Personal air pollution exposures in NYC bicycle commuters: Evidence from the Biking & Breathing study

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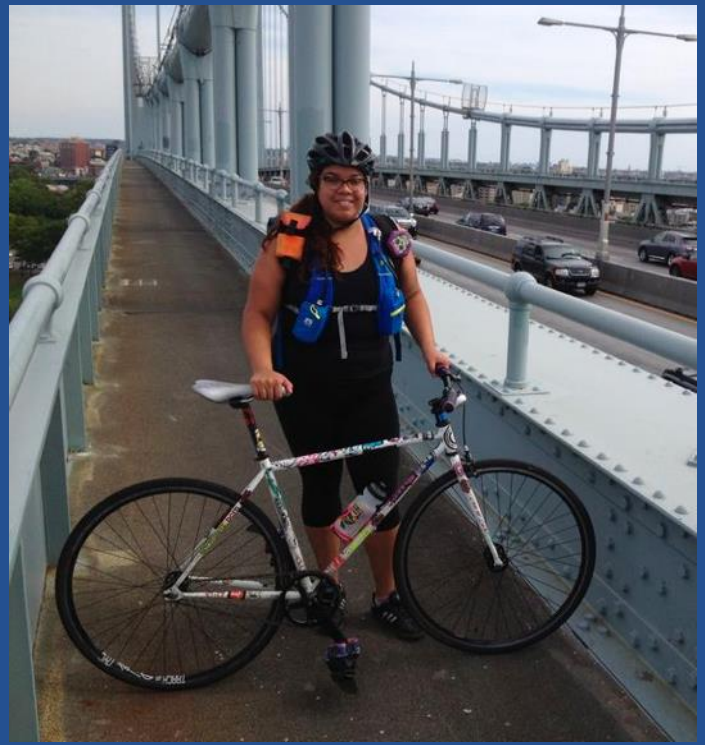
Motivating questions

- Can we reliably estimate potentially inhaled dose "in the wild"?
  - Yes we can, using readily available hardware.
- Does measuring dose change our understanding of the risk incurred during cycling?
  - Yes it does. A dose metric reveals that for cyclists in our study, the majority of their 24 hr black carbon dose occurs during cycling.
- How much health risk are cyclists taking on?
  - Too early to say. We are still gathering the data to assess this, but pilot evidence suggests that cycling exposures predict higher blood pressure.
- What can cyclists and urban planners do to minimize risk?
  - Route cyclists away from vehicle emissions!

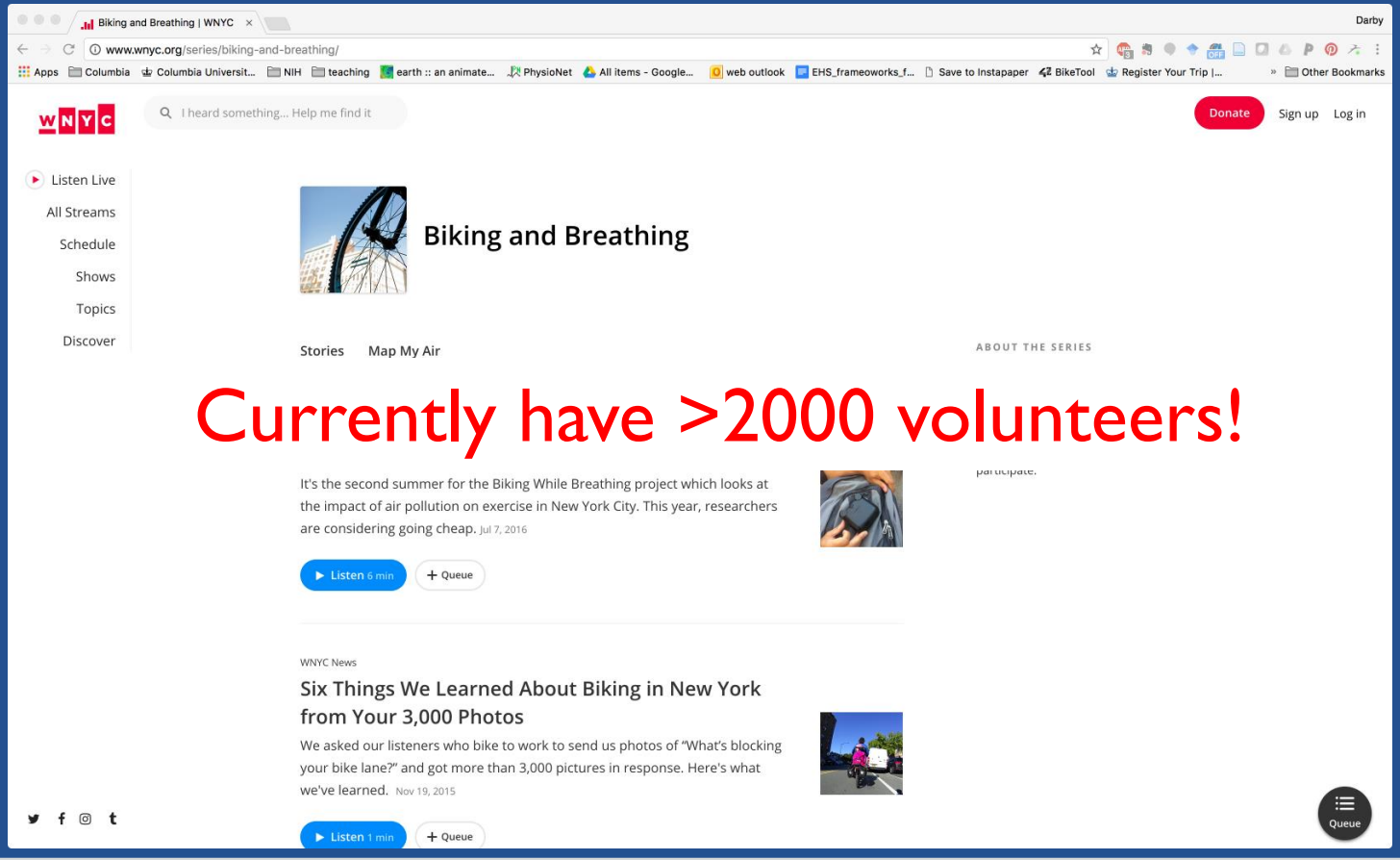
Background and study design

Study design

- In partnership with WNYC, recruit bike commuters who ride 45±15 minutes each way.
- Ask them to carry out six 24 -hour monitoring sessions bracketing at least one commute ride.
- Epi hypothesis: short duration air pollution dose increase post-exposure BP and decrease heart rate variability.
- (exploit both within- and between-participant variation)



