Fundamentals of Catastrophe Modeling

CAS Ratemaking & Product Management Seminar
Catastrophe Modeling Workshop
March 15, 2010

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Fundamentals of Cat Modeling

Example of cat modeling terminology:

"The Company's 100-year return period loss shall be derived from results produced by Version 6.0 catastrophe modeling software, using near term perspective, but no demand surge or secondary uncertainty."

"It would be so nice if something made sense for a change."
– Alice, from Lewis Carroll's, Alice's Adventures in Wonderland

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Fundamentals of Cat Modeling

"Prediction is very hard – especially when it's about the future"
– Yogi Berra

Agenda

- What is a catastrophe model?
- Why use cat models?
- How cat models work
- Cat model inputs
- Cat model outputs & analytics
- Considerations/adjustments

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What Is a Catastrophe Model?

A computerized system that generates a robust set of simulated events and:

- Estimates the magnitude/intensity and location
- Determines the amount of damage
- Calculates the insured loss

Cat models are designed to answer:

- Where future events can occur
- How big future events can be
- Expected frequency of events
- Potential damage and insured loss

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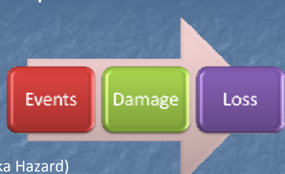
Three Components of a Catastrophe Model



- Events (aka Hazard)
  - Stochastic event set
  - Intensity calculation
  - Geocoding & geospatial hazard data
- Damage (aka Vulnerability)
  - Structural damage estimation
- Loss (aka Financial Model)
  - Insurance and reinsurance loss calculation

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Types of Perils Modeled within the P&C Industry

Natural Catastrophes:

- Hurricane
- Earthquake – Shake & Fire Following
- Tornado / Hail
- Winter storms (snow, ice, freezing rain)
- Flood
- Wild Fire

Man-Made Catastrophes:

- Terrorism

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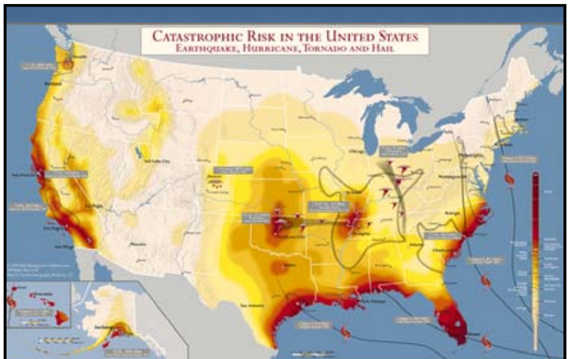

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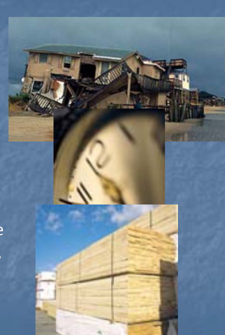
Types of Losses Modeled

- Direct
  - Physical damage to buildings, outbuildings, and contents (coverages A, B, C)
  - Work Comp; deaths, injuries
- Indirect
  - Loss of use
  - Additional Living Expense
  - Business Interruption
- Loss Amplification / Demand Surge
  - For large events, higher materials, labor and repair delays
  - Residual demand surge



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Uses of Catastrophe Models

Primary Metrics:
- Average Annual Loss (AAL): Expected Loss
- Probable Maximum Loss (PML)/Exceedance Probability (EP)

Potential Uses:
- Ratemaking (rate level and rating plans)
- Portfolio management & optimization
- Underwriting/risk selection
- Loss mitigation strategies
- Allocation of cost of capital, cost of reinsurance
- Reinsurance/risk transfer analysis
- Enterprise risk management
- Financial & capital adequacy analysis (rating agency)

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Advantage of Cat Models

Catastrophe models provide comprehensive information on current and future loss potential.

- Modeled Data:
  - Large number of simulated years creates a comprehensive distribution of potential events
  - Use of current exposures represents the latest population, building codes and replacement values
- Historical Data:
  - Historical experience is not complete or reflective of potential due to limited historical records, infrequent events, and potentially changing conditions
  - Historical data reflects population, building codes, and replacement values at time of historical loss.
  - Coastal population concentrations and replacement costs have been rapidly increasing.

