Interpreting On-Road Concentration Measurements

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Background

Problem:

- Routine regional monitoring may not capture air pollution issues due to local sources that cause exposure burden in some communities

Solution:

- Use a mobile monitor to "fill in the gaps"
  - Mobile monitor is used to screen for areas with high concentrations that may be caused by local sources
- Follow up with other tools to quantify source emissions

Objectives

- Develop measurement and analysis schemes to study neighborhood level air pollution and sources
- Identify high pollution areas (hotspots)

b. Illustrative multi-pollutant hotspots

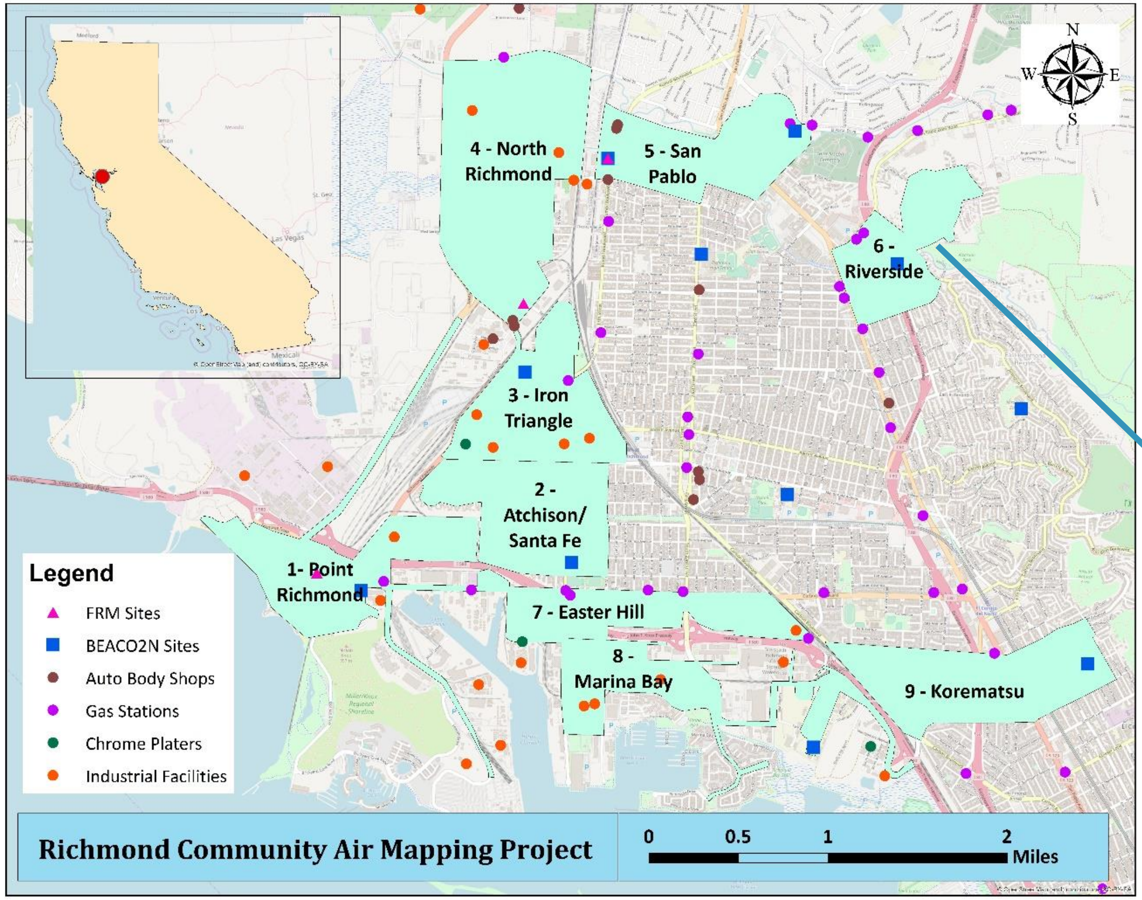
c. Description of identified hotspots

ID	BC	NO	NO_2	N_{days}	Plausible sources / hypotheses
A	+	~	+	38	Truck traffic and intersection
B	+	+	+	29	Metals recycling business
C	+	+	+	41	Cement plant and automotive shop
D	+	×	~	28	Warehouses with forklifts
E	+	~	+	23	Car dealer, vehicle "smog check"
F	+	×	~	17	Near recycling business; trucks; near I-880 frontage road
G	+	+	+	26	Towing lot, residential "hangout" area

Apte, J.S., Messier, K.P., Gani, S., Brauer, M., Kirchstetter, T.W., Lunden, M.M., Marshall, J.D., Portier, C.J., Vermeulen, R.C. and Hamburg, S.P., 2017. High-resolution air pollution mapping with google street view cars: exploiting big data. *Environmental Science & Technology*, *51*(12), pp.6999-7008.

