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Introduction to Catastrophe Models and Working with their Output

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- Natural Hazard Risk and Cat Models
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- Practical Issues

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Natural Hazard Risk and Cat Models

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Earthquake

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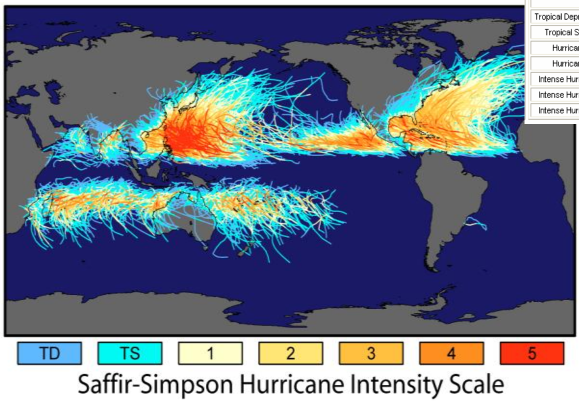
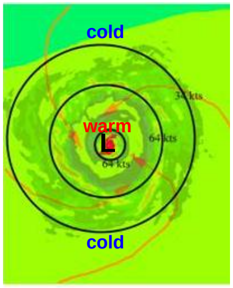
Tropical Cyclone (Hurricane)

Tropical Cyclone Windspeed Scale				
Strength	Category	1 Minute Maximum Sustained Winds		
		knots	mph	km/h
Tropical Depression	TD	<34	<39	<63
Tropical Storm	TS	34-63	39-73	63-118
Hurricane	Cat 1	64-82	74-95	119-153
Hurricane	Cat 2	83-95	96-110	154-177
Intense Hurricane	Cat 3	96-113	111-130	178-210
Intense Hurricane	Cat 4	114-135	131-155	211-250
Intense Hurricane	Cat 5	>135	>155	>250



Source: NASA



Source: NOAA

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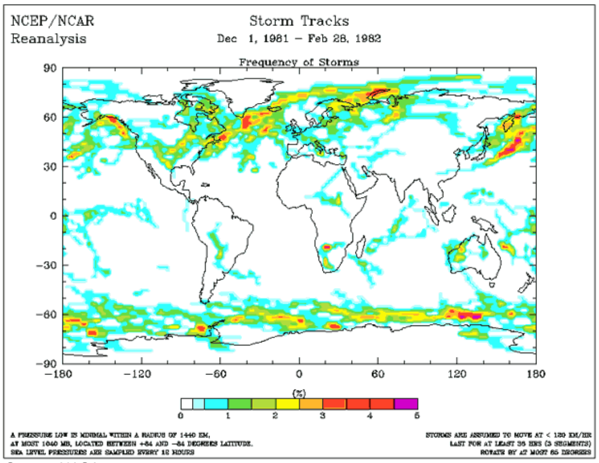
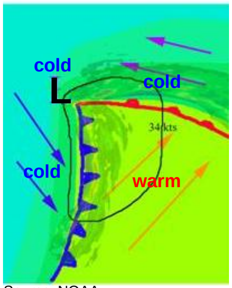
Extra Tropical Cyclone (Windstorm)



Source: NASA



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Windstorm v Hurricane

	Windstorms	Hurricanes
Source of energy	Jet-stream at approximately 8-10km	The sea surface: when temperatures > 26c
Damage distribution	Asymmetric: Right hand side of storm	Symmetrical: All round the storm
Typical scale of damage	200 – 1,000 km	50 – 200 km
Speed of motion of storm	50 – 100 mph	0 – 25 mph
Typical damaging "Longevity"	12 hours – 1 day	1 day – 2 weeks (if remains over sea)
Maximum possible windspeeds	Gusts to 125 mph (c.f. Cat 2 Hurricane)	Gusts to 200 mph (Cat 5 Hurricane)
Typical Latitudes (Northern Hemisphere)	40 – 70 degrees	10 – 30 degrees
Structure	Cold air wraps round into the centre	Warm air in the centre

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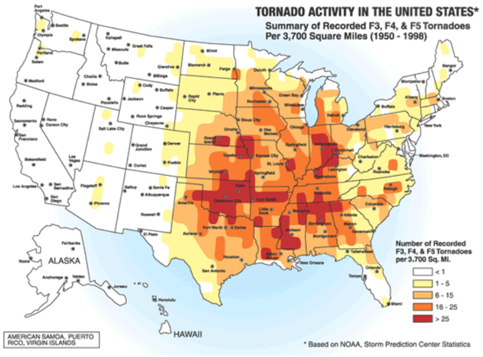
Tornado



