# Finding Needles in a Haystack: Using a GOES Nowcasting Model to Forecast Initiation

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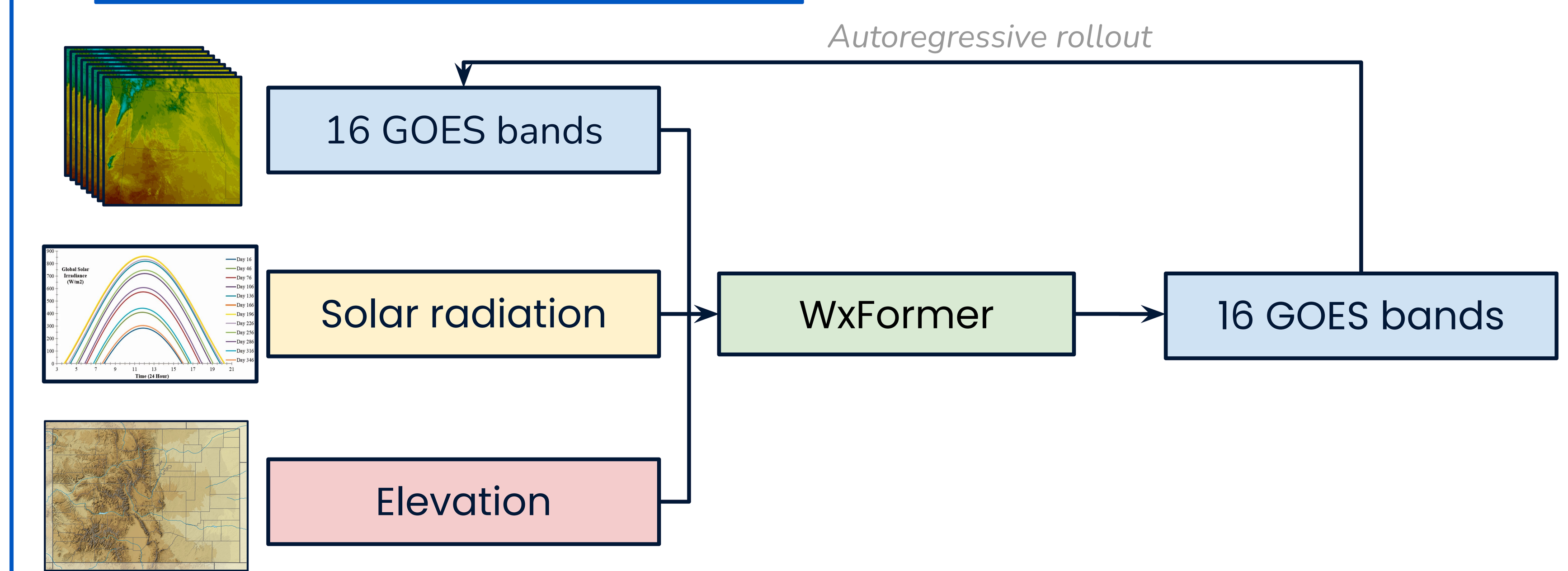
## Background

- Severe storms caused $47 billion in damage in 2024, with 17 billion-dollar disaster events.
- The development of storms are difficult to model due to their nature as chaotic systems.
- Short-term forecasts of severe weather are possible with traditional numerical weather prediction models, nowcasting still exhibits errors in storm placement and timing.

## Objective

- Can machine learning (ML) help us nowcast severe convective storms?
  - Using ML allows forecasts to be completed in minutes as opposed to hours.
- Initial model trained using GOES satellite imagery
  - Continuous monitoring of western hemisphere.
  - Continental United States data available with 5 minute temporal and 2km spatial resolution.
  - Model predicts GOES satellite imagery using data from previous timestep.

