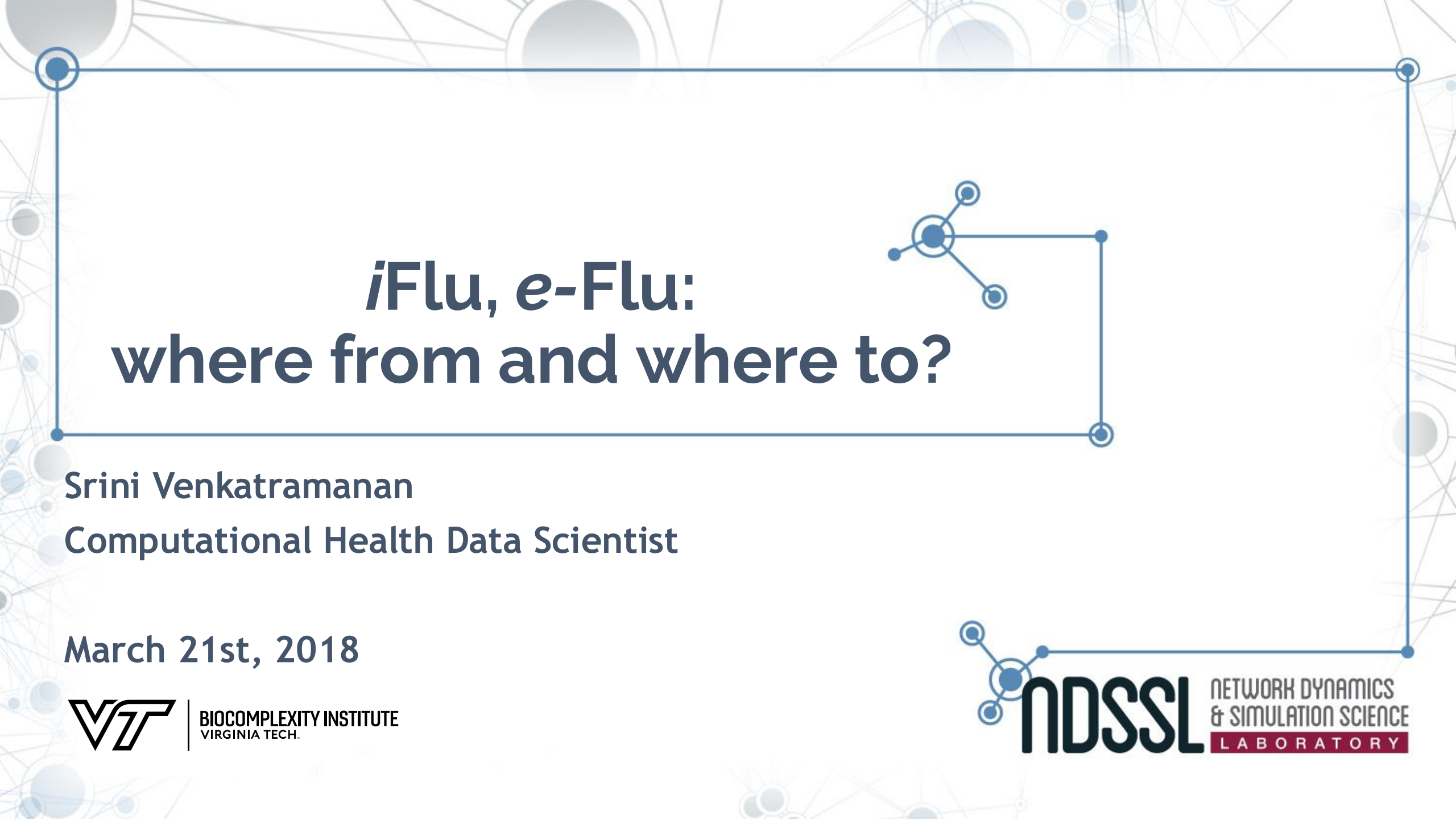




*i*Flu, *e*-Flu: where from and where to?

Srini Venkatramanan
Computational Health Data Scientist

March 21st, 2018



BIOCOMPLEXITY INSTITUTE
VIRGINIA TECH.



Outline

Introduction

Modeling

Forecasting

Crowdsourcing

Scope

- Scope of this talk:

- Digital/computational trends in influenza surveillance
- Models of influenza spread at the population level
- Types of forecasts that get generated
- Involvement of human experts in the process

Introduction

Modeling

Forecasting

Crowdsourcing

- Not covered:

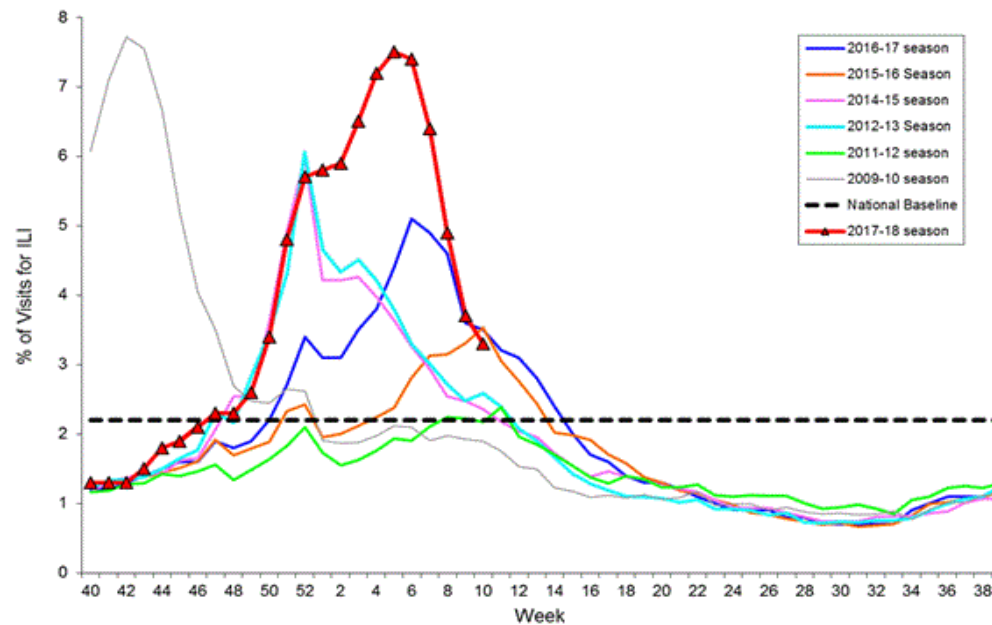
- Influenza evolution at the sub-human level
- Viral phylodynamics
- Hospitalization and mortality Surveillance
- Interventions and counterfactuals
- Pandemic preparedness efforts

Introduction

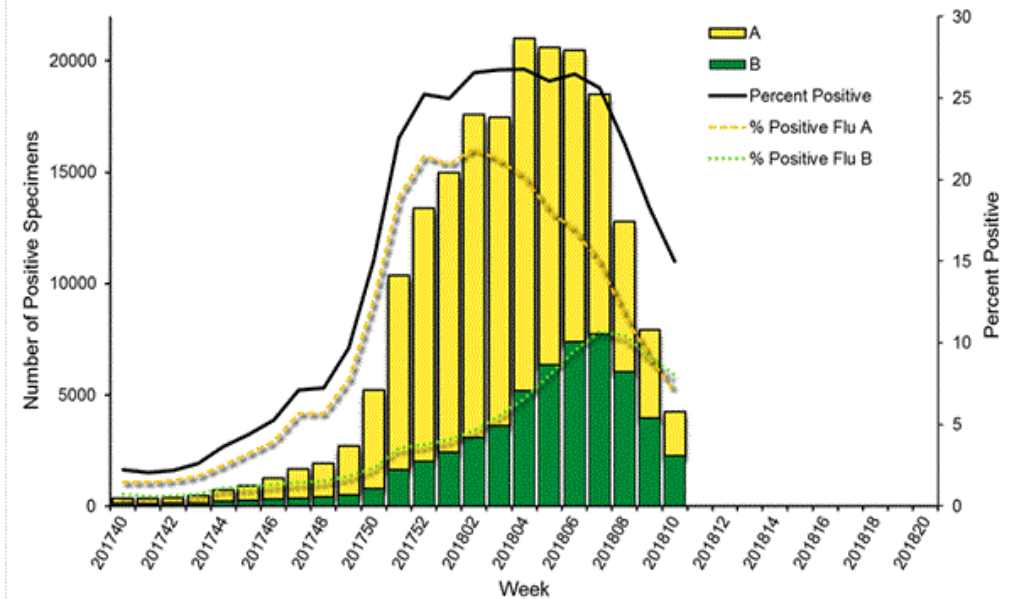
Influenza surveillance in the United States

- CDC ILINet
 - U.S. Outpatient Influenza-like Illness Surveillance Network
- WHO/NREVSS Virological Surveillance

