How does PM 2.5 and cloud cover correlate with air pollution in New York City?

Alex Silbert, Aarav Worah, Nana Shigematsu, Megan Caherly.

Emily Hollyday, Science Teacher
West End Secondary School
Manhattan, New York
United States of America
March 4, 2021

Abstract:

Our inspiration for the research is how much better the environment got during the shutdowns that happened during the pandemic. Our research question is: “how does air quality correlate with cloud cover and temperature?” Our hypothesis states that when PM 2.5 is higher then cloud cover will be greater and temperature would be higher. Condensation nuclei are things like dust, ice, or sea salt that cause water to condense. Our objective was to collect data on a daily basis over the course of a week, by observing the sky outside of our homes and using the PurpleAir website to track the air quality in raw PM 2.5 levels. We also downloaded the data taken each hour by the PurpleAir website and used that to be more exact and specific. Although our results are not completely straightforward, we found patterns that show connections between PM 2.5, cloud cover, and temperature.In the data, we found that over the course of a week in December 2020 (the 15th to the 22nd), we noticed that the air quality got worse and the cloud cover increased. The data we collected during that very week was right after a massive snowstorm caused by a cold front which could very heavily cause high cloud cover and alter the air quality.

Key Words: air quality, cloud cover, temperature, pollution, and PM 2.5.

Introduction:

According to health.ny.gov, “fine particulate matter ($PM_{2.5}$) is an air pollutant that is a concern for people's health when levels in air are high. $PM_{2.5}$ are tiny particles in the air that reduce visibility and cause the air to appear hazy when levels are elevated. Outdoor $PM_{2.5}$ levels are most likely to be elevated on days with little or no wind or air mixing. The term fine particles, or particulate matter 2.5 ($PM_{2.5}$), refers to tiny particles or droplets in the air that are two and one half microns or less in width. Particles in the $PM_{2.5}$ size range are able to travel deeply into the respiratory tract, reaching the lungs. “

Air pollution causes cloud cover to be larger, and higher cloud cover increases the air pollutants. Air pollution is a very deadly issue all over the world, and affects the world and people inside it in various ways. When lockdown was lifted, the air pollution started to get worse again. People started traveling places and going to work in cars again; oil refineries were back open; factories were up and running again; and electricity was being used like it had been pre-pandemic. This increase in air pollution could lead to greater cloud cover

because aerosols are seeds for water droplets to form in clouds. Air pollution can contribute to warmer temperatures because the cloud cover traps the heat close to the surface, which is why an increase in cloud cover and it's density is so important. Clouds form when water vapor turns into liquid water droplets. The droplets go onto floating and rising little particles in the sky, like dust. Many aerosols become the clouds' nuclei. When there are more aerosols in the air, there is usually a higher number of cloud condensation nuclei. This could cause a lot of smaller cloud droplets instead of larger particles. Aerosols are basically any small particle or liquid droplet which is suspended in the atmosphere (Vaidyanathan, 2014). Aerosols can cause the earth to be warmer or cooler. Light colored aerosols reflect sunlight back to space, while dark colored aerosols absorb the sunlight.

Air pollution has caused an increase in cloud cover for nearly 200 years. Clouds can reflect the sun's rays back into space, which cools the Earth. They can also trap heat close to the Earth's surface, which warms it up. Often, they do a little of both. Clouds have the ability to heat the planet much more than CO2, depending on the type of cloud, its geography and its altitude. And to make things more complicated, cloud particles can have various sizes, shapes and various traits. The increase in cloud cover is very important towards global warming.

Throughout the pandemic, air pollution has been decreasing and some industries like the oil industry have been less profitable also. During shutdowns caused by the COVID-19 pandemic, satellites found that there was a decrease in some air pollutants, but there is still a ton of air pollution. Roads aren't as busy and airports aren't having as many flights fly out each day. In addition, industrial activities have started decreasing, so it helps with the decrease of carbon dioxide. Oil refinery operations in Shandong province, for instance, were at their lowest since 2015. Researchers in several countries around the world have reported improvements in air quality after the shutdown measures. In particular, São Paulo, Brazil, China and India have recently reported large decreases in pollutant concentrations, but their air quality is still much worse than that of NYC. Air quality has improved over quarantine, but it is still very bad. As things get back to normal, it is going back up, and if it continues and we don't make a change, the rate of global warming will increase manifold.

Now that the streets have opened back up and there are more people driving, more of the air has been polluted, and asthma attacks are getting more frequent. Harvard scientists suggest that exposure to air pollution is connected to higher COVID-19 death rates. The Bronx has been hit massively because there are many highways, so the air quality is always poor there. There have been many more deaths in those areas due to this. This is an example of environmental injustice. Factories and highways and new projects are purposely located near poorer and predominantly people of color neighborhoods, so those people and their children are suffering. The air and heavy fog in those places burns in the lungs of the residents of that neighborhood, giving various health conditions and breathing issues. In fact, it's not just that asthma attacks have been occuring more because of this and how it leaves people susceptible for COVID, but I can actually give children living in those places asthma.

