GLOBEPROGRAM®
A Worldwide Science & Education Program

Soil (Pedosphere)

Soil Moisture Gravimetric Protocol

Overview

This module provides step-by-step instructions in how to determine soil moisture. Field samples of soil are collected and weighed, with water content, and after the soil has been dried. The difference is the weight of soil moisture. In this instance, **gravimetric** means determining the amount of moisture in the soil, by weight.

Learning Objectives:

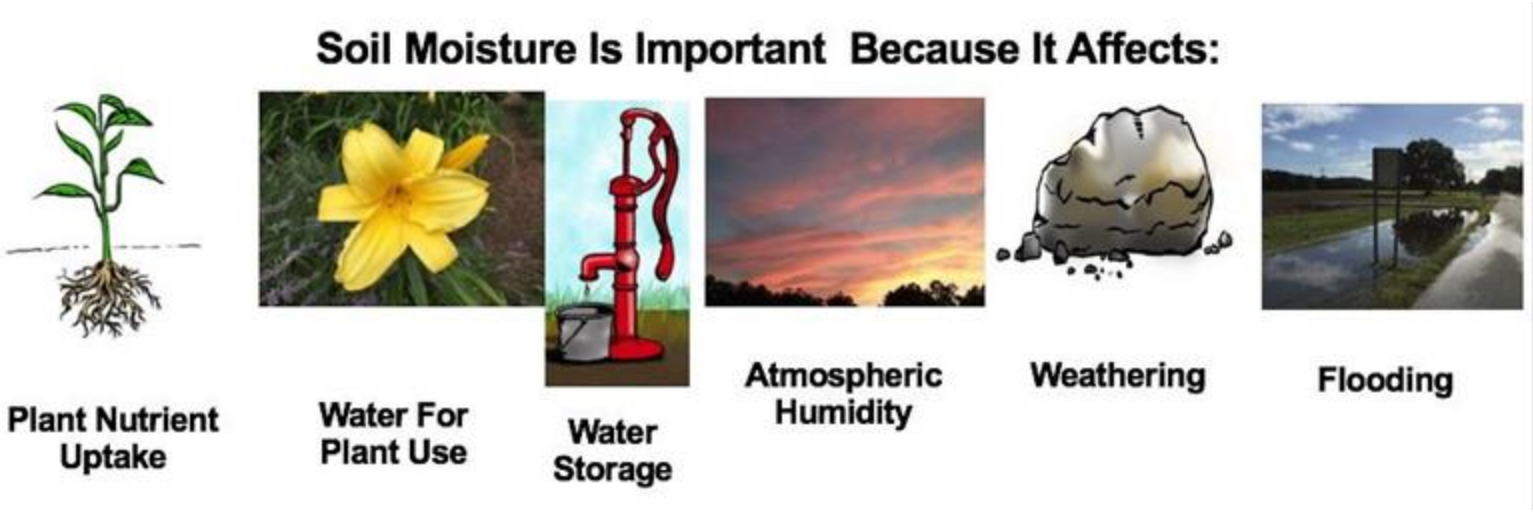
After completing this module, you will be able to:

- Explain why soil moisture is worth studying
- Determine a schedule for taking this measurement
- Choose a sampling pattern
- Take soil moisture samples
- Measure gravimetric soil moisture content
- Report these data to GLOBE
- Visualize these data using GLOBE's Visualization Site

Estimated time needed for completion of this module: 1.5 hours

The Role of Soil Moisture in the Environment

Soil acts like a sponge spread across the land surface. It absorbs rain and snowmelt, slows run-off and helps to control flooding. The absorbed water is held on soil particle surfaces and in pore spaces between particles. This water is available for use by plants. Some of this water evaporates back into the air; some of this water is transpired by plants; some drains through the soil into groundwater.



Why your measurements matter:

With this measurement, students may investigate how soil moisture:

- Relates to precipitation
- Relates to surface, soil, and/or air temperatures
- How soil moisture varies diurnally and annually as well as over days or weeks
- How soil moisture relates to plant phenology

Image credit: NASA

How your measurements can help us understand interactions of the soil with the rest of the Earth system

Soil data field campaign, Yanco, Australia. Both field measurements from the ground as well as remote sensing from air craft support our understanding of soil moisture. These are used in combination with satellite data from NASA missions such as GRACE and SMAP. Image credit: Amy McNally, NASA.

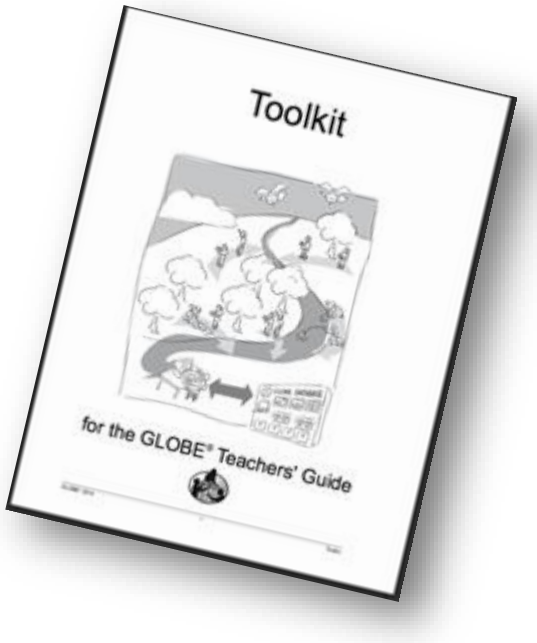
The SMAP satellite creates a global soil moisture map every three days. It measures the volumetric soil moisture in the top 5 cm of the soil. See the GLOBE SMAP Soil Moisture Protocol to work with scientists and provide needed on-the-ground measurements to help validate the satellite's soil moisture estimates. Image credit: NASA.

Summary of Protocol

Where	GLOBE Soil Moisture Site
Frequency	Ideally, 12 or more times per year at the same site, at daily, weekly or monthly intervals
Prerequisites	Site definition using the Site Definition Sheet
Needed Documents	Gravimetric Soil Moisture Protocol and
	Soil Moisture Data Sheet-Star Pattern or
	Soil Moisture Data Sheet-Transect Pattern or
	Soil Moisture Data Sheet- Depth Profile
Time required	• 5-10 minutes preparation before sampling 10-15 minutes to collect samples* • 5 minutes to weigh wet samples • 5 minutes to weigh dry samples • Samples dry under heating lamps for 2 days or in a drying oven overnight. *Some sample collection methods may require additional time

Instrument Specifications

The following resources summarize the measurements associated with each protocol, associated skill level, scientific specifications for the instruments, and how to access the equipment you need (purchase, build, or download).



By using instruments with GLOBE specifications, you ensure your data are accurate and comparable to GLOBE investigations conducted by others.

Where to find specifications for instruments used in GLOBE investigations

Required Equipment for Fieldwork and Sampling

For **all sample patterns**:

- A defined Soil Moisture & Temperature Site marked with a permanent marker or flag
- Marker flags (if you can keep them placed permanently)
- Compass
- Trowel (1 per student group)
- Permanent marker
- Heating lamp(s) or soil drying oven (for low-tech option, leave the soil out in the open air)

For **Transects**:

- Rulers marked in millimeters (1 per student group)
- 13 sample containers (sealable bags or cans) labeled with date and a container number
- 50 meter tape or 50 meter rope marked every 5 meters

For **Star Patterns** :

- 6 soil sample containers
- Meter stick marked in millimeters

For **Depth Profiles**:

- 5 soil sample containers
- A meter stick
- A soil auger

Note: Containers or plastic bags should be weighed and labeled with mass and container number before bringing to the field. Depending on the context, gloves and protective eyewear may be recommended.

Preparations before you go to the field

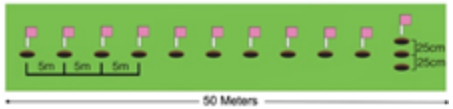
Mark your trowel at the 5 cm mark from the tip to ensure you go no deeper when you take samples.

Calibrate the scale or balance according to the manufacturer's directions. If using an electronic balance, check that the balance is measuring in grams and is zeroed properly. Measure and record the mass of each container (without the lid) or plastic bag to the nearest 0.1 g.

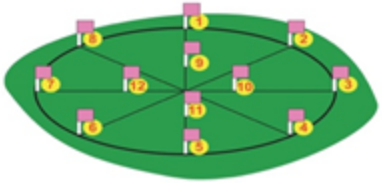
Label each container with:

- Mass of the container or plastic bag to the nearest 0.1g
- Container number

Select your Sampling Strategy Based on Research Goals: Choose One of the Three Options Below



Transect Pattern Sampling: This transect sample pattern will measure soil moisture over a large area. SMAP measurement techniques sense moisture contained in the top 5 cm of soil and their measurements are averaged over areas of 100's of square meters or more. **This sampling pattern allows students to see spatial variations in surface soil moisture measurements**. It is also useful for comparison with soil moisture data collected remotely from satellites or aircraft.



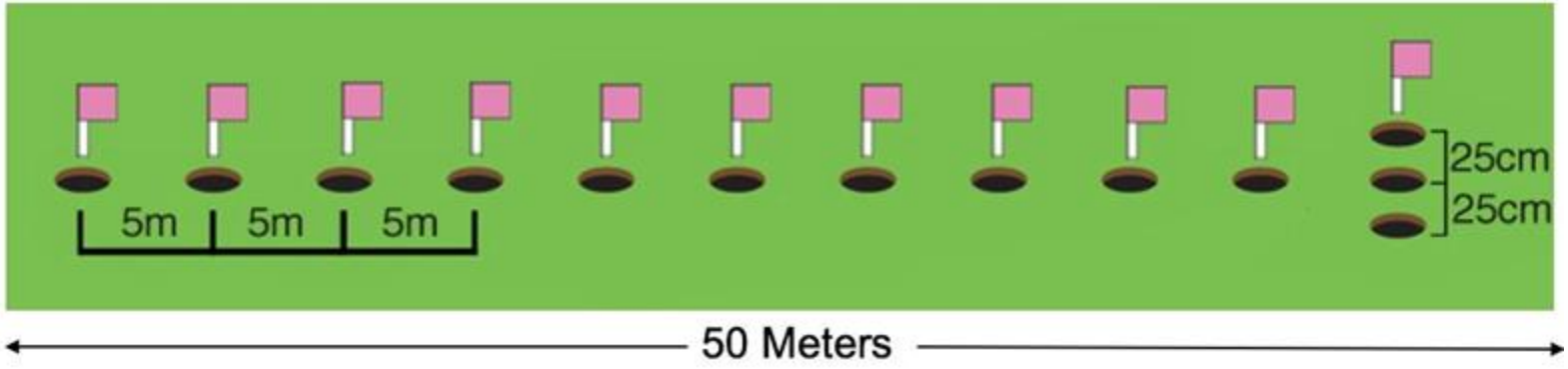
The Star Pattern involves collecting soil samples from 12 different locations at twelve different time periods in a 2 m x 2 m star-shaped area. For each of the 12 locations, three spots are chosen within 25 cm of each other. Samples from the top 5 cm and from 10 cm deep are collected at each of the three spots, for a total of 6 samples at each location on the star. **This sampling method can be easily coordinated with the** *Soil Temperature Protocol*, whereby students collect their soil temperature measurements at the same depths and locations as the soil moisture measurements.