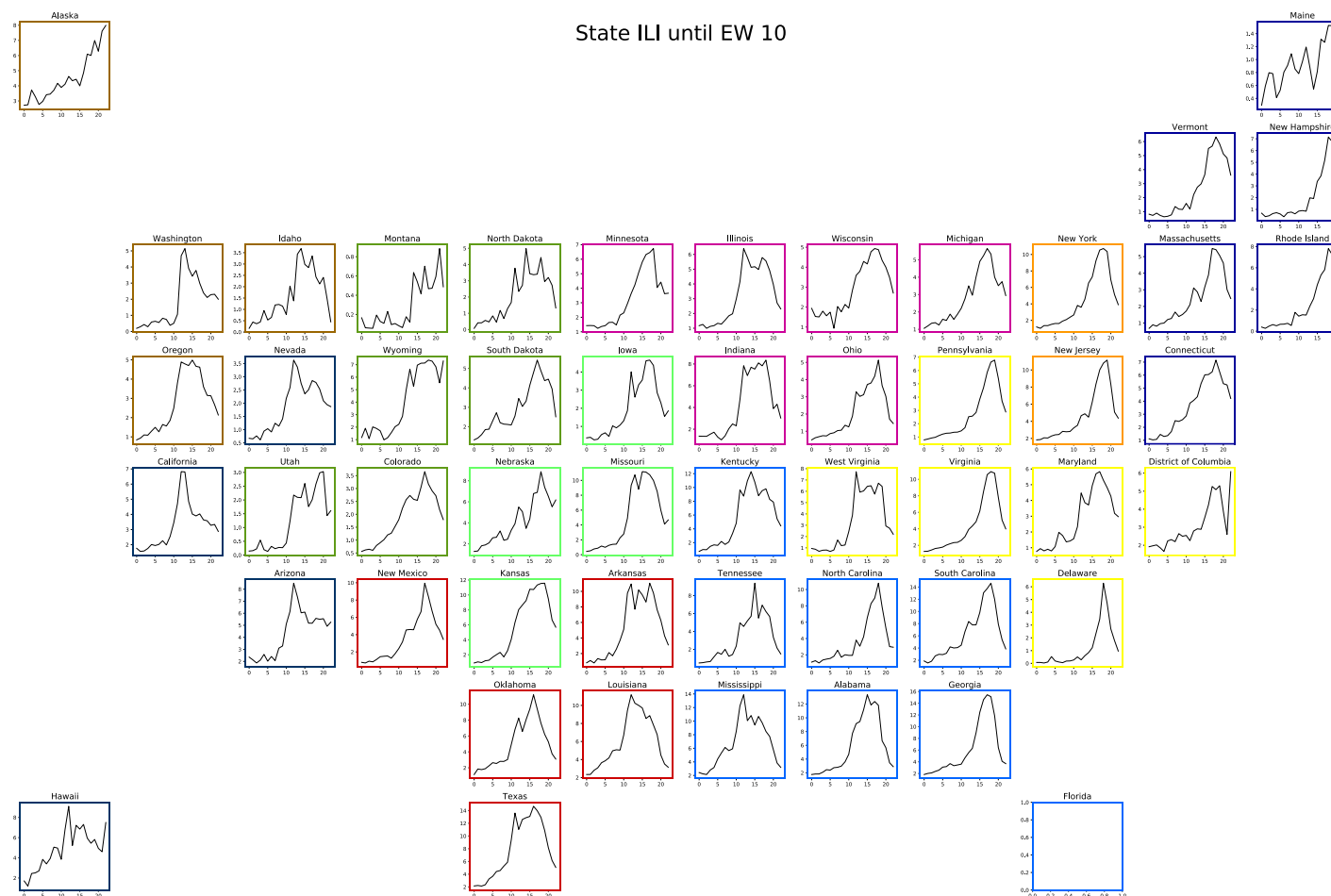
Percentage of Visits for Influenza-like Illness (ILI) Reported by the U.S. Outpatient Influenza-like Illness Surveillance Network (ILINet), Weekly National Summary, 2017-2018 and Selected Previous Seasons



Influenza Positive Tests Reported to CDC by U.S. Clinical Laboratories, National Summary, 2017-2018 Season

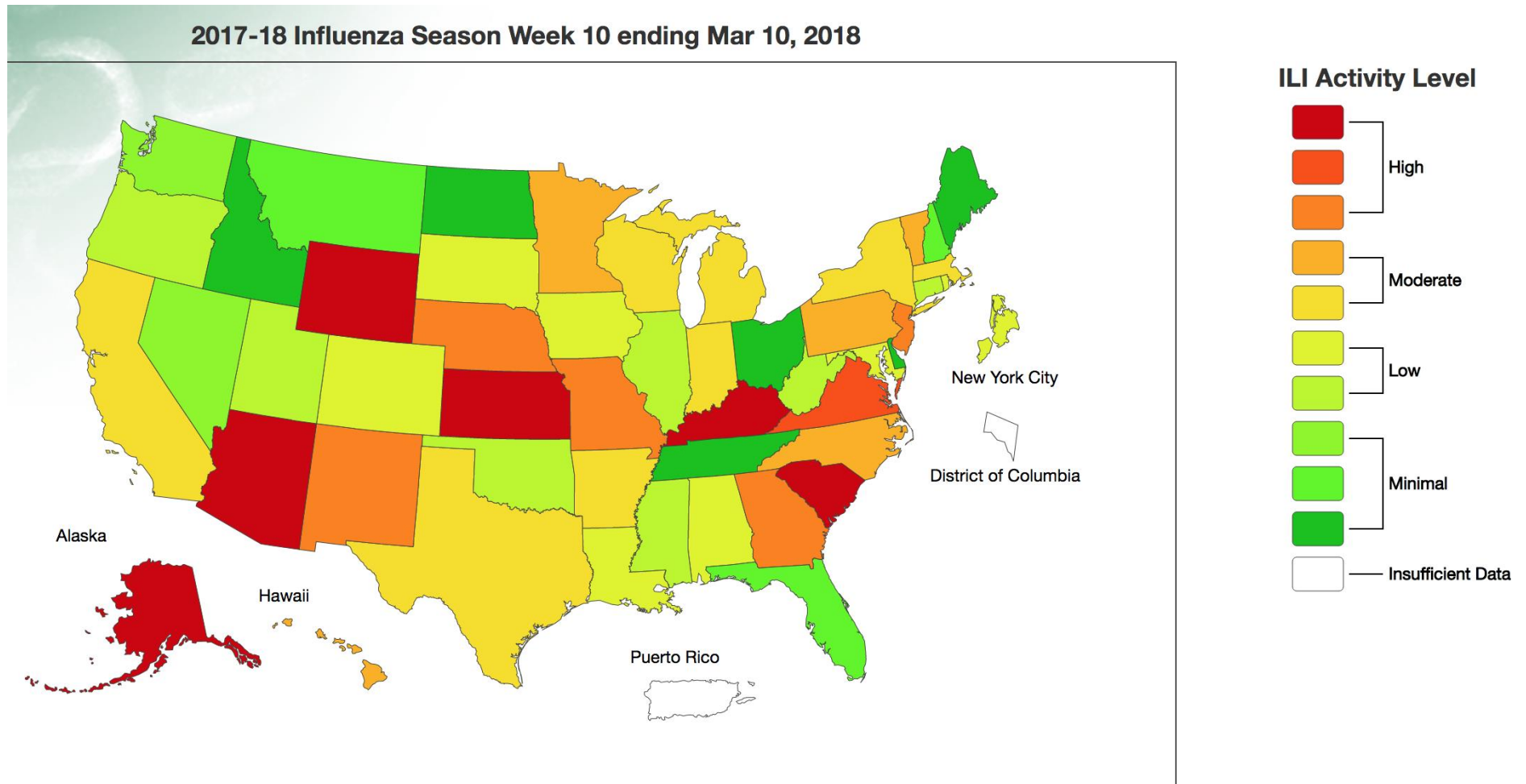


State level ILI surveillance



Made available before start of 2017-18 season. Covers past 6 influenza seasons

Spatial activity map



Using proportion of outpatient ILI visits to healthcare providers to measure activity level within a state

Other data streams

Participatory
surveillance



Search-based
surveillance



WebMD

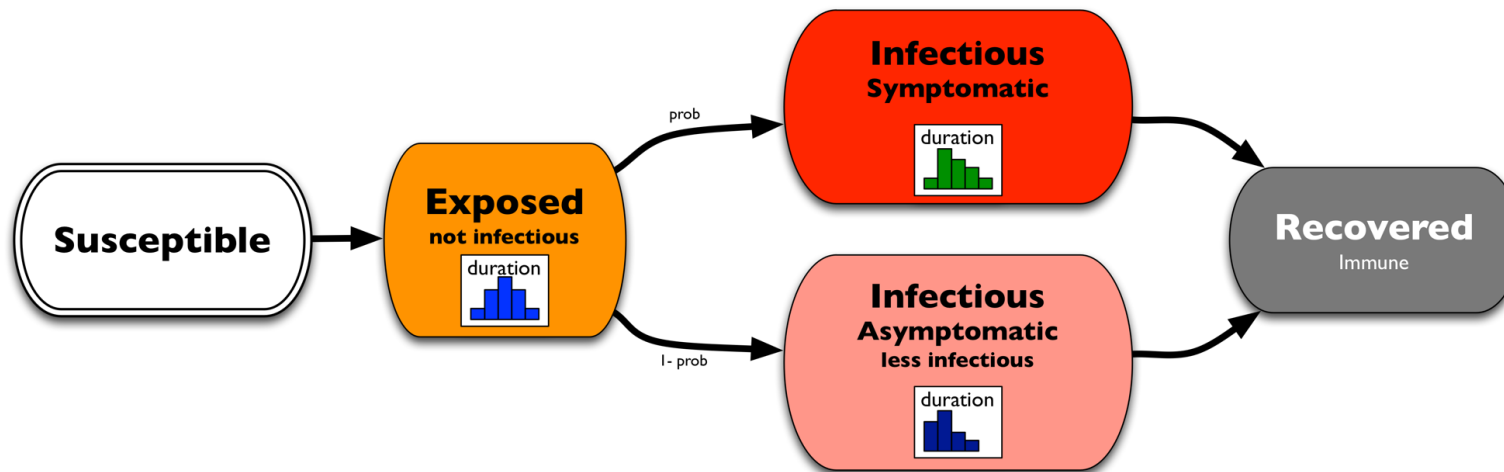
Social/News media
surveillance



Modeling

Disease Model

- Individuals in the population step through S, E, I and R states
- The duration spent in Exposed (E) and Infectious (I) states are given by incubation and infectious periods
- Probability of infection of a susceptible individual is proportional to:
 - Duration of time spent in contact with an infected individual
 - Number of infected individuals in the population

