



# *A Fresh Spin on Tornado Occurrence and Intensity in Ontario*

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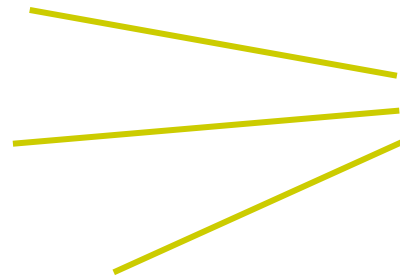
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# Outline

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- Some 'fresh' definitions
- Updated Ontario database
- Updated Canadian database and synthesized tornado data
- Future work
- VORTEX-2

# Fresh Tornado- Related Definitions



*How fresh? Lemony fresh!*



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# What is a tornado?

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**From the AMS Glossary of Meteorology  
(circa 2010):**

- **Tornado** — A violently rotating column of air, in contact with the ground, either pendant from a cumuliform cloud or underneath a cumuliform cloud, and often (but not always) visible as a funnel cloud.

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  - *Includes waterspouts*
  - *Excludes dust devils and gustnadoes*

# What is a funnel cloud?

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**From the AMS Glossary of Meteorology  
(circa 2005):**

- **Funnel cloud** — A funnel-shaped cloud of condensation, usually extending from a deep convective cloud, and associated with a violently rotating column of air that is not in contact with the ground (hence not a tornado).



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# What is a funnel cloud?

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From the **AMS Glossary of Meteorology**  
(circa **2006**):

- **Funnel cloud** — A condensation cloud, typically funnel-shaped and extending outward from a cumuliform cloud, associated with a rotating column of air (a vortex) that **may or may not be in contact with the ground**. If the rotation is violent and in contact with the ground, the vortex is a tornado.



# What is a funnel cloud?

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- *Now fully consistent with new tornado definition*

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# Updated Ontario Tornado Database



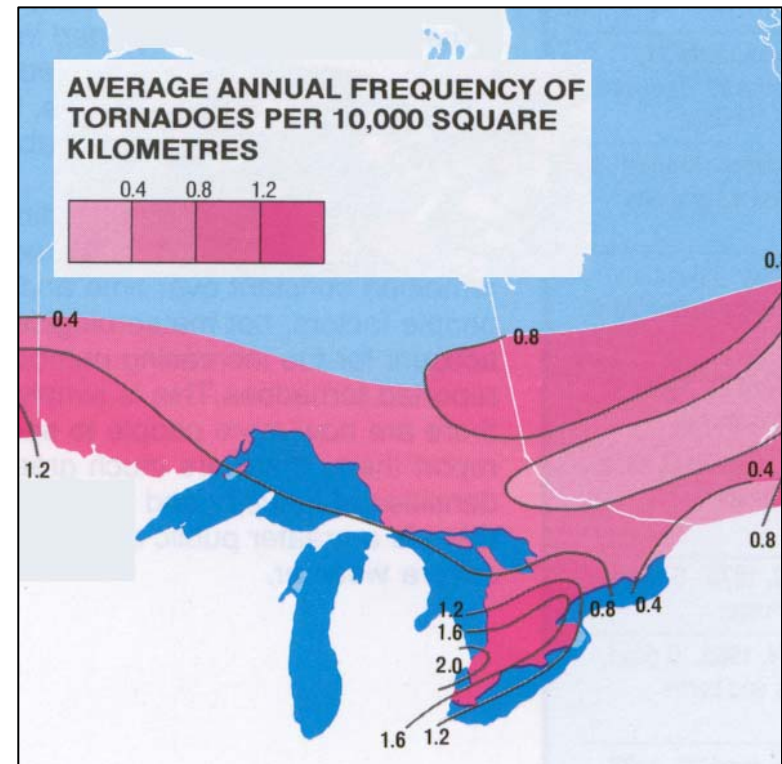
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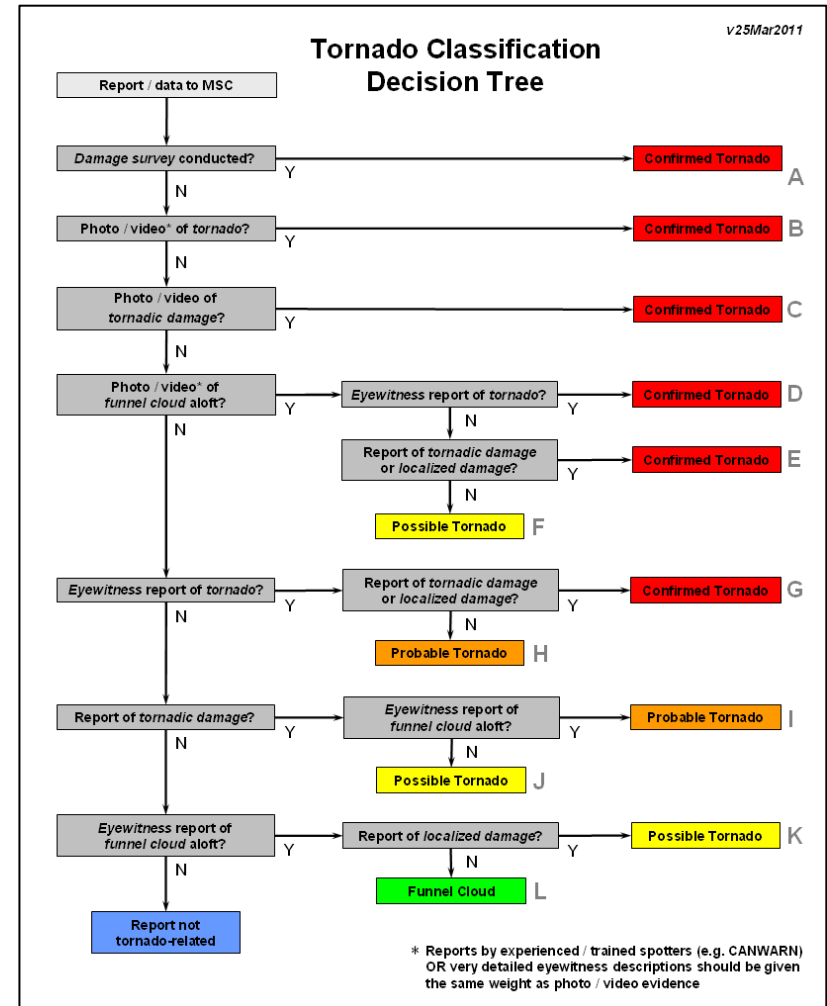
# First Cdn Tornado Database

- Mike Newark of EC began assembling Ontario tornado database in 1970s
- Expanded to all of Canada
- Published 1950-1979 Canadian tornado climatology (Newark, 1984)
- Extended to 1992 by variety of others



# Tornadoes in Ontario Project

- TOP project started in 2003 with goal to improve quality of tornado database (Sills et al. 2004)
- Developed Tornado Classification decision tree to enhance consistency when classifying: confirmed, probable, or possible



# Tornadoes in Ontario Project

- Developed Wind Damage Rating Table using work of Fujita, Newark, Grazulis, and EC experiences
- More consistency when rating tornadoes on Fujita scale

TOP - Wind Damage Rating Table							
v 17.03.04		Fujita Scale Rating, Speed (km h <sup>-1</sup> ) and Damage Description					
Code	Indicator	F0 60 - 110	F1 120 - 170	F2 180 - 240	F3 250 - 320	F4 330 - 410	F5 420 - 510
AH	<i>Well-built, well-anchored house</i>	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 exterior walls removed from frame house, upper story of brick house destroyed	Frame house destroyed to foundation, two-story brick house left with only a few walls standing	Frame house obliterated and debris swept from foundation, brick house destroyed to foundation
UH	<i>Well-built, unanchored house</i>	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, summer cottage carried away and destroyed	Two-story house moved entirely off its foundation and destroyed	
MH	<i>Mobile home</i>	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			
IB	<i>Steel reinforced industrial building</i>	Some roofing / siding materials removed, awnings and canopies damaged, antenna or satellite dish bent	Large areas of roofing material stripped away, partial structural failure of roof	Roof removed, partial structural failure of walls	Structural failure of some exterior walls	Extensive structural failure with one or more interior walls still standing	Structure destroyed to foundation
OB	<i>Large open building (arena, school gym)</i>	Some roofing / siding materials removed, awnings and canopies damaged, antenna or satellite dish bent	Partly unroofed and/or one unreinforced wall down				



# Tornadoes in Ontario Project

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- Re-invigorated damage survey program to ensure high-quality data coming in to database (annual training, large network)
- Created new tornado data from 1993 to 2011
- Revisited all significant events before 1993 (F2+, long tracks, out of season, etc.)
- Added hundreds of historic events before 1918, going back to 1792!



