



## Measuring Earth with GPS, Unit 1: Introduction to GPS Jigsaw

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*GPS stations precisely record the position of the solid ground they are on. Their location is measured in the north–south direction, east–west direction, and vertical direction.*

### Part 1: Becoming an “expert” in your team

Circle the team to which you are assigned:

Team 1: Reference frames

Team 2: Direction of motion

Team 3: Speed of motion

Answer the questions on the handout that is specifically for your team.

### Team 1: Reference frames

A reference frame is a point of view. To describe how a single location is moving, we describe the motion relative to something fixed. Whatever we hold fixed gives us our reference frame. For example, if you use a moving car as a fixed reference frame, a person walking down a street would appear to be moving quickly backwards. There are two commonly used reference frames in North America:

1. NAM08 (North American Reference Frame): The interior region of North America is considered fixed and all else moves compared to it.
2. IGS08 (based on the International Terrestrial Reference Frame): Hot spot volcanoes above mantle plumes are considered fixed and all else moves compared to them.

The arrows on the maps are GPS vectors. The arrow originates at a GPS station. It points in the direction that the station is moving, and its length indicates the station's speed.

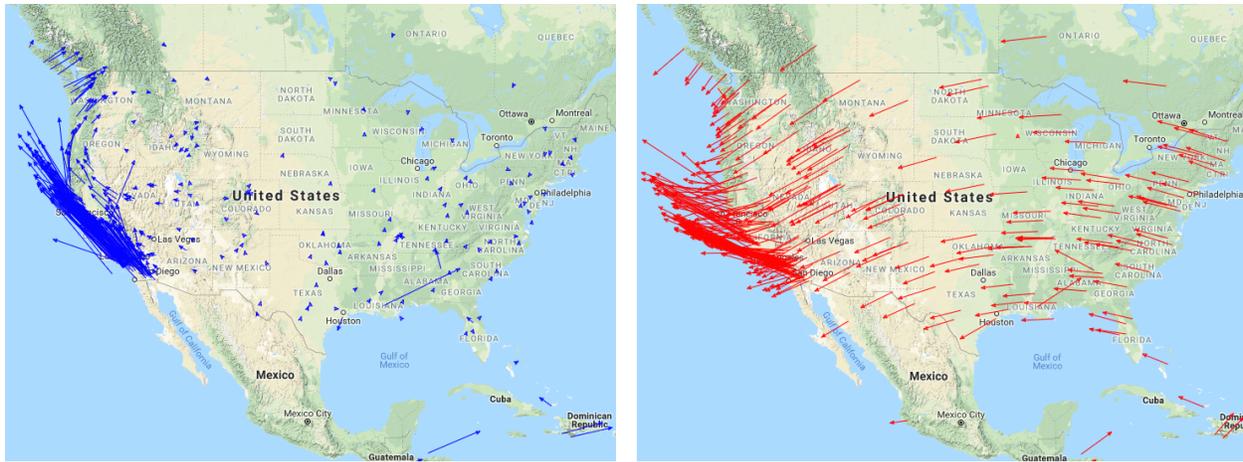


Figure 1. Screenshots from UNAVCO's GPS Velocity Viewer showing vectors indicating motions for GPS stations across North America. The stations are the same between the two maps. Maps from <https://www.unavco.org/software/visualization/GPS-Velocity-Viewer/GPS-Velocity-Viewer.html>

1. Which reference frame would show central and eastern United States as not moving?

NAM08      IGS08

2. Explain why the arrows from the same GPS stations are different (direction and speed) between the maps above.

3. Circle the reference frame shown in each map:

Left:    NAM08    IGS08

Right:    NAM08    IGS08

Explain your answers:

4. Figure out an analogy to explain reference frames to a fourth grader.

### Team 2: Direction of motion

GPS stations are attached to the ground, so they move if the ground moves. They record data in three directions: north–south, east–west, and vertical. These three directions need to be combined to determine the overall direction of motion of the GPS station.

