Challenge Problem 7: Influenza-Like Illnesses

Ssu-Hsin Yu, SSCI

Tom Dietterich, Oregon State

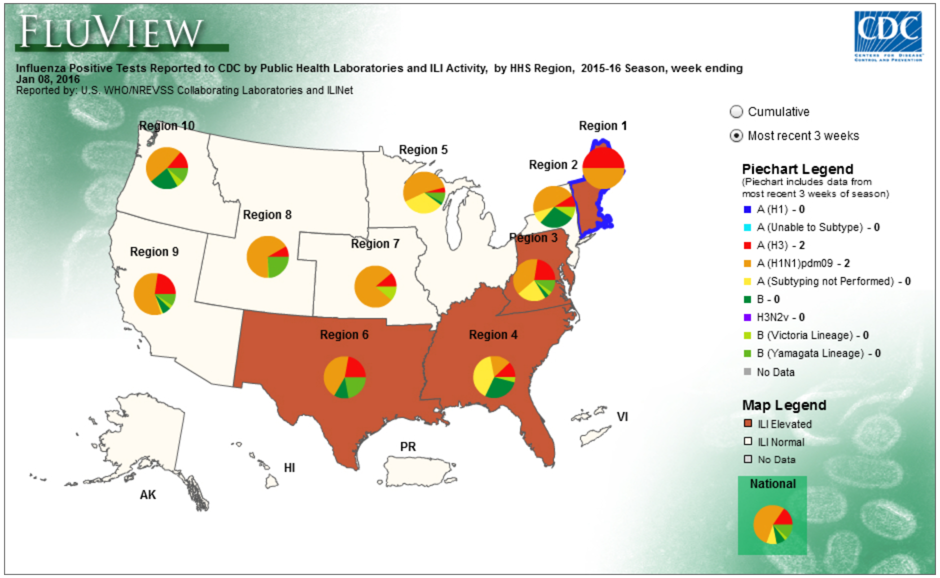
Chad Scherrer, Galois

Influenza-Like Illnesses (ILI)

- 5 million cases of severe illness each year world wide
- 200,000-500,000 deaths annually
- Spreads by
  - contact of mucous with eyes, nose, mouth
  - inhaled aerosol particles
  - touch (e.g., hand-to-hand or hand-surface-hand)
- Virus is shed one-half to one-day after infection for a period of 5 days (longer in children and immunocompromised people)

CDC U.S. Outpatient Influenza-like Illness Surveillance Network (ILINet)

- Percentage of doctor visits that are flu-related
- Weekly reports
- Aggregated to CDC Regions
- Broken out by age ranges



FLUVIEW

Influenza Positive Tests Reported to CDC by Public Health Laboratories and ILI Activity, by HHS Region, 2015-16 Season, week ending Jan 08, 2016
Reported by: U.S. WHO/NREVSS Collaborating Laboratories and ILINet

○ Cumulative
● Most recent 3 weeks

Piechart Legend
(Piechart includes data from most recent 3 weeks of season)