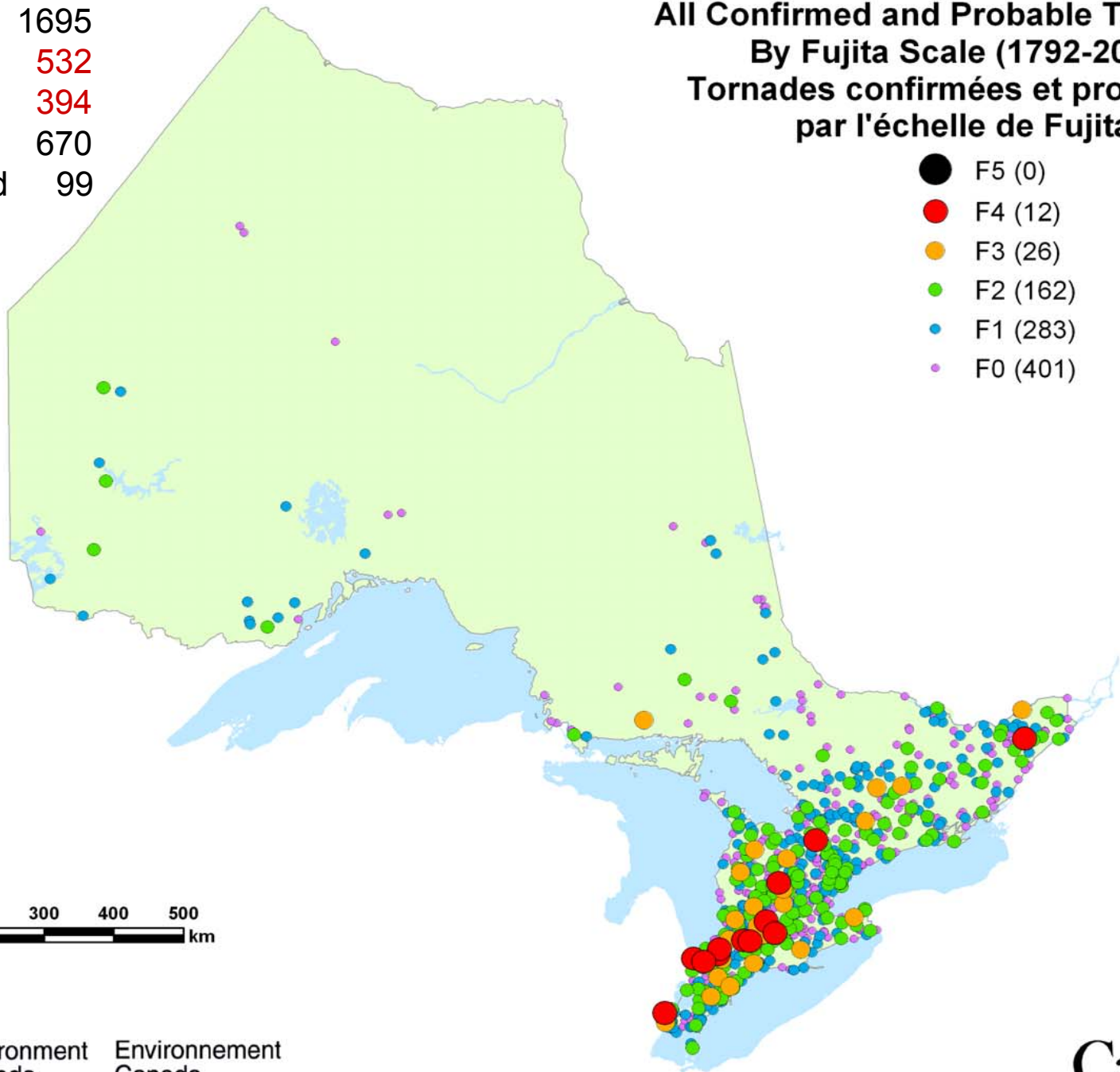


Total	1695
Confirmed	532
Probable	394
Possible	670
Unclassified	99

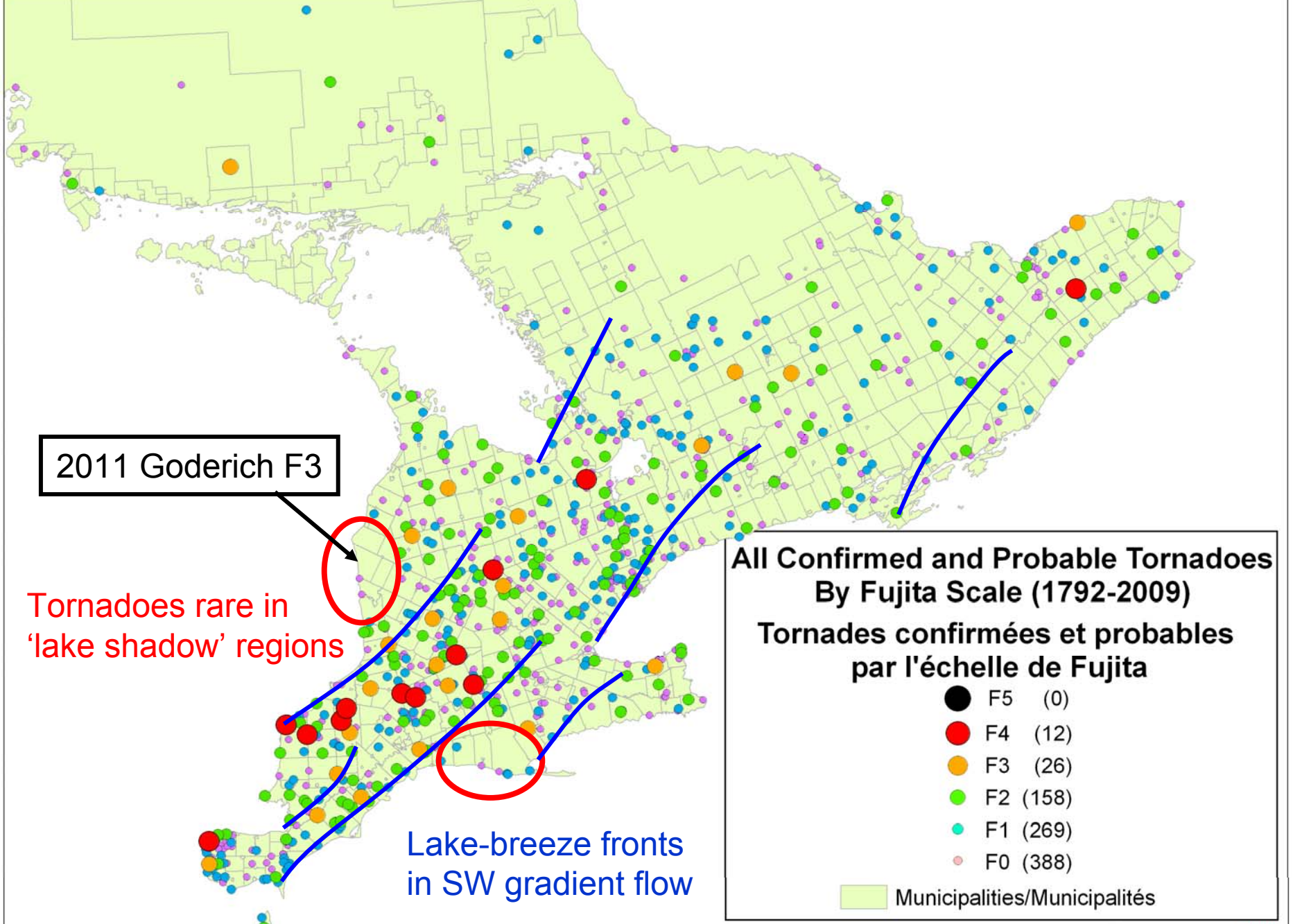
## All Confirmed and Probable Tornadoes By Fujita Scale (1792-2009)

