Catastrophe Modeling

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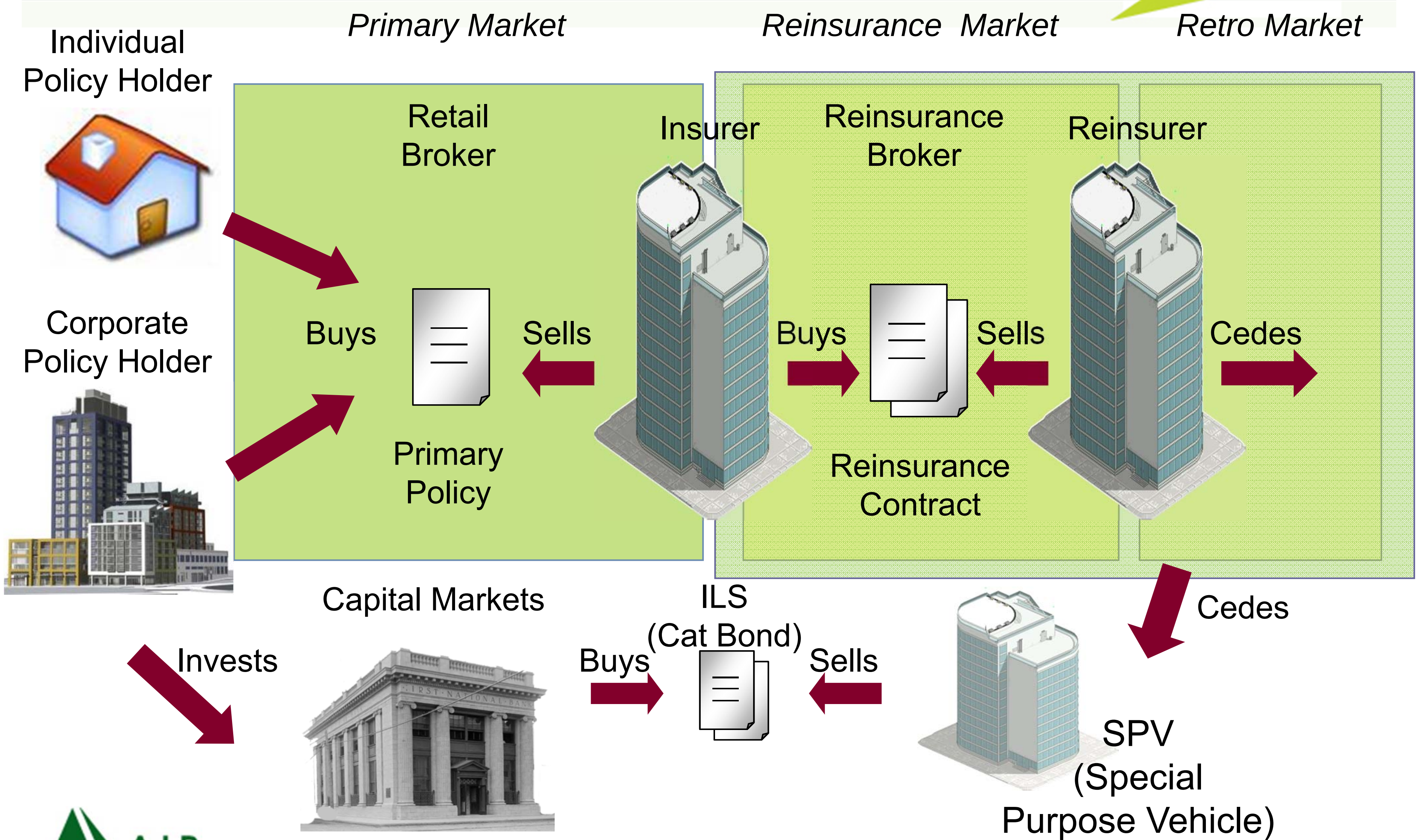
Agenda

- Introduction
- What makes a good catastrophe model?
- AIR's Catastrophe Model Framework
- How can catastrophe models be used throughout the insurance industry value chain?

About AIR Worldwide

- AIR, founded the catastrophe modeling industry in 1987, and today models the risk from natural catastrophes and terrorism in more than 90 countries
- More than 400 insurance, reinsurance, financial, corporate, and government clients rely on AIR software and services for catastrophe risk management
- AIR is a member of the Verisk Insurance Solutions group at Verisk Analytics

AIR Serves All Segments of the Insurance Industry



More Than 400 Insurance, Reinsurance, Financial, Corporate and Government Clients Rely on AIR

- **More than 50%** of U.S. property premiums written by insurers have in-house AIR models
- **Over 90%** of reinsurance capacity in the U.S. is priced using AIR models
- **Seven of the top ten** U.S. insurance brokers rely on AIR models
- **Three of the top five** U.S. wholesale brokers rely on AIR models
- **Twenty of the top twenty-five** Florida residential writers rely on AIR models
- **All top 10** reinsurance brokers rely on AIR models

A Brief History of Catastrophe Modeling in the U.S.

Decade of the 00s: Introduction of Wildfire, Winter Storm, Crop Loss and Offshore Assets (Gulf of Mexico) Models

Late 1980s

US Hurricane, Tornado & Earthquake Models Introduced

1992, 1994

Cat Models capture the attention of the industry

Hurricane Andrew (1992) $16B

Northridge EQ (1994) $12B

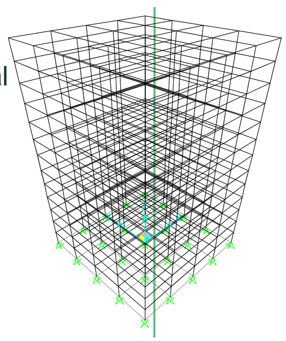
11 Insolvencies after Hurricane Andrew

Mid-1990

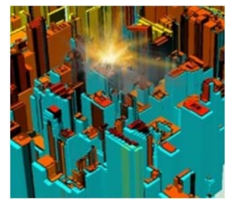
First Catastrophe Bond Issued Transferring Risk to Capital Markets

2000

Introduction of Performance-Based Earthquake Engineering (PBEE)



2001, 2002



World Trade Center Attack

First Terrorism, Workers' Comp Models Introduced One Year Later

2004, 2005

Record Breaking Hurricane Seasons of 2004 & 2005

Hurricane Katrina (2005) $41B

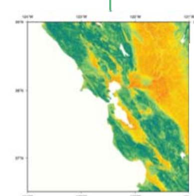
3 Insolvencies after Hurricane Katrina

2006

Introduction of First Hurricane Models Conditioned on Warm Sea-Surface Temperatures

2009

US Quake Models Updated to Reflect Latest USGS National Seismic Hazard Maps



2010

US Hurricane Model Features Unified Catalog Enabling Basinwide Risk Assessment

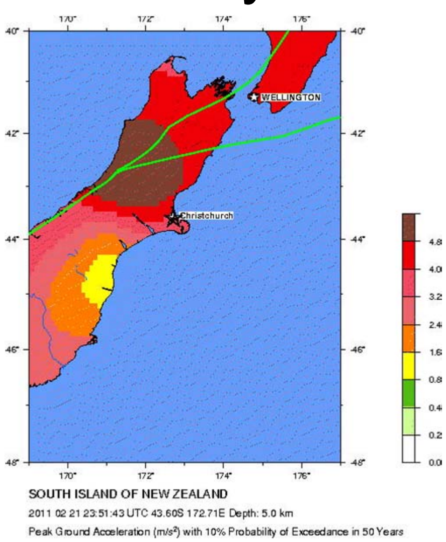
New Technologies for Improving Exposure Data Quality

Historical Data Is Insufficient for Catastrophic Risk Analysis

- Low credibility – there is not enough of it relative to the exposed risk
- Normalization problems – failure to portray today's conditions
  - Exposure growth as population migrates toward risky coastal areas
  - Replacement cost increases for structures
  - Expansion of policy coverage and endorsements (loss of use, etc…)
  - Effect of stronger building codes
- By contrast, cat model simulations offer
  - Volumes of data at low marginal cost (up to 100,000 years each run)
  - Reflection of today's reality (exposure profiles, policy conditions)
  - Scenario testing on property and geographic attributes

What Questions Are Catastrophe Models Designed to Answer?

- Where are future events likely to occur?
- How intense are they likely to be?
- For each potential event, what is the estimated range of damage and insured loss?
- Catastrophe models are designed to estimate the probability of loss, not forecast future events



What Makes a Good Catastrophe Model?

Key Requirements for a Robust Catastrophe Model

- Model must be consistent and unbiased when tested against a wide range of historical datasets
- Model should produce reasonable and unbiased loss estimates in real time
- Model components should be independently validated and obey basic physical expectations of the underlying hazard

After Building the Model from the Bottom Up, AIR Then Validates the Overall Model from the Top Down

- Industry level historical event loss validation using
  - AIR industry exposure databases
  - Reliable reported/observed insured losses
  - Trended losses – "as-if" they were to occur today
- Company level historical event loss validation using
  - Exposure corresponding to the claims
  - Sufficiently large data sets
- Loss exceedance probability distribution validation
  - Average annual losses (AAL)
  - High-frequency (low return period) losses

There is Equally Great Emphasis on Evaluating the Tail Events

- Statistical models can be used to estimate tail losses based on a (short) history of observed losses; however, large uncertainties will exist in their estimated frequency
- Assess the reasonability of extreme loss producing scenarios
  - Does the exceedance probability distribution contain large loss events?
  - Are these events physically realistic?
  - Are the average loss ratio and average claim count and size reasonable?

