Explore Tectonic Motions of the Western United States GPS Data

Student worksheet

Are the tectonic plates still moving? Yes! But don't take my word for it; let's explore evidence of plates moving today to see how the land beneath your feet is moving, crumpling, squishing, and stretching. In this activity, you will study the map on the poster Tectonics Motions of the Western United States to look for evidence of different types of crustal motion in the Pacific Northwest region (Oregon/Washington), the Basin and Range region (Utah/Nevada), and California, then consider the hazards and societal impact that might result due to these motions.

(optional) What's GPS and how can GPS pinpoint a location on Earth?

The Global Positioning System (GPS) is used to study how Earth's tectonic plates move and deform. GPS monuments are cemented into the ground to measure how the underlying plate moves in three directions (north-south, east-west, and up-down). While GPS units in a car measure movement in miles per hour, high-precision GPS units used for scientific studies measure movement as slow as a few millimeters in a year. Even those few millimeters can be important—as the crust slowly moves, leading to earthquakes occurring.

First watch a video, NASA's Brief History of Geodesy (http://bit.ly/nasawhatisgeodesy), then have a discussion about geodesy and uses of GPS. Your teacher will demonstrate how satellites pinpoint the location of a GPS station using bubble gum, string, and a gumdrop model of a GPS monument. Afterwards answer the questions below and sketch a diagram of the demonstration.

1. What do the pieces of bubble gum represent? How far above the Earth would they actually be?

2. What does the string represent?

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

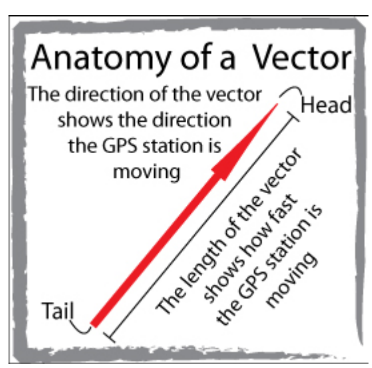
4. Why wouldn't one or two satellites work?

5. Sketch a diagram of the demonstration, labeling the GPS, Earth, Satellites, and string.

What's a GPS vector? What does it show?

A brief overview of velocity vectors shown on the map

Each vector represents a data point from a GPS monument and is called a *velocity vector* **(or vector).** Remember that the GPS monuments are affixed to the ground. If the GPS monuments are moving, then the ground is moving. The tail of the vector is the location of the GPS. The vector points in the direction the plate is moving *at that GPS monument*. The *length* of the vector arrow represents how fast the ground is moving at that spot. The longer the vector, the faster the ground is moving. **The vector shows the speed and direction of the ground at the GPS station.**



Note about reference frames:

Every tectonic plate on Earth is in motion. Since every location on the Earth is moving, how do you say how fast something is moving? You can only compare how fast one place is moving compared to another place. Scientists compare the motion of one tectonic plate or region *relative* to another tectonic plate to more easily view the differences in motion. For this activity, we are using a reference frame where the interior areas of the North American plate, such as Kansas or Nebraska, are not moving. In scientific terms, the vectors displayed on these maps are displayed in the *North American Reference Frame.* At this time, there are GPS does not work under water in the ocean, so no vectors are displayed in the ocean for observed data.

Explore the map: Tectonic Motions of the Western United States.

Questions to help orient you to the map:

1. What do the red vectors represent? (hint: read the "What's a GPS vector" above) Where is the GPS station located compared to the vector?

2. What is the scale for the vectors? Using a ruler, measure the vector scale on the map:

- 10 mm/yr = ________ mm

- Draw a vector representing 20 mm/yr here:

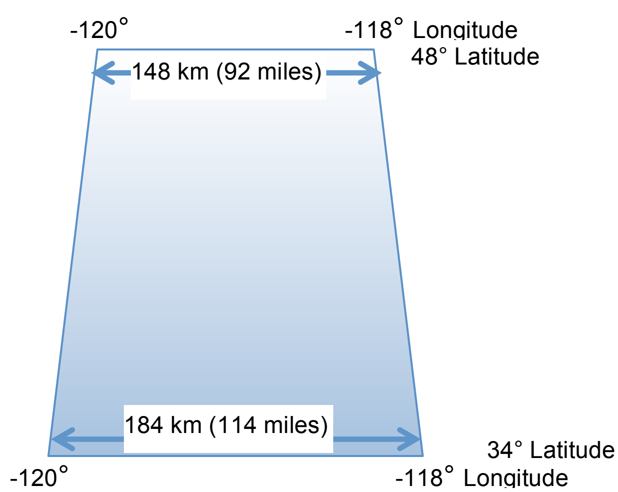
3. What do the yellow lines on the map represent?

