

# Causality-Encoded Spatiotemporal Graph Convolution Network for Real-time Disease Forecasting

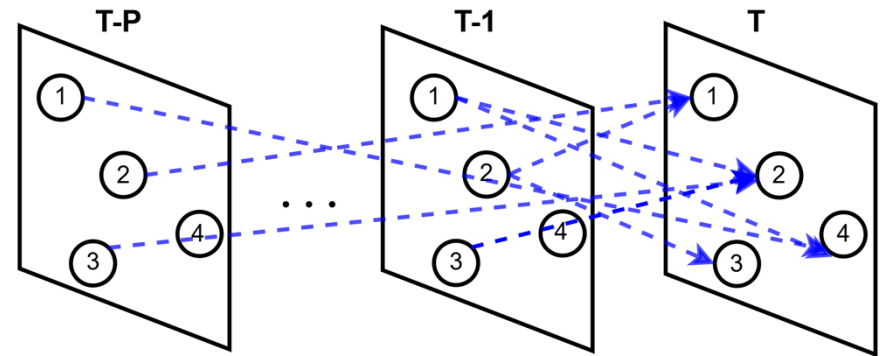
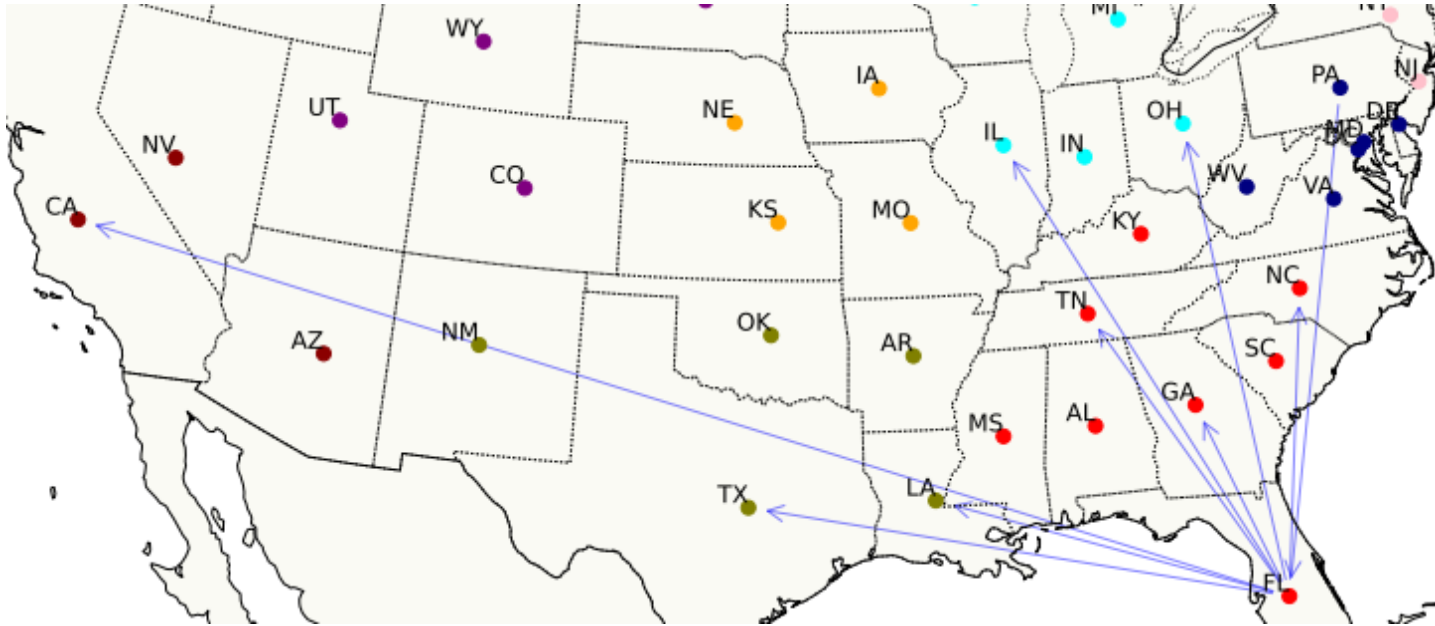
Jingyuan Chou, Aniruddha Adiga, Gurshan Kaur, Srinivasan  
Venkatramanan, Bryan Lewis, Madhav Marathe  
Biocomplexity Institute, University of Virginia

# Motivation

- The spread patterns of disease vary across time
- GNNs provide a natural framework to model Spatiotemporal (ST) data
  - Require large amount of data
  - Static graph structure cannot adequately model the time-varying ST patterns
- Important characteristic of disease spread:
  - **lead/lag between time series at different locations**
  - Identify the causal relationships

