



DRAFT

INTRO TO GPS

Name: _____

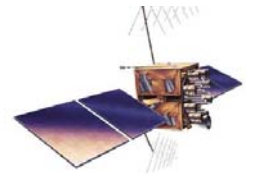
TECHNOLOGY

Today's Date: _____

Technology is amazing. The Global Positioning System, known as GPS, has been around for many years, and its applications are many. In a nutshell, GPS can be used to locate where you are on the Earth, and people are most familiar with GPS units in cars to help with directions, or for recreation, like hiking. A specific type of GPS called **differential GPS**, or dGPS, is extremely precise and can be used to show tectonic plate movement of 1 millimeter!



Basically, there are 24 GPS **satellites** cruising 12 miles above the Earth moving at about 7500 kilometers an hour. That's almost 2 kilometers a second - yes, a second. The satellites send out radio wave signals in all directions.



Receivers can tell how long it takes for the radio waves to reach them, and using some math, computers can calculate the **distance** between the receiver and the satellite.

dGPS is so much more accurate because it uses some very fancy computing to take out errors due to the atmosphere and inaccurate clocks, for example, The picture to the right shows a **GPS Monument**. Inside the dome is the GPS antenna that receives the radio waves and sends the signal to the attached receiver.



Let's see how knowing the distance from a satellite helps.

PART I: Pinpointing Location Demonstration

Watch the demonstration of how GPS works and answer the questions that follow.

1. What does the length of string represent?

2. How many satellites are needed to pinpoint the location of a spot on the Earth?

3. Why wouldn't one or two satellites work? Can you draw a diagram to show this?

4. Draw the setup of the demonstration



in the space to the right.

Using GPS to Study Tectonic Plate Movement

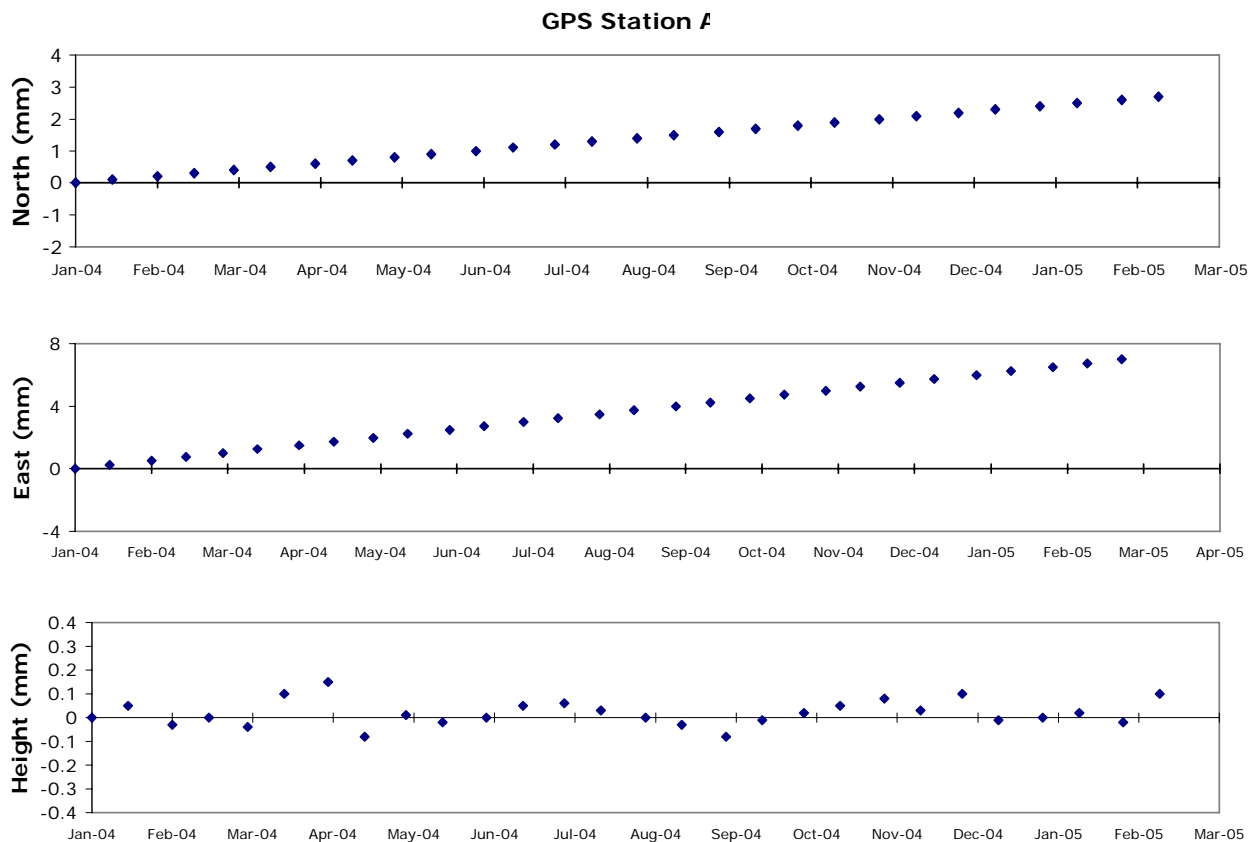
There are hundreds of GPS receivers around the globe. Depending on what type of tectonic boundary exists (converging, diverging, or transform), the Earth's crust will change shape, not to mention what happens during earthquakes and volcanic activity. dGPS is used to measure how far plates move in all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

