Impacts of Mesovortices on the Evolution of Hurricane Harvey (2017)

A. Addison Alford[1] and Michael I. Biggerstaff[1,2,3]

[1]School of Meteorology, University of Oklahoma, Norman, OK; [2]Cooperative Institute for Mesoscale Meteorological Studies, University of Oklahoma, Norman, OK; [3]Advanced Radar Research Center, University of Oklahoma, Norman, OK

1. Introduction

- Asymmetric dynamics are vital to tropical cyclone (TC) evolution before and during landfall.
- Mesovortices/vortex Rossby waves (VRWs; e.g., Montgomery and Kallenbach 1997) impact the evolution of primary vortex. However, the attendant symmetrization process (i.e. impact to primary vortex) has not been observed in high temporal resolution. Local impacts (i.e. instantaneous flow) are also difficult to observe.
- Hurricane Harvey (2017) provides an opportunity to examine both from ground-based platforms.

2. Data and Methods

- The Shared Mobile Atmospheric Research and Teaching (SMART) radar 2 (Biggerstaff et al. 2005) collected ~18 hours of data.
- Radial velocity data were processed objectively by Py-ART (Helmus and Collis 2016) and subjectively by Solo3. The data were interpolated to a Cartesian grid via Natural Neighbor interpolation.
- The WSR-88D in Corpus Christi, TX (KCRP) was similarly processed.
- The two radar datasets were objectively analyzed via 3DVAR dual-Doppler wind synthesis (Potvin et al. 2012) to retrieve the 3-D flow.
- Analysis resolution is 1 km in the horizontal and vertical. The origin of the analyses is centered at KCRP.

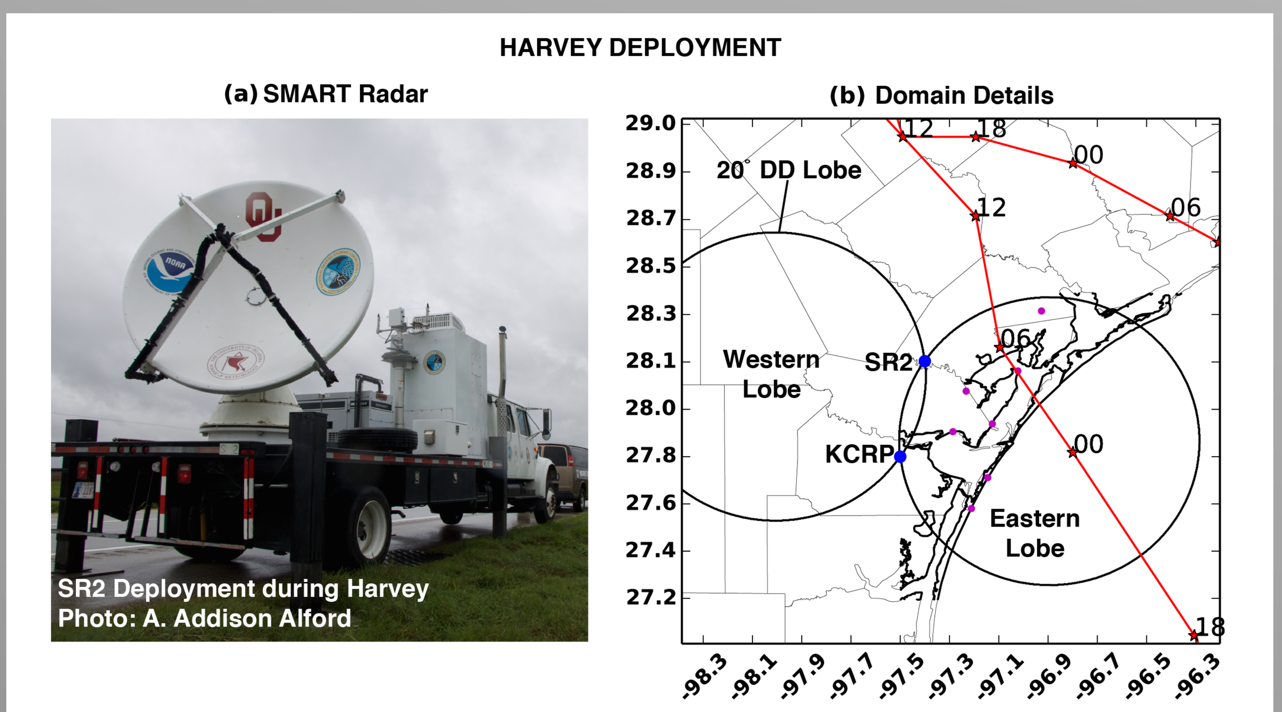
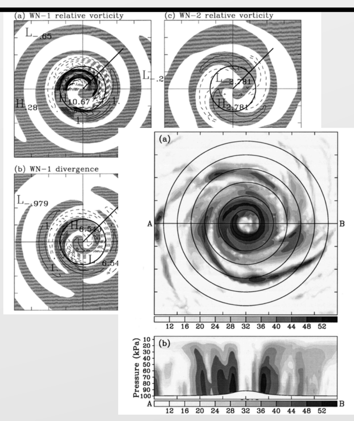


