Modeling highway-generated air pollution in a residential urban neighborhood

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Project Motivation

- About 10% of the United States population lives within 100 m of a highway.
- Accurate exposure estimates to quantify health effects require knowledge of the spatial and temporal variations in highway-generated air pollution.

Objectives

- Develop a model that predicts highway-generated air pollution concentrations on an hourly basis with 20 m x 20 m spatial resolution.
- Use the model to assign personal exposures to highway-generated air pollution.

Methodology

- Conduct intensive air pollution monitoring in a mobile research lab.
- Develop a model to extrapolate from individual monitoring events to all meteorological and traffic conditions in the study area.
- Combine model results with personal time-activity histories to estimate exposures.

Research Lab

- PNC, particle size distribution, NO/NO_X, CO, PPAH, BC, $PM_{2.5}$

Instrumentation

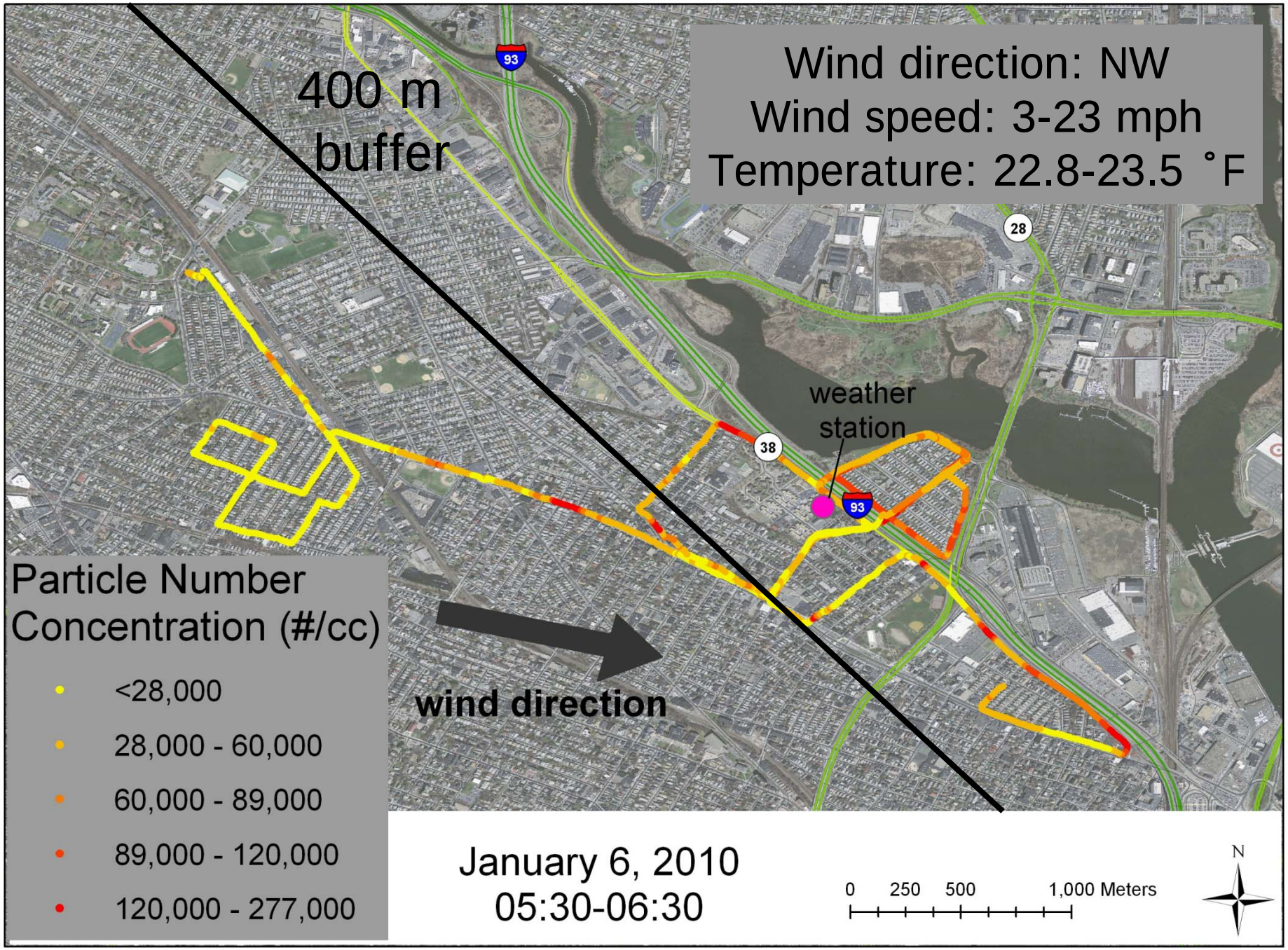
Parameter	Equipment
Particle number concentration	condensation particle counter
Particle size distribution	scanning mobility particle sizer
NO/NO_X	chemiluminescence analyzer
CO	gas filter correlation analyzer
PPAH	photoelectric aerosol sensor
Black carbon (BC)	aethalometer
$PM_{2.5}$	laser photometer