The Film *The Day After Tomorrow* Has Epic Floods

[FALSE]

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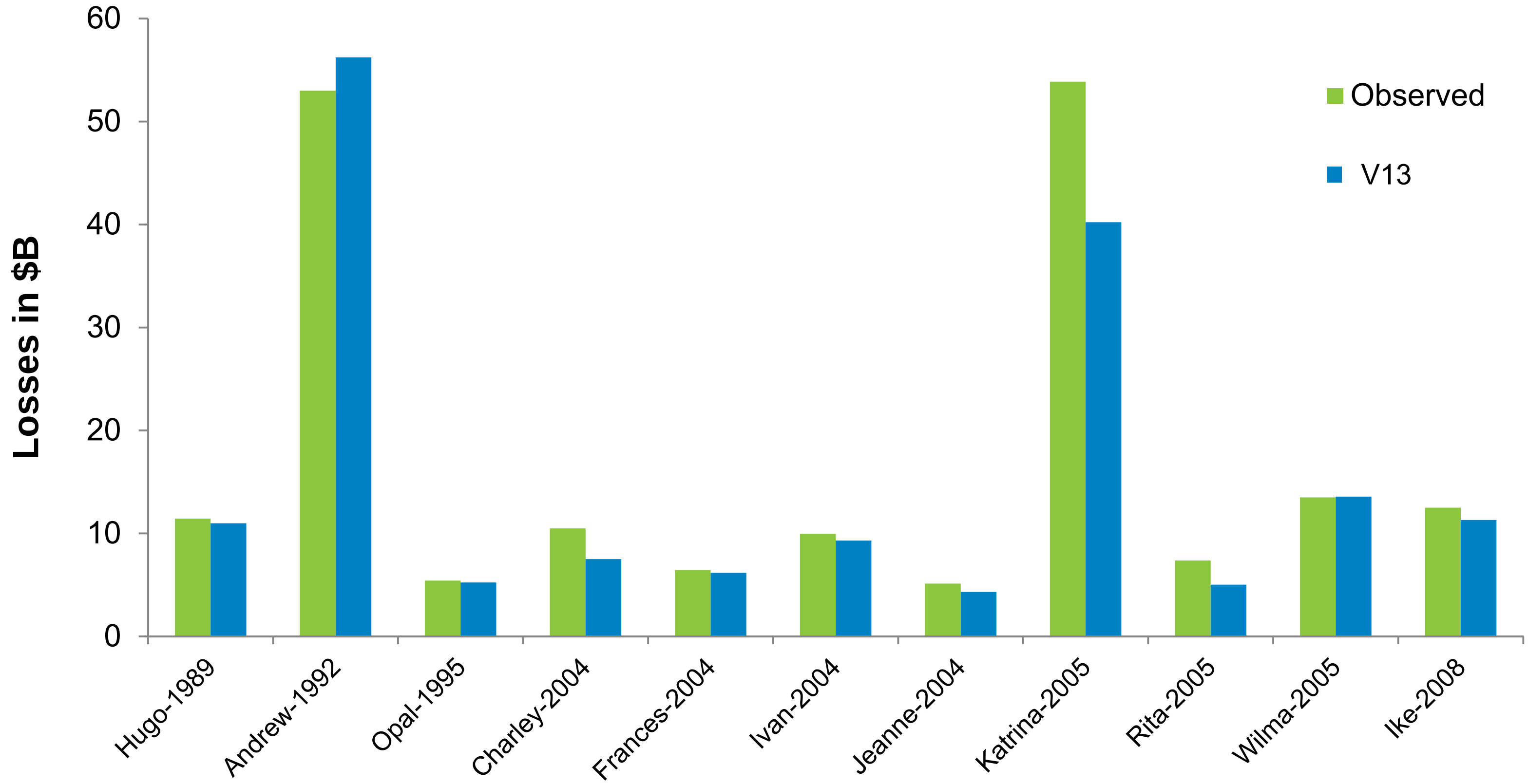
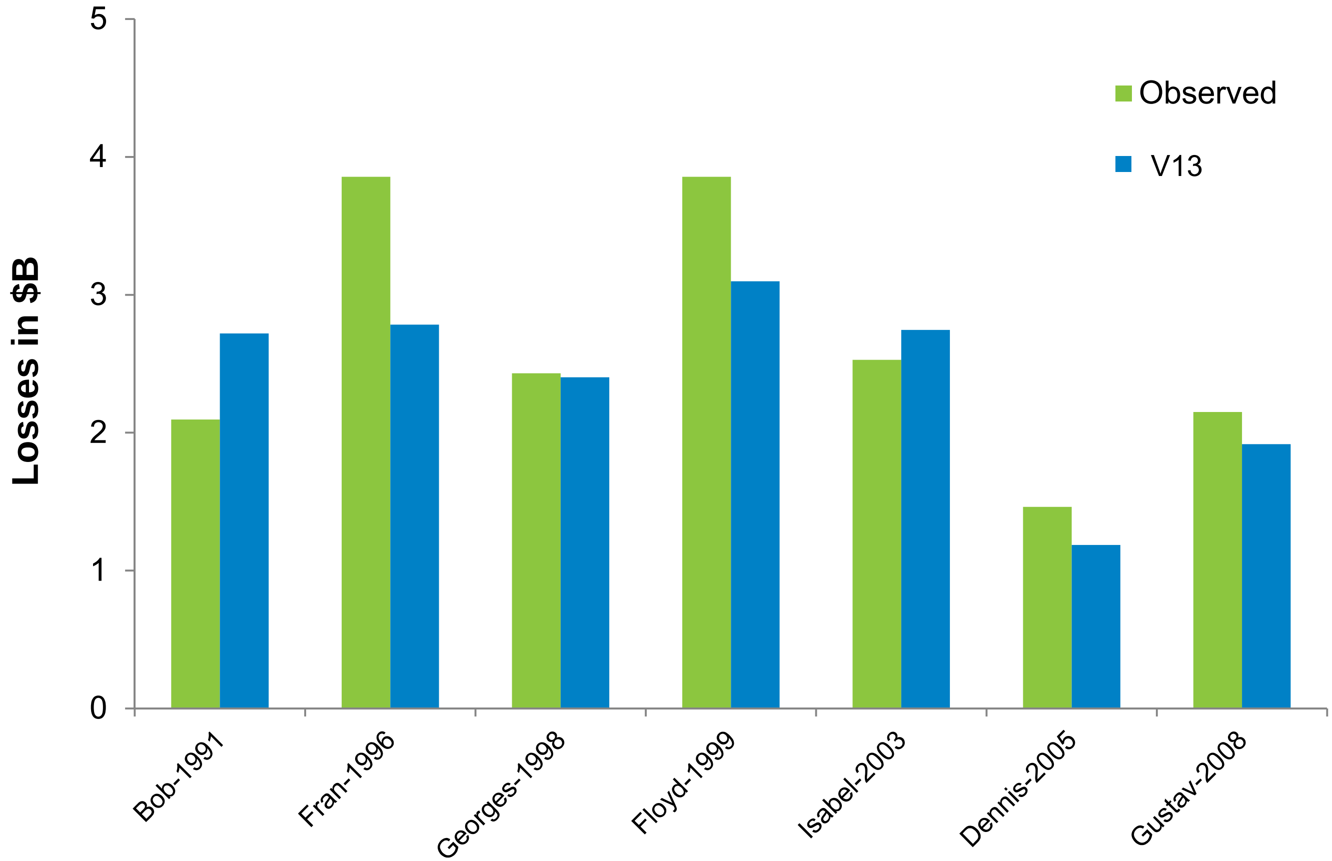
...But Entertaining

