Comparing Aerosols and Surface Temperature

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Abstract

Air quality has an effect on many things, possibly even surface temperature. Aerosols are a suspension of tiny particles floating in the atmosphere that can come from many sources. Certain types can scatter and absorb sunlight, affecting climate and temperature. Surface temperature is the temperature at or near a surface. The goal of this project is to better understand the relationship between aerosols and surface temperature. The independent variable is the time, the dependent variables are aerosols and surface temperature, and the controlled variables are the time of day and the method in collecting the data. Aerosol measurements were measured with a sun photometer when the sun was not cloud covered. Surface temperature was measured using an IR thermometer directly after the aerosols. The hypothesis states, if the surface temperature is warmer, then there will be higher levels of AOT, because the aerosols soak up the sun's radiation waves and reflect it on the surface causing higher surface temperatures. The results showed that when the surface temperature was high, the amount of aerosols were lower. The data did not support the hypothesis. The revised hypothesis states if the surface temperature is warmer, then there will be higher levels of AOT, because the aerosols soak up the sun's radiation waves and reflect it on the surface causing higher surface temperatures. This project is important to the real world because aerosols and increased surface temperature are causing many problems for humans and the environment.

Keywords: aerosols, surface temperature, atmosphere

Comparing Aerosols and Surface Temperature

Research Question and Hypothesis

This experiment is designed to answer the question, what is the relationship between aerosols and surface temperature? The independent variable is the time. The dependent variables measured are aerosol optical thickness and surface temperature measured in Celsius. The controls for this experiment are the time of day and following GLOBE protocols. The hypothesis states, if the surface temperature is warmer, then there will be higher levels of AOT, because the aerosols soak up the sun's radiation waves and reflect it on the surface causing higher surface temperatures.

Introduction and Research

The atmosphere is made up of tiny particles floating in the air called aerosols. AOT stands for aerosol optical thickness. AOT is a measure of how aerosols affect the sunlight that reaches earth. "These tiny objects are made up of molecules of gas and small solid and liquid particles suspended in the air" (Gelber, p. 25). Aerosols develop from human activity and travel on wind and water. They develop in both the troposphere and the stratosphere. While in the stratosphere, aerosols may last for several years. In the troposphere, they may only last for a few days. Aerosols have an impact on the air and climate because they determine the amount of sunlight that comes to earth. Climate is a representation of how the atmosphere and landscape undergo different weather patterns over time (Gelber, p.1). Scientists collect aerosol measurements to study and predict the climate and to better understand the atmosphere (GLOBE, 2014).

Clouds play a big part in the atmosphere and affect temperature and balance. They cover over two thirds of the earth and there are over a hundred variations (Oman, p.57). NASA has placed satellites that collect data about clouds and energy (GLOBE, 2014). Clouds are held up by vertical currents of air until the droplets inside get too heavy and fall back to earth (Oman, p.59). “A cloud is a visible mass of water droplets or ice crystals suspended in the atmosphere above the earth” (Ruth, p.17). Ruth stated, “the water molecules in clouds scatter all wavelengths of visible sunlight equally” (p.44). Most clouds dwell in a range of 6 meters above the ground. Noctilucent clouds are made up of ice crystals and are visible at night because they have escaped the earth’s shadows (Oman, p.64).

Aerosols have big effects on clouds and precipitation. Aerosols decrease precipitation because the particles make the size of water droplets in clouds smaller. Aerosols can also lead to taller clouds which can produce more lightning and stronger rain. Different kinds of aerosols have different effects on clouds such as reflective aerosols, which can brighten clouds and make them last longer (Przyborski, 2010). An aerosol’s effect on light depends mostly on the color and composition of the particles. Bright colored particles tend to reflect light back to the clouds and make them brighter and longer lasting. Darker aerosols tend to absorb more light. These are called reflective aerosols (GLOBE, 2014). These aerosols seem like they should impact surface temperature.

The GLOBE current temperature is a measure of temperature, humidity, wind speed, sun angle, and cloud cover put together (GLOBE, 2014). This is important because each of these aspects relate to aerosols in some way. It relates to aerosols because the amount of aerosols in the atmosphere depends on the sun and how many clouds are in the sky. The temperature is a major part of aerosols because if it is warm or cold, that will determine the amount of aerosols in the atmosphere (GLOBE, 2014).

