Workshop 1: Catastrophe Modeling: Modeled Catastrophes, Basic Concepts and Commonalities

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CAS Ratemaking and Product Management Seminar

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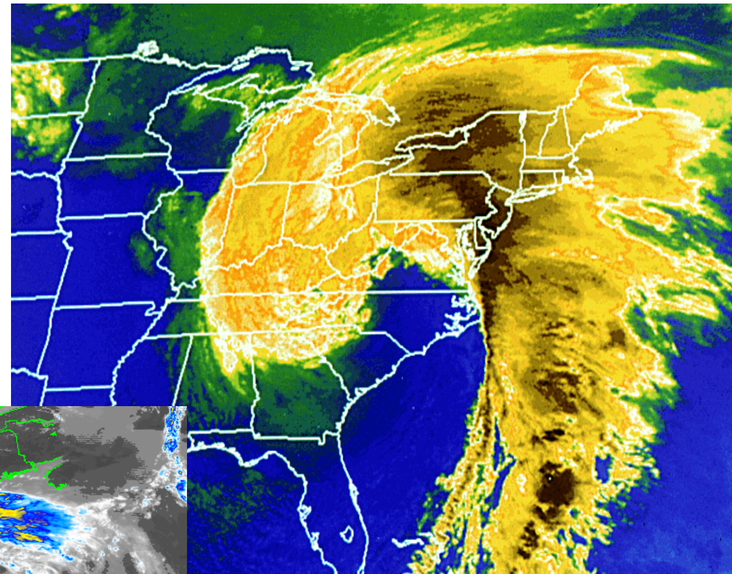
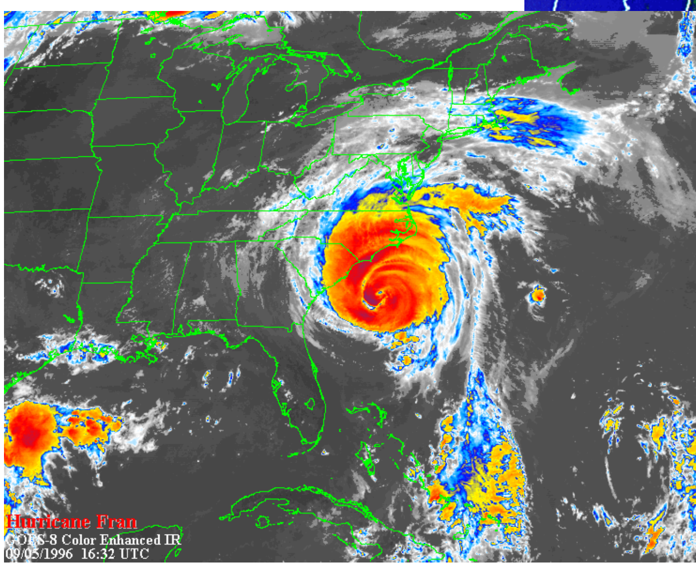
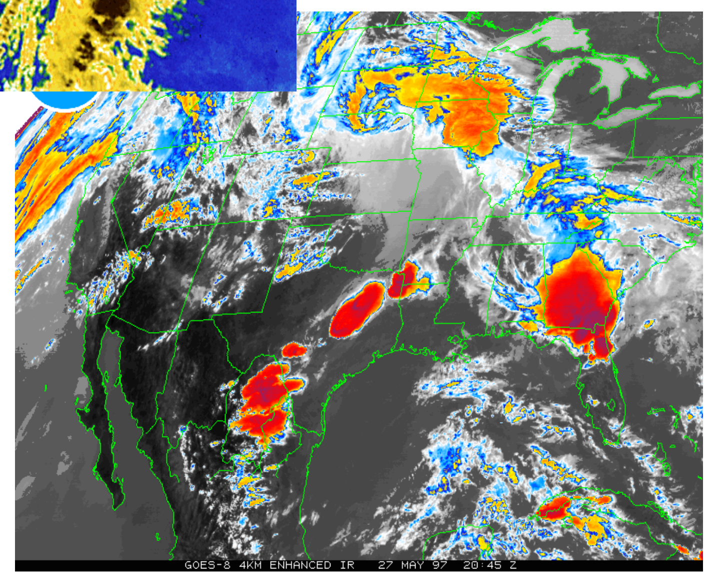
Modeling Extreme Events

