Mapping diesel particulate in Portland neighborhoods

8/23/23

The problem with diesel

The State of California reports that diesel particulate is "responsible for about 70% of California's estimated known cancer risk attributable to toxic air contaminants." DEQ reported in 2015 that diesel exhaust causes lung and bladder cancer, certain heart attacks and other blood clotting diseases, coronary artery disease, malignant childhood brain tumors, decreased cognitive functioning, increased incidence of Lou Gehrig's disease, acute bronchitis, and asthma. A study by Bishop et al. found diesel particulate causes dementia and Alzheimer's disease. Immediate symptoms include eye and throat irritation, coughing and phlegm, swollen airways, bronchial irritation, nausea, headaches, lightheadedness, and fatigue.

By 2015, virtually every diesel vehicle in California had a filter, removing 90% of particulate before it went airborne. Today, most industrial diesel trucks in Portland lack a filter. The 2019 Oregon Diesel Bill HB 2007 allows Oregon diesel vehicles to continue to operate without a filter until 2029 and beyond.

Through information requests we obtained 2020 industrial diesel truck ownership data from ODOT and 2018 government and personal diesel truck and bus ownership data from DMV. Our analysis of these records concluded that these are the largest unfiltered Portland-area diesel fleets:

Carrier	Total Fleet	Filtered	Unfiltered
Reddaway	3,307	1,199	2,108
TriMet	1,730	725	1,005
Safeway	1,214	243	971
Penske	936	174	762
UPS	693	16	677
PGE	911	278	633

TriMet recently switched to renewable diesel fuel called R99 which reduces diesel particulate emissions by 50% and reduces emissions that cause climate change by 70%. According to the Intergovernmental Panel on Climate Change of the United Nations, black carbon, the majority component of diesel particulate matter, is the third largest driver of climate change after carbon dioxide and methane emissions.

Mapping diesel particulate

This report provides diesel particulate data for 295 Portland-area sites collected with a Grimm MiniWRAS on foot or with an electric scooter. In the first half of 2023 we sampled 643 locations. The only other publicly available diesel particulate data for Portland is from four Portland-area sites where DEQ has operated Magee Aethalometers since 2017.

The maps and graphs in this report are made from Portland data collected from the following air monitors:

1. Grimm MiniWRAS: a $38,000 mobile air monitor that records 41 channels of different particle sizes from .01 – 35 microns in diameter.
2. PocketLab Air: $348 mobile air monitors that record particles .3 to 2.5 microns as well as GPS, humidity, carbon dioxide, ozone, dew point, temperature, and barometer data.
3. PurpleAir: $300 stationary air monitors that record particles .3 to 2.5 microns every two minutes. Some in Portland have been collecting since 2016.
4. Magee Aethalometer: $29,000 stationary air monitor that measures color change in filter media on which diesel particulate is collected.
5. Nephelometer - $7,000 PM 2.5 air monitor.

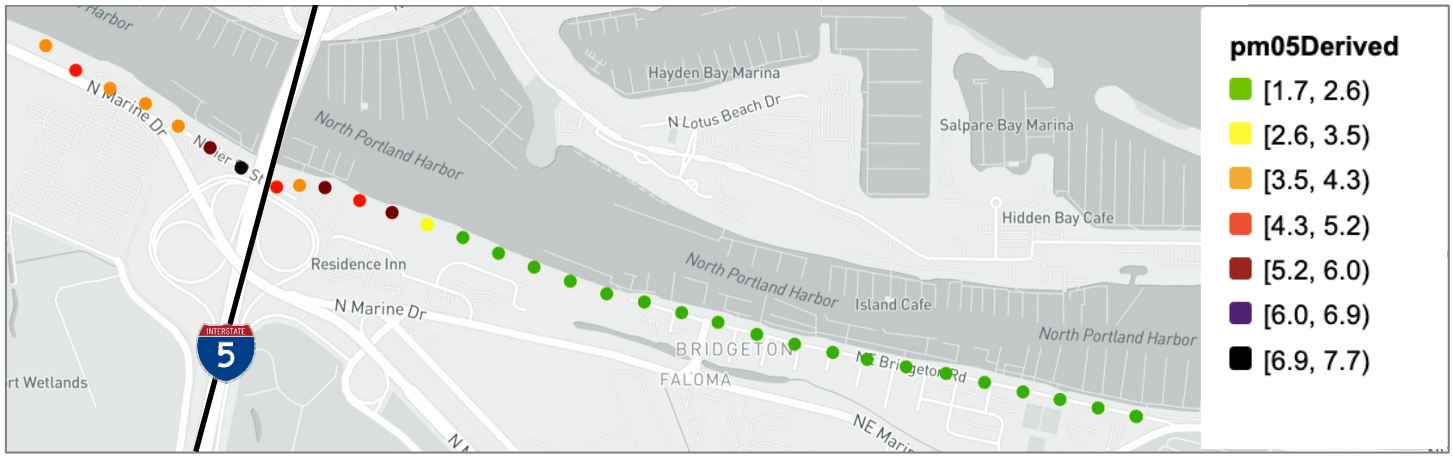
We wrote software that converts MiniWRAS particle counts to mass, expressed as micrograms per cubic meter (µg/m3). These results are plotted on Mapbox maps color-coded by airborne concentraton. Our software downloaded all PurpleAir PM2.5 data ever collected in Portland and can instantly graph one or more device's results for any time period.

Using NOAA archives we included the atmospheric inversion data for the time of each sample expressed in meters for the ceiling height, and stability on a scale A to G, G being the least windy. Stable air and low ceilings typically mean poor urban air quality as the inversion concentrates air pollution at ground level.

Cascadia Action works with 56 Portland Neighborhood Association boards, 16 Portland-area churches and synagogues, and nine other local nonprofit groups to protect human health by regulating industrial and publicly-owned diesel vehicles.

Questions can be sent to greg@portlandcleanair.org
Our procedures for MiniWRAS monitoring are here: http://portlandcleanair.org/files/reports/MiniWRAS%20procedures.pdf

MiniWRAS sample, Bridgeton Neighborhood February 9th 2023, 5:02 pm – 5:39 pm



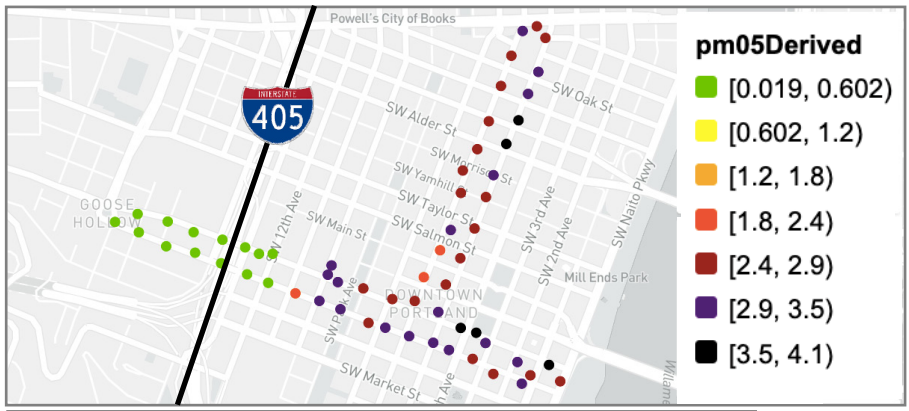
The map above shows airborne diesel particulate this winter on both sides of I-5 in the Bridgeton neighborhood in NE Portland. We carried the MiniWRAS on foot mounted to the front of a mountaineering backpack. Bridgeton residents living east of I-5 tell us that they smell highway odors in summer, but not in winter. This pattern was confirmed with our samples in Bridgeton which always found that their winter wind was blowing to the west. This also matches the annual wind pattern at Portland International Airport which is tracked with an anemometer.