PART II: 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

dGPS 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 dGPS receivers show are very small - millimeters or centimeters at most. But just think how much movement that would mean over thousands of years!

PART III: 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?

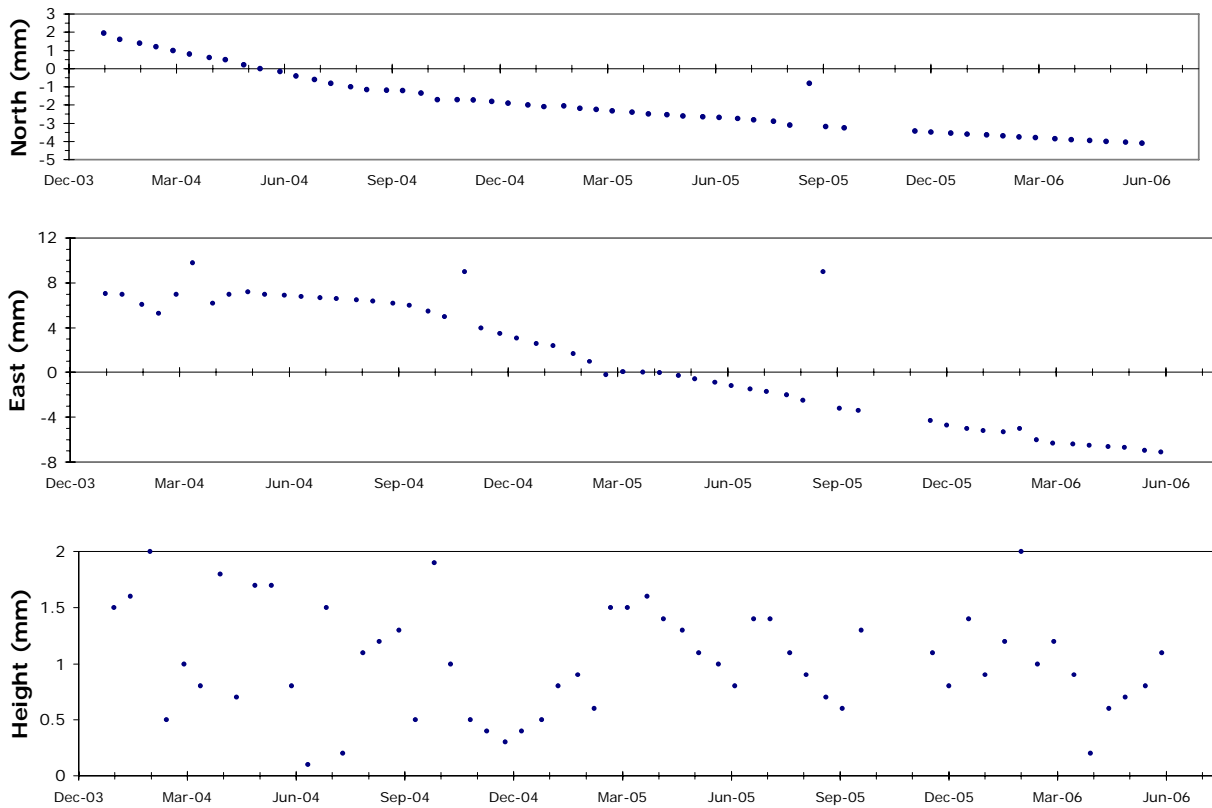
PART IV: Analyzing GPS Station B Movement:

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

GPS Station B



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?

