Multi-Resolution Analysis of the Convective Structure of Tropical Cyclones for Short-Term Intensity Guidance

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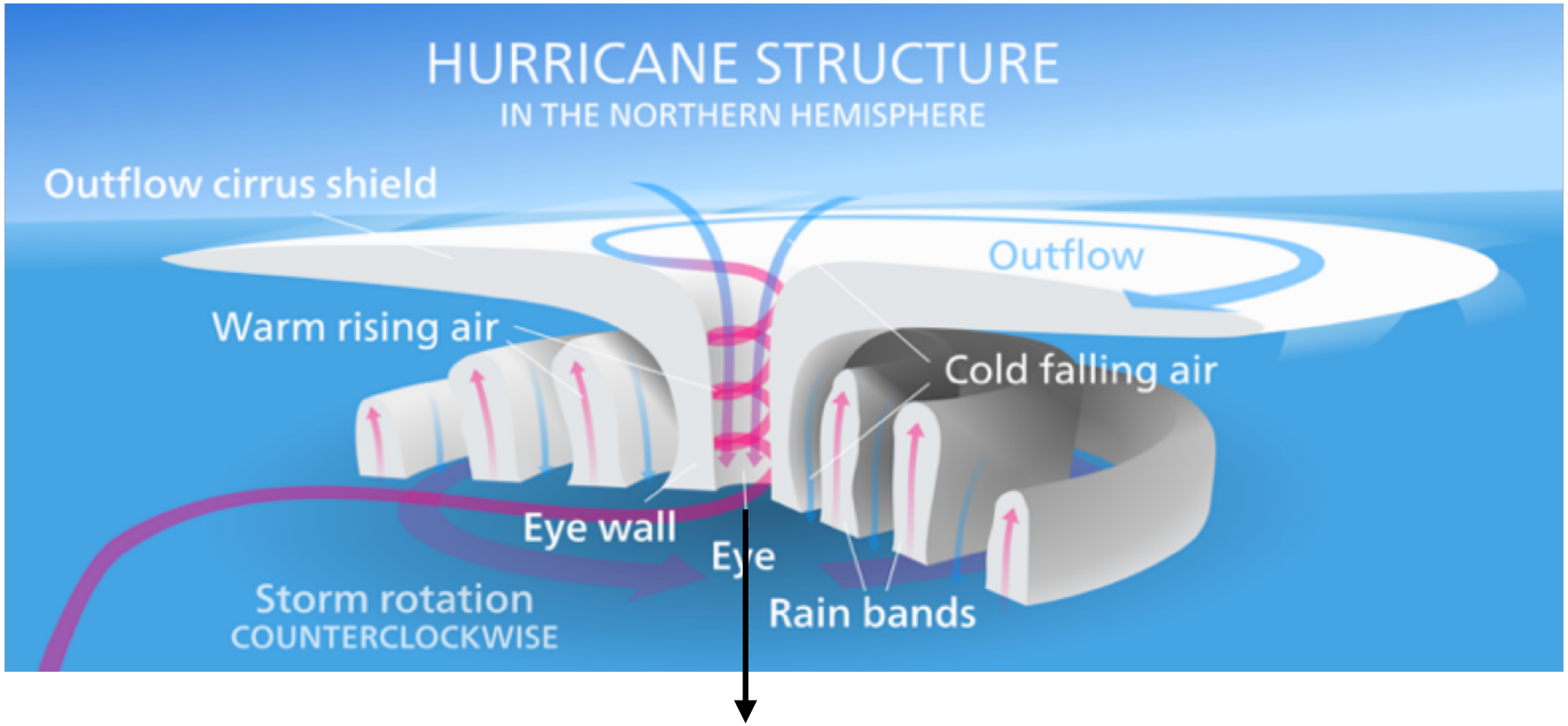
Key Definitions

Tropical cyclone (TC) — A localized, intense low-pressure wind system forming over tropical oceans

Hurricane - A TC with sustained windspeed $\geq$ 63 knots

Rapid Intensification (RI) - A $\geq$30 knot increase in wind speed over 24 hours

Convective Structure → Intensity



A more defined a cyclone's eye, the greater the intensity of the storm.

