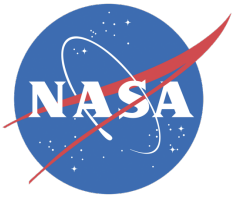
National Aeronautics and Space Administration



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

Version 2.0

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NASA Goddard Space Flight Center
Greenbelt, Maryland, USA

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GLOBE Data User Guide
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Prepared by:
Helen Amos
Senior Research Scientist, Science Systems and Applications, Inc.

Updated by:
Lisa Dallas
GLOBE Data and Information System (DIS) Manager, GSFC Science Data Systems Branch

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):

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):

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
Theresa Schwerin	Institute for Global Environmental Strategies (IGES)
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. Between version releases, updates are posted on the GLOBE Data User Guide landing page of the GLOBE website.

Questions or comments concerning this document should be addressed to:

GLOBE Implementation Office
science@nasaglobe.org

Change History Log

Revision	Effective Date	Description of Changes
v1.0	11 July 2019	Version 1.0 released
v2.0	23 Sep 2019	Description of GLOBE Observer elevation data
v2.0	06 Oct 2019	Aerosol dark voltage maximum value increased from 0.02 to 0.08
v2.0	08 Oct 2019	Datetime conforms with ISO-8601 format
v2.0	08 Oct 2019	Corrected release date for land cover feature in GLOBE Observer app
v2.0	21 Feb 2020	Updated latitude, longitude, and elevation variables in Appendix 2
v2.0	26 Jan 2020	GLOBE API-Out variables formerly output as strings are now output as integers, floats, and Booleans as appropriate
v2.0	08 April 2020	Release of Jupyter Notebook for pulling Mosquito Habitat Mapper (MHM) Data
v2.0	24 June 2020	Release of Jupyter Notebook for pulling MHM protocol bundle data from a user-defined geographic region
v2.0	08 July 2020	Release of Jupyter Notebook used to compare MHM bundle data.
v2.0	28 May 2021	ADAT and API provide the ability to pull data by GLOBE Team name
v2.0	30 Dec 2022	Version 2.0 released, incorporating all changes reported from September 2019 through May 2022

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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
NASA	National Aeronautics and Space Administration
NOAA	National Oceanic and Atmospheric Administration
NSF	National Science Foundation
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 Earth science and education program sponsored by NASA and supported by NSF, NOAA, and the US Department of State that provides students and citizen scientists the opportunity to contribute Earth observations. The GLOBE Program started in 1995, includes more than 126 participating countries, has a mobile app (GLOBE Observer), and has more than 220 million observations contributed from trained students and citizen scientists in its database. This User Guide is a technical document intended to help scientists and researchers understand, access, and use available GLOBE data. All GLOBE science data is freely accessible to all members of the public. A GLOBE system account is not required to access GLOBE science 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 of publication and is updated at the major milestones. Upon approval, this document is placed under configuration control. Approved changes are listed in the document's Change History Log.

Pending updates to the GLOBE Data User Guide are listed on the GLOBE website's GLOBE Data User Guide landing page under the heading "User Guide Updates". Each update notice describes an approved change to GLOBE data (e.g., a change in variable(s) formats, addition of variable(s), etc.) Once a new version of the UG is released that incorporates these changes, the update notices are removed from the GLOBE Data User Guide landing page and archived.

Submitting Suggested Changes

Suggested updates, additions, edits, and corrections are welcomed. Please email your suggestion(s) to science@nasaglobe.org 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. GLOBE Educators (i.e., classroom teachers, informal educators) receive training to become certified for data entry for all of the GLOBE protocols. Protocols are specific data collection methods. Trained GLOBE Educators teach those protocols to their students, and then collect and contribute measurements to the GLOBE database. Today there are more than 38,000 schools, and 220,000 citizen scientists in the GLOBE network who have contributed 220 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 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 was re-activated in 2019 for the South American Solar Eclipse, and plans are to re-activate it for future Eclipse events. All observations submitted through the GLOBE Observer app are stored in the GLOBE database. Today there are close to 1 million 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 trained Educators; and (2) GLOBE Basic Account Holders. GLOBE Educators complete protocol training by attending an in-person workshop or by completing a set of online training modules that include an introductory module, a module for a particular sphere, and a module for a protocol within the sphere (e.g., *Atmosphere* and *Air Temperature*). Once completed, the user may enter data for **any** of the other GLOBE protocols **in any sphere**. GLOBE Educators may submit data via a variety of methods, including the GLOBE Observer App. A user must request a GLOBE Educator account; requests are reviewed and approved by a user's GLOBE Country Coordinator.

Any user from a GLOBE participating country can obtain a GLOBE Basic Account. GLOBE Basic Account Holders contribute environmental data for the four protocols available to citizen scientists via the GLOBE Observer app. Basic Account Holders are guided through an in-app tutorial before submitting data for the first time for any of the citizen science protocols. Users may complete any/all of the four tutorials.

NOTICE
GLOBE, in accordance with NASA policy, promotes the full and open sharing of all science data with research and applications communities, private industry, academia, and the public. A GLOBE account is not required to access GLOBE observation data.

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 science@nasaglobe.org.

1.2 Data Set Characteristics

1.2.1 Sampling frequency

Discrete. Users can report a single observation at a site, or return to that site periodically to report one or more observations over a period of months-to-years.

1.2.2 Time

Time is reported in UTC (Universal Coordinated Time). Date and time formats conform to the ISO-8601 standard.

1.2.3 Spatial coverage

Worldwide. More than 126 countries participate in GLOBE (see Figure 2). Visit the GLOBE website to see the complete list of countries.

1.2.4 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 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. Observations submitted through the GLOBE Observer app for the four protocols available to citizen scientists are associated with the nearest 100-meter x 100-meter MGRS grid box based on the measured (or entered directly by the user) latitude and longitude from the user's smartphone Global Positioning System (GPS). A GLOBE measurement site and "site ID" is generated based on the associated MGRS grid box (see Appendix 2). In the future, if a measurement resolves to the same

grid box and the site for this box is already defined, then those measurements are associated with that site.

In addition, data submitted through the GLOBE Observer app is also associated with a "true" measurement location. The "true" location of an Observer measurement is the latitude and longitude recorded by the Global Position System (GPS) reading from a person's mobile device. The GLOBE Observer app does not convey GPS elevation, but instead a Google web service is used that determines elevation based on WGS84 EGM96 geoid height. Thus, the four GLOBE observer protocols available to citizen scientists will have two sets of location data:

Site Location Variables	True Location Variables
latitude	<protocol name>:measurement latitude
longitude	<protocol name>:measurement longitude
elevation	<protocol name>:measurement elevation

In June 2022, GLOBE added the "location method" and "location accuracy" as output from both the ADAT and API-Out tools for the four GLOBE Observer protocols. The location method can either be "Automatic" indicating that the phone-derived latitude and longitude were used, or "Manual", indicating that the user entered values for latitude and longitude. The location accuracy in meters is calculated by the phone. Users are instructed to wait to enter measurement data until the reported accuracy is within 12 meters or less. Measurements with a "manual" location method will not have a "location accuracy" value.

Appendix 2 provides the units and definitions for these and all other GLOBE data variables.

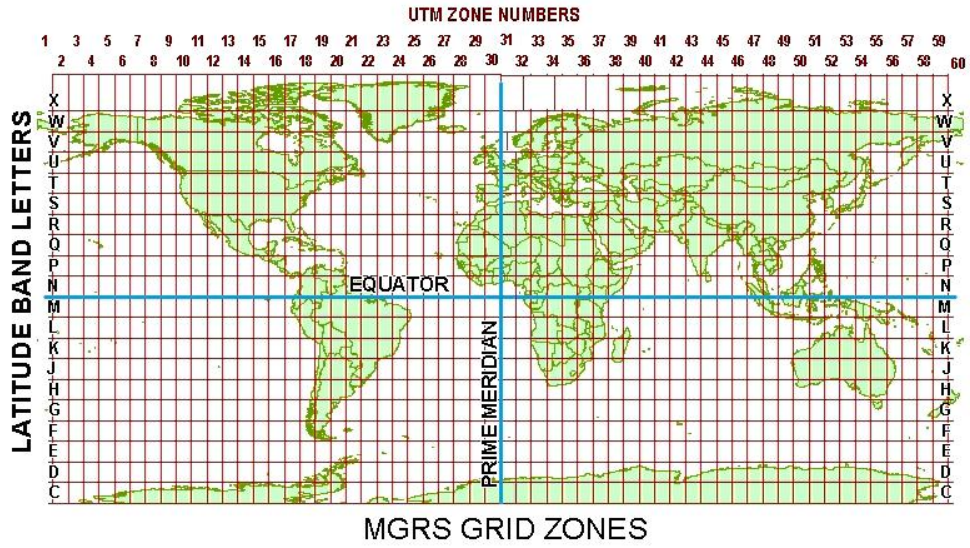


Figure 1. Military Grid Reference System (MGRS) Grid Zones.
Source: National Geospatial Intelligence Agency.

Figure 2. Participating GLOBE countries. Current as of December 2022. 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 (e.g., GLOBE school or GLOBE Team) and individuals (numerical user ID). Spatial and temporal resolutions vary depending on the requirement of a protocol.

1.4 User Privacy

The GLOBE Data and Information System (DIS) assigns a unique numerical ID to each Member and Educator account. Each measurement submitted to the GLOBE database is associated with the numerical ID of the user that submitted the measurement. There is no way for any website visitor or GLOBE account holder to associate a userID with the user's name, email, or any other identifying information.

In addition, all photos that are submitted as part of an observation are screened for faces and identifiable location information, such as license plates or street signs. Before 2022, these photos were manually screened by GLOBE Program staff. Since early 2022, Amazon Web Services "Rekognition" computer vision platform performs the screening and blurs those features such that they are no longer recognizable. The "sanitized" photo is then stored in the database. Any photos that do not pass the automated screening process are then manually screened by GLOBE program staff and are either rejected or accepted into the database based on the photo's content.

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 documentation about GLOBE science protocols available online. GLOBE Educators can submit data five ways: desktop data entry forms, email data entry, application programming interfaces (APIs), the GLOBE data entry app, and the newly added sphere modules from within the GLOBE Observer app. Ingest of data submitted via email lacks the ability to process images.

Users with a GLOBE Basic Account are limited to the four citizen science protocols in the GLOBE Observer app to collect and submit observations of clouds, mosquito habitats, land cover, and tree height.

In 2021, the GLOBE Program began an effort to migrate data entry for all GLOBE protocols into the GLOBE Observer app, with a goal of eventually replacing the current GLOBE Data Entry app. At present, data entry for GLOBE atmosphere and hydrosphere protocols is available from the GLOBE Observer app for GLOBE Educators (GLOBE Members do not see the option to enter atmosphere or hydrosphere data.) Eventually, data entry for all GLOBE protocols will be available within the GLOBE Observer app for GLOBE educators and the existing GLOBE Data Entry app will be decommissioned. The redesigned GLOBE data entry includes improvements such as dynamic site definition based on the user's GPS location, as well as automated prompting for all information required for selected protocol(s). Users see the list of existing sites within their immediate area and can opt to have the observation associated with one of these sites, or they can choose to dynamically create a new site. Figure 3 depicts the "Home" screen of the GLOBE Observer app for GLOBE Educators. GLOBE Basic Account Holders see the same screen except for the "Atmosphere Data Entry" button.

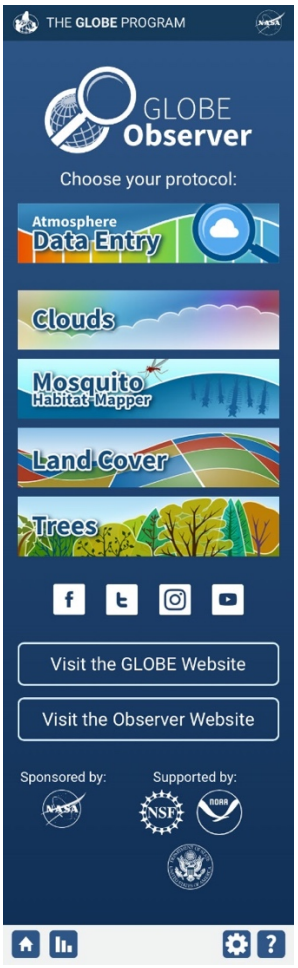


Figure 3. GLOBE Observer app home screen.

A Hydrosphere module was added to the GLOBE Observer app in Summer 2022, with expectations to be followed by Biosphere and the Pedosphere modules in 2023.

2.1 GLOBE Educator Training

Training for GLOBE Educators has traditionally occurred at in-person workshops, which are offered around the world and teach the appropriate data collection procedures for various protocols. As of 2017, educators can also be trained online ("eTraining") by completing several required online training modules. Any visitor to the GLOBE website can view the content of GLOBE's eTraining modules. However, for a GLOBE user to complete eTraining assessments and be labeled as trained, one of the following must be true:

- Outside the United States: The user has an approved GLOBE Educator account and eTraining is approved by the user's GLOBE Country Coordinator
- Within the United States: the user has a GLOBE Basic or GLOBE Educator account

The GLOBE Teacher's Guide is a foundational resource for educators training their students to take 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 take measurements as well as guidance on instrumentation. Protocols are intended to be used as written, using instruments that meet certain specifications to ensure consistency and data accuracy worldwide. Participants should not submit data if it does not follow the protocol. Protocols include instructions for instrument calibration. The landing page for the Teacher's guide on the GLOBE website contains a list of the Scientific Instruments for Collecting GLOBE Data as well as clothing incorporating the GLOBE logo.

2.2 GLOBE Science Protocols

List 1 provides a list of GLOBE science protocols 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. You must be a GLOBE Educator or a **trained** GLOBE Basic Account holder within the United States to enter data for all protocols listed, except for clouds, mosquitos, land cover, and tree height, which are the four protocols available to citizen scientists in the GLOBE Observer App.

List 1. GLOBE Science Protocols[1]

Atmosphere

- Aerosols
- Air Temperature
- Barometric Pressure
- Clouds (Sky Conditions)
- Precipitation
- Relative Humidity
- Surface Ozone*
- Surface Temperature
- Water Vapor
- Wind

Hydrosphere

- Alkalinity
- Conductivity
- Dissolved Oxygen
- Freshwater Macroinvertebrates
- Mosquitoes[2]
- Nitrates
- pH
- Salinity
- Water Temperature
- Water Transparency (Turbidity)

Biosphere

- Biometry[3]
- Carbon Cycle
- Green-Down (Senescence)
- Green-Up
- Land Cover
- Lilac Phenology*
- Phenological Gardens

Pedosphere (Soil)

- Bulk Density
- Frost Tube
- Soil Characterization
- Soil Fertility
- Soil Infiltration
- Soil Moisture – Gravimetric
- Soil Moisture – Sensors*
- Soil Moisture – SMAP
- Soil Particle Density
- Soil Particle Size Distribution
- Soil pH
- Soil Temperature

* Scheduled for retirement in 2022 or 2023
[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.
[3] The Biometry protocol consists of several measurements including Graminoid Biomasses, Vegetation Covers, and Tree Height. The GLOBE Observer app contains a tool for measuring tree height that may be used by untrained GLOBE users.

2.3 GLOBE Observer Mobile App

This section provides greater detail about the four protocols available to citizen scientists in the GLOBE Program's app, GLOBE Observer. 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 (as well as periodic software updates) and to upload any data collected for the protocols. Collected data can be stored on the user's phone until the user is within range of a wifi or cellular network and can upload the 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. The GLOBE Observer app lets GLOBE Basic Account holders (as well as GLOBE Educators) collect and report cloud, mosquito habitat, land cover, and tree height observations.

GLOBE Educators have access to the "All GLOBE Data Entry" portion of the app, which allows them to enter data for all of GLOBE's protocols. At this writing, only the GLOBE Atmosphere and Hydrosphere protocols are available within GLOBE Observer as shown in Figure 3.

Photographs/Images

The GLOBE Observer app gives users 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.

It should be noted that most cell phone cameras auto-correct picture attributes such as contrast, clarity, and color saturation (to varying degrees depending on the make and model of the phone and user settings). This should be considered when evaluating observations that report sky color and sky visibility. User reported values for these attributes may outweigh what is represented in the corresponding photo.

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 in the GLOBE database as .jpg files.

Figure 4. 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 (S’COOL) [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 cloud observation are below.

Required elements of a cloud 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.

Dust events have been reported by GLOBE Observer users using the clouds tool through the obscuration option. Users enter the photographs of the event manually to capture the horizon and not the sky. The NASA GLOBE Clouds team created a section for dust observations with descriptions on how to report the dust event and submit photographs of the horizon. The section also contains information about dust events worldwide and available educator resources. A quality-assured GLOBE Dust dataset is available for download from the GLOBE Observer website.

The NASA GLOBE Clouds team at Langley Research Center matches GLOBE Observer cloud observations to corresponding satellite data for NASA's Aqua and Terra satellites. Users can opt-in to receive notifications on their phone about satellite flyovers, use the satellite overpass tool within the GLOBE Observer Clouds module, or send an email with satellite overpasses via the online satellite overpass calculator to see scheduled flyover times. 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. Observations are matched to multiple geostationary satellites, CERES instruments onboard Aqua and Terra, and CALIPSO. Guides on how to read the satellite match tables for geostationary, Aqua and Terra satellites, as well as for matches with the CALIPSO satellite are all available on the NASA GLOBE Clouds website. Complete documentation of the satellite matching method is also available that include details on satellite footprint definition.

More information is available on how to make cloud observations in the GLOBE Observer app. Also available is a toolkit for informal educators on the GLOBE Observer website.

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 several eclipse data sets from the event, are posted on the GLOBE Observer website.

Before major solar eclipses, this special, limited time tool is planned to be added to the app to allow citizen scientists to submit air temperature data in addition to the 4 protocols normally available to citizen scientists. For more information about the eclipse tool, please visit the Eclipse area of the GLOBE Observer website.
The temporary Eclipse tool was added to the GLOBE Observer app in 2019 in support of the eclipses on July 2019 and December 2020, both over parts of Chile and Argentina.

Current eclipse data sets available through Vis (clouds and air temperature):

- August 21, 2017 (path of totality over North America)
- July 2, 2019 (path of totality over South America)
- December 14, 2020 (path of totality over South America)

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 A user will need to use a lens with a 60x magnification or higher. The app is optimized for identification of the following genera and species:

- *Culex,* many species of which are implicated in a wide variety of diseases, including West Nile Virus
- *Anopheles*, the genus primarily responsible for transmission of malaria
- *Aedes,* many species of which are implicated in the transmission of pathogens causing a variety of diseases in humans, including dengue, chikungunya, yellow fever and Zika. *Aedes aegypti* and *Aedes albopictus,* in particular, are two species which originated in tropical and humid subtropical regions in Africa and Asia and are now invasive disease vectors in a variety of regions and environments.

It should be noted that any genus/species identification supplied by citizen scientists should be validated by scientists through examination of the associated voucher photographs.

Tutorials, an instructional video, and additional training resources about Mosquito Habitat Mapper are available on the GLOBE Observer website, where you will also find a toolkit for informal educators. The app also contains a tutorial for taking a mosquito measurement.

2.3.4 GLOBE Observer Land Cover

In September 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 compare 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, The GLOBE Program 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 take land cover observations using the GLOBE Observer app can be found on the GLOBE Observer website, where you will also find a toolkit for informal educators.

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. Upon first use of the app, the user is asked to select the preferred system of measurement (either Metric or English) for entering their height and stride length. The user is asked his/her height, then the Trees tool estimates stride length in meters (L) and height of phone camera (h) of the user:

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

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 A and B as shown in Figure 5. The user will then walk to the base of the tree, counting steps, and entering the number of steps into the app. The user must be at least 12 steps from the base of the tree and 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.

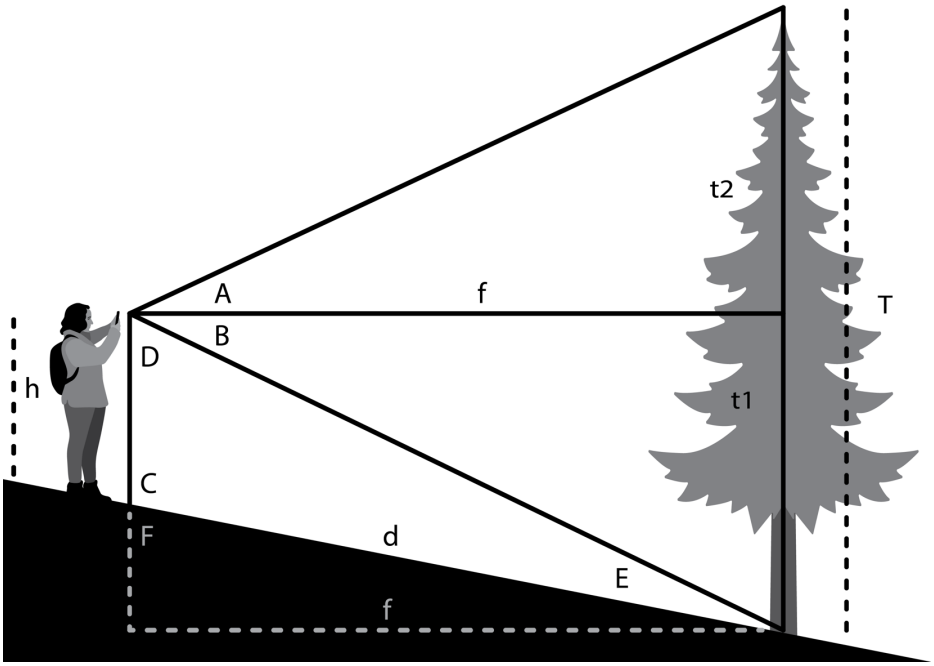


Figure 5. Geometry of tree height measurement. Schematic of tree height observation made using the Trees tool in the GLOBE Observer mobile app. 0 degrees is straight down, 90 degrees at the horizon, 180 degrees is straight up.

