Ambient Air Pollutants (O_3, PM_{10}) and Childhood Respiratory Hospitalizations: Preliminary Results

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Background

- The literature lacks consistency as to the effects of air pollutants on respiratory health.
- Few studies have examined the association in children, a susceptible subpopulation of particular concern.
- Most previous work has focused on one small area or town or limited to a short period of time.
- Geographic variation or disparity of effects were rarely studied.
- Few studies compared results by using different statistical methods in the same population

Objectives and Design

- **Objectives:**
  1. **Examine the association between O_3 and PM_{10} concentration and childhood respiratory hospital admissions using sophisticated analysis methods.**
  2. **Investigate this association in different geographic areas (urban or rural areas) in NYS.**
  3. **Complement the surveillance program and follow-up on trends identified by surveillance.**

- **Population**
  - **Children 0-17 years old residing in New York State, 1991 – 2001**

- **Case**
  - **Hospitalization for respiratory diseases**

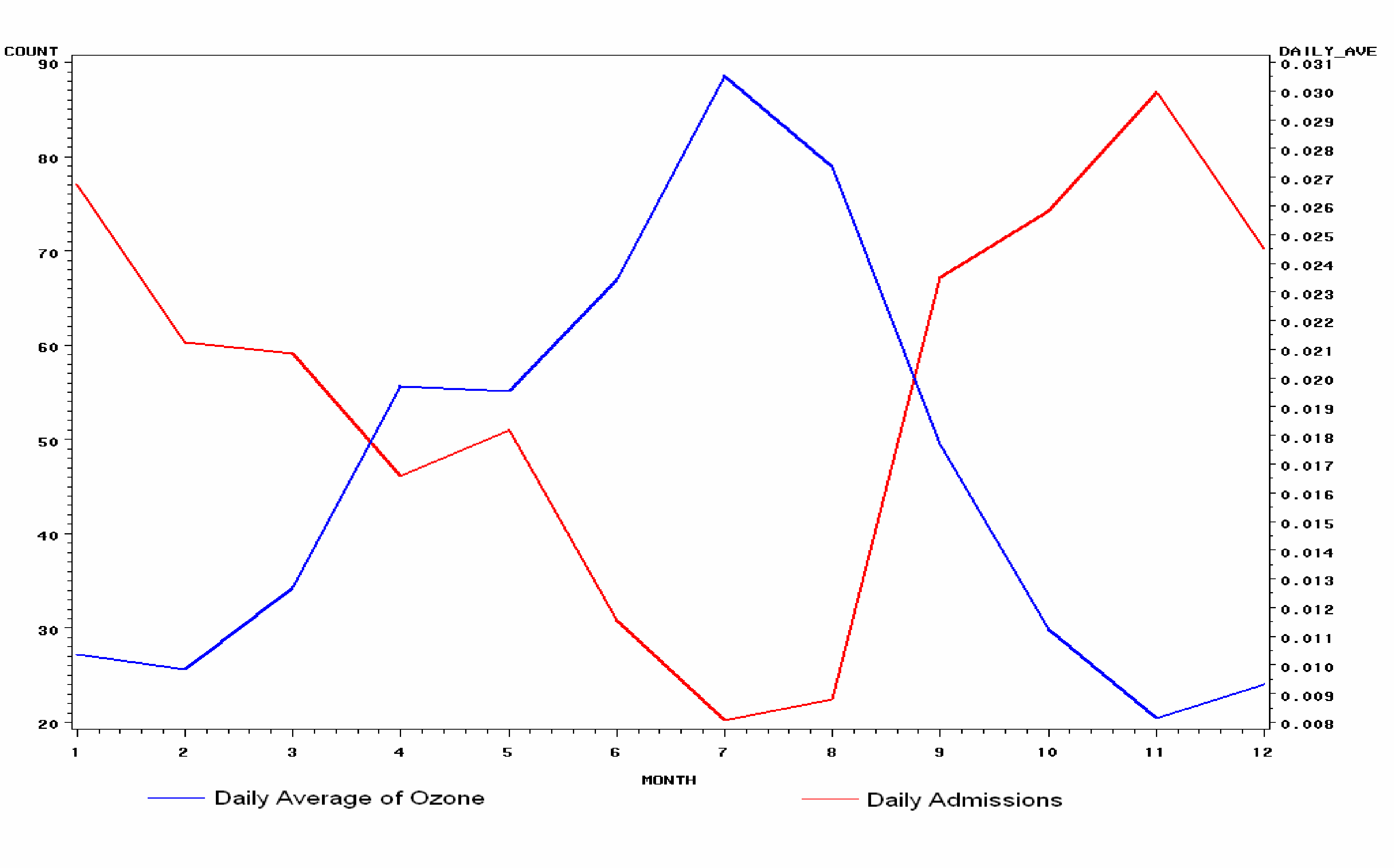
Statistical Methods

- Case-crossover
  – An alternative to time-series method analyzing for health-related effects of air pollution
- Generalized Additive Model (GAM)
  – Widely used in environmental epidemiology

Why Use These Methods?

- Assess short-term variation in pollution and outcomes
- Strong seasonal effects can be smoothed
- Control for day-of-week effect, weather, long-term time trend, and auto-correlation
- The effects of ambient pollutants on health outcomes are very small. Sensitive and sophisticated models are needed
- Some confounders are controlled by design since the same population is examined repeatedly under various exposure conditions

Comparison of Daily Admission and Daily Average of O_3 concentration in NYC in 1995



Case-crossover

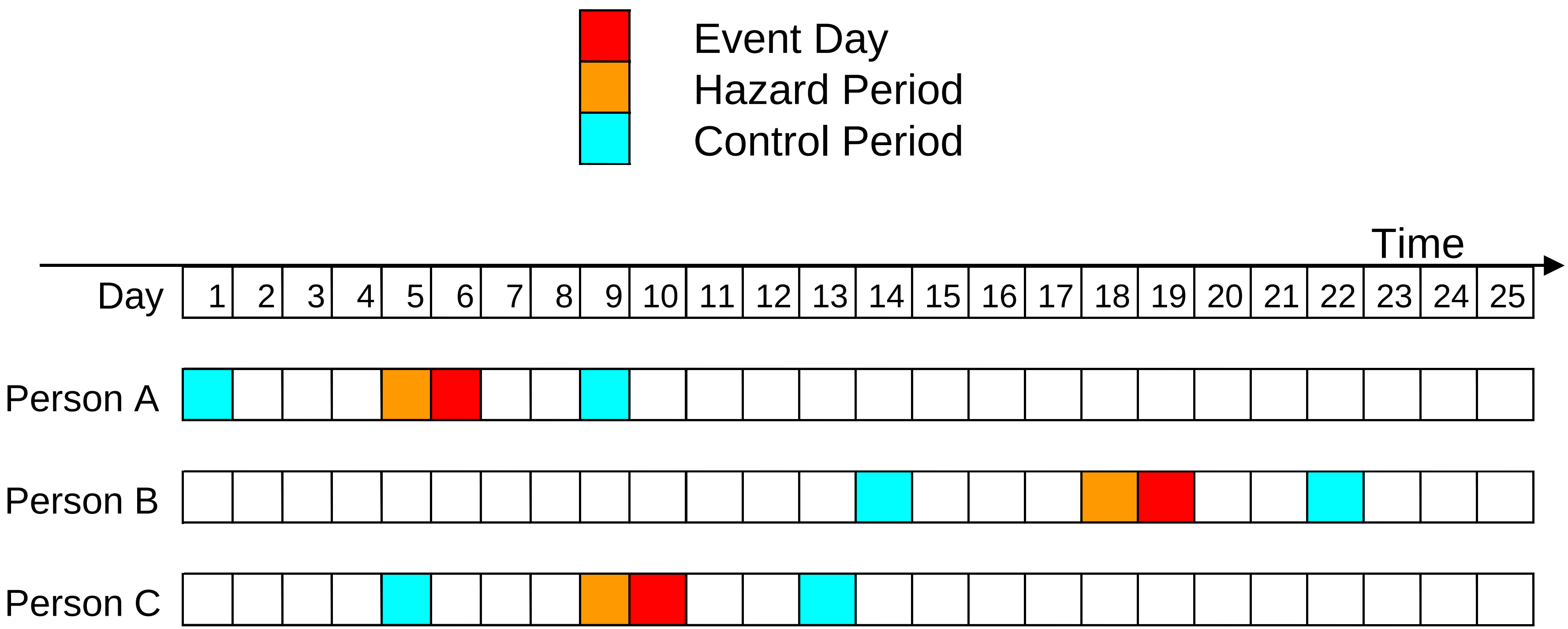
(Ref: Maclure M., 1991; Navidi W., 1998; Bateson TF, 1999)