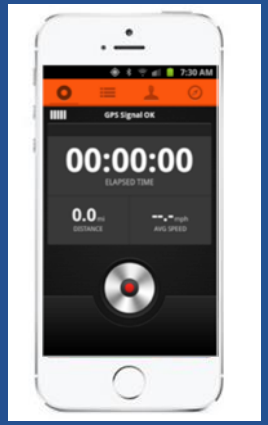
wnyc.org/streets - ongoing partnership with WNYC for recruitment and outreach



Environmental Sensors

MicroAeth
Black Carbon

MicroPEM
PM2.5



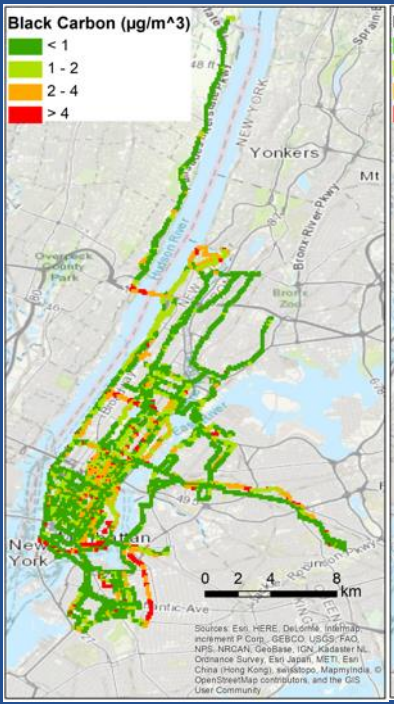
Smart Phone App for GPS

Physiological Sensors

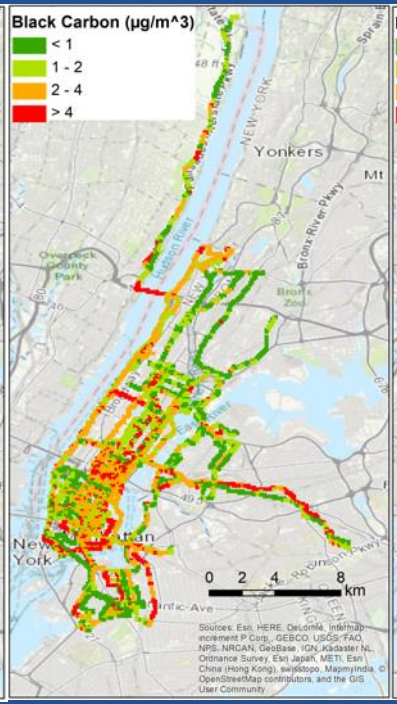
Hexoskin biometric shirt:
- Minute ventilation (via Dual band RIP sensors)
- ECG

ABPM for
Blood pressure

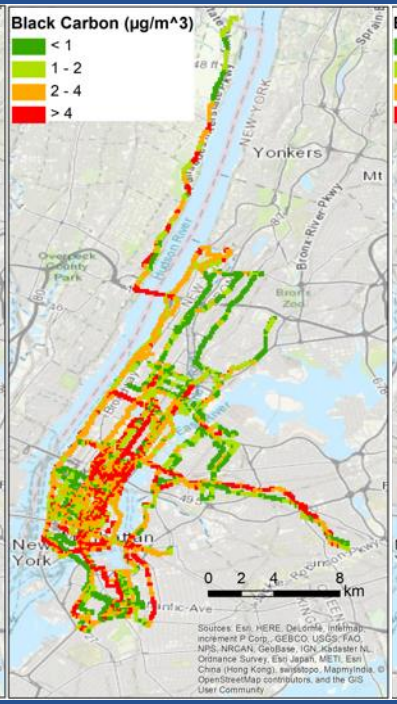
What can hyper-local AP data offer?



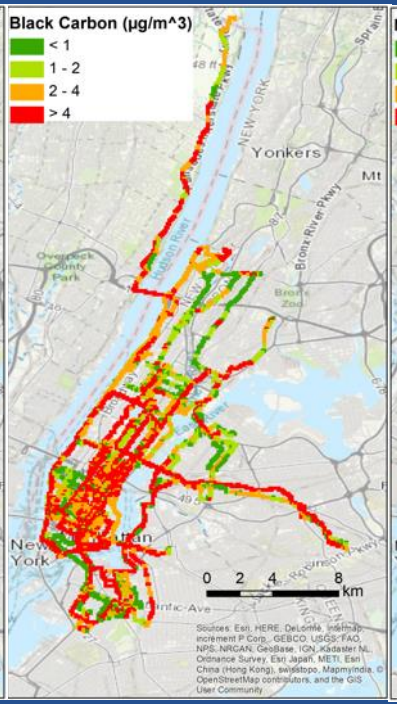
10 percentile



median



mean



90 percentile

N (# of points in each 100m x 100m grid)

Study status

- NIH R21/R33 "Phased innovation" grant - 2 year validation phase followed by 3 year implementation phase
- Validation phase: lab testing + deployment in 45 participants (all data shown today from this phase)
- We advanced to the implementation phase in March of 2017
- Target enrollment for Phase II: ~150 (~90 completed so far)

