7 Observing Earth's Moving Surface

PROBLEM SOLVING

2 CLASS SESSIONS

ACTIVITY OVERVIEW

NGSS CONNECTIONS

In this activity, students learn how to analyze and interpret data from GPS measurements over time, which they use to determine the rate and direction of tectonic plate movement. They work collaboratively in groups and then share their findings. While students do not provide explanations for the motions shown in the GPS data in this activity, the analyzed data display the types of plate boundary interactions students will encounter in subsequent activities.

NGSS CORRELATIONS

Performance Expectations

Working towards MS-ESS2-2: Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales.

Working towards MS-ESS3-2: Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects.

Disciplinary Core Ideas

MS-ESS2.A Earth's Materials and Systems: The planet's systems interact over scales that range from microscopic to global in size, and they operate over fractions of a second to billions of years. These interactions have shaped Earth's history and will determine its future.

MS-ESS3.B Natural Hazards: Mapping the history of natural hazards in a region, combined with an understanding of related geologic forces, can help forecast the locations and likelihoods of future events.

Science and Engineering Practices

Analyzing and Interpreting Data: Analyze and interpret data to provide evidence for phenomena.

Constructing Explanations and Designing Solutions: Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) and the assumption that theories and laws that describe nature operate today as they did in the past and will continue to do so in the future.

Crosscutting Concepts

Patterns:

Graph, charts, and images can be used to identify patterns in data.

Patterns in rates of change and other numerical relationships can provide information about natural and human designed systems.

Scale, Proportion, and Quantity:

Phenomena that can be observed at one scale may not be observable at another scale.

Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small.

Proportional relationships (e.g., speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes.

Stability and Change: Stability might be disturbed either by sudden events or gradual changes that accumulate over time.

Connections to Engineering, Technology, and Applications of Science: Interdependence of Science, Engineering, and Technology: Engineering advances have led to important discoveries in virtually every field of science, and scientific discoveries have led to the development of entire industries and engineered systems.

Connections to Engineering, Technology, and Applications of Science: Influence of Science, Engineering, and Technology on Society and the Natural World:

The uses of technologies and any limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. Thus, technology use varies from region to region and over time.

Technologies extend the measurement, exploration, modeling, and computational capacity of scientific investigations.

Common Core State Standards—Mathematics

MP.4: Model with mathematics.

6.NS.C.5: Understand that positive and negative numbers are used together to describe quantities having opposite directions or values (e.g., temperature above/below zero, elevation above/below sea level, credits/debits, positive/negative electrical charge); use positive and negative numbers to represent quantities in real-world contexts, explaining the meaning of zero in each situation.

Common Core State Standards—ELA/Literacy

SL.8.1: Engage effectively in a range of collaborative discussions (e.g., one-on-one, in groups, teacher-led) with diverse partners on grade 8 topics, texts, and issues, building on others' ideas and expressing their own clearly.

WHAT STUDENTS DO

Students analyze and interpret GPS data that show movement of Earth's surface.

MATERIALS AND ADVANCE PREPARATION

- *For the teacher*
  - 1 Scoring Guide: ANALYZING AND INTERPRETING DATA (AID)
  - 1 Visual Aid 7.1, "Interpreting GPS Time-series Data Plots"

- *For each student*
  - 3 copies of Student Sheet 7.1, "Analyzing and Interpreting GPS Data"
  - 1 clear metric ruler
  - 1 Scoring Guide: ANALYZING AND INTERPRETING DATA (AID) (optional)

Each student will need three copies of Student Sheet 7.1. Make sure to print enough copies for the class and a few extra copies in case some students need to redo their diagrams.

TEACHING SUMMARY

GET STARTED

1. Introduce the idea that movement is change in position over time.
   a. Ask students, "How do you know something has moved?"
   b. Demonstrate movement while students watch.
   c. Ask, "What information would you need to prove that something moved?"

DO THE ACTIVITY

2. Introduce GPS.
   a. Start by asking students, "What do you know about GPS?"
   b. Guide students through reading the introduction and Guiding Question.
   c. Project Visual Aid 7.1, "Interpreting GPS Time-series Data Plots."
   d. Complete Visual Aid 7.1 with the class.
3. Students analyze and interpret GPS data for Hayfork, California.
   a. Direct students' attention to the GPS time-series plots in the Student Book.
   b. Handout Student Sheet 7.1, "Analyzing and Interpreting GPS Data."
   c. Work with the class to estimate the movement of the Hayfork GPS station.
   d. Work with the class to plot the movement of the Hayfork GPS station.
4. Groups analyze the GPS data for Alaska and Iceland.
   a. Assign pairs of students to each set of data.
   b. Hand out a fresh copy of Student Sheet 7.1 to each student.
   c. Assist students as needed in answering Question 2 on Student Sheet 7.1.
   d. Allow time for students to share their results within their groups.
   e. Ask students why they think these observed movements are happening on Earth's surface.
5. Students analyze and interpret data for two stations in southern California.
   a. Hand out a fresh copy of Student Sheet 7.1 to each student.
   b. Ask the class whether the stations are moving together or apart.

