A Guide to Reading Air Quality Reports

Introduction

The reports in this folder were created by Air Partners, a group from the Franklin W. Olin College of Engineering collaborating with ACE (Alternatives for Community and Environment) to build an air quality monitoring network in the city of Roxbury, MA. Each month, subscribers to the Air Partners email list will receive a link to a Dropbox folder containing visualizations of the previous month's air quality data collected by the network of sensors. The goal of this document is to make it easier to understand the information contained in these visualizations and reports, and to give insight into how they were created.

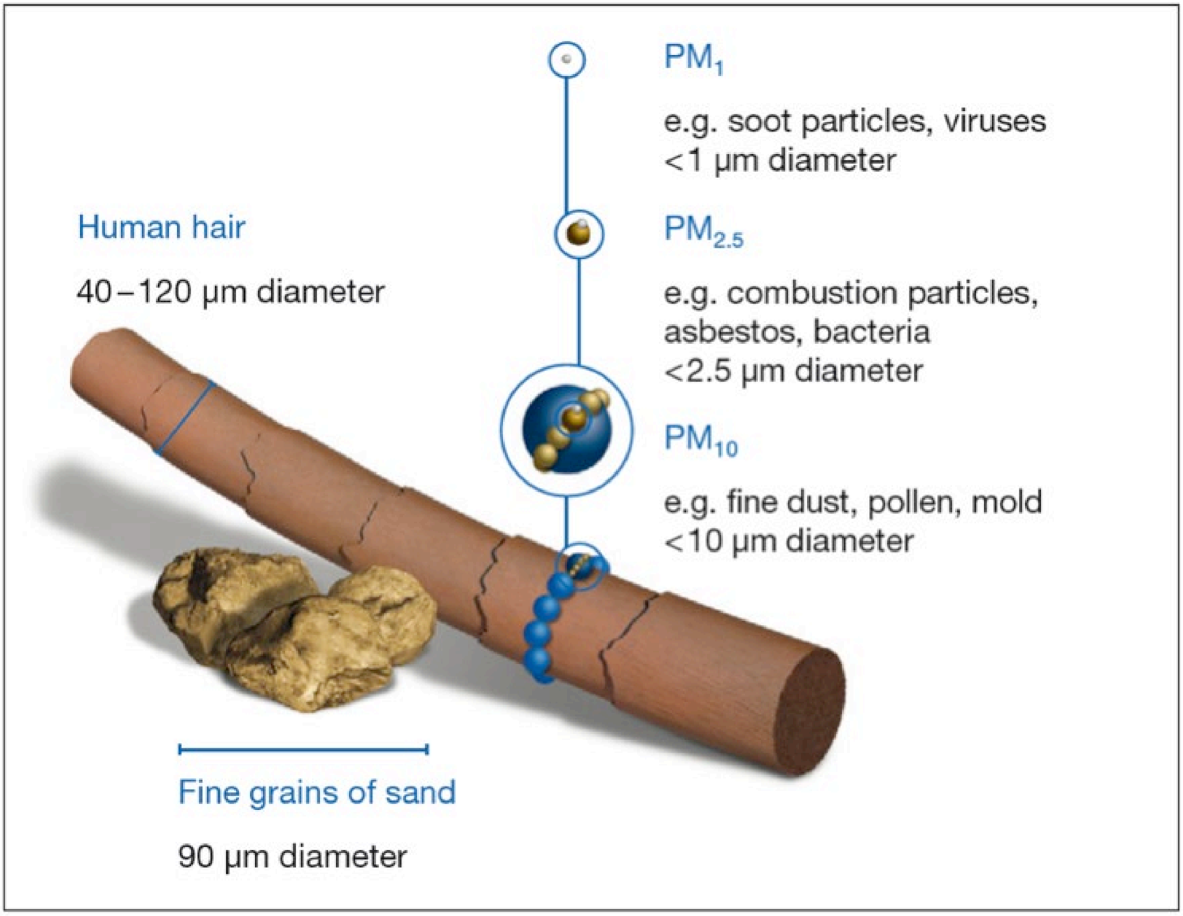
Glossary

PM: Particulate Matter; small droplets or particles suspended in the air. There are strong correlations between the concentration of PM in the air and various health issues and disorders, from