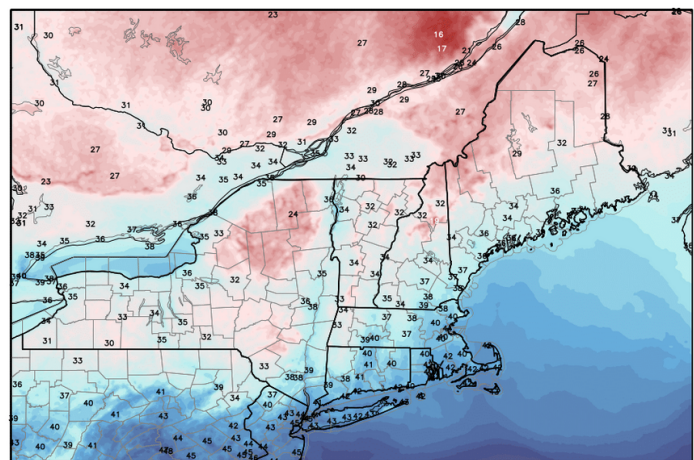
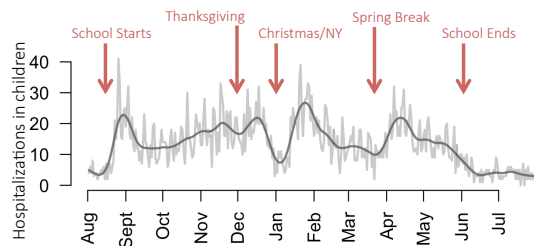
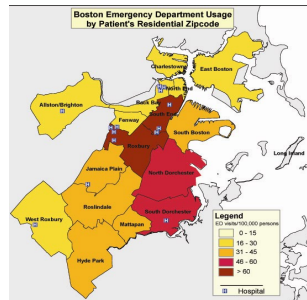


# Analytic Solutions for Real-Time Biosurveillance

## Models for Risk of Asthma Exacerbations in Urban Environments

CDRL – A007.3  
HDTRA1-15-C-0004  
Consultancy Report



# **Analytic Solutions for Real-Time Biosurveillance: Models for Risk of Asthma Exacerbations in Urban Environments Consultancy Report**

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## I. Acknowledgements

ISDS is extremely grateful to the Boston Public Health Commission (BPHC) for spearheading the development of the use case and for providing the event venue. We thank all the participants for contributing their tremendous subject matter expertise to the discussion. This work supported by contract # HDTRA1-15-C-0004 to ISDS from the Defense Threat Reduction Agency (DTRA). Opinions expressed do not necessarily reflect the views of DTRA, BPHC, or the ISDS Membership.

### Models for Risk of Asthma Exacerbations in Urban Environments: Consultancy Participants

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## II. ISDS and Analytic Solutions for Real-Time Biosurveillance

The International Society for Disease Surveillance (ISDS) is a 501©(3) organization with a mission to advance the science and practice of health surveillance worldwide. In health surveillance we include the overlapping fields of public health surveillance, animal health surveillance, zoonotic disease surveillance, and surveillance of the environment to monitor health threats and provide situational awareness. ISDS advances its mission through a broad portfolio of activities involving multi-stakeholder collaborations to provide capacity-building assistance to members and the surveillance community worldwide; actively shape national and international health surveillance policy; and expand our global surveillance Community of Practice (CoP).

ISDS fills the need for a practical forum and coordinating mechanism for collaboration among subject matter experts (SMEs) from stakeholder groups that may normally not interact but who, when brought together, enable innovative approaches to problems and solutions that are not possible by any one group alone. The objective of the *Analytic Solutions for Real-Time Biosurveillance* project is to advance analytic capabilities in real-time biosurveillance (BSV) by expediting next-generation solutions to currently intractable problems through focused consultancies that join end-user problem owners from civilian and military public health agencies with solution developers in academia, industry, and government. This approach helps to clarify key gaps in surveillance capabilities and to develop the requirements for knowledge management, algorithms, models, visualizations, and other solutions to address these gaps. For more information about this project, see: <http://www.syndromic.org/cop/analytic-solutions/isds-consultancies>

### III. The Boston Use Case

Julia Gunn and Margaret Reid from the Boston Public Health Commission (<http://www.bphc.org/>) co-submitted a use-case to ISDS for consideration as a consultancy (Appendix A). The ISDS Analytic Solutions Advisory Group (ASAG), consisting of SMEs in surveillance practice, research, and policy reviewed the case and found the problem well suited for a consultancy format. Drs. Howard Burkom and Ian Painter providing expertise on technical matters and SMEs. ISDS provided overall project management and event coordination.

#### Problem Description

Asthma exacerbation can be triggered by a number of environmental factors and respiratory viral infections. Asthma control plans are essential in preventing exacerbation. An early warning of increased atmospheric/environmental risk would enable public health agencies to alert asthmatic patients and providers. These alerts would also include prevention messaging and allow asthmatics to ensure that their plans are up to date. BPHC seeks analytic methods for forecasting conditions that are associated with asthma exacerbations. The forecast should consider the impact of respiratory infections (rhinovirus, influenza), temperature extremes, anomalous air quality measurements, and pollen. Available data sources are emergency department visit records, weather data, air quality data, and pollen counts.

Regarding the type of solution sought, the prediction calculations and alerting communications must be available at a minimum on a daily basis without impacting other routine processing operations. The stratification of predictions by geography and by demographic factors should be as fine as the data will support. Electronic near real time data feeds are required. The analytical processes must be automated. The model and system needs to support continuous model training.

### IV. Agenda

In light of the problem description and the preliminary solution requirements, the goals of this consultancy were to:

1. Identify a practical model to forecast environmental conditions that are likely to result in asthma exacerbations;
2. Define systems requirements to automate the processing notifications of issues (environmental and technical).
3. Communicate environmental conditions and actions to a variety of stakeholders at different levels of the socio-ecological model.

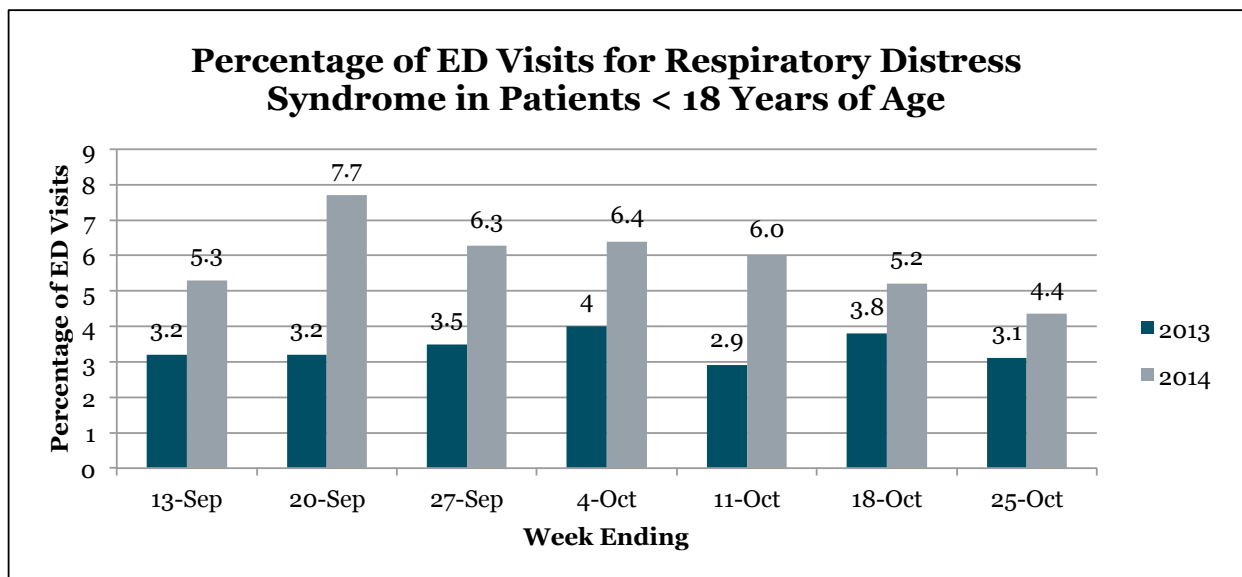
### Socio-Ecological Model



For meeting notes and presentation slides, see Appendices B – L.

<b>Consultancy Day 1: March 30, 2016</b>	
9:00	<b>Meet and Greet with Continental Breakfast</b>
10:00	<b>Welcome to the BPHC</b> <i>Monica Valdes Lupi, Executive Director, BPHC</i>
10:15	<b>Welcome to the Consultancy – Introductions</b> <i>Laura Streichert, ISDS</i>
10:45	<b>Use Case Goals and Requirements</b> <i>Julia Gunn, BPHC</i>
11:00	<b>The Asthma Problem in Boston</b> <i>Margaret Reid, Director, Division of Healthy Homes and Community Supports, BPHC</i> <ul style="list-style-type: none"> <li>• What is the BPHC program?</li> <li>• What are the factors that make asthma worse and may cause asthma?</li> <li>• If we could anticipate events, what would we like to know?</li> <li>• How would we use this information?</li> </ul> <i>Moderated Group Discussion</i>
12:00	<b>Lunch Provided</b>
12:45	<b>Syndromic Surveillance for Asthma</b> <i>Julia Gunn, BPHC</i> <ul style="list-style-type: none"> <li>• Boston's Syndromic surveillance system</li> <li>• What makes it particularly useful? (ex: near real time info)</li> <li>• Examples of how we use it for asthma</li> <li>• Summary of data features: <ul style="list-style-type: none"> <li>▪ Date range of benchmark set</li> <li>▪ Number of hospitals and total records</li> <li>▪ Relevant data fields</li> <li>▪ Summary of syndrome classification</li> <li>▪ Age distributions</li> </ul> </li> </ul> <i>Moderated Group Discussion</i>
1:45	<b>Environmental Data Sources</b> <i>Steve Babin, JHU/APL, moderator</i> <i>Haig Iskenderian, MIT Lincoln Laboratory, presenter</i> <i>Ivanka Stajner, NOAA, presenter</i> <ul style="list-style-type: none"> <li>• Relationship to exacerbations, availability and timeliness, quality, coverage and resolution (time and space)</li> <li>• Weather: temperature, solar radiation, precipitation</li> <li>• Air Quality: Ozone, PM2.5, Sulfur Dioxide</li> <li>• Pollen, mold, allergens</li> <li>• Other environmental risk factors?</li> <li>• How to combine with healthcare-seeking data</li> </ul> <i>Moderated Group Discussion</i>
2:45	<b>Coffee Break</b>

3:00	<b>Modeling Approaches</b> <i>Howard Burkom, JHU/APL, moderator, presenter</i> <i>Rosalind Eggo, London School of Hygiene and Tropical Medicine, presenter</i> <i>Kathy Ensor, Rice University, presenter</i> <i>Anna Buczak, JHU/APL, presenter</i> <i>Jon Levy, Boston University School of Public Health, presenter</i> <ul style="list-style-type: none"> <li>• Basic concept</li> <li>• Past applications</li> <li>• Advantages, disadvantages, obstacles for exacerbation risk modeling in City of Boston with available data</li> </ul> <i>Moderated Group Discussion</i>
4:30	<b>Group Discussion</b> Determining utility, practicality, cost, timeliness, availability, and relevance. <ul style="list-style-type: none"> <li>• How can it be brought to bear on asthma? Are there other criteria?</li> <li>• Are there data sources that meet the criteria that we have not yet considered?</li> </ul>
4:45	<b>Wrap-Up and Plan for Day 2</b>
5:00	<b>Adjourn</b>
6:30	<b>Group Dinner</b> – Teranga Restaurant, 1746 Washington St, Boston, MA 02118



Consultancy Day 2: March 31, 2016	
8:00	<b>Continental Breakfast</b>
8:30	<b>Recap of Day 1 and Goals for Day 2</b> <i>Julia Gunn, BPHC</i>
9:00	<b>Translating the Model</b> <i>Margaret Reid, BPHC</i> <ul style="list-style-type: none"> <li>• What is the utility of models for decision-making at different levels?</li> <li>• How would we communicate information to different audiences?</li> <li>• How will information be communicated to and used by different stakeholders?</li> </ul> <i>Moderated Group Discussion</i>
9:30	<b>Operationalizing the Model</b> <i>Julia Gunn, BPHC, moderator</i> <i>George Mathew, MIT Lincoln Laboratory, presenter</i> <i>Karen Stark, Digital Infuzion, presenter</i> <ul style="list-style-type: none"> <li>• How do we operationalize a model into an automated system?</li> <li>• System architecture</li> <li>• Informatics including what the output would look like</li> <li>• Privacy and security requirements</li> <li>• Performance metrics</li> <li>• Automated updating of the model</li> </ul> <i>Moderated Group Discussion</i>
10:30	<b>Break</b>
10:45	<b>Moderated Group Discussion</b> <i>Julia Gunn, BPHC</i> <ul style="list-style-type: none"> <li>• What do we need to build and what would it take? (e.g., money, time, technology)</li> <li>• Are there available resources?</li> <li>• BPHC data request procedures</li> <li>• Other Uses</li> <li>• Future Considerations</li> </ul>
12:00	<b>Next Steps and Closing</b> <i>Laura Streichert, ISDS</i>
12:15	<b>Working Lunch</b> Meeting Hotwash and Open Discussion
1:30	<b>Adjourn</b>



## V. Evaluation Results

Fourteen participants completed the online survey. The respondents described their primary position as: Local PH practitioner (1); State PH practitioner (1); CDC or other federal public health agency representative (1); other federal agency (e.g. NOAA); Academic researcher (8); Other (2), who identified themselves as an Epidemiologist and pediatrician and a researcher and developer in an FFRDC.

A pre-consultancy call was held in preparation for the in-person meeting. The purpose of the pre-consultancy call was to review the context and goals of the meeting, summarize the problem, present the agenda, identify SME presenters, discuss consultancy logistics, and answer any participant questions. All respondents indicated “neutral” or “agree” in regards to achieving the goals of the pre-consultancy call, as seen in the table below. In the evaluation of the pre-consultancy call 53.85% of participants agreed that the pre-consultancy call clarified the purpose and the goals of the consultancy.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Did not attend call	Total	Weighted Average
The pre-consultancy call clarified the purpose and goals of the consultancy	0.00% 0	7.69% 1	0.00% 0	53.85% 7	15.38% 2	23.08% 3	13	4.00
The consultancy agenda was clearly presented during the pre-consultancy call	0.00% 0	0.00% 0	0.00% 0	46.15% 6	30.77% 4	23.08% 3	13	4.40
The pre-consultancy call clarified any questions you had about the consultancy	0.00% 0	7.69% 1	23.08% 3	38.46% 5	7.69% 1	23.08% 3	13	3.60
The pre-consultancy call resolved any concerns regarding logistics of the consultancy	0.00% 0	15.38% 2	15.38% 2	23.08% 3	23.08% 3	23.08% 3	13	3.70
I felt fully prepared for the consultancy after attending the pre-consultancy call.	0.00% 0	7.69% 1	38.46% 5	30.77% 4	0.00% 0	23.08% 3	13	3.30

When evaluating how well the consultancy objectives were met during the meeting, the participants deemed all of the objectives to be “partially” or “fully” met, as seen in the table below. 75% of participants indicated that the objectives of “describing the asthma problem in Boston” and “understanding the features and availability of environmental data sources,” were fully met.

