Approaches for Assessing Exposure to Traffic-Related Pollution for Tracking

CALIFORNIA ENVIRONMENTAL HEALTH TRACKING PROGRAM

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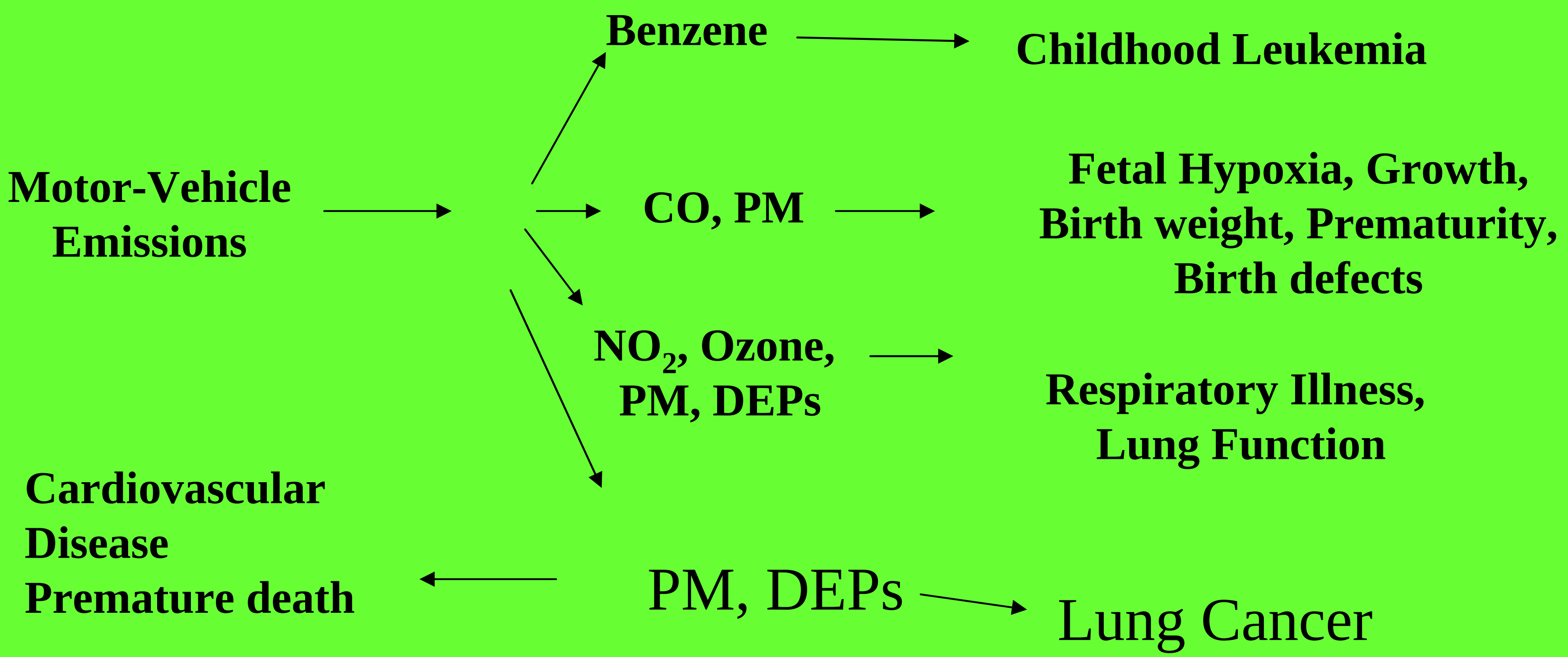
The significance of traffic-related pollutants

- Traffic contributes to high proportion of overall air pollution burden
  - e.g.: 99% of CO burden and 76% of NO_2 burden in London attributable to traffic
- Major source of greenhouse gas emissions (CO_2)
- Increasing recognition of association with wide spectrum of health effects

Health Effects Associated with Motor-Vehicle Emissions



Issues for routine surveillance of traffic exposures

- Routinely collected data
- Standardized collection of data
- Ease of obtaining accurate data inputs
- Indicator or marker is accurate proxy for exposure – specificity for pollutants?

Exposure Approaches

- **Traffic Indicators**
  - Self-reported traffic density
  - Distance from residence to roadway
  - Traffic density by census block group
  - Buffering

- **GIS w/dispersion or regression modeling**

- **Geostatistical kriging/other interpolation methods**

- **Integrated meterological-emission models**

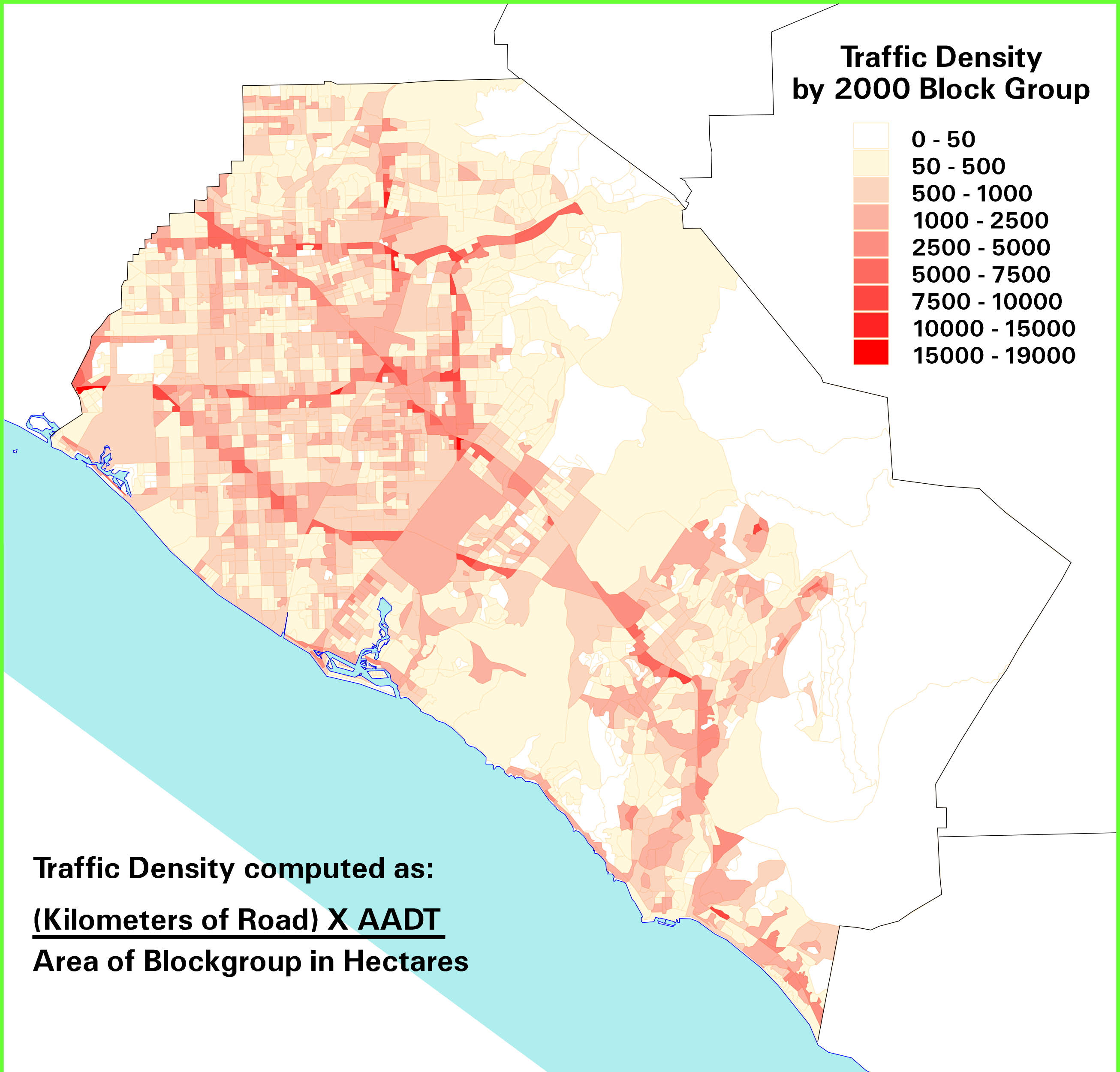
- **Personal/Environmental monitoring**

- **Model Evaluation/Comparison**
  - **Which approach performs best with least cost of resources?**

