CWE-8
June 7-11, 2026
London, ON, Canada

Coupled WRF and damage analysis of the 21 May 2022 Canadian derecho

Franklin T. Lombardo [a], Christoph Gatzen [b], Lisa Schielicke [b,c],
Morgan Schneider [b], David M. L. Sills [b], Garrett Statum [a], Jeffrey Trapp [a]

[a] *University of Illinois Urbana-Champaign, Urbana, IL, US, lombaf@illinois.edu*
[b] *Canadian Severe Storms Laboratory, Department of Civil & Environmental Engineering, Western University, London, ON, CA, cgatzen@uwo.ca*
[c] *Department of Physics and Astronomy, Western University, London, Ontario, Canada, lschieli@uwo.ca*

SUMMARY

For high-impact storm damage across Ontario and Quebec we discuss gust producing low-level processes. In May 2022, a derecho affected densely populated regions of south-east Canada. The processes that cause derecho wind damage are not well understood. Convection resolving numerical models are capable of simulating the overall evolution of the associated thunderstorm systems, but uncertainties remain with respect to the fine-scale wind structure close to the ground. At the CSSL, a thorough damage analysis is available for the event. Here, we aim to find connections between a convection resolving model and a damage analysis. Modelled high wind intensity at 80 meters above the ground is compared to the damage intensity picture. We follow the work by Killion (2024) and distinguish individual downbursts, mesovortices, the rear inflow jets, and combinations of these processes using the WRF model. Additionally, we discuss which of these processes are dominant in the case presented.

Keywords: *WRF, derecho, extreme wind*

1. INTRODUCTION

In May 2022, a thunderstorm system affected densely populated regions of south-east Canada with the metropolitan areas of the Greater Toronto Area, Ottawa, and Montreal at the same day as it moved along a 1000 km path (Gatzen, 2025). This event affected nearly half of Canada's population (TWN, 2025) and caused significant damage. Such systems may fulfill the criteria for derechos after (Johns and Hirt, 1987), e.g. when their damage path exceeds 400 km. Even though derechos have been studied in the last decades, the processes that cause the wind damage are not well understood. For example, convection resolving numerical models are capable of simulating the overall evolution of the associated thunderstorm systems, but great uncertainties remain with respect to the fine-scale wind structure close to the ground. Given that derechos are responsible for extreme winds and significant damage, they are likely important to design of structures (Roegner et al., 2024). Therefore, it is imperative to also understand the near-surface wind structure for engineering and whether the use of an isolated downburst (Fujita and Wakimoto, 1981) for simulation and modelling is appropriate.

To better understand near-surface processes in both disciplines, assessments have typically focused on damage at the ground given the lack of observations (e.g., Fujita and Wakimoto, 1981). In this work, we aim to find connections between a convection resolving model and a damage analysis.

For this, we follow the work by Killion (2024) and distinguish individual downbursts, mesovortices, the rear inflow jets, and combinations of these processes using the WRF model. Additionally, we discuss which of these processes are dominant in the case presented. The overall goal is to help bridging the gap between analyzed processes associated with modelled high wind intensity at 80 meters above the ground and the corresponding near-surface damage.

2. DAMAGE DATA

At the Canadian Severe Storms Lab, a thorough damage analysis is available for the event of May 2022 that indicates highly variable wind intensity, with smaller areas of intense damage embedded in the large-scale damage path. Damage data is available from the Northern Tornadoes Project (NTP, 2022). Figure 1 shows localized damage from the 21 May 2022 derecho near Plevna, Ontario. For the damage in Figure 1, trees have fallen in generally in one direction and the length scale of this isolated damage is approximately 400 m. There are numerous examples of similar character of damage throughout this event.

Figure 1. Localized damage from the 21 May 2022 derecho near Plevna, Ontario

3. WEATHER RESEARCH AND FORECASTING (WRF) MODEL

A simulation-based methodology using the Advanced Research core of the Weather Research and Forecasting (WRF) model version 4.4 (Skamarock and Klemp, 2008) will be used to simulate the event. The output from WRF provides the necessary 4D data for mechanism identification and wind characterization as in Killion (2024). It also has the advantage over a purely idealized modeling approach in that it allows for time-evolving and spatially heterogeneous synoptic- and meso-scale forcings of the MCS event and wind generation. This modeling approach has a limitation, however, in that even the presumed best simulation will fail to perfectly replicate the actual event (although it is equally true that even the presumed best observations will fail to faithfully represent all details of the actual event).

4. VORTEX AND FLOW FIELD ANALYSIS

Mesovortices are small-scale vortices embedded in convective Systems such as QLCS, squall lines, bow echoes of derechos with a typical width of 1 to 6 km. Mesovortices can live several minutes to several hours. They are associated with damaging straight-line winds, tornadoes, and downbursts. In this work, we will analyze mesovortices and flow fields using the kinematic vorticity number method (Schielicke et al., 2016). At each grid point, rotational and deformational flow components are compared and a vortex is defined in simply-connected regions of prevailing rotation. The advantage of this method is that it allows to identify vortices of different scales and in different flow environments (such as high-shear) independent of vertical vorticity magnitudes and thresholds. Mesovortices will are tracked over time and their properties (circulation, size, lifetime) are analysed as well as their connection to wind speed. Flow fields will also be analysed with respect to their kinematic properties.

