RMS MODEL USE & UNCERTAINTY
CAMAR
10.10.2012

Anders Ericson
VP MPM, ACAS, MAAA

Christos Mitas, PhD
Senior Director, Modeling

AGENDA

Introduction to Cat Models

RMS History & Market Overview

Model Components, Model Building and Use

Deep Uncertainty or Aleatory Variability

Uncertainty in Cat Risk

Stochastic event sets – Generation and calibration

Vulnerability – contrasting perils and data availability

Exposure modeling – salient features

Actuarial Model Use

Accidental Ecosystem

Resilient Risk Management

Actuarial Implications

The way forward

INTRODUCTION TO CAT MODELS

RMS HISTORY AND MARKET OVERVIEW

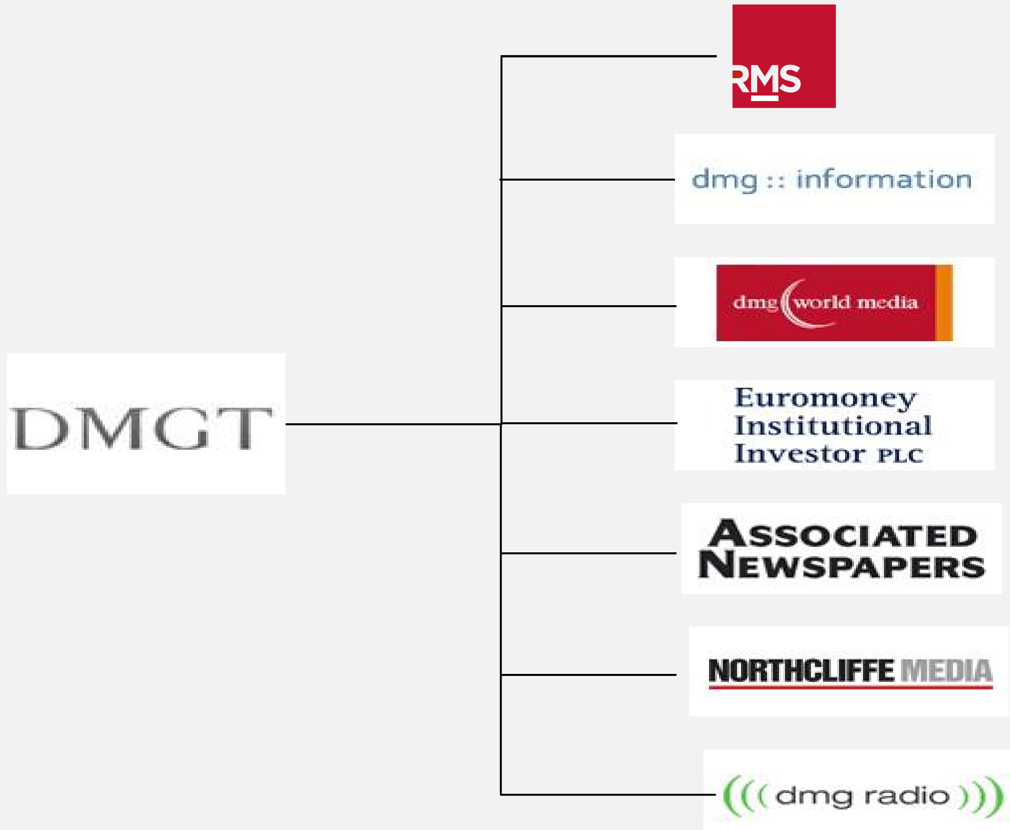
- Founded at Stanford University in 1988 in Silicon Valley, California
- Currently headquartered in Newark, California with offices in the U.S., U.K., France, Switzerland, Japan, Bermuda, India, and China
- Multi-disciplinary skills, from science and engineering to insurance
- Solely focused on risk management issues
- Independent and objective information source
- Provides catastrophe risk management and quantification solutions to the $1 trillion dollar global insurance industry

RMS

DMGT CORPORATE STRUCTURE

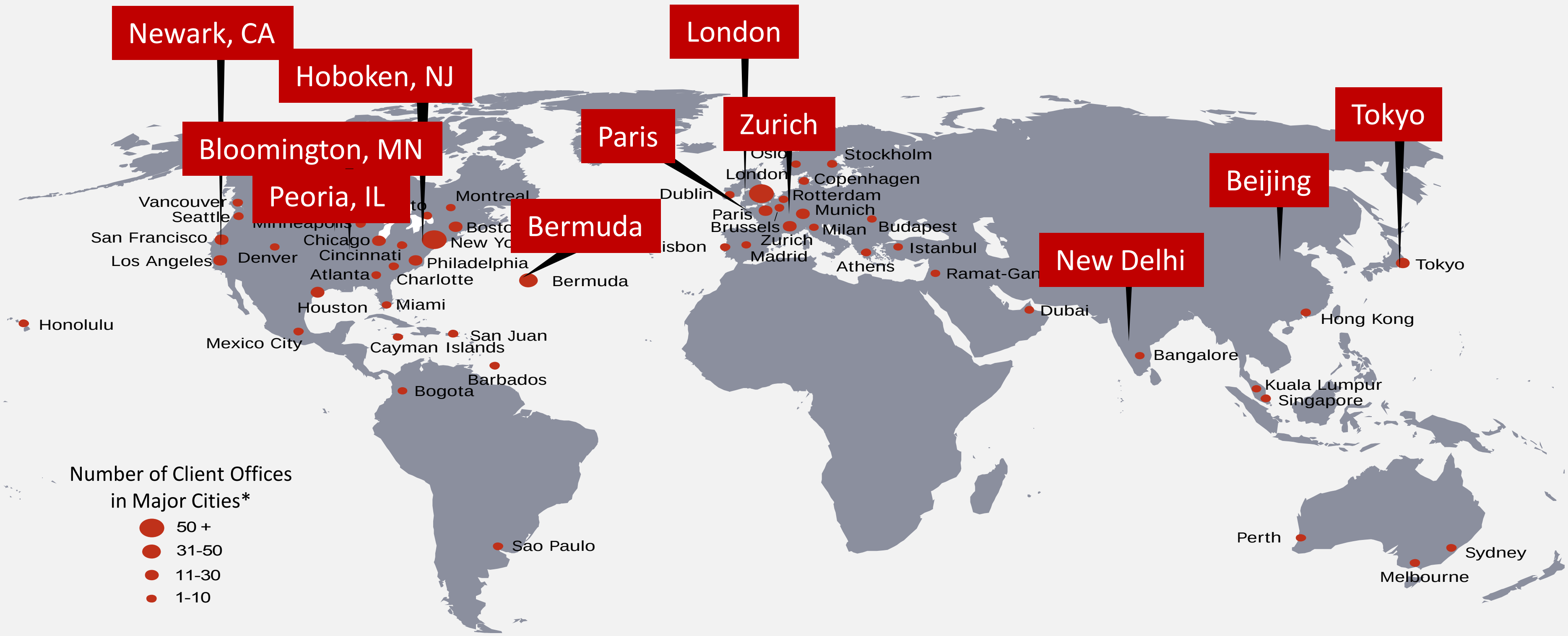
Wholly owned subsidiary of Daily Mail and General Trust, Plc since 1998

Control and ownership remains independent of any individual or company in the insurance or reinsurance market



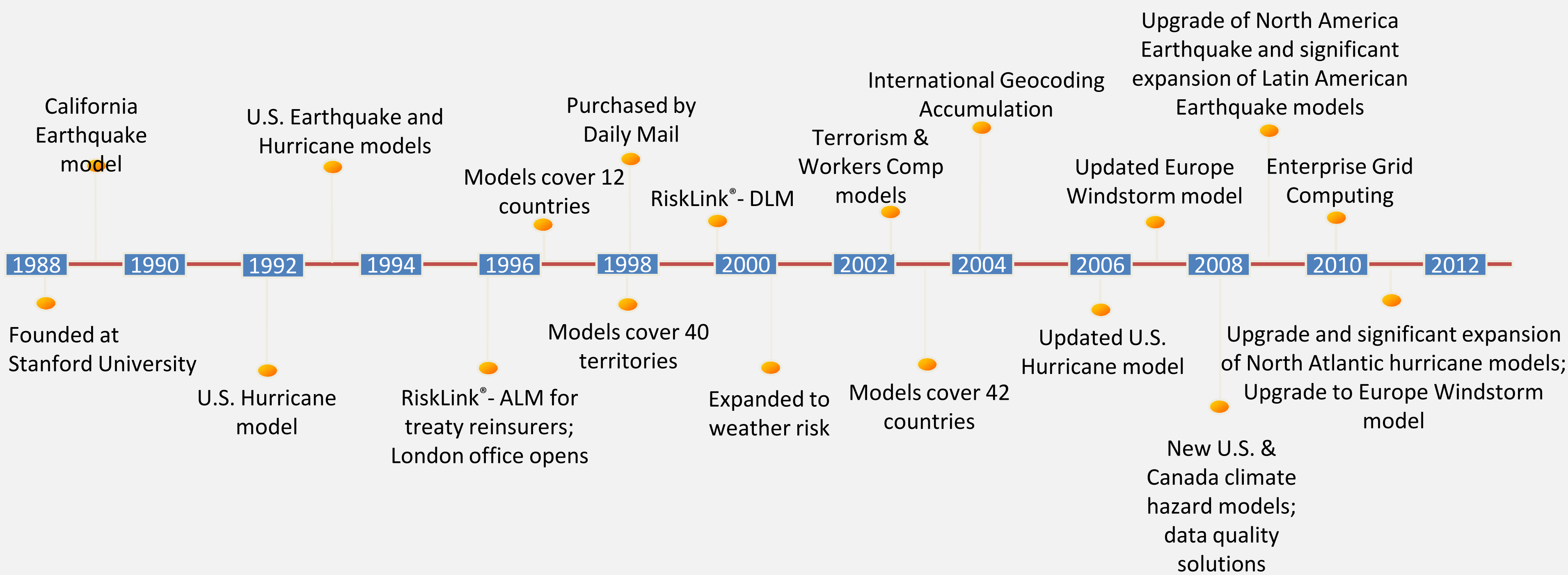
RMS

RMS Offices

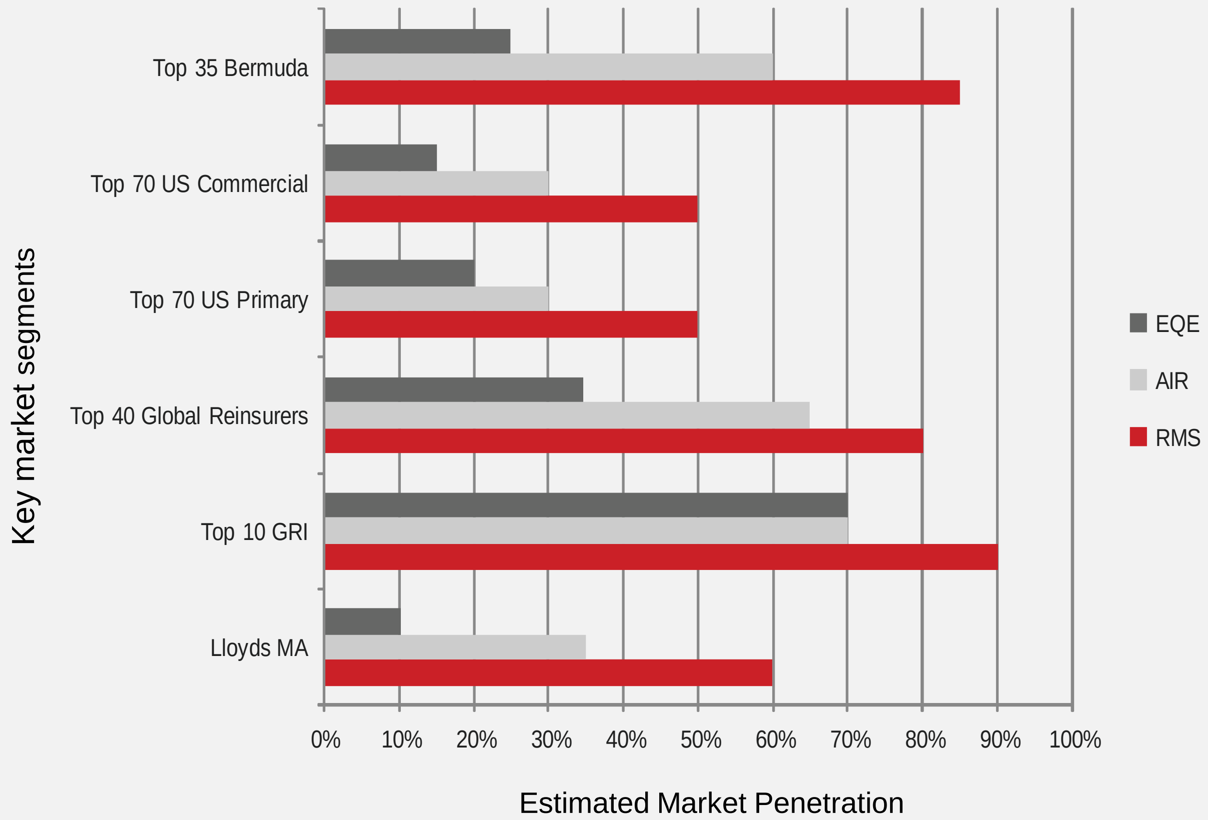


*Excluded multiple campuses of one company in the same city

RMS Evolution



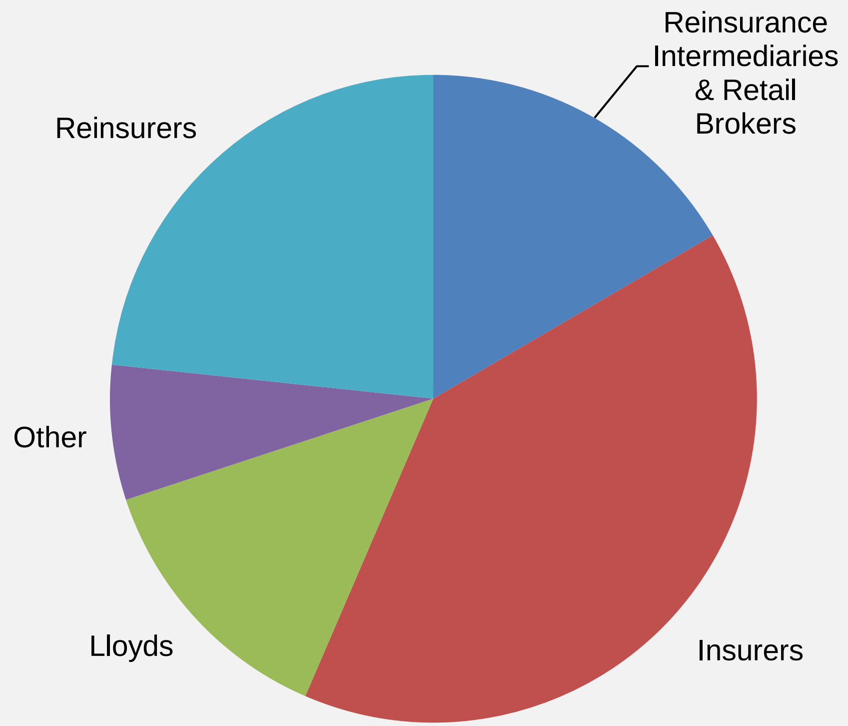
MARKET PENETRATION



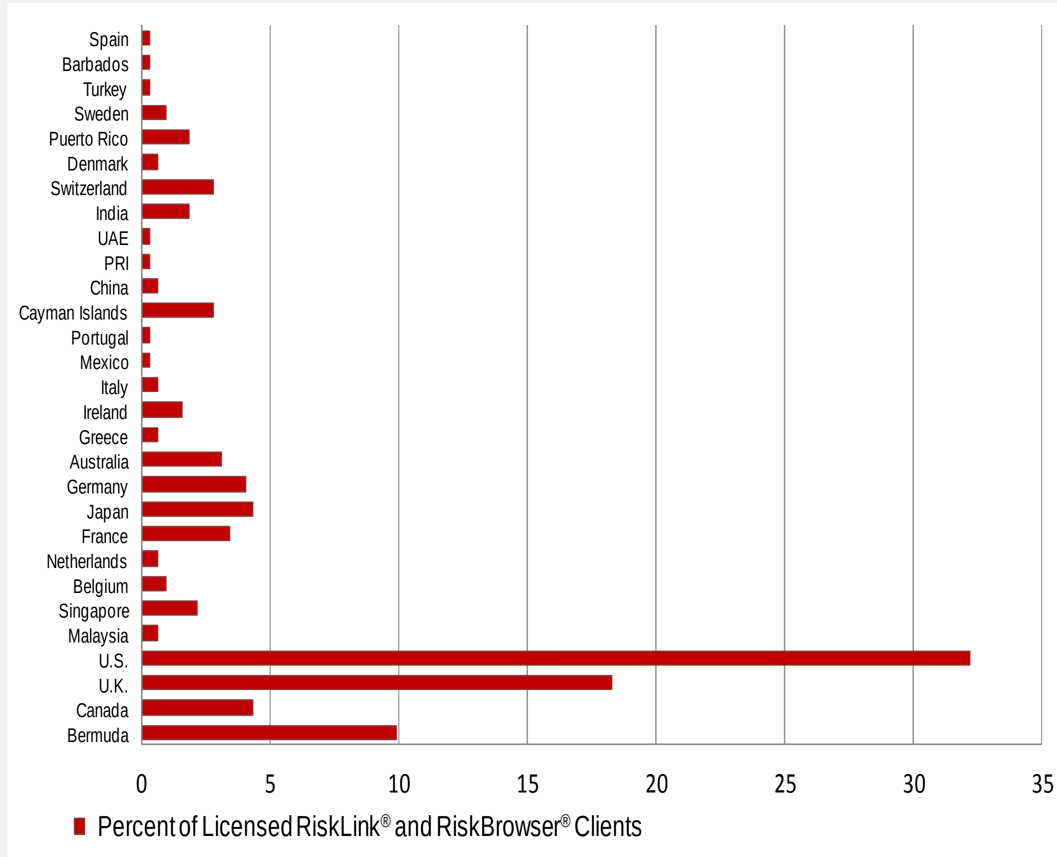
Source: Independent market surveys, public client lists, and internal RMS data. Data based on RiskLink, Classic/2, and Worldcat clients.

