7B.5 THE TORNADOES IN ONTARIO PROJECT (TOP)

David M. L. Sills*, Sarah J. Scriver and Patrick W. S. King
Cloud Physics and Severe Weather Research Division,
Meteorological Service of Canada, Toronto, Ontario, Canada

1. INTRODUCTION

A tornado event database is important for several reasons. It allows a tornado climatology to be established for a region and facilitates climate change and risk analysis studies. It provides data for verification of operational watches / warnings and evaluation of radar algorithms. It also enables the study of relationships between tornado occurrence and a variety of weather features, such as lake breeze fronts (e.g. King et al. 2003, Sills and King 2002). Clearly, a high quality database is needed to satisfy the requirements for each of these uses.

The Tornadoes in Ontario Project (TOP) was initiated to improve the quality of the tornado database for the Canadian province of Ontario. This project has three components:

1) improving the quality of the data coming into the database each year,
2) updating the existing database to the current year, and
3) revising the existing database.

Each of these components will be discussed in more detail in the following text. In addition, it will be shown that the quality of new data created via TOP has some promising improvements over data in the existing database.

2. BACKGROUND

Michael Newark of the Atmospheric Environment Service (now the Meteorological Service of Canada or MSC) was the first to establish a tornado database for Ontario with events for 1918 through 1992. He used this database, as well as data from other regions of Canada, to publish a national tornado climatology incorporating data from 1950 to 1979 (Newark, 1984). To create the database, he developed a probabilistic methodology for identifying tornadoes, using confirmed, probable and possible categories, and spent roughly a decade sifting through newspaper clippings, photographs, and reports as well as conducting damage surveys. Knowledge of such phenomena as downbursts, derechos and gustnadoes was in its infancy at that time, and it is expected that some of the tornadoes in Newark's database, particularly those in the possible category, are non-tornadic wind phenomena.

Newark's database has several shortcomings that are shared by tornado databases in other regions and countries. These are discussed in detail elsewhere (Doswell and Burgess 1988, Grazulis 1993, Kelly et al. 1978) but include population bias, rare event bias, paths from discrete tornadoes that were combined into one long path, etc.

3. IMPROVING INCOMING DATA

We decided that the best way to begin improving the database was to ensure the quality of any new data coming into it. Tornado data typically originate from three different sources:

- eyewitness reports (and sometimes accompanying visual evidence) from the public, trained spotters, CANWARN members and police,
- newspaper clippings via a clipping service, and
- damage investigations by MSC staff.

As part of TOP, operational staff in Ontario were educated on the information needed via public reports in order to improve the database. This included a reminder that public reports of severe weather are scientific data and should be treated as such. Another issue was that operational follow-up on public reports of damage had fallen off somewhat by the late 1990's, reducing the chances of confirming damage as tornadic or non-tornadic.

---

* *Corresponding author address:* David M. L. Sills, Cloud Physics and Severe Weather Research Division, Meteorological Service of Canada, Toronto, Ontario, Canada, M3H 5T4; e-mail address: David.Sills@ec.gc.ca

In 1999, a more aggressive damage survey initiative was undertaken by the lead author. Of particular importance were weak damage events where post-event evidence would be hard to come by. In 2004, the operational damage survey program in Ontario was reinvigorated and is now likely better than at any time in the past.

Another weak point in the incoming data process was a lack of operational consistency when classifying damaging wind events (tornadic or otherwise) and rating them using the Fujita scale (Fujita, 1981). To address this, we developed and tested two tools: the Tornado Classification Decision Tree and the Wind Damage Rating Table.

3.1 The Tornado Classification Decision Tree

To maintain consistency with the Newark database, we decided to retain the probabilistic approach with confirmed, probable and possible categories. In a province as large as Ontario, with many areas of very low population density, we hoped this approach would allow more flexibility when interpreting results than use of a binary, or yes-no, system.

We defined the confirmed category so that events must have definitive evidence of a tornado, usually consisting of some sort of visual evidence or a combination of eyewitness reports and damage reports (within 30 km and 30 min of each other). We defined the probable category to include events where all available evidence pointed to the likelihood of a tornado, though definitive evidence was not available.

The possible category was defined to include events that had either ambiguous or unreliable tornado evidence. As with Newark's work, the inclusion of possible events allows for future event re-evaluation and possible extension of the database. Combining confirmed and probable events likely gives the best representation of actual tornado occurrence without including potentially non-tornadic events (e.g. microbursts).

Two other types of reports had to be dealt with: non-tornadic funnel clouds and waterspouts. It is the experience of the authors that reports of non-tornadic funnel cloud sightings are generally unreliable unless accompanied by corroborating evidence. However, since some of these could potentially lead to the identification of a tornadic event, they were set aside in a separate "Funnel Cloud" category.