Exposure Assessment of Traffic-Related Pollutants

Complexity	Method	Limitations:
Complex	More complex modeling (e.g. ADMS- Urban)	Computationally complex, cost
	GIS w/ dispersion modeling GIS w/ regression-based models	More data inputs (e.g. meteorology, building configurations, emissions, etc.)
	Residence near fixed air monitors	Assumes homogenous exposure
	Distance-weighted traffic volume	Misclassification (e.g. building heights)
Simple	Census block-group traffic density	Misclassification (e.g. wind)

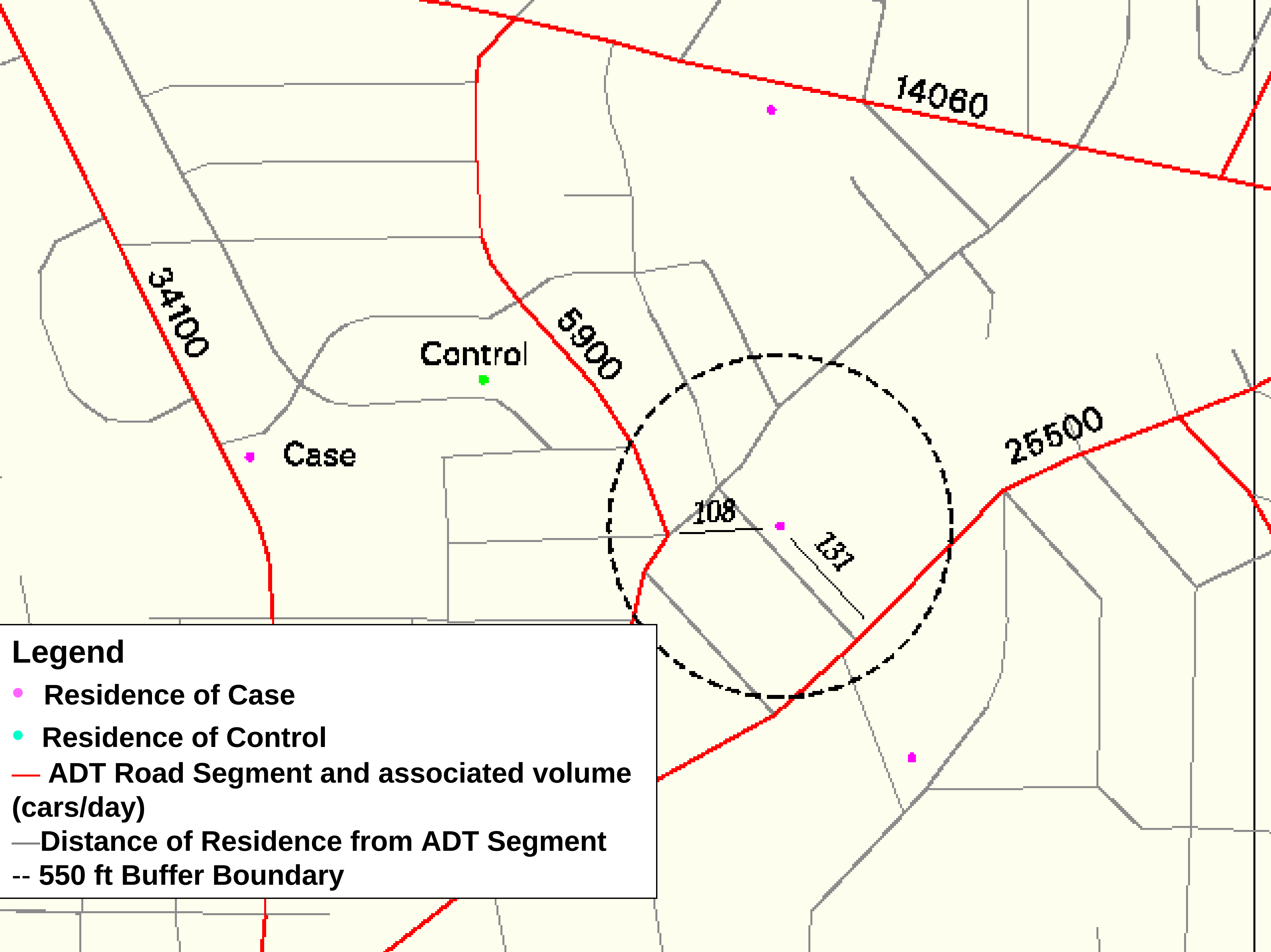
Orange County, CA



Traffic density – Evaluation results

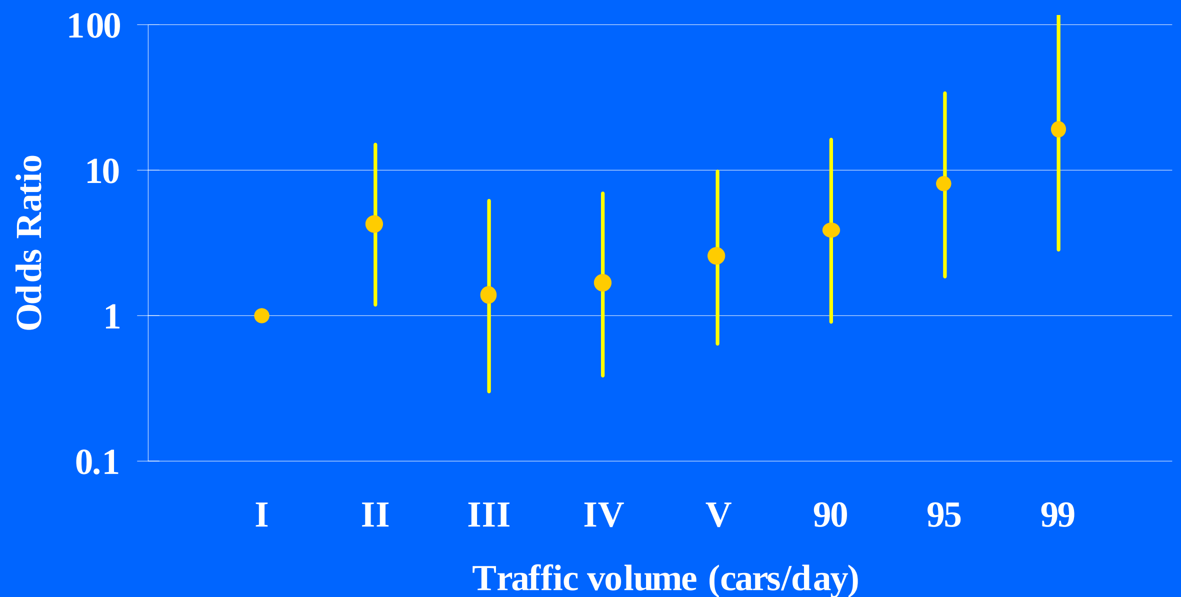
Air Pollutant	CO	1,3 – Butadiene	Benzene
Traffic Density (log) r	0.65	0.56	0.67

Source: Hertz et al, 2000


14060
34100
5900
Control
Case
108
131
25500
Legend
Residence of Case
Residence of Control
ADT Road Segment and associated volume (cars/day)
Distance of Residence from ADT Segment
-- 550 ft Buffer Boundary


1.0
0.5
0
Normalized Air Pollution Concentration
Street to Residence
Weighting Distance

Risk of 2 or more medical care visits vs. 1 visit for asthma by quintile of traffic volume on nearest street (girls)



(adjusted for race and type of visit)

