MODELLING AND QUANTIFICATION OF THE ECONOMIC IMPACT OF EXTREME CLIMATE-RELATED RISKS

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What is risk? Risk to Whom or to What? How is Risk Measured?

- Exposure
  - Population
  - Buildings (residential, commercial, public)
  - Infrastructure (bridges, dams, ports, etc.)
  - Crops and Livestock

- Impact
  - Fatalities, injuries
  - Monetary losses
  - Resiliency
Why Are Cat Risk Models Built?

To support decisions about **risk management**

- Risk Retention
- Risk Mitigation and Control
- Risk Financing/Transfer
- Risk Avoidance
Cat Risk Models Serve All the Segments of the Insurance Industry

**Primary Insurance Market**
- Individual Policy Holder
  - Buys
- Corporate Policy Holder
  - Buys
- Insurer
  - Sells
  - Buys
- Reinsurer
  - Sells

**Reinsurance Market**
- Individual Policy Holder
  - Buys
- Corporate Policy Holder
  - Sells
- Insurer
  - Buys
  - Sells
- Reinsurer
  - Buys
  - Sells

**Retro Market**
- Individual Policy Holder
  - Buys
- Corporate Policy Holder
  - Sells
- Capital Markets (Hedge Funds, Money Managers, etc.)
  - Buys
  - Sells
- Broker
  - Buys
  - Sells
- SPV (Special Purpose Vehicle)
  - Buys
  - Sells
- Insurer
  - Buys
  - Sells
- Reinsurer
  - Buys
  - Sells
- Catastrophe Bond
  - Buys
  - Sells

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Who Else Uses Catastrophe Risk Models?

• Catastrophe/relief funds and risk pools (e.g., California Earthquake Authority, Caribbean Catastrophe Risk Insurance Facility, Pacific Catastrophe Risk Insurance Pilot)
• Rating Agencies (S&P, Moody’s, Fitch)
• Real estate management and investment
• Mortgage lending Institutions
• Major banks (WB, ADB, IADB, etc.)
• In US, Fannie Mae, Freddie Mac and the secondary mortgage market
• Major Corporations (Dow Chemical, Devon Energy, Arkema, Sony, General Motors, etc.)
• Governments and their departments (U.S. Department of Homeland Security, the U.S. Navy, the Risk Management Agency, a division of the U.S.D.A., Mexican Government, etc.)
Why Do Corporations Need Catastrophe Risk Models?

- Accurately quantify, help mitigate, and manage catastrophe risk

- Are the conventional Catastrophe Risk Models enough?
  - Catastrophe Risk Engineering Models more appropriate

Primary needs

- Risk assessment and mitigation
  - Explicitly includes business interruption
- Post-catastrophe response
  - Damage assessment and repair concepts
A Brief History of Catastrophe Modeling in the Insurance Industry

US Hurricane, Tornado & Earthquake Models • Introduced

Cat Models capture the attention of the industry
US Hurricane Andrew (1992) • $16B
Northridge EQ (1994) • $12B

First Catastrophe Bond Issued Transferring Risk to Capital Markets

Introduction of Performance-Based Earthquake Engineering (PBEE)

US Hurricane Andrew (1992)
Northridge EQ (1994)

1992, 1994

Mid-1990s

2000

• World Trade Center Attack

First Catastrophe Bond Issued Transferring Risk to Capital Markets

US Hurricane Andrew (1992) • $16B
Northridge EQ (1994) • $12B

Introduction of Performance-Based Earthquake Engineering (PBEE)

Decade of the 00s: Introduction of Wildfire, Winter Storm, Crop Loss and Offshore Assets (Gulf of Mexico), Pandemic Flu Models

Hurricane Katrina (2005) • $41B

Record Breaking Hurricane Seasons of 2004 & 2005

Introduction of First Hurricane Models Conditioned on Warm Sea-Surface Temperatures

2001, 2002

2004, 2005

2006

2009

2011

2012

Introduction of Tsunami Model for the Pacific

Tohoku Earthquake

11 Insolvencies after Hurricane Andrew and several after Northridge

3 Insolvencies after Hurricane Katrina

MODER DEVELOPMENT TIMELINE
What is the Coverage Worldwide of Cat Risk Models for the Insurance Industry?

- Most of them are for the developed parts of the world or for fast-growing countries where the insurance industry is mature.
- A large portion of the world (i.e., most of the developing countries) is currently left out.
- Things are slowly changing
  - Sovereign Risk Financing Initiatives (Caribbean, Pacific Islands Countries, South America, Mexico, etc.)
  - The Global earthquake Model (GEM) (http://www.globalquakemodel.org/)
  - CAPRA (http://www.ecapra.org/)
What is Risk Assessment?

**Risk** = probability of damage and loss to population and assets

*(Loss Valued in Human and Financial terms)*

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(Loss Valued in Human and Financial terms)
The Objectives Dictate the Risk Analysis Approach

Increasing Effort & Complexity

Hazard/Risk Index or Profile

Pros: fast, low data requirements, output easy to understand
Cons: Low resolution, subjective

Historical Scenario

Pros: based on event-specific data, good for frequent hazards
Cons: misses extreme events, potential impacts of climate change

Probabilistic

Pros: accounts for both frequent/low-impact and rare/extreme events
Cons: high data/expertise requirements, need to ensure outputs can be understood
The risk modeling approach is conceptually simple

1. Identify Study Region
2. Characterize Hazard
3. Define and Overlay Exposure
4. Model Damage
5. Estimate Losses
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Identification of the Study Region
Flood hazard modeling at a regional scale

Inaccuracies often tolerated:

- Poor accuracy digital elevation model
- Presence of levees, dykes, and adoption of flood control infrastructures,
- Disregard of tide effects
- If levees are modeled, they are added after the inundation area is computed
- Hydraulic models replaced by purely statistical models
Flood Hazard Modeling at an Urban Scale: none of these simplifications would be acceptable.
The risk modeling approach is conceptually simple

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Hazard Characterization – Tropical Cyclone Peril

Where?
How Strong?
How frequent?

