NASA GLOBE Clouds: Documentation on How Satellite Data is Collocated to Ground Cloud Observations

Version 4.0

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1 Abbreviations

Acronym	Descriptions and Weblinks
ASDC	NASA's Atmospheric Science Data Center
CALIPSO	Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation, https://www-calipso.larc.nasa.gov/
CERES	Clouds and the Earth's Radiant Energy System, https://ceres.larc.nasa.gov/
GLOBE	Global Learning and Observations to Benefit the Environment, https://www.globe.gov
GOES	Geostationary Operational Environmental Satellite, https://www.goes.noaa.gov/
FLASHFlux	Fast Longwave and Shortwave Flux, https://ceres.larc.nasa.gov/data/#flashflux-ssf-level-2
MODIS	Moderate Resolution Imaging Spectroradiometer, https://terra.nasa.gov/about/terra-instruments/modis
NASA	National Aeronautics and Space Administration
NOAA-20	National Oceanic and Atmospheric Administration 20, previously known as JPSS-1 (Joint Polar Satellite System) 1.
S'COOL	Students' Cloud Observations On-Line, https://scool.larc.nasa.gov
SatCORPS	Satellite ClOud and Radiation Property retrieval System, https://satcorps.larc.nasa.gov/
SSF	Single Scanner Footprint
VIIRS	Visible Infrared Imaging Radiometer Suite, https://ncc.nesdis.noaa.gov/VIIRS/

2 Abstract

The NASA GLOBE Clouds team at NASA Langley Research Center in Hampton, Virginia, USA receives all overhead cloud reports from human observers submitted through the GLOBE (Global Learning and Observations to Benefit the Environment) Program. This work is part of the NASA Earth Science Education Collaborative (NESEC), which is led by the Institute for Global Environmental Strategies (IGES) and supported by NASA under cooperative agreement award number NNX16AE28A.

The ground-based cloud observations submitted through various protocols and methods, including the GLOBE Observer mobile app, are then collocated with satellite observations of

clouds from various Earth-observing platforms, a process referred to as a satellite comparison. This document is a guide to how the ground-satellite collocation or satellite comparison is done by the team. A full description of The GLOBE Program's dataset can be found in the GLOBE Data Users Guide.

3 Background

Ground-satellite collocation, or satellite comparison of cloud observations, started in 2017 for GLOBE participants when the S'COOL (Students' Cloud Observations On-Line) Project merged with GLOBE and became NASA GLOBE Clouds. The S'COOL Project (Chambers et al., 2003 and 2017) collected cloud observations from students, teachers, and the general public and sent a personalized email to each participant whenever there was a ground-satellite collocation of cloud observations to report.

The NASA GLOBE Clouds team compares GLOBE cloud observations to corresponding satellite data. GLOBE participants can "opt in" to receive notifications on their mobile device about polar orbiting satellite flyovers or check online (see satellite overpass schedule tool). If an observer's cloud observation is collocated to satellite data, and the user opted-in to receive emails from GLOBE, the user will receive a Satellite Comparison Table for every collocation (see satellite comparison table example) through a personalized email from NASA within roughly one week of submitting their observation. The NASA GLOBE Clouds team uses an application programming interface or API specific for the team to pull cloud observations daily from the GLOBE Program's database. The cloud observations can then be compared to multiple geostationary satellites and CERES instrument onboard NOAA-20. Historically the team also compared to Aqua,Terra, and CALIPSO. The satellite comparison table includes images from these satellites centered on the observation location.

3.1 Science Team Collaborations

The collocation process for GLOBE ground cloud observations with satellite data involves collaboration with various teams. The NASA GLOBE Clouds team works side-by-side with NASA's ASDC (Atmospheric Science Data Center) team where the system is housed. In addition, the CERES FLASHFlux and SatCORPS teams each develop and maintain portions of the satellite comparison process and code, for low Earth orbit and geostationary satellites respectively.

The CERES and CALIPSO teams have collaborated since the beginning of S'COOL, and there are long-term, strong positive relationships in place that support the ongoing success of the collocation efforts. This includes understanding the history, science objectives, and constraints of each team. In addition, all these teams are based at NASA Langley Research Center, which provides unique advantages for ongoing contact.

These collaborations inform decisions to add and/or remove satellites in collocation processes and to modify code for best data usage.

Details on the systems processes for satellite collocations can be found in the Technical publication, *NASA Langley Research Center GLOBE Cloud Process*, NASA-TP-20240013399, available to NASA civil servants and contractors (Rizzi et al., 2024).

3.2 Description of GLOBE participants

Individuals contributing cloud observations need to be in a GLOBE country. These individuals fall into two groups: those that have received formal GLOBE protocol training, and those that are trained via the tutorials supplied with the GLOBE Observer app. Users that receive formal training are often classroom educators who want to teach their students the protocols (i.e., methods) to collect and enter data for GLOBE's additional protocols (i.e., beyond what is available in the GLOBE Observer app.) Users that have received formal training can enter data through other mechanisms in addition to the GLOBE Observer mobile app, including data entry desktop forms, GLOBE's Data Entry mobile app, and email data entry. GLOBE Observer mobile app users need only view the tutorials supplied within the app before submitting data. Detailed steps for the clouds protocol can be found on the NASA GLOBE Clouds webpage.