Source: English et al. 1999

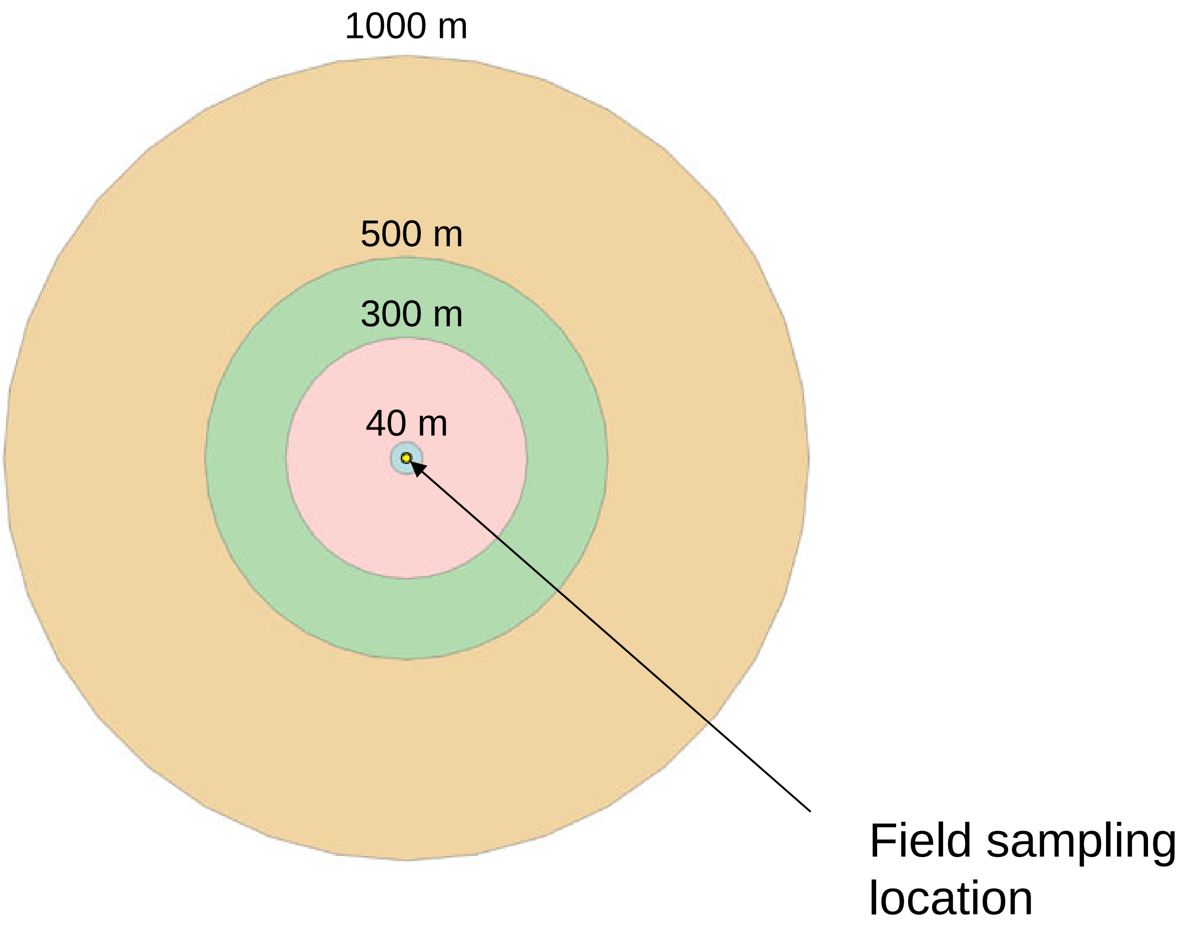
Passive Monitoring Methods

- **Gradko tubes** – Palmes style diffusion tubes with triethanolamine coated metal screens.
- 37 locations
- Two-week sampling period (10 – 20 days).
- Located at libraries, churches and police stations.
- Weather covers used to protect from rain and limit sampling rate.

Precision of Diffusion Tubes by Monitoring Period

	San Diego 2003	**Alameda 2004**	
Number of Duplicates	37	50	
Intraclass Correlation Coefficient	0.97	0.86	
Mean Coefficient of Variation	3.3%	6.4%	
Precision (Sc)	0.5 ppb	1.0 ppb	
Mean Relative Deviation	4.7%	9.1%	

Define Buffers



Traffic measurements

Within varying buffer sizes:

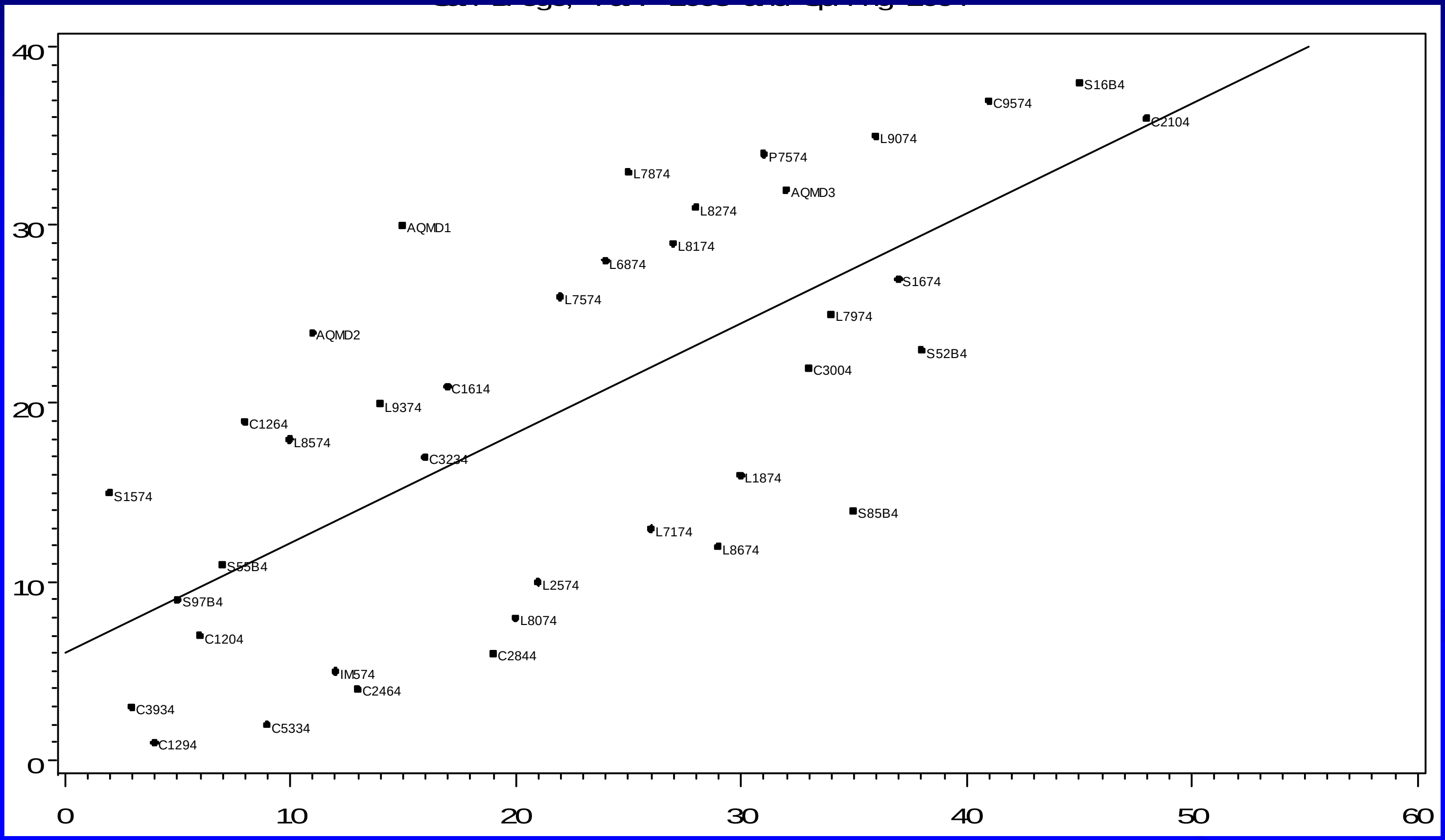
- Maximum traffic counts
- Distance-weighted traffic w/Gaussian dispersion
- Traffic volume (cars-km/hr)

Correlation of indicator ranks with ranks of NO_2 values

	r (spearman)	p
• Max. traffic in 300 m buffer:	0.57	<0.001
• Gaussian adjusted max traffic in 1000 m buffer:	0.48	0.002
• Sum of all volumes in 300 m buffer	0.69	<0.0001
• Sum of all volumes between 40 and 300 m	0.68	<0.0001

