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Bicycle Facilities and the Uptake of Air Pollution by Active Travelers

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RESEARCH TEAM

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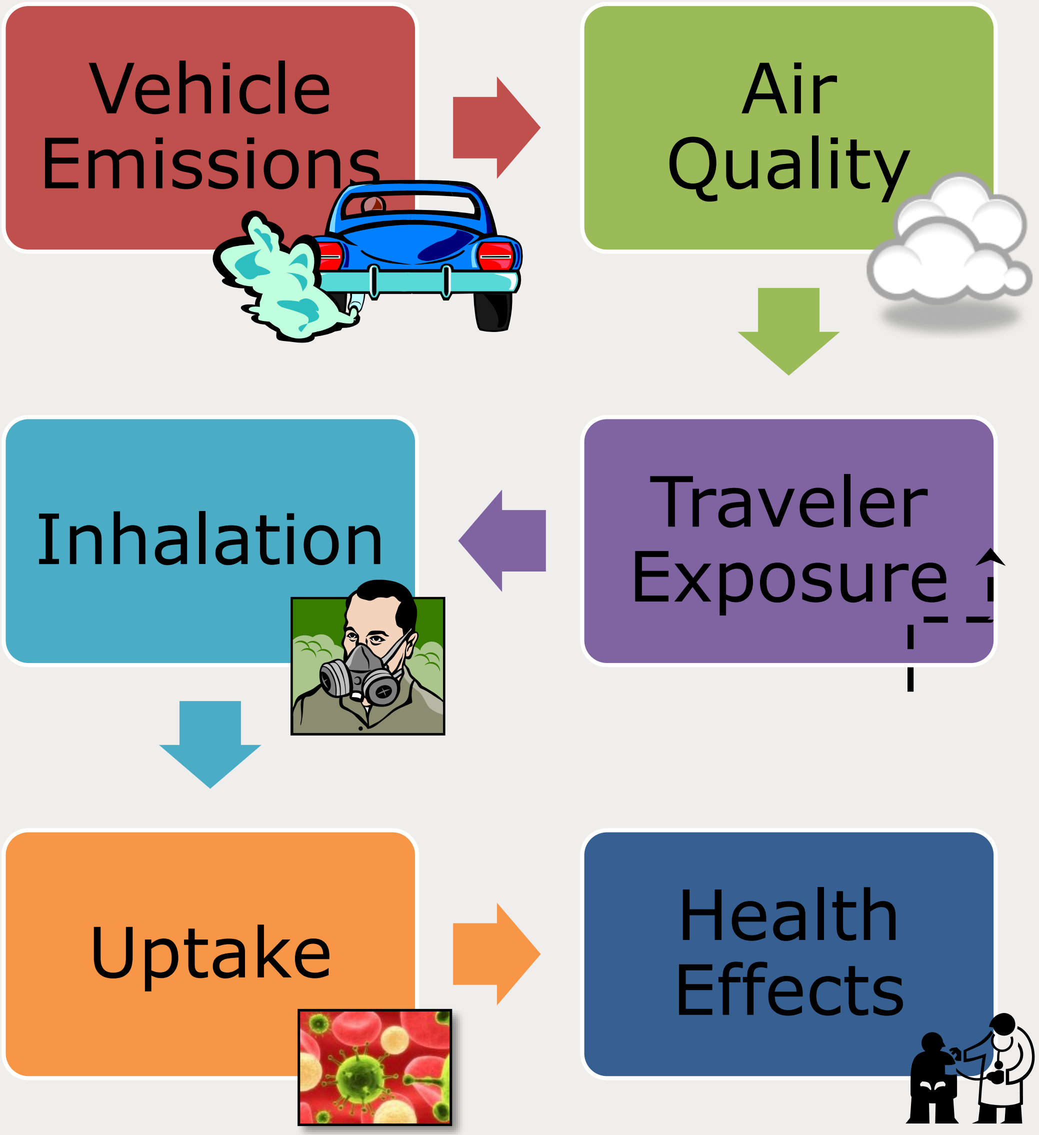
Outline