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Flood

The town of Tewkesbury on 22 July 2007, and during normal conditions

Hailstorm

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Natural Disasters 80 – 08 - Deadliest

Date	Loss event	Region	Overall losses* (US$m)	Insured losses* (US$m)	Fatalities
26.12.2004	Earthquake, Tsunami	South Asia	10,000	1,000	220,000
29-30.4.1991	Cyclone, storm surge	Bangladesh	3,000	100	139,000
8.10.2005	Earthquake	Pakistan, India	5,200	5	88,000
2-5.5.2008	Cyclone Nargis	Myanmar	4,000		84,500
July-Aug 2003	Heat wave	Europe	13,800	10	70,000
12.05.2008	Eathquake	China	85,000	300	70,000
21.6.1990	Earthquake	Iran	7,100	100	40,000
8-19.12.1999	Flash flood, landslides	Venezuela	3,200	220	30,000
26.12.2003	Earthquake	Iran	500	19	26,200
7.12.1988	Earthquake	Armenia	14,000		25,000

* Original values
As at January 2009

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Natural Disasters 80 – 08 - Costliest

Date	Loss event	Region	Overall losses* (US$m)	Insured losses* (US$m)	Fatalities
25-30.8.2005	Hurricane Katrina	USA	125,000	61,600	1,322
17.1.1995	Earthquake	Japan: Kobe	100,000	3,000	6,430
12.5.2008	Earthquake	China: Sichuan	85,000	300	70,000
17.1.1994	Earthquake	USA: Northridge	44,000	15,300	61
6-14.9.2008	Hurricane Ike	USA, Caribbean	38,000	15,000	168
May - Sep 1998	Floods	China	30,700	1,000	4,159
23.10.2004	Earthquake	Japan: Niigata	28,000	760	46
23-27.8.1992	Hurricane Andrew	USA	26,500	17,000	62
June - Aug 1996	Floods	China	24,000	450	3,048
7-21.9.2004	Hurricane Ivan	USA, Caribbean	23,000	13,800	125

* Original values
As at January 2009

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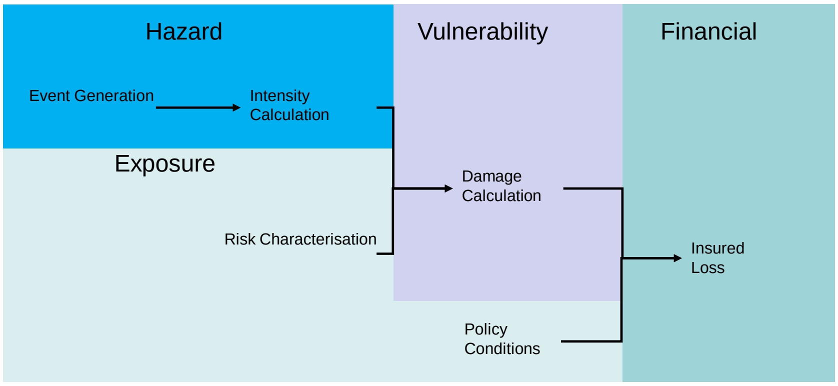
What is a cat model?



Vendor Models

There are a variety of commercial vendor models, the main ones are:

- RMS
- AIR
- EQECAT

Plus broker developed models, usually to complement the vendor models

Simple Cat model output

Event	Freq	Loss
1	0.20	5
2	0.20	10
3	0.10	10
4	0.10	10
5	0.10	20
6	0.10	20
7	0.10	20
8	0.10	50
9	0.10	100
10	0.05	200

Modelled Events　Event Specific　Portfolio Specific

Cat model output is normally provided in a file giving the details of all the events:

- Event Loss Table ("ELT") – RMS terminology
- Event by Event ("EBE") – EQECAT terminology)

Common Measures

The ***Occurence Exceedance Probability ("OEP")*** gives the probability of a loss of a given size or larger in a year.

The ***Annual Exceedance Probability ("AEP")*** gives the probability of total losses in the year of a given size or larger.

