RMS® CCRA® Training Program

Severe Convective Storm Modeling Exercise: Analyzing the Historical Record of Tornadoes in the U.S.

ANSWER KEY

Learning Objectives:

The purpose of this exercise is to familiarize you with the type of historical data that has been typically used in tornado/hail models for developing the stochastic event set, using the U.S. historical catalogue of tornado events as an example. The RMS Severe Convective Storm model no longer relies solely on observational data but also leverages meteorological methods to determine event placement and frequency. This exercise will highlight the issues that are brought about by using only historical storm data to develop a stochastic event set. By the end of the exercise, you will have learned:

- The types of information provided in a historical catalogue of events.
- How this information can be used to inform catastrophe model assumptions.
- Basic temporal and spatial methods for evaluating data completeness and potential bias in the historical record.

In addition to this handout, you have been provided with an Excel file (Tornado Reports by Year.xlsx) containing the record of reported tornado events in the United States between 1950 and 2010 based on data from the National Weather Service.

Background on the Fujita Scale and the U.S. Historical Catalogue of Tornadoes

The Fujita scale was originally developed to distinguish weak and strong tornadoes. The wind speed/expected damage relationship was a "guesstimate" for a well-constructed or strong wood frame house. In 2007, the Enhanced Fujita scale was introduced. This new scale has a more refined estimate of tornado strength through the use of highly detailed structural vulnerability estimates and ground surveys.

Tornadoes in the U.S. historical record prior to February 2007 are categorized according to the original Fujita scale. The scale is "conditional," that is, events are classified based on observed damage in the area impacted. F-ratings are not based on any direct measurement of peak wind speeds.

F-Rating	Observed Damage	Estimated 3-Second Peak Wind Speed (mph)
F0	Light	45-78
F1	Moderate	80-118
F2	Considerable	119-161
F3	Severe	162-209
F4	Devastating	210-261
F5	Incredible	262-317

The use of the Fujita scale to classify tornado damage began in 1971 in the U.S. During the early 1970s an initiative was undertaken to classify pre-1970s tornadoes based on the photographic and written documentation of the damage. Any classification of a tornado's damage is a subjective process, but this is particularly true for those tornadoes occurring prior to the mid-1970s.

Several groups have made attempts to create a historic tornado catalogue for the U.S. The primary databases include:

- National Weather Service database, archived at the National Climatic Data Center (covering storms since 1950). This is considered the "official database," derived from the reports in the publication *Storm Data* and its predecessor, *Climatological Data National Summary - Storm Data and Unusual Phenomena.*
- The University of Chicago (DAPPLE) database, work by T. T. Fujita and collaborators at the Univ. of Chicago (covering tornadoes from 1916 to 1985). This database was developed specifically for the Nuclear Regulatory Commission (NRC) for the purpose of site risk assessment. It is based on the NWS database from 1950-1985, supplemented by the Report of the Chief of the Weather Bureau (1916-1934) and publications in Monthly Weather Review (1935-1949).
- The Tornado Project, work of Tom P. Grazulis contained in "Significant Tornadoes, 1680-1995." This nine year project, funded by the Nuclear Regulatory Commission (NRC) and the National Science Foundation (NSF), was initiated to resolve differences between the two independently designed databases, for tornadoes of intensity F2 or greater. F4/F5 tornadoes were brought into agreement via an individual's subjective decisions. About 2,000 other tornadoes differing by >1 F-rating and about 5,000 other tornadoes differing by 1 F-rating were also reviewed.

Which database is best? RMS chose to use the NWS database as the primary data source in development of prior tornado/hail models, before meteorological and numerical approaches had been refined. This was selected because evidence produced by members of the National Severe Storm Laboratory indicated that this database was most consistent with the tornado databases of other countries, where equally intense tornadoes occur, but with a lower frequency. RMS' frequency assessments are based on meteorological parameters, and are no longer extracted from these databases.

