

CALIPSO Low Laser Energy Technical Advisory for Data Users

Issued: October 10, 2018

Applies to: CALIOP level 1 and level 2 products, V4.20 and earlier

Data dates: September 2016 to present

Since September 2016, CALIOP has been experiencing low energy laser shots due to decreased pressure inside the laser canister. These low energy shots primarily occur over the South Atlantic Anomaly (SAA) region and have significant impact on data quality for affected profiles. This document briefly describes the issue and provides guidance for data users on how to identify affected profiles in the CALIOP level 1B and level 2 data products.

1. Background

In September 2016, CALIOP began experiencing low laser energy shots because of decreased pressure inside the canister of the laser. Since then, the pressure has decreased into a regime whereby coronal arcing across the laser q-switch causes intermittent reductions in laser energy. These low energy shots primarily occur over the South Atlantic Anomaly (SAA) region (Sect. 5), where energetic particles trapped in the inner Van Allen radiation belts make their closest approach to the surface, thereby increasing the occurrence of coronal arcing.

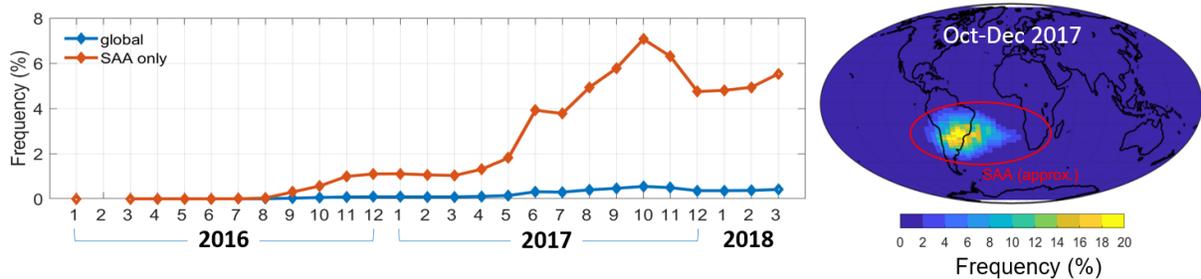


Fig. 1 Monthly frequency of low energy laser shots ($E_{532} < 80$ mJ) from Jan. 2016 to Mar. 2018, globally and in the SAA region (left). Spatial distribution of low energy shot frequency from Oct. to Dec. 2017 (right).

Figure 1 shows an increase in the frequency of low energy shots, particularly in the second half of 2017. As of March 2018, ~6% of all laser shots within the SAA have low energies, whereas the global frequency remains less than 1%.

To provide a sense of scale, Figure 2 compares the late 2017 distribution of laser energies in the SAA (red) to the distribution prior to the coronal arcing issue (blue). There is now a spread in the distribution of laser energies, and a substantial fraction of low energy shots has 532 nm laser energy less than 10 mJ. Energies this low significantly impact data quality. It is important to note that there is no impact on data quality when laser energies are nominal (97% of all level 1B profiles, globally).

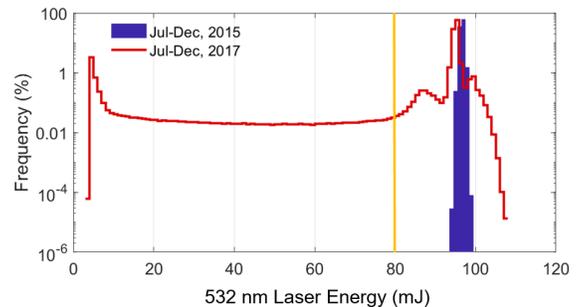


Fig. 2 Distributions of 532 nm laser energy in SAA for last six months of 2015 (blue) and 2017 (red). Yellow line is the recommended low energy threshold of 80 mJ.

An example of the impact on data quality in the SAA region is shown in Figure 3. For affected profiles, the level 1B attenuated backscatter is extremely low and noisy. As a consequence, there are many false feature detections (primarily as low confidence ice clouds) and misdetections of optically thin aerosol layers in the level 2 vertical feature mask. The measured and retrieved optical properties of legitimate layers within affected profiles are also highly uncertain.

