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Towards understanding wind-driven hail events, with a focus on Canada

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SUMMARY
An important aspect of severe thunderstorms is that they are frequently accompanied by damaging winds. Traditionally, however, strong winds and the other phenomena associated with severe storms (such as hail) are considered in isolation. When combined with hail, strong winds not only increase the impact energy (i.e., damage potential) of the hail, but the resultant change in impact angle of wind-driven hail also impacts surfaces that would typically be protected from the hail. This results in extreme damage to the siding and windows of buildings, potentially resulting in building envelope failures, severe damage to vehicles, as well as decimation of agricultural crops of all kinds. Moreover, estimates of wind speed and hail size collected during the Alberta Hail Project (AHP), which ran from 1956 to 1985, indicated that there was a tendency for winds at the time of hailfall to increase with increasing hail size. However, the conclusion of the AHP represented the end of dedicated hail research in Canada, and this finding was never explored in detail. Wind-driven hail events have been documented in North America, Europe, and Australia. Here we posit that, globally, wind-driven hail events are more common and are responsible for more damage than traditional hail report data would suggest.

Keywords: wind-driven hail, hailstorm, building envelope, severe thunderstorm, siding, PVC, vinyl siding, window

1. INTRODUCTION

The majority of the literature on hail impacts (rightly) focuses on hail damage to roofs, vehicles and crops, from mainly vertical hail trajectories, focusing on terminal fall velocity and other indicators of hail damage (see Fig. 1). No such widely available research and guidance exists for impacts to siding, windows and building envelopes from wind-driven hail events (WHEs; T. Marshall, pers. comm.). This lack of research represents a gap in our understanding of WHE risk. Additionally, for risk modelling, we need to ascertain whether WHEs are more common in some hail-prone regions than in others.

1.1. Research in Canada

In 2022, in its inaugural year, the Northern Hail Project (NHP) documented several large WHEs that damaged buildings and crops. Also included in our analysis are several "null" cases that, although producing large hail, did not appear to have had a wind-driven component and did not generate damage reports of the same severity. The WHEs were characterized by high concentrations of 4–6 cm hail and were accompanied by winds approaching or exceeding 90 km h^{-1}. This combination resulted in severe damage to crops and the siding and windows of buildings (see Fig. 2).

Figure 1. Debarking of a tree (left) from a WHE in Casorezzo, Italy, on 18 August 1986 (image courtesy @PavanFederico00 [Twitter]) and severe damage to a vehicle (right) from another WHE in Digoin, France, on 22 June 2022 (photo taken by Christophe Asselin [Chroniques Chaotiques]).

Figure 2. Severe vinyl siding damage (right-hand side wall only) (left) and contrasting damage to wooden and vinyl siding (right) on surfaces exposed to wind-driven hail.

Using information from ground surveys and media reports, we have begun to compare, and contrast, events without high winds—the aforementioned "null" cases—and to identify thresholds for combinations of wind speed and hail size when damage to the building envelope and crops becomes significant (i.e., building envelope is compromised or crop damage is near 100%). Here we will present our methodology and preliminary results from our analysis.

1.2. Recent High Impact Hail Events

Canada's first billion-dollar hailstorm occurred in Calgary, Alberta on 13 June 2020, when 5–6 cm hail was accompanied by winds exceeding 70 km h^{-1}. The result was devastating damage to vehicles and the siding (see right-hand panel in Fig. 2), roofing and windows of houses. Below, we highlight this event along with multiple WHEs that were documented by the NHP in 2022.
These events, along with several "probable" cases (possible WHEs requiring additional study to confirm their nature) and several "null" cases are summarized in Table 1.

Table 1: List of wind-driven hail events (confirmed and probable) and "null" cases.