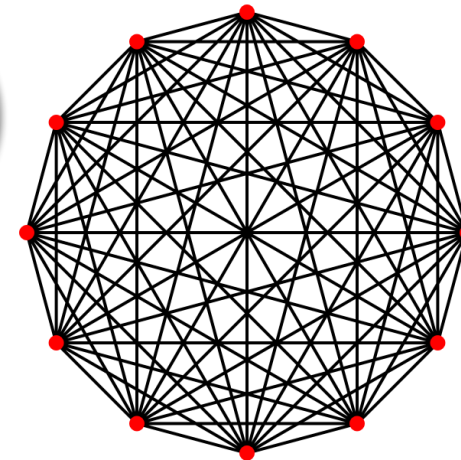


Kermack and
McKendrick SIR
model

$$\frac{dS}{dt} = -\beta IS$$

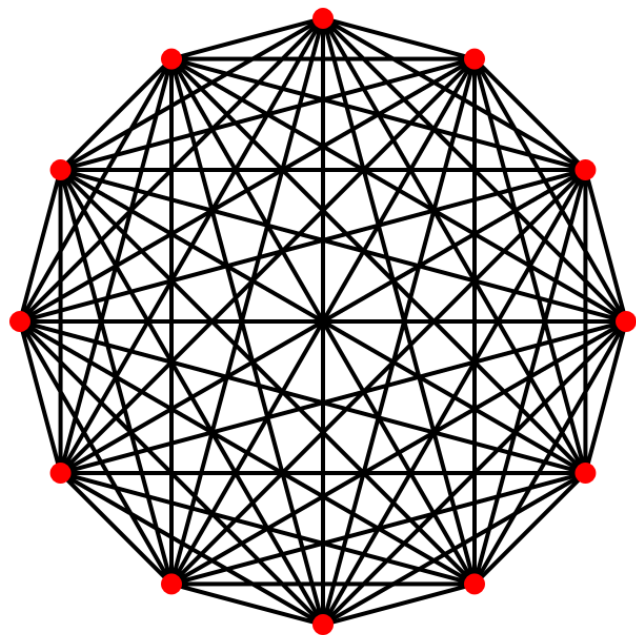
$$\frac{dI}{dt} = \beta IS - \nu I$$

$$\frac{dR}{dt} = \nu I$$

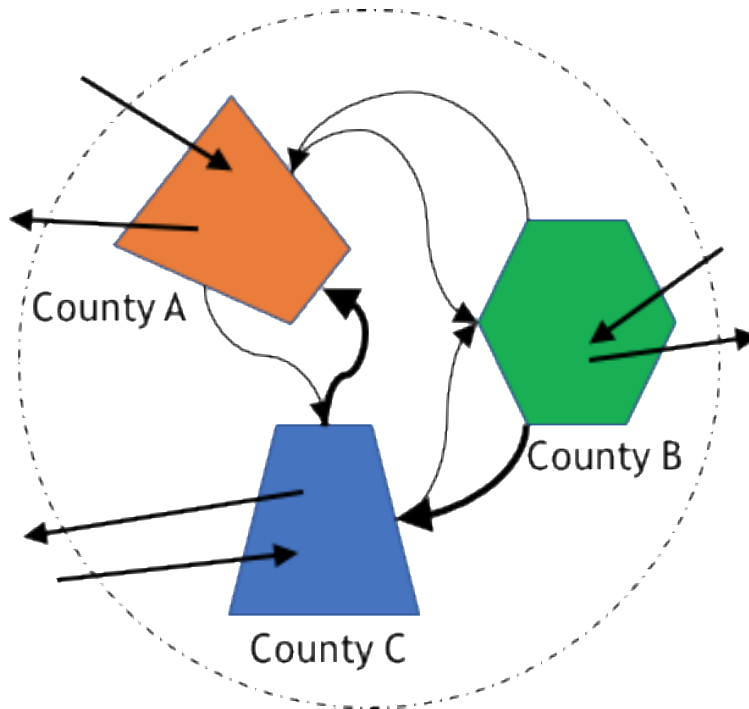


Compartmental
(all-meet-all)

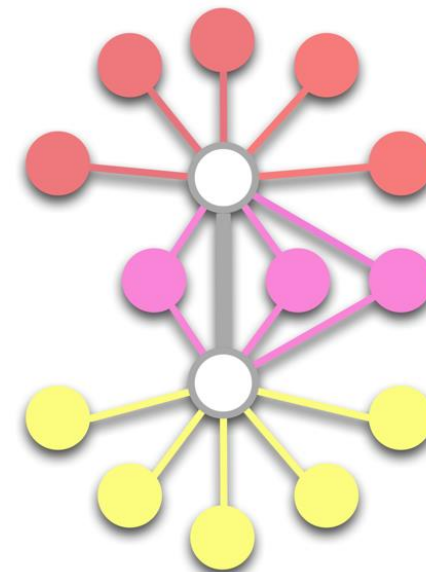
Population interaction models



Compartmental
(all-meet-all)



Patch model
(mixed)



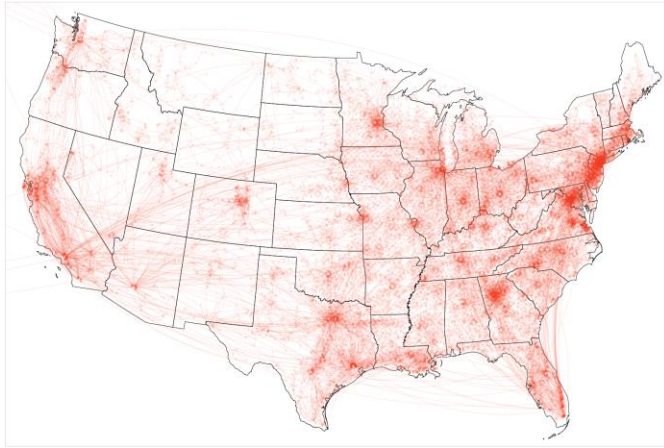
Home **School**
Other **Work**

Agent-based
(contact network)

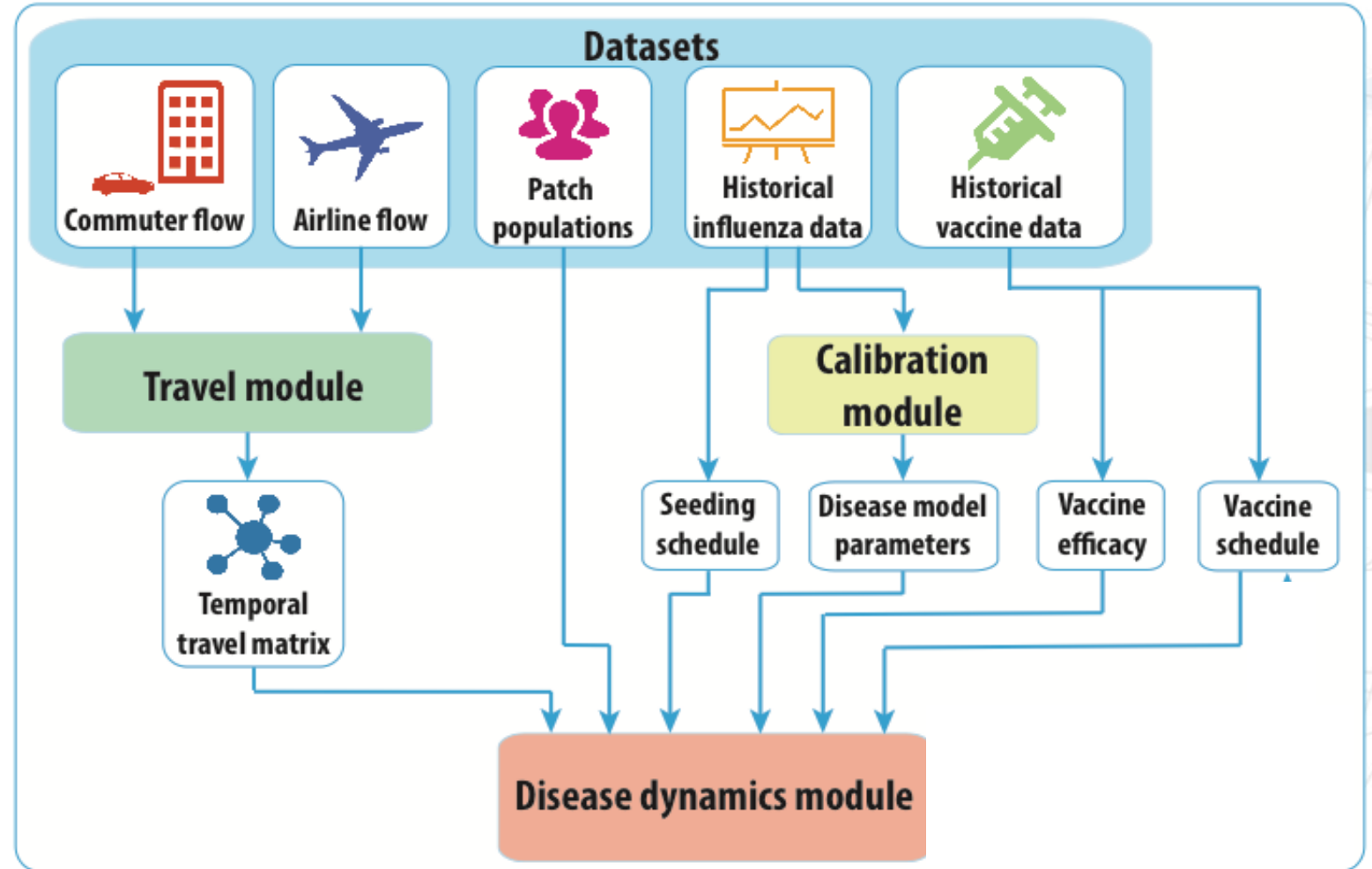
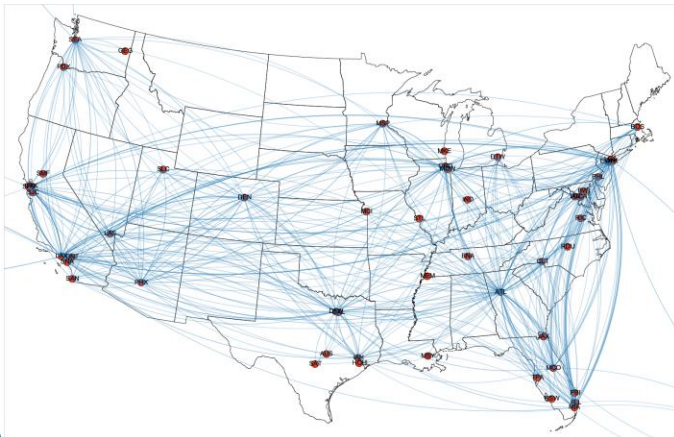
Models can be deterministic or stochastic.

