60 THE NORTHERN TORNADOES PROJECT – OVERVIEW AND INITIAL RESULTS

David Sills[1*], Gregory A. Kopp[2], Emilio Hong[2],
Joanne Kennell[2], Aaron Jaffe[2], and Lesley Elliott[2]

[1]Meteorological Research Division,
Environment and Climate Change Canada, King City, ON
[2]Faculty of Engineering, University of Western Ontario, London, ON

1. PROJECT AND MOTIVATION

The Northern Tornadoes Project (NTP) is a collaboration between the University of Western Ontario's Faculty of Engineering and the Meteorological Research Division of Environment and Climate Change Canada (ECCC). The Project is focused on the detection of tornadoes across Canada, particularly in non-urban areas.

It is known that intense thunderstorms occur in many sparsely populated areas of Canada but tornadoes associated with such storms are rarely reported (Sills et al. 2012). This results in large gaps in our tornado climatology (Fig. 1).

A study to determine Canada's 'tornado prone' regions attempted to fill in these gaps using statistical modelling (Sills et al. 2012). The results suggest that only ~30% of the tornadoes that occur in Canada are being verified (Fig. 2). Cheng et al. (2013) used a similar but more conservative method and estimated that ~50% of tornadoes are verified.

Accordingly, the main goals of the NTP are to:

- enhance our understanding of actual tornado occurrence and risk in Canada,
- validate the statistical modelling, and
- improve methods for the detection of tornado damage paths, particularly in rural / remote locations.

2. DETECTION PROCESS AND DATA

A multi-step tornado event detection process has been established for the NTP. First, two-day tornado potential forecasts are generated to prepare the team for possible action. When potentially tornadic storms have occurred, Doppler radar imagery is used to identify supercell tracks. Areas of damage are also identified based on public reports (often via social media). Next, ground surveys are conducted in areas with potentially tornadic damage, including drone flights where possible. High-resolution satellite data with 3-5-m nominal resolution (via planet.com) are also used to identify potentially tornadic damage paths, particularly in forested areas. Preliminary classification (tornado vs. downburst) and rating using the EF-scale (Canadian version, Sills et al. 2014) is often provided at this time (often in collaboration with ECCC offices).

Once tornado damage paths are identified, aircraft flights are made and geo-referenced imagery with 5-10-cm nominal resolution is obtained and processed. Analysis of such imagery allows more detailed investigations of damage patterns (e.g., directions that trees are down), path lengths and widths, and damage intensity in areas where ground surveys are difficult. Lastly, final decisions are made on tornado classification and rating.

3. PROJECT RESULTS FOR 2017 AND 2018

3.1 Overall Results

The map in Fig. 3 shows tornadoes that the NTP either found ('new') or for which the NTP investigation resulted in improved event data ('improved'). The 2017 pilot focused on events in the heavily forested regions of Ontario and Quebec resulting in 18 new and improved tornadoes. The 2018 pilot focused on detecting all EF1+ tornadoes in Ontario and investigating all significant tornado events across Canada, and 22 new and improved tornadoes resulted. In 2017, 12 aerial surveys were conducted while 10 were made to date in 2018.

The number of new tornadoes found by the NTP compared to the total number of verified tornadoes (by ECCC and NTP) is of interest. Focusing on

* *Corresponding author address:* David M. L. Sills, Meteorological Research Division, ECCC, 14780 Jane Street, King City, Ontario, Canada, L7B 1A3; e-mail: David.Sills@canada.ca

Ontario and Quebec, in 2017 there were 12 and 14 verified tornadoes, respectively. A total of nine new tornadoes were found by the NTP, resulting in an increase of 35%. In 2018, there were 16 and 6 verified tornadoes for Ontario and Quebec, respectively. A total of 12 new tornadoes were found, resulting in a 55% increase.

3.2 Significant Events

There were a number of climatologically significant tornado events that occurred in the NTP study areas during the 2017 and 2018 pilot seasons.

An outbreak of 11 tornadoes was uncovered by the NTP in southwestern Quebec after three waves of supercell thunderstorms affected the area on 18 Jun 2017. The tornado outbreak is the largest recorded in Quebec and one of the largest recorded in Canada. The outbreak included tornadoes with damage rated at EF0 (1), EF1 (5), EF2 (4) and EF3 (1). The NTP found seven of the 11 tornadoes using mainly satellite imagery in heavily forested areas, and improved the event data for the remaining four tornadoes. Fig. 4 shows the damage assessed in association with the Ste-Anne-du-Lac EF3 tornado, including that visible via high-resolution satellite imagery, aerial imagery and ground surveys.