## Model Architecture




## Results

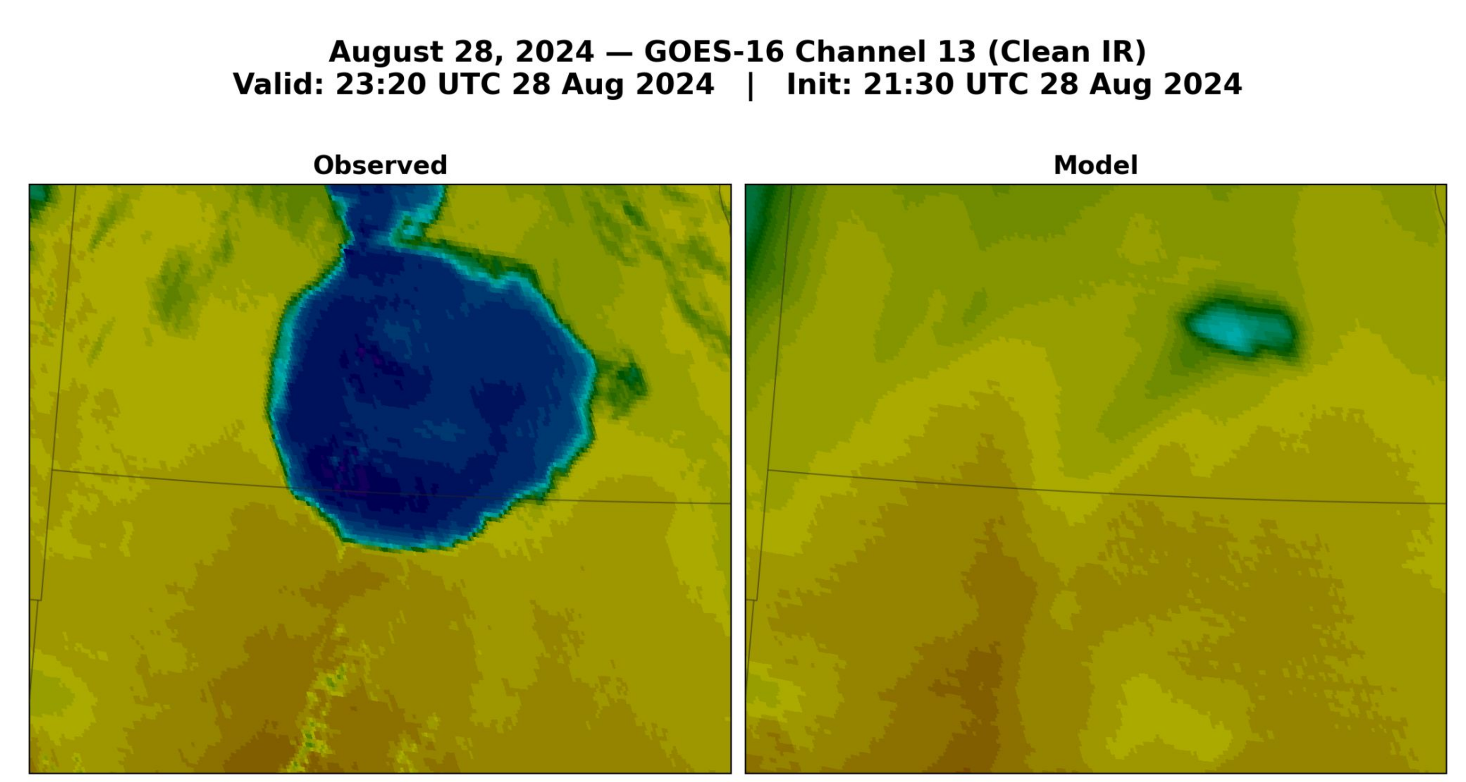
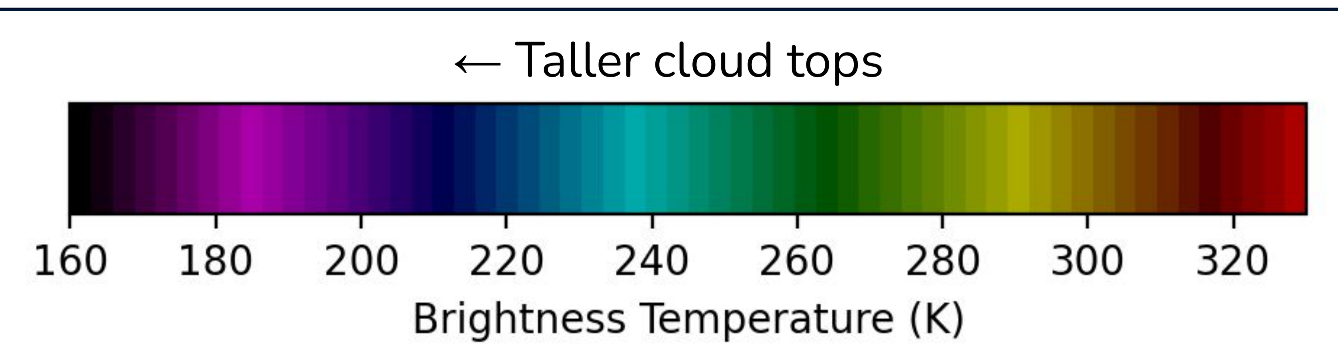



