

JAMES MARTIN 21ST CENTURY SCHOOL

# Adventures in Outcome Space

THE EXPANDING ROLE OF THE ACTUARY IN CATASTROPHE  
LOSS ESTIMATION AND MANAGEMENT

ICA 2014

Washington DC

April 3<sup>rd</sup> 2014

Peter Taylor

# In brief ...

- We'd like single numbers, single EP Curves and simple distributions

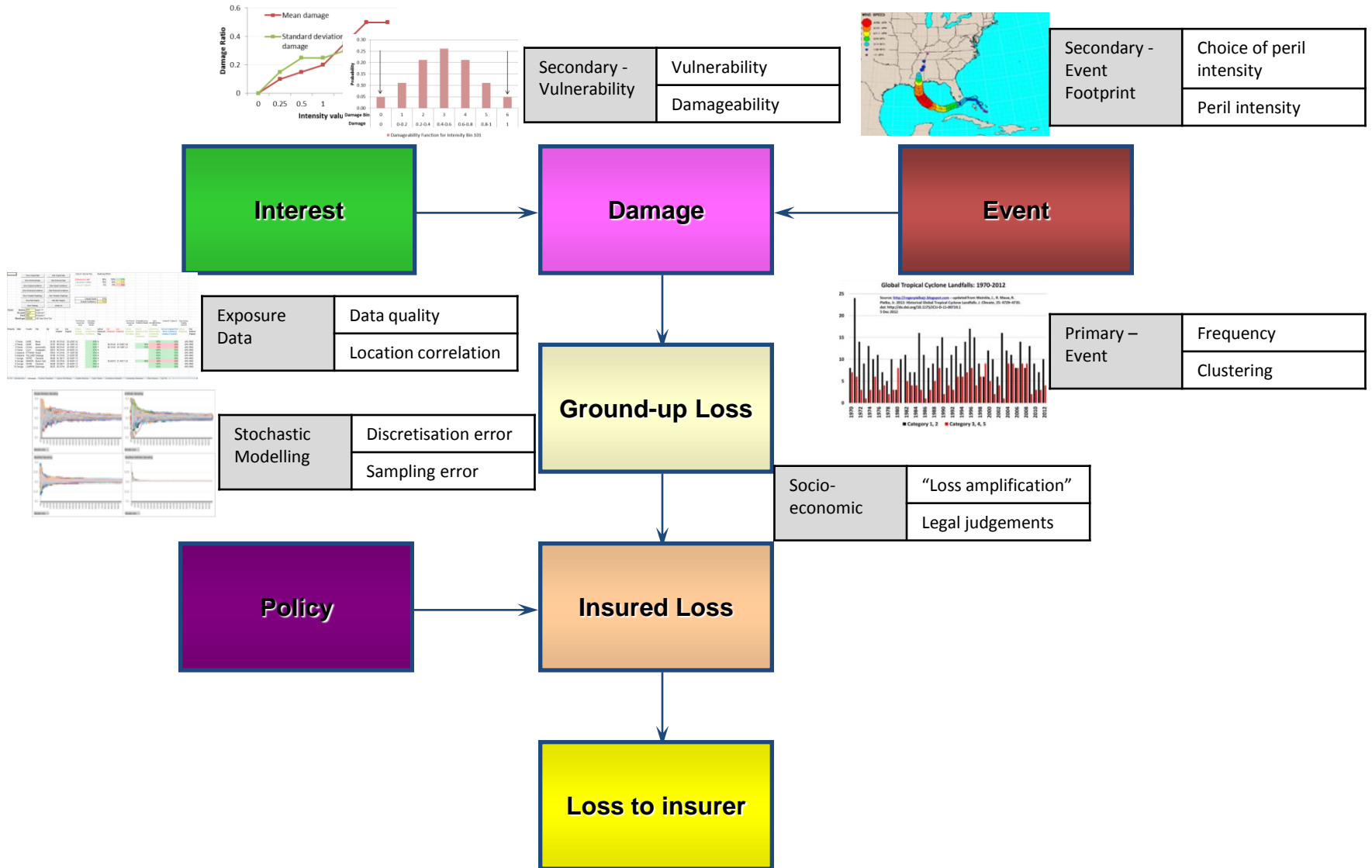
BUT

- We find many dimensions, EP sheaves, and multi-modal distributions

AND

- This gives us new ways to price and set capital

# Uncertainties in a Cat Loss Model



# Model Building Checklist

- Events ...
- Event Frequencies ...
- Event Footprints ...
- Intensity Vulnerabilities ...
- Damage Functions ...
- Discretisation ...
- Sampling ...
- Policy T&Cs ...

How defined?  
Basis of values?  
Validation?

Why these  
values?

How done?

*and all for those pesky exposure data*

# Variants of EP Curves

- EP of Means
  - Take all the mean losses and rank order them across Years simulated
- Full EP
  - Take all samples of losses and rank order them across Years\*Samples
- EP of Wheatsheaf Means
  - Take the means by return period of all the individual rank-ordered samples



# Toy Model



<http://www.bathsheba.com/sculpt/>

# Toy Model

- Illustrative Excel model of “splat” events with probabilistic intensity and vulnerability
- Exposures can be set with clustering or not
- Financial Module example is for location deductibles and overall policy limit, excess, and share



# Toy Model – Dictionaries

ToyModel\_v7 - Microsoft Excel

PerilName: Flood

Model: Toy Model    Area: 10x10 Grid    Peril: Flood

In this simple model, we define a grid of a world 10 by 10 for a given peril

	1	2	3	4	5	6	7	8	9	10
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										

Index	From	To	Interval
1	0	0	()
2	0	1	()
3	1	2	()
4	2	3	()
5	3	4	()
6	4	5	()
7	5	6	()
8	6	7	()
9	7	8	()
10	8	9	()
11	9	10+	()

Index	From	To	Interval
1	0	0	()
2	0	0.1	()
3	0.1	0.2	()
4	0.2	0.3	()
5	0.3	0.4	()
6	0.4	0.5	()
7	0.5	0.6	()
8	0.6	0.7	()
9	0.7	0.8	()
10	0.8	0.9	()
11	0.9	1	()
12	1	1	()

AreaPerilID	Cell
1	(1:1)
2	(1:2)
3	(1:3)
4	(1:4)
5	(1:5)
6	(1:6)
7	(1:7)
8	(1:8)
9	(1:9)
10	(1:10)
11	(2:1)
12	(2:2)
13	(2:3)
14	(2:4)

Introduction    **Reference Dictionaries**    Event Generator    Vulnerability Generator    Exposure Generator    Financials    DictAreaPeril    DictEvent    DictHazardIntensit

Ready    80%

# Toy Model – Event

ToyModel\_v7 - Microsoft Excel

In this spreadsheet we identify "Events". These are defined as occurring in a certain time (e.g. day) with maximum intensity that can be used to cause damage via Vulnerability functions.

To define an "Event" we must define the frequency in some form (e.g. assign a notional year) a footprint (the area extent) and the intensity "bins" which are the distributions of intensity at a given area for a given peril (termed AreaPeril).

We can generate an illustrative Event by using random numbers for locations and for intensity and then set the footprint size based on the intensity:

EventID: 1 Name: Flood 10x10 Ref: 1 X-co-ord: 8 -ord: 8 Intensity: 9 (max 10) Year Range: 1 to 1,000 Year: 12

Recalculate

Events: 100 Generate Events and Footprints

Event randomly located onto the AreaPeril grid

Choice of intensity distribution function

Randomly Generated Event Footprint (irrespective of location)

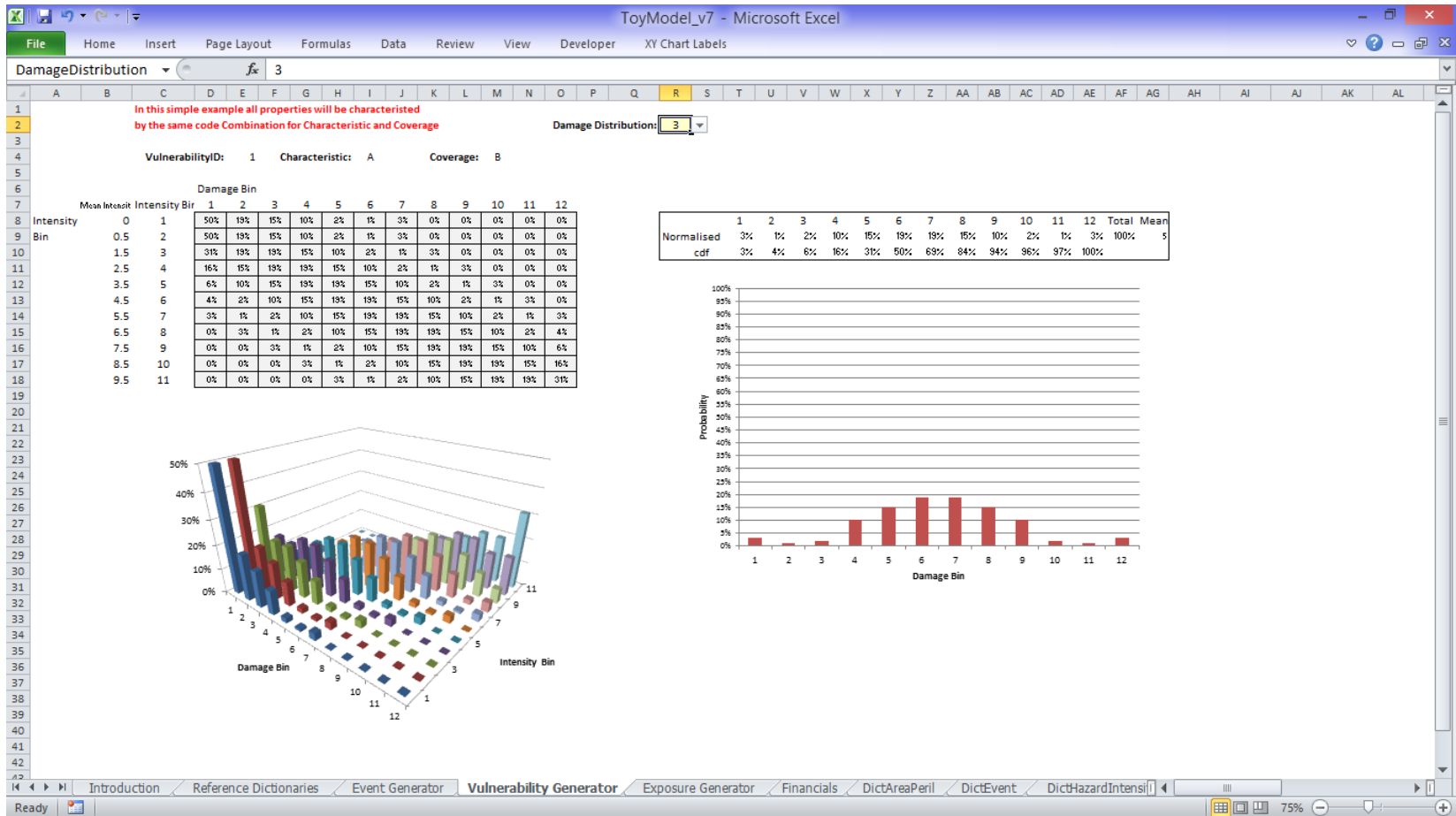
Miss Factor: Y (e.g. for flood) Intensity Distribution: 1 Simple example using one distribution scaled by intensity