Data Collected

- Collect data representing all typical weather conditions.
- Currently have data from 6-hour blocks on >35 days representing:
  - Weekdays, Saturdays, Sundays
  - Summer, Fall, Winter, Spring
  - Morning and Afternoon

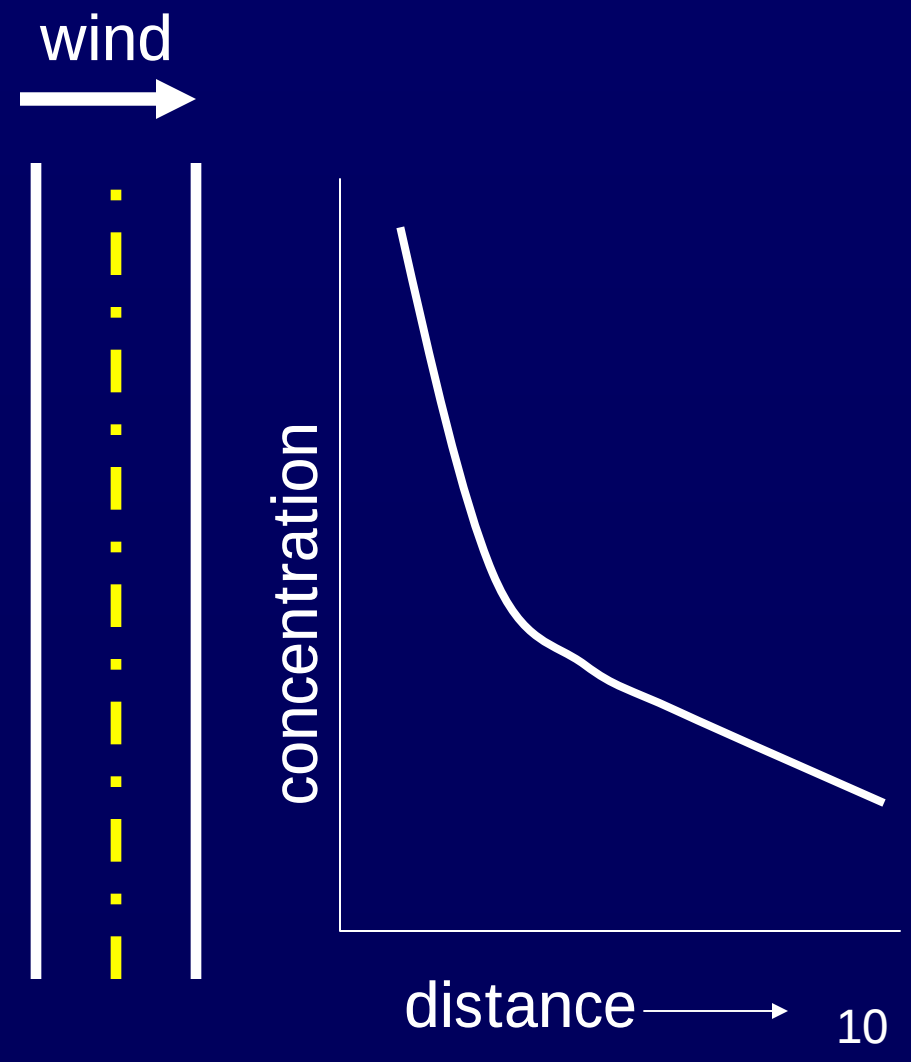
Ultrafine Particles

- Diameter <100 nm.
- More toxic per unit mass than particles with larger diameters (e.g., Dockery et al., 2007).
- Currently, in the USA, particles are regulated by mass ($PM_{2.5}$, PM_{10}), not number.


400 m
buffer
Wind direction: NW
Wind speed: 3-23 mph
Temperature: 22.8-23.5 ˚F
93
28
38
weather
station
Particle Number
Concentration (#/cc)
<28,000
28,000 - 60,000
60,000 - 89,000
89,000 - 120,000
120,000 - 277,000
wind direction
January 6, 2010
05:30-06:30
0 250 500 1,000 Meters
N

California Line Source Dispersion Model (CALINE4) Overview

- Gaussian model designed to model CO.
- Inputs: Meteorology, source strength, and site geometry.
- Output: Pollutant concentrations at designated receptors.
- Predicts air quality impacts within 500 m of source.