asthma[1] to cardiovascular diseases[2], and even mental/neurological disorders[3]. There are three size classifications of PM that are detected by our sensors: PM_{10}, $PM_{2.5}$, and PM_1. PM data are reported as mass concentration ($\mu g/m^3$), which can be interpreted as the total mass of these particles in a volume of air about the size of a stove.

PM_{10}: Mass concentration ($\mu g/m^3$) of particles smaller than 10 µm in diameter, which is about 10 times smaller than a grain of sand. These particles are the largest of the three PM classifications measurable by the Modulair-PM instruments, and they are typically generated by construction work, road dust, and windblown dust. PM_{10} is regulated by the National Ambient Air Quality Standards (NAAQS), which are enforced by the Environmental Protection Agency (EPA).[4]

$PM_{2.5}$: Mass concentration ($\mu g/m^3$) of particles smaller than 2.5 µm in diameter, which is about 40 times smaller than a grain of sand. Sources of these pollutants are usually a mixture of fossil fuel combustion (gas-powered vehicles, diesel buses, motorcycles, airplanes, etc.), food cooking (typically produced from cooking, especially on gas-powered appliances), and chemical reactions in the atmosphere between gas-phase pollutants that generate PM. Like PM_{10}, $PM_{2.5}$ is also regulated by the NAAQS.[4]

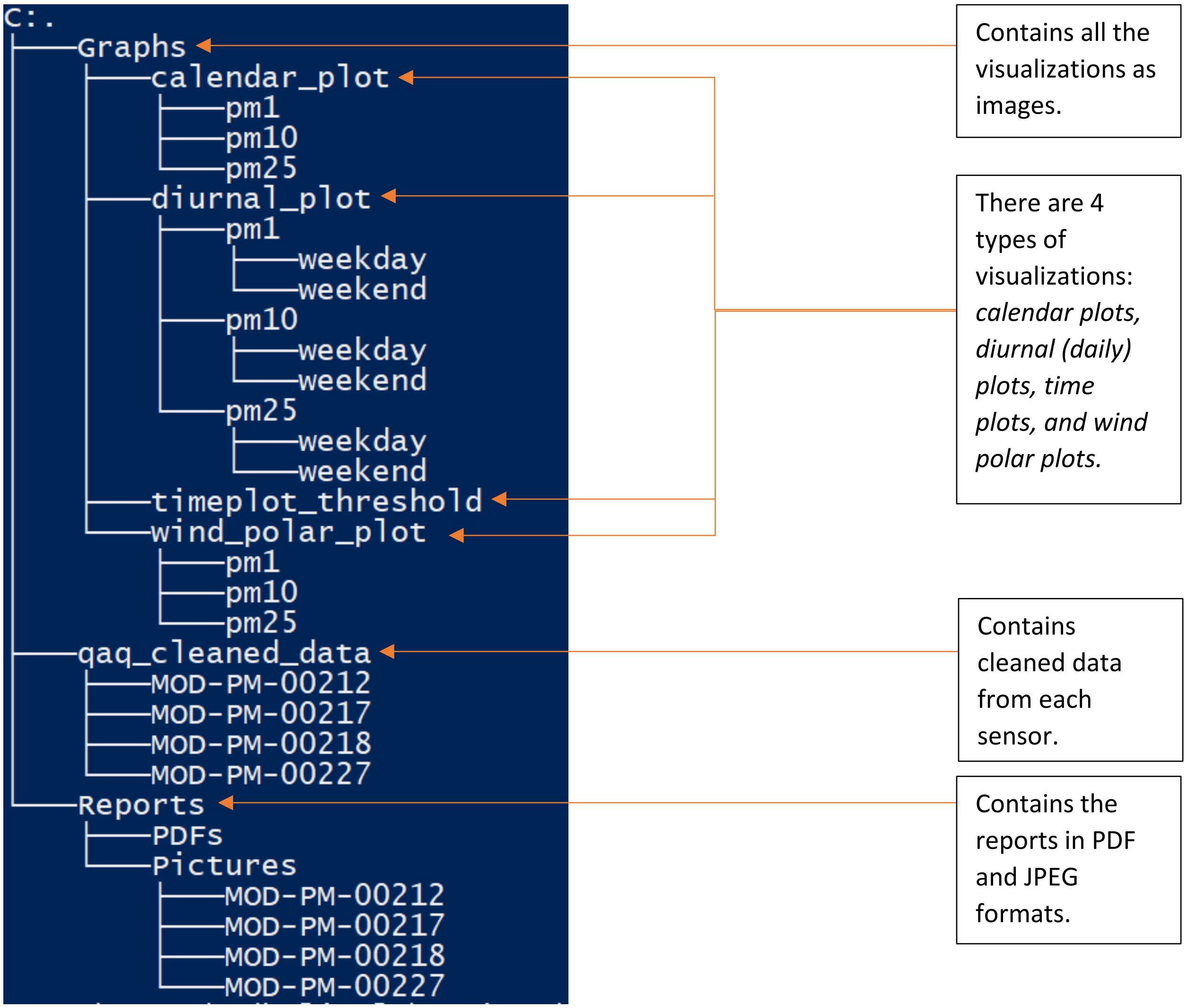
PM_1: Mass concentration ($\mu g/m^3$) of particles smaller than 1 µm in diameter, which is about 50 times smaller than a grain of powdered sugar. Sources of these pollutants include combustion (fossil fuels, fires, and cooking), and chemical reactions in the atmosphere. PM_1 is not regulated by the NAAQS, despite increasing evidence from epidemiology studies that the smallest particles are responsible for most adverse health impacts.[5][6]