	Objective not met at all	Objective partially met	Objective fully met	Not present for the discussion	Total
To describe the potential value of being able to model risk factors that exacerbate asthma in Boston.	0.00% 0	41.67% 5	50.00% 6	8.33% 1	12
To describe the asthma problem in Boston	0.00% 0	16.67% 2	75.00% 9	8.33% 1	12
To describe how Boston Public Health Commission would use the information if they could anticipate factors that trigger asthma attacks.	8.33% 1	58.33% 7	33.33% 4	0.00% 0	12
To describe the patterns of syndromic surveillance for asthma surveillance in Boston.	0.00% 0	41.67% 5	58.33% 7	0.00% 0	12
To understand the features and availability of environmental data sources (e.g., weather, particulate data)	0.00% 0	25.00% 3	75.00% 9	0.00% 0	12
To present results of a sample of models for asthma surveillance.	0.00% 0	25.00% 3	66.67% 8	8.33% 1	12
To describe strategies for translating a model for asthma.	0.00% 0	50.00% 6	41.67% 5	8.33% 1	12
To describe functional requirements for operationalizing a model in Boston.	0.00% 0	50.00% 6	41.67% 5	8.33% 1	12
To provide a greater understanding of how the consultancy work fits into the long term goals of the Biosurveillance Ecosystem (BSVE).	16.67% 2	58.33% 7	16.67% 2	8.33% 1	12

One of the primary functions of ISDS and the Boston consultancy is to bring together SMEs from different fields and mechanize multi-stakeholder collaborations. After attending the consultancy, 83% of participants indicated that they would contact another consultancy attendee; 42% of participants are interested in requesting syndromic surveillance data from the BPHC; and 75% of participants responded that they would look into the data sources presented at the meeting.

Open-ended responses to—*What did you gain from attending this consultancy?*—included:

- Limited understanding of asthma problem in Boston ☐
- Appreciation for asthma problem in Boston
- Better understanding of models
- The role of colds in asthma
- Very interesting information from a variety of engaging presenters
- Excellent ideas for implementation for Houston.
- Better understanding of existing data sources -Path forward to better utilize BPHC syndromic data
- I very much enjoyed learning from and listening to the diverse talks and appreciating the complexity of this project.

Open-ended responses to— *What worked well during the consultancy?* — included:

- Ample time for free discussion during and after talks
- A good group
- Most of it - meeting flowed well and content was compelling
- It was a great (somewhat eclectic) group of scientist and well-organized program.
- Experts were willing to share their work and opinion

- I appreciated the small group size and the engaging dialogue that represented different points of view. If there had been time, perhaps some additional discussion on other "warning system" structures, design, that may also work to help address BPHC's needs would have been interesting (e.g., additional audience, spatial, and temporal considerations).

Open-ended responses to— *What would you change in the consultancy?* — included:

- Dinner location
- Not much - maybe more time for structured group discussion or directed case work would have helped yield specific deliverables
- At little bit more insight as to what role "a consultancy" plays.
- I would start the meeting with norms/ground rules. At one point, one of the attendees was not being considerate of a speaker. I think this would have been limited or even avoided if we had a set of ground rules about communication, listening, etc.

## VI. Next Steps

- 42% of respondents expressed interest in getting access to BPHC data.
- 75% of participants expressed interest in the presented data sources.
- 21 participants indicated interest in working collaboratively on a manuscript to submit to OJPHI. Follow up calls are being scheduled.
- Explore opportunities for funding for model development.

## Appendix A: Use Case

Public Health Practice Problem Definition	
Models for Risk of Asthma Exacerbations in Urban Environments	
CONTACT INFORMATION	
Submitter name:	Julia Gunn
Jurisdiction or affiliation:	Boston Public Health Commission (BPHC)
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Email:	jgunn@bphc.org
Co-submitters and affiliations:	Margaret Reid, Boston Public Health Commission
PROBLEM DESCRIPTION	
<p><b>Summarize the problem:</b></p> <p>Asthma exacerbation can be triggered by a number of environmental factors and respiratory viral infections. Asthma control plans are essential in preventing exacerbation. An early warning of increased atmospheric/environmental risk would enable public health agencies to alert asthmatic patients and providers. These alerts would also include prevention messaging and allow asthmatics to ensure that their plans are up to date. BPHC seeks analytic methods for forecasting conditions that are associated with asthma exacerbations. The forecast should consider the impact of respiratory infections (rhinovirus, influenza), temperature extremes, anomalous air quality measurements, and pollen. Available data sources are emergency department visit records, weather data, air quality data, and pollen counts.</p>	
SOLUTION REQUIREMENTS	
<p><b>Describe the type of solution you are seeking (e.g., anomaly detection, signal validation, data quality characterization):</b></p> <p>The prediction calculations and alerting communications must be available at a minimum on a daily basis without impacting other routine processing operations. The stratification of predictions by geography and by demographic factors should be as fine as the data will support. Electronic near real time data feeds are required. The analytical processes must be automated. The model and system needs to support continuous model training.</p>	
<p><b>Describe what type of solution would enable you to implement it in your practice setting (e.g., Do you need an algorithm? Do you need code? If you need code, does it have to be written in any particular programming language?).</b></p> <ul style="list-style-type: none"> <li>Analytic program – must be supported by SQL, will consider SAS or R</li> <li>Integration into existing health department surveillance systems</li> <li>Exporting outputs (neighborhood; city map) – heat map</li> <li>Automated alerting</li> <li>Continuous model training (code, IT systems)</li> </ul>	
<p><b>Describe who will use the solution. For example, how many users will there be and what level of skill do the users have? Are the users all within a single jurisdiction/organization?</b></p> <p>The BPHC asthma program in the Division of Healthy Homes and Community Supports would be the end user of the system. The number of BPHC end users is anticipated to be less than five. Automated alerting of an aberration to the asthma program staff would be beneficial. The output would be messaged to the asthma community using other communication systems.</p>	

**Note any other constraints:**

Information is processed every day

**VALIDATION****Does a gold standard exist with which to validate the proposed solutions?**

- ☐ Gold standard exists within the provided data set (e.g., an outbreak signal nested within baseline data)
- ☐ Gold standard exists in a separate data set, which can be provided to the workgroup (e.g., laboratory data to validate ED data)
- ☐ Gold standard exists but cannot be furnished
- × Gold standard does not exist

**INPUT DATA****List the minimum data elements that can be provided to address the problem:**

- Syndromic surveillance ED visits 2008-2015 (Asthma and ILI syndrome)
- Weather data (available on line)
- Pollen data (available on line)
- Air quality data (available on line)

**How much historical data can be provided?** 8 years

## Appendix B: Summary of Notes

(See presentation slides in Appendices below)

### Use Case Goals and Requirements

#### **The Problem**

- Asthma
  - Asthma exacerbations are common and numerous.
  - Current interventions focus on individual actions.
- Boston
  - Diverse neighborhoods with varying distributions of children, racial and ethnic makeup, and commonly used languages.
  - Health inequities disproportionately affect certain groups within Boston.
- Data
  - BPHC has ED reports for the past 8 years.
  - Looking for appropriate environmental data streams to bring into the model.

#### **The Goals**

- Identify a practical model to forecast environmental conditions that are likely to result in asthma exacerbations.
- Define systems requirements to automate the processing notifications of issues (environmental and technical).
- Communicate environmental conditions and actions to a variety of stakeholders at different levels:
  - Policy
  - Community
  - Organizational
  - Interpersonal
  - Individual

#### **Requirements**

- Data streams: electronic, near real time (24 hours), Boston specific
- Model: automated processes, daily outputs, ideally in SQL but will consider SAS or R.
- System: auto notification, multiple data stream inputs, private and secure to protect health information.

### Environmental Data Sources

*Haig Iskenderian, MIT Lincoln Laboratory*

*Ivanka Stajner, NOAA*

There are numerous environmental data sources at the local and national level, with varying quality.

- Local
  - Hourly and sub-hourly reports are good for analysis of real time weather and tracking weather changes within an individual day:
    - ASOS (Automated Surface Observing Program)
    - CWOP (Citizen Weather Observation Program)
  - Daily weather summaries are good for historical data and when changes within the day are unimportant:
    - COOP (National Weather Service (NWS) Cooperative Observer Program).
    - CoCoRaHS (Community Collaborative Rain, Hail, and Snow Network).

- National
  - Air Quality: <http://airquality.weather.gov/>
  - Dust, ozone, and smoke: <ftp://tgftp.nws.noaa.gov/SL.us008001/ST.opnl/DF.gr2/DC.ndgd/GT.aq/>
  - PM2.5: <http://para.nomads.ncep.noaa.gov/pub/data/nccf/com/aqm/para/>
  - Historical data available on request.

Weather prediction models differ in resolution and require different computer involvement.

- 3km model forecasting out to 15 hours, 24 times per day.
- 12km model that forecasts out to 84 hours, 4 times per day.
- For a neighborhood model you will need a fine model (1km or 3km).

### **Modeling Approaches**

*A discrete event simulation model of pediatric asthma exacerbations:*

*Jonathan Levy, Boston University School of Public Health*

- Discrete event simulation (DES) is a systems science approach involving modeling of a complex systems that evolves over time and is used for many health policy analyses.
- Overarching idea: examine the effects of small changes in exposure on asthma health care utilization outcomes, where observational studies are underpowered.
- Pollution sources:
  - NO<sub>2</sub>, PM<sub>2.5</sub>, and Mold
- Model application:
  - Simulate a large number of children to detect potentially small changes in outcomes and costs.
  - Evaluate/validate outputs from baseline simulation.
  - Apply model to approximate benefits and costs of alternative intervention strategies.

*Epidemics of the “common cold” and the dynamics of severe asthma exacerbation:*

*Rosalind Eggo, London School of Hygiene and Tropical Medicine*

- Linking virus transmission to asthma:
  - Need to know virus prevalence to determine how at risk the population is; data at a large scale are not available from surveys or samples.
  - Use a model of realistic respiratory virus transmission to infer prevalence.
- Conclusions:
  - Common cold transmission model provides a harmonious explanation for the patterns of severe asthma exacerbations seen in Texas.
  - Prevalence of infection is a shifting baseline of risk to the population driven by contact patterns of children in school.
  - Variation in school calendars can alter the risk baseline in a strongly non-linear way.

---

### *Disease Prediction*

*Anna Buczak, JHU-APL*

- Goal: create a capability that transforms how decision makers predict the incidence of infectious disease, enabling them to reduce morbidity and save lives through effective mitigation efforts.
- Predicting Infectious disease Scalable Method (PRISM):
  - Provides a novel disease prediction method
    - Predictions performed for several diseases: dengue and malaria.
    - Prediction of peak location for influenza.
  - Flexible, scalable methodology:

- Predictions are at various geographical resolutions: province, district, region, county.
- Method of analogues for influenza successfully predicts (4 weeks out):
  - Incidence at peak
  - Total number of cases

---

*Toward Asthma Air Aware Day Alert for Houston, TX*  
*Kathy Ensor, Rice University*

- Objectives:
  - Identify the most severe days
  - Make school nurses aware of pollution and its potential impact
  - Do not overwhelm the already overwhelmed system
- Approach:
  - Employed case-crossover design + conditional logistic regression to determine the risk from multiple pollutants.
  - Concentration response was used to identify concentration levels suitable to employ warning.
  - Created a model to predict the high-risk days based on pollution.
- Asthma Warning System Pilot:
  - Model uses simple inputs:
    - NO<sub>2</sub> levels observed from 9pm to 2am the night before
    - 8 hours maximum ozone level for the day before
    - Forecast of weather (apparent temperature, cloud cover, and precipitation for the day of)
  - Alert is issued between 5 and 6am via e-mail to school nurses.
  - The nurses would then prepare accordingly if a warning was given.

---

*Bayesian Network Approaches*  
*Howard Burkom, JHU-APL*

- Concept: Population-based Bayes Networks
  - Method of combining information from the monitored population.
  - Not Bayesian statistics in the sense of hierarchical modeling, fixed/random effects (could incorporate).
  - Not an agent-based Bayesian model representing every individual as a separate node with properties.

---

## **Translating the Model**

### **Feasibility:**

- Data streams for the model need to be identified and prioritized based on the target populations in Boston.
  - Can we use syndromic data to find the most important stressors in clusters of high-risk groups?

### **Impact:**

- Reduce racial and ethnic disparities in ED and hospitalizations.
- Reduce geographic disparities.

### **Intervention Levels:**

- Policy/System
  - Alerting school nurses



- Alert policy could follow extreme cold/heat alerts in Boston
  - Cross-institution communication is central to addressing this problem
  - Community
    - Communication targets based on language and location
  - Organizational
    - Focus around school-based intervention with nurses?
  - Interpersonal
  - Individual
- 

## **Operationalizing the Model**

### *Operationalizing Models*

*George Mathew, MIT Lincoln Laboratory*

#### **Milestones:**

- Requirements gathering
- Architecting
- Project plan: how to implement
- Resource Allocation: getting human capital and funding from all of the agencies
- Development/Integration
- Piloting
- Production
- System Usage Issue Tracking
- System Refactoring/Models Refactoring
- Upgrades

#### **Approaches:**

- Incremental: go for the low hanging fruit
  - Full Scale Implementation
- 

## **Themes and Next Steps**

#### **Themes:**

- Form policy changes across the socio-ecological model.
- Build on partnerships and inter-agency communications.
- Alerting people without actions will create panic.
- Using data will create the immediate actions that need to be taken and will inform staffing policies (e.g. school nurses).
- Simple data streams, no more than 6 input variables.
- Model sustainability.

#### **Next Steps:**

- Funding: CDC, BSVE, R21, NIH, NSF
- Share data with developers
- Create special session about the model at 2016 ISDS conference.
- Formulate an incremental model

Forecasting Asthma: Boston Use Case

The problem: Asthma

- Asthma and exacerbations are common
- Multiple triggers
  - Viral illness (Influenza, RSV)
  - Air quality
  - Pollen
  - Many others
- Current efforts have focused on individual interventions
- Early warning
  - Notify health providers, patients
  - Prevention messages
- Policy considerations


Neighborhood	Zip Code
Downtown	02101
Admission/Highland	02118
	02108
	02109
Back Bay (Boston Hill, Downtown, West End)	02116
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## Requirements

- Data streams
  - Electronic
  - Near real time
  - Boston specific
- Models
  - Automated processes (every day)
  - Function in Sql, will consider SAS or R
  - Processing times
  - Daily outputs
- System
  - Automation
    - BPHC program staff of environmental problems
    - Technical staff of system failure
    - Output communicated to other systems
  - Multiple data streams with differing data structure
  - Privacy/security – protected health information

## Practical Model

- There is no gold standard
- Time sensitive for response
- Reasonable processing time



### The Asthma Problem in Boston

International Society for Disease Surveillance Consultancy  
March 30-31, 2016  
Boston Public Health Commission

Margaret Reid, RN MPA  
Director; Division of Healthy Homes and Community Supports  
Boston Public Health Commission

### Presentation Objectives

- To inform subsequent conversations through providing:
  - Boston asthma data on trends, overall burden and disproportionately burdened populations
  - Introduction to asthma and outdoor environmental factors
  - BPHC asthma program description
  - Thoughts on communication strategies and a framework for applying models

### Health Inequities Experienced by Boston Residents

Indicator	Year(s)	Race/Ethnicity			
		Asian	Black	Latino	White
<b>Chronic Disease</b>					
Asthma (Percent of Adults)	2013	2.8% (0.2-5.3)	11.9% (9.4-14.4)	11.9% (8.8-15.1)	11.8% (9.5-14.2)
Asthma Emergency Department Visits (per 1,000 residents)	2012	2.8	21.8	12.7	4.1
Diabetes Hospitalizations (per 1,000 residents)	2012	0.6	3.9	2.3	1.4
Diabetes Deaths (per 100,000 residents)	2012	n<5	39.5	23.9	14.3
Heart Disease Hospitalizations (per 1,000 residents)	2012	4.1	13.6	9.9	9.0
Heart Disease Deaths (per 100,000 residents)	2012	44.6	155.9	80.2	144.9
Hypertension (Percent of adults)	2013	16.2% (9.9-22.4)	36.7% (33.0-40.5)	26.2% (22.0-30.3)	18.6% (16.7-20.6)
Obesity (Percent of adults)	2013	15.3% (8.9-21.6)	33.0% (29.3-36.8)	27.3% (23.1-31.6)	16.2% (13.9-18.4)

NOTES: Gray text in tables represents rates based on counts less than 20 and should be interpreted with caution. Black text in tables represents rates based on counts of at least 20.  
Shaded in red are rates or percentages that are higher/worse than the corresponding rate for White residents.