In conclusion, over the past few decades as society has advanced, we have amassed a rapid increase in air pollution, which has had many effects on our planet and its occupants. Over the course of quarantine, we have been forced to stay inside and not use all of our everyday forms of transportation and factories have closed, so the air quality has gone down. In the beginning of our collection of data, we noticed low temperatures, little to no cloud cover, and good quality air. This was because when the pandemic started, the pollution levels went down, since no one was allowed to go anywhere (Zangaria, 2020). Now that we are out of lockdown and things are starting to open back up, the pollution levels have started to rise again. This is something that we can tell because earlier in lockdown, based on various articles, there was clearer water, more breathable air, and lighter and fewer clouds, and breathing was easier in many places. As we get further into the quarantine, our

old habits have come to life. Based on the data we collected, we conclude that over the past few decades as our society has advanced, we have amassed a rapid increase in air pollution, which has had many effects on our planet and global warming. Things are getting back to normal in the sense of the use of cars, factories opening, oil rigs opening up, and electricity being used at the same rate (Olumhense, 2020). To back this up, in the data we found in our everyday collections, we noticed that as the air quality got worse and a higher number, the cloud cover increased. As a result of this, the progress we made over quarantine has been destroyed already, yet we saw how much of a difference there was. If we stay inside and stay safe from the pandemic, we also save our environment and stop the burning of fossil fuels from killing our planet (Patel, 2020). Also as we have seen this progress, we should take into account using things that may be smaller contributors towards greenhouse gas emissions, and maybe bike places more, or use electricity less, or even work at home more. Not only will our environment become healthier all over because of global warming, but those suffering because of environmental injustice will be able to live safer lives and raise kids without various underlying health conditions and breathing issues. We thought that if we brought awareness to this and what's been effective, our environment would be safer. We also wanted to bring awareness to things in our environment that have changed because of air pollution, and how that's impacted global warming.

Methods:

Globe Procedure: First, download the "GLOBE observer app" and open GLOBE clouds. Next, follow the directions and make observations. When you are done, submit them. Then you will get an email from NASA, saying "NASA GLOBE observer cloud satellite match." This will match you with a photo satellite data that compares to the observations that you entered before. Lastly, upload the photo to the google slides. https://www.globe.gov/web/s-cool/home/satellite-comparison.

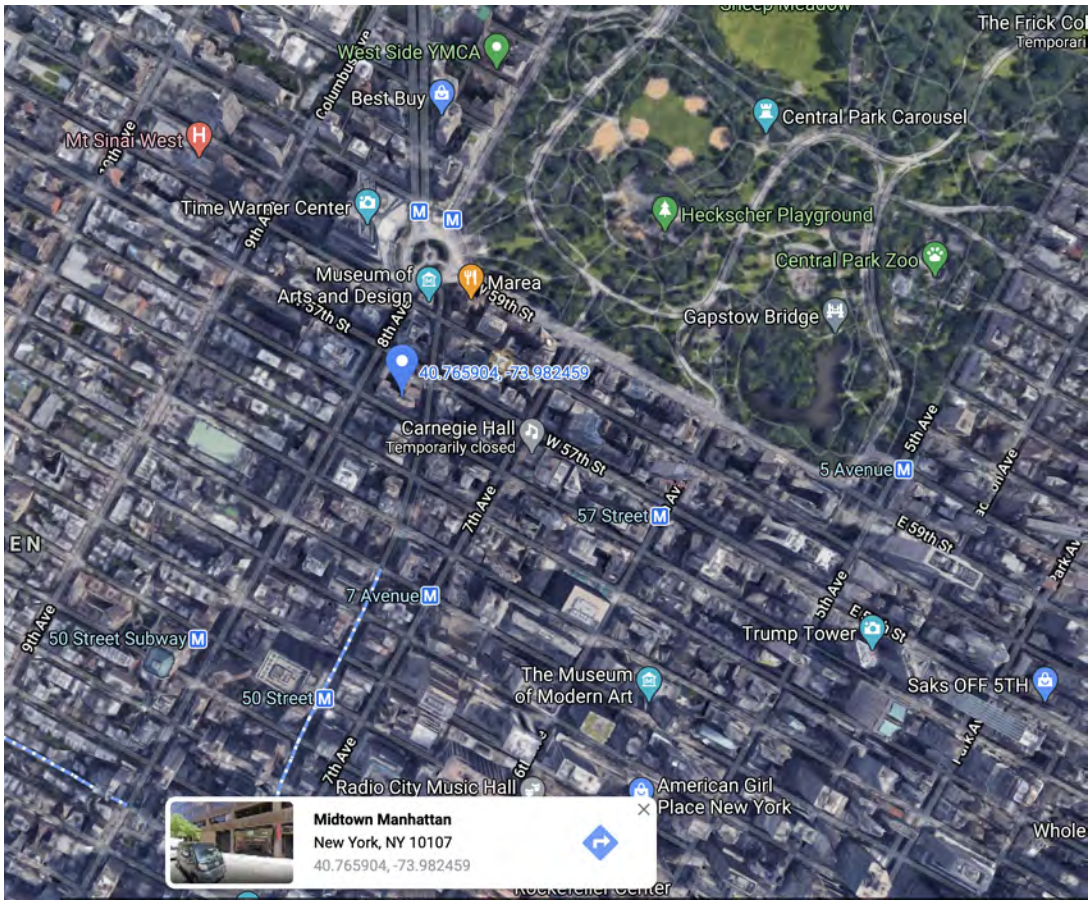
Purple Air Procedure: Find an observation point, take a photo of the sky and keep in mind that it's better to get a clear shot of the sky, unless you're unable to.
go to the website, https://www.purpleair.com/map
and change the map data layer to "Raw PM 2.5 in µg/m^3".
Zoom in on an exact area on the map that interests you and is near you, and take a screenshot.

Materials: Purple Air and Globe websites and phone camera.