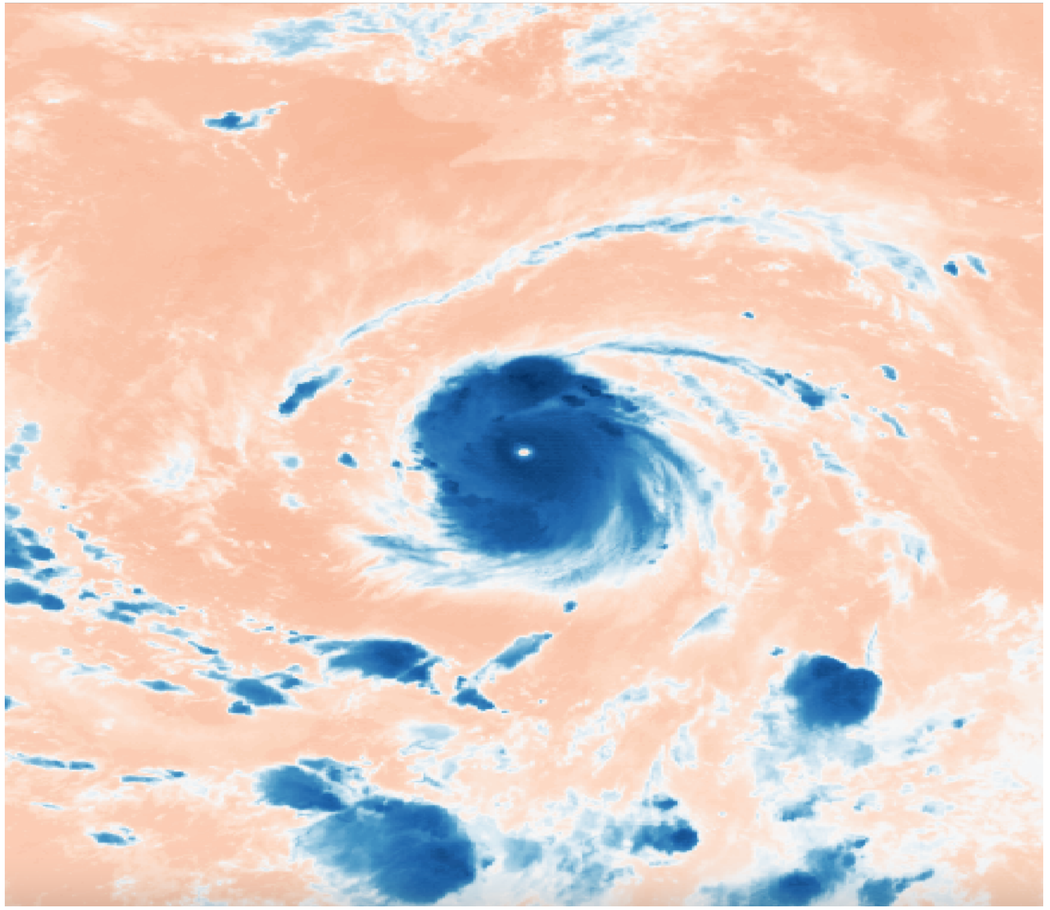
Photo courtesy of the Interdisciplinary Teaching about Earth for a Sustainable Future Center

Infrared Imagery as a Proxy for Convection

Infrared images show cool, cloud top coverage and warm, ocean surface

Previous work used summary statistics of infrared imagery to predict rapid intensification events

This potentially loses critical directional and finer-scale details about the storms convective pattern



