ATMO 611 – Satellite Data Applications Lab Assignment #6

50 Points Total Available

Identifying Aerosol with CALIPSO – DUE Tuesday, December 12th, 2017

This lab will give you experience with Expedited Images of CALIPSO backscatter data, Vertical Feature Mask, and Aerosol Sub-Type. You'll also learn how to plot the backscatter data on your own using Matlab. Questions to be answered are labeled **Q1**, **Q2**, etc. and are highlighted in Red. More guidance will be provided as to how detailed a response I am expecting for each question or the specificity of the answer. Matlab coding on your own are highlighted in Green as **C1**, **C2**, etc.

1 SIMPLE CALIPSO FIGURE ANALYSIS

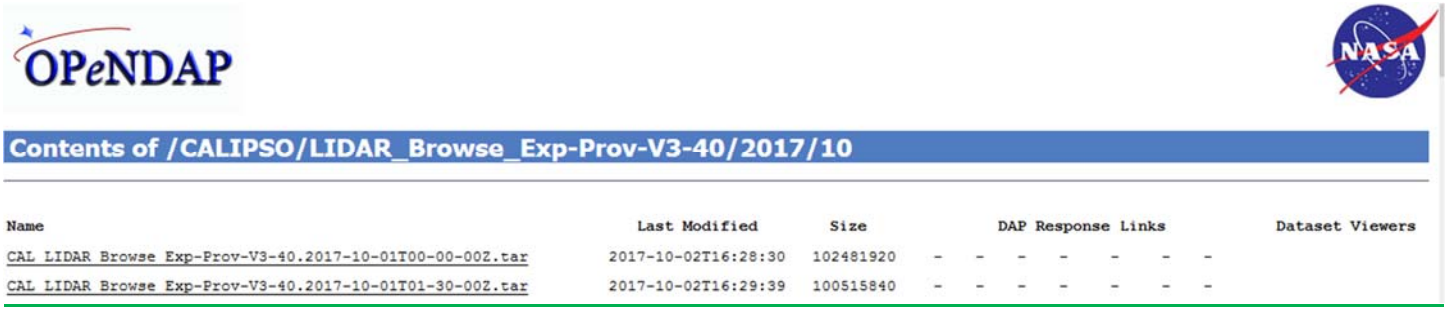
1) Download pre-made "Expedited Images" from the CALIPSO team

In order to familiarize ourselves with the different types of CALIPSO products we're simply going to download and analyzie pre-existing figures to look at an interesting event. Note: this is NOT the normal way to access these images. The standard data access to "Expedited Images" is still not functional and is only limited to 2016 and 2017 through a specially set up portal. This put a damper on the cool examples I've used in the past since they are from 2015 (when CALIOP caught 4 different profiles across a dust plume in the Atlantic from the Sahara). Unfortunately, that means we're limited to the two years of data that they're temporarily hosting as zipped tar files. Click on the link below and then Click on "2017/" and then "10/"

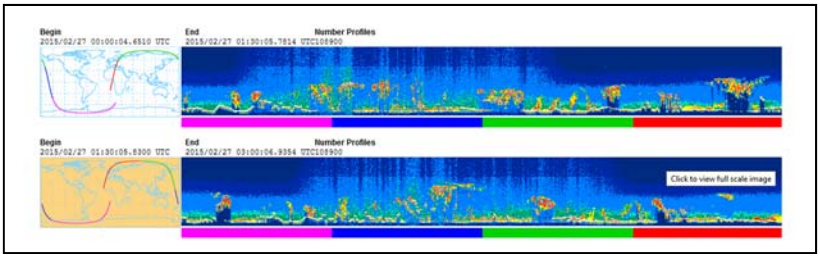
https://opendap.larc.nasa.gov/opendap/CALIPSO/LIDAR_Browse_Exp-Prov-V3-40/contents.html

After you'll see a long list of links (see image below). Scroll down and click on:

`CAL_LIDAR_Browse_Exp-Prov-V3-40.2017-10-17T01-30-00Z.tar`



We're going to download this single .tar file that will contain images for an enitre orbit (which includes 4 separate pieces that are represented by different colors (magental, blue, green, and red). When the main site was working you would have been able to see this:



You'll need to be able to unzip the file to get to the images. (I use 7-Zip but there are several different software tools that allow you to open these types of files). Once you download the file, unzip/extract the data into a folder on your computer. Inside the folder you will find a bunch of images. Take out and save the following images to include in your lab and to use for Q1 questions below (You will save and include 11 in this step):

1) Find the Thumbnail image that has a TAN background. This image shows the FULL ORBIT.