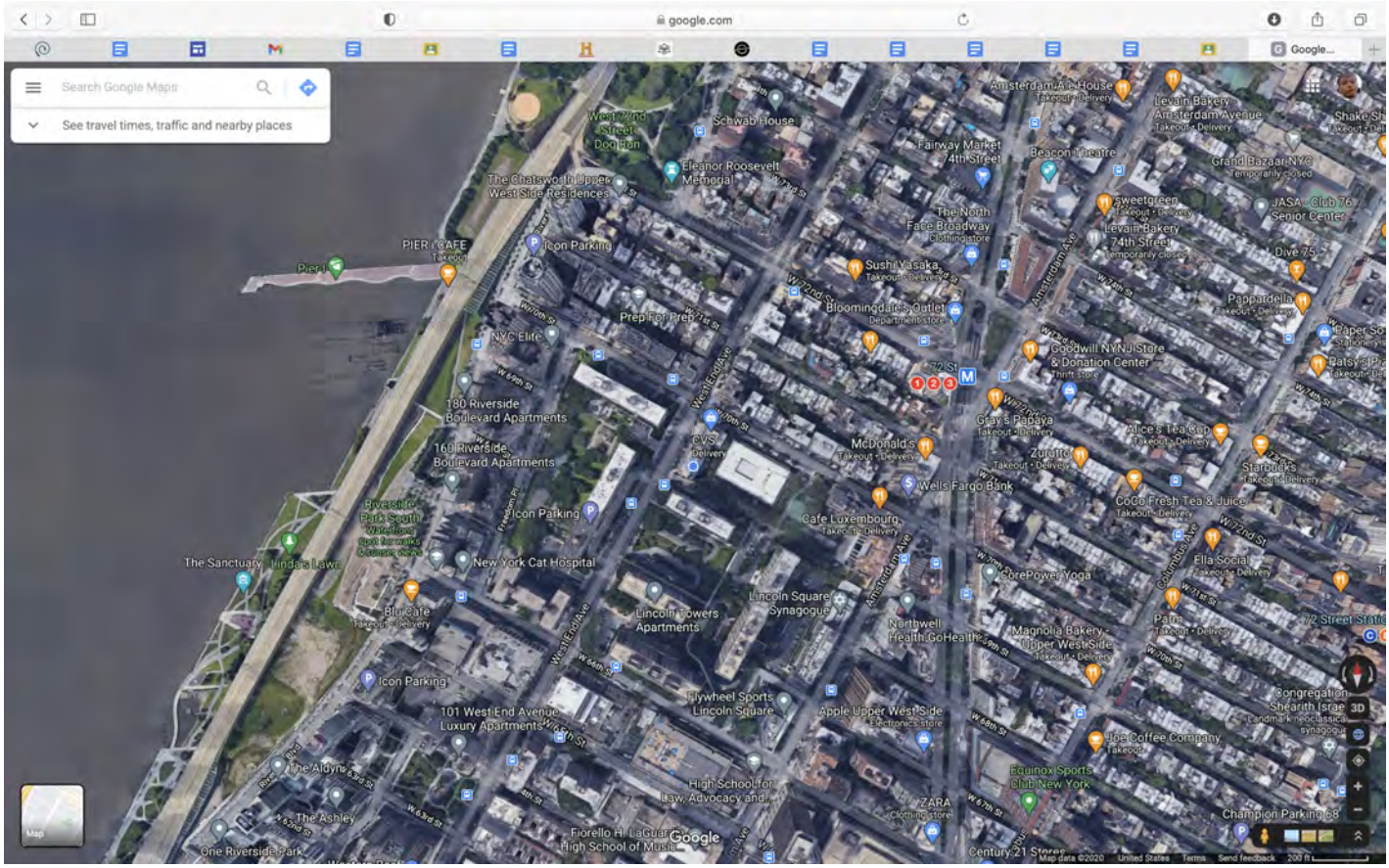
Study Sites:

Site 1: Upper West Side/Midtown, 78th and Riverside Drive

Study Site 2: 56th St. between Broadway and 8th Ave; Latitude 40.765904, Longitude -73.982459
Climate: The winds are pretty harsh most of the time, and there's cold air in the winter, but it gets really hot in the summer.



Study Site 3:
200 West 70th street on West End Avenue between Riverside and Amsterdam; 40.778480,-73.985428
There are buildings everywhere, and a river on one side, with a smaller park, and a big park on the other side.



Research Question: How does the PM 2.5 and cloud cover correlate with the temperature in New York City?

Hypothesis: When air pollution is higher then cloud cover will be greater and temperature would be higher.

Results:

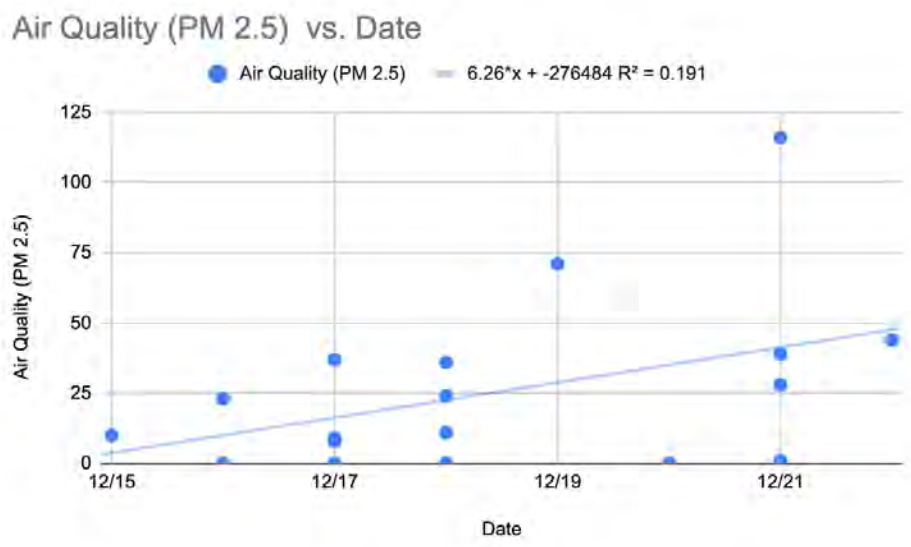


Figure 1. The graph shows you how the air quality was on each day, and how it changed over the course of December. From December 15th to December 22nd, air quality ranged from 0 PM 2.5 to 125 PM 2.5.

