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Mapping Air Quality Throughout the Greater Richmond Area

A BETTER BREATH

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Introduction

In a new collaborative project, the Science Museum of Virginia, the University of Richmond and VCU is collecting and analyzing data on the spatial and temporal variability in air quality data for the City of Richmond. This work builds on earlier research that mapped the urban heat island effect in the city which studied and identified specific neighborhoods and communities that are highly vulnerable to heat stress and related health concerns. This follow-up study examines whether similar patterns exist for air quality in the city.

Pollution and poor air quality have detrimental effects on human and environmental well-being, and they are often tied to complex societal factors. For example, multiple studies have already documented the correlation between air pollution and COVID-19 infection and mortality rates. Our analysis aims to identify connections between social, demographic, and economic variables and spatial patterns of pollution in Richmond, Virginia.

Figure 1. Comparison of air quality before and after the nationwide lockdown due to the spread of COVID-19. Taken in front of the India Gate in New Delhi, the left side of the picture shows how polluted the air was in October 2019 compared to the clear sky in April 2020.

Background

Following principles of citizen-science, 15 PurpleAir air quality sensors are being hosted at homes and businesses in the RVA. These sensors measure temperature and humidity and use laser particle counters to quantify the concentration of suspended particles of varying sizes. We focused on the measurements of atmospheric particulate matter of fewer than 2.5 micrometers (µg) in size (PM2.5) since these particles have been shown to severely impact human health. The higher the PM2.5 level, the worse the air quality. The lungs usually block coarser particles like PM10, and finer particles like PM1 have not been studied enough to be considered a threat to human health.

When the temperature rises, air quality tends to worsen since the convection of cool and warm air creates an atmospheric lid that traps air pollutants thus increasing their concentration. An increase in humidity also affects the light scattering used to measure particulate matter by the sensors, which can result in increased PM2.5 readings. So, throughout a typical spring-to-summer transition, we would expect increasing PM2.5 measurements due to higher humidity and higher temperatures. We were curious whether this seasonal trend would be disrupted by the community actions taken in response to the COVID-19 crisis and whether our new sensor network would be able to detect any associated changes in air quality.

Figure 2. Picture of the UR4 air quality sensor. This sensor is located on the side of the Jepson Hall building on the University of Richmond campus.

Figure 3. Close-up picture of the UR4 sensor.

