# Objectively Identifying Transverse Cirrus Bands in Tropical Cyclones using a Convolutional Neural Network

17D.6

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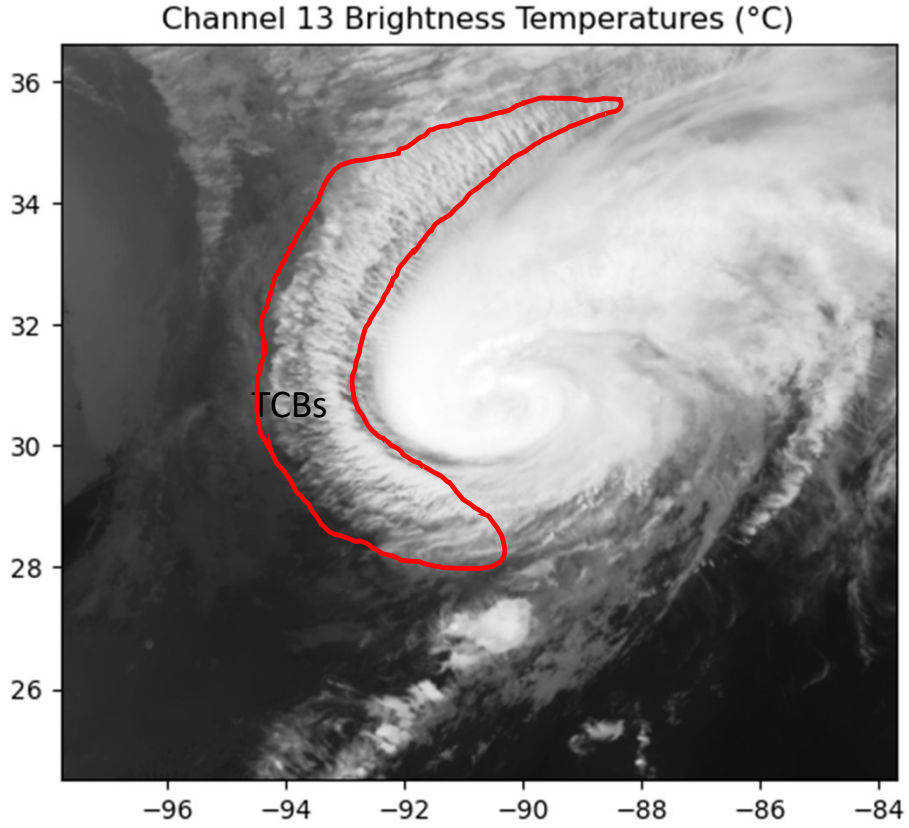
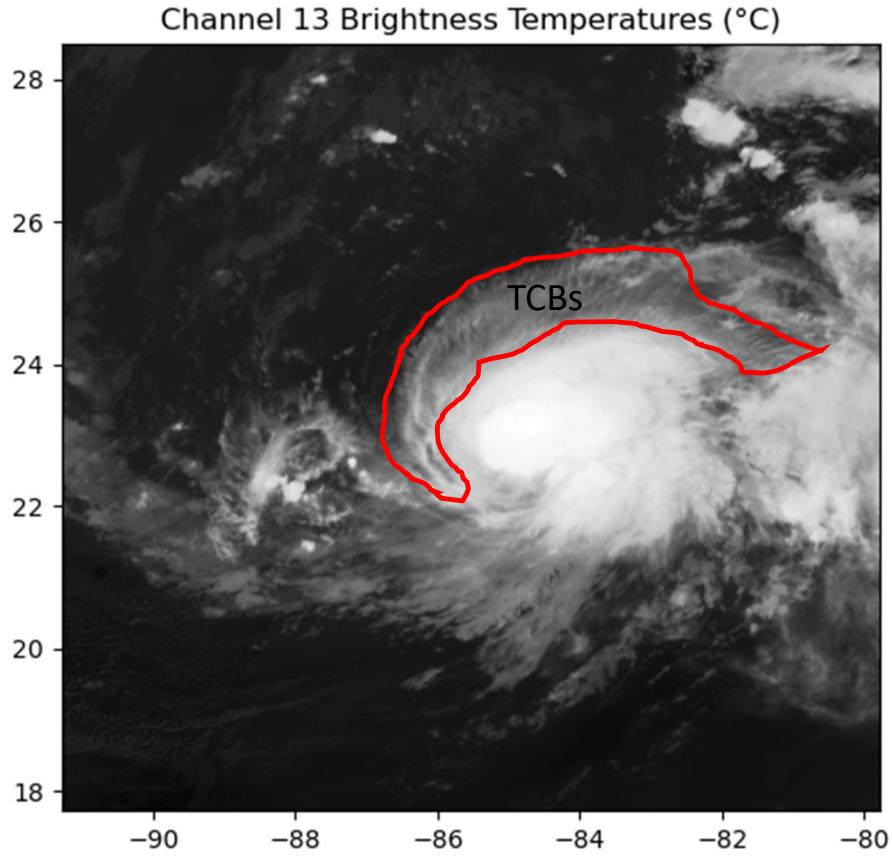
# Motivation

- TCBs have been subjectively associated with the TC diurnal pulse (Dunion et al. 2014)
- Possible relationship of TCBs to TC intensity and structure has not been quantified.
- TCBs have been related to low static stability and high vertical wind shear in the upper levels (Kawashima 2021) and, consequently, smaller Richardson number.