Hurricane Felix, 2017

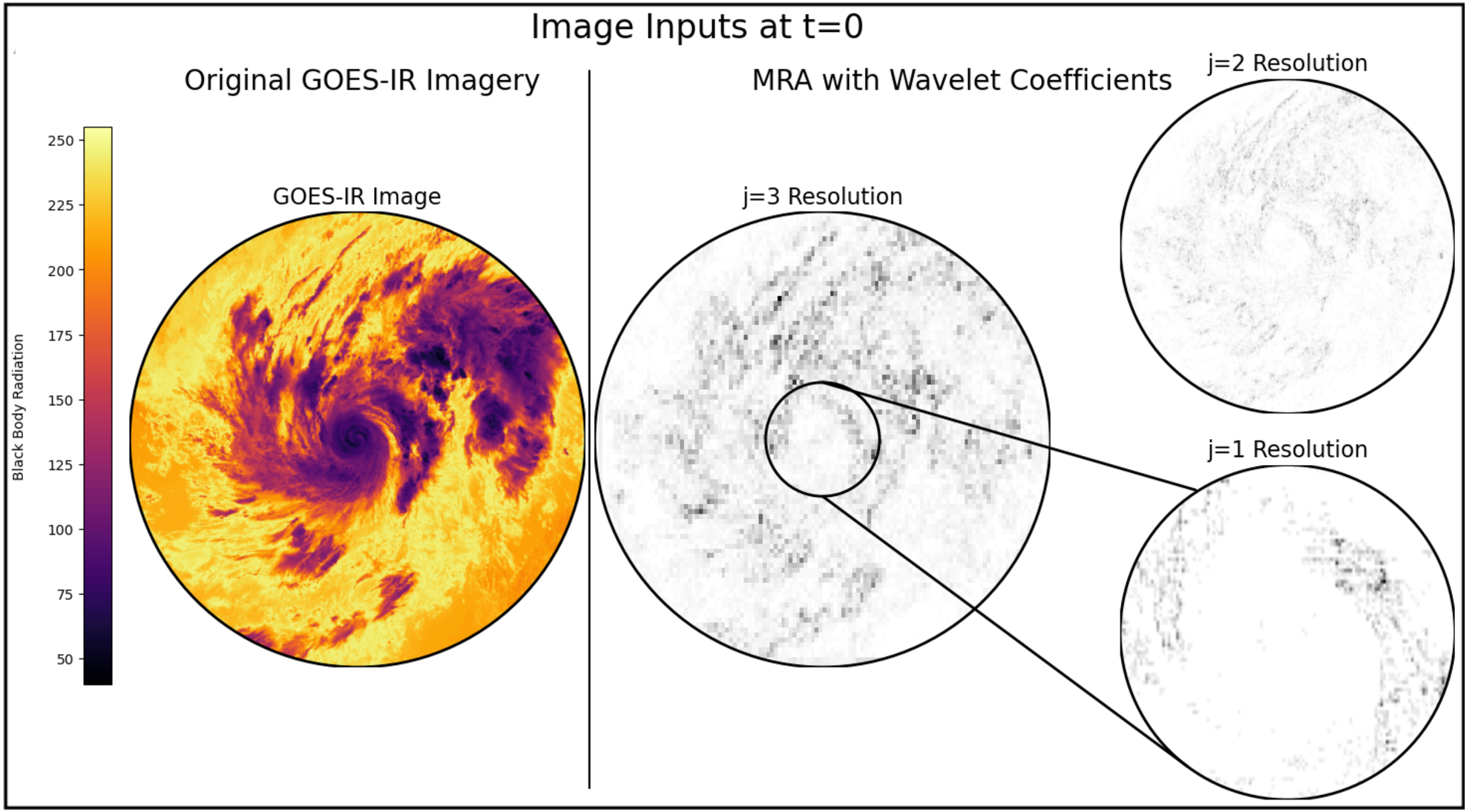
Wavelet Coefficients Encode Signal Changes

Wavelets are mathematical functions used to decompose images into structures on different scales

We can express each image $f(x)$ as

$$f(x) = \sum_{j,n,k} c_{j,n}^{k} \psi_{j,n}^{k}(x)$$

where $\psi_{j,n}^{k}(x) = 2^{-j}\psi^{k}(2^{-j}x - n)\ \forall j \in \mathbb{Z}^{+}, 1 \leq k \leq 3, n \in \mathbb{Z}^{2}$



