The Effects of Relative Humidity on Aerosol Cluster Sizes

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Abstract

This project focuses on the question; how do Relative Humidity levels affect aerosol cluster sizes? The hypothesis states that when Relative Humidity levels are higher, aerosol cluster sizes will be larger and when Relative Humidity levels are lower, aerosol cluster sizes will be smaller. This applies to the real world because it affects people and it can contribute to the spread of Coronavirus on a day to day basis. The Relative Humidity percentage showed the correlation predicted in the hypothesis but the rest of the data proved the opposite. Though the hypothesis was supported, a revised hypothesis was made to include what was viewed with the wet and dry bulb temperatures and it states, “when Relative Humidity levels are higher, cluster sizes will be larger, and when Relative Humidity levels are lower, cluster sizes are smaller. When the air temperature (dry bulb) was lower, the aerosol levels were higher and when the wet and dry bulb temperatures were higher, aerosol levels were lower.” This project applies to the real world because it affects people in many aspects. It shows the effects of Global Warming and how the globe is ever changing due to humans and pollution.

Keywords: relative humidity, coronavirus, aerosol optical thickness, air quality index, and aerosols

The Effects of Air Pollution on Water Quality

Question

The question this project focuses on states, How do Relative Humidity levels affect aerosol cluster sizes?

Hypothesis

The hypothesis of this project states that if Relative Humidity levels are higher, aerosol cluster sizes will be larger and when Relative Humidity levels are lower, aerosol cluster sizes will be smaller.

Clusters will be larger when the Relative Humidity is higher because with higher levels of Relative Humidity, water droplets are more abundant. Water droplets count as aerosols so with the added aerosols in the air, cluster sizes will be larger because of the particles' lack of area in which to move around. Clusters will be smaller when the Relative Humidity is lower because with lower levels of Relative Humidity, water droplets are less abundant, giving the already formed particles more area to spread out and move around in, rather than bunching up into clusters.

The independent variable of this project is the level of aerosols being collected. The dependent Variable of this project is the Relative Humidity that is being collected. The controlled variables of this project are the location of the testing, the method of testing, and the sky conditions. The controlled group of this project is non existent because the student is measuring

the weather and the perimeters of the atmosphere which depend upon atmospheric conditions and environmental factors to change in any way.

Introduction and Research

Aerosols are tiny particles in the air directly linked with the Air Quality Index (AQI). Aerosol Optical Thickness (AOT) is the measurement of urban haze, smoke particles, desert dust, sea salt, and other particles distributed within a column of air from the instrument to the top of the atmosphere. Some particles are naturally produced, like from volcanoes or sand. Most of these particles though, are human made. Human caused examples are; plastic, pesticides, hair spray, chimney smoke and soot, factory smoke, the list goes on. Aerosols are the cause for the haze that is often seen in Gettysburg and many parts of the world. The larger the particles, the less solar energy that reaches Earth's surface. AOT is measured with a sun photometer which is pointed directly at the sun. AOT is the measurement of the thickness of the amount of particles in a particular solar beam between the Earth and the sun. The largest voltage reading during the testing is recorded. They increase haze, decrease visibility, and affect air quality. Aerosols can be taken with a handmade sun photometer from Drexel University, but in most cases it is taken with a Calitoo sun photometer (NASA, 2005).

Humidity is related to aerosols because of the water droplet form it takes. Aerosols also consist of water particles so humidity plays a big role in aerosol levels. Humidity is the amount of water vapor present in the atmosphere at the time of the testing. Relative Humidity refers to this amount relative to the amount of water vapor in the atmosphere when the air is saturated. Relative

Humidity is measured using a sling psychrometer which reads a wet and dry bulb thermometer. Dry Bulb is the air temperature that is not affected by the vapor in the air which is indicated by the wet bulb. It is called "Dry Bulb" because the air temperature is indicated by a thermometer not affected by the moisture of the air (GLOBE, 2020).

Coronavirus as many know by now is spread through the contact of human droplets from the mouth. This directly ties into Relative Humidity (being water vapor) and aerosols as well. Coronavirus are a type of virus that makes up several different strands of illnesses. The newest and most profound one as of lately is SARS-CoV-2 also known as Covid-19. This strand of the virus has sparked a global pandemic that has been raging since late November/beginning of December of 2019. This pandemic has since killed 1.89 million people and infected 87.4 million people worldwide, with America leading in both categories. Coronavirus mainly affects the respiratory system which has helped its deadly contagiousness (hopkinsmedicine, 2020).