Given the significant impact on data quality, data users are strongly discouraged from using CALIOP level 1B and level 2 data that contain low laser energies as defined in Section 2 for scientific analyses. The purpose of this document is to provide guidance on how to identify affected profiles so they can be excluded.

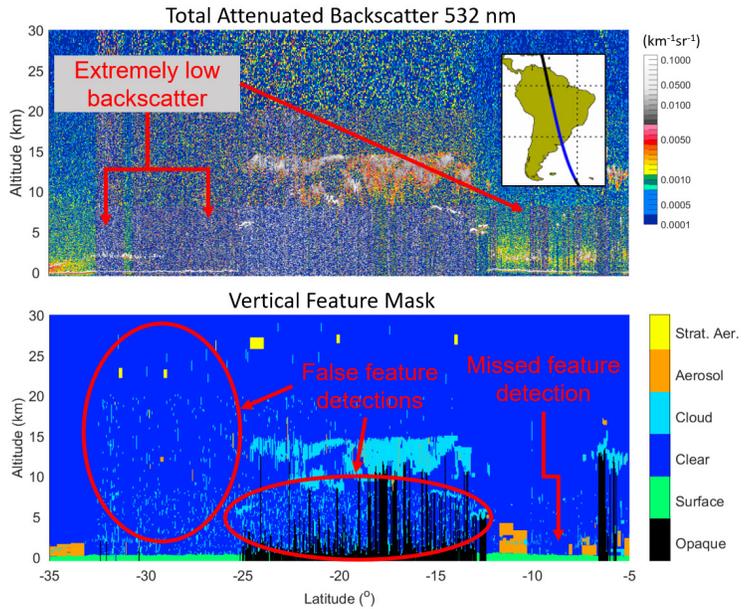


Fig. 3 Level 1B total attenuated backscatter 532 nm (top) and level 2 vertical feature mask (bottom) for a granule in the SAA: V4.10 2017-10-22T17-23-03ZD at 17:40Z.

2. Recommended Actions

Based on the current understanding of the impact of low laser energies on data quality, the CALIPSO team recommends excluding profiles affected by 532 nm laser energies less than 80 mJ. The 532 nm laser energies are reported in the CALIOP level 1B data products as “Laser_Energy_532” in units of Joules (rather than mJ). Due to onboard horizontal averaging, low energy shots can impact multiple level 1B profiles. Section 2.1 describes how to account for onboard averaging to identify affected profiles in level 1B products. Since level 2 algorithms operate on 80 km “chunks” of level 1B data at a time, all profiles within an 80 km chunk are potentially impacted by low energy shots. Section 2.2 describes how to identify affected chunks in the level 2 data products.

2.1 Identifying Affected Level 1B Profiles

Profiles in the level 1B data product are reported at 1/3 km horizontal resolution, including the values of laser energy. However, various levels of onboard averaging have been applied to profile data (e.g., attenuated backscatter, etc.) prior to downlink. Table 1 shows the horizontal averaging for various regions of the atmosphere. If a single 1/3 km profile has a low energy laser shot, then the entire 5 km horizontal average above 30.1 km containing that low energy laser shot is affected. Similarly, the entire 1 km horizontal average between 8.3 and 20.2 km would be affected if a single 1/3 km profile within that horizontal interval has a low laser energy.

Altitude range (km)	Horizontal resolution (km)
30.1 to 40.0	5
20.2 to 30.1	5/3
8.3 to 20.2	1
-0.5 to 8.3	1/3
-2.0 to -0.5	1/3

Table 1. Level 1B horizontal averaging.

In order to exercise maximum caution, the CALIPSO team recommends excluding all profiles within the entire 5 km horizontal averaging interval¹ containing a low laser energy shot (532 nm laser energy < 80 mJ). For the October – December 2017 time period, this excludes 3% of all CALIOP level 1 profiles, globally. The 532 nm laser energies are reported in the CALIOP level 1B data products as “Laser_Energy_532” in units of Joules (rather than mJ).