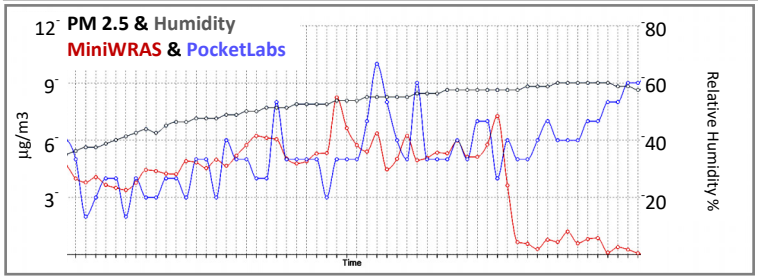
As we got near I-5, airborne nanoparticles .01 - .5 microns in diameter tripled. We understand this is caused by diesel particulate and up to 10% brake dust. Residential woodsmoke and forest fire smoke is also this size range but doesn't emanate from highways.

The map at the bottom left shows a similar plume of diesel particulate being blown to the east from I-405 this winter in downtown Portland. However, there nanoparticles quadrupled. These streets are the Portland Transit Mall, Downtown Portland's transit hub along 5th and 6th avenues. More than half of TriMet's diesel busses are unfiltered -- these emit four times as much diesel particulate as a filtered diesel bus, despite using the much cleaner R99 renewable diesel.

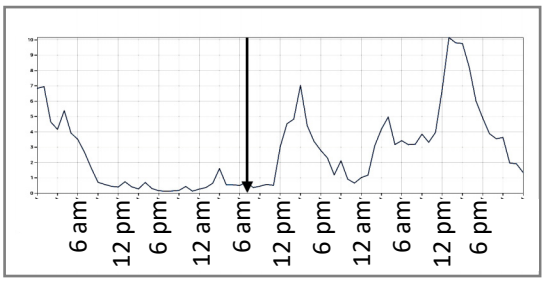
The black arrows on the PurpleAir graphs at the bottom right indicate the time of the MiniWRAS samples, showing that we sampled at a relatively low level of air pollution. It was worse at 3 pm. The PocketLab graph at lower left matches the MiniWRAS closely until we crossed the highway into cleaner air.

MiniWRAS sample, downtown Portland
April 25th 2023, 7:02 am– 8:04 am

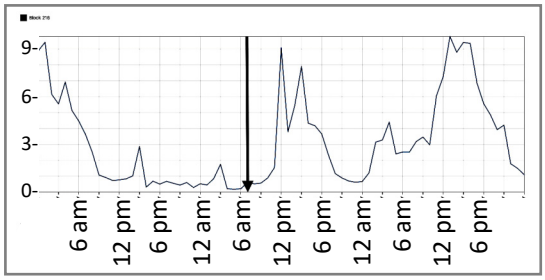




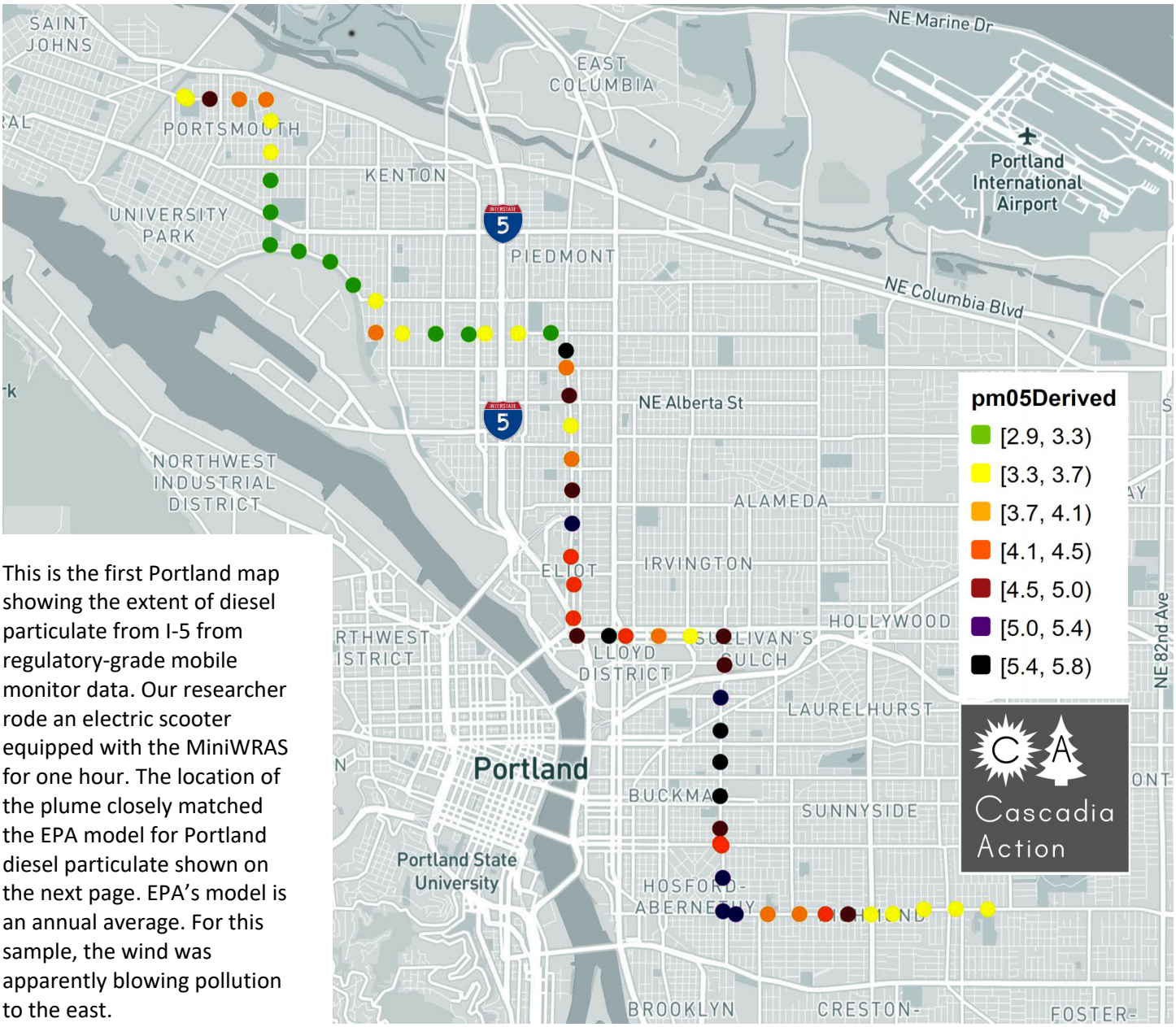
Eliot Tower PurpleAir PM 2.5
(4/25/23) 7:02 am – 8:04 pm
Location: approx. center of the sample.



Block 216 PurpleAir
(4/25/23) 7:02 am – 8:04 am
Location: 450ft from sample route.



MiniWRAS sample, Eastside Portland May 2023, 5/9/23 8:50 pm – 9:54 pm

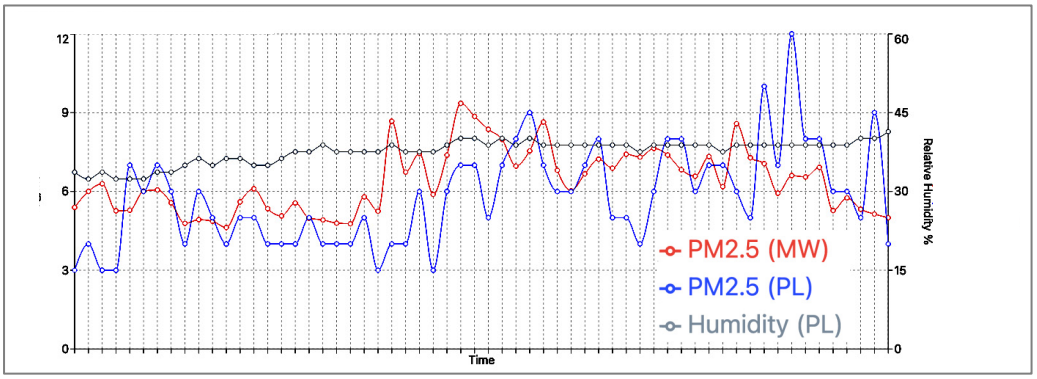


This is the first Portland map showing the extent of diesel particulate from I-5 from regulatory-grade mobile monitor data. Our researcher rode an electric scooter equipped with the MiniWRAS for one hour. The location of the plume closely matched the EPA model for Portland diesel particulate shown on the next page. EPA's model is an annual average. For this sample, the wind was apparently blowing pollution to the east.