Hurricane Eta, 2020

Concise

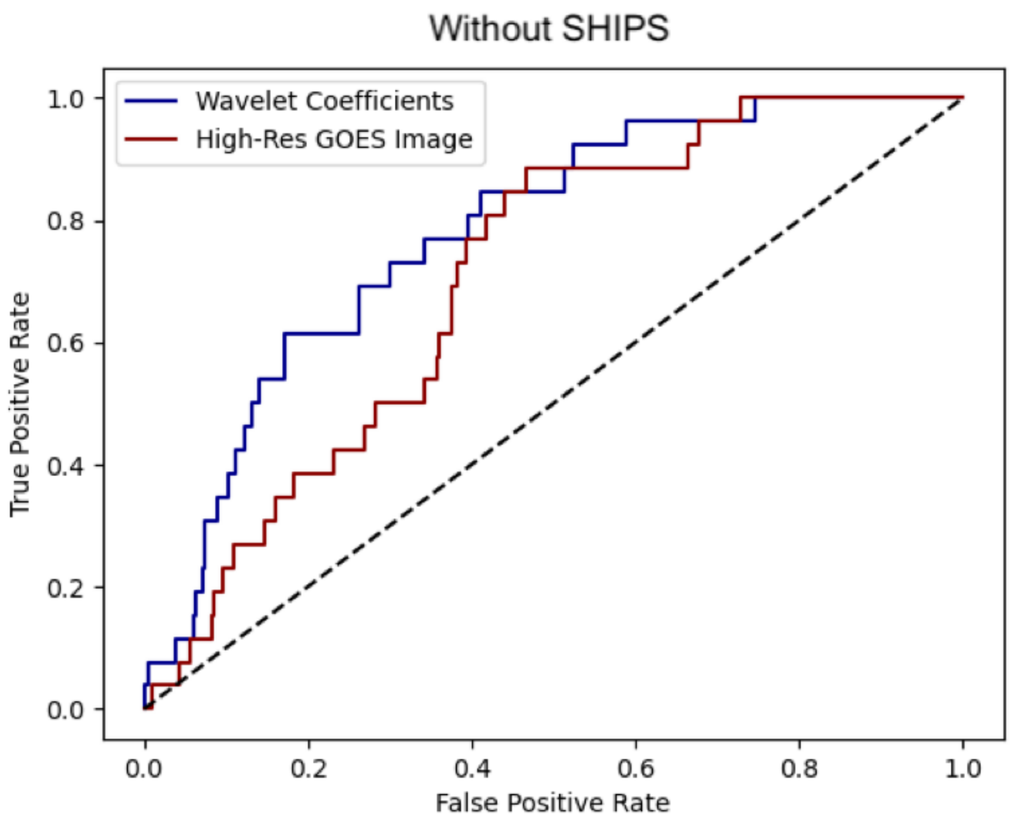
Interpretable

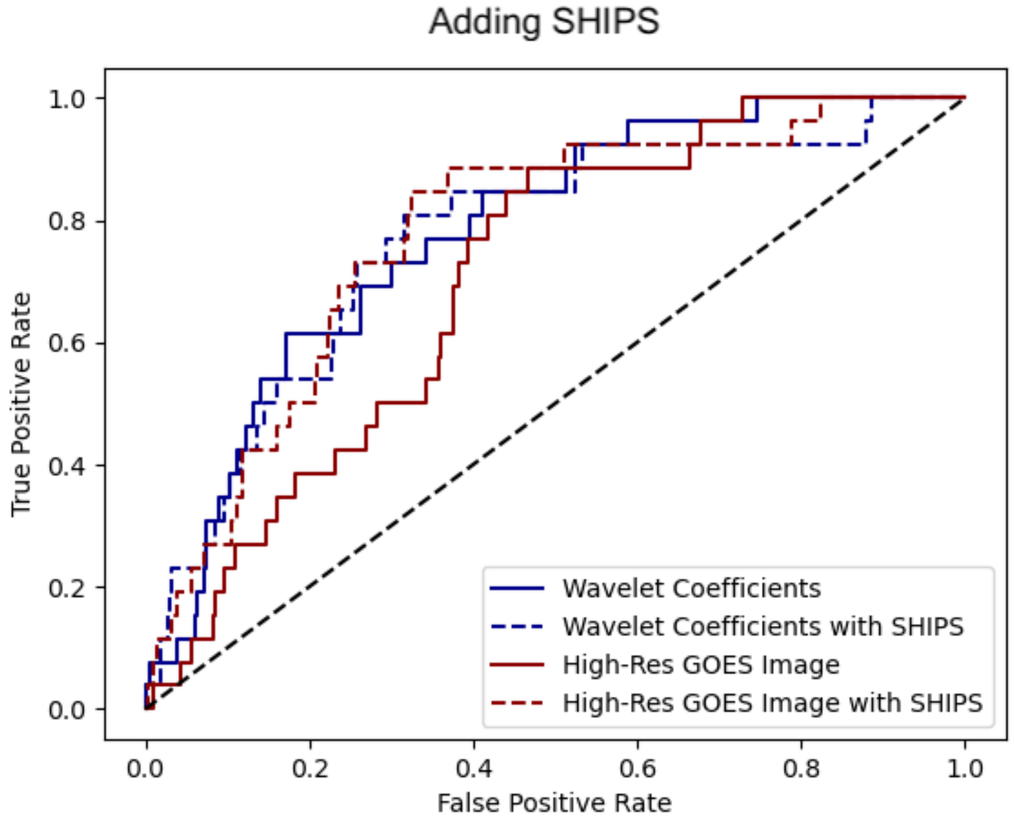