x	y	Intensity	Miss Factor	Remainder	Cell	AreaPeril	1	2	3	4	5	6	7	8	9	10	11	Central Mean
1	1	0	0	0	(1:1)	1	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	
1	2	0	0	0	(1:2)	2	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	
1	3	0	0	0	(1:3)	3	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	
1	4	0	0	0	(1:4)	4	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	
1	5	0	0	0	(1:5)	5	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	
1	6	0	0	0	(1:6)	6	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	
1	7	0	0	0	(1:7)	7	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	
1	8	0	0	0	(1:8)	8	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	
1	9	0	0	0	(1:9)	9	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	
1	10	0	0	0	(1:10)	10	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	
2	1	0	0	0	(2:1)	11	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	
2	2	0	0	0	(2:2)	12	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	
2	3	0	0	0	(2:3)	13	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	
2	4	0	0	0	(2:4)	14	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	
2	5	0	0	0	(2:5)	15	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	
2	6	0	0	0	(2:6)	16	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	
2	7	0	0	0	(2:7)	17	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	
2	8	0	0	0	(2:8)	18	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	

Value:	0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	
Intensity:	1	2	3	4	5	6	7	8	9	10	
Bin:	2	3	4	5	6	7	8	9	10	11	
Normalised	1%	2%	10%	18%	19%	18%	18%	10%	2%	1%	
cdf	1%	3%	13%	31%	50%	68%	87%	97%	99%	100%	
Total Mean											5

Select destination and press ENTER or choose Paste

# Toy Model – Vulnerability



# Toy Model – Exposure

ToyModel\_v7 - Microsoft Excel

ExposureRandom     $f_x$      $=+RAND()*10$

1 Exposures randomly generated.

2

3 Define Exposures randomly with or without Clustering

4

5

6

7 Cluster:  Y means that results will cluster around the first 100 results

8

9 Exposures:  Maximum 1,000   

10

11

12 Can be used to Generate Exposures dictionary (which can be used for Output but is not needed for Kernel calculation)

13 Determined from x and y Co-ords    Determined from Cell    Determined from Characteristic

14

15

16

17 100 chosen:

LocationID	Ref1	Coverage	x	y	TIV	Cell	AreaPerilID	Characteristic	VulnerabilityID
1	Risk 1	B	4.4	6.5	730,189	(6,7)	47	A	1
2	Risk 2	B	9.4	1.3	149,590	(10,2)	92	A	1
3	Risk 3	B	8.5	3.8	843,167	(9,4)	84	A	1
4	Risk 4	B	6.7	3.7	323,961	(7,4)	64	A	1
5	Risk 5	B	6.4	7.6	463,165	(7,8)	68	A	1
6	Risk 6	B	7.1	7.9	498,366	(8,8)	78	A	1
7	Risk 7	B	3.6	1.3	201,052	(4,2)	32	A	1
8	Risk 8	B	0.1	9.0	32,437	(1,9)	9	A	1
9	Risk 9	B	0.9	7.0	560,628	(1,7)	7	A	1
10	Risk 10	B	9.7	9.0	347,060	(10,9)	99	A	1
11	Risk 11	B	5.5	7.7	413,735	(6,8)	58	A	1
12	Risk 12	B	8.8	1.3	49,501	(9,2)	82	A	1
13	Risk 13	B	2.1	9.3	417,560	(3,10)	30	A	1
14	Risk 14	B	0.4	5.4	958,079	(1,6)	6	A	1
15	Risk 15	B	3.9	2.7	130,376	(4,3)	33	A	1
16	Risk 16	B	1.6	8.6	473,034	(2,9)	19	A	1
17	Risk 17	B	1.9	1.4	919,389	(2,2)	12	A	1
18	Risk 18	B	9.4	7.0	226,201	(10,7)	97	A	1
19	Risk 19	B	7.8	4.4	462,154	(8,5)	75	A	1
20	Risk 20	B	8.1	7.5	136,772	(9,8)	88	A	1
21	Risk 21	B	2.8	4.3	935,181	(3,5)	25	A	1
22	Risk 22	B	4.7	2.0	718,594	(5,3)	43	A	1
23	Risk 23	B	1.2	3.7	324,845	(2,4)	14	A	1
24	Risk 24	B	0.6	4.2	369,200	(1,5)	5	A	1
25	Risk 25	B	6.2	3.1	1,008,391	(7,4)	64	A	1
26	Risk 26	B	4.9	8.2	349,126	(5,7)	47	A	1
27	Risk 27	B	6.1	8.0	169,239	(7,7)	67	A	1

Randomly generated:

x	y	TIV	x	y	
8.6	8.1	392,772	0.5	0.5	100
5.5	1.6	311,664	0.5	1.5	100
3.1	8.3	748,305	0.5	2.5	100
4.1	2.0	583,478	0.5	3.5	100
0.5	0.7	308,545	0.5	4.5	100
8.1	7.9	1,062,516	0.5	5.5	100
0.2	7.3	1,011,714	0.5	6.5	100
1.6	3.3	1,322,894	0.5	7.5	100
3.1	7.8	411,133	0.5	8.5	100
9.7	6.8	333,424	0.5	9.5	100
3.3	6.0	1,298,273	1.5	0.5	100
9.3	6.3	228,795	1.5	1.5	100
8.6	0.2	680,564	1.5	2.5	100
3.6	7.1	317,953	1.5	3.5	100
8.6	3.1	277,828	1.5	4.5	100
5.3	1.0	876,404	1.5	5.5	100
4.2	3.1	239,163	1.5	6.5	100
3.0	4.1	873,009	1.5	7.5	100
2.8	7.4	1,333,398	1.5	8.5	100
6.6	1.7	489,462	1.5	9.5	100
5.9	7.2	1,179,479	2.5	0.5	100
9.4	8.3	1,156,697	2.5	1.5	100
5.0	9.5	1,407,012	2.5	2.5	100
8.4	3.8	1,191,757	2.5	3.5	100
8.6	8.4	875,766	2.5	4.5	100
6.1	8.2	346,899	2.5	5.5	100
1.7	9.8	565,816	2.5	6.5	100

Benchmark:

Introduction    Reference Dictionaries    Event Generator    Vulnerability Generator    Exposure Generator    Financials    DictAreaPeril    DictEvent    DictHazardIntensit

Ready    60%

# Toy Model – Policy Terms

ToyModel\_v7 - Microsoft Excel

AD12 0.2

**Financial Structures**

**Prog**  
The profile that identifies the grouping of items.  
Defaults here to one for one Account.

Prog ID	Prog Name	Account
1	Toy 2014 renewal	1

**Programme**  
Defines items to be treated together for calculation.  
Defaults to list of exposures.

ProgID	ItemID	Level	AggID
1	1	1	1
1	2	1	2
1	3	1	3
1	4	1	4
1	5	1	5
1	6	1	6
1	7	1	7
1	8	1	8
1	9	1	9
1	10	1	10
1	11	1	11
1	12	1	12
1	13	1	13
1	14	1	14
1	15	1	15
1	16	1	16
1	17	1	17
1	18	1	18
1	19	1	19
1	20	1	20
1	21	1	21
1	22	1	22
1	23	1	23
1	24	1	24
1	25	1	25
1	26	1	26
1	27	1	27
1	28	1	28
1	29	1	29
1	30	1	30
1	31	1	31
1	32	1	32
1	33	1	33
1	34	1	34
1	35	1	35
1	36	1	36
1	37	1	37
1	38	1	38
1	39	1	39
1	40	1	40

From Exposures  
Set to Level 1 for coverage  
Set to Level 2 for policy  
Set to Aggregate to policy (this is a grouping field)

**Policy Terms and Conditions**  
Identifies how to apply distinct Policy terms to Programmes and Layers.

ProgID	Level	AggID	LayerID	PolicyTCID
1	1	1	1	1
1	1	2	1	1
1	1	3	1	1
1	1	4	1	1
1	1	5	1	1
1	1	13	1	1
1	1	14	1	1
1	1	15	1	1
1	1	16	1	1
1	1	17	1	1
1	1	18	1	1
1	1	19	1	1
1	1	20	1	1
1	1	21	1	1
1	1	22	1	1
1	1	23	1	1
1	1	24	1	1
1	1	25	1	1
1	1	26	1	1
1	1	27	1	1
1	1	28	1	1
1	1	29	1	1
1	1	30	1	1
1	1	31	1	1
1	1	32	1	1
1	1	33	1	1
1	1	34	1	1
1	1	35	1	1
1	1	36	1	1
1	1	37	1	1
1	1	38	1	1
1	1	39	1	1
1	1	40	1	1

Policy is defined by ProgID and LayerID; currently no policy details such as inception/expiry dates are used in the RI Kernel as it damages all policies submitted.