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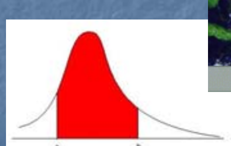
How Cat Models Work

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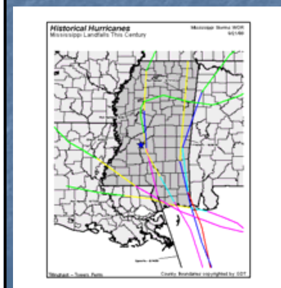
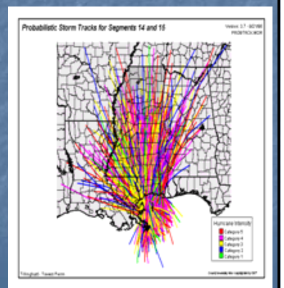
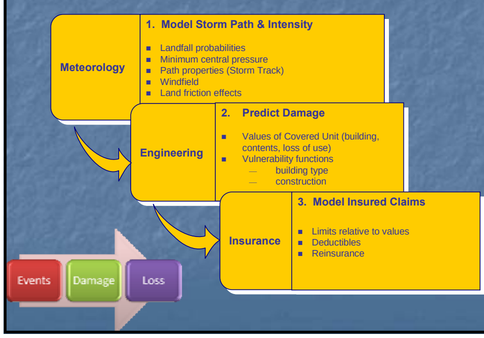
Catastrophe Modeling Process

Historical event information is used.... to create a robust set of events.





Catastrophe Modeling Process - Hurricane



Cat Model Input

High Quality Exposure Information Is Critical

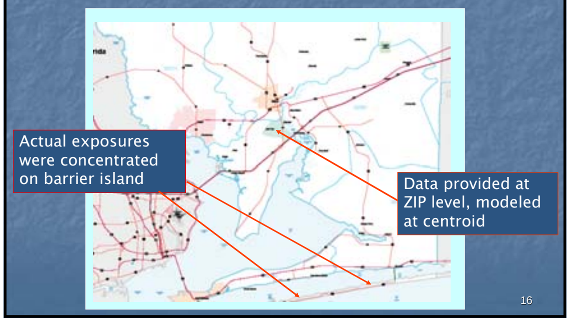
Examples of key exposure detail:

- Replacement value (not coverage limit)
- Street address (location)
- Construction
- Occupancy

The model can be run without policy level detail or other location specific attributes, but the more detail the better.

Cat Model Input

Example: Policy level vs. ZIP aggregate



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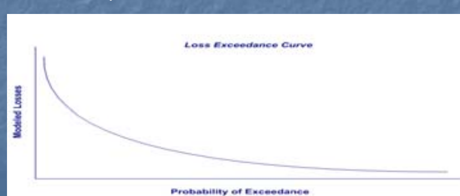
Cat Model Output

Model results are expressed as a distribution of probabilities, or the likelihood of various levels of loss.

- Event-by-event loss information
- Probability distribution of losses



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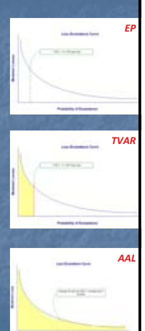
Analysis
EP
TVAR
AAL

Cat Model Output

Modeled loss distributions can be used for a wide variety of analysis, including:

- Exceedance Probability (EP) *a.k.a. PML*
  - Occurrence
  - Aggregate
- Tail Value at Risk (TVAR)
- Average Annual Loss (AAL)



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Exceedance Probability (EP)

Analysis
EP
TVAR
AAL

Exceedance Probability:
Probability that a certain loss threshold is exceeded.