CLIENTS ACROSS ALL INSURANCE SEGMENTS

- 9 of the top 10 global reinsurance intermediaries
- 29 of the top 35 global reinsurance companies
- 85% penetration of the Bermuda insurance and reinsurance market
- Investment banks, lenders, industry organizations, and governments



USERS BY GEOGRAPHY



RMS

MAJOR COMPONENTS OF A TYPICAL CAT MODEL

Hazard Component

At the core of every Cat model is the Hazard Component

It describes the full stochastic event set and the damage causing hazard

It is typically the result of a physical simulation models

Exposure Component

The Exposure Component is the part that manages subjects at risk

Exposures are geo-coded and their physical attributes are captured

Also, affected exposures are identified for each stochastic event

Vulnerability Component

In the vulnerability component, exposures are combined with the hazard footprints for each stochastic event to establish damage potentials

Financial Model Component

Given the damage output from the Vulnerability Component, the Financial Model Component determines:

Contract payouts and

Calculates summary metrics – like EP

RMS

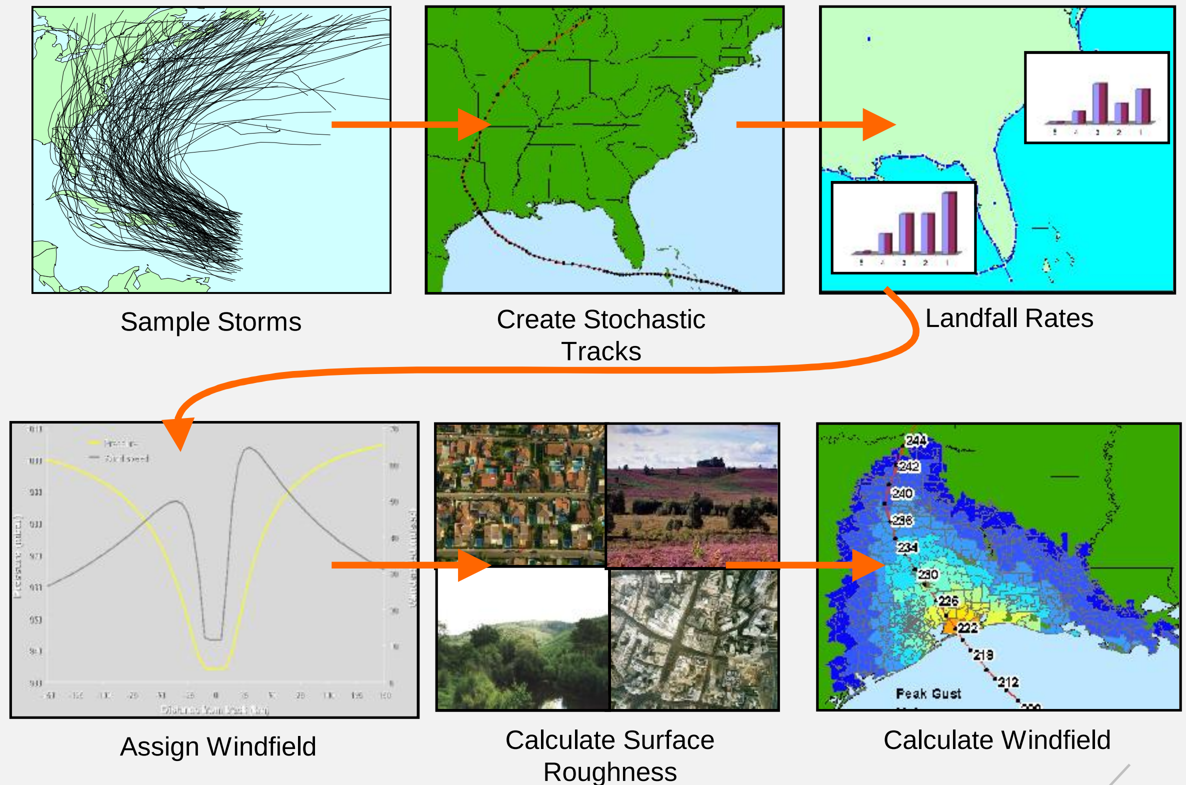
HURRICANE MODEL COMPONENTS

Cat models are typically structured into various components that mimic the natural process resulting in damage and financial loss

- A stochastic event component which simulates physical parameters, location, and frequency for each storm in a set of stochastic storms covering the full range of potential hurricanes
- A hazard model determines the relevant variables, for example the peak-gust wind speed for each stochastic storm and analyzed location
- A vulnerability module that links hazard and exposure to damage
- A financial model that estimates the loss given the damage

GENERATION OF THE EVENT SET

From Historic Storms to Stochastic Windfields



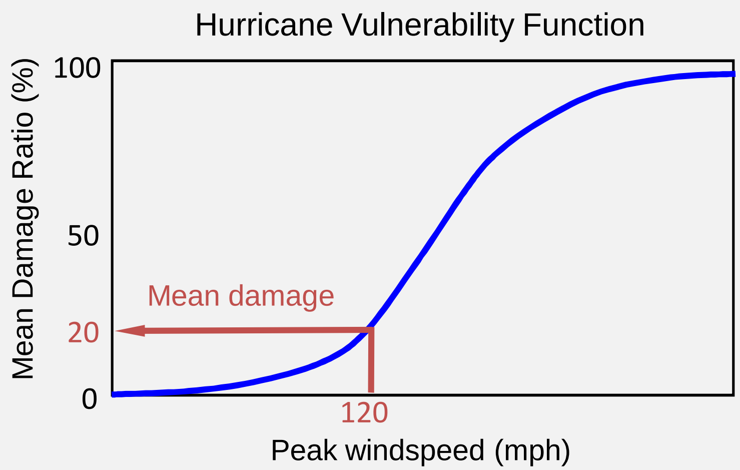
RMS

HOW IS A BUILDING'S VULNERABILITY CLASSIFIED?

Vulnerability functions are region-specific and vary by building class, occupancy class, age, and height

Vulnerability functions are calibrated with actual damage and loss data from past tropical cyclones

The Vulnerability Function relates the expected amount of damage to the severity of the hazard, such as the peak windspeed or ground motion



Vulnerability is measured by the Mean Damage Ratio

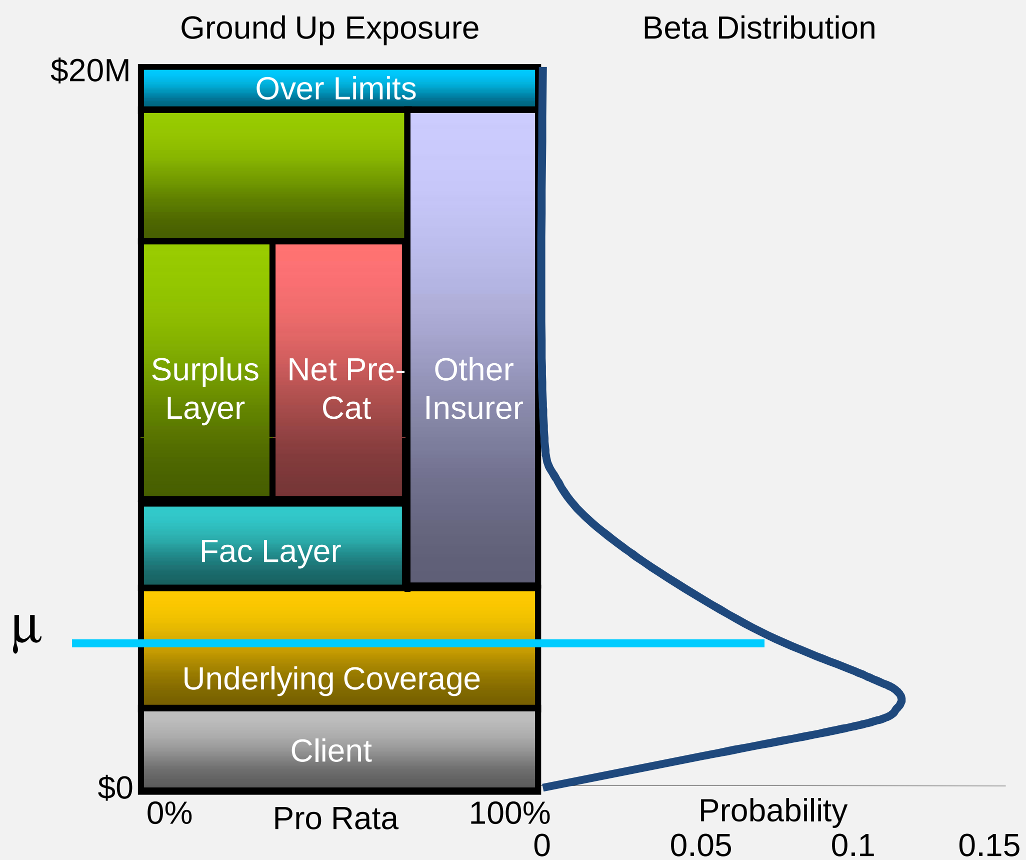
$$MDR = \frac{\text{average loss}}{\text{replacement value}}$$

FINANCIAL MODELING: ALLOCATING LOSS

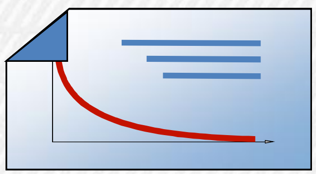
Loss for a given event is borne by multiple participants

Variability around mean drives potential loss to higher layers

Exceedance probability curves can be generated for each participant



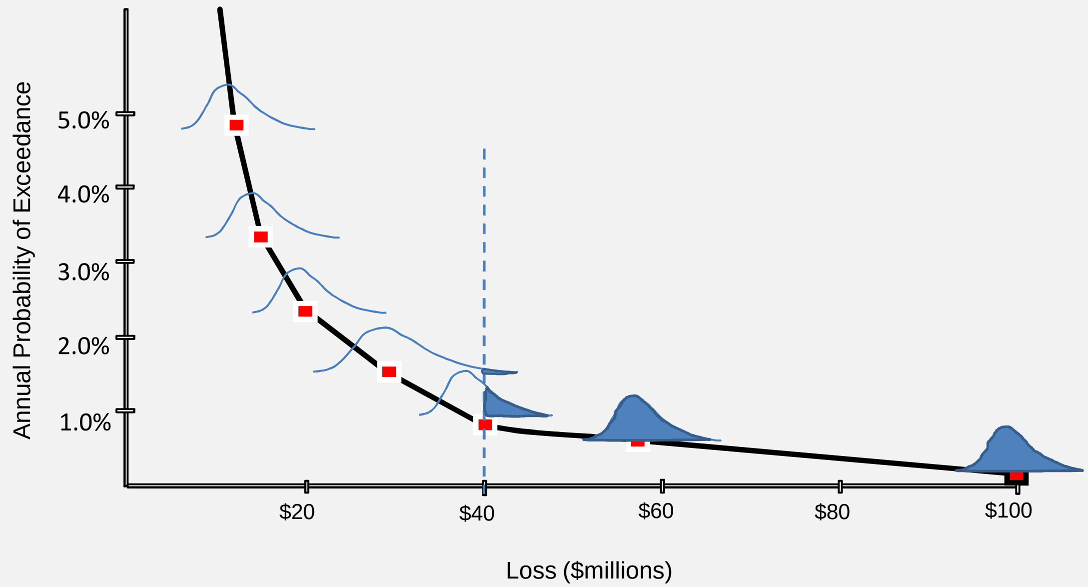
CLIENTS GATHER KEY METRICS FROM OUR MODEL TO GUIDE BUSINESS DECISIONS



- EP curve: the probability of exceeding a loss level in a given year. Most often referred to as 'return period'
  - Two types of EP curve: dance Probability (OEP) and Aggregate Exceedance Probability (AEP)
  - OEP: Probability that the single largest event in a year will exceed a loss threshold
  - AEP: Probability that the aggregate event losses in a year will exceed a loss threshold (considers multiple events per year)
- Average Annual Loss (AAL): the amount of modeled premium an insurer needs to collect in order to cover the average peril loss over time
  - Combination of event frequency and mean event loss

EXCEEDANCE PROBABILITY (EP) ANALYSIS

Event ID	Annual Probability	Loss	Cumulative Probability
Event 1	0.01%	$100	0.01%
Event 2	0.5%	$50	0.51%
Event 3	0.3%	$40	0.81%
Event 4	0.65%	$25	1.45%
Event 5	0.9%	$20	2.34%
Event 6	1.0%	$15	3.32%
Event 7	1.5%	$12	4.77%
…	…	…	…



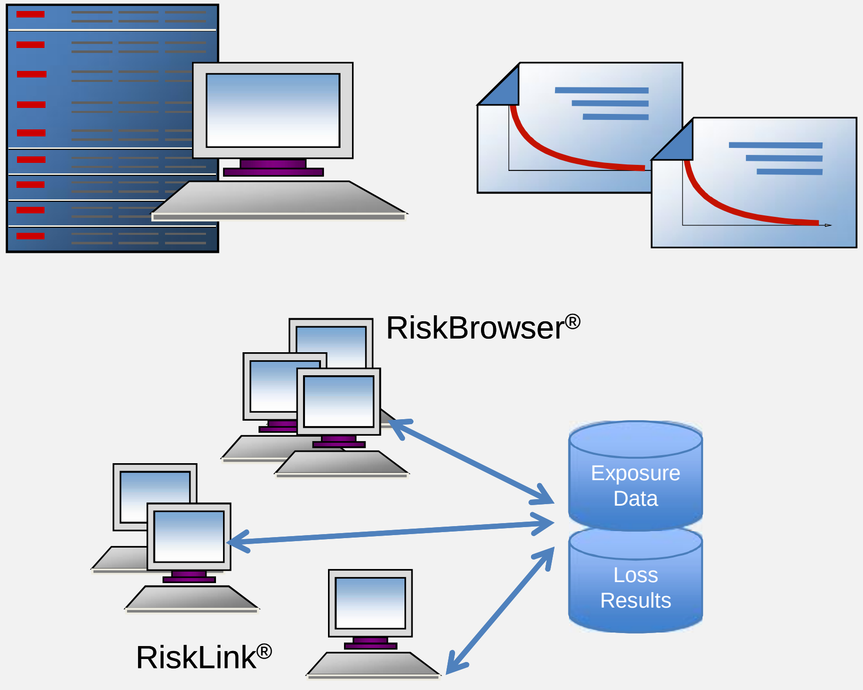
The loss-exceedance curve plots the probability of exceeding a particular loss level in a year

Provides information to assess solvency issues and manage portfolios

RMS

HOW ARE RMS MODELS USED IN THE MARKET?

- **Portfolio Management**
  - Determine risk drivers
  - Evaluate capital adequacy
  - Allocate capital
  - Estimate post-event losses
  - Accumulation management
- **Risk Transfer**
  - Determine reinsurance needs
  - Structure and price risk transfer
  - Communicate with counterparties
  - We are an independent party
- **Underwriting**
  - Establish guidelines
  - Differentiate risks
  - Analyze policy structures
  - Develop pricing



DEEP PERIL UNCERTAINTY OR ALEATORIC VARIABILITY

- The amount of inherent (or aleatoric) variability in both North American Hurricane and Tornado makes experience rating very difficult or impossible
- Building component based models is the only realistic choice
- They can utilize relevant data sources for each component
  - Achieving greater information content and application of specific scientific knowledge
- And are able to “extrapolate” beyond observed loss records to reveal more complete set of potential loss scenarios

NORTH AMERICAN HURRICANE ALEATORIC VARIABILITY

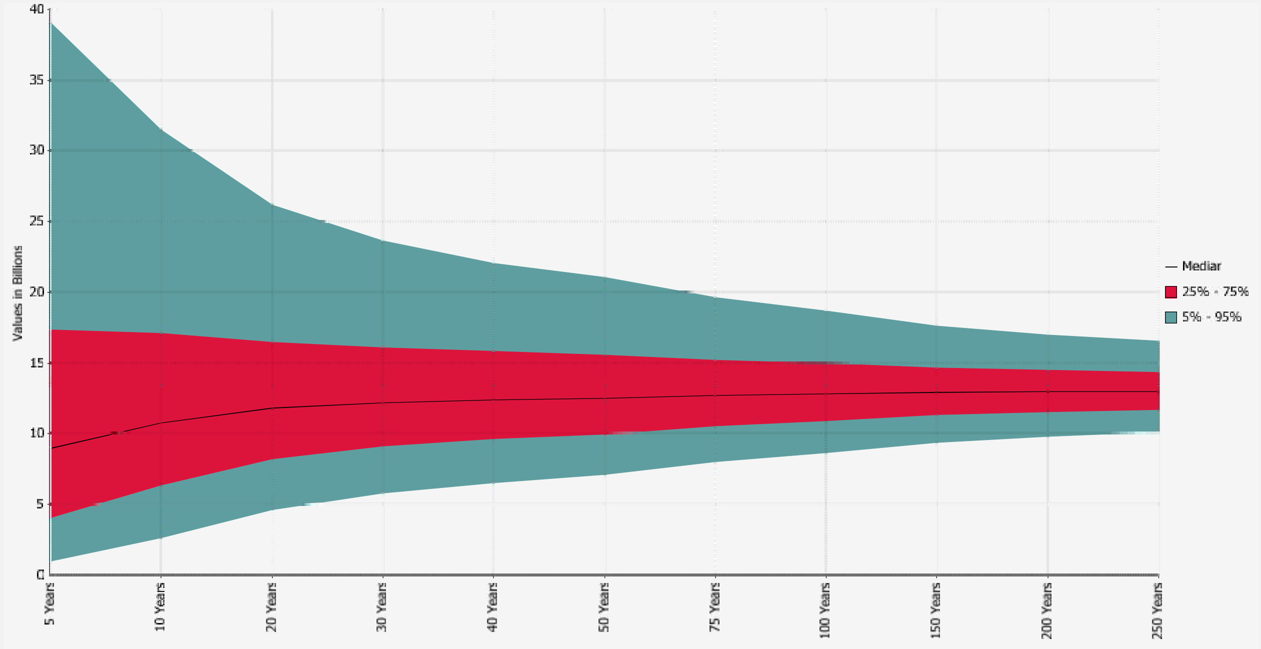
Simulation based on North American Industry AEP

Underlying AAL = $13.2b

AAL estimate has only a 50% probability to fall in red area

Median well below AAL for shorter experience periods

Trend in Distribution Statistics for AAL Estimates Based on Various Experience Periods