### Tornades confirmées et probables par l'échelle de Fujita

- F5 (0)
- F4 (12)
- F3 (26)
- F2 (162)
- F1 (283)
- F0 (401)



0 50 100 200 300 400 500 km



2011 Goderich F3

Tornadoes rare in 'lake shadow' regions

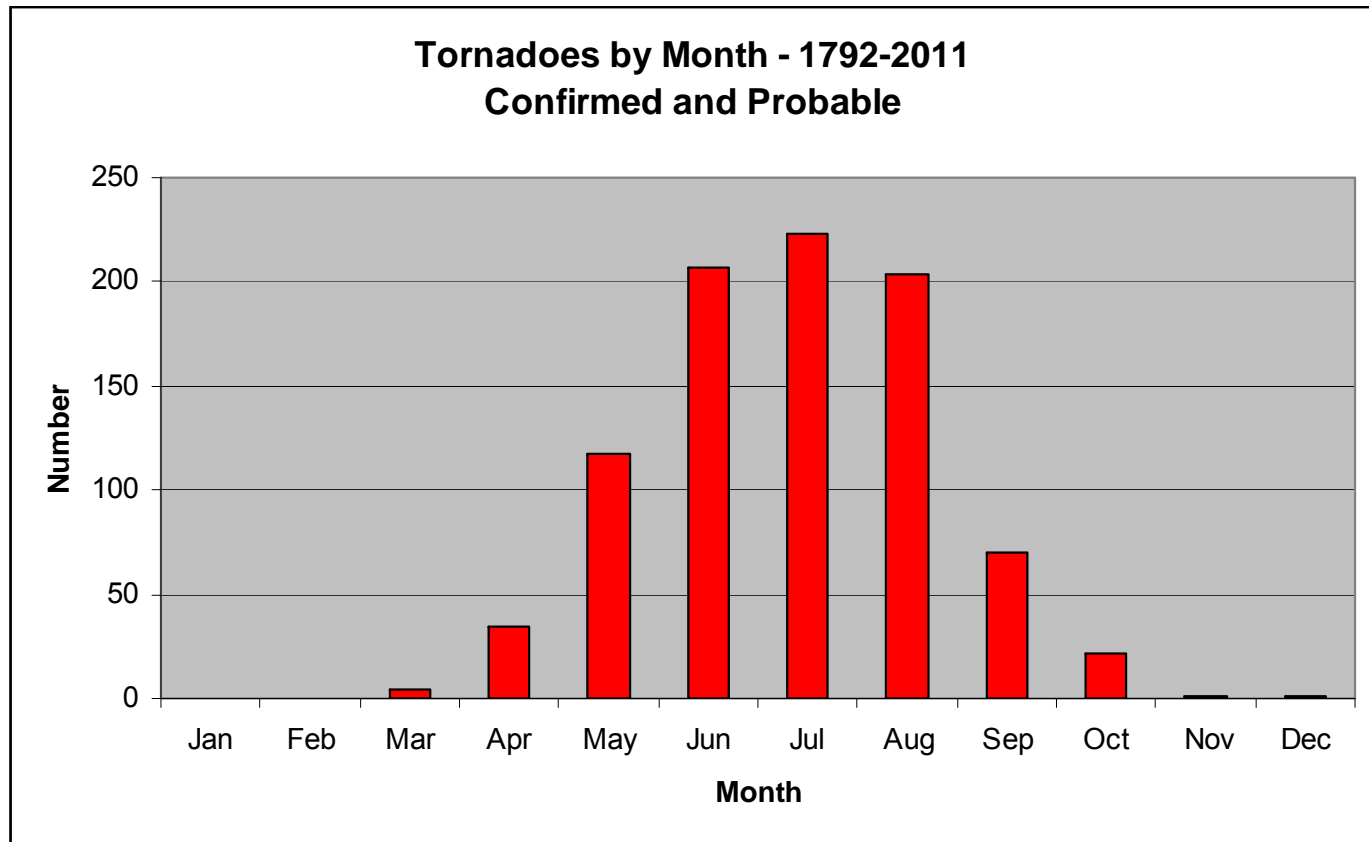
Lake-breeze fronts in SW gradient flow

**All Confirmed and Probable Tornadoes By Fujita Scale (1792-2009)**  
**Tornades confirmées et probables par l'échelle de Fujita**

- F5 (0)
- F4 (12)
- F3 (26)
- F2 (158)
- F1 (269)
- F0 (388)

