

unconstrained default, modified default, and opaque. The lowest uncertainties are found for transparent layers in which the AOD, and thus extinction coefficient, can be directly retrieved (or “constrained”) using the transmission loss through the layer. All other cases require a default value based on the type and subtype of the layer being analyzed.

CATS ice cloud lidar ratios are assigned based on relationships with layer integrated depolarization ratio and geographic location, shown in Table 6, as retrieved from CPL and CALIPSO data. Values of 18.0 sr and 22.0 sr are used for liquid water clouds and clouds of unknown phase, respectively. For aerosols, the lidar ratio is assigned from a look-up table based on the aerosol type and the values are very similar to those used in CALIPSO, CPL and GLAS algorithms, as shown in Table 7. If this lidar ratio remains unmodified through the solution process, we describe this category as “unconstrained default” or just default.

Table 6: CATS Ice Cloud Default Lidar Ratios

Location	Land Type	Sp
Mid-Latitude	Land	24.0
Mid-Latitude	Ocean	30.0
Tropics	Land	28.0
Tropics	Ocean	32.0

Table 7: CATS Aerosol Default Lidar Ratios

Aerosol Type	532 nm	1064 nm
Marine	25.0	45.0
Marine Mixture	45.0	40.0
Dust	45.0	55.0
Dust Mixture	35.0	45.0
Clean/Background	55.0	35.0
Polluted Continental	65.0	35.0
Smoke	70.0	40.0
Volcanic	45.0	35.0

This parameter reports the lidar ratio in use at the conclusion of the extinction processing for each layer, equivalent to the “Final Lidar Ratio” in CALIPSO data products.

Ice Water Path (Provisional)

Ice water path (IWP) is the integral of ice water content (IWC) from ice cloud layer top to layer base, reported for each ice cloud layer within a 5 km profile. Ice water path has units of gm^{-2} . For Mode 7.2 data, only the 1064 nm IWP is reported. For Mode 7.1 data, both the 532 and 1064 nm IWP is reported. The IWC is calculated as a parameterization function of the CATS ice particle extinction retrievals as outlined in the CATS ATBD.

Ice Water Path Uncertainty (TBD)

For version 1.03, the uncertainty in the IWP contains fill values (-999.99). For future versions, the uncertainty in the IWP will be reported for each ice cloud layer within a 5 km profile. The values reported will be absolute uncertainties, not relative, thus the units will be identical to the units of the IWP (gm^{-2}).

Layer Effective Multiple Scattering Factor (Provisional)

The layer effective multiple scattering factors, for each layer within a 5 km profile, are reported at each wavelength according to layer type and subtype. Values range from just above 0, which indicates significant contributions to the backscatter signal from multiple scattering, to 1, which corresponds to minimal (if any) multiple scattering (single scattering only). Multiple scattering effects are different for various aerosols particle types, ice particles, and water droplets. The CATS and CALIPSO ATBDs provides a discussion of multiple scattering factors for ice clouds and several aerosol types. For CATS, the layer effective multiple scattering factors are:

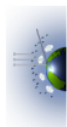
- *Ice Clouds*: Comparing CATS and CPL lidar ratios and extinction coefficients within a cirrus cloud result in a value of 0.77 at 1064 nm and ~ 0.77 at 532 nm (Note: this value at 532 nm is still being tested and Mode 7.1 532 nm L2 data will be released at a later date). Scaling the CALIPSO layer effective multiple scattering factor of 0.60 using instrument measurement geometries also yield the same values.
- *Water Clouds*: A value of 0.60 is used for water cloud effective multiple scattering factors at both wavelengths based on scaling the CALIPSO values. More work in the future will be conducted to update this value for future versions.
- *Aerosols*: A value of 1.00 is used for both wavelengths because simulations of multiple scattering effects on AOD retrievals suggest the effects are small in most cases. CALIPSO also uses a value of 1.0.

5.4 CATS Geolocation

CATS Geolocation (Validated Stage 1)

Knowledge of the location of the CATS laser spot on the earth is required for the useful analysis of the CATS backscatter data. The location of the CATS laser spots are calculated from the position, velocity, and attitude information found in the ISS Broadcast Ancillary Data (BAD) together with the known angular offset of the laser line-of-site (LOS) vector from the instrument's nadir vector in the CATS L1B processing. The geolocation parameters reported in the CATS L2O data products have three elements for each 5 km L2O profile. These elements represent the first, mean, and last value of the 13 L1B profiles that make up one 5km L2O profile:

1. **Index Top Bin (all IFOVs)** – The bin id of the CATS data frame where the top of the CATS profile is located, as computed from the ISS BAD.
2. **CATS Latitude (all IFOVs)** – Ground latitude of the CATS laser spot, in degrees, as computing from the ISS BAD.
3. **CATS Longitude (all IFOVs)** – Ground longitude of the CATS laser spot, in



- degrees, as computing from the ISS BAD.
4. **CATS Angle (all IFOVs)** – The off-nadir viewing angle of the CATS laser spot, in degrees, as computing from the ISS BAD.
 5. **Lidar Surface Altitude (all IFOVs)** - This is the surface elevation at each laser IFOV footprint, in kilometers above local mean sea level, obtained from identifying the backscatter return of the earth's surface.
 6. **Solar Azimuth Angle** – Solar azimuth angle, in degrees, reported for each 5 km L2O profile. Solar azimuth angle values are interpolated from the ancillary meteorological data provided by the GMAO.
 7. **Solar Zenith Angle** - Solar zenith angle, in degrees, reported for each 5 km L2O profile. Solar zenith angle values are interpolated from the ancillary meteorological data provided by the GMAO.

5.6 Instrument Parameters and Laser Energy

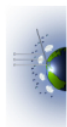
There are several parameters that report details on instrument constants, calibration, performance, and laser energy. These parameters are:

1. **Horizontal Resolution** - This is an HDF metadata field that defines the horizontal resolution of the CATS data profiles, which is currently set to 5 km.
2. **Bin Size** - This is an HDF metadata field that defines the size, in kilometers, of the CATS vertical (range) bins. The bin size is 60 meters or 0.06 km.
3. **Number Bins** - This is an HDF metadata field that defines the number of vertical bins in each CATS data frame. Since the CATS data frame ranges from -2.0 km to 28.0 km, and the bin size is 0.06 km, there are 533 bins in each profile.
4. **Number 5 km Profiles** - This is an HDF metadata field that defines the number of 5 km CATS L2O profiles in the granule file.
5. **Bin Altitude Array** – Altitude, in kilometers, at the middle of each of the 533 vertical bins in each CATS data frame, which ranges from roughly -2.0 km to 30.0 km.

5.7 Time and Profile Parameters

The following parameters are reported in the Level 2O data product to identify each 5 km CATS L2O record (profile).

1. **Profile UTC Date** - This is an HDF metadata field that defines the date (DDMMYYYY) of each 5 km CATS L2O record.
2. **Profile UTC Time** - This is an HDF metadata field that defines the time, in fraction of the day, of each 5 km CATS L2O record. The time reported in the CATS L2O data products have three elements for each 5 km L2O profile. These elements represent the first, mean, and last value of the 13 L1B profiles that make up one 5km L2O profile
3. **Profile ID** - This is an HDF metadata field that contains the ID number of each 5 km CATS L2O record.



4. **Day Night Flag** - This is an HDF metadata field that identifies the illumination condition (day or night) of each 5 km CATS L2O record.

5.7 Ancillary Data

There are two ancillary data parameters, other than those already listed from GMAO and the ISS, in the CATS L2O data products:

1. **Surface Type (all IFOVs)** - International Geosphere/Biosphere Programme (IGBP) classification of the surface type at each laser IFOV footprint. The IGBP surface types reported by CATS are the same as those used in the CERES/SARB surface map.
2. **DEM Surface Altitude (all IFOVs)** - This is the surface elevation at each laser IFOV footprint, in kilometers above local mean sea level, obtained from the 1x1 km GMTED2010 digital elevation map (DEM) (see http://topotools.cr.usgs.gov/gmted_viewer/ for details).

5.9 Quality Flags

Feature Type Score (Provisional)

The feature type score provides a numerical confidence level for the classification of layers by the CATS cloud-aerosol discrimination (CAD) algorithm, reported for each atmospheric layer within a 5 km profile.

The CATS feature type score is similar to the CALIPSO CAD Score, but the CATS feature type score is an integer value ranging from -10 to 10 for each atmospheric layer (CALIPSO CAD Score ranges from -100 to 100). Table 8 illustrates that the sign of the feature type score identifies a layer as either cloud (positive) or aerosol (negative), while the magnitude of the feature type score represents the confidence in our classification. A value of 10 indicates complete confidence that the layer is a cloud, while -10 indicates the accurate classification of an aerosol layer. When the feature type score equals 0, the layer is just as likely to be a cloud as it is an aerosol, and thus the classification is undetermined. If the optical and physical properties of the layer are considered invalid for clouds and aerosols, these layers are assigned a feature type score of -999.

Table 8. The interpretation of the CATS Feature Type Score.