PART V: Building a GPS Monument

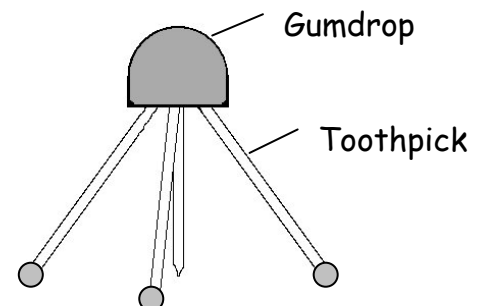
A GPS Monument is a dome-shaped device on legs that holds the GPS antenna. The antenna is attached to the GPS receiver which is usually located about 5 - 10 meters away.

Materials: 8 toothpicks, 2 different colored gumdrops, modeling clay, ruler, graph paper, 2 pieces of transparency

Procedure:

Build **two** GPS stations using the diagram to the right. Use gumdrops of different colors.

1. Insert 3 toothpicks diagonally into the gumdrop. These will act as the legs.
2. Insert a slightly shorter toothpick sticking straight down from the middle of the gumdrop. The tip of this toothpick should be just barely above the surface. This will be the 'place marker'.

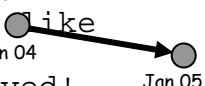


3. Put very small pieces of clay on the bottom of the legs (not the place marker). The clay will act as a cement to hold the GPS station in place. In reality the legs of a GPS station are cemented deep into the ground so that if the ground moves, so does the GPS station.

PART VI: Moving Your GPS Stations

Let's model the movement of your GPS station to mirror the data for GPS Station A and therefore Tectonic Plate A.

1. In order to simulate that the station moves with the tectonic plate beneath it, place your GPS station on a piece of transparency which we'll call Tectonic Plate A.
2. You will need to poke a small hole through the transparency right below the place marker (the toothpick hanging straight down from the bottom of the gumdrop). The hole should be large enough to get the tip of your pencil through.
3. Using the grid paper provided, position your GPS Station so that the place marker is over point A. We'll now officially name your GPS station as Station A. What color gumdrop is Station A?

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4. Note that the grid paper has the cardinal directions (N, S, E, and W) on the top. Also note that the grid is larger than 1 millimeter, but we'll assume that each square is 1 mm long.
 5. Using the time series for Station A, find out how far and what direction Tectonic Plate A moved between Jan '04 and Jan '05. Figure out how many squares (mm) it moved E/W and how many squares (mm) it moved N/S.
 6. Move Tectonic Plate A (with Station A) to that point by sliding the transparency along the grid paper in the N/S direction first, then the E/W direction. The place marker should be right over the spot where the station is in Jan '05.
 7. Put a small dot through the hole in the transparency indicating that's where the station was in Jan 05. Label that spot "Jan 05" (you'll have to move the transparency first . . .).
 8. With a straight edge, connect the locations with arrows like this:

and then measure the line to see how far it actually moved!

That shows you how far and the direction of movement the GPS station (and therefore Tectonic Plate A) moved!

Now let's model the movement of GPS Station B.

9. Now we're going to move GPS Station B. What color is it? _____

Use the Time Series for GPS Station B to find its N/S and E/W movement between Jan 04 and Jan 05.

10. Put GPS Station B on the second piece of transparency and put the place marker right over point B on the grid paper. Poke a hole under the place marker.

11. Move it to its Jan 05 resting point. Mark it and label it with the date (Jan 05). Then draw an arrow from Jan 04 to Jan 05.
12. According to this data, GPS Station B moved that far in just 1 year. Go back to the Time Series for Station B and see how far it moved between Jan 05 and Jun 06. Plot a new point for Jun 06. Draw another arrow from Jan 05 to Jun 06.
13. The whole time period on the Station B Time Series is 2 1/2 years. Draw an arrow from the original starting point (Jan 04) to the final date (Jun 06). Measure that line.
14. Assuming it moved the same amount in the next 2 1/2 years, put a point where it would be at the end of 5 years.
15. If you were to do some calculations, you would learn that GPS Station B moved about 15 mm in 2.5 years. How far, on average, is it moving every year?
16. Calculate how far it would move in 100,000 years. Your answer will be in millimeters. Convert that number to meters by dividing by 1000 (1 m = 1000 mm).
17. How far in meters would it move in 100,000,000 years? Convert to kilometers by again dividing by 1000. Holy Cow!!!