1. Goals
2. Data Collection
3. Intake/Uptake
4. Modeling Results
5. Conclusions
6. Next Steps

Framework

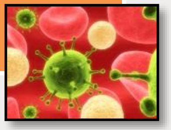
Adapted from Ott,
Stieneman & Wallace, 2007



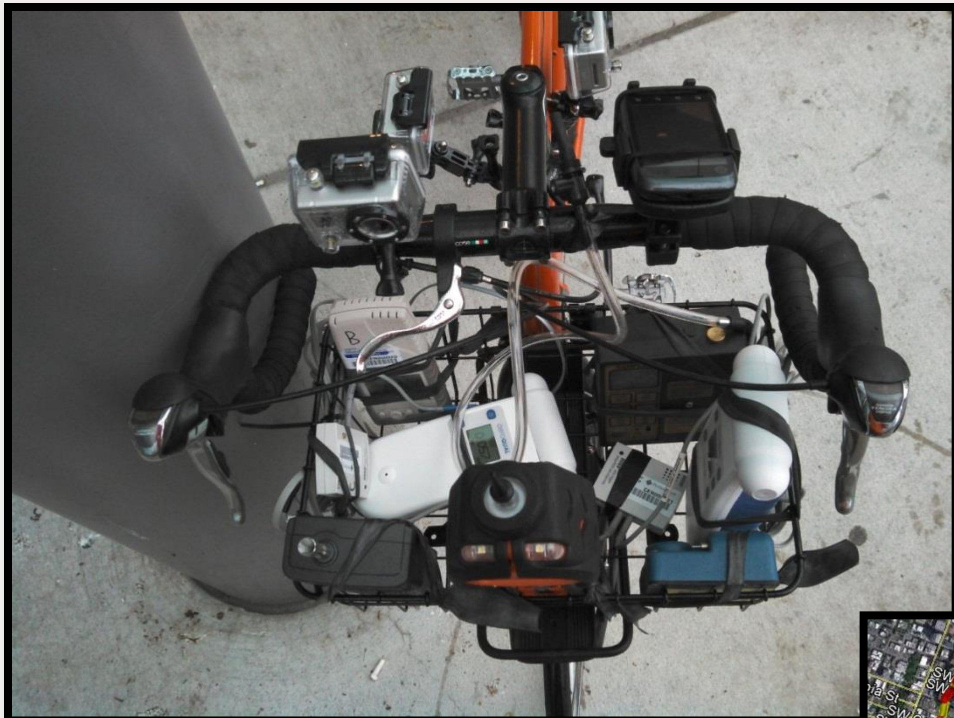
