Calitoo Aerosol Data Show Some Correlation to Satellite Data from MODIS and LIDAR

Abstract

An aerosol is a suspension of fine solid particles or liquid droplets in the air or in another gas. Aerosols are always around. They have an impact on both weather and climate. They can also affect the health of living things. There are several types of instrument that measure Aerosol Optical Thickness/Depth (AOT/AOD). Junior scientists can use a hand-held instrument called a Calitoo. The Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations, better known as "CALIPSO", is an amazing satellite that offers a "3-D perspective on earth's clouds and aerosols that will answer questions about how they form, evolve, and affect our weather, climate, water supply, and air quality" (Dunbar 12). Another satellite instrument found on the Terra and Aqua satellites that measures AOT/AOD is MODIS. The Moderate Resolution Imaging Spectroradiometer (MODIS) measures 36 spectral bands, which include, blue, green, and red bands. These were the bands that were used to measure AOT/AOD data with the Calitoo. Our research question was "What is the correlation between AOT/AOD data taken with the Calitoo and the data from Terra's and Aqua's MODIS and CALIPSO's LIDAR?" To answer this question, our research team asked for assistance from NASA personnel, Dr. Margaret Pippin, Scientist Angela Rizzi and Scientist Marile Colon Robles. Based on the scientists' suggestions, NASA WorldView and NASA IDEA were used to extract MODIS and LIDAR data. Results of a correlation were mixed depending on which satellite instrument and which visualization tool were used. A suggestion for future research would be to concentrate only on MODIS data, take the Calitoo readings over a longer period of time, or collaborate with schools around the world and use CALIPSO data to compare AOT and type of aerosols in various locations.

Key words: #satellites, #aerosols, #CALIPSO, #Calitoo, #MODIS, #GLOBE research

Research Question

"What is the correlation between AOT/AOD data taken with the Calitoo and the data from Terra's and Aqua's MODIS and CALIPSO's LIDAR?"

The research question is of scientific interest because it is always good to know that the instruments on a satellite are accurate and the scientists on the ground are also accurate. It also is of value to scientists knowing how different instruments look at the same topic in different ways. The topic of "aerosols," as a whole, is important because aerosols in the atmosphere affect the sun's rays entering Earth's system. Depending on the type of aerosol, energy from the sun can be blocked from hitting Earth's surface or trapped and not able to radiate back into space.

Introduction

Aerosols, both good and bad, are always around people. They can have a huge impact on people's everyday lives. Both man-made and natural, some aerosols can harm humans. For example, smoke can cause respiratory health issues, especially in the young and old. Volcanic ash can cause flying aircraft to malfunction. If aerosols fill the atmosphere, they could eventually block the sun's rays from entering the Earth's atmosphere or trap heat energy in the atmosphere (Przyborski, 2010). The general public should realize how many aerosols are anthropogenic. This means that many of the aerosols have been released into the atmosphere by human activities.

Luckily, scientists have realized the need to monitor aerosols in the atmosphere. CALIPSO's mission is to "Study how clouds and aerosols play a role in regulating Earth's weather, climate and air quality" (Lorentz, 2011). CALIPSO, Cloud Aerosol-Lidar and Infrared Pathfinder Satellite Observations recently left the "A-Train" satellites and joined the "C-Train" satellites, along with CloudSat (Przyborski, 2012). CALIPSO is also a Satellite Partner of GLOBE. Instead of just gathering CALIPSO data, the research in this report also compared CALIPSO AOT/AOD numbers to MODIS data and data collected with a Calitoo.

Research Methods

Once a research question was finalized, a list of "What we know…" and "What we need to know…" was developed. Aerosols was a beginning point for research, then narrowed the research down to how each instrument works. This would be important later when the data was starting to be analyzed. Although, originally, the research was centered on CALIPSO and the Calitoo, it was soon realized that the LIDAR on CALIPSO measured aerosols differently (active remote sensing) than the Calitoo did (passive). Still, we wanted to find out if any correlation existed. To help make the research more worthwhile, aerosol data was also collected from MODIS (another passive instrument).