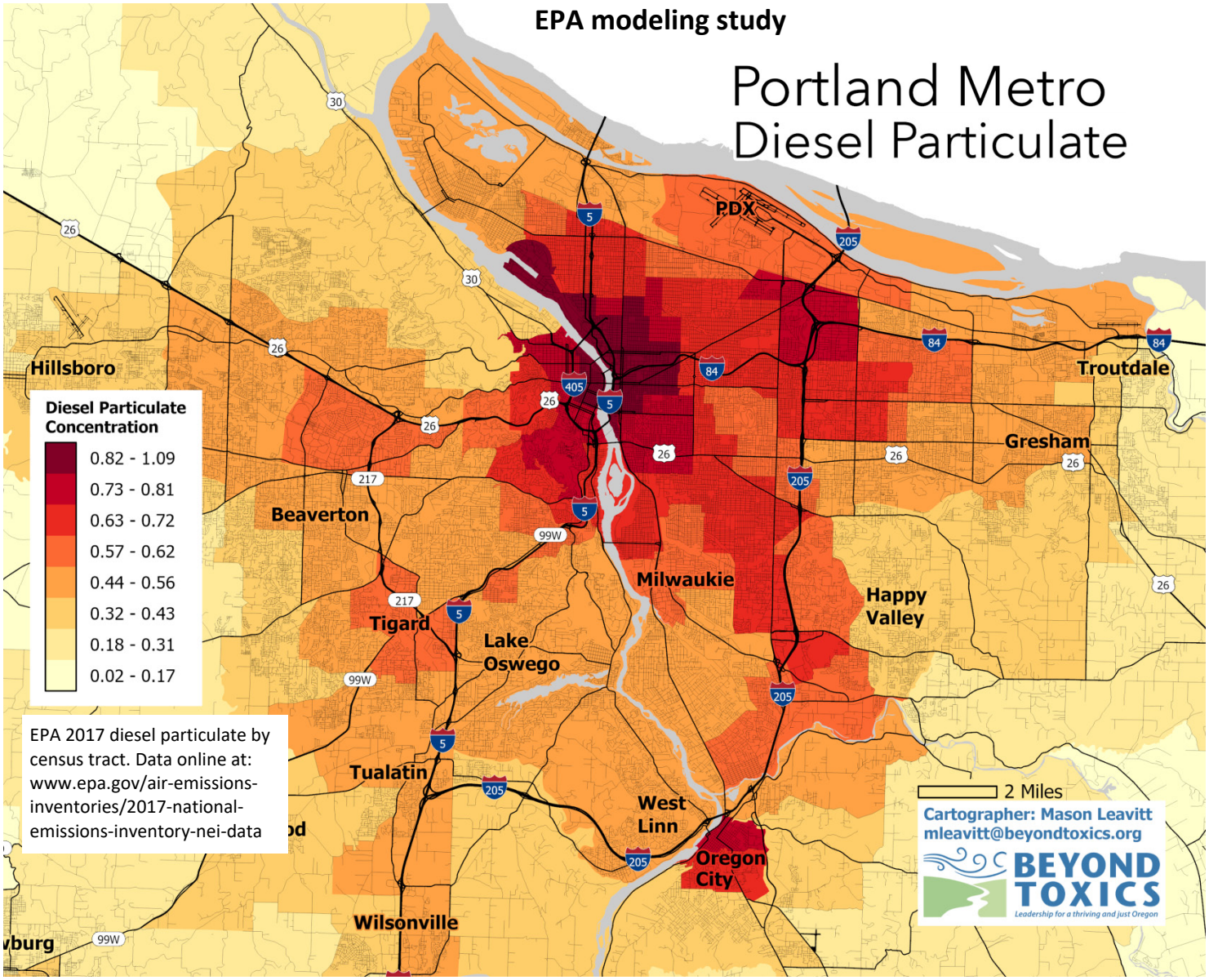
The graph at the bottom right shows PocketLab PM2.5 data for this sample closely matched MiniWRAS PM2.5 results. MiniWRAS is accurate within 60-95% of the best stationary diesel particulate monitors such as a $120,000 Grimm condensation particle counter with a heated inlet. The PocketLab only uses a laser, so is expected to not detect most diesel particulate. PM2.5 is associated with diesel particulate.

Inversion 9 pm – 10 pm:
Ceiling: 400m. Pasquill Stability: E - Slightly Stable.

PocketLab and inversion data

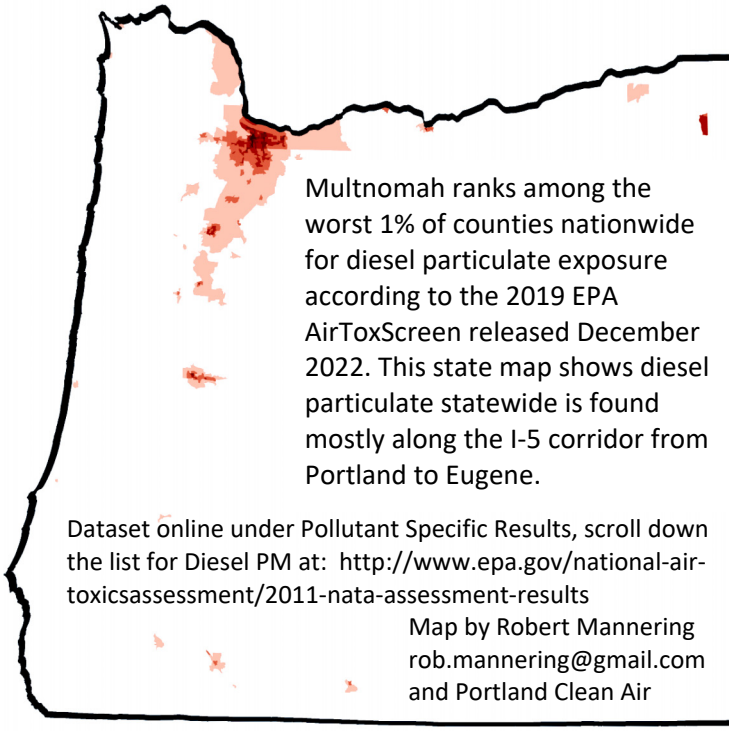


EPA modeling study



Our maps of MiniWRAS data closely match the EPA model for airborne diesel particulate above, from EPA National Emissions Inventory mapped by Beyond Toxics. This model also matches more than a decade of ODOT 24-hour truck counts, included on page eight of this report. This model is based on proprietary nationwide diesel truck data modeled to assume highways and truck stops would be the most concentrated truck routes. While diesel powered vehicles are only 6% of Oregon vehicles on the road, they emit 60 - 70% of all particulate emissions from all on-road vehicles combined, according to DEQ.

This map is an annual average. We found that people living near Portland highways are downwind of the highway about half the year. Neighborhoods east of I-5 are downwind in winter, which is worse as frequent winter inversions trap pollution at ground level more often.