Source: https://gasre.com/fit-iso-16890-new-test-standard-air-filters-more-informative-and-closer-application-reality

Structure of Reports Folder

After downloading the zip file, titled by the year and previous month (for this tutorial, we will use data from June 2022, so the name of this directory is '2022-06'), the folder structure would look like the image on the next page. To gain access to the reports, download the zip file from Dropbox and 'Extract All' the files. The reports for each sensor will be in "Reports" and "PDFs". There are three main folders at the top level: 'Graphs', 'Reports', and 'qaq_cleaned_data'.

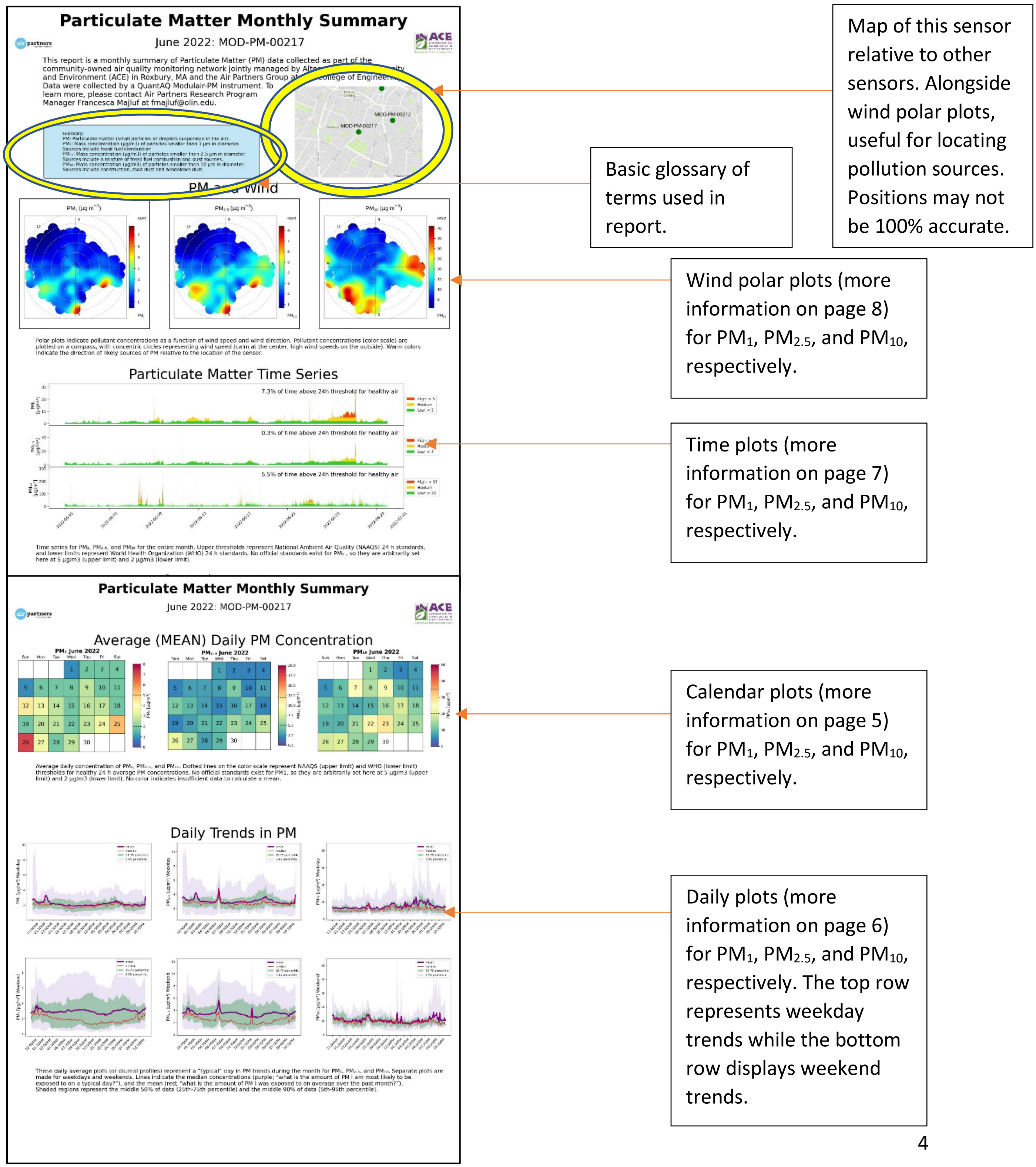


The directory 'qaq_cleaned_data' contains the data extracted from the sensors; these data were used to create the plots and visualizations in the other directories. Subscribers with data analysis experience are free to download and use these data for their own analysis. (The datasets are in .pckl (Pickle) format.) Historical data can also be interactively explored via the Air Partners Data Exploration Tool, which can be found on airpartners.org.

The 'Graphs' directory includes four types of visualizations. These four types of plots are all contained in summary reports for each sensor that can be found in the 'Reports' directory. The 'PDFs' folder contains these reports in .pdf format (best format for printing), while the 'Pictures' folder contains these reports in .jpg format.

Reports

One report is made for each sensor. For more information on the graphs made on the reports, read below. Below shows an annotated figure of both pages of a report from June 2022.

