How to generate a histogram of CALIPSO feature aerosol optical depth with basic data quality screening using MATLAB

Let's say you are interested in creating a histogram of CALIPSO aerosol optical depth for only dust layers over the Saharan Desert in August 1st – August 3rd, 2010. Here we provide an example of how to do this from the level 2 aerosol layer products and how to apply some basic quality screening to improve data quality. The following zip file contains the MATLAB script, *generate_monthly_statistics.m* that takes you through the process. This document describes that script in greater detail.

The MATLAB code and associated sample data that accompanies this example can be downloaded as a zip file from the Tools section of the CALIPSO Data User's Guide. Please unzip *generate_montly_statistics.zip* and copy the .mat files and .hdf file to your active MATLAB directory to follow along.

Step 1. Get relevant CALIPSO data.

For this example, we have already included the subsetted hdf files in the zip file above. If you prefer to use the CALIPSO Search and Sub-setter Tool to acquire these files yourself, follow the link and select the Layer Optical Depth 532 nm from the LIDAR Level 2 5-km Aerosol Layer Product. By default, the tool will include Layer Information which contains important quality assurance flags that we will use for quality screening later. Select the temporal range from 2010-08-01 to 2010-08-03, and for the geospatial range, select the bounding box of (10°N, 35°N; 10°W, 30°E). Follow the instructions to download the .hdf files.

Step 2. Open the CALIPSO files and extract relevant data.

Go through each file one-by-one and extract the feature optical depth (AOD), feature optical depth uncertainty, feature classification flags, extinction QC, and the CAD score arrays using the readHDF.m routine available in the Tools section of this User's Guide:

```
for n = 1:numFiles

    product_name = 'Feature_Optical_Depth_532';
    [info, AOD] = readHDF(filenames(n,:),product_name,[0 0],[-9 -9]);

    product_name = 'Feature_Optical_Depth_Uncertainty_532';
    [info, dAOD] = readHDF(filenames(n,:),product_name,[0 0],[-9 -9]);

% and so on…
```

Step 3. Selectively screen the AOD.

In this example, we use a logical array called `useSamples` to indicate which layers we wish to keep and which to discard. Its size is identical to the AOD array (number of altitudes x number of profiles) and elements that are 'true' will tell us which AOD elements to include in the histogram while elements that are 'false' will be excluded. If you prefer a more technical definition,

suppose an element in `useSamples` is 'false' at indices (*i*, *j)*. Then we will exclude the corresponding element in AOD at indices (*i*, *j)*.

How to keep only dust layers

The CALIPSO feature classification flags (FCF) contain feature type and subtype information for each layer in a bit-mapped integer. FCF values are defined in the CALIPSO Data Products Catalog. For our purposes, aerosol layers that are classified as 'Dust' have a subtype = 2. In order to determine which aerosol layers are classified as dust, use the following function to extract subtype information and then screen out all layers are not dust (subtype =2).

```
[ftype, subtype] = get_feature_type_and_subtype(FCF);
useSamples(subtype ~= 2) = false;
```

Quality screen with AOD uncertainty

CALIPSO extinction is retrieved in an iterative process that sometimes does not converge to a solution. When the retrieved extinction begins to grow without bound, the extinction uncertainty is assigned a value of 99.99 to indicate the solution has "blown up". Feature optical depth values should not be used when the optical depth uncertainty is 99.99.

```
useSamples(AOD_Uncer > 99.9) = false;
```

Quality screen with extinction QC flags

The CALIPSO extinction QC flags summarize the final state of the extinction retrieval. During the iterative process to find a solution, the lidar ratio may be adjusted. Often, we have most confidence in solutions when the lidar ratio is unchanged during the extinction retrieval (extinction QC = 0) or if the retrieval is constrained (extinction QC = 1). See the final lidar ratio and extinction QC entries in the CALIPSO Layer Products Data Quality Summaries for more details.

```
useSamples(~(extQC == 0 | extQC == 1)) = false;
```