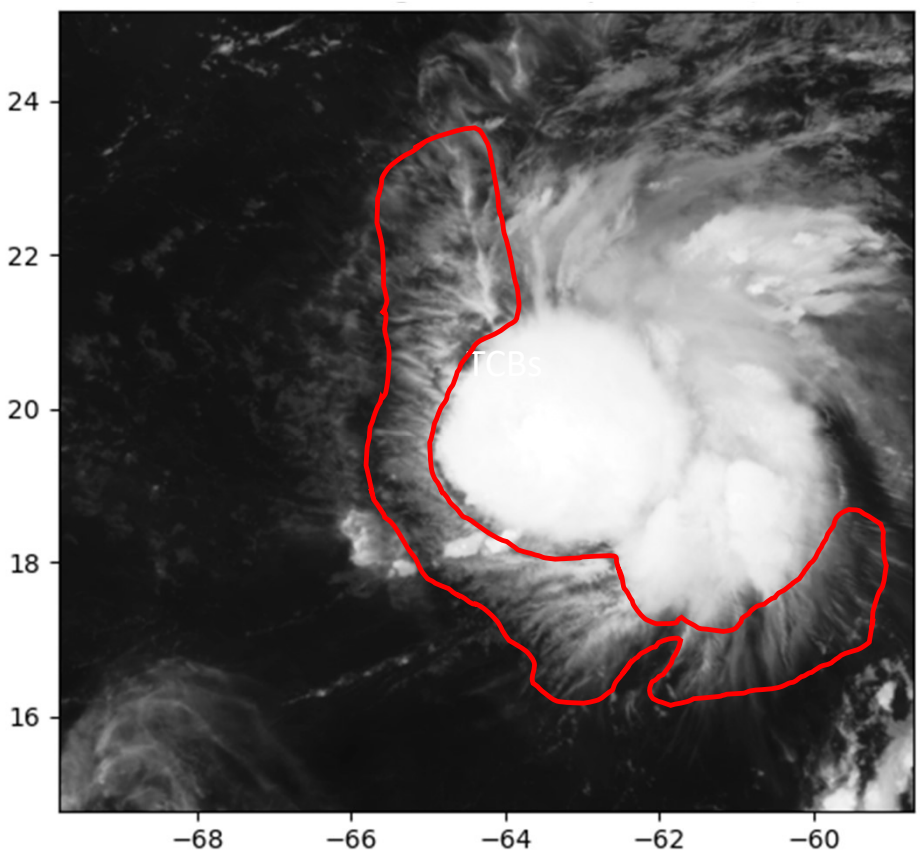
# Methods

- Miller et al. (2018) developed an image classification model to identify TCBs in MODIS true-color imagery.
  - The model determined whether TCBs existed in an image, but not their spatial structure
- We will use a U-Net to identify the spatial structure of TCBs in an image
- Channel 13 (Clean-IR, 10.35µm) and 8 (Upper-Level Water Vapor, 6.2µm) were chosen due to their ability to work in the day and night time.



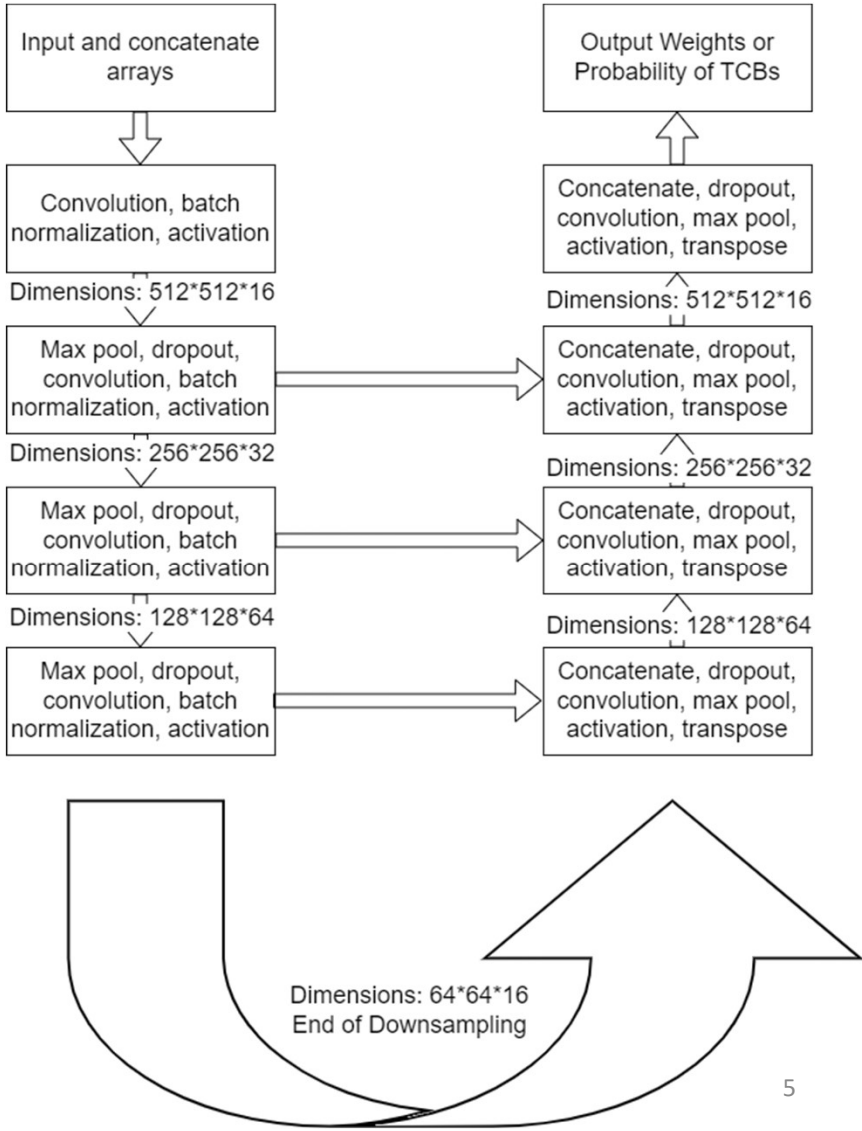
# Data

- Tropical cyclone best track data is from the HURDAT2 dataset (Landsea and Franklin 2013).
- Environmental wind shear data is from the Statistical Hurricane Intensity Prediction Scheme (SHIPS) dataset (DeMaria and Kaplan 1994).
- A total of 184 training images from 2018-2023 were used, along with 58 validation images, to create the model.
- A total of 104 Atlantic 2018-2022 tropical cyclones are used to create the study results (not for training).
  - 2023 is not included because the season had not concluded at the time the results were first produced.

