National Aeronautics and Space Administration

Global Learning and Observations to Benefit the Environment (GLOBE) Data User Guide

Version 1.0

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Prepared by:
Helen Amos
Senior Research Scientist, Science Systems and Applications, Inc.

Approved by:
Allison Leidner
GLOBE Program Manager

Approved by:
Anthony (Tony) Murphy
GLOBE Implementation Office Director

GLOBE Data User Guide
Contributors

Contributors (in alphabetical order):

Name	Affiliation
Travis Andersen	GLOBE Implementation Office
Becky Boger	Brooklyn College
Dixon Butler	Youth Learning as Citizen Environmental Scientists
Brian Campbell	NASA Wallops Flight Facility
Marilé Colón Robles	SSAI / NASA Langley Research Center
J. Brant Dodson	SSAI / NASA Langley Research Center
Holli Kohl	SSAI / NASA Goddard Space Flight Center
Russanne Low	Institute for Global Environmental Strategies
Peder Nelson	Oregon State University
Dave Overoye	Science Systems and Applications, Inc.
Margaret Pippin	NASA Langley Research Center
Kristen Weaver	SSAI / NASA Goddard Space Flight Center

SSAI = Science Systems and Applications, Inc.

With thanks to the following individuals for thoughtful feedback (in alphabetical order):

Name	Affiliation
Lin Chambers	NASA Langley Research Center
Lisa Dallas	NASA Goddard Space Flight Center
Trena Ferrell	NASA Goddard Space Flight Center
Allison Leidner	NASA Headquarters
Tony Murphy	GLOBE Implementation Office
Todd Toth	NASA Goddard Space Flight Center

Preface

This document is under GLOBE Project configuration control. Once this document is approved, GLOBE-approved changes are handled in accordance with the change control requirements as described in the GLOBE Change Management Plan, and changes to this document shall be made by complete revision.

Questions or comments concerning this document should be addressed to:

GLOBE Implementation Office
help@globe.gov

Change History Log

Revision	Effective Date	Description of Changes
v1.0	July 10, 2019	Version 1.0 released

Table of Contents

List of Figures

List of Tables

Abbreviations

Abbreviation	Definition
ADAT	Advanced Data Access Tool
API	Application Programming Interface
CALIPSO	Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation
CERES	Clouds and the Earth's Radiant Energy System
csv	Comma Separated Values
GLOBE	Global Learning and Observations to Benefit the Environment
GPS	Global Positioning System
I/O	Input/Output
JSON	JavaScript Object Notation
MGRS	Military Grid Reference System
MODIS	Moderate Resolution Imaging Spectroradiometer
MUC	Modified UNESCO (United Nations Educational, Scientific, and Cultural Organization) Classification
S'COOL	Students' Cloud Observations On-Line
SMAP	Soil Moisture Active Passive
STEM	Science, Technology, Engineering, and Math
UTC	Coordinated Universal Time
Vis	GLOBE Visualization System

Abstract

The Global Learning and Observations to Benefit the Environment (GLOBE) Program is an international science and education program that provides students and citizen scientists the opportunity to contribute Earth observations. The GLOBE Program started in 1995, includes more than 120 participating countries, has a mobile app (GLOBE Observer), and has more than 160 million observations contributed from trained students and citizen scientists in its database. GLOBE data are all made freely available to everyone. This User Guide is a technical document intended to help scientists and researchers understand, access, and use available GLOBE data.

Purpose and Scope

The purpose of the GLOBE Data User Guide is to help scientists and researchers understand, access, and use available GLOBE data. The scope includes data collected by GLOBE-trained teachers and students, automated weather stations, as well as data collected by citizen scientists using the tools in the GLOBE Observer mobile application.

Document Review, Approval, and Update

This document is reviewed, approved and updated in accordance with the GLOBE Change Management Plan. This document is approved by the relevant stakeholders.

The GLOBE Data User Guide presents a snapshot of technical information about GLOBE data that is current at the time of signature. It is reviewed periodically thereafter to ensure currency at major milestones such as the addition of new tools to the GLOBE Observer mobile app, addition/modification of GLOBE science protocols, or if major program/project changes occur. The GLOBE Data User Guide contains the best-known information at the time it is documented and will be updated at the major milestones. Upon approval, this document will be placed under configuration control. Approved changes will be listed in the document's Change History Log.

Submitting Suggested Changes

Suggested updates, additions, edits, and corrections are welcomed. Please email your suggestion(s) to help@globe.gov and include the following information:

- **Suggested change (**please be as specific as possible)
- **Rationale for change**
- **Version of the guide**
- **Section**
- **Page number**
- **Your name**
- **Email address**
- **Date**
- **How are you using GLOBE data?**

1. Background

The Global Learning and Observations to Benefit the Environment (GLOBE) Program is an international science and education program that provides students and the public worldwide with the opportunity to participate in data collection and the scientific process, and contribute meaningfully to our understanding of the Earth system and global environment. Announced by the U.S. Government on Earth Day in 1994, GLOBE launched its worldwide implementation in 1995. Classroom teachers receive training to become certified in GLOBE protocols. Protocols are specific data collection methods. Classroom teachers then teach those protocols to their students, and then collect and contribute measurements to the GLOBE database. Today there are more than 34,000 schools, and 143,000 citizen scientists in the GLOBE network who have contributed 160 million observations. Live statistics about GLOBE are updated continuously on the GLOBE website.

In 2016, the GLOBE Observer mobile application (hereafter "app") was launched to broaden opportunities for teachers, students, and people who are outside formal classroom settings to contribute Earth observations. The app is a tool that allows users to collect and submit data for a subset of GLOBE protocols that do not require equipment or extensive training. Currently, four kinds of observations can be collected and submitted through the app: clouds, land cover, mosquito habitats, and trees. In 2017, a temporary Eclipse tool inside the app was created to facilitate the collection of air temperature observations during the 2017 North American Solar Eclipse. The Eclipse tool is being re-activated in 2019 for the South American Solar Eclipse. User observations can include photographs. All observations submitted through the GLOBE Observer app are stored in the GLOBE database. GLOBE data are all made freely available to everyone. Today there are more than 230,000 observations submitted through the GLOBE Observer app. The GLOBE Observer app can be downloaded for free from Google Play or the Apple App Store.

There are primarily two types of individuals contributing measurements to GLOBE's database: (1) GLOBE member; and (2) GLOBE Participant. GLOBE members are typically those that completed protocol training; use the program in a classroom setting or do work for the program in addition to contributing data. A GLOBE Participant's primary focus is contributing environmental data and may have yet to complete protocol training. Once a GLOBE member has completed training for a particular sphere and a protocol within the sphere (e.g., *Atmosphere* and *Air Temperature*) the member may enter data for any of the other GLOBE protocols in any sphere. Observers using the GLOBE Observer app are guided through tutorials supplied within the app before submitting data. GLOBE-trained members can, and do, use the GLOBE Observer app.

1.1 Citation for GLOBE Data

Global Learning and Observations to Benefit the Environment (GLOBE) Program, *Date Data was Accessed*, https://www.globe.gov/globe-data.

NOTICE
If you publish a peer-reviewed article with GLOBE data, please credit the program and let us know so we can advertise your work on the GLOBE Publications page. Send the citation for your published article to help@globe.gov.

1.2 Data Set Characteristics

Sampling frequency: Discrete. Users can report a single observation at a site, or return to that site over a period of time and report multiple observations over a period of months-to-years.

Time: Time is reported in UTC (Universal Coordinated Time).

Spatial coverage: Worldwide. More than 120 countries participate in GLOBE (see **Figure 2**).

Spatial characteristics: GLOBE data are point data. Each GLOBE observation is associated with a point latitude and longitude location.

For naming and visualization purposes, data submitted through the GLOBE Observer app or GLOBE Data Entry app are associated with the Military Grid Reference System (MGRS) (see **Figure 1**). An explanation of the MGRS grid, including examples, is available from the National Geospatial Intelligence Agency. GLOBE observations submitted through either app are associated with the nearest 100-meter x 100-meter MGRS grid box based on the measured latitude and longitude from the user's smartphone Global Positioning System (GPS). A "site ID" is generated based on the associated MGRS grid box (see Appendix 2).

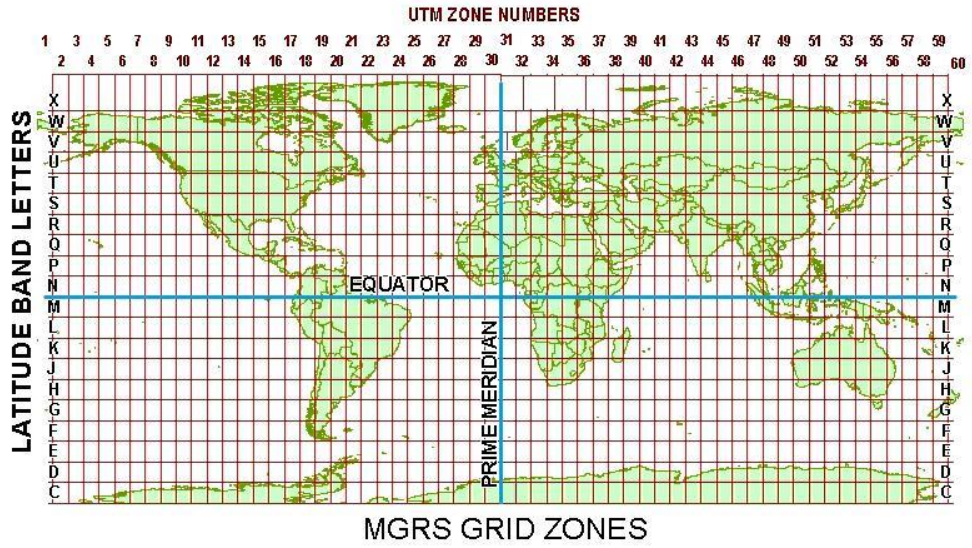


Figure 1. Military Grid Reference System (MGRS) Grid Zones. Source: National Geospatial Intelligence Agency.

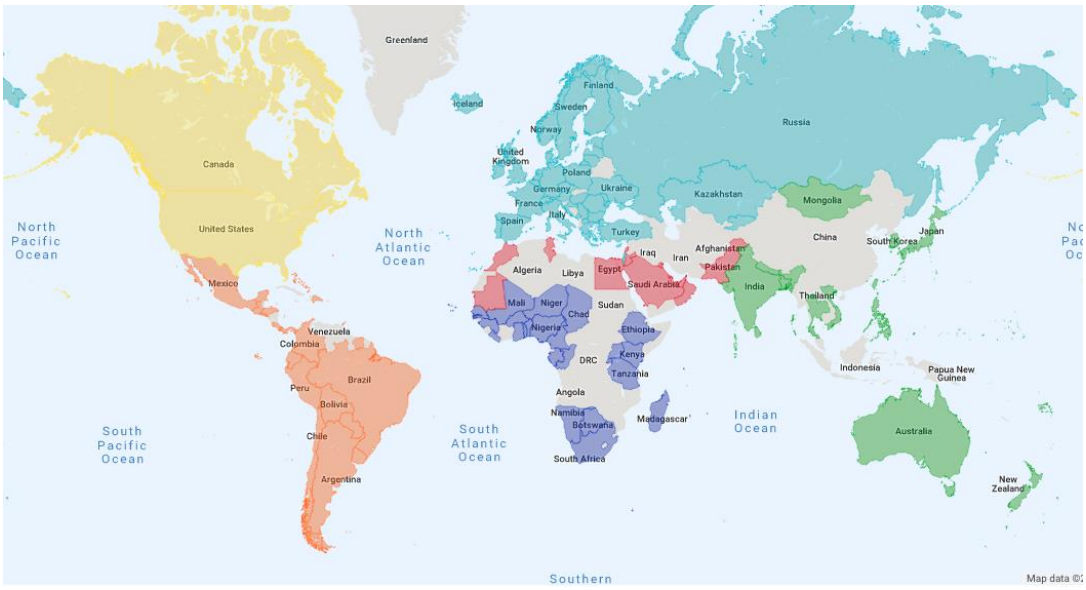


Figure 2. Participating GLOBE countries. Current as of May 2019. Source: GLOBE.

1.3 Data Set Variables and Metadata

Appendix 1 provides the lists of metadata associated with the GLOBE data. **Appendix 2** provides a list of GLOBE data variables that can be downloaded. The metadata list includes descriptions and units for each variable in the GLOBE data set. The variables correspond to the measurements recorded in the GLOBE database.

Each observation submitted to GLOBE can be identified spatially, temporally, and by unique identifiers associated with entities and individuals. Spatial and temporal resolutions vary depending on the requirement of a protocol.

2. Methods and Materials

There are more than 40 GLOBE science protocols (data collection methods) for collecting Earth observations. GLOBE protocols are grouped by subject matter: atmosphere, hydrosphere, biosphere, and pedosphere. **Table 1** provides a list of GLOBE science protocols. There is extensive documentation online about GLOBE science protocols. Trained GLOBE members are the intended audience for these protocols. GLOBE members can submit data five ways: desktop data entry forms, email data entry, application programming interfaces (APIs), the GLOBE data entry app, and the GLOBE Observer app. Ingest of data submitted via email lacks the ability to process images.

Citizen scientists can use the tools in the GLOBE Observer app to collect and submit observations of clouds, mosquito habitats, land cover, and tree height. (There are plans to add more protocols in the future to the Observer app.) Trained GLOBE members can, and many do, use the GLOBE Observer app too.

2.1 GLOBE Teacher Training

Training for GLOBE teachers has traditionally been accomplished at in-person workshops, which are offered around the world and teach the appropriate data collection procedures for various protocols. As of 2017, teachers can also be trained online (“eTraining”) using online modules. These modules can be used as a review for current GLOBE teachers, or as additional training during GLOBE workshops

The GLOBE Teacher’s Guide is a foundational resource for teachers training their students to collect measurements. It is also a useful resource for scientists who want to know more about the procedures for collecting GLOBE data. The GLOBE Teacher's Guide is an online collection of background information, science protocols (data collection procedures), and learning activities organized by Earth spheres: atmosphere, biosphere, hydrosphere, and pedosphere (soil). Protocols provide step-by-step instructions on how to gather measurements as well as guidance on instrumentation. Protocols are intended to be used as written, using instruments that meet certain specifications in order to ensure data accuracy worldwide. Participants should not submit data if it does not follow the protocol. Protocols include instructions for instrument

calibration. Instruments, as well as instrument suppliers, are available here: Scientific Instruments for Collecting GLOBE Data.

2.2 Protocols for trained GLOBE members

Table 1 provides a list of GLOBE science protocols for students grouped by Earth sphere. The links in the table will take you directly to the science protocol page in an internet browser window, which includes the science protocol of interest plus supporting protocols.

Table 1. GLOBE Science Protocols[1]

Atmosphere (10)		
Aerosols	Precipitation	Surface Temperature
Air temperature	Relative Humidity	Water Vapor
Barometric Pressure	Surface Ozone	
Clouds		
Hydrosphere (10)		
Alkalinity	Mosquitoes[2]	Salinity
Conductivity	Nitrates	Water Temperature
Dissolved Oxygen	pH	Water Transparency (Turbidity)
Freshwater Macroinvertebrates		
Biosphere (11)		
Biometry	Green Up	Phenological Gardens
Carbon Cycle	Land Cover	
Green Down (Senescence)	Lilac Phenology	
Pedosphere (Soil) (12)		
Bulk Density	Soil Infiltration	
	Soil Moisture - Gravimetric	Soil Particle Size Distribution
Soil Characterization	Soil Moisture - Sensors	Soil pH
Soil Fertility	Soil Moisture - SMAP	Soil Temperature

[1] Table only includes protocols for which data is publicly available through the GLOBE database.

[2] The Mosquito Habitat Mapper tool in the GLOBE Observer app is the GLOBE protocol for collecting and submitting mosquito measurements. The original GLOBE Mosquito Larvae protocol was retired in 2018. Students using the GLOBE Observer Mosquito Habitat Mapper are still encouraged to define a GLOBE Hydrosphere Study Site, as they did with the original Mosquito Larvae protocol, if they collect specimens in a natural water body, so that they can monitor other water quality parameters that may impact survival of immature mosquitoes.

2.3 GLOBE Observer Mobile App

In this section, we go into greater detail about the GLOBE Observer app. Tools in the Observer app (e.g., clouds, tree height) mimic the science protocols for trained GLOBE members (**Table 1**). Observations collected using the GLOBE Observer mobile app are intended to be completed using a smartphone or other mobile device (e.g., tablet) with a built-in camera. GLOBE Observer tools are designed to work offline so they can be used in remote regions, although a cellular or wifi network is needed to download the app and periodically upload data. Date, time, latitude, longitude, and elevation are logged automatically at the beginning of each new observation using the mobile device's clock and GPS. Tools in the GLOBE Observer app let users collect and report cloud, mosquito habitat, land cover, and tree height observations.

Photographs/Images

In the GLOBE Observer app, users have the option to take photographs with their device (e.g., smartphone, tablet) and send those images to GLOBE as part of their observation. For the cloud and land cover tools in the GLOBE Observer app, photos/images are taken in the four cardinal directions (north, south, east, west), as well as up and down to capture the overhead and surface conditions. North is the magnetic north pole (not the geographic north pole). Users can take these six photos in "automatic mode" or "manual mode". Automatic mode uses the device's internal compass and accelerometer and captures each photo when the user is in the correct orientation and pointed in the correct direction. Images captured in automatic mode are a standard size of 1920 pixels x 1080 pixels. Manually uploaded images are stored at the full mobile device resolution at which they were taken. For the mosquitoes protocol, images are captured and stored at their original photo resolution - no cropping or resizing is performed.

Images are stored in the app on the user's device until they are uploaded to GLOBE; images are deleted from the app after being sent to conserve memory on the user's device. Images taken with the user's device are stored as .jpg files.

Figure 3. Taking directional images with GLOBE Observer app. Image of a user making a cloud observation with the GLOBE Observer mobile app. The user is taking a south-facing sky photo in “automatic mode.” South is indicated by the “S” in the white circle on the smartphone’s display screen. In automatic mode, the smartphone must be held horizontally with screen lock turned off as demonstrated in the image. Image credit: Heather Mortimer, NASA.

2.3.1 GLOBE Observer Clouds

In 2016, GLOBE Observer launched with a single tool: GLOBE Observer Clouds. GLOBE Clouds is based on the predecessor Students’ Cloud Observations Online [Chambers et al., 2017]. In the GLOBE Observer app, users locate, photograph, and classify the cloud cover of the overhead sky. Each GLOBE Observer cloud observation contains information about the percent of sky covered by clouds, the presence of obscuration, and surface conditions (e.g., snow or ice on the ground). An obscuration occurs when more than 25% of the sky is obscured by either sand, smoke, haze, heavy snow, fog/stratus, spray, dust, blowing snow, heavy rain, or volcanic ash. Optional fields for cloud observations are: sky color; sky visibility; presence of low-, mid-, and high-level clouds and contrails; types of clouds and contrails; and visual opacity. Users are encouraged to conduct their observations in an outdoor area with a relatively unobstructed view of the sky. Users have the option to take photographs of the sky (north,

south, east, west, up) and surface conditions (down). The app guides users to align their smartphone cameras in the correct direction and tilted to a 14 degree angle, then automatically takes the photographs. GLOBE Observer Clouds requires no additional equipment beyond a smartphone. Required and optional elements of a clouds observation are below. Trained GLOBE members who log into GLOBE Observer with a GLOBE ID can also enter air temperature, relative humidity, and pressure.

Required elements of a clouds observation include total cloud cover or obscuration covering more than 25% of the sky; and surface conditions. Total cloud cover categories are: no clouds (0%), few (>0-105%), isolated (10-25%), scattered (25-50%), broken (50-90%), overcast (90-10%). Obscuration types include: sand, smoke, haze, heavy snow, fog/stratus, spray, dust, blowing snow, heavy rain, and volcanic ash. Surface conditions (yes/no) include: snow/ice, standing water, muddy, dry ground, leaves on trees, and raining/snowing.

Optional elements of a clouds observation include cloud types, opacity, sky color, and visibility. Observers qualitatively estimate cloud altitude by low, mid, and high and then identify cloud types for each level. High cloud types include: contrails, cirrus, cirrocumulus, and cirrostratus. Mid-level clouds include: altostratus, and altocumulus. Low clouds include: fog/stratus, stratocumulus, cumulus, nimbostratus, and cumulonimbus. Observers can report percent cloud cover for all clouds present at each level (low, mid, high). Observers can also report opacity for each altitude level and cloud type as opaque, transparent, or translucent. Observers also have the option to report the darkest blue observed in the sky and also qualitatively report sky visibility. Sky color categories are: deep blue, blue, light blue, pale blue, and milky. Sky visibility categories are: unusually clear, clear, somewhat hazy, very hazy, and extremely hazy.

The NASA GLOBE cloud team at Langley Research Center matches GLOBE Observer cloud observations to corresponding satellite data. Users can opt-in to receive notifications on their phone about satellite flyovers or use the satellite overpass tool available here. If a user's clouds observation is matched to satellite data, the user will receive a Satellite Match email from NASA within one week of submitting the observation (example). Observations are matched to multiple geostationary satellites, CERES instruments onboard Aqua and Terra, and CALIPSO (see GLOBE's satellite comparison page). Complete documentation of the satellite matching method is here.

More information about how to make cloud observations in the GLOBE Observer app is here. A toolkit for informal for educators is here.