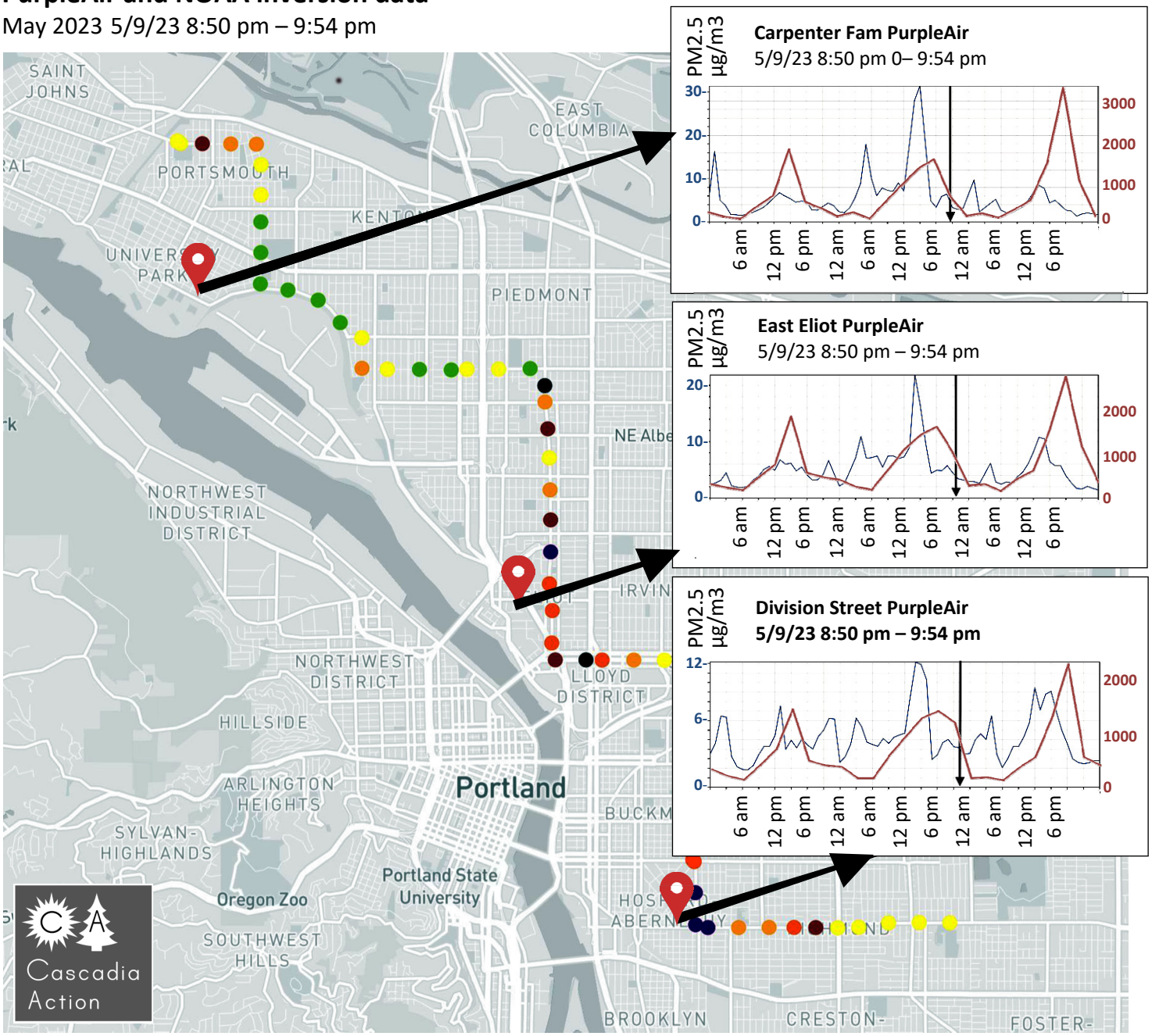
Multnomah ranks among the worst 1% of counties nationwide for diesel particulate exposure according to the 2019 EPA AirToxScreen released December 2022. This state map shows diesel particulate statewide is found mostly along the I-5 corridor from Portland to Eugene.

Dataset online under Pollutant Specific Results, scroll down the list for Diesel PM at: http://www.epa.gov/national-air-toxicsassessment/2011-nata-assessment-results

Map by Robert Mannering
rob.mannering@gmail.com
and Portland Clean Air

PurpleAir and NOAA inversion data

May 2023 5/9/23 8:50 pm – 9:54 pm



The map above shows the same 1-hour weekday MiniWRAS scooter ride from page three. These graphs show three days of PM2.5 data collected by three stationary PurpleAir sensors located near our scooter route. PM2.5 is depicted by the blue line in the graphs at the top right.

The red line, calculated using NOAA online inversion software, shows the altitude of the atmospheric ceiling, also referred to as inversion – when a warm layer of air traps cool air from the surface. A low ceiling traps air pollution close to the ground. Generally this happens daily in late evening and early morning, and more often in winter. The time of the scooter ride is indicated by black arrows on the graphs above; we sampled during a time of relatively low air pollution.

The most dangerous particulate air pollution in Portland is mostly caused by unfiltered trucks, and concentrated at ground level during inversion events. We found the PurpleAir is the best way to check how polluted the air is at a specific time. Big inversions take time to have an effect. Our software, which made the graphs above, requires a two week wait to get new data. So we now check the PurpleAir website for real time air quality when planning MiniWRAS data collection.

We will be taking many samples using this scooter route above next winter. Now that we understand how to determine inversion events using PurpleAir, we will take samples during times of high diesel particulate air pollution caused by inversions.

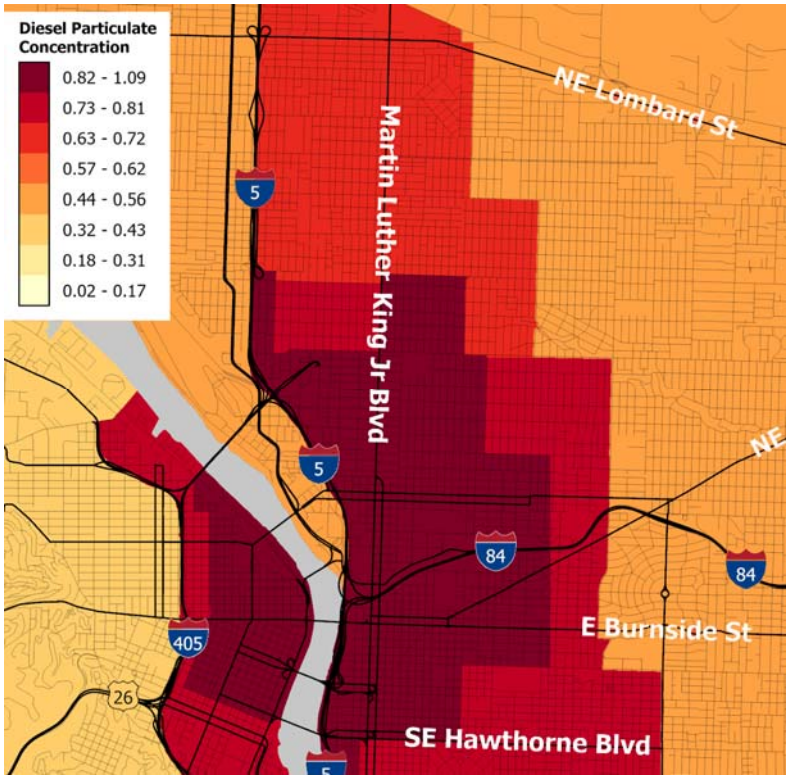
The map on the right is the EPA diesel particulate model, recolored in Photoshop by Cascadia Action to model our winter MiniWRAS results in the I-5 corridor. The areas west of highways are recolored to show low levels of airborne diesel particulate in winter.

We assume the EPA model is correct—that the wind reverses direction in summer and blows to the west. Bridgeton residents report the same predominant wind directions as Portland International Airport wind monitor data. Bridgeton wind appears to consistently blow in the opposite direction as the rest of the I-5 corridor.

It would be ideal to have wind data from wind monitors other than the Portland airport but we could not find such data sources. Buying and siting an anemometer is not feasible as it must be mounted up high to be accurate, such as on top of a tall building. Drones do not use an anemometer, but instead measure how it is being pushed using GPS. We couldn't find a reasonably priced wind drone for sale online.