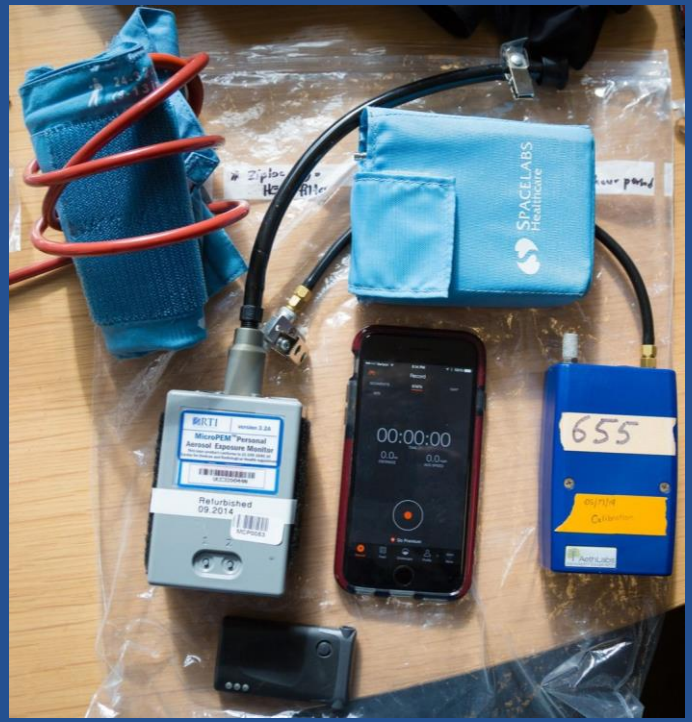


Photo: WNYC (http://www.wnyc.org/story/biology-teacher-reflects-bicycles-bridges-and-breathing)

Does measuring dose change our understanding of the risk incurred during cycling?

Questionnaire → Central site → Residential → Modeled Personal → Measured Personal → Measured Potential Inhaled Dose

- By definition: inhaled mass of particulate matter

  (mass concentration x V_E)
- For fine particles, it's a first approximation of the mass deposited in the lung
- "potential" ← other factors affect deposition
- Requires estimates of tidal volume (liters of air per breath) and respiration rate (breaths per minute), along with high frequency pollution data
- Minute ventilation acts a multiplier on concentrations

Minute ventilation

Hexoskin Shirt

- Hexoskin shirt measures all three proxies for minute ventilation → model missing data
  - Dual band RIP sensors (RR, Tidal Volume) RIP = Respiratory Inductance Plethysmography
  - Heart rate ECG sensor (and HRV)
  - 3 axis accelerometry
- Lab validation on 17 participants compared to gold standard (reported on previously)