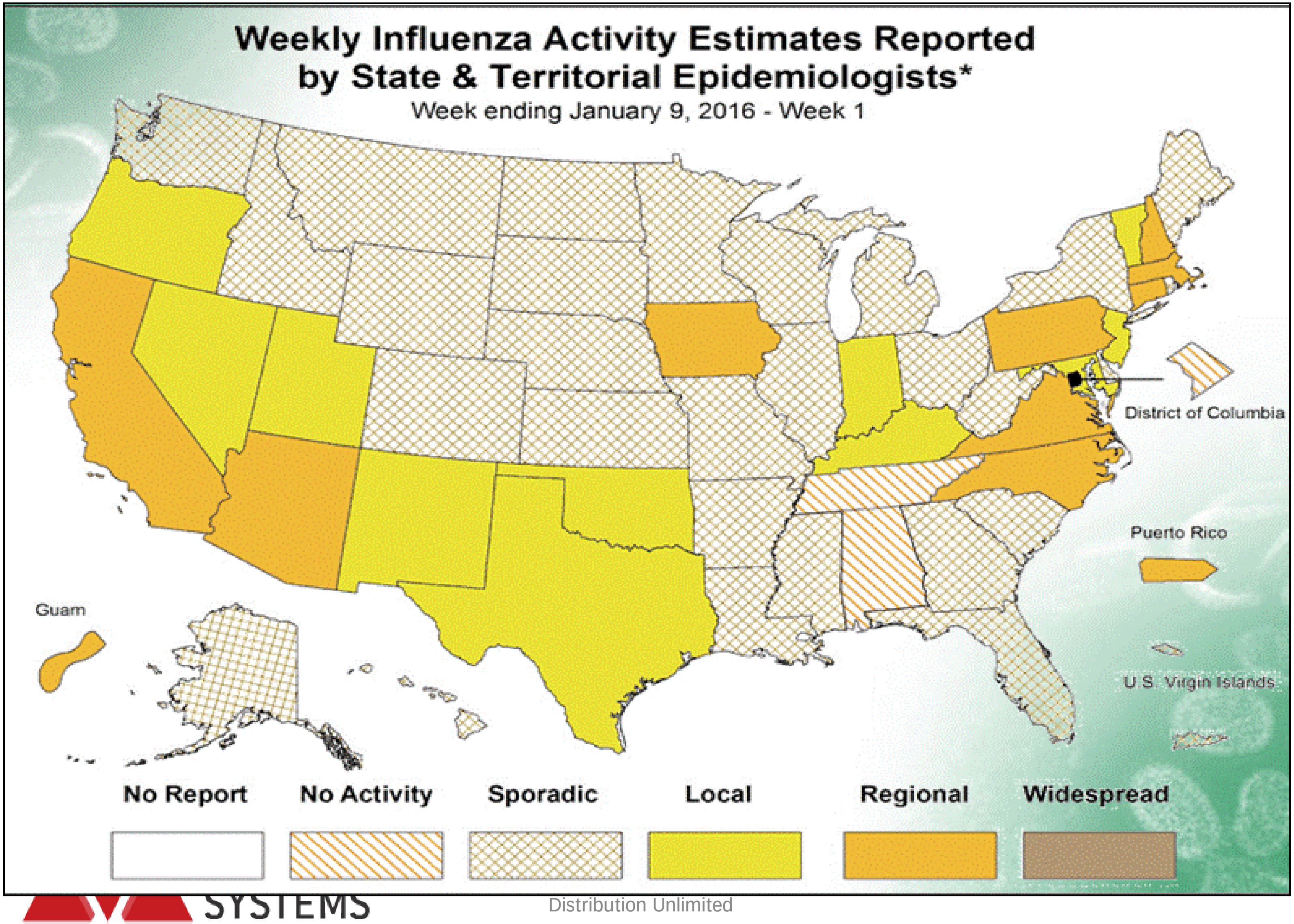
- 🟦 A (H1) - 0
- 🟦 A (Unable to Subtype) - 0
- 🟥 A (H3) - 2
- 🟧 A (H1N1)pdm09 - 2
- 🟨 A (Subtyping not Performed) - 0
- 🟩 B - 0
- 🟪 H3N2v - 0
- 🟩 B (Victoria Lineage) - 0
- 🟩 B (Yamagata Lineage) - 0
- ⬜ No Data

Map Legend

- 🟥 ILI Elevated
- □ ILI Normal
- □ No Data

http://gis.cdc.gov/grasp/fluview/fluportaldashboard.html

Weekly State-Level Estimates


Weekly Influenza Activity Estimates Reported
by State & Territorial Epidemiologists*
Week ending January 9, 2016 - Week 1
District of Columbia
Puerto Rico
U.S. Virgin Islands
Guam
No Report
No Activity
Sporadic
Local
Regional
Widespread

