Severe Convective Storm Risk

• Risk dependent on:
  – Frequency and severity of hazard
  – Location relative to hazard
  – Structural vulnerability
  – Portfolio structure and conditions
US Severe Convective Storms
Tornado Statistics

Doppler radar era

Number of Occurrences per Year
US Convective Storms
Hail Statistics

- **Observed max hail size**
  - <1 inch
  - 1-2 inches
  - 2-3 inches
  - 3-4 inches
  - 4-5 inches
  - >5 inches

**Bar Chart**
- **Number of Days**
- **Year**
  - 1990 - 2014

**Pie Chart**
- **Month**
  - Jun: 20%
  - Jul: 16%
  - Aug: 12%
  - Sep: 6%
  - Oct: 3%
  - Nov-Jan: 3%
  - Feb: 2%
  - Mar: 6%
  - Apr: 13%
  - May: 19%

**Pie Chart Details**
- **Mar**: 6%
- **May**: 19%
- **Jun**: 20%
- **Jul**: 16%
- **Aug**: 12%
- **Sep**: 6%
- **Oct**: 3%
- **Nov-Jan**: 3%
- **Feb**: 2%

- **Total Hail Events**: 236
US Annual Insured Losses

$0.5B increase per year on average
US Average Annual Insured Loss by State
1990-2015

![Map showing US Average Annual Insured Loss by State from 1990-2015. The map uses color coding to represent millions of 2015 USD losses. States with higher losses are shaded in darker colors, indicating higher economic impact due to tornadoes.](image-url)
Tornadoes and Hail
Worldwide Statistics

Source: Swiss Re CatNet®.
# Worldwide Insured Losses

## 2014 Swiss Re Sigma Catastrophes

The 20 most costly insurance losses in 2014

<table>
<thead>
<tr>
<th>Insured loss (in USD m)</th>
<th>Victims</th>
<th>Date (start)</th>
<th>Event</th>
<th>Country</th>
</tr>
</thead>
<tbody>
<tr>
<td>2935</td>
<td>-</td>
<td>18.05.2014</td>
<td>Severe thunderstorms, large hail</td>
<td>US</td>
</tr>
<tr>
<td>2502</td>
<td>26</td>
<td>08.02.2014</td>
<td>Snow storm</td>
<td>Japan</td>
</tr>
<tr>
<td>2190</td>
<td>6</td>
<td>08.06.2014</td>
<td>Wind and hail storm Ela</td>
<td>France, Germany, Belgium</td>
</tr>
<tr>
<td>1700</td>
<td>6</td>
<td>14.09.2014</td>
<td>Hurricane Odile</td>
<td>Mexico</td>
</tr>
<tr>
<td>1669</td>
<td>21</td>
<td>05.01.2014</td>
<td>Winter storm</td>
<td>US</td>
</tr>
<tr>
<td>1269</td>
<td>2</td>
<td>03.06.2014</td>
<td>Severe thunderstorms, large hail, tornadoes</td>
<td>US</td>
</tr>
<tr>
<td>1220</td>
<td>33</td>
<td>27.04.2014</td>
<td>Thunderstorms, large hail, 83 tornadoes, severe flash floods</td>
<td>US</td>
</tr>
<tr>
<td>1084</td>
<td>-</td>
<td>02.04.2014</td>
<td>Severe storms, large hail, tornadoes</td>
<td>US</td>
</tr>
<tr>
<td>ns</td>
<td>7</td>
<td>15.06.2014</td>
<td>Major fire and explosion at oil refinery</td>
<td>Russia</td>
</tr>
<tr>
<td>905</td>
<td>-</td>
<td>27.09.2014</td>
<td>Thunderstorms with winds up to 108 km/67 miles per hour, hail, flash floods</td>
<td>US</td>
</tr>
<tr>
<td>852</td>
<td>-</td>
<td>30.11.2014</td>
<td>Hailstorm</td>
<td>Australia</td>
</tr>
<tr>
<td>678</td>
<td>-</td>
<td>12.04.2014</td>
<td>Thunderstorms, large hail, tornadoes</td>
<td>US</td>
</tr>
<tr>
<td>ns</td>
<td>-</td>
<td>07.07.2014</td>
<td>Fire at petrochemical plant</td>
<td>US</td>
</tr>
<tr>
<td>635</td>
<td>-</td>
<td>10.05.2014</td>
<td>Thunderstorms, hail, tornadoes, flash floods</td>
<td>US</td>
</tr>
<tr>
<td>632</td>
<td>68</td>
<td>12.10.2014</td>
<td>Cyclone Hudhud</td>
<td>India</td>
</tr>
<tr>
<td>592</td>
<td>-</td>
<td>27.03.2014</td>
<td>Thunderstorms, winds up to 129 km/80 miles per hour, large hail, tornadoes</td>
<td>US</td>
</tr>
<tr>
<td>545</td>
<td>3</td>
<td>14.06.2014</td>
<td>Thunderstorms, &gt;100 tornadoes, hail</td>
<td>US</td>
</tr>
<tr>
<td>539</td>
<td>2</td>
<td>11.08.2014</td>
<td>Torrential rains trigger severe floods</td>
<td>US</td>
</tr>
<tr>
<td>ns*</td>
<td>47</td>
<td>13.07.2014</td>
<td>Fighting at airport destroys aircrafts</td>
<td>Libyan Arab Jamahiriya</td>
</tr>
<tr>
<td>530</td>
<td>-</td>
<td>01.01.2014</td>
<td>Floods</td>
<td>UK</td>
</tr>
</tbody>
</table>