Fig. 1. (a) Photo of SMART Radar 2 during Hurricane Harvey. (b) Schematic showing Harvey's track (red line) through the KCRP-SR2 dual-Doppler domain (black circles). The purple dots denote Texas Tech StickNet positions.

3. Impacts to Vortex



- Ideal simulations (right, Wang 2002, JAS) show rainbands coupled to axisymmetrizing VRWs emanating from eyewall asymmetries.
- Between 21 UTC to 23 UTC on 25 Aug. 2017, multiple convective rainbands formed from vorticity asymmetries propagating around eyewall over the ocean. The rainbands were quickly sheared, suggesting VRW propagation was suppressed in general.
- Concurrently, the symmetric component (wavenumber [WN] 0) of vorticity increased beginning near 2240 UTC. At radii between 18-25 km from the center of circulation, low WN components significantly reduced and WN0 components increased rapidly.
- Dual-Doppler maximum observed winds also increased.

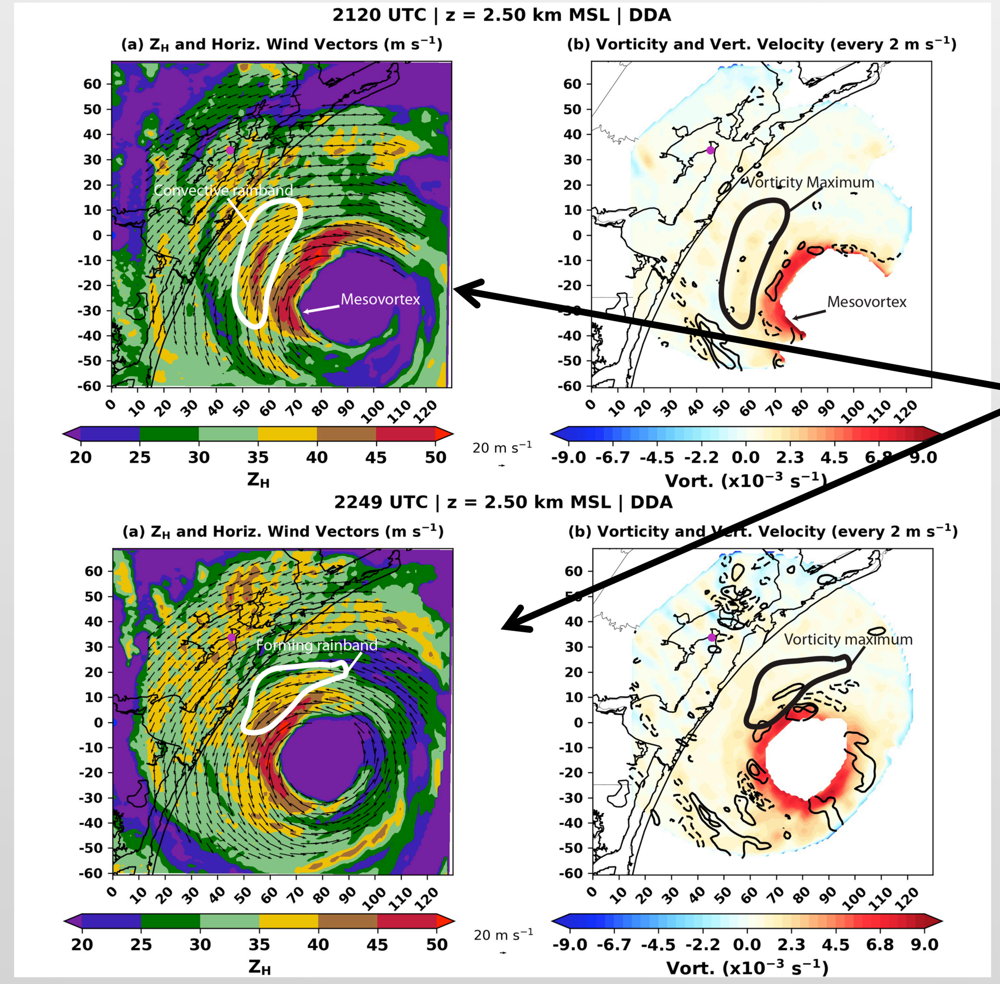


Fig. 2. Dual-Doppler analyses at 2120 and 2249 UTC. (a) In each analysis, radar reflectivity is shaded and horziontal wind vectors are overlain. (b) Vertical vorticity is shown in the shading and vertical velocity is indicated by the black contours (every 2 m s^{-1} excluding the 0 m s^{-1} contour).

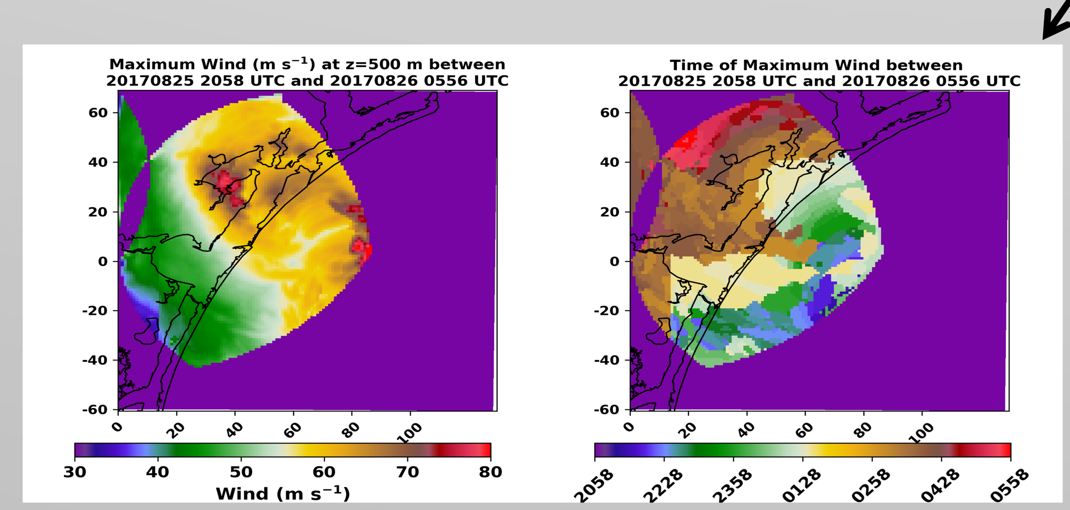


Fig. 3. (a) Maximum dual-Doppler observed wind at 500 m. (b) The dual-Doppler analysis time at which the maximum wind was observed.

