Evaluation of Retrospective HAFS Forecasts With a Large Airborne Radar Dataset

Andrew T. Hazelton[a,b],

Michael Fischer[a,b], George R. Alvey III[a,b], Lewis J. Gramer[a,b], Robert F. Rogers[a,b], Xiaomin Chen[c], Ghassan J. Alaka, Jr[b], Sundararaman Gopalakrishnan[b], Frank Marks[b]

[a]University of Miami CIMAS, [b]NOAA Atlantic Oceanographic and Meteorological Laboratories, [c]University of Alabama-Huntsville

HAFS Model and Retrospectives

- Hurricane Analysis and Forecast System (HAFS)
- 3-year retros of initial version (2020-2022) of HAFS-B
- Looking to evaluate the model using structure metrics beyond just track and intensity[1]

TC-RADAR Dataset

- TC-RADAR dataset developed by Fischer et al. (2022)[2]
- Compiles P-3 Tail Doppler Radar (TDR) from 1997-present
- We used the "merged analyses" for full coverage

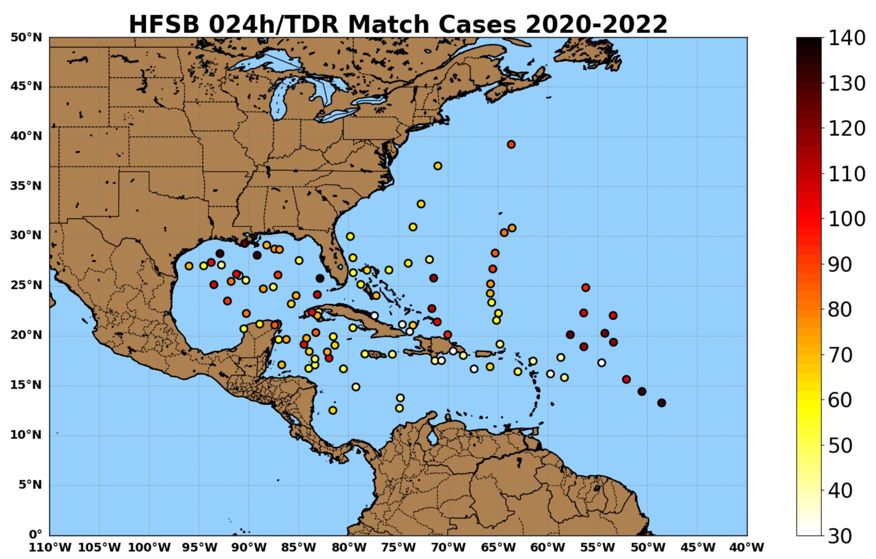

Figure 1: Plot of locations of TCs used in this study. The observed point from TC-RADAR is used. The points are shaded by the maximum intensity of the TC (kt).

Composite Comparisons

- Model data filtered where dBZ < 0 (to simulate real radar)
- HAFS-B composite vortex was too narrow compared to observations

