GPS Measurement Protocol

Purpose

To determine the latitude, longitude, and elevation of your school and of all your GLOBE sites

Overview

The GPS receiver will be used to determine the latitude, longitude and elevation of your school or of your GLOBE sites.

Student Outcomes

Science Concepts

Earth and Space Sciences

Earth materials have different physical properties (magnetism).

Physical Science

Position of an object can be described by locating it relative to another object.

Materials have measurable properties (magnetism).

Magnets attract and repel each other.

Geography

Tools and technologies have distinct characteristics and capabilities.

Use appropriate geographic tools.

Latitude and longitude may be displayed on maps.

Scientific Inquiry Abilities

Using a GPS receiver to determine latitude and longitude

Using a compass to determine true north and south

Identify answerable questions.

Design and conduct scientific investigations.

Use appropriate mathematics to analyze data.

Time

15 minutes to 60 minutes per site

Level

All

Frequency

Once per site

Materials and Tools

GPS receiver

Magnetic compass

Tape measure

Pencil or pen

GPS Protocol Data Sheet

Offset GPS Work Sheet

Preparation

Determine locations to be visited. Bring GPS unit, data sheets, and pen or pencil to field sites. Identify sites where GPS location measurement is not possible because the signal is blocked. For there sites, compass, measuring tape, and *Offset GPS Data Work Sheet* should be also brought.

Prerequisites

None

GPS Protocol – Introduction

Have you ever considered how you describe your location, or how to give directions to a place? When you tell a friend where to meet, you will most likely give the location relative to a place or object you're both familiar with. For example "let's meet outside the main entrance of our school". In this case you will both go to the same location because you know the local environment of your school – it is a system that is referenced to your own experience. However, should you plan to meet in a new location unfamiliar to both of you, such as a nearby city, you will need to find a more general framework of reference. For example you could use road systems or topographic references such as rivers or hills. If you want to locate all GLOBE schools and their study sites, you would have to resort to a more universal reference system.

The geographic locating system used is a set of lines called *latitude* and *longitude* that are mapped, like a grid, onto the spherical surface of the Earth. By convention, zero degrees longitude passes through Greenwich England and zero degrees latitude is the Equator. Locations are identified as being east and west of zero longitude and north and south of zero latitude. At any location it is also possible to further specify ones position by measuring the elevation, or height of the location above or below the average sea level. By reporting their latitude, longitude and elevation each GLOBE school may be individually located.

Figure GPS-P-1: Diagram of one example of a GPS Receiver

For you, the GLOBE student, the hand-held GPS receiver provides a simple and accurate way to measure your latitude, longitude and, when corrected, elevation. These instruments are sufficiently accurate to distinguish the two ends of a classroom or to determine your location well within an area the size of a single pixel (30 m X 30 m) of a LandSat image. Besides the location, GPS instruments also provide the time, as well as additional measurements such as the speed of travel between two points, and distance and direction between any two locations. Insights into the GPS system as a whole, provide an understanding of the measurements it produces and how a simple measurement relies on a sophisticated science and technology infrastructure.

Offset

What if you cannot make a GPS latitude and longitude measurement at a study or sample site because the GPS satellite signals are obscured by thick foliage or a building? See Figure GPS-P-2. You can move from your site to a nearby location where the GPS receiver can receive the satellite signals. This is known as an offset location. You can then determine the location of your desired site by measuring the compass direction and distance between the offset location and your site. In general, you need to use trigonometric skills to determine the desired location. However, if you restrict yourselves to moving directly North or South from your site, you can determine the latitude and longitude of your site using only arithmetic and some knowledge about our planet.

Our planet is almost a sphere. By dividing Earth's circumference of 39,941 kilometers by 360 degrees, we learn that there are 110.95 kilometers (or 110,950 meters) in a degree of circumference. By dividing this by 10,000 we

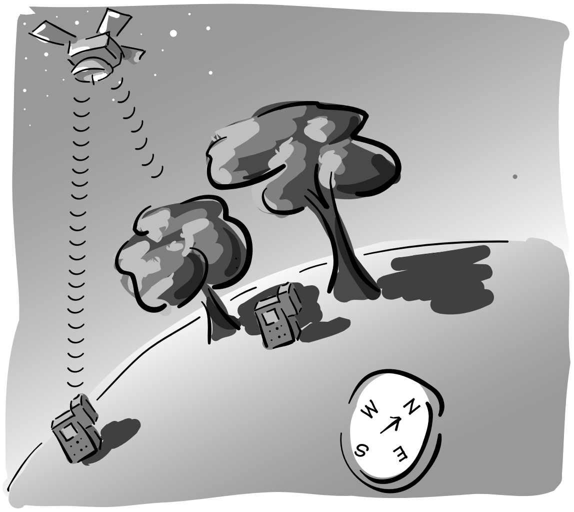


Figure GPS-P-2: Clear and Blocked Views to a GPS Satellite

learn how many kilometers or meters are in one ten thousandth of a degree of circumference (0.0111 km/0.0001 degrees or approximately 11 meters/0.0001 degrees). GPS receivers typically present locations to the nearest 0.0001 degrees, which is approximately 11 meters of latitude on Earth. Knowing the distance north or south between your site and an offset location allows you to determine the difference in their latitudes.

