Infrastructure and Methods to Support Real Time Biosurveillance

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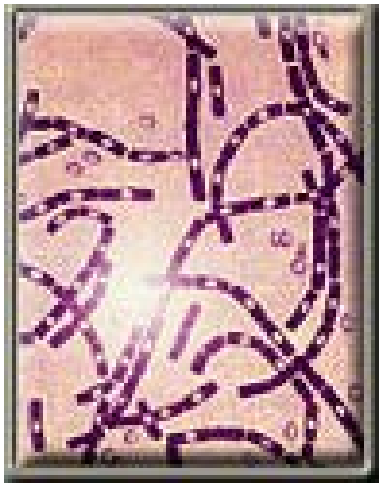
Category A agents

- Anthrax (*Bacillus anthracis*)•
- Botulism (*Clostridium botulinum toxin*)»
- Plague (*Yersinia pestis*)»
- Smallpox (*Variola major*)»
- Tularemia (*Francisella tularensis*)»
- Viral hemorrhagic fevers

  (*filoviruses* [e.g., Ebola, Marburg] and *arenaviruses* [e.g., Lassa])



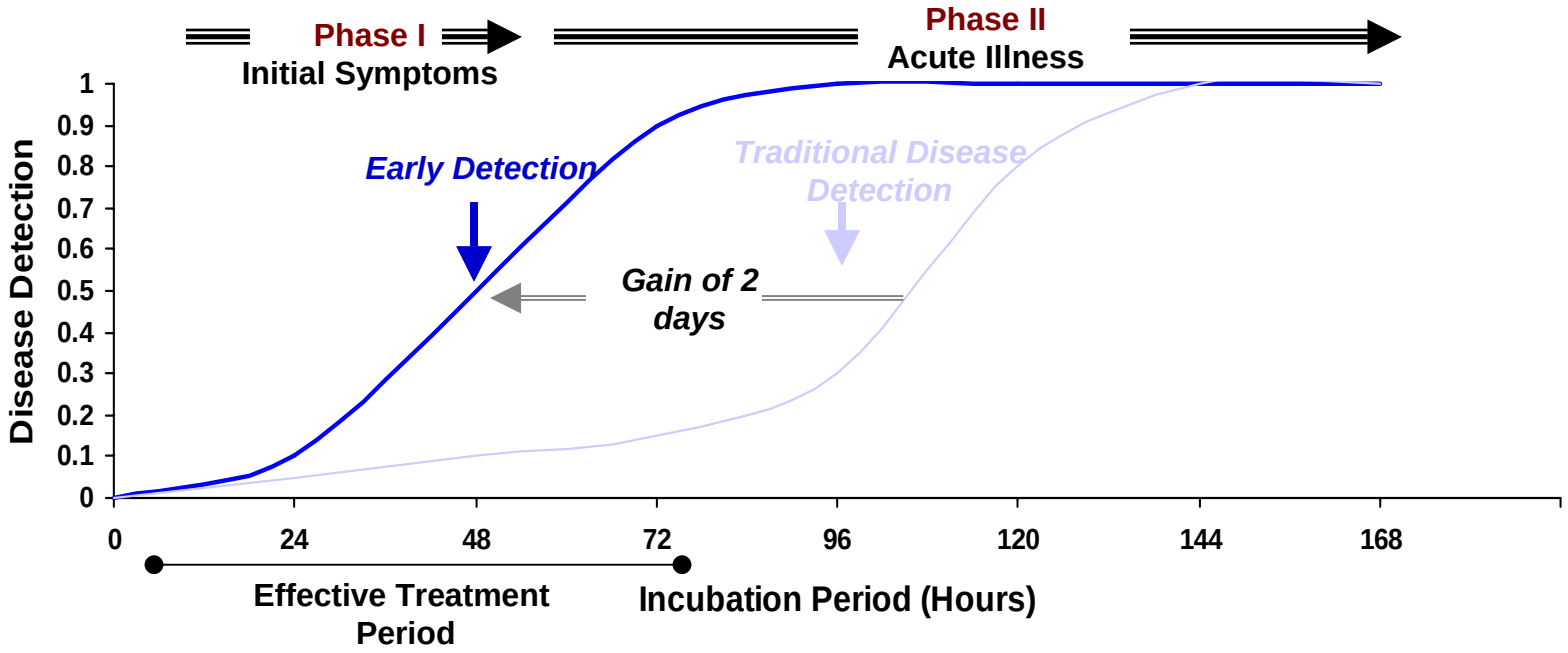
Natural history—Anthrax

- Incubation is 1-6 days
- Flu like symptoms followed in 2 days by acute phase, including breathing difficulty, shock.
- Death within 24 hours of acute phase
- **Treatment must be initiated within 24 hours of symptoms**

Attack scenario—Anthrax

- State sponsored terrorist attack
- Release of Anthrax, NYC subway
- No notification by perpetrators
- **1% of the passengers exposed during rush hour will contract the disease**

Need for early detection



But . . .

- Until now, there has been no real time surveillance for *any* diseases
- The threat of bioterrorism has focused interest on and brought funding to this problem

Where can real time information have a beneficial effect?

- Diagnosis
  - ✓ Decision Support
- Response
  - ✓ Coordination
  - ✓ Communication
- Surveillance
  - ✓ Detection
  - ✓ Monitoring

Surveillance of what?

- Environment
  - ✓ Biological sensors
- Citizenry
  - ✓ Health related behaviors
  - ✓ Biological markers
- Patient populations
  - ✓ Patterns of health services use
  - ✓ Biological markers

Syndromic surveillance

- Use patterns of behavior or health care use, for early warning
- Example, *influenza-like illness*
- Really should be called “prodromic surveillance”

Early implementations

- Drop in surveillance
  - ✓ Paper based
  - ✓ Computer based
- Automated surveillance
  - ✓ Health care data
  - ✓ “Non-traditional” data sources

Syndromes tracked at WTC 2001

TABLE. Definitions and frequency of syndromes under surveillance — New York City, 2001

Syndrome	Description	Potential BT agent/exposure
Anxiety	Anxiety reaction including somatic complaints, insomnia	None
Asthma	Exacerbation of underlying respiratory condition	None
Botulism-like	Cranial nerve impairment with weakness	Botulinum toxin
Death	Unexplained death with history of fever	Many
Gastrointestinal	Diarrhea/gastroenteritis (including vomiting or abdominal cramps)	Food/water
Inhalational	Smoke or dust inhalation	None
Neurologic	Meningitis, encephalitis, or unexplained acute encephalopathy	Venezuelan Equine Encephalitis
Rash	Rash with fever (both must be present)	Smallpox
Respiratory	Upper- or lower-respiratory infection with fever	Anthrax, plague, tularemia
Sepsis	Sepsis or nontraumatic shock	Many
Trauma	Trauma	None
None of the above	Not in any of the above categories	None
Missing	Form left blank	—

Syndromic Surveillance for Bioterrorism Following the Attacks on the World Trade Center --- New York City, 2001. *MMWR.* 2002;51((Special Issue)):13-15.

Health care data sources

- Patient demographic information
- Emergency department chief complaints
- International Classification of Disease (ICD)
- Text-based notes
- Laboratory data
- Radiological reports
- Physician reports (not automated)
- ?new processes for data collection?

"Non traditional data sources"

- Pharmacy data
- 911 operators
- Call triage centers
- School absenteeism
- Animal surveillance
- Agricultural data

Data Integration

- Technical challenges
- Security issues
- Political barriers
- Privacy concerns

Data Issues

- Data often collected for other purposes
- Data formats are nonstandard
- Data may not be available in a timely fashion
- Syndrome definitions may be problematic

Data quality

- Data often collected for other purposes
  - ✓ What do the data represent?
  - ✓ Who is entering them?
  - ✓ When are they entered?
  - ✓ How are they entered? Electronic vs. paper

Measured quality/value of data

	CC: all resp	ICD: upper resp	ICD: lower resp	CC or ICD: all resp
sens [95% CI]	.49 [.40-.58]	.67 [.57-.76]	.96 [.80-.99]	.76 [.68-.83]
spec [95% CI]	.98 [.95-.99]	.99 [.97-.99]	.99 [.98-.99]	.98 [.95-.99]

Syndrome definition

- May be imprecise
- Sensitivity/Specificity tradeoff
- Expert guided vs. machine-guided?