### Asthma ED Visits\* by Age, FY2004-FY2013

FY	Ages 0-2	Ages 3-5	Ages 6-17	Ages 18-44	Ages 45-64	Ages 65+
2004	369.0	334.7	176.6	89.6	121.6	66.9
2005	299.3	294.6	161.6	86.7	112.7	61.4
2006	346.8	344.0	172.4	84.1	102.0	61.7
2007	323.9	328.5	150.6	81.9	97.4	57.1
2008	351.7	388.2	166.9	86.9	105.9	66.1
2009	279.9	315.9	145.7	81.1	112.7	64.0
2010	278.6	322.0	149.3	79.2	103.7	60.7
2011	196.7	271.7	141.8	72.8	104.7	63.4
2012	180.4	266.0	148.9	66.1	100.1	58.0
2013	203.4	293.9	147.4	72.7	103.6	69.6
% Change 2004-2013**	-47	-16	-17	-22	-10	No Significant Trend

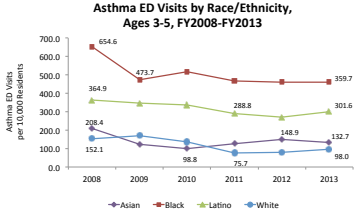
\* Age-specific rates per 10,000 residents. \*\* Based on trend analysis using regression (p<0.05).  
NOTE: This analysis includes ED visits that resulted in hospitalizations and observation stays. ED visits that resulted in hospitalizations are included in both ED visit analyses and hospitalization analyses.  
DATA SOURCE: Acute Hospital Case Mix Database, Massachusetts Center for Health Information and Analysis (CHIA)  
DATA ANALYSIS: Boston Public Health Commission Research and Evaluation Office

### Asthma Hospitalizations\* by Age, FY2004-FY2013

FY	Ages 0-2	Ages 3-5	Ages 6-17	Ages 18-44	Ages 45-64	Ages 65+
2004	80.3	12.7	14.6	9.8	31.0	16.4
2005	71.6	56.0	31.1	9.4	30.8	17.4
2006	104.8	81.7	40.8	9.8	26.9	16.7
2007	97.0	87.3	39.8	9.6	24.7	14.9
2008	128.5	93.4	42.0	9.9	31.7	41.5
2009	114.3	89.5	45.7	10.6	35.9	41.6
2010	99.1	101.5	38.2	11.7	36.1	41.7
2011	89.5	78.8	40.0	9.5	34.8	41.1
2012	73.0	89.1	39.0	7.7	26.8	31.1
2013	67.5	71.7	36.0	7.6	25.4	34.0
% Change 2004-2013**	No Significant Trend	+26	No Significant Trend	-14	No Significant Trend	No Significant Trend

\* Age-specific rates per 10,000 residents. \*\* Based on trend analysis using regression (p<0.05).  
NOTE: This analysis includes ED visits that resulted in hospitalizations. ED visits that resulted in hospitalizations are included in both ED visit analyses and hospitalization analyses.  
DATA SOURCE: Hospitalized Discharge Database, Massachusetts Center for Health Information and Analysis (CHIA)  
DATA ANALYSIS: Boston Public Health Commission Research and Evaluation Office


### Asthma ED Visits by Race/Ethnicity, Ages 3-5, FY2008-FY2013



NOTE: This analysis includes ED visits that resulted in hospitalizations and observation stays. ED visits that resulted in hospitalizations are included in both ED visit analyses and hospitalization analyses.  
DATA SOURCE: Acute Hospital Case Mix Database, Massachusetts Center for Health Information and Analysis (CHIA)  
DATA ANALYSIS: Boston Public Health Commission Research and Evaluation Office

## Appendix E: Syndromic Surveillance Slides

**Boston Asthma Nurses Collaborative (BANC)**

<b>Purpose:</b> Updates Resources Networking Address Challenges Share best practices Cross communication and care coordination	 <p>Supportive network specifically for asthma nurses caring for those with asthma in schools, community health centers, hospitals and health maintenance organizations in Boston</p>	<b>Participants:</b> BPHC (convener) Community Health Center Nurses Hospital Nurses Boston Public School Asthma Nurse Leads & School Nurses Charter School Nurses ABCD Head Start Health Managers
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### Outdoor Pollutants

- Extensive evidence of the relationship between outdoor air factors and asthma exacerbations.
  - Ozone
  - Carbon Monoxide
  - Sulfur Dioxide
  - Nitrogen Dioxide
  - Particulate Matter
  - Environmental Tobacco Smoke

### Other Outdoor Air Factors

- Cold Air
- Temperature Variation
- Pollens and Mold

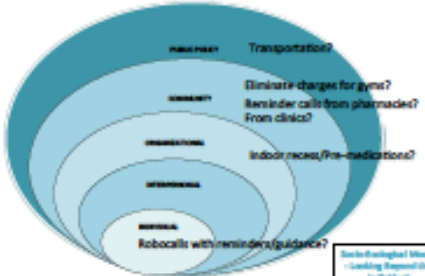
Thunderstorm-related asthma: what happens and why  
 G. D'Amato, C. Vitale, M. D'Amato, L. Cecchi, G. Uccardi, A. Molino, A. Vatrella, A. Sanduzzi, C. Maesano and L. Annesi-Maesano, 2016

- Thunderstorm asthma describes an observed increase in acute bronchospasm cases following the occurrence of thunderstorms in the local vicinity
- Thunderstorms are a risk for asthma attacks in patients suffering from pollen allergy.
- Thunderstorm asthma occur as a result of thunderstorm relation to the following:
  - High humidity
  - Increased air pollen concentrations
  - Increased mold spore air concentrations
  - Temperature increase
  - Wind speed increase
- Being outdoors during a thunderstorm has the potential to severely exacerbate asthma symptoms

### Current Communication Strategies

- YouTube
- Tweets
- Blogs
- Group lists
- BEAH
- Newsletters
- Stream Alerts
- Everbridge
- Meetings/Professional Development Events
- Radio/TV/BusTails (when funding is available)

### Who/How to Communicate?



The diagram consists of four concentric circles representing different levels of communication:

- POPULATION:** Transportation?
- COMMUNITY:** Climate changes for gyms? Reminder calls from pharmacies? From clinics?
- INTERPERSONAL:** Indoor molds/Pre-medications?
- INDIVIDUAL:** Robocalls with reminders/guidance?

Source: Everbridge® Model - Looking Beyond the Individual

## Syndromic Surveillance: Boston

## Syndromic Surveillance Reporting Regulations

- BPHC Board of Health regulation first passed in 2004 requires:
  - Hospital emergency departments to report syndromic data
  - Information to be sent includes:
    - Visit date
    - Unique patient identifier (HIPAA-compliant)
    - Age, gender, and race/ethnicity
    - Zip code of primary residence
    - Chief complaint (Within 24 hours)
    - ICD-9/10 codes when available (First three)
    - Disposition
  - Daily electronic transfer

## Boston Syndromic Surveillance System

- Developed in 2004 for the Democratic National Convention – Go live July 2004
- All 10 Boston emergency departments report daily visits for the previous 24 hours
- Automatic electronic transfer
- Chief complaints are categorized into various syndrome groups
- Analyzed for increased activity, significant events, or situation awareness

## Chief Complaints

## Chief Complaint Dictionary

Fever	Respiratory	Cough	Hypoxia	SOB	Cold
chills	shortness of breath	bringing up blood	color change	apnea	cold
chills	bronchitis	cough	color off	apneic episode	cold air
cough/fever	bronchitis	cough	cyanosis	breathing difficulty	cough
delirium	bronchitis	cough	cyanosis	breathing fast	cough

## EMT-P to Standardize Data

Natural language processing program

Created by the University of North Carolina

Uses Perl, Java, and the National Institute of Health's Unified Medical Language System®



## EMT-P and UMLS: The Boston Experience

- Training – Not all terms map
  - Hd = dialysis
  - scd = sickle cell disease
  - ooc = out of control
- One to Many (EMT-P)
  - Boston - Many to One
- Terms with multiple meanings
  - OD: Overdose vs Right eye
  - ST: Sore throat vs Sinus tachycardia
  - Context matters

Preprocessing Input	Output
FEVER, VOMMITING, BODY PAIN	body pain fever vomiting
N/V/D	diarrhea nausea vomit
NVD	diarrhea nausea vomit
THROWING UP	vomiting
NAUSEA VOMITING DIARRHEA	diarrhea nausea vomit
ABD PAIN,NAUSEA,EMESIS,DIARRHEA	abdominal pain diarrhea emesis nausea
Cugh	cough

## Impact

- Decrease processing time
- Fewer unique terms
  - Original (unaltered chief complaints): 22, 748 unique words.
  - Standardized: 14,893 unique words
- Facilitates identification of new terms – Ongoing language evolution
  - Standardization
  - Evolving health care problems (STEMI)
  - Evolving care (Narcan)

Asthma		
asthma	asthma	reactive airway
asthma	astma	reactive airway disease
asthina	asthma	status asthmaticus
asthma	asthema	swelling
astha	asthma	swelling
asth	asthma	swelling
astham	bronchospasm	swheeze
asthama	bronchospasm	swheeze
asthmatic	acute asthma	swheezes
asthma	heezing	swheezing
asthma-adult	r a d	swheazy
asthma-pediatric	r a d	swheezing
asthmae	r a d	
asthmatic	rad	

## ILI Syndrome Definition

**CDC Definition**  
Influenza-like Illness:  
Fever ( $\geq 100^{\circ}$  F [ $\geq 37.8^{\circ}$  C], oral or equivalent) -AND- Cough and/or sore throat (in the absence of a known cause)



**NPHC Syndrome Definition**  
ILI: Narrow: Flu or ("Fever" and ("Cough" OR "Sore throat"))

## Flu Wheezing



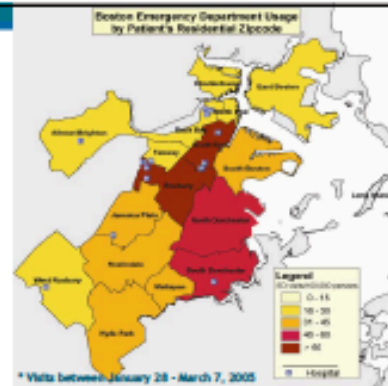
**ILI**



**Asthma**

Regions associated with Boston emergency department visits: February-March, 2016

	Number of Visits
All	64,313
Boston	34,627 (54%)
Massachusetts (Excluding Boston)	26,461 (41%)
New England/ New York	1,625 (3%)
Other US	842 (1%)
Unknown	758 (1%)



### Day of the week effect

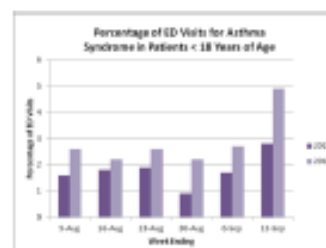
	Number of Asthma Visits
Sunday	116
Monday	122
Tuesday	118
Wednesday	113
Thursday	103
Friday	106
Saturday	104

### Enterovirus D68 (EV-D68)

- One of more than 100 non-polio enteroviruses
- 2014, national outbreak associated with severe respiratory disease
  - Children with asthma were at high risk
  - Supportive treatment only

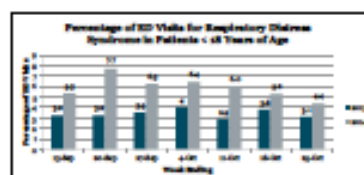
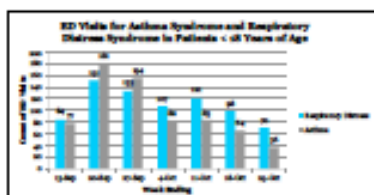
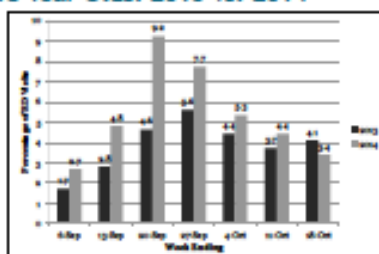
## Biosurveillance Challenges

- Limited laboratory testing
- No case definition
- No reporting requirement
- Bridge asthma and infectious disease surveillance





## Percentage of Asthma Syndrome Visits: <18 Year Olds: 2013 vs. 2014



## Response

- Surveillance**
  - Syndromic surveillance (current and historical visits for asthma)
- Health care sites**
  - Enhanced infection control
  - Monitoring alcohol studies
- Public health guidance and alerts including asthma specific information**
- Pushed information via the RPHC asthma program networks**
- Schools: Up to date asthma control plans**



## Influenza, 2012-2013



### The never ending flu season: 2013-2014



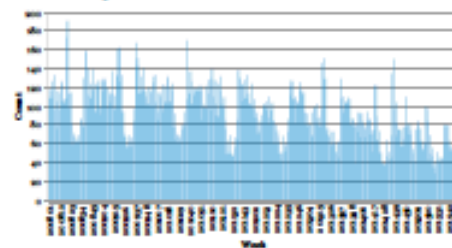
### Influenza 2014-2015



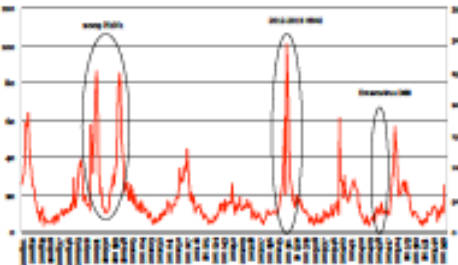
### Number of visits for Boston residents: 2008-2015

- Asthma
  - All: 22,827
  - 18 years of age and younger: 14,978
- ILI
  - All: 21,227
  - 18 years of age and younger: 10,823

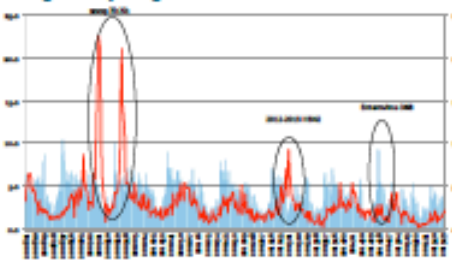
### Asthma Syndrome Visits: Boston 2008-2015