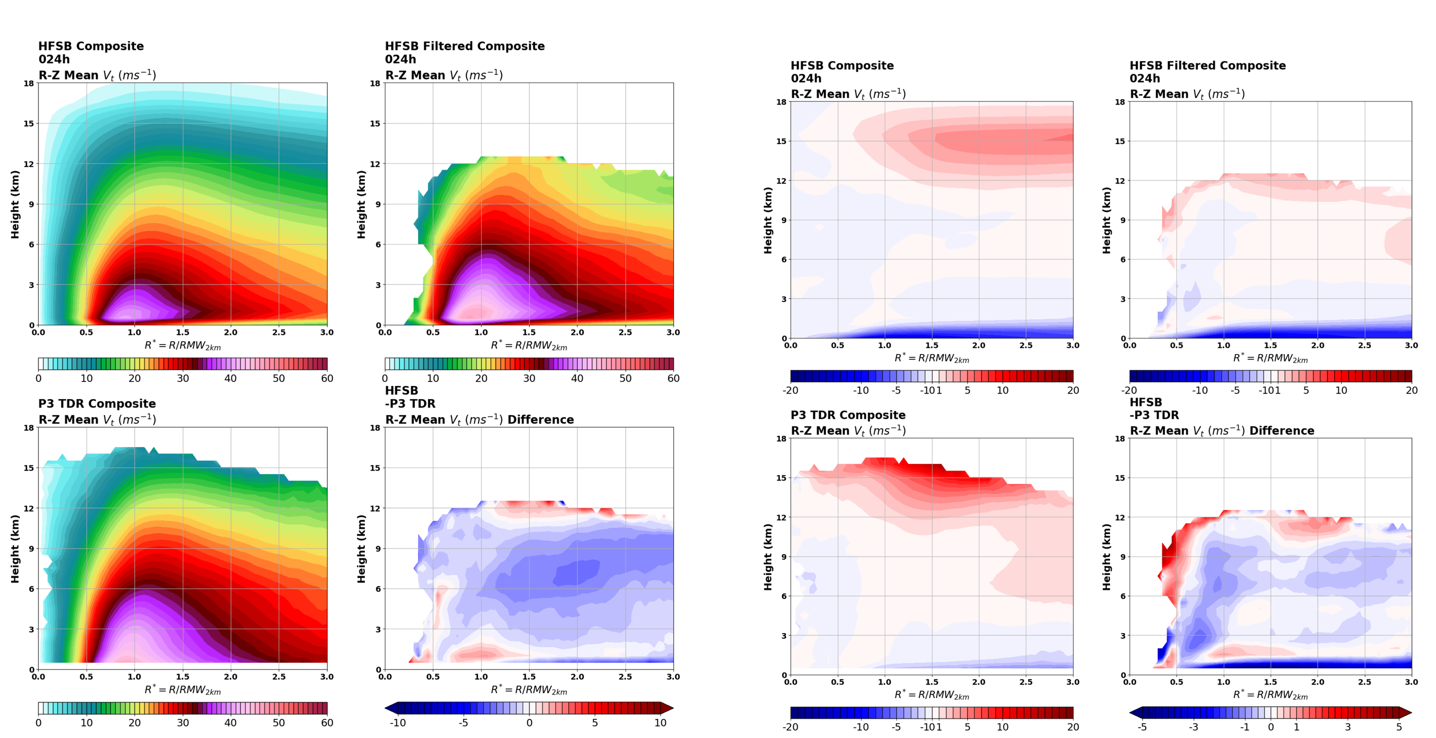

Figure 2: Composites of tangential and radial wind for HAFS-B and the TDR data, along with a difference plot between the model and radar data.

Key Points

1. Airborne radar is a key tool for model evaluation.
2. Composite structure shows that HAFS-B produces vortices that are too narrow.
3. This methodology can be applied to physics comparisons, case studies, etc.

Structure Metrics

- Comparison of several metrics of horizontal and vertical structure, including: RMW, the "alpha" horizontal decay rate[3], Vortex Rossby number, vortex depth[4], and RMW slope[5]
- Negative intensity bias tends to be associated with a positive RMW bias and negative vortex depth bias
- The spread in RMW is larger for larger RMW