Modeling the Data

- Establishing baseline
- Developing forecasting methods
- Detecting temporal signal
- Detecting spatial signal

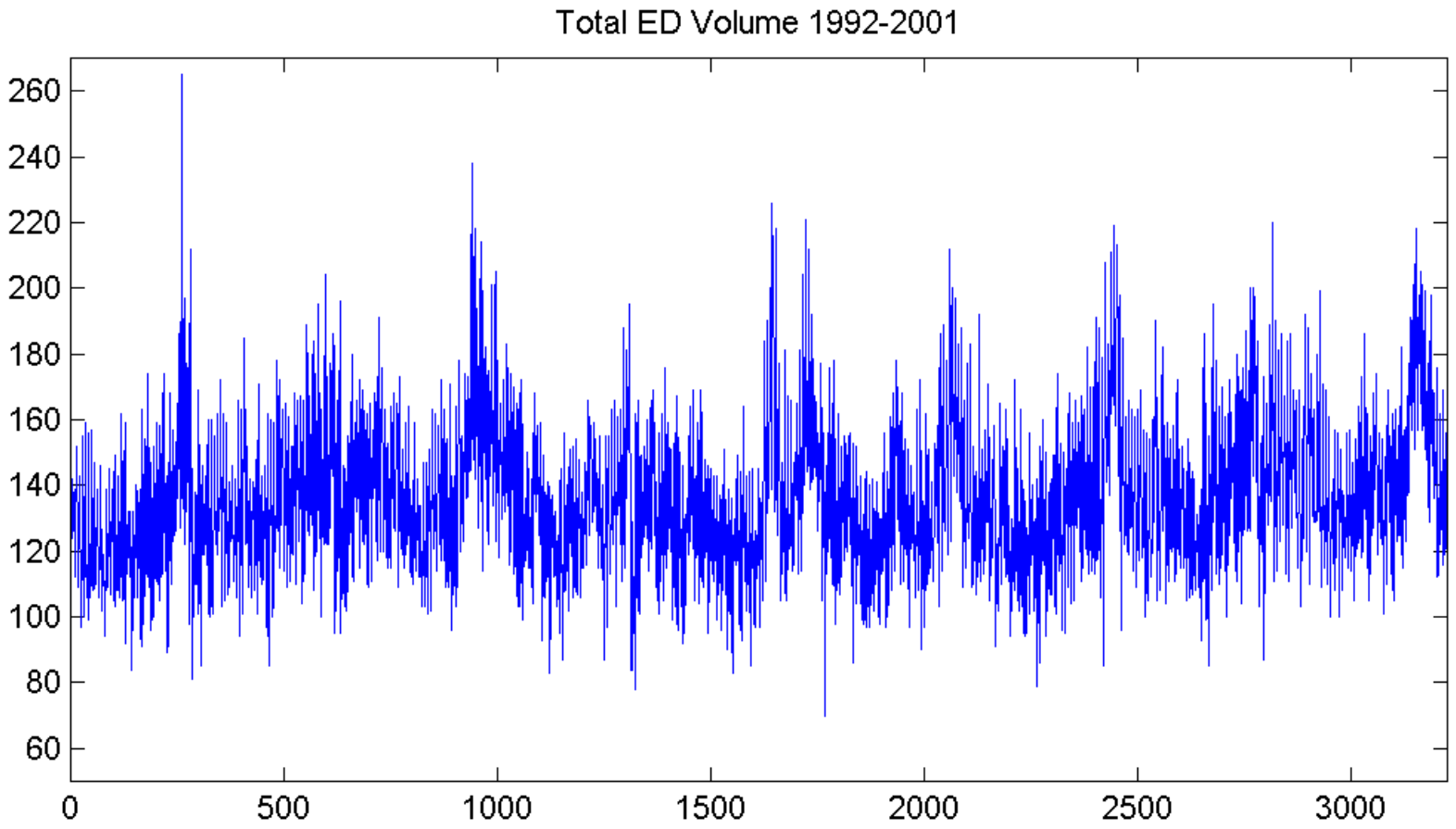
Baseline

- Are data available to establish baseline?
  - ✓ Periodic variations
    - ☞ Day
    - ☞ Month
    - ☞ Season
    - ☞ Year
    - ☞ Special days
  - ✓ Variations in patient locations
    - ☞ Secular trends in population
    - ☞ Shifting referral patterns
    - ☞ Seasonal effects

