

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

Version 1.0

Last updated: March 26, 2019

Citation:

Colón Robles, M., T. Rogerson, and J.B. Dodson, 2019: NASA GLOBE Clouds: Documentation on How Satellite Data is Collocated to Ground Cloud Observations (v1.0), Accessed Date, <https://www.globe.gov/web/s-cool/home/satellite-comparison>.

Contributors (in alphabetical order):

Dr. Helen Amos

Dr. Kristopher Bedka

Dr. Lin Chambers

Douglas Spangenberg

Jason Tackett

Jessica Taylor

Table of Contents

Abbreviations	2
Abstract	2
Background	2
Description of GLOBE participants	3
Description of Ground Observations	3
Collocation of Ground Observations with Satellite Data	5
Footprint Definition	7
1. Geostationary Satellites	7
2. Aqua and Terra	9
3. CALIPSO	9
Reconciling GLOBE and Satellite Classifications	11
Altitude	11
Opacity	11
Cloud Cover	11
Cloud Phase and Temperature	12
Useful Links	12

Abbreviations

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
S'COOL	Students' Cloud Observations On-Line, https://scool.larc.nasa.gov

Abstract

The NASA GLOBE Clouds team at NASA Langley Research Center in Hampton, Virginia, USA receives all cloud observations submitted through the GLOBE (Global Learning and Observations to Benefit the Environment) Program. Cloud observations submitted through various protocols and methods, including the GLOBE Observer mobile app, are then collocated with satellite data from various Earth-observing platforms, a process referred to as a satellite match. This document is a guide to how the ground-satellite collocation or satellite match is done by the team.

Background

Ground-satellite collocation, or satellite matching of cloud observations, started in 2016 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 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 at NASA Langley Research Center matches GLOBE cloud observations to corresponding satellite data (<https://www.globe.gov/web/s-cool>). Users can “opt in” to receive notifications on their mobile device about satellite flyovers or check online (see [satellite overpass schedule tool](#)). If an observer's cloud observation is matched to satellite data, and the user opted-in to receive emails from GLOBE, the user will receive a Satellite Match Table for every collocation (see [satellite match table example](#)) in a personalized email from NASA within one week of submitting their observation. Observations can be matched to multiple geostationary satellites, CERES instruments onboard Aqua and Terra, and CALIPSO (see [satellite comparison: Earth observing satellites](#)). The satellite match table includes images from these satellites centered on the observation location.

Description of GLOBE participants

Individuals contributing cloud observations need to be in a GLOBE country (see map of participating countries, <https://www.globe.gov/globe-community/community-map>). These individuals, or citizen scientists, are either formal GLOBE members or GLOBE Observer mobile app users, the basic difference being their level of training. Formal GLOBE members are classroom teachers who are required to attend in-person training or complete online eTraining courses and exams before leading student groups in the collection and submission of data on one or multiple GLOBE protocols (i.e., data collection methods) (<https://www.globe.gov/get-trained/protocol-etraining/etraining-modules/16867642/12267>). These GLOBE members become certified in particular protocols, like the clouds protocol, and teach their students how to follow those data collection protocols. Formal GLOBE members can enter data through various platforms: data entry desktop form, data entry mobile app, email data entry app, or use the GLOBE Observer mobile app (<https://www.globe.gov/globe-data/data-entry>). GLOBE Observer mobile app users need only view the tutorials supplied within the app before submitting data. Note that GLOBE-trained teachers and students can, and do, use the GLOBE Observer app. Detailed steps for the clouds protocol can be found on the NASA GLOBE Clouds webpage (<https://www.globe.gov/web/s-cool/home/observation-and-reporting>).

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 (<https://www.globe.gov/web/s-cool/home/observation-and-reporting/sky-color>); sky visibility (<https://www.globe.gov/web/s-cool/home/observation-and-reporting/sky-visibility>); presence of low-, mid-, and high-level clouds and contrails; types of clouds and contrails (<https://www.globe.gov/web/s-cool/home/observation-and-reporting/cloud-type>); and opacity (<https://www.globe.gov/web/s-cool/home/observation-and-reporting/cloud-visual-opacity>; see **Table 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 (<https://www.globe.gov/web/s-cool/home/observation-and-reporting/globe-observer-tips-and-tricks>). **Table 1** shows the required and optional fields for both GLOBE-trained participants and GLOBE Observer users. Data submitted via email cannot include images (see <https://www.globe.gov/globe-data/data-entry>).

