The Actuarial Profession
making financial sense of the future

Momentum 2011
Rachel Evans

Catastrophe Models:

Inputs, outputs, uncertainty & Solvency II

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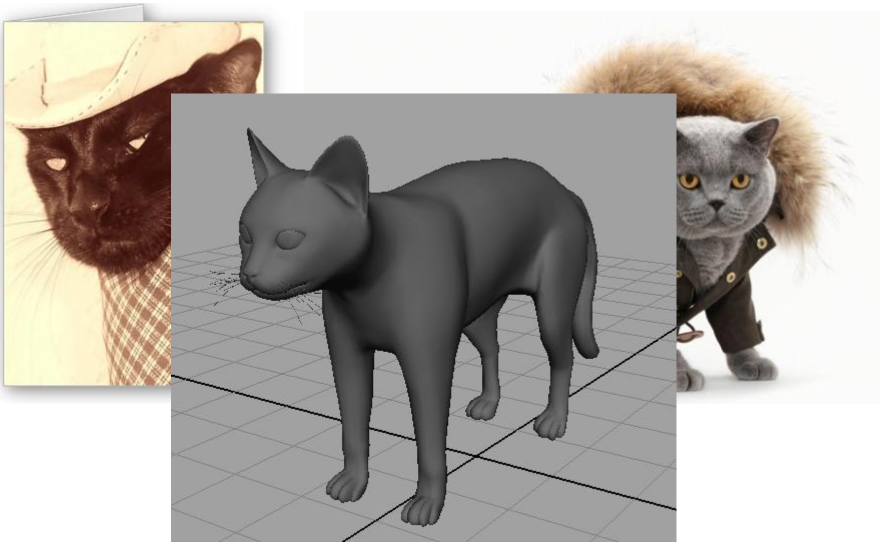
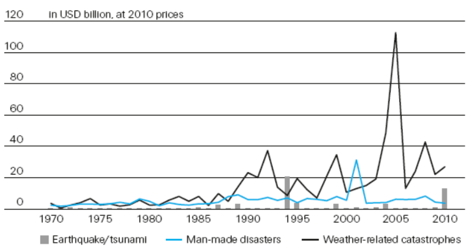
Cat modelling?



Contents

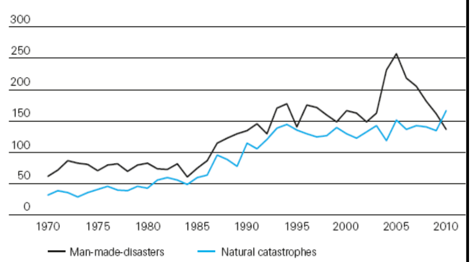
Insured Losses and Number of Events

Insured losses 1970-2010



Source: Swiss Re Economic Research & Consulting

Number of events 1970-2010



Source: Swiss Re Economic Research & Consulting

- **2010 Economic losses = $218bn**
- **2010 Insured losses = $43bn**
- **2010 is the first year on record where the number of natural catastrophes > man-made catastrophes**

Economic Losses by Region - 2010

Region	Economic loss in USD m	as a % of GDP
Asia	74 840	0.28%
Latin America and Caribbean	53 378	1.10%
Europe	35 204	0.19%
North America	20 551	0.13%
Oceania/Australia	13 131	0.95%
Africa	337	0.02%
Seas/Space	20 623	–
World Total	218 064	0.31%

Source: Swiss Re Economic Research & Consulting

- **Total economic loss of $218 billion for 2010**
- **Of the $43 billion of insured losses the split between natural and man-made is:**
  - **$40 billion – Natural**
  - **$3 billion – Man-made**
- **2010 ranks 7th in the last 41 years in terms of insured losses**

Cat Losses Globally - 2010

	Number	%	Victims	%	Insured loss USDm	%
Natural	**167**	**55%**	**299,127**	**98%**	**39,869**	**92%**
Floods	69	23%	11,027	4%	6,393	15%
Storms	63	21%	1,702	1%	20,126	46%
Earthquakes	13	4%	227,050	74%	12,943	30%
Droughts, bush fires, heat waves	9	3%	58,276	19%	10	0%
Cold, frost	10	3%	1,024	0%	397	1%
Hail	1	0%	28	0%		0%
Other	2	1%	20	0%		0%
Man-made	**137**	**45%**	**6,446**	**2%**	**3,605**	**8%**
Major fires, explosions	27	9%	783	0%	1,060	2%
Aviation disasters	16	5%	820	0%	1,070	2%
Maritime disasters	27	9%	1,192	0%	1,262	3%
Rail disasters	7	2%	337	0%	117	0%
Mining accidents	18	6%	903	0%	78	0%
Collapse of buildings / bridges	6	2%	283	0%	-	0%
Miscellaneous	36	12%	2,128	1%	18	0%
Total	**304**		**305,573**		**43,474**	