Covid-19 spreads via water droplets and becomes vapor in the air which travels to its next unlucky victim. With the possible correlation between Relative Humidity and aerosols, predictions as to how well the virus is transmitted on very humid days compared to a non humid day can begin. This project is important not just to the US, but the entire world because it can effectively help predict when the Coronavirus is the easiest to transmit amongst people. It can help warn people when they are at a higher risk of getting the virus, masked or not.

This experiment is designed to test the question, “How do Relative Humidity levels affect aerosol cluster sizes?” The independent variable of this project is the level of aerosols being collected. The dependent variable of this project is the Relative Humidity that is being collected. The controlled variables of this project are the location of the testing, the method of testing, and

the sky conditions. The controlled group of this project is non existent because the student is measuring the weather and atmosphere perimeters which depend upon atmospheric conditions and environmental factors to change in any way. The hypothesis of this project states that if Relative Humidity levels are higher, aerosol cluster sizes will be larger and when Relative Humidity levels are lower, aerosol cluster sizes will be smaller.

Image 1

Location of the Aerosol and Relative Humidity test collection site.

Note: This image shows the location of the testing, the student's driveway. The site is made up of rocks and surrounded on both sides by grass followed by a stream and trees. Runoff is uncommon and no farms or other sources of pollution are near the testing site. There is a house on either side of the location, but they are located more than 100 feet away. The location experiences a humid

continental climate whose harshness is reduced thanks to the tree canopy. The coordinates of the testing site are 39.8953665,-77.4334124.

Materials

- 1 Calitoo [cnes and Tenum]
- 1 Sling Psychrometer [eisco]
- 1 Logbook
- 1 Pen
- Water
- Psychrometric Chart

Procedures

To test the hypothesis, measurements were taken whenever the sky was permitting at the testing location. Measurements were collected in front of the student's house located in the woods near a stream. There were a total of 8 dates of collection, with five measurements taken for the aerosols and one measurement taken for the Relative Humidity. The following are the steps that were taken to carry out the experiment. Data collection was dependent on the sun because aerosols cannot be measured if there are clouds blocking the sun, and it is not possible to determine if the measurement is reflecting the cloud particles or actual aerosols.

1. Remove tools from the storage area in the house.
2. Walk to the middle of the driveway located in an area near some trees and a stream.
3. Set tools down.
4. Record date, time, and name on the data sheet.
5. If clouds are permitting (not blocking the sun) remove aerosol Calitoo from supplies and take data. Line the instrument up with the sun so that the sun spot is in the target area.

Before use, allow the Calitoo to connect to nearby satellites. Click three times to record the data in the Calitoo. Later the data can be retrieved by holding the button down until mode reading appears. Record data on data sheet.

6. Relative Humidity should be recorded after wetting the padded bulb, swing the psychrometer around until a minute has been counted in your head. Then record the data on the indicated area of the data sheet for later. These are all based on the hopes that the surrounding wind will not cause too much of a fluctuation in the testing results. The measurements should follow GLOBE Protocols and the data should be recorded as measurements progress.
7. Pack up tools and return them to their storage.
8. The independent variable is the level of aerosols. The dependent variable is the Relative Humidity levels. The controls for this experiment are the locations of the testing, water type used to wet the wet bulb of the sling psychrometer, cloud conditions, and the method of testing. The control group is non existent because the student is measuring the weather and atmosphere perimeters which depend upon atmospheric conditions and environmental factors to change in any way.
9. The following protocols were used to carry out the aerosol and Relative Humidity measurements. They were all taken from GLOBE and were utilized to discover a possible correlation between aerosols (air quality) and Relative Humidity.

Aerosols

1. Determine whether or not the sun is blocked by clouds and if not, turn the sun photometer on. If the sun is covered, aerosol data cannot be obtained for that day.