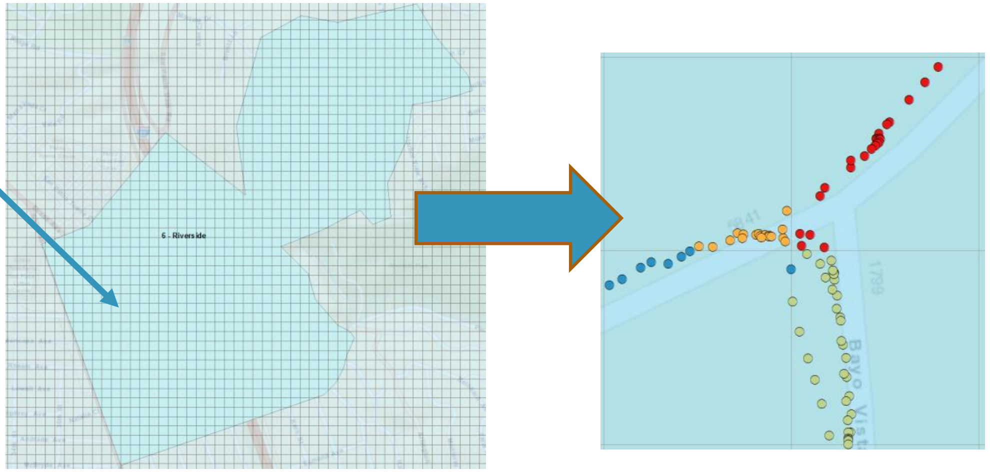
Alexeeff et al., High-resolution mapping of traffic related air pollution with Google street view cars and incidence of cardiovascular events within neighborhoods in Oakland, CA. *Environmental Health* (2018) 17:38. https://doi.org/10.1186/s12940-018-0382-1

Methods



Instrumented vehicle measures concentrations during drives on multiple days through "polygons" (communities) within the study domain

Repeated samples are **aggregated within 30m grid cells over multiple measurement days**



~20 grid visits completed in 6 months

Methods - Measurement system

Using medium/lower cost instruments

Daily and weekly instrument checks are performed by driver and technician

Pollutant	Instrument
PM_1, $PM_{2.5}$, PM_4, PM_{10}	TSI DRX
Ultrafine Particle Number	Testo DiSCmini
Black Carbon	MicroAeth AE51
Nitrogen Oxides	2b Technologies 410
Total VOC	RAE Systems ppbrae3000
Carbon Dioxide	LI-COR LI-820
Methane, Ethane	Picarro gas scouter

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Measurement System - Precision

