Fine-Delineated Tropical Cyclone Detection from Geostationary Satellites and IBTrACS data using Advanced Neural Networks

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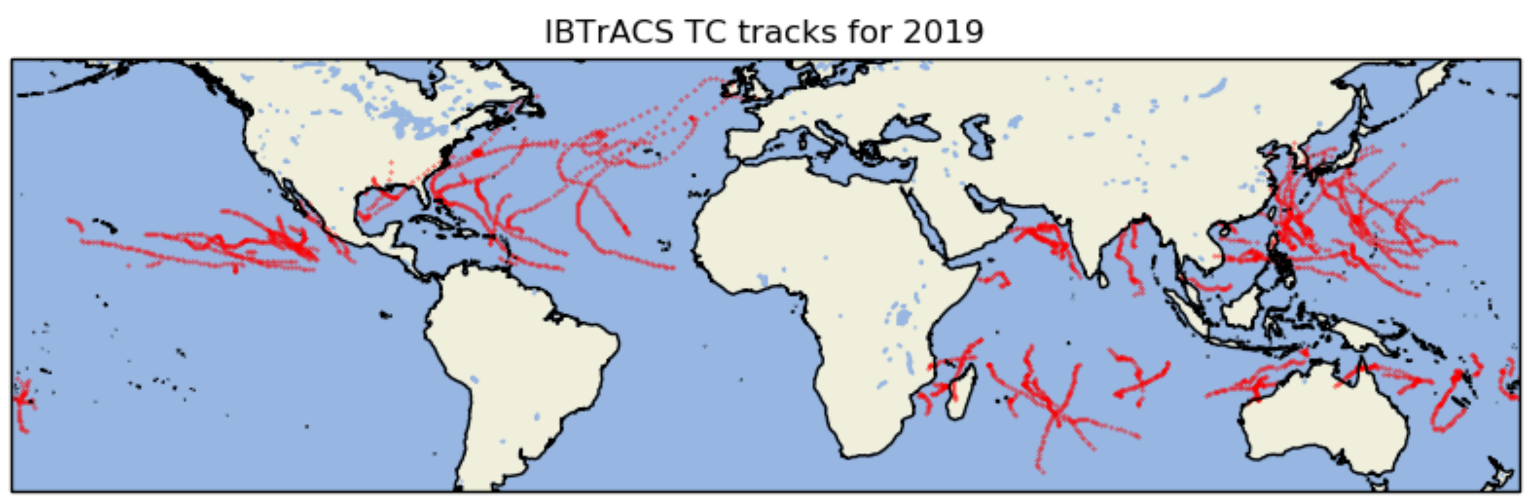
INTRODUCTION

- Tropical Cyclones (TCs) are among the most severe and catastrophic weather phenomena which can cause human life losses and significant infrastructure damages in large scales.
- Accurate TC characterizations are needed for better understanding TCs, improving their predictions, and estimating their impacts.
- Finely delineated TC detections provide valuable information regarding the location and region of interest (ROI) of the TC circulation including rainbands.

In this study, we (1) introduce a high-resolution gridded TC ROI dataset which fuses International Best Track Archive for Climate Stewardship (IBTrACS) and InfraRed (IR) longwave channel of geostationary satellites, and (2) an advanced neural network structure, termed as U-NET, to learn TC patterns and use them to delineate TC in fine details from the fused spatially distributed TC ROIs.

