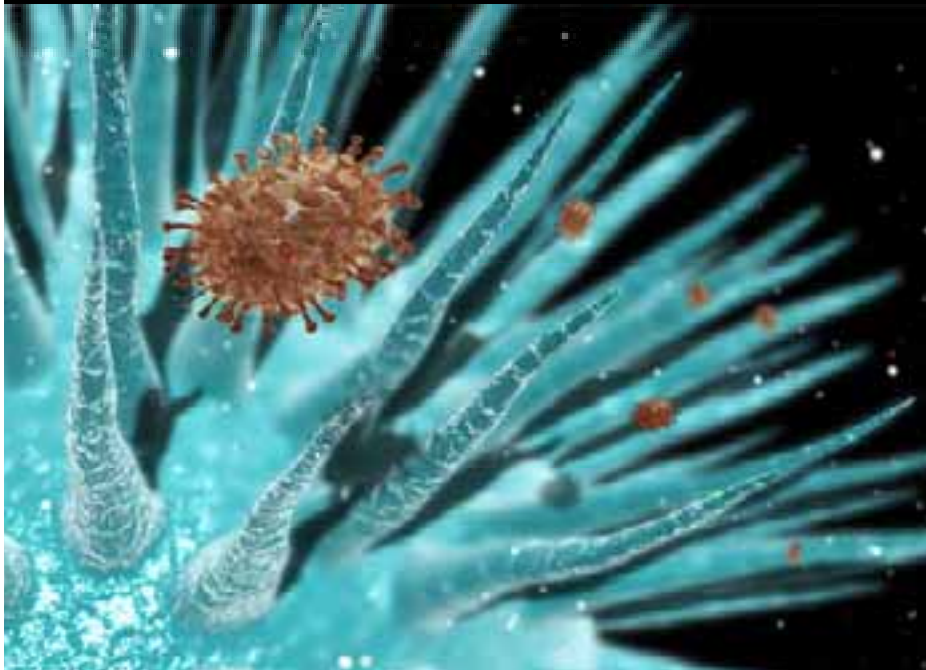


The Spatio-Temporal Spread of Influenza in Virginia, 2005-2008



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Community Health



Outline

- Influenza background
- Influenza Surveillance Data
- Study Objectives
- Methods and Analysis
 - Statistical
 - Exploratory visualization
 - Geostatistical
- Conclusions



Influenza

- Common, highly contagious, acute respiratory disease
- Well-defined seasonal variation
- Spatio-temporal characteristics of the seasonal influenza activity have been less well-defined

According to the CDC, every year in the United States, on average:

- 5% to 20% of the population gets the flu
- more than 200,000 people are hospitalized from flu complications, and
- about 36,000 people die from flu. Some people, such as older people, young children, and people with certain health conditions, are at high risk for serious flu complications.



Influenza Strains

- Type B
 - Remains fairly constant, no rapid mutation
- Type A
 - Strains circulating vary by year, and can have different characteristics in spread, timing, etc
 - H1N1
 - H3N2



Negative stained transmission electron micrograph (TEM) showing recreated 1918 influenza virions. Photo Source: CDC's Public Health Image Library, Dr. Terrence Tumpey and Cynthia Goldsmith



Why do we care about influenza?

- Possibility of influenza pandemic
- Changing strains
- Understanding how the spread of disease progresses, both temporally and spatially, may help pandemic preparation planning efforts



1918 Influenza pandemic. Source: CDC



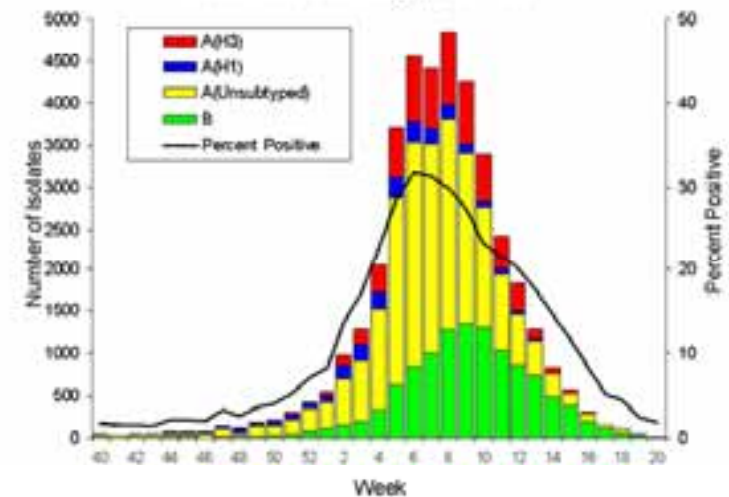
Influenza Surveillance Objectives

- To define and monitor trends in influenza-like illness (ILI) activity and compare circulating strains to those in the current vaccine.

Percentage of Visits for ILI & ARI Reported by Sentinel Providers and BioSense Outpatient Facilities, National Summary



U.S. WHO/NREVSS Collaborating Laboratories National Summary, 2007-08

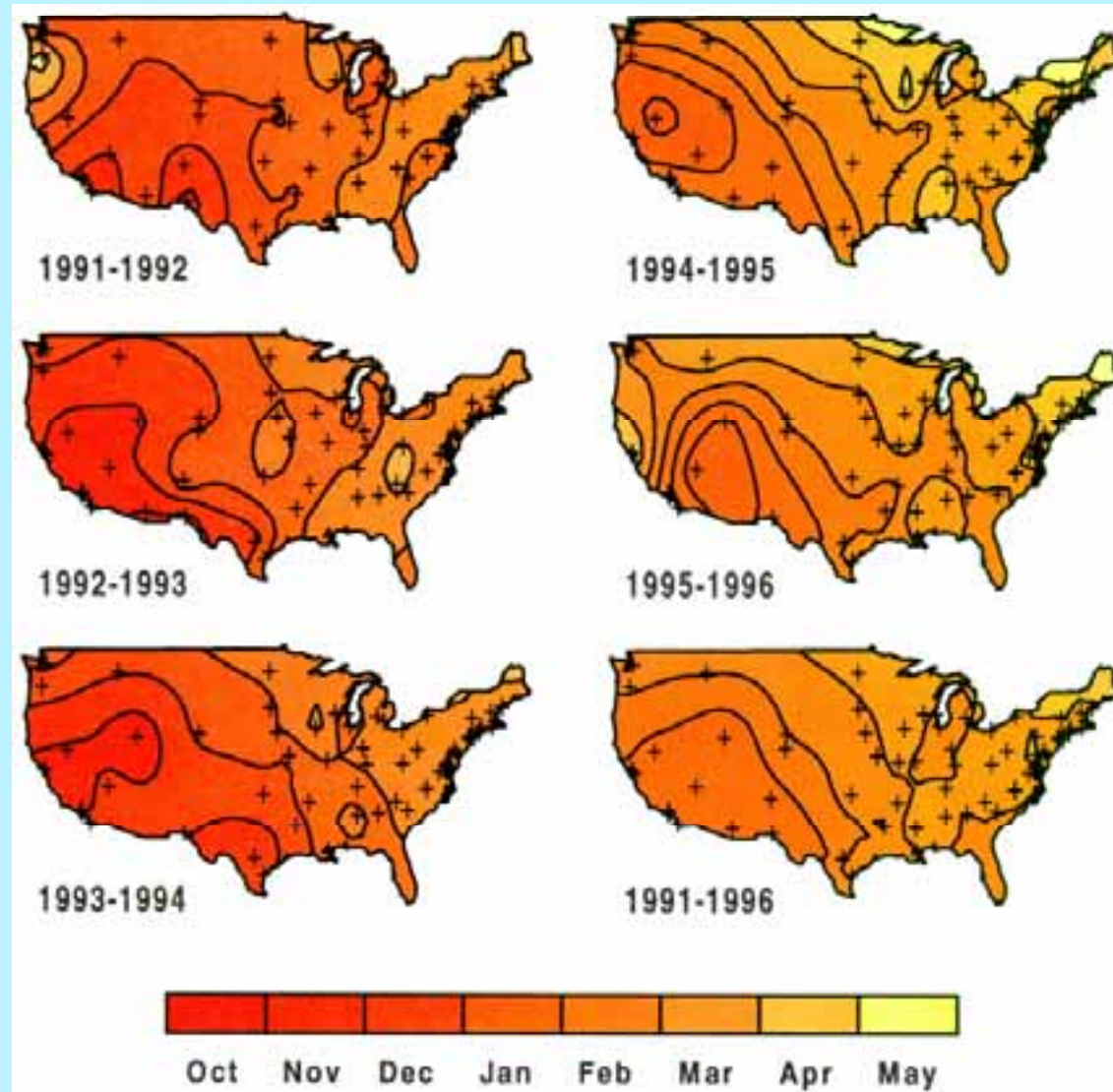




Spatio-Temporal Spread of Infectious Disease

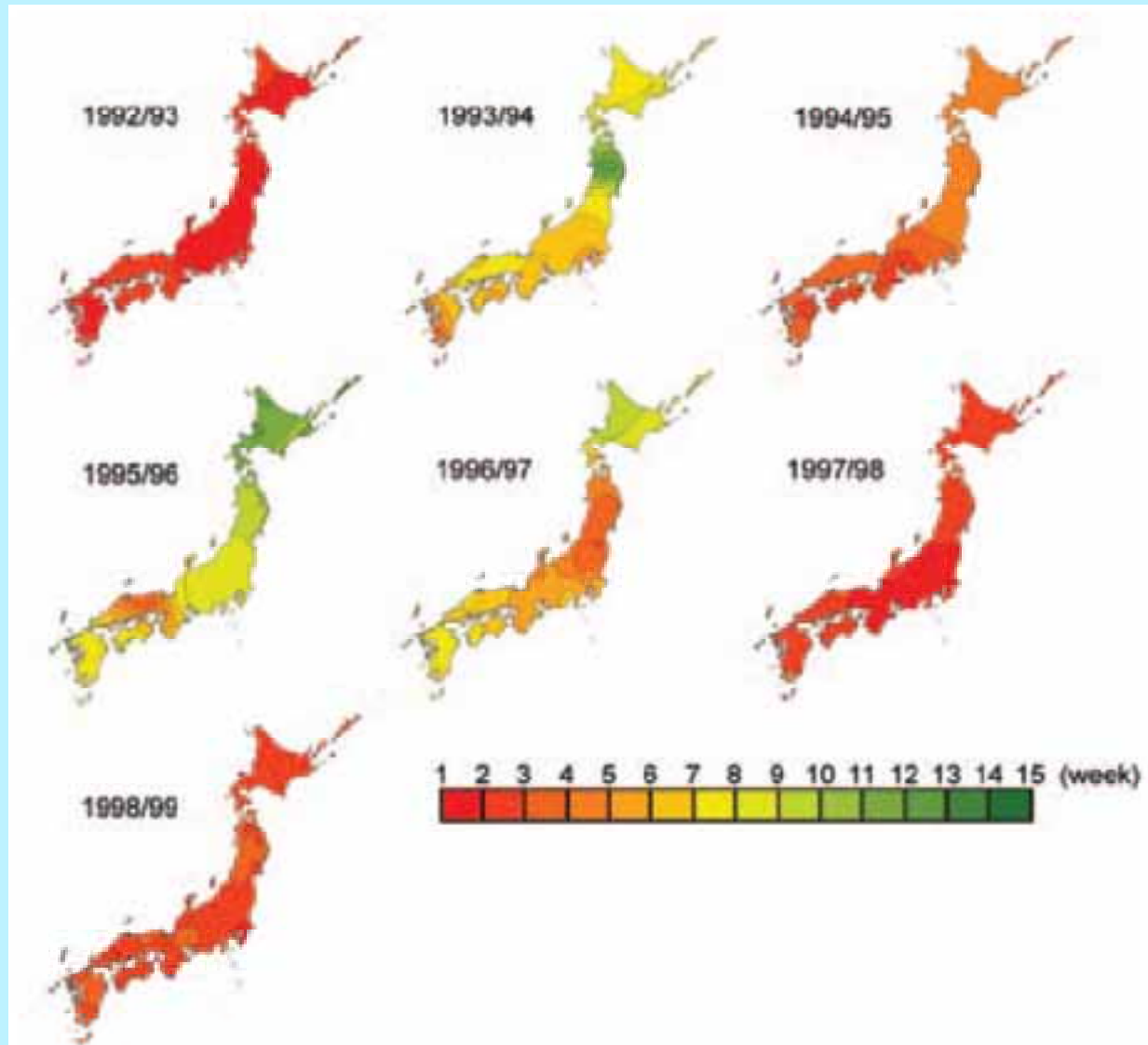
- Previous studies have attempted to use GIS to visually display the geographic spread of seasonal infectious diseases
 - Application of geostatistical tools to aid in characterization of the spread of disease
- Kriging interpolation
 - Statistical method for spatial interpolation
 - Irregularly spaced data are transformed into a regular grid of data that can be used to construct contour maps
 - Applied to illustrate and clarify spatiotemporal relationships in epidemiologic research
 - Use disease data at known points to create a prediction map of disease
 - Used to model peak weeks of disease activity