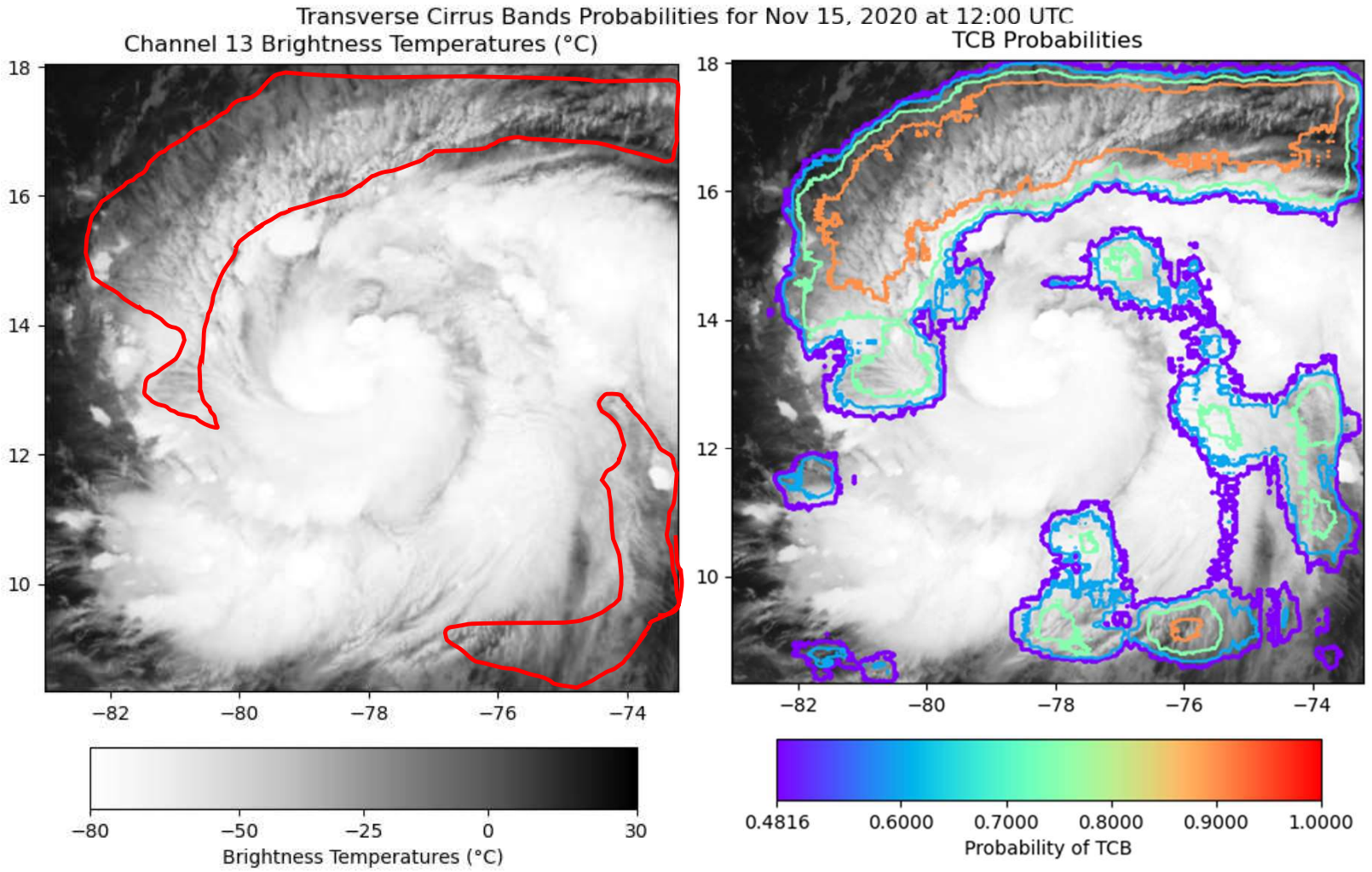


# U-Net Training Flow Chart

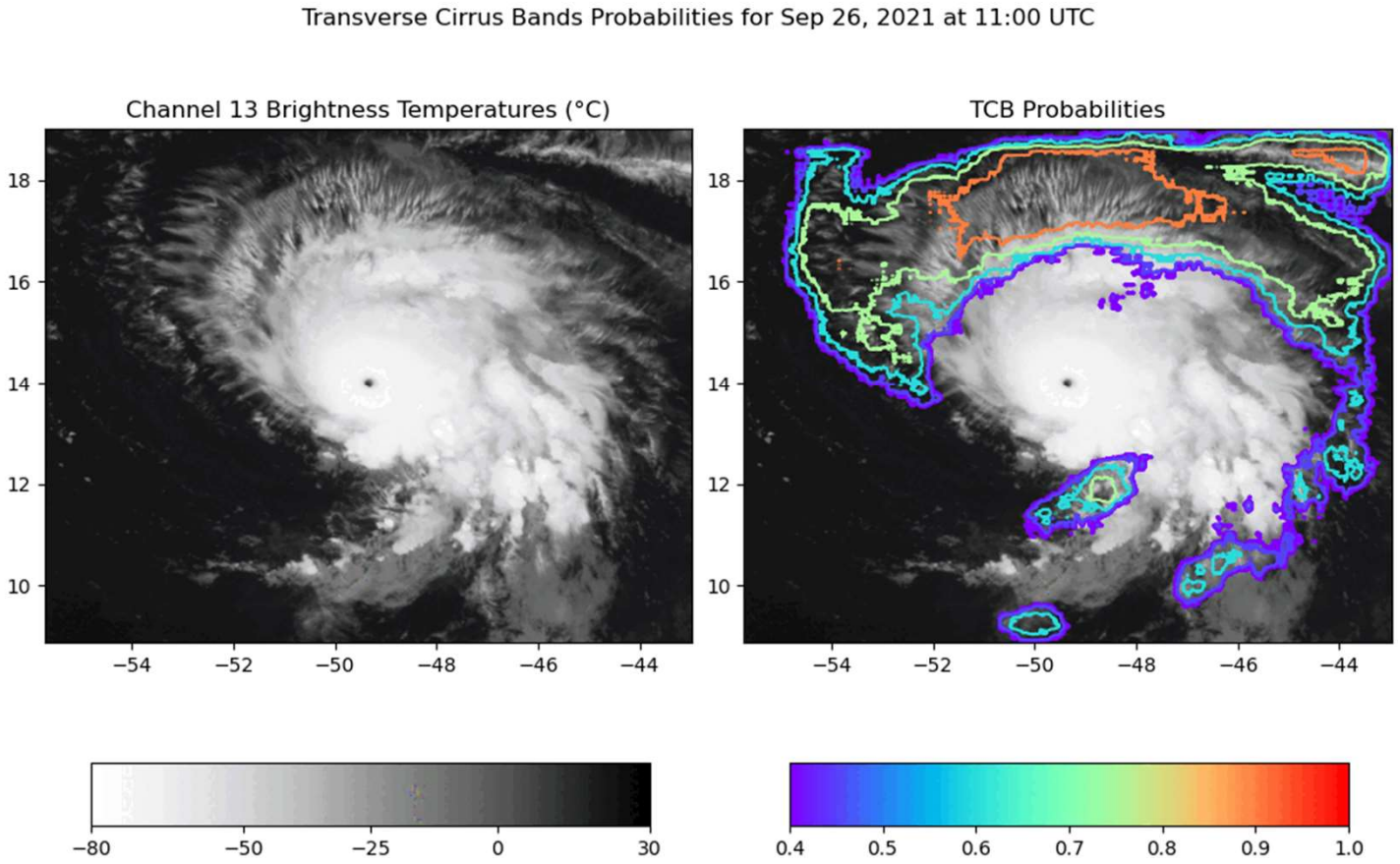
- U-Net: Convolutional Neural Network (CNN) model that can downsample and upsample images to learn.
- Left path of figure: repeated convolutions, max pooling, batch normalizations, and activation layers that decrease the image's size while increasing the number of convolution filters (Ronneberger et al. 2015).
- Right path of figure: generally the same as the left path, except that it increases the image size (Ronneberger et al. 2015).
- Arrows between the two paths: the connection present between the down and upsample paths, which accounts for information lost in downsampling (Ronneberger et al. 2015).



