1-12-2018

Northern Tornadoes Project. Northern Tornadoes Flyover Project: Summary Technical Report of the Year 1 Pilot Study

Gregory A. Kopp
Western University

Emilio S. Hong
University of Western Ontario, ehong27@uwo.ca

David Sills
Environment and Climate Change Canada, dsills3@uwo.ca

Joanne Kennell

Follow this and additional works at: https://ir.lib.uwo.ca/ntp_reports

Part of the [Environmental Engineering Commons](#)

Citation of this paper:

Kopp, Gregory A.; Hong, Emilio S.; Sills, David; and Kennell, Joanne, "Northern Tornadoes Project. Northern Tornadoes Flyover Project: Summary Technical Report of the Year 1 Pilot Study" (2018). *Project Reports*. 3.

https://ir.lib.uwo.ca/ntp_reports/3

Northern Tornadoes Flyover Project: Summary Technical Report of the Year 1 Pilot Study

Gregory A. Kopp, Emilio Hong and Joanne Kennell
Faculty of Engineering, University of Western Ontario

David Sills
Environment and Climate Change Canada

12 January 2018

Summary

The objectives of the Year 1 Pilot Study were to (i) develop a methodology for determining tornado occurrence in Northern Ontario, and (ii) obtain research quality data for at least one event. Because of the isolation of many regions, the approach assumed the use of radar data analysis combined with aerial surveys. These objectives were achieved. Aerial surveys were conducted for a total of seven events in Ontario and southern Quebec and 15 confirmed or probable tornadoes identified. Archival geo-tagged imagery was obtained for six of these events. Ten confirmed or probable tornadoes were identified in Ontario, five of which were not in the OSPC database. In addition, 5 tornadoes were confirmed in Quebec. For the 2017 season, the OSPC had a list of 10 verified tornadoes, as of December 21, 2017. The pilot project raises this number to 15. In total, 4 EF2 tornadoes and 1 EF3 tornado were identified via aerial photography. The remainder were EF1 or EF0.

UPDATE – 1 March 2021

Based on the analysis of newly available Planet.com high-resolution satellite imagery and the use of related tools, events were reassessed and six additional tornadoes were discovered. However, four tornadoes were reassessed as downbursts. Overall, an additional two tornadoes were added to the 2017 count. The updated events are listed in a revised 2017 summary table appended at the end of this document.

There is a “black hole” of tornado-observation data in the unpopulated, mostly forested regions of northern Ontario, which is depicted in Figure 1. Statistical modelling involving lightning and population data suggests that approximately 230 tornadoes per year occur in Canada, although only about 60 are verified per year, on average. Thus, accurately characterizing tornado occurrence on a national scale is important. Filling known gaps in such characterizations is required in order to accurately assess tornado risk.

Key indicators for the formation of tornadoes in Ontario can be different from those widely studied in the Great Plains region of the United States (e.g., the 2011 Goderich F3 tornado). To improve tornado prediction and achieve improved warnings, further research on the meteorological indicators for Ontario tornadoes is required.

Tornado risk also depends on occurrence rates, intensities, track lengths and widths. Tree blow-down patterns could indicate intensity of tornadoes, which is an area of current research. Effects of species, soils and other factors on typical wind-throw speeds in tornadoes are unresolved for northern species/regions. Thus, there remains much to be learned for this common Damage Indicator.

Northern Ontario is a large region and sampling over such an expansive area is challenging. Northwestern Ontario (see Figure 1) is known to experience strong thunderstorms and tornadoes and efforts should be focused in this area in particular.

Figure 1. Regional boundaries in Northern Ontario as used by ECCC.

The objectives of the Year 1 Pilot Study were to (i) develop a methodology for determining tornado occurrence in Northern Ontario, and (ii) obtain research quality data for at least one event. Because of the isolation of many regions, the approach assumed the use of radar data analysis combined with aerial surveys.

Methodology

The research methodology is as follows:

1. The meteorologist embedded at ECCC follows the meteorological predictions for several days in advance, with a particular emphasis on examining the possibility of severe weather.
2. When severe weather occurs, storm conditions are tracked by the meteorologist for conditions favourable for the formation of tornadoes. Supercell positions are identified and tracked. Radar data and imagery are examined, particularly for features commonly indicating tornadoes. In isolated areas, the resolution is limited, making the analysis challenging.
3. When radar and other meteorological data show evidence of tornadoes, locations are used to identify possible positions of tornadoes. Flight tracks are developed by the meteorologist and engineer for the aerial survey company (KBM Resource Group, Thunder Bay), who then fly these. Examples of flight tracks are provided in Appendix 1, Figures 17 - 19.
4. Following the aerial survey, KBM provides geo-tagged images with a resolution of up to 10cm/pixel. These are imported into Geographical Image Software (GIS) for analysis. Visual analysis of the imagery is conducted, looking for downed trees on the track. Damaged areas are outlined, as shown in Appendix 1, Figures 21 – 23.
5. The damaged areas are assessed for track details and intensity of damage using the Canadian EF-Scale. Results are presented in tabular format (e.g., Table 1) and visually (e.g., the Appendix 1 figures).

The report on the June 14 Dryden Tornado, included as the Appendix 1, illustrates the steps in this process.