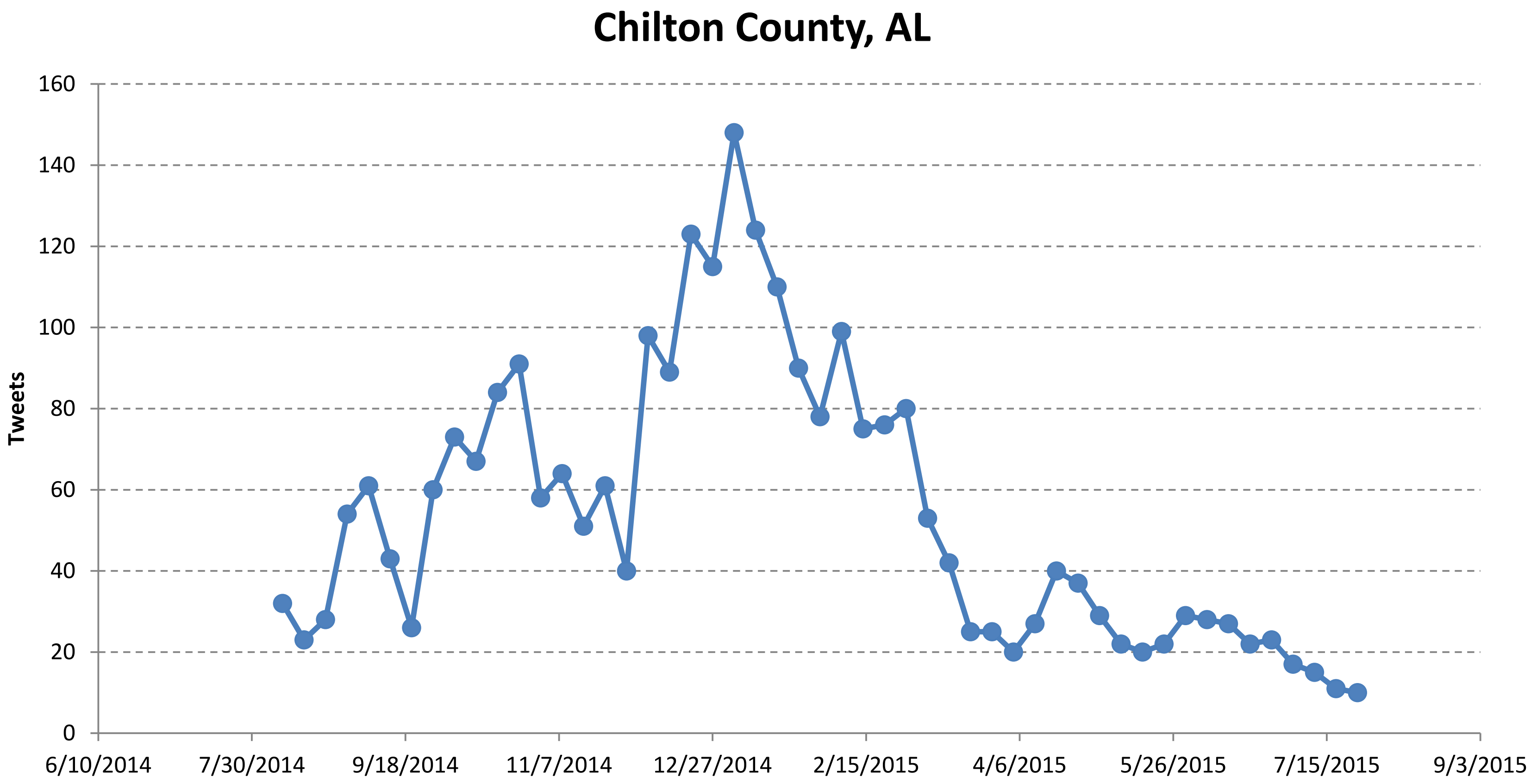
State and District Reports ("Prediction Regions")

- State-level data
  - Massachusetts, North Carolina, Rhode Island and Texas
- Within-state district data
  - Mississippi and Tennessee

Useful Covariates

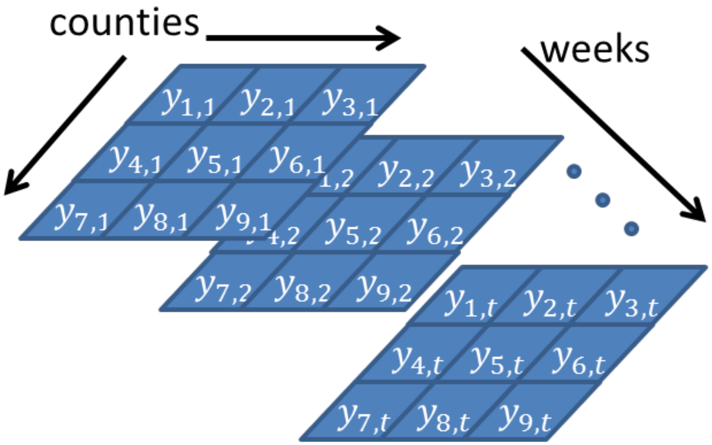
- Tweets (per county per week)
  - keywords “flu” and “influenza”
  - number of tweets (not retweets)
- Cumulative Vaccination Percentage (weekly) of Medicare recipients
- Demographic information (population by age brackets)
- Geographic information: adjacent counties