RMS

NORTH AMERICAN TORNADO ALEATORIC VARIABILITY

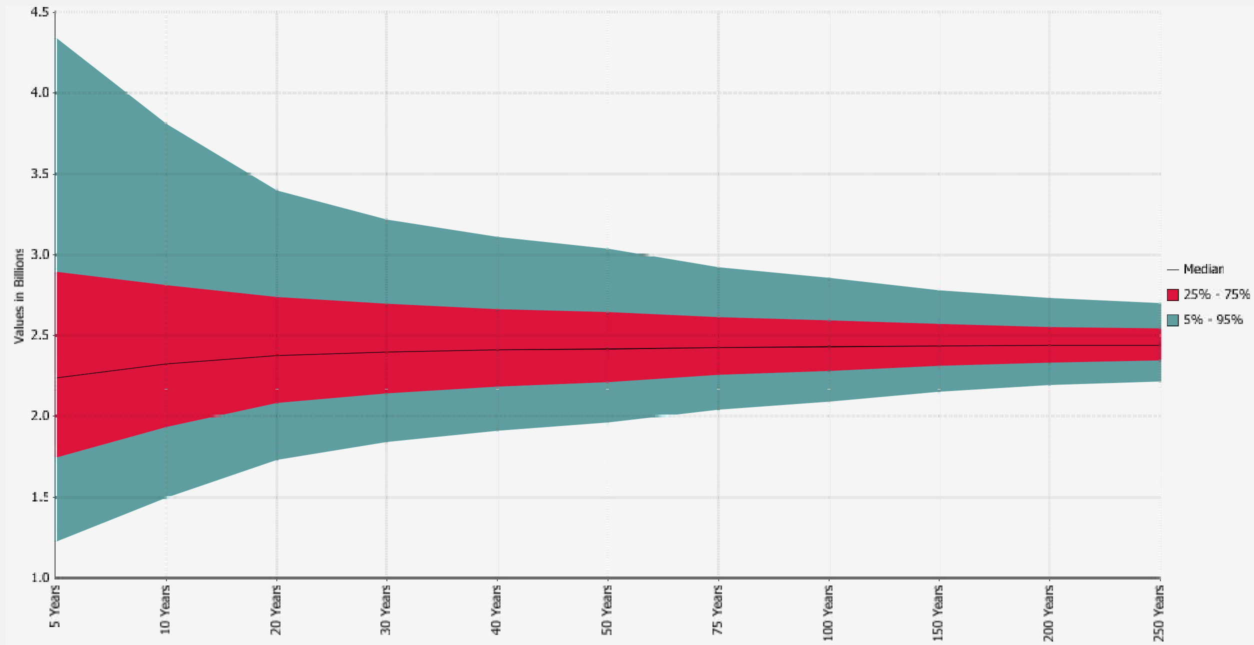
Simulation based on North American Industry AEP

Underlying AAL = $2.4b

AAL estimate has only a 50% probability to fall in red area

Median well below AAL for shorter experience periods

Trend in Distribution Statistics for AAL Estimates Based on Various Experience Periods



OKLAHOMA TORNADO ALEATORIC VARIABILITY

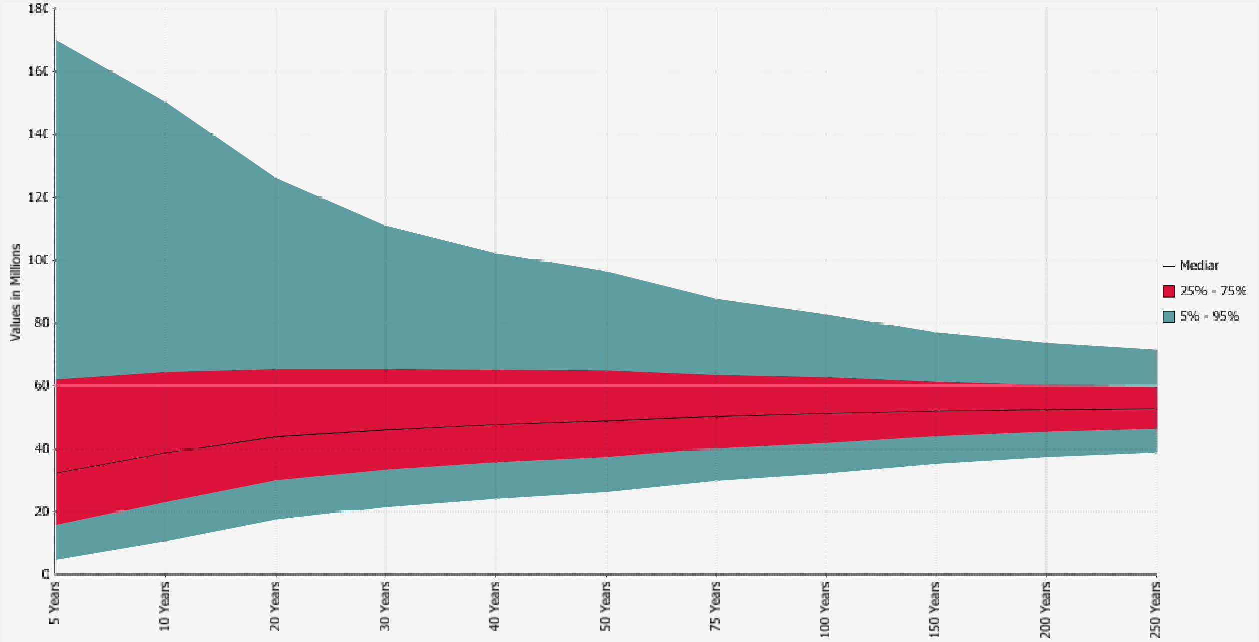
Simulation based on Oklahoma Industry AEP

Underlying AAL = $54m

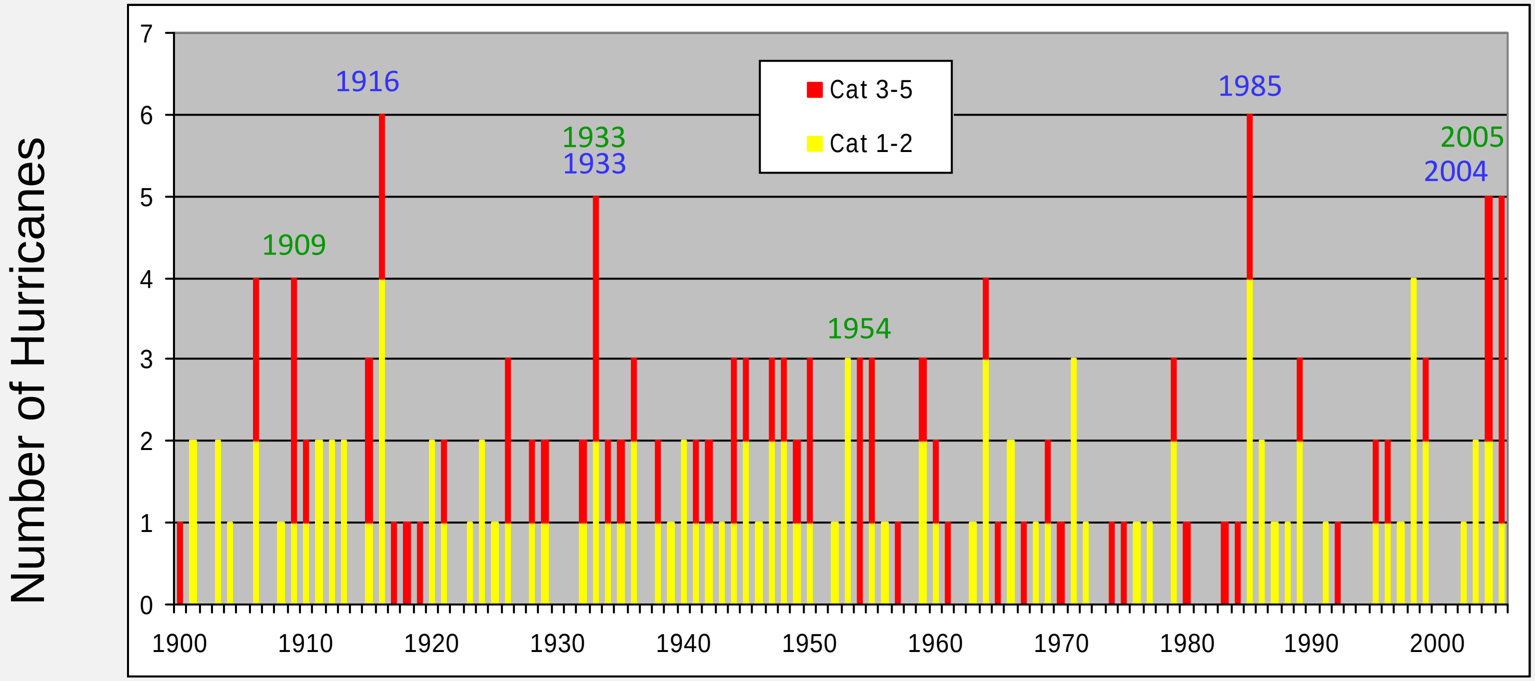
AAL estimate has only a 50% probability to fall in red area

Median well below AAL for shorter experience periods

Trend in Distribution Statistics for AAL Estimates Based on Various Experience Periods



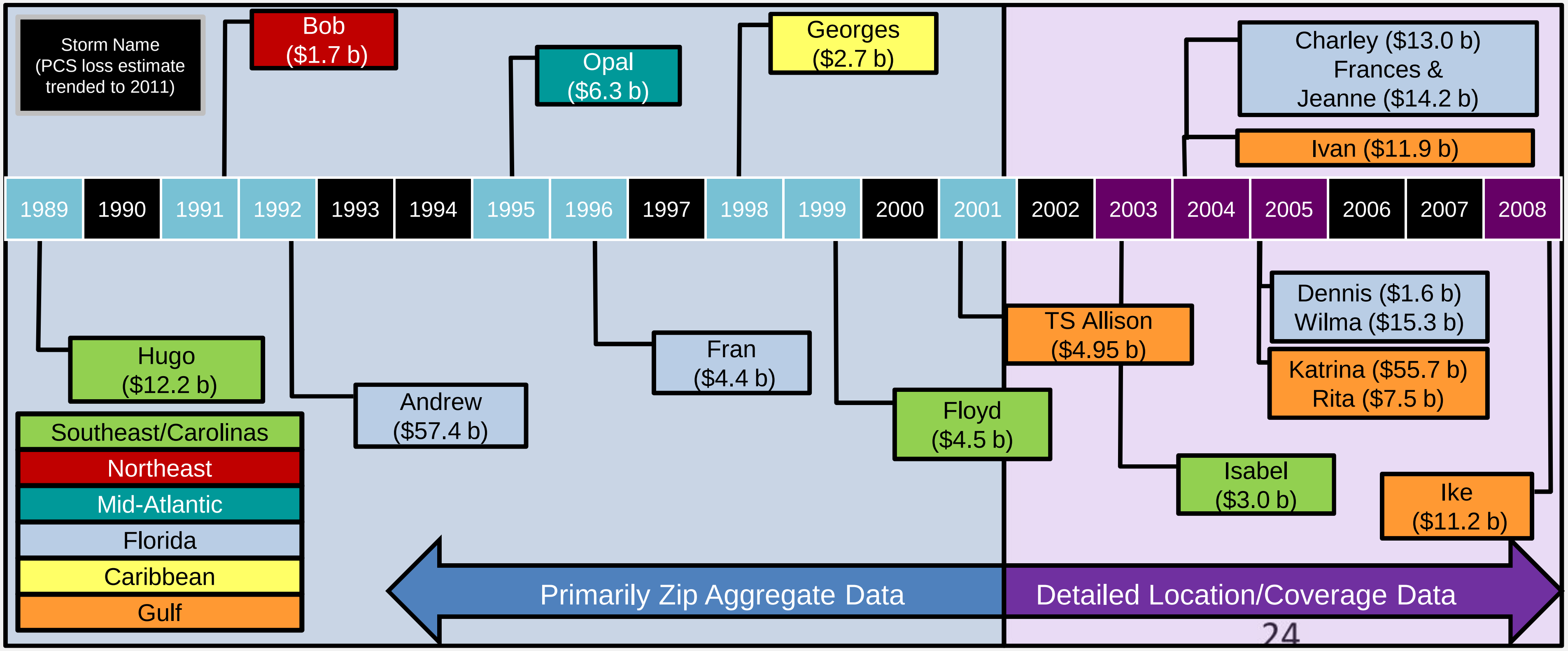
U.S. Hurricane Landfalls: HURDAT Data



Years with five or more landfalls denoted in blue
Years with three or more Cat 3-5 storms denoted in green

Twenty Years of Loss Data

- Engineering driven development
- Each region uses data and information specific to that region
- Calibrated with $18 billion claims data – increasing detail
- 20 years of claims data – total $18 billion in-house



BUT, UNCERTAINTY REMAINS

One example – where we have the most U.S. Claims data

2004 AND NEWER CLAIMS DATA

Qualitative Ranking of Vulnerability Curves from Highly Data-driven to Engineering Based

MAIN SOURCES OF UNCERTAINTY EXAMPLE: US EQ

Model Related Uncertainty

1- Seismic Source Model
- Maximum magnitude
- Rapture mechanism
- Seismic rates
- Event depth

2 - Ground Motion Model
- Empirical relationships
- Soil and site condition
- Directivity impact
- Soil aggregation

3 –Vulnerability Model
- Structure performance
- Translation of structural deformation to damage
- Non-structural components
- Building inventory
- BI

Non-Model Related Uncertainty

4 - Exposure
- Industry Exposure (IED)
- Data quality
- Polity structure
- Account / locations
- Under Insurance

5 – PLA & Non-Modeled Loss
- Demand surge / PLA
- Contingent BI
- Catastrophic damage to infrastructure
- Non related event claims
- Cause of Loss

RMS

NO SUCH THING AS A 'PERFECT' MODEL

Every model user should acknowledge and understand its uncertainties, or be at risk of:

Misinterpreting results

Over-interpreting results

Not prepared for reality

UNCERTAINTY IN CAT RISK

RMS

UNCERTAINTY IN CATASTROPHE RISK

Christos Mitas, PhD

Uncertainty in catastrophe risk

RMS

OUTLINE

- Introduction
- Some specific examples of uncertainty in the *Europe Windstorm* model.
- How does it differ from the *North America Hurricane* model?
- Similarities and difference with other types of cat models (*flood*, *earthquake*, *terrorism*).
- Complete the picture with non-modeled risk.
- A note on Resilient Risk Management

INTRODUCTION

WHAT IS A CAT MODEL?

- A mathematical model which incorporates spatial and temporal features of a physical system able to produce catastrophic events.... and ...
- A mathematical model which quantifies property damage in a probabilistic way ... and...
- A model which determines the relevant characteristics of property... and...
- An actuarial-financial model able to assign economic loss to damage and aggregate this loss to various levels.

- In a nutshell, it's a multi-component system coupling numerous models which are validated in isolation, and finally validated at the end output – loss!

HOW DOES UNCERTAINTY CREEP IN A CAT MODEL?

- Each component, by nature, has uncertainties associated with it.
- The coupling of different components has also uncertainties.
- The validation data of each component exhibit measurable uncertainty, either because of spatial and temporal parameterized scales, or observational errors.
- Finally, the targets of a cat model (which invariably consist of experienced and perceived loss metrics) include large uncertainties due to their socio-economic nature, under-reporting, and spatio-temporal errors.

MAJOR COMPONENTS OF A CAT MODEL

Hazard

A stochastic catalogue of **plausible events**, equipped with both frequency of appearance and severity.

Vulnerability

An engineering model which quantifies the **ratio of incurred loss to exposure**, given the **characteristics** of the exposed property and the **intensity of hazard**.

Exposure

A geospatial and economic model which quantifies the rebuild value of buildings based on several primary characteristics

Financial Model

Economic loss (aka Ground-Up loss) which is aggregated at various spatial, Line-of-Business, account, and portfolio levels. Various financial perspectives depending on the applied insurance contracts.

RMS

HAZARD:

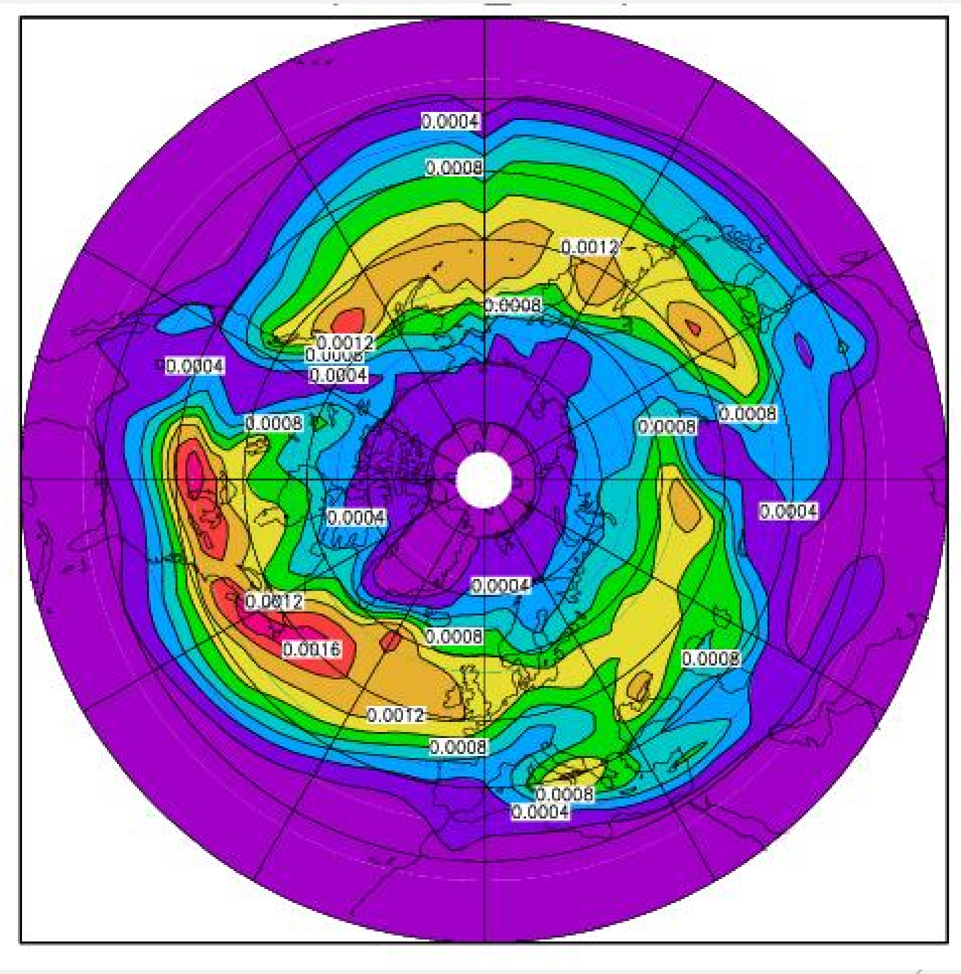
WHAT IS AN EVENT?

