SEVERE CONVECTIVE STORM MODELING

UNIT 4

RMS® CCRA® Training Program

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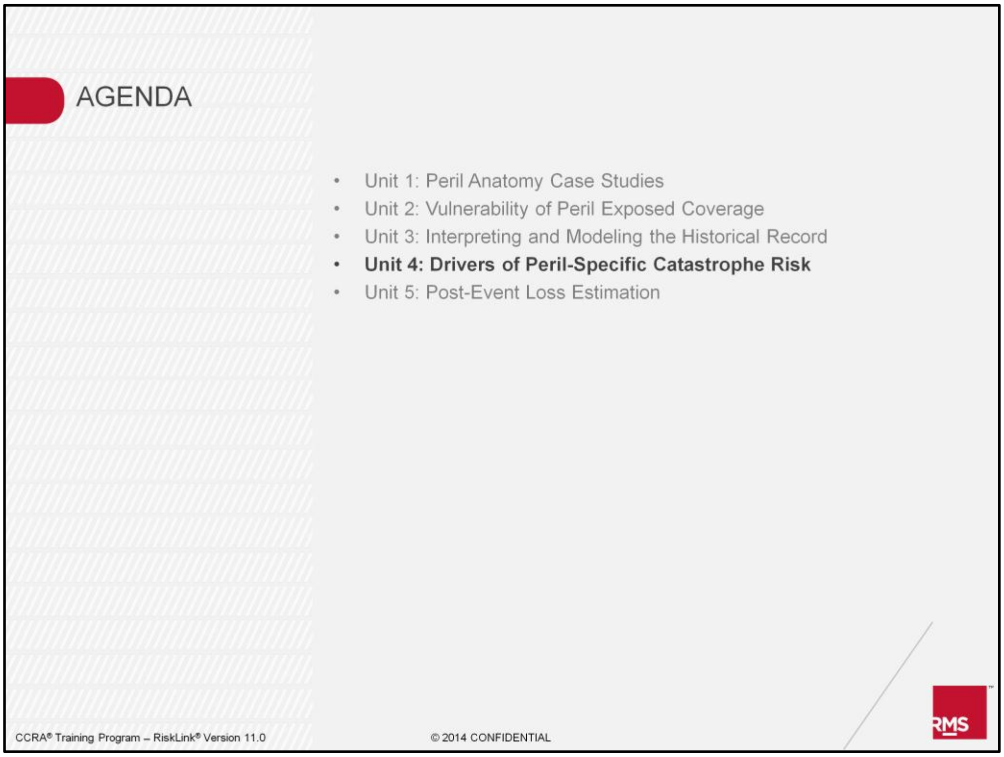
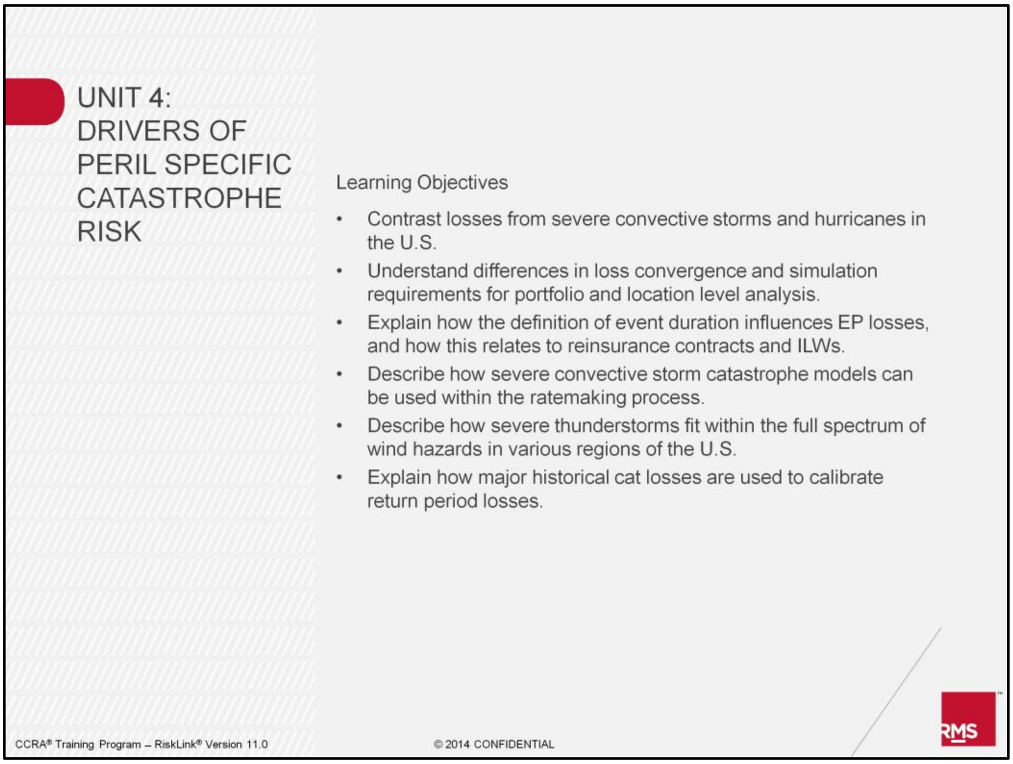
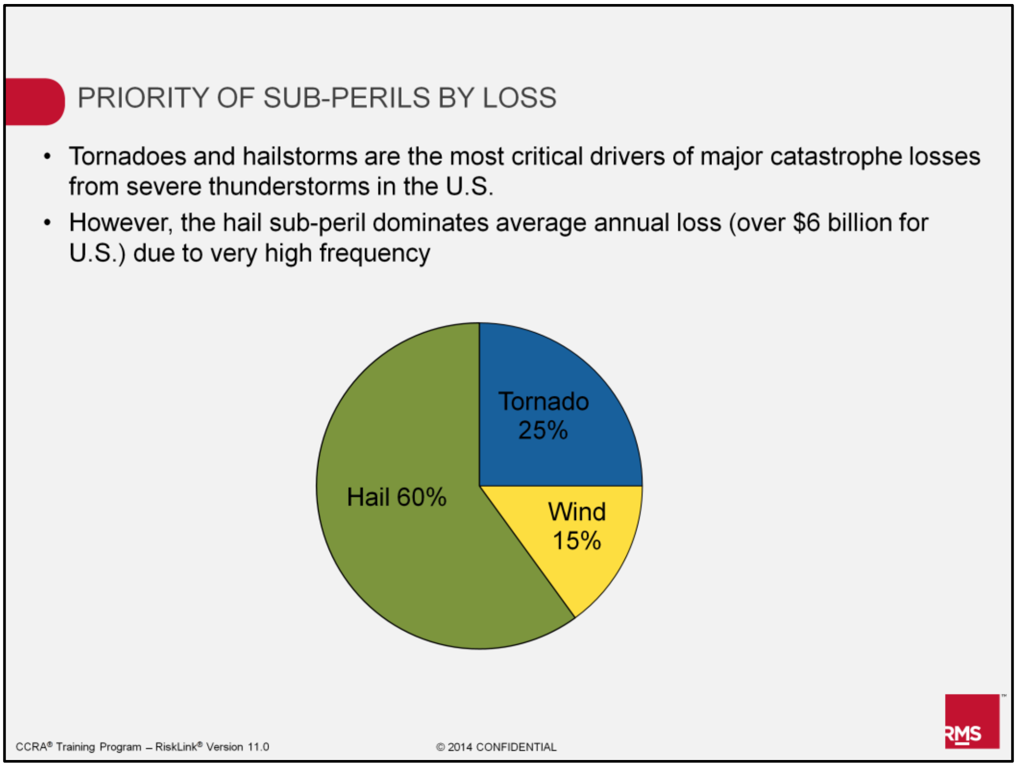


This unit discusses the vulnerability module of the severe convective storm model.



At the end of this unit you should have a good understanding of each of the five learning objectives listed on this slide.

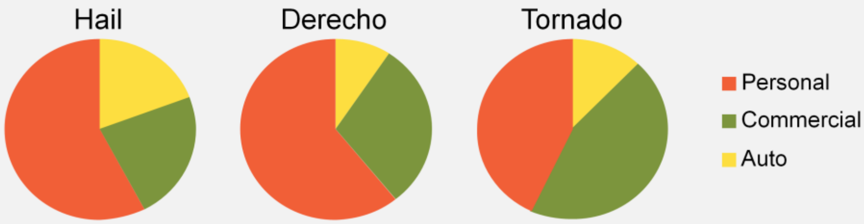


As a review, this is an exhibit that we introduced in Unit 1. On an annualized basis, hail, by far, is the most dominant of the three perils.

We will start by breaking down a catastrophe loss event where hail is the dominant source and we will begin to profile which lines of business tend to take on most of the loss from a hail-dominant event. We will then do the same for tornado and straight-line wind dominant events.