- Extreme event losses are highly variable and are a key driver of enterprise risk profile
- The high severity and low frequency of extreme events are not amenable to estimation via traditional actuarial methods
- Technology, science and engineering allow us to improve dramatically upon traditional approaches
  - Historical loss data is scarce
  - Property values change
  - Repair and replacement costs change
  - New properties continue to be built in areas of high hazard
- Modeling of detailed exposure allows incorporation of actual policy conditions
- Modeling of extreme event risk provides more complete picture of your company's current risk profile and the potential impact on financial results
- Modeling adds stability to the insurance markets

Extreme Wind Events…







Earthquakes, Floods…

Terrorism Attacks

CONVENTIONAL

- Bombs
  - Portable
  - Car
  - Van
  - Delivery Truck
  - Large Truck
- Airplane crash
  - General aviation
  - Large commercial airliner

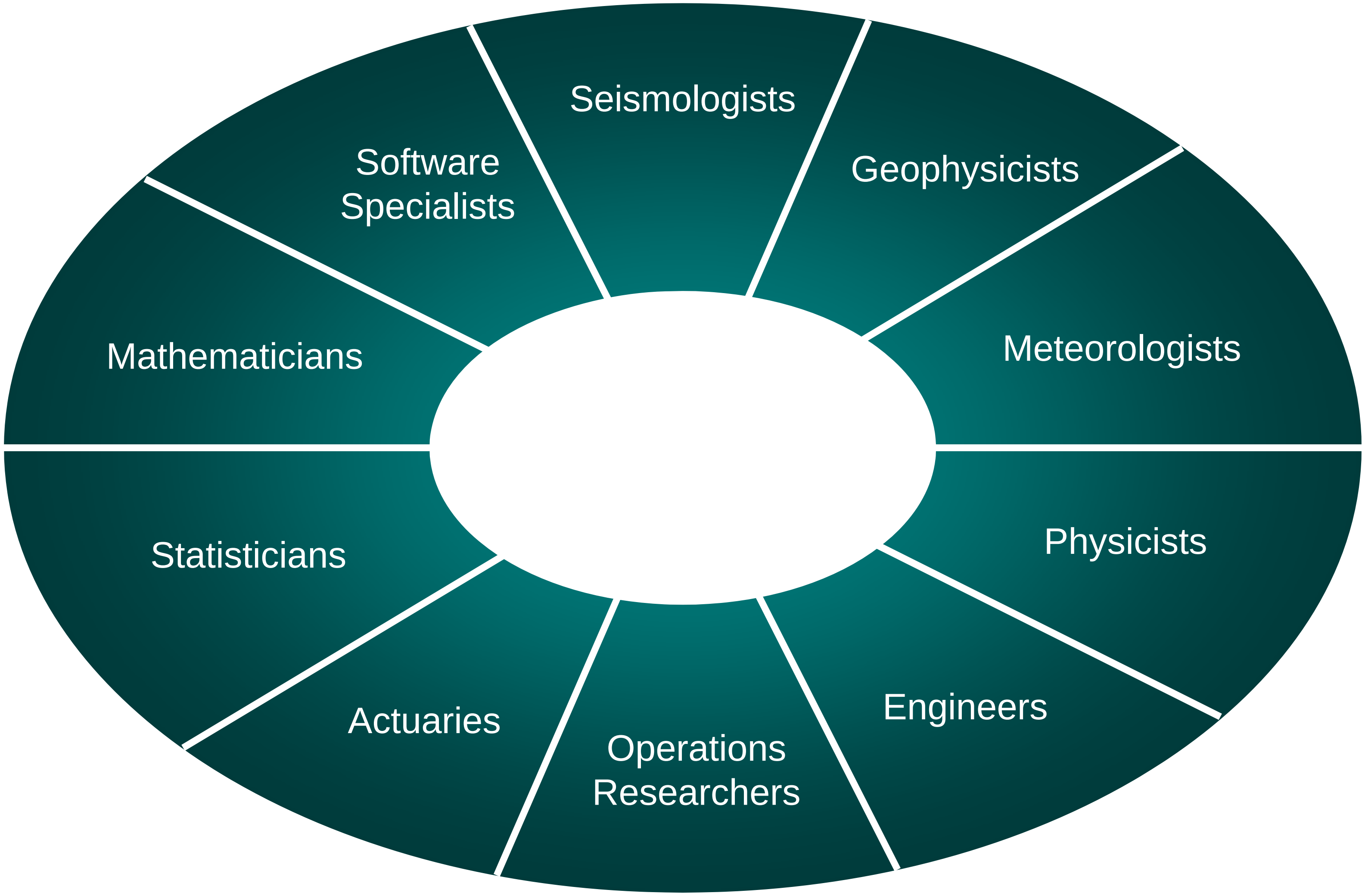
CBRN

- Chemical
  - Sarin (GB)
  - VX Nerve
- Biological
  - Anthrax
  - Small pox
- Radiological
  - Cesium 137
  - Cobalt 60
- Nuclear
  - Suitcase type
  - Medium
  - Large