- Case-crossover design can be viewed as a matched case-control study with cases only and each individual/population serves as its own control.

- For each case patient, exposure in a “hazard period” just before an event is compared to the patient’s exposure at control periods which are not followed by an event.

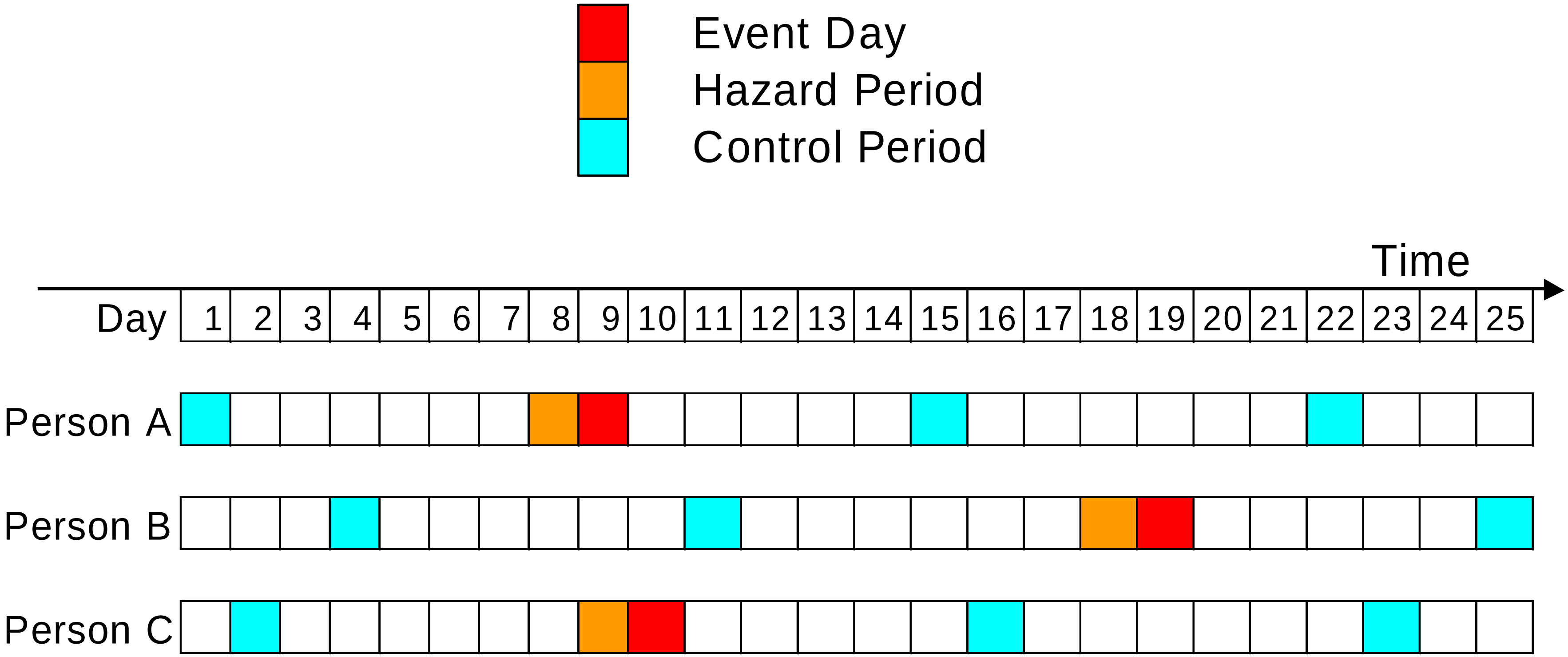
Symmetric Bi-Directional

(Ref: Dr. Thomas Bateson's Lecture on Case-crossover)



Time-stratified

(Ref: Dr. Thomas Bateson's Lecture on Case-crossover)



Generalized Additive Model (GAM)

(Ref: Hastie TJ, 1990; Scheartz J, 1994; Dominici F, 2000)

- Non-linear model with smooth functions
- Applied to various types of distribution such as Gaussian, Poisson, Binomial, etc:

$$g(E(Y)) = S_0 + \sum_{i=1}^{P} S_i(X_i)$$

E(Y): expected value of Y

g: link function. S: smoothing function

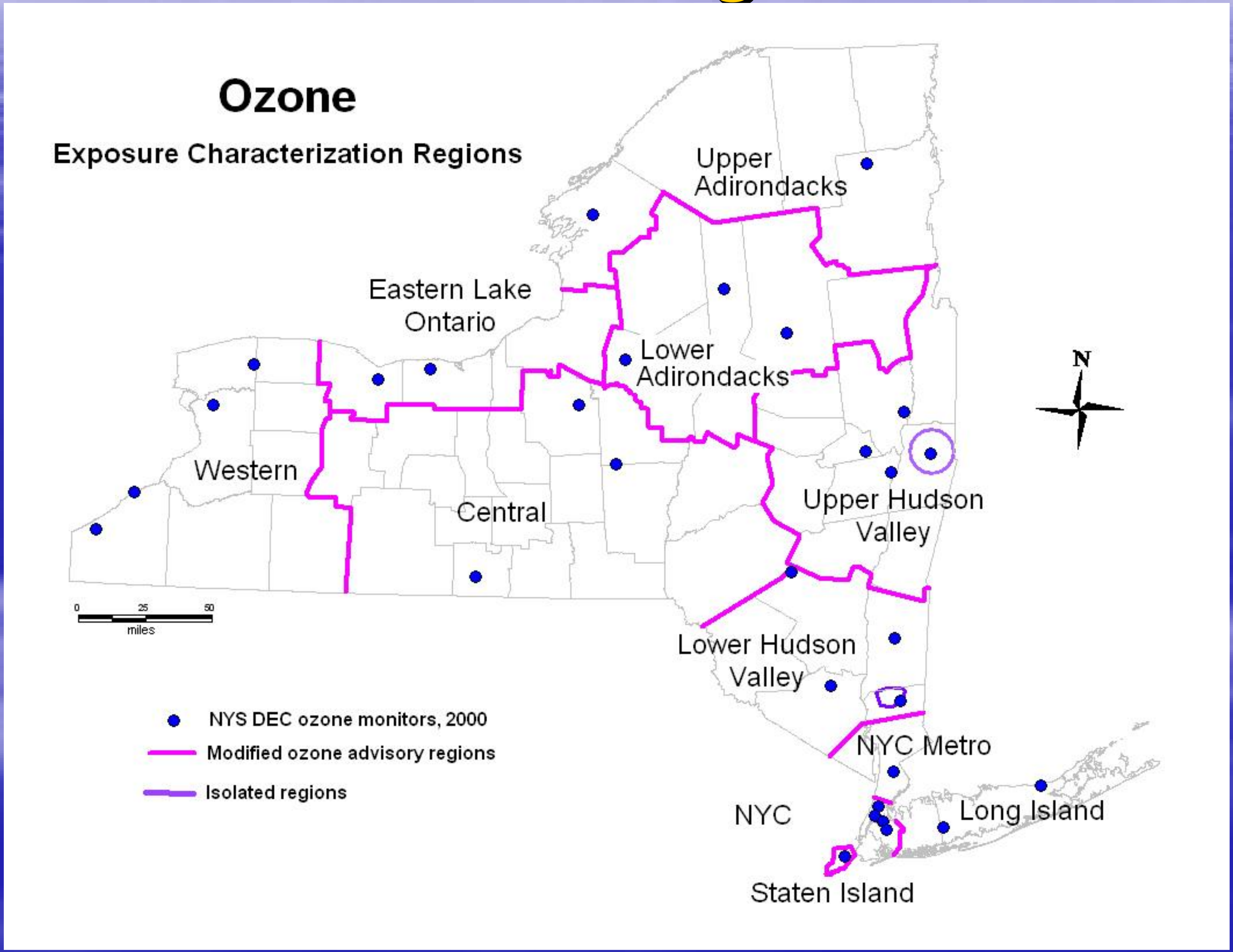
Statistical Methods

- **<u>Case-crossover</u>**
  - Symmetric bi-directional referents: pre- and post-7 and 14 days of the hazard day
  - Time stratified window size: 28 days (i.e., referents are pre- or post-7, 14, 21 or 28 day of the hazard day)
  - Analyze with conditional logistic regression
- **<u>Generalized Additive Model (GAM)</u>**
  - Smoothing methods were used to model the seasonal / metrological effects
- Adjusts for temperature, relative humidity, barometric pressure, and day of the week
- The lagged effect was also checked (lag0-lag6)