The 5 km horizontal averaging interval is easily identified in level 1B data product. The 5 km interval starts at the first profile reported in the product and each 5 km interval spans 15 single-shot profiles (at 1/3 km resolution each). The following pseudocode evaluates all 532 nm laser energies (Energy532) within each 15 single-shot horizontal averaging interval and identifies the level 1B profiles that should be excluded from science analysis.

```
horizontalAveragingInterval = 15; % single-shot profiles within interval
numSingleShotProfiles = length(Energy532);
for i = 1:horizontalAveragingInterval:numSingleShotProfiles
    if any( Energy532(i:i+ horizontalAveragingInterval-1) < 0.08 )
        % exclude profiles i through i+horizontalAveragingInterval-1
    end
end
```

2.2 Identifying Affected Level 2 Profiles

Profiles are reported in the CALIOP level 2 layer and profile products at 5 km horizontal resolution. However, all level 2 algorithms (feature detection, extinction retrieval, cloud-aerosol discrimination, etc.) operate on 80 km “chunks” of level 1B data at a time. Given that features could be detected at horizontal resolutions as large as 80 km, it is possible for errors in one segment of the 80 km chunk to affect layers elsewhere in the chunk during the top-down retrieval. In particular, the false features detected in Figure 3 would cause errors in legitimate features detected at lower altitudes within the chunk.

In order to exercise maximum caution, the CALIPSO team recommends excluding all level 2 profiles within an 80 km chunk containing a low laser energy shot (532 nm laser energy < 80 mJ). For the October – December 2017 time period, this excludes 10% of all CALIOP level 2 profiles, globally.

The latest release of CALIOP level 2 data products, V4.20, now includes an SDS which reports the minimum laser energy within a chunk. Previous versions of level 2 products do not report laser energy information, so it is necessary to acquire matching level 1B files. The following sections describe how to identify affected profiles for V4.20 and for earlier versions.

¹ For simplicity, excluding the entire 5 km interval covers all CALIOP altitude ranges. If user analysis is restricted to a lower altitude range, then profiles only need to be excluded for the horizontal averaging interval of the altitude range analyzed according to Table 1. Below 8.3 km, only single shot profiles with low energy need to be excluded.

For Data Version 4.20

The V4.20 level 2 data products include science data sets for both 532 nm single-shot laser energy and the minimum 532 nm laser energy for each 80 km chunk. The latter SDS, named `Minimum_Laser_Energy_532`, is reported for each level 2 profile. Because the horizontal resolution of the level 2 product is 5 km, the minimum laser energy is replicated 16 times for all profiles within the 80 km chunk. Affected profiles are therefore identified by simply evaluating the minimum laser energy reported for that profile, as in the example below.

```
for i = 1:numLevel2Profiles
    if MinimumLaserEnergy532(i) < 0.08 )
        % exclude level 2 profile i
    end
end
end
```

For Data Versions 4.10 and earlier

In data releases V4.10 and earlier, laser energy is not reported in level 2 data products. In order to identify level 2 chunks affected by low laser energy, the matching level 1B granules must be acquired² and their laser energies must be matched to corresponding level 2 profiles.

The following pseudocode demonstrates how to identify affected level 2 chunks. Corresponding level 1B and level 2 granules can be identified using the date/time information in their filenames³. Level 1B profiles can be matched to level 2 profiles either using the [Profile_Time](#) or [Profile_ID](#) science data sets⁴. These data sets report information for the first, midpoint, and last single-shot profile within each 5 km profile. Profile time (in seconds) is used in the example below.

```
num5kmProfilesPerChunk = 16;
numLevel2Profiles = size(profileTimeL2,1);
for i = 1:num5kmProfilesPerChunk:numLevel2Profiles
    chunkStartTime = profileTimeLevel2(i,1); % first time
    chunkEndTime = profileTimeLevel2(i+num5kmProfilesPerChunk-1,3); % last time

    inTimeRange = profileTimeLevel1 >= chunkStartTime &...
        profileTimeLevel1 <= chunkEndTime;

    if any( Energy532(inTimeRange) < 0.08 )
        % exclude level 2 profiles i through i+num5kmProfilesPerChunk-1
    end
end
end
```