It was decided that waterspouts not affecting land would be omitted from the database for the time being. Work on a waterspout database for Ontario has been undertaken by Wade Szilagyi of MSC and it is anticipated that the tornado and waterspout databases may be combined at some time in the future.

Once the event classifications had been finalized, a decision tree was developed so that storm data from various sources could be used to consistently place events in the appropriate categories. The Tornado Classification Decision Tree is shown in Fig. 1.

As designed, the reliability of the data source decreases as one goes down the left side of the tree, beginning at the top with damage investigation data and ending at the bottom with a report of a funnel cloud. The terminal nodes represent the highest allowed classification for the given evidence. For example, a photograph of a tornado results in a "confirmed" event while an eyewitness report of a tornado is a "probable" event. These classifications can be reduced at the discretion of the user if the available evidence is ambiguous or suspect.

Each terminal node is given a letter and this letter is entered into the database along with any reduction factor (e.g. B, -1). In this way, the type of evidence associated with each event enters the database. In addition, any future revisions to the decision tree can easily be reflected in the database using the terminal node identifiers.

Definitions for the italicized terms on the decision tree are given in Appendix A.

3.2 The Wind Damage Rating Table

In addition to the need for consistent event classification, there was also a need to ensure that wind damage was rated consistently. Several sources of information on the F-scale had been used in Ontario up to this point and a document was needed to bring all of these sources, and sources based on new science, together in one location. Fig. 2 shows a few example rows from the rating table.

The rating table lists damage indicators down the left side and F-scale ratings with associated wind speeds across the top. Descriptions of damage are included at the appropriate locations within the

