Multi-Doppler Radar Analysis of Hurricane Matthew's Eyewall Replacement Cycle

Authors: Alex DesRosiers[1], Ting-yu Cha[2], Michael Bell[2], and Jonathan Martinez[2]

1. University of Florida Department of Environmental Engineering Sciences 2. Colorado State University Department of Atmospheric Science

Introduction

In an eyewall replacement cycle (ERC) a secondary concentric eyewall forms from rain bands around the original one. The ERC process occurs in a mature tropical cyclone (Houze et al. 2007) due to mechanisms still up for debate. During Hurricane Matthew's passage through the Bahamas and along the Florida Coast in 2016, it began an ERC. This phenomena occurred in close proximity to land allowed for it to be observed on both the NOAA WP-3D's Tail Doppler Radar (TDR) and Miami's NEXRAD ground based radar simultaneously. The suite of observations allowed for a triple Doppler analysis of four complete passes through Hurricane Matthew while the secondary eyewall was strengthening and the primary was decaying. This study adds new observations in an effort to gain more information about the eyewall replacement cycle in tropical cyclones.

Data

- NOAA WP-3D 3-cm TDR
- KAMX NEXRAD 10-cm Doppler Radar
- LROSE Lidar Radar Open Software Environment
- Hurricane Research Division Wind Center Fixes
- Best Track Data (HURDAT 2)
- SHIPS Wind Shear
- Solo II QC Algorithm
- SAMURAI 3DVAR Analysis

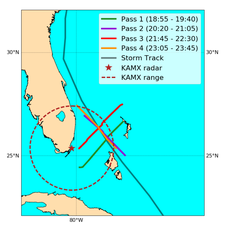


Figure 1. Data collection locations

Process

- Convert TDR data to sweep files and run them through the medium solo-based automated quality control algorithm.
- Manually edit the sweeps for all four passes in Solo II in addition to the automated QC to remove incorrect data.
- Compile sweeps for each pass into a 3D analysis netCDF file using SAMURAI and evaluate it for any further QC that may be needed.
- Edit KAMX radar data using Solo II.
- Using differences derived from the KAMX radar, reflectivity bias corrections were applied to the TDR data.
- Run SAMURAI using the edited TDR data from each pass and the edited KAMX sweep closest to the HRD wind center fix time of each pass to create a triple Doppler analysis.
- Plot the resulting NetCDF analysis files to document the evolution of Matthew's core during the ERC.

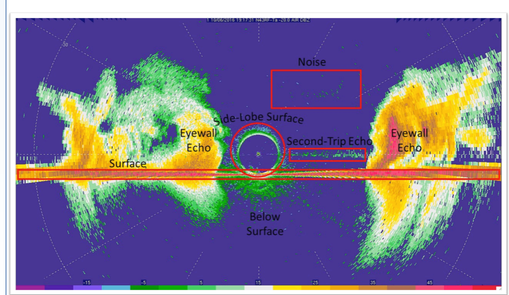


Figure 2. Sample TDR radar sweep displayed in Solo II radar editing software before editing taken from the eye of Hurricane Matthew. This Sweep shows the non-meteorological features that will be removed in the QC process.

Radar Quality Control

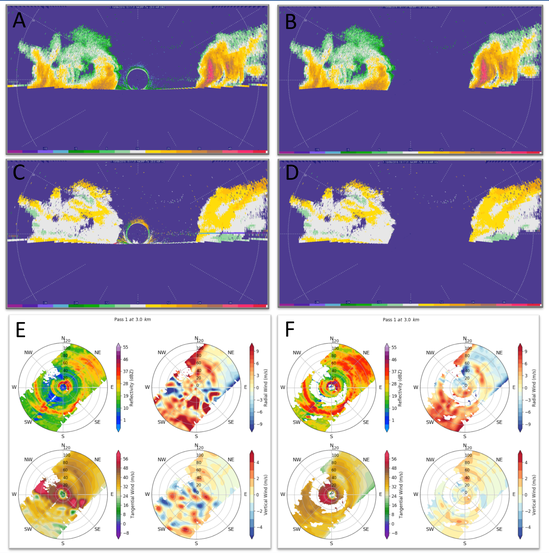


Figure 3. An example reflectivity field after the QC algorithm is applied (A) and after manual QC (B). An example velocity field after the QC algorithm is applied (C) and after manual QC (D). A 3km vertical level cross section of the resulting Samurai analysis after the QC algorithm (E) and after manual QC (F).

- False data removed by the manual QC process improves the analysis' representation of the storm.
- A tangential wind maximum incorrectly stretches across the TDR coverage swath prior to manual QC.
- Vertical and radial wind components become more realistic after the manual QC process takes place.
- The noise removed from the moat reveals clear air.