² Tip: rather than download entire level 1B files to acquire laser energies (~450 MB/granule), the [CALIPSO Search and Subsetting Web Application](#) can be used to download smaller level 1B files that still contain laser energies (~11 MB/granule) by selecting the “532nm Calibration” parameter group.

³ On extremely rare occasions, the date/time information does not match between the level 1B and level 2 granule filenames due to file generation errors.

⁴ The pseudocode example assumes `Profile_Time` (or `Profile_ID`) increase monotonically. On extremely rare occasions, these values can be non-monotonic or exhibit duplicate values within a granule due to on-board timing issues.

Example of Removing Affected Profiles

Figure 4 demonstrates how a level 2 vertical feature mask looks after excluding 80 km chunks affected by low laser energies. The original vertical feature mask contains many false feature detections as the granule passed through the SAA. By excluding 80 km chunks having low laser energy (denoted in gray), the data quality of the remaining profiles is still on par with CALIOP retrievals which are unaffected by coronal arcing.

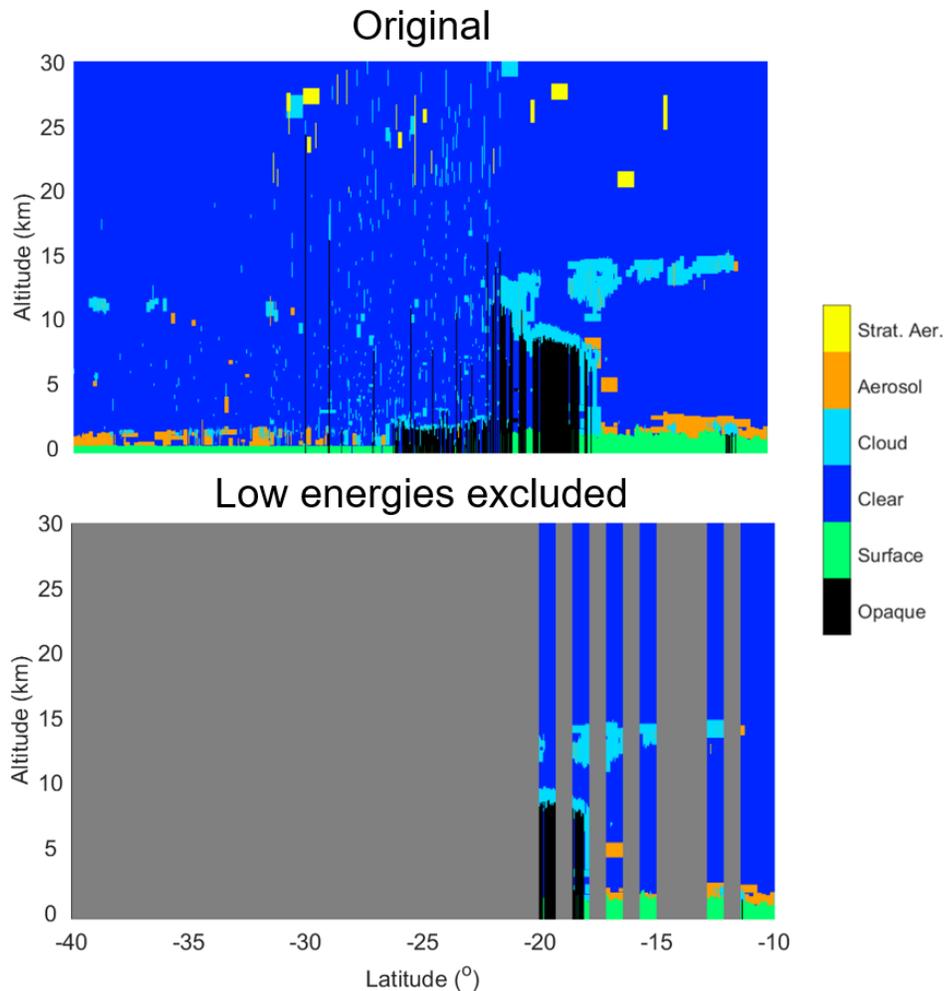


Fig. 4. Vertical feature mask before (top) and after (bottom) excluding 80 km chunks affected by low laser energy ($E_{532} < 80$ mJ). V4.10 granule 2017-10-25T03-56-30ZN at approximately 4:30Z.

3. Final Notes

Given the impact of low energy laser shots on data quality, the CALIPSO team recommends following the guidance outlined in this document to exclude affected data. Doing so retains 97% of level 1B data and >90% of level 2 data (since ~Oct. 2017) which has equal data quality as unaffected CALIOP observations. The recommendations of the CALIPSO team may evolve further as impacts on data quality are continually assessed.

4. Relevant Resources

CALIPSO Data Advisory Webpage:

https://www-calipso.larc.nasa.gov/resources/calipso_users_guide/advisory.php

Laser_Energy_532 description:

https://www-calipso.larc.nasa.gov/resources/calipso_users_guide/data_summaries/l1b/index.php#laser_energy_532

Minimum_Laser_Energy_532 description:

https://www-calipso.larc.nasa.gov/resources/calipso_users_guide/data_summaries/layer/index_v420.php#minimum_laser_energy_532

Profile_Time (level 1) description:

https://www-calipso.larc.nasa.gov/resources/calipso_users_guide/data_summaries/l1b/index.php#profile_time

Profile_Time (level 2) description:

https://www-calipso.larc.nasa.gov/resources/calipso_users_guide/data_summaries/layer/index.php#profile_time

Profile_ID (level 1) description:

https://www-calipso.larc.nasa.gov/resources/calipso_users_guide/data_summaries/l1b/index.php#profile_id

Vertical and horizontal resolution of CALIOP data:

https://www-calipso.larc.nasa.gov/resources/calipso_users_guide/essential_reading/index.php#altitude_array

CALIPSO Search and Subsetting Web Application:

<https://subset.larc.nasa.gov/calipso/>

5. Coordinates of South Atlantic Anomaly (SAA)

The following coordinates define a polygon that encapsulates the SAA. Given that the size of the SAA expands and contracts depending on the level of solar activity, the polygon will be larger than the SAA at any given time. It is intentionally broad. CALIOP data within these coordinates from September 2016 onward are susceptible to data quality issues caused by low laser energy.

LAT	LON	LAT	LON	LAT	LON	LAT	LON
-40	-80	-34.2	5	1.6	-15	-10.9	-91.8
-41	-75	-32.8	10	2	-20	-13.5	-92.4
-43	-70	-31.3	15	2.2	-25	-16.5	-92.8
-43.75	-65	-29.7	20	2.2	-30	-19.9	-93
-43.5	-60	-28.1	25	2	-35	-22.7	-92.8
-43.25	-55	-26.3	30	1.7	-40	-24.9	-92.4
-43	-50	-23.4	35	1.3	-45	-26.5	-91.8
-42.7	-45	-15	34	0.8	-50	-27.5	-91
-42.3	-40	-13	30	0.2	-55	-29	-90
-41.8	-35	-10	25	-0.5	-60	-33	-85
-41.2	-30	-7.4	20	-1.3	-65	-40	-80
-40.5	-25	-5.2	15	-2.2	-70		
-39.7	-20	-3.4	10	-3.2	-75		
-38.8	-15	-2	5	-4.3	-80		
-37.8	-10	-0.8	0	-5.5	-85		
-36.7	-5	0.2	-5	-6.9	-90		
-35.5	0	1	-10	-8.7	-91		