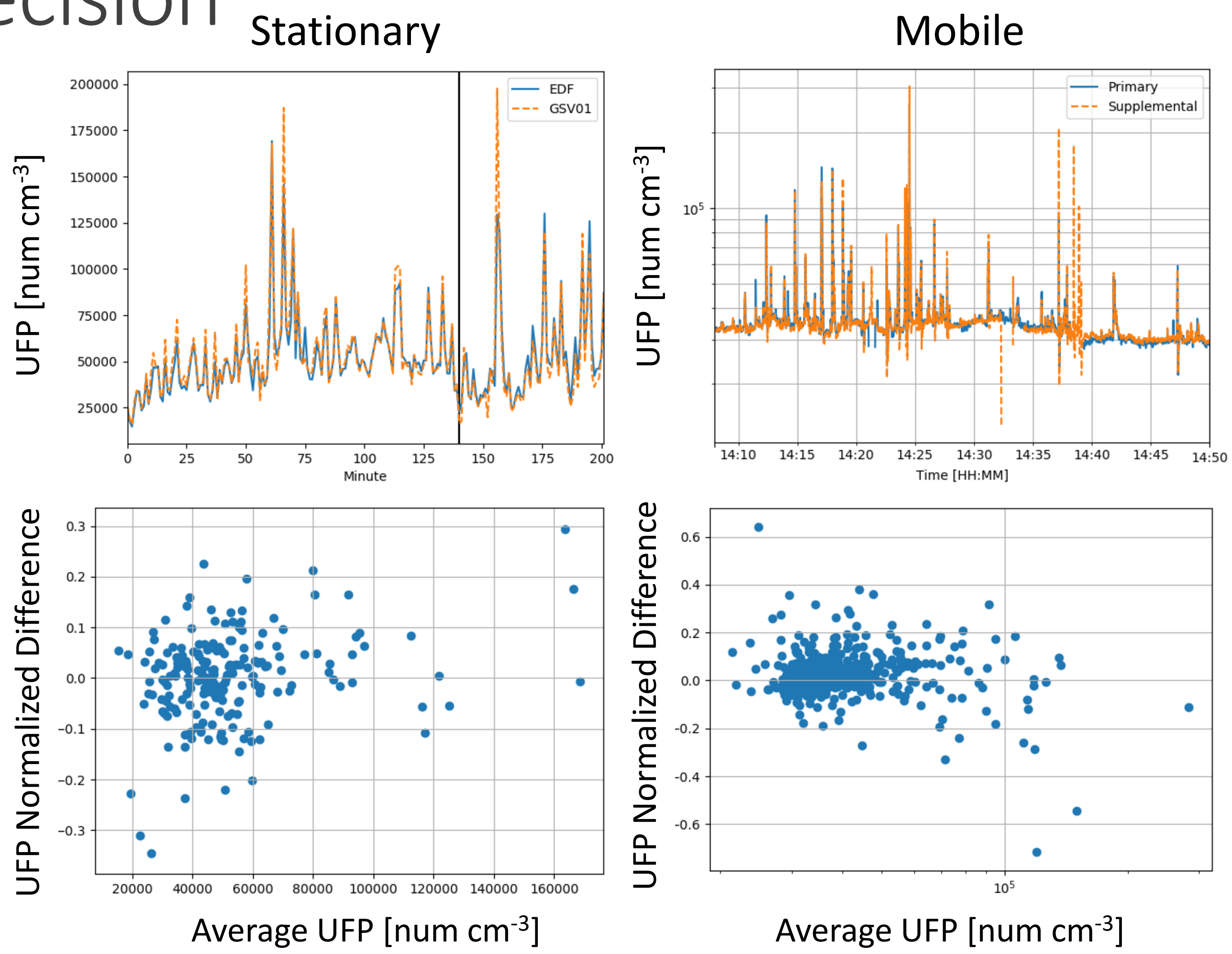
Two measures to quantify precision:

- Standard deviation of normalized differences: $\mathrm{COV} = \left(\frac{1}{n}\sum\left(\frac{d_i}{\sqrt{2}\bar{C}_i}\right)^2\right)^{1/2}$
- Standard deviation of differences within concentration bins: $\mathrm{STD} = \left(\frac{1}{n}\sum\left(\frac{d_i}{\sqrt{2}}\right)^2\right)^{1/2}$

d_i – Differences, $\bar{C}_i$ - Average

Averaging Time	Pollutant	*COV*	STD*
Stationary - 60 min	$PM_{2.5}$	21.0 (12.6 – 29.1) %	3.11 μg m^{-3}
	BC	13.1 (11.3 – 14.8) %	0.200 μg m^{-3}
	UFP	3.8 (2.6 – 5.2) %	1890 cm^{-3}
Mobile - 1 sec	$PM_{2.5}$	22.5 (21.5 – 23.4) %	1.35 μg m^{-3}
	BC		4.06 μg m^{-3}
	UFP	5.3 (4.5 – 6.2) %	1650 cm^{-3}

* Using 0-50th percentile of observations



Top: Time series of collocated 1 minute (left) and 1 second (right) average UFP.
Bottom: Normalized (by average concentration) differences of UFP.
Vertical black line divides collocation on two different days