Results

Table 1 summarizes the details of the events that were identified as part of the Year 1 Pilot Study. Note that at the time of writing, the Huntsville aerial imagery has not been received. As well, some of the tornado tracks and intensities have not been finalized. Because of the slow start to the season, the June 18 outbreak around Hébertville, Quebec was also included in the study, which included a ground survey since there were damaged structures (including a destroyed house, e.g., DOD-10 for the wood-frame house Damage Indicator, DI).

In total, 15 confirmed or probable tornadoes were identified during the project. Archival-quality, geo-tagged imagery was acquired for 12 of these. Due to the isolation of the regions studied, trees were the primary DI. Important non-tree DIs are also included in the analysis (Table 1). As can be seen, 4 EF2 tornadoes and 1 EF3 tornado were identified.

Table 2 presents the 2017 tornadoes in the Ontario Storm Prediction Centre (OSPC) database as of December 21, 2017. There were 10 confirmed or probable tornadoes, five of which are in Table 1 and were surveyed as part of this project. (It is noted that Western researchers also did the ground survey confirming the first tornado of the year, April 11 near London). Combining Table 1 and Table 2, it is apparent that there were 15 tornadoes in Ontario in total, with the current project identifying five of these. These five would not have been

identified without the project, and most of these occurred in Northwestern Ontario (the Timmins event was in Northeastern Ontario). In addition, it is observed that Ontario had nine days with tornadoes, with two of these days having at least three tornadoes.

For strong tornadoes (i.e., EF2 or greater), the methodology was effective and relatively simple. Figure 3 shows a series of images from the July 6 Quetico tornado. Because of the intensity, the consistent tree damage allowed the track length and width, Degree-of-Damage (DOD), and intensity to be assessed in a straightforward manner. Satellite data could also be used to identify the tornado.

For weaker tornadoes, the damage was often just above the threshold for tree fall such that the damage tracks were patchy. This made tornado tracks more difficult to identify and separate from downburst damage. Figure 21 in the Appendix provides examples of this for the June 14 Dryden tornado. Part of this issue could be resolved by obtaining higher resolution imagery (greater than the 10cm/pixel) to better identify fallen trees, as well as having cameras using a forward-facing oblique angle. Such approaches will be incorporated in Year 2.

Recommendations and Conclusions

Several recommendations have arisen through the Year 1 Pilot Study to improve the methodology:

1. The resolution of 10cm/pixel was insufficient in some cases, making tornado assessments uncertain in these situations. The particular issue is related to intermittent damage where there are relatively few trees down in some areas. This was hindered by the fact that there was evidence that, in some cases, damage from this year occurred at locations with previous treefalls/damage. It would appear that 2-3cm/pixel would be sufficient to resolve this issue. To achieve this, the aircraft will have to fly at a lower height, which will increase costs.
2. Manual treefall identification is costly and slow. Automated damage detection should be a priority. This will be of importance for the efficient use of algorithms to estimate tornado intensity based on treefall patterns, which is a planned research topic in Year 2.
3. Stereoscopic imagery is included with all flights. However, we made no use of this data in Year 1. This should be investigated as a priority to determine if it can make both manual and automated identification of damage more reliable and efficient. LiDAR data could also be used. The July 14 Dryden Tornado had LiDAR data acquired, but this has not been analyzed. It should be, for the same reasons.
4. Image processing with laptops is inefficient. Computers with higher-powered graphics cards are required.
5. To better identify tracks, prior to the costly high-resolution flights, either (i) manned reconnaissance flights should be used, or (ii) a method based on satellite imagery used. The former was used for the July 25 Dryden event, which had seven supercells spanning an area of more than 100,000 km². For the July 6 Quetico Tornado, the latter approach was used. Both methods should be refined in Year 2.
6. Most of the tree damage was caused by wind-throw (i.e., uprooting). A geotechnical analysis is required to connect this into the intensity analysis. There were some hints of topographic effects, which should be analyzed further.

7. Long-range radar has limitations in Canada, so identification of supercell storms and tornadoes further north than the events identified this summer will continually pose a challenge.
8. Using the developed approach in southern Ontario's populated areas will be useful as well, but will have different challenges. These should be augmented by ground surveys, since particular structural details are necessary for accurate assessment with the EF-Scale.

Several conclusions can be made from the Year 1 Pilot Study:

1. The developed methodology works well (notwithstanding the recommendations indicated above) and it is possible to identify tornadoes in unpopulated regions of the country.
2. Aerial surveys were conducted for a total of seven events in northern Ontario and southern Quebec with 15 confirmed or probable tornadoes identified. Archival geo-tagged imagery was obtained for six of these events. Ten confirmed or probable tornadoes were identified in Ontario, five of which were not in the OSPC database. In addition, five tornadoes were confirmed in Quebec.
3. For the 2017 season, the OSPC had a list of 10 verified tornadoes, as of December 21, 2017. The pilot project raises this number to 15. In total, 4 EF2 tornadoes and 1 EF3 tornado were identified via aerial photography. The remainder were EF1 or EF0.