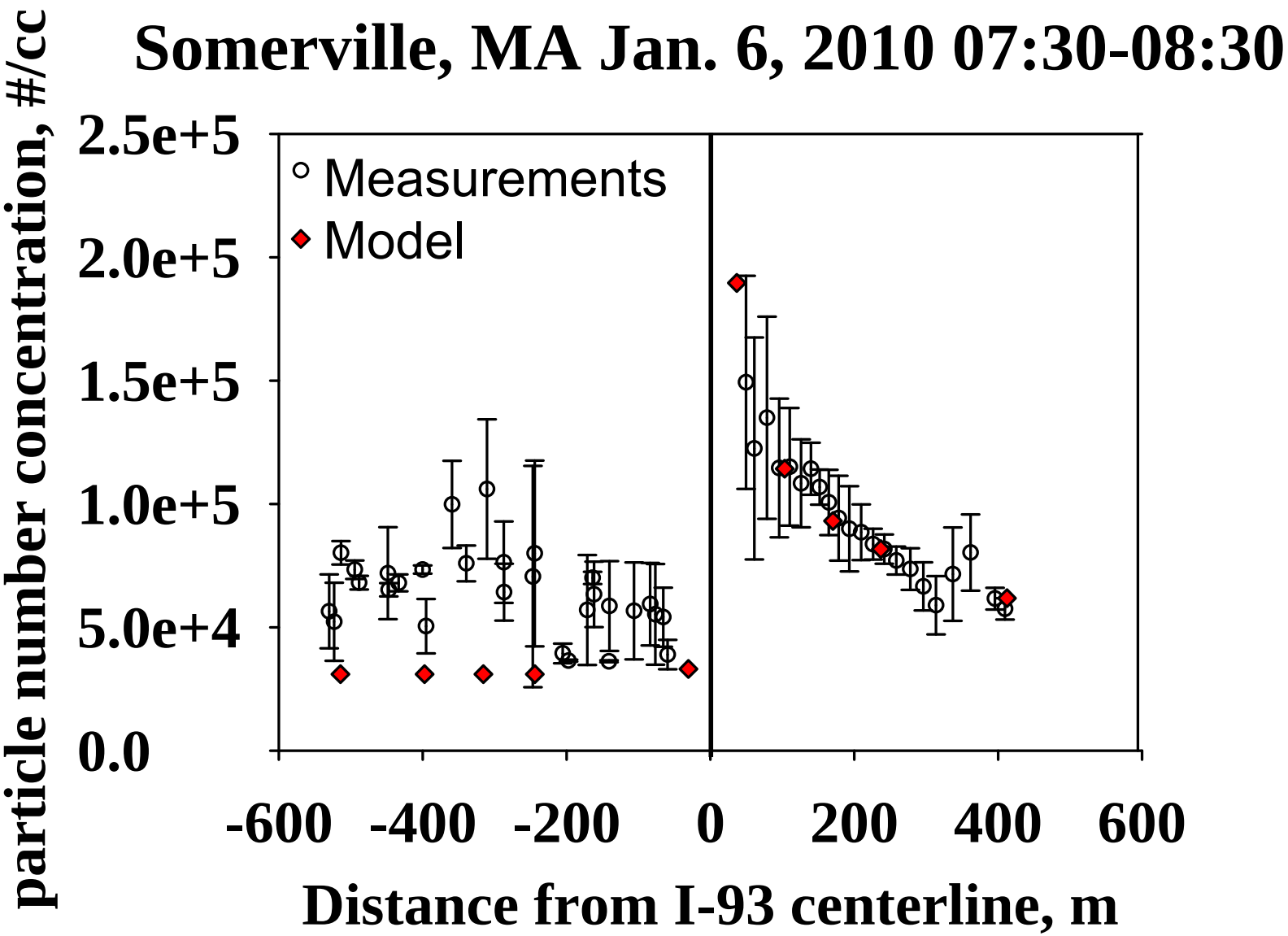


Source Strength

- Reported as emission factors.
  - e.g., g/vehicle-mile
- Usually tabulated.
- Since tables don't exist for ultrafines...

... we fit the emission factor to data as a model parameter (after Gramotnev et al., 2004).

