

Structural Forecasting for Tropical Cyclone Intensity Prediction: Providing Insight with Deep Learning

Trey McNeely¹

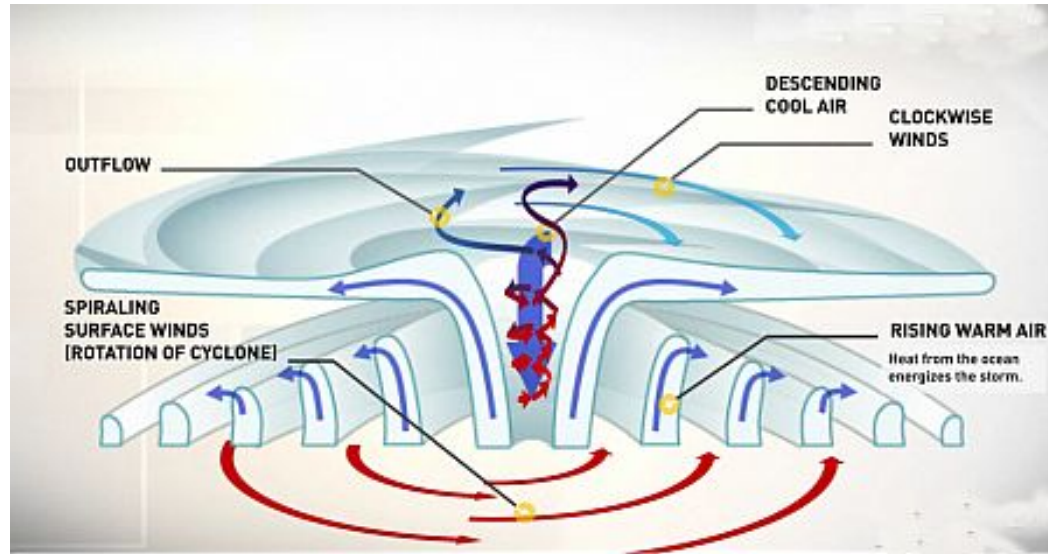
Joint with Niccolò Dalmaso¹, Kimberly M. Wood², and Ann B. Lee¹

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Statistics and Data Science

²Mississippi State University
Geosciences

NeurIPS 2020:
Tackling Climate Change with ML

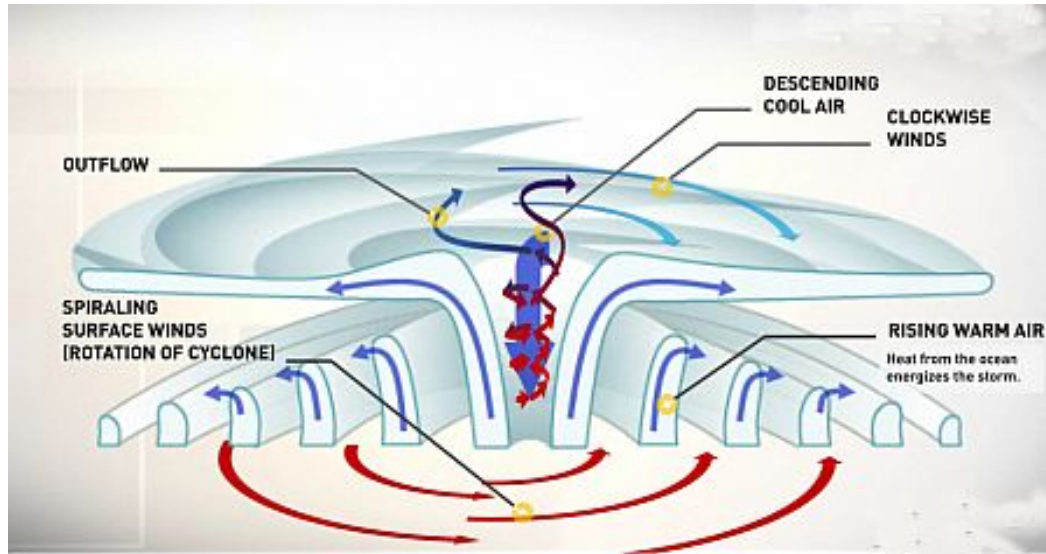
Tropical Cyclones are highly-organized, axisymmetric storms.



(left) Anatomy of a TC.

- Strong convection results in higher, colder cloud tops.

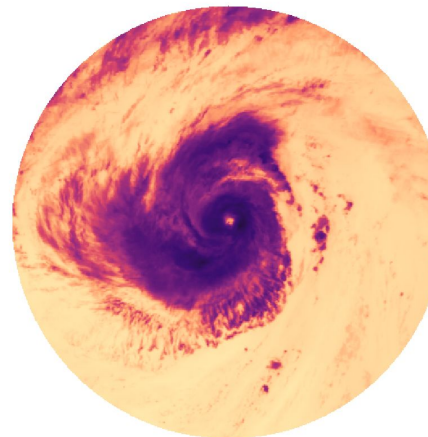
Tropical Cyclones are highly-organized, axisymmetric storms. Infrared imagery serves as a proxy for convective strength.



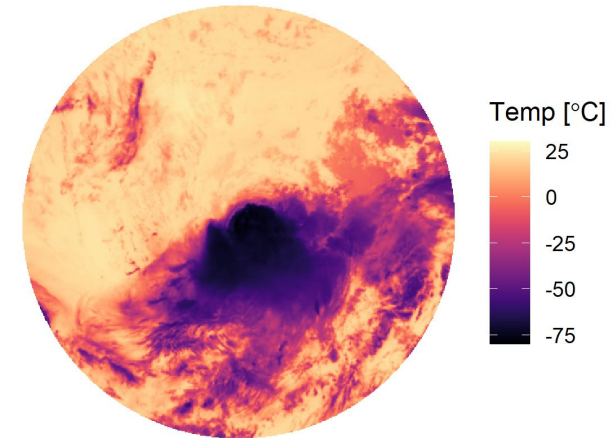
(left) Anatomy of a TC.

- Strong convection results in higher, colder cloud tops.