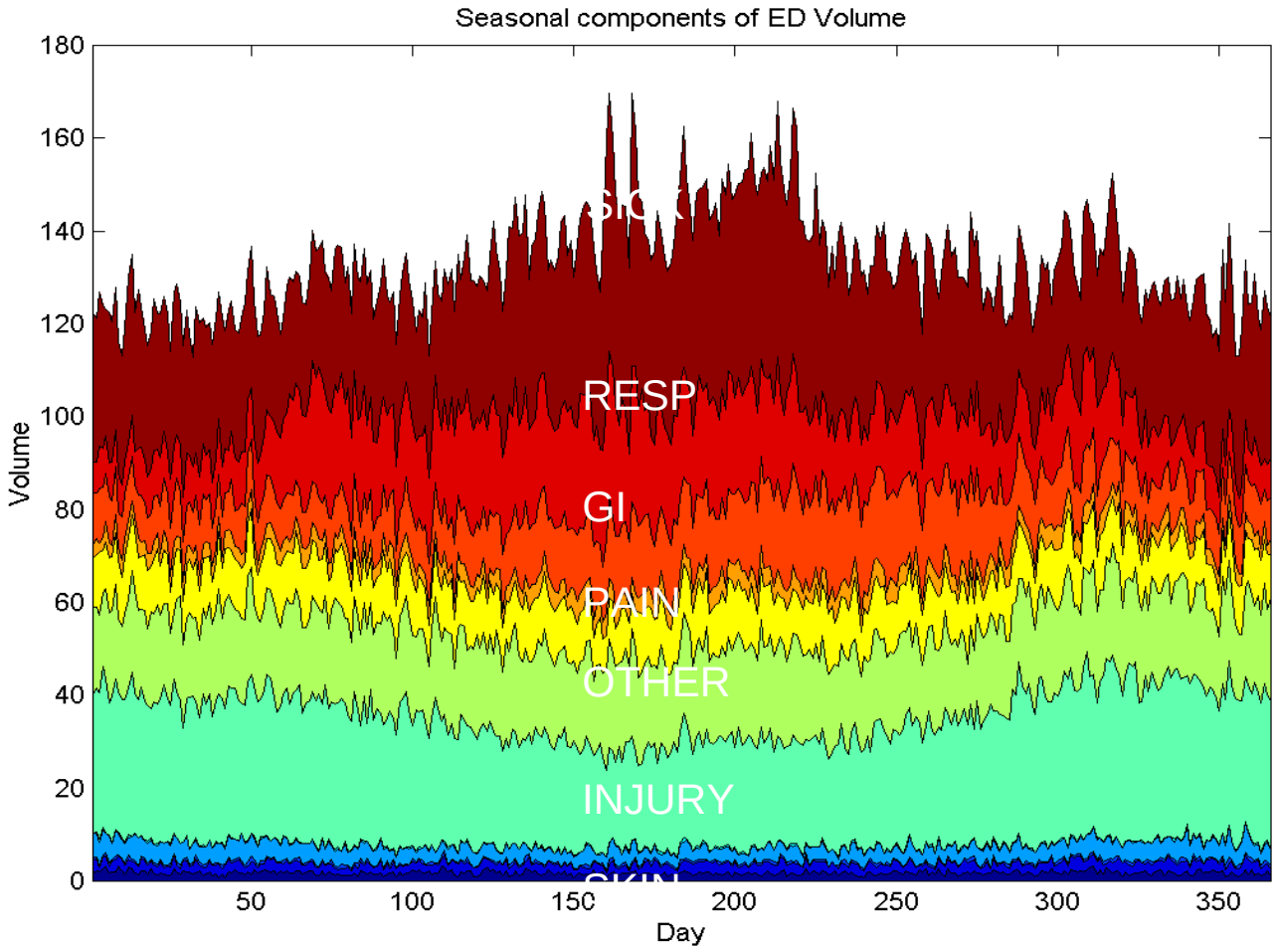
Boston data

- Syndromic surveillance
- Influenza like illness
- Time and space

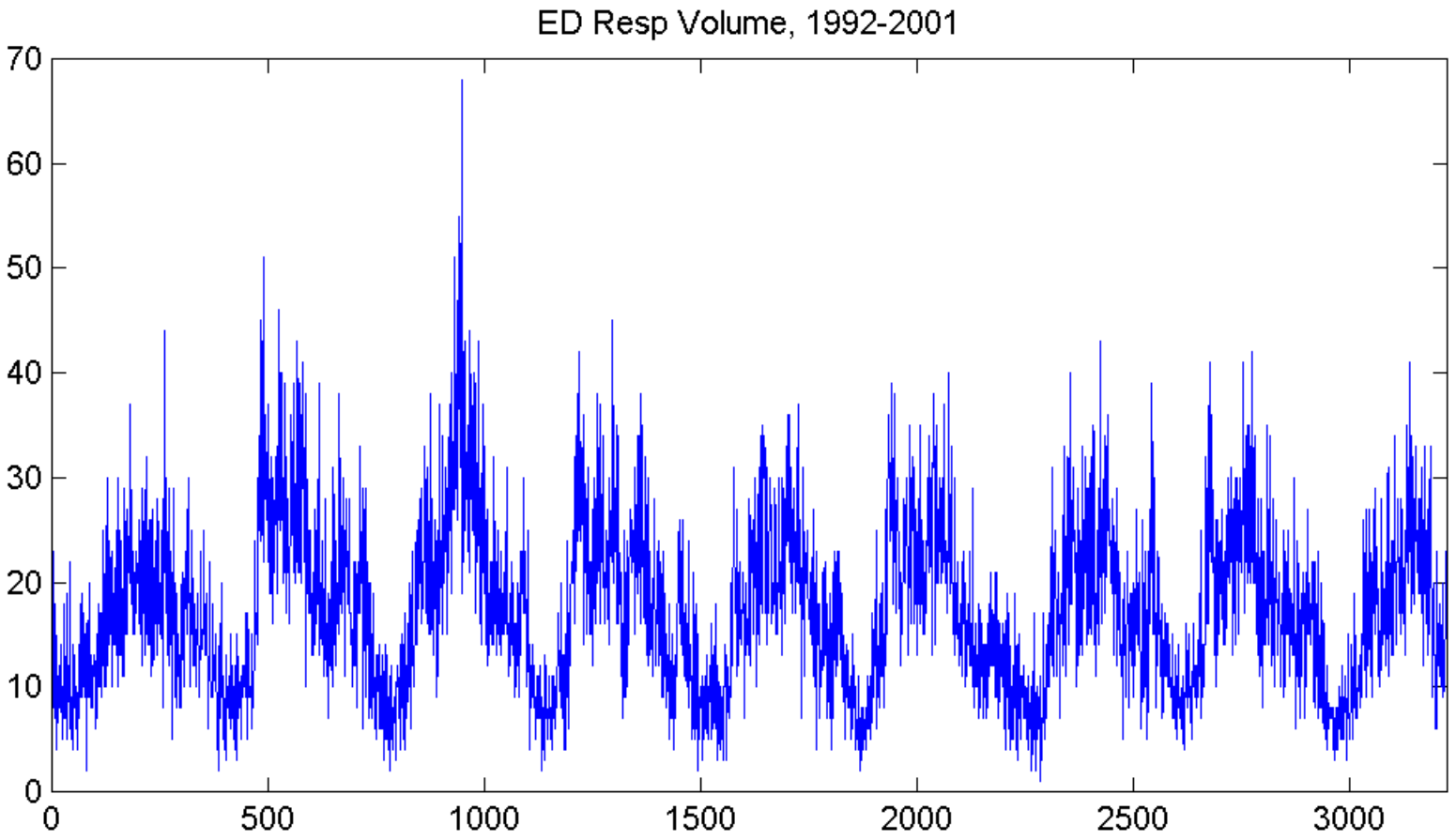
Forecasting



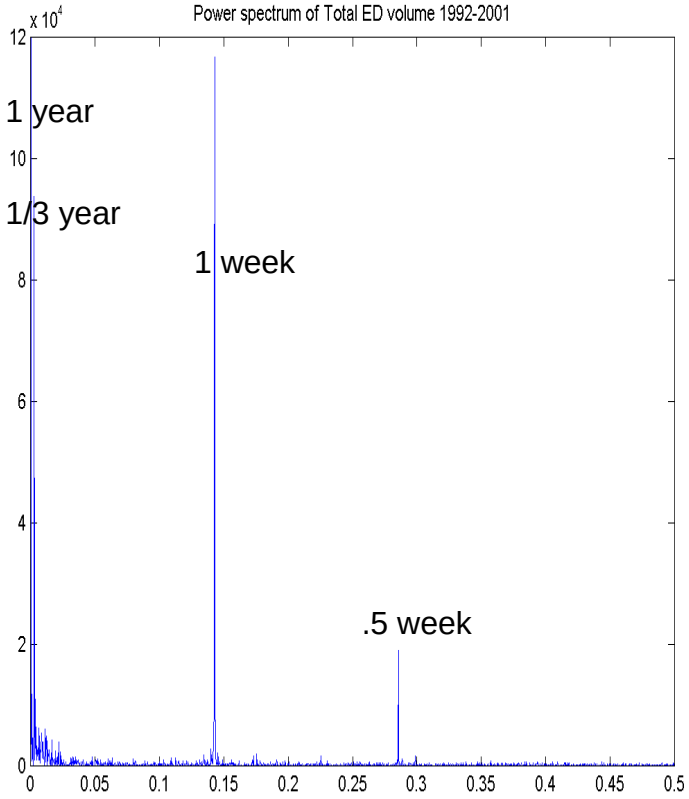
Components of ED volume

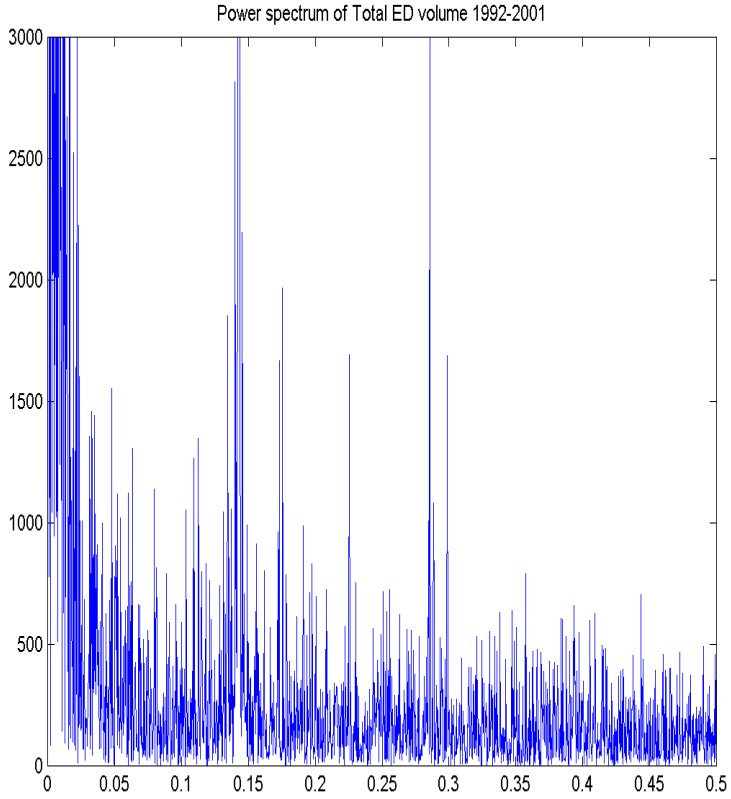