2) For the Magenta Orbit (Orbit part 1, meaning it's traveling from N to S) Find and Save the Following Images (you'll need to find those denoted V3.40_1 and check the image title for the description):

- **a) 532 nm Total Attentuated Backscatter**
- **b) 532 nm Perpendicular Attenuated Backscatter**
- **c) 1064 nm Attenuated Backscatter**
- **d) Vertical Feautre Mask**
- **e) Aerosol Sub Type**

2) For the Blue Orbit (Orbit part 2 V3.4_2)

- **a) 532 nm Total Attentuated Backscatter**
- **b) 532 nm Perpendicular Attenuated Backscatter**
- **c) 1064 nm Attenuated Backscatter**
- **a) Vertical Feature Mask**
- **b) Aerosol Sub Type**

Q1 – (15 points) CALIPSO EXPEDITED IMAGE ANALYSIS: You may not need to download raw CALIPSO data and manipulate it for your particular science goal or question. You may simply need to confirm (or deny) the presence of a feature (cloud or aerosol) during a specific event. This question lets you practice your image evaluation techniques and helps you familiarize yourself with the expected values for certain features.

1) (1 pt) Starting with the Total ORBIT Thumbnail Image

a) Which color section of the orbit passes over Africa?

b) Which color section passes over the South Atlantic?

2) (5 pts) For the Magenta Orbit (Orbit part 1)

a) Are features enhanced in the 532 nm Total Attenuated Backscatter? At what altitudes do you see these features (Hint: there are two types)?

b) Are features enhanced in the 532 nm Perpendicular Attenuated Backscatter? (Note: If it's "not enhanced" It would be plain dark blue like the background)

c) Are features enhanced in the 1064 Attenuated Backscatter? Is the attenuation for some features similar to the 532 or much lower in intensity than the 532?

d) Using the information from 2a), b), and c) and the Chart "Lidar Signal Interpretation" from Lecture 8 what Particle Types can be found in this image (Non-spherical + Coarse, Non-spherical + Fine, Spherical + Coarse, or Spherical + Fine).

e) Looking at the Vertical Feature Mask and Aerosol Sub Type figures does their assessment match your decision using the chart from class?

3) (5 pts) For the Blue Orbit (Orbit part 2)

a) Are features enhanced in the 532 nm Total Attenuated Backscatter? At what altitudes do you see this feature?

b) Are features enhanced in the 532 nm Perpendicular Attenuated Backscatter? (Note: If it's "not enhanced" It would be plain dark blue like the background)

c) Are features enhanced in the 1064 Attenuated Backscatter? Is the attenuation for some features similar to the 532 or much lower in intensity than the 532?

d) Using the information from 3a), b), and c) and the Chart "Lidar Signal Interpretation" from Lecture 8 what Particle Types can be found in this image (Non-spherical + Coarse, Non-spherical and Fine, Spherical + Coarse, or Spherical + Fine).

e) Looking at the Vertical Feature Mask and Aerosol Sub Type figures does their assessment match your decision using the chart from class?

4) (2 pts) Based on your class notes, the locations of the orbits, and the information from the Vertical Feature Mask and Aerosol Sub Type images what do you think the sources are for the aerosol in the Magenta orbit section? How do you think these aerosol end up in the atmosphere?

5) (2 pts) Based on your class notes, the locations of the orbits, and the information from the Vertical Feature Mask and Aerosol Sub Type images what do you think the sources are for the aerosol in the Blue orbit section? What types of clouds do these aerosol typically impact?