Layer Type	CAD Score
Cloud	1 to 10
Aerosol	-10 to -1
Undetermined	0
Bad Data	-999

The CATS CAD algorithm is a multidimensional probability density function (PDF) technique that is based on the CALIPSO algorithm. The PDFs were developed based on CPL measurements obtained during over 11 field campaigns and 10 years. The attributes



of the operational CATS PDFs depend on the CATS mode of operations. Measured cloud/aerosol properties available include layer altitudes and thickness, attenuated backscatter, depolarization, and attenuated backscatter color ratio (1064/532-nm). Ancillary data, such as mid-layer temperature can also be utilized. More details about the CATS CAD algorithm are available in the CATS ATBD.

Cloud Phase Score (Provisional)

The cloud phase score provides a numerical confidence level for the classification of cloud phase by the CATS cloud phase (CP) algorithm, reported for each atmospheric layer within a 5 km profile.

The CATS CP score is similar to the CATS Feature Type Score, but the sign of the CP score identifies a layer as either ice (positive) or liquid water (negative), while the magnitude of the CP score represents the confidence in our classification. A value of 10 indicates complete confidence that the layer is an ice cloud, while -10 indicates the accurate classification of a liquid water cloud. When the CP score equals 0, the layer is just as likely to be ice as it is liquid water, and thus the classification is undetermined. If the optical and physical properties of the layer are considered invalid for ice clouds and liquid water clouds, these layers are assigned a CP score of -999. More details about the CATS CP algorithm are available in the CATS ATBD.

Opacity Flag

For CATS, a feature is considered opaque if it is the lowest layer detected in a 5 km profile and the earth’s surface is not detected. The opacity flag has a value of either 1 (opaque layer) or 0 (transparent layer). Please note that the opacity flag distinguishes when the backscatter signal becomes completely attenuated due to that feature.

Lidar Ratio Selection Method

This is an integer indicating a specific lidar ratio selection method, as defined by Table 9.

Table 9. Definition of CATS Lidar Ratio Selection Method Flag

Interpretation of Values
0 = generic default
1 = aerosol GEOS5 lookup table
2 = cloud lookup table
3 = 1064 lidar ratio used 532 OD (for ice clouds only)
4 = constrained result using clear zone just below layer
5 = constrained result with opaque layer
6 = lowered lidar ratio by a max of 15sr to reach layer bottom
7 = raised lidar ratio by a max of 15sr to reach layer bottom
8 = open slot (not used)
9 = missing

Constrained Lidar Ratio Flag

This is an integer indicating the constrained lidar ratio condition, as defined by Table 10.

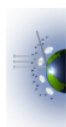


Table 10. Definition of CATS Constrained Lidar Ratio Flag

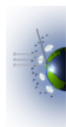
Interpretation of Values
0 = useful value using nominal “constrained” procedure
1 = useful value using opaque “constrained” procedure
2 = constrained lidar ratio outside thresholds
3 = below layer clear zone too small
4 = clear zone signal error > threshold
5 = Tp_sq < allowed min
6 = Tp_sq at or below 0.0
7 = useful 1064 lidar ratio using 532 OD (for ice clouds only)
8 = Tp_sq at or below 0.0 in opaque cloud conditions
9 = missing

Extinction QC Flag

This is an integer indicating a specific extinction condition, as defined by Table 11.

Table 11. Definition of CATS Extinction QC Flag

Interpretation of Values
-1=calculation not attempted
0 = layer extinction analysis nominal
1 = layer hit earth’s surface before layer bottom reached, adjusted bottom
2 = Tp_sq below min, lowering lidar ratio thru iteration process
3 = Tp_sq above max, raising lidar ratio thru iteration process
4 = # of iterations maxed out
5 = signal inside layer saturated before bottom
6 = layer is opaque, layer OD= -1
7 = open slot (not used)
8 = layer OD out of bounds (invalid) OD= -999.99
9 = layer OD invalid because final lidar ratio out of bounds



5.10 Metadata Parameters

Below is a list of metadata parameters not discussed in the previous sections:

Parameter
ProductID
Product_Version_Number
Product_Creation_Date
Product_Creator
Granule_Start_DateTime
Granule_Stop_DateTime
Granule_Production_DateTime
Granule_Start_Latitude
Granule_Start_Longitude
Granule_Stop_Latitude
Granule_Stop_Longitude
Granule_Start_RDM
Granule_Stop_RDM
Granule_Start_Record_Number
Granule_Stop_Record_Number
LIB_Input_Version_Number

6.0 Data Release Versions

CATS Level 2 Layer Data Product			
Night/Day Granules layer products			
Release Date	Version	Data Date Range	Maturity Level
March 2016	1.03	3/25/2015 to Present (Mode 7.2)	Provisional
June 2016	1.04	2/10/2015 to Present (All Modes)	Provisional