Table 1. Required and optional fields in GLOBE Clouds

Required Observations	Optional Observations																		
<p>Total Cloud Cover</p> <ul style="list-style-type: none"> - No clouds 0 - few > 0-10 - Isolated 10-25 - scattered 25-50 - broken 50-90 - overcast 90-100 <p>Or</p> <p>Obscuration covering more than 25% of the sky</p> <ul style="list-style-type: none"> - sand - smoke - haze - heavy snow - fog/stratus - spray - dust - blowing snow - heavy rain - volcanic ash 	<p>Cloud Types - <i>Observers qualitatively estimate cloud altitude by low, mid, and high and then identify cloud types for each level.</i></p> <table border="1" data-bbox="699 409 1474 640"> <thead> <tr> <th data-bbox="699 409 954 451">High Clouds</th> <th data-bbox="954 409 1198 451">Mid Level Clouds</th> <th data-bbox="1198 409 1474 451">Low Clouds</th> </tr> </thead> <tbody> <tr> <td data-bbox="699 451 954 483">- contrails</td> <td data-bbox="954 451 1198 483">- altostratus</td> <td data-bbox="1198 451 1474 483">- fog/stratus</td> </tr> <tr> <td data-bbox="699 483 954 514">- cirrus</td> <td data-bbox="954 483 1198 514">- altocumulus</td> <td data-bbox="1198 483 1474 514">- stratocumulus</td> </tr> <tr> <td data-bbox="699 514 954 546">- cirrocumulus</td> <td></td> <td data-bbox="1198 514 1474 546">- cumulus</td> </tr> <tr> <td data-bbox="699 546 954 577">- cirrostratus</td> <td></td> <td data-bbox="1198 546 1474 577">- nimbostratus</td> </tr> <tr> <td></td> <td></td> <td data-bbox="1198 577 1474 609">- cumulonimbus</td> </tr> </tbody> </table> <p>Opacity - <i>Observers can also report opacity for each altitude level and cloud type as opaque, transparent, or translucent.</i></p>	High Clouds	Mid Level Clouds	Low Clouds	- contrails	- altostratus	- fog/stratus	- cirrus	- altocumulus	- stratocumulus	- cirrocumulus		- cumulus	- cirrostratus		- nimbostratus			- cumulonimbus
High Clouds	Mid Level Clouds	Low Clouds																	
- contrails	- altostratus	- fog/stratus																	
- cirrus	- altocumulus	- stratocumulus																	
- cirrocumulus		- cumulus																	
- cirrostratus		- nimbostratus																	
		- cumulonimbus																	
<p>Surface Conditions (yes/no)</p> <ul style="list-style-type: none"> - snow/ice - standing water - muddy - dry ground - leaves on trees - raining/snowing 	<p>Sky Color and Visibility</p> <p><i>Observers have the option to report the darkest blue observed in the sky and also a qualitative report sky visibility.</i></p> <table border="1" data-bbox="699 976 1474 1197"> <thead> <tr> <th data-bbox="699 976 1105 1018">Sky Color</th> <th data-bbox="1105 976 1474 1018">Sky Visibility</th> </tr> </thead> <tbody> <tr> <td data-bbox="699 1018 1105 1050">- deep blue</td> <td data-bbox="1105 1018 1474 1050">- unusually clear</td> </tr> <tr> <td data-bbox="699 1050 1105 1081">- blue</td> <td data-bbox="1105 1050 1474 1081">- clear</td> </tr> <tr> <td data-bbox="699 1081 1105 1113">- light blue</td> <td data-bbox="1105 1081 1474 1113">- somewhat hazy</td> </tr> <tr> <td data-bbox="699 1113 1105 1144">- pale blue</td> <td data-bbox="1105 1113 1474 1144">- very hazy</td> </tr> <tr> <td data-bbox="699 1144 1105 1176">- milky</td> <td data-bbox="1105 1144 1474 1176">- extremely hazy</td> </tr> </tbody> </table>	Sky Color	Sky Visibility	- deep blue	- unusually clear	- blue	- clear	- light blue	- somewhat hazy	- pale blue	- very hazy	- milky	- extremely hazy						
Sky Color	Sky Visibility																		
- deep blue	- unusually clear																		
- blue	- clear																		
- light blue	- somewhat hazy																		
- pale blue	- very hazy																		
- milky	- extremely hazy																		