2. Hold the instrument about chest-high or, if possible, sit down and brace the instrument against the knees.
3. Adjust the orientation of the sun photometer until the sunlight spot is centered in the target area. Be sure the pointing is stable before the voltages are recorded. Small movements of the sun photometer will cause the voltage to vary by a few millivolts.
4. Click through each screen, making sure the dot is centered and all information has stabilized so it is properly measured and recorded within the Calitoo.
5. Repeat all steps 4-9 four more times, making sure to hold the button at the last screen to ensure all data is recorded in the Calitoo.
6. Turn off the sun photometer. (GLOBE, 2020).

Relative Humidity

1. Stand far enough away from other people and the instrument shelter so they will not be hit by the psychrometer.
2. Stand in the shade if possible, with your back to the sun.
3. If there is no shade near the shelter, move to a shady spot nearby, but not too close to trees or buildings.
4. 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.
5. Open the sling psychrometer case by pulling out the slider, which contains the two thermometers. 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.

6. Record the dry bulb temperature. 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.
7. Sling the psychrometer for 3 minutes. Let the psychrometer stop whirling on its own! Do not stop it with your hand or other object. Read the wet bulb temperature to 0.5˚ C (from the thermometer with the wick attached).
8. Record the wet bulb temperature.
9. Determine the Relative Humidity using a psychrometric chart or the sliding scale found on the cases of some psychrometers. This can also be left blank as the GLOBE data site can calculate Relative Humidity from the wet and dry bulb temperatures.
10. When finished, close it, and return it to the shelter properly (GLOBE, 2020)

Data Summary

Relative Humidity (%) and Wet and Dry Bulb (°C) vs. Aerosols

Table 1

Data Table showing AOT, Wet and Dry Bulb Temperatures and Relative Humidity Values taken over the last two months

Date	Red AOT	Blue AOT	Green AOT	Dry (°C)	Wet (°C)	Humidity %
12-10-20	0.585	0.601	0.585	9	9	100
	0.586	0.604	0.589			

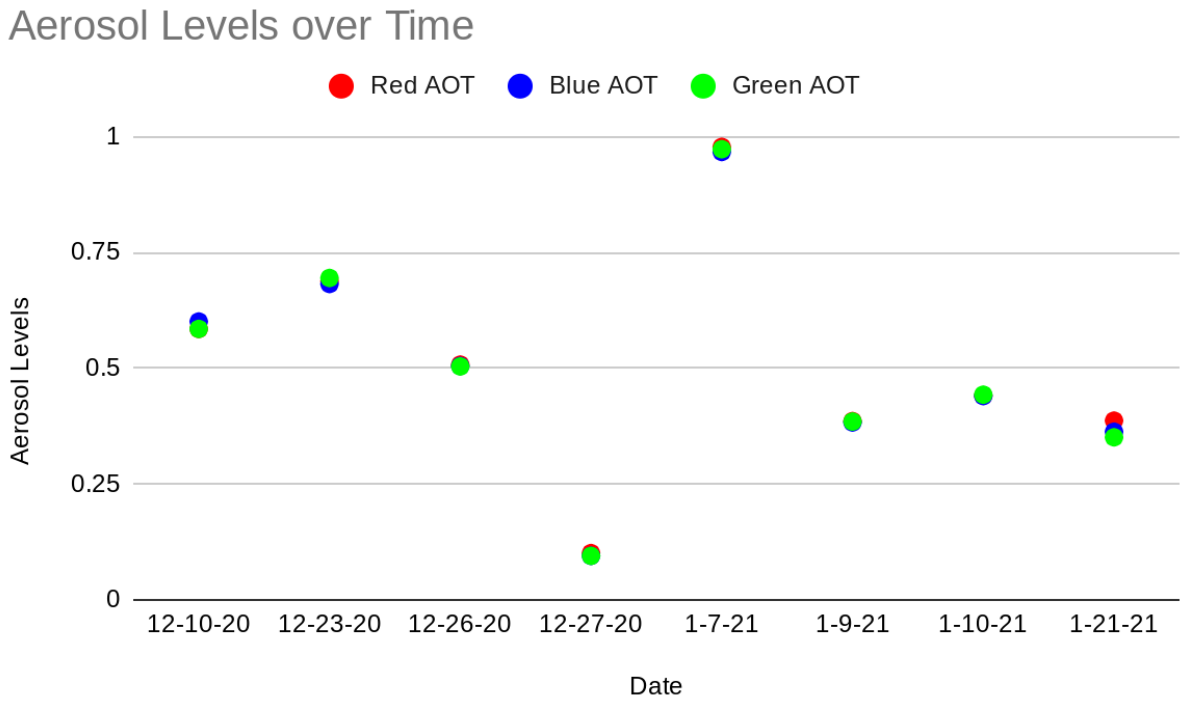
	0.588	0.604	0.589			
	0.601	0.617	0.604			
	0.586	0.604	0.592			
12-23-20	0.688	0.682	0.695	5	7	0
	0.747	0.743	0.76			
	0.945	0.939	0.955			
	0.715	0.711	0.724			
	0.622	0.617	0.632			
12-26-20	0.508	0.505	0.504	4	2	70
	0.495	0.494	0.497			
	0.538	0.535	0.535			
	0.517	0.516	0.518			
	0.499	0.499	0.5			
12-27-20	0.101	0.095	0.095	4	8	0
	0.102	0.092	0.095			
	0.107	0.102	0.103			
	0.111	0.105	0.107			
	0.62	0.605	0.571			
1-7-21	0.978	0.967	0.973	6	6	100
	0.983	0.977	0.981			
	0.964	0.957	0.964			
	0.965	0.957	0.966			
	0.953	0.948	0.956			
1-9-21	0.386	0.383	0.385	2	6	0
	0.377	0.373	0.377			
	0.284	0.282	0.287			
	0.293	0.292	0.297			
	0.297	0.296	0.301			
1-10-21	0.441	0.44	0.443	2	4	0
	0.44	0.438	0.44			
	0.463	0.461	0.463			
	0.468	0.466	0.47			
	0.465	0.463	0.466			
1-21-21	0.387	0.363	0.351	8	7	87

