

# Traffic-Related Air Pollution in a Densely Populated Urban Area

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2008 Annual Meeting

International Society for Exposure Science / International Society for  
Environmental Epidemiology

October 14, 2008

# Background

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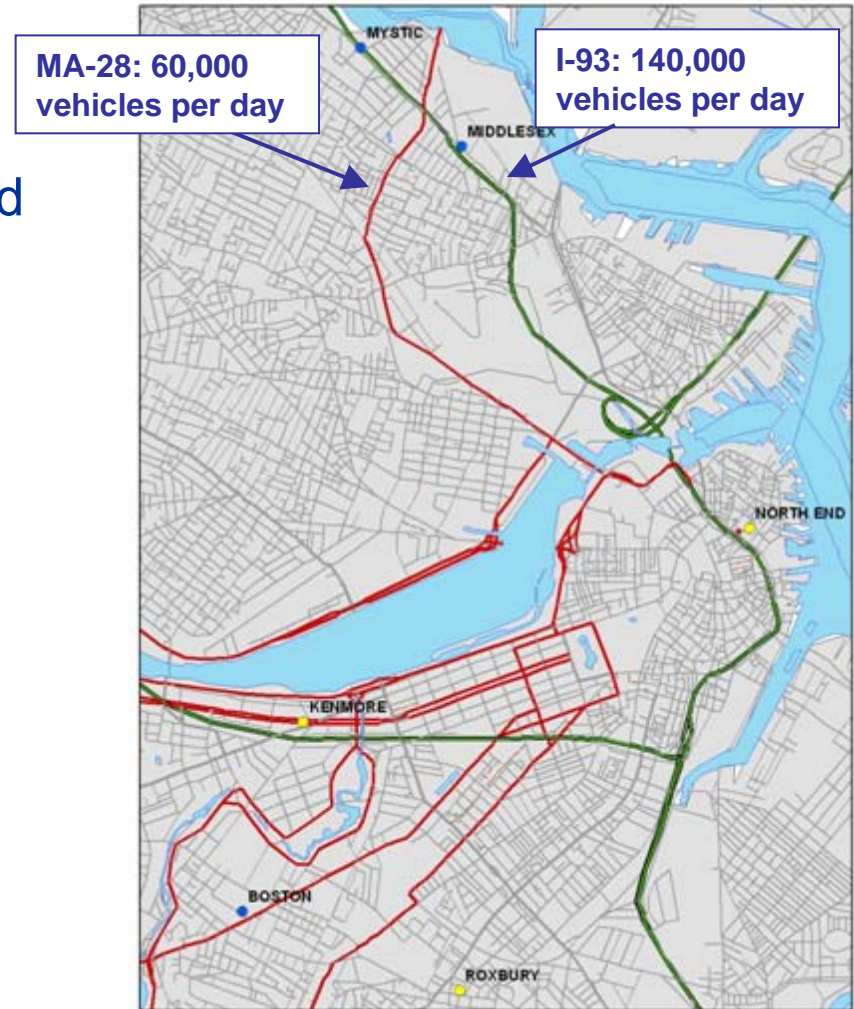
- Combustion exhaust from on-road vehicles produces areas of localized air pollution
- Proximity to heavily trafficked roads associated with increased risks of various respiratory and cardiopulmonary illnesses
- A consideration for environmental impact assessments of current and proposed land use



Leonard P. Zakim Bunker Hill Bridge  
over the Charles River between Boston  
and Somerville, MA

# Specific Aims

- Develop a prototype tool for evaluating local traffic-related air quality impacts on a neighborhood scale
- Demonstrate the utility of the tool
- Focus on one of the most heavily traveled and densely populated areas of Massachusetts



# Approach

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- Measurements and analysis that allow contributions of local traffic to be separated from other sources
- Characterize current impact of local traffic on two indicators of traffic-related air pollutants
  - black carbon (BC)
  - nitrogen dioxide (NO<sub>2</sub>)
- Forecast change in traffic-related air pollution associated with a mixed-used development proposed for the area