Figure 1. At valid time 23:20 UTC the observed image (left) shows a well-developed supercell and the model, initialized two hours prior, fails to develop the storm entirely.



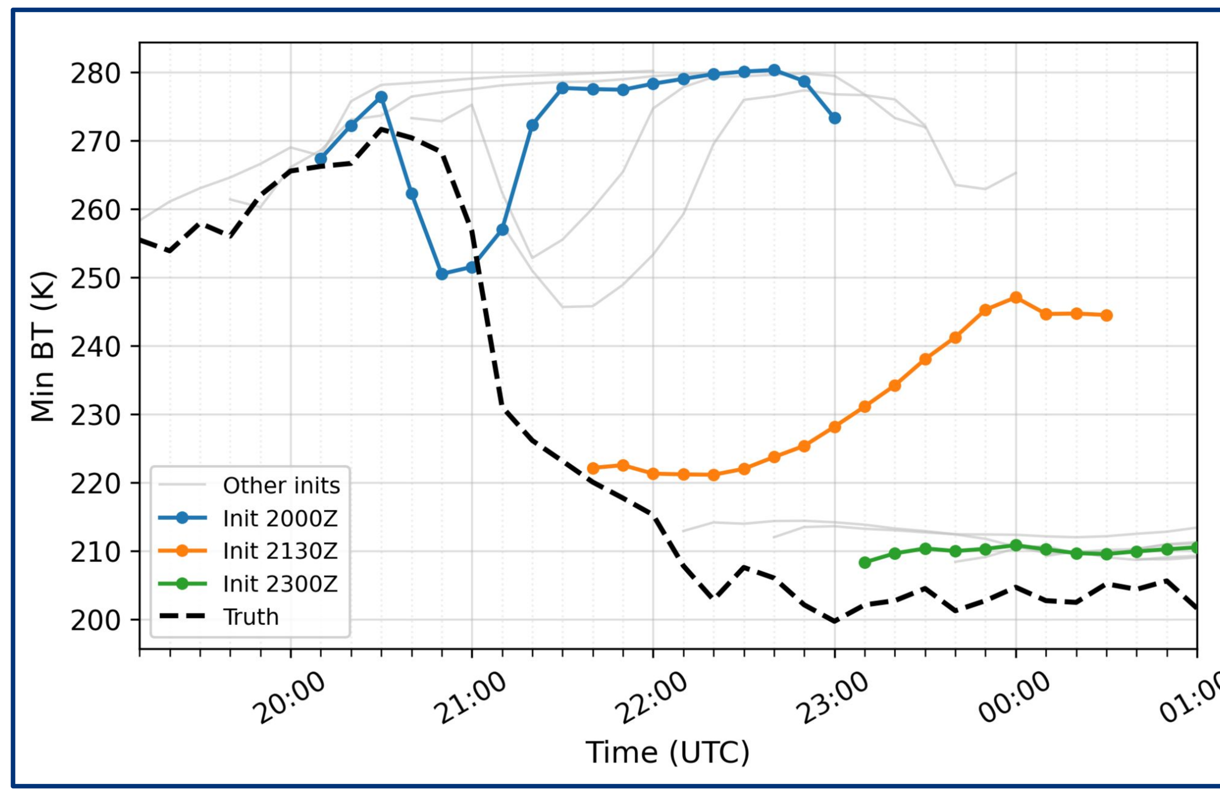




Figure 2. Minimum brightness temperature for the Dakotas supercell case across different initialization times. Early model initializations consistently lag or miss the observed intensification. Later inits closer to maturity perform better but none capture the full magnitude.