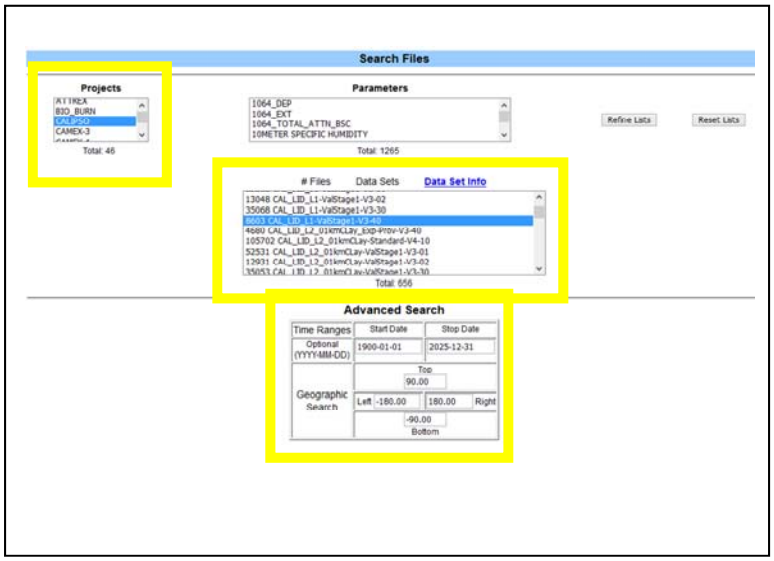
2 MATLAB VISUALIZATION OF BACKSCATTER, FEATURE MASK and SUBTYPE

1) ORDER ACTUAL CALIPSO data files, not the Expedited Quick Views

We'll be ordering the "real" data from the old data access site ASDC (since that is still up and running). Go to the website below.

https://eosweb.larc.nasa.gov/HORDERBIN/HTML_Start.cgi

1) Select "**CALIPSO**" from the "Projects" menu.
2) Leave the "Parameters" Untouched
3)Select "**CAL_LID_L1-ValStage1-V3-40**" from the "Data Sets " panel
4) In the "Advanced Search" section type in **2017-10-17** for the Start Date and **2017-10-17** for the Stop Date.
5) Leave the Day/Night option on "**Both**"



NOTE: You'll need an account to get data. So if you don't have an account, make one.

NOTE: We're only using ValStage1-V3-40 because it's the only one that has the date I want to use as an example!

6) Click "Get Results." This will bring you to the site where you can actually order the data. Make sure to choose the correct orbit time.

7) We'll be selecting a SPECIFIC File to Order. Click the box to select the following data file:

CAL_LID_L1-ValStage1-V3-40.2017-10-16T23-49-59ZN.hdf

8) Leave both the Read Software and Metadata Files boxes unclicked, makes rue that the Data Format is selected to be "Uncompressed", check that your email is correct, and the choose FTP as your Order Type

9) Click "Submit Order" and then click "Confirm Order"

2) DOWNLOAD DATA

You should receive an email for your order (just like you did for the CloudSat data) with the file to download. Follow the URL link and right click and save the single file. Now that we have the data file drag and drop it into Matlab to open up the HDFTool window. This will let you browse the variables that are contained in the file. You can copy and paste code from the "Data Import Command" to add to the codes you'll be downloading.

3) DOWNLOAD VIEWING SOFTWARE

This lab is different in that instead of being given pieces of code to type along with instructions you'll simply download the pre-written code provided below and add a few modifications:

Download the following zip file containing several .m files from the class website or Laulima:

a) make_lidar_image.m (zip)

Unpack the zip file and save all the .m files in the folder where you have stored your two CALIPSO .hdf files.

You will not be opening or modifying the readHDF.m code or some of the others contained in the zip file. Some of the codes require these other small scripts to run.

1) Let's start with the layer data code

a) Go to Matlab and open the **make_lidar_image.m** code and read the description.

b) Drag and drop your 10/17/2017 Layer data file into Matlab command window to open it in the HDFTool

c) Select "Total_Attenuated_Backscatter_532" from the variable list

d) Copy and paste code from the "Data Import Command" into the make_lider_image.m code after the code below.

```
% Get the color inf
[rgb colors_532 color_bar color_bar_labels] = kathys_lidar_colors('useGrayScale');
% The following code was inserted here to show how the colors are assigned to each pixel
(data elements within the attenuated backscatter profiles).

Total_Attenuated_Backscatter_532 = hdfread('G:\MET 611 Satellite Data
Apps\ATMO611_Labs\Lab 7 CALIPSO Aerosol Types\CALIPSO Data 2017\CAL_LID_L1-ValStage1-V3-
40.2017-10-16T23-49-59ZN.hdf', '/Total_Attenuated_Backscatter_532', 'Index', {[1  1],[1
1],[55935    583]});
```

e) To make sure that the array is the proper orientation we need to transpose it. I've also renamed it to something shorter and easier to deal with (i.e. data_TAB532):

```
data_TAB532 = Total_Attenuated_Backscatter_532';
```