Surface temperature is the temperature of the land surface. It is determined by how long the sun has been warming the surface or how long it has been cloudy. Heat waves in Pennsylvania are common at least once or twice a year (Gelber, p.97). To measure surface temperature, an IRT (infrared thermometer) needs to be used. Relative humidity is the amount of water vapor present in the atmosphere. It relates to aerosols because the amount of water vapor depends on the amount of aerosols in the atmosphere. To measure relative humidity a sling psychrometer or digital hydrometer is required.

The ocean and atmosphere work together and are connected to move fresh water and heat across the globe. The ocean can store more heat than the land surface. Most of the earth's energy is stored in the ocean. Ocean currents are a major part of how heat gets to the poles. The amount of heat transferred to the poles affects different weather patterns and the amount of sunlight that reaches the surface. The temperature in the atmosphere depends on how much energy is absorbed into the atmosphere (NOAA, 2014). Aerosols in the atmosphere absorb the sunlight's energy and scatter sunlight radiation affecting the amount of sunlight that reaches the surface (GLOBE, 2014).

There are many things floating around in the atmosphere, but oxygen and nitrogen are the two most important elements (Walker, pg. 57). The entire atmosphere is connected by constant collisions of air molecules (Walker, pg.21). Air molecules do not scatter sunlight equally, causing the sky to be blue (Ruth, pg.48). Sunlight moves in invisible waves and is white (Ruth, pg.52). Sunlight is a type of energy called electromagnetic radiation (Ruth, pg.47). Warm air soaks up water vapor from the ocean. Carbon dioxide and water keep humans alive in the atmosphere (Walker, pg.76). This is important because the energy from the sun affects the amount of aerosols present in the atmosphere and the temperature of the land surface. Things such as carbon dioxide and water play an important part in the atmosphere because they are elements that most living things need to stay alive.

Materials and Methods

Materials

- Calibrated and aligned GLOBE sun photometer (Calitoo)
- Digital Voltmeter
- Watch
- Thermometer
- Hygrometer of Sling psychrometer (eisco)
- GLOBE cloud sheet
- Barometer (H-B instrument barometer)
- Aerosols Data Sheet
- Hand-held Infrared Thermometer (IRT) (SPER Scientific 800103)
- Thermal Glove
- Data sheets
- Logbook
- Pen
- Chromebook
- Bottle of water

Methods

Aerosols

1. Turn the sun photometer on.

2. Face the sun and point the sun photometer at the sun. (Do not look directly at the sun!)

3. Adjust the pointing until the maximum voltage appears in the digital voltmeter. Record this value on the Data Sheet.

4. Record the time when the maximum voltage was observed as accurately as possible, to the nearest 15 seconds.

5. Repeat steps 3-9 at least twice and not more than four times.

6. Turn off both the sun photometer.

7. Note any clouds in the vicinity of the sun in the comments (metadata) section. Be sure to note the types of clouds by using the GLOBE Cloud Chart.

8. Do the Cloud Protocols and record observations on the Aerosols Data Sheet.

9. Do the Relative Humidity Protocol and record the observations on the Aerosols Data Sheet.

a) Stand far enough away from other people and the instrument shelter in order to not hit them with the psychrometer. Stand in the shade if possible with back to the sun. If there is no shade near the shelter, move to a shady spot nearby, but not too close to trees or buildings.

b) Keep the sling psychrometer as far away as possible from the body to prevent body heat from changing the temperature readings. This is very important in cold weather. Do not touch or breathe on the temperature-sensing parts of the thermometer as this, too, may affect the reading.

c) Open the sling psychrometer case by pulling out the slider, which contains the two thermometers.

d) Wait three minutes to allow the thermometer to read the current air temperature and then read the current dry bulb temperature to 0.5˚ C using the thermometer with no wick attached. Make sure eyes are level with the instrument.

e) Record the dry bulb temperature.

f) Check to be sure that there is still distilled water in the reservoir, and that the wick is wet. If it is dry, add distilled water to the reservoir.

g) Sling the psychrometer for 3 minutes

h) Let the psychrometer stop whirling on its own! Do not stop it with hand or other object.

h) Read the wet bulb temperature to 0.5˚ C (from the thermometer with the wick attached).

i) Record the wet bulb temperature.

j) Determine the relative humidity using a psychrometric chart or the sliding scale found on the cases of some psychrometers. Can also leave this blank as GLOBE can calculate relative humidity from the wet and dry bulb temperatures.

k) When done with the instrument, close it up and return it to the shelter properly.