3.3 Description of Ground Observations

Each GLOBE cloud observation contains information about the percent of sky covered by clouds, the presence of obscurations, 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, spray, dust, blowing snow, heavy rain, or volcanic ash, preventing the user from seeing the sky or clouds. Optional fields for cloud observations are: sky color, sky visibility, presence of low-, mid-, and high-level clouds and contrails, and opacity (see **Table 1 and figure 1**).

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 GLOBE Observer mobile app guides users to align their smartphone camera in the correct direction and tilted to a 14 degree angle, then automatically takes the photographs. **Table 1** shows the required and optional fields for both GLOBE-trained participants and GLOBE Observer users. Data submitted via email cannot include images. The GLOBE Program's Data Entry website has more information.

Table 1. Required and optional fields in GLOBE Clouds

Observation	Detailed Options	Required
Total Cloud Cover	No Clouds, Few <10%, Isolated 10-25%, Scattered 25-50%, Broken 50-90%, Overcast90-100%	Y
Obscuration (if 25% sky covered)	Sand, Spray, Smoke, Dust, Haze, Blowing Snow, Heavy Rain, Fog, Volcanic Ash	Y
Sky Color (if <50% cloud cover)	Deep Blue, Blue, Pale Blue, Light Blue, Milky	N
Sky Visibility (if <50%cloud cover)	Unusually Clear, Clear, Somewhat Hazy, very Hazy, Extremely Hazy	N
Cloud Types by Height	**High:** Short-lived Contrails, Persistent Contrails, Persistent Spreading Contrails, Cirrus, Cirrostratus, Cirrocumulus **Middle:** Altostratus, Altocumulus **Low:** Fog/Stratus, Nimbostratus, Stratocumulus, Cumulus, Cumulonimbus	N
Opacity by Height	Opaque, Transparent, Translucent	N
Cloud Cover by Height	No Clouds, Few <10%, Isolated 10-25%, Scattered 25-50%, Broken 50-90%, Overcast90-100%	N
Pictures	App assists in directional photos North, South, East, West, Up, and Down	N
Surface Condition	Yes/No: Snow/Ice, Standing Water, Muddy, Dry Ground, Leaves on Tress, Raining/Snowing	Y

Figure 1. Sample of pictures volunteers can take using The GLOBE Program's GLOBE Observer app.

All cloud observations receive multiple labels tracking the individual who submitted the observation, the location, and time. Identification numbers are also used to track which protocol was used to report the cloud observations, since cloud observations can be reported through multiple protocols, or specified steps.

The cloud observation identification number is a combination of all these identification numbers (individual, location, time, and protocol). The cloud observation identification number has four main sections and is found in the first column in the GLOBE clouds dataset. The first set of numbers are the protocol identification (ID) number (see table 2 for details), followed by the site ID and the user ID both set by The GLOBE Program, and ending with the date and time.

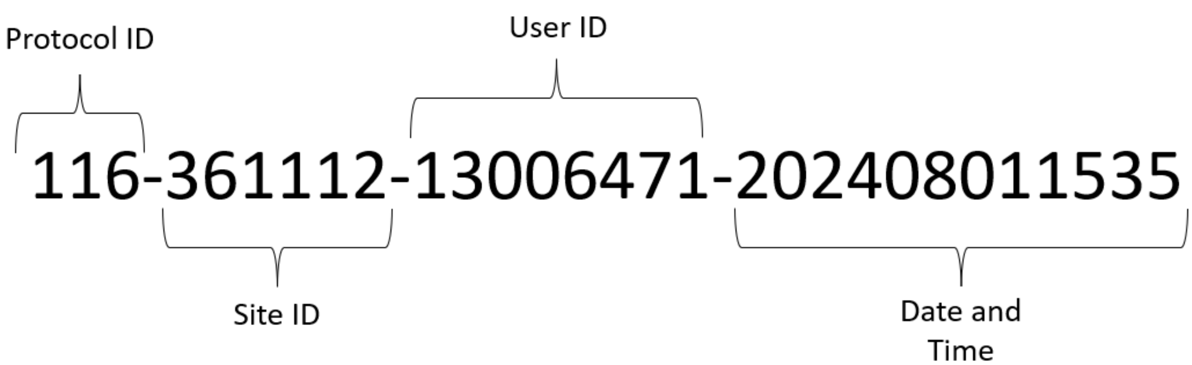


Table 2. Protocol identification number listing that reports or has reported sky conditions through The GLOBE Program.

GLOBE Protocol	Protocol Identification number
Aerosols	101
Clouds 1 day	103
Surface Temperature	109
Water Vapor	110
Clouds	116, 883
Integrated Atmosphere	150
Integrated Hydrology	301

4 Collocation of Ground Observations with Satellite Data

The NASA GLOBE Clouds team collocates submitted observations with those from multiple geostationary satellites, and to the CERES instrument onboard NOAA-20. This process is referred to as a satellite comparison. A satellite comparison table is produced that summarizes collocation results. The table is then sent in a personalized email to the ground observer (see **figure 2**).