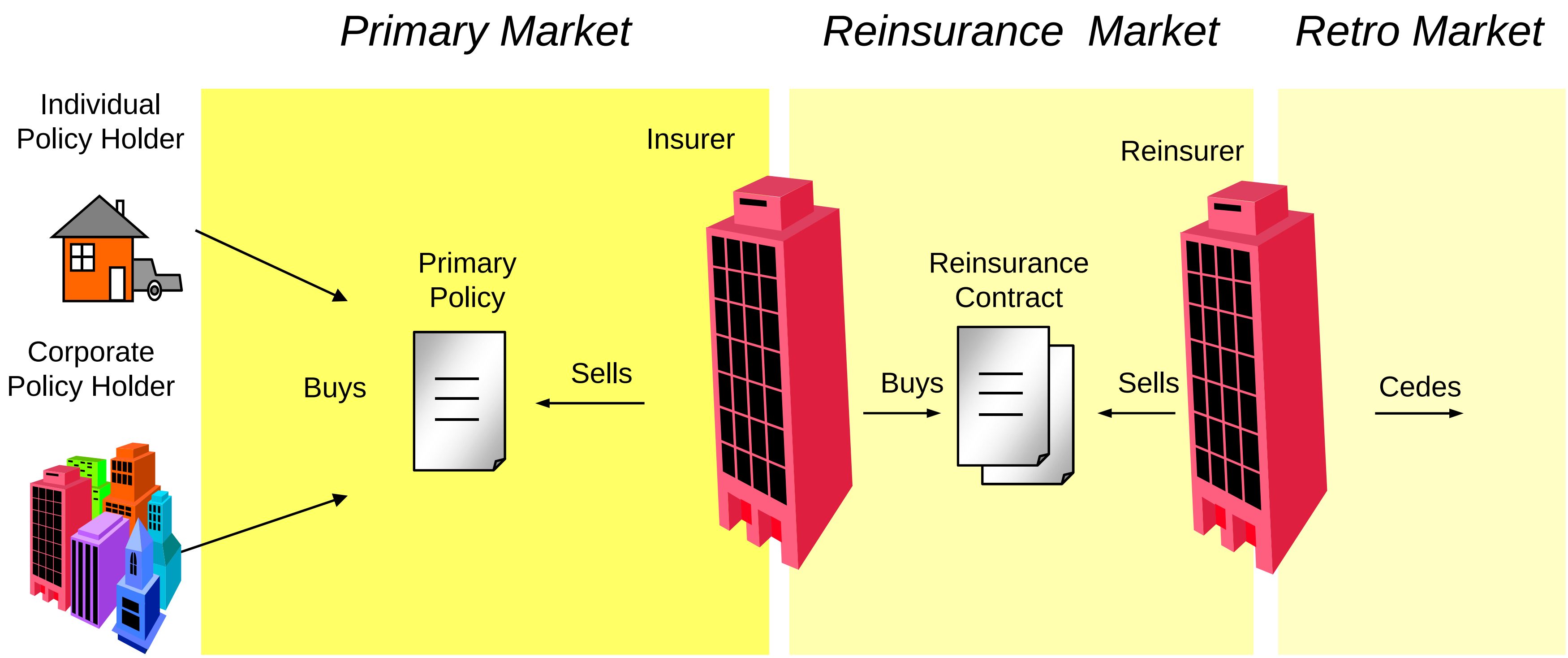
Catastrophe Models are Global

Tropical Cyclones (Typhoons, Hurricanes)	Tornadoes, Hailstorms & Straight-line Windstorms	Extratropical Cyclones (i.e. Winterstorms)	Earthquake (Shake)	Earthquake (Fire Following)	Terrorism
Australia	Canada	Austria	Australia	Canada	United States
Caribbean	United States	Belgium	Canada	Japan	
Hawaii		Canada	Caribbean	United States	
Hong Kong		Denmark	Chile		
Japan		France	Colombia		
Philippines		Germany	Greece		
Taiwan		Ireland	Israel		
United States		Luxembourg	Indonesia		
		Netherlands	Italy		
		Norway	Japan		
		Switzerland	Mexico		
		Sweden	New Zealand		
		UK-Includes Flood	Philippines		
		United States	Portugal		
			Taiwan		
			Turkey		
			United States		
			Venezuela		