2.3.2 GLOBE Observer Solar Eclipse

GLOBE Observer was modified to support the August 21, 2017 total solar eclipse, Eclipse Across America. In addition to the standard clouds data collection already available in the app, a special temporary tool allowing untrained users to report air temperature data was added for the eclipse. Observers were asked to acquire a meteorological thermometer, either a traditional

alcohol-filled glass model or a digital version, to measure temperature. The goal was to have observers measure the eclipse-induced temperature depression, which complemented temperature measurements from automated weather stations. Observers provided a nearly unbroken record of temperature measurements along the path of totality across the United States. This unique feature of the data would be difficult and expensive to replicate with automated stations. In addition to air temperature measurements, observers were encouraged to submit cloud observations periodically during the eclipse. Dodson et al. [2019] detail an analysis of GLOBE Observer cloud cover and surface temperature data reported during the 2017 eclipse. More information about the 2017 eclipse, including GLOBE data from the event, is here.

2.3.3 GLOBE Observer Mosquito Habitat Mapper

In May 2017, the Mosquito Habitat Mapper tool was added to the GLOBE Observer app. There are four steps that users can take when using the Mosquito Habitat Mapper - and it is important to note that users do not have to do all of the steps to make observations. The first step involves identifying potential mosquito breeding habitats and taking pictures of them. To do this, users simply walk around their home, school, or neighborhood and look for standing water sources - natural or artificial- where an adult mosquito might lay her eggs. For example, users might find discarded items such as cans or bottles, old tires, and water storage containers such as animal feeding bowls and bird baths. Taking a picture of these potential mosquito breeding habitats completes the first step. The app then prompts users to eliminate the standing water source or cover it with a lid or a net when possible, thereby reducing the risk of mosquito-transmitted diseases in the user's community.

After this there are two optional steps. The app guides users through these identification activities step-by-step. One is to sample and count the mosquito larvae that users find in the water source, and the other is to use a microscope or cell phone magnifier to identify the larva type (*Aedes, Anopheles*, and *Culex*). A user will need to use a lens with a 60x magnification or higher. The app is optimized for identification of *Aedes aegypti* and *Aedes albopictus,* two species implicated in transmission of pathogens causing a wide variety of diseases in humans, including dengue, chikungunya, yellow fever and Zika. These two species originated in tropical and humid subtropical regions worldwide and are now invasive in a variety of environments. The app also allows for identification of mosquitoes from the genus *Culex,* many species of which are implicated in a wide variety of diseases, including West Nile Virus. The app also enables the identification of *Anopheles*, the genus primarily responsible for transmission of malaria.

Tutorials, an instructional video, and additional training resources about Mosquito Habitat Mapper are available on the GLOBE Observer website. More information about how to make mosquito observations in the GLOBE Observer app is here. A toolkit for informal educators is here.

2.3.4 GLOBE Observer Land Cover

In October 2018, Land Cover was added to the GLOBE Observer app. Land cover has been a GLOBE student protocol since the 1990s [Larsen Becker et al., 1998]. In the GLOBE Observer app, participants locate, photograph, and classify land cover for a 100-meter x 100-meter area. Users photograph surface conditions and land cover in the up, down, east, west, north, and south directions. Date, time, elevation, latitude, and longitude are logged by the user's device. The app guides users to align their smartphone cameras in the correct direction, adjust to an angle that best captures the land cover, and captures the photographs. Users enter yes/no information about surface conditions (e.g., snow and ice on the ground), then have the option to classify the land cover types seen in each photo. Users classify land cover in each photo, so there may be a different land cover classification in an east-facing photo compared to a west-facing photo. Next, users have the option to estimate percent cover for each type of land cover selected for each photo. Percentages may add up to more than 100 percent, since vegetation has vertical structure. Lastly, GLOBE Observer users are asked to match their overall land cover classification to the MODIS land cover classification. If there is a difference between their classification and the MODIS classification, users may flag that pixel. Differences may occur because of land cover or land use change or because of the difference in scale between MODIS (500 meters) and GLOBE Observer (100 meters).

GLOBE Observer land cover classifications are based on the Modified UNESCO Classification (MUC) and the International Geosphere-Biosphere Programme (IGBP) Land Cover Type Classification used in the MODIS Land Cover Product. Historically, GLOBE has used the MUC system for land cover protocol. Remote sensing land cover classification products widely use IGBP, which distinguishes land cover by plant functional type rather than ecosystem type (e.g., evergreen broad leaf forest vs. tropical forest). Because GLOBE land cover was meant to be a source of verification for remote sensing scientists, the GLOBE Observer app combines IGBP and MUC. Users select land cover types in line with IGBP and then provide a small amount of additional information about plant height and density that makes it possible to map IGBP land cover classifications to the MUC system.

The land cover tool in the GLOBE Observer app differs from the student protocol primarily in the classification system. To make GLOBE Observer land cover compatible with the historic GLOBE land cover measurement data, the combination of all estimates in all directions is converted into a single MUC code for the observed 100-m x 100-m pixel. Students, teachers, and others doing the traditional GLOBE land cover protocol collect the latitude and longitude for the center of a 90-m x 90-m homogenous pixel. They then photograph the site facing north, south, east, and West and estimate the MUC land cover type. GLOBE members can change the calculated MUC code in the GLOBE Observer app.

More information about how to make land cover observations in the GLOBE Observer app is here. A toolkit for informal educators is here.

2.3.5 GLOBE Observer Trees

In March 2019, Trees was added to the GLOBE Observer app. Participants locate, measure the height of, and take a photograph of trees. Each GLOBE Observer tree height observation includes finding a tree or trees and taking tree height measurements using the smartphone cameras and the Trees tool built-in angle measuring, clinometer techniques. The user is asked his/her height, then the Trees tool estimates stride length (L) and height of phone camera (h_c) of the user:

$$L = 0.413 \times \textit{person's height}$$
$$h_c = \textit{user's height} - 10.14 \text{ cm}$$

The user will first choose a tree and find a spot that allows a clear view of the top and bottom of the tree. The app then guides the user to use their smartphones to align to the bottom of the tree and then to the top of the tree, calculating the respective angles. The user will then walk to the base of the tree, counting steps, and entering the number of steps into the app. The user is warned if the distance to the tree is large (> 50 steps) as large distances are prone to larger measurement errors. At the base of the tree, the user will record the latitude and longitude.

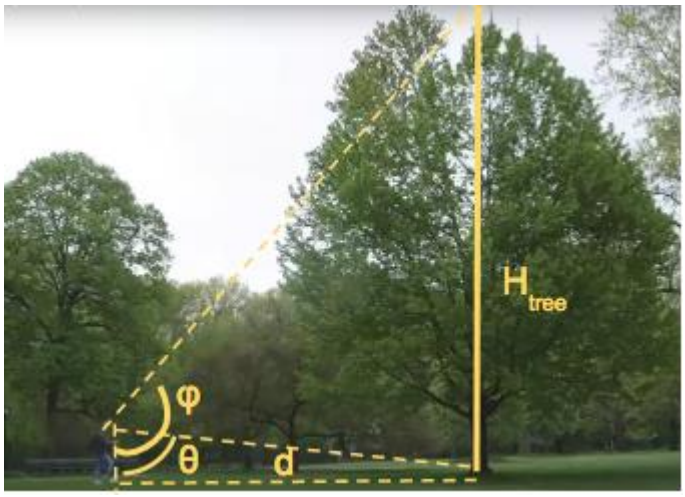


Figure 4. Geometry of tree height measurement. Schematic of tree height observation made using the Trees tool in the GLOBE Observer mobile app. 0 degrees is straight down, 90 degrees at the horizon, 180 degrees is straight up.

Tree height is computed as follows:

n : number of steps
L : stride length (meters)
h_c : camera height (meters)
H_{tree} : full tree height (meters)
h1 : upper tree height (meters)
h2 : lower tree height (meters)
α : app-measured top angle (degrees)
β : app-measured bottom angle (degrees)

$$\varphi = \text{radians}(90 - \beta)$$

$$\theta = \text{radians}(90 - \alpha)$$

$$\lambda = \arctan(h_c/(nL)) - \varphi$$

$$h_1 = \tan(\theta)$$

$$h_2 = \tan(\varphi)$$

$$d = nL\cos(\lambda)$$

$$H_{tree} = d(h_1 + h_2)$$

Based on user testing, the error in H_{tree} is most sensitive to the ability to accurately estimate the distance to the tree. This is directly related to the ability to estimate a user's stride length (L). This error can be mitigated by users validating the stride length the app automatically estimates for them. Most users are able to measure the top (α) and bottom (β) angles to a level of accuracy that results in relatively small H_{tree} error (2-3%) when users are less than 100 steps away from the tree base. If the user is a very large number of steps away from the tree, the angle measurement uncertainties begin to result in larger H_{tree} measurement error. The app warns users when they are more than 50 steps away.

Included in the app is an optional measurement of the tree circumference. A user needs a tape measure for measuring the circumference of the tree. Finally, before the user submits an observation, the user is asked to review and make any changes to the measurements. The user can review their measurements by clicking on the "My Map" button within the Trees tool. If they choose to change any of the app calculations, the data is flagged.

More information about how to make tree height observations in the GLOBE Observer app is here. A toolkit for informal educators is here.

Table 2. Required and optional trees fields

Required Observations[1]	Optional Observations
Surface conditions (yes/no) • snow/ice • standing water • muddy • dry ground • leaves on trees • raining/snowing	
Select a tree • move to a location where you can see its base and top • measure the base of the tree • measure the top of the tree • walk to the tree using a natural stride, counting steps	**Photograph your tree**
Review • camera height • stride length • number of steps • distance to tree	**Measure tree circumference (tape measure required)**

[1]Upon setting up the Trees tool in the GLOBE Observer app, users are required to (1) specify if they want to use English or metric measurements and (2) enter their height. Data is only stored in metric.

3. Quality Assurance

Training

GLOBE requires training to ensure quality and consistency in data collection. GLOBE users must complete the necessary training either by attending a GLOBE workshop or by completing online eTraining modules and assessment tests to enter data via the GLOBE desktop data entry forms or through the GLOBE data entry app. The user must complete three modules and take the corresponding assessment tests as follows to become a trained GLOBE user via eTraining,:

- Introduction to GLOBE
- Introduction to a Sphere (Atmosphere, Biosphere, Hydrosphere, or Pedosphere)
- Protocol Module (from the same sphere as the introduction module)

The user can enter data for any of the GLOBE protocols after complete a workshop or the required eTraining modules and assessments.

Best Practices Guides

In addition to training, written step-by-step instructions are given in the Teacher's Guide for each science protocol, providing rigorous guidance on best practices for making observations. The science protocols are intended to be used as written, using instruments that meet certain specifications in order to ensure data accuracy worldwide. A list of instruments, as well as instrument suppliers, are available here: Scientific Instruments for Collecting GLOBE Data.

Completeness
A measurement must contain all required elements before it can be submitted and stored in the GLOBE database.

Range and Logic Checks
Observations submitted to GLOBE must pass range and logic checks before the data are allowed in the database. For example, future time cannot be entered and minimum values cannot be greater than maximum values. Instant feedback is provided at the time of data entry to indicate if the value(s) pass checks and likewise will be stored in the GLOBE database. For example, the enforced maximum value for dark voltage in the aerosol protocol is 0.02. If a GLOBE participant tries to enter 0.03, she/he will get an error message and not be allowed to submit. The data entry form does not default to a value (e.g., 0.02) when an error message is triggered; a valid value must be entered by the participant in order to submit. Documentation on the range and logic checks is here**.**

Location Data
Location data has become more accurate over time. From 1995-2014, GLOBE members had two options to enter the latitude and longitude coordinates associated with their measurement site: (1) GPS or (2) other. Before 2014, teachers were encouraged at in-person GLOBE trainings to use Garmin or GeoTrack GPS devices. The "other" category includes techniques such as estimating latitude and longitude coordinates from a map. Not all techniques categorized as "other" are known. GLOBE requested five decimal places for all reported latitude and longitude coordinates to achieve high and consistent spatial accuracy. Four significant digits after the decimal place implies 100-meter accuracy; five digits implies 5-meter accuracy. After 2014, GPS is the standard for obtaining latitude and longitude coordinates.

In the GLOBE Observer app, a person's location is automatically located on a map. The Land Cover and Trees tools in the GLOBE Observer app have a button users can press to refresh their automatic GPS location to potentially improve the location accuracy. If users judge that their device places their location incorrectly as indicated by a red pin on the map, users have the option to manually adjust their location on map. If using the GLOBE data entry app, the measurement is associated with the user's GLOBE site's latitude and longitude.

Photo Approval
Photos submitted through the GLOBE Observer app are screened before being added to the public GLOBE database. Photos containing inappropriate content, faces, or personally identifiable information (e.g., automobile license plate numbers) are removed or blurred.

Known Issues

Protocol	Issue
All GLOBE	**Latency.** On average, GLOBE measurements are submitted one month after being taken. Latency is decreasing with increased uptake of the GLOBE Observer app.
All GLOBE, 2013 and earlier	**Timestamp.** In 2012 and 2013, the GLOBE database migrated from an Oracle to a Postgres system. As a result, most all measurements in the database were assigned “created at” timestamps relevant to the date of migration versus the date of original measurement. In the GLOBE database, GLOBE measurements are each associated with three timestamps: “measured at” (aka “measured on” when temporal resolution is just to the day), “created at”, and “updated at”. The “measured” timestamps records when the measurement was observed and is the timestamp relevant for research. The “created” timestamp indicates when a record of the measurement was created in the GLOBE database and “updated” indicates when the measurement was last updated in the GLOBE database for various reasons. The “measured at” timestamp was not impacted by the Oracle-to-Postgres migration.

4. Applications and Terms of Use

Terms of Use

GLOBE promotes full and open sharing of its data for educational and scientific purposes. Use of data should be crediting to the GLOBE Program (see 1.1 Citation for GLOBE Data)

Any downloading and use of these data signifies a user's agreement to comprehension and compliance of the NASA Earth Science Data & Information Policy.

Ensure all portions of metadata are read and clearly understood before using these data in order to protect both user and NASA interests. **GLOBE data users are strongly encouraged to read and understand the science protocol(s) relevant to your data of interest (see Methods and Materials).**

Applications

Appropriate applications of GLOBE data may include, but are not limited to, community engagement, STEM education, student research, citizen science investigations, and scientific research in Earth, social, and biological and health sciences.

Browse the GLOBE Publications page to see previous applications of GLOBE data.

NOTICE
If you publish a peer-reviewed article with GLOBE data, please credit the program and let us know so we can advertise your work on the GLOBE Publications page. Send the citation for your published article to help@globe.gov.

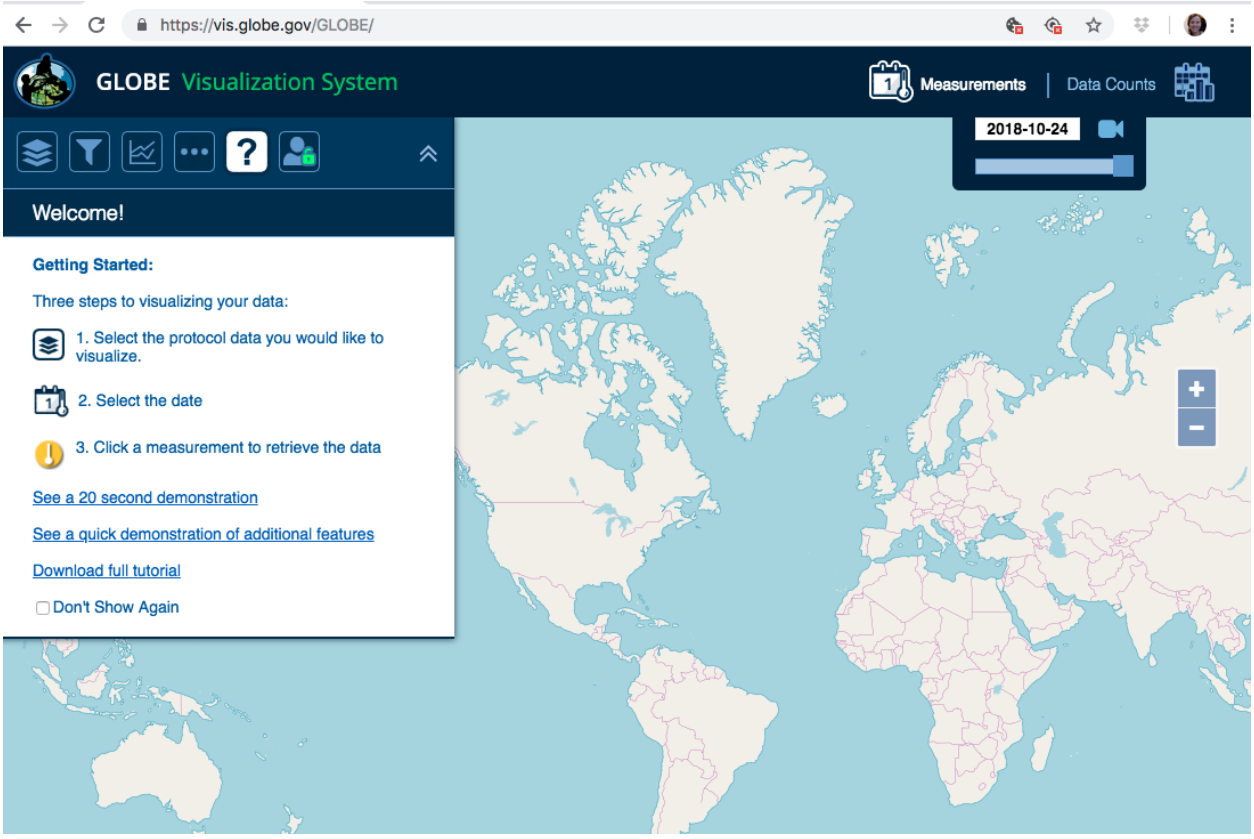
5. Data Visualization

GLOBE data can be viewed on a map in your web browser using the GLOBE Visualization System. A tutorial on how to use the GLOBE Visualization System is already embedded in the mapping tool and appears when users visit the site. This PowerPoint tutorial includes additional instruction. A brief example of how to view data using the GLOBE Visualization System is below.

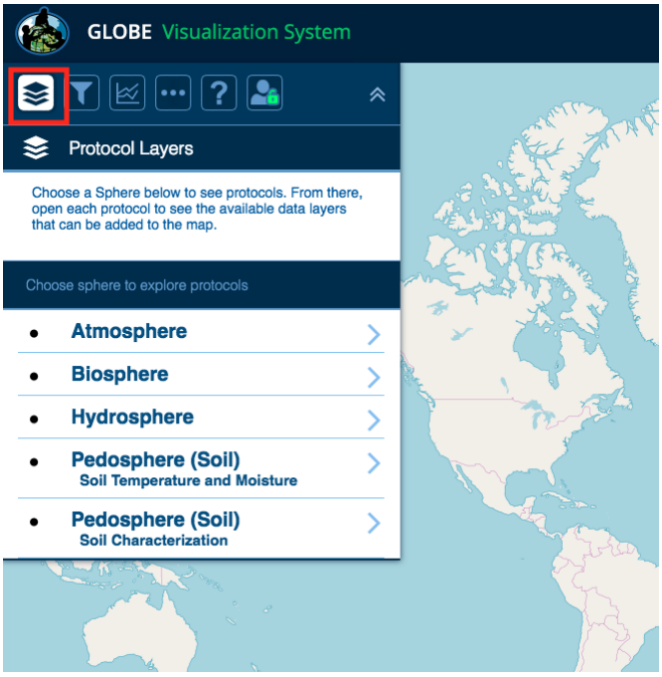
Quick links
See cloud cover on a map.
See land cover photos on a map.
See mosquito habitats on a map.
See tree heights on a map.

Example: View 2017-2018 cloud cover data on a map with the GLOBE Visualization System

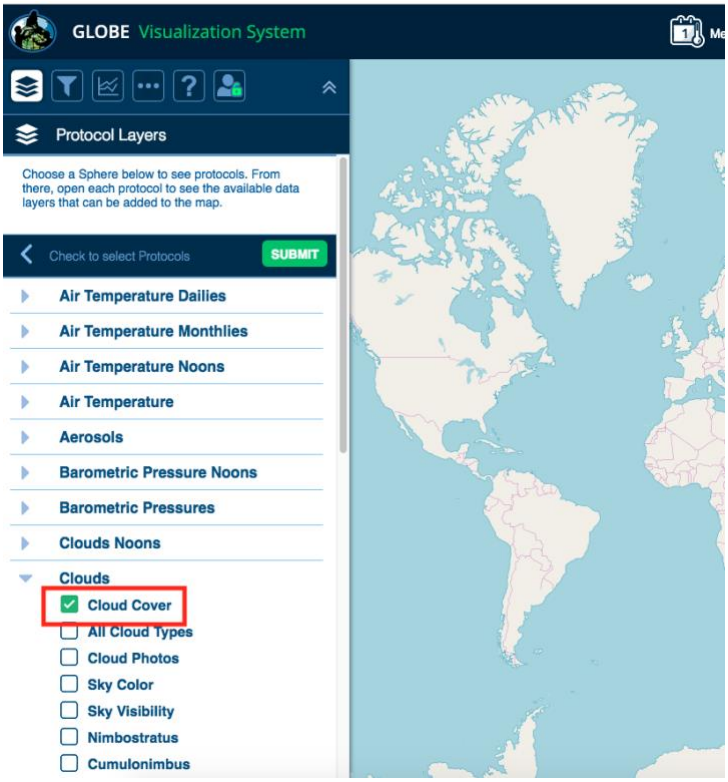
Step 1: Go to https://vis.globe.gov/GLOBE/. Here's the landing page.