BUILD UNDERSTANDING

6. Students reinforce their abilities to interpret time-series plots.
   a. Use Analysis item 1 for students to practice interpreting basic GPS movement data.
   b. (AID ASSESSMENT) Introduce vertical movement data as part of time-series plots.
   c. (AID ASSESSMENT) Use Analysis item 3 to introduce rapid earth movement as detected by GPS stations.
7. Use Analysis item 4 to help students understand that small annual movements can add up to large movements over geological time.
8. Use Analysis item 5 to link back to the issue of finding a location to store nuclear waste.

TEACHING STEPS

GET STARTED

1. Introduce the idea that movement is change in position over time.

    a. Ask students, "How do you know something has moved?"

    Students may respond that something changes location, or it changes places. They may say that they can see it move. Follow up by asking, "If it didn't change location, could it have still moved?" Expect students to say something about it changing location but going back to the original spot. They also might say that if it is moving very slowly, then they couldn't see it move.

    b. Demonstrate movement while students watch.

    While students watch, walk across the room. Ask, "Did I move?" They will, of course, agree that you did. Tell them to close their eyes. Walk a few steps, and tell them to open their eyes. Ask "Did I move? How do you know?" Students will likely say yes because your position changed.

    Do a third demonstration. This time, start walking. Tell students to close their eyes, and then move a couple steps and return to the place where you told them to close their eyes. Ask "Did I move?" Students who didn't close their eyes (even though they were supposed to) will say that you moved, but those who did close their eyes might say you did not. Explain that you did.

    c. Ask, "What information would you need to prove that something moved?"

    Students may say a video, pictures of some sort, or being able to track the object moving. Explain that video is simply a lot of pictures taken very close together in time. Use this as the segue into GPS as a continuous tracking of a position on Earth's surface.

DO THE ACTIVITY

2. Introduce GPS.

    a. Start by asking students, "What do you know about GPS?"

    Students will likely mention that they use GPS in cars and on phones to provide directions. Explain that the type of GPS used in cars and on phones is accurate to within a few meters, which is fine for driving or hiking. Tell students that there are other kinds of GPS that are much more accurate, and some systems can measure movements as small as 1 mm.

b. Guide students through reading the introduction and Guiding Question.

Use the introduction to introduce the term *GPS* and emphasize that scientists can use the very accurate GPS to monitor even small movements of the ground.

c. Project Visual Aid 7.1, "Interpreting GPS Time-series Data Plots."

Use the graphs on Visual Aid 7.1 to help students understand how to interpret the graphs showing movement. Be sure that students understand that they use the y-axis scale to determine how far, in millimeters, the station has moved. Remind them to pay attention to the labels on the axes. The y-axis indicates movement in millimeters in a north–south or east–west direction. The x-axis represents time in years.

d. Complete Visual Aid 7.1 with the class.

Work through the top three graphs on the left with the class. Then allow students time to analyze the top three graphs on the right. Share the correct responses before moving on to the graphs in the bottom section. In this section, students combine the information from the north–south graph with that of the east–west graph in order to determine the actual direction of movement.

If students struggle with combining the information from the two graphs, consider using analogies, such as asking, "If you moved 1 mile north, followed by 1 mile east, in what direction would your finish point be from your starting point?" (Answer: Northeast) "What would have been a shorter, more-direct route to that same point?" (Answer: A straight line between the starting point and the finishing point)

3. Students analyze and interpret GPS data for Hayfork, California.

a. Direct students' attention to the GPS time-series plots in the Student Book.

Allow students time to examine the maps and GPS plots. Tell them that they will first work through the Hayfork, California, data as a class. Explain that the data represent years of movement of a GPS station. The top graph represents movement in a north–south direction. The bottom graph represents movement in an east–west direction. By looking at the scale on the axes, students should be able to estimate how many millimeters the GPS station moved during the time period shown by the graph.

b. Handout Student Sheet 7.1, "Analyzing and Interpreting GPS Data."