Descriptive

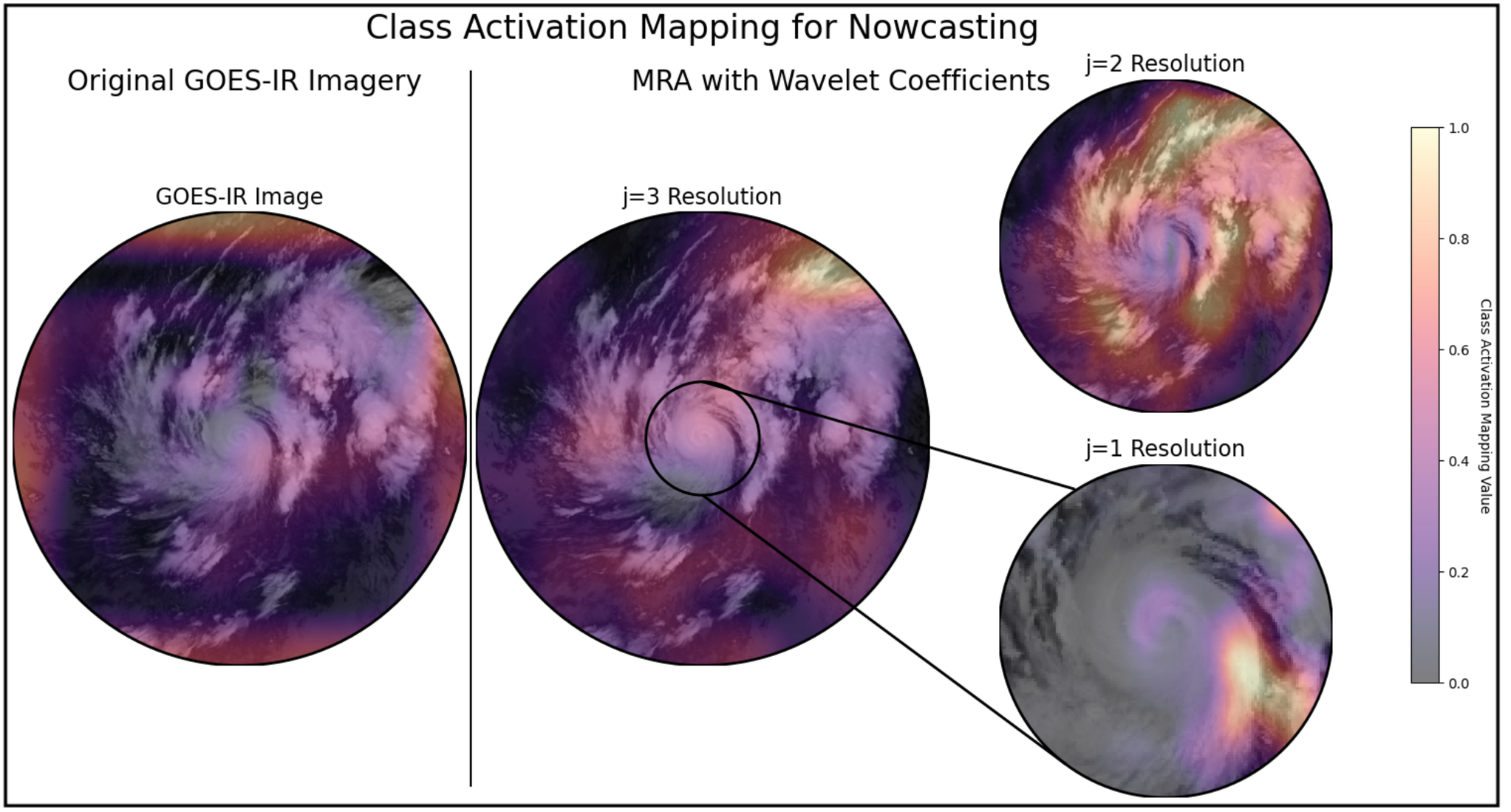
Input = 24-hour sequence of images in the wavelet space $S_{\leq t}$