Events are usually defined by a spatial pattern denoting the extent and intensity of a relevant hazard variable (wind, shake, water depth, etc.)

HAZARD:

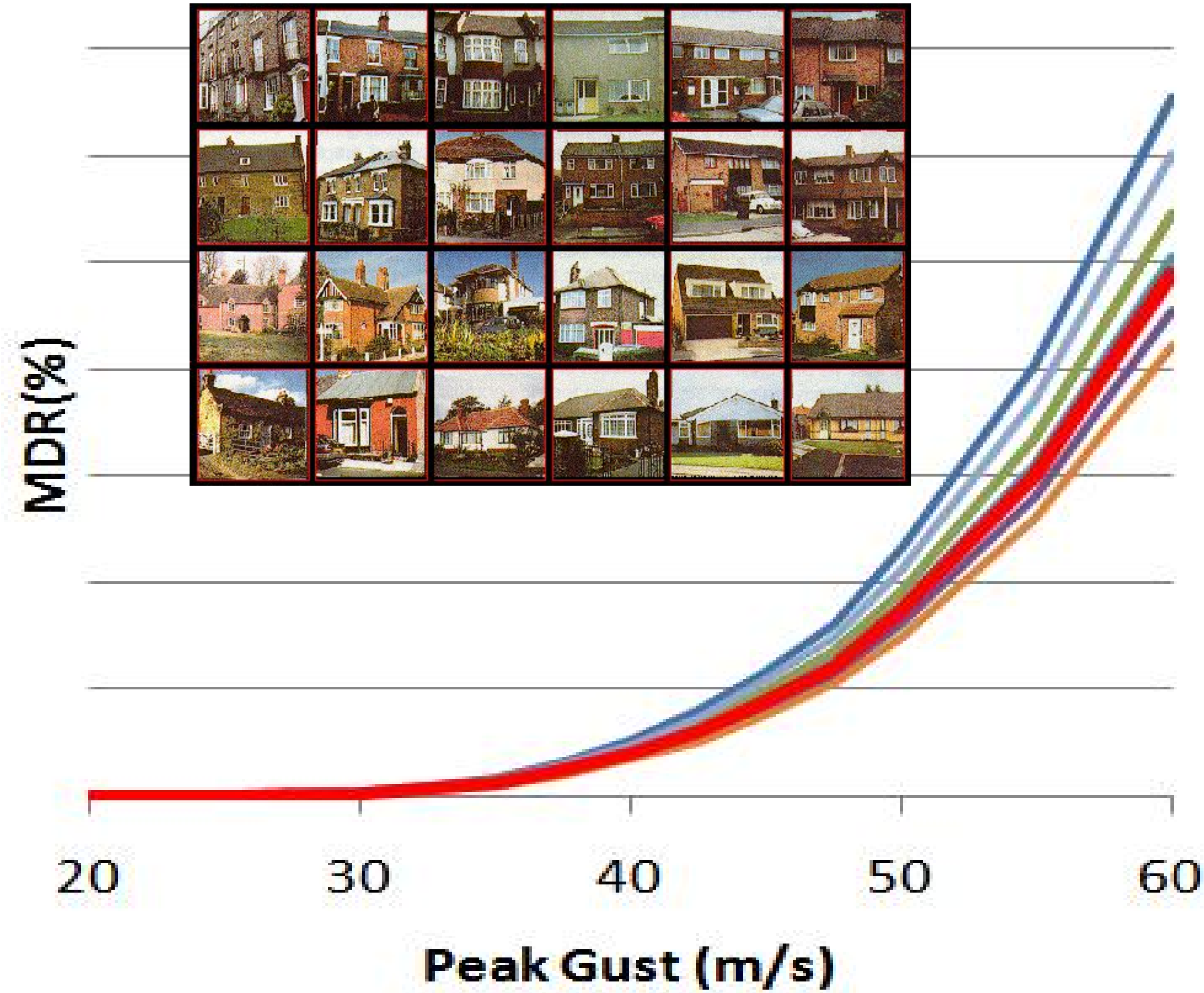
WHAT IS PLAUSIBLE?

Plausibility is achieved by using models of the physical system that produces the catastrophic event (atmosphere, ocean, tectonic plates, etc.) to span its full variability (observed and unobserved)



VULNERABILITY: MEAN LOSS RATIO

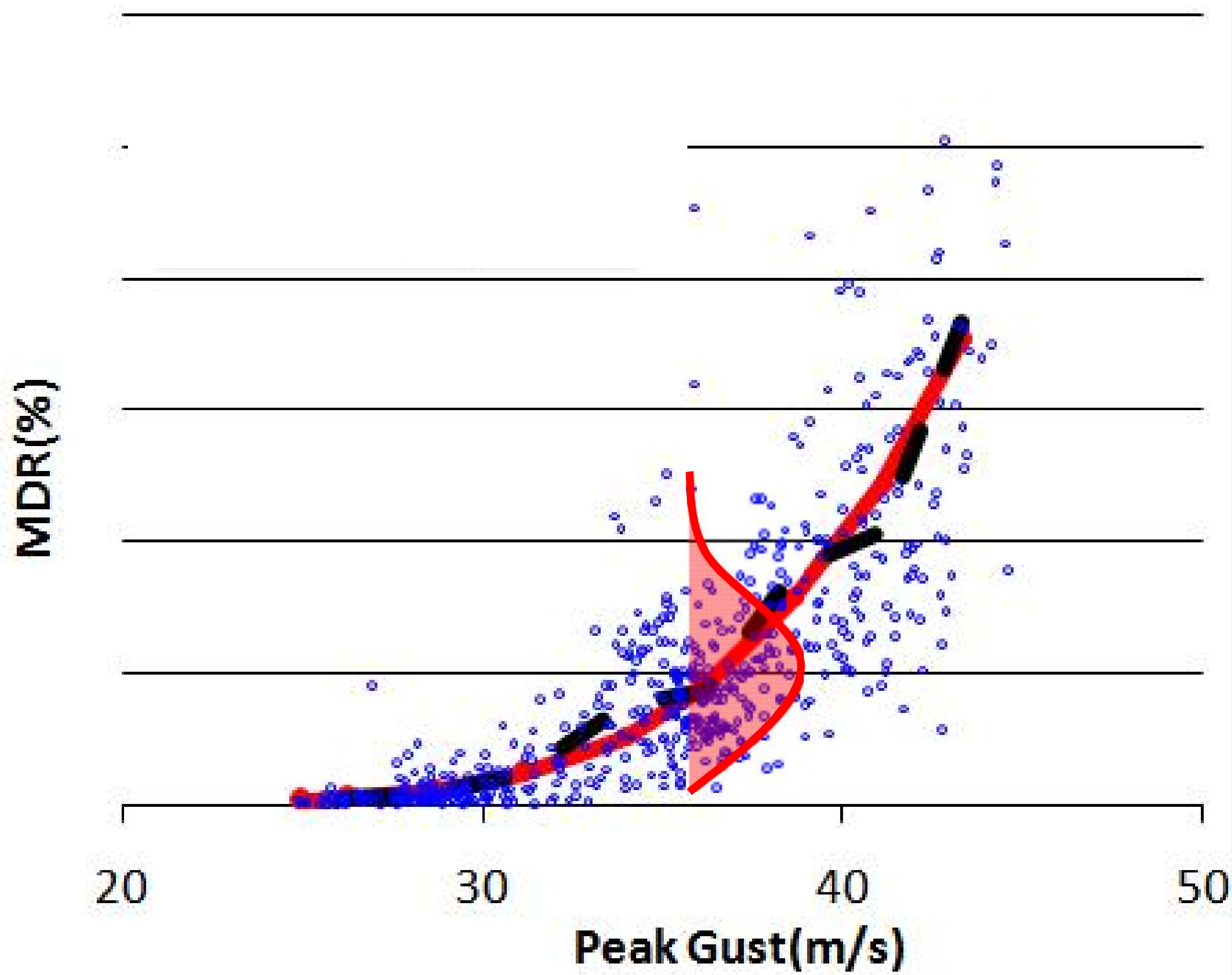
A building is characterized by a small number of primary characteristics. For every combination of these, we assign a mapping between the realized hazard and a **mean** loss ratio.



VULNERABILITY: IS MDR ENOUGH?

Not really... So, we capture the uncertainty around the mean loss ratio, by specifying a distribution with this given mean, and a standard deviation.

The chosen distribution is the Beta



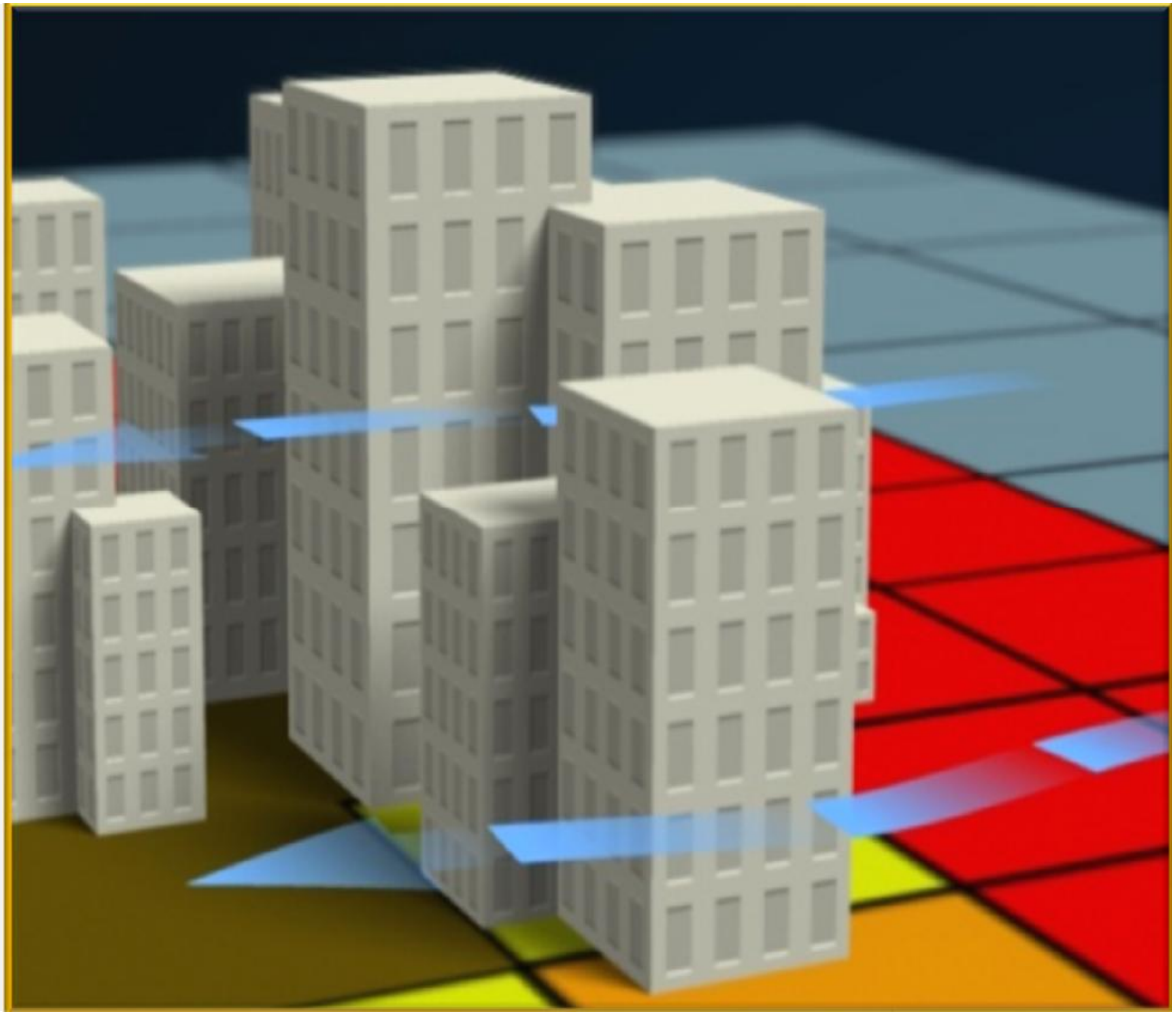
EXPOSURE:

IS IT REALLY UNCERTAIN?

The way a cat model treats exposure is *deterministic*.

However, the exposure is captured at a level of geospatial detail which varies greatly by region and peril.

This introduces errors stemming from applying the coupled components at too coarse a resolution.

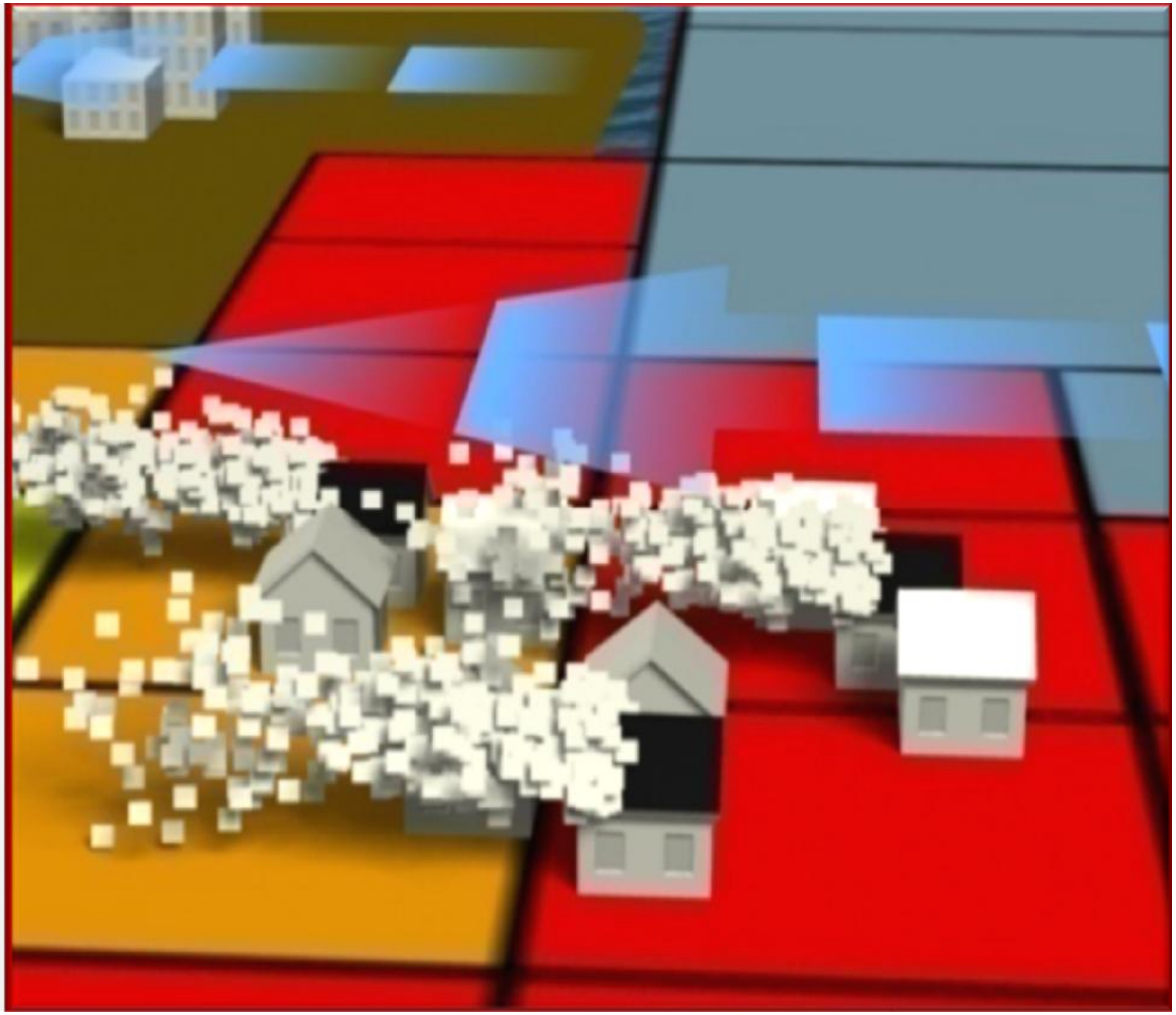


EXPOSURE:

CHANGES AND NON-LINEAR EFFECTS

Modeling the rebuild cost of buildings also carries ambiguity due to potential changes in economic conditions.

Also, a very large catastrophe might affect this cost by amplifying the loss due to demand surge, claims inflation, etc.

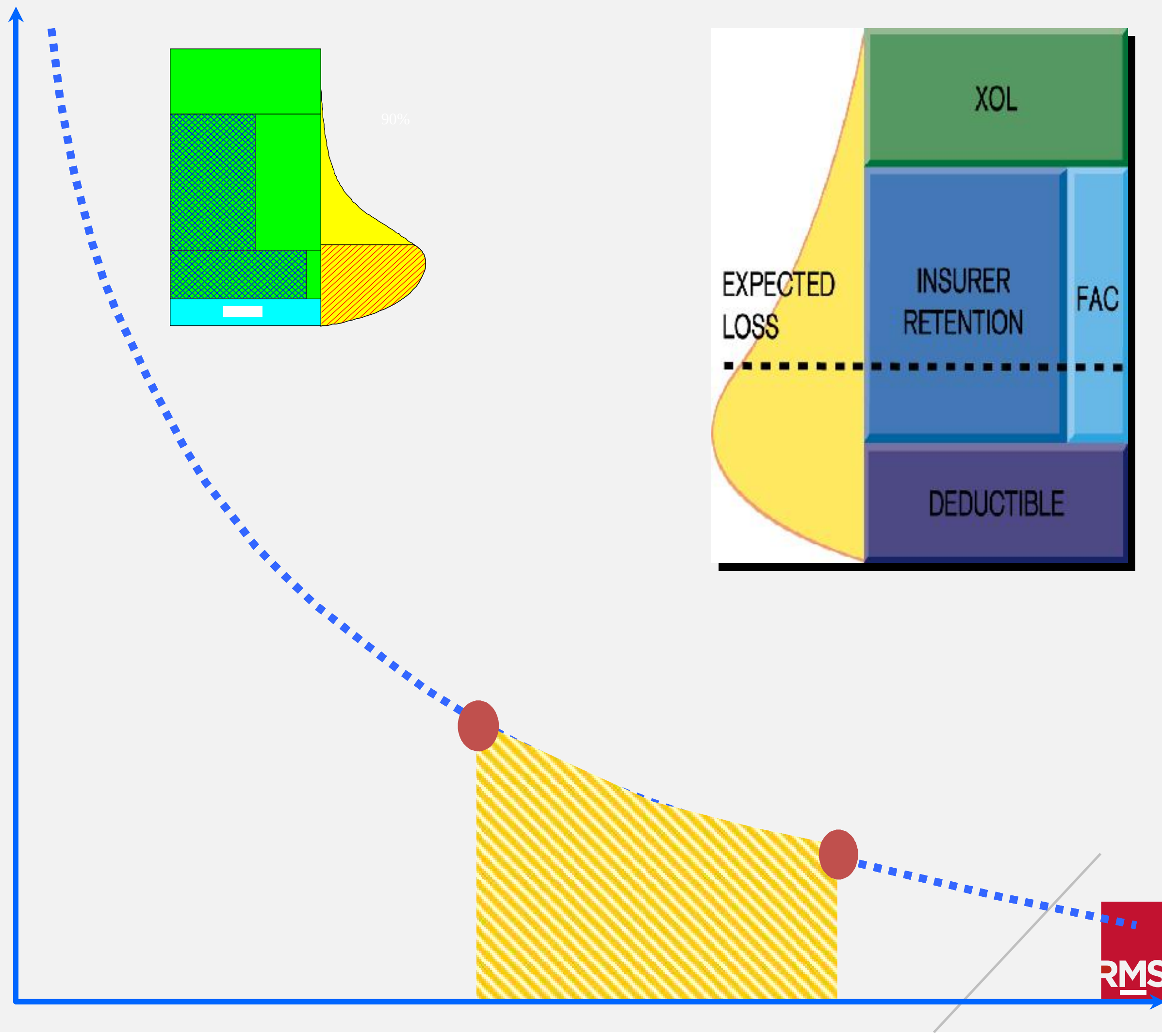


FINANCIAL MODEL:

ANALYTICAL VS. SIMULATION

Currently, cat models use analytical methods for most of their calculations of aggregation. Usually, simulation is used for the coarser loss resolution (e.g.. portfolio).