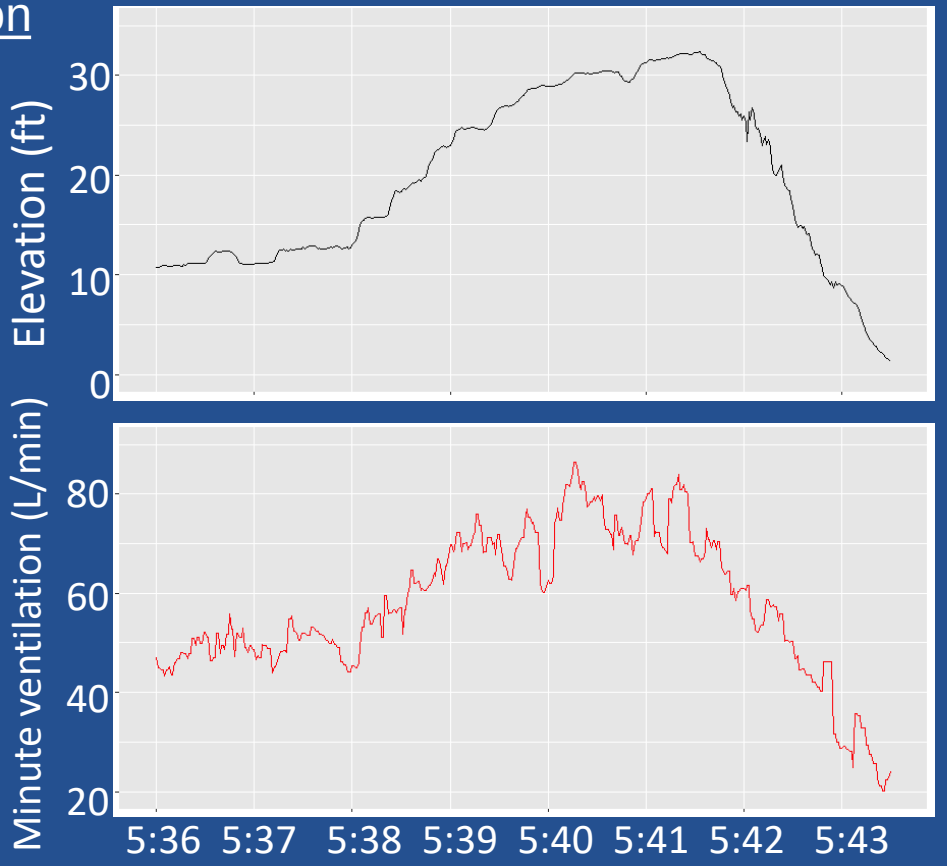
ECG sensors for heart rate & hrv

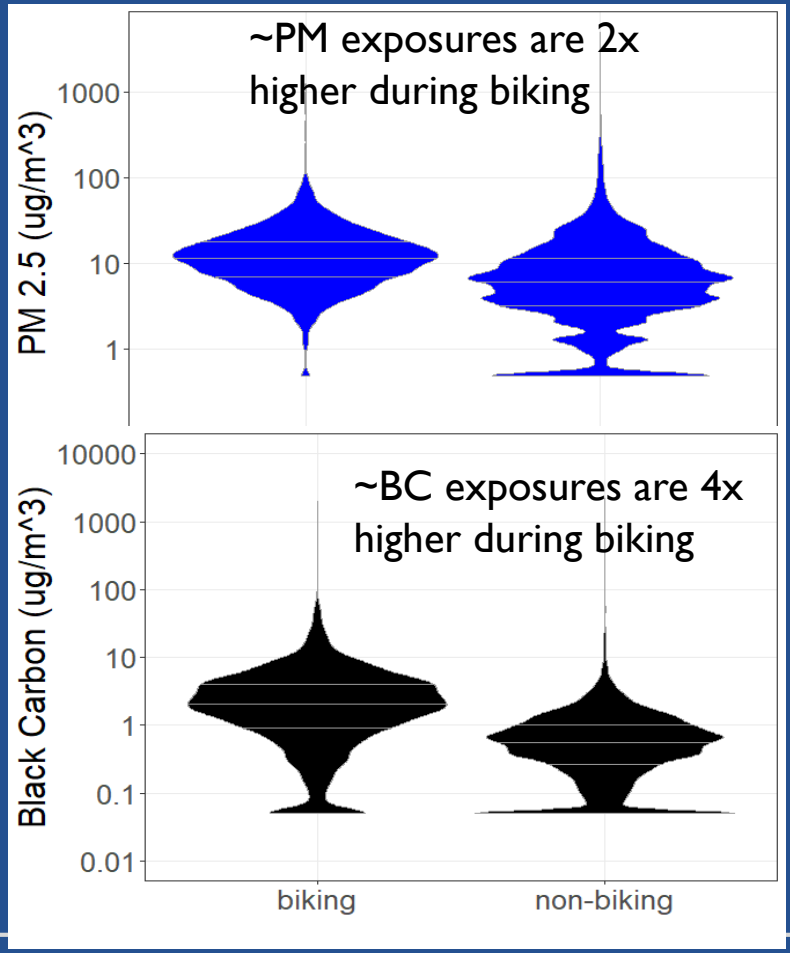
RIP sensors

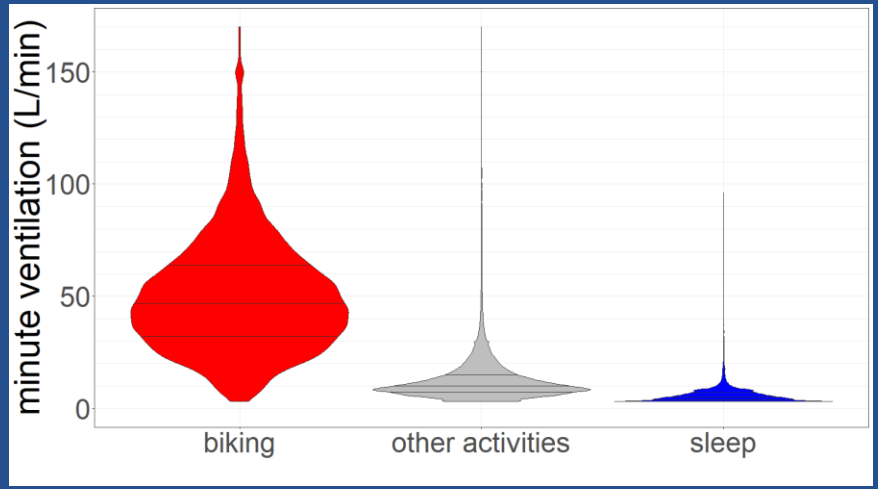
Accelerometer in data logger

Minute ventilation vs elevation

Biker 02 Session 1

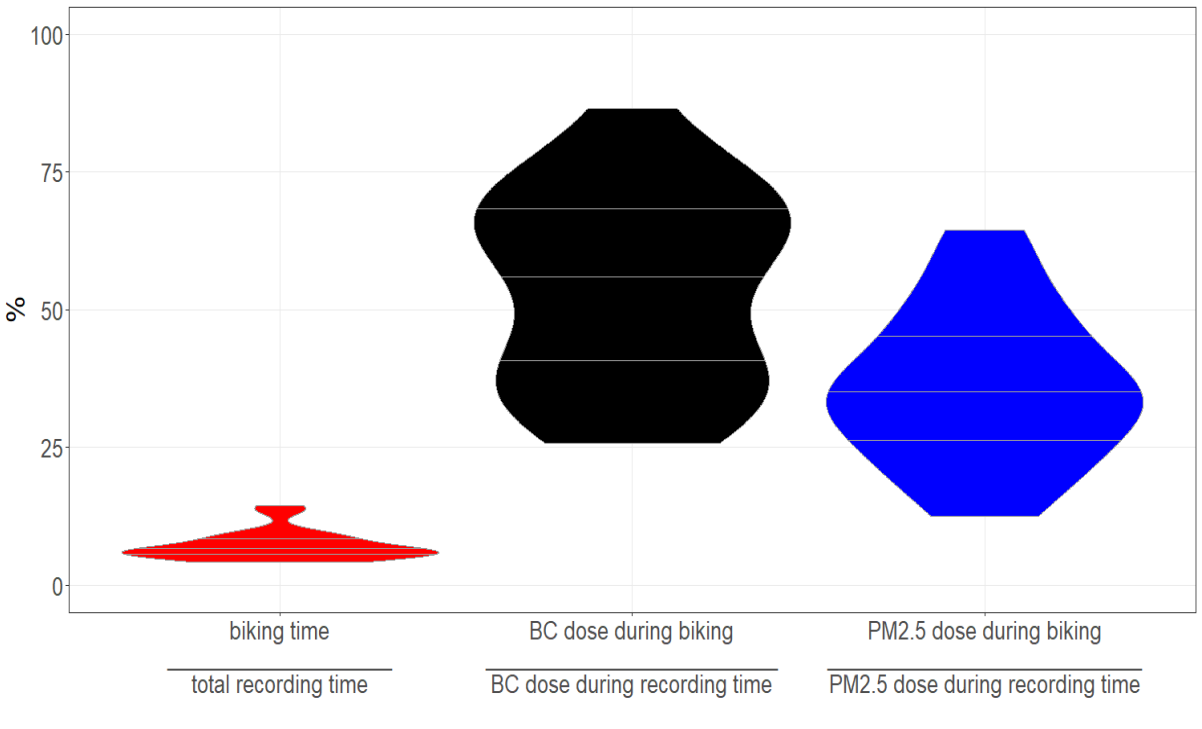