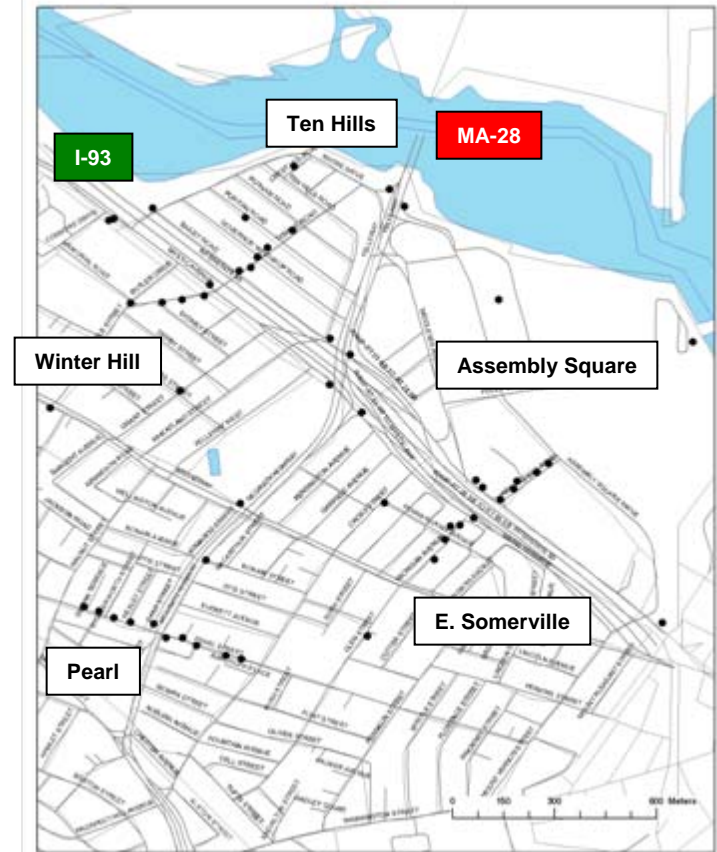
# Spatial Dimension

- Data Collection

- Nitrogen dioxide (NO<sub>2</sub>), 2-week average
- 49 locations; proximate to highways and surface streets
- Two periods
  - Nov. 1 – Nov 15, 2007
  - Nov 29 – Dec 13, 2007
- 98 samples

- Analysis

- Linear mixed effects model with an autoregressive covariance structure including
  - Random site-specific intercept ( $\mu_i$ )
  - Background NO<sub>2</sub> during period  $j$
  - Traffic density within 50m of site  $i$  (TD <sub>$i$</sub> )
  - Neighborhood or area (Area)



Map of NO<sub>2</sub> Sampling Locations

$$[\text{NO}_2]_{ij} = \beta_0 + \mu_i + \beta_1 \text{Background}_j + \beta_2 \text{TD}_i + \beta_3 \text{Area} + \beta_4 \text{TD}_i * \text{Area}$$

# Temporal Dimension

- Data Collection
  - Black carbon (BC), 1-hour average
  - Two locations adjacent to I-93
  - Two seasons, 1 month-long periods
    - Winter, Dec 14, 2006 – Jan 10, 2007
    - Summer, Jul 17, 2007 – Aug 15, 2007
  - 2,164 measurements
- Analysis
  - Linear mixed effects model with an autoregressive covariance structure including
    - Random site-specific intercept ( $\mu_i$ )
    - Background BC at hour  $j$
    - Traffic count at site  $i$  during hour  $j$  ( $TC_{ij}$ )
    - Day of week, hour of day, wind direction, and wind speed ( $Z_{ij} \dots Z_{pj}$ )



Map of BC Sampling Locations

$$\text{LN}[\text{BC}]_{ij} = \beta_0 + \mu_i + \beta_1 \text{Background}_j + \beta_2 \text{TC}_{ij} + \beta_3 Z_{1j} + \dots + \beta_p Z_{pj}$$

# Application/Demonstration

- Mixed use development
  - 145 acre site, ~300,000 ft<sup>2</sup> building space
  - Residential, office, retail, big box retail
  - Increased traffic on I-93, MA-28, and adjacent surface streets