Demonstrate how to use Student Sheet 7.1 by first having students write "Hayfork, California" in one of the spaces for location. Explain that the graph space on Student Sheet 7.1 allows the GPS movement data to be plotted. Point out that the y-axis represents north–south movement and the x-axis represents east–west movement.

c. Work with the class to estimate the movement of the Hayfork GPS station.

Ask students to use the north–south time-series plot in the Student Book to estimate how far the Hayfork GPS station moved in a northerly or southerly direction over the time period represented by the graph. They should see that it moved about 100 mm to the north. Now ask students to look at the east–west time-series plot and estimate the movement of the GPS station. They should note that it moved about 80 mm to the west.

d. Work with the class to plot the movement of the Hayfork GPS station.

Explain that the graph paper on Student Sheet 7.1 can be used for plotting the overall movement of the GPS stations. Tell students that they begin at the center of the graph, at the dot. They should draw a line along the y-axis to represent the amount that the station moved north or south. Then they should draw a line from that point along the x-axis to represent the amount that the station moved east or west. For Hayfork, this means moving 100 mm north and then 80 mm west. Finally, they should draw an arrow from the starting point (the dot) to the ending point. This arrow represents the overall movement of the GPS station during the time period. The overall direction is shown by the arrow. The length of the arrow indicates the relative speed of movement. Longer arrows indicate faster movement.

Teacher's note: Question 2 on Student Sheet 7.1 is not used for the Hayfork or Yellowstone data; it is used to compare the relative movement of pairs of GPS stations.

4. Groups analyze the GPS data for Alaska and Iceland.

a. Assign pairs of students to each set of data.

Point out that each pair of time-series plots represents GPS stations in the same region.

b. Hand out a fresh copy of Student Sheet 7.1 to each student.

Allow time for each pair of students to analyze the data set they were assigned. For the Alaska data, students should be able to determine that Station AC51 has moved toward the southeast (approximately 100 mm S, 20 mm E). They should also find that Station AC43 has moved toward the northwest (approximately 340 mm N, 100 mm W).

For the Iceland data, students should be able to determine that Station AKUR has moved toward the northwest (approximately 225 mm N, 100 mm W), and Station HOFN has moved toward the Northeast (approximately 140 mm N, 150 mm E). Sample student responses for both stations are found at the end of this activity.

c. Assist students as needed in answering Question 2 on Student Sheet 7.1.

Make sure students look at the locations of their GPS stations on the map and compare the locations with the directions of the arrows they drew on the graphs on Student Sheet 7.1. They should be able to see that the Alaska stations are moving toward one another and the Iceland stations are moving apart. In later activities, they will learn about converging and diverging plate boundaries and can refer back to these data at that time.

d. Allow time for students to share their results within their groups.

Allow time for group discussions before engaging the class in a discussion. Key points to emphasize include the fact that some locations on Earth's surface are moving towards each other and some are spreading away from each other. Also point out that the speeds of movement are different, and the speeds are slow. For the last point, draw (or have students draw) lines that are between 20 mm and 400 mm long (representing the range of values that they encountered). Point out that it took about 10 years for this movement to occur.

e. Ask students why they think these observed movements are happening on Earth's surface.

Students may be surprised to discover that Earth's surface is moving, particularly that parts of Earth' surface are moving towards each other and other parts are spreading away from each other. Ask students what they think causes these observed movements and what they indicate about Earth's surface. Some students may have prior knowledge of how Earth's surface is broken into plates and that the plates move; other students may not. Encourage all responses at this point.

5. Students analyze and interpret data for two stations in southern California.

a. Hand out a fresh copy of Student Sheet 7.1 to each student.

Direct students' attention to the time-series plots for Southern California in the Student Book. Tell students to work in their groups, using a clean copy of Student Sheet 7.1, to analyze the data.

They should find that Station P514 moved northwest (340 mm north, 300 mm west) and Station P580 also moved northwest (70 mm north, 60 mm west). Sample student responses for both stations are found at the end of this activity.

b. Ask the class whether the stations are moving together or apart.

Use Question 2 on Student Sheet 7.1 to engage students in a conversation about the relative motion of the two stations. Sample student responses for both stations are found at the end of this activity. Students will note that they are moving in approximately the same direction. Ask about the speed of movement of the two stations. Students should realize that one station (P514) is moving much faster than the other. If you think that students may have heard of the San Andreas fault, you might consider telling the class that the two stations are on opposite sides of the fault line. Otherwise, leave this information until later when students learn about transform plate boundaries.

BUILD UNDERSTANDING

6. Students reinforce their abilities to interpret time-series plots.

a. Use Analysis item 1 for students to practice interpreting basic GPS movement data.