Previous Research



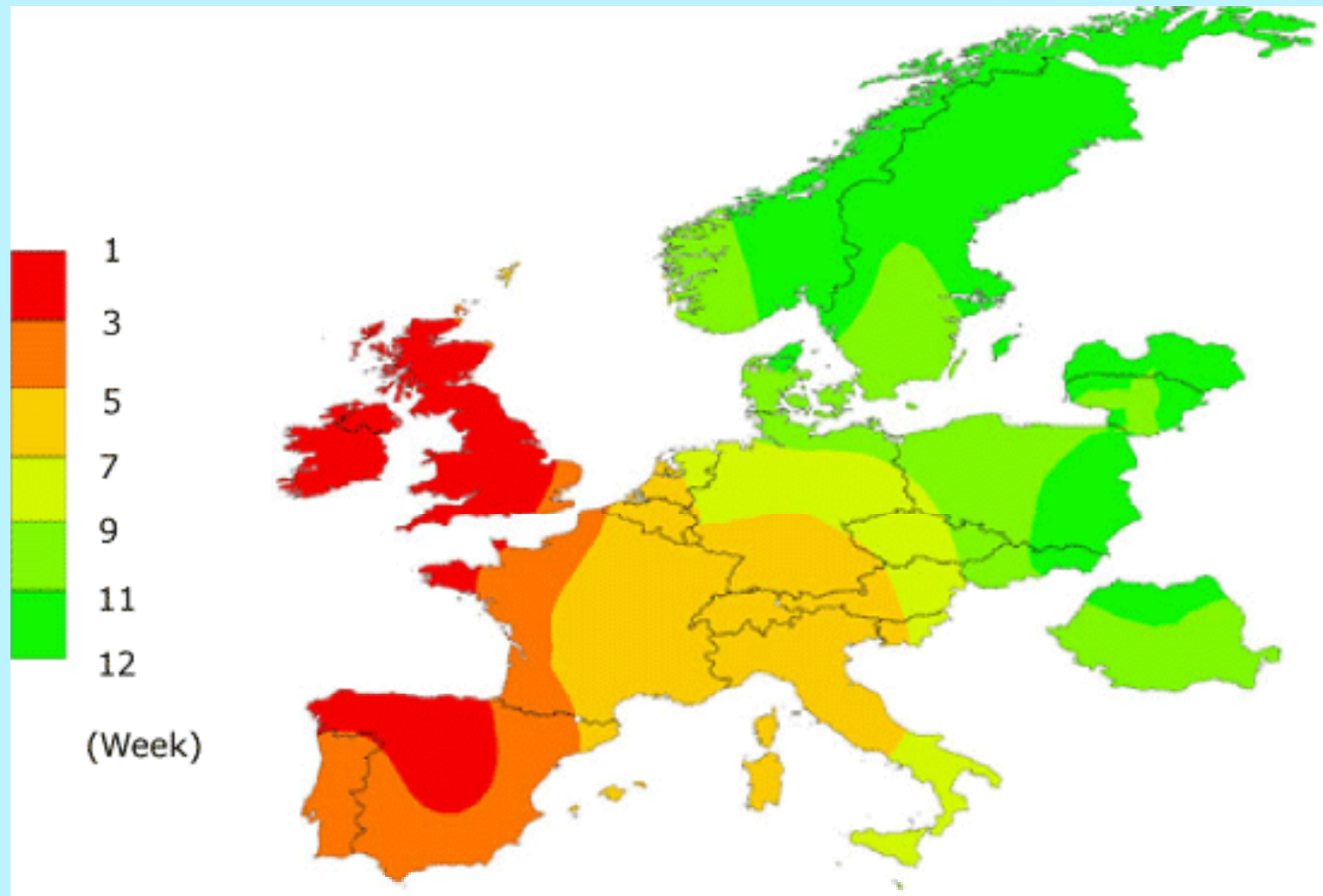
Torok *et al.* Visualizing geographic and temporal trends in rotavirus activity in the United States, 1991 to 1996. *Pediatr Infect Dis J.* 1997; 16(10): 941-

Previous Research



Sakai *et al.* Geographic and Temporal Trends in Influenzalike Illness, Japan, 1992-1999. *Emerging Infectious Disease*, 2004; 10(10): 1822-1826.

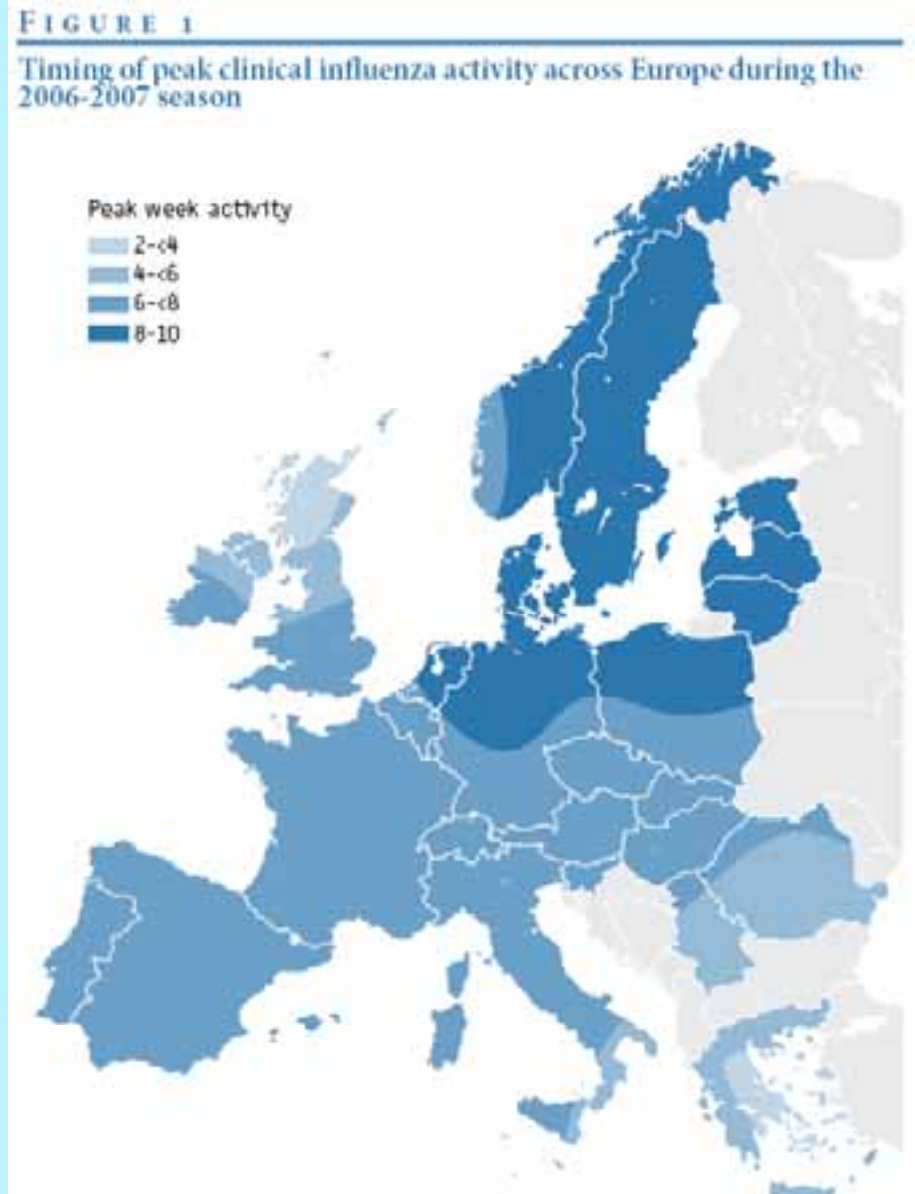
Previous Research



Saito *et al.* Geographic mapping method shows potential for mapping influenza activity in Europe. *Eurosurveillance*, 2005; 10(43): 2824.

Previous Research

Arkema *et al.* Epidemiological and virological assessment of influenza activity in Europe, during the 2006-2007 winter. *Euro Surveill.* 2008; 13(34): 18958.





Study Objectives

- To examine the spatio-temporal characteristics of seasonal influenza activity in Virginia using a combination of statistical and GIS techniques.
- To determine whether GIS mapping techniques are useful for interpreting influenza surveillance data.



Methods Overview

- Data Collection
 - Influenza sentinel surveillance data in Virginia
- Statistical Analysis
 - Characterization of influenza season using time series graphs and correlations
- Exploratory Visualization
 - Distribution of sentinel facilities, time series choropleth maps
- Geostatistical Analysis
 - Kriging modeling interpolation to illustrate the spatio-temporal spread of influenza
- Software
 - ArcGIS 9.2, ArcMap with Spatial Analyst and Geostatistical extension



ILI Surveillance in Virginia

- Electronic data feeds from sentinel facilities used to collect information on cases of ILI
 - Hospital emergency departments (ED) and urgent care (UC) facilities
 - Chief complaints text parsing for ILI
 - Note: Virginia ILI surveillance using these data did not begin until the 2007-08 influenza season, but data from the previous two years were available for analysis
- Laboratory Reports
 - Sentinel Physicians used to provide specimens
 - Outbreak investigations
 - Other reports (from DCLS and other laboratories)

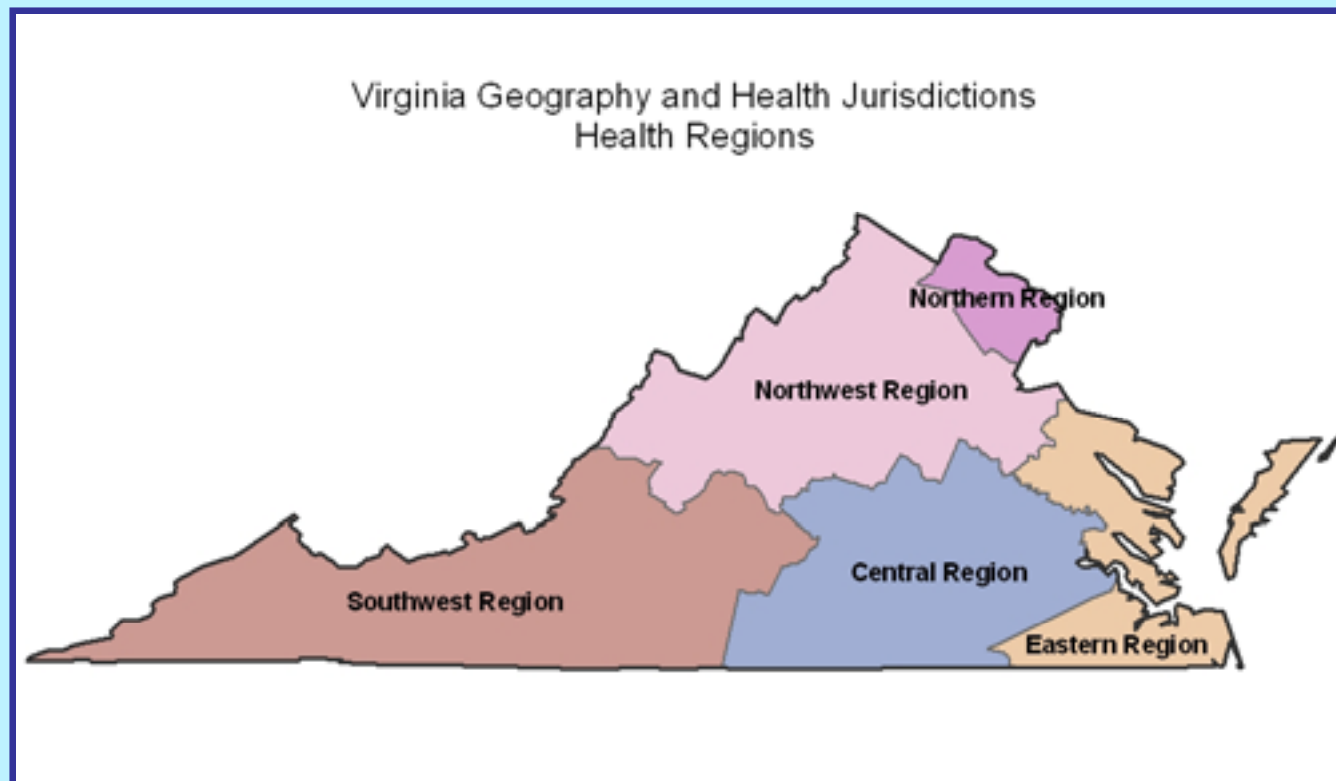
ILI Definition

- A case of ILI is defined as an individual with a fever \geq to 100 ° F (37.8°C) and a cough and/or sore throat in the absence of another known cause.
- Virginia ILI Surveillance Definition: Fever with sore throat and/or cough



