# Machine Learning Application of the Tropical Cyclone Precipitation, Infrared, Microwave, and Environmental Dataset (TC PRIMED)

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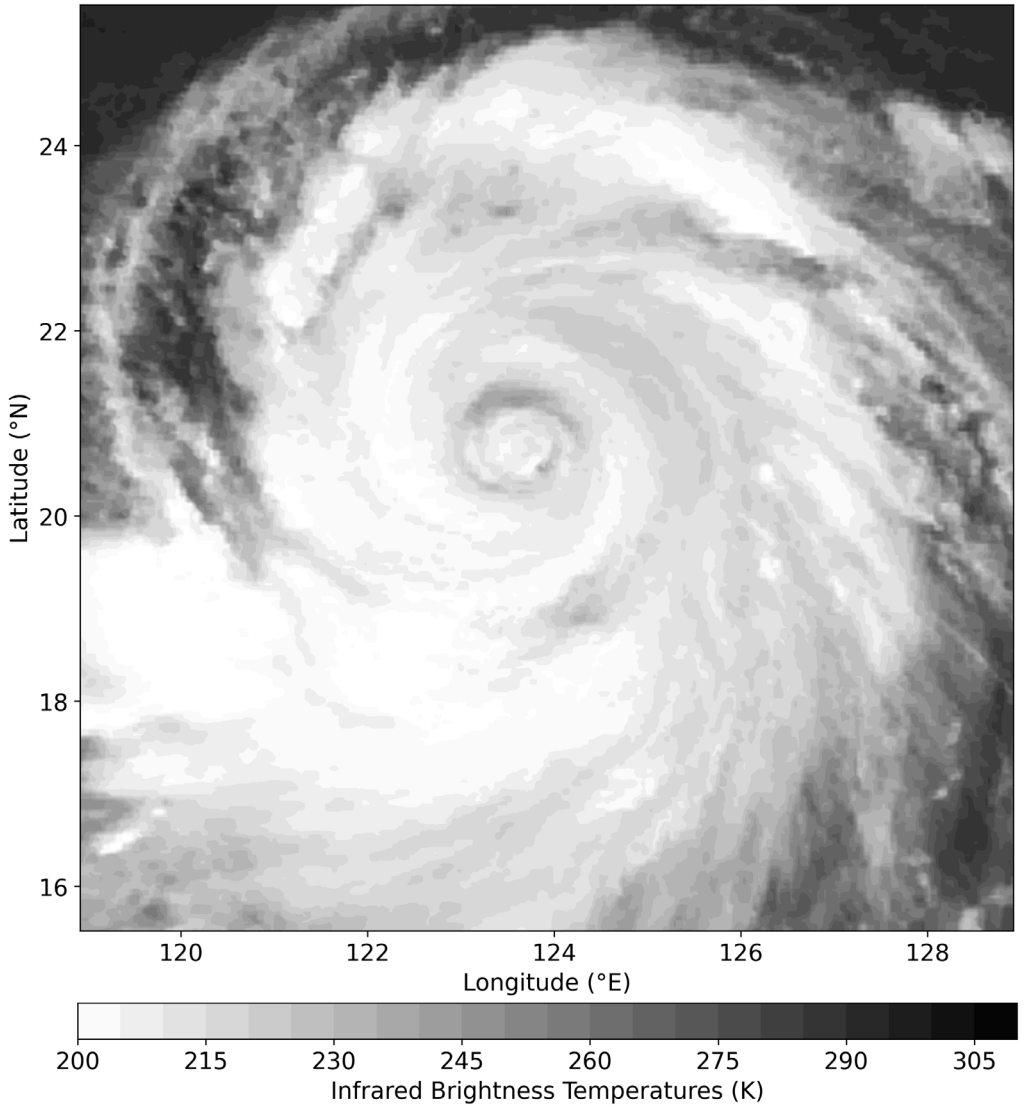
Connecting Models and Observations