Forecasting

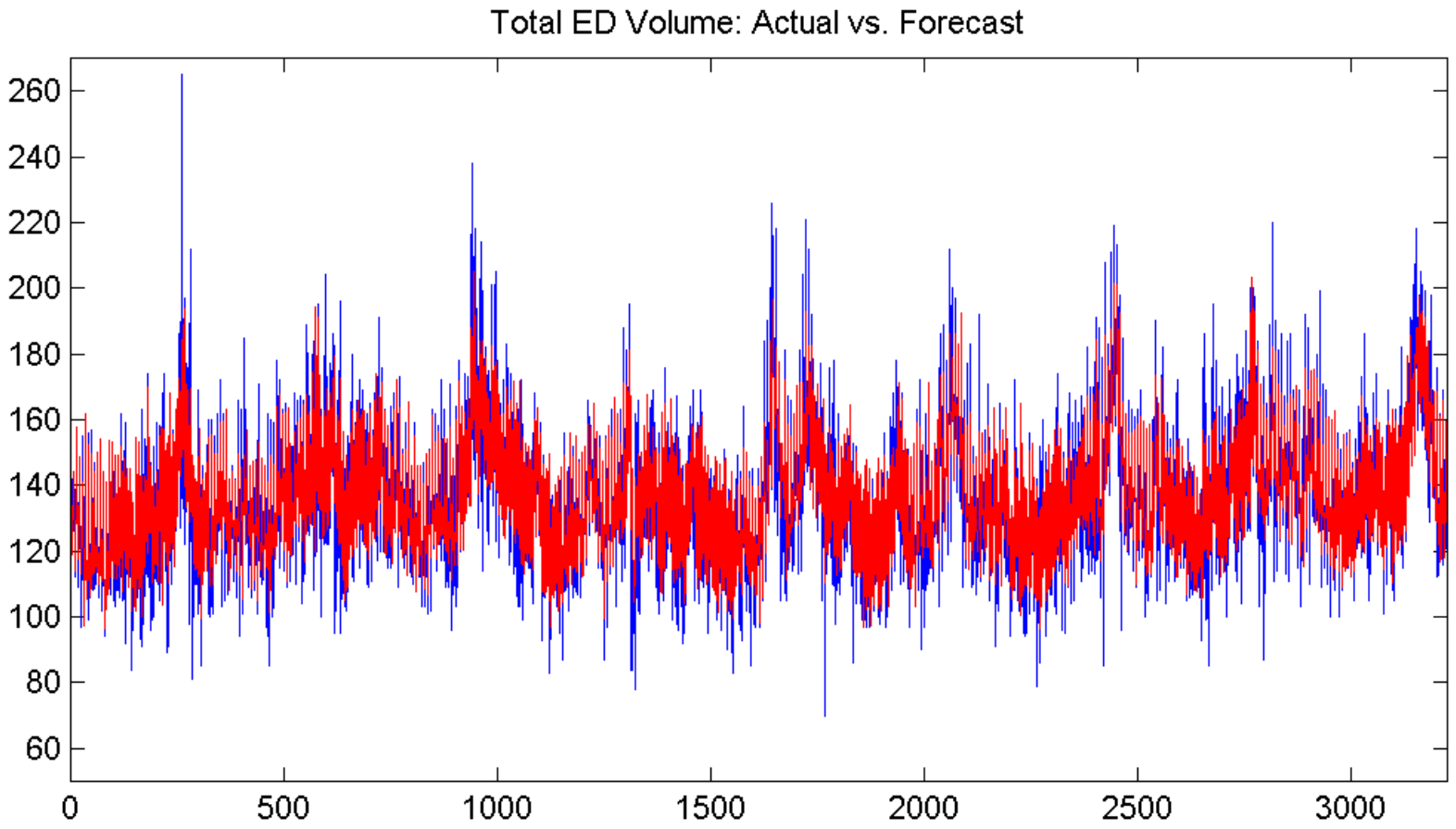


Principal Fourier component analysis





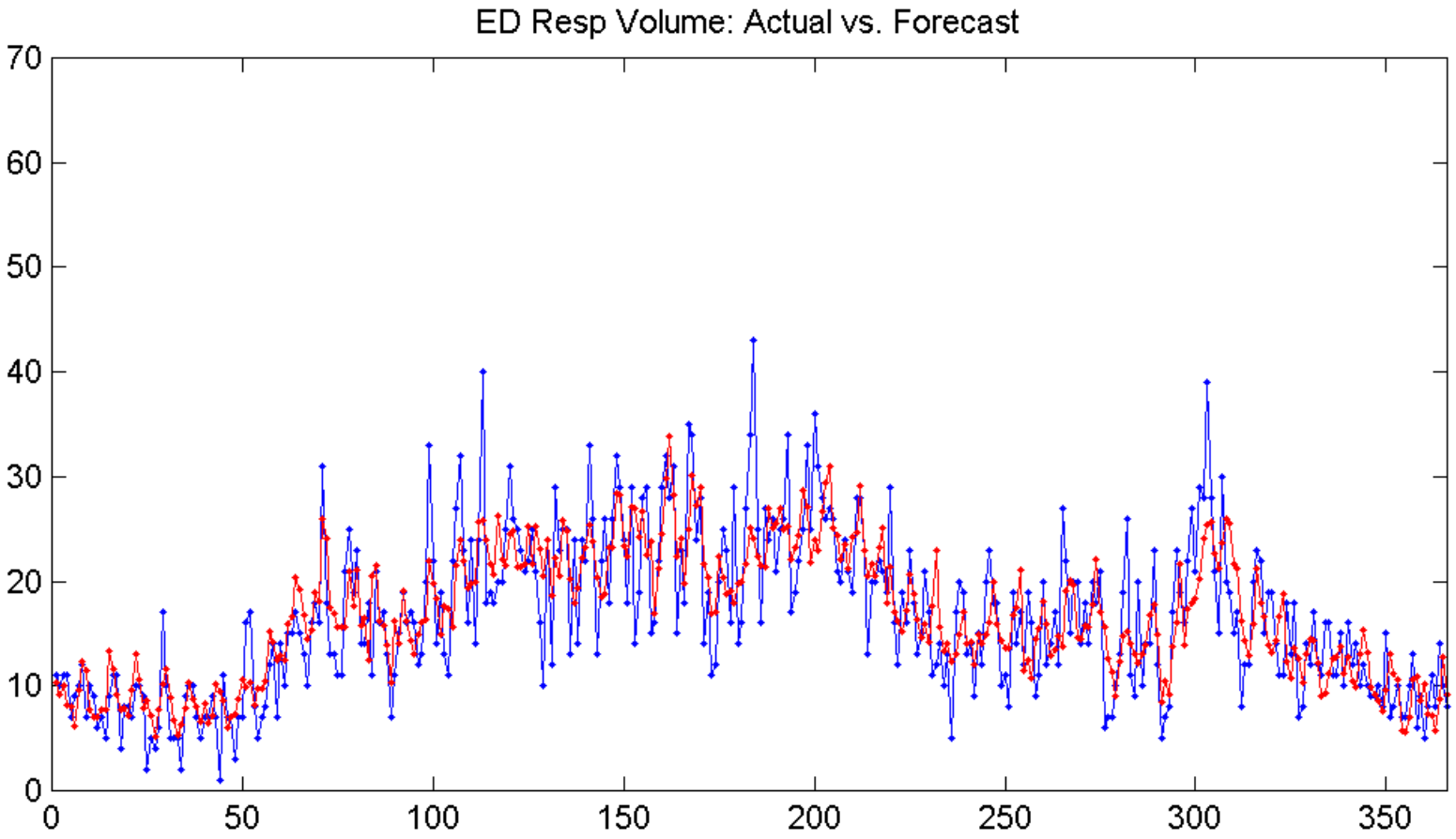
ARIMA modeling



Forecasting performance

- Overall ED Volume
  - Average Visits: 137
  - ARMA(1,2) Model
  - Average Error: 7.8%

