Applying new exposure tools to ARB efforts: Mobility-based exposure modeling and intake fraction

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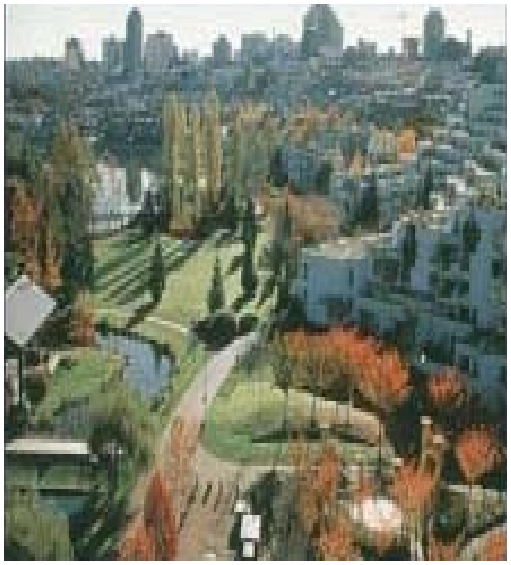
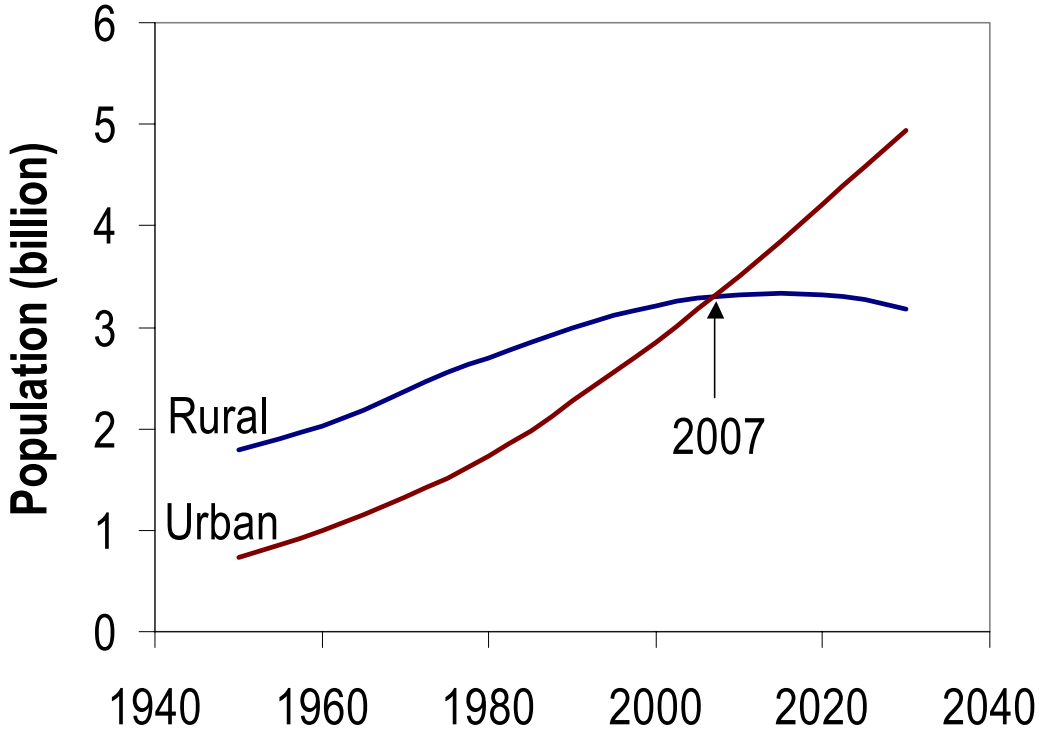


Urbanization



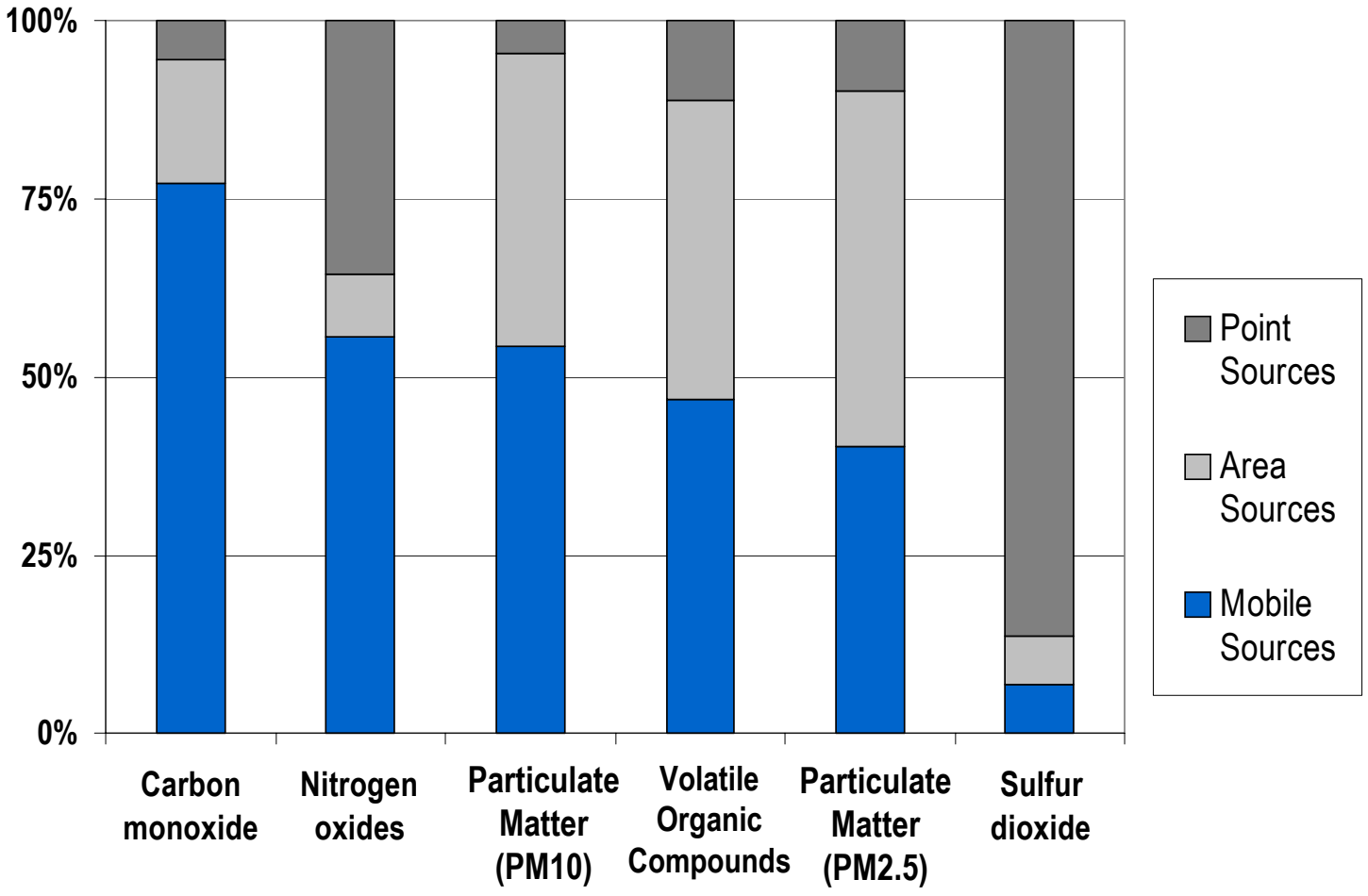
USA: 75–80% urban

California: ~85% urban

Sources: United Nations; US Census

Source apportionment

Fraction of Emissions



Source: US EPA (1999)

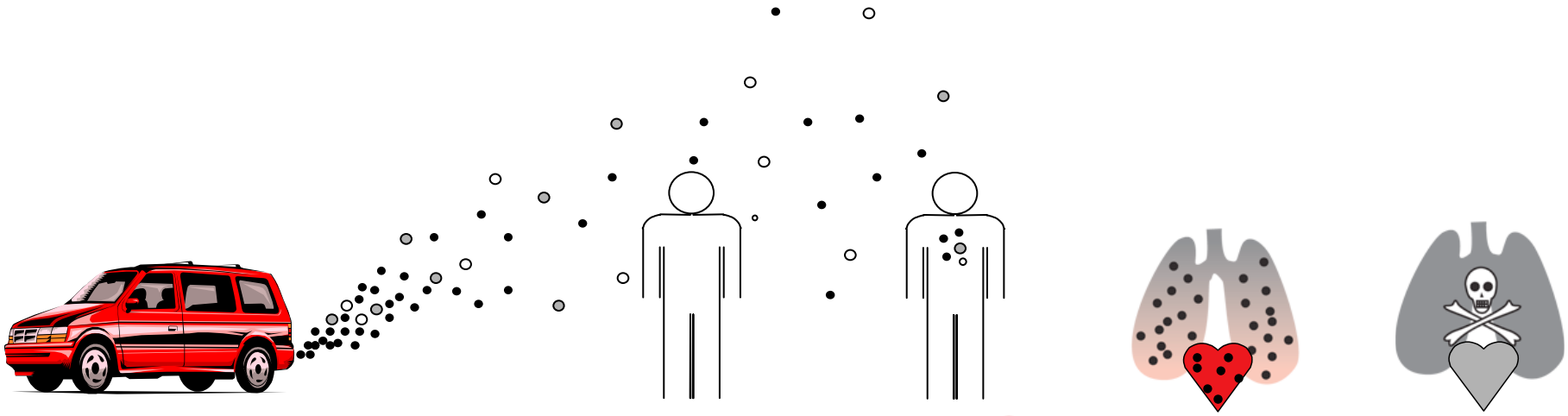
Air pollution and health

- Globally, ~ 800,000 deaths y^{-1} due to urban air pollution (~ 1% of annual deaths) (WHO, 2002).
- Individual constituents

Lead	Particulate matter
CO	Benzene
NO_x	Ozone

- Pollutant mixtures, e.g., traffic exhaust
  - Adverse birth outcomes (Wilhelm and Ritz, 2003)
  - Asthma attacks and bronchitis (Kim et al., 2004)
  - Lung cancer (Pope et al., 2002)
  - Heart attacks (Peters et al., 2004)