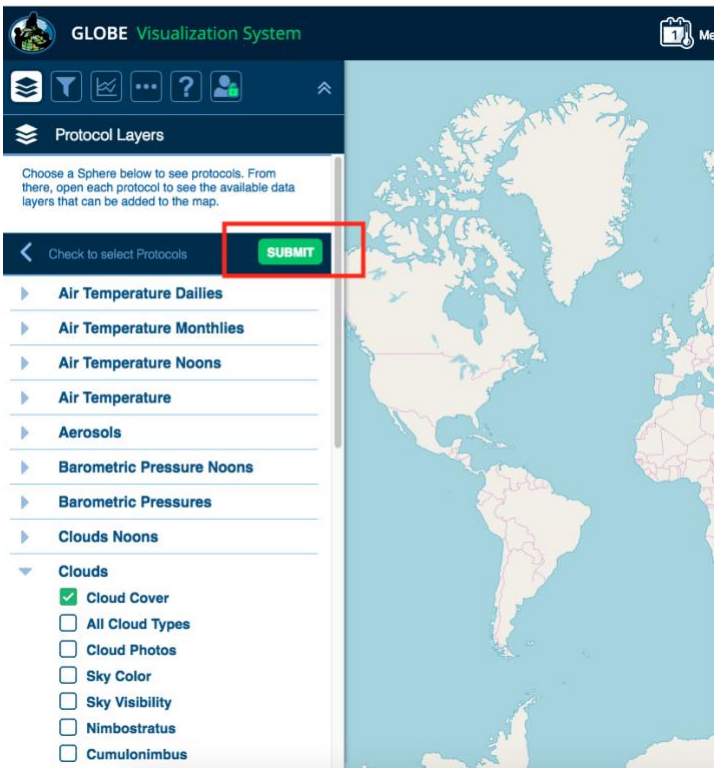
Step 2: Select layers



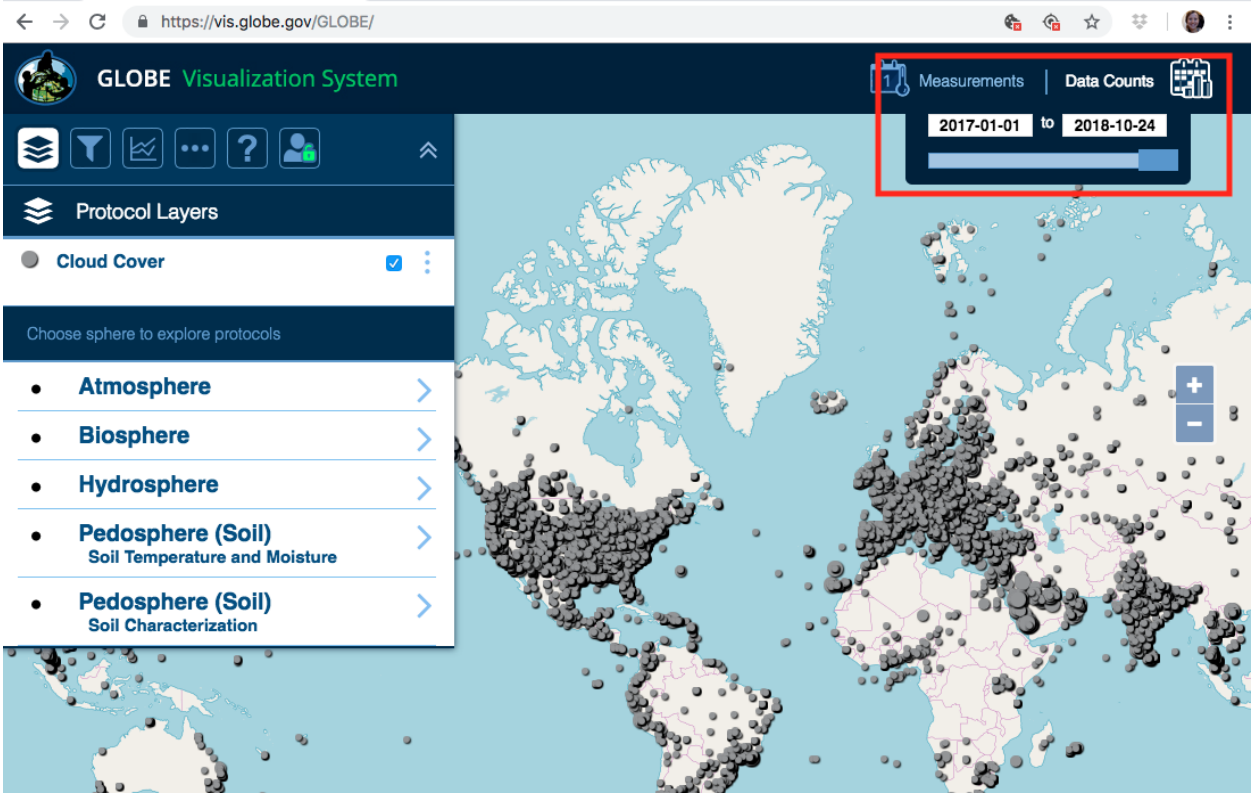
Step 3: Select Atmosphere >> Clouds >> Cloud Cover



Step 4: Click “Submit”

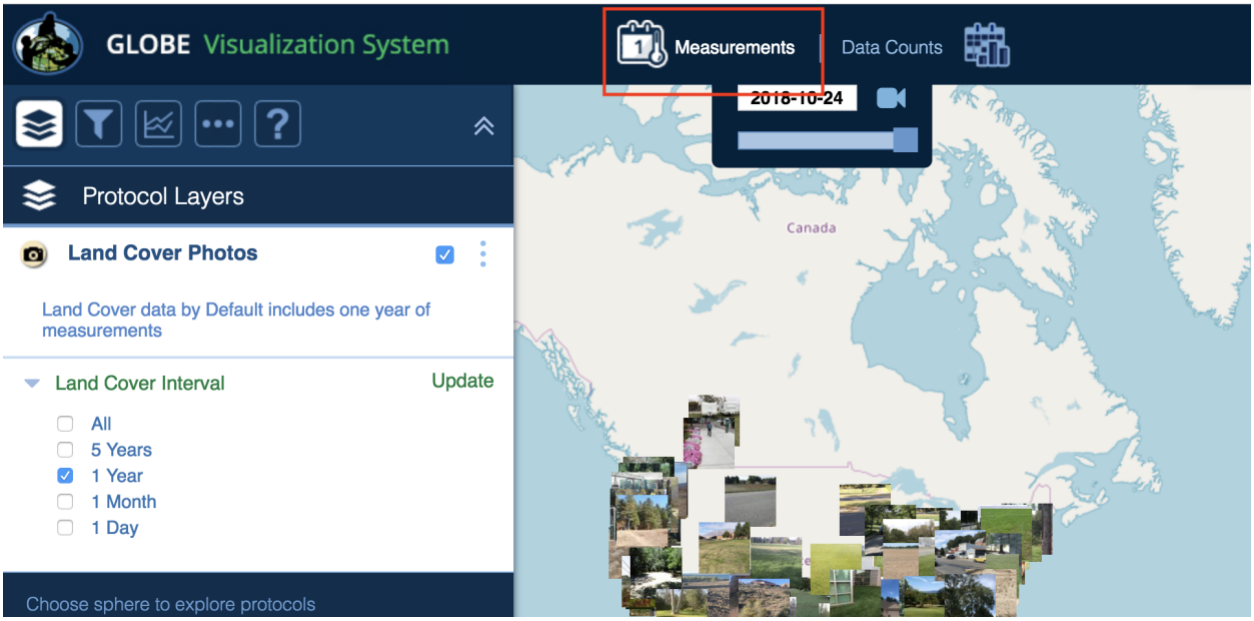


Step 5: Go to “Data Counts” and enter 1 January 2017 as the start date. In this case I left the end date as the present day (24 October 2018). Cloud cover data will appear on the map.



Note: Data Counts displays the total number of observations at that site for the period requested. If you click on the point to see the graph, the graph shows the total number per month and defaults to a 5-year period. In other words, if there were 10 observations per month for a year at a specific school site, and you chose a six month period within that year, you would see a dot indicating (6x10) = 60 measurements during that period. If you clicked on the dot, you would see 10 dots per month on the chart for a period of 5 years with the most recent date having the most recent data in the date range you selected.

To see images on a map, you need to have “Measurements” selected.



6. Data and Photo Access

This section describes how to access GLOBE data. **GLOBE data users are strongly encouraged to read and understand the science protocol(s) relevant to your data of interest (see Materials and Methods).**

File format:
If using the GLOBE Advanced Data Access Tool (ADAT) or Visualization System (Vis), then data are downloaded in tabular format as a csv (comma separated values) file. If using the API-out, then data are returned as JSON (JavaScript Object Notation) or GeoJSON file.

Photo file format:
Photos are downloaded as JPG format.

Photo file naming convention:
orignial.jpg (Current naming)

New naming convention coming in 2019:
protocol_latlon_yyyymmddTHHMMZ_direction_photoid.jpg

Table 4. Elements of the photo file name

Attribute	Description	Options
protocol	GLOBE protocol with which the photo is associated	CLD : clouds LC : land cover MHM : mosquito habitat mapper SDA : atmosphere site description SDB : biosphere site description SDH : hydrosphere site description SDS : soil site description TH : tree height
latlon	Latitude and longitude of the site the measurement is associated with. Direction indicated by N (north), S (south), E (east), W (west). Latitude and longitude values are positive three-digit integers.	latitude range = [N090,S090] longitude range = [W180,E180]
yyyymmddTHHMMZ	Date and time of measurement in Coordinated Universal Time (UTC). When the photo represents a site (i.e., SDA, SDB, SDH, SDS), this datetime represents when the photo was added to the site definition.	yyyy : four-digit year mm : two-digit month range = [01,12] dd : two-digit day range = [01,31] HH : two-digit hour range = [00,23] MM : two-digit minute range = [00,59]
direction	Direction photo was taken. For Mosquito Habitat Mapper, photos are not taken in a specific direction. The *direction* attribute instead indicates if the photo is a water source or mosquito body part.	Direction: NORTH SOUTH EAST WEST UP DOWN For Mosquito Habitat Mapper, WS : watersource FB : fullybody AB : abdomen Multiple images are differentiated by a number. “1” is always left off the first photo. Example: FB; FB2
photoid	Unique integer number assigned to each photo	

Examples:

South-facing cloud photo from Maryland
GLOBECLD_N038W076_20190110T1132Z_SOUTH_834887.jpg

Downward land cover photo from Oregon
GLOBELC_N044W123_20190110T1132Z_DOWN_917653.jpg

Photos of the mosquito's water source for their breeding habitat, and two photos of the abdominal segment of a mosquito larva from South Africa
GLOBEMHM_S034E022_20190110T1132Z_WS_928202.jpg
GLOBEMHM_S034E022_20190110T1132Z_AB_928203.jpg
GLOBEMHM_S034E022_20190110T1132Z_AB2_928204.jpg

6.1 Accessing tabular data (includes photos) through ADAT

Tabular data, including URL links to photos, can be accessed through either the GLOBE Advanced Data Access Tool (ADAT) or the GLOBE Visualization System (Vis). The Vis system is preferred for viewing data on a map and then optionally exporting data for a specific school, or exporting the data on the map layer. In general, use Vis to answer a question like "where was protocol x data submitted on this day", or "in this time frame, which sites were the most active" (data counts), or "Plot the last year's worth of temperature data from this school". ADAT is preferred for exporting data across protocols, dates and optionally other filters. Use ADAT to answer a question like "I need all the Aerosol and Temperature data recorded for this 3 year period in the United States and Canada", or "I need all barometric pressure measurements for the last 15 years world wide". Note ADAT returns data for a maximum of five protocols.

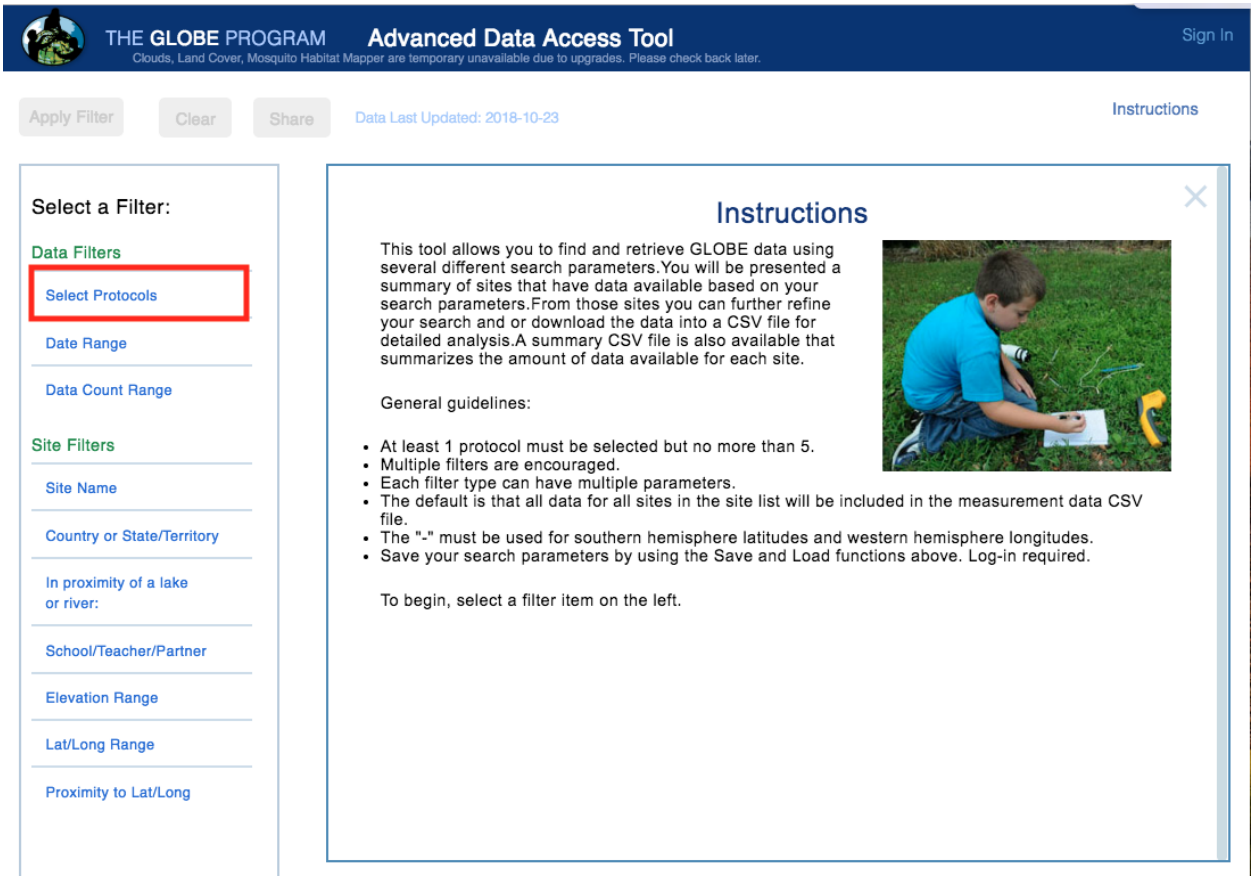
Simplified instructions for how to use the visualization system and ADAT are available when you launch the tool. A more detailed tutorial is available on the GLOBE website. This PowerPoint tutorial includes additional instruction.

For illustrative purposes, two examples are below of how to query GLOBE data using ADAT.

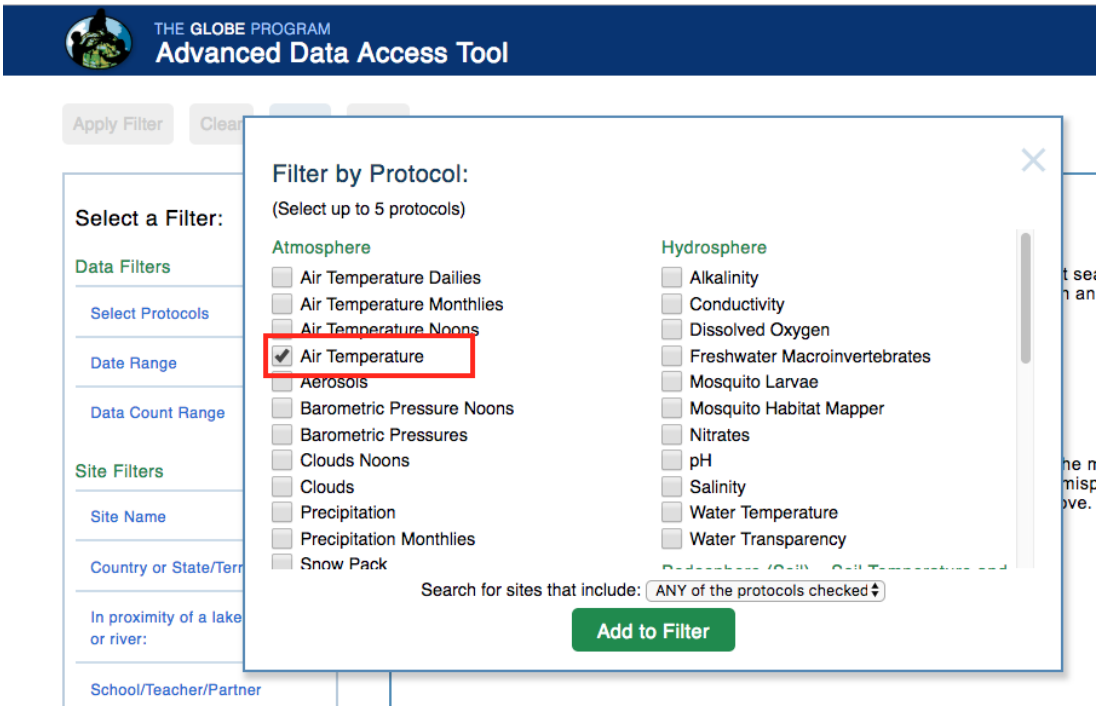
Example: Via ADAT, download GLOBE air temperature data from California for 2017-2018

Step 1: Go to https://datasearch.globe.gov

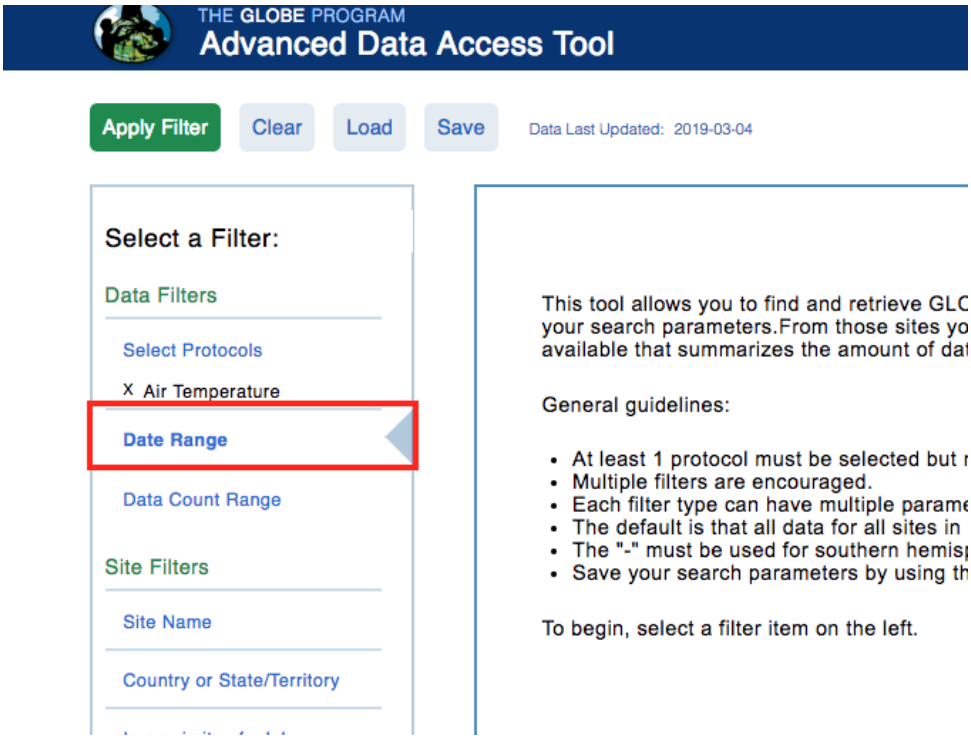
Step 2: In the bar on the left, Select Filters >> Data Filters>> Select Protocols



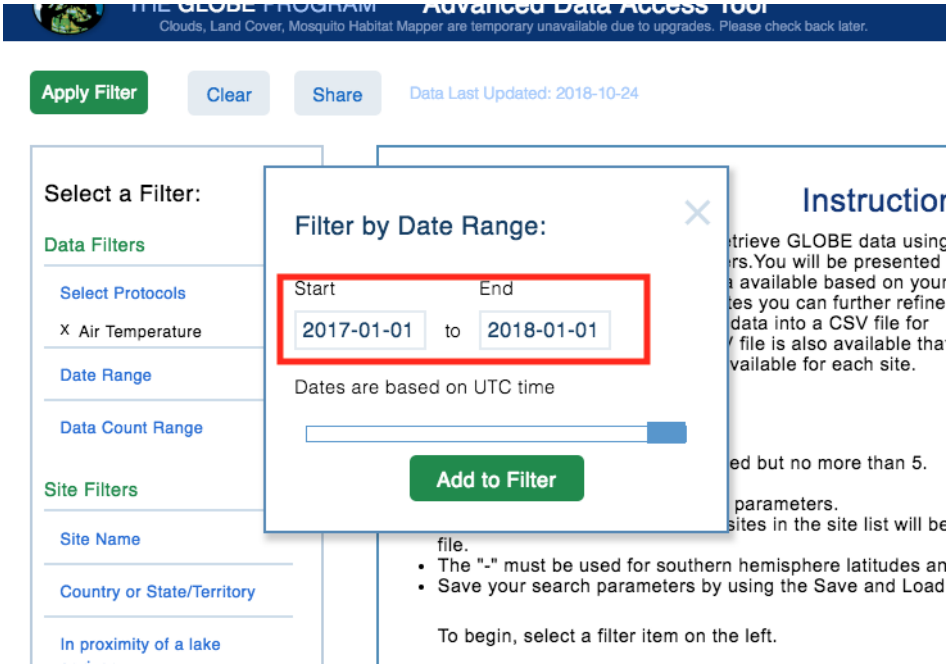
Step 3: Select air temperature. Click “Add to Filter”



Step 4: Select Date Range

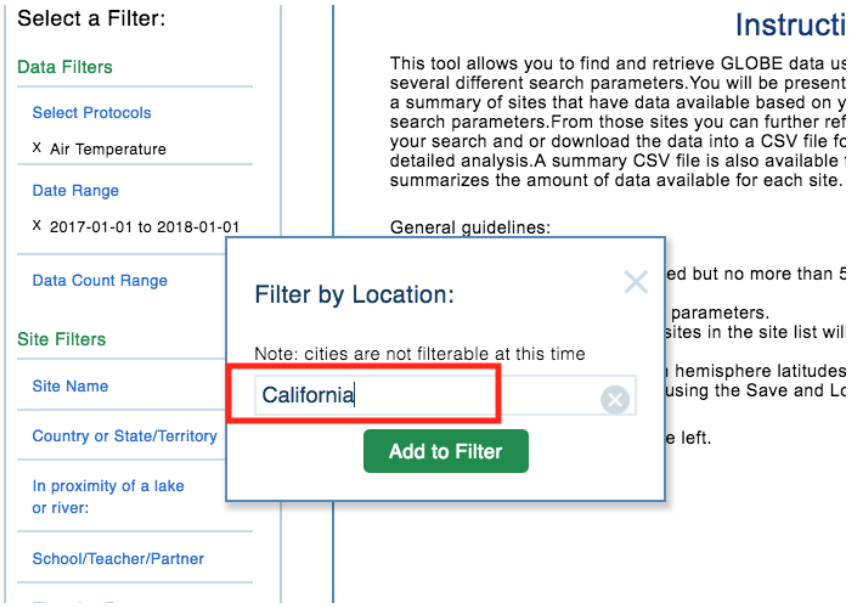


Step 5: Enter 1 January 2017 as the Start Date and 1 January 2018 as the End Date. Click “Add to Filter” when done.

