008) NAM08

Processed Daily Position Time Series



Calculating Velocity for Anchorage, Alaska

Answer the following questions for the time series.

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

Copper Landing (AC15): \_\_\_\_\_ Strandline (AC51): \_\_\_\_\_

Moose Point (AC36): \_\_\_\_\_

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 indicate units and direction (circle one).

Cooper Landing (AC15):

\_\_\_\_\_ (north / south) \_\_\_\_\_ (east / west) \_\_\_\_\_ (up / down)

Strandline (AC51):

\_\_\_\_\_ (north / south) \_\_\_\_\_ (east / west) \_\_\_\_\_ (up / down)

Moose Point (AC36):

\_\_\_\_\_ (north / south) \_\_\_\_\_ (east / west) \_\_\_\_\_ (up / down)

4. What pattern is displayed in the vertical time-series?

**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.

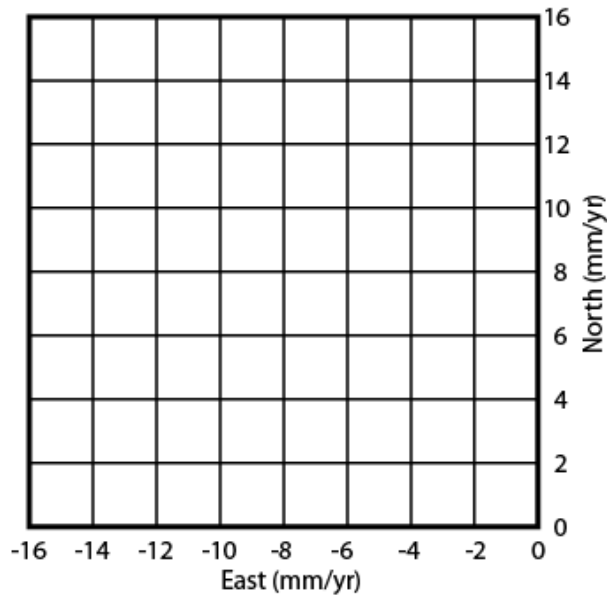
Symbolizing GNSS station movement as a vector is as simple as plotting the east and north movements on a grid, and then connecting them with a line to the origin (0,0). The resulting line is a length of the total magnitude of the stations east and north movement combined. The orientation of the line, 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.

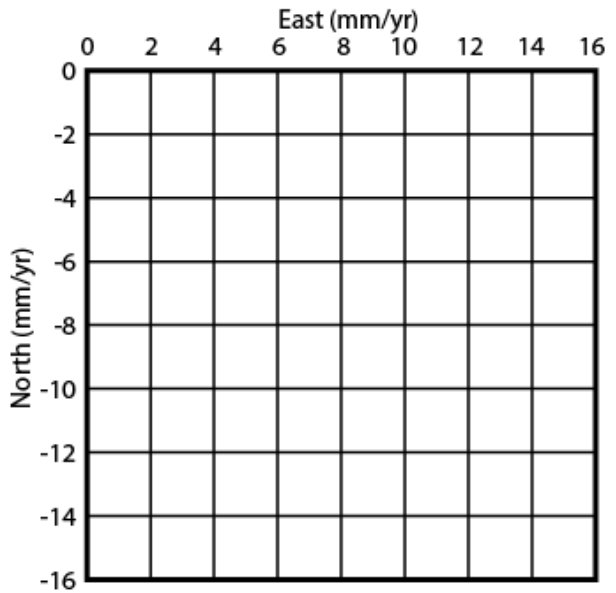
Cooper Landing (AC15): \_\_\_\_\_ Strandline (AC51): \_\_\_\_\_