Analysis item 1 is the most straightforward of the three Analysis items. One plot actually shows no motion; both N–S and E–W plots show horizontal lines.

b. (AID ASSESSMENT) Introduce vertical movement data as part of time-series plots.

Analysis item 2 introduces a graph that has been omitted from the previous time-series plots that students have encountered. The third graph shows vertical movement (up–down) of the station. Ask students to name a type of landform where it might be particularly useful to know the vertical movement of the ground. If nobody suggests it, guide students toward understanding that volcano-monitoring stations provide valuable information about up–down movement of the ground as changes in the magma underground may cause movements at the surface. This information can be used to help scientists predict the likelihood of an eruption. This Analysis item can be scored with the AID Scoring Guide. A sample Level-4 response is provided in Sample Responses to Analysis.

c. (AID ASSESSMENT) Use Analysis item 3 to introduce rapid earth movement as detected by GPS stations.

The time-series plots show a sudden ground movement in 2010. If students are having trouble suggesting what type of event might cause the ground to move suddenly, draw their attention to the location. If necessary, point out that this region of North America experiences earthquakes. This particular earthquake originated in Baja California, Mexico, on April 4. It had a magnitude of 7.2 and was felt throughout the region. This Analysis item can be scored with the AID Scoring Guide. A sample Level-4 response is provided in Sample Responses to Analysis.

7. Use Analysis item 4 to help students understand that small annual movements can add up to large movements over geological time.

   Many students will not be impressed by mere millimeters of movement of a GPS station. Remind students that motion of the station means that the ground underneath it is moving at rates undetectable without GPS technology. To impress that these motions have significant meaning for Earth, Analysis item 4 provides perspective that small-millimeter movements add up over time. Indeed, a 15-mm annual movement over 10 million years is 150 km of movement!

8. Use Analysis item 5 to link back to the issue of finding a location to store nuclear waste.

   Analysis item 5 allows students to review the overall picture of why GPS is important in studying Earth. It is useful in that it allows minute movements of Earth's surface to be visualized, and is helpful in understanding hazards such as earthquakes and volcanoes. Use Analysis item 6 to help students make a connection to why information about movement of the land could be helpful in deciding where to store nuclear waste.

EXTENSION

Students may be interested to find out how the ground in their particular region is moving according to GPS data. UNAVCO, a consortium that handles the majority of GPS data in the United States, has a way to zoom into GPS stations on a map. Go to the *Third Edition Geological Processes* page of the SEPUP website at *www.sepuplhs.org/middle/third-edition*, and read the information on how to use UNAVCO's website to locate the nearest GPS station.

REVISIT THE GUIDING QUESTION

How can GPS data help us understand Earth's surface?

GPS allows scientists to both monitor the slow motion of the ground beneath a GPS station that is otherwise undetectable and capture sudden changes, such as earthquakes, causing the ground to shift. GPS data also show vertical motion of the ground. Analysis of such data shows that Earth's surface is moving slowly. These slow movements can become significant over very long periods of time. Analysis also shows that different parts of Earth's surface are moving in different directions and at different speeds.

ACTIVITY RESOURCES

KEY VOCABULARY

GPS

REFERENCES

For Southern California, Yellowstone, and Alaska regions:
UNAVCO. (2014). *PBO network monitoring*. Retrieved from *http://www.unavco.org/instrumentation/networks/status/pbo*

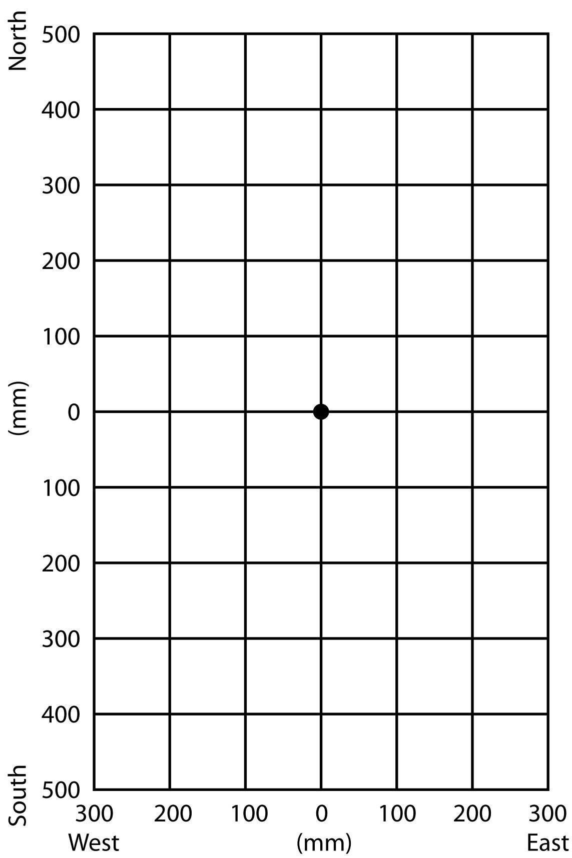
For Iceland region:
Nevada Geoditic Laboratory. (n.d.). *MAGNET + other GPS networks map*. Retrieved from *http://geodesy.unr.edu/NGLStationPages/gpsnetmap/GPSNetMap.html*