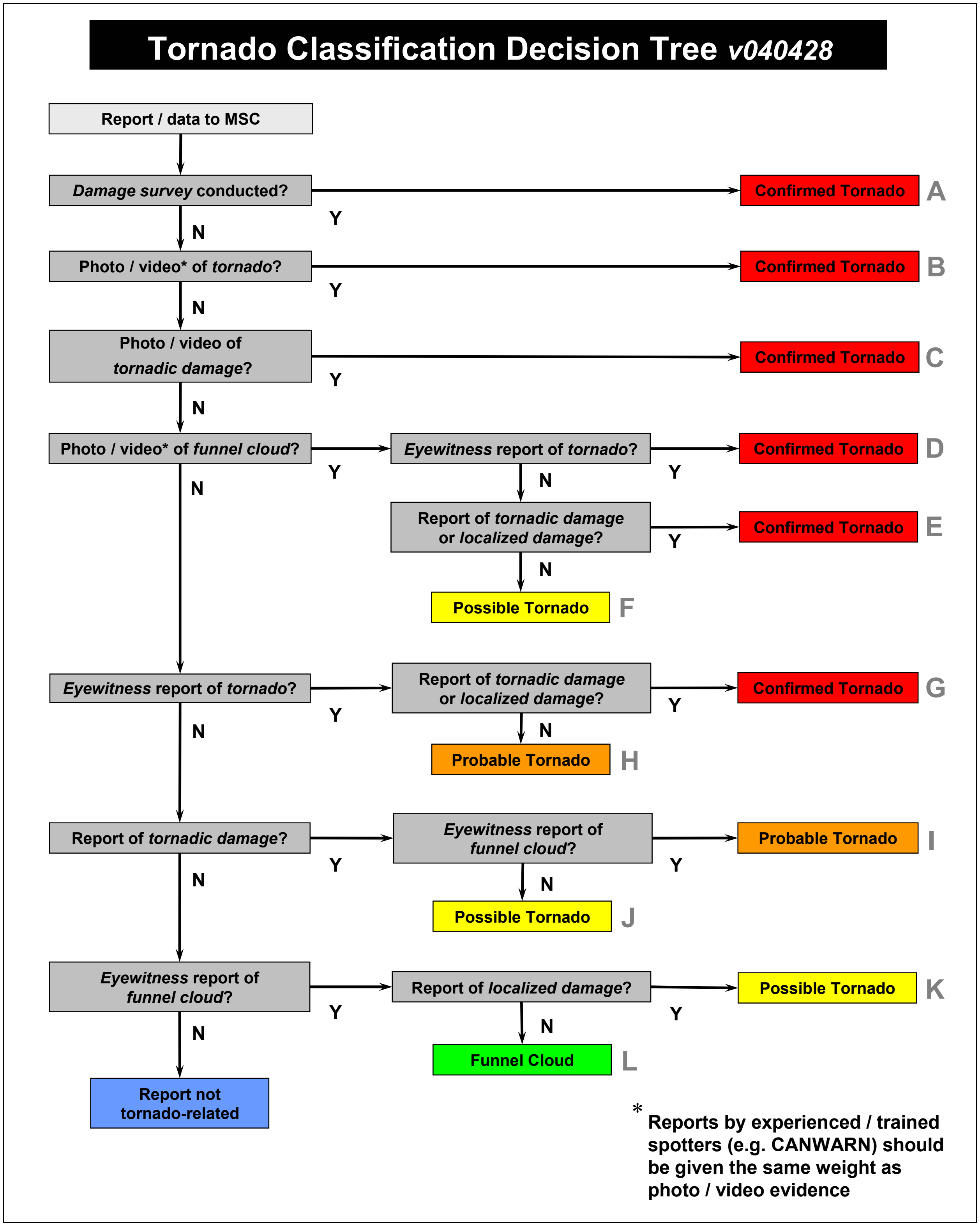

Figure 1. The decision tree developed and tested for TOP. Italicized terms are defined in Appendix A.

TOP - Wind Damage Rating Table

v 04.08.04 — Page 1

		Fujita Scale Rating, Speed (km h^{-1}) and Damage Description						
		F0	F1	F2	F3	F4	F5	
Code	**Indicator**	60 - 110	120 - 170	180 - 240	250 - 320	330 - 410	420 - 510	**Notes**
AH	*Well-built, well-anchored house*	Some roofing / siding materials removed, chimneys, awnings and canopies damaged, antenna or satellite dish bent	Large areas of roofing / siding material removed, partial structural failure of roof, attached garages may be destroyed	Well-attached roof removed from house, frame house may have other structural damage	Roof and some exterior walls removed from frame house, upper story of brick house destroyed	Frame house destroyed to foundation, two-storey brick house left with only a few walls standing	Frame house obliterated and debris swept from foundation, brick house destroyed to foundation	If roof and walls not fastened properly, maximum rating should be either F2 OR the rating of the adjacent house. Brick house refers to solid brick construction, NOT brick veneer.
UH	*Well-built, unanchored house*	Some roofing / siding materials removed, chimneys, awnings and canopies damaged, antenna / satellite dish bent	Large areas of roofing / siding material removed, partial structural failure of roof, attached garages may be destroyed, one-story house shifted on its foundation, summer cottage may be rolled over	Structural damage to house, one-story house moved entirely off its foundation, two-story house shifted on its foundation, summer cottage rolled over and/or carried a short distance	One-story house moved entirely off its foundation and destroyed, two-story house sustains major structural damage and is moved entirely off its foundation	Two-storey house moved entirely off its foundation and destroyed		
MH	*Mobile home*	Awnings and canopies damaged, antenna / satellite dish bent, unanchored mobile home shifted on its foundation	Unanchored mobile home overturned and destroyed though still recognizable, anchored mobile home has partial structural failure	Mobile home obliterated and rendered unrecognizable				

Figure 2. Part of the wind damage rating table developed and tested for TOP.

table. Notes, references, and update information are also provided.

Each damage indicator is assigned a code, and this code is entered into the tornado database. For example, if the F-scale rating was based on the roof being completely removed from a well-built, well-anchored house, a rating of F2 and a code of AH would be entered into the database. This allows easy revision of ratings if the table is changed at some time in the future.

4. UPDATING THE TORNADO DATABASE

For the next phase of the project, we used the new classification and rating tools to update the Newark database with a new TOP database covering the period from 1993 to 2003.

News clippings for the period were obtained and items related to wind phenomena were extracted. The operational severe storm log was also combed for items related to wind phenomena. Lastly, all damage survey reports and any available video and photographic evidence for the period were gathered.

For each event, the available data were processed using the new classification and rating tools and a physical archive file was created to store associated clippings, photographs, videotapes, etc. Summary sheets for each event were also created and place at the front of each physical archive file. The physical files are to be placed in the national tornado archives stored at the Meteorological Service of Canada headquarters in Toronto.

Using a desktop computer, data for tornado events were entered into a spreadsheet, including the following parameters:

- Tornado classification, code and reduction factor
- Event start time (local and UTC)
- F-scale rating and code
- Start and end point latitude and longitudes
- Path length, width and direction of motion
- Human and animal dead and injured
- Property damage (thousands of unadjusted Canadian dollars)
- Ontario watch region
- Nearest community
- F-scale rating notes
- Miscellaneous notes

4.1 Results

Some results from the 1993-2003 TOP database will be discussed in this section. Detailed climatological and statistical analysis will be presented in a future paper.