Data Interpretation Hotspots

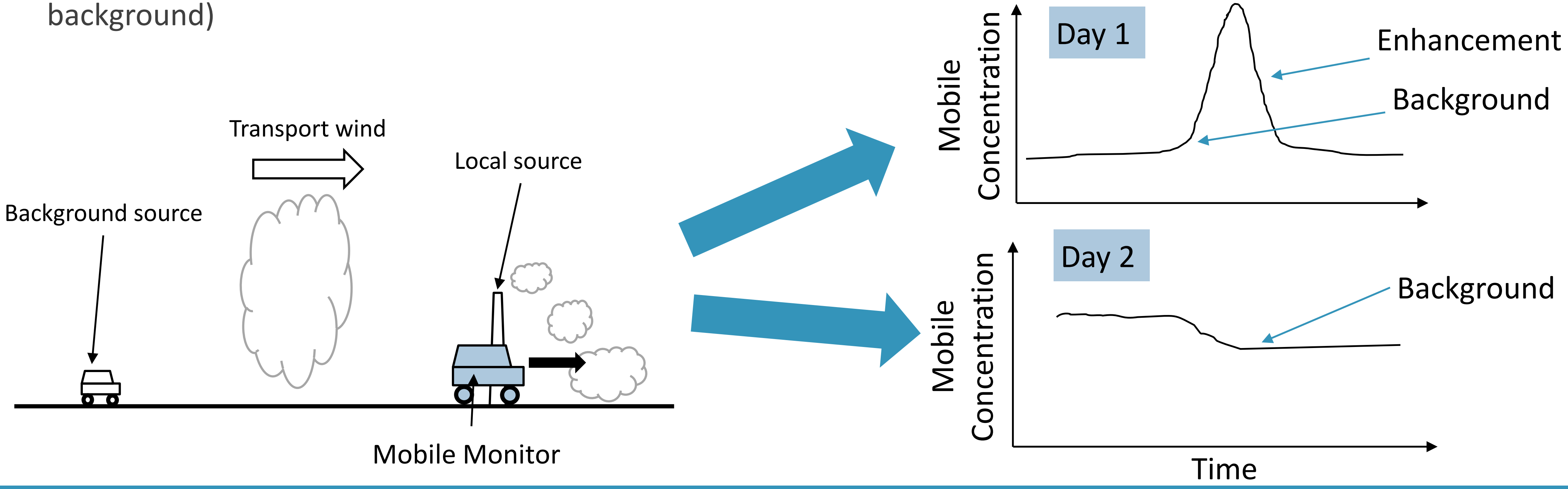
Interpreting Mobile Observations

Observations are impacted by “background” sources and “local” sources within the study domain

- We analyze the concentration enhancement caused by local sources

Mobile observations are a “snapshot”

- We aggregate repeated observations at the same location to derive stable values (of enhancement and background)

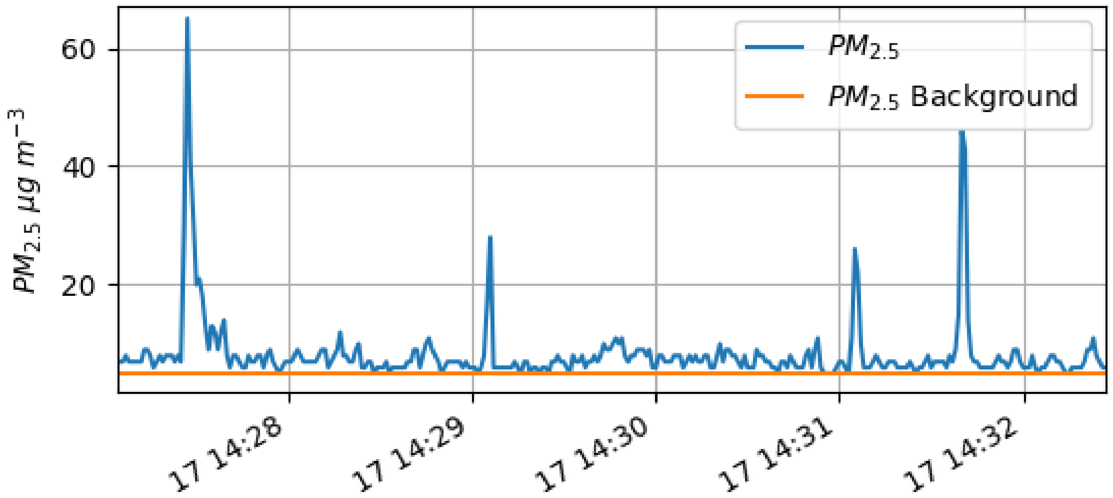


Mobile Background

We needed estimate a background concentration to interpret mobile observations

We used the 5th percentile of observations over a 10 minute window as an estimate of background