The Calitoo data was taken at Medford Memorial Middle School, Medford, NJ. (39.888458° latitude and -74.825242° longitude). The specific spot was on a sidewalk/driveway in the back of the school by an open field. Readings were taken over a six-week period during the winter. The winter weather had a huge impact on how much data was collected. During the winter in Medford, NJ, there are many cloudy days. As per the Calitoo and GLOBE guidelines, data can only be taken on sunny days when there are not any clouds obstructing the sun. The GLOBE protocols that were used were the Aerosol Protocols to collect AOT data. In addition, the angle of the Sun was very low in the morning and late afternoon. This provided a very small window of possible observation.

The way of collecting data was to go into the field midday and have one person use the Calitoo to collect data, and another person to write the data down. The last person in the research team would input data into the GLOBE database. The data always had a reliability of at least 92% or above. This was a potential source for error since the higher the reliability, the better. The Calitoo made data collection much easier since the apparatus could calculate AOT data by itself. The overall Aerosol protocol required no calculation while collecting data. Analyzing the data required minimal calculations, only to average the data for each different wavelength on each different day.

Figure 1. Medford Memorial Middle School (aerial view). The field in the lower part of the image, is the field where data was taken. (Google Maps, accessed 3/20/19)

Figure 2. Sidewalk/driveway where scientists stood to take AOT data with the Calitoo.
(Photo: Jessica Chernoff 2019)

Figure 3. Another angle of the spot were AOT data was taken.
(Photo: Jessica Chernoff 2019)

Figure 4. Jess and Mac taking Calitoo measurements.
(Photo: James Moriarty 2019)

Via collaboration with Dr. Margaret Pippin, Scientist Angela Rizzi and Scientist Marile Colon Robles, all from NASA Langley, it was suggested to first use visualization data from NASA Worldview. Unfortunately, Worldview did not produce the information needed. Dr. Pippin then suggested using NASA's Infusing Satellite Data into Environmental Applications, or NASA IDEA. This tool seemed better suited to finding Terra MODIS data on AOT/AOD. No calculations were required to analyze the satellite data. To collect data from the satellite sources only required use of a color key to determine the AOT data.

More work was needed to gain CALIPSO data. This information was gained from the NASA CALIPSO site. Thanks to Scientist Marile Colon Robles for allowing the use of her Power Point slides to follow the protocol for collecting the LIDAR data.

1. Click here https://www-calipso.larc.nasa.gov/products/lidar/browse_images/production/
2. Click Products then Lidar browse images
3. Click on version 3.40
4. Click on the days with data taken (blue box)
5. Orbit tracks are shown, pick closest to location
6. Nighttime is the shaded/cream colored map, daytime is white colored.
7. Choose the map with the track that moves over your location
8. There is an array of data at your fingertips!

Sample of CALIPSO data

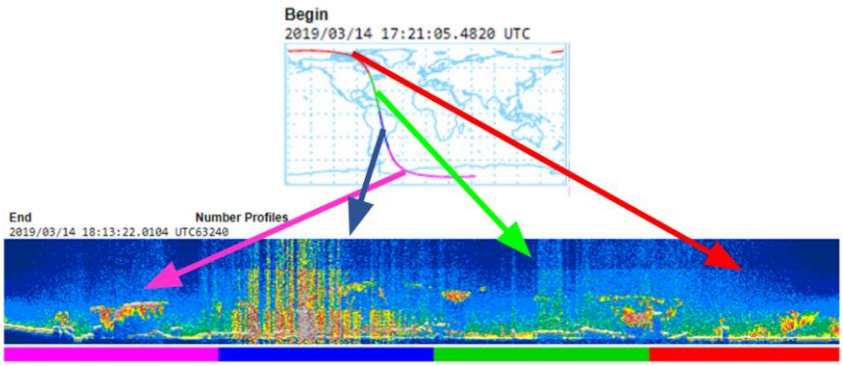


Figure 5. The CALIPSO data is showing how each different part of the orbital track is labeled a different color, and how it is separated for more accurate readings.

Results

The results show a lot of information. One of the first pieces of information that was noticed was that the Blue AOT data from the Calitoo fluctuates a lot more than the others. More importantly, there is a correlation between Calitoo data and MODIS data.