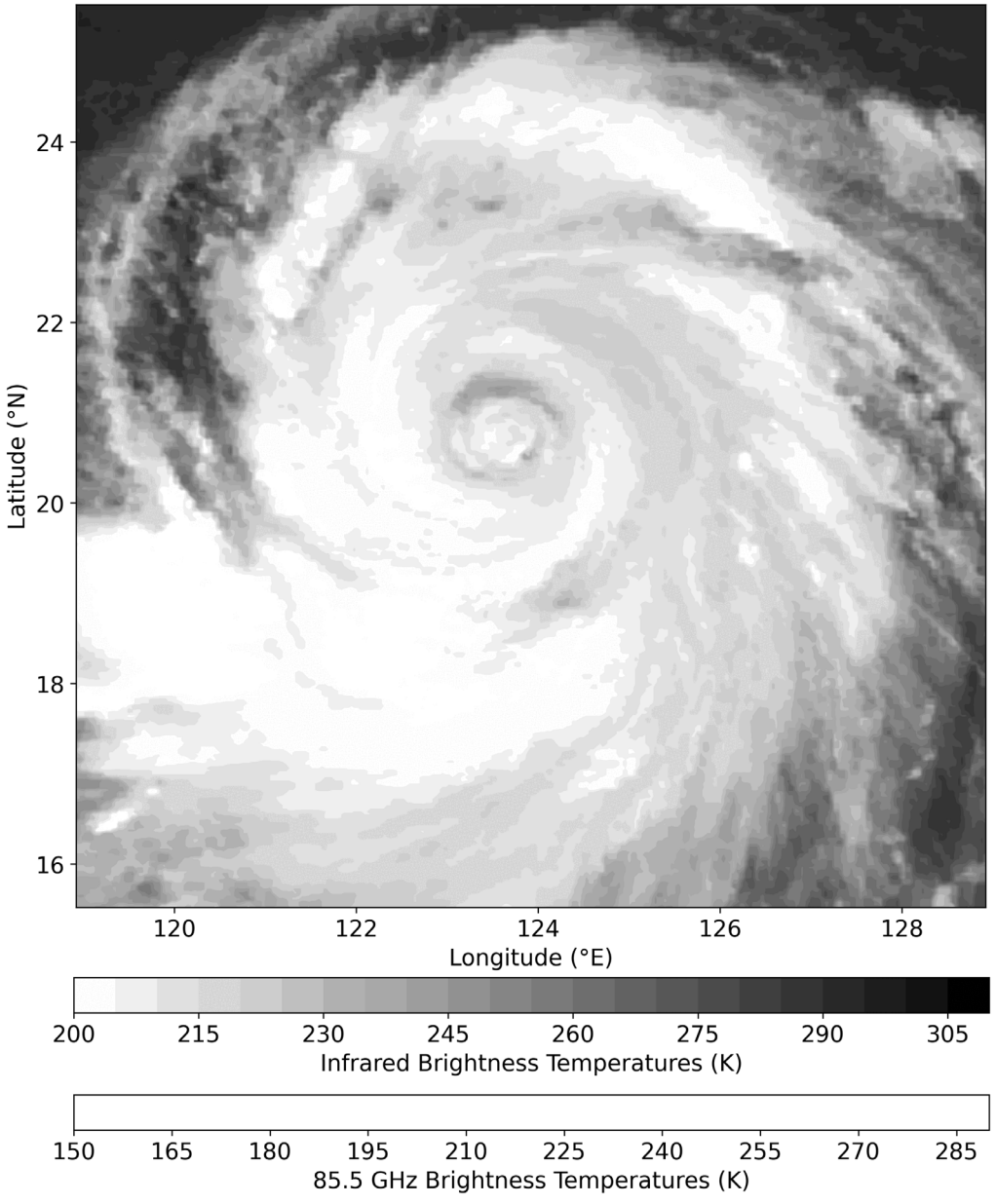
# Why passive microwave?

- When forecasting tropical cyclones, forecasters rely on satellite imagery
- Infrared/visible imagery from geostationary satellites provide good continuous observation
- But observations in infrared/visible channels are limited to cloud tops



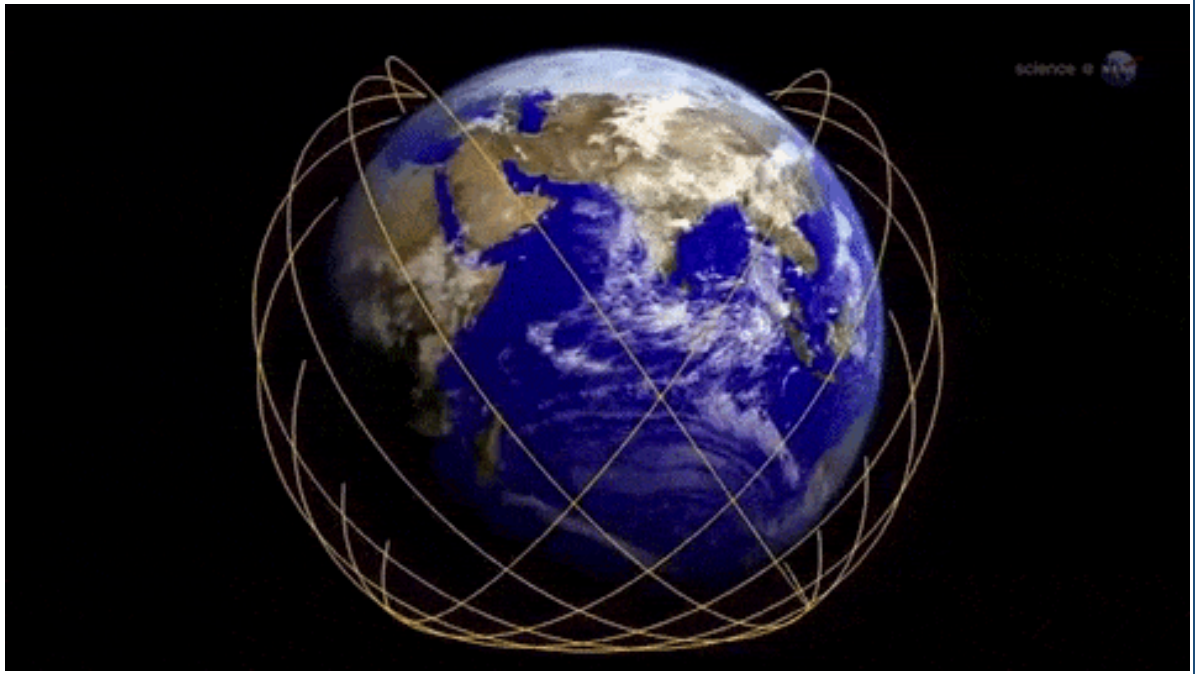
# Why passive microwave?