Depth Profile Pattern Sampling: Use the Star Pattern and take samples down a profile. Using an auger takes a bit of extra time, but this effort gathers valuable data and complements the *Soil Characterization Protocol* as well as *The Digital Multi-Day Max/Min/Current Air and Soil Temperatures Protocol.*

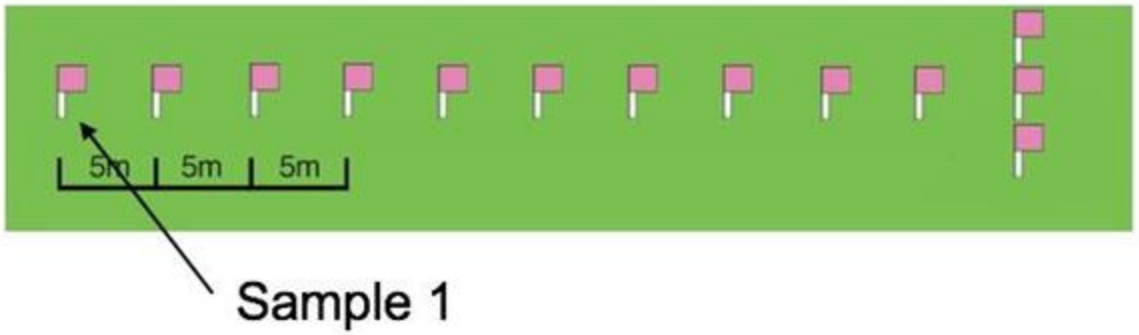
Option 1. Transect Pattern Sampling

This transect sample pattern will measure soil moisture over a large area. SMAP measurement techniques sense moisture contained in the top 5 cm of soil and their measurements are averaged over areas of 100's of square meters or more. This sampling pattern allows students to see spatial variations in surface soil moisture measurements. It is also useful for comparison with soil moisture data collected remotely from satellites or aircraft.

- Samples are taken every five meters over a 50 meter transect to capture soil moisture variation along a broad swath.
- Each time you visit this transect you collect 13 samples of the top 5 cm of soil.
- Off-set each sample set at least 25 cm from the previous ones.



Laying out a transect



Stretch out your measuring tape or rope along the transect.

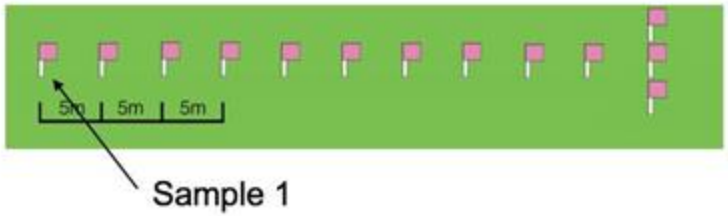
Sample points should be marked every 5 meters along the transect and numbered starting with 1.

Two extra points should be offset 25 cm from the end point as shown, and labeled 12 and 13.

Stand at the first sample and take a compass reading looking along the transect.

To take a compass reading, hold the compass level and stand at sampling point 1 facing sampling point 12. Point the compass toward sampling point 12 and rotate the compass's bezel (azimuth ring) until the arrow inside the compass housing lines up with the red (north) end of the magnetic needle. Record the degree mark that aligns with the arrow as your compass reading.

Taking samples along a transect



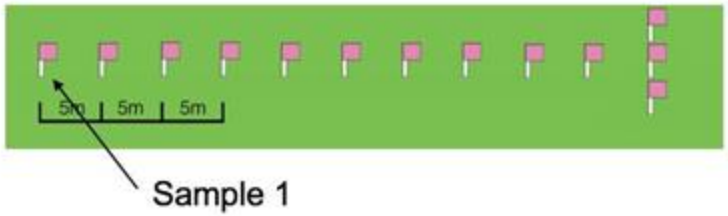
Cut or pull away any grass or groundcover above every sample point.

Dig a hole 10-15 cm in diameter down to 5 cm.

Leave this soil loose in the hole.

Remove any rocks larger than a pea (about 5 mm), large roots, worms, grubs, and other animals from the loose soil.

Collecting samples along a transect



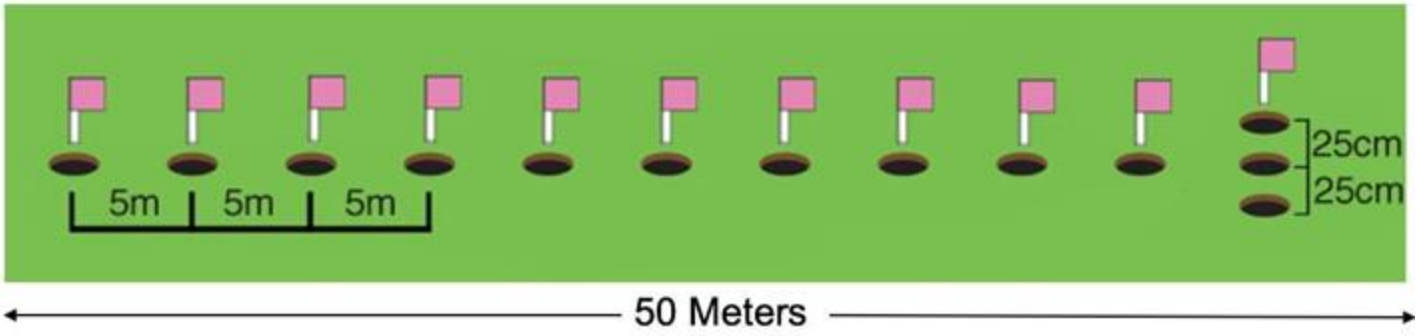
Use your trowel to fill a soil container with at least 100 g of the loose soil.

Immediately seal the container to hold in the moisture.

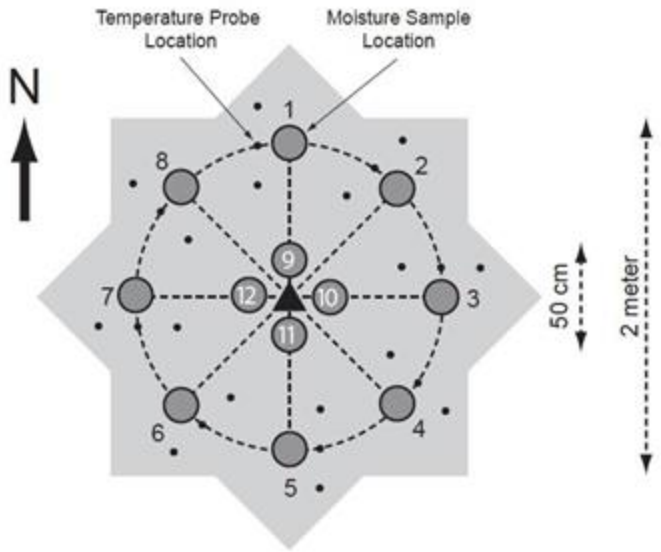
If you are using resealable bags, label each bag with the date, site name, and location along the transect.

Repeat procedure for all 13 samples along the transect

- Continue to collect a sample at each sampling point along the transect.
- Remember to remove rocks, large roots, and animals.
- Seal each container immediately.
- Record the container number, mass, and distance to the start point of the transect on the Data Entry app or Data Entry Sheet next to the appropriate Sample Number.
- You should have 13 containers of soil: 11 taken from along the transect plus two extras at the end. You are done!