REVIEW OF RECENT THUNDERSTORM LOSSES BY LINE OF BUSINESS

- Since 1990, there have been over $115 billion in industry losses attributed to thunderstorm events. The average annual loss is almost comparable to that for hurricanes in the U.S., but is much less variable.
- The largest thunderstorm catastrophe loss is ~$5.0 billion (2011)



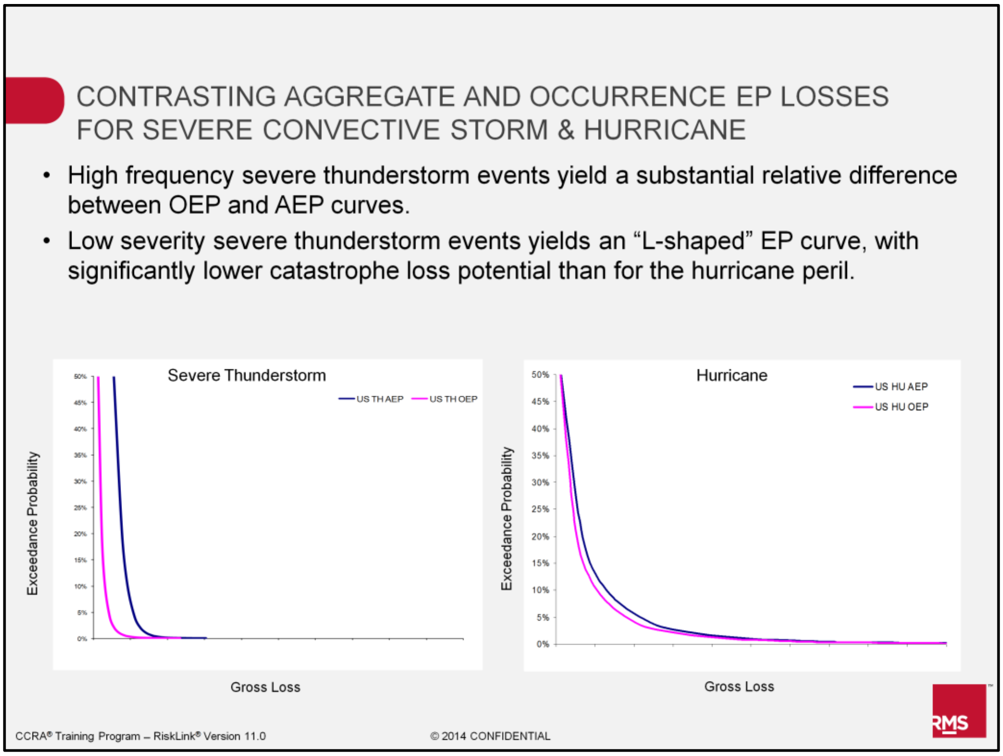
Based on segmentation of severe thunderstorm industry losses between 1998 and 2005 by the peril contributing the most to the total loss.

The three pie charts at the bottom of this slide illustrate some of the differences between the perils.

This is based on a review of severe thunderstorm industry-level losses for all of the catastrophes in the Property Claims Services (PCS) database between 1998 and 2005. Severe thunderstorm loss is put into one of three buckets; hail, derecho, or tornado, based on which peril caused the majority of loss. We then look at the relative amount of loss from each of these catastrophe events for personal lines versus commercial lines versus automobile lines.

For hail, personal lines and auto lines tend to constitute the majority of the loss in those events. This has a lot to do with the vulnerability of those different structures. Personal lines tend to have weaker or more vulnerable roofing materials or cladding. The exterior elements of a building are more vulnerable in personal lines risks in most cases relative to commercial, which might have gravel or built-up roofs and masonry exteriors.

Contrast that with the tornado example on the far right, and we get a very different relativity by line of business. For tornadoes, the severity of an event is much higher. Business interruption can become very significant when there is a major amount of damage to a facility and its contents. Commercial lines losses tend to be a much higher percentage of the total loss. Derechos tend to be somewhere in between. The loss breakdown by line for derecho events is similar to hail with the key difference being low-end wind events. Hundred mile an hour winds tend to have less effect on automobiles than hail, so that relative amount of loss to the auto line is less for derechos than for hail.



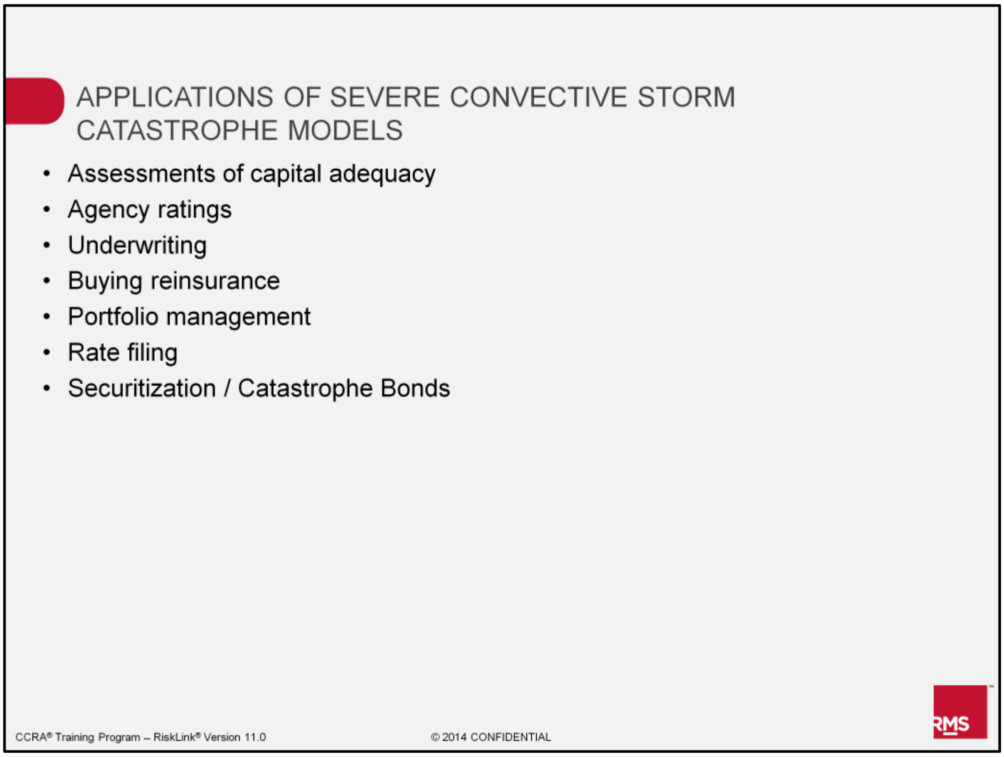
This slide looks at the difference between an occurrence point of view and an annual aggregate point of view of loss for severe thunderstorms, and then contrasts that with hurricane.

High frequency severe thunderstorm events yield a very substantial difference between the occurrence-based EP curve and an aggregate-based EP curve. The plot on the bottom left is showing the probability of exceeding a given loss level for severe thunderstorms from one event, which is the OEP curve shown in pink, and from the aggregation of all events in a given year, which is the dark-blue curve.

Notice there is a much greater separation between the occurrence curve and the aggregate curve for severe thunderstorms than for hurricane. This also holds true for many of the other perils such as earthquake and relates specifically to the high frequency of severe thunderstorms.

EP curves for severe thunderstorm events tend to be much more L-shaped than what you would see for hurricane. This is because the severe thunderstorm events tend to have relatively low severity. In the situations where there is large severity, like a tornado, the spatial scale of impact is fairly small. And for those reasons the peak loss potential, or the high-end losses, tend to be capped or limited to the $5 billion to $10 billion range for the industry. Rarely would an event ever exceed that level. For hurricane, however, the scale of some events and their severity could easily produce $30 billion, $40 billion, or $50 billion of loss at some of the higher return periods.

Therefore, the very different shape between these two curves reflects the frequency of those events and their relative severity.



The RMS Severe Convective Storm model is an event based model, based on hundreds of thousands of simulated events that can have a combination of hail, tornado, and straight-line wind footprints. The event set has several uses within the insurance industry, including portfolio management and risk differentiation:

<u>Assessments of capital adequacy</u> – North American severe convective storms are not generally significantly large enough events to reach reserve caps. While insurers buy catastrophe cover for their key peril, which on the east coast is U.S. hurricane, for many, severe convective storm is the second peril and the one that affects their reserves planning each year.

<u>Agency ratings</u> – In a given year, a regional insurer might have one large tornado/hail/wind storm event, or a few smaller events. This can increase the company's overall loss ratio, which may negatively affect their AM Best rating (potentially downgraded from A- to B+, for example). By quantifying the return period of loss, the insurer can make more educated portfolio management decisions to recover storm related losses and maintain or improve their AM Best rating.

<u>Underwriting</u> – Insurers want to know what their net catastrophe loss and average annual loss are likely to be.

<u>Buying reinsurance</u> – Severe convective storms are the key peril for many insurers with regional portfolios concentrated in the Central Plains and Midwest, and, therefore, probabilistic risk assessment is a key component of their catastrophe cover purchasing process.