**Policy Profile Values**  
Values applicable to the calculation of policy terms and conditions.

PolicyTCID	Rule	AllocRul	Ccy	Deductible	Limit	Share
1	12	-1	USD	5,000		
2	2	0	USD	1,000,000	1,000,000	0.2

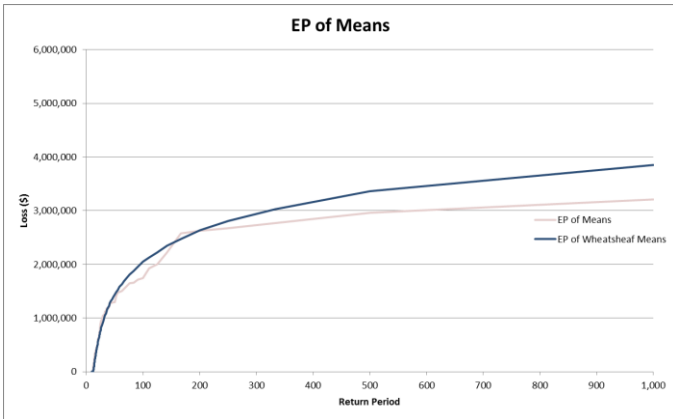
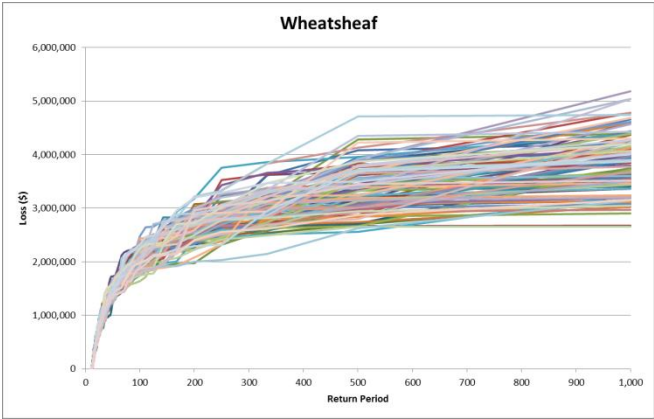
1 Layer  
Two distinct Terms and Conditions - one a location deductible and one a policy  
Allocation Rule to determine level of detail of outputs (and whether needed for subsequent level calculation). Valid values: -1 = allocate and ITEMID=OUTPUTID 0 = Don't allocate (e.g. at top level) 1 = allocate back to ITEMs  
Calculation rules (formulae/algorithms) applicable to these Terms and Conditions. Current valid values: 1 = Deductible and Limit 2 = Deductible and Limit and Share 12 = Deductible only  
We currently use one common format for all PolicyTCIDs for simplicity even though Oasis generally won't accept nulls. This will change with Release 1.3 where users can define their own profiles

Location-specific deductibles

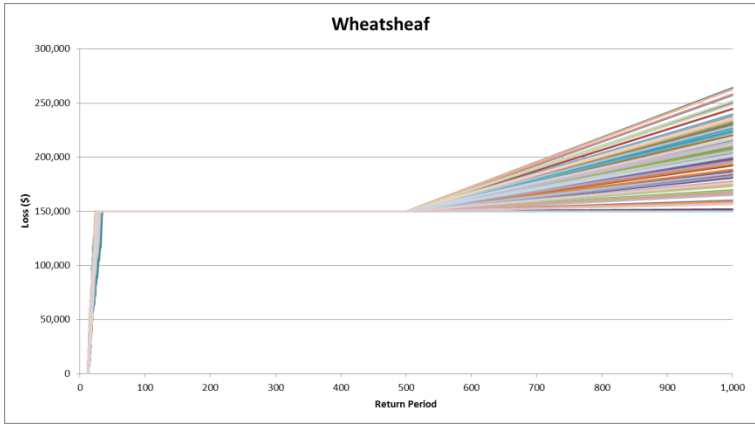
Introduction Reference Dictionaries Event Generator Vulnerability Generator Exposure Generator Financials DictAreaPeril DictEvent DictHazardIntensif

Ready 65%

# EP Curves (AEP)



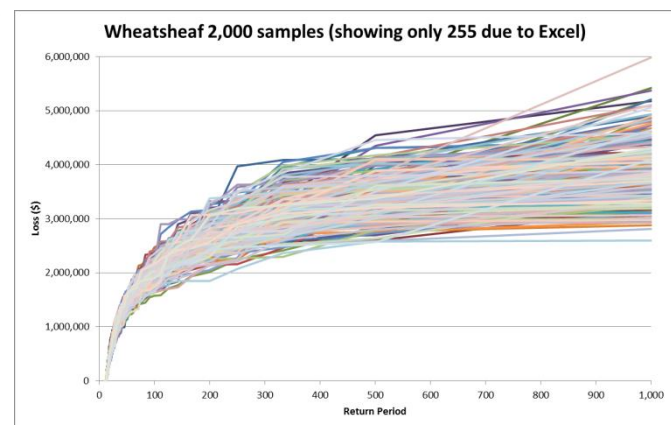
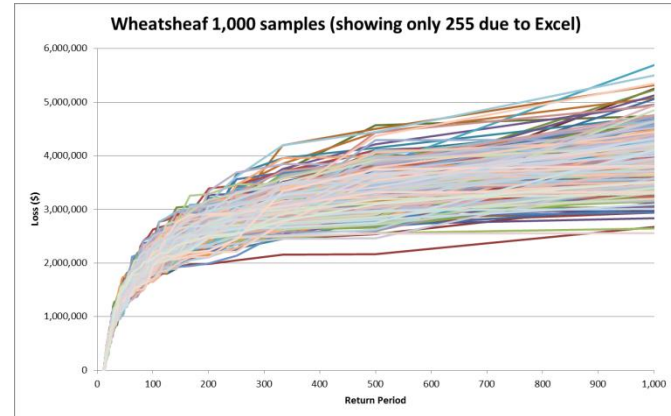
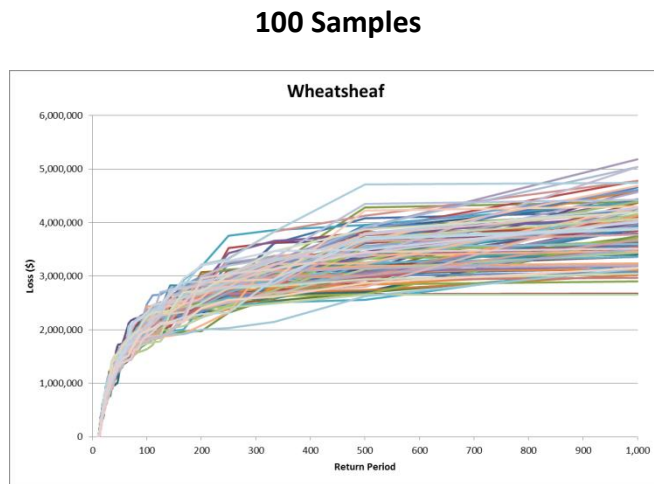
FM



15% share of \$1m xs \$1m  
location deductible of \$500

FM AEP curve shows effect of second event in a year

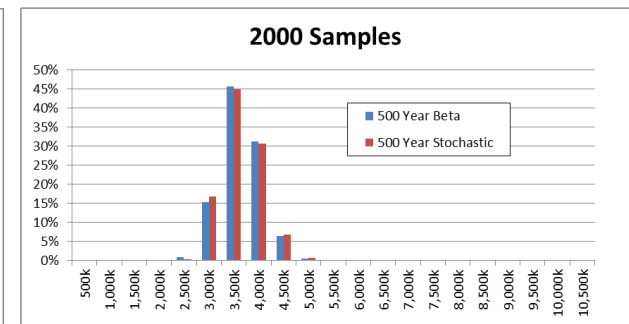
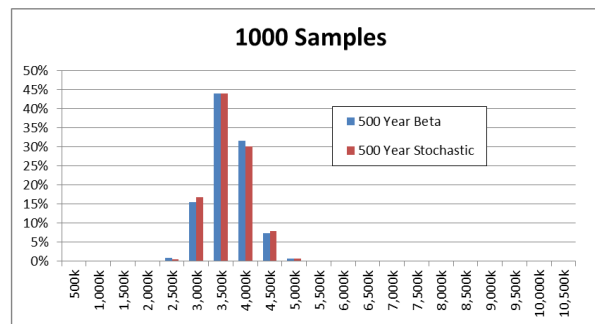
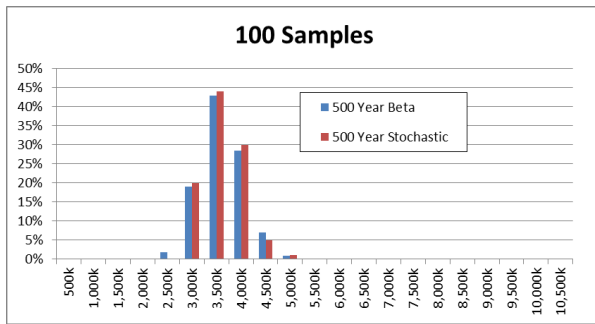
# Increase number of samples ...



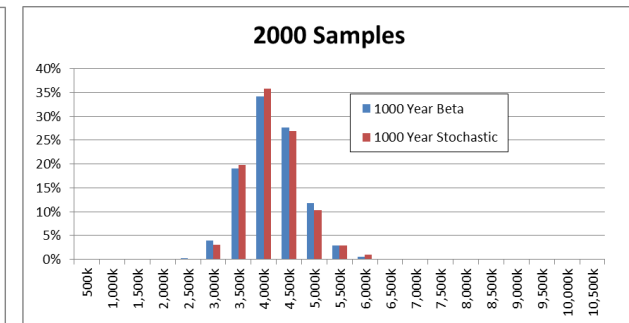
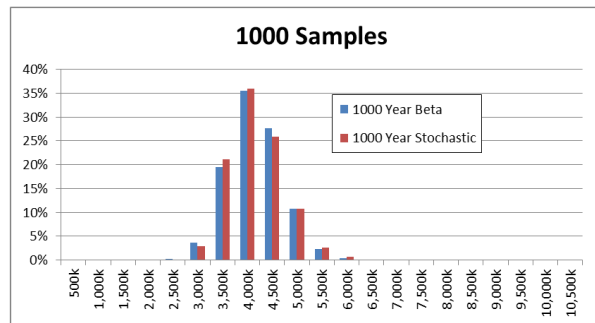
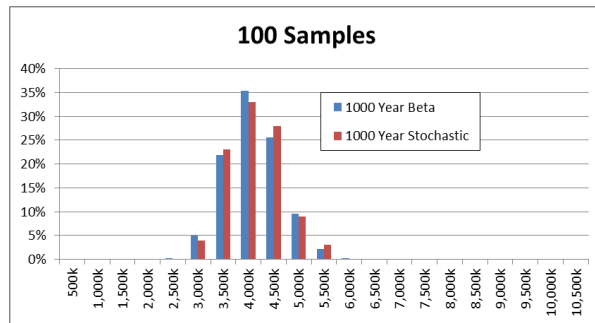
Stays the same shape – because spread comes from years not samples

# VaR distributions

## 500 Year EP distributions



## 1,000 Year EP distributions



	500 Year	1,000 Year
Mean	3,361,410	3,848,093
SD	438,110	548,500
CoV	13%	14%

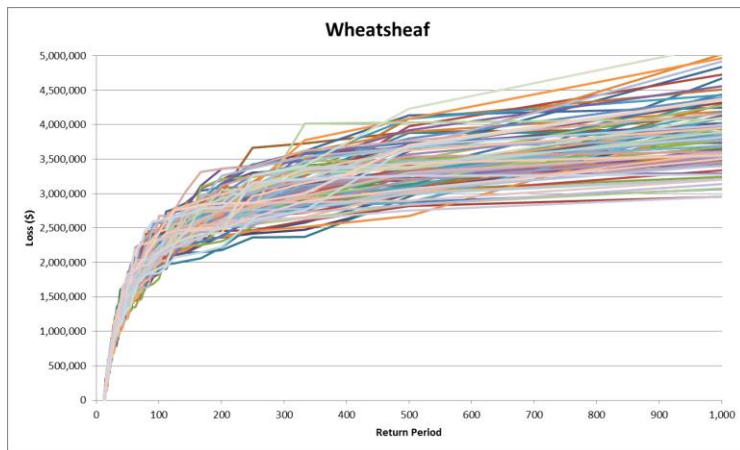
	500 Year	1,000 Year
Mean	3,405,662	3,901,880
SD	413,698	538,189
CoV	12%	14%

