Urban Air Quality Impacts Inferred from Ground-Based Monitoring Networks Due to Geographic Variability and COVID-19 Pandemic

Abigail Maben

Faculty Advisor: Dr. Shantanu Jathar

Department of Mechanical Engineering

Introduction and Background

Human exposure to high levels of air pollutant levels (specifically fine particulate matter) is known to cause adverse health outcomes. Air pollution concentrations are dependent on both natural and anthropogenic sources with primary sources including combustion processes, wildfires, construction, roads, agriculture, and vehicles. The United States Environmental Protection Agency (EPA) regulates various air pollutants, which include fine particulate matter ($PM_{2.5}$), nitrogen dioxide (NO_2), and carbon monoxide (CO) through mass concentration measurements. These concentrations have been proven to spatially vary in cities in the United States. Understanding the extent of the variability with both time and space can give insight to the potential health implications for people living in urban areas. Variability in air pollution exposure can occur due to factors such as geographic location and significant changes in human activity.

Project Goals

1. Create a reliable network of autonomous low-cost $PM_{2.5}$ sensors to determine the spatiotemporal variability of $PM_{2.5}$ number concentrations and size distributions in a mid-size city using portable optical particle spectrometers (POPS).
2. Analyze EPA ground measurement $PM_{2.5}$, NO_2, and CO data from the 17 largest metropolitan areas in the United States to determine air quality variability due to the COVID-19 pandemic.

