Modelling Effects of Air Pollution on Acute Asthma Outcomes in Chicago

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Project Questions and Objectives

Objective 1:

To model the spatio-temporal behavior of ozone and particulate matter in Chicago

Objective 2:

To develop and apply statistical models to assess the short-term respiratory health effects of daily fluctuations in air pollution in Chicago over four summers in the 1990s.

Environmental health question:

Given the relatively clean urban environment of present-day Chicago, what role does degraded air quality play in the incidence of acute asthma events?

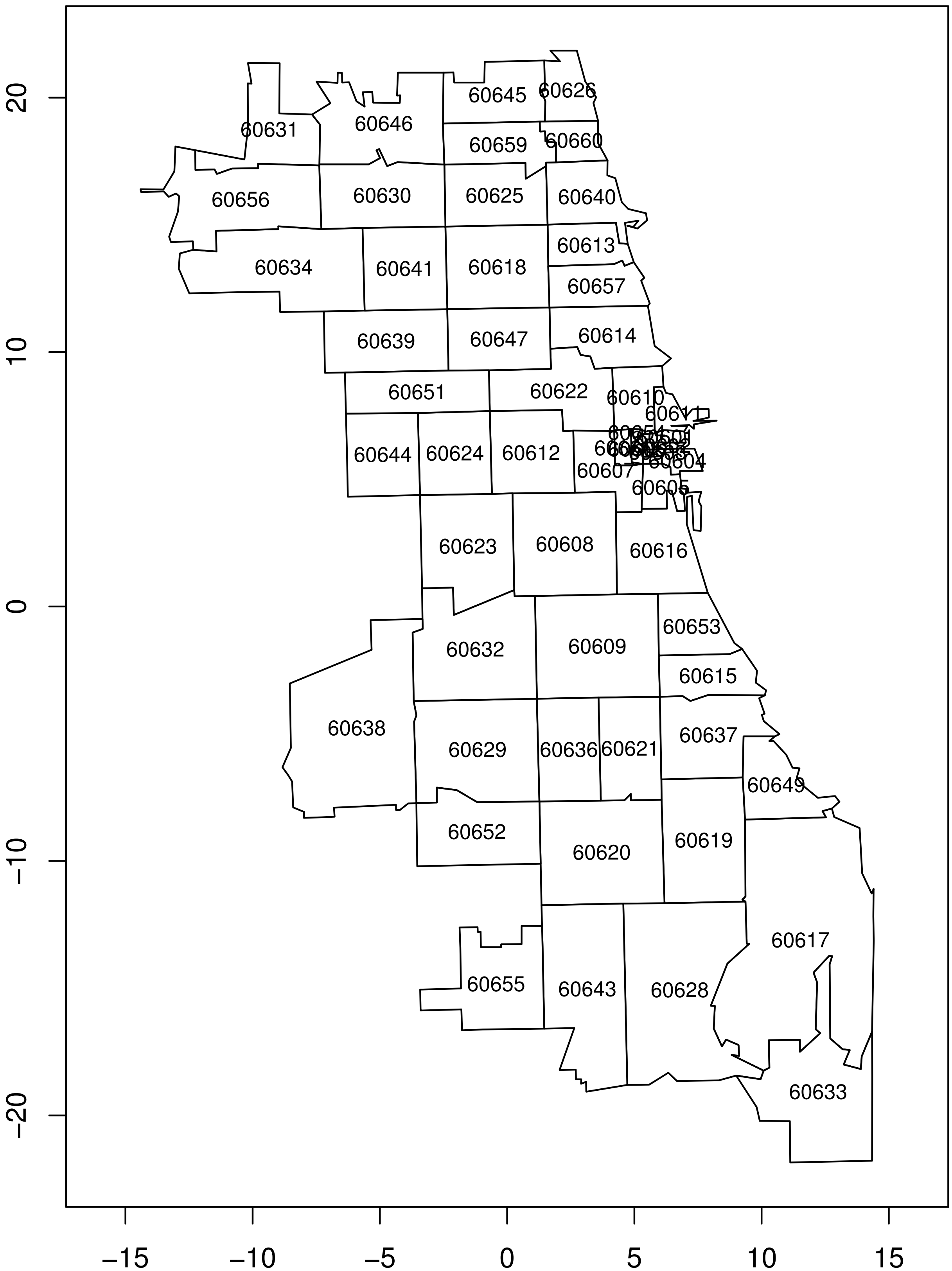
Statistical question:

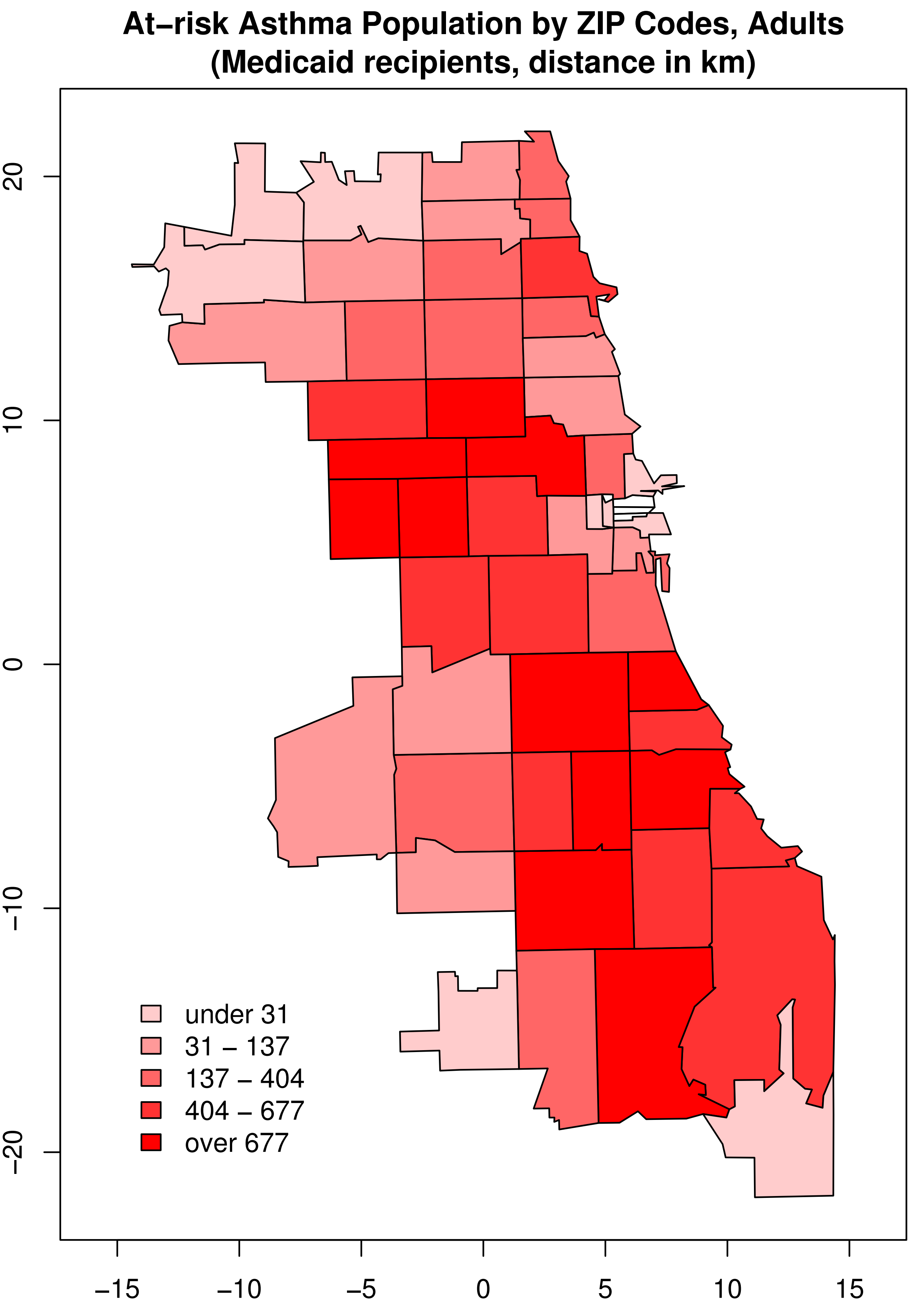
How can one construct models to account adequately for **space-time variability** across the urban area and to exploit **longitudinal data** as they relate to the incidence of asthma?

