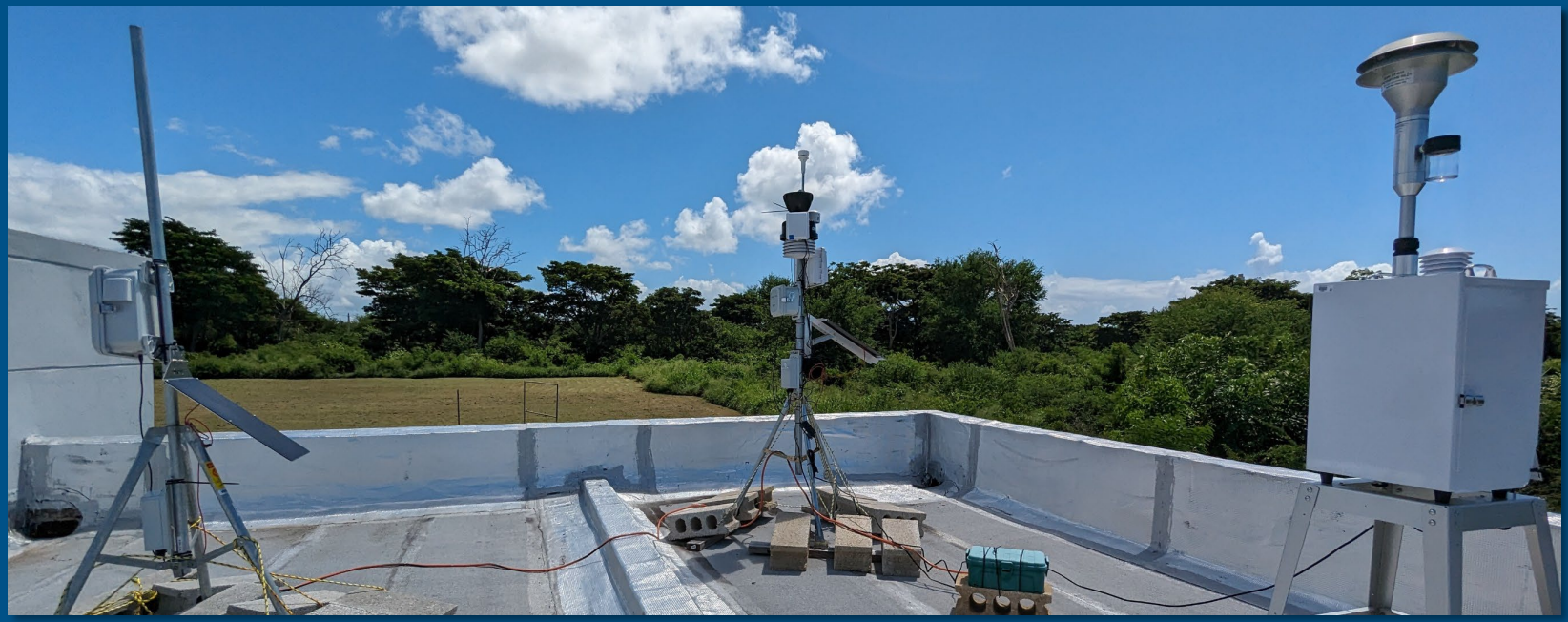
Puente Jobos Particulate Matter Community Monitoring Study

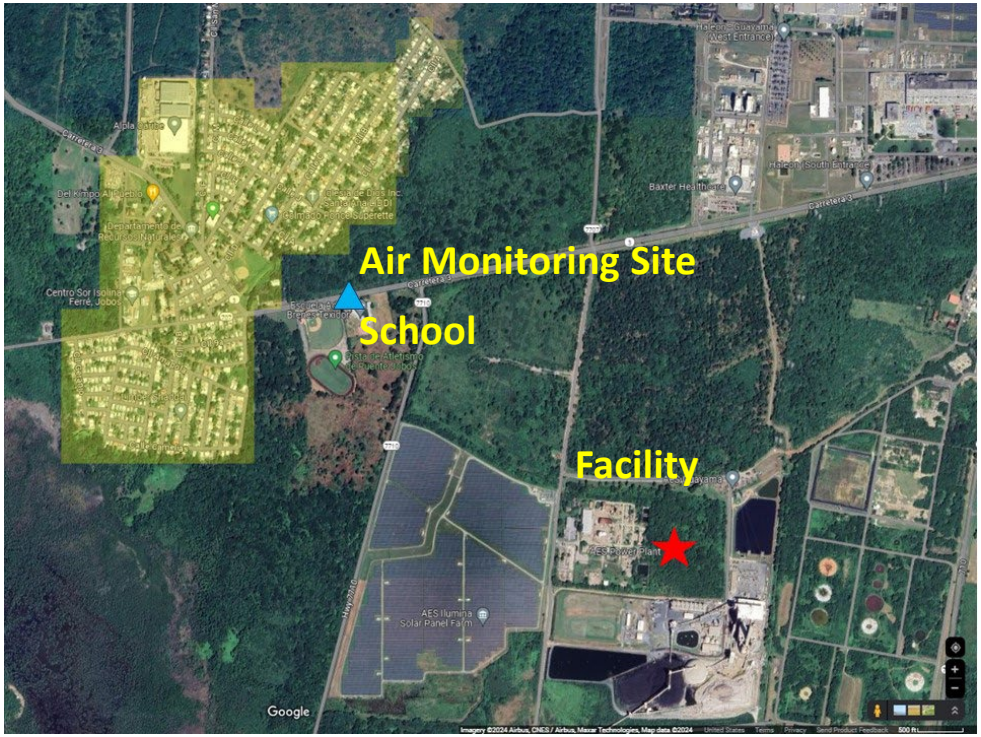
Amara Holder[1], Gavin Lau[2], Sarah Pender[2], Matt Landis[1], Maribel Colón[1], Farnaz Nojavan[1], Kasey Kovalcik[1], Gary Norris[1], Gayle Hagler[1]

[1]EPA Office of Research and Development

[2]EPA Region 2



Project Background

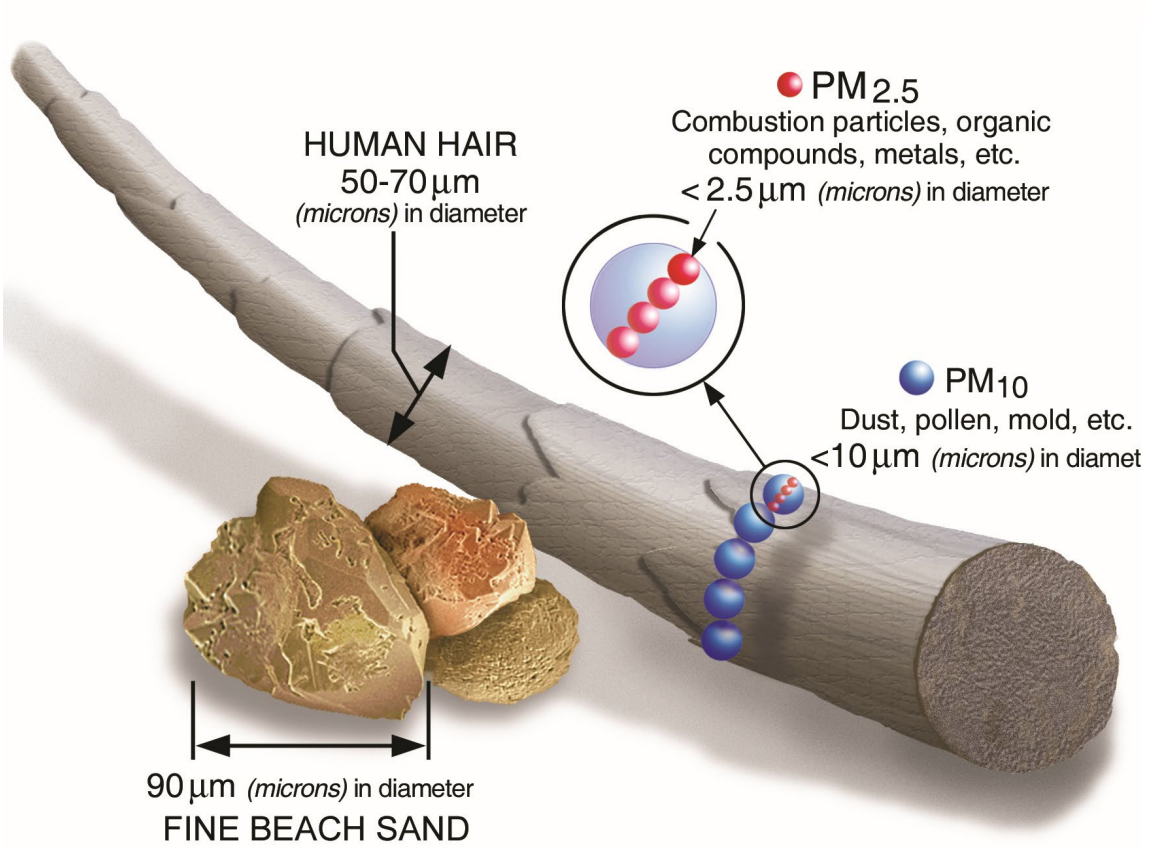


Fugitive dust = particles that enter air from open sources
Coal combustion residuals = byproduct of burning coal

