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Improving Understanding of Stress Exposure in Minority Communities with Asthma: Using Geographic Information Systems (GIS) Data Collection Methods

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EDM Forum: Improving Understanding of Stress Exposure in Minority Communities with Asthma: Using Geographic Information Systems (GIS) Data Collection Methods

Faculty: Jeffrey Blossom, M.A., CGA at Harvard University (moderator); Elliot Israel, M.D., Harvard Medical School; Brigham and Women's Hospital; and Francine Laden, Sc.D., Brigham and Women’s Hospital

Tuesday, October 21, 2014
Welcome

Beth Johnson, M.P.H.
- Senior Manager, Research and Education in HSR
- Project Manager, Electronic Data Methods (EDM) Forum
- Managing Editor, eGEMs

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Today’s Moderator

➔ Jeffrey Blossom, M.A.
  – Senior GIS Specialist, The Center for Geographic Analysis (CGA) at Harvard University
  – PESBART Steering Committee
Learning Objectives

At the conclusion of the session, participants will be able to:

→ Learn the basic principles of geographic information systems (GIS), including:
  – Geocoding
  – Variable collection methodologies
  – Mapping and analysis
→ Review the application of GIS in environmental epidemiology
→ Understand the challenges and limitations of utilizing and interpreting GIS data in health outcomes research
Poll Question: What is Your Experience with GIS?

- Never heard of it
- Heard of it, but don’t know what it is
- Know what it is
- Know what it is, and have used it before
- Use it regularly
Today’s Faculty

Elliot Israel, M.D.

Francine Laden, Sc.D.
Improving Understanding of Stress Exposures in Minority Communities with Asthma: Using Geographic Information (GIS) Data Collection Methods

October 21, 2014
EDM Forum Webinar
GOALS

• Understand GIS Capabilities

• Understand GIS Applications in Environmental Epidemiology Research

• Understand Potential Challenges and Limitations
AGENDA - Elliot Israel, MD

• Background: BELT and PESBART studies
• Basics of geographic information systems (GIS) and its application in environmental epidemiology
• Review PESBART as a case study of using GIS to enhance the utility of study data to understand the influence of environmental factors such as:
  • Pollution
  • Stress
  • Socioeconomic Factors
  • Access to goods and services, including care
  • Climate
  • Allergens

on baseline and outcome data in large studies
Background – The BELT Study

- The US Black population bears a disproportionate burden of asthma.

- We conducted an AHRQ-sponsored study (BELT) in which we compared two asthma treatment medications in over 1000 Black patients. We followed these patients’ asthma control for a year and collected genetic samples.

- Stressors such as exposure to environmental pollution, crime, and poverty have been associated with worse asthma morbidity in patients with asthma.

- Information related to these factors were not collected in the original data set.

- Geographic information system (GIS) data can allow post-hoc evaluation of these factors.
BELT – Sites

• Real-World Study
• 20 Sites
  ❖ Urban and rural
  ❖ 9 academic; Rest mix of health clinics, private practices
**BELT Study Structure**

**Figure 1. BELT Study Diagram**

**BELT Entry Criteria**
- Physician diagnosis of asthma
- Self-identified Black
- Smoke < 10 pack years
- Already on LABA/ICS or ICS alone with ACQ ≥ 1.25

**Visit 1**
- Consent & History
- ACQ, SFD
- AQLQ, ASUI
- Baseline spirometry
- Saliva for genotyping
- Randomize: TIO/ICS or LABA/ICS

**Visit 2**
- Spirometry
- ACQ, SFD
- AQLQ, ASUI
- AE/SAE Review
- Medication Review

**Visit 3**
- Spirometry
- ACQ, SFD
- AQLQ, ASUI
- AE/SAE Review
- Medication Review

**Visit 4**
- Spirometry
- ACQ, SFD
- AQLQ, ASUI
- AE/SAE Review
- Medication Review

**Visit 5**
- Spirometry
- ACQ, SFD
- AQLQ, ASUI
- AE/SAE Review
- Medication Review

**Month**
- 0
- 1
- 2
- 3
- 4
- 5
- 6
- 7
- 8
- 9
- 10
- 11
- 12*
- 13
- 14
- 15
- 16
- 17
- Up to 18*

**Visit 2**
- Months 2-5, 7-11, 13-17: ACQ, SFD, Asthma Exacerbation Questionnaire completed monthly in between study visits

*For those who enrolled in time for these visits (see Methods).