Inhalation

Traveler Exposure

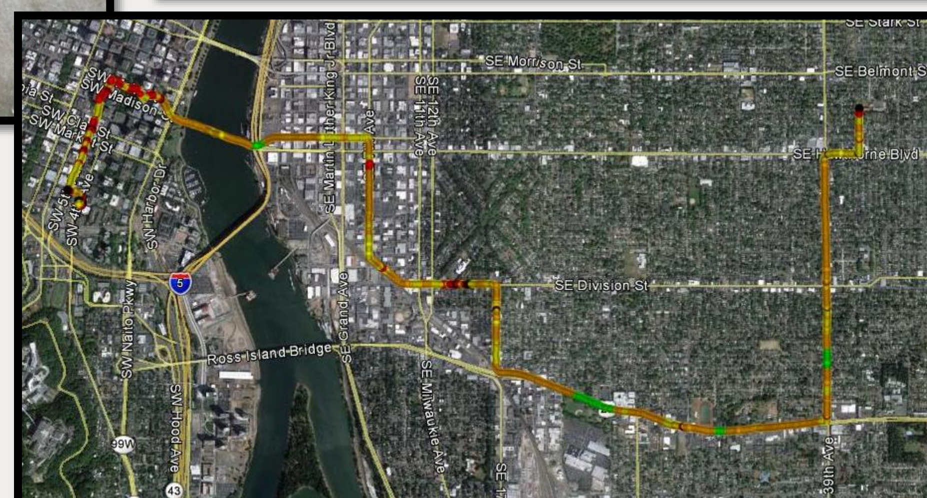
Uptake



Data Collection



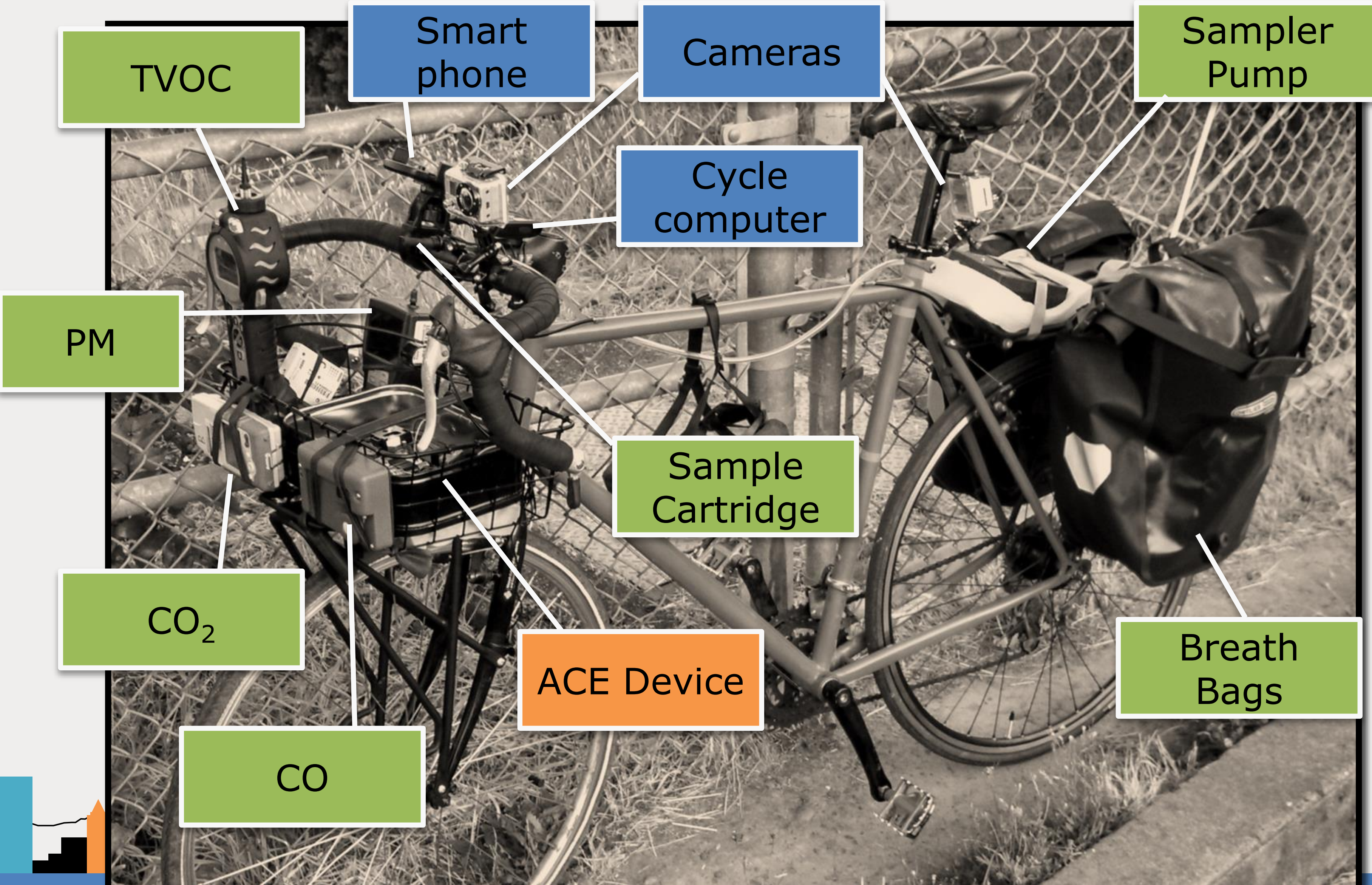
- 75 breath VOC samples
- 13 days
- 3 subjects
- 123 compounds