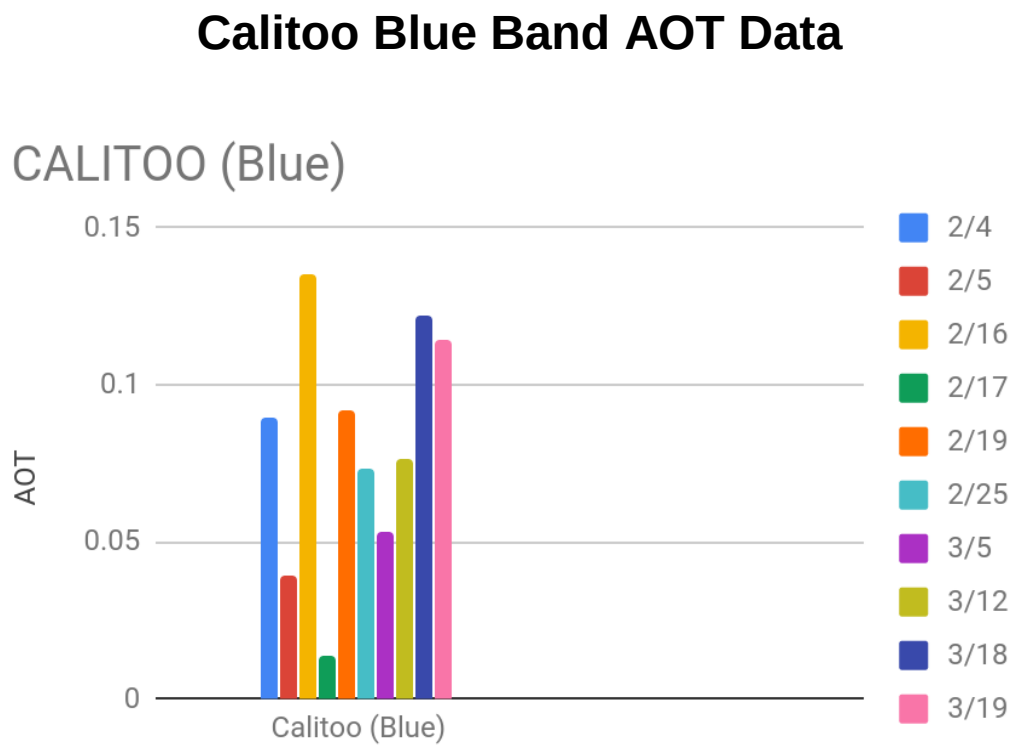


Figure 6. AOT data collected with the Calitoo specifically showing the Blue wavelength. For the Calitoo data, each trial that day was averaged which resulted in one AOT number. Most of the data falls below the 0.15 line. This data is below most of the other wavelengths because the location this data was taken is not close enough to the ocean for sea salt to have an effect on the AOT.

Calitoo Green AOT data

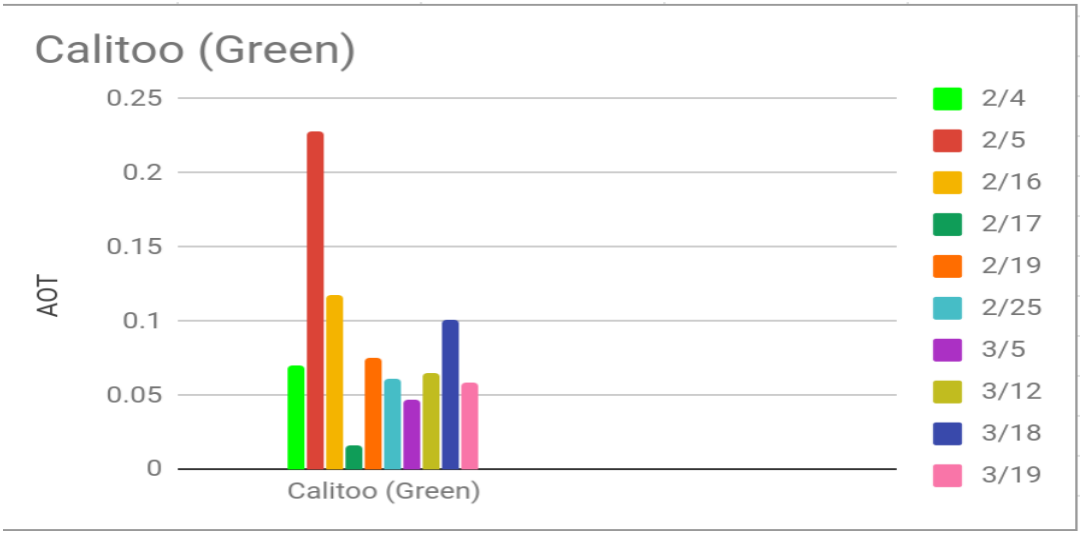


Figure 7. This is Calitoo AOT data taken from the green wavelength. Each day, trials were averaged resulting in one AOT number for each day. All of the data is relatively close together. Except for one outlier, it is unsure why.

