THE **GLOBE** PROGRAM

A Worldwide Science and Education Program

Soil (Pedosphere) • SMAP

Soil Moisture Protocol

Goals and Objectives of this Module

Overview

This module:

- Describes how taking surface soil moisture samples supports the SMAP mission
- Provides step-by-step instructions in how to do the protocol

Learning Objectives

After completing this module, you will be able to

- Explain why soil moisture is worth studying
- Explain what the SMAP mission measures
- Determine when to take measurements for comparison with SMAP
- Define a Soil Moisture Site for taking SMAP Block Pattern data
- Take soil moisture samples of the top 5 cm of soil
- Measure gravimetric soil moisture content and sample bulk density
- Calculate gravimetric and volumetric soil water content
- Report these data to GLOBE
- Visualize these data using GLOBE's Visualization Site

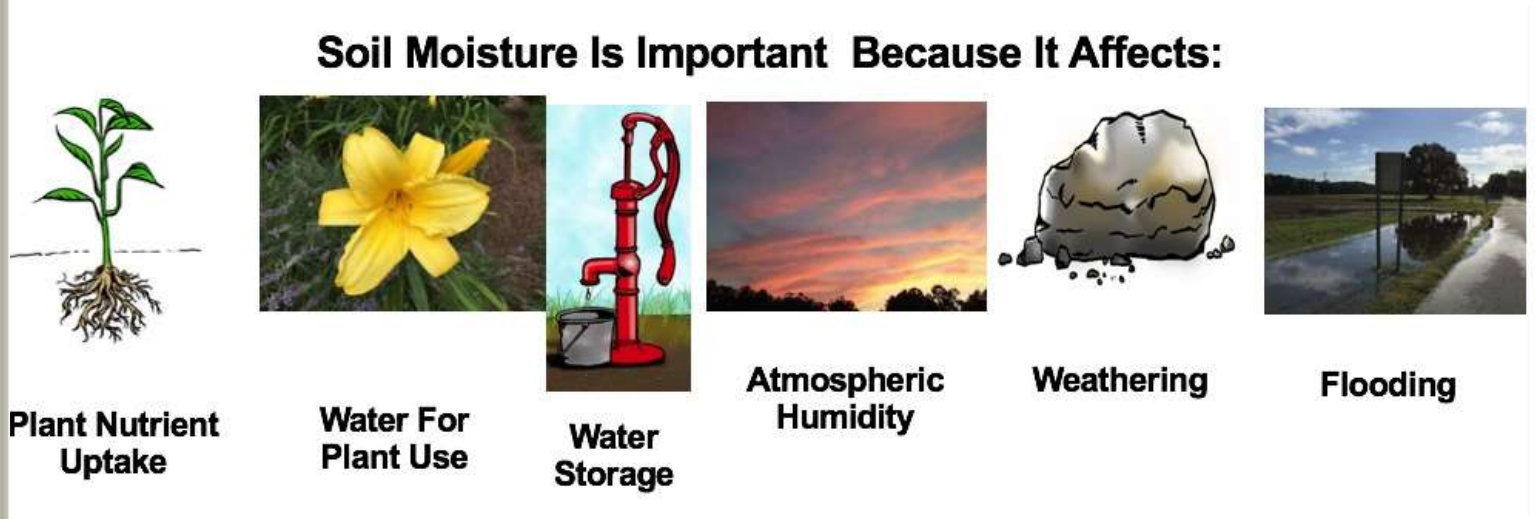
Estimated time needed for completion of this module: 1.5 hours

SMAP Soil Moisture Protocol

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 during times of little precipitation.

Some of this water evaporates back into the air; some drains through the soil into groundwater.



The Soil Moisture Active Passive (SMAP) Satellite

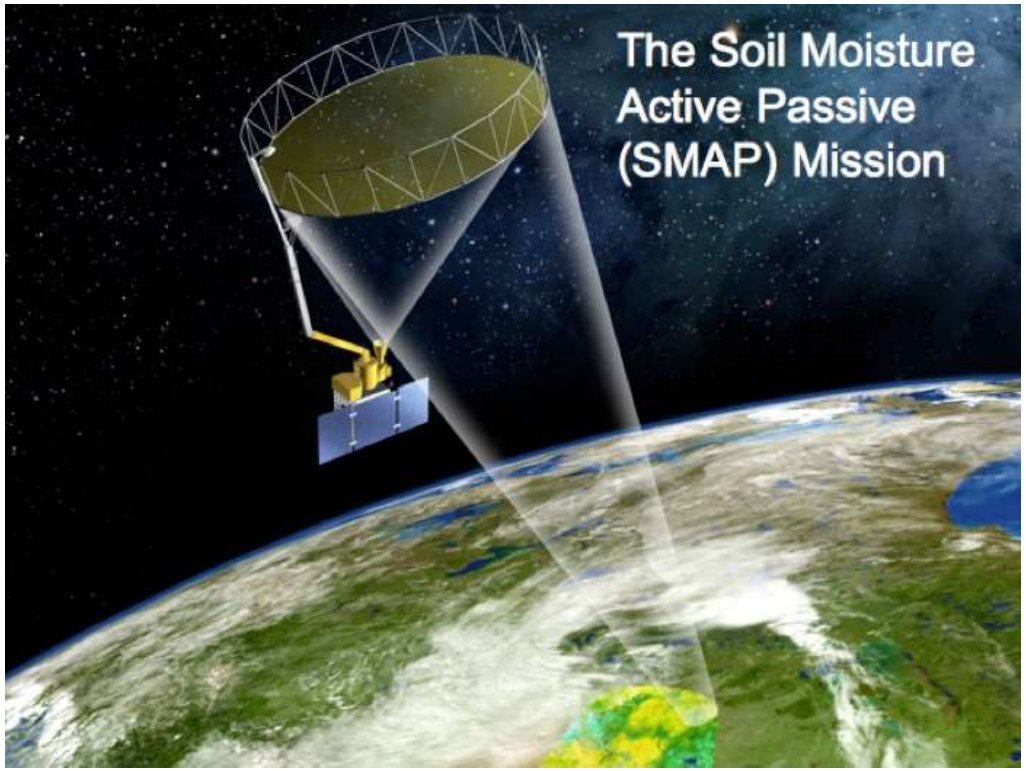


Image: NASA

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. The GLOBE SMAP Soil Moisture Protocol provides scientists with on-the-ground measurements to help validate the satellite's soil moisture estimates.

SMAP Soil Moisture Protocol Required Materials

- Heating lamp that can reach a sustained 60-90°C (for 2 or 3 days) such as a 250 watt infrared food heating lamp (with one or two bulbs) or a room heating lamp; alternatively a soil drying oven maybe used, but is not required
- A balance or scale with 0.1 g sensitivity (600 g capacity recommended, 400 g minimum capacity required)
- Sealable plastic bags (e.g., Zip-Lock bag)
- Tin cans (repurposed cat food, tuna, or small pineapple cans 5 cm deep without a lip. **Note: edges may be sharp.**
- Plastic wrap to seal the tin cans; rubber bands to hold the wrap around the can.
- A graduated cylinder with at least 100 mL capacity (500 mL recommended)
- Trowel
- GPS device for site definition
- A meter stick and a ruler marked in millimeters
- Permanent markers to label the soil containers

Define your sampling site before you go into the field to sample the soil. Locate your sampling site in the Data Entry app and be ready to enter all relevant data outside.