Industry Loss Validation for Larger Historical Storms



Industry Loss Validation for Smaller Historical Storms



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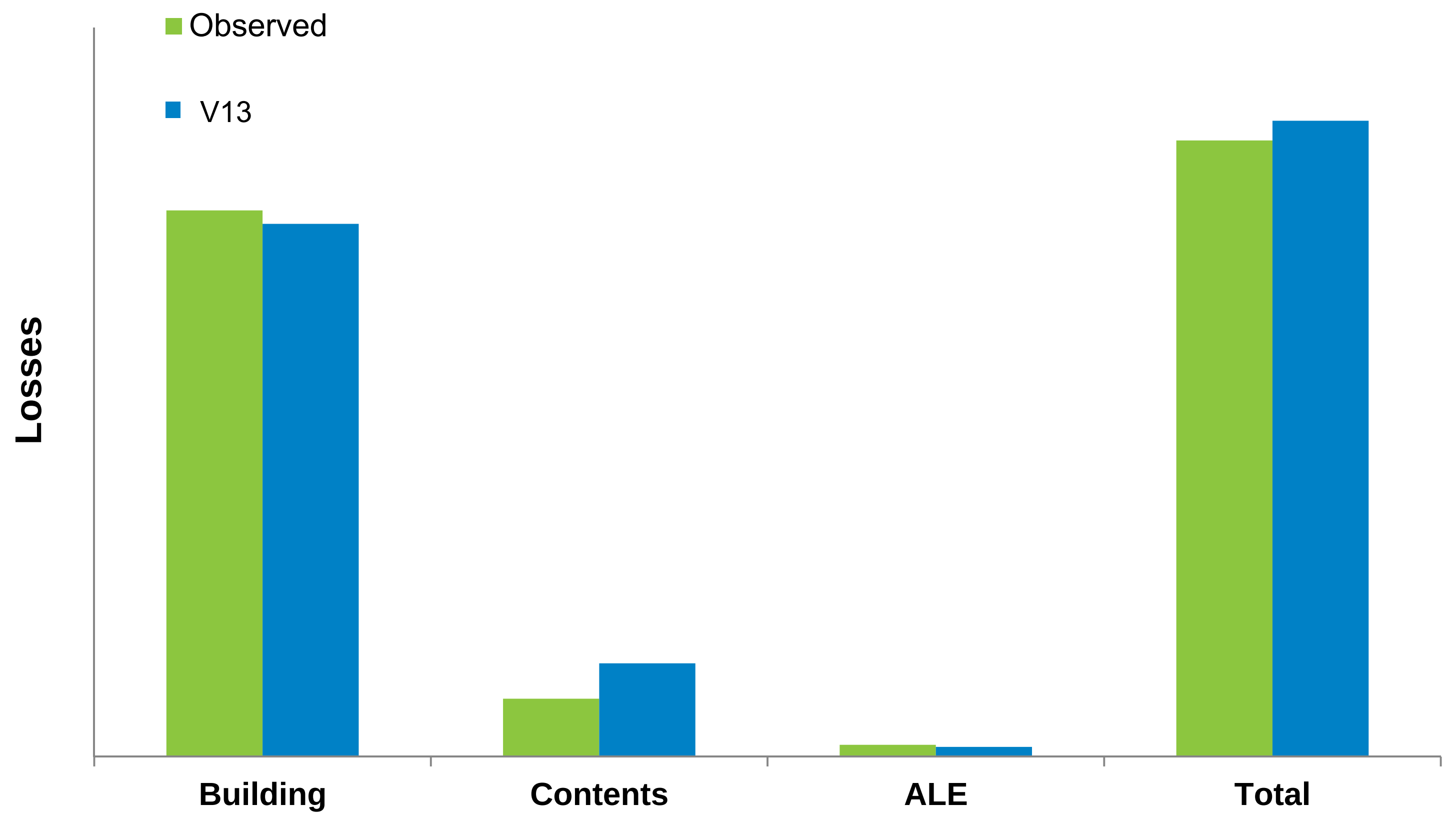
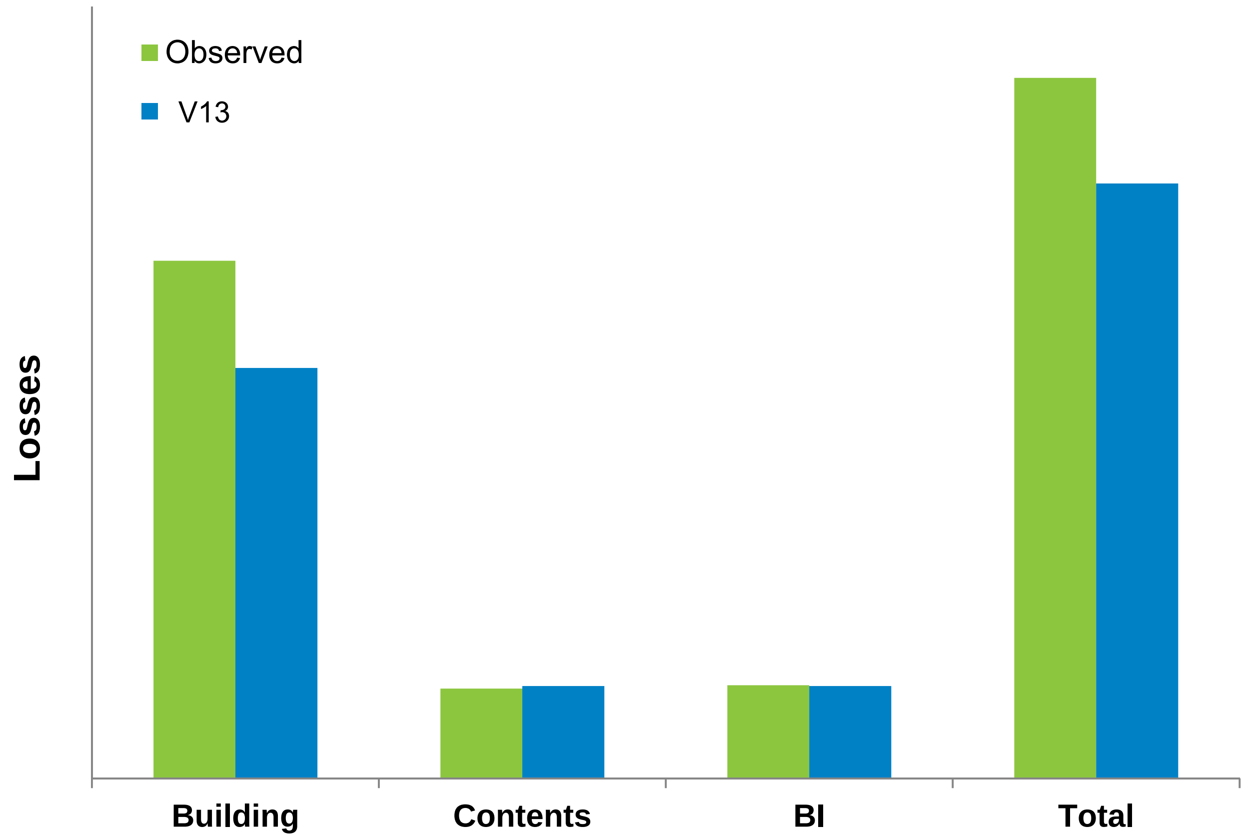
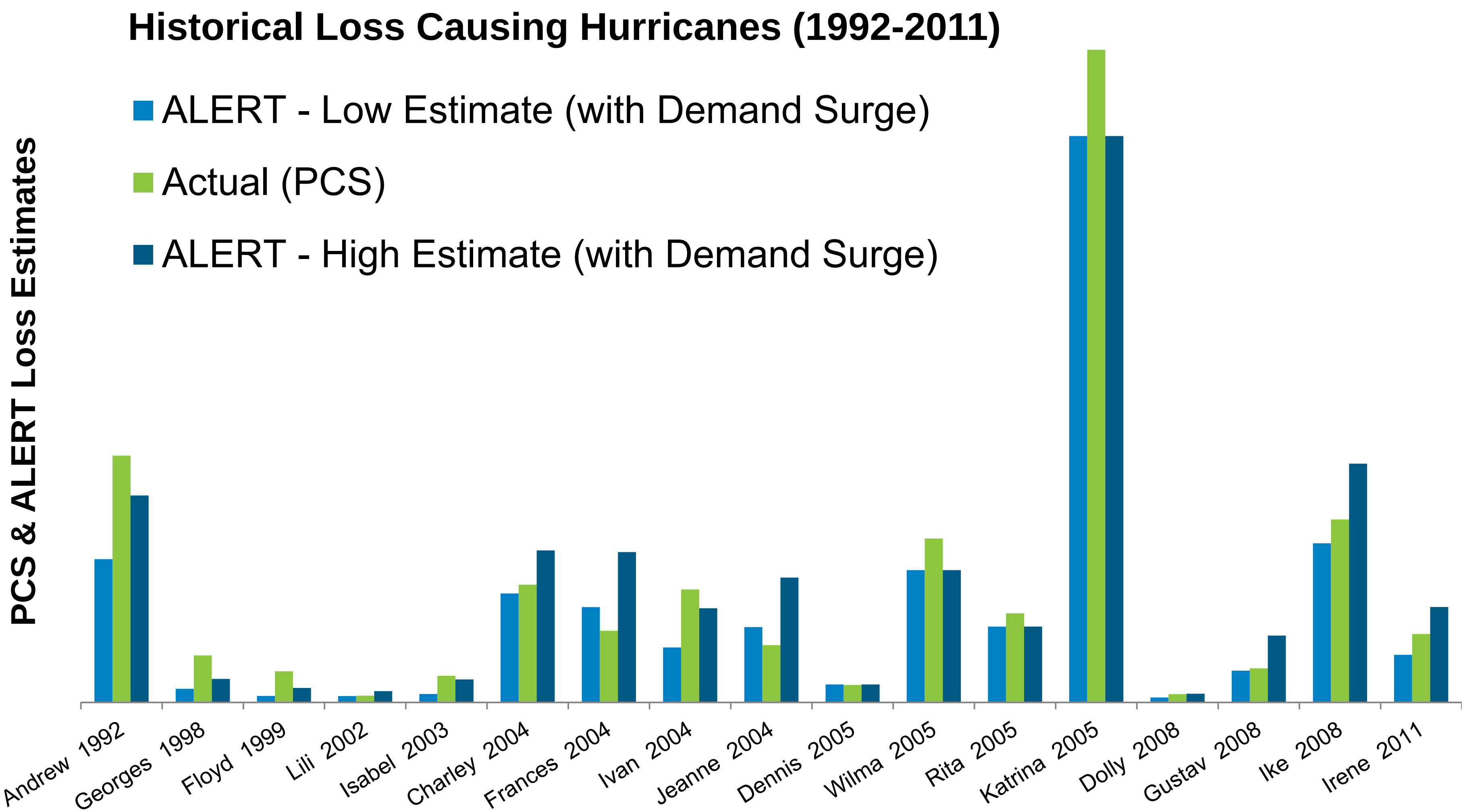
Single Family Homes – Loss Validation for Combined Claims by Coverage



Commercial - Loss Validation by Coverage

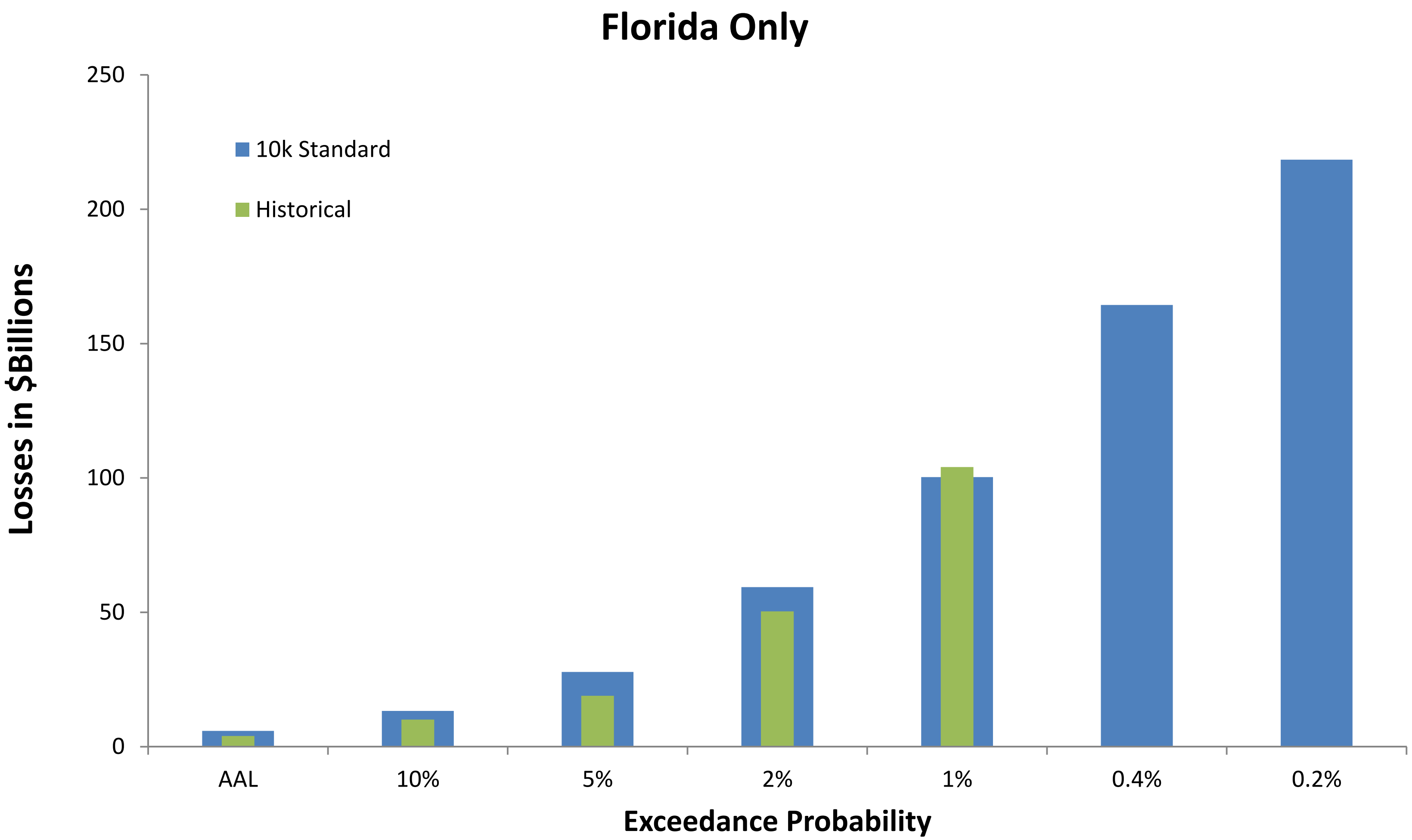


Model Should Produce Reasonable and Unbiased Loss Estimates in Real Time



ALERT: Low & high estimates for Hurricanes Dennis, Wilma, Rita, and Katrina represent the single, final loss estimate for each storm and not a range of (low-to-high) losses.