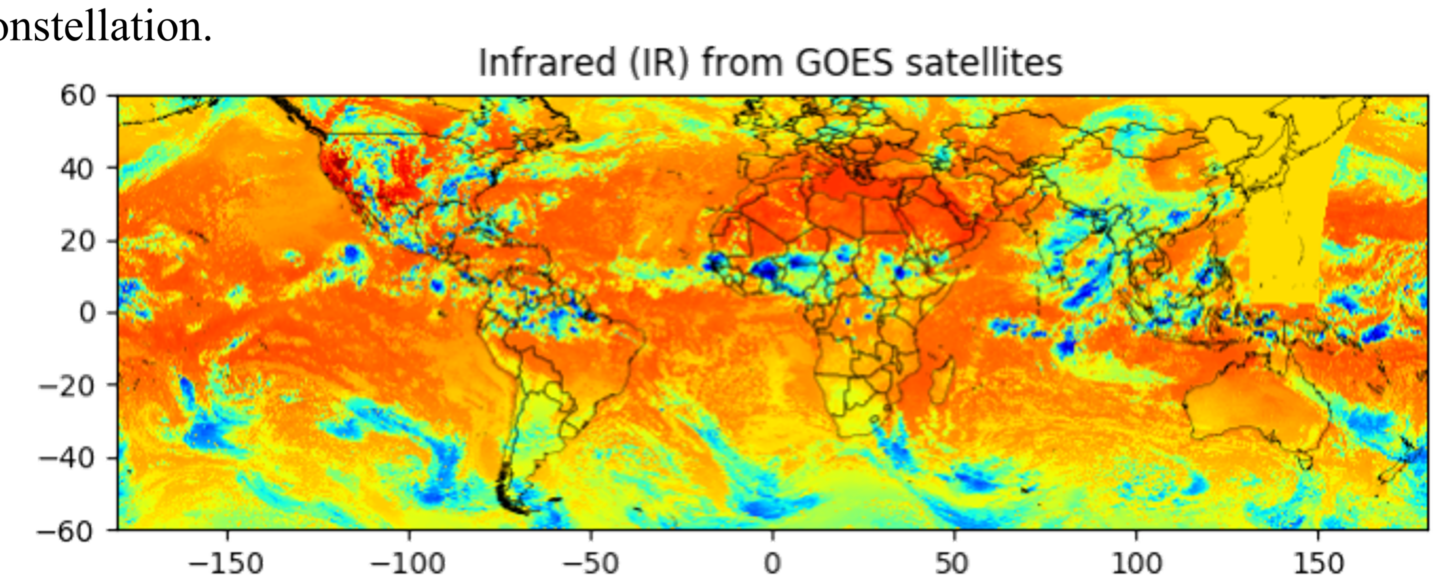
IBTrACS Dataset

- The National Oceanic and Atmospheric Administration's (NOAA's) National Climatic Data Center (NCDC) provides tropical cyclone best tracks by synthesizing tracks.
- IBTrACS[1] dataset is a historical record of tropical cyclones tracks providing 3-hourly information regarding tropical cyclone statistics such as storm centers, storm radii for Northwest, Northeast, Southwest and Southeast directions, minimum sea level pressure, maximum sustained wind speed.
- The IBTrACS dataset is available since 1848 to present, and its records are updated every year in August. The latency of the dataset is not desired for real-time hurricane tracking, however, it provides tremendously valuable information that will be used to locate and identify past tropical cyclones.



Geostationary Dataset

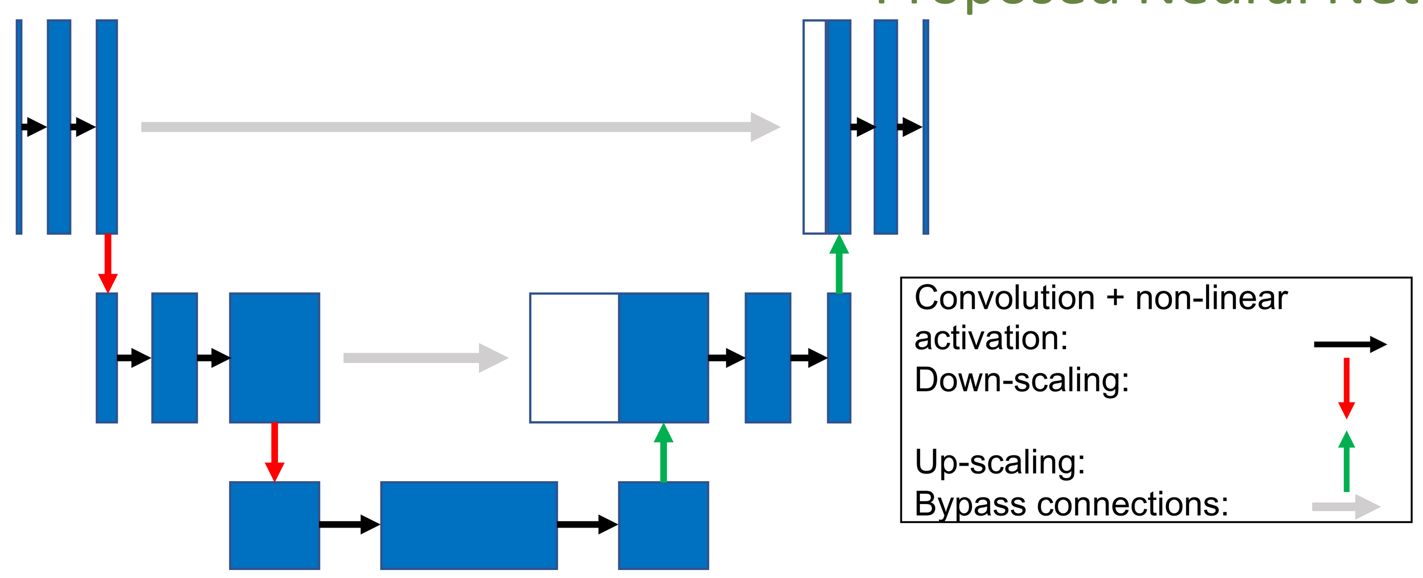
GOES constellation offers a variety of information and continuous monitoring of the state of the atmosphere. Frequent revisits and fine-scale spatial and spectral resolutions in the quasi-global scale allows models and simulations to closely follow weather phenomena ranging from convective to synoptic scale including TCs. In addition, the long operational record of this constellation makes it a unique source for extracting historical patterns. The core data used in this study is the infrared channel (10.7 µm) of GOES data from the previous generation of this constellation.