Event Date	Location(s)	Notes
Confirmed WHE		
13 June 2020	Calgary, Alberta	Canada's first $1-billion hail event.
19 June 2022	Wapella/Langbank, Saskatchewan	Several reports of siding, window and vehicle damage from a long-track hailstorm. Point ground surveys conducted.
16 July 2022	Ponoka, Alberta	Detailed ground survey of crop and building damage.
18 July 2022	Redcliff/Bow Island, Alberta	WHE damage documented during wind damage-focused survey (storm produced EF2 tornado and downburst winds).
Probable WHEs		
23 June 2022	Binscarth, Manitoba	Significant but localized damage to siding, windows and vehicles; up to baseball-sized hail reported.
27 June 2022	Eckville, Alberta	Swath of clearly visible hail damage to crops on satellite imagery. Farmers noted 100% crop losses.
7 July 2022	Oyen and Calgary, Alberta	Significant damage to house siding reported in Oyen, moderate damage to siding reported in Tuscany neighbourhood of Calgary.
1 August 2022	Markerville, Alberta	New Canadian record hailstone found by NHP field team near Markerville. Severe vehicle and crop damage was reported several kilometres east of this location.
"Null" Cases		
16 June 2022	West of Montréal, Québec	Multiple reports of up to 7.5-cm hail; no reports of widespread crop or structural damage.
6 July 2022	Lake Winnipegosis to O-Chi-Chak-Ko-Sipi FN, Manitoba	Radar indicated up to 7.5-cm hail; no reports of structural or crop damage.
9 July 2022	Near Woodglen, Alberta	Radar indicated up to 7-cm hail; no reports of building or crop damage.

2. DATA SOURCES AND METHODOLOGY

Measurements (or estimates) of both hail sizes and accompanying wind speeds were obtained from ground damage surveys, interviews with eyewitnesses, and social and news media reports. These data were supplemented with information from remote sensing observation platforms (i.e., weather radar). Because representative instrumented measurements of convective storm winds are rare, we also used the Canadian version of the Enhanced Fujita (EF) Scale to estimate wind speeds based on adjacent damage indicators. Quantitative sources include direct measurements of hail collected from either field teams or residents, semi-quantitative measurements of hail size from photos of hail containing reference objects, and weather stations (when available). This combination of information from multiple complementary sources provides insights on key hail size and wind speed thresholds associated with damage to homes and crops from WHEs.

2.1 Preliminary Findings

The majority of housing stock in Canada uses vinyl siding—an inexpensive cladding material made of long, interlocking strips of polyvinyl chloride plastic. In every case surveyed, the most visible and severe damage was noted to vinyl siding and other vinyl components (e.g., window frames). Ground surveys indicated that adjacent homes clad with other types of siding (e.g., stucco or wood) showed no clear visible damage, while sheet metal (e.g., garage doors) only showed minor dents. Preliminary findings for selected WHEs are provided in Table 2.

Table 2: Cases with combined wind and hail observations.

Event Date	Location(s)	Notes
13 June 2020	Calgary, Alberta	5–6 cm hail accompanied by 70 km h^{-1} winds.
19 June 2022	Wapella/Langbank, Saskatchewan	Moderate to severe siding damage, broken house and car windows. 3–5 cm hail. Wind damage to vegetation and light structures indicated gusts of 65–80 km h^{-1}. Point surveys conducted.
16 July 2022	Ponoka, Alberta	Ground survey of crop and building damage. Hail in Ponoka was 4–5 cm, possibly larger west of town. Instrumented observation of an 85 km h^{-1} gust; wind damage indicators suggest winds approached 90 km h^{-1} in portions of the swath.
18 July 2022	Redcliff/Bow Island, Alberta	Buildings suffered moderate to severe wind damage from tornadic and downburst winds accompanied the 4–4.5 cm hail. Corn crops decimated.

A detailed ground survey (see Fig. 3) conducted following the 16 July WHE in Ponoka found that the most severely damaged homes suffered intrusion of hail, water and tree debris through broken windows. Additionally, water intrusion through a combination of severely damaged siding and exterior wall insulation in conjunction with wind-driven rain was observed. Crops, including canola, grains and corn, suffered 100% losses; wind damage to trees nearby the 100% crop loss indicated winds had approached 80–90 km h^{-1}. An 85 km h^{-1} gust was measured by a nearby (~20 km) Alberta Climate Information Services station located within the hailswath.

Figure 3. Severe vinyl siding damage (left) and 100% loss of corn crop (right) west of Ponoka, Alberta.

4. RESEARCH GOALS AND PRODUCTS

Several important questions remain with respect to WHEs: How often do they occur? Is wind-driven hail ubiquitous for hail events in some regions but not others? And, perhaps most importantly for engineering and risk management applications, what is the minimum wind speed required to start generating severe impacts to lateral surfaces and to crops. That is, what combinations of hail size and wind speed represent a threshold for the onset of severe damage? We intend to develop a hail intensity scale (similar to the EF-scale for winds) that can be applied in Canada and elsewhere. This will be coupled with an analysis of the antecedent meteorological conditions associated with WHEs, providing an understanding of the underlying mechanisms resulting in WHEs, which in turn will also help to improve weather alerts for WHEs.