List of Major Insured Losses Globally 1970-2010

Insured loss USDm Indexed to 2010	Victims	Date	Event	Country
72,302	1836	25-8-2005	Hurricane Katrina	US, Gulf of Mexico
24,870	43	23-8-1992	Hurricane Andrew	US, Bahamas
23,131	2982	11-9-2011	World Trade Centre	US
20,601	61	17-1-1994	Northridge Earthquake	US
20,483	136	6-9-2008	Hurricane Ike	US, Caribbean
14,876	124	2-9-2004	Hurricane Ivan	US, Caribbean
14,028	35	19-10-2005	Hurricane Wilma	US, Mexico
11,266	34	20-9-2005	Hurricane Rita	US, Gulf of Mexico
9,295	24	11-8-2004	Hurricane Charley	US, Cuba
9,041	51	27-9-1991	Typhoon Mirelle	Japan
8,043	71	15-9-1989	Hurricane Hugo	US, Puerto Rico
8,000	562	27-2-2010	Chilean Earthquake	Chile
7,794	95	25-1-1990	Storm Daria	France, UK, Belgium
7,594	110	25-12-1999	Storm Lothar	Switzerland, UK, France
6,410	54	18-1-2007	Storm Kyrill	Germany, UK, Belgium
5,951	22	15-10-1987	Storm and floods	France, UK, Netherlands
5,941	38	26-8-2004	Hurricane Frances	US, Bahamas

Source: Swiss Re Economic Research & Consulting

Brief History of Cat Models

- **Two main events drove significant changes and development in catastrophe models:**
  - **The 1992 hurricane Andrew**
  - **The 1994 earthquake in Northridge, CA**
- **Prior to these events cat models were based on Probable Maximum Loss (PML) estimates by mainly calculating exposure concentrations**
- **Events resulted to a wealth of R&D in both hazard and vulnerability**
- **Cat-modelling industry had to respond to the challenge of reliably quantifying the loss potential of catastrophic events**

Hurricane Andrew series. Source: NASA

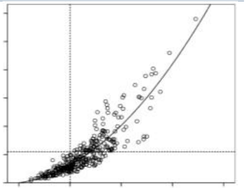
Northridge Earthquake. Source: US DOT

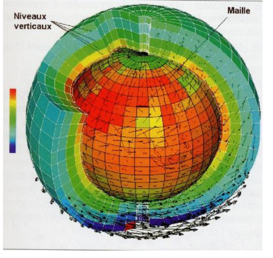
Cat Model Evolution

Simple PML estimates – e.g. deterministic scenario approaches

Regression techniques and actuarial analysis.

Fully probabilistic cat models





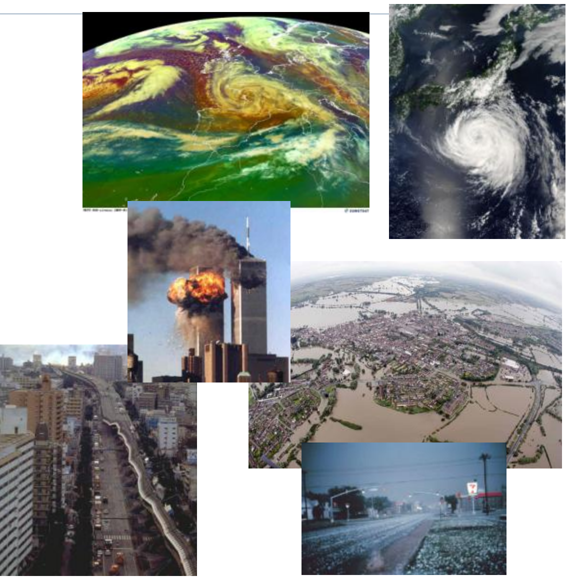
- Cat models are complex tools that require interdisciplinary science and large teams of experts to be built
- They are becoming the accepted market standard for pricing reinsurance
- Number of defaults of reinsurance companies has reduced during the last 8-10 years.