Example Tweets



Distribution Unlimited

Proposed Model


counties
weeks
$y_{1,1}$ $y_{2,1}$ $y_{3,1}$
$y_{4,1}$ $y_{5,1}$ $y_{6,1}$
$y_{7,1}$ $y_{8,1}$ $y_{9,1}$
$y_{1,2}$ $y_{2,2}$ $y_{3,2}$
$y_{4,2}$ $y_{5,2}$ $y_{6,2}$
$y_{7,2}$ $y_{8,2}$ $y_{9,2}$
$y_{1,t}$ $y_{2,t}$ $y_{3,t}$
$y_{4,t}$ $y_{5,t}$ $y_{6,t}$
$y_{7,t}$ $y_{8,t}$ $y_{9,t}$

Joint multivariate Gaussian $y_{c,t}$ latent "propensity"

c: county t: week

$$p(Y) \propto \exp\left(-\tfrac{1}{2}\tau_1 Y^T (D_w - W)\, Y\right)$$

$$W = \begin{cases} w_{(c,t)(c,j)} = \rho & \text{where } j = t-1 \text{ or } t+1, \\ w_{(c,t)(i,t)} = 1 & \text{if } i \text{ is a neighboring county of } c \\ w_{(c,t)(i,j)} = 0 & \text{otherwise} \end{cases}$$

$$(D_w)_{(c,t)(c,t)} = \Sigma_{(i,j)} w_{(c,t)(i,j)}$$

Covariates

$$X_{c,t} = \left[\log\left(\frac{S_{c,t}+\epsilon_2}{\widetilde{N}_c}\right), \quad \log\left(\frac{V_{c,t}+\epsilon_3}{1-V_{c,t}+\epsilon_3}\right)\right]^{\boldsymbol{T}}$$

$S_{c,t}$: number of flu-related tweets from county *c* in week *t*.

$V_{c,t}$: cumulative percentage of Medicare recipients filing flu vaccination claims from county *c* in week *t*.

$\widetilde{N}_c = \Sigma_g N_{c,g} U_g$: Twitter user demographics adjusted population of county *c*

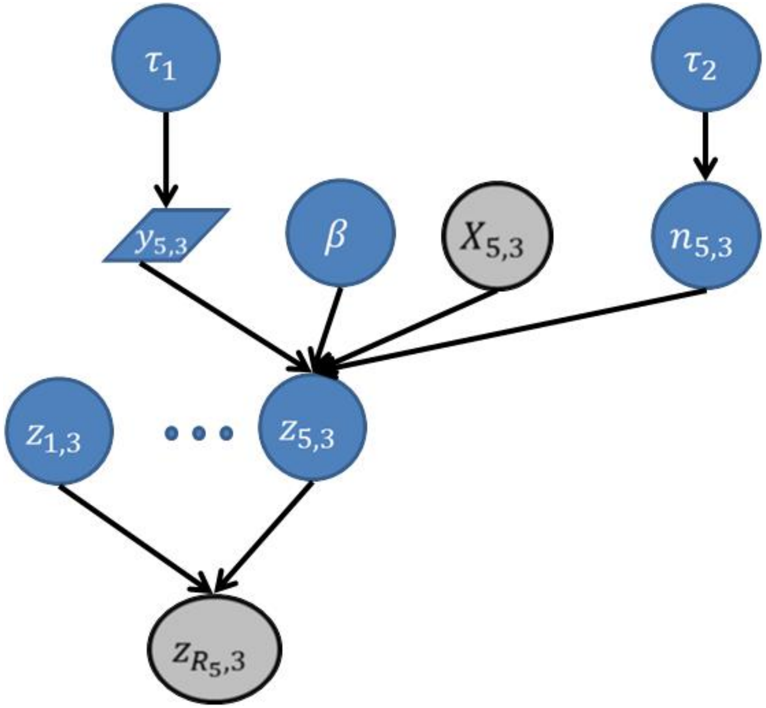
$N_{c,g}$: population of county c belonging to age group *g*.