Unlike the U.S., there is only one major tornado database in Canada which is maintained by Environment Canada. This database consists of tornado reports since 1912.

In addition to the Fujita damage rating, the tornado databases include the location of spin-up, the length of the path (subset of U.S. reports only), and the approximate width of path (subset of U.S. reports only).

Exercise Part 1: Temporal Analysis

Use the Excel workbook and the following tables (based on the same data) to examine estimates of tornado frequency and severity in the United States over different time periods.

U.S. Tornado Reports: All Intensities

Years Considered	Total Reported	Years in Sample	Average Number Per Year
All Years (1950-2010)	55,149	61	904
1950-1959	4,791	10	479
1960-1969	6,803	10	680
1970-1979	8,566	10	857
1980-1989	8,182	10	818
1990-1999	12,134	10	1,213
2000-2010	14,673	11	1,334

1. How do estimates of overall tornado frequency differ based on sampling various years of the historical record? List at least one key difference and a hypothesis that might explain it.

   Answer:
   Over time there has been a significant increase in the number of reported tornadoes. More than twice the number of tornadoes have been reported in more recent decades (1920s and 2000s) as compared to the 1950s. The increase is approximately linear. A little over 100 more tornadoes per year by decade have been reported. A large spike appears in the 1990s, which is very important. This is coincidental to when the National Weather Service (NWS) implemented a much more sophisticated weather radar system and a more rigorous approach to issuing storm warnings to the public. In addition, they became more aggressive in their pursuit of observations to validate the warnings they would issue.

U.S. Tornado Reports by F-Rating – Average # Reports

Decade	F0	F1	F2	F3	F4	F5	All Intensities
1950-1959	127	166	138	36	11	1	479
1960-1969	214	226	186	44	10	1	680
1970-1979	272	341	183	47	11	1	857
1980-1989	330	330	121	31	6	0	818
1990-1999	737	328	106	34	8	1	1,213
2000-2010*	831	359	105	31	7	1	1,334

**After January 2007 the EF scale is used.*

2. Now consider reports by intensity (F-rating) and by decade. How do estimates of tornado frequency change over time for different intensity ratings?

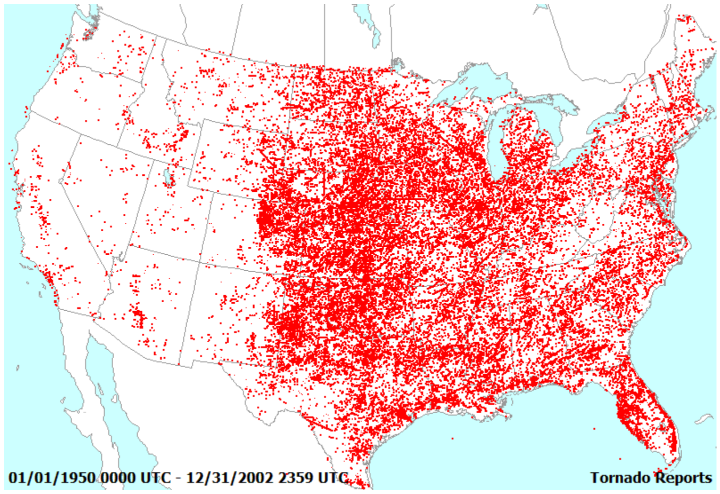
   Answer:
   The most dramatic increase in tornado frequency is for those rated F0 or F1 (weak tornadoes). Stronger tornadoes are more stable over time. F2 and greater tornadoes have not had a significant increase over time. In fact, the frequency of F2 and F3 tornado reports has actually decreased since the early 1970s.

3. Compare the trends for F0 and F1 tornadoes with those for F2 and stronger tornadoes. What might explain the differences in reporting between these groupings?