When to Take SMAP Soil Moisture Measurements

1. Determine your latitude and longitude
2. Determine when SMAP will overfly your site by entering your latitude and longitude on the SMAP Overflights Tool
3. Look for days when the satellite flies over your location in the morning
4. Decide upon your sampling schedule.
5. Try to collect soil moisture samples as close as possible to 6:00 AM +/- three hours local time on SMAP morning overpass days.

Image: NASA

Hint

SMAP flies in an orbit with an 8-dy repeat pattern.

Calibrate Your Balance

Calibrate the balance according to the manufacturer's directions. Record the standard mass used to calibrate the balance on the data entry app.

If using an electronic balance, check that the balance is measuring in grams and is zeroed properly.

Preparing Your Sample Containers for the Field

1. Get the mass of each sampling container.

If you are using a can, get the mass without the lid.

2. Label the Container with:

- The mass of the container
- A unique identifying number In the Field.

if you are using bags, add:

- Sampling date
- Sampling time
- Sample number

3. Record the mass to the nearest 0.1 g on the Data Entry app under, "Empty Container Mass."

Final Preparations to Define Your Site and Begin Measurements

1. Join the SMAP Community on the GLOBE website.
2. Complete the first part of the Data Entry app in Soil Moisture.
3. Mark your trowel 5 cm from the tip to ensure you go no deeper when you take samples.
4. Gather the required equipment:
   - Labeled sample can and lid or plastic wrap & rubber band
   - Meter stick or tape measure
   - GPS receiver or smart phone with GPS app
   - Smart phone with GLOBE Data Entry app or data entry sheet
   - Flags or other markers to define your site

Hint

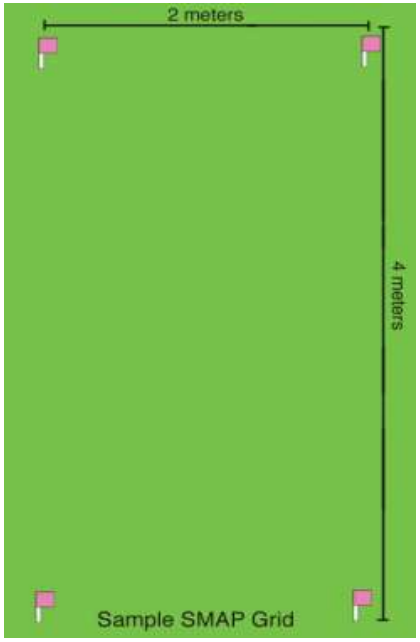
Remember it is important to try to collect the soil moisture samples at approximately the same time every day to ensure measurement consistency. If you can, take soil moisture samples no later than 9:00 AM local time.

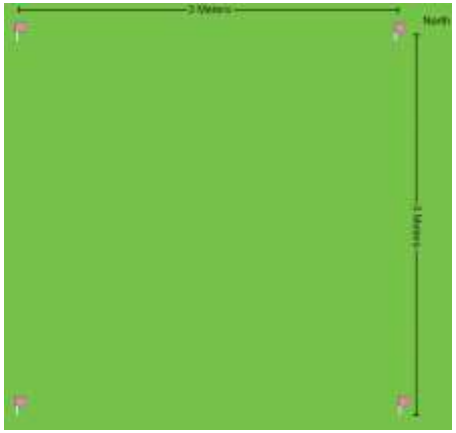
SMAP Soil Moisture Site Selection

Select a site that is large enough for one year of measurements spaced 25 cm apart and:

- flat
- uniform in surface cover
- not under trees or other tall plants
- relatively free of rocks

Try to avoid an area that is irrigated unless it is located in a large field that is consistently irrigated.





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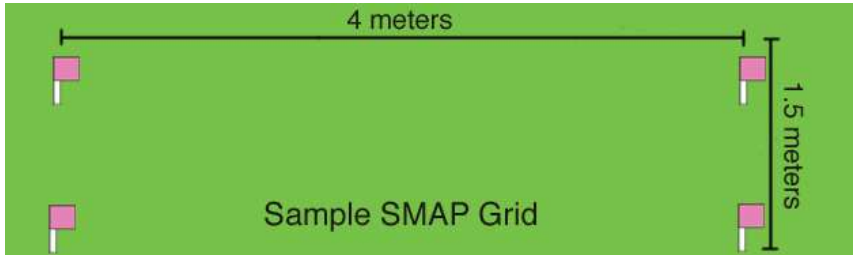
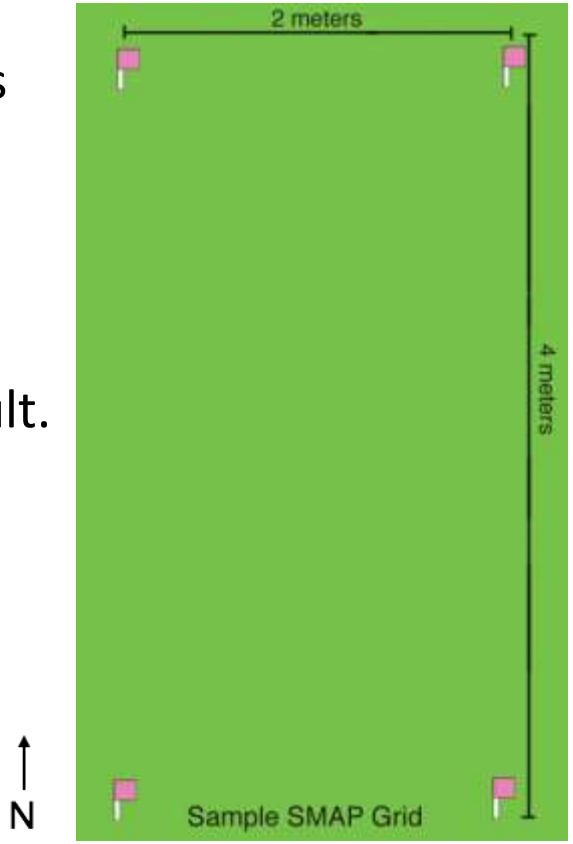
SMAP Soil Moisture Site Considerations

Note: SMAP sampling grids can be rectangular or other shapes as long as the sampling sites are as uniform as possible.

A site may be under trees, but the area should be free of surface roots and comparison with SMAP may be difficult.

A site that is representative or a large area such as a field is ideal where possible.