	1.828	1.782	1.705			
	0.502	0.485	0.478			
	0.586	0.563	0.556			
	0.375	0.352	0.342			

Note. This data table displays all of the data collected for AOT and Relative Humidity.

Figure 1:

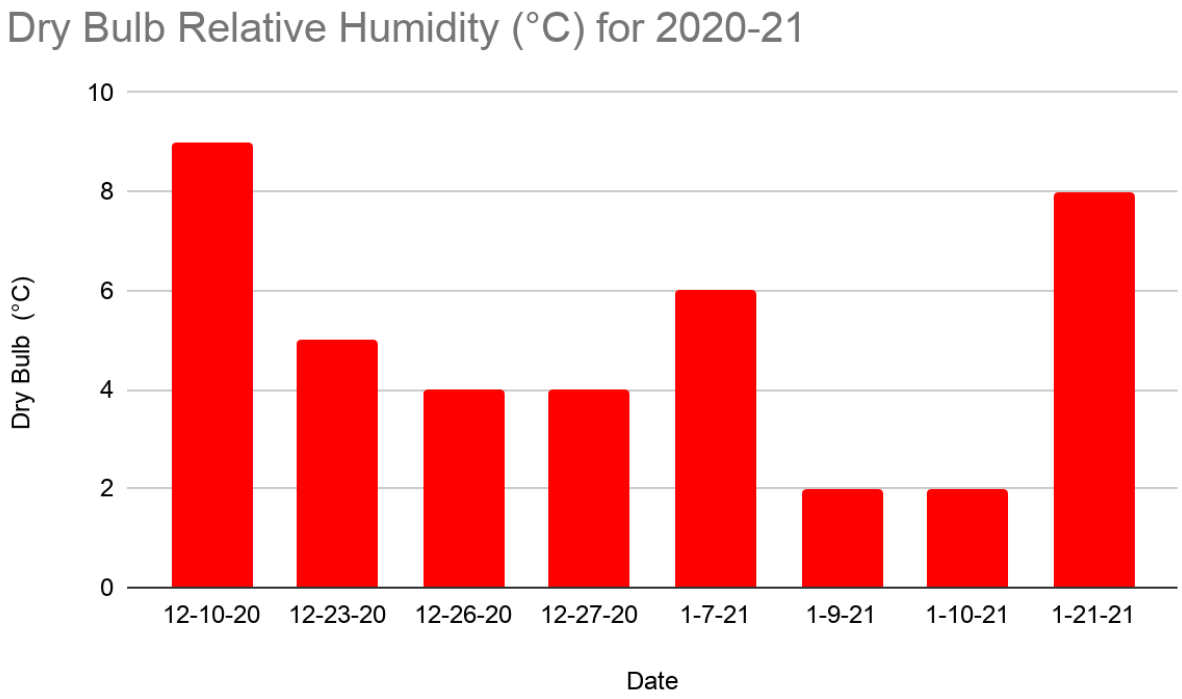
This graph shows the aerosol measurements collected throughout the project.