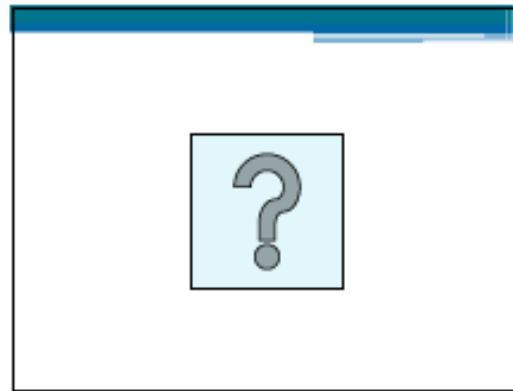
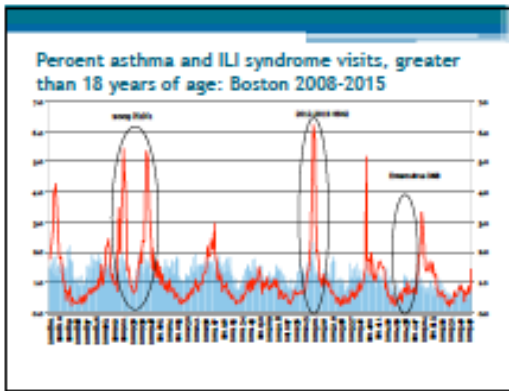


### Asthma and ILI Syndrome Visits: Boston 2008-2015



### Percent asthma and ILI syndrome visits, 18 years of age and younger: Boston 2008-2015






## Appendix F: Weather Observations and Forecasts Slides

# Weather Observations and Forecasts


Halg Iskenderian

30 March 2016

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## Topics


- What kind of weather information is available in the Boston area?
  - Surface observations
  - Gridded surface data
  - Numerical weather model forecasts
  - Thunderstorm forecasts
- General weather factors of concern:
  - Extreme temperature and humidity
  - Rapid temperature changes
  - Precipitation

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## Surface Weather Observations

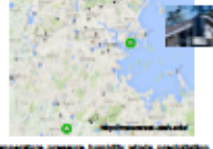
- Hourly and sub-hourly reports
  - Good for analysis of real-time weather, extremes and weather changes within a day
  - ASOS very good quality, CWOP varying quality

**Automated Surface Observing System (ASOS)**




Temperature, pressure, humidity, winds, precipitation, weather, visibility, etc...

**Global Weather Observer Program (CWOP)**




Temperature, pressure, humidity, winds, precipitation, solar radiation (batteries)

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## Surface Weather Observations


- Daily weather summaries
  - Good for historical analysis of weather when changes within a day are not important
  - COOP good quality data, CoCoRaHS varying quality

**National Weather Service (NWS) Cooperative Observer Program (COOP) Cooperative**




Monthly temperature, monthly humidity, rainfall, snowfall, snow depth

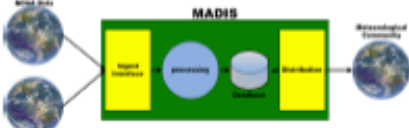
**Community Collaborative Rain, Hail and Snow Network (CoCoRaHS)**



Daily Precipitation, snow, hail, significant weather

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## Meteorological Assimilation Data Ingest System (MADIS)



**MADIS contains data from:**


- Mesocarta (Radar, transportation, fire, air quality, energy, personnel, etc.)
- ASOS network
- Climate networks


MADIS processing performs quality checks on data

MADIS data are archived back to 2001

<https://madis.noaa.gov/>

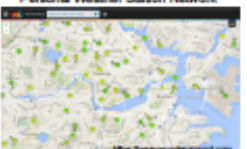
**Example of MADIS Data Locations**



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## Other Surface Weather Observations

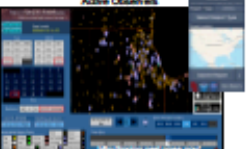
**Weather Underground Personal Weather Station Network**




Temperature, pressure, humidity, winds, precipitation

**Crowd Source Observations**


**Active Observers**



**Passive Observers**



- Temperature
- Headlight use
- Speed
- Braking
- Wiper use
- Throttle and stability control

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## Gridded Analyses

- **Real-time Mesoscale Analysis (RTMA)**
  - Assimilates many sources of weather data
  - Creates surface weather analyses (temperature, humidity, winds, pressure, cloud, visibility)
  - 2.5 km horizontal resolution updated hourly

Example of NOAA/RTMA Temperature Analysis



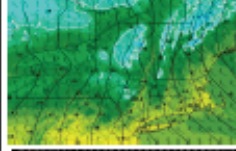
<http://img.ncep.noaa.gov/>

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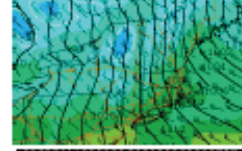


## Numerical Weather Forecasts Differences in Horizontal Resolution

6 Hour Temperature Forecast with 3 km Model<sup>1</sup>



6 Hour Temperature Forecast with 12 km Model<sup>2</sup>



<sup>1</sup>NOAA's 3 km High Resolution Rapid Refresh (HRRR) model makes forecasts out to 18 hours, 30X per day  
<sup>2</sup>NOAA's 12 km North American Mesoscale (NAM) model makes forecasts out to 84 hours, 6X per day

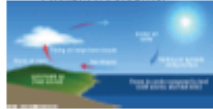
- Other weather models provide forecasts out to 2 weeks in the future
- Weather models provide forecast of pressure, temperature, humidity, winds, precipitation, clouds, visibility, many other quantities

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## Sea Breeze

Formation of a Sea Breeze



Sea Breeze Impact on Temperature



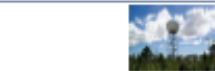
- Sea breezes can cause rapid temperature, wind, and air quality changes
- Fine-scale observations and models needed to diagnose and forecast

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## Thunderstorm Observations

Radar Depiction of Precipitation Intensity



COMPLETED WORLDWIDE INSTALLATIONS  
WITHIN THE CONTIGUOUS U.S.

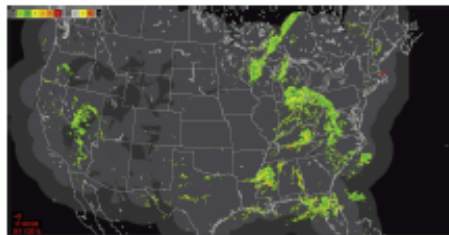


NATIONAL WEATHER SERVICE  
NWS/NCEP/NOAA

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## Radar Mosaic

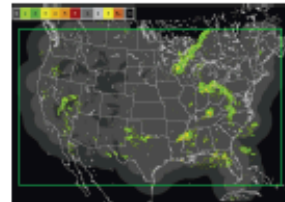


Combine multiple radars into single radar scene

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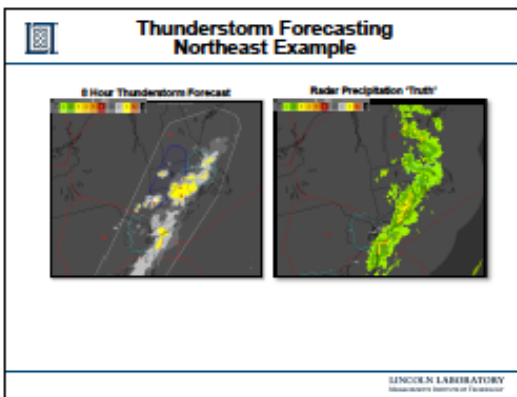


## 0-8 Hour Thunderstorm Forecast for the Federal Aviation Administration



- Tracking of thunderstorms tends to do better for first few hours of forecast
- Numerical models tend to do better after first few hours of forecast
- Combine thunderstorm tracking and HRRR numerical model
- 3 km resolution first 2 hours, 3 km thereafter out to 8 hours
- Updated every 5 min first 2 hours, every 15 minutes 2-8 hours

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### Summary

- Numerous sources of surface weather observations exist
  - Sub-daily vs. daily
  - Varying data quality
  - MADIS quality controls and archives many surface observations
- Observations can be gridded to create a continuous surface analysis field
- Numerical weather models use observations to predict weather conditions
  - Varying grid resolution, updates, forecast length
- Thunderstorm forecasts blend radar precipitation tracking and numerical models

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## Appendix G: NOAA/National Weather Service Air Quality and Weather Predictions




# NOAA/National Weather Service Air Quality and Weather Predictions

Ivanka Stajner  
with the air quality prediction implementation team  
and Eric Rogers


Boston March 30, 2016




## Overview




- Background on air quality (AQ) predictions
- Predictions and verification for:
  - Ozone
  - PM2.5
  - Smoke
  - Dust
- Access to AQ predictions
- Weather variables:
  - Predictions
  - Tools
  - Archive
  - Verification




## Background




- Ongoing implementation of NOAA/NWS National Air Quality (AQ) Forecast Capability operationally to provide graphical and numerical guidance, as hourly gridded pollutant concentrations, to help prevent loss of life and adverse health impacts from exposure to poor AQ
  - Exposure to fine particulate matter and ozone pollution leads to premature deaths: 50,000+ annually in the US (Science, 2005; recently updated to 100,000 deaths; Fann, 2011, Risk Analysis)
- Direct impact on reducing loss of life: AQ forecasts have been shown to reduce hospital admissions due to poor air quality (Veldert, 2006, J. of Human Resources)
- NOAA's AQ forecasting leverages partnerships with EPA and state and local agencies






## National Air Quality Forecast Capability Capabilities as of 3/2016




- Improving the basis for air quality alerts
- Providing air quality information for people at risk


Prediction Capabilities:

- Operations:
  - Ozone nationwide
  - Smoke nationwide
  - Dust over CONUS
  - Fine particulate matter (PM2.5) predictions
- Testing of improvements:
  - Ozone
  - Smoke
  - PM2.5





## Ozone predictions



Operational predictions at <http://airquality.weather.gov> over expanding domains since 2004

Model: Linked numerical prediction system

- Operationally integrated on NCEP's supercomputer
- NOAA/NWS Community Multiscale Air Quality (CMAQ) model
- NOAA/NWS South American Monsoon (SAM) numerical weather prediction

Observational input:

- WRF reanalysis weather observations
- WRF emissions inventory


Gridded forecast guidance products


- On WRF forecast guidance and forecast updates
- On WRF forecast guidance and forecast updates
- On WRF forecast guidance and forecast updates
- On WRF forecast guidance and forecast updates
- On WRF forecast guidance and forecast updates


Verification basis, near-real time: Ground level surface observations of surface ozone

Customer outreach/feedback:


- State & Local AQ forecasts coordinated with EPA
- Public and Private Sector AQ coordination







## PM2.5 predictions

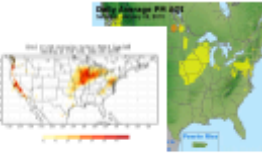


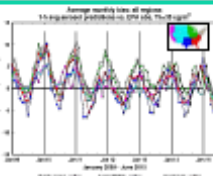
Predictions for WRF at 12km resolution over CONUS (Plus 100 counties only before summer 2014)

- CMAQ
- CMAQ model, AEROC-4 scenario
- Real-time emissions

Operational prediction flow, testing like correction post-processing algorithm

- Publicly available since February 2016
- Real-time correction applied
- Testing improvements to wildfire emissions


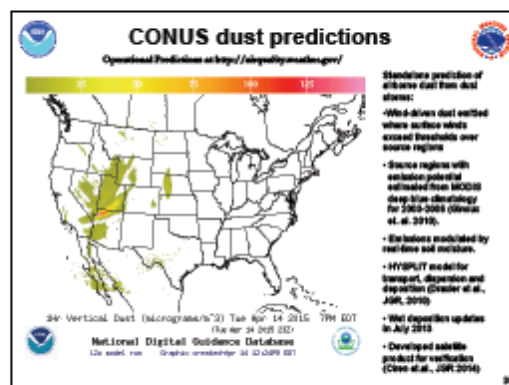
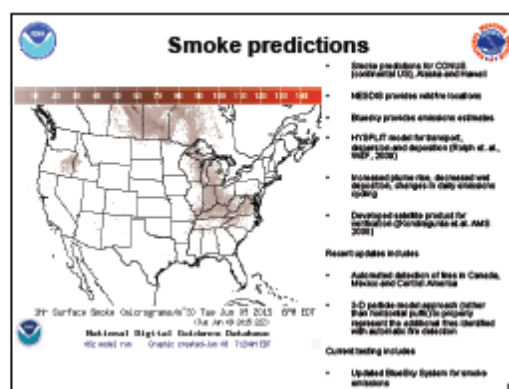
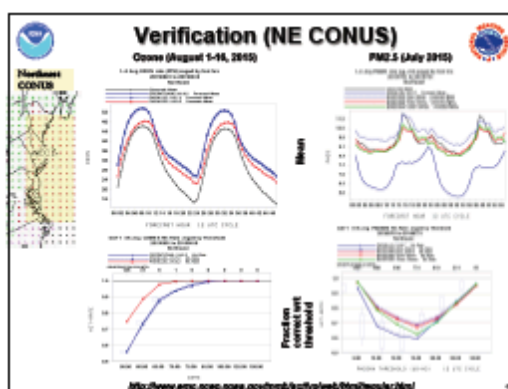





Forecast challenges

- Improving sources for wildfire smoke and dust - in testing since summer 2014
- Chemical mechanisms eg. SOA
- Meteorology eg. PSL height
- Chemical/boundary conditions these boundary inputs





# Access to AQ predictions



**For ozone, smoke and dust:**



- Current graphical predictions are available at  
<http://airquality.weather.gov/>
- Current grib files are available at  
[ftp://ftp.noaa.gov/SW\\_MOS0000/ST\\_opsMDF/g2DC.ndps/GT.aq/](ftp://ftp.noaa.gov/SW_MOS0000/ST_opsMDF/g2DC.ndps/GT.aq/)

**Historical data can be requested at the following link:**  
[http://www.ncdc.noaa.gov/data/4AS/Stations/select?  
 dataset=mo-250\\_01&subjectBy=STATION&appName=tools&is-PLE&typesort=  
 citypopulation&sort=id](http://www.ncdc.noaa.gov/data/4AS/Stations/select?dataset=mo-250_01&subjectBy=STATION&appName=tools&is-PLE&typesort=citypopulation&sort=id)

**Detailed product can be requested by choosing the VMO headers.** As the request gets processed a link is sent in the email to pick up the data.