Community Concerns Expressed to EPA in 2022

- Fugitive dust from coal combustion residuals at nearby facility ★ is impacting air quality in the community – expressed particular concern about a nearby school
- Questioned whether the official Puerto Rico Department of Natural and Environmental Resources (PR-DNER) air monitoring site ▲ location represents the air quality in the community
- Concerned about what chemicals/compounds are in particulate matter

Project Background



- Presentation will focus on two particulate matter (PM) measurements that are both regulated under the National Ambient Air Quality Standards (NAAQS)
  - $PM_{2.5}$
  - PM_{10}
- Coal combustion residuals are expected to be mostly in the PM_{10} size range due to their larger size
- Emissions from coal and other combustion sources (vehicle exhaust, wood burning) are typically in the $PM_{2.5}$ size range

Project Background: Official Air Quality Monitoring in Puente Jobos by PRDNER

Began operation in 2020

- $PM_{2.5}$ (1 sample every 3 days) last sampled in 2022
- PM_{10} (1 sample every 6 days)
- Approved and audited by EPA

- 1999-2017, PM monitoring was conducted by PRDNER at a school near the intersection of PR Rd 3 and 707
  - The site closed after Hurricane Maria
- In 2020 a new site was established by PRDNER at a school about 1000 ft east of the previous location on PR Rd 3
- The 2020 earthquake and COVID-19 lockdown led to missing data
- Operations resumed in Fall 2021
- There have been no historical NAAQS attainment issues at the Guayama sites related to $PM_{2.5}$ and PM_{10}

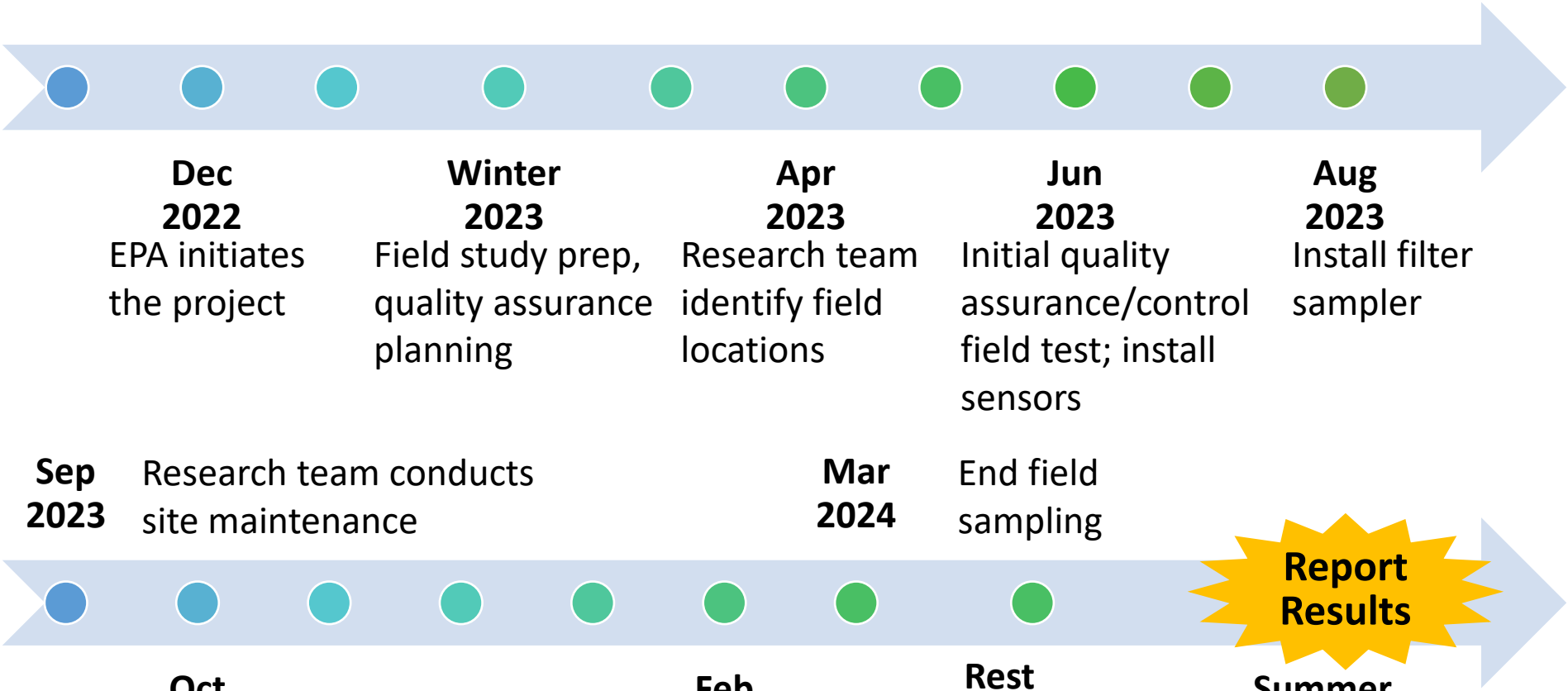
Link to data:

https://www.epa.gov/outdoor-air-quality-data

Community Input to Project Design

Community Input	EPA Action
Concerns about coal combustion residuals on air quality	Developed project to measure particulate matter (PM) concentrations in Puente Jobos
Does air monitoring site represent air quality in the community?	Deployed sensors at school (Escuela Adela Brenes Texidor) and nearby areas
Concerns about more than $PM_{2.5}$	Added sensors for PM_{10}
What is in the particles we are breathing in?	Added a regulatory monitor to measure PM_{10} mass and the compounds in PM_{10}
What is the air quality in surrounding neighborhoods?	Added four downwind sites in neighboring communities
How will we know what is happening with the project?	Provided monthly updates via newsletters and periodic presentations

Project Timeline



Dec 2022
EPA initiates the project

Winter 2023
Field study prep, quality assurance planning

Apr 2023
Research team identify field locations

Jun 2023
Initial quality assurance/control field test; install sensors

Aug 2023
Install filter sampler

Sep 2023
Research team conducts site maintenance

Mar 2024
End field sampling

Report Results

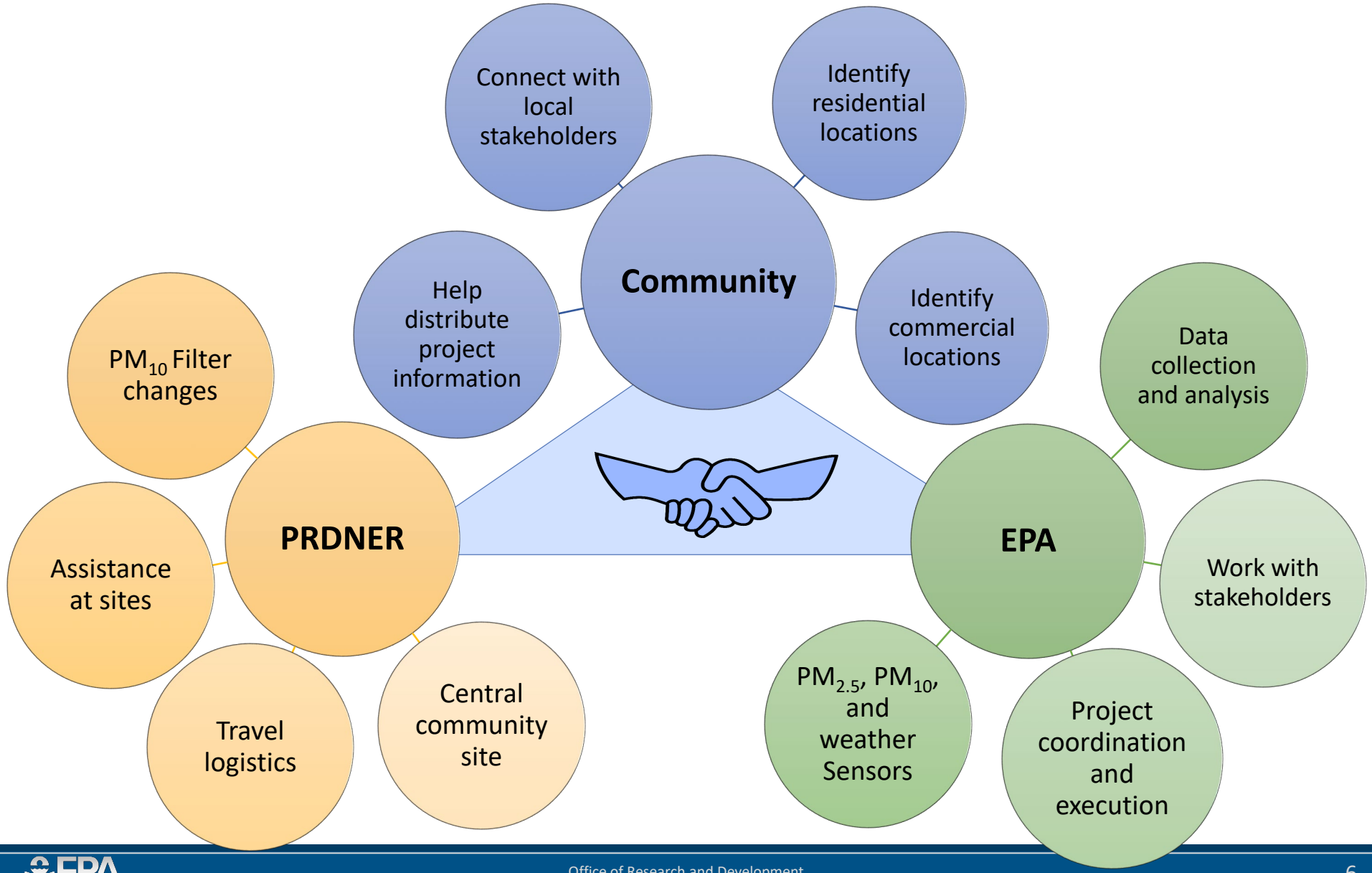
Oct 2023
Research team conducts site maintenance