Collocation of Ground Observations with Satellite Data

The NASA GLOBE Clouds team collocates submitted observations multiple geostationary satellites, CERES instruments onboard Aqua and Terra, and CALIPSO. This process is referred to as a satellite match. A satellite match table is produced that summarizes collocation results. The table is then sent in a personalized email to the ground observer (see **image 1**).

Cloud properties such as height and coverage are generally not directly measured by satellites, with the partial exception of CALIPSO. The passive-observing satellite instruments carried by geostationary and Aqua/Terra satellites instead directly measure the visible and infrared radiation reflected/emitted by Earth. Cloud properties are estimated by an automated retrieval algorithm, which calculates the most likely cloud properties in a given location based on the measured radiance. Some algorithms also use data from other sources, such as additional satellite instruments. The retrieval algorithms are complex, and can introduce errors for a variety of reasons beyond uncertainties in the direct satellite measurements. The satellite-retrieved cloud properties should not be considered absolute truth, but rather the best estimate of cloud properties that can be provided by satellite observations.

CALIPSO is a somewhat different case because the onboard lidar directly measures the presence, altitudes, and extinction rates of hydrometeors, aerosol particles, and other small objects in the atmosphere. However, CALIPSO requires a retrieval algorithm to determine other meteorological properties, such as distinguishing cloud hydrometeors from aerosol particles. The cloud/aerosol height and opacity provided by CALIPSO are likely to be highly accurate, but other properties are subject to uncertainties from the retrieval algorithm.

Image 1. Example Satellite Match Table

The left column in white lists all the observations reported and compared with satellite data.

The green column (right) displays your observations that are compared to satellite data (middle columns) including **latitude/longitude, date & time, and observed total cloud cover.**

You report **cloud opacity, cover, and type** for each height (high, mid, low). Satellites report **cloud altitude, phase, opacity, and cover.**

NASA Cloud Observation and Satellite Match			
Satellite	GEO	Terra	Your Observation
Universal Date/Time 2018-04-11	21:05	21:06	21:08
Latitude Range	18.89 to 19.53	18.79 to 19.59	Latitude 19.21
Longitude Range	-156.2 to -155.56	-156.27 to -155.47	Longitude -155.8
Total Cloud Cover	Broken 79.43%	Broken 69.27%	Overcast (>90%)
HIGH	No Clouds	Few (0.91%) 6.51 (km) Ice 266.92 (K) Translucent	
MID	Broken 68.22% 3.12 (km) Mixed 281.4 (K) Opaque	Broken 60.99% 3.94 (km) Mixed 278.34 (K) Opaque	Altostratus Overcast (>90%)
LOW	Isolated 11.21% 1.26 (km) Water 292.44 (K) Translucent	Few (7.36%) 1.5 (km) Water 287.24 (K) Translucent	
Corresponding NASA Satellite Images. Click to view image →	GOES-15 Infrared GEO Tutorial	MODIS Rapid Response Worldview MODIS Guide	Sky Visibility : no report Sky Color : no report North South West Up Down
Are there any comments you would like to add? Be sure to add the name of the satellite for our record.	<div style="border: 1px solid black; padding: 5px; margin: 10px auto; width: 80%;"> <p>Questions or comments? Submit them here and remember to include the name of the satellite(s) in question.</p> </div>		Surface Conditions Snow/Ice No Standing Water No Muddy No Dry Ground No Leaves on Trees Yes Raining or Snowing Yes
	<input type="button" value="Submit Comment"/>		

The circles represent cloud cover.

- No Clouds 0%
- Few >0-10%
- Isolated 10-25%
- Scattered 25-50%
- Broken 50-90%
- Overcast 90-100%
- Obscured 100%

Sky and cloud pictures submitted with your observations will appear next to the satellite images.