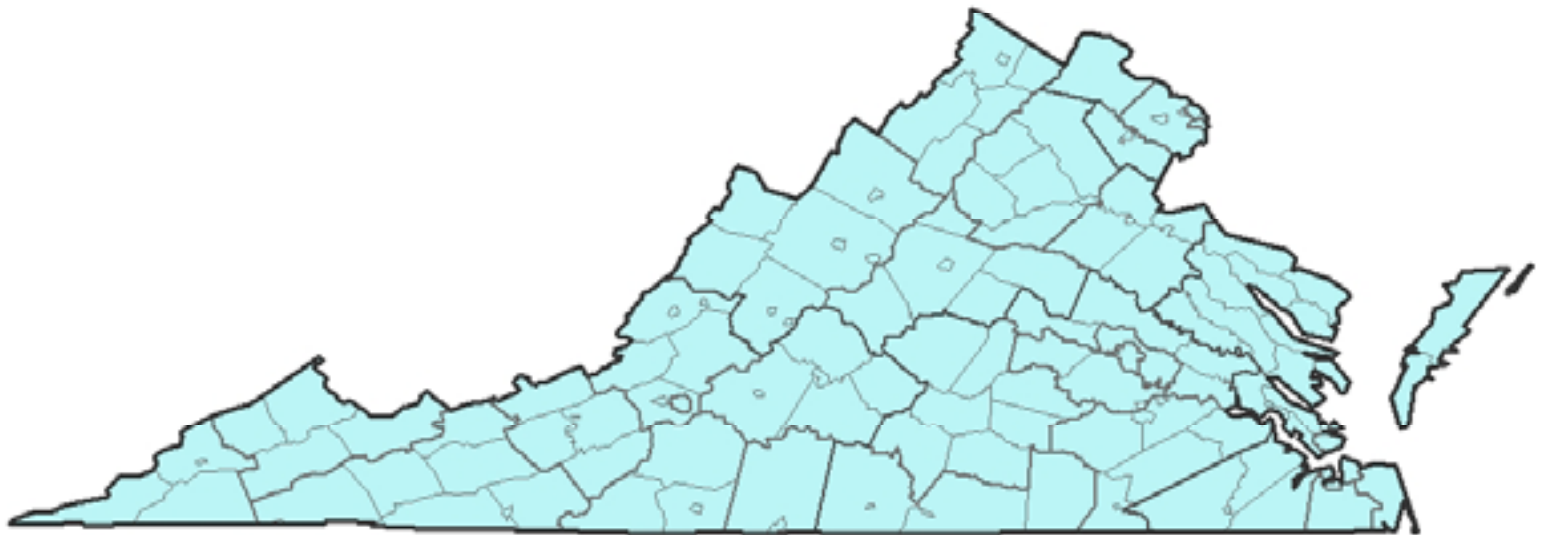
Virginia Geography and Jurisdictions

- 5 Health Regions
- 35 Health Districts
- Counties/Cities



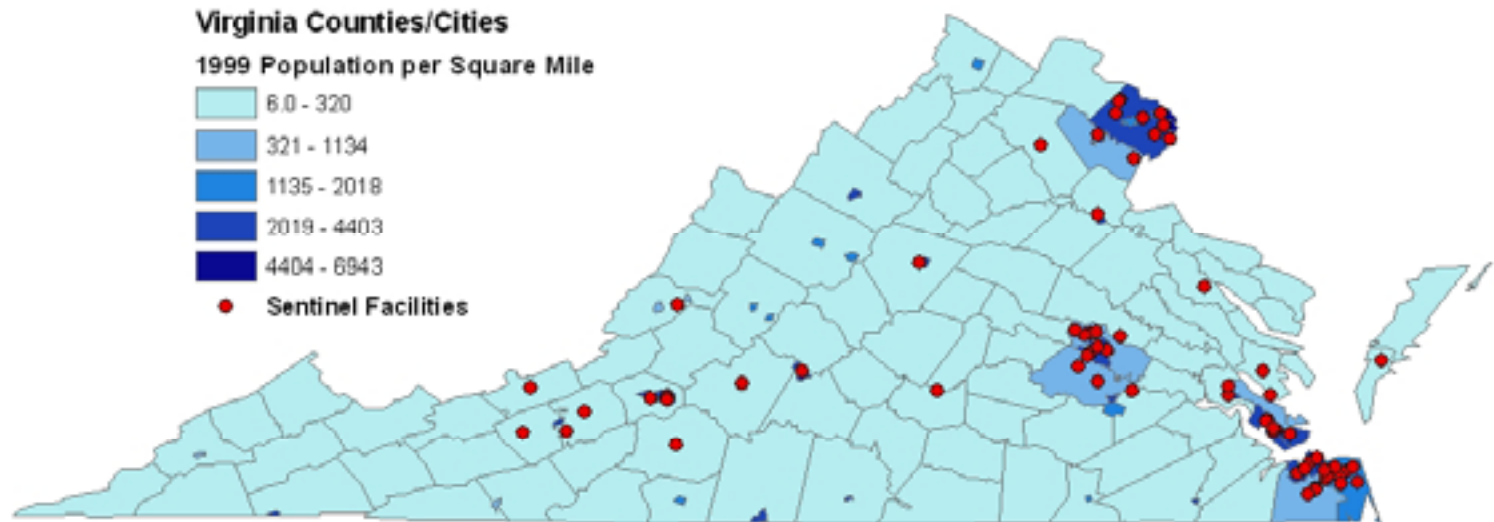
Virginia Geography and Jurisdictions

Virginia Geography and Health Jurisdictions
Cities / Counties



Influenza Surveillance Coverage

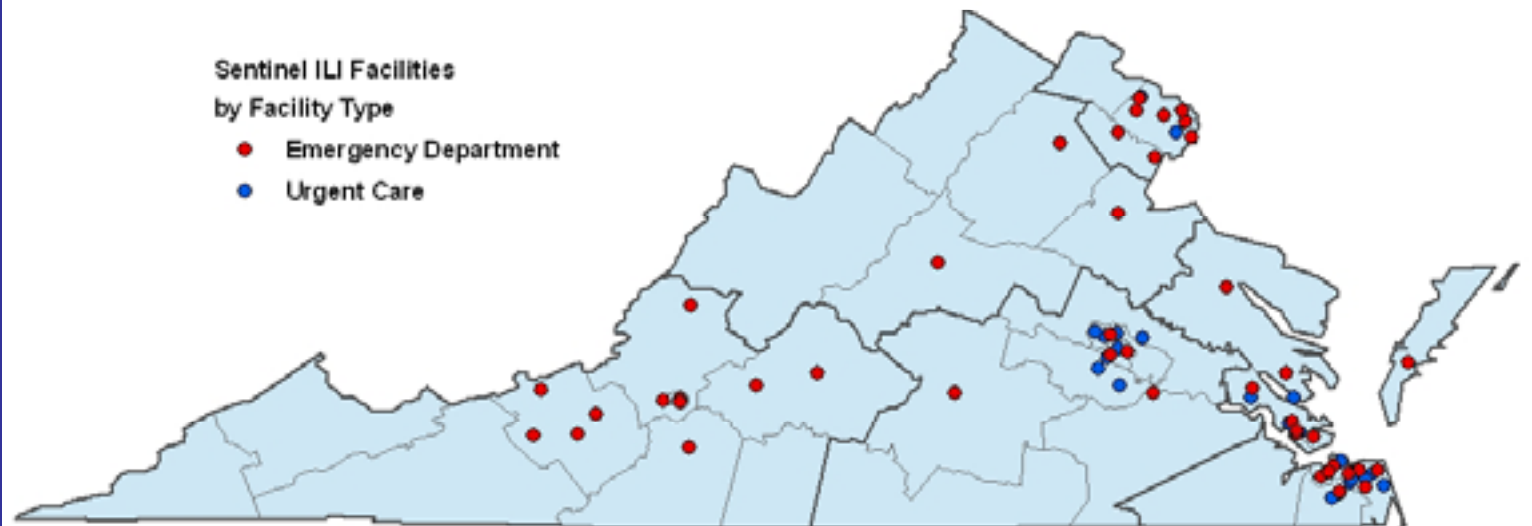
Distribution of Facilities Participating in ILI Sentinel Surveillance 2005-2008, and Population Density by County in Virginia





Influenza Surveillance Coverage

Distribution of Facilities Participating in ILI Sentinel Surveillance
in Virginia by Type of Facility, 2005-2008



Sentinel Facilities 2005-06

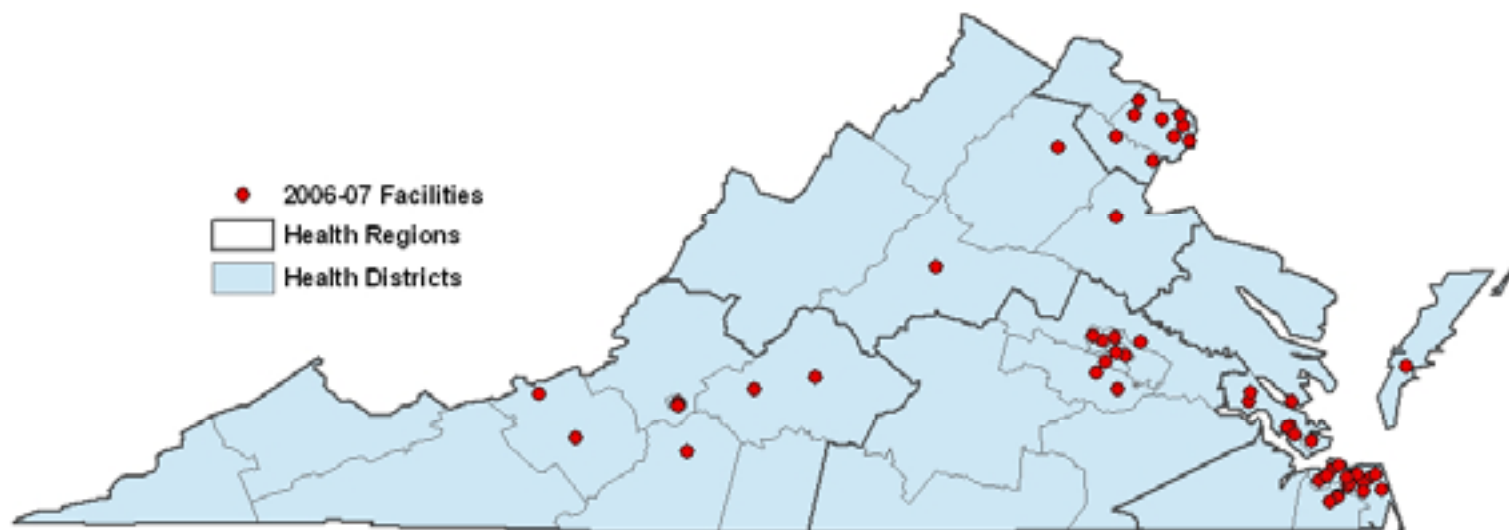
Distribution of Facilities Participating in ILI Sentinel Surveillance
in Virginia, 2005-2006 Influenza Season



Note: The Virginia Department of Health did not start using this sentinel facility system for ILI surveillance until the 2007-08 influenza season.

Sentinel Facilities 2006-07

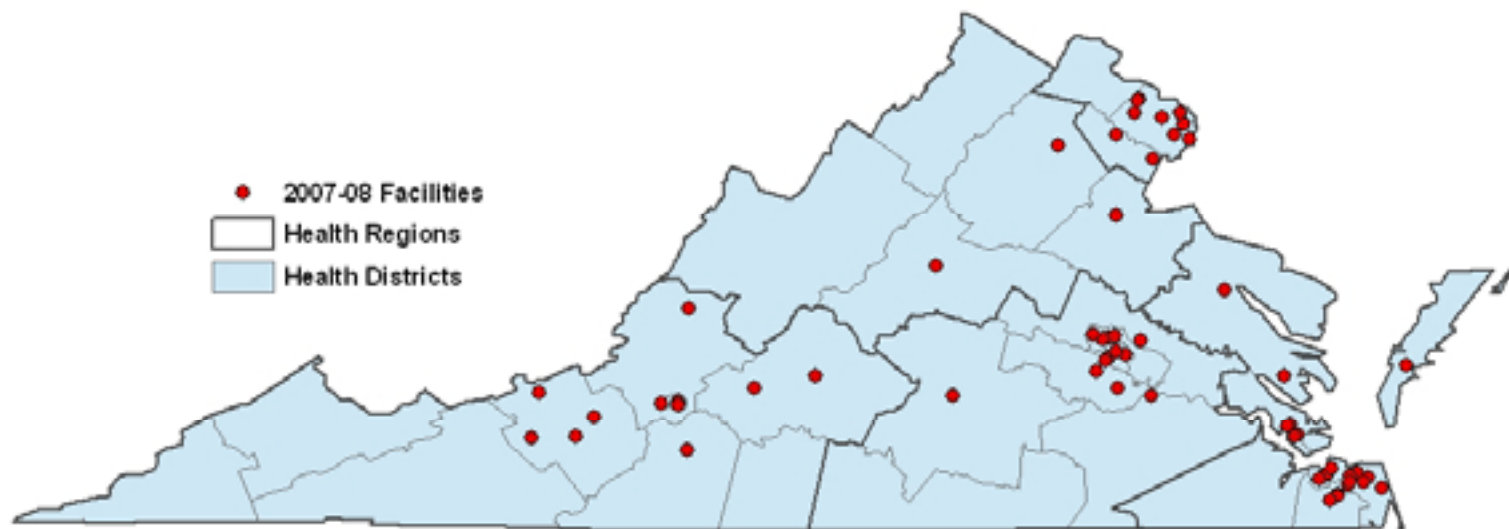
Distribution of Facilities Participating in ILI Sentinel Surveillance
in Virginia, 2006-2007 Influenza Season



Note: The Virginia Department of Health did not start using this sentinel facility system for ILI surveillance until the 2007-08 influenza season.

Sentinel Facilities 2007-08

Distribution of Facilities Participating in ILI Sentinel Surveillance in Virginia, 2007-2008 Influenza Season





Influenza Surveillance Limitations

- Not all regions of Virginia have comparable coverage in the system
 - Participating facilities are not evenly distributed or necessarily aligned with population distributions
 - VDH is currently working to bring more facilities online



Source: National Library of Medicine



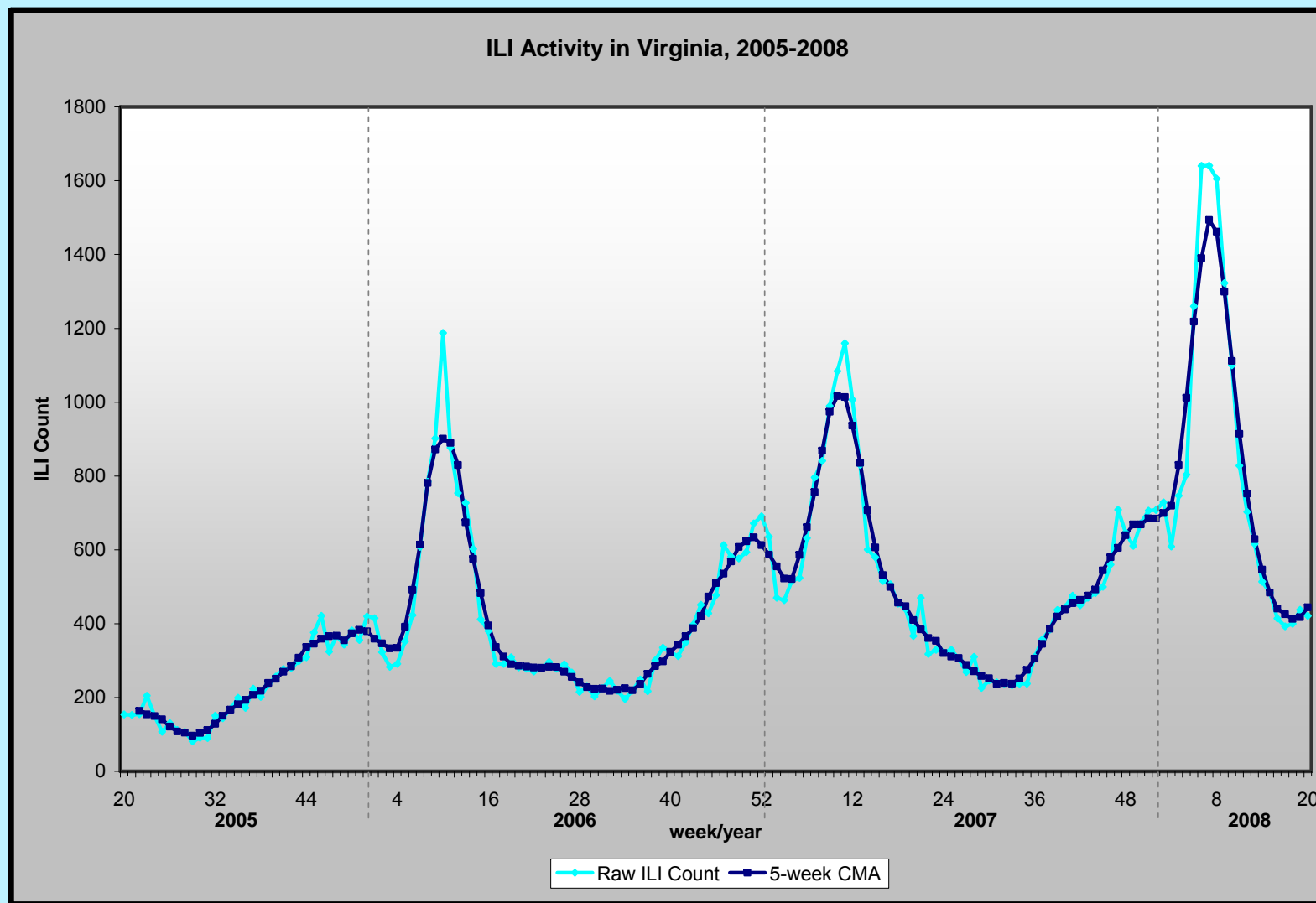
Statistical Analysis

- Time-series graphs
 - Annual variation by week
 - Variation by region
- Laboratory specimens
 - Specimen type by week (2007-08 season only)
 - Specimen type by region
 - Correlation between laboratory and ILI surveillance

Note: The Virginia Department of Health did not start using this sentinel facility system for ILI surveillance until the 2007-08 influenza season, so data from 2005-2007 do not represent official VDH surveillance data, but rather what the surveillance would have looked like had this newer surveillance system been used.

