

# CALIPSO Quality Statements: Lidar Level 2 Vertical Feature Mask Version Releases: 1.10, 1.20



---

[Introduction](#) | [Documents and References](#) | [Data Products Descriptions](#) | [Data Release Versions](#)

---

## Introduction

This document provides a high-level quality assessment of the Level 2 lidar vertical feature mask product, as described in Section 2.7 of the [CALIPSO Data Products Catalog \(Version 2.3\)](#) (PDF). As such, it represents the minimum information needed by scientists and researchers for appropriate and successful use of these data products. We strongly suggest that all authors, researchers, and reviewers of research papers review this document for the latest status before publishing any scientific papers using these data products.

The purpose of these data quality summaries is to inform users of the accuracy of CALIOP data products as determined by the CALIPSO Science Team and Lidar Science Working Group (LSWG). This document is intended to briefly summarize key validation results; provide cautions in those areas where users might easily misinterpret the data; supply links to further information about the data products and the algorithms used to generate them; and offer information about planned algorithm revisions and data improvements.

## Additional Documentation and References

### Algorithm Theoretical Basis Documents (ATBDs)

- [PC-SCI-202.02 - Feature Detection and Layer Properties Algorithms](#) (PDF)
- [PC-SCI-202.03 - Scene Classification](#) (PDF)

### General References

- [PC-SCI-503 : CALIPSO Data Products Catalog \(Version 2.3\)](#) (PDF)
- Data analysis overview: [Fully automated analysis of space-based lidar data: an overview of the CALIPSO retrieval algorithms and data products](#) (PDF)
- [Additional publications](#) (journal articles and conference proceedings about CALIPSO science, algorithms, and data processing)
- [CALIPSO Data Read Software](#)

## CALIPSO Lidar Level 2 Vertical Feature Mask

This data product describes the vertical and horizontal distribution of cloud and aerosol layers observed by the CALIPSO lidar. Cloud and aerosol discrimination for detected features is reported as a single value, the CAD\_Score, which can be found in the [Lidar Level 2 Cloud and Aerosol Layer](#) data products. In this data product clouds and aerosols are distinguished by the "feature type" bits, and the CAD\_Score is interpreted in the following fashion:

If CAD\_Score > 0, feature is a cloud.

If CAD\_Score < 0, feature is a aerosol.

Use of the CAD\_Score to produce the feature typing QA bits, can be found below.

### Latitude

Latitude, in degrees, of the laser footprint. One value is reported at the temporal midpoint of a 15 shot average for each 5 km chunk of the Feature\_Classification\_Flag data.

### Longitude

Longitude, in degrees, of the laser footprint. One value is reported at the temporal midpoint of a 15 shot average for each 5 km chunk of the Feature\_Classification\_Flag data.

### Profile Time (TAI)

Time expressed in [International Atomic Time](#) (TAI). Units are in seconds, starting from January 1, 1993. One value is reported at the temporal midpoint of a 15 shot average for each 5km chunk of the Feature\_Classification\_Flag data.

### Profile Time (UTC)

Time expressed in [Coordinated Universal Time](#) (UTC), and formatted as 'yymmdd.fxxxxx', where 'yy' represents the last two digits of



year, 'mm' and 'dd' represent month and day, respectively, and 'ffffff' is the fractional part of the day. One value is reported at the temporal midpoint of a 15 shot average for each 5km chunk of the Feature\_Classification\_Flag data.

### Day-Night Flag

Indicates the lighting conditions at an altitude of ~24 km above mean sea level; 0 = day, 1 = night.

### Land-Water Flag

This is a 30 arc second resolution land/water mask provided by the [SDP toolkit](#). It is an 8-bit integer indicating the surface type at the lidar footprint:

- 0 = shallow ocean
- 1 = land
- 2 = coastlines
- 3 = shallow inland water
- 4 = intermittent water
- 5 = deep inland water
- 6 = continental ocean
- 7 = deep ocean

Please see section 4.5 in [PC-SCI-503 : CALIPSO Data Products Catalog \(Version 2.3\)](#) (PDF) for more information.

### Feature Classification Flags [beta]

For each layer, we report a set of feature classification flags that provide assessments of (a) feature type (e.g., cloud vs. aerosol vs. stratospheric layer); (b) feature subtype; (c) layer ice-water phase (clouds only); and (d) the amount of horizontal averaging required for layer detection. The complete set of flags is stored as a single 16-bit integer. The following table is reproduced from the CALIPSO Data Products Catalog.