Elevation

All measurements of elevation are made using mean sea level as a point of reference. For example, Mount Everest has an elevation of 8,850 meters above mean sea level. Since sea level fluctuates daily with tides, the mean sea level surface is used as the reference. The reference surface that passes through the global mean sea level and is shaped by Earth's gravitational field is known as the *geoid*. This surface is not smooth because of the irregular distribution of Earth's gravity field.

GPS receivers must also use a reference for determining elevation. Unfortunately, the geoid is very complicated and too large to fit in the internal memory of most GPS receivers. Instead, they contain a simplified shape for a smooth surface known as the *reference ellipsoid*. All GPS elevation measurements are made against the reference ellipsoid. See Figure GPS-P-3. While the geoid and reference ellipsoid may overlap in some areas, in others they may differ by more than 100 meters. Because of this, the elevation of your location measured with a GPS receiver may be significantly different from the elevation determined by other methods (for example, topographic maps). The GLOBE server will automatically make the geoid correction to your elevation once you have entered your GPS measurements for latitude, longitude, and elevation for your site.

Magnetic Variation

On Earth, the magnetic North and South poles do not line up exactly with the true North and South poles (along our planet's rotation axis). Earth's magnetic north pole is slowly moving and is currently located in Canada's Northwest Territories about 11 degrees from the North Pole. Additionally, the magnetic properties of Earth's composition vary slightly among locations. As a result, there is a unique distortion to Earth's magnetic field at any given place. Typically a small variation of a few degrees must be added or subtracted from magnetic compass bearings to determine the direction of true North. This variation is known as *magnetic variation* or *magnetic declination* and its value depends on your location. Figure GPS-P-4 is a world map of magnetic declination. Use this figure to determine true north at your location. You may also use a topographic map to determine the magnetic variation and true North at your location. You will need to use the true North heading for the *Measuring Wind Direction Field Guide* in the *Atmosphere Investigation* and for the *Offset GPS Field Guide* in this Investigation. Be sure to adjust your compass to true North according to the following directions.