Cloud properties such as height and coverage are generally not measured directly but must be inferred from visual or instrumental observations. Instruments carried by geostationary and the polar orbiting NOAA-20 satellite include passive radiometric instruments that receive visible and infrared radiation reflected/emitted by the Earth and its atmosphere. These measurements can be interpreted with automated, empirical, and theoretically based algorithms to infer a wide range of cloud characteristics. Some algorithms also use data from other sources, such as additional satellite instruments. The retrieval algorithms are complex and rely on simplifying assumptions and ancillary information that can at times lead to errors in the retrieved cloud properties.

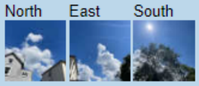
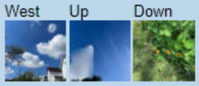
No single cloud observation method or system, whether it be human visual, or from an active or passive satellite or ground-based sensor, is able to provide a complete and accurate depiction of cloud properties across the Earth under the many conditions that naturally occur. Instead, this is best achieved by combining all of this information in optimal ways that exploit their various strengths and avoid or minimize their various limitations.

Figure 2. Example Satellite Comparison Table

GLOBE Cloud Observations Paired with NASA Satellite Data

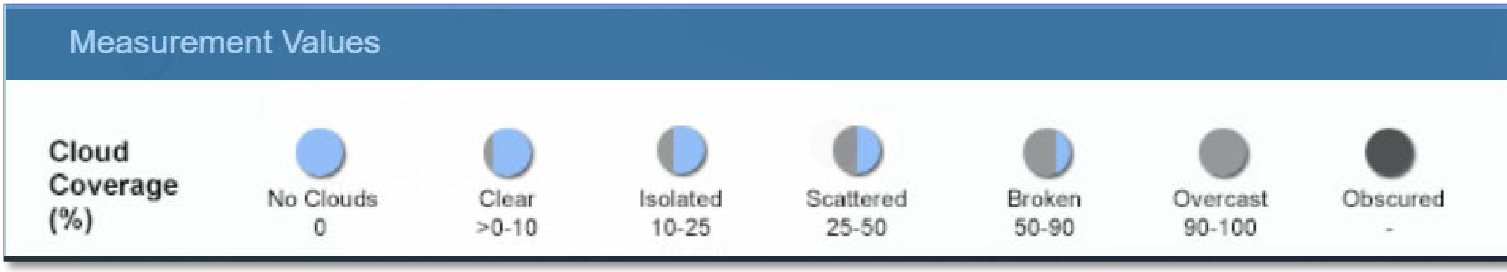
Total Satellite Comparisons: 1,254

Useful Resources: How to Read My NASA GLOBE Clouds Satellite Comparison Table, How to Compare My Cloud Observations with Satellite Data, Cloud Cover, Cloud Type, Cloud Opacity, Satellites

Observation	GLOBE	METEOSAT-10 Satellite	Terra Satellite	NOAA-20 Satellite
Universal Date/Time	2023-08-16 11:22:00	2023-08-16 11:10	2023-08-16 11:28	2023-08-16 11:14
Latitude	51.45	51.13 to 51.77	51.01 to 51.81	51.04 to 51.84
Longitude	-0.98	-1.3 to -0.66	-1.38 to -0.58	-1.3 to -0.5
Total Cloud Cover	Scattered (25-50%)	Scattered 27.87%	Scattered 44.35%	Broken 60.24%
High Clouds	Short Lived Contrails: 1 Non Spreading Contrails: 3	No Clouds	Cover: Few (1.70%) Altitude: 10.25 (km) Phase: Ice 226.95 (K) Opacity: Transparent	Cover: Few (4.20%) Altitude: 8.27 (km) Phase: Ice 241.06 (K) Opacity: Transparent
Mid Clouds		Cover: Few (1.64%) Altitude: 2.08 (km) Phase: Water 284.68 (K) Opacity: Transparent	No Clouds	Cover: Isolated 19.38% Altitude: 2.48 (km) Phase: Water 277.9 (K) Opacity: Translucent
Low Clouds	 Cumulus Cover: Scattered (25-50%) Opacity: Opaque	Cover: Scattered 26.23% Altitude: 0.91 (km) Phase: Water 291.24 (K) Opacity: Transparent	Cover: Scattered 42.65% Altitude: 0.98 (km) Phase: Ice/Water Mix 286.09 (K) Opacity: Transparent	Cover: Scattered 36.65% Altitude: 1.43 (km) Phase: Water 283.08 (K) Opacity: Translucent
GLOBE Cloud Photos and Corresponding NASA Satellite Images. Click image to view --> *Note: Photos submitted though GLOBE need approval before being displayed, this may take a few days.*	**GLOBE Photos** North East South  West Up Down 	***METEOSAT-10*** Visible  Infrared  GEO Tutorial	***MODIS Terra*** Worldview  Worldview Tutorial	***VIIRS NOAA-20*** Worldview  Worldview Tutorial
Sky Conditions, Surface Conditions and Observer Comments	**Sky Conditions** Sky Visibility : Clear Sky Color : Blue **Surface Conditions** Snow/Ice : No Standing Water : No Muddy : No Dry Ground : No Leaves on Trees : Yes Raining or Snowing : No	Are there any comments you would like to add? Be sure to add the name of the satellite for our record. Submit Comment		

