

A vertical collage on the left side of the cover, featuring a blue-tinted background. It includes a city skyline at the top, a network diagram with nodes and lines, a 3D city model, a dashed white line, a multi-story building, a mathematical formula
$$= \sqrt{\sum_{i=1}^N [L_i^2 \cdot r_i \cdot (1 +$$
, a satellite image of a hurricane, a stylized sun icon, and a flooded street with a car at the bottom.

THE 2008 U. S. SEVERE CONVECTIVE STORM SEASON

RMS Special Report

EXECUTIVE SUMMARY

The 2008 U.S. severe convective storm season, fraught with damage-causing hail, tornadoes, and straight-line winds, was the costliest and deadliest in a decade. With nearly as much total insured loss as 2008's Hurricane Ike, which has a Property Claim Services¹ (PCS) estimate of \$11.5 billion as of April 2009, this extremely active storm season was ultimately responsible for 125 fatalities and over \$10.5 billion in insured loss—with the top five events causing close to 50% of the total insured loss (Table 1). NOAA's National Weather Service stated that the period from January 2008 through July 2008 was the most active of any year in the modern historical record, which dates back to 1950. Although no single event loss totaled more than \$1.3 billion, the high frequency of tornado outbreaks, which totaled over 1,690, and the extent of losses from tornado, hail, and straight-line winds, caught many insurers by surprise.

The 2008 severe convective storm season caught the insurance industry by surprise predominantly because a year like 2008 has not occurred for a number of years, and thus did not feature in many companies' claims histories, especially as exposure has grown so rapidly. Many aggregate insurance covers were exhausted in 2008 and earnings receded throughout the year, as both primary insurers and reinsurers' losses grew. Fortunately, the season ended early, with no reported losses after the month of August.

Table 1. The top five insured severe convective storm losses in 2008 (Source: Property Claim Services)

| Date of Event | States Affected | Insured Loss (\$ millions) |
|---------------------|--|-------------------------------|
| May 22–26, 2008 | CO, IA, KS, MN, NE, OK, WY | \$1,325 |
| May 29–June 1, 2008 | IL, IN, KS, MN, NE, OK | \$1,100 |
| February 5–6, 2008 | AL, AR, IN, KY, MS, OH, TN, TX | \$955 |
| April 9–11, 2008 | AR, OK, TX | \$800 |
| June 5–8, 2008 | IA, IL, IN, KS, MI, MN, MO, NE, OK, WI | \$725 |
| Total | | \$4,905 |

The amount of early season activity caught many off guard and was partially responsible for the large number of fatalities. The season began with record winter activity, as Wisconsin recorded its first January tornado in four decades. The majority of the early season activity was concentrated in the Southeast U.S., with seven states experiencing over 200% of their annual tornado frequency in the first half of the year. During the season, two events threatened major urban centers in the Southeast and Midwest. In March 2008, Atlanta was surprised by a tornado measuring EF2 on the Enhanced Fujita (EF) Scale², which caused damage to several landmark buildings. In August, Chicago experienced a moderate derecho (i.e., a straight-line windstorm spawned by a band of thunderstorms) that was responsible for wind gusts over 90 mph (145 km/hr) along the edge of Lake Michigan. Although these two cities sustained only moderate damage, these events serve as a reminder that large severe storm urban disasters are possible and not unprecedented. In addition to these two events, three other severe convective storm events are highlighted in the report: the February 5-6, 2008 "Super Tuesday" outbreak that spawned severe weather from Texas to Ohio with 87 confirmed tornados, 5 of which were rated EF4; the May 22, 2008 Windsor, Colorado event, measuring EF3 on the EF Scale and the May 25, 2008 Parkersburg, Iowa event, measuring EF5 on the EF Scale.

¹ Property Claim Services (PCS) is a division of the Insurance Services Office (ISO) and provides metrics around catastrophe loss to the insurance industry.

² The Enhanced Fujita (EF) Scale was implemented in 2007 to replace the former Fujita Scale, a damage scale used to determine the intensity of a tornado.

This paper examines the severe storm activity of the 2008 season, highlighting the factors that lead to active U.S. severe storm seasons, and offering insight into probabilistic modeling of the severe convective storm peril through a discussion of the 2008 activity in relation to the 2008 RMS® U.S. Severe Convective Storm Model and its methodology. A probabilistic loss model shows clearly how frequently such a year as 2008 can be expected, and that worse years can also be expected with a relatively high probability. The value of catastrophe modeling analytics is therefore just as applicable for the proper assessment and management of U.S. exposure to severe convective storm risk as earthquake or hurricane risk.

INTRODUCTION

According to the National Oceanic and Atmospheric Administration (NOAA), 75% of the world's tornadoes are spawned in the United States. Climatologically, across the U.S., in a given severe convective storm season that spans January to December, severe weather activity peaks in May, with a second significant peak in September and October in the Southeast U.S. Damage from tornadoes may vary widely, depending on severe storm activity and location. A large and dangerous tornado may cause little damage in open plains, but devastate a densely populated town or city. Along with tornadoes, severe storms can create devastating straight-line winds, damaging hail, lightning strikes, and flash flooding. Often, it is hail that may contribute most to insured losses for an outbreak or single storm.

According to the 2008 RMS® U.S. Severe Convective Storm Model, hailstorms are responsible for 60% of the average annual loss (AAL) from severe storms in the U.S., compared to 25% for tornadoes and 15% for straight-line winds. This is primarily due to the nature of hailstorm events, which typically have larger footprints and occur much more frequently than tornadoes. In addition, any storm outbreak containing tornadoes often includes multiple reports of hailstones, many of which are of damaging size. Overall, damaging hail and wind associated with severe convective storms can significantly increase insured losses, particularly for the residential and automobile lines of business. In the reporting of severe storm activity by NOAA, straight-line wind, hailstorm, and tornado reports are combined (e.g., see Figure 6).

Severe convective storm events tend to be very complex when compared to larger windstorms, such as hurricanes and extra-tropical storms. Events can last multiple days, contain multiple perils, and cover multiple states. Storms can occur at any point throughout a year, and every state in the continental U.S. has had at least one historical damaging event. During the peak of the storm season in May, events are generally concentrated in the Southern Plains states³, such as Oklahoma, northern Texas, and Kansas. As the seasons change, the risk moves to different parts of the country. Outbreaks during the cool season months (October through April) are usually confined to the Southeast U.S., where temperatures and dew points are still high enough to support violent thunderstorms.

