

Explore Tectonic Motions of the Western United States with GPS Data

Student worksheet

Are the tectonic plates still moving? How do we know? Let's explore evidence of the plates moving using current data to see how the land beneath your feet is moving, crumpling, squishing, and stretching. In this activity, you will study the map on the [Tectonics Motions of the Western United States](#) poster 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 is 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—a slowly moving crust leads to earthquakes.

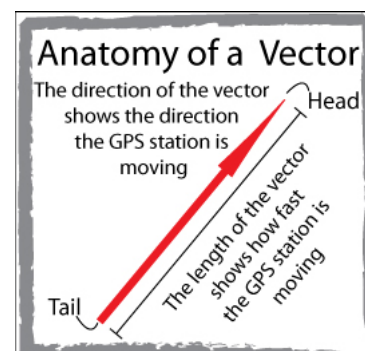
First watch this video, [NASA's Brief History of Geodesy](http://bit.ly/nasawhatisgeodesy) (<http://bit.ly/nasawhatisgeodesy>), and then discuss the uses of geodesy and GPS. Next, after watching a demonstration of how satellites pinpoint the location of a GPS station, answer the questions below and sketch a diagram of the demonstration.

1. What is geodesy? What can we do with geodesy?
2. What do the pieces of bubble gum represent? How far above the Earth would they actually be?
3. What does the string represent?
4. How many satellites are needed to pinpoint the location of a spot on Earth?
5. 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 are the arrows shown on the poster?

Each arrow originates at a GPS station, and points in the direction that the station is moving. Its length is proportional to the station's speed (velocity). The longer the arrow, the faster the ground is moving. The GPS stations are anchored into rock or deep into soil so we can see how the whole area is moving. If the GPS stations are moving, then the ground is moving. This type of arrow, that shows both the speed and direction, is called a vector. At this time, GPS does not work under water, so no vectors are displayed in the ocean for observed data.



Note about reference frames:

Every tectonic plate on Earth is in motion. Since every location on the Earth is moving, how do we know how fast a single place is moving? For plate motions, we think of one plate or region as fixed and not moving. We then compare the motions of other places to this fixed place. For example, in this activity, the interior region of North America, such as Kansas and Nebraska is fixed and not moving.

This reference frame, called the *North American Reference Frame*, shows the motion of the regions of the western United States compared to this fixed region. This allows scientists to view the differences in motions on the North American tectonic plate and other adjoining plates, such as the Pacific plate.

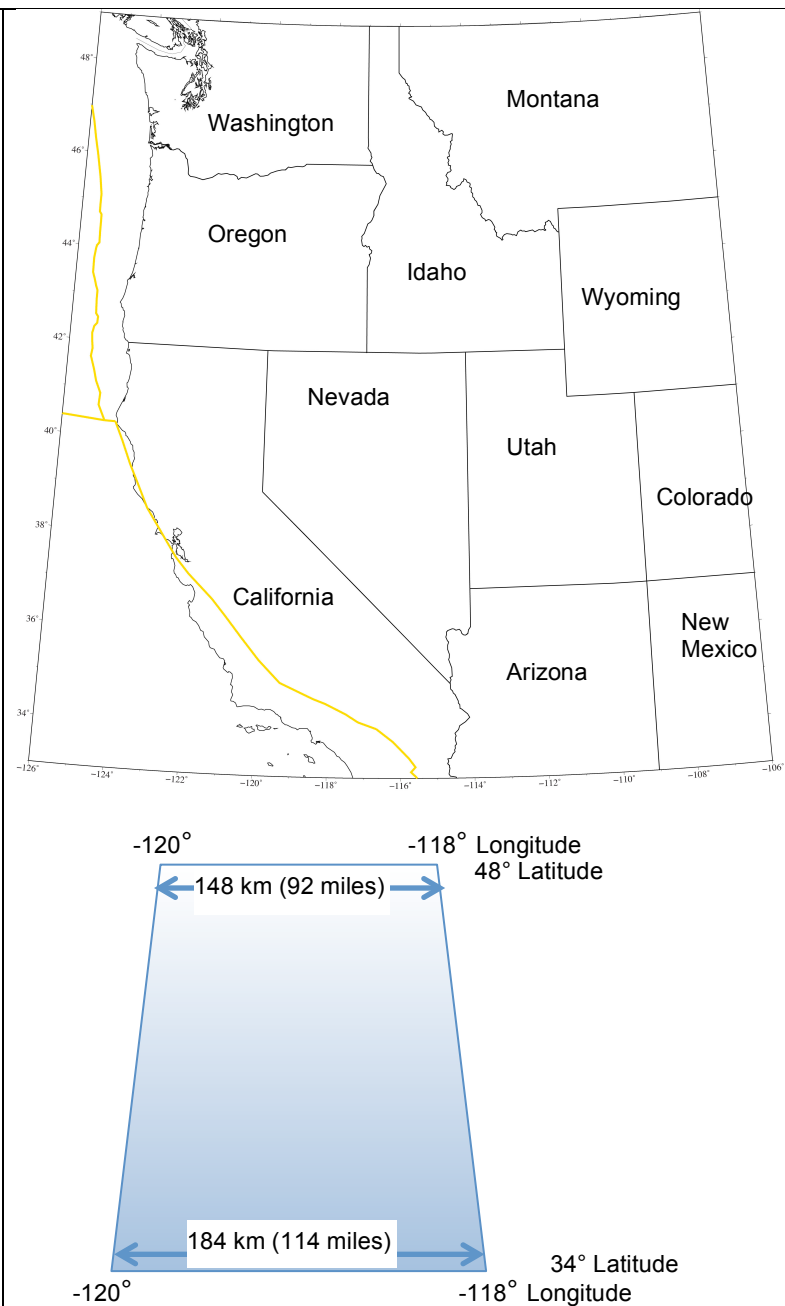
Explore the map: Tectonic Motions of the Western United States.