- Observations in certain passive microwave channels can penetrate through cloud tops
- Forecasters gain insight into location of low-level precipitation, strength of convection, structure of tropical cyclones: guides forecast of hurricane threat like intensity and rainfall
- Useful data for tropical cyclone research and forecast product development

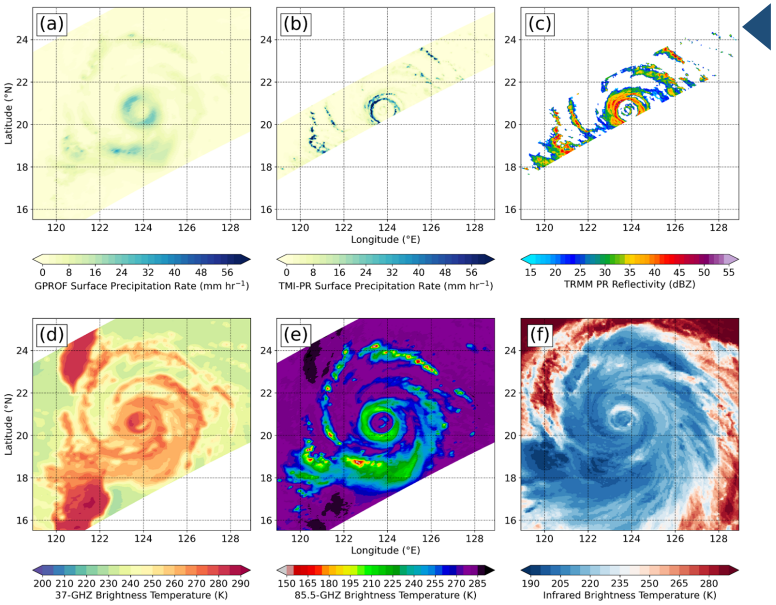


# Passive microwave observations

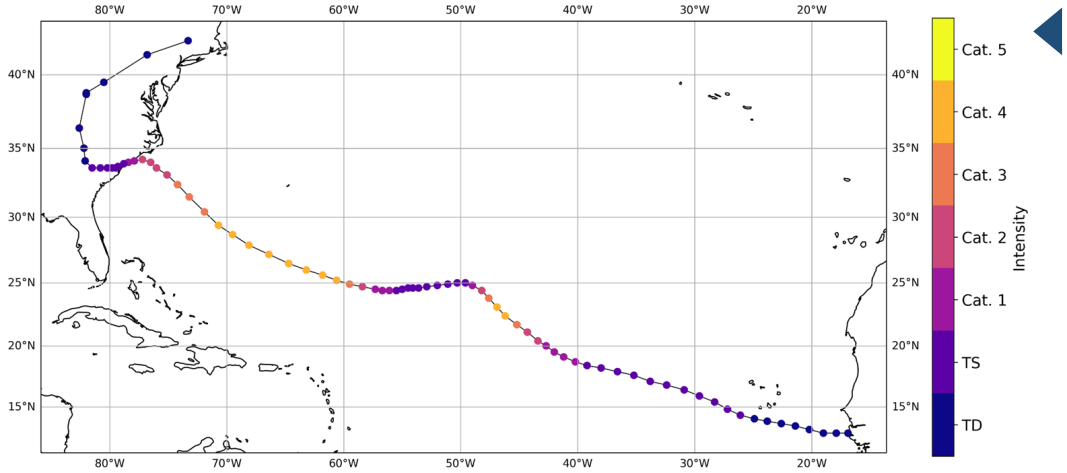
- Passive microwave observations come from low-Earth-orbiting satellites
- Collocating passive microwave data in a user-friendly format is non-trivial
- We set out to build capacity for the utilization of passive microwave data in research and forecast product development: TC PRIMED