Measurement using Simulation

Trial	Loss 1	Loss 2	Loss 3	Total Losses	Max Loss
1				0	0
2	10			10	10
3	15			15	15
4	18			18	18
5	5	5	5	15	5
6	10	10	10	30	10
7	25	20		45	25
8	5			5	5
9	15			15	15
10	10	5		15	10

Example

- 10 trials
- 15 losses
- Total losses and maximum single loss calculated for each trial

Measurement using Simulation: AEP

Trial	Loss 1	Loss 2	Loss 3	Total Losses	Max Loss
7	25	20		45	25
6	10	10	10	30	10
4	18			18	18
3	15			15	15
5	5	5	5	15	5
9	15			15	15
10	10	5		15	10
2	10			10	10
8	5			5	5
1				0	0

Sorted by total losses

- 1 in 10 year aggregate loss = 30

Note strictly we should interpolate to get percentiles, but we haven't done here and in subsequent slides. In the example here 30 is in fact the 85^{th} percentile (1 in 7 year)

Measurement using Simulation: OEP

Trial	Loss 1	Loss 2	Loss 3	Total Losses	Max Loss
7	25	20		45	25
4	18			18	18
3	15			15	15
9	15			15	15
2	10			10	10
6	10	10	10	30	10
10	10	5		15	10
5	5	5	5	15	5
8	5			5	5
1				0	0

Sorted by max loss

- 1 in 10 year event loss = 18

Note the Max Loss gives an approximation to the true OEP – for example, it does not use the information given the 2nd and subsequent largest losses in the year.

Uncertainty in Modelling

Lots of sources of uncertainty in Catastrophe modelling.

One way to classify these uncertainties:

- Primary - “whether or not an event happens and if so how big it will be” (not in terms of loss)
- Secondary - “it is the uncertainty in the amount of loss given that a particular event has occurred”

Secondary Uncertainty in Cat Modelling

Sources of secondary uncertainty include:

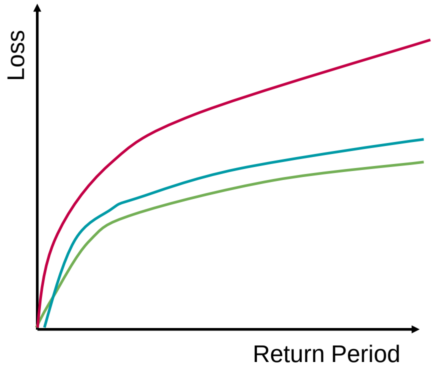
- Hazard Uncertainty (e.g. ground motion attenuation or terrain effects)
- Vulnerability Uncertainty
- Specification Uncertainty (e.g. detail of model)
- Portfolio Data Uncertainty

Secondary Uncertainty in Cat Modelling

Loss amounts normally expressed as distributions and parameters of distribution given for each event – e.g.

- RMS – beta distribution used
- EQECAT – different distributions used for different perils / territories: lognormal, beta or normal
- AIR – no explicit secondary uncertainty

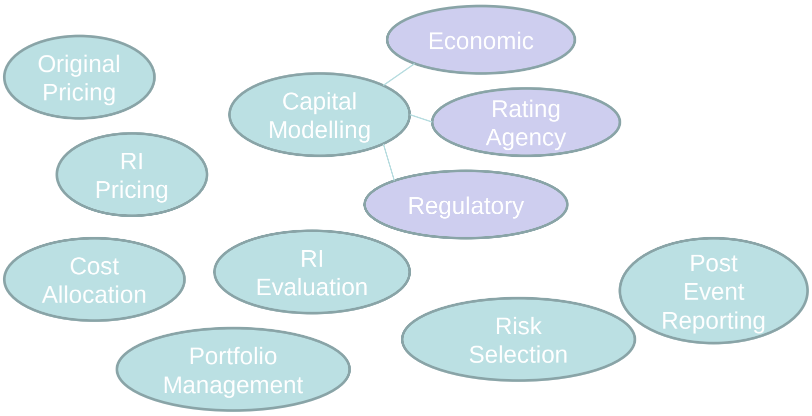
Model results



- Many models, many results…
- Model strengths and limitations
- Performance against historic events?
- Limited data for calibration by modelling companies
  - Access to loss information
  - Industry exposure
- Exposure data limitations?

Applications

Applications



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Practical Issues

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Communication: Return Periods

What is the return period for an event?