Air-pollution health-effects paradigm

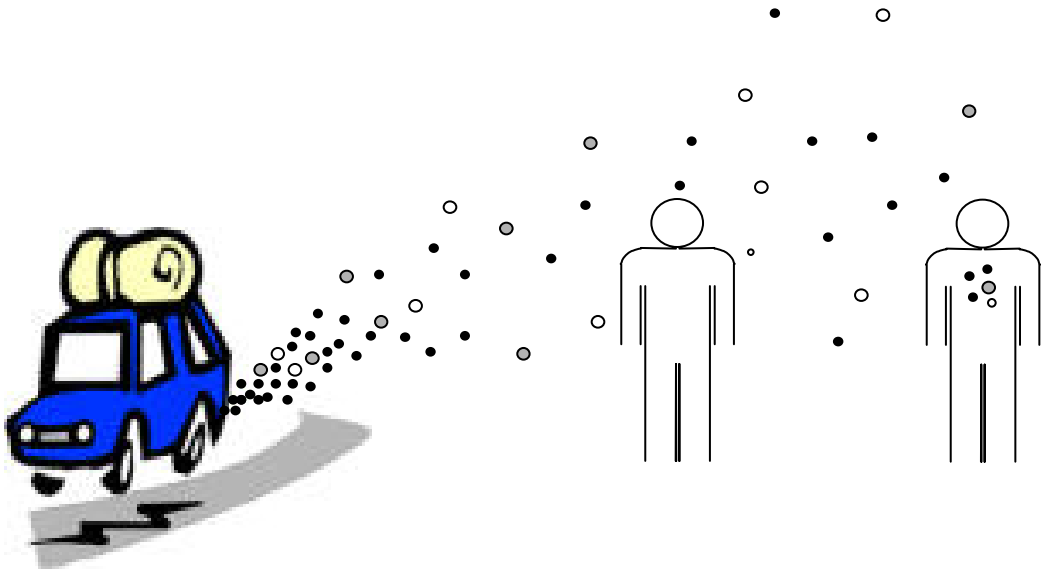


emissions → concentration → exposure → intake → dose → health effects

Today's agenda

Theme: Use of two new exposure assessment tools

- Intake fraction (focus: vehicle emissions)
- Mobility-based model of inhalation of air toxics



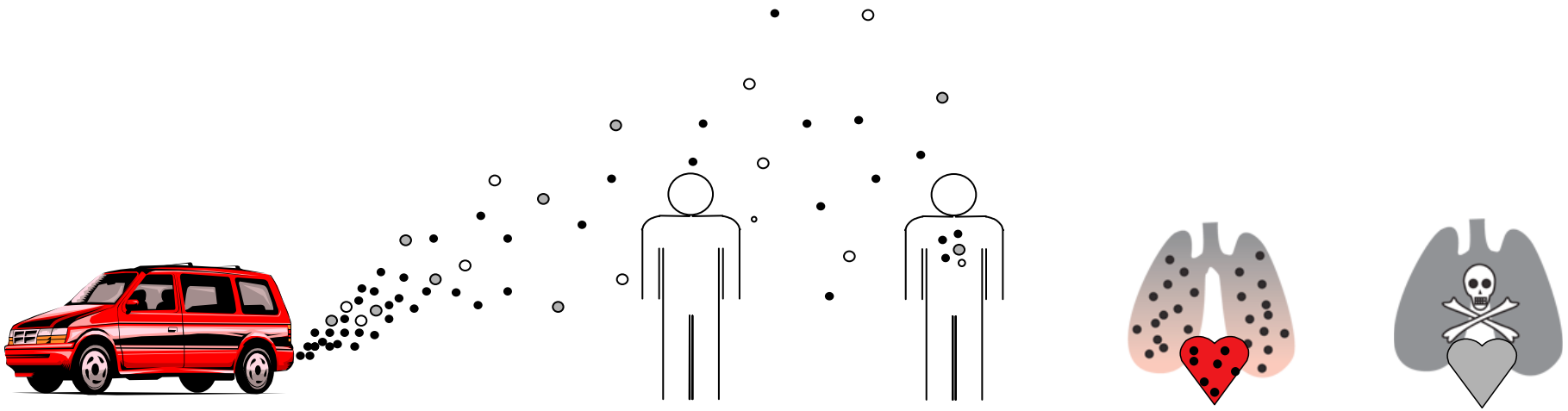
Intake fraction is still relatively new

- **Kirk Smith, 1993, "Fuel combustion, air pollution exposure, and health"**
- **Bennett et al., 2002, "Defining intake fraction"**
- **Chairman's Air Pollution Seminar Series, May 23, 2001:**

Rethinking Exposure Assessment Using
Dose Fractions

William W Nazaroff, Ph.D.
University of California, Berkeley

Topic #1: Intake fraction (iF)



emissions → concentration → exposure → intake → dose → health effects

emissions → intake

$$\text{intake fraction} = \frac{\text{intake rate}}{\text{emission rate}}$$

Based on: Smith, 1993

Introduction to intake fraction

$$\text{Health impact} \sim \text{Emissions} \times \text{Intake fraction} \times \text{Toxicity}$$

units :

$$\text{health impact} \sim \text{grams emitted} \times \frac{\text{grams inhaled}}{\text{gram emitted}} \times \frac{\text{health impact}}{\text{gram inhaled}}$$

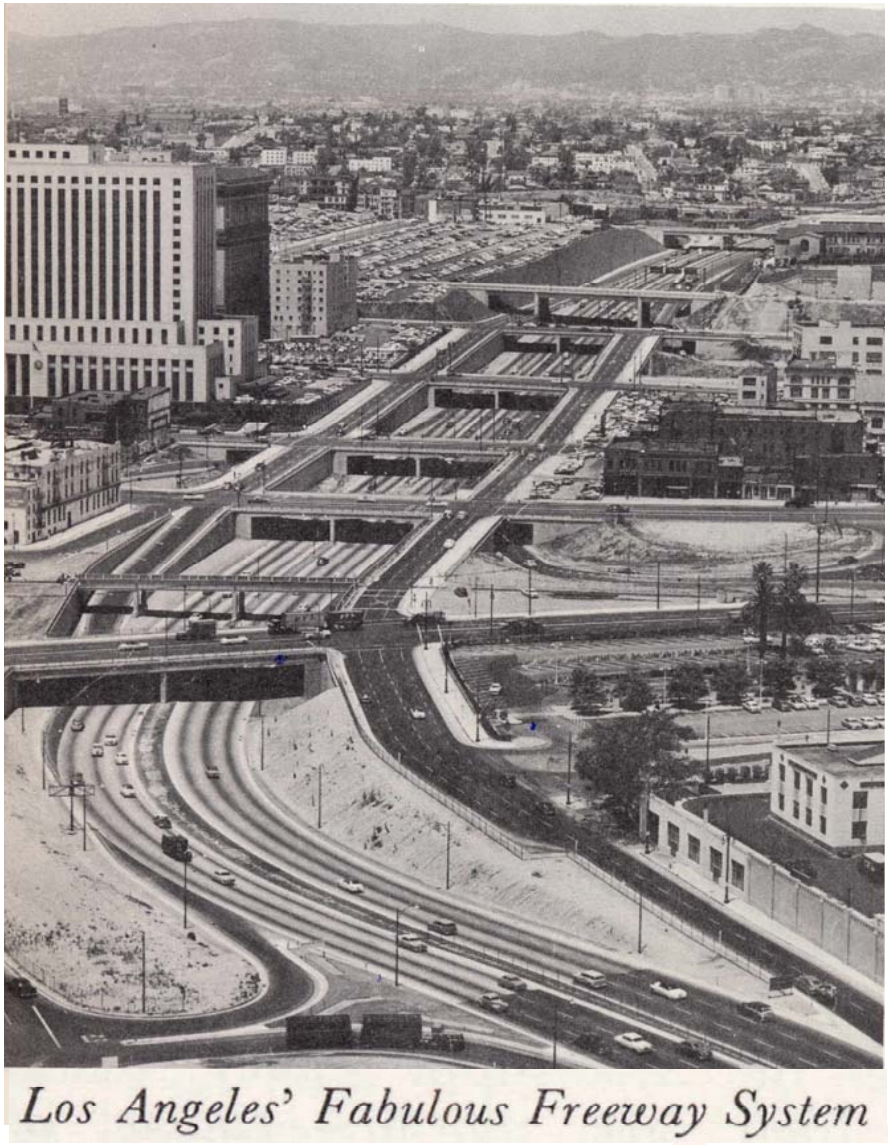
Determinants of intake fraction:

- Size of the exposed *Population*
- *Proximity* between emissions and people
- *Persistence* of the pollutant in the environment

Case study: South Coast vehicle emissions

South Coast Air Basin:
15 million people
16,000 km^2 area
500 million vehicle-km per day

An introduction to the South Coast (1)…



"Spreading for miles inland and along the ocean, **the city has grown horizontally rather than vertically.**

…This growth has given rise to the fabulous freeway system of roads."

- 1957 Rand McNally Atlas

Photo: 1957 Rand McNally Cosmopolitan World Atlas

An introduction to the South Coast (2)…

"**In terms of air pollution potential, there are probably few areas less suited for urban development.**

...the surrounding mountains, frequent low inversion heights, and stagnant air conditions... trap pollutants in the air basin."

