Predicting Lightning Initiation using Deep Learning

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Background

Lightning presents safety challenges to people and property. Currently, the majority of lightning safety guidance is reactive. “When thunder roars, go indoors,” is commonly stated, meaning that lightning must have already occurred nearby before a person will respond and take shelter. Additionally, most injuries or fatalities occur as the storm approaches, or as it’s moving away, at which time rainfall may not be present (Figure 1). Therefore, reactive safety guidance does not always protect people from the time of greatest risk.

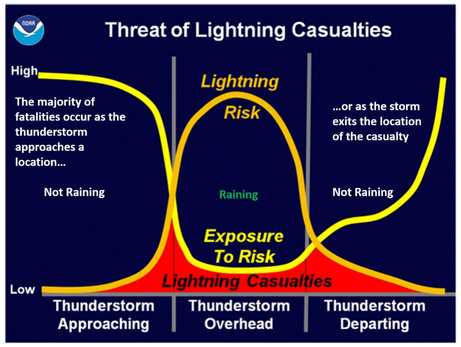

Figure 1: Lightning casualties as a function of lightning risk (number of flashes overhead; orange) versus the exposure of people to the risk (people located outside). Original image, John Jensenius, NWS Retired, annotation from NASA SPoRT.

Methodology: Convolutional Neural Network (CNN) and Long Short-Term Memory (LSTM) Network

- This project develops a physically-based deep learning model to produce lightning initiation probabilities out to 15 minutes.
  - This timescale matches the temporal scales known for inferred electrification from radar and satellite data.
- A combination of a CNN and LSTM was determined to be the best performing model architecture (Figure 2).
  - The CNN is used to capture the spatial storm characteristics, while the LSTM captures the temporal evolution.
- The Lightning-AI model uses time-lagged WSR-88D radar data at the 0°C and −20°C temperature levels.
  - Horizontal reflectivity, differential reflectivity and correlation coefficient
- The model was trained/tuned using two years (2018 – 2019) worth of data over the April – September time range.
  - Geostationary Lightning Mapper (GLM) data are used as the model target variable.

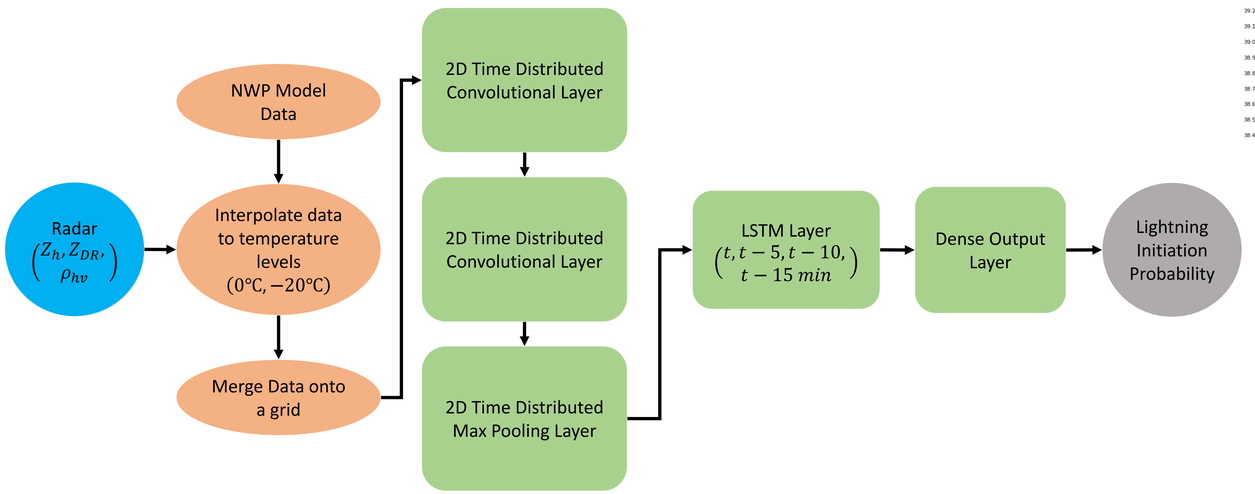

Figure 2: Lightning-AI model overview

Model Performance

- The Lightning-AI model was validated over the April – September 2020 time period.
- The maximum Critical Success Index (CSI) was determined to be 0.64, with a ~80% probability of detection (POD) and ~20% false alarm rate (FAR), using a 40% probability threshold (Figure 3).
- Model performance varies with time-of-year and is likely related to storm mode.