# TC PRIMED Products

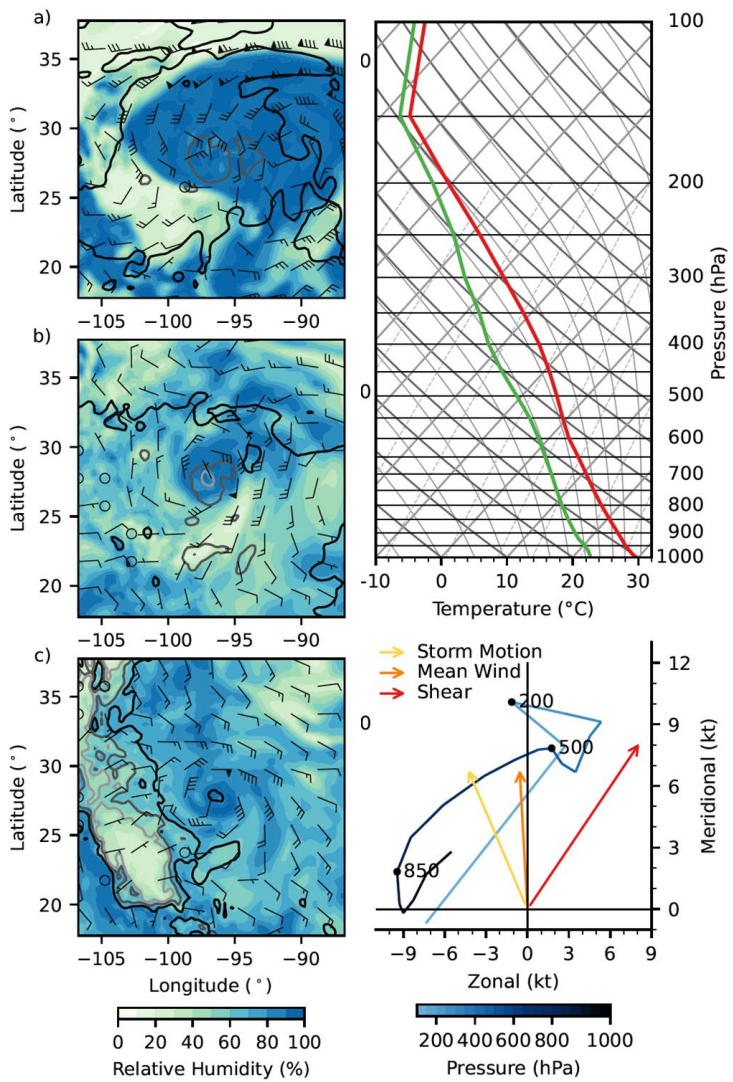



- NASA inter-calibrated microwave brightness temperatures
- NASA passive-microwave-based retrieved rainfall
- NASA precipitation radar variables (TRMM/GPM)
- Nearly-coincident infrared brightness temperature




- Tropical cyclone track and intensity information collected by the National Hurricane Center, Central Pacific Hurricane Center, and the DoD's Joint Typhoon Warning Center

- ECMWF Fifth-Generation (ERA5) reanalysis fields
- Environmental diagnostics calculated from ERA5



# TC PRIMED Summary

- Current state of TC PRIMED
  - Global tropical cyclone observations from 1998 – 2021
  - 2,300 tropical cyclones
  - 197,000 satellite observations (NASA, JAXA, NOAA, DoD, EUMETSAT)

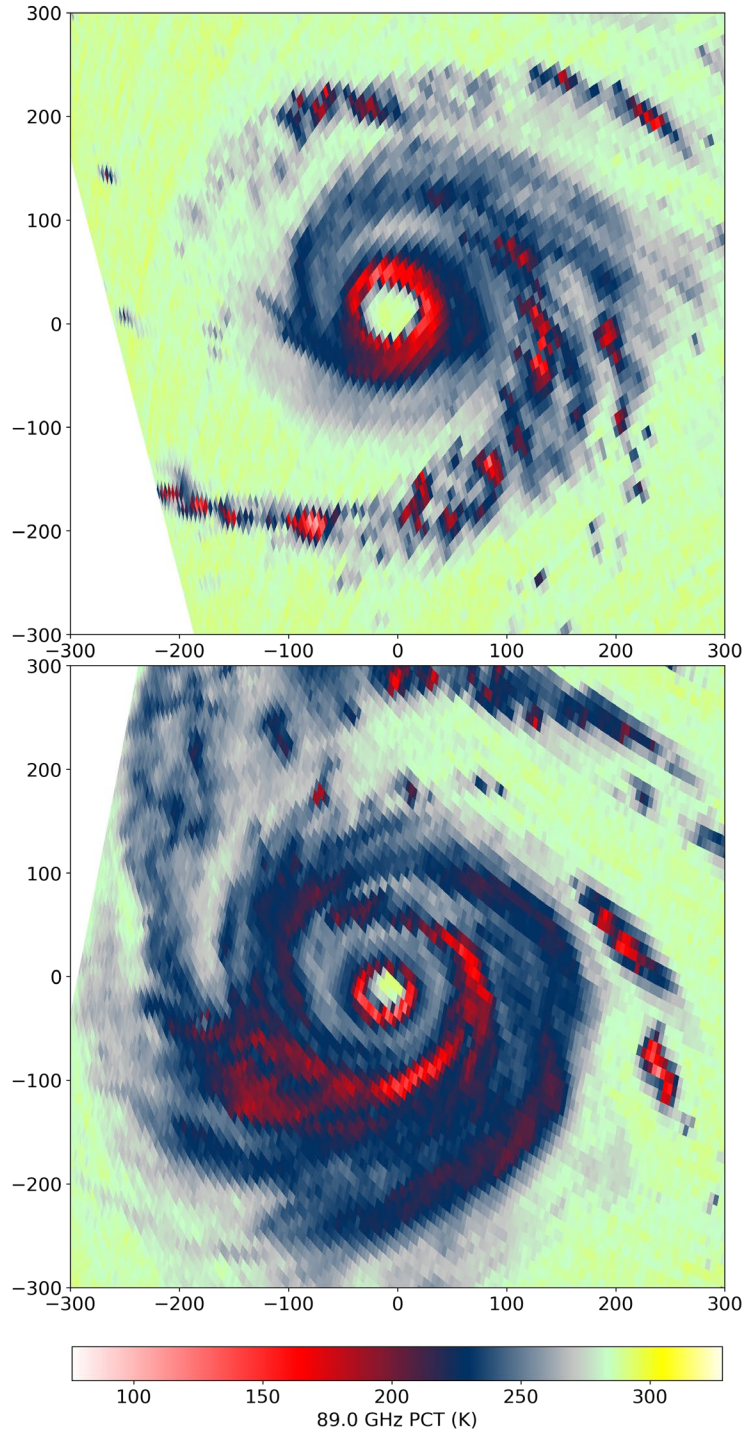
- TC PRIMED now available on the cloud through the NOAA Open Data Dissemination program (NODD); awaiting final publication by the NOAA National Centers for Environmental Information (NCEI)