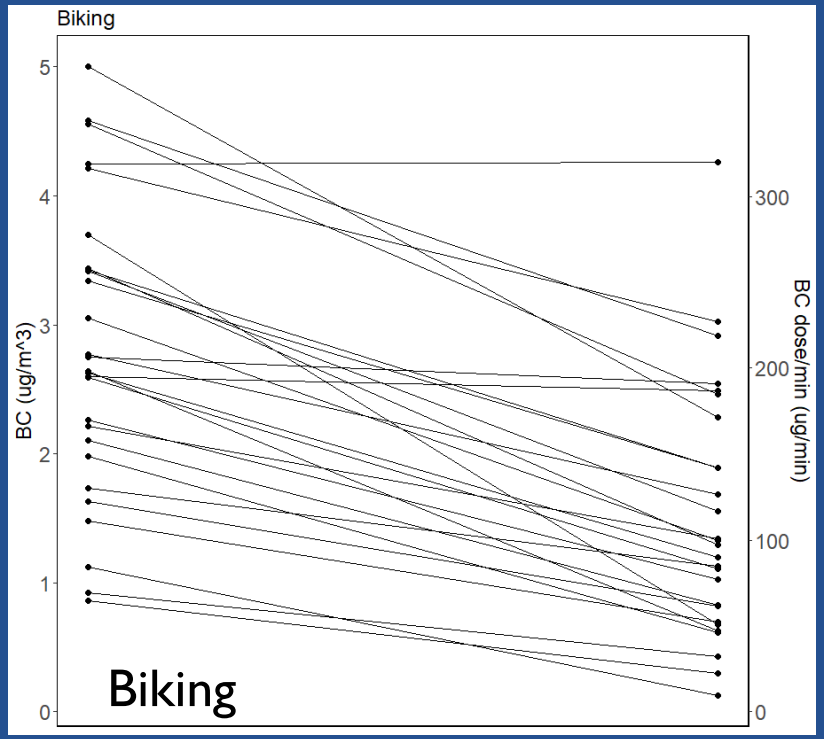


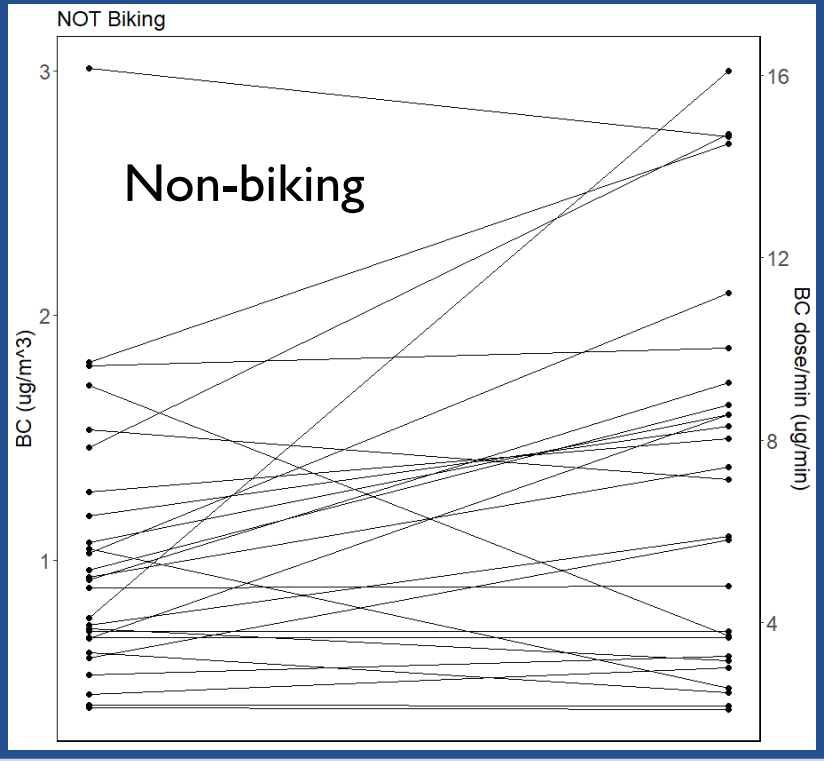
	Min	1st Q	Median	Mean	3rd Q	Max
Biking	3	32	47	50	64	170
Other	3	7.3	10	13	15	170
Sleep	3	3.6	5.0	5.9	7.0	96

Biking period only accounts for ~ 7% of 24-hr period, but 55% of total 24-hr black carbon dose and 35% of total 24-hr $PM_{2.5}$ dose