**For PM<sub>2.5</sub>:**

- Current grib files are available at [http://beta.nceps.noaa.gov/pub/data/tc/bcm/  
 ampm/](http://beta.nceps.noaa.gov/pub/data/tc/bcm/ampm/)

**NCEP Weather Model  
predictions, verification, useful links**

**material provided by Eric Rogers (NCEP/EMC)**



## Mesoscale Branch Models

### NAM, NAM nests, RAP, HRRR, Hiresw


NAVJAP/HRRR/Hiresw - OUTPUT GRIDSDIRECTORIES

This web page shows the location of the various output grids created from the operational NCEP NAM, RAP, HRRR, and Hiresw forecasts. The file naming convention is:


Reference page: <http://www.emc.ncep.noaa.gov/web/branchgrid/>

- Links to grid directories
- Output grid resolution, frequency
- Map of grid domain coverage
- Links to file locations on the NCEP FTP server (past data and recent predictions)
- Links to NCEP Model Analysis and Diagnosis (MAD) and MOC model web pages


Click on the grid directory link to get a complete directory grid listing. For 1/2 degree grids, for 1/4 degree grids, for 1/8 degree grids, for 1/16 degree grids, for 1/32 degree grids, for 1/64 degree grids, for 1/128 degree grids, for 1/256 degree grids, for 1/512 degree grids, for 1/1024 degree grids, for 1/2048 degree grids, for 1/4096 degree grids, for 1/8192 degree grids, for 1/16384 degree grids, for 1/32768 degree grids, for 1/65536 degree grids, for 1/131072 degree grids, for 1/262144 degree grids, for 1/524288 degree grids, for 1/1048576 degree grids, for 1/2097152 degree grids, for 1/4194304 degree grids, for 1/8388608 degree grids, for 1/16777216 degree grids, for 1/33554432 degree grids, for 1/67108864 degree grids, for 1/134217728 degree grids, for 1/268435456 degree grids, for 1/536870912 degree grids, for 1/1073741824 degree grids, for 1/2147483648 degree grids, for 1/4294967296 degree grids, for 1/8589934592 degree grids, for 1/17179869184 degree grids, for 1/34359738368 degree grids, for 1/68719476736 degree grids, for 1/137438953472 degree 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## Tools and archive



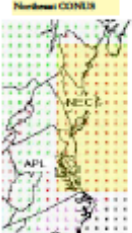
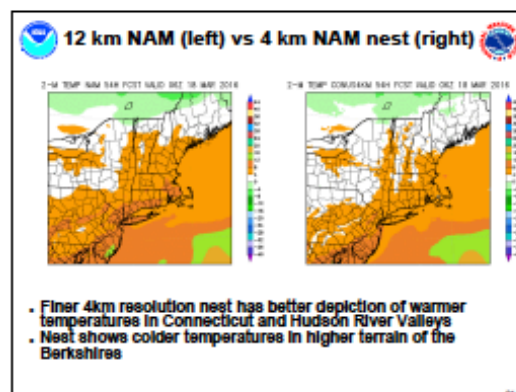
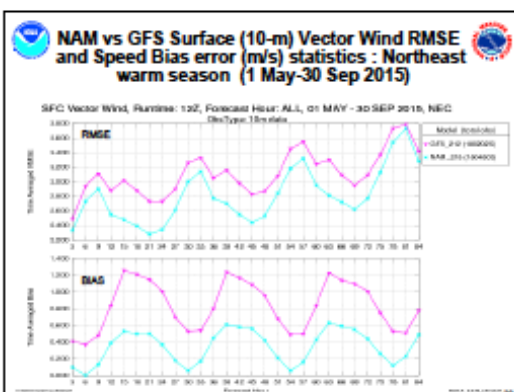
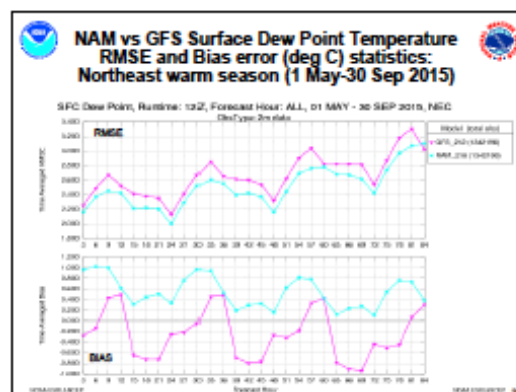
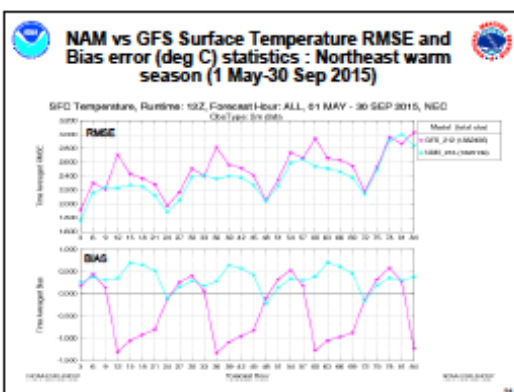
- GRIB2 tools: <http://www.ncep.noaa.gov/pmb/docs/grib2/>
- BUFRKIT software to decode/display BUFR station data: <http://wdfb.noaa.gov/tools/BUFRKIT/>
- Long-term archive: <http://nomads.ncep.noaa.gov/index.php>  
<http://nomads.ncep.noaa.gov/NAMGrid210/> (NAM predictions for the last year)  
<http://www.ncep.noaa.gov/data/ncdc/1313a/subquery?STATION=&appname=&outdate=FILE> (NAM predictions since 2000)





## Verification



- Historical precipitation skill scores for NCEP models:  
<http://www.emc.ncep.noaa.gov/mmb/tyr/tyrprvrt.html>
- Real-time NAM, GFS, RAP time series (last 10-30 days) verification vs upper-air and surface data at  
<http://www.emc.ncep.noaa.gov/mmb/mmbp/mmbvrt/>
- Real-time HIRSW vs NAM nests time series verification (last 10-30 days) vs upper-air/surface data at  
[http://www.emc.ncep.noaa.gov/mmb/mmbp/mmbvrt/mmbvrt.htm#\\_new\\_2007](http://www.emc.ncep.noaa.gov/mmb/mmbp/mmbvrt/mmbvrt.htm#_new_2007)
- Monthly near-surface (2-m Temperature, RH, 10-m Wind) GFS and NAM statistics from Dec 2010-present  
[http://www.emc.ncep.noaa.gov/mmb/mmbsearch/mmbvrt/nearstc\\_vrt.html](http://www.emc.ncep.noaa.gov/mmb/mmbsearch/mmbvrt/nearstc_vrt.html)








## Summary

- NOAA National Weather Service produces operational predictions of:
  - Weather variables (temperature, moisture, wind,...)
  - Ozone
  - PM2.5
  - Smoke
  - Dust
- Examples and links were provided for:
  - Real-time predictions
  - Archive
  - Tools
  - Verification

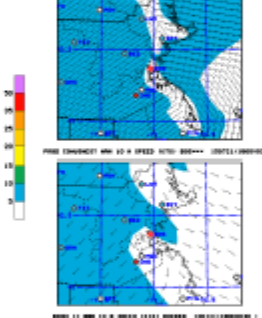
35

## BACKUP



## 4 km NAM nest (top) vs 12 km NAM (bottom)



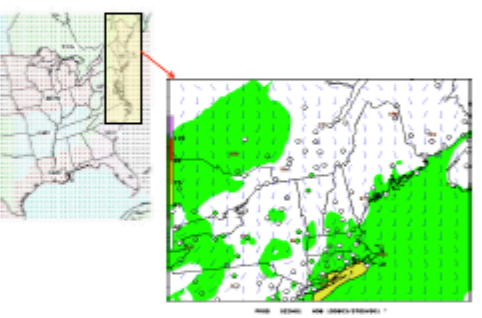
- Finer 4km resolution nest shows stronger wind over coastal ocean
- Also tends to resolve planetary boundary layer height differently in the coastal region

Figure provided by Jeff McQueen

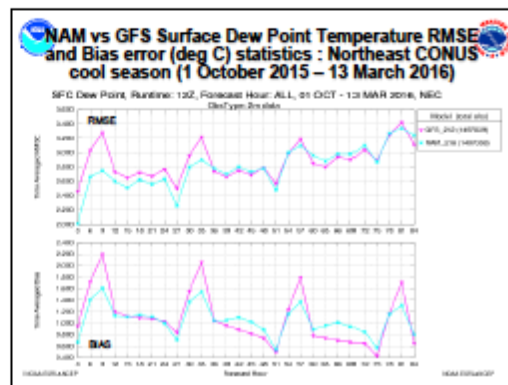
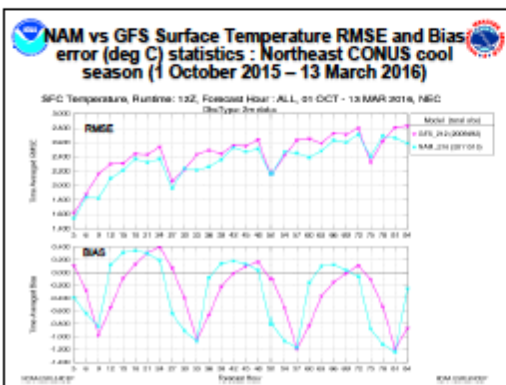
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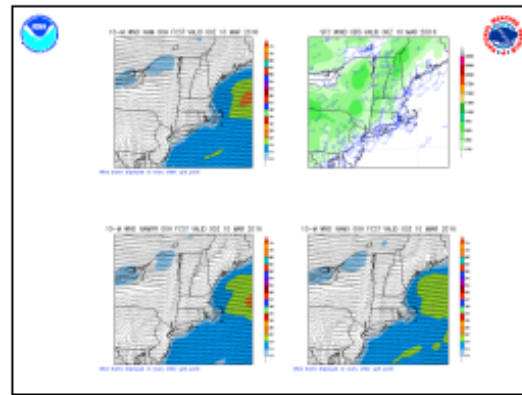
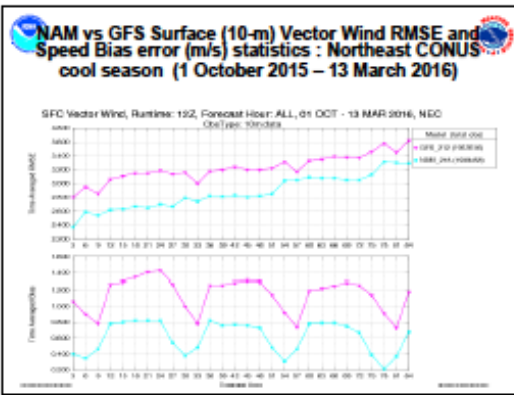



## Ozone (North East)



28





## Appendix H: A Discrete Event Simulation Model of Pediatric Asthma Exacerbation Slides

### A discrete event simulation model of pediatric asthma exacerbations

Jonathan Levy  
Professor of Environmental Health,  
Boston University School of Public Health

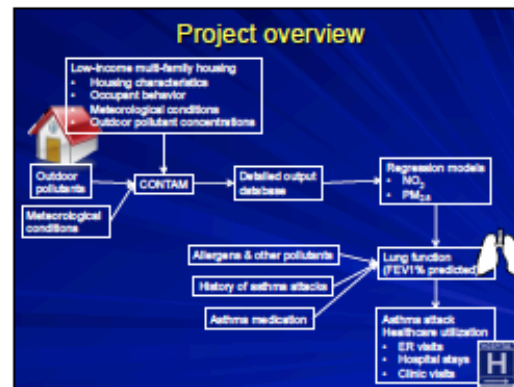
Analytic Solutions for Real-Time Biosurveillance  
Models for Risk of Asthma Exacerbations in Urban Environments  
March 30-31, 2016

### Discrete event simulation (DES)

- A systems science approach involving modeling of a complex system that evolves over time given changes in state variables that occur at defined points in time
  - Accounts for multiple individual attributes
  - Captures interactions and non-linear effects
  - Keeps track of prior history
- Used for many health policy analyses:
  - Schizophrenia, malaria, cardiovascular disease, breast cancer, depression, end-stage liver disease, peptic ulcer disease

### Environmental asthma policy model

- Developed by our group under an R21 from NIH
- Applied to case study of energy efficiency upgrade in multifamily housing (HUD)
- Currently being linked with electronic medical record data to parameterize model and characterize feedback loops
- Overarching idea: Examine the effects of small changes in exposure on asthma health care utilization outcomes, where observational studies are underpowered



### Pollution sources

- NO<sub>2</sub>: gas stove use, use of gas oven for supplemental heating in winter, outdoors
- PM<sub>2.5</sub>: cooking, environmental tobacco smoke (ETS), outdoors
- Humidity (mold): cooking, breathing, showering, dishwasher

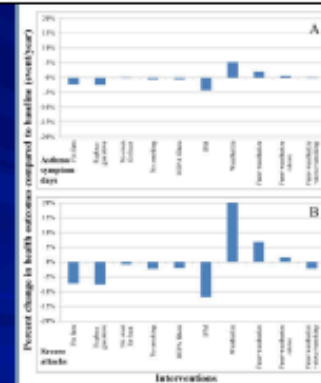
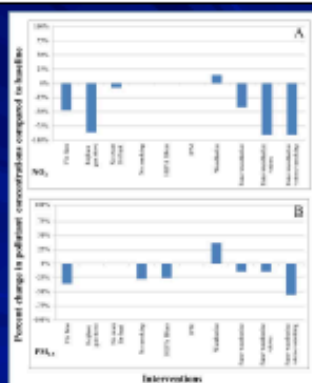
### Model application

1. Simulate a large number of children to detect potentially small changes in outcomes and costs
2. Evaluate/validate outputs from baseline simulation
3. Apply model to approximate benefits and costs of alternative intervention strategies



Intervention	Rationale	Modeling
1. Fix kitchen and bathroom fans	Proper spot ventilation will reduce exposure to pollutants associated with cooking and routine bathroom fan use during shower events (30 abx)	Assumed kitchen fan was operated 100% of time during cooking events (100 abx); turned bathroom fan 'off' during shower events (30 abx)
2. Replace gas with electric stove	Gas stoves are a source of $\text{NO}_2$ from cooking and supplemental heating; replacement with electric stoves will reduce exposure	Removed $\text{NO}_2$ stove source, substituting the replacement of gas stoves with electric stoves
3. Fix heating system (install radiant heating)	Functional heating will eliminate the need to heat with stove, and thus reduce pollutant exposures	Eliminated $\text{NO}_2$ source associated with the use of gas stove for supplemental heating
4. Smoke-free housing policy	Cigarettes are major source of indoor $\text{PM}_{2.5}$ ; removal of this source will lower exposures	Removed smoking sources
5. Use High-Efficiency Particulate Air (HEPA) filter	HEPA reduce exposure to particles from smoking and other sources	Reduced $\text{PM}_{2.5}$ by 30%

Intervention	Rationale	Modeling
6. Integrated Pest Management	Elimination of pest pathways will reduce allergen levels	Eliminated number of homes with holes to wall
7. Weatherize (air sealing, window replacement)	Elimination of air pathways will conserve energy	Blocked households in the highest categories of wall infiltration rates (category 2 and 3) down to one category. Category 1, equivalent to an efficient level of air exchange, remains the same
<b>Combined interventions</b>		
A. Weatherize (W) + fix exhaust fans (F1)		
B. Weatherize (W) + fix exhaust fans (F1) + replace gas stove (S2)		
C. Weatherize (W) + fix exhaust fans (F1) + replace gas stove (S2) + non-smoking policy (N4)		



## Linkage to prospective surveillance

- Simulation model with appropriate stressors (e.g., respiratory infections, temperature, air quality) could characterize how daily changes influence outcomes of interest
- Model could be programmed to identify characteristics of high-risk days
  - In general
  - Related to stressors of interest
  - Modifiable subset
- Stressor forecasting could be linked to model outputs to characterize likely high-risk days

