Multi-model Multi-target Approaches for Forecasting Seasonal Influenza in the United States

Srini Venkatramanan*, Lijing Wang, Arindam Fadikar, Bryan Lewis*, Jiangzhuo Chen, Henry Carscadden, Prathyush Sambaturu, Anil Vullikanti, Madhav Marathe*

NSSAC Division, Biocomplexity Institute & Initiative, University of Virginia

Contact:{*srini, brylew, marathe*}@virginia.edu

Influenza-Like Illness (ILI) Forecasting

Why?

- Decision support at local/regional/national level
- Demand estimation and resource allocation
- Situation awareness and behavioral nudging

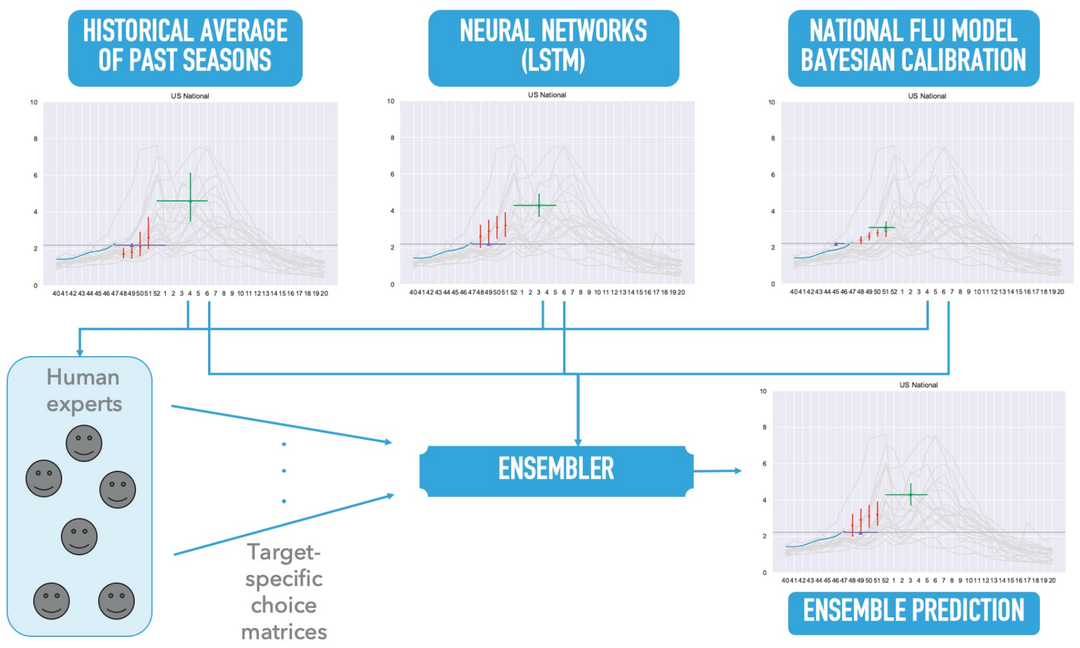
What?

- Short-term indicators (ILI%, activity level, hospital visits)
- Seasonal targets (onset, duration, peak)

How?

- Statistical/Machine learning methods for time series
- Mechanistic approach with Bayesian calibration

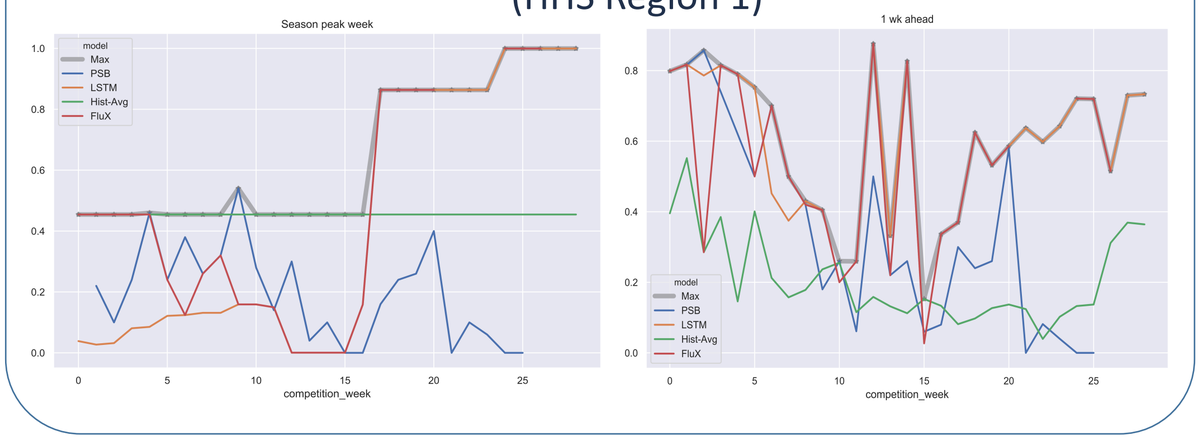
Forecasting ILI% (CDC FluSight)



