

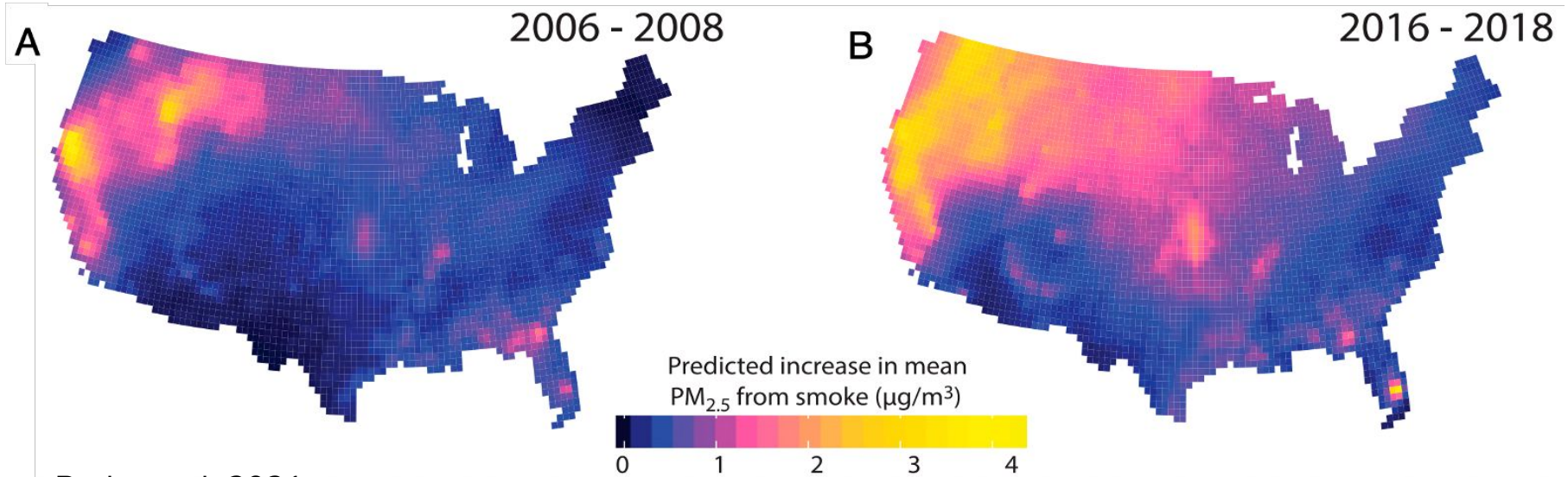
# Simulating the Air Quality Impact of Prescribed Fires Using a Graph Neural Network-Based PM<sub>2.5</sub> Emissions Forecasting System

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**NeurIPS 2023**

# Increasing PM<sub>2.5</sub> from Wildfires



Burke et al. 2021

# Prescribed Burning Effective Land Management Tool

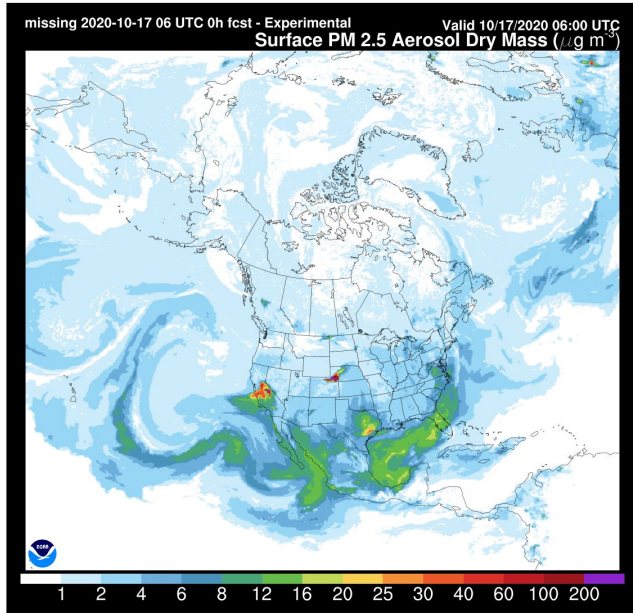


Prescribed burns can prevent and reduce destructiveness and spread of wildfires

Trade-off:

- Immediate increase in  $PM_{2.5}$  pollution

# 2 Methods to Predict $\text{PM}_{2.5}$ of Prescribed Burns



## Chemical Transport Model (CTM)

- Can consider chemical reactions of pollutants
- Complicated and computationally expensive due to extensive calculations
- Time intensive

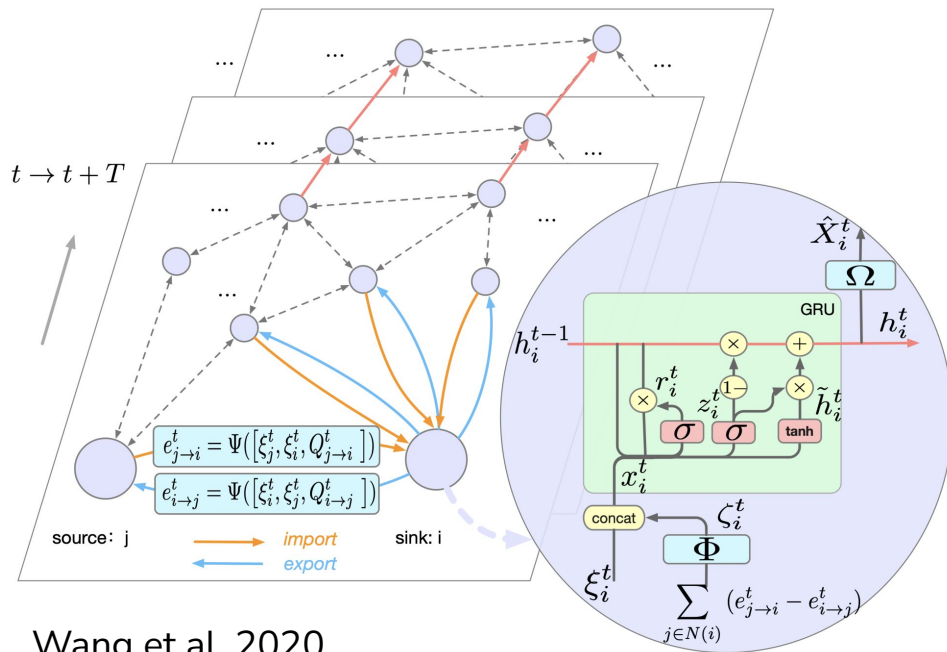
## Machine Learning

- Several orders faster than CTMs
- Can emulate outcomes of CTM with similar, if not improved, accuracy

# Graph Neural Network (GNN)

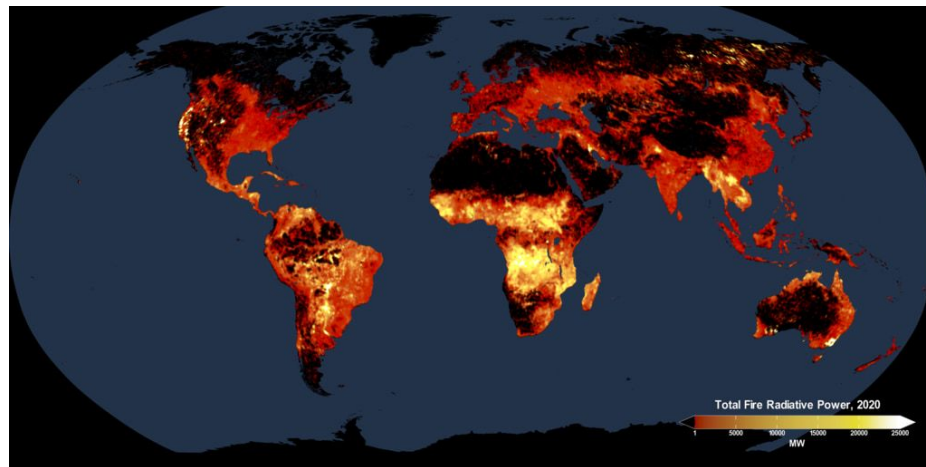
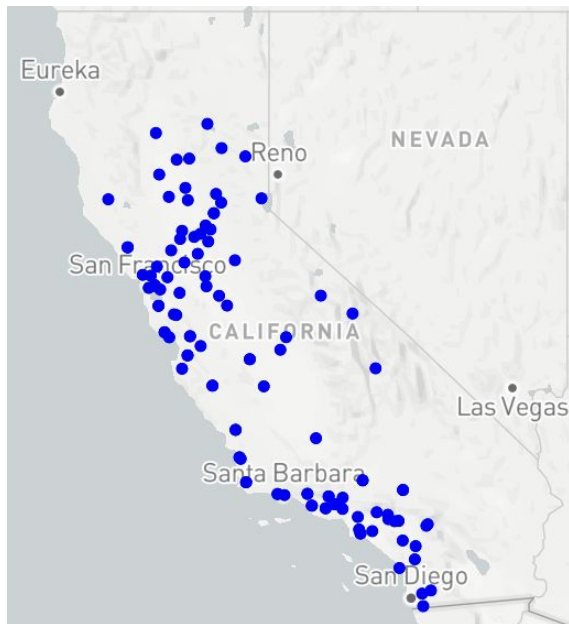
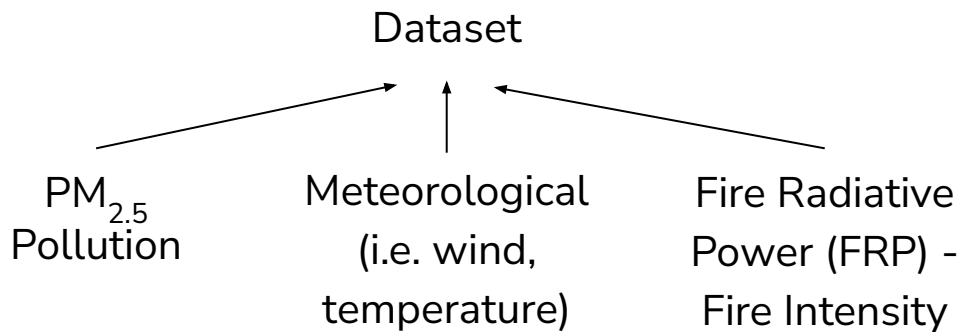
GNN Outperforms MLP and LSTM in forecasting PM2.5 at an hourly resolution