Abbreviations: ACQ, Asthma Control Questionnaire; AE, adverse event; AQLQ, Asthma Quality-of-Life Questionnaire; ASUI, Asthma Symptoms Utility Index; ICS, inhaled corticosteroids; LABA, long-acting beta-agonists; Max Rev Reversibility with 4 puffs of albuterol SAE, serious adverse event; SFD, Symptom Free Day Questionnaire; TIO, tiotropium.
BELT – Specific Aims

1. To determine, in a practice-based, real-world, randomized, prospective, comparative effectiveness trial, whether in self-identified Black patients with asthma, treatment with LABA/ICS is superior to use of a non-β-adrenergic bronchodilator (tiotropium) combined with ICS (TIO/ICS).

2. To conduct genetic analyses to determine whether, in the 20% of self-identified Black patients with asthma bearing Arg16Arg of ADRB2, treatment with LABA/ICS is superior to use of a non-β-adrenergic bronchodilator (tiotropium) combined with ICS.
BELT - Outcomes

**Primary Outcome:**
- Time to asthma exacerbation, defined as an event of worsening asthma requiring corticosteroids

**Secondary Outcomes:**
- Patient-reported Outcomes (AQoL, ACQ, ASUI, SFD)
- Spirometry (FEV1)
- Rescue Medication Use
- Time to asthma deterioration, defined as an event of worsening of asthma that did not require corticosteroids

**Data Collected (at Baseline, 1m, 6m, 12m and some out to 18m):**
- Saliva Sample (Baseline visit only)
- Lung function via spirometry (All study visits)
- Adverse events, concomitant medications (All study visits)
- Asthma quality of life and asthma symptom measures via AQoL, ACQ, ASUI, SFD (All study visits and monthly)
- Medication adherence (Periodically throughout the study)
PESBART – Effects of Physical Environment and Stress in Black subjects in relation to Asthma severity and Response to Therapy

Study Aims:

1. To leverage the outcome and genetic data collected in the BELT study by collecting geographic information system (GIS) data from BELT subject addresses

2. To enhance the sustainability and relevance of the dataset by involving teams of stakeholders
PESBART Steering Committee

Elliot Israel MD, Principal Investigator; Professor of Medicine at Harvard Medical School; Physician-Investigator, Pulmonary & Critical Care Medicine at Brigham and Women’s hospital; Research focus: Asthma and Asthma Pharmacogenetics

Francine Laden ScD, Co-Investigator; Associate Professor of Medicine at the Channing Division of Network Medicine, Harvard Medical School; Research focus: Environmental Epidemiology, Environmental modeling

Barbara Yawn MD MSc, Co-Investigator; Director of Research at the Olmsted Medical Center in Minneapolis, MN; Research focus: Primary and Respiratory Care; Co-Investigator of BELT study and responsible for secure BELT address transfer for geocoding

Benjamin Raby MD MPH, Co-Investigator; Associate Professor of Medicine at Channing Division of Network Medicine, Harvard Medical School; Research focus: Genetic Epidemiology, Pulmonology and Pharmacogenetics

Jeffrey Blossom MA; Senior GIS Specialist at the Center for Geographic Analysis at Harvard University

Jane Lanzillotti, MS; Senior Project Manager at Harvard Clinical Research Institute the Data Coordinating Center for PESBART
PESBART Stakeholder Team

Gary Adamkiewicz PhD; Senior Research Scientist at the Harvard School of Public Health; Advisor to World Health Organization and EPA Scientific Advisory Board on Environmental Justice; Research focus: Indoor air quality and Environmental Justice

Sebastien Haneuse PhD; Associate Professor of Biostatistics, Harvard School of Public Health; Research focus: Design and analysis of observational and epidemiological studies, Biased sampling schemes, Bayesian modeling