Feb 2024
Final quality assurance/control field test

Rest of 2024
Lab and data analysis

Summer 2025

Collaboration has been a Key Component



Communication was a Priority during Data Collection

- Study team provided routine updates on research progress during the data collection phase (July 2023 through March 2024)
- Updates included summaries of preliminary data collected during the month and any notable research activities
- Monthly project updates available in English and Spanish versions

Particulate Matter Research Study in the Guayama and Salinas area of Puerto Rico: Research Project Updates for August, 2023

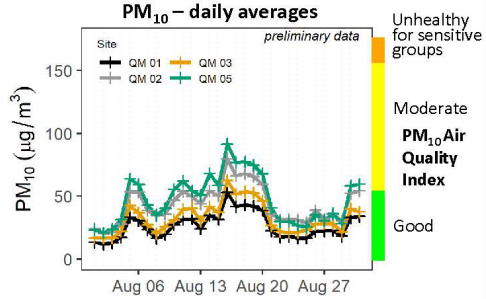
Field Study Updates:

- In August, the EPA research team installed the sampler to collect air filters for PM_{10} chemical analysis. EPA provided training to DNER collaborators on how to maintain the sampler for the project. The team visited several sites to check on sensor equipment, download data, and connect two sensors to the internet.
- One PM_{10} sensor (QM 04) malfunctioned and the sensor's data are not shown in the newsletter. Assessment of the sensor (QM 04) is underway. Several PA sensors did not have online data available to include.

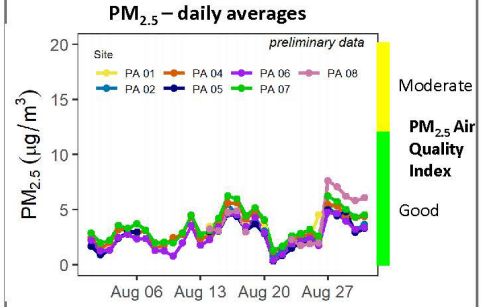
Photo credit: Maribel Colon

Photo credit: Matt Landis

Summary of data from online sites for August, 2023



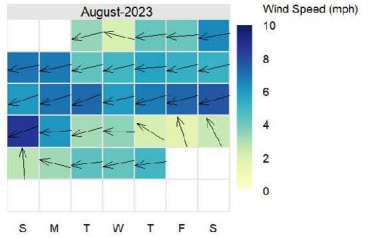
Interpreting the data: PM_{10} trends were similar throughout the community but some locations (QM02 and QM05) reported higher average values. The data are still preliminary and further analysis may be needed to control for variation in this newer model sensor technology. During August, there were five days when the air quality at some sites was **Moderate**, due to elevated PM_{10}.



Interpreting the data: $PM_{2.5}$ was approximately the same across all locations for most of August. All days had **Good** air quality for $PM_{2.5}$.

For more information about the Air Quality Index: Daily average plots of $PM_{2.5}$ and PM_{10}, show the Air Quality Index (AQI) on the righthand side, which is an indicator of how clean or polluted is the air. More information on the AQI is available at https://www.airnow.gov/aqi/aqi-basics/.

Daily average wind speed (color) and wind direction (arrow)



Interpreting the data: The wind ranged from light to moderate breezes, often from the East.

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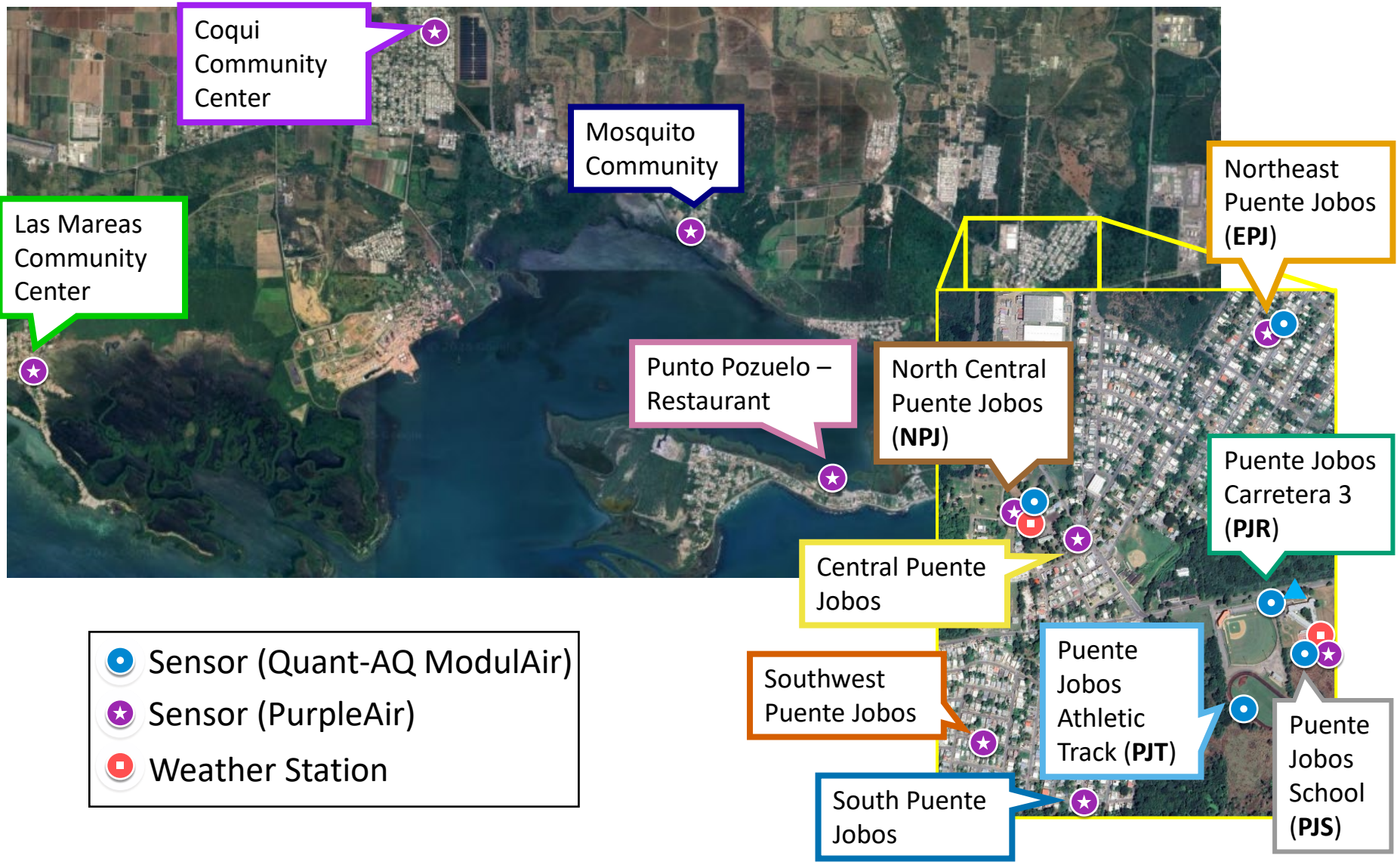
Community Monitoring Sites