The Alonsa, Manitoba supercell tornado of 3 Aug 2018 had the only tornado damage in North America rated at EF4 (or higher) in 2018. It was the most intense damage recorded in Canada since the 2007 Elie, Manitoba F5 tornado. It was also the first EF4 (or higher) tornado confirmed in Canada using the EF-scale that was implemented here in 2013 (see Sills et al. 2014). Note that the location of the tornado is shown on the map in Fig. 3. For this case, the NTP improved tornado data and documented remote sensing-based indicators of tornado damage that can be used in future analyses. With no forests in this area, satellite data analysis focused on impacts to vegetation in fields, as shown in Fig. 5. Fig. 5 also shows drone imagery in an area observed by the satellite, and finally a ground survey photograph showing that the satellite was seeing mainly scattered tree damage and grass discolouration.

Lastly, a high-impact tornado event in Ottawa, Ontario and nearby areas in Ontario and Quebec occurred when two waves of supercell thunderstorms struck the area on 21 Sep 2018. The preliminary NTP analysis indicates that there were six tornadoes in total with damage rated at EF1 (4), EF2 (1) and EF3 (1). The tornado locations can be seen in Fig. 3 (note that one additional weak tornado occurred in the same are earlier in the year). EF3 damage to a residential home that was investigated during the ground survey is shown in Fig. 6. To date, NTP found one of the six tornadoes and improved tornado event data for the remaining five. This was the latest occurrence (in the year) of EF3+ tornado damage in Canada since the 26 Sep 1898 F3 tornado in Merriton (now St. Catharines), ON, and preliminary estimates suggest that this tornado event is among the most costly ever in Canada at around $300M in insured losses (IBC 2018).

4. SUMMARY AND FUTURE WORK

Investigations during the 2017 and 2018 tornado seasons identified 21 tornadoes that would otherwise have gone unverified and improved event data for another 19 tornadoes. Several climatologically significant tornado events were included in these investigations.

While the new tornadoes increase the tornado totals by a significant percentage (~30-50%), statistical modelling suggests that actual tornado occurrence could be as high as two to three times the recorded rate. Thus, there may be even more tornadoes to be identified, and efforts to enhance tornado detection will be intensified in the future.

Future NTP activities will include:

- working with Western Libraries to provide a publicly accessible digital archive for all project materials,
- strengthening detection capacity and working relationships across Canada,
- continuing to investigate new approaches to damage assessment in non-urban areas (e.g., trees, crops) making the best use of project team expertise, and
- attempting to automate the detection of damage paths present in high-resolution satellite data.

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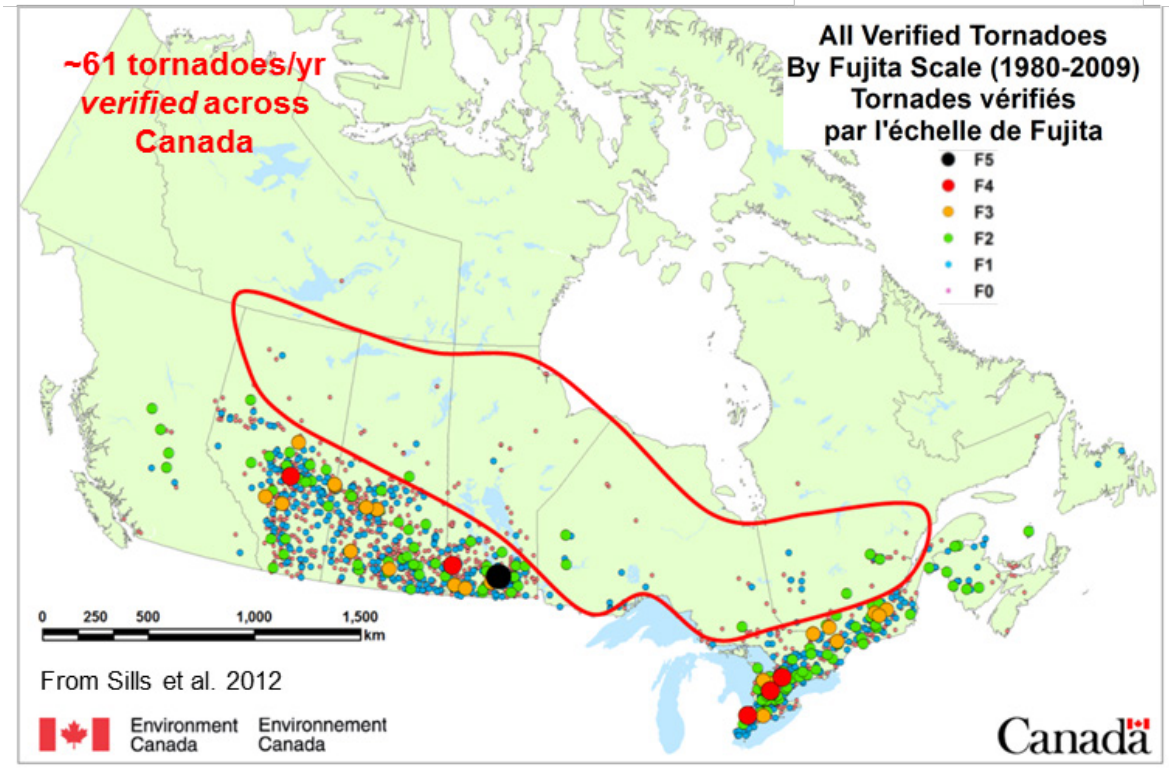