Laura Kubzansky PhD, MPH; Professor of Social and Behavioral Sciences, Harvard School of Public Health; Research focus: Psychosocial Epidemiology (social stress and its impact on chronic disease)

Jacqueline Rodriguez-Louis MEd MPH: Program Coordinator, Partners Asthma Center at Brigham & Women’s hospital; Lead asthma instructor at the Community Health Education Center in Boston; Focus: Patient Advocacy

Laurita Kaigler-Crawlle MS; Project Director Massachusetts Asthma Action Partnership (MAAP); Focus: Patient Advocacy
PESBART Stakeholder Team

Michael Wechsler MD; Professor of Medicine and Director of Pulmonary & Critical Care Medicine at National Jewish Health in Denver, CO; Co-Investigator of BELT study; Research focus: Clinical Decision Making, Phenotyping

Anne Fuhlbrigge MD; Assistant Professor of Medicine at Harvard Medical School, Co-Chair of the Asthma Exacerbation Subcommittee at the NHLBI/AHRQ Asthma Outcomes Workshop; Co-Investigator of BELT study; Research focus: Asthma Outcomes

Wilson Pace MD; Professor of Family Medicine at University of Colorado School of Medicine; Director of the American Academy of Family Physicians National Research Network; Co-Investigator of BELT study; Research focus: Practice-based Research Methodology, Clinical Decision Making

Rosalind Wright MD, MPH; Professor and Vice Chair of the Clinical & Translational Research Department at Mount Sinai School of Medicine; Research focus: Developmental Epidemiology, Asthma Disparities, Environmental and Stress Exposures
PESBART Stakeholder Tasks

• Formulate research questions of interest using GIS and BELT outcome data

• Review categories and listings of available GIS variables

• Select GIS variables to help answer these questions

• Select BELT outcome needed to answer these questions
Overview: How Do We Use GIS?

We cross-reference someone’s location with information about that location to allow us to understand their environment

• Pollution
  ▪ Measuring stations
  ▪ Distance to nearest road
  ▪ Types of factories and pollution controls

• Psychosocial
  ▪ Stress related to social factors such as crime, condition of housing, poverty, etc.

• Access to resources
  ▪ Medical care
  ▪ Green spaces
  ▪ Fresh fruit
Harvard Center for Geographic Analysis (CGA)
Jeff Blossom MA

- What is GIS?
- Geocoding the BELT dataset
- PESBART Variable collection methodologies
- Analysis and mapping
What is GIS?

Geographic Information System (GIS) defined:

A collection of computer hardware and software designed for capturing, storing, updating, manipulating, analyzing, displaying, and publishing all forms of geographically referenced information.

- People performing different roles are required.
- Common methodologies are applied within a GIS.
What is GIS?

Geographic Coordinate System – a common reference used to map things on Earth.

- Use lines of longitude and latitude.

42.3744,-71.1166 is the latitude, longitude location of Harvard Yard

- Any location on Earth can be represented by the intersection of a longitude, latitude line.
What is GIS?
Geographic Information Systems (GIS)

Geographic feature representation: **points, lines, polygons**

- **Points** – U.S. City centers
- **Lines** – U.S. Interstates
- **Polygons** – U.S. States
Geographic **Information** Systems (GIS)

Information about the geographic features – stored in tabular form

**Points – U.S. Cities**
Geographic **Information** Systems (GIS)

Information about the geographic features – stored in tabular form

**Lines – U.S. Interstates**
Geographic **Information** Systems (GIS)

Information about the geographic features – stored in tabular form

Polygons – U.S. States
Geographic Information System (GIS)

- Hardware
- Software
- Data
- Methodology
- People
- Management

A common set of tools and procedures

A well managed system of information

Data Files

Database
Geocoding:

The process of assigning geographic coordinates to descriptive information.

- Most commonly used with addresses.