Table 1. Summary of Results from the 2017 Study

Event Name and Date	Contribution	UWO Contribution	Initial Detection of Event	Date of Flights	# of Supercells	# of Verified Tornadoes	Verified by ECCC	Event Details	Damage Indicator(s)	Maximum Degree of Damage	Track Length	Max Width	Max EF- Scale Wind Speed (km/h)	EF Rating	Storm Motion (Degrees)
Dryden, Ontario	New Tornado Identified	Aerial survey based on radar	Radar detection	June 27 th , 2017	2	1 Probable		Dryden – Reports of some tree damage from witnesses. Aerial survey found significant tree damage. Some damage resembled downburst damage.	CT – Trees	3	1700 m	420 m	175	EF1	NA – to come
Hébertville, Québec	Tornado Data Improved	Aerial and ground survey	Witness	July 10 th - July 18 th , 2017	4	5 Confirmed 1 Possible	QSPC Surveyed	Saint-Anne du Lac – Tornado confirmed by ground survey. House completely destroyed.	CT – Trees	6	22600 m	680 m	235	EF3	NA – to come
18/06/2017	Tornado Data Improved	Aerial and ground survey	Witness				QSPC Surveyed	Hébertville – Tornado confirmed by ground survey. One home found to have complete failure.	FR12 – One or Two Family Residences CT – Trees	10 6		1370 m	220	EF2	NA – to come
	New Tornado Verified	Aerial and ground survey	Witness				QSPC Surveyed	Lac Noir – Tornado confirmed by ground survey.	FR12: One or Two Family Residences CT – Trees	5 6		480 m	125	EF0	NA – to come
	Tornado Verified	Aerial survey based on witness	Witness					L-Etango – Unconfirmed and unrelated tornado. Report and video sent to QSPC.							
	Tornado Verified	Aerial survey based on witness	Witness					Lac de la Bolduc – Significant tree damage for a 9.3 km track.	CT – Trees	6	9900 m	550 m	220	EF2	NA – to come
	Tornado Data Improved	Aerial and ground survey	Witness				QSPC Surveyed	Lac des Bolducs – Relatively long narrow track of damage.	CT – Trees	3	1800 m	210 m	NA – to come	EF1	NA – to come
Québec, Ontario	Tornado Data Improved	Aerial survey based on witness	Witness	July 27 th , 2017	1	1 Confirmed	Verified by QSPC	Québec – Tree damage spotted. Aerial survey did not capture the full track, satellite found track of 9 km.	CT – Trees	6	9000 m	320 m	100	EF2	NA – to come
06/07/2017	Tornado Identified	Aerial survey based on witness	Witness	August 16 th , 2017	1	1 Probable		Timmins – Damage paths cut through the Timmins airport. Some scattered damage found on aerial surveys. May be downbursts. Measuring equipment recorded wind speeds of 100 km/h.	CT – Trees	2	NA – to come	NA – to come	100	EF0	315
20/07/2017	New Tornado Identified	Aerial survey based on witness and recon flight	Radar detection	October 10 th , 2017	7	1 Probable	Not Verified	Supercell A – Tree damage spotted north of the supercell track traveling from the southwest. Significant amount of CT and some EF1 damage.	CT – Trees	5	3000 m	200 m	145	EF1	240
25/07/2017	Tornado Data Improved	Ground survey conducted by Environment and Change Canada	Radar and witness	Not yet flown. The three listed trees will all be flown.	2	3 Confirmed	Verified by QSPC	Utterson – Hundreds of trees uprooted.	CT – Trees	4	4200 m	250 m	160	EF1	240
04/08/2017	Tornado Data Improved		Radar and witness				Verified by QSPC	Fairy Lake – Damaged many homes and trees uprooted.	CT – Trees	4	6250 m	100 m	150	EF1	280
	Tornado Data Improved		Radar and witness				Verified by QSPC	Rebecca Lake – Ground surveys confirmed rafting. Extensive tree damage.	CT – Trees	5	16000 m	200 m	190	EF2	240
Québec, Ontario	Tornado Data Improved	Aerial survey based on radar	Radar detection	September 6 th , 2017	7	1 Probable 1 Confirmed 1 Probable	Verified by QSPC	Western Lake – Damage found at location (80 km NW of Québec). Damage to a residential cabin and nearby trees.	FR12 – One or Two Family Residences CT – Trees	2 5	N/A	30 m	120	EF0	315
22/09/2017	New Tornado Identified	Aerial survey based on radar	Radar detection					Québec – Damage found scattered along long tracks. Tornado confirmed.	CT – Trees	4	1800 m	430 m	140	EF1	NA – to come
	New Tornado Identified	Aerial survey based on radar	Radar detection					Québec – Probable tornado, more information to come.	CT – Trees	NA – to come	NA – to come	NA – to come	NA – to come	NA – to come	NA – to come

* Older EF-1 Tornado identified from Dryden July 25th aerial imagery. More analysis and research is to be conducted to determine potential date. Tornado resulted in CT damage. D&D 5, path length of 2200 m, maximum width of 220 m and maximum wind speeds of 175 km/h. Additional damage paths discontinuous. Some damage determined to be downburst. Overlap with extensive tree damage from 2005 downburst event.
 ** Another older tornado identified from Dryden July 25th aerial imagery. EF rating, track, width yet to be determined.