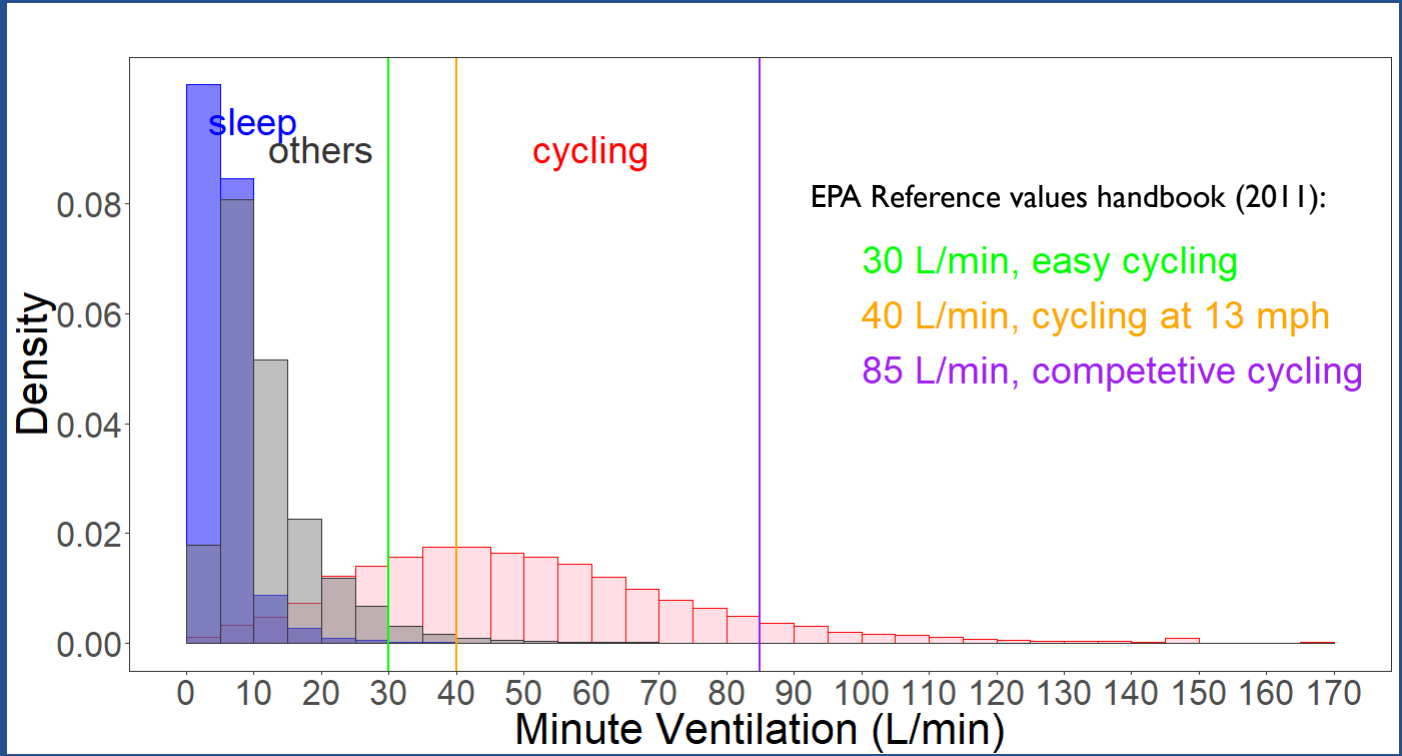


Minute Ventilation affects exposure ranking during biking and non-biking periods





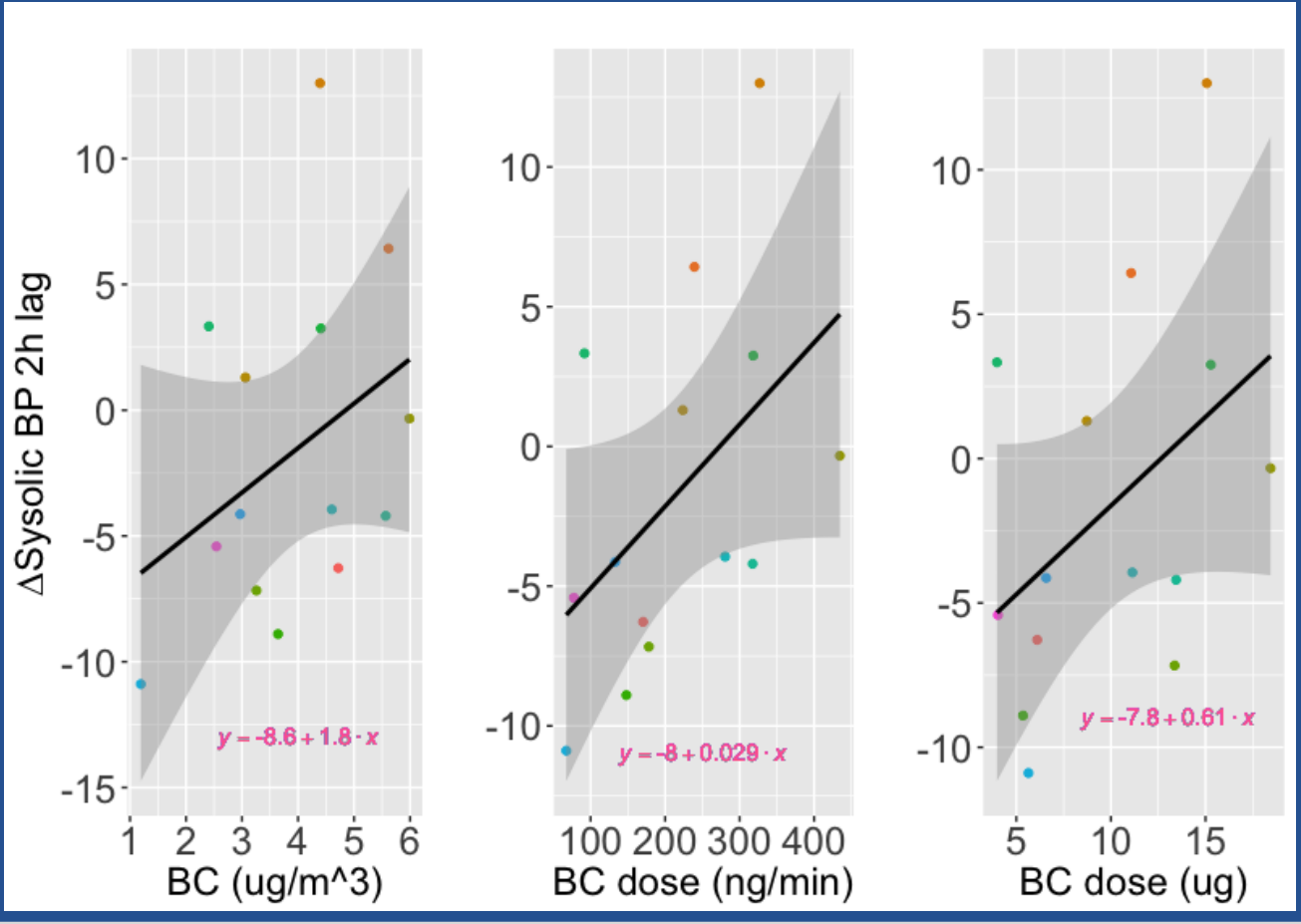
EPA reference value captures the central tendency of our data, but masks a lot of variation.

