Analysis and Reconstruction of the 1974 Tornado Super Outbreak

RMS Special Report

RMS

Risk Management Solutions

INTRODUCTION

The Super Outbreak of tornadoes that occurred on April 3-4, 1974 was the most intense and widespread tornado outbreak in recorded history. In total, 148 tornadoes spanned 13 states producing about 900 square miles (2331 square km) of tornado damage in less than 18 hours. This report reviews the event's meteorological and damage characteristics, describes the impact subsequent research had on tornado risk models, and examines the property losses possible if the outbreak were to occur today.

METEOROLOGICAL CHARACTERISTICS

Looking back, the atmospheric characteristics preceding the super outbreak provided clear evidence of the high potential for widespread tornado development. On the evening of April 2, 1974 a deep area of low pressure (983 millibars) over the Colorado-Kansas border created strong winds blowing from the south over the lower Mississippi River Valley. This forced high-humidity air northward from the Gulf of Mexico to the lower Midwest and Ohio Valley states. This moist layer of air was "capped" by warm, dry air, which limited thunderstorm development and created highly unstable atmospheric conditions. Recognizing this, the National Oceanic and Atmospheric Administration (NOAA) issued preliminary severe weather alerts on the morning of April 2 for much of the central and southern plains states.

During the morning of April 3, the center of low pressure moved northeastward to the Iowa-Illinois border. As the air warmed up during the day and winds converged near the ground, an explosive and sudden outbreak of thunderstorms developed around 2:00 pm Central Daylight Time (CDT). Three major squall lines of thunderstorms oriented in a southeast-northwest direction developed (see Figure 1). The most northerly line covered central Illinois, the central line extended from northwestern Kentucky to central Indiana, and the southern line ran along the Tennessee-North Carolina border. Most of the tornadoes were produced by individual thunderstorm cells within these lines. The individual tornadoes moved northeastward at 40-60 mph (65-95 km/hr), while the larger scale squall-line systems advanced toward the southeast.

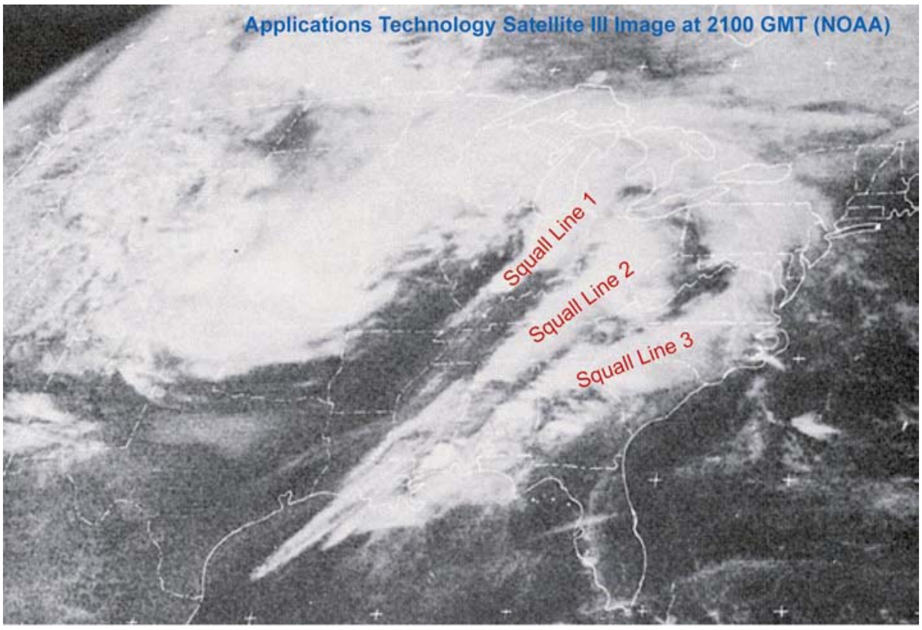

Figure 1: Satellite image of the Eastern U.S. at 21:00 GMT on April 3, 1974

Up to 15 destructive tornadoes occurred simultaneously during the Outbreak. Among the suite of tornadoes produced, the longest life of any single tornado was two hours and five minutes. Ninety percent of the tornadoes, however, lasted less than 40 minutes. Many of these tornadoes were part of 'families' or a sequence of tornadoes spawned in succession by a single thunderstorm cell. Dr. Ted Fujita identified 30 such tornado families that comprised 74% of the Outbreak's tornadoes and resulted in 98% of the 315 deaths. The longest-lasting tornado family existed for nearly five hours, while the average life was approximately two hours.

The total path length of all tornadoes combined was approximately 2,600 miles (4,185 km), covering a total area of approximately 900 square miles (2331 square km). Dating back to the late 1800s, no other single-day event has surpassed the super outbreak in terms of the number of tornadoes or the area they affected.