f) Note that the last part of the data import specifies [55935 583] as the size of the number of profiles (x-axis) and 583 as the number of altitude layers (y-axis). We don't want the FULL orbit we only want a subsection (that I know is interesting). We can add in a little short line of code to specify that section of time. Now we need to enter a line of code to choose these profiles. This should be entered right after the line in which we transposed the data array. Since the code make_lidar_image.m uses "data" to identify the backscatter code, you should rename your array (now that it's transposed and the segment is chosen) so the rest of the code can work on its own. Note you can change this range to get a better view of your features.

```
% Specify the specific segment that we want:
  data = data_TAB532(:, 15000:40000);
```

g) Now, we need to give it a figure number (their code asks for this); Scroll down to the end of the code where the figure is produced. Add a line of code right before to identify the figure number:

```
figureNum1 = 1    % ← YOU ADD THIS……

figure(figureNum1) % ← YOU ADD the "1" TO THIS……
clf
if addColorbar,
    image(out_img)
    lidar_colorbar(rgb,color_bar,color_bar_labels,'vert');
else
    colormap(rgb/255);
    image(out)
end
```

h) Save the file with the same name. Don't re-name it.

i) Run the code

j) You should get a VERY grainy version of the backscatter images you find on their website without the proper altitudes or latitudes or colorbar. This is the best that you can get with the code they provide. We need to add in a few extra lines of code to fix this problem by loading the latitude and altitude data and correctly adding the color bar, a title and axes labels.

This is an IMAGE so we'll need to use the "image" command. Their original code doesn't specify the axes correctly. For images it automatically flips the y-axes so zero is on top (odd). And, for the Lidar backscatter images we want the Latitudes to match the ones on the CALIPSO data page, so we want the latitude to go have the positive value on the left and negative on the right. That means we have to flip both axis to get them the way we want them. See the code below to load the Latitude and altitude files. Make sure to change the path to match where your data is stored and put this immediately after the last "end" from the previous part of the code.

```
Latitude_full = hdfread('E:\MET 611 Satellite Data Apps\ATMO611_Labs\Lab 7 CALIPSO
Aerosol Types\CALIPSO Data 2017\CAL_LID_L1-ValStage1-V3-40.2017-10-16T23-49-59ZN.hdf',
'/Latitude', 'Index', {[1  1],[1  1],[56160      1]});
Latitude_double = double(Latitude_full);    % Doubles that latitude data
Latitude = Latitude_double(15000:40000, :); % Specifies the same time/latitude range

metadata = hdfread('CAL_LID_L1-ValStage1-V3-40.2017-10-16T23-49-59ZN.hdf',...
           '/metadata', 'Fields', 'Lidar_Data_Altitudes', 'FirstRecord',1 ,...
           'NumRecords',1);         % Loads the altitude data from you file
altitudes_raw=metadata{1};          % reads the altitude information from the metadata
```

```
altitudes = double(altitudes_raw);  % Makes altitude double

image (Latitude, altitudes, out)
set(gca, 'Ydir', 'normal')  % Reverses the y-axes so zero is on the bottom
set(gca, 'Xdir', 'reverse') % Reverses the x-axes to match CALIPSO website

% Adding the colorbar
lidar_colorbar(rgb,color_bar,color_bar_labels,'vert');  % adds the color bar

% Adding a title and axes label
title({'532nm Total Attenuated Backscatter km^{-1} sr^{-1} 10-17-2017'},'FontSize',15)
xlabel('Latitude','FontSize',12)   % x axis label
ylabel('Altitude','FontSize',12)   % y axis label
```

k) Run the code again. This time you should get an image (still grainy) but with the proper axes and color bar. Save this image.

l) Save the figure to include with your lab write up. Stretch it to make it look nicer. (If you're keeping track you're up to 12 figures now)

C1 – (10 points) ON YOUR OWN→ Write CODE to Extract and Plot:

a) (5 points) Perpendicular_Attenuated_Backscatter_532 from the same 10-17-2017 file

b) (5 points) Attenuated_Backscatter_1064 from the same 10-17-2017 file

c) save both figures (to be presented with the total 532 figure in the lab, we're up to 14 figures now!)

NOTE: You can either make two new codes based on your 532 nm (code) or you can add to this current code to loade more data and plot the new figures. Your choice.

NOTE: use the same colorbar for everything.