PART VII: Comparing Motions of Different Stations:

Now for the part that truly interests geologists and geophysicists that study the movement of the plates. Let's compare the motion of Plate A compared to Plate B.

1. Put your GPS Stations back on points A and B. Now, move them in the general direction their time series plots showed they move (don't worry about exact distances). Describe how they move in relation to each other.
2. What type of boundary is this?
3. Name a famous fault on the West Coast where this type of movement occurs.

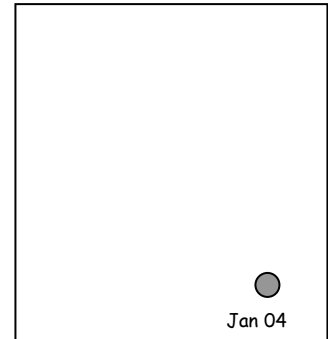
Let's look at some real data from GPS stations along this fault! BEMT is a station east of the San Andreas Fault, and SBCC is on the west side of the fault.

A note about the dates on actual time series plots: the years are divided into tenths, which can be confusing. Each tick mark on the X-axis is a tenth, and only some are labeled. Use the conversion table below to help:

0	.1	.2	.3	.4	.5	.6	.7	.8	.9	1	
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec

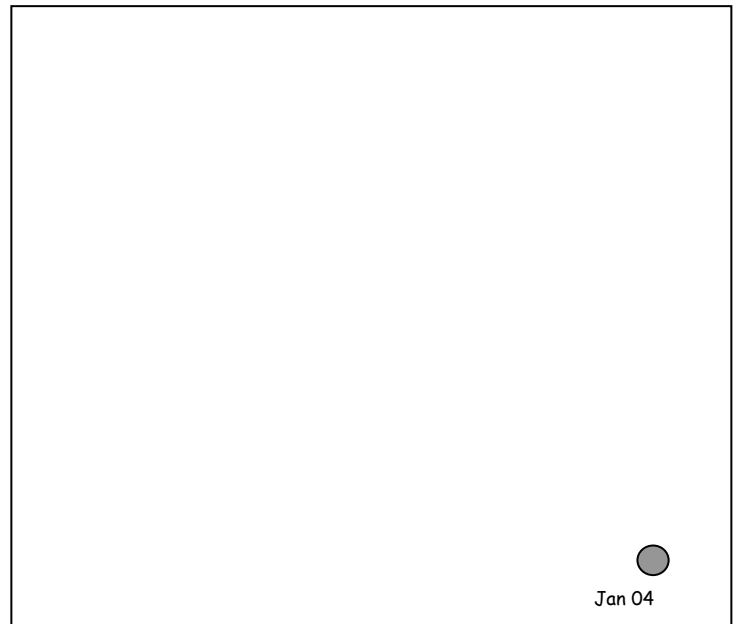
Analyzing Station BEMT in Twenty Nine Palms, CA.

4. What are the dates of data collection?
5. What general direction is BEMT moving?
6. How far North did it move between 2004.0 and 2007.0?
7. How far West did it move in the same time period?
8. In the box to the right, measure out N and W movement and draw an arrow to indicate the new position.
9. How far did it actually move in 3 years?
10. How far, on average, does BEMT travel each year?



Analyzing Station SBCC in Mission Viejo, CA, near the coast:

11. What are the dates of data collection?
12. What general direction is SBCC moving?
13. How far North did it move between 2004.0 and 2007.0?
14. How far West did it move in the same time period?
15. In the box to the right, measure out N and W movement and draw an arrow to indicate the new position.
16. How far did it actually move in 3 years?



17. How far, on average, does SBCC travel each year?
18. Using your two GPS Monuments, model how BEMT and SBCC are moving. Use a new piece of grid paper if necessary.
19. Describe the motion of these two stations compared to each other. Is one moving faster?
20. What type of tectonic plate boundary do you think exists between BEMT and SBCC? Is it converging, diverging, or transform? How do you know?
21. Note the Height plot for SBCC. How far up or down did it move between 2004.0 and 2007.0?