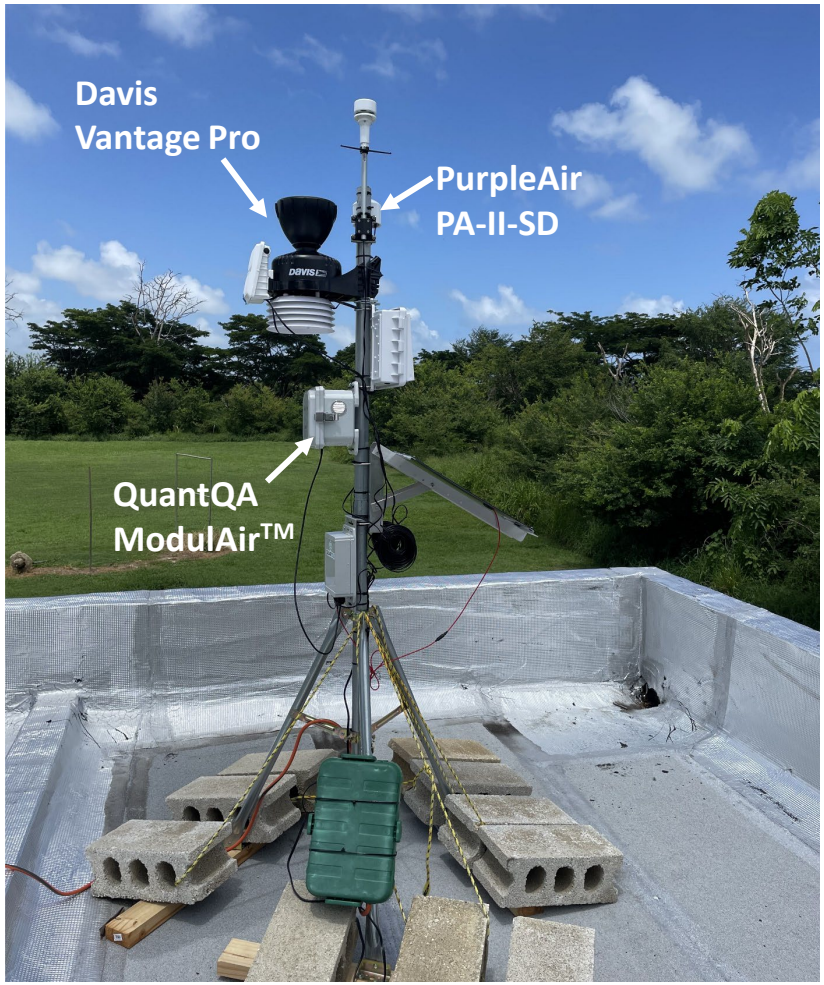
Sensor Measurement

Used three lower-cost sensor packages

1. **QuantAQ ModulAir™ PM**
Sensor package measures PM_{10} and $PM_{2.5}$ and is sensitive to the larger particles in dust, data reports online, but not public

2. **PurpleAir PA-II-SD Sensor**
Sensor package measures $PM_{2.5}$, does not respond to dust, data reports online and is public

3. **Davis Vantage Pro**
Sensor packages measures temperature, relative humidity, wind speed and wind direction, data reports online, but not public



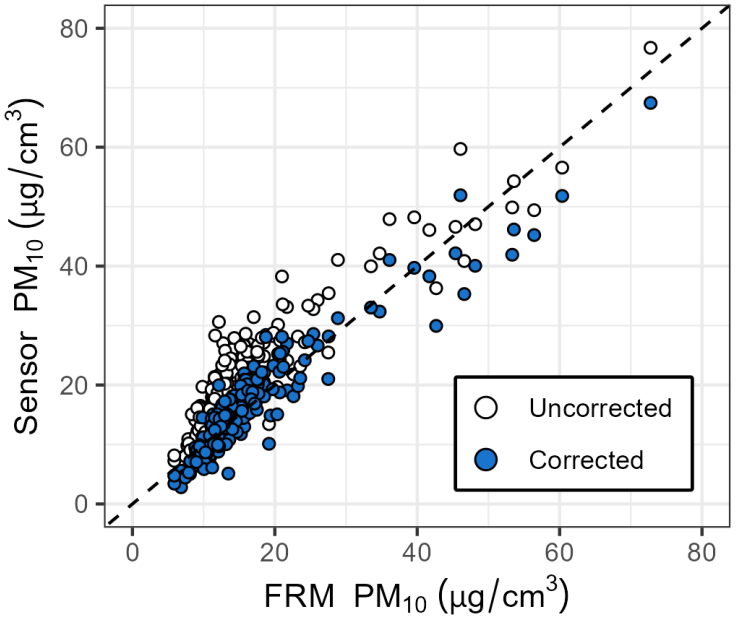
PM Filter Measurement Methods

Used a federal reference method (FRM) filter sampler MetOne Sequential Sampler (E-SEQ-FRM) to collect daily PM_{10} filters

PM_{10} concentration was first determined from filter mass, then filters were measured for trace element composition (e.g., magnesium, calcium, phosphorous, etc.). We used two approaches to measure the type and amount of elements:

- An X-ray fluorescence (XRF) technique was used to measure elements and is the standard method used for the chemical speciation network across the US.
  → *The team found that element measurements for many samples were below this method's detection limit.*
- We next used inductively coupled mass spectrometry (ICP-MS) method since it is more sensitive and can measure many more compounds at lower concentrations.

QuantAQ ModulAir Quality Control Procedures



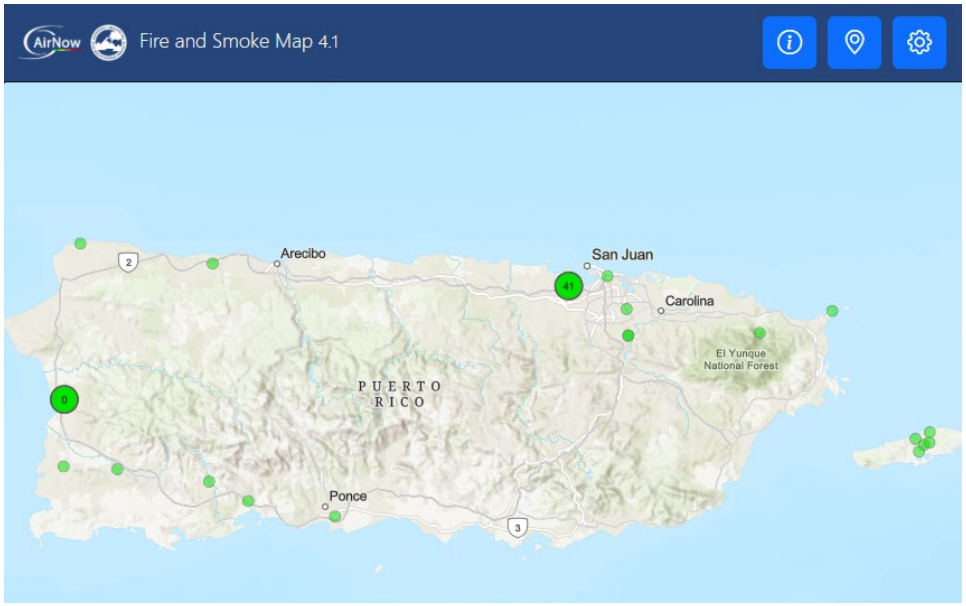
The accuracy of the raw sensor data is improved by using a linear correction equation that accounts for site specific features like PM size, relative humidity, and temperature

- Collocated sensors side-by-side to compare with each other and increase precision
  - Before study in Ponce from Apr 26 to Jun 11, 2023
  - After study in Puente Jobos from Feb 21 to Mar 13, 2024

- A long-term collocation at the school (PJS) was used to increase the accuracy of the PM_{10} concentration compared to the federal reference method (FRM) filter measurement
  - Puente Jobos from Jun 16, 2023 to Mar 13 2024

PurpleAir Quality Control Procedures

- PurpleAir are only sensitive to smaller particles in $PM_{2.5}$, but do not report accurate data for PM_{10}
- Used established correction procedure to improve accuracy of PurpleAir $PM_{2.5}$ data following the methodology used on EPA's AirNow Fire and Smoke Map



AirNow Fire and Smoke Map, showing sensor measurements (small circles) in Puerto Rico