10. Do the Barometric Pressure Protocol and record observations on the Aerosols Data Sheet.

a) Record the time and date on the Atmosphere Data Sheet. (Skip this step if using Aerosols, Ozone, or Water Vapor Data Sheet.)

b) Tap gently on the glass cover of the aneroid barometer to stabilize the needle

c) Read the barometer to the nearest 0.1 millibar (or hectopascal)

d) Record this reading as the current pressure.

e) Set the “set needle” to the current pressure.

11. Read and record the current temperature to the nearest 0.5˚ C following one of the air

temperature protocols.

12. Complete the rest of the Aerosols Data Sheet.

Surface Temperature

1. When necessary, either wrap the IRT in a Thermal Glove before arriving at the study site or place the IRT outdoors for at least 30 minutes prior to data collection. For more details, refer to the Thermal Glove -or- Place IRT Outdoors For At Least 60 Minutes section of this protocol.

2. Complete the top section of the Surface Temperature Data Sheet

3. Take cloud observations following GLOBE Cloud Protocols.

4. If there is no snow on the ground anywhere in the Site, then check either “Wet” or “Dry” for the Site’s Overall Surface Condition field on the Surface Temperature Data Sheet.

5. Check the box that corresponds to the method used to prevent the IRT from experiencing thermal shock.

6. Pick 9 Observation Spots that are in open areas within the site and are at least 5 meters apart. The Spots should also be away from trees and buildings that create a shadow on the land and in locations that have not been recently disturbed by people or animal traffic. (Note: It is best to take readings at the 9 individual Observation Spots within seconds of each other.)

7. Go to one of the nine Observation Spots and stand so that there is no shadow on the Spot.

8. Record the Current Time and its corresponding Universal Time (UT) on the Surface Temperature Data Sheet.

9. Hold the infrared thermometer (IRT) (wrapped in a Thermal Glove when necessary) with arm extended straight out and point the instrument straight down at the ground.

Surface Temperature reading from digital display of infrared thermometer (IRT)

The above pictures show correct use of IRT, a) without a Thermal Glove and b) with Thermal Glove

10. Hold the IRT (wrapped in a Thermal Glove when necessary) as still as possible. Press and release the recording button. [Release the recording button for the instrument to register and hold the spot's surface temperature.]

11. Read and record the surface temperature from the digital display screen located on the top of the IRT. (Note: Surface Temperature is recorded in Celsius to the nearest tenth degree, ie. 25.8)

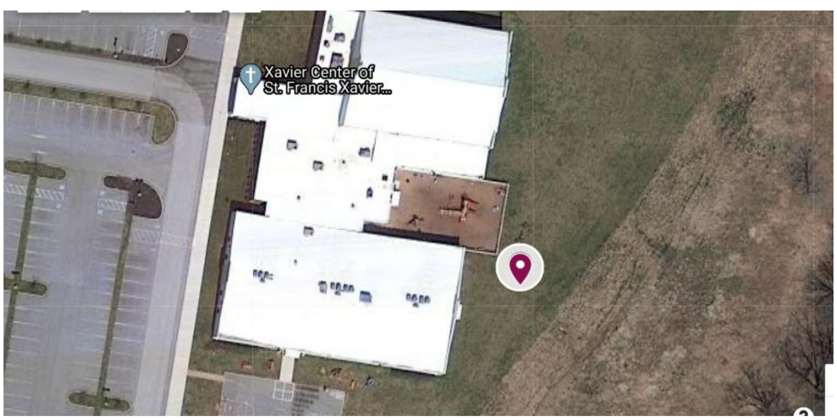
12. Measure and record the snow depth in millimeters at the Observation Spot.