The 2008 Severe Convective Storm Season: Intensity and Damage Statistics⁴

There were nearly 1,700 tornadoes in 2008, causing 125 fatalities (Figure 1). The 2008 season was the second most active tornado season on record, behind 2004, and the season with the most fatalities since 1998. From January to June, more tornadoes were recorded than any other season in the modern historical record (i.e., since 1950), with February, January, and May ranking as the first, second, and third most active on record, respectively. Figure 2, showing month-by-month activity for the past 5 years (2004–2008), clearly illustrates the outstanding aspects of the 2008 season. In particular, there is elevated early season activity in the Northern Plains and Midwestern states in January and February and a reduction in activity in the Southeast U.S. in October and November. In a typical year, secondary peak activity in the later months comes from tornadoes that are spawned by the remnants of tropical cyclones, as was especially evident in 2004 when hurricanes Frances, Ivan and Jeanne were responsible for spawning tornadoes (Verbout et al., 2007).

In May 2008, activity reached its peak as expected, with average tornado counts doubling in eleven states, including Alabama, Arkansas, Georgia, Kansas, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, and Virginia. The Southeast U.S. was particularly busy early and mid-season, with a single February event—the “Super Tuesday” outbreak—claiming 57 lives.

³ In this paper, the states of North Dakota, South Dakota, Montana, Nebraska, Wyoming, Kansas, Colorado, Oklahoma, and Texas are considered Plains States while Ohio, Indiana, Illinois, Iowa, Michigan, Minnesota, and Wisconsin are referred to as Midwest States.

⁴ General information on statistics from the 2008 U.S. severe convective storm season was retrieved from <http://www.spc.noaa.gov> and <http://www.tornadoproject.com>.

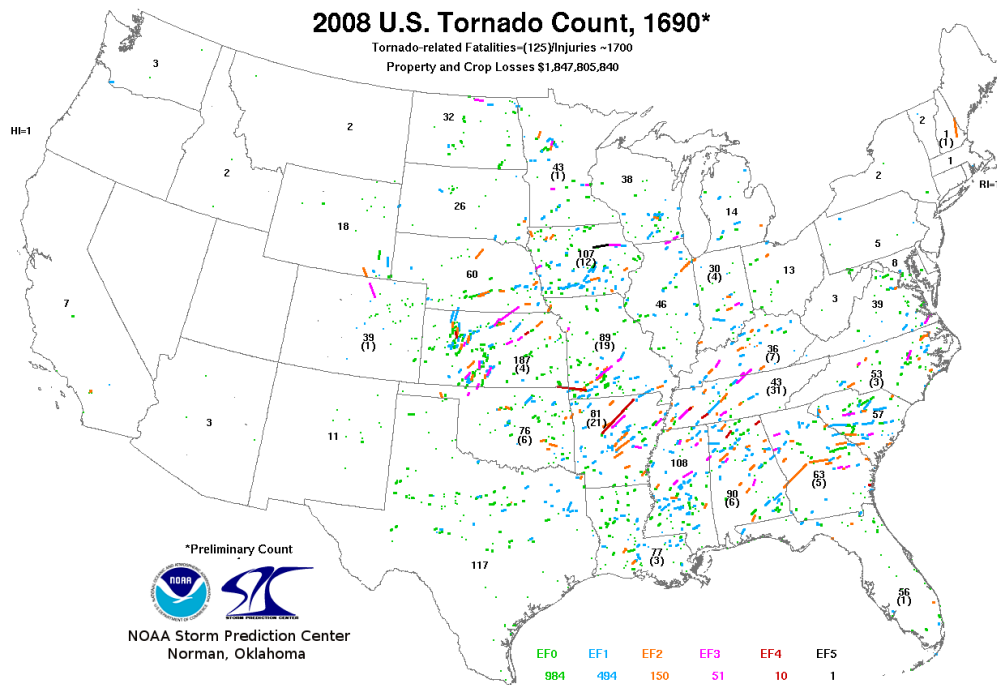


Figure 1: Tracks of all tornadoes during the 2008 U.S. tornado season (Source: NOAA)

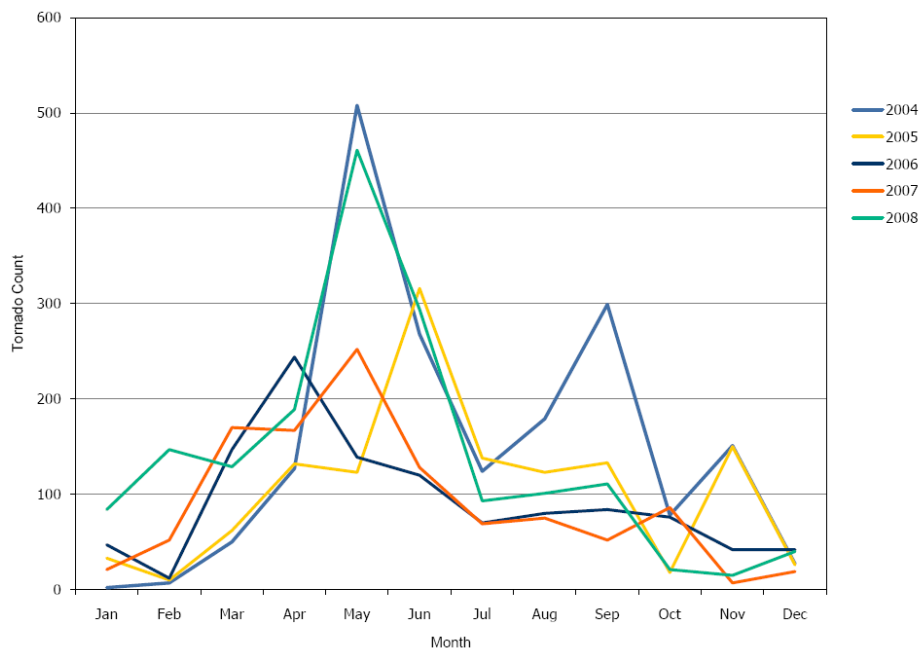


Figure 2: U.S. tornado outbreaks from January through December for the years 2004 through 2008 (Source of data: NOAA)

In 2008, severe storm high magnitude losses did not correlate with historical peril frequency. The largest insured losses were reported in Minnesota, as shown in Figure 3. These losses occurred mainly from an outbreak in late May associated with the same storm system that damaged parts of Colorado and Iowa. The large losses were associated with tornadoes, hail, and powerful straight-line winds. Texas was the second hardest hit state during 2008, due to its large geographical area and high frequency of severe convective storm events, such as the three successive events that occurred in April.

Total insured losses from tornado, hail, and straight-line wind perils for 2008, as reported to the Property Claim Services (PCS) of the Insurance Services Organization (ISO), were over \$10.5 billion through August of 2008. There were no losses reported to PCS in September through December of 2008. If more widespread activity had occurred during these months, as is typical (see Figure 2), losses may have exceeded \$12 billion for the entire year.