Moose Point (AC36): \_\_\_\_\_

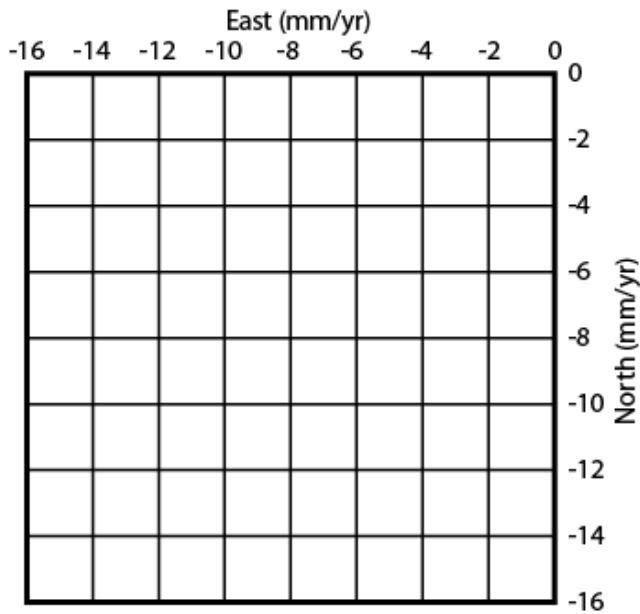
Cooper Landing (AC15):



Strandline (AC51):

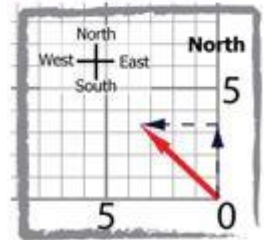
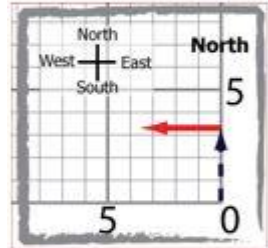
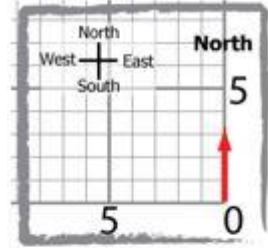


Moose Point (AC36):



To Draw a Vector:

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





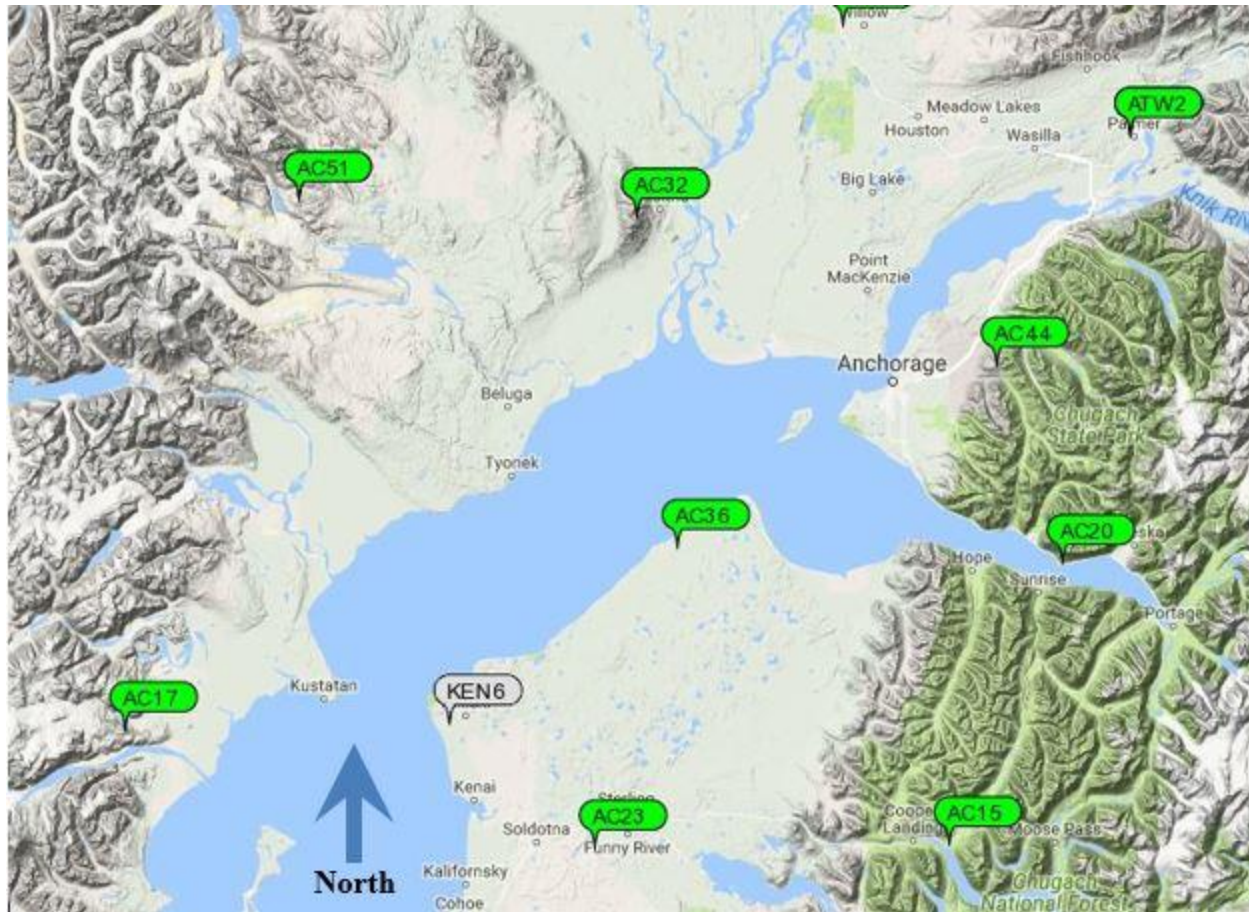
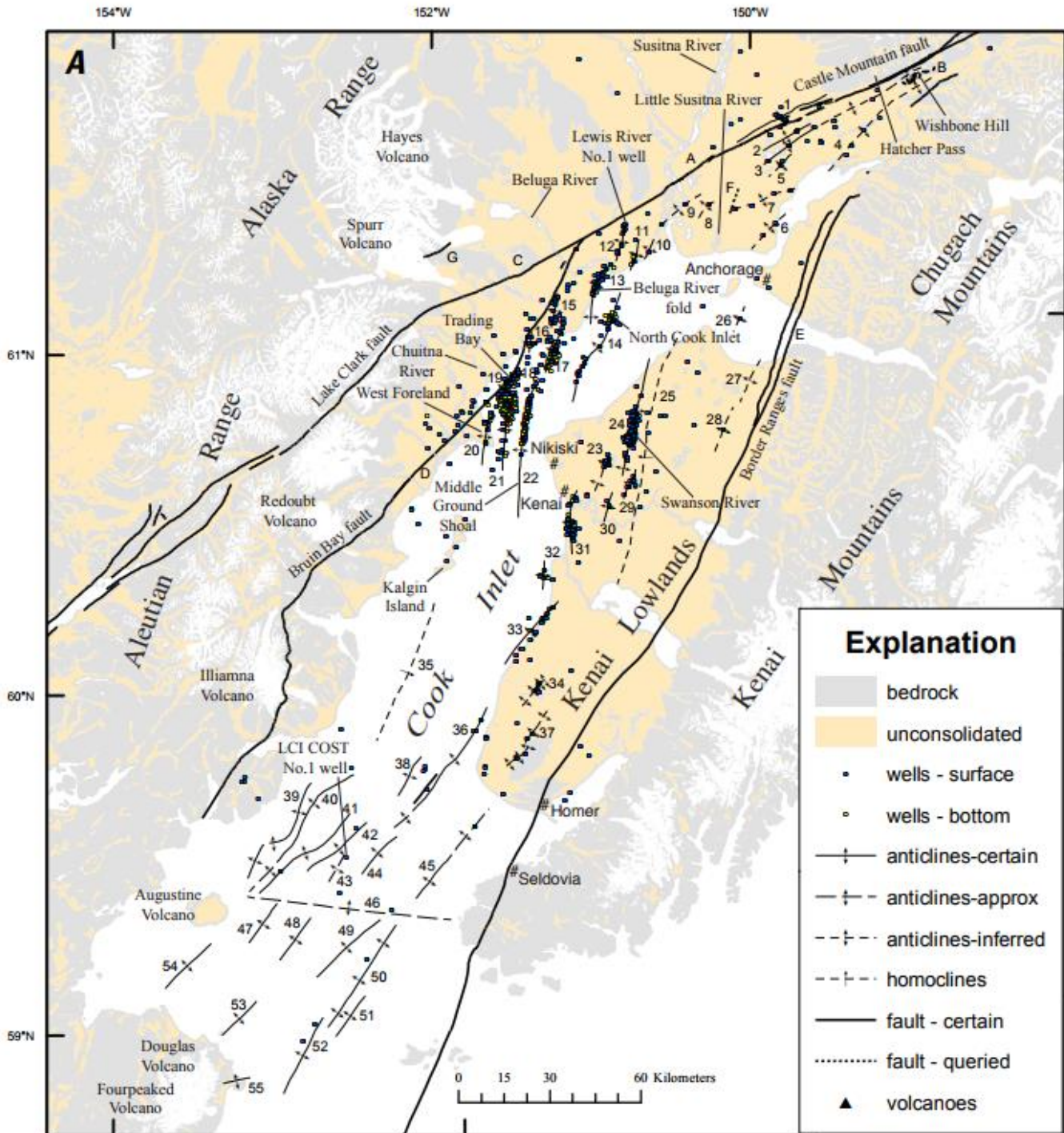


