Analysis of Aerosol Loading in the Baltimore-Washington Corridor using Ground, Profile, and Aircraft Datasets

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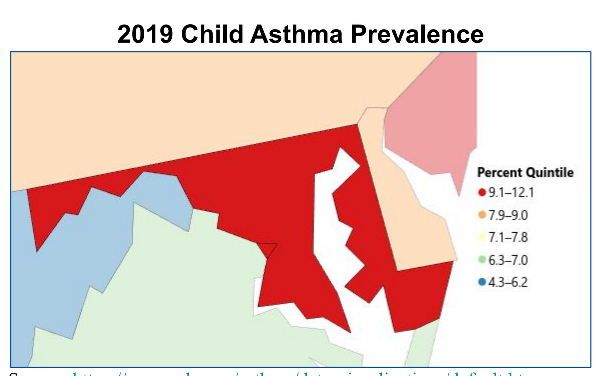
Background and Purpose

- **Particulate Matter (PM)** is defined as an atmospheric pollutant of either ≤10 micrometers (μm) or (PM_{10}), or ≤2.5 μm ($PM_{2.5}$) in diameter. At ground level, it is a pollutant that poses a threat to human respiratory health. Long-term exposure is linked to the development and worsening of chronic respiratory illness.
- This investigation uses site data to examine aerosols, small atmospheric pollutants, in the Baltimore-Washington corridor. We profile PM and identify the health ramifications related to the PM in the area.
- Prevalence of asthma in individuals under 18 is high in this mid-atlantic state compared to the rest of the United States. Maryland has a 9.6% prevalence, much higher than the national median of 5.8%. And in the neighboring District of Columbia we see the highest percentage of children with asthma in the country (12.1%).
- This tells us there is a relatively large group of people in the area with existing asthma at potential risk of health complications due to PM pollution.



Source: https://www.cdc.gov/asthma/data-visualizations/default.htm

Figure 1. Map of the state of Maryland and the District of Columbia (D.C.). The color key shows the percentage of the population under the age of 18 that has Asthma. Both Maryland (9.6%) and D.C. (12.1%) fall within the highest percent quintile in the country (9.1-12.1%)

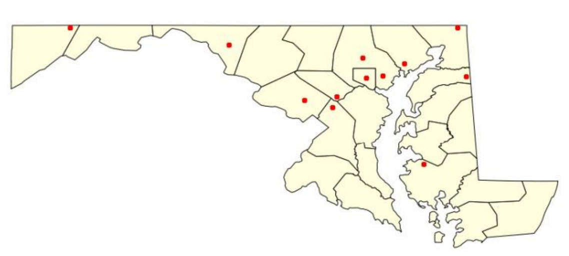
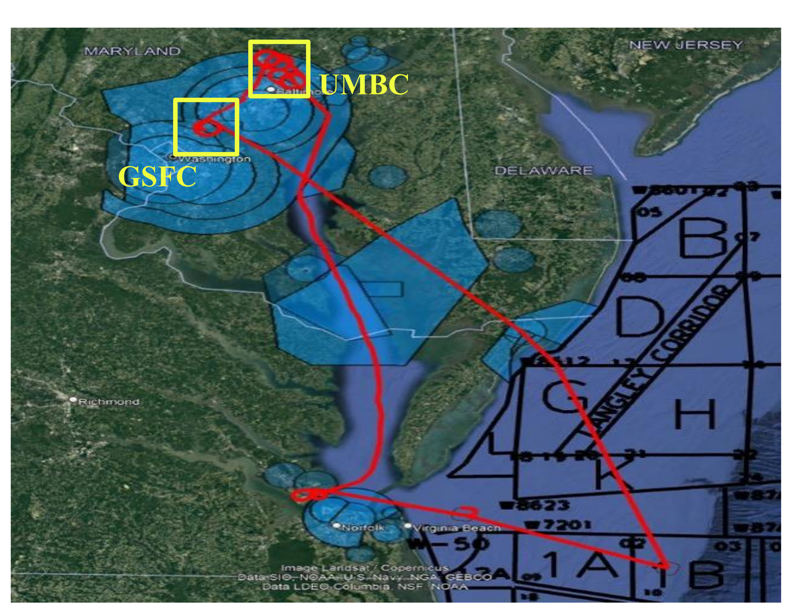