Tree height is computed as follows:

Values reported by user via the app:

n : number of steps to the tree
H : user height

Values measured using the app:

A : app-measured top angle (degrees)
B : app-measured bottom angle (degrees)

Calculated values:

T : full tree height (meters)
d : ground distance to tree (meters)
L : stride length (meters)
h : camera height (meters)
f : horizontal distance to tree (meters)
t1 : lower tree height (meters)
t2 : upper tree height (meters)

Table 1. Tree Height Calculation – Derived Values

Step/Description	Formula
Estimated stride length based on user height	L = H * 0.413
Calculate ground distance based on number of steps and stride length	d = n * L
Estimated camera height based on user height	h = H – 0.1014

Step/Description	Formula
Law of Sines	Sin(E) / h = Sin(D) / d
Multiply by h	Sin(E) = h * Sin(D) / d
Take inverse sine (arcsin)	E = arcsin(h * Sin(D) / d)

Step/Description	Formula
Properties of a triangle	F = 180 – C and C = 180 – (D + E)
Substitute for C	F = 180 – (180 – (D + E))
Simplify	F = D + E

Step/Description	Formula
Basic trigonometry, opposite side over hypotenuse	f / d = Sin(F)
Multiply by d	f = d * Sin(F)
Substitute for F	f = d * Sin(D + E)
Substitute for E	f = d * Sin(D + arcsin(h * Sin(D) / d))
Properties of a triangle	D = 90 – B
Substitute for D	f = d * Sin(90 – B + arcsin(h * Sin(90 – B) / d))

Step/Description	Formula
Basic trigonometry, opposite side over adjacent side	t1 / f = Tan(B) and t2 / f = Tan(A)
Multiple by f	t1 = f * Tan(B) and t2 = f * Tan(A)
Total tree height is the combination of t1 and t2	T = t1 + t2
Substitute for t1 and t2	T = f * Tan(B) + f * Tan(A)
Distributive property	T = f (Tan(B) + Tan(A))
Substitute for f	T = d * Sin(90 – B + arcsin(h * Sin(90 – B) / d)) * (Tan(B) + Tan(A))

Final formula:
$$T = d * \sin(90 – B + \arcsin(h * \sin(90 – B) / d)) * (\tan(B) + \tan(A))$$

Based on user testing, the error in T 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 (A) and bottom (B) angles to a level of accuracy that results in relatively small T error (2-3%) when users are less than 100 (but greater than 11) 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 T 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.

The GLOBE Observer website provides details about taking tree height observations in the GLOBE Observer app, as well as a toolkit for informal educators.

List 2. Required and optional trees fields

Required Observations[1]

- **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
- **Review**
  - camera height
  - stride length
  - number of steps
  - distance to tree

Optional Observations

- **Photograph your 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 Educators must complete the necessary training either by attending an in-person GLOBE workshop or by completing online eTraining modules and assessment tests to enter data via the GLOBE data entry forms for desktop, via the GLOBE Data Entry app, through the GLOBE Observer "All Data Entry" option (currently available for atmosphere and hydrosphere protocols), and via email data entry. The user must complete three modules and take the corresponding assessment tests as follows to become a trained GLOBE Educator 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 completing 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 GLOBE 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, is available on the GLOBE website.

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 0.08. 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 the data. Documentation about the date entry range and logic checks is available on the GLOBE website.

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 by the GPS on the user’s device. The 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. Section 1.2 Data Set Characteristics explains how location is stored for measurements submitted via the GLOBE Observer app. If using the GLOBE Data Entry app, GLOBE data entry desktop forms, or email data entry, the measurement is associated with the user’s GLOBE site’s latitude and longitude.

Elevation:
GLOBE's GPS protocol states that a site's elevation is in relation to mean sea level (MSL). In 1995, the thinking was that sites would be defined over land only and so the elevation would be based upon the topographic elevation difference from MSL. Most GPS devices in the 1990s and early 2000s used the ellipsoid model to determine elevation, which could be as much as 100m off from the geoid height. GLOBE's former database converted the GPS elevation values to geoid heights and presented those geoid heights on the legacy Vis system. In 2014, GLOBE discontinued this practice because more recent GPS devices are capable of determining elevation using the geoid height themselves. The GLOBE Observer app does not convey GPS elevation, but instead a Google web service is used that determines the height from MSL based upon the WGS84 EGM96 geoid height. It includes both bathymetry and topography values. The consumer of GLOBE data can assume that a returned elevation value for a site is based upon the geoid height of the landform from MSL. In other words, if the coordinates are over dry land, it will be the topographic height. If the coordinates are over the ocean or sea, then elevation is reported is the distance of the seafloor from MSL expressed as a negative value.

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 (PII) (e.g., automobile license plate numbers or street signs) are removed or have the faces and/or PII 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 data, 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 a “createDate” timestamps relevant to the date of migration versus the date of original measurement. The “createDate is no longer surfaced in the API-Out and ADAT tools. 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), “createDate”, and “updateDate”. The “measured” timestamps records when the measurement was observed and is the timestamp relevant for research. The “createDate” timestamp indicates when a record of the measurement was created in the GLOBE database and “updateDate” indicates when the measurement was last updated in the GLOBE database for various reasons (and is also no longer surfaced in API-out and ADAT tools). 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 (See Appendix I and II of this document.). **GLOBE data users are strongly encouraged to read and understand the science protocol(s) relevant to your data of interest (see Section 2 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 science@nasaglobe.org.

5. Data Visualization

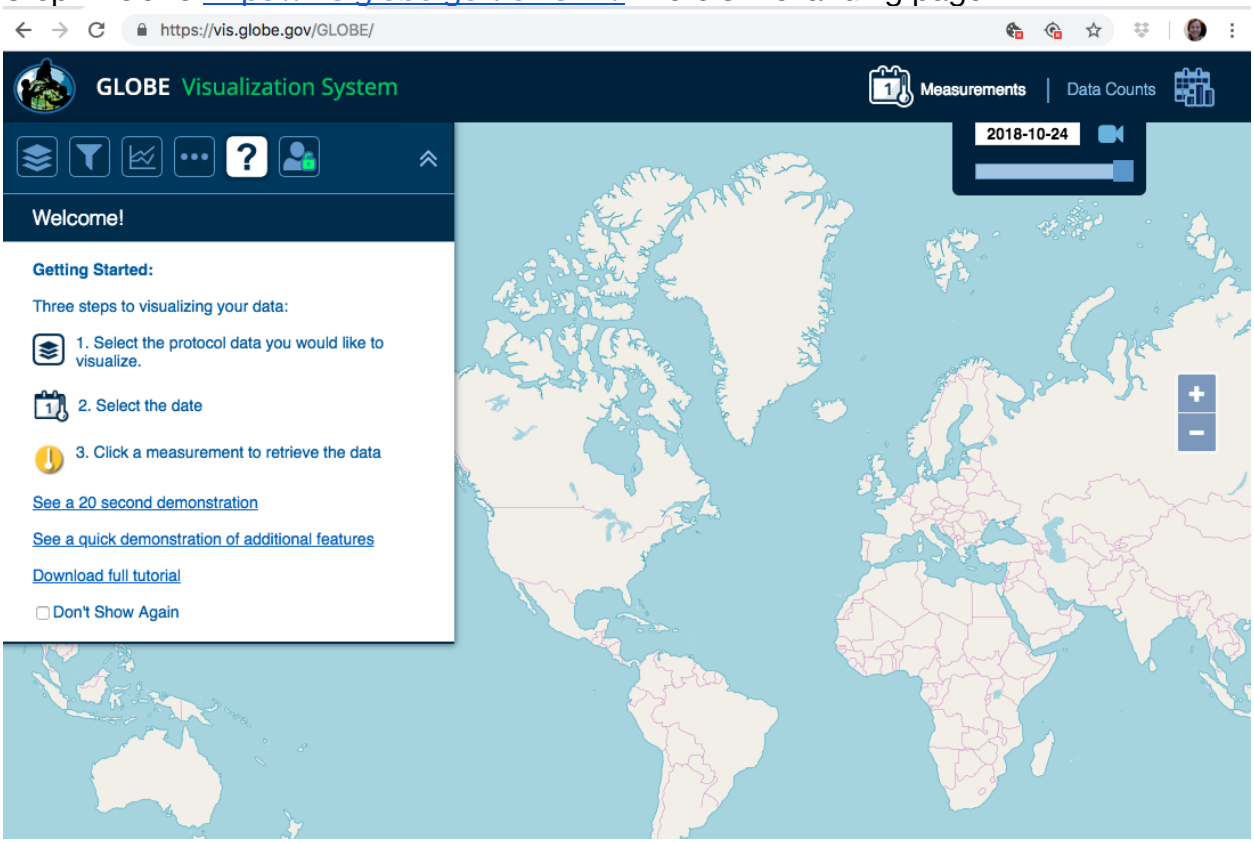
GLOBE data can be viewed on a map in your web browser using the GLOBE Visualization System. A tutorial on how to use the GLOBE Visualization System is already embedded in the mapping tool and appears when users visit the site. An additional tutorial for the visualization system (PowerPoint) is available on the GLOBE website. Below are several links to examples of how data is displayed in the GLOBE Visualization System, also simply referred to as "GLOBE Vis." The instructions for producing these visualizations follow the links. In general, users can view data values for one or more selected protocols *for a single day* by selecting the "Measurements" tab. To see an estimate of the amount of data available for a specified protocol and time range, select the "Data Counts" tab.

Quick links

See cloud cover on a map.
See land cover photos on a map.
See mosquito habitats on a map.
See tree height photos on a map.

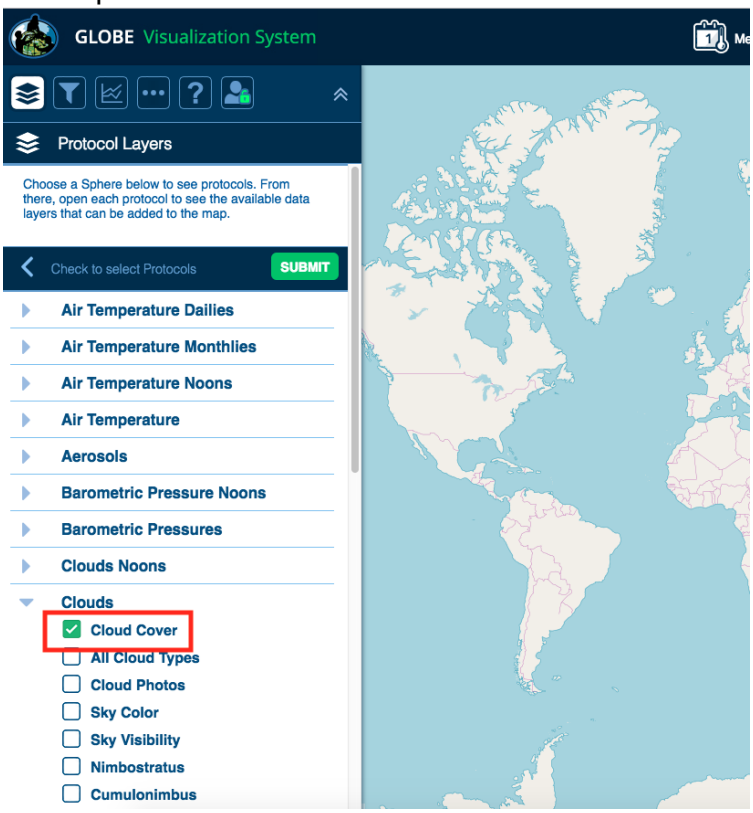
Example: View 2017-2018 cloud cover data on a map with the GLOBE Visualization System

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

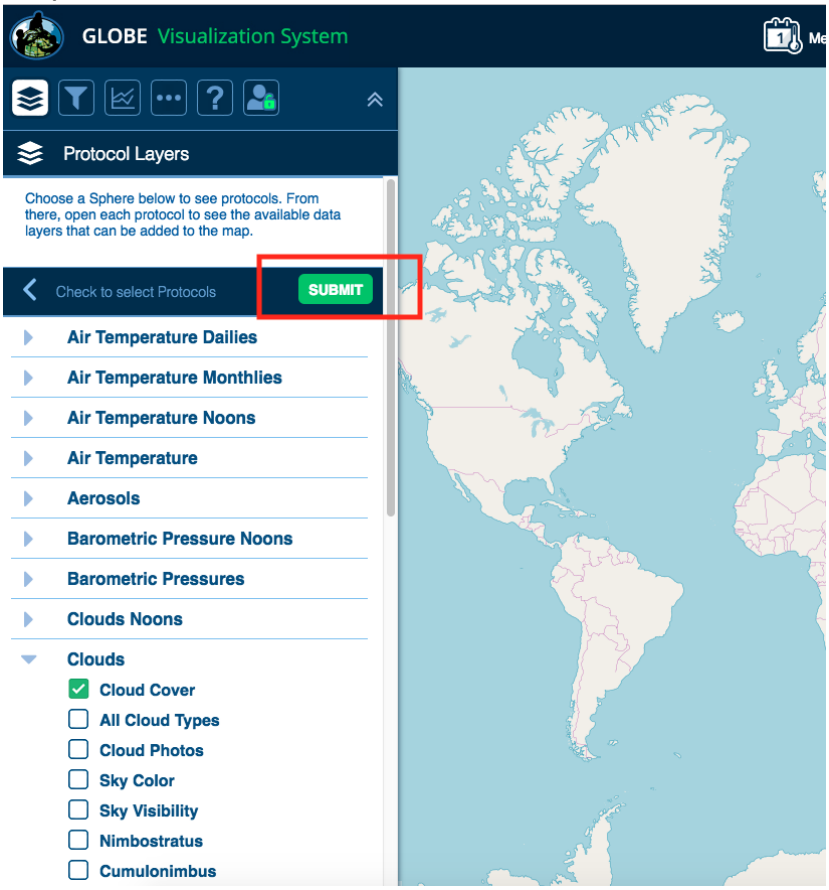


Step 2: Select layers by clicking the button:

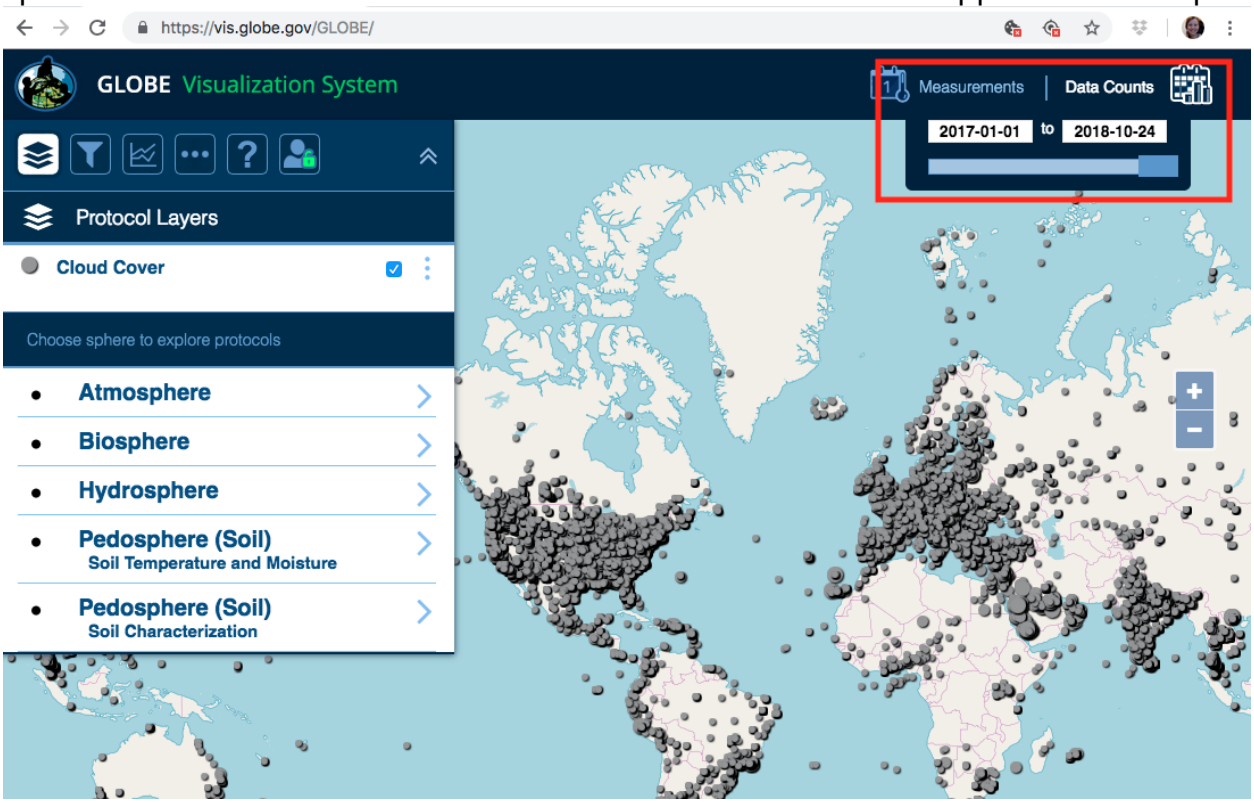
Step 3: Next, select the sphere(s) containing the protocol(s) you want to visualize, the protocol(s), and the subset(s) of data for the protocol. For this example, Select Atmosphere >> Clouds >> Cloud Cover



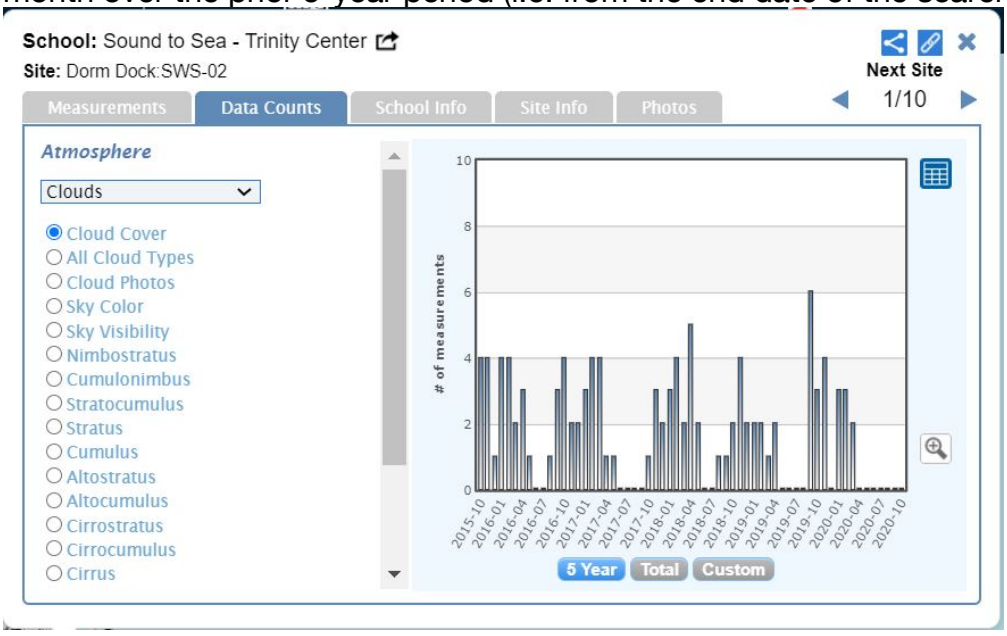
Step 4: Click “Submit”



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



Note: Data Counts displays sites that have data for the period requested. The size of the dot indicates the amount of available data (i.e., larger dots mean a larger amount of data at that site relative to other sites.) Clicking on an individual point (i.e., site) opens a pop-up window containing a graph showing the total number of observations per month over the prior 5-year period (i.e. from the end date of the search back 5 years).