13. Repeat steps 7-12 at each of the remaining eight Observation Spots.

14. Record any other information that explains the environmental conditions of the day or site in the Comments field.

Image 1

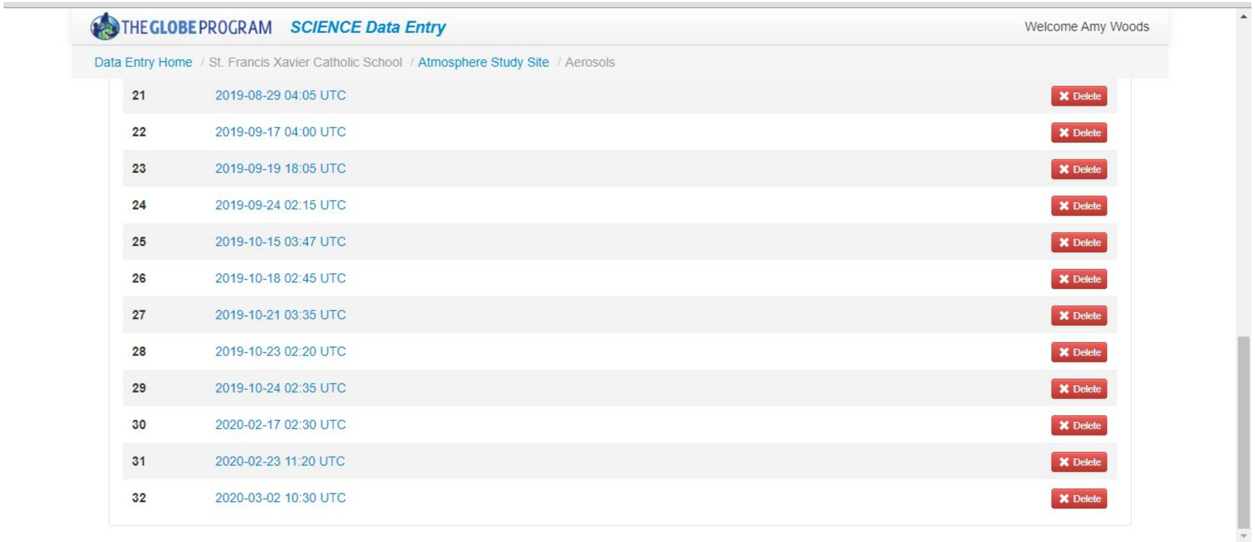
Location of Aerosol and Surface Temperature Data Collection



Note: This map marks where the data for aerosols and surface temperature was collected.

Image 2

Screenshot of Entered GLOBE Data



THE GLOBE PROGRAM SCIENCE Data Entry Welcome Amy Woods

Data Entry Home / St. Francis Xavier Catholic School / Atmosphere Study Site / Aerosols

21	2019-08-29 04:05 UTC	Delete
22	2019-09-17 04:00 UTC	Delete
23	2019-09-19 18:05 UTC	Delete
24	2019-09-24 02:15 UTC	Delete
25	2019-10-15 03:47 UTC	Delete
26	2019-10-18 02:45 UTC	Delete
27	2019-10-21 03:35 UTC	Delete
28	2019-10-23 02:20 UTC	Delete
29	2019-10-24 02:35 UTC	Delete
30	2020-02-17 02:30 UTC	Delete
31	2020-02-23 11:20 UTC	Delete
32	2020-03-02 10:30 UTC	Delete

Note. This shows a screenshot of aerosol data entered. Surface temperature data was also entered.

Results

Table 1

Averages of Aerosols

Date	Rounded Ave AOT Red	Rounded Ave AOT Green	Rounded Ave AOT Blue
29-Aug	0.148	0.121	0.108
17-Sep	0.202	0.162	0.145
19-Sep	0.204	0.185	0.187
24-Sep	0.137	0.12	0.115
10-Oct			
15-Oct	0.098	0.084	0.079
18-Oct	0.038	0.036	0.037
21-Oct	0.141	0.126	0.119
23-Oct	0.057	0.048	0.046
24-Oct	0.115	0.108	0.112
17-Feb	0.105	0.088	0.081
23-Feb	0.316	0.311	0.306
02-March	0.155	0.127	0.114

Note. This data table shows the data averages for the aerosols, there are some blank spaces because the weather/schedule did not permit for measurements to be taken that day.