	500 Year	1,000 Year
Mean	3,394,864	3,921,974
SD	398,142	560,300
CoV	12%	14%

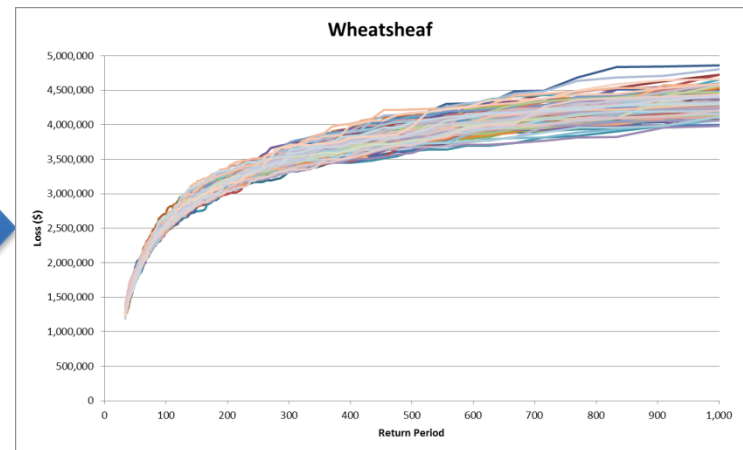


# Increase number of years

1,000 Years



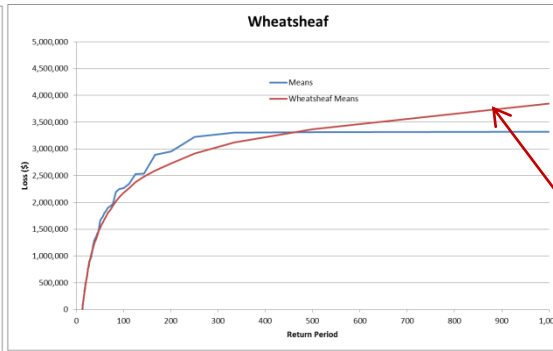
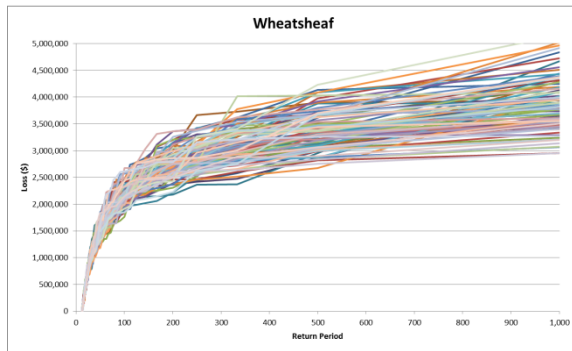
10,000 Years



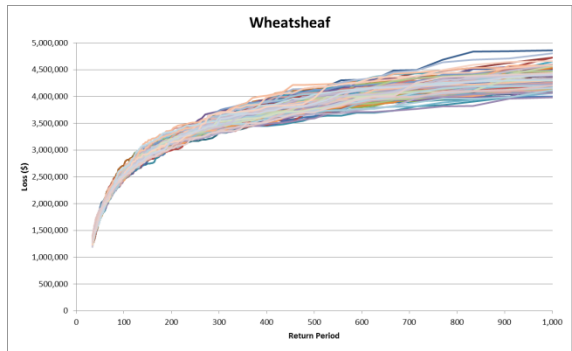
Shows central tendency because number of years has increased

# Effect of number of years

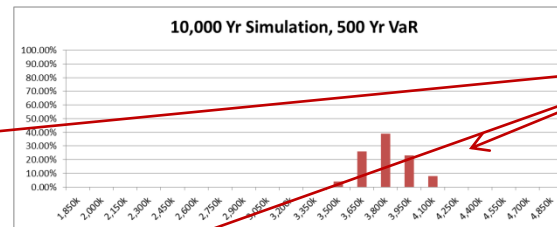
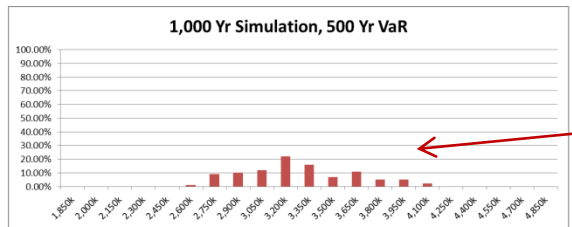
1,000 Years



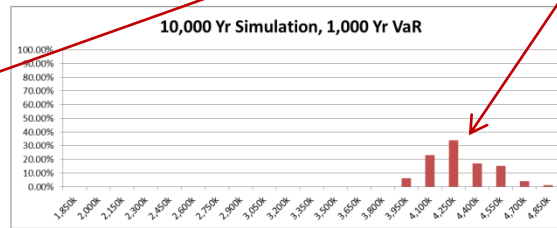
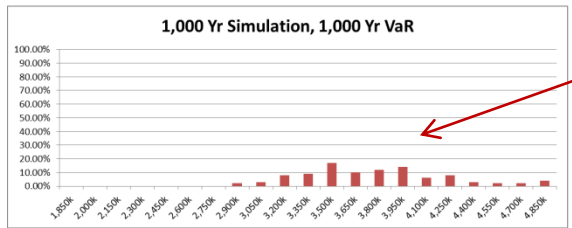
10,000 Years