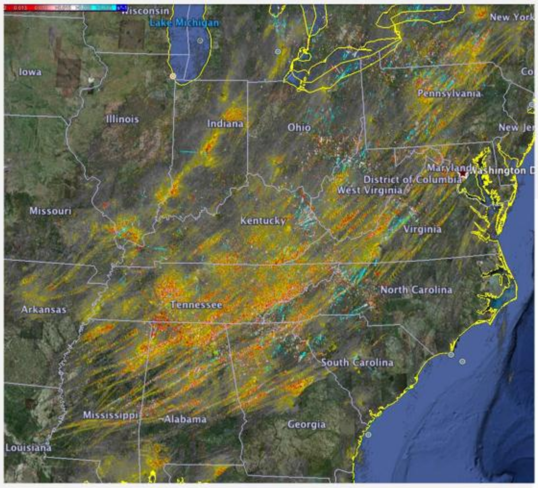
<u>Portfolio management</u> – Insurers want key return periods for different regions of the country.

<u>Rate filing</u> – A catastrophe model would be useful for demonstrating what the cost of providing coverage is, and to show how the rate is built up.

<u>Securitization / Catastrophe Bond</u> – RMS has performed securitizations for the severe convective storm peril.

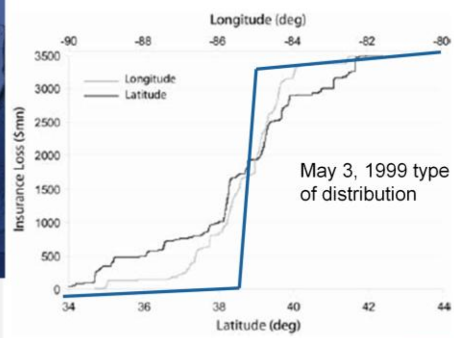
The event based approach for severe convective storm modeling can help users achieve the usages explained above.

INSIGHTS FROM PAST EVENTS – APRIL 2011 OUTBREAK EXAMPLE



Bright reds, oranges, and yellows show tracks of where rotation was strongest as detected by NWS Doppler radars during the April 27, 2011 tornado outbreak.

- In a major outbreak, losses can be distributed over a large area and therefore effect multiple concentrations within a portfolio.



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We want to reinforce a point made in Unit 3 with a different example that relates to why it is very important to develop a model that is event based despite some of these limitations. The key reason why that is critical is to capture the correlation of risk between different locations geographically.

The April 2011 outbreak demonstrates this concept. Unlike the May 3, 1999 event, where almost all the loss was driven by one tornado that hit Oklahoma City, the April 2011 outbreak had over 300 tornadoes. Although nearly 40% of the loss was dominated by a tornado with a track in excess of 80 miles in length, a majority of the event loss came from other storms.

The exhibit on the lower right illustrates this in a more technical way. This plot was produced by reconstructing the 1974 super outbreak both from the point of view of hazard and from a point of view of exposure with today's exposure distribution in the Midwest. We then modeled the loss from that event. What this is illustrating is the cumulative loss geographically within that event.

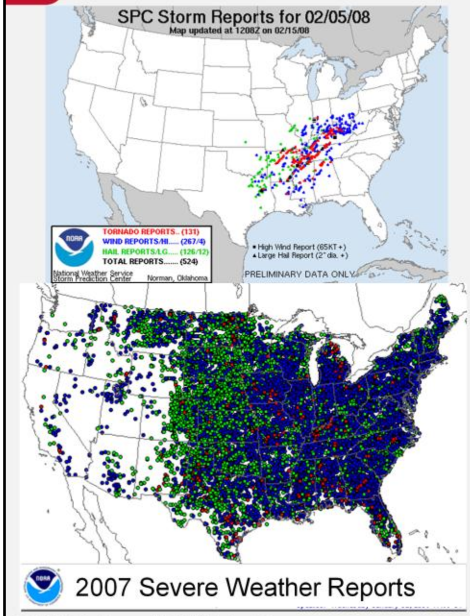
We have insurance loss on the vertical axis and latitude and longitude along the horizontal. Longitude is the light gray curve where we are looking at the accumulation of loss as one goes from west to east in these 2-degree increments, approximately 200-kilometer increments. Latitude is similar. The black curve, or the darker of the two curves, is going from south to north, again in these 2-degree or approximately 200-kilometer increments that are labeled along the axis.

This is showing that you do not see a single tornado that is a major spike accounting for almost all the insurance loss. Whether we look along a north/south segment, looking across all the tornadoes in the north/south direction, or we look at the east/west direction, there is not one tornado in this overall outbreak that is contributing most of the loss. The loss is fairly evenly distributed across this entire region.

In contrast, the blue line represents what this image would look like for the May 3, 1999 event, where one tornado dominated almost all of the insurance loss from that event.

This is one of the critical issues in developing a model in a way to simulate outbreaks appropriately, addressing the clusters of tornadoes or hailstorm occurrences that exist within that outbreak and having that event-based approach that captures and preserves the correlation of risk within those outbreaks. There are situations like this where there can be widespread effects that accumulate to the total of that loss rather than one major urban tornado.

WHAT IS AN EVENT?



- Historically, there have been multiple ways to define an event:
  - An individual tornado track, hailstorm, or straight-line wind occurrence.
  - A cluster of perils in a state or region.
  - Clusters of events over many days that may span several states.
  - PCS definition: tied to the synoptic systems
  - Events can last multiple days

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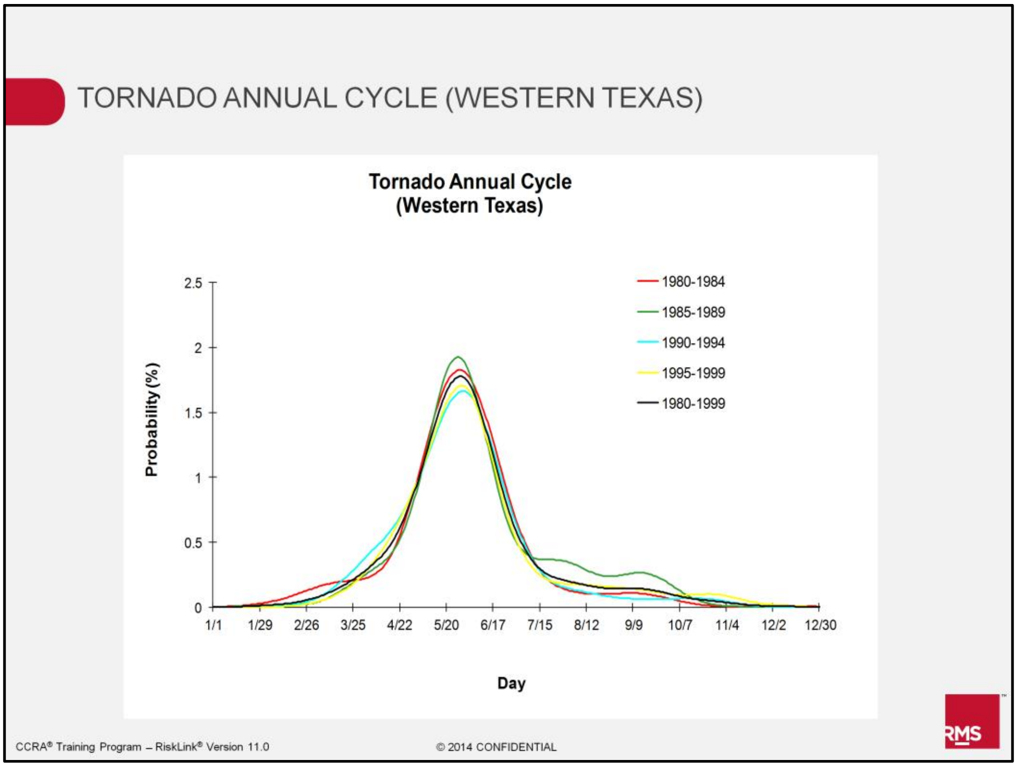
Depending on the specific application of severe convective storm modeling, an event can be defined in several ways. In the scientific community, an event can be segmented by individual thunderstorm tracks, as well as by an accumulation of these tracks over time that can be defined by a larger scale synoptic feature.