Reproduced from [PC-SCI-503 : CALIPSO Data Products Catalog \(Version 2.3\)](#) (PDF)

**Table 45: Feature Classification Flag Definition**

| Bits  | Field Description                                                   | Bit Interpretation                                                                                                                                                                   |
|-------|---------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1-3   | Feature Type                                                        | 0 = invalid (bad or missing data)<br>1 = "clear air"<br>2 = cloud<br>3 = aerosol<br>4 = stratospheric feature<br>5 = surface<br>6 = subsurface<br>7 = no signal (totally attenuated) |
| 4-5   | Feature Type QA                                                     | 0 = none<br>1 = low<br>2 = medium<br>3 = high                                                                                                                                        |
| 6-7   | Ice/Water Phase                                                     | 0 = unknown / not determined<br>1 = ice<br>2 = water<br>3 = mixed phase                                                                                                              |
| 8-9   | Ice/Water Phase QA                                                  | 0 = none<br>1 = low<br>2 = medium<br>3 = high                                                                                                                                        |
| 10-12 | Feature Sub-type                                                    |                                                                                                                                                                                      |
|       | If feature type = aerosol, bits 10-12 will specify the aerosol type | 0 = not determined<br>1 = clean marine<br>2 = dust<br>3 = polluted continental<br>4 = clean continental<br>5 = polluted dust<br>6 = smoke<br>7 = other                               |



|       |                                                                                                          |                                                                                                                                                                                                                                               |
|-------|----------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|       | If feature type = cloud, bits 10-12 will specify the cloud type.                                         | 0 = low overcast, transparent<br>1 = low overcast, opaque<br>2 = transition stratocumulus<br>3 = low, broken cumulus<br>4 = altocumulus (transparent)<br>5 = altostratus (opaque)<br>6 = cirrus (transparent)<br>7 = deep convective (opaque) |
|       | If feature type = Polar Stratospheric Cloud, bits 10-12 will specify PSC classification.                 | 0 = not determined<br>1 = non-depolarizing PSC<br>2 = depolarizing PSC<br>3 = non-depolarizing aerosol<br>4 = depolarizing aerosol<br>5 = spare<br>6 = spare<br>7 = other                                                                     |
| 13    | Cloud / Aerosol /PSC Type QA                                                                             | 0 = not confident<br>1 = confident                                                                                                                                                                                                            |
| 14-16 | Horizontal averaging required for detection (provides a coarse measure of feature backscatter intensity) | 0 = not applicable<br>1 = 1/3 km<br>2 = 1 km<br>3 = 5 km<br>4 = 20 km<br>5 = 80 km                                                                                                                                                            |

#### List of the data quality summaries and user notes for the feature classification flags.

- Bits 1-3, Feature Type

- Invalid (bad or missing data)

- Features are labeled as invalid when the feature integrated attenuated backscatter,  $\gamma'_{532}$ , is outside the limit,  $0 < \gamma'_{532}$ . If the limit,  $\gamma'_{532} > 1$ , is exceeded then the feature will be classified as a cloud with a confidence value of 0, (Bits 4-5). These types of features may be found below some strongly attenuating features. This occurs because the feature finding algorithm has overestimated the attenuation of the overlying feature due to the low SNR of the signal below the previous feature that was found.

- "Clear Air"

- This indicates areas where no features were found. This does not guarantee that there are no features present. Aerosol or cloud layers may be present but they are below the detection threshold.

- Cloud / Aerosol

- When clouds are reported the value of the feature subtype flag (Bits 10-12) will all be zero. For this data release, a value of zero indicates "not reported" rather than that all clouds have been classified as low overcast transparent, as is stated in the data products catalog.

The cloud aerosol discrimination (CAD) algorithm uses the feature integrated color ratio,  $\chi'$ , and the feature mean attenuated backscatter coefficient,  $\langle \beta'_{532} \rangle$ , to compute the CAD\_Score. [These parameters depend on the quality of the 532 nm and 1064 nm channel calibrations.](#) Significant errors in the calibration of either channel may result in the misclassification of a particular feature.

The current probability distribution functions of  $\chi'$  vs.  $\langle \beta'_{532} \rangle$  for clouds and aerosols that are used by the CAD algorithm were generated using [CPL data](#). Due to the differences between CALIOP and the CPL instruments (e.g. SNR), and the limited number of the CPL observations, these PDFs were adjusted to provide the best cloud-aerosol discrimination results for the entire globe. The current [algorithm \(v 1.10\)](#) (PDF) has difficulty correctly classifying optically dense biomass burning aerosol layers as an aerosol layer. Users should also be aware that clouds embedded within optically dense aerosols will likely be identified by the feature finder algorithm as one feature and, consequently, these features will likely be classified as clouds.