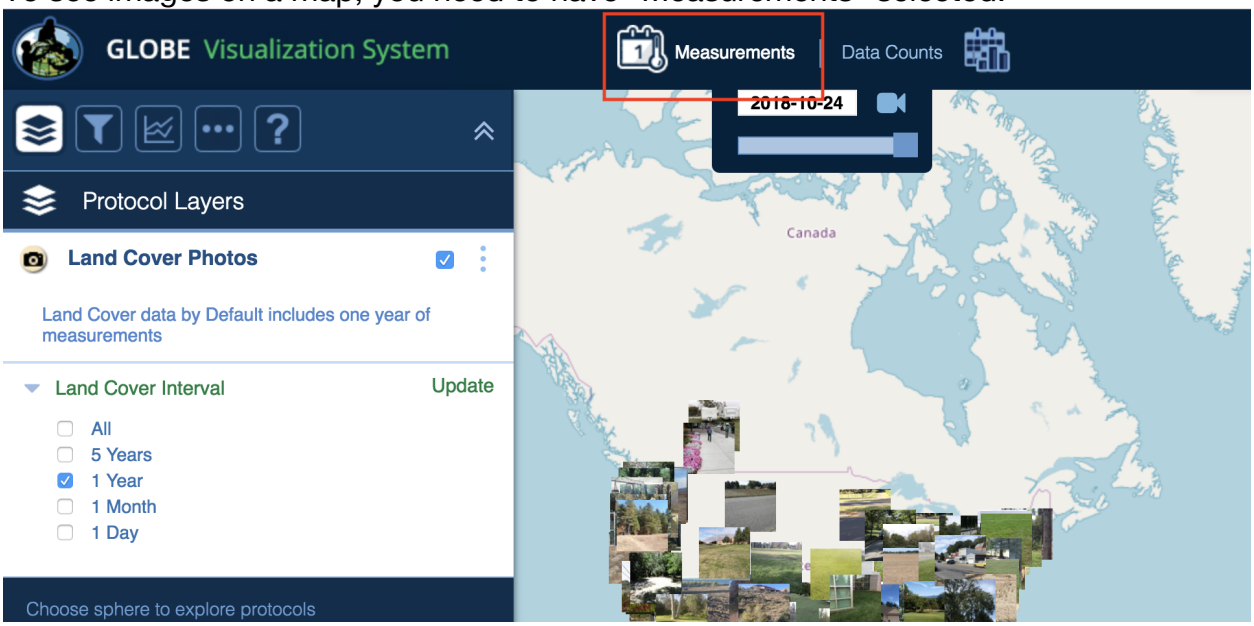


Users can adjust the graph to display total number of observations on a yearly, quarterly, or monthly basis.

Users can further customize a visualization or get help with the following options:

Icon	Action
	Options for filtering data based on criteria such as location
	Allows you to change the base map and toggle display of the map grid
	Option for creating a multi-site plot
	Displays quick instructions as well as access to quick demos and links to detailed tutorials.

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.
Photos are associated with the following protocols in GLOBE:
1. Clouds
2. Land Cover
3. Mosquito Habitat Mapper
4. Trees

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

New naming convention coming in TBD:
protocol_latlon_yyyymmddTHHMMZ_direction_photoid.jpg

Table 2. Elements of the suggested 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 : fullbody 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

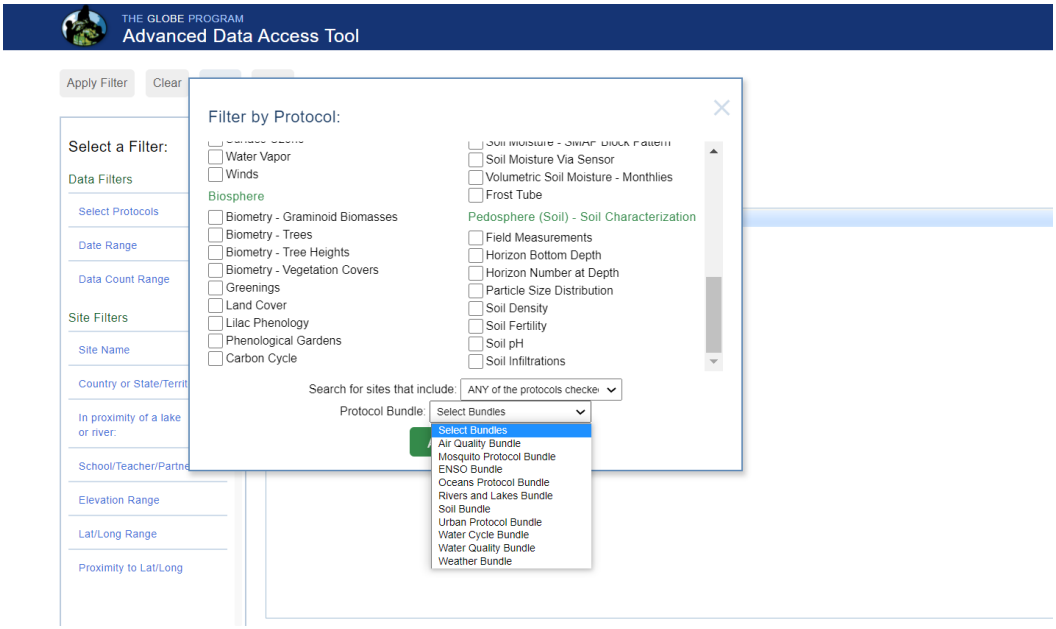
Downward land cover photo from Oregon
GLOBELC_N044W123_20190110T1132Z_DOWN_917653.jpg

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 last year's 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 worldwide."

ADAT also includes the ability to retrieve data for selected GLOBE Protocol Bundle(s), which are groupings of GLOBE Protocols that are commonly examined together to study a particular system or phenomenon. Examples of GLOBE Protocol Bundles include "Air Quality", "Agriculture", and "Weather".



Note that very larger data sets (> 1 million records) should be retrieved with GLOBE's API as described in Section 6.2, or the user should narrow the specified search filters to reduce the size of the data set.

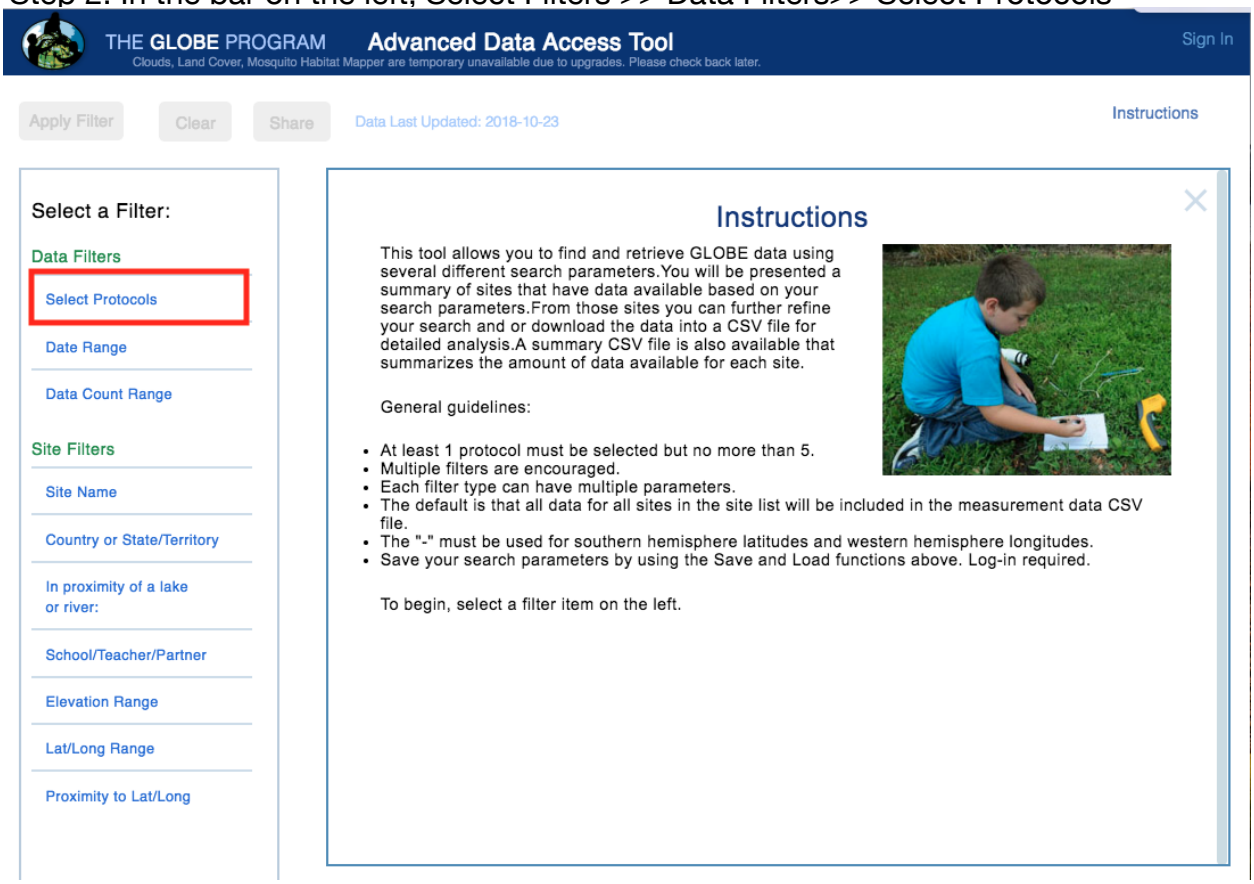
Simplified instructions for how to use the visualization system and ADAT are available when you launch the tool. This PowerPoint tutorial provides additional instruction.

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

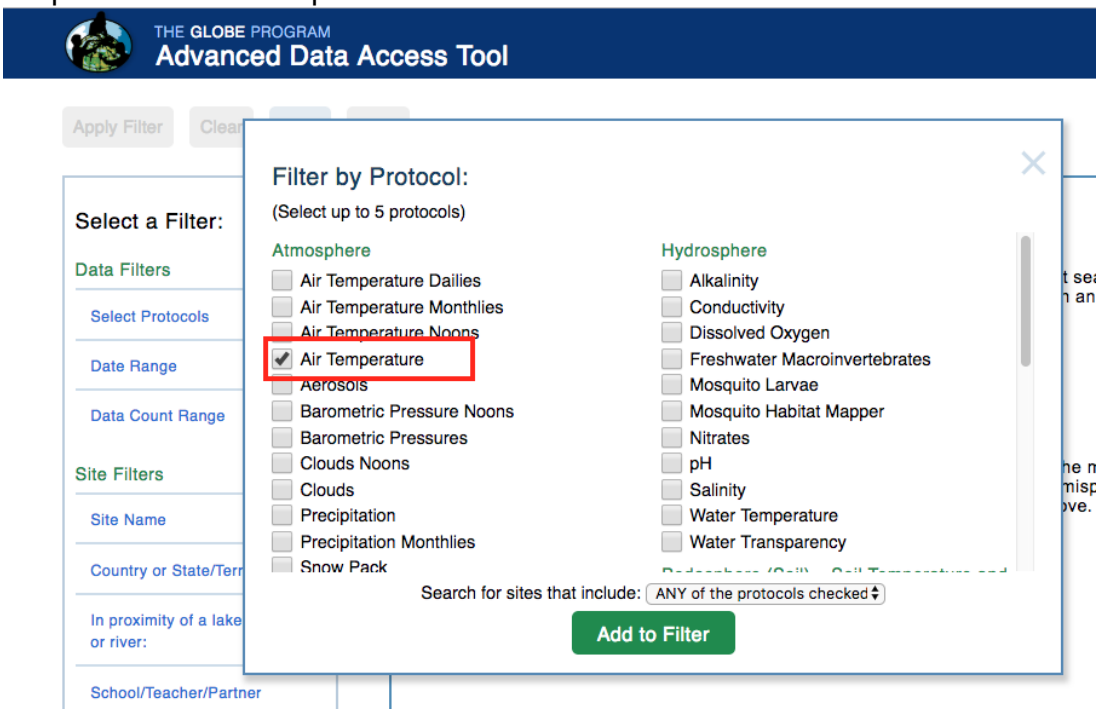
Example: Via ADAT, download GLOBE air temperature data from California for 2017-2018

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

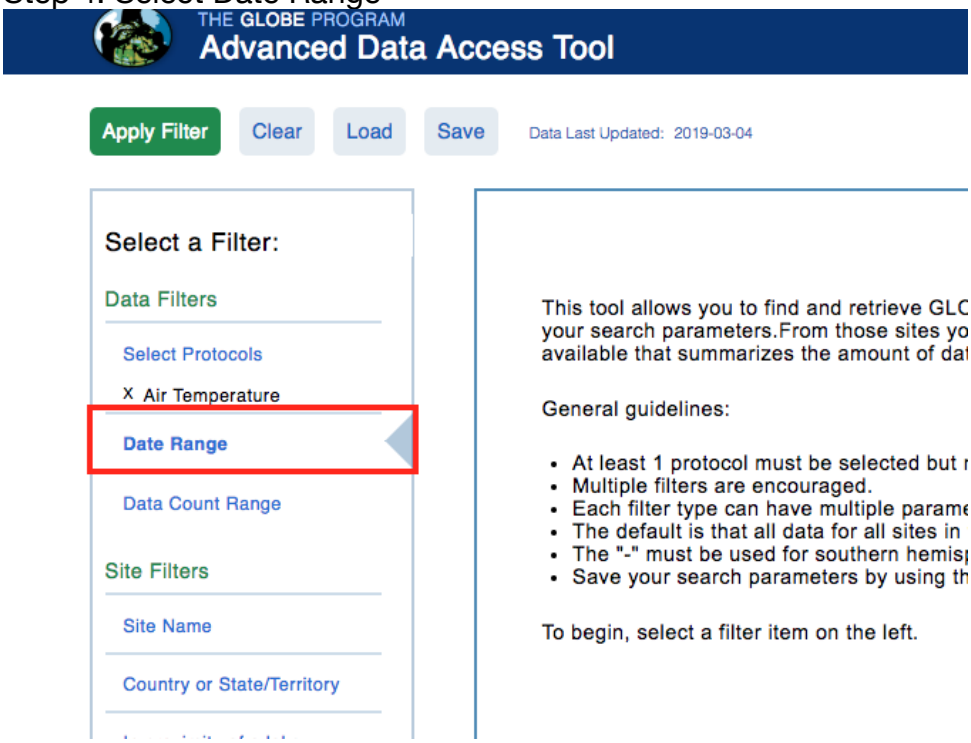
Step 2: In the bar on the left, Select Filters >> Data Filters>> Select Protocols



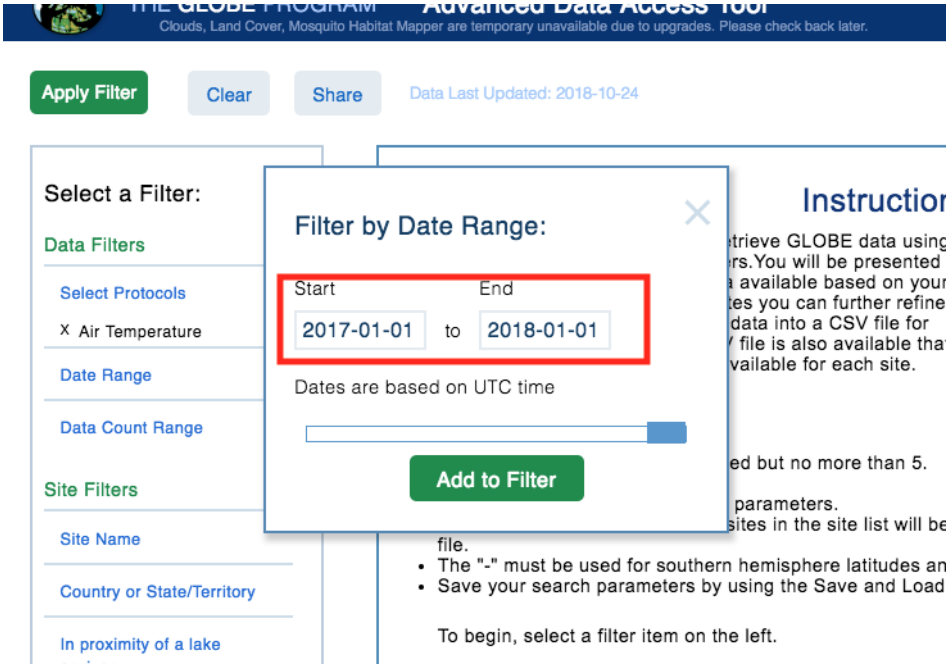
Step 3: Select air temperature. Click “Add to Filter”



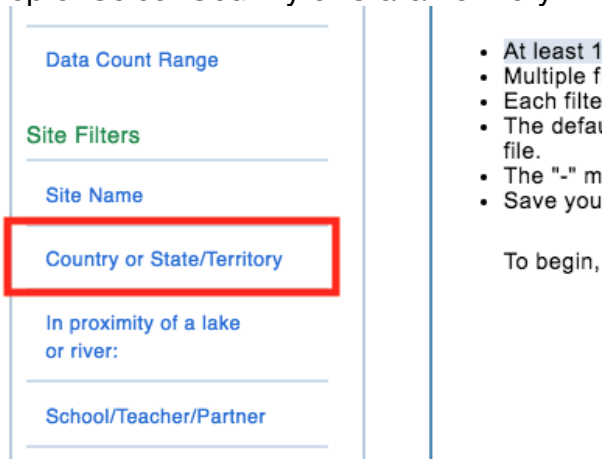
Step 4: Select Date Range



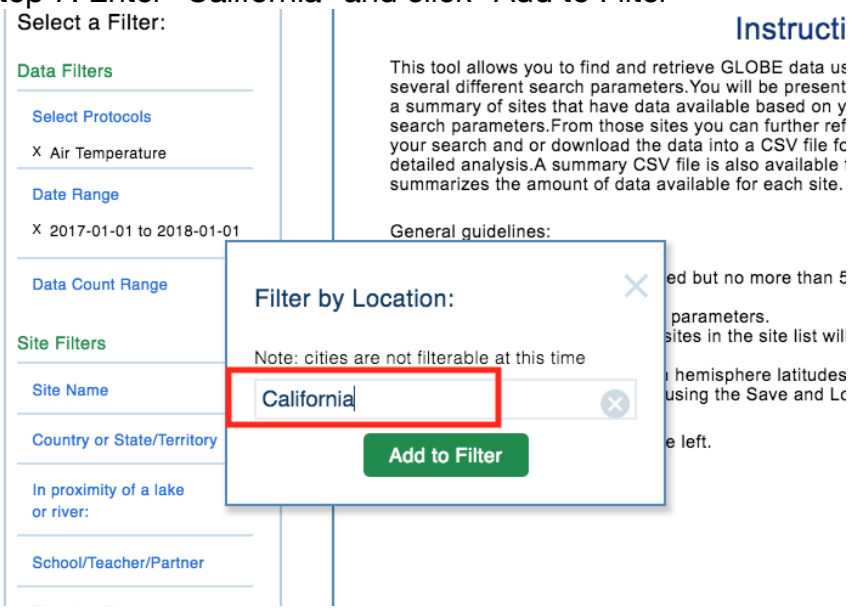
Step 5: Enter 1 January 2017 as the Start Date and 1 January 2018 as the End Date. Click “Add to Filter” when done.