■ Municipalities/Municipalités

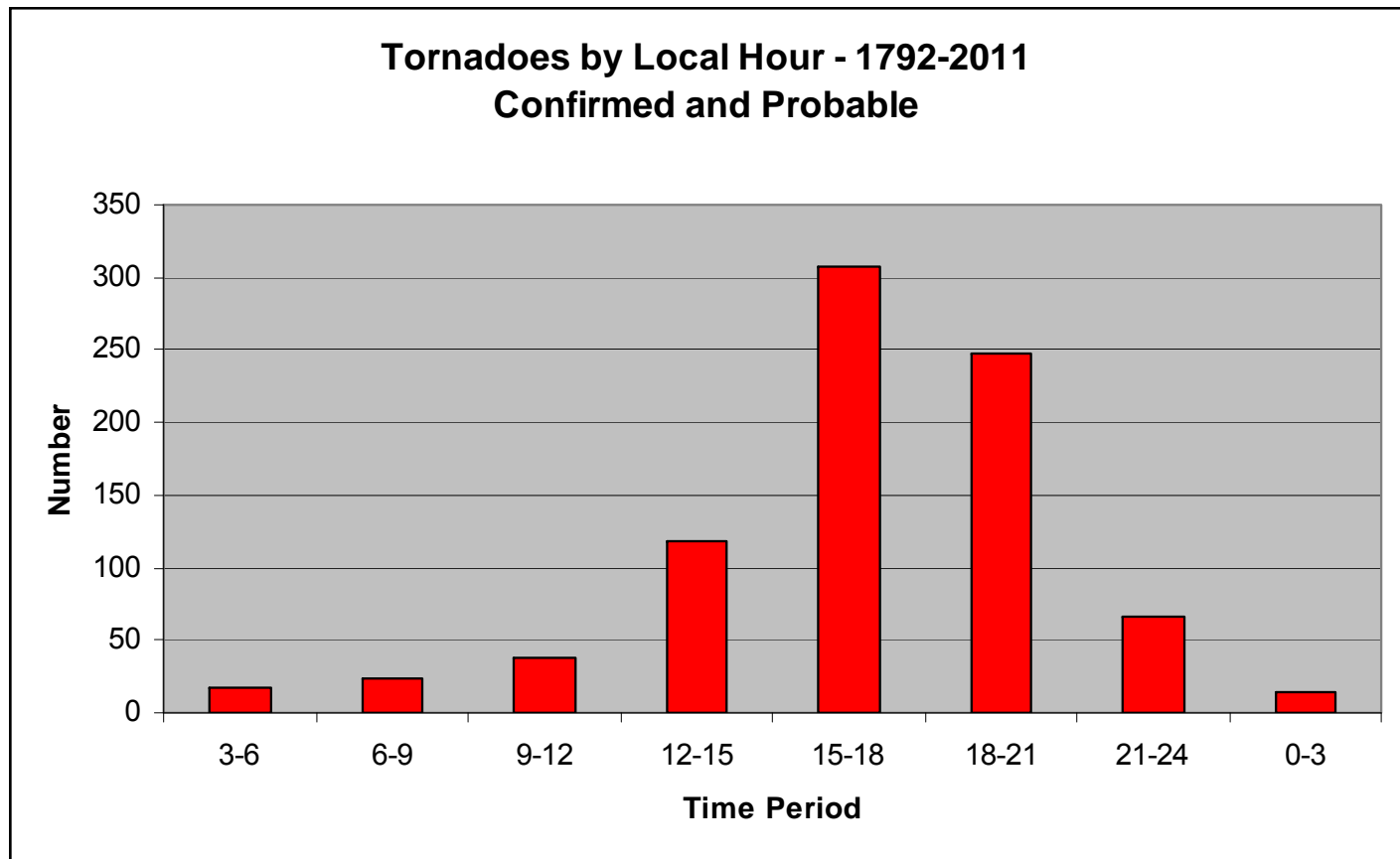
# By Month



- July is peak month



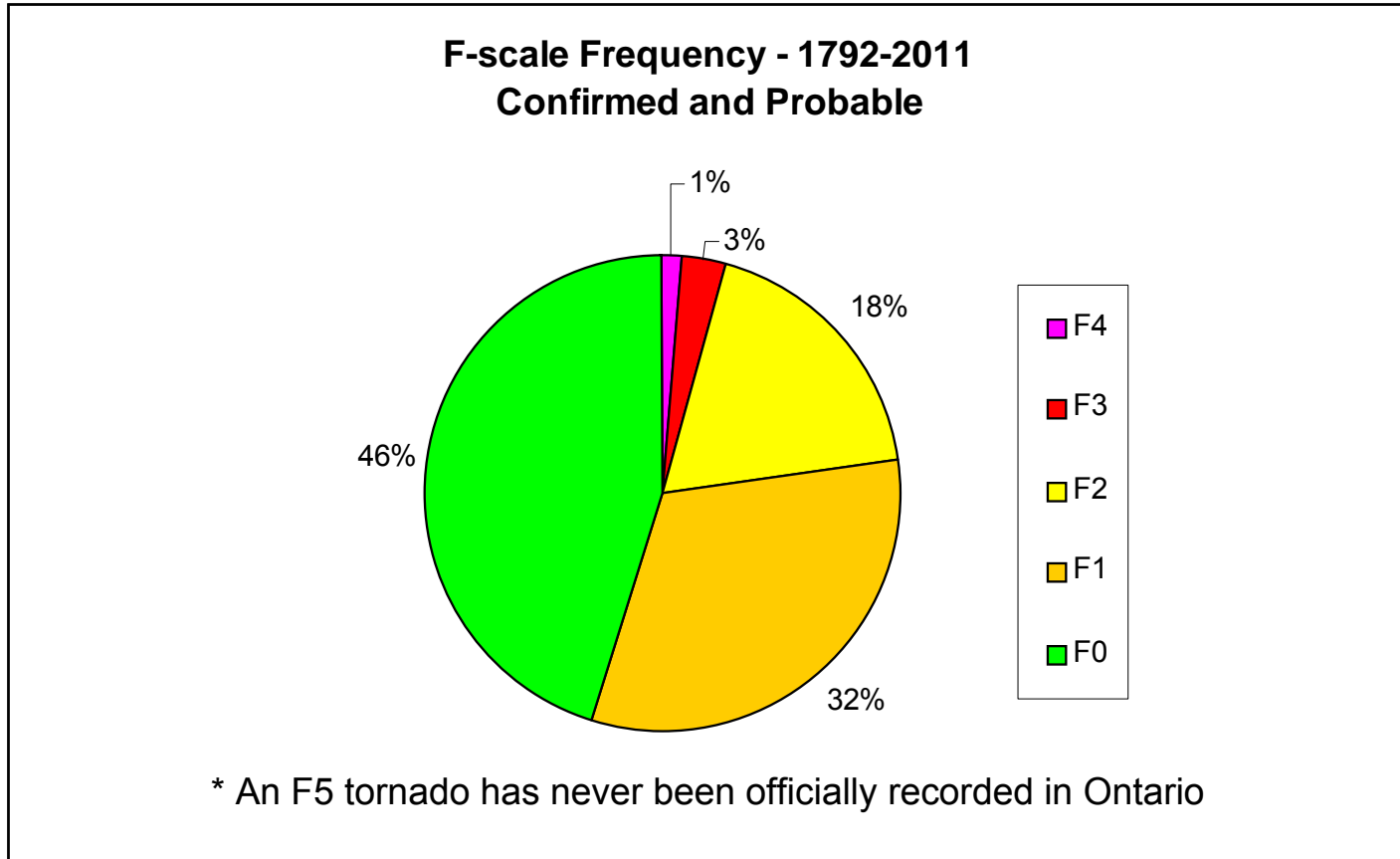
# By Local Hour



- Late afternoon is peak period



# By Fujita Rating

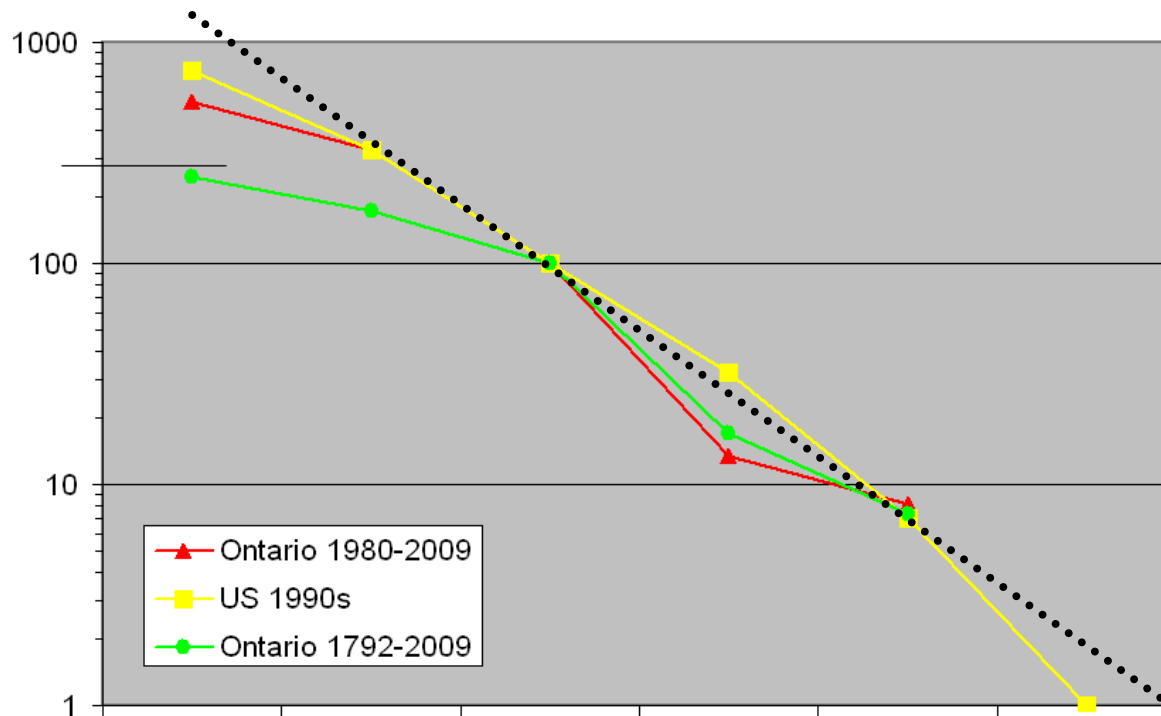


- Strong and violent tornadoes only 22%



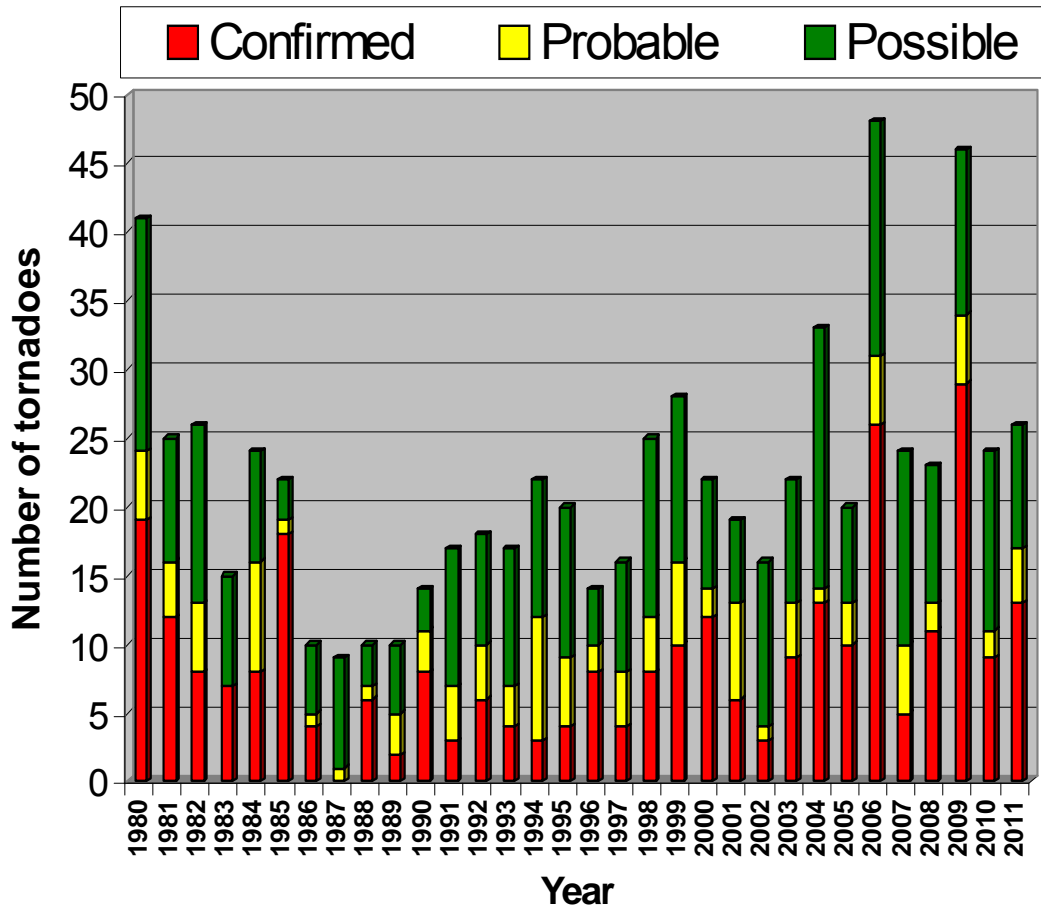
# TOP Data Quality

- Log-linear plot of US and Ontario tornado data normalized to 100 F2s with F2-F4 slope shown (after Brooks and Doswell, 2001)



# Ontario tornado stats '80-'11

## Tornado Occurrence in Ontario 1980-2011



- Ontario has an average of **9** 'confirmed', **4** 'probable' and **10** 'possible' tornadoes per year using the 1980-2011 dataset.

- Using just 'confirmed' and 'probable', that is **13** tornadoes per year average.

- There is an average of **7** 'tornado *days*' per year using just 'confirmed' and 'probable' tornadoes.

- *Last F4* → 31 May 1985



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# Updated Canadian Database and Synthesized Tornado Data