Chicago Asthma Medicaid Database

- IDPA $200,000$ people on Medicaid in Chicago
- Medicaid (IDPA) claims data
  - "summers" 1995–1998
  - April 1 through October 31
  - Avoids flu season and low ozone season
- "Asthma cohort" $\longleftarrow$ at least one asthma claim during study period
  - About 20,000 adult (15,000 children) asthma patients in our data set
  - Mostly poor, mostly women (adults)
  - Most on Medicaid for full three years
- Event types and dates:
  - Hospitalizations and ED visits
  - Short-term beta-agonists (Albuterol) ($\sim 135,000$ adult; $\sim 58,000$ child events)
- Subject ID, ZIP-code of residence, gender, age

ZIP Code Boundaries




At−risk Asthma Population by ZIP Codes, Adults
(Medicaid recipients, distance in km)
20
10
0
−10
−20
−15
−10
−5
0
5
10
15
under 31
31 – 137
137 – 404
404 – 677
over 677

Chicago Air Pollution Database

- Ozone: 11 monitors
  - Hourly ozone
  - Max-8-hr average ozone
  - Ordinary spatial Kriging assuming isotropy
  - Matérn covariance function
  - Predicted values of ozone (and se) at each ZIP centroid
  - Spatially resolved exposure measure!
- PM10: 18 monitors
  - Observations spaced 6 days apart
  - Monitor and day effect ANOVA model to predict PM10 for any given monitor on any given day
  - Daily average based on the fitted values

Chicago Weather and Pollen Databases

- Weather: Average of O'Hare and Midway:
  - temperature, humidity
  - visibility, wind, precipitation
- Pollen:
  - combined trees, grasses, weeds
  - smoothing used for imputation of missing values

Major Aspects of Project

1. Space-time ozone modeling across urban area
2. **Validation of Beta-agonist as Asthma Outcome**
3. **Mapping asthma outcomes aggregated by ZIP-code**
4. Aggregate data time series analysis of asthma outcomes
5. Spatio-longitudinal analysis of asthma outcomes

Validation of Beta-Agonist (BA) as an Asthma Outcome

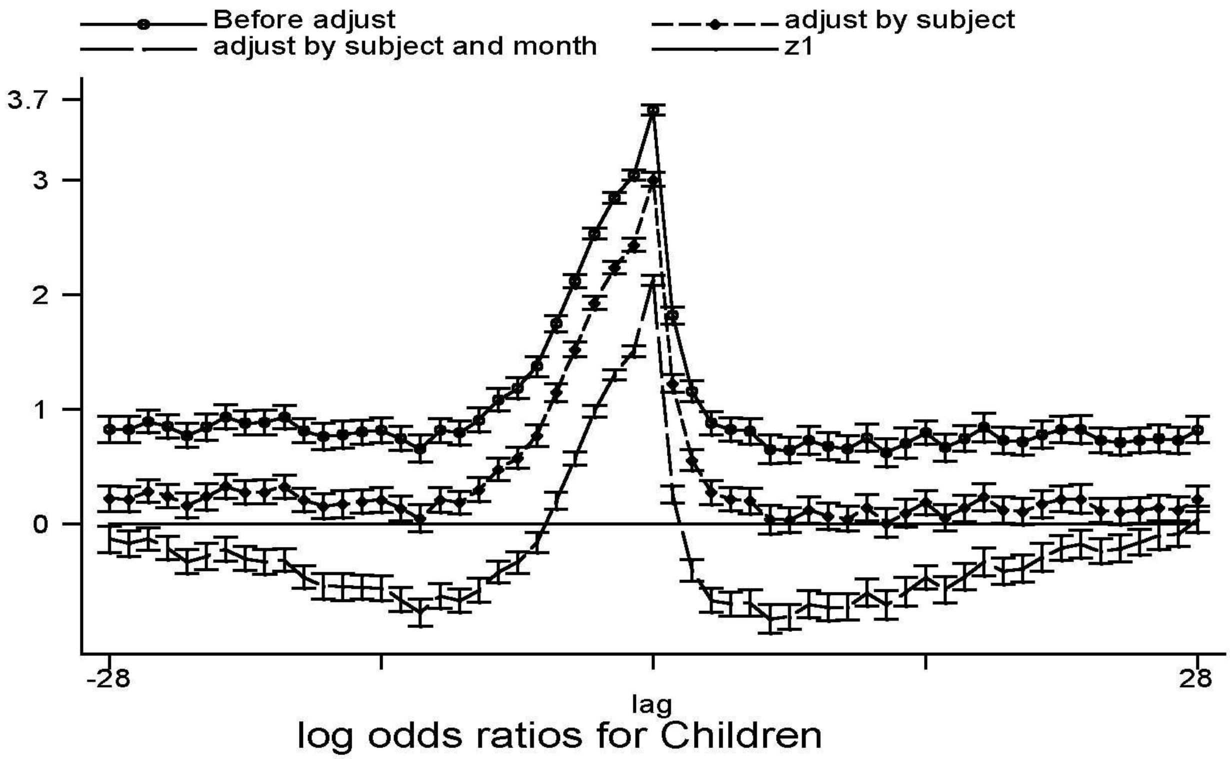
- Why use BA (Albuterol)?
  - often-used non-steroid bronchodilators
  - specific to asthma
  - running prescriptions, quick use
  - large counts