U_g : percentage of Twitter users belonging to age group *g*.

$\epsilon_2 = 0.1,\ \epsilon_3 = 0.001$

Flu Prevalence

$$\log\left(\frac{z_{c,t}+\epsilon_1}{1-z_{c,t}+\epsilon_1}\right) = \beta^T X_{c,t} + y_{c,t} + n_{c,t}$$



c: county index; *t*: week index

$X_{c,t}$: covariates for each county c and week t

$y_{c,t}$: latent propensity

$z_{c,t}$: ILI rate (between 0 and 1) of county *c* in week *t*

$n_{c,t}$: zero-mean Gaussian noise with variance $1/\tau_2$

$\epsilon_1 = 0.0001$: a small number to ensure numerical stability

Aggregated Observations

$$z_{R_i,t} = \sum_{c \in R_i} \left(\frac{N_c}{N_{R_i}} \right) z_{c,t}$$

R_i : set of counties in area i; the area can be a HHS Region, a state or a district in a state

$z_{R_i,t}$: reported ILI rate of area i in week t

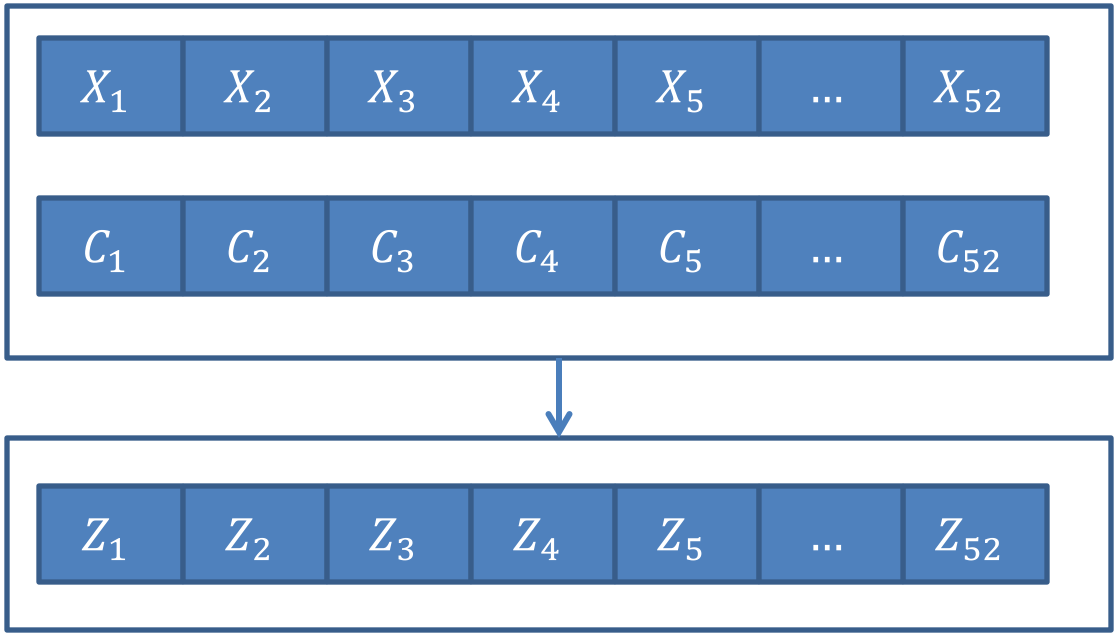
N_c : population of county c

N_{R_i} : population of area i

Phase 1 Task: Reconstruction

- Given:
  - weekly covariates and observations for an entire year
    - tweets, vaccination, CDC ILI reports + whole state estimates
- Find:
  - weekly ILI prevalence for all counties in the Prediction Regions
- Metrics:
  - Population-adjusted Squared Error
  - Start and Peak of the epidemic