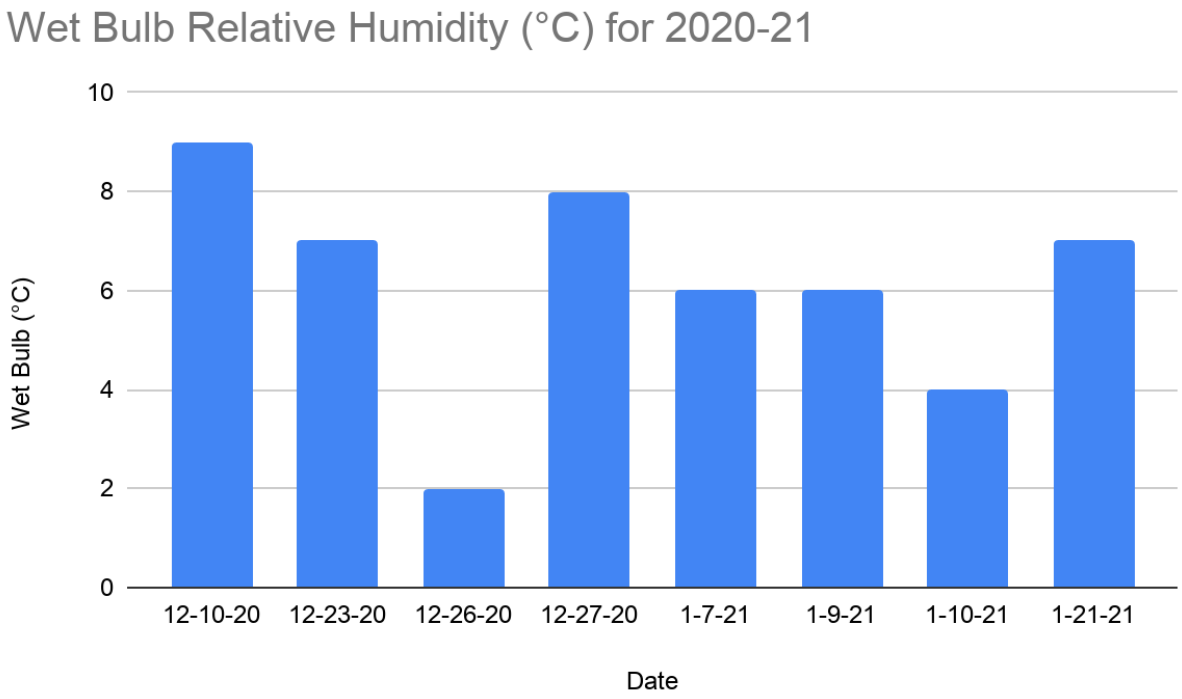
Note: This graph displays the aerosol data collected over the past two months. The significance of the dots is that when the dots on the graph are farther apart, that means that the aerosol particles are small. When the dots on the graph are close together, the aerosol particles in the air are larger, which can cause more respiration issues and atmospheric effects. The aerosols followed a pattern of increase and then decrease.

Figure 2:

These graphs show the Wet and Dry bulb temperature measurements collected throughout the project.