- At a specific location or for a region?
- For the hazard or its impact?
- For that specific peril or for any peril?
- For a specific portfolio, a combination of portfolios, or for the industry?
- Gross, reinsurance recovery or net

Communication: Return Periods

	Gross				Recovery 10 xs 10				Net			
Trial	Loss 1	Loss 2	Loss 3	Total	Loss 1	Loss 2	Loss 3	Total	Loss 1	Loss 2	Loss 3	Total
1				0				0				0
2	10			10	0			0	10			10
3	15			15	5			5	10			10
4	18			18	8			**8**	10			10
5	5	5	5	15	0	0	0	0	5	5	5	15
6	10	10	10	**30**	0	0	0	0	10	10	10	30
7	25	20		45	10	10		20	15	10		**25**
8	5			5	0			0	5			5
9	15			15	5			5	10			10
10	10	5		15	0	0		0	10	5		15
		90th percentile		**30**		90th percentile		**8**		90th percentile		**25**

Combining OEPs*

- Two independent OEPs

Return Period	A	B	AB	A+B	AB/A+B
1 in 10 years	12.5	20.8	33.9	33.3	102.0%
1 in 20 years	29.8	38.9	60.9	68.6	88.8%
1 in 25 years	37.7	46.8	71.6	84.5	84.8%
1 in 50 years	67.3	76.1	111.6	143.4	77.9%
1 in 100 years	108.3	116.1	156.0	224.4	69.5%
1 in 150 years	130.8	145.0	187.9	275.8	68.1%
1 in 200 years	146.9	166.1	211.4	312.9	67.6%
1 in 250 years	160.9	182.6	229.7	343.5	66.9%
1 in 500 years	222.1	238.1	281.4	460.2	61.2%
1 in 1,000 years	272.1	289.8	323.2	561.9	57.5%

Significant diversification, increasing towards tail

* Different perils, portfolios or regions

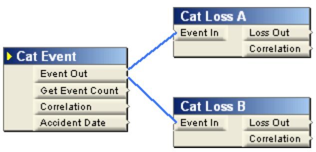
Combining OEPs

- Two linked OEPs with severe tails

Return Period	A	B	AB	A+B	AB/A+B
1 in 10 years	0.0	-	0.0	0.0	102.5%
1 in 20 years	0.5	-	0.5	0.5	108.2%
1 in 25 years	0.9	-	1.0	0.9	109.6%
1 in 50 years	4.4	-	5.9	4.4	132.0%
1 in 100 years	14.7	0.0	26.4	14.8	178.6%
1 in 150 years	25.9	4.4	54.2	30.3	178.7%
1 in 200 years	36.0	20.2	80.9	56.1	144.1%
1 in 250 years	45.3	41.2	105.2	86.6	121.6%
1 in 500 years	80.4	146.5	210.6	226.9	92.8%
1 in 1,000 years	135.4	290.6	359.7	426.1	84.4%

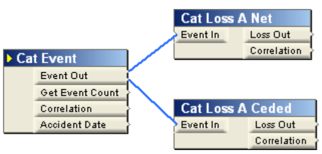
Catastrophic sub-additivity failure

Combining Secondary Uncertainty



Separate portfolios

- Need to capture secondary uncertainty correlation implied by cat model
- > 0% but less than 100%



Split portfolio

- Losses arise from the same original risks
- Suggests secondary uncertainty correlation of 100% (or close to)

Risk Appetite / RI buying

- Can lead to potential misunderstanding of reinsurance buying policies
- Buying to a given loss return period:
  - By peril, by region?
  - All perils, by region?
  - All perils, all regions?
- Managing net aggregate risk appetite

Risk Appetite / RI buying - Example

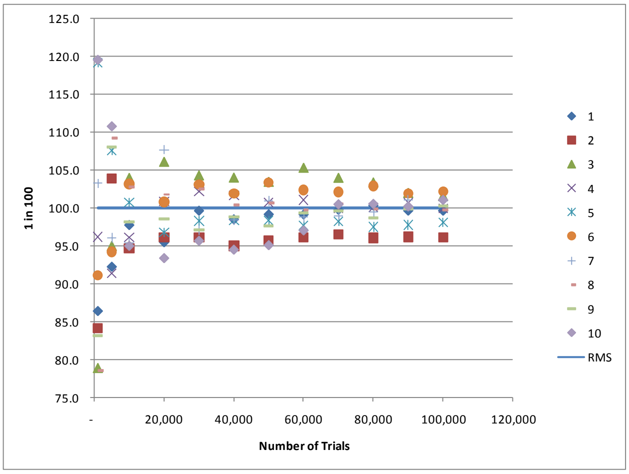
- Reinsurance attaches at £20m with limit up to 1 in 200
- Internal expectation that a 1 in 200 event will cost £20m
- But exposure to many perils all protected to 1 in 200
- 1 in 200 net aggregate loss could be many times expected £20m