- Maintain, update, and add more products to TC PRIMED

# Tropical Cyclone Secondary Eyewalls

- Some tropical cyclones form secondary eyewalls, which can lead to:
  - intensity fluctuations
  - larger area of hazards like strong winds, heavy rain, and storm surge

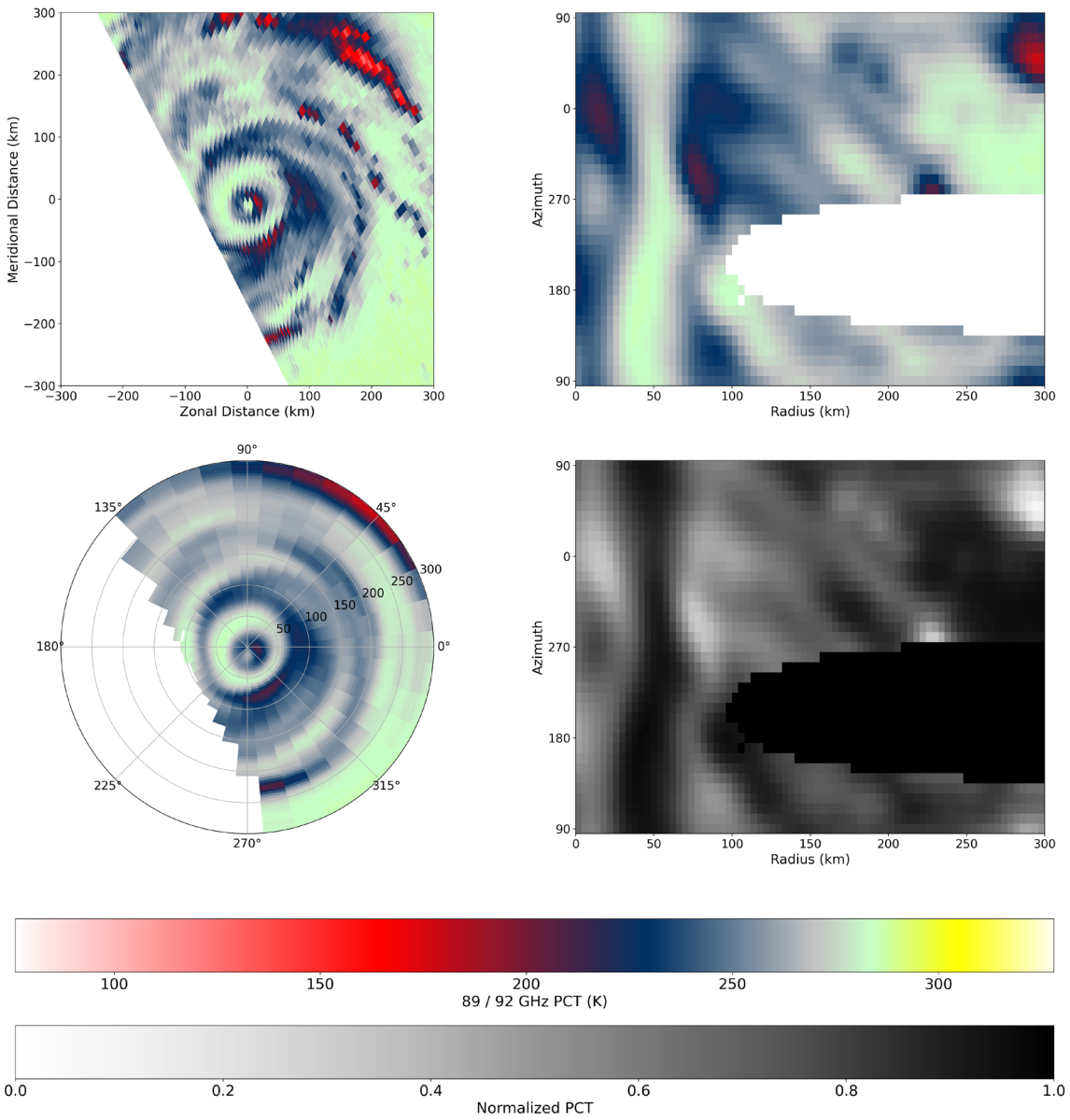
- To use TC PRIMED to study tropical cyclone secondary eyewalls, need a way to label secondary eyewalls across different passive microwave sensors in TC PRIMED