Figure 2. Map of the state of Maryland, by counties. U.S. Environmental Protection Agency (EPA) ground measurement sites for particulate matter are marked in red

Methods

Figure 3. Between July 6 and July 12, the **NASA P3B Aircraft (P3B)**, equipped with aerosol sampling instruments, conducted several science flights over the Mid-Atlantic region. Atmospheric data collected during the flights was uploaded to the **2022 NASA Student Airborne Science Activation (SaSa) Data Archive**.



- Measurements of aerosol optical and microphysical properties taken by NASA's **Langley Aerosol Research Group Experiment (LARGE)** instrument are used in this study to examine the presence of PM in the atmosphere above sites of interest.
- Measurements of aerosol optical depth from NASA Goddard Space Flight Center's **Aerosol Robotic Network (AERONET)** are used in tandem with U.S. Environmental Protection Agency (EPA) **AirNow** ground data on PM, GSFC **Micro-Pulse LiDAR Network (MPLNET)**, and LARGE's airborne assessment to form a comprehensive picture of the PM pollution in the area.

Data Overview

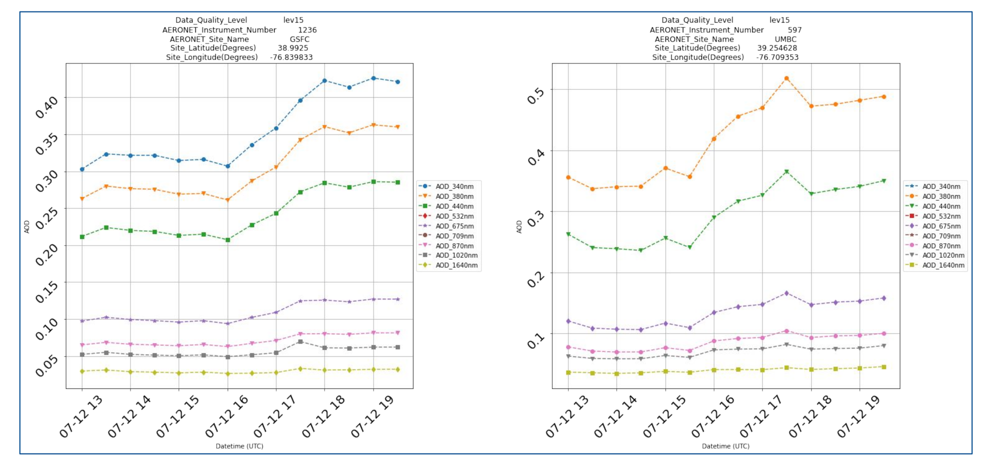


Figure 4. Aerosol Optical Depth (AOD) measurements taken by AERONET over UMBC and GSFC during a sub-period of the NASA P3B's science flights. The consistency in the spacing of AOD by wavelength shows that the same type of aerosol is being observed over this period. We see a jump in AOD around 17:00, which is also reflected in the smoke cloud touchdown identified in Figure 6.