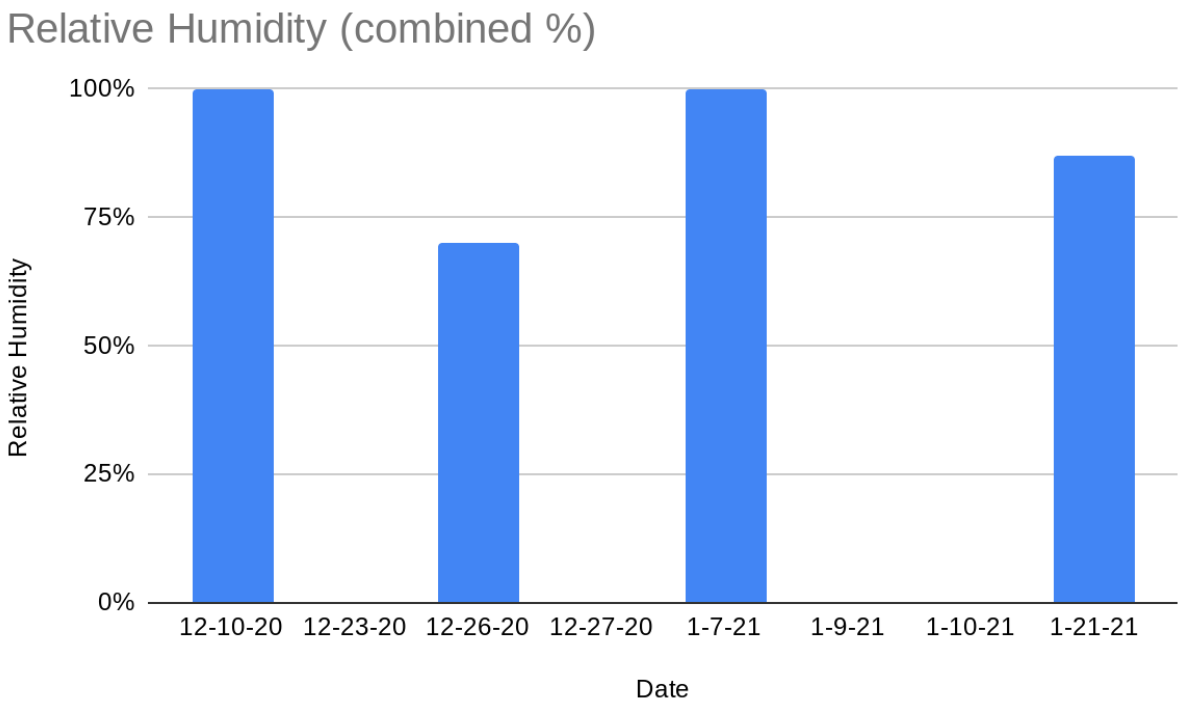


Note: This graph displays the Dry Bulb temperature collected over the past two months.



Note: This graph displays the Wet Bulb temperature collected over the past two months.

Figure 3:



Note: This graph displays the combined Relative Humidity levels in percentage form that were taken over the past two months. The blank spots of the graph indict where a proper percentage could not be calculated due to the wet bulb being higher than the dry bulb. With this now combined percentage, it appeared when combined Relative Humidity increased, aerosol levels increased and when Relative Humidity levels decreased, aerosol levels decreased. There didn't appear to be any significant effect on the cluster sizes with the combined Relative Humidity, but there was an effect seen with the wet and dry bulb temperatures.

Figure 4:

Note: A physical graph was not possible to make for this comparison due to the need of making a scatter plot mixed with a line chart which Google doesn't offer. If the graphs are looked at

carefully though, a correlation is visible. As stated before, the significance of the dots is that when the dots on the graph are farther apart, that means that the aerosol particles are small. When the dots on the graph are close together, the aerosol particles in the air are larger, which can cause more respiration issues and atmospheric effects. When the wet and dry bulb temperatures went down, Aerosol levels seemed to rise and when wet and dry bulb levels rose, Aerosol levels went down. Overall the clusters were relatively close together but on certain days like December 10 and 23 and January 7 and 21, the clusters were more spread out compared to the other testing days when they were more packed together. The correlation here appears to be that the aerosol particles rise after being low, and it causes the clusters to be more spread out compared to when the wet and dry bulb temperature levels were lower and the particles stayed closer together.