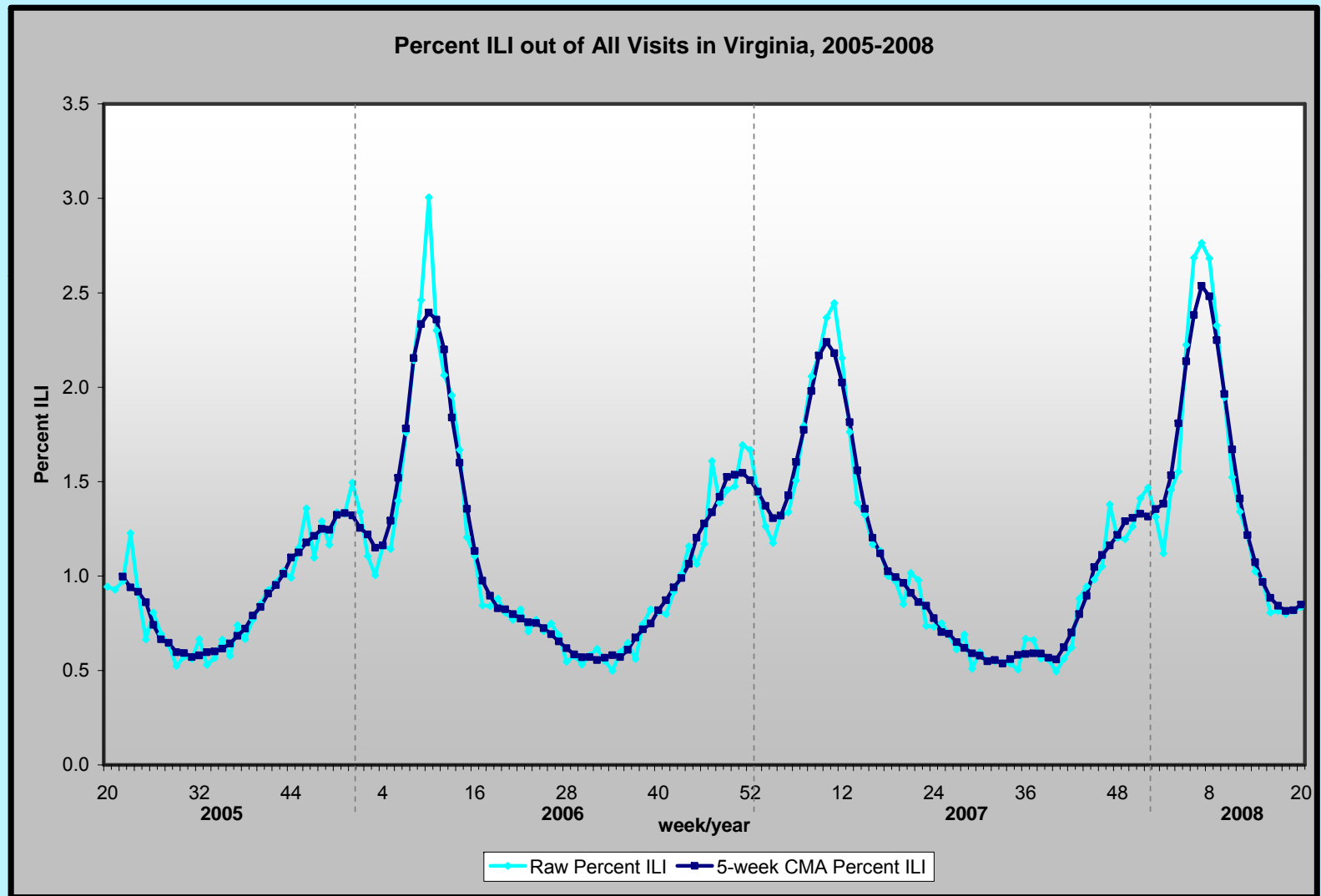


Seasonal Variation in ILI, 2005-2008



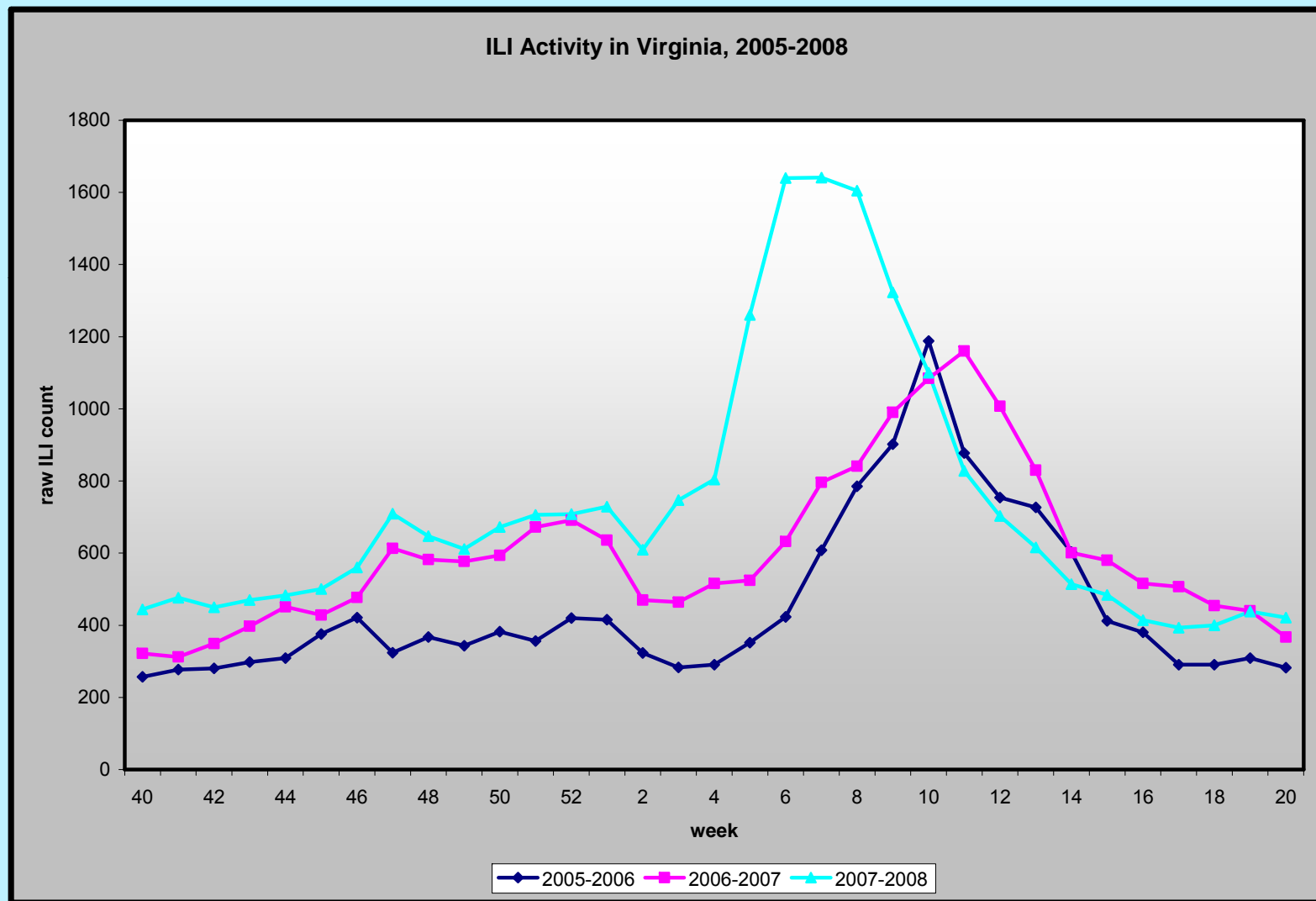


Seasonal Variation in ILI, 2005-2008



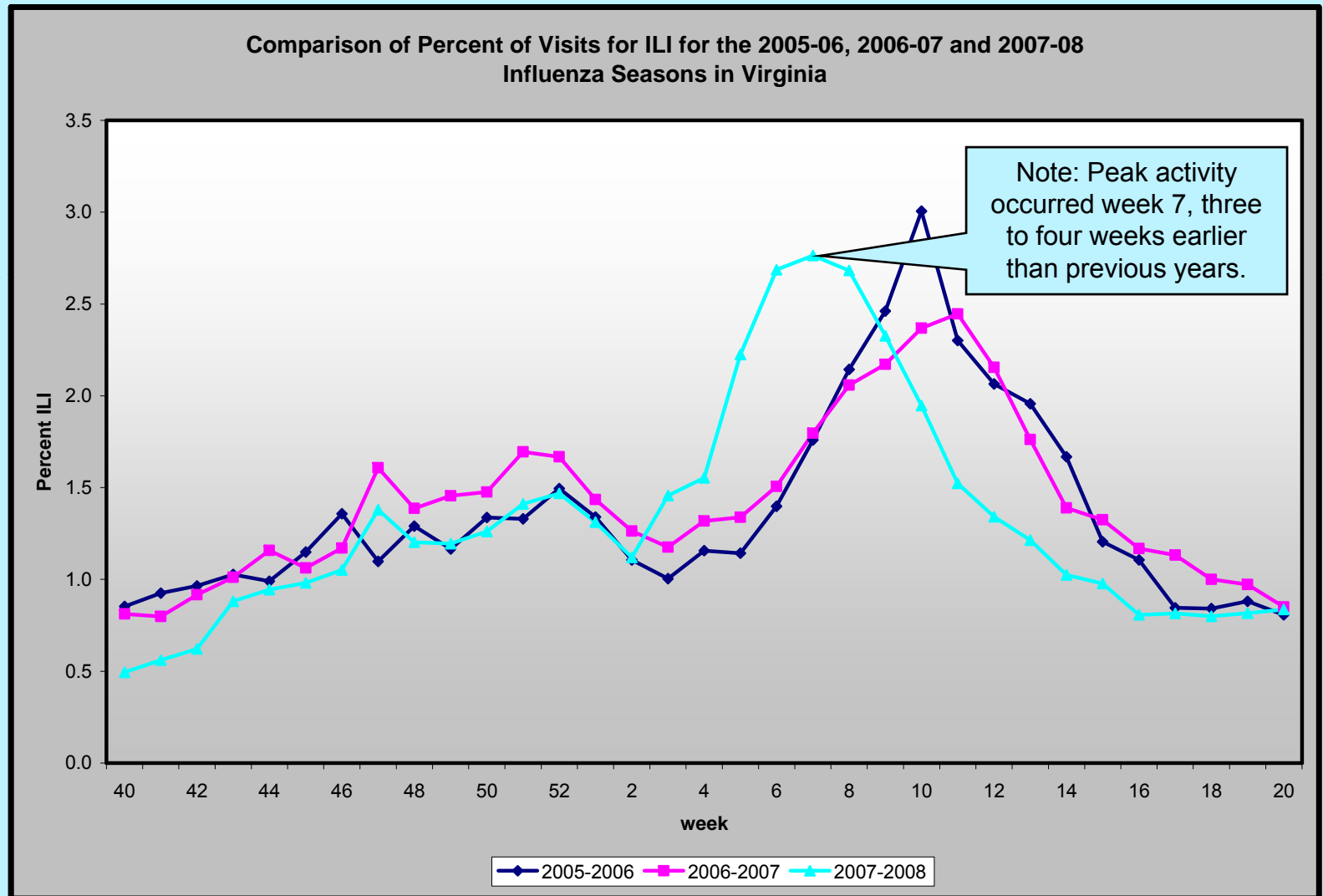


Seasonal Variation in ILI, 2005-2008

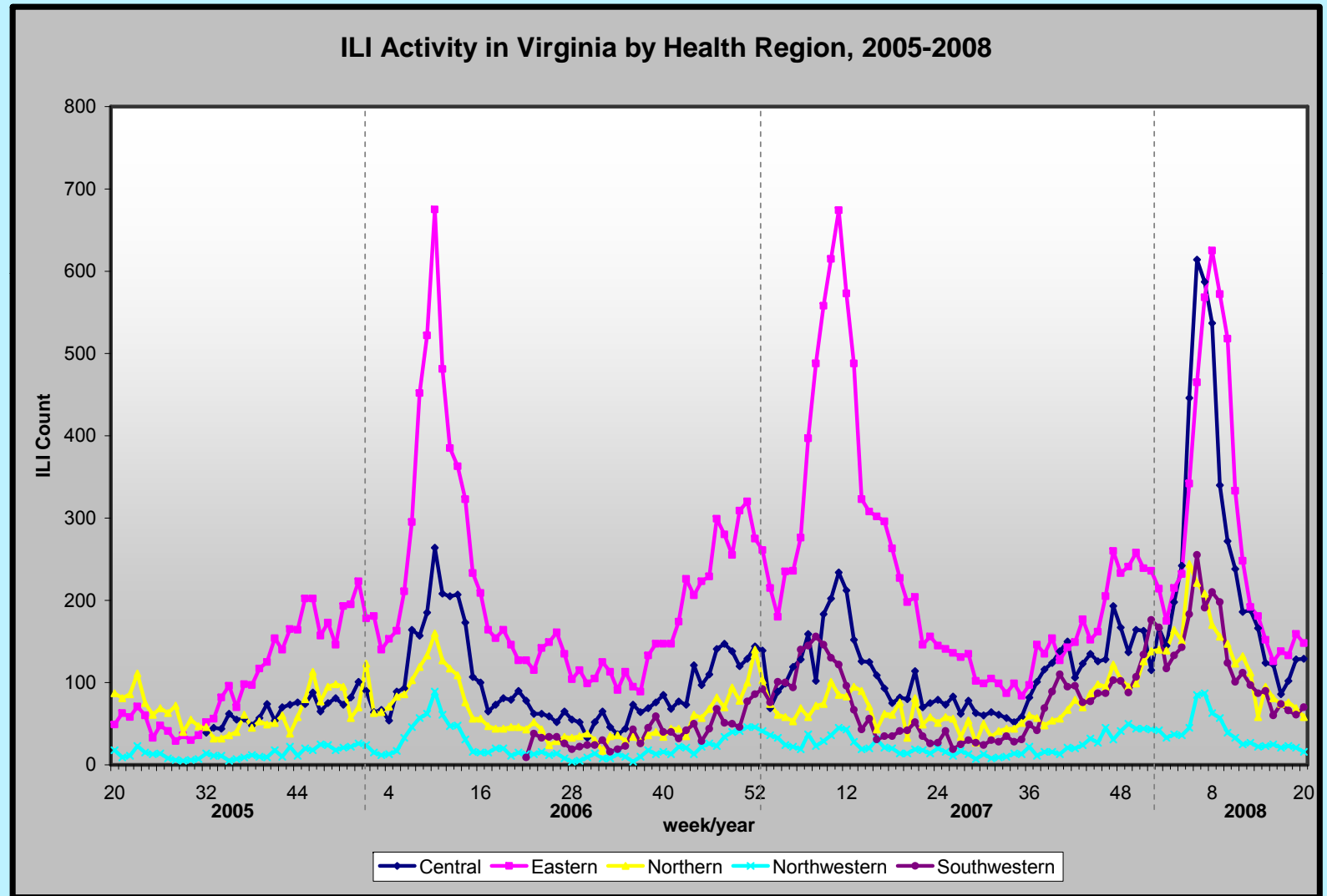




Seasonal Variation in ILI, 2006-2008

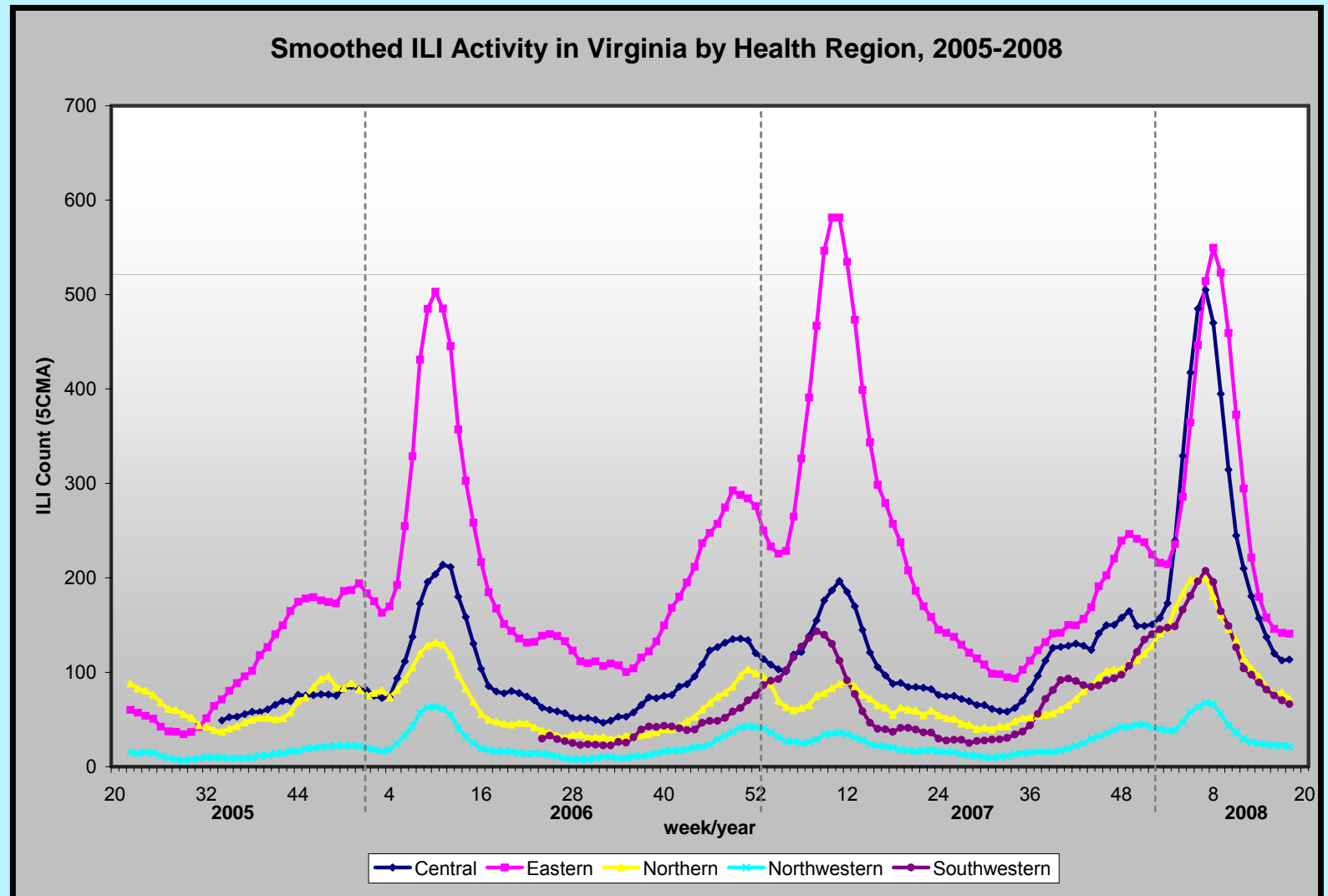


Seasonal Variation by Region

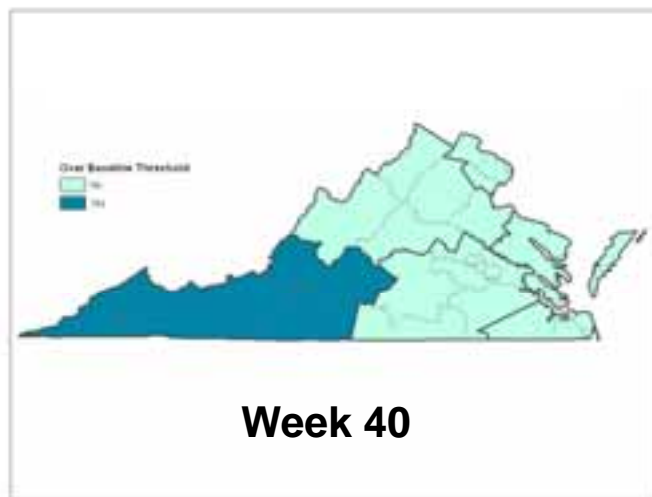