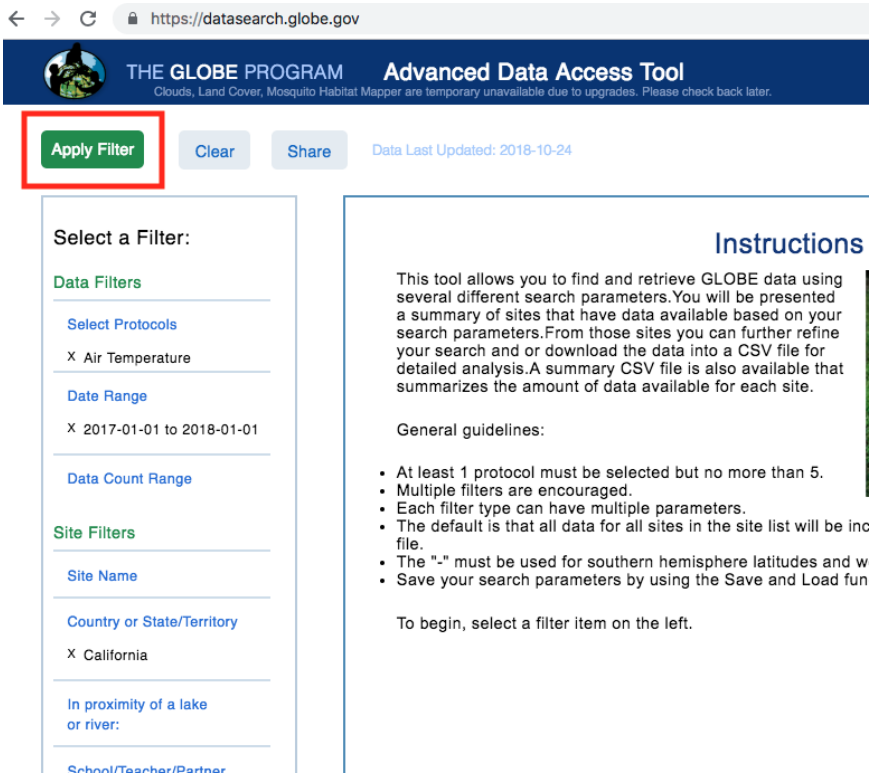


Step 6: Select Country or State/Territory

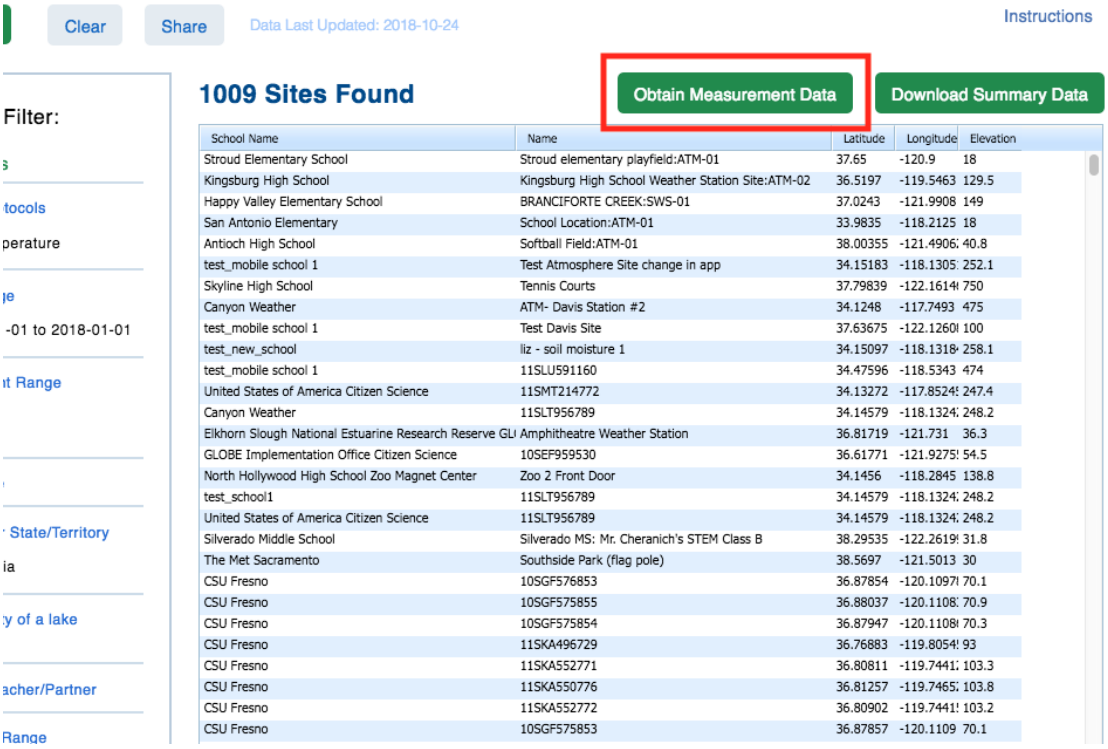
Step 7: Enter “California” and click “Add to Filter”



Step 8: Click “Apply Filter” to query your data selection.

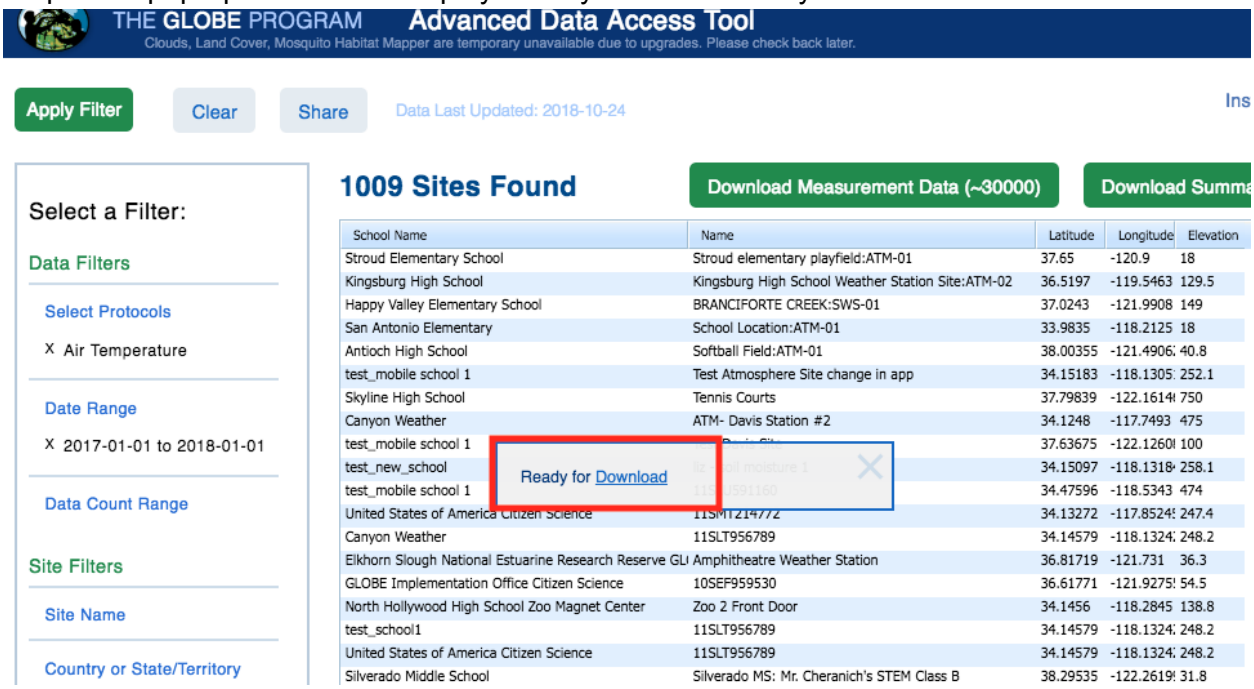


Step 9: Click on “Obtain Measurement Data” to download air temperature data to a csv file.



Step 10: Click “Download Measurement Data”

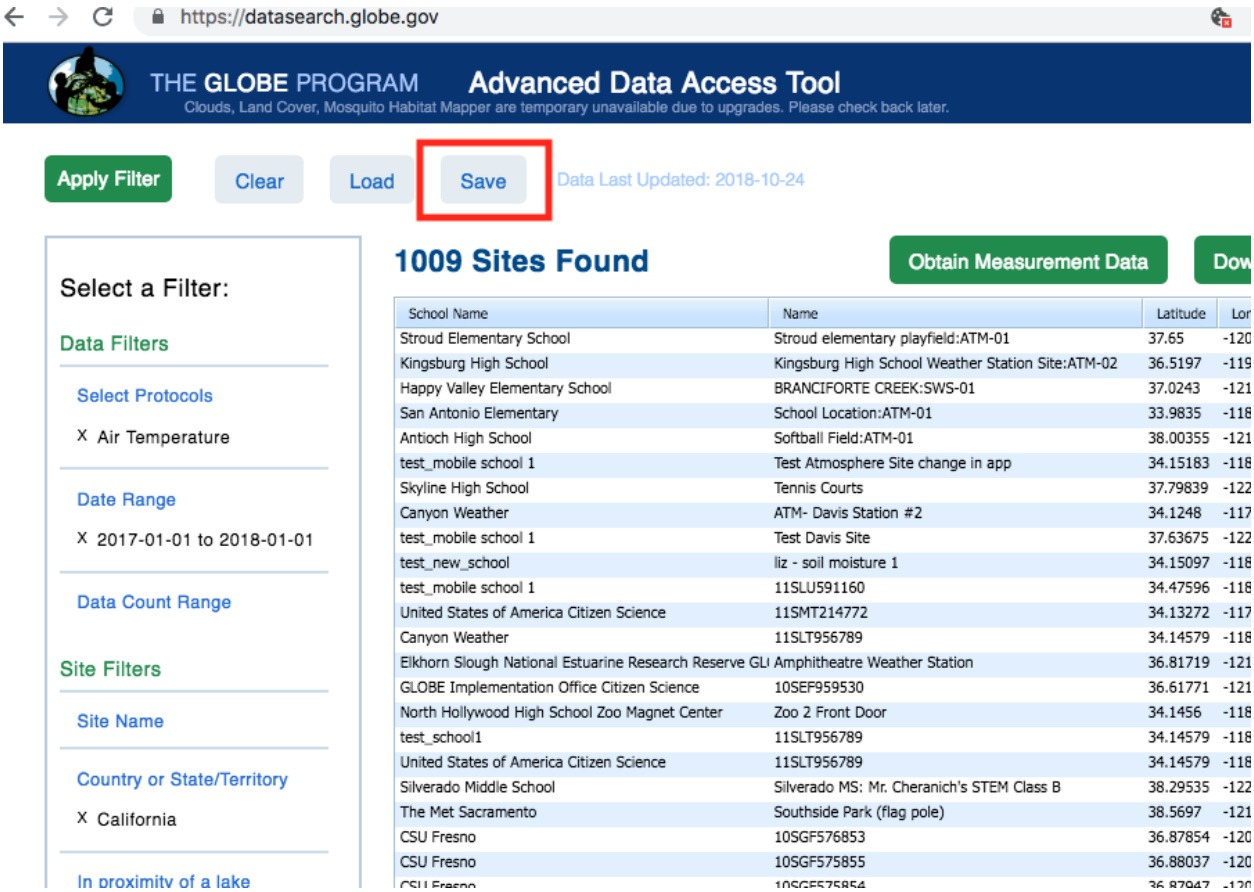
Step 11: A pop-up window will display when your data is ready. Click “download’.



The data will be downloaded as a compressed (*.zip) file. Unzip the file to retrieve the tabular csv data file.

Tip #1: ADAT limits downloads to 1,000,000 rows of data. This may mean having to download large data sets, such as air temperature, in batches.

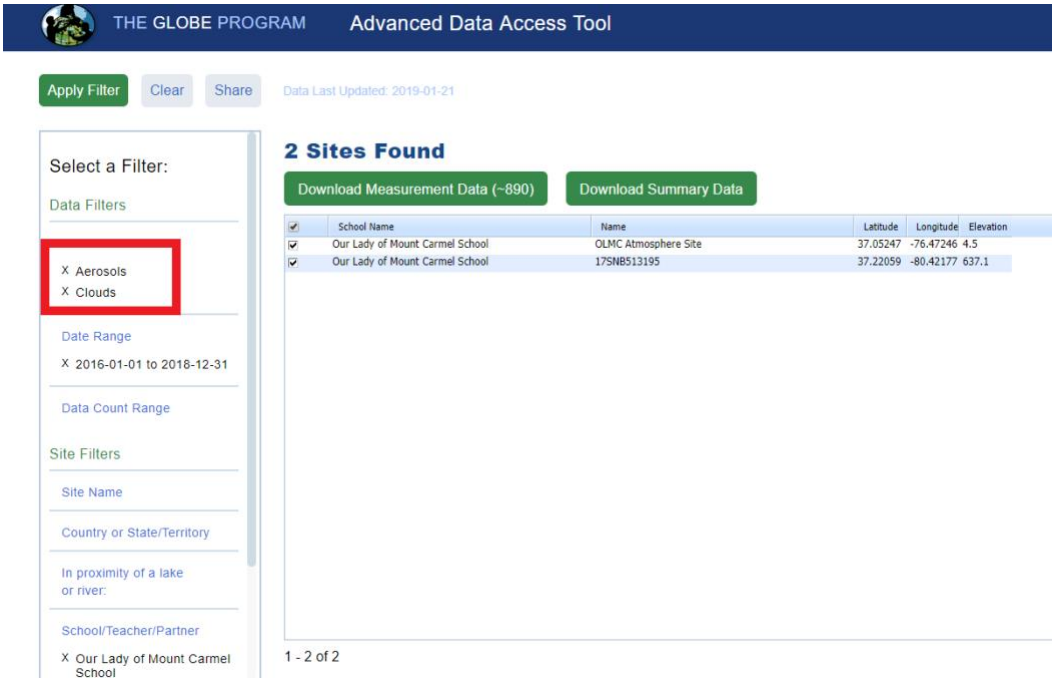
Tip #2: If you have a GLOBE account and are logged in, you can save your search filters. This comes in handy when you want to repeat a search in the future, share your search filters with someone else, or contact help@globe.gov for help troubleshooting ADAT. You can sign up for a GLOBE account on www.globe.gov


https://datasearch.globe.gov
THE GLOBE PROGRAM
Advanced Data Access Tool
Clouds, Land Cover, Mosquito Habitat Mapper are temporary unavailable due to upgrades. Please check back later.
Apply Filter
Clear
Load
Save
Data Last Updated: 2018-10-24
Select a Filter:
Data Filters
Select Protocols
X Air Temperature
Date Range
X 2017-01-01 to 2018-01-01
Data Count Range
Site Filters
Site Name
Country or State/Territory
X California
In proximity of a lake
1009 Sites Found
Obtain Measurement Data
Dow
School Name
Name
Latitude
Lor
Stroud Elementary School
Stroud elementary playfield:ATM-01
37.65
-120
Kingsburg High School
Kingsburg High School Weather Station Site:ATM-02
36.5197
-119
Happy Valley Elementary School
BRANCIFORTE CREEK:SWS-01
37.0243
-121
San Antonio Elementary
School Location:ATM-01
33.9835
-118
Antioch High School
Softball Field:ATM-01
38.00355
-121
test_mobile school 1
Test Atmosphere Site change in app
34.15183
-118
Skyline High School
Tennis Courts
37.79839
-122
Canyon Weather
ATM- Davis Station #2
34.1248
-117
test_mobile school 1
Test Davis Site
37.63675
-122
test_new_school
liz - soil moisture 1
34.15097
-118
test_mobile school 1
11SLU591160
34.47596
-118
United States of America Citizen Science
11SMT214772
34.13272
-117
Canyon Weather
11SLT956789
34.14579
-118
Elkhorn Slough National Estuarine Research Reserve GL
Amphitheatre Weather Station
36.81719
-121
GLOBE Implementation Office Citizen Science
10SEF959530
36.61771
-121
North Hollywood High School Zoo Magnet Center
Zoo 2 Front Door
34.1456
-118
test_school1
11SLT956789
34.14579
-118
United States of America Citizen Science
11SLT956789
34.14579
-118
Silverado Middle School
Silverado MS: Mr. Cheranich's STEM Class B
38.29535
-122
The Met Sacramento
Southside Park (flag pole)
38.5697
-121
CSU Fresno
10SGF576853
36.87854
-120
CSU Fresno
10SGF575855
36.88037
-120

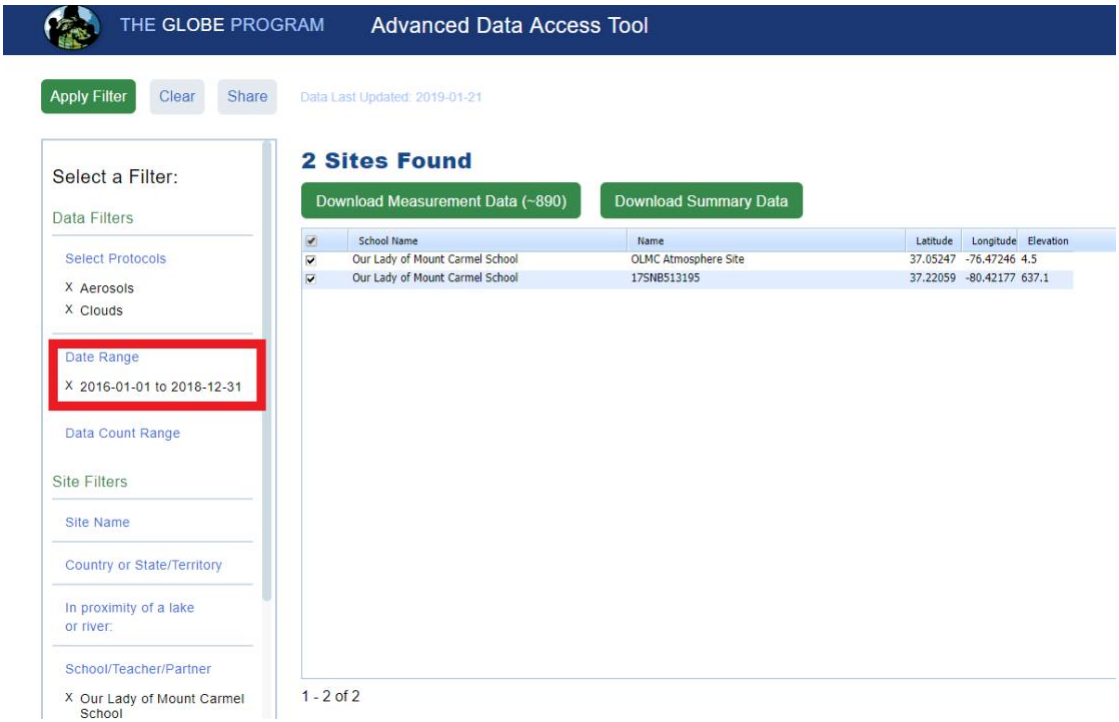
Example: Via ADAT, download GLOBE aerosol and cloud data from a particular school for 2016-2018

Some GLOBE protocols are performed together, such as the cloud and aerosol protocols for GLOBE-trained students. If a user wants aerosol data, cloud data does not automatically download at the same time. In ADAT, users must explicitly search for the data sets associated with different protocols, even if those protocols were collected together. Here is an example of a query for cloud and aerosol protocols collected together at Our Lady of Mount Carmel School, Virginia, USA.