Table 2

Averages of Surface Temperature

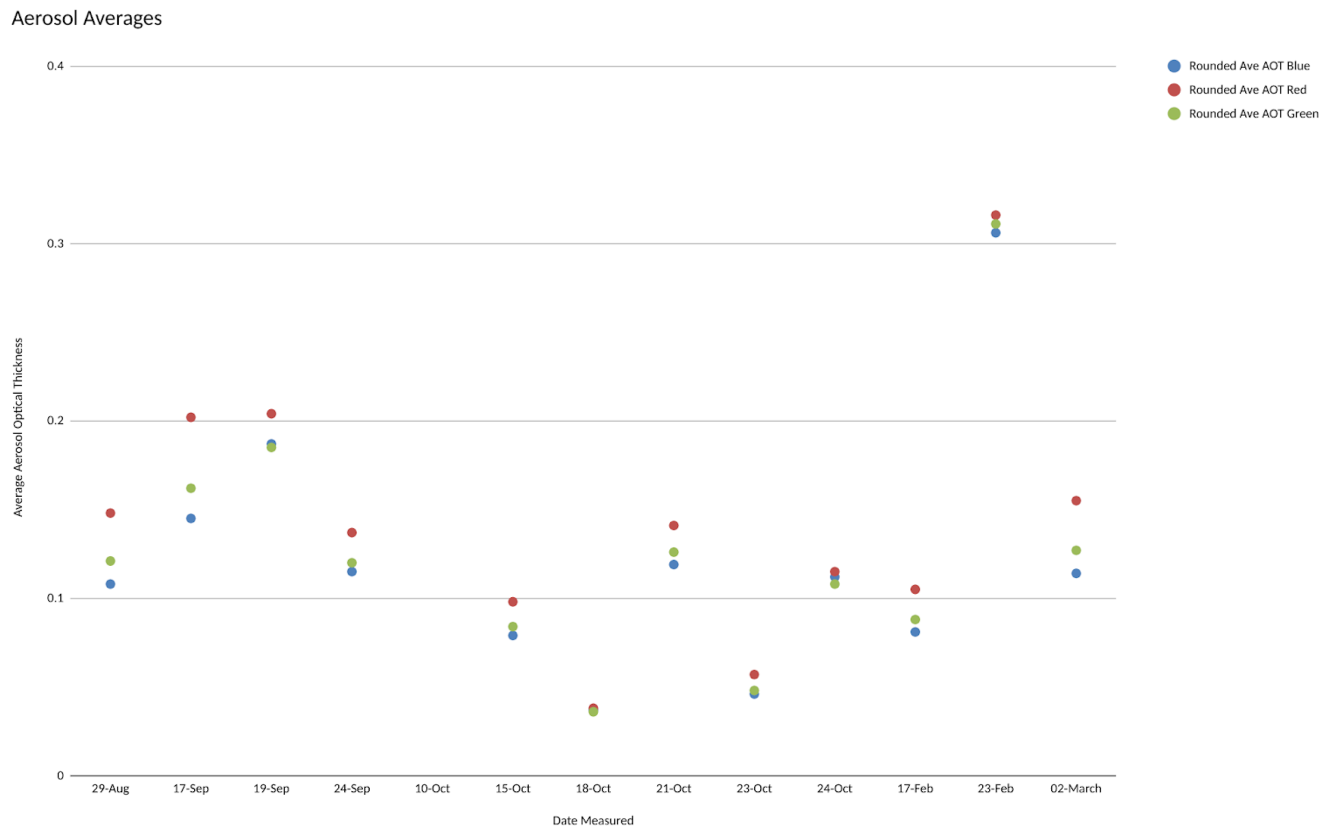
Date	Average Surface Temperature (C)
29-Aug	
17-Sep	
19-Sep	39.8
24-Sep	44
10-Oct	33.7
15-Oct	
18-Oct	19

21-Oct	24.6
23-Oct	
24-Oct	21.2
17-Feb	20.12
23-Feb	21.59
02-March	18.94

Note. This data table shows the data averages for surface temperature, the blank spaces indicate days where the weather did not permit for measurements to be taken.