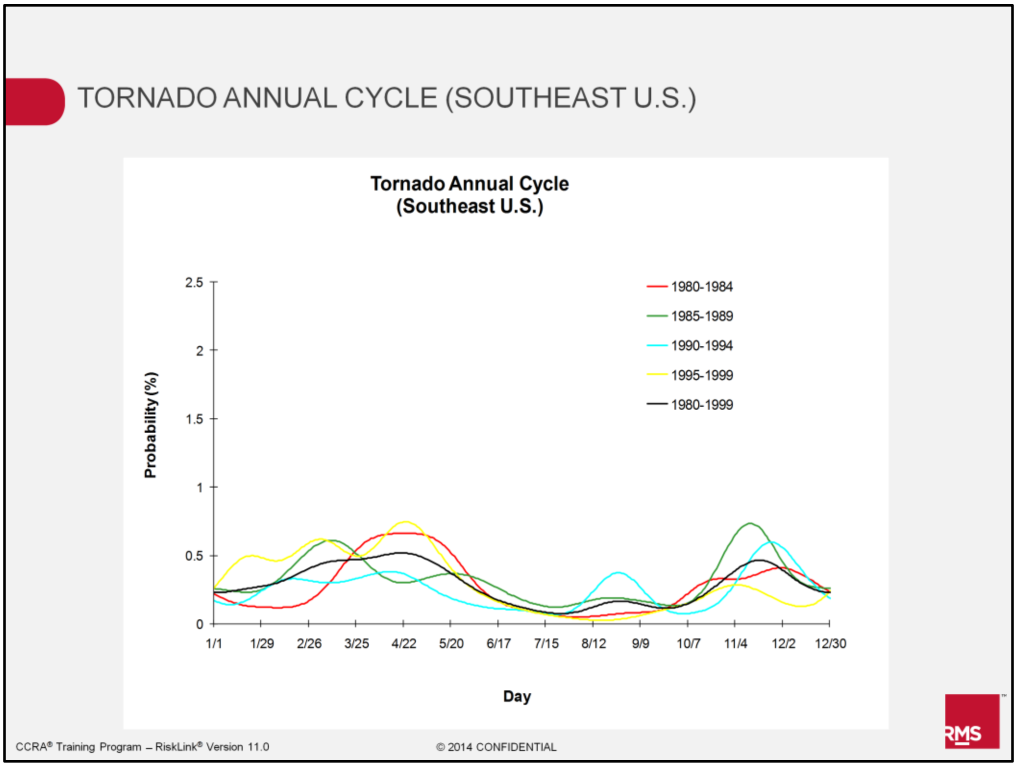
The RMS model's treatment of events considers durations of events that are consistent with the PCS and meteorological definition of an event. That is different than the way in which some other applications might view the duration of an event. Reinsurance treaties, for example, may have an hours clause that limits the amount of loss payout to a pre-defined window which can vary by reinsurer. The more standard hours clause is around 72 hours, but some may span up to a full week.



Another consideration relates to the erosion of capital or the accumulation of loss throughout a year. There are some regional differences in when that would occur within a given year. Depending on where a portfolio is located and based on the historic information, you can have a perspective or an understanding of the rate at which that loss is expected to occur and what part of the year those losses would be expected to occur.

There are two regions that are polar opposites on the end of this spectrum. One would be a region like western Texas where the severe thunderstorm and tornado season is extremely predictable, to the point where you could almost plan the week to go to west Texas if you want to see a tornado. In this exhibit, when we look at the probability of having a tornado on a given day of the year you can see a very sharp peak in the probability. The season in which severe thunderstorm losses would occur in western Texas is confined largely to May and June.

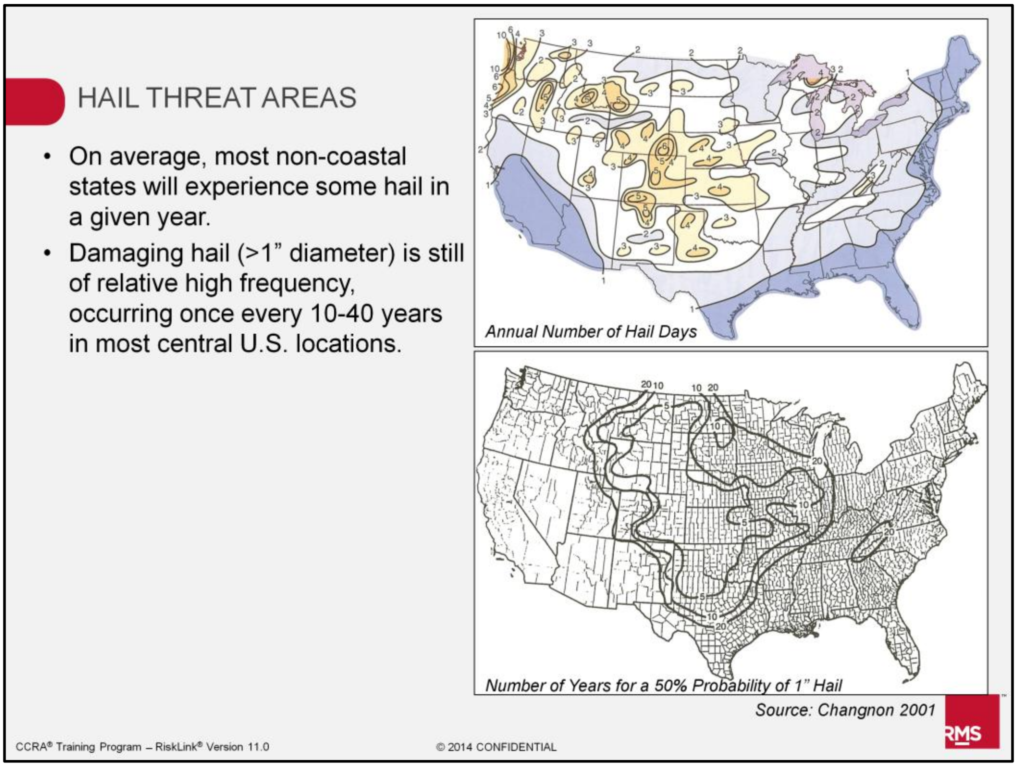
There are other regions in the country where there really is not a severe thunderstorm season. Those losses tend to be more constant throughout the year and not confined specifically to these two months in the spring.



The best example is the southeastern U.S.

This is the same type of exhibit with the same vertical scale. We are looking at probability by day throughout the year. Each of these curves represents a segment in time from the historic catalog. The probability is relatively low and relatively consistent through the entire course of the year. The only point where it is fairly predictable is between July, August, and September, when the southeast will have relatively low severe thunderstorm losses.

Outside of that, there is relatively consistent and constant loss that could be expected from severe thunderstorms in that region. Anywhere else across the country, there is variation between these two spectrums.

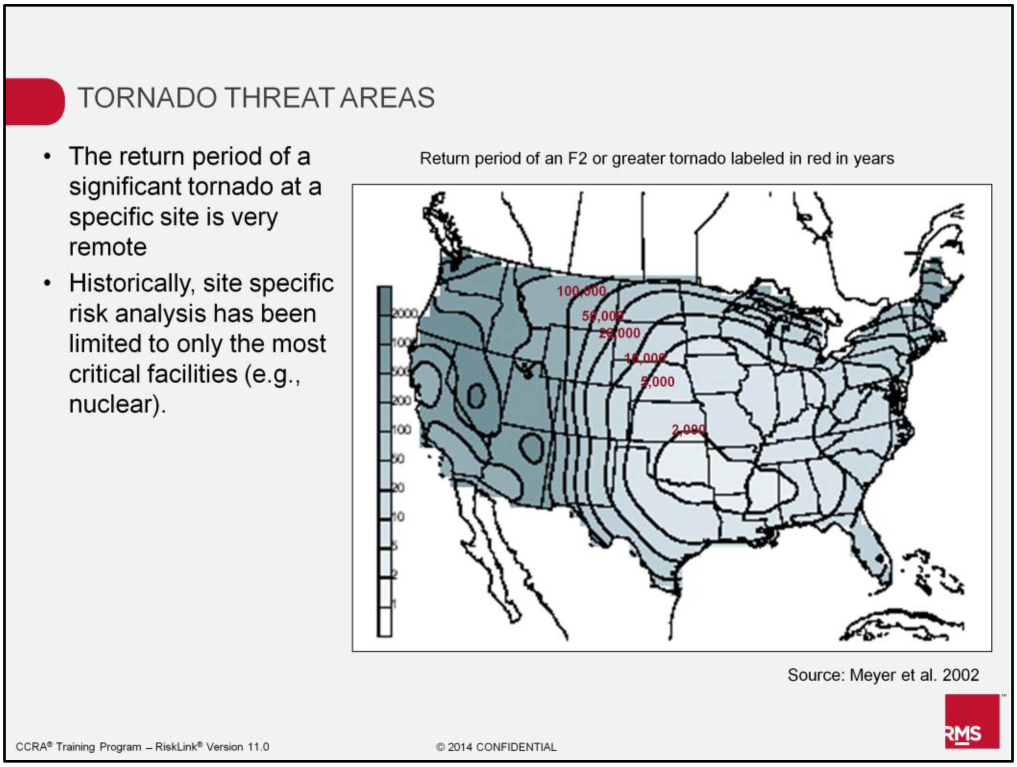


This slide was shown in Unit 1. Look at this now with a slightly different lens, focusing on the bottom-right exhibit and looking at the gradient in the probability of hail occurring at that location.