Analysis presented today uses enhancements

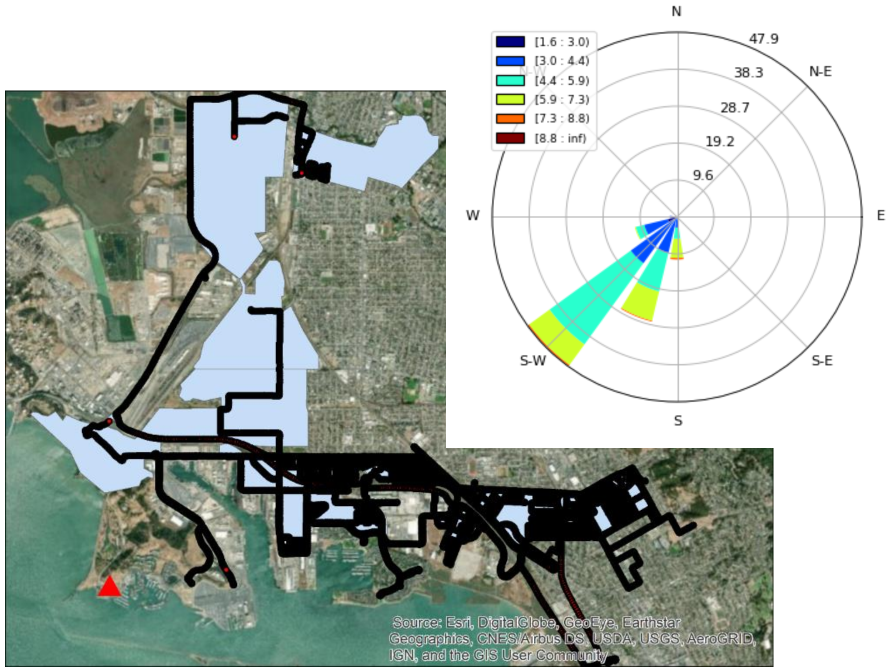


$PM_{2.5}$ background and enhancement example

Mobile Background

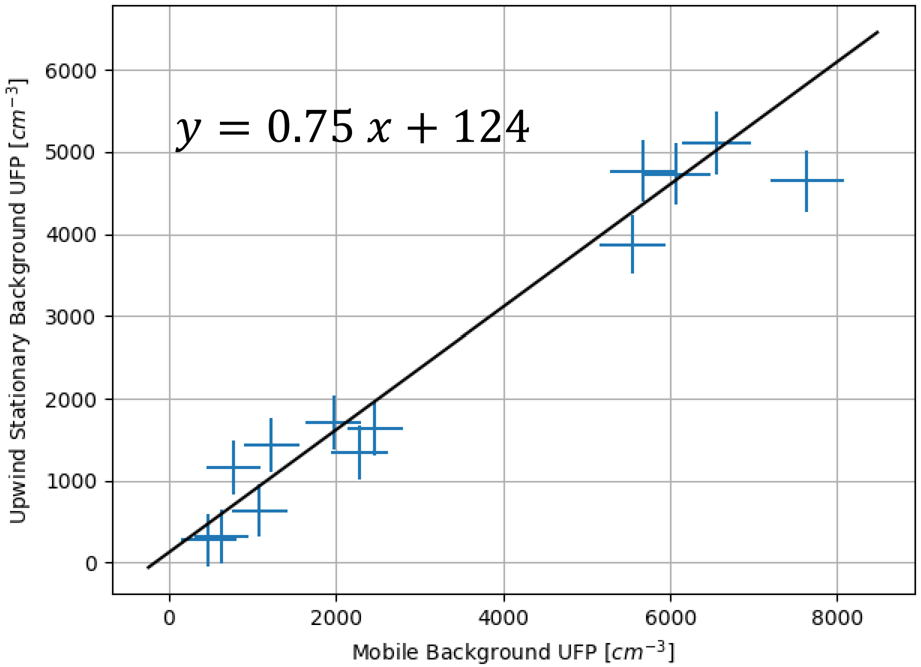
We compared mobile background with measurements made at a stationary upwind location