Top Down Validation of the AIR Florida Hurricane State-wide Loss Distribution

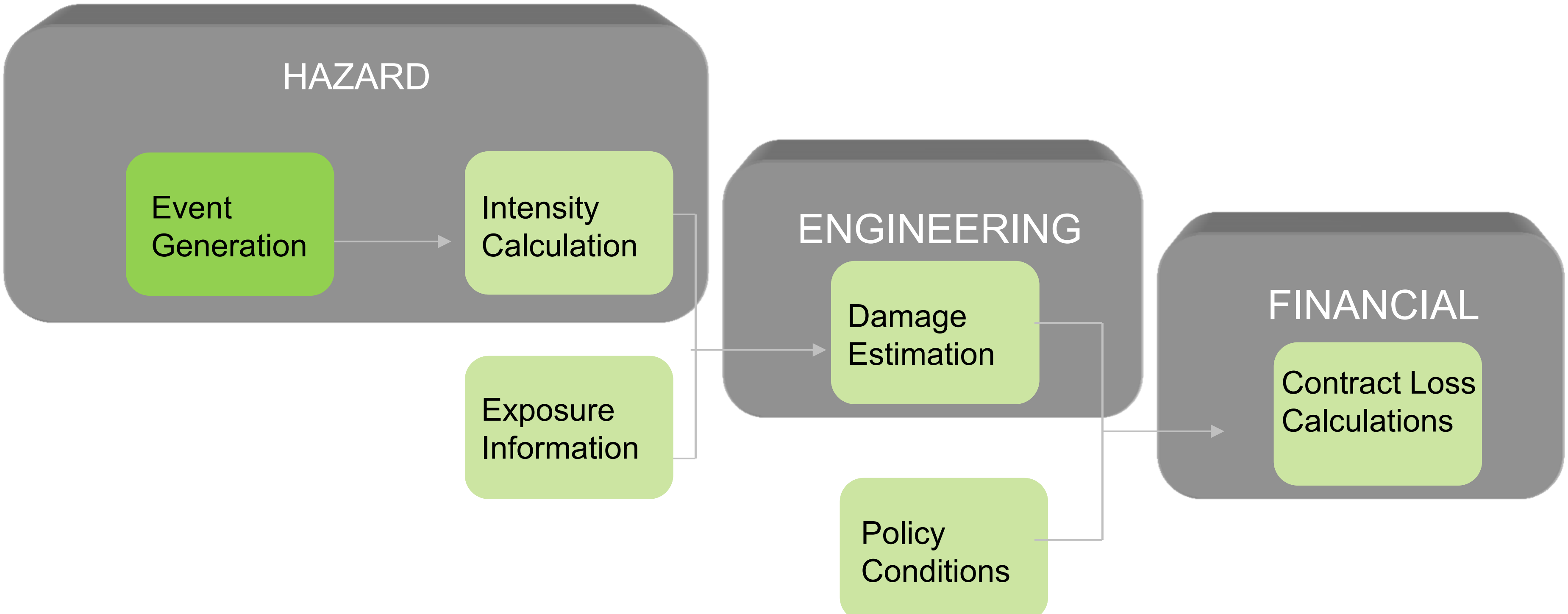


AIR Provides Materials to External Organizations to Assist with Independent Validation

- Florida Commission on Hurricane Loss Projection Methodology
  - http://www.sbafla.com/methodology/ModelerSubmissions/tabid/785/Default.aspx
- For example:
  - Form A-6: Personal Residential Output Ranges
  - Table 4: Modeled Annual Occurrence Rates
    - Form M-1: Annual Occurrence Rates
  - Table 9: Modification Factors to Vulnerability Functions
    - Form V-2: Mitigation Measures – Range of Changes in Damage
  - Figure 64: Percentage Change in Weighted Average Loss Costs by County – Frame Owners
    - Form A-8: Percentage Change in Personal Residential Output Ranges by County
- RAA Model Comparisons

AIR's Catastrophe Model Framework

Catastrophe Modeling Framework: Event Generation



- Where are future events likely to occur?
- How intense are they likely to be?
- How frequently are they likely to occur?

Developing Event Generation Module for Hurricanes Begins with Collection and Cleaning of Historical Storm Data

Wind Speed and Central Pressure Along Storm Track

Lat	Lon	Time	Wind Speed	Central Pressure	Status
16.00	-73.70	08/11/06Z	55	999	TROPICAL STORM
16.30	-75.40	08/11/12Z	60	995	TROPICAL STORM
16.70	-76.80	08/11/18Z	65	993	HURRICANE-1
17.40	-78.10	08/12/00Z	65	992	HURRICANE-1
18.20	-79.30	08/12/06Z	75	988	HURRICANE-1
19.20	-80.70	08/12/12Z	80	984	HURRICANE-1
20.50	-81.60	08/12/18Z	90	980	HURRICANE-2
21.70	-82.20	08/13/00Z	90	976	HURRICANE-2
23.00	-82.60	08/13/06Z	105	966	HURRICANE-3
24.40	-82.90	08/13/12Z	95	969	HURRICANE-2

Data sources include:

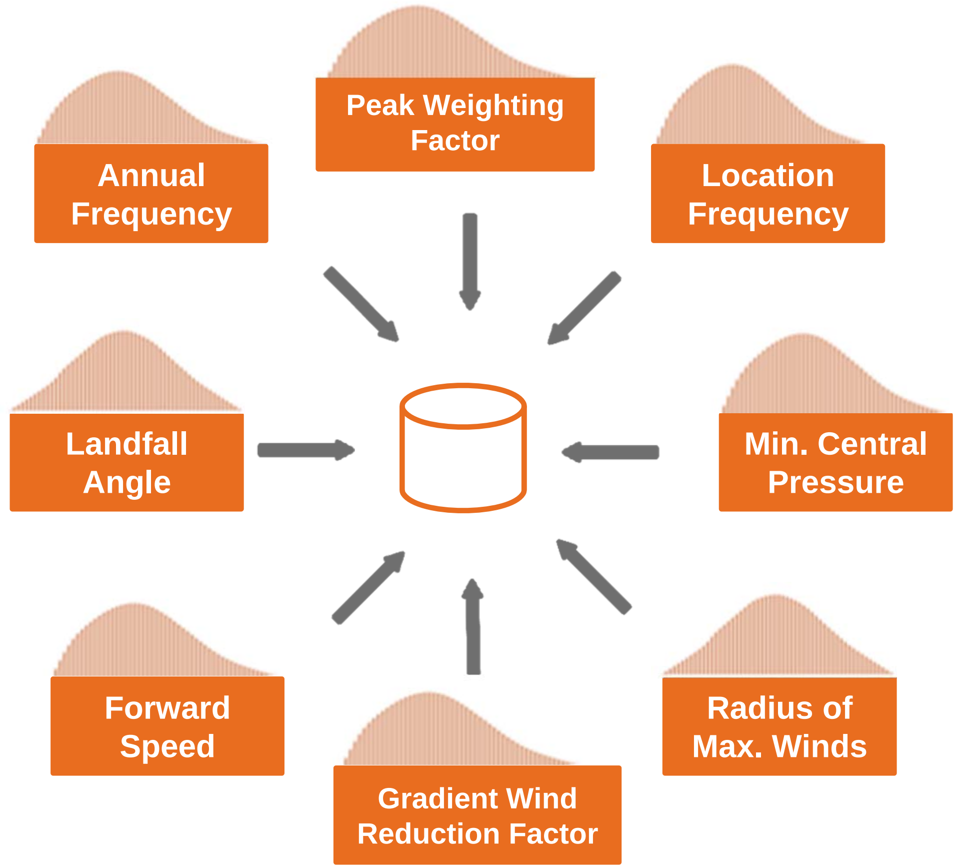
- NOAA
- National Hurricane Center
- National Weather Service
- National Climatic Data Center

Detailed Landfall Characteristics

		Central Pressure		RMax		Forward Speed	
Hurricane	Date	(in)	(kPa)	nmi	km	kt	km/hr
Galveston	9/9/00	27.64	93.6	14	26	10	18
Central Gulf	9/13/19	27.99	94.8	32	39	10	18
New England	9/21/38	27.76	94.0	50	93	40	24
•	•	•	•	•	•	•	•
•	•	•	•	•	•	•	•
•	•	•	•	•	•	•	•
Helene	9/27/58	27.52	93.2	20	32	14	26
Donna	9/11/60	28.87	97.1	34	63	20	37

AIR Catalogs Are Generated Through a Sampling Process Involving Historical and Climatological Data

- There is uncertainty associated with the historical data and with the data used in describing the catastrophic events
- AIR captures part of this uncertainty by creating distribution functions that fit historical and climatological data
- These probability distributions are sampled to create a catalogue that contains a set of physically plausible events



AIR's Stochastic Catalog Contains Storm Parameters for Each Event in a Given Year

Catalog methodology facilitates straight-forward modeling of multiple event seasons