- The first column from left to right lists all the variables reported. GLOBE ground observers report cloud cover and cloud opacity for each height. Satellites report cloud altitude, cloud phase, cloud opacity, and cloud cover.
- The second column in light blue displays the GLOBE ground observations which includes surface conditions and sky photographs.
- All following columns will contain information from each satellite platform (geostationary and low Earth orbit satellites).
- The circles next to cloud cover reports are a visual representation of the values reported (see **figure 3**).

Figure 3. Cloud cover measurement values represented in circles with various shades of blue and gray.



- The small pictures found at the bottom of each satellite column are the satellite images taken by the corresponding satellite at about your same location and time. The images are centered in the latitude and longitude of the cloud observation.

4.1 Historical Satellite Collocations

Collocations to low Earth orbiting satellites depend on satellite data availability which is limited by satellite overpass times. When a GLOBE Clouds observation is taken within 15 minutes of a satellite overpass, the observation is collocated to satellite data from low Earth orbiting satellites. The NASA GLOBE Clouds team uses the CERES Fast Longwave and Shortwave Flux Single Scanner Footprint (FLASHFlux SSF) data products to collocate GLOBE cloud observations to NOAA-20. Collocations to NOAA-20 sarted January 2023.

Comparisons to instruments onboard the following satellites have ended:

- Aqua 31 March 2023
- CALIPSO 1 July 2023
- Terra 13 February 2025

See Appendix 2 for further details of comparisons with Terra and Aqua, and Appendix 3 for details on comparisons with CALIPSO.

4.2 Footprint Definition

The satellite derived products (visible and infrared images) provided in the satellite comparison table are centered on the latitude/longitude reported with the observations.

4.2.1 Geostationary Satellites

The NASA Langley SatCORPS team, provides geostationary satellite data to the NASA GLOBE Clouds team. Comparisons to geostationary satellites include both a visible and an infrared image, remapped to 1.0-km resolution. The resolution of the images, before remapping, can range between 1-3 km for visible and 2-4 km for infrared projections, depending on the satellite. The full image displayed in the satellite comparison table covers 400x400km, with a 40 km diameter area marked by a red circle. **Table 3** displays the geostationary satellites used for collocation including the latitude and longitude bounds of the area within the satellites field of view.

Cloud products from geostationary satellites are stored on the NASA GLOBE Clouds system for up to a month after they are collected. Any observations submitted to the GLOBE Program beyond a month from the observation date/time cannot be collocated to geostationary satellites. Cloud retrievals must produce at least 75% valid data (or absence of “no retrieval” flags) within the 40-km footprint surrounding the ground observer to produce a satellite collocation. In general, about 2-5% of the total number of pixels over an entire satellite image might result in a “no retrieval” flag for the cloud product retrieval. This can happen with weak cloud signatures and conflicting (or bad) input data. Although it happens in low percentages for an entire satellite image, these “no retrieval” pixels can cluster more near an observer’s location within the 40-km footprint.

GOES satellites provide half hourly data, as well as hourly full disk data (view of the Earth centered on the Equator; see NOAA Geostationary Satellite Server for examples) over North and South America. Meteosat 11, Meteosat 8, and Himawari-8 provide cloud data over other parts of the world that re derived once per hour for the full disk. Ground observations will be collocated if observations are within 15 minutes to the available data. This means that areas within the GOES fields of view will match or compare if observations are within 15 minutes from every half hour or hourly data, as long as the cloud products retrieve at least 75% valid data. Locations within the Meteosat and Himawari fields of view will result in collocation if observations are within 15 minutes from every hour, as long as the cloud products retrieve at least 75% valid data.

In Summary:
Comparisons to geostationary satellites occur if observations are within 15 minutes from every half hour to hourly data within the GOES field, and 15 minutes within every hour in locations within the Meteosat and Himawari fields of view (see Table 4). Spatially, the comparison includes all geostationary data within a 40 km radius circle around the ground observation and includes both an infrared and visible image (Colón Robles et al., 2020).