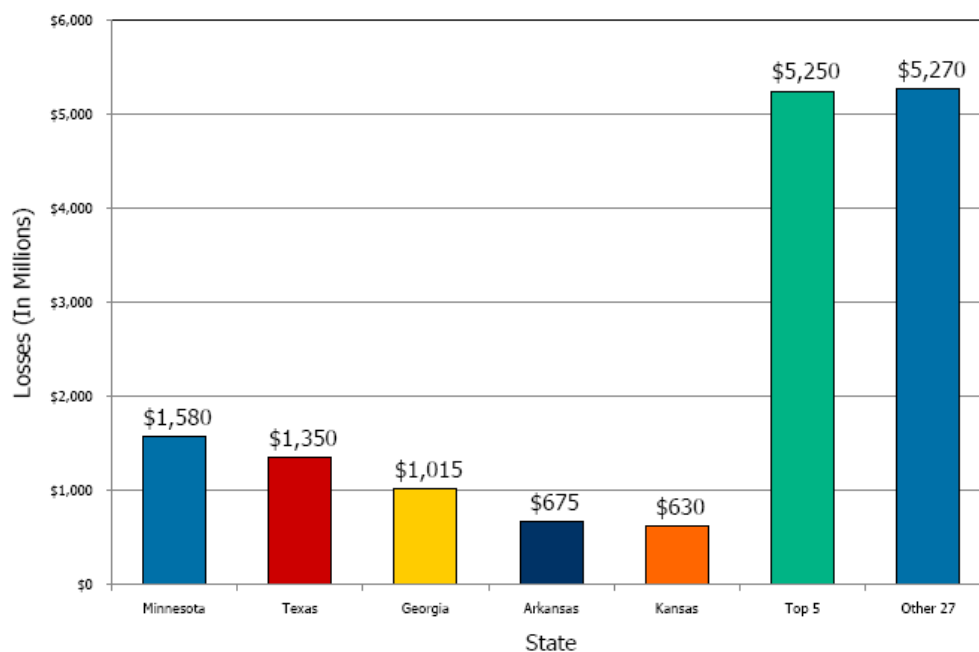


Figure 3: Insured losses (in \$ millions) from the 2008 U.S. severe convective storm season, as reported by the Property Claim Services (PCS) of the Insurance Services Office (ISO); top 5 losses in the states of Minnesota, Texas, Georgia, Arkansas, and Kansas are compared to the rest of the impacted states

CAUSES OF HEIGHTENED SEVERE STORM ACTIVITY IN THE U.S.

There are three basic meteorological conditions needed to develop and sustain a severe convective storm: instability, a trigger, and wind shear. First and foremost is instability—warm, moist air near the Earth's surface trapped beneath cooler, dryer air at higher levels by an inversion. For the storm to develop, however, a trigger such as a front, a sea breeze or flow over a mountain range is needed to provide localized lifting strong enough to carry surface air above the inversion. Once this happens, free convection (Figure 4) can produce storm clouds with tops 6 to 9 mi (10 to 15 km) or higher. Finally, wind shear is needed to organize the updrafts and downdrafts to prevent the storm from collapsing onto itself. When conditions are favorable, many individual storm cells can form.

Many factors govern the availability of these conditions for severe convective storm development, and above-average severe storm activity can be attributed to several factors including movements and changes in the jet stream, sea surface temperatures (SSTs), regional circulations, and boundaries between air masses.

General Circulations

Mesoscale parent systems, which are responsible for the majority of large severe outbreaks, are energized by temperature and moisture gradients created at the boundaries of air masses with different properties. Several scenarios can cause these boundaries to be more intense or conducive to heightened severe weather. A wave-like jet stream can steer low-pressure systems and their accompanying cold fronts farther south into the South Central and Southeast U.S., clashing with warm and moist maritime air originating from the Gulf of Mexico. The jet stream will also increase vertical shear, an important ingredient for thunderstorm formation.

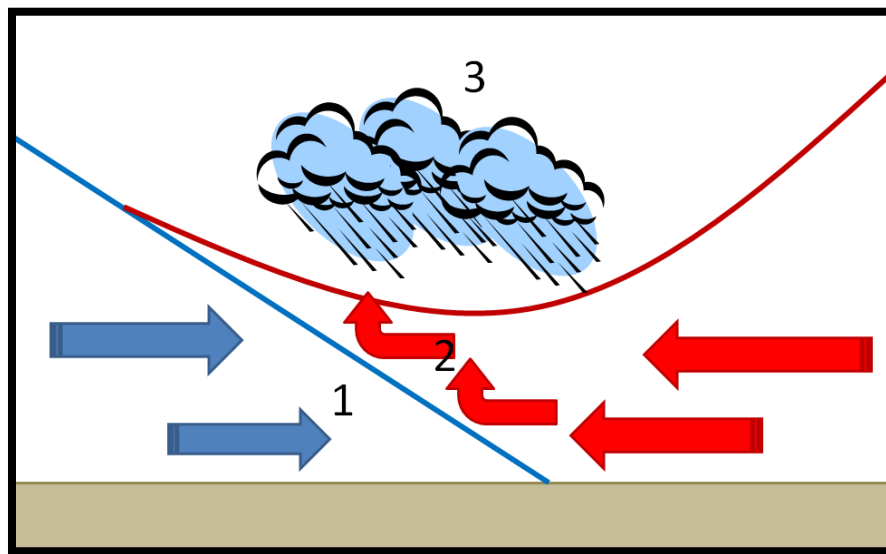


Figure 4: An example of a boundary between cold and warm air masses and the resultant convection: (1) First, cold air moves into warmer air and cuts beneath it; (2) then, warm air is forced to rise and overtops the encroaching cold air; and (3) finally, rising air creates convection

Increased SSTs in the Gulf of Mexico can cause the maritime air mass over the southern U.S. to become moister and warmer than normal, creating sharper moisture and temperature gradients over the region, thereby providing more energy to systems that develop. Drought and dry conditions, including a farther than normal intrusion of dry continental air from Northern Mexico and the Southwest U.S. can cause dry mid-level tropospheric air to spill over low-pressure systems moving east over the Rocky Mountains, causing instability and increased mixing and convection (Figure 5). In addition, strong, dry conditions can enhance dry lines (the

meeting of dry and moist air masses), a phenomenon commonly responsible for severe weather outbreaks in the Central U.S.