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# Background

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- Tornado resilience measures written into National Building Code of Canada in 1995 based on forensic studies of Barrie / Grand Valley F4 tornadoes of 1985
- Measures include anchors in manufactured and permanent structures, masonry ties in permanent structures (schools, hospitals, auditoriums)
- Relatively inexpensive for new buildings
- BUT implementation required clear definition of 'tornado-prone' regions of Canada
- Definition could not be developed until recently...



# Objective

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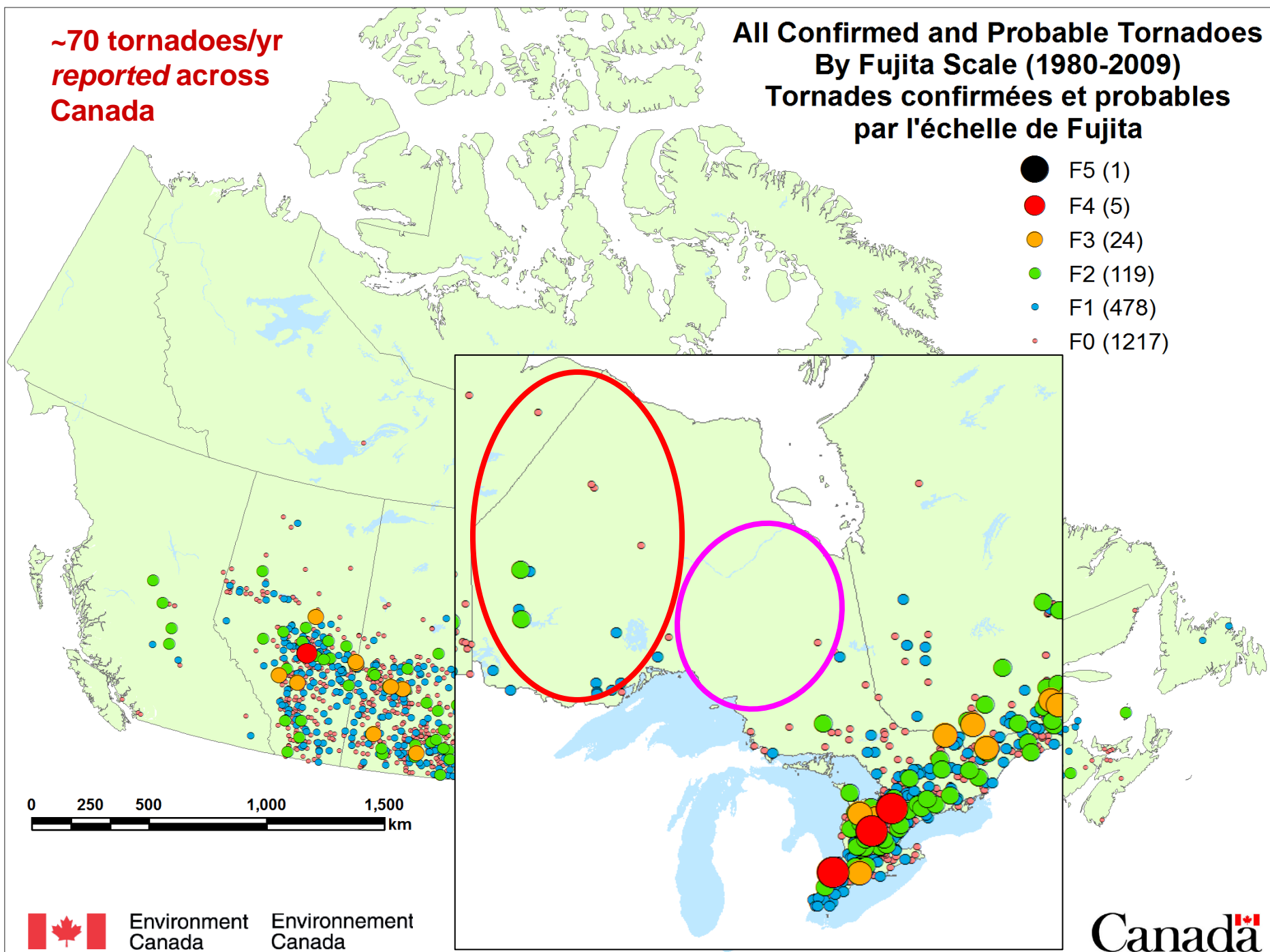
- Needed to build an updated 30-year national database
  - Last database by Newark 1950-1979, so this one 1980-2009
  - Five regions all with their own databases, needed to be merged
- Needed a methodology to fill known gaps in data
  - Under-reporting in rural / remote areas
  - Any inconsistencies between regions