Table 3. List of geostationary satellites used for collocation

Geostationary Satellite	Area Coverage by GLOBE Regions*	Instrument Onboard the satellite used for collocation	Latitude bounds	Longitude bounds
GOES West (GOES-18) https://www.goes.noaa.gov/goesfull.html	North America, Latin America and Caribbean, Pacific Ocean	Imager	60N-60S	105-180W
GOES East (GOES-16) https://www.star.nesdis.noaa.gov/GOES/fulldisk.php?sat=G16	North America, Latin America and Caribbean, Atlantic Ocean	Advanced Baseline Imager (ABI)	60N-60S	37.5-105W
Meteosat-9 https://www.goes.noaa.gov/f_meteo.html	Europe and Eurasia, Near East and North Africa, Africa, Asia and Pacific Indian Ocean	Spinning Enhanced Visible and Infrared Imager (SEVIRI)	60N-60S	37.5W-41E
Meteosat-10 https://www.goes.noaa.gov/f_meteo.html	Europe and Eurasia, Near East and North Africa, Africa, Asia and Pacific Indian Ocean	Spinning Enhanced Visible and Infrared Imager (SEVIRI)	60N-60S	41-95E
Himawari-9 https://www.goes.noaa.gov/f_himawari-8.html	Asia and Pacific Pacific Ocean	Advanced Himawari Imager (AHI)	60N-60S	95-180E

**GLOBE Countries and Regions - https://www.globe.gov/globe-community/community-map*

Table 4. List of geostationary satellites used through the duration of GLOBE Clouds dataset

Geostationary Satellite	Start Date	Last Comparison Date
GOES-19	2025-04-25	Current
GOES-18	2023-04-05	Current
GOES-17	2020-02-25	2023-03-27
GOES-16	2017-12-27	2025-04-27
GOES-15	2017-01-01	2020-02-29
GOES-13	2017-01-01	2018-01-02
HIMAWARI-9	2023-02-01	Current
HIMAWARI-8	2017-01-01	2022-12-22
METEOSAT-11	2018-03-06	2023-03-21
METEOSAT-10	2017-01-01	Current
METEOSAT-9	2019-01-23	Current
METEOSAT-8	2016-12-21	2022-06-01

4.2.2 NOAA-20

The NASA GLOBE Clouds team uses the CERES FLASHFlux SSF data product to compare GLOBE cloud observations to NOAA-20. The team commenced comparisons of ground observations to NOAA-20 on 1 January 2023.

A 0.4 degree latitude/longitude radius is used around the ground observation as a footprint for Aqua and Terra. The NOAA-20 satellite has a higher orbit at 824 km then Terra and Aqua 705 km orbit. As a result, a 0.6 degree latitude/longitude radius is used around the ground observation as a footprint for NOAA-20. Any satellite data within this defined footprint are averaged to provide the comparison. Observations are compared to data derived by instruments onboard a satellite if the following are met:

- the satellite swath is within the radius defined around the observation
- the satellite passes over the footprint within 15 minutes before or after the observation
- data from the satellite are available for the location and time

Collocations include true color images from the VIIRS instrument on board NOAA-20, which follow in the legacy of the MODIS instruments onboard Terra and Aqua. These images are centered on the location of the observation and displayed using NASA's Worldview Visualization platform (see NASA's EOSDIS WorldView).

GLOBE Observer app users can opt to be notified of NOAA-20 overpasses. Satellite overpass schedules can also be obtained by using the satellite overpass calculator.

4.3 Reconciling GLOBE and Satellite Classifications

4.3.1 Altitude

Altitude is the height at which the instruments onboard satellite detects a cloud. Algorithms designed by scientists are the way altitude is detected, which detections of altitude are based on observations and weather forecast model data. Cutoff values have been defined by where cloud types are generally encountered as defined by meteorologist (see the World Meteorological Organization's Definitions of Clouds). The NASA GLOBE Clouds team uses these same altitude ranges to compare satellite detection of clouds with ground observations (**Table 5**). A possible consequence of this set definition is that a single cloud layer, an extensive nimbostratus cloud for example, can be split by the satellite into two levels because the cloud may extend beyond the arbitrary cut-off definitions.

Table 5. Definition of altitude ranges to define the three basic cloud levels

Altitude range of satellite observation (km)	GLOBE cloud type
Above 6	High clouds (contrails, cirrus, cirrocumulus, or cirrostratus)
2-6	Mid-level clouds (altostratus or altocumulus)
0-2	Low clouds (fog/stratus, stratocumulus, cumulus, nimbostratus, or cumulonimbus)

4.3.2 Opacity

Satellites measure opacity in terms of optical depth. This is a non-dimentional quantity that contains information about how much of the Sun's light is able to penetrate the cloud. The following ranges have been defined to best compare ground observations of sky opacity to satellite data (**table 6**).

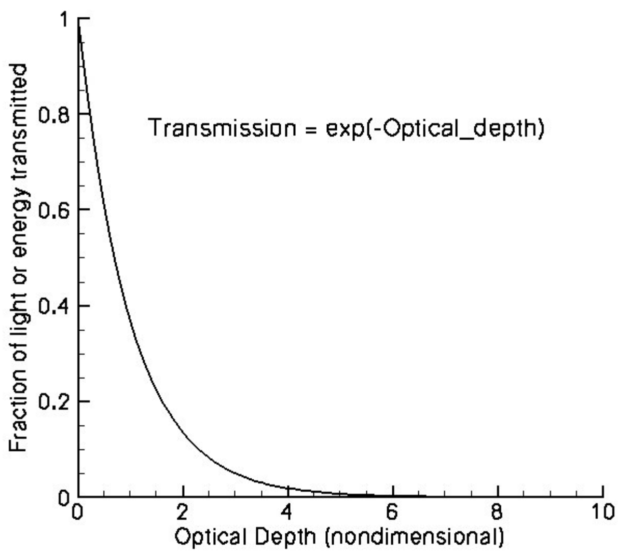


Figure 4. Optical Depth values comparted to fraction of light transmitted.