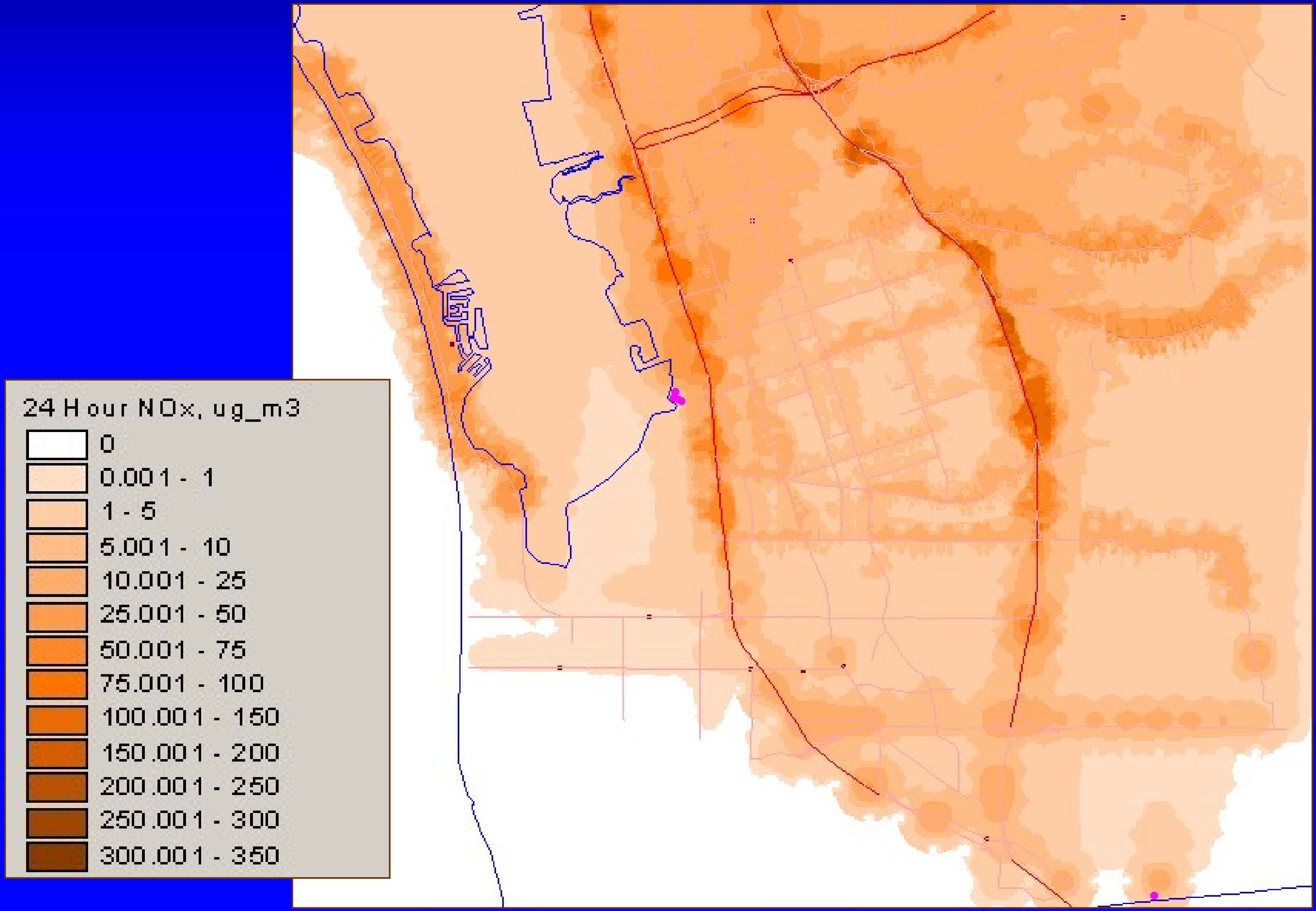
Correlation of ranks of NO2 values in center of buffer and traffic volume within 300 m