**~70 tornadoes/yr  
reported across  
Canada**

**All Confirmed and Probable Tornadoes  
By Fujita Scale (1980-2009)  
Tornades confirmées et probables  
par l'échelle de Fujita**

- F5 (1)
- F4 (5)
- F3 (24)
- F2 (119)
- F1 (478)
- F0 (1217)



# Statistical Approach

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- Use new lightning flash density climatology to model tornado incidence, but use a population density mask to adjust for population bias
- In high population areas, use observed tornado count
- Otherwise, true tornado count is modeled as a Poisson regression with lightning flash density as predictor, and weighted by population density

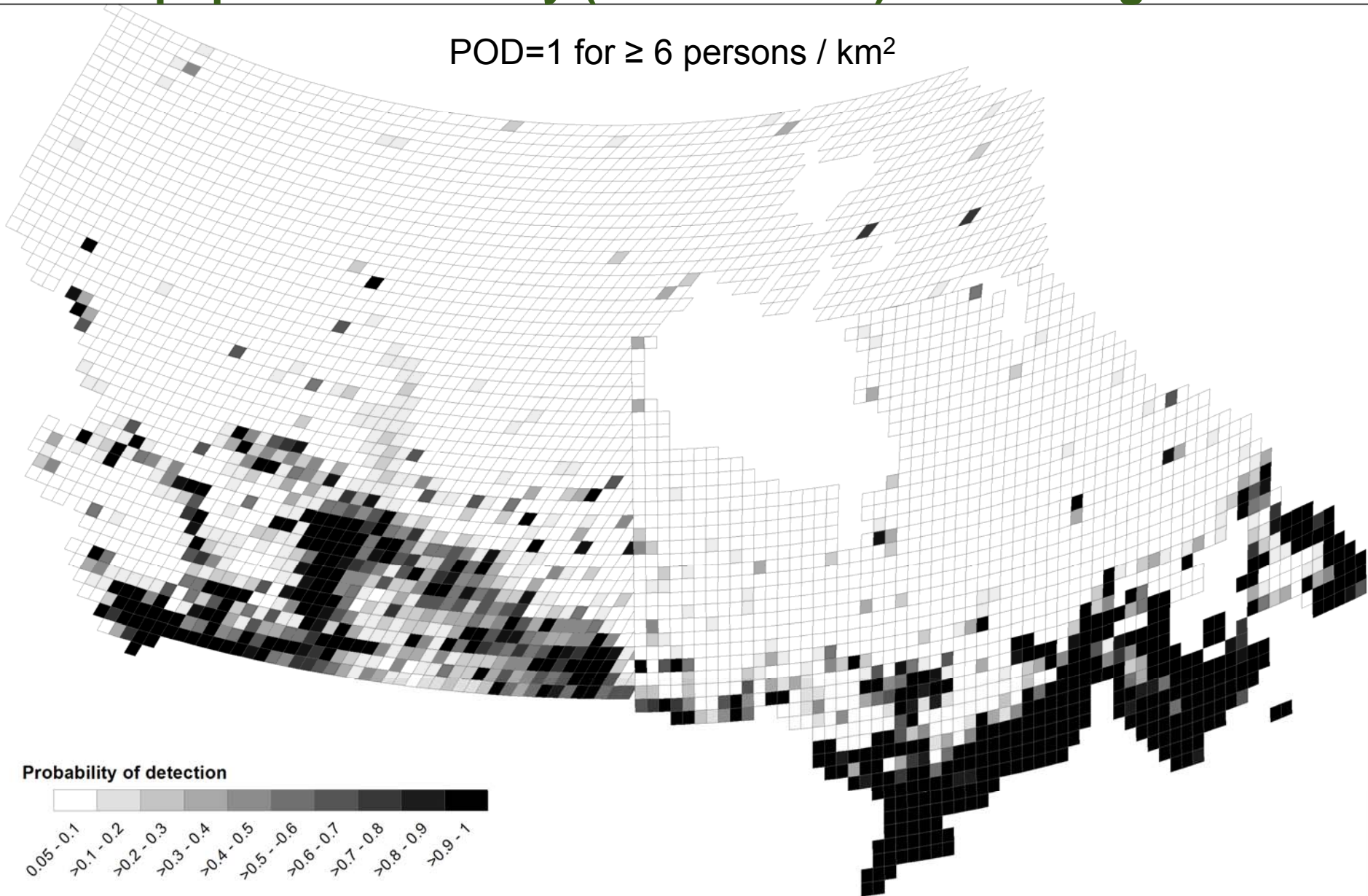




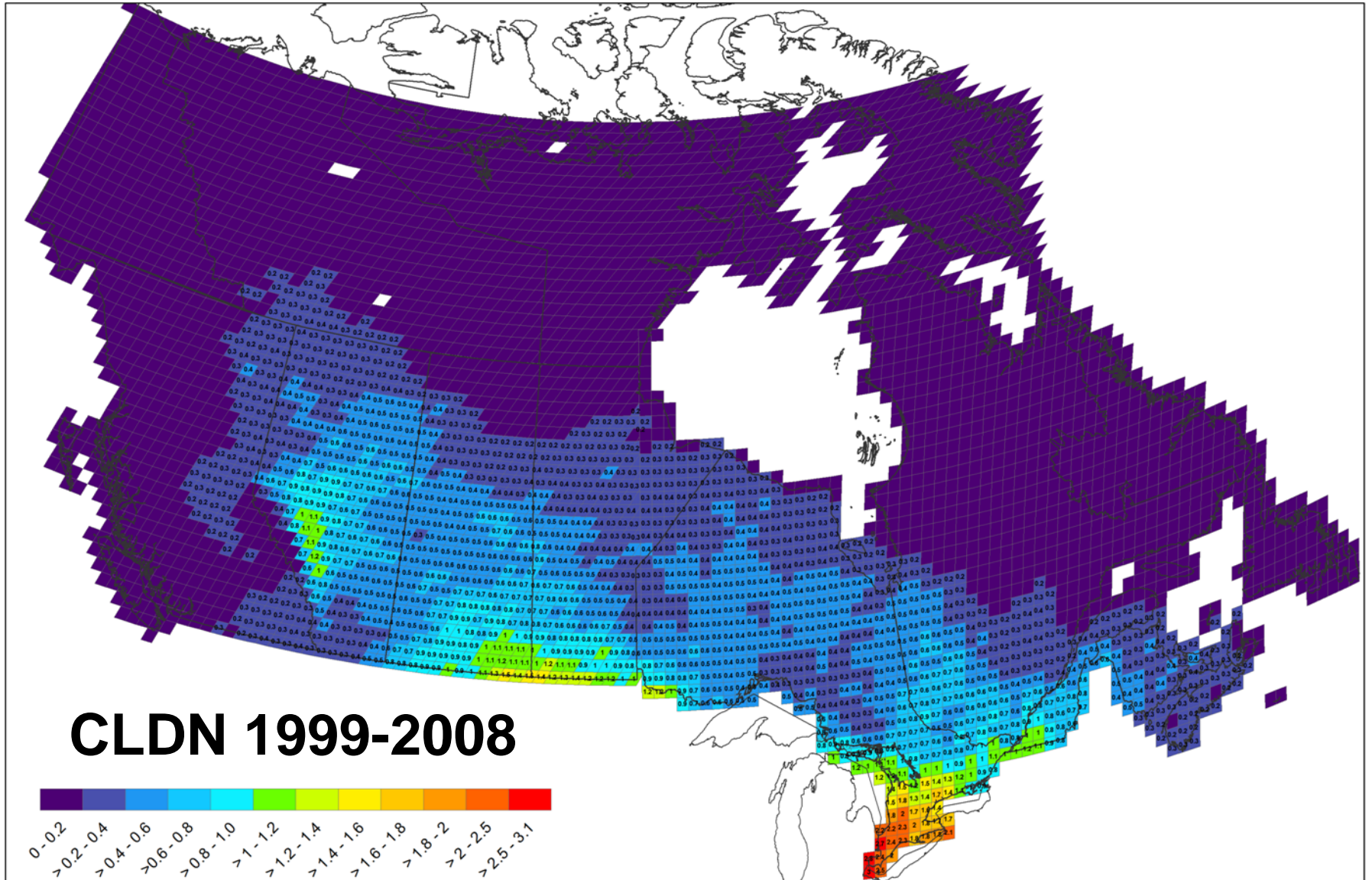
# 'Probability of detection' weighting mask based on population density (2001 census) on 50 km grid