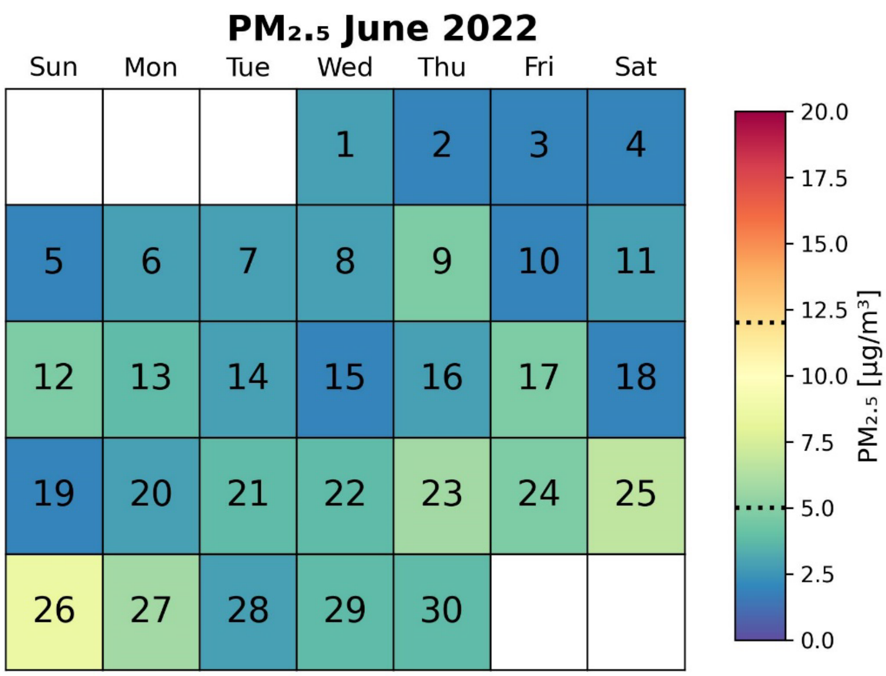


Graphs

As mentioned previously, there are four types of graphs used in the reports: calendar plots, diurnal (daily) plots, time plots, and wind polar plots.

Calendar Plots

Calendar plots represent the average levels of PM on every day of the month. On each report, there are three calendar plots – one for each of the different size classifications of PM (PM_1, $PM_{2.5}$, and PM_{10}). The color of each day represents the average concentration of PM; green or blue days indicate low average concentrations, while yellow and red days indicate higher concentrations of PM. White days indicate that there is insufficient data to calculate an average, which can indicate that either a sensor was deployed/removed or that it malfunctioned.



The plot above displays $PM_{2.5}$ concentrations during June 2022 from the air quality sensor near the Dearborn Academy in Roxbury. A couple of things to note are that the end of the month shows more greens and yellows compared to the beginning of the month, indicating higher levels of $PM_{2.5}$ as the month progressed. (This is especially true during the weekend of June 25-26.) These increases concentrations could be attributed to several sources, including increased road traffic, or increased rates of atmospheric chemistry owing to warmer, sunnier weather.

The dashed lines on the color bar indicate the regulatory standards for annual average PM concentrations, set by the National Ambient Air Quality Standards (NAAQS, top) and the

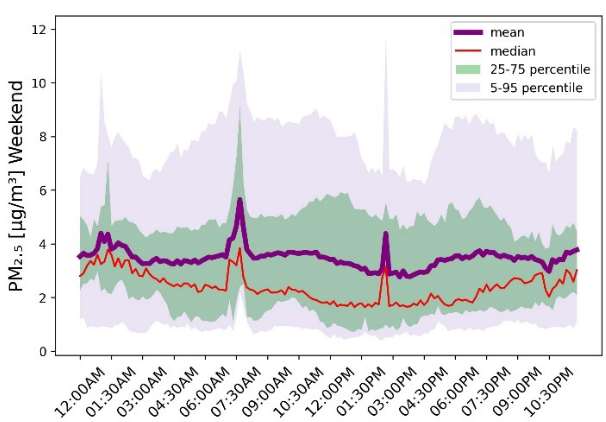
World Health Organization (WHO, bottom) for each size classification of PM. There are no standards set for PM_1, so the dashed lines on those plots are arbitrarily set at 5.0 µg/m^3 and 2.0 µg/m^3.