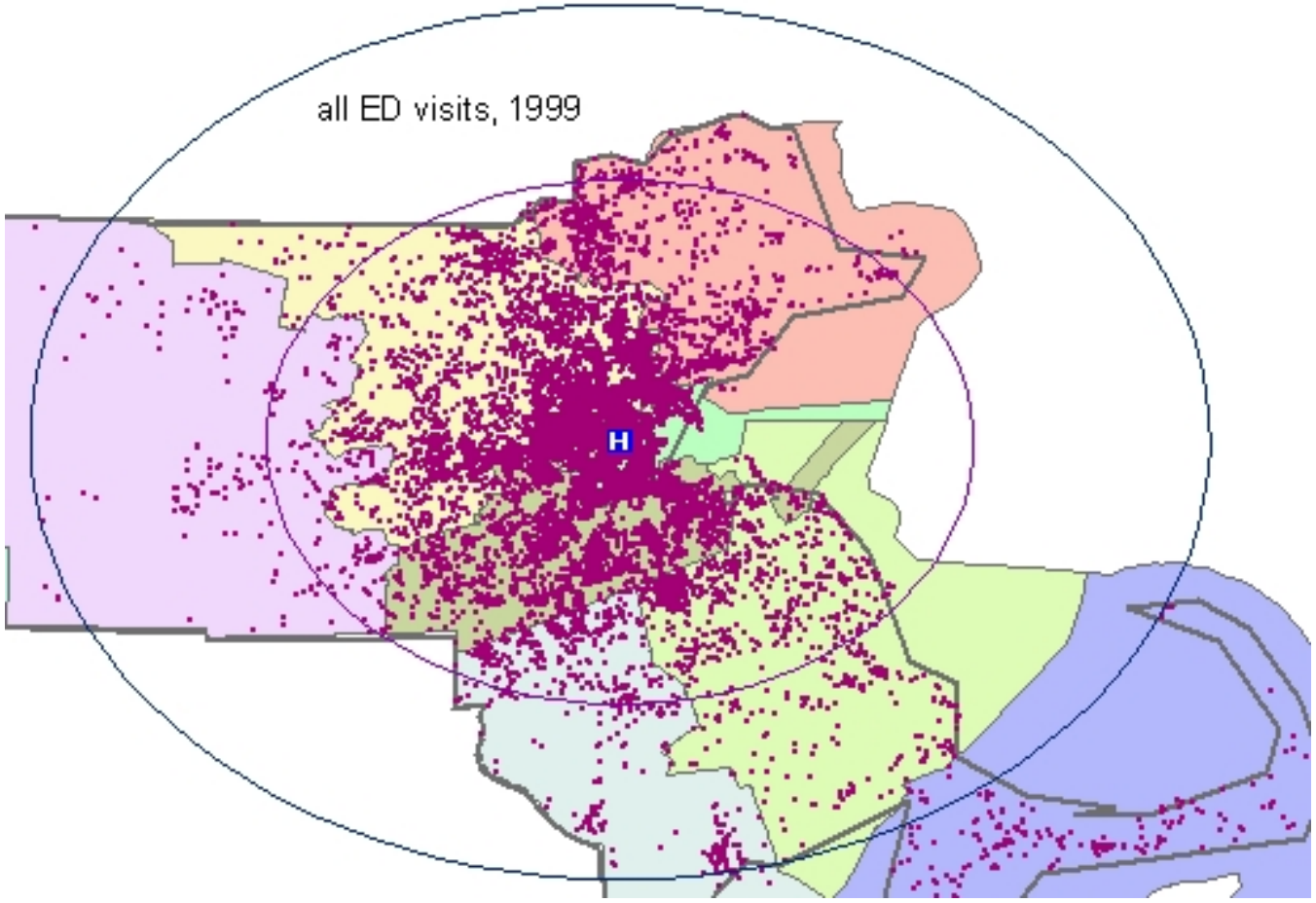
Forecasting



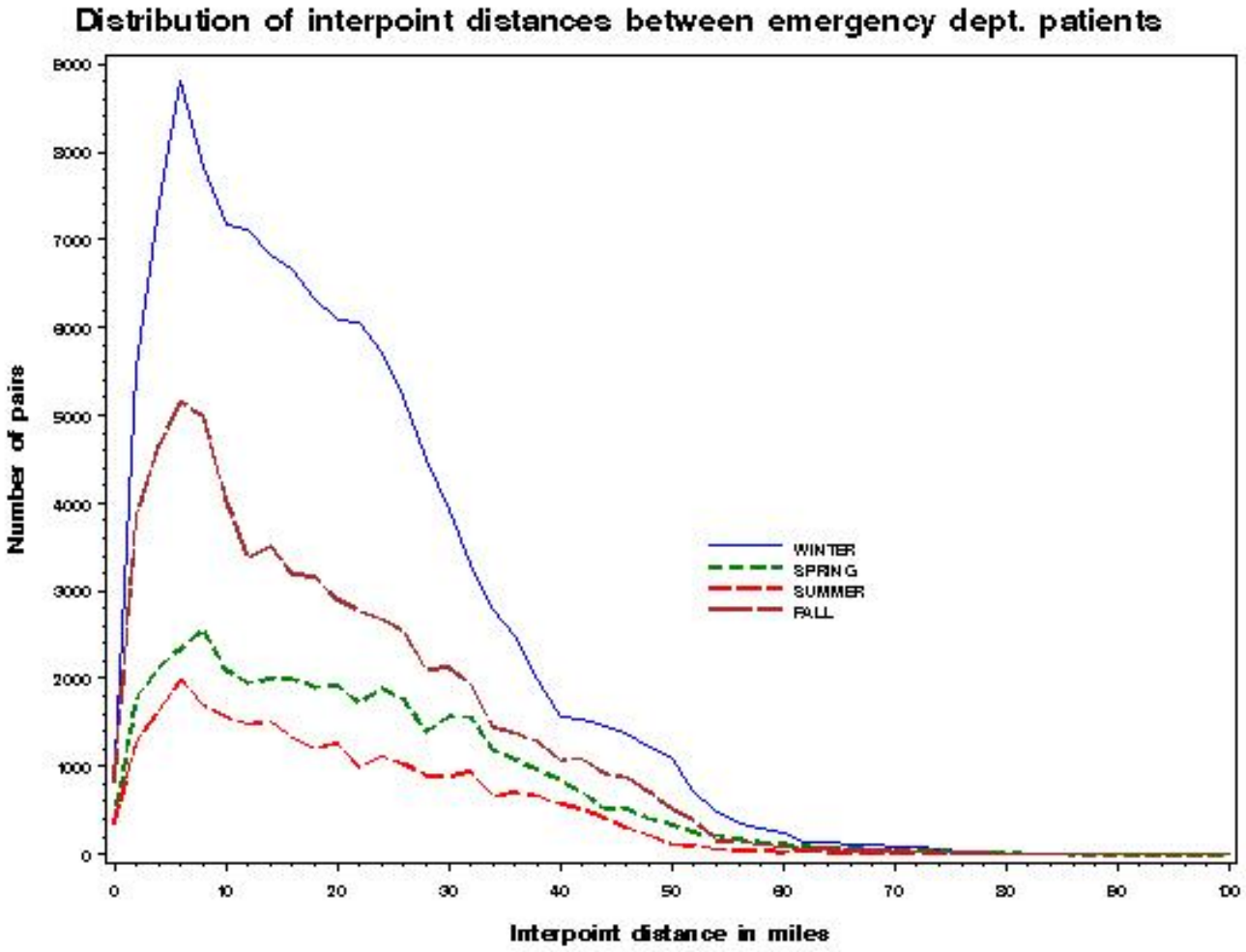
Forecasting performance

- Respiratory ED Volume
  - Average Visits: 17
  - ARMA(1,1) Model
  - Average Error: 20.5%