Phase 1



X_1 X_2 X_3 X_4 X_5 … X_{52}

C_1 C_2 C_3 C_4 C_5 … C_{52}

Z_1 Z_2 Z_3 Z_4 Z_5 … Z_{52}

Tweets & Vaccinations

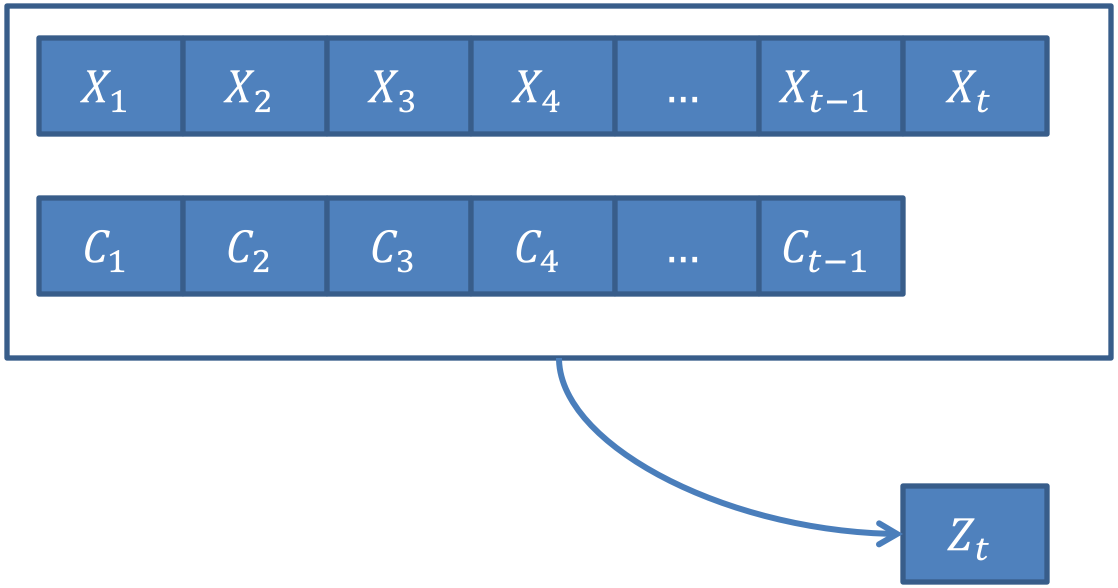
CDC Regions + CDC State Data

Prediction Regions

Phase 2 Task: Weekly Nowcast for 2015-16

- Given:
  - Covariates for weeks $1, \ldots, t$
  - ILI Observations for weeks $1, \ldots, t-1$
- Find:
  - County observations for week t for the Prediction Regions
- Metrics:
  - Same as Phase 1