(right) IR images for two TCs



Hurricane Edouard (95 kt)
Category 2



Hurricane Nicole (45 kt)
Tropical Storm

Data

Merge-IR

- Geostationary satellite imagery
- 4-km, 30-min resolution
- 2000-present

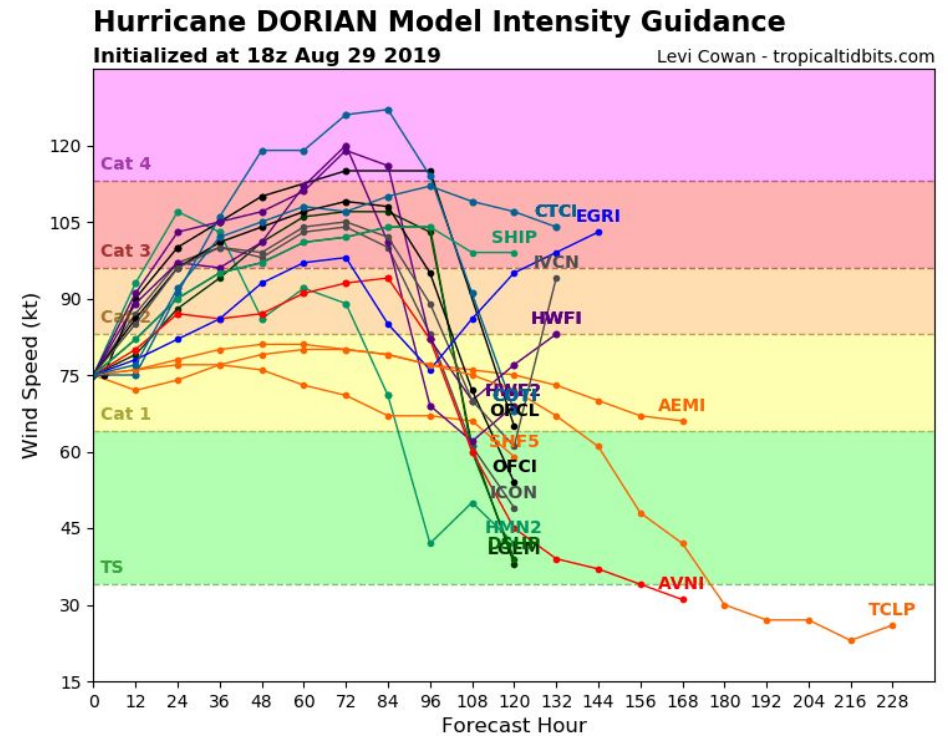
John Janowiak, Bob Joyce, Pingping Xie (2017), NCEP/CPC L3 Half Hourly 4km Global (60S - 60N) Merged IR V1, Edited by Andrey Savtchenko, Greenbelt, MD, Goddard Earth Sciences Data and Information Services Center (GES DISC), Accessed: 3/18/2020-7/3/2020, [10.5067/P4HZB9N27EKU](https://doi.org/10.5067/P4HZB9N27EKU)

Hurdat2

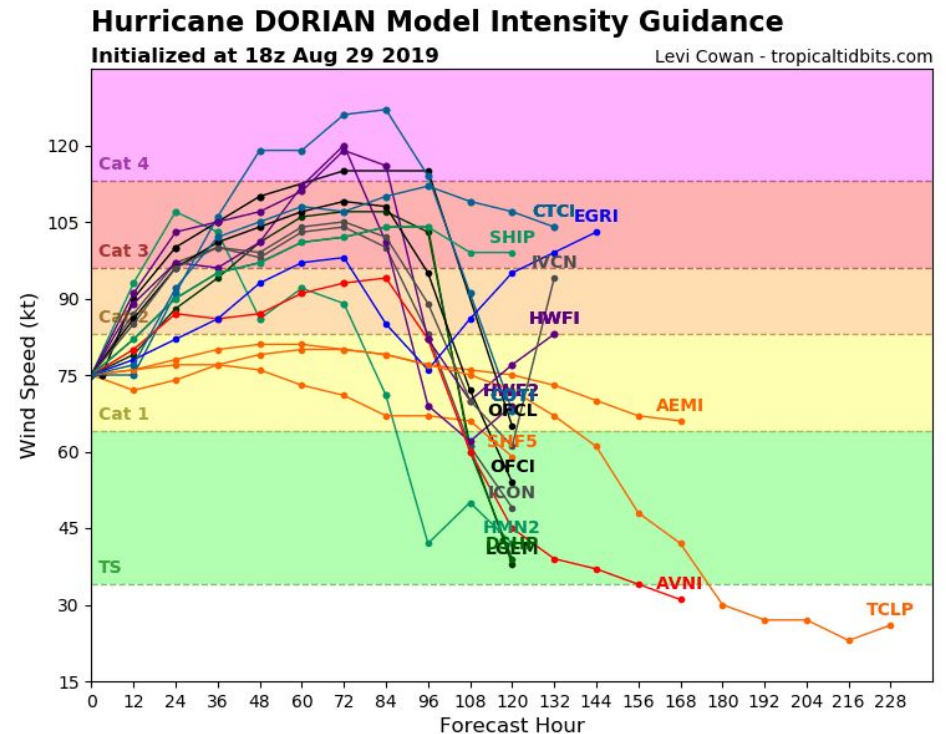
- Hurricane best-track data
- 6hr resolution
- TC location, intensity

Landsea, C. W. and J. L. Franklin, 2013: Atlantic Hurricane Database Uncertainty and Presentation of a New Database Format. Mon. Wea. Rev., 141, 3576-3592

Spatio-temporal information in IR imagery is underutilized. What do scientists and forecasters need?



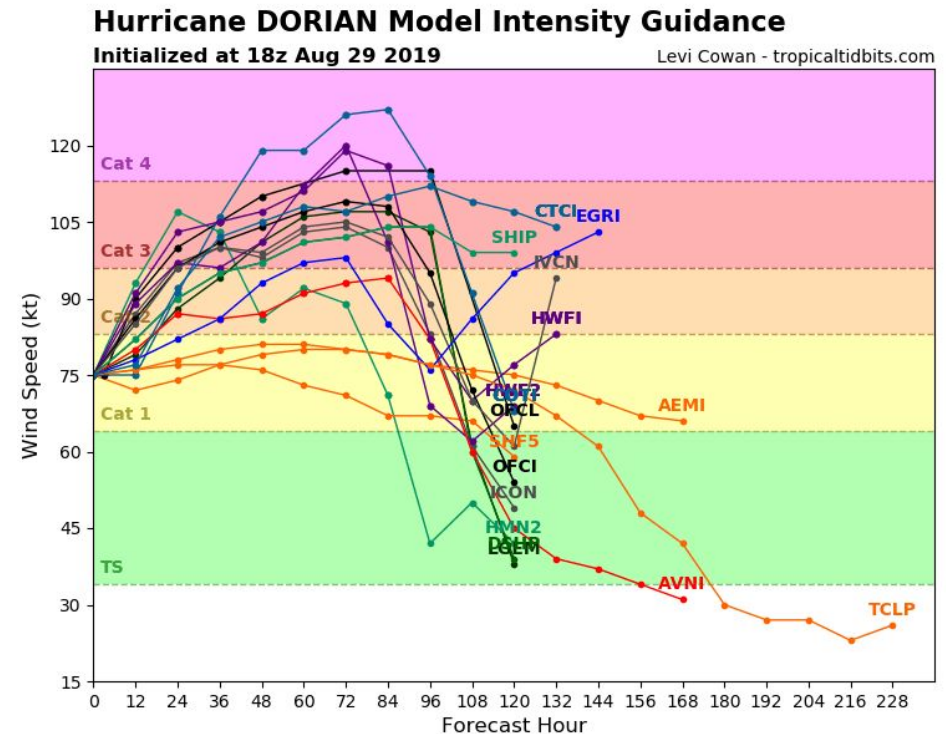
Spatio-temporal information in IR imagery is underutilized. What do scientists and forecasters need?



Scientists and forecasters require a concise, interpretable, and descriptive quantification of the spatio-temporal evolution of TCs.