I calculated the mean of the air quality data. It was almost exactly 24 PM 2.5. My first steps in doing this was putting all of the data in columns and then in the scatter plot. We are all in relatively close neighborhoods and areas so I combined the data for the total mean. This was necessary because some data was unlabeled and already mixed so I couldn't find it for every location. Next, I counted how much data was collected overall, and it was 19 pieces of data total. I then added all of the data and got 457. After this, I divided it by 19 and got the mean of 24 PM 2.5. This meant that in all of our locations combined, there was an air quality of about 24 PM 2.5. This is important because even though we are in fact in different locations, our average was still so unhealthy. To make matters worse, most of Megan's data showed an air quality average of almost 0 PM 2.5! This means that Aarav, Nana, and my data, all from different places, were very high. If I took away those five days from Megan, the average of the rest of our location's air quality would be about 32.57 raw PM 2.5. These are very unhealthy conditions and demonstrate how unhealthy our city is that these conditions are so similar in different locations.

There is a positive trend in the data. The equation of the scatter plot Air Quality vs date was 6.26*x + -276484 R^2=0.191. The slope of this trendline was 6.26. The slope means that with each piece of data, the air quality was consistently going up by 6.26.

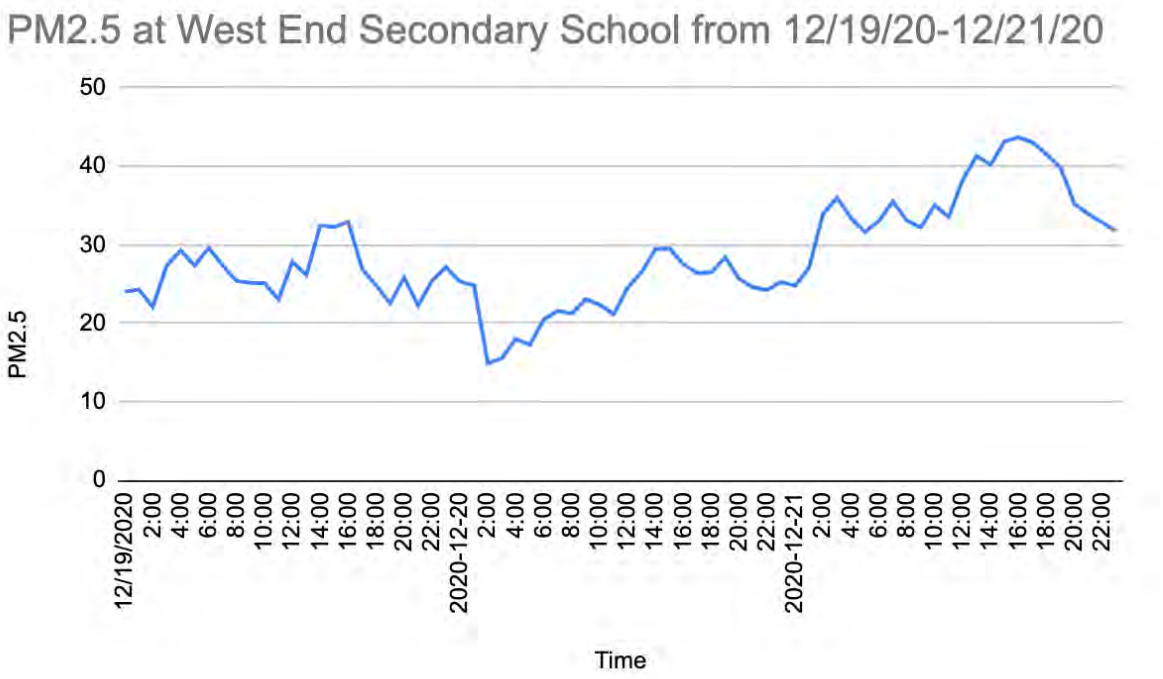


Figure 2. This graph is the same as the graph above, but is arranged in a line graph with more data. The PM 2.5 varies almost every day, and on the 21st, the air quality got worse, because of the snowstorm, as you can see in the photos below. The graph here is more accurate in terms of our hypothesis since there is more data, taken every hour, from the three days.

