Analysis of flood-insurance in minimizing cost to homeowner for Nashville, TN

-Raghav Sharma

Background and Motivation

The Cumberland River crested downtown Nashville at 51.86ft in May 2010, the highest level recorded since the Cumberland Dam system was built in early 1960s.

$2 billion
Private property losses

10%
Nashville properties in 100-yr flood plain

- Average annualized cost to Nashville homeowners from riverine flooding.
- Impact of flood insurance in minimizing flood losses.

Methodology

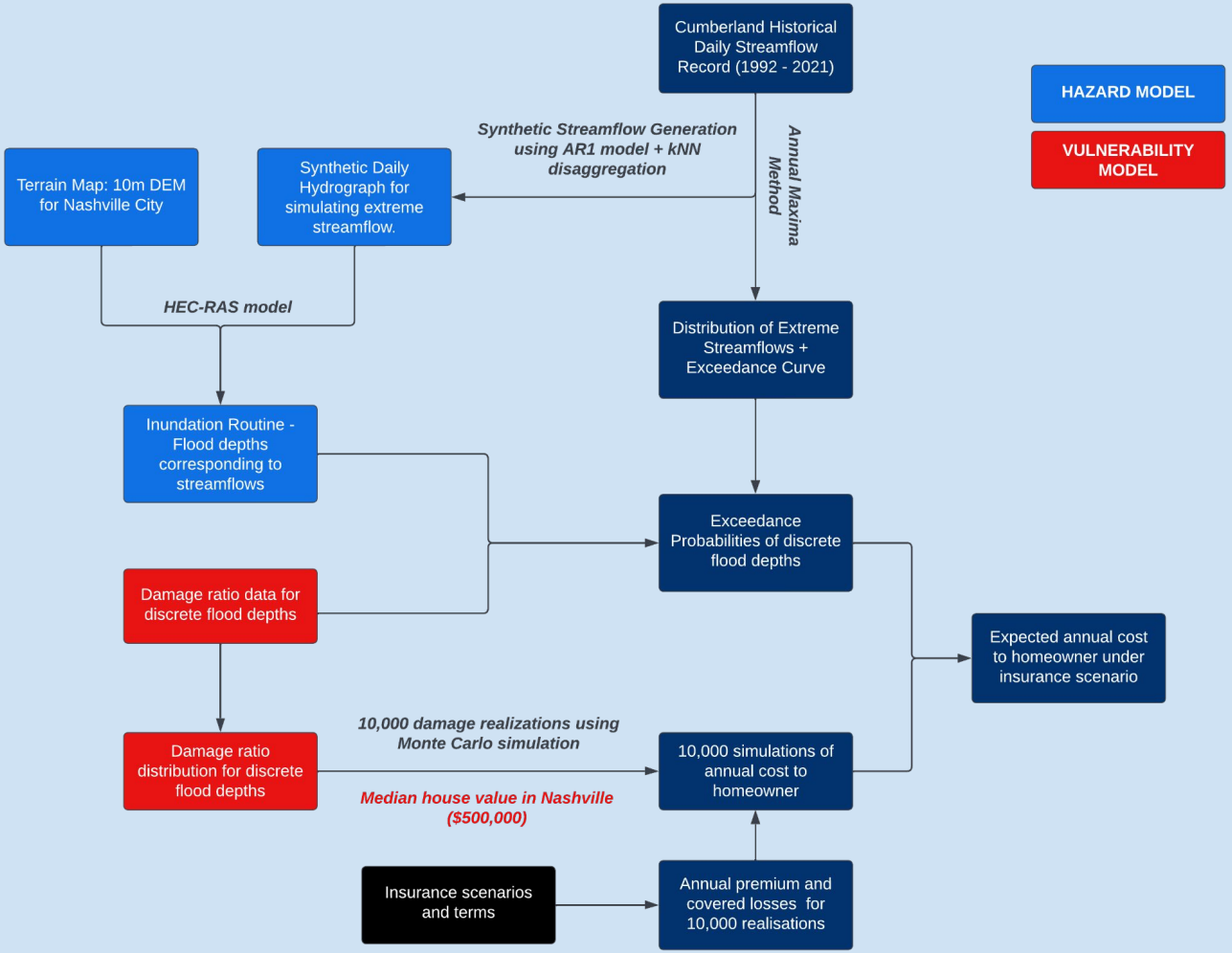
Data used

1. Cumberland Historical Streamflow Record - USGS StreamStats (Station ID: 03431500)
2. 10m DEM Nashville City - USGS