Discussion and Analysis

It seemed when the air temperature (found with the dry bulb) decreased, aerosol levels rose and the clusters became more bunched up creating larger pockets of air pollution and more hazardous consequences for those suffering from respiratory issues. This correlation was seen on December 10 and 23 and January 7 and 21. There is no clear explanation as to why the data shows this correlation due to prior knowledge indicating that it should really be showing the opposite. An explanation will hopefully be found and formulated after further research and endeavours. When the air temperature (found with the dry) increased, aerosol levels decreased and the clusters spread out more. Again, no clear explanation can be given as to why this correlation occurred, but future data collection will be conducted to find one. The correlation viewed with the combined Relative Humidity (found with the combined wet and dry bulbs) in percentage form was, when Relative

Humidity levels rose, aerosol levels rose and when Relative Humidity levels decreased, aerosol levels decreased. This correlation can be proven with evidence of past projects and other research. This pattern occurred because of the increase in water presence, aerosol levels rose because of the added particulate matter. When Relative Humidity levels decreased, it decreased the amount of particulate matter in the air, therefore decreasing the levels of aerosols. This leaves the question of how the coronavirus is affected by this. Based on what the data has proven, a person is more likely to contract the virus through an enlarged aerosol particle on days when it is less humid compared to days when it is extremely humid.

Conclusion

This project focuses on the question; “How do Relative Humidity levels affect aerosol cluster sizes?” The hypothesis states that if Relative Humidity levels are higher, aerosol cluster sizes will be larger, and when Relative Humidity levels are lower, aerosol cluster sizes will be smaller. The data partially supported the hypothesis and did prove to show a correlation. The combined Relative Humidity percentage (found with the combined wet and dry bulb) showed the correlation predicted in the hypothesis but the rest of the data proved the opposite of what was stated in the hypothesis. Though the hypothesis was partially supported by the percentage Relative Humidity, a revised hypothesis was still made to include what was viewed with the air temperature/wet and dry bulbs and it states, “when Relative Humidity levels are higher, cluster sizes will be larger, and when Relative Humidity levels are lower, cluster sizes are smaller. When the air temperature (dry bulb) was lower, the aerosol levels were higher and when the air temperature (dry bulb) temperatures were higher, aerosol levels were lower.” Based on what the data has proven, a person is more likely to contract the virus through an enlarged aerosol particle

on days when it is more humid compared to days when it is less humid. There might have been too much of a lag time between aerosol measurements and the Relative Humidity data collection. For future testing, an attempt will be made to mitigate this lag. A few stray clouds may have gone unnoticed as well which can drastically affect the aerosol data outcome. To mitigate this problem, the sky will continue to be monitored before each measurement is taken to insure the fullest possible accuracy.

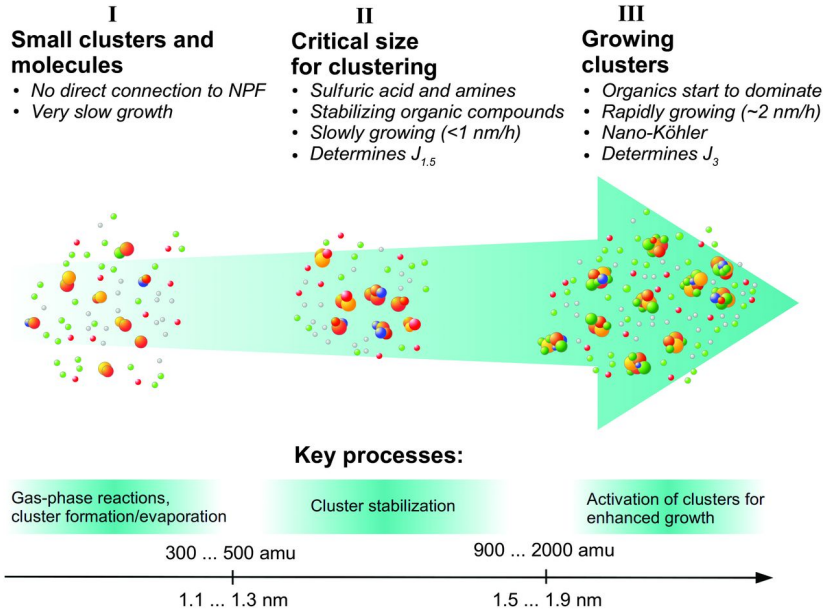
In conclusion, the hypothesis of this project was partially supported, but the revised hypothesis states that, “when Relative Humidity levels are higher, cluster sizes will be larger, and when Relative Humidity levels are lower, cluster sizes are smaller. When the air temperature (dry bulb) was lower, the aerosol levels were higher and when the wet and dry bulb temperatures were higher, aerosol levels were lower.”