# Hurricane Iota (AL312020), Advisory 8A, Winds of 74 knots

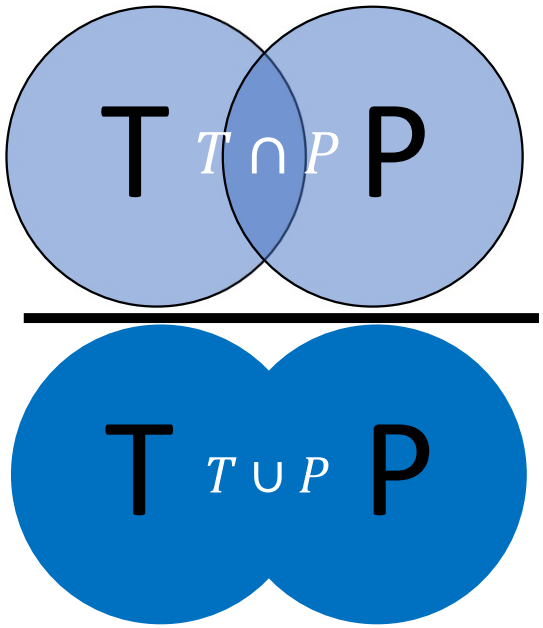


# Hurricane Sam



# Error Statistics and the Jaccard Score

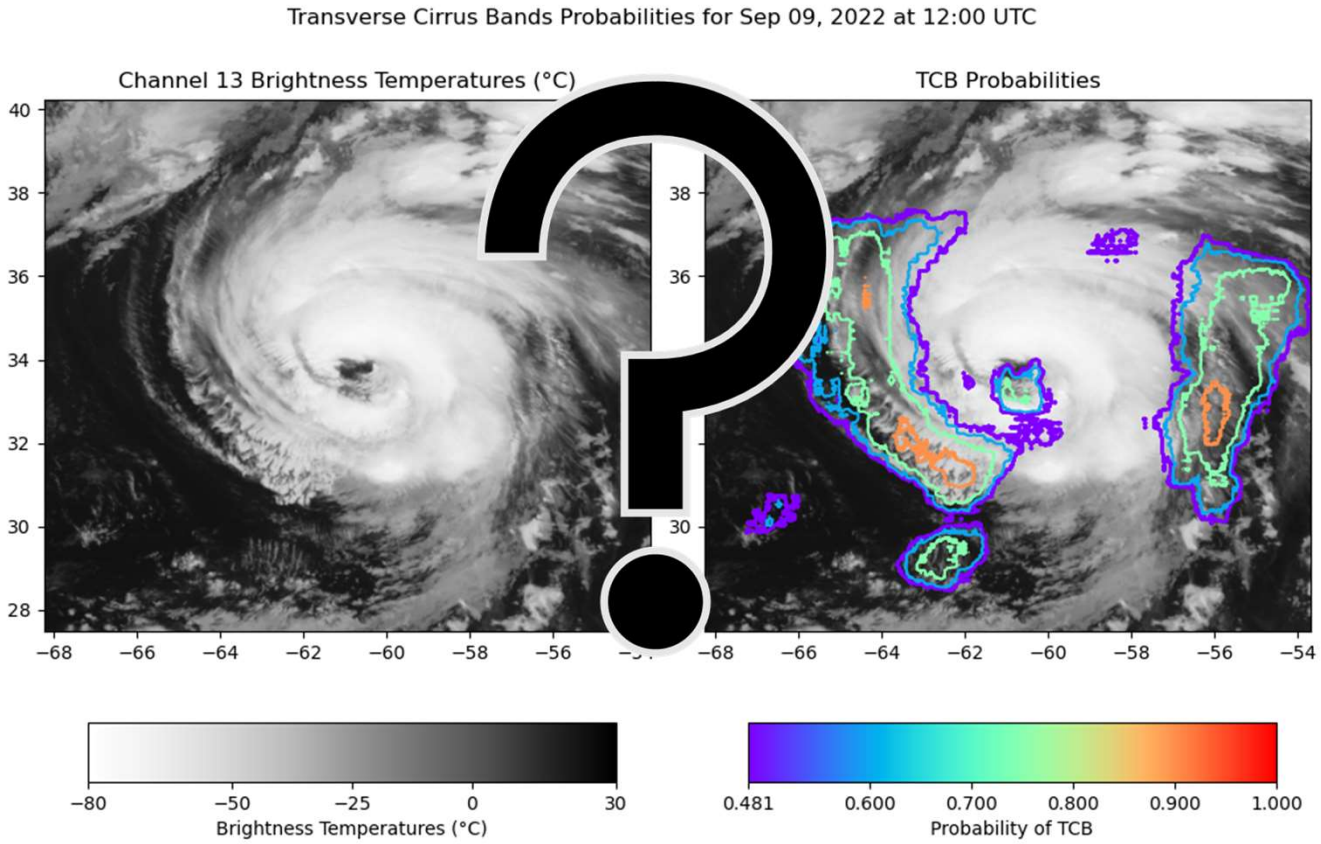
- $J(T,P) = \frac{|T \cap P|}{|T \cup P|}$
- Where T is the true value and P is the predicted value