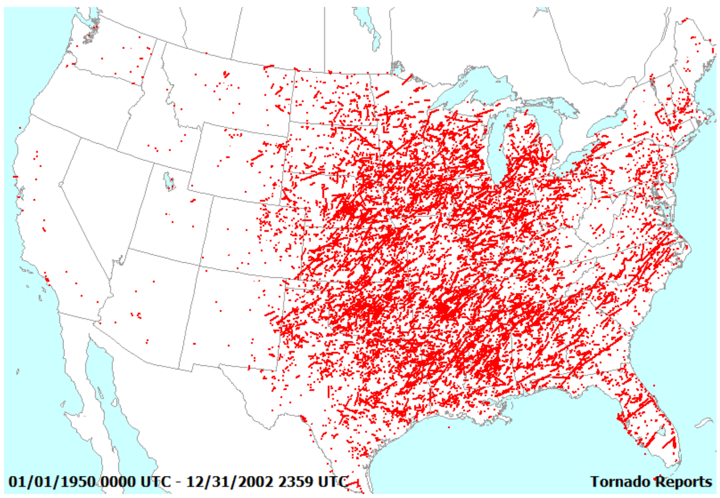
   Answer:
   The differences are linked to the adoption of the Fujita scale in real-time versus forensic classifications of historical tornadoes. Prior to the adoption of the Fujita scale in the 1970s, historic tornadoes were classified by viewing any photos that existed as well as reading reports (from newspapers, etc.). These classifications tended to be conservative since they were not based on real-time observations.

Exercise Part 2: Spatial Analysis

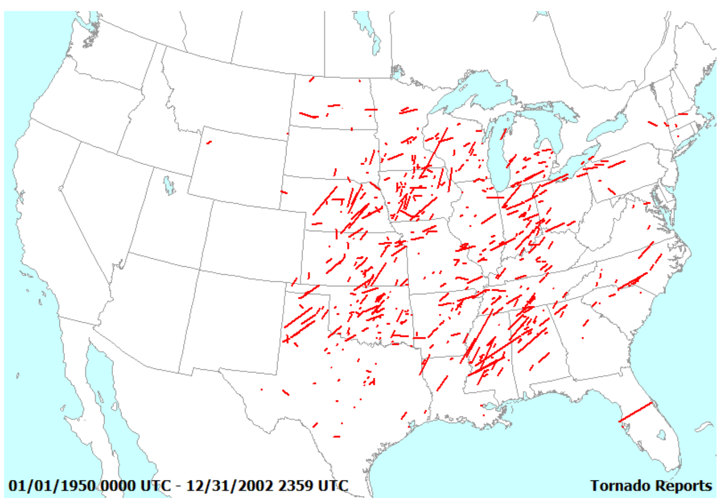
Now, examine the following maps, which plot the locations of reported tornadoes throughout the U.S. by intensity category.



EF0-EF1 Tornadoes



EF2-EF3 Tornadoes



EF4-EF5 Tornadoes

4. List at least two patterns that you observe.

   Answer:
   There appear to be population biases for weak tornadoes (EF0 and EF1) along Interstate 35 (from Texas to Minnesota) and Interstate 44 (in Oklahoma). There also appears to be population biases in the Denver metropolitan area and the Rockies in the north east corner of Colorado. Weak tornadoes (EF0 and EF1) are short-lived and have short tracks so they appear mostly as dots on the map. EF2 and EF3 tornadoes have a much longer track. EF4 and EF5 have the longest track and the lowest frequency. There frequency of tornado reports decreases with the strength of the tornado.

5. What do these patterns imply about hazard levels in different parts of the U.S.?

   Answer:
   There is a high relative frequency of weak tornadoes in Florida and Colorado but a low relative frequency of stronger tornadoes. There is a negative correlation with topographic features such as the Rocky Mountains or the Appalachians.

6. What do these patterns imply about data completeness or potential bias in the catalogue?

   Answer:
   There appears to be a bias toward populated areas, such as Denver, Colorado; Lubbock, Texas; and along Interstate 35. There is also an anomalous low frequency in Missouri. This may be a population bias or it may be related to the topography.