Summary of the Northern Ontario Flyover Project

Table 2. Summary of the 2017 Tornadoes in the OSPC Database as of December 21, 2017

Date	Location	Rating
April 11	NE of London	EF1 - confirmed
July 6	Ottertrack Lake, Quetico Prov. Park	EF2 - confirmed
July 12	Lake Simcoe near Georgina Island	EF0 - confirmed (Supercell Waterspout)
July 12	N of Lucan	EF0 - confirmed
August 4	Huntsville	EF1 - confirmed
August 4	Huntsville, Rebecca Lake	EF2 - confirmed
August 4	Utterson (SW of Huntsville)	EF1 - confirmed
August 11	Leamington	EF0 - confirmed
August 11	Hawkesville (NW of Kitchener)	EF2 - confirmed
September 22	Werner Lake (NW of Kenora)	EF0 - probable

Figure 3. Aerial imagery from the July 6 Quetico Tornado. The upper image shows the overall track. The middle image shows the area circled in red in the upper image. The lower image shows the area circled in red in the middle image. Resolution in source images is 10cm/pixel.

Appendix 1 – Technical Report on the June 14, 2017 EF1 Dryden Tornado

NORTHERN ONTARIO STORM SUMMARY

DRYDEN – JUNE 14, 2017

1. Summary

In the evening hours of June 14, 2017, several severe thunderstorms developed in northwestern Ontario that tracked from the southwest to the northeast. Daytime temperatures were reaching highs near 26°C, and the atmosphere was rather moist with dew points around 16°C. Near Fisherman's Cove and Dryden, Ontario, two supercell storms were detected on radar.

Of the two supercell storms detected, it was determined through the utilization of a high-resolution imaging from an aerial survey conducted on June 27th that one of the storms resulted in EF-1 tornadic and EF-0 downburst tree damage on the ground. These results were determined after an in-depth analysis of the photographs taken along the supercell tracks.

2. Meteorological Conditions

2.1 Storm Prediction

The NOAA/NWS Storm Prediction Centre (SPC)'s Day 1 Convective Outlook on June 14 indicated a "Marginal" and "Slight" risk of severe thunderstorms in northwestern Ontario (Figure 1). The associated probabilities of damaging winds, hail, and tornadoes are also shown (Figure 2). The SPC outlook was predicting a 2 percent chance of tornadoes within northwestern Ontario. This percentage means there was a 2 percent probability of at least one tornadic event occurring within 40 kilometres of the region shaded in green. Additionally, according to the 22Z Significant Tornado Parameter (Figure 3) produced by the SPC Mesoscale Analysis model, there was a moderate chance (values between 0.5 and 1) for tornadoes to develop in northwestern Ontario.

Figure 1: Storm Prediction Center (SPC) Day 1 Severe Weather Outlook issued at 12Z and valid for June 14th, 2017.

Figure 2: Storm Prediction Center (SPC) Day 1 Hail Outlook (A), Tornado Outlook (B), and Damaging Wind Outlook (C) issued at 12Z and valid for June 14th, 2017.

Figure 3: SPC Mesoscale Analysis Significant Tornado Parameter at 22Z valid for June 14th, 2017. Mixed-layer CIN (J/kg) is also represented (shaded).

The combination of moderate effective shear and CAPE, along with an approaching occluded cold front from the southwest, were the necessary ingredients needed for severe thunderstorm development. The Ontario Storm Prediction Centre (OSPC) started issuing Severe Thunderstorm Warnings at 6:26 pm EDT and Tornado Warnings (shown below) at 7:07 pm EDT for the Dryden and Vermillion Bay regions.

Issued at 2017-06-14 7:07PM EDT by Environment Canada:

Tornado warning continued for:

Dryden - Vermillion Bay, Ont. (047410)

Tornado warning ended for:

Kenora - Grassy Narrows - Whitedog, Ont. (047310)

Current details:

At 6:07 p.m. CDT, Environment Canada meteorologists are tracking a severe thunderstorm that is possibly producing a tornado. Damaging winds, large hail and locally intense rainfall are also possible.

Doppler radar indicates a potential tornado just northwest of Vermillion Bay moving northeastwards at 50 km/h.

This is a dangerous and potentially life-threatening situation.

Take cover immediately, if threatening weather approaches. If you hear a roaring sound or see a funnel cloud, swirling debris near the ground, flying debris, or any threatening weather approaching, take shelter immediately.

Go indoors to a room on the lowest floor, away from outside walls and windows, such as a basement, bathroom, stairwell or interior closet. Leave mobile homes, vehicles, tents, trailers and other temporary or free-standing shelter, and move to a strong building if you can. As a last resort, lie in a low spot and protect your head from flying debris.

Lightning kills and injures Canadians every year. Remember, when thunder roars, go indoors!

The Office of the Fire Marshal and Emergency Management recommends that you take cover immediately if threatening weather approaches.

Tornado warnings are issued when imminent or occurring thunderstorms are likely to produce or are producing tornadoes.

Please continue to monitor alerts and forecasts issued by Environment Canada. To report severe weather, send an email to ec.cpio-tempetes-ospc-storms.ec@canada.ca or tweet reports using #ONStorm.

END/OSPC

Figure 4: The Weather Network (TWN) Weather Alert for June 14th, 2017. Warnings were provided by Environment and Climate Change Canada.