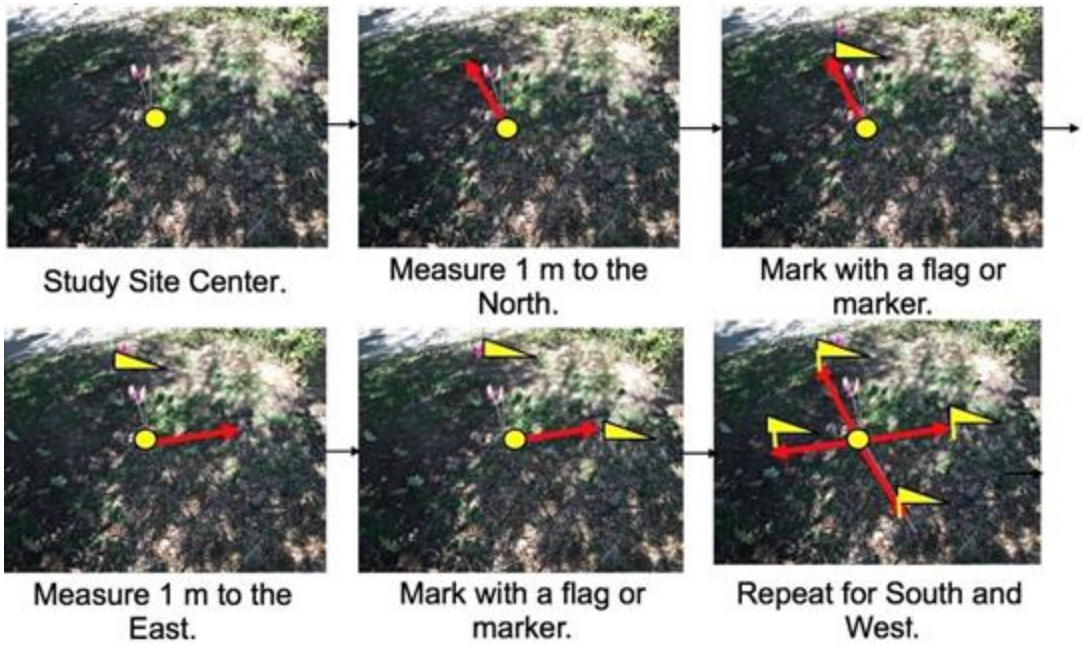


Option 2. Star Pattern Sampling Overview



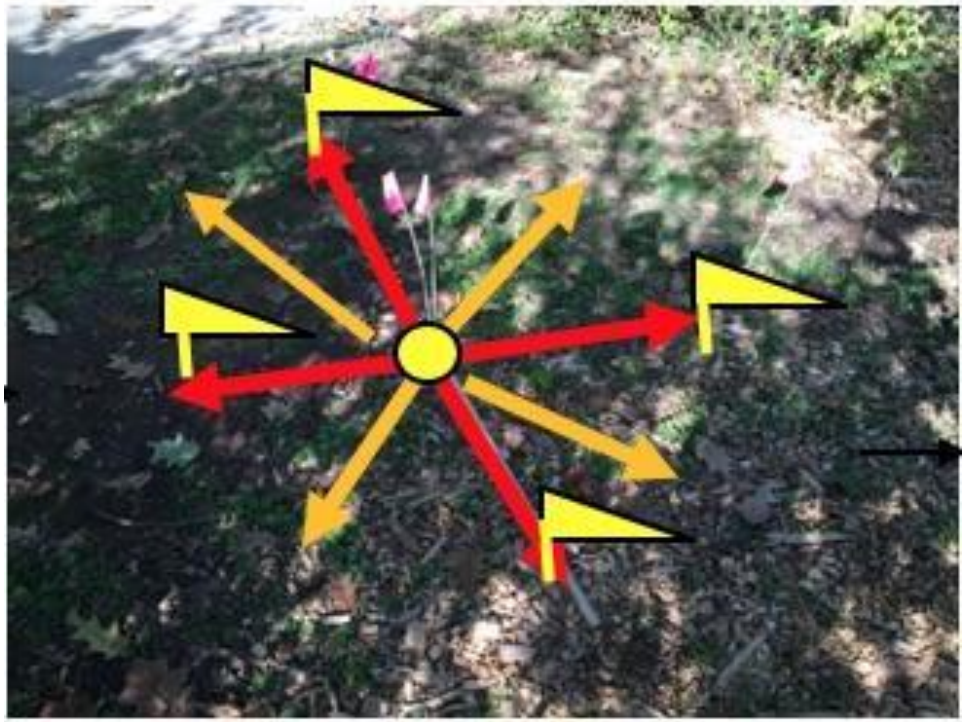
The Star Pattern involves collecting soil samples from 12 different locations at twelve different time periods in a 2 m x 2 m star-shaped area. For each of the 12 locations, three spots are chosen within 25 cm of each other. Samples from the top 5 cm and from 10 cm deep are collected at each of the three spots, for a total of 6 samples at each location on the star. This sampling method can be easily coordinated with the *Soil Temperature Protocol*, whereby students collect their soil temperature measurements at the same depths and locations as the soil moisture measurements.

Set up the star pattern



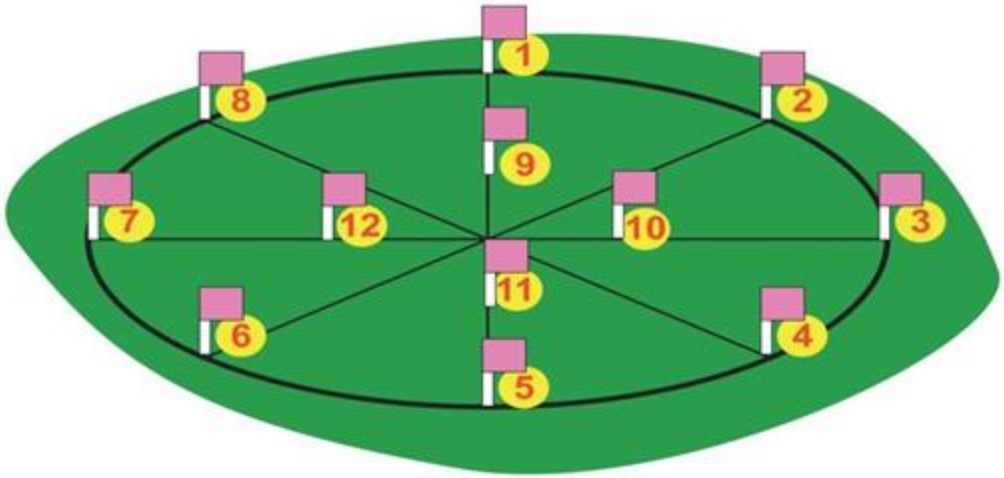
- Locate the place where you took the GPS reading as your center spot and mark it with some sort of permanent marker. With the Star Pattern, 1-3 pairs of samples are collected from 0-5 cm & 10 cm depth. (Note: only one pair of samples is needed at each location. Your students may wish to take up to three samples at each location to obtain information about the variation in soil conditions found at the sampling site.)
- Each flag is a site around which soil samples will be taken.
- If you are going to take measurements for only part of a year, time your measurements so they cross a drying/wetting seasonal cycle.

Set up the star pattern



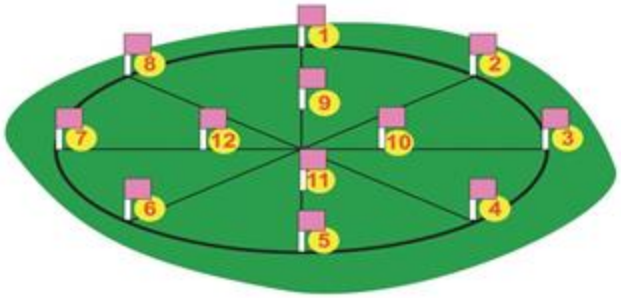
Repeat the same process, this time marking out 1 m from the center of your star, using the directions NE, NW, SE and SW (in orange).

Marking the inner ring



In the four cardinal directions, measure 25 cm from the center and place a flag.

Taking samples in a star sampling pattern- 0-5 cm



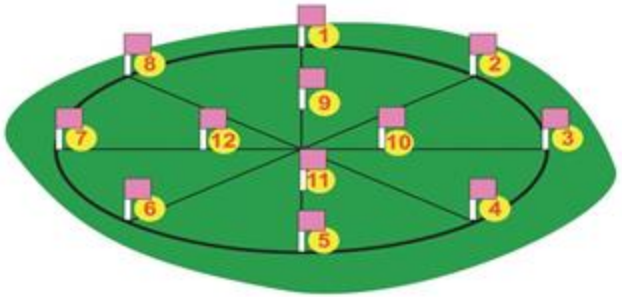
- Locate a sampling point on your sampling star.
- Cut or pull away any grass or groundcover above every sample point.
- Dig a hole 10-15 cm in diameter down to 5 cm.
- Leave this soil loose in the hole.
- Remove any rocks larger than a pea (about 5 mm), large roots, worms, grubs, and other animals from the loose soil.

Taking samples at 10 cm depth

Remove all of the soil from the hole down to a depth of 8 cm.

Take a soil sample that contains the soil between 8 and 12 cm.

Remove any rocks larger than a pea (about 5 mm), large roots, worms, grubs, and other animals.



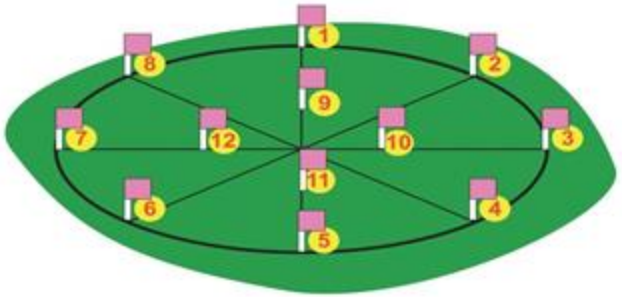
Taking two more sets of samples

Take samples from 0 – 5 cm and 10 cm from two more holes 25 cm from the first.

You should have a total of six soil samples from the three holes

Return remaining soil to the holes.

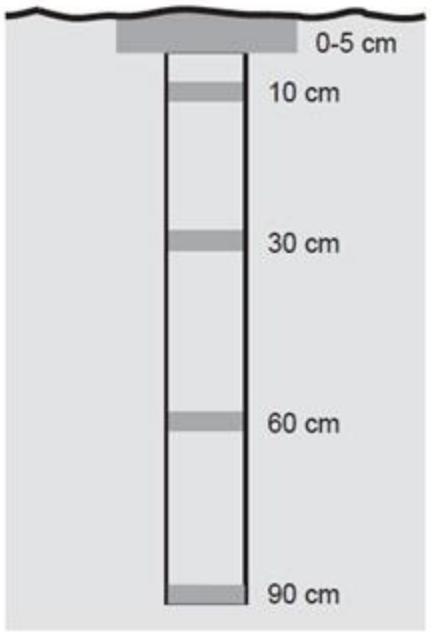
Replace the soil first out last in to minimize soil disturbance.



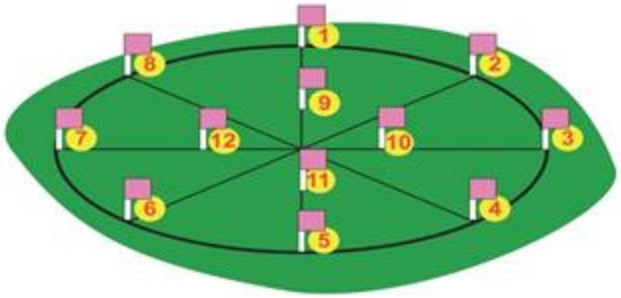
3. Depth Profile Pattern Sampling Overview

The Depth Profile involves taking a sample of the top 5 cm and the use of an auger to take soil samples at depths of 10 cm, 30 cm, 60 cm, and 90 cm. Using an auger takes a bit of extra time, but this effort gathers valuable data and complements the *Soil Characterization Protocol* as well as *The Digital Multi-Day Max/Min/Current Air and Soil Temperatures Protocol.*

For this protocol, use the Star Pattern Sampling.