Year	Event ID	Day	LF Num	SS	LF Seg	CP	Max Wind Speed	Landfall Lat	Landfall Long	Radius Max Wind	Forward Speed	Landfall Angle
1	1	280	1	1	7	984	80	28.291	-96.492	12	15	20
3	2	231	1	3	22	963	113	29.472	-83.236	11	14	23
4	3	269	1	2	43	979	96	34.891	-76.42	13	23	32
4	4	230	1	2	5	969	102	27.048	-97.297	12	19	45
5	5	285	1	2	4	975	97	26.002	-97.16	14	18	34
8	6	289	1	4	10	944	132	26.689	-93.713	9	20	18
8	7	204	1	1	39	987	76	32.689	-79.563	16	18	19
9	8	245	1	3	30	957	114	25.952	-80.131	12	16	23
11	9	290	1	2	43	979	98	34.93	-76.33	18	16	20
.	.	.	.	.	.	.	.	.	.	.	.	.
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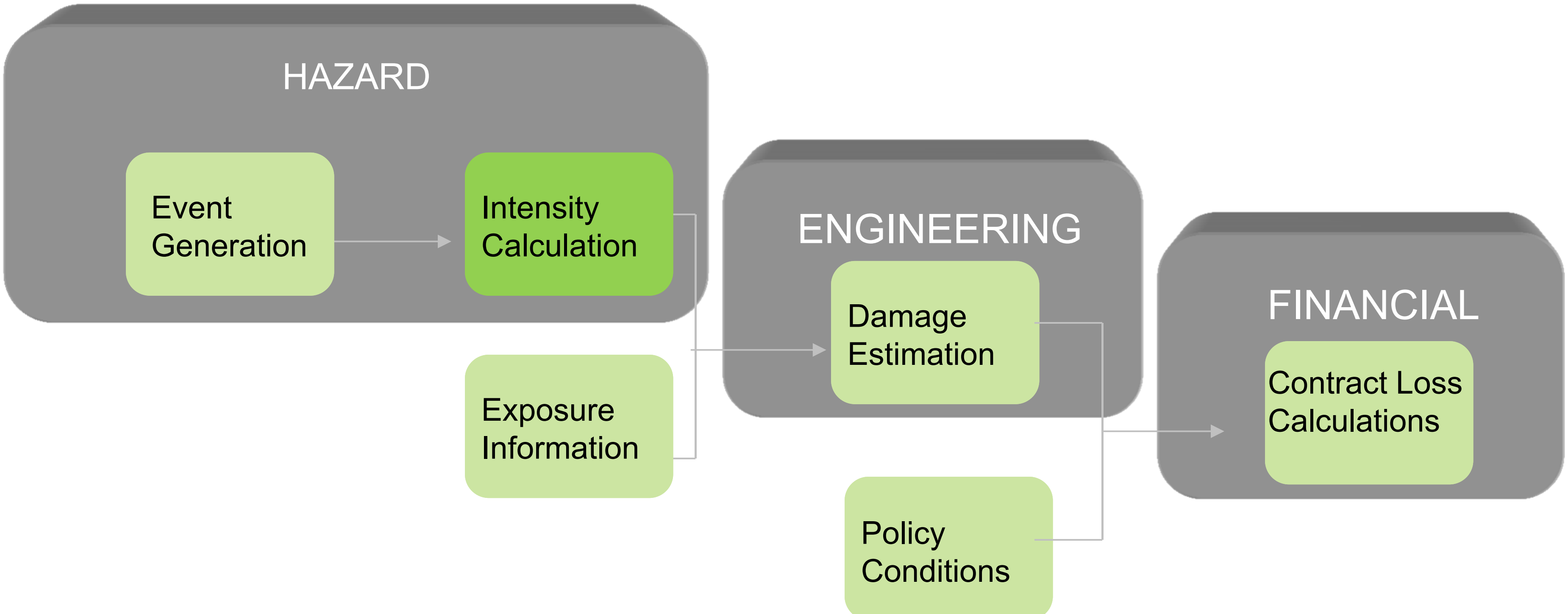
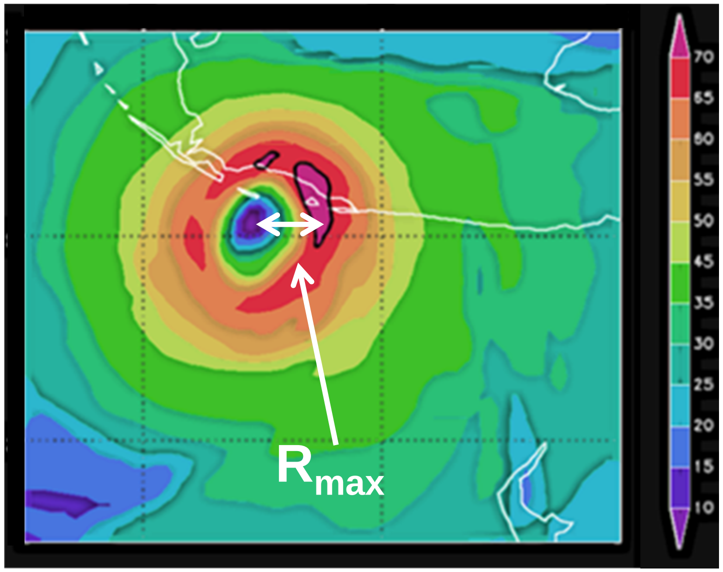
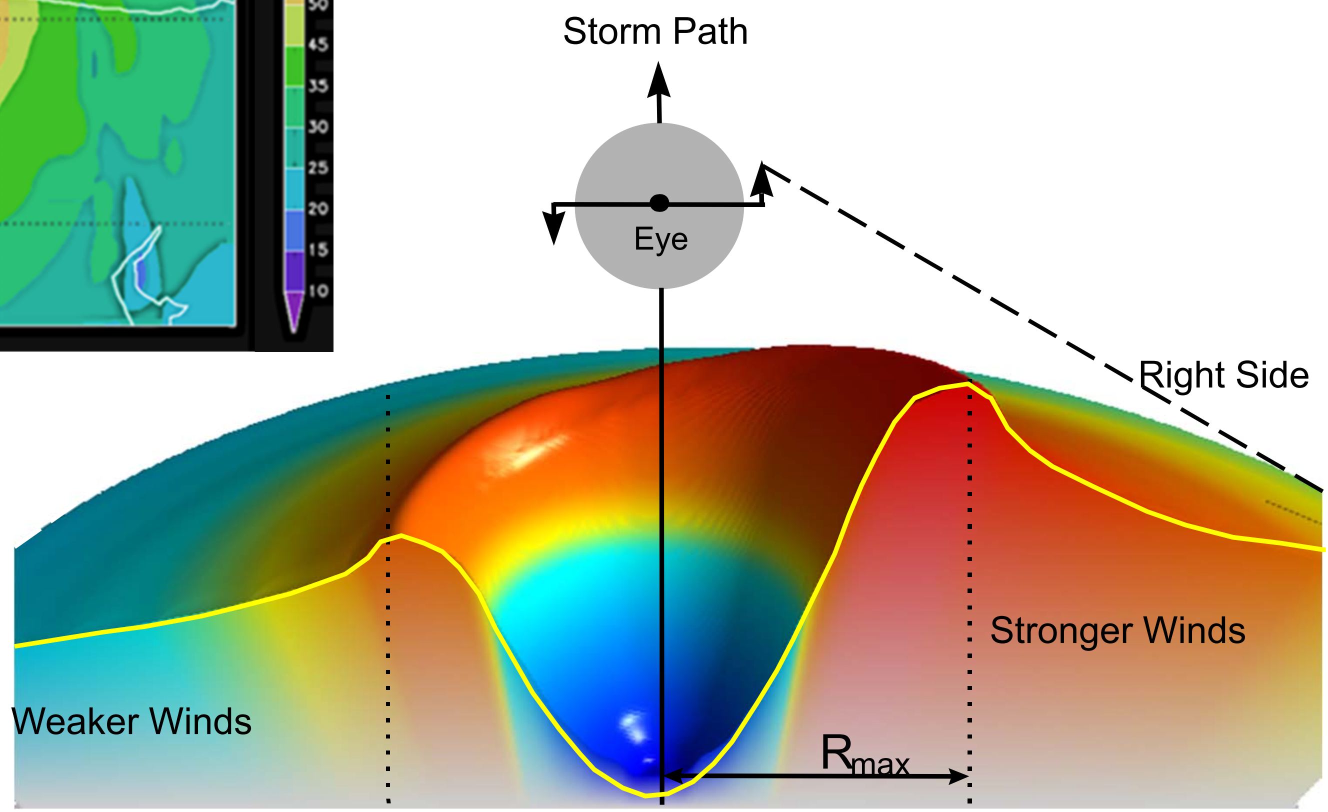
Catastrophe Modeling Framework: Intensity Calculation



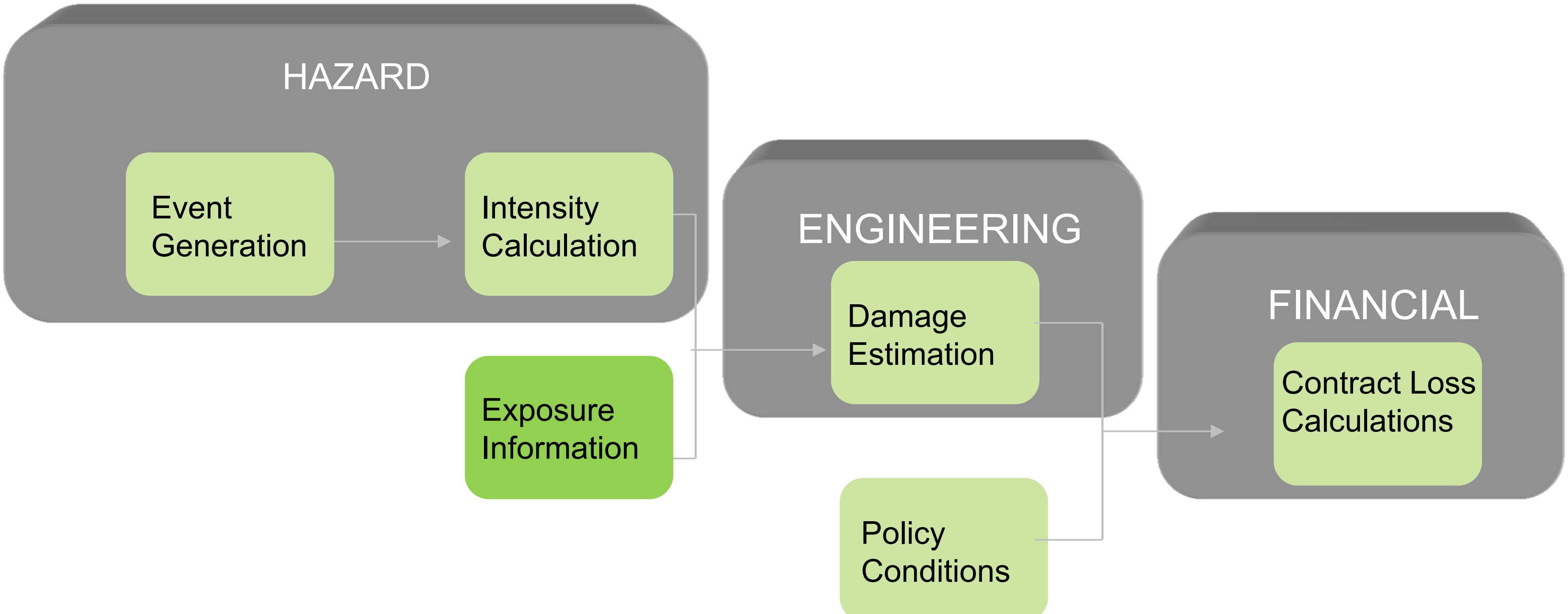
- What is the intensity of each event at each location?
- How do local conditions affect the intensity?

Calculating Local Intensity: Understanding the Storm Wind Field





Catastrophe Modeling Framework: Exposure Information



- Where are the properties located?
- What are the characteristics for each property?