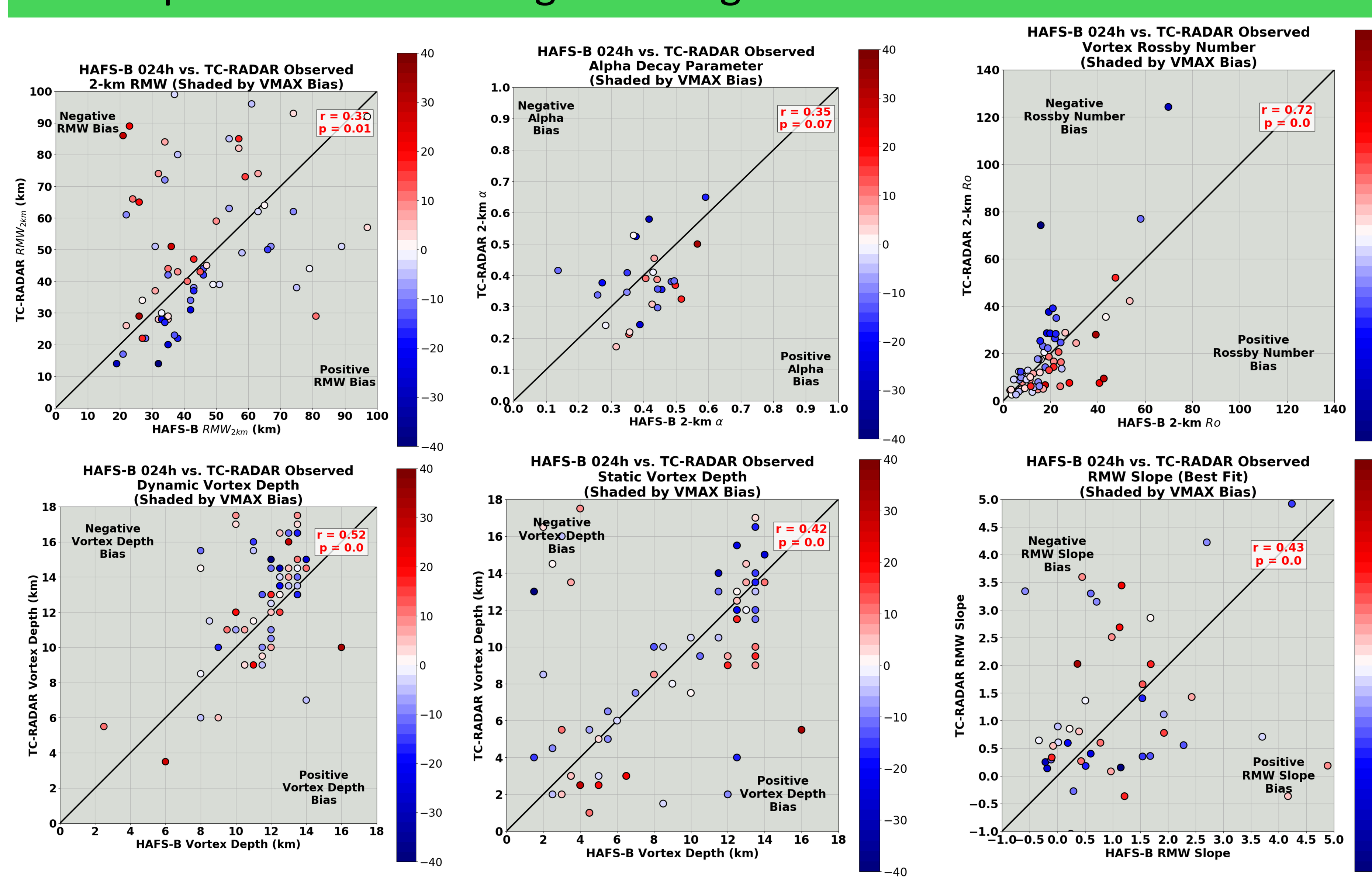

Figure 3: HAFS-B vs. TDR comparisons of horizontal and vertical structure: 2-km RMW, alpha wind decay parameter, vortex Rossby number, dynamic vortex depth, static vortex depth, and RMW slope.

Case Study: Hurricane Ida (2021)

- Vmax was close to observed
- Core was too large (ERC ongoing)
- Too dry on west side (qualitative comparison of dBZ)
- Observed vortex was deeper than forecast

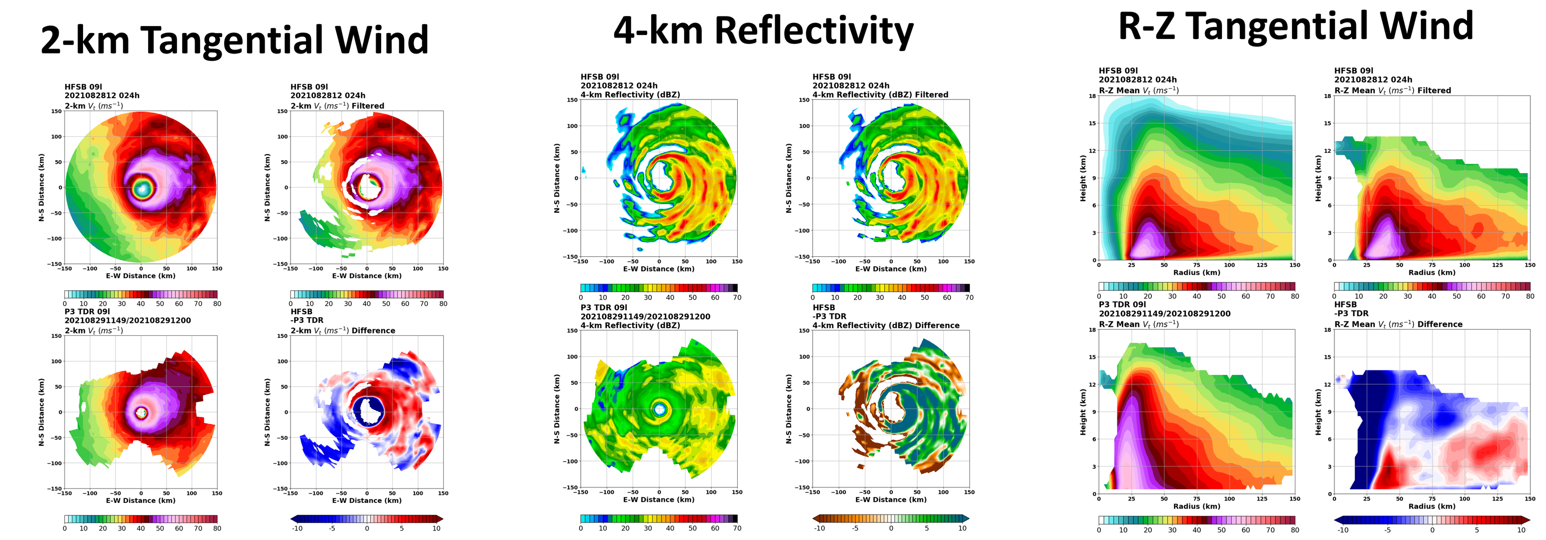

Figure 4: Comparison between a 24-h forecast of HAFS-B for Hurricane Ida and a P-3 TC-RADAR composite. The comparisons include reflectivity and tangential wind.