Your observations also include information about **Surface Conditions** when you made the observation.

Footprint Definition

The NASA GLOBE Clouds team uses a 0.4 degree latitude/longitude radius around the ground observation as a footprint. Any satellite data within this defined footprint are averaged to provide the comparison. Observations are matched 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

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

1. Geostationary Satellites

Matches 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 match table covers 400x400km, with a 40 km diameter area marked by a red circle. **Table 2** displays the geostationary satellites used for collocation including the latitude and longitude bounds of the fields of view they can observe.

Table 2. 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-15 (GOES West) https://www.goes.noaa.gov/goesfull.html	North America, Latin America and Caribbean, Pacific Ocean	Imager	60N-60S	105-180W
GOES-16 (GOES East) 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-11 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-8 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-8 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>

Cloud products from geostationary satellites are available 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 America. Meteosat 11, Meteosat 8, and Himawari-8 data run 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 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.

2. Aqua and Terra

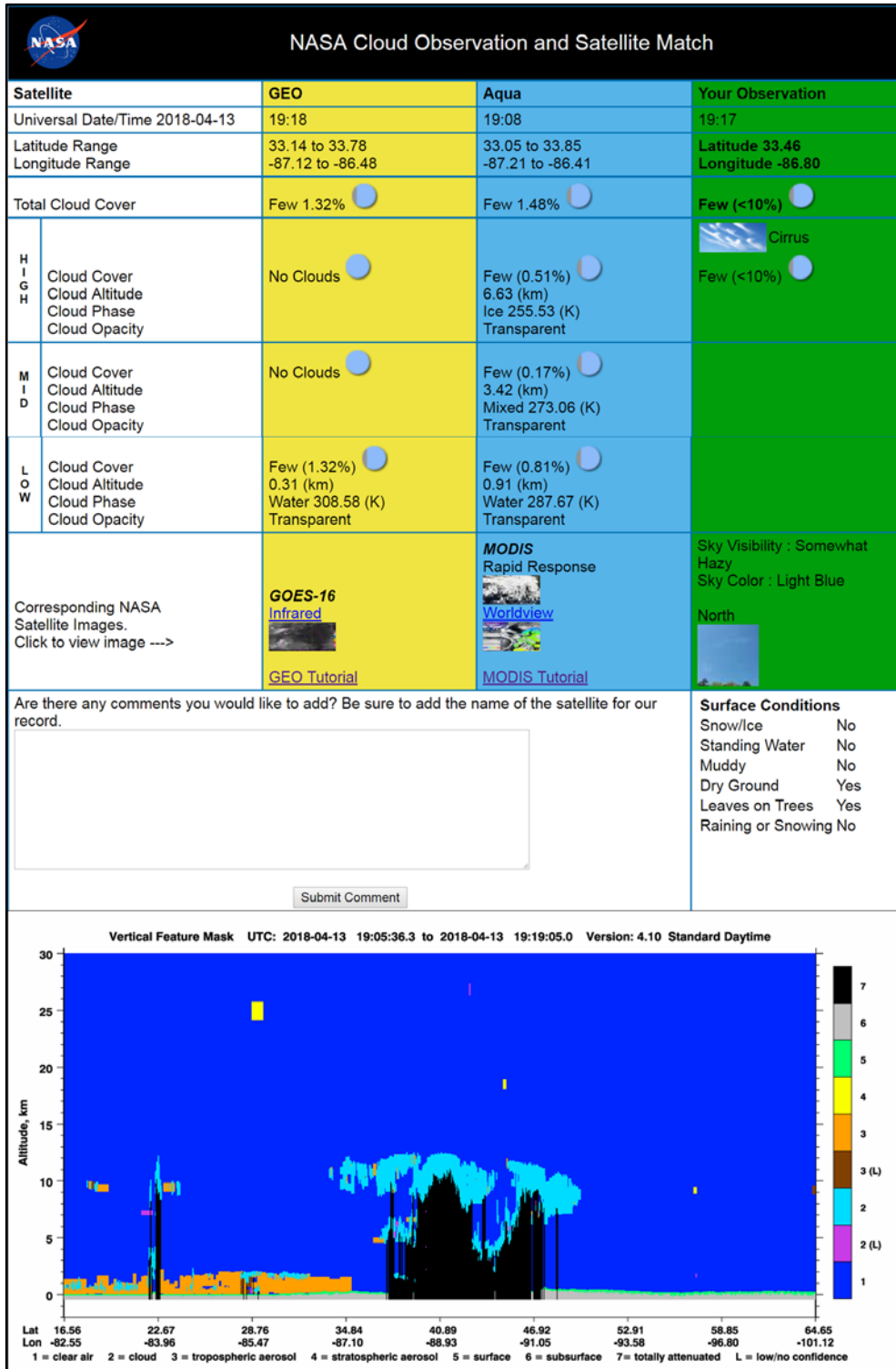
Observations are collocated to CERES instruments onboard the Terra and Aqua satellites if their latitude and longitude values fall within a 0.4 degree latitude/longitude radius around the ground observation, and if observations are within 15 minutes before or after the satellite passes over the observing site. Collocations include true color images from the MODIS instruments onboard Terra and Aqua, 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 Aqua and Terra overpasses. Satellite overpass schedules for Aqua and Terra can also be obtained by using the satellite overpass calculator (see https://scool.larc.nasa.gov/GLOBE/globe_overpass-en.html).