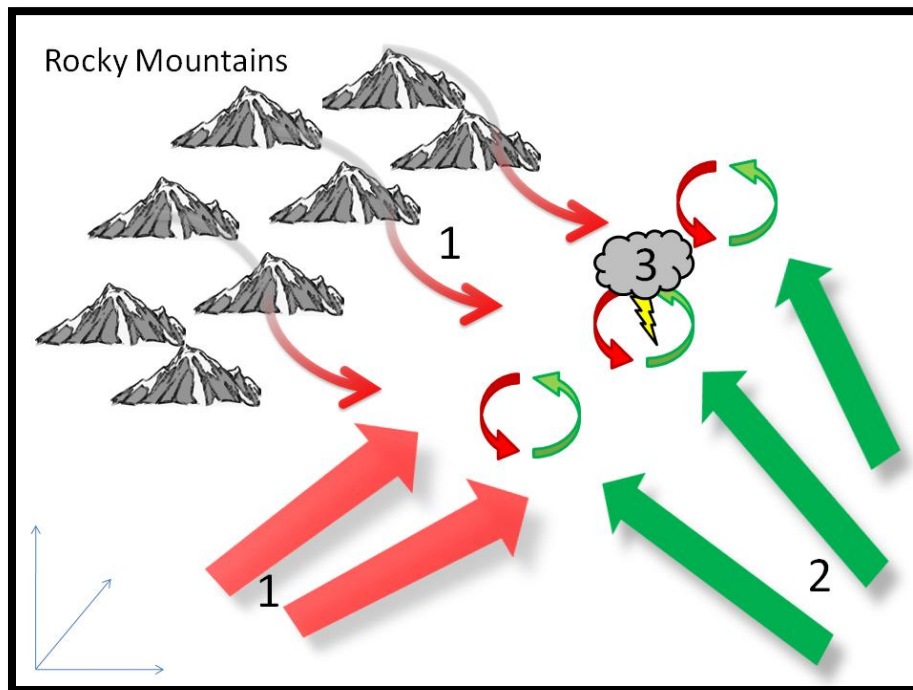


Figure 5: Dry and moist air meet on the eastern edge of the Rocky Mountains: (1) First, air descends from the Rocky Mountains, drying in the process, and along with already dry air from the southwest, moves east; (2) then, moist air from the deep south moves westward and northward; (3) and, a dry line forms where these air masses meet, mixing ensues as moist air rises, creating convection

La Niña and the El Niño-Southern Oscillation (ENSO)

NOAA and the National Center for Environmental Prediction (NCEP) confirmed that a La Niña formed in the fall of 2007 and strengthened during the early months of 2008. La Niña is the counterpart to the more well-known El Niño and is identified by cooler than normal sea surface temperatures (SSTs) in the eastern Pacific Ocean. Cooler SSTs in the equatorial Pacific suppress tropical convection in the area and lead to changes in the global general circulation, affecting weather patterns in the U.S. Researchers at the National Severe Storm Laboratory (NSSL) have found that there is a significant correlation between lower SSTs in the equatorial Pacific and a rise in the intensity and frequency of tornadoes in some parts of the U.S. (Marzban and Schaefer, 2001). Winter outbreaks from November through February in the northern Ohio Valley and north-central Midwestern states are most significantly tied to La Niña events (Cook and Schaefer, 2008). However, this signal is not nearly as strong as the correlation between Atlantic hurricane activity and La Niña/El Niño. In fact, the body of research and climatological record of La Niña and El Niño, as well as consistent long-term tornado climatology, is not complete enough to draw any definitive conclusions regarding the connections between severe weather in the U.S. and El Niño or La Niña. The NOAA Storm Prediction Center (SPC) cautions that no definitive connection between La Niña and increased tornado activity can currently be proven.

THE 2008 U.S. SEVERE CONVECTIVE STORM SEASON: KEY EVENTS

In this section, five events from the 2008 U.S. severe convective storm season are highlighted. The season began with an unusually large and early outbreak in January that spanned from Oklahoma to Wisconsin and was accompanied by winter storm conditions as well. It was followed by another unusually early and large outbreak in February, known as the “Super Tuesday” outbreak, which was responsible for 57 deaths in the Southeast U.S. In mid-March, Atlanta withstood an isolated tornado and was lucky to escape with minor to moderate damage. May, which is climatologically the most active tornado month, saw numerous significant outbreaks, including an EF5 tornado in Iowa and a significant tornadic event in Colorado. In August, Chicago was affected by a significant derecho event, underscoring the vulnerability of Midwestern metropolitan areas.

The Enhanced Fujita Scale

In 2007, the Enhanced Fujita (EF) scale replaced the Fujita (F) scale for classifying the intensity of a tornado and the 2008 severe convective storm season was only the second season that the EF scale was utilized. In both scales, damage sustained from the tornado is used as the main indicator for estimating the intensity of the event, based on its wind speed. The EF scale was developed from 2000 through 2004, using more recent tornado damage surveys, increasing the list of damage indicators and improving the accuracy of their associated wind speeds and category⁵.

Table 2. The Fujita and Enhanced Fujita scales

| F Scale | Wind speed (mph) | EF Scale | Wind speed (mph) | Damage |
|----------------|-------------------------|-----------------|-------------------------|---------------------|
| F0 | 45–78 | EF0 | 65–85 | light damage |
| F1 | 79–117 | EF1 | 86–110 | moderate damage |
| F2 | 118–161 | EF2 | 111–135 | considerable damage |
| F3 | 162–209 | EF3 | 136–165 | severe damage |
| F4 | 210–261 | EF4 | 166–200 | devastating damage |
| F5 | 262–317 | EF5 | > 200 | total destruction |

January 7–10: Central and Northern Plains

The early January outbreak was unusual in its severity and location. Wisconsin experienced the first January tornado to occur in the state since 1967. Over 70 confirmed tornadoes were reported in the January 7–10 outbreak, which covered portions of the Plains and Midwest states, including Missouri, Wisconsin, and Arkansas (Figure 6). This storm system was responsible for over \$700 million in insured loss, although this estimate also includes losses from ice, snow, freeze, and flood caused by the winter storm that accompanied the severe convective storm events. In total, there were close to 85 confirmed tornadoes for the month, making it the second most active January on record since 1953 (National Climate Data Center, 2009).

⁵ For more information on the development of the EF scale, see <http://www.spc.noaa.gov/efscale/ef-ttu.pdf>.

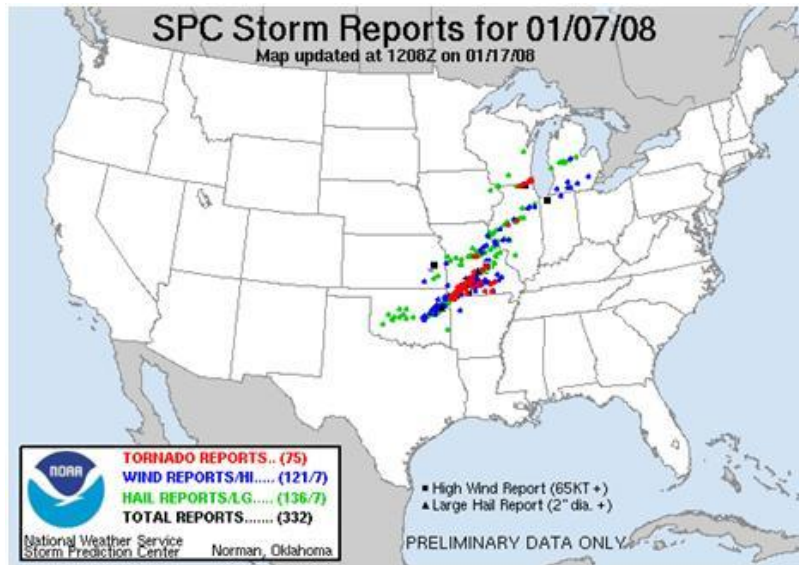


Figure 6: NOAA Storm Prediction Center (SPC) storm reports map for the early January outbreak (January 7-10, 2008), showing tornado, wind, and hail reports throughout the impacted region (Source: NOAA)

The January 7–10 outbreak was the second largest on record for the month (Storm Prediction Center, 2009). What makes this outbreak so unusual is its relatively northern location. Prior historical outbreaks, though not uncommon, have generally occurred in the Southeast U.S. at the boundary between the warm and moist Gulf air, and the cold continental air mass. The more northerly position of severe weather was not unprecedented, and is a reminder that severe weather can strike during any month across a large portion of the continental U.S.