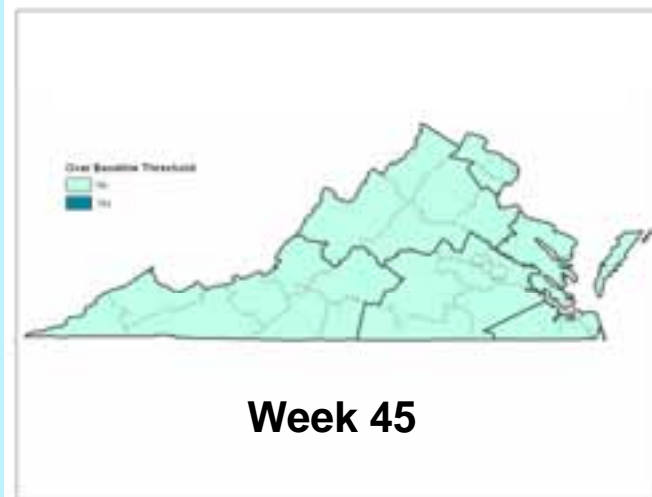
Seasonal Variation by Region



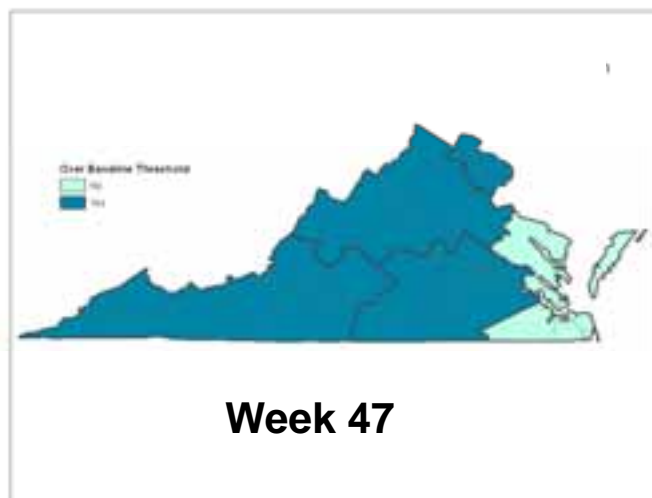
Time-Series Maps by Health Region, 2007-08 Season



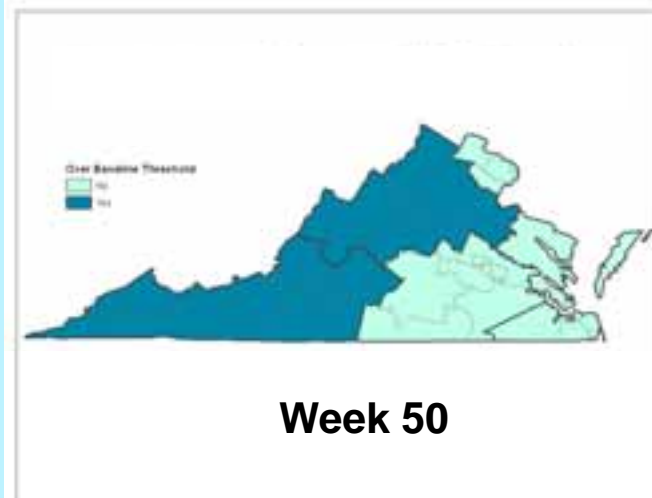
Week 40



Week 45

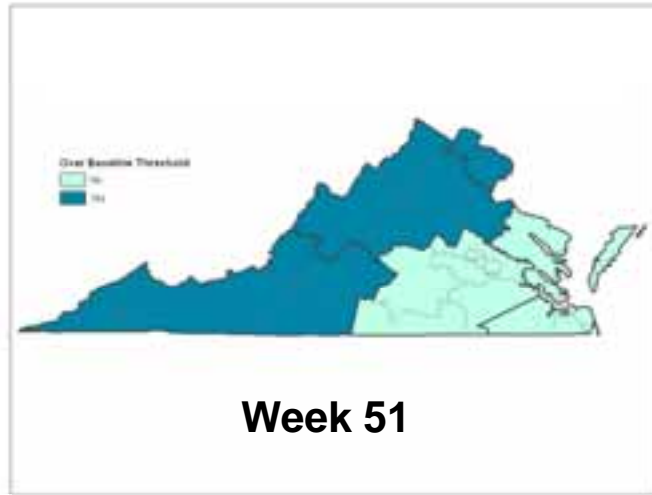


Week 47

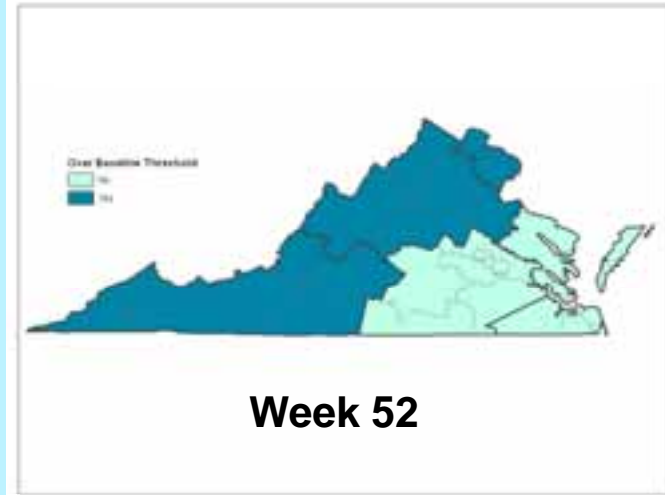


Week 50

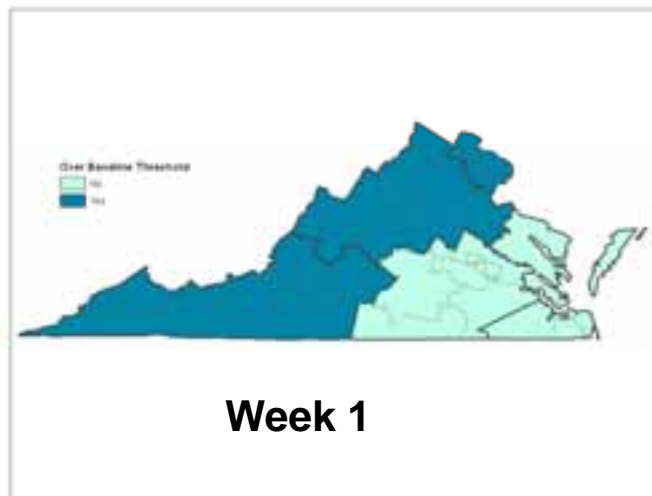
Time-Series Maps by Health Region, 2007-08 Season