POD=1 for  $\geq 6$  persons / km<sup>2</sup>

Probability of detection



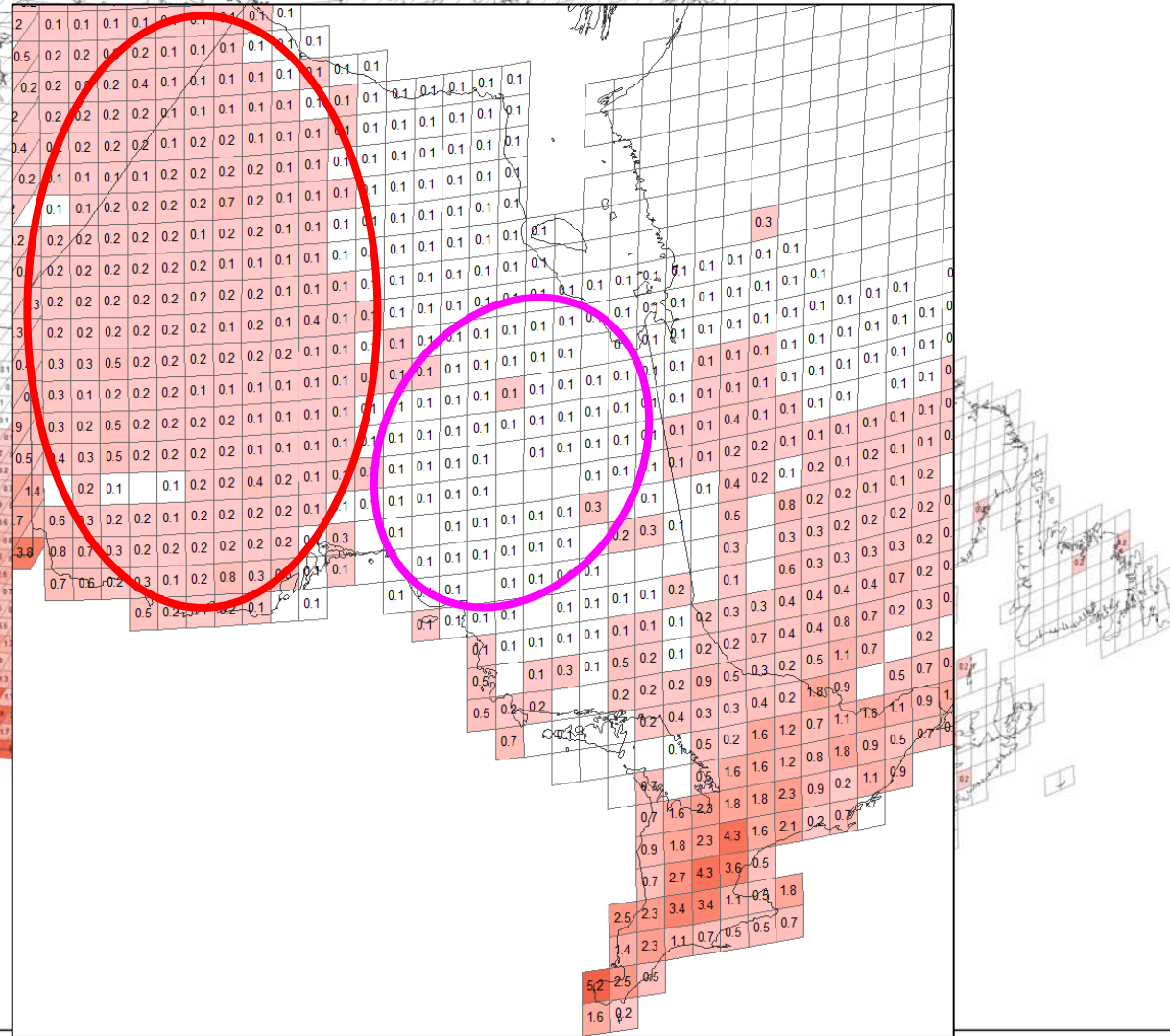
# Lightning flash density (flashes/km<sup>2</sup>/year) on 50 km grid



# Resulting tornado density on 50 km grid

Option 5 (50km grid) - F0-F5 Normalized to (Tornado / yr / 10,000 sqkm)

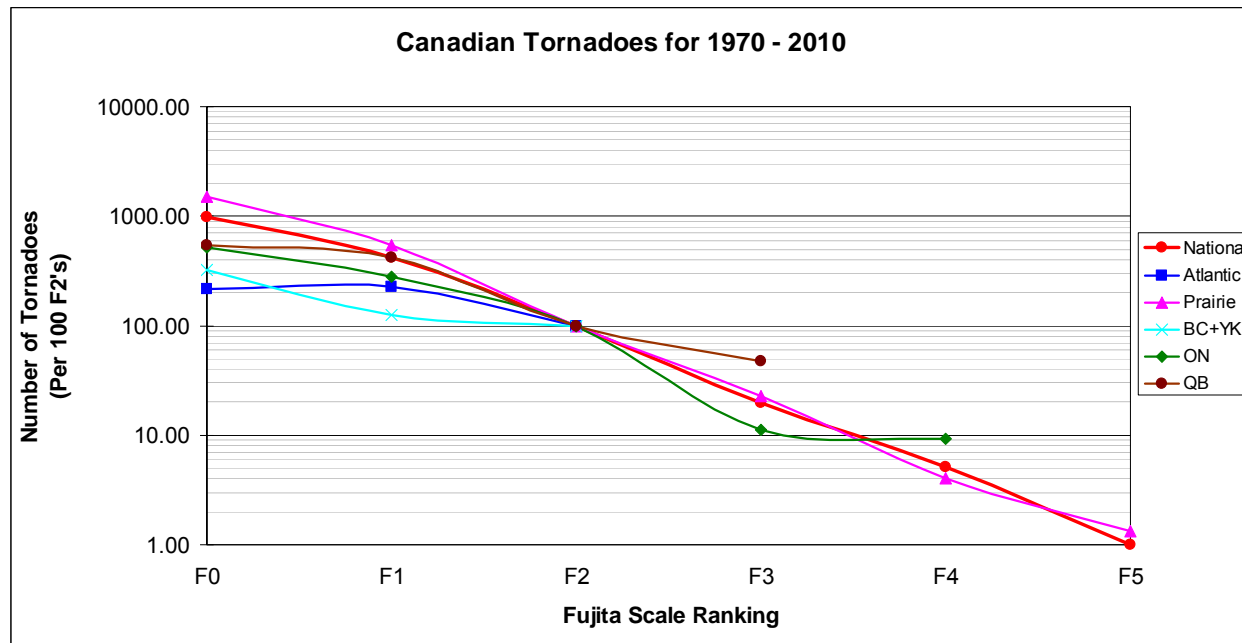
**~250 tornadoes/yr  
modelled across  
Canada!**





# Partitioning by F-scale

- Use F2-F4 slope relationship (Brooks and Doswell, 2001) for Ontario and modelled tornado counts to partition by F-scale rating



- *Assumption: all areas of Canada have similar F2-F4 slope*



# 'Tornado-Prone' Definitions

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## 1. Prone to Significant Tornadoes

Probability of an F2-F5 tornado is estimated to exceed  $10^{-5} / \text{km}^2 / \text{year}$ . F0-F1 tornadoes will be more frequent.