2.2 Storm Conditions

Figure 5 shows a modified Pickle Lake (WPL), Ontario, atmospheric sounding for June 15 00Z. Pickle Lake is located approximately 390 km northeast of Dryden. This make the sounding more realistic to the atmospheric conditions that were occurring near Dryden, the surface temperature was increased to 26°C and the dew point to 16°C. Inputting these values created a sounding which showed an environment with moderate instability (962 J/kg), and a weak capping inversion (-8 J/kg). The SPC Mesoscale Analysis MLCAPE on June 14 22Z indicated an environment with moderate instability (approximately 250 to 1000 J/kg), and weak convective inhibition with values ranging between 0 and -25 J/kg (Figure 6). This matches the modified sounding results.

Figure 5: Modified RAOB atmospheric sounding for Pickle Lake, ON for June 14th, 2017.

Figure 6: SPC MLCAPE (J/kg) and MLCIN (shaded regions) for June 14 at 22Z.

Figure 7: WPC 21Z surface analysis valid for June 14 showing the approaching occluded cold front.

Additionally, the high equilibrium level (270 hPa or approximately 9,600 metres), indicated that thunderstorm tops would extend beyond this height from the ground, which is favourable for the production of supercell thunderstorms. The combination of daytime heating and an approaching

occluded cold front (Figure 7) were easily enough to break through the very weak cap, resulting in a strong potential for severe thunderstorm development.

As the occluded cold front tracked into northwestern Ontario, the region contained moderate effective bulk shear (30-40 knots) (Figure 8) and moderate helicity (100 to 200 m^2/s^2) (Figure 9). This balance between moderate CAPE, shear, and helicity was very favourable for supercell development.

Figure 8: SPC effective bulk shear (knots) for June 14th at 22Z.

Figure 9: SPC 0-1km helicity (m^2/s^2) for June 14th at 23Z.

2.3 Radar Analysis and Imagery

Figure 10 shows the 1.5° Dryden (XDR) short-range reflectivity, as well as the tracks of the supercell storms that occurred near Fisherman's Cove (Supercell A) and Dryden (Supercell B).

Figure 10: Radar reflectivity (dBZ) and track of Supercell A as seen by the XDR radar.

The radar reflectivity data show a strong reflectivity core of 68 dBZ at 2230Z for Supercell A and 61 dBZ at 2210 for Supercell B. These high core values were determined using a program called

Aurora. By zooming in on the mesocyclone, the individual pixels can be distinguished. By selecting an individual pixel, Aurora will output the selected pixels reflectivity value. A strong reflectivity core is a good indicator of a mesocyclone with a strong updraft – a property that is often required for the production of hail and tornadoes.

Figure 11 also shows the XDR echo top data of the supercells, which shows a storm top of roughly 13 and 12 km. This storm, although not as deep as seen in stronger supercells, is still deep enough that a weak supercell could form.

Figure 11: Maximum echo top height (m) of the two tracked supercells.

Radial velocity data is used to distinguish areas of rotation, with positive values representing movement away from the radar, and negative values towards. By examining Figure 12 using Aurora, the maximum velocity of Supercell A was determined to be 18 m/s towards and 6 m/s away at 2230Z. For Supercell B, the maximum velocities are approximately 15 m/s towards and 6 m/s away at 2320Z. These values result in maximum delta-V's (addition of away and towards) of 24 m/s and 21 m/s, respectively. Delta-V is the quantity of inbound and outbound radial velocity and is used to determine storm rotation strength. These storms are considered weak mesocyclones.

Figure 12: Maximum radial velocity (m/s) of the supercells that occurred on June 14th, 2017 near Dryden, Ontario.

After analysis of the 0.5° radar reflectivity, a very distinctive hook echo (Figure 13) could be seen on radar at 2340Z with Supercell B. A hook echo is a pendant or hook-shaped weather radar signature. It is found in the lower portions of a storm as air and precipitation flow into a mesocyclone resulting in a curved feature seen in radar reflectivity. It often indicates the occurrence of a tornado.

Figure 13: Hook echo of Supercell B that occurred on June 14th, 2017 near Dryden, Ontario at 2340Z.

2.4 Supercell Track

After analyzing archived radar imagery to find the potentially tornadic supercells near Dryden, Ontario, the track of the mesocyclones were plotted in Google Earth (Figure 14). The tracks were estimated by following the path of the mesocyclones in Aurora, and pinpointing areas of apparent rotation. The latitude and longitude of the centre of rotation were used to create the supercell track.

Figure 14: Track of the potentially tornadic supercells near Dryden, Ontario on June 14th. The locations of reported damage (Dryden and Fisherman's Cove are noted on the image).

2.5 Reported Damage

Location	Latitude	Longitude	Description
Dryden	49.7679	-92.8077	Trees down east of Dryden and at Eagles Landing Golf Course in Dryden
Fisherman's Cove	50.3984	-93.0683	Report of trees down across highway

Table 1: Locations of tree damage determined during the aerial flight.

Figure 15: Images of the supercell near Dryden, Ontario. Images were gathered from Twitter.

Figure 16: Images of the tree damage at Eagles Landing Golf Course near Dryden, Ontario.

3. Flight Track

Flights were performed by the company KBM Resources Group located in Thunder Bay, Ontario. Figure 17 shows the areas that were surveyed by KBM. The aerial survey was conducted with a resolution of 10 centimetres per pixel, flown at a height of 15,000 feet, and used a 3-band camera (RGB). The flights were conducted on June 27th. The coordinates used by KBM Resources Group for Flight A were (50.32520, -93.13438) and (50.46762, -93.00559) and for Flight B were (49.69495, -92.87206) and (49.83791, -92.74365). The flight and supercell tracks do not line up. This is due to the tracks of the supercells being analyzed at a much later date with only the 0.5° short-range radial velocity data being available.