Exposure Data Relevant for Modeling

Location			
Geocode Match Level	Street Address	City	Postal Code

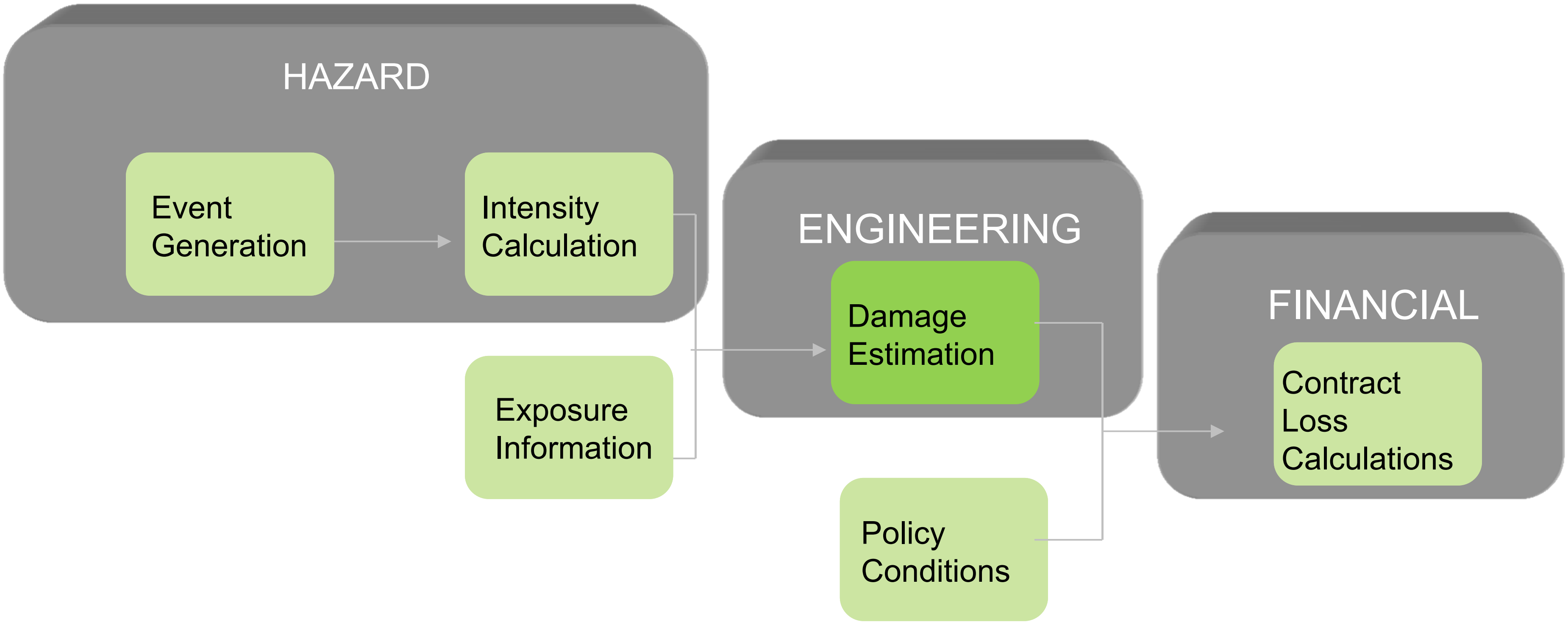
Replacement Value
Building

Policy Terms		
Perils	Limits	Deductibles

Primary Building Characteristics			
Construction	Occupancy	Age	Height

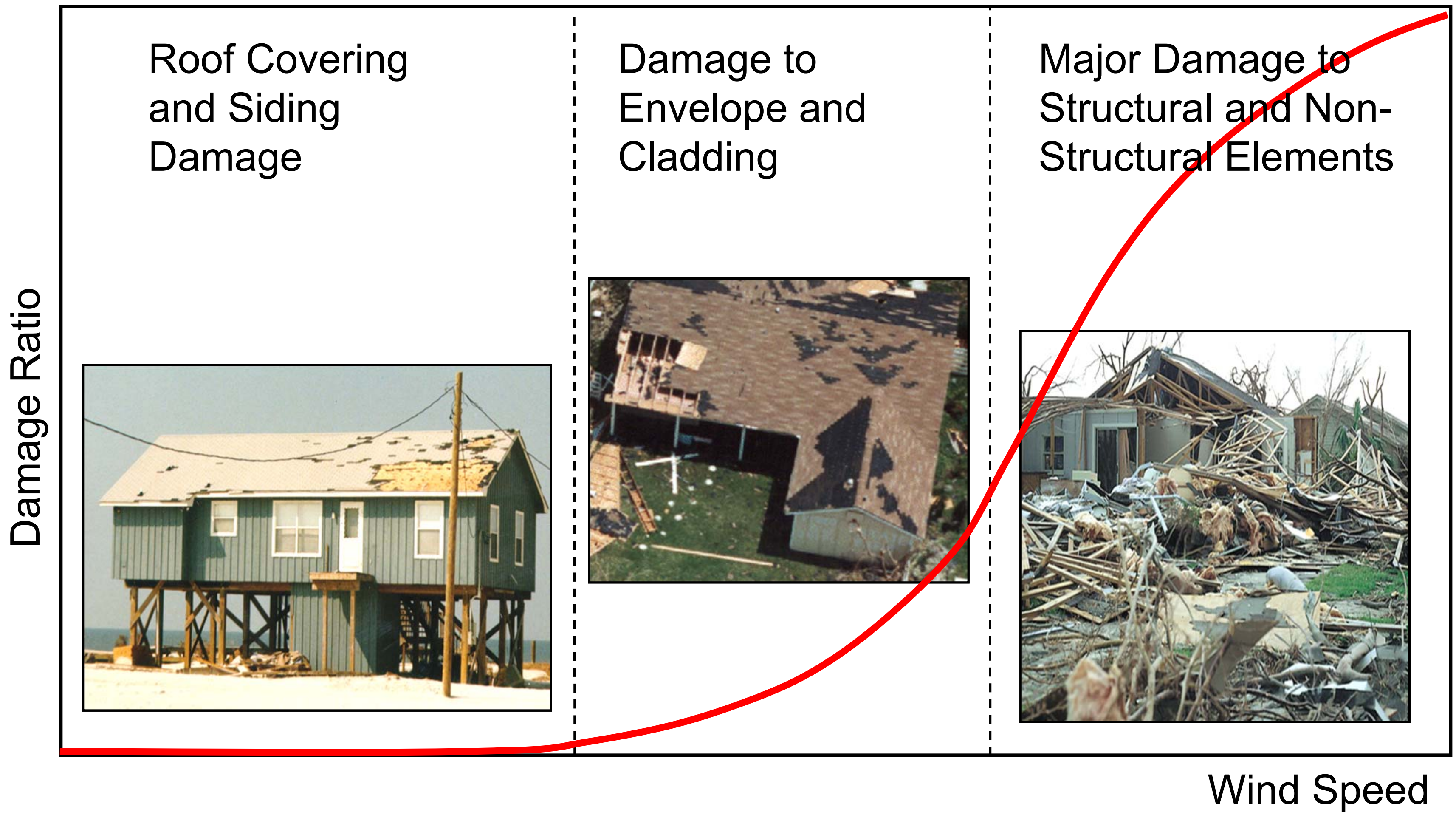
Secondary Building Characteristics					
Window Protection	Glass Type	Glass Percentage	Roof Geometry	Roof Covering	Roof Covering Attachment
Roof Deck	Roof Deck Attachment	Roof Anchorage	Wall Type	Wall Siding	Exterior Doors
Soft Story	Building Shape	Torsion	Foundation Type	Foundation Connection	Special EQ Resistant Systems

Catastrophe Modeling Framework: Damage Estimation



- What level of damage is experienced at each location?

Damage Function — Residential Wood Frame



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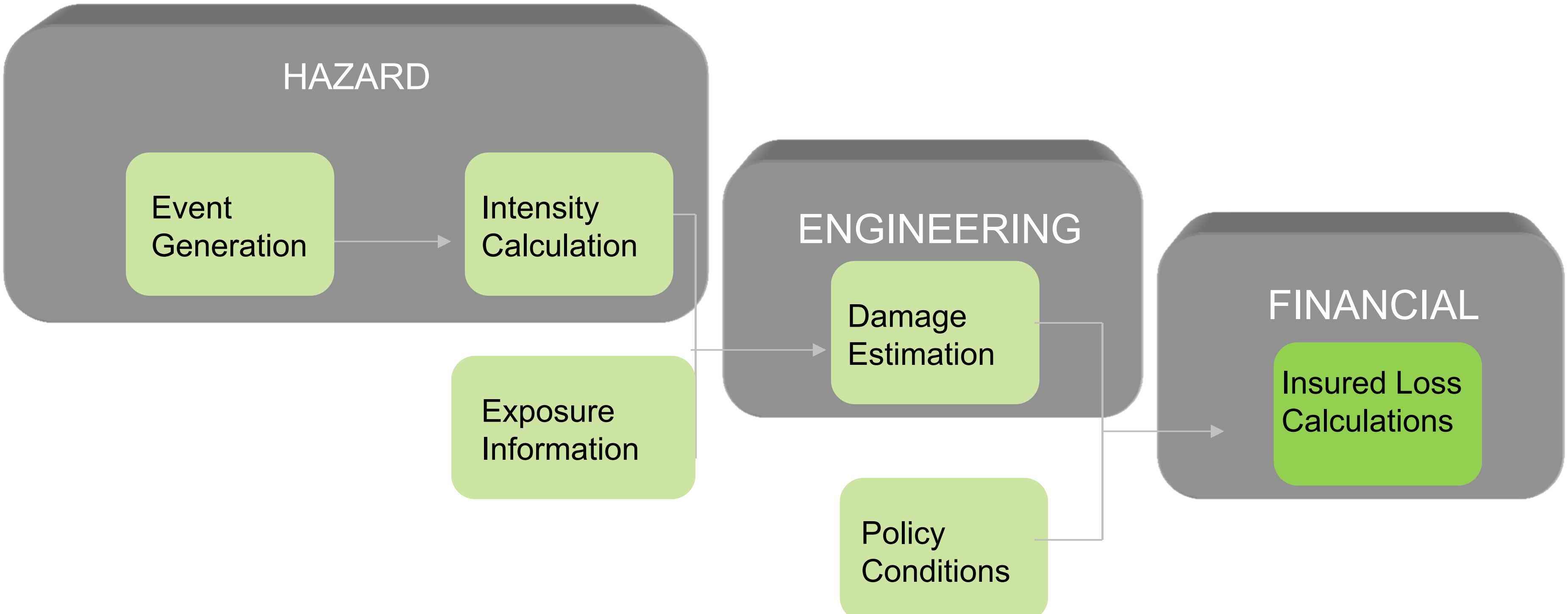
Catastrophe Modeling Framework: Insured Loss Calculation



- What is the insured loss to a property, policy or contract?