Rank of NO_2 Values

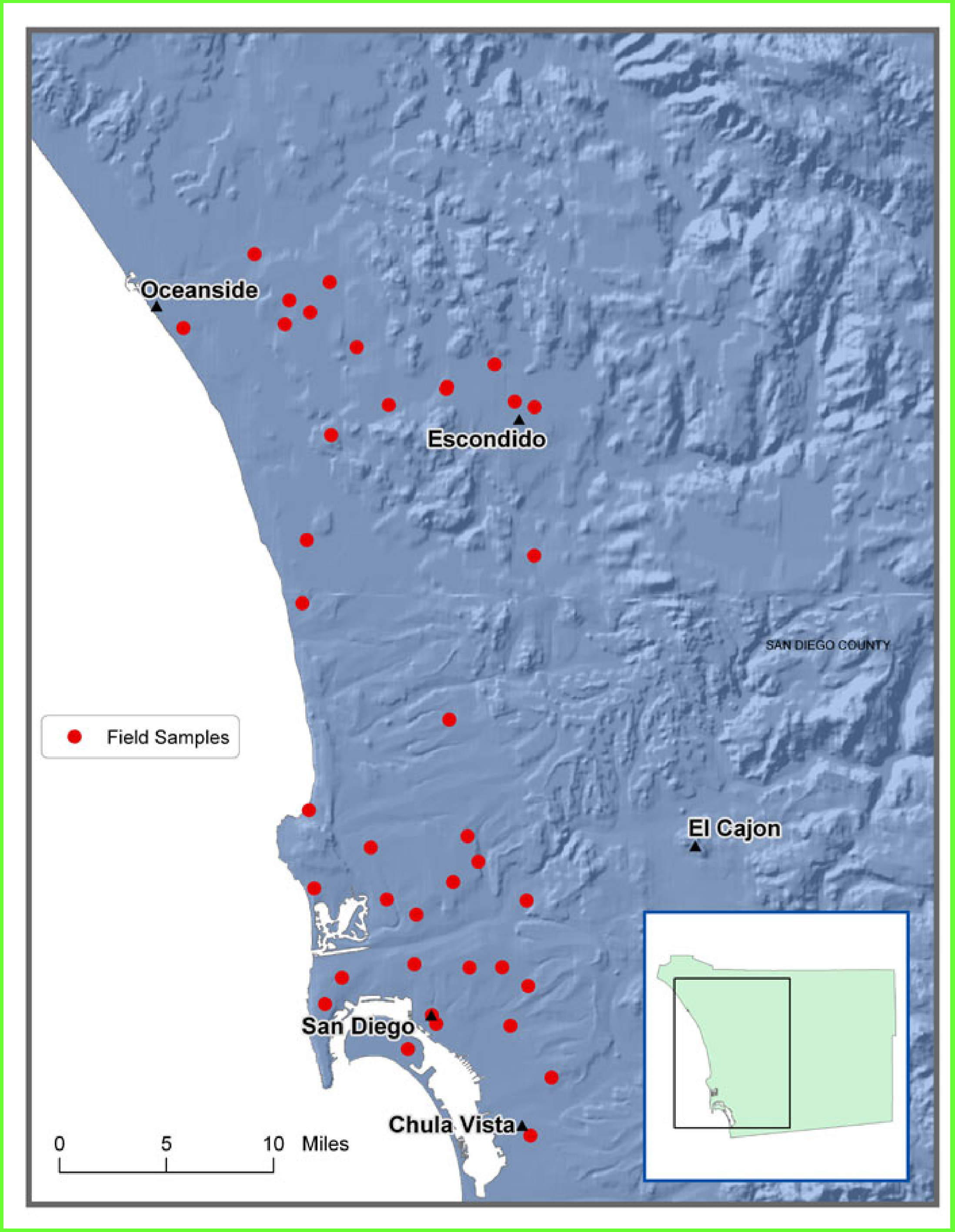


Rank of sum of traffic volume (cars-km/hr) in 300 m buffer

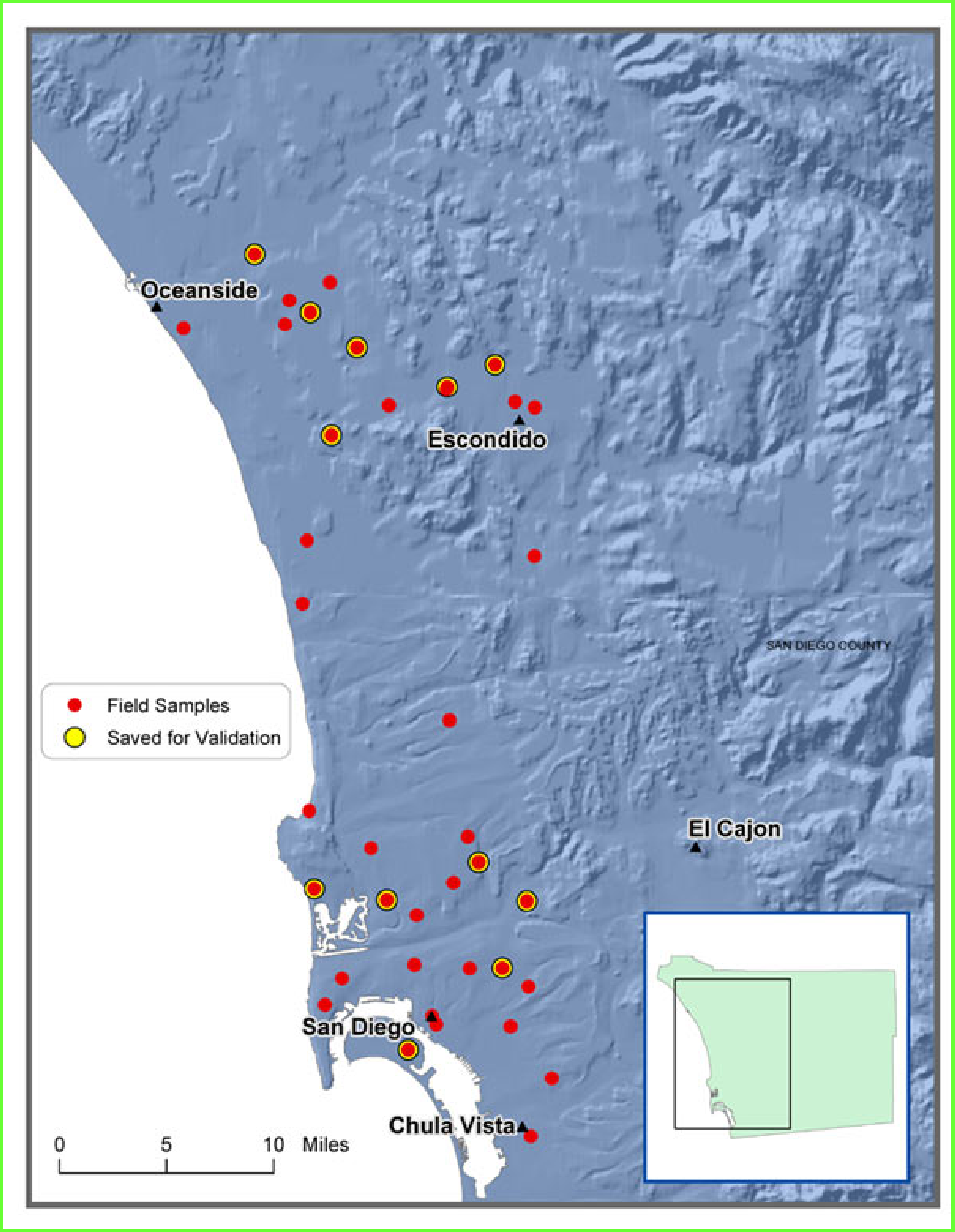
Modeled total NOx for 2000, San Diego County