*Not shown.

Severe Convective Storm Risk Modeling
Why is it so difficult?
Basic Cat Modeling Methodology
The four box model approach

Hazard
- Where, how often and how strong?

Exposure
- Where, what and characteristics?

Vulnerability
- What damage degree?

Economics
- Property value
- Contents
- Coverage type
- Expected loss
- What is covered?
Hazard Considerations

• Likelihood of tornado hitting any one point is extremely remote due to localized nature

• Hail swath and tornado path characteristics

• Hail and tornado historical records contain many biases
Exposure Considerations
Damage relative to location and time

- Spatial correlation of damage
- Large wind speed gradient from outer to inner circulation
- Building orientation
Example: Joplin Tornado

Source: US Army Corps of Engineers
Hypothetical Scenario

- 250m wide tornado
- EF2 — winds to 135 mph (60 m/s)
- Moving from WSW to ENE
- Debris impact would be low-moderate
• The most vulnerable areas for this site:
  – upwind-facing windows coinciding with peak pressures on roof
  – lee-side overhead doors

• If envelope compromised then:
  – uplift on roof from inside and out
  – significant content damage
  – greater likelihood of total loss
Exposure Considerations

Building Contents

Exposure Considerations

Business Interruption

Emergency Generator

Building

- 2 substations, 4,000 distribution poles and transmission towers, 1,500 transformers, and 110 miles of transmission/distribution lines
- 50 cell towers downed or destroyed
- 4,000 leaking water lines, 25 broken fire-service lines
- 3,500 gas meters and 55,000ft of gas main damaged

"Ten days after... restored power to all customers who were able to receive service."

Source: NIST (2014)

Source: NOAA
Vulnerability Considerations
Tornadoes vs Straight-line Winds

- Building codes and standards do not include loads from tornado winds
- Stationary vs non-stationary
- Strength of wall-to-roof and wall-to-floor connections

Source: Orwig PhD Dissertation, Examining Strong Winds from a Time-Varying Perspective

Source: NIST report on Joplin tornado
Structural Performance in Tornado Winds
Tilt-Up Panel Walls

• Not only vulnerable in EQ

• FEMA observations:
  – Catastrophic collapse in several locations
  – Some failures from overload on long span roof system
  – Most failures occurred at wall-to-roof connections

Source: FEMA (2012)
Structural Performance in Tornado Winds
Tilt-Up Panel Walls

• Tilt-Up Concrete Association (TCA) task force report after Joplin
  - Initial failures occurred in steel joist roof system
  - Panels themselves were very robust (were generally intact despite collapse)
  - "Tilt-Up construction played no role in the failure."
  - Recommendations:
    o Develop procedure for more predictable collapse performance
    o Establish roof system design criteria "that has ultimate failure capacities...similar to over-strength requirements for certain elements in the seismic design..."
    o Send recommendations to ICC, FEMA, Steel Deck Institute, Steel Joist Institute, and others to develop standard codes, procedures, and products

Severe Convective Storm Modeling
Challenges and Obstacles

• Highly localized, short-lived phenomena

• Large model domain coupled with high frequency makes probabilistic modeling computationally intensive
  – Most of southern Canadian provinces and entire eastern 2/3 of the United States is vulnerable to severe thunderstorms
  – Millions of years of simulation required for single location convergence

• Hail data are based on subjective reports (e.g. pea-, penny-, baseball-sized), and are mostly along roadways