Calitoo Red AOT data

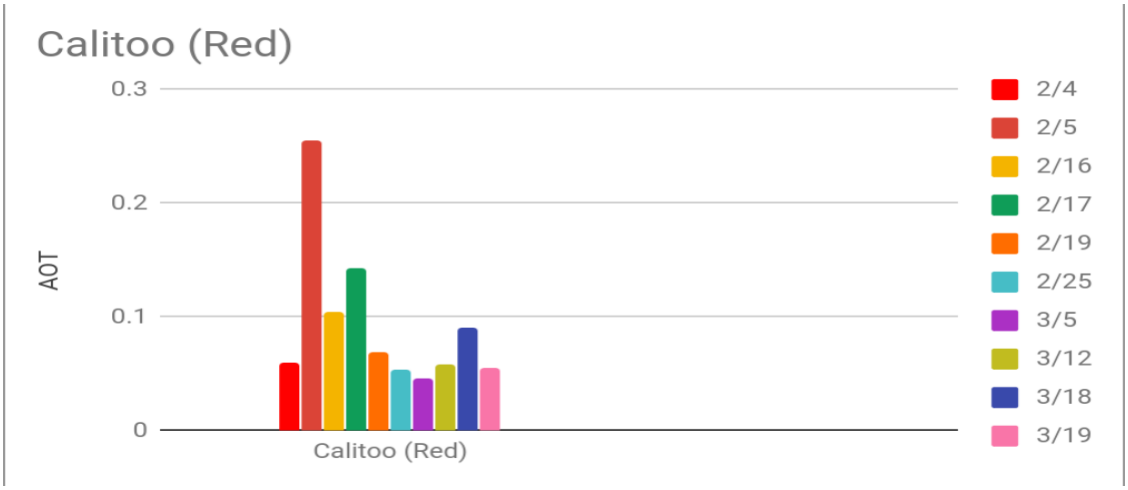
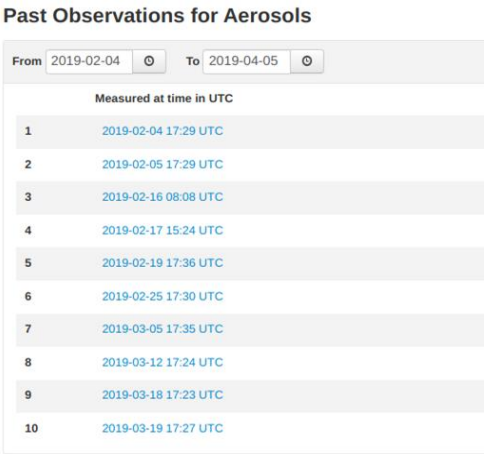


Figure 8. Red AOT data: AOT data collected with the Calitoo, specifically the Red wavelength. Each day the data was averaged resulting in one AOT number. All of the data is very similar except for one date, it is unclear why this is; however, the Green data showed a similar anomaly on that date.

MODIS TERRA data/Calitoo AOT data.

Date	MODIS TERRA (from NASA IDEA)	Calitoo
2/4	0.0-0.1	0.0732
2/5	No data	0.1743
2/16	0.1-0.2	0.1193
2/17	No data	0.0577
2/19	0.0-0.1	0.0788
2/25	No data	0.0628
3/5	No data	0.0484
3/12	0.0-0.1	0.2949
3/18	0.1-0.15	0.1045
3/19	0.0-0.05	0.0764

Figure 9. This Calitoo AOT data has been averaged to compare to MODIS TERRA data taken from NASA IDEA. This is how we noticed a correlation, and all but two days correlated; those two days were outside of the range.



Past Observations for Aerosols

From 2019-02-04 To 2019-04-05

	Measured at time in UTC
1	2019-02-04 17:29 UTC
2	2019-02-05 17:29 UTC
3	2019-02-16 08:08 UTC
4	2019-02-17 15:24 UTC
5	2019-02-19 17:36 UTC
6	2019-02-25 17:30 UTC
7	2019-03-05 17:35 UTC
8	2019-03-12 17:24 UTC
9	2019-03-18 17:23 UTC
10	2019-03-19 17:27 UTC

Figure 10. This is the data entry sheet from GLOBE. There are ten data entries. There are so few entries because data can only be taken on days when there are no clouds obstructing the sun.