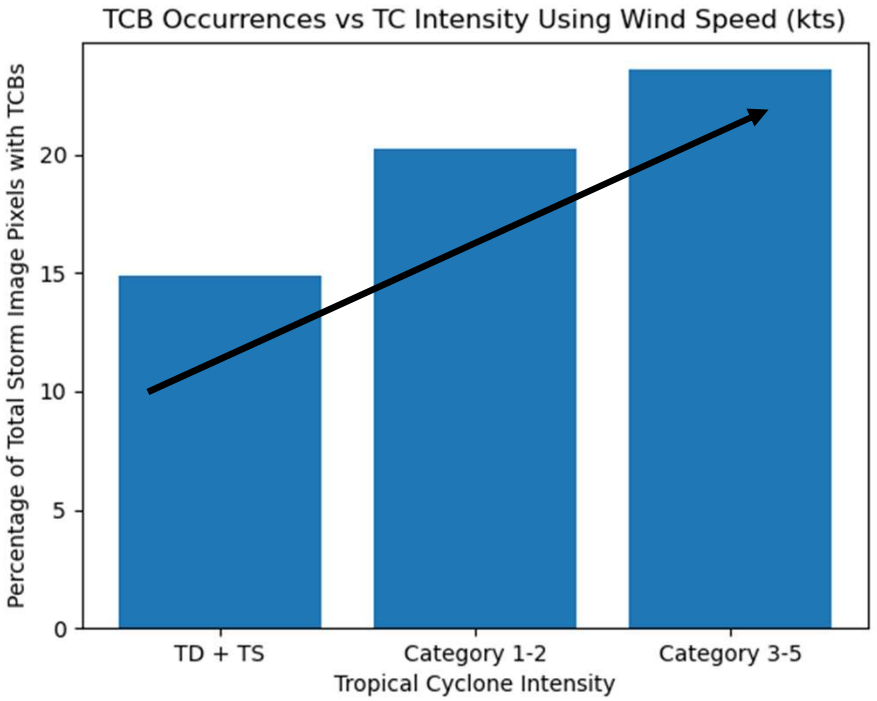

- Error statistics were computed using 43 manually identified TCB images that were not included in the training dataset.
- The maximum Jaccard Score of 0.36 occurred at a probability threshold of 0.48.
  - Threshold: used as the cutoff for whether TCBs are present at a pixel.

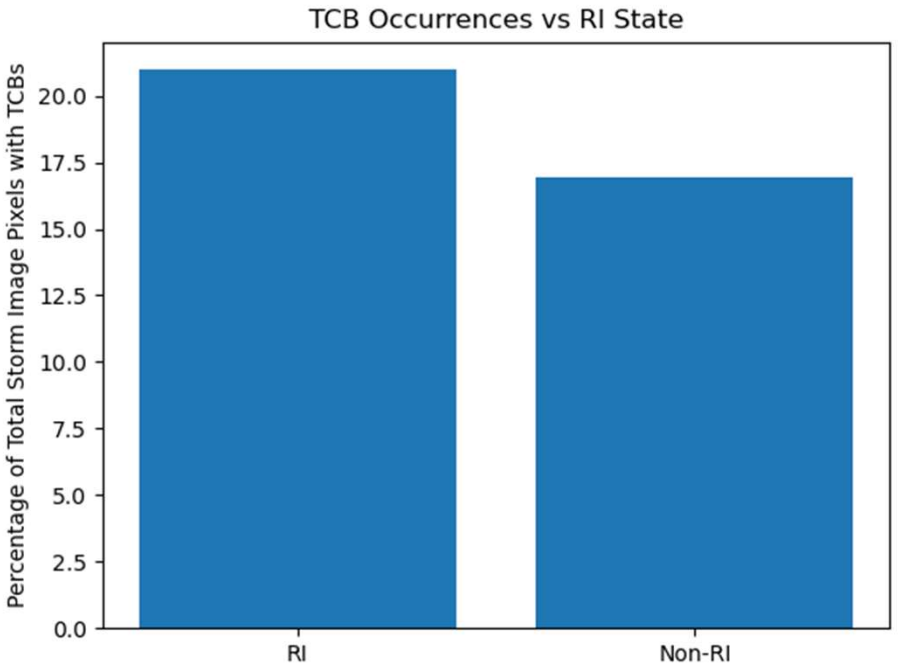
# Research Questions

- Is there a relationship between TCBs and intensity change?
- Is there a relationship between TCBs and rapid intensification?
- Is there a relationship between TCBs and the diurnal cycle?
- In what shear-relative quadrants of the storm do TCBs tend to occur?



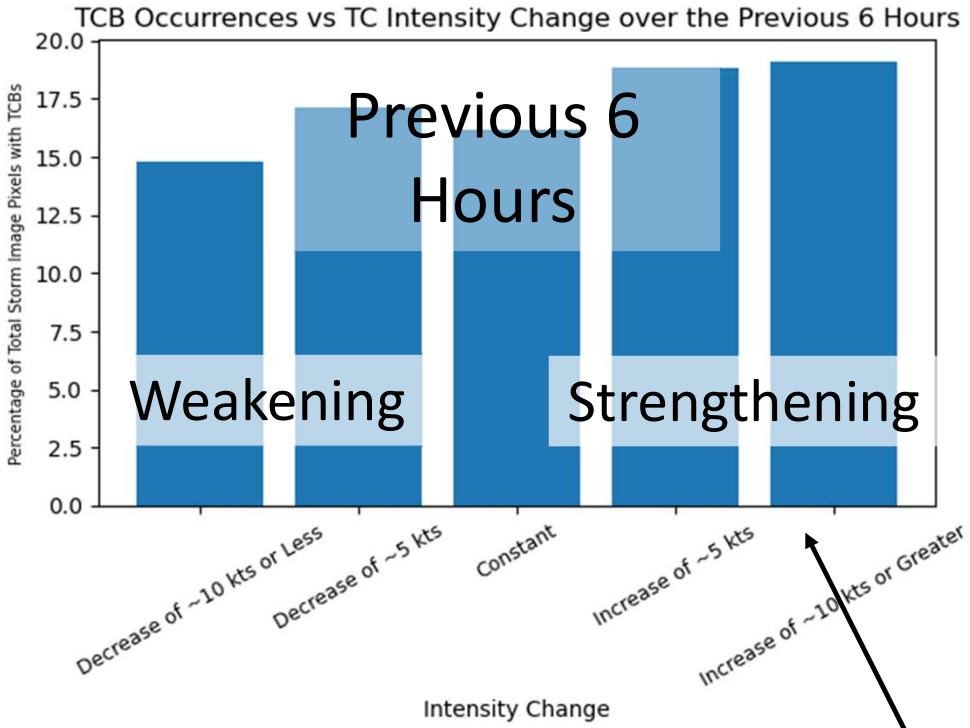
# TCBs, Tropical Cyclone Intensity, and Rapid Intensification