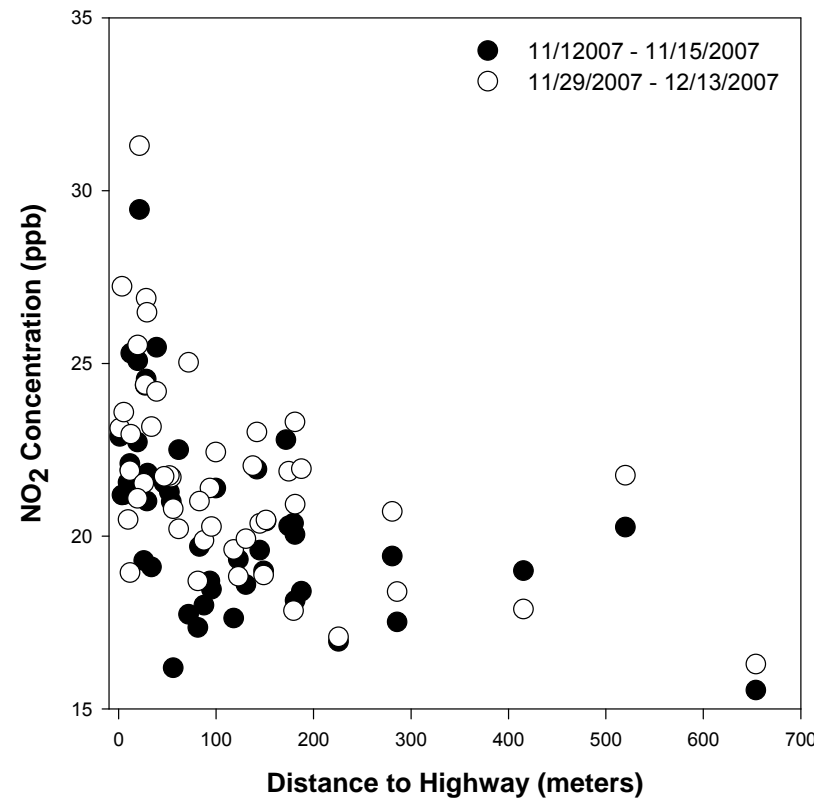
Projected Percent Increase in Average Daily Traffic Counts on Roadways Near the Planned Redevelopment for 2018 Compared to Current Conditions		
Roadway Name	No Build	Build
Interstate 93	11%	13%
Fellsway (MA-28)	35%	43%
McGrath Highway (MA-28)	31%	36%
Mystic Avenue	23%	24%
Broadway	13%	19%
Local Streets	9%	9%
Estimates based on VHB analysis (VHB 2007 and 2008).		



Schematic of Proposed Development

# NO<sub>2</sub> Levels

- Two-week averages
  - Mean (SD): 20.6 (2.7) ppb
  - Range: 15 – 32 ppb
- NO<sub>2</sub> weakly correlated with distance (m) to highway
  - I-93: -0.19 ( $p=0.06$ )
  - MA-28: -0.28 ( $p=0.006$ )
- NO<sub>2</sub> strongly correlated with traffic density (TD)
  - TD<sub>25m</sub>: 0.61 ( $p<0.0001$ )
  - TD<sub>50m</sub>: 0.60 ( $p<0.0001$ )
  - TD<sub>100m</sub>: 0.48 ( $p<0.0001$ )



# NO<sub>2</sub> Modeling

- Two-week average NO<sub>2</sub> significantly associated with traffic density in each neighborhood except Pearl Street
  - Maximum of 4 ppb per 10<sup>4</sup> km-ADT in East Somerville
  - Minimum of 2 ppb per 10<sup>4</sup> km-ADT in Assembly Square