Results provide evidence that mobile background is a useful measure of background



Mobile background drive route during comparison with stationary measurements

▲ - Stationary monitor



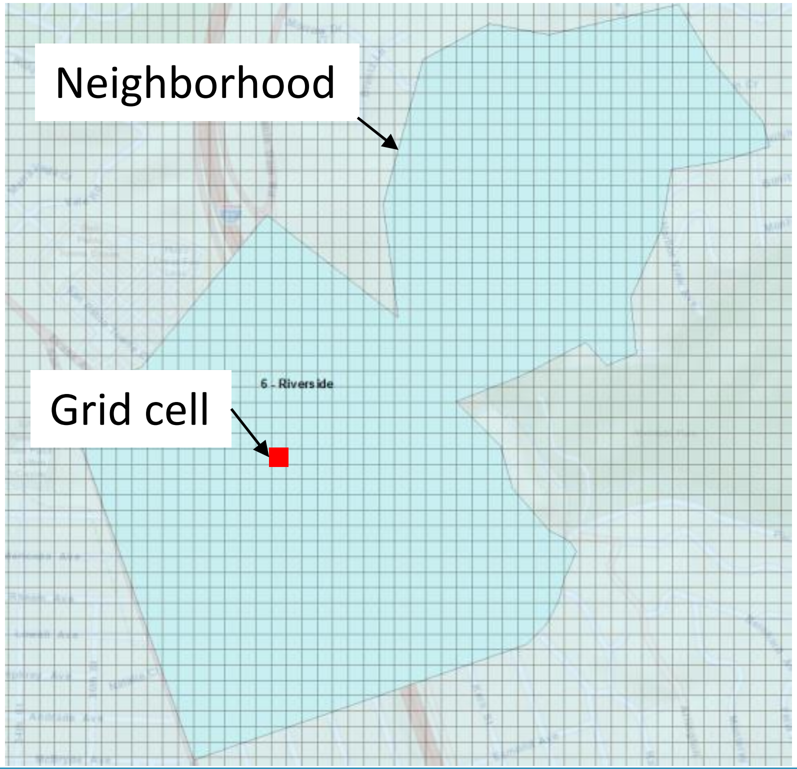
Comparison of 10 minute average UFP at stationary upwind monitor with UFP mobile background.

Hotspot Method

The hotspot method selects grid cells that are associated with higher concentrations during the measurement period

For every grid cell

Define surrounding neighborhood



Conduct paired difference t test:

Compute Differences: $C_{diff} = (C_{grid} - C_{neighborhood})_{Visit\ 1}, (C_{grid} - C_{neighborhood})_{Visit\ 2}, \dots, (C_{grid} - C_{neighborhood})_{Visit\ n}$

test $\overline{C_{diff}} > 0$ at 95% confidence

(Optional) Account for multiple comparisons for test

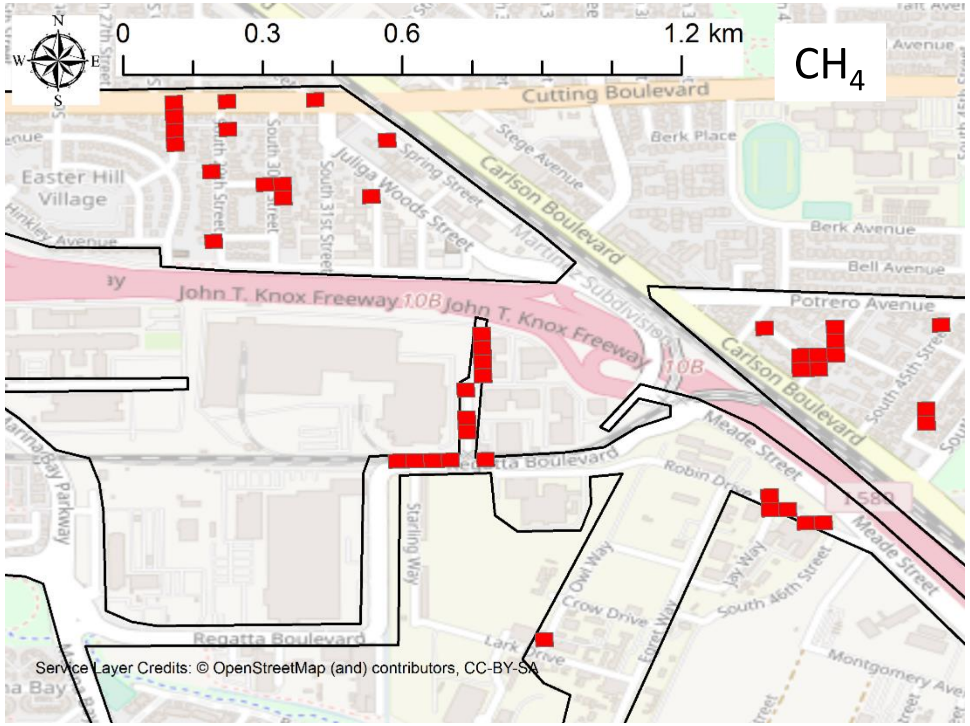
C_{grid} and $C_{neighborhood}$ are the background-subtracted "enhancements"