Data Fusion For TC Mask Generation

- We fuse IBTrACS dataset with the Infrared channel of GOES satellites by defining an ill-posed area of influence for every TC event using the IBTrACS information and then finetune the geometric shapes and the location using the GOES data.
- The TC geolocation and geometric information are derived from bounded GOES data using the manual thresholds of 220 K and 250 K.

Proposed Neural Network Structure and Training Strategy

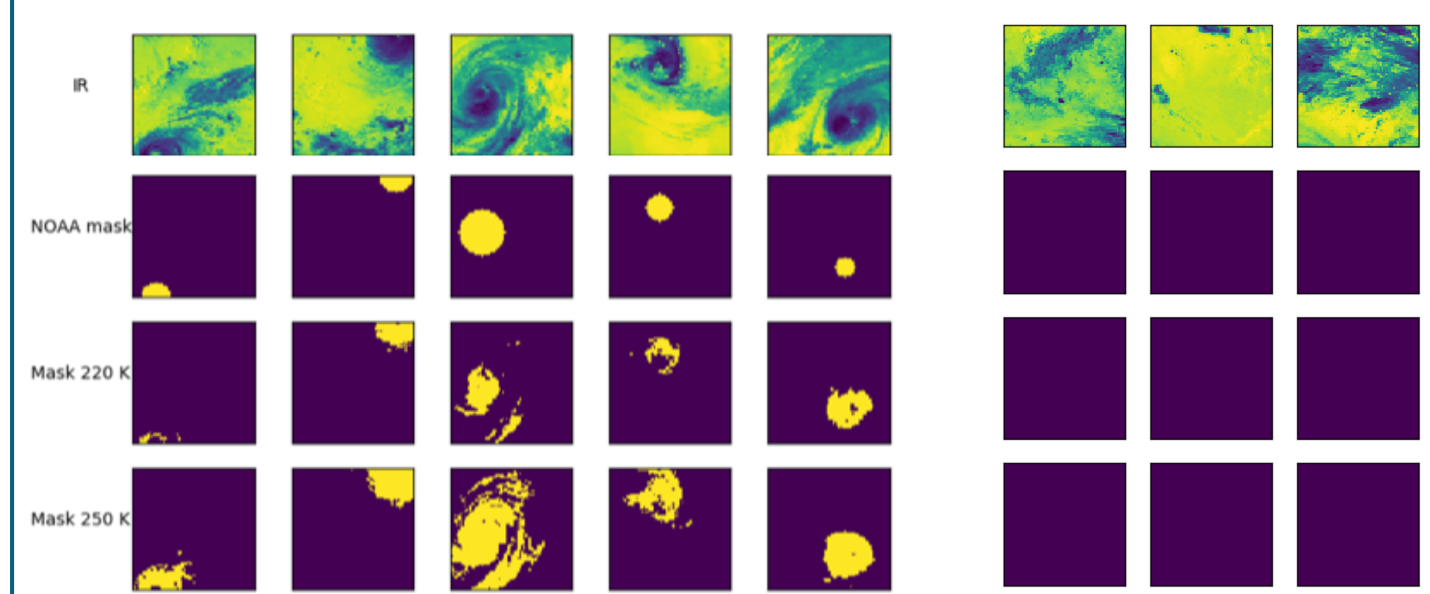


We created the training data by including positive and negative samples;

- + Positive sampling will ensure that the training data will contain valid TC events.
- + We augment positive TC samples in order to increase the generalizability and accuracy of the model.
- Negative sampling will help in removing non-TC type events and reduce model confusion between TC and non-TC events.
- Including negative samples will lower misclassification and allow better capturing of the geometric details.

