Applied Machine Learning Methods to Predict the Air Quality Impact of Wildfires in Northern California

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ProjectX

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Wildfires

- 7,948 fires occurred in California in 2018
- 1,975,086 acres of land were destroyed
- Resources worth $635M were diverted
- 22,905 structures were destroyed

Air Quality

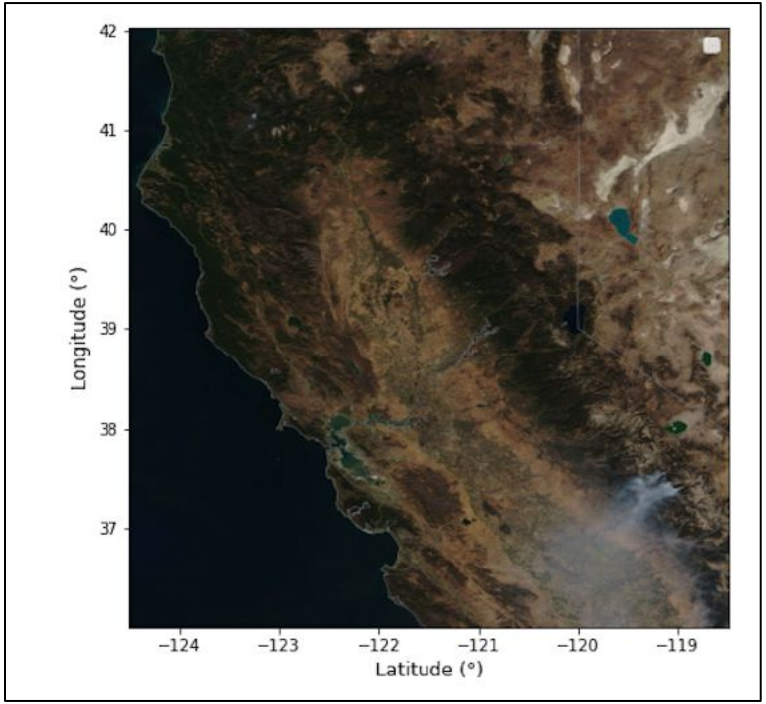
- **Fine Particulate Matter** (**$PM_{2.5}$**) : Small breathable pollutants harmful to human health

- **$PM_{2.5}$** levels reached 453µg/m^3 in Northern California during October 2021

- The World Health Organisation recommended safe limit for **$PM_{2.5}$** is 10µg/m^3

Domain: Northern California

- **36°N to 42°N, 118.5°W to 124.5°W**
- Varied land uses and topographies
- Prone to high-impact wildfires
- Frequent and severe droughts induced by climate change



Datasets

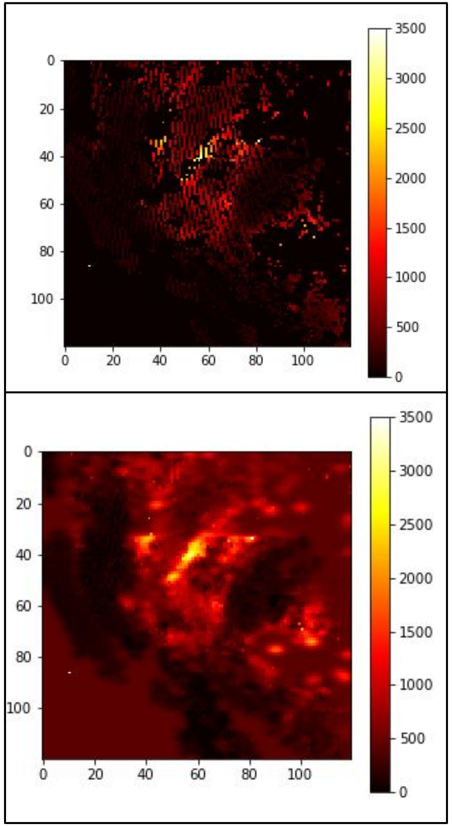
- Moderate Resolution Imaging Spectroradiometer **(MODIS)**
  - Collected from the Terra and Aqua Satellites
- NCEP North American Regional Reanalysis **(NARR)**
  - Satellite and deterministic model generated data
- Date Range: January 1st, 2010-December 31st, 2019

Datasets

- Four Categories
  - Fire: MODIS Fire
  - Air Quality: MODIS Aerosol Optical Depth (AOD)
  - Meteorological: NARR
  - Land Cover: MODIS Vegetation Index product
- Custom grid: 120X120 grid with 0.05^{o} by 0.05^{o} grid cells