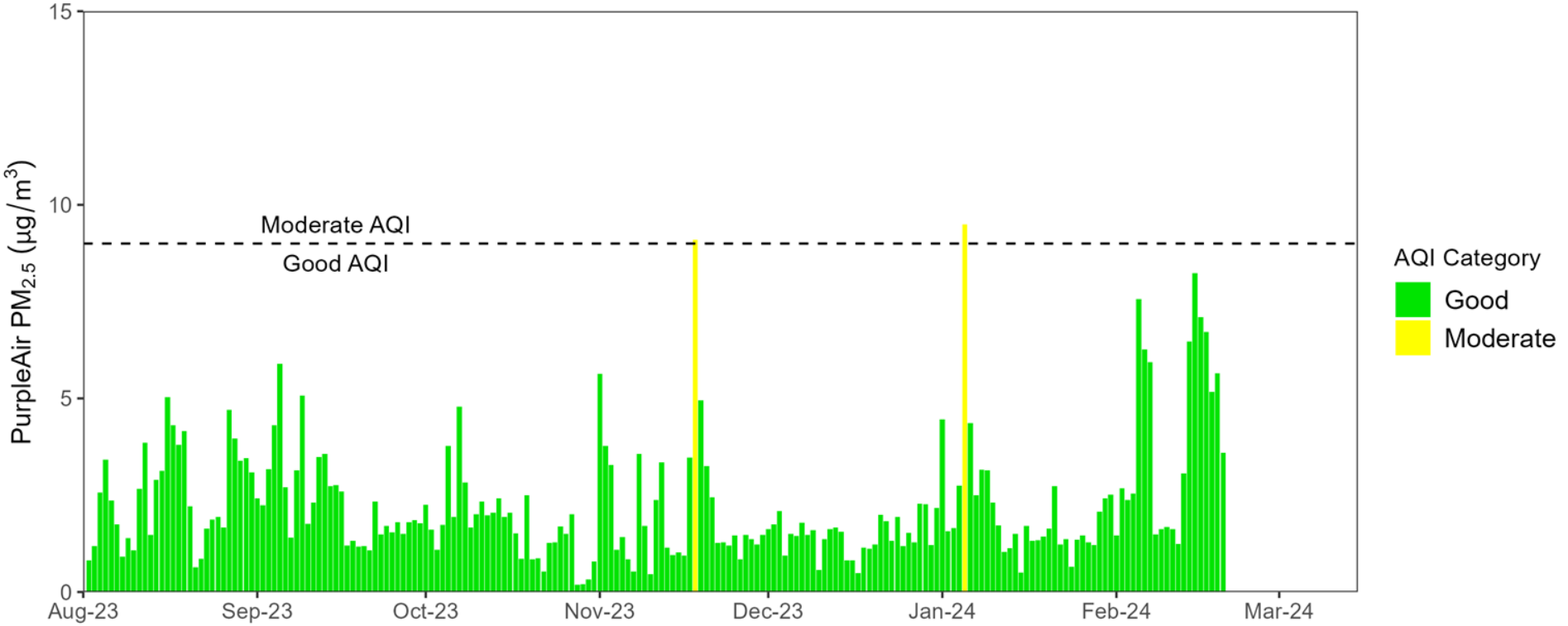
- Correction developed from a U.S.-wide study of PurpleAir sensor compared to $PM_{2.5}$ FRM filter measurements
- QuantAQ $PM_{2.5}$ data was corrected to collocated PurpleAir in this study to provide comparable concentrations across study sensors

Air Quality Index (AQI) Refresher

AQI Color	Levels of Concern	$PM_{2.5}$ Limits $\mu g/m^3$	PM_{10} Limits $\mu g/m^3$	Description of Air Quality
Green	Good	0 – 9.0	0 – 54	Air quality is satisfactory, and air pollution poses little or no risk
Yellow	Moderate	9.1 – 35.4	55 – 154	Air quality is acceptable. However, there may be a risk for some people, particularly those who are unusually sensitive to air pollution.
Orange	Unhealthy for Sensitive Groups	35.5 – 55.4	155 – 254	Members of sensitive groups may experience health effects. The general public is less likely to be affected.
Red	Unhealthy	55.5 – 125.4	255 – 354	Some members of the general public may experience health effects; members of sensitive groups may experience more serious health effects.
Purple	Very Unhealthy	125.5 – 225.4	355 – 424	Health alert: The risk of health effects is increased for everyone.
Maroon	Hazardous	225.5 +	425 +	Health warning of emergency conditions: everyone is more likely to be affected.

Only Good (green) and Moderate (yellow) AQI Categories were observed during our study

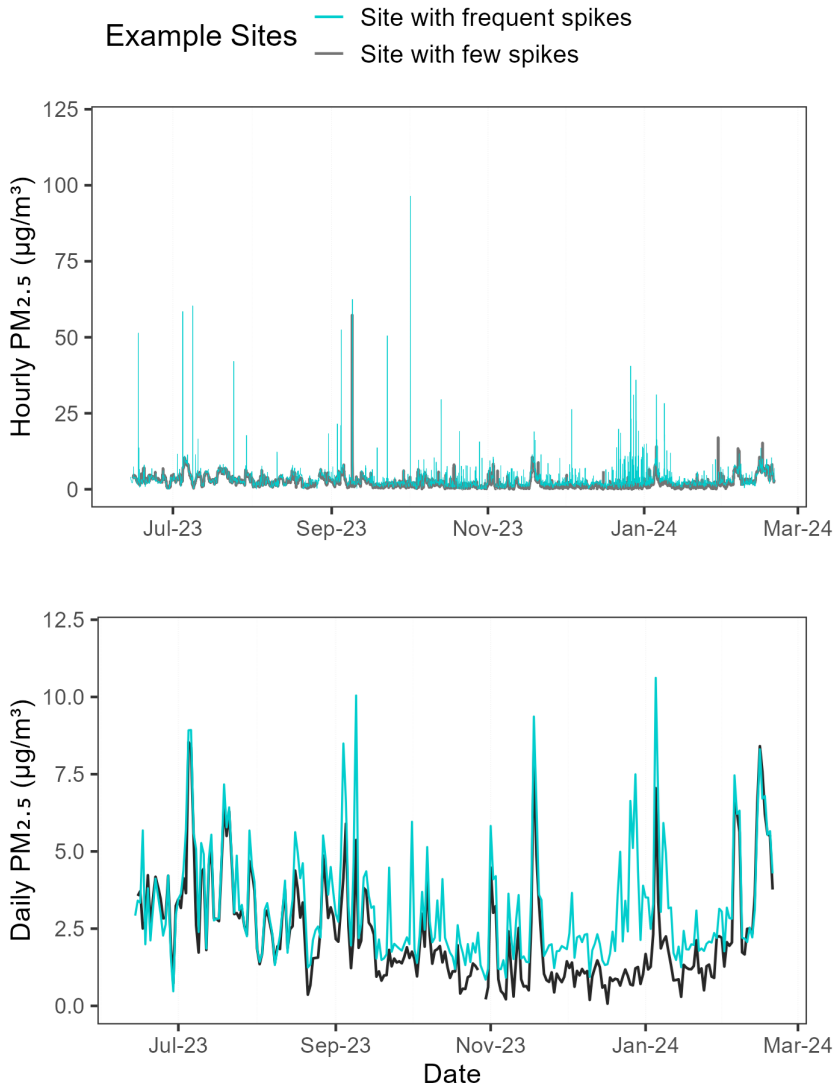
$PM_{2.5}$ Concentrations During the Study



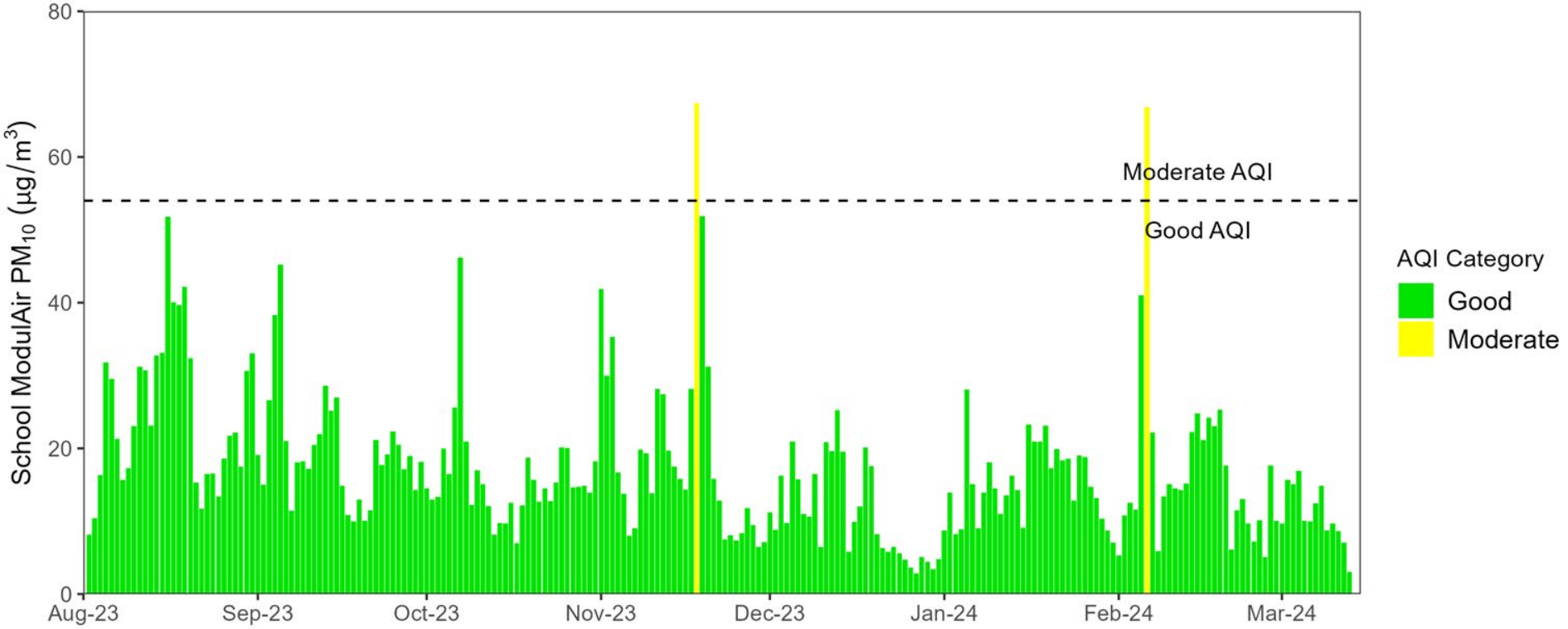
During the study, the $PM_{2.5}$ concentrations were generally in the Good AQI category meaning air quality is satisfactory, and air pollution poses little or no risk