The three MiniWRAS samples at the bottom of this page and on the next page were taken in the I-5 corridor last winter. These three samples clearly show winter wind blowing diesel particulate to the east from I-5. We thought

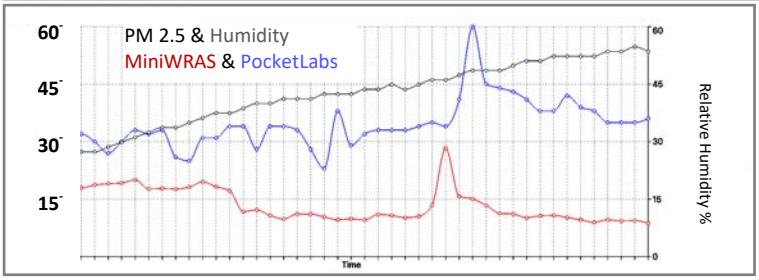
Winter wind theory for I-5 corridor diesel particulate



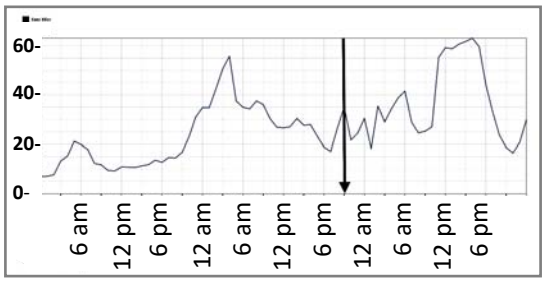
neighborhoods closest to the highway would be the worst air quality. But we found that the diesel particulate plume often began five to eight blocks from I-5, presumably from cleaner air blowing the pollution this distance away from the source. In summer the wind in this area of the I-5 corridor is expected to be opposite, blowing the pollution to the west.

MiniWRAS sample, Eliot Neighborhood

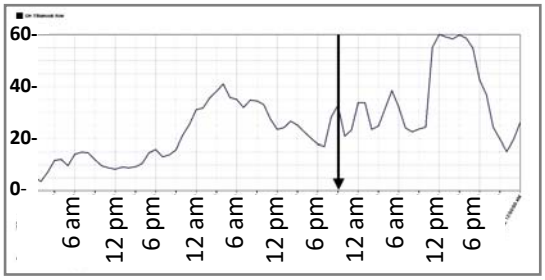
February 1st 2023, 8:59 pm – 9:47 pm



East Eliot PurpleAir PM 2.5
(2/1/23) 8:59 pm – 9:47 pm
Location: approximate center of the sample.

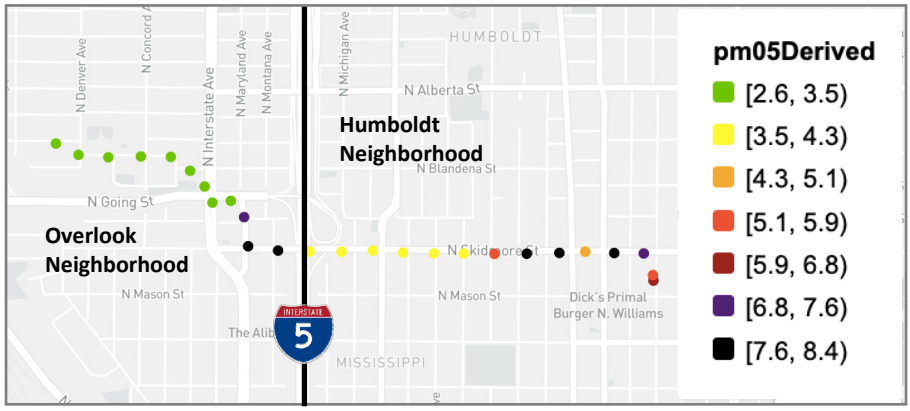


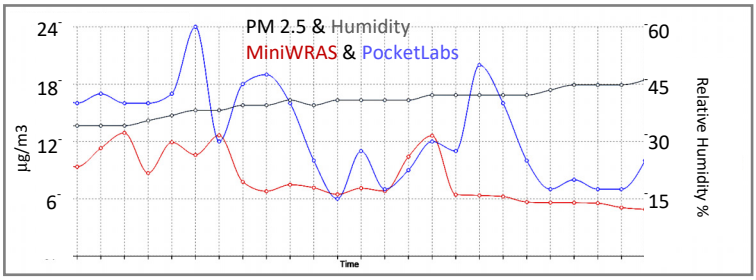
GH Tillamook Row PurpleAir PM 2.5
(2/1/23) 8:59 pm – 9:47 pm
Location: 500 ft from sample route.



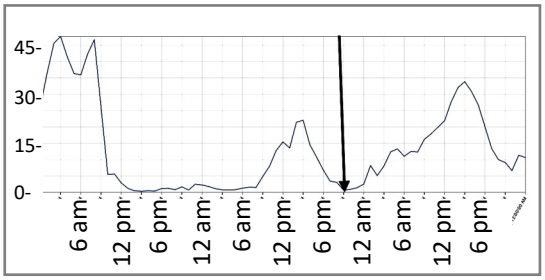
MiniWRAS sample, Humboldt and Overlook neighborhoods

March 21st 2023, 9:23 pm – 9:53 pm

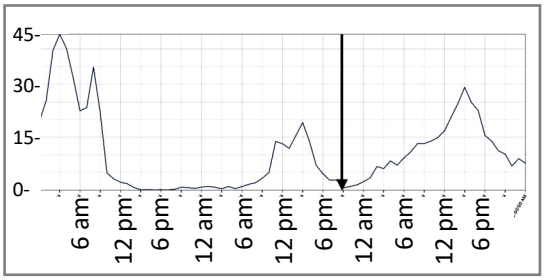




East Eliot PurpleAir
(3/21/23) 9:23 pm – 9:53 pm
Loc: 1.26 Miles from apprx sample center/route.



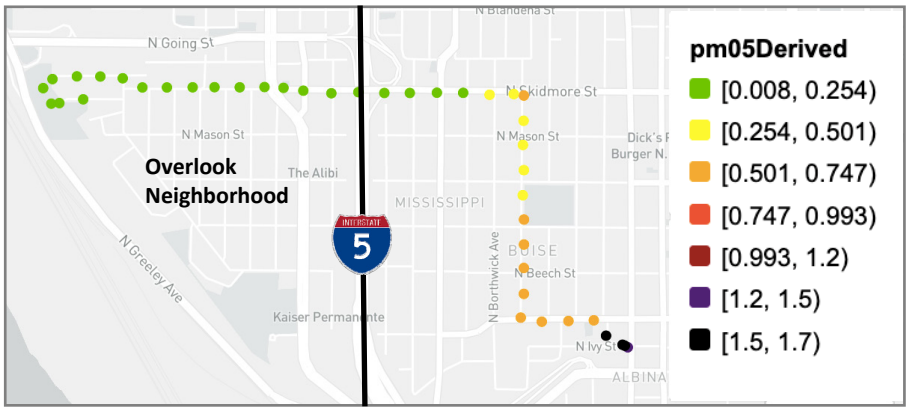
Carpenter Fam PurpleAir
(3/21/23) 9:23 pm – 9:53 pm
Loc: 3200ft from apprx sample center/route.

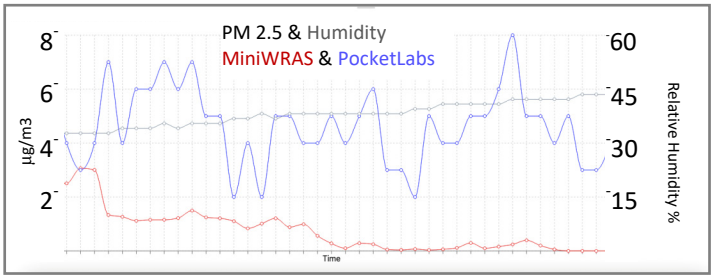


In 1997, Dr. Bert Brunekreef et al. published a study in *Epidemiology* of 1,191 children attending schools near freeways. The study found chronic respiratory symptoms were significantly associated with schools 2.25 blocks from a highway. Vehicle exhaust contains nitrogen dioxide (NO2). According to the EPA, breathing air with a high concentration of NO2 can irritate the respiratory system, aggravate asthma, cause coughing, difficulty breathing, respiratory infections, and increase hospital admissions and emergency room visits. Vehicle exhaust also contains carbon monoxide which can cause headaches, dizziness, and nausea. Vehicle exhaust contains polycyclic aromatic hydrocarbons, and some metals, both of which can cause cancer.