Results

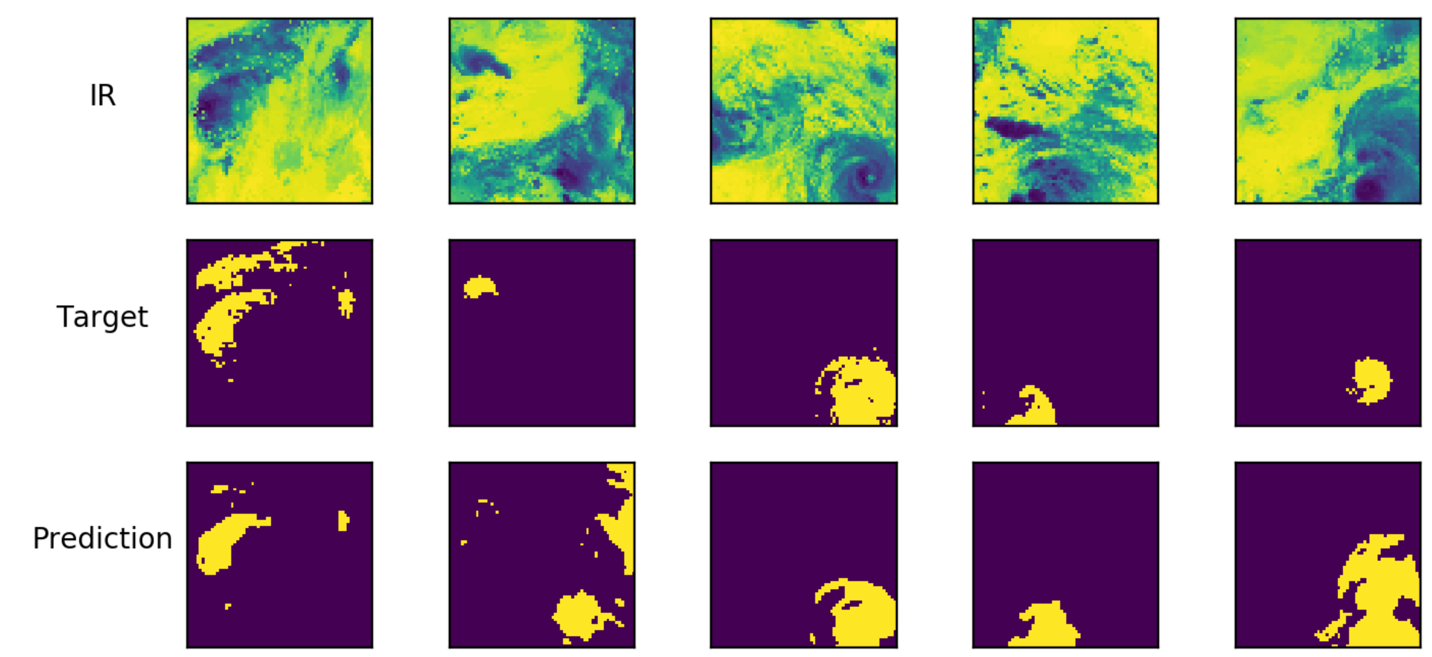
Data Fusion

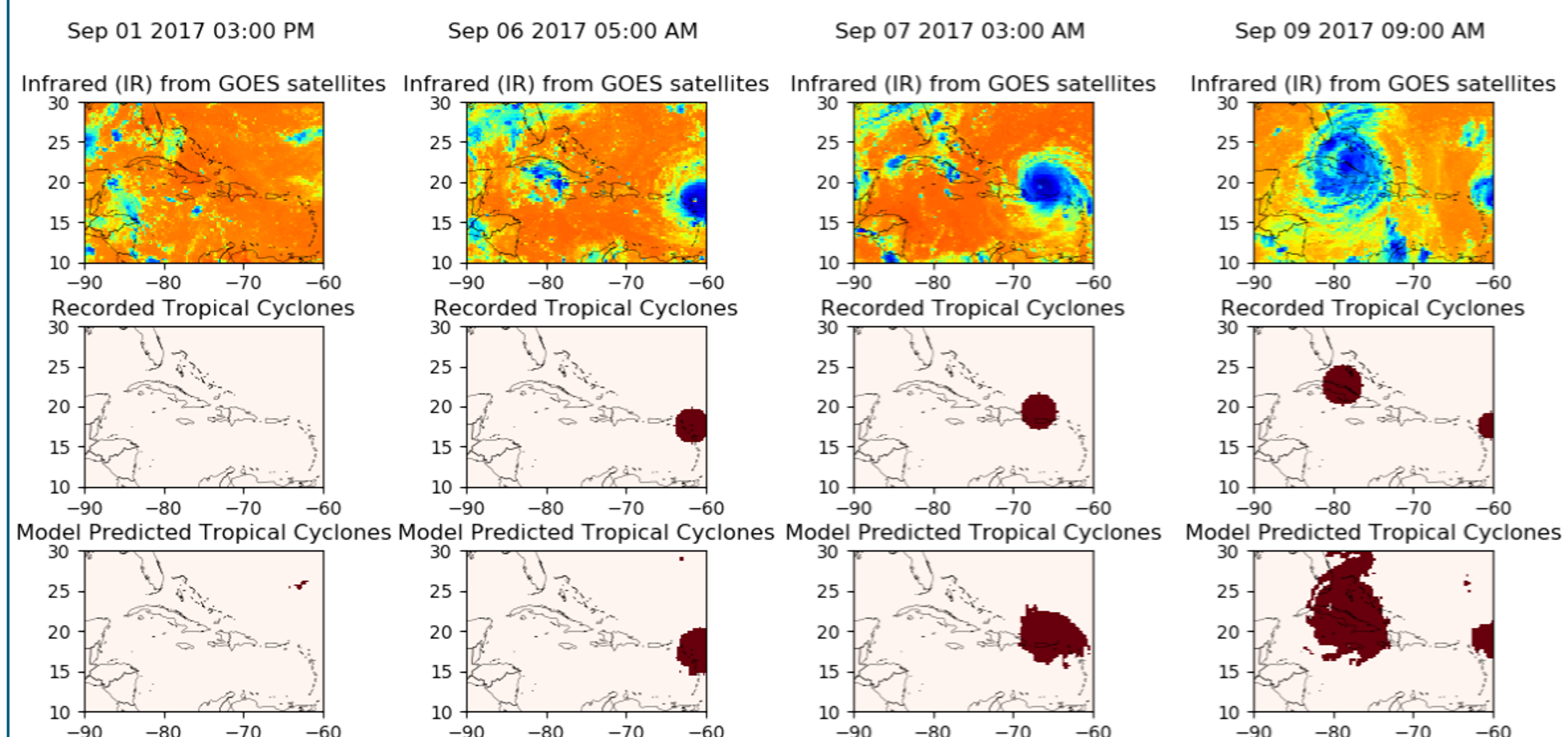


Left 5 columns demonstrate randomly selected good samples and the right 3 columns show the negative samples.

Model Detection

Below are few samples from test set with rows from top to bottom being the Infrared images, Target TC mask and model segmentations, respectively. The results show our model is capable of systematic noise reduction (e.g. first and second columns from left) and complete detection of TC geometry (e.g. last column from left).





The time sequence screenshots of Tropical Cyclone Irma over Florida and Caribbean islands (time direction is from left to right).

Table of performances for IBTrACS and our proposed model for 2017

	IBTrACS	Our Model
Probability of Detection	0.512	0.721
False Alarm Ratio	0.419	0.587
Critical Success Index	0.374	0.356
Correlation	0.613	0.764
RMSE (per image)	21.23	17.86

Concluding Notes

- The proposed work demonstrates an effective high temporal and spatial resolution near-real-time TC detection model capable of capturing fine geometric characteristics in global scales.
- The defined training sampling method enabled the model to reduce false alarms sourcing from non-TC events.
- The model yields higher False Alarm Ratio and lower Critical Success Index compared to IBTrACS data, mainly due to the extended and finer model segmentations.

REFERENCES AND ACKNOWLEDGEMENTS

- [1] Knapp, K. R., Kruk, M. C., Levinson, D. H., Diamond, H. J., & Neumann, C. J. (2010). The international best track archive for climate stewardship (IBTrACS) unifying tropical cyclone data. Bulletin of the American Meteorological Society, 91(3), 363-376.

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