Figure 1. Map of 1980-2009 verified tornadoes across Canada, and a large area where storms often occur but few reports are received (red outline). Adapted from Fig. 1 in Sills et al. 2012.

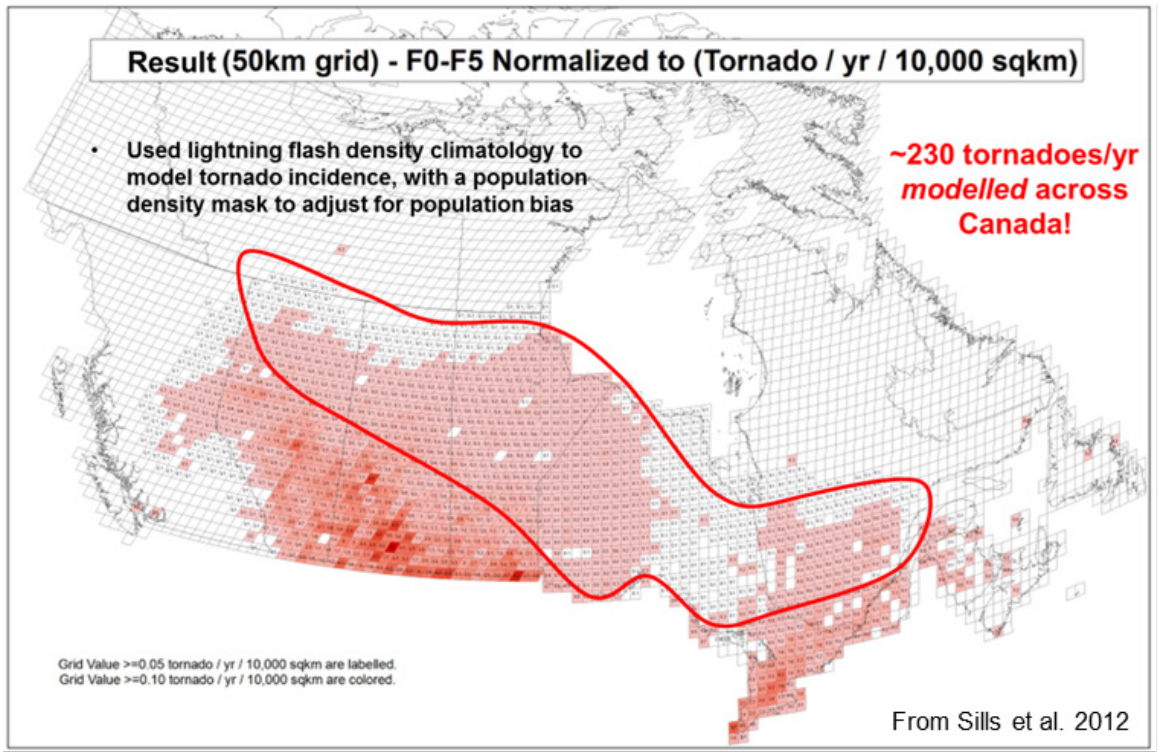

Figure 2. Map showing results of statistical modelling of tornado occurrence across Canada, with the red low-report outline from Fig. 1 superimposed. Adapted from Fig. 6 in Sills et al. 2012.

