SCIENCE

Automated Detection and Characterization of Mesocyclones in X-band Radar Observations

Student researcher: Raychel E. Nelson, Senior

Purdue University is about 70 km from the nearest National Weather Service WSR-88D radar in Indianapolis, Indiana. When combined with the curvature of Earth and variations in atmospheric density, this distance corresponds to a beam height greater than 1 km above ground level, with little to no observation of the lower atmosphere over campus. This is a problem because the meteorological phenomena that pose the largest threats to life and property (e.g. tornadoes, microbursts) develop at these low altitudes.

The X-band Teaching and Research Radar (XTRRA) was installed atop Wang Hall near the Purdue University campus in 2018. Because of its proximity to the campus, the XTRRA provides observations of the lower atmosphere above campus, an area that operational National Weather Service radar beams overshoot. Now that XTRRA data (e.g., Figures 1a, b) are available, we can capitalize on the potential of having a weather radar in our backyard.

In this study, we developed an algorithm to automatically detect and characterize mesocyclones using XTRRA observations. Starting from XTRRA Doppler velocity returns (e.g., Figure 1b), we first calculate the azimuthal shear (e.g., Figure 1c). Next, we evaluate how much area is covered by gates with azimuthal shear equal to or greater than a predefined threshold (e.g., Figure 1d). We tested different thresholds for mesocyclone strength and found that a threshold of 0.005 s^{-1} was optimal for detection.

Future work includes refining this algorithm to enumerate specific storm objects in order to verify areas of high azimuthal shear as mesocyclones. Because many Doppler velocity signatures mimic those of mesocyclones (e.g., Figure 1d), additional quality control is needed. Once the algorithm is refined and fully tested, we plan to incorporate it into a hazardous weather warning system for the Purdue campus.

Research advisor Robin L Tanamachi writes: "Raychel Nelson's research explores how the XTRRA data can be used to create more timely and accurate weather warnings for Purdue's population. Gap-filling radars are already used to augment tornado warnings in the southern Great Plains; Nelson's research seeks to expand this practice to the Great Lakes region."

(a) XTRRA radar reflectivity (in dBZ), (b) Doppler velocity (in $m s^{-1}$), (c) azimuthal shear (in s^{-1}), and (d) regions of azimuthal shear $\geq 0.005 s^{-1}$ at 23:30:04 UTC on May 27, 2019, of an approaching squall line. The elevation angle of 2.4 degrees corresponds to about 2 km above ground level at a range of 45 km from the radar, where the mesocyclone of interest lies (d, circled in orange). Other areas of high azimuthal shear shown in (d) are nonmesocyclone false positives that need to be eliminated by further quality control.