Catastrophe Modeling

John Duda
Food for thought…

What is the impact of scientific advance on catastrophe risk management?
  • *What should be its impact on catastrophe risk management?*

What are the impacts of market forces, reinsurance and regulation on catastrophe risk management?
  • *What should be their impact on catastrophe risk management?*
Agenda Slide

Section 1  The Science of Catastrophe Modeling
Section 2  Catastrophes in Canada
Section 3  The Mechanics of Catastrophe Modeling
Section 4  Catastrophe Risk Management
## Top 20 Insured Losses of 2008

<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>20000</td>
<td>136</td>
<td>06.09.2008</td>
<td>Hurricane Ike, winds up to 195 km/h; offshore damage, floods</td>
<td>US, Caribbean: Gulf of Mexico, Haiti et al</td>
</tr>
<tr>
<td>4000</td>
<td>135</td>
<td>26.08.2008</td>
<td>Hurricane Gustav, winds up to 240 km/h; offshore damage, floods</td>
<td>US, Caribbean: Gulf of Mexico, Haiti et al</td>
</tr>
<tr>
<td>1325</td>
<td>7</td>
<td>22.05.2008</td>
<td>Tornadoes, storms, winds up to 320 km/h, heavy rain, hail</td>
<td>US</td>
</tr>
<tr>
<td>1321</td>
<td>15</td>
<td>29.02.2008</td>
<td>Winter storm Emma, winds up to 150 km/h; floods</td>
<td>Germany, Austria, Czech Rep et al</td>
</tr>
<tr>
<td>1300</td>
<td>130</td>
<td>10.01.2008</td>
<td>Snow storms, freezing rain across the country</td>
<td>China</td>
</tr>
<tr>
<td>1100</td>
<td>-</td>
<td>29.05.2008</td>
<td>Thunderstorms, winds up to 137 km/h, hail</td>
<td>US</td>
</tr>
<tr>
<td>973</td>
<td>4</td>
<td>29.05.2008</td>
<td>Storm Fila, thunderstorms, hail; floods, landslides</td>
<td>Germany, Belgium, UK, France et al</td>
</tr>
<tr>
<td>955</td>
<td>56</td>
<td>05.02.2008</td>
<td>Tornadoes, winter storms, floods</td>
<td>US</td>
</tr>
<tr>
<td>800</td>
<td>-</td>
<td>09.04.2008</td>
<td>Storms, hail, heavy rain, floods</td>
<td>US</td>
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<tr>
<td>745</td>
<td>12</td>
<td>04.01.2008</td>
<td>Winter storm, heavy rain, snow, floods, mudslides</td>
<td>US</td>
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<tr>
<td>725</td>
<td>16</td>
<td>05.06.2008</td>
<td>Storms over Midwest, hail, rain; floods</td>
<td>US</td>
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<tr>
<td>635</td>
<td>22</td>
<td>10.05.2008</td>
<td>Tornadoes, winds up to 280 km/h, hail</td>
<td>US</td>
</tr>
<tr>
<td>560</td>
<td>2</td>
<td>15.03.2008</td>
<td>Thunderstorms, tornadoes, hail</td>
<td>US</td>
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<tr>
<td>550</td>
<td>-</td>
<td>13.01.2008</td>
<td>Floods caused by heavy rain</td>
<td>Australia</td>
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<tr>
<td>525</td>
<td>5</td>
<td>23.07.2008</td>
<td>Hurricane Dolly, winds up to 160 km/h, heavy rain; floods</td>
<td>US, Mexico, Gulf of Mexico</td>
</tr>
<tr>
<td>500</td>
<td>-</td>
<td>13.11.2008</td>
<td>Three urban forest fires, Santa Ana winds up to 130 km/h</td>
<td>US</td>
</tr>
<tr>
<td>470</td>
<td>-</td>
<td>17.04.2008</td>
<td>Thunderstorms, hail</td>
<td>US</td>
</tr>
<tr>
<td>ns</td>
<td>-</td>
<td>01.05.2008</td>
<td>Fire at Universal Studios</td>
<td>US</td>
</tr>
<tr>
<td>ns</td>
<td>-</td>
<td>05.01.2008</td>
<td>Gas explosion at steel plant</td>
<td>US</td>
</tr>
<tr>
<td>ns</td>
<td>-</td>
<td>03.06.2008</td>
<td>Explosion and fire at gas processing plant</td>
<td>Australia</td>
</tr>
</tbody>
</table>