Note the Wheatsheaf Mean is a good estimator

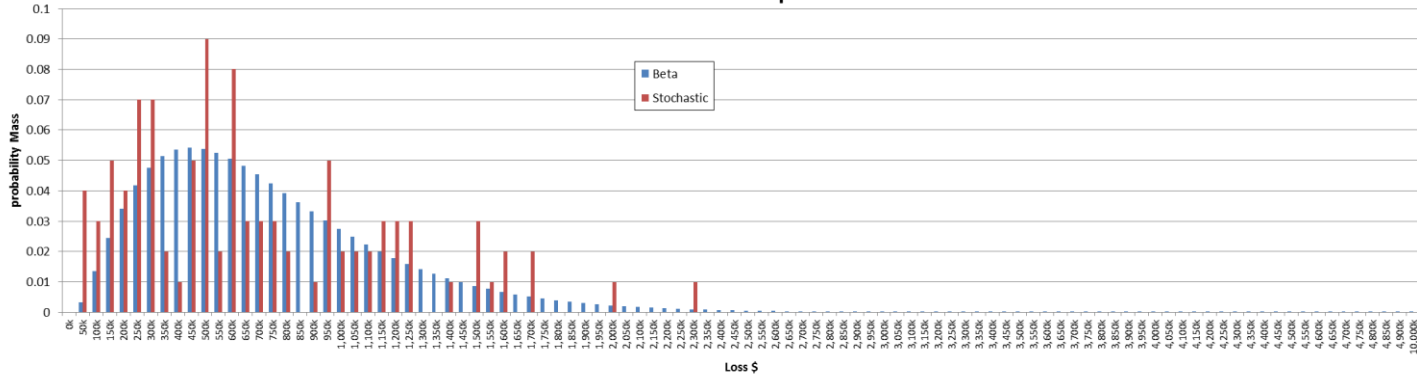


Central tendency

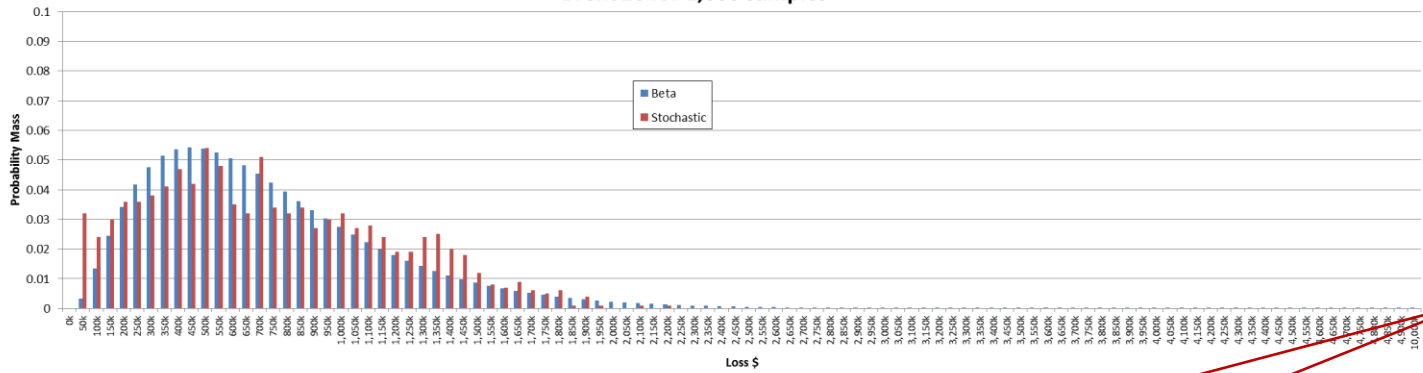


# ELTs by Sample size

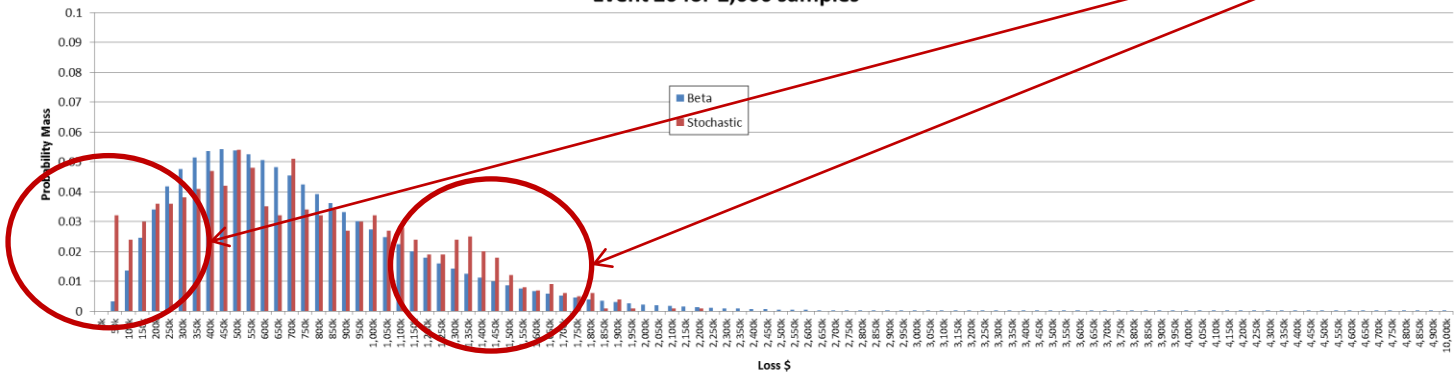
Event 20 for 100 samples



Event 20 for 1,000 samples

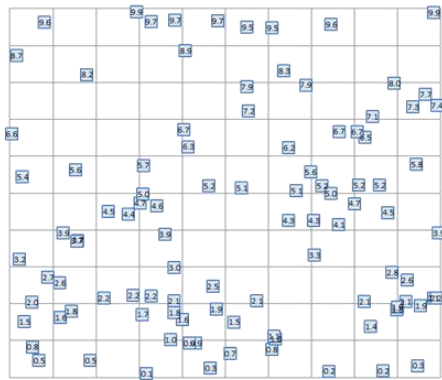


Event 20 for 2,000 samples

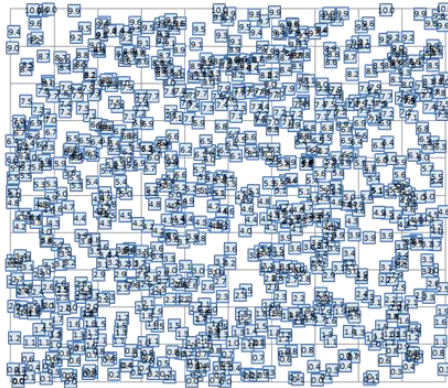


# Increase number of exposures

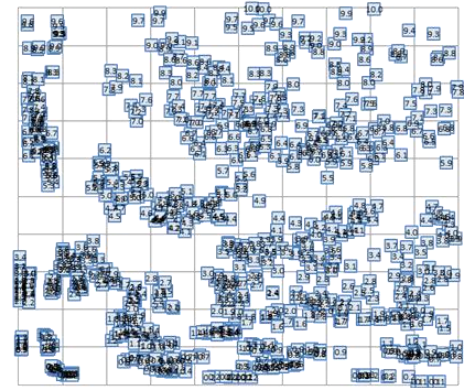
100



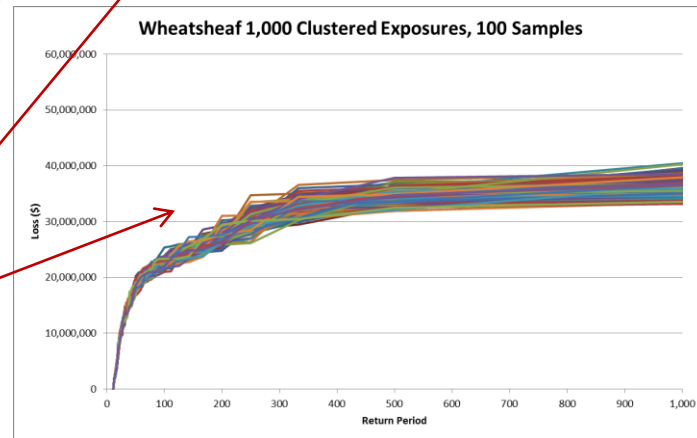
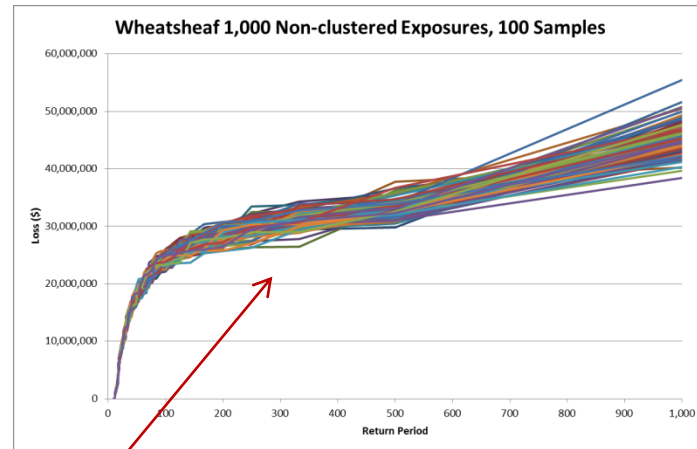
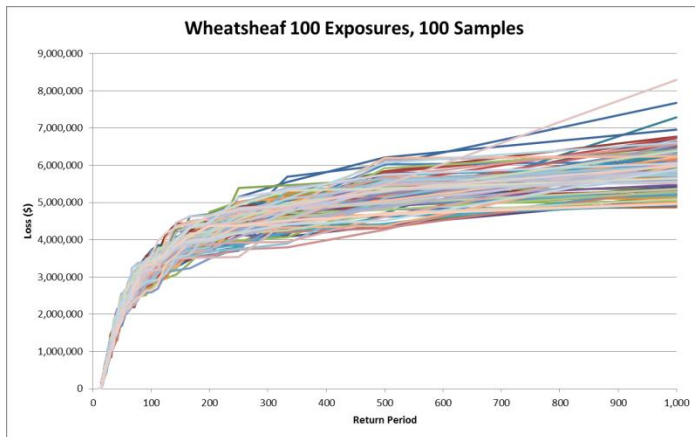
1,000



1,000 Clustered

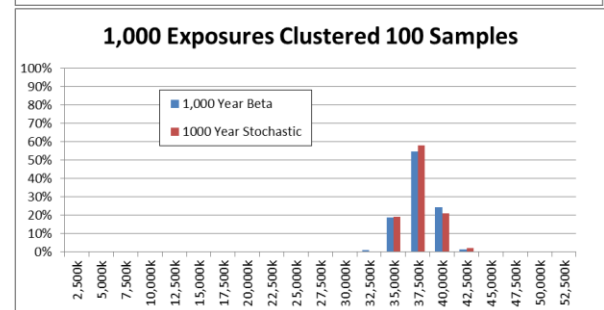
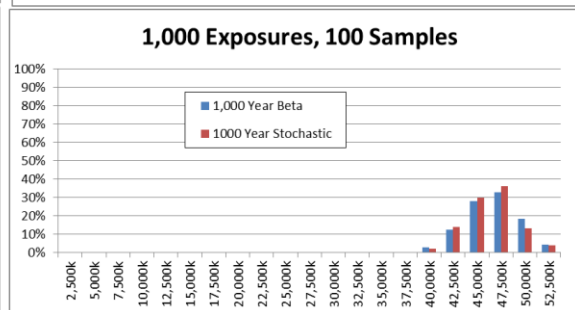
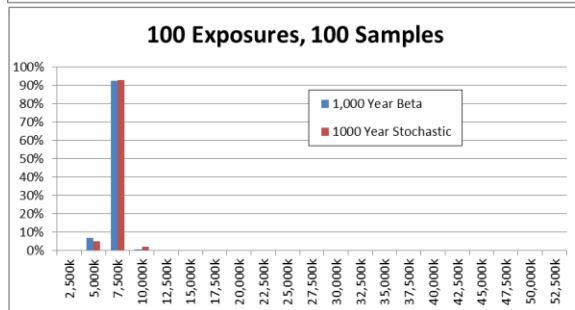
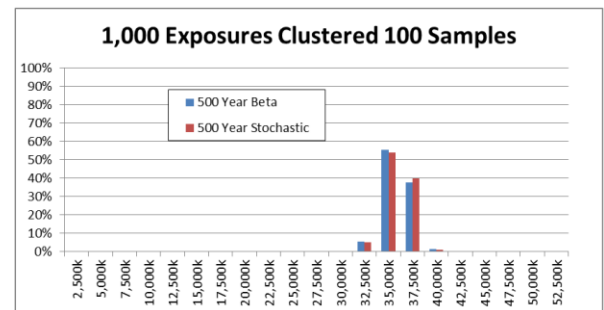
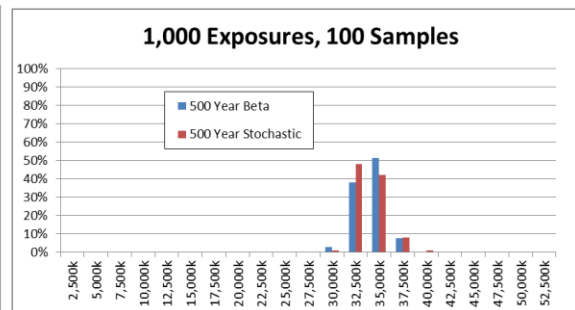
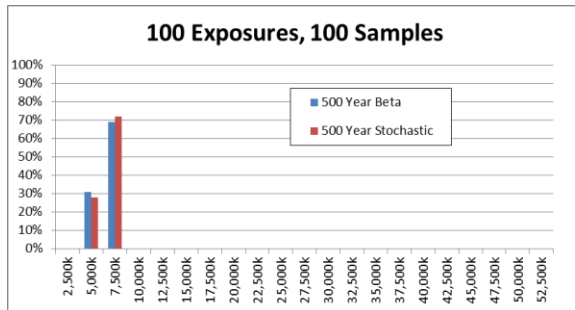


# Effect of number of exposures



Non-clustered  
higher EP perhaps  
due to "miss  
factor"