In total, 191 tornado events were identified and entered into the database, including 67 confirmed, 40 probable and 84 possible events (plotted in Figs. 3a and 3b). Considering just confirmed and probable tornadoes, there were 2 F3, 7 F2, 34 F1 and 64 F0 events (plotted in Figs. 4a and 4b).

We found that the primary evidence for tornado classification was from newspaper clippings (43%), followed by eyewitness reports (34%) and MSC staff damage investigations (22%). However, for a given year, any one of these sources could dominate.

Combining the 1993-2003 TOP database with the existing Newark database yields a continuous tornado event record from 1918 to 2003. Events will be added annually starting in the current year. A plot of confirmed and probable events from the combined database is shown in Figs. 5a and 5b.

4.2 Evaluating Data Quality

Brooks and Doswell (2001) found that the distribution of tornadoes by F-scale ranking in the United States (the most comprehensive national tornado database) has been approaching log-linear and note that this is consistent with standard statistical distributions of rare events. They also discovered that, since the 1950s, the slope of the tornado distribution has been relatively constant for F2 through F4 tornadoes, and therefore argued that this slope is an indicator of the true tornado distribution.

In Fig. 6, confirmed and probable tornado data from the Newark and TOP databases are plotted on the same graph as United States tornado data from the 1990s. Data are normalized to 100 F2 tornadoes. It can be seen that Newark data and the United States data are very similar between F2 and F4. However, F0 and F1 tornadoes from the Newark data fall below the F2-F4 slope line, indicating under-reporting of weak tornadoes in the database.

There are no F4 tornadoes in the TOP database. However, the normalized number of F0 through F3 events matches the United States data very closely. This appears to indicate that there is far less under-reporting of weak tornadoes in the TOP database than the Newark database.

We would like to claim that this is entirely due to improved data quality measures taken as part of TOP. However, part of this improvement for weak events can be attributed to improvements in data sources. This includes the introduction of a storm spotter network, the proliferation of consumer-grade video and still cameras, and the availability and use of newspaper clipping services.

5. REVISING THE EXISTING DATABASE

The final component of the project is revision of the Newark database, including application of the new tools developed for TOP. There are also a number of past events that have surfaced and need to be added. Since Newark's database already contains over 1000 events, this will be quite a time consuming project and may take several more years to complete. We may begin by re-evaluating just the most significant events.

6. CONCLUSIONS

The Tornadoes in Ontario Project was undertaken to improve the quality of Ontario's tornado database for use in a variety of operational and research activities. We have developed a Tornado Classification Decision Tree and a Wind Damage Rating Table to improve the consistency of incoming data, and have used these tools with data from various sources to create a 1993-2003 dataset. These tools will next be used to extend and revise the original Newark tornado database for Ontario that covers the period from 1918-1992.

We hope to export this methodology to other regions of Canada and work towards developing an updated national tornado climatology.

ACKNOWLEDGEMENTS

Many thanks to Neil Comer of MSC-Ontario Region for producing the tornado data maps. We would also like to acknowledge the ongoing support of division chief Stewart Cober. This article is dedicated to fellow MSC meteorologist and tornado researcher, Brian Murphy, who passed away earlier this year.