Event Damage Characteristics

Following the super outbreak, Dr. Ted Fujita and his colleagues initiated the most extensive aerial tornado survey ever conducted. The aerial survey was complemented by the collection of vast amounts of engineering data on the performance of individual structures subject to wind and debris loads. It took Fujita's team nearly 10 months to confirm the characteristics of each of the tornadoes in the event depicted in Figure 2. The F-scale classification statistics of the Outbreak are shown in Table 2.

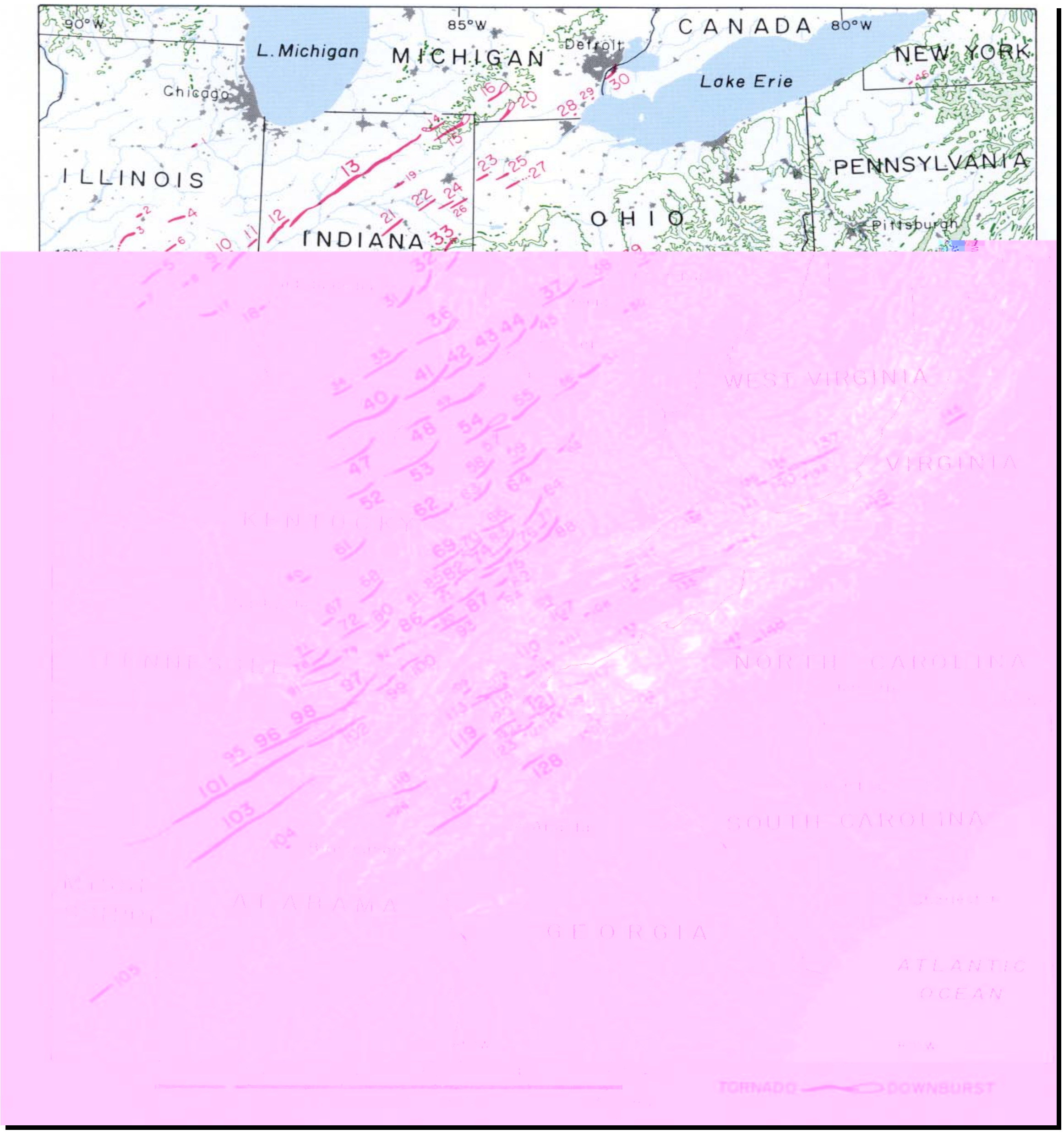

Figure 2: Map of the 1974 Tornado Super Outbreak

Peak F-Rating	No. of Tornadoes	Total Length (mi)	Mean Width (mi)	Total Area (sq mi^2)
F5	6	302	0.487	147
F4	24	858	0.457	392
F3	35	710	0.366	260
F2	30	360	0.185	67
F1	31	295	0.062	18
F0	21	46	0.028	1

Table 2: F-scale classification statistics from super outbreak

A total of 315 people were killed, more than 6,000 people were injured, and over 27,590 buildings were damaged. Of those that died, 74% were killed while in houses or buildings, 17% in mobile homes, 6% in automobiles, and 3% while seeking shelter. The economic damage amounted to $600 million. Ten of the thirteen affected states were declared disaster areas. The greatest storm activity and damage was spread across Alabama, Georgia, Tennessee, Kentucky, Indiana, Illinois and Ohio. Table 3 summarizes the damage in these states.