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8 Property and business interruption, excluding liability and life insurance losses
9 US natural catastrophe figures: with the permission of Property Claim Services (PCS)/incl. NFIP flood losses
10 Dead and missing
10 ns = not shown

Swiss Re, sigma No 2/2009
Canada Fails to Crack Top 20

**Hail**

<table>
<thead>
<tr>
<th>Date</th>
<th>Country</th>
<th>Place</th>
<th>Event</th>
<th>No. of victims/amount of damage in original currency and (USD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>16.2.-18.2.</td>
<td>United States</td>
<td>AL, TX</td>
<td>Hail and thunderstorms; damage to vehicles and homes</td>
<td>USD 100–300m insured loss</td>
</tr>
<tr>
<td>30.3.-1.4.</td>
<td>United States</td>
<td>TX, AR, OK</td>
<td>Hail, storms and tornadoes; damage to cars, buildings</td>
<td>USD 100–300m insured loss</td>
</tr>
<tr>
<td>3.6.</td>
<td>China</td>
<td>Henan, Zhoukou</td>
<td>Hail, storm with winds up to 84 km/h; damage to agriculture</td>
<td>10 dead 100 injured CNY 160m (USD 23m) total damage</td>
</tr>
<tr>
<td>22.6.-23.6.</td>
<td>Germany</td>
<td>Emden, Lower Saxony</td>
<td>Hail, thunderstorms, heavy rain; damage to 30,000 new cars</td>
<td>insured loss ns</td>
</tr>
<tr>
<td>13.7.-14.7.</td>
<td>Slovenia</td>
<td>Kamnik, Murska Sobota</td>
<td>Hail, storms; damage to houses, business, forestry, agriculture</td>
<td>EUR 40m (USD 56m) insured loss</td>
</tr>
<tr>
<td>15.9.</td>
<td>Slovenia</td>
<td></td>
<td>Hail, storms; damage to textile, forestry, cars</td>
<td>EUR 70m (USD 97m) insured loss</td>
</tr>
<tr>
<td>4.9.-6.9.</td>
<td>Canada</td>
<td>Saskatchewan</td>
<td>Hail storm; damage to agriculture</td>
<td>CAD 132m (USD 107m) insured loss</td>
</tr>
</tbody>
</table>
How many points make a curve?
Catastrophe Model Framework

Hazard

- Historic Event Catalogue
  - Location
  - Intensity

- Parameters
  - Spatial
  - Temporal
  - Physical

- Synthetic Events
  - Location
  - Intensity

- Physical Model
  - Location
  - Intensity

Exposure

- Portfolio Exposure Data
  - Location
  - Parameters

- Insurance Coverage
  - Limits
  - Deductibles

Vulnerability

- Damage Function
  - Location
  - Type

Loss

- Insured Loss
  - Location
  - Coverage

- Probability Distribution
  - Frequency
  - Severity

Aon Benfield
# Lessons Learned

<table>
<thead>
<tr>
<th>Event</th>
<th>Year</th>
<th>Insured Loss</th>
<th>Illustrative Modeling Lessons Learned</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hurricane Andrew</td>
<td>1992</td>
<td>$16 billion</td>
<td>Damage vs. Loss, demand surge</td>
</tr>
<tr>
<td>Northridge Earthquake</td>
<td>1994</td>
<td>$14 billion</td>
<td>Damage vs. Loss, construction quality, demand surge, unknown faults</td>
</tr>
<tr>
<td>Kobe Earthquake</td>
<td>1995</td>
<td>$4 billion</td>
<td>First world earthquake casualties</td>
</tr>
<tr>
<td>Hurricane Fran</td>
<td>1996</td>
<td>$2 billion</td>
<td>Rain fall, tree damage</td>
</tr>
<tr>
<td>Winterstorm Lothar, Martin, and Anatol</td>
<td>1998</td>
<td>$10 billion</td>
<td>Intensification, demand surge and settlement practices</td>
</tr>
<tr>
<td>Tropical Storm Allison</td>
<td>2001</td>
<td>$2 billion</td>
<td>Catastrophic localized flooding</td>
</tr>
<tr>
<td>World Trade Center</td>
<td>2001</td>
<td>$35 billion</td>
<td>Terrorism Risk</td>
</tr>
<tr>
<td>Hurricanes Charley, Frances, Jeanne and Ivan</td>
<td>2004</td>
<td>$25 billion</td>
<td>Hurricane clustering, calibration/variability of commercial vulnerabilities</td>
</tr>
<tr>
<td>Sumatra Earthquake</td>
<td>2004</td>
<td>$3 billion</td>
<td>Tsunami Risk</td>
</tr>
<tr>
<td>Hurricanes Katrina, Rita and Wilma</td>
<td>2005</td>
<td>$75 billion</td>
<td>Levee failure, super-cat loss amplification, high - rise vulnerability, activity rates</td>
</tr>
<tr>
<td>Hurricane Ike</td>
<td>2008</td>
<td>$20 billion</td>
<td>Significant losses inland</td>
</tr>
</tbody>
</table>