Depth profile: star sampling pattern- 0-5 cm



- Locate a sampling point on your sampling star.
- Cut or pull away any grass or groundcover above every sample point.
- Dig a hole 10-15 cm in diameter down to 5 cm.
- Leave this soil loose in the hole.
- Remove any rocks larger than a pea (about 5 mm), large roots, worms, grubs, and other animals from the loose soil.

Depth Profile- taking samples at 30, 60, and 90 cm

Use the auger to obtain samples centered at 30, 60, and 90 cm

Place samples in containers

Use your trowel to fill a soil container with at least 100 g of the loose soil. If a soil oven will be used to dry the soil, a can (not a plastic bag) should be used as a sample container. Immediately seal the container to hold in the moisture.

If you are using resealable bags, label each bag with the date, site name, and location in your star sample grid.

Return remaining soil to the hole. Replace the soil - last out, first in-, to minimize disturbing the soil.

At the end of the sampling process, you should have 5 containers of soil taken from your depth profile.

You are done!

Soil Moisture Gravimetric – Lab Measurements

Required Materials for Lab Procedures

- Soil drying method (either soil drying oven or approved warming/heat lights)
- Thermometer capable of measuring to 110°C (if using a drying oven)
- Soil Samples in containers suitable for your drying method
- Balance or scale with 0.1 g sensitivity and at least 400 g capacity (600 g recommended)
- Hot pads or oven mitts
- GLOBE Data Entry app
- Permanent marker

Soil Moisture Gravimetric Lab Procedure

- If using an electronic balance, check that the balance measures in grams and is zeroed properly.
- If you are using sample cans, remove the lids from each soil sample.
- If you are using bags, get the mass with the bag closed.
- Weigh each sample and record the mass to the nearest 0.1 g as the Wet Mass.
- Select the Date Entry page that corresponds to your collection method – Star Pattern, Transect, or Depth Profile.

Note: Calibrate your scale or balance according to the manufacturer's instructions.

Drying Soil Samples

If using an oven, place the uncovered sample cans in the soil drying oven.

- Set the temperature so that it doesn't exceed 105 ◦C.
- Samples are often dry after 10 hours at 105 ◦C.
- For cooler ovens, allow more time.

If using heat lamps, place open sample bags under the 250 watt lamps.

- Samples can take 2 - 3 days to dry completely.
- If you can't leave the lamps on overnight, turn them back on the next morning.
- Carefully remove the samples from the drying source using the hot mitts.

If air drying, open the bag and place it in a dry area.

- This method should dry the soil in 2 - 5+ days, depending on the indoor environmental conditions

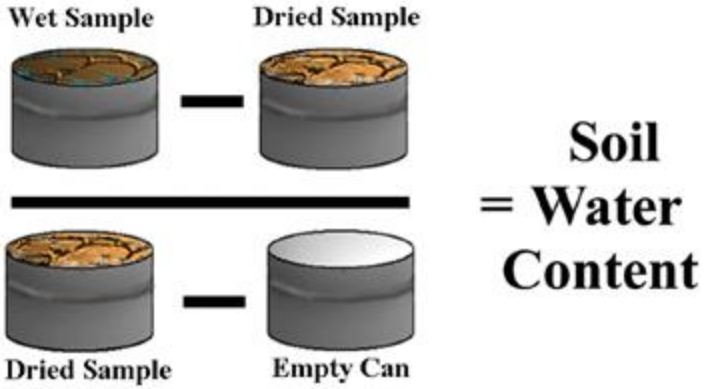
Determine if Samples are Dry

- To test if the sample is dry, weigh it, and then dry it for an additional period of time (e.g. 30 minutes).
- Weigh it again. If the mass of the sample has not changed by more than 0.3 g, the sample may be considered dry.
- Repeat as necessary.
- When your samples are dry, record the drying time and drying method in the Data Entry App or Data Entry Sheet.
- Weigh and record the **Dry Mass** for each container.

Determining Soil Water Content

Unless you will use these samples for other lab analyses, return the dried soil to the site to fill in holes so site may be used in future years.

- Empty the soil from the containers.
- Clean and dry each container. You may save the soil samples for further tests.
- Use this formula to calculate Soil Water Content:



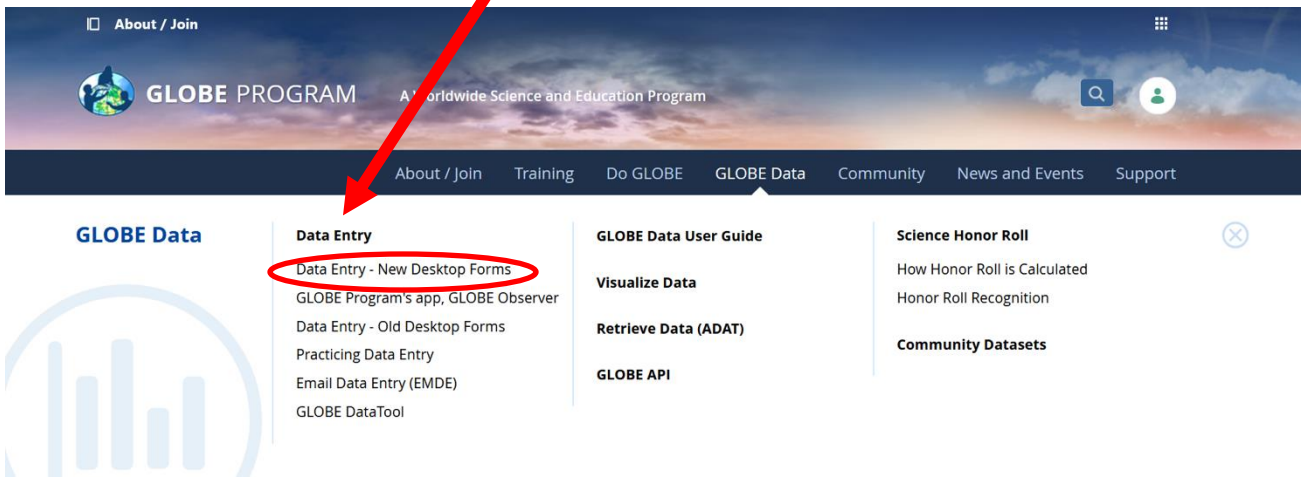
Reporting Data to GLOBE

Two Options for Uploading Data:

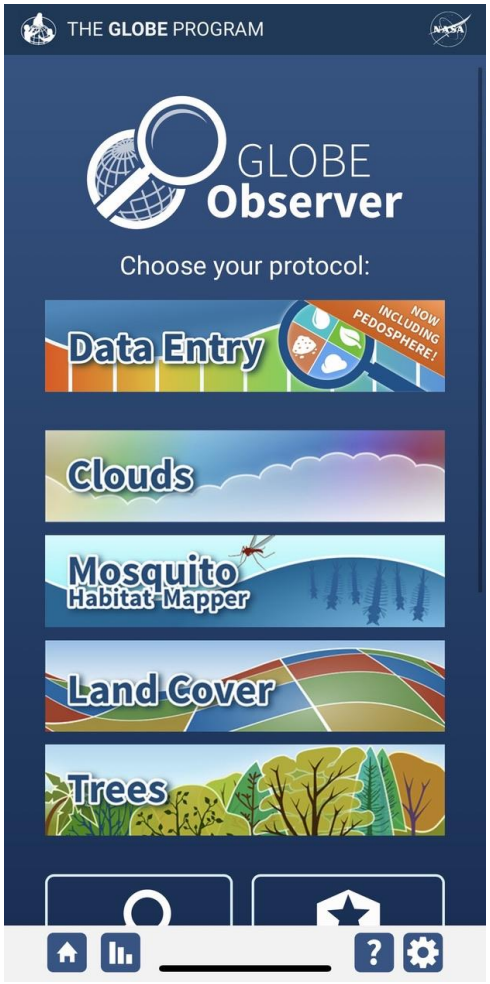
These methods all allow users to submit environmental data – collected at defined sites, according to protocol, and using approved instrumentation – for entry into the official GLOBE science database.

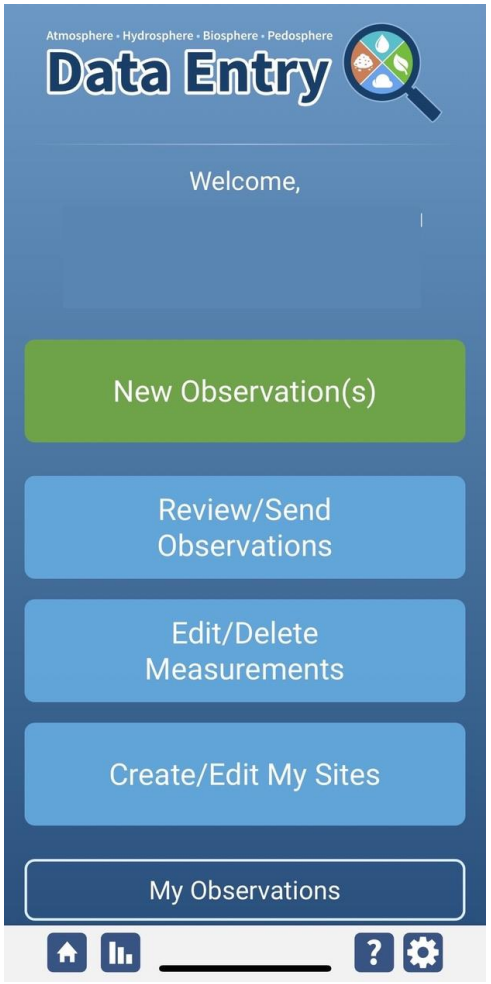
1. Download the GLOBE Observer mobile app from the App Store.

2. Data Entry: Visit globe.gov, click on the "GLOBE Data" tab, then underneath "Data Entry" click on "Data Entry – New Desktop Forms".