There is a significant undertaking by RMS to move towards simulation at the finest level of loss resolution (i.e. location).

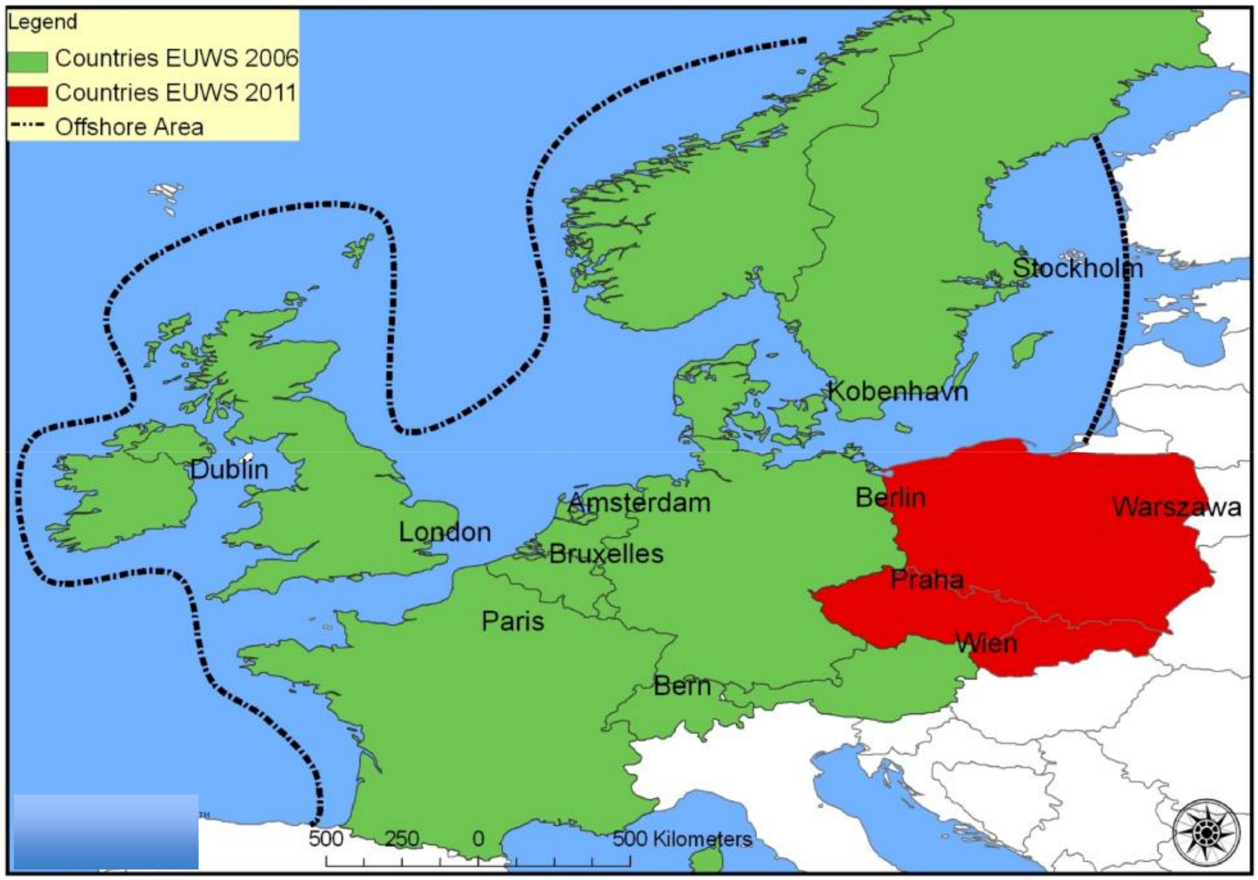


RMS

EUROPE WINDSTORM MODEL

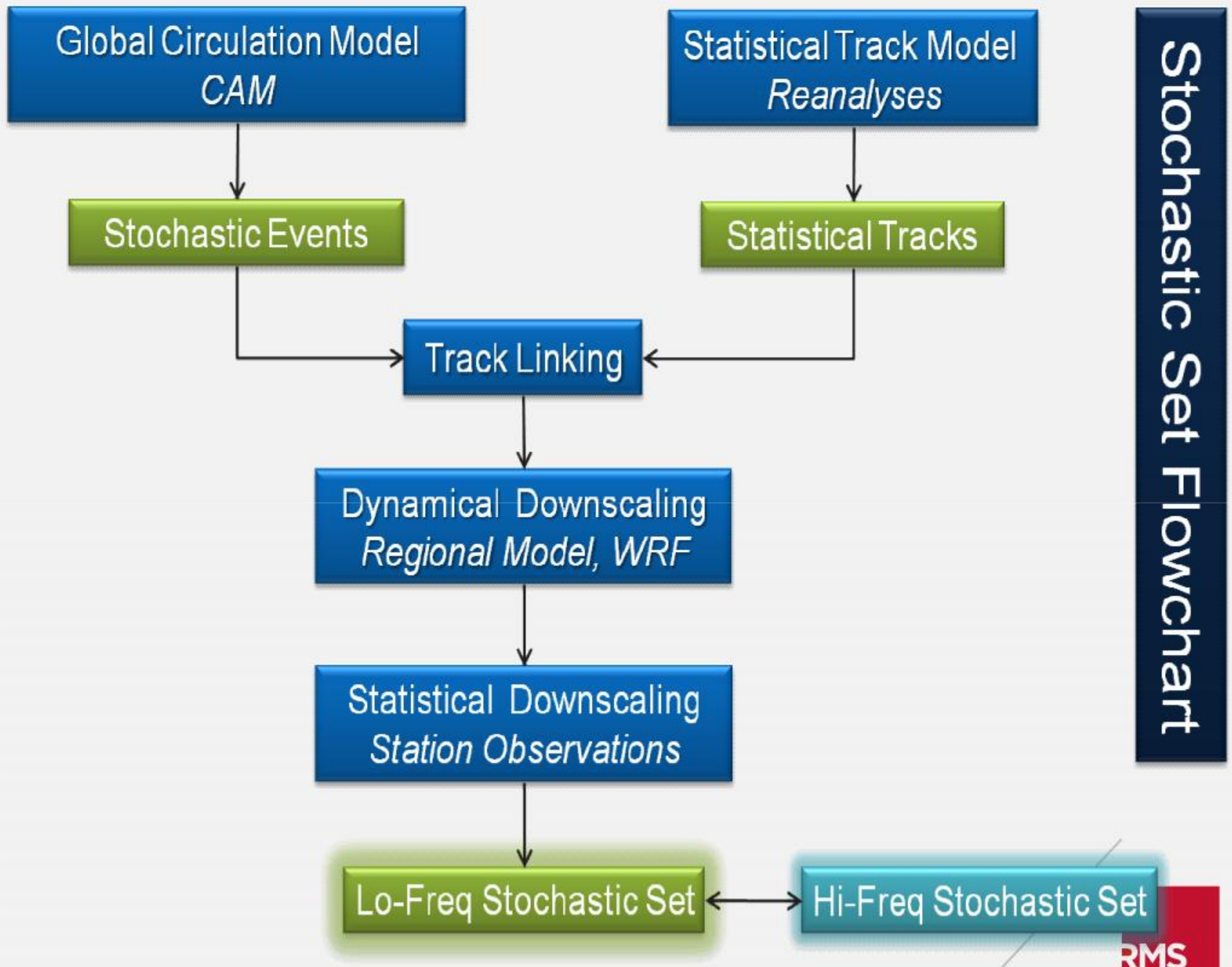
HIGH-LEVEL DESCRIPTION

Represent windstorm risk by modeling storms at the synoptic and mesoscale (i.e. convective) scales.



RECIPE FOR MAKING A HAZARD COMPONENT

Europe Windstorm



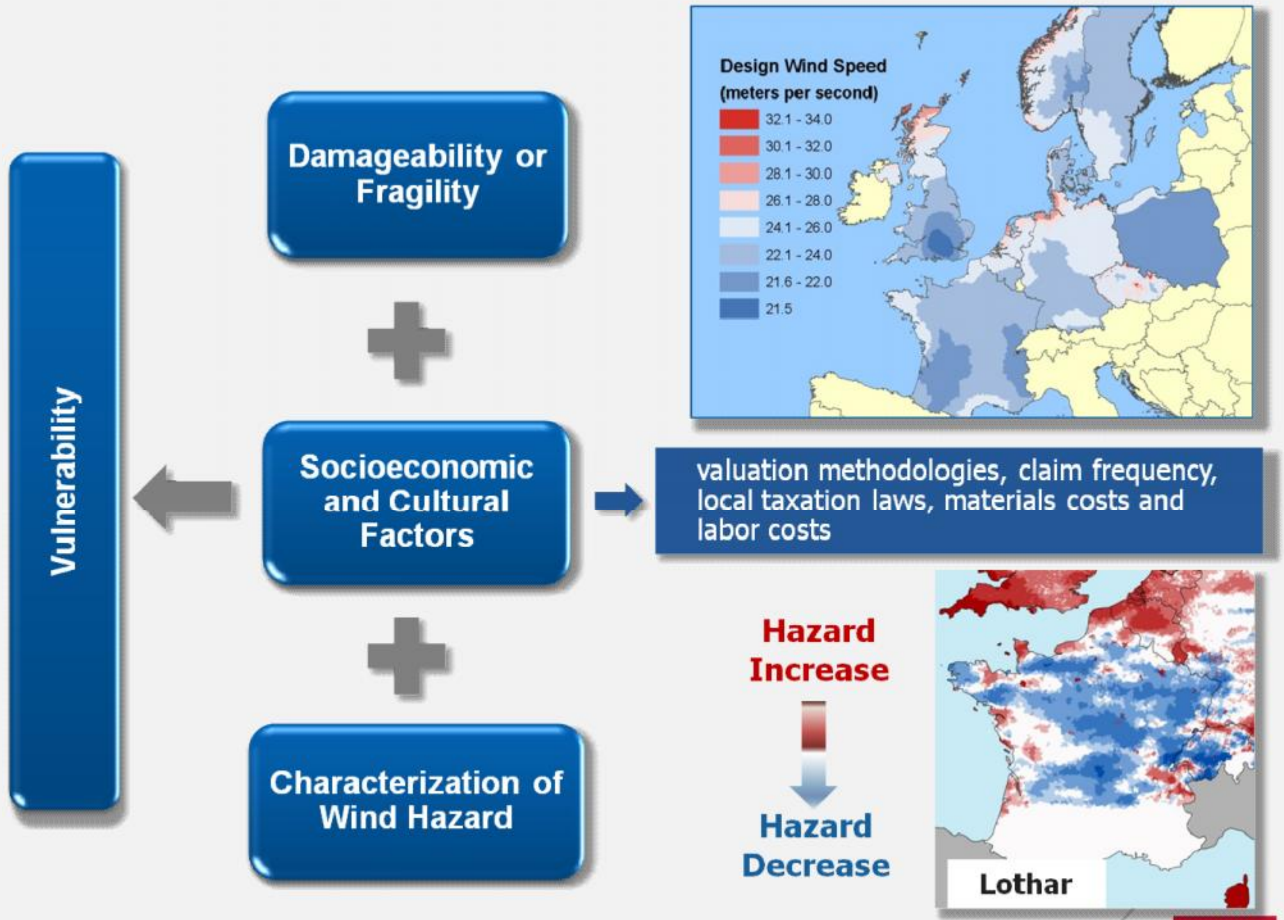
WHERE DOES AMBIGUITY COME IN?

A LAUNDRY LIST OF MODELING DECISIONS MADE DURING DEVELOPMENT

- Which Global Climate Model?
  - At which resolution?
  - For how many years?
- Which regional model?
  - Which resolution is optimum
  - and practical?
- Which reanalysis set?
- Which tracking algorithm?
- How does one go from station observations (irregular network) to
  - Meteorological model resolution
  - Cat model resolution
- How should the observed data with limited record length be extrapolated? Should they be extrapolated?
- How much actuarial/meteorological data are enough for the high-frequency model?

RECIPE FOR MAKING A VULNERABILITY COMPONENT

Europe Windstorm



RMS

WHERE DOES AMBIGUITY COME IN?

CONTINUING THE LAUNDRY LIST ...

- Which valuation methodology (there are at least two wide-spread ones)
- Which material and labor costs?
  - And how certain and/ore current they are?
- How to estimate social and cultural factors, like propensity for claiming, even at small loss?
- How certain is the hazard?
  - By region or country?
  - How big is the observational error?
- How much confidence is there in the damageability model?
  - Are there enough engineering data?
  - For the kind of properties of interest?

- Is the damage represented in the claims captured by the single hazard parameter (in this example, peak gust)?
  - Maybe duration of event is important

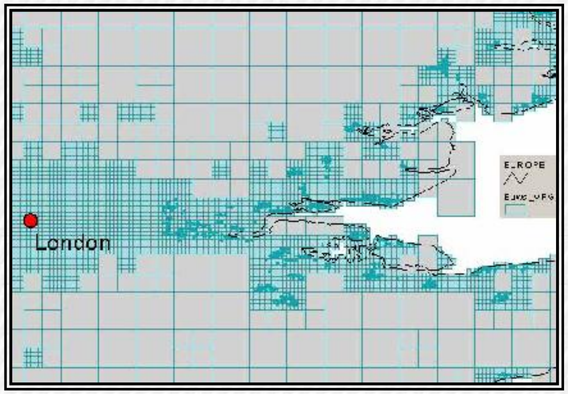
RMS

EXPOSURE AMBIGUITY

Windstorms **Lothar** and **Martin** in France (1999)

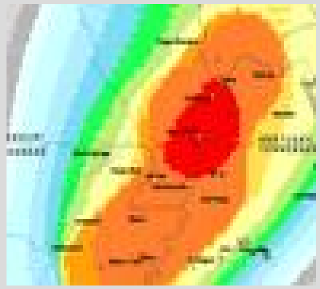
WHERE DOES AMBIGUITY COME IN?

CONTINUING THE LAUNDRY LIST ...

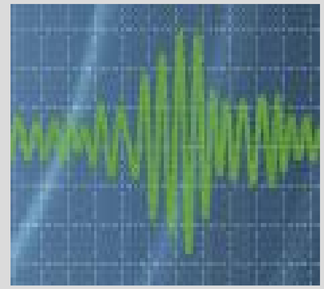


- Exposure is coded as a lump sum of total sums insured:
  - Applicable at postal code level
  - Number of buildings comprising the exposure is approximate
- Exposure characteristics are captured only partially:
  - For example, only occupancy is specified (Residential, Commercial, or Industrial)
  - What does one assume for the rest? RMS develops an **inventory** which is used to fill in the gaps.
- How much does the inventory represent a specific client portfolio make-up?