Hourly $PM_{2.5}$ During the Study

- Some sites had frequent high hourly concentrations, called “spikes”
- Although these spikes have high concentration, they are short in duration
- We can compare two sites to see the impact of frequent spikes on daily averages:
  - Frequent spikes: Southwest Puente Jobos
  - Few spikes: Punto Pozuelo
- A single spike at Southwest Puente Jobos was high as 96 μg/m³ while Punto Pozuelo was only 2.1 μg/m³
- Because the spikes are short, they have a minimal impact on the daily $PM_{2.5}$ which was 3.2 μg/m³ at Southwest Puente Jobos and 2.3 μg/m³ at Punto Pozuelo

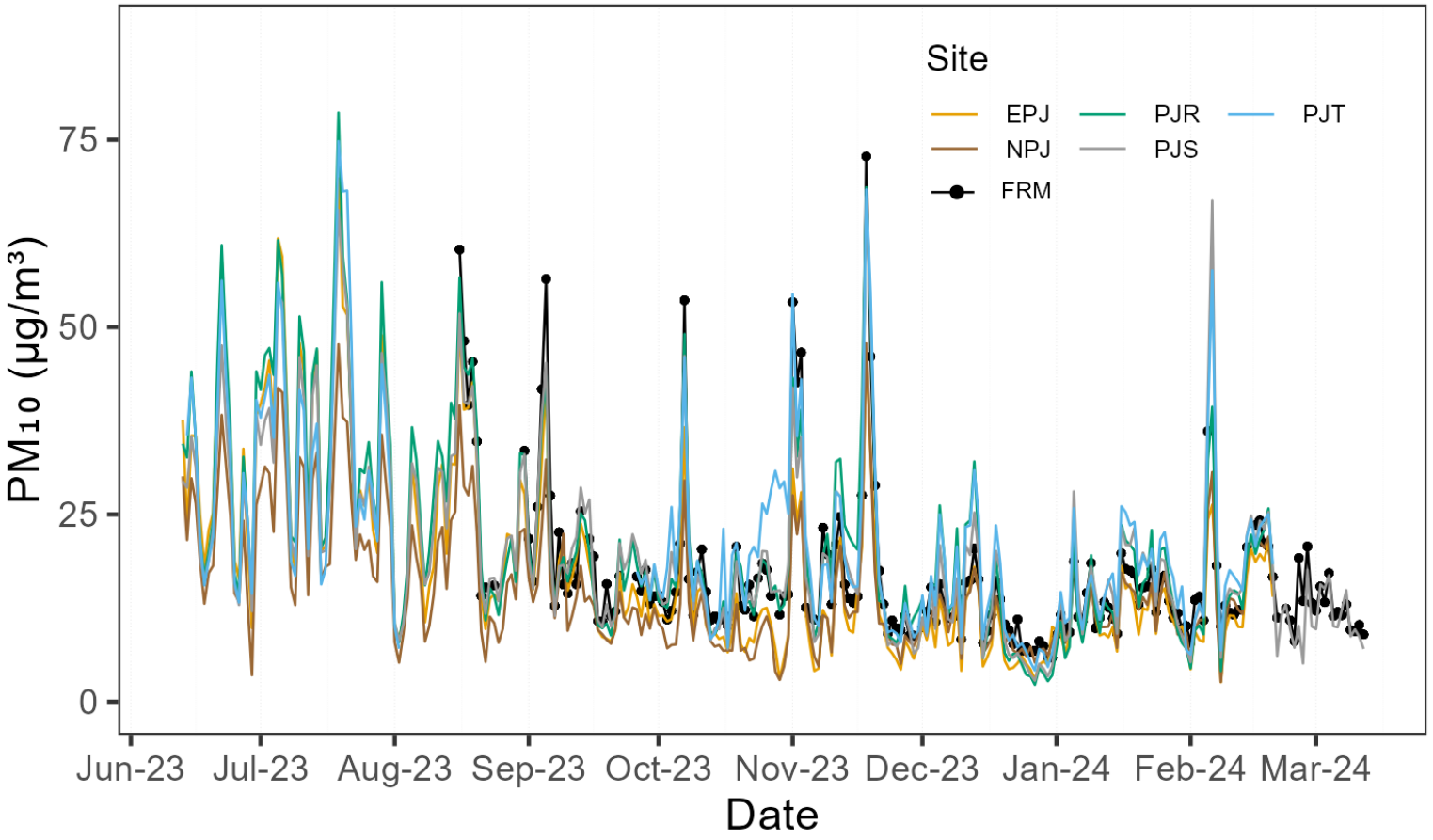


PM_{10} Concentrations During the Study



The PM_{10} concentrations were generally in the Good AQI category throughout the study meaning air quality is satisfactory, and air pollution poses little or no risk

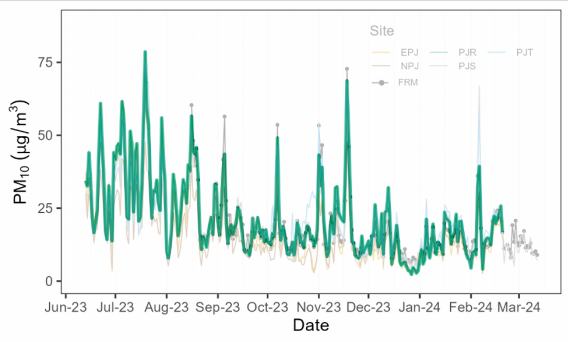
PM_{10} Variation Across the Community



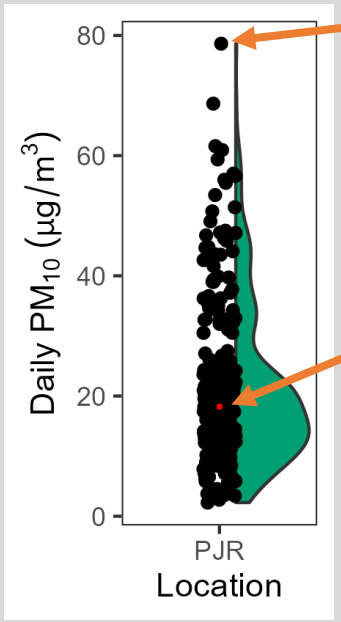
PM_{10} concentrations trends follow a similar pattern across the Puente Jobos Community

Statistical Approach to Comparing Across Sites

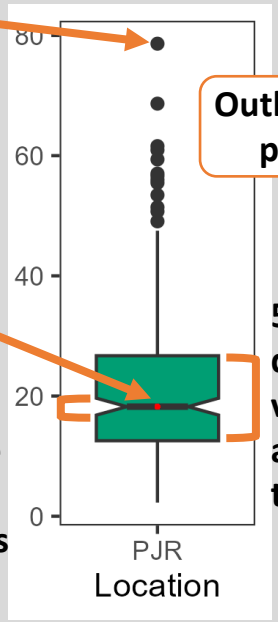
Difficult to identify which site is higher from daily averaged time series



Use statistical analysis to compare across sites



Develop a distribution of each PM_{10} data point during the study to identify what concentrations were observed most often



Highest daily value observed

Outlier data points

Median daily value

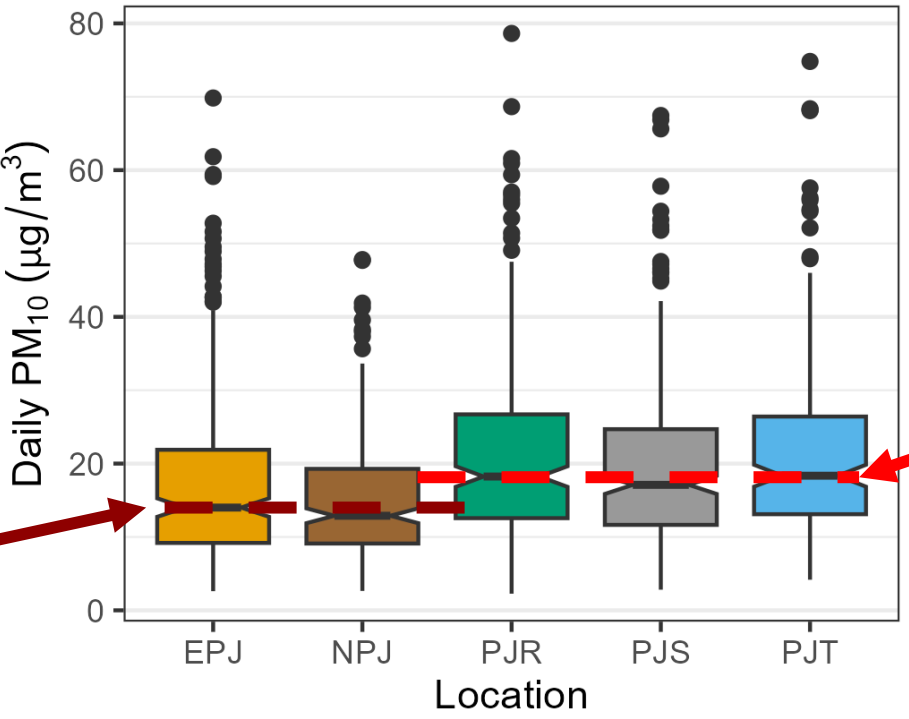
The 95% confidence interval of median lies between the notches