State	No. of Tornadoes	Deaths	Injuries	Economic Damage ($ M)
Alabama	8	86	949	50
Georgia	7	17	104	15
Illinois	13	2	20	11
Indiana	20	49	768	>100
Kentucky	26	77	1,377	110
Ohio	9	3	41	>150
Tennessee	28	50	635	30

Table 3: Super outbreak damage statistics for key states

Damage and loss statistics about some of the most devastating individual tornadoes follows. The map reference number is provided in parentheses after each of the tornado headings.

Xenia, Ohio Tornado (37)

The most deadly tornado in the entire Outbreak devastated Xenia (pop 25,000) in Greene County, Ohio shortly after 3:30 pm CDT. Thirty-four people were killed and more than 1,600 injured. The F5 tornado destroyed around 1,300 buildings, while 2,000 others sustained some damage resulting in a loss of over $130 million.

Brandenburg, Kentucky Tornado (47)

The state's most severe tornado (F5), which hit Brandenburg in Meade County, was the first of 26 to impact Kentucky. It was even noted to have caused a significant fall and subsequent rise in the level of the Ohio River as it passed over. Across the entire state, 6,625 families had damaged property and between 1,800 and 2,000 of the state's farms incurred damage.

Alabama Tornadoes (96, 97, & 98)

Two tornadoes (96 & 98) caused 55 of the 86 deaths in Alabama and injured 408 people. Over 1,100 buildings, 200 mobile homes, and numerous motor vehicles were destroyed or heavily damaged. The first tornado (96) formed near Newburg (Franklin County) at 6:30 pm CDT and moved northeastward. The second (98) followed a parallel track approximately 30 minutes later, and located only a half-mile north of the first. The second tornado caused 11 more deaths and 121 injuries after crossing into Tennessee. One home was hit by two tornadoes (97 & 98), unroofed during the first pass and blown entirely away during the second.

Other Severe Weather

Tornadoes were not the only agents of damage. A severe thunderstorm hit St. Louis at about 1:05 pm CDT. This storm, which had high winds and baseball-size hail, caused 25 injuries and $45 million in damage; a record hail loss at the time. Hail up to three inches in diameter was also observed near Charlotte, North Carolina. Heavy snow and freezing rain affected northern Michigan, along with damaging wind gusts and flash flooding that washed out some roads and bridges. Missouri, Michigan, Mississippi, New York, West Virginia, Virginia, North Carolina, and South Carolina were also affected by either tornado or severe thunderstorm activity.

INFLUENCE ON MODELING AND PUBLIC POLICY

In the 1970s, the Nuclear Regulatory Commission actively supported tornado risk probability research to aide in their regulatory decisions. The creation of the Fujita damage scale in 1971 provided a critical means of translating observed damage into wind speed estimates. However, prior to the 1974 Super Outbreak, researchers were unable to characterize the intensity distribution within a tornado's path.

Fujita's extensive aerial survey after the 1974 Super Outbreak provided the necessary data to develop an empirical relationship for the width of each F-scale damage area within a tornado path. As an example, Fujita found that the swath of the F5 damage area within an F5 tornado was very narrow, usually less than 20 miles (32 km) wide. This survey data provided a new means for assessing tornado intensity probabilities that accounted for the gradation of damage within the tornado path. A schematic drawing by Fujita in the late 1970s illustrates this method (see Figure 3). To this day, this relationship remains the basis for estimating the intensity distribution within tornadoes.

Research from the 1974 event also provided further evidence of intense vortices embedded inside a tornado and led to the discovery of downbursts (small scale damaging downdrafts) that were recognized as the cause of several major airline accidents in the following decade.