SMAP Soil Moisture Site Selection

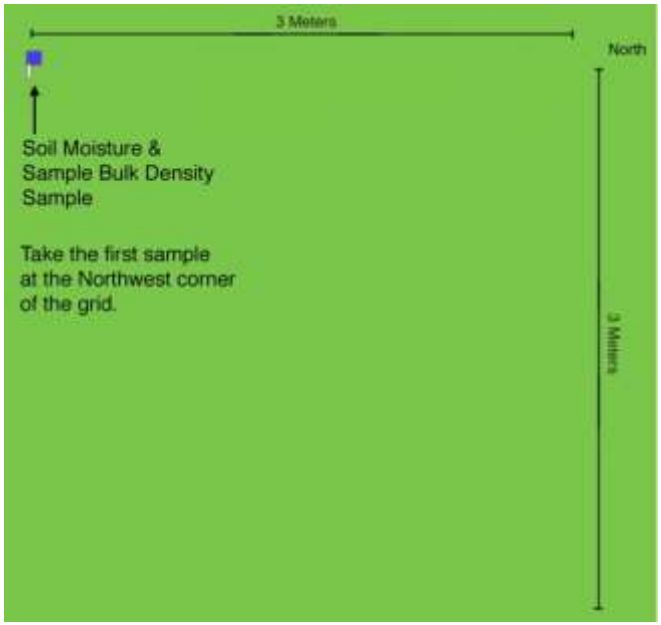
Use a meter stick or tape measure to lay out the grid.

Mark all four corners of the grid with some sort of permanent markers.

SMAP Sampling Instructions for Measuring Sample Bulk Density

The first time you take a SMAP Soil Moisture sample and for every tenth sample after that, take a Sample Bulk Density Sample. See the next slide for instructions.

Note: sample for the first time at the Northwest corner of the grid.



Prepare to Take a Soil Sample

At the sampling spot, remove any grass or other groundcover.

Taking a SMAP Soil Moisture Sample of Known Volume

Push the can all the way into the soil so the bottom of the can is even with the ground surface.

If the soil is hard, place a wooden block on top of the can and pound it into the soil with a hammer.

If the soil is so hard that pounding it into the ground will bend the sample can, take a sample using a trowel and sealable bag and wait until the ground has softened to take the can sample.

Removing the Sample Can from the Ground

Using a trowel or shovel, remove the can and the soil surrounding it.

Make sure you dig around the can to remove it. If your trowel is not fully under the can, you might lose soil sample during the extraction process.

Scrape off the soil to level it with the tome of the can.

If a rock or twig sticks out, discard this sample, wipe out the can, and take a fresh sample.

It is essential that the volume of the soil sample is the same as the volume of the can, so be sure to wipe off all soil clinging to the outside of the can.

Seal the Can to Keep All the Moisture in the Sample

Cover the labeled can with the lid or other moisture tight cover.

Your sample is now ready for weighing and drying in the lab

Routine Collection of a Surface Soil Sample

Dig your trowel 5 cm into the soil to loosen it.

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

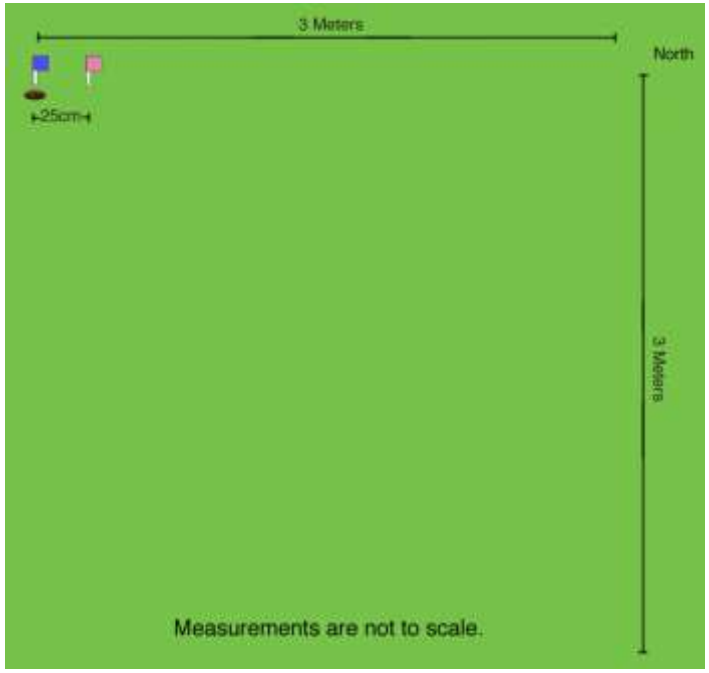
Scoop soil into the pre-marked, sealable bag.

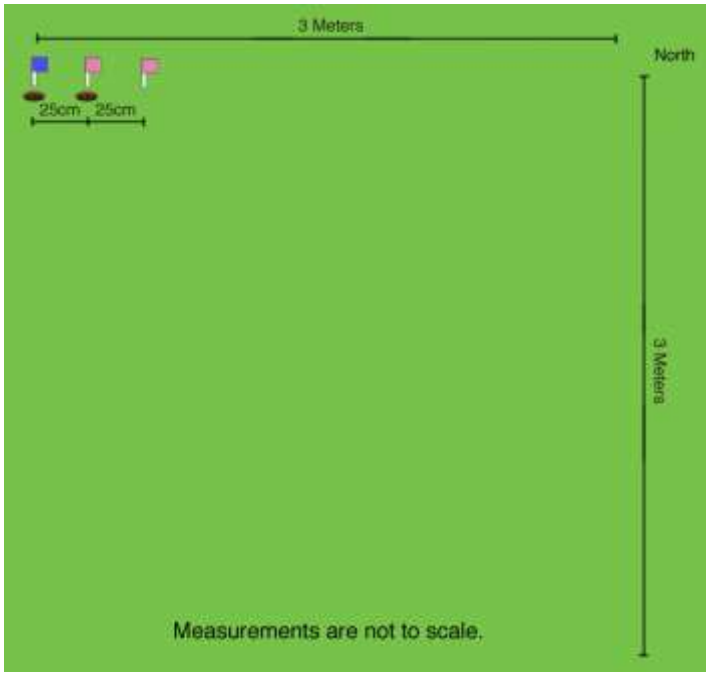
Seal the bag containing the sample.