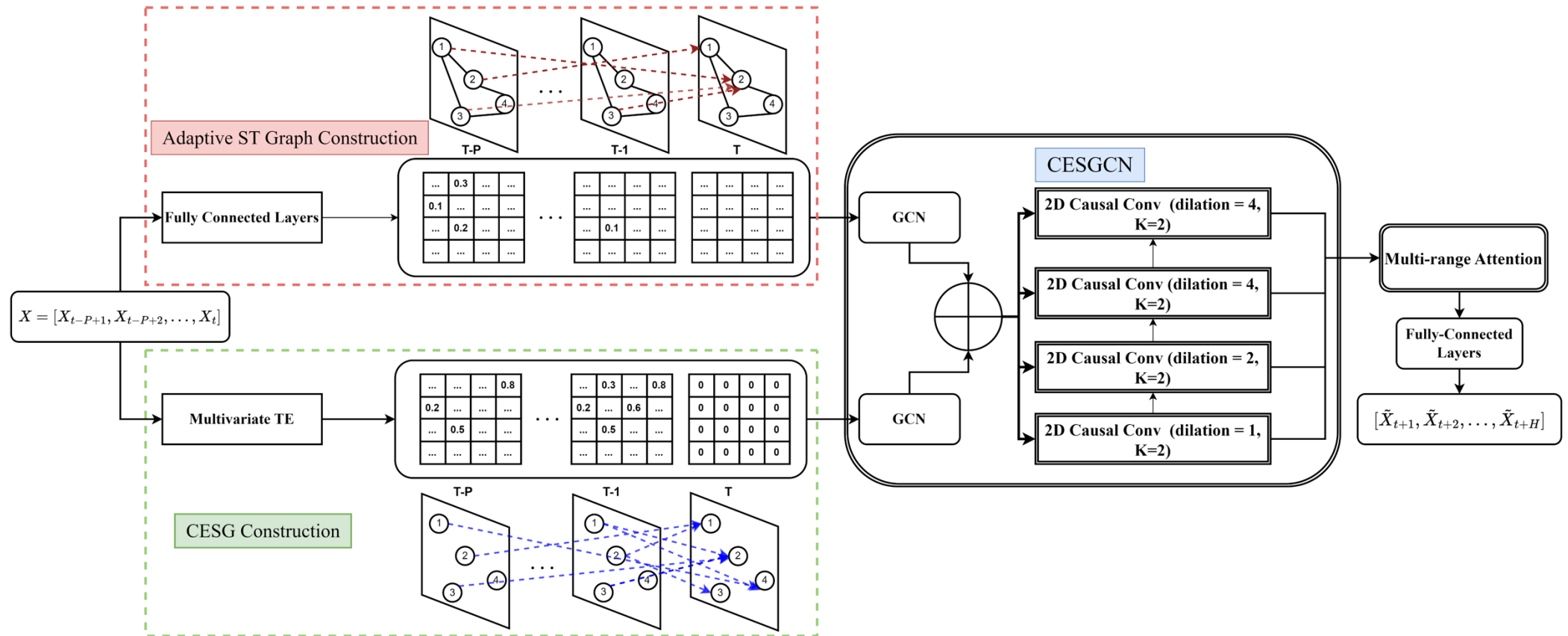
# Spatiotemporal Causal Relationship

- **Transfer Entropy:** measuring the amount of directed transfer of information between two random processes



# CESGCN

- CESGCN (Causality-Encoded Spatiotemporal Graph Convolution Network)

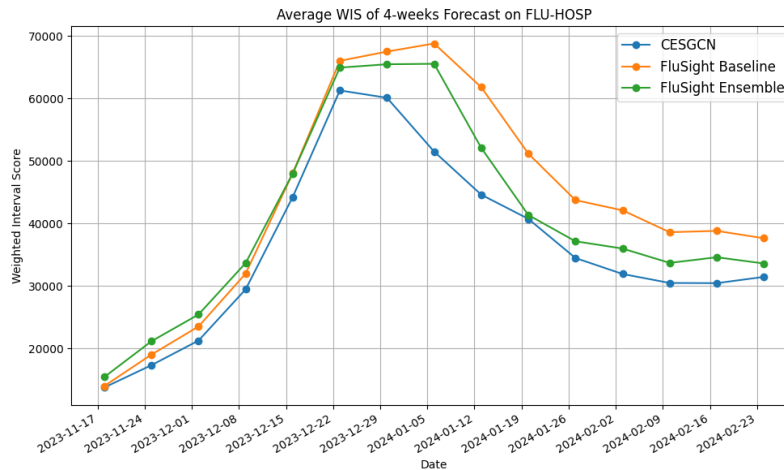


# Evaluation

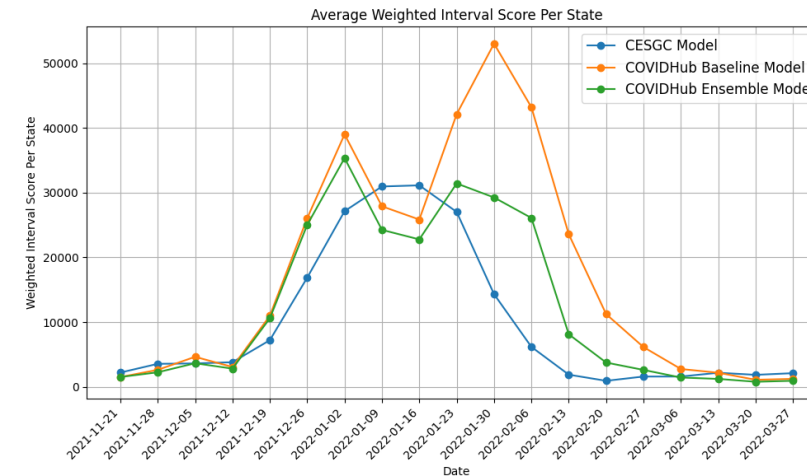
- Datasets: COVID-HOSP; COVID-CASE; FLU-HOSP