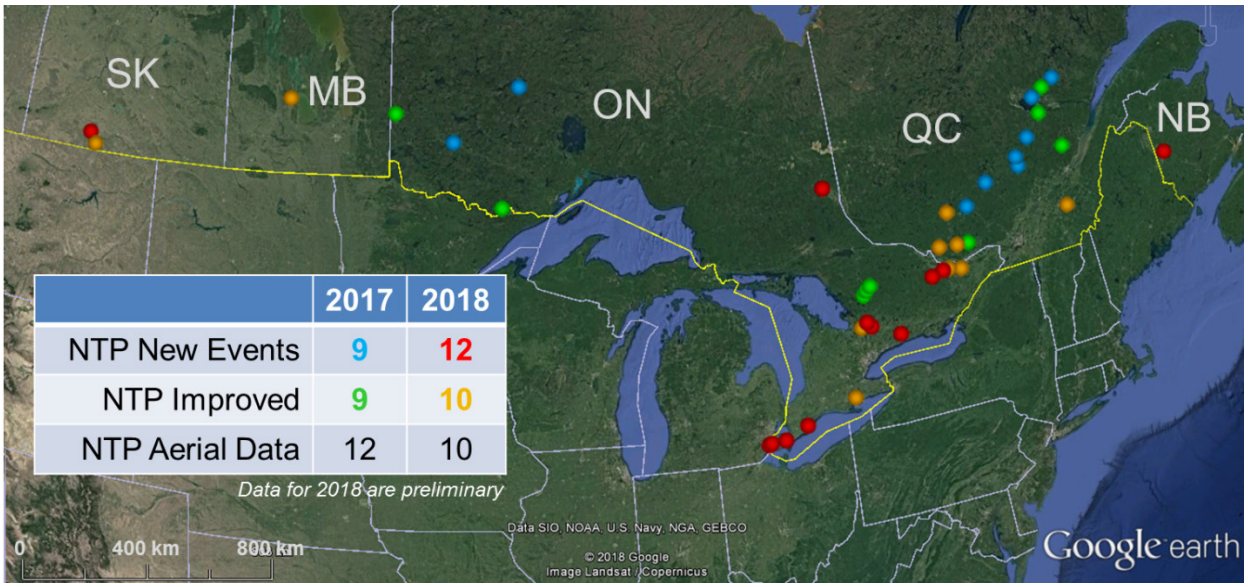

Figure 3. Map showing the 'new' and 'improved' tornadoes investigated by the NTP. The 2017 pilot focused on events in the heavily forested regions of Ontario and Quebec (cool colours). The 2018 pilot focused on capturing all EF1+ events in Ontario and all significant tornado events across Canada (warm colours).

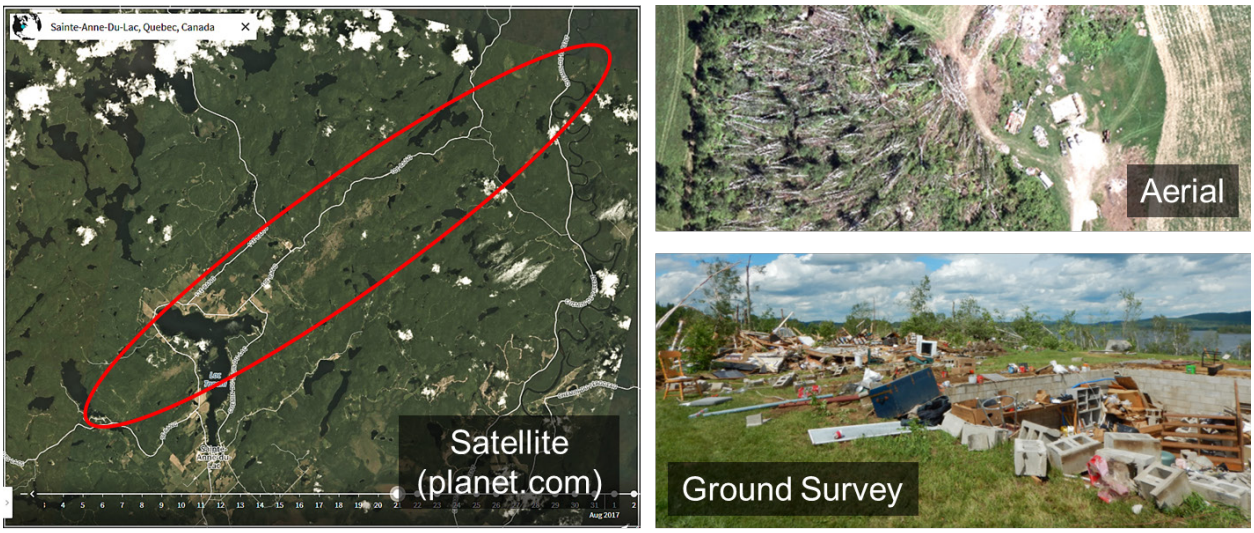

Figure 4. Images showing the EF3 damage assessed in association with the 18 Jun 2017 Ste-Anne-du-Lac, Quebec tornado. Clockwise from left: high-resolution satellite imagery (from planet.com, red outline marks area with visible forest damage in a long narrow path), aircraft aerial imagery and ground survey photographs.

Figure 5. The Alonsa, Manitoba EF4 tornado resulted in impacts to vegetation that were visible from high-resolution satellite imagery (from planet.com), NTP drone imagery and NTP ground survey photography. The damage included felled trees and discoloured grasses.


Figure 6. EF3-rated tornado damage in Dunrobin, Ontario. The tornado that caused this damage was the strongest of the six tornadoes that day.