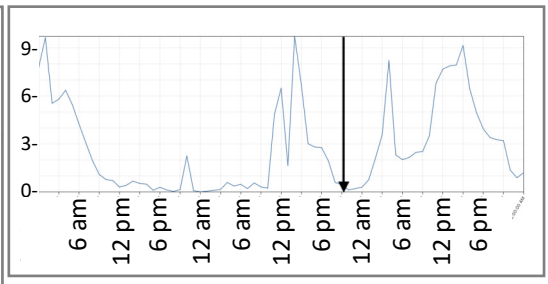
MiniWRAS sample, Boise & Overlook neighborhoods

April 25th 2023, 9:05 pm – 9:51 pm

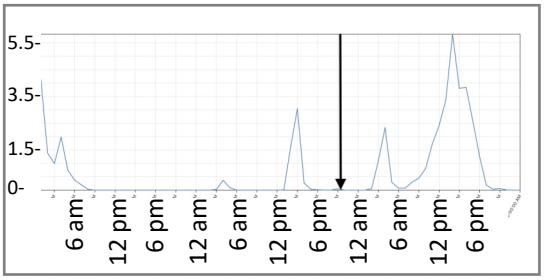




Overlook at the Perch PurpleAir
(4/25/23) 9:05 pm – 9:51 pm
Loc: 2400 ft from sample route.



Sabin PurpleAir
(4/25/23) 9:05 pm – 9:51 pm
Loc: 4700 ft from sample route.

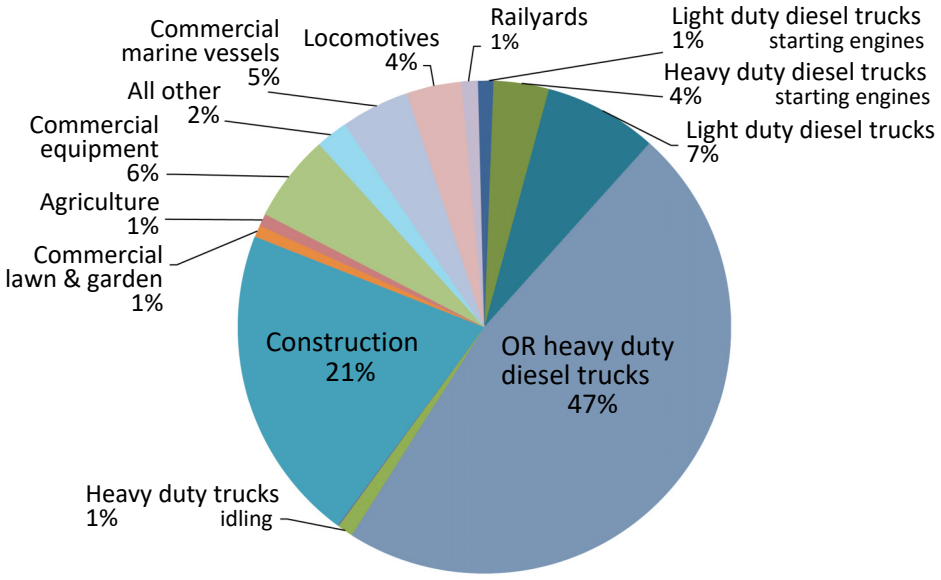


EPA calculated that 60% of diesel particulate in Multnomah County is caused by diesel trucks; 52% of these trucks are commercial industrial trucks, and most of them are unfiltered short-haul trucks pacing back and forth, making deliveries in Portland. This explains why most of the diesel particulate we found on the MiniWRAS was directly downwind of highways.

The MiniWRAS recorded two to four times as much diesel particulate often starting about five to eight blocks downwind of the freeway. The plume extended up to two miles downwind from the truck route. Portland Clean Air and Beyond Toxics mapped more than a decade of Oregon Department of Transportation's 24-hour truck counts, shown below. Unfiltered in-city short-haul diesel trucks use the highways as a hub to get to each delivery location.

Diesel particulate sources for Multnomah County

2019 EPA AirToxScreen released December 2022

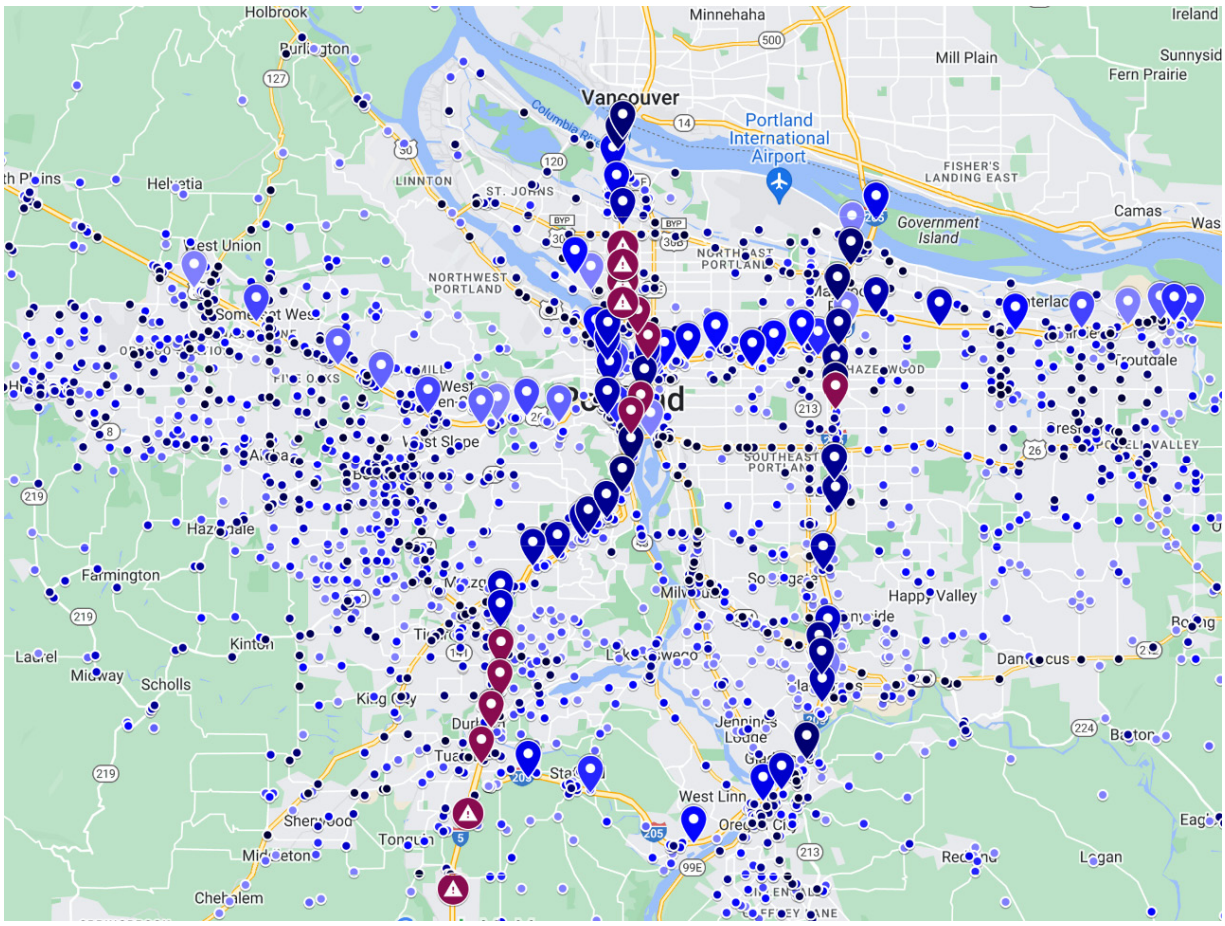


This graph made from EPA data available here: www.epa.gov/AirToxScreen/2019-airtoxscreen-assessment-results#state
From the dropdown menu, download the Oregon file.
Multnomah ambient concentrations for diesel particulate were copied from Access and graphed in Excel. Sources less than 1% were omitted.