LSTM method

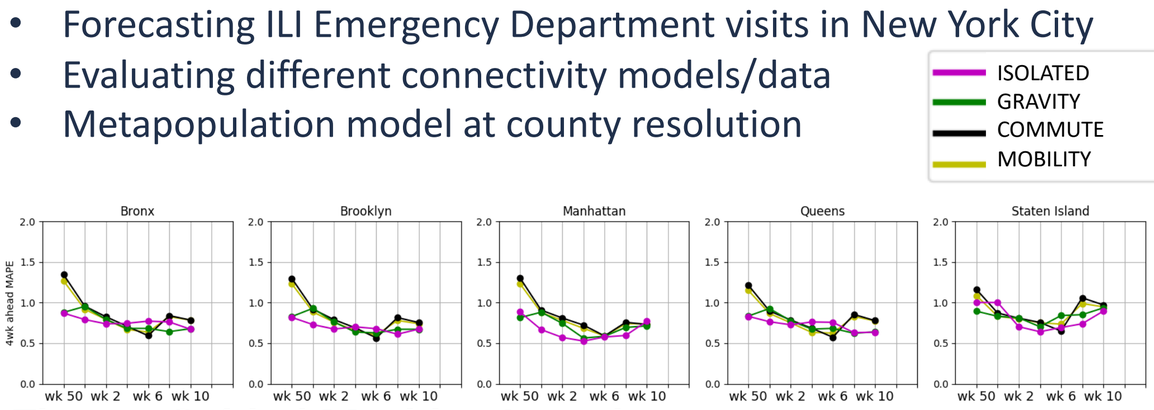
- Single step forecasting for ILI%. Multi-step by chaining forecasts
- Separate models for National and HHS Regions
- Two methods to produce point & binned forecasts based on last layer's activation function (linear->point, softmax->binned)

Model voting behavior (HHS Region 1)



High-resolution Influenza Forecasting

- Forecasting ILI Emergency Department visits in New York City
- Evaluating different connectivity models/data
- Metapopulation model at county resolution



Theory-Guided Machine Learning

- Combining causal methods with artificial neural networks
- Trained to forecast high resolution (county level) surveillance data using population structure and low resolution (state level) surveillance [1]

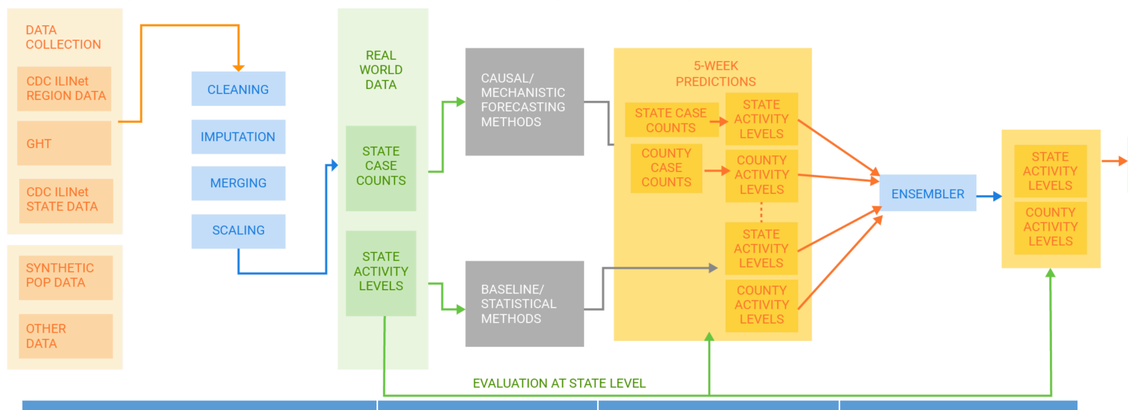
Forecasting Activity Level Indicators

Goal: Forecast activity indicator at state level (scale 1-10)

Rationale: Actionable target and easier to convey/interpret

Statistical methods:

- Naïve (persistent) baseline, Ordinal regression
- Region-week specific Markov model, Support Vector Regression
- Holt-Winters (additive seasonality), Seasonal ARIMA
- Weighted ensemble by retrospective performance