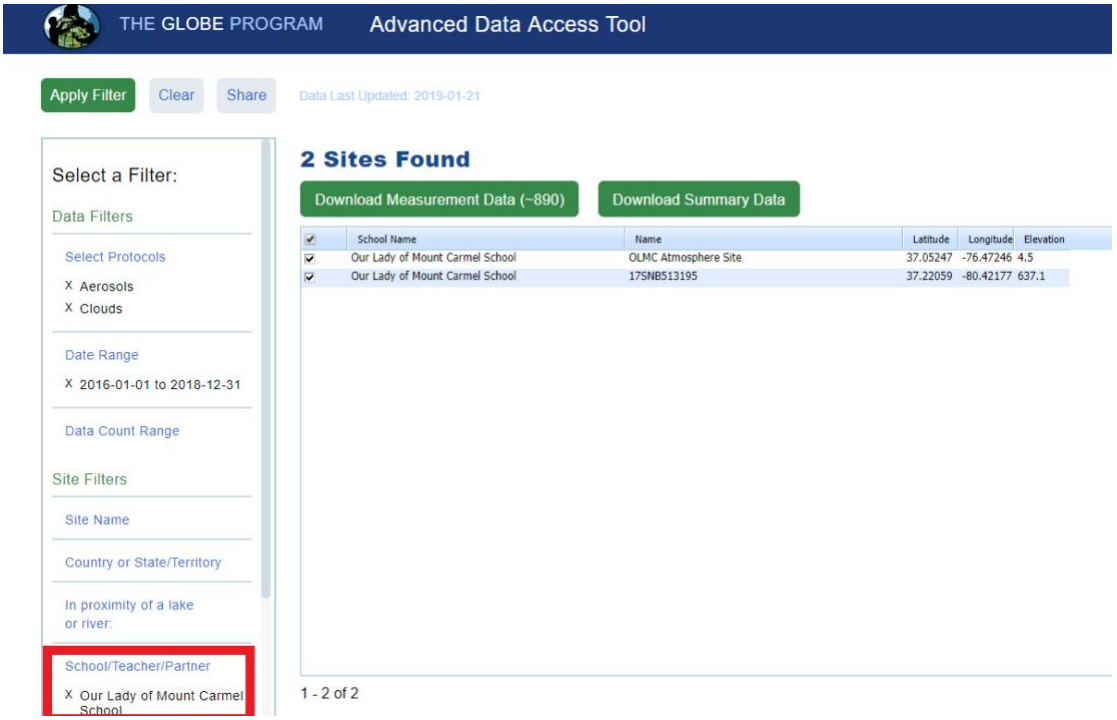
Step 1: Select “aerosols” and “clouds”.



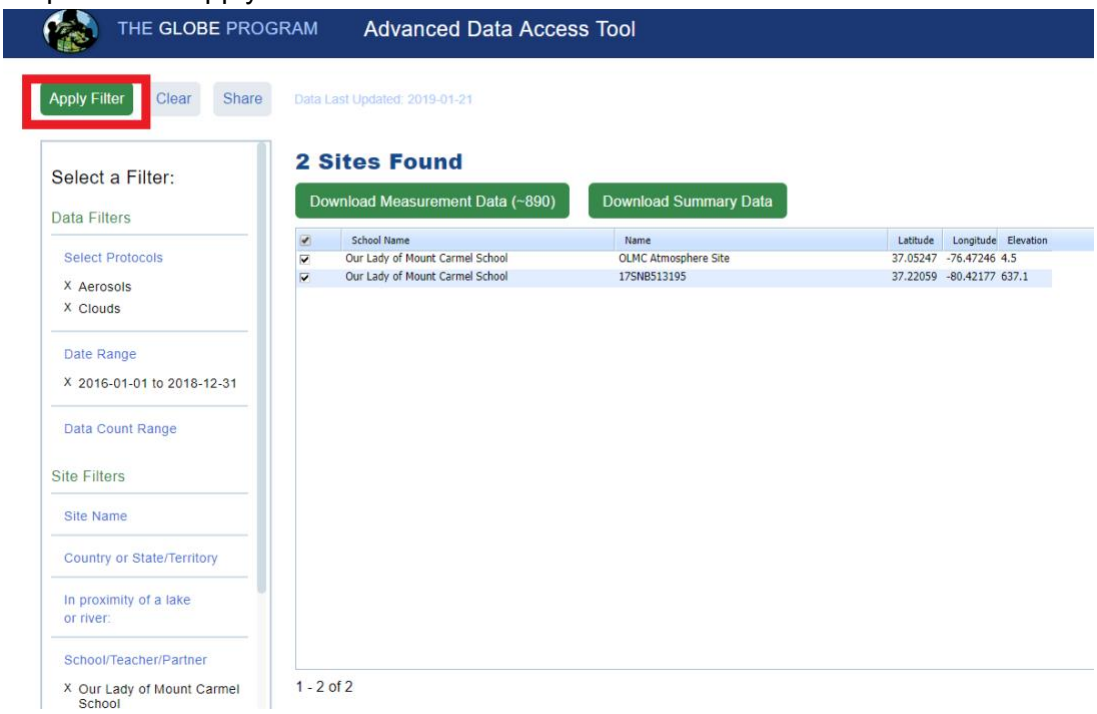
Step 2: Select desired date range.



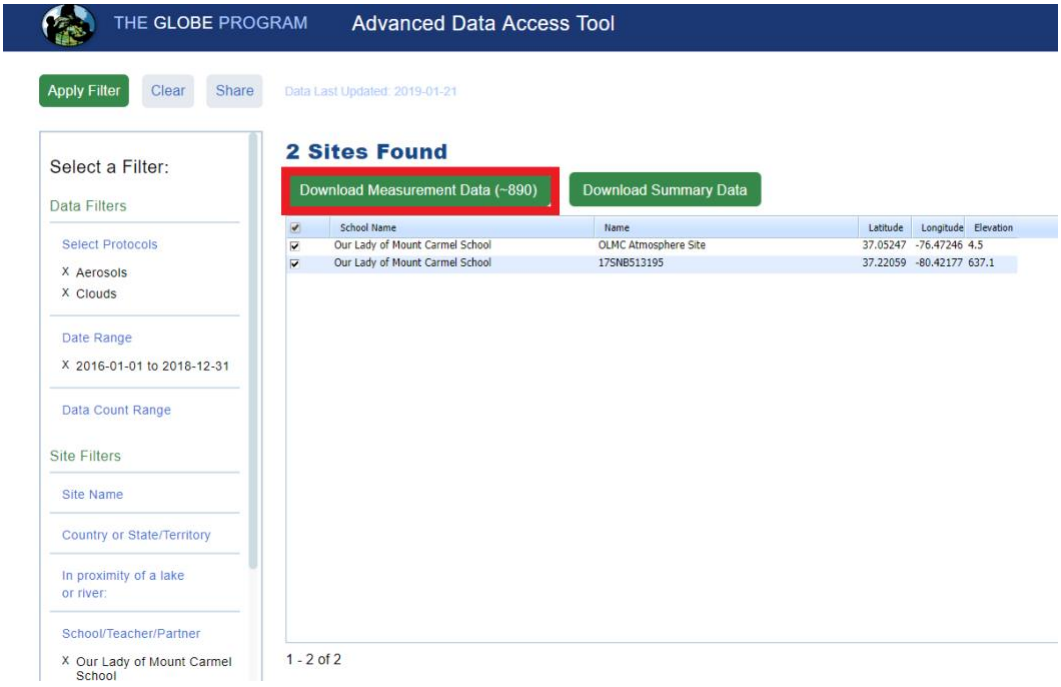
Step 3: Select desired GLOBE school. In this example, we want Our Lady of Mount Carmel School.



Step 4: Click “Apply Filter”



Step 5: Click “Download Measurement Data”



6.2 Accessing data through the API

In 2019, GLOBE developed an API-out tool. The API-out expands the options available to end users to query and retrieve GLOBE data. The API-out is provided in addition to GLOBE's existing methods for querying and retrieving data: ADAT and Vis. While ADAT and Vis are built more for general audiences, programmers and developers are the intended end user of the API-out tool. The API out uses the open-source Swagger UI for visually constructing and testing database queries and uses Elasticsearch to perform database queries. The API-out overcomes key limitations of ADAT and Vis by providing end users a way to retrieve large batches of GLOBE data and automate data retrieval (e.g., write code to automatically retrieve new GLOBE observations every day). The API-out tool also offers a significant speed-up in query time. Appendix 1 lists the metadata returned through the API that is provided for each recorded measurement.

6.3 Example Data

Want to get started with GLOBE data? Here is an example dataset to explore:

North American Solar Eclipse, August 21, 2017. Data are available in csv and xlsx (Excel) format.

Report Issues in the Data

Users are encouraged to report errors or inconsistencies they discover in GLOBE data. Please report issues to help@globe.gov and include the following information in your email:

- Your name
- Your organization
- Brief description of how you are using GLOBE data
- Date (approximate) issue was discovered
- Description of the issue

Acknowledgements

GLOBE is sponsored by the U.S. National Aeronautics and Space Administration (NASA) with support from the National Science Foundation (NSF), National Oceanic and Atmospheric Administration (NOAA) and Department of State.

References

Larsen Becker, M., R. G. Congalton, R. Budd, A. Fried, 1998: A GLOBE Collaboration to Develop Land Cover Data Collection and Analysis Protocols. *J Sci Edu & Technol*, 7(1), 85-96, https://doi.org/10.1175/BAMS-D-15-00248.1

Chambers, L.H., M.A. McKeown, S.A. McCrea, A.M. Martin, T.M. Rogerson, and K.M. Bedka, 2017: CERES S'COOL Project Update: The Evolution and Value of a Long-Running Education Project with a Foundation in NASA Earth Science Missions. *Bull. Amer. Meteor. Soc.*, 98, 473–483, doi: 10.1175/BAMS-D-15-00248.1.

Dodson, J. B., M. Colón Robles, J. E. Taylor, C. C. DeFontes, and K. L. Weaver, 2019: Eclipse Across America: Citizen Science Observations of the 21 August 2017 Total Solar Eclipse. Submitted to *J. Appl. Meteor. Climatol*., in review.

Appendix 1. API Metadata

Metadata returned through the API that is provided for each recorded measurement. The example below is for an air temperature measurement from the GLOBE aerosol protocol.

Definition	Example - Aerosol measurement
Protocol Information	
protocol	ait_temps
pid	68887527
Measurement Information	
measuredDate (UTC, yyyy-mm-ddTHH:MM:SSZ)	2018-10-10 Note: measuredDate is the relevant datetime information for users
createDate (UTC, yyyy-mm-ddTHH:MM:SSZ)	2018-10-10T15:06:00
updateDate (UTC, yyyy-mm-ddTHH:MM:SSZ)	2018-10-10T15:06:00
publishDate (UTC, yyyy-mm-ddTHH:MM:SSZ)	2018-10-11T08:13:00
latitude (degrees north)	45.1245
longitude (degrees east)	-117.4832
elevation (meters above sea level)	512

countryCode[1]	USA
countryName	united-states
User Information	
userID	1529487
organizationName	Littleton Middle School
organizationID	25765
siteName	Weather Station:ATM-01
siteId	23092

[1] Country and State/Region associated with the location of the measurement, *not* the organization to which the user belongs.

Appendix 2. Data Variables, Units, and Definitions

The list below provides units and definitions of the GLOBE data variables users can download through ADAT. Universal metadata variables are provided at the top, then measurement-level variables are provided in alphabetical order by protocol thereafter.

Variable	Units	Definition
Metadata variables		
obs_id		An identification code referencing the observation
org_name		The name of the reporting school or other institution. *Guidance: org_name should not include commas (,).* ● *Good: "Smith Company LLC"* ● *Bad: "Smith Company, LLC"*
site_name		The name assigned to the site where the data were collected; the name is selected by the reporting person as part of site definition. Guidance: org_name should not include commas (,). ● Good: "CacheCreek123" ● Bad: "CacheCreek, 123" Note: There are two ways a site name is generated. (1) GLOBE schools create their own site_name. (2) The GLOBE Observer app, on the other hand, automatically assigns a site_name to an observation; the site_name is not created by the user. The GLOBE Observer app generates a site_name based on the MGRS grid. This gives a brief overview of MGRS.
userid		An identification code referencing the observer of the data
latitude	decimal degrees north	The latitude of the site where data were observed. Range: [-90, 90]
longitude	decimal degrees east	The longitude of the site where date were observed. Range: [-180, 180]

elevation	meters above sea level	The elevation of the site where data were observed
measured_on	dd/mm/yyyy	The date only of when the data were observed in UTC
measured_at	yyyy-mm-ddTHH:MM	The date and time when the data were observed in UTC
solar measured at:	yyyy-mm-ddTHH:MM	The date and time when the data were observed in solar time which is the apparent local time based on the position of the sun at the site
solar noon at:	yyyy-mm-ddTHH:MM	Date and time in UTC when local solar noon occurs at the measurement site
Measurement-level data variables		
aerosols:sensor_wavelength_nm	nanometers (nm)	Wavelengths the sun photometer is using to make measurements Note: All wavelengths appear in a single column and it is dependent on the instrument. All measurements are associated with the minute the observers began their observation.
aerosols:aerosol_optical_thickness	unitless	Aerosol optical thickness per wavelength for each time stamp Note: This page explains how aerosol optical thickness (AOT) is computed by the GLOBE database based on the wavelength-specific voltage reported by the observer.
aerosols:transmission_percent	percent (%)	Percentage of sunlight at the wavelength reaching the ground
aerosols:comments		Comments on the aerosols measurement Note: Before May 2016, serial numbers were not recorded. Some observers recorded serial numbers in the comments.
aerosols:observed_sky_color		Sky color Options: [deep blue, blue, light blue, pale blue, milky]

		Note: a guide to sky color is provided on page 10 of the GLOBE cloud protocol
aerosols:observed_sky_clarity		Sky clarity (i.e., visibility) Options: [unusually clear, clear, somewhat hazy, very hazy, extremely hazy] Note: a guide to sky visibility is provided on page 10 of the GLOBE cloud protocol
aerosols:associated_remote_sensor		Satellite mission or instrument to which aerosol observation may be compared Note: open text field filled in by observer
aerosols:remote_sensor_overflight_time	yyyy-mm-ddTHH:MM	Time the associated remote sensor most nearly flies over the aerosol measurement site in UTC Note: open text field filled in by observer
aerosols:remote_sensor_maximum_elevation_angle_degrees	degrees	The highest angle the satellite mission is above the horizon for the location and time of the aerosol measurement Note: open text field filled in by observer
aerosols:aerosol_photometer_type		The type of instrument (sun photometer) used to measure aerosols
aerosols:aerosol_photometer_serial_number		The serial number of the instrument used to measure aerosols Note: not available before May 2016
air_temps:current_temp	degrees Celsius	Ambient temperature at time of measurement
air_temps:comments		Comments on current air temperature measurement
air_temp_dailies:current_temp	degrees Celsius	Current ambient air temperature recorded at time of maximum and minimum temperature
air_temp_dailies:minimum_temp	degrees Celsius	The minimum air temperature since the previous day's temperature report

air_temp_dailies:maximum_temp	degrees Celsius	The maximum air temperature since the previous day's temperature report
air_temp_dailies:comments		Comments on air temperature measurement
air_temp_monthlies:number of days reported		Number of days in the month on which ambient air temperature observations were reported
air_temp_monthlies:number of obs		Number of ambient air temperature observations reported in the month
air_temp_monthlies:maximum temp (deg C)	degrees Celsius	Maximum ambient air temperature reported in the month
air_temp_monthlies:minimum temp (deg C)	degrees Celsius	Minimum ambient air temperature reported in the month
air_temp_monthlies:average temp (deg C)	degrees Celsius	Monthly average ambient air temperature
air_temp_noons:current_temp_c	degrees Celsius	The ambient air temperature at the time of the measurement and measured within one hour of local solar noon
air_temp_noons:comments		Comments on air temperature measurements
barometric_pressures:pressure_method		Type of barometer use to measure atmospheric pressure
barometric_pressures:pressure	millibars (mb)	Atmospheric pressure at the measurement site
barometric_pressures:sea_level_pressure	millibars (mb)	Atmospheric pressure at the measurement site adjusted to the value that would be observed if the sight were at sea level; these values allow pressure comparisons independent of topography.
barometric pressure noons:pressure	millibars (mb)	Barometric pressure **NOT** adjusted to sea level pressure (i.e., station pressure) measured closest to and within one hour of local solar noon
barometric pressure noons:sea level pressure	millibars (mb)	Barometric pressure adjusted to sea level pressure measured closest to and within one hour of local solar noon

barometric pressure noons:pressure method		The method or type of instrument used to measure barometric pressure
barometric pressure noons:comments		Comments reported on the barometric pressure temperature readings
biometry_trees:dominant_genus		Genus of the species of tree that dominates at a land cover site
biometry_trees:dominant_species		Species of tree that dominates at a land cover site
biometry_trees:codominant_genus		Genus of the species of tree that codominates or is second in prevalence at a land cover site
biometry_trees:codominant_species		Species of tree that codominates or is second in prevalence at a land cover site
biometry_trees:mixed_dominant		A flag indicating that one species of tree does not dominate the land cover site
biometry_trees:dominant_average_height_m	meters (m)	The average height of the five tallest trees of the dominant species
biometry_trees:dominant_average_circumference_cm	centimeters (cm)	The average circumference of the five tallest trees of the dominant species
biometry_trees:dominant_number_of_trees		The number of trees of the dominant species found in the 30 meter x 30 meter land cover site
biometry_trees:codominant_average_height_m	meters (m)	The average height of the five tallest trees of the codominant species
biometry_trees:codominant_average_circumference_cm	centimeters (cm)	The average circumference of the five tallest trees of the codominant species
biometry_trees:codominant_number_of_trees		The number of trees of the codominant species found in the 30 meter x 30 meter land cover site

biometry_trees:comments		Comments on the biometry measurements
conductivities:water_body_state		The state of the water body Options: [normal, frozen, flooded, dry, unreachable]
conductivities:conductivity_micro_siemens_per_cm	microsiemens per centimeter	Conductivity
conductivities:electrical_conductivity_mfg		Manufacturer of the conductivity meter
conductivities:electrical_conductivity_model		Model number of the conductivity meter
conductivities:comments		Comments on the conductivity measurement
dissolved_oxygens:water_body_state		The state of the water body, either normal, frozen, flooded, dry, or unreachable
dissolved_oxygens:dissolved_oxygen_via_kit_mgl	milligrams per liter (mg L^{-1})	Dissolved oxygen amount as measured using a measurement kit
dissolved_oxygens:dissolved_oxygen_via_probe_mgl	milligrams per liter (mg L^{-1})	Dissolved oxygen amount as measured by a probe
dissolved_oxygens:salinity_via_dokit_ppt	parts per thousand (ppt)	Salinity of the sample used to measure dissolved oxygen
dissolved_oxygens:oxygen_kit_mfg		Manufacturer of the dissolved oxygen kit
dissolved_oxygens:oxygen_kit_model		Model of dissolved oxygen kit
dissolved_oxygens:oxygen_probe_mfg		Manufacturer of the dissolved oxygen probe

dissolved_oxygens:oxygen_probe_model		Model of dissolved oxygen probe
dissolved_oxygens:comments		Comments on the dissolved measurement measurement
freshwater_macroinvertebrates:year	yyyy	The year when freshwater macroinvertebrates were measured
freshwater_macroinvertebrates:season		The season when freshwater macroinvertebrates were measured
freshwater_macroinvertebrates:habitat_type		Habitat type Options: [all habitats combined, riffle, run, pool]
freshwater_macroinvertebrates:area_percent	percent (%)	Percentage estimate of area that was sub sampled
freshwater_macroinvertebrates:number_of_collection_samples		Number of samples collected
freshwater_macroinvertebrates:number_of_taxa_reported_for_habitat_type		Number of different taxa reported of this habitat
freshwater_macroinvertebrates:taxonomic_rank		Taxonomic rank Options: [family, genus, species]
freshwater_macroinvertebrates:taxon_latin_name		Taxon Latin name
freshwater_macroinvertebrates:taxonomic_rank_level_one_above		Taxonomic one level higher rank Options: [phylum, class, order]
freshwater_macroinvertebrates:taxon_latin_name_level_one_above		Taxon one level higher Latin name
freshwater_macroinvertebrates:taxonomic_rank_level_two_above		Taxonomic two levels higher rank Options: [phylum, class, order]
freshwater_macroinvertebrates:taxon_latin_name_level_two_above		Taxon two levels higher Latin name

freshwater_macroinvertebrates:number_of_organisms_in_taxon		Number of organisms found in the taxa
freshwater_macroinvertebrates:is_subsampled		Was subsampling used? Options: [yes,no]
freshwater_macroinvertebrates:comments		Comments on the macroinvertebrate measurement
graminoid_biomasses:average_green_mass_g	grams	Average mass of green graminoid (grass) samples
graminoid_biomasses:average_green_percent	percent (%)	
graminoid_biomasses:average_brown_mass_g	grams	Average mass of brown graminoid (grass) samples
graminoid_biomasses:average_brown_percent	percent (%)	Average percent of brown biomass in the three samples
graminoid_biomasses:number_of_samples		Number of graminoid (grass) samples
graminoid_biomasses:comments		Comments on the graminoid biomass measurement
greenings:year	yyyy	Year of measurement
greenings:greening_cycle_number		Greening cycle Note: in some locations there is more than one cycle in a year.
greenings:vegetation_type		Type of vegetation for which greening was observed Options: [tree, shrub, graminoid, other]
greenings:vegetation_label		Species or common name
greenings:genus		Genus of the plant whose green-up is measured

greenings:species		Species of the plant whose green-up is measured
greenings:in_understory		Is green-up or green-down observed for a plant that is the understory? Options: [yes, no]
greenings:stage		A reference for if the measurement is related to green-up or green-down phenophase Options: [up,down]
greenings:leaf_state		The state of a leaf at time of observation during phenophase Options: [color change, fallen, snow covered, budburst, dormant, length measurable, lost, no shoot, swelling]
greenings:predomoinate_leaf_color		At time of measurement the most frequent color observed in Munsell color notation Options: [2.5R:4/12 2.5R:4/2 2.5R:4/4 2.5R:4/6 2.5R:4/8 2.5Y:6/6 2.5Y:8/12 2.5Y:8/6 5G:4/2 5G:6/2 5G:7/4 5G:8/4 5GY:3/2 5GY:4/8 5GY:5/10 5GY:6/10 5GY:7/12 5R:3/4 5Y:8/4 5YR:7/12 7.5YR:3/4 7.5YR:5/4 7.5YR:6/4 7.5YR:8/4]

greenings:leaf_color_list		A whitespace delimited list of up to 4 leaf colors observed at time of measurement Example: “2.5R:4/12 2.5R:4/12 2.5R:4/12”
greenings:leaf_length_mm	millimeters (mm)	Length of emerged leaves
greenings:number_of_same_plants	Integer	Number of plants observed of a given spies
greenings:comments		Comments on green-up and green-down measurement
humidities:relative_humidity_percent	percent (%)	Relative humidity

humidities:dewpoint	degrees Celsius	Dew point temperature. Dew point is computed based on data entered by the GLOBE member:
		
		If a sling psychrometer is used, wet bulb and dry bulb temperatures along with standard pressure based off elevation of the GLOBE site are used to determine relative humidity.
		