## What would you need?

- Ability to forecast stressors and behaviors
- Epidemiological evidence connecting stressors with outcomes (directly or indirectly)
- Model with dynamic/seasonal behavior
- Strategy for regular updating and calibration of model

## Limitations

- Limited literature linking stressors to lung function, lung function to outcomes
- Challenge to characterize behavioral responses
- Simplified medication assignment
- Need to characterize detailed multivariate attributes of individuals to provide realistic model outputs




## Acknowledgements

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- Kadin Tseng
- Daniel Kamalic
- Lindsay Underhill
- Kimberly Vermeer
- Sharon Lee
- NIEHS (R21ES017522)
- HUD (MAHJU0008-12)

## References

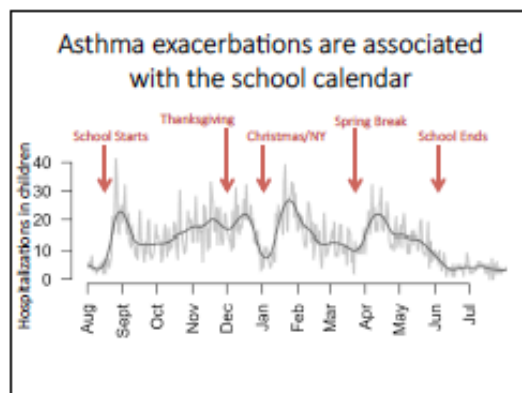
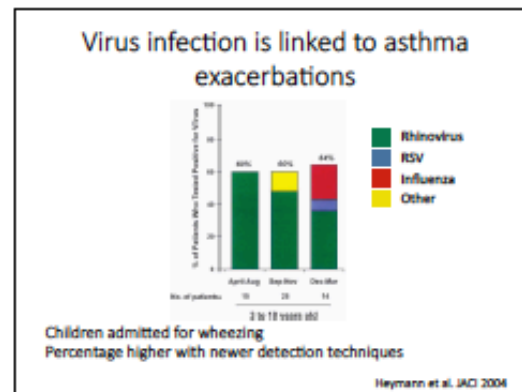
- Fabian MP, Adamkiewicz G, Stout NK, Sandel M, Levy JI. A simulation model of building intervention impacts on indoor environmental quality, pediatric asthma, and costs. *J Allergy Clin Immunol* 133: 77-84 (2014).
- Fabian MP, Stout NK, Adamkiewicz G, Geggel A, Ren C, Sandel M, Levy JI. The effects of indoor environmental exposures on pediatric asthma: A discrete event simulation model. *Environ Health* 11:56 (2012).
- Fabian MP, Adamkiewicz G, Levy JI. Simulating indoor concentrations of NO<sub>2</sub> and PM<sub>2.5</sub> in multifamily housing for use in health-based intervention modeling. *Indoor Air* 22: 12-23 (2012).
- Adamkiewicz G, Zota AR, Fabian MP, Chahine T, Julien R, Spengler JD, Levy JI. Moving environmental justice indoors: understanding structural influences on residential exposure patterns in low-income communities. *Am J Public Health* 101: S238-S245 (2011).

## Appendix I: Epidemic of the “Common Cold” and the Dynamics of Severe Asthma Exacerbation Slides

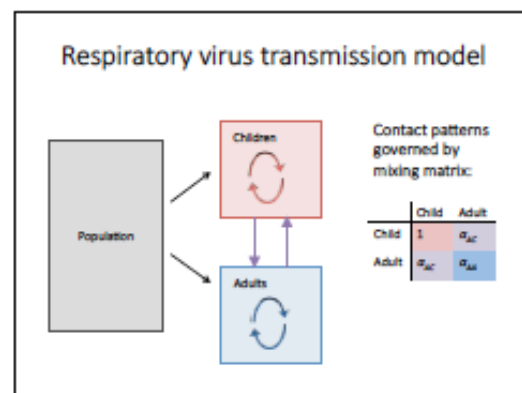
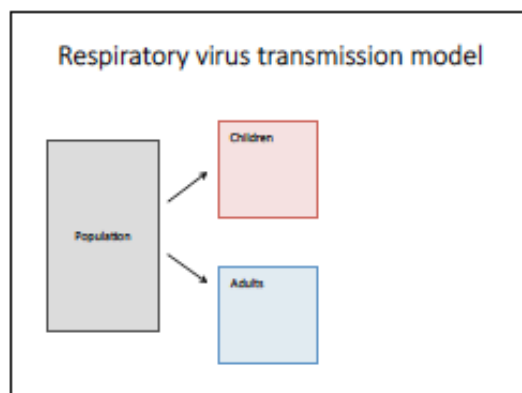




### Epidemics of the “common cold” and the dynamics of severe asthma exacerbation

RM Eggo, JG Scott, AP Galvani & LA Meyers  
[r.eggo@lshtm.ac.uk](mailto:r.eggo@lshtm.ac.uk)  
 Boston Public Health Commission – March 2016

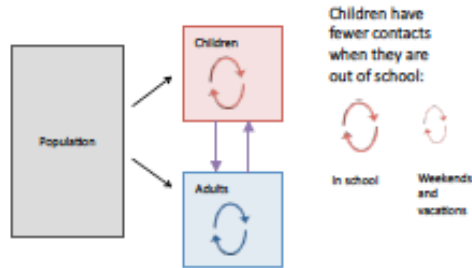


- ### Linking virus transmission to asthma
- Need to know virus prevalence to determine how at risk the population is
    - Data at a large scale are not available from surveys or samples
  - Use a model of realistic respiratory virus transmission to infer prevalence

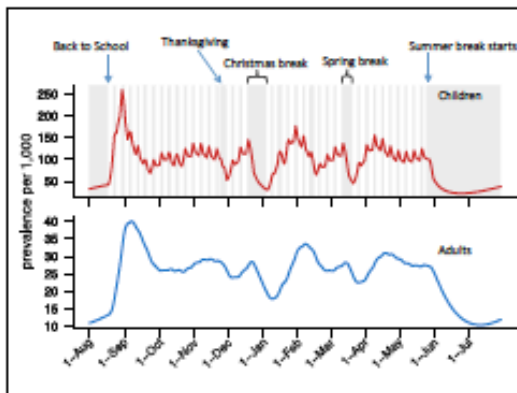
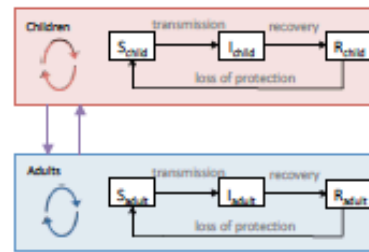




## Respiratory virus transmission model

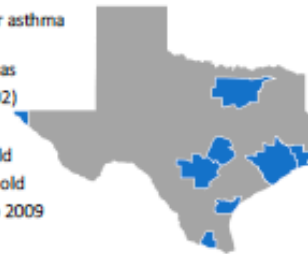


## Respiratory virus transmission model



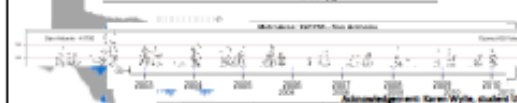
## Hospitalization Data

- Hospitalizations for asthma (ICD-9)
- 8 metropolitan areas
- 12.5m people (2002)
- 59% of population
- Child: 5-18 years old
- Adult: 19-55 years old
- Daily data: 2003 to 2009
- More than 65,000 hospitalizations
- Big study, big diverse state



## Model Components

Data	Source	Description
Common Cold	SRI transmission model	4-day aggregated common cold prevalence
Influenza prevalence	Hospitalization records	Daily state level hospitalizations per million due to influenza, in adults and children. Smoothed
Day of week	Calendar	
Time trend	Daily index value	
Local intercept	Metropolitan boundary	Geographic variation in baseline hospitalization rate
Low temperature	CDC Wonder	Daily maximum temperature in counties in the metropolitan area, Celsius
Diurnal	AQI	Daily ozone, Air Quality Index value
PM 2.5	CDC Wonder	Maximum daily PM 2.5 for counties in the metropolitan area, $\mu\text{g}/\text{m}^3$

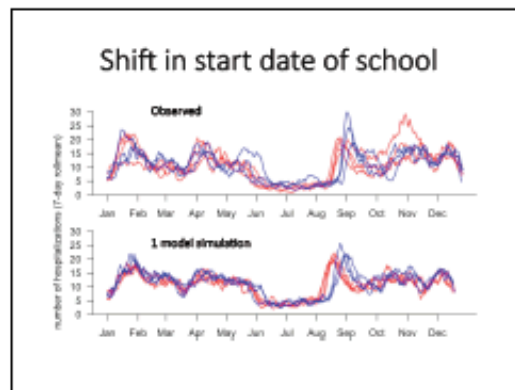
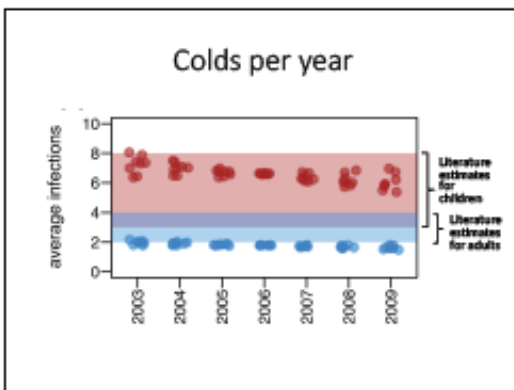
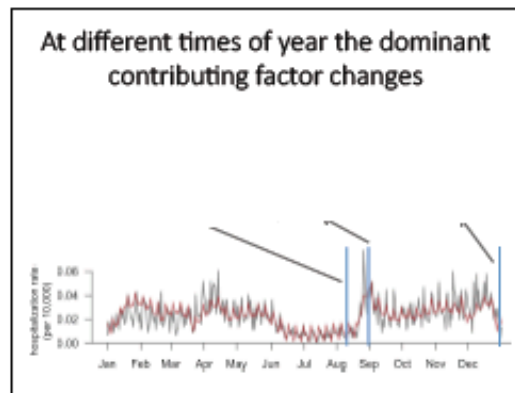
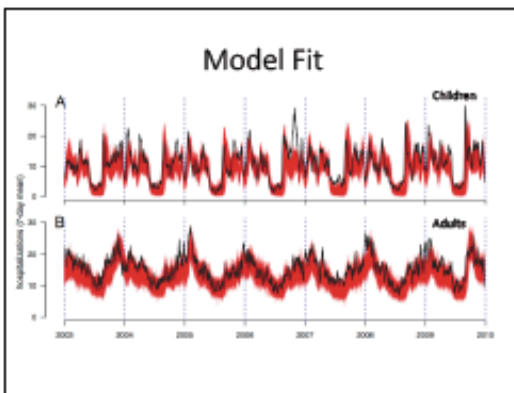


## Best fitting model

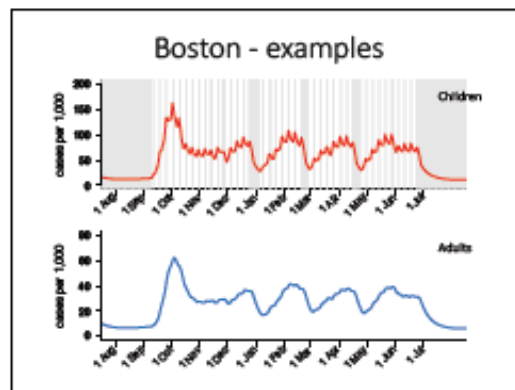
Data	Source	Description
Common Cold	SRI transmission model	4-day aggregated common cold prevalence
Influenza prevalence	Hospitalization records	Daily state level hospitalizations per million due to influenza, in adults and children. Smoothed

Day of week	Calendar	
Time trend	Daily index value	
Local intercept	Metropolitan boundary	Geographic variation in baseline hospitalization rate
Low temperature	CDC Wonder	Daily maximum temperature in counties in the metropolitan area, Celsius

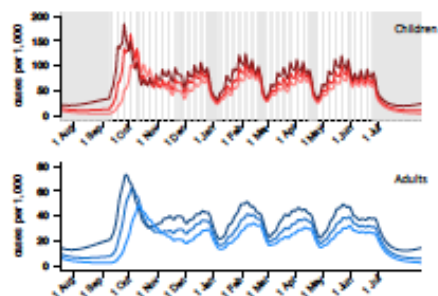
Diurnal	AQI	Daily ozone, Air Quality Index value
PM 2.5	CDC Wonder	Maximum daily PM 2.5 for counties in the metropolitan area, $\mu\text{g}/\text{m}^3$



- ### Conclusions
- Common cold transmission model provides a harmonious explanation for the patterns of severe asthma exacerbations seen in Texas
  - Prevalence of infection is a shifting baseline of risk to the population driven by contact patterns of children in school
  - Variation in school calendars can alter the risk baseline in a strongly non-linear way



## Boston - examples



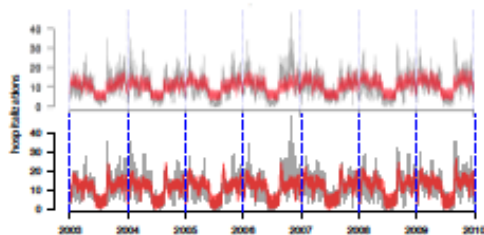
## Acknowledgments

Karen Wylie – UT Austin  
 Tom Hladish – University of Florida  
 Simon Cauchemez – Institut Pasteur  
 Texas Advanced Computing Center

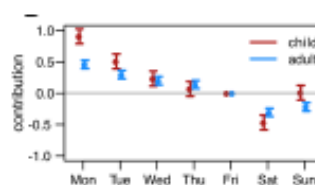
Published January: 10.1073/pnas.1518677113  
 r.egger@lshtm.ac.uk



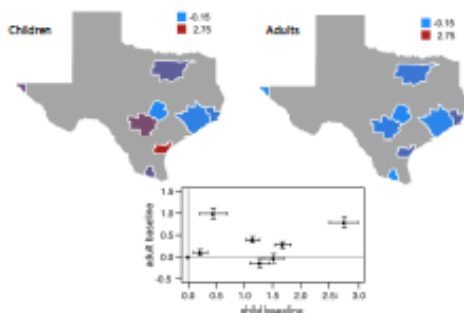
## What if kids are just allergic to school?



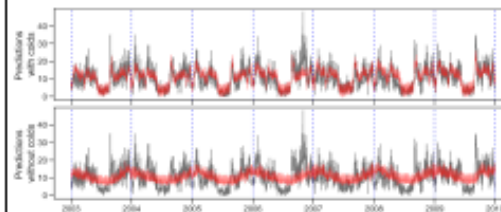
## Day of week coefficient

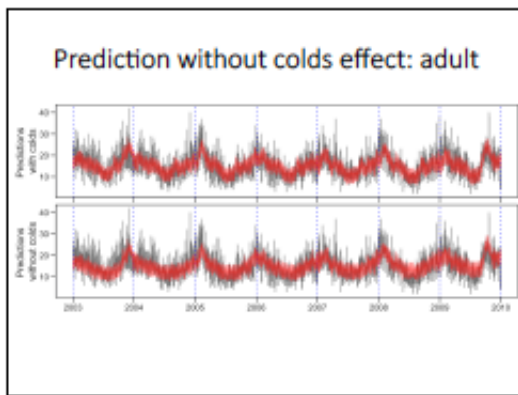


## City-specific baseline



## Prediction without colds effect: child






## Appendix J: Disease Prediction

# Disease Prediction

**March 30, 2016**  
ISDS Consultancy - Boston

**Anna L. Buczak, PhD**  
Anna.buczak@jhupl.edu  
443-778-8350





### Outline

- Challenges of disease prediction
- Predicting Infectious disease Scalable Method (PRISM)
  - › Method description
  - › Dengue in Peru
  - › Dengue in Philippines
  - › Malaria in South Korea
- Predicting Influenza
  - › PRISM for predicting peak location
- Conclusions

### PRISM Overview

- Predicting Infectious disease Scalable Method (PRISM)
  - PRISM is a novel data mining method (based on Fuzzy Association Rule Mining) to predict disease outbreaks.
  - The method looks at a large amount of data found in various predictor variables, e.g., rainfall, temperature, vegetation indices, past incidence.
  - The proof of concept in Peru with dengue was promising, leading to the extension of the method for dengue in the Philippines and for malaria prediction in Korea.