Interpolation

- Spatial kriging applied to NARR and AOD datasets to estimate missing values
    - **Top:** Un-interpolated AOD
      Bottom: Interpolated AOD
    - Determines missing values based on distance-dependent variance



Data Transformation

- Yeo-Johnson Power Transformation: Mean = 0, Standard Deviation = 1
- Dimensionality Reduction
  - Principal Component Analysis
  - Autoencoding

Baseline Model

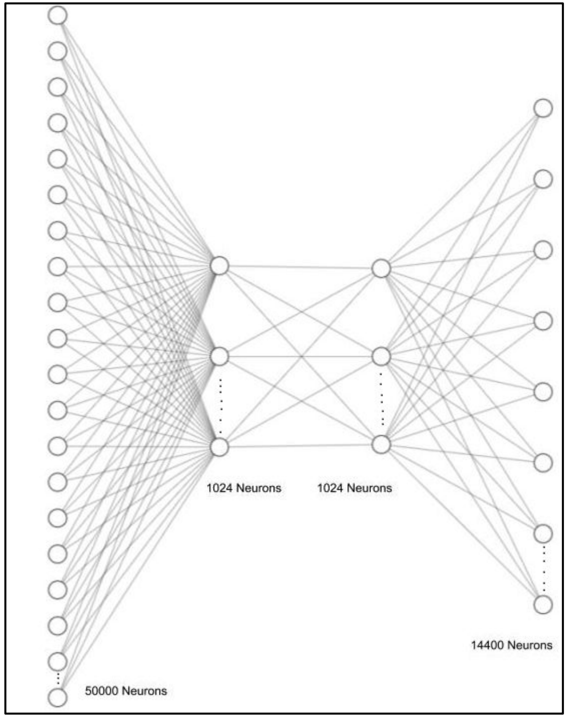
Persistence: Next day = Current day

Deep Learning Models

Basic: Artificial Neural Network
Time Series: Recurrent Neural Network

Neural Networks Overview

- Network of nodes connected by weights
- Capable of learning complex nonlinear functions
- Computationally expensive to train
- Rapidly developing field



Experiments

- **Inputs:** Fire, vegetation, weather data from previous day
  Output: AOD prediction of next day

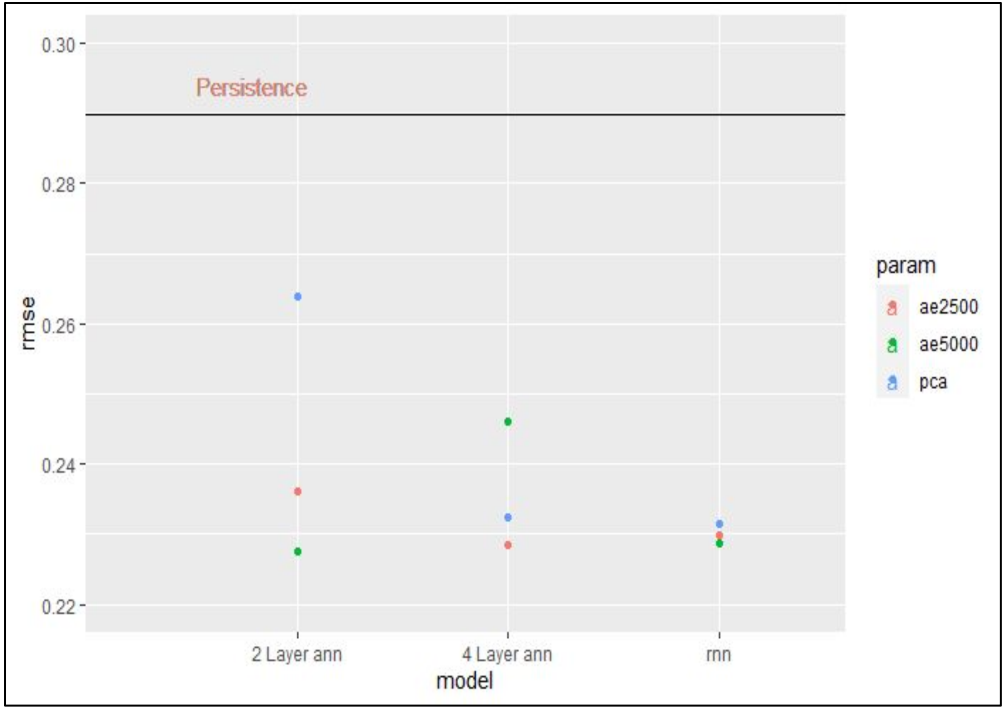
- Code in Python and R

- Autoencoding and model training on Google Cloud AI Platform

- Several hours to train each model

Results

- Neural networks provided improved performance compared to baseline
- Decreased variability in performance with more parameters
- Dimensionality reduction shows no clear trend