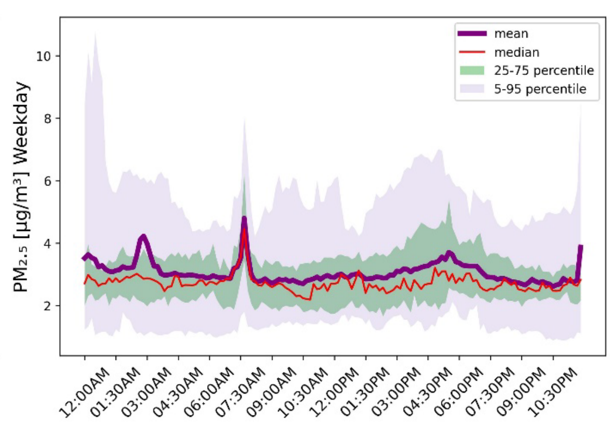
Diurnal Plots

Diurnal plots visualize PM concentrations for a "typical" day during the month for which the report was generated. There are six diurnal plots made for each sensor, which consist of two plots for each PM size classification (PM_1, $PM_{2.5}$, and PM_{10}), one for a typical weekday and one for a typical weekend day. The key components of these diurnal plots are the mean line (dark purple), the median line (red), the 25-75 percentile shaded region (dark green), and the 5-95 percentile shaded region (light blue).

The *median* of a group of data is the "middle value", or the *most likely concentration that might be experienced at that sensor over the course of the typical day in that month*. The *mean*, on the other hand, is the average of a set, or in this case, *the amount of PM the sensor may have been exposed to on average over the course of the month.* These two values will differ if there are a significant number of plumes in the set. For example, in the graph below, the mean line is always above the median line. When this happens, a person's exposure to PM at that sensor is largely contributed by plumes of pollutants.

Shaded regions represent important ranges in the data over the course of the month. The 25-75 percentile region, which shows the middle 50% of the data, displays *the most frequent concentrations of PM that occur on a typical day.* Using the graph below as reference, this means that on a typical day, the concentration of $PM_{2.5}$ on a weekend at 12:00PM is more frequently between 1.0 µg/m^3 and 5.5 µg/m^3 (using the edges of the shaded region) and is most likely to be around 2.0 µg/m^3 (median line). The 5-95 percentile region, which shows the middle 90% of the data, displays *the highest and lowest amounts of PM that have occurred throughout the month*. This means that at 12:00PM, at some point in the month, there was a day where the recorded concentration of $PM_{2.5}$ was about 8.5 µg/m^3, which is above the World Health Organization (WHO)'s annual average for healthy air.