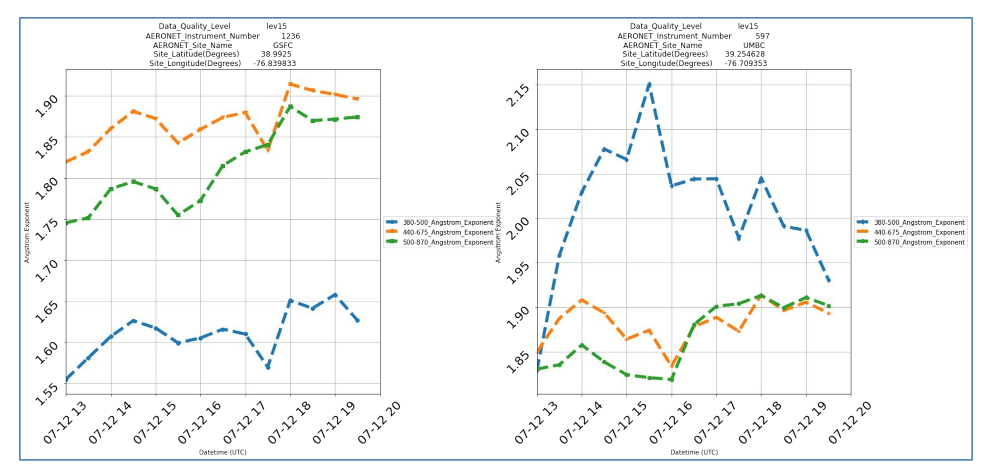


Figure 5. The **absorption Angstrom exponent (α)** describes the spectral dependence of light absorption by aerosols. It is related to particle size in that: values less that 1 suggest dominance by coarse particulate matter (PM_{10}), while values greater than 1 indicate fine particulate matter ($PM_{2.5}$). An examination of the Angstrom exponent over UMBC and GSFC shows that from the columnal perspective of AERONET, the air pollution profile is dominated by $PM_{2.5}$. Those with chronic respiratory diseases face greater health risks as a result of $PM_{2.5}$ than PM_{10} because it is more likely to enter and deposit itself in deeper parts of the lungs than larger PM.

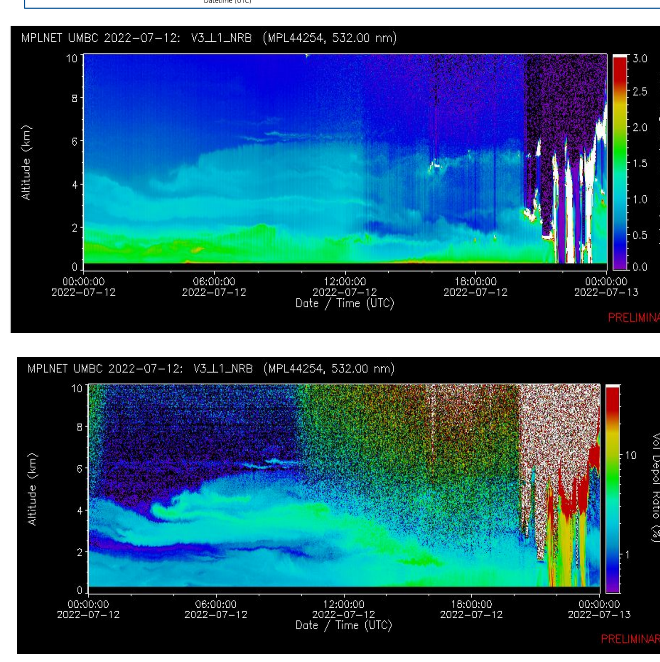


Figure 6. NASA **Micro-Pulse LiDAR Network (MPLNET)** data taken from UMBC is used to profile the air over the course of the flight day. From the measurements of backscatter, we can identify three distinct layers of air mass. From the Volume Depolarization Ratio measurement we observe a large smoke cloud passing over the MPL site, initially in that middle layer of air. It passes while descending toward surface level, before hitting surface level around 17:00 UTC. We then see rain starting at about 20:00 and lasting a few hours. But then, the LiDAR sees aerosol data immediately afterward. We can infer that the same wind that carried the smoke cloud across the area carried aerosols from a neighboring area to over the LiDAR. We investigate this hypothesis in Figure 8.