Map of PurpleAir Sensors

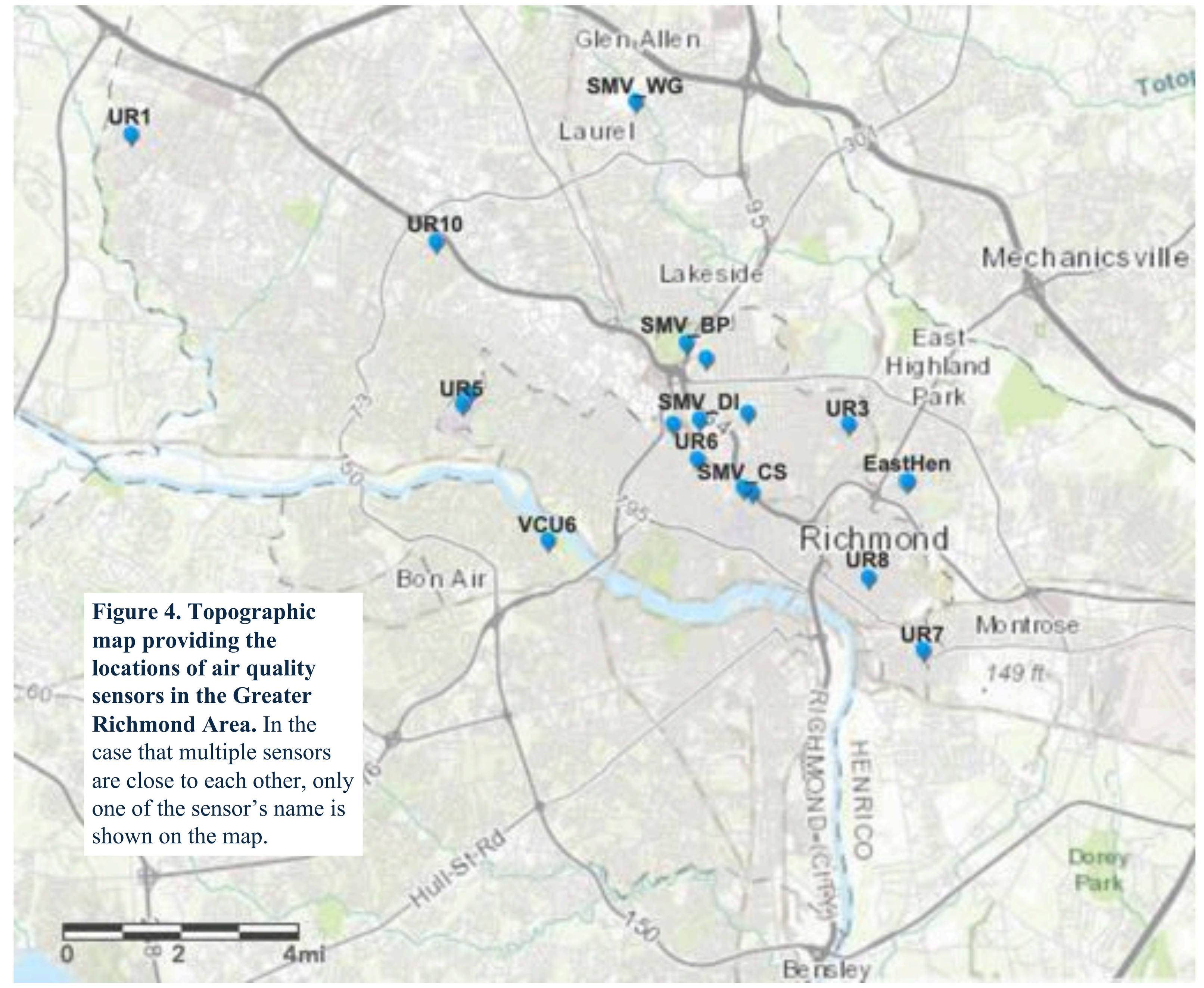

Figure 4. Topographic map providing the locations of air quality sensors in the Greater Richmond Area. In the case that multiple sensors are close to each other, only one of the sensor's name is shown on the map.

Bus Burned in Richmond Riot

Figure 5. Photo taken of the burning GRTC Pulse bus in Richmond, Virginia during a protest.

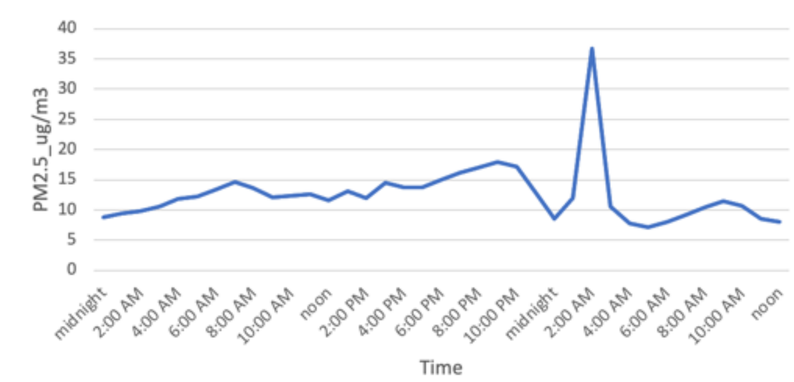

Figure 6. Hourly averages of PM2.5 air quality shown as a line graph. The data was collected from midnight of May 29th to noon of May 30th using the PurpleAir sensor located on Clay St.

On May 29th, hundreds of people marched down the streets in Richmond to protest George Floyd's death. Some protesters set a GRTC Pulse bus on fire. The PurpleAir sensor on Clay St. captured the air quality data from this event. From the graph the large spike can be seen when the bus was destroyed on May 30th around 2:00 AM.