Figure 17: Actual flight tracks (green) conducted by KBM Resources Group. The supercell tracks are indicated by the red and yellow lines.

4. Flight Results

Once the aerial imagery was conducted and uploaded by KBM, the TIFF and GDB files were transferred from KBM's FTP site to an external drive. The higher resolution TIFF files were uploaded into ArcGIS and were used to analyze regions of damage. The GDB files were also uploaded into ArcGIS, however they could not be used for analysis as the resolution was too low. Nevertheless, since these files were geotagged, they were converted to KML files and used in Google Earth. This was a very useful step since it made it convenient to compare the aerial imagery with historical Google Earth images in order to distinguish old versus new tree damage.

4.1 Supercell A

The track of the aerial survey imagery is shown in Figure 18. The track is approximately 18 kilometres long. No new tree damage was not found along the track.

Figure 18: Flight track of Supercell A conducted by KBM Resources Group. No new damage was found along the track.

4.1 Supercell B

The partial track of Supercell B overlaid on top of the aerial survey imagery is shown in Figure 19. The area within the red circle is where new tree damage was spotted. The flight track is roughly 18 kilometres long. Figure 20 shows the tracks of the spotted damage. After detailed analysis of the entire path of the supercell, tornadic and downburst tree damage was found east of Dryden (Figure 21), covering an area of roughly 6.62 ha and 16.68 ha, respectively (see Appendix C). By zooming into the tornado damage, the tree fall direction was determined to be from a few directions (south to northeast), but mainly towards the northeast (Figure 22) – consistent with the track of the parent supercell. A contour line (see Appendix B) was created to show the intensity of the tornadic damage (Figure 23). Although there is no evidence of rotation in the damage, which is not uncommon, the damage was determined to be the result of a probable EF-1 tornado with a path length of 1700 metres and a maximum width of 415 metres. The tornado was rated with a Degree of Damage (DoD) 5 for the DI-CT (trees), with a maximum wind speed of 150 km/h.

There was also divergent downburst damage south of the tornado track. The damage is not in the direction of motion – the motion is mainly towards the southeast (Figure 24) of the parent storm, however, there is a video online of intense rain and wind near Dryden, which is consistent with a downburst. The downburst damage was given a rating of EF-0 with a DoD of 3 for the DI-CT with a maximum wind speed of 100 km/h.

Figure 19: Partial track of Supercell B (yellow) and flight track (green) overlaid on the aerial survey imagery collected by KBM Resources Group. The region circled in red is where new tree damage was located.

Figure 20: Tracks of the damage (red) produced by Supercell B. The northern path contains the most damage, which appears tornadic and is close to the direction of motion of the parent storm. The two southern tracks are part of a larger downburst.

Figure 21: Tornado damage (Image A) and downburst damage (Image B) determined after analysis of the aerial imagery in the circled area of Figure 19. The yellow line indicates the damage path from Figure 20.

Figure 22: Tornado damage found near a home east of Dryden, Ontario. Tree fall direction is mainly towards the northeast.

Figure 23: Downburst damage found south of the tornado track. Tree fall direction is mainly towards the southeast.

5. Conclusions

On June 14, 2017, at least two supercell storms developed near Dryden, Ontario. After an aerial survey with a resolution of 10 centimetres per pixel and flown at 15,000 feet was coordinated, and after analysis of the aerial imagery using ArcGIS and Google Earth, it was determined that tree damage from the June 14th Supercell B was caused by a downburst and a tornado. The downburst damage was rated EF-0, while the tornado damage was the result of a probable EF-1 tornado with a path length of 1700 metres and a maximum width of 415 metres. This tornado event has been added to the Ontario Tornado Database.

Appendix A

Atmospheric Sounding: A measurement of properties such as wind speed, temperature and moisture, vertically in the atmosphere.

Capping Inversion: An elevated atmospheric inversion layer that caps a convective layer below.

Convective Available Potential Energy (CAPE): The amount of energy a parcel of air would have if lifted vertically through the atmosphere to the equilibrium level.

Convective Inhibition (CIN): The amount of energy preventing air parcels rising from the surface to the level of free convection.

Downburst: An area of strong, downward moving air associated with a downdraft from a thunderstorm.

Echo Top: Radar indicated top of an area of precipitation.

Effective Bulk Shear: The shear difference from the storm's inflow base to the equilibrium level associated with the most unstable air parcel in the lowest 300 mb.

Equilibrium Level: On an atmospheric sounding, the level above the level of free convection (LFC) at which the temperature of a rising air parcel once again equals the environment temperature.

Helicity: The tendency of air in the lower levels of the atmosphere to "corkscrew" and encourage the formation of storms with mesocyclone circulations.

Inversion: A reversal of the normal behaviour of temperature in the atmosphere where temperature increases with height.

Level of Free Convection (LFC): Height at which a parcel of air, when lifted, becomes warmer than its surroundings and rises.

Occluded Front: Occurs when a cold front overtakes a warm front and often occur near strong low-pressure systems. They are usually associated with unstable weather.