Model	MAPE	+/-1 Accuracy	MCC
Naïve baseline	0.341	77%	**0.2714**
SARIMA	0.329	78%	0.2711
Ensemble	**0.323**	**79%**	0.2408

Narrative Summary Generation

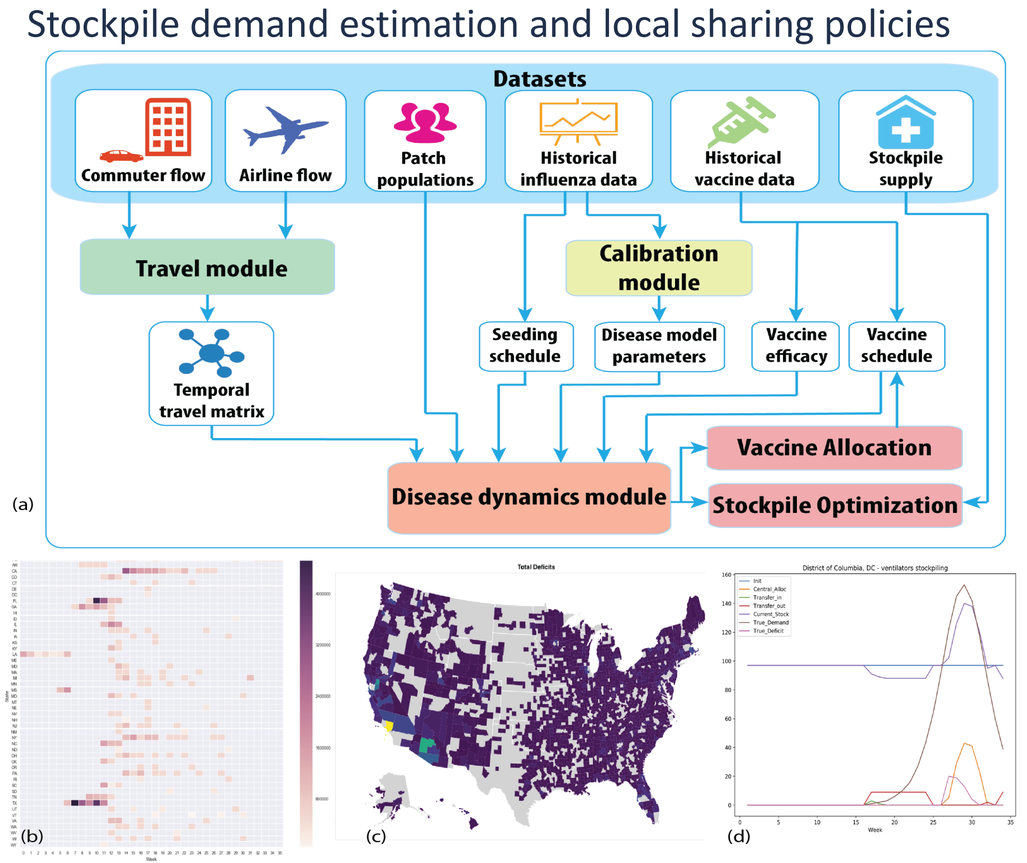
- Extracting key spatiotemporal trends in seasonal influenza [2]
- Works with surveillance and forecast data in-season
- Auto-generated narrative using Min. Description Length (MDL)

State	T-2	T-1	T	T+1	T+2
AK	6	6	8	9	10
ID	8	9	9	10	10
OR	8	10	7	7	6
WA	6	8	10	10	10

→ States in *HHS Region 10 except Oregon* are forecast to *continue* experiencing *high* activity levels for the *next two weeks*.

Stockpile Allocation by Forecasting Epidemics (SAFE)

- Vaccine allocation profiles based on short-term forecasting [3]
- Stockpile demand estimation and local sharing policies



Selected References

[1] Wang L, Chen J, Marathe M (2019). **DEFSI: Deep learning based epidemic forecasting with synthetic information.** Proceedings of IAAI.

[2] Sambaturu P, Bhattacharya P, Chen J, Lewis B, Marathe M, Venkataramanan S, Vullikanti A (2018). **An automated approach for finding spatio-temporal patterns in disease spread.** JMIR Preprints. 20/11/2018:12842

[3] Venkatramanan S, Chen J, Fadikar A et al (2019). **Optimizing spatial allocation of seasonal influenza vaccine under temporal constraints**. To appear in PLOS Computational Biology.

National Institutes of Health
NSF
CDC Centers for Disease Control and Prevention