50% of daily values are in this box

Use these boxes to compare across sites; when the notches do not overlap for two boxes the medians are significantly different

Southern Sites Have Higher PM_{10} During the Study

Box Plots of Daily Averaged PM_{10} during the study



PM_{10} medians in the north central and northeast part of the community

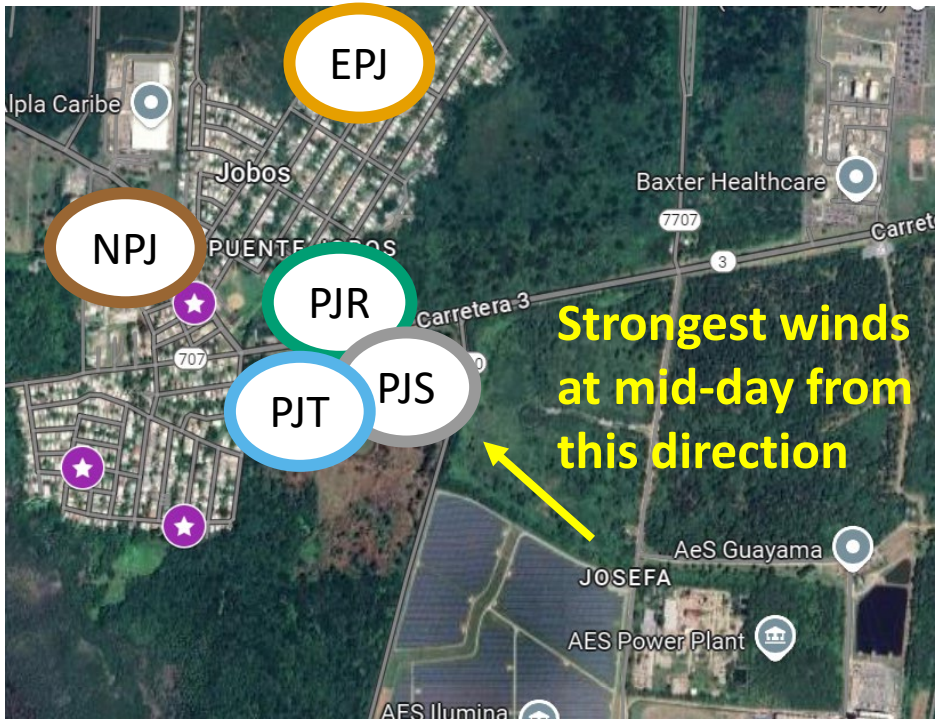
PM_{10} medians in the southern part of the community

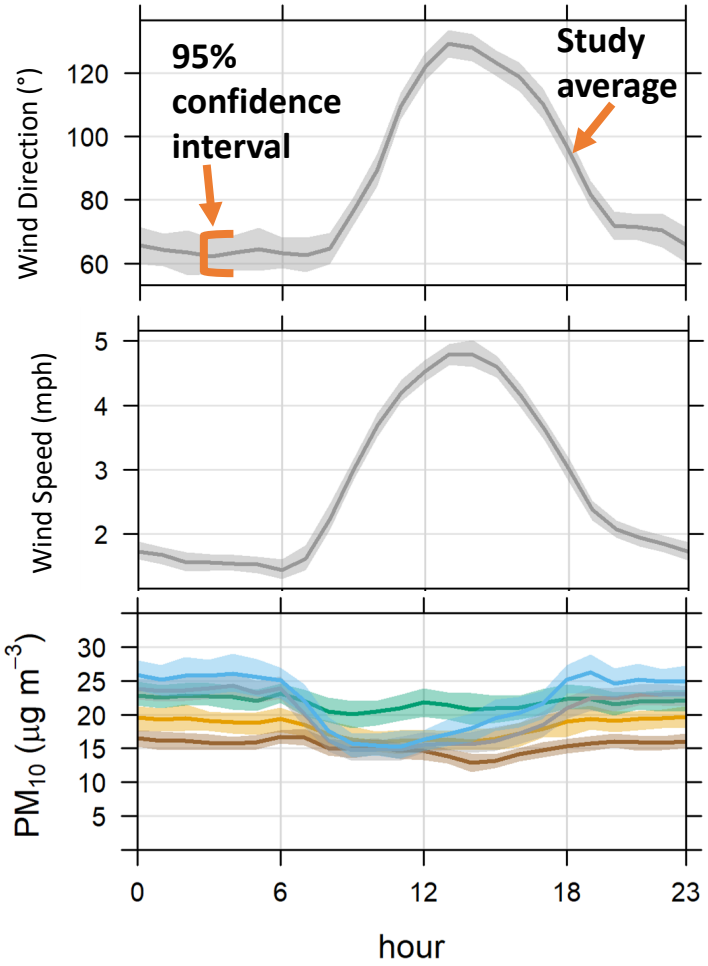
Sites in the south (Near Rd 3, School, Track) have higher median values and higher maximum daily values than the sites in central and northern Puente Jobos

- ~13 µg/m³ in the North-Central
- ~18 µg/m³ in the Southwest

PM_{10} Concentration and Wind Trends, by Hour of Day, During the Study

- Overnight winds are very low, during the day winds increase and shift from coming out of the northeast to coming out of the southeast
- PM_{10} decreases during the day, while winds increase suggesting regional, rather than local, dust sources





Plot shows wind speed and wind direction at the school site (PJS) averaged by hour of the day and corresponding PM_{10} concentrations across the community

PM_{10} Trace Elements Measured During Study

Element	Average ($\mu g/m^3$)	Standard Deviation ($\mu g/m^3$)	75% of observations above the limit of detection	
			XRF	ICP-MS
Mg	0.262	0.163	Yes ✓	Yes ✓
V	0.00068	0.0005	No ✗	Yes ✓
Pb	0.00094	0.0058	No ✗	Yes ✓
As	0.00009	0.00009	No ✗	Yes ✓
Tl	0.0000056	0.0000023	No ✗	No ✗

Mg = magnesium; V = vanadium; Pb = lead; As = arsenic; Tl = Thallium

While average PM_{10} concentration was 16.7 $\mu g/m^3$, with a standard deviation of 10.5 $\mu g/m^3$, trace elements were present at much lower concentrations, sometimes below the limit of detection of the standard method.

Even at low concentrations, trace elements can be used in combination to estimate different PM_{10} source contributions, based upon scientific research studying emissions from different source types ("source profiles").

Positive Matrix Factorization (PMF) to Identify PM_{10} Sources

PMF is a widely used statistical research model that takes into account:

1. The chemical signature of different PM_{10} sources ("source profiles") can be used to identify their contributions.
2. The chemistry of what is measured in a large enough sample set can reveal different sources.

Crustal – PM_{10} related to sand or soil, distinguished by aluminum, silicon, and others

Building Demolition – PM_{10} distinguished by copper and lead

Coal Emissions and Ash – PM_{10} distinguished by a wide variety of elements; includes stack and fugitive emissions

Diesel and Oil Combustion – PM_{10} distinguished by vanadium and nickel

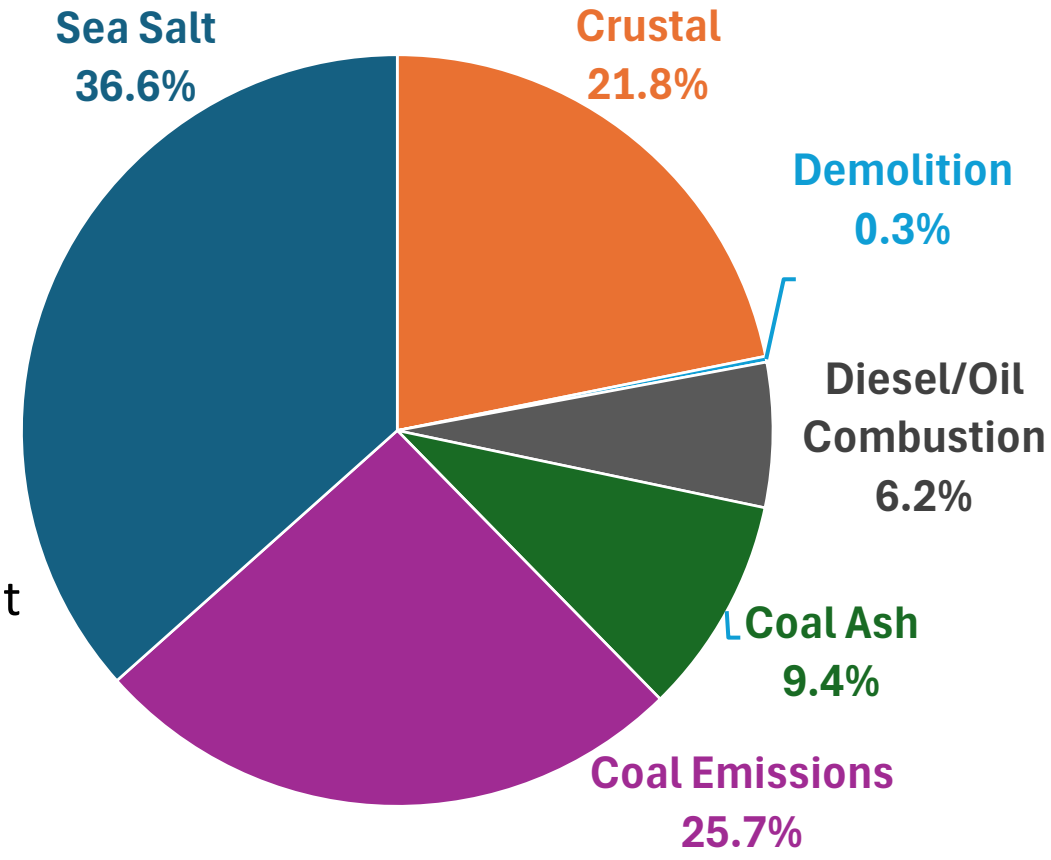
Sea Salt – PM_{10} related to sea derived aerosol distinguished by sodium and magnesium