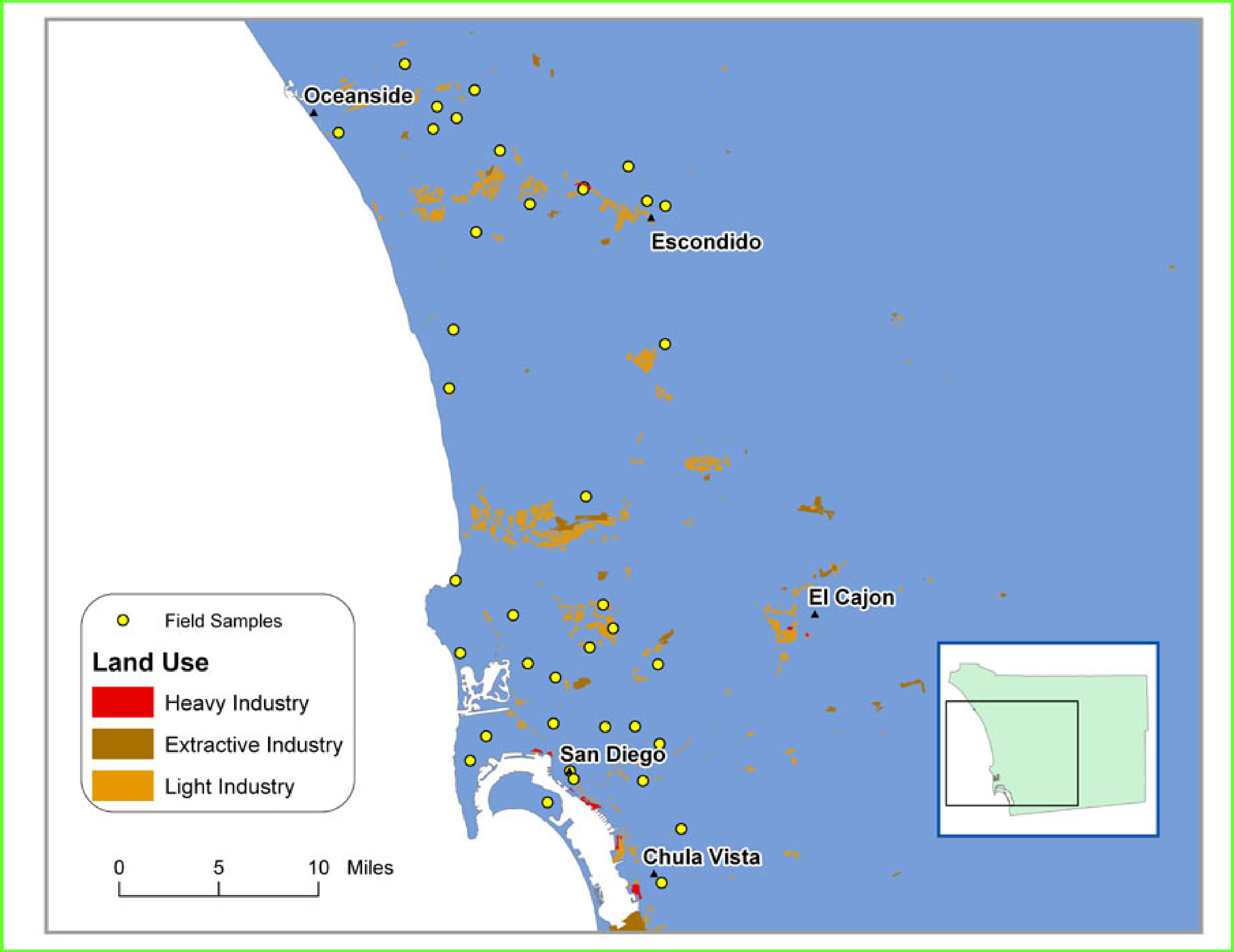
Land Use Regression: Sampling Locations



Twelve Removed for Validation

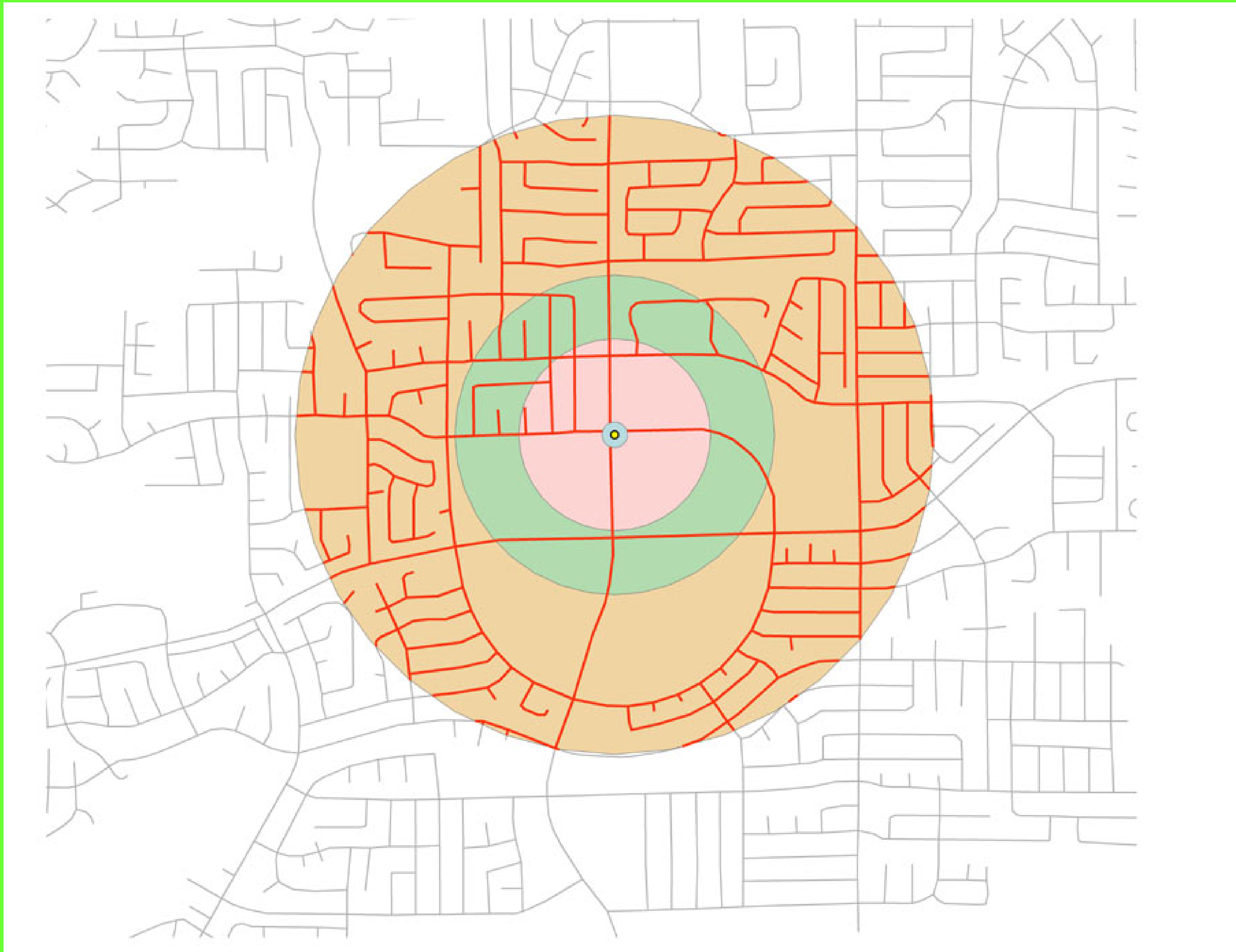


Industrial Land Use (2003)



Source: San Diego Association of Governments

Clip to Buffers



Final Model

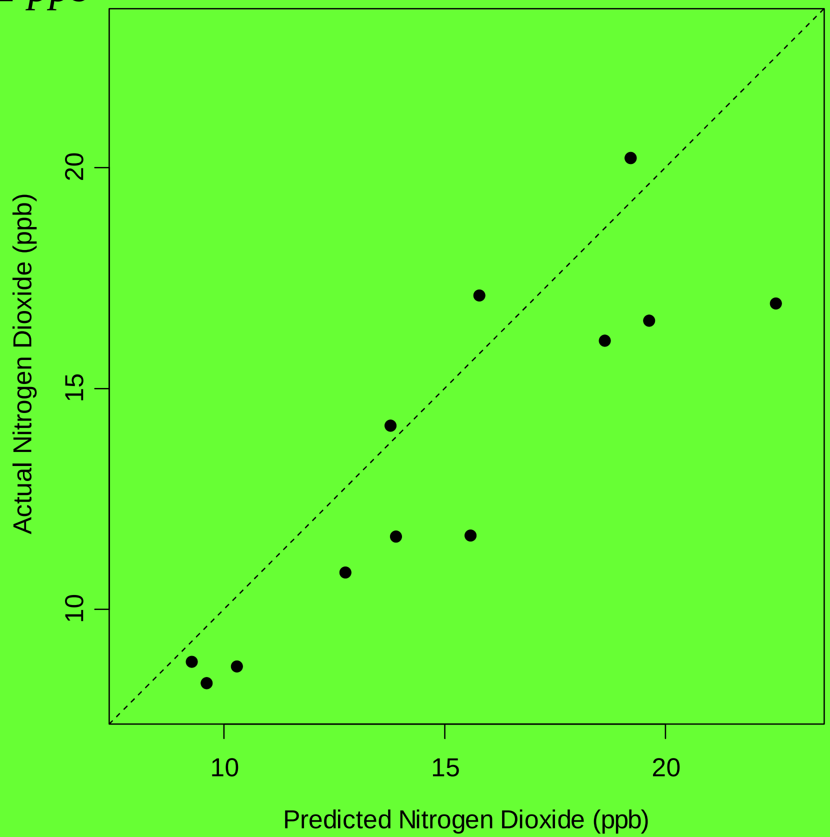
R-Squared 79%

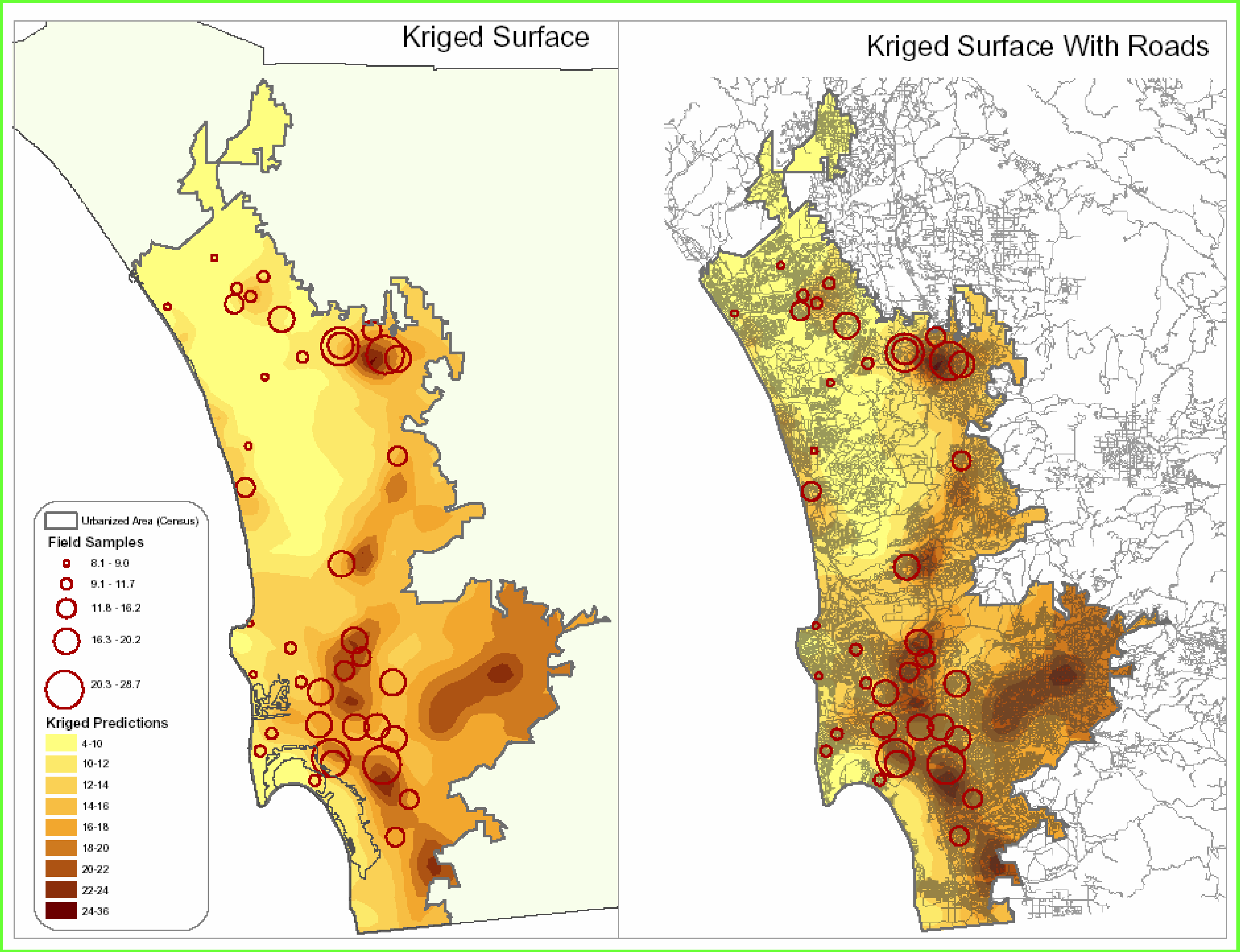
	Value	SE	t	p	VIF
(Intercept)	5.3051	1.1039	4.81	0.0000	-
Road Length (40m)	29.4083	7.0382	4.18	0.0002	1.05
Traffic Volume (40-300m)	0.0017	0.0004	4.23	0.0002	1.29
Traffic Volume (300-1000m)	0.0002	0.0001	3.72	0.0007	1.08
Distance to Coast	0.0003	0.0001	4.62	0.0001	1.25