- The analysis also known as Probable Maximum Loss (PML)
- Most common analysis type used
- Curve shows the probability of exceeding various loss levels
- Used for portfolio management and reinsurance buying decisions

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Occurrence EP calculation

Analysis
EP
TVAR
AAL

Pulled From Event Table → EVENTID, Frequency, Loss
$1 - e^{(-Rate)}$ → Probability
1 - Prob → Probability of Non Occurrence
$P_1 * P_2 * P_3 \ldots$ → Probability of Non Exceedance
1/(1- Prob Non-Exceed) → Return Time

EVENTID	Frequency	Loss	Probability	Probability of Non Occurrence	Probability of Non Exceedance	Return Time
440342	0.00003961	$58,639,127	0.000040	0.999960	0.999960	25,247
440886	0.000020668	$47,522,356	0.000021	0.999979	0.999921	12,624
440032	0.00003961	$38,446,768	0.000040	0.999960	0.999900	10,012
438477	0.000011779	$38,132,441	0.000012	0.999988	0.999861	7,169
441153	0.000015183	$35,186,472	0.000015	0.999985	0.999849	6,611
437848	0.000037957	$35,172,216	0.000038	0.999962	0.999834	6,008
440465	0.000015356	$32,355,961	0.000015	0.999985	0.999796	4,892
...	...	...	...	...	...	...
438740	0.000015875	$7,615,676	0.000016	0.999984	0.995056	202
439334	0.000037957	$7,580,918	0.000038	0.999962	0.995040	202
444785	0.000011547	$7,564,402	0.000012	0.999988	0.995003	200
440905	0.00003876	$7,489,443	0.000039	0.999961	0.994991	200
444490	0.000015056	$7,468,328	0.000015	0.999985	0.994953	198
440247	0.000039453	$7,457,007	0.000039	0.999961	0.994938	198
439578	0.000014681	$7,391,786	0.000015	0.999985	0.994898	196
...	...	...	...	...	...	...

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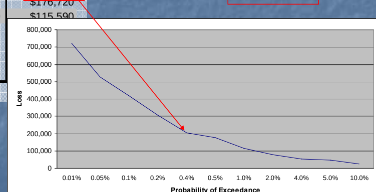
Occurrence EP

Analysis
EP
TVAR
AAL

Probability of Non-Exceed	Avg Return Time (Years)	OEP (000s)
99.99%	10,000	$722,725
99.95%	2,000	$528,513
99.90%	1,000	$419,679
99.80%	500	$307,386
99.60%	250	$203,773
99.50%	200	$176,720
99.00%	100	$115,590
98.00%	50	
96.00%	25	
95.00%	20	
90.00%	10	

This company has a 0.4% chance of experiencing a loss of $204M <u>or</u> higher



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Exceedance Probability

Return Period Terminology

"250-year return period EP loss is $204M"

- Correct terminology
  - "The $204M loss represents the 99.6 percentile of the annual loss distribution"
  - "The probability of exceeding $204M in one year is 0.4%"
- Incorrect terminology
  - It does not mean that there is a 100% probability of exceeding $204M over the next 250 years
  - It does not mean that 1 year of the next 250 will have loss ≥ $204M

Note: Return Periods are single year probabilities

Exceedance Probability

Occurrence vs Aggregate

Occurrence Exceedance Probability (OEP)

- Event loss
- Provides information on losses assuming a single event occurrence in a given year
- Used for occurrence based structures like quota share, working excess, etc.

Aggregate Exceedance Probability (AEP)

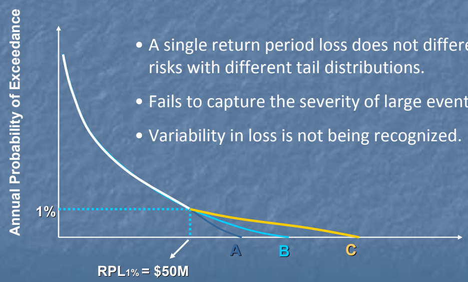
- Annual loss
- Provides information on losses assuming one or more occurrences in a year
- Used for aggregate based structures like stop loss, reinstatements, etc.
- AEP ≥ OEP