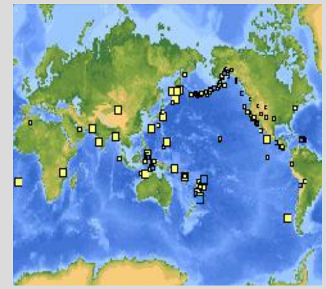
COUPLE ALL COMPONENTS TOGETHER



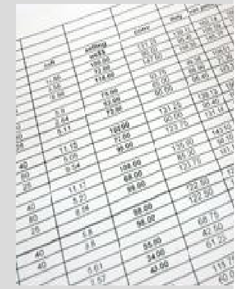
Define Event



Assess Risk



Apply Exposure



Calculate Damage

Quantify Financial Loss

Stochastic Event Module

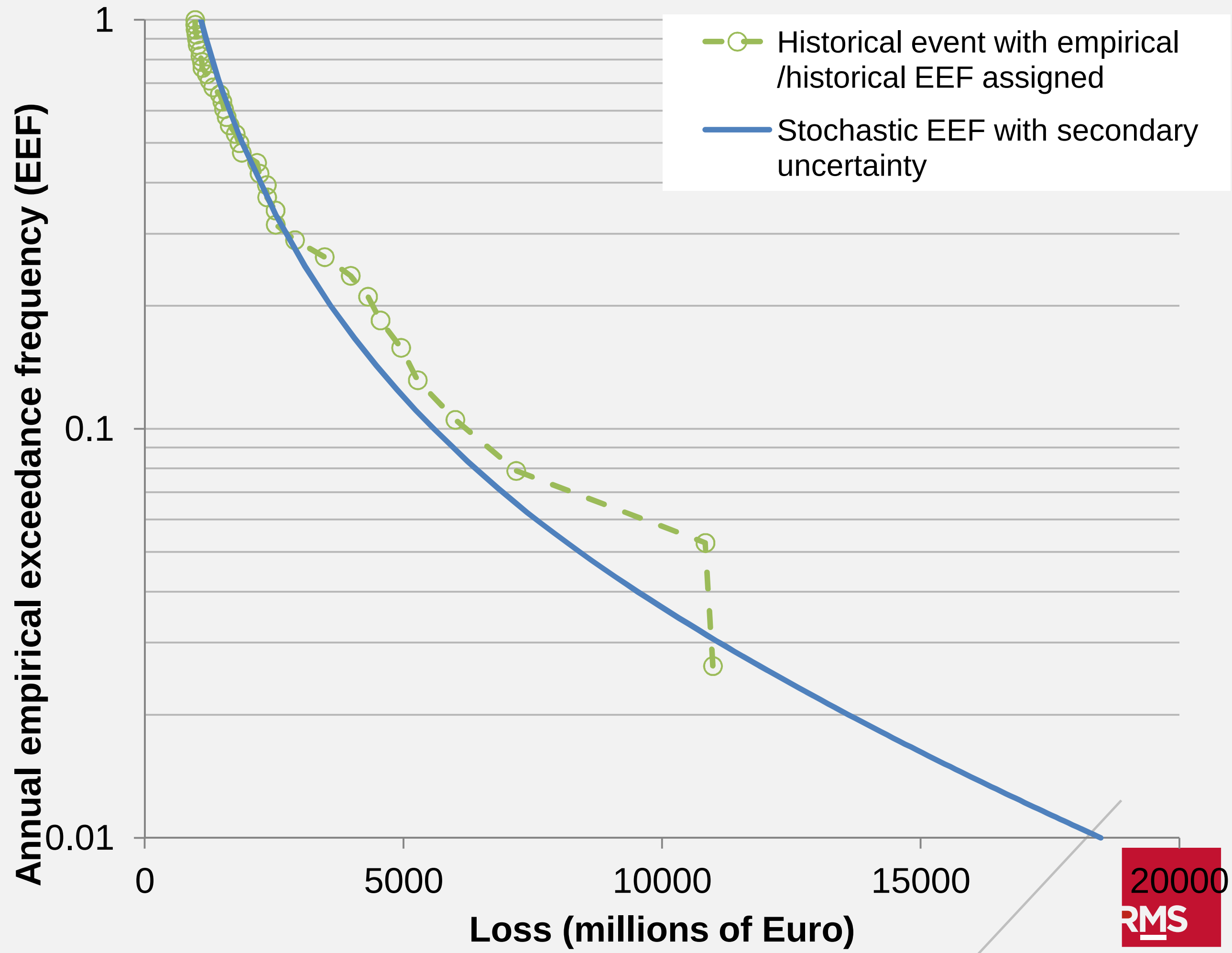
Hazard Module

Geocoding/ Exposure Module

Vulnerabil Module

LOSS CALIBRATION

Once the model components are well-calibrated, loss targets need to be achieved by the catastrophe model.

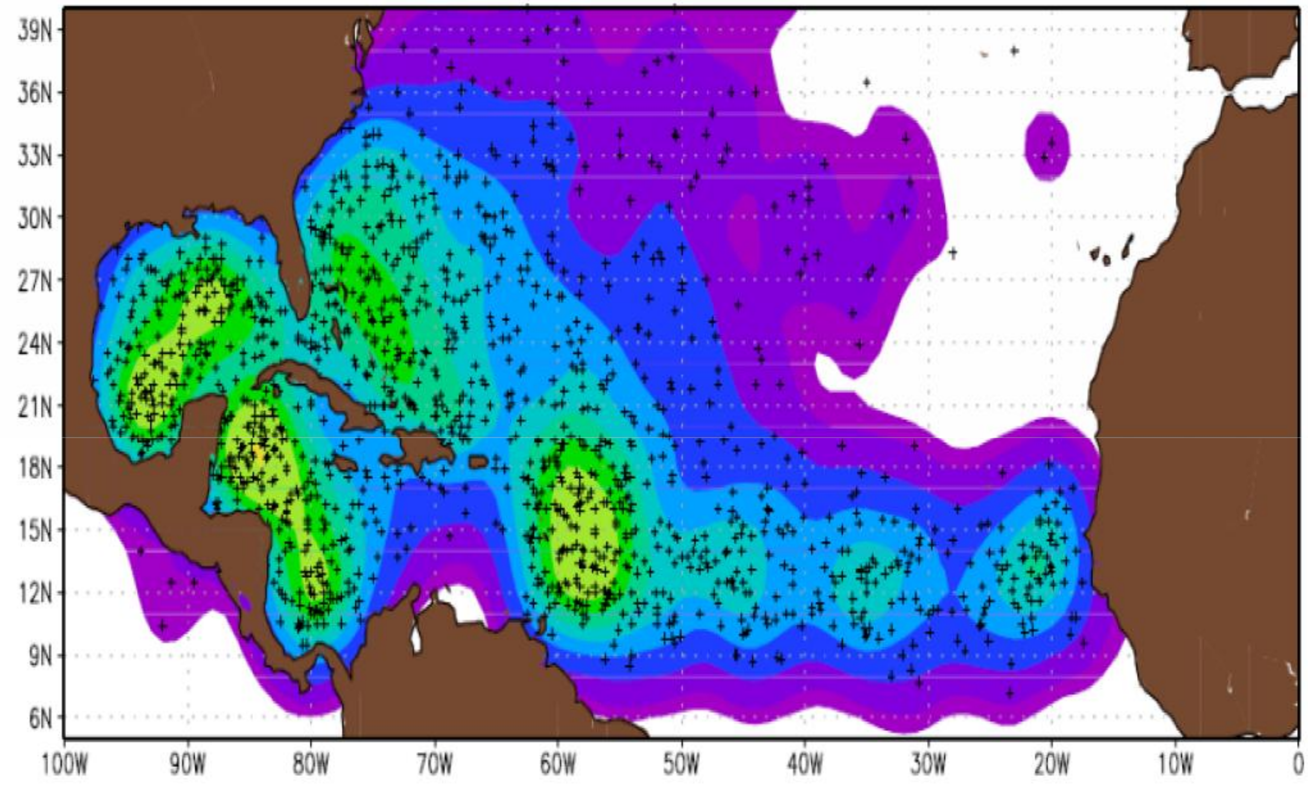


RMS

NORTH ATLANTIC HURRICANE MODEL

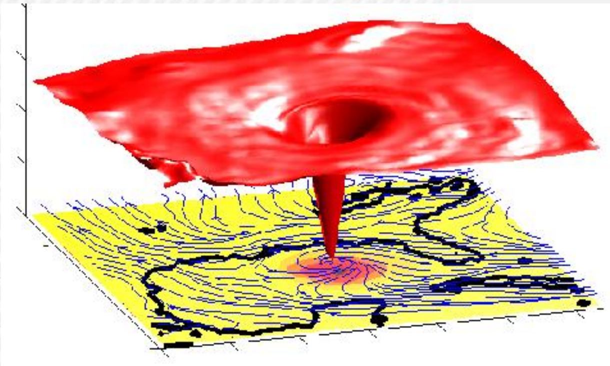
HIGH-LEVEL DESCRIPTION

Represents the risk of Cat 1-5 hurricanes which originate in the North Atlantic and are likely to affect North America and the Caribbean.



RECIPE FOR MAKING A HAZARD COMPONENT

North Atlantic Hurricane



Track model

- lon/lat
- ~~Central Pressure~~
- Vmax

↓

Rmax – Shape param

Wind field model

1' mean winds eq over water

↓

Site coefficient model

3" gust over local terrain

RMS

DIFFERENT KIND OF DECISIONS, BUT SIMILAR EFFECT...

Hazard

Track model

- Are there enough data to calibrate?
- Are the assumptions of normality valid?

Wind model

- Is the parametric model sophisticated enough?
- What are the uncertainties of the parameters used?

Vulnerability

Similar kind of data as in Europe Windstorm, but with significantly more spatial, temporal, and LOB resolution for primary damage curves.

Insurance industry captures many more primary characteristics than in Europe.

Exposure

Great variation of exposure characteristics through domain: US and Canada vs. Mexico and Caribbean

Contacts are sometimes defined with respect to other perils, like storm surge, which we model, BUT untangling the observed and modeled loss data can be difficult.

RMS

A SPECTRUM OF MODELS FOR BOTH NATURAL AND MAN-MADE CATASTROPHES

- Flood
- Earthquake
- Terrorism

All of these catastrophe models share the probabilistic nature of hazard and vulnerability and the static nature of exposure.

There are major differences in the methodologies to create reasonable and plausible stochastic sets, but the output (frequency and severity of loss) remains the same.

NON-MODELED CATASTROPHE RISK

- There are many perils for which the Cat Modeling industry does not provide a model. Prominent examples include volcanic eruptions, landslides, subsidence, tsunamis.
- Note that we do see rapid progress in these areas, but they lag behind compared to hurricanes, synoptic storms, floods, earthquakes, and terrorism (which in RMS we call Tier 1 models when applied to the US, Europe, or Japan).
- The academic community provides substantial help to fill these gaps, but not as Catastrophe Models. Mostly as products for back of envelop calculations of Probable Maximum Loss.
- An important non-modeled risk is also the *dependency* across perils and regions. Especially for global Re/Insurance companies which they need to make various assumptions on this dependency.

RMS

A NEW PARADIGM IN CAT MODELING

RESILIENCY

- An approach to risk management that makes explicit what we all know intuitively – that **catastrophe risk is characterized by deep uncertainty**, and a responsible strategy demands a continuous dialogue between what we know and what we do not know.
- In a resilient framework, a company not only seeks to **maximize its returns** based on its view of the risk landscape, it also looks to **minimize its regret** given the uncertainties in the maps that describe the terrain ahead.

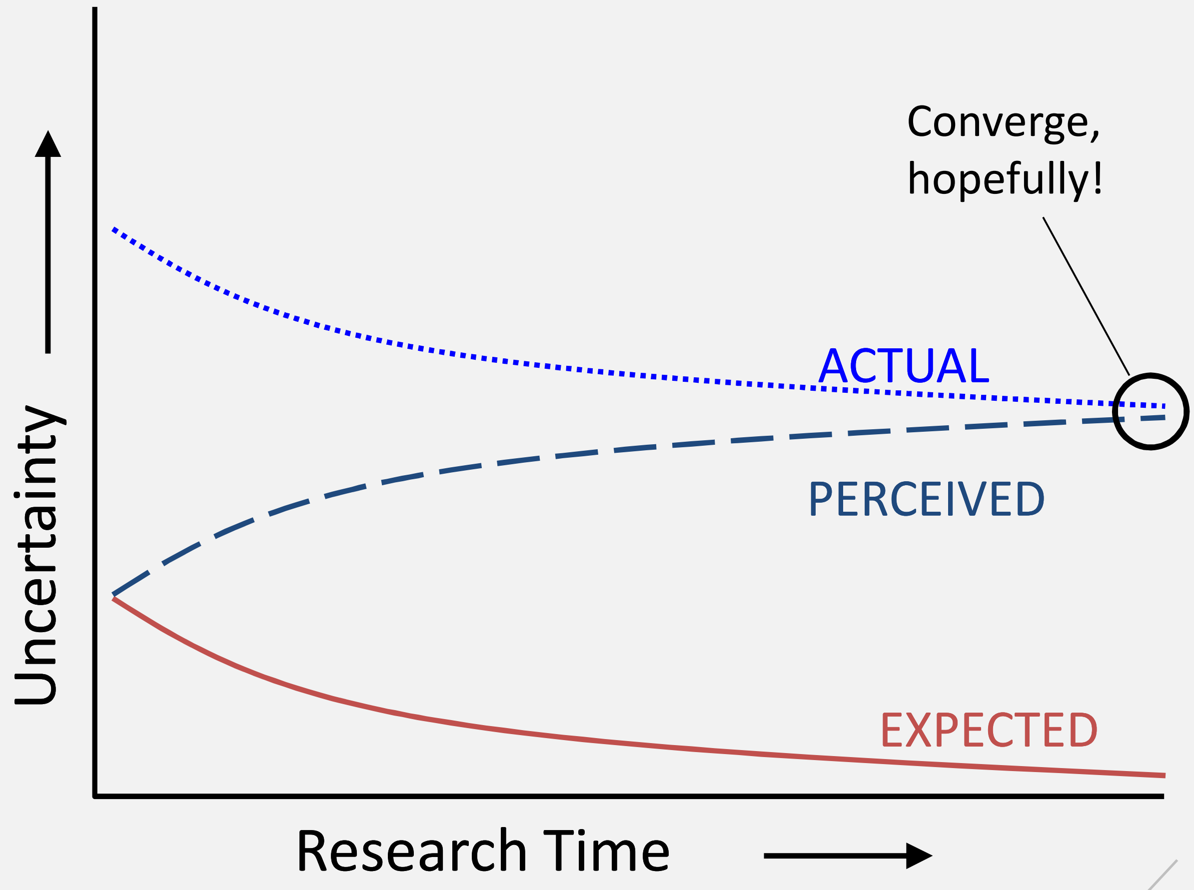
Hemant Shah, CEO of RMS

www.reactionsnet.com, CEO Risk Forum 2012

RMS

AN APHORISM

The more you research, the more you understand the true uncertainty



From: Reiter, L. and Allen, C. (2000). Geological issues in sitting U.S. nuclear facilities. 31st International Geological Congress (Rio de Janeiro, 6-15 August 2000), Abstracts volume.

RMS

ACTUARIAL MODEL USE

MORE THAN 2 DECADES OF MODEL USE IN PERSPECTIVE

1989 - 2012

- Models were introduced over twenty years ago
- The software has undergone significant improvements
- Models have become much more sophisticated
- Coverage has expanded by region and by peril
- Their use is now embedded into business practices
- In short, they have become important and valuable tools

RMS

THE LAST 2 YEARS IN PERSPECTIVE

Natural catastrophe events of unexpected magnitudes

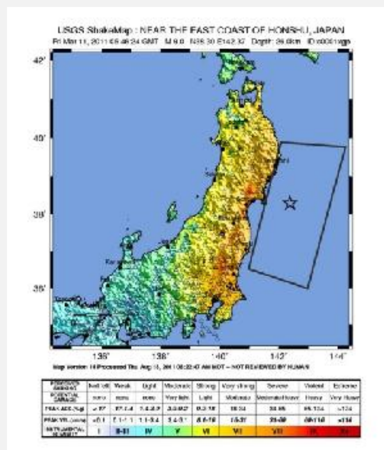
Major model releases for North American hurricane and European windstorm

Have strained the current paradigm of model release and model reliance

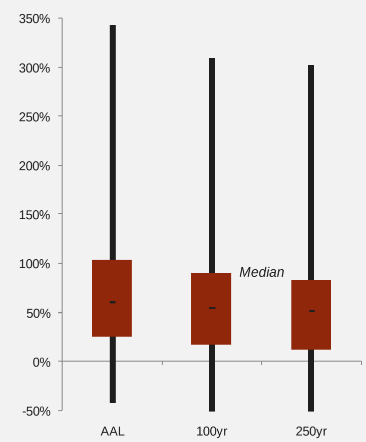
NZ EQ: ULTRA LIQUEFACTION

THAI FLOODS: NON-MODELED HIGH TECH ACCUMULATIONS IN RIVER DELTAS

TSUNAMI: A GLOBAL NON-MODELED LOSS POTENTIAL



JAPAN EQ: EXCEEDED THEORETICAL MAXIMUM MAGNITUDE



V11 MODEL CHANGES IN RESULTS

RMS

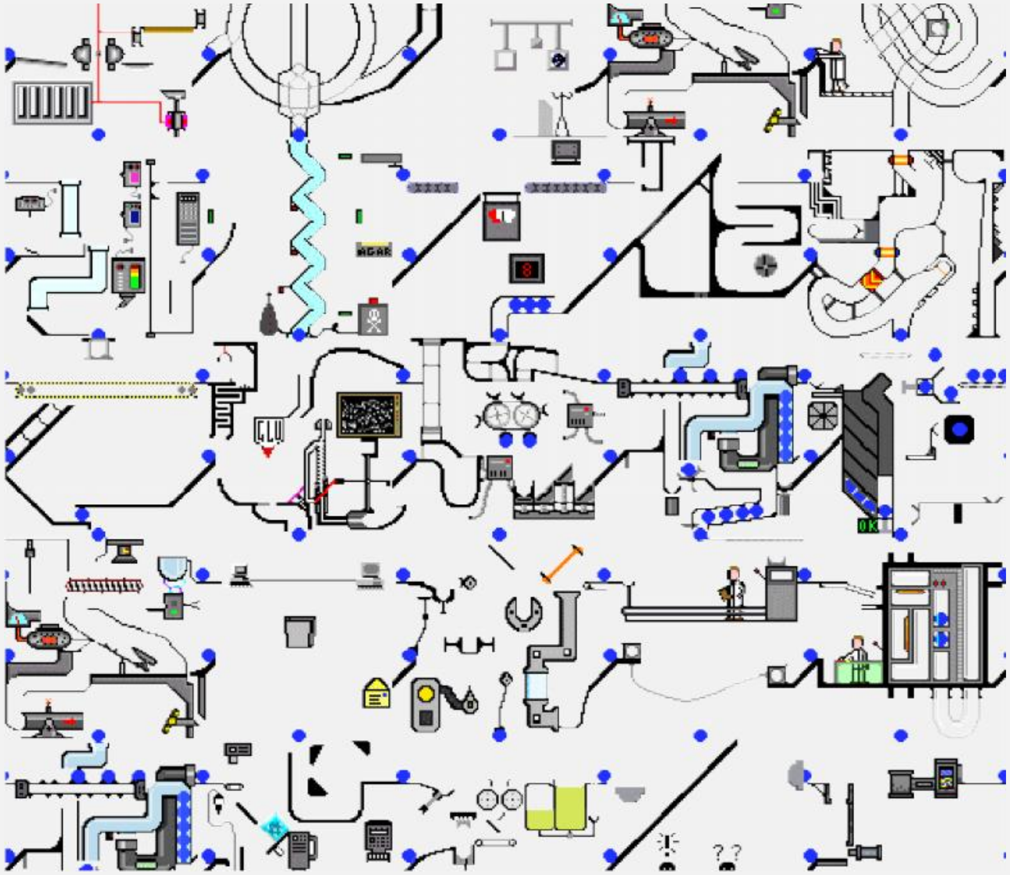
ACCIDENTAL ECOSYSTEM

The current modeling ecosystem

From development and release of models

To how insurers and reinsurers use them

May appears as a somewhat accidental, over-engineered and creaky machine



courtesy enterarena.blogspot.com

TODAY'S MODELING CHALLENGES CALL FOR A NEW PARADIGM

MODELS

- Too many surprises
- Can't control key assumptions
- Lack of insight into drivers of risk
- Doesn't facilitate understanding by all

RESILIENT RISK MANAGEMENT

Maximize return – optimize to top of a pinnacle?