**North–south:** The y-axis is labeled north, so the GPS station is moving northward if the numbers over time are increasing and southward if the numbers over time are decreasing.

**East–west:** The y-axis is labeled east, so the GPS station is moving eastward if the numbers over time are increasing and westward if the numbers over time are decreasing.

**Vertical:** The y-axis is labeled height, so the GPS station is rising if the numbers over time are increasing and lowering if the numbers over time are decreasing.

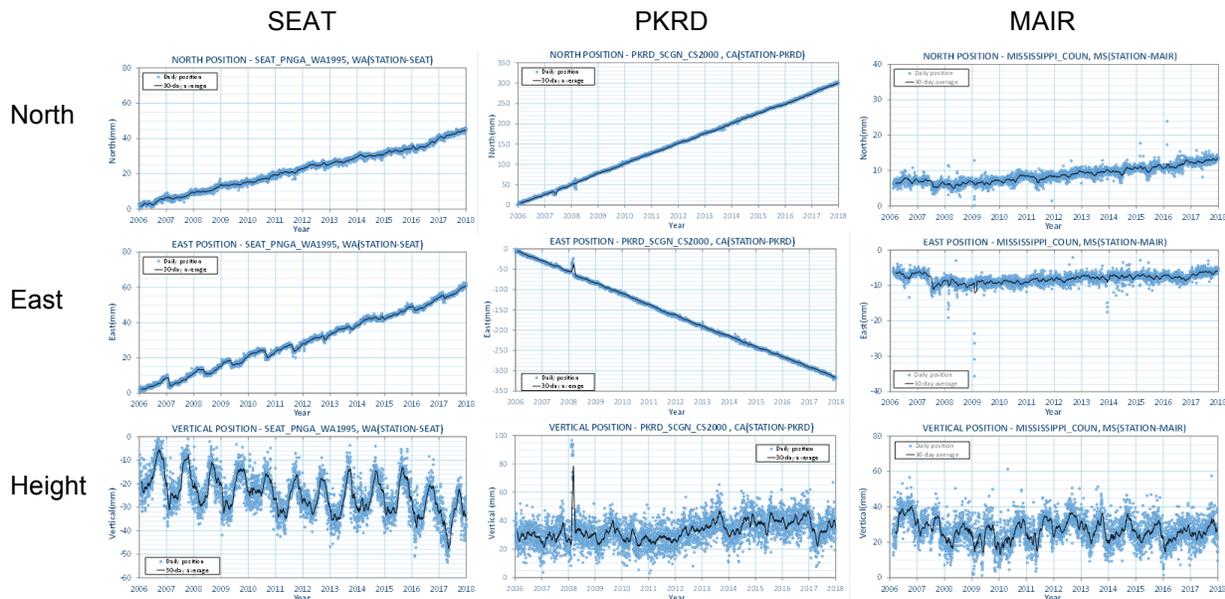


Figure 1. Graphs from UNAVCO’s PBO Network Monitoring. The top graph shows north, the middle graph shows east, and the bottom graph shows height. The bottom (x) axis shows time from 2006 to 2018 for all graphs. Left (SEAT): Data from a GPS station in Seattle, Washington. Middle (PKRD): Data from a GPS station in Los Angeles, California. Right (MAIR): Data from a GPS station in Mississippi. Graphs from <https://www.unavco.org/instrumentation/networks/status/pbo>

1. In what horizontal direction is each of the GPS stations moving?  
 Choices: north northeast east southeast south southwest west northwest not moving

SEAT: \_\_\_\_\_ PKRD: \_\_\_\_\_ MAIR: \_\_\_\_\_

2. Draw what the graphs would look like if a station was moving southwest:

3. Explain to a fourth grader how you determined your answers.

|       |      |
|-------|------|
| North |      |
| East  |      |
|       | Time |

### Team 3: Speed of motion

GPS stations record horizontal motion in two directions: north–south and east–west. You can use the information provided in a time–distance graph to calculate the speed of motion. Speed is how far something traveled (distance) over a period of time. To calculate the speed:

- 1) Figure out a starting date and an ending date on the graph.
- 2) Calculate the distance by measuring the position at the ending date and subtracting the position at the starting date.
- 3) Calculate the time by measuring the time at the ending date and subtracting the time at the starting date.
- 4) Take the calculated distance and divide it by the calculated time to figure out the speed.