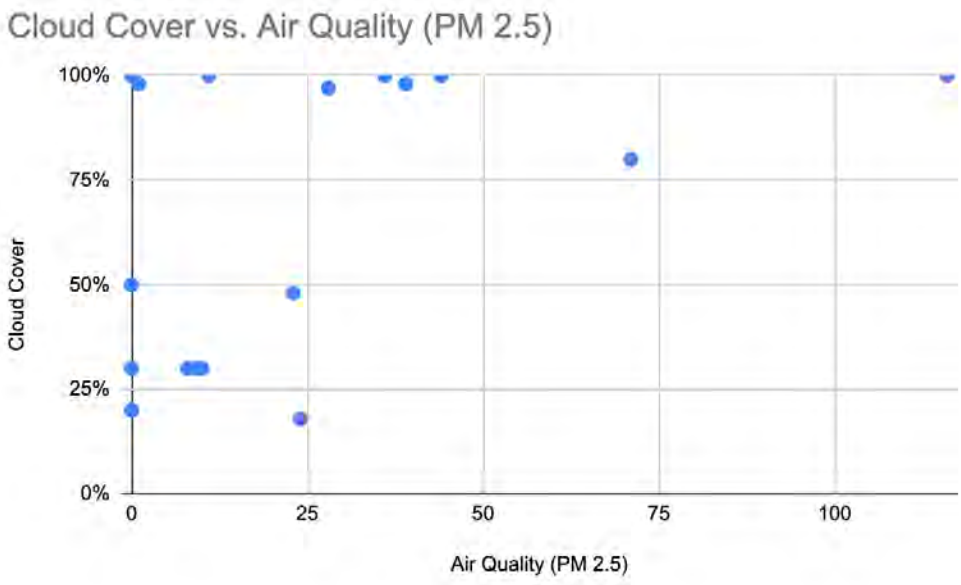


Figure 3. This graph shows the relationship between the cloud cover and air quality. The graph shows that it is likely that the cloud cover will be past 50% when the PM 2.5 is greater. There were no days where the cloud cover was lower than 50% when the air quality was past 25 PM 2.5. All of the cloud cover data is near 100% when the air quality is considered satisfactory but getting worse (between 25 and 50 PM 2.5). When the air quality is considered completely satisfactory (between 0 and 25 in air quality), the cloud cover is average, about 50%.

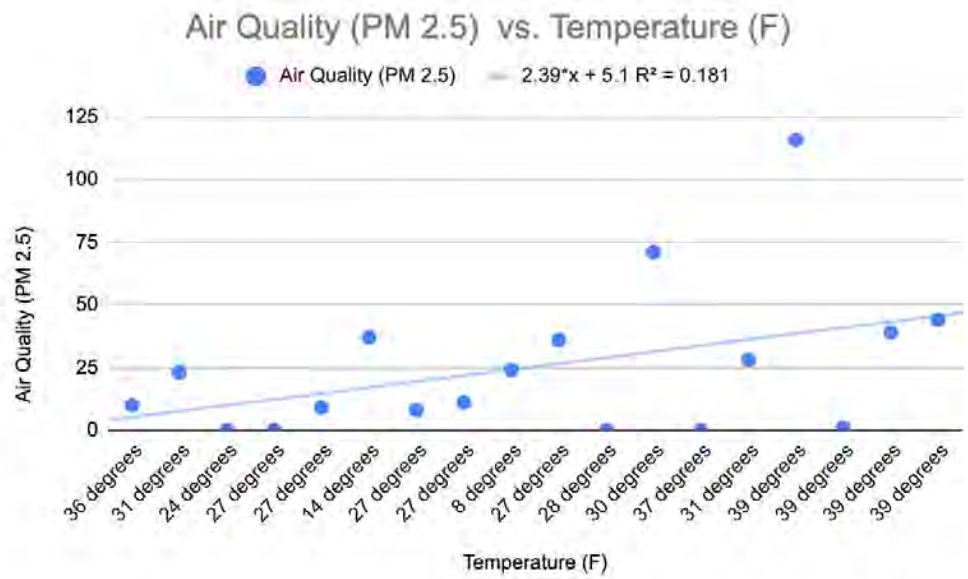


Figure 4. This graph represents the way that PM 2.5 and the temperature correlate. As the graph shows, the higher the PM 2.5 is, the more that the temperature rises. There is also a positive trend line that shows us that most of the data has a positive correlation. Our highest example is when the air quality hit almost 125 PM 2.5, it was 39 degrees outside. This might be an example of some sort of correlation.