OEP vs. AEP

Probability of Non-Exceed	Avg Return Time (Years)	AEP [1] (000s)	OEP [2] (000s)	Impact [2] vs. [1] % Change
99.99%	10,000	$736,485	$722,725	-1.9%
99.95%	2,000	$540,121	$528,513	-2.1%
99.90%	1,000	$430,857	$419,679	-2.6%
99.80%	500	$318,322	$307,386	-3.4%
99.60%	250	$215,240	$203,773	-5.3%
99.50%	200	$188,344	$176,720	-6.2%
99.00%	100	$126,574	$115,590	-8.7%
98.00%	50	$87,128	$78,449	-10.0%
96.00%	25	$58,750	$52,776	-10.2%
95.00%	20	$50,913	$45,750	-10.1%
90.00%	10	$29,064	$26,161	-10.0%

The "Problem" with EP as a Risk Metric

Analysis
EP
TVAR
AAL



- A single return period loss does not differentiate risks with different tail distributions.
- Fails to capture the severity of large events.
- Variability in loss is not being recognized.

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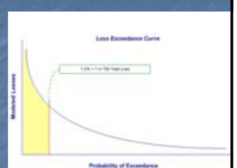
Tail Value at Risk (TVAR)

Analysis
EP
TVAR
AAL

Tail Value at Risk (TVAR):

Average value of loss above a selected EP return period.



- Tail Value at Risk (TVaR) also known as Tail Conditional Expectation (TCE)
- Example:
  - 250-year return period loss equals $204 million
  - TVAR is $352 million
  - Interpretation: "There is a 0.4% annual probability of a loss exceeding $204 million. Given that at least a $204M loss occurs, the average severity will be $352 million."
- TVAR measures not only the probability of exceeding a certain loss level, but also the average severity of losses in the tail of the distribution.

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Tail Value at Risk (TVAR)

Analysis
EP
TVAR
AAL

Probability of Non-Exceed	Avg Return Time (Years)	TCE (000s)	OEP (000s)
99.99%	10,000	$807,006	$722,725
99.95%	2,000	$646,019	$528,513
99.90%	1,000	$556,503	$419,679
99.80%	500	$456,362	$307,386
99.60%	250	$351,867	$203,773
99.50%	200	$319,354	$176,720
99.00%	100	$229,728	$115,590
98.00%	50	$161,737	$78,449
96.00%	25	$112,859	$52,776
95.00%	20	$100,233	$45,750
90.00%	10	$67,927	$26,161

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Average Annual Loss (AAL)

Analysis
EP
TVAR
AAL

Average Annual Loss:
Average loss of the entire loss distribution

- "Area under the curve"
- Pure Premium
- Used for pricing and ratemaking
- Can be calculated for the entire curve or a layer of loss
- Also called catastrophe load or technical premium
- Estimate of the amount of premium required to balance catastrophe risk over time.
- The amount of premium needed on average to cover losses from the modeled catastrophes, excluding profit, risk, non-cats, etc.
- By-product of the EP curve

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Average Annual Loss
Occurrence EP calculation

Analysis
EP
TVAR
AAL

Pulled From Event Table → EVENTID, Frequency, Loss
$1 - e^{(-Rate)}$ → Probability
1 - Prob → Probability of Non Occurrence
$P_1 * P_2 * P_3 \ldots$ → Probability of Non Exceedance
1/(1- Prob Non-Exceed) → Return Time
Rate * Loss → AAL
∑ AAL → Total AAL

EVENTID	Frequency	Loss	Probability	Probability of Non Occurrence	Probability of Non Exceedance	Return Time	AAL	Total AAL
440342	0.00003961	$58,639,127	0.000040	0.999960	0.999960	25,247	$2,322.70	$376,113.19
440886	0.000020668	$47,522,356	0.000021	0.999979	0.999921	12,624	$982.19	
440032	0.00003961	$38,446,768	0.000040	0.999960	0.999900	10,012	$1,522.88	
438477	0.000011779	$38,132,441	0.000012	0.999988	0.999861	7,169	$449.16	
441153	0.000015183	$35,186,472	0.000015	0.999985	0.999849	6,611	$534.24	
437848	0.000037957	$35,172,216	0.000038	0.999962	0.999834	6,008	$1,335.03	
440465	0.000015356	$32,355,961	0.000015	0.999985	0.999796	4,892	$496.86	
...	...	...	...	...	...	...	...	
438740	0.000015875	$7,615,676	0.000016	0.999984	0.995056	202	120.89886	
439334	0.000037957	$7,580,918	0.000038	0.999962	0.995040	202	287.74891	
444785	0.000011547	$7,564,402	0.000012	0.999988	0.995003	200	87.346155	
440905	0.00003876	$7,489,443	0.000039	0.999961	0.994991	200	290.2908	
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440247	0.000039453	$7,457,007	0.000039	0.999961	0.994938	198	294.2013	
439578	0.000014681	$7,391,786	0.000015	0.999985	0.994898	196	108.51882	
...	...	...	...	...	...	...	...	