- CARB 2002 Almanac

Case study: South Coast vehicle emissions

Method:

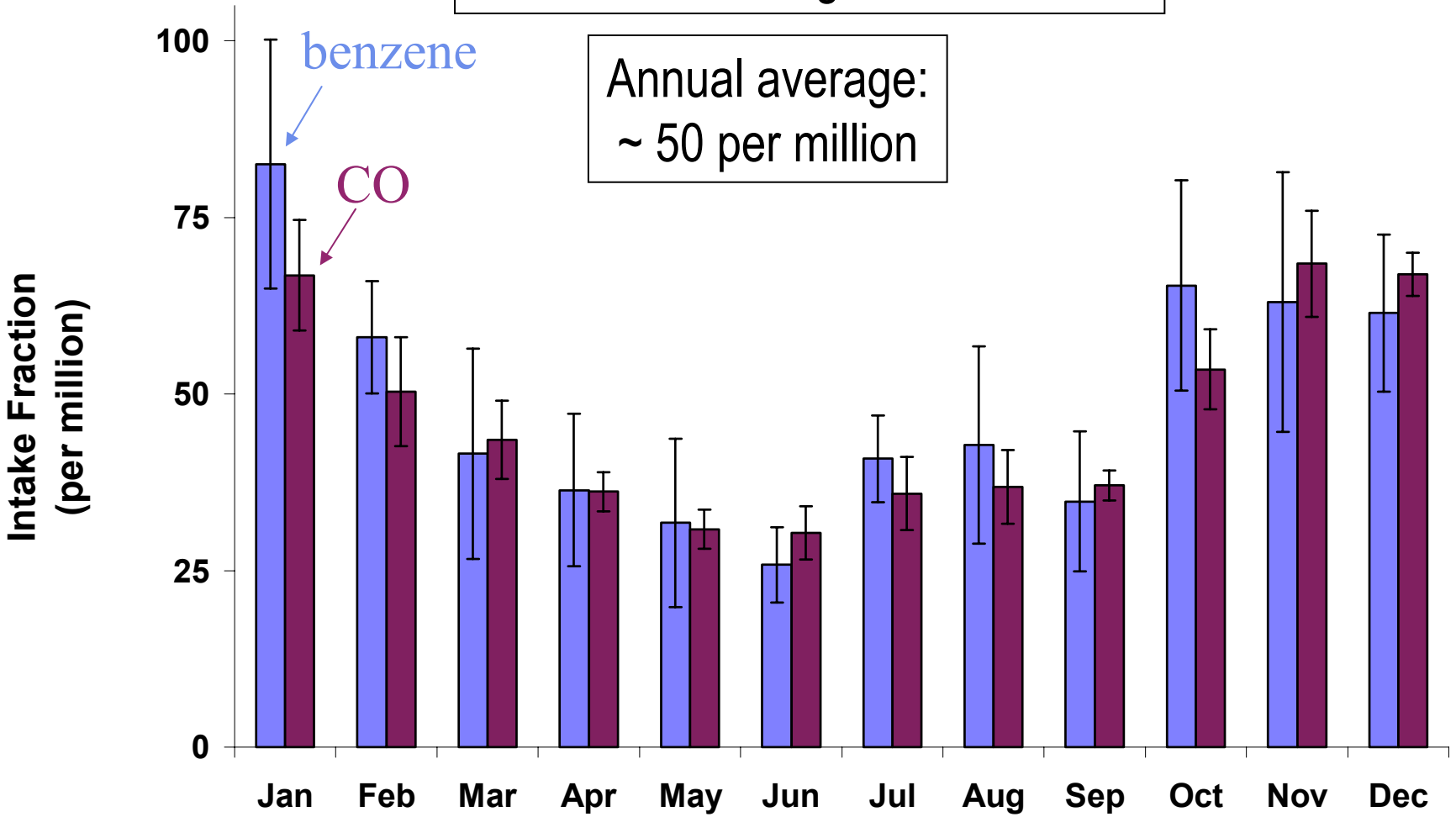
- Analyze monitoring and emissions data for carbon monoxide and benzene
- Census data: where people live
- Account for time spend indoors, outdoors, and in-vehicle

reference: JD Marshall et al., *Atmos. Environ.* **37**, 3455, 2003.

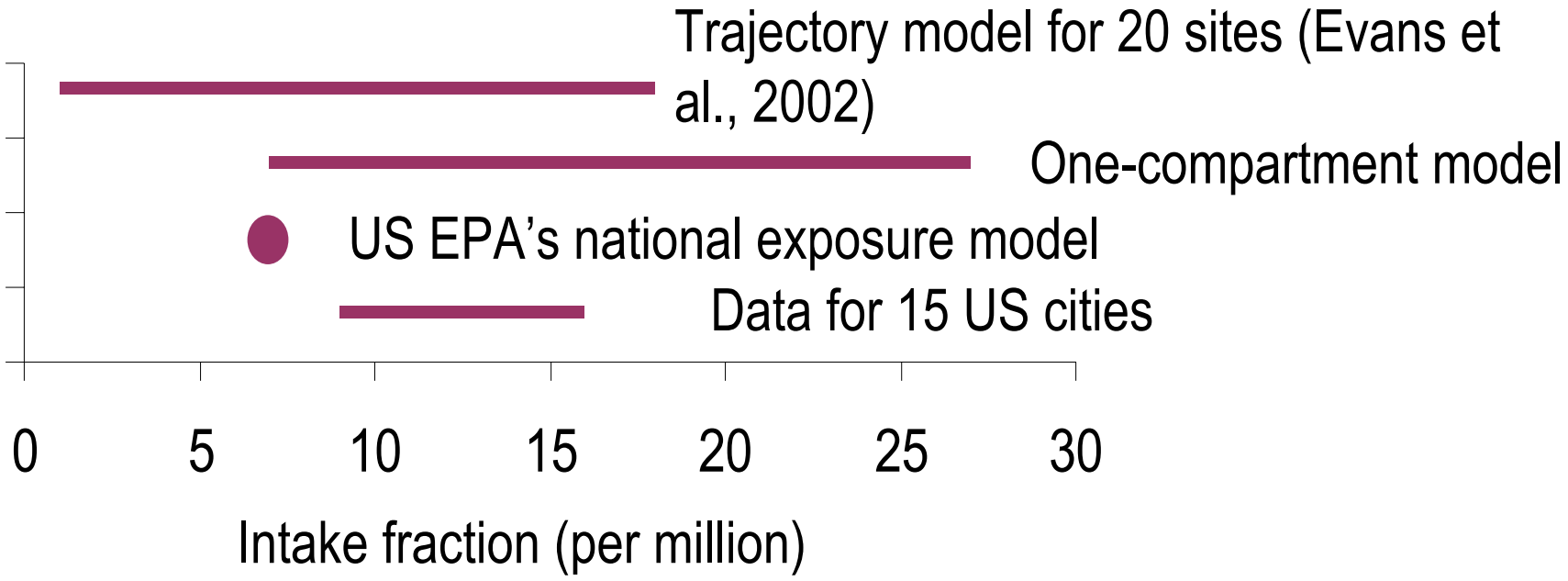
Case study results: South Coast vehicle iF

Intake Fraction = grams inhaled / grams emitted

Annual average: ~ 50 per million



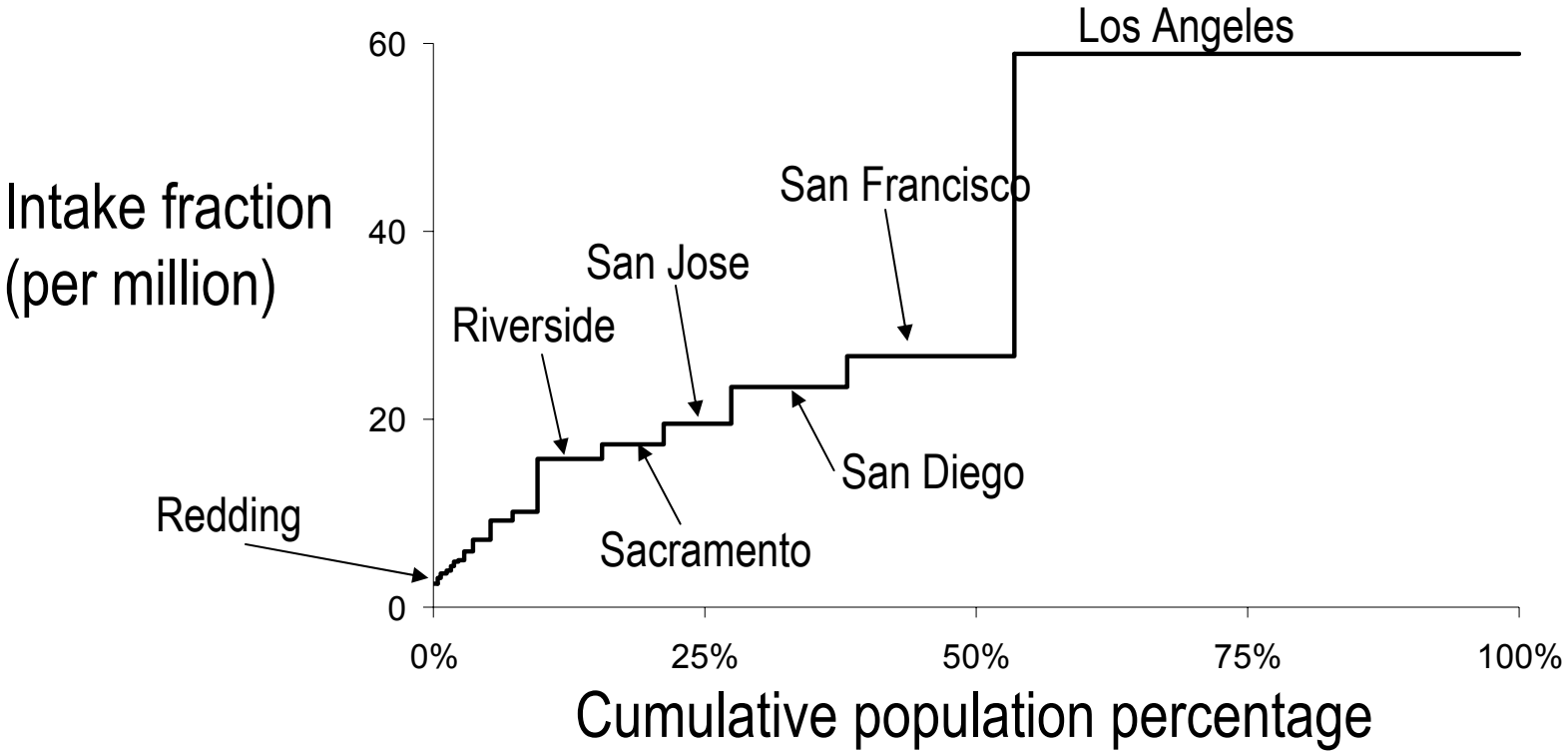
Vehicle iF for US urban areas



Best estimate: 14 +/- 7 per million

reference: JD Marshall et al., *Atmos. Environ.* **39**, 1363, 2005. Results are for nonreactive emissions.