- Stratospheric

- The current classification algorithm calls any feature with its base above the tropopause as a stratospheric feature. While there exist bonafide observations of relatively dense stratospheric aerosol layers (plume from the Soufriere Hills, Montserrat eruption on May 20, 2006), some high altitude cirrus clouds and deep convective clouds have been misclassified as stratospheric features. We believe that the misclassification is due to an incorrect location of the tropopause that is provided by the GMAO GEOS-4 meteorological data set. Please query the feature type QA bits when using this data product.

In the Antarctic region where polar stratospheric clouds (PSCs) have been observed, there may be times when a vertical strip of the PSC may be classified as cloud. In many situations this happens because the base of the PSC drops below the GMAO- reported tropopause or because the PSC is vertically adjacent to a cloud system in the

troposphere. The current version of the feature finding algorithm reports only a single feature even if its vertical extent spans the tropopause.

Surface/Subsurface

Please see the comments on the Lidar\_Surface\_Elevation [Lidar Level 2 Cloud and Aerosol Layer](#).

No signal

This is the value given to any region below a fully attenuating atmospheric feature.

◦ Bits 4-5, Feature Type QA

Invalid

Not applicable. Always 0.

"Clear Air"

Not applicable. Always 0.

Cloud / Aerosol

For the feature, if  $\text{abs}(\text{CAD\_Score}) > 0.70$ , then the confidence value is high.

If  $0.5 < \text{abs}(\text{CAD\_Score}) < 0.7$ , then the confidence value is medium.

If  $0.2 < \text{abs}(\text{CAD\_Score}) < 0.5$ , then the confidence value is low.

If  $\text{abs}(\text{CAD\_Score}) < 0.2$ , then the confidence value is none.

Stratospheric

For this description use  $H_t$  to indicate the tropopause altitude.

For the feature, if  $\text{Base\_Altitude} > H_t + 2.5\text{km}$ , then the confidence value is high.

If  $H_t + 2.5\text{km} < \text{Base\_Altitude} < H_t + 1.0\text{km}$ , then the confidence value is medium.

If  $H_t + 1.0\text{km} < \text{Base\_Altitude} < H_t$ , then the confidence value is low.

Surface / Subsurface

Always high.

No signal

Not applicable. Always 0.

◦ Bits 6-7, Ice/Water Phase

Not reported in this data release. Filled with 0.

◦ Bits 8-9, Ice/Water Phase QA

Not reported in this data release. Filled with 0.

◦ Bits 10-12, Feature Sub-type

Not reported in this data release. Filled with 0.

◦ Bit 13, Cloud / Aerosol / PSC Type QA

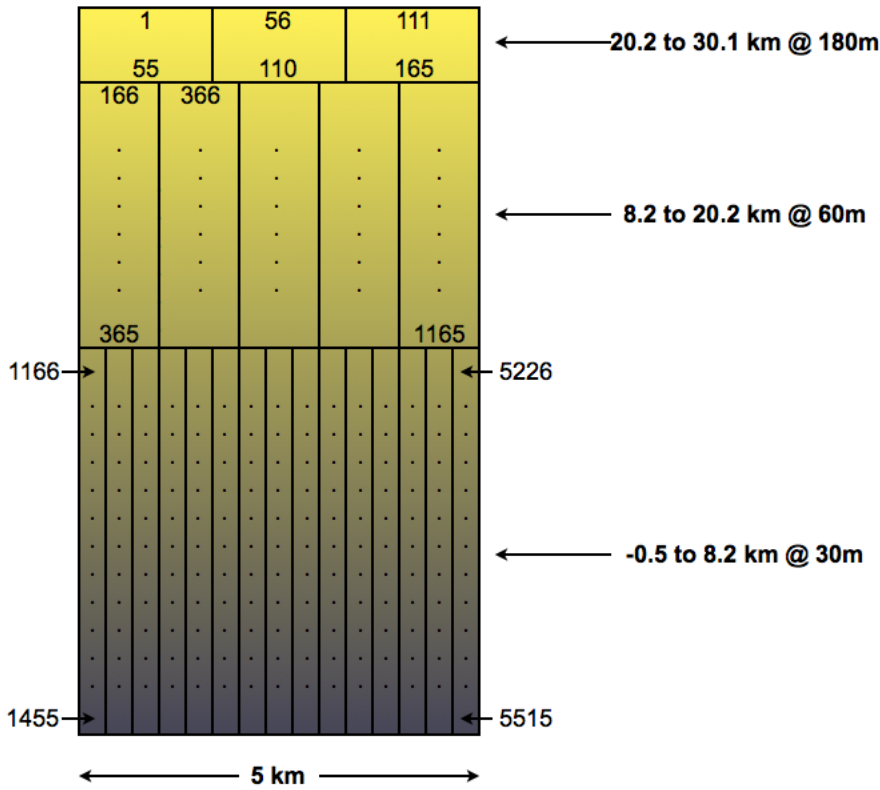
Not reported in this data release. Filled with 0.