Soil Moisture Site Creation



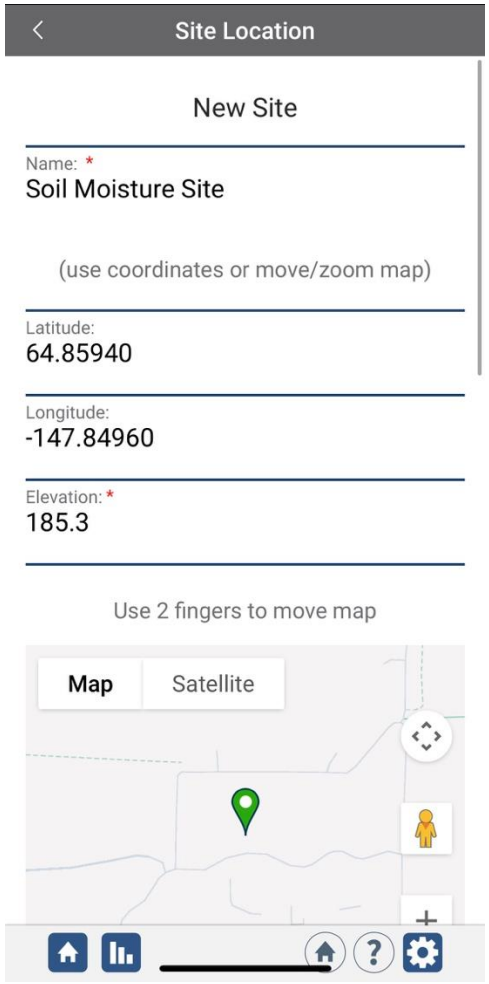


If this is your first time making Soil Moisture or Temperature observations at this location, you will need to create a new site before entering data.

Open the GLOBE Observer App and select “Data Entry”.

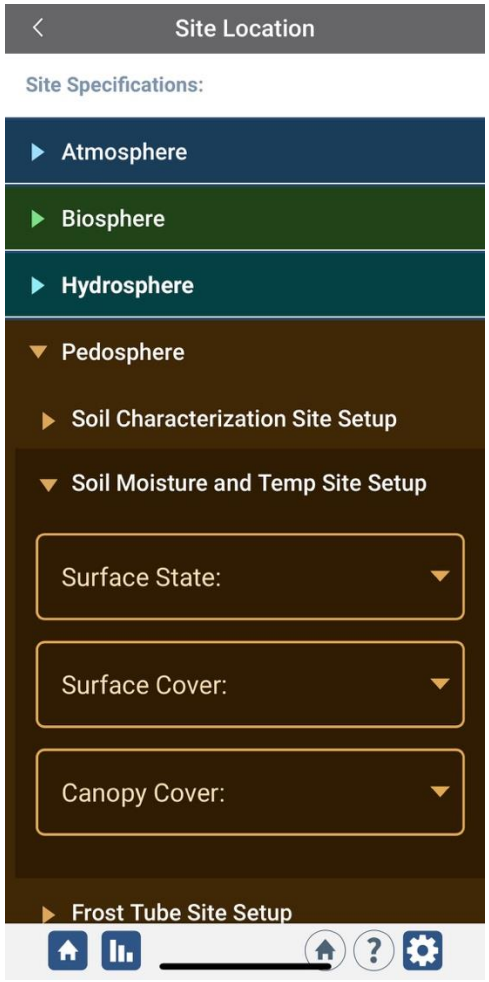
Next, click “Create/Edit My Sites”

Soil Moisture Site Creation



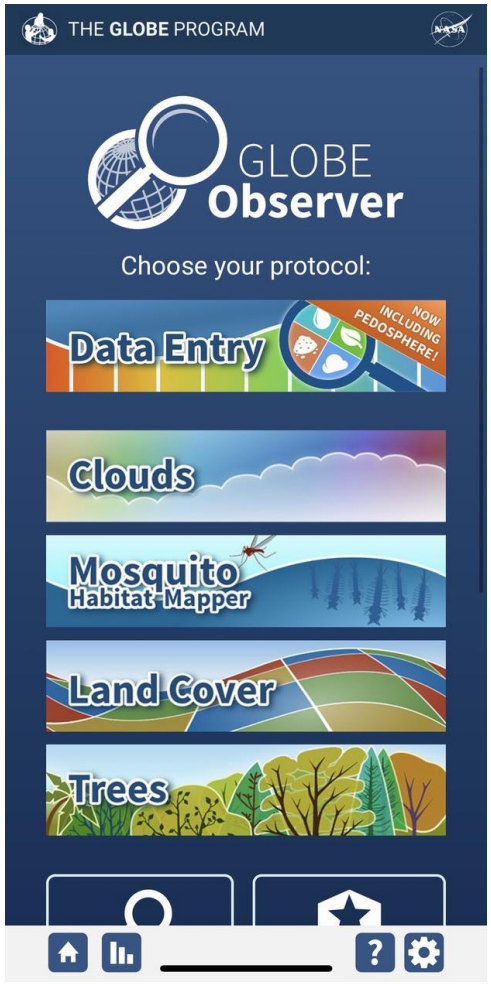
- Enter a name for your new site.
- Use the map box to make sure the green popup is in the correct site location.
- If you used a separate GPS device to locate your site, you can enter the coordinates manually.

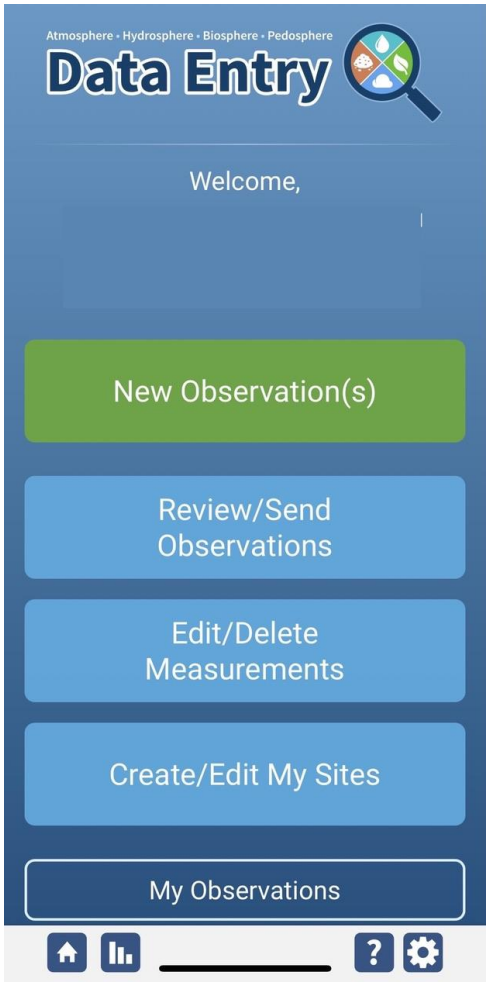
Soil Moisture Site Creation



- Scroll down to the Pedosphere tab
- Select Soil Moisture and Temp Site Setup
- Enter the surface state, surface cover, and canopy cover information for you new site.
- At the bottom of the page, select “Send Site”

Soil Moisture Gravimetric Data Entry



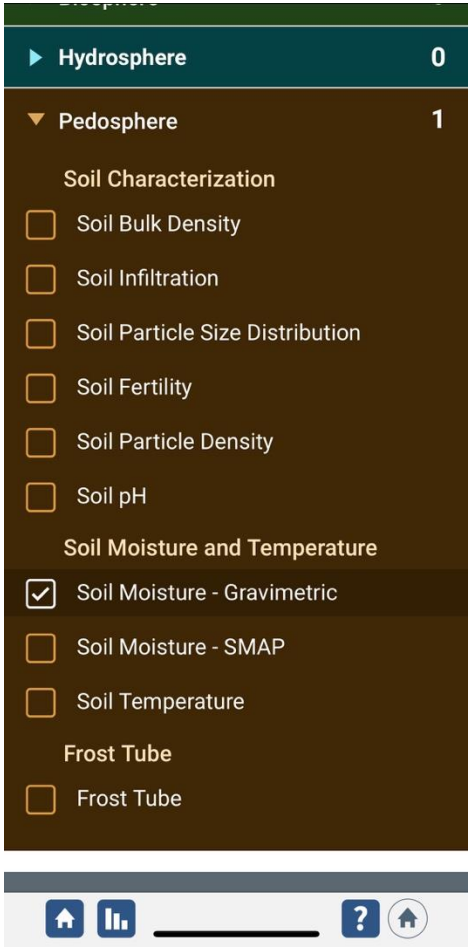


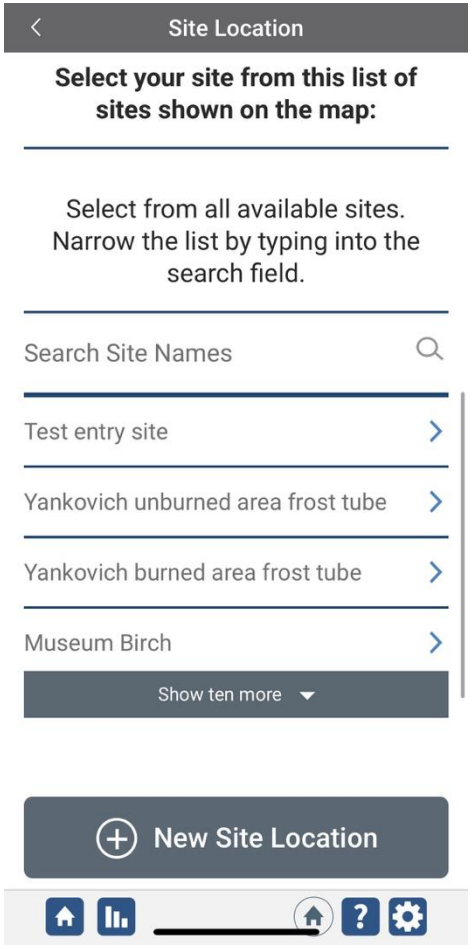
To enter data, first return to the GLOBE Observer main page by clicking the home button in the bottom left.

Select “Data Entry”.