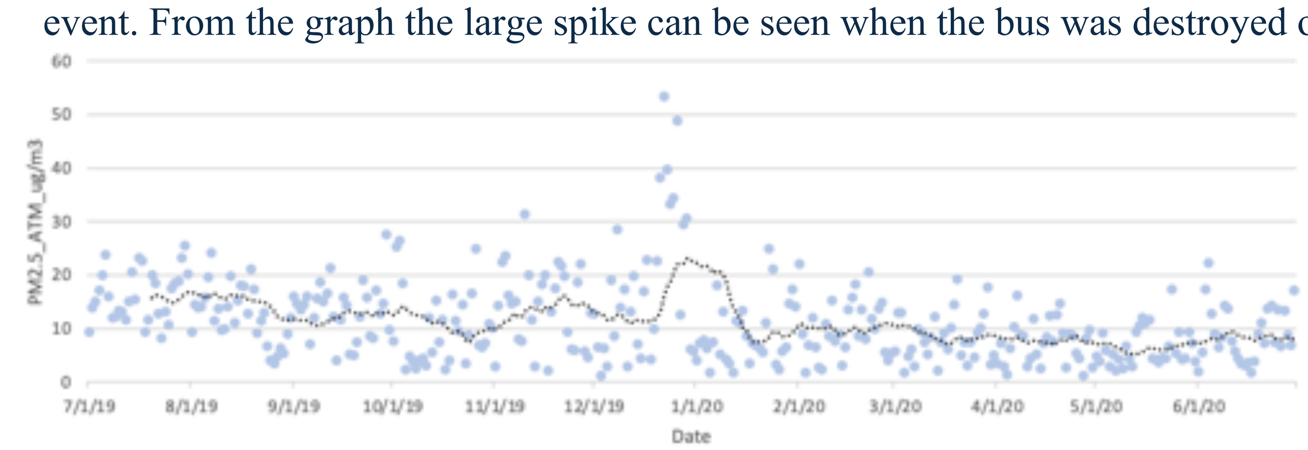

Figure 7. The pattern of PM2.5 data shown over a 12-month long period. The data was collected from UR5, a sensor located on the Tyler Hanes Commons building on the University of Richmond campus.