- Q: Is using BA prescriptions as a marker for asthma outcome reasonable?

  $\longrightarrow$ Examine association between BA and hospital admits / ED visits (more traditional outcomes), **lagged** by one or more days

- Odds ratio (OR)
  - crude OR
  - subject-adjusted OR
  - subject- and time-adjusted OR

Association (log OR) between BA and ED/Hospital Admits



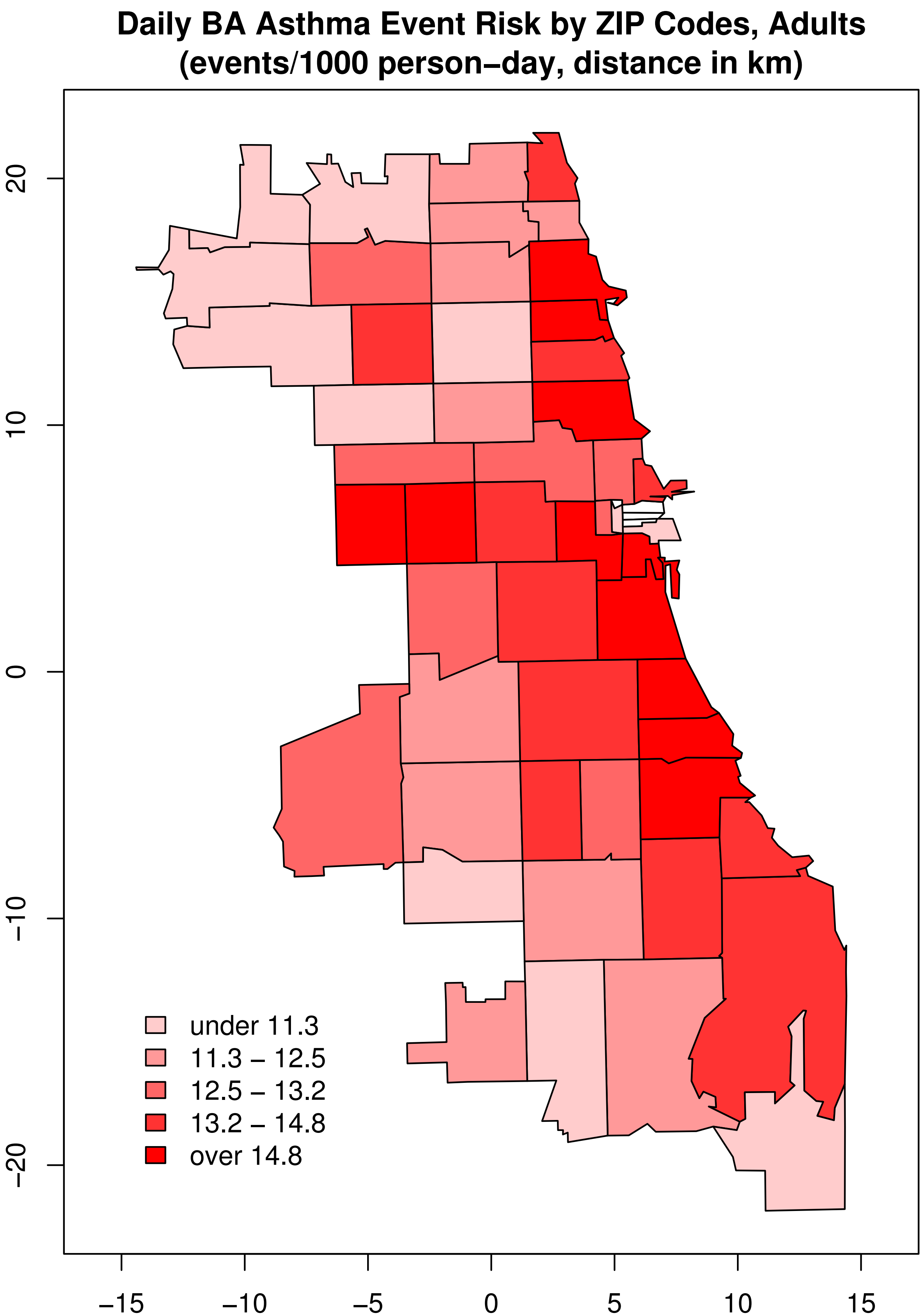
(Note: positive lag = BA before ED)