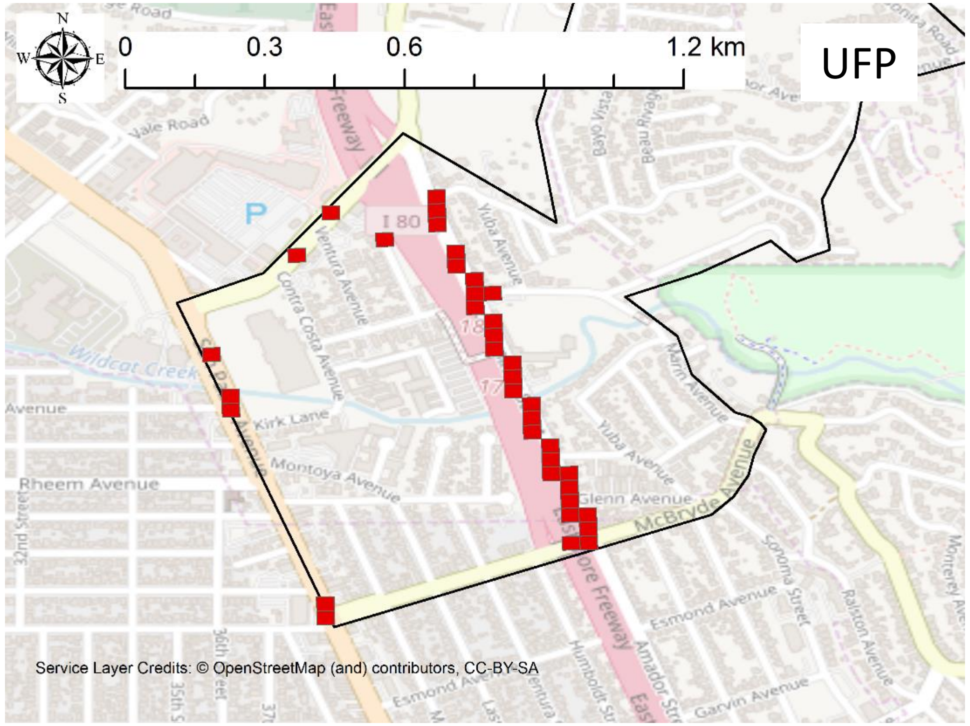
Hotspot Example

Example of UFP and CH_4 hotspots in two polygons

UFP hotspots are likely caused by traffic emissions

Some CH_4 hotspots are nearby facilities





Next Steps - Mapping

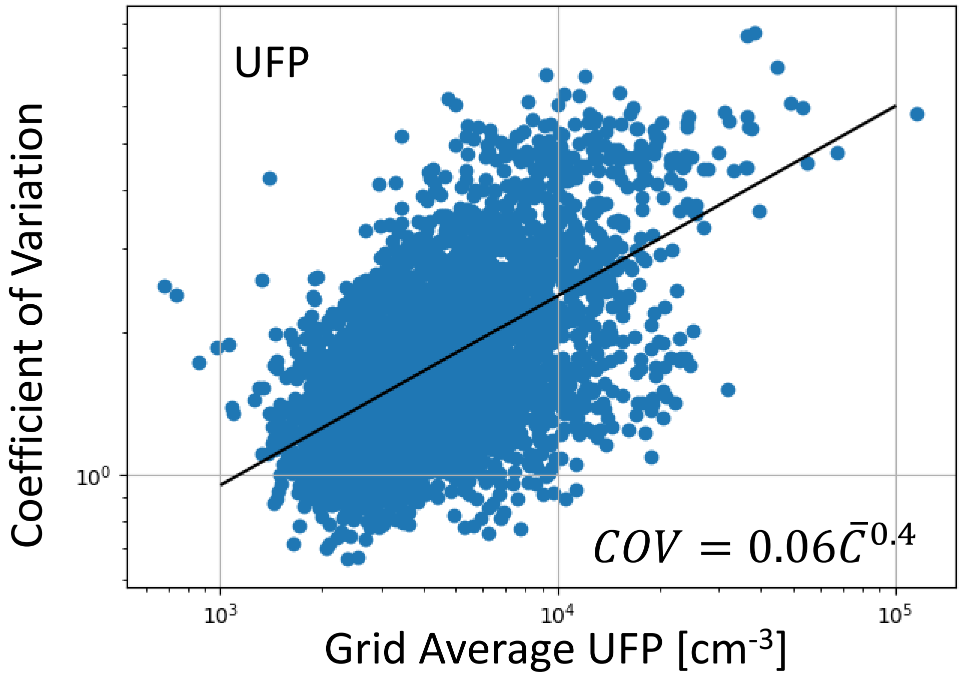
Mapping – Concentration Variation

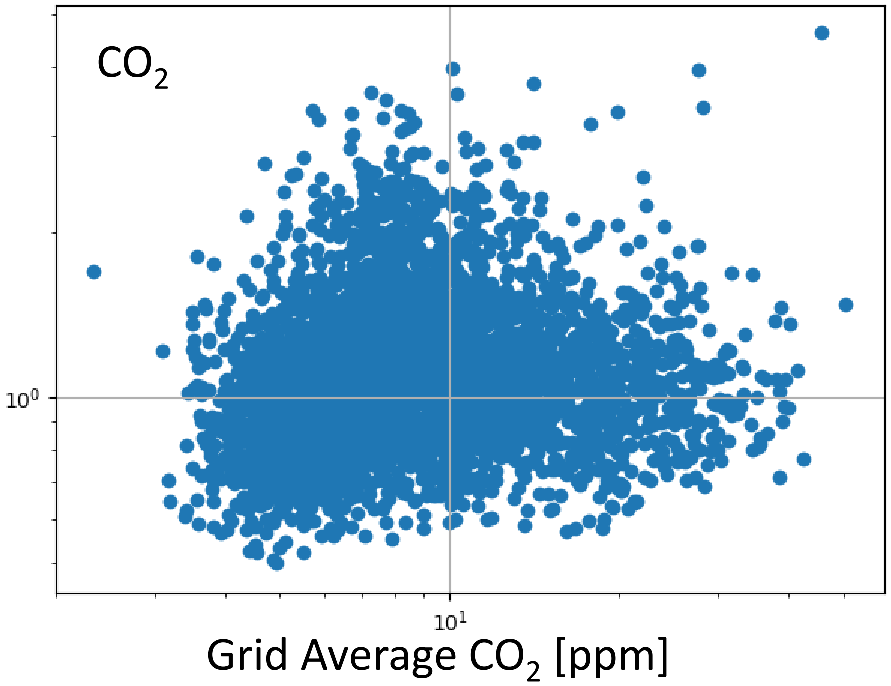
To present concentration “maps” we must estimate the variation within grid cells

Useful model for concentration variance: coefficient of variation (COV) is constant over the domain

Some pollutants have increasing COV at higher concentrations

- Data described by skewed distribution - caused by dispersion and variation of emissions





Pollutant	COV	Std Err/ Mean
CO_2	1.14	25%
UFP	1.83	41%

Standard error is based on 20 visits to a grid cell

Discussion and Conclusions

Hotspot method is useful to identify locations associated with high concentrations

Mobile background method provides a useful measure of background concentration

Coefficient of variation for UFP varies from about 1 – 6, and ratio of standard error to mean for a grid cell over 20 repeated visits varies from about 22% - 134%

Potential biases: Measurements are made on roads in traffic – observations are potentially biased due to following vehicles

Questions?

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