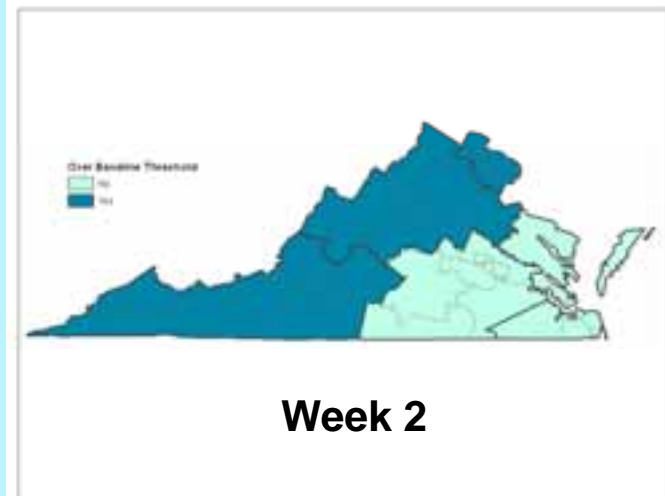
Week 51



Week 52

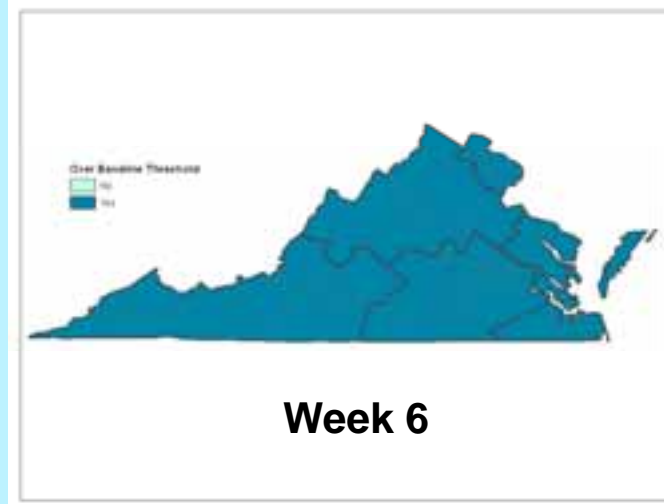
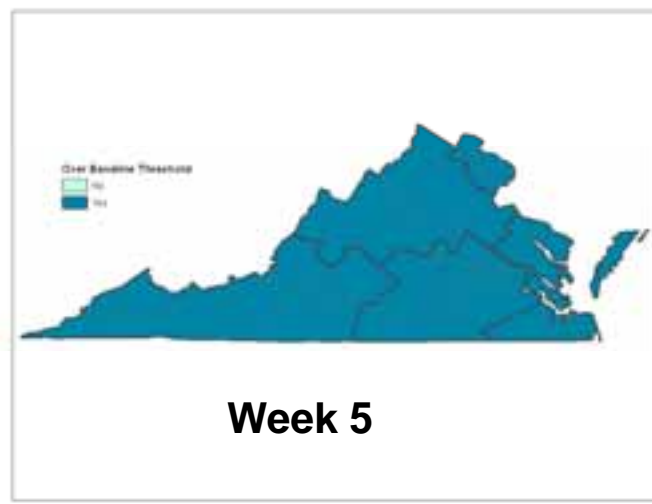
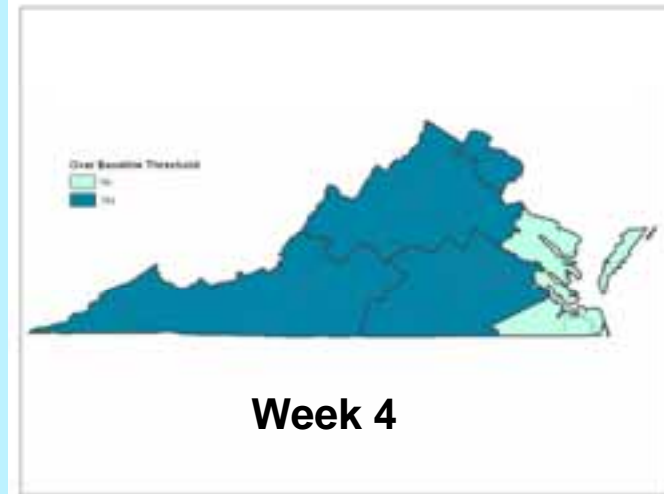
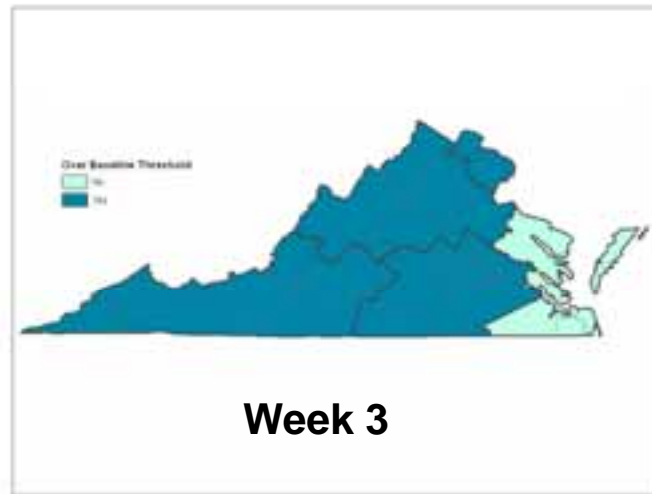


Week 1

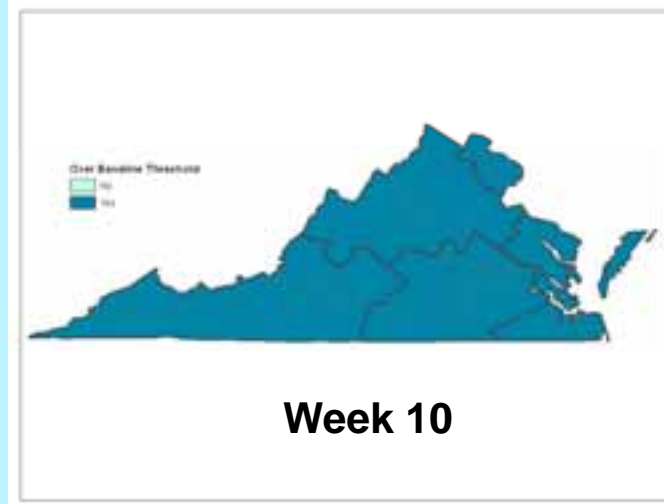
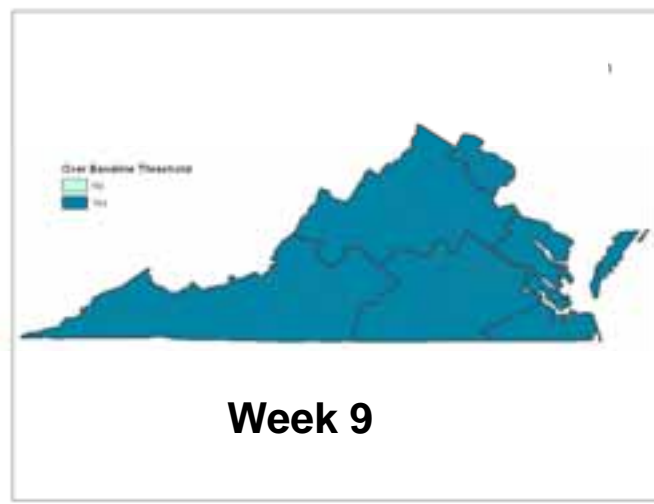
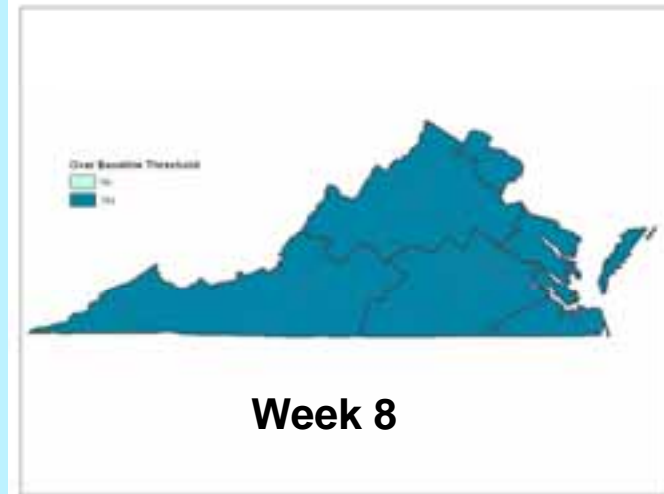
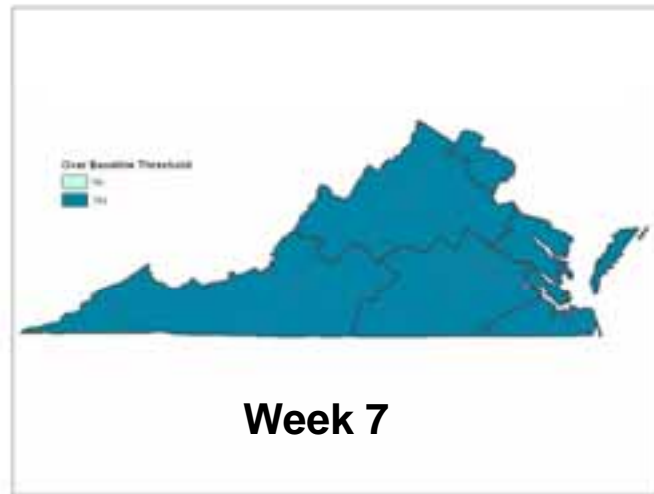


Week 2

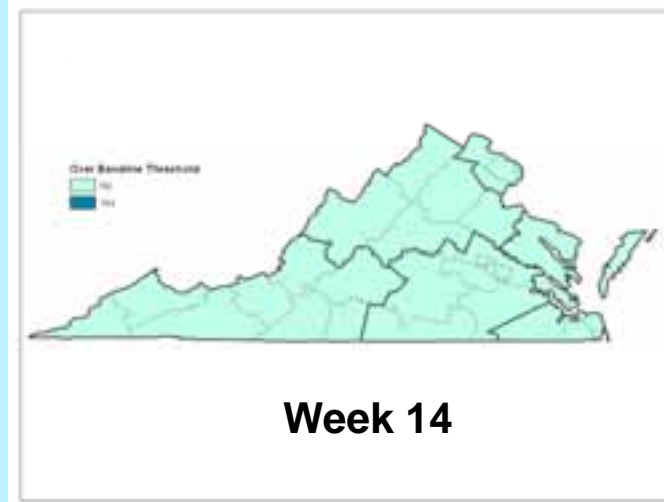
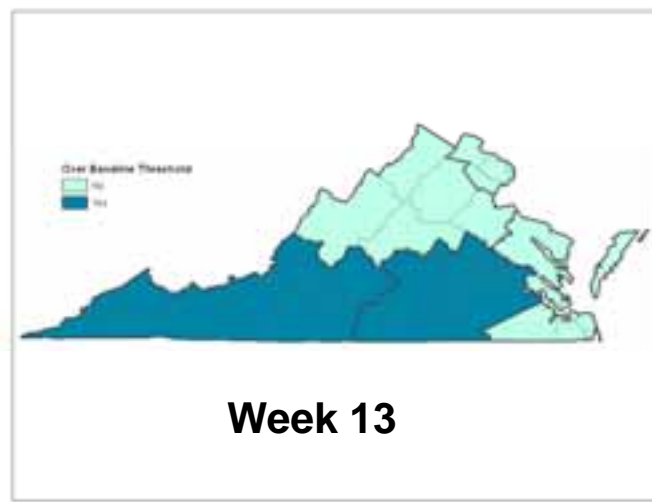
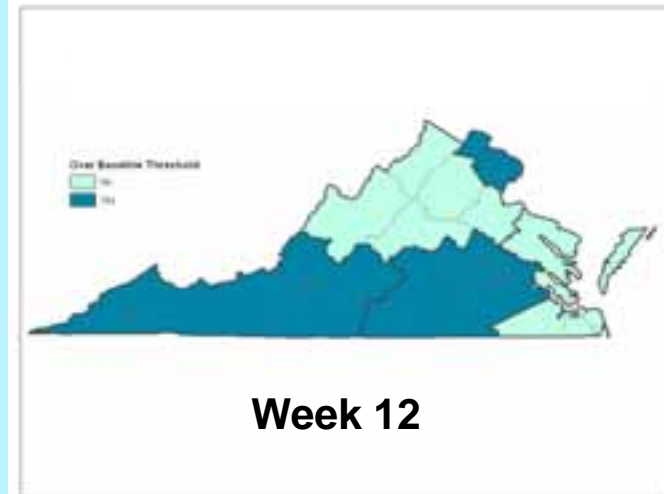
Time-Series Maps by Health Region, 2007-08 Season



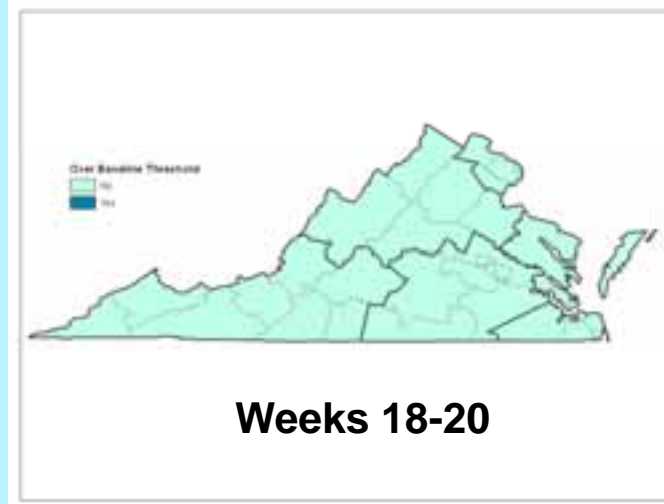
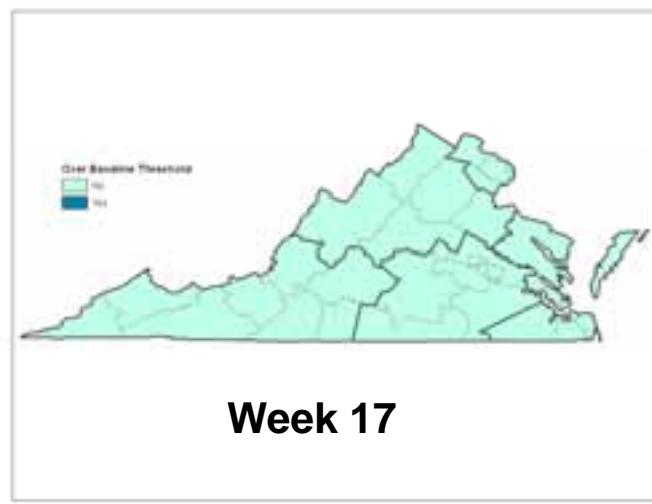
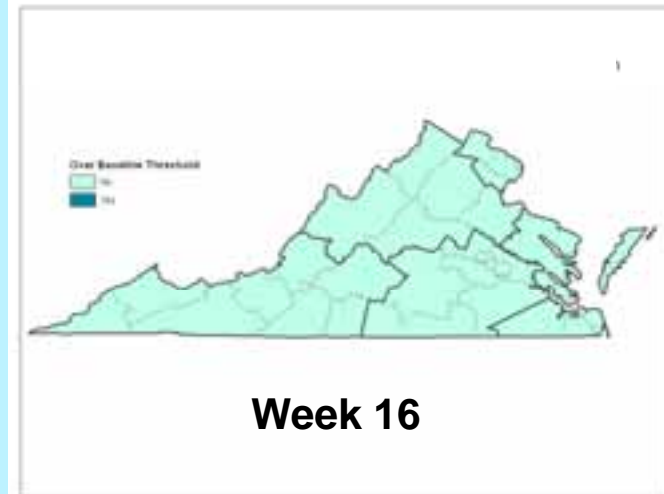
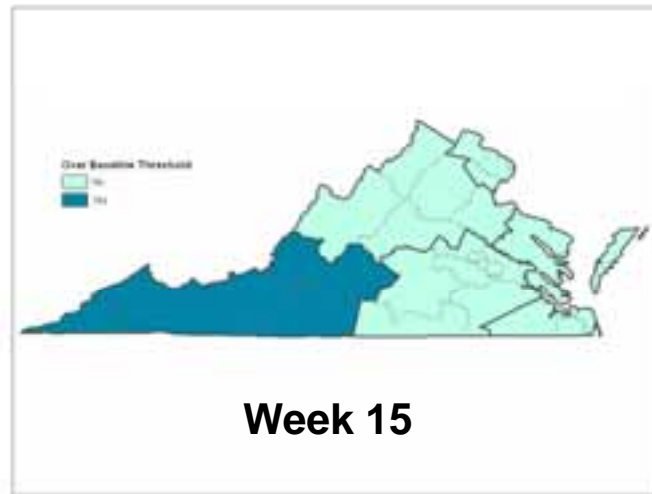
Time-Series Maps by Health Region, 2007-08 Season