Source: VJ Dowling and Partners and Aon Benfield Canada
After the Loss

- Post Loss Inflation / Demand surge / “Loss Amplification”
- Recognition that socioeconomic forces can dramatically increase losses
- Based on accumulated effects of previous events
- Economic demand surge
  - Increase in the costs of building materials and labor costs as demand exceeds supply
- Claims inflation
  - Adjusters under pressure to settle quickly
  - Lack of adjusters leads to less experienced being used
- Political influence
  - Payment of claims not strictly covered by policy
- “Super cat” – exaggerates these effects if loss is in a major urban centre
Agenda Slide

Section 1  The Science of Catastrophe Modeling
Section 2  Catastrophes in Canada
Section 3  The Mechanics of Catastrophe Modeling
Section 4  Catastrophe Risk Management
Catastrophes, eh?
Earthquake

Earthquakes in or near Canada, 1627 - 2007
Top 10 Earthquakes in Canada
More Recent Earthquakes in Canada

- Recent earthquakes (most recent is shown in yellow)
- M < 2.0
- M ≥ 3.0
- M ≥ 4.0
- M ≥ 5.0
- M ≥ 6.0
Most Recent Earthquake in Eastern Canada*

Magnitude 3.2
Chateau Bromont

*as at May 21, 2009
Historical Seismicity in Eastern Canada

- 1925 Charlevoix-Kamouraska M6.2
- 1929 Grand Banks (or Laurentian Slope) M7.2 (US$ 20 million economic losses – tsunami and 200km far from coasts)
- 1935 Timiskaming (or Témiscaming) M6.2
- 1944 Cornwall-Massena M5.6
- 1988 Saguenay M5.9

Eastern Canada Earthquake Risk

= rare big earthquakes

X large sum insured in large areas
Earthquake Model Framework

A probabilistic study involves determining the occurrence probabilities of earthquakes, then estimating ground motion and associated damages, and later the loss exceedence probabilities.
Detailed View of the Earthquake Model Framework
Secondary Uncertainty

[Map of Eastern Canada with different zones labeled A, B, C, D]
Secondary Uncertainty

Loss as %age exposure due to M7.5 events at A,B,C,D
Winterstorm & Severe Convective Storm

Back to Chateau Bromont...

10,000 Yr Return Period  500 Yr Return Period
Winterstorm
Winterstorm Model Framework

Hazard  Exposure  Vulnerability  Loss
Severe Convective Storm
Severe Convective Storm

Uniform Exposure Loss Costs

Source: RMS
Agenda Slide

Section 1  The Science of Catastrophe Modeling
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Welcome to Chateau Bromont

We know what it is

We know where it is

We can guess at how much it is worth

We can model it
<table>
<thead>
<tr>
<th>Field</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACCNUNUM</td>
<td>CB</td>
</tr>
<tr>
<td>LOCNUM</td>
<td>ISO2A</td>
</tr>
<tr>
<td>CNTRYSCHEME</td>
<td>CA</td>
</tr>
<tr>
<td>CNTRYCODE</td>
<td>GC</td>
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<tr>
<td>STATECODE</td>
<td>J2L1KG</td>
</tr>
<tr>
<td>POSTALCODE</td>
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</tr>
<tr>
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<td>Stansfield</td>
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<tr>
<td>STREETNAME</td>
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<tr>
<td>OCCSCHEME</td>
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<tr>
<td>OCCTYPE</td>
<td>1</td>
</tr>
<tr>
<td>BLDGSHEME</td>
<td>2</td>
</tr>
</tbody>
</table>