Who Builds Cat Models

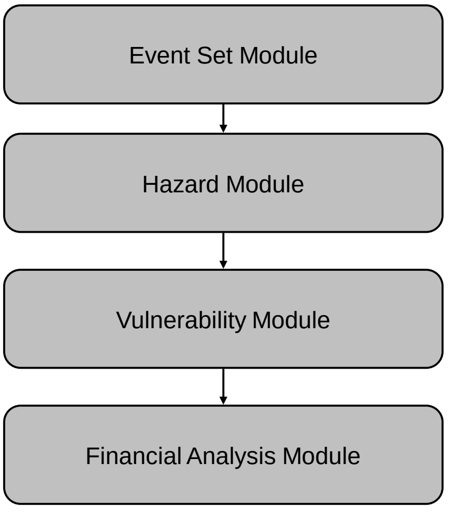
- Currently there are four main vendors of catastrophe models:
  - AIR Worldwide
  - EQECAT
  - RMS
  - ERN (focusing mainly on South America)
- Other industry specialists develop catastrophe models as well:
  - Broking houses (e.g. AON-Benfield, Guy Carpenter, Willis, etc)
  - Reinsurers (e.g. Munich Re, Partner Re, Swiss Re)
- Broking houses tend to develop models for areas where a cat model does not already exist from a main vendor
- Reinsurance companies use proprietary cat models for internal risk management and pricing

What Perils Are Modelled

- "Primary" perils
  - US Hurricane
  - US Earthquake
  - Japan Earthquake
  - Typhoon
  - European Windstorm
  - European Flood
- "Secondary" perils
  - Hail
  - Storm surge
  - Terrorism
  - Conflagration
  - Pandemic



Basic Cat Model Components



Event Loss Table

Event ID	Event Rate	Mean Loss	α	β
185670	0.0001	155,367,215	1.23	0.15
146723	0.0001	125,250,456	0.85	0.12
162354	0.003	23,458,798	0.65	0.15
097243	0.001	255,445,778	1,29	0,64

...
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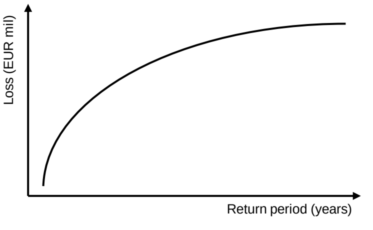
Exceedance Probability Curve



Cat Model Inputs and Outputs

INPUTS

- Location of risk
- Sum insured
- Construction class
- Type of occupancy
- Number of floors
- Existence of a basement
- Type of roof
- Insurance terms
- Reinsurance terms

OUTPUTS

Event Loss Table (ELT)

uncertainty params

Event ID	Event Rate	Mean Loss	α	β
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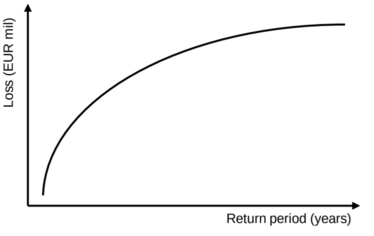
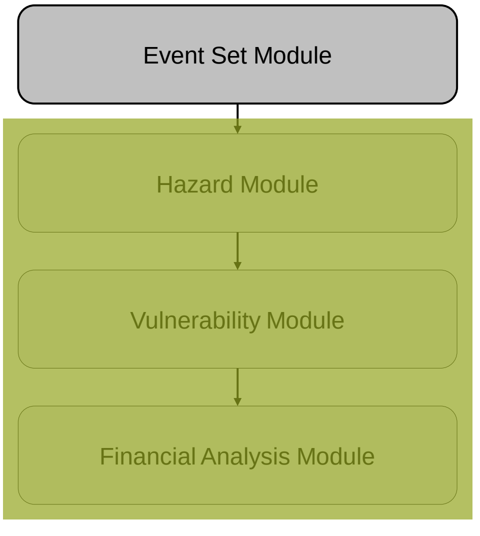
Exceedance Probability Curve