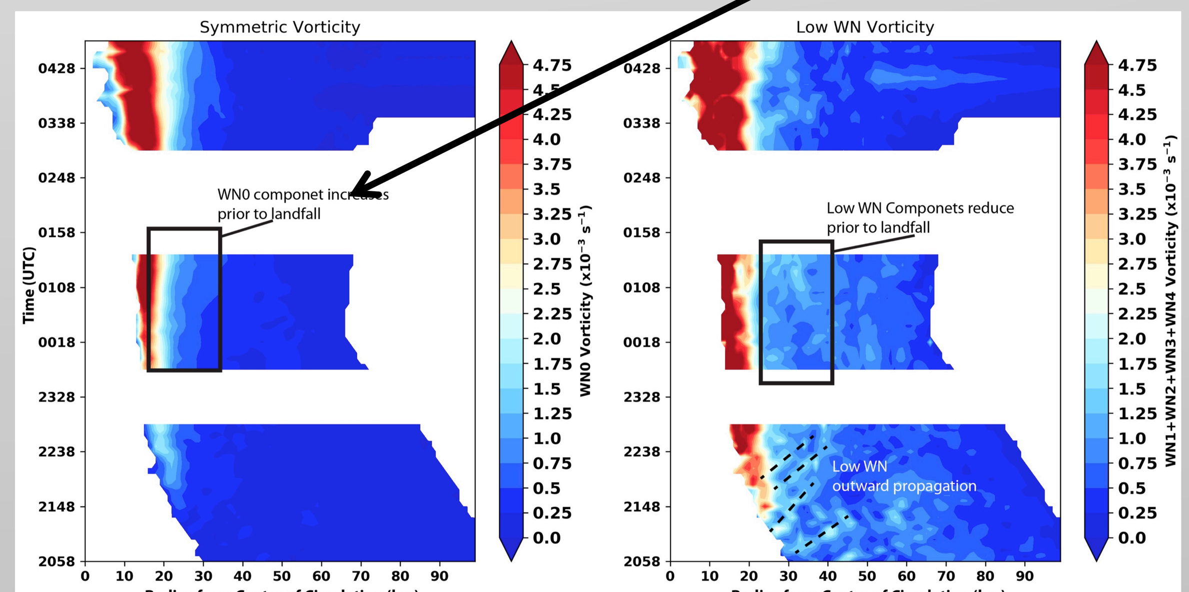


Fig. 4. Hovmoller diagram of (a) WN0 radial vorticity and (b) low WN radial vorticity prior to and during Harvey's landfall. The dashed lines in (b) indicate likely outward propagating VRWs with phase speeds 4-6 m s^{-1}.

4. Mesovortices at Landfall

- Observations of mesovortices/VRWs suggest tangential and radial wind maxima exist with at least some structures aloft.
- Mesovortices were observed to propagate against the mean wind (not shown), suggesting mesovortices were tied to VRW processes.
- The strong radial component of winds suggest redistribution of potential vorticity is possible. Radial inward (outward) advection of barotropic vorticity was observed on the downwind (upwind) portion of mesovortices at 500 m.
- During landfall (shortly after 0300 UTC), the maximum winds observed aloft did not decrease until near 0400 UTC in the dual-Doppler analyses.
- Mesovortices/VRWs and attendant momentum redistribution were likely responsible for Harvey maintaining its strength aloft.