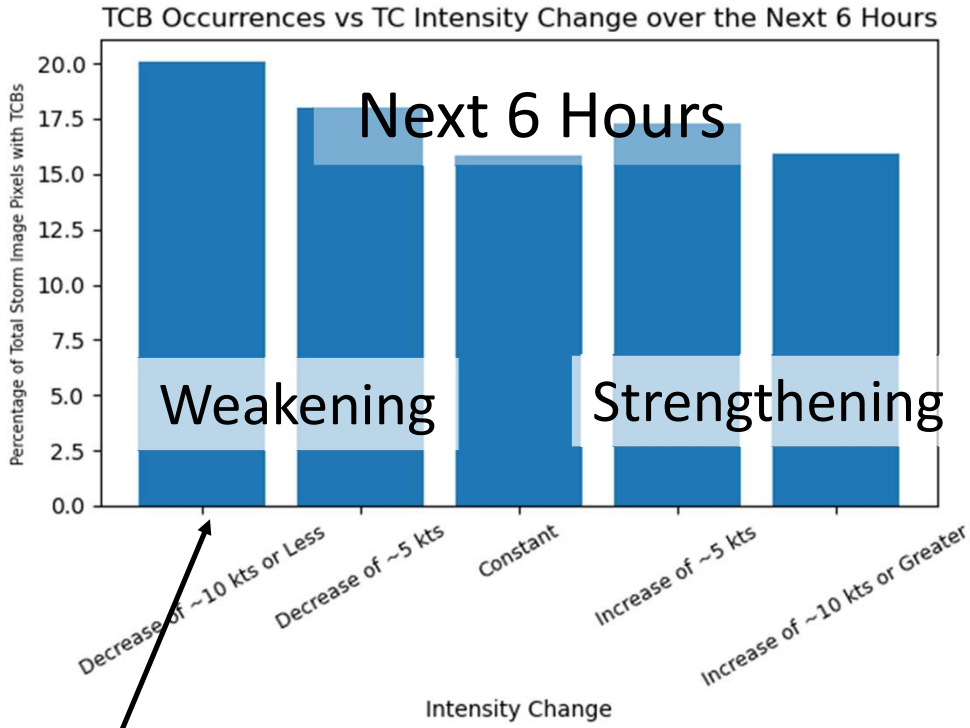



- Rapid Intensification: 30-knot wind increase or more in 24 hours (NHC).
- Stronger tropical cyclones and rapidly intensifying tropical cyclones have more TCBs.

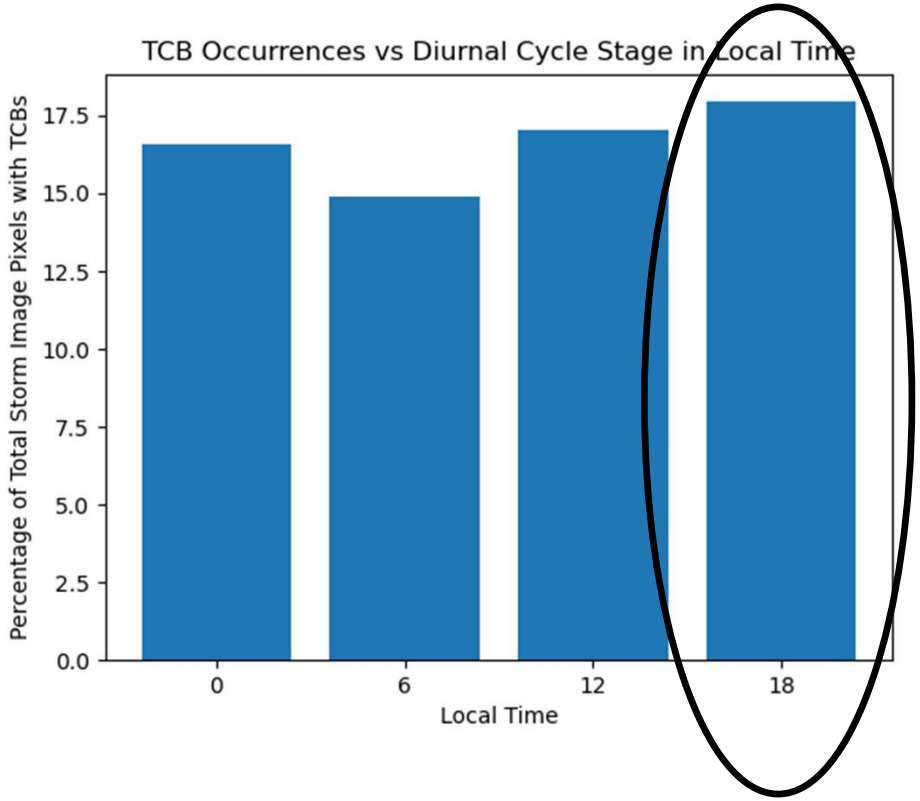
# TCBs and Tropical Cyclone Intensity Changes