3. 100 Damage Ratios for each flood depth
4. Insurance Terms with max coverage of $250,000:

Insurance A: $1500 annual premium, deductible = $1,250

Insurance B: $1200 annual premium, deductible = $5,000

Insurance C: $900 annual premium, deductible = $10,000



Synthetic Streamflow Generation

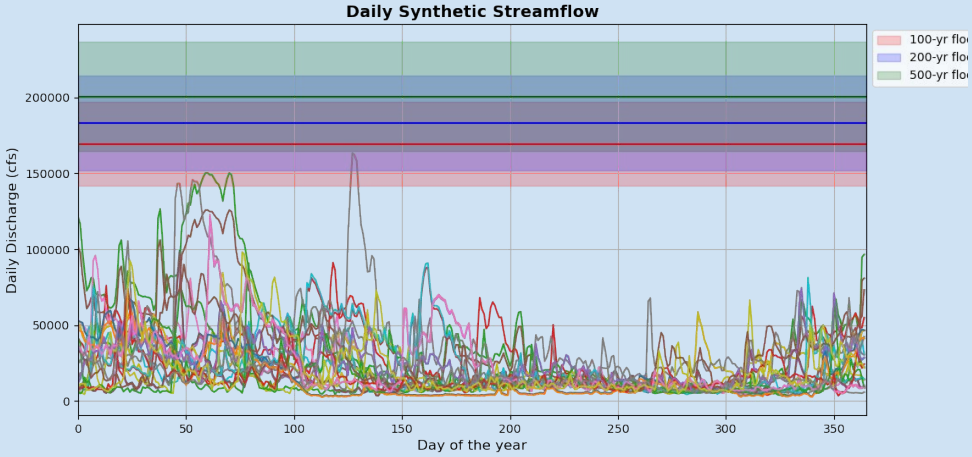
Generates daily streamflow series satisfying the range of reasonable future conditions and preserves statistical patterns in historical streamflow

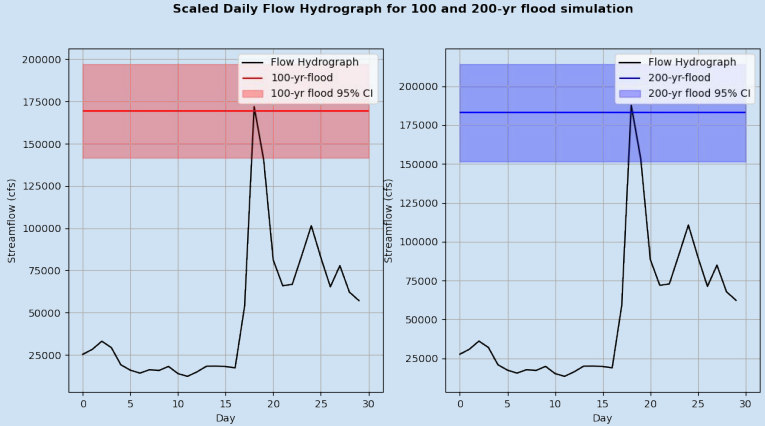
Sample an annual flow from AR(1) model (Qs)

Sample a historical year with similar flow (Qh ~ Qs) using k-nearest neighbors.