Parameters of Linear Mixed Model for Nitrogen Dioxide Analysis				
Neighborhood	Range in Traffic Density (50m Buffer) [km*ADT]	$\beta$ Estimate	Standard Error	P-value
Winter Hill	138 – 23,097	0.000243	0.000053	<.0001
Assembly Square	0 – 27,174	0.000200	0.000055	0.0007
Ten Hills	69 – 22,878	0.000241	0.000062	0.0004
East Somerville	69 – 13,745	0.000399	0.000087	<.0001
Pearl Street	440 – 12,435	0.000097	0.000107	0.3676
m	meters			
km	kilometers			
ADT	average daily traffic			

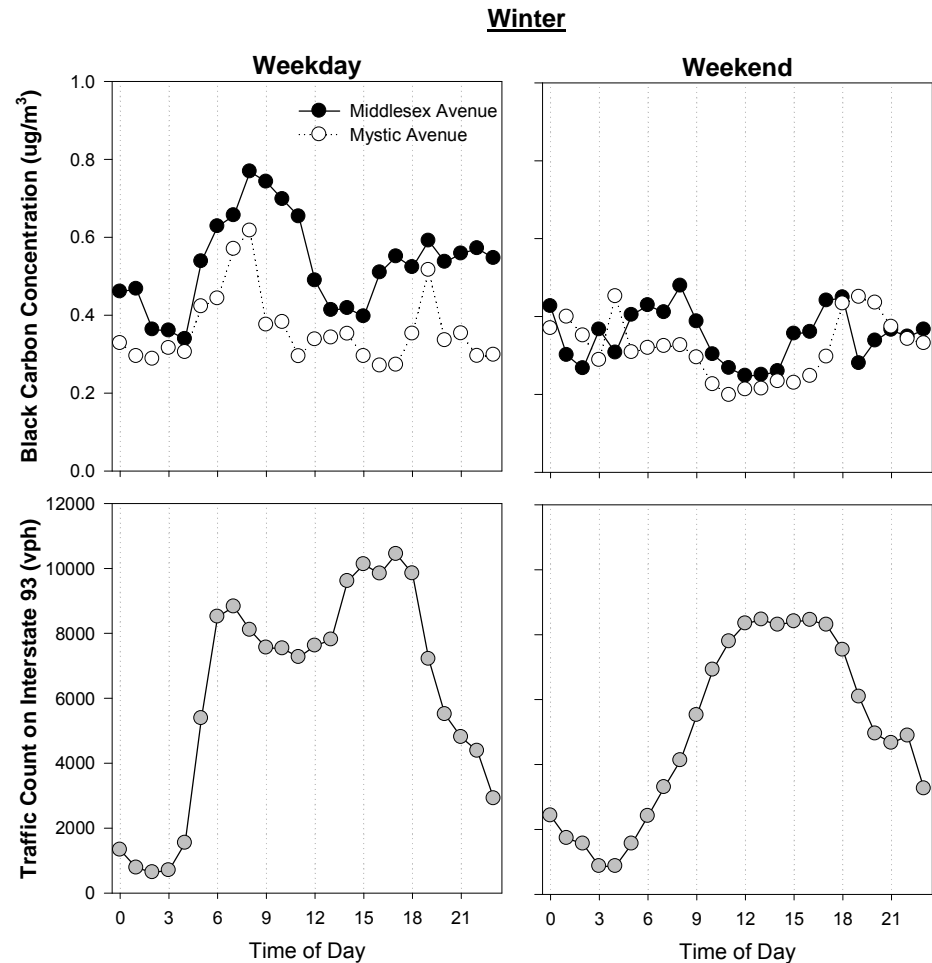
# BC Levels

- Substantial seasonal variation
- Levels comparable between sites
- Hourly BC correlated with corresponding weekday traffic counts

One-Hour Average Black Carbon Concentrations Adjacent to Interstate 93 in Somerville, MA By Season						
Site	N	Mean (SD)	Median	25th%	75th%	95th%
<b>Summer</b>						
Middlesex	605	1.01 (0.69)	0.82	0.51	1.36	2.37
Mystic	505	0.92 (0.60)	0.82	0.49	1.22	2.06
<b>Winter</b>						
Middlesex	592	0.55 (0.41)	0.45	0.28	0.70	1.37
Mystic	469	0.57 (0.62)	0.34	0.25	0.62	2.03
SD		standard deviation				
$\mu\text{g}/\text{m}^3$		micrograms per cubic meter				
Summer BC concentrations measured at Middlesex between 7/17 – 8/15/2007 and at Mystic between 5/16 – 6/6/2007.						
Winter BC concentrations measured at Middlesex between 12/14/2006 – 1/10/2007 and at Mystic between 2/1 – 2/28/2007.						