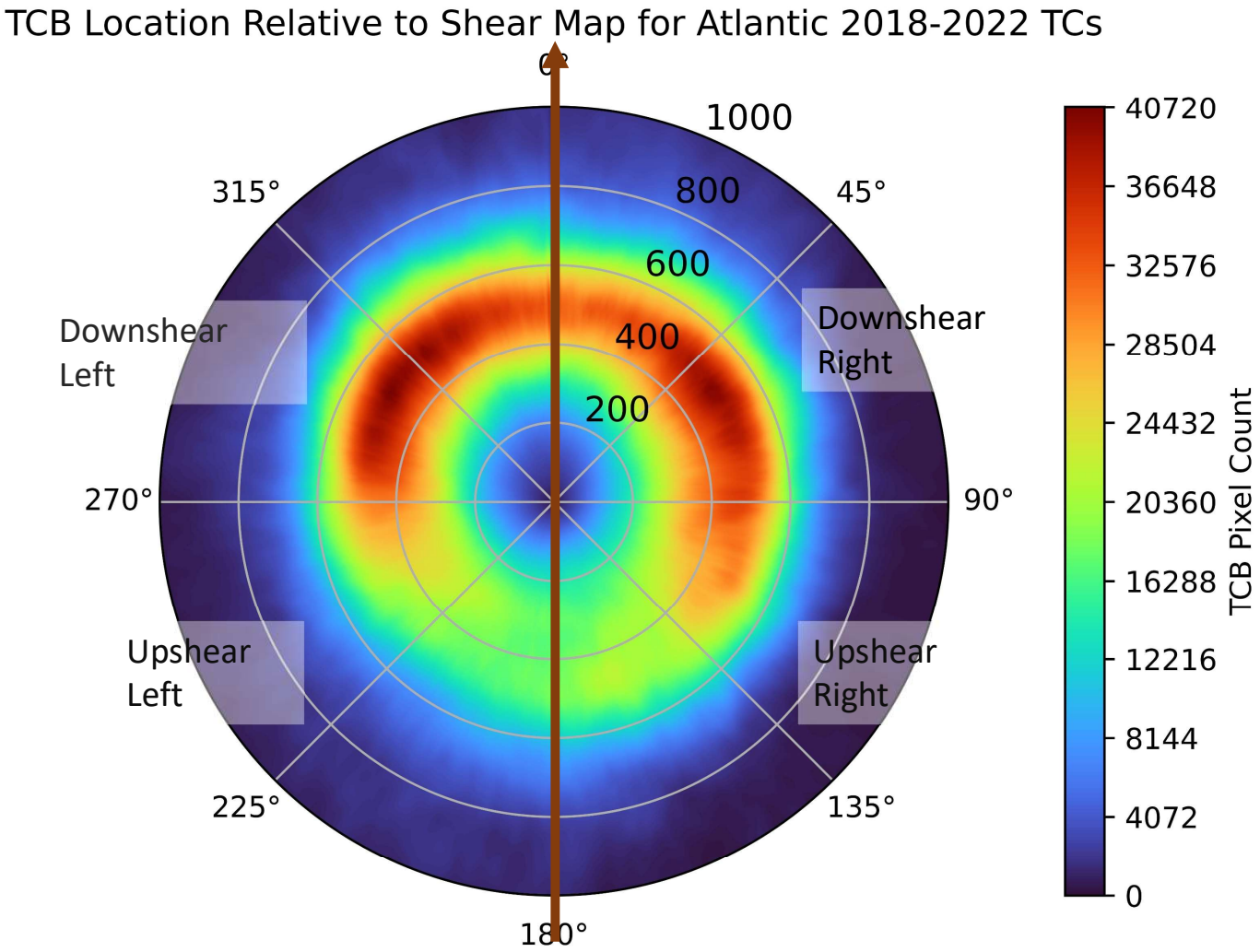

TCBs appear to be more closely related to intensification over the previous 6 hours than over the following 6 hours

# TCBs and the Diurnal Cycle




More TCBs occur in the evening hours (around 6 p.m. local time) than in the morning hours (around 6 a.m. local time).

# Shear-Relative Occurrence of TCBs




- TCB pixels are sorted into 50 kilometer and 0.5 degree bins.
- Greater TCB occurrence is related to the downshear quadrants of tropical cyclones.

# Conclusion and Future Work

- TCBs are more common in stronger TCs, but the relationship to intensity change is not yet clear.
  - Appear to be more common in rapidly intensifying TCs than those that are not rapidly intensifying.
  - Appear to be more closely related to previous intensity change the future intensity change.
- TCBs are more common in the evening hours than in the morning hours.
- TCBs occur more frequently in the downshear quadrants of tropical cyclones.
- More research into the relationship of TCBs and future and past intensity changes will be done.
- Additional error statistics and significance testing will be performed to assess the robustness of these relationships.
  - This includes improving the U-Net through additional training cases and architecture modification.

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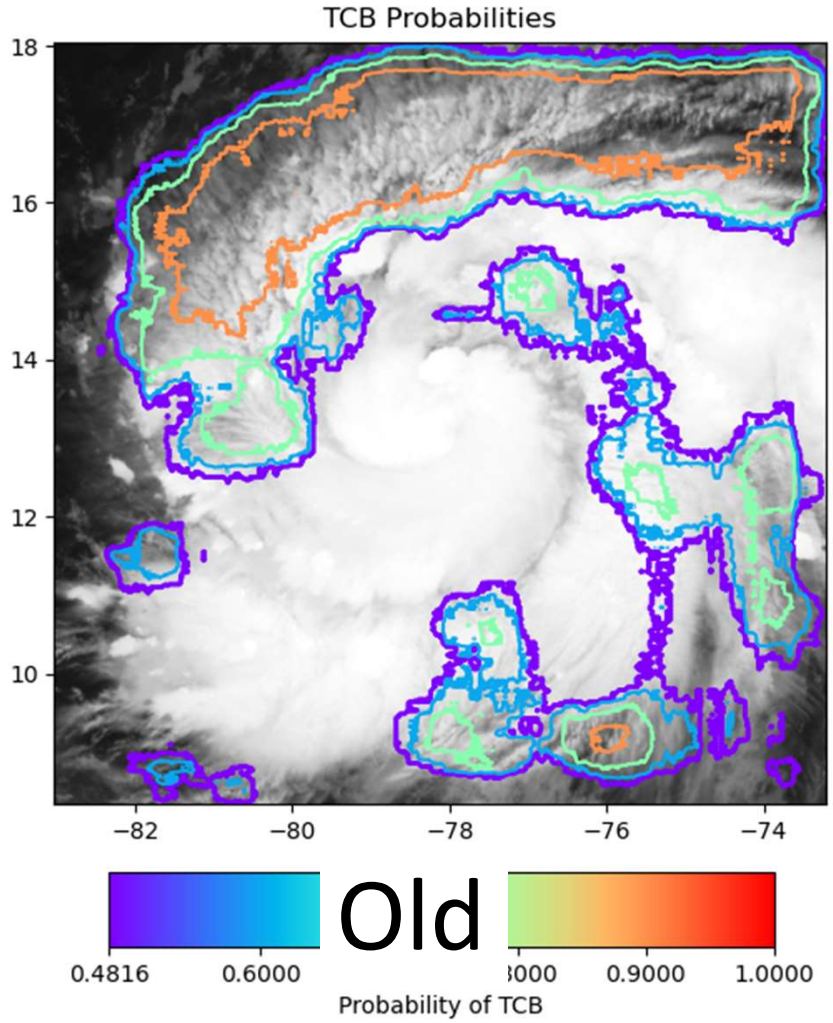
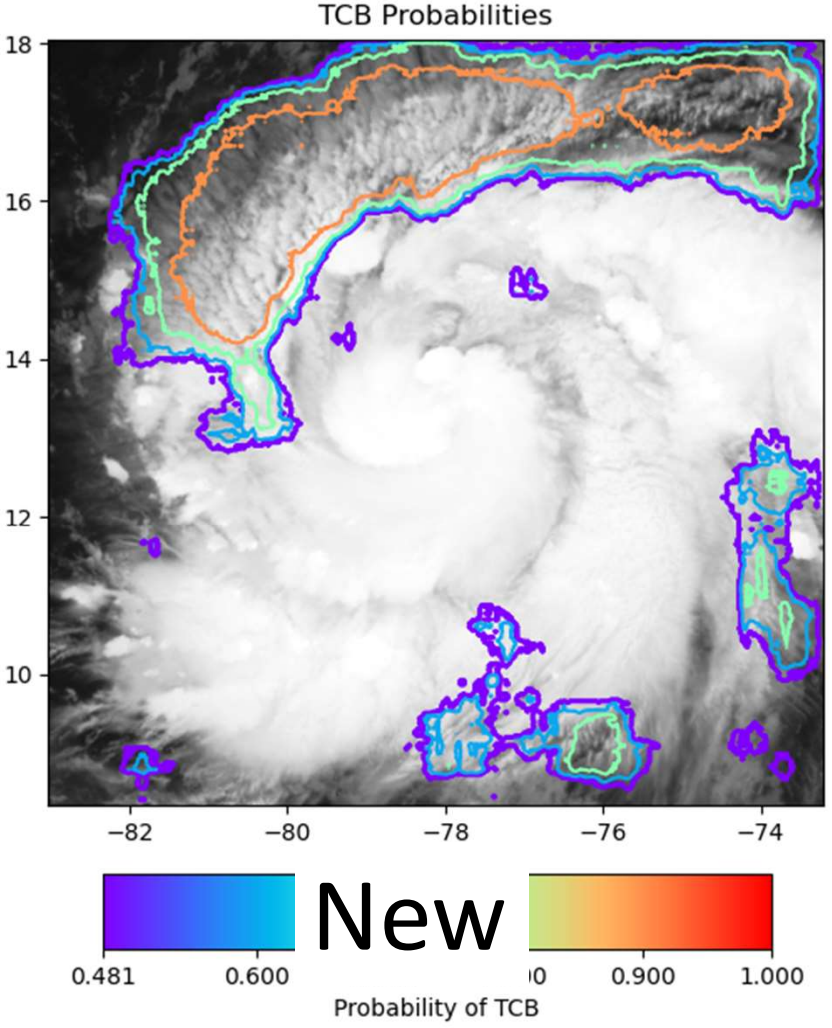
Ronneberger, O., P. Fischer, and T. Brox, 2015: U-Net: Convolutional Networks for Biomedical Image Segmentation.