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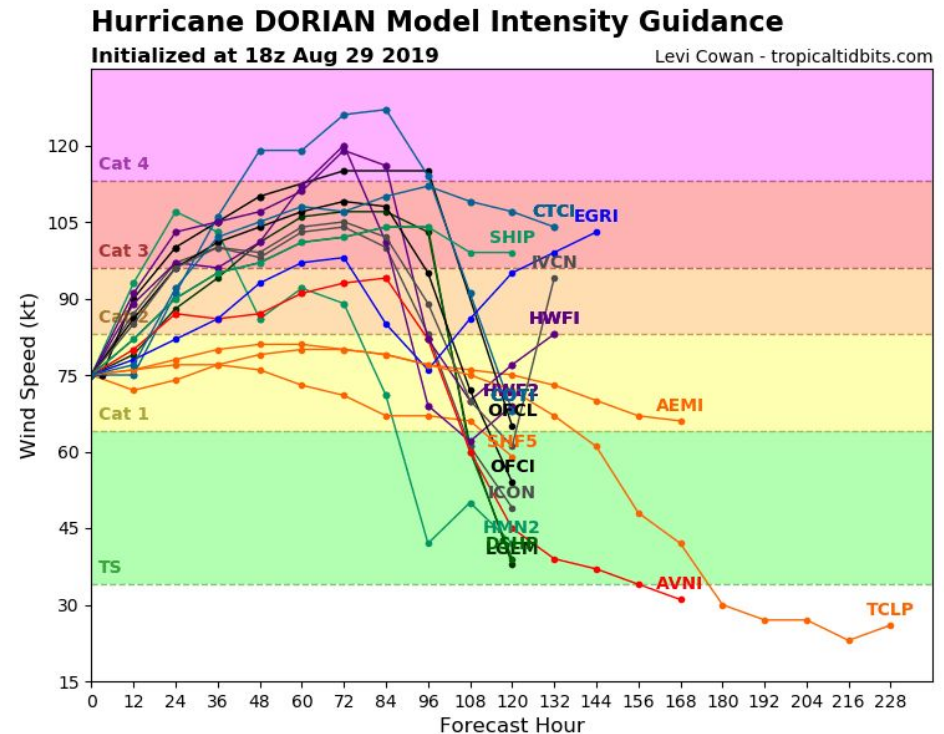
- High-resolution data
 - Concise



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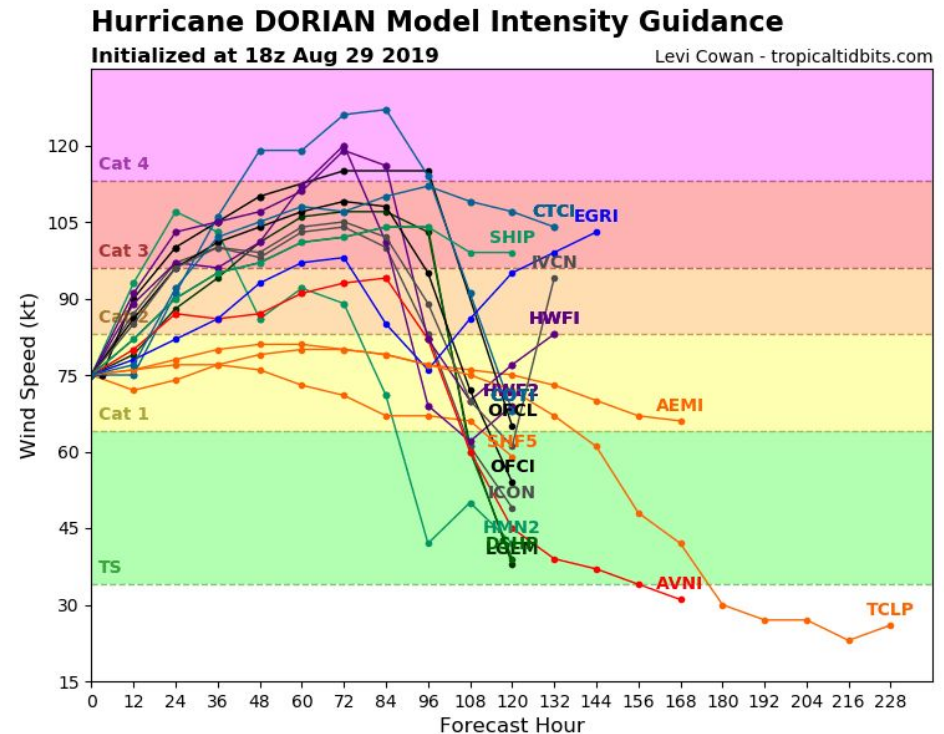
- High-resolution data
 - Concise
- Human-in-the-loop
 - Interpretable



Scientists and forecasters require a concise, interpretable, and descriptive quantification of the spatio-temporal evolution of TCs.

Spatio-temporal information in IR imagery is underutilized. What do scientists and forecasters need?

- High-resolution data
 - Concise
- Human-in-the-loop
 - Interpretable
- Complex spatial structures
 - Descriptive



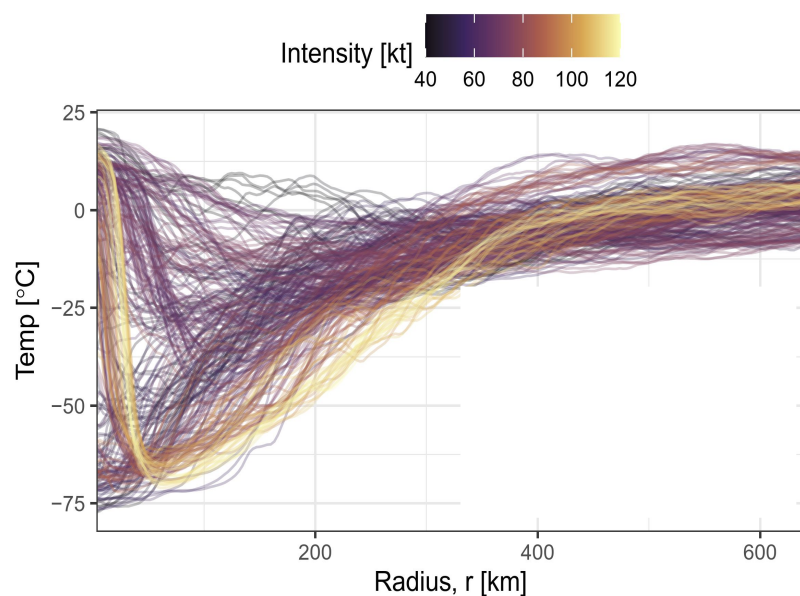
Scientists and forecasters require a concise, interpretable, and descriptive quantification of the spatio-temporal evolution of TCs.

The ORB framework converts threshold-based and area-averaged features into continuous functions.

ORB: global Organization, Radial structure, and Bulk morphology

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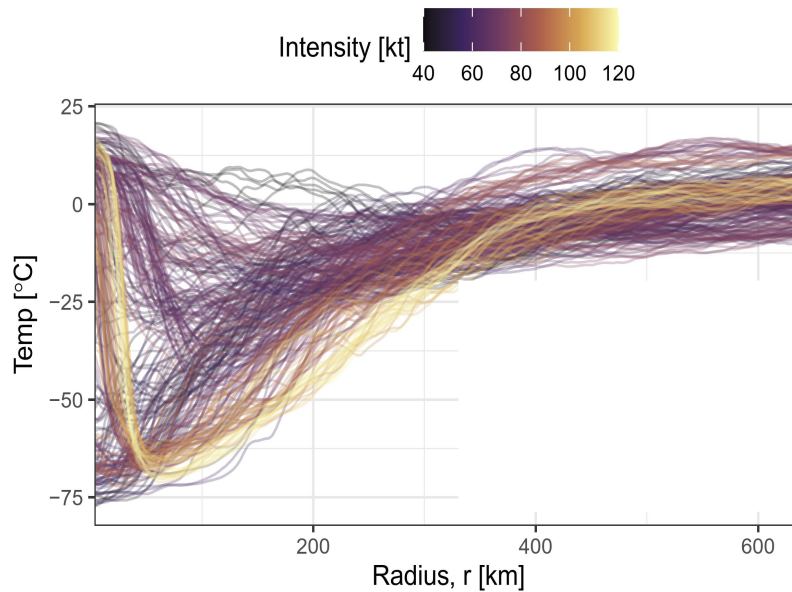