		If a hygrometer is used, relative humidity and ambient air temperature are used.
		
		Dewpoint is determined based off the following calculation.
		
		tk = dry_bulb_temp + 273.15;
		es = 6.11*exp(19.834-(5417.7/tk));
		ea = es*humidity_percent/100.0;
		tdk = -5417.7/(ln(ea/6.11) - 19.834);
		td = tdk - 273.15;

humidities:comments		Comments on humidity measurement
humidities monthlies:averaged month		Month for which humidity measurements are averaged
humidty monthlies:number of days reported		Number of days in month on which humidity measurements were reported
humidity monthlies:number of obs		Number of humidity observations reported in the month

humidity monthlies:max relative humidity (%)	percent (%)	Maximum reported relative humidity in the month
humidity monthlies:min relative humidity (%)	percent (%)	Minimum reported relative humidity in the month
humidity monthlies:average relative humidity (%)	percent (%)	Monthly average relative humidity Monthly average relative humidity provided only when there is at least 21 days reported or there is >2000 individual measurements.
humidity monthlies:maximum dewpoint (deg C)	degrees Celsius	Dew point temperature associated with the maximum relative humidity measurement in the month Monthly maximum dewpoint provided only when there is at least 21 days reported or there is >2000 individual measurements.
humidity monthlies:minimum dewpoint (deg C)	degrees Celsius	Dew point temperature associated with the minimum relative humidity measurement in the month Monthly minimum dewpoint provided only when there is at least 21 days reported or there is >2000 individual measurements.
humidity monthlies:average dewpoint (deg C)	degrees Celsius	Monthly average dew point temperature Monthly average dewpoint provided only when there is at least 21 days reported or there is >2000 individual measurements.
humidity noons:dewpoint	degrees Celsius	The dewpoint measurement closest to and within one hour of local solar noon
humidity noons:comments		Comments on the relative humidity measurement
humidity noons:relative humidity (%)	percent (%)	The relative humidity measurement closest to and within one hour of local solar noon
hydrology_alkalinities:water_body_state		The state of the water body, either normal, frozen, flooded,dry, or unreachable
hydrology_alkalinities:alkalinity_via_direct_mgl	milligrams per liter (mg L^{-1})	Alkalinity measured directly
hydrology_alkalinities:alkalinity_via_drop_mgl	milligrams per liter (mg L^{-1})	Alkalinity measured by the number of drops used in an alkalinity kit

hydrology_alkalinities:alkalinity_kit_mfg		Alkalinity kit manufacturer
hydrology_alkalinities:alkalinity_kit_model		Alkalinity kit model number
hydrology_alkalinities:drops_alkalinity_kit_mfg		Manufacturer of the kit that uses drop and color change to measure alkalinity
hydrology_alkalinities:drops_alkalinity_kit_model		Model number of the kit that uses drop and color change to measure alkalinity
hydrology_alkalinities:comments		Comments on the alkalinity measurement
hydrology_phs:water_body_state		The state of the water body Options: [normal, frozen, flooded,dry, unreachable]
hydrology_phs:ph		pH of the water body
hydrology_phs:ph_method		The method used to measure water body pH: paper, pen, or meter
hydrology_phs:ph_meter_model		Model number of the pH meter used
hydrology_phs:ph_meter_mfg		Name of the pH meter manufacturer
hydrology_phs:ph_buffer_4		Was the pH 4 buffer used in calibration? Options: [yes, no]
hydrology_phs:ph_buffer_7		Was the pH 7 buffer used in calibration? Options: [yes, no]
hydrology_phs:ph_buffer_10		Was the pH 10 buffer used in calibration? Options: [yes, no]
hydrology_phs:comments		Comments on measurements of water body pH

land_covers:name		Name of the land cover site. Guidance: land_cover_sites:name should not include commas (,). ● Good: “MountRainier123” ● Bad: “MountRainer, 123” Note: There are two ways a site name is generated. (1) GLOBE schools create their own site_name. (2) The GLOBE Observer app, on the other hand, automatically assigns a site_name to an observation; the site_name is not created by the user. The GLOBE Observer app generates a site_name based on the MGRS grid.
land_covers:muc_code		MUC code of the land cover site
land_covers:muc_name		Name of the land cover site MUC code
land_covers:muc_description		Description of the land cover site MUC code
land_covers:comments		Comments on land cover site measurement
land_covers: data_source		Descriptor indicating whether the data were reported by a GLOBE member at a defined land cover site, or reported from the GLOBE Observer app. Options: [Site Definition, GLOBE Observer]
land_cover_site_with_photos: name		Name of the land cover site
land_cover_site_with_photos: activated_at		Date when the land cover site photos were taken
land_cover_site_with_photos: muc_code		MUC code of the land cover site
land_cover_site_with_photos: muc_name		Name of the land cover site MUC code
land_cover_site_with_photos: muc_description		MUC description for a site for which photos are available
land_cover_site_with_photos: comments		Comments on land cover site measurement

land_cover_site_with_photos: direction		Direction in which the photo was taken Options: [north, east, south, west]
land_cover_site_with_photos: caption		Photo caption
land_cover_site_with_photos: date_taken	mm/dd/yyyy	Date when land cover site photos were taken in UTC
land_cover_site_with_photos: file_name		Name of the file where the land cover site photo is stored
lilacs:year	yyyy	Year when lilac phenophases were observed
lilacs:plant_phenophase		Lilac phenophase
lilacs:lilac_type		Lilac type Options: [common, cloned]
lilacs:shrub_label		Type of lilac plant Options: [common, cloned]
lilacs:genus		Lilac genus
lilacs:species		Lilac species
lilacs:height_cm	centimeters (cm)	Height of the lilac plant
lilacs:plant_health		
lilacs:planted_date	mm/dd/yyyy	Date when the lilac bush was planted in UTC
lilacs:planted_height_cm	centimeters (cm)	Initial height of the lilac plant
lilacs:died_date	mm/dd/yyyy	Date when the lilac bush died in UTC

lilacs:comments		Comments on lilac phenology measurements
mosquitoes:season		The season in which the mosquito observation is made Options: [fall, winter, spring, summer, dry, wet] Note: The Mosquito Larvae protocol (mosquitoes:*) was retired in 2018. Mosquito Habitat Mapper (mosquito_habitat_mapper:*) replaced it as the sole mosquito protocol.
mosquitoes:comments		Comments on the mosquito observations Note: The Mosquito Larvae protocol (mosquitoes:*) was retired in 2018. Mosquito Habitat Mapper (mosquito_habitat_mapper:*) replaced it as the sole mosquito protocol.
mosquitoes:water_body_depth_gt_50cm		Size of the water body being sampled greater than (“gt”) 50 cm Options: [TRUE (t), FALSE (f)] Note: The Mosquito Larvae protocol (mosquitoes:*) was retired in 2018. Mosquito Habitat Mapper (mosquito_habitat_mapper:*) replaced it as the sole mosquito protocol.
mosquitoes:water_body_size_m	meters (m)	The approximate size of the water body being sampled (<1 m, 1-10 m, 10 m) Note: The Mosquito Larvae protocol (mosquitoes:*) was retired in 2018. Mosquito Habitat Mapper (mosquito_habitat_mapper:*) replaced it as the sole mosquito protocol.
mosquitoes:shaded_area_percent	percent (%)	Percent of the water body being sampled that is in the shade Note: The Mosquito Larvae protocol (mosquitoes:*) was retired in 2018. Mosquito Habitat Mapper (mosquito_habitat_mapper:*) replaced it as the sole mosquito protocol.
mosquitoes:plants		Plant presence in the water body being sampled Options: [TRUE (t), FALSE (f)] Note: The Mosquito Larvae protocol (mosquitoes:*) was retired in 2018. Mosquito Habitat Mapper (mosquito_habitat_mapper:*) replaced it as the sole mosquito protocol.
mosquitoes:algae		Algal presence in the water body being sampled Options: [TRUE (t), FALSE (f)] Note: The Mosquito Larvae protocol (mosquitoes:*) was retired in 2018. Mosquito Habitat Mapper (mosquito_habitat_mapper:*) replaced it as the sole mosquito protocol.

mosquitoes:odor		Presence of odor from sampled water body Options: [sewage, normal, none] Note: The Mosquito Larvae protocol (mosquitoes:*) was retired in 2018. Mosquito Habitat Mapper (mosquito_habitat_mapper:*) replaced it as the sole mosquito protocol.
mosquitoes:surface_oil		Oil presence on the water's surface Options: [none, flecks] Note: The Mosquito Larvae protocol (mosquitoes:*) was retired in 2018. Mosquito Habitat Mapper (mosquito_habitat_mapper:*) replaced it as the sole mosquito protocol.
mosquitoes:turbidity_subjective		A subjective assessment by the individual making the observation if the water in which the mosquitoes were found is turbid or clear Note: The Mosquito Larvae protocol (mosquitoes:*) was retired in 2018. Mosquito Habitat Mapper (mosquito_habitat_mapper:*) replaced it as the sole mosquito protocol.
mosquitoes:container_types		The type of container in which the mosquito sample is found Options: [plastic bottle, cement tank] Note: multiple containers can be recorded at a single site. Note: The Mosquito Larvae protocol (mosquitoes:*) was retired in 2018. Mosquito Habitat Mapper (mosquito_habitat_mapper:*) replaced it as the sole mosquito protocol.
mosquitoes:most_freq_habitat_type		Most frequently observed type of mosquito habitat Options: [natural, artificial] Note: The Mosquito Larvae protocol (mosquitoes:*) was retired in 2018. Mosquito Habitat Mapper (mosquito_habitat_mapper:*) replaced it as the sole mosquito protocol.
mosquitoes:net_pole_size_cm	centimeters (cm)	Length of the pole on the net used (if used at all) to collect mosquitoes Note: The Mosquito Larvae protocol (mosquitoes:*) was retired in 2018. Mosquito Habitat Mapper (mosquito_habitat_mapper:*) replaced it as the sole mosquito protocol.
mosquitoes:net_diameter_cm	centimeters (cm)	Diameter of the net used (if used at all) to collect mosquitoes Note: The Mosquito Larvae protocol (mosquitoes:*) was retired in 2018. Mosquito Habitat Mapper (mosquito_habitat_mapper:*) replaced it as the sole mosquito protocol.
mosquitoes:container_water_level_percent_median	percent (%)	Median percent water level in the containers sampled (e.g., 50%) Note: The Mosquito Larvae protocol (mosquitoes:*) was retired in 2018. Mosquito Habitat Mapper (mosquito_habitat_mapper:*)

		replaced it as the sole mosquito protocol.
mosquitoes:lid_types		The type of lid associated with each container in which mosquito samples were found Options: [plastic, wood, clay, metal, none] Note: The Mosquito Larvae protocol (mosquitoes:*) was retired in 2018. Mosquito Habitat Mapper (mosquito_habitat_mapper:*) replaced it as the sole mosquito protocol.
mosquitoes:most_freq_container_color		A flag indicating if most of the sampled containers have a light or dark color Note: The Mosquito Larvae protocol (mosquitoes:*) was retired in 2018. Mosquito Habitat Mapper (mosquito_habitat_mapper:*) replaced it as the sole mosquito protocol.
mosquitoes:most_freq_cleaning_frequency		Most common cleaning frequency of the containers or water bodies sampled (e.g., 1-2 times/week, >2 times/week) Note: The Mosquito Larvae protocol (mosquitoes:*) was retired in 2018. Mosquito Habitat Mapper (mosquito_habitat_mapper:*) replaced it as the sole mosquito protocol.
mosquitoes:number_of_collection_samples		Number (integer) of samples collected Note:The protocol asked for at least three samples taken at least two minutes apart. Note: The Mosquito Larvae protocol (mosquitoes:*) was retired in 2018. Mosquito Habitat Mapper (mosquito_habitat_mapper:*) replaced it as the sole mosquito protocol.
mosquitoes:larvae_genus		Genus of the mosquitoes sampled Options: [Aedes, Culex, Anopheles] Note: The Mosquito Larvae protocol (mosquitoes:*) was retired in 2018. Mosquito Habitat Mapper (mosquito_habitat_mapper:*) replaced it as the sole mosquito protocol.
mosquitoes:larvae_species		Species of the mosquitoes sampled (e.g., aegypti, africanus) Note: The Mosquito Larvae protocol (mosquitoes:*) was retired in 2018. Mosquito Habitat Mapper (mosquito_habitat_mapper:*) replaced it as the sole mosquito protocol.
mosquitoes:larvae_count		Number (integer) of mosquito larvae present Note: The Mosquito Larvae protocol (mosquitoes:*) was retired in 2018. Mosquito Habitat Mapper (mosquito_habitat_mapper:*) replaced it as the sole mosquito protocol.

mosquitoes:larvae_count_ratio		This is the ratio of the number of larvae reported / the number of collection samples Note: The Mosquito Larvae protocol (mosquitoes:*) was retired in 2018. Mosquito Habitat Mapper (mosquito_habitat_mapper:*) replaced it as the sole mosquito protocol.
mosquito_habitat_mapper:water_ source_type		High-level classification of the mosquito habitat type, ● container: artificial ● container: natural ● flowing: still water found next to river or stream ● still: lake/pond/swamp
mosquito_habitat_mapper:water source		Further classification of the mosquito habitat type Options: [can, bottle, pond, cistern]
mosquito_habitat_mapper:larvae _count		Number (integer) of mosquito larvae present
mosquito_habitat_mapper:mosquito_pupae		Are mosquito pupae present? Options: [TRUE (t), FALSE (f)]
mosquito_habitat_mapper:mosquito_adults		Are adult mosquitoes present? Options: [TRUE (t), FALSE (f)]
mosquito_habitat_mapper:last_last_identify_stage		Flag indicating the last identification stage a user completed in the Mosquito Habitat Mapper tool in the GLOBE Observer mobile app
mosquito_habitat_mapper:genus		Genus of the mosquitoes Options: [Aedes, Anopholese, Culex]
mosquito_habitat_mapper:species		Species of the mosquitoes (e.g., aegypti, incerta)
mosquito_habitat_mapper:breeding_ground_eliminated		Was the breeding ground eliminated? Options: [TRUE (t), FALSE (f)]
mosquito_habitat_mapper:extra_data		Optional entry if user wants to report the presence of a mosquito species that is not part of the prompts in the GLOBE Observer mobile app
mosquito_habitat_mapper:comments		Comments about the mosquito observation
nitrates:nitrate_and_nitrite_mgl	milligrams per liter (mg L^{-1})	Concentration of both nitrates and nitrites of a water body in milligrams per liter

nitrates:nitrite_only_mgl	milligrams per liter (mg L^{-1})	Concentration of nitrites of a water body
nitrates:comments		Comments on water body nitrate measurement
nitrates:water_body_state		The state of the water body Options: [normal, frozen, flooded,dry, or unreachable
nitrates:nitrate_kit_mfg		Manufacturer of the nitrate measurement kit
nitrates:nitrate_kit_model		Model name of the nitrate measurement kit
ozone_one_hour_after_noons:ozone_ppb	parts per billion (ppb)	Surface Ozone to be measured approximately one hour after an ozone strip is exposed to the elements. Ozone concentration is measured one after the initial atmospheric measurements were conducted and those measurements were observed within 1 hour of Local Solar Noon.
ozone_one_hour_after_noons:ozone_flag		Surface Ozone to be measured approximately one hour after an ozone strip is exposed to the elements. Flag value of missing is reported if something happens to the strip during the period of exposure. Protocol requirements expect that if the initial atmospheric measurements were conducted within 1 hour of Local Solar Noon that the reading of the ozone strip is to occur approximately one hour after local solar noon.
ozone_one_hour_after_noons:ozone_method		Surface Ozone to be measured approximately one hour after an ozone strip is exposed to the elements. Ozone method is the process used to measure Ozone concentrations. As of April 2019 only one method is defined (GLOBE 2000 method).
ozone_one_hour_after_noons:comments		Comments on the measurement of ozone concentration
ozones:ozone_ppb	parts per billion (ppb)	Ozone concentration Note: Surface Ozone to be measured approximately one hour after an ozone strip is exposed to the elements.
ozones:ozone_flag		Surface Ozone to be measured approximately one hour after an ozone strip is exposed to the elements. Flag value of missing is reported if something happens to the strip during the period of exposure.

ozones:ozone_method		The method used to measure ozone concentration. As of April 2019 only one method is defined (GLOBE 2000 method).
ozones:comments		Comments on the measurement of ozone concentration
phenological_gardens:year	yyyy	The year when measurements of a phenology garden were taken
phenological_gardens:common_name		The common name of the plant in a phenology garden observed
phenological_gardens:plant_number		The number of the plant in a phenology garden observed
phenological_gardens:planted_date	mm/dd/yyyy	The date in UTC when the plant in a phenology garden was planted
phenological_gardens:genus		The genus of the plant in a phenology garden that was observed
phenological_gardens:species		The species of the plant in a phenology garden that was observed
phenological_gardens:plant_state		The state (phenophase) of the plant in a phenology garden that was observed
phenological_gardens:height_cm	cm	Measure of height of each plant in autumn of year except snowdrops
phenological_gardens:comments		Comments on phenology garden measurements
phenological_gardens:fertilizer_types_dates	mm/dd/yyyy	Type(s) of fertilizer applied to garden and date(s) of application
phenological_gardens:watered_dates	mm/dd/yyyy	Date(s) on which the garden was watered
phenological_gardens:pruned_dates	mm/dd/yyyy	Date(s) on which plant was pruned

precipitations:snowfall accumulation flag		A notation if the snowfall amount is missing or was a trace Options: [missing, trace]
precipitations:ph method		The method used to measure pH Options: [pH paper, pH meter]
precipitations:vis total liquid equivalent	millimeters (mm)	The liquid equivalent depth of new precipitation (rain or melted snow) that has accumulated since last observation
precipitations:occurrence type		The type of precipitation observed Options: [rain, snow, rain mixed with snow, no occurrence, unknown]
precipitations:liquid accumulation	millimeters (mm)	The depth of precipitation (rain or melted snow) since the previous measurement of precipitation
precipitations:snowfall accumulation	millimeters (mm)	Depth of snowfall since the previous measurement of precipitation
precipitations:liquid accumulation flag		A notation if the liquid accumulation amount is missing or was a trace
precipitations:days accumulated		The number of days precipitation has accumulated since the previous measurement (maximum allowed is 7 days)
precipitations:pH		The pH of the rain and/or melted snow
precipitations:vis rain depth	millimeters (mm)	The depth of rainfall since the previous measurement of precipitation
precipitations:vis snow depth	millimeters (mm)	The depth of snowfall since the previous measurement of precipitation
precipitations:comments		Comments on the precipitation measurement
salinities:water_body_state		The state of the water body Options: [normal, frozen, flooded,dry, unreachable]

salinities:salinity_via_hydrometer_ppt	parts per thousand (ppt)	Salinity as measured using a hydrometer
salinities:salinity_via_titration_ppt		Salinity in parts per thousand as measured by titration
salinities:tide_latitude	decimal degrees north	The latitude of the location for which tide information is reported. Range: [-90, 90]
salinities:tide_longitude	decimal degrees east	The longitude of the location for which tide information is reported. Range: [-180, 180]
salinities:tide_location_description		Description of the location for which tide information is reported
salinities:before_salinity_measurement_tide_at	HH:MM	Time in UTC of high or low tide preceding the salinity measurement
salinities:before_salinity_measurement_tide_type		Type of tide Options: [high, low]
salinities:after_salinity_measurement_tide_at		Time of high or low tide following the salinity measurement
salinities:after_salinity_measurement_tide_type		Type of tide Options: [high, low]
salinities:salinity_kit_mfg		Name of the manufacturer of the salinity kit used
salinities:salinity_kit_model		Salinity test kit model number
salinities:comments		Comments on salinity measurement
sky_condition_noons:cloud_cover		Total amount of sky covered by clouds measured within one hour of local solar noon Options: [Blank None (0%) Few or Clear (1-10%) Isolated (10-25%) Scattered (25-50%) Broken (50-90%)