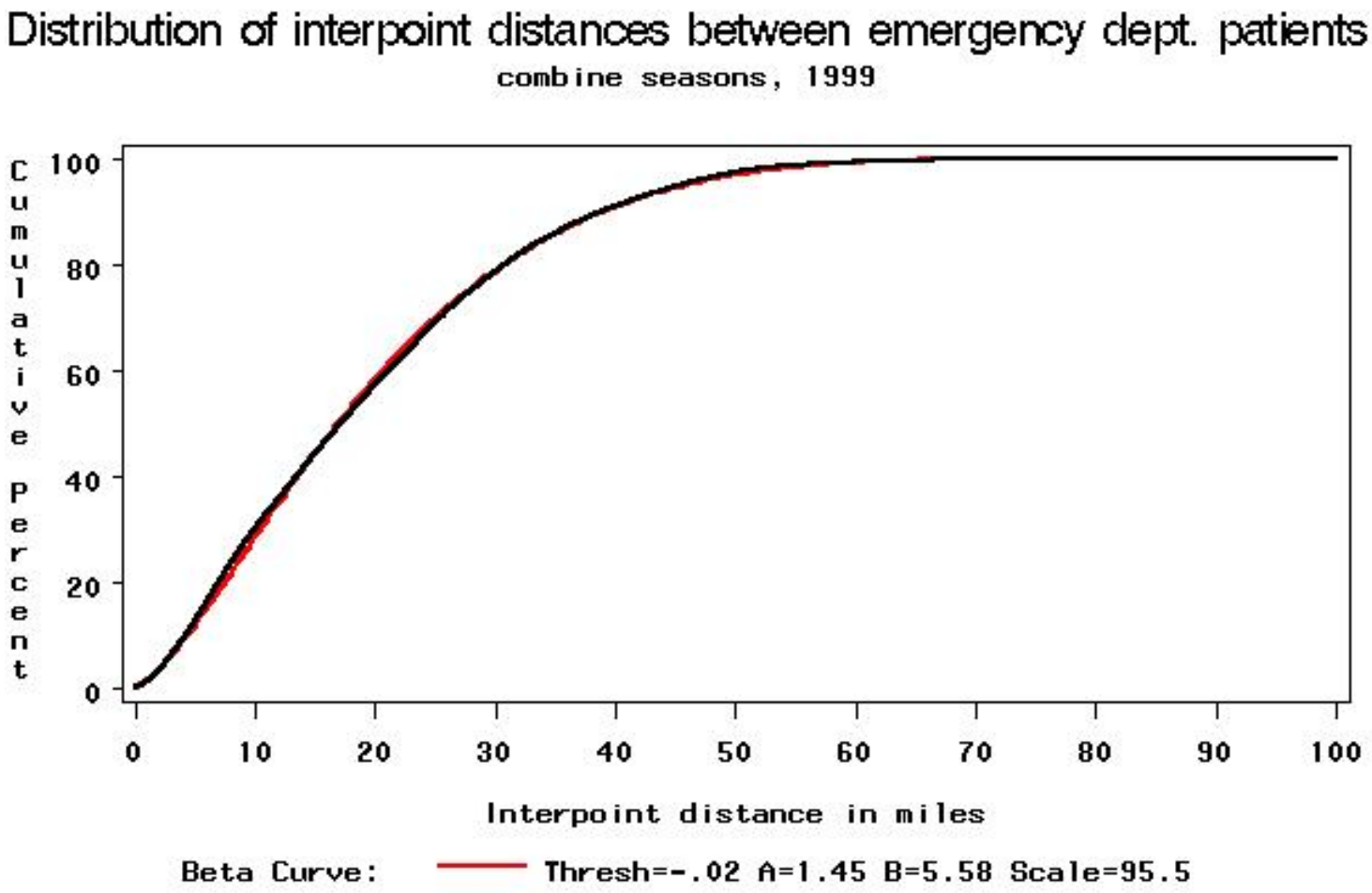
GIS



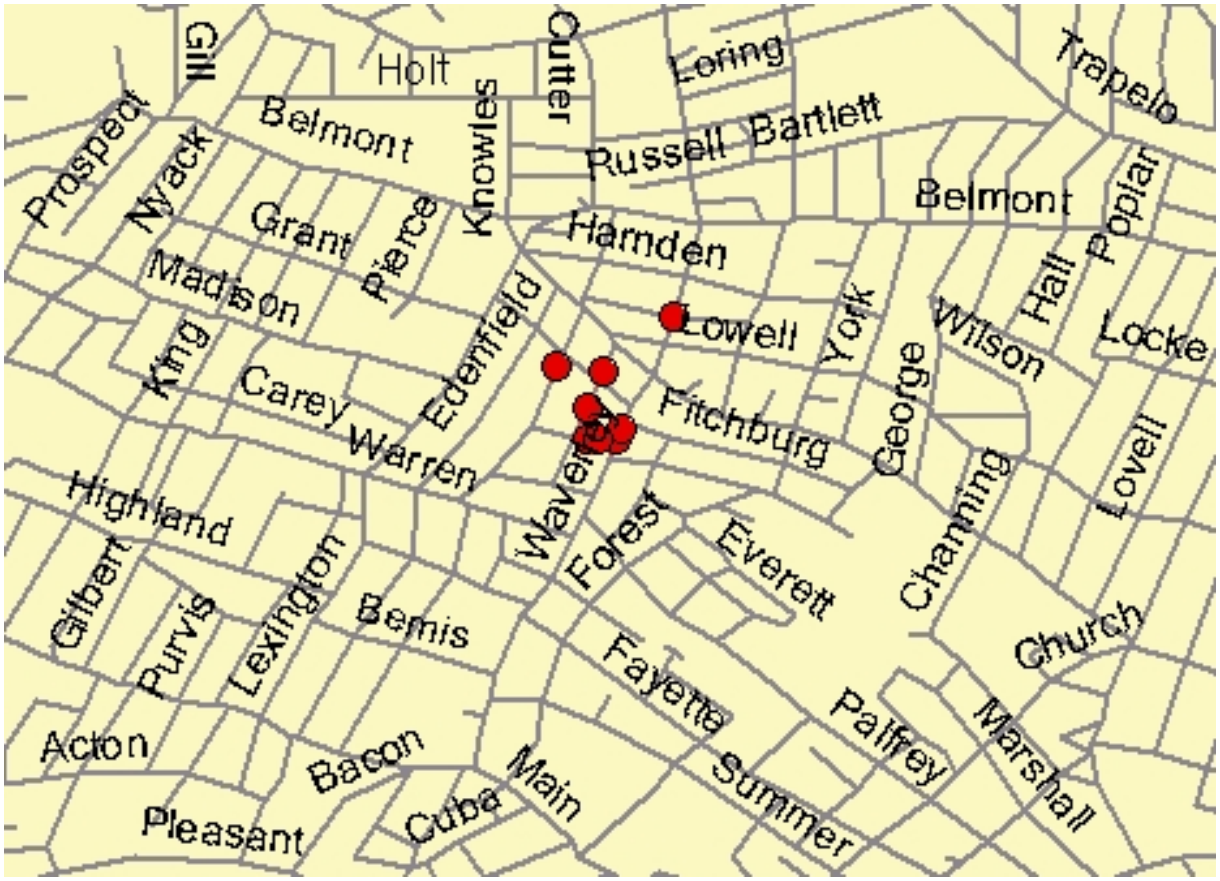
Seasonal distributions



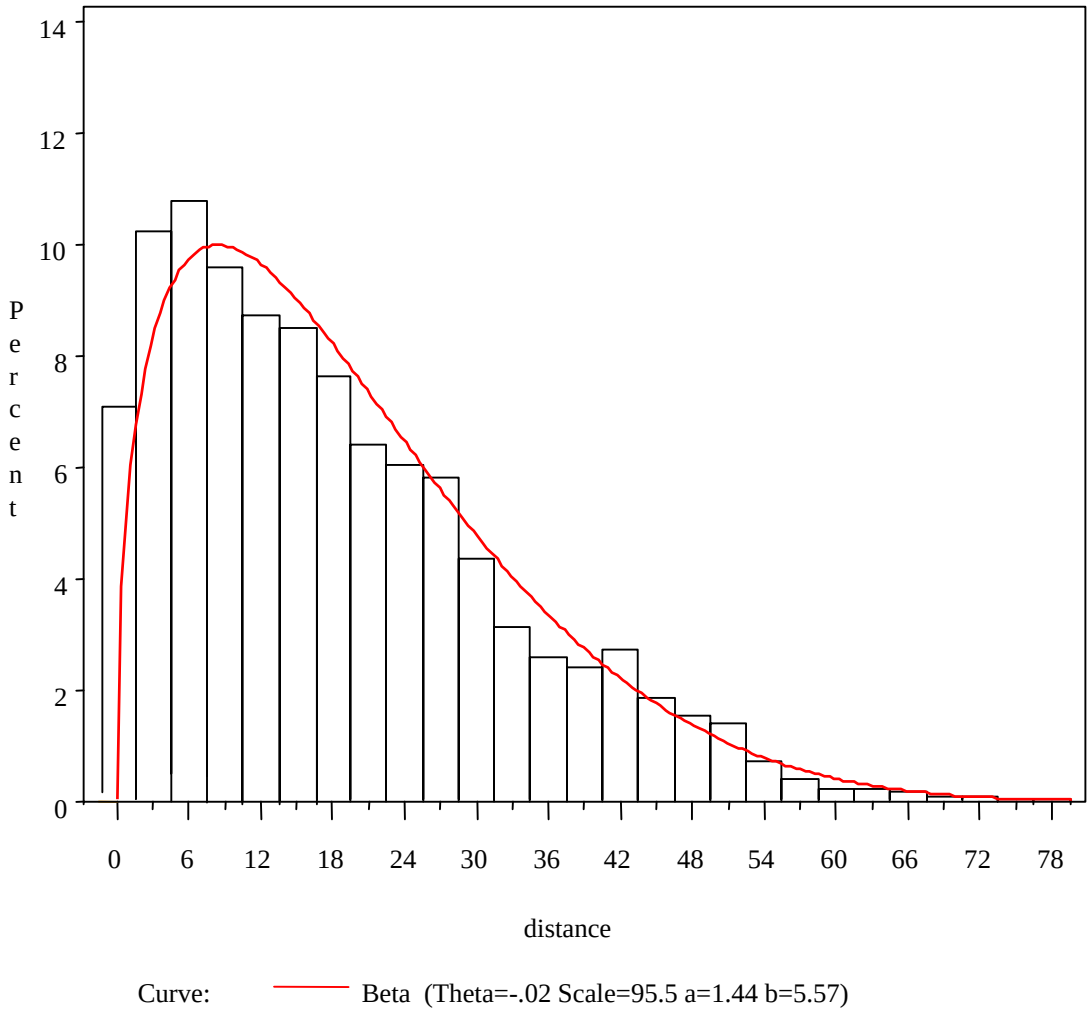
A curve fit to the cumulative distribution



A simulated outbreak



The cluster


14
12
10
8
6
4
2
0
Percent
0
6
12
18
24
30
36
42
48
54
60
66
72
78
distance
Curve:
Beta (Theta=-.02 Scale=95.5 a=1.44 b=5.57)

EMERGENCY DEPARTMENT SCOPE

Actual Versus Forecasted Visits

Syndrome	Actual	Forecast
Dermatological	3	3
Gastro-Intestinal	11	10
General Surgical	1	1
Genito-Urinary	2	1
Infection	4	3
Injury	41	33
Internal Medicine	0	2
Meningitis	0	2
Neurological	6	3
Pain	8	4
Respiratory	17	18
Psychological	4	2
General Sickness	20	17
Other	20	20
Total Visits	**139**	**120**

ED SCOPE HOME

Sampled on Thu, Sep 19 2002 At 2:45 PM

View Prior Actuals vs Forecasts

Discussions | Subscribe... | Discussions not available on http://g14709/

Major issues

- Will this work at all???
- Can we get better data?
- How do we tune for a particular attack?
- What to do without training data?
- What do we do with all the information?
- How do we set alarm thresholds?
- How do we protect patient privacy?

Will this work at all?