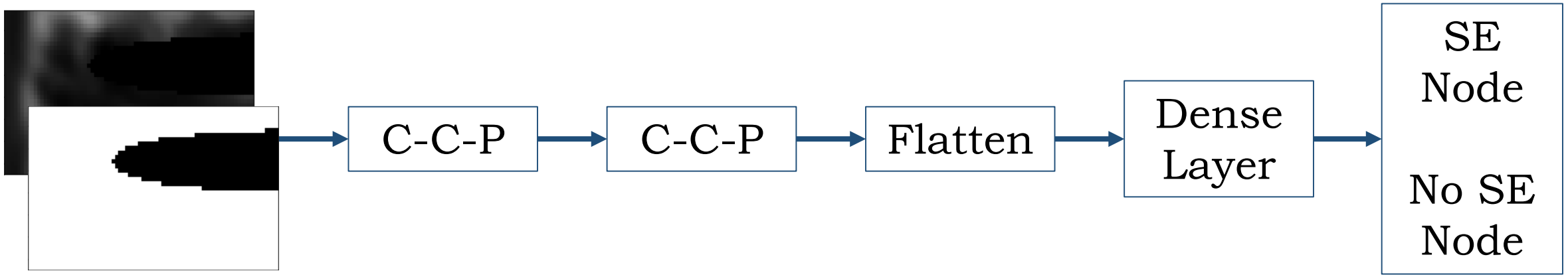
# Methods

- Use secondary eyewall labels from Cheung et al. (*in review*)
  - hand-labeled select storms from 2016 – 2020
  - AMSR2, GMI, and SSMIS sensors
  - apply filter (Mueller et al. 2006) to reduce resolution differences

- Convolutional Neural Network
  - 89 – 92 GHz polarization corrected brightness temperature
    - normalized by min / max
      - $\mathrm{PCT(norm)} = \frac{\mathrm{PCT} - \mathrm{PCT(min)}}{\mathrm{PCT(min)} - \mathrm{PCT(max)}}$



# CNN Architecture




| | # SE | # No SE | % SE |
|---|---|---|---|
| training | 59 | 629 | 9.4 |
| validation | 13 | 134 | 9.7 |
| testing | 13 | 137 | 9.5 |

C = Convolution Layer, leaky ReLU (32, 3 x 3)

P = Pooling Layer, average (32, 2 x 2)

Dense Layer = 200 nodes, leaky ReLU

Represent SE / No SE labels as numerical values using one-hot encoding, softmax

Custom weighted categorical cross entropy loss function

# Preliminary Results

| Training | | Truth | |
|---|---|---|---|
| | | Yes | No |
| Predicted | Yes | 59 | 0 |
| | No | 0 | 629 |

| Validation | | Truth | |
|---|---|---|---|
| | | Yes | No |
| Predicted | Yes | 7 | 6 |
| | No | 6 | 128 |

| Testing | | Truth | |
|---|---|---|---|
| | | Yes | No |
| Predicted | Yes | 6 | 8 |
| | No | 7 | 129 |

- Model is overfitting on the training data
  - small sample size of secondary eyewall cases
  - sub-optimal model architecture
  - sample not generalized enough