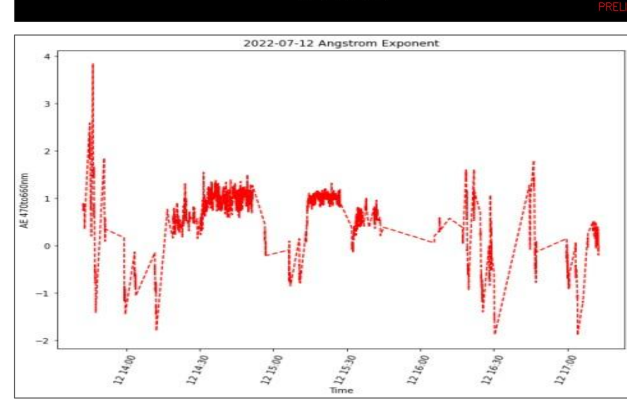


Figure 7. The absorption Angstrom exponent data taken from the P3B flight data on wavelengths from 470 to 660nm. The calculated values show an Angstrom exponent over 1 for about one third of the flight, and an Angstrom exponent less than 1 for about two thirds. This shows that there was a dominance of coarse particles around the plane at most points during the flight.

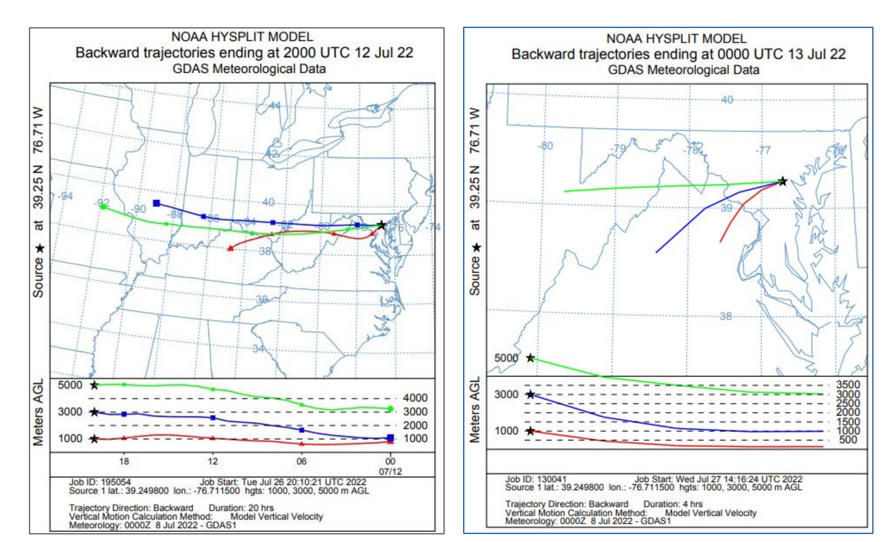


Figure 8. We examine two HYSPLIT backward trajectory models to observe the origination direction of the smoke episode observed during the day. We see that the wind carrying the smoke originates from further west of Maryland and descends toward the surface as it approaches UMBC. We also confirm our hypothesis that aerosols are carried into the area from nearby after the rain event.