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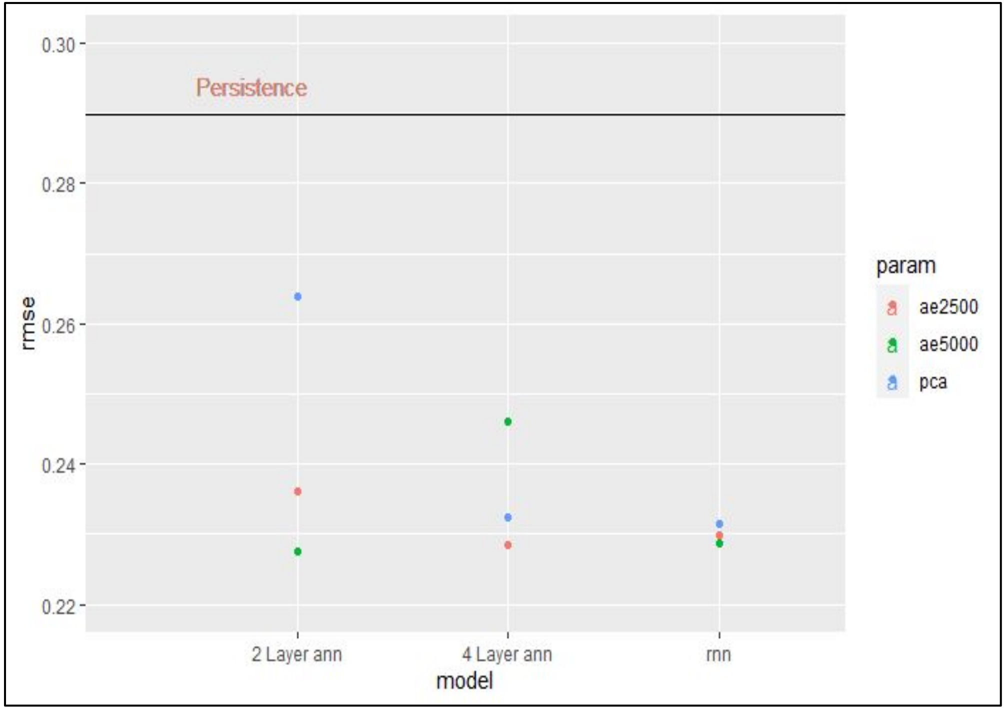

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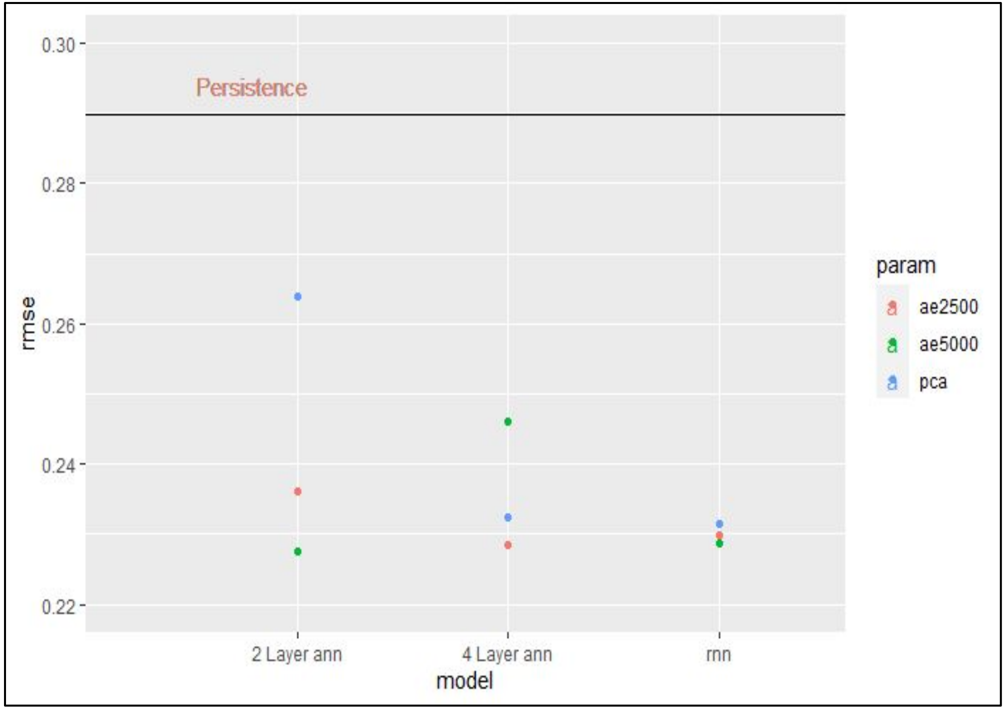
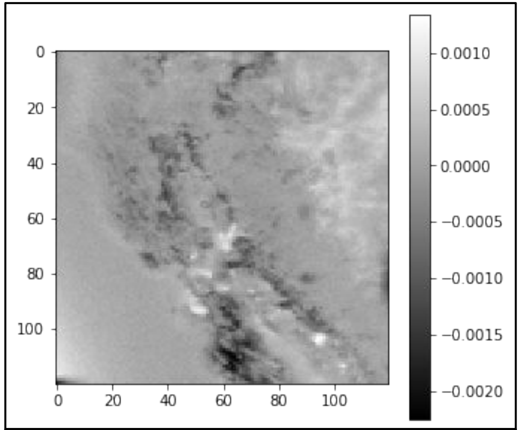