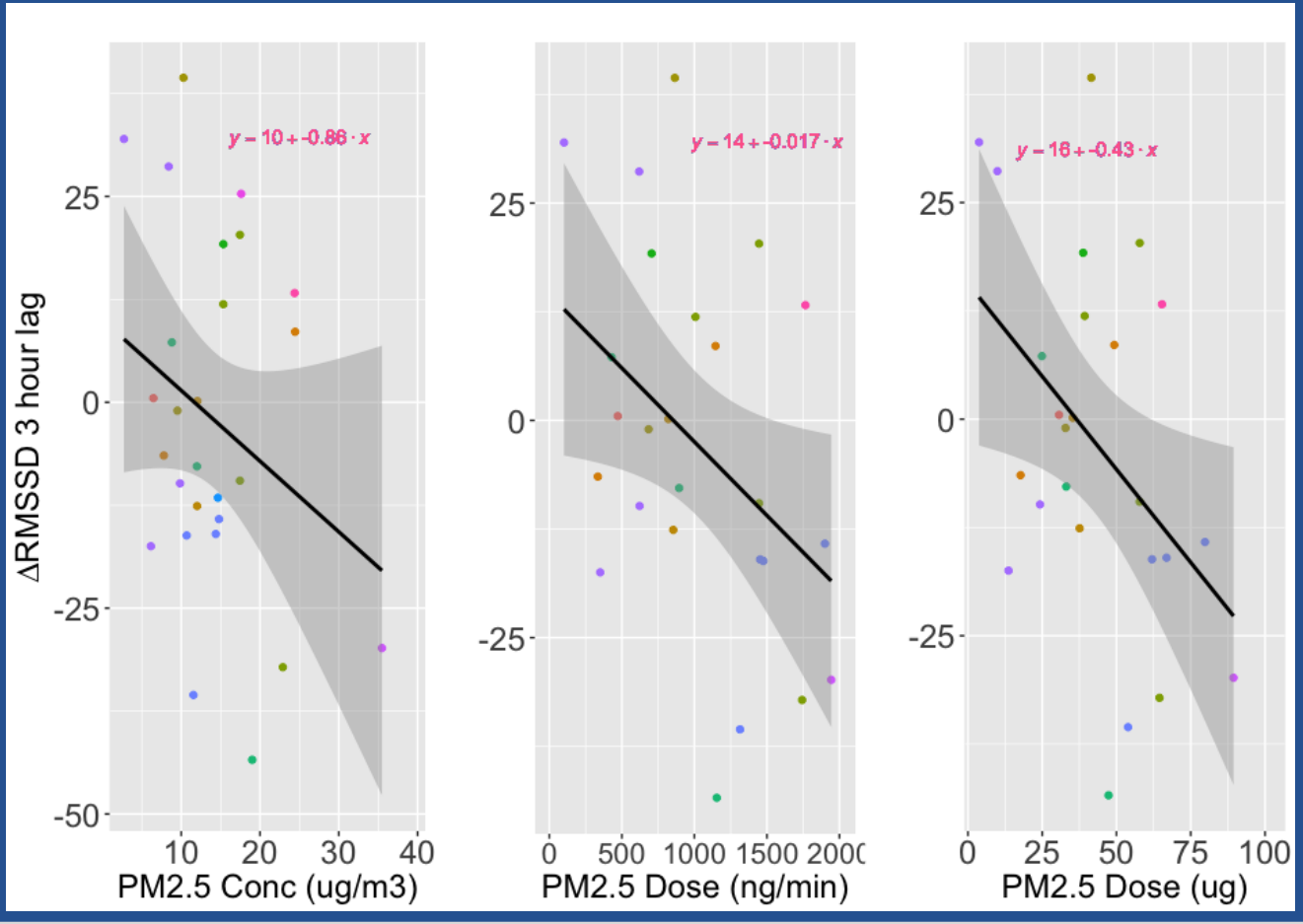


How much health risk are cyclists taking on?

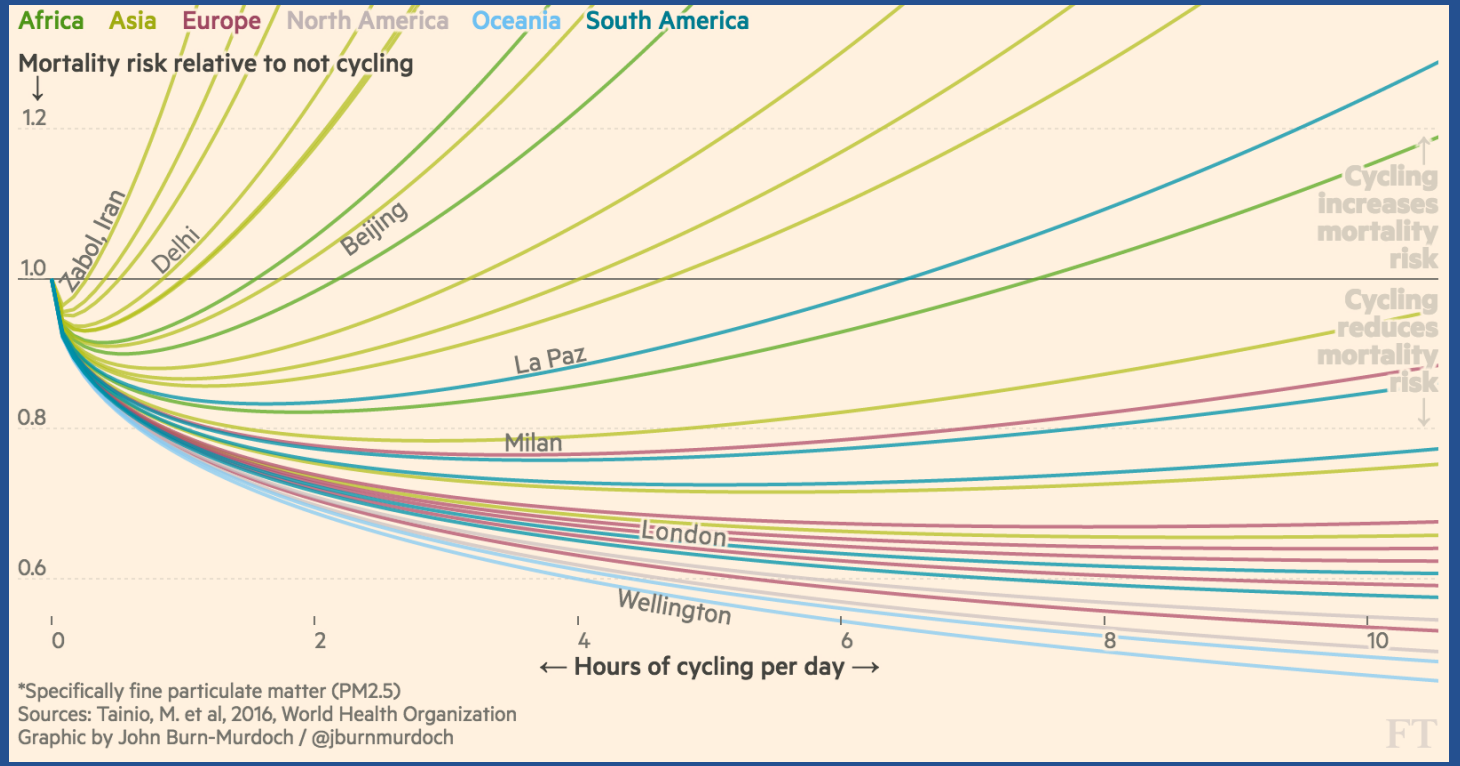
We know surprisingly little about the health effects of short duration exposures

- Time series studies – pollution peaks trigger increases in morbidity & mortality
- Chamber studies (human and animal) – exposure affects HRV and BP, but exposures are much higher (10x)
- Few studies examining the acute effects of routine exposures
- Do short duration peaks matter beyond their contribution to the average? ⇔ How much should policymakers worry about short-duration peaks?