# BC Levels

- Substantial seasonal variation
- Levels comparable between sites
- Hourly BC correlated with corresponding weekday traffic counts
  - <0.1 to 0.20 when upwind
  - 0.26 to 0.40 when downwind



# BC Modeling

- Higher traffic counts on I-93 associated with significantly higher BC during both summer and winter
  - When sites are downwind of I-93, 15% to 18% increase in 1-h BC per inter-quartile change in traffic count
  - No association with traffic count during upwind conditions

Percent Increase in Hourly Black Carbon Concentrations for Each IQR Increase in Hourly I-93 Traffic Counts.				
Season	IQR	Wind Direction	% Increase (95% CI) per IQR	P-value
Summer	5308	Downwind	<b>15.4 (1.9–30.8)</b>	0.025
		Upwind	7.7 (-5.9–23.3)	0.611
Winter	5693	Downwind	<b>18.0 (4.3–33.4)</b>	0.025
		Upwind	3.3 (-5.9–23.3)	0.28
IQR Inter-quartile range CI Confidence Interval $\mu\text{g}/\text{m}^3$ micrograms per cubic meter				
Results from linear mixed models stratified by season. IQR change is 5308 and 5693 vehicles per hour in summer and winter, respectively. Summer is defined as 5/16-6/6/2007 and 7/17–8/15/2007, while winter is defined as 12/14/2006-1/10/2007 and 2/1-2/28/2007. Significant values at 0.05 level in bold.				

# Predictive Modeling

- Change in 24-h BC and 2-week NO<sub>2</sub> with increased traffic
  - 2018 vs. 2008: ~0.02 µg/m<sup>3</sup> BC and 0.4 ppb NO<sub>2</sub> (2% increase)
  - 2018 Build vs. 2018 No Build: ~0.3% increase in BC and NO<sub>2</sub>
- Predictions indicate that local traffic accounts for approximately 15% of 20% of the BC and NO<sub>2</sub> in these neighborhoods

Estimated Increase in Daily Average Black Carbon Concentration due to Projected Traffic Counts on I-93		
Season	Projected Increase in Traffic Count on I-93	Estimated Increase in Concentration of BC
Difference between 2018 Build Condition and 2018 No Build Condition		
Summer	1.8 %	0.35 %
Winter	1.8 %	0.32 %
Difference between 2018 Build Condition and Current Conditions		
Summer	13 %	2.3 %
Winter	13 %	2.1 %
BC                      black carbon Estimated from VHB traffic analysis (VHB, 2008) and mixed model results.		

Assumes fleet-wide emissions and background levels are constant

# Conclusions

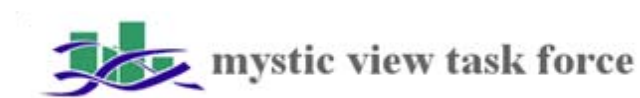
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- Developed a preliminary approach for evaluating local traffic-related air quality impacts on a neighborhood scale
- Methodology allows contributions of local traffic to neighborhood-scale air quality to be separated from contributions of other sources
- Extent to which the approach can be generalized to a broader area will be explored with complementary data obtained in Cambridge MA
- If successful, may be a useful means to provide a context for interpreting local traffic contributions at the neighborhood scale and addressing community-based cumulative exposure needs

# Acknowledgements

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- Financial and field support from the Mystic View Task Force, Somerville, MA
- Cooperation from the City of Somerville, Federal Realty Investment Trust, and the City of Cambridge
- Analytical chemistry contributions from Thomas Jankun and Brian Leaderer, Yale School of Public Health



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