February 5–6: Southeast “Super Tuesday”

The month of February is quiet on average, as the jet stream is typically too far south to usher warm, moisture-rich air far enough inland to impinge on the cold continental air mass. However, February 2008 was unusually active, with several severe outbreaks in the southern states, including the largest tornado outbreak day of the year—February 5, which became known as the “Super Tuesday” outbreak because of its occurrence during the presidential primary elections. In fact, nearly half of all of the fatalities recorded from severe convective storms in 2008 occurred in the Southeast U.S. over a two-day span from February 5–6. This tremendous outbreak in the Dixie Alley⁶ region caused 57 deaths and produced 87 confirmed tornadoes (with 131 reported tornadoes, as shown in Figure 7(a)), the strongest receiving a rating of EF4. The event was responsible for nearly \$1 billion in insured damage, nearly half of which occurred in the state of Tennessee.

Throughout the two-day event, a long-lived squall line moved from eastern Illinois to West Virginia while most of the tornadic outbreaks were confined to the southern states of Arkansas, Mississippi, Tennessee, and Alabama (Figure 7(a)). Several storms in northeast Arkansas caused 14 fatalities, with 32 more fatalities occurring in southwest Tennessee and 4 in northern Alabama. EF4 tornadoes were responsible for 27 deaths during the outbreak. Along with producing 87 confirmed tornadoes, over 260 wind reports and 120 hail reports were recorded.

Wintertime outbreaks tend to have a higher fatality rate due to the shortened length of day and limited visibility of night-time tornadoes. Of the 57 fatalities that occurred during these two days (as shown in Figure 7(b)), 31

⁶ Dixie Alley is the name given to the area in the Southeast U.S. that has a high risk of tornado activity. This area includes Louisiana, Arkansas, Mississippi, Alabama, Georgia, and Tennessee.

occurred in mobile homes, 20 in permanent residential structures, 5 in commercial or government buildings, and 1 in a vehicle. Mobile homes are the site of the majority of tornado-related fatalities, as they provide little structural protection from violent storms. Even when properly tied down to the foundation, full destruction of a mobile home can occur at EF2 or weaker intensity.

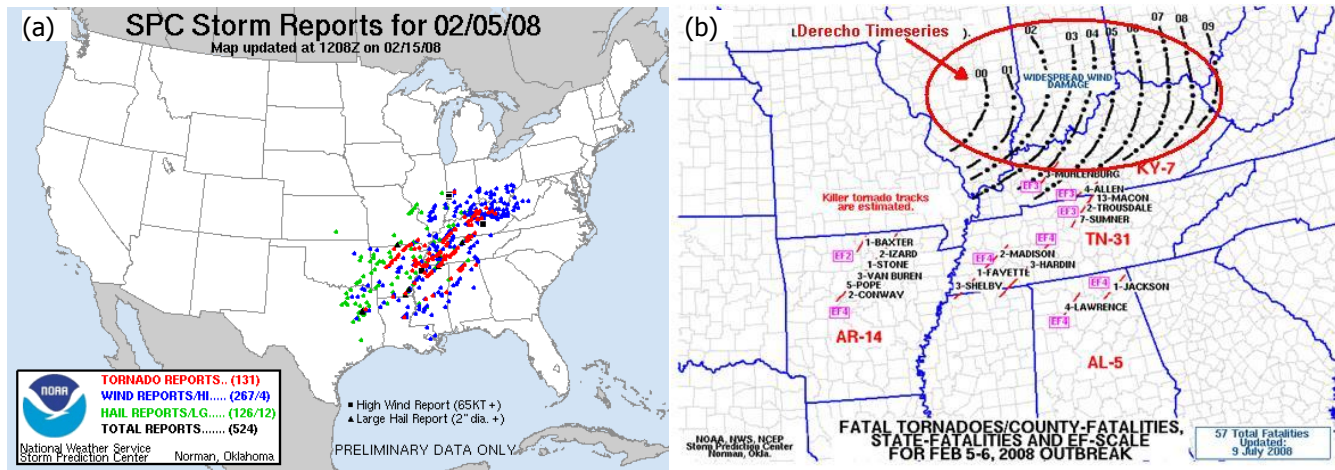


Figure 7: Maps of the "Super Tuesday" outbreak of February 5–6, 2008: (a) tornado, wind, hail reports from the NOAA Storm Prediction Center (SPC); and (b) close-up of tornado paths, intensities, and fatalities per state (Source: NOAA)

March 14: Downtown Atlanta

Large, destructive, urban tornadoes are the biggest threat to loss of property and life from severe convective storms. These scenarios dominate the tail of the severe convective storm exceedance probability (EP) curve, which is used by risk managers to determine the probability of exceeding various levels of loss. Although these instances are extremely rare, major urban centers, such as Oklahoma City, Oklahoma, Fort Worth, Texas, Miami, Florida and Salt Lake City, Utah, have experienced tornadoes that have caused major damage, reminding the insurance industry that these mega-disasters do occur.

On March 14, 2008, at 9:30 p.m. local time, a tornado tore through the downtown Atlanta area, surprising the inhabitants of the city, as the day was not anticipated to have intense storm activity. The strength of the tornado reached an intensity of EF2 and was accompanied by hail and strong straight-line winds (Figure 8). It damaged the Philips Arena and Georgia Dome, while professional and collegiate basketball games were in progress. In addition, key commercial buildings were seriously damaged, including the CNN Center, the World Congress Center, and the Omni Hotel.



*Figure 8: Footprint of the tornado's intensity through downtown Atlanta on March 14, 2008
(Source: National Weather Service, 2008)*

Although the SPC had issued only a slight chance of tornado-producing storms that evening, by 9:26 p.m. local time, a severe storm spawned a tornado 6 mi (10 km) west of downtown Atlanta. Because of its isolated nature, the storm drifted southeast instead of having a more typical northward component. The tornado caught the city and the SPC off guard, as it was spawned by an isolated severe storm and was not part of a larger outbreak. This scenario was atypical, as tornado-spawning thunderstorms usually tend to be part of a larger cluster of activity, due to the amount of energy and shear needed in the atmosphere for development. On the following day, larger-scale severe weather occurred along the southeast coastline of the U.S.