For example: “1737 Cambridge St., Cambridge, MA” is geocoded to the latitude, longitude coordinates of 42.3756, -71.1132

Results from geocoding are used for:

- Map production
- Analysis within a GIS
- Route finding, navigation
- Communicating WHERE things are
Geocoding BELT addresses

- All 1,075 address locations were geocoded using ArcGIS 10.2 software
- A sample was verified in Google Maps and Bing Maps
- The result: precise geographic locations for each BELT subject
- Collection of social and environmental variables based on these locations is now possible.
Variable collection methods

- **Proximity** – How close each address is to the nearest pharmacy, emergency room, grocery store, bus stop, etc.

- **Density** – How many pharmacies, grocery stores, etc., are within a certain distance from each address.
Variable collection methods

- Overlay – Using data published at different geographic areas, and determining which area each address is in.
- U.S. Census block group and tracts
- Municipal areas
Mapping and analysis

Used prescription drug for asthma, per block group, per 1,000 people

Source: ESRI Business Analyst Demographics, 2013
Environmental Epidemiology and GIS
Francine Laden ScD

- What is Environmental Epidemiology?
- Examples using GIS
- Research questions in PESBART
John Snow: “The First Epidemiologist”

Map of Residences of Cholera Cases
Environmental Epidemiology

The branch of epidemiology concerned with the discovery of the environmental exposures that contribute to or protect against adverse health outcomes and the identification of public health and health care actions to manage the risks associated with harmful exposures.

Prepared by the International Society of Environmental Epidemiology
http://en.wikipedia.org/wiki/Environmental_epidemiology
Environmental Exposures:

- External factors –
  - Naturally occurring
  - Introduced by human activities
- Involuntary
- Proximate - (e.g. directly leading to a health condition)
  - Chemicals, physical agents and microbiological pathogens
- Distal
  - Social conditions, climate change
Vulnerability and Susceptibility

- Developmental state
- Pre-existing medical conditions
- Acquired and genetic factors
- Socioeconomic factors
How is GIS used in Environmental Epidemiology

• Exposure estimation
  • E.g. air pollution, traffic exposure, UV light, noise

• Definition of populations

• Surveillance of disease
Example: Air pollution and Adverse Health Outcomes

- Air pollution exposure has been associated with a multitude of health outcomes, e.g.
  - Cardiovascular disease
  - Asthma
  - Lung cancer
  - Birth outcomes

- GIS has been used to obtain estimates of exposure in time and space at the individual level
Figure 1 1999–2007 PM$_{2.5}$, 1988–1998 PM$_{2.5}$, and PM$_{10}$ monitor locations, as well as regions of the conterminous U.S.
Predicted PM2.5 Concentrations

Figure 2 Means of monthly predicted PM$_{2.5}$ concentrations on a 6 km grid over the conterminous U.S. (5$^{th}$ to 95$^{th}$ percentiles shown) for A) 1999–2007 and B) 1988–1998.
Example: Green Space in Barcelona, Spain

NDVI. Source: Landsat 5 TM data, NASA.

Major green spaces. Source: Ecologic Map

Amoly et al. EHP epub ahead of print
Beneficial associations between behavioral indicators and longer time spent in green space and beaches and residential surrounding greenness.
Example: Obesogenic Neighborhood Features and Adolescent Weight

Figure 1. Map of Minneapolis/St. Paul MN with residences of EAT 2010 participants

Note: Residences of participants are indicated by points (randomly perturbed for privacy) and colored according to the six obesogenic neighborhood environmental clusters identified by spatial latent class analysis (see Table 5 for description of clusters).
PESBART Stakeholder Tasks

• Formulate research questions of interest using GIS and BELT outcome data

• Review categories and listings of available GIS variables

• Select GIS variables to help answer these questions

• Select BELT outcome needed to answer these questions
Stakeholder Research Questions

Excerpted from Stakeholder’s lists of questions:

• Did subjects with household incomes lower than their state’s poverty level experience more asthma exacerbations than subjects with household incomes higher than their state poverty level?

• How does access to health care (i.e. a clinic, hospital, pharmacy) impact the number and/or severity of asthma exacerbations or quality of life?