Problems with crude OR:

...Artifactually high association:

- some subjects in poorer respiratory health
- varying periods of respiratory health, by subject
- does not capture "short-term" association

Mapping asthma outcomes aggregated by ZIP-code



Daily BA Asthma Event Risk by ZIP Codes, Adults
(events/1000 person−day, distance in km)
20
10
0
−10
−20
−15
−10
−5
0
5
10
15
under 11.3
11.3 − 12.5
12.5 − 13.2
13.2 − 14.8
over 14.8

Statistical Problem

Data: observed, **average** (over space and time)
disease risk within ZIP code (**areal unit**)

Target: **predicted** disease risk (given data)
point-by-point

Why model variation in disease risk ?

- description of disease incidence

  . . . spatial interpolation

  $\longrightarrow$ disease risk **mapping**

- place spatial epidemiologic studies in context by displaying background risk

- interpret (variation in) disease risk at **point** versus **area** level

  - smooth variation across areal units
  - account for (differences in) sampling variability across areal units
  - borrow information across units

- understand areal data aggregation

- improve statistical efficiency in spatial regression models

Statistical Approach: Model Risk Aggregation

- $R(x)$ is **log asthma-risk** at location x
- Then . . .

$$Y_i \sim \text{Poisson}\left(\text{person-time} \times e^{\bar{R}_i}\right)$$

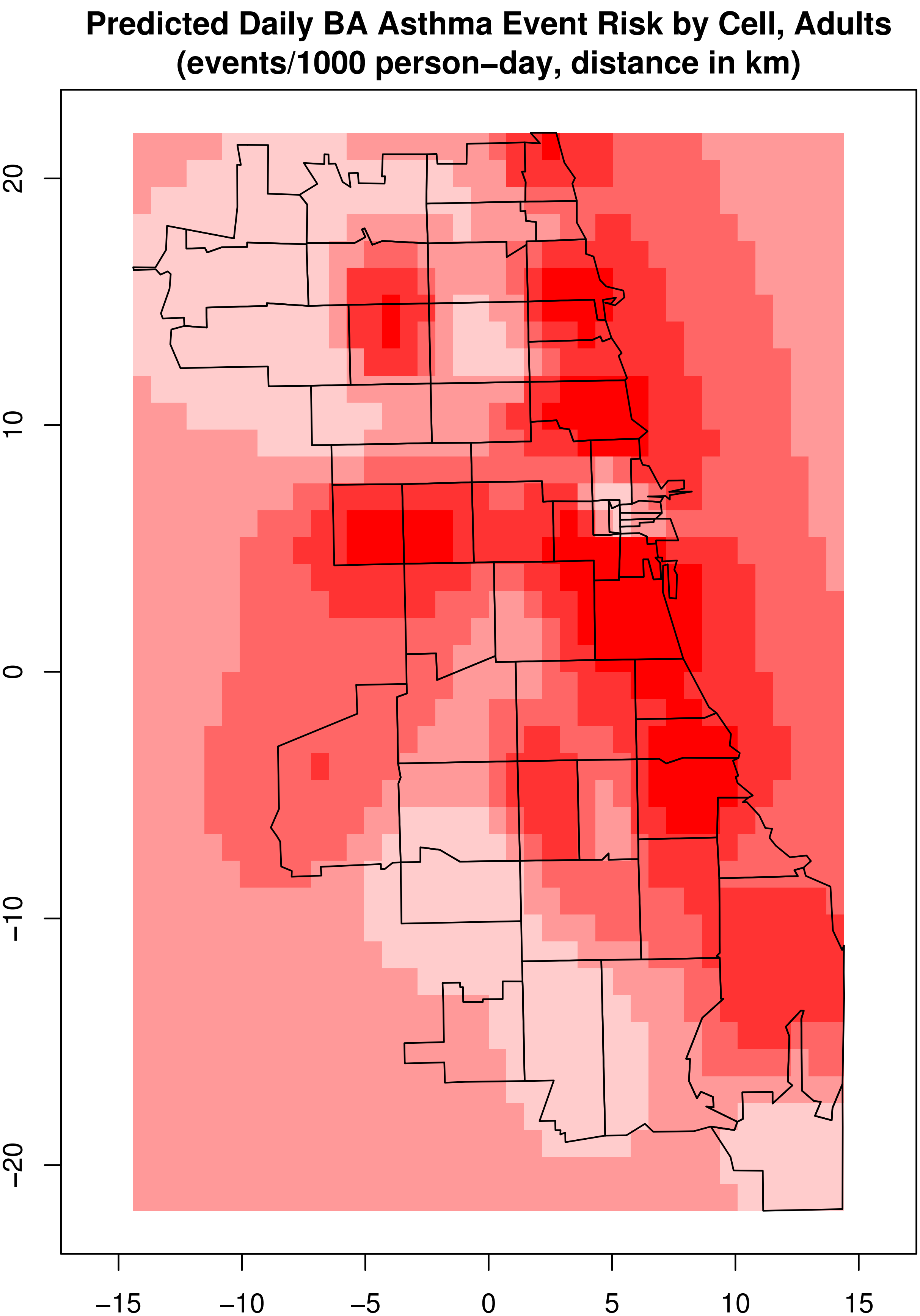
  where $\bar{R}_i = \text{ave}\{R(x)\} =$ **average log-risk** over ZIP i