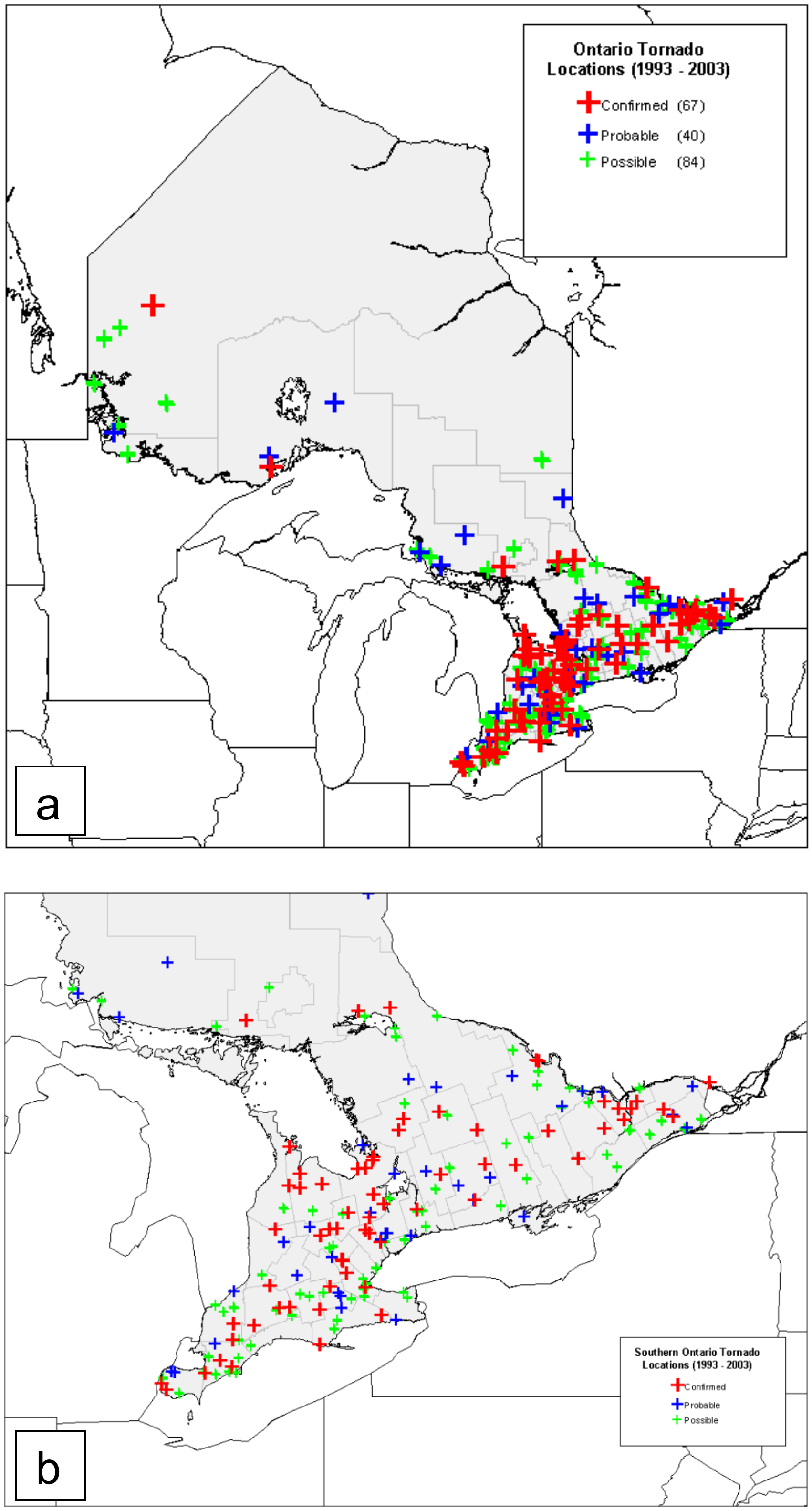

Figure 3a,b. Maps of (a) all Ontario tornadoes and (b) southern Ontario tornadoes for the period 1993-2003 (confirmed - red, probable – blue, possible - green).