Figure 1. Map of Network of the Americas GPS stations in the Anchorage rendered using the GAGE Velocity Viewer (<http://www.unavco.org/software/visualization/GPS-Velocity-Viewer/GPS-Velocity-Viewer.html>). Base image from Google Maps.

6. Copy the vectors from the previous page onto the map. Vectors should start at the base of the station label.
7. Look at the Velocity Viewer Map or the figures on the following pages, paying attention to faults and tectonic plate boundaries. 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? Look at the figures on next two pages.
8. Imagine you were a geologic consultant for a building project. What geologic hazards exist in the area, and how would you advise a contractor about building in this area?



Figure 2. Location and Extent of Tertiary Structures in Cook Inlet Basin, Alaska, and Mantle Dynamics that Focus Deformation and Subsidence. [https://pubs.usgs.gov/pp/1776/d/pp1776d\\_text.pdf](https://pubs.usgs.gov/pp/1776/d/pp1776d_text.pdf)



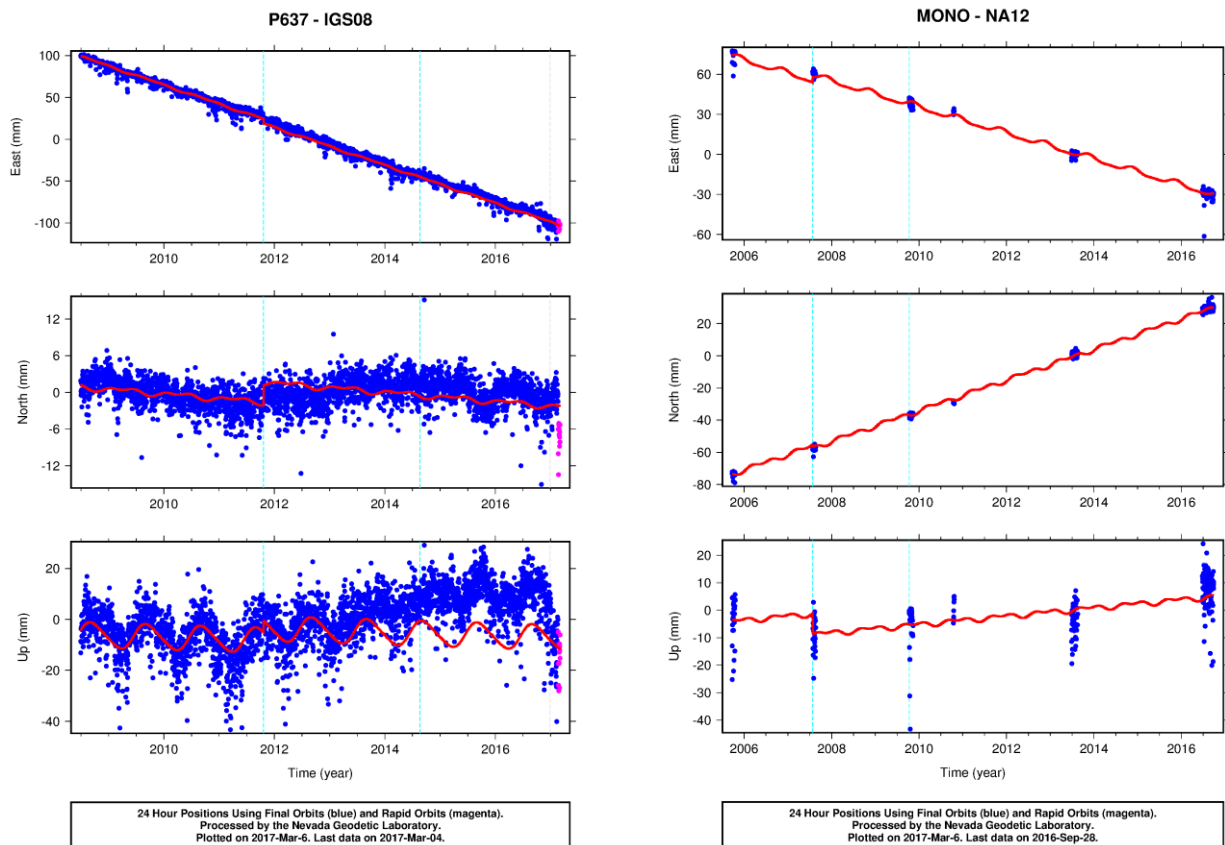




## Periodicity of Measurements

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>).



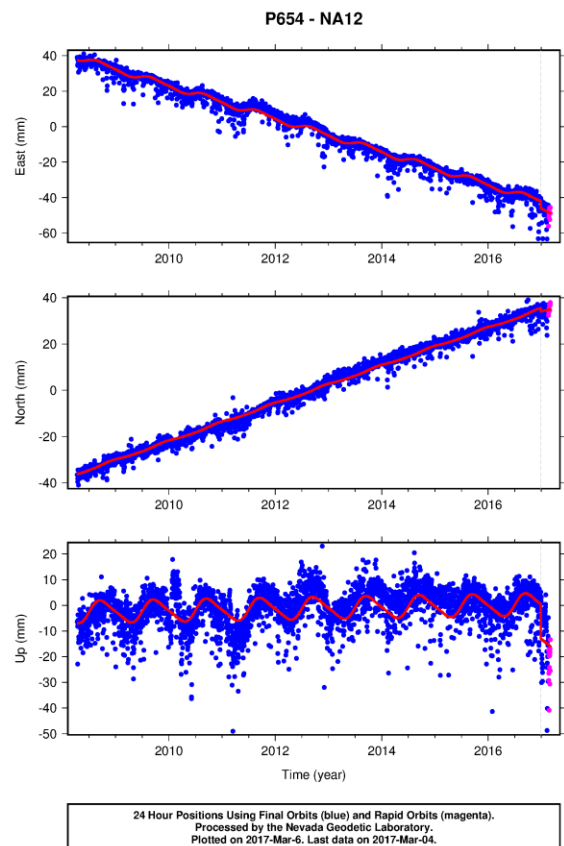
9. Which site is a campaign-style measurement and which is the continuous station?
10. Note the vertical cyan lines in each of the graphs. These represent potential disturbances in the normal signal. How does the expression of the change differ between campaign versus continuous stations?
11. Are the 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?



## 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?

Component	Exemplary	Basic	Nonperformance