Figure 1

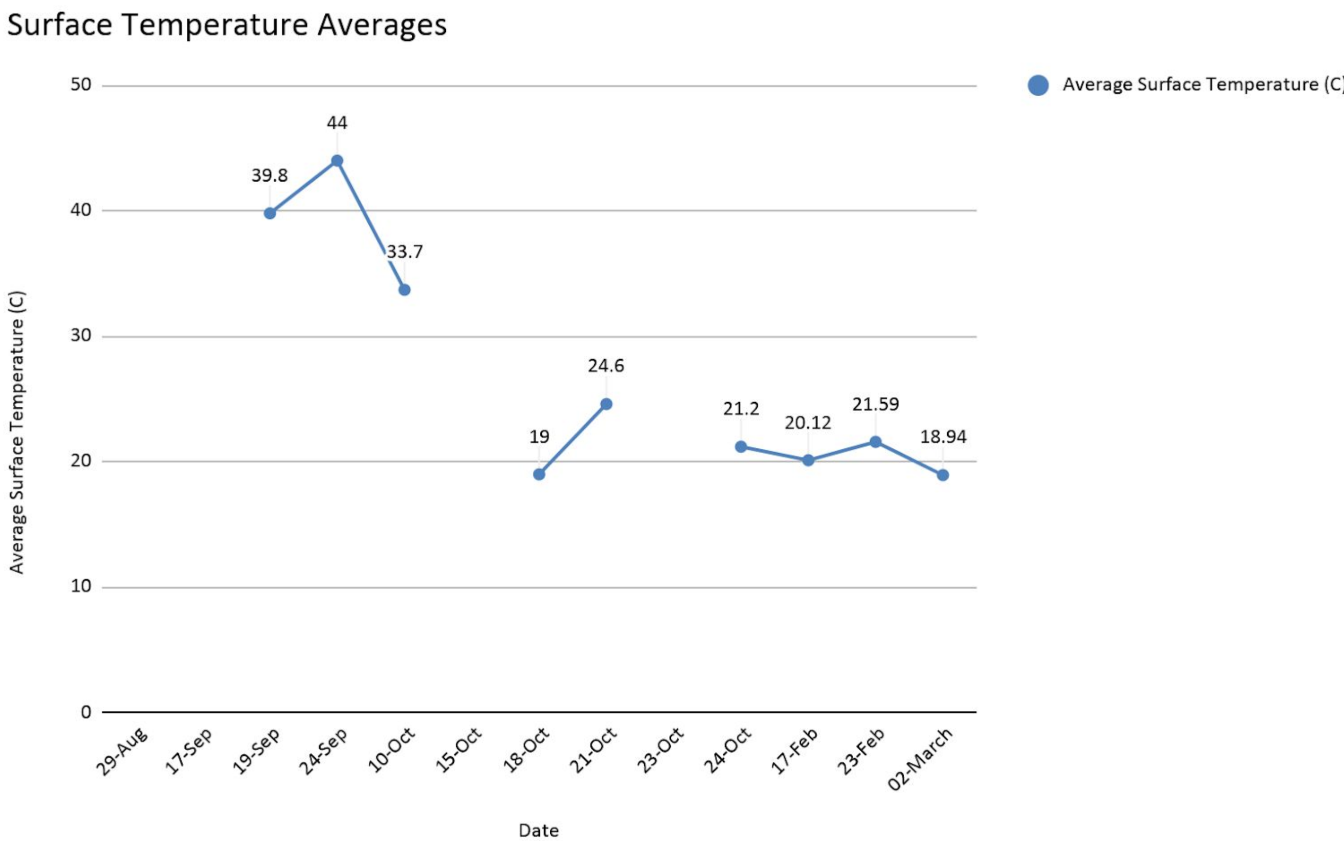
Rounded Averages of Aerosols



Note. This graph shows the rounded averages of the aerosol measurements data, the blank spaces indicate the days where the weather did not permit for measurements to be taken.