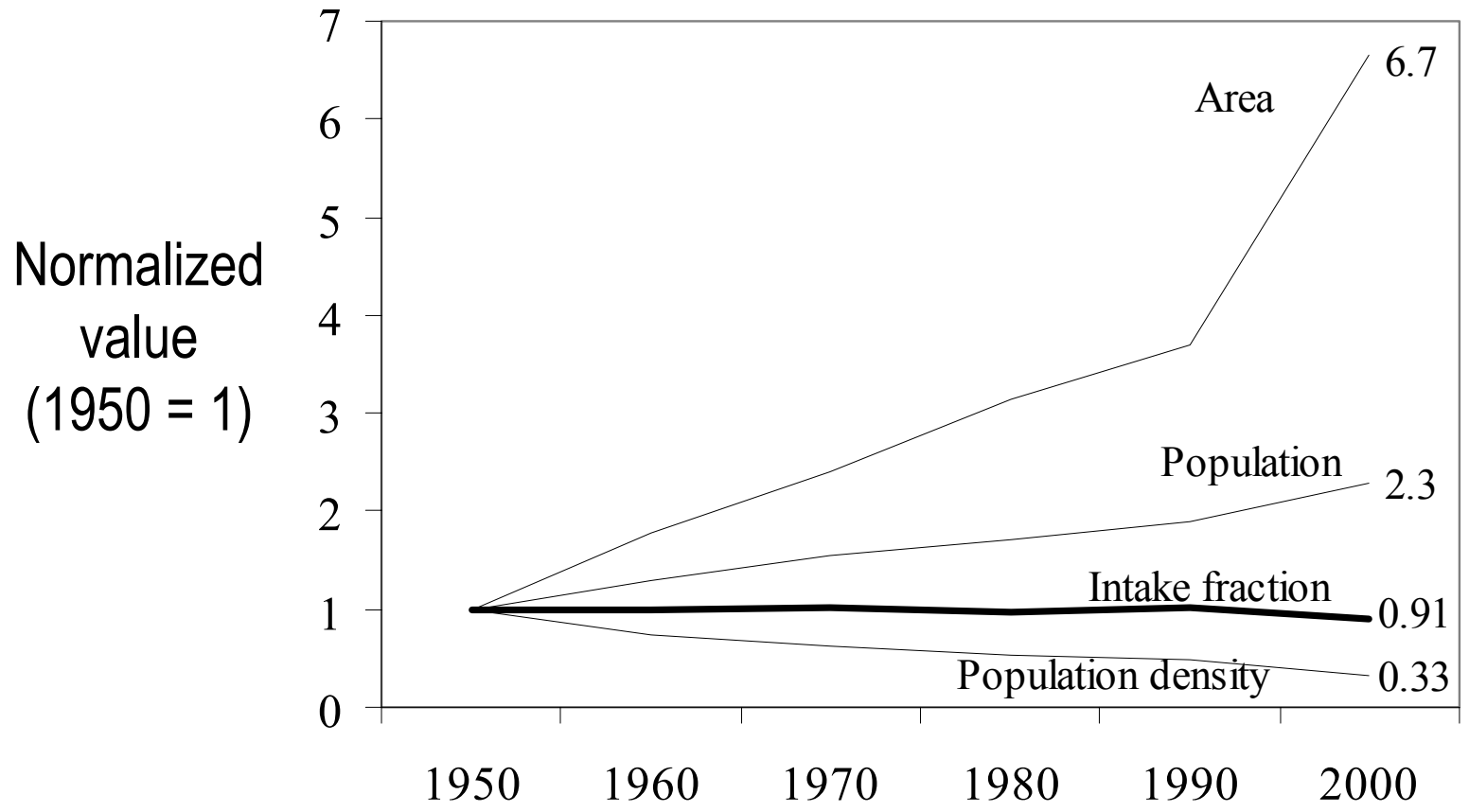
Vehicle iF for California urban areas



Mean value: 38 per million

Basis: One-compartment model; US Census Urbanized Areas data for California

Urban vehicle iF: US average, 1950 - 2000



Basis: One-compartment model; US Census Urbanized Areas data

Policy uses of intake fraction

Health impact ~ Emissions × Intake fraction × Toxicity

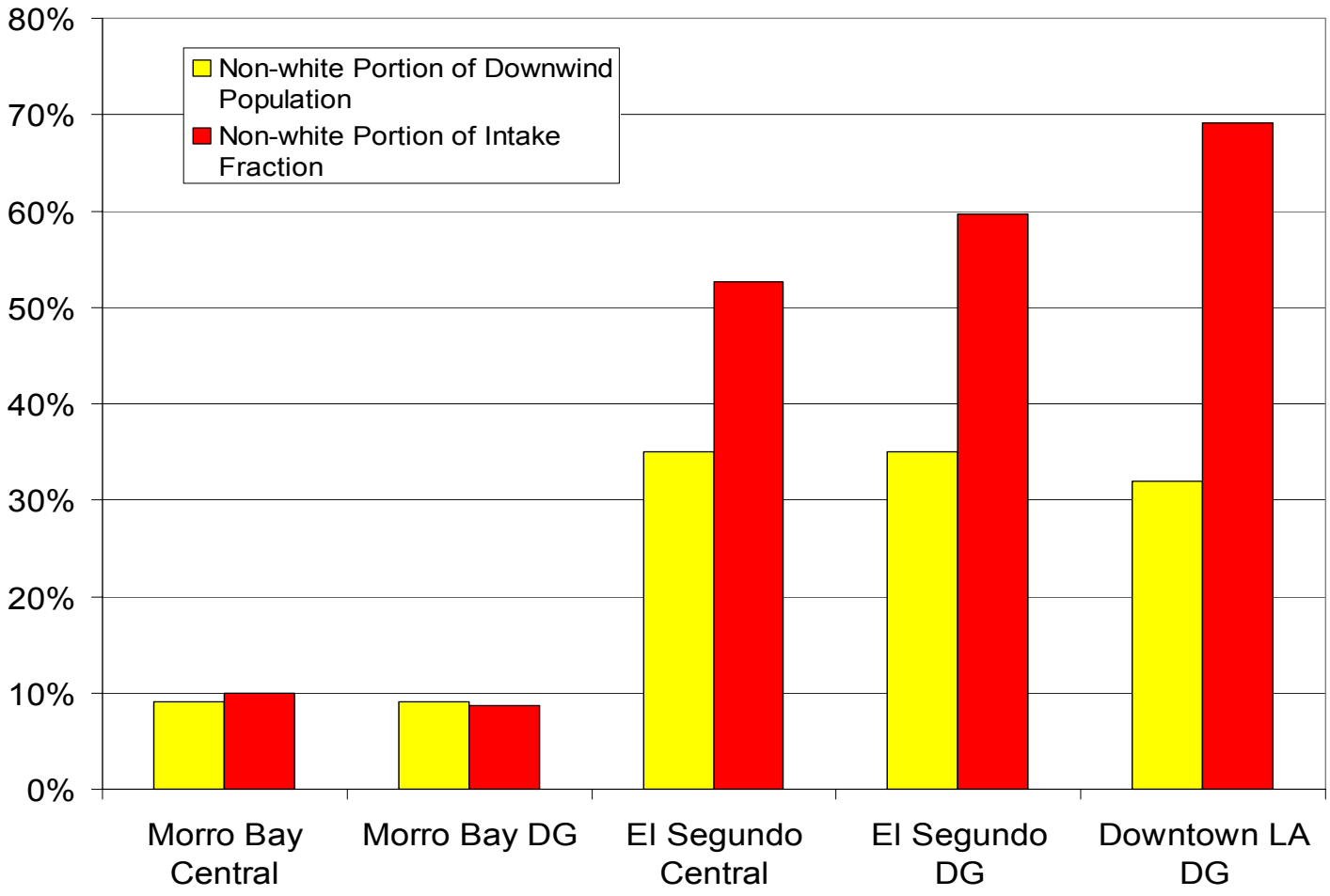
units :

$$\text{health impact} \sim \text{grams emitted} \times \frac{\text{grams inhaled}}{\text{gram emitted}} \times \frac{\text{health impact}}{\text{gram inhaled}}$$

Specific applications:

- Health risk assessment, cost-benefit analyses
- *Prioritization* among emission sources
- Uses with incomplete information

iF & Environmental justice: Preliminary results



Source: GA Heath et al.; values are for central-station power plants ("central") and for smaller-scale distributed electricity generation sites ("DG"). Differences are mainly attributable to location and stack height.