We know where it is, we know what it is, we guessed at how much it is worth.
We tell the model where it is
We import the where/what/etc
The model confirms where it is.
The model confirms what it is worth.
The model confirms what it is
We select several perils to run.
We run the model
We get results
<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
<th>J</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name:</td>
<td>Chateau Bromont</td>
<td>IV:</td>
<td>600,303,000</td>
<td>Ground-Up Loss (before primary deductible)</td>
<td>Gross Loss (after primary deductible)</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>4</td>
<td>Critical Prob.</td>
<td>Return Period</td>
<td>Severe Convective Storm</td>
<td>Earthquake &amp; Fire Following</td>
<td>Winterstorm</td>
<td>Severe Convective Storm</td>
<td>Earthquake &amp; Fire Following</td>
<td>Winterstorm</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>0.01%</td>
<td>10,000</td>
<td>21,144,751</td>
<td>91,163,032</td>
<td>26,450,349</td>
<td>955,922</td>
<td>53,294,485</td>
<td>4,088,888</td>
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<tr>
<td>6</td>
<td>0.10%</td>
<td>1,000</td>
<td>6,677,147</td>
<td>295,006</td>
<td>4,669,274</td>
<td>0</td>
<td>47</td>
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<tr>
<td>7</td>
<td>0.20%</td>
<td>500</td>
<td>3,772,277</td>
<td>141</td>
<td>2,905,175</td>
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<tr>
<td>8</td>
<td>0.40%</td>
<td>250</td>
<td>1,696,704</td>
<td>-</td>
<td>1,639,411</td>
<td>0</td>
<td>-</td>
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</tr>
<tr>
<td>9</td>
<td>1.00%</td>
<td>100</td>
<td>261,500</td>
<td>-</td>
<td>676,372</td>
<td>0</td>
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<td>0</td>
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<tr>
<td>10</td>
<td>2.00%</td>
<td>60</td>
<td>14,831</td>
<td>-</td>
<td>309,149</td>
<td>0</td>
<td>-</td>
<td>0</td>
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</tr>
<tr>
<td>11</td>
<td>4.00%</td>
<td>25</td>
<td>44</td>
<td>-</td>
<td>116,137</td>
<td>0</td>
<td>-</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>10.00%</td>
<td>10</td>
<td>0</td>
<td>-</td>
<td>15,239</td>
<td>0</td>
<td>-</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>20.00%</td>
<td>5</td>
<td>0</td>
<td>-</td>
<td>803</td>
<td>0</td>
<td>-</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>50.00%</td>
<td>2</td>
<td>0</td>
<td>-</td>
<td>0</td>
<td>0</td>
<td>-</td>
<td>0</td>
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</tr>
<tr>
<td>15</td>
<td>Pure Premium</td>
<td>31,037</td>
<td>33,833</td>
<td>40,333</td>
<td>3,585</td>
<td>23,565</td>
<td>3,140</td>
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<tr>
<td>16</td>
<td>Standard Deviation</td>
<td>1,207,539</td>
<td>2,702,356</td>
<td>756,324</td>
<td>1,051,859</td>
<td>2,433,208</td>
<td>472,529</td>
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<tr>
<td>17</td>
<td>Coefficient of Variation</td>
<td>39</td>
<td>80</td>
<td>10</td>
<td>70</td>
<td>103</td>
<td>150</td>
<td>150</td>
<td></td>
</tr>
</tbody>
</table>

Proprietary & Confidential
That Was EP

Ground-up Winterstorm Loss for Chateau Bromont

Corresponding TCE = $8.5m

500 yr OEP
Agenda Slide

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The Challenge

- Many catastrophe models and many results
  - 3 “wrong” answers better than 1?

- Regulation
  - Compliance vs. catastrophe risk management

- Models are constantly changing
  - Alignment with business planning and pricing

- Reinsurance purchase
  - Cost of capital

- What’s next?
  - Earthquake forecasting
Many Catastrophe Models

EQ

CANADA

West Coast

East Coast
Many Catastrophe Models

Model A
Best Fit
Model B
Model C

Return Period

Loss

Opinions?

Model reliance?