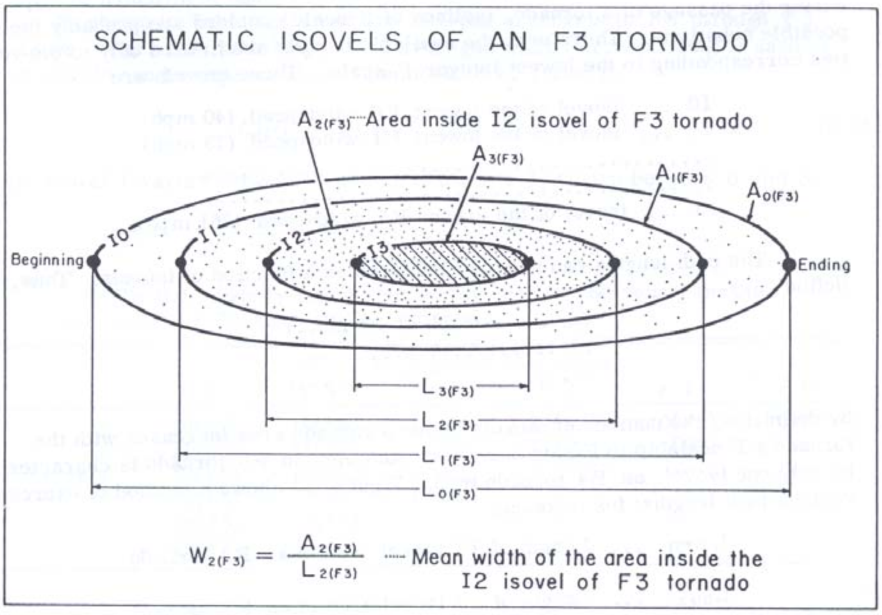

Figure 3: Contours of maximum wind speeds (isovels) by F-rating inside a hypothetical F3 tornado

Aside from the scientific advances, the outbreak also led to NOAA's rapid expansion of its weather radio network. During the 1974 event, tornado warnings were being posted so frequently, that they could not be transmitted from the National Weather Service (NWS) offices fast enough using teletype. Commercial radio stations also had difficulty re-transmitting the information. After the Outbreak, NOAA initiated an immediate expansion of its Weather radio network across the country, along with a modernization program that allowed the National Weather Service to adopt new technology, improving weather warning lead-times and accuracy.

HAZARD AND PROPERTY LOSS RECONSTRUCTION

Based on Fujita's detailed color map of the event's tornadoes and intensity ratings, RMS reconstructed the tornado and downburst hazard from the 1974 Outbreak. This process involved digitization of all 148 tornado paths and downburst areas followed by calibration of these areas to account for adjustments made to path sizes in the map's original production. The intensity within each tornado was derived based on the area/intensity relationships established by Fujita and his collaborators as a result of their extensive aerial survey.

Because of the extraordinarily localized impacts of these phenomena, RMS used land use cover data to disaggregate its 2003 U.S. Industry Exposure Database by line of business and coverage to a resolution of 984 feet (300 m). This detailed resolution was needed to accurately represent the average loss potential from an individual historic event.

RMS' reconstruction and modeling effort suggests that a repeat of the 1974 Super Outbreak today would cause a record level of economic and insurance losses. The insurance losses would likely reach as much as $3.5 billion for wind losses alone. Unlike recent major tornadoes, such as the 1999 Oklahoma City Tornado, the impacts of a super outbreak would be distributed over quite a large area, with losses exceeding the $500 million mark in Ohio, Indiana, and Kentucky. A repeat of the 1974 Outbreak would surpass the $3.13 billion insurance loss (PCS July 28, 2003) recorded for the May 2-11, 2003 sequence of tornadoes that impacted 18 states. While there were more tornadoes in the May 2003 outbreak (~190 tornadoes), the area impacted by intense tornadoes was actually less than the 1974 Super Outbreak.

References

Abbey, R. F., and T. T. Fujita, 1975: Use of Tornado Path Lengths and Gradations of Damage to Assess Tornado Intensity Probabilities. Ninth Conf. Severe Local Storms, Norman, OK.

Fujita, T. T., 1974: Jumbo Tornado Outbreak of 3 April 1974. *Weatherwise*, Vol. 27, No. 3.

Fujita, T. T., 1974: Superoutbreak Tornadoes of April 3, 1974 as seen in ATS Pictures. Sixth Conf. Aerospace and Aeronautical Meteor, El Paso, TX.

Fujita, T. T., 1975: Statistics of April 3-4 1974 Tornadoes. SMRP letter to colleagues.

Fujita, T. T., 1978: Workbook of Tornadoes and High Winds For Engineering Applications. SMRP Research Paper 165.

Fujita, T. T., 1992: Memoirs of an effort to unlock mystery of severe storms during the 50 years, 1942-1992. Wind Research Laboratory, Department of Geophysical Sciences, The University of Chicago, pp. 298.

Grazuilis, T. P., 1993: Significant Tornadoes, 1680-1991. Environmental Films, St. Johnsbury, VT.

Hoxit, L. R., and C. H. Chappell, 1975: Tornado Outbreak of April 3-4, 1974; Synoptic Analysis. NOAA Tech Report ERL-338-APCL 37.