Take the daily streamflow from that year in the historical record and scale it by (Qs/Qh)

Select a 30-day series around largest streamflow and scale it to desired streamflow value





Example 30-day hydrograph scaled to 100 and 200-yr streamflows

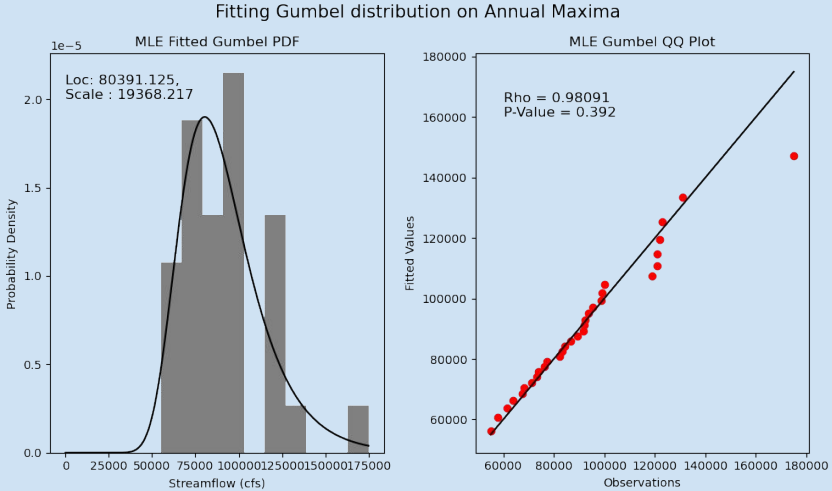
Nashville Extremes & Exceedance Curve

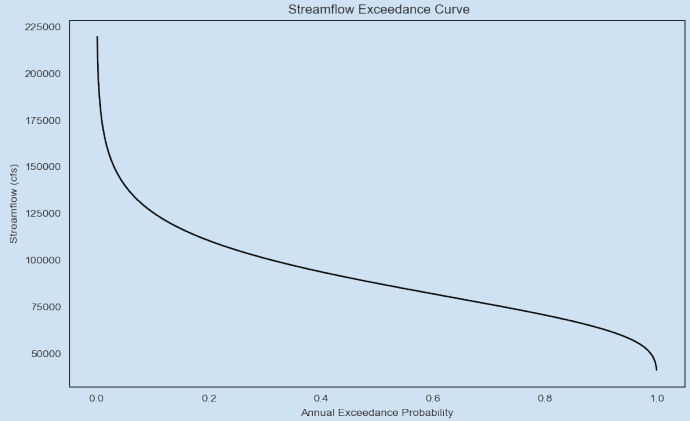
Annual Maxima method for estimating extreme streamflows.

Fit lognormal, Pareto, and Gumbel distributions to annual maxima data.

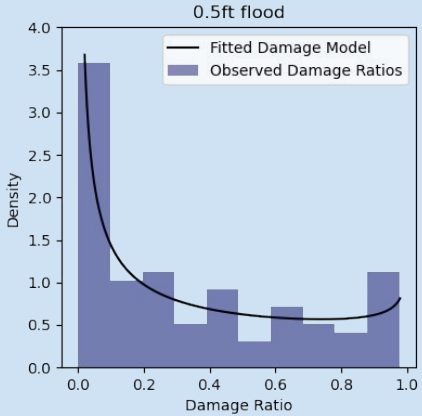
Identify best fit using QQ plots - Gumbel

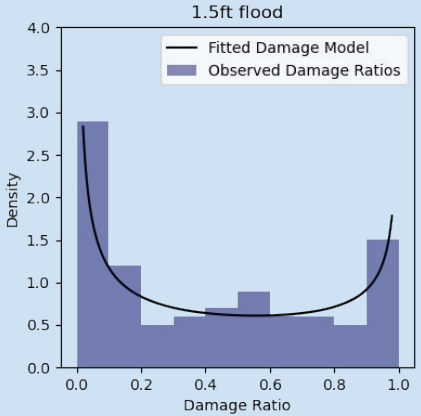
Develop streamflow exceedance curve to determine exceedance probability and return periods of each streamflow.