A Robust Financial Model Must Accurately Account for Wide Breadth of Policy Conditions

Limits		Deductibles		Reinsurance
Site Limits	Blanket Policy Limits	Combined ($ or %)	Attachment Point	Proportional Facultative
Coverage Specific Limits	Excess Policy Limits	Combined Excluding Time ($ or %)	Blanket	Non-Proportional Facultative
Building	Blanket Policy Sub-Limits	Coverage Specific ($ or %)	Franchise	Surplus-Share
Appurtenant Structures	Excess Policy Sub-Limits	Building	Minimum / Maximum	Catastrophe Excess of Loss
Contents		Appurtenant Structures	Percent of Loss	Aggregate Excess of Loss
Time Element		Contents		Quota Share
		Time Element		Per Risk Treaties
		CEA Mini-Policy		

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Summary: Distinguishing Features of the AIR U.S. Hurricane Model

- Greater model stability over time
- Superior (and consistent) capture of inland loss potential
- More measured approach for capturing the sensitivity of the risk to climate
- Consistent view of storm surge risk
- Superior understanding of building vulnerability
- Appropriately captures the effects of wind *duration*
- Greater transparency

Hurricane – Modeled and Non-Modeled Perils

Modeled Perils

- Wind (includes direct wind, and implicitly includes damage from wind-debris, wind-driven rain and tree failure)
- Storm surge

Modeled Coverages

- *Coverage A* - Dwelling
- *Coverage B* - Other Structures
- *Coverage C* – Contents / Personal Property
- *Coverage D* – Additional Living Expense / Business Interruption

Non Modeled Perils

- Riverine or Hurricane-induced Flooding
- Loss from Levee or Dam Failures

Non Modeled Loss Components

- Loss Adjustment Expenses
- Hazardous Waste Removal
- Loss inflation due to political pressure

How Can Catastrophe Models be Used Throughout the Insurance Industry Value Chain?

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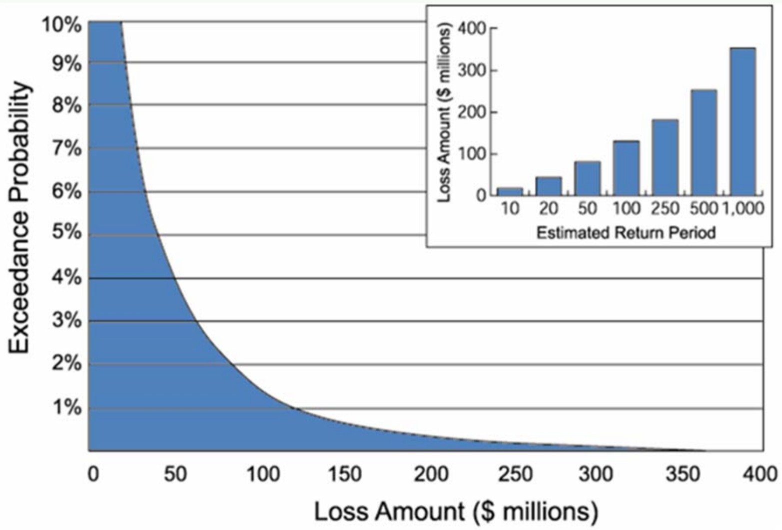
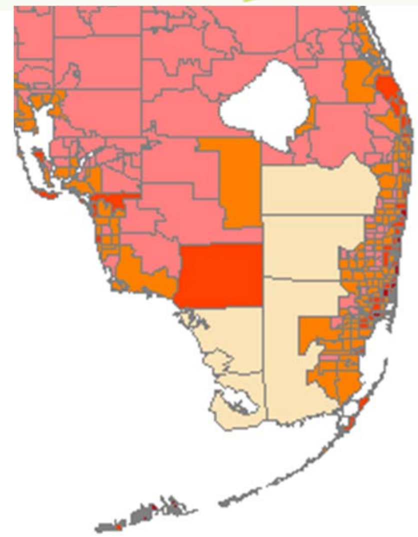
Catastrophe Models Provide a Wide Range of Outputs





Event	Year	Contract Loss	Event Info
270007942	2353	1,995,714,211	Class 3 Hurr TX GOM
270003822	1143	1,994,490,277	Class 3 Hurr FL GOM GA
110044047	6410	1,993,822,104	MW 7.4 EQ Los Angeles
270021674	6488	1,992,783,613	Class 3 Hurr GOM AL FL GA MS
270018191	5445	1,992,529,830	Class 3 Hurr MA RI ME NY CT
270021539	6447	1,992,239,441	Class 3 Hurr FL BF
110010511	1539	1,991,950,215	MW 6.6 EQ Los Angeles
270014761	4407	1,991,795,632	Class 2 Hurr TX GOM LA
270029332	8763	1,990,905,697	Class 3 Hurr GOM FL AL GA MS
110014872	2164	1,990,461,843	MW 6.5 EQ San Francisco
270006759	1983	1,989,857,449	Class 2 Hurr LA GOM MS AL
270023332	6984	1,989,268,193	Class 3 Hurr SC TN NC KY GA
270008182	2423	1,989,078,459	Class 2 Hurr NC SC VA

Insurers Use Catastrophe Models Across Multiple Functional Areas

- Manage the impact of catastrophe risk on surplus
- Communicate with ratings agencies
- Accumulation/risk-aggregation management

- Identify areas to grow or retract based on model-based risk metrics
- Perform model-based analyses to understand and manage the drivers of catastrophe risk

- Use models to evaluate reinsurance purchases or issuance of Cat Bond
- Streamline efficiency of communication with reinsurance intermediaries

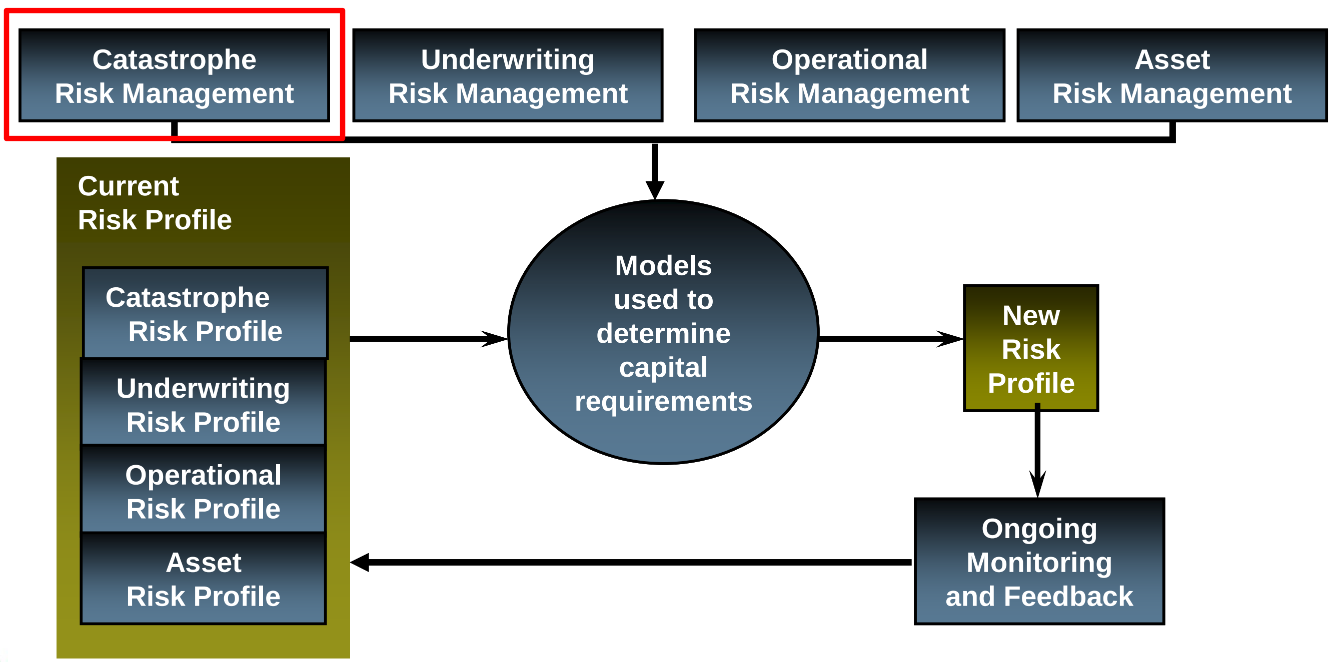
- Use model outputs in rate filings and in pricing of individual policies or programs

- Advance planning, resource deployment, post-event communications

- Catastrophe model output used for risk selection and pricing at the point of sale

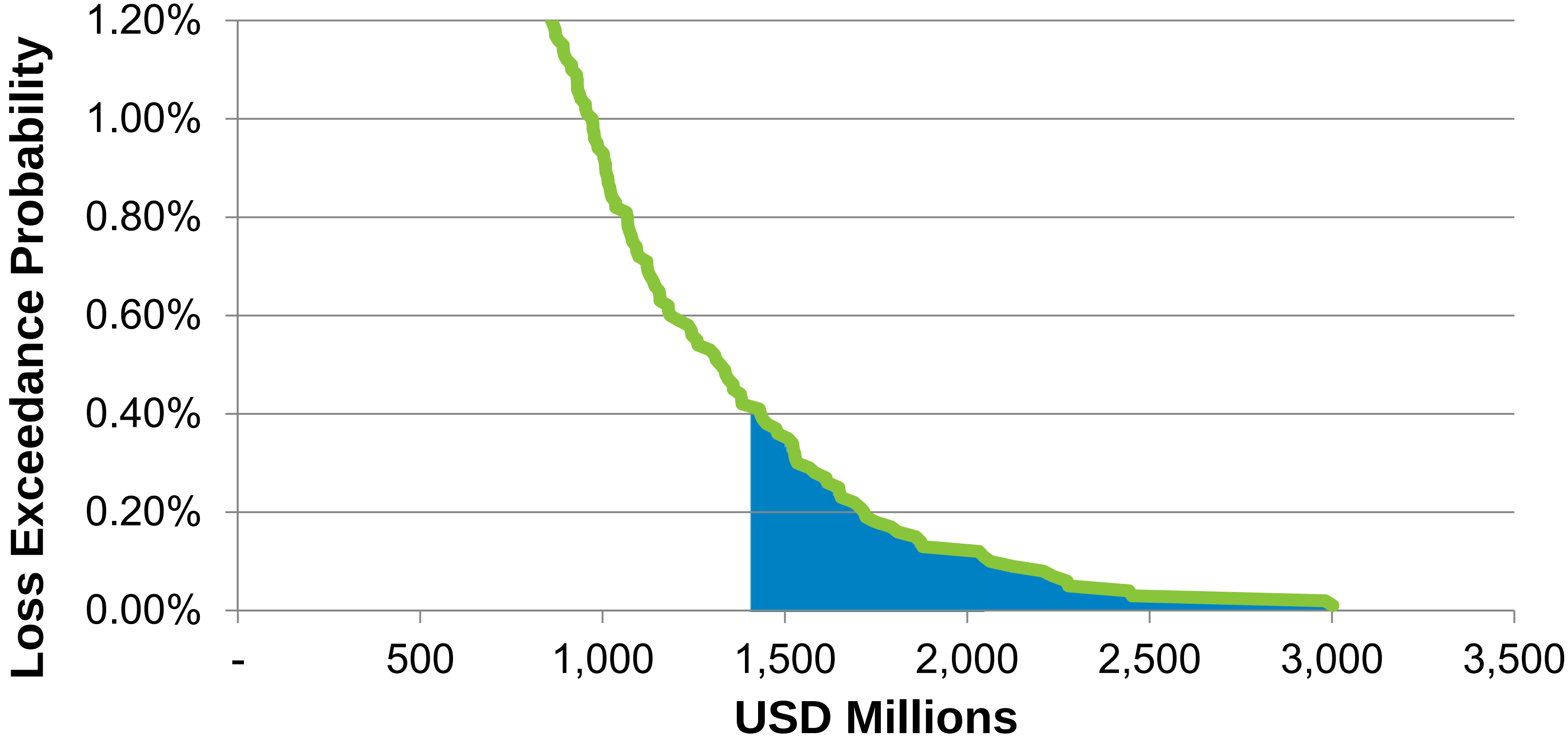
What is ERM and Why Does it Require Model Results?