On-Road Sampling Example

Paired subjects; ambient & breath VOC
(20-30 minutes, 3-5 miles)

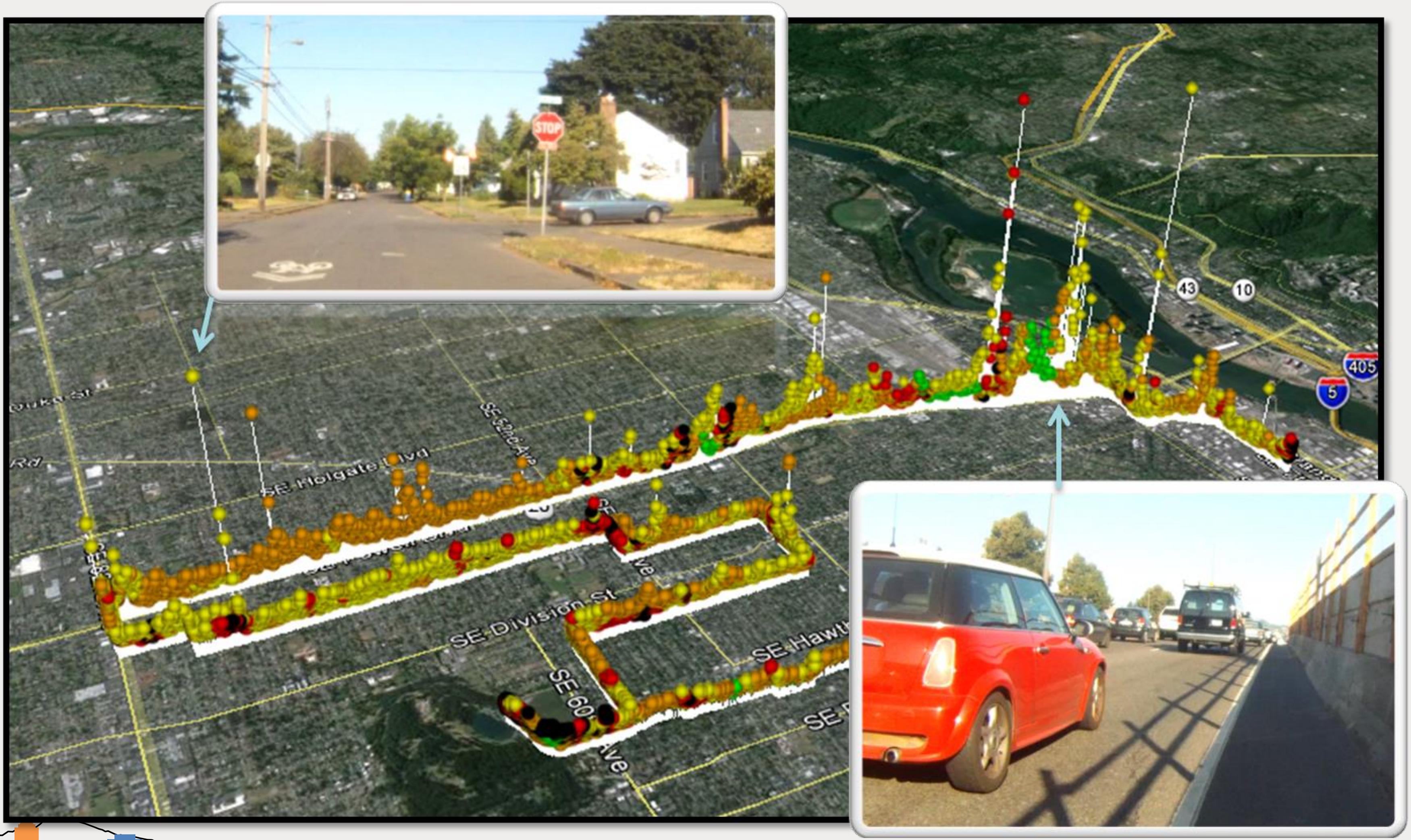
Sampling Equipment



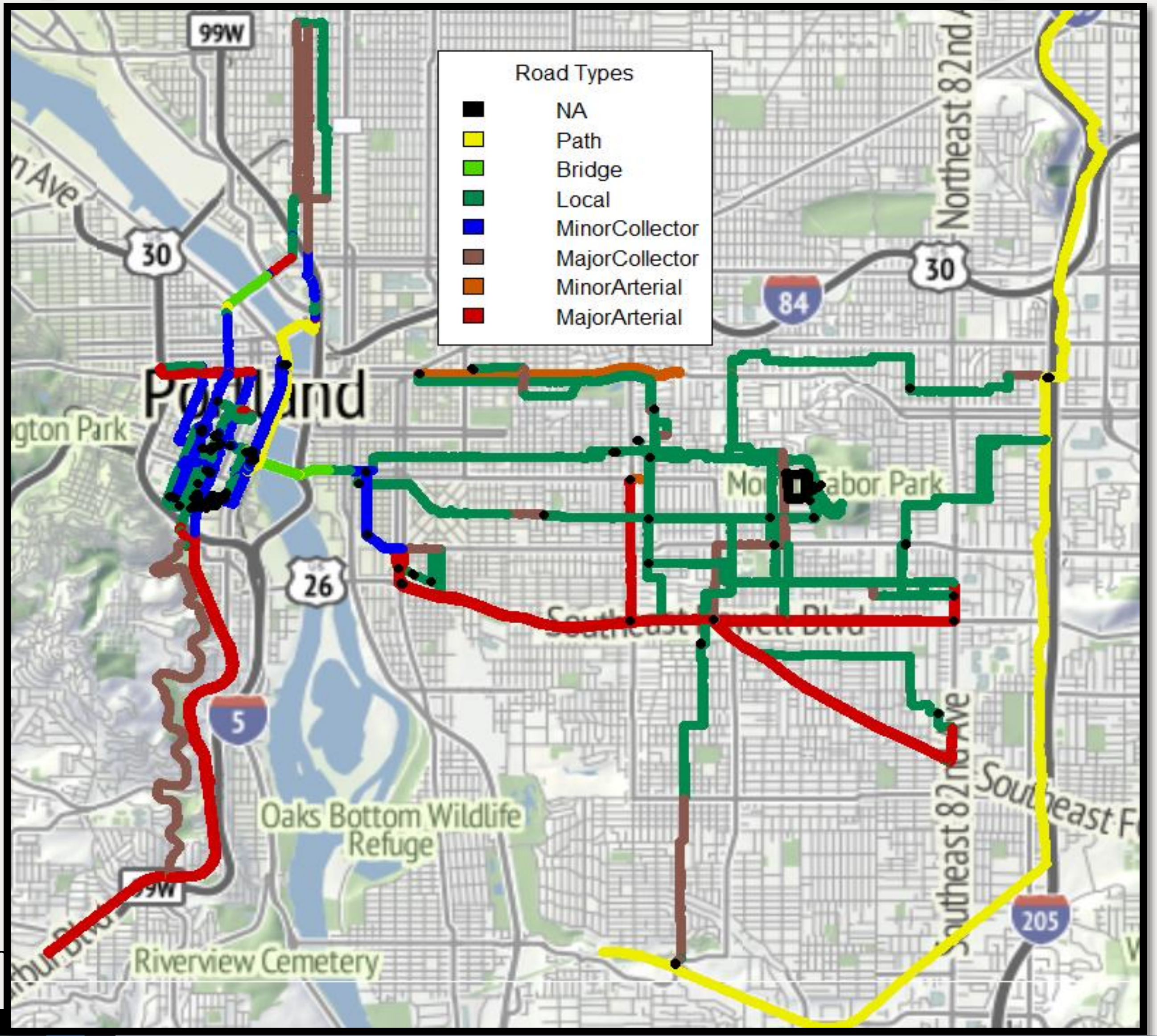
Breath Sampling

- Developed as medical screening
- End-tidal breath good proxy for blood concentrations
  - Low water-solubility VOC
  - Hydrocarbons like benzene, toluene,…
- Requires *very precise* instrumentation
- New standard for analysis with GC/MS