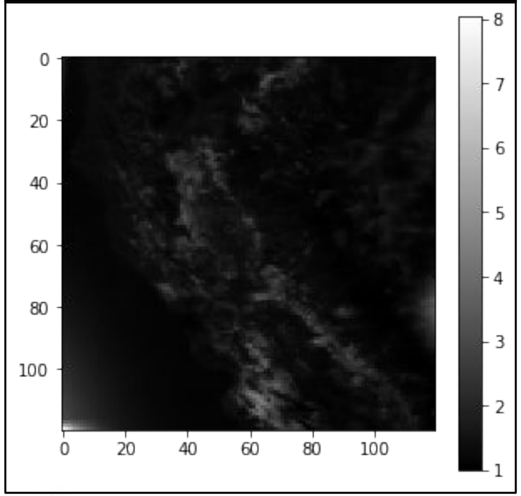
Analysis of Results

- **Top:** 2-layer ANN AOD predictions
  Bottom: AOD training labels

- Results are not state-of-the art and need refinement

- Not yet feasible to implement our models in real-world scenario

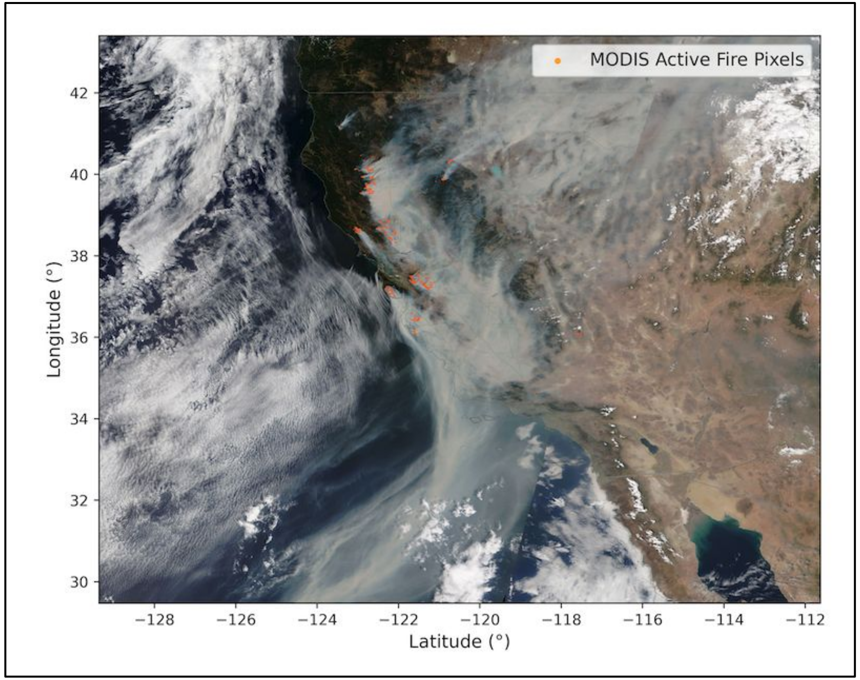




Relevance

- Predicting trends of air quality during disasters essential for damage control

- Possible use in analyzing changing trends of air quality



Future Work

- Refinement of scope and models needed for real-world use

- Further interpolation and transformation methods to improve input features

- Improve model precision and work towards publishable results

Conclusion

- Environmental data well-suited for ML applications

- Deep learning models provide improved predictions

- ML has potential for high-resolution, timely, and relevant predictions of wildfire air quality impacts

Thank you!

Any questions?

GitHub Repo: https://github.com/GAInTheHouse/BadgerX

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