Figure 2

Rounded Averages of Surface Temperature)



Note. This graph shows the rounded averages of the surface temperature data, the blank spaces indicate the days where weather did not permit for measurements to be taken.

Discussion

The trends in the data showed that the surface temperature averages started high at 45 °C and then gradually decreased to 19 °C. However, the aerosols averages for the most part stayed together in the same range. The temperature seemed to have a significant effect on the aerosols. When the temperature was low, then there was a higher amount of aerosols. When the temperature was high, there were lower AOT values. The wind direction seemed to have no effect on the aerosols. The data was analyzed using Google Sheets.

Conclusion

The question this project focused on was what is the relationship between surface temperature and aerosols? The hypothesis states if the surface temperature is warmer, then there will be higher levels of AOT, because the aerosols soak up the sun's radiation waves and reflect it on the surface causing higher surface temperatures. The hypothesis was not supported by the data because the results were very different from the predictions. The trend in the data was that when the surface temperature increased, aerosols decreased and when surface temperature decreased, aerosols increased. This was surprising at first but then the data made it clear that the hypothesis was not supported. The revised hypothesis states if the surface temperature is warmer, then there will be lower levels of AOT, because the aerosols absorb the sun's energy and scatter it in the atmosphere preventing it from reaching the Earth's surface and warming it. There was some difficulty during the project because when the clouds were covering the sun, the aerosol measurements could not be taken. There will be a continuation of this project for future competitions. In future testing, water vapor could be added to see what effect it might have on aerosols. This project matters in the real world because there can be dangerous chemicals in aerosols from things like hairspray and air fresheners. When people breathe these in it could cause damage to the kidney, heart, and lungs. Surface temperature matters because changes in the temperature either heat or cool the air above which could lead to wind movement.

I'm a Collaborator

I feel that this badge fits me because I collaborated with a student from Gettysburg High School and we exchanged data. This data was shared for the days when one was able to collect data and the other was not.

I'm a Data Scientist

During the course of my project I collected data several times during the week when weather permitted. During this time I used a sun photometer, barometer, and a sling psychrometer to collect data and make it into data tables.

I Make An Impact

I hope that my research will have a positive impact on my community and will make people more aware of what's in our atmosphere. Most people are unaware of what they are breathing in and this could lead to serious problems in the future.

Citations

Flannery, Tim. *Atmosphere of Hope*. Australia, The Text Publishing Company, 2015.

Gelber, Ben. *The Pennsylvania Weather Book*. Ben Gelber, 2002.

GLOBE, editor. "Aerosols Protocol Field Guide." *GLOBE*, 2014, www.globe.gov/documents/348614/a557fa2d-e4cb-429a-9bd4-e049b0ab023c. Accessed 29 June 2019.

GLOBE, editor. "Relative Humidity Protocol." *GLOBE*, 2014, www.globe.gov/documents/348614/89f8c44d-4a99-494b-ba81-1853b80710b4. Accessed 2 Sept. 2019.

GLOBE, editor. "S-cool." *GLOBE*, www.globe.gov/web/s-cool. Accessed 12 July 2019.

GLOBE, editor. "Surface Temperature Protocol." *GLOBE*, 2014, www.globe.gov/documents/348614/7537c1bd-ce82-4279-8cc6-4dbe1f2cc5b5. Accessed 28 Aug. 2019.

NOAA, editor. "Energy in the Ocean and Atmosphere." *NOAA*, oceanservice.noaa.gov/education/pd/oceans_weather_climate/energy_oceans_atmosphere.html. Accessed 11 Sept. 2019.

Oman, Anne H. *Weather Nature in Motion*. National Geographic Society, 2005.

Przyborski, Paul. “Aerosols: Tiny Particles, Big Impact.” *NASA*, NASA, 2 Nov. 2010, earthobservatory.nasa.gov/features/Aerosols/page4.php.

Ruth, Maria Mudd. *A Sideways Look at Clouds*. Canada, Mountaineers Books, 2017.

Walker, Gabrielle. *An Ocean of Air*. Great Britain, Bloomsbury, 2007.