## 2. Prone to Tornadoes

Probability of an F0-F1 tornado is estimated to exceed  $10^{-5} / \text{km}^2 / \text{year}$ .

## 3. Tornadoes Observed - Rare

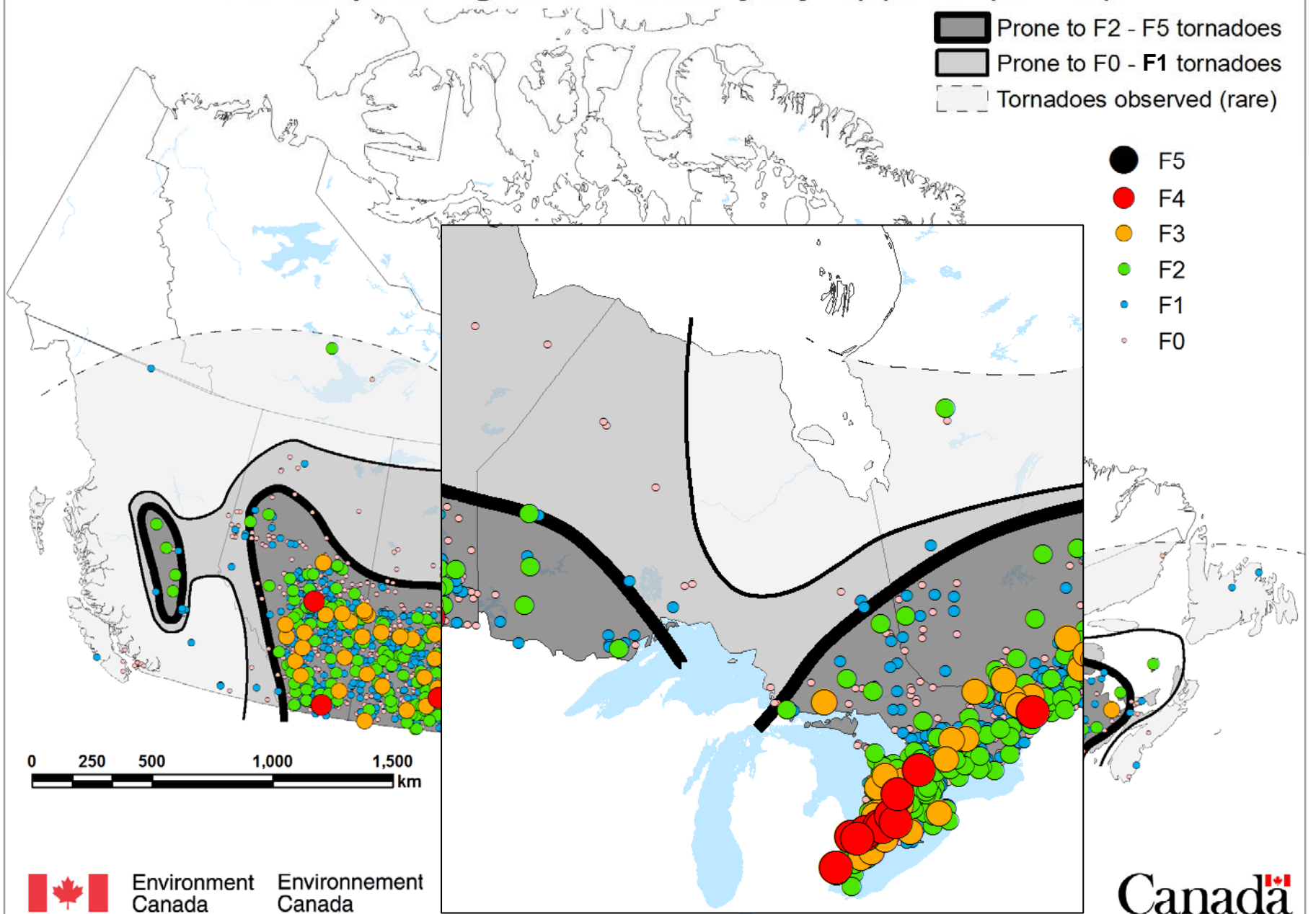
Tornadoes observed, but probability of a tornado is between  $10^{-5}/\text{km}^2/\text{year}$  and  $10^{-6}/\text{km}^2/\text{year}$ .

*(threshold of  $10^{-5} / \text{km}^2 / \text{year}$  consistent with engineering literature)*



# All confirmed and probable tornadoes by Fujita (F) scale (historical-2009)

## Tornado-prone regions of Canada by Fujita (F) scale (shaded)



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# Future Work

# Future Work

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- Continue with analysis of both databases and get work written up in journal papers
- Extend modelling to all of North America
- Adopt EF-scale in Canada
  - have already done parallel evaluation and have recommended implementation
  - 2013?
  - working on improving damage indicators with wind engineers at Western University



# Acknowledgements

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- Heather Auld, Joan Klaassen, Vincent Cheng, Brad Rousseau, Patrick McCarthy, Lesley Elliott, James Waller, Simon Eng, Mark Shephard, Sharon Stone

# References

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- 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.
- Fujita, T.T., 1981: Tornadoes and downbursts in the context of generalized planetary scales. *J. Atmos. Sci.*, **38**, 1511-1534.
- Newark, M. J., 1984: Canadian Tornadoes, 1950-1979. *Atmos.-Ocean*, **22**, 343-353.
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# VORTEX-2



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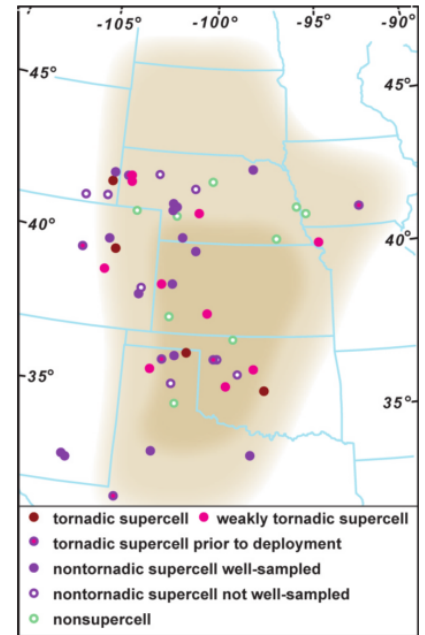
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# VORTEX2 in 2009-2010

- Fully mobile experiment with ~50 mobile measurements platforms roaming US Great Plains
- Measurement platforms: 10 mobile radars, 'mobile mesonet' of instrumented vehicles, mobile balloon launchers, StickNet rapid-deploy surface instruments, tornado 'pods' to measure inside tornado, photogrammetry teams





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# Thanks!



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