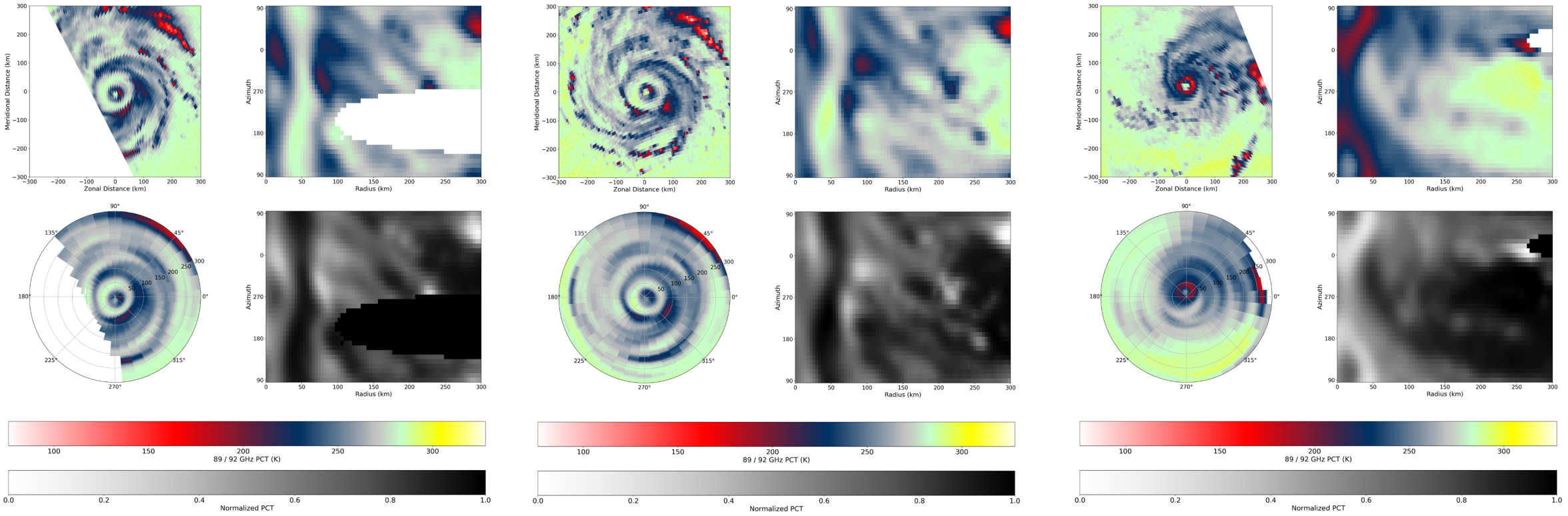
# Model Next Steps

- Analyze model results to understand patterns behind hits, misses, and false alarms.

Hit

Miss

False Alarm



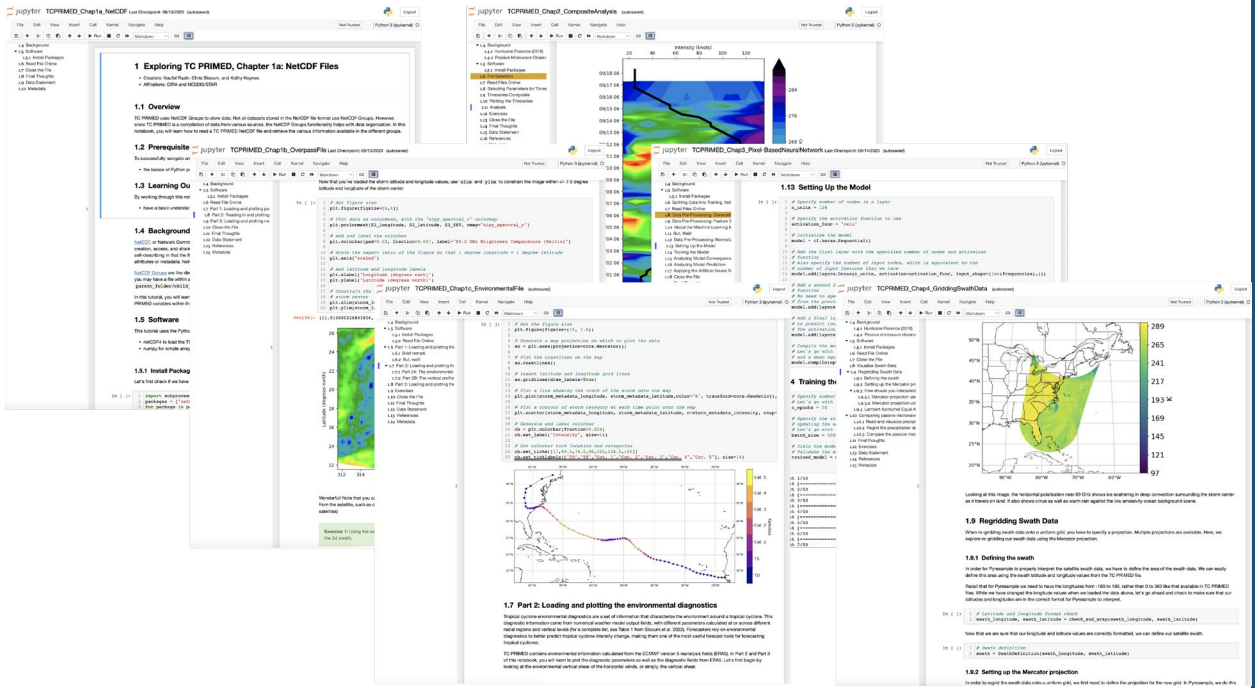
# Secondary Eyewall Summary

- Add more labels from other sensors
- Generalize samples through data augmentation
- Improve CNN to have a TC PRIMED label of secondary eyewalls
- Employ explainable AI methods to understand if the model is keying in on the physical features
- Investigate secondary eyewalls using TC PRIMED