$$\bar{T}(r) = \frac{1}{2\pi} \int_0^{2\pi} T_b(r, \theta) d\theta$$

Area-averaged features →
functions of radius

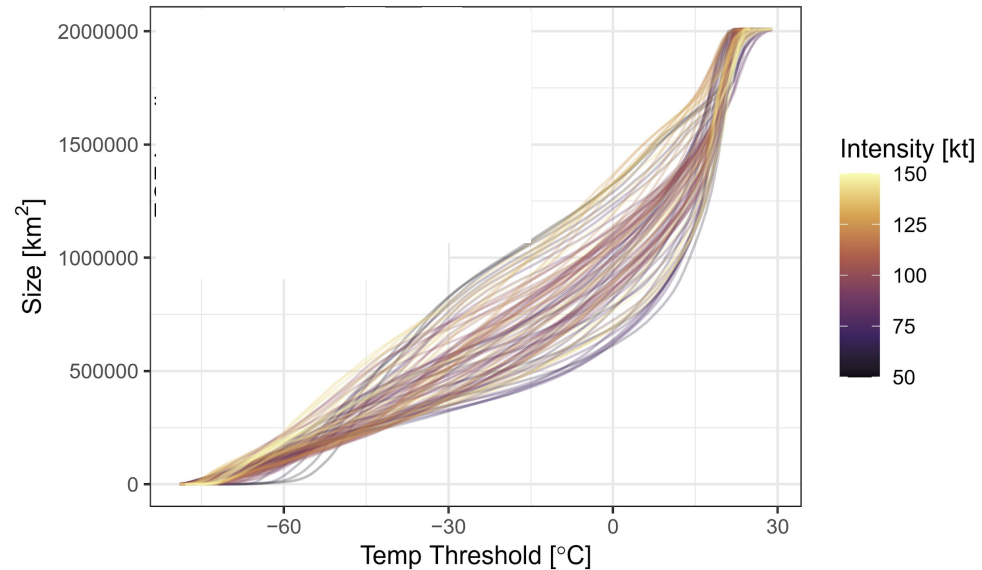
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$$\bar{T}(r) = \frac{1}{2\pi} \int_0^{2\pi} T_b(r, \theta) d\theta$$

Area-averaged features →
functions of radius



$$\mathcal{L}(c) = \{\mathbf{s} \mid T_b(\mathbf{s}) \leq c\}$$

$$\text{Size}(c) = |\mathcal{L}(c)|$$

Threshold-based features →
functions of level set thresholds

ORB functions can be used to nowcast changes in TC intensity.

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Unlocking GOES: A Statistical Framework for Quantifying the Evolution of Convective Structure in Tropical Cyclones

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DORIT HAMMERLING

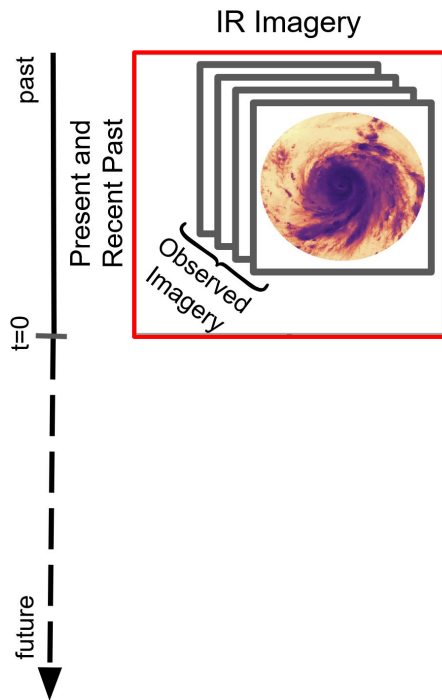
Department of Applied Mathematics and Statistics, Colorado School of Mines, Golden, Colorado

(Manuscript received 2 December 2019, in final form 31 July 2020)

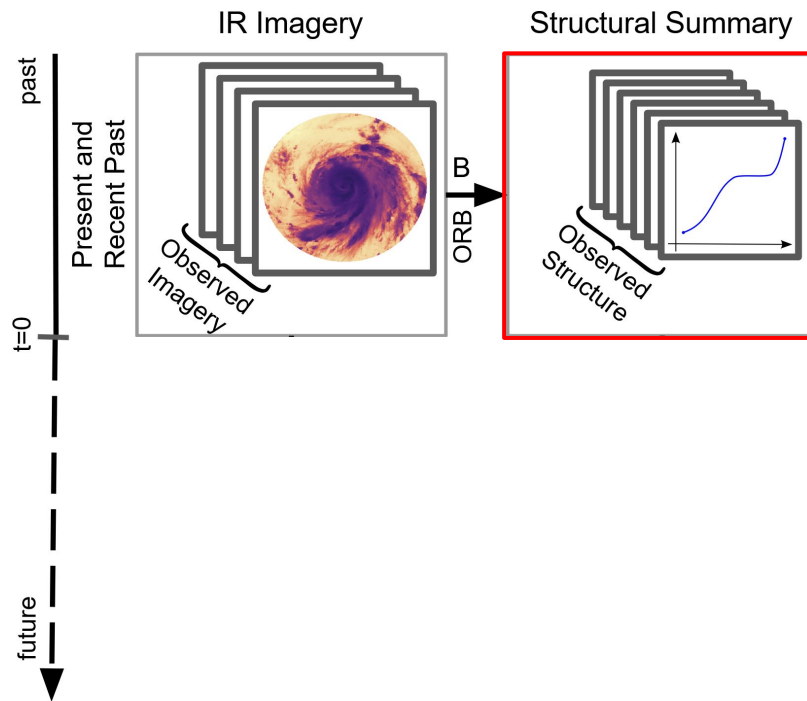
Additive models for nowcasting intensity change from ORB functions

ORB performs as well as environmental features (wind shear, ocean temperature, etc)

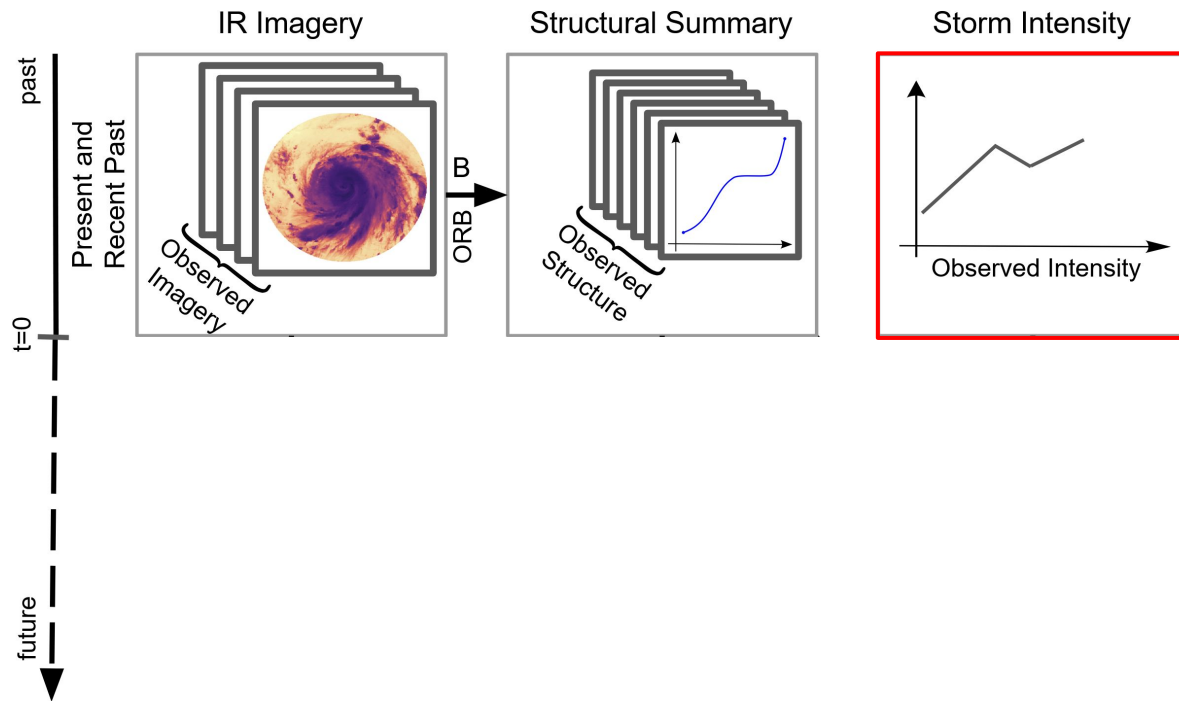
By projecting ORB functions into the future, we can convert nowcasting models into forecasts.