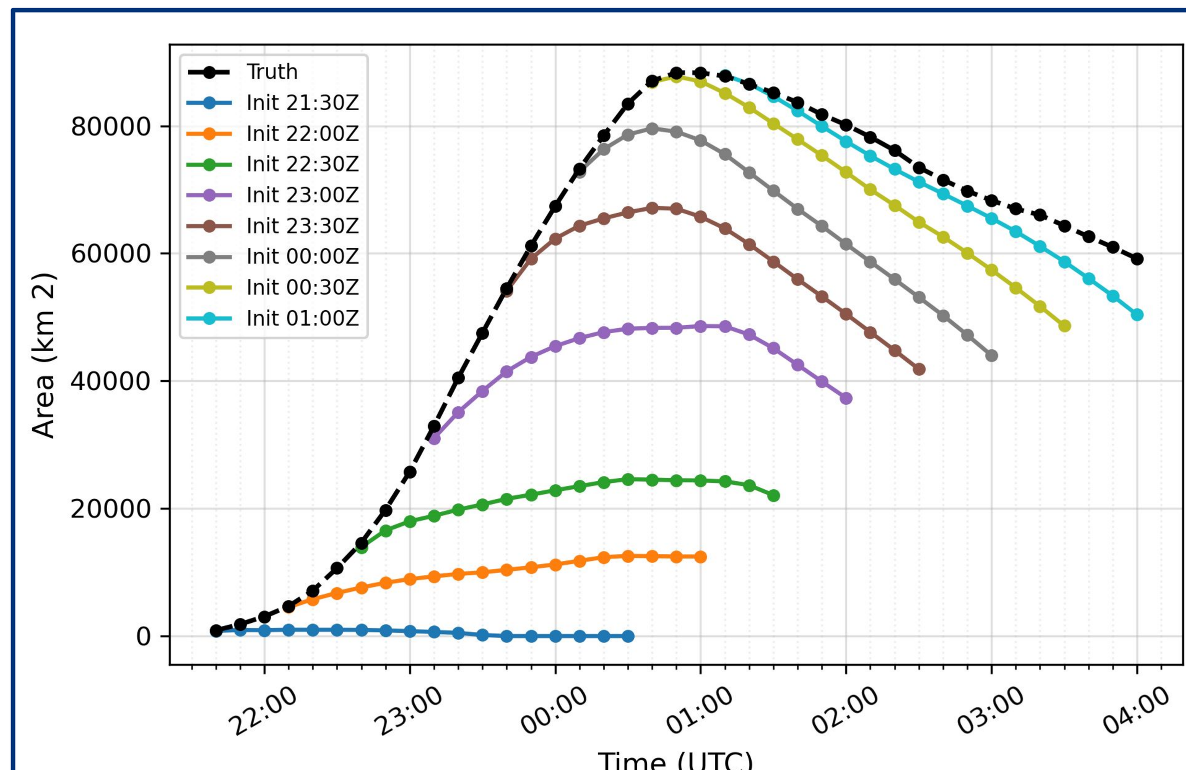



Figure 3. Areal extent of cold cloud tops below 240K (-27.7°F), representing areas of towering cumulonimbus. Plot shows observed (black dashed) vs model forecasts by init time. All inits underestimate storm extent, even when initialized near peak intensity.

## Conclusions

- **Model does not reliably capture convective initiation:** storms fail to develop pre-initiation and during strengthening the model consistently under-develops or decays storms prematurely.
- Even during mature phases, the model captures peak cloud-top temperature intensity but not the spatial extent of the cold cloud shield.
- Despite this, model shows apparent skill at learning atmospheric dynamics–jet streaks, upper-air cyclones, and advection of features from outside domain and is worth further investigation.

## Future Work

- **Incorporate HRRR analysis fields** (e.g. CAPE) as additional inputs to give the model more context on the convective environment.
- **Resample training data** to better represent convective initiation, a key limitation in current model performance.
- **Explore multi-step training approaches** to reduce cumulative error during learning.

## References

Schreck, J.S., Sha, Y., Chapman, W. et al. Community Research Earth Digital Intelligence Twin: a scalable framework for AI-driven Earth System Modeling. npj Clim Atmos Sci 8, 239 (2025). https://doi.org/10.1038/s41612-025-01125-6

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