Next, click “New Observation(s)”

Soil Moisture Data Entry

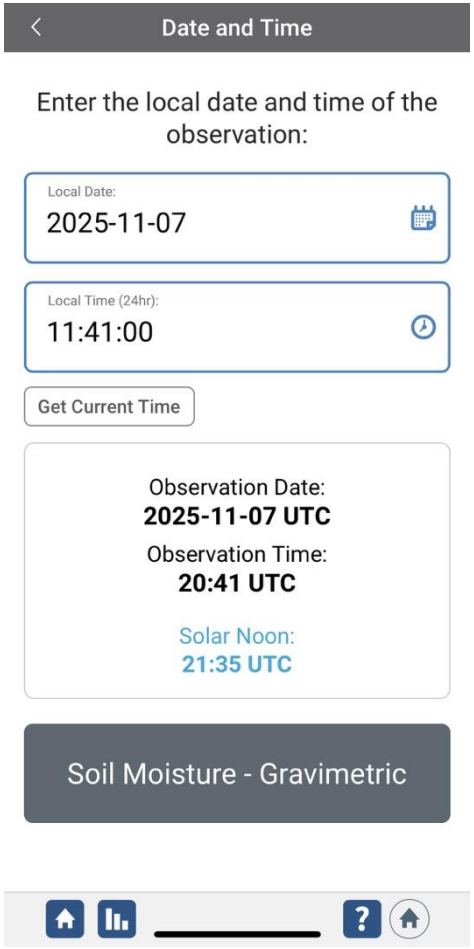




Under the Pedosphere tab, select “Soil Moisture – Gravimetric” then click Continue at the bottom of the page.

Next, select your Soil Moisture Site. Existing sites near you will show up below “Search Site Names”

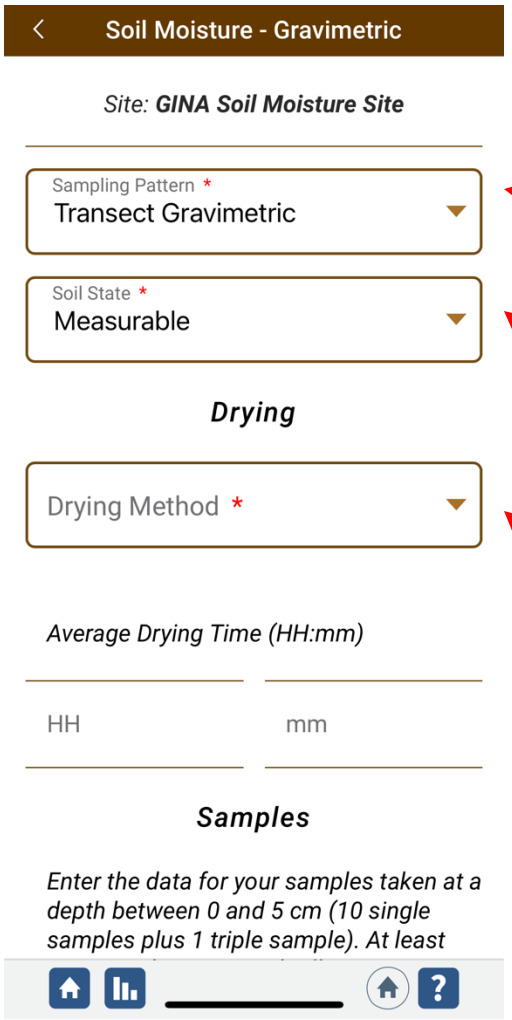
Soil Moisture Data Entry



Next, enter the date and time you took the measurements.

Select Soil Moisture - Gravimetric to enter your data.

Transect Sampling Data Entry

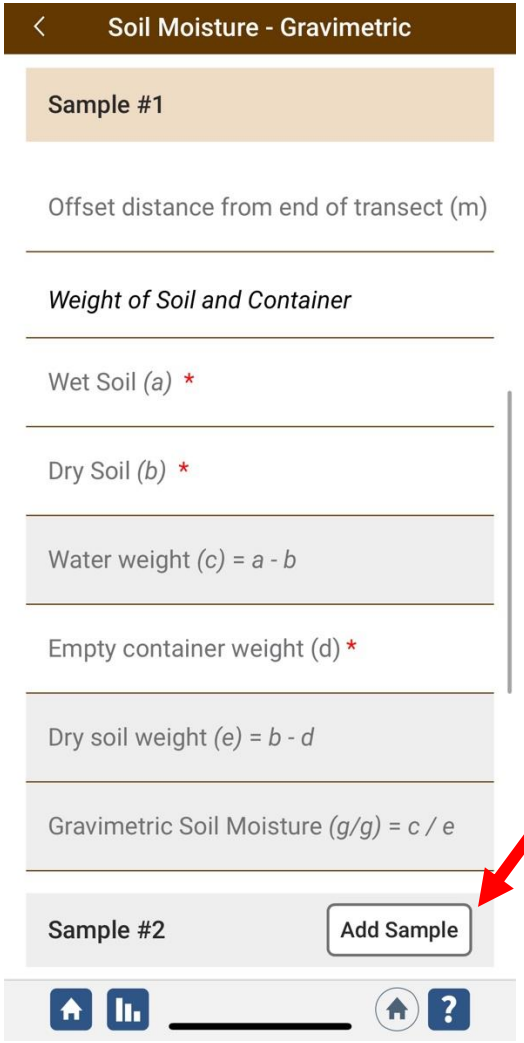


If you sampled along a transect, select "Transect Gravimetric" under Sampling Pattern.

Next choose a soil state from the dropdown.

Under Drying, select your drying method and enter the average drying time.

Example of Transect Data Entry

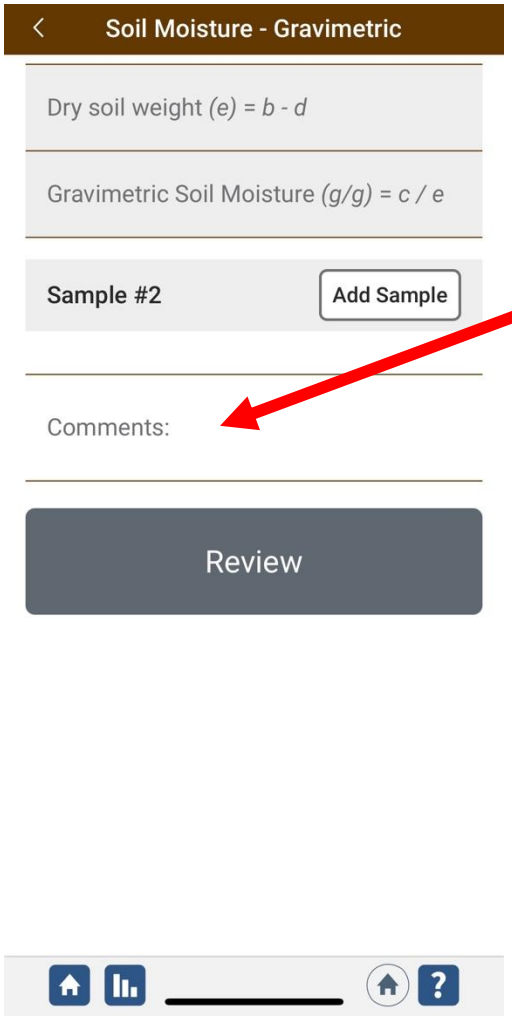


Enter the sample information for your first transect sample as directed.

Click “Add Sample” to start the next sample.

Continue adding samples until you have entered all your transect data.

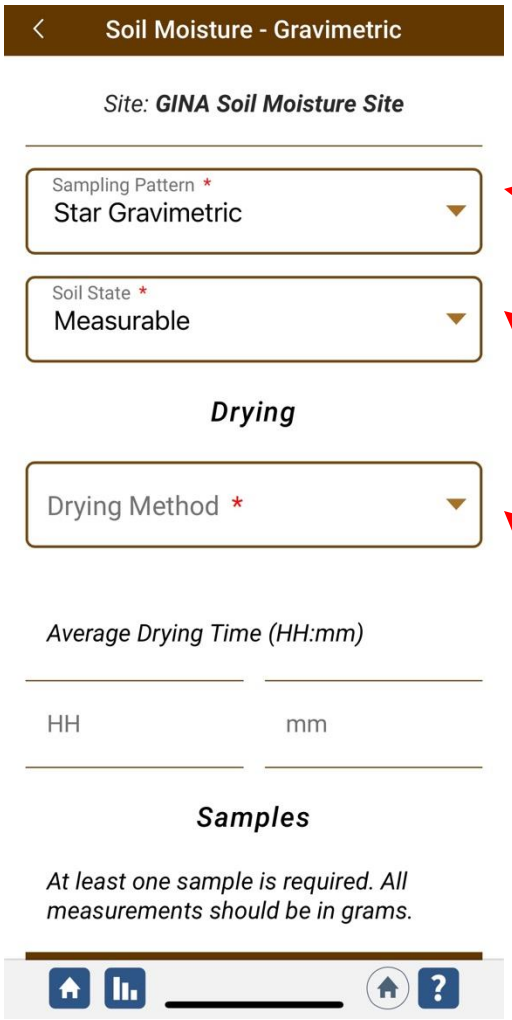
Example of Transect Data Entry



Add any comments or metadata related to your samples or site in the Comments box.

When you have finished, click “Review” to check that your entries are correct before submitting.