National mobility based model

Commuter flow network



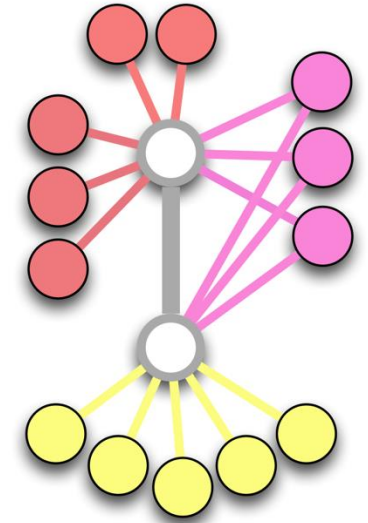
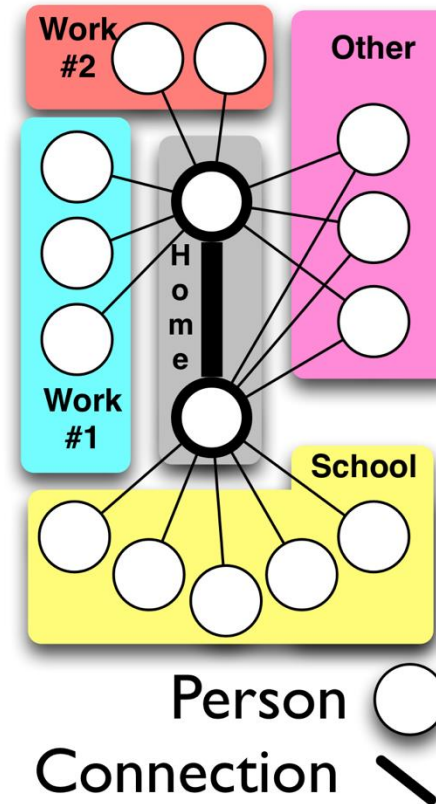
Airline network



High resolution social contact networks



Schedule creates contacts



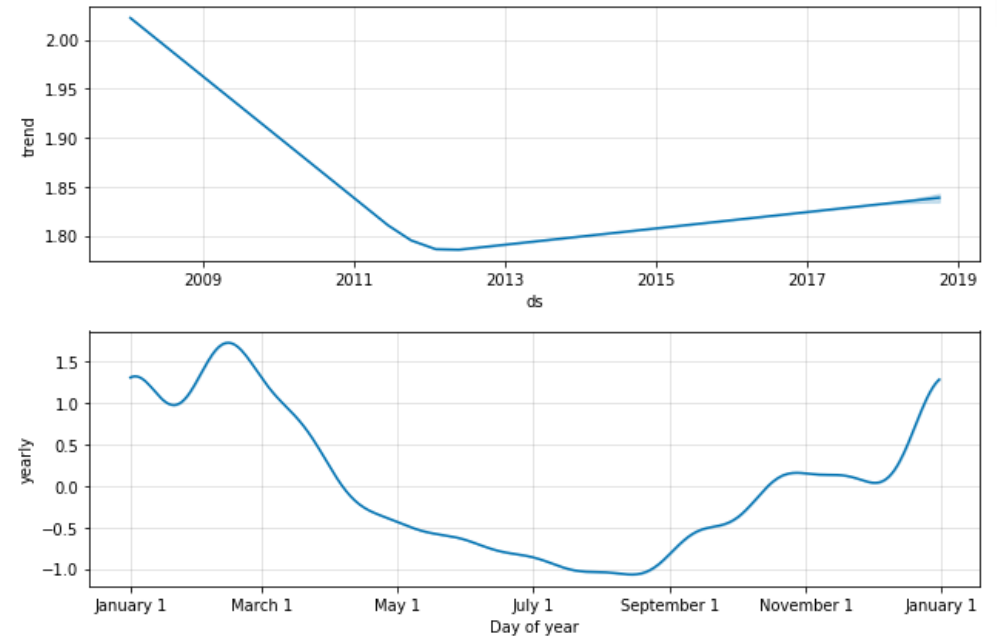
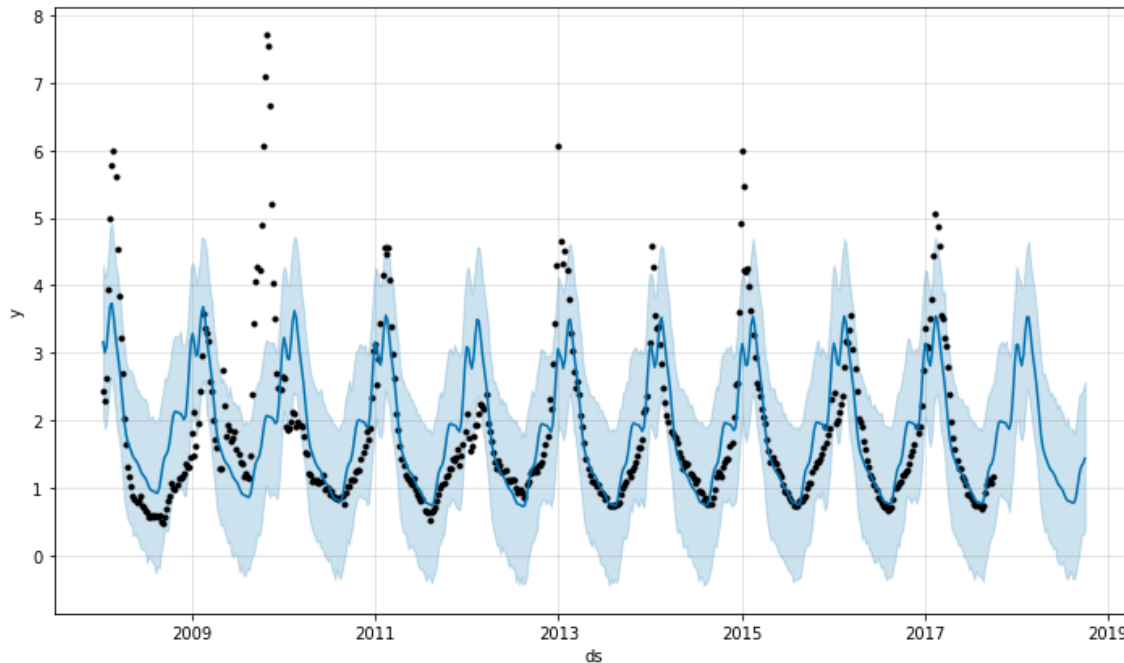
Contacts represented
as a graph

Forecasting

Statistical forecasts

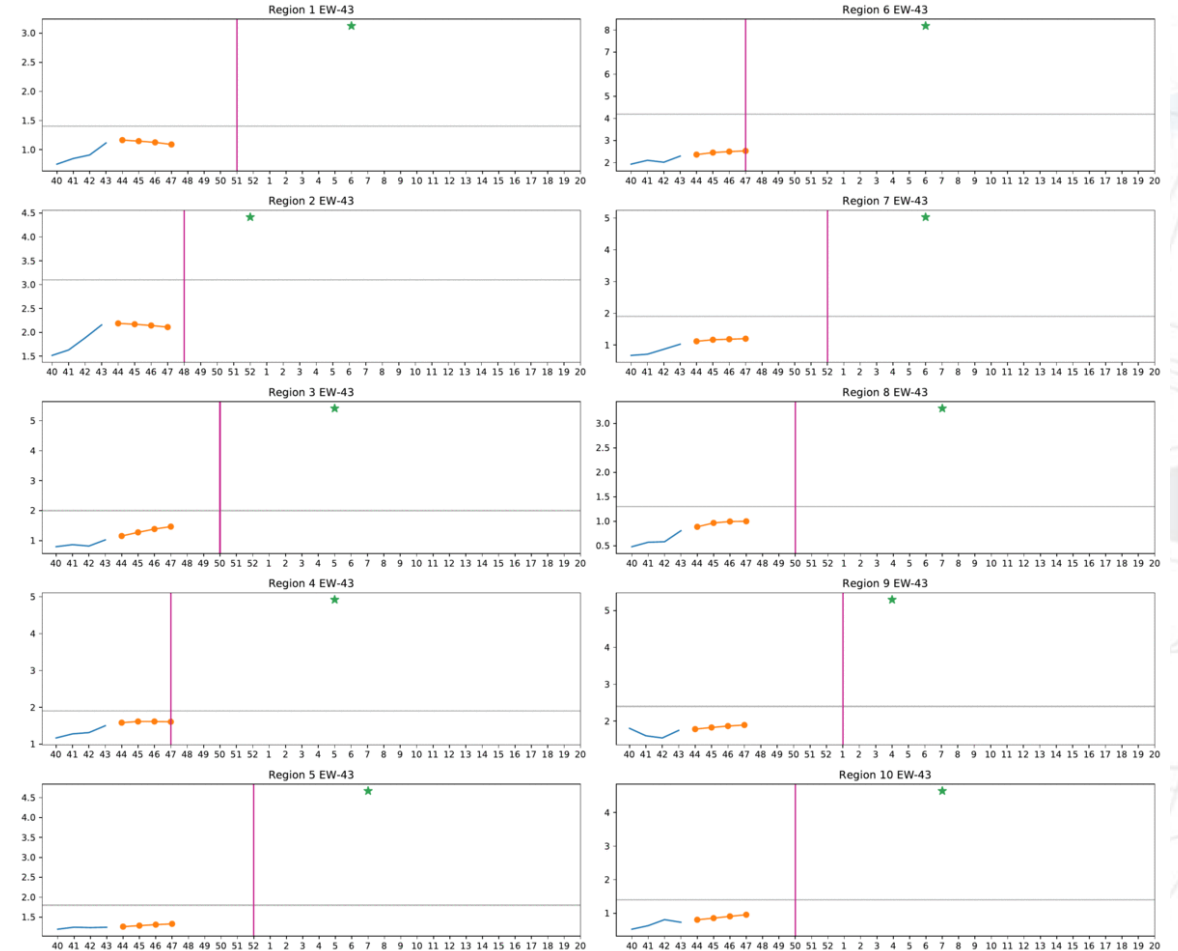
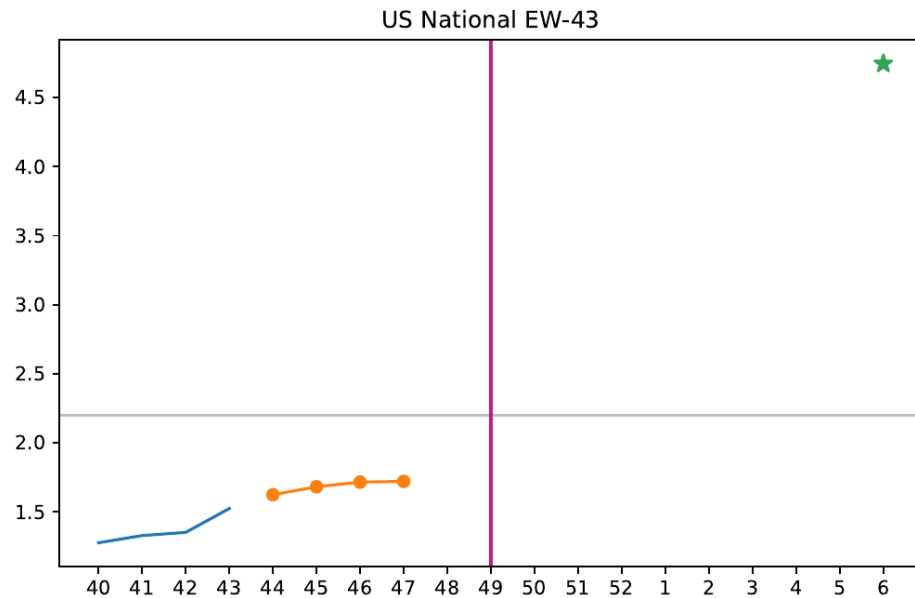
- Time series models
 - Look for trend and seasonality in the data
 - ARMA models (Auto-regression and moving average)