Phase 2



X_1 X_2 X_3 X_4 … X_{t-1} X_t

C_1 C_2 C_3 C_4 … C_{t-1}

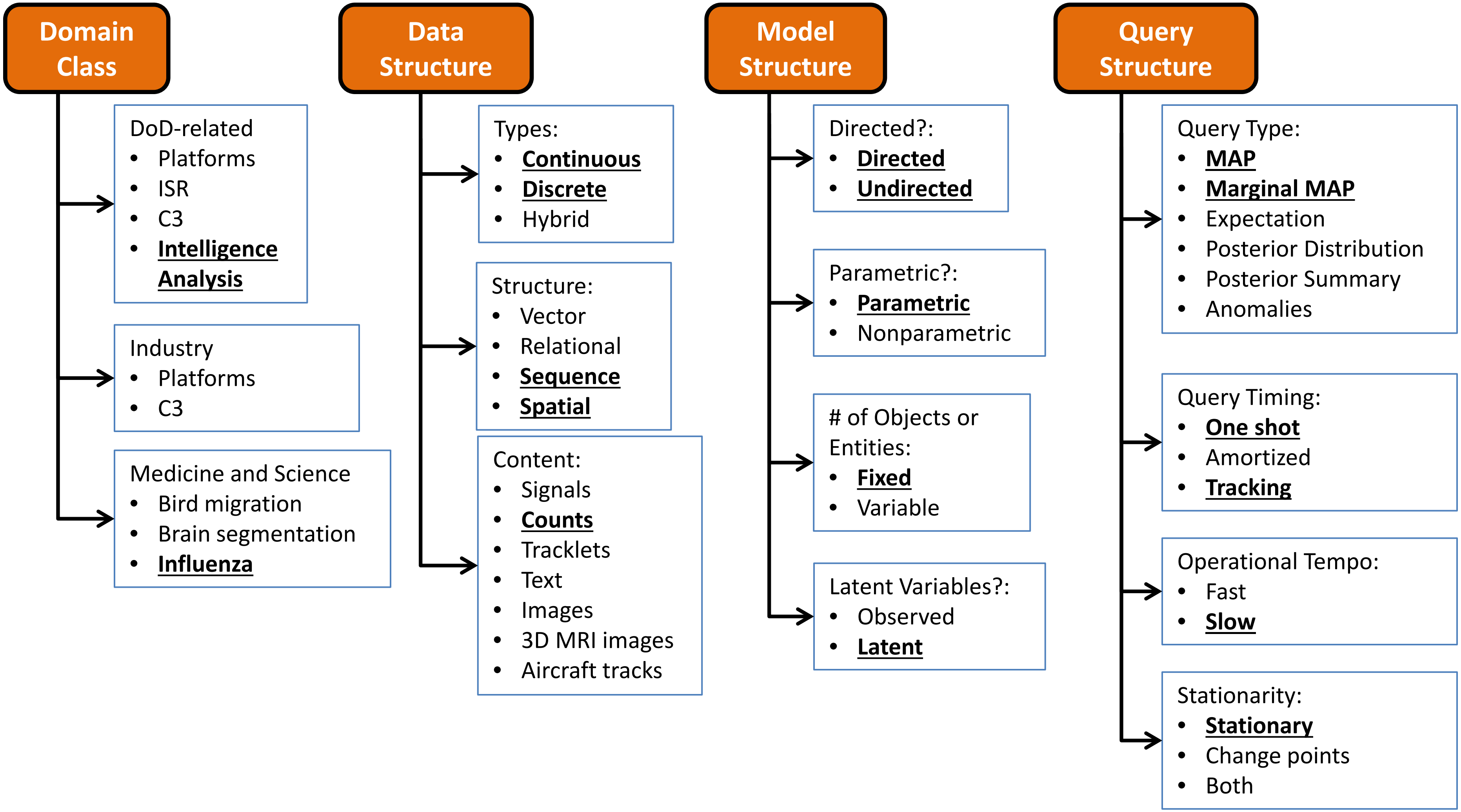
Z_t

Tweets & Vaccinations

CDC Regions + CDC State Data

Prediction Regions

Challenge Problem Dimensions



Domain Class

DoD-related
- Platforms
- ISR
- C3
- **Intelligence Analysis**

Industry
- Platforms
- C3

Medicine and Science
- Bird migration
- Brain segmentation
- **Influenza**

Data Structure

Types:
- **Continuous**
- **Discrete**
- Hybrid

Structure:
- Vector
- Relational
- **Sequence**
- **Spatial**

Content:
- Signals
- **Counts**
- Tracklets
- Text
- Images
- 3D MRI images
- Aircraft tracks

Model Structure

Directed?:
- **Directed**
- **Undirected**

Parametric?:
- **Parametric**
- Nonparametric

# of Objects or Entities:
- **Fixed**
- Variable

Latent Variables?:
- Observed
- **Latent**

Query Structure

Query Type:
- **MAP**
- **Marginal MAP**
- Expectation
- Posterior Distribution
- Posterior Summary
- Anomalies

Query Timing:
- **One shot**
- Amortized
- **Tracking**

Operational Tempo:
- Fast
- **Slow**

Stationarity:
- **Stationary**
- Change points
- Both

CP#7 Next Evaluation Period

- Timeline
  - PI Meeting – 90 days: Beta Period Begins
  - PI Meeting – 45 days: Final Deadline for CP6 and CP7 solutions
  - July ??: PI Meeting

CP#7 Materials Available Now

- http://ppaml.galois.com/wiki/wiki/CP7FluSpread
- http://ppaml.kitware.com/midas/

Email address for questions, issues, etc.:

ppaml-support@community.galois.com

Micro-breakout today at 1:30pm

Future Challenge Problems

- CP8: Recognition of Interleaved Desktop Activities
- CP9: Anomaly Detection??
- CP10: Exploratory Data Analysis Hackathon??

Micro-Breakout Monday at 1:30pm

PPAML Summer School 2016

Where:

- Portland, Oregon

When:

- July 25th to August 5th, 2016

How:

- Online Announcement
  - http://ppaml.galois.com/wiki/wiki/SummerSchools/2016/Announcement
- Application Form
  - https://www.tfaforms.com/406358
- Email and forum announcements forthcoming