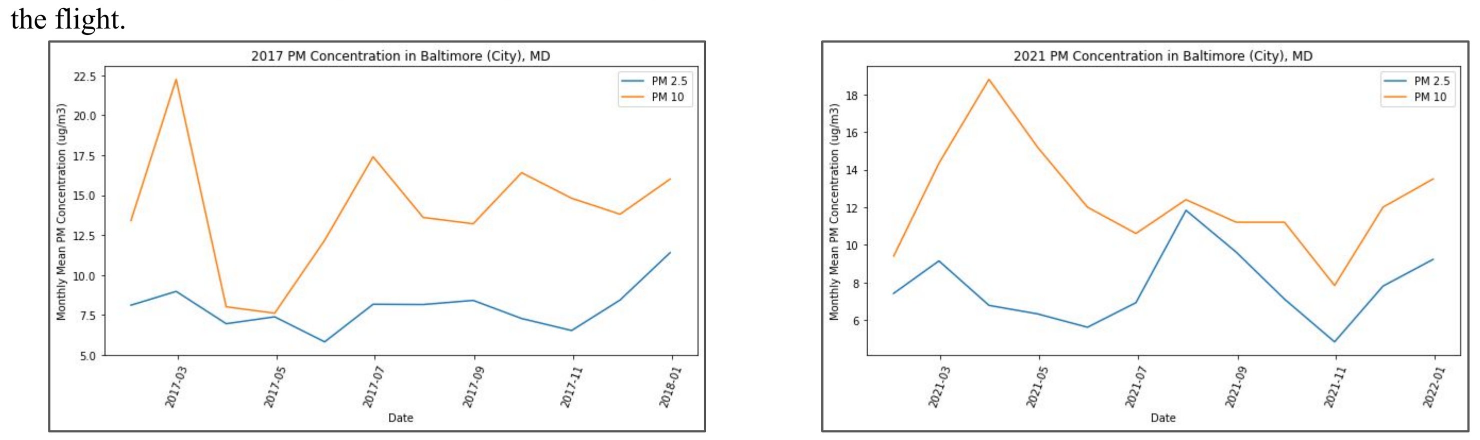


Figure 9. In Baltimore, Maryland, PM pollution presents a potential cause for concern. In 2017, the average monthly concentration of ground level $PM_{2.5}$ in Baltimore, Maryland was 7.93 μg/m^3. This showed no decline between 2017 and 2021, when the average concentration was 7.77μg/m^3. Despite this apparent decrease, there have been air quality episodes during that time. In 2019, Baltimore's annual $PM_{2.5}$ concentration was a much higher 11.2 μg/m^3, failing to meet the World Health Organization (WHO) target for an annual concentration of ≤10 μg/m^3.

Findings and Conclusions

- The data shows a high percentage of children with asthma in Maryland and D.C., and identifies an air quality episode of PM pollution by a moving mass of smoke.
- As of September 2021, the World Health Organization (WHO) sets an annual air quality guideline for $PM_{2.5}$ concentration of ≤5 μg/m^3. Through different methods of measurement, the Our examination of AERONET, LARGE, and MPLNET data in Maryland shows us a profile of the air around a primary reference point (UMBC) in the Baltimore-Washington area. This area does not meet that guideline, and in a five-year period has shown no significant reduction in PM pollution.
- Asthma alone affects 5.8% of the population of children under 18 in the United States. Comparatively, in the state of Maryland, 9.6% of children are affected. Because of this, we must ensure that an air quality standard is maintained as to not be hazardous to sensitive groups.
- Exposure to short and long-term PM pollution has been linked with the aggravation and worsening of respiratory illnesses, with one such illness being asthma. Reduced lung function growth in children has also been attributed to long-term PM exposure, which contributes to development of respiratory diseases at a young age. The International Agency for Research on Cancer (IARC) has even concluded that $PM_{2.5}$ is carcinogenic to humans and is closely related to the risk of lung cancer.
- The PM pollution in the Baltimore-Washington corridor and air quality episodes like the one observed in this investigation may be a contributor to the asthma issue in the area.

Next Steps

- In our AERONET data for the absorption Angstrom exponent, we see a much higher value in the 380-500 nm wavelength at UMBC. In the future, this and similar occurrences should be examined to learn what kind of significance they hold to this investigation.
- In order for us to move forward with pollution risk-management and protecting at-risk groups, further examinations of air quality must be made. To determine how effectively to curb PM pollution, trajectory models for particulate matter should be used to identify sources that affect this area. Places from which pollution is sourced should all take measures to reduce their air pollution.
- Additionally, the scale of the investigation must be increased to a greater area of interest. There are other states, such as California, New York, and New Jersey with similarly high percentages of childhood asthma where this investigation would benefit many people.
- Improving air quality will greatly reduce the risk posed by PM pollution to vulnerable groups, and reduce the risk of development of asthma, lung cancer, and other respiratory diseases in the general public.

Acknowledgements and Reference

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