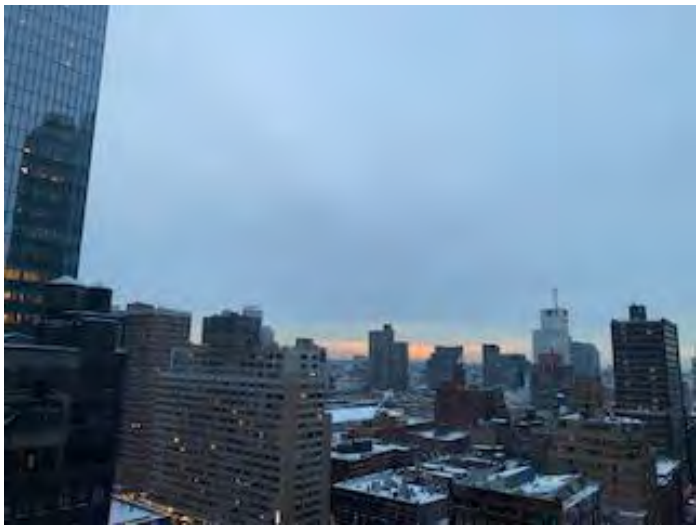
Figure 5

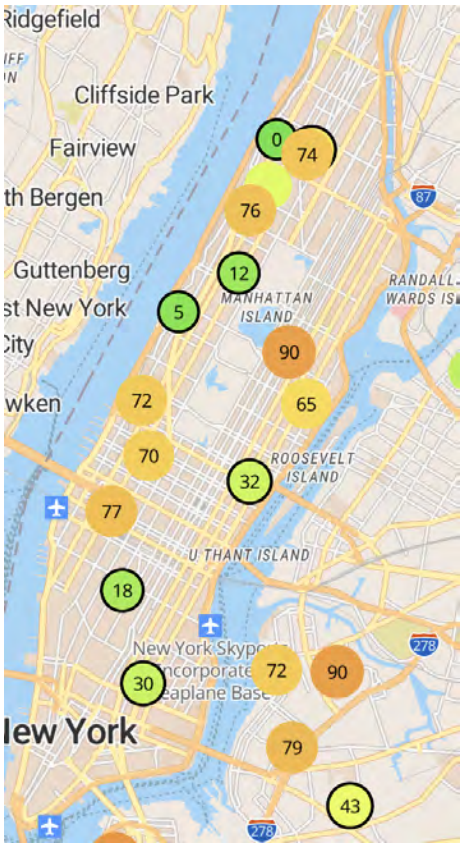
Data Source: **GLOBE Observer App**
Satellite Matching: **Open in New Window**
Measured At: **2020-12-20 18:31:00**
Solar Measured At: **2020-12-20 13:37:00**
Total Cloud Cover: **overcast**
Cloud Type: **Cirrostratus**
Cloud Type: **Altostratus**
Short Lived Contrails: **0**
Spreading Contrails: **0**
Non-Spreading Contrails: **0**
Cloud Cover Mid: **overcast**
Opacity Mid: **opaque**
Cloud Cover High: **overcast**
Opacity High: **opaque**
Snow Ice: **True**
Standing Water: **False**
Muddy: **False**
Dry Ground: **False**
Leaves On Trees: **False**
Raining Snowing: **False**
Is Citizen Science: **True**
Mv Updated At: **2020-12-20**

Data Source: **GLOBE Observer App**
Satellite Matching: **Open in New Window**
Measured At: **2020-12-21 21:21:00**
Solar Measured At: **2020-12-21 16:26:00**
Total Cloud Cover: **broken**
Cloud Type: **Cirrostratus**
Cloud Type: **Altostratus**
Short Lived Contrails: **0**
Spreading Contrails: **0**
Non-Spreading Contrails: **0**
Cloud Cover Mid: **broken**
Opacity Mid: **translucent**
Cloud Cover High: **broken**
Opacity High: **opaque**
Snow Ice: **True**
Standing Water: **False**
Muddy: **False**
Dry Ground: **False**
Leaves On Trees: **False**
Raining Snowing: **False**
Is Citizen Science: **True**
Mv Updated At: **2020-12-22**

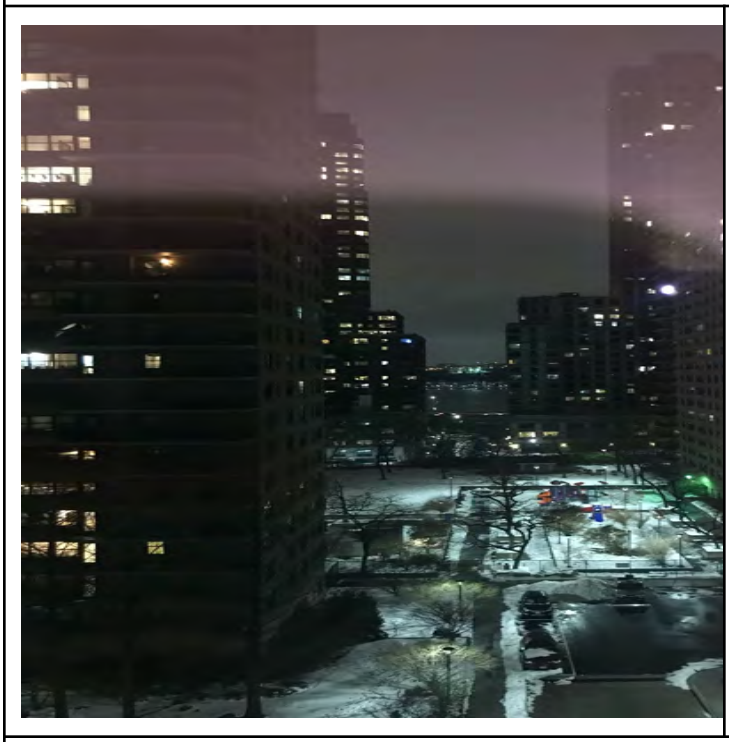
Data Source: **GLOBE Observer App**
Satellite Matching: **Open in New Window**
Measured At: **2020-12-21 15:14:00**
Solar Measured At: **2020-12-21 10:19:00**
Total Cloud Cover: **overcast**
Cloud Type: **Cirrostratus**
Cloud Type: **Altostratus**
Cloud Type: **Nimbostratus**
Cloud Type: **Stratus**
Short Lived Contrails: **0**
Spreading Contrails: **0**
Non-Spreading Contrails: **0**
Cloud Cover Low: **overcast**
Opacity Low: **opaque**
Cloud Cover Mid: **overcast**
Opacity Mid: **opaque**
Cloud Cover High: **overcast**
Opacity High: **opaque**
Snow Ice: **True**
Standing Water: **False**
Muddy: **False**
Dry Ground: **False**

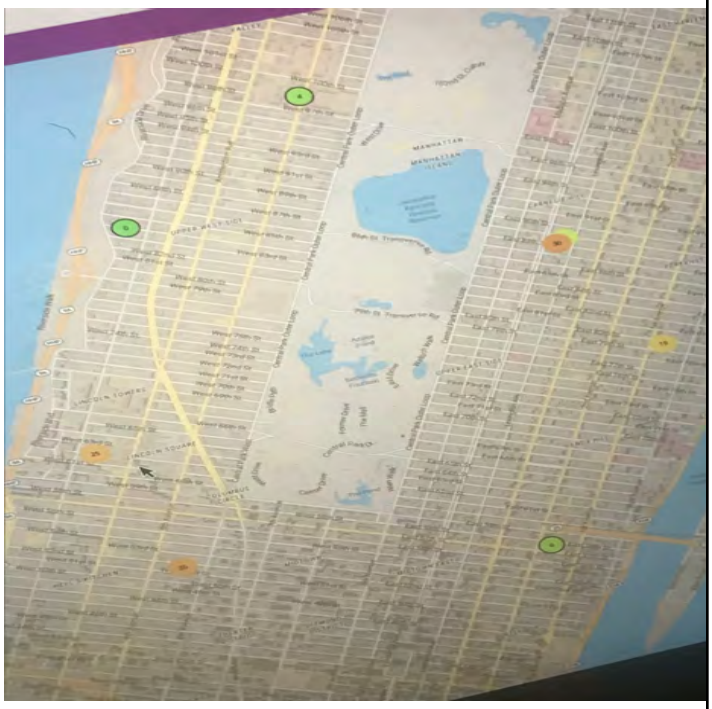
These are the cloud observations we collected from the Globe Observer App. This data was collected on the Upper West Side of Manhattan.