Intake fraction summary

- Intake fraction values are consistent among estimation methods, and average values are consistent over time
- Typical urban intake fraction values are higher in CA than US
- Intake fraction is a tool; it can be used to incorporate population exposures into economic & policy analyses

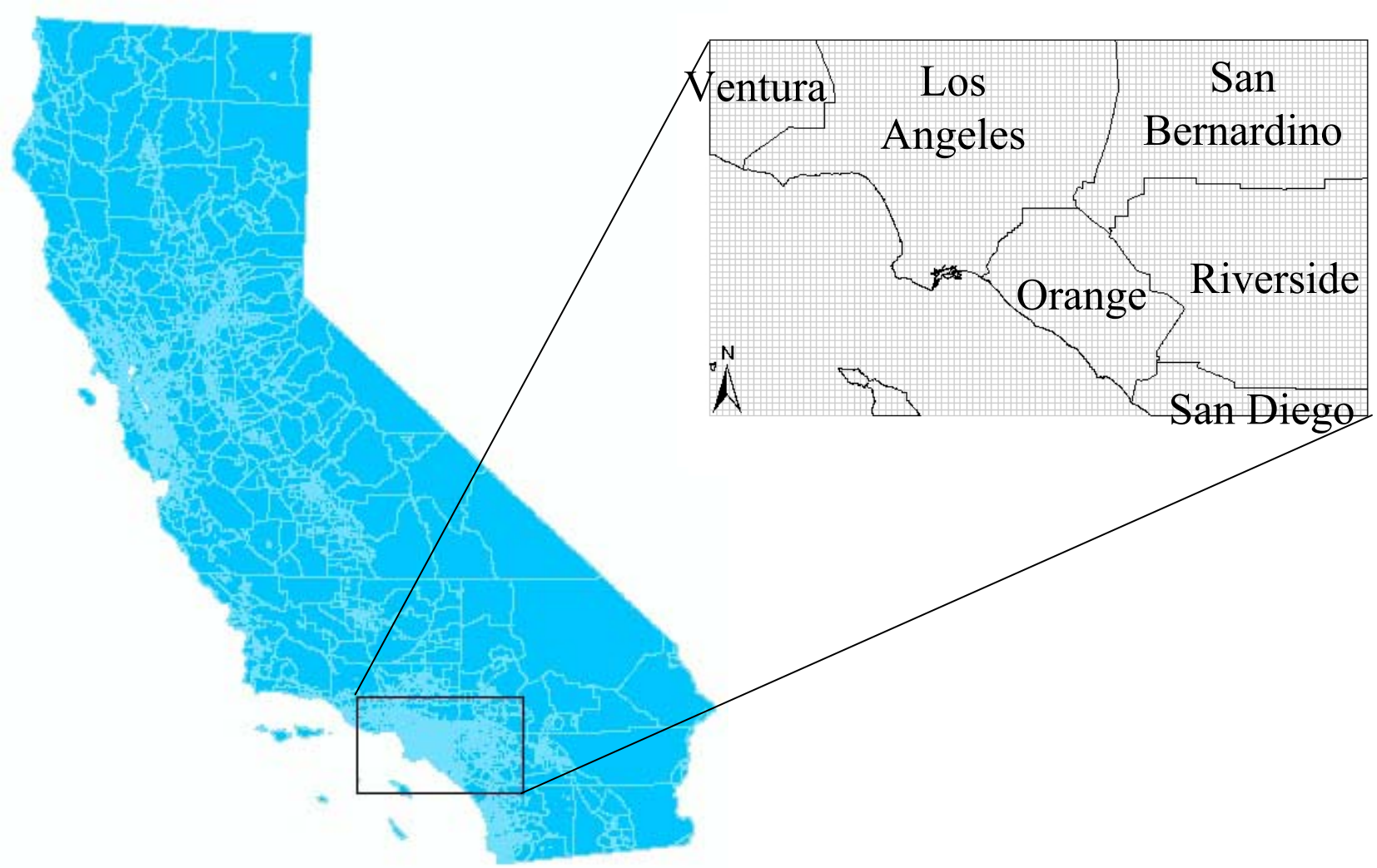



Topic #2: Mobility-based inhalation model

- Complex spatial & temporal variability
  - Air pollution
  - People
- Use of (home-based) census data is common
- Goal: Mobility-based GIS inhalation analysis for ambient air pollution