Figure GPS-P-3: Geoid and Ellipsoid Surfaces

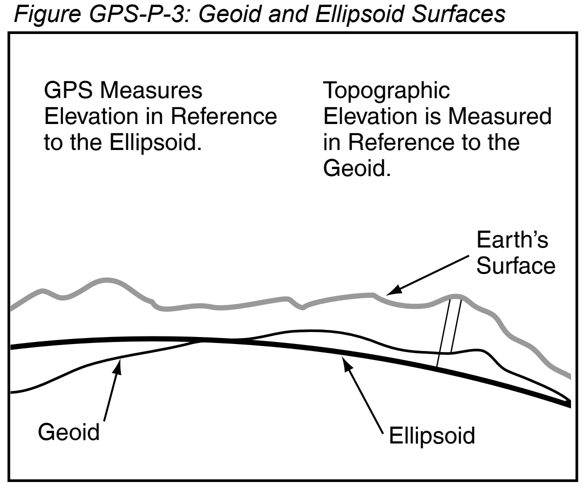
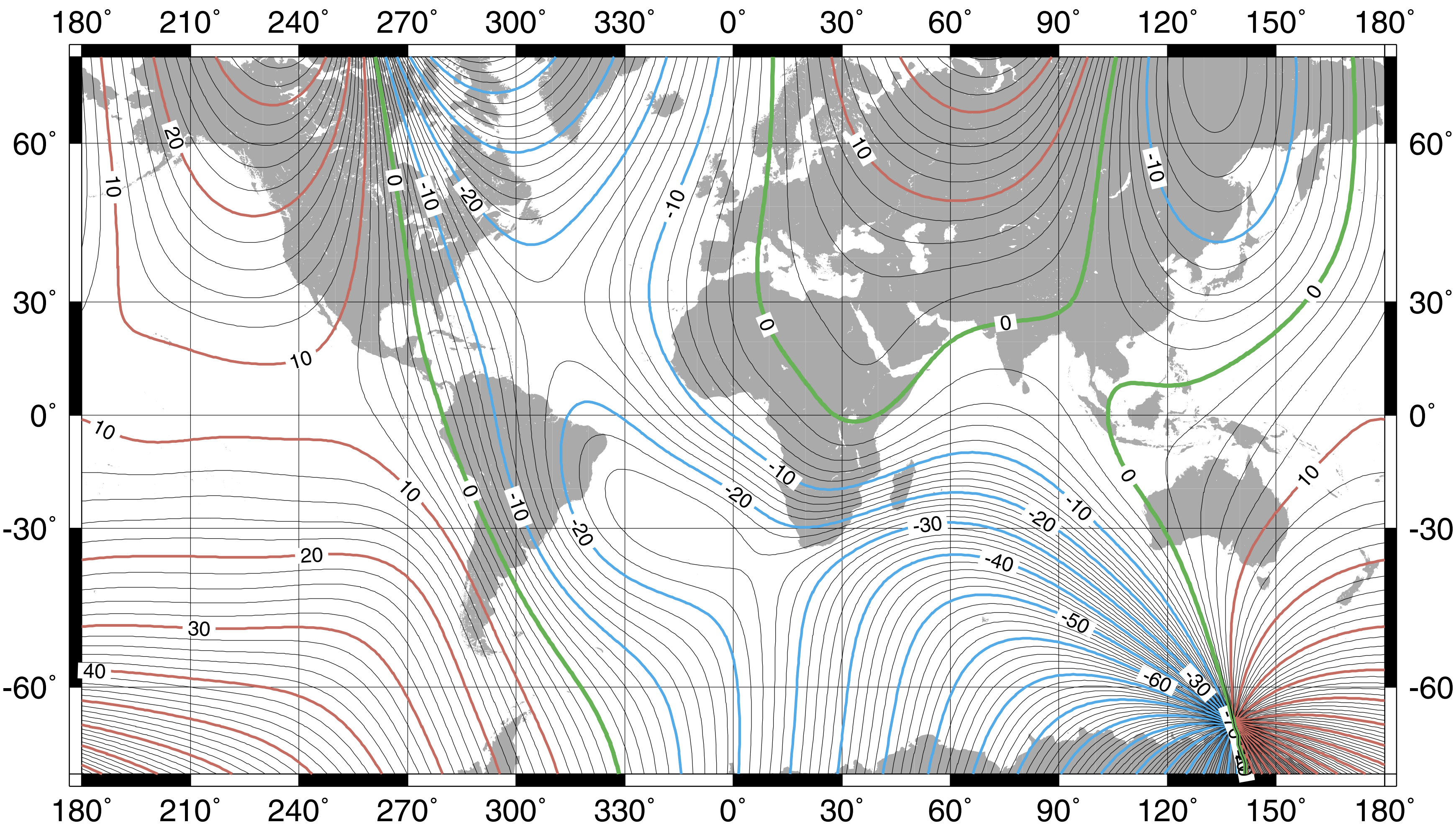


Figure GPS-P-4

World Magnetic Declination Map



Units (Declination) : degrees
Contour Interval : 2 degrees
Map Projection : Mercator

How to determine the direction of true North at your location: Determine the magnetic declination at your location using the map above. Add this value to zero degrees (magnetic North). The result represents the direction to true North at your location. Note: Please remember that if your declination value is negative, you must subtract this from zero degrees.

Credit: U.S. Geological Survey USGS/Ft. Collins, CO, USA

Compass: True North

The magnetic needle in a compass is attracted by the magnetism of the Earth, and that is why it always points North. However, there are really two North Poles on the Earth. One is the *True North Pole* which is located geographically at the top of the earth (at 90° North latitude); and the other is the *Magnetic North Pole*, an area of highly magnetic rock under central Canada.

Maps and directions are based on True North while the compass needle points to Magnetic North. Magnetic declination is the angle between True North and Magnetic North. Its size and direction depends on where you are on the Earth. It is necessary to determine the declination to take accurate compass bearings. Compasses either have a mechanism to set the angle of declination or a scale to determine declination.

Because compasses are attracted to metal objects they will give incorrect readings if the user is close to, or wearing, metal objects including watches, keys, etc.