Table 6. Opacity values selected to compare the three options for ground observers

Optical depth ranges from satellite	Opacity category for ground observer
Above 10	Opaque
3-10	Translucent
Transparent	Transparent

With the presence of any clouds, the ability for Sunlight to reach the Earth's surface decreases dramatically. For example, even at low optical thicknesses recorded by the satellite (but greater than zero) less than 5% of the Sun's light is getting through the cloud. At a high optical thickness, the light coming through is truly a tiny fraction. The graph to the right shows this concept in relation to optical depth range.

However, the human eye has a logarithmic sensitivity to light levels, so deciding on the right cut-offs numbers to organize the satellite data into the ground opacity bins is a challenge. Furthermore, the report of the Visual Opacity by a ground observer is a subjective process. If you are interested, you may want to analyze the correspondence between your reports and the satellite opacity, and let us know if you find a cut-off or a specific range of data that routinely falls into a specific ground opacity category.

4.3.3 Cloud Cover

The same categories and values are used for both ground and satellite reports (see **Table 1**). The thing to realize here, though, is that the satellite, using a nice two dimensional (flat) view of the sky from above, can calculate a quite precise cloud fraction. The ground observer has to estimate the cloud cover from their single point of view on the ground, and is providing a subjective estimate of cloud fraction not a measurement. With the optical effects that come from looking at the sides of clouds and through varying layers of the atmosphere, that can be quite a challenge.

4.3.4 Cloud Phase and Temperature

Cloud phase and temperature are collected from the satellite data and reported to help ground observers best compare the cloud properties with the cloud type observed. Cloud phase (liquid, ice, or both mixed) is determined based on the measured cloud temperature in Kelvin. **Table 7** shows how cloud phase is classified (see parameter SSF-107 for CERES example). Data are collected for the altitude range and reported on the satellite comparison table.

Table 7. Cloud phase Classifications

Cloud phase classification	Values
Liquid	1
Mixed	1 < value < 2
Ice	2

Note - for a remote sensing instrument, the cloud temperature is not always accurate for thin clouds, because heat energy from a lower level cloud or the ground can contaminate the signal. Also, in the atmosphere, liquid water can exist below 0 degrees Celsius, the normal freezing point of water, unless something happens to start the process of forming ice crystals. However, below -40 degrees Celsius, a process called homogeneous nucleation occurs, and water will spontaneously freeze.

5 GLOBE Clouds and Compared Satellite Data Available

The NASA GLOBE Clouds team is making available a curated, analysis-ready GLOBE dataset that includes the GLOBE Clouds data and the satellite compared data. The data is provided as CSV files and posted on the GLOBE Observer website. These are subsets of GLOBE data that have been post-processed by a scientist on the GLOBE team and are being made available for broader use by the community.

Georeferenced subsets of the clouds data sets are also available:

Dust data, https://observer.globe.gov/get-data/dust-data
Eclipse data, https://observer.globe.gov/get-data/eclipse-data

List of data variables, units, and definitions is available at https://www.globe.gov/web/s-cool/home/satellite-comparison/data-variable-units-and-definitions.

Appendix 1: References

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Appendix 2: Historical Satellite Comparisons: Terra and Aqua

SATELLITE COLLOCATIONS TO AQUA ENDED ON 31 MARCH 2023 AND TO TERRA ENDED ON 13 FEBRUARY 2025.

Modernization of Code for Aqua and Terra Satellite Comparisons

On April 3, 2022, the code used for satellite comparisons was rewritten into Python modernizing the infrastructures and updating several bugs found in the original software.

When a GLOBE Clouds observation is taken within 15 minutes of a satellite overpass, the observation is compared to satellite data. However, the code used to perform the comparing specifically to Aqua and Terra was written over 20 years ago in Fortran.

Technical Changes

- The new code uses a slightly extended comparing window of +/- 15:59.9 (compared to 15:00 previously). This was done to maintain backwards compatibility, as the old code previously compared certain observations within this time rage. This has a side effect of generating about 7% more comparisons than before.
- The new code makes proper use of default values in the FLASHFlux* satellite data product. Default values are values that signal the data is missing and should not be used. Data with these values are ignored while they were previously zeroed and then used.
- The new code considers the full comparison window even if this window extends across multiple days. For example, an observation made on 1/1/2022 at 23:50 could be compared to data from 1/2/2022 before 00:05. The old code did not consider comparison windows that extended across multiple days.
- The new code uses hourly FLASHFlux SSF data while the old code used FLASHFlux SSFS** data, this may create minor variations. The FLASHFlux SSFS data product specially created for S'COOL and used when the team transitioned to The GLOBE Program. This smaller subset was an average of the FLASHFlux SSF data product and made it easier to manage by the team. FLASHFlux SSFS is no longer made available.