Experience?
Many Catastrophe Models

- Select preferred cat model event set as starting point

- Agree ‘Best Fit’ PML curves for each exposure
  - Earthquake
  - Winterstorm
  - Severe Convective Storm

- Develop ‘rules’ to adjust original severities of preferred cat model (from event point of view) to match ‘Best Fit’ curves
  - X% of first $Am
  - Y% of next $Bm etc
Many Catastrophe Models

Source: GEM
Reinsurance + Retention = $PML_{250} + \frac{N}{25} \left( PML_{500} - PML_{250} \right)$

[Where $N$ is the current fiscal year minus 1997]

<table>
<thead>
<tr>
<th>Item</th>
<th>Calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deductibles:</td>
<td>As per policy conditions</td>
</tr>
<tr>
<td>Post-Event Inflation:</td>
<td>Demand surge or Loss amplification? How much?</td>
</tr>
<tr>
<td>Co-Insurance:</td>
<td>As per policy conditions</td>
</tr>
<tr>
<td>Loss Adjustment Expenses:</td>
<td>How much? Is it implicitly modeled?</td>
</tr>
<tr>
<td>Debris Removal:</td>
<td>How much? Is it implicitly modeled?</td>
</tr>
<tr>
<td>Automobile Physical Damage:</td>
<td>How much? Is it modeled?</td>
</tr>
<tr>
<td>Under-Insurance:</td>
<td>How much? Is it implicitly modeled?</td>
</tr>
</tbody>
</table>
Regulation

- Models now include Post Loss Amplification
- Loss Adjustment Expenses – Typically 8% to 12% in US Cat Losses
- Debris Removal – 1% to 2%
- Under Insurance / Insurance to Value
  - Models assume 100% ITV unless values adjusted
  - If TIVs understated modeled loss will be equally understated (Kelowna fires)
- Other
  - Business Interruption / Additional Living Expenses – modeled adequately?
  - Data quality / missing data
Changes to RMS Eastern Canada Earthquake Model

Source: RMS
Collusive Pricing

Consumer Foundation of America & Center for Economic Justice, in a Letter to the NAIC

- “…RMS seems clearly to be engaged in collusive pricing activity…”
- “It is shocking and unethical that scientists at these modeling firms appear to have completely changed their minds at the same time after over a decade of using models they assured the public were scientifically sound.”

An objection to rising rates from a consumer advocate group is unsurprising. Will rates rise anyway?

Should models be regulated? Modelers have customers too…
Reinsurance

- Market is quite capable of reacting even without updated models

- Supply & Demand
  - Cost of capital
  - Other regions pay the price for US losses to some extent
What’s next?

- Earthquakes are generally the most feared of natural hazards because they occur without warning. Hurricanes can be tracked; floods rise in a systematic way; volcanic eruptions are preceded by a variety of phenomena.

- The devastation caused by the North Sumatra earthquake, December 2004, and the subsequent tsunami has once again demonstrated our vulnerability to the effects of a great earthquake.

- Historical records from around the world suggest that, while rare, similar large events (M ≈ 9) have occurred elsewhere. For example, there is strong evidence that a similar earthquake occurred in the Cascadian subduction zone in 1700.

- Smaller, but also very destructive earthquakes (M > 6.5) occur every year, many in populated areas.

- Earthquakes, until very recently, have not been forecast with any significant degree of success.

Source: http://www.pnsn.org/ (Ruth Ludwin)
http://www.virtualmuseum.ca
Earthquake Forecasting

 oggi, le mappe di rischio sono largamente utilizzate per caratterizzare la probabilità di una regione specifica subire scosse di terremoto a causa di un terremoto di magnitudo. Tuttavia, le mappe di rischio non sono considerate previsioni terremotate, ma piuttosto un strumento per i piani, gli ingegneri ed i gestori di emergenza.

 Le previsioni terremotate, d'altra parte, forniscono una probabilità di un terremoto avvenire in un luogo specifico in un periodo di tempo fisso nel futuro.

 Storicamente, una grande varietà di approcci sono stati applicati al problema delle previsioni terremotate.

 Mentre non si è mai dimostrato che un approccio singolo sia stato consistentemente con successo per il previsionismo a breve termine di eventi terremotati di grande magnitudo, si è verificato notevole successo nelle previsioni a lungo termine di grandi evento terremotati.
Earthquake Forecasting

- PI forecast, published 2002 for large earthquakes, M ≥ 5, ~ 2000 to 2010
- Success rate = 24 out of 26 actual events
Food for thought…

ål What is the impact of scientific advance on catastrophe risk management?
  • *What should be its impact on catastrophe risk management?*

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  • *What should be their impact on catastrophe risk management?*