Azimuthally Averaged Evolution

Figure 4. Secondary circulation and reflectivity

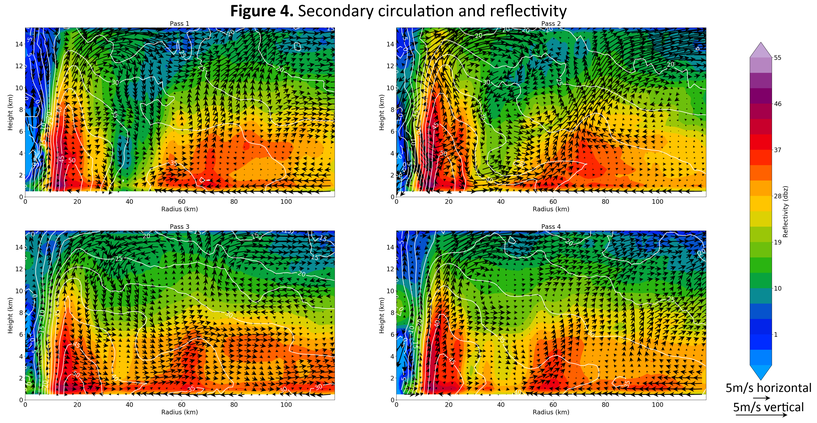


Figure 5. Vorticity and angular momentum

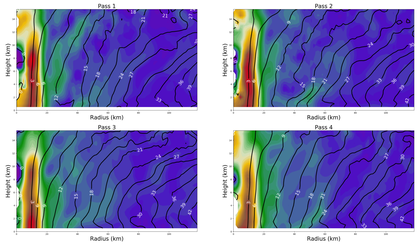


Figure 6. Expansion of the primary circulation

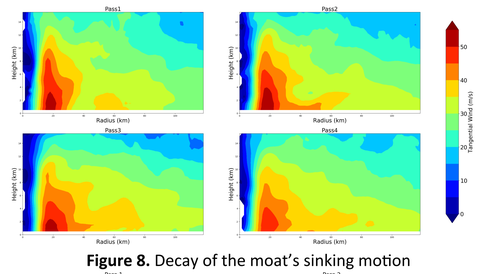


Figure 7. Blocking of radial inflow

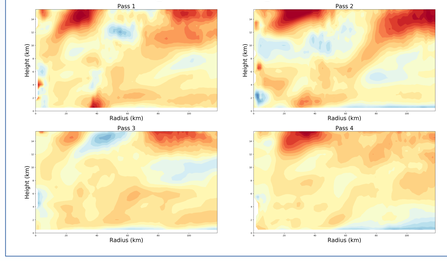
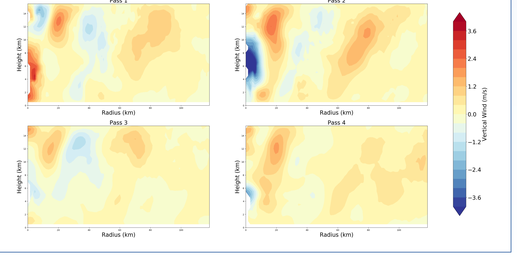


Figure 8. Decay of the moat's sinking motion



Changing Vertical Wind Shear

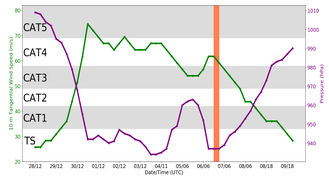


Figure 9. Matthew's intensity

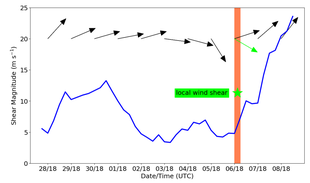


Figure 10. Wind shear affecting storm

- Matthew began to approach less favorable vertical wind shear during the analysis time highlighted in orange.
- The adverse conditions caused Matthew to begin weakening and continue to do so until dissipation.

Discussions and Limitations

- There is an appreciable difference between the analysis produced by the automatic QC algorithm and analysis that has also undergone manual QC.
- There is a clear blocking of inflow to the primary eyewall being caused by the secondary eyewall consistent with findings in Hurricane Rita's ERC. (Bell et al. 2012)
- Throughout the passes, the moat decays and fills while its sinking motion weakens.
- Minor limitations impacted this study:
  - Attenuation in the 3-cm radar makes the signal farther away from the radar weaker.
  - Subjectivity is introduced in the manual QC process.

Conclusions

- The blocking of radial inflow caused by the secondary eyewall likely contributes to the decay of the primary eye wall.
- The expansion of the wind field during this ERC is evident.
- The increase in vertical wind shear prevented Matthew from fully completing its ERC and re-intensifying after.
- Manual QC is vital to the quality of the retrieved wind field

Future Improvements and Work

- A shear relative analysis will help determine what kind of role the outside environment played in interrupting this ERC.
- This data set does not capture the entire ERC and an analysis of flights before and after this time period would be beneficial.
- A thorough analysis of the vortex dynamics of Matthew's ERC can shed light on the mechanisms responsible for both the decay of the moat region and collapse of the primary eyewall.

Acknowledgements

This work has been supported by the National Science Foundation Research Experiences for Undergraduates Site in Climate Science at Colorado State University under the cooperative agreement No. AGS-1461270.

References

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