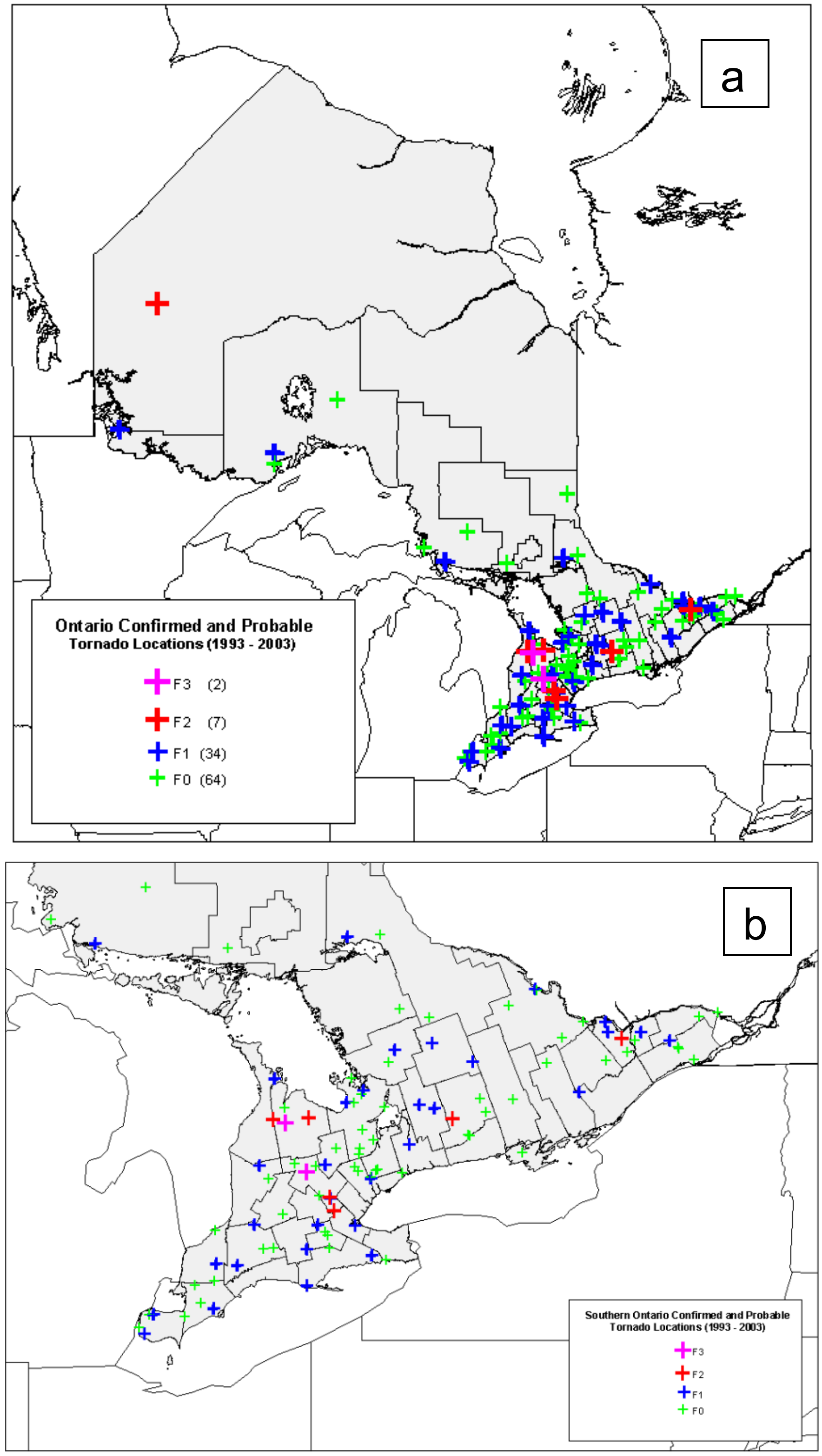

Figure 4a,b. Maps of (a) confirmed and probable tornadoes for all of Ontario and (b) confirmed and probable tornadoes for southern Ontario for the period 1993-2003 (F3 – magenta, F2 – red, F1 – blue, F0 – green).