Spacing Your Samples

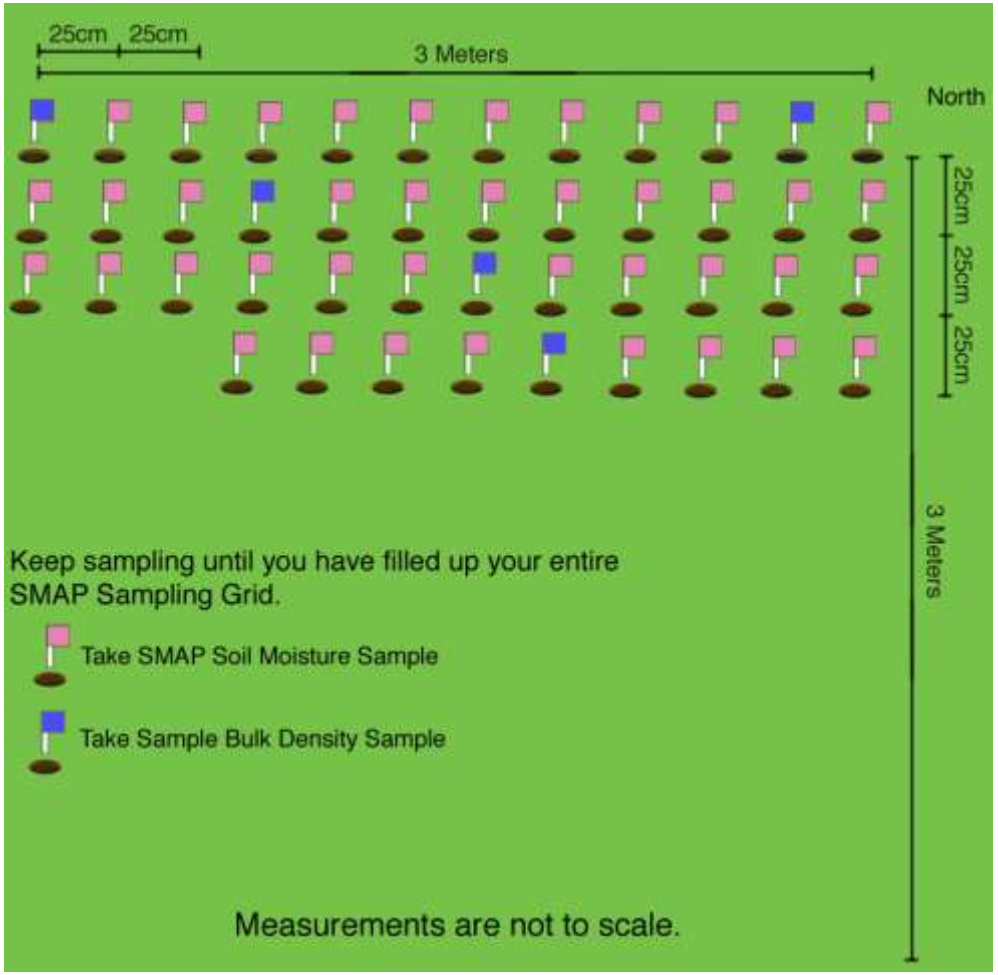
On the next SMAP overfly day, move 25 cm over from the previous sample.

During a year, no sample should be taken within 25 cm of any others





SMAP Soil Moisture Sampling Grid Example



SMAP Soil Moisture Lab Measurements

SMAP Soil Moisture – Lab Instructions

To finish the SMAP Soil Moisture Protocol and determine the gravimetric and volumetric soil moisture content of your samples, complete the following steps.

SMAP Soil Moisture Lab- Required Materials

- Either a soil drying oven or heat lamps
- Thermometer capable of measuring to 105° C (if using a conventional drying oven)
- Soil Samples in containers suitable for your drying source
- Balance or scale with 0.1g
- sensitivity and at least 400 g capacity (600 g recommend)
- Hot pads or oven mitts
- GLOBE Data Entry app or Data Sheet
- Permanent marker

What to Do With Samples Collected in a Can

If you will be using heat lamps to dry your soil sample:

Label a sealable bag with:

- container (empty bag) mass
- sample number
- sample collection date
- site name

Uncover the can and immediately transfer the soil sample into the labeled bag. **Be sure to transfer all the soil.**

Weigh the sample in the bag. Record the mass to the nearest 0.1 g as the *Wet Mass* next to the appropriate sample container number on the Data Entry app. Or on the Data Sheet

Measuring the Wet Mass of Samples

Calibrate the balance according to the manufacturer's directions.

If using an electronic balance, check that the balance is measuring in grams and is zeroed properly.

Place the sample on the scale.

Record the mass to the nearest 0.1 g as the *Wet Mass* on the Data Entry app or Data Sheet.

If the sample is in a can, be sure to remove the lid before weighing.

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Drying Samples

Open the sample bag and roll the edges down to create a larger open area.

If the sample is in clumps, break them up with your hand outside the plastic bag. Do not touch the soil sample directly.

Dry your sample by placing the open bag 30-40 cm below the 250 watt infrared heating lamp or other drying source.

Carefully remove the sample from the drying source using hot mitts.

Weigh the sample after drying it for the recommended 2-3 days.

Initial Dry Sample Mass: 146.3 g

Determining That the Sample Is Dry

To determine if the water is gone, dry the sample for an additional period of two or more hours, and then weigh it again.

If the mass has changed by 0.3 g or more, dry the sample some more, and weigh it again.

Repeat these steps until the mass of the sample has not changed by 0.3 g.

Then the sample can be considered dry.

SMAP Soil Moisture – Sample Bulk Density Lab Protocol For Samples Collected in a Can

If you have a soil drying oven, complete all soil collection and drying using sample cans. Measure sample bulk density every tenth time a sample is collected by pushing the can into the soil. For other times you can simply place soil in the sample can just as your would a bag.

Measure the wet sample mass to the nearest 0.1 grams.

Wet mass is 398.0 g.

Dry the sample according to the protocol.

Measure the dry sample mass to the nearest 0.1 grams.

Dry mass is 348.0 g.

Images courtesy, Izolda Trakhtenberg

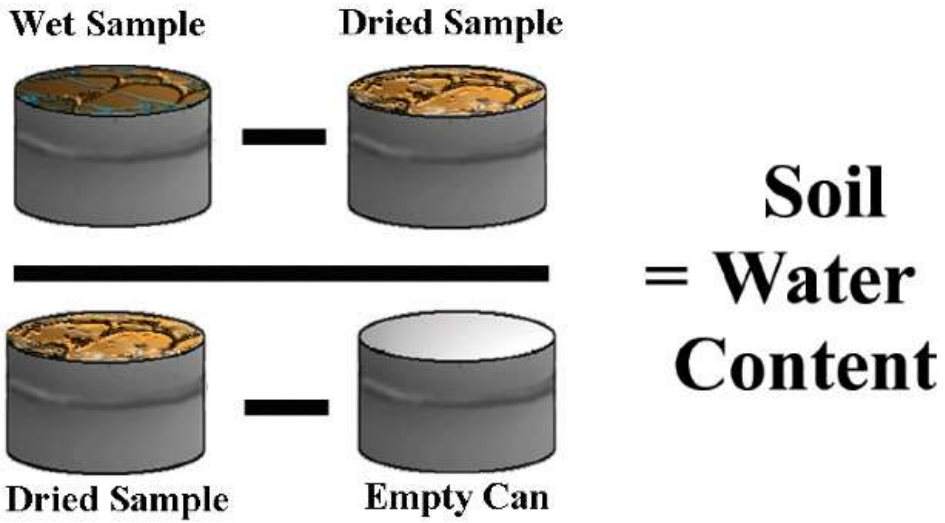
Record the Dry Mass

When your sample is dry, on the Data Entry app or Data Sheet fill in:

- The drying time and drying method
- The *Dry Mass* next to the appropriate container number
- The mass of the sealable bag

Calculating Gravimetric Soil Water Content

Use this formula to calculate Gravimetric Soil Water Content



Measuring Sample Bulk Density – Filling the Graduated Cylinder

- After all the soil in a can has been transferred to a bag or dried in a soil oven, weighed, and emptied you will measure the volume of the clean, dry can by using a graduated cylinder filled with water.