- A syndromic surveillance system operating in the metro DC area failed to pick up the 2001 anthrax mailings
- Is syndromic surveillance therefore a worthless technology?
- Need to consider the parameters of what will be detectable
- Do not ignore the monitoring role

Getting better data

- Approaches to standardizing data collection
  - ✓ DEEDS
  - ✓ Frontlines of Medicine project
  - ✓ National Disease Epidemiologic Surveillance System, NEDSS

Tuning for a particular attack

- Attacks may have different “shapes” in the data
- Different methods may be more well suited to detect each particular shape
- If we use multiple methods at once, how do we deal with multiple testing?

Will this work at all?

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No training data

- Need to rely on simulation
- Imprint an attack onto our data set, taking in to account regional peculiarities
  - ✓ Artificial signal on probabilistic noise
  - ✓ Artificial signal on real noise
  - ✓ Real signal (from different data) on real noise

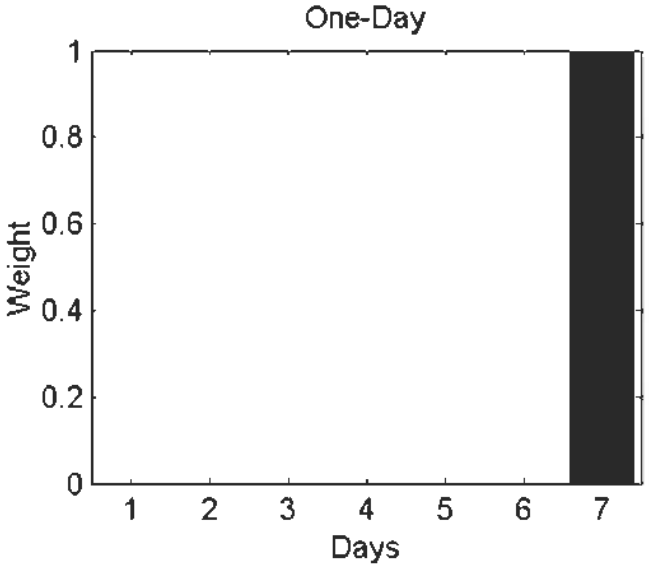
What do we do with all of this information?

- Signals from same data using multiple methods?
- Signals from overlapping geographical regions?
- Signals from remote geographical regions?

