Spatial Gradients of Key Meteorological and Air Quality Variables in NYC Subway Stations

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Background:

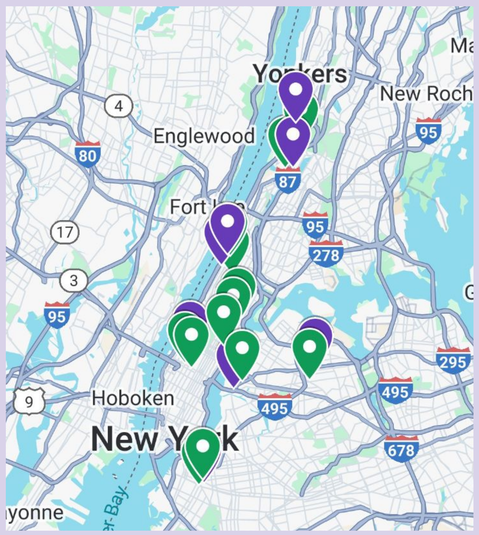
Air pollution remains a pressing environmental issue, particularly in metropolitan areas such as New York City. Metrics like the Air Quality Index (AQI) and heat index are commonly used to assess environmental conditions in subway stations since they harbor high concentrations of pollutants such as particulate matter (PM 2.5) and carbon monoxide (CO). PM 2.5 are microscopic particles produced by railway friction, electrical equipment, and braking systems. These can penetrate deep into the lungs and bloodstream, posing serious health risks such as cardiovascular and respiratory diseases. Our project analyzes real-time data collected from multiple subway stations across the city. By calculating and comparing metrics like AQI and heat index in underground and aboveground environments, we hope to identify the specific factors contributing to elevated PM 2.5 levels in subway systems. This is particularly relevant for low-income communities and people of color, who often rely on public transit for longer commutes and are disproportionately affected. Through our findings, we hope to raise awareness of environmental disparities and support data-driven improvements to transit ventilation and public health policy.

Research Objectives:

Motivation:
Identify causes of air pollution in varying subway station designs, varying foot traffic, and varying train activity

Question:
What are some sources and sinks of harmful particulate matter in NYC subway stations?

Study Area and Field Sampling:



Map of Stations Visited around NYC (green) and ambient air quality sensors locations (purple)

Data Collected:

Carbon Monoxide (CO) (ppm)

Carbon Dioxide (CO_2) (ppm)

$PM_{1.0}$ (µg/m³)

$PM_{2.5}$ (µg/m³)

$PM_{10.0}$ (µg/m³)

Relative Humidity (%)

Temperature (°F)

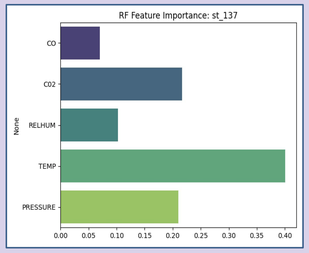
Pressure (hPa)

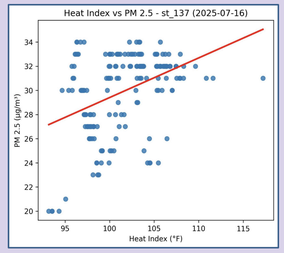
Methods:

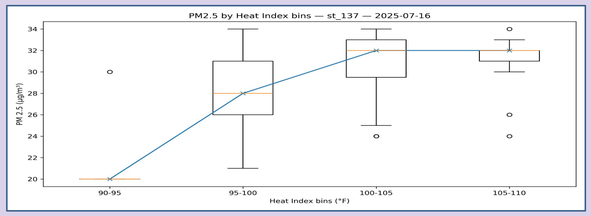
Procedure:
Air Quality data was collected in 13 stations across NYC using a Personal Air Monitor by 2B Tech. Data collected was in 10 minute blocks, one block in the middle of the platform, one at the edge of the platform, and one within the station nearest to an exit. Additionally data was collected from Purple Air API for ambient air quality closest to each station. Python and machine learning was then used to analyze the data as time series plots, violin plots, bar graphs, linear regressions, and random forest feature importance analysis.