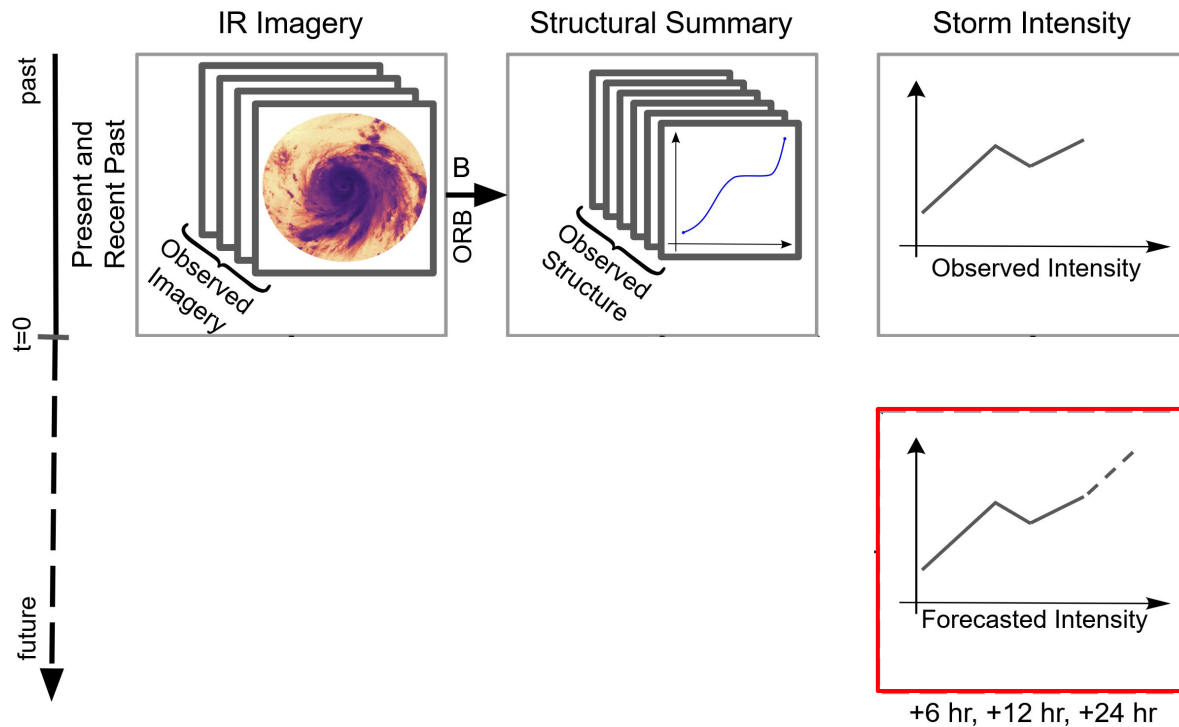
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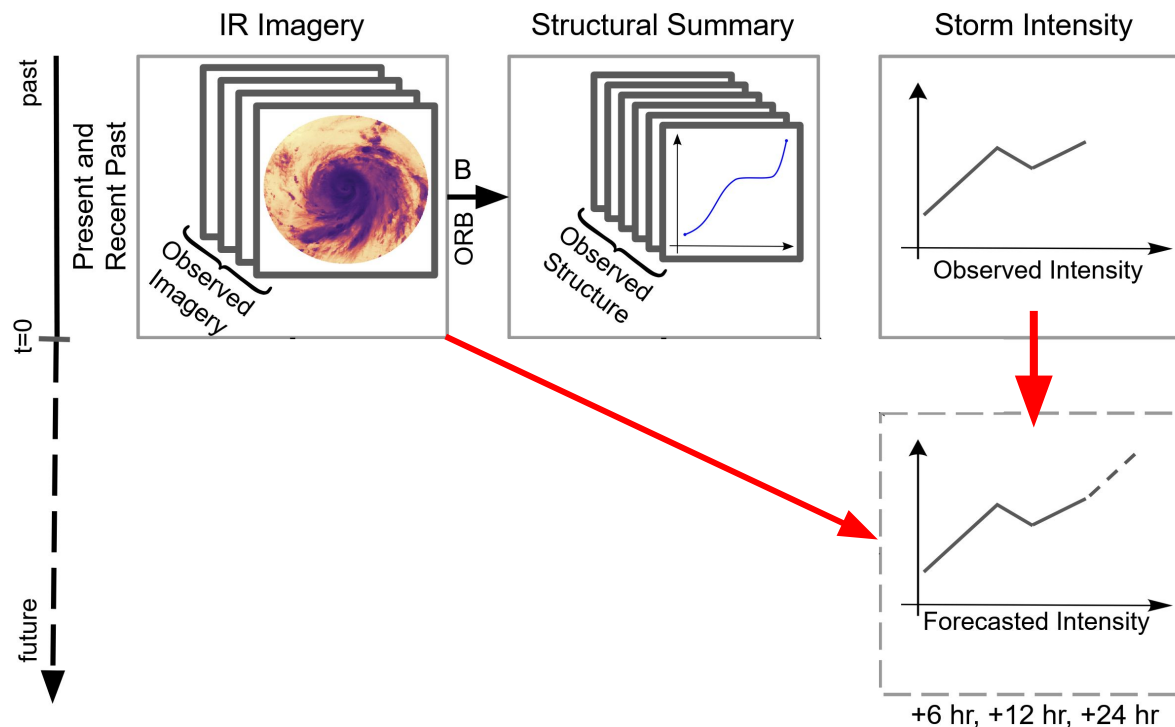
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End-to-end Deep Learning