Name____ Date__________

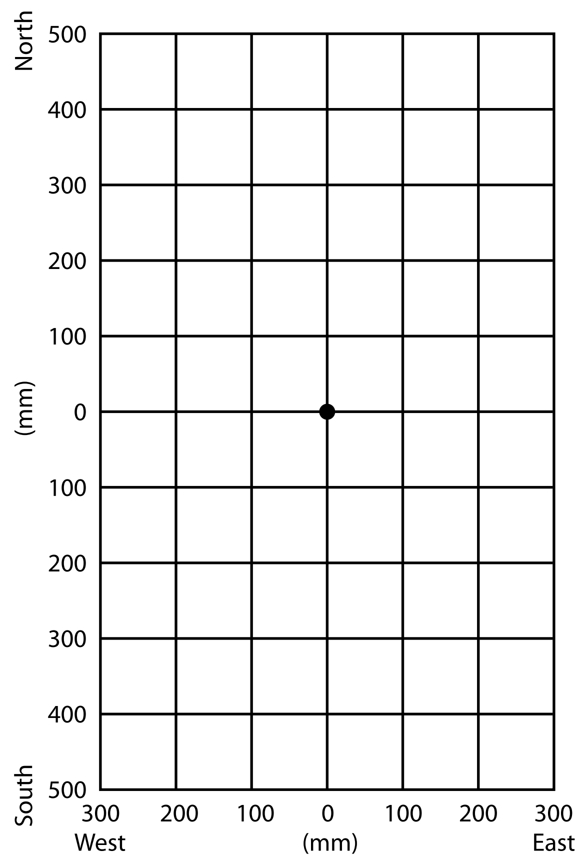
STUDENT SHEET 7.1

ANALYZING AND INTERPRETING GPS DATA

Location ___________________________



Location ___________________________



1. Describe the movement of each of the GPS stations over the time period.

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2. Are the stations moving closer together or farther apart? How do you know?

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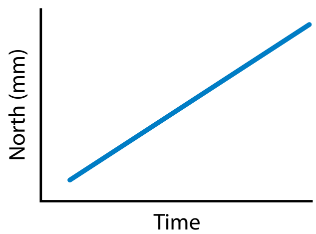
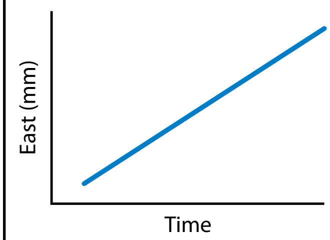
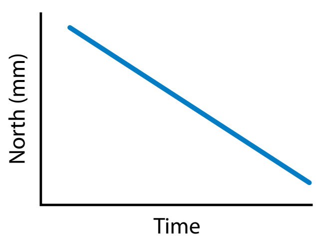
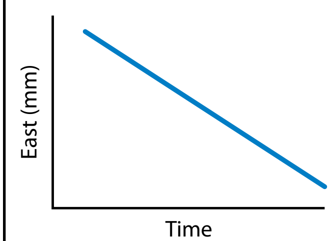
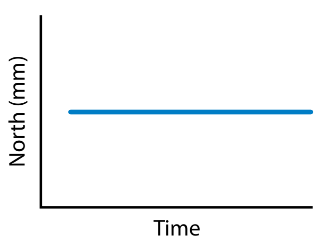
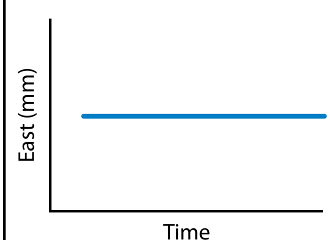
VISUAL AID 7.1

INTERPRETING GPS TIME-SERIES DATA PLOTS

To interpret GPS data, you must carefully analyze the labels on the axes to determine the type of motion.

If GPS data look like this...	... the station is moving toward the ...	If GPS data look like this...	... the station is moving toward the ...
			
			
			
When combining N-S and E-W plots that look like this...	**the overall direction the station is moving is towrds the...**	**When combining N-S and E-W plots that look like this...**	**the overall direction the station is moving is towrds the...**