Using GPS to Study Tectonic Plate Movement

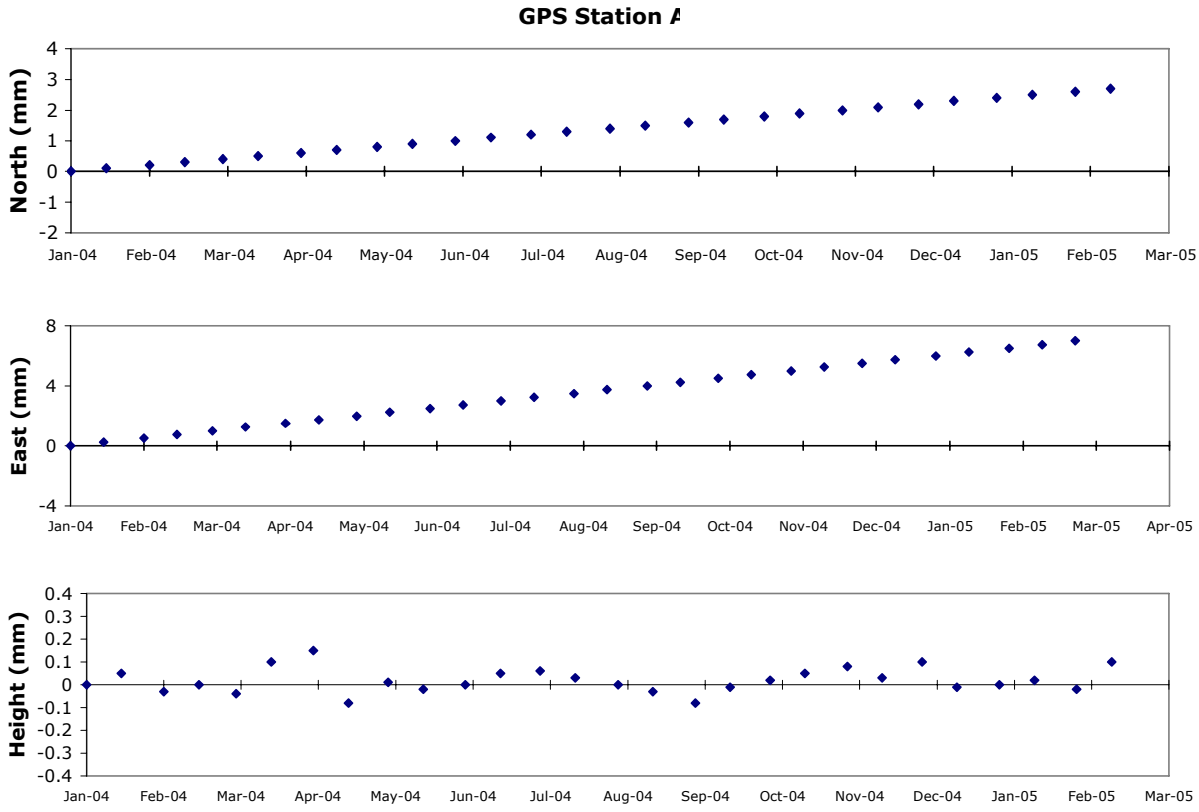
There are hundreds of GPS receivers around the globe. Depending on what type of tectonic boundary exists (converging, diverging, or transform), the Earth's crust will change shape, not to mention what happens during earthquakes and volcanic activity. GPS is used to measure how far plates move in all directions, including up and down.

Understanding GPS Time Series Plots

GPS stations are designed to collect data in 3 components, or parts:

- East/West movement over time (abbreviated E/W)
- North/South movement over time (abbreviated N/S)
- Height (up/down) movement over time

GPS information is represented in **Time Series Plots**, or just **Time Series**. These graphs show horizontal (N/S, E/W) and vertical (up/down) movement over time where time is always on the X-axis. Here's what they look like:



Close inspection of time series plots reveals many things:
a) All 3 have a 'zero' line with positive numbers above the line and negative numbers below the line.
b) The 'East' plot shows East and West movement—anything moving in the 'positive' direction is moving east, and anything moving in the 'negative' or opposite direction is moving West.
c) The same is true for North/South—movement in a positive direction is movement to the North, and anything moving in the negative direction is moving South.
d) Height is vertical movement either up or down following the same rules as the East and North plots.
e) The scale on the axes will vary and the units may vary as well.

Some helpful hints to understand time series plots include:
f) Most time series do not show the 'zero' line—it's added here for clarification.
g) Most time series do not include gridlines, so it's helpful to use a ruler or straightedge (a clear one is best) to calculate how much movement there is.
h) Height plots vary a lot—it's tougher to accurately pinpoint the vertical position.
i) Usually N/S and E/W movement easier to see a pattern with compared to height. But remember that there are a lot of errors that must be corrected, so the data won't always be perfect, or in a clear pattern.
j) The data in the example above is very linear—usually it's a lot messier.
k) Sometimes the time scale is difficult to understand—it's not always shown by months—so be careful.
l) The examples shown above only have 2 plots per month. In reality, there will be hundreds of points on a time series. Real receivers collect a measurement every 15 seconds! That's 5,760 measurements a day. These are averaged to get one point for each day that shows up on a time series.
m) Not all plots start right at '0' on the y-axis.
n) The movements that GPS receivers show are very small—millimeters or centimeters at most. But just think how much movement that would mean over thousands of years!