• Did BELT subjects living in areas of high social stress (unemployed, on food stamps, crowded housing conditions, etc.) experience worse lung function than BELT subjects living in low social stress areas?

• Did exposure to specific environmental pollutants correlate to worse quality of life or asthma symptom measures?
Stakeholder Research Questions

Excerpted from Stakeholder’s lists of questions, continued:

• How do community level stressors - for example neighborhood crime - impact asthma exacerbations and health care utilization (HCU)?

• Did BELT subjects living in climates with extreme weather conditions (excessively hot, humid, etc.) or high pollen counts experience more asthma exacerbations than BELT subjects living in places with temperate climates or low pollen counts?

• Are quality of life or asthma symptom measures worse during time periods which reflect likely dominance of indoor exposures (for example areas where temperatures are below 60°F might reflect days when windows are closed)?
Summary of GIS Variables of Interest by Stakeholders

- **Climate** (temperature, season)
- **Socioeconomic status/neighborhood stress**
  - Poverty
  - Density of poor housing conditions
  - Disadvantage index
  - Crime
  - Unemployment
- **Pollution**
  - Distance to traffic
  - Distance to emitters
  - Monitored levels of air pollution
Summary of BELT Outcomes of Interest by Stakeholders

• Asthma control and severity
• Exacerbations
• Deteriorations
• Lung function
• Symptoms
### Stakeholder-requested GIS variables collected

<table>
<thead>
<tr>
<th><strong>Air Quality</strong></th>
<th><strong>Community Amenity Access</strong></th>
<th><strong>Crime and Chronic Stress</strong></th>
<th><strong>Consumer Spending</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance to major road</td>
<td>Distance to and densities of: Pharmacies, hospitals, subway stations, bike paths, libraries, supermarkets, athletic centers, day care centers.</td>
<td>Alcohol consumption, homicides, rapes, robberies, assaults, thefts, auto thefts.</td>
<td>Prescription drugs for asthma, Vitamin D supplements, total medical expenditures, groceries, fitness, pet products, vet visits.</td>
</tr>
<tr>
<td>Mileage of major roads nearby</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pollen severity, AQI, Ozone, SO2, CO, NO2, PM$_{2.5}$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distance to nearest factory, factories nearby</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Demographic</strong></th>
<th><strong>Economic</strong></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Educational attainment, race, age, rural/urban, household size, tenure, multiple family and single parent households.</td>
<td>Unemployment, poverty, income inequality, median household income, community economic growth or decline, food stamps, delayed rent or mortgage payments.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Challenges – Protecting Patient Confidentiality

- GIS locations are considered identifiable information
- Depending upon the scale (block group, street level, etc.), you could discover where an individual person lives
- Have to be very careful to strip all identifiers (patient names, phone numbers, addresses) from geocoded information
- If you don’t have patient consent, should limit maps to block group or higher level
  - For example, if rural address may need county level
Challenges – Unavailability of All GIS data requested by the Stakeholders

Review of GIS variables requested but **not** collected

<table>
<thead>
<tr>
<th>Air Quality</th>
<th>Community Amenity Access</th>
</tr>
</thead>
<tbody>
<tr>
<td>Idling laws, busses with emissions controls, number of stoplights, traffic counts, advocacy to improve air quality.</td>
<td>Public health programs, outreach programs, subsidized public transportation, MD’s per capita, mixed use development, zoning regulations.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Crime and Chronic Stress</th>
<th>Consumer Spending</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abandoned or foreclosed homes, domestic abuse, calls to 911, protection orders, litter, graffiti, vandalized buildings, neighborhood disorder, divorce rate, deaths, ambulance data, domestic abuse, criminal victimization</td>
<td>Non-prescription drugs for asthma, Primateen mist, Metanephryn, taking medicine or receiving treatment for mental health or emotional problems.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Housing conditions</th>
<th>Social</th>
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<tbody>
<tr>
<td>Mold, dust mites, rodent, roach, and bed bug infestations and exposers.</td>
<td>General Social Survey, Gallup Well-Being Index, psychosocial measures, Behavioral Risk Factor Surveillance System survey.</td>
</tr>
</tbody>
</table>
Challenges