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Summary Report (Sample)

Probability of Non-Exceed	Avg Return Time (Years)	AOP (000s)	OEP (000s)	Impact [2] vs. [1] % Change
99.99%	10,000	$736,485	$722,725	-1.9%
99.95%	2,000	$540,121	$528,513	-2.1%
99.90%	1,000	$430,857	$419,679	-2.6%
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98.00%	50	$87,128	$78,449	-10.0%
96.00%	25	$58,750	$52,776	-10.2%
95.00%	20	$50,913	$45,750	-10.1%
90.00%	10	$29,064	$26,161	-10.0%
Portfolio Summary				
Insurance In Force (000s)		$6,097,908	$6,097,908	0.0%
Premium In Force (000s)		$41,694	$41,694	0.0%
Risk Count		21,697	21,697	0.0%
Average Annual Loss & Ratios				
Average Annual Loss		$10,231,100	$10,231,100	0.0%
PML:Premium - 100 year		3:1	2.8:1	
PML:Premium - 250 year		5.2:1	4.9:1	
Loss Ratio (%)		24.5%	24.5%	
Loss Cost (%)		0.168%	0.168%	

PML/Premium ratios can be used as a relative risk measure.

This company should expect around $10M in losses each year.

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Considerations/Adjustments

- Actuarial Standard of Practice 38
- Warm Sea Surface Temperatures (WSST)
- Demand Surge
- Storm Surge
- Secondary Uncertainty
- Misc. (Sea Surface Temperature, Variance, Model Selection)

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Considerations
ASOP 38
WSST
DS
SS
SU
Misc.

Actuarial Standard of Practice (ASOP) 38

ASOP 38: Using Models Outside the Actuary's Area of Expertise

Five key responsibilities:

1) Determine appropriate reliance on experts
2) Have a basic understanding of the model
3) Evaluate whether the model is appropriate for the intended application
4) Determine that appropriate validation has occurred
5) Determine the appropriate use of the model

"The model said so" is not sufficient

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Considerations
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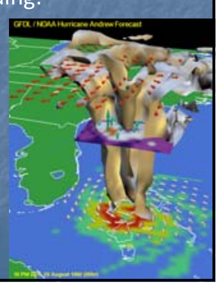
Warm Sea Surface Temperature

There are many mechanisms that influence Atlantic Hurricane activity, including:

- Atlantic sea surface temperatures
- El-Niño; Vertical wind shear (ENSO)
- Upper atmosphere winds (QBO)
- Atlantic pressure distribution (NAO; Bermuda High)



Considerations
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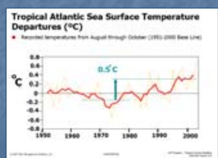
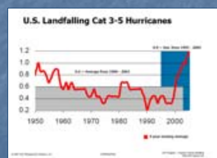
Misc.

Warm Sea Surface Temperature

There has been a historical correlation between Atlantic Sea Surface temperatures and the frequency and intensity of hurricane landfalls in the United States.

- Modelers use different terminology to represent: Near-Term, Medium-Term, Warm Sea Surface, Prospective Frequency





Note: Models are probabilistic, they are not prediction models.

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Considerations
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Misc.

Demand Surge

Demand Surge:

A sudden and usually temporary increase in the cost of materials, services, and labor due to the increased demand following a catastrophe.

Also referred to as Loss Amplification.