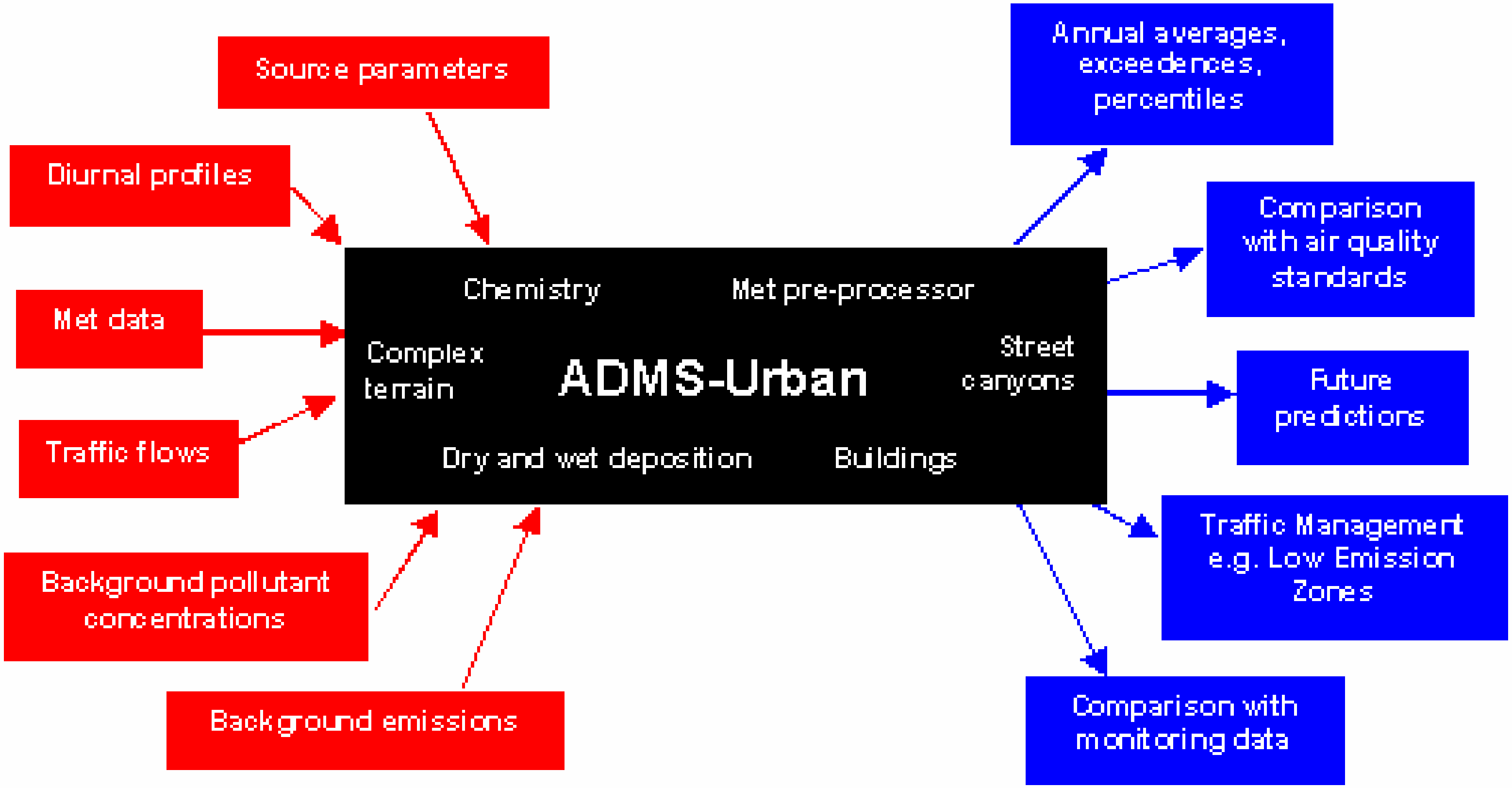
Predictions

All Validation Samples

On average predicts to within 2.1 ppb




Kriged Surface
Kriged Surface With Roads
Urbanized Area (Census)
Field Samples
8.1 - 9.0
9.1 - 11.7
11.8 - 16.2
16.3 - 20.2
20.3 - 28.7
Kriged Predictions
4-10
10-12
12-14
14-16
16-18
18-20
20-22
22-24
24-36


Source parameters
Diurnal profiles
Met data
Traffic flows
Background pollutant concentrations
Background emissions
Chemistry
Met pre-processor
Complex terrain
ADMS-Urban
Street canyons
Dry and wet deposition
Buildings
Annual averages, exceedences, percentiles
Comparison with air quality standards
Future predictions
Traffic Management e.g. Low Emission Zones
Comparison with monitoring data

Evaluation/Comparison of Models

- Factor of 2: (percent of predicted values between 0.5 and 2 of observed values)
- Fractional Bias (between -2 and 2; 0 is complete agreement between obs and predicted values)

Comparison of approaches

	ADMS-Urban (n=38) (all sources plus background)	Land Use Regression (n=12)
R^2	0.60	0.79
Fraction of 2	100%	100%
Fractional Bias	17.8%	11.9%
% within 5 ppb	68.4%	100%

Comparison of approaches

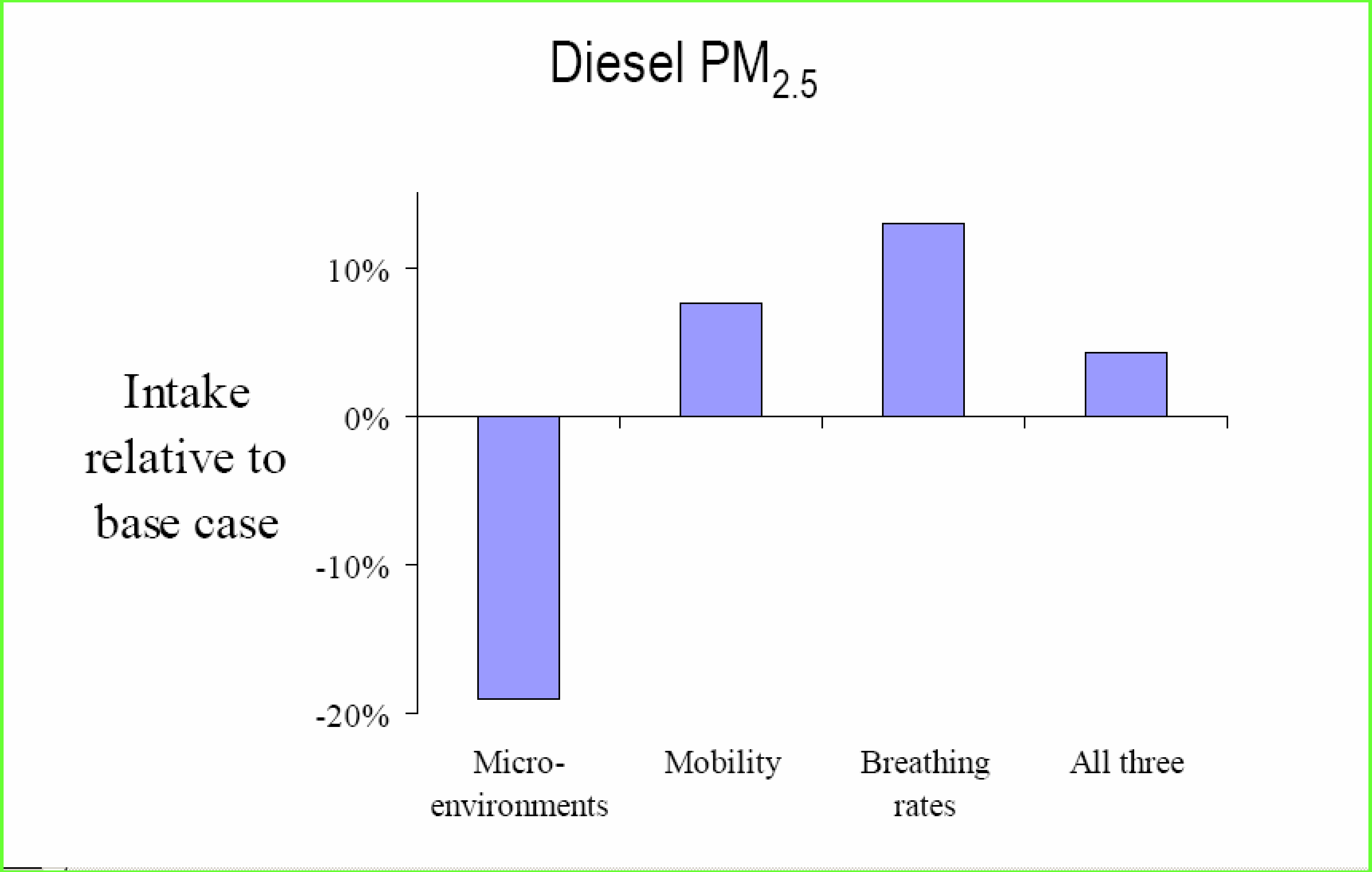
- Collins, 1998 - UK
  - Compared kriging, regression, and hybrid models to NO2 measurements (Palmes tubes)