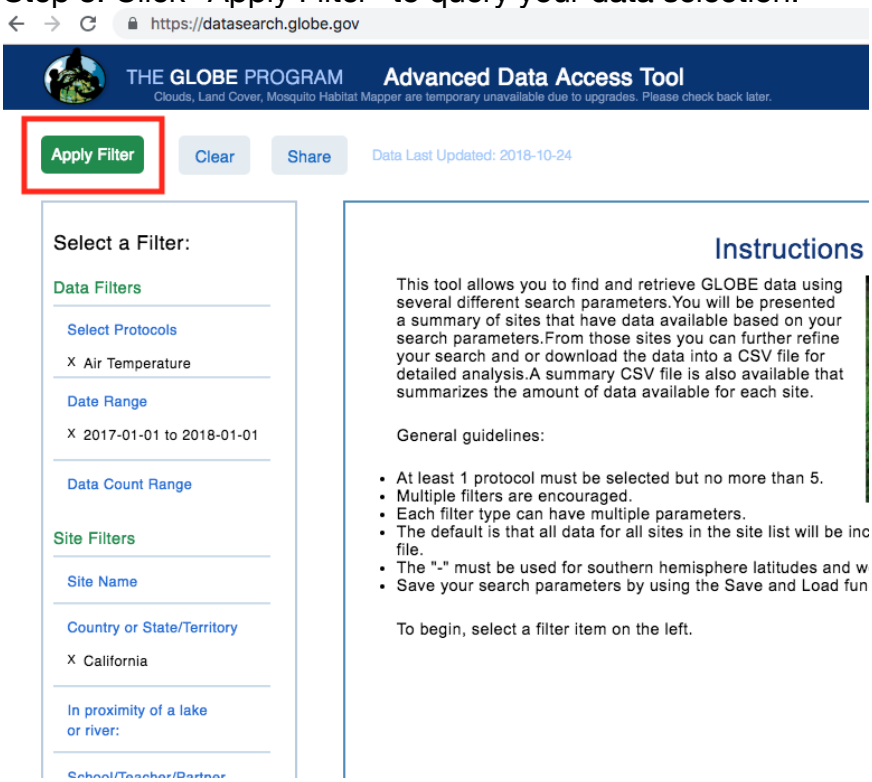
Step 6: Select Country or State/Territory



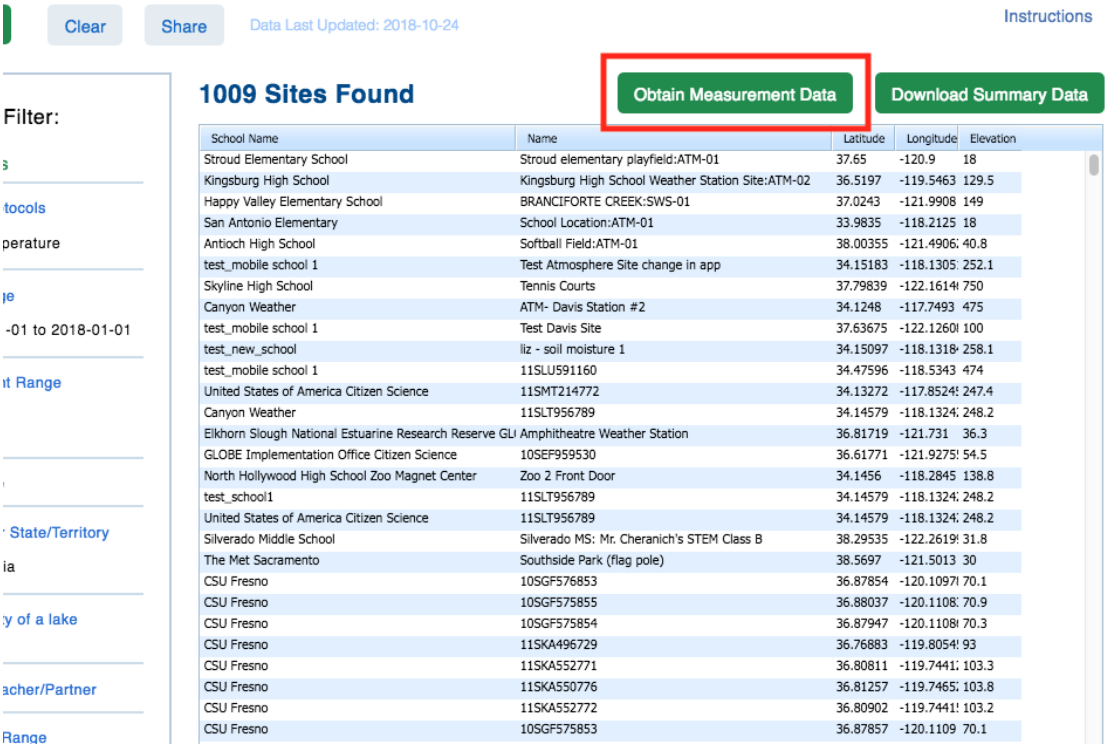
Step 7: Enter “California” and click “Add to Filter”



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

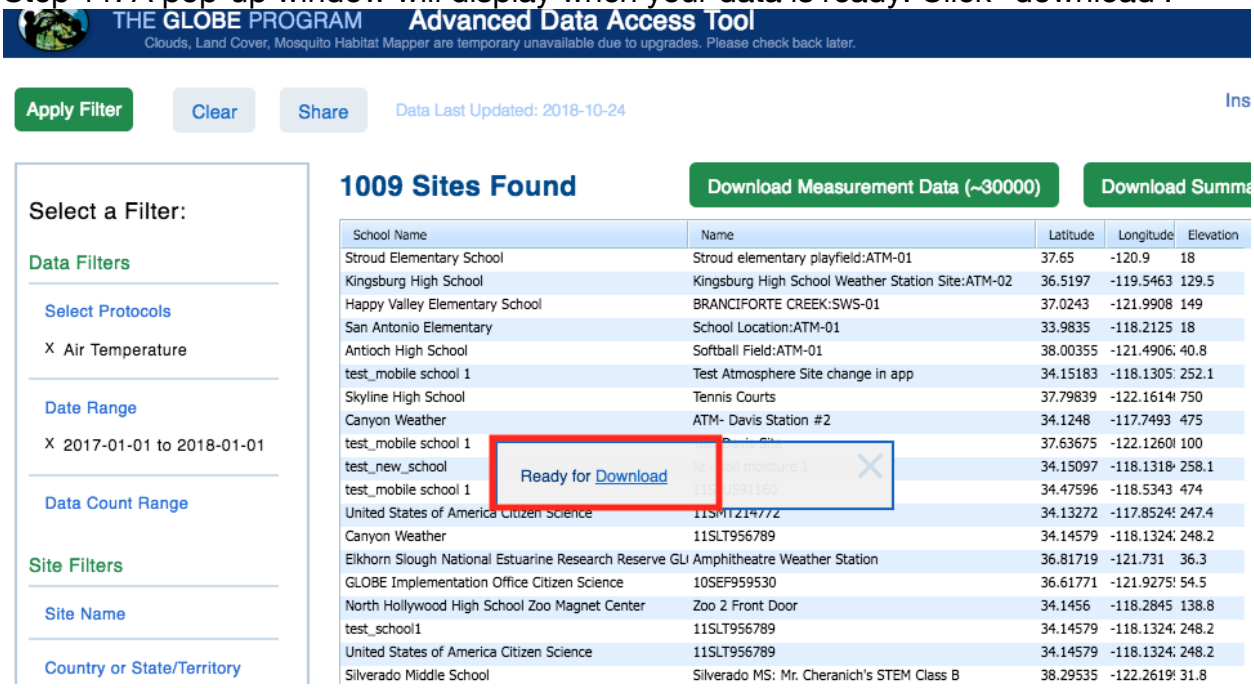


Step 9: Click on “Obtain Measurement Data” to download air temperature data to a csv file.



Step 10: Click “Download Measurement Data”

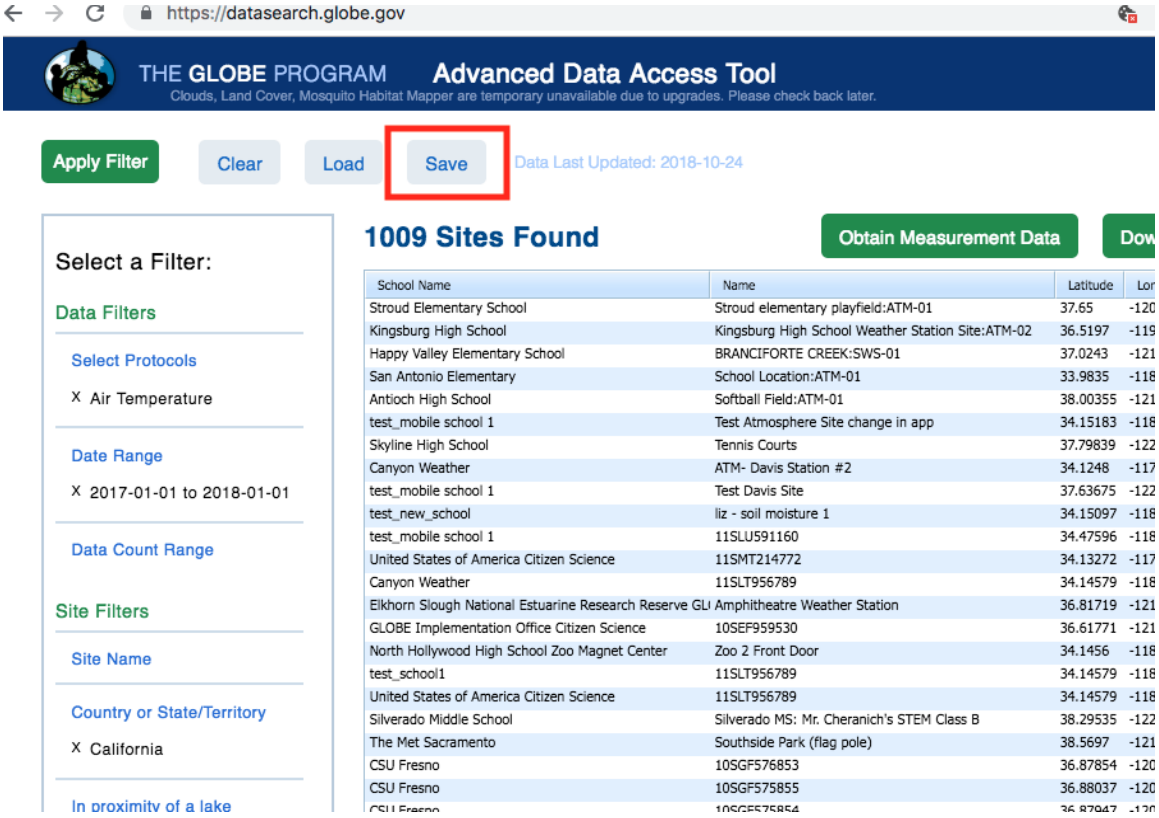
Step 11: A pop-up window will display when your data is ready. Click “download’.



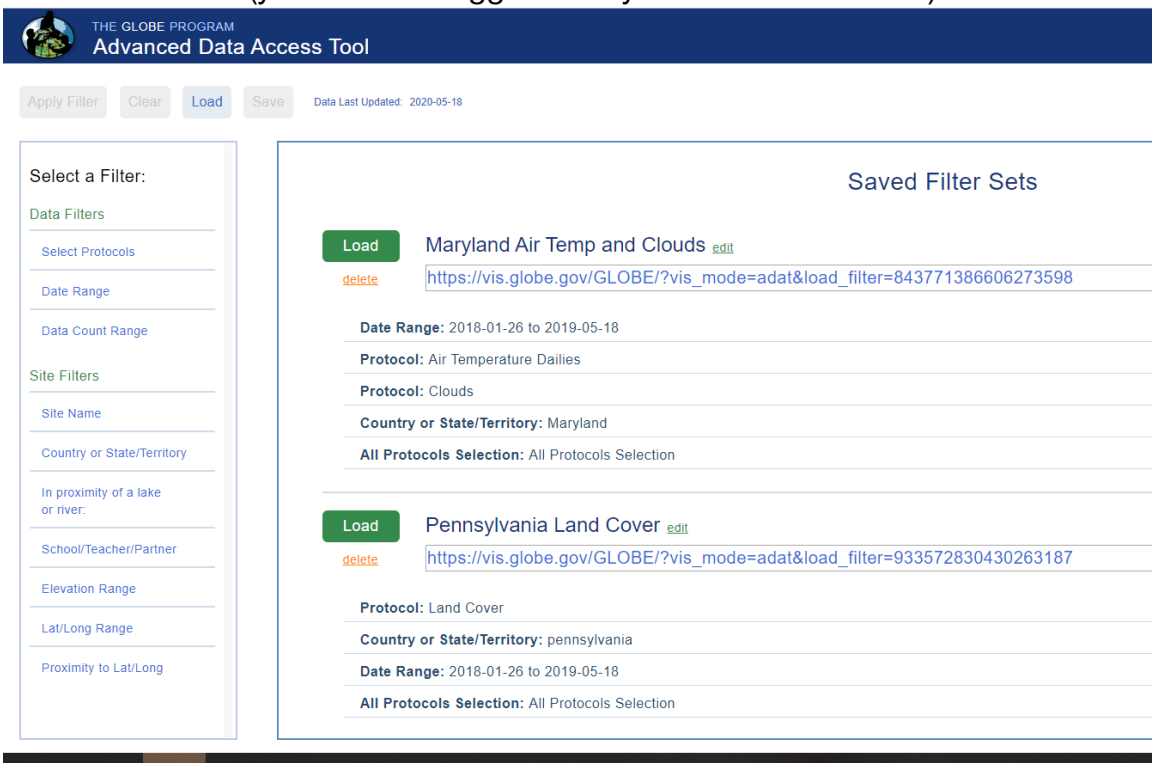
The data will be downloaded as a compressed (*.zip) file. Unzip the file to retrieve the tabular csv data file.

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. As an alternative, use the GLOBE API to download large datasets (see Section 6.2).

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 science@nasaglobe.org for help troubleshooting ADAT. (You can sign up for a GLOBE account on www.globe.gov.) Upon clicking “Save” you will be asked to name the search filter set, which will then be stored under your GLOBE account within the GLOBE system.



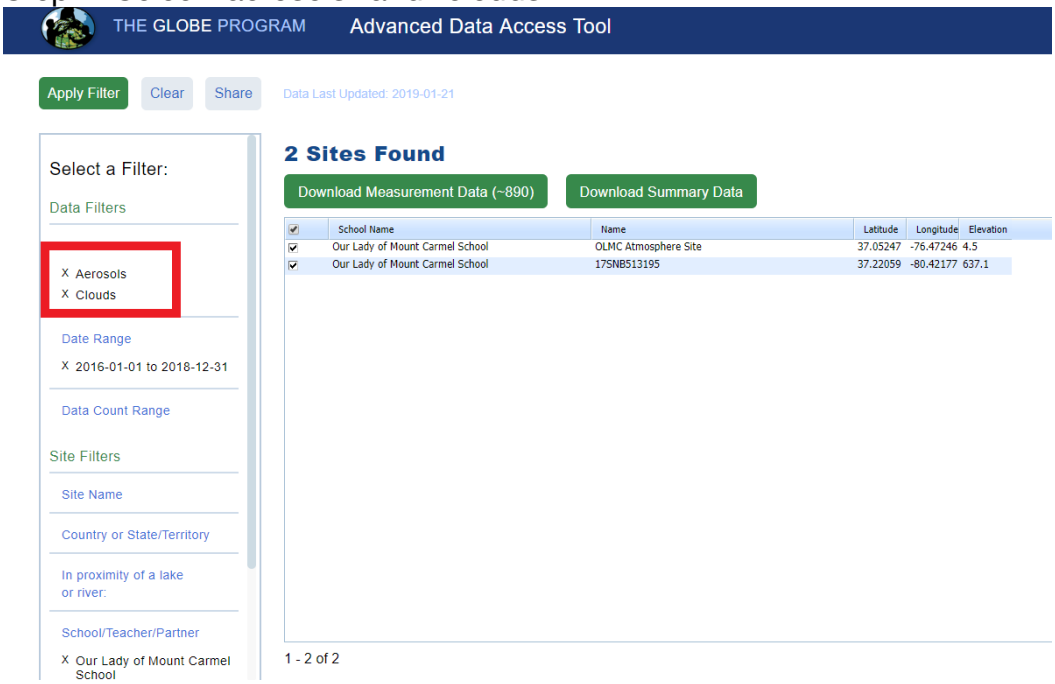
To access the saved filter set, click “Load”, select from your list of saved filter set(s), and click “Load” (you must be logged in to your GLOBE Account):



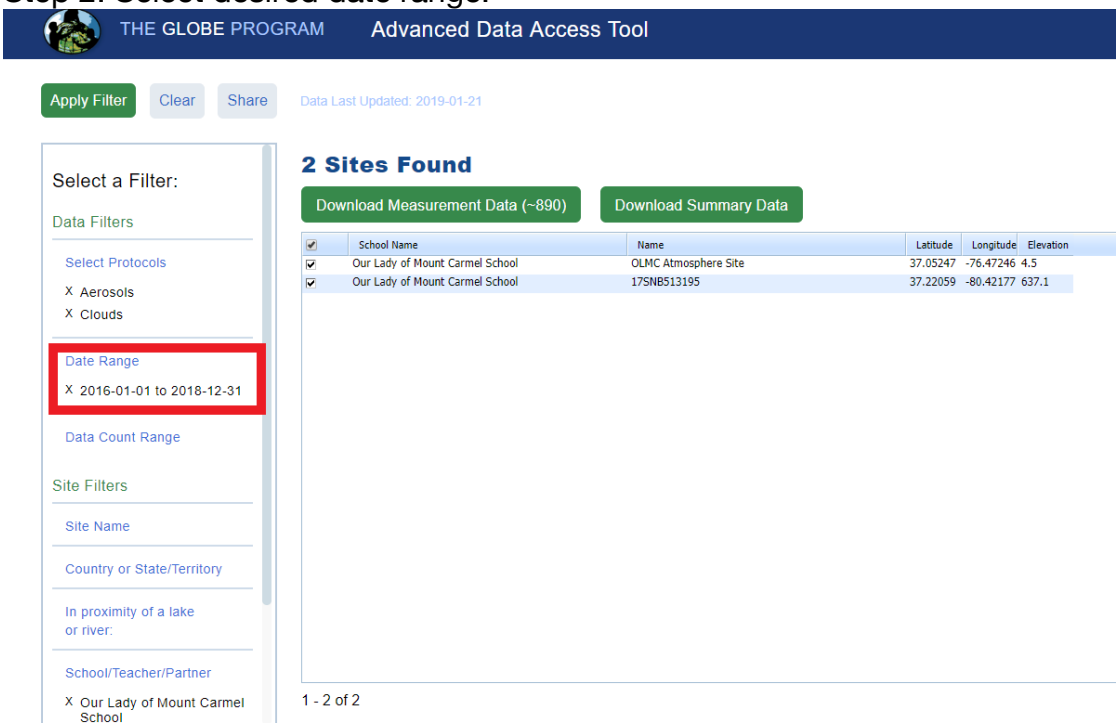
Example: Via ADAT, download GLOBE aerosol and cloud data from a particular school for 2016-2018

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.

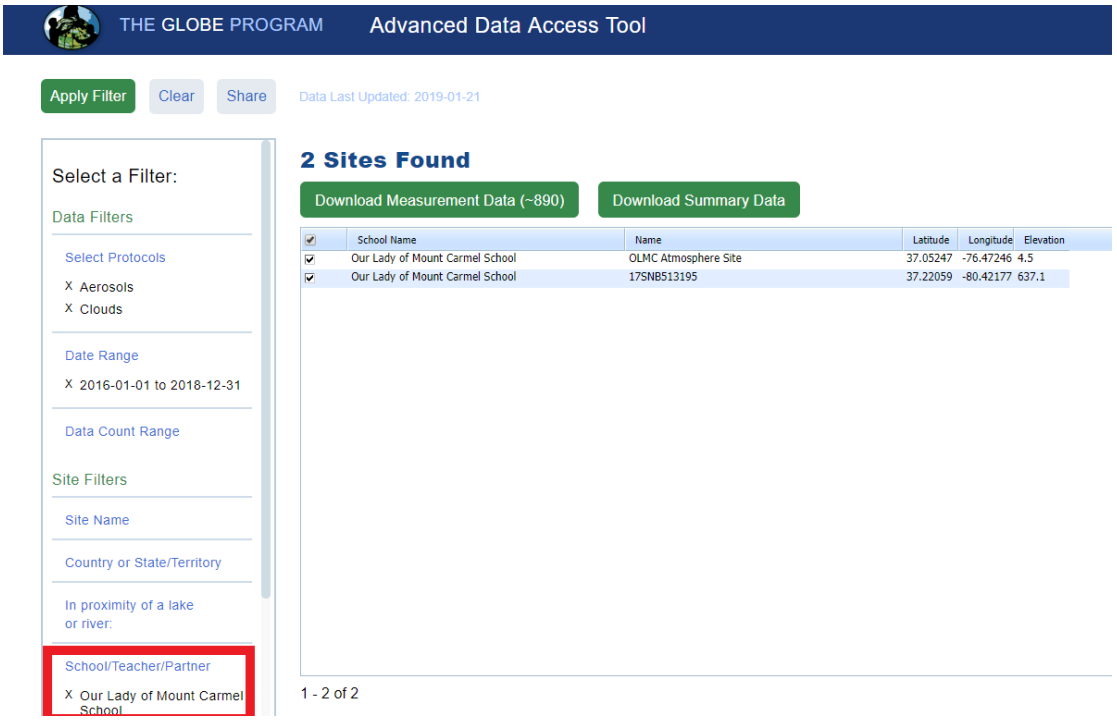
Step 1: Select “aerosols” and “clouds”.



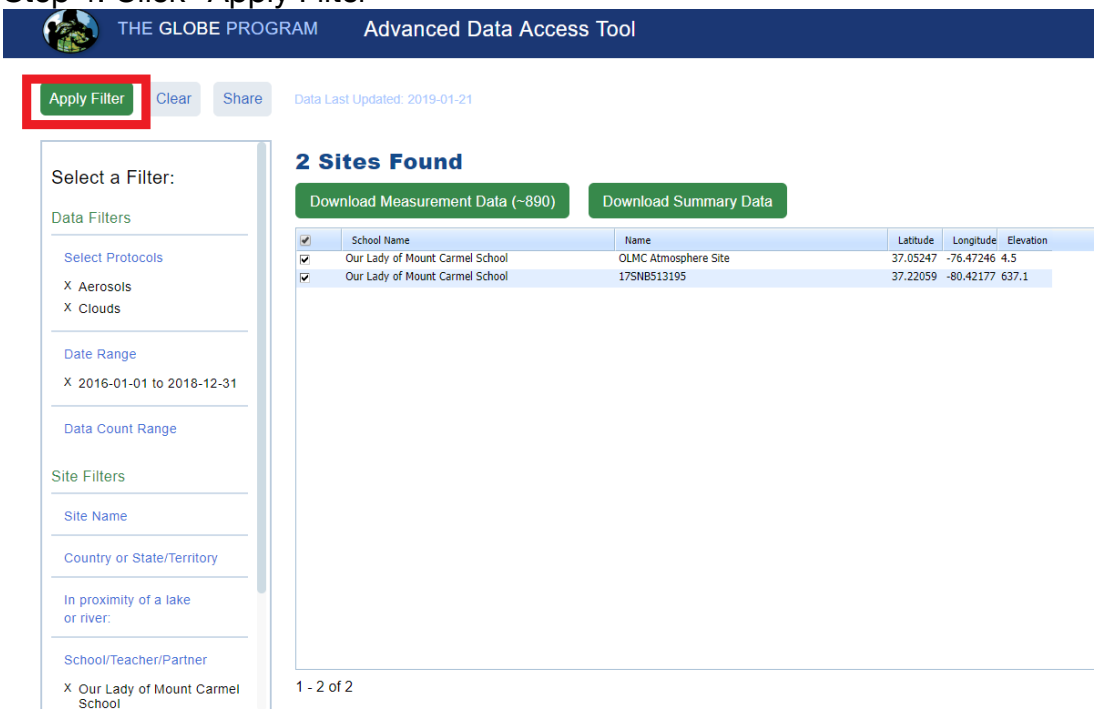
Step 2: Select desired date range.