Multnomah County 24-hour truck counts 2019 Oregon Department of Transportation

Key

- 15,657 – 19,930
- 13,602 – 15,656
- 12,062 – 13,601
- 11,066 – 12,061
- 10,737 – 11,065
- 9,630 – 10,732
- 8,510 – 9,629
- 7,651 – 8,509
- 6,877 – 7,650
- 6,340 – 6,876
- 5,777 – 6,339
- 5,026 – 5,776
- 2,521 – 5,025
- 1,776 – 2,520
- 1,419 – 1,775
- 1,074 – 1,418
- 866 – 1,073
- 697 – 865
- 550 – 696
- 405 – 549
- 281 – 404
- 159 – 280
- 53 – 158
- 0 – 52



DEQ diesel modeling is not accurate

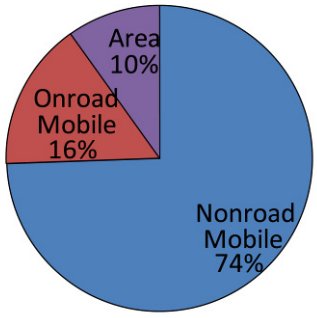
Portland Air Toxics Solutions (PATS) is the most recent Oregon Department of Environmental Quality (DEQ) study to model diesel particulate in Portland. PATS was released to the public in 2012 and used 2005 emissions data modeled to show expected 2017 air pollution.

PATS did not use diesel monitoring or ODOT 24-hour truck count data to inform their model. These omissions led to the incorrect view shown below, that falsely shows diesel particulate worse in Washington County than Multnomah County. Multnomah daily diesel truck counts are far higher.

DEQ's emphasis on nonroad sources is not supported by data. ODOT and DMV do not collect records on nonroad diesel vehicles in Oregon, such as excavators, bulldozers, backhoes, road graders, and portable generators.

DEQ PATS modeled 2017 sources of diesel particulate

PATS incorrectly concluded 74% of diesel particulate came from nonroad sources such as backhoes, bulldozers etc. – here is the graph from their study:



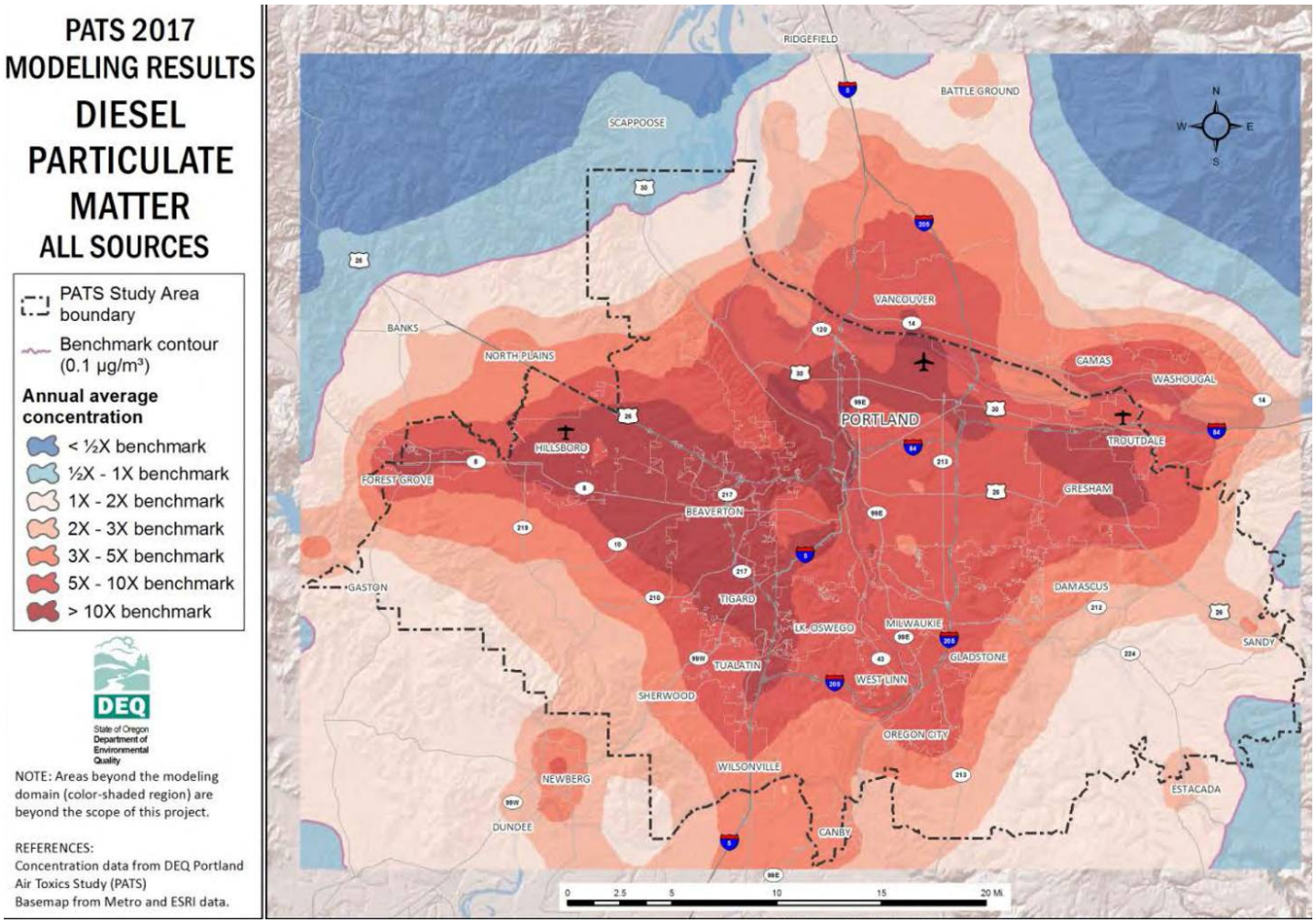
Neighbors for Clean Air (NCA) is a Portland nonprofit that lobbies the Oregon legislature regarding diesel particulate laws. Their website incorrectly reports:

> "The majority of this pollution, 65%, is caused by out of date construction and off-road equipment." which is false, and not cited, but presumably is referencing PATS.

neighborsforcleanair.org/whatwedo/

NCA is one of only two lobbyists that the Oregon legislators hear from on this issue; the other is Oregon League of Conservation Voters. Oregon legislators often depend solely on information provided by lobbyists.

DEQ is taking Aethalometer monitor readings at four Portland locations. An Aethalometer is a $29,000 device that measures diesel particulate. DEQ also received a $1,333,659 EPA grant that paid for 10 mobile AethLabs microAeth diesel particulate monitors at $13,995 each. While the locations of most DEQ monitors aren't ideal, they are useful as a baseline to measure the change in diesel particulate both far from and near the source.



DEQ Portland Aethalometer data

On March 22, 2023, Cascadia Action collected MiniWRAS data at the DEQ air monitoring site in Tualatin. This site is a building adjacent to I-5, filled with air pollution monitors including an Aethalometer sampling through pipes that protrude through the roof.