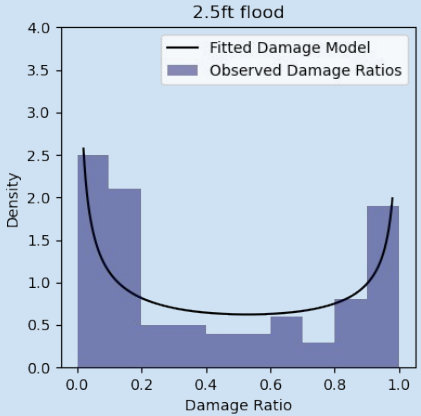


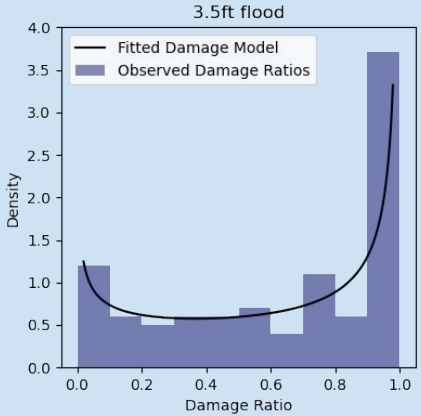


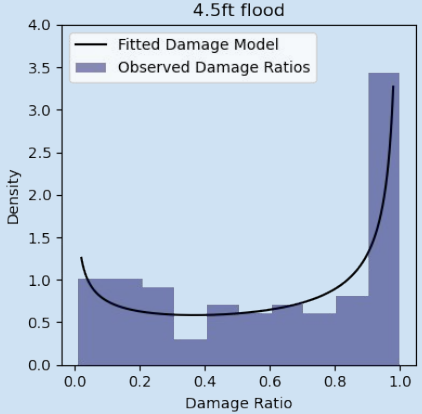
Damage Ratio Data (Vulnerability Model)