Q2 – (10 points) CALIPSO VALIDATED DATA ANALYSIS: These questions are based on the three figures you just produces (Total Attenuated Backscatter at 532 nm, Perpendicular Attenuated Backscatter at 532 nm (PAB532) and Attenuated Backscatter at 1064 nm. Answer the following questions based on these figures:

1) (2) Starting with the 532 nm Total Attenuated Backscatter image

a) There are three different features (which represent three different types of signals… I realize these images are grainy and it is difficult to identify them, try your best). What are the approximate latitudes (start-finish) for each?

b) What are the approximate altitudes (top-bottom) of these features occur?

2) (1) Next looking at the 532 nm Perpendicular Attenuated Backscatter. Which features are still enhanced in the Perpendicular? Which are not?

3) (1) Finally, look at the 1064 nm Attenuated Backscatter. Which features are enhanced at this wavelength? Which are not (realizing this is very grainy, do your best)?

4) (6) Based on the above information (where we see enhanced signals) what information do we now have on each of the three features? Refer to the table from Lecture 8 and Lecture 13 "Lidar Signal Interpretation.

a) Which feature(s) are likely due to spherical fine particles? Based on this information what do you think the spherical fine features represent?

b) Which features(s) are likely due to non-spherical coarse particles? Based on this information what do you think the non-spherical coarse features represent?

c) Which features(s) are likely due to non-spherical fine particles? Based on this information what do you think the non-spherical fine particles represent?

4) Vertical Feature Mask and Subtype Comparison with Validated Backscatter Plots

Using the same method that you did in part 1 find the expedited image files for the closest time period to the above Validated Data (10/17/2017 at 00:00). Once you find this .tar file open it up and find the Vertical Feature Mask and Subtype images for the first part of the orbit. Include these images with the lab (we're up to 16 figures now).

Q3 – (8 points) Comparison between your Validated Data plots and the Vertical Feature Mask and Aerosol Subplot

1) (3 pts) Looking at the VFM Plot

a) What are the two main feature types you see in the plot?

b) Which feature type is found highest in the atmosphere? Lowest?

c) Does this match your assessment from Q3?

2) (3 pts) Looking at the Aerosol Subtype Plot:

a) Which two types of aerosol are most prominent?

b) Does this match your assessment from Q3?

c) What other aerosol types are identified?

3) (2 pts) Using your knowledge of the orbit path (where it traveled over the globe) justify the aerosol types determined by the Subtype algorithm as a function of latitude.

4 LAB REPORT WRITE UP - Provide the following in digital format by Tuesday, December 17th, 2017:

1) (2 points) – A brief summary/conclusion of the labs main goal.
2) (14 points) – Coding question C1 and Figures

Figures:
a) Thumbail Image of the Full Orbit for 10/17/2017 01:30
b) Magenta Orbit 1 – 532 nm Total Attenuated Backscatter for 10/17/2017 01:30
c) Magenta Orbit 1 – 532 nm Perpendicular Attenuated Backscatter for 10/17/2017 01:30
d) Magenta Orbit 1 – 1064 nm Attenuated Backscatter for 10/17/2017 01:30
e) Magenta Orbit 1 – Vertical Feature Mask for 10/17/2017 01:30
f) Magenta Orbit 1 – Aerosol Subtype for 10/17/2017 01:30
g) Blue Orbit 2 – 532 nm Total Attenuated Backscatter for 10/17/2017 01:30
h) Blue Orbit 2 – 532 nm Perpendicular Attenuated Backscatter for 10/17/2017 01:30
i) Blue Orbit 2 – 1064 nm Attenuated Backscatter for 10/17/2017 01:30
j) Blue Orbit 2 – Vertical Feature Mask for 10/17/2017 01:30
k) Blue Orbit 2 – Aerosol Subtype for 10/17/2017 01:30
l) 532 nm Attenuated Backscatter for Validated Data 10/17/2017
m) 532 nm Perpendicular Attenuated Backscatter for Validated Data 10/17/2017
n) 1064 Attenuated Backscatter for Validated Data 10/17/2017
o) Expedited Image (Magenta Orbit 1) – Vertical Feature Mask for 10/17/2017 00:00
p) Expedited Image (Magenta Orbit 1) – Aerosol Subtype for 10/17/2017 00:00

NOTE: you can make these multi-panel figures in Word or whatever word processing software you're using. You do not need to make the multi-panel figures in Matlab.

3) (33 points) – Science/Interpretation Question Q1, Q2, and Q3
4) (1 point) – emailing code