Flexible Array of Radars and Mesonets (FARM) statement concerning preliminary peak wind speed determinations based on Doppler On Wheels (DOW) data obtained in the Greenfield, Iowa tornado of 21 May 2024

Summary: (23 June 2024)

A Doppler On Wheels (DOW) mobile radar deployed just east of Greenfield, Iowa on 21 May 2024. DOW scientists calculate peak wind speeds as high as 309-318 mph occurred in a narrow region on the right side of the tornado. Since the tornado was very small and fast moving, these peak winds were likely experienced for less than a second at specific locations in town. These are among the highest wind speeds ever determined using DOW data.

All wind speed determinations in tornadoes have uncertainty (damage-based determinations have very large uncertainty and sampling biases), and are not accurate to an exact mph values. Therefore, scientists report tornado wind speeds within a range, or with uncertainty.

These values are preliminary and detailed analysis is ongoing.

—---

More detail:

The DOW scanned over Greenfield at heights of about 30-50 m (100-160 feet) above the ground every 7 seconds, measuring Doppler velocities.

The tornado was unusually small and was narrowing as it passed through town. It was moving very fast, at nearly 45 mph (20 m/s). The DOW directly measured Doppler velocities as high as 263-271 mph (118-121 m/s). DOW measurements are used to calculate peak tornado wind speeds using methods described in Wurman et al (2021a) and an upcoming American Society of Civil Engineering (ASCE) formal standard for determining tornado wind speeds from proximate radar measurements. DOW scientists calculate peak ground-relative wind speeds, in a very narrow swath to the immediate east of the path of the center of the tornado circulation, as high as 309-318 mph (138-142 m/s). Since the tornado was very small and fast moving, these peak winds were likely experienced for less than a second at specific locations in town.

DOW measurements have resulted in peak wind speed determinations of over 300 mph in only two other tornadoes. Wurman et al. 2007 originally reported 302 mph in the Bridgecreek, Oklahoma, 3 May 1999 tornado. This was subsequently revised upwards in Wurman et al. 2021, to 321 mph, using improved techniques. Wurman et al. 2014 reported 291-336 mph and Bluestein et al. 2015 reported 313 mph in extremely small extremely rapidly moving sub-tornado scale vortices in the El Reno, Oklahoma 31 May 2013 tornado. In this case, these would have resulted in very short, much less than one-second wind gusts.

—---

Background concerning radar measurements in tornadoes:

Traditional direct wind speed measurements using anemometers are nearly impossible in the most intense portions of violent tornadoes. It is exceedingly rare that anemometers are in the exact right place at the exact right time. And, even if they were, they would likely be destroyed by flying debris. So, to determine wind speeds in the most intense parts of violent tornadoes, other methods, including damage assessment and radar measurements are used.

Radar-measured Doppler velocities are different than anemometer wind measurements.

1. Doppler radars measure the speed of airborne objects, usually raindrops or slowly flying insects. But, in the case of tornadoes, radars measure the speed of airborne debris, which in the case of violent tornadoes crossing

neighborhoods, includes branches, trees, portions of houses, rocks, and other large objects. Typically these move more slowly than the wind. See Dowell et al. (2005) and Kosiba and Wurman (2023).

2. Radars measure winds well above the surface, higher than most surface-mounted anemometers. In Greenfield, the measurements were at 100-160 feet above the ground, well above most structures. Recent research suggests that winds at these levels are less intense than those near the surface. See Kosiba and Wurman (2013, 2023). We do not adjust wind speeds for this factor since we don't yet know enough about how wind speeds in individual tornadoes vary with height.

3. Radars measure the average velocity of objects in volumes, not at precise points. Therefore, peak measured velocities are less than those occurring at individual points in these volumes. See Burgess et al. (1993) and Wurman et al. (2021b). The methods used to adjust raw Doppler speeds to peak ground-relative speeds correct for this smoothing.

4. Radars only measure the component of the velocity which is towards and away from the radar. Sideways components are not measured. So, the speed of objects moving at angles to the radar beams are underestimated. The methods used to adjust raw Doppler speeds to peak ground relative speeds use the speed and direction of the tornado to correct for this factor.

5. Peak wind gusts determined using Doppler radar measurements may occur for different durations at individual locations. In the particular case of Greenfield, the tornado was very small, and the tornado was moving so fast, up to 45 mph. So, the peak DOW-determined wind gusts lasted for only very short periods, probably about ⅕ to 1 second.

—---

Selected References:

D. W. Burgess, R. J. Donaldson Jr., P. R. Desrochers, “Tornado detection and warning by radar” in *The Tornado: Its Structure, Dynamics, Prediction and Hazards, Geophys. Monogr.* (Amer. Geophys Union, 1993), **Vol. 79**, pp. 203–221.
D. C. Dowell, C. Alexander, J. Wurman, L. Wicker, Centrifuging of scatterers in tornadoes. *Mon. Weather Rev.* **133**, 1501–1524 (2005).

J. Wurman, P. Robinson, C. Alexander, Y. Richardson, Low-level winds in tornadoes and potential catastrophic tornado impacts in urban areas. *Bull. Am. Meteorol. Soc.* **88**, 31–46 (2007).

K. A. Kosiba, J. Wurman, The three-dimensional structure and evolution of a tornado boundary layer. *Weather Forecast.* **28**, 1552–1561 (2013).

J. Wurman, K. A. Kosiba, P. Robinson, T. Marshall, The role of multiple vortex tornado structure in causing storm researcher fatalities. *Bull. Am. Meteorol. Soc.* **95**, 31–45 (2014).

H. B. Bluestein, J. C. Snyder, J. B. Houser, A multiscale overview of the El Reno, Oklahoma, tornadic supercell of 31 May 2013. *Weather Forecast.* **30**, 525–552 (2015).

Wurman, J., K. Kosiba, B. Pereira, P. Robinson, A. Frambach, A. Gilliland, T. White, J. Aikins, R. J. Trapp, S. Nesbitt, M. N. Hanshaw, and J. Lutz, 2021: The FARM (Flexible Array of Radars and Mesonets). *Bull. Amer. Meteor. Soc.*, **102**, E1499–E1525,

Kosiba, K., and J. Wurman, 2023: The strongest winds in tornadoes are very near the ground. *Communications Earth & Environment*, **4**, 50