Minimise regret
- search out stable plateaus?

CALL FOR A NEW PARADIGM

IN THE CLIENT UNDERSTANDING AND USE OF CAT MODELS,

WHICH EXPLICITLY ACKNOWLEDGES A NEED FOR:

1. resilient risk management
2. understanding implied bets
3. owning "a view of risk"

RMS

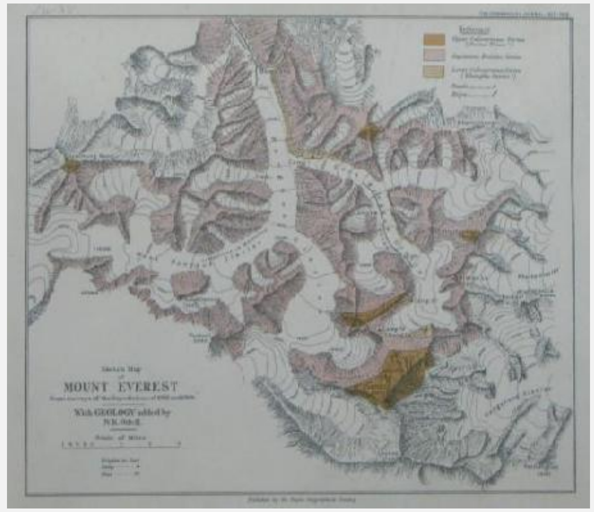
CALL FOR A NEW PARADIGM

IN THE RMS DEVELOPMENT OF CAT MODELS,

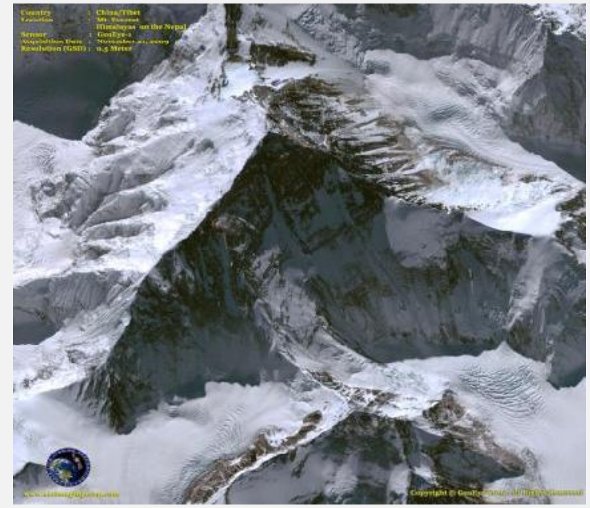
WHICH EXPLICITLY ACKNOWLEDGES THAT:

1. catastrophe risk is characterized by deep uncertainty
2. learning is ongoing
3. “unknown unknowns” persist

THE RISK DOESN'T CHANGE



EARLY MAP OF EVEREST FOLLOWING THE 1920S MALLORY EXPEDITIONS (COURTESY ROYAL GEOGRAPHICAL SOCIETY)



TODAY'S HIGH-RES SATELLITE IMAGES REVEAL MORE DETAIL

But our understanding of it does...and we must anticipate that it will

THE FUTURE? AN IMPROVED "ECOSYSTEM"

Accidental Ecosystem

- ✕ Performance bound
- ✕ Opaque models
- ✕ Uncertainty hidden
- ✕ Point metrics
- ✕ Workarounds common

Problems when models are "wrong"

Resilient Modeling

- ✓ Fast, Nimble
- ✓ High Definition
- ✓ Transparent calculations
- ✓ Multi-view
- ✓ Adaptable to the Business

Fewer surprises, Milder Consequences

RMS

ONE SIZE DOES NOT FIT ALL

- Understanding of uncertainty & sensitivity
- Complete picture
- Tuned to fit the business
- Plugged into decisions

An Emerging Requirement: Build an Own View of Risk

RMS

RMS - PROVIDE REFERENCE VIEW

Build world-class (and increasingly transparent) models with an official rms reference point

WHERE DOES THE ACTUARY FIT IN?

- RISK TOLERANCE
- CAPITAL REQUIREMENTS
- PRICING METHODOLOGIES
- EXPECTED LOSS & RISK LOAD COSTS
- ALEATORY VARIABILITY AND EPISTEMIC UNCERTAINTY

SOLVENCY RISK TOLERANCE & CAPITAL

- A complete solvency understanding is helped by many metrics
- Exposure based metrics like total exposed limits
- Deterministic loss scenarios like the Lloyd's RDS
- Probabilistic loss metrics like OEP, AEP, and TCE

SOLVENCY RISK TOLERANCE & CAPITAL

The more meaningful metrics are less certain

- Total exposed limits are relatively certain
  - But not really meaningful
- Loss scenarios are more meaningful
  - But more uncertain
- Probabilistic EPs are most meaningful
  - But most uncertain

EPISTEMIC UNCERTAINTY

- Is an additional risk to the aleatory variability of the peril itself
- It includes both model risk and parameter risk
- Unlike aleatory variability it can be reduced
  - More and better data
  - Better scientific understanding of the physical process
- Secondary uncertainty includes both aleatory variability and epistemic uncertainty

RMS

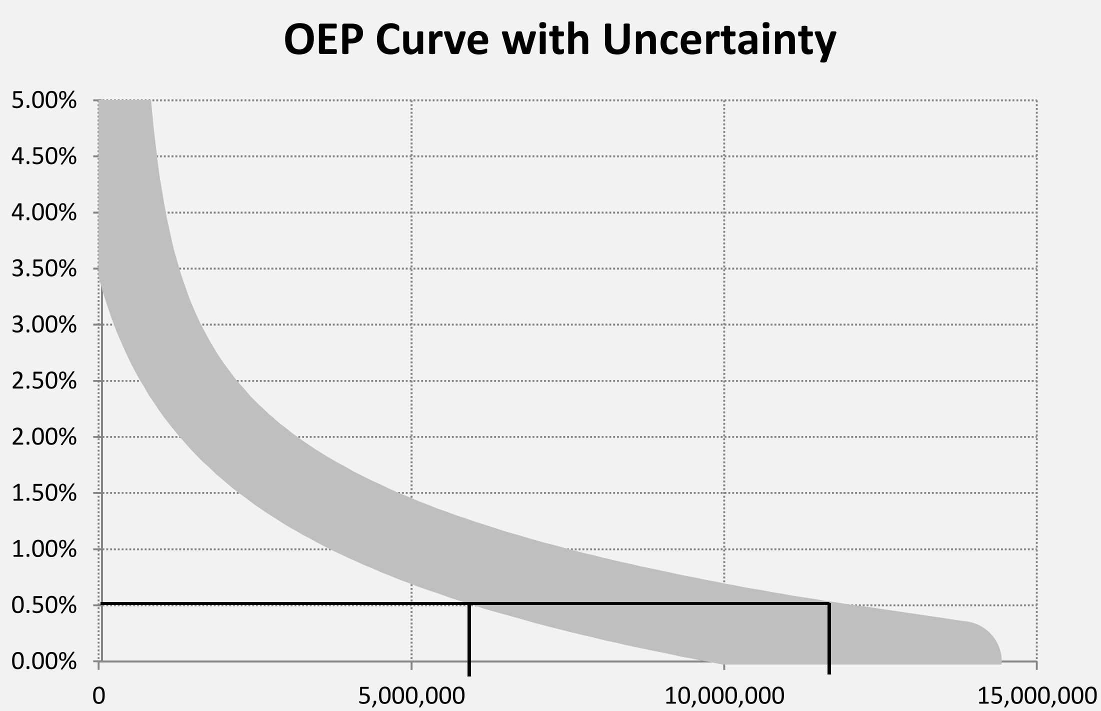
EPISTEMIC UNCERTAINTY

- Its magnitude can be explored through sensitivity testing
- It matters to solvency
- And to pricing and profitability
- And to risk communications…

OEP EPISTEMIC UNCERTAINTY

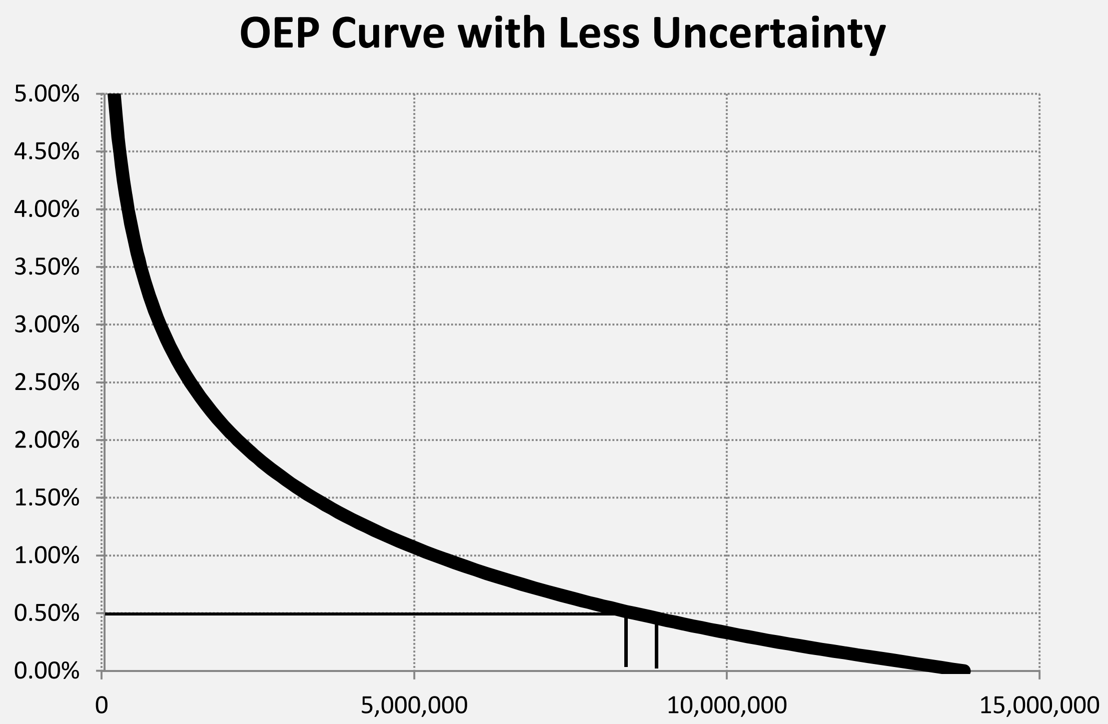
200 Year PML somewhere between $8m +/- $2.5m

How should PML be reported?



OEP EPISTEMIC UNCERTAINTY

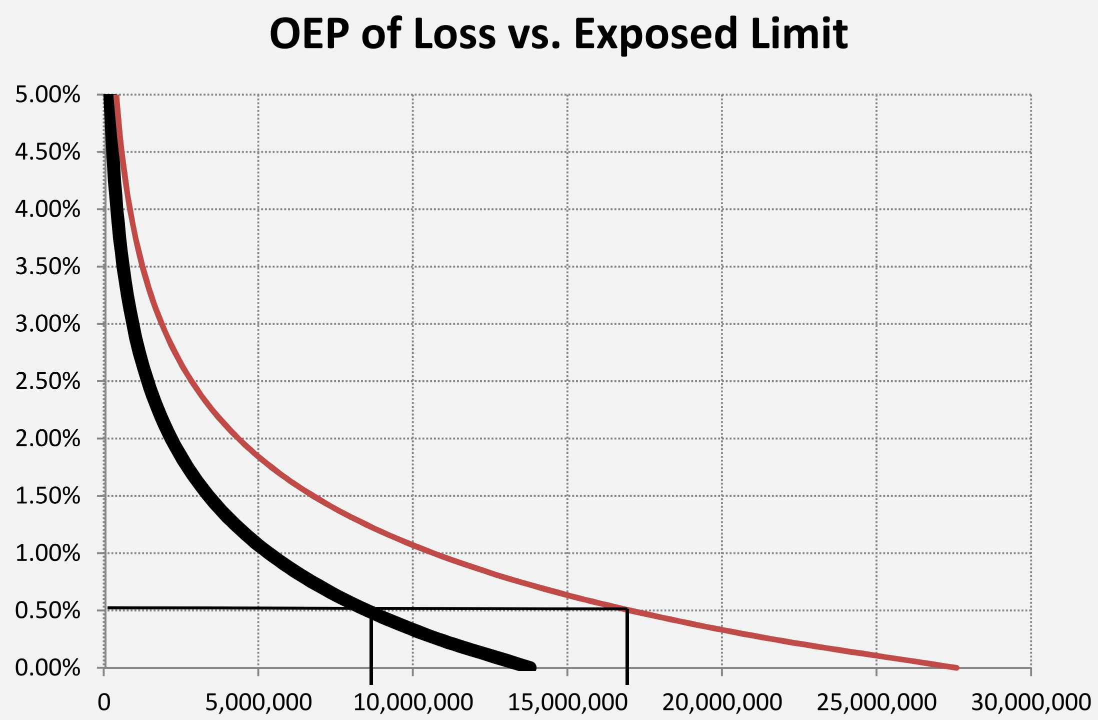
200 Year PML somewhere between $8m +/- $0.2m



WHAT'S YOUR POTENTIAL DOWNSIDE?

Exposed Limits OEP measurers worst case

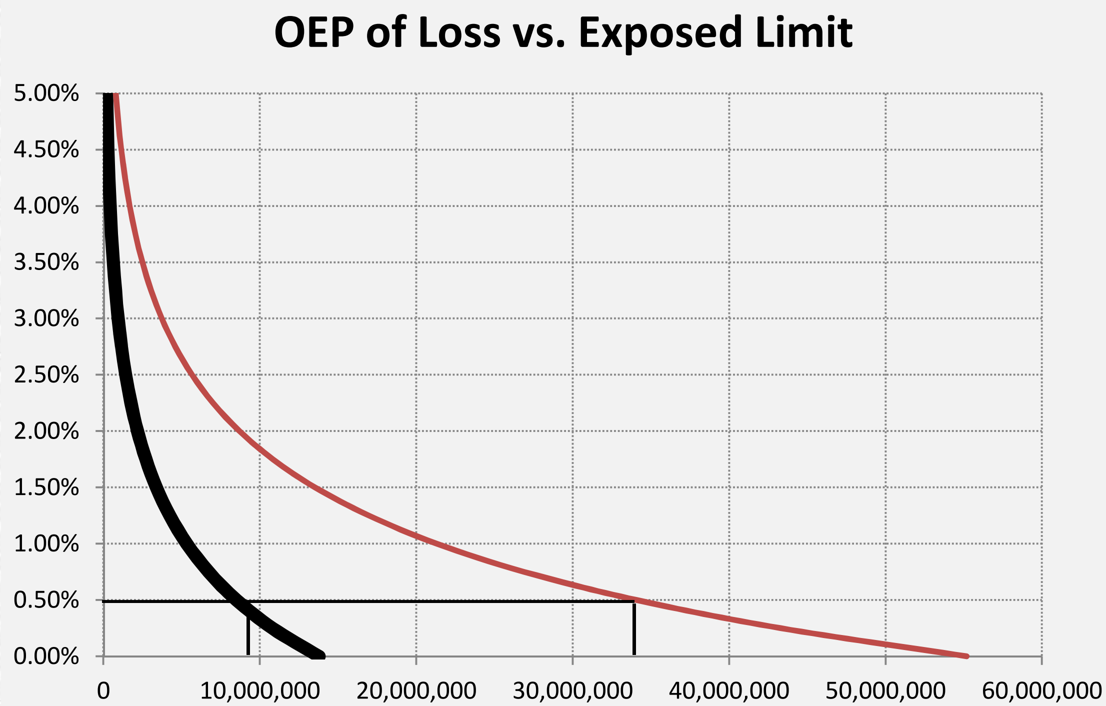
200 Year PML Ratio ~2x



WHAT'S YOUR POTENTIAL DOWNSIDE?

Exposed Limits OEP measurers worst case

200 Year PML Ratio ~4x



OEP, AEP AND THE OCCURRENCE LOSS SEVERITY

- The typical Cat model output
  - OEP - annual max occurrence loss exceedence probability
  - AEP - annual aggregate loss exceedence probability

- Exceedence is simply 1 – CDF(X), where CDF is the standard cumulative distribution function
  - OEP: X = max occurrence loss in a year random variable
  - AEP: X = aggregate annual losses random variable

- For sensitivity testing, it can be helpful to consider CDF of the occurrence loss random variable
  - The occurrence loss severity curve
  - Can be constructed from RMS ELT output
    - Simply normalize by overall occurrence rate

HURRICANE OCCURRENCE SEVERITY EXAMPLE

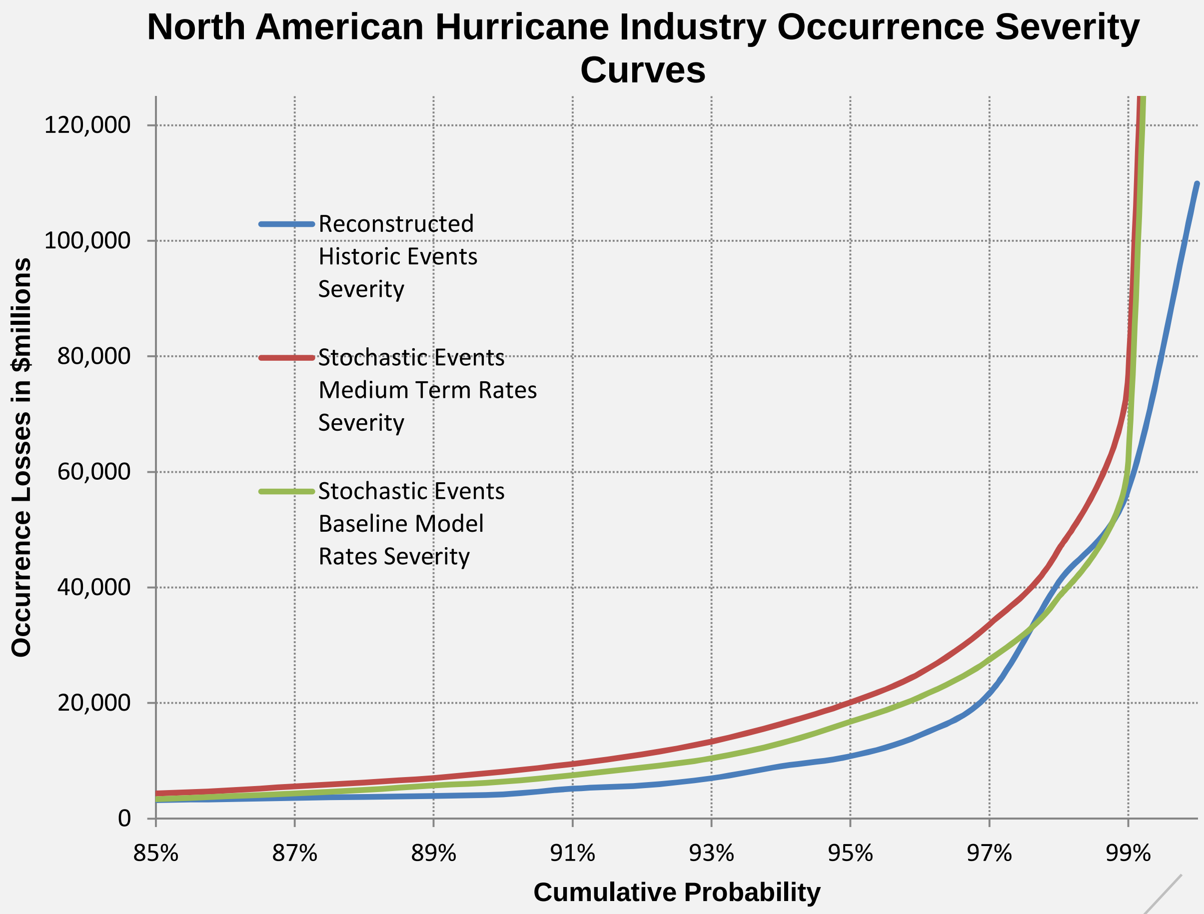
Depend on exposures

Depend on event set

Shape depends on relative event rates – overall rate is separate

Shape and level depend on vulnerability

Can be used as step towards OEP/AEP uncertainties



FROM SOLVENCY AND CAPITAL TO PRICING

- Whatever the solvency is, the supporting capital has a cost
- The Risk Load in pricing formulae covers this cost
- Contrasting required risk loads with achieved risk loads gives insight into profitability
- Should both aleatory and epistemic risk costs be accounted for in pricing
  - If so, how?