• Tornado wind measurements are scarce, damage serves as a proxy for wind speed
  – Rating based on maximum damage observed, which is often a small fraction of total path area
  – Under-classification common in rural areas
  – Original intensity scale was the Fujita scale, Enhanced Fujita scale adopted in 2007 in US and 2013 in Canada
Tornado/Hail Risk
Reinsurer’s Perspective

• Treaty perspective
  – Tropical Cyclones are major driver of loss in United States for national accounts
  – Tornado/Hail exposure drives losses for regional accounts
  – Only large outbreaks or severe urban tornadoes penetrate cat treaties
  – Cedent loss experience common

• Single risk perspective
  – Damage paths of severe thunderstorms are very localized
  – Probability of direct strike by tornado VERY low
  – Direct hit by single tornado can result in a large loss, regardless of industry impact
  – Highly correlated losses over small areas
  – Cedent loss experience is scarce

RISK PERSPECTIVE MATTERS!
Modelling results

- What results to the models produce
- How do we interpret them
- Art over Science?
Sample company 1

- Subject income: US$ 125m +
- State exposure: Gulf
- Line of Business: 100% Homeowner
## What results do the models produce?

What does a Tornado Hail Exceedance Probability curve actually look like

<table>
<thead>
<tr>
<th>Timeframe</th>
<th>Model 1</th>
<th>Model 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>250 yrs</td>
<td>29,434,411</td>
<td>139,136,506</td>
</tr>
<tr>
<td>100 yrs</td>
<td>21,511,483</td>
<td>92,203,743</td>
</tr>
<tr>
<td>50 yrs</td>
<td>16,430,800</td>
<td>76,290,532</td>
</tr>
<tr>
<td>25 yrs</td>
<td>12,886,620</td>
<td>66,236,499</td>
</tr>
<tr>
<td>10 yrs</td>
<td>9,316,345</td>
<td>28,162,146</td>
</tr>
<tr>
<td>5 yrs</td>
<td>6,950,018</td>
<td>17,591,706</td>
</tr>
<tr>
<td>AAL</td>
<td>16,538,553</td>
<td>30,175,009</td>
</tr>
</tbody>
</table>

- **Actual Tornado Hail Loss experience**
  - 2015: 18.04m, 5.47m, 3.24m
  - 2014: 16.01m, 10.16m, 8.49m
  - 2013: 16.87m, 10.01m, 9.15m
  - 2012: 20.28m, 5.35m, 2.36m
  - 2011: 13.80m, 3.45m, 2.55m
  - 2010: 3.64m, 2.59m, 1.67m
  - 2009: 10.80m, 6.82m, 4.33m
  - 2008: 6.012m, 4.24m, 2.44m
Observations

• Model 1
  • looks very light throughout curve
  • 10 yr return period is just 9.31m yet company has incurred 9 events exceeding that number in past 8 years

• Model 2
  • looks appropriate up to the 10 year period - 10 yr return period is 28.16m and largest loss in period is 20.28m
  • How credible is curve excess of 10 years?? – the 25 year return number infers a very steep increase in expected loss at $66.23m
  • Much higher losses reflected at higher return periods
Possible actions

• Blend the models?
• Might make the upper return period numbers reflect a reasonable number
  • 250 year return period number would be $84.50m
  • However - 10 year RP number would be just $18.5m – still looks light

• Ignore model 2 and load model 1 by how much?

  • Load the whole curve by 250% ?
  • 10 year return period loss is $23.29m
  • 250 year return period number $73.58m
Conclusion

• Loading the whole curve produced by model 1 by a factor of 250% gives us a viewpoint which seems to match our knowledge of the company and their recent experience.

• Company purchases 160m of vertical protection
  – close to a 250 return period event for Hurricane
  – excess of a 250 return period (no matter what model) event for TH
Sample company 2

- Subject income: US$ 275 m +
- State exposure: Upper Mid West
- Line of Business: 85% Homeowner
  10% Commercial,
  5% Auto
What results do the models produce?