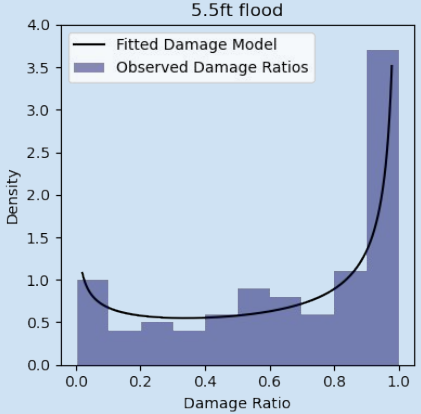


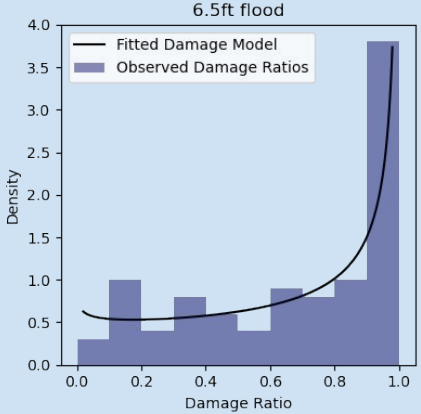




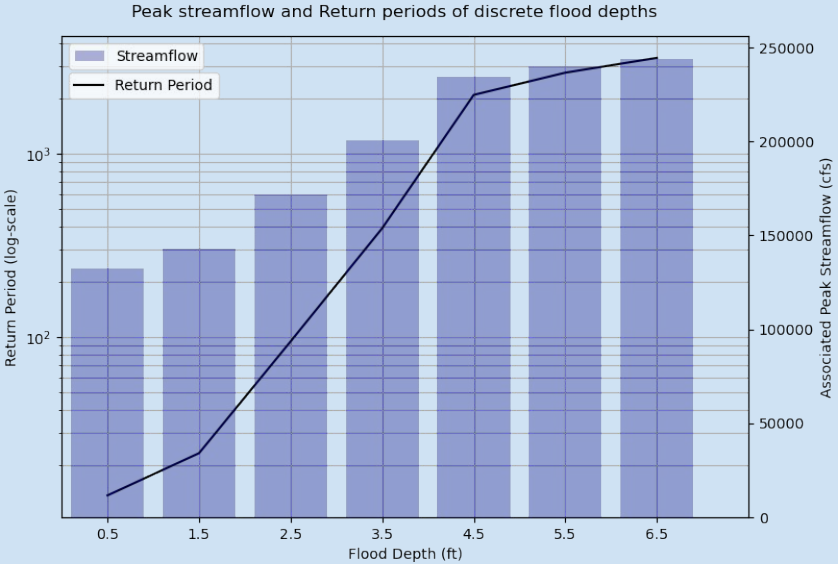






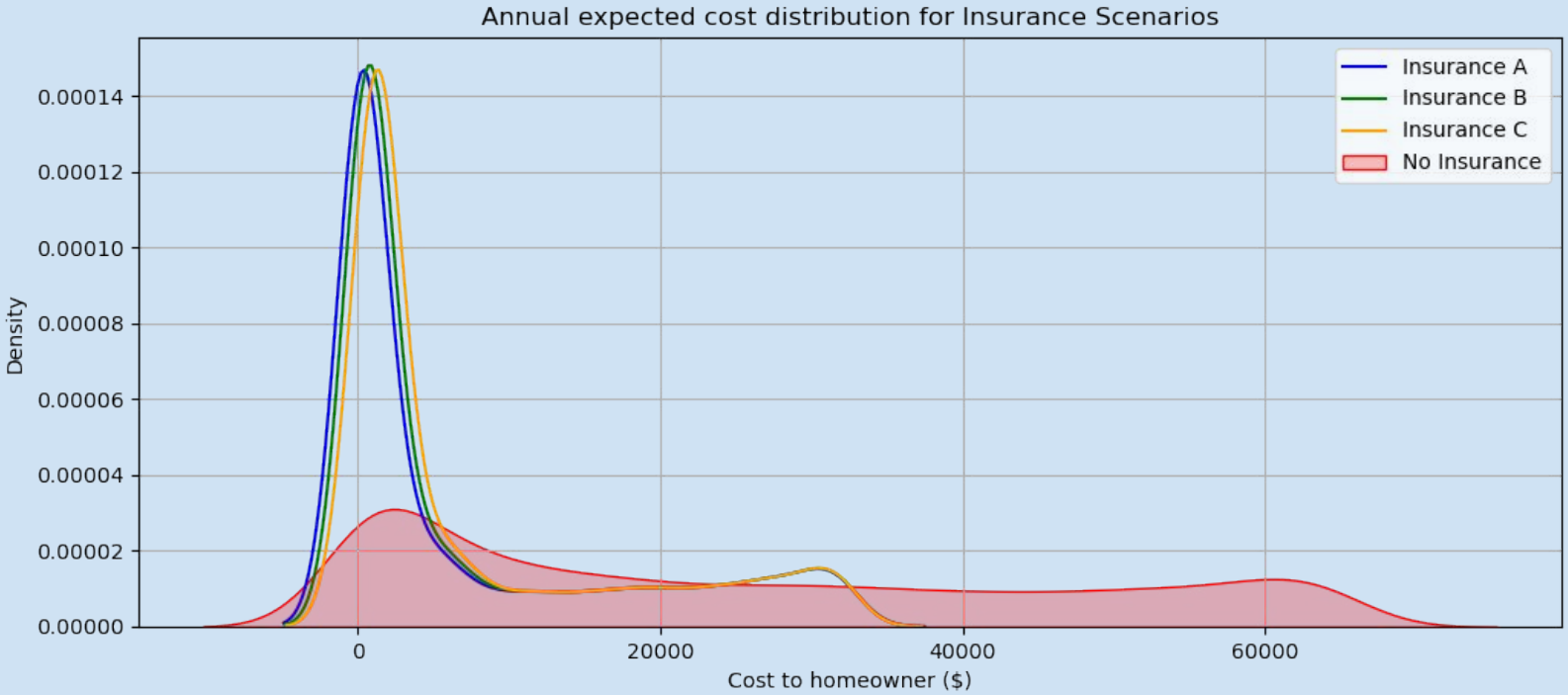


HEC-RAS model results and streamflow

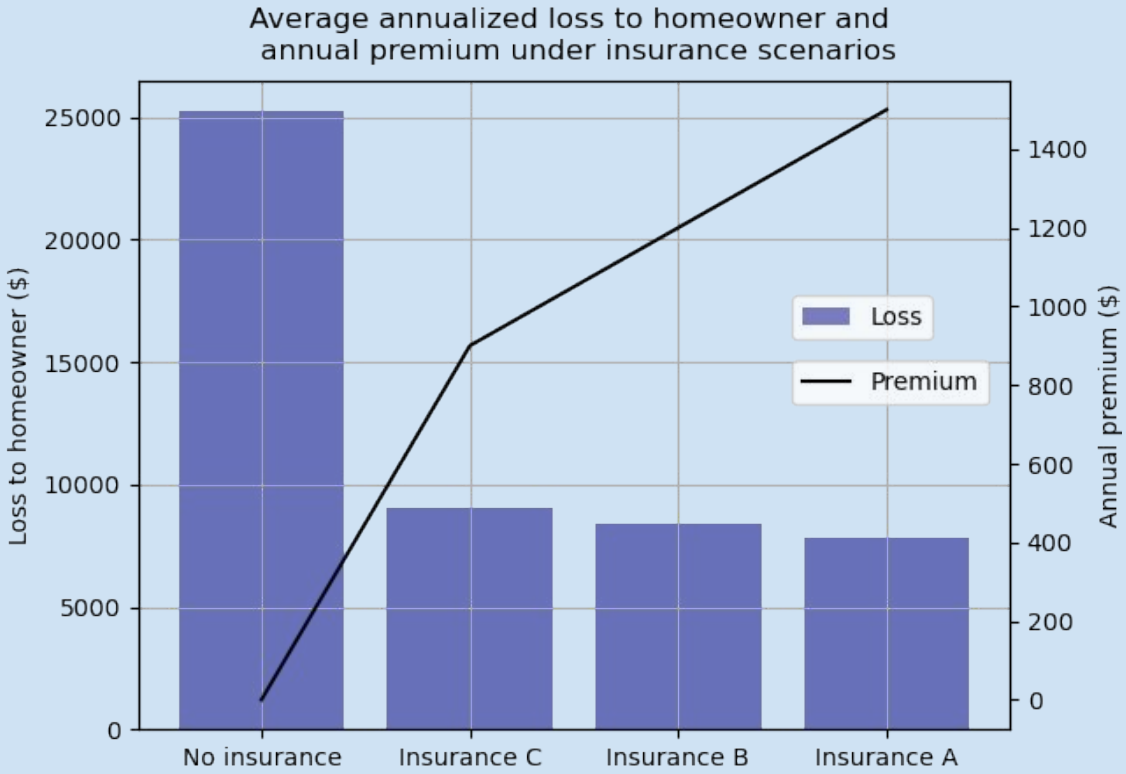


HEC-RAS simulation for 100-yr streamflow

Distribution of annualized cost to homeowner



Average annualized cost to homeowner



Limitations

1. Absence of formal vulnerability/damage functions linking flood depth to reconstruction costs.

2. Lack of building footprint data and first-floor elevation for exposure model.