Star Sampling Pattern Data Entry

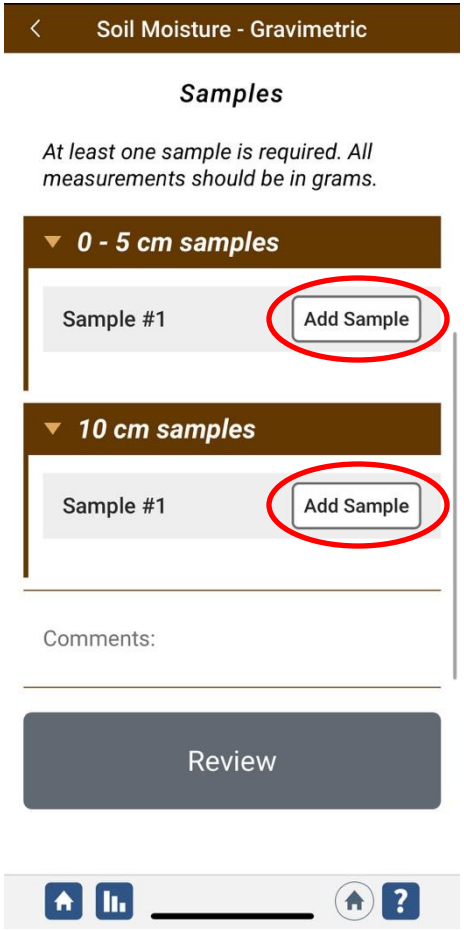


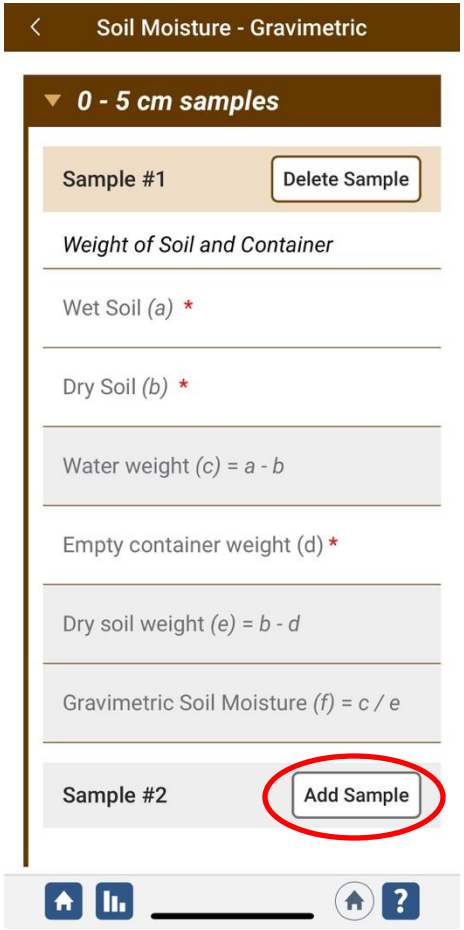
If you sampled using a star pattern, select “Star Gravimetric” under Sampling Pattern.

Next choose a soil state from the dropdown.

Under Drying, select your drying method and enter the average drying time.

Star Sampling Pattern Data Entry



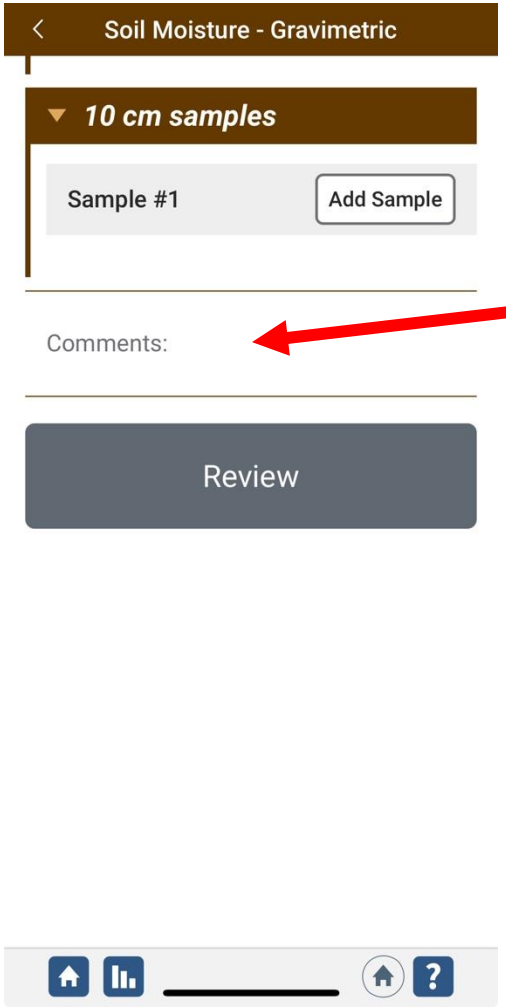


Next, click “Add Sample” to add a 0-5 cm sample.

Enter the sample information as directed.

Continue adding 0-5cm samples or 10cm samples until you have entered all your data.

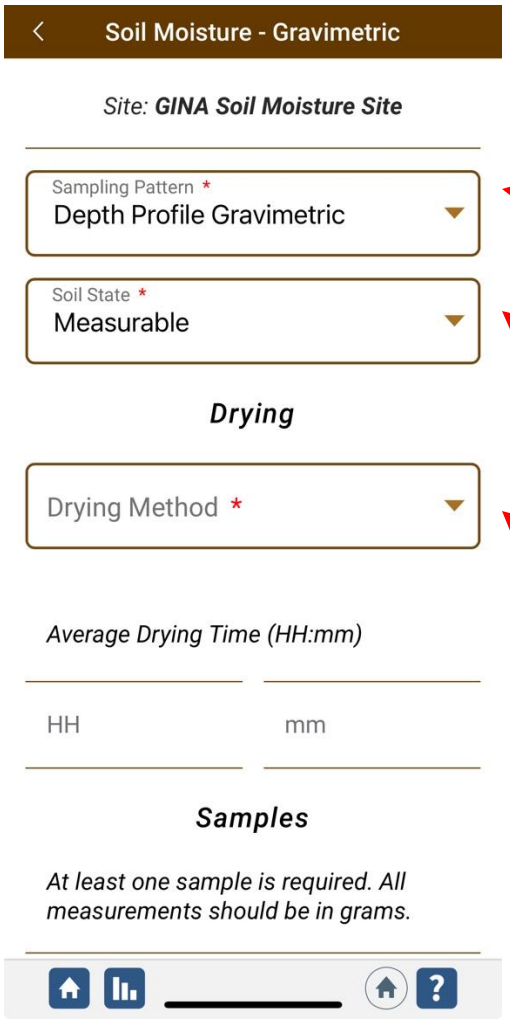
Star Sampling Pattern Data Entry



Add any comments or metadata related to your samples or site in the Comments box.

When you have finished, click “Review” to check that your entries are correct before submitting.

Depth Profile Data Entry

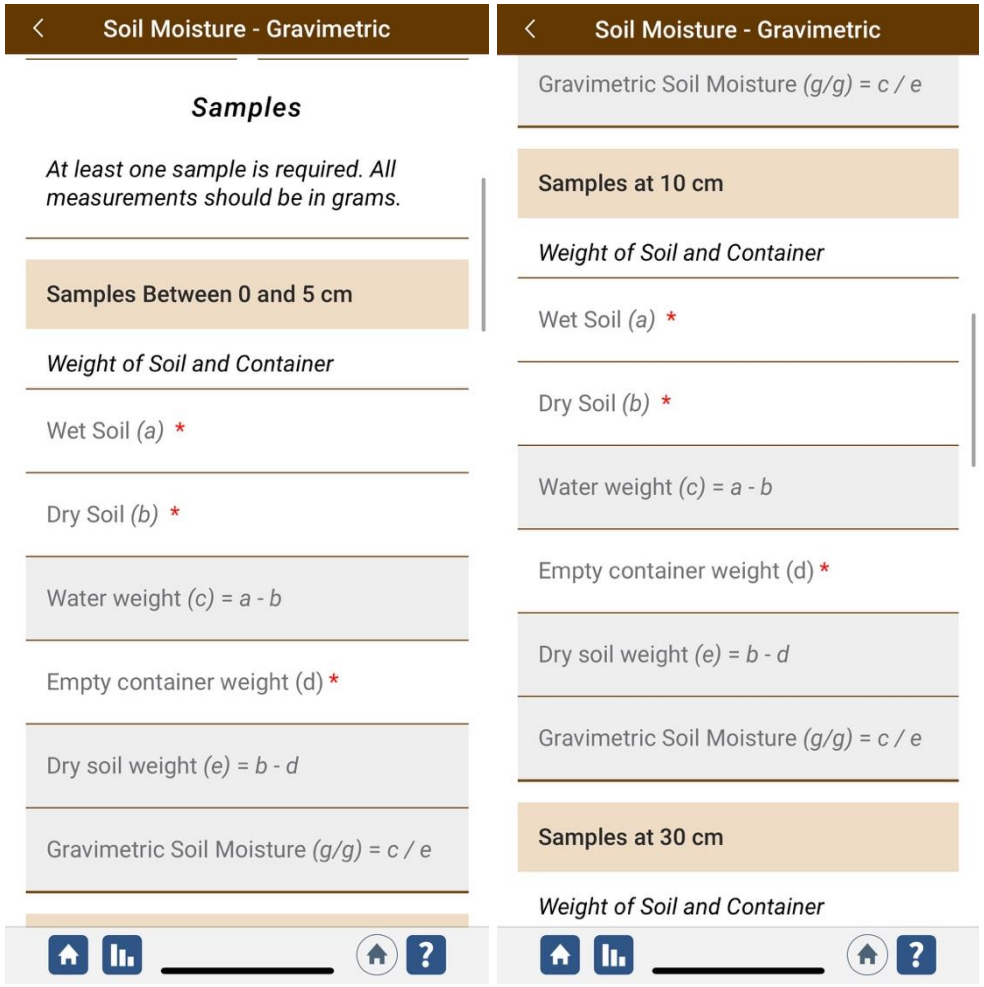


If you sampled using a depth profile, select “Depth Profile Gravimetric” under Sampling Pattern.

Next choose a soil state from the dropdown.

Under Drying, select your drying method and enter the average drying time.

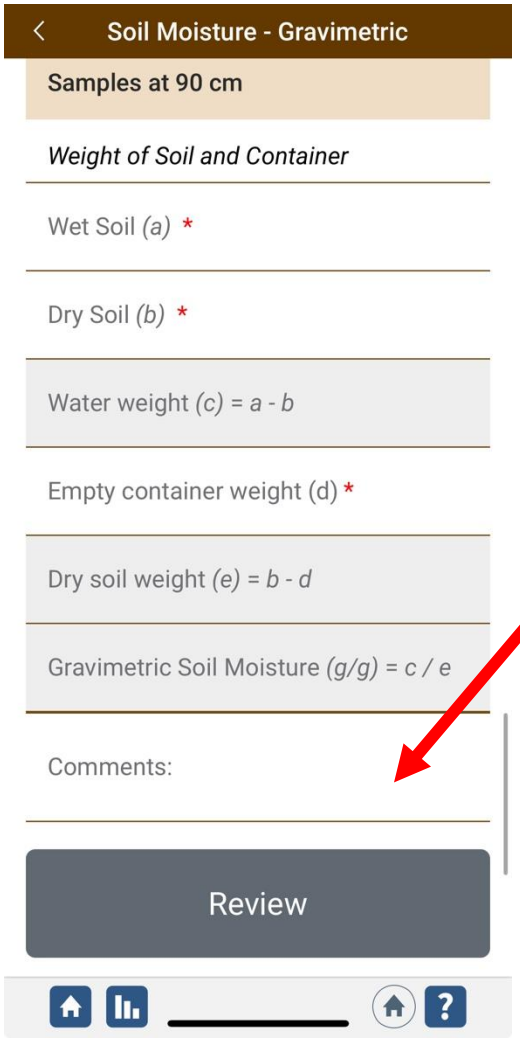
Depth Profile Data Entry



Under “Samples”, enter the sample information for samples between 0 and 5 cm.