What does a Tornado Hail Exceedance Probability curve actually look like

<table>
<thead>
<tr>
<th></th>
<th>Model 1</th>
<th>Model 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>250 yrs</td>
<td>94,685,085</td>
<td>140,074,397</td>
</tr>
<tr>
<td>100 yrs</td>
<td>66,192,960</td>
<td>105,011,783</td>
</tr>
<tr>
<td>50 yrs</td>
<td>48,131,517</td>
<td>72,191,260</td>
</tr>
<tr>
<td>25 yrs</td>
<td>33,179,415</td>
<td>55,470,609</td>
</tr>
<tr>
<td>10 yrs</td>
<td>20,711,948</td>
<td>38,049,550</td>
</tr>
<tr>
<td>5 yrs</td>
<td>14,322,457</td>
<td>28,295,282</td>
</tr>
<tr>
<td>AAL</td>
<td>20,572,365</td>
<td>26,165,192</td>
</tr>
</tbody>
</table>

- Actual Tornado Hail Loss experience
  - 2015  12.35m, 8.84m, 8.06m
  - 2014  24.96m, 17.99m, 9.22m
  - 2013  10.74m, 6.61m, 4.95m
  - 2012  8.71m, 4.41m
  - 2011  10.00m, 4.12m
  - 2010  18.65m, 6.51m,
  - 2009  nil
  - 2008  11.34m, 8.29m,
Observations

• Model 1
  • Once again lighter through curve
  • closer to experience -10 yr return period is 20.70m with only one loss greater than in within the period.

• Model 2
  • Appears penal when compared to experience - 10 yr return period is 38.04m and largest loss in period is 24.98m
  • Once again the curve accelerates steeply - the 25 year return number infers an RP loss of 55.45m
## Possible actions

- Load a model or blend them?
- Blending 50/50 might make sense – or you may wish to load model 1 by 50%

<table>
<thead>
<tr>
<th></th>
<th>50/50</th>
<th>Model 1 * 50%</th>
</tr>
</thead>
<tbody>
<tr>
<td>250</td>
<td>117.37 m</td>
<td>142.02 m</td>
</tr>
<tr>
<td>100</td>
<td>85.50 m</td>
<td>99.28 m</td>
</tr>
<tr>
<td>50</td>
<td>60.15 m</td>
<td>72.19 m</td>
</tr>
<tr>
<td>25</td>
<td>44.32 m</td>
<td>49.75 m</td>
</tr>
<tr>
<td>10</td>
<td>29.38 m</td>
<td>31.06 m</td>
</tr>
<tr>
<td>5</td>
<td>21.30 m</td>
<td>21.49 m</td>
</tr>
</tbody>
</table>
Conclusion

• Either approach produces a return period result up to 10 years which makes sense but blending does provide some relief to the higher return period loss estimates.

• Company purchases 135m of vertical protection
  – just in excess of a 250 return period event for TH on a blended approach
  – Just within the 250 return period for TH on a loaded approach

In this instance a blended approach may be considered appropriate
Sample company 3

- Subject income: US$ 700m
- State exposure: Broad Central and Mid West Footprint
- Line of Business: 90% Homeowner, 2% Commercial, 8% Auto
What results do the models produce?

What does a Tornado Hail Exceedance Probability curve actually look like

<table>
<thead>
<tr>
<th></th>
<th>Model 1</th>
<th>Model 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>250 yrs</td>
<td>278,412,245</td>
<td>339,991,249</td>
</tr>
<tr>
<td>100 yrs</td>
<td>209,235,520</td>
<td>251,986,847</td>
</tr>
<tr>
<td>50 yrs</td>
<td>169,945,778</td>
<td>196,837,394</td>
</tr>
<tr>
<td>25 yrs</td>
<td>135,261,749</td>
<td>144,661,308</td>
</tr>
<tr>
<td>10 yrs</td>
<td>93,780,417</td>
<td>93,745,562</td>
</tr>
<tr>
<td>5 yrs</td>
<td>66,255,199</td>
<td>65,866,201</td>
</tr>
<tr>
<td>AAL</td>
<td>162,336,269</td>
<td>143,583,367</td>
</tr>
</tbody>
</table>

- Actual Tornado Hail Loss experience
  - 2015  12.35m, 8.84m, 8.06m
  - 2014  22.41m, 19.37m, 16.19m
  - 2013  67.32m, 27.96m, 22.86m
  - 2012  41.67m, 36.96m, 29.00m
  - 2011  101.27m, 36.63m, 30.52m
  - 2010  41.56m, 20.71m
  - 2009  29.60m, 23.17m, 23.09m
  - 2008  60.61m, 17.08m, 16.56m
Observations

• Both models far closer together

• Both models reflect reasonable losses vs experience for period

• 5yr losses of $65m and 10yr loss of $93m

• Two 60m losses and one loss Xs 100m within period

• Standard loadings for growth and ALAE should be applied, no need to further manipulate model curves

• Slight difference at high return periods
Conclusion

• Overall both models produce credible curves

• You may wish to blend the two to get a consensus view at the higher return periods.

• Selecting one curve over another is justifiable

• The much larger footprint and exposure base produced results far closer in agreement from the two models.
Thank you
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