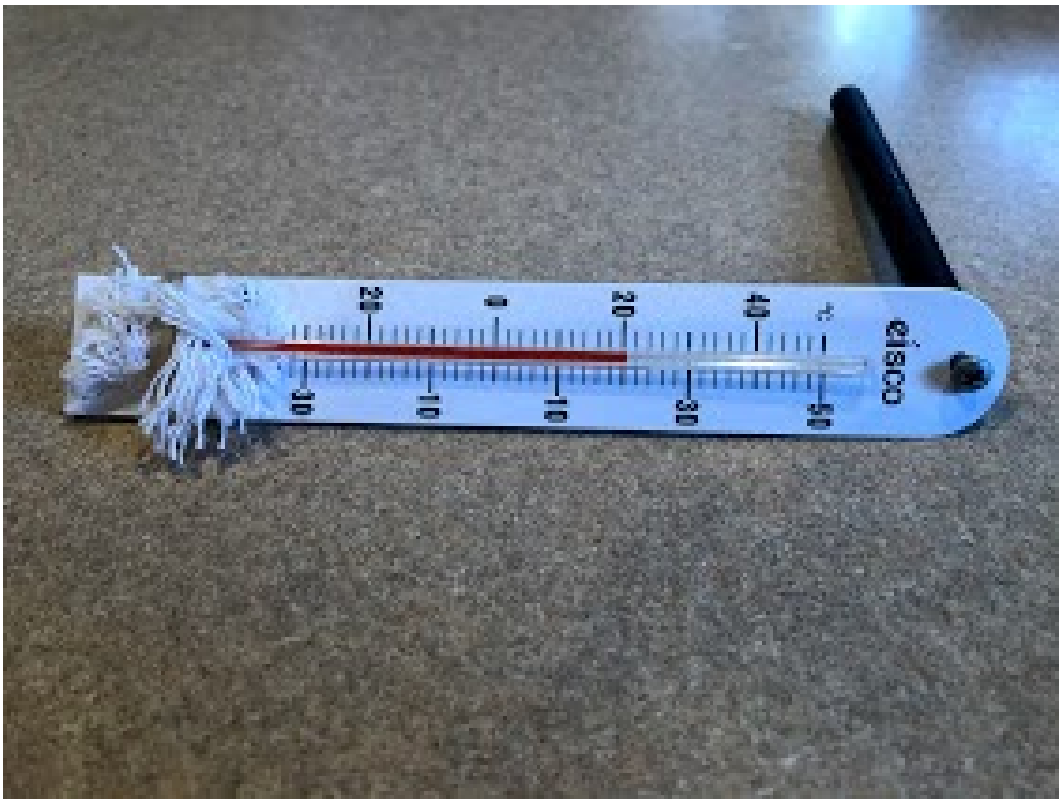
Application

In future data collection, temperature will be added in as a possible factor in cluster sizes, and PM2.5 will be added in as a companion to the aerosols to see how temperature and Relative Humidity levels affect them. This project will slowly be advanced through different additions of measurements for further competitions such as GLOBE SRS and GLOBE IVSS. This project applies to the real world, because it affects people in many aspects. It shows the effects of Global Warming once again, and how the globe is ever changing with rising sea levels, dying forests and animals all because of humans and their pollution, a major one being aerosols. This project also affects humans on a more personal level with the pandemic that has been sweeping through the

world since late 2019. This project helped give a little insight into the world of coronavirus and hopefully brings another little puzzle piece to light in figuring out how to stop this virus.

Pictures


I
Small clusters and molecules
• No direct connection to NPF
• Very slow growth
II
Critical size for clustering
• Sulfuric acid and amines
• Stabilizing organic compounds
• Slowly growing (<1 nm/h)
• Determines $J_{1.5}$
III
Growing clusters
• Organics start to dominate
• Rapidly growing (~2 nm/h)
• Nano-Köhler
• Determines J_3
Key processes:
Gas-phase reactions, cluster formation/evaporation
Cluster stabilization
Activation of clusters for enhanced growth
300 ... 500 amu
900 ... 2000 amu
1.1 ... 1.3 nm
1.5 ... 1.9 nm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