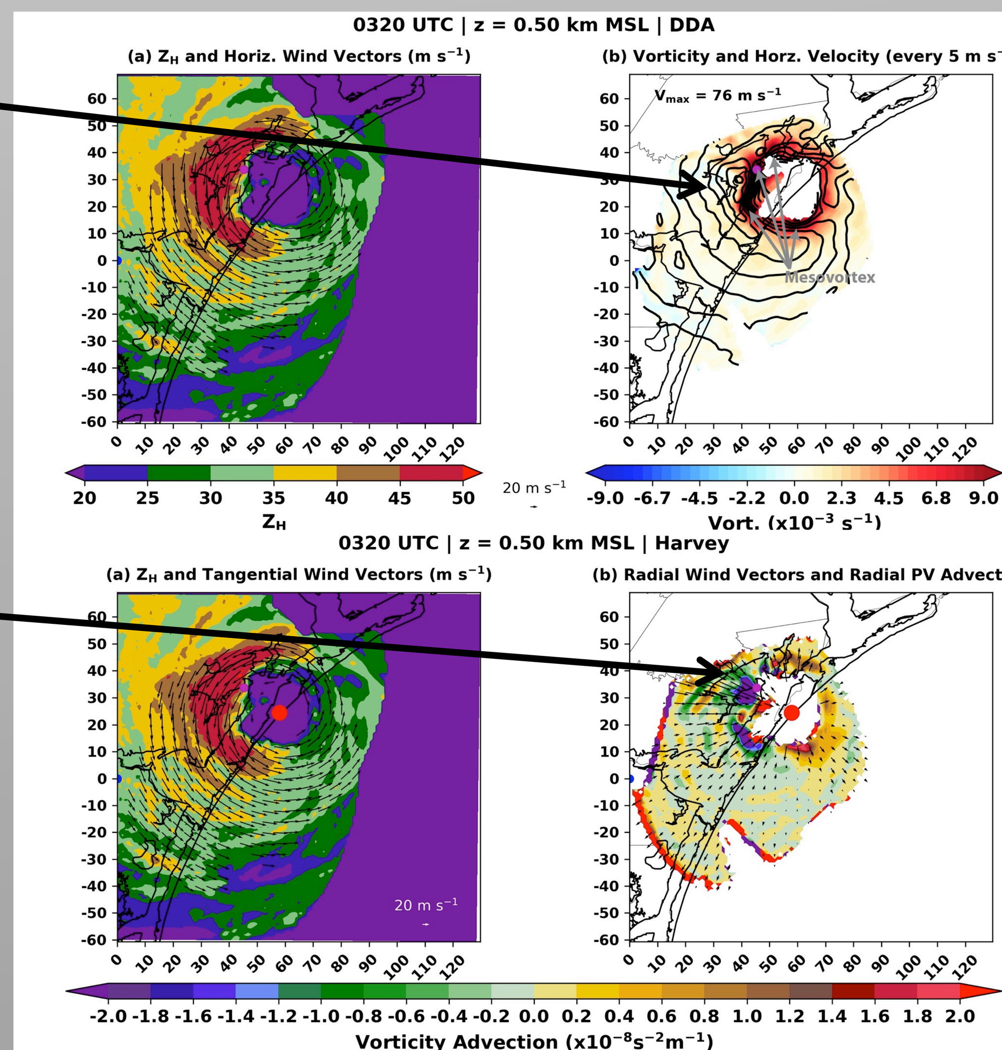


Fig. 5. Dual-Doppler analysis at 0320 UTC on 26 August 2017. (a) Radar reflectivity (shading) and horizontal wind vectors are shown. (b) Vertical vorticity (shading) and horizontal winds (contours) are shown. (c) As in (a), but the wind vectors are the tangential component of the wind relative to the objectively identified center of circulation. (d) The radial component of the winds are shown by the vectors and the radial advection of barotropic PV shaded.

5. Impacts at Surface

- 500 m winds were projected to 10 m using a standard log profile (Alford et al. 2018, GRL).
- Projections had a RMSE of ~4 m s^{-1} compared to Texas Tech StickNets.
- The strongest surface winds were associated with mesovortices (5-10 m s^{-1} perturbation relative to background flow).