On-Road Sampling



Exposure Data coverage



~40 hours of data over 13 days

- GPS and sensor data 1 second resolution

- Breath & ambient samples 30 minutes

Inhalation

Exposure Conc'n × Breath Rate × Duration = Intake Dose

$$\frac{\text{mg}}{\text{m}^3} \qquad \frac{\text{m}^3}{\text{sec}} \qquad \text{sec} \qquad \text{mg}$$

Breath Rate:

$$V_T \times f_B$$

$$\left(\frac{\text{m}^3}{\text{breath}}\right) \qquad \left(\frac{\text{breaths}}{\text{sec}}\right)$$

Bicyclists’ Exertion

- External work
  - Speed & acceleration
  - Weight & slope
  - Wind & drag
  - Rolling resistance (tires, road)
- Personal factors (minor effects)
  - Basal metabolic rate
  - Fitness (exercise response)

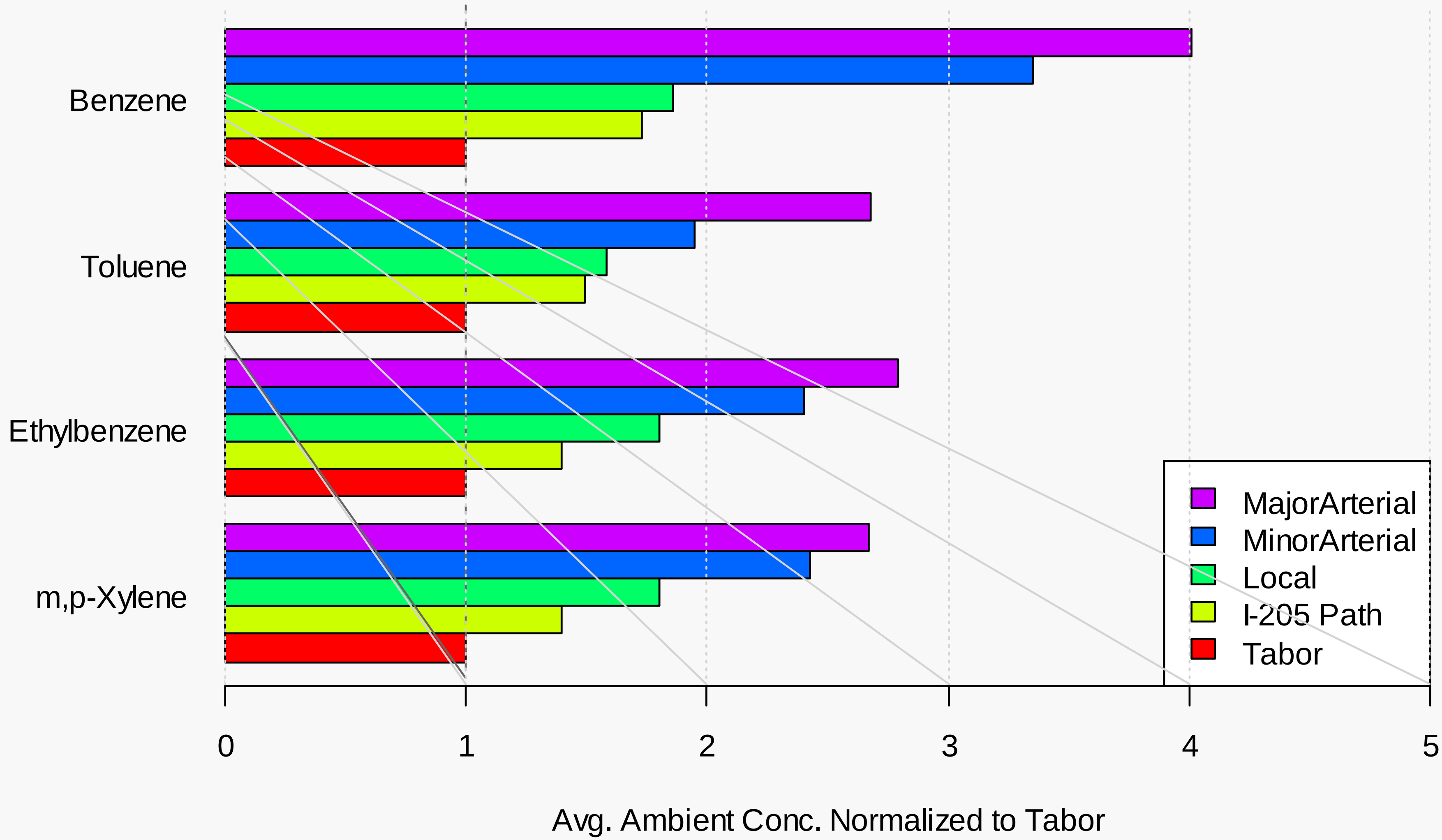
Bicyclist Uptake Studies

- Blood/urine samples (x1)
  - Metabolites of BTEX compounds (VOC)
  - Urban bikers > rural bikers
- Induced sputum samples (x1)
  - Lung-deposited black carbon
  - Bicyclists > transit riders
- Modeled uptake (x3)
  - Doses increases with exertion