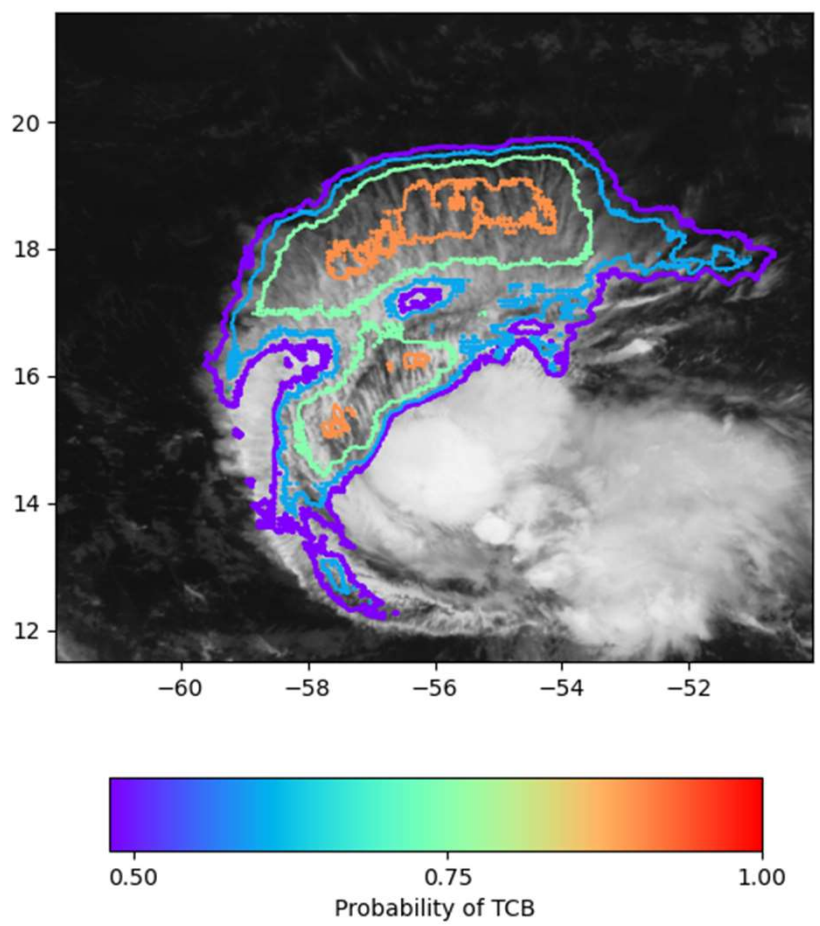
# Extra Slides

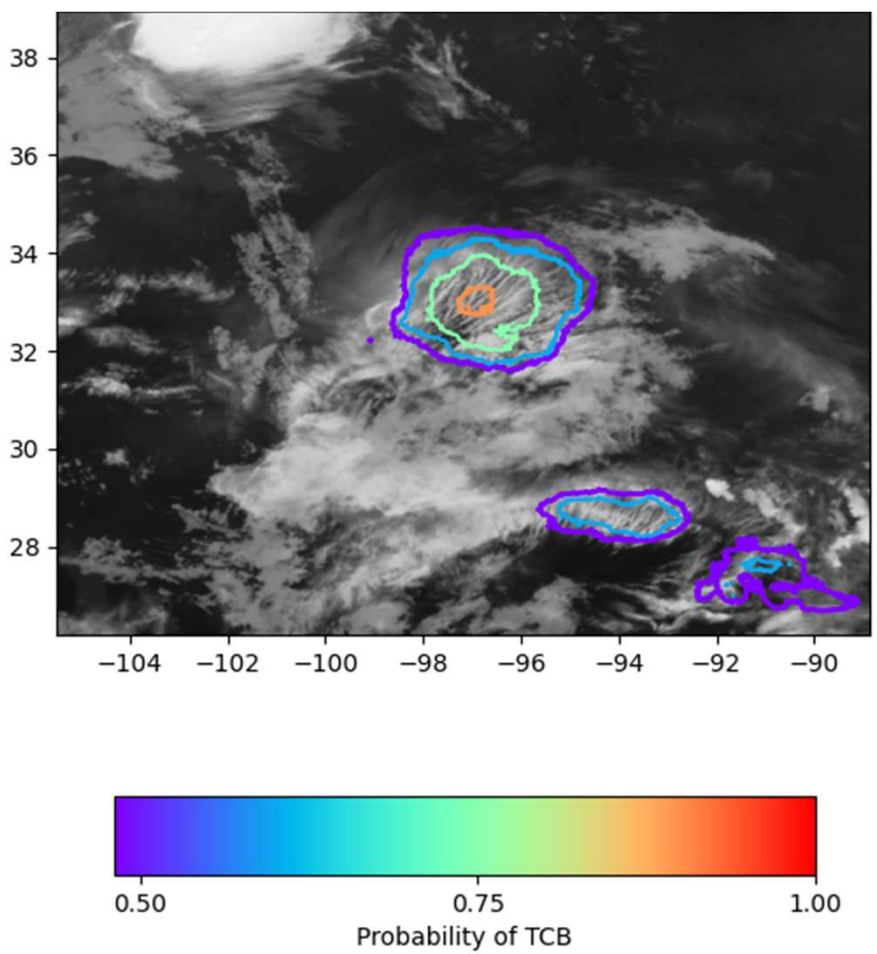
# Potential New Model?- First Kernel size of 5*5 instead of 3*3



# Model when adding in GOES-16 ABI Band 4 (1.37 um)



# TCB Comparison to Different RI Thresholds