	Gross OEP			Net OEP			Net AEP		
Return Period	A	B	AB	A	B	AB	A	B	AB
1 in 10 years	12.5	20.8	34.1	12.5	20.0	20.0	13.9	22.5	27.6
1 in 20 years	29.8	38.9	60.9	20.0	20.0	20.0	20.0	26.8	35.4
1 in 25 years	37.8	46.5	71.6	20.0	20.0	20.0	20.1	28.5	38.3
1 in 50 years	67.3	76.3	112.0	20.0	20.0	20.0	23.7	35.4	45.9
1 in 100 years	108.2	116.5	156.1	20.0	20.0	20.0	31.8	42.8	57.1
1 in 150 years	130.4	144.4	188.4	20.0	20.0	50.2	38.9	47.0	69.5
1 in 200 years	146.8	166.0	211.4	20.0	20.0	74.2	40.4	52.0	86.7
1 in 250 years	160.8	182.9	229.5	33.8	37.1	92.8	45.8	57.7	104.7
1 in 500 years	221.5	237.7	279.6	94.5	91.7	143.5	98.5	100.0	157.2
1 in 1,000 years	271.4	287.6	323.0	144.4	141.6	187.2	148.4	151.0	202.2

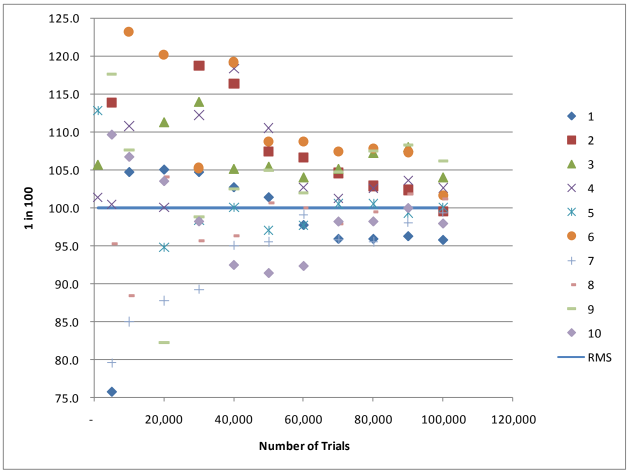
Convergence

- The DFA result will contain ‘stochastic error’, important to ensure sufficient simulations are run:
  - Compare to output from vendor models, both as a check on convergence and that the correct ELTS are being used
  - No set rules for number required, will depend on:
    - Peril
    - Simulation technique used (e.g. use of Latin Hypercube?)

Convergence - WSSS

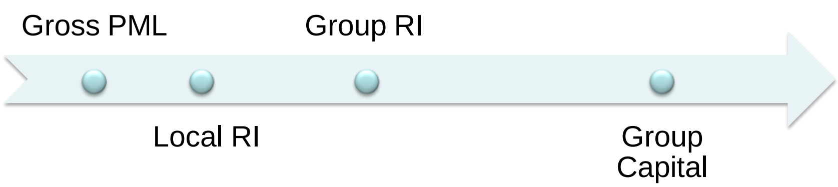


Convergence - EQ



Convergence

- Practical constraints limit the number of trials possible



Considerations for Integration in ICAS

- Which catastrophe model should be used? Are adjustments required?
  - Are all natural catastrophe exposures covered?, e.g. dam burst in UK or Ireland river flood
  - UK River Flood hours clause treatment
- Are all losses in the company from the same event linked?
- Are results from the capital model consistent with original cat model output?

Embedding the Capital Model

- Reinsurance value analysis
- Reinsurance premium allocation
- Technical pricing

Risk Selection and Underwriting

- Output from models can be used to support underwriting
- Can identify areas that have high exposure to natural perils,
  - reduces risk as measured by the model but,
  - some models do not have the required level of granularity or credibility – especially true in “emerging” markets.
  - can conflict with internal view of risk.

Rating Agency Considerations

Agency	Return Period	Gross / Net	Annual / OEP	Individual / Aggregate
S&P Model	1 in 250 only	Gross with associated reinsurance	Annual	Aggregate
AM Best	Greater of 1 in 100 WS and 1 in 250 EQ + 2nd loss greater of 1 in 100 WS and 1 in 100 EQ	Gross and net independent	OEP (and TVaR)	Wind and quake separate. TVaR is aggregate.
Fitch	Various 1 in 10 to 1000	Gross and net independent	Annual	Aggregate

Other issues

- Clustering / Seasonality
- Climate Change
- Post Loss Amplification

Summary

Summary – "Getting the balance right"

Cat models…

- have enormous influence in our industry
- are complex and not well understood
- results can be misinterpreted and misused

Important to understand issues and moderate their influence on decision making