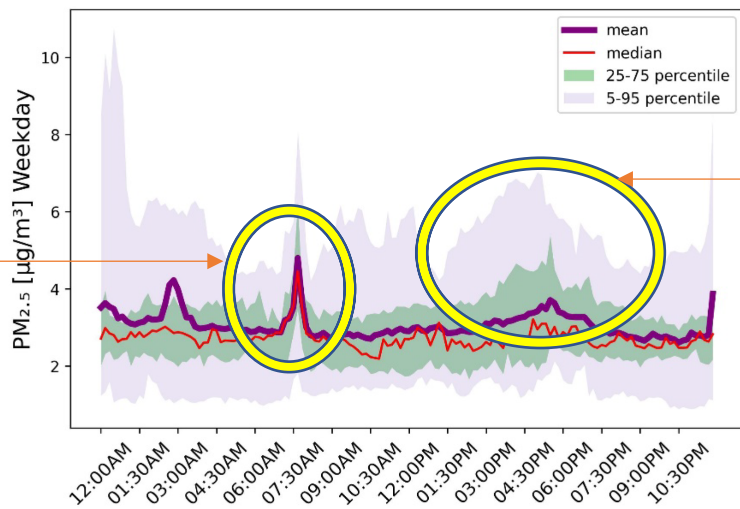




Above are two diurnal plots showing the $PM_{2.5}$ trends of weekends and weekdays over the course of June 2022. There are a few insights to be gathered from these graphs. One important one is that between the two graphs, the y-axis of the weekday graph is smaller than that of the weekend graph, indicating that during June 2022, air pollution concentrations were higher during weekends than during the weekdays. This could be due to increased road transportation on weekends due to travelers driving through Roxbury for recreational or leisure activities, or increased cooking activities on weekends. This is made more evident by the graph having larger shaded regions, illustrating that weekends experience more PM plumes than weekdays.

On the weekday graph, there is a spike on the mean and median line at around 7:30AM, which is commonly when the morning commute starts on a weekday and when traffic is at its worst. During the later half of the day, from 1:30PM to 7:30PM, the shaded regions and mean line indicate significant pollution plumes, which could result from midday cooking activities and the evening commute, which is highest around 5:00PM. (Similar conclusions can be drawn from the weekend diurnal plot.)

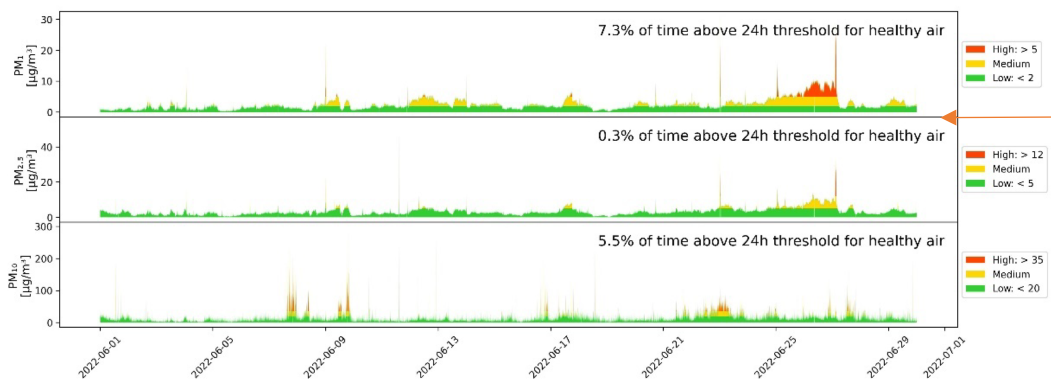
Spike in mean and median indicate overwhelming number of upward plumes, most likely from morning commute.



Large upward trends at tops of 25-75 and 5-95 shaded regions, as well as slight peak in mean line, can result from the evening commute.

Time Plots

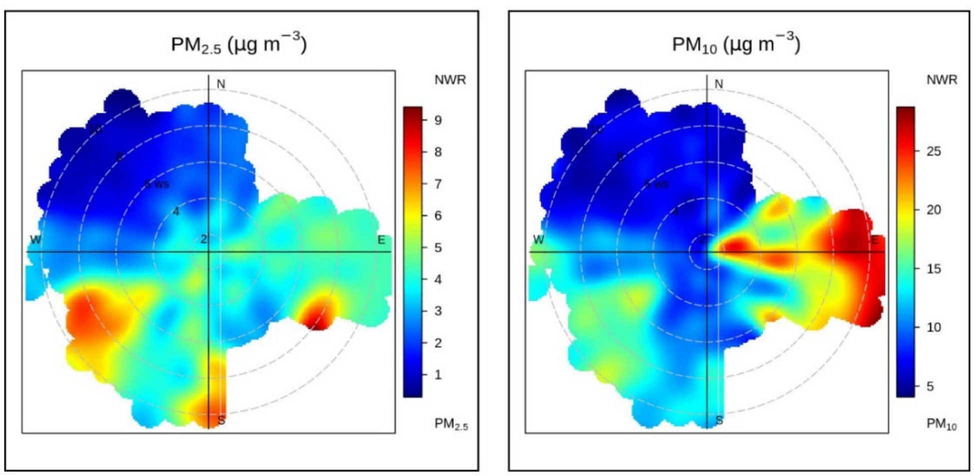
Time plots display all the data collected for each type of PM on a time series. The data used to make these plots are also used to make calendar plots, except that instead of calculating averages per hour or per day, the time plot displays that data with no averaging. The time plot uses the same thresholds as the calendar plot for coloring and determining when concentrations exceed NAAQS or WHO thresholds. Green points are below the WHO annual threshold; yellow data are greater than the WHO standard; and red NAAQS standard. Below is a time plot from the sensor nearby the Dearborn STEM Academy in Roxbury for the month of June 2022.