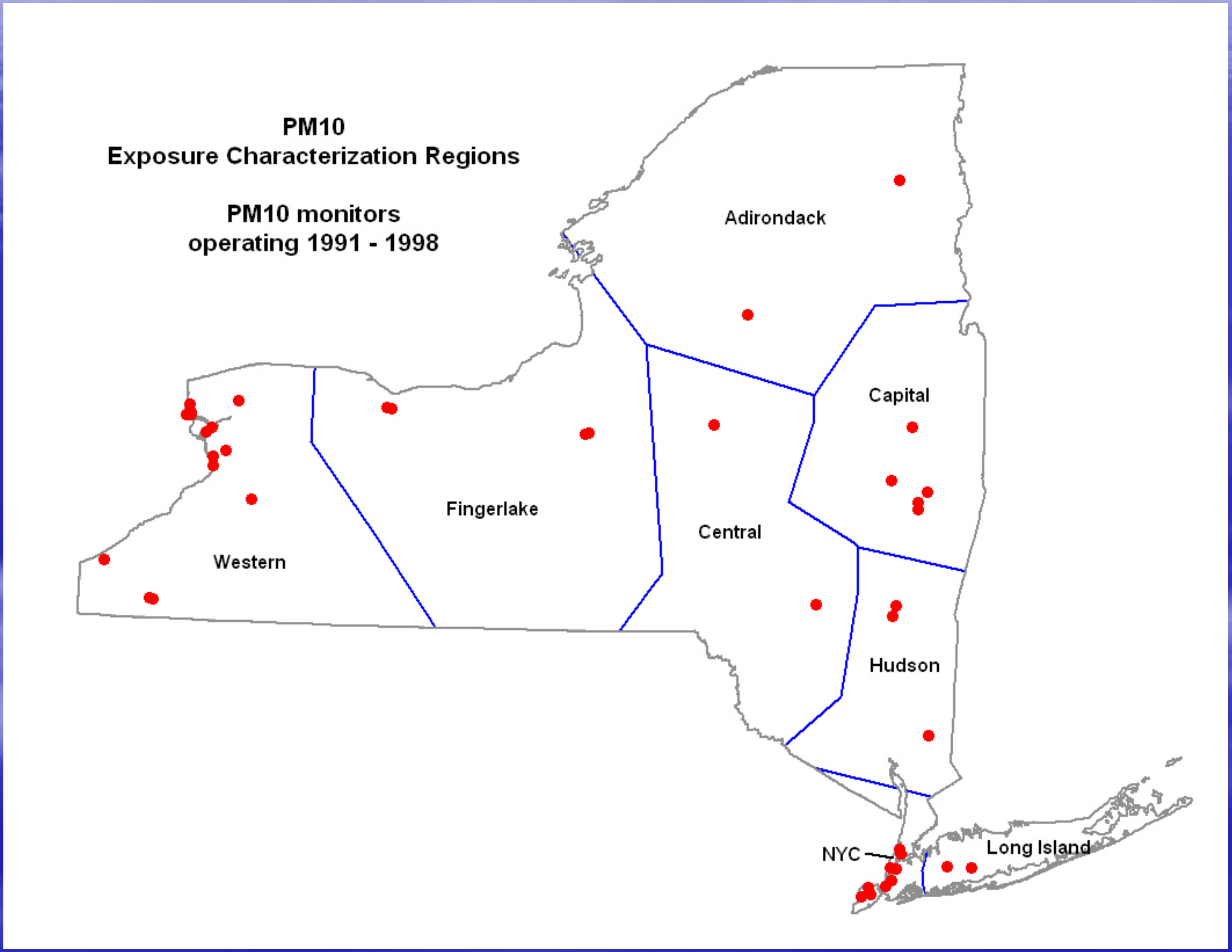
Pollutant region definitions

- O_3 regions (N=11) based on spatial and temporal correlation among air monitors within NYSDEC's O_3 advisory regions developed by staff from BTSA at CEH, NYSDOH.
- PM_{10} regions (N=8) based on spatial and temporal correlation among monitors and limited monitoring frequency.
- Assumption: All residents within one regions have similar exposure.

Ozone regions



PM_{10} regions



Regions chosen for this analysis

- **Ozone**
  - Selected the five regions with highest asthma hospital admission rates in NYS:
    - NYC excluding Staten Island (urban)
    - Upper Adirondacks (rural)
    - Lower Adirondacks (rural)
    - Staten Island (urban)
    - Lower Hudson Valley (suburban)
  - The analyses have not been conducted for other regions yet
- **PM_{10}**: Analyses were applied to all eight PM_{10} regions

Summary Measures of Pollutants

O_3

- Entire year and ozone season (April - October)
  - 24-hour average
  - 8-hour average (10am-6pm)
  - one-hour maximum (24 hours)
  - **one-hour maximum (8 hours: 10am-6pm)**
- Interquantile range (IQR) defined as 75th quartile (Q3) - 25th quartile (Q1): 20 ppb

PM_{10}

- Daily average taken for every 6th day
- Interquantile range (IQR) defined as 75th quartile (Q3) - 25th quartile (Q1): 12.5 ug/m^3

Distribution of Air Pollutants and Meteorological Measures

Variable	Mean	SD	Min value	25th %tile	Median	75th %tile	Max value
O_3 (ppb)	42.5	19.3	0.5	30.0	39.3	52.7	252.3
PM_{10} (µ g/m^3)	19.56	10.92	1.00	12.00	17.04	24.50	90.00
Temperature (ºF)	54.37	16.05	4.71	41.71	54.50	68.92	92.17
Relative humidity(%)	65.37	14.90	10.00	54.87	65.83	77.04	98.75
Station Pressure (inch Hg)	30.02	0.22	29.11	29.87	30.01	30.16	30.80