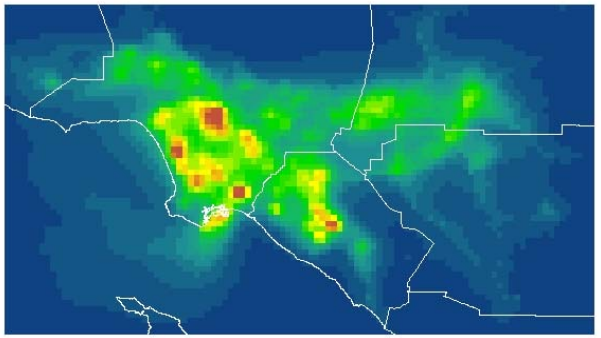



Case study location: South Coast

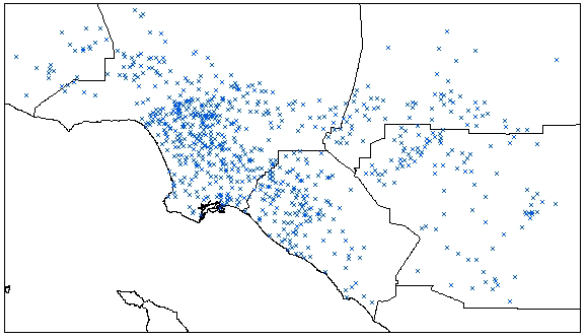


Approach

1. Ambient concentrations (CAMx model)
   - 5 air toxics
   - One year



2. Time-location-activity survey
   - ~ 29,000 person-days
   - “Geo-coded” locations

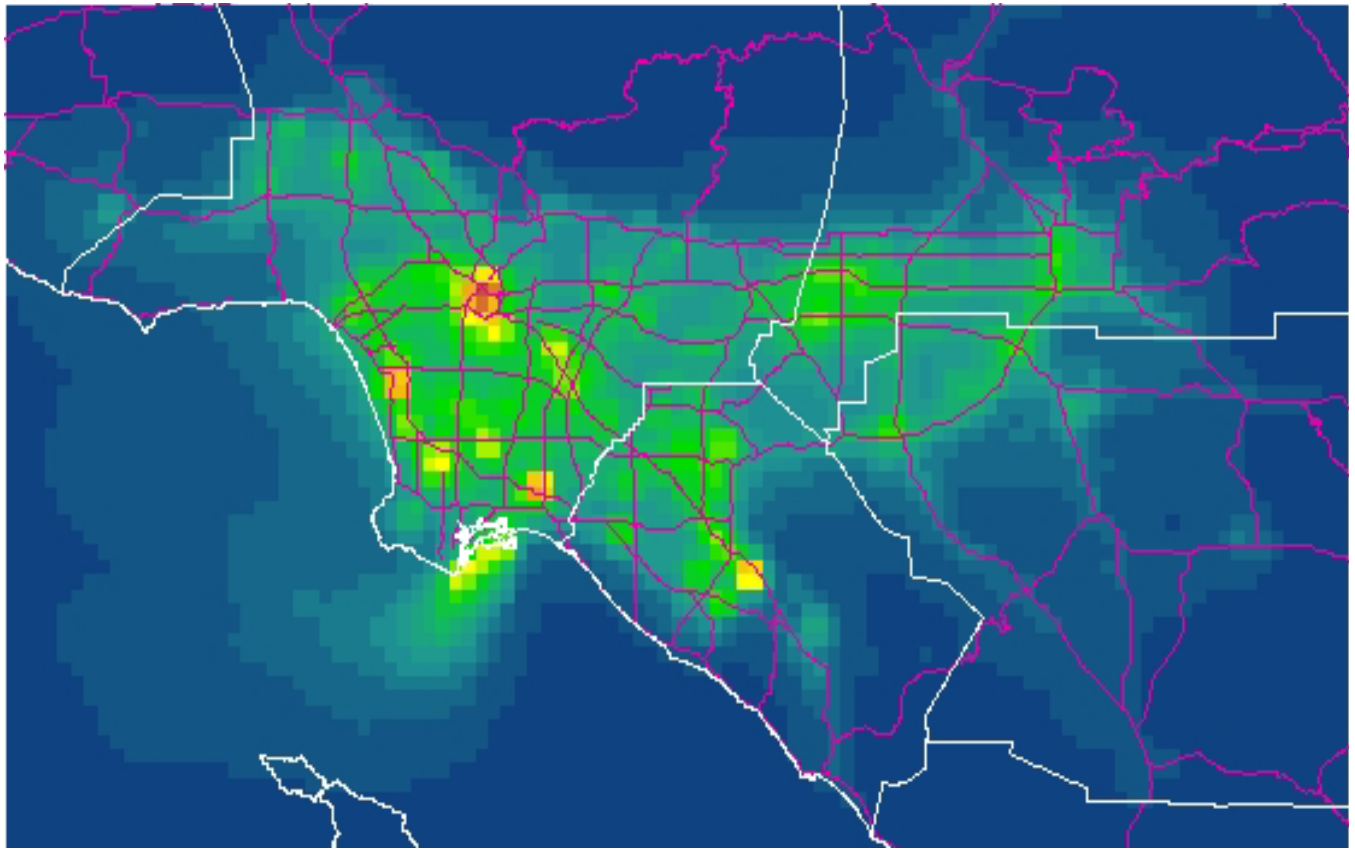


3. Breathing rates
   - Age, gender, activity level (Layton 1993)

4. Microenvironments
   - Indoors, outdoors, in-vehicle
   - Monte Carlo

(1) Concentrations

Diesel $PM_{2.5}$

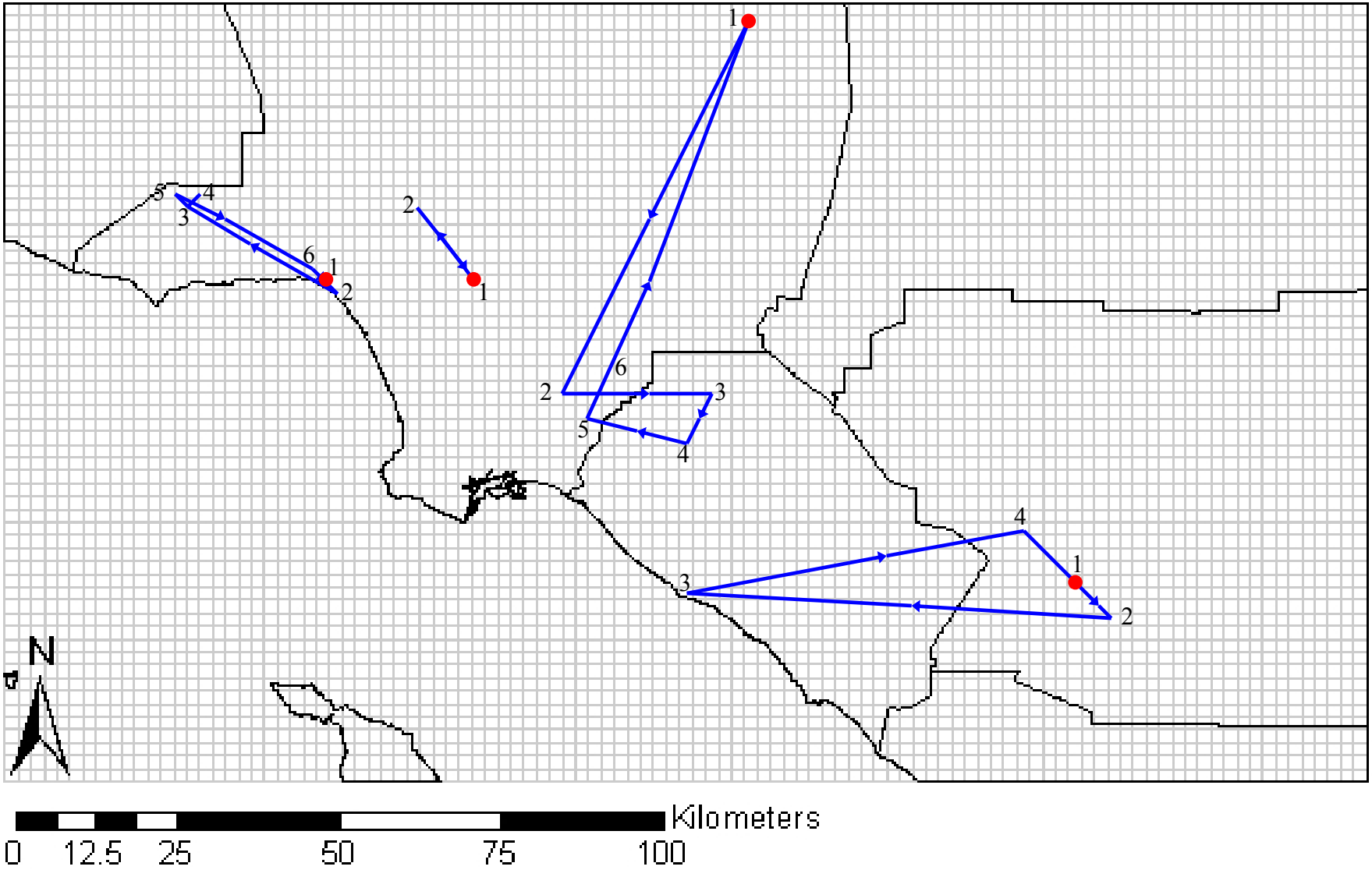


8:00 am, Nov 3, 1998

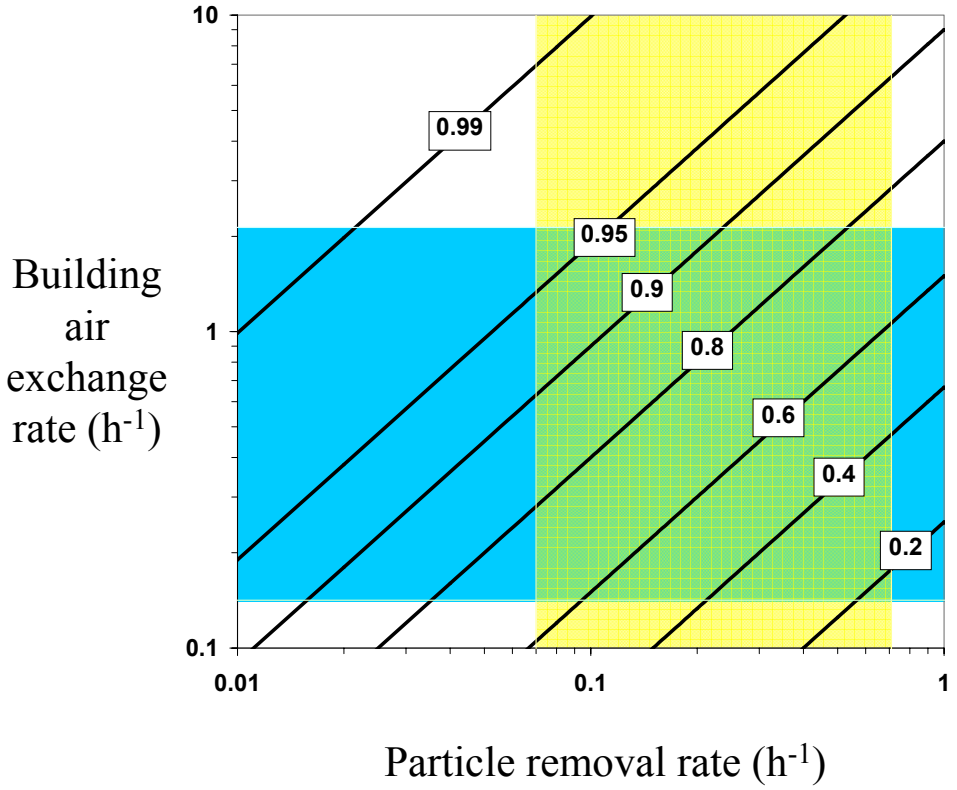
Concentration ($\mu g\ m^{-3}$)

0 20 40

(2) Mobility



(4) Micro-environment factors: $PM_{2.5}$ into residences



X — Time-averaged indoor-outdoor $PM_{2.5}$ ratio

Ranges shown are two standard deviations from mean

(Ozkaynak et al., 1996)

Los Angeles, winter (Wilson et al., 1996)

Basis: $I/O = Pa/(k+a)$

P = particle penetration

k = particle removal rate (h^{-1})

a = air exchange rate (h^{-1})

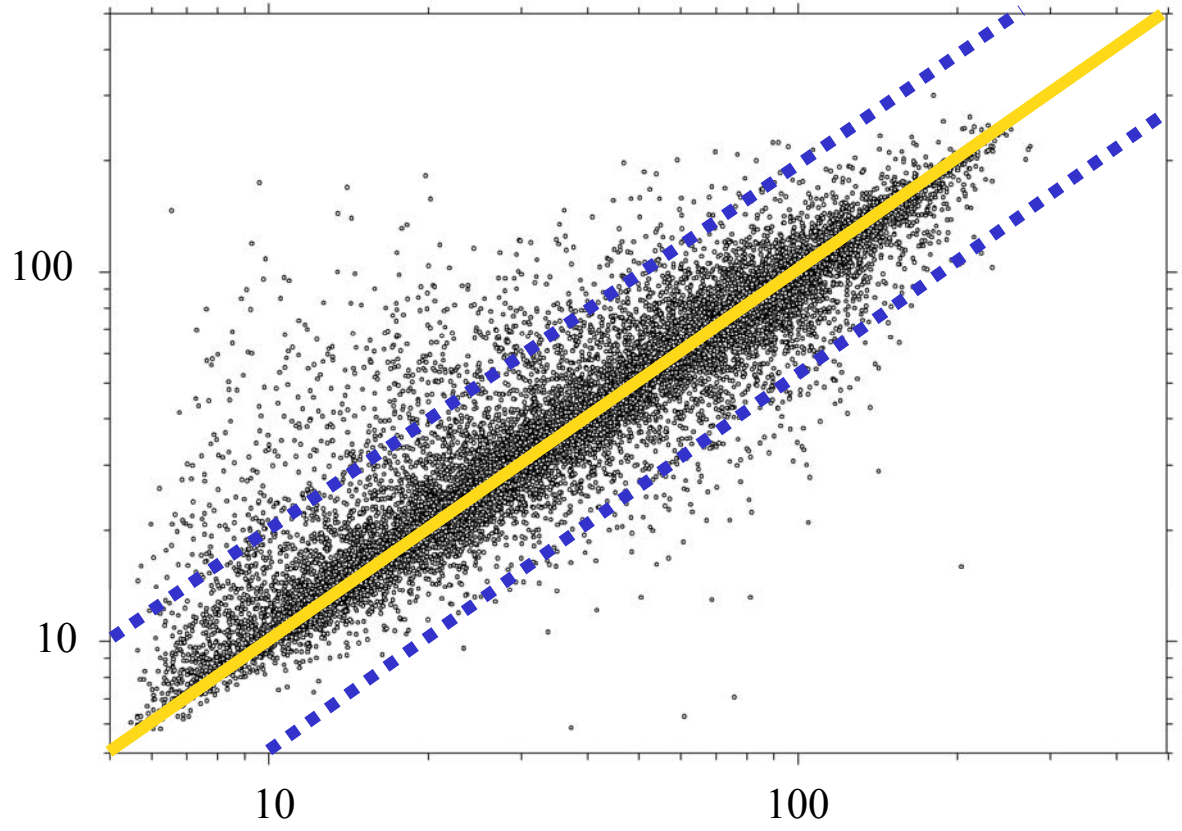
Results

- Output: 24-hour inhalation rate ($\mu g\ d^{-1}$) for each pollutant for each individual

Mobility can increase or decrease exposures

Diesel $PM_{2.5}$ Inhalation intake ($\mu g\ d^{-1}$)