Three Basic Parts of the Compass

1. The *magnetic needle* (See A in the Figure GPS-P-5) is attracted by the magnetic North Pole of the earth. The magnetic end (red) always points to magnetic north.
2. The *graduated dial* (B) is used to set the desired bearing. The bearing is read in degrees at the sighting arrow (C) at the top of the compass. The dial is graduated in 2 degree increments from 0 to 360 degrees. The cardinal directions are at 0 (or 360), 90 degrees, 180 degrees and 270 degrees which correspond to North, East, South and West.
3. The *base plate* (D) has an orienting arrow (E) and a sighting arrow (C). Some models also have mirror sights attached. These components are used to line up the magnetic needle and point out the "line of travel".

Setting Compass Bearings

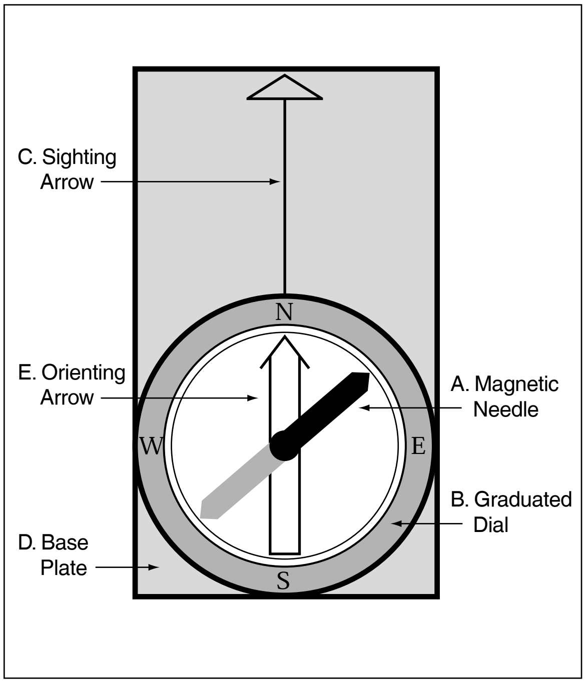
Step 1:
Set the dial (B) to the desired degree reading (the direction in which you want to travel) so that the correct compass bearing lines up with the sighting arrow (C).

Step 2:
While holding the compass level, turn your body until the red end of the magnetic needle (A) lines up with the red orienting arrow (E). "Put the red in the shed" is a useful saying to help students remember what to do. The red orienting arrow is considered the "shed."

Step 3:
Your direction or objective will now lie straight ahead in the direction you are holding the compass (the direction in which the sighting arrow points).

Be sure to choose an object ahead of you in line with your compass bearing and walk toward it. This allows you to walk without looking down at your compass. Every few paces stop and check that you are still traveling in the desired compass direction.

Figure GPS-P-5: Compass Example



Teacher Support

Measurement Logistics

1. Students must determine the latitude, longitude, and elevation of their school, and for all other GLOBE study sites.
2. Remember, the location and elevation of each site must be determined only once.
3. If you or your school do not own a GPS receiver and you are borrowing one, you may want to determine all the sites for which you need to take GPS measurements. This would allow you to collect GPS data for all the sites in a short period of time (e.g., a week).
4. Locations of GPS measurements: Some GLOBE study sites should provide clear views of the sky and thus good satellite reception (e.g., Atmosphere study site). Others, especially the Land Cover and Phenology sites, may offer poor GPS reception due to heavy canopy cover. The school location is to be determined at the front or main entrance to the school, thus building may block satellite reception to some extent. In these cases use the *Offset GPS Protocol Field Guide*.

Student Preparation

The Learning Activities in this Investigation provide additional exercises to help students understand the measurements of time, relative and absolute position, and angles, all the basic elements incorporated in the GPS measurement.

Helpful Hints

Before you use a GPS to receiver make sure that it is set to display the following units:

- Time as Universal Time (UT)
- Elevation in meters
- Latitude and longitude in decimal degrees

If it does not, follow the manufacturer's directions or user's manual to make these adjustments.

Please note that some GPS receivers are not able to display latitude and longitude readings in decimal degrees. If you are using one of these receivers, you should set it to read in degrees and decimal minutes and then convert the latitude and longitude readings to decimal degrees before reporting them to GLOBE. To do so, use the formula and follow the example given below:

Converting from Degrees and Decimal Minutes to Decimal Degrees:

1 degree = 60 minutes

Reading in decimal degrees = **degrees + decimal minutes/**(60 minutes/degree)

Example:

A latitude reading is given as **15** degrees and **39.03** minutes N.

Latitude in decimal degrees = **15** degrees + **39.03** minutes/(60 minutes/degree) =
15 degrees + **0.6505** degrees = **15.6505** degrees

Site	GPS Measurement Location
School	Main entrance
Atmosphere study site	Instrument shelter location
Hydrology study site	Surface water sampling location
Soil study sites: Soil Characterization site Soil Moisture site Soil Temperature	 Soil profile location Center of the soil moisture star pattern Soil Moisture or Atmosphere site locations
Land Cover sample sites	Center of 90 m x 90 m homogeneous area
Phenology	Location of the tree, shrub, or one meter square grass area used for the Green-Up and Green-Down measurements.