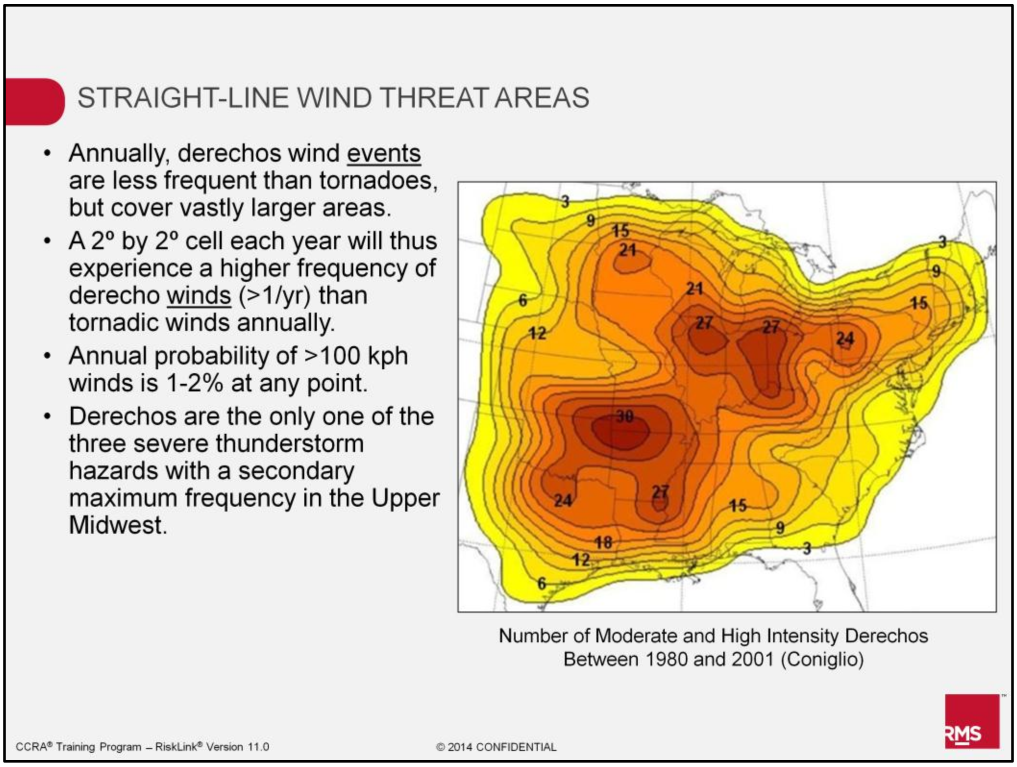
When we look at a place like Kansas, the probability of hail of one inch or greater occurring in that state is fairly uniform. There is some variation, but it is fairly uniform. If we were to try and establish a probability for two inch or greater hail, which would be less certain, you might see somewhat higher variability. In general, the variation is fairly small. It is much less than what we might see if we were looking at the variation in wind risk in Florida from a hurricane.

So the rating territories that one would define for severe thunderstorms tend to be very large relative to what a rating territory might be for an earthquake or hurricane peril. In some cases it may be one-third to two-thirds of the state, if not even larger, depending on how much an individual insurer wants to differentiate that.

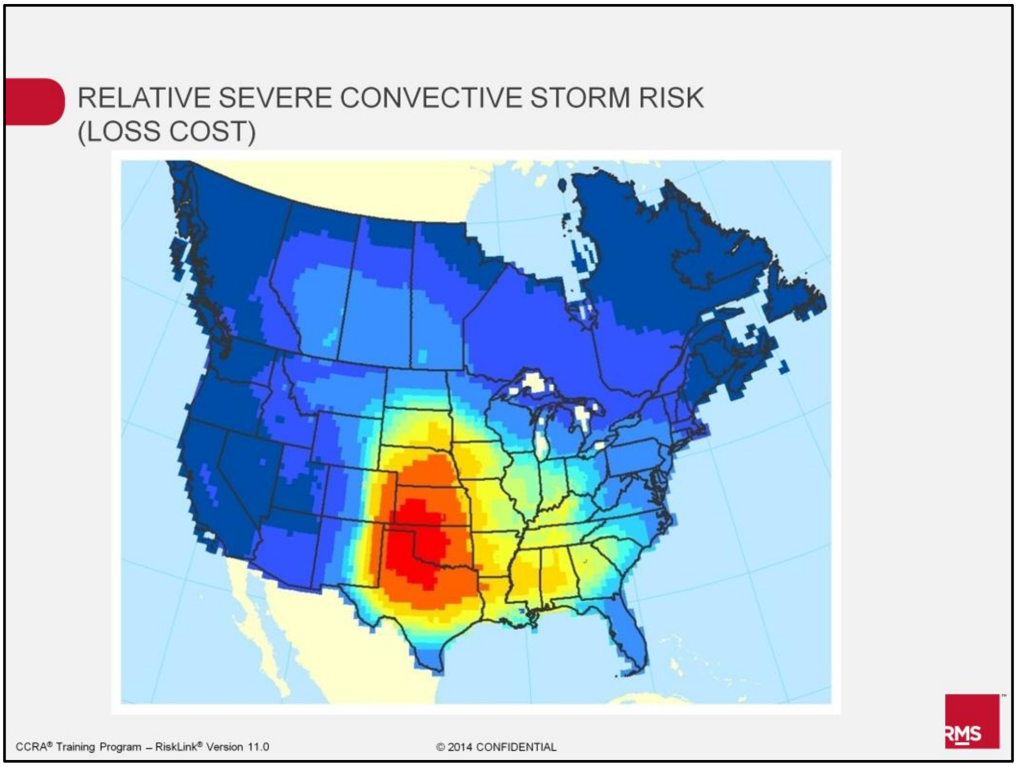
Again, hail is the predominant source of annualized loss, so hail is going to be the predominant contributor to the loss caused from severe thunderstorms.



But there would also be a component from tornadoes and from straight-line winds. This is another exhibit from Unit 1 to again illustrate that even when we look at the tornado risk or the straight-line wind risk, the gradient and the frequency of these hazards still tend to be fairly smooth.



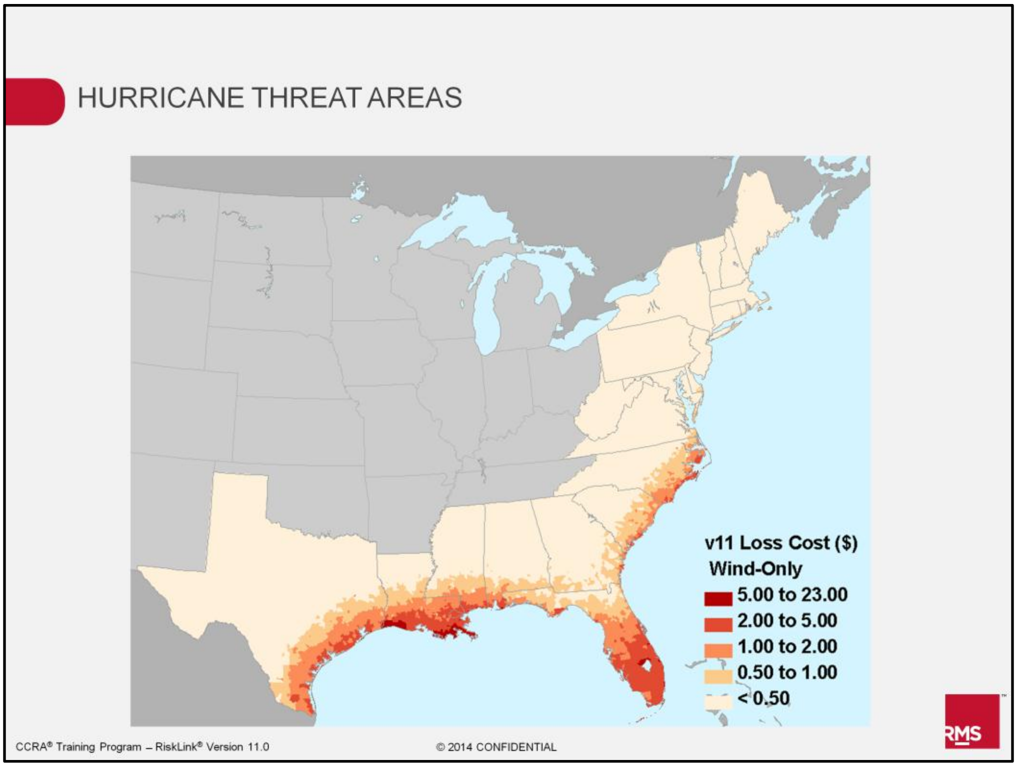
Derechos are less frequent wind events than tornadoes, but cover vastly larger areas, with more than one on average affecting a two by two degree cell each year. We are looking at rating territories in the inland areas of the U.S. that will be fairly large relative to what we might see in a coastal zone.



When we roll up each of these pieces to develop a loss cost map for the U.S. using the severe convective storm model in RiskLink, this is the output that we would get.