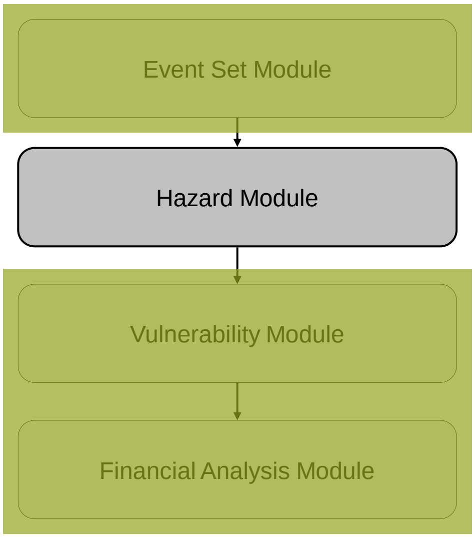


Event Set Module



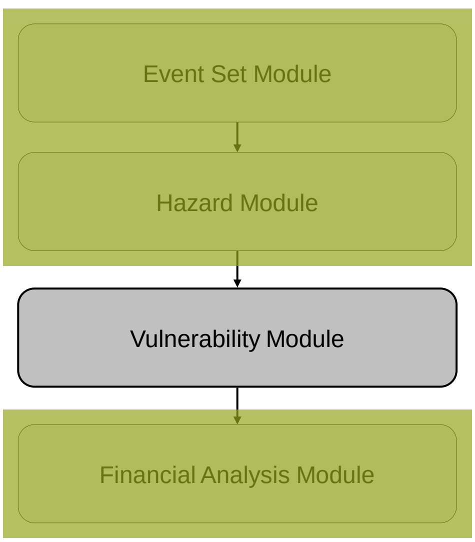
- A typical event set of a stochastic catastrophe model consists of thousands of events
- Large number of events is required to reliably estimate high return period losses (smooth EP curve)
- Event catalogue captures the severity/intensity combination of possible events in different geographical regions
- In many cases independence of arrival is assumed for events

Hazard Module

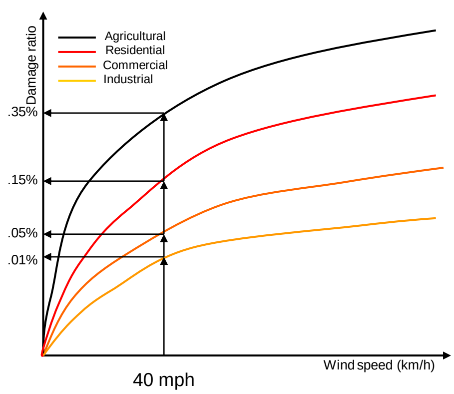


- This module describes how the occurrence of an event is affected by the hazard characteristics of the area
- Events are overlaid on hazard characteristics to get a metric of hazard that is used as input to the next module

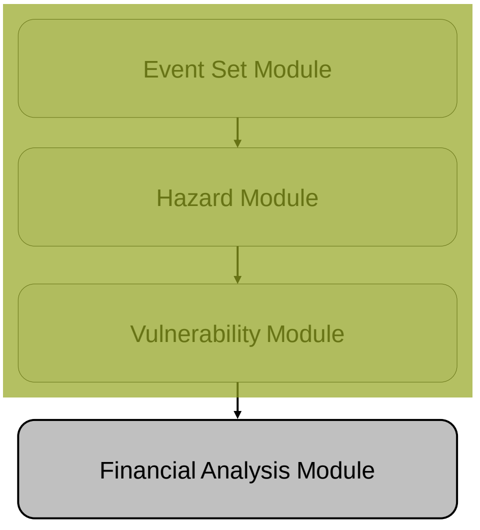
Vulnerability or Damageability Module



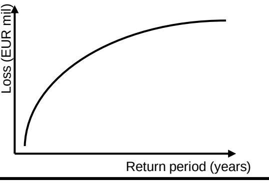
- The part of the model where the hazard metric is transformed to a damage ratio and ultimately to a monetary loss
- This is done with the application of vulnerability curves for different lines of business



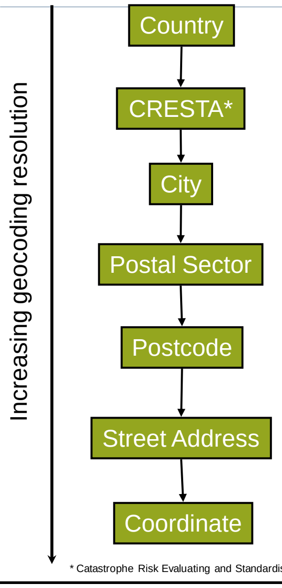
Financial Analysis Module



- The part of the model where insurance and reinsurance structures are applied and portfolio-wide losses are calculated
- Event Loss Tables (ELTs) are calculated
- Exceedance Probability (EP) curves are obtained