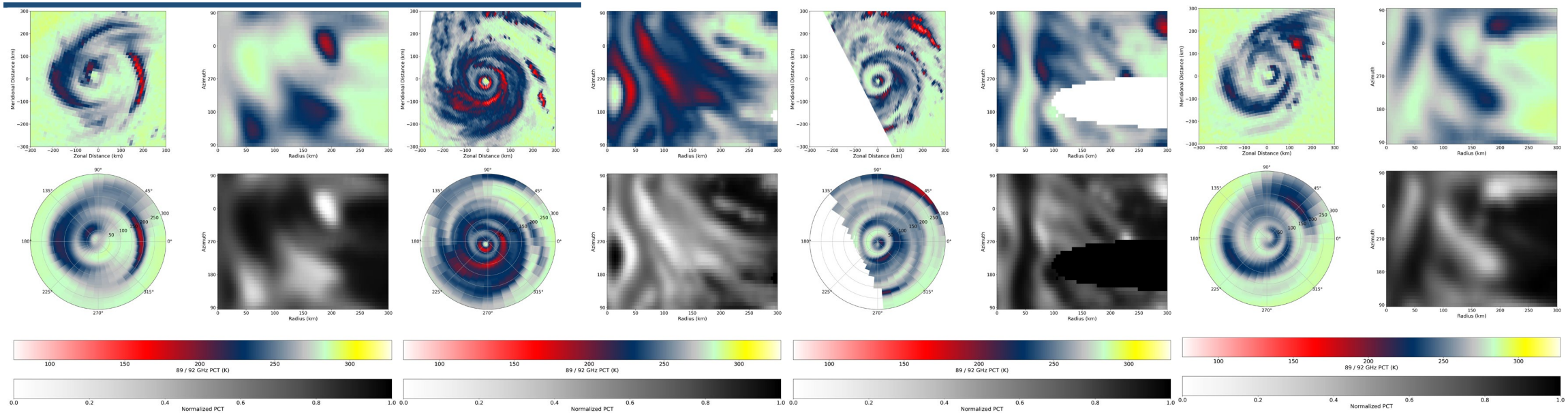
# Extras

# Using TC PRIMED to Promote the Use of Satellite Passive Microwave Data

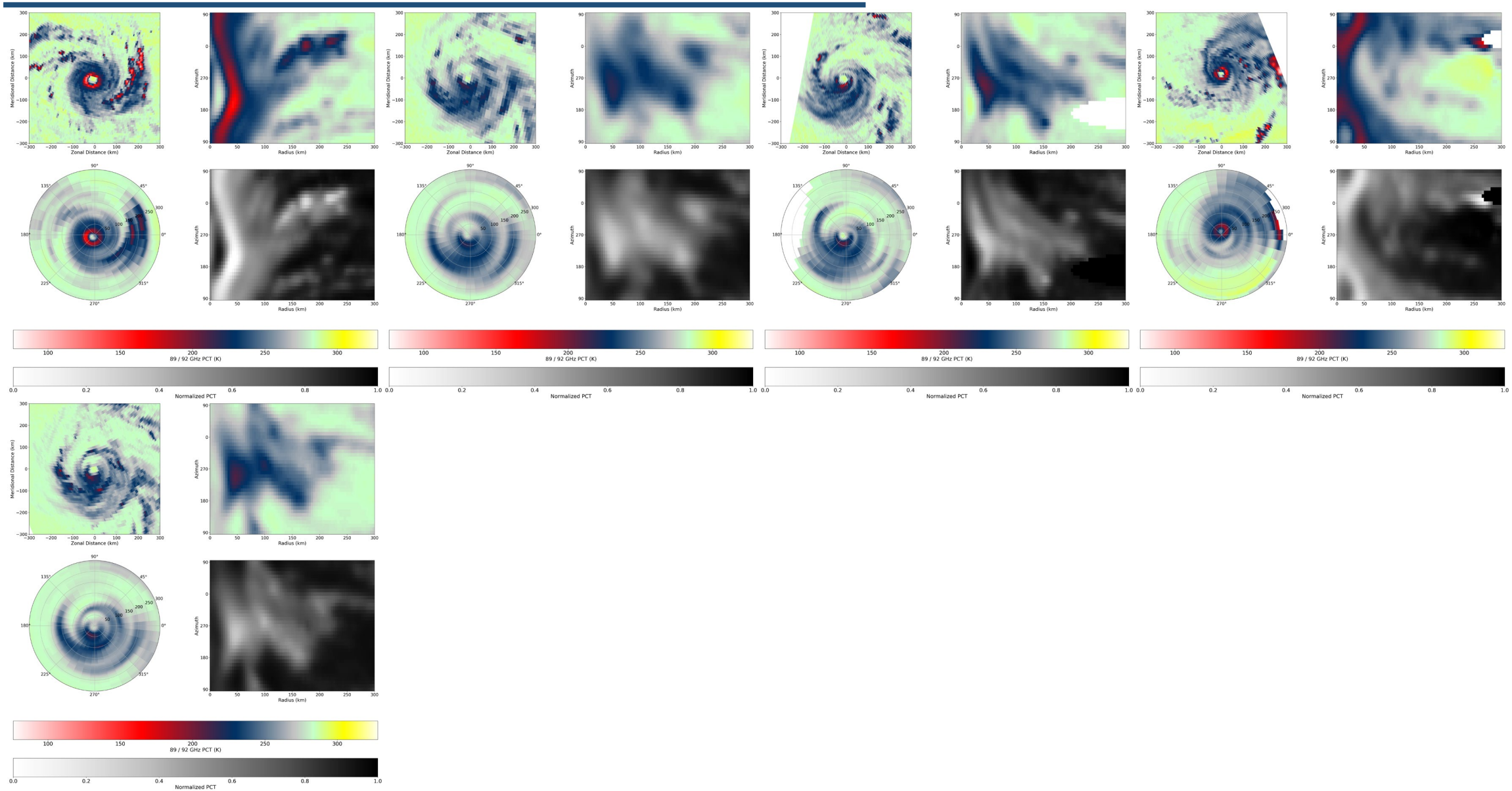
- NCAI project to develop set of Jupyter notebook learning journeys
- Users will learn from the very basic knowledge of understanding the file and data types to applying TC PRIMED for analysis and AI



# Hits (testing set)



# False Alarms (testing set)



# Misses (testing set)