| Datasets<br>Metric<br>Window Size | COVID-CASE  |             |             |             |             |             | COVID-HOSP  |             |             |             |             |            | FLU-HOSP    |             |             |             |           |             |
|-----------------------------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|------------|-------------|-------------|-------------|-------------|-----------|-------------|
|                                   | RMSE        |             | MAPE        |             | MAE         |             | RMSE        |             | MAPE        |             | MAE         |            | RMSE        |             | MAPE        |             | MAE       |             |
|                                   | 1           | 4           | 1           | 4           | 1           | 4           | 1           | 4           | 1           | 4           | 1           | 4          | 1           | 4           | 1           | 4           | 1         | 4           |
| AR                                | 21373       | 48407       | 79.1        | 193         | 12188       | 24500       | 126         | 608         | 15.7        | 60.8        | 272         | 484        | 70.1        | 216         | 52.3        | <u>63.9</u> | 70.0      | 121         |
| ARMA                              | 21325       | 49412       | 77.2        | 206         | 10155       | 25400       | 115         | 515         | 14.6        | 53.4        | <u>96</u>   | 576        | 91.6        | 216         | 37.4        | 64.6        | 69.0      | 121.9       |
| STJGCN                            | 12259       | 26159       | 134         | 519         | 9211        | 11824       | 355.9       | 534.5       | 53.3        | 103.4       | 213         | <u>354</u> | 130         | 198.4       | 72.3        | 363         | 61.3      | 213         |
| DCRNN                             | 13765       | 26440       | 96.6        | 208         | 25764       | 50369       | 121         | 240         | 22.5        | 48.8        | 237         | 456        | 58.3        | 115         | <u>33.8</u> | 221         | <u>56</u> | 116.5       |
| STGCN                             | 13970       | 29435       | 75.02       | 102         | 21679       | 47708       | 177.5       | 367.7       | 29.8        | <u>37</u>   | 193         | 374        | 87.5        | 170.6       | 64.7        | 167         | 63        | <u>94</u>   |
| GMAN                              | 23808       | 50028       | 839         | 752         | 9268        | 11255       | 256.7       | 407.6       | 69.2        | 88.1        | 283         | 520        | 132         | 192         | 85          | 197         | 80.4      | 130         |
| AGCRN                             | <b>4693</b> | <b>8673</b> | 73.7        | <b>74.7</b> | <u>4413</u> | <u>8102</u> | 289.4       | 583.6       | 44.8        | 50.4        | 297.8       | 581.2      | 66.4        | 133         | 39.4        | 207.8       | 78.2      | 132.2       |
| Epi-ColaGNN                       | 16136       | 31819       | 97.5        | 196         | 24748       | 48908       | <u>59.8</u> | <u>105</u>  | <u>12.6</u> | 43.8        | 239         | 438        | <b>48.1</b> | <u>93.2</u> | 37.1        | 226.3       | 58.5      | 121.1       |
| EpiGNN                            | 9679        | 21200       | <u>67.5</u> | 109         | 18275       | 42803       | 171.1       | 368.1       | 54.7        | 150.3       | 575.3       | 1002       | 58.5        | 114.6       | 139.3       | 176.9       | 83.7      | 116.7       |
| CNNRNN-Res                        | 14521       | 34082       | 84.2        | 135.7       | 24106       | 50351       | 167         | 320         | 30.7        | 40          | 254         | 512        | 73.3        | 138.7       | 56.4        | 212         | 68        | 109         |
| Cola-GNN                          | 11994       | 23145       | 112         | 322         | 29301       | 55470       | 86.5        | 160.6       | 16.4        | 58.8        | 340         | 648        | 53.4        | 104.3       | 35.6        | 186         | 72.8      | 97          |
| CESGCN                            | <u>7065</u> | <u>8690</u> | <b>66.7</b> | <u>97.5</u> | <b>4170</b> | <b>6122</b> | <b>54.7</b> | <b>59.9</b> | <b>11.9</b> | <b>19.5</b> | <b>83.6</b> | <b>336</b> | <u>51.1</u> | <b>87.7</b> | <b>29</b>   | <b>52.1</b> | <b>48</b> | <b>81.8</b> |

Table 1: Performance Table



WIS of 4-week forecast in 2024 Flu season for FLU-HOSP



WIS of 1-week forecast FOR COVID-CASE