Forecasts made for 2017-18 at the beginning of season



Short-term vs Seasonal forecasts

- Short-term: Forecasting next four weeks ILI %
- Seasonal: Forecasting peak intensity, peak week



Flu Forecasting 2017-18

Innovative partnership will extend cutting-edge flu forecasting research to millions

December 1, 2017



A new partnership between the Biocomplexity Institute of Virginia Tech and AccuWeather could dramatically change the level of flu knowledge and awareness for people across the U.S.

AccuWeather Helps Brands Get Ahead of the Flu with Application of Virginia Tech's EpiCaster Outbreak Projections

November 28, 2017; 1:12 PM

Share ! f t in G+

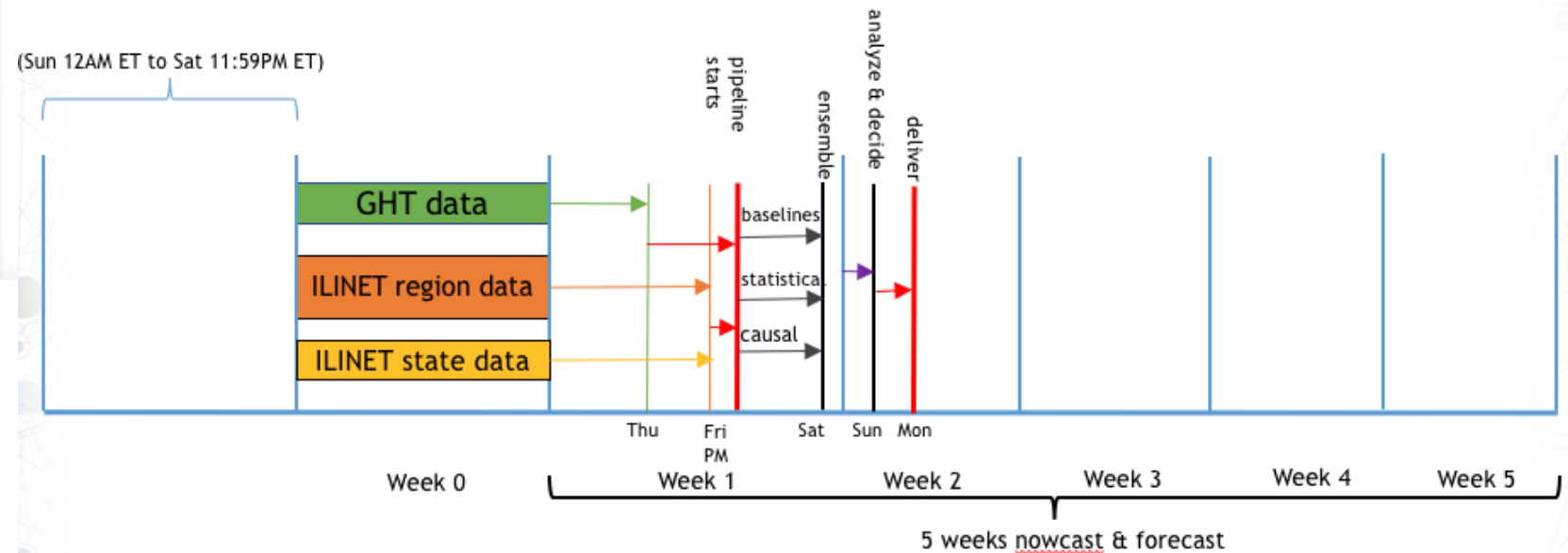
Best-in-class EpiCaster data enables AccuWeather to deliver personalized information to people weeks before flu outbreaks affect their location.

AccuWeather Global Weather Center -- November 28, 2017 -- AccuWeather, the largest and fastest growing source of weather forecasts and warnings as well as a global leader of digital media and weather-related big data, today announced an agreement with the Biocomplexity Institute of Virginia Tech.

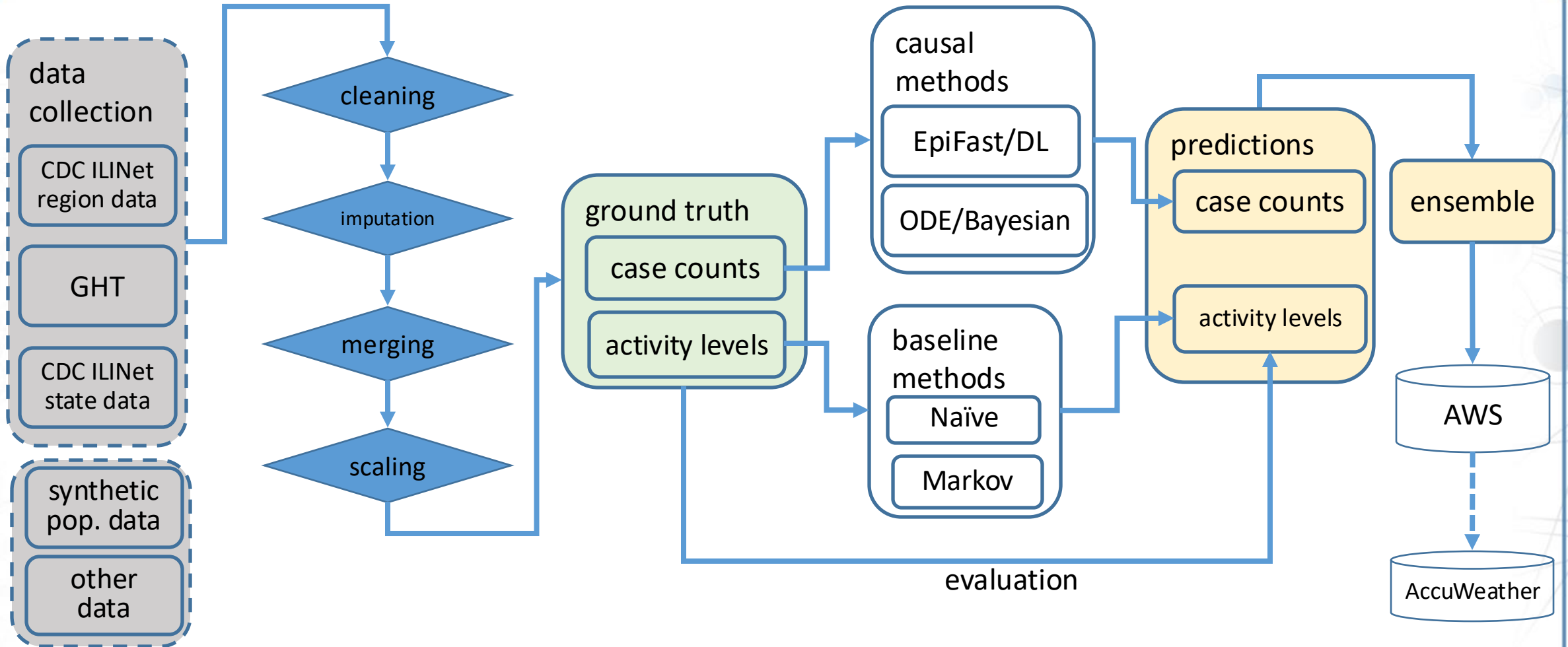
AccuWeather to offer users innovative flu forecasts from Virginia Tech's Biocomplexity Institute