- Converts **point-scale** problem in $R(\cdot)$ to **area-scale** problem in $\bar{R}_i$
- An estimate of $\bar{R}_i$ is

$$\widehat{\bar{\bar{R}}}_i = \log\left(\frac{\#\ \text{events}}{\text{person-time}}\right),$$

  the observed log risk in ZIP i

- $\widehat{\bar{\bar{R}}}_i$'s are used to **predict** $R(x)$ at every x


Predicted Daily BA Asthma Event Risk by Cell, Adults
(events/1000 person−day, distance in km)
20
10
0
−10
−20
−15
−10
−5
0
5
10
15

Major Aspects of Project

1. **Space-time ozone modeling across urban area**
   - new statistical space-time models
   - exploit physical models such as CMAQ
   - improve air pollution exposure measurement
2. Validation of Beta-agonist as Asthma Outcome
3. Mapping asthma outcomes aggregated by ZIP-code
4. **Aggregate data time series analysis of asthma outcomes**
5. **Spatio-longitudinal analysis of asthma outcomes**

CISES Ozone-Asthma Co-Investigators

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Alexis Zubrow (CISES, Programmer/Analyst)

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Longitudinal Analysis of Asthma Outcomes

Data:

$Y_{ijt} = I($event, person j, ZIP i, day $t)$

$i =$ ZIP; $j =$ person in ZIP; $t =$day

$x_{ij} =$ (**unobserved**) location

Hazard model:

$$\Pr(Y_{ijt} = 1) = e^{R(x_{ij})+S_{ijk}+\beta' z_{ijt}}$$

where:

- $R(x)$ is baseline **log-asthma risk** at x
- $S_{ijk} =$ all unobserved factors for person (i, j) in time "window" k
- $z_{ijt} =$ covariates for person (i, j), day t

Confounding control and efficiency:

- $\widehat{\beta}$ adjusted for spatially and within-person slowly-varying factors
- $\widehat{\beta}$ has improved statistical efficiency

Model fit: Conditional logistic regression

Longitudinal Data Analysis
Preliminary Model Fit
Adults

Odds ratios for Risk of BA Prescription Fill

Conditional Logit Model

	Odds ratio	St. Err.	Z
ozone (20ppb)	1.005	.007	0.81
pm10 (15mg/m3)	.999	.004	-0.22
log(pollen) (std)	1.009	.004	2.11
temp (5F)	.984	.003	-5.20
rel hum (10%)	.997	.003	-0.95

Average Odds Ratios across 51 ZIP Codes

	Odds ratio	St. Err.	Z
ozone (20ppb)	1.032	.022	1.47