**GOAL:** Create a capability that transforms how decision makers predict the incidence of infectious disease, enabling them to reduce morbidity and save lives through effective mitigation efforts.

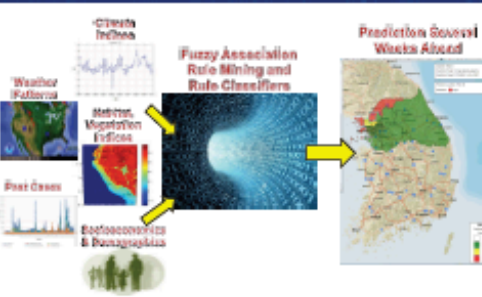



### Disease Prediction Challenges


- Gigabytes of historical data (~447 GB)
- Data is messy
- Making sense of all that data is a hard problem
  - › Data associations are difficult to identify
    - With 100 variables there are about  $2.5 \times 10^6$  possible rules with 6 antecedents
    - With 100 variables there are about  $1.5 \times 10^6$  possible combinations of inputs to prediction models with one pre-specified output
- Predicting Infectious disease Scalable Method (PRISM) – a novel method
  - › Not agent-based
  - › Leverages existing best-of-breed large data analytic approaches (Fuzzy Association Rule Mining) to automatically find rules in the data
    - Does not generate all theoretically possible combinatorial rules
    - Does not make any assumptions about the rules that are to be extracted, removing a bias that humans might have

W. Agazzi, T. Inselkötter, and A. Bressan, "Mining Association Rules between Data of Some Large Databases", Proceedings of the International Conference on Management of Data, Washington, D.C., pp. 265-278, May 1995.  
K.M. Park, A. Fu, and M.H. Wang, "Mining Fuzzy Association Rules in Databases", ACM SIGMOD Record, 27(1), pp. 41-48, New York, NY, 1996.

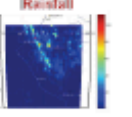
### Machine Learning and Data Mining for Disease Prediction



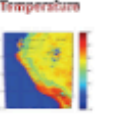
### Predictor Variables



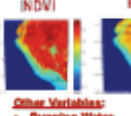
**Past Cases**



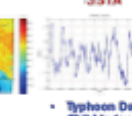
**Rainfall**




**Temperature**




**NDVI**



**EVI**



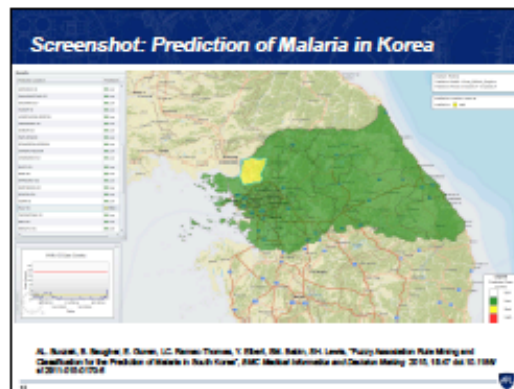
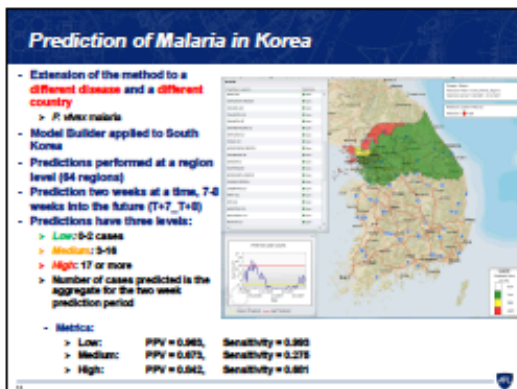
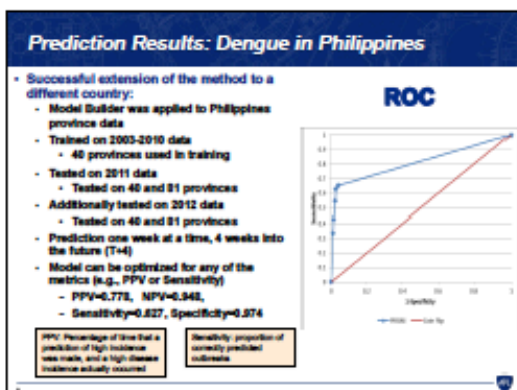
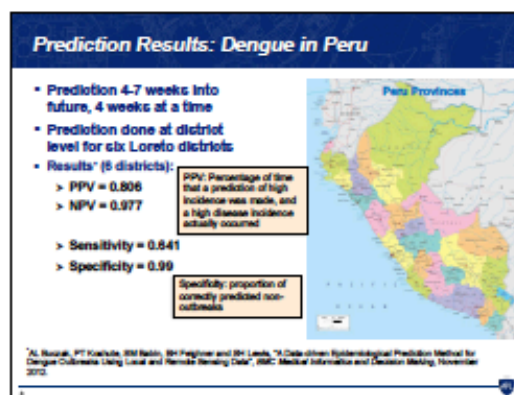
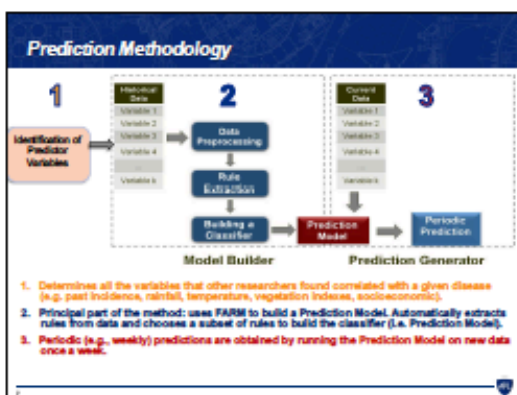
**SSTA**



**SOI**

**Other Variables:**

- Running Water
- Sanitation
- Electric Lighting
- Elevation
- Typhoon Data
- Child Injuries
- International Aid:
  - Mosquito Nets
  - Financial Aid

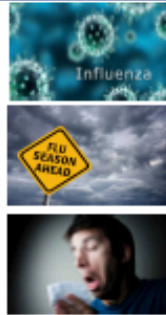




## Influenza Prediction - Goal

- Analysis of the military influenza-like-illness (ILI) incidence with the goal of prediction of:

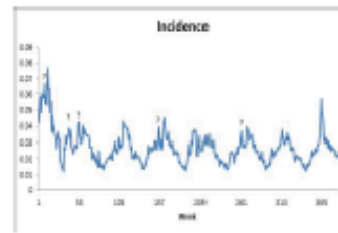
- Weeks of peak ILI incidence
- Incidence rate at peak
- Total number of cases



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## Determination of Peak Location (1)

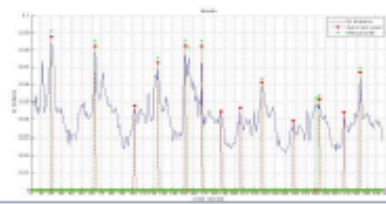
- Definition of peak is somewhat ambiguous
- Four peak detection algorithms developed



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## Determination of Peak Location (2)

- Best algorithm still identified some spurious peaks
- Telecon with Matt Biggerstaff from CDC to discuss peak location
- Final algorithm: algorithm 3 with some modifications:
  - Mostly one peak per season
  - When a peak's value was within 5% of the value of the highest peak for a given season, it was added as a peak to overcome problems with reporting



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## Predictor Variables

- Past Military influenza like illnesses (ILI) data (AFHSC)
- Rate of ILI reported (CDC)
- Rate of positive Lab tests for Flu (CDC)
- P&I Mortality Rate (CDC)
- Rate of hospitalization due to Influenza (CDC)
- Rainfall (NASA)
- Temperature (NOAA)
- Relative humidity – derived from temperature and Dew Point
  - Ratio of the partial pressure of water vapor in the air-water mixture to the saturated vapor pressure of water
- Specific humidity – derived from temperature and pressure
  - Ratio of water vapor to dry air in a particular mass
- Atmospheric pressure (NOAA)
- Dew Point (NOAA)
  - Temperature below which the water vapor in a volume of humid air at a given constant barometric pressure will condense into liquid water at the same rate at which it evaporates
- Most predictor variables are used with time stamps T-1, ..., T-12

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## Results

- Data divided into:
  - Training set: 8/27/2008-7/31/2011
  - Fine-tuning set: 8/1/2010 to 7/31/2011
  - Testing set: 8/7/2011 to 1/8/2013
- Prediction performed for T+4, T+6 (3 weeks) at a time
- Two approaches for building classifiers developed:
  - Build three classifiers; one for predicting a peak at T+4, one for T+5 and one for T+6. Outputs of the classifiers fused by an OR statement: IF (Predicted\_Peak\_T+4 OR Predicted\_Peak\_T+5 OR Predicted\_Peak\_T+6) THEN Predicted\_Peak\_4\_6
  - One classifier is trained that predicts a peak 4-6 weeks out

Method	PPV	NPV	Sensitivity	Specificity
Fusion	0.3786	0.9050	0.8216	0.8421
One classifier 1	0.5062	0.9892	0.6917	0.9770
One classifier 2	0.6033	0.9055	0.8063	0.9052

AL. Buzsak, B. Baughar, E. Guven, L. Moniz, SM. Babic, J. P. Chelvin. "Prediction of Peaks of Seasonal Influenza in Military Healthcare Data." Accepted for publication by Biomedical Engineering and Computational Biology Journal.2016.

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## Summary

- APL developed a set of methods for disease prediction:
  - PRISM:
    - Provides a novel disease prediction method
    - Predictions performed for several diseases: dengue and malaria
    - Prediction of peak location for influenza
  - Flexible, scalable methodology
    - Predictions are 4-6 weeks out
    - Predictions are at various geographical resolutions: province, district, region, county
- Method of analogues for influenza successfully predicts (4 weeks out):
  - Incidence rate at peak
  - Total number of cases

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## Method of Analogues

- Method of Analogues uses past time sequences of values to predict future sequences of values



## Prediction Metrics

- Prediction accuracy should be quantified:
  - Overall accuracy: proportion of predictions that are correct:  $(TP+TN)/(TP+TN+FP+FN)$
  - Positive Predictive Value (PPV): proportion of positive predictions that are outbreaks:  $TP/(TP+FP)$
  - Negative Predictive Value (NPV): proportion of negative predictions that are non-outbreaks:  $TN/(TN+FN)$
  - Sensitivity: proportion of correctly predicted outbreaks:  $TP/(TP+FN)$
  - Specificity: proportion of correctly predicted non-outbreaks:  $TN/(TN+FP)$
  - False Alarm Rate: proportion of incorrectly predicted non-outbreaks:  $FP/(FP+TN)$

	Actual Positive	Actual Negative
Prediction Positive	True Positive (TP)	False Positive (FP)
Prediction Negative	False Negative (FN)	True Negative (TN)



## Appendix K: Towards Asthma Air Aware Day Alert for Houston, TX Slides

### Toward ASTHMA AIR AWARE DAY Alert for Houston, TX

Loren H. Raun, Ph.D.  
Katherine (Kathy) B. Ensor, Ph.D.  
Rice University

#### Our example e-mail to school nurses

##### Objectives:

- Identify the most severe days
- Make nurses aware of pollution and its potential impact
- Do not overwhelm the already overwhelmed system

##### Today is a Houston Asthma Air Aware Day

Consider taking the following precautions to prevent an asthma exacerbation. Modify actions according to the needs of your population while also minimizing disruption or opportunities for exercise.

1. Notify PE teachers, coaches or appropriate staff.
2. Monitor asthma student for symptoms of asthma exacerbation. If needed, adjust outdoor recess for asthmatic students.
3. Review asthma maintenance medication regimen compliance and availability of rescue medication with development as needed.
4. Review Asthma Action Plans. Examine students who might be at risk due to lack of compliance with maintenance medication.

Raun et al. Environmental Health 2014, 13:88 <http://www.ehjournal.net/content/13/1/88>  
RESEARCH Open Access  
Using community level strategies to reduce asthma attacks triggered by outdoor air pollution: a case crossover analysis  
Loren H Raun,2\*, Katherine B Ensor1 and David Perera1,4

#### Approach

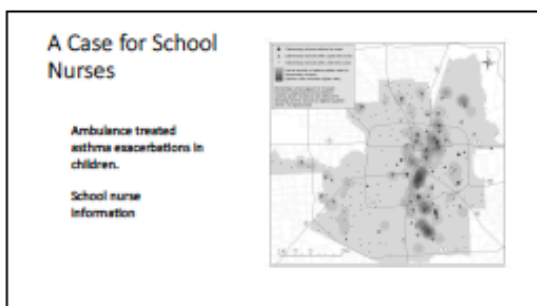
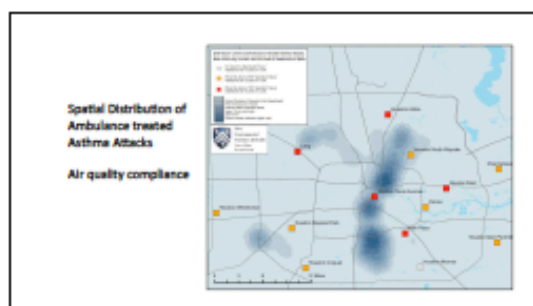
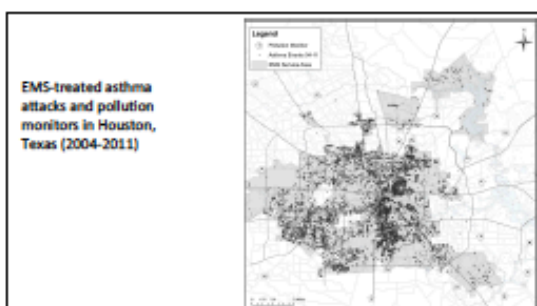
- Employed case-crossover design + conditional logistic regression to determine the risk from multiple pollutants
  - Study design manufactures controls – removes differences across subjects
  - Must deal with varying correlations in multiple pollutants
  - We have several strategies underway to address this issue – taking into account both the dynamic spatial and temporal structure
    - Schwenmberger, Rejzler and Ison (2014) logistical model approach to multipollutant modeling
    - Melnikow, Raun and Ensor (2014) Dynamic PCA approach to Houston multi-pollutant modeling
- Concentration response was used to identify concentration levels suitable to employ warning.
- Created a model to predict the high risk days based on pollution.