Output = $\mathbb{P}(Y = 1 \mid S_{\leq t}) - \mathbb{P}(Y = 1)$, where $Y = 1$ means RI event at t

Compare results between initial images and images in the wavelet space



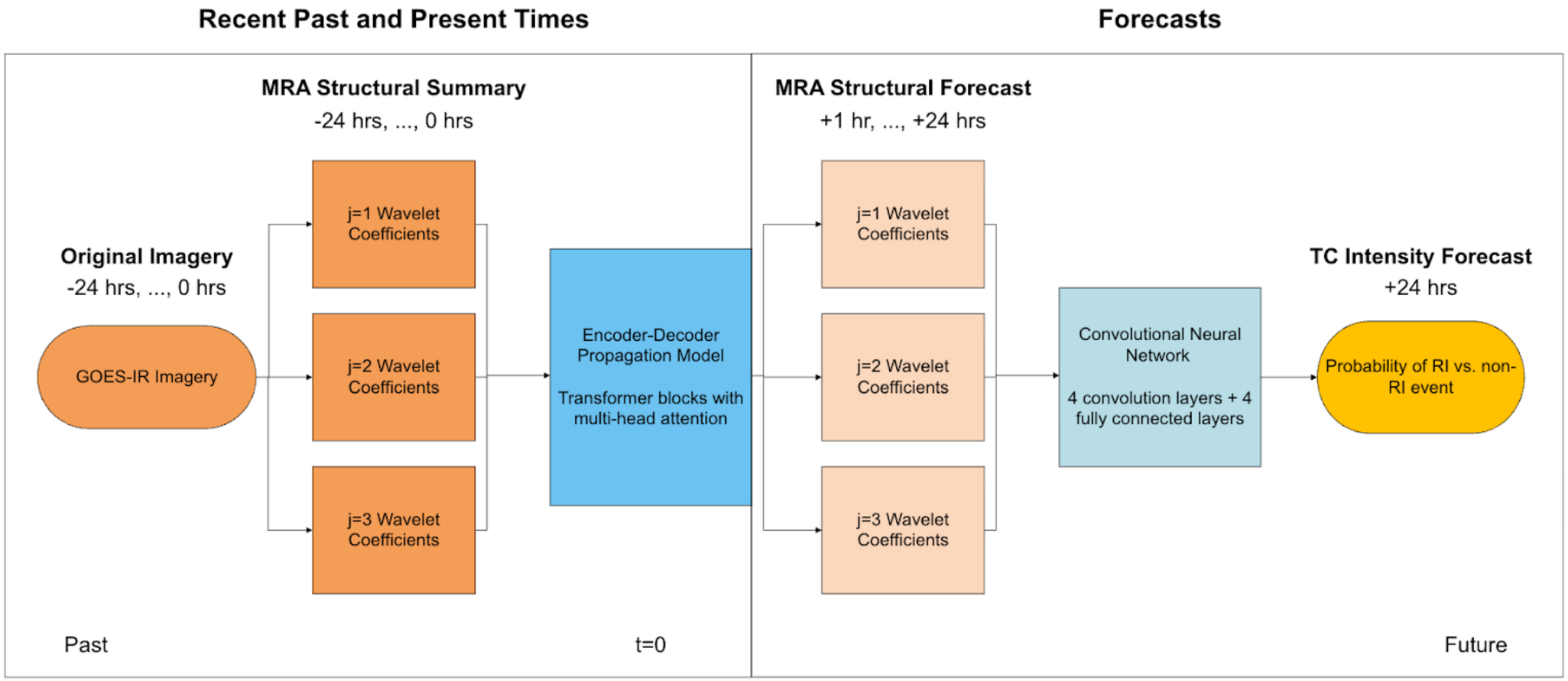




Hurricane Eta, 2020

How can we transition from nowcasting to forecasting?

Proposed Structural Forecasting Architecture



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