Results

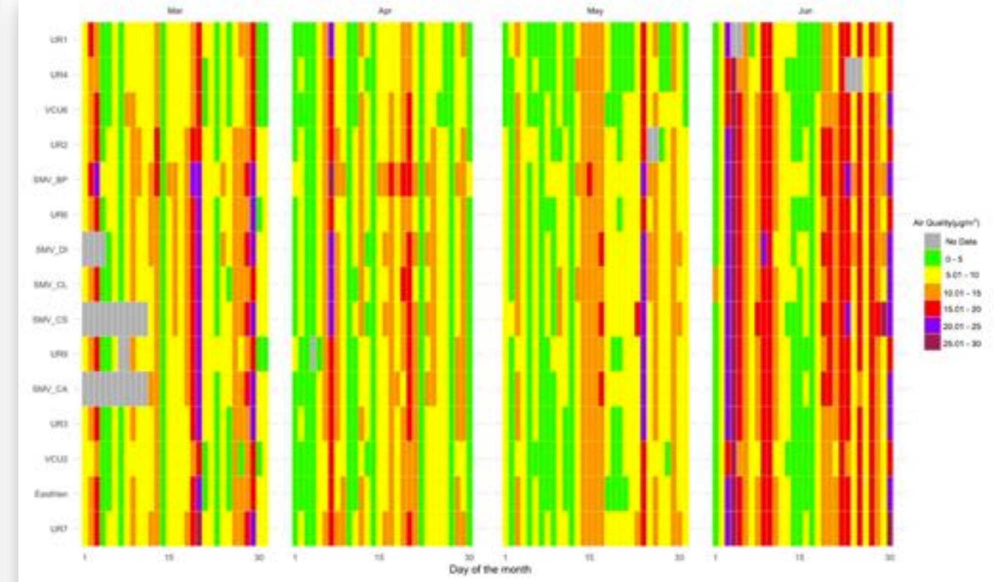

Figure 8. Daily average PM2.5 concentration from March to June using the raw data from PurpleAir. Daily values are provided for each of the 15 sensors installed in homes and businesses of the RVA. The individual sensors are labeled along the y-axis and match the labels on the map in Figure 4. The daily average PM2.5 concentration recorded at the sensor is depicted by the different colors for each day, with warmer colors like red and purple representing poorer air quality.

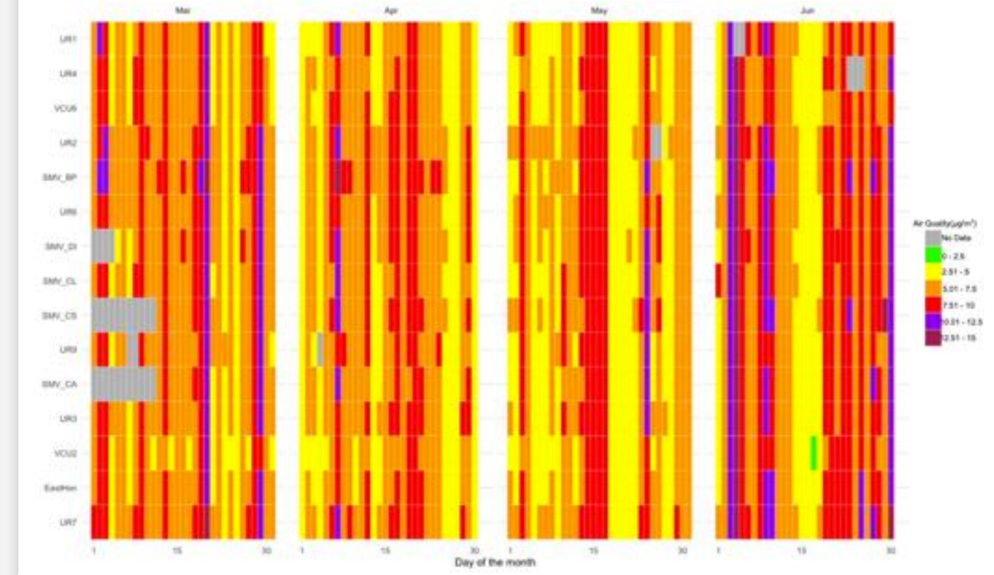

Figure 9. Daily average PM2.5 concentration from March to June using the temperature and relative humidity-corrected data. To account for factors such as temperature and humidity on PM2.5, the correction formula PM2.5 = 0.39*PA +0.0024*T -0.050*RH + 5.19 (PA = Original PM2.5, T = Temperature, and RH = Relative Humidity) was applied to the raw concentrations from the sensors.

Figure 10. Line graph of the daily average PM2.5 concentration from March to June using the raw data from PurpleAir. Daily values are provided for 1 sensor located at Vasen Brewing Company in the Scott's Addition District.

Discussion

The results indicate that, on average, PM2.5 levels slowly rose throughout March, dropped suddenly between March and April, then rose again throughout the summer. The sudden drop in PM2.5 can be attributed to Virginia Executive Order 55, which was effective March 30th, 2020. This stay-at-home order substantially decreased the amount of traffic in the city. Nationwide, vehicle mileage bottomed out on April 9th, recovering to about 90% of pre-pandemic levels by mid June.

The PM2.5 concentrations measured at Scott's Addition, an area of the city identified by the urban heat island analysis as likely to have elevated pollution levels, were significantly lower during the month of April following the executive order (7.6 µg/m³) than for March, before the executive order went into effect (9.8 µg/m³, $p<0.05$). For the entire sensor network, the mean PM2.5 concentrations in April (7.7 µg/m³) were also significantly lower than for March (9.4 µg/m³, $p< 0.05$).

Acknowledgments

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