#### Case-crossover Design

- In the case-crossover design, each individual experiencing a health event serves as his or her own reference.
- Individuals act as their own control. Provides a pseudo case-control design for observational studies.
- Ambient air pollution is used as a proxy for personal exposure.
- Concentrations at similar times when the study individual is not experiencing the health event are the reference concentrations.
- The reference concentrations are statistically compared with the concentrations at the time individual experienced the health event. (same for spatial differences)
- Conditional logistic regression, conditioning on subject, is applied to estimate the association of pollution and increased relative risk of the health event while controlling for confounding factors.

#### Study Characteristics

- Data obtained from the Houston Fire Department EMS call database
- The working assessment was asthma and treatment administered was nebulized albuterol
- There were n = 11,754 cases from 2004-2011
- The working assessment input is determined by EMS personnel and identifies the primary reason for treatment.
- Pollution data were obtained from the Texas Commission of Environmental Quality (TCEQ).
- Hourly data from 35 ozone, 13 NO<sub>2</sub>, 9 CO, 9 PM<sub>2.5</sub>, and 8 SO<sub>2</sub> monitors in the Houston Metropolitan Area were used.
- The daily average values of ozone, NO<sub>2</sub>, CO, PM<sub>2.5</sub>, and SO<sub>2</sub> were calculated across monitors.



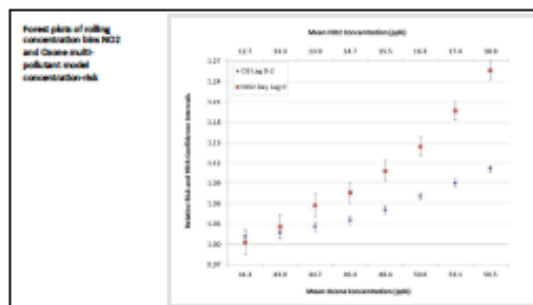
Houston counts

	month	count	med_o3	med_no2	med_pm10	count_o3_500
1	1-Jan	1410	43.739948	13.3841792	34.3397172	1194
2	1-Feb	1258	34.1791827	11.827821	31.3158461	974
3	1-Mar	1136	44.1382827	10.9534008	42.3743032	1000
4	1-Apr	1235	47.1703813	8.8751608	35.4327793	901
5	1-May	1040	43.4252467	7.51125	36.125	753
6	1-Jun	880	36.1704618	6.9763831	37.6014701	708
7	1-Jul	119	31.6122574	6.5246470	27.2985512	752
8	1-Aug	1050	40.5216796	7.8481188	31.3817763	786
9	1-Sep	1284	40.4319327	10.2477370	40.3885928	943
10	1-Oct	1583	41.1410216	10.9467187	40.3885928	943
11	1-Nov	1113	33.7285177	10.1535537	32.4142146	1086
12	1-Dec	974	38.7921708	11.5481664	41.6651976	1074

Pollutant	Lag	RR	95% CI		95% CI		95% CI	
			RR	95% CI	RR	95% CI	RR	95% CI
Analysis of relative risk for EMS-treated asthma attacks per 100 increase in single pollutant	NO <sub>2</sub> (ppb)	0 Day	1.12	1.07-1.17	1.08	1.06-1.10	1.11	1.06-1.16
		1 Day	1.04	0.99-1.09	1.02	0.99-1.05	1.03	1.00-1.11
		2 Day	1.03	0.98-1.07	1.00	0.96-1.11	1.01	0.96-1.06
		3 Day	1.02	0.96-1.06	1.00	0.96-1.12	1.00	0.95-1.05
		0 to 7	1.08	1.03-1.13	1.07	0.98-1.17	1.08	1.03-1.13
	O <sub>3</sub> (ppb)	0 Day	1.07	1.02-1.09	1.00	0.99-1.08	1.04	1.00-1.10
		1 Day	1.03	0.98-1.09	1.00	0.94-1.04	1.04	1.00-1.07
		2 Day	1.02	0.97-1.04	1.00	0.94-1.08	1.01	0.97-1.04
		3 Day	1.01	0.96-1.04	1.00	0.94-1.08	1.00	0.94-1.05
		0 to 7	1.04	1.00-1.08	1.00	0.94-1.07	1.00	1.00-1.10
CO (ppm)	0 Day	1.04	1.00-1.07	1.00	0.98-1.04	1.17	1.00-1.18	
	1 Day	1.04	1.00-1.07	1.00	0.94-1.06	1.04	1.00-1.10	
	2 Day	1.03	0.98-1.08	1.00	0.94-1.07	1.07	1.00-1.15	
	3 Day	1.01	0.96-1.04	1.00	0.94-1.08	1.04	0.97-1.06	
	0 to 7	1.07	1.03-1.11	1.00	0.94-1.08	1.17	1.00-1.27	
PM <sub>10</sub> (µg/m <sup>3</sup> )	0 Day	1.03	0.98-1.08	1.00	0.96-1.04	1.00	0.97-1.06	
	1 Day	1.02	0.97-1.07	1.00	0.94-1.06	1.00	0.97-1.07	
	2 Day	1.04	1.00-1.07	1.00	0.94-1.07	1.00	1.00-1.12	
	3 Day	1.03	0.98-1.06	1.00	0.94-1.07	1.01	0.94-1.06	
	0 to 7	1.04	1.00-1.07	1.00	0.94-1.08	1.03	0.97-1.10	
SO <sub>2</sub> (ppb)	0 Day	1.03	0.97-1.08	1.00	0.94-1.11	1.02	0.94-1.09	
	1 Day	0.99	0.93-1.07	0.96	0.90-1.07	1.00	0.93-1.06	
	2 Day	1.02	0.97-1.07	1.00	0.94-1.12	1.00	0.94-1.07	
	3 Day	0.99	0.94-1.04	1.00	0.94-1.12	0.97	0.90-1.05	
	0 to 7	1.03	0.98-1.10	1.00	0.94-1.11	1.01	0.95-1.12	

\*RR and 95% CI represent the relative risk and 95% confidence interval, respectively.

†RR and 95% CI represent the relative risk and 95% confidence interval, respectively, controlling for the other pollutants.



Relative risk for multi-pollutants by quartile of concentrations during study period

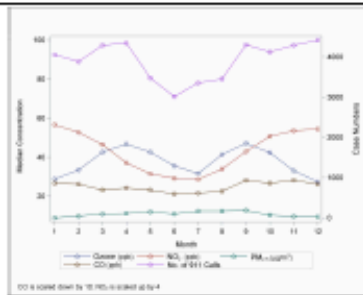
		Q 1 NO <sub>2</sub> ≤ 7 ppb	Q 1 NO <sub>2</sub> 8-11 ppb	Q 2 NO <sub>2</sub> 11-15 ppb	Q 4 NO <sub>2</sub> ≥ 15 ppb
Relative Risk and Confidence Interval					
Q 1 O <sub>3</sub> < 28 ppb	Cases	507	362	685	508
	Days	349	232	443	317
	OR	0.99 (0.91-1.04)	0.91 (0.80-1.02)	0.99 (0.92-1.04)	0.99 (0.91-1.05)
	NO <sub>2</sub>	0.99 (0.91-1.04)	0.81 (0.68-0.96)	0.98 (0.91-1.05)	1.29 (1.17-1.42)
Q 2 O <sub>3</sub> 28-36 ppb	Cases	537	526	574	595
	Days	394	384	422	446
	OR	1.00 (0.99-1.02)	1.00 (0.99-1.02)	1.00 (1.00-1.02)	1.00 (0.98-1.02)
	NO <sub>2</sub>	0.45 (0.41-0.50)	0.87 (0.80-0.95)	0.98 (0.94-1.02)	1.24 (1.21-1.27)
Q 3 O <sub>3</sub> 36-48 ppb	Cases	508	572	568	567
	Days	331	388	386	382
	OR	1.00 (1.00-1.07)	1.04 (1.00-1.07)	1.02 (1.01-1.03)	1.00 (1.01-1.00)
	NO <sub>2</sub>	0.55 (0.52-0.61)	0.81 (0.75-0.87)	1.00 (1.00-1.00)	1.44 (1.38-1.50)
Q 4 O <sub>3</sub> > 48 ppb	Cases	496	546	584	592
	Days	318	389	420	417
	OR	1.15 (1.08-1.24)	1.09 (1.06-1.13)	1.07 (1.06-1.08)	1.06 (1.04-1.07)
	NO <sub>2</sub>	0.75 (0.67-0.85)	0.86 (0.80-0.90)	1.12 (1.09-1.15)	1.44 (1.38-1.50)

\*95% Bayes Log P < 0.001 Bayes Log P

## Aggregate pollution findings

- Ozone and NO<sub>2</sub> concentrations dip in June and July as do the number of EMS cases.
- July has the lowest frequency of days when the maximum eight hour average concentration of ozone met or exceeded 76 parts per billion at a monitor.
- These lower ozone concentrations in June and July coincide with high daily rain frequency in these months.
- Correlation between daily measures of air pollutant concentrations and apparent temperature indicate the strongest correlations between daily pollutants were between NO<sub>2</sub> and CO ( $r = 0.74$ ) followed by NO<sub>2</sub> and SO<sub>2</sub> ( $r = 0.57$ ), by CO and SO<sub>2</sub> ( $r = 0.56$ ), daily PM<sub>2.5</sub> and ozone ( $r = 0.42$ ). The correlation between ozone and NO<sub>2</sub> was ( $r = 0.23$ ).
- The strongest correlation between a pollutant and apparent temperature was for NO<sub>2</sub> ( $r = -0.54$ ).

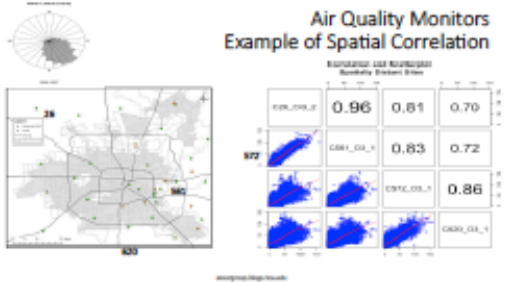
Number of EMS-treated asthma calls in Houston by month and median pollution concentration (2006-2011)



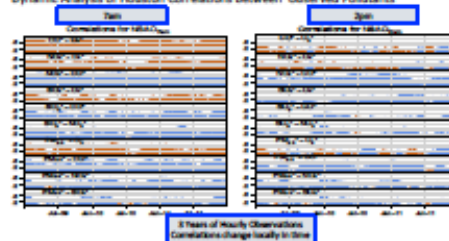
## Asthma Warning System Pilot

- Following this research, a pilot study was designed and implemented using a predictive model to create a warning for nurses in the Houston Independent School District.
- The goal is something SIMPLE. Our simple model uses
  - NO<sub>2</sub> levels observed from 9pm to 2am the night before
  - 8 hour maximum ozone level for the day before
  - Forecast of weather (apparent temperature, cloud cover, precipitation) for day of
  - Alert is issued between 5 and 6am via e-mail to school nurses
- The nurses would then prepare accordingly if a warning was given.

## Air Quality Monitors Example of Spatial Correlation



## Toward Multi-Pollutant Model Dynamic Analysis of Houston Correlations between Observed Pollutants



### Limitations – so many....but

- Observational study with biases
- EMS based – population is not represented as a whole and this is especially true for asthma but fits our goal of reducing EMS calls for asthma.
- We ran our models on the RODE data and obtained similar results. We have also done similar analysis using admissions data for Texas Children's Hospital.
- Multi-pollutant modeling for acute health impact is problematic and we are addressing this issue further.
- Statistical methods can be improved, but not sure we will get better knowledge
  - Spatial-temporal work has been conducted but we were unable to get it published.
  - Fell back to case-crossover with spatial averages.
- Model forecast for warning days – over predicts high risk days, but not severely. Further, the over prediction may be appropriate.

## Appendix L: Bayesian Network Approaches Slides

**ISDS Consultancy on  
Predictive Capability for Asthma  
Exacerbations in Boston:  
Modeling Session  
Bayesian Network Approaches**

Howard Burkum  
Johns Hopkins Applied Physics Laboratory

[http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1839158/pdf/AMIA2006\\_0604.pdf](http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1839158/pdf/AMIA2006_0604.pdf)  
**AMIA Annual Symposium, 2006-684-8**  
**Detecting Asthma Exacerbations in a Pediatric  
Emergency Department Using a Bayesian Network**  
David I. Sanders, MD, MS<sup>1</sup>, Daniela Aronow, MD, PhD<sup>2,3</sup>  
<sup>1</sup>Dept. of Biomedical Informatics, <sup>2</sup>Dept. of Emergency Medicine,  
Vanderbilt University Medical Center, Nashville, TN

**Objective:** To develop and evaluate a Bayesian network to identify patients eligible for an asthma care guideline using only data available electronically at the time of patient intake.

**Electronic medical records, computerized decision support, and expert systems are being used to improve patient care.**

Variable	Values
Asthma Exacerbation	Present, Absent
History of Asthma	Number of visits: 0, 1, >1
Allergy Status	Number of visits: 0, 1, >1
Chief Complaint	1-6: major complaints
Age Group	0-5, 6-11, 12-17, 18-24, 25-34, 35-44, 45-54, 55-64, 65-74, 75-84, 85-94, 95-104

Figure 1: On the left is displayed the Bayesian network structure; on the right are network variables and possible values.

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**Sample Detection Performance Results**

Figure 2: ROC curves for the final Bayesian network.

	80	85	90	95
Sensitivity (%)	96.8	97.4	98.3	98.8
Specificity (%)	95.8	95.4	94.7	93.8
Positive PV (%)	97.8	98.3	98.8	99.3
Negative PV (%)	29.2	32.8	36.8	40.8
Negative LR	0.21	0.18	0.11	0.07

Diagnosis	Number
Upper respiratory infection	13 (1.3%)
Viral syndrome	8 (0.8%)
Comp	7 (0.7%)
Comp	4 (0.4%)
Other	4 (0.4%)

**Fusion Capability Designed to Answer:**

- How would an experienced health monitor make investigation decisions given the luxury of examining all data sources every day?
- How can the principal information supporting these decisions be presented most conveniently?
- What follow-up data details would this monitor find most helpful in deciding whether and how to investigate?

**Concept: Population-based Bayes Networks**

- Method of combining information from the monitored population
  - Algorithm results from multiple data streams of varying relevance (not raw data)
  - More than a rule set: an analytic umbrella that can also include report-based results, incomplete data updates, other multivariate methods
- Not Bayesian statistics in the sense of hierarchical modeling, fixed/random effects (could incorporate)
- Not an agent-based Bayesian model representing every individual as a separate node with properties

**A Bayesian Belief Network for Murray Valley encephalitis virus risk assessment in Western Australia**

Source: [http://www.sciencedirect.com/sci...](http://www.sciencedirect.com/science/article/pii/S0950268805000000)

Figure 3: Bayesian Belief Network for Murray Valley encephalitis virus risk assessment.

```

graph TD
    H[HealthWQ Fusion BN] --> HI[Health Indicator BN]
    H --> WQ[Water Quality BN]
    HI --> B1[degree of belief that an outbreak is underway]
    WQ --> B2[degree of belief that water supply is contaminated]
    HI --> A[Syndromic Algorithm Outputs Selected, Filtered Health Data External Information]
    WQ --> A
    WQ --> B3[WQ Algorithm Outputs Selected, Filtered Sensor Data External Information]
  
```

[illegible]

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