Globe Visualization Page

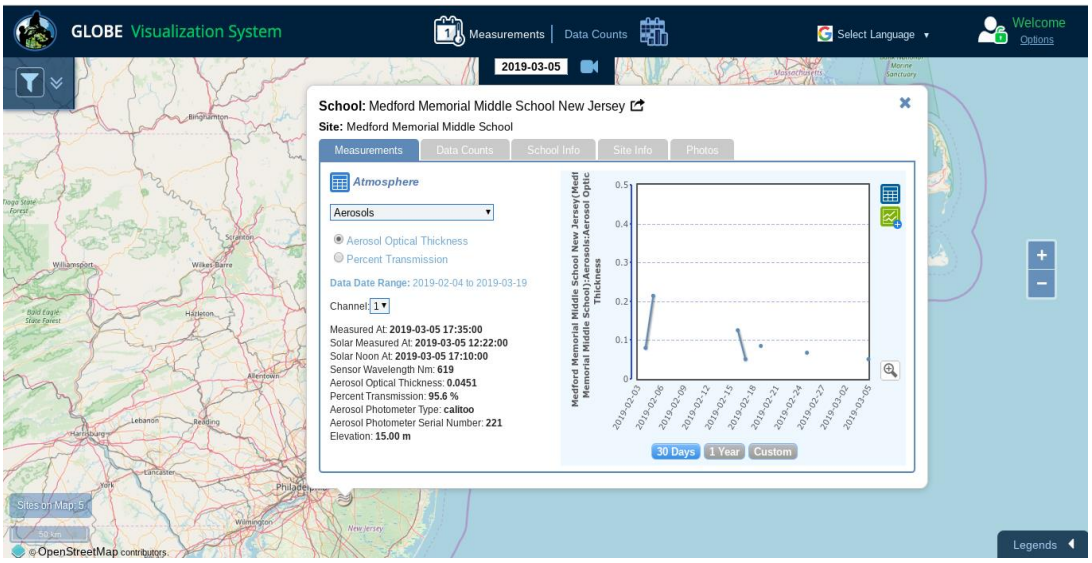


Figure 11. This is a screenshot (in the Globe Visualization Page) of data taken on March 5th, 2019.

Discussion

The results are interpreted as mixed. This is because some of the sources showed correlation while others did not. Identifying a correlation with CALIPSO data is difficult. The data found

can only be used if the satellite track was within 10 km of Medford Memorial Middle School. And to take Calitoo data, there had to be a sunny day with no clouds obstructing the sun.

There are other sources of error, as well. One possible error is human error while taking data with the Calitoo. Another problem is lack of data entries. There was a limited amount of days to take data because of cloud cover. Another issue is the way the Calitoo takes data. It is different from the way CALIPSO takes data. CALIPSO uses a laser that shoots out energy and based on how much energy is reflected back to the satellite, the scientists can tell how much and what type of aerosols are in the air. The Calitoo takes data through a column of air. The Calitoo takes the data as a whole, not from a specific spot in the air like CALIPSO. This is why a correlation was never found between CALIPSO data and Calitoo data.

Using MODIS data was much better for the research. MODIS measures the energy coming from the aerosols. It is a passive remote sensing instrument. MODIS uses 3 different spatial resolutions -- different level of detail (Lindsey, 3). Theoretically, MODIS is the same as the Calitoo, but takes a larger swath of data. A further reason why MODIS was better is because MODIS and Calitoo data were direct AOT numbers, while CALIPSO took into account the different types of aerosols. The research question was only somewhat answered since CALIPSO data can't really be compared to Calitoo data. This is a point worth noting for other junior scientists who wish to compare ground measurements to satellite measurements. But a correlation was found between MODIS Terra data from NASA IDEA and the Calitoo data that was taken.

Future research could have multiple schools collaborating and comparing Calitoo data from their regions. Another interesting project would be to gather CALIPSO data, partner with other schools, and analyze the backward trajectory of aerosols to discover how aerosols move in the atmosphere and affect the climate/weather. Overall, even if the research question cannot be fully answered, the correlation is still somewhat there. Also, learning how much more CALIPSO can do is more important in the broad scope of our research.