US EPA National Ambient Air Quality Standards (NAAQS):

O_3 8-hour primary standard: 80 ppb

1-hour primary standard: 120 ppb (No 24-hour standard)

PM_{10} 24-hour primary standard: 150 µg/m^3

Definition of Respiratory Diseases

- ICD-9 codes:
  - 466 Acute bronchitis and bronchiolitis (0-4 years)
  - 490 Bronchitis, not specified as acute or chronic (0-4 years)
  - 491 Chronic bronchitis
  - 492 Emphysema
  - 493 Asthma
  - 496 Chronic Obstructive Pulmonary Disease (COPD)

Respiratory Disease Distribution

Disease	N	%
0-17 yrs old		
Chronic Bronchitis	515	.24
Emphysema	111	.05
Asthma	213,905	99.7
COPD	27	.01
0-4 yrs old		
Acute Bronchitis and Bronchiolitis	85,010	42.55
Bronchitis, not specified	641	.32
Chronic Bronchitis	258	.13
Emphysema	31	.02
Asthma	113,820	56.97
COPD	15	.01

Percent change (95% CI) in daily admissions with an increase of O_3 IQR during O_3 season, *Case-crossover & GAM method*

Area	Lag Day	Sym. Bi-directional % increase (CI)	Time-stratified % increase (CI)	GAM % increase (CI)
Upper Adirondacks	2	**10.04 (1.09, 19.77)**	**9.49 (0.49, 19.28)**	**10.33 (2.37, 18.91)**
	4	**15.88(6.74, 25.80)**	**15.43 (6.09, 25.60)**	**13.98 (5.94, 11.68)**
Lower Adirondacks	2	**14.34 (3.55, 26.24)**	**12.61 (1.77, 24.60)**	8.46 (-0.68, 18.45)
	5	**11.12 (0.80, 22.50)**	7.90 (-2.20, 19.04)	6.64 (-2.26, 16.35)
Staten Island	2	**6.35 (1.46, 11.18)**	**7.38 (0.67, 14.55)**	4.32 (-1.34, 10.00)
NYC	1	**0.72 (0.05, 1.40)**	**0.63 (0.19, 1.08)**	**1.02 (0.12, 1.94)**
Lower Hudson Valley	0	-4.08(-9.18, 1.31)	**-5.72 (-10.87, -0.27)**	-3.45 (-7.79, 1.09)
	4	-5.27(-10.39, 0.15)	**-8.80 (-13.85, -3.45)**	**-6.92(-11.41, -2.21)**

1. Meteorological effects include temperature, relative humidity and barometric pressure were controlled in all models
2. Statistically significant results in bold and red
3. IQR: interquantile range=20ppb, statewide
4. O_3: 1-hr maximum in 8 hrs

Percent change in daily hospital admissions with an increase in PM_{10} IQR, *Case-Crossover & GAM methods*

Region	Lag Day	Symmetric Bi-directional % increase (CI)	Time-stratified % increase (CI)	GAM % increase (CI)
Capital	0	5.33(-3.13, 13.78)	**8.70 (0.08, 17.32)**	**11.63 (4.62, 18.63)**
	2	2.61(-5.45, 10.67)	1.48(-6.81, 9.76)	**10.78 (3.47, 17.81)**
NYC	1	1.35(-0.67, 3.37)	1.75(-0.30, 3.80)	**1.71 (0.01, 3.42)**
	2	**3.34 (1.34, 5.33)**	**3.66 (1.64, 5.68)**	**2.29 (0.60, 3.98)**
	6	-1.88(-3.91, 0.16)	-1.05(-3.13, 1.02)	**-2.50 (-4.22, -0.78)**
Long Island	5	**6.03 (1.30, 10.75)**	**4.91 (0.18, 9.64)**	3.49(-0.60, 7.58)
Hudson	5	**-14.40 (-26.16, -2.64)**	-7.83(-19.95, 4.30)	-7.20(-16.85, 2.45)
Western	0	-4.78(-12.76, 3.21)	-8.04(-16.12, 0.05)	**-7.51 (-14.62, -0.41)**
	3	-2.73(-11.06, 5.61)	-0.68(-9.01, 7.65)	**-7.29 (-14.54, -0.04)**
Adirondack	0	-12.20(-31.68, 7.28)	-13.48(-33.96, 7.01)	**-19.10 (-37.06, -1.14)**