- GLOBE asks that this measurement be made three times.
- Remember to read the bottom of the Meniscus.
- Clean any drops off the rim of the graduated cylinder to avoid water entering the can that isn't included in your measured volume.
- Record your reading as the Initial Volume.

Measuring Sample Bulk Density – Filling the Can

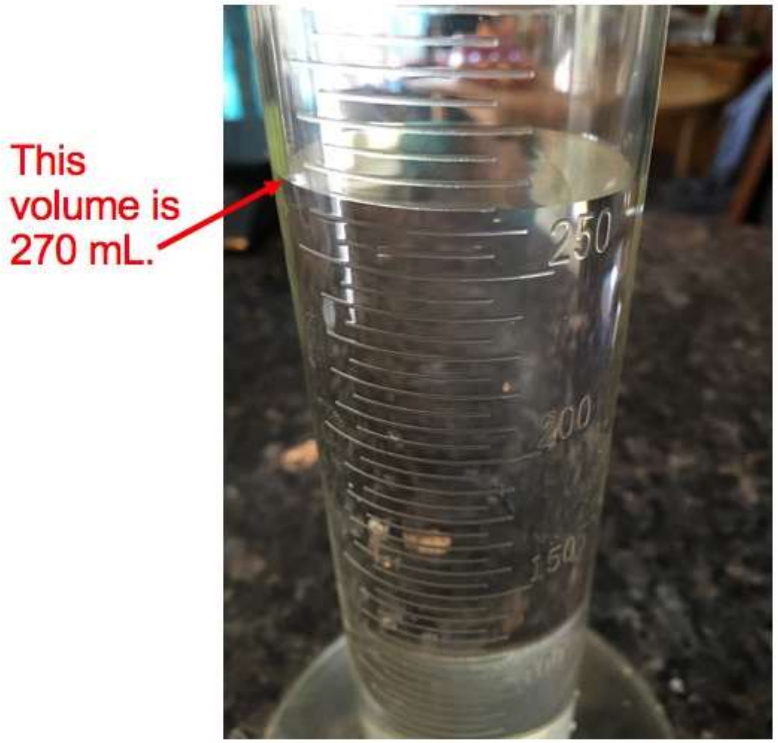
Set the can on a level surface.

Ensure that the can rim is not dented so that the water will have a flat surface.

Pour the water into the can until it is full to the brim.

Measuring Sample Bulk Density – Reading the Final Volume

- Record the volume left in the graduated cylinder as the final volume.
- If you are using a graduated cylinder with a volume less than the sample can, the water in the graduated cylinder will not fill the can entirely.
- In this case, fill the cylinder, record the volume, and empty it into the can. Repeat this, recording the volume each time. When the can is filled, read the amount of water left in the cylinder; this is your final volume. The initial volume is the sum of the starting amounts to which in the cylinder was filled.



Calculating Can Volume

The volume of this sample can would be 500 mL – 270 mL =230 mL.

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- $V_{can} = V_{initial} - V_{final}$
- If you filled the graduated cylinder twice, $V_{can} = V_1 + V_2 - V_{final}$
- If you filled the cylinder three times, $V_{can} = V_1 + V_2 + V_3 - V_{final}$

Calculating Sample Bulk Density

The volume of the can is the average of the three measurements taken.

- $V_{avg} = V_{can1} + V_{can2} + V_{can3}$

The Sample Bulk Density is the mass of the dry soil divided by the volume of the sample.

$$\text{Sample Bulk Density} = (M_{dry} - M_{container}) / V_{avg3} \text{ (g/ml)}$$

Note: 1 milliliter = 1 cubic centimeter so density units are also (g/cc)

The term “Sample Bulk Density” is used in GLOBE to distinguish this quantity from the bulk density measured following the Bulk Density Protocol, which requires sieving the dry sample and measuring the weight and volume of any rocks and sticks in the sample.

Calculating Volumetric Soil Moisture Content

SMAP measures volumetric soil moisture content, so the GLOBE gravimetric soil moisture content data must be converted for comparison with the satellite data.

Volumetric soil moisture content = $Volume_{water}$ / $Volume_{soil}$

The density of water is approximately 1 g/ml.

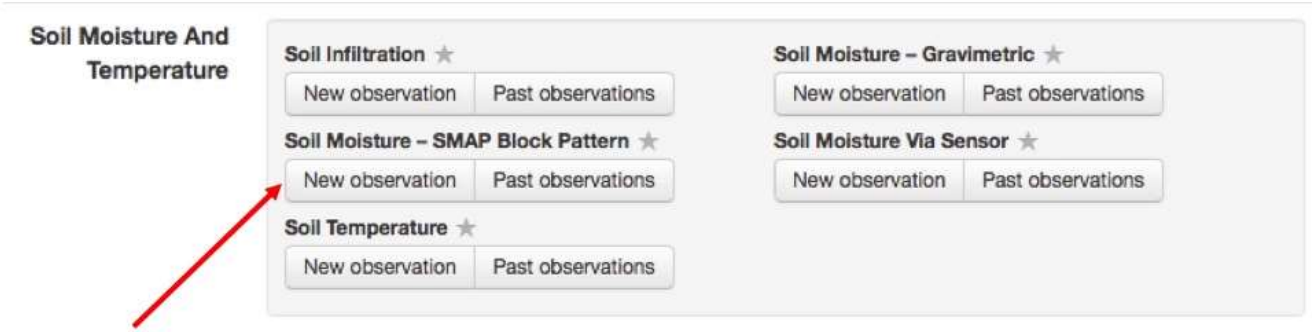
- $V_{water} = Mass_{water} / Density_{water}$

So the water volume in milliliters or cubic centimeters is equal to the water mass in grams.

- $Volume_{soil} = (Mass_{dry} - Mass_{container})$ / Sample Bulk Density (g/ml)
- OR
- Volumetric soil moisture content = $Volume_{water}$ / $Volume_{can}$

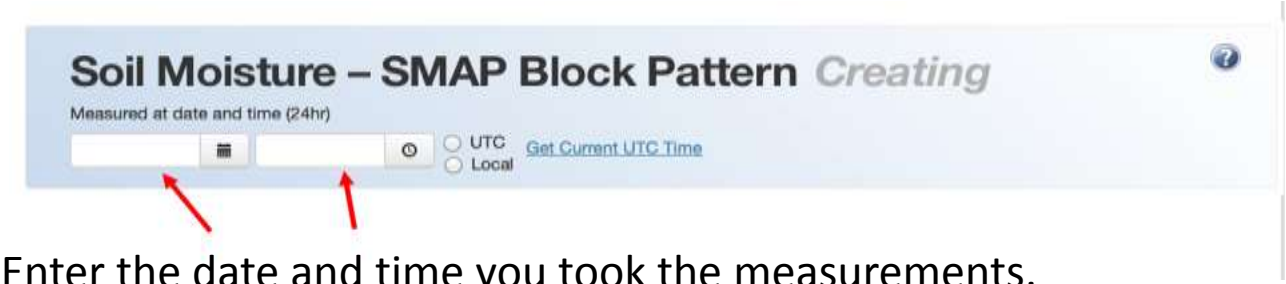
SMAP Soil Moisture Data Entry

- On the GLOBE Data Entry app, click on *Data Entry.*
- Select your organization, and click on your site.
- Under *Soil Moisture – SMAP Block Pattern*, click on *New observation*. On the GLOBE.gov website, click on *Live Data Entry*.
- You will be prompted to log in with your email address and password.
- Select your organization, and click on your site.