Time-Series Maps by Health Region, 2007-08 Season

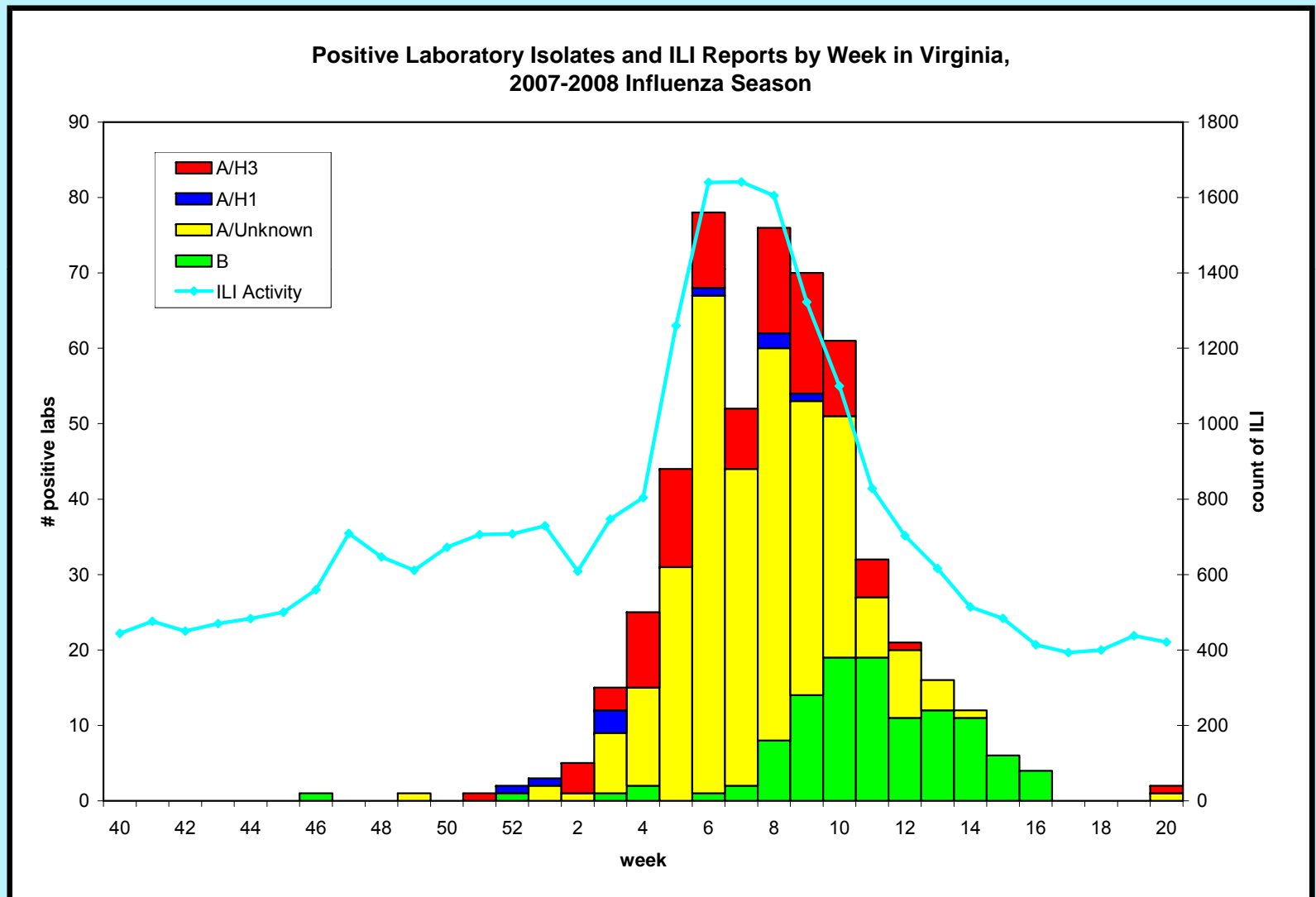


Time-Series Maps by Health Region, 2007-08 Season



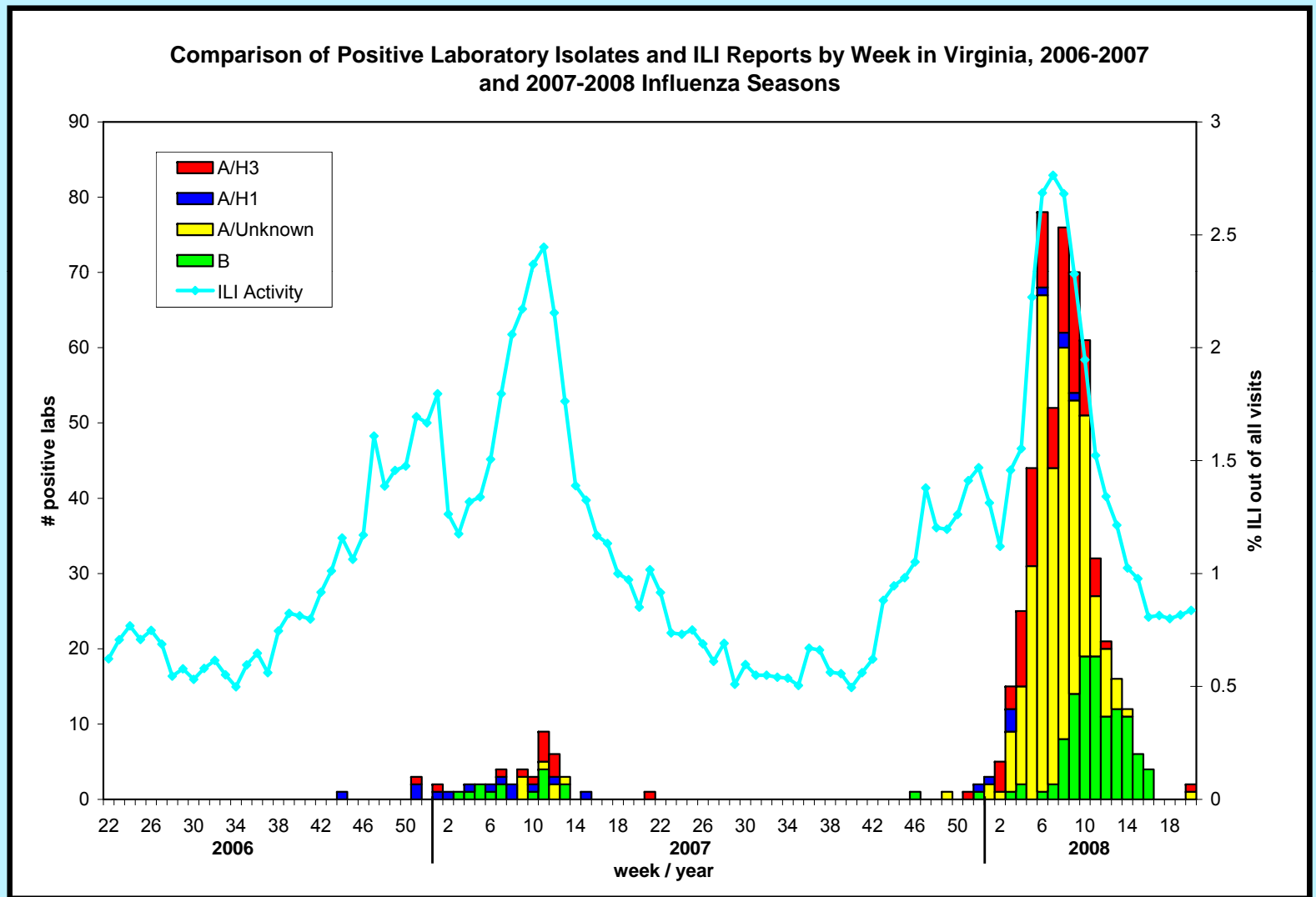


Laboratory Surveillance



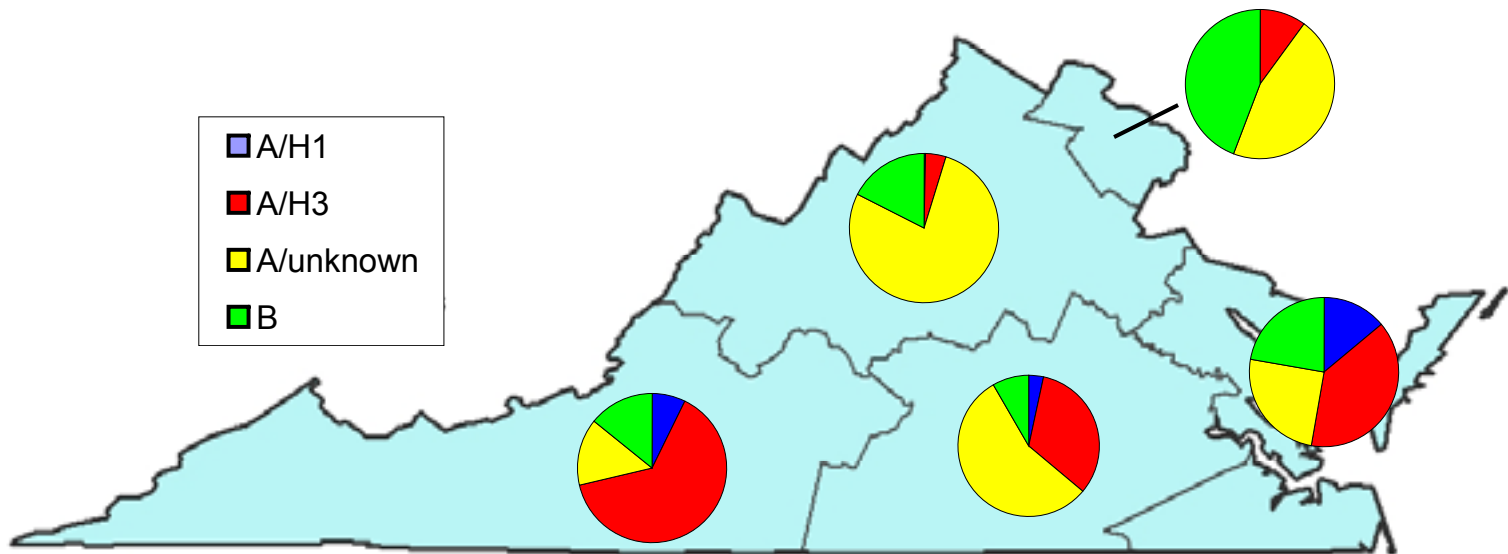


Laboratory Surveillance



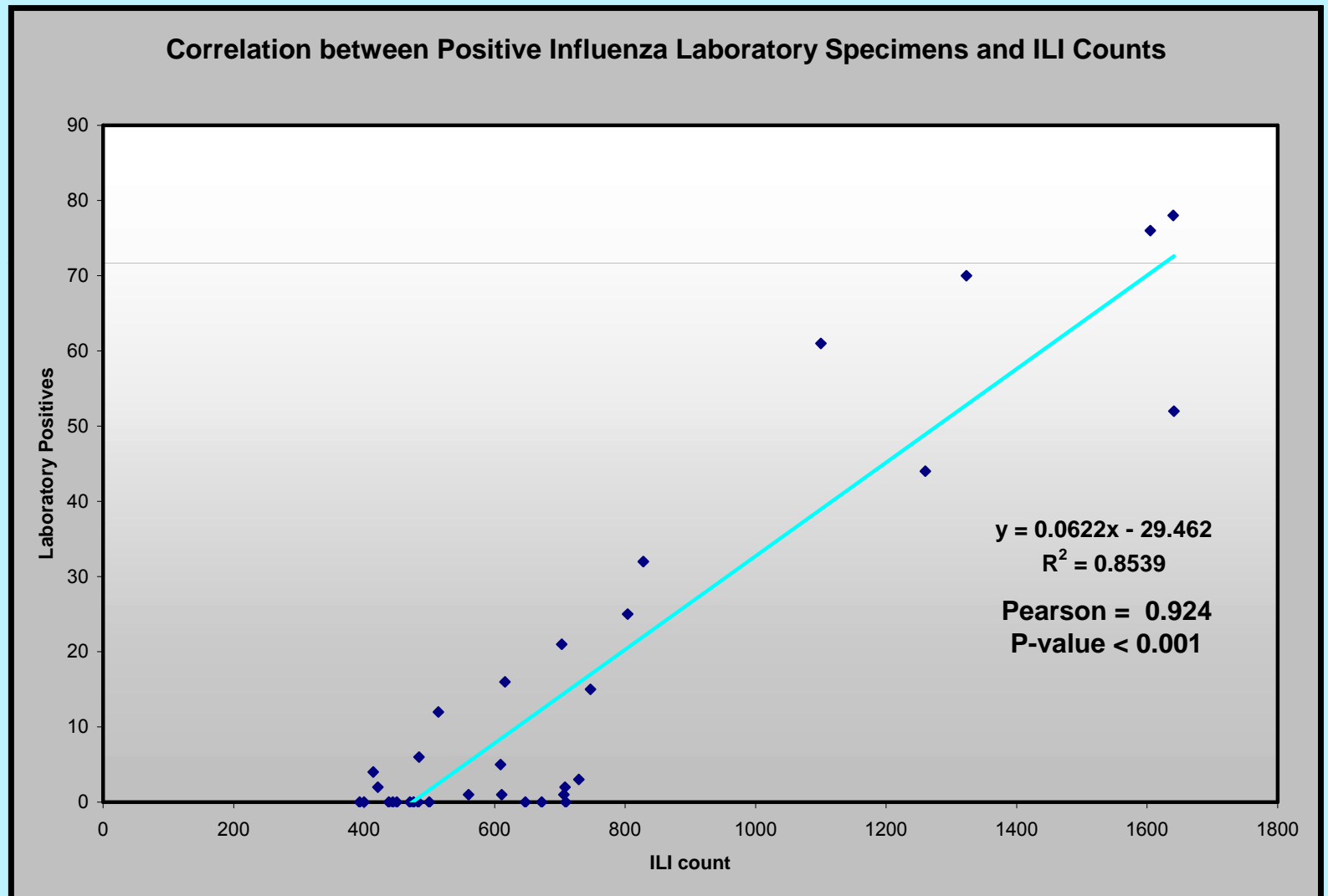
Labs by Region, 2007-2008

Positive Influenza Laboratory Specimens by Type and Region





Correlation Analysis





Geostatistical Analysis

- Data Preparation
 - Data smoothing
 - Identification of peak week of influenza activity by sentinel facility
 - Geocoding
- Exploratory Spatial Analysis
 - Histograms
 - QQ plots
 - Trend analysis
- Kriging Modeling