By Ashley Williams, AccuWeather staff writer
December 07, 2017, 9:36:12 AM EST



Production Pipeline for AccuWeather

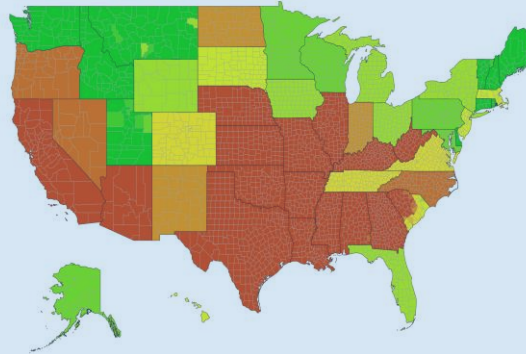


Activity level forecasts

Forecasts

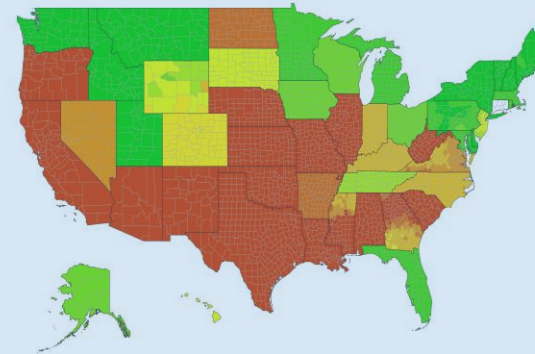
1 week ahead

flu activity level by county, week of 2017-12-27



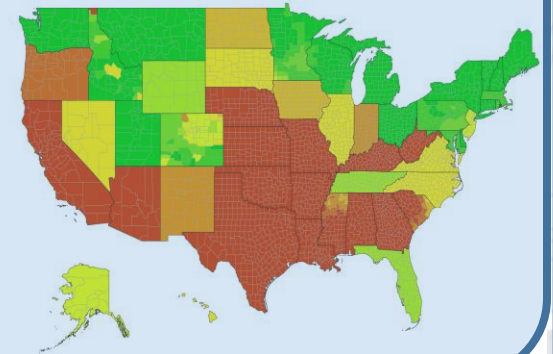
2 weeks ahead

flu activity level by county, week of 2018-01-03

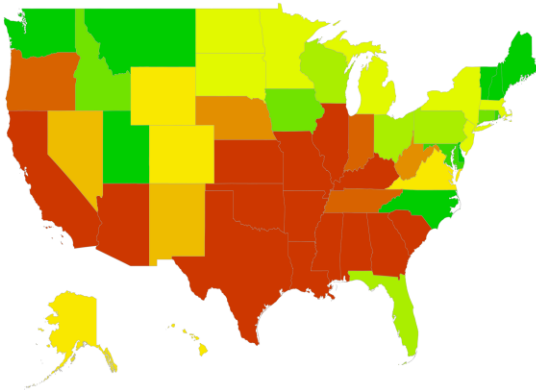


3 weeks ahead

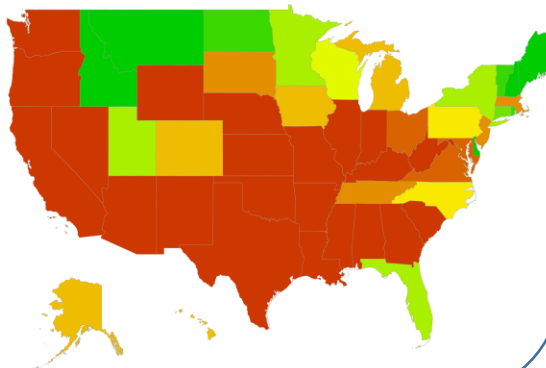
flu activity level by county, week of 2018-01-10



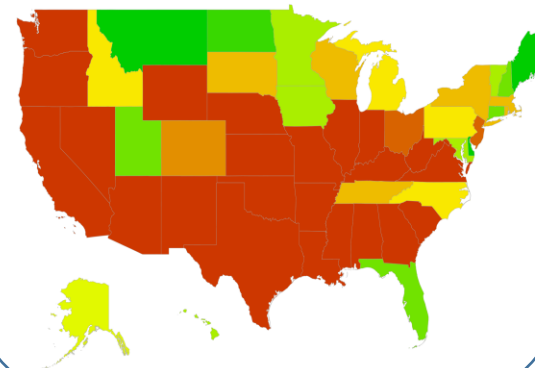
CDC ground truth of 2017-18 season week 51 ending Dec-23-2017



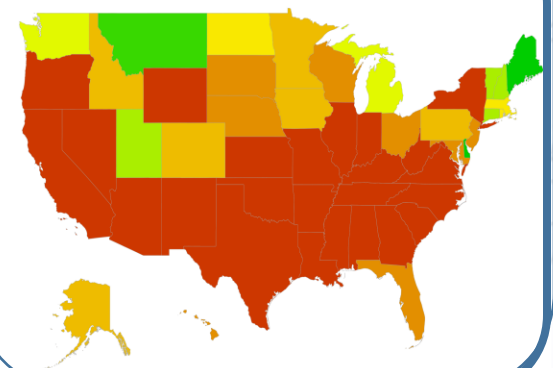
CDC ground truth of 2017-18 season week 52 ending Dec-30-2017



CDC ground truth of 2017-18 season week 1 ending Jan-06-2018



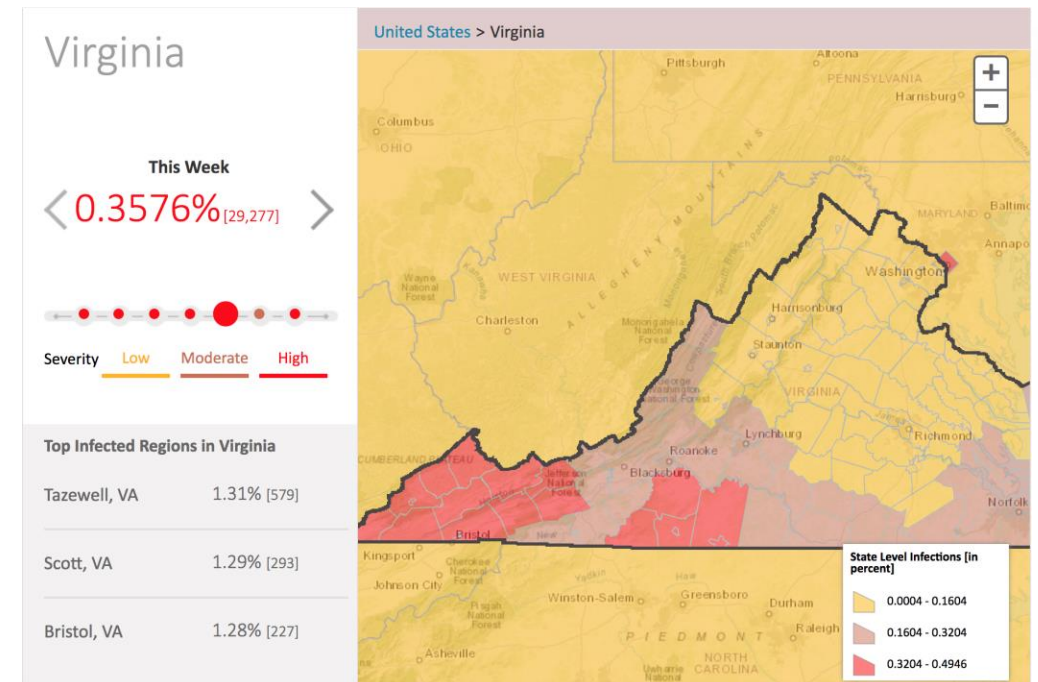
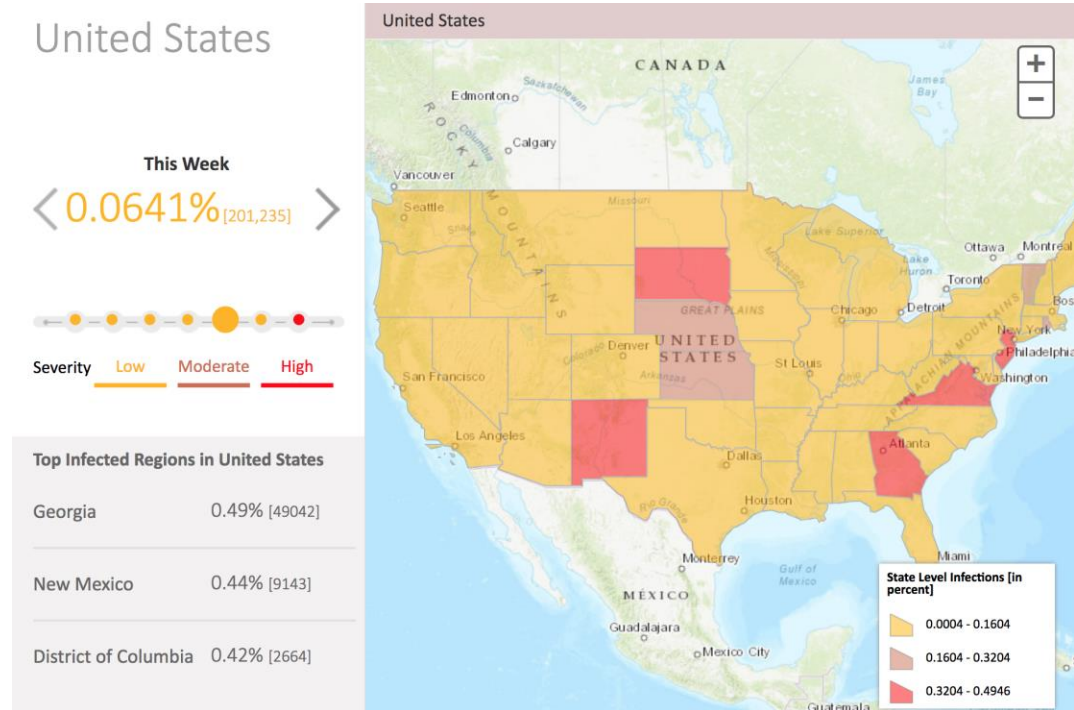
CDC ground truth of 2017-18 season week 2 ending Jan-13-2018



Observed ground truth

EpiCaster

- National level influenza forecasts down to the county resolution
- Calibration/validation done at state level.
- <http://epicaster.vbi.vt.edu/epicaster/epicaster.html>