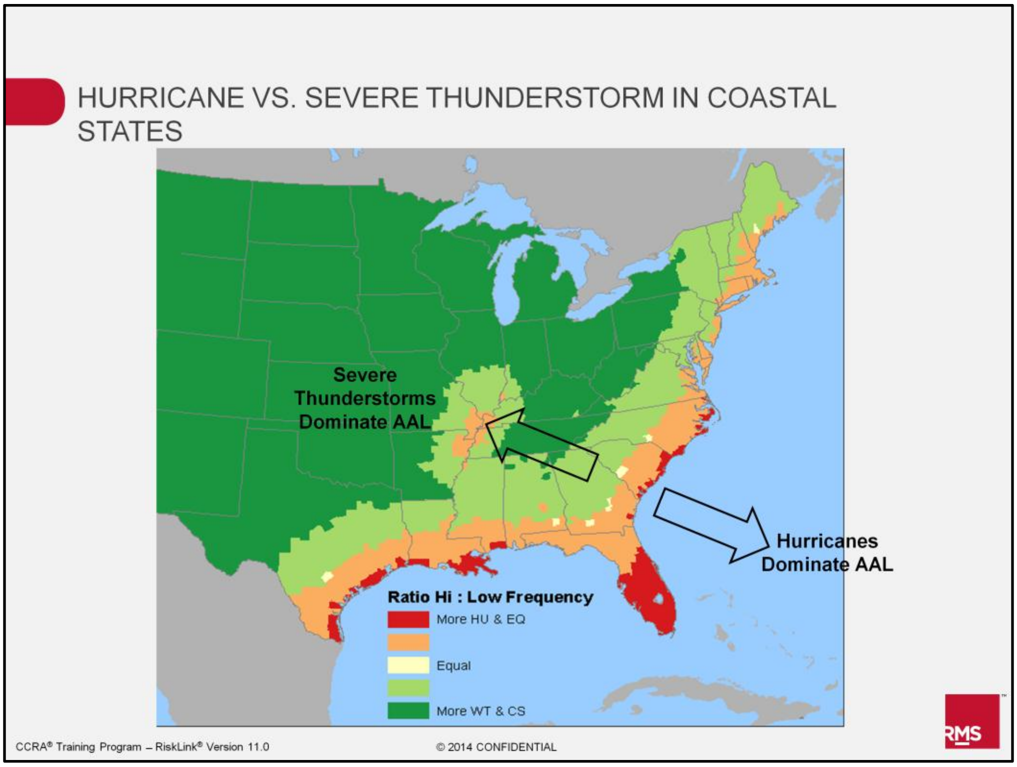
You can see again that the gradients are very smooth, where territories might have sharp definition or sharp gradient would be where there is a drastic change in elevation, like the western U.S. versus the plains states or the Appalachian Mountains.

This is purely looking at severe convective storm risk, but when trying to establish a rate, again, there are multiple perils that need be considered in developing that rate. We will focus on the coastal states to give a sense of contrasting this loss cost that you see from the severe convective storm model and a loss cost you would get from the hurricane model.



This is a view of the average annual loss by ZIP Code for the 21 coastal hurricane states in the Gulf and the Atlantic, as well as Washington D C. When you look at this, focus in on some of the states where the hurricane risk, or loss cost, tends to be relatively low. Georgia is a very good example. Virginia is a great example as well. States that are predominantly inland, have very little coastline, or have low hurricane frequency in that location, such as the Georgia coastline, have fairly low hurricane loss cost.

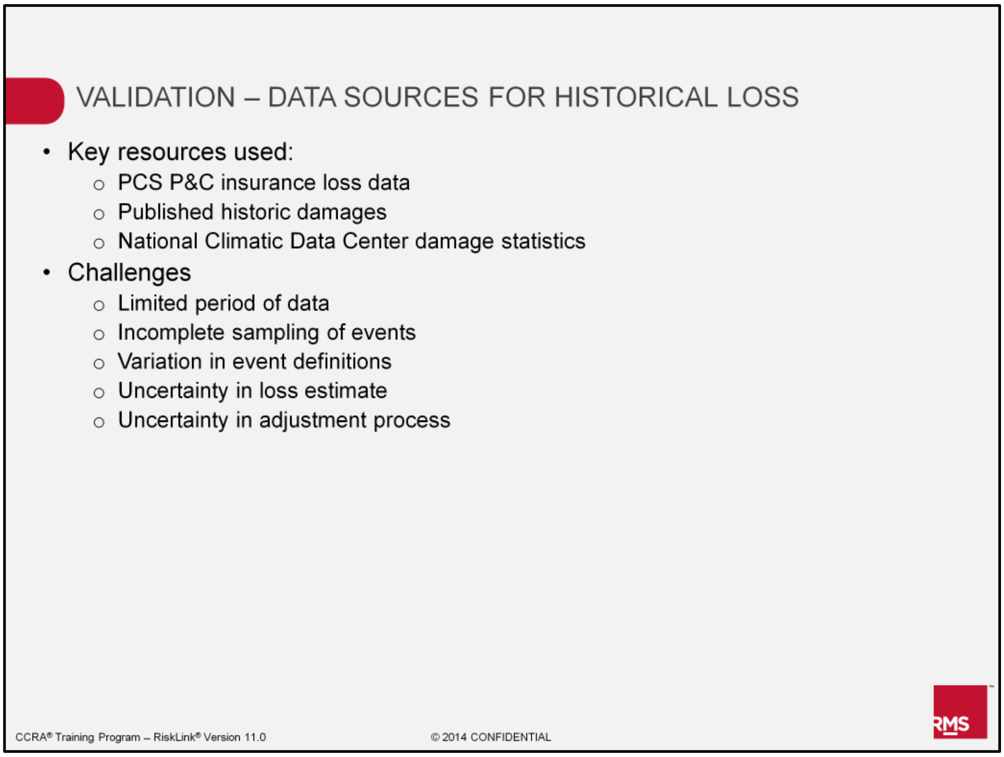
When you look at this map imagine where you would expect to see the transition point or the breaking point between a loss cost that would be hurricane dominant and one that would be dominated by severe thunderstorm risk.



This exhibit illustrates from the RMS model where that breaking point actually occurs. We are looking at the ratio of the hurricane average loss to the tornado, hail, or severe thunderstorm average annual loss based on the RMS hurricane and severe convective storm models.

That breaking point in the shades of green is where severe thunderstorm risk tends to dominate the average annual loss relative to hurricane. In some cases, this is a fairly surprising exhibit, where the average annual loss for severe thunderstorms tends to be dominant in some of the inland parts of coastal states that are largely considered to have hurricane risk. The reason for that is that the hurricane risk does have a very sharp gradient with the coastline. So as we get near the coast, the ratio is perhaps 25 times the hurricane risk to the severe thunderstorm risk right along the coastline. But that average annual loss tends to decay fairly rapidly as one goes inland, to a point that severe thunderstorm risk does dominate the loss cost in those states once you get several coastal tiers or several tiers of counties inland.

When developing a loss cost in these states, particularly for an area like inland Virginia, a severe thunderstorm risk assessment will be a significant part of that process and hurricane may become a secondary component in those inland parts of these states.



Next we will talk about how severe thunderstorm models are calibrated based on historic loss information to ensure that the model is producing losses that are appropriate and reasonable. Also, that all of the decisions and interpretations of historic data that happen in the development of that model prove to be realistic and make sense against appropriate benchmarks.

The data sources that are used for this validation process are predominantly the Property Claims Services (PCS), a property and casualty insurance loss database that goes back to about 1950, with the most reliable periods of that information from the 1970s to the present.

There are also published historic damages that go even further back in time than 1950 which are leveraged, where possible, in the validation process. These are damage statistics from the National Climactic Data Center, which is part of NOAA, that archive information that is either gathered by the National Weather Service or the other branches of NOAA. And each of these data sources are used and interpreted to try to piece together an historic catalog of insurance loss that can then be normalized and assigned to a single view of exposure to compare against a model.

The challenges with this are that the period of data is fairly limited. In some cases, like the Property Claims Services database, the sampling of events is incomplete. It focuses only on catastrophes, so not every source of loss is included. Benchmarking against aggregate sources of loss is more difficult using that resource.

There is variation in the definition of an event between PCS and how it would be treated in a catastrophe model. So that also has to be considered when looking at benchmarks. And there is inherent uncertainty in the loss estimate and how it is adjusted or normalized to get a consistent set of exposures across all of the years.