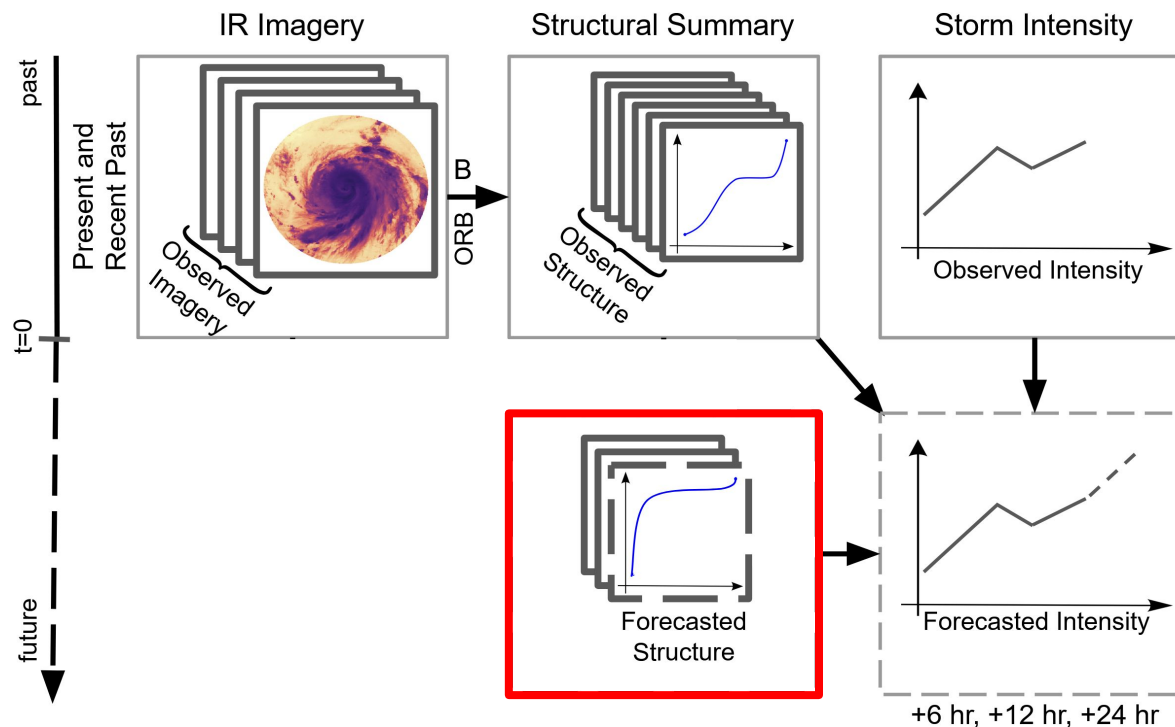
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End-to-end Deep Learning

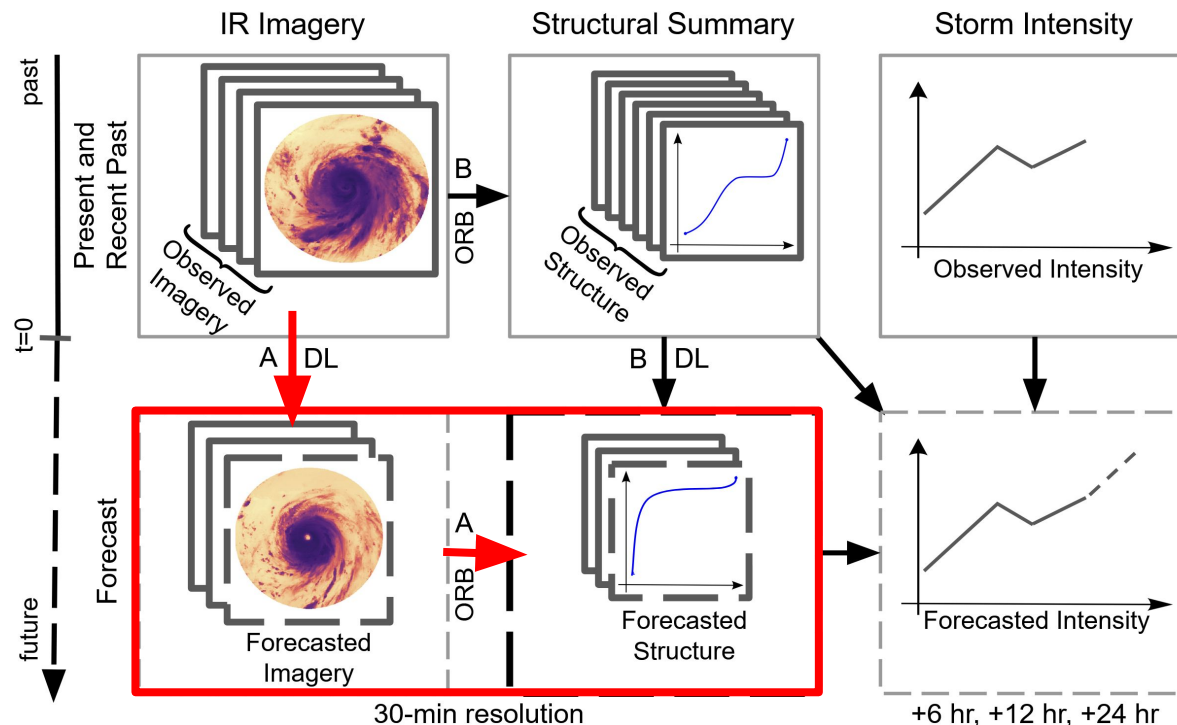
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End-to-end Deep Learning **Pathway A**

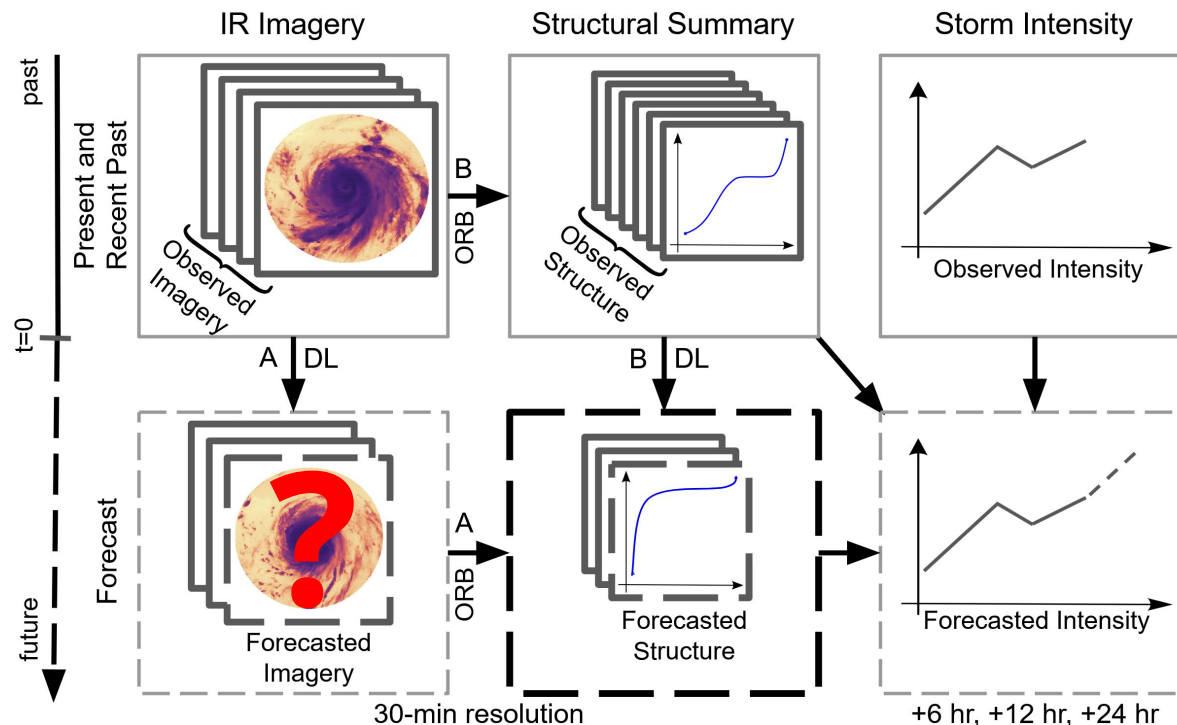
- Not adoptable by operations 1) Deep learning
2) ORB



By projecting ORB functions into the future, we can convert nowcasting models into forecasts.