# Effect of number of exposures

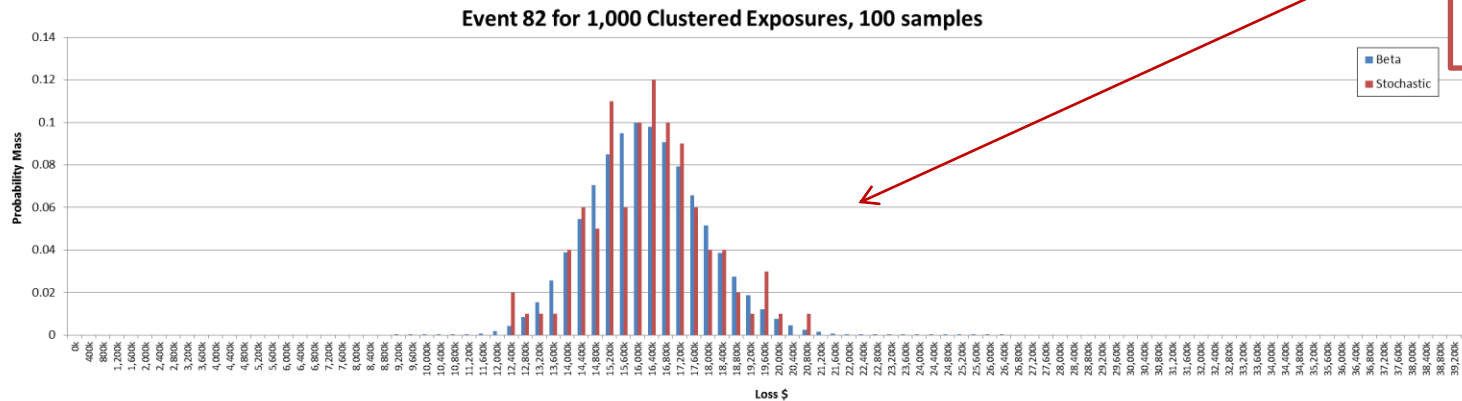
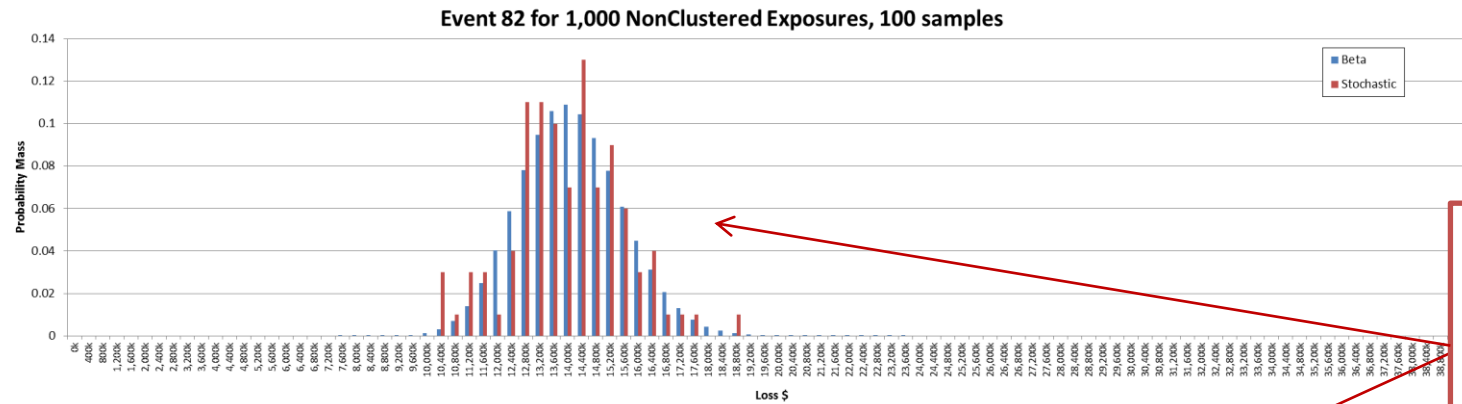
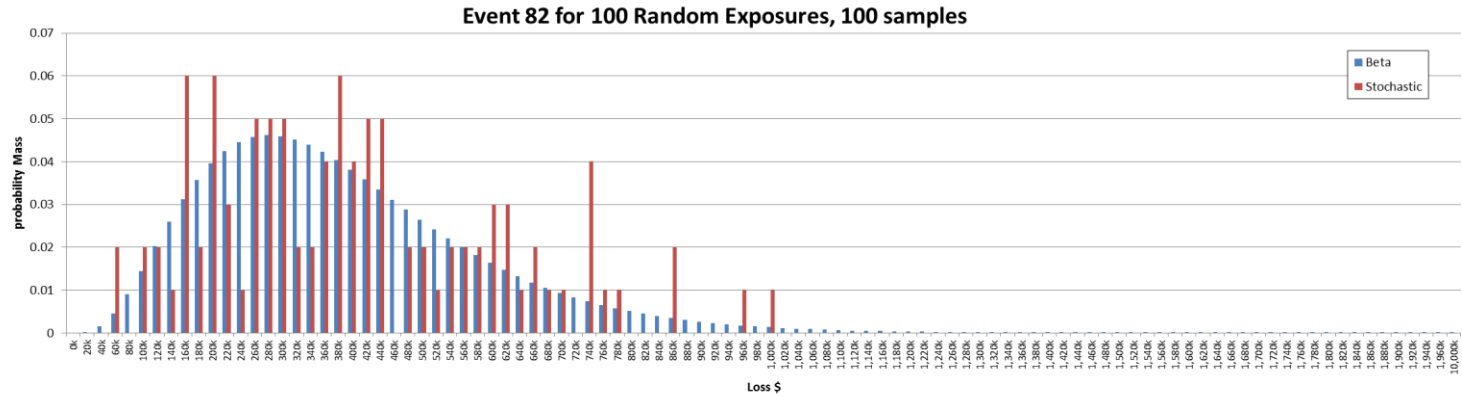


	500 Year	1,000 Year
Mean	5,224,129	5,883,480
SD	436,609	607,373
CoV	8%	10%

	500 Year	1,000 Year
Mean	32,845,391	45,387,871
SD	1,506,786	2,849,788
CoV	5%	6%

	500 Year	1,000 Year
Mean	34,628,182	36,408,825
SD	1,326,389	1,659,239
CoV	4%	5%

# Effect of number of Exposures



Smoother,  
sometimes  
clustered  
greater  
sometimes  
less

# The Zeitgeist





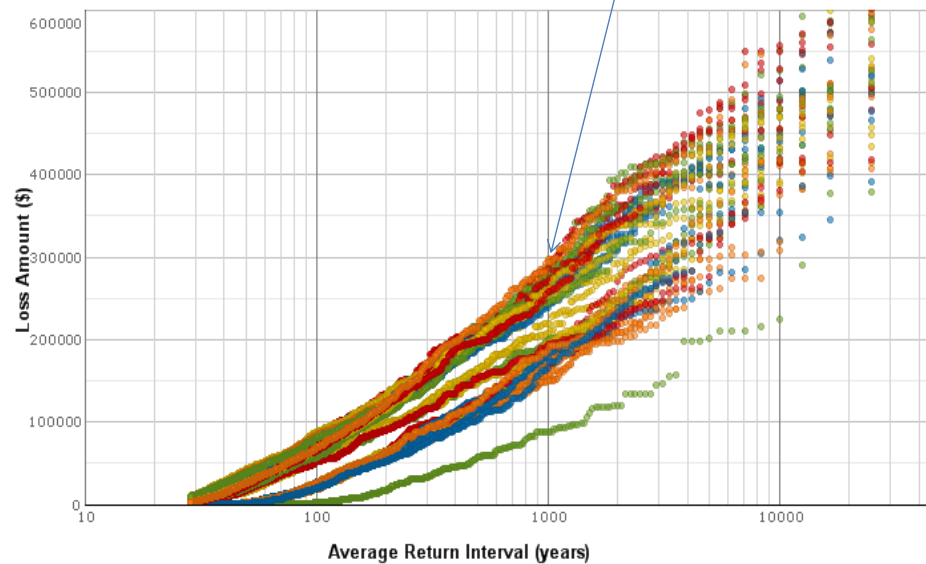
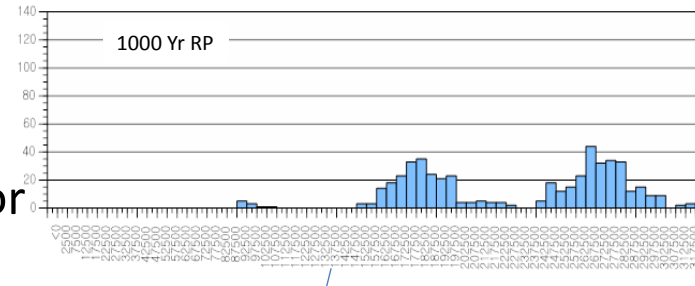
# Ensemble - Data



Occupancy - Industrial  
L.A., 1991, 2-story, Level 0 for  
all subtypes; 50 simulations,  
with 50,000-yr walkthrough  
each

TU: 40%  
BSW\_C: 20%  
BSW\_M: 20%  
W\_E: 10%  
CBF: 7%  
LS: 3%

Loss Distribution



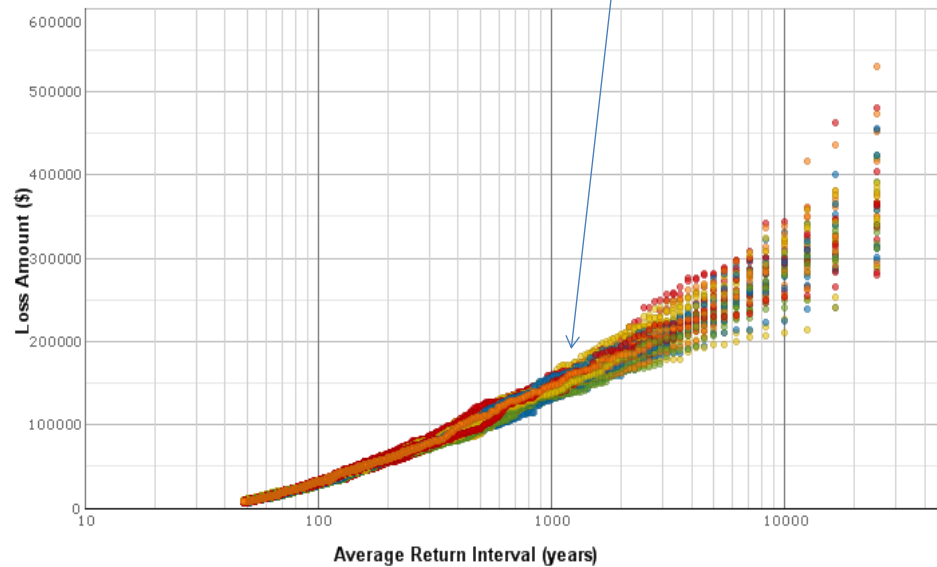
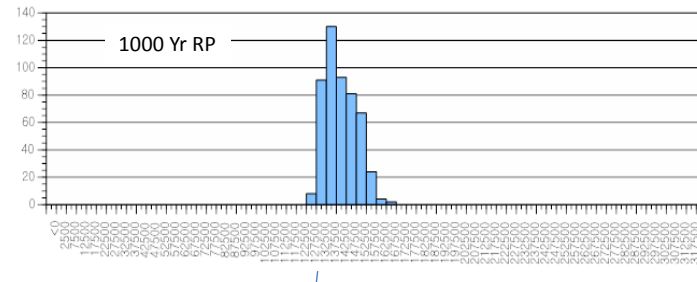
# Ensemble - Data