Sources of demand surge

- Cost of materials: supply shortages; demand > supply; potential price gouging
- Labor: limited labor in impacted area leads to labor shortage; imported labor is expensive (travel & housing costs – limited housing available) & not familiar with local building codes
- Services: pressure on transportation, warehousing and packaging

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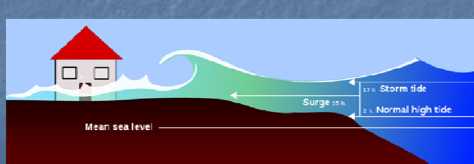
SU
Misc.

Storm Surge

Storm Surge:

Rising sea surface due to hurricane winds

- Amount of surge impacted by intensity of winds (stronger winds = more surge) and depth of offshore water (shallower = more surge)
- Katrina generated a 27-foot storm tide in Mississippi



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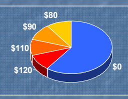
Secondary Uncertainty

Secondary Uncertainty:

Uncertainty in the size of loss, given that a specific event has occurred.



Payout is $0 or a range between $80 and $120. The uncertainty in amount (given a payout) is the secondary uncertainty.

Identical events can cause different amounts of loss, resulting in a range of possible values with different probabilities.

Primary Uncertainty:

Uncertainty around the occurrence or non-occurrence of unknown events.

Secondary Uncertainty
What does it look like in a real event?

Secondary Uncertainty

Probability of Non-Exceed	Avg Return Time (Years)	[1] w/Sec Unc. (000s)	[2] w/o Sec Unc. (000s)	Impact [2] vs. [1] % Change
99.99%	10,000	$722,725	$655,641	-9.3%
99.95%	2,000	$528,513	$510,665	-3.4%
99.90%	1,000	$419,679	$383,027	-8.7%
99.80%	500	$307,386	$301,641	-1.9%
99.60%	250	$203,773	$184,426	-9.5%
99.50%	200	$176,720	$159,126	-10.0%
99.00%	100	$115,590	$101,876	-11.9%
98.00%	50	$78,449	$70,866	-9.7%
96.00%	25	$52,776	$46,609	-11.7%
95.00%	20	$45,750	$40,613	-11.2%
90.00%	10	$26,161	$25,632	-2.0%

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Variance

The amount of variance is important to consider in order to gauge the relative riskiness.

Measures:

Standard Deviation (SD)

- Measure of volatility around a number
- Measured in same currency
- Example: 100-year EP of $100M, SD of $300M
- Cannot compare the SD of one analysis to the SD of another

Coefficient of Variation (CV or COV)

- Standard Deviation ÷ Mean
- The larger the CV, the greater the variability around the mean loss
- CV has no "units" (better than using SD for comparison purposes)
- "Secondary Uncertainty" in the size of a loss

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Considerations
ASOP 38
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Other Considerations

Missing pieces of loss estimates…

- inconsistent claims adjusting (1 vs. 100s vs. 1000s of claims)
- inconsistent claims paying practices (flood vs. surge, whole vs. part)
- loss adjustment expense
- legal and regulatory environment
- others…

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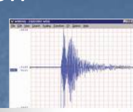
Considerations
ASOP 38
WSST
DS
SS
SU
Misc.

Model Selection

It is important to consider several factors when considering which models to use (vendors/perils):

- Market share / acceptance
- Ease of use
- Corporate cat management plans
- Underwriting guidelines
- Reinsurance buying history
- Peril / geographic coverage
- The "Best" answer



Risk Management Solutions RMS

EQECAT

AIR WORLDWIDE

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Modeling Terminology

"The Company's 100-year return period loss shall be derived from results produced by Version 6.0 catastrophe modeling software, using near term perspective, but no demand surge or secondary uncertainty."

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Fundamentals of Cat Modeling Summary

- Cat models provide more comprehensive information on current and future loss potential than historical data.
- High quality exposure information is critical
- Modeled output can be used for a variety of metrics/analytics, including:
  - EP/PML
  - TVAR
  - AAL
- Important to consider issues such as: projected sea surface temperature, demand surge, storm surge, secondary uncertainty, etc.

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