RMS APPLICATION OF PCS HISTORICAL LOSS DATABASE

- State level loss estimates by cat code with constituent perils listed:
    - Tornadoes, hail, wind, and others
- Filtered database to exclude events where dominant source of loss was from perils other than wind/hail
- RMS loss adjustment process includes factors for:
    - Population growth (state level)
    - Annual inflation
    - Growth in gross domestic product
    - Market penetration

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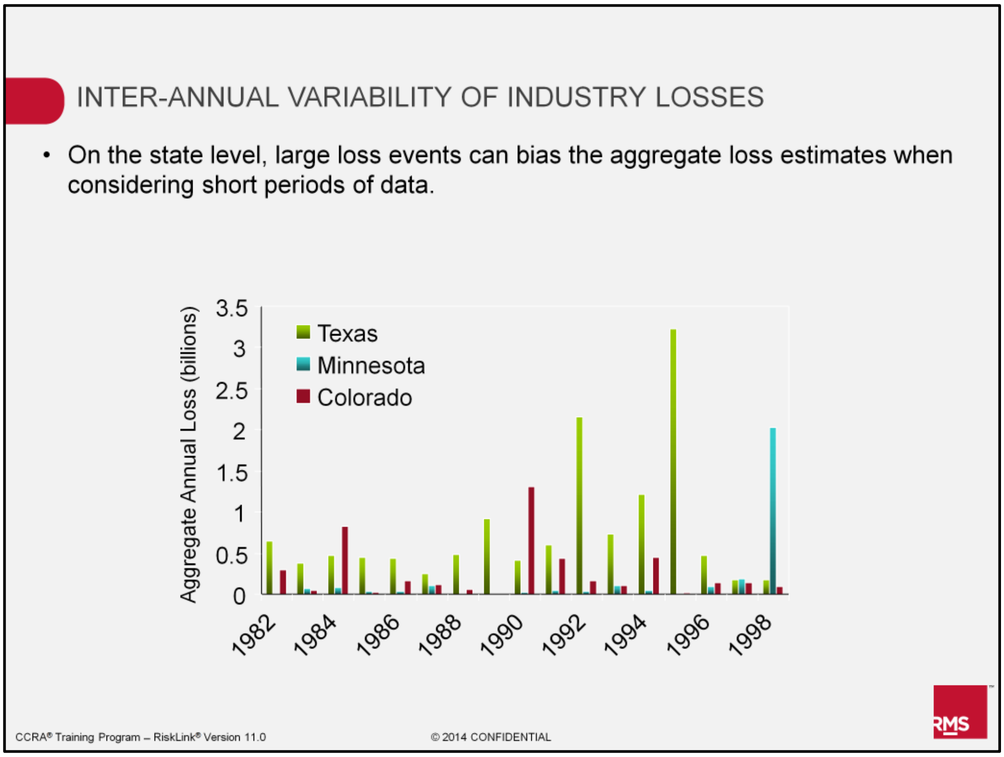
With all of those challenges noted and addressed, in advance of doing a calibration we focus on looking at state-level estimates of loss where there is a coded peril of tornado, hail, or wind in the historic loss database. By going through that process, we filter out or exclude events where the dominant source of loss is from a peril other than wind or hail. For example, a hurricane clearly would be excluded from this calibration process, as well as the winter storms or the Pacific Northwest wind storms that we noted earlier. Events that do include straight-line winds and are dominant would be included in this process of loss calibration.

We would then go through that historic catalog and make adjustments to those losses using statistical or actuarial techniques to normalize those values to a consistent set of today's exposure. This enables us to benchmark any analysis results we get from our own industry view of exposure from our model against this external resource.

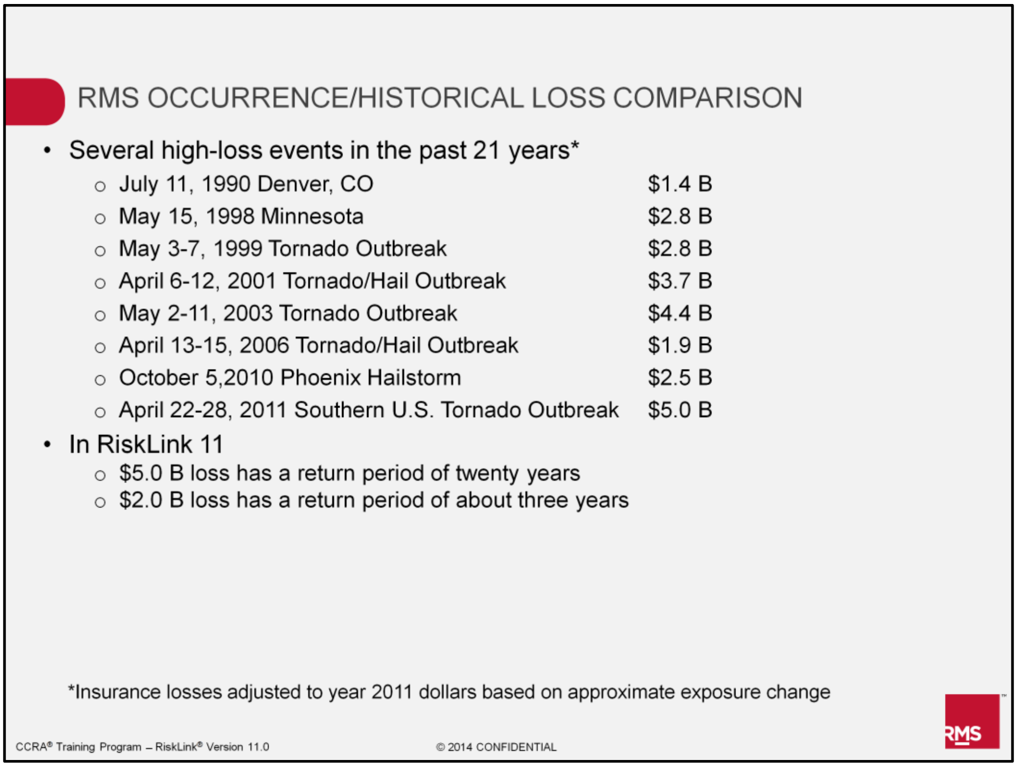


There are some special considerations that need to be made when looking at this on a state level.

In Minnesota, when benchmarking a model result against historic losses, we need to be very in tune to the frequency of severe thunderstorms and the losses that have occurred recently to make sure there is not a bias in interpretation of the targets or the historic losses when we make those comparisons against the model.

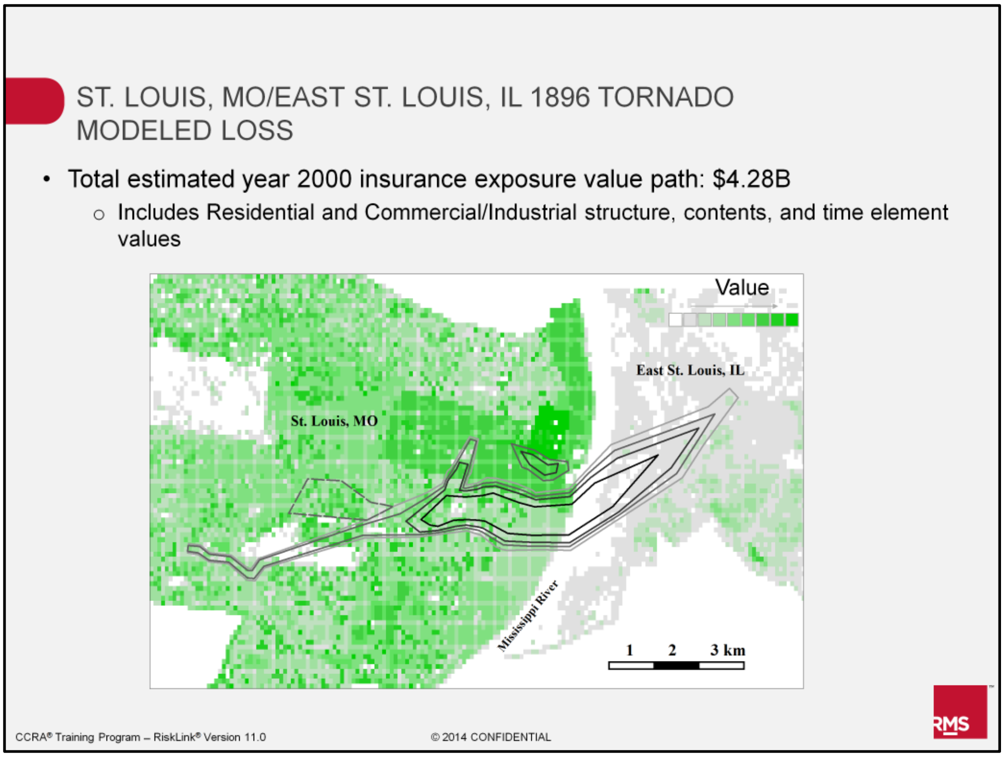
Notice the blue bar for Minnesota in 1998. There was a major hail event that affected the Minneapolis area on the 15th of May 1998. At the end of that same month the derecho we showed as the case example in Unit 1 also affected parts of Minneapolis and the areas to its east. So there were two major catastrophes in the same year. And the two of those accounted for a loss level that was close to a hundred-year return period for that state. Prior to that, loss levels in the state of Minnesota had been very low.

So when we are looking at benchmarking a model against historic loss data, whether it be industry data or from the point of view of an individual company, we need to look at as long a range of years as possible if we are looking at states where the frequency is lower and there has been a major catastrophe in recent years. We might need to look at a regional level or even a national level, to make sure a bias is not introduced by that one catastrophe.



This is a look at the major severe thunderstorm related events that have happened in the last 21 years. There were several major events between 1990 and 2011, each of which exceeded a billion dollars and six of which exceeded $2 billion. In RiskLink 11.0, the loss level for a three-year return period for the U.S. industry of all lines of business would be around $2.0 billion. As we have six events that exceed that level in the last 21 years, the model seems to predict frequency of events as well.

When we look at a $5.0 billion threshold, which in the RMS model has a return period of about twenty years, we have seen one of those in the last 20 years. This is not the most rigorous test, but it gives you some relationship between the historic losses and our model to provide some context around the types of results that our model produces.