Under Soil Moisture And Temperature, click on *New observation*.

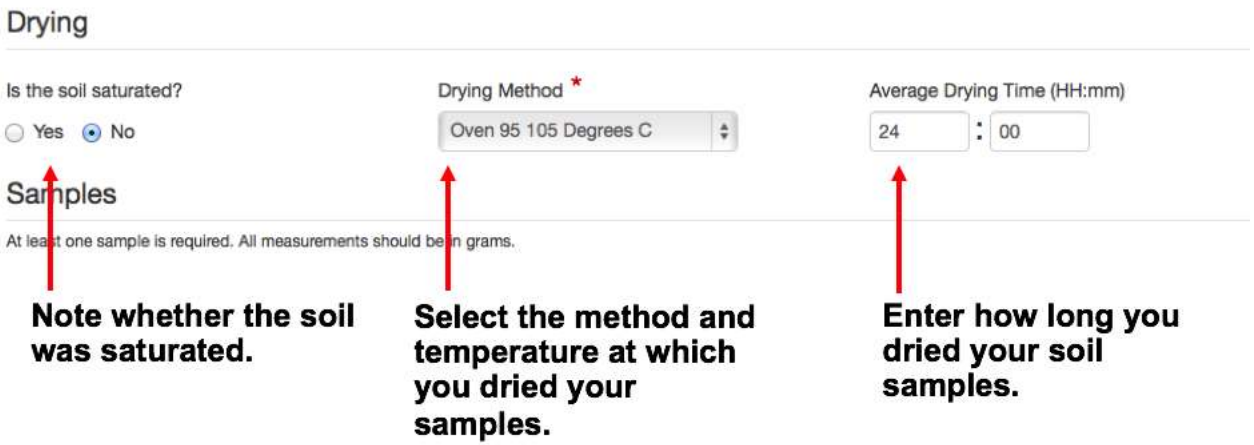
SMAP Soil Moisture Data Entry-Metadata



Enter the date and time you took the measurements.

Be sure to choose Local or UTC time.

Once you have entered the date, the data entry page will appear below.



Entering Gravimetric Soil Moisture Data

Weight Measurement

Wet soil *(a)* *	Dry soil *(b)* *	Water weight *(c)*
g	g	*a - b* = ***0.00 g***
Empty container weight *(d)* *	**Dry soil weight *(e)***	**Gravimetric Soil Moisture *(f)***
g	*b - d* = ***0.00 g***	*c / e* = ***0.00 g/g***

Enter your SMAP Soil Moisture data for your 0-5 cm sample.

Entering Gravimetric Soil Moisture Data - Examples

Weight Measurement

Wet soil *(a)* *	Dry soil *(b)* *	Water weight *(c)*
398.4 g	348.5 g	*a - b* = ***49.90 g***

Empty container weight *(d)* *	Dry soil weight *(e)*	Gravimetric Soil Moisture *(f)*
31.5 g	*b - d* = ***317.00 g***	*c / e* = ***0.16 g/g***

These wet and dry soil mass measurements are in the appropriate range and typical for samples dried in a can

Weight Measurement

Wet soil *(a)* *	Dry soil *(b)* *	Water weight *(c)*
146.8 g	132.5 g	*a - b* = ***14.30 g***

Empty container weight *(d)* *	Dry soil weight *(e)*	Gravimetric Soil Moisture *(f)*
10.5 g	*b - d* = ***122.00 g***	*c / e* = ***0.12 g/g***

These wet and dry soil mass measurements are in the appropriate range and typical for samples dried in bags.

Entering Container Volume Data

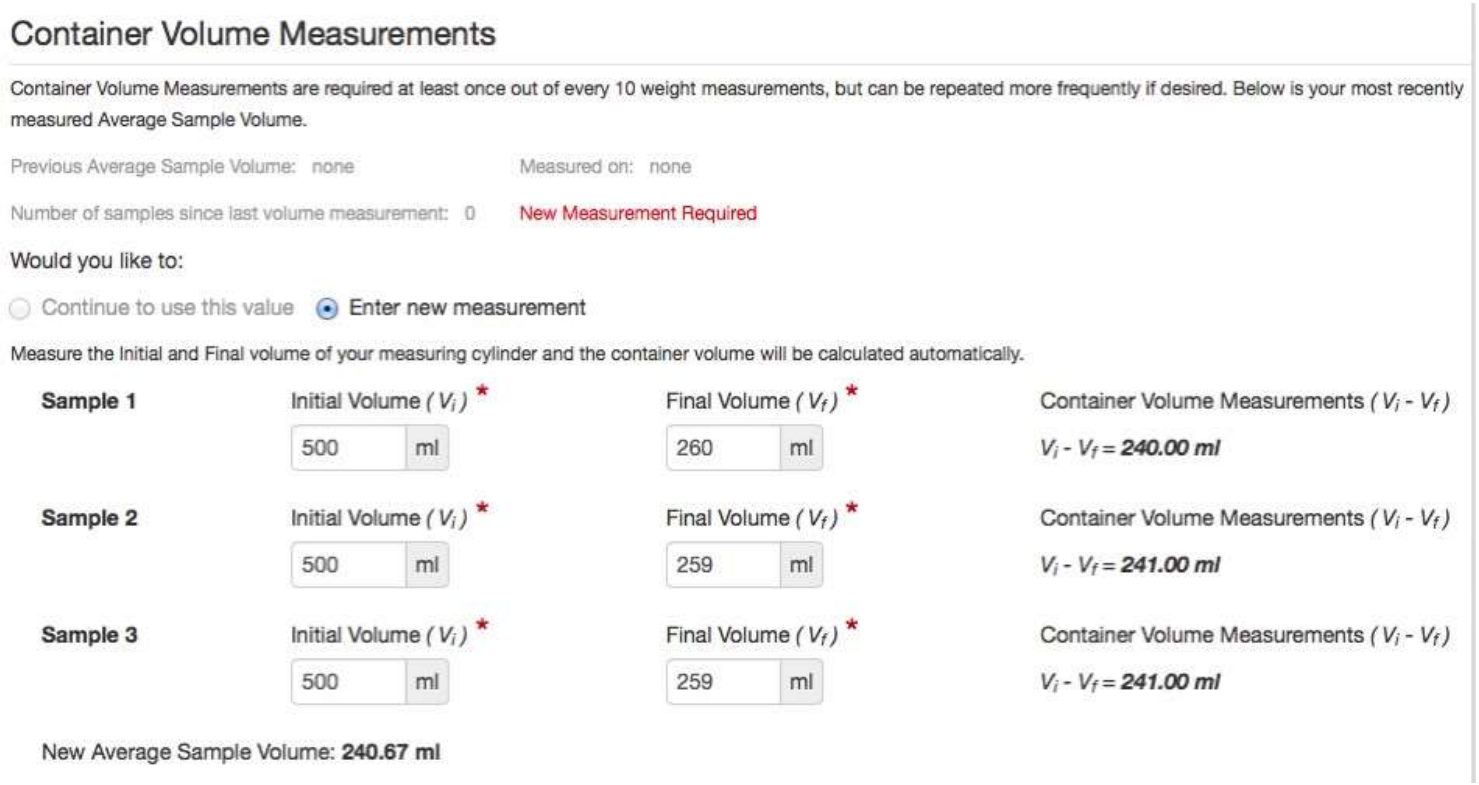
If you are reporting sample bulk density measurements, you will need to report the volume of your sampling can.