COVID-19 Analysis

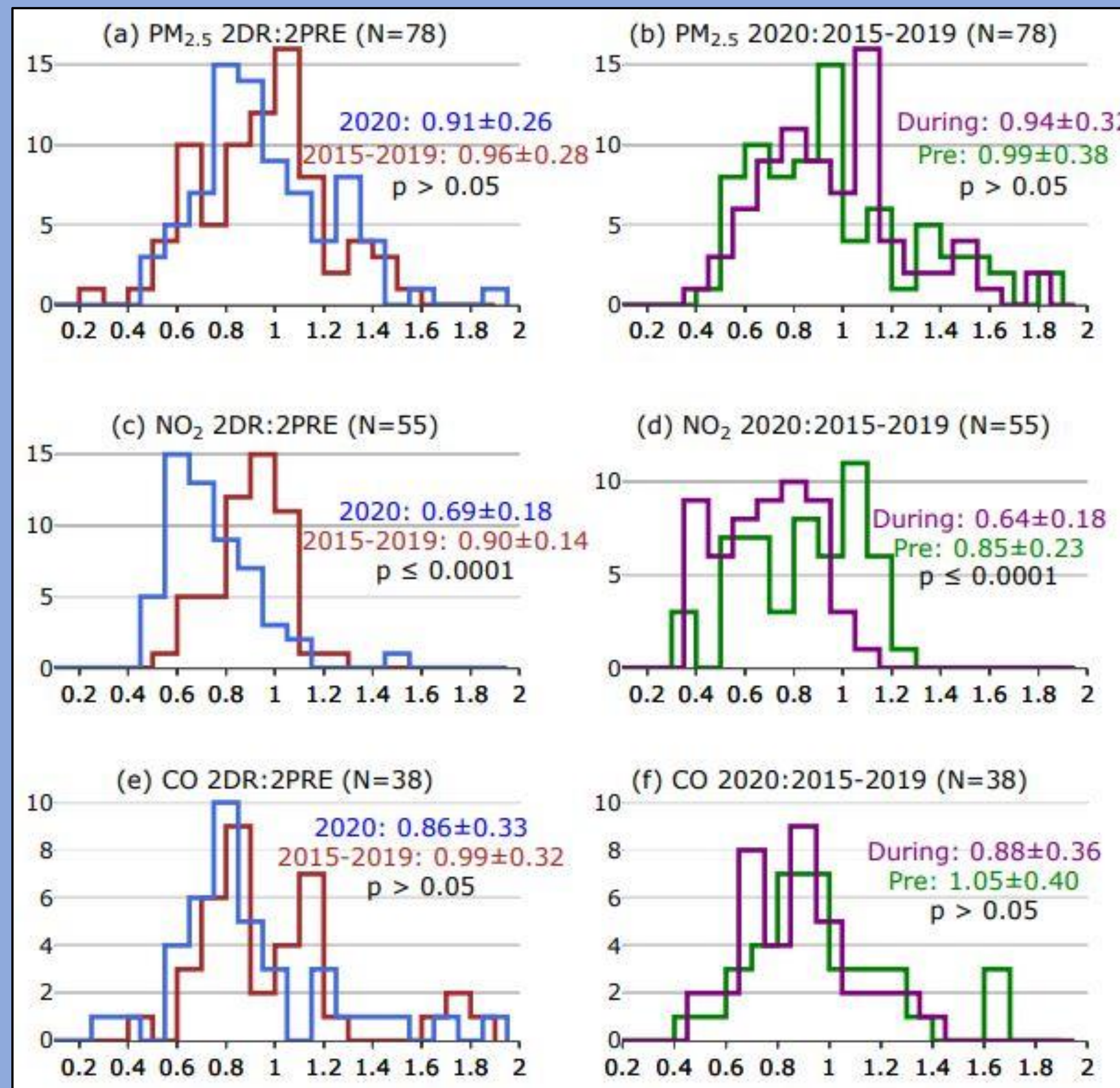


Figure 1: Histograms of 2-week period ratios comparing COVID time periods and normal time periods with N as the number of sites analyzed.

Methods:

- Analyzed three pollutants ($PM_{2.5}$, NO_2, CO)
- Studied 4-week period and 2-week period.
- Four time periods:
  - Pre-COVID (Feb-Mar)
  - During-COVID (Apr-May)
  - Normal Year (2015-2019)
  - COVID Year (2020)
- Analyzed changes in two sets of ratios:
  - Pre-COVID (PRE) vs. During-COVID (DR) for same year
  - 2020 vs. 2019 for same weeks

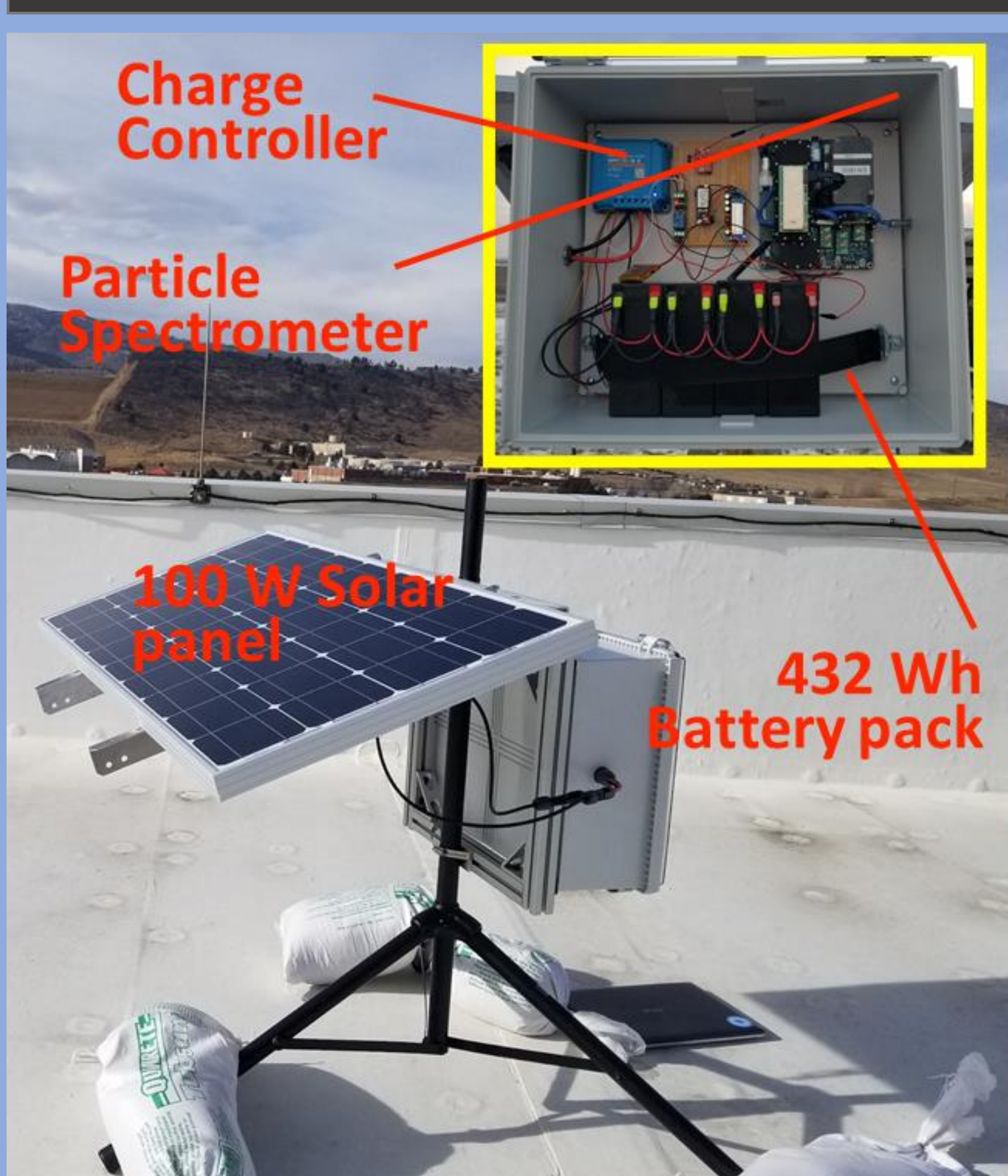
Results:

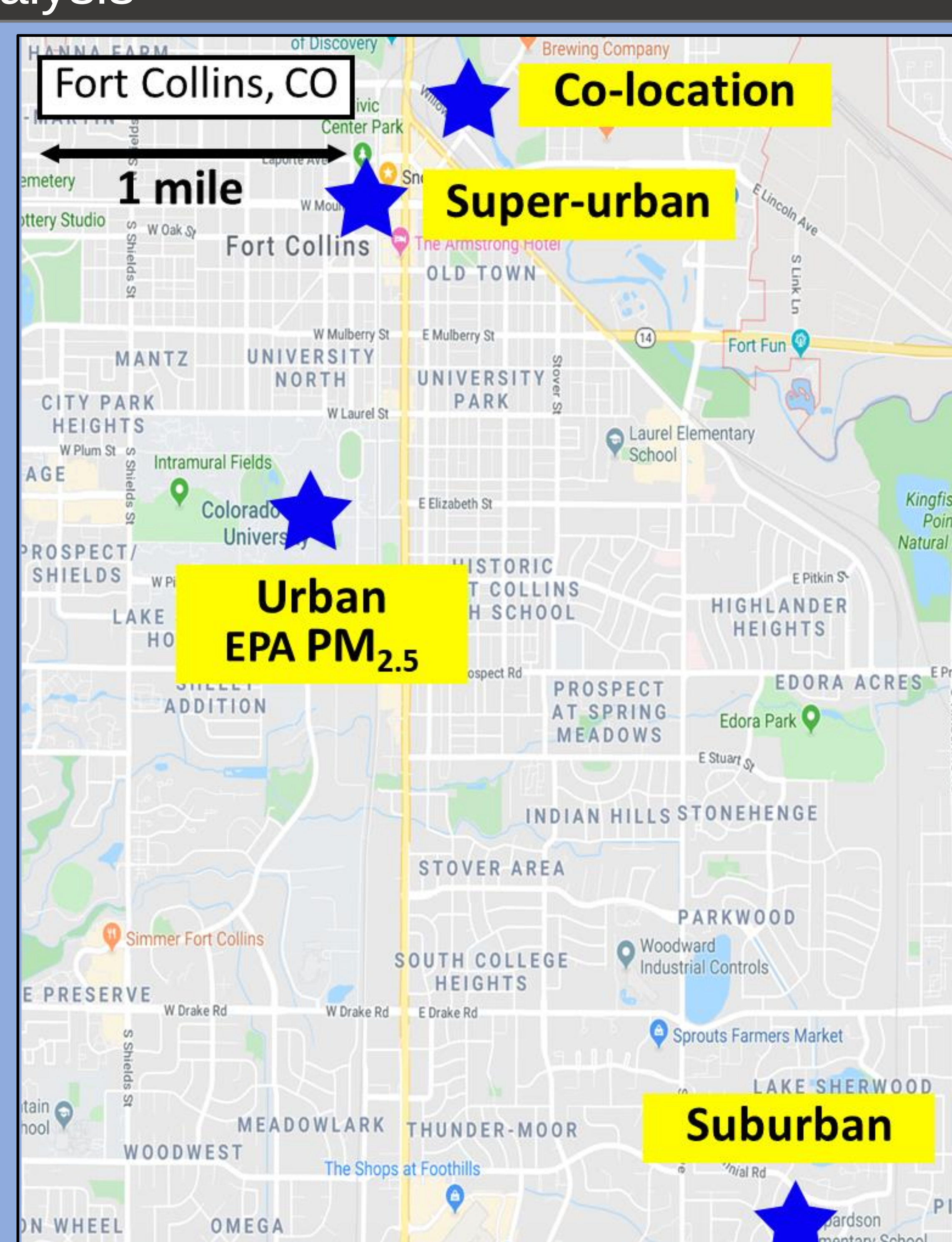
- $PM_{2.5}$
  - No significant changes for all time periods
- NO_2
  - 19% decrease for 4 weeks
  - 21% decrease for 2 weeks
- CO
  - 18% decrease for 4 weeks
  - No significant changes for 2 weeks