Insured damage caused by the storm was approximately \$340 million. While the damage was significant, the inhabitants of Atlanta were fortunate, as past direct hits by tornadoes in other metropolitan areas have caused much more damage and loss of life (e.g., the 1999 tornado outbreak caused, at the time of occurrence, nearly \$1 billion in insured loss to Oklahoma alone). This tornado serves as a reminder that urban areas in the Southeast U.S. are at risk from severe convective storm catastrophes, particularly in the cool season months (October through April).

In order to examine the loss from the Atlanta tornado, RMS analyzed the property across the state of Georgia against the entire suite of stochastic events in the RMS® U.S. Severe Convective Storm Model. A loss level of \$340 million, which resulted from the March 14, 2008, Atlanta tornado, has a corresponding return period of approximately 5 years, as illustrated in the exceedance probability (EP) curve in Figure 9. As one can see, this type of event has an extremely short return period, with a corresponding 20% annual probability of exceeding \$340 million in insured losses across the state. Moreover, small variations in the Atlanta tornado's track could have resulted in a major increase in losses, based on the high density of exposure in central Atlanta.

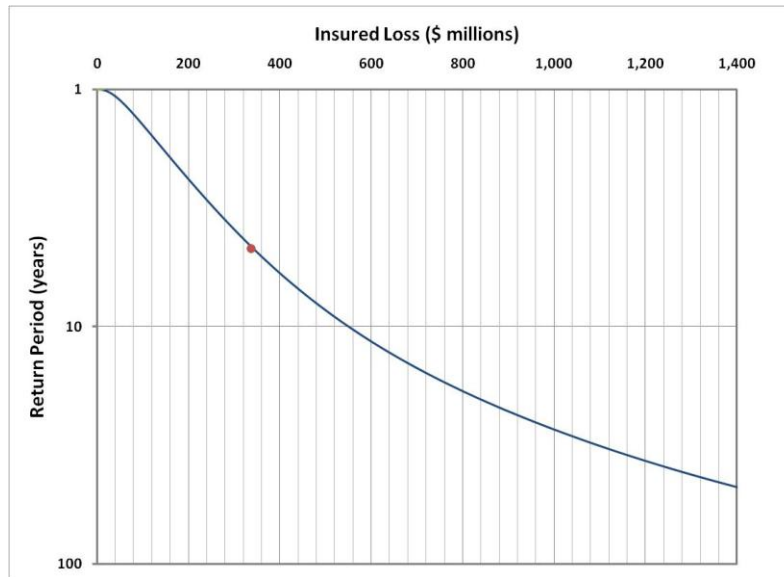


Figure 9: Severe convective storm risk in Georgia: loss exceedance curve of insured loss versus return period based on the 2008 RMS® Severe Convective Storm Model, highlighting (red dot) the historical event of the 2008 Atlanta tornado

May 22–26: Great Plains and Southeast

The Parkersburg, Iowa, Windsor, Colorado, and Hugo, Minnesota tornadoes were part of separate severe systems during a major spring outbreak across the Great Plains and Southeast U.S., which generated large hail and deadly tornadoes. From May 22 through May 26, the states of Colorado, Iowa, Kansas, Minnesota, Nebraska, Oklahoma, and Wyoming sustained insured losses. This particular outbreak was the costliest severe convective storm catastrophe of 2008, with a loss in excess of \$1.3 billion and \$800 million sustained in Minnesota alone.

Across the continental U.S., May is historically the most active month for tornado generation. The combination of abundant moisture, high levels of atmospheric shear, and strong low-pressure systems marching across the Central U.S. provide the most favorable environment for severe convective storms found anywhere on Earth. The consequences of this awesome display of atmospheric force have been felt consistently for the last few years, with tragedies such as the Greensburg, Kansas event in 2007, which leveled an entire town. May 2008 was particularly violent, with a rare high plains EF3 tornado tearing along the edge of the Colorado town of Windsor, and the second EF5 tornado in two years destroying the entire town of Parkersburg in Iowa (Figure 10).



Figure 10: Destruction caused by the May 25, 2008, Parkersburg tornado in Iowa, measuring EF5 on the EF Scale

The first two days of May 2008 began with over 90 tornado, hail, and wind reports collected by NOAA, with 7 fatalities reported in Arkansas. A week later, 80 tornadoes touched down in the Central and Southeast U.S. states, claiming 23 lives. This heightened activity continued into the second half of the month and a major outbreak in the western Plains States began on May 22. Early on May 22, 2008, around 11:30 a.m. local time, Windsor, Colorado, with a population of 17,000, was struck by an EF3 tornado, causing Colorado's fourth costliest catastrophe, and the costliest disaster outside the Denver metropolitan area in the state's history. According to PCS, the insurance industry sustained a \$200 million loss from this event. A state of emergency was declared by Colorado Governor Bill Ritter and the National Guard was activated. The Windsor Tornado was spawned by one of many northwestward moving storm cells. Two cells narrowly missed Fort Collins, a city of 120,000 people. Losses could have multiplied had a tornado struck Fort Collins directly.

Several strong storms produced violent tornadoes across the northern plains from May 23 through May 26, but the worst was a deadly EF5 tornado in Parkersburg, Iowa, which killed 7 people. Severe weather in Northern Iowa caused an estimated \$160 million in insured damage that day. More than 220 homes and over 20 businesses were destroyed, as well as a high school. The last time a tornado of this intensity occurred in Iowa was on June 13, 1976. A few days following the event, RMS deployed reconnaissance personnel to investigate the damage.

The violent EF5 tornado was estimated at 0.7 mi (1.1 km) wide as it moved through Parkersburg and enlarged to 1.2 mi (2 km) wide before dissipating east of the town. The tornado traveled nearly 43.5 mi (70 km) with most of the track traversing open farmland. As part of the reconnaissance effort, RMS joined local experts, including Tim Marshall, Failure and Damage Consultant, of Haag Engineering, to perform both an aerial and a ground survey. Approximately 370 structures were reviewed and assigned an EF rating (Figure 11) of EF0 through EF5, based on the observed damage. The typical damage to wood-frame residential structures was the failure of the connections between a structure's wood framing and its concrete foundation. There were 33 homes that slid off of their foundation, most of which were assigned a rating of EF2, corresponding to considerable damage.⁷

⁷ For more information, see Marshall et al., 2008.