ΔSysolic BP 2h lag
10
5
0
-5
-10
-15
y = -8.6 + 1.8 · x
1 2 3 4 5 6
BC (ug/m^3)
10
5
0
-5
-10
y = -8 + 0.029 · x
100 200 300 400
BC dose (ng/min)
10
5
0
-5
-10
y = -7.8 + 0.61 · x
5 10 15
BC dose (ug)


y = 10 + -0.86 · x
y = 14 + -0.017 · x
y = 16 + -0.43 · x
ΔRMSSD 3 hour lag
25
0
-25
-50
10
20
30
40
PM2.5 Conc (ug/m3)
0
500
1000
1500
2000
PM2.5 Dose (ng/min)
0
25
50
75
100
PM2.5 Dose (ug)

In most settings, however, the exercise-related benefits of cycling outweigh the risks…

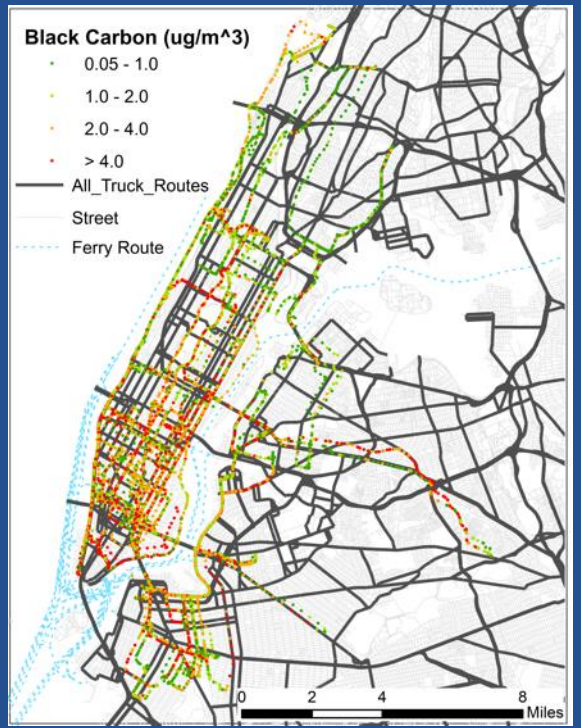


The greatest health risk associated with cycling is not doing it!

(https://ig.ft.com/sites/urban-cycling/)

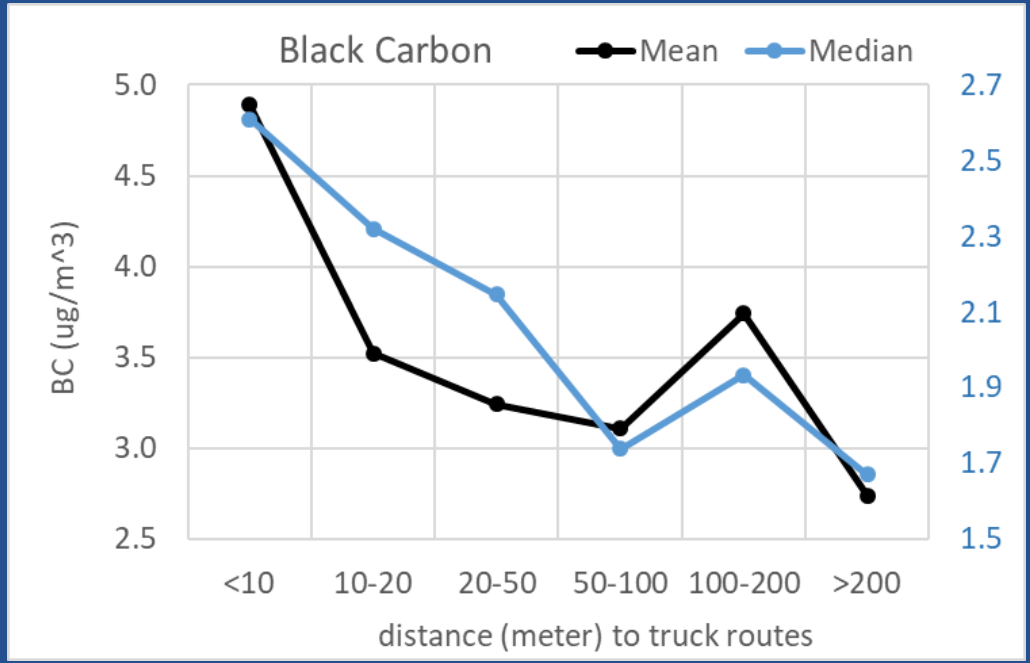
What can cyclists and urban planners do to minimize risk?

40% of the total biking routes in NYC are along or within 50 m of a designated truck route.



55% of the distance that our volunteers rode are along or within 50 meters of a designated truck route.

And it matters: BC exposures are higher close to truck routes



Mean BC of < 50m of truck routes = 4.30 ug/m^3

Mean BC of > 50m of truck routes = 3.10 ug/m^3

(p-value = 0.015)

Concluding thoughts

- The data quality criteria demanded by health research is generally quite high, but varies with study design.
  - To make comparisons across individuals (as in a cohort study), quality requirements are particularly high.
- Estimating minute ventilation is feasible and impacts exposure estimates even beyond physical activity periods.
- Health researchers are just beginning to explore the research potential of high frequency personal air samplers – lots to learn!

Acknowledgements

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WNYC (Fred Mogul)

www.wnyc.org/streets

Our amazing study participants who tolerate way too many sensors.