These wet and dry soil mass measurements are in the appropriate range and typical for samples dried in a can

These wet and dry soil mass measurements are in the appropriate range and typical for samples dried in bags.

Entering Container Volume Data-Example

- Enter your three sets of Initial and Final Volume data.
- The website will calculate the average can volume and the volumetric soil moisture.



Container Volume Measurements

Container Volume Measurements are required at least once out of every 10 weight measurements, but can be repeated more frequently if desired. Below is your most recently measured Average Sample Volume.

Previous Average Sample Volume: none Measured on: none

Number of samples since last volume measurement: 0 New Measurement Required

Would you like to:

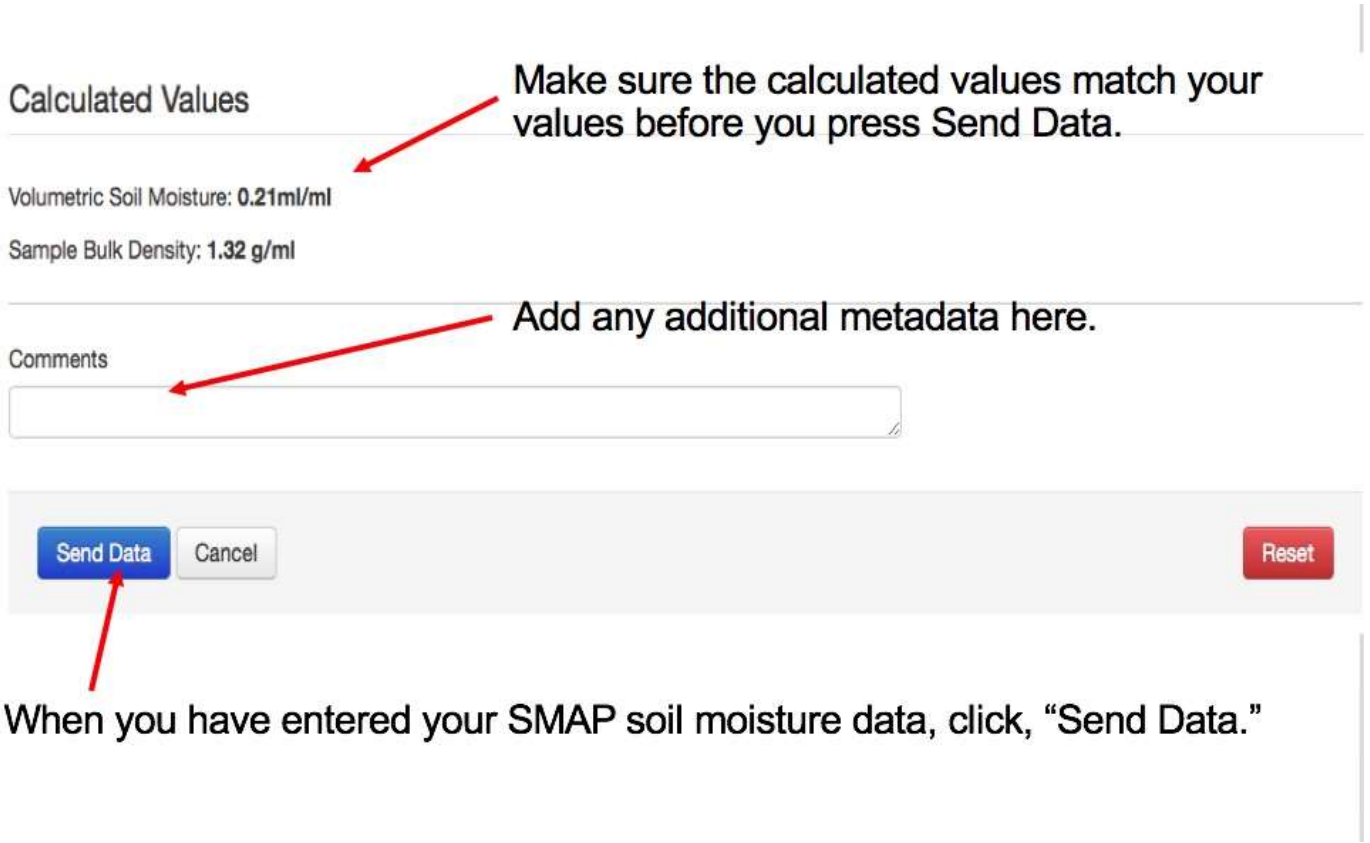
○ Continue to use this value ◉ Enter new measurement

Measure the Initial and Final volume of your measuring cylinder and the container volume will be calculated automatically.

	Initial Volume (V_i) *	Final Volume (V_f) *	Container Volume Measurements (V_i - V_f)
Sample 1	500 ml	260 ml	$V_i - V_f$ = ***240.00 ml***
Sample 2	500 ml	259 ml	$V_i - V_f$ = ***241.00 ml***
Sample 3	500 ml	259 ml	$V_i - V_f$ = ***241.00 ml***

New Average Sample Volume: **240.67 ml**

SMAP Soil Moisture – Lab Data Entry



Data Entry System Responses

If your data is within the appropriate ranges for Gravimetric Soil Moisture (Depth Profile), you will see the image below.