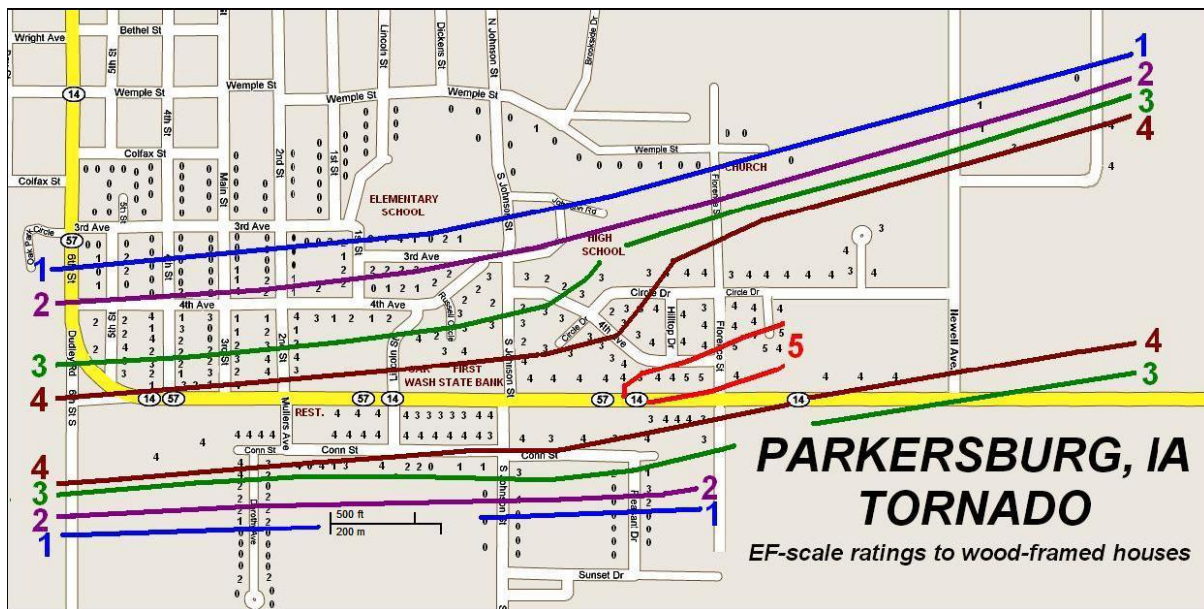


Figure 11: Damage Surveys from the Parkersburg, Iowa tornado of May 25, 2008: representative damage by EF scale rating of EF0 to EF5 (above) and locations (below) of the 370 wood-frame residential structures within the Parkersburg tornado damage path (Marshall et al., 2008)

August 4: Chicago Metropolitan Area Derecho

Chicago, Illinois, the third largest city in the U.S., has the distinction of being the largest urban area with a moderate to high severe convective storm risk. A major tornado tracking through downtown Chicago has been the focus of many recent studies, as the resulting financial loss will be extreme. Based on RMS internal analyses, a large EF5 event could cause an estimated \$20 billion in damage. In late summer 2008, a derecho struck Chicago, serving as a reminder of the risk from these types of storms.

A derecho is a large-scale wind system that is formed from multiple thunderstorms that usually align themselves into a bow-shaped line called a "bow echo." Although tornadoes can be associated with the tail ends of derechos, damaging hail and strong straight-line winds are most commonly associated with derechos. Since derechos can stretch over 62 mi (100 km) in length, large areas are often affected by the damaging winds. The radar image in Figure 12 from the derecho on August 4, 2008, exhibits a classic bowed line of storms, highlighted by the white line. White arrows additionally depict the approximate movement of strong winds covering a large area, particularly when compared to the size of a tornado track.

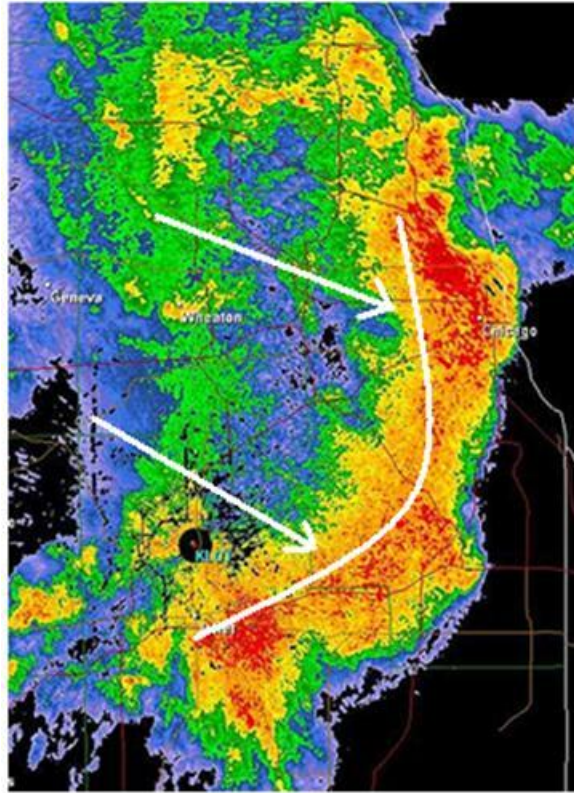


Figure 12: Radar image of the derecho in the Chicago area on August 4, 2008. Bowed line and arrows (added by RMS) indicate storm line and movement of winds (Source: KLOT radar station, National Weather Service)

As the convective line approached Chicago, tornadoes were spawned in Bloomington, Indiana, located 23 mi (37 km) from Chicago, and Elmhurst, Illinois, approximately 15 mi (24 km) from Chicago. Tornado sirens were activated in Chicago, interrupting a Chicago Cubs game and causing the evacuation of Wrigley Field. The Chicago O'Hare International Airport was closed, with cancelled flights impacting air travel across the U.S. Thousands of people in the region were forced to move into shelters. As the derecho passed over Chicago, a wind gust of 94 mph (151 km/hr) was recorded at the Harrison-Dever Crib observation station on Lake Michigan. The derecho moved southeast and continued to spawn tornadoes, with another tornado confirmed in Griffith, Indiana and widespread damaging winds propagating across northern Indiana. Though damage from this system was not extensive in the greater Chicago area, a million people lost power throughout Illinois, Indiana, and Ohio. Altogether, the derecho event produced an insured loss of \$180 million, the majority of which was sustained in Illinois. Given the high amount of exposure around Chicago, this region is extremely vulnerable to costly severe convective storm catastrophes.

SEVERE CONVECTIVE STORM RISK MODELING

According to the Property Claim Services (PCS) of ISO, as of April 2009, the U.S. insurance industry sustained a \$10.5 billion loss from the severe convective storms of 2008. The amount paid out by the insurance industry will be slightly higher, as PCS does not capture losses below \$25 million on an industry basis or those not affecting “a significant number of policyholders and insurers”. According to the 2008 RMS® U.S. Severe Convective Storm Model, a loss of \$10.5 billion across the insured property at risk from severe convective storms in the U.S. has a very short return period of between 2 and 3 years. This model estimate includes high frequency events causing loss below \$25 million that may not be a part of the reported PCS figures.

Severe Convective Storm Risk: Average Annual Loss

To put the 2008 U.S. insurance industry loss of \$10.5 billion into perspective, the yearly aggregate losses to the industry from 1998 through 2008, trended to 2008 dollars, are shown in Figure 13. As one can see, over the last decade, there have been several active years that have exceeded \$10 billion in loss, including 1998, 2003, and 2008. In addition, if one considers these losses over the last ten years, the average annual loss (AAL) is approximately \$6.4 billion (i.e., performing a simple average calculation across the 10 years).