|      | GNN  | LSTM | MLP  |
|------|------|------|------|
| MAE  | 5.23 | 5.73 | 6.24 |
| RMSE | 6.72 | 7.32 | 7.83 |

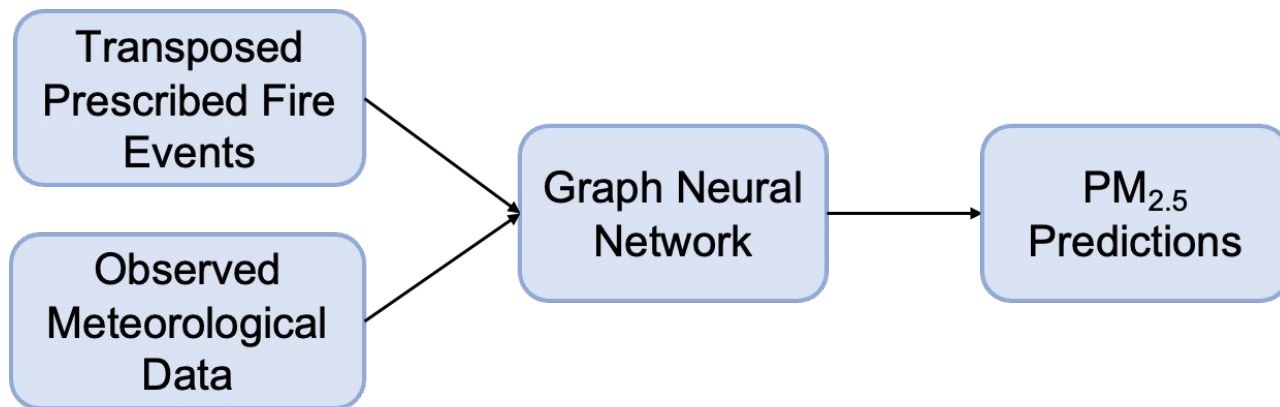


Wang et al. 2020

# Dataset



# Pipeline for $\text{PM}_{2.5}$ Prediction of Simulated Prescribed Burns



## Expt. 1) Determining Optimal Time for Prescribed fires

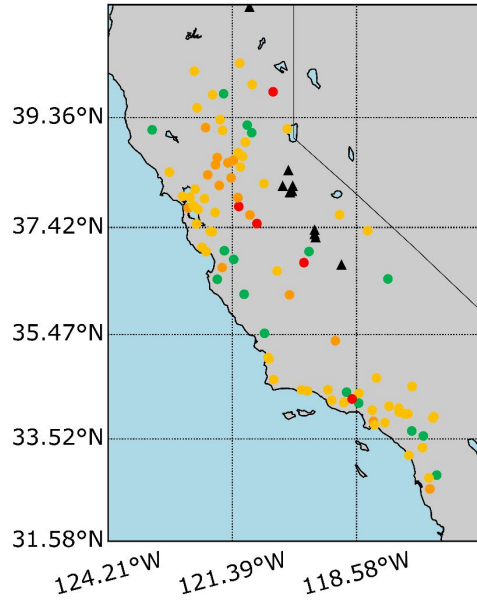
- Prescribed fire event (1/3/21 - 1/15/21) was transposed to target times throughout the year 2021 at 24-hour time steps
- Fire variables incorporate both transposed and observed fire events

Results of PM<sub>2.5</sub> Predictions Based On Simulated Prescribed Fires

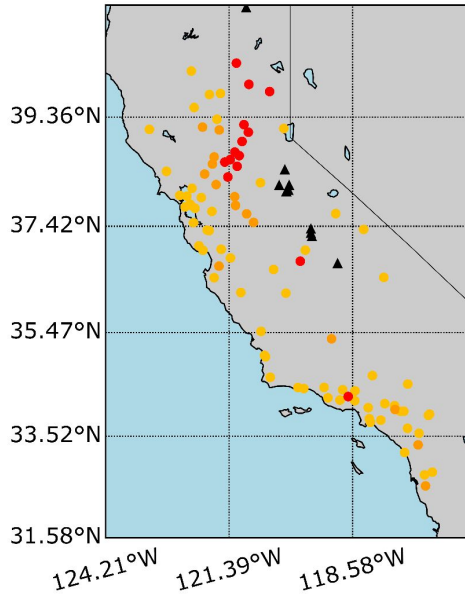