Conclusion

The conclusion was reached through extensive research, specifically when data was analyzed from NASA WorldView, NASA IDEA and CALIPSO data. There was no correlation between Calitoo data and CALIPSO data. However, there was some correlation between MODIS data and Calitoo data. Almost always, except for one outlier, (February 5th) red data taken was close to blue data taken, while green was always higher than both. The ideas were correct because blue (sea/coast) aerosols were less than green and red aerosols, because Medford is not near the beach. It was also learned that aerosols at each wavelength don't necessarily compare to each other. More research that should be added is more ways to collect satellite data and to find alternatives for the GLOBE student to collect AOT data. Another way other research could be added is by expanding the whole GLOBE Aerosols program in total. After talking with NASA scientists, the research group realized there were so many bigger things to do with AOT data. Imagine this, a group of students from across the globe studying CALIPSO data to get a worldwide view of aerosols.

Badges

- Be a **Collaborator**
  - Jessica Chernoff, Macary George, and James Moriarty (CSEP group) all collaborated with another Aerosol Research Team from their school. Data was taken separately, and this allowed for more accurate results, so that data could also be compared to ensure accuracy and precision.
- Be a **Data Scientist**
  - To answer the research question, "What is the correlation between AOT/AOD data that was taken with the Calitoo compared to the data from MODIS and CALIPSO?" data was taken with the Calitoo and plugged into the GLOBE site. Then, bar graphs were made with the data in Google Sheets; between Calitoo data and CALIPSO/MODIS data. Limitations of the data, and made inferences about past, present, or future events were included in the report. Data from NASA IDEA and NASA WorldView

were used to help answer the research question. Multiple data sets were used to answer our research question.

- Be a **STEM Professional**
  - With the great help of Dr. Margaret Pippin from the Langley Research Center, access to CALIPSO data became available. The CSEP group was also very lucky to have the opportunity to ask her multiple questions about the research. This enhanced research methods, since Dr. Pippin gave advice to look at many websites. This led to improved analysis of data taken; it allowed for more accurate results. Also, Dr. Pippin allowed the group to have a more sophisticated analyses, because this allowed to compare Calitoo data with CALIPSO/MODIS data.

Additional Note: Controlled Fire in New Jersey

Recently, after Calitoo data had been taken by the research group, a controlled fire in the early hours on 3/13/19 happened in over seven counties across NJ. This research group wanted to see the effects on AOT data taken by MODIS and CALIPSO. Here is what was found.

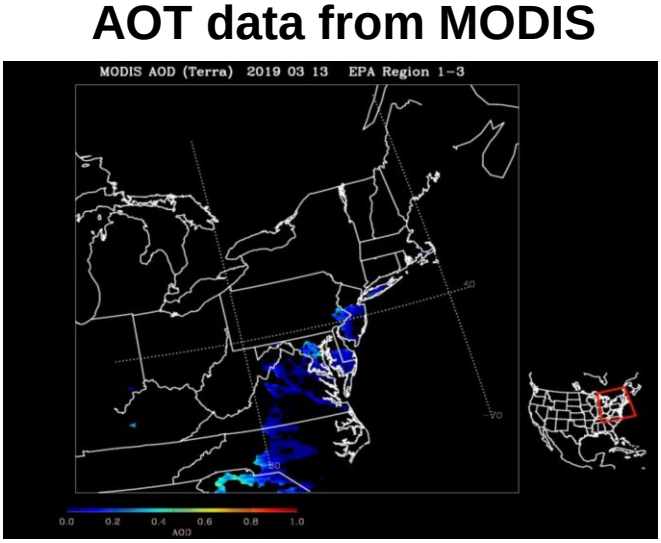


Figure 12. This is AOT data taken by MODIS on 3/13/19. As seen on the PA/NJ line, there is a huge jump that reaches up to 0.4. The data that is normally collected is similar to the dark blue. (0.0-0.2)

Significantly higher AOT data was found along the NJ/PA border; the AOT taken by MODIS reaches up to 0.2-0.4 range. CALIPSO had a track that was close enough to the area on the days just after the fire. There was a significant amount of attenuation, (an extensive amount of thin material clumped together in one area) which creates a higher AOT data. This jump in data shows how much of an effect controlled fires have on the aerosols that people breathe.