		Overcast (90-100%)]
sky_condition_noons:cirrus		Cirrus clouds were observed Options: [yes, no]
sky_condition_noons:cirrocumulus		Cirrocumulus clouds were observed Options: [yes, no]
sky_condition_noons:cirrostratus		Cirrostratus clouds were observed Options: [yes, no]
sky_condition_noons:altostratus		Altostratus clouds were observed Options: [yes, no]
sky_condition_noons:altocumulus		Altocumulus clouds were observed Options: [yes, no]
sky_condition_noons:cumulus		Cumulus clouds were observed Options: [yes, no]
sky_condition_noons:nimbostratus		Nimbostratus clouds were observed Options: [yes, no]
sky_condition_noons:stratus		Stratus clouds were observed Options: [yes, no]
sky_condition_noons:stratocumulus		Stratocumulus clouds were observed within one hour of local solar noon Options: [yes, no]
sky_condition_noons:cumulonimbus		Cumulonimbus clouds were observed within one hour of local solar noon Options: [yes, no]
sky_condition_noons:fog		Fog obscured at least 25% of the sky within one hour of local solar noon Options: [yes, no]
sky_condition_noons:smoke		Smoke obscured at least 25% of the sky within one hour of local solar noon Options: [yes, no]
sky_condition_noons:haze		Haze obscured at least 25% of the sky within one hour of local solar noon Options: [yes, no]

sky_condition_noons:volcanic_ash		Volcanic ash obscured at least 25% of the sky within one hour of local solar noon Options: [yes, no]
sky_condition_noons:dust		Dust obscured at least 25% of the sky within one hour of local solar noon Options: [yes, no]
sky_condition_noons:sand		Sand obscured at least 25% of the sky within one hour of local solar noon Options: [yes, no]
sky_condition_noons:spray		Spray obscured at least 25% of the sky within one hour of local solar noon Options: [yes, no]
sky_condition_noons:heavy_rain		Heavy rain obscured at least 25% of the sky within one hour of local solar noon Options: [yes, no]
sky_condition_noons:heavy_snow		Heavy new snow obscured at least 25% of the sky within one hour of local solar noon Options: [yes, no]
sky_condition_noons:blowing_snow		Blowing snow obscured at least 25% of the sky within one hour of local solar noon Options: [yes, no]
sky_condition_noons:short_lived_contrails		Total number (integer) of short lived contrails observed within one hour of local solar noon
sky_condition_noons:spreading_contrails		Total number (integer) of persistent spreading contrails observed within one hour of local solar noon
sky_condition_noons:non_spreading_contrails		Total number (integer) of persistent non-spreading contrails observed within one hour of local solar noon
sky_condition_noons:comments		Comments made by the observer
sky_condition_noons:is_citizen_science		Flag indicating if the measurement site ID was MGRS-generated Options: [TRUE, FALSE] TRUE: observation came from the GLOBE Observer app FALSE: observation did not come from the GLOBE Observer app
Sky_conditions:sky condition id		Identification number (integer) for the latitude and longitude of the observation

Sky_conditions: observation id		Identification number (integer) for the latitude, longitude, date, and time of the observation
Sky_conditions: measured at	yyyy-mm-ddTHH:MM:SS	The date and time of measurement in UTC
Sky_conditions: solar measured at	yyyy-mm-ddTHH:MM:SS	Solar noon for the latitude and longitude of the observation in UTC
sky_conditions:cloud_cover		Total amount of sky covered by clouds irregardless of altitude Options: [Blank None (0%) Few or Clear (1-10%) Isolated (10-25%) Scattered (25-50%) Broken (50-90%) Overcast (90-100%)]
sky_conditions:cirrus		Cirrus clouds were observed Options: [TRUE, FALSE] Note: Data downloaded from Vis returns X. Data downloaded from ADAT returns TRUE.
sky_conditions:cirrocumulus		Cirrocumulus clouds were observed Options: [TRUE, FALSE] Note: Data downloaded from Vis returns X. Data downloaded from ADAT returns TRUE.
sky_conditions:cirrostratus		Cirrostratus clouds were observed Options: [TRUE, FALSE] Note: Data downloaded from Vis returns X. Data downloaded from ADAT returns TRUE.
sky_conditions:altostratus		Altostratus clouds were observed Options: [TRUE, FALSE] Note: Data downloaded from Vis returns X. Data downloaded from ADAT returns TRUE.
sky_conditions:altocumulus		Altocumulus clouds were observed Options: [TRUE, FALSE] Note: Data downloaded from Vis returns X. Data downloaded from ADAT returns TRUE.

sky_conditions:cumulus		Cumulus clouds were observed Options: [TRUE, FALSE] Note: Data downloaded from Vis returns X. Data downloaded from ADAT returns TRUE.
sky_conditions:nimbostratus		Nimbostratus clouds were observed Options: [TRUE, FALSE] Note: Data downloaded from Vis returns X. Data downloaded from ADAT returns TRUE.
sky_conditions:stratus		Stratus clouds were observed Options: [TRUE, FALSE] Note: Data downloaded from Vis returns X. Data downloaded from ADAT returns TRUE.
sky_conditions:stratocumulus		Stratocumulus clouds were observed Options: [TRUE, FALSE] Note: Data downloaded from Vis returns X. Data downloaded from ADAT returns TRUE.
sky_conditions:cumulonimbus		Cumulonimbus clouds were observed Options: [TRUE, FALSE] Note: Data downloaded from Vis returns X. Data downloaded from ADAT returns TRUE.
sky_conditions:comments		Comments made by the observer
sky_conditions:fog		Fog obscured >25% of the sky Options: [TRUE, FALSE] Note: Data downloaded from Vis returns X. Data downloaded from ADAT returns TRUE.
sky_conditions:smoke		Smoke obscured >25% of the sky Options: [TRUE, FALSE] Note: Data downloaded from Vis returns X. Data downloaded from ADAT returns TRUE.
sky_conditions:haze		Haze obscured >25% of the sky Options: [TRUE, FALSE] Note: Data downloaded from Vis returns X. Data downloaded from ADAT returns TRUE.

sky_conditions:volcanic_ash		Volcanic Ash obscured >25% of the sky Options: [TRUE, FALSE] Note: Data downloaded from Vis returns X. Data downloaded from ADAT returns TRUE.
sky_conditions:dust		Dust obscured >25% of the sky Options: [TRUE, FALSE] Note: Data downloaded from Vis returns X. Data downloaded from ADAT returns TRUE.
sky_conditions:sand		Sand obscured >25% of the sky Options: [TRUE, FALSE] Note: Data downloaded from Vis returns X. Data downloaded from ADAT returns TRUE.
sky_conditions:spray		Sea spray obscured >25% of the sky Options: [TRUE, FALSE] Note: Data downloaded from Vis returns X. Data downloaded from ADAT returns TRUE.
sky_conditions:heavy_rain		Heavy rain obscured >25% of the sky Options: [TRUE, FALSE] Note: Data downloaded from Vis returns X. Data downloaded from ADAT returns TRUE.
sky_conditions:heavy_snow		Heavy snow obscured >25% of the sky Options: [TRUE, FALSE] Note: Data downloaded from Vis returns X. Data downloaded from ADAT returns TRUE.
sky_conditions:blowing_snow		Blowing snow obscured >25% of the sky Options: [TRUE, FALSE] Note: Data downloaded from Vis returns X. Data downloaded from ADAT returns TRUE.
sky_conditions:short_lived_contrails		Number (integer) of short lived contrails observed
sky_conditions:spreading_contrails		Number (integer) of persistent spreading contrails observed
sky_conditions:non_spreading_contrails		Number (integer) of persistent, non-spreading contrails observed

sky_conditions:is_citizen_science		Options: [TRUE, FALSE] TRUE: the observer used the GLOBE Observer app to enter the data and they do not have a GLOBE account FALSE: the observer has a GLOBE account and used the GLOBE Observer app, the GLOBE Data Entry website, the GLOBE Email Data Entry form, or the GLOBE Data Entry app to enter the data
Sky_conditions: is globe trained		Options: [TRUE, FALSE] TRUE: the observer did a GLOBE or GLOBE Observer training FALSE: the observer has not done a GLOBE or GLOBE Observer training
sky_conditions: cloud cover low		Total amount of sky covered by low clouds (cumulus, fog/stratus, stratocumulus, nimbostratus, cumulonimbus) Total amount of sky covered by clouds irregardless of altitude Options: [Blank None (0%) Few or Clear (1-10%) Isolated (10-25%) Scattered (25-50%) Broken (50-90%) Overcast (90-100%)]
sky_conditions: opacity low		Average opacity of low clouds observed (cumulus, fog/stratus, stratocumulus, nimbostratus, cumulonimbus) Options: [Blank Transparent (satellite optical depth = transparent) Translucent (satellite optical depth = 3-10) Opaque (satellite optical depth = above 10)] This page explains how the GLOBE Clouds Team at NASA Langley Research Center compares reported opacity to satellite data.
sky_conditions: cloud cover mid		Total amount of sky covered by mid clouds (altostratus, altocumulus) Total amount of sky covered by clouds irregardless of altitude Options: [Blank None (0%) Few or Clear (1-10%) Isolated (10-25%) Scattered (25-50%) Broken (50-90%) Overcast (90-100%)]

sky_conditions: opacity mid		Average opacity of mid clouds observed (altostratus, altocumulus) Options: [Blank Transparent (satellite optical depth = transparent) Translucent (satellite optical depth = 3-10) Opaque (satellite optical depth = above 10)] This page explains how the GLOBE Clouds Team at NASA Langley Research Center compares reported opacity to satellite data.
sky_conditions: cloud cover high		Total amount of sky covered by high clouds (contrails: short-lived, persistent non-spreading, persistent spreading, cirrus, cirrocumulus, cirrostratus) Total amount of sky covered by clouds irregardless of altitude Options: [Blank None (0%) Few or Clear (1-10%) Isolated (10-25%) Scattered (25-50%) Broken (50-90%) Overcast (90-100%)]
sky_conditions: opacity high		Average opacity of high clouds observed (contrails: short-lived, persistent non-spreading, persistent spreading, cirrus, cirrocumulus, cirrostratus) Options: [Blank Transparent (satellite optical depth = transparent) Translucent (satellite optical depth = 3-10) Opaque (satellite optical depth = above 10)] This page explains how the GLOBE Clouds Team at NASA Langley Research Center compares reported opacity to satellite data.
sky_conditions: snow/ice		Presence of snow and/or ice on the ground Options: [TRUE, FALSE] Note: Data downloaded from Vis returns X. Data downloaded from ADAT returns TRUE.
sky_conditions: standing water		Presence of standing water on the ground Options: [TRUE, FALSE] Note: Data downloaded from Vis returns X. Data downloaded from ADAT returns TRUE. Note: standing water includes large bodies of water

sky_conditions: muddy		Ground was reported as muddy Options: [TRUE, FALSE] Note: Data downloaded from Vis returns X. Data downloaded from ADAT returns TRUE.
sky_conditions: dry ground		Ground was reported as dry Options: [TRUE, FALSE] Note: Data downloaded from Vis returns X. Data downloaded from ADAT returns TRUE.
sky_conditions: leaves on trees		Options: [TRUE, FALSE] Note: Data downloaded from Vis returns X. Data downloaded from ADAT returns TRUE. TRUE: More than 50% of the trees have leaves (this includes evergreens) FALSE: Less than 50% of the trees have leaves (this includes evergreens)
sky_conditions: raining/snowing		The observation was taken while it rained or snowed Options: [TRUE, FALSE] Note: Data downloaded from Vis returns X. Data downloaded from ADAT returns TRUE.
sky_conditions: north photo url		URL link to image taken in the north cardinal direction Note: this variable only appears when data is downloaded from ADAT (not Vis)
sky_conditions: north caption		Comments made by the observer about the image Note: this variable only appears when data is downloaded from ADAT (not Vis)
sky_conditions: south photo url		URL link to image taken in the south cardinal direction Note: this variable only appears when data is downloaded from ADAT (not Vis)
sky_conditions: south caption		Comments made by the observer about the image Note: this variable only appears when data is downloaded from ADAT (not Vis)
sky_conditions: east photo url		URL link to image taken in the east cardinal direction Note: this variable only appears when data is downloaded from ADAT

		(not Vis)
sky_conditions: east caption		Comments made by the observer about the image Note: this variable only appears when data is downloaded from ADAT (not Vis)
sky_conditions: west photo url		URL link to image taken in the west cardinal direction Note: this variable only appears when data is downloaded from ADAT (not Vis)
sky_conditions: west caption		Comments made by the observer about the image Note: this variable only appears when data is downloaded from ADAT (not Vis)
sky_conditions: up photo url		URL link to image taken in the upward direction Note: this variable only appears when data is downloaded from ADAT (not Vis)
sky_conditions: up caption		Comments made by the observer about the image Note: this variable only appears when data is downloaded from ADAT (not Vis)
sky_conditions: down photo url		URL link to image taken in the downward direction Note: this variable only appears when data is downloaded from ADAT (not Vis)
sky_conditions: down caption		Comments made by the observer about the image Note: this variable only appears when data is downloaded from ADAT (not Vis)
snowpacks:snow_depth	millimeters (mm)	Depth of the snowpack
snowpacks:depth_flag		Options: [trace, missing]
snowpacks:liquid_equivalent	millimeters (mm)	Depth of the melted (i.e., liquid) snowpack
snowpacks:liquid_equivalent_flag		Options: [trace, missing]

snowpacks:ph		pH of the melted snowpack
snowpacks:ph_method		Method used to measure snowpack pH Options: [pH paper, pH meter]
snowpacks:comments		Comments on the snowpack measurement
soil_characterizations:horizon_number		Horizon number of the soil characterization measurements
soil_characterizations:horizon_top_depth_cm	centimeters (cm)	Soil horizon top depth
soil_characterizations:horizon_bottom_depth_cm	centimeters (cm)	Soil horizon bottom depth
soil_characterizations:reference_depth_level_5cm		Number of the soil horizon at 5 cm depth
soil_characterizations:reference_depth_level_10cm		Number of the soil horizon at 10 cm depth
soil_characterizations:reference_depth_level_30cm		Number of the soil horizon at 30 cm depth
soil_characterizations:reference_depth_level_50cm		Number of the soil horizon at 50 cm depth
soil_characterizations:reference_depth_level_60cm		Number of the soil horizon at 60 cm depth
soil_characterizations:reference_depth_level_90cm		Number of the soil horizon at 90 cm depth
soil_characterizations:collected_on	mm/dd/yyyy	Day soil sample was collected for characterization measurements in UTC
soil_characterizations:moisture_estimate		Moisture of the soil horizon Options: [wet, moist, dry]
soil_characterizations:structure		Soil horizon structure Options: [granular,

		blocky, platy, prismatic, columnar, single grained, massive, unknown]
soil_characterizations:consistence		Soil horizon consistency Options: [loose, friable, firm, extra firm]
soil_characterizations:main_color_code		Code of the primary soil horizon color
soil_characterizations:secondary_color_code		Code of the secondary soil horizon color, if secondary soil horizon is present
soil_characterizations:texture_field_estimate		Soil horizon texture as determined by feel (see Soil Texture Triangle) Options: [sand, silt, clay, combination]
soil_characterizations:rock_quantity_estimate		Presence of rocks in the soil horizon Options: [many, few, none]
soil_characterizations:root_quantity_estimate		Presence of roots in the soil horizon Options: [many, few, none]
soil_characterizations:carbonates		Presence of carbonate in the soil horizon Options: [much, few, none]
soil_characterizations:ph		pH of the soil horizon
soil_characterizations:ph_method		Method used to measure soil pH Options: [pH paper, pH meter]
soil_characterizations:bulk_density_g_per_cm3	grams per cubic centimeter (g cm^{-3})	Bulk density of the soil horizon
soil_characterizations:particle_density_g_per_cm3	grams per cubic centimeter (g cm^{-3})	Soil particle density

soil_characterizations:porosity_percent	percentage (%)	Percentage of the soil horizon that is empty and/or filled with water
soil_characterizations:clay_percent	percentage (%)	Percentage of soil particles that are clay
soil_characterizations:sand_percent	percentage (%)	Percentage of soil particles that are sand
soil_characterizations:silt_percent	percentage (%)	Percentage of soil particles that are silt
soil_characterizations:texture		Soil horizon texture based on the measured percentages of sand, silt, and clay (see Soil Texture Triangle)
soil_characterizations:comments		Comments on soil characterization measurements
soil_densities:horizon_number		Number of the horizon for which density measurements are provided
soil_densities:horizon_top_depth_cm	centimeters (cm)	Top depth of horizon for which densities were measured
soil_densities:horizon_bottom_depth_cm	centimeters (cm)	Bottom depth of horizon for which densities were measured
soil_densities:reference_depth_level_5cm		Number of the soil horizon at 5 cm depth
soil_densities:reference_depth_level_10cm		Number of the soil horizon at 10 cm depth
soil_densities:reference_depth_level_30cm		Number of the soil horizon at 30 cm depth
soil_densities:reference_depth_level_50cm		Number of the soil horizon at 50 cm depth
soil_densities:reference_depth_level_60cm		Number of the soil horizon at 60 cm depth
soil_densities:reference_depth_level_90cm		Number of the soil horizon at 90 cm depth

soil_densities:collected_on	mm/dd/yyyy	Date when samples were collected for soil densities measurements
soil_densities:bulk_density_g_per_cm3	grams per cubic centimeter (g cm^{-3})	Bulk density of soil sample.
soil_densities:particle_density_g_per_cm3	grams per cubic centimeter (g cm^{-3})	Particle density
soil_densities:porosity_percent	percent (%)	Ratio of bulk density to particle density
soil_densities:comments		Comments on soil density measurement
soil_fertilities:horizon_number		Horizon number of the soil characterization measurements
soil_fertilities:horizon_top_depth_cm	centimeters (cm)	Soil horizon top depth
soil_fertilities:horizon_bottom_depth_cm	centimeters (cm)	Soil horizon bottom depth
soil_fertilities:reference_depth_level_5cm		Number of the soil horizon at 5 cm depth
soil_fertilities:reference_depth_level_10cm		Number of the soil horizon at 10 cm depth
soil_fertilities:reference_depth_level_30cm		Number of the soil horizon at 30 cm depth
soil_fertilities:reference_depth_level_50cm		Number of the soil horizon at 50 cm depth
soil_fertilities:reference_depth_level_60cm		Number of the soil horizon at 60 cm depth
soil_fertilities:reference_depth_level_90cm		Number of the soil horizon at 90 cm depth

soil_fertilities:collected_on	mm/dd/yyyy	Date when samples were collected for soil fertility measurements
soil_fertilities:nitrate_estimate		Soil nitrate estimate from the NPK (nitrogen-K, phosphorus-P, potassium-K) kit Options: [high, medium, low, none]
soil_fertilities:phosphate_estimate		Soil phosphate estimate from the NPK (nitrogen-K, phosphorus-P, potassium-K) kit Options: [high, medium, low, none]
soil_fertilities:potassium_estimate		Soil potassium estimate from the NPK (nitrogen-K, phosphorus-P, potassium-K) kit Options: [high, medium, low, none]
soil_fertilities:comments		Comments from the NPK kit results
soil_infiltrations:max_flow_rate_mm_per_min	millimeters per minute (mm min^{-1})	The maximum flow rate of all the sequence measurements for the given date and site.
soil_infiltrations:min_flow_rate_mm_per_min	millimeters per minute (mm min^{-1})	The minimum flow rate of all the sequence measurements for the given date and site.
soil_infiltrations:average_saturated_soil_water_content_g_per_g	grams per gram (g g^{-1})	Gravimetric soil moisture of the sample taken where the infiltration measurement was taken
soil_infiltrations:comments		Comments on soil infiltration measurement
soil_layer_descriptions:horizon_number		Horizon number of the soil characterization measurements
soil_layer_descriptions:horizon_top_depth_cm	centimeters (cm)	Soil horizon top depth
soil_layer_descriptions:horizon_bottom_depth_cm	centimeters (cm)	Soil horizon bottom depth
soil_layer_descriptions:reference_depth_level_5cm		Number of the soil horizon at 5 cm depth
soil_layer_descriptions:reference_depth_level_10cm		Number of the soil horizon at 10 cm depth

soil_layer_descriptions:reference_depth_level_30cm		Number of the soil horizon at 30 cm depth
soil_layer_descriptions:reference_depth_level_50cm		Number of the soil horizon at 50 cm depth
soil_layer_descriptions:reference_depth_level_60cm		Number of the soil horizon at 60 cm depth
soil_layer_descriptions:reference_depth_level_90cm		Number of the soil horizon at 90 cm depth
soil_layer_descriptions:collected_on	mm/dd/yyyy	Date on which soil horizon samples were collected in UTC
soil_layer_descriptions:moisture_estimate		Soil horizon moisture Options: [wet, moist, dry]
soil_layer_descriptions:structure		Soil horizon structure Options: [granular, blocky, platy, prismatic, columnar, single grained, massive, unknown]
soil_layer_descriptions:consistence		Soil horizon consistency Options: [loose, friable, firm, extra firm]
soil_layer_descriptions:main_color_code		Code of the primary soil horizon color
soil_layer_descriptions:secondary_color_code		Code of the secondary soil horizon color, if there is one
soil_layer_descriptions:texture_field_estimate		Soil horizon texture as determined by feel
soil_layer_descriptions:rock_quantity_estimate		Presence of rocks in the soil horizon Options: [many, few, none]
soil_layer_descriptions:root_quantity_estimate		Presence of roots in the soil horizon Options: [many, few, none]

soil_layer_descriptions:carbonates		Presence of carbonate in the soil horizon Options: [much, some, none]
soil_layer_descriptions:comments		Comments on soil characterization measurements
soil_moisture_for_smap:depth_level_cm	centimeters (cm)	Moisture for the top 5 cm
soil_moisture_for_smap:saturated_flag		A flag indicating that the surface soil was saturated at the time of measurement
soil_moisture_for_smap:gravimetric_soil_moisture_g_per_g	grams per gram (g g^{-1})	Gravimetric surface soil moisture measurement taken following the SMAP Block Pattern protocol
soil_moisture_for_smap:average_sample_volume_ml	milliliters (ml)	Average of the sample volume measurements taken following the SMAP Block Pattern protocol
soil_moisture_for_smap:first_volume_measurement	milliliters (ml)	Volume of water poured into the can. Volume is measured three times; this is the first of those three measurements.
soil_moisture_for_smap:volumetric_soil_moisture_ml_per_ml	milliliters per milliliter (ml ml^{-1})	Volumetric surface soil moisture measurement taken following the SMAP Block Pattern protocol
soil_moisture_for_smap:sample_bulk_density_g_per_ml	grams per milliliter (g ml^{-1})	Sample bulk density used in converting up to 10 gravimetric soil moisture measurements to volumetric soil moisture
soil_moisture_for_smap:comments		Comments on surface soil moisture measurements taken following the SMAP Block Pattern protocol
soil_moisture_for_smap:soil_state		The ground surface conditions at the time of when a measurement was observed. A soil moisture value can only be determined when the value of “measureable” is selected. Values [snow, measurable, frozen, frozen_water, graupel,

		hail]
soil_moisture_via_sensors:depth_level_cm	centimeters (cm)	Depth in cm of the sensor soil moisture measurement: 10, 30, 60, or 90 centimeters
soil_moisture_via_sensors:moisture_method		Type of sensor used to measure soil moisture
soil_moisture_via_sensors:saturated_flag		A flag indicating if soils are fully saturated and there is standing water.
soil_moisture_via_sensors:meter_reading		Soil moisture meter reading
soil_moisture_via_sensors:installation_date	mm/dd/yyyy	Date soil moisture sensor was installed at the site in UTC
soil_moisture_via_sensors:water_content_g_per_g	grams per gram ($g\ g^{-1}$)	Soil moisture meter reading converted to grams per gram by application of a calibration curve based on 15 or more gravimetric measurements
soil_moisture_via_sensors:comments		Comments on the soil moisture measurements taken using sensors
soil_particle_size_distributions:horizon_number		Students number horizons starting at surface going downward up to 1 meter in depth
soil_particle_size_distributions:horizon_top_depth_cm	centimeters (cm)	The depth from the surface to the top of each horizon
soil_particle_size_distributions:horizon_bottom_depth_cm	centimeters (cm)	This is the depth from the surface to the bottom of each horizon
soil_particle_size_distributions:reference_depth_level_5cm		A means of referencing the soil characteristics including the horizon number for the specified depth based upon the depth level falling between the top and bottom depth of of the measured soil horizon.
soil_particle_size_distributions:reference_depth_level_10cm		A means of referencing the soil characteristics including the horizon number for the specified depth based upon the depth level falling between the top and bottom depth of of the measured soil horizon.
soil_particle_size_distributions:reference_depth_level_30cm		A means of referencing the soil characteristics including the horizon number for the specified depth based upon the depth level falling between the top and bottom depth of of the measured soil horizon.