3. Simplifying assumptions like using average depth in the region for every household, use of median house value.

4. Uncertainties in depth estimation due to coarse DEM.

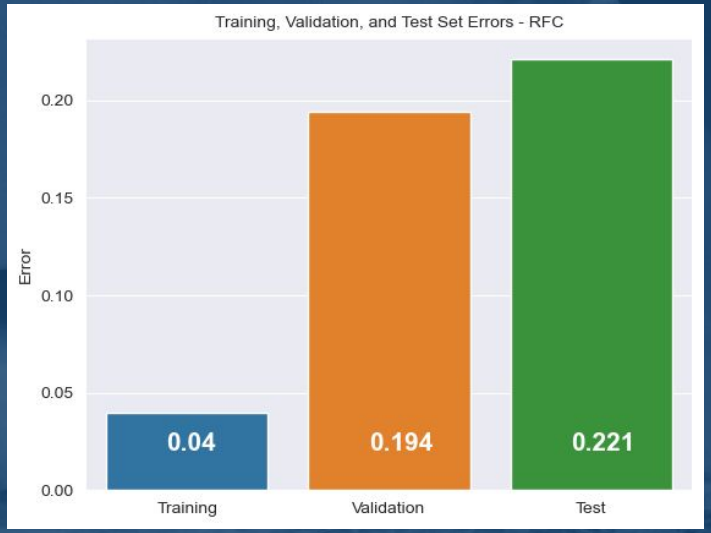
Other Projects

- **ML model for fast flood model error prediction.**

Objective: To predict errors of fast flood model given domain characteristics and use predicted error for model correction and improving accuracy.

Built a tree-ensemble model for predicting fast flood model errors for generalizing error analysis across multiple domains and topographies with 80% test set accuracy.

Predictor variables: Inland Distance, Elevation, Distance from nearest water body, Fast Flood Model Depth, and Water Level Forcing.