|                                   | Jan   | Feb   | Mar   | Apr   | May   | Jun   | Jul   | Aug   | Sep   | Oct   | Nov   | Dec   |
|-----------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Mean ( $\mu\text{g}/\text{m}^3$ ) | 15.62 | 15.64 | 14.69 | 15.18 | 14.76 | 15.92 | 18.44 | 21.73 | 18.55 | 16.95 | 19.94 | 18.73 |
| Max ( $\mu\text{g}/\text{m}^3$ )  | 36.49 | 39.06 | 39.10 | 38.76 | 40.85 | 42.04 | 47.25 | 60.13 | 43.44 | 45.61 | 40.54 | 45.32 |

# March is Optimal & August Results in Most Pollution

March



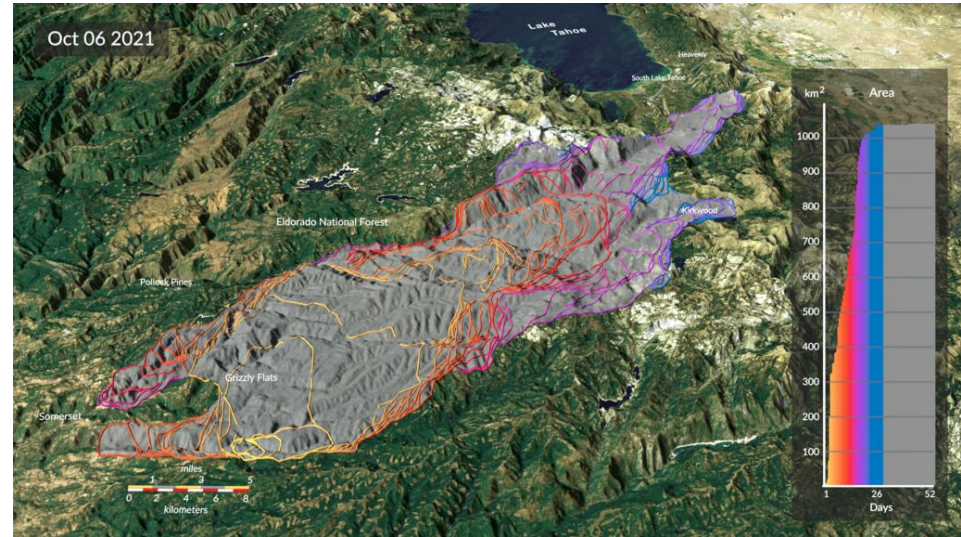
August



- Good
- Moderate
- Unhealthy for Sensitive Individuals
- Unhealthy
- Very Unhealthy
- Hazardous
- ▲ Prescribed Fire Locations