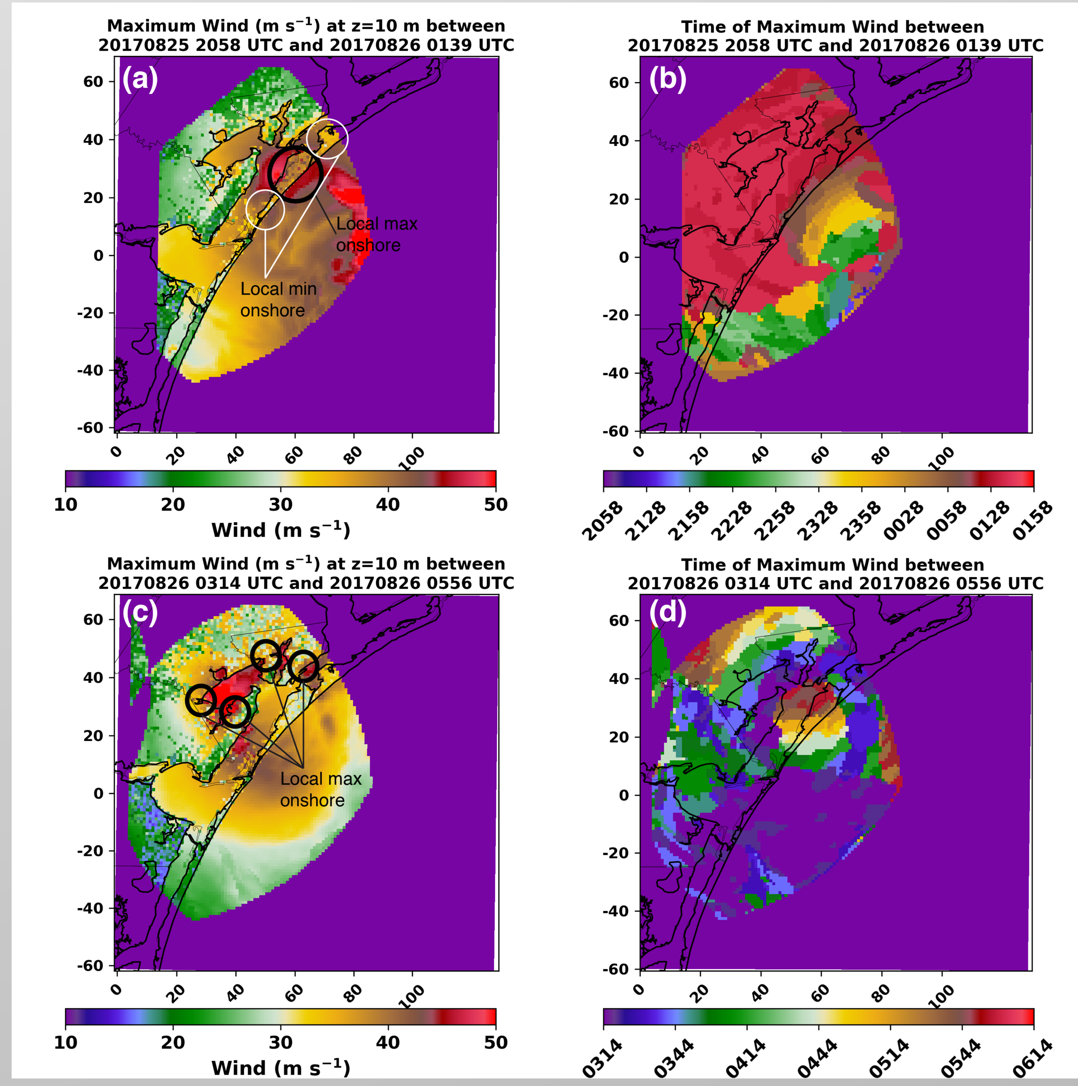


Fig. 6. As in Fig. 3, but for the 10 m wind. Figure 3 of Alford et al. (2018, GRL).

6. Conclusions

- VRW and mesovortex processes resulted in the partial symmetrization of Harvey prior to landfall. This represents the first high temporal resolution verification of modeled VRW intensity feedbacks over the ocean.
- Mesovortices/VRWs at landfall redistributed momentum in the inner core, allowing Harvey to maintain intensity at landfall.
- 10 m wind estimates suggest mesovortices/VRWs play a key role in the distribution of maximum winds that impact coastal communities.

Acknowledgements

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References

Contact

Email: addisonalford@ou.edu
Twitter: @addisonalford
Twitter: @OU_SRs