Analyzing GPS Station A Movement:
Now it's your turn to analyze the sample time series plots for GPS Station A shown above. Answer the following questions:

1. What are the units of measurement for these time series?

2. What are the dates of data collection—from when to when?

3. How far East did the station (and therefore Tectonic Plate A) move between Jan 04 and Jan 05? Remember to use a straightedge to help.

4. How far West did Plate A move?

5. How far North did Plate A move between Jan 04 and Feb 05?

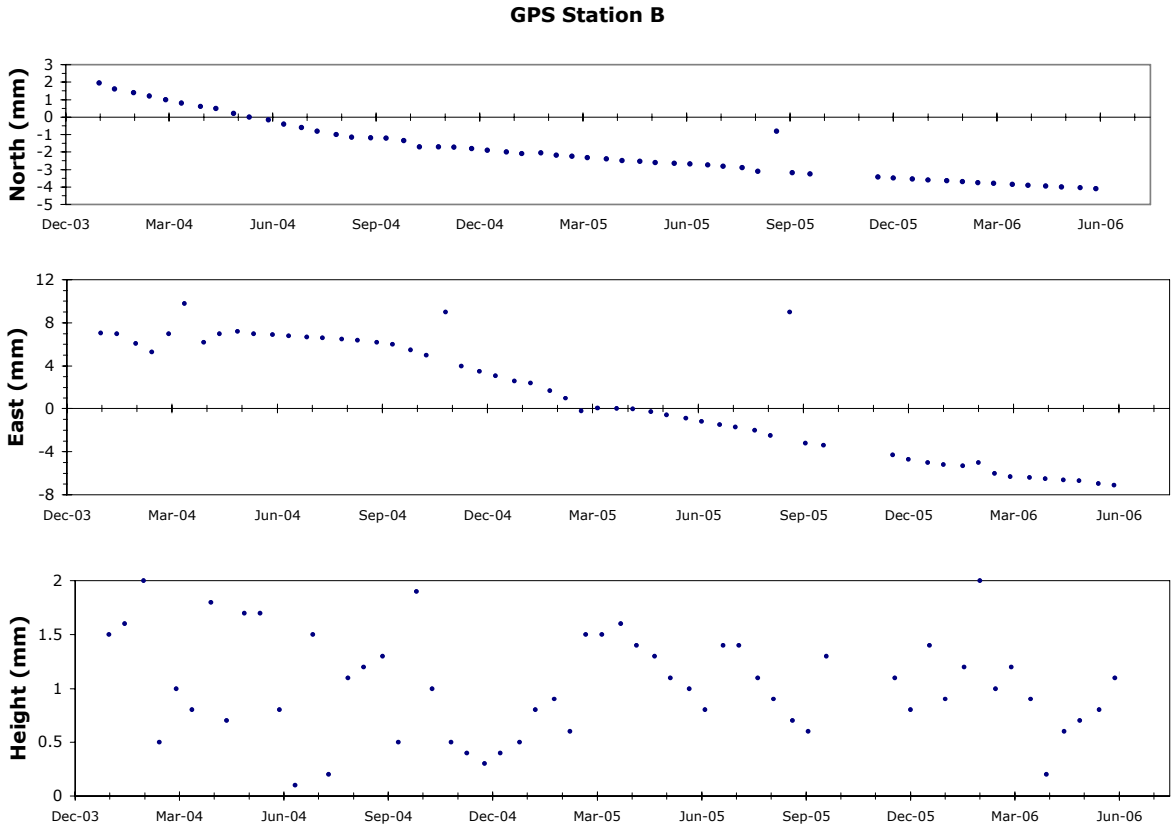
6. How far South did Plate A move?

7. Is there any pattern, or trend, for the Height time series?

Analyzing GPS Station B Movement:
GPS Station A has a fairly straightforward time series plot, but oftentimes they are more complicated. Next, you will look at a time series for GPS Station B and answer questions about it. Let's assume that GPS Station B is located on Tectonic Plate B. Review the hints about how to read a time series if you get stuck.

Some things you'll notice right away:

- The time series is over a longer period of time.
- There is more variation in the data.



Answer the following questions about GPS Station B:

1. What are the units of measurement for these time series?

2. What are the dates of data collection—from when to when?

3. Was Plate B moving North or South? How do you know?

4. How far North or South did Plate B move between Jan 04 and Jan 05?

5. Was Plate B moving East or West? How do you know?

6. How far East or West did it move over the whole time period of data collection?

7. Does anything else stand out? Do you see any problems with the data? List 3 or 4 things.

What's going on with those strange bits of data?
a) You'll notice that it's pretty messy on the E/W time series at the beginning. Sometimes it takes a while to get good data analysis.
b) The height time series is very random. Again, this is common because it's a lot harder to measure with pinpoint accuracy. But sometimes you'll see very clear trends in the up or down direction.
c) There is an 'outlier' in Nov of 04 on the E/W time series. Sometimes there will be outliers and there are many reasons for them—data miscalculation, equipment failure, human error, etc.

8. There are outliers on both the N/S and the E/W time series around Aug of 05, and then a time when no data was collected. What do you think happened there?