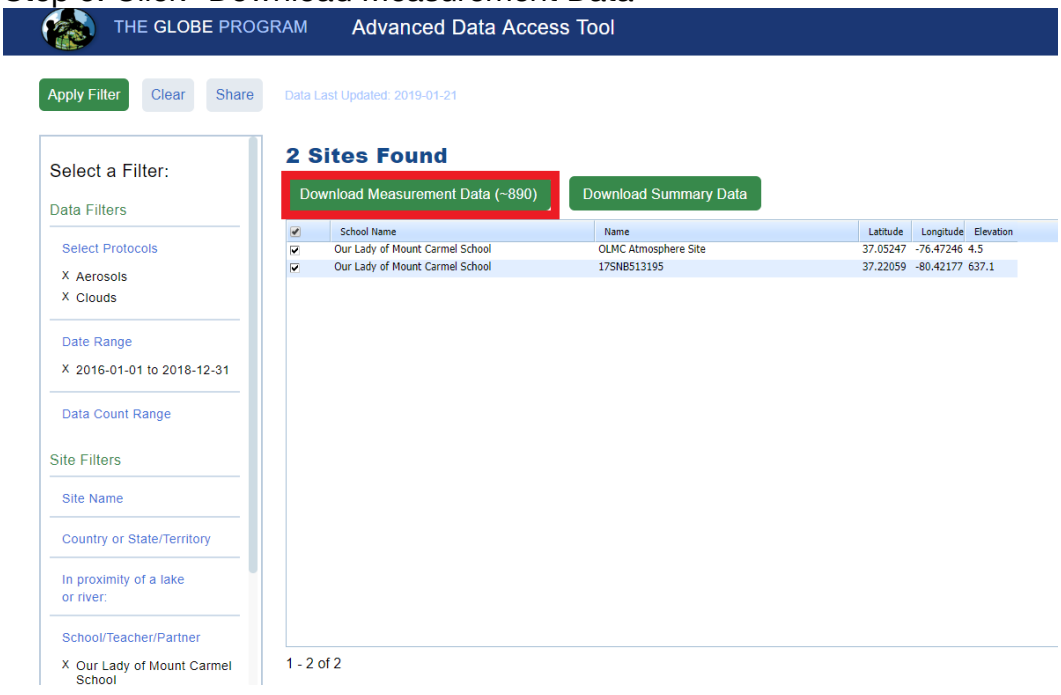
Step 3: Select desired GLOBE school. In this example, we want Our Lady of Mount Carmel School.



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. Users have the option of requesting results in a custom JSON format, or in GeoJSON format. Access to the API-out tool as well as detailed instructions for use are available on the GLOBE API-Out landing page.

6.2.1 Jupyter Notebooks

GLOBE provides access to three Python-based Jupyter Notebooks which can be used to pull data from the GLOBE API related to the Mosquito Habitat Mapper protocol. These notebooks were developed in support of the GLOBE Mission Mosquito Project. Each notebook includes code and instructions for pulling the data, removing outliers and graphing the results.

2020-04-08 Python Notebook to retrieve and graph MHM data

The mosquitoes.zip file includes code and instructions for use.

2020-06-24 Python Notebook for Selecting Data on a Map

Python notebook used to pull all MHM protocol bundle data from a geographic region defined by the user. User draws a region on a map and all bundle data is returned for that region. The bundler.zip file contains the code and usage instructions.

2020-07-08 Python Notebook for Non-Linear Regression MHM Protocols

Python notebook used to compare MHM protocol bundle data. Uses linear regression as initial parameters for non-linear regression between two protocols. The regression.zip file contains the code and usage instructions.

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 science@nasaglobe.org 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

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References

Larsen Becker, M., R. G. Congalton, R. Budd, A. Fried, 1998: A GLOBE Collaboration to Develop Land Cover Data Collection and Analysis Protocols. *Journal of Science Education & Technology*, 7(1), 85-96, https://doi.org/10.1023/A:1022540300914

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. *Bulletin of the Amer. Meteor. Soc.*, 98, 473–483, https://doi.org/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. *J. Appl. Meteor. Climatol*., 58(11), 2363-2385 https://doi.org/10.1175/JAMC-D-18-0297.1.

A full list of GLOBE publications is available on the GLOBE website. A curated list of publications related to the GLOBE Observer app tools is on the GLOBE Observer website.

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 collected using the GLOBE Aerosols Protocol.

Definition	Example - Aerosol measurement
protocol	Name of the selected GLOBE protocol, e.g. air_temps
pid	68887527 (unique ID used internally by GLOBE DIS)
measuredDate (UTC, yyyy-mm-ddTHH:MM:SSZ)	2018-10-10
createDate (UTC, yyyy-mm-ddTHH:MM:SSZ)	2018-10-10T15:06:00 (Date used internally by DIS; returned with custom JSON format only)
updateDate (UTC, yyyy-mm-ddTHH:MM:SSZ)	2018-10-10T15:06:00 (Date used internally by DIS; returned with custom JSON format only)
publishDate (UTC, yyyy-mm-ddTHH:MM:SSZ)	2018-10-11T08:13:00 (Date used internally by DIS; returned with custom JSON format only)
organizationID	25765 Unique ID assigned to each organization (school, partnership, etc.)
organizationName	Littleton Middle School
siteId	23092 Unique ID assigned to each measurement site
siteName	Weather Station:ATM-01
countryName	united-states The country in which the user's *organization* resides (note: this is not the country in which the actual measurement resides)
countryCode	Three letter country code associated with **countryName** based on ISO 3166 International Standard
latitude (degrees north)	45.1245
longitude (degrees east)	-117.4832
elevation (meters above sea level)*	512
userID	1529487
<protocol>:GlobeTeams	The name(s) of the team(s) that this measurement has been credited to (this applies to measurements dated on or after 01/01/2019.

** See note in Section 3 about elevation over water bodies*

Appendix 2. Data Variables, Units, and Definitions

The list below provides units and definitions of the GLOBE data variables users can download through the Advanced Data Access tool (ADAT). Universal metadata variables are provided at the top, then measurement-level variables are provided in alphabetical order by protocol thereafter. For protocols with large quantities of variables, the tables are split into groupings, with thematic labels where possible.

Universal metadata variables (no protocol label)

Variable	Units/Format	Definition
organization_id	n/a	The GLOBE ID assigned to the school or organization
org_name	n/a	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_id	n/a	The GLOBE ID assigned to site.
site_name	n/a	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. Read a brief overview of MGRS.
latitude	decimal degrees north	The latitude of the measurement site. Sites are associated with the lower-left corner of the 100x100m MGRS grid cell. Range: [-90, 90] *See also "measured latitude".*
longitude	decimal degrees east	The longitude of the measurement site. Sites are associated with the lower-left corner of the 100x100m MGRS grid cell. Range: [-180, 180] *See also "measured longitude"'*.
elevation	meters above sea level	The elevation of the measurement. Sites are associated with the lower-left corner of the 100x100m MGRS grid cell. *See note in Section 3 about elevation over water bodies.* *See also "measured elevation"*.
measured_on	yyyy-mm-dd	The date only of when the data were observed in UTC. (Spreadsheet programs may convert to a different date format automatically).

Universal metadata variables (labeled by protocol)

Variable	Units/Format	Definition
<protocol>:userid	n/a	The numerical GLOBE user-id of the person that submitted the measurement.
<protocol>:measured at	yyyy-mm-ddTHH:MM:SS	The date and time when the data were observed in UTC. This is listed for each protocol returned in ADAT.
<protocol>:solar measured at	yyyy-mm-ddTHH:MM:SS	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 (this applies to a subset of the GLOBE protocols.)
<protocol>:solar noon at	yyyy-mm-ddTHH:MM:SS	Date and time in UTC when local solar noon occurs at the measurement site (this applies to a subset of the GLOBE protocols.)
<protocol>:globe teams	n/a	A list of all of the GLOBE Teams to which this measurement has been credited (this field may be blank, or may contain one to several GLOBE Team names)

Measurement-level data variables

Measurement-level variables in alphabetical order by protocol name. Protocols with many variables were divided into multiple tables, with thematic labels where possible.

- Aerosols
- Air Temperature
- Air Temperature Dailies
- Air Temperature Monthlies
- Air Temperature Noons
- Alkalinity
- Barometric Pressure
- Barometric Pressure Noons
- Biometry – Graminoid Biomasses
- Biometry – Tree Height
    - Surface Conditions and Photos
- Biometry – Trees
- Biometry – Vegetation Covers
    - Canopy Cover
    - Ground Cover
    - Shrub Cover
- Carbon Cycle
- Clouds/Sky Conditions
    - Cloud Types
    - Obscurations
    - Contrails
    - Citizen Science/Training
    - Cloud Cover and Opacity by Altitude
    - Surface Conditions
    - Photos and Captions
- Clouds/Sky Conditions Noons
    - Cloud Types
    - Obscurations
    - Contrails
    - Citizen Science/Training
    - Cloud Cover and Opacity by Altitude
    - Surface Conditions
- Conductivity
- Dissolved Oxygen
- Freshwater Macroinvertebrates
- Frost Tube
- Greenings (Green-up/Green-Down)
- Land Cover
    - Surface Conditions
    - Photo URLs and Directional Classifications
- Lilac Phenology
- Mosquitoes
- Mosquito Habitat Mapper
- Nitrates
- pH
- Phenological Gardens
- Precipitation
- Precipitation Monthlies
- Relative Humidity
- Relative Humidity Monthlies
- Relative Humidity Noons
- Salinity
- Snow Pack/Solid Precipitation
- Soil Characterization – Field Measurements
- Soil Characterization – Horizon Number at Depth/Horizon Bottom Depth
- Soil Characterization – Particle Size Distribution
- Soil Density
- Soil Fertility
- Soil Infiltration
- Soil Moisture - Gravimetric
- Soil Moisture – Sensors
- Soil Moisture – SMAP Block Pattern
- Soil Moisture Monthlies aka Volumetric Soil Moisture Monthlies
- Soil pH
- Soil Temperature
- Soil Temperature Dailies
- Soil Temperature Monthlies
- Soil Temperature Noons
- Surface Ozone
- Surface Ozone One Hour After Noons
- Surface Temperature
- Surface Temperature Noons
- Water Temperature
- Water Transparency
- Water Vapor
- Water Vapor Noons
- Wind

Aerosols

Variable	Units/Format	Definition
aerosols:comments	n/a	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	n/a	Sky color. Options: [deep blue, blue, light blue, pale blue, milky] *Note: a guide to sky color is provided on page 14 of the GLOBE Clouds Protocol*
aerosols:observed sky clarity	n/a	Sky clarity (i.e., visibility). Options: [unusually clear, clear, somewhat hazy, very hazy, extremely hazy] *Note: a guide to sky color and clarity/visibility is provided on page 14 of the GLOBE Clouds Protocol*
aerosols: associated remote sensor	n/a	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 (deg)	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	n/a	The type of instrument (sun photometer) used to measure aerosols
aerosols:aerosol photometer serial number	n/a	The serial number of the instrument used to measure aerosols *Note: not available before May 2016*
aerosols:aot 505 measured	--	--
aerosols:aot 625	--	--
aerosols:aot 465	--	--
aerosols:aot 540	--	--
aerosols:aot 619	--	--
aerosols:aot misc	--	--
aerosols:aot 505 calculated	--	--
aerosols:aot 505 all	--	--
aerosols:transmission percent at 505nm	--	--
aerosols:transmission percent at 625nm	--	--
aerosols:transmission percent at 465nm	--	--
aerosols:transmission percent at 540nm	--	--
aerosols:transmission percent at 619nm	--	--

Air Temperature

Variable	Units/Format	Definition
air_temps:current_temp (deg C)	degrees Celsius	Ambient temperature at time of measurement
air_temps:comments	n/a	Comments on current air temperature measurement

Air Temperature Dailies

Variable	Units/Format	Definition
air temp dailies:current temp (deg C)	degrees Celsius	Current ambient air temperature recorded at time of maximum and minimum temperature
air temp dailies:minimum temp (deg C)	degrees Celsius	The minimum air temperature since the previous day's temperature report
air temp dailies:maximum temp (deg C)	degrees Celsius	The maximum air temperature since the previous day's temperature report
air temp dailies:comments	n/a	Comments on air temperature measurement

Air Temperature Monthlies

Variable	Units/Format	Definition
air temp monthlies:averaged month	yyyy-mm-01	First day of the month for which air temperature measurements are averaged. (Spreadsheet programs may automatically convert to a different date format.)
air temp monthlies:number of days reported	n/a	Number of days in the month on which ambient air temperature observations were reported
air temp monthlies:number of obs	n/a	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 Temperature Noons

Variable	Units/Format	Definition
air temp noons:current temp (deg 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	n/a	Comments on air temperature measurements

Alkalinity

Variable	Units/Format	Definition
hydrology alkalinities:water body state	n/a	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 (mg)l	milligrams per liter (mg L^{-1})	Alkalinity measured by the number of drops used in an alkalinity kit
hydrology alkalinities: alkalinity kit mfg	n/a	Alkalinity kit manufacturer
hydrology alkalinities: alkalinity kit model	n/a	Alkalinity kit model number
hydrology alkalinities:drops alkalinity kit mfg	n/a	Manufacturer of the kit that uses drop and color change to measure alkalinity
hydrology alkalinities:drops alkalinity kit model	n/a	Model number of the kit that uses drop and color change to measure alkalinity
hydrology alkalinities: comments	n/a	Comments on the alkalinity measurement

Barometric Pressure

Variable	Units/Format	Definition
barometric pressures: pressure method	n/a	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

Variable	Units/Format	Definition
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	n/a	The method or type of instrument used to measure barometric pressure
barometric pressure noons: comments	n/a	Comments reported on the barometric pressure temperature readings

Biometry – Graminoid Biomasses

Variable	Units/Format	Definition
graminoid biomasses: average green mass g	grams (g)	Average mass of green graminoid (grass) samples
graminoid biomasses: average green (%)	percent (%)	Average percent of green biomass in the three samples
graminoid biomasses: average brown mass g	grams (g)	Average mass of brown graminoid (grass) samples
graminoid biomasses: average brown (%))	percent (%)	Average percent of brown biomass in the three samples
graminoid biomasses: number of samples	n/a	Number of graminoid (grass) samples
graminoid biomasses: comments	n/a	Comments on the graminoid biomass measurement

Biometry – Tree Height

Variable	Units/Format	Definition
tree heights:biometry id	n/a	Measurement ID for an entire Biometry protocol measurement
tree heights:biometry trees id	n/a	ID for a tree sample set (up to 5 individual trees) within a Biometry protocol measurement
tree heights:biometry trees sample id	n/a	ID for a single tree within a tree sample set within a Biometry protocol measurement
tree heights:data source	n/a	Indicates if the measurement was entered via the GLOBE Observer Trees tool or some other data entry method
tree heights:tree latitude	n/a	Latitude for a single tree within a tree sample set within a Biometry protocol measurement
tree heights:tree longitude	n/a	Longitude for a single tree within a tree sample set within a Biometry protocol measurement
tree heights:tree elevation	n/a	Elevation for a single tree within a tree sample set within a Biometry protocol measurement
tree heights: measurement latitude	decimal degrees north	Latitude recorded by the GPS of a participant using the GLOBE Observer app at the time of measurement. Range: [-90,90]
tree heights: measurement longitude	decimal degrees east	Longitude recorded by the GPS of a participant using the GLOBE Observer app at the time of measurement.
tree heights: measurement elevations	meters (m) above sea level	Elevation at the latitude/longitude location recorded by the GPS of a participant using the GLOBE Observer app at the time of measurement.
tree heights:height avg(m)	meters (m)	Tree height value If the data was entered via the GLOBE Observer Trees tool, this number represents a single height measurement; if the data was entered via the GLOBE Biometry protocol, this number is an average of from 1-3 height measurements for a single tree within a tree sample set within a Biometry Protocol measurement.
tree heights: circumferences	centimeters (cm)	Tree circumference
tree heights:genus	n/a	Tree genus *Note: This value currently can't be entered via the Trees tool in the GLOBE Observer app.*
tree heights:species	n/a	Tree species *Note: This value currently can't be entered via the Trees tool in the GLOBE Observer app.*
tree heights:comments	n/a	Comments from the observer about the tree height measurement
tree heights:location method	n/a	Indicates if the measurement location was determined by the device GPS or if the user entered it manually
tree heights:location accuracy (m)	meters (m)	The estimated accuracy within meters of the calculated measurement location determined by the device GPS

Biometry – Tree Height, continued (Surface Conditions and Photos)

Variable	Units/Format	Definition
tree heights:snow ice	n/a	True/False indicating if this surface condition is present (this value is blank if the user submitted data via a means other than the GLOBE Observer app.)
tree heights:standing water	n/a	True/False indicating if this surface condition is present (this value is blank if the user submitted data via a means other than the GLOBE Observer app.)
tree heights:muddy	n/a	True/False indicating if this surface condition is present (this value is blank if the user submitted data via a means other than the GLOBE Observer app.)
tree heights:dry ground	n/a	True/False indicating if this surface condition is present (this value is blank if the user submitted data via a means other than the GLOBE Observer app.)
tree heights:leaves on trees	n/a	True/False indicating if this surface condition is present (this value is blank if the user submitted data via a means other than the GLOBE Observer app.)
tree heights:raining snowing	n/a	True/False indicating if this surface condition is present (this value is blank if the user submitted data via a means other than the GLOBE Observer app.)
tree heights:tree photo urls	n/a	The URL of the photo taken of the tree, if available.