Continue adding information for samples at each depth that you collected.

Depth Profile Data Entry



Add any comments or metadata related to your samples or site in the Comments box.

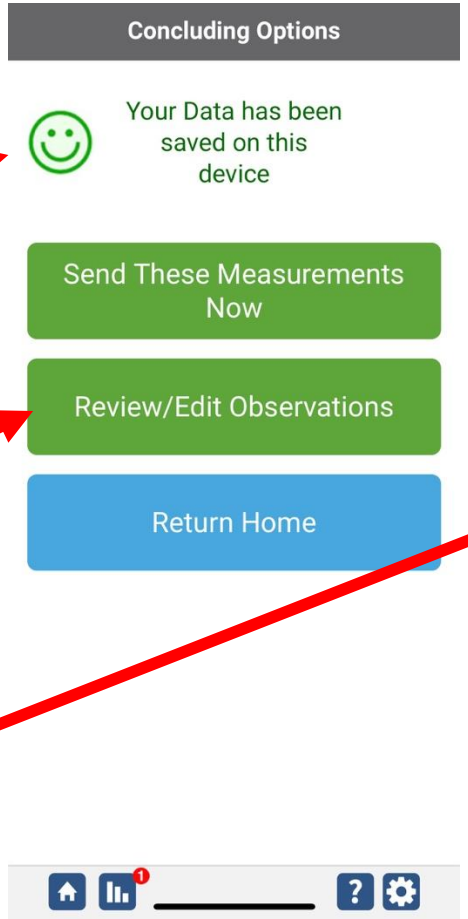
When you have finished, click “Review” to check that your entries are correct before submitting.

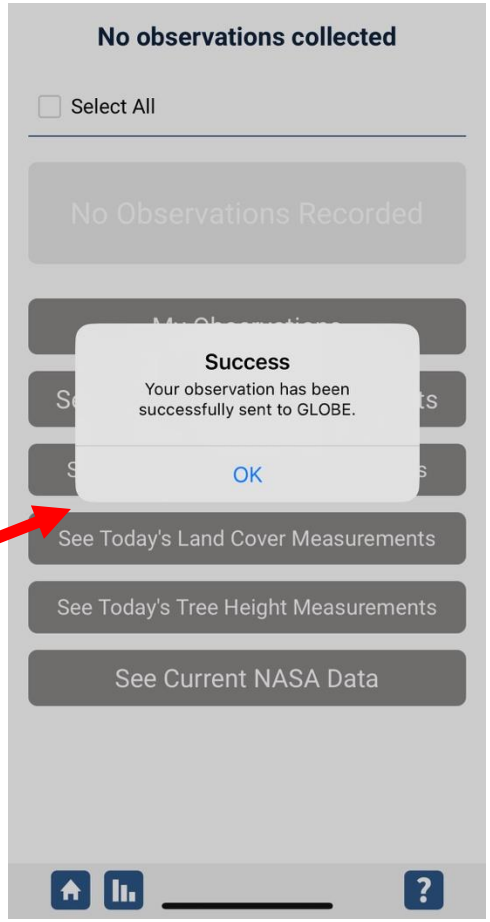
GLOBE Data System Response

If your observations are within the appropriate ranges, you will see a green smiley face.

You can review or edit your observation if needed.

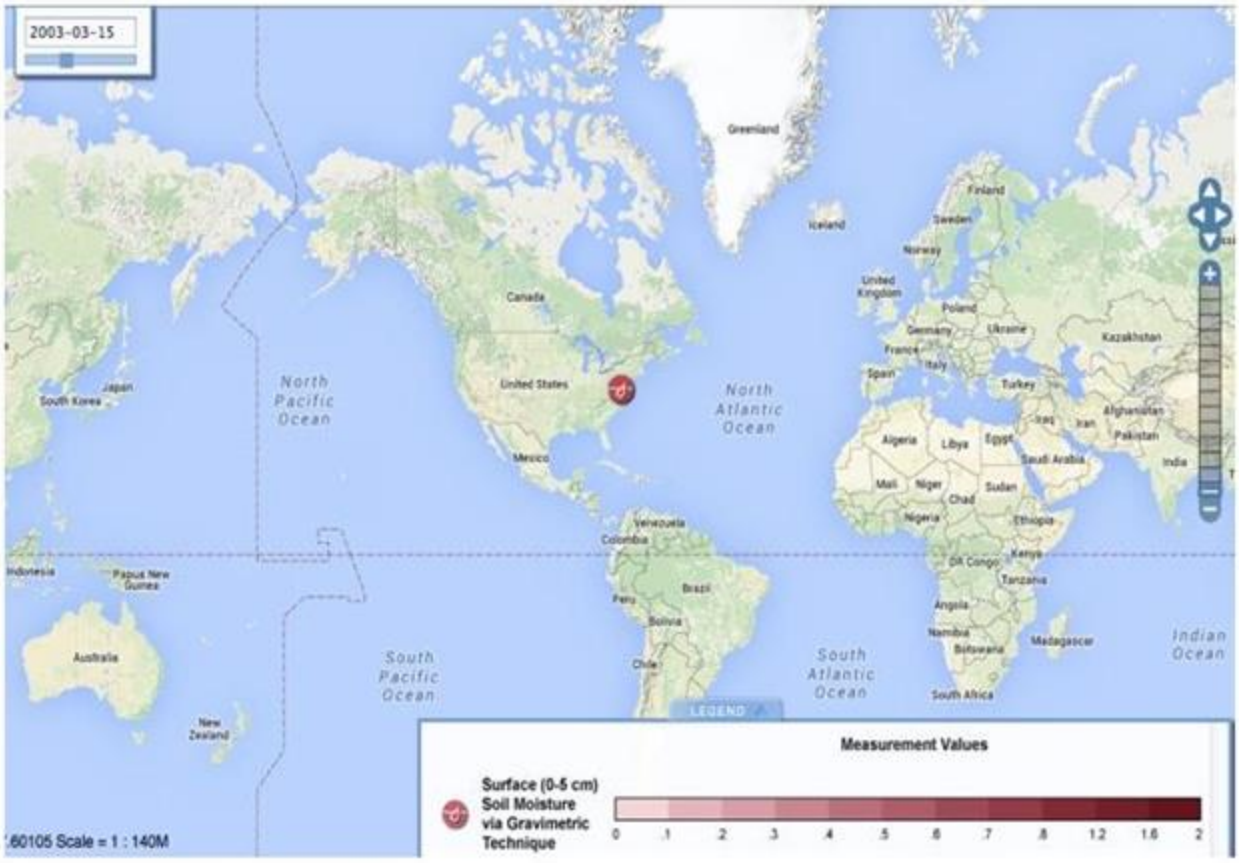
When ready, select “Send these measurements now” to send your data to GLOBE. When it has been sent, you will see a “Success” message.





Soil Moisture Gravimetric 0 - 5 cm Data Visualization

Visualization for the first horizon shows the soil moisture for 0-5 cm.



Soil Moisture Gravimetric 0 - 5 cm Data Visualization

Visualization for the first horizon shows the soil moisture for 0-5 cm. Data from this protocol and the SMAP Protocol are combined.

Questions for Further Investigations

- What other GLOBE schools have patterns of soil moisture similar to yours?
- How many weeks of the year is your soil relatively wet or relatively dry?
- Does soil moisture change during the winter?
- Which areas around your school are usually dry or wet? Why?
- Which holds the most water: clay, sand, or silt? Why?
- Does the type of land cover affect the amount of water that enters the soil? Does it affect the rate at which soil dries out following a rainstorm?
- How are soil moisture and relative humidity related?
- How are soil moisture and soil, surface and air temperature related?
- How does the porosity of a soil horizon relate to the amount of water that horizon can hold?
- How does soil water content change from one horizon to another in the same profile?
- What happens to the downward flow of water if there is a coarse textured (sandy) horizon overlying a horizon with high clay content? What happens to water flow if a clayey horizon is found over a sandy horizon?

Frequently Asked Questions

1. What should people do if they forgot to weigh the empty soil containers before filling them with samples in the field?

The soil collection containers can be weighed at the end of the soil moisture protocols after emptying the dried soil and cleaning the containers thoroughly. Remember that any dried soil left in the container will lead to an inaccurate container mass.

2. What should people do if the soil is frozen?

Take soil moisture measurements during times when the soil is thawed.

3. What should people do if the site was accidentally watered?

Take the data as usual, but check the flag on the *Data Sheet* to indicate artificially watered site. These data are still useful, and depending on conditions, the soil moisture may be affected by the watering for several days. If a large area, > 1 km2 within 3 km of your site is irrigated, record this as metadata and report it to GLOBE. This is important for interpretation of observations.

4. What should people do if the soil is snow covered?

If the soil is not frozen, brush off the snow and proceed with the sample collection.

Request for your feedback on this module! Please provide us with feedback about this module. This is a community project and we welcome your comments, suggestions and edits!
Questions after reviewing this module? Contact GLOBE: help@nasaglobe.org

Credits

Slides: Izolda Trachtenberg, Dixon Butler, Russanne Low

Photographs: Izolda Trachtenberg

Illustrations: Rich Potter

Cover Art: Jenn Glaser, *ScribeArts*

More Information:

GLOBE Program

NASA Earth Science

NASA Global Climate Change: Vital Signs of the Planet

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