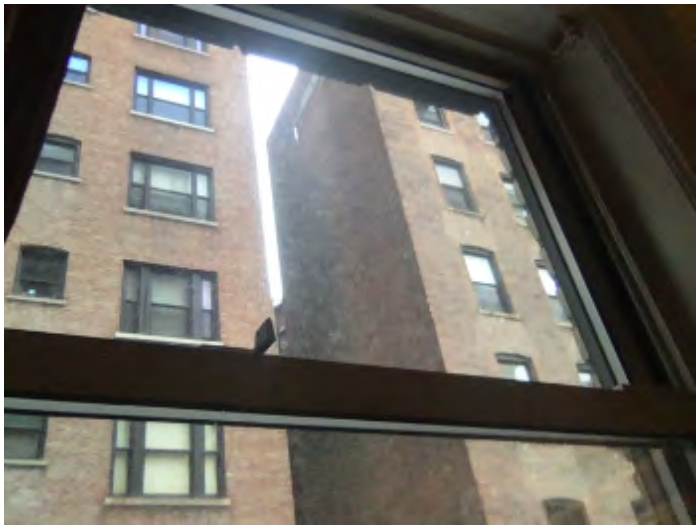
12/19/20 Taken in 56th street, Midtown. Some clouds with mostly clear sky, and very dry, no precipitation. Most data taken is between yellow and orange, which means that the air quality is fine. From the purple air website, these air qualities are acceptable.However, if they are exposed for 24 hours there may be a moderate health concern for a very small number of people who are unusually sensitive to air pollution.

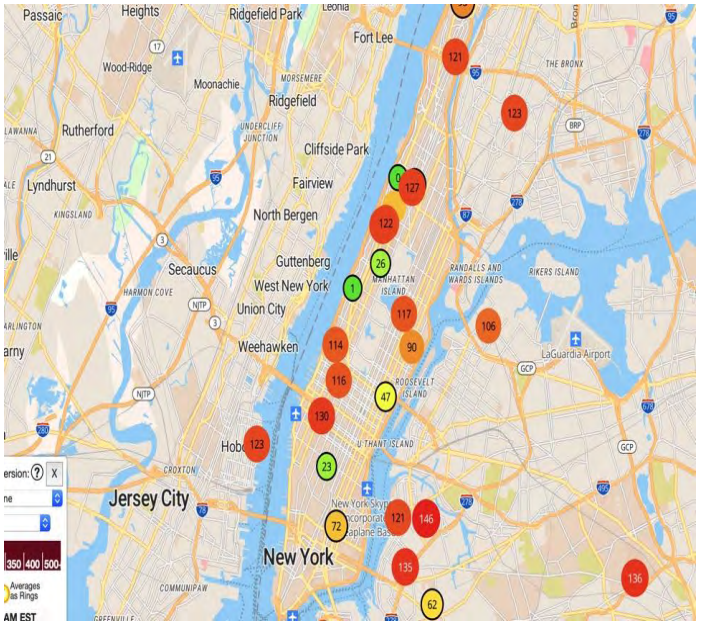




12/20/20 Taken in 64th and west end, Upper West Side. The temperature today was a high of 36 degrees and was cloudy. A little bit of snow from a few days ago was still left on the ground due to the freezing

temperatures, as well as a few rain showers. The air quality was pretty healthy in comparison to other days but not good and still bad for the lungs of people.





12/21/20 Taken in 78th, Riverside. It was cloudy and foggy, and the temperature was very similar to the temperature on 12/20/20. This is important because the pictures show how the air qualities barely changed as well, which could tell us that there is more correlation.

Discussion:

The temperature on 12/21 didn't fluctuate a whole lot, and reached a high of 39 degrees, compared to 12/20's 36 high. According to CBS New York, the temperatures on 12/19 were supposed to be very similar to 12/20's weather and since the 21st and 20th had similar numbers, the weather on 12/19 also connects to the 21st. It was much more cloudy on the 20th and the 21st with cloud covers of 97% and 100%. On the 19th the cloud cover was only at 20%, which also seemed to result in a higher temperature than the temperature on 12/20. On 12/20 the temperature was mainly at 31 degrees which is lower than 12/19's 36 degrees. We believe that this could correlate because we see other similar characteristics on the data chart. Our hypothesis is that when the cloud cover is lower, it is hotter, when the cover is higher it is colder.

The data from 12/15 and 12/16 shows that on 12/15 the cloud cover was at 30% and the temperature was 36 degrees. On 12/16, the cloud cover was at 48% and the temperature was 31. This backs up our theory that when the cloud cover is lower, it is warmer. The snowstorm was on 12/16-12/17 and it has impacted a lot of the air quality on the following days. As you can see from the images, as the days went on, the air quality got severely worse and the mark seems to be getting darker. The increase of the air quality might be from the snow storm since the temperature is very low, household heatings might have increased tremendously.