End-to-end Deep Learning Pathway A

- Not adoptable by operations 1) Deep learning
- 2) ORB



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End-to-end Deep Learning

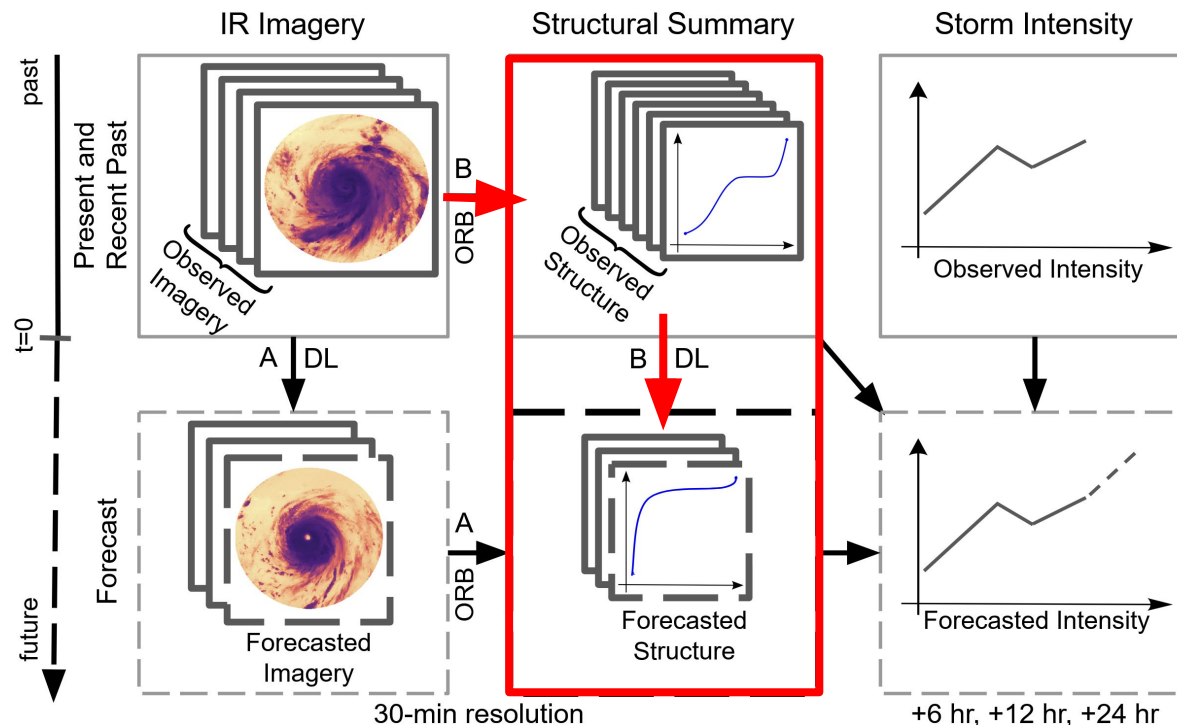
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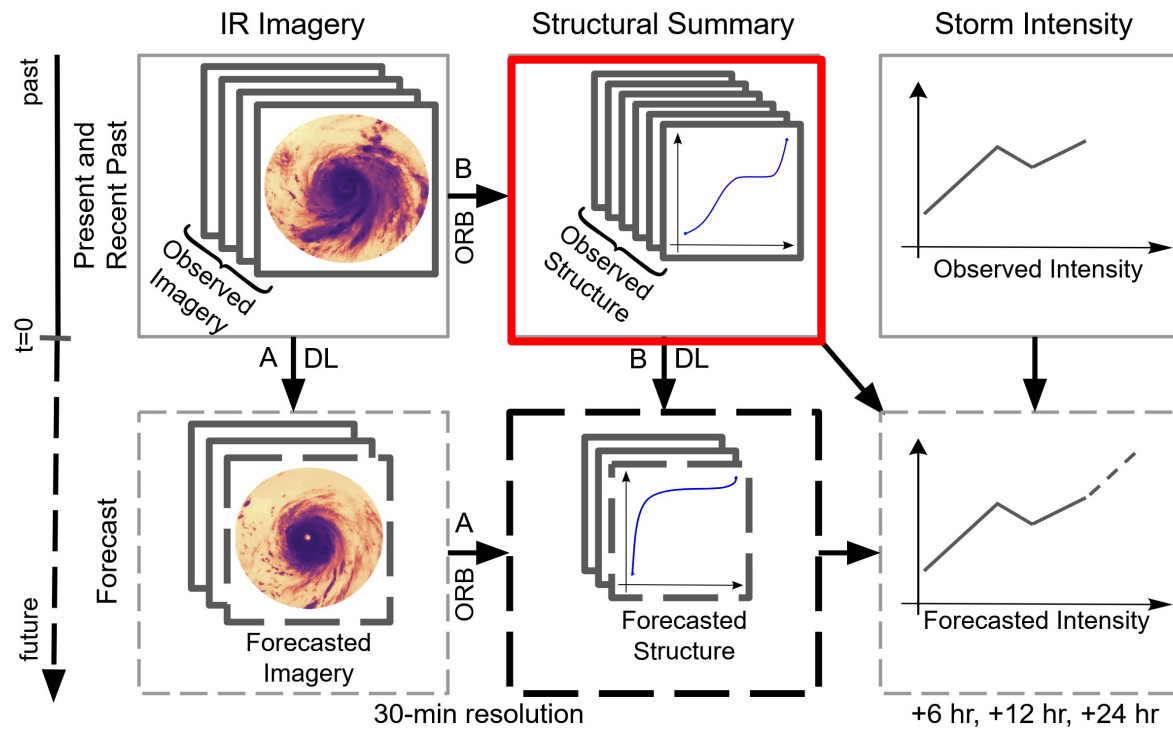
Pathway A