What is a Tornado?

A tornado is a violently rotating column of air that extends from the base of a thunderstorm to the ground. The most destructive tornadoes occur from supercells, which are rotating thunderstorms – called mesocyclones. It is not exactly known how tornadoes form, as only 10 percent of all supercells will result in a tornado. However, meteorologists look for particular radar signatures which could indicate a mesocyclone is producing a tornado, such as a hook echo. Currently, tornadoes are ranked on the Enhanced Fujita Scale, ranging from EF-0 to EF-5. This relatively new rating system (launched

in Canada on April 1, 2013) incorporates numerous damage indicators such as building type, structures, barns and outbuildings, and trees. Below is a diagram showing where a tornado is likely to form within a supercell thunderstorm.

Figure 4: Diagram of a tornado producing supercell. (<https://www.qschw.com.au/how-does-weather-happen-tornados/>)

Appendix B

Creating Contour Lines for Induced Tornado Tree Damage in Forested Regions

Steps:

1. Identify the start and end locations of damage and draw lines outlining the edge of the damage (see Example 1)
2. Draw a series of boxes where the length is equal to the maximum width (see Example 1).
3. Calculate/estimate the percentage of trees down in each box to determine the Degree of Damage (DoD) to get wind speed (see Example 2).
4. Adjust wind speed as necessary to account for conditions (e.g. soil).
5. Use the wind speeds from the DoD to get an EF rating (see Example 3).
6. Create contour line (see Example 4).

Example 1

Example 2

DOD	Damage Description	EXP*	LB*	UB*
1	Small limbs broken (less than 2 cm diameter)	70	55	85
2	Large branches broken (2-8 cm diameter)	90	65	110
3	Up to 20% of mature trees snapped and/or uprooted	115	80	150
4	More than 20% of mature trees snapped and/or uprooted	150	105	190
5	More than 50% of mature trees snapped and/or uprooted	190	145	230
6	More than 80% of mature trees snapped and/or uprooted; numerous trees may be denuded/debarked by missiles with only stubs of largest branches remaining	235	190	275

Table A: Degree of Damage (DOD) for Expected (EXP), Lower Bound (LB) and Upper Bound (UB).

Example 3

F/EF Rating	F-Scale Wind Speed Rounded to 10 km/h	EF-Scale Wind Speed Rounded to 5 km/h
0	60-110	90-130
1	120-170	135-175
2	180-240	180-220
3	250-320	225-265
4	330-410	270-310
5	420-510	315 or more

Table B: Comparison of F-Scale and EF-Scale wind speeds (adapted for Environment Canada) associated with damage ratings.

Example 4

Length 1700 m, max path width 415 m

Appendix C

Determining Hectares of Trees Damaged by Tornadoes

Steps:

1. Using the boxes created in Step 2 of Appendix B, determine the size of the area within each box (see Example 1).
2. Using the estimation of the percentage of downed trees in each box from Step 3 in Appendix B, multiply the percentage by the area of the box to determine the total area of damage (see Example 1).
3. Convert to hectares (if required).

Example 1

Calculation Example: (Size of Box) X (Percentage of Trees Down) X (Percent of Area with Trees) X (0.0001 ha / 1 m²)

Box 1: (285 m X 285 m) X (0.15) X (1.00) X (0.0001 ha / m²) = 1.22 ha

Box 2: (335 m X 335 m) X (0.20) X (1.00) X (0.0001 ha / m²) = 2.24 ha

Box 3: (415 m X 415 m) X (0.25) X (0.30) X (0.0001 ha / m²) = 1.29 ha

Box 4: (415 m X 415 m) X (0.50) X (0.15) X (0.0001 ha / m²) = 1.29 ha

Box 5: (370 m X 370 m) X (0.00) X (0.40) X (0.0001 ha / m²) = 0.00 ha

Box 6: (270 m X 270 m) X (0.40) X (0.20) X (0.0001 ha / m²) = 0.58 ha

Total Hectares = 6.62 ha

A similar calculation was completed for the downburst damage.