Geocoding – Importance of Data



- As with every other model, accuracy of data is of paramount importance
- Cat models not only use data for their event set, hazard and vulnerability parts but also for locating and describing the risks of a portfolio
- Currently: Strong emphasis on capturing accurate and appropriate data, especially in the context of Solvency II
- Projects such as CRESTA have helped the standardization of exposure accumulations globally (www.cresta.org)

* Catastrophe Risk Evaluating and Standardising Target Accumulations

Typical Lines of Business modelled

- Main Lines of Business (LOB) Modelled:
  - Residential
  - Commercial
  - Industrial
  - Agricultural
- For each LOB losses break down by:
  - Damage to Buildings (B)
  - Damage to Contents (C)
  - Business Interruption (BI) or Additional Living Expenses (ALE)

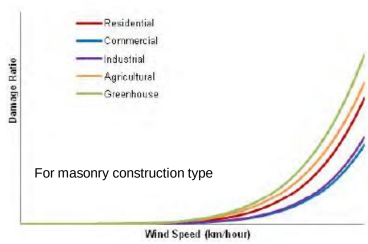
Source: AIR

Source: University of Berkley

Modelling Damage to Buildings

- Damage to buildings typically account for the largest proportion of losses
- Catastrophe models have a suite of vulnerability curves to model damage to buildings for different occupancy classes and construction types
- For the same type of construction type, commercial and industrial buildings tend to experience lowest damage
- Agricultural risks are usually the most vulnerable structures (e.g. Greenhouse can suffer total losses – Damage ratio of 1 or 100% of SI)

Source: AIR

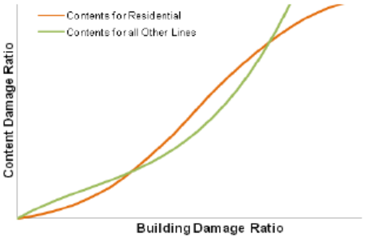


Modelling Damage to Contents

- Contents' damage modelling is challenging
- Claims data for contents damage are more limited than buildings
- Catastrophe models typically have less vulnerability curves for contents than for buildings
- Commercial buildings (offices, hospital) can take large contents losses as they may contain electronic and other valuable equipment

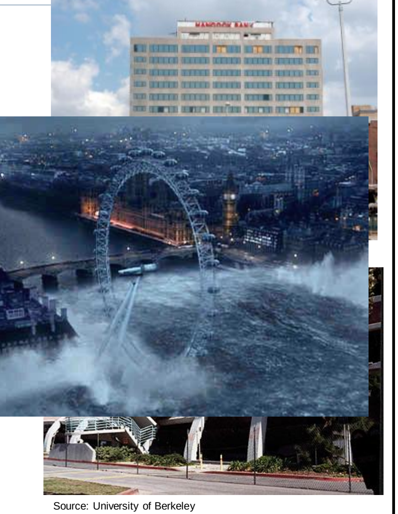
Source: BBC

Source: AIR



Modelling Business Interruption

- Business Interruption can be direct or indirect
  - Direct: Office-space has suffered damages and needs to be repaired
  - Indirect: Access to office is not possible or main supply lines are down
- Hurricane has the potential of making site inaccessible for an extended period of time
- Earthquake BI losses are of very low frequency but have of course the potential of destroying building thus severely impacting operations
- Flood can have a high BI claim potential if flood waters remain in the property for more than 10-12 hours
- Business Interruption is modelled based on simple multiplicative factors on the final loss estimates. Factors depend on return period and are peril specific.