Near the end of the month, PM_1 and $PM_{2.5}$ levels are high, which is reflected in the calendar plots and could result from increased traffic due to vacation time starting in late June.

Wind Polar Plots

Wind polar plots portray the directions that different pollutants are coming from. Warmer (red and yellow) colors represent higher concentrations of PM, while cooler (blue and green) colors represent lower concentrations. Data are superimposed on a compass, indicating the direction of wind associated with pollutant concentrations. Concentric circles on the plot indicate wind speed (lower in the middle; higher on the outside). The position of warmer colors on these figures indicates the direction from which primary pollutant sources originate at a particular sensor. Multiple areas of warmer colors indicate pollutant sources from multiple directions.



Above shows two polar plots taken from the same sensor for different types of PM. The sensor is located on a parking lot northeast of Nubian Station, which is the busiest bus station in Roxbury. The left plot implies that there are high levels of $PM_{2.5}$ emerging from the general direction of that station (to the southwest of the sensor), which makes sense considering that a primary source of $PM_{2.5}$ is the burning of fossil fuels. However, the right plot conveys a different story; it indicates that larger particles are coming from due east of the lot. Northeast of the parking lot is a large construction site, which creates PM_{10} due to the dust, large piles of gravel, and diesel machinery.

These plots are created by collecting wind data from Logan Airport. Wind speed and wind direction at specific times are matched with the levels of the different types of PM read by the sensor to create this plot. To fill in the spaces between our readings, we use an algorithm called Non-parametric Wind Regression (NWR). This creates different lines of best fit through our data and uses all those trend lines to fill in the gaps.

Bibliography

1) Lin, Mei, et al. "The Influence of Ambient Coarse Particulate Matter on Asthma Hospitalization in Children: Case-Crossover and Time-Series Analyses." *National Institute of Environmental Health Sciences*, U.S. Department of Health and Human Services, 1 June 2002, https://ehp.niehs.nih.gov/doi/abs/10.1289/ehp.02110575.
2) Brook R. D., et al., American Heart Association Council on Epidemiology and Prevention, Council on the Kidney in Cardiovascular Disease, and Council on Nutrition, Physical Activity and Metabolism, *Circulation* ***121***, 2331–2378 (2010).
3) Potter NA, Meltzer GY, Avenbuan ON, Raja A, Zelikoff JT. Particulate Matter and Associated Metals: A Link with Neurotoxicity and Mental Health. *Atmosphere*. 2021; 12(4):425. https://doi.org/10.3390/atmos12040425
4) *EPA*, Environmental Protection Agency, https://www.epa.gov/criteria-air-pollutants/naaqs-table.
5) Wang, Xu, et al. "Ambient Particulate Matter (PM1, PM2.5, PM10) and Childhood Pneumonia: The Smaller Particle, the Greater Short-Term Impact?" *Science of The Total Environment*, Elsevier, 1 Feb. 2021, https://www.sciencedirect.com/science/article/abs/pii/S0048969721005775.
6) Hu, Kejia, et al. "Mortality Burden Attributable to PM1 in Zhejiang Province, China." *Environment International*, Pergamon, 3 Oct. 2018, https://www.sciencedirect.com/science/article/pii/S0160412018308213.