<b>General Considerations</b>	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.
<b>10 pts</b> <b>Questions 1–8 and Vector Plots</b>	<b>9–10 points:</b> 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.	<b>5–8 points:</b> 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.	<b>0–4 points:</b> 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.
<b>5 pts</b> <b>Question 9</b>	<b>5 points:</b> 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.	<b>3–4 points:</b> Students recognize 2 of the 3 previous points. And/Or Are missing a critical aspect from one or more points.	<b>0–2 points:</b> Students recognize 1 of the 3 previous points. And/Or Are missing a critical aspect from one or more points.

<p><b>5 pts</b> <b>Questions 10-13</b></p>	<p><b>9–10 points:</b> 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</p>	<p><b>3–4 points:</b> Students recognize 2 of the 3 previous points.  And/Or  Are missing a critical aspect from one or more points.</p>	<p><b>0–2 points:</b> Students recognize 1 of the 3 previous points.  And/Or  Are missing a critical aspect from one or more points.</p>
<p><b>10 pts</b> <b>Write-up or Discussion</b></p>	<p><b>9–10 points:</b> The discussion is well written and includes all of the following components:</p> <ul style="list-style-type: none"> <li>• Justification of survey type</li> <li>• Social implication</li> <li>• Discussion of accuracy and precision of results</li> </ul>	<p><b>5–8 points:</b> 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.</p>	<p><b>0–4 points:</b> 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.</p>