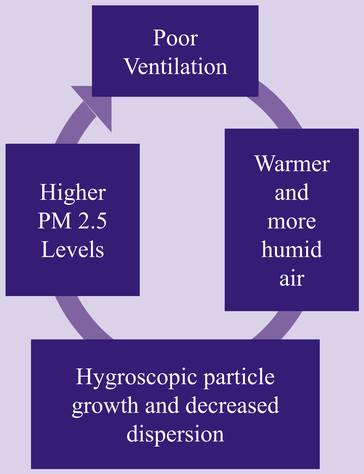
Results and Observations:

Influence of Heat Index on PM 2.5

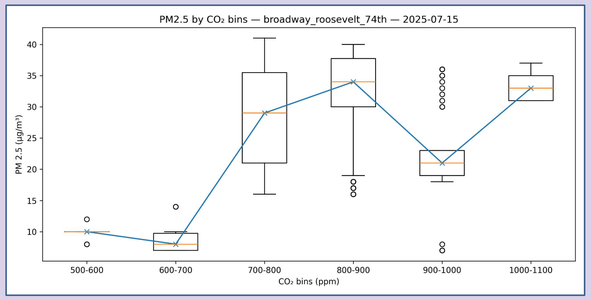






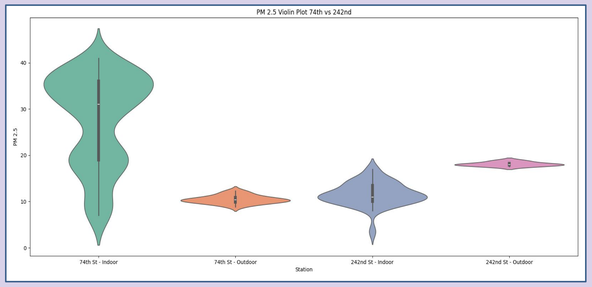


CO_2 Presence In subway stations



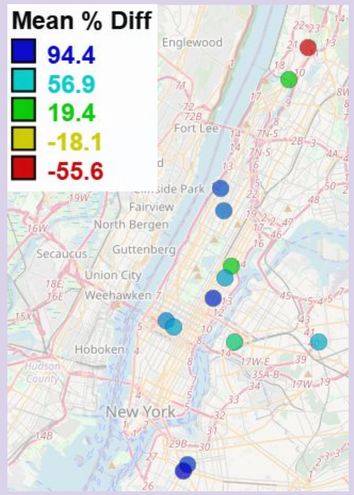
- Max CO_2 Values:
  1. 96th St: **1657** ppm
  2. 72nd St: **1555** ppm
  3. 137th St: **1308** ppm
- At 74th Broadway when CO2 exceeded 700 ppm, PM 2.5 exceeded 9 µg/m³ **8.965517%** of the time.

Differences between Above ground Stations



- 242nd street and 74th despite both being above ground station, had very different mean percent levels. 242nd street had a **-55.6%** mean difference between indoor and outdoor PM levels compared to 74th street which has a **56.9%** difference.

Results and Observations Continued:



- The Mid-Dark Blue stations with a mean difference **94.4%** were poorly ventilated, crowded, and contained PM traps such as construction.
- Greener areas with a mean difference of **19.4%** such as 225th street, 96th street and Court Square were properly ventilated, had lots of open space, and had little to no crowding
- 242nd, the only red station,with a mean difference of **-55.6%** had no crowds, not a lot of train movement, and was surrounded by lots of trees

Conclusions and Discussions:

- CO_2 was often a leading factor for $PM_{2.5}$ readings. CO_2 is a marker for $PM_{2.5}$, not a direct cause:
  - It is a byproduct of human activity (construction, crowding, and walking) which can lead to increased $PM_{2.5}$ and CO_2.
  - The MTA should utilize ventilation shafts with fans to exhaust polluted air and bring in fresh air into underground stations

- Above ground stations does not guarantee clean air; pollutant buildup can still occur through poor air flow. Poor airflow can trap $PM_{2.5}$ from sources such as construction, and railway systems.
  - The MTA should utilize control ventilation and sensors to adjust ventilation rates based off real time conditions, which would be energy efficient while sustaining low AQI levels

- Heat waves in NYC can cause PM to remain stagnant in the air in indoor with lack of proper ventilation
  - Linked to high humidity which allows particles to absorb water and grow in size and can't properly disperse in the air

References:

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