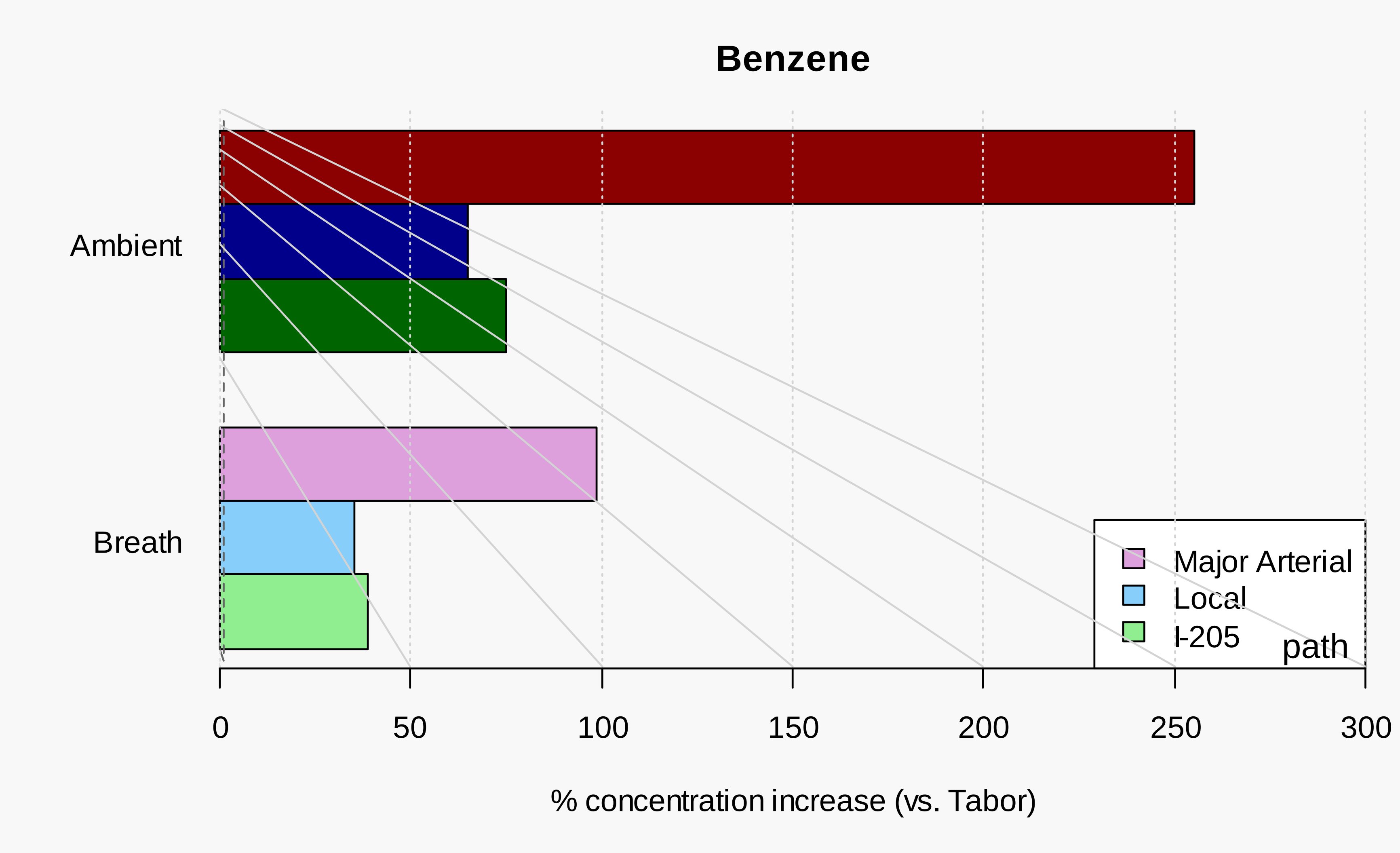
PSU Uptake Research

- New approach
- High-resolution intake/uptake measurement
- Breath sampling in bags

Some Exposure Results



Results Ambient & Breath



Regression - SURE Models

- Each of the select compounds is its own equation (same specification)
- Error correlations across equations for each observation are allowed
- Advantage: better use of the available information

Regression - SURE Models

Dep. Variables: breath/ambient concentrations

1. Benzene
2. Toluene
3. Ethylbenzene
4. m,p-Xylene
5. o-Xylene
6. 1,3,5-Trimethylbenzene
7. 2-Ethyltoluene
8. 1,2,4-Trimethylbenzene
9. 1,2,3-Trimethylbenzene

Breath concentrations

$$C_{breath} = \beta_0 + \beta_1 C_{ambient} + \beta_2 C_{preAmbient} + \beta_3 \frac{C_{preBreath}}{C_{preAmbient}}$$

(+) (+) (+)

- "History" impacts are significant
- Ambient coefficient 1.5 to 2.5 times bigger than preAmbient

$$\beta_1 > \beta_2$$

Change of Breath concentrations

$$\Delta C_{breath} = \beta_0 + \beta_1 \Delta C_{ambient} + \beta_2 \frac{C_{preBreath}}{C_{preAmbient}} + \beta_3 TVOC_{CV}$$

(+) (-) (-)

- "History" impacts are still significant
- Rate of change negatively affected by high *relative* breath concentrations

- High variability in $TVOC_{CV}$ reduces breath concentrations

Clearance impacts?
Policy/design implications?

Breath/Ambient concentration as a function of Road Type

$$C_{breath} = \beta_0 + \beta_1 \, \mathbf{RoadType}$$