- A framework for mapping (identifying), measuring, monitoring, and managing a wide variety of risks, both independently and in combination
  - Catastrophe risk is the greatest threat to solvency
  - Catastrophe risk also highly correlated to operational and asset disruptions



Portfolio Optimization Through Tail Value at Risk Management

- Tail value-at-risk (TVaR): average of all simulated event losses beyond specified probability, such as 1% or 0.4%

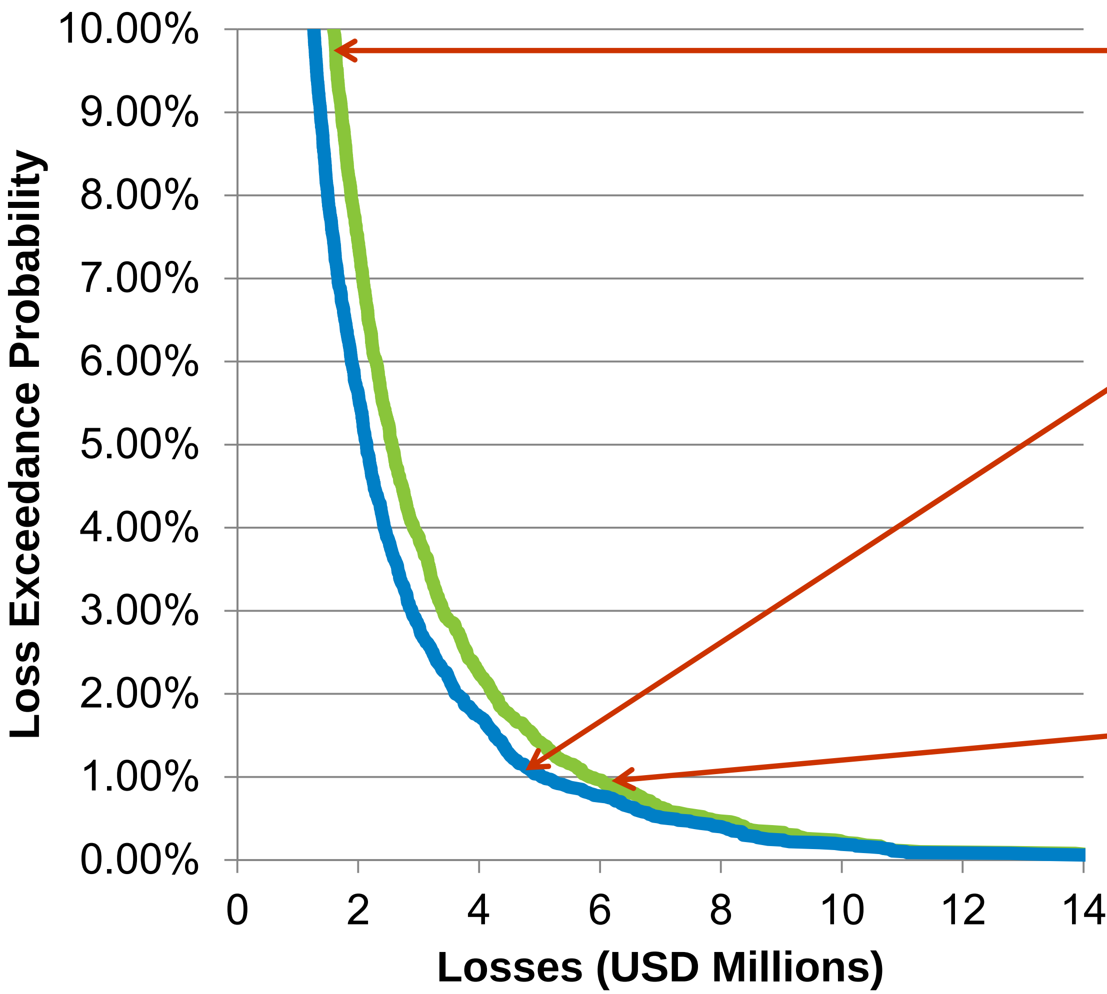


TVaR is a standard output of AIR software products

Catastrophe Risk Transfer Decisions Have Several Elements

- Main goal: modify EP curve net of transfer so that enterprise-wide risk appetite and tolerance goals are achieved
  - But trade-offs in ERM among catastrophe and other risks (credit, liquidity) may ensue
  - Traditional reinsurance most common mechanism, but new ways of risk transfer such as issuance of Cat Bond is gaining popularity
- Price per unit (rate on line) determined by supply and demand for capital
  - But often depends on “technical prices” derived using model results
- Quantity of transfer often directly determined by model results
  - Occurrence (XOL) retention, top limit, and coinsurance
  - Aggregate (XOL) retention and limit
  - Per-risk and facultative retentions and limits on large single risks
  - Participation in state funds determined indirectly by models

Software Users Analyze Occurrence and Aggregate EP Curves to Understand Risk Transfer Needs



Retentions also selected based on how often the enterprise can “take a hit” and for how much

Coverage for severe events (“the big one”) based on maximums at selected return periods

Reinstatement and drop-down provisions selected based on probability of multiple covered events

Direct Insurance Premiums Are Determined By Many Complex, Interdependent Base Rates and Differentials

- Base Rates
  - Set to provide sufficient overall revenue to insure entire portfolio
  - In regulated environments, include provisions for specific cost components
    - Normal losses (non-catastrophe)
    - Catastrophe retained losses
    - Catastrophe risk transfer (e.g. reinsurance) costs
    - Expenses, taxes and profit
- Rating Factors
  - Set to equitably distribute premiums among risks of different loss potential
    - Geographic location (territory, building code zone)
    - Property attributes (construction, occupancy, mitigation features)
    - Coverage modifiers (deductibles, coinsurance)
    - Marketing preferences (multi-policy discount)

Typical Rating Algorithm and Base Premium Formula – Modeled Losses Enter in Several Places

Expected losses – cat and non-cat

Risk transfer costs, including reinsured cat losses

$$P = \frac{E[L_C + L_N] + K + F}{1 - (c + t + \pi)}$$

Variable expenses (percent of premium)

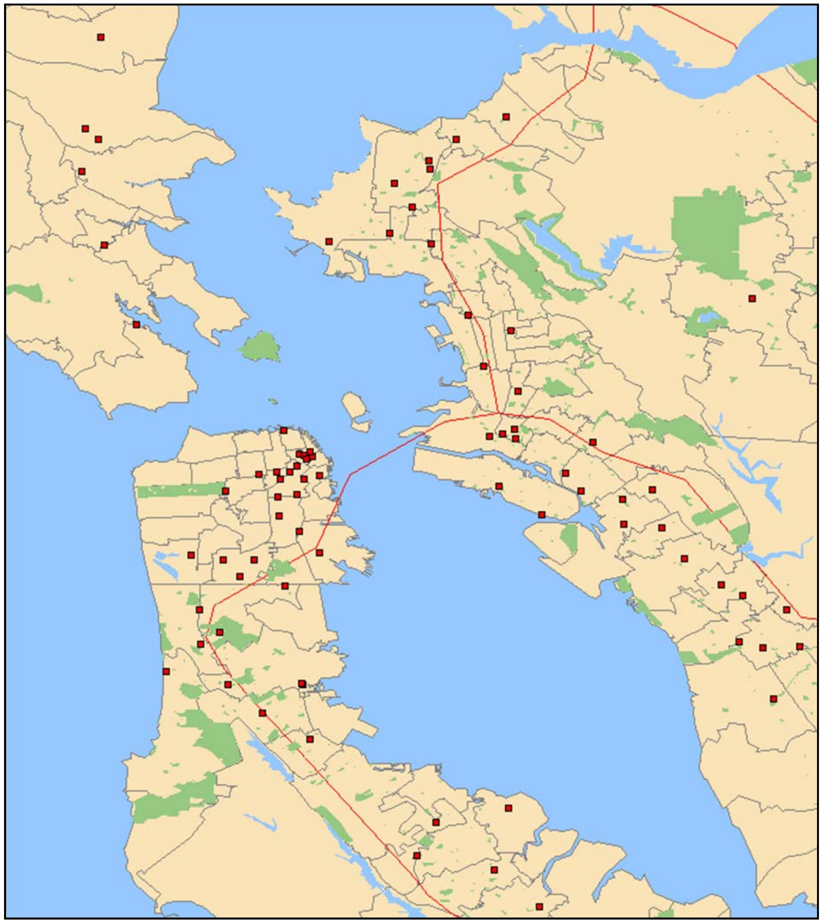
Fixed overhead expenses (not a percent of premium)

Then: Base Premium [**P**]
x Construction Type factor
x Territory factor
x Amount of Insurance factor
x Deductible factor
x Mitigation discount
x Building Code Zone discount
x Multi-Policy discount
<u>+ Policy Fees</u>
= Final Premium

- Allocation of base premiums (via rating factors) should be based on relative loss potential – including catastrophe losses from models
- Relative loss potential should be measured using both expected losses and a measure of risk (volatility)

The Role of Models in the Underwriting Workflow

- **Risk Selection**
  - Quickly assess whether new policies meet underwriting guidelines
  - Manage catastrophe risk on the ‘front-end’ before a policy goes on the books, not just at the portfolio level
- **Loss Analysis:** Produce potential loss result and EP curve for your location which will guide you through the underwriting process, help you set coverage terms and pricing



Summary

- Models provide valuable management information through evaluation of risk within a structured framework
- Quality model input data is key to deriving valuable model output for effective risk management
- AIR's robust catastrophe model framework enables AIR to develop the most consistent and comprehensive hurricane model available
- Modeled losses can be supplemented with factors to account for additional sources of loss if warranted
- Catastrophe modeling drives sound underwriting and portfolio management decisions and produces a quantifiable and significant return on investment