✓ Note: This highlights the important issue of interoperability and standards

Protecting patient privacy

- HIPAA and public health
- Mandatory reporting vs. syndromic surveillance
- The science of anonymization
- Minimum necessary data exchange
- Special issues with geocoded data


One-Day
Weight
Days
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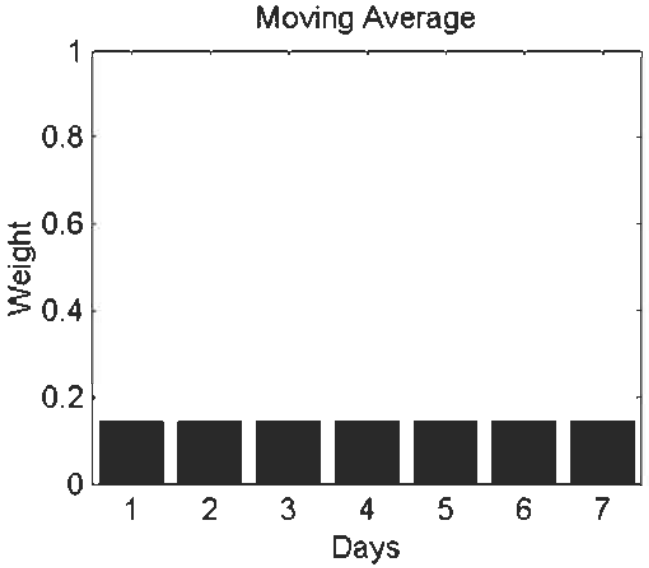
0.2
0.4
0.6
0.8
1
1
2
3
4
5
6
7


Moving Average
Weight
Days
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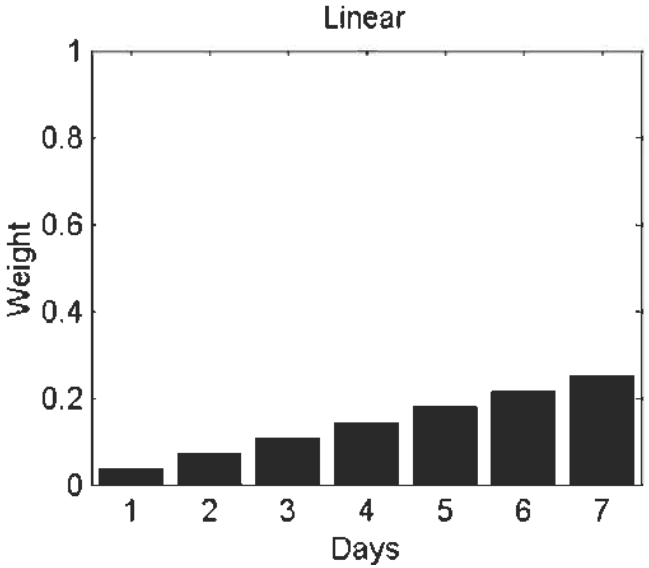
6
7


Linear
Weight
Days
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0.2
0.4
0.6
0.8
1
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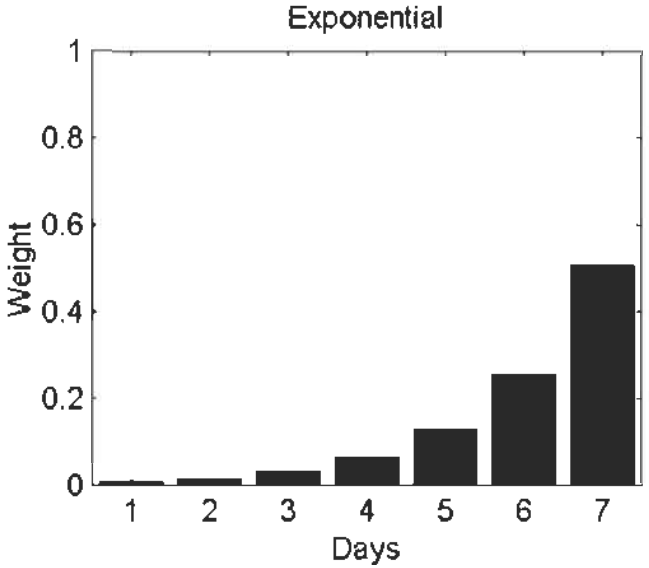
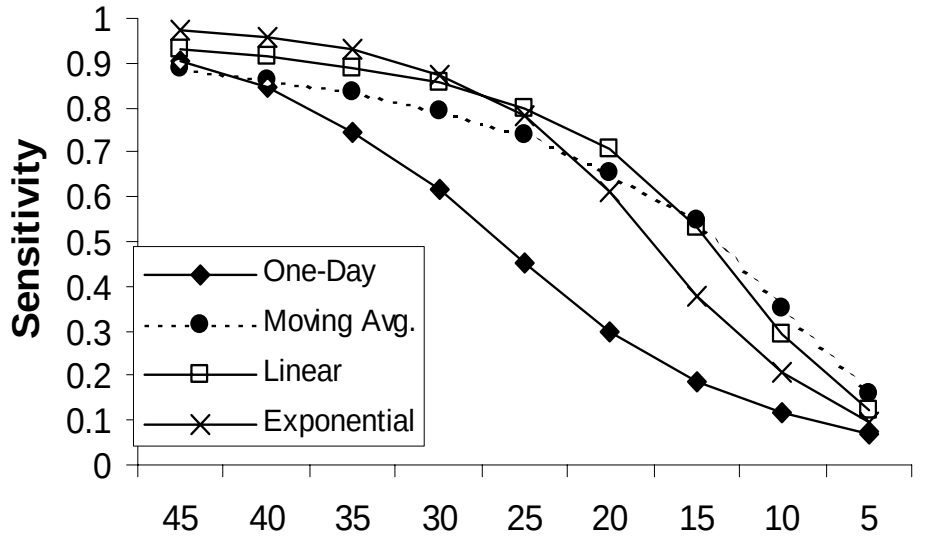
7

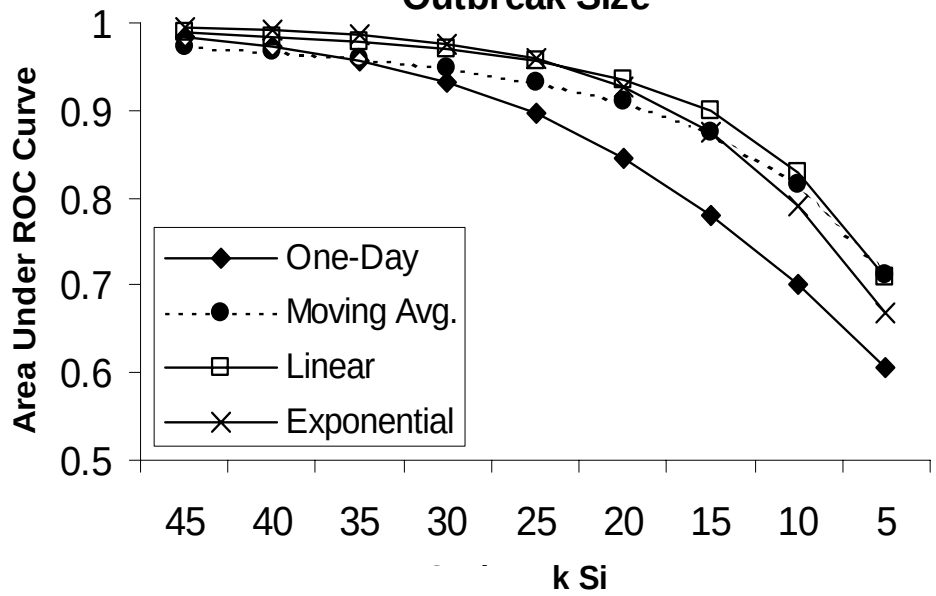

Exponential
Weight
Days
0
0.2
0.4
0.6
0.8
1
1
2
3
4
5
6
7

Performance

Table 1. Detection performance of filters given simulated outbreaks 7-days long and 20 visits per day, with 95% confidence intervals shown.

Filter Type	Sensitivity	Specificity
One Day	**0.30** [0.28,0.32]	**0.97** [0.96,0.98]
Moving Avg	**0.65** [0.64,0.68]	**0.97** [0.96,0.97]
Linear	**0.71** [0.69,0.73]	**0.97** [0.96, 0.97]
Exponential	**0.61** [0.60,0.64]	**0.97** [0.96, 0.98]


Sensitivity
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
One-Day
Moving Avg.
Linear
Exponential
45
40
35
30
25
20
15
10
5
Outbreak Size


Area Under ROC Curve
1
0.9
0.8
0.7
0.6
0.5
One-Day
Moving Avg.
Linear
Exponential
45
40
35
30
25
20
15
10
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