Questions to help orient you to the map:

1. What do the red vectors represent?
(Hint: read the "What's a GPS vector" above)
2. What is the scale for the vectors?
[Look at the bottom of the map]
Using a ruler, measure the vector scale on the map:
 - 10 mm/yr = _____ mm
 - Draw a vector representing 10 mm/yr here:
3. What are the yellow lines on the map?

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.
4. Why is the map scale 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

- On your map, draw an outline of each of the regions:
 - Pacific Northwest (Washington / Oregon / Northern California region)
 - Basin & Range (Nevada / Utah region)
 - California
 - Other Regions?
- In general, what general direction is the land moving in each region? Measure two to four representative vectors (the lengths of the arrows) using the vector scale bar on the map for each region. Sketch these vectors and label their velocities and directions. Where is the ground squishing together (compressing)? Pulling apart (extending)? Twisting? Sliding past?

- Pacific Northwest (Washington / Oregon / Northern California region)

- Basin & Range (Nevada / Utah region)

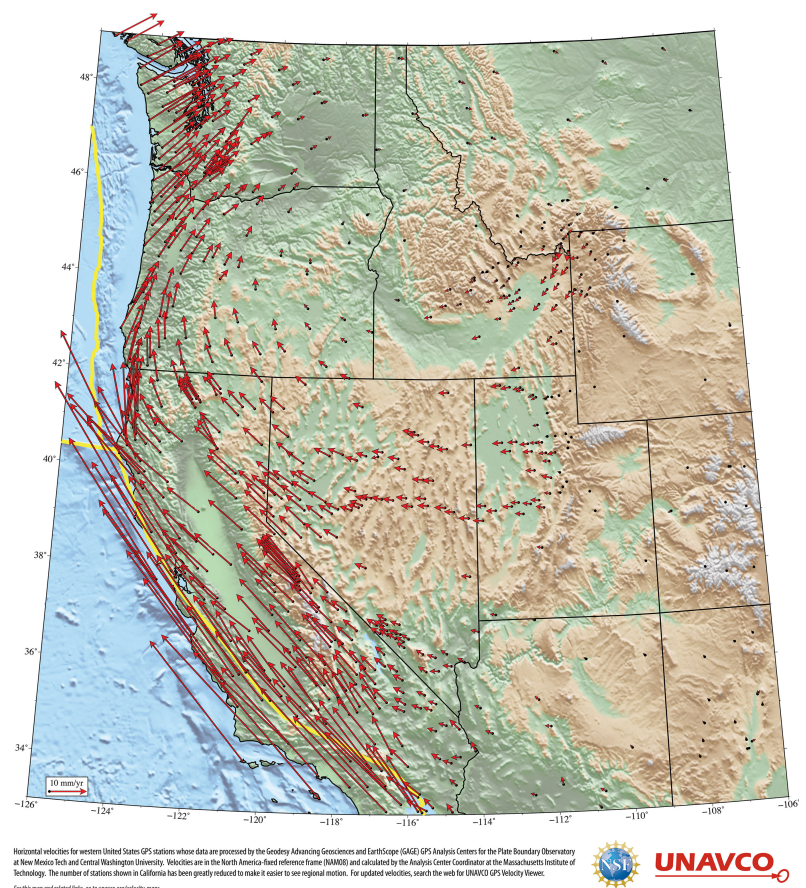
- California

- Other Regions?

- Circle on the map areas where the velocity changes:

- Vectors point in similar direction but have very different lengths (speeds)
- Vectors are pointing different directions from each other
- From the coast to inland,**
- Across/ near a plate boundary** (heavy yellow lines on map),
- From east to west within a state,** and/or
- From north to south.**

- How are the motions similar and different between the regions? What does this indicate?

Tectonic Motions of the Western United States

Pull your observations together

How is the ground changing shape over time (thousands of years) and where? Describe the resulting motion of the land in those areas if motion continues to move as it does today.

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

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?

California: Based on the motions observed on either side of the plate boundary in California, what type of plate boundary is this?

Societal impacts of plate motion

Identify two places that you think would be most likely to have earthquakes. Why did you choose these areas? Describe the vectors to support why you think these particular places would be more likely to have earthquakes. [Optional] Look at a [seismic hazard map](#) – what is the level of seismic hazard associated with the areas you chose?

Explore more using the online tool, the UNAVCO GPS Velocity Viewer: (Google search for UNAVCO GPS Velocity Viewer)

Turn on and off the layers showing earthquakes, volcanoes, faults, and plate boundary layers. Try different GPS/GNSS data sources to change the reference frame or to show modeled data.

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?

*When zooming out to see the world, change the number of vectors displayed to **1 in 20** or **1 in 10**.
Posters are available online; search for UNAVCO Velocity Map Posters.