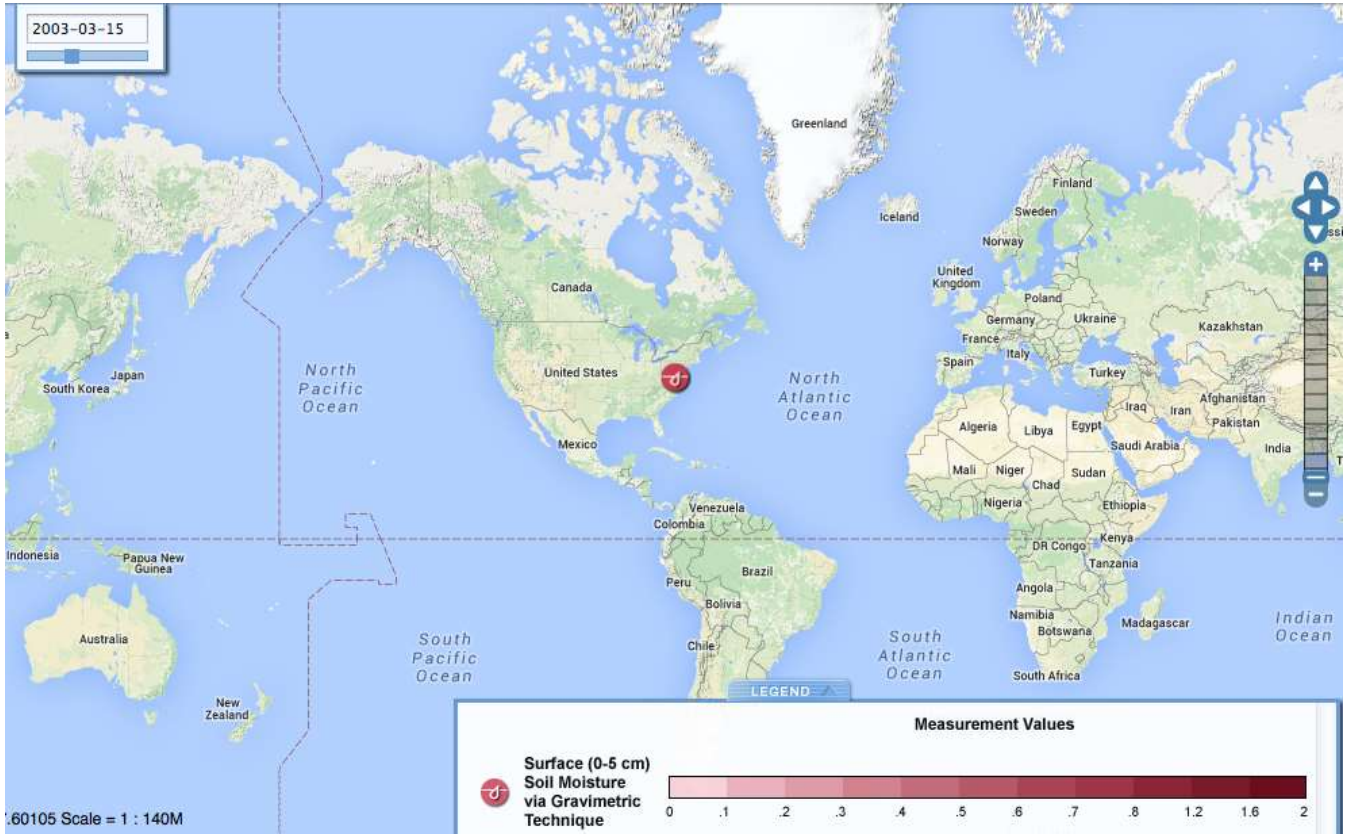
If your data is not within the appropriate range or has other issues, you will see the following:

Address the errors in the page details and resubmit your data.

Hint **If your data are not within the range the Data Entry System accepts, contact GLOBE Community Support.**

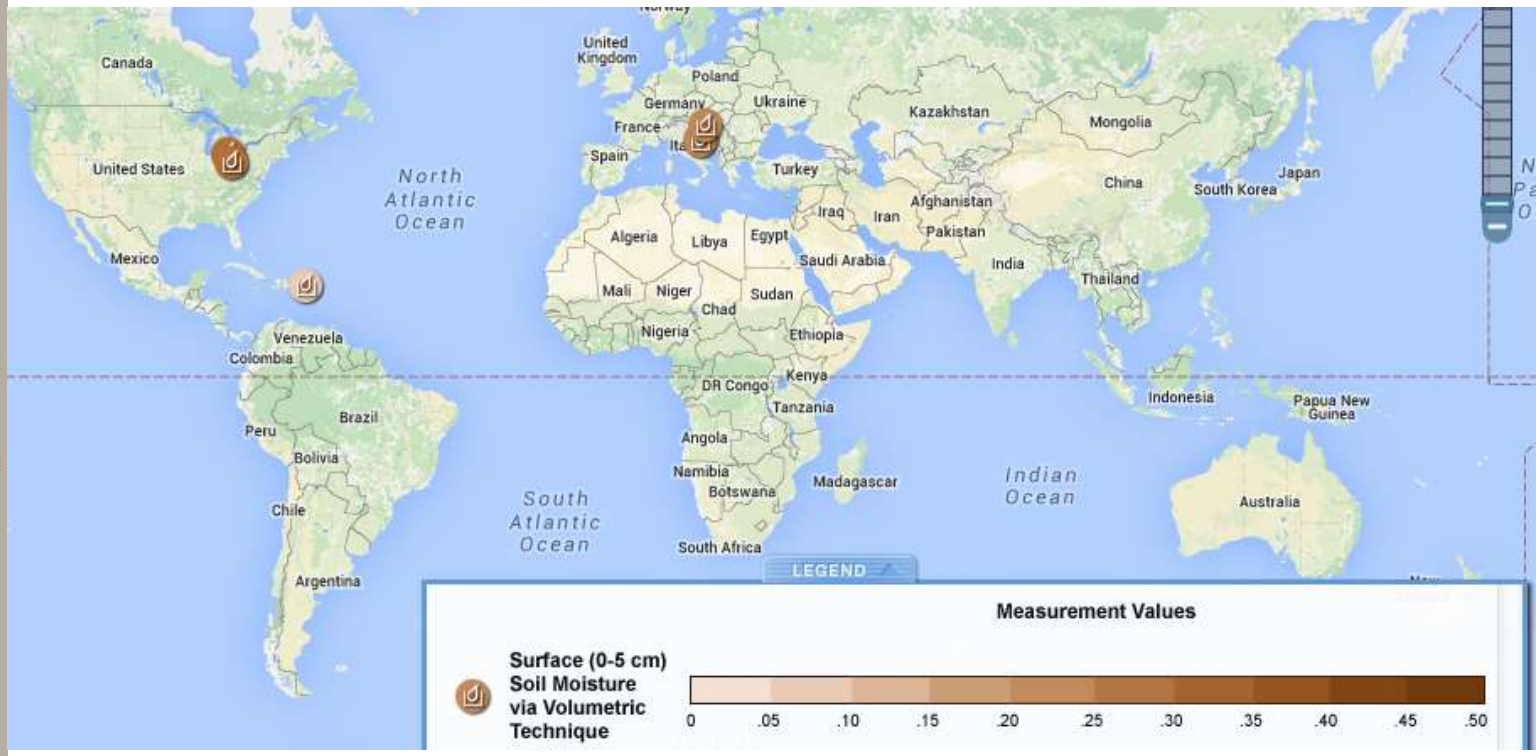
Gravimetric Surface Soil Moisture Visualization

Visualization data layer for 0-5 cm gravimetric soil moisture



Volumetric Surface Soil Moisture Visualization

Visualization data layer for 0-5 cm volumetric soil moisture



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