soil_particle_size_distributions:reference_depth_level_50cm		A means of referencing the soil characteristics including the horizon number for the specified depth based upon the depth level falling between the top and bottom depth of of the measured soil horizon.
soil_particle_size_distributions:reference_depth_level_60cm		A means of referencing the soil characteristics including the horizon number for the specified depth based upon the depth level falling between the top and bottom depth of of the measured soil horizon.
soil_particle_size_distributions:reference_depth_level_90cm		A means of referencing the soil characteristics including the horizon number for the specified depth based upon the depth level falling between the top and bottom depth of of the measured soil horizon.
soil_particle_size_distributions:collected_on	mm/dd/yyyy	Date soil was collected on in UTC
soil_particle_size_distributions:clay_percent	percent (%)	Percent clay particles in sample
soil_particle_size_distributions:sand_percent	percent (%)	Percent sand particles in sample
soil_particle_size_distributions:silt_percent	percent (%)	Percent silt particles in sample
soil_particle_size_distributions:texture		Taken from the textural triangle (see Soil Texture Triangle in the particle size distribution protocol)
soil_particle_size_distributions:comments		Comments on particle size distribution
soil_phs:horizon_number		Horizon number of the soil characterization measurements
soil_phs:horizon_top_depth_cm	centimeters (cm)	Soil horizon top depth
soil_phs:horizon_bottom_depth_cm	centimeters (cm)	Soil horizon bottom depth
soil_phs:reference_depth_level_5cm		A means of referencing the soil characteristics including the horizon number for the specified depth based upon the depth level falling between the top and bottom depth of of the measured soil horizon.
soil_phs:reference_depth_level_10cm		A means of referencing the soil characteristics including the horizon number for the specified depth based upon the depth level falling between the top and bottom depth of of the measured soil horizon.

soil_phs:reference_depth_level_30cm		A means of referencing the soil characteristics including the horizon number for the specified depth based upon the depth level falling between the top and bottom depth of of the measured soil horizon.
soil_phs:reference_depth_level_50cm		A means of referencing the soil characteristics including the horizon number for the specified depth based upon the depth level falling between the top and bottom depth of of the measured soil horizon.
soil_phs:reference_depth_level_60cm		A means of referencing the soil characteristics including the horizon number for the specified depth based upon the depth level falling between the top and bottom depth of of the measured soil horizon.
soil_phs:reference_depth_level_90cm		A means of referencing the soil characteristics including the horizon number for the specified depth based upon the depth level falling between the top and bottom depth of of the measured soil horizon.
soil_phs:collected_on	mm/dd/yyyy	Date soil sample was collected on in UTC
soil_phs:ph		pH of the soil horizon
soil_phs:ph_method		Method used to measure soil pH Options: [pH paper, pH meter]
soil_phs:comments		Comments on the soil pH measurement
soil_temp_dailies:depth_level_cm	centimeters (cm)	The depth reported as a positive number below the ground surface. It is the depth at which measurements where collected.
soil_temp_dailies:minimum_temp_c	degrees Celsius	The lowest soil temperature measured since the previous day's temperature report
soil_temp_dailies:maximum_temp_c	degrees Celsius	The highest soil temperature measured since the previous day's temperature report
soil_temp_dailies:average_temp_c	degrees Celsius	The average soil temperature since the previous day's temperature report
soil_temp_dailies:comments		Comments on soil temperature measurements

soil_temp_noons:depth_level_cm	centimeters (cm)	The depth reported as a positive number below the ground surface. It is the depth at which measurements where collected.
soil_temp_noons:current_temp_c	degree Celsius	The soil temperature closest to local solar noon and within one hour of local solar noon.
soil_temp_noons:comments		Comments on soil temperature measurements
soil_temp_sub_days:depth_level_cm	centimeters (cm)	The depth reported as a positive number below the ground surface. It is the depth at which measurements where collected.
soil_temp_sub_days:current_temp_c	degrees Celsius	The soil temperature at the measurement time.
surface_temperature_noons: average_surface_temperature_c	degrees Celsius	Average of surface temperatures taken within one hour of solar noon for one homogeneous site (1-9 observations)
surface_temperature_noons: surface_condition		Surface condition (wet or dry) taken within one hour of solar noon for one homogeneous site
surface_temperature_noons: average_snow_depth_mm	millimeters (mm)	Average snow depth taken with surface temperature observations taken within one hour of solar noon for one homogeneous site (1-9 observations)
surface_temperature_noons: snow_depth_flag		Flag indicating that the land surface was covered by snow
surface_temperature_noons: number_of_samples_taken		Number of places on the ground at which surface temperature was measured
surface_temperature_noons: comments		Comments on surface temperature measurements
surface_temperature_noons: surface_cover_type		Cover type (e.g. grass, asphalt, etc.) taken within one hour of solar noon for one homogeneous site
surface_temperature_noons: homogeneous_site_short_length_m	meters (m)	Width of surface temperature homogeneous area if dimensions less than 30 m x 30 m
surface_temperature_noons: homogeneous_site_long_length_m	meters (m)	Length of surface temperature homogeneous area if dimensions less than 30 m x 30 m

surface_temperature_noons:site_area_m_squared	square meters (m^2)	Area of surface temperature homogeneous area site
surface_temperatures:average_surface_temperature_c	degrees Celsius	Average of surface temperatures for one homogeneous site (1-9 observations)
surface_temperatures:surface_condition		Surface condition (wet or dry) taken for one homogeneous site
surface_temperatures:average_snow_depth_mm	millimeters (mm)	Average snow depth taken with surface temperature observations for one homogeneous site (1-9 observations)
surface_temperatures:snow_depth_flag		Snow flag taken with surface temperature observations for one homogeneous site Options: [yes; no]
surface_temperatures:number_of_samples_taken	integer	Number of surface temperature samples taken
surface_temperatures:comments	text or blank	Comments about surface temperature measurement
surface_temperatures:surface_cover_type		Cover type (e.g. grass, asphalt, etc.) taken for one homogeneous site
surface_temperatures:homogeneous_site_short_length_m	meters (m)	Width of homogeneous area if dimensions less than 30 m x 30 m
surface_temperatures:homogeneous_site_long_length_m	meters (m)	Length of homogeneous area if dimensions less than 30 m x 30 m
surface_temperatures:site_area_m_squared	square meters (m^2)	Area measured
transparencies:comments		Comments on the transparency measurement
transparencies:water_body_state		The state of the water body, either normal, frozen, flooded,dry, or unreachable
transparencies:transparency_disk_image_disappearance_m	meters (m)	The depth at which the Secchi disk cannot be seen

transparencies:transparency_disk_does_not_disappear		A flag indicating that the Secchi disk could be seen even when resting on the bottom
transparencies:tube_image_disappearance_cm	centimeters (cm)	The depth at which the pattern at the bottom of the turbidity tube cannot be seen
transparencies:tube_image_does_not_disappear		A flag indicating that the pattern at the bottom of the turbidity tube could be seen even when the tube was full
tree heights:measured at	yyyymmdd THH:MM:SS	Date tree height was measured
tree heights: tree latitude	decimal degrees north	Latitude of the tree measured
tree heights: tree longitude	decimal degrees east	Longitude of the tree measured
tree heights: elevation	meters above sea level	Elevation of tree being measured
tree heights:height	meters (m)	Tree height Note: this is an average of up to four height measurements
tree heights: circumferences	centimeters (cm)	Tree circumference
tree heights:genus		Tree genus
tree heights:species		Tree species

tree heights:comments		Comments from the observer about the tree height measurement
vegetation_covers:canopy_cover_observations_count		The total number of observation samples where each sample is when one looks directly overhead while conducting the protocol. It is the sum of canopy_cover_plus_count and canopy_cover_minus_count
vegetation_covers:canopy_cover_plus_count		The number of observations with canopy cover along diagonals
vegetation_covers:canopy_cover_minus_count		The number of observations without canopy cover along diagonals
vegetation_covers:canopy_cover_tree_count		Number of observations with tree canopy along diagonals
vegetation_covers:canopy_cover_shrub_count		Number of observations with shrub canopy along diagonals
vegetation_covers:canopy_cover_deciduous_count		Number of observations with deciduous canopy along diagonals
vegetation_covers:canopy_cover_evergreen_count		Number of observations with evergreen canopy along diagonals
vegetation_covers:canopy_cover_plus_percent	percent (%)	The percentage based upon canopy_cover_plus_count / canopy_cover_observations_count regardless of the type of vegetation canopy.
vegetation_covers:canopy_cover_tree_percent	percent (%)	Percent of tree canopy cover.
vegetation_covers:canopy_cover_shrub_percent	percent (%)	Percent of shrub canopy cover.
vegetation_covers:canopy_cover_deciduous_percent	percent (%)	Percentage of the canopy cover that is deciduous trees
vegetation_covers:canopy_cover_evergreen_percent	percent (%)	Percentage of the canopy cover that is evergreen trees
vegetation_covers:ground_cover_observations_count		Number of canopy cover observations taken

vegetation_covers:ground_cover_plus_count		Number of observations with ground cover along diagonals
vegetation_covers:ground_cover_minus_count		Number of observations without ground cover along diagonal
vegetation_covers:ground_cover_green_count		Number of observations with green ground cover
vegetation_covers:ground_cover_brown_count		Number of observations with brown ground cover
vegetation_covers:ground_cover_graminoid_count		Number of observations with graminoid ground cover
vegetation_covers:ground_cover_forb_count		Number of observations with forb ground cover
vegetation_covers:ground_cover_other_count		Number of observations with other ground cover
vegetation_covers:ground_cover_shrub_count		Number of observations with shrub ground cover
vegetation_covers:ground_cover_dwarf_shrub_count		Number of observations with dwarf shrub ground cover
vegetation_covers:ground_cover_plus_percent	percent (%)	Percent ground cover
vegetation_covers:ground_cover_green_percent	percent (%)	Percent green ground cover
vegetation_covers:ground_cover_brown_percent	percent (%)	Percent brown ground cover
vegetation_covers:ground_cover_graminoid_percent	percent (%)	Percent of graminoid ground vegetation type
vegetation_covers:ground_cover_forb_percent	percent (%)	Percent of forb ground vegetation type
vegetation_covers:ground_cover_other_percent	percent (%)	Percent of other ground vegetation type

vegetation_covers:ground_cover_shrub_percent	percent (%)	Percent shrub ground cover
vegetation_covers:ground_cover_dwarf_shrub_percent	percent (%)	Percent dwarf shrub ground cover
vegetation_covers:shrub_cover_observations_count		Total observation samples used in determining percentage of shrub cover
vegetation_covers:shrub_cover_plus_count		The number of observation samples where a shrub was present
vegetation_covers:shrub_cover_minus_count		The number of observation samples where a shrub was not present
vegetation_covers:dwarf_shrub_cover_observations_count		Total observation samples used in determining percentage of dwarf shrub cover
vegetation_covers:dwarf_shrub_cover_plus_count		The number of observation samples where a dwarf shrub was present
vegetation_covers:dwarf_shrub_cover_minus_count		The number of observation samples where a dwarf shrub was not present
vegetation_covers:shrub_cover_plus_percent	percent (%)	Percentage of shrub coverage at the site
vegetation_covers:dwarf_shrub_cover_plus_percent	percent (%)	Percentage of dwarf shrub coverage at the site
vegetation_covers:comments		Comments about vegetation covers
water_temperatures:comments		Comments about water temperature
water_temperatures:water_body_state		State of water body site Options: [normal, frozen, flooded, dry, unreachable]
water_temperatures:water_temp_c	degrees Celsius	Temperature of water
water_temperatures:temperature_method		Method used thermometer or probe

water_temperatures:thermometer_probe_mfg		Manufacturer of thermometer probe
water_temperatures:thermometer_probe_model		Thermometer probe model
water_vapor_noons:precipitable_water	cm	Precipitable water vapor measured within 1 hour of local solar noon
water_vapor_noons:comments		Comments on water vapor measurement
water_vapor_noons:observed_sky_color		Sky color Options: [deep blue, blue, light blue, pale blue, milky] Note: a guide to sky color is provided on page 10 of the GLOBE cloud protocol.
water_vapor_noons:observed_sky_clarity		Sky clarity (i.e., visibility) Options: [unusually clear, clear, somewhat hazy, very hazy, extremely hazy] Note: a guide to sky visibility is provided on page 10 of the GLOBE cloud protocol.
water_vapor_noons:associated_remote_sensor		Satellite mission or instrument to which water vapor observation may be compared Note: open text field filled in by observer
water_vapor_noons:remote_sensor_overflight_time	mm/dd/yy HH:MM	Time the associated remote sensor most nearly flies over the water vapor measurement site in UTC Note: open text field filled in by observer
water_vapor_noons:remote_sensor_maximum_elevation_angle	degrees	The highest angle the satellite mission is above the horizon for the location and time of the water vapor measurement Note: open text field filled in by observer

Water_vapors: precipitable_water	cm	Precipitable water vapor measured
water_vapors:comments		Comments on water vapor measurement
water_vapors:observed_sky_color		Sky color Options: [deep blue, blue, light blue, pale blue, milky] Note: a guide to sky color is provided on page 10 of the GLOBE cloud protocol
water_vapors:observed_sky_clarity	unusually clear, clear, somewhat hazy, very hazy, extremely hazy	Sky clarity (i.e., visibility) Options: [unusually clear, clear, somewhat hazy, very hazy, extremely hazy] Note: a guide to sky visibility is provided on page 10 of the GLOBE cloud protocol
water_vapors:associated_remote_sensor	Text	Satellite mission or instrument to which water vapor observation may be compared Note: open text field filled in by observer
water_vapors:remote_sensor_overflight_time	mm/dd/yy HH:MM	Time the associated remote sensor most nearly flies over the water vapor measurement site in Universal Coordinated Time (UTC) Note: open text field filled in by observer
water_vapors:remote_sensor_maximum_elevation_angle	degrees	The highest angle the satellite mission is above the horizon for the location and time of the water vapor measurement Note: open text field filled in by observer

Appendix 3. MUC code derivation

This appendix contains a description of the methodology for determining MUC codes for a pixel given one or more GLOBE Observer land cover measurements in one or more directions. This only applies to land cover observations submitted via the GLOBE Observer app.

1. Sum the percent coverage for each direction by MUC Code
    a. *I.e.*, sum all "01n" MUC Code percentages for each direction (north, south, east, west). If the user put 50% 01n coverage in all N/E/S/W directions, the sum would be 200%. If the user input 20% coverage for the 02b MUC Code in only the N and E directions, the sum would be 40%.
2. Divide the sum per MUC code by the number of directions the user input. For example, if the user input 4 directions – divide by 4. In the case above, 01n has 200%/4 = 50% overall, while 02b has 40%/4 = 10% overall.
    a. Note: divide by the total number of directional measurements made, not the number of times a specific MUC code shows up in a given direction. Even though 02b was only reported in 2 directions, the user made a total of 4 directional measurements.
3. If any individual MUC code percent is greater than 60%, use that MUC code to store as the representative value for that pixel, and lookup the corresponding MODIS values to use for the associated map color.
    a. If two or more MUC codes exceed 60%, use the one with the highest value.
    b. If two or more MUC codes exceed 60% and are equal, we have no way of choosing one over the other, so the system will randomly choose one.
4. If no individual MUC code exceeds 60%, sum MUC codes percentages by MODIS grouping.
5. Use the highest total MUC-MODIS grouping to determine the representative MODIS color, and use the highest MUC code value from within the grouping for the representative GLOBE pixel MUC code.
    a. Since GLOBE's MUC code does not exactly map to the land cover app MUC codes which have the letter suffix, store the MUC code as 01 in the GLOBE database with the "n" suffix stored separately.
    b. For the example initially provided:
        i. On the Map page - display the code with the suffix if used (01n) on the user's map. Use the 01n to lookup the correct MODIS match (Evergreen Needle leaf forests) and color. Display that color on the map's pixel.
        ii. On the user's review page, the user will see: Overall Land Cover: MUC Code 01n – Closely Spaced, Evergreen – Needle Leaved.

There are 3 MODIS land cover classifications that do not map exactly to specific MUC codes, and are not measured directly, but instead are a combination of one or more MUC codes.

1. Mixed Forests
    a. Dominated by trees with a percent canopy cover of greater than 60% and height exceeding 2 meters. It consists of tree communities with interspersed mixtures or mosaics of the four forest cover types. None of the forest type exceed 60% of landscape.
2. Woody Savannas (open canopy – 30-60% trees)
    a. Lands with herbaceous and other understory systems, and with forest canopy cover between 30-60%. The forest cover height exceeds 2 meters.
3. Savannas (open canopy with grass)
    a. lands with herbaceous and other understory systems, and with forest canopy cover between 10-30%. The forest cover height exceeds 2 meters.

Reference:
http://studentclimatedata.unh.edu/climate/albedo/MODISLandcoverClass_definitions.pdf

To see if any of these calculated values should be used to represent the pixel color:

1. If the sum of any single forest grouping of MUC codes are less than 60%.
    a. *I.e.*, all Evergreen Needleaf Forests (00, 01n, 03, 1, 11n, 13) or all Evergreen Broadleaf Forests (01b, 11b) or Deciduous Needleleaf (02n, 12n), or Deciduous Broadleaf (02b,12n).
2. Then sum all forest types (the combination of all four forest MUC codes listed above).
3. If the sum of all forest types is greater than 60%,
    a. use the “Mixed Forests” color for MODIS matching on the map,
    b. use the one forest MUC code with the highest percentage from the grouping with the highest percentage to store in the GLOBE databased to represent the pixel
        i. *I.e.*, if Evergreen Needleaf Forests is the highest percentage grouping, choose the MUC code from that grouping which has the highest value (like 01n).
    c. On the user’s review page, the user will see: Overall Land Cover: Mixed Forest. Dominant MUC Code 01n – Closely Spaced, Evergreen – Needle Leaved.
4. If the sum of forest types is 30-60%:
    a. If the sum of Grasslands (41,42,43,44) and Forest types** totals at least 90%* of the classification
        i. *I.e.*, if forest is 30% and grass at least 60%, or forest 40%, grass at least 50% etc)
    b. Use the “Woody Savanna” color for MODIS matching on the map
    c. From the grouping (all Forests combined or Grasslands) which totals the highest percentage, use the highest MUC code from that grouping to represent the pixel

        i. *I.e.,* if there's more total forest, choose the MUC code from the forest groupings which is highest. If there's more grass, choose the MUC code from the grass grouping.
    d. On the user's review page, the user will see: Overall Land Cover: Woody Savanna. Dominant MUC Code 01n – Closely Spaced, Evergreen – Needle Leaved.
5. If the sum of the forest types is 10-30%:
    a. If the sum of Grasslands (41,42,43,44) and Forest types[**] totals at least 90%[*] of the classification
        i. *I.e.,* if forest is 10% and grass at least 80%, or forest 20%, grass at least 70% etc.
    b. Use the "Savanna" color for MODIS matching on the map
    c. Use the highest MUC code from the grass grouping to represent the pixel
    d. On the user's review page, the user will see: Overall Land Cover: Savanna. Dominant MUC Code 41 – Tall Grass

[**] All MODIS forest type groupings are summed. No differentiation is made between "open" and "closed" trees.

[*] 90% - it is assumed that trees plus grass must be at least 90% of the constituents before this is considered a savanna or woody savanna. If they total less than 90%, it is not a savanna.