****Fast Longwave and Shortwave Flux (FLASHFlux) data product:*** It is a low latency (< 7 days from observations) TOA and parameterized surface radiative fluxes at CERES Single Scanner Footprint (SSF) level and global gridded fluxes. Suitable for quick-look assessment, educational and applied science uses. Not intended for appending to other CERES data products for long-term variability studies.

The daytime binary ***SSF SCOOL (or SSFS)* validation product contains all subsetted footprints over SCOOL validation sites which have a solar zenith angle of less than 90 degrees. The nighttime binary SSF SCOOL validation product contains all subsetted footprints over SCOOL validation sites which have a solar zenith angle greater than or equal to 90 degrees.

Appendix 3: Historical Satellite Comparisons: CALIPSO

SATELLITE COLLOCATIONS TO CALIPSO ENDED ON 1 JULY 2023.

CALIPSO carried a combination of active and passive sensors. The active sensor was an onboard lidar that actively emited a light beam towards the earth that was reflected back to the instrument allowing a somewhat more direct measurement of the Earth and atmosphere. The data received by CALIPSO also required interpretation with retrieval algorithms to infer the presence, altitudes, and extinction rates of hydrometeors, and to distinguish clouds from aerosol particles, and other small objects in the atmosphere.

CALIPSO measured the vertical profile of the atmosphere using a laser beam with an approximately 70-meter width at the Earth's surface. This resulted in a very narrow swath of observations, leading to fewer satellite comparisons to ground observations as compared to the other satellites. Ground observations that were within 10 km and 15 minutes of CALIPSO's path resulted in a collocation. Observations that were compared, or collocated, with CALIPSO received a link to the vertical feature mask for their latitude and longitude. The CALIPSO vertical feature mask described the vertical and horizontal distribution of cloud and aerosol layers observed by the CALIPSO lidar. Different features designated by CALIPSO (e.g. cloud or aerosol, or the cloud ice/water phase) were available for each layer detected (see **image 4**). A summary of these results is *not* displayed on the satellite comparison table as is done with the other possible satellites/instruments.

Image 4. Example Ground Observation with Satellite Collocation with CALIPSO

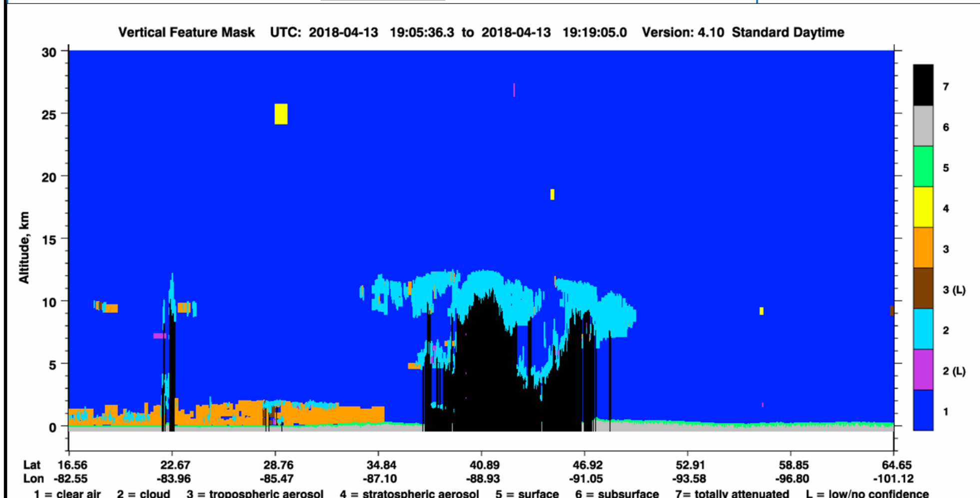
NASA Cloud Observation and Satellite Match

Satellite	GEO	Aqua	Your Observation
Universal Date/Time 2018-04-13	19:18	19:08	19:17
Latitude Range Longitude Range	33.14 to 33.78 -87.12 to -86.48	33.05 to 33.85 -87.21 to -86.41	**Latitude 33.46** **Longitude -86.80**
Total Cloud Cover	Few 1.32%	Few 1.48%	**Few (<10%)**
HIGH: Cloud Cover Cloud Altitude Cloud Phase Cloud Opacity	No Clouds	Few (0.51%) 6.63 (km) Ice 255.53 (K) Transparent	Cirrus Few (<10%)
MID: Cloud Cover Cloud Altitude Cloud Phase Cloud Opacity	No Clouds	Few (0.17%) 3.42 (km) Mixed 273.06 (K) Transparent	
LOW: Cloud Cover Cloud Altitude Cloud Phase Cloud Opacity	Few (1.32%) 0.31 (km) Water 308.58 (K) Transparent	Few (0.81%) 0.91 (km) Water 287.67 (K) Transparent	
Corresponding NASA Satellite Images. Click to view image --->	***GOES-16*** Infrared GEO Tutorial	***MODIS*** Rapid Response Worldview MODIS Tutorial	Sky Visibility : Somewhat Hazy Sky Color : Light Blue North

Are there any comments you would like to add? Be sure to add the name of the satellite for our record.