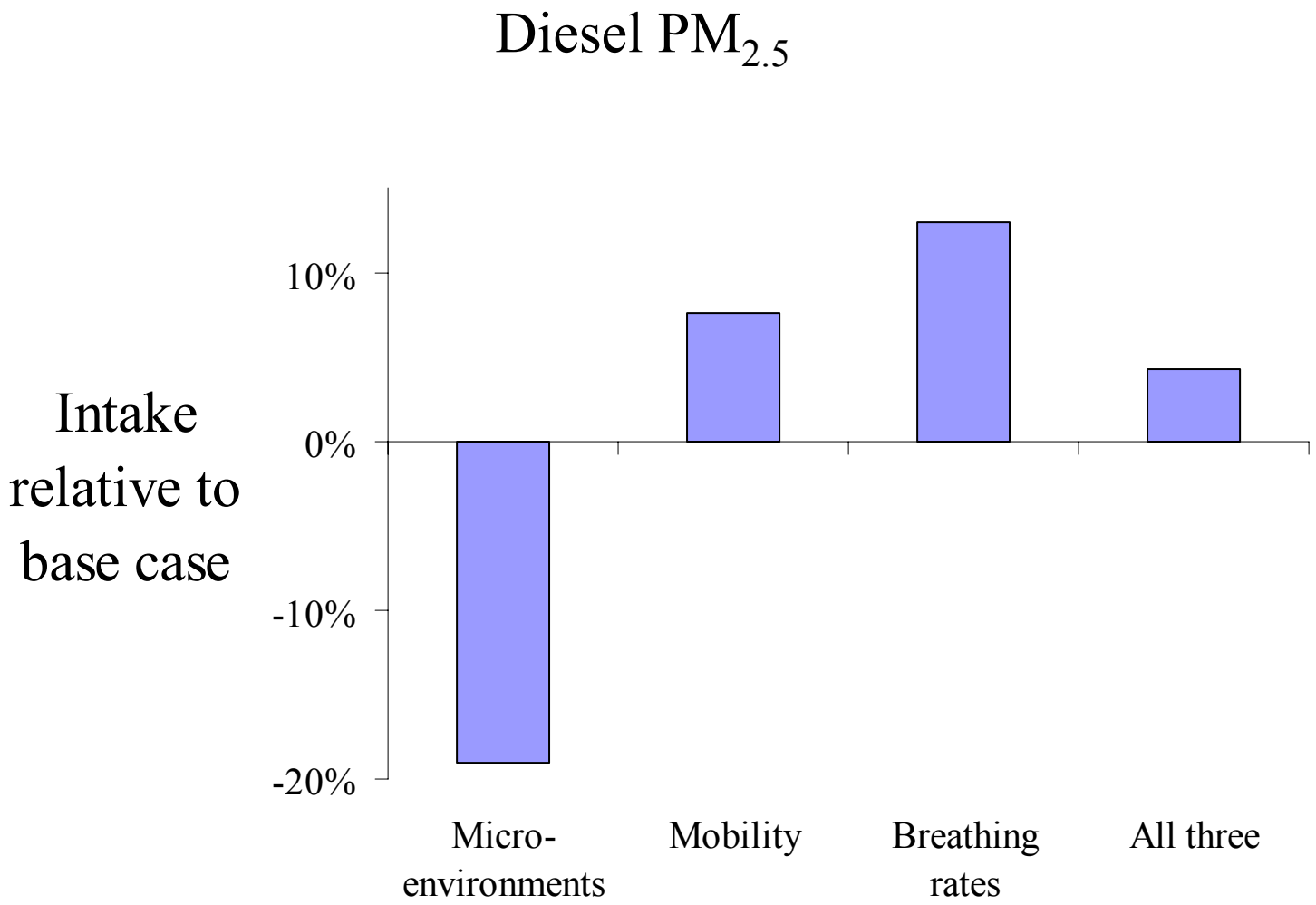
With mobility



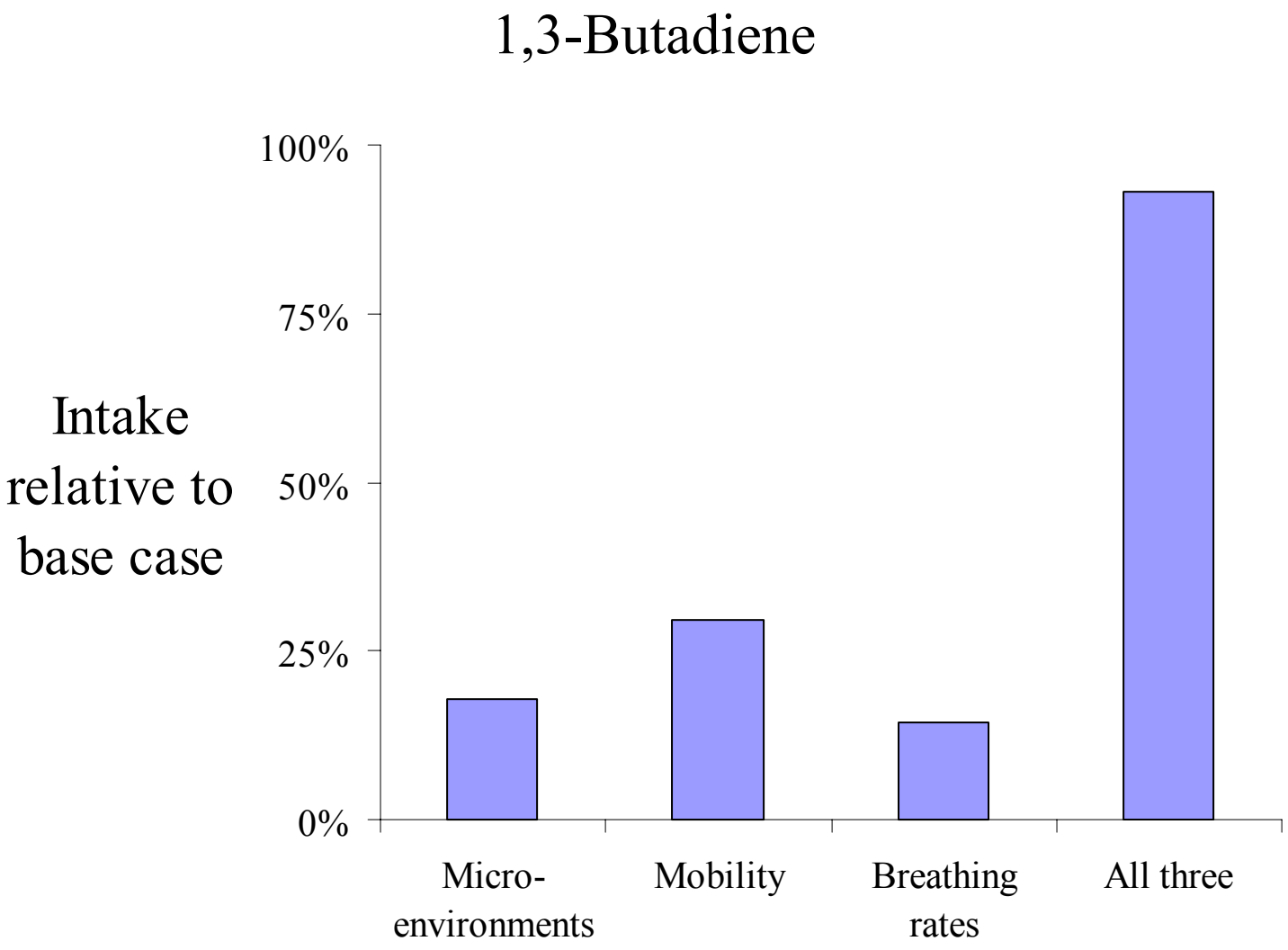
If they stayed at home

Lines: 1:1 and factor of two

Factors influencing exposure estimation

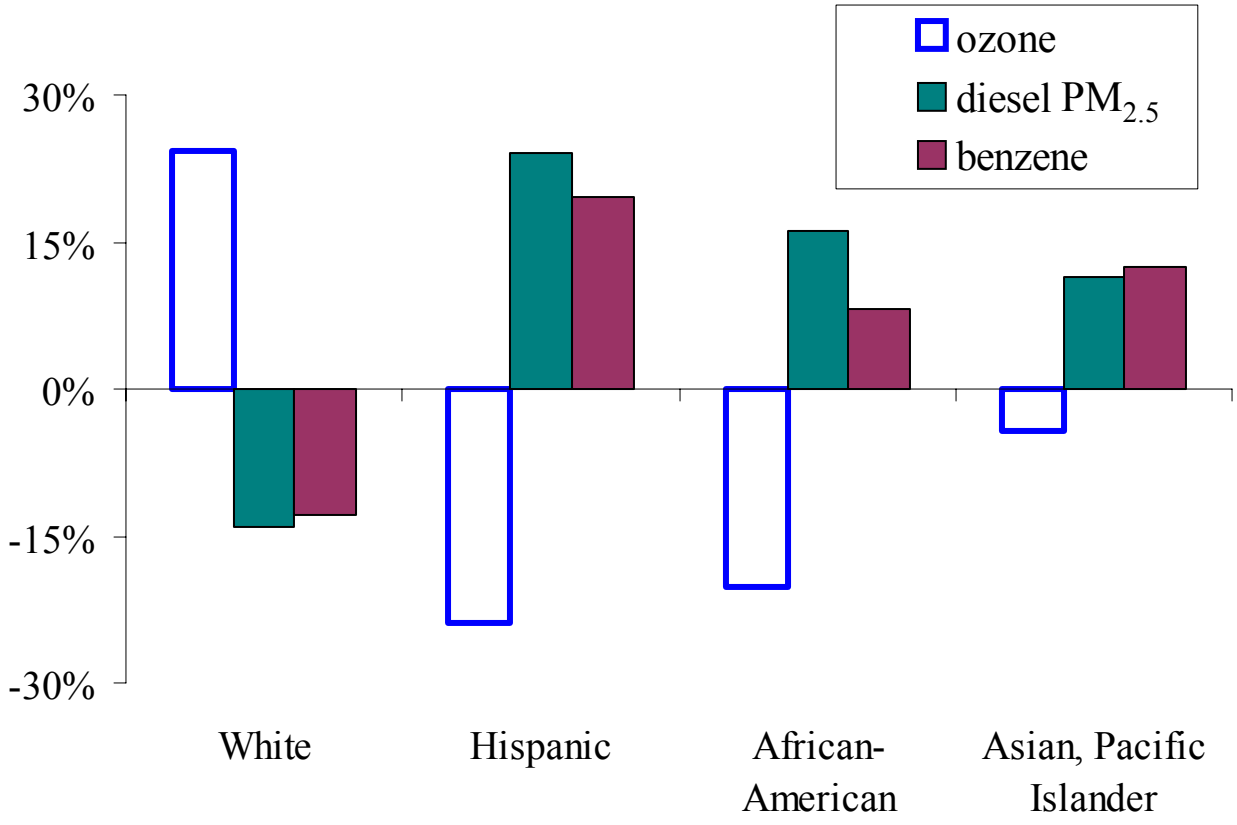


Factors influencing exposure estimation



Intakes and ethnicity

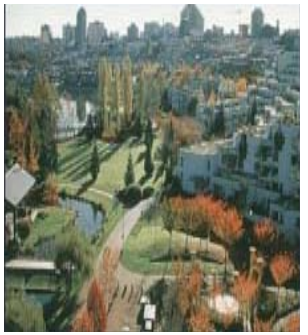
Median intake, relative to population median