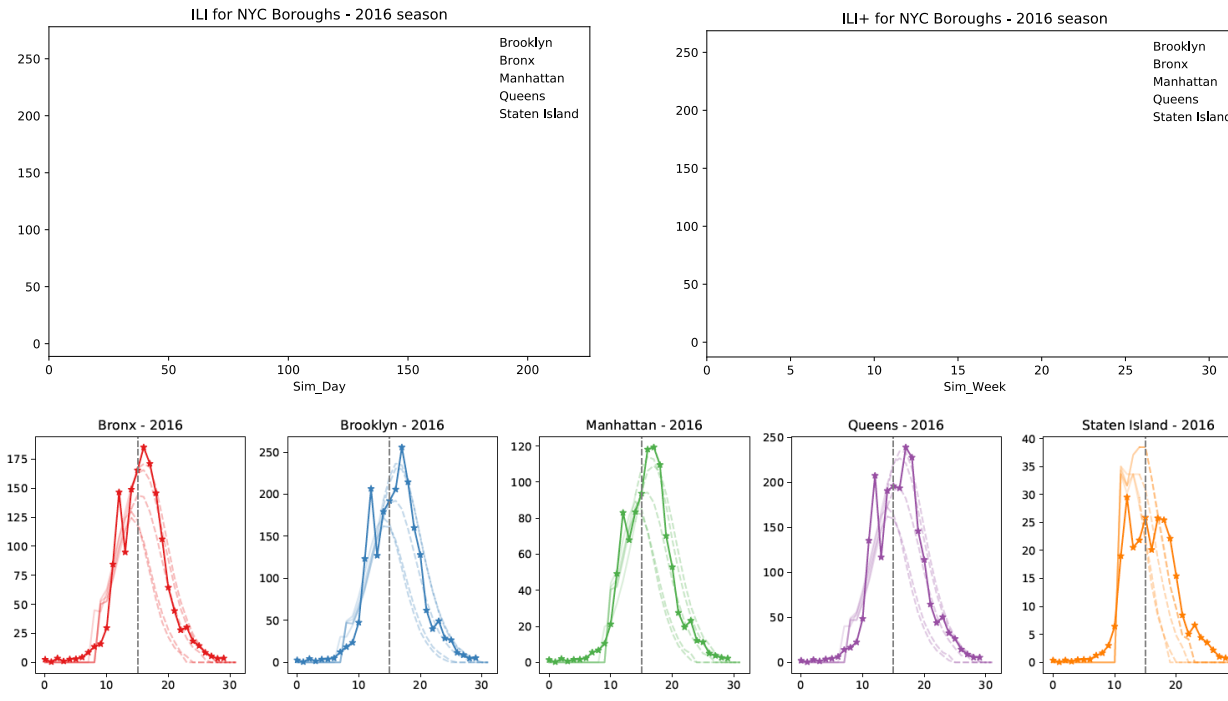


High resolution forecasts

- Case study with New York City ILI ED visits. (Available from <https://a816-healthpsi.nyc.gov/epiquery/>)