CALIPSO Vertical Feature Mask from 3/20

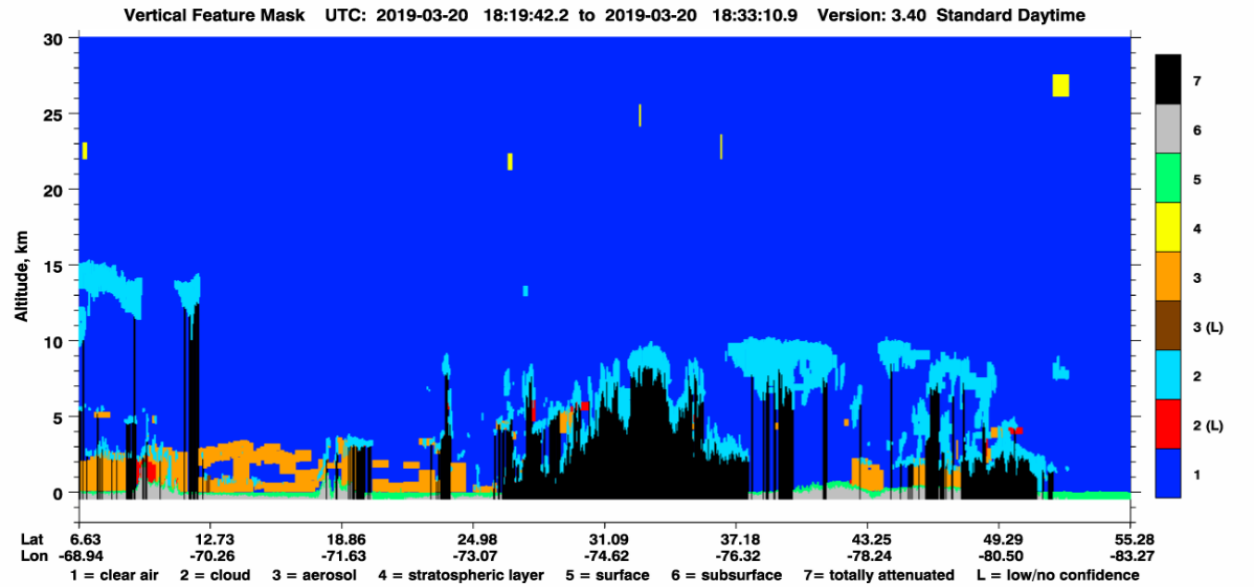


Figure 13. This is CALIPSO data from 3/20/19, assuming that the aerosols from the controlled burn moved. It makes sense that attenuated aerosols fill the air where the controlled burn air would have moved based on wind directions.

Bibliography

Dunbar, B. (n.d.). CALIPSO Mission Overview. Retrieved March/April, 2019, from https://www.nasa.gov/mission_pages/calipso/mission/

Dunbar, B. (n.d.). MISSION NEWS. Retrieved March/April, 2019, from https://www.nasa.gov/mission_pages/calipso/news/index.html

Kahn, R. A., & Gaitley, B. J. (2015, May 14). An analysis of global aerosol type as retrieved by MISR. Retrieved March/April, 2019, from https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2015JD023322

Liu, B., Ma, Y., Gong, W., Zhang, M., Wang, W., & Shi, Y. (2018, July 03). Comparison of AOD from CALIPSO, MODIS, and Sun Photometer under Different Conditions over Central China. Retrieved from https://www.nature.com/articles/s41598-018-28417-7

Maccachernone, B. (n.d.). MODIS DATA. Retrieved from https://modis.gsfc.nasa.gov/data/

Przyborski, P. (2010, November 10). Aerosols: Tiny Particles, Big Impact. Retrieved March/April, 2019, from https://earthobservatory.nasa.gov/features/Aerosols/page3.php

Przyborski, P. (2012, June 5). A-Train. Retrieved March/April, 2019, from https://atrain.nasa.gov/

Przyborski, P. (2012, November 04). Aerosols: Tiny Particles, Big Impact. Retrieved March/April, 2019, from https://earthobservatory.nasa.gov/features/Aerosols/page3.php

Przyborski, P. (n.d.). Remote Sensing. Retrieved April, from

https://earthobservatory.nasa.gov/features/RemoteSensing/remote_08.php

Sea- Salt Aerosols. (n.d.). Retrieved from http://magde.info/main/texts/PhD/Chap2.PDF