PART VIII: Analyzing Interesting Time Series Plots

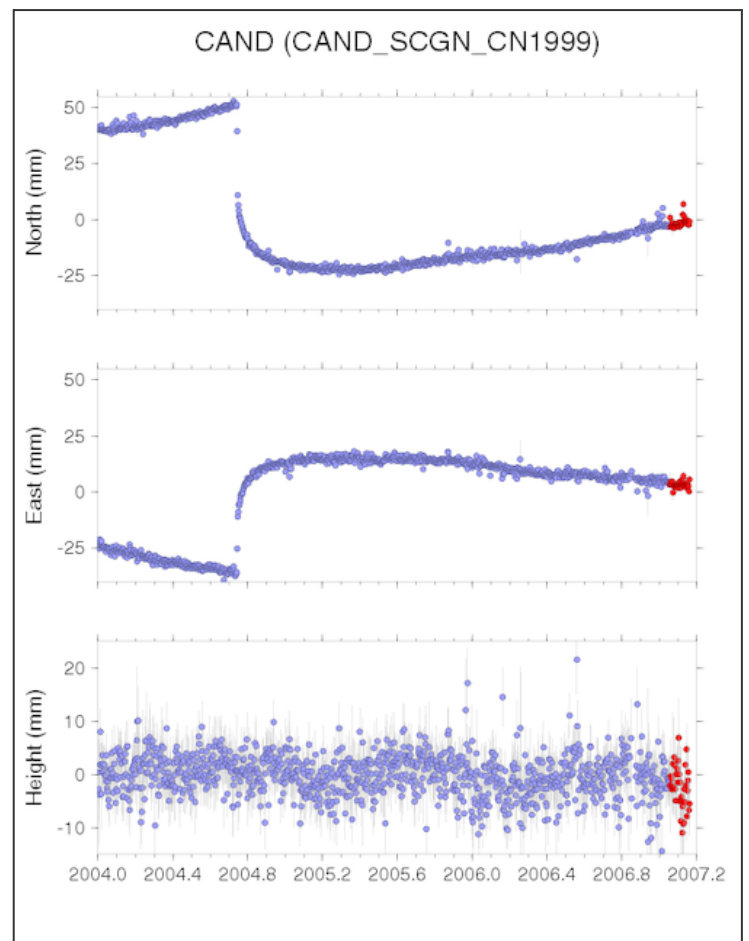
Occasionally, time series plots will reveal some interesting behaviors of GPS Stations. Here are a couple intriguing ones.

Station CAND is near Parkfield, CA. Obviously something big happened around 2004.7 (late Sept, 2004).

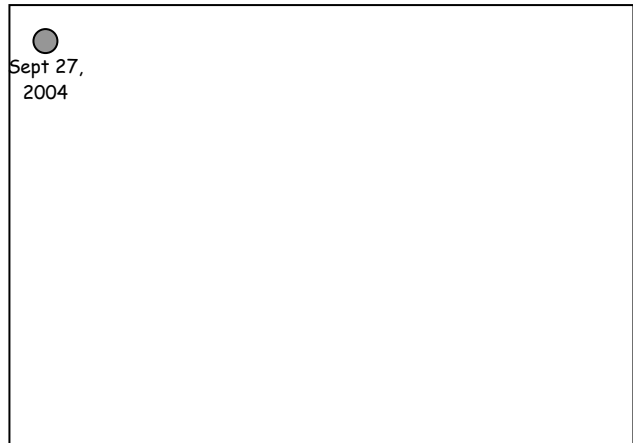
1. What do you think could have caused that big of a movement?

If you guessed earthquake, you're right. It was the September 28th, 2004 Parkfield Earthquake, magnitude 6.0.

2. What was the general direction of CAND before the quake?
3. What was the general direction of CAND after the quake?
4. What was the direction of CAND during the quake?



5. After the quake, there were a series of aftershocks and continued movement of the ground. About how far did CAND slip during the quake and shortly after it, from 2004.7 to 2004.8?



6. In the space to the right measure out and draw an arrow to show the direction and how far CAND moved during the time period noted in #5!

Here's another interesting one a little closer to home.

Here is Station P697 located on the Southeast side of Mt. St. Helens.

This station is measuring a lot more than the movement of the tectonic plate underneath it. It's also measuring the movement of the side of the volcano itself!