Conclusions:

- All pollutants had a decrease in concentration during to the pandemic restrictions, however not all can be attributed to a COVID effect.
- High p values for all $PM_{2.5}$ data and 2-week CO data indicate that the differences were likely year-to-year variability rather than a COVID effect.
- NO_2 had the most significant decreases due to being more influenced by traffic emissions.
- Sites with an increase in $PM_{2.5}$ concentrations were primarily located in the southeastern region of the United States due to abnormal changes in meteorology during 2020.

POPS Analysis

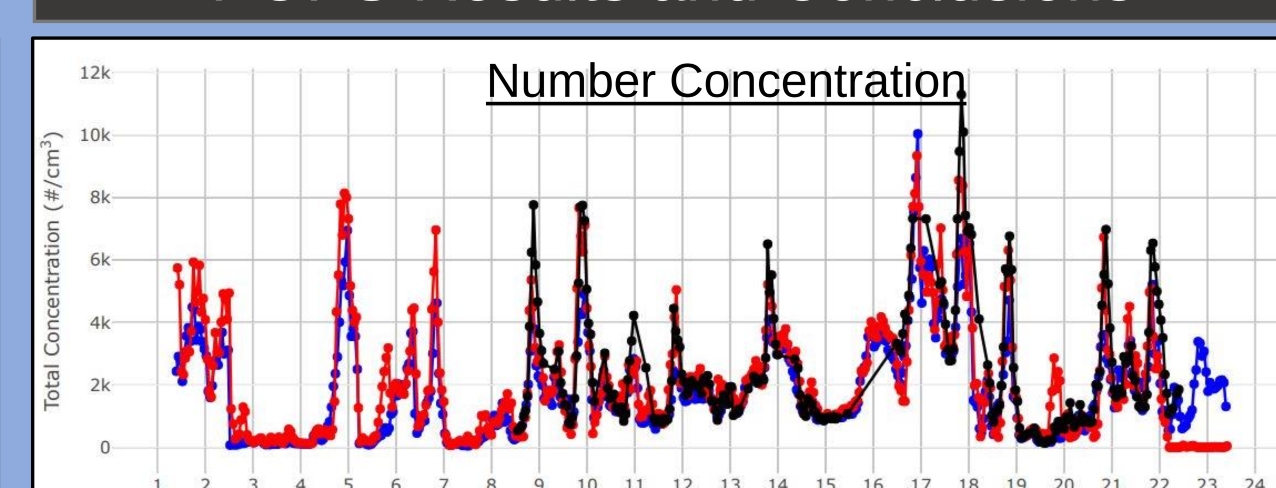




Methods:

1. Calibration and a week-long co-located study
2. A two-week network study in the field at the locations in the map above with the urban site in the same location as the EPA mass concentration sensor
3. A week-long co-located study to see if the calibration of the three POPS drifted while in the field

POPS Results and Conclusions



- Number concentrations had little to no variability for all sites and a strong correlation between the sites which can be seen in the time series above with the colors representing the different sites.
- Volume concentrations had more variability and lower correlations with the suburban site having an overall increase of 27% and the super-urban site having an overall decrease of 23% when compared to the urban site.
- The differences observed for the trends are due to variability in sources. Traffic and restaurant emissions tend to be smaller in diameter than natural sources causing the super-urban site to decrease in volume concentration.
- The suburban site will experience greater effects of natural sources, such as dust, which tend to be on the larger end of $PM_{2.5}$ size distributions, causing the suburban site to experience an increase in volume concentration in comparison to the urban site.

References:

Boldo, E. et. all. (2011). Health impact assessment of a reduction in ambient PM2.5 levels in Spain. Environmental International, 37(2), 342-348.

Tucker, G. W. (2000). An overview of PM2.5 sources and control strategies. Fuel Processing Technology, 65-66, 379-392.

Pinto, J. P. et. all. (2004). Spatial Variability of PM2.5 in Urban Areas in the United States. Air & Waste Management Association, 54, 440-449.