

Introduction

Phased Array Radar is a major leap in tropical cyclone research, offering fast, high-resolution observations by electronic radar beam steering. The Airborne Phased Array Radar (APAR) concept utilizes this, enabling simultaneous kinematic and microphysical measurements, which are critical for understanding changes in tropical cyclone (TC) intensity and structure. Radar simulator software like AOSPRES help test the accuracy of retrievals and guide the development of future airborne radar systems.

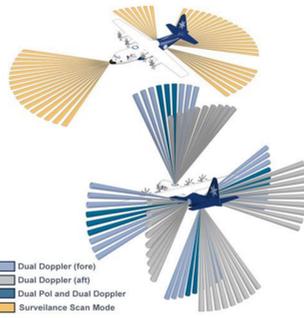


Figure 1. APAR Concept (UCAR Comet)

Tropical cyclone (TC) kinematics involve both the primary (tangential winds) and secondary (radial and vertical) circulations, which together govern storm structure and intensity. Vertical wind shear can disrupt storm alignment and induce asymmetries, making it a key factor in understanding TC intensity change.

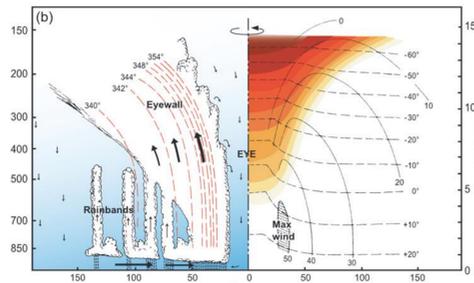


Figure 2. Radial and vertical wind cross section (left) and tangential velocity (right) illustration of a tropical cyclone (Wallace and Hobbs, 2006)

Research Goal

Use AOSPRES and SAMURAI deduced 3D wind fields to investigate tropical cyclone structure.



Methods

AOSPRES

The APAR Observing Simulation, Processing, and Research Environment (AOSPRES) is a virtual environment used to simulate radar properties measured along a hypothetical APAR flight path. This allows for radar performance testing, interpretation of complex storm processes by utilizing resulting dual-pol and kinematic variables.

SAMURAI

Spline Analysis at Mesoscale Utilizing Radar Aircraft Instrumentation (SAMURAI) is a 3D variational data assimilation tool that uses cubic b-splines to find the most likely state of the atmosphere given a set of observations. (Cha and Bell 2023) The output is high resolution cartesian wind field variables (u, v, w), used to compute radial and tangential wind components.

Results & Discussion

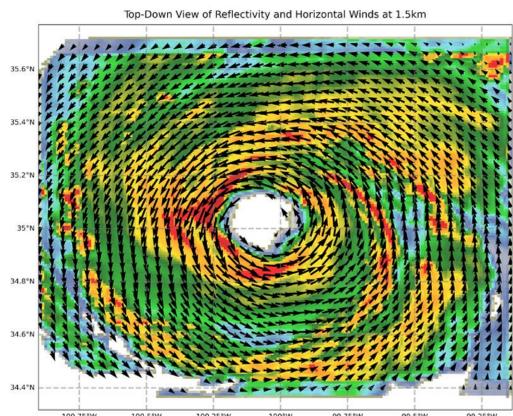


Figure 3. Earth-relative top-down horizontal view simulated tropical cyclone with reflectivity contours and wind quivers at 1.5km

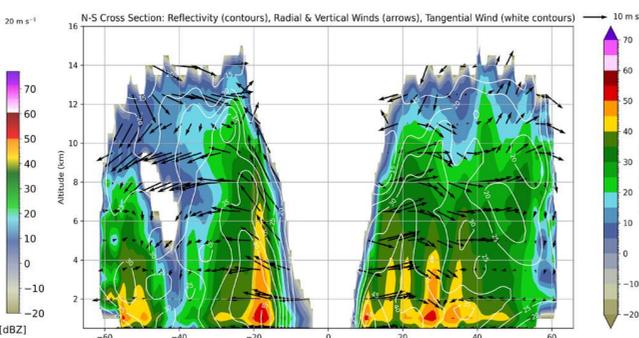


Figure 4. Earth-relative N-S vertical cross-section of simulated reflectivity, tangential wind magnitude (white contours) and radial/vertical wind quivers (black arrows)

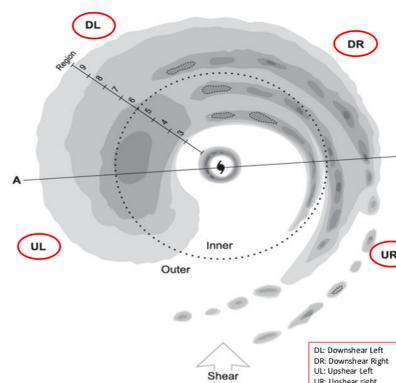


Figure 5. Idealized plan-view of a tropical cyclone as affected by environmental shear (Hence & Houze, 2011)

- Figure 3 shows a top down horizontal plan view, while Figure 4 presents a vertical cross-section of primary and secondary circulations, highlighting stronger winds near the eyewall and lower levels.
- Past studies prove that the intensity, evolution, and structure of TCs are affected by environmental shear and quadrant analysis (Figure 5) simplifies the understanding of the resulting asymmetries.