◦ Bits 14-16, Horizontal Averaging

Nothing to report.



## Layout of the Feature\_Classification\_Flag data block



The Feature\_Classification\_Flag values are stored as an 5515 element array (as rows in the HDF file) for a 5 km "chunk" of data. The numbers in this image indicate the column indices for the array. Only start and end indices are shown.

Reproduced from [PC-SCI-503 : CALIPSO Data Products Catalog \(Version 2.3\)](#) (PDF) section 2.7

### Profile Spatial Resolution

| Altitude Region |          | Vertical Resolution (meters) | Horizontal Resolution (meters) | Profiles per 5 km | Samples per Profile |
|-----------------|----------|------------------------------|--------------------------------|-------------------|---------------------|
| Base (km)       | Top (km) |                              |                                |                   |                     |
| -0.5            | 8.2      | 30                           | 333                            | 15                | 290                 |
| 8.2             | 20.2     | 60                           | 1000                           | 5                 | 200                 |
| 20.2            | 30.1     | 180                          | 1667                           | 3                 | 55                  |
| <b>Total</b>    |          |                              |                                |                   | 545                 |

## Data Version Releases

| Lidar Level 2 Vertical Feature Mask (VFM) Information<br>Half orbit (Day) geolocated data radiances |         |                                     |                                                                                                                                           |
|-----------------------------------------------------------------------------------------------------|---------|-------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------|
| Release Date                                                                                        | Version | Data Date Range                     | Maturity Level                                                                                                                            |
| March 2007                                                                                          | 1.20    | March 01, 2007 to November 11, 2007 | <ul style="list-style-type: none"> <li>Layer Heights - Provisional</li> <li>Aerosol/Cloud/Stratospheric Classifications - Beta</li> </ul> |
| December 8, 2006                                                                                    | 1.10    | June 13, 2006 to March 13, 2007     | <ul style="list-style-type: none"> <li>Layer Heights - Provisional</li> <li>Aerosol/Cloud/</li> </ul>                                     |

**Data Quality Statement for the release of the CALIPSO Lidar Level 2 Vertical Feature Mask Products Version 1.20, March 2007**

Description Coming Soon.

**Data Quality Statement for the release of the CALIPSO Lidar Level 2 Vertical Feature Mask Products Version 1.10, December 8, 2006**

The CALIPSO vertical feature mask (VFM) data product reports a single 16-bit integer for each lidar altitude resolution element in the data stream downlinked from the satellite. Upon decoding each of these bit-mapped integers, users will obtain information describing layer location (both vertically and horizontally), layer type, and the amount of horizontal averaging required for the layer to be detected. Given the accuracy of the CALIPSO altitude registration, the layer locations reported in the VFM appear to be quite accurate. In optically dense layers, the lowest altitude where signal is observed is reported as the base. In actuality, this point may lie well above the true base. In this release, the layers which are reported represent a choice in favor of high reliability over maximum sensitivity. Weakly scattering layers sometimes will go unreported, in the interest of minimizing the number of false positives.

A preliminary version of the algorithm to discriminate cloud and aerosol has been used in this release. Overall, the algorithm performance is fairly good at labeling cloud as cloud and somewhat less successful in labeling aerosol as aerosol. Several types of misclassifications are fairly common and users should watch for them. The most common misclassification is portions of dense aerosol layers being labeled as cloud. The algorithm operates on individual profiles, so small regions within an aerosol layer are sometimes labeled as cloud. These misclassifications are often apparent from study of Level 1 browse images. Actual clouds occurring within aerosol layers appear to be correctly classified as cloud most of the time. Additionally, portions of the bases of some cirrus clouds are mislabeled as aerosol, and some tropospheric polar clouds are erroneously labeled as aerosol. Improvements to the cloud/aerosol discrimination algorithm are underway and misclassifications should be greatly reduced in future data releases.