Submit Comment

Surface Conditions	
Snow/Ice	No
Standing Water	No
Muddy	No
Dry Ground	Yes
Leaves on Trees	Yes
Raining or Snowing	No



Appendix 4: Useful Links

1. Data Quality Summary FLASHFlux SSF for Terra and Aqua - https://ceres.larc.nasa.gov/documents/DQ_summaries/FLASH_SSF_DQS_Version3C.pdf
2. Data Quality Summary of CERES SSF NOAA-20 - https://ceres.larc.nasa.gov/documents/DQ_summaries/CER_SSF_NOAA20_Edition1B.pdf
3. Satellite Overpass Schedule Tool - https://scool.larc.nasa.gov/GLOBE/globe_overpass-en.html
4. Satellite Comparison Table Example - https://www.globe.gov/web/s-cool/home/satellite-comparison/how-to-read-a-satellite-match
5. NASA's EOSDIS WorldView - https://worldview.earthdata.nasa.gov/
6. CALIPSO - Data User's Guide - Browse Image Tutorial - https://www-calipso.larc.nasa.gov/resources/calipso_users_guide/browse/index.php
7. CALIPSO Quality Statements - https://asdc.larc.nasa.gov/documents/calipso/quality_summaries/CALIOP_L1ProfileProducts_3.01.pdf
8. NOAA Geostationary Satellite Server (with full disk images) - https://www.goes.noaa.gov/
9. Example Ground Observation with Satellite Collocation with CALIPSO:
    a. Satellite Match Table - https://scool.larc.nasa.gov/cgi-bin/NASA-GLOBESatMatch.cgi?observation_id=116-111805-39703922-201804131917
    b. Corresponding CALIPSO Vertical Feature Mask - https://www-calipso.larc.nasa.gov/data/BROWSE/production/V4-10/2018-04-13/2018-04-13_18-38-38_V4.10_3_6.png

10. Satellite and GLOBE data sets available for download - https://observer.globe.gov/get-data/clouds-data
11. List of Data Variables, Units, and Definitions - https://www.globe.gov/web/s-cool/home/satellite-comparison/data-variable-units-and-definitions

Appendix 5: Recent Team Publications Using NASA GLOBE Clouds

Autore, A. M., Dodson, J. B., Duda, D. P., Robles, M. C., Weaver, K. L., Taylor, J. E., Rogerson, T. M., & Kohl, H. (2025). GLOBE Eclipse 2024: A Case Study of the Effects of the April 2024 Total Solar Eclipse on Cirrus Clouds and Contrails in the United States of America. Bulletin of the AAS, 56(9). https://doi.org/10.3847/25c2cfeb.d9ddc39b

Dodson, J.B., M. Colón Robles, T. Rogerson, J.E. Taylor, (2022). Do citizen science Intense Observation Periods increase data usability? A deep dive of the NASA GLOBE Clouds data set with satellite comparisons. Earth and Space Science, DOI: https://doi.org/10.1029/2021EA002058

Colón Robles, M., Amos, H. M., Dodson, J. B., Bouwman, J., Rogerson, T. M., Bombosch, A., Farmer, L., Burdick, A., Taylor, J. E. & Chambers, L.H., (2020). Clouds around the world: How a simple data challenge became a worldwide success. Bulletin of the American Meteorological Society. DOI: https://doi.org/10.1175/BAMS-D-19-0295.1

Dodson, J.B., Colón Robles, M., Taylor J.E., DeFontes, C.C., Weaver K.L., (2019). Eclipse Across America: Citizen Science Observations of the 21 August 2017 Total Solar Eclipse. Journal of Applied Meteorology & Climatology, https://doi.org/10.1175/JAMC-D-18-0297.1

Colón Robles, M., T. M. Rogerson, H. Amos, J. Taylor, and T. Harte, (2019). Leveraging thousands of contrail observations from GLOBE citizen scientists. Fall Meeting 2019, San Francisco, CA, Amer. Geophys. Union. https://agu.confex.com/agu/fm19/meetingapp.cgi/Paper/611549

Starke, M., H. Amos, N. Arnold, T. M. Rogerson, and M. Colón Robles, 2019: Global cloud cover: A comparison of satellite, model, and volunteer-reported data. Fall Meeting 2019, San Francisco, CA, Amer. Geophys. Union, Abstract IN51E-0679, https://agu.confex.com/agu/fm19/meetingapp.cgi/Paper/537030.

Colón Robles, M., L. Farmer, J.B. Dodson, J.L. Tackett, C.C. DeFontes, K. Ivey, T.M. Rogerson, J. Taylor, (2018). Citizen science cloud observations compared to near ground cloud observations from CALIPSO and MODIS satellite data over the Drake Passage
AGU Fall Meeting Abstracts 2018, IN22B-07, https://agu.confex.com/agu/fm18/meetingapp.cgi/Paper/412875