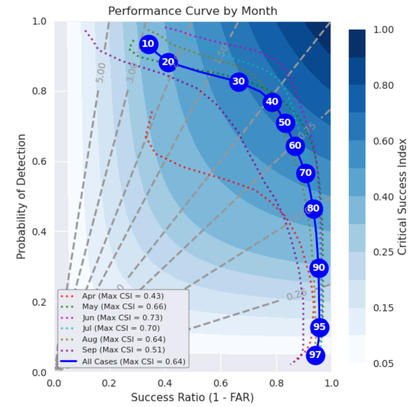

Figure 3: Lightning-AI model performance curve.

Case Study

- On August 4, 2022, a lightning strike in Lafayette Square, just next to the White House, resulted in 3 fatalities and 1 injury.
  - All four people were huddled under a tree, taking shelter from the storm.
- The Lightning-AI model indicated a > 40% lightning initiation probability within 10 miles of Lafayette Square ~25 min before the first strike in the area and > 2 hr before the fatal strike (Figure 5).
  - In this case, the Lightning-AI model also shows its utility in forecasting lightning initiation before rainfall when the risk is the greatest (Figure 4a-f).

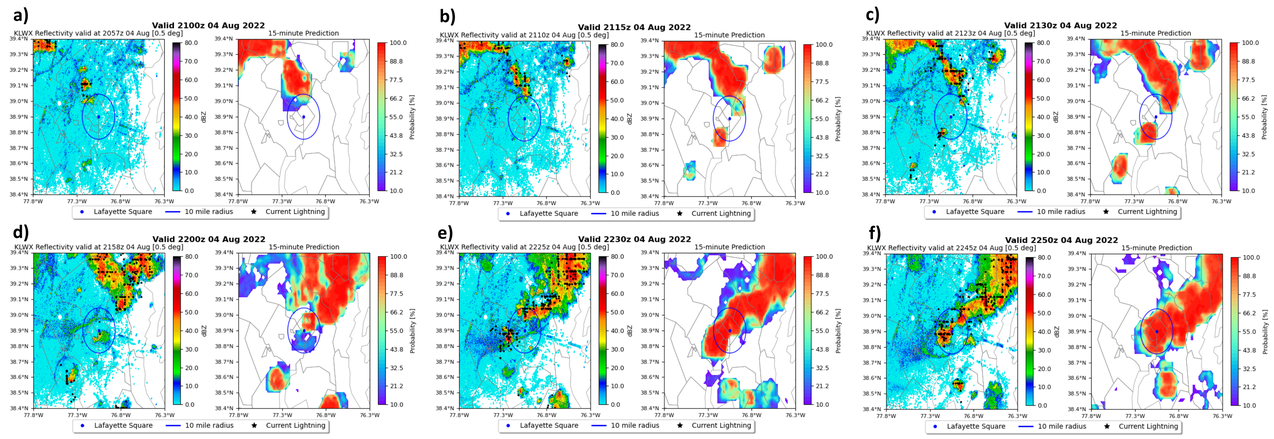

Figure 4: Base reflectivity with previous 15 min GLM lightning initiation locations (left) and Lightning-AI probabilities for the next 15 min (right) for (a) 2100Z, (b) 2115Z, (c) 2130Z, (d) 2200Z, (e) 2230Z, and (f) 2250Z on 04 August 2022.

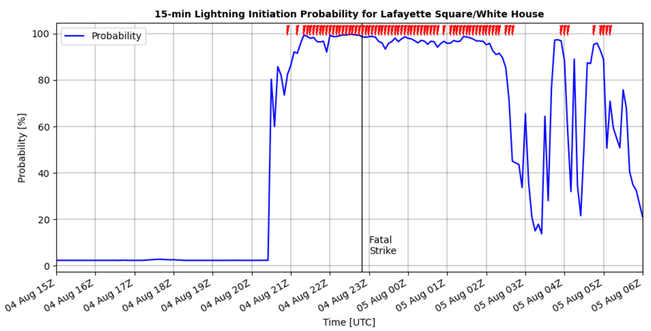

Figure 5: Max Lightning-AI probability as a function of time within a 10-mile radius of Lafayette Square with observed lightning denoted by the red lightning bolt.