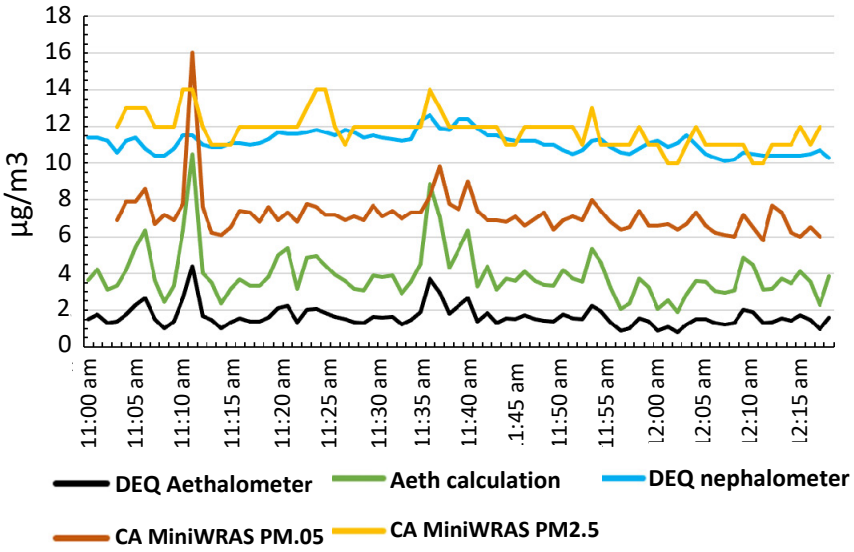
There are two interesting results on the graph at the top right. The yellow and turquoise lines at the top show that our MiniWRAS and the DEQ nephalometer agreed on the level of PM2.5. The black and red lines show that the MiniWRAS and DEQ aethalometer agreed on the relative changes in diesel particulate minute by minute.

The green line is our calculation of total airborne diesel particulate from Aethalometer data. EPA reported that "Portland/Seattle diesel particulate is 42% black carbon; brown carbon and various compounds make up the rest." So we divided the DEQ black carbon data by 0.42 to make the green line. Either this equation is incorrect, or may be because MiniWRAS is 60-95% accurate compared to the best stationary diesel particulate monitors, depending on humidity.

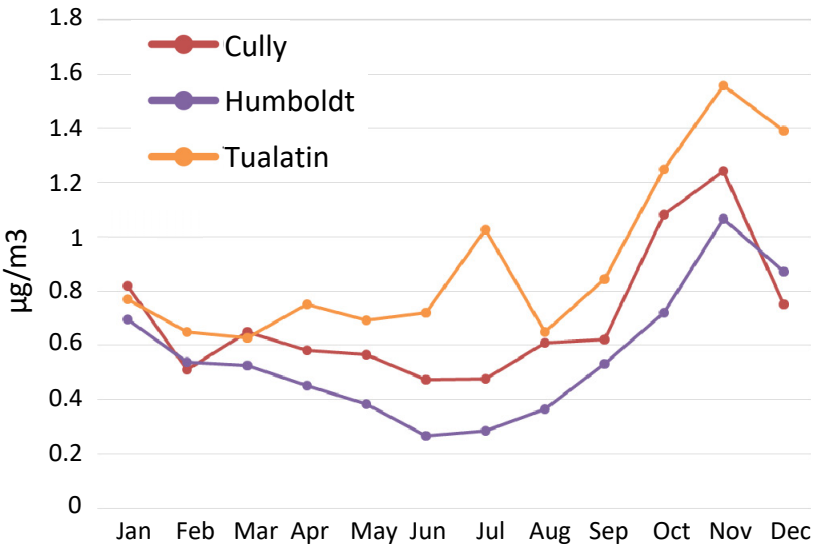
Cascadia Action has graphed 35 years of DEQ stationary particulate data collected at 12 sites, available here: http://portlandcleanair.org/files/i5.html

DEQ collects diesel particulate data at four of those sites, three of which we graphed on the right. We chose to present 2019 data because 2020 was skewed by historic wildfires. We recently sent DEQ an information request for 2021-2023 Portland Aethalometer data. These graphs show that diesel particulate is worse in the winter due to more frequent inversions. At 8:00 am airborne diesel particulate is far worse due to more frequent unfiltered diesel truck activity. Another increase in airborne diesel particulate occurs nightly at 10 pm, which is due to daily inversions caused by cooler evening temperatures.

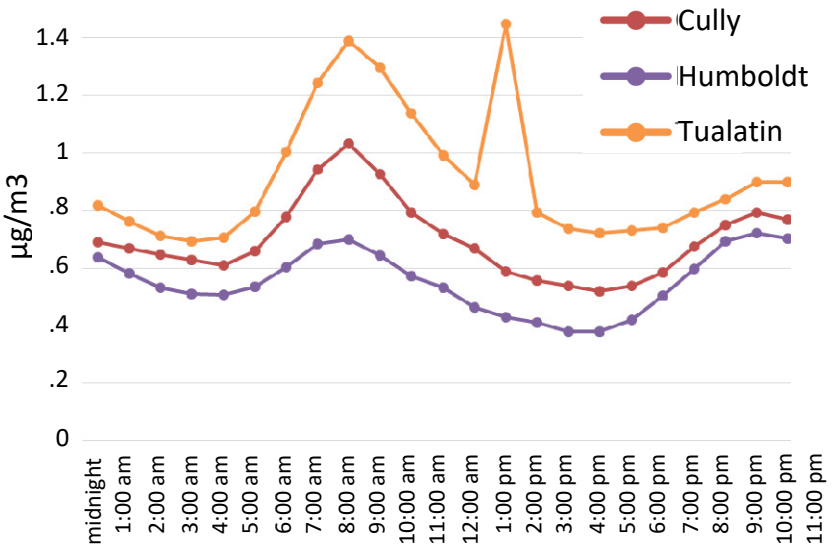
2023 MiniWRAS and DEQ Aethalometer collocation data



2019 DEQ Portland Aethalometer data averaged by month



2019 DEQ Portland Aethalometer data averaged by hour



Acknowledgements

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Alexandra Ruhf is our researcher and a board member. She has a Master's degree in Neuroscience from University of Washington and ten years of health care employment experience helping patients with heart and vascular imaging. She currently works at the neuroscience department of Oregon Health Sciences University as a study coordinator. Alexandra's report citing the health effects of diesel particulate is here: http://portlandcleanair.org/files/reports/new%20PCA%20diesel%2012.pdf

Christopher Dieringer is our software writer. He has a BS in Industrial Engineering and BS Manufacturing Engineering from Oregon State University and a MS Computer Science from Georgia State University. He has worked in semiconductors, software security, brain research, and commerce firms. Chris automates our data visualizations with web design, replacing the need for GIS and Excel.

Greg Bourget is our executive director and lead researcher. He has a BA in political science from Humboldt State University and has been employed in mass outreach with 18 nonprofit environmental protection organizations since 1991. Greg works to connect 82 participating Portland organizations, staff, and volunteers working with this monitor project. Greg's report on diesel particulate monitoring options is here: http://portlandcleanair.org/files/reports/Diesel%20particulate%20monitoring.pdf

Mason Leavitt works as a GIS technician at Beyond Toxics, a Eugene, Oregon nonprofit addressing industrial air pollution. He has a BA in Geography as well as Spatial Data Science from the University of Oregon and has three years experience with data analysis and cartographic design. Mason created the EPA diesel particulate model maps on pages four and six.

Robert Wright is our meteorology advisor. He has a Master's degree in meteorology from University of Utah, over 25 years of experience as a meteorologist in the United States Air Force and 11 years of meteorological applications development for a Washington DC company. Robert advises us on the effect of atmospheric conditions on pollution concentration to determine when measurements are collected.

Seth Woolley is our data expert and board member. He has over 20 total years of professional software engineering experience including 14 years with geospatial data analysis systems and six years in digital security auditing. He is currently employed as a senior programmer working on Doppler-radar-collected moisture and airborne particulate data. Seth solves our math and physics needs with software code.

Teadoro (Teddy) Holt is our data analyst and a board member. He has an AS in Natural Science from Sierra College and two years of hands-on chemistry experience at Sierra and Portland Community Colleges. He is working towards a Bachelor's degree in Environmental Science from Portland State University with a minor in Climate Change Science. Teadoro provides data management and analysis, map and graph making, atmospheric forecasting, and procedure writing for this diesel particulate monitoring effort.