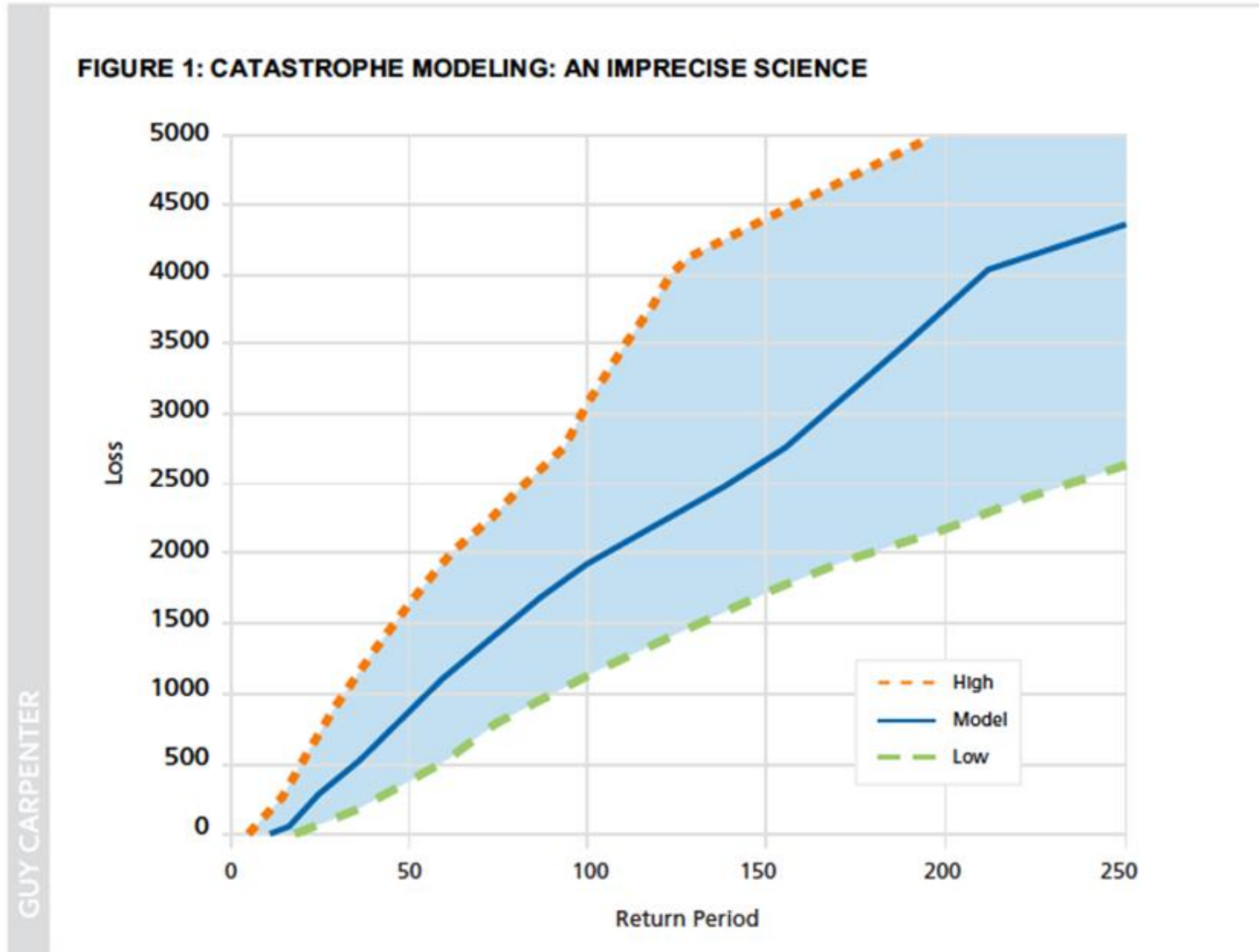
CODA Type  
L.A., 1991, 2-story, Level 2

TU: 100%

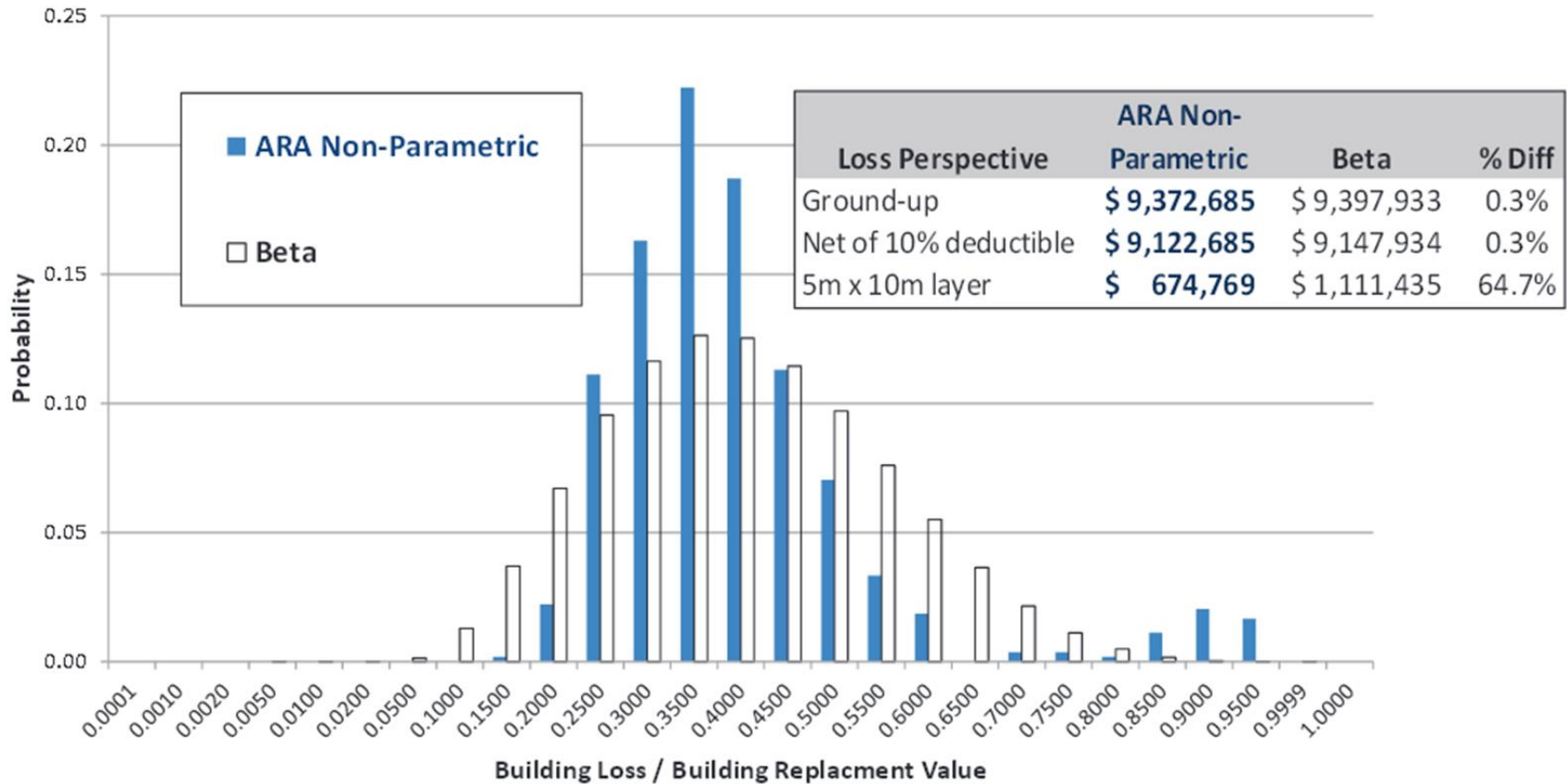
Loss Distribution



# The Way Forward

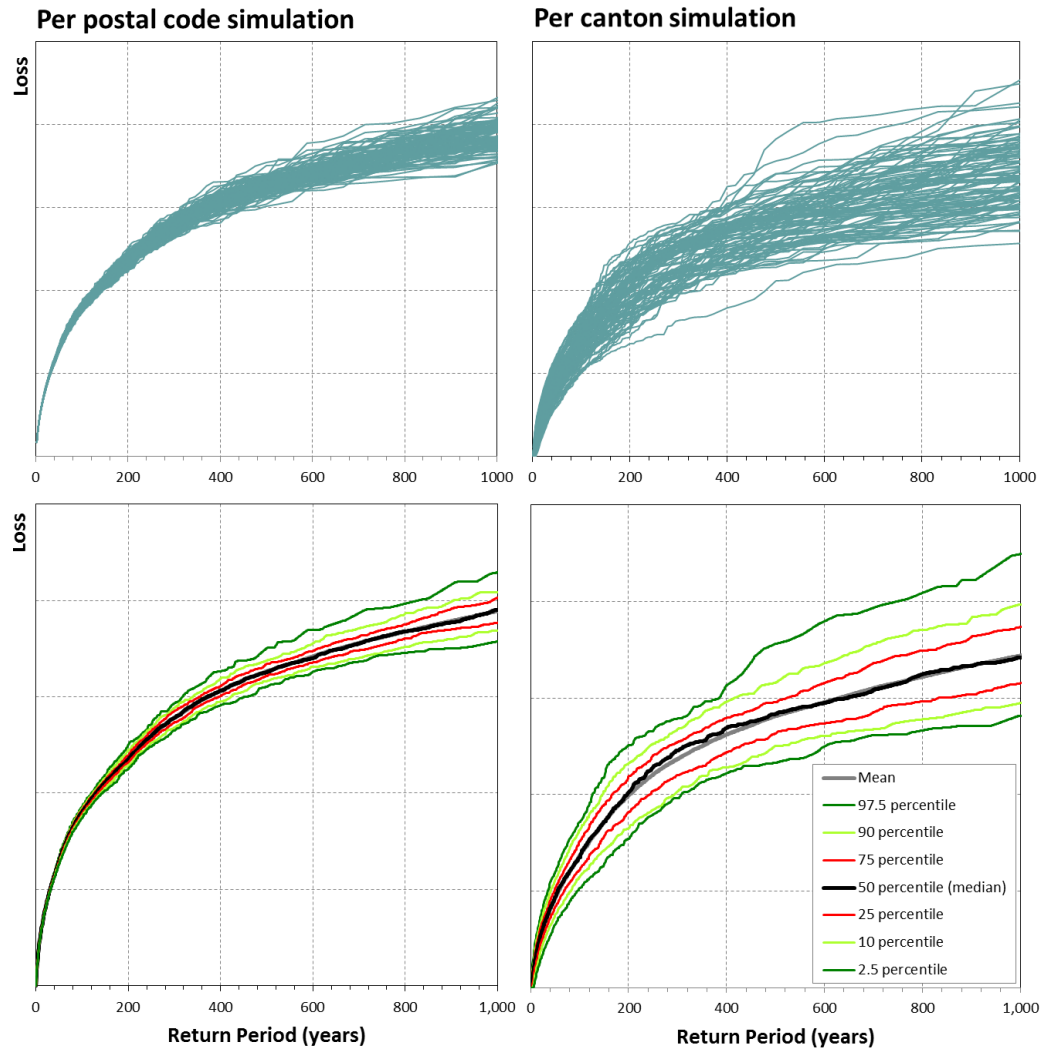


# ARA Discrete Calculation



Distribution of High Rise Steel Frame Residential Building Ground-up Loss in Suburban Terrain: 160 mph, 3-sec gust in open terrain (126 mph, 1-min sustained in open terrain)