Emission Factor Calibration



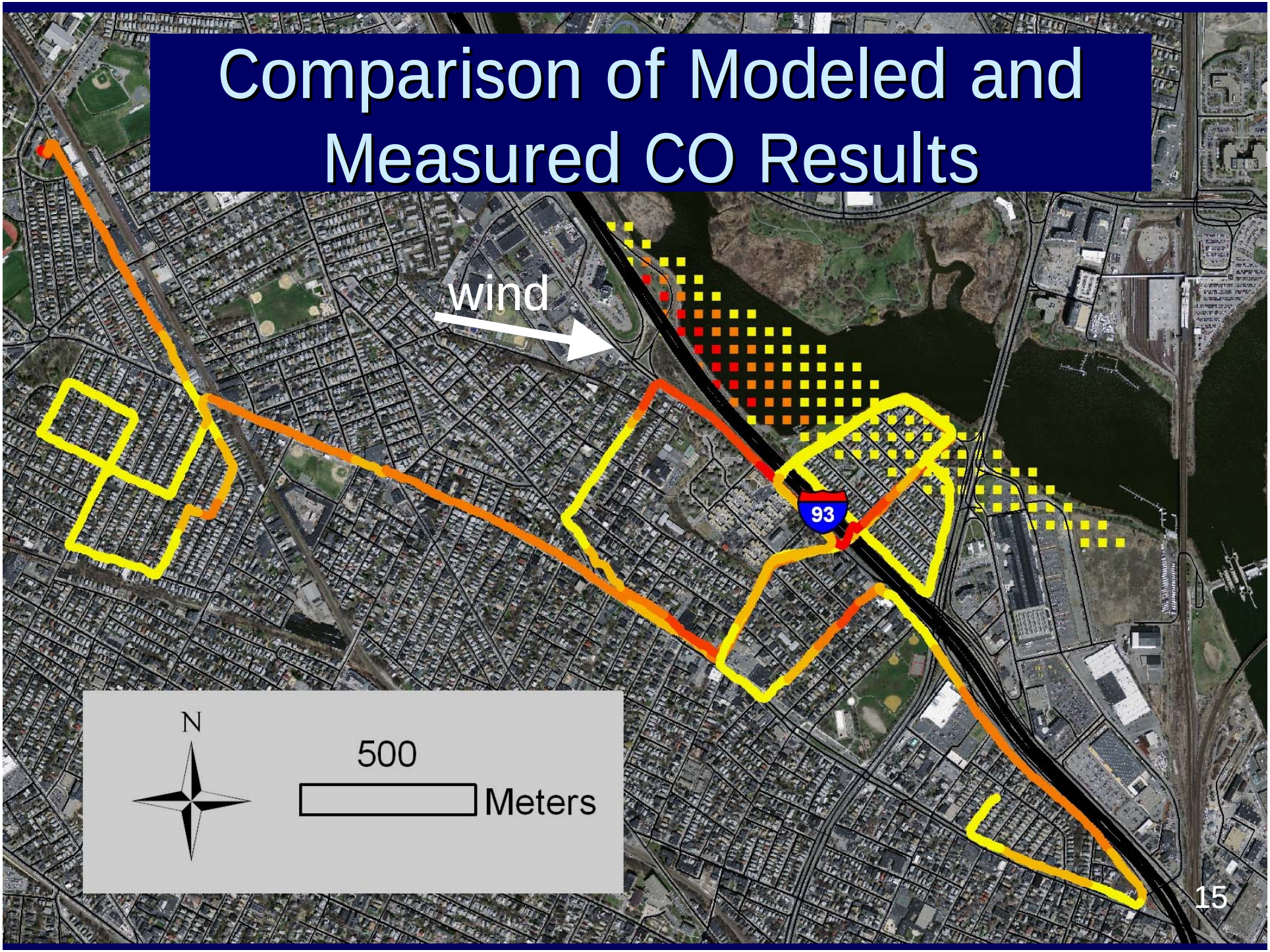
Emission Factor Results

Study	Emission factor (x 10^{14} particles/ veh-mile)	particle size range (nm)
This study	9-18	7 – 225
Gramotnev et al., 2003	4.5	<100
Birmili et al., 2009	3.4 (±0.3)	< 500
Zhu and Hinds, 2005	8.3	7 – 1,000

Some possible explanations for our relatively high emission factor

- Noise barriers shield neighborhoods from highway-generated pollution.
- Colder temperatures than other studies.
- Vehicle speeds may also play a role.

Comparison of Modeled and Measured CO Results



Conclusions

- Generally good agreement between model results and measurements.
- Large variation on 1-hour timescale.
- Noise barrier and hills likely have strong effect on highway-generated pollutant mixing.
- More sophisticated models (e.g., QUIC) are needed to accurately predict concentration variations over complex urban terrain.

Next Steps

- Validate emission factor estimate using additional days of data.
- Develop Quick Urban & Industrial Complex (QUIC) Dispersion Model to include noise barrier and elevation.
- Determine which other roads may significantly contribute to particle levels.

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