GPS Protocol
Field Guide

Task
Measure the latitude, longitude, and elevation of your school or a GLOBE study site.

What You Need
- ❑ GPS receiver
- ❑ *GPS Data Sheet*
- ❑ Watch
- ❑ Pen or pencil

In the Field
1. Take the GPS receiver to the exact location you would like to determine latitude, longitude, and elevation.
2. Turn on the receiver, making sure that you are holding it vertical and you are not blocking the antenna's view of the sky. In most receivers the antenna is internal and is located at the top of the receiver.
3. After an introduction message, the receiver will start to search for satellites. Some receivers may display the previous latitude, longitude, and elevation values while it is locking onto satellite signals.
4. Wait for the receiver to indicate that at least four satellites have been acquired and that a good measurement is available. In most receivers, this is indicated by the appearance of a "3-D" message.
5. At one minute intervals and without moving the receiver more than one meter, make five recordings on a copy of the *GPS Investigation Data Sheet* of all digits and symbols for the following displayed values:
   a. Latitude
   b. Longitude
   c. Elevation
   d. Time
   e. Number of satellites
   f. "2-D' or "3-D" status icons
6. Turn off the receiver.
7. Average all five latitudes, longitudes, and elevations.
8. Confirm for yourself that your results make sense. You should be able to get a rough estimate of your latitude and longitude by looking at a globe or local map.
9. Copy and submit all GPS readings as your site location to the GLOBE Student Data Archive.
10. Follow this protocol at each site that you need to determine latitude, longitude, and elevation.

Offset GPS Protocol

Field Guide

Task

Measure the latitude and longitude of your school or a GLOBE study site when a GPS receiver is unable to make an accurate measurement.

What You Need

- ❑ GPS receiver
- ❑ Magnetic compass
- ❑ Tape measure
- ❑ Watch
- ❑ Pencil or pen
- ❑ *Offset GPS Measurements Data Sheet*

In the Field

1. Determine the direction of true North at your location using Figure GPS-P-4.
2. Go to your desired site and mark it with a flag or other obvious marker.
3. Follow the *GPS Field Guide* to confirm that good GPS reception is not possible.
4. Use the compass to determine true North.
5. Move either North or South to reach the nearest open area in which you can successfully follow the *GPS Field Guide*. This is your offset location.
6. Follow the *GPS Field Guide* and record your latitude and longitude. Mark this as the offset location.
7. Record whether the offset location is North or South of your site.
8. Measure the distance between the offset location and your site in meters and record it on the *Offset GPS Data Work Sheet.*
9. Divide this distance by 110,000 meters per degree to determine the latitude difference (in ten thousandths of a degree) between the offset location and your site.
10. Depending on the direction of your offset location:
    - If you moved to the north of your site, subtract this value from the latitude of the offset location to determine the latitude of your site.
    - If moved to the south of your site, add this value to the latitude of the offset location to determine the latitude of your site.
11. The longitude of your site is the same as that of the offset location.
12. Determine the elevation of your site by using a topographic map.

Frequently Asked Questions

1. How long does it take for a GPS receiver to determine latitude, longitude, and elevation?

The GPS receiver may require anywhere from several seconds to several minutes to acquire a sufficient number of satellites after it has been activated. This depends on the availability of GPS satellites overhead at the time of your measurement, on the presence of obstructions, and on the energy level of your receiver's batteries. If it takes more than five minutes to get a satellite lock, change your batteries and try again.

2. The receiver is not displaying latitude or longitude. Why?

The receiver has many functions available on various display screens besides the "Location " screen that usually appears first when the unit is powered up. Please read the manual and familiarize yourself with these other functions of your GPS receiver.

3. The receiver displays "Insufficient Satellites", " Poor Signal Reception", or similar message. What should we do?

Do not record data if any such messages appear. When the receiver has a good view of the sky, waiting or moving slightly will usually cause these messages to disappear. Standing close to the receiver or a group of people hovering around the receiver may block the receiver's view to the satellites and may cause intermittent signal losses which will prompt the messages to appear. Stand back or hold the receiver high. In thick foliage or heavy canopy, the receiver may be unable to lock to the requisite four satellites. Because the satellites move in the sky, trying again at a later time may provide better results. If problems persist due to obstructions, follow the *Offset GPS Field Guide.*