Conclusion:

Our conclusion for our project was reached from the results of our data. The end result ended up being that the air quality may relate to the percentage of cloud cover and the temperature. Our hypothesis was, “when air pollution is higher, then cloud cover will be greater and temperature would be higher.”

Increased temperature as a result of global warming causes worse air quality. Our research is important because it relates to global warming. Clouds trap heat close to the Earth's surface, warming the planet. (Vaidyanathan, 2014) It also says that they have the ability to heat the planet much more than CO2, depending on the type of cloud, its geography and its altitude. Some kinds of clouds insulate Earth and keep it warm, while other kinds shade the planet and keep it cool. High, thin cirrus tend to trap the heat emitted by Earth, which warms up the planet and low, thich cirrus tends to shade and cool Earth by reflecting sunlight back to space (American Museum of Natural History). This shows the correlation between cloud cover and global warming. The CDC also has findings similar to ours on how air pollution causes increase in cloud cover, which is harmful for the earth. Soot and polluted air particles become aerosols which form clouds. As those aerosols increase, so does the cloud cover, and these clouds trap heat in the atmosphere (Zangaria, 2020). In a healthy and clean environment, adding a tiny bit of pollution has a massive effect on cloud formation. The article stated that "ultimately, it [aerosols] affects the amount of clouds that are out there, and also the properties of the clouds—the area, for example, they cover over the globe.” This relates to our research because we investigated the cloud cover everyday and how that might have a correlation to all of the other factors we are investigating.

There are some improvements that we could have made during the process of collecting data and interpreting it. For example, I feel as if we could have added more days to our data collected, for a more varied range of data. I also feel as if we could have made our data clearer so that the graphs could come out better. In the future, some protocols that can be made in this project is that we can set aside a certain time period that data has to be collected, and you can’t skip days. I feel that this is vital, because you want consistent data in the graph. Another protocol that could be added is that there should be more of a variety in the program we use. We only had one person who used the GLOBE Cloud Observer App, but I feel that we should have had more people collecting cloud observations.

Badge Narratives:

For the “I make an impact” badge we made an instagram page, @wess_scientists, where we posted photos and data of our work and we hoped that if we would share our work and results, our audience would be educated more about air quality and how it affects the temperature and the cloud cover. Our goal is for our audience to learn and educate them more about the weather and air quality in NYC during the pandemic. Recently, we presented our work and our instagram page to middle school students from Syracuse, New York. We had them go to our instagram page and tell us their opinion and noticings of all of our posts. All of the students seemed interested and also educated which was our goal and now are more informed of how pollution and air quality has been affecting lots of other factors that relate to weather.

For the “I am a Data Scientist” badge, we were able to overcome it from all of the data taking to find the result of our question. To find the true answer to our question, we took datas of the air quality, cloud cover, and the temperature every day to see how the air quality would affect the cloud cover and temperature. From all of the datas, we made a graph that sums up all of the datas. We found that from the accuracy of our datas, our hypothesis was correct and that air quality does affect the cloud cover and temperature.

We overcame the “I am a STEM professional” badge by collaborating with two NASA scientists, Angie and Margaret. They provided numerous suggestions for our project, such as gathering more data from the PurpleAir website so that our final graph would make sense and our hypothesis would be easier to prove. They also suggested that we get more than 3 days to make any correlations between air pollution, clouds, and temperature so that we could make a more accurate conclusion. Despite the fact that we were unable to add more days to our project, we did provide details about the day the snowstorm occurred, which was two days prior to the three days we selected. We also discussed how the snowstorm impacted PM 2.5 levels in the days following the storm, as well as how the increase in air quality relates to cloud cover and temperature. They helped us improve our final project and make an upgrade which we are very thankful of.

Bibliography/Citations:

Olumhense, E. (2020). *For Some Near the Cross Bronx Expressway, COVID-19 is an Environmental Justice Issue, Too*. Retrieved from https://www.thecity.nyc/2020/9/28/21492252/cross-bronx-expressway-covid-19-environmental-justice-nyc

Patel, K. (2020). *How the coronavirus is and is not affecting the environment*. Retrieved from https://earthobservatory.nasa.gov/blogs/earthmatters/2020/03/05/how-the-coronavirus-is-and-is-not-affecting-the-environment/

Vaidyanathan, G. (2014). *How does air pollution affect clouds?* Retrieved from https://www.scientificamerican.com/article/how-does-air-pollution-affect-clouds/

Zangaria, S., Hill, D. T., Charette, A. T., & Mirowsky, J. E. (2020). *Air quality changes in New York City during the Covid pandemic*. Retrieved from https://www.sciencedirect.com/science/article/pii/S0048969720340183

Acknowledgements:

The CDC and US EPA websites helped us to compare our findings with those of liable websites, and allowed us to adjust what data to analyze. The articles, “How does air pollution affect clouds?” By Gayathri Vaidyanathan, “How the coronavirus is and is not affecting the environment”, by Kasha Patel, “Air quality changes in New York City during the Covid pandemic” by Shelby Zangaria, Dustin T. Hill, Amanda T. Charette, and Jaime E. Mirowsky (November 10, 2020), and “For Some Near the Cross Bronx Expressway, COVID-19 is an Environmental Justice Issue, Too” by Ese Olumhense (September 28, 2020). These articles gave a lot of validation to our evidence, and enabled us to write an essay on our subject and back our hypothesis and create analysis. The PurpleAir website was also a crucial tool to decipher the everyday air quality in our neighborhoods and find our data. We would also like to thank Angela Rizzi and Dr.Margaret Pippin for helping us improve our project by meeting with us to give us feedback.