Summary: Mobility-based exposure analysis

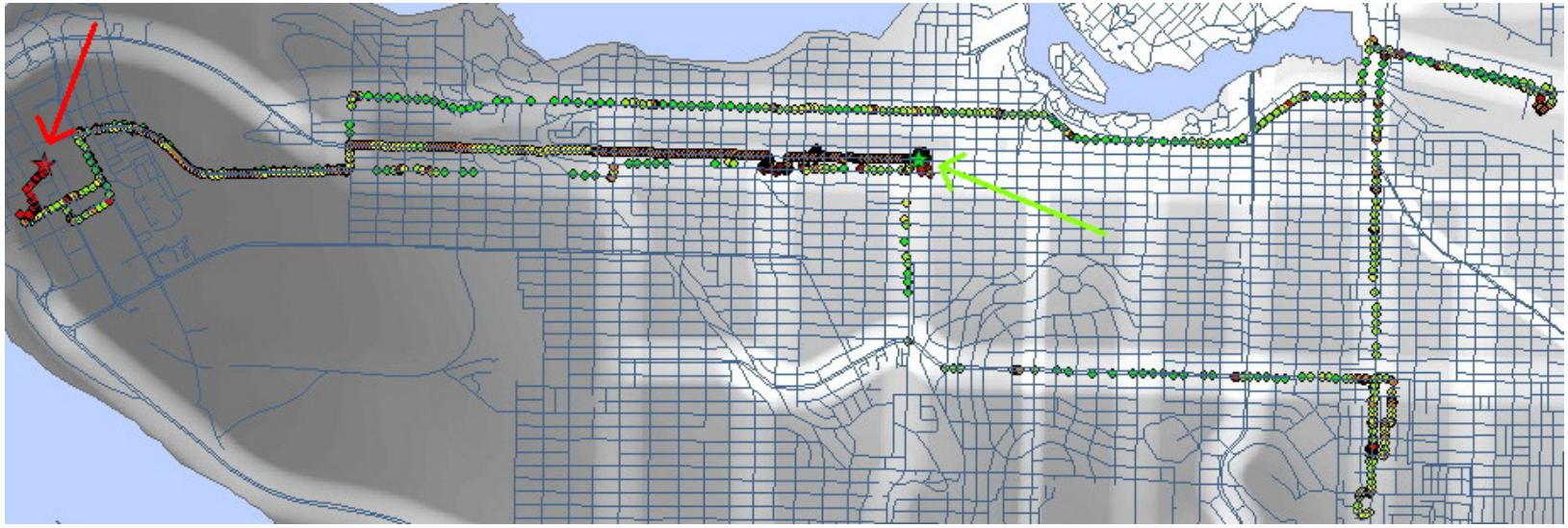
1. Variability in exposures among individuals
2. Mobility has modest (factor of ~ 2 or less) impact on intake
3. Distributions by ethnicity



Future research (1)

- Intake fraction handbook
- Exposure distributions & environmental justice
- GPS mobility data (E. Nethery, MS candidate, UBC):

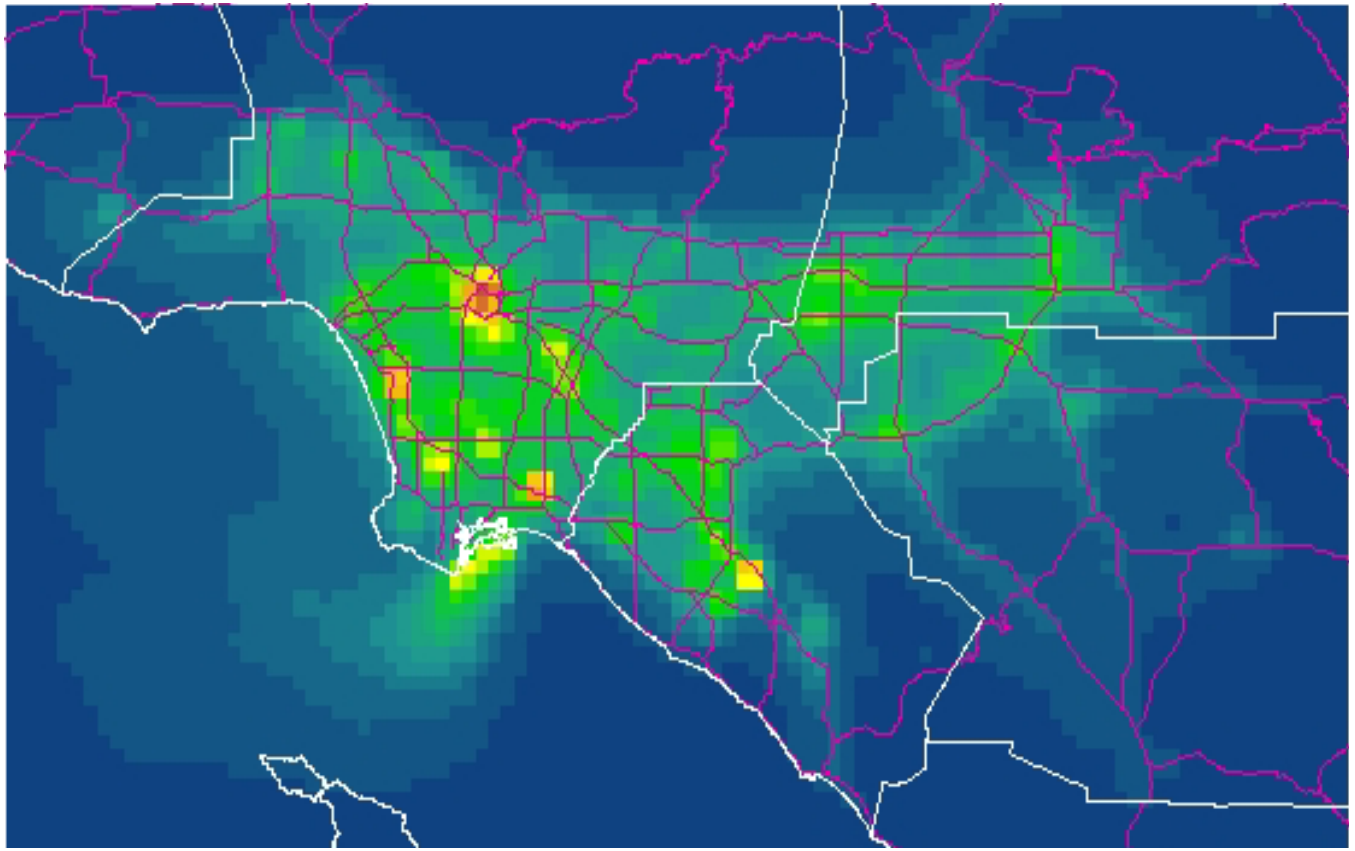


Future research (2): Policy analysis

LA Port truck traffic

Future research (2): Policy analysis

Diesel $PM_{2.5}$



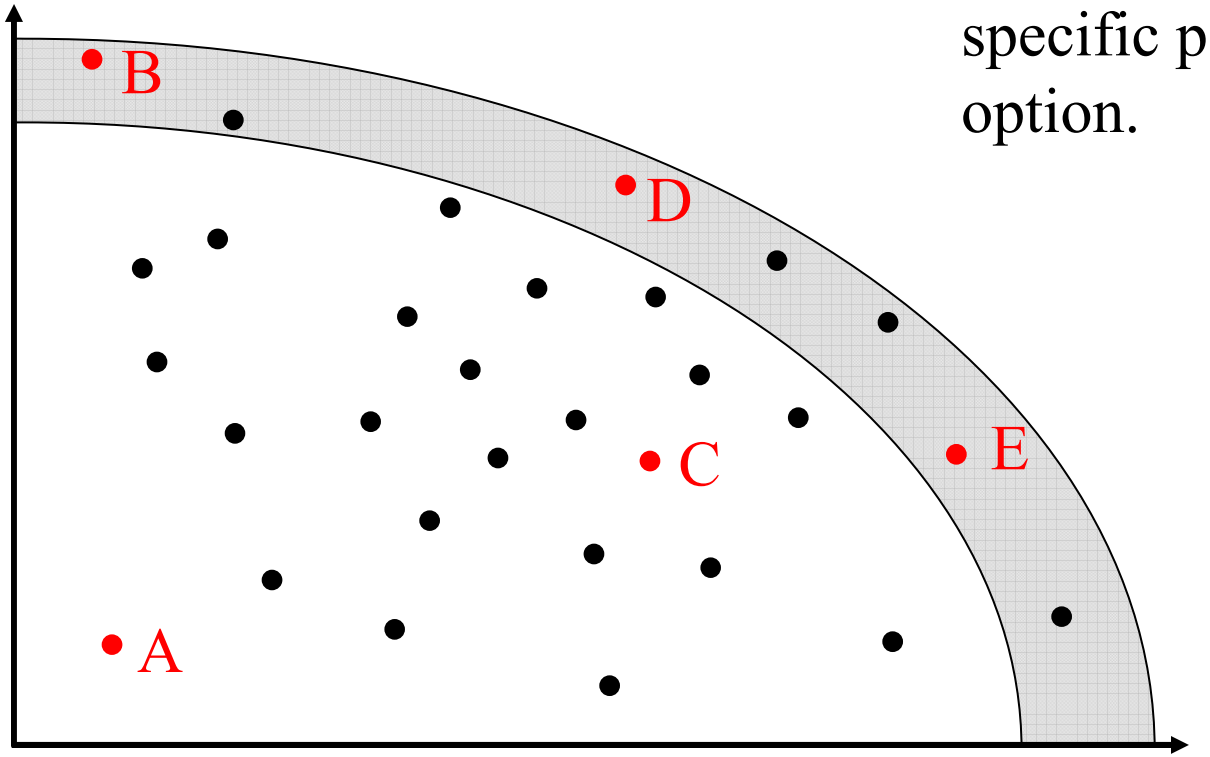
8:00 am, Nov 3, 1998

Concentration ($\mu g\ m^{-3}$)

0 20 40

Future research (2): Policy analysis

Each dot is a specific policy option.



Reference: (Levy et al., submitted)

Acknowledgements

- Professors William Nazaroff (Environmental Engineering), Tom McKone (Public Health), and Elizabeth Deakin (Urban Planning)
- Patrick Granvold, Abby Hoats (GIS-based inhalation model);
- Garvin Heath (White/non-white intake fraction)

Thank you.