Biometry – Trees

Variable	Units/Format	Definition
biometry trees:dominant genus	n/a	Genus of the species of tree that dominates at a land cover site
biometry trees:dominant species	n/a	Species of tree that dominates at a land cover site
biometry trees:codominant genus	n/a	Genus of the species of tree that codominates or is second in prevalence at a land cover site
biometry trees:codominant species	n/a	Species of tree that codominates or is second in prevalence at a land cover site
biometry trees:mixed dominant	n/a	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	n/a	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	n/a	The number of trees of the codominant species found in the 30-meter x 30-meter land cover site
biometry trees:comments	n/a	Comments on the biometry measurements

Biometry – Vegetation Covers (Canopy Cover)

Variable	Units/Format	Definition
vegetation covers:canopy cover observations count	n/a	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	n/a	The number of observations with canopy cover along diagonals
vegetation covers:canopy cover minus count	n/a	The number of observations without canopy cover along diagonals
vegetation covers:canopy cover tree count	n/a	Number of observations with tree canopy along diagonals
vegetation covers:canopy cover shrub count	n/a	Number of observations with shrub canopy along diagonals
vegetation covers:canopy cover deciduous count	n/a	Number of observations with deciduous canopy along diagonals
vegetation covers:canopy cover evergreen count	n/a	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

Biometry – Vegetation Covers, continued (Ground Cover)

Variable	Units/Format	Definition
vegetation covers:ground cover observations count	n/a	Number of canopy cover observations taken
vegetation covers:ground cover plus count	n/a	Number of observations with ground cover along diagonals
vegetation covers:ground cover minus count	n/a	Number of observations without ground cover along diagonal
vegetation covers:ground cover green count	n/a	Number of observations with green ground cover
vegetation covers:ground cover brown count	n/a	Number of observations with brown ground cover
vegetation covers:ground cover graminoid count	n/a	Number of observations with graminoid ground cover
vegetation covers:ground cover forb count	n/a	Number of observations with forb ground cover
vegetation covers:ground cover other count	n/a	Number of observations with other ground cover
vegetation covers:ground cover shrub count	n/a	Number of observations with shrub ground cover
vegetation covers:ground cover dwarf shrub count	n/a	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

Biometry – Vegetation Covers, continued (Shrub Cover)

Variable	Units/Format	Definition
vegetation covers:shrub cover observations count	n/a	Total observation samples used in determining percentage of shrub cover
vegetation covers:shrub cover plus count	n/a	The number of observation samples where a shrub was present
vegetation covers:shrub cover minus count	n/a	The number of observation samples where a shrub was not present
vegetation covers:dwarf shrub cover observations count	n/a	Total observation samples used in determining percentage of dwarf shrub cover
vegetation covers:dwarf shrub cover plus count	n/a	The number of observation samples where a dwarf shrub was present
vegetation covers:dwarf shrub cover minus count	n/a	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	n/a	Comments about vegetation covers

Carbon Cycle

Variable	Units/Format	Definition
carbon cycle:plot size m sqr	square meters (m^2)	The area of the Carbon Cycle Plot in meters squared
carbon cycle:site type	n/a	"Standard" or "Non-Standard"
carbon cycle:total biomass g per m sqr	grams per meter squared ($g\ m^{-2}$)	Total biomass of all measured vegetation in grams per meter squared
carbon cycle:total carbon storage g c per m sqr	grams per meter squared ($g\ m^{-2}$)	Total carbon storage of all measured vegetation in grams carbon per meter squared
carbon cycle:tree biomass g per m sqr	grams per meter squared ($g\ m^{-2}$)	Total biomass of all measured trees (greater than 15 centimeters circumference at breast height) in grams per meter squared
carbon cycle:tree carbon storage g c per m sqr	grams per meter squared ($g\ m^{-2}$)	Total carbon storage of all measured trees (greater than 15 centimeters circumference at breast height) in grams carbon per meter squared
carbon cycle:tree diversity	n/a	Tree species diversity calculated using Shannon's Diversity Index. The lower the value the lower the diversity.
carbon cycle:herbaceous biomass g per m sqr	grams per meter squared ($g\ m^{-2}$)	Total biomass of all sampled herbaceous vegetation in grams per meter squared
carbon cycle:herbaceous carbon storage g c per m sqr	grams per meter squared ($g\ m^{-2}$)	Total carbon storage of all sampled herbaceous vegetation in grams carbon per meter squared
carbon cycle:shrub biomass g per m sqr	grams per meter squared ($g\ m^{-2}$)	Total biomass of all sampled shrubs/saplings in grams per meter squared (saplings are tree less than 15 centimeters circumference at breast height)
carbon cycle:shrub carbon storage g c per m sqr	grams per meter squared ($g\ m^{-2}$)	Total carbon storage of all sampled shrubs/saplings in grams carbon per meter squared (saplings are tree less than 15 centimeters circumference at breast height)
carbon cycle:shrub percent coverage deciduous	percent (%)	Percent cover of deciduous shrubs/saplings on the Plot
carbon cycle:shrub avg height deciduous (m)	meters (m)	Average height in meters of deciduous shrubs/saplings measured
carbon cycle:shrub biomass deciduous g per m sqr	grams per meter squared ($g\ m^{-2}$)	Total biomass of all sampled deciduous shrubs/saplings (less than 15 centimeters circumference at breast height) in grams per meter squared
carbon cycle:shrub percent coverage evergreen	percent (%)	Percent cover of evergreen shrubs/saplings on the Plot

Carbon Cycle, continued

Variable	Units/Format	Definition
carbon cycle:shrub avg height evergreen (m)	meters (m)	Average height in meters of evergreen shrubs/saplings measured
carbon cycle:shrub biomass evergreen g per m sqr	grams per meter squared ($g\ m^{-2}$)	Total biomass of all sampled evergreen shrubs/saplings (less than 15 centimeters circumference at breast height) in grams per meter squared
carbon cycle:tree sample number	n/a	Number assigned to the tree for identification purposes
carbon cycle:tree species group	n/a	Species group of the tree, needed for allometric equations that estimate biomass from circumference measurements.
carbon cycle:tree cbh (cm)	centimeters (cm)	Tree circumference in centimeters at breast height (1.35 m)
carbon cycle:tree dead date	yyyy-mm-dd	Date a tree was recorded as 'dead.' (Spreadsheet programs may automatically convert to a different date format.)
carbon cycle:tree removed date	yyyy-mm-dd	Date a tree was recorded as removed from the Plot. (Spreadsheet programs may automatically convert to a different date format.)
carbon cycle:tree plot biomass g per plot	grams (g)	Total biomass (in grams) of all measured trees (greater than 15 centimeters circumference at breast height) on the Plot
carbon cycle:tree aboveground biomass g	grams (g)	Total aboveground biomass (in grams) of all measured trees (greater than 15 centimeters circumference at breast height) on the Plot
carbon cycle:tree foliage biomass g	grams (g)	Total foliage biomass (in grams) of all measured trees (greater than 15 centimeters circumference at breast height) on the Plot
carbon cycle:tree stem biomass g	grams (g)	Total stem biomass (in grams) of all measured trees (greater than 15 centimeters circumference at breast height) on the Plot
carbon cycle:tree branch biomass g	grams (g)	Total branch biomass (in grams) of all measured trees (greater than 15 centimeters circumference at breast height) on the Plot
carbon cycle:tree coarse root biomass g	grams (g)	Total coarse root biomass (in grams) of all measured trees (greater than 15 centimeters circumference at breast height) on the Plot
carbon cycle:tree comments	n/a	Comments pertaining to an individual tree on the Plot
carbon cycle:comments	n/a	Comments pertaining to this Carbon Cycle measurement

Clouds/Sky Conditions

Variable	Units/Format	Definition
sky conditions:measurement latitude	decimal degrees north	Latitude recorded by the GPS of a participant using the GLOBE Observer app at the time of measurement. Range: [-90,90] *Note: See also "latitude"*.
sky conditions:measurement longitude	decimal degrees east	Longitude recorded by the GPS of a participant using the GLOBE Observer app at the time of measurement. *Note: See also "longitude"*.
sky conditions:measurement elevation	meters (m) above sea level	Elevation at the latitude/longitude location recorded by the GPS of a participant using the GLOBE Observer app at the time of measurement. *Note: See also "elevation"*.
sky conditions:observation id	n/a	Identification number (integer) for the latitude, longitude, date, and time of the observation
sky conditions:cloud cover	n/a	Total amount of sky covered by clouds regardless 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:sky color	n/a	Sky color Options: [deep blue, blue, light blue, pale blue, milky] *Note: a guide to sky color is provided on page 14 of the GLOBE Clouds protocol.*
sky conditions:sky clarity	n/a	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 14 of the GLOBE Clouds protocol.*
sky conditions:location method	n/a	Indicates if the user's device GPS was used to determine the measurement location, or if the user entered it manually
sky conditions:location accuracy(m)	meters (m)	The estimated accuracy within meters of the measurement latitude and longitude as determined by the device GPS
sky conditions:comments	n/a	Comments made by the observer

Clouds/Sky Conditions, continued (Cloud Types)

Variable	Units/Format	Definition
sky conditions:cirrus	n/a	Cirrus clouds were observed Options: [TRUE, FALSE] *Note: Data downloaded from Vis returns X. Data downloaded from ADAT returns TRUE.*
sky conditions:cirrocumulus	n/a	Cirrocumulus clouds were observed Options: [TRUE, FALSE] *Note: Data downloaded from Vis returns X. Data downloaded from ADAT returns TRUE.*
sky conditions:cirrostratus	n/a	Cirrostratus clouds were observed Options: [TRUE, FALSE] *Note: Data downloaded from Vis returns X. Data downloaded from ADAT returns TRUE.*
sky conditions:altostratus	n/a	Altostratus clouds were observed Options: [TRUE, FALSE] *Note: Data downloaded from Vis returns X. Data downloaded from ADAT returns TRUE.*
sky conditions:altocumulus	n/a	Altocumulus clouds were observed Options: [TRUE, FALSE] *Note: Data downloaded from Vis returns X. Data downloaded from ADAT returns TRUE.*
sky conditions:cumulus	n/a	Cumulus clouds were observed Options: [TRUE, FALSE] *Note: Data downloaded from Vis returns X. Data downloaded from ADAT returns TRUE.*
sky conditions:nimbostratus	n/a	Nimbostratus clouds were observed Options: [TRUE, FALSE] *Note: Data downloaded from Vis returns X. Data downloaded from ADAT returns TRUE.*
sky conditions:stratus	n/a	Stratus clouds were observed Options: [TRUE, FALSE] *Note: Data downloaded from Vis returns X. Data downloaded from ADAT returns TRUE.*
sky conditions:stratocumulus	n/a	Stratocumulus clouds were observed Options: [TRUE, FALSE] *Note: Data downloaded from Vis returns X. Data downloaded from ADAT returns TRUE.*
sky conditions:cumulonimbus	n/a	Cumulonimbus clouds were observed Options: [TRUE, FALSE] *Note: Data downloaded from Vis returns X. Data downloaded from ADAT returns TRUE.*

Clouds/Sky Conditions, continued (Obscurations)

Variable	Units/Format	Definition
sky conditions:fog	n/a	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	n/a	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	n/a	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	n/a	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	n/a	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	n/a	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	n/a	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	n/a	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	n/a	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	n/a	Blowing snow obscured >25% of the sky Options: [TRUE, FALSE] *Note: Data downloaded from Vis returns X. Data downloaded from ADAT returns TRUE.*

Clouds/Sky Conditions, continued (Contrails)

Variable	Units/Format	Definition
sky conditions:contrail cover deprecated	n/a	*Note: This field is no longer used*
sky conditions:short lived contrails	n/a	Number (integer) of short lived contrails observed (This value is "null" if the user selects "skip contrails" when entering a cloud observation, or if the user indicates if the sky is "obscured".)
sky conditions:spreading contrails	n/a	Number (integer) of persistent spreading contrails observed (This value is "null" if the user selects "skip contrails" when entering a cloud observation, or if the user indicates if the sky is "obscured".)
sky conditions:non spreading contrails	n/a	Number (integer) of persistent, non-spreading contrails observed (This value is "null" if the user selects "skip contrails" when entering a cloud observation, or if the user indicates if the sky is "obscured".)

Clouds/Sky Conditions, continued (Citizen Science/Training)

Variable	Units/Format	Definition
sky conditions:is citizen science	n/a	Options: [TRUE, FALSE] TRUE: the observer used the GLOBE Observer app to enter the data and they do not have a GLOBE Educator account FALSE: the observer has a GLOBE Educator 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	n/a	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

Clouds/Sky Conditions, continued (Cloud Cover and Opacity by Altitude)

Variable	Units/Format	Definition
sky conditions:cloud cover low	n/a	Total amount of sky covered by low clouds (cumulus, fog/stratus, stratocumulus, nimbostratus, cumulonimbus) 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	n/a	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)] An explanation of the comparison of reported opacity to satellite data from the GLOBE Clouds Team at NASA Langley Research Center is on the GLOBE Clouds page.
sky conditions:cloud cover mid	n/a	Total amount of sky covered by mid clouds (altostratus, altocumulus) 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	n/a	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)] An explanation of the comparison of reported opacity to satellite data from the GLOBE Clouds Team at NASA Langley Research Center is on the GLOBE Clouds page.
sky conditions:cloud cover high	n/a	Total amount of sky covered by high clouds (contrails: short-lived, persistent non-spreading, persistent spreading, cirrus, cirrocumulus, cirrostratus) 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	n/a	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)] An explanation of the comparison of reported opacity to satellite data from the GLOBE Clouds Team at NASA Langley Research Center is on the GLOBE Clouds page.

Clouds/Sky Conditions, continued (Surface Conditions)

Variable	Units/Format	Definition
sky conditions:snow/ice	n/a	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	n/a	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	n/a	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	n/a	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	n/a	Options: [TRUE, FALSE] TRUE: More than 50% of the trees have leaves (this includes evergreens) FALSE: Less than 50% of the trees have leaves (this includes evergreens) *Note: Data downloaded from Vis returns X. Data downloaded from ADAT returns TRUE.*
sky conditions:raining snowing	n/a	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.*

Clouds/Sky Conditions, continued (Photos and Captions)

Variable	Units/Format	Definition
sky conditions:north photo url	n/a	URL 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	n/a	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	n/a	URL 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	n/a	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	n/a	URL 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	n/a	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	n/a	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	n/a	Comments made by the observer about the image *Note: this variable only appears when data is downloaded from ADAT (not Vis)*
sky conditions:upward photo url	n/a	URL link to image taken in the upward direction *Note: this variable only appears when data is downloaded from ADAT (not Vis)*
sky conditions:upward caption	n/a	Comments made by the observer about the image *Note: this variable only appears when data is downloaded from ADAT (not Vis)*
sky conditions:downward photo url	n/a	URL link to image taken in the downward direction *Note: this variable only appears when data is downloaded from ADAT (not Vis)*
sky conditions:downward caption	n/a	Comments made by the observer about the image *Note: this variable only appears when data is downloaded from ADAT (not Vis)*

Clouds/Sky Conditions Noons

Variable	Units/Format	Definition
sky condition noons:observation id	n/a	Identification number (integer) for the latitude, longitude, date, and time of the observation
sky condition noons:cloud cover	n/a	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:sky color	n/a	Sky color Options: [deep blue, blue, light blue, pale blue, milky] *Note: a guide to sky color is provided on page 14 of the GLOBE Clouds protocol.*
sky condition noons:sky clarity	n/a	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 14 of the GLOBE Clouds protocol.*
sky condition noons: comments	n/a	Comments made by the observer

Clouds/Sky Conditions Noons, continued (Cloud Types)

Variable	Units/Format	Definition
sky condition noons:cirrus	n/a	Cirrus clouds were observed Options: [yes, no]
sky condition noons: cirrocumulus	n/a	Cirrocumulus clouds were observed Options: [yes, no]
sky condition noons: cirrostratus	n/a	Cirrostratus clouds were observed Options: [yes, no]
sky condition noons: altostratus	n/a	Altostratus clouds were observed Options: [yes, no]
sky condition noons: altocumulus	n/a	Altocumulus clouds were observed Options: [yes, no]
sky condition noons:cumulus	n/a	Cumulus clouds were observed Options: [yes, no]
sky condition noons: nimbostratus	n/a	Nimbostratus clouds were observed Options: [yes, no]
sky condition noons:stratus	n/a	Stratus clouds were observed Options: [yes, no]
sky condition noons: stratocumulus	n/a	Stratocumulus clouds were observed within one hour of local solar noon Options: [yes, no]
sky condition noons: cumulonimbus	n/a	Cumulonimbus clouds were observed within one hour of local solar noon Options: [yes, no]

Clouds/Sky Conditions Noons, continued (Obscurations)

Variable	Units/Format	Definition
sky condition noons:fog	n/a	Fog obscured at least 25% of the sky within one hour of local solar noon. Options: [yes, no]
sky condition noons:smoke	n/a	Smoke obscured at least 25% of the sky within one hour of local solar noon. Options: [yes, no]
sky condition noons:haze	n/a	Haze obscured at least 25% of the sky within one hour of local solar noon. Options: [yes, no]
sky condition noons: volcanic ash	n/a	Volcanic ash obscured at least 25% of the sky within one hour of local solar noon. Options: [yes, no]
sky condition noons:dust	n/a	Dust obscured at least 25% of the sky within one hour of local solar noon. Options: [yes, no]
sky condition noons:sand	n/a	Sand obscured at least 25% of the sky within one hour of local solar noon. Options: [yes, no]
sky condition noons:spray	n/a	Spray obscured at least 25% of the sky within one hour of local solar noon. Options: [yes, no]
sky condition noons:heavy rain	n/a	Heavy rain obscured at least 25% of the sky within one hour of local solar noon. Options: [yes, no]
sky condition noons: heavy snow	n/a	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	n/a	Blowing snow obscured at least 25% of the sky within one hour of local solar noon. Options: [yes, no]

Clouds/Sky Conditions Noons, continued (Contrails)

Variable	Units/Format	Definition
sky condition noons:contrail cover deprecated	n/a	*Note: This field is no longer used*
sky condition noons: short lived contrails	n/a	Total number (integer) of short lived contrails observed within one hour of local solar noon (This value is “null” if the user selects “skip contrails” when entering a cloud observation, or if the user indicates if the sky is “obscured”.)
sky condition noons: spreading contrails	n/a	Total number (integer) of persistent spreading contrails observed within one hour of local solar noon (This value is “null” if the user selects “skip contrails” when entering a cloud observation, or if the user indicates if the sky is “obscured”.)
sky condition noons:non spreading contrails	n/a	Total number (integer) of persistent non-spreading contrails observed within one hour of local solar noon (This value is “null” if the user selects “skip contrails” when entering a cloud observation, or if the user indicates if the sky is “obscured”.)

Clouds/Sky Conditions Noons, continued (Citizen Science/Training)

Variable	Units/Format	Definition
sky condition noons:is citizen science	n/a	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 condition:is globe trained	n/a	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

Clouds/Sky Conditions Noons, continued (Cloud Cover and Opacity by Altitude)

Variable	Units/Format	Definition
sky condition noons:cloud cover low	n/a	Total amount of sky covered by low clouds (cumulus, fog/stratus, stratocumulus, nimbostratus, cumulonimbus) Options: [Blank, None (0%), Few or Clear (1-10%), Isolated (10-25%), Scattered (25-50%), Broken (50-90%), Overcast (90-100%)]
sky condition noons:opacity low	n/a	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)] An explanation of the comparison of reported opacity to satellite data from the GLOBE Clouds Team at NASA Langley Research Center is on the GLOBE Clouds page.
sky condition noons:cloud cover mid	n/a	Total amount of sky covered by mid clouds (altostratus, altocumulus) Options: [Blank, None (0%), Few or Clear (1-10%), Isolated (10-25%), Scattered (25-50%), Broken (50-90%), Overcast (90-100%)]
sky condition noons:opacity mid	n/a	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)] An explanation of the comparison of reported opacity to satellite data from the GLOBE Clouds Team at NASA Langley Research Center is on the GLOBE Clouds page.
sky condition noons:cloud cover high	n/a	Total amount of sky covered by high clouds (contrails: short-lived, persistent non-spreading, persistent spreading, cirrus, cirrocumulus, cirrostratus) Options: [Blank, None (0%), Few or Clear (1-10%), Isolated (10-25%), Scattered (25-50%), Broken (50-90%), Overcast (90-100%)]
sky condition noons:opacity high	n/a	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)] An explanation of the comparison of reported opacity to satellite data from the GLOBE Clouds Team at NASA Langley Research Center is on the GLOBE Clouds page.

Clouds/Sky Conditions Noons, continued (Surface Conditions)

Variable	Units/Format	Definition
sky condition noons:snow/ice	n/a	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 condition noons:standing water	n/a	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 condition noons:muddy	n/a	Ground was reported as muddy Options: [TRUE, FALSE] *Note: Data downloaded from Vis returns X. Data downloaded from ADAT returns TRUE.*
sky condition noons:dry ground	n/a	Ground was reported as dry Options: [TRUE, FALSE] *Note: Data downloaded from Vis returns X. Data downloaded from ADAT returns TRUE.*
sky condition noons:leaves on trees	n/a	Options: [TRUE, FALSE] TRUE: More than 50% of the trees have leaves (this includes evergreens) FALSE: Less than 50% of the trees have leaves (this includes evergreens) *Note: Data downloaded from Vis returns X. Data downloaded from ADAT returns TRUE.*
sky condition noons:raining snowing	n/a	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.*

Conductivity

Variable	Units/Format	Definition
conductivities:water body state	n/a	The state of the water body Options: [normal, frozen, flooded, dry, unreachable]
conductivities:conductivity micro siemens per cm	microsiemens per centimeter (µS/cm)	Conductivity
conductivities:electrical conductivity mfg	n/a	Manufacturer of the conductivity meter
conductivities:electrical conductivity model	n/a	Model number of the conductivity meter
conductivities:comments	n/a	Comments on the conductivity measurement

Dissolved Oxygen

Variable	Units/Format	Definition
dissolved oxygens:water body state	n/a	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	n/a	Manufacturer of the dissolved oxygen kit
dissolved oxygens:oxygen kit model	n/a	Model of dissolved oxygen kit
dissolved oxygens:oxygen probe mfg	n/a	Manufacturer of the dissolved oxygen probe
dissolved oxygens:oxygen probe model	n/a	Model of dissolved oxygen probe
dissolved oxygens:comments	n/a	Comments on the dissolved measurement

Freshwater Macroinvertebrates

Variable	Units/Format	Definition
freshwater macroinvertebrates:year	yyyy	The year when freshwater macroinvertebrates were measured
freshwater macroinvertebrates:season	n/a	The season when freshwater macroinvertebrates were measured
freshwater macroinvertebrates:habitat type	n/a	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	n/a	Number of samples collected
freshwater macroinvertebrates:number of taxa reported for habitat type	n/a	Number of different taxa reported of this habitat
freshwater macroinvertebrates:taxonomic rank	n/a	Taxonomic rank Options: [family, genus, species]
freshwater macroinvertebrates:taxon latin name	n/a	Taxon Latin name
freshwater macroinvertebrates:taxonomic rank level one above	n/a	Taxonomic one level higher rank Options: [phylum, class, order]
freshwater macroinvertebrates:taxon latin name level one above	n/a	Taxon one level higher Latin name
freshwater macroinvertebrates:taxonomic rank level two above	n/a	Taxonomic two levels higher rank Options: [phylum, class, order]
freshwater macroinvertebrates:taxon latin name level two above	n/a	Taxon two levels higher Latin name
freshwater macroinvertebrates:number of organisms in taxon	n/a	Number of organisms found in the taxa
freshwater macroinvertebrates:is subsampled	n/a	Was subsampling used? Options: [yes,no]
freshwater macroinvertebrates: comments	n/a	Comments on the macroinvertebrate measurement

Frost Tube

Variable	Units/Format	Definition
frost tubes:frost tube installed	yyyy-mm-ddTHH:MM:SS	The date the Frost Tube was installed at the site.
frost tubes:height above ground (cm)	centimeters (cm)	The length of the Frost Tube that extends above the surface.
frost tubes:depth below ground (cm)	centimeters (cm)	The length of the Frost Tube that extends below the surface
frost tubes:total length (cm)	centimeters (cm)	The total length of the Frost Tube
frost tubes:depth of freezing (cm)	centimeters (cm)	Distance in the inner tube of the Frost Tube from the soil surface to the boundary between the ice layer and unfrozen water. This represents the depth of freezing between the soil surface and the underlying unfrozen soil.
frost tubes:permafrost	n/a	Flag to indicate permafrost. Options: [present, absent, unknown]
frost tubes:permafrost state	n/a	If permafrost is present, indicates the state of the permafrost. Options: [continuous, discontinuous, unknown]
frost tubes:permafrost depth to table (cm)	centimeters (cm)	If permafrost is present, indicates the distance from x to Y
frost tubes:permafrost measured on	yyyy-mm-ddTHH:MM:SS	If permafrost is present, the date the permafrost was measured.
frost tubes:comments	n/a	Comments pertaining to the Frost Tube measurement.