- 1) Deep learning
- 2) ORB

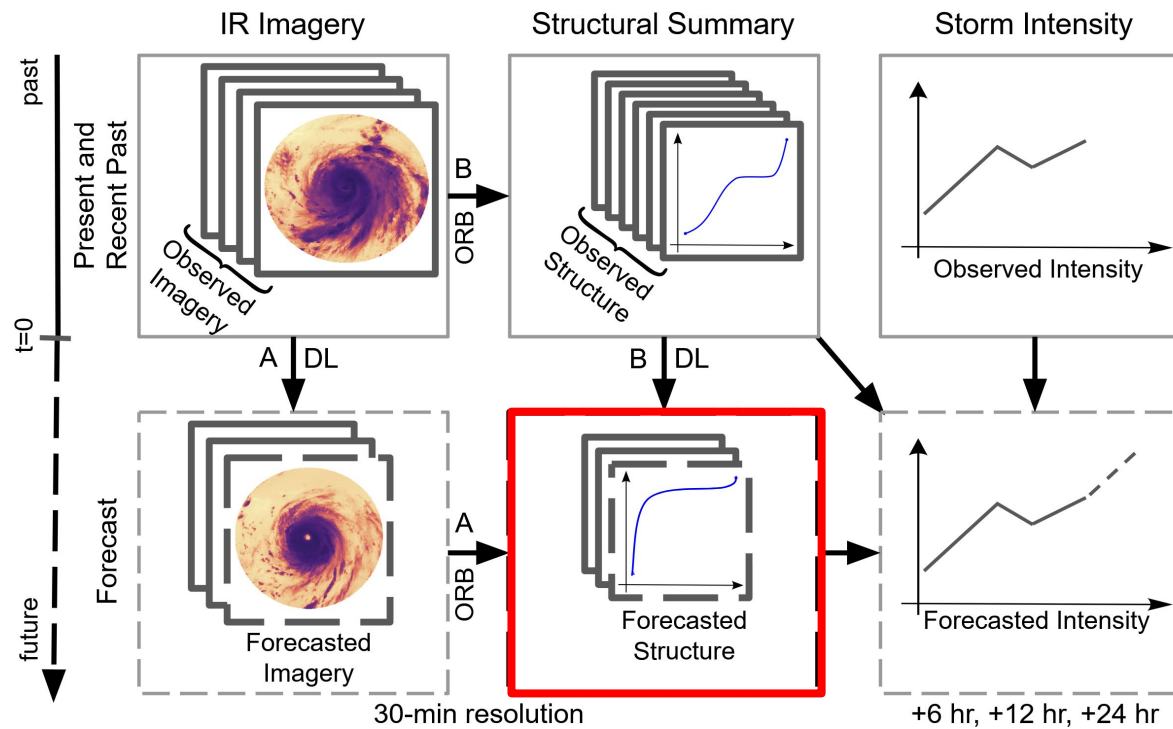
Pathway B

- 1) ORB
- 2) Deep learning

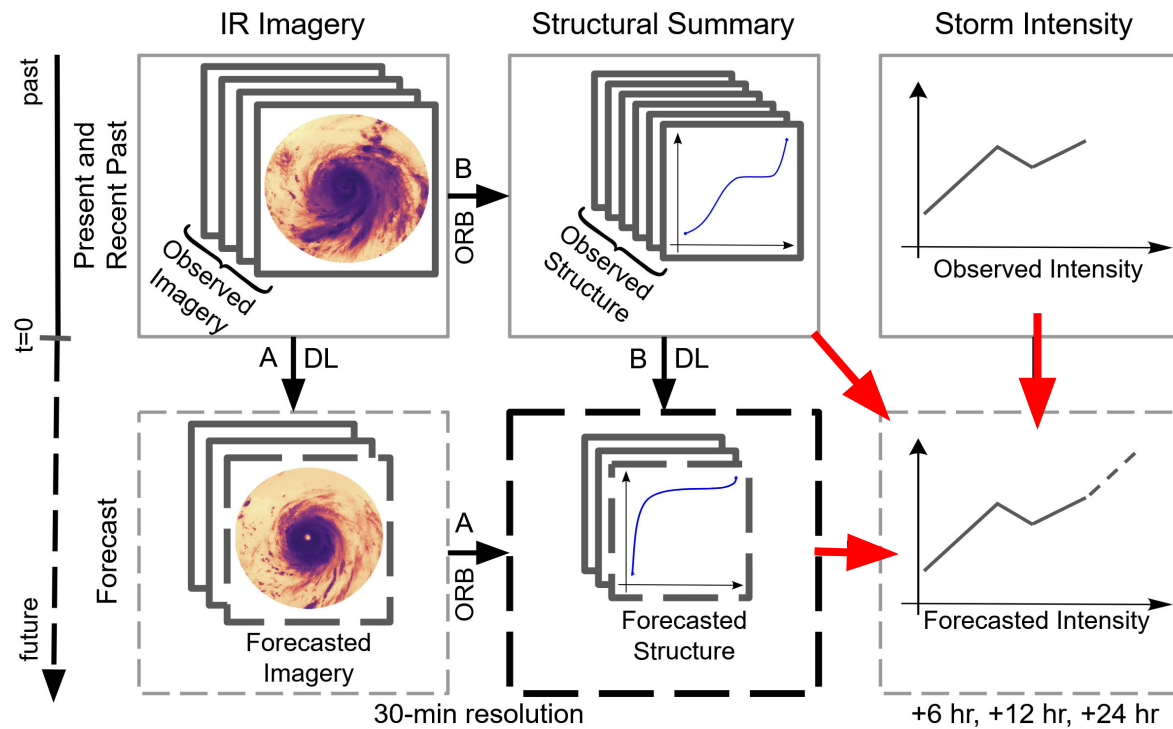




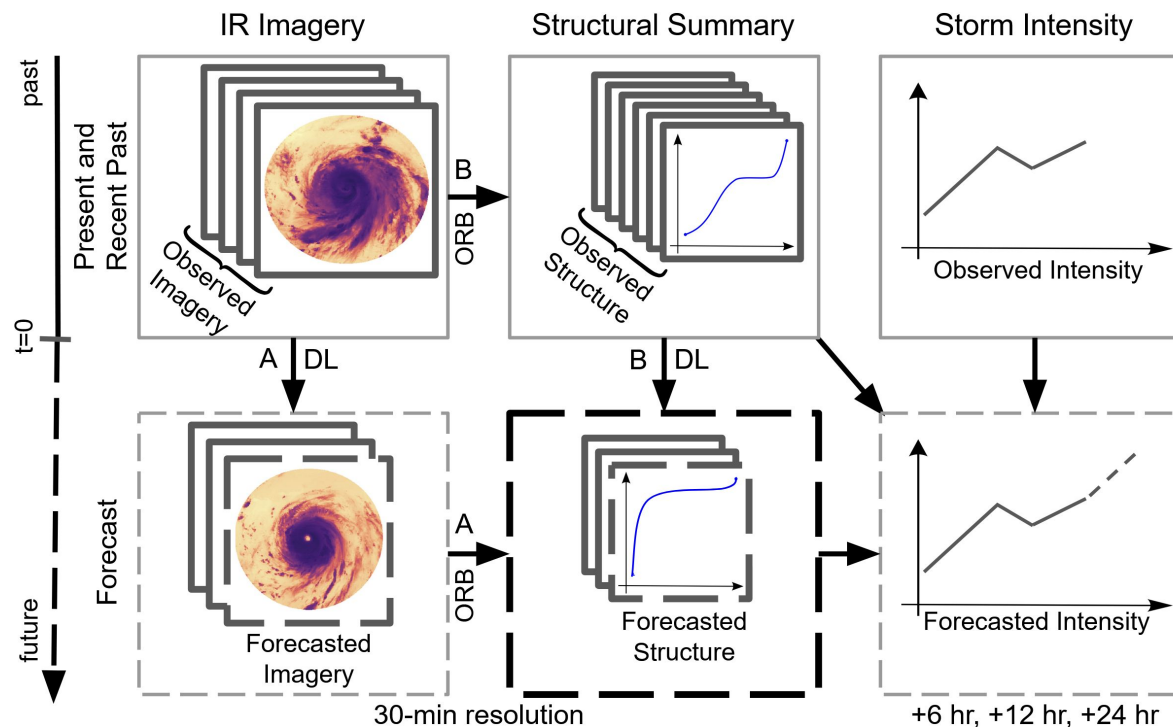
- Summarize IR imagery with ORB functions
- Project ORB functions into near-future
- Apply proven nowcasting models to get intensity forecasts
- Compare results with NHC official forecast and an end-to-end model



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 - Is ORB rich enough?
 - Compare RMS error to benchmarks

Thank You