- Uneven distribution of some of the data (crime, weather, etc.) across geographically diverse patient populations
Air Quality Index (AQI) coverage

- 2013 AQI Stations
- BELT Locations
Distance to nearest 2013 AQI station

Miles

BELT subjects (1,075)

Min: 0.1
Max: 50.9
Mean: 6.6
Std. Dev.: 8.1
BELT subjects (1,075)

Days with AQI data at nearest station, 2013

Min 171
Max 365
Mean 321.7
Std. Dev. 59.2
2013 PM_2.5 Stations

BELT Locations

PM_2.5 coverage

- 2013 PM_2.5 Stations
- BELT Locations

55
Distance to nearest 2013 PM$_{2.5}$ station

- Min: 0.1 miles
- Max: 73.6 miles
- Mean: 8.6 miles
- Std. Dev.: 11.7 miles

BELT subjects (1,075)
Days with PM\_2.5 data at nearest station, 2013

- Min: 5.0
- Max: 365.0
- Mean: 250.2
- Std. Dev.: 116.3

BELT subjects (1,075)
Challenges – PESBART Case Study

We took one of the Stakeholder questions to see what we could find:

• Are quality of life or asthma symptom measures worse during time periods which reflect likely dominance of indoor exposures (for example areas where temperatures are below 60°F might reflect days when windows are closed)?
Analysis of First Stakeholder Research Question

- **Intent of Question:** To arrive at an indirect measure of indoor air quality (no indoor GIS data available): when temperatures are very hot or cold, windows are more likely to be closed, thus potentially increasing exposures to indoor pollutants

- **Details needed:**
  - The specific BELT quality of life or asthma symptom measures (examples include asthma questionnaire scores, lung function scores, adverse events). We chose scores of the Asthma Symptom Utility Index to start.
  - What temperature cut-offs should be used for excessive heat or cold? Gary provided 64°F and 85°F, with interest in the mean daily temps above and below 64°F to capture air exchange, window opening and home heating.
BELT Questionnaire Data Excerpt

ASU1: How many days were you bothered by coughing in the past two weeks?
ASU2: On average, how severe was your coughing in the past two weeks?
ASU3: How many days were you bothered by wheezing in the past two weeks?

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<tr>
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<th>ASU2</th>
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<td>1/1/2011</td>
<td>1 - 3 days</td>
<td>Mild</td>
<td>4 - 7 days</td>
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<td>7/6/2012</td>
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<td>.</td>
<td>Not at all</td>
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<tr>
<td>1/20/2012</td>
<td>1 - 3 days</td>
<td>Mild</td>
<td>1 - 3 days</td>
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<tr>
<td>1/11/2013</td>
<td>Not at all</td>
<td>Mild</td>
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PESBART Climate Data Excerpt

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Using GIS data - Caveat

• Does the group data represent the individual?
  ▪ Berkson error – measure part of the true exposure
  ▪ For example, if you use a central site monitor it is on average right for the general population but not necessarily for the individual

• Is geographic location correctly defining exposures?
  ▪ Classical error – measure the true exposure plus noise
  ▪ For example, if the monitor isn’t calibrated properly it could measure high for everybody

• False addresses
THANKS!

Feel free to contact us:

For GIS-related questions:
  • Jeff Blossom, Center for Geographic Analysis
    jblossom@cga.harvard.edu

For BELT or PESBART-related questions:
  • Jane Lanzillotti, Harvard Clinical Research Institute
    jlanzillotti@hcri.harvard.edu

For environmental epidemiology questions:
  • Francine Laden, Channing Lab, Harvard School of Public Health
    nhfrl@channing.harvard.edu
Poll Question: How interested are you to use GIS data in your research?

- Very interested
- Somewhat interested
- Not at all interested
Submitting Questions

To submit a question:

1. Click in the Q&A box on the left side of your screen
2. Type your question into the dialog box and click the Send button
Thank You

Please take a moment to fill out the brief evaluation which will appear in your browser.