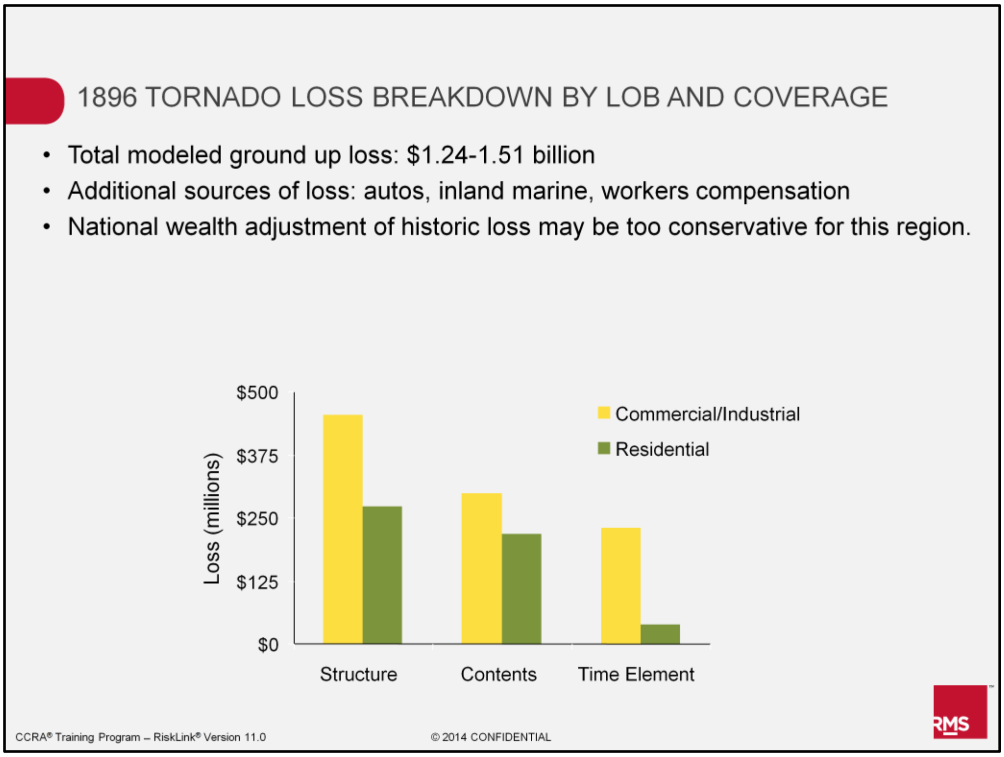
We also look at earlier parts of the historic catalog to try and extend data that we benchmark against in history.

One example we looked at for this purpose is a tornado that hit St. Louis in 1896. This was a key focal point for RMS because this tornado event is the largest single-loss tornado in the 125-year history for which there are reliable records, based on adjusting past tornado losses for changes in wealth over time.

One of the key objectives of this process is to validate the approach of using national wealth statistics to adjust up historic tornado losses to see if that is a reasonable approach that we could use for model loss validation.

The process that we used was first to analyze the historic event to define the hazard, which is outlined in the different shades of gray and black representing the bounding area of the tornado, and then to assess that hazard relative to the exposure that it would pass over today. In other words, using today's exposure information to determine what the loss would be today, and compare that against a wealth adjustment to a historic loss to see how close those two have become and whether or not that is an appropriate way to benchmark or to look at historic loss data. When we do that, the exposure within this tornado path is about $4.28 billion.

The Mississippi River, shown in white, separates St. Louis, Missouri and East St. Louis, Illinois. Notice there is a very strong break in the amount of exposure value between these two locations. This is due to the depreciation of exposure values over time in East St. Louis.

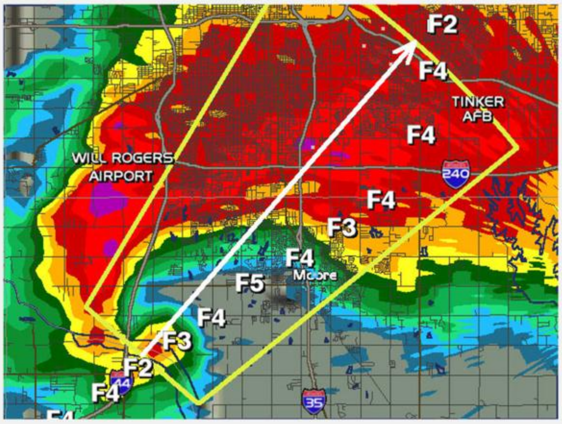


When we estimate the total modeled loss based on the most current exposure data (with a little over $4 billion of exposure in that region based on that severity of the tornado), the loss is about $1.25 to $1.5 billion. When we use simple economic adjustments, like wealth adjustments, to try and estimate the loss from this event, we get a figure between $2 billion and $3 billion.

This indicated to us that when we go further and further back in time to losses from very early events and try to adjust those up using economic factors like wealth, much uncertainty in the historic loss estimate is introduced. It is very challenging for us to use data that old for loss calibration. So we do not go back that far in a catalog when trying to calibrate our model, rather we use this event to try and put some bounds around what types of loss would be observed in a major historic event, because that wealth adjustment proved not to be sufficient. It did not capture the depreciation of values in East St. Louis.

Also for this event there was a relative amount of loss for different lines of business. This underscores the fact that a major urban tornado like this can cause commercial and industrial losses that can very easily supersede what you would see for the residential line. If a hail dominant event of the same level affected this area, this would be reversed.

THE "BIG ONES": METRO TORNADO DISASTERS – OKLAHOMA CITY 1999 REVISITED



- On May 3, 1999, a tornado struck the Oklahoma City area causing $1.5 B loss (2009 dollars).
- If the event were to occur today we estimate $2.3 B loss.
- What if this occurred today in Dallas or Chicago?

City	Tornado Insured Loss (in billions)	Direct Exposure (in billions)	Mean Damage Ratio
Oklahoma City	$2.3	$26.8	8.6%
Dallas	$17.5	$189.5	9.3%
Chicago	$25.2	$342.8	7.4%

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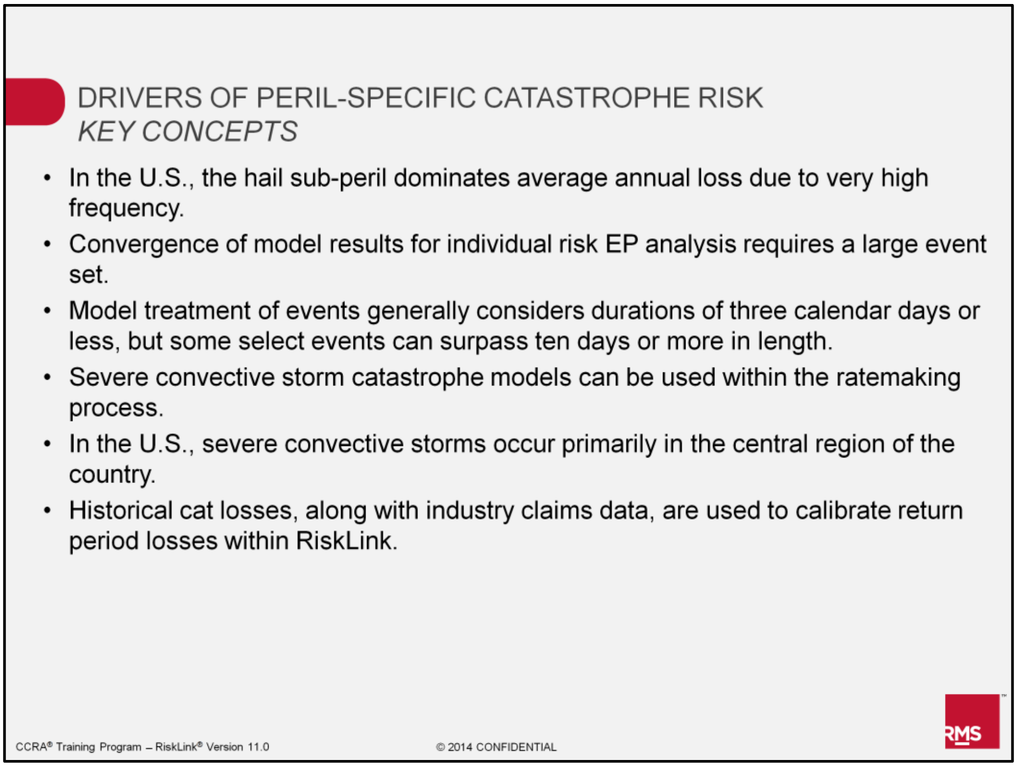
Another approach we have used is to reconstruct and model past events, such as metro area tornados. This helps to put some boundaries around historic losses and understand the peak magnitude of loss that can be expected from severe thunderstorms. If the May 3, 1999 Oklahoma City tornado event were to reoccur today in Oklahoma City, we could expect losses to total an estimated $2.3 billion. If this event were to affect another major urban area more directly, the loss from this event could increase substantially, as seen in the Dallas and Chicago estimates on this slide.



This slide summarizes the key points from Unit 4. If any of these points are unclear, please revisit the associated slides within the unit.