3. CALIPSO

CALIPSO measures the vertical profile of the atmosphere using a laser beam with an approximately 70-meter width at the Earth's surface. This results in a very narrow swath of observations, leading to fewer satellite matches to ground observations as compared to the other satellites. Ground observations that are within 10 km and 15 minutes of CALIPSO's path will result in a collocation. Observations that are matched, or collocated, with CALIPSO receive a link to the vertical feature mask for their latitude and longitude. The CALIPSO vertical feature mask describes the vertical and horizontal distribution of cloud and aerosol layers observed by the CALIPSO lidar ([see CALIPSO- Data User's Guide - Browse Image Tutorial](#)). Different features are designated by CALIPSO (e.g. cloud or aerosol, or the cloud ice/water phase) are available for each layer detected (see **image 2**). A summary of these results is *not* displayed on the satellite match table as is done with the other possible satellites/instruments.

Image 2. Example Ground Observation with Satellite Collocation with CALIPSO



Reconciling GLOBE and Satellite Classifications

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 - <https://cloudatlas.wmo.int/clouds-definitions.html>). The NASA GLOBE Clouds team uses these same altitude ranges to compare satellite detection of clouds with ground observations (**Table 3**). 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 3. 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)

Opacity

Satellites measure opacity in terms of optical depth. The following ranges have been defined to best compare ground observations of sky opacity to satellite data (**table 4**)

Table 4. Opacity values selected to match the three options for ground observers

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

Cloud Cover

The same categories and values are used for both ground and satellite reports (see **Table 1**).

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. **Table 5** shows how cloud phase is classified (see parameter SSF-107 for CERES example - https://ceres.larc.nasa.gov/documents/collect_guide/pdf/SSF_CG_R2V1.pdf). Data are collected for the altitude range and reported on the satellite match table.

Table 5. Cloud phase Classifications

Liquid	Value = 1
Mixed	Value >1 but < 2
Ice	Value = 2

Useful Links

1. Satellite Overpass Schedule Tool - https://scool.larc.nasa.gov/GLOBE/globe_overpass-en.html
2. Satellite Match Table Example - <https://www.globe.gov/web/s-cool/home/satellite-comparison/how-to-read-a-satellite-match>
3. Satellite Comparison: Earth Observing Satellites - <https://www.globe.gov/web/s-cool/home/satellite-comparison/earth-observing-satellites>
4. NASA's EOSDIS WorldView - <https://worldview.earthdata.nasa.gov/>
5. CALIPSO - Data User's Guide - Browse Image Tutorial - https://www-calipso.larc.nasa.gov/resources/calipso_users_guide/browse/index.php
6. CALIPSO Quality Statements - https://eosweb.larc.nasa.gov/sites/default/files/project/calipso/quality_summaries/CALIO_P_L2VFMProducts_3.01.pdf
7. NOAA Geostationary Satellite Server (with full disk images) - <https://www.goes.noaa.gov/>
8. 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