UPDATED Summary of the Northern Ontario Flyover Project

Event Name and Date D/M/Y	Contribution	Data Contribution	Initial Detection of Event	Date of Flights	# of Supercells	Project Classification	Current ECCC Classification	Event Details	Damage Indicator(s)	Maximum Degree of Damage	Track Length (m)	Max Width (m)	Max EF-Scale Wind Speed (km/h)	EF Rating	Storm Motion (Degrees)
Dryden, Ontario 14/06/2017	New Tornado Identified	Aerial survey based on radar	Radar detection	June 27 th , 2017	2	Probable tornado	N/A	Dryden – Reports of some tree damage from witnesses. Aerial survey found significant tree damage. Some damage resembled a tornado damage track and a separate area of damage resembled downburst damage.	CT – Trees	5	1700	420	145	EF1	255
						N/A	N/A	Fisherman’s Cove – Second hand report of tree damage.	No tornado verified.						
Southern Québec, Québec 18/06/2017	Tornado Data Improved	Aerial and ground survey	Witness reports	July 10 th - July 18 th , 2017	10	Confirmed tornado	Confirmed EF2 tornado (QSPC)	Lac Tapani (Sainte-Anne-du-Lac) – Tornado confirmed by ground survey. Residence completely destroyed. Other buildings damaged. Tornado track extended using satellite imagery.	CT - Trees	6	30500	1300	230	EF3	230
						FR12 – One or Two Family Residences	9								
	Tornado Data Improved	Aerial and ground survey	Witness reports	Sainte-Anne-du-Lac flown again January 17 th , 2018		Confirmed tornado	Confirmed EF2 tornado (QSPC)	Lac Vert (Hébertville) – Tornado confirmed by ground survey. A home and a chalet had extensive damage. Other buildings damaged. Tornado track extended using satellite imagery.	CT - Trees	6	22800	900	210	EF2	240
						FR12 – One or Two Family Residences	7								
	New Tornado Identified	Aerial and ground survey	Witness reports			Confirmed tornado	Unclassified	Lac Noir (Sainte-Monique) – Tornado confirmed by ground survey. Significant tree damage and minor building damage was found. Tornado track extended using satellite imagery.	CT - Trees	5	8500	650	145	EF1	235
						FR12 – One or Two Family Residences	2								
	New Tornado Identified	Aerial and ground survey	Witness reports			Confirmed tornado	Confirmed EF1 <i>microburst</i> (QSPC)	Lac des Cornes (Chute-Sainte-Phillippe) – Relatively long narrow track of damage. Ground survey found evidence of minor tree damage but missed more significant damage areas. Tornado passed through group of cottages that experienced minor damage. Tornado track extended using satellite imagery.	CT - Trees	5	12300	460	145	EF1	235
						FR12 – One or Two Family Residences	1								
	Tornado Data Improved	Aerial survey	Witness reports			Confirmed tornado	Confirmed EF1 tornado (QSPC)	Lac de la Boiteuse (Lamarche) – Significant tree damage. \$100K cottage shifted on weak foundation and other cottages damaged. Tornado track extended using satellite imagery.	CT - Trees	5	11500	500	170	EF1	230
						FR12 – One or Two Family Residences	5								
	Tornado Data Improved	Analysis from witness description	Witness photo	None		Confirmed tornado	Confirmed EF0 tornado (QSPC)	Mare-du-Sault (L’Étape) – Tornado confirmed by video. Report and photo sent to QSPC. Could not find track using satellite imagery. However, photos and witness description used to estimate track length, width and storm motion.	No DI	No DoD	1500	50	90	EF0	220
	New Tornado Identified	Satellite-based survey	Pilot report	None		Confirmed tornado	Unclassified	Lac Tom (La Tuque) – Confirmed using satellite imagery, pilot photos and ground photos. Extensive tree damage along track.	CT – Trees	6	6700	1100	210	EF2	225
	New Tornado Identified	Satellite-based survey	Satellite	None		Confirmed tornado	N/A	Lac de la Corneille (ZEC Gros-Brochet) – Confirmed using satellite imagery.	CT – Trees	6	13700	1200	210	EF2	235
	New Tornado Identified	Satellite-based survey	Satellite	None		Confirmed tornado	N/A	Manawan (ZEC Boullé) – Confirmed using satellite imagery.	CT – Trees	5	4800	330	145	EF1	220
New Tornado Identified	Satellite-based survey	Satellite	None	Confirmed tornado	N/A	Lac Bachon (ZEC Kiskissink) – Confirmed using satellite imagery.	CT – Trees	6	9600	500	190	EF2	215		
New Tornado Identified	Satellite-based survey	Satellite	None	Confirmed tornado	N/A	Rivière Beauséjour (ZEC Onatchiway) – Confirmed using satellite imagery.	CT – Trees	5	3300	150	145	EF1	225		
Quetico, Ontario 06/07/2017	Tornado Data Improved	Aerial survey based on witness	Witness reports	July 27 th , 2017	1	Confirmed tornado	Confirmed EF2 tornado (OSPC)	Quetico – Tree damage spotted. Aerial survey did not capture the full track, satellite imagery extended track to 9 km.	CT - Trees	6	17000	510	190	EF2	315
Huntsville, Ontario 04/08/2017	Tornado Data Improved	Ground survey conducted by Environment and Climate Change Canada	Radar and witness reports	March 17 th , 2018	2	Confirmed tornado	Confirmed EF1 tornado (OSPC)	Utterson – Hundreds of trees uprooted.	CT - Trees	5	5300	450	170	EF1	210
	Tornado Data Improved		Radar and witness reports			Confirmed tornado	Confirmed EF1 tornado (OSPC)	Fairy Lake – Damage to homes and trees uprooted.	CT – Trees	4	8270	100	140	EF1	235
						Tornado Data Improved	Radar and witness reports	Confirmed tornado	Confirmed EF2 tornado (OSPC)	Rebecca Lake – Ground surveys confirmed rating. Extensive tree damage.					
Kenora, Ontario 22/09/2017	Tornado Data Improved	Aerial survey based on radar	Radar and witness reports	September 30 th and October 6 th , 2017	7	Confirmed tornado	Probable EF0 tornado (OSPC)	Werner Lake – Damage found at location (80 km NW of Kenora). Damage to a remote cabin and nearby trees. Additional downburst damage in aerial imagery, but was the result with a different storm as the tree fall was from the northwest. Additional tree damage was determined to be old.	CT - Trees	4	N/A	30	120	EF0	315
									FR12 – One or Two Family Residences	2					