4. Label the states on the map to the right.

Note:

- **The distance between each degree of latitude** (e.g. measuring along a north-south line) is approximately 69 miles (111 kilometers)*
- **The distance between each degree of longitude** (e.g. measuring along an east-west line) decreases slightly as you go north from the equator. On this map, the distance between lines of longitude decreases by about 11 miles from the bottom of the map to the top of the map

5. Why is the map different between the top & bottom of the map?



* Source: NOAA National Hurricane Center Latitude/Longitude Distance Calculator, retrieved from http://www.nhc.noaa.gov/gccalc.shtml Aug 21, 2015

Guiding questions as you explore

1. In general, what direction is the land moving (directions that the vectors point) in the Pacific Northwest (Oregon/Washington), Basin & Range (Nevada/Utah), and California? Measure some of the motions in terms of the vector speed (the lengths of the vectors) and write them below. If it helps to draw a miniature map, use this space and illustrate.
   - Pacific Northwest
   - Basin & Range
   - California
2. What do you notice about the velocities of the land in these three regions compared to other regions? Why are there are so many GPS stations in the far western United States (close or on the coast)?
3. In general, how are the motions in California, Pacific Northwest (Oregon/Washington), and Basin & Range (Nevada/Utah) similar and different? What does this indicate?
4. Now, go into more detail.
   - For each region, describe how the velocity of the land changes from the coast to inland, across/ near a plate boundary (heavy yellow lines on map), from one side of a state to another, and/or from north to south. Use the vector scale bar to make measurements. Provide some examples in the space below of the general map location and velocities, and directions.
     - Pacific Northwest (Oregon/Washington)
     - Basin & Range (Nevada/Utah)
     - California … Which side of the plate is moving faster?
   - Where are there vectors that are very different in length or direction from each other? For example, describe locations where the vectors are moving in a similar direction but different speeds or where they are moving in different directions. What does this indicate?

Pull your observations together

Describe the resulting motion of the land in those areas over time if it continues to move as it does today. How is the ground changing shape over time (thousands of years) … Is it squishing together? Pulling apart? Twisting? Where? What else might happen?

Pacific Northwest: Based on the motions observed in Washington, Oregon, and very northern California, what type of plate boundary is off the coast of the Pacific Northwest (Convergent, Divergent, or Transform)?

Basin & Range: Based on the motions observed from Utah to western California, what is happening in this region? Given enough time, what kind of plate boundary could develop (Convergent, Divergent, or Transform)?

California**:** Based on the motions observed on either side of the plate boundary in California, what type of plate boundary is this? (Convergent, Divergent, or Transform)?

Considering what you know about tectonic plates… do the plates move smoothly along the plate boundaries or in sudden movements? Using the vector motion data, where would you most expect to find earthquakes? What regions of the west would be at risk greatest risk based on this information?

What other data would be helpful to find out more about the regional tectonic picture?

Explore more using the online tool, the UNAVCO GPS Velocity Viewer:

(Google search for UNAVCO GPS Velocity Viewer)
http://www.unavco.org/software/visualization/GPS-Velocity-Viewer/GPS-Velocity-Viewer.html

Explore the Western United States with the vectors, then turn on and off the layers showing earthquakes, volcanoes, faults, and plate boundary layers. What do you notice?

There's more to explore – zoom out and explore the world*!* (Change the number of vectors displayed to **1 in 20** or **1 in 10**) Explore for a while then change the data source to another reference frame.

Using just the GPS velocity vectors, can you predict the types of plate boundaries in different areas of the world? Check your predictions by turning on the plate boundaries layer.

What other types of data were useful for understanding the plate motions? How do they complement each other?