Quality screen with CAD Score

CAD Score reflects the confidence our scene classifier has that the feature under consideration is either an aerosol or a cloud. When CAD = -100, we have most confidence that the feature is an aerosol and when CAD = 100, we have most confidence the feature is a cloud. CAD = 0 says we really do not know. So, what CAD values should we accept, then? This sometimes depends on the situation and aerosol subtypes involved, but a good rule of thumb is to reject aerosol layers with CAD scores between 0 and -20. This is not guaranteed to screen out all bad stuff, but our analysis of version 3.01 data suggest most layers whose retrievals were suspicious due to possible misclassification had CAD values in this range. If you want to be very conservative, you can screen out features with CAD scores > -80 and preserve only the layers which we have higher confidence that they are aerosols.

For this example, we choose to screen out |CAD| < 20.

```
useSamples(CAD > -20) = false;
```

Now that we have an array indicating which AOD samples to exclude, we can use it to screen out what we don't want. The following MATLAB expression extracts only elements from the AOD array where useSamples is true and stores them in the AOD_screened array.

```
AOD_screened = AOD(useSamples);
```

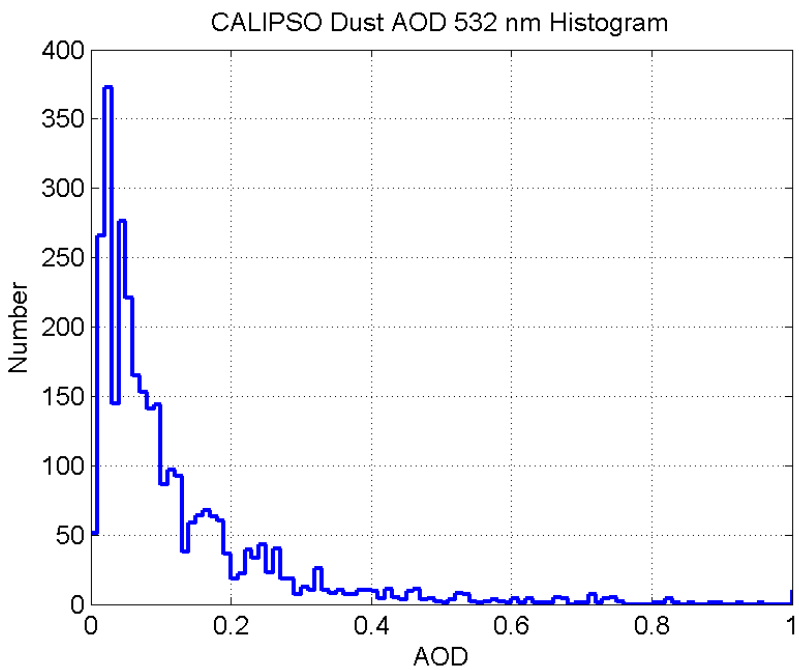
Step 4. Generate the histogram

The histogram bins were defined as `dAOD = 0:0.01:1` at the beginning of the example code along with the histogram array, `AOD_hist`. Now we can use the MATLAB histogram function to get the number of `AOD_screened` samples which fall into each bin. This is applied for each granule and the histograms for each `AOD_screened` array are added to the histograms from all previous granules.

```
AOD_hist = AOD_hist + hist(AOD_screened,dAOD);
```

Step 5. Make the histogram figure

The histogram generated by this program is shown below.



Summary and discussion

This example showed how to create a histogram of CALIPSO feature optical depth values for dust aerosols over the Saharan Desert with some basic quality screening. Though we only looked at feature optical depth values, the same approach can be taken for other data in the level 2 aerosol layer products. Bear in mind that for data where the extinction retrieval is not applied (integrated attenuated backscatter, for instance), the quality screening for extinction uncertainty and extinction QC is not necessary – but screening by CAD score still is! Furthermore, the screening techniques used in this example are different than those used in the level 2 *profile* products since the flags used for screening are stored differently than for the level 2 *layer* products. An example of how to screen profile products is given here by the "Generate Mean Extinction Profile" example in the Tools section of the CALIPSO Data User's Guide.