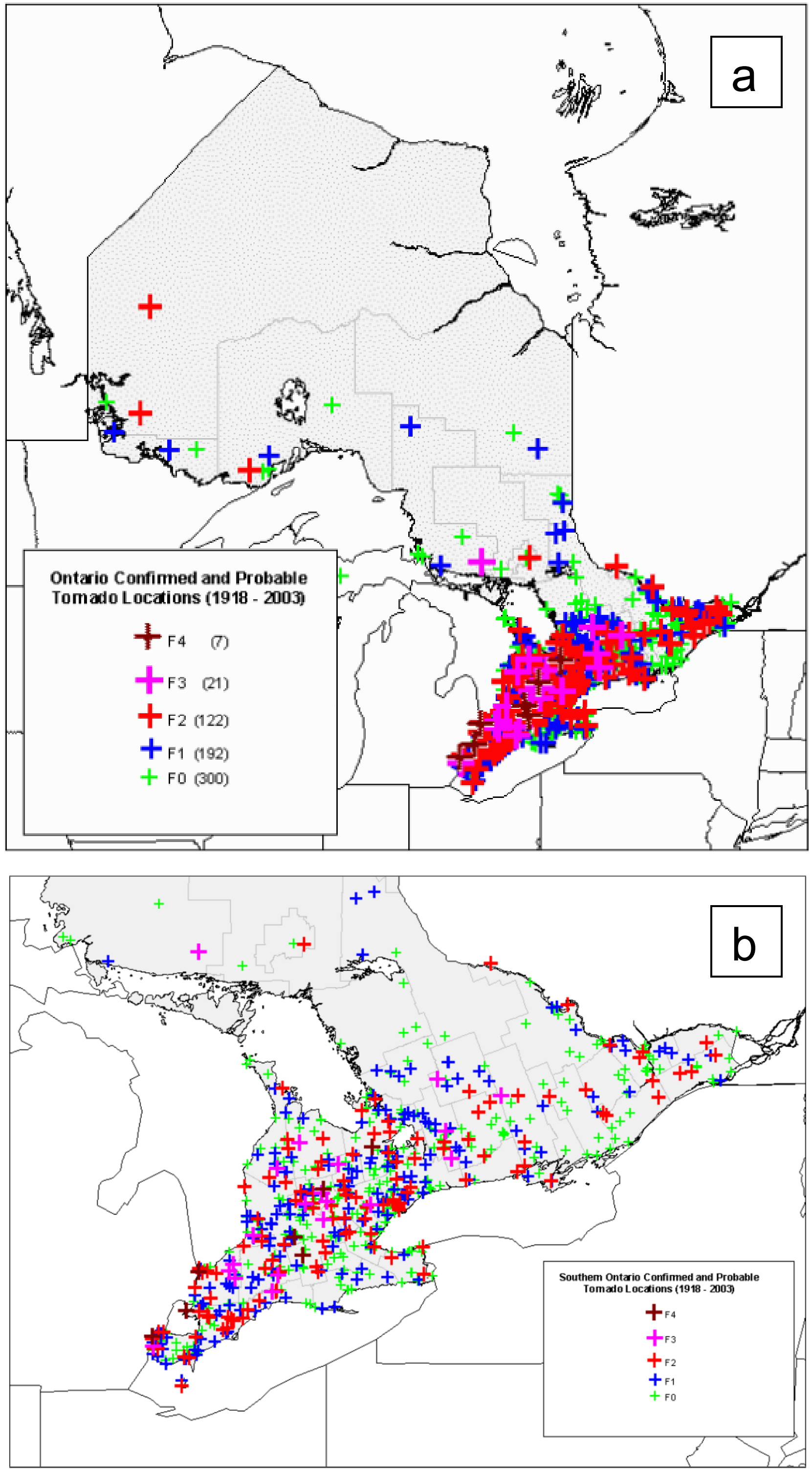

Figure 5a,b. Maps of (a) confirmed and probable tornadoes for all of Ontario and (b) confirmed and probable tornadoes for southern Ontario for the period 1918-2003 (F4 – brown, F3 – magenta, F2 – red, F1 – blue, F0 – green).

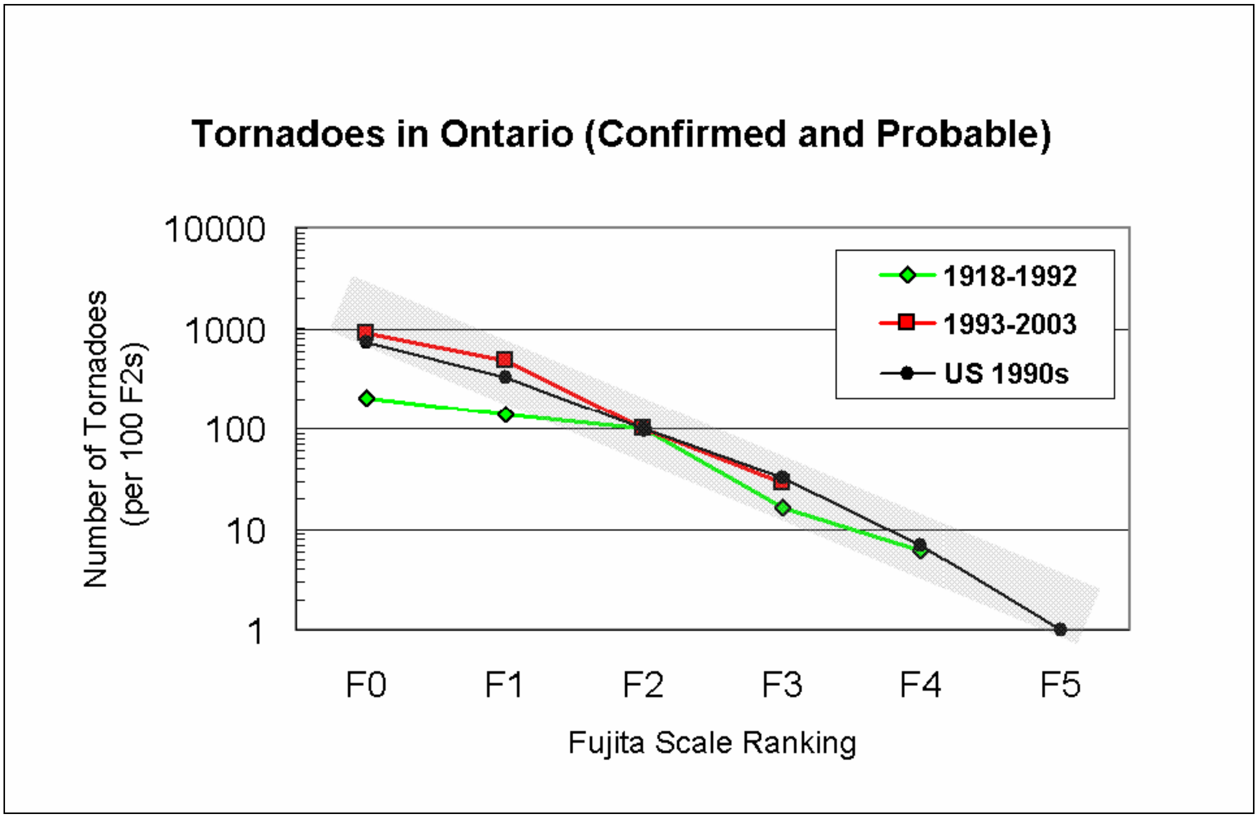

Figure 6. Tornado events by F-scale ranking from the Newark database (green), the TOP database (red) and US 1990s data (black). Events have been normalized to 100 F2 tornadoes. The slope of the line between F2 and F4 is shown by the grey hatched area.