## Expt. 2) Quantifying PM<sub>2.5</sub> Trade-off of Prescribed Fires

- Prescribed fire at location of Caldor fire in the spring of 2021 would have prevented the Caldor fire, which burned in fall of 2021
- Simulated effects of 3 prescribed fires in early 2021
  - Artificially increased FRP of prescribed fires
- Excluded FRP values at the Caldor Fire location during the fall



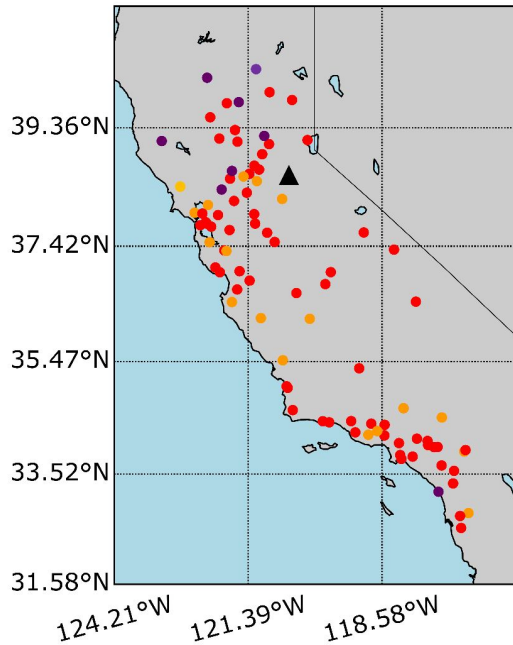
# Long-term Benefits Outweigh Immediate Pollutant Costs

Comparing the Predicted PM<sub>2.5</sub> Effect of Simulated Prescribed Burns  
With Baseline PM<sub>2.5</sub> Predictions

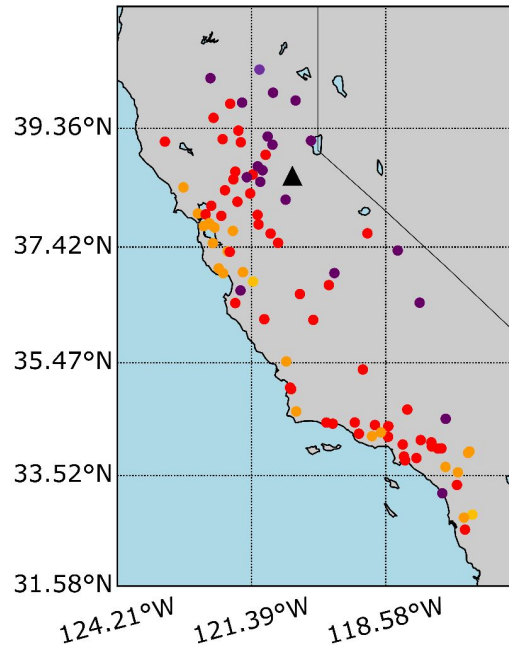
|                                   | 3/21/21 - 5/31/21            |                                       | 8/14/21 - 10/21/21     |                                |
|-----------------------------------|------------------------------|---------------------------------------|------------------------|--------------------------------|
|                                   | Simulated<br>Prescribed Burn | Without Prescribed<br>Burn (Baseline) | Removed Caldor<br>Fire | With Caldor Fire<br>(Baseline) |
| Mean ( $\mu\text{g}/\text{m}^3$ ) | 6.83                         | 6.52                                  | 10.49                  | 16.24                          |
| Max ( $\mu\text{g}/\text{m}^3$ )  | 55.78                        | 54.12                                 | 83.61                  | 177.32                         |

# Long-term Benefits Outweigh Immediate Pollutant Costs

Removed Caldor Fire



With Caldor Fire (Baseline)



- Good
- Moderate
- Unhealthy for Sensitive Individuals
- Unhealthy
- Very Unhealthy
- Hazardous
- ▲ Caldor Fire Location

# Conclusions

- Development of the prescribed fire simulation pipeline
- First to apply ML to simulate effects of prescribed fires

# Future Work

- Physics-based modeling to improve prescribed fire simulation