	Adjusted R2
• Kriging:	43.9%
• GIS w/dispersion (CALINE3):	62%
• Land Use Regression (traffic volume, land cover, altitude):	81.7%

Maximum/Minimum values for residential areas (Collins, 1998)

	Max	Min	% >monitored average
• Kriging	21.64	41.67	35%
• GIS w/dispersion	18.15	82.45	9%
• GIS w/Regression	23.06	58.16	17%

Factors influencing exposure estimation:
South Coast Air Basin, CA : Based on time-activity data and CAMx model (Marshall, et al. unpublished data)



Discussion

- Each approach has limitations/strengths
  - High-end modeling is costly, requires highly trained staff, requires many data inputs
    - Potential for error if model inputs are not specified correctly or are not current
    - Models need to be evaluated, updated
    - Cost can be lower once model is running and staff is in place
    - Models that measure intra-urban variation at small scale (not regional models) necessary to capture spatial variation from traffic

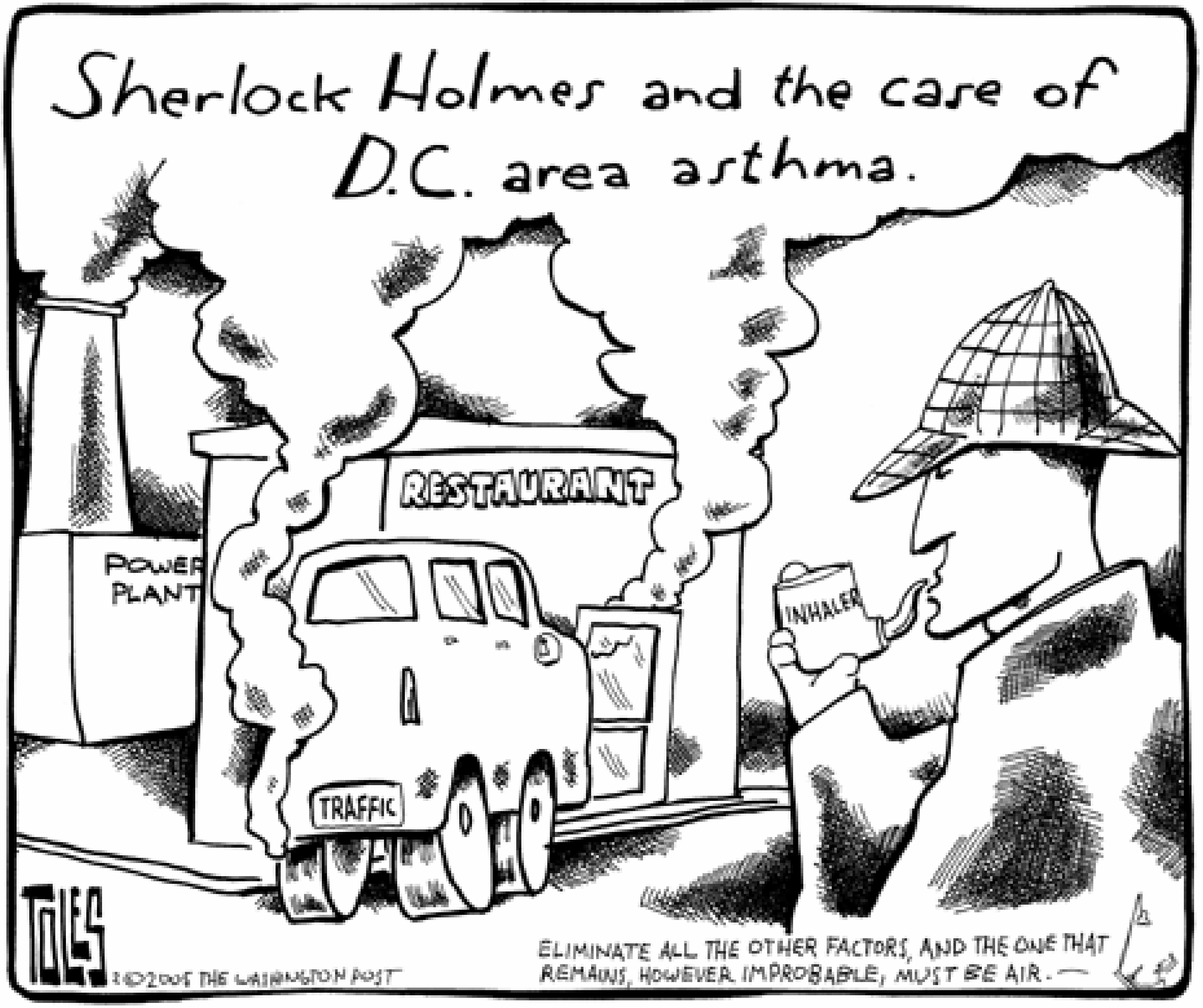
Discussion, cont.

- Need for evaluation at
  - different measurement heights and wind speeds
  - Wind direction parallel to roads
  - Range of pollution concentrations

- Pollution specific models
  - Is NO_2 good proxy for other pollutants?
    - cost

Discussion, cont.

- Acute vs. chronic disease:
  - Hourly estimated data for acute conditions (modeling)
  - Average annual for chronic conditions (average annual traffic, monthly/seasonal pollutant levels)
- Cross-sectional vs. cohort study design
- Primary data collection – representation of sampling period


Sherlock Holmes and the case of D.C. area asthma.
RESTAURANT
POWER PLANT
TRAFFIC
INHALER
TOLES
THE WASHINGTON POST
ELIMINATE ALL THE OTHER FACTORS, AND THE ONE THAT REMAINS, HOWEVER IMPROBABLE, MUST BE AIR. —

Approaches

- Distance of residence from road
  - Easy to calculate (errors inherent in geocoding dependent on accuracy of street network)
  - Associated with …
  - Does not take into account varying levels of traffic density

- Traffic Density on nearest road to residence
  - Can be coupled with distance to compute distance-weighted traffic density
  - Rjinders et al. finds personal and env. measurements of NO2 related to distance and traffic volume at nearest road
  - Associated with repeated medical visits for asthma (English, et al)
  - Automated distance-weighted traffic density service for CA developed by CEHTP
  - Does not take into account prevailing upwind/downwind (misclassification)
  - Can partition out car and truck traffic
  - Could model home and workplace address
  - No specificity of pollutant