Greenings (Green-Up/Green-Down)

Variable	Units/Format	Definition
greenings:year	yyyy	Year of measurement
greenings:greening cycle number	n/a	Greening cycle Note: in some locations there is more than one cycle in a year.
greenings:vegetation type	n/a	Type of vegetation for which greening was observed Options: [tree, shrub, graminoid, other]
greenings:vegetation label	n/a	Species or common name
greenings:genus	n/a	Genus of the plant whose green-up is measured
greenings:species	n/a	Species of the plant whose green-up is measured
greenings:in understory	n/a	Is green-up or green-down observed for a plant that is the understory? Options: [yes, no]
greenings:stage	n/a	A reference for if the measurement is related to green-up or green-down phenophase Options: [up,down]
greenings:leaf state	n/a	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	n/a	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	n/a	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	n/a	Number of plants observed of a given spies
greenings:comments	n/a	Comments on green-up and green-down measurement

Land Cover

Variable	Units/Format	Definition
land covers:measurement latitude	decimal degrees north	Latitude recorded by the GPS of a participant using the GLOBE Observer app at the time of measurement. Range: [-90,90]
land covers:measurement longitude	decimal degrees east	Longitude recorded by the GPS of a participant using the GLOBE Observer app at the time of measurement.
land covers:measurement elevation	meters (m) above sea level	Elevation at the latitude/longitude location recorded by the GPS of a participant using the GLOBE Observer app at the time of measurement.
land covers:site_name	n/a	Name of the land cover site. Guidance: land covers:site_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	n/a	MUC code of the land cover site
land covers:muc details	n/a	Code that indicates alignment of MUC and IGBP classifications (See Appendix 4)
land covers:muc description	n/a	Description of the land cover site MUC code
land covers:field notes	n/a	Comments on land cover site measurement
land covers:location method	n/a	Indicates if the measurement location was determined by the device’s GPS (“automatic”) or if the user supplied it manually (“manual”)
land covers:location accuracy (m)	meters (m)	Accuracy of this location within “x” meters
land covers:data source	n/a	Descriptor indicating whether the data were reported by a GLOBE Educator via a method other than the app (“GLOBE Data Entry Site Definition”) or reported from the GLOBE Observer app (“GLOBE Observer App”)

Land Cover, continued (Surface Conditions)

Variable	Units/Format	Definition
land covers:snow ice	n/a	True/False indicating if this surface condition is present (this value is blank if the user submitted data via a means other than the GLOBE Observer app.)
land covers:standing water	n/a	True/False indicating if this surface condition is present (this value is blank if the user submitted data via a means other than the GLOBE Observer app.)
land covers:muddy	n/a	True/False indicating if this surface condition is present (this value is blank if the user submitted data via a means other than the GLOBE Observer app.)
land covers:dry ground	n/a	True/False indicating if this surface condition is present (this value is blank if the user submitted data via a means other than the GLOBE Observer app.)
land covers:leaves on trees	n/a	True/False indicating if this surface condition is present (this value is blank if the user submitted data via a means other than the GLOBE Observer app.)
land covers:raining snowing	n/a	True/False indicating if this surface condition is present (this value is blank if the user submitted data via a means other than the GLOBE Observer app.)

Land Cover, continued (Photo URLs and Directional Classifications)

Variable	Units/Format	Definition
land covers:north classifications	n/a	MUC code(s) and associated percentage(s) assigned for this direction
land covers:east classifications	n/a	MUC code(s) and associated percentage(s) assigned for this direction
land covers:south classifications	n/a	MUC code(s) and associated percentage(s) assigned for this direction
land covers:west classifications	n/a	MUC code(s) and associated percentage(s) assigned for this direction
land covers:north photo url	n/a	URL for the photo in the north direction
land covers:north caption	n/a	Caption for the photo in the north direction (currently n/a for entry from the GLOBE Observer Land Cover tool.)
land covers:north extra data	n/a	Extra data associated with the photo in this direction
land covers:east photo url	n/a	URL for the photo in the east direction
land covers:east caption	n/a	Caption for the photo in the east direction (currently n/a for entry from the GLOBE Observer App Land Cover tool.)
land covers:east extra data	n/a	Extra data associated with the photo in this direction
land covers:south photo url	n/a	URL for the photo in the south direction
land covers:south caption	n/a	Caption for the photo in the south direction (currently n/a for entry from the GLOBE Observer Land Cover tool.)
land covers:south extra data	n/a	Extra data associated with the photo in this direction
land covers:west photo url	n/a	URL for the photo in the West direction
land covers:west caption	n/a	Caption for the photo in the west direction (currently n/a for entry from the GLOBE Observer Land Cover tool.)
land covers:west extra data	n/a	Extra data associated with the photo in this direction
land covers:upward photo url	n/a	URL for the photo in the upward direction
land covers:upward caption	n/a	Caption for the photo in the upward direction (currently n/a for entry from the GLOBE Observer Land Cover tool.)
land covers:upward extra data	n/a	Extra data associated with the photo in this direction
land covers:downward photo url	n/a	URL for the photo in the downward direction
land covers:downward caption	n/a	Caption for the photo in the downward direction (currently n/a for entry from the GLOBE Observer Land Cover tool.)
land covers:downward extra data	n/a	Extra data associated with the photo in this direction

Lilac Phenology

Variable	Units/Format	Definition
lilacs:year	yyyy	Year when lilac phenophases were observed
lilacs:plant phenophase	n/a	Lilac phenophase
lilacs:lilac type	n/a	Lilac type Options: [common, cloned]
lilacs:shrub label	n/a	Type of lilac plant Options: [common, cloned]
lilacs:genus	n/a	Lilac genus
lilacs:species	n/a	Lilac species
lilacs:height (cm)	centimeters (cm)	Height of the lilac plant
lilacs:plant health	n/a	Options: [healthy, no change]
lilacs:planted date	yyyy-mm-dd	Date when the lilac bush was planted in UTC. (Spreadsheet programs may automatically convert to a different date format.)
lilacs:planted height (cm)	centimeters (cm)	Initial height of the lilac plant
lilacs:died date	yyyy-mm-dd	Date when the lilac bush died in UTC. (Spreadsheet programs may automatically convert to a different date format.)
lilacs:comments	n/a	Comments on lilac phenology measurements

Mosquitoes

Note: The Mosquito Larvae protocol (mosquitoes:*) was retired in 2018. Mosquito Habitat Mapper (mosquito habitat mapper:*) replaced it as the sole mosquito protocol.

Variable	Units/Format	Definition
mosquitoes:season	n/a	The season in which the mosquito observation is made Options: [fall, winter, spring, summer, dry, wet]
mosquitoes:comments	n/a	Comments on the mosquito observations
mosquitoes:water body depth at 50cm	n/a	Size of the water body being sampled greater than ("gt") 50 cm Options: [TRUE (t), FALSE (f)]
mosquitoes:water body size m	meters (m)	The approximate size of the water body being sampled (<1 m, 1-10 m, 10 m)
mosquitoes:shaded area percent	percent (%)	Percent of the water body being sampled that is in the shade
mosquitoes:plants	n/a	Plant presence in the water body being sampled Options: [TRUE (t), FALSE (f)]
mosquitoes:algae	n/a	Algal presence in the water body being sampled Options: [TRUE (t), FALSE (f)]
mosquitoes:odor	n/a	Presence of odor from sampled water body Options: [sewage, normal, none]
mosquitoes:surface oil	n/a	Oil presence on the water's surface Options: [none, flecks]
mosquitoes:turbidity subjective	n/a	A subjective assessment by the individual making the observation if the water in which the mosquitoes were found is turbid or clear
mosquitoes:container types	n/a	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.
mosquitoes:most freq habitat type	n/a	Most frequently observed type of mosquito habitat Options: [natural, artificial]
mosquitoes:net pole size cm	centimeters (cm)	Length of the pole on the net used (if used at all) to collect mosquitoes
mosquitoes:net diameter cm	centimeters (cm)	Diameter of the net used (if used at all) to collect mosquitoes
mosquitoes:container water level percent median	percent (%)	Median percent water level in the containers sampled (e.g., 50%)
mosquitoes:lid types	n/a	The type of lid associated with each container in which mosquito samples were found Options: [plastic, wood, clay, metal, none]

Mosquitoes, continued

Variable	Units/Format	Definition
mosquitoes:most freq container color	n/a	A flag indicating if most of the sampled containers have a light or dark color
mosquitoes:most freq cleaning frequency	n/a	Most common cleaning frequency of the containers or water bodies sampled (e.g., 1-2 times/week, >2 times/week)
mosquitoes:number of collection samples	n/a	Number (integer) of samples collected Note: The protocol asked for at least three samples taken at least two minutes apart.
mosquitoes:larvae genus	n/a	Genus of the mosquitoes sampled Options: [Aedes, Culex, Anopheles, other]
mosquitoes:larvae species	n/a	Species of the mosquitoes sampled (e.g., aegypti, albopictus)
mosquitoes:larvae count	n/a	Number (integer) of mosquito larvae present
mosquitoes:larvae count ratio	n/a	This is the ratio of the number of larvae reported / the number of collection samples

Mosquito Habitat Mapper

Variable	Units/Format	Definition
mosquito habitat mapper: measurement latitude	decimal degrees north	Latitude recorded by the GPS of a participant using the GLOBE Observer app at the time of measurement. Range: [-90,90] *Note: See also "latitude"*.
mosquito habitat mapper: measurement longitude	decimal degrees east	Longitude recorded by the GPS of a participant using the GLOBE Observer app at the time of measurement. *Note: See also "longitude"*.
mosquito habitat mapper: measurement elevations	meters (m) above sea level	Elevation at the latitude/longitude location recorded by the GPS of a participant using the GLOBE Observer app at the time of measurement. *Note: See also "elevation"*.
mosquito habitat mapper: data source	n/a	Indicates if the data was entered via the GLOBE Observer App (currently, that is the only option)
mosquito habitat mapper: water source type	n/a	High-level classification of the mosquito habitat type Options: [container: artificial, container: natural, flowing: still water found next to river or stream, still: lake/pond/swamp]
mosquito habitat mapper: water source	n/a	Further classification of the mosquito habitat type Options: [can, bottle, pond, cistern]
mosquito habitat mapper: larvae count	n/a	Number (integer) of mosquito larvae present
mosquito habitat mapper: mosquito eggs	n/a	Are mosquito eggs present? Options: [TRUE, FALSE]
mosquito habitat mapper: mosquito egg count	n/a	*This field is currently not used.*
mosquito habitat mapper: mosquito pupae	n/a	Are mosquito pupae present? Options: [TRUE (t), FALSE (f)]
mosquito habitat mapper: mosquito adults	n/a	Are adult mosquitoes present? Options: [TRUE (t), FALSE (f)]
mosquito habitat mapper: last identify stage	n/a	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	n/a	Genus of the mosquitoes Options: [Aedes, Anopheles, Culex] *Note: This is unvalidated data submitted by citizen scientists and should be validated by scientists through examination of associated voucher photographs.*
mosquito habitat mapper: species	n/a	Species of the mosquitoes (e.g., aegypti, albopictus) *Note: This is unvalidated data submitted by citizen scientists and should be validated by scientists through examination of associated voucher photographs.*

Mosquito Habitat Mapper, continued

Variable	Units/Format	Definition
mosquito habitat mapper: breeding ground eliminated	n/a	Was the breeding ground eliminated? Options: [TRUE (t), FALSE (f)]
mosquito habitat mapper: extra data	n/a	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: water source photo urls	n/a	URL of the mosquito water source photo
mosquito habitat mapper: larva full body photo urls	n/a	URL of the mosquito full body photo
mosquito habitat mapper: abdomen closeup photo urls	n/a	URL for the mosquito abdomen photo
mosquito habitat mapper: comments	n/a	Comments about the mosquito observation
mosquito habitat mapper: location method	n/a	Indicates if the measurement location was determined automatically by device GPS or entered manually
mosquito habitat mapper: location accuracy (m)	meters (m)	For locations determined by device GPS, this is the estimate of accuracy within “n” meters

Nitrates

Variable	Units/Format	Definition
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	n/a	Comments on water body nitrate measurement
nitrates:water body state	n/a	The state of the water body Options: [normal, frozen, flooded, dry, or unreachable
nitrates:nitrate kit mfg	n/a	Manufacturer of the nitrate measurement kit
nitrates:nitrate kit model	n/a	Model name of the nitrate measurement kit

pH

Variable	Units/Format	Definition
hydrology phs:water body state	n/a	The state of the water body Options: [normal, frozen, flooded,dry, unreachable]
hydrology phs:ph	n/a	pH of the water body
hydrology phs:ph method	n/a	The method used to measure water body pH: paper, pen, or meter
hydrology phs:ph meter model	n/a	Model number of the pH meter used
hydrology phs:ph meter mfg	n/a	Name of the pH meter manufacturer
hydrology phs:ph buffer 4	n/a	Was the pH 4 buffer used in calibration? Options: [yes, no]
hydrology phs:ph buffer 7	n/a	Was the pH 7 buffer used in calibration? Options: [yes, no]
hydrology phs:ph buffer 10	n/a	Was the pH 10 buffer used in calibration? Options: [yes, no]
hydrology phs:comments	n/a	Comments on measurements of water body pH

Phenological Gardens

Variable	Units/Format	Definition
phenological gardens: year	yyyy	The year when measurements of a phenology garden were taken
phenological gardens: common name	n/a	The common name of the plant in a phenology garden observed
phenological gardens: plant number	n/a	The number of the plant in a phenology garden observed
phenological gardens: planted date	yyyy-mm-dd	The date in UTC when the plant in a phenology garden was planted. (Spreadsheet programs may automatically convert to a different date format.)
phenological gardens: genus	n/a	The genus of the plant in a phenology garden that was observed
phenological gardens: species	n/a	The species of the plant in a phenology garden that was observed
phenological gardens: plant state	n/a	The state (phenophase) of the plant in a phenology garden that was observed
phenological gardens: height cm	centimeters (cm)	Measure of height of each plant in autumn of year except snowdrops
phenological gardens: comments	n/a	Comments on phenology garden measurements
phenological gardens: fertilizer types dates	yyyy-mm-dd	Type(s) of fertilizer applied to garden and date(s) of application. (Spreadsheet programs may automatically convert to a different date format.)
phenological gardens: watered dates	yyyy-mm-dd	Date(s) on which the garden was watered. (Spreadsheet programs may automatically convert to a different date format.)
phenological gardens: pruned dates	yyyy-mm-dd	Date(s) on which plant was pruned. (Spreadsheet programs may automatically convert to a different date format.)

Precipitation

Variable	Units/Format	Definition
precipitations: snowfall accumulation flag	n/a	A notation if the snowfall amount is missing or was a trace Options: [missing, trace]
precipitations:ph method	n/a	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	n/a	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	n/a	A notation if the liquid accumulation amount is missing or was a trace
precipitations:days accumulated	n/a	The number of days precipitation has accumulated since the previous measurement (maximum allowed is 7 days)
precipitations:pH	n/a	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	n/a	Comments on the precipitation measurement

Precipitation Monthlies

Variable	Units/Format	Definition
precipitation monthlies:averaged month	yyyy-mm-01	First day of the month for which precipitation measurements are averaged. (Spreadsheet programs may automatically convert to a different date format.)
precipitation monthlies:number of days reported	n/a	Number of days in month on which precipitation measurements were reported
precipitation monthlies:number of obs	n/a	Number of precipitation observations reported in the month
precipitation monthlies:liquid accumulation mm	millimeters (mm)	Accumulation of liquid precipitation reported for the month
precipitation monthlies:liquid accumulation flag	n/a	Flag for precipitation monthlies marked trace for trace precipitation reported.

Relative Humidity

Variable	Units/Format	Definition
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	n/a	Comments on humidity measurement

Relative Humidity Monthlies

Variable	Units/Format	Definition
humidity monthlies: averaged month	yyyy-mm-01	First day of the month for which humidity measurements are averaged. (Spreadsheet programs may automatically convert to a different date format.)
humidity monthlies:number of days reported	n/a	Number of days in month on which humidity measurements were reported
humidity monthlies:number of obs	n/a	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.

Relative Humidity Noons

Variable	Units/Format	Definition
humidity noons:comments	n/a	Comments on the relative humidity measurement
humidity noons:dewpoint	degrees Celsius	The dewpoint measurement closest to and within one hour of local solar noon
humidity noons:relative humidity (%)	percent (%)	The relative humidity measurement closest to and within one hour of local solar noon

Salinity

Variable	Units/Format	Definition
salinities:water body state	n/a	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	n/a	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	n/a	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	n/a	Type of tide Options: [high, low]
salinities:after salinity measurement tide at	n/a	Time of high or low tide following the salinity measurement
salinities:after salinity measurement tide type	n/a	Type of tide Options: [high, low]
salinities:salinity kit mfg	n/a	Name of the manufacturer of the salinity kit used
salinities:salinity kit model	n/a	Salinity test kit model number
salinities:comments	n/a	Comments on salinity measurement

Snow Pack/Solid Precipitation

Variable	Units/Format	Definition
snowpacks:snow depth	millimeters (mm)	Depth of the snowpack
snowpacks:depth flag	n/a	Options: [trace, missing]
snowpacks:liquid equivalent	millimeters (mm)	Depth of the melted (i.e., liquid) snowpack
snowpacks:liquid equivalent flag	n/a	Options: [trace, missing]
snowpacks:ph	n/a	pH of the melted snowpack
snowpacks:ph method	n/a	Method used to measure snowpack pH Options: [pH paper, pH meter]
snowpacks:comments	n/a	Comments on the snowpack measurement

Soil Characterization – Field Measurements

Variable	Units/Format	Definition
soil layer descriptions: horizon number	n/a	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	n/a	Number of the soil horizon at 5 cm depth
soil layer descriptions: reference depth level 10cm	n/a	Number of the soil horizon at 10 cm depth
soil layer descriptions: reference depth level 30cm	n/a	Number of the soil horizon at 30 cm depth
soil layer descriptions: reference depth level 50cm	n/a	Number of the soil horizon at 50 cm depth
soil layer descriptions: reference depth level 60cm	n/a	Number of the soil horizon at 60 cm depth
soil layer descriptions: reference depth level 90cm	n/a	Number of the soil horizon at 90 cm depth
soil layer descriptions: collected on	yyyy-mm-dd	Date on which soil horizon samples were collected in UTC. (Spreadsheet programs may automatically convert to a different date format.)
soil layer descriptions: moisture estimate	n/a	Soil horizon moisture Options: [wet, moist, dry]
soil layer descriptions: structure	n/a	Soil horizon structure Options: [granular, blocky, platy, prismatic, columnar, single grained, massive, unknown]
soil layer descriptions: consistence	n/a	Soil horizon consistency Options: [loose, friable, firm, extra firm]
soil layer descriptions: main color code	n/a	Code of the primary soil horizon color
soil layer descriptions: secondary color code	n/a	Code of the secondary soil horizon color, if there is one
soil layer descriptions: texture field estimate	n/a	Soil horizon texture as determined by feel
soil layer descriptions: rock quantity estimate	n/a	Presence of rocks in the soil horizon Options: [many, few, none]
soil layer descriptions: root quantity estimate	n/a	Presence of roots in the soil horizon Options: [many, few, none]
soil layer descriptions: carbonates	n/a	Presence of carbonate in the soil horizon Options: [much, some, none]
soil layer descriptions: comments	n/a	Comments on soil characterization measurements

Soil Characterization – Horizon Number at Depth/ Horizon Bottom Depth

Variable	Units/Format	Definition
soil characterizations: horizon number	n/a	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	n/a	Number of the soil horizon at 5 cm depth
soil characterizations: reference depth level 10cm	n/a	Number of the soil horizon at 10 cm depth
soil characterizations: reference depth level 30cm	n/a	Number of the soil horizon at 30 cm depth
soil characterizations: reference depth level 50cm	n/a	Number of the soil horizon at 50 cm depth
soil characterizations: reference depth level 60cm	n/a	Number of the soil horizon at 60 cm depth
soil characterizations: reference depth level 90cm	n/a	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	n/a	Moisture of the soil horizon Options: [wet, moist, dry]
soil characterizations: structure	n/a	Soil horizon structure Options: [granular, blocky, platy, prismatic, columnar, single grained, massive, unknown]
soil characterizations: consistence	n/a	Soil horizon consistency Options: [loose, friable, firm, extra firm]
soil characterizations: main color code	n/a	Code of the primary soil horizon color
soil characterizations: secondary color code	n/a	Code of the secondary soil horizon color if secondary soil horizon is present
soil characterizations: texture field estimate	n/a	Soil horizon texture as determined by feel (see Soil Texture Triangle) Options: [sand, silt, clay, combination]

Soil Characterization – Horizon Number at Depth/Horizon Bottom Depth, cont.