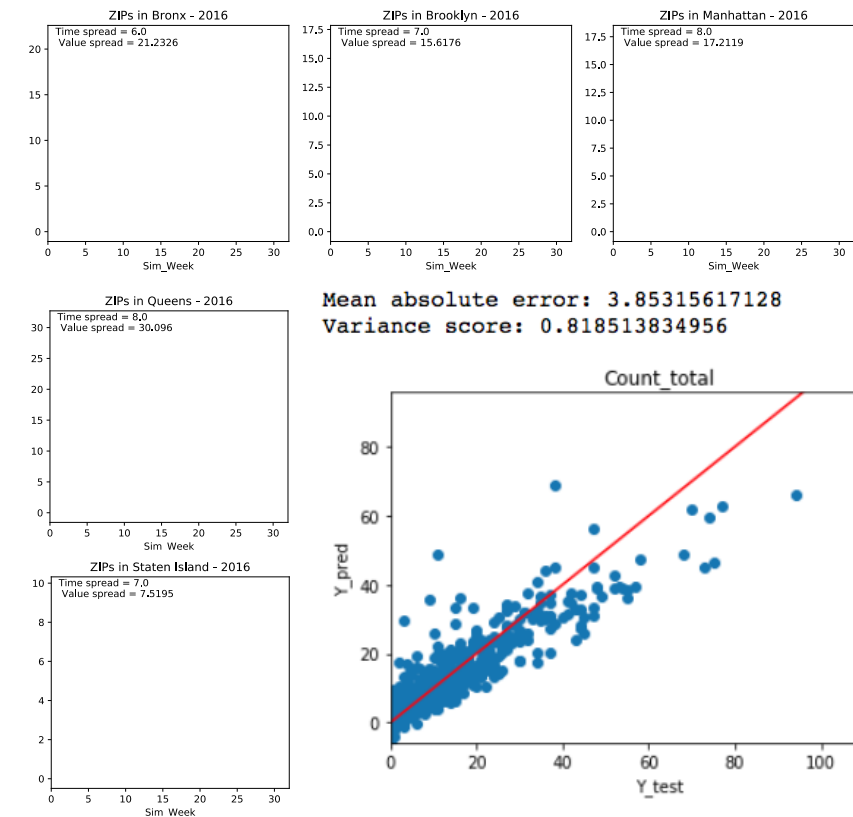
Borough level data

- Mechanistic model between counties
- Short term and long term forecasts



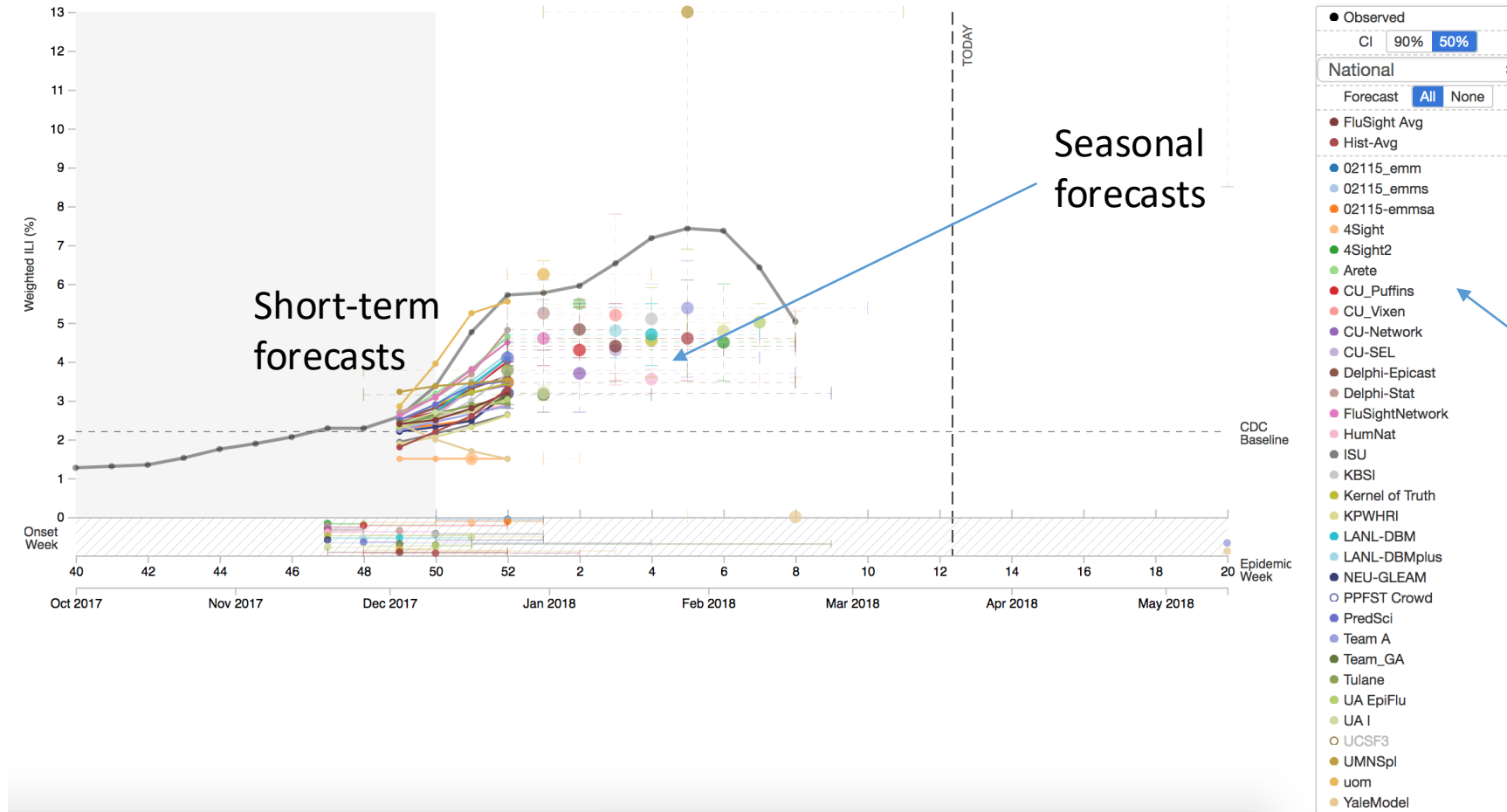
Zip code level data

- Regression model for short-term forecasts



Crowdsourcing

CDC FluSight Challenge

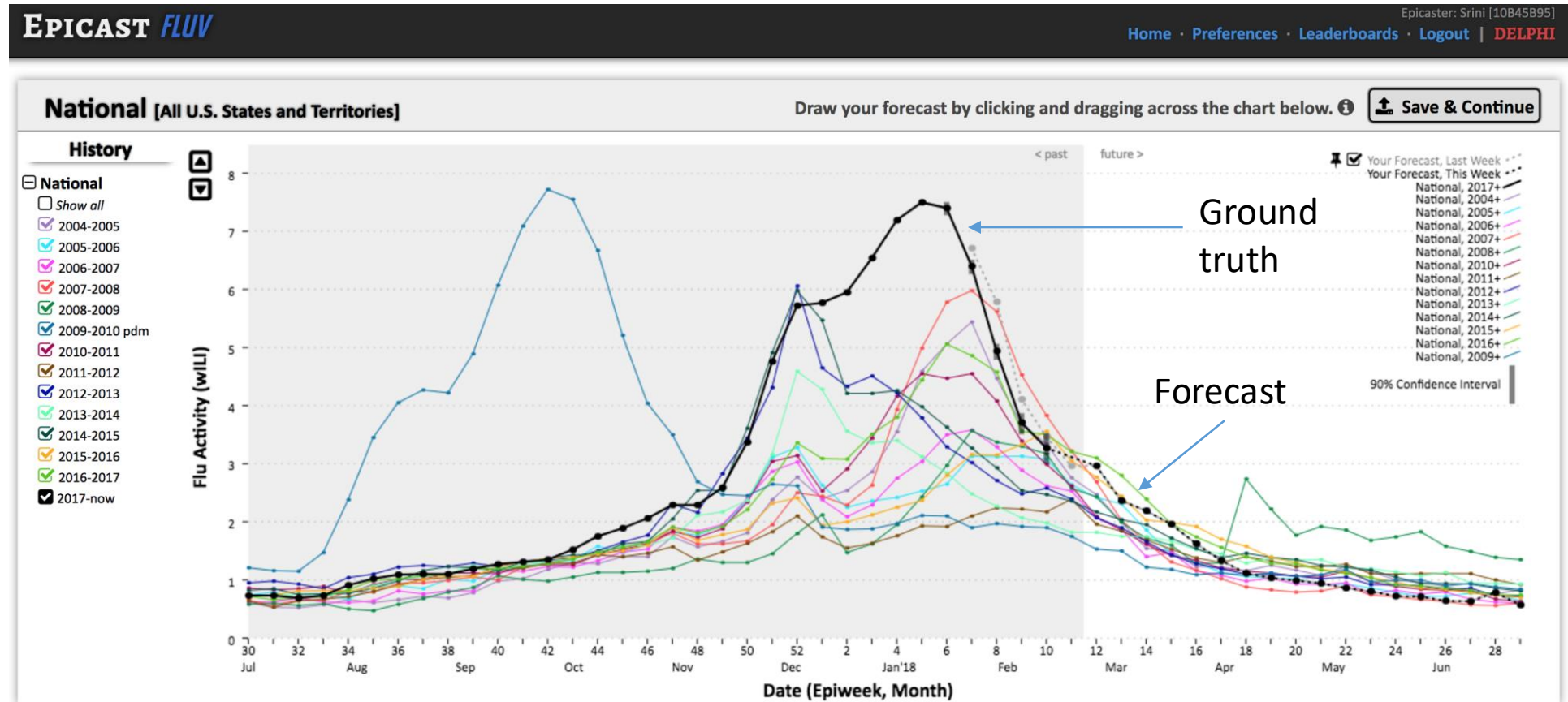


Participating Teams

predict.phiresearchlab.org/

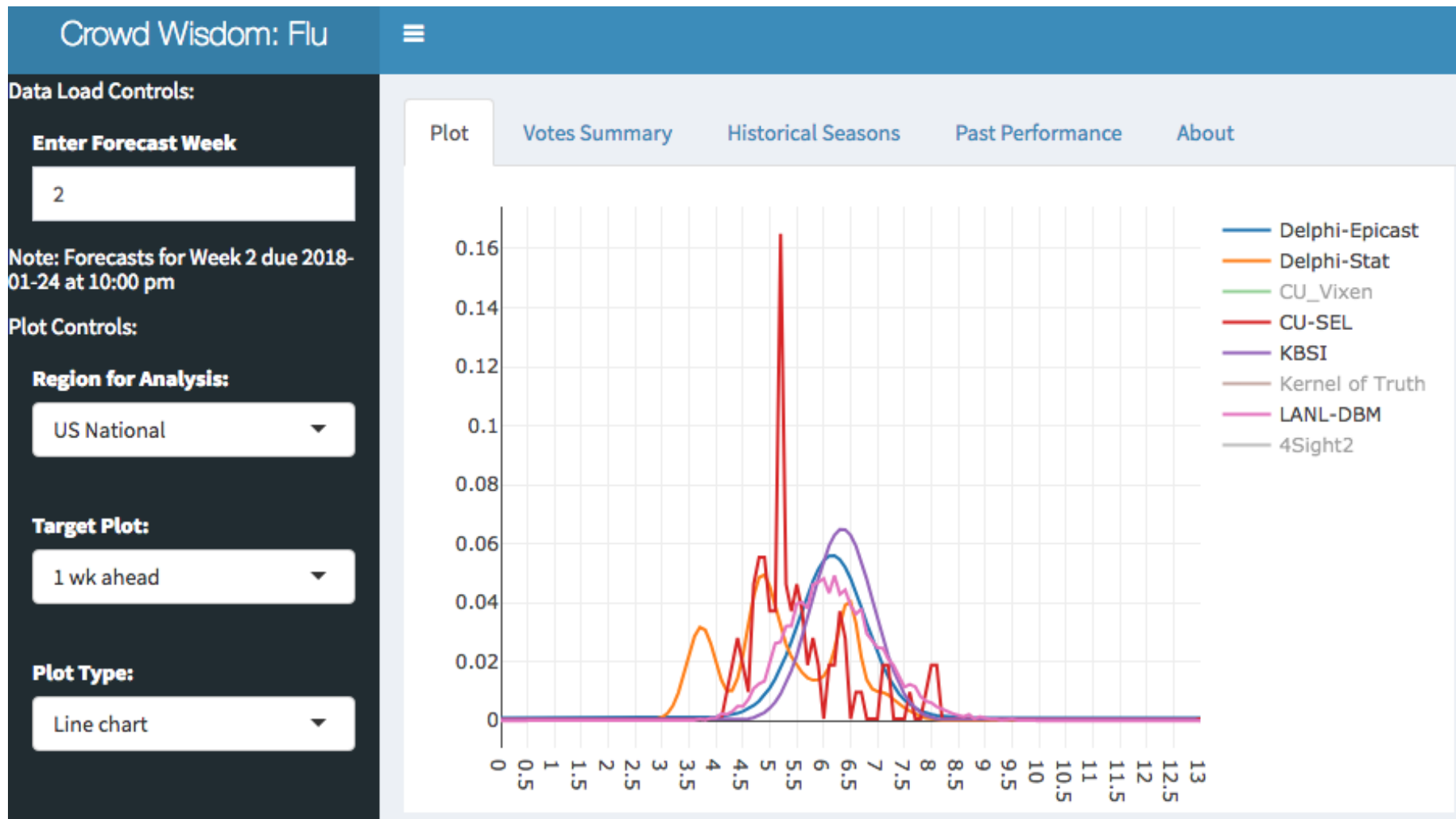
EpiCast (Delphi CMU)

- Crowd-sourced forecasting of ILI curve



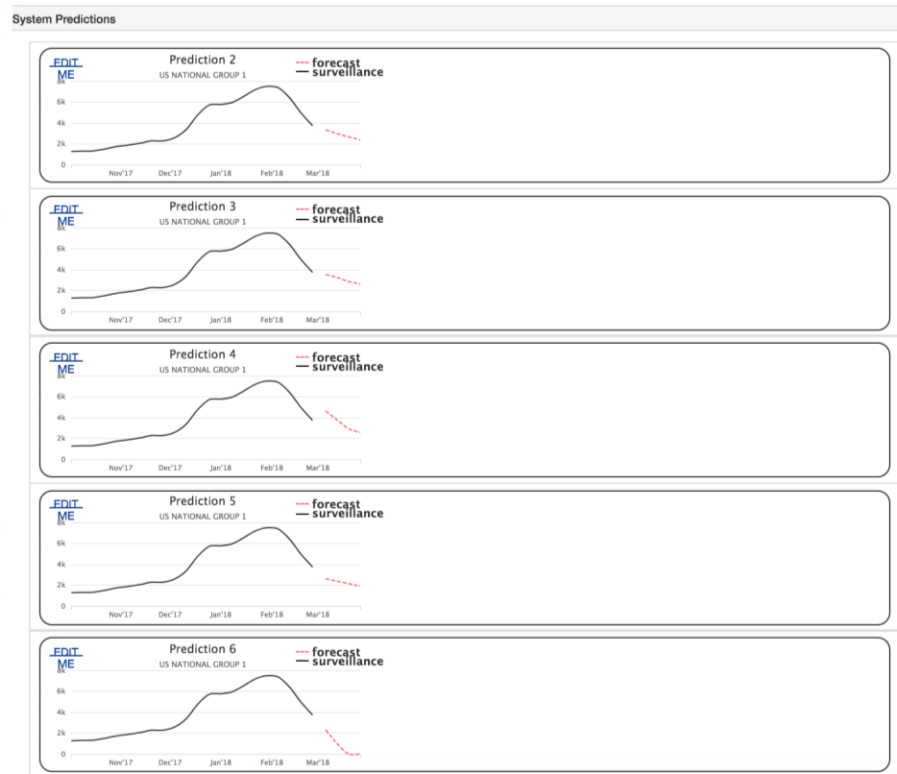
<https://epicast.org/>

Crowd Wisdom: Flu



My4Sight

- Crowd-sourced evaluation of other teams' predictions using My4Sight
- Weekly evaluations by NDSSL staff/students



User Rankings



Narrative Summary

- Current situation and model forecasts summarized verbally with highlights (partially automated)

Analysis: Analyses of historical trends and the current surveillance data show:

- Trends - High levels of activity have dropped dramatically and most states have retreated to low levels.
 - This marks the 12th consecutive week above the national threshold for the influenza season, the longest such streak recorded by influenza surveillance.
 - 6 states are now reporting the highest level of activity (down from 12)
 - 25 states are reporting low levels of activity (up from 14)
 - Only 3 states show steady increases in total counts (if not activity level) of cases of influenza over the last 2 weeks of data: Alaska, Hawaii, and Wyoming
- Influenza B - Influenza B continues to increase its influence.
 - A majority (51%) of typed cases in the past 3 weeks have been caused by influenza B
 - In the last week of data, all regions have had more or nearly equal numbers of positive influenza tests of type B compared to type A
 - Influenza B, while still a serious infection, is generally less severe than Influenza A and is associated with milder overall severity.
- National season - The 2017-2018 has been unprecedented in its impact. It has caused the longest sustained period of states experiencing the highest levels of activities, which includes 9 weeks above 5% activity nationally (2009 had only 6 weeks above 5%). It has caused significantly more hospitalizations than previous seasons.

Sample from the Narrative summary for EW10

Forecast: In the coming weeks we forecast:

- Activity levels to continue declining across nearly all states leaving only a handful at a high level by mid-April.
- The majority of states will be experiencing low levels of activity by the end of March, these will be well spread across the entire country.
- Expect pockets of diminishing high activity to remain. Look for high to moderate activity to linger in with Arizona, a cluster in the central Plains (Wyoming, Nebraska, Kansas), and possibly some states in the central mid-Atlantic (Kentucky, Virginia) and Southeast (Carolinas and Georgia).
- Influenza B activity will continue to dominate Influenza A as activity overall subsides.
- Overall national level of activity will continue to decline and should exit "official" influenza season in 1-2 weeks.

Going forward...

- Global dynamics modeling - Multiple strains (FluA, FluB)
- What-if forecasts (vaccine coverage, school/work closures)
- Better LONG-term forecasts - for planning purposes
- Holy grail: Personalized forecasts

We need you!

- Expert feedback on improving models and forecasts
- Narrative summary aimed at clinicians/hospital administration
- Finer resolution modeling within VT Blacksburg campus

Thank you!



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