Application to Physics Study

- 4 experiments with different microphysics and PBL configurations (TC-PBL on/off)[6]
- All compared with TC-RADAR composite
- All experiments produced too narrow of a vortex
- Experiments without TC-PBL were especially weak
- Observations used for model evaluation/improvement

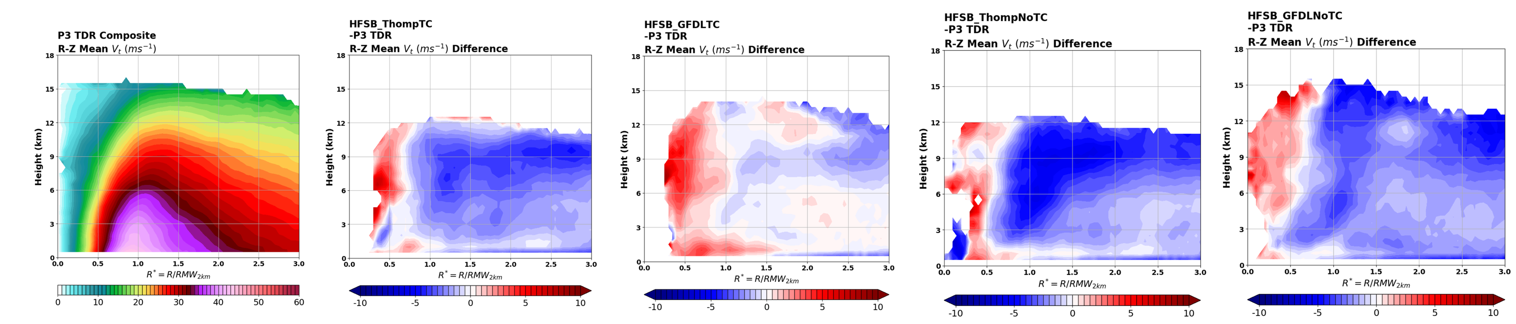

Figure 5: Composites of tangential wind for TC-RADAR and 4 HAFS physics experiments.

Ongoing/Future Work

- Full comparison of HAFS-A and HAFS-B
- Real-time plots including difference plots
- Inclusion of 2023 data (e.g. Franklin, Lee, Idalia)
- New metrics such as vortex tilt

[1]Hazelton, A. T., Harris, L., and S-J Lin, 2018: Evaluation of tropical cyclone forecasts in a high-resolution version of the multiscale GFDL fvGFS model, *Wea. Forecasting*, **33**, 419-442.

[2]Fischer, M. S., Reasor, P. D., Rogers, R. F., and J. F. Gamache, 2022: An Analysis of Tropical Cyclone Vortex and Convective Characteristics in Relation to Storm Intensity Using a Novel Airborne Doppler Radar Database. *Mon. Wea. Rev.*, **150**, 2255–2278.

[3]Mallen, K. J., M. T. Montgomery, and B. Wang, 2005: Reexamining the Near-Core Radial Structure of the Tropical Cyclone Primary Circulation: Implications for Vortex Resiliency. *J. Atmospheric Sci.*, **62**, 408–425.

[4]DesRosiers, A. J., M. M. Bell, P. J. Klotzbach, M. S. Fischer, and P. D. Reasor, 2023: Observed Relationships Between Tropical Cyclone Vortex Height, Intensity, and Intensification Rate. *Geophys. Res. Lett.*, **50**, e2022GL101877.

[5]Hazelton, A. T., Rogers, R., and R. E. Hart, 2015: Shear-relative asymmetries in tropical cyclone eyewall slope, *Mon. Wea. Rev.*, **143**, 883-903.

[6]Hazelton, A. T., Chen., X., Alaka, G. J.. Jr., Alvey, G. R. III, and S. Gopalakrishnan, 2024: Sensitivity of HAFS-B Tropical Cyclone Forecasts to Planetary Boundary Layer and Microphysics Parameterizations, *Wea. Forecasting*, **39**, 655–678.