# Aon Elements

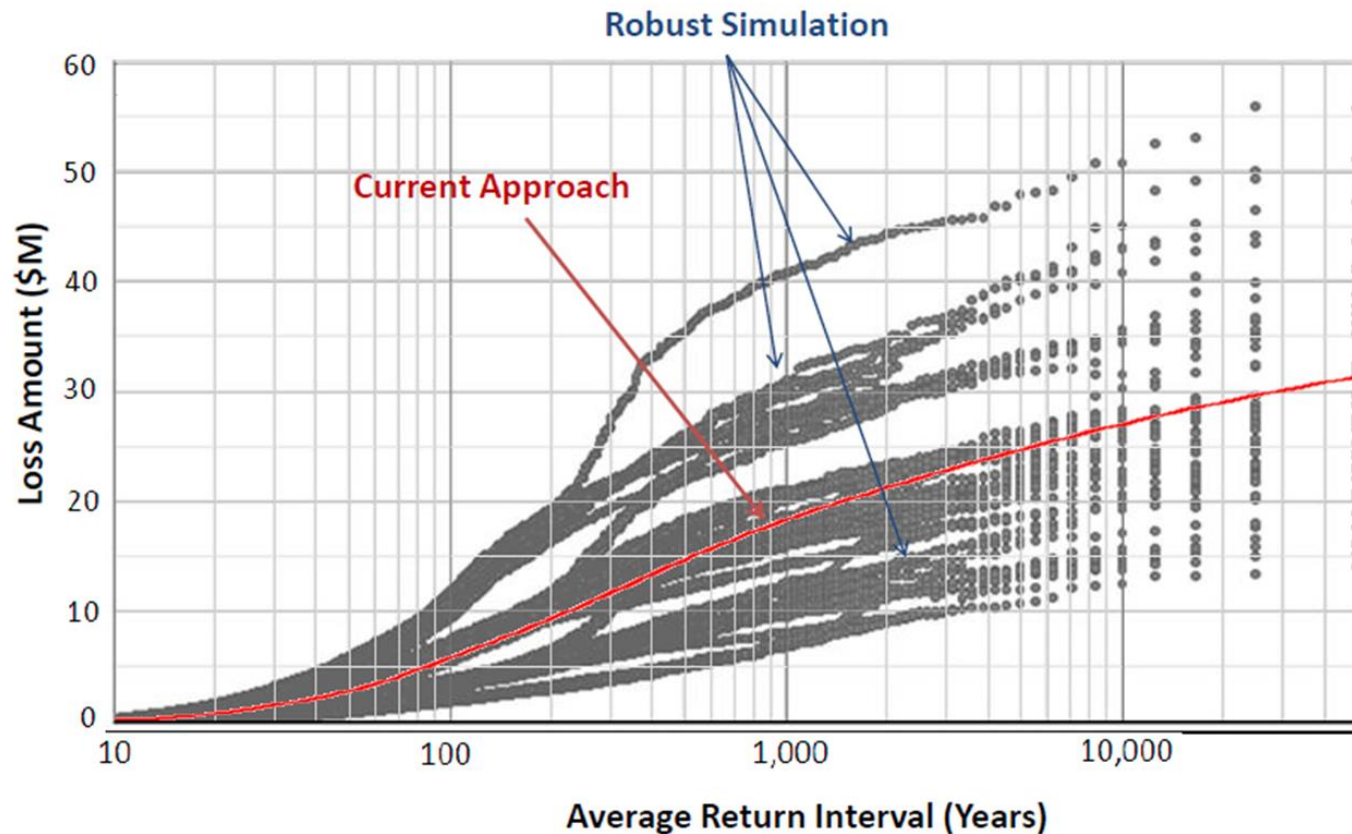


# ImageCat Robust Simulation ...



RAA | Re Ed

## A Framework for More Robust Uncertainty Assessment



# GFS Dendrograms

Base  
Th, 00 GMT

252	84	12	108	36	156	180	60	228
276	300	324	348	372				

Tu 08.04 12 GMT **Fr Sa Su Mo Tu We Th**

Cluster 1 9 Member (45 %)

Cluster 2 4 Member (20 %)

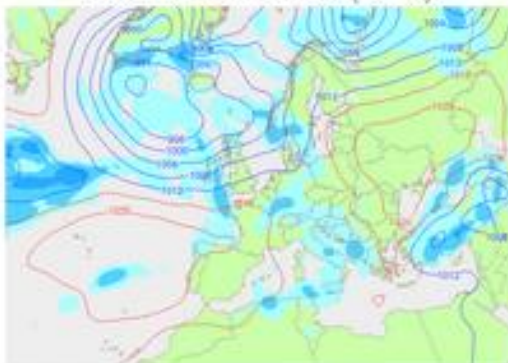
Cluster 4 4 Member (20 %)



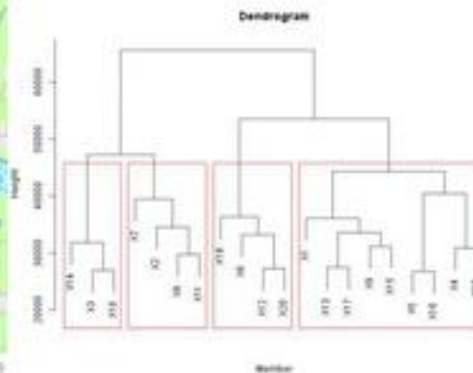
Precipitation D02 (mm/h) Tue 08/04/14 1200Z (Thu 00+300) Precipitation D02 (mm/h) Tue 08/04/14 1200Z (Thu 00+300) Precipitation D02 (mm/h) Tue 08/04/14 1200Z (Thu 00+300)

Cluster 3 3 Member (15 %)

Dendrogram

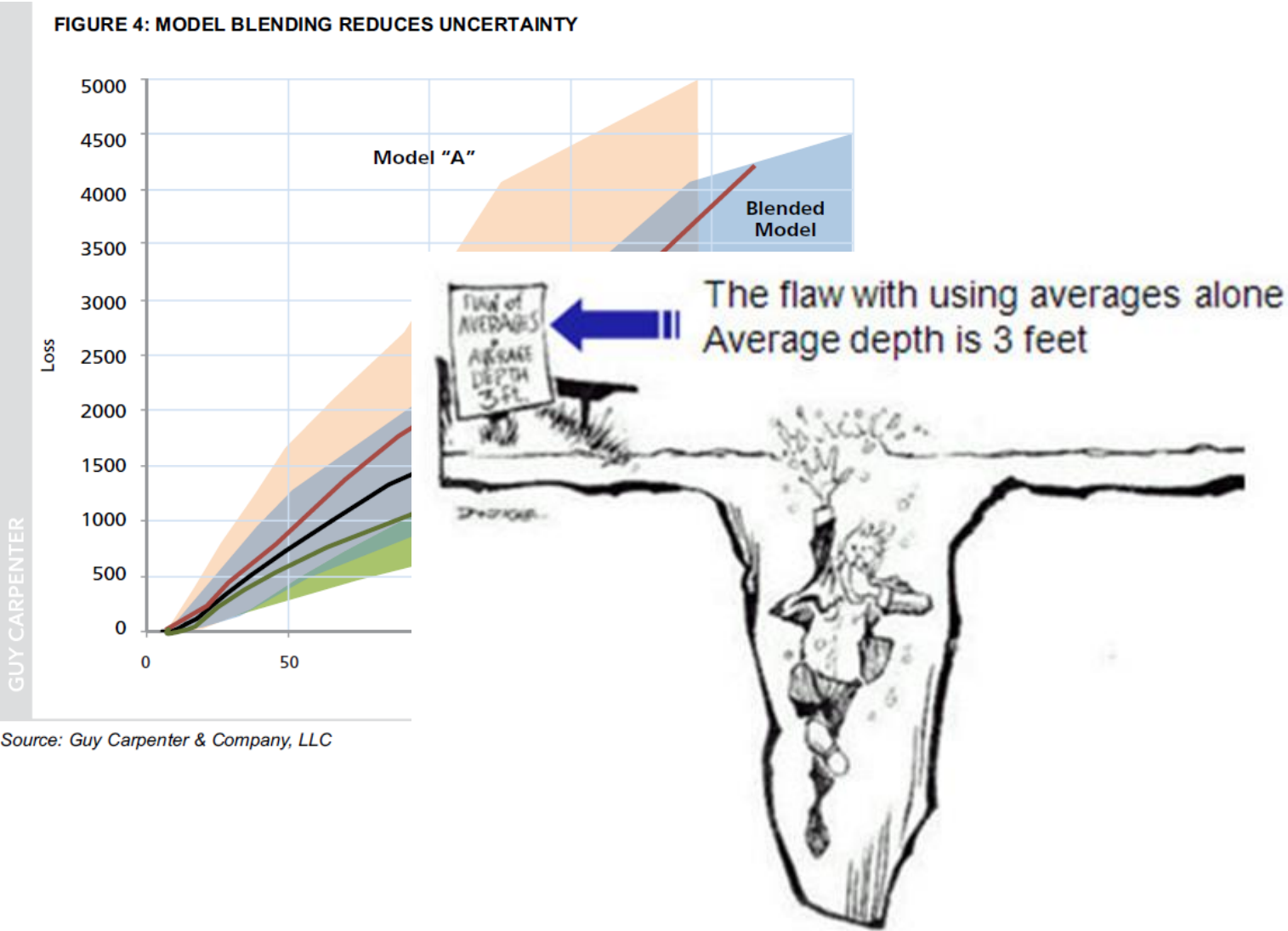


Precipitation D02 (mm/h) Tue 08/04/14 1200Z (Thu 00+300)



# Not the way forward!

FIGURE 4: MODEL BLENDING REDUCES UNCERTAINTY



Source: Guy Carpenter & Company, LLC





SO WHAT?

# Implications for Pricing

- Depends on pricing approach ...
- If you price in the cost of capital:
  - See what your spread of EP curves is
  - Check out any multi-modes for causes
  - Take a view to pick the EP curve
  - Apply your VaR/TVaR or whatever rule
  - Build a portfolio pricing system

# Implications for Capital

- What's the question?
  - “SCR at 99.5% annual VaR?”
  - “What's your confidence level for that figure?”
- Purchase protection if VaR has CoV
- Model outwards ri
- Model time aggregations
- Consider seasonal capital

*“Tell me what you know.  
Tell me what you don’t know.  
Then tell me what you think.  
Always distinguish which is which.”*



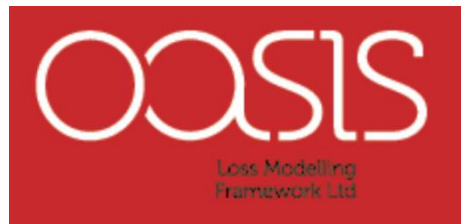
US Secretary of State, Colin Powell



[peter.taylor@philosophy.ox.ac.uk](mailto:peter.taylor@philosophy.ox.ac.uk)

**Thank You!**

[peter.taylor@oasislmf.org](mailto:peter.taylor@oasislmf.org)



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