- Applying a 298° (8.2 m/s) shear (Figure 6) to the earth-relative quadrant analysis (Figure 7) results in stronger tangential winds, and low-level inflow which supports convection in the DL, while the UL exhibits suppressed convection (Figure 8). Vertical wind shear tilts the vortex, enhancing convergence and inflow downshear, consistent with literature findings.

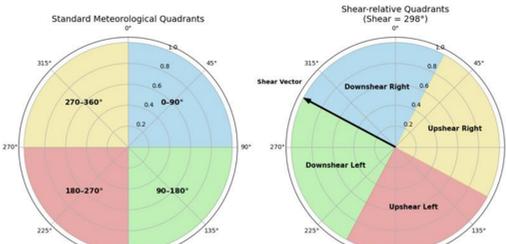


Figure 6. Comparison of earth-relative (meteorological) quadrants and shear-relative quadrants with a 298° environmental wind shear applied.

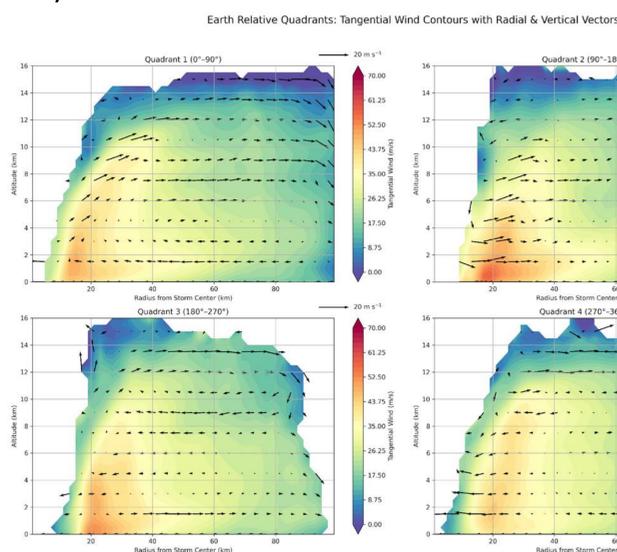


Figure 7. Earth-relative quadrant analysis with tangential wind magnitude and radial and vertical wind vectors

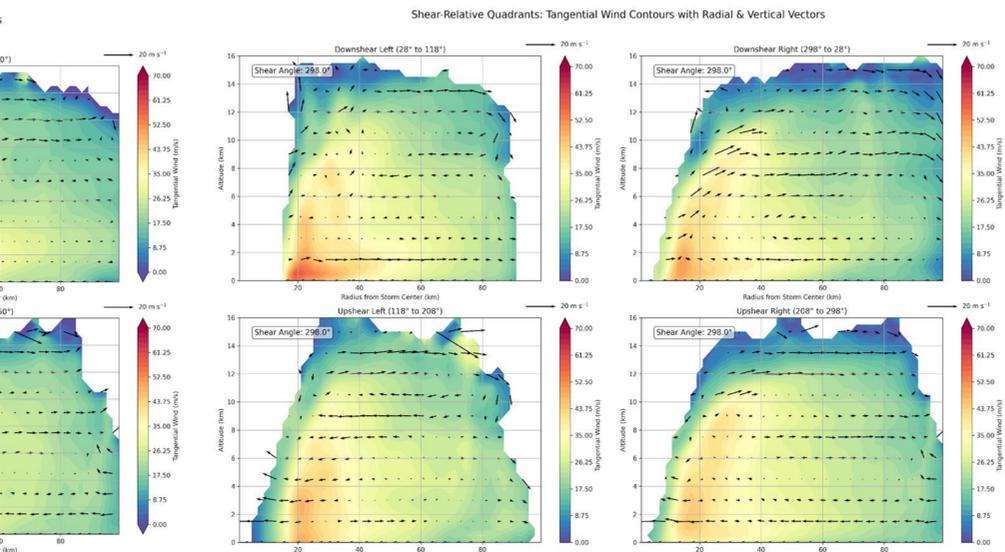


Figure 8. Shear-relative quadrant analysis with tangential wind magnitude and radial and vertical wind vectors

Summary

- The SAMURAI analysis was successfully completed, reconstructing high-resolution 3D wind fields. Results were compared to prior studies for validation.
- Concepts like APAR will aid in understanding TC dynamics.
- Environmental wind shear is a critical factor in TC dynamics analyses.

Future Work

- Future studies can include kinematic and microphysical analysis of tropical cyclones to achieve the full picture.
- By relating hydrometeors via Particle Identification Diagrams (Figure 9) to kinematic properties within specific quadrants as affected by shear, the connection between microphysics and storm dynamics becomes clearer.

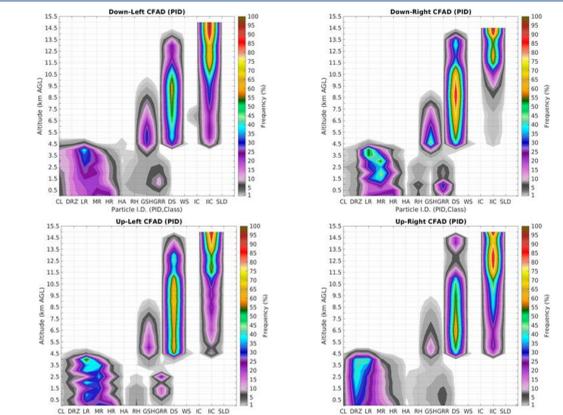


Figure 9. Particle Identification Diagrams generated from AOSPRES under 298° environmental shear

References and Acknowledgements

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