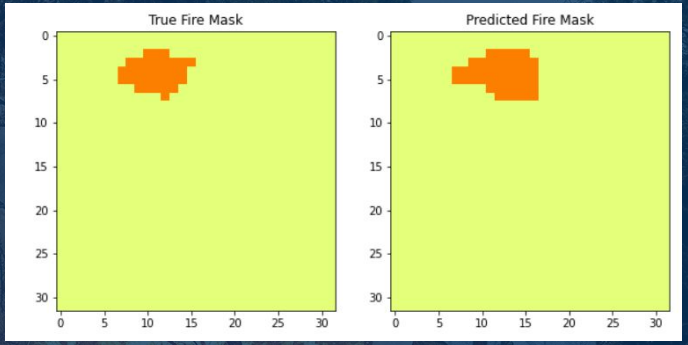
Other Projects

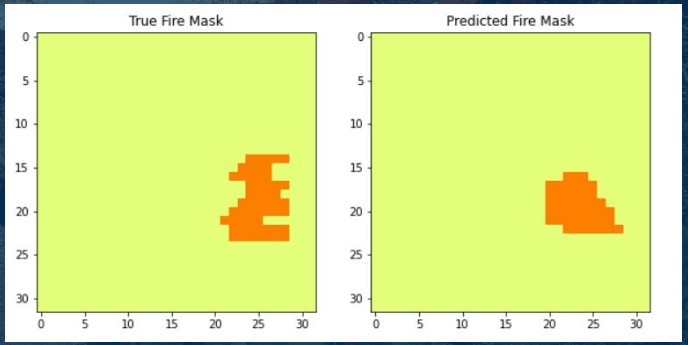
- **DL model for predicting next day wildfire spread**

Objective: To predict next day wildfire mask given previous day fire mask and meteorological / physical features from satellite data.

Built a U-Net like CNN model with a contraction and expansion path for image segmentation into fire/no-fire regions.

Input features: Elevation, Wind Direction, Wind Velocity, Min/Max Temp, Humidity, ERC, Precip, Drought Index, Population Density, Vegetation, Previous Fire Mask





THANK YOU