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Development of a Canadian Severe Storms Event Database

Connell S. Miller[a], David M.L. Sills[b], Julian C. Brimelow[c], Gregory A. Kopp[d]

[a]Canadian Severe Storms Laboratory, Faculty of Engineering, Western University, London, Ontario, Canada, connell.miller@uwo.ca
[b]Canadian Severe Storms Laboratory, Faculty of Engineering, Western University, London, Ontario, Canada, david.sills@uwo.ca
[c]Canadian Severe Storms Laboratory, Faculty of Engineering, Western University, London, Ontario, Canada, jbrimelo@uwo.ca
[d]Canadian Severe Storms Laboratory, Faculty of Engineering, Western University, London, Ontario, Canada, gakopp@uwo.ca

Summary

This study presents the design and initial development of a Canadian Severe Storms Event Database (CSSED) that integrates high-quality field measurements and remote sensing for severe convective storms. The database unifies three complementary programs under Western University's Canadian Severe Storms Laboratory (CSSL): the Northern Tornadoes Project (NTP) for tornado and downburst observations, the Northern Hail Project (NHP) for hailswath observations, and the Northern Mesonet Project (NMP) for surface weather / lightning observations. The database further incorporates radar-derived signatures that indicate severe storms, including Maximum Estimated Size of Hail (MESH) and low-level rotation tracks. This study outlines the initial steps of the development of the CSSED including data ingestion, quality control, and creation of an interactive viewer within the Canadian Mesonet Portal. Finally, we describe use cases where CSSED could provide assistance for AI model development and enable validation of CFD simulations of near-surface wind fields during severe convective events.

Keywords: *severe convective storms, database, wind, precipitation*

1 INTRODUCTION

Severe convective storms produce highly localized wind and hail loads that challenge conventional design assumptions and lead to significant impacts on infrastructure (Kopp et al. 2017) and agriculture (Miller et al. 2025b). In Canada, these events are often underobserved because large portions of the country are sparsely populated and beyond the reach of dense, traditional observing networks (Cheng et al. 2013; Butt et al. 2024). To address this gap, the Canadian Severe Storms Laboratory (CSSL) at Western University was founded in 2024 with a vision of becoming the authoritative source for severe convective storms research and data in Canada, thereby improving the safety and well-being of Canadians. To this end, the CSSL is comprised of three complementary projects that focus on different aspects of severe convective storms: the Northern Tornadoes Project (NTP), the Northern Hail Project (NHP), and the Northern Mesonet Project (NMP). Together, these programs create a unique opportunity: a unified, research-grade, national database of severe storm events and signatures that enables multihazard analysis and serves as a foundation for future model development and validation.

2 CSSED DATA

2.1 NTP Database

The NTP has systematically documented Canadian tornado events since 2017 and downburst events since 2019, leveraging in-person drone and ground surveys, high-resolution satellite imagery, and social media reports to reveal otherwise undetected events (Sills et al. 2020). This effort has improved our understanding of Canada's tornado climatology, allowed for tornado alert verification (Sills and Elliott 2023), enabled development of tornado hazard maps for the National Building Code of Canada, and produced robust geospatial datasets of damage paths along with event metadata. The event metadata captured by NTP includes the exact location and timing of the storm, the full path of the storm, and the width and length of the damage footprint. Each event

is rated for intensity using the Enhanced Fujita (EF) scale, and those ratings are supported by evidence such as photographs, aerial imagery, and satellite data. Since 2017, NTP has documented nearly a thousand tornadoes and over 500 downbursts, many of which would have gone undetected, especially in remote regions.

2.2 NHP Database

The NHP, founded in 2022, is building a modern hail observation program including deploying monitoring networks such as disdrometers and hailpads, sampling and preserving hail collected from hail swaths for analysis, and monitoring vegetation health following hailstorms using multispectral cameras mounted on drones and high-resolution satellite imagery (Brimelow et al. 2023). This effort has improved our understanding of Canada's hail climatology, improved loss estimates (Goda et al. 2025), and produced robust geospatial datasets of radar-derived hailswaths along with event metadata. The event metadata captured by NHP includes locations of hail-damaged homes, vehicles, and crops; along with radar-based hail estimates in those areas. It also includes actual measured hailstones from those storms, noting their diameter and mass.

2.3 NMP Database

The NMP, launched in 2024, was created to improve monitoring of severe convective storms by expanding the coverage of real-time, high-quality weather observations across Canada. Its goal is to make severe weather data more accessible and reliable for analysis and forecasting. This is achieved through a network of specialized, high-density weather stations installed and maintained by NMP, as well as through the Canadian Mesonet Portal: a centralized platform that provides public access to surface weather observations nationwide (Miller et al. 2025a). Figure 1 shows an example of the Canadian Mesonet Portal user interface. The stations found on the Canadian Mesonet Portal deliver high-resolution measurements of wind speed and direction, temperature, humidity, atmospheric pressure, and rainfall. In addition to surface data, the portal integrates radar-based indicators of severe storms, such as Maximum Estimated Size of Hail (MESH) (Witt et al. 1998) and low-level rotation tracks, which help identify hail-producing storms and tornado potential. Lightning density data is also included, and plans are underway to incorporate social media reports.