PRICING WITH EPISTEMIC UNCERTAINTY

- Given an aleatory variability model:
  - Price = AAL + Risk Load + Expenses

- Given multiple aleatory risk models:
  - $P_1 = AAL_1 + RL_1 + Exp_1$
  - $P_2 = AAL_2 + RL_2 + Exp_2$
  - ---
  - $P_N = AAL_N + RL_N + Exp_N$

- What price should be charged to account for all epistemic uncertainty?
  - Average(P_1, P_2,…,P_N)?
  - Average(P_1, P_2,…,P_N) + Epistemic Risk Load?

- Failing to account for epistemic uncertainty differences could adversely impact portfolio strategy and composition

RMS

ILLUSTRATIVE PRICING EXAMPLE

Assume a choice between two risks with different sensitivities to model parameters

Note: epistemic RL based on volatility in technical price across models

Aleatory Model	Price by Model Risk 1	Price by Model Risk 2
1	1,084	631
2	1,034	523
3	1,069	1,064
4	1,063	1,037
5	1,050	1,262
6	1,008	722
7	1,086	1,113
8	1,073	1,433
9	1,012	1,291
10	1,045	1,147
Average	**1,052**	**1,022**
Selected Price	1,065	1,100
Excess Profit	**13**	**78**
Pricing Risk	**-32**	**-422**
Epistemic RL	**7**	**75**
Actual Profit	**6**	**3**

RMS

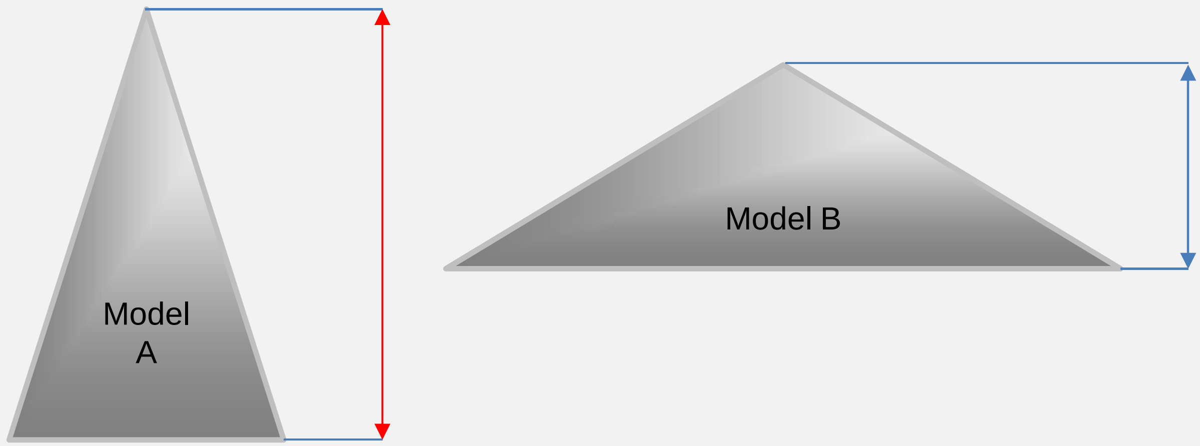
BENEFIT OF PRICING BASED ON ALL RISK

- Accounting for all risk in pricing achieves more equitable capital cost allocation
- Can also temper price relativities where expected loss costs and relative uncertainties are different
- Thus reducing chance of betting too big on unstable parts of the underlying model – especially for risk covers

	Risk A	Risk B	Price Relativity
Loss Cost	750	500	
Risk Loads			
Aleatory	750	500	
Epistemic	200	500	
Expense Ratio %	35%	35%	
Price w/o Epistemic RL	2,308	1,538	66.7%
Price w/ Epistemic RL	2,615	2,308	88.2%
Change	13.3%	50.0%	32.4%

RMS

WHAT MODEL-RELATED BETS ARE YOU TAKING?



Optimize to a specific model or model parameter

Or

Temper based on understanding of model and parameter uncertainty

What are the potential consequences of uncertainty?

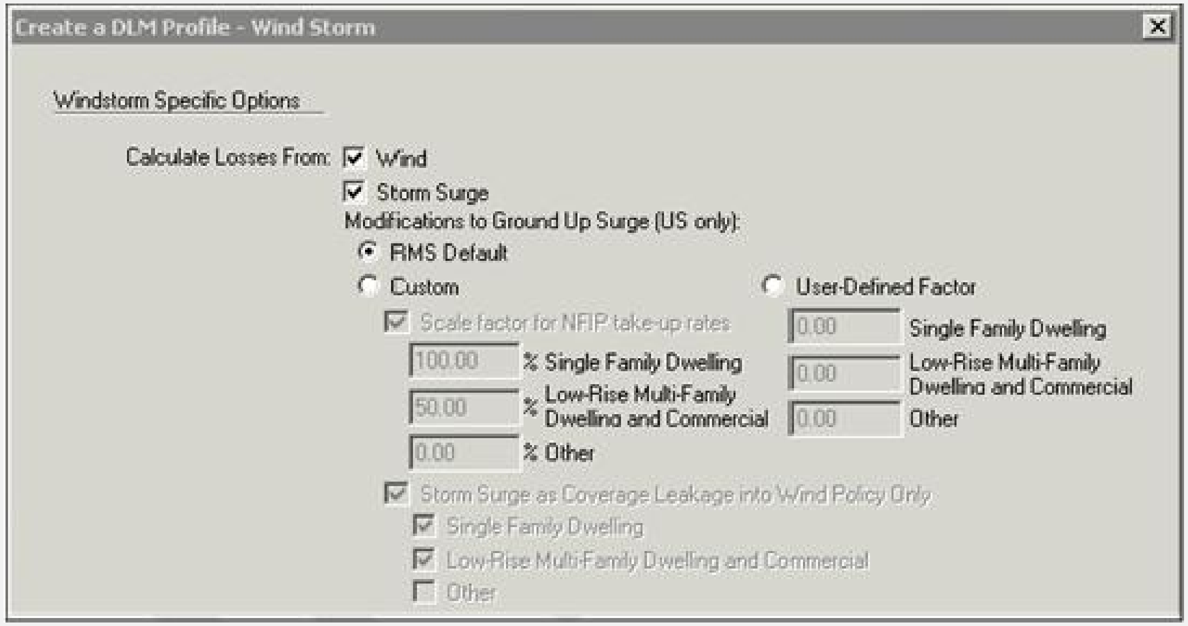
TAKING CONTROL - OWN THE VIEW OF RISK

ADJUSTMENTS,
ALTERNATIVES,
OWN
EXPERIENCE

“There is no single correct Approach”

ABI Industry Good Practice for Catastrophe Modeling, Dec 2011

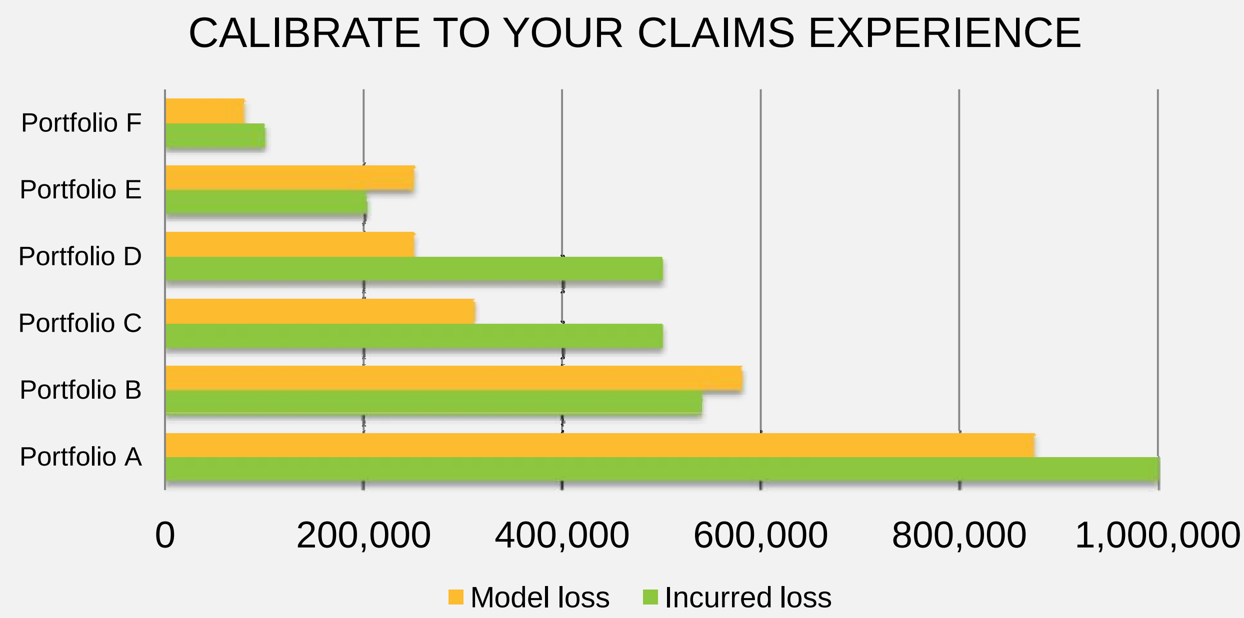
ADJUST THE REFERENCE VIEW



TODAY - USER-DEFINED SURGE LEAKAGE LEVELS

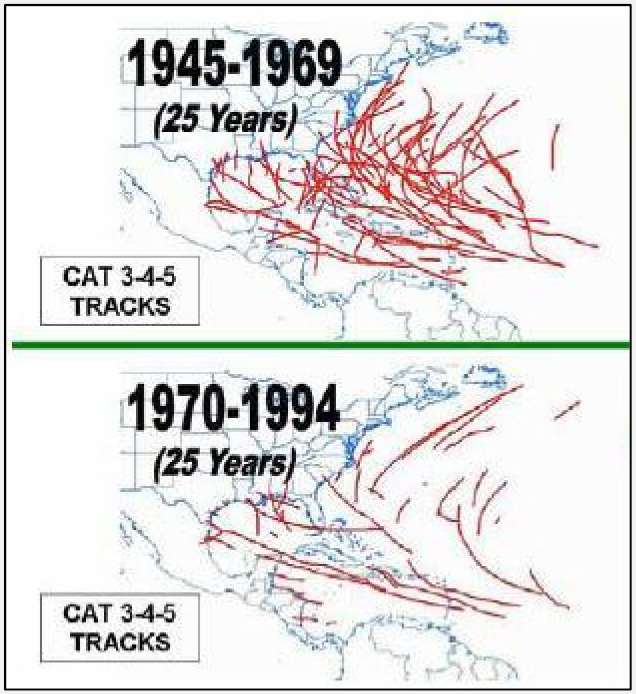
- Calibrate to your own loss data
- Integrate your own research
- Take your own perspective

ADJUSTING THE REFERENCE VIEW



ADJUST THE REFERENCE VIEW

- Calibrate to your own loss data
- Integrate your own research
- Take your own perspective



ADJUST EVENT FREQUENCIES

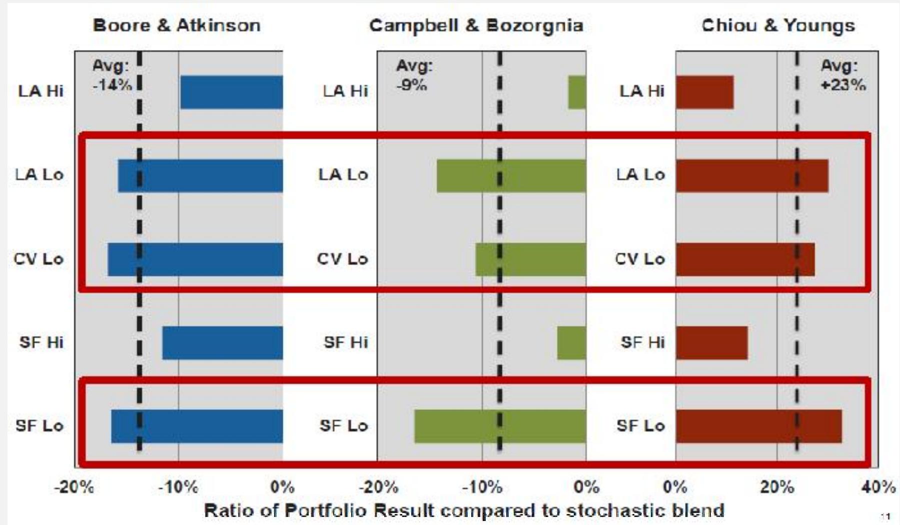
RMS

RISKLINK BUILT IN SENSITIVITY TESTS

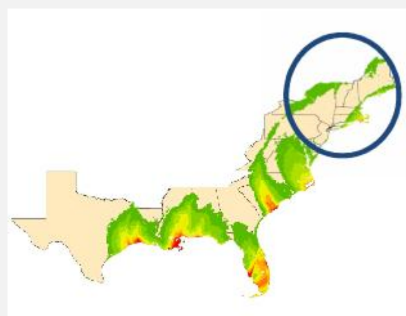
Multiple Attenuations functions

Hurricane Vulnerability ranges

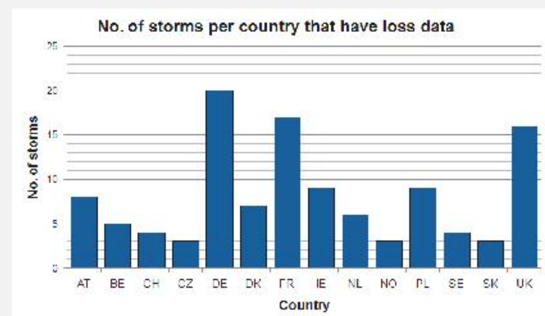
European windstorm vulnerability ranges



2009 US EQ ATTENUATION FUNCTIONS



2011 US HU VULNERABILITY RANGES – VARY BY REGION



2013 EU WS VULNERABILITY RANGES – VARY BY REGION

RMS

REAL-TIME ANALYTIC TECHNOLOGY

Is the force that will drive

- Our ability to deliver
- And your ability to access the speed, transparency, and nimbleness required to find this new paradigm

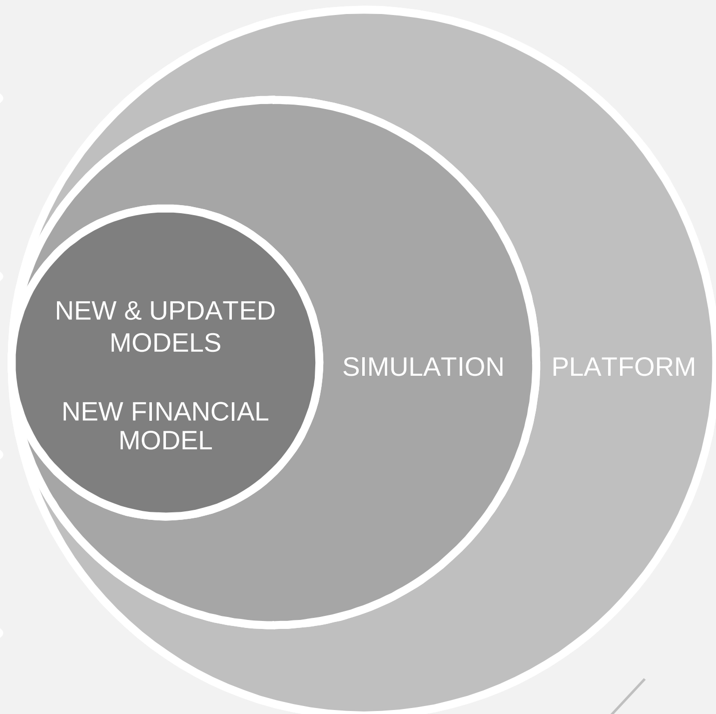
THE RMS(ONE)

HIGH PERFORMANCE
- More runs in greater detail

HD SIMULATION METHODOLOGY
- **Location level loss**
- **No analytic artifacts Timeline**

NEW FINANCIAL MODEL
- Arithmetic !
- Contract Definition Language

OPEN PLATFORM
- Ability to change components



THERE WILL BE NEW QUESTIONS AND CHALLENGES

What will happen when I try and file rates?

How will I convince my rating agency of my own view?

I don't have the expertise or time to create my own view

I need a stable view to manage my business

Is RMS backing down on v11?

Photo Courtesy N. Laughton/ B Grylls

RMS