REFERENCES

Brooks, H. E., and C. A. Doswell III, 2001: Some aspects of the international climatology of tornadoes by damage classification. *Atmos. Res.*, **56**, 191-201.

Doswell, C. A. III, and D. W. Burgess, 1988: On some issues of the United States tornado climatology. *Mon. Wea. Rev.*, **116**, 495-501.

Fujita, T.T., 1981: Tornadoes and downbursts in the context of generalized planetary scales. *J. Atmos. Sci.,* **38**, 1511-1534.

Grazulis, T., 1993: *Significant Tornadoes. 1680-1991*. Environmental Films, St. Johnsbury, VT, 1326 pp.

Kelly, D. R., J. T. Schaefer, R. P. McNulty, C. A. Doswell III and R. F. Abbey, Jr., 1978: An augmented tornado climatology. *Mon. Wea. Rev.*, **106**, 1172-1183.

King, P. W. S., M. Leduc, D. M. L. Sills, N. R. Donaldson, D. R. Hudak, P. I. Joe, B. P. Murphy, 2003: Lake breezes in southern Ontario and their relation to tornado climatology. *Weather and Forecasting,* **18**, 795-807.

Newark, M. J., 1984: Canadian Tornadoes, 1950-1979. *Atmos.-Ocean,* **22**, 343-353.

Sills, D. M. L. and P. W. S. King, 2000: Landspouts at lake breeze fronts in southern Ontario. Preprints, 20th Conference on Severe Local Storms, Orlando, FL, Amer. Meteorol. Soc., 243-246.

APPENDIX A

The following are definitions used for the decision tree in order of appearance.

Damage Survey

A thorough investigation of the damage caused by winds associated with a severe local storm. Data for the investigation may be obtained via a site investigation and/or collected from other sources.

Tornado

There is no widely accepted peer-reviewed definition of a tornado. However, the following definition suggested by Chuck Doswell in his 2001 “What is a tornado?” online essay (found at http://www.cimms.ou.edu/~doswell/a_tornado/atornado.html) is used since it appears to embody the current scientific understanding of tornadoes:

"A vortex extending upward from the surface at least as far as cloud base (with that cloud based associated with deep moist convection), that is intense enough at the surface to do damage at one or more points along its path, should be considered a tornado."

Note that this definition:

- places no restrictions on the type of underlying surface (i.e. land or water),
- places no restrictions on the type of parent cloud (i.e. towering cumulus or cumulonimbus),
- does not require a funnel cloud to be present,
- requires surface winds of damaging intensity but not damage (important in places like the Prairies where there is little around to be damaged), and
- allows a single vortex that causes periodic damage to be identified as a single tornado.

A photograph, video or eyewitness description of a tornado should include:

- a funnel cloud extending from cloud base to the surface, or
- a funnel cloud extending part way to the surface plus a vertically-oriented vortex made visible by rotating debris at the surface, or
- a vertically-oriented vortex beneath a deep, moist convective cloud made visible by rotating debris at the surface.

Tornadic Damage

Tornadic wind damage has the following characteristics:

- damage path is longer than it is wide,
- damage gradient is high, and
- damage vectors (downed trees, corn stalks, etc.) show a convergent pattern.

Tornadic damage often appears to be 'chopped up' or chaotic and damage vectors may show swirls, vortex marks, or a herringbone pattern.

Funnel Cloud

As with the tornado, there is no widely accepted peer-reviewed definition of a funnel cloud. The following definition has been used for TOP:

“A condensation cloud, typically funnel shaped and extending from the base of a cumuliform cloud, associated with a rapidly rotating column of air. A funnel cloud may or may not be present with a tornado and, when present, may not extend fully to the surface.”

A video or eyewitness description of a funnel cloud should indicate rotation, since non-rotating, quasi-funnel-shaped clouds are often seen with convective storms. A photograph of a funnel cloud can sometimes show striations indicative of rotation.

Eyewitness

An eyewitness is a person having first-hand experience with an event. If the eyewitness cannot be reached (e.g. due to death in historical cases), then the account of the eyewitness via a close relation is admissible.

Localized Damage

Localized wind damage means an isolated area of wind damage occurring on a local scale. An example would be damage to a farm with neighbouring farms having little to no damage. Reports of trees down across a wide area would not be considered localized damage.