5. RESULTS

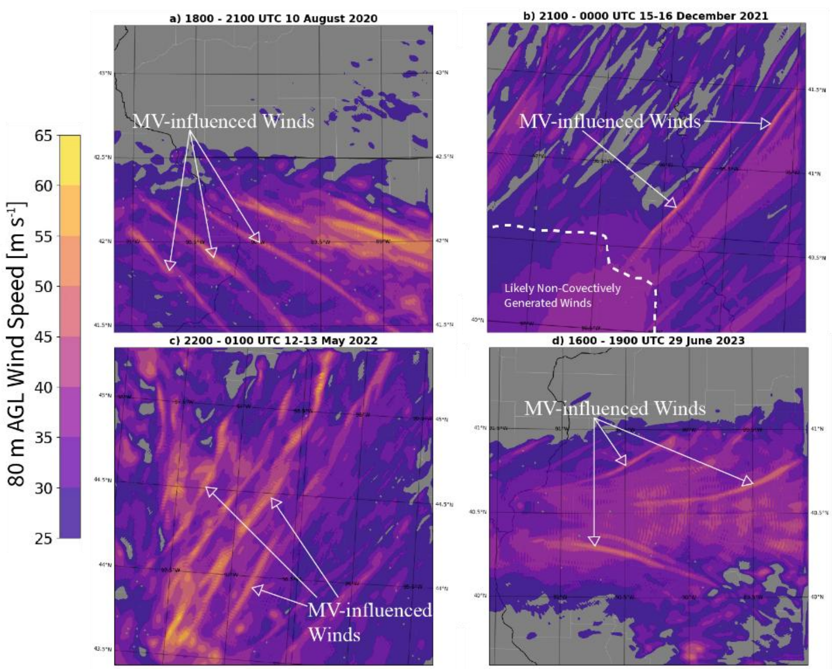

Figure 2. WRF simulations from four derecho events in the United States. Mesovortex influenced winds denoted by arrows. From Killion et al. (in review).

Work from other derecho events in the United States using WRF has shown long narrow swaths of higher winds from mesovortices (Killion et al., in review). An example of this is shown in Figure 2. Initial comparisons are underway to determine which scales of damage from the 21 May 2022 derecho can possibly be linked to storm-scale mechanisms such as mesovortices.

ACKNOWLEDGEMENTS

The first author would like to thank the Northern Tornadoes Project for partially funding this work.

REFERENCES

Fujita, T. Theodore, and Roger M. Wakimoto. "Five scales of airflow associated with a series of downbursts on 16 July 1980." Monthly weather review 109, no. 7 (1981): 1438-1456.

Gatzen, Christoph, David Sills, Simon Eng, Lesley Elliot, Aaron Jaffe, Connell Miller, Mark Gartner, and Gregory Kopp. Interpreting the damage from the 2022 Canadian derecho. No. ECSS2025-316. Copernicus Meetings, 2025.

Johns, Robert H., and William D. Hirt. "Derechos: Widespread convectively induced windstorms." Weather and Forecasting 2, no. 1 (1987): 32-49.

Killion, Kyle Jarrard. "Quantification of mechanisms for damaging wind generation in simulated derecho events." MS Thesis., University of Illinois at Urbana-Champaign, 2024.

Killion, K.J., Trapp, R.J. and Lombardo F.T. (in review). Quantification of Mechanisms for Severe Wind Generation in Simulated Derecho Events. Submitted to Monthly Weather Review.

Northern Tornadoes Project 2022 Annual Report (NTP, 2022). https://doi.org/10.5206/ntpr1894

Roegner, D. T., Lombardo, F. T., Wienhoff, Z. B., Rhee, D. M., Wagner, M. A., and Wood, R. L. (2024). The influence of thunderstorm type on extreme near-surface wind speeds: Iowa case study. *Journal of Wind Engineering and Industrial Aerodynamics*, *251*, 105805.

Schielicke, L., Névir, P., & Ulbrich, U. (2016). Kinematic vorticity number – a tool for estimating vortex sizes and circulations. Tellus A: Dynamic Meteorology and Oceanography, 68(1). https://doi.org/10.3402/tellusa.v68.29464

Skamarock, W. C., and Klemp, J. B. (2008). A time-split nonhydrostatic atmospheric model for weather research and forecasting applications. *Journal of computational physics*, *227*(7), 3465-3485.

The Weather Network (TWN, 2025). https://www.theweathernetwork.com/en/news/weather/forecasts/nearly-half-of-canadas-population-hit-by-derecho-why-it-was-harmful