IQR: interquantile range= 12.5 ug/m^{3}, PM_{10}: daily average every 6^{th} day

Discussion

	Pros	Cons
Case-crossover	Control for certain potential time-varying confounders without the necessity of fitting complex smoothing models as in GAM and ARIMA Each individual / population forms its own control thus avoiding improper selection of controls	Case-crossover is particularly useful for estimating acute or transient effects. If cumulative effects exist, it can result in bias
GAM	GAM can model variables non-linearly, which smoothes time-varying confounders more flexible and fit real data better than linear model No problem with cumulative effects as in case-crossover	Result is sensitive to the selection of the degrees of freedom and less resistant to confounding by time trends

Summary: O_3

- The analyses found significant positive associations between O_3 (1-hour maximum in 8 hours) and respiratory hospitalizations in four of the five regions with increased asthma rates (NYC, upper and lower Adirondacks, and Staten Island).

- Depending on the method, a 20 ppb increase in O_3 was associated with higher increases in respiratory admissions in rural areas (9.5% - 12.6% in upper and lower Adirondacks) than in urban areas (0.6% in NYC and 6.4% in Staten Island).

- The most common exposure lag is 2 days prior to the admissions, but also seen at 1, 4 and 5 days. Later effects were found in rural areas only.

- Results from case-crossover and GAM analyses were consistent.

Summary: PM_{10}

- Case-crossover and GAM indicated that a 12.5 ug/m^3 increase in PM_{10} with a 2-day lag was associated with an increase from about 2.3% to 10.8% in respiratory admissions in NYC and in Capital region, but with an 4.9% increase in Long Island with 5-day lag.

- On the other hand, the analyses showed significantly negative associations between PM_{10} concentration and respiratory hospitalizations in Hudson, Western Region and Adirondack area.

Hospital Access and SES Information in Five Target Regions of O_3

Region	Number of Hosp. per 100 Sq. Mi.	Median Household Income	% African American	% Hispanic or Latino
Upper Adirondacks	0.2	33,946	2.69	2.52
Lower Adirondacks	0.1	34,936	4.63	3.26
Staten Island	10.2	55,039	13.51	16.62
NYC	29.6	37,304	33.10	35.15
Lower Hudson Valley	0.4	51,394	8.80	10.86

Public Health Implication

- Determined the most appropriate and best methods to examine the associations between ambient pollutants and health endpoints.
- Provided information to the surveillance team, including study regions, most appropriate exposure indicators, lag periods, and statistical methods.
- Identified high risk and target regions for future surveillance and intervention efforts.
- Identified other confounders, such as SES, meteorological factors, other sources of environmental exposure, and local geographic factors for future investigation and surveillance

Discussion and Next Steps

Associations differ in different regions of NYS – geographic disparity

- Different SES distributions and limited access to hospitals in some regions?
- Misclassification in exposure assessment?
- Other geographic-related confounders (e.g., hospitalization policy or local exposures)?
- Hospitalization is a crude indicator for asthma?

Next steps:

- Investigate potential reasons for the geographic disparity
- Re-examine the associations stratified on demographics and subgroups of diseases
- Cumulative or long-term exposure to air pollutants on respiratory admissions using survival analysis on ICHIS data
- Association between air pollutants (O_3, PM_{10}) and infant mortality