If you prefer to visualize it in a different way, the equation is:  $\text{speed} = \text{distance} / \text{time}$

1. Pick a ten-year interval and fill in the table below to calculate the speed in the two directions that the GPS station is recording. Units are included for you.

|  | North–South      | East–West        |
|--|------------------|------------------|
| 2) Distance (difference in position from the beginning to the end) | millimeters (mm) | millimeters (mm) |
| 3) Time (years from the beginning to the end)                      | 10 years         | 10 years         |
| 4) Rate (distance divided by time)                                 | mm/year          | mm/year          |

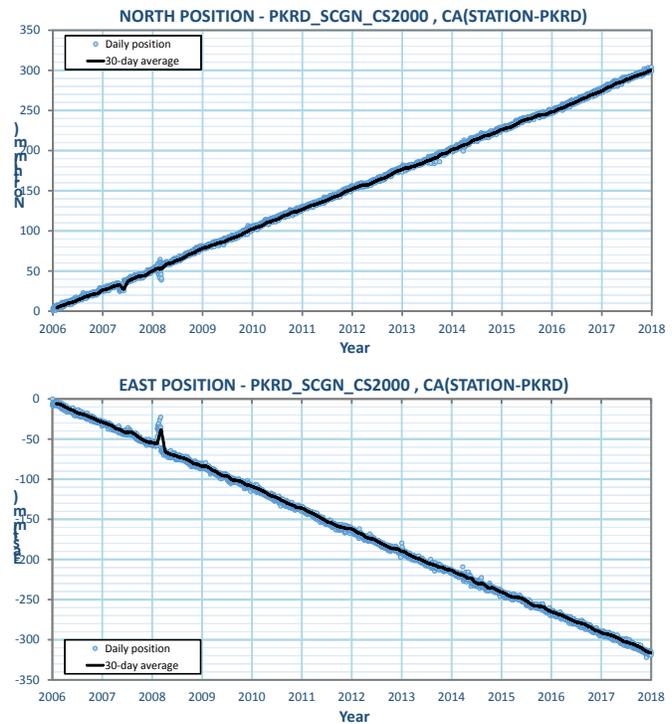


Figure 1. Graphs from a GPS station in Los Angeles, California (PKRD). The top graph shows movement north–south, and the bottom graph shows movement east–west. The bottom (x) axis shows time from 2006 to 2018. Graphs from <https://www.unavco.org/instrumentation/networks/satus/pbo/overview/PKRD>

2. Explain to a fourth grader how you determined your answers.

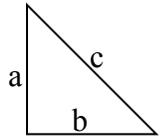


To figure out the overall speed a station is moving the speeds in the two horizontal directions (north–south and east–west) need to be combined. There is a cool math trick that you can use to do so:

- 1) Square the north–south speed (multiply the north–south speed by itself)
- 2) Square the east–west speed
- 3) Add these two numbers together
- 4) Take the square root of the sum

If you prefer to visualize it in a different way, this is the equation (it's called the Pythagorean Theorem, often written as  $a^2 + b^2 = c^2$ ):

$$\text{total rate} = \sqrt{(\text{north–south rate})^2 + (\text{east–west rate})^2}$$



7. How fast is your station moving? (remember to include units)
8. If possible, draw a line in the space below indicating how far your station moves each year.
9. How far will your station move over a lifetime (100 years)?
10. If you change the reference frame, how are your responses to Questions 6 and 7 affected?
11. Horizontal motion is generally a result of tectonic plate movement. Vertical motion can be due to plate tectonics, or it can be affected by the water cycle (this often has a seasonal trend, but there can also be a long-term trend if an area is losing or gaining water over time). Explain WHY you think your station is moving the way it is.