Average Sources of PM_{10} During the Study

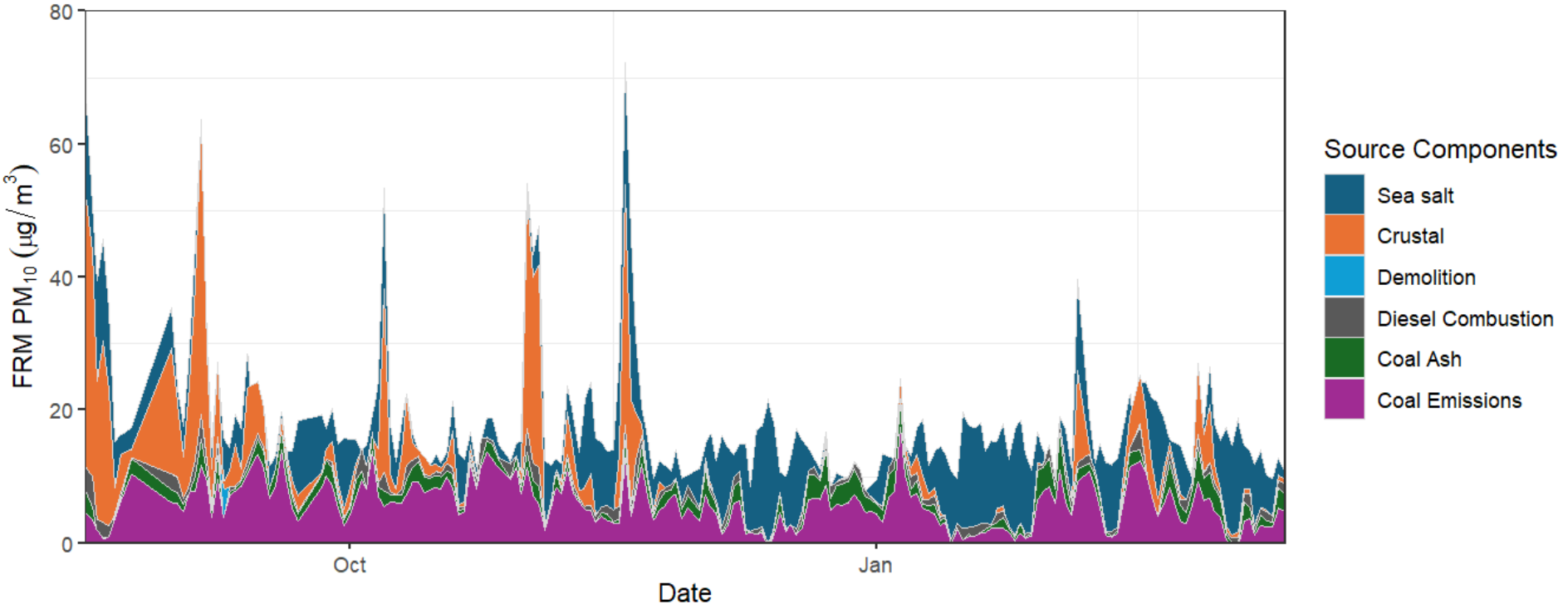
This pie chart shows the major sources contributing to PM_{10} throughout the entire study derived from the PMF model results

Observations from research team, from looking in more detail at PMF results in a time series:

- PM_{10} associated with sea salt increased on days when it was windier
- PM_{10} associated with coal emissions (stack) decreased on days when it was windier
- Days with the highest PM_{10} also had the highest crustal component
- This method was able to identify when the shelter covering the basketball court near the school was demolished



Sources of PM_{10} Over Time



- Days with the highest PM_{10} concentration happen during days with the largest crustal contribution
- Potential sources could include local crustal sources and long-distance transport (e.g., Saharan dust)
- Coal emissions, coal ash, and diesel combustion have a more constant contribution across each month in the study

Conclusions

- Air quality in the Puente Jobos community was generally good during the study period (June 2023 – March 2024)
- The current PRDNER monitoring site located at the entrance to the school (AQS ID: 72-057-0012) measured some of the highest PM_{10} concentrations throughout the community and was similar in concentrations to the site on the other side of the school.
- Several sources contribute to PM_{10} at the school including those associated with the coal ash and emissions, sea salt, and crustal material
- The man-made PM_{10} at the school is mostly made up of combustion sources (diesel/oil, coal emissions and ash)
- The highest PM_{10} concentrations at the school were associated with crustal compounds

Sensor Resources

- **Air Sensor Toolbox Website**
  - English: https://www.epa.gov/air-sensor-toolbox
  - Spanish: https://espanol.epa.gov/espanol/caja-de-herramientas-de-sensores-de-aire
- **Enhanced Air Sensor Guidebook**
  - English: https://www.epa.gov/air-sensor-toolbox/how-use-air-sensors-air-sensor-guidebook
  - Spanish: https://cfpub.epa.gov/si/si_public_record_report.cfm?Lab=CEMM&dirEntryId=356426
- **Air Sensor Collocation Guide**
  - English: https://www.epa.gov/air-sensor-toolbox/air-sensor-collocation-instruction-guide
  - Spanish: https://espanol.epa.gov/espanol/guia-de-instrucciones-de-colocalizacion-de-sensores-de-aire-0

Project Contacts

- EPA Region 2
  - Gavin Lau (lau.gavin@epa.gov)
  - Sarah Pender (pender.sarah@epa.gov)

- EPA Office of Research and Development
  - Amara Holder (holder.amara@epa.gov)
  - Gayle Hagler (hagler.gayle@epa.gov)

Appendix: ICP-MS Summary Data for All Elements

Element	Average (μg/m³)	Standard Deviation (μg/m³)
Ag	9.06E-06	1.68E-05
Al	1.32E-01	1.98E-01
As	8.66E-05	9.25E-05
Ba	3.90E-03	3.38E-03
Be	3.54E-05	1.15E-05
Bi	9.88E-05	3.52E-04
Ca	3.48E-01	3.77E-01
Cd	2.17E-05	1.90E-05
Ce	2.57E-04	4.67E-04
Co	1.07E-04	1.11E-04
Cr	2.54E-04	2.54E-04
Cs	2.83E-06	1.62E-05
Cu	3.20E-03	1.99E-02
Dy	1.77E-05	2.79E-05
Fe	1.18E-01	1.44E-01
Gd	2.86E-05	5.21E-05
Ge	4.83E-06	5.10E-06

Element	Average (μg/m³)	Standard Deviation (μg/m³)
K	2.01E-01	1.19E-01
La	1.11E-04	1.80E-04
Li	1.32E-04	1.50E-04
Mg	2.62E-01	1.63E-01
Mn	4.33E-03	5.61E-03
Mo	1.50E-04	2.79E-04
Na	1.59E+00	9.76E-01
Nd	1.16E-04	2.18E-04
Ni	4.52E-04	3.35E-04
P	3.07E-02	1.95E-02
Pb	9.44E-04	5.77E-03
Pd	8.27E-06	9.48E-06
Pt	1.35E-05	2.76E-05
Rb	2.54E-04	3.27E-04
Rh	2.03E-05	7.53E-06
S	4.61E-01	2.43E-01
Sb	6.62E-04	3.81E-03

Element	Average (μg/m³)	Standard Deviation (μg/m³)
Se	2.18E-04	9.88E-05
Si	2.47E-01	3.84E-01
Sm	2.49E-05	4.41E-05
Sn	2.81E-04	6.04E-04
Sr	2.46E-03	2.44E-03
Tb	9.91E-06	5.60E-06
Ti	2.81E-03	3.30E-03
Tl	5.31E-06	3.97E-06
V	6.80E-04	4.92E-04
W	1.87E-05	6.82E-05
Y	9.30E-05	1.16E-04
Zn	5.13E-03	2.51E-03