Variable	Units/Format	Definition
soil characterizations: rock quantity estimate	n/a	Presence of rocks in the soil horizon Options: [many, few, none]
soil characterizations: root quantity estimate	n/a	Presence of roots in the soil horizon Options: [many, few, none]
soil characterizations: carbonates	n/a	Presence of carbonate in the soil horizon Options: [much, few, none]
soil characterizations:ph	n/a	pH of the soil horizon
soil characterizations: ph method	n/a	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	n/a	Soil horizon texture based on the measured percentages of sand, silt, and clay (see Soil Texture Triangle)
soil characterizations: nitrate estimate	n/a	Amount of nitrate Options: [high, medium, low, none, unknown]
soil characterizations: phosphate estimate	n/a	Amount of phosphate Options: [high, medium, low, none, unknown]
soil characterizations: potassium estimate	n/a	Amount of potassium Options: [high, medium, low, none, unknown]
soil characterizations: comments	n/a	Comments on soil characterization measurements

Soil Characterization – Particle Size Distribution

Variable	Units/Format	Definition
soil particle size distributions: horizon number	n/a	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	n/a	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 the measured soil horizon.
soil particle size distributions: reference depth level 10cm	n/a	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 the measured soil horizon.
soil particle size distributions: reference depth level 30cm	n/a	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 the measured soil horizon.
soil particle size distributions:reference depth level 50cm	n/a	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 the measured soil horizon.
soil particle size distributions:reference depth level 60cm	n/a	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 the measured soil horizon.
soil particle size distributions:reference depth level 90cm	n/a	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 ofthe measured soil horizon.
soil particle size distributions:collected on	yyyy-mm-dd	Date soil was collected on in UTC. (Spreadsheet programs may automatically convert to a different date format.)
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	n/a	Taken from the textural triangle (see Soil Texture Triangle in the particle size distribution protocol)
soil particle size distributions:comments	n/a	Comments on particle size distribution

Soil Density

Variable	Units/Format	Definition
soil densities:horizon number	n/a	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	n/a	Number of the soil horizon at 5 cm depth
soil densities:reference depth level 10cm	n/a	Number of the soil horizon at 10 cm depth
soil densities:reference depth level 30cm	n/a	Number of the soil horizon at 30 cm depth
soil densities:reference depth level 50cm	n/a	Number of the soil horizon at 50 cm depth
soil densities:reference depth level 60cm	n/a	Number of the soil horizon at 60 cm depth
soil densities:reference depth level 90cm	n/a	Number of the soil horizon at 90 cm depth
soil densities:collected on	yyyy-mm-dd	Date when samples were collected for soil densities measurements. (Spreadsheet programs may automatically convert to a different date format.)
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	n/a	Comments on soil density measurement

Soil Fertility

Variable	Units/Format	Definition
soil fertilities:horizon number	n/a	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	n/a	Number of the soil horizon at 5 cm depth
soil fertilities:reference depth level 10cm	n/a	Number of the soil horizon at 10 cm depth
soil fertilities:reference depth level 30cm	n/a	Number of the soil horizon at 30 cm depth
soil fertilities:reference depth level 50cm	n/a	Number of the soil horizon at 50 cm depth
soil fertilities:reference depth level 60cm	n/a	Number of the soil horizon at 60 cm depth
soil fertilities:reference depth level 90cm	n/a	Number of the soil horizon at 90 cm depth
soil fertilities:collected on	yyyy-mm-dd	Date when samples were collected for soil fertility measurements. (Spreadsheet programs may automatically convert to a different date format.)
soil fertilities:nitrate estimate	n/a	Soil nitrate estimate from the NPK (nitrogen-K, phosphorus-P, potassium-K) kit Options: [high, medium, low, none]
soil fertilities:phosphate estimate	n/a	Soil phosphate estimate from the NPK (nitrogen-K, phosphorus-P, potassium-K) kit Options: [high, medium, low, none]
soil fertilities:potassium estimate	n/a	Soil potassium estimate from the NPK (nitrogen-K, phosphorus-P, potassium-K) kit Options: [high, medium, low, none]
soil fertilities:comments	n/a	Comments from the NPK kit results

Soil Infiltration

Variable	Units/Format	Definition
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	n/a	Comments on soil infiltration measurement

Soil Moisture – Gravimetric

Variable	Units/Format	Definition
soil moisture via gravimetrics:depth level (cm)	centimeters (cm)	Moisture for the top 5 cm
soil moisture via gravimetrics:moisture method	n/a	Options: [star gravimetric, transect gravimetric, hole depth gravimetric, smap]
soil moisture via gravimetrics:saturated flag	n/a	A flag indicating that the surface soil was saturated at the time of measurement
soil moisture via gravimetrics:water content (g per g)	grams per gram ($g\ g^{-1}$)	Gravimetric surface soil moisture measurement taken following
soil moisture via gravimetrics:comments	n/a	Comments on surface soil moisture measurements taken
soil moisture via gravimetrics:soil state	n/a	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 “measurable” is selected. Options: [snow, measurable, frozen, frozen water, graupel, hail]

Soil Moisture - Sensors

Variable	Units/Format	Definition
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	n/a	Type of sensor used to measure soil moisture
soil moisture via sensors: saturated flag	n/a	A flag indicating if soils are fully saturated and there is standing water.
soil moisture via sensors: meter reading	n/a	Soil moisture meter reading
soil moisture via sensors: installation date	yyyy-mm-dd	Date soil moisture sensor was installed at the site in UTC. (Spreadsheet programs may automatically convert to a different date format.)
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	n/a	Comments on the soil moisture measurements taken using sensors

Soil Moisture – SMAP Block Pattern

Variable	Units/Format	Definition
soil moisture for smap: depth level cm	centimeters (cm)	Moisture for the top 5 cm
soil moisture for smap: saturated flag	n/a	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	n/a	Comments on surface soil moisture measurements taken following the SMAP Block Pattern protocol
soil moisture for smap: soil state	n/a	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 “measurable” is selected. Options: [snow, measurable, frozen, frozen water, graupel, hail]

Soil Moisture Monthlies aka Volumetric Soil Moisture Monthlies

Variable	Units/Format	Definition
volumetric soil moisture monthlies:averaged month	yyyy-mm-01	First day of the month for which soil moisture measurements are averaged. (Spreadsheet programs may automatically convert to a different date format.)
volumetric soil moisture monthlies:number of days reported	n/a	Number of days in the month on which soil moisture observations were reported
volumetric soil moisture monthlies:number of obs	n/a	Number of soil moisture observations reported in the month
volumetric soil moisture monthlies:depth level (cm)	centimeters (cm)	Depth at which soil moisture measurements were taken
volumetric soil moisture monthlies:maximum soil moisture (ml per ml)	milliliters per milliliter (ml ml^{-1})	Maximum soil moisture measurement reported in the month
volumetric soil moisture monthlies:minimum soil moisture (ml per ml)	milliliters per milliliter (ml ml^{-1})	Minimum soil moisture measurement reported in the month
volumetric soil moisture monthlies:average soil moisture (ml per ml)	milliliters per milliliter (ml ml^{-1})	Average soil moisture measurement reported in the month

Soil pH

Variable	Units/Format	Definition
soil phs:horizon number	n/a	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	n/a	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 the measured soil horizon.
soil phs: reference depth level 10cm	n/a	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 the measured soil horizon.
soil phs: reference depth level 30cm	n/a	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 the measured soil horizon.
soil phs: reference depth level 50cm	n/a	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 the measured soil horizon.
soil phs: reference depth level 60cm	n/a	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 the measured soil horizon.
soil phs: reference depth level 90cm	n/a	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 the measured soil horizon.
soil phs:collected on	yyyy-mm-dd	Date soil sample was collected on in UTC. (Spreadsheet programs may automatically convert to a different date format.)
soil phs:ph	n/a	pH of the soil horizon
soil phs:ph method	n/a	Method used to measure soil pH Options: [pH paper, pH meter]
soil phs:comments	n/a	Comments on the soil pH measurement

Soil Temperature

Variable	Units/Format	Definition
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.

Soil Temperature Dailies

Variable	Units/Format	Definition
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	n/a	Comments on soil temperature measurements

Soil Temperature Monthlies

Variable	Units/Format	Definition
soil temp monthlies: averaged month	yyyy-mm-01	First day of the month for which soil temperature measurements are averaged. (Spreadsheet programs may automatically convert to a different date format.)
soil temp monthlies: number of days reported	n/a	Number of days in month on which soil temperature measurements were reported
soil temp monthlies: number of obs	n/a	Number of soil temperature observations reported in the month
soil temp monthlies: depth level (cm)	centimeters (cm)	Depth at which soil temperature measurements were reported
soil temp monthlies: maximum temp (deg C)	degrees Celsius	Maximum soil temperature reported during the month
soil temp monthlies: minimum temp (deg C)	degrees Celsius	Minimum soil temperature reported during the month
soil temp monthlies: average temp (deg C)	degrees Celsius	Monthly average soil temperature

Soil Temperature Noons

Variable	Units/Format	Definition
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	n/a	Comments on soil temperature measurements

Surface Ozone

Variable	Units/Format	Definition
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	n/a	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	n/a	The method used to measure ozone concentration. As of April 2019 only one method is defined (GLOBE 2000 method).
ozones:comments	n/a	Comments on the measurement of ozone concentration

Surface Ozone One Hour After Noons

Variable	Units/Format	Definition
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	n/a	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	n/a	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	n/a	Comments on the measurement of ozone concentration

Surface Temperature

Variable	Units/Format	Definition
surface temperatures: average surface temperature c	degrees Celsius	Average of surface temperatures for one homogeneous site (1-9 observations)
surface temperatures:surface condition	n/a	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	n/a	Snow flag taken with surface temperature observations for one homogeneous site Options: [yes; no]
surface temperatures: number of samples taken	n/a	Number of surface temperature samples taken
surface temperatures: comments	n/a	Comments about surface temperature measurement
surface temperatures: surface cover type	n/a	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

Surface Temperature Noons

Variable	Units/Format	Definition
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	n/a	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	n/a	Flag indicating that the land surface was covered by snow
surface temperature noons: number of samples taken	n/a	Number of places on the ground at which surface temperature was measured
surface temperature noons: comments	n/a	Comments on surface temperature measurements
surface temperature noons: surface cover type	n/a	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

Water Temperature

Variable	Units/Format	Definition
water temperatures: comments	n/a	Comments about water temperature
water temperatures: water body state	n/a	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	n/a	Method used thermometer or probe
water temperatures: thermometer probe mfg	n/a	Manufacturer of thermometer probe
water temperatures: thermometer probe model	n/a	Thermometer probe model

Water Transparency

Variable	Units/Format	Definition
transparencies:comments	n/a	Comments on the transparency measurement
transparencies:water body state	n/a	The state of the water body Options: [normal, frozen, flooded, dry, 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	n/a	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	n/a	A flag indicating that the pattern at the bottom of the turbidity tube could be seen even when the tube was full

Water Vapor

Variable	Units/Format	Definition
water vapors:precipitable water	centimeters (cm)	Precipitable water vapor (cm of water in a vertical column of atmosphere directly above the observer) measured
water vapors:comments	n/a	Comments on water vapor measurement
water vapors:observed sky color	n/a	Sky color Options: [deep blue, blue, light blue, pale blue, milky] *Note: a guide to sky color is provided on page 14 of the GLOBE Clouds protocol.*
water vapors:observed sky clarity	n/a	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 14 of the GLOBE Clouds protocol.*
water vapors:associated remote sensor	n/a	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*

Water Vapor Noons

Variable	Units/Format	Definition
water vapor noons: precipitable water	centimeters (cm)	Precipitable water vapor (cm of water in a vertical column of atmosphere directly above the observer) measured within 1 hour of local solar noon
water vapor noons: comments	n/a	Comments on water vapor measurement
water vapor noons: observed sky color	n/a	Sky color Options: [deep blue, blue, light blue, pale blue, milky] *Note: a guide to sky color is provided on page 14 of the GLOBE Clouds protocol.*
water vapor noons: observed sky clarity	n/a	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 14 of the GLOBE Clouds protocol.*
water vapor noons: associated remote sensor	n/a	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*

Wind

Variable	Units/Format	Definition
winds:speed mps	meters per second (mps)	Wind speed (usually reported via automated weather station)
winds:speed flag	n/a	--
winds:gust mps	meters per second (mps)	Wind gust speed (usually reported via automated weather station)
winds:direction	degrees	Direction the wind is coming from, with 0 = north *Note: Automated weather stations may give a precise number, while data entered through Atmosphere Data Entry in the GLOBE Observer app gives the options: [north, northeast, east, southeast, south, southwest, west, northwest] stored as numeric values.*
winds:direction flag	n/a	--
winds:direction precision	n/a	Number with a range of 1 to 180
winds:wind direction method	n/a	Method used for measuring wind direction Options: [automated, GLOBE instrument]
winds:comments	n/a	Comments related to the wind observation

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 types 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 heighte exceeds 2 meters.

Reference: Definition of MODIS Land Cover Classes

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 Needleleaf 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 Needleleaf 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

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

Appendix 4. MUC Alignment with IGBP

This appendix provides an explanation of the **land_covers:muc_details** field. The MUC details field describes the added details needed to align MUC with the classification systems used by satellites, primarily the International Geosphere-Biosphere Programme IGBP, which is the basis for the MODIS classification system. This field is left blank where no reasonable alignment could be made.

The MUC classifies land cover and land use into nine primary categories, each of which contain secondary, tertiary, and, in some cases, quaternary categories based on ecosystem type. The IGBP Land Cover Type Classification is based on plant functional types. The GLOBE Observer hybrid classification system builds on the primary and secondary-level MUC classes that tend to be grouped by plant or land use type. In some cases, GLOBE Observer Land Cover's system requires additional information from end users not in the original GLOBE Land Cover measurement protocol. For example, users indicate whether shrubs are closely or loosely spaced to determine which of IGBP's shrubland classifications best match the MUC's evergreen or deciduous shrubland classifications. Not all classification types had a corresponding category or definition in the other system. IGBP's mixed forest did not align with any GLOBE MUC classification, but could be derived from the data provided based on user estimates of the density of tree cover. MUC's xeromorphic or tall grassland classifications did not align with any category in the IGBP system.

For example, the MUC code for loosely space evergreen needleleaf trees is 11, and the MUC code for loosely spaced evergreen broadleaf trees is also 11, but the IGBP differentiates between the two. The GO land cover tool differentiates the MUC between these two by adding a n or b to the MUC code, and this differentiating code is in the MUC details field.

The tables below indicate where the **land_covers:muc_details** field will be needed and what the value represents.

Trees (Closely Spaced)

GO App Land Cover Key	MUC Classification	IGBP Classification
Evergreen – needle-leaved	MUC 01n, Closed Needle-leaved Evergreen Forest	1, Evergreen Needleleaf Forests
Evergreen – broad-leaved	MUC 01b, Closed Broad-leaved Evergreen Forest	2, Evergreen Broadleaf Forests
Deciduous – needle-leaved	MUC 02n, Closed Needle-leaved Deciduous Forest	3, Deciduous Needleleaf Forests
Deciduous – broad-leaved	MUC 02b, Closed Broad-leaved Deciduous Forest	4, Deciduous Broadleaf Forests
Extremely dry	MUC 03, Extremely Xeromorphic	--
Not sure which	MUC 0, Closed Forest	1, Evergreen Needleleaf Forests

Trees (Loosely Spaced)

GO App Land Cover Key	MUC Classification	IGBP Classification
Evergreen – needle-leaved	MUC 11n, Evergreen Needle-leaved Woodland	8, Woody Savannas
Evergreen – broad-leaved	MUC 11b, Evergreen Broad-leaved Woodland	8, Woody Savannas
Deciduous – needle-leaved	MUC 12n, Deciduous Needle-leaved Woodland	8, Woody Savannas
Deciduous – broad-leaved	MUC 12b, Deciduous Broad-leaved Woodland	8, Woody Savannas
Extremely dry	MUC 13, Extremely Xeromorphic Woodland	8, Woody Savannas
Not sure which	MUC 0, Closed Forest	1, Evergreen Needleleaf Forests

Shrubs (Closely Spaced)

GO App Land Cover Key	MUC Classification	IGBP Classification
Tall Evergreen	MUC 21c, Mainly Evergreen Shrubland or Thicket	6, Closed Shrublands
Tall Deciduous	MUC 22c, Mainly Deciduous Shrubland or Thicket	6, Closed Shrublands
Tall Extremely Dry	MUC 23c, Extremely Xeromorphic Shrubland	6, Closed Shrublands
Short Evergreen	MUC 31c, Mainly Evergreen Dwarf-Shrubland or Dwarf-Thicket, Heath	6, Closed Shrublands
Short Deciduous	MUC 32c, Mainly Deciduous Dwarf-Shrubland or Dwarf-Thicket, Heath	6, Closed Shrublands
Short Extremely Dry	MUC 33c, Extremely Xeromorphic (Subdesert) Dwarf Shrubland	6, Closed Shrublands
Not sure which	MUC 3c, Dwarf-Shrubland or Dwarf Thicket, Heath	6, Closed Shrublands

Shrubs (Loosely Spaced)

GO App Land Cover Key	MUC Classification	IGBP Classification
Tall Evergreen	MUC 21l, Mainly Evergreen Shrubland or Thicket	7, Open Shrublands
Tall Deciduous	MUC 22l, Mainly Deciduous Shrubland or Thicket	7, Open Shrublands
Tall Extremely Dry	MUC 23l, Extremely Xeromorphic Shrubland	7, Open Shrublands
Short Evergreen	MUC 31l, Dwarf Thicket	7, Open Shrublands
Short Deciduous	MUC 32l Dwarf-Shrubland or Dwarf-Thicket, Mainly Deciduous	7, Open Shrublands
Short Extremely Dry	MUC 33l, Extremely Xeromorphic Dwarf-Shrubland	7, Open Shrublands
Not sure which	MUC 3l, Dwarf-Shrubland or Dwarf Thicket, Heath	7, Open Shrublands

Herbaceous/Grassland

GO App Land Cover Key	MUC Classification	IGBP Classification
Tall Grass	MUC 41, Tall Grasslands	--
Medium Grass	MUC 42, Medium-Tall Grassland	10, Grasslands
Short Grass	MUC 43, Short grassland	10, Grasslands
Ferns or Flowers	MUC 44, Forb Vegetation	10, Grasslands

Barren

GO App Land Cover Key	MUC Classification	IGBP Classification
Dry Salt Flats	MUC 51, Barren Land, Dry Salt Flats	16, Barren
Sandy	MUC 52, Barren Land, Sandy Areas	16, Barren
Bare Rock	MUC 53, Barren Land, Bare Rock	16, Barren
Perennial Snowfields	MUC 54, Barren Land, Perennial Snowfields	15, Permanent Snow and Ice
Glaciers	MUC 55, Barren Land, Glaciers	15, Permanent Snow and Ice
Dirt/Other	MUC 56, Barren Land, Other	16, Barren

Wetlands

GO App Land Cover Key	MUC Classification	IGBP Classification
In Freshwater Riverine (Riverine)	MUC 61 Wetland, Riverine	11, Permanent Wetlands
In Salt/Brackish Tidal (Estuarine)	MUC 63 Wetland, Estuarine	11, Permanent Wetlands
In Freshwater Lake or Pond (Lacustrine)	MUC 64 Wetland, Lacustrine	11, Permanent Wetlands

Open Water

GO App Land Cover Key	MUC Classification	IGBP Classification
Freshwater	MUC 71, Open Freshwater	17, Water Bodies
Marine	MUC 72, Open Marine Water	17, Water Bodies

Cultivated

GO App Land Cover Key	MUC Classification	IGBP Classification
Crops or Pastures	MUC 811, Cultivated Land, Agriculture, Row Crop, and Pasture	12, Croplands
Orchards	MUC 812, Cultivated Land, Agriculture, Orchard, and Horticulture	12, Croplands
Other Agriculture	MUC 814, Cultivated Land, Agriculture, Confined Livestock and Other Agriculture	12, Croplands
Athletic Field, Golf Course, Cemetery	MUC 82, Cultivated Land, Non-Agriculture	12, Croplands

Urban

GO App Land Cover Key	MUC Classification	IGBP Classification
Residential Property	MUC 91, Urban, Residential	13, Urban and Built-up Lands
Commercial Property	MUC 92, Urban, Commercial and Industrial	13, Urban and Built-up Lands
Roads and Parking	MUC 93, Urban, Transportation	13, Urban and Built-up Lands
Other	MUC 94, Urban, Other	13, Urban and Built-up Lands