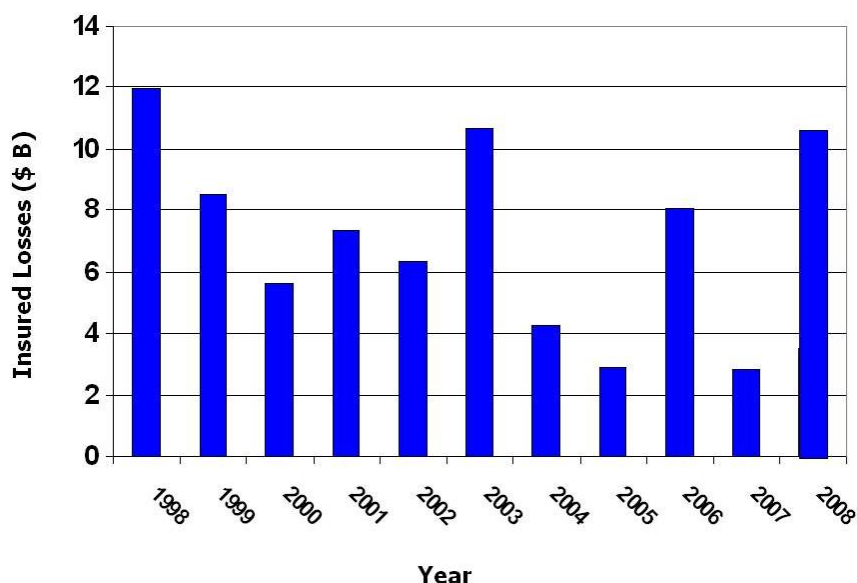


Figure 13: Yearly insured losses (1998–2008) from U.S. severe convective storms, trended to 2008 dollars (Source of data: Property Claim Services)

Of course, losses from the past 10 years are not representative of all past or future losses from severe convective storm risk, and should be considered only as the 10-year sample they represent. Moreover, the tornadoes associated with the 2004 and 2005 hurricanes are not included in the PCS estimate, as they are considered part of the hurricane loss. The RMS® U.S. Severe Convective Storm Model calculates an AAL based upon a simulated event set, spanning hundreds of thousands of years. Specifically, the RMS model calculates an AAL of around \$8.8 billion across the property at risk from severe convective storms in the U.S. This represents an accurate estimate of AAL for insured property against tornado, hail, and straight-line wind perils across the U.S.

Severe Convective Storm Risk: Aggregate versus Occurrence Exceedance Probability

Beyond AAL, however, a full picture of the severe convective storm risk to the insurance industry can be understood through the loss exceedance curves. Figure 14 shows an aggregate exceedance probability (AEP) curve and an occurrence exceedance probability (OEP) curve for U.S. property at risk from the severe convective storm peril. An aggregate exceedance probability (AEP) curve illustrates the probability that one or more occurrences (i.e., severe convective storms) will combine in a year to exceed a certain level of loss; an OEP curve shows the probability that a single storm will exceed a certain level of loss.

In Figure 14, the large disparity between the aggregate (in blue) and occurrence (in red) perspectives is highlighted. Unlike other natural hazard perils, such as earthquakes, severe convective storms are high frequency events with a low severity impact (in most cases). As a result, the differences in the AEP and OEP curves are significant. Depending on the business purposes, an insurer or reinsurer may be interested in looking at both perspectives. The OEP curve is more commonly used for pricing per event insurance, such as catastrophe programs and single event coverage. The AEP curve is used more to price aggregate insurance covers, as well as for portfolio management.

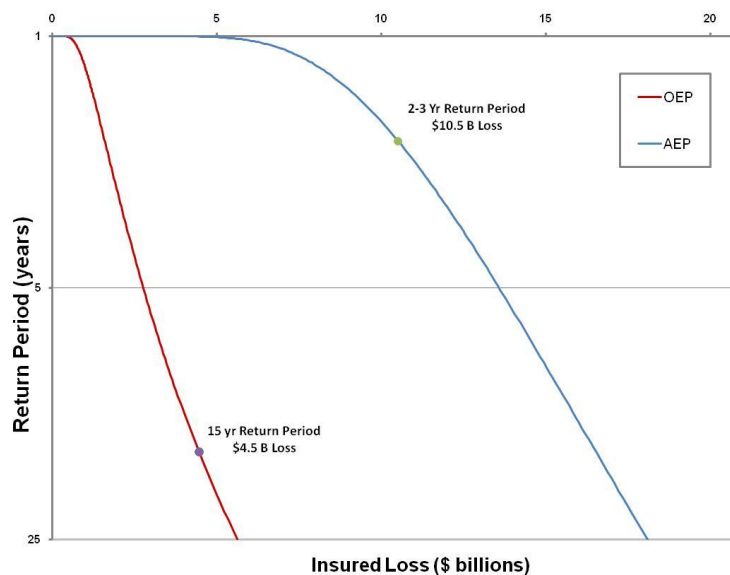


Figure 14: Severe convective storm risk across the U.S.: an aggregate exceedance probability (AEP) and occurrence exceedance probability (OEP) curve of insured loss versus return period based on the 2008 RMS® Severe Convective Storm Model, highlighting the relatively short return periods experienced on both an aggregate and single occurrence level

Two points have been plotted on the graph: a \$10.5 billion aggregate loss level on the AEP curve, and a \$4.5 billion occurrence loss level on the OEP curve. The point on the AEP curve highlights the loss level of 2008, along with its corresponding return period. The point on the OEP curve highlights the largest occurrence loss from a severe convective storm from the last 25 years, adjusted to 2008 dollars. This single loss, occurring in 2003, was an outbreak that lasted nine days and produced widespread hail damage across the Great Plains, Southeast U.S., and Ohio River Valley.

The 2008 season caught many insurers and reinsurers by surprise, predominantly because such a season has not occurred for a decade, and thus does not feature in many companies' claims histories, especially as exposure has grown so rapidly. However, the \$10.5 billion loss for the season was far from unprecedented. The RMS U.S. Severe Convective Storm Model indicates that the 2008 total insured loss corresponds to a 2 to 3 year return period, highlighting the potential for much larger aggregate season losses. And, the relatively high number of small losses, which were less than \$1 billion for all but two of the 2008 events reported by PCS,

serve as a reminder that the high frequency nature of severe convective storms can allow losses to continually increase throughout the course of a year.

This report demonstrates that the value of catastrophe modeling analytics is as applicable for the proper assessment and management of U.S. exposure to severe storm risk as earthquake or hurricane risk. A probabilistic loss model can clearly show how frequently a storm season like 2008 can be expected, and that worse years can also be expected with a relatively high probability.

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