$$C_{ambient} = \beta_0 + \beta_1 \, \mathbf{RoadType}$$

- Road type is a dummy variable (5 different types of roads, Tabor the reference)
- Road type is a much better predictor of ambient than breath concentrations

- Arterials have 1.5 to 2.5 higher ambient concentrations than local/bike paths
- Major arterials 25% more than minor

- Non-linear AADT impacts?

Wrapping up

- The method works: exposure predicts breath concentrations
  - Breath elasticity to exposure: 0.3-0.5
- Significant history effects
- Significant road-type effects
- Minimal subject-specific effects

Future Work

We have a novel data set of direct uptake measurements

- Much more analysis work to do!

1. AADT impacts
2. Policy and Design Implications
3. Bicycle network/facility design guidance for pollution dose impacts
4. Extend to pedestrians

Thank you!

- Bigazzi, A. and M. Figliozzi, "Review of Urban Bicyclists' Intake and Uptake of Traffic-Related Air Pollution." *Transport Reviews*, Forthcoming 2014.
- Bigazzi, A., W. Luo, M. Figliozzi, J. Pankow, and L. Isabelle, "Measuring urban bicyclists' uptake of traffic-related volatile organic compounds using ambient and breath concentrations." 93rd Annual Meeting of the Transportation Research Board, Washington D.C., January 2014.

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http://web.cecs.pdx.edu/~maf/

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