3 CSSED VIEWER (CANADIAN MESONET PORTAL)

To make the CSSED useful beyond raw data files, an interactive viewer will be developed within the Canadian Mesonet Portal. This viewer acts as the front door to CSSED, allowing users to visually explore individual severe storm events. Tornado paths and downburst swaths from the Northern Tornadoes Project will be able to be displayed alongside hail swaths and radar-derived hail size estimates from the Northern Hail Project. Weather station data and lightning strikes from the Northern Mesonet Project will appear as additional layers, giving a complete picture of each event. The user interface that already exists as part of the Canadian Mesonet Portal is designed for flexibility, which makes it a useful platform for the CSSED. Users will be able to zoom into specific regions, filter events by date, province, hazard type, or intensity, and click on individual storm tracks to see detailed information such as path length, maximum width, estimated hail size, and associated damage reports. Each event includes links to supporting evidence like photos, survey notes, and radar imagery, making it easy to verify what happened on any given date.

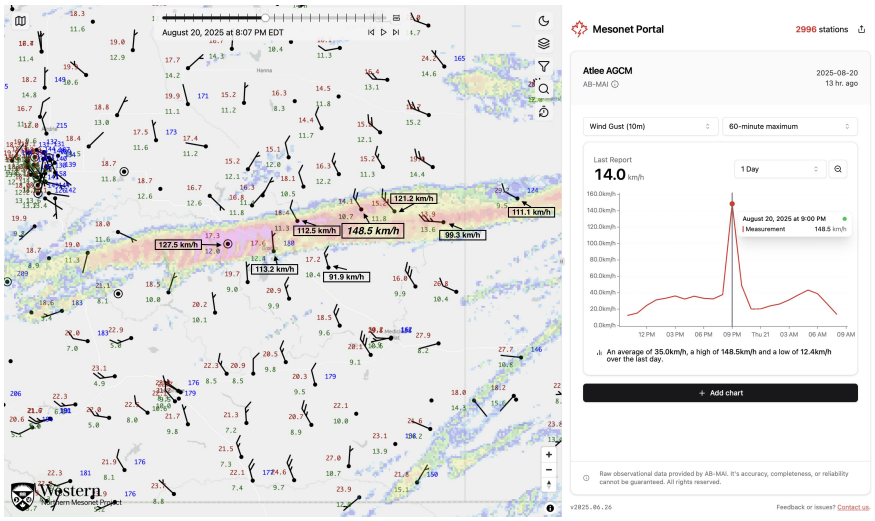

Figure 1: Canadian Mesonet Portal view from the downburst / hailstorm in Brooks, AB on August 20, 2025. Computer-drawn annotations have been added to indicate any peak wind gusts that exceeded 90 km/h.

Beyond visualization, the viewer supports data export for research and operational use. Users can download selected layers in formats such as GeoJSON, CSV, or NetCDF, or capture map snapshots for presentations and reports. For advanced users, API endpoints will be available to automate workflows and integrate CSSED data into modeling systems or machine learning pipelines. This viewer transforms CSSED from a static database into a dynamic platform for discovery and analysis. It enables meteorologists to study storm behavior, engineers to validate wind and hail models, and emergency managers to understand historical risk patterns.

4 CSSED POTENTIAL USE CASES

The CSSED is designed to support a wide range of practical and scientific applications. One of the most promising areas is artificial intelligence and machine learning. By providing a harmonized dataset from tornado paths, hail swaths, radar signatures, lightning strikes, and surface weather observations, CSSED offers a foundation for training models that could predict severe weather impacts. For example, researchers could potentially use these data to develop algorithms that estimate hail size or tornado potential from radar patterns and environmental conditions.

Another important application is engineering and risk assessment. Severe storms produce extreme wind and hail loads that challenge building design standards. CSSED provides real-world data that engineers can use to validate or support computational fluid dynamics (CFD) simulations of near-surface wind fields during severe convective storms. Damage footprints and intensity ratings help researchers understand how structures fail under these conditions, while mesonet data provides the environmental context needed to model storm dynamics accurately. This information can guide improvements in building codes and resilience strategies, reducing future losses.

Emergency managers and insurers can also use the database to analyze historical storm patterns, identify high-risk regions, and improve response planning. The integration of radar, lightning, and surface observations also makes CSSED a valuable resource for developing real-time decision-support tools, such as nowcasting systems that anticipate severe weather impacts before they occur.

5 CONCLUSIONS

The ongoing development of the Canadian Severe Storms Event Database (CSSED) marks an important step towards a unified platform that integrates survey-based tornado/downburst documentation (NTP), radar- and ground-based hail observations (NHP), along with mesonet and lightning data (NMP). In the future, this will also include flash-flooding data from severe convective storms. The CSSED viewer, hosted within the Canadian Mesonet Portal, will transform this data into an interactive platform that supports visualization, filtering, and export for a wide range of users. Researchers can explore storm footprints alongside radar signatures and lightning data, while engineers and emergency managers can access detailed event records to inform risk assessments and resilience planning. By bridging observational gaps in Canada's severe storm climatology, CSSED provides the foundation for advanced applications such as machine learning models for impact prediction and computational simulations. Future work will focus on expanding the database to include additional radar products, social media reports, and real-time data streams, as well as developing APIs for automated integration into forecasting and modelling systems.

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