Generating the stochastic catalog of potential future events
The risk modeling approach is conceptually simple

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Assembling an Exposure Database

Building and maintaining an integrated, centralised and *spatially-enabled* database is the most effective way to manage exposure information.
The Scale of the Risk Assessment and the Peril Dictate the Exposure Data Collection

- Regional vs. urban vs. site-specific studies

**Level of detail increases**

- Perils with very localized effects. The impact of flood, tsunami, landslide, rockslide, hail risk studies require a more detailed exposure database than risk studies for other perils (e.g., earthquake ground shaking and wind)
Specific location of buildings is necessary for urban scale studies and for perils with localized effects.
Clusters of Buildings Within Delineated Polygons: Appropriate for Regional Studies and Perils without (or with Limited) Localized Effects
The risk modeling approach is conceptually simple

1. Identify Study Region
2. Characterize Hazard
3. Define and Overlay Exposure
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5. Estimate Losses
Mean Damage Function for California Wood Frame Buildings of given Vintage based on Claims Data (1994 M6.7 Northridge Earthquake)
The risk modeling approach is conceptually simple

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5. Estimate Losses
Catastrophe Models Provide a Wide Range of Outputs

Exceedance Probability (EP) Curve - Occurrence

<table>
<thead>
<tr>
<th>Exceedance Probability (%)</th>
<th>Loss Amount (millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>0</td>
</tr>
<tr>
<td>1%</td>
<td>50</td>
</tr>
<tr>
<td>2%</td>
<td>100</td>
</tr>
<tr>
<td>3%</td>
<td>150</td>
</tr>
<tr>
<td>4%</td>
<td>200</td>
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<tr>
<td>5%</td>
<td>250</td>
</tr>
<tr>
<td>6%</td>
<td>300</td>
</tr>
<tr>
<td>7%</td>
<td>350</td>
</tr>
<tr>
<td>8%</td>
<td>400</td>
</tr>
<tr>
<td>9%</td>
<td>450</td>
</tr>
<tr>
<td>10%</td>
<td>500</td>
</tr>
</tbody>
</table>

Estimated Return Period

<table>
<thead>
<tr>
<th>Loss Amount (millions)</th>
<th>Estimated Return Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>10</td>
</tr>
<tr>
<td>100</td>
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<tr>
<td>550</td>
<td>800</td>
</tr>
<tr>
<td>600</td>
<td>900</td>
</tr>
</tbody>
</table>

Event | Year | Company Loss | Event Info
270011986 | 3657 | 2,811,789 | Class 5 Hurr FL LA BF MS TX
2700127822 | 5454 | 2,672,028 | Class 5 Hurr NY NJ CT MA PA
110128230 | 4470 | 1,951,563 | Mw 8.1 EQ New Madrid
270004221 | 1295 | 1,946,088 | Class 5 Hurr FL BF SS SJ VQ
270019211 | 5872 | 1,786,625 | Class 5 Hurr TX FL LA BF MS
270018458 | 5649 | 1,658,905 | Class 4 Hurr NY CT NJ MA NH
270006717 | 2023 | 1,634,955 | Class 4 Hurr FL BF SS SJ VQ
270010779 | 3294 | 1,625,767 | Class 5 Hurr FL NC SC TN BF
110128356 | 2917 | 1,605,027 | Mw 8.3 EQ San Francisco
27010551 | 3232 | 1,562,932 | Class 5 Hurr FL AL JM MS LA
270022466 | 6869 | 1,562,240 | Class 2 Hurr FL PQ DR GA BF
270016561 | 5063 | 1,475,085 | Class 5 Hurr FL BF GA SC
110124693 | 4350 | 1,465,897 | Mw 8.2 EQ San Francisco
270007716 | 2349 | 1,444,885 | Class 5 Hurr FL MS JM AL LA
270021324 | 6512 | 1,397,006 | Class 4 Hurr FL CJ JM BF TD
Standard Output is the Loss Annual Exceedance Probability Curve

Exceedance Probability (EP) Curve - Occurrence

The Average Annual Loss (AAL) is the mean, or average, loss over a long period of time.
How Do Parametric Insurance and Catastrophe Bonds Fit in the Cat Risk Modeling Framework?

HAZARD
- Event Generation
  - Landfall Location & Cent. Press.
  - 1st Generation Parametric
    - Cat-in-a-Box
    - Carvill Hurricane Index
  - 2nd Generation Parametric
    - Measured Wind Speed at Concentrations of Exposure
- Intensity Calculation
  - Local Wind Speed

ENGINEERING
- Exposure Information
- Damage Estimation

FINANCIAL
- Insured Loss Calculations
- Insured Loss

Modeled Loss & Hybrids
- Modeled Loss bonds
- Modeled Loss/PCS hybrids
- Modeled Loss/Parametric hybrids

Industry Loss
- ILW
- PCS Bonds

Indemnity
- Indemnity bonds

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Beyond Economic Losses: Integrated Risk

Risk can be further factored by social, economic, political factors that influence vulnerability to obtain a risk index.
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Workshop

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