Data Preparation

- Data smoothing
 - Adjusted ILI count data with 5 week un-weighted centered moving average to smooth the data
- Identification of peak week of influenza activity by sentinel facility
 - Peak week defined as first week highest ILI count was observed for each facility during the season
- Each sentinel facility then ranked in order of peak activity
 - The first week was defined when the first peak was observed in any of the facilities during the season
 - Subsequent weeks numbered accordingly
- Geocoding of sentinel facilities



Kriging Analysis

- Kriging uses a weighed moving average interpolation to produce the optimal spatial-linear prediction
 - Based on the spatial information in the semivariogram
 - No transformations applied (data was fairly normally distributed)
 - K-Bessel pattern



Kriging Analysis

- Created filled-contour maps from the kriging weights for the measured values
 - The isobars on the contour maps represent interpolated time of peak activity distributed spatially at 1-week intervals
- Also produced standard error prediction maps for the kriging weights
 - Illustrates geographic areas with good/poor prediction

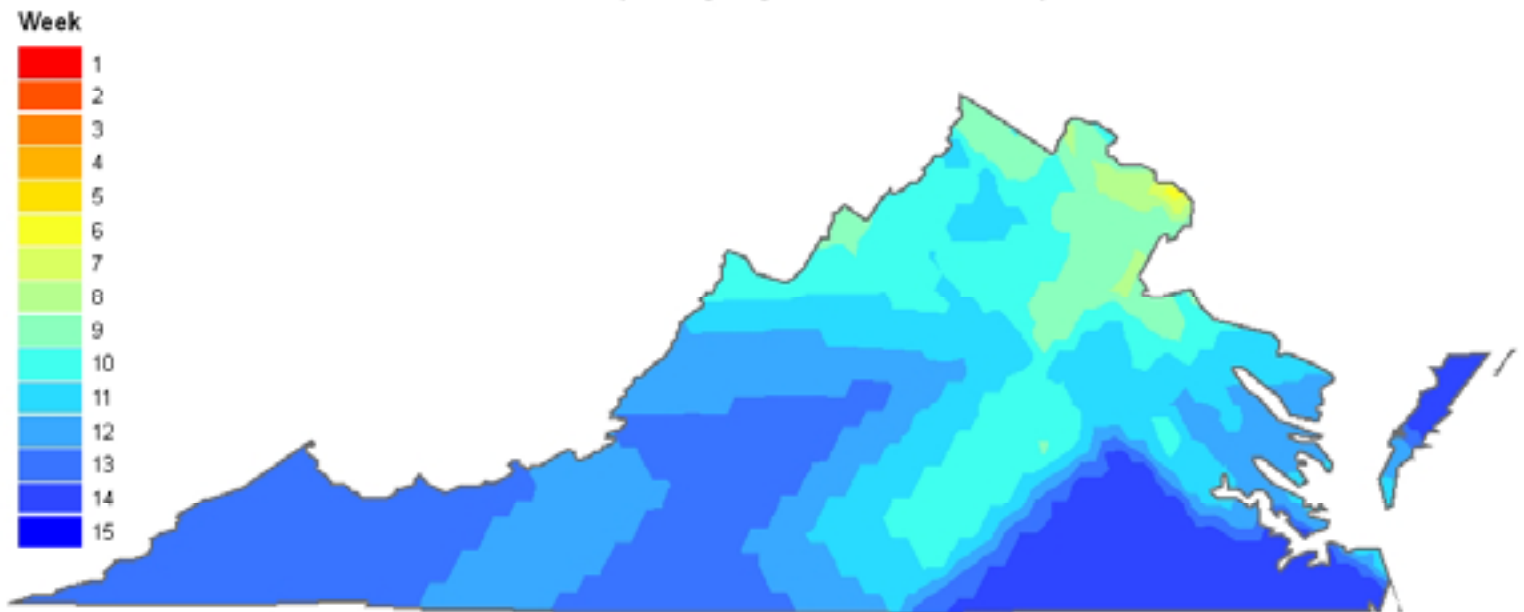
2005-2006 Kriging Analysis

2005-2006 Influenza Season Timing of Peak ILI Activity by Week in Virginia
Ordinary Kriging Prediction Map



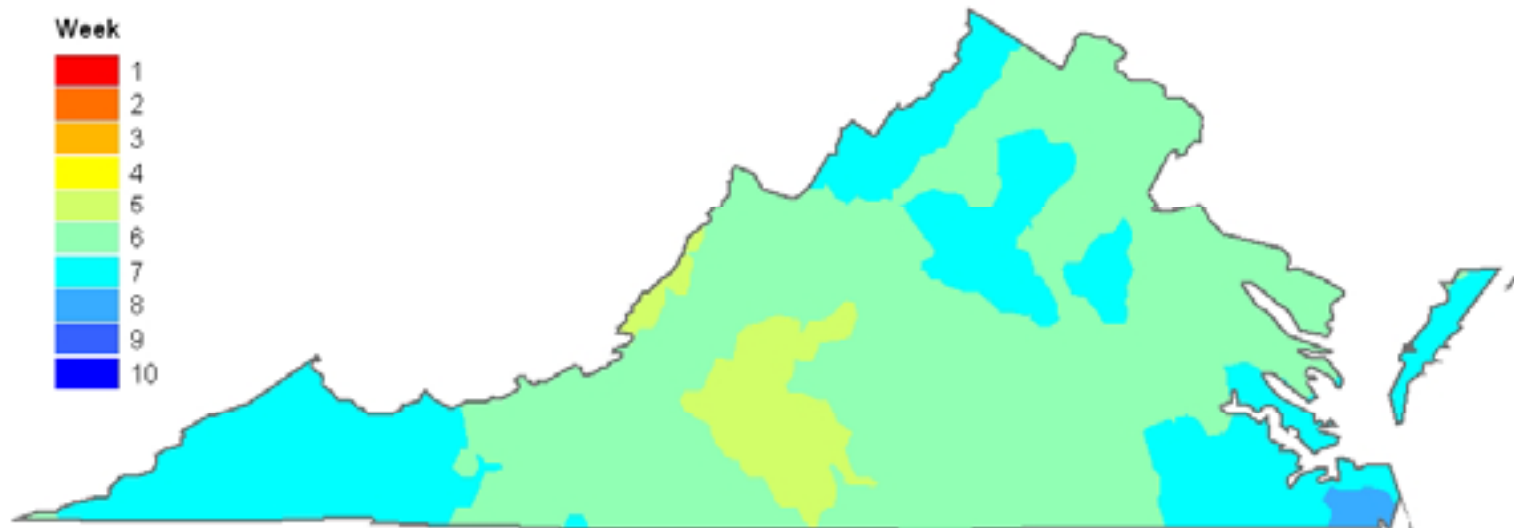
2006-2007 Kriging Analysis

2006-2007 Influenza Season Timing of Peak ILI Activity by Week in Virginia
Ordinary Kriging Prediction Map



2007-2008 Kriging Analysis

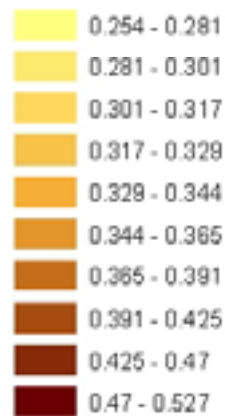
2007-2008 Influenza Season Timing of Peak ILI Activity by Week in Virginia
Ordinary Kriging Prediction Map



2005-2006 Prediction Error

2005-2006 Influenza Season Timing of Peak ILI Activity by Week in Virginia
Ordinary Kriging Prediction Standard Errors Map

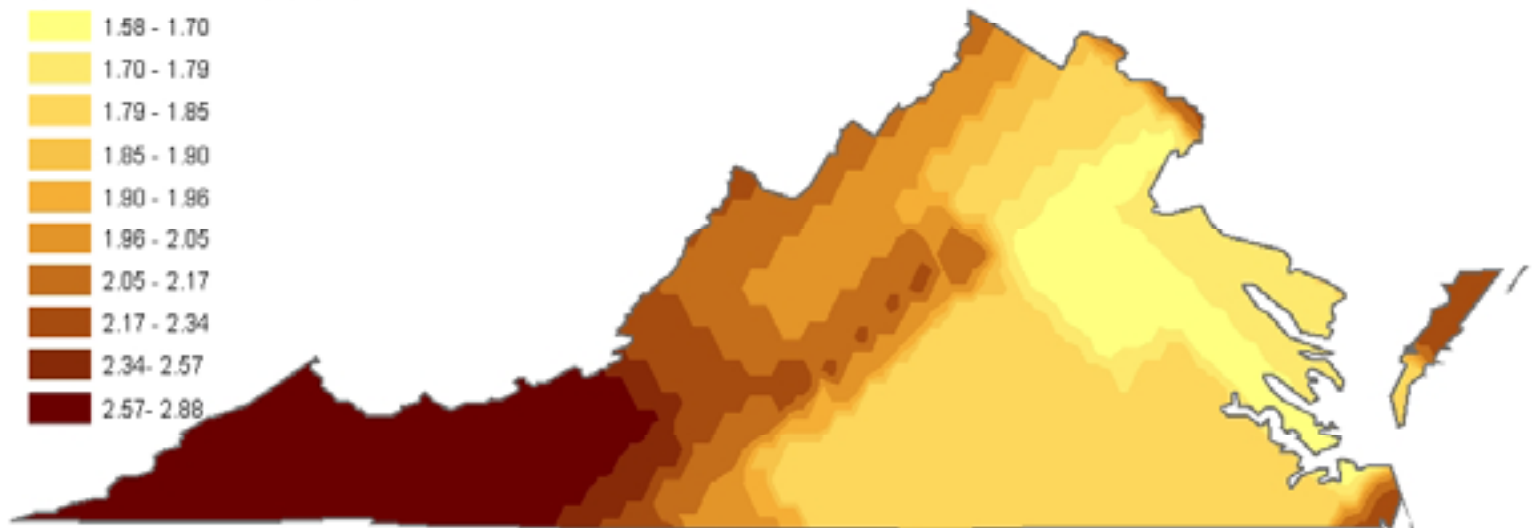
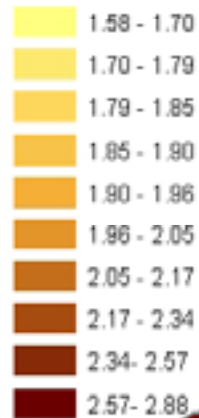
Prediction Standard Errors



2006-2007 Prediction Error

2006-2007 Influenza Season Timing of Peak ILI Activity by Week in Virginia
Ordinary Kriging Prediction Standard Error Map

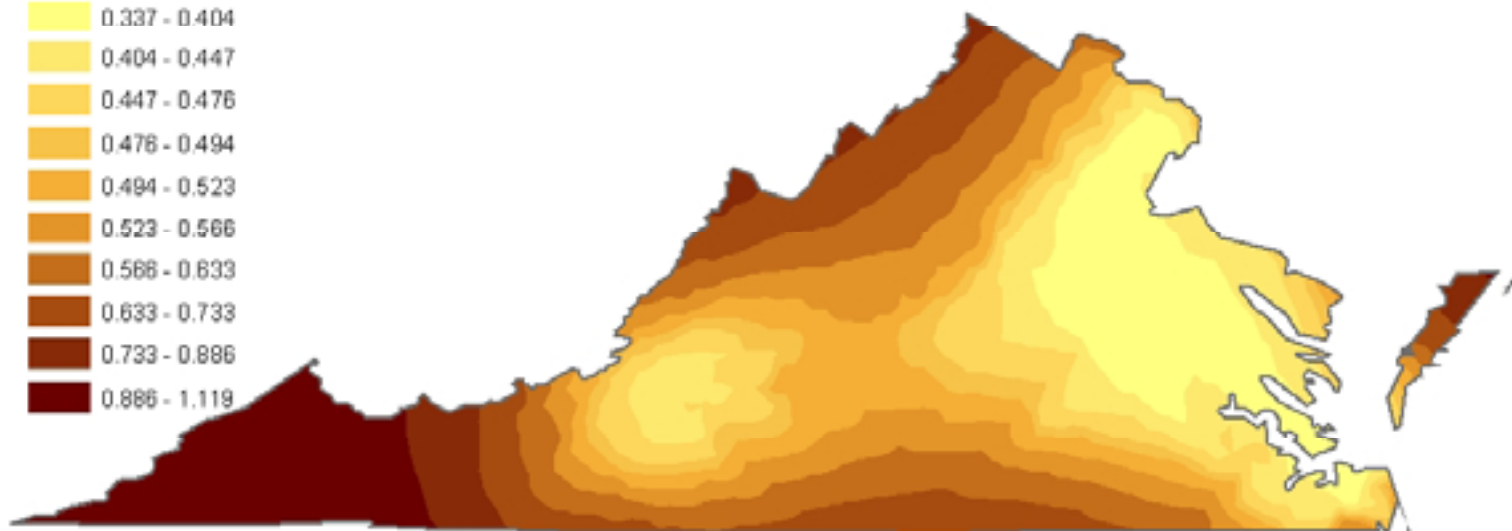
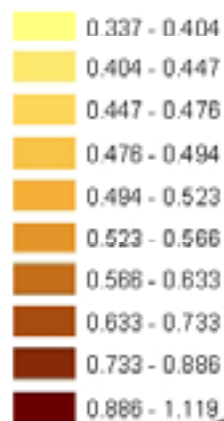
Prediction Standard Errors



2007-2008 Prediction Error

2007-2008 Influenza Season Timing of Peak ILI Activity by Week in Virginia
Ordinary Kriging Prediction Standard Error Map

Prediction Standard Errors





Conclusions

- Trends unclear
 - Northeast to southwest?
- Relatively little variation in timing of peak activity across the state (1-4 weeks)
- Prediction improving over time



Limitations

- Limited number of years of data available
- Limited coverage of Virginia health facilities, particularly in some regions
- Small geographic region
 - Might see more obvious trends if look at larger regions, or regions with greater population density



Future Directions

- Expand analyses as additional years of data become available and more sentinel facilities submit data
- Expand geostatistical analyses to account for differences in the spatio-temporal spread of influenza by patient age (younger ages peak earlier?)
- Consider differences in type of facility (i.e. does peak activity occur at different times in UC vs. ED facilities?)

Acknowledgements

- Virginia Department of Health, Office of Epidemiology, Division of Surveillance and Investigation
 - Michael Coletta, Enhanced Surveillance Coordinator
 - Diane Woolard, Division Director
- Virginia Commonwealth University, Department of Epidemiology and Community Health
 - Elizabeth Eustis Turf, Associate Professor
 - Kate Young, Department Chair



Background image from National Geographic Society, Science Image Library.
<http://science.nationalgeographic.com/science/photos/influenza/flu-virus.html>



Questions?

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