1. What direction is it moving during the following time periods:

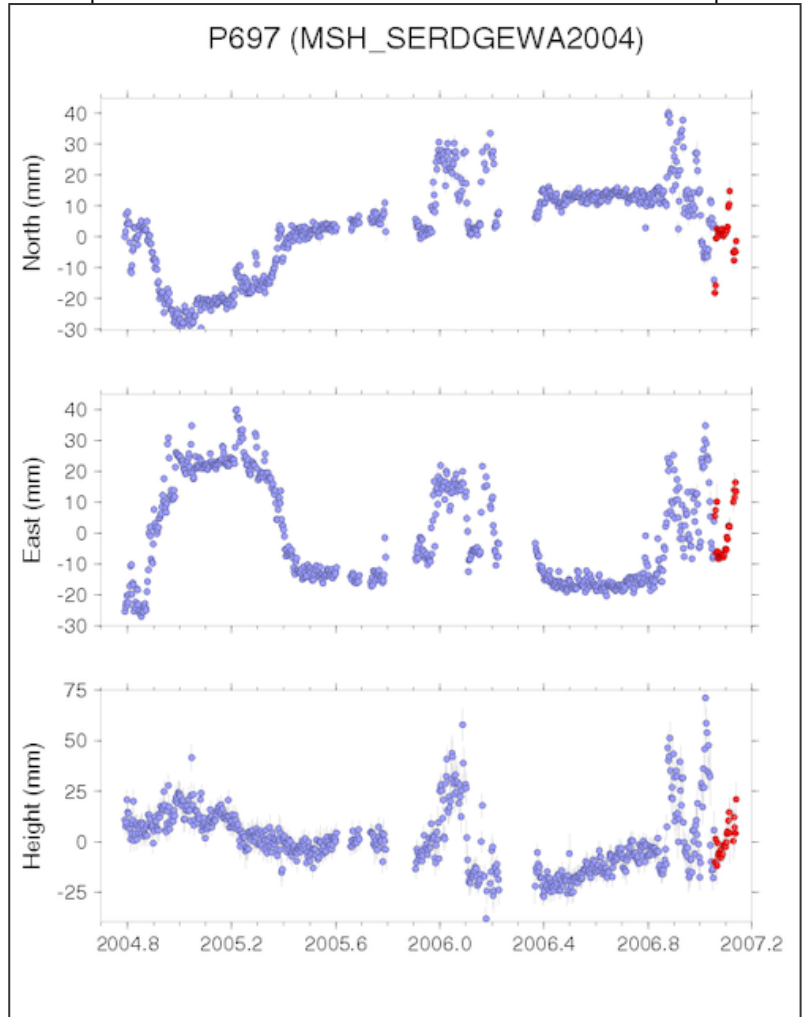
2004.8 to 2005.0?

2005.0 to 2005.4?

2005.4 to 2005.9?

2. Describe what happened during 2005.9 and 2006.2. Note that you need to discuss Height as well!

3. Did this same process happen again? When?



4. Can you hypothesize what's happening considering what you know about what's building inside the crater?

Instructor notes for INTRO TO GPS

Grades: 6 - 8

Notes:

Students don't need to know how the satellites work - only that the receivers can detect VERY small movements on the Earth in N/S, E/W, and Height. (or do they - can they get away with the triangulation idea of zooming in on one position)

Receiver needs to talk to the satellites so need to consider where to put the monuments to get the best data.

Translate small changes to large changes by looking at larger scope of time.

Specifics:

- ❖ Know the metric system - millimeter, centimeter, meter, kilometer
- ❖ Using cardinal directions perfectly
- ❖ Be able to read time series plots of N/S, and E/W
- ❖ The larger the vector arrow, the more the movement.

Students need to know that GPS data provides evidence to support that converging plates are moving towards each other, diverging plates are moving in opposite directions away from each other, and that transform boundaries are sliding past one another in opposite directions.

Showing pictures/video helps with these concepts
Looking at time series plots provides the hands-on

Improvements

Have students draw the diagonal line when it's necessary. Put points X and Y at the ends of the lines and have them connect points X and Y.

Implementation Ideas:

Give graph paper separately

Make class set of nice big time series to use each period

Try CARH and CAND for transform boundary

Have the kids determine what kind of boundary this is - or if they haven't gotten that far, tell them it's called a transform boundary and then discuss it more in detail later.