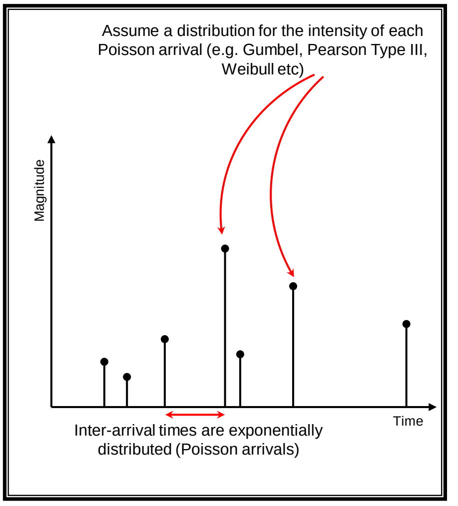


Source: University of Berkeley

The Issue of Event Clustering

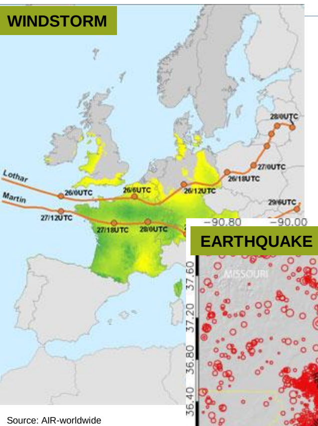
- Group of events occurring over a short time span, affecting a particular geographical region
- Marked Poisson processes are frequently used in statistical modelling of natural phenomena.
- Generalized Extreme Value theory is used and underlying assumptions are made for the distribution of extremes, tails etc.

Example of a marked-Poisson process

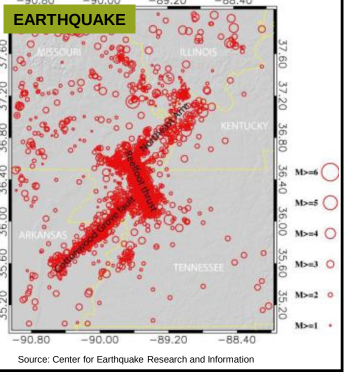


The Issue of Event Clustering (Cont'd)

- The assumption of independence of event arrivals has been challenged as inadequate
- Past historical experience has shown that arrivals of events are not independent
- Most notable windstorm clustering example is Martin and Lothar windstorms in Europe in 1999
- Most notable recent example of Earthquake clustering is the two M>8.5 earthquakes in Sumatra in 2004. (recent quakes in Christchurch New Zealand and Japan?)
- The use of a negative binomial distribution (instead of a Poisson) can capture some of the effect but not effectively



Source: AIR-worldwide

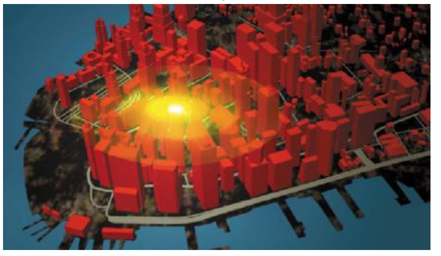


Source: Center for Earthquake Research and Information

Modelling Terrorism Risk

- Terrorism modelling suffers from lack of data
- Most attempts are to identify hotspots – deterministic approach – and then apply a series of scenarios
- Scenario approach more intuitive although vendors provide fully probabilistic models
- WTC attacks have been the defining event for developing these models

Lower Manhattan Blast Impact

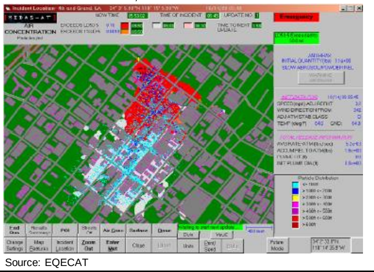


Source: RMS

Exposure Concentration Tool, NY

Source: AIR

Athrax Release Effect, LA

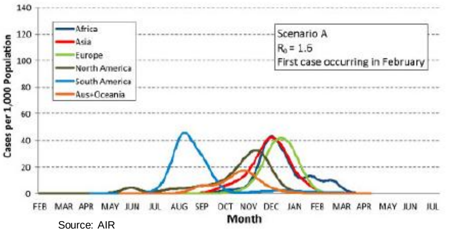


Source: EQECAT

Modelling Pandemic

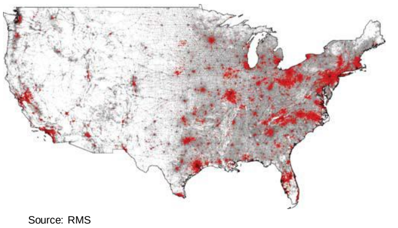
- Pandemic models are usually scenario based models although probabilistic models of typical influenza virus exist.
- H1N1 did not have the typical modelling behaviour of influenza and thus existing models could not be used to calculate losses.
- H1N1 had the potential of having a significant impact on operations.
- Typical BI contracts are triggered by "physical damage". Claims could not be made during the H1N1 pandemic.
- New insurance products are now available to cover for this.

H1N1-like influenza expansion scenarios



Source: AIR

Pandemic modelling – Expansion phase



Source: RMS

IGP-CAT SII

- Industry Good Practices for Catastrophe Modelling and Solvency II (IGP-CAT SII)
  - The initiative was structured around **workshops** on good practices for modelling of catastrophe risk in the context of Solvency II.
  - ABI & FSA acted as a facilitator of the discussion covering the topics:
    1. *Governance around catastrophe modelling*
    2. *The use of third party service providers*
    3. *Catastrophe modelling documentation*
    4. *Use and management of catastrophe model data*
    5. *Model selection and model change policy*
    6. *Options and settings of catastrophe models*
    7. *Catastrophe model validation*
    8. *Multi-modelling approaches*
    9. *Treatment of uncertainty in catastrophe modelling output*
  - FSA will **use the information gathered to inform its review process** of firms' internal models for catastrophe risk.

IGP-CAT SII (Cont'd)

- **All solicited parties accepted the invitation and participated:**

  Facilitators: ABI, FSA

  Cat Vendors*: AIR, EQECAT, RMS*

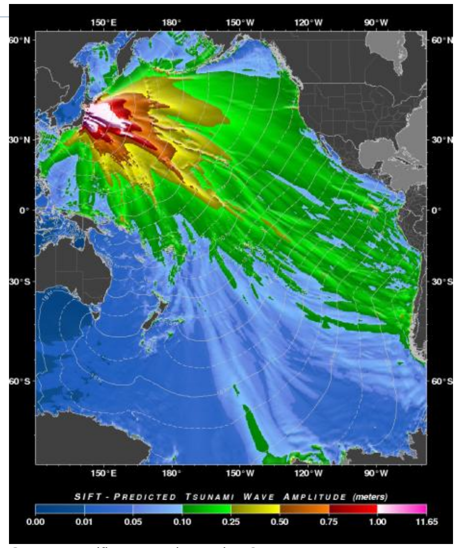
  Reinsurance brokers*: Aon Benfield, Guy-Carpenter, Willis*

  Undertakings: *Allianz, Aviva, Hiscox, Kiln, Lloyd's, Munich Re, RSA*
- **Discussions showed a very good degree of collaboration and openness.**
- **Four day-long meetings of discussions were held, with additional work in sub-groups being done between the workshops.**
- **The outcome was a 60-page document on IGP-CAT SII.**
- The ABI have decided to publish the outcome of the workshops.

FSA restricted

Japan Earthquake and Tsunami

- Devastating Earthquake of 9.0 M off the eastern coast of Honshu on Friday, March 11
- Earthquake was followed by a tsunami impacting the northeast coast of Honshu
- 4 million people resided in the areas impacted by the tsunami
- Area impacted by tsunami accounts for 3% of Japanese GDP
- Nuclear disaster in Fukushima Daiichi was not avoided but the situation was not as disastrous as potentially could have been



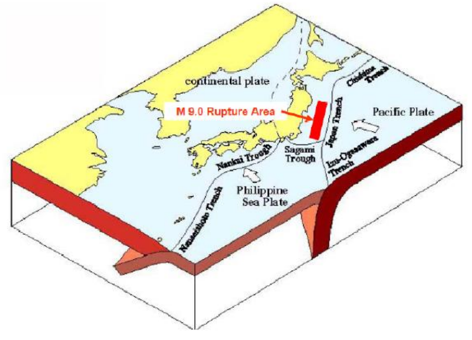
Source: Pacific Tsunami Warning Center

Tsunami Effects

Ishinomaki

Source: GeoEye, Digital Globe, NY Times

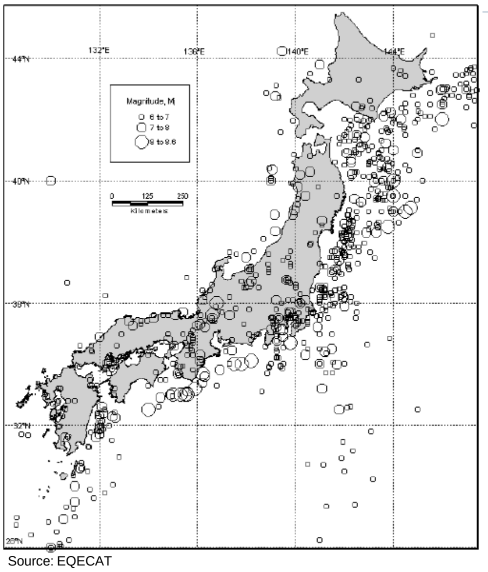
Modelling the Effects of Earthquake



- All commercially available catastrophe models are able to model earthquake
- Earthquake modelling includes the effects of ground-shaking and fire-following earthquake
- Event catalogues of available cat models did not include an event of this magnitude (largest event thought possible was 8.3M)
- Cat modelling vendors had to combine losses from two events to provide their customers with losses from this event

AIR's modeled inland penetration of the tsunami at Ishinomaki, north of Sendai.

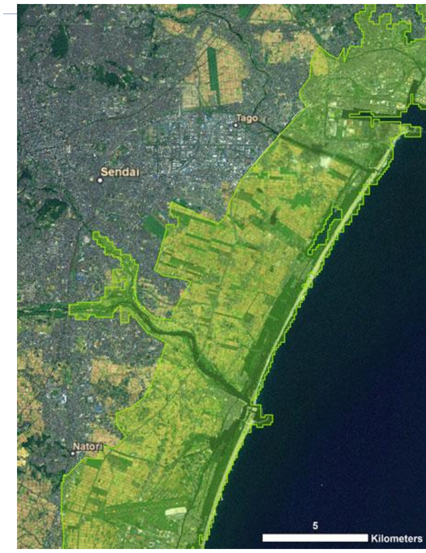
Modelling the Effects of Earthquake (2)



Source: EQECAT

- Historically, the Tohoku earthquake is the largest earthquake in the history of Japan
- Largest earthquakes in history:
  - August 3, 1361 – 8.4M
  - October 28, 1707 – 8.4M
  - December 23, 1854 – 8.4M
  - August 26, 887 – 8.3M
  - November 29, 684 – 8.3M
- Earthquake scale is logarithmic
  - 8.4M and 9M earthquake events are not of about the same intensity

Modelling the Effects of Tsunami

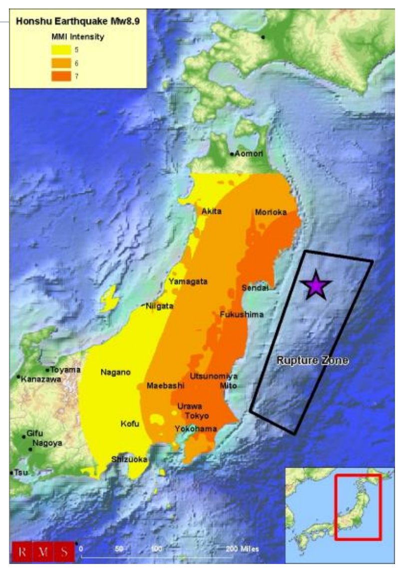


AIR's modeled inland penetration of the tsunami at Ishinomaki, north of Sendai.

- No commercially available catastrophe model exists for tsunami
- Tsunami is extremely difficult to model as it requires high granularity of topography and location of risks
- Besides depth, speed of water is crucial, making modelling the effects of tsunami even more challenging
- Catastrophe modelling vendors have created footprints of the tsunami impact based on satellite images, elevation data, tsunami wave heights and reports of flooded sites.

(Re)Insurance Implications

- Economic losses from event based on EQECAT may exceed $100 billion
- Credit Swiss preliminary estimate of economic loss: $185 billion
- RMS puts economic losses between $200-$300 billion
- Economic losses from Hurricane Katrina were between $120-$150 billion
- Japan earthquake and tsunami will not have a significant impact on the P&C reinsurance industry



Cat Events Financial Impact Comparison

Comparison of losses – Size of economy matters

Event	Estimated Economic Losses	Country GDP	% of GDP	% of insured losses
Chile EQ	**$30 bn**	**$300 bn**	**10%**	**25%**
Christchurch EQ	**$20 bn**	**$120 bn**	**16.7%**	**75%**
Hurricane Katrina US	**$125 bn**	**$13,000 bn**	**0.96%**	**58%**
Japan EQ &TS	**$200 bn***	**$5,500 bn**	**3.63%**	**10%**

- **Japan earthquake is the single most costly event seen globally**
- **Size of the Japanese economy is large**
- **Economy can absorb the event even though take-up rates / coverage of insurance are low**

* Estimate does not include any losses coming as a results of the nuclear accident in the Fukushima Daiichi plant

Insured Losses

- **Insured losses have not settled yet**
- **Current estimates put total insured losses to $20-$40 bn**
  - **Property Losses: $18 - $26 bn**
  - **Life Losses: $3 - $8 bn**
  - **Lloyd's losses: £890 mn**

Questions?

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