Multi-disciplinary Research and Modeling Team



Catastrophe Models Are Used in All Segments of the Insurance Industry



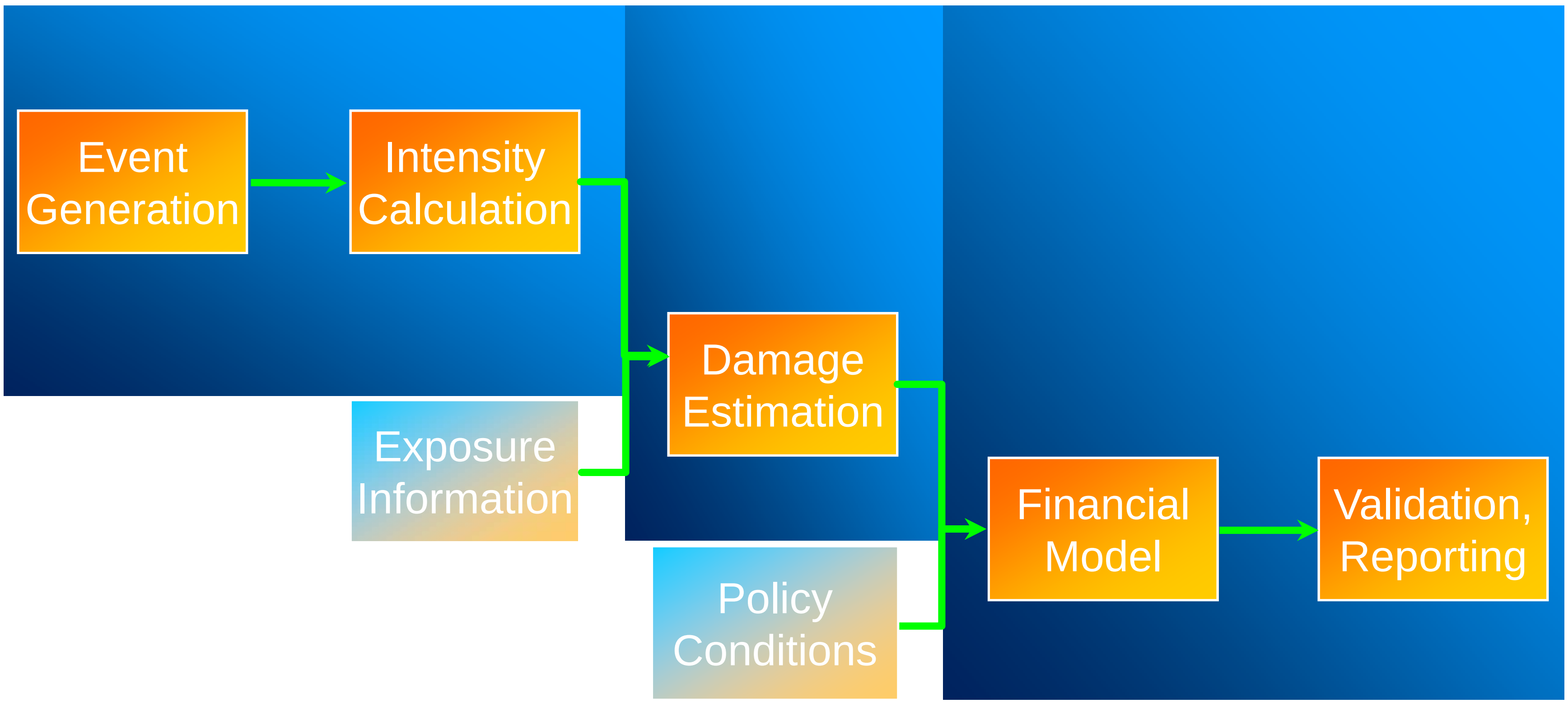
What Questions are Catastrophe Models Designed to Answer?

- Where are future events likely to occur?
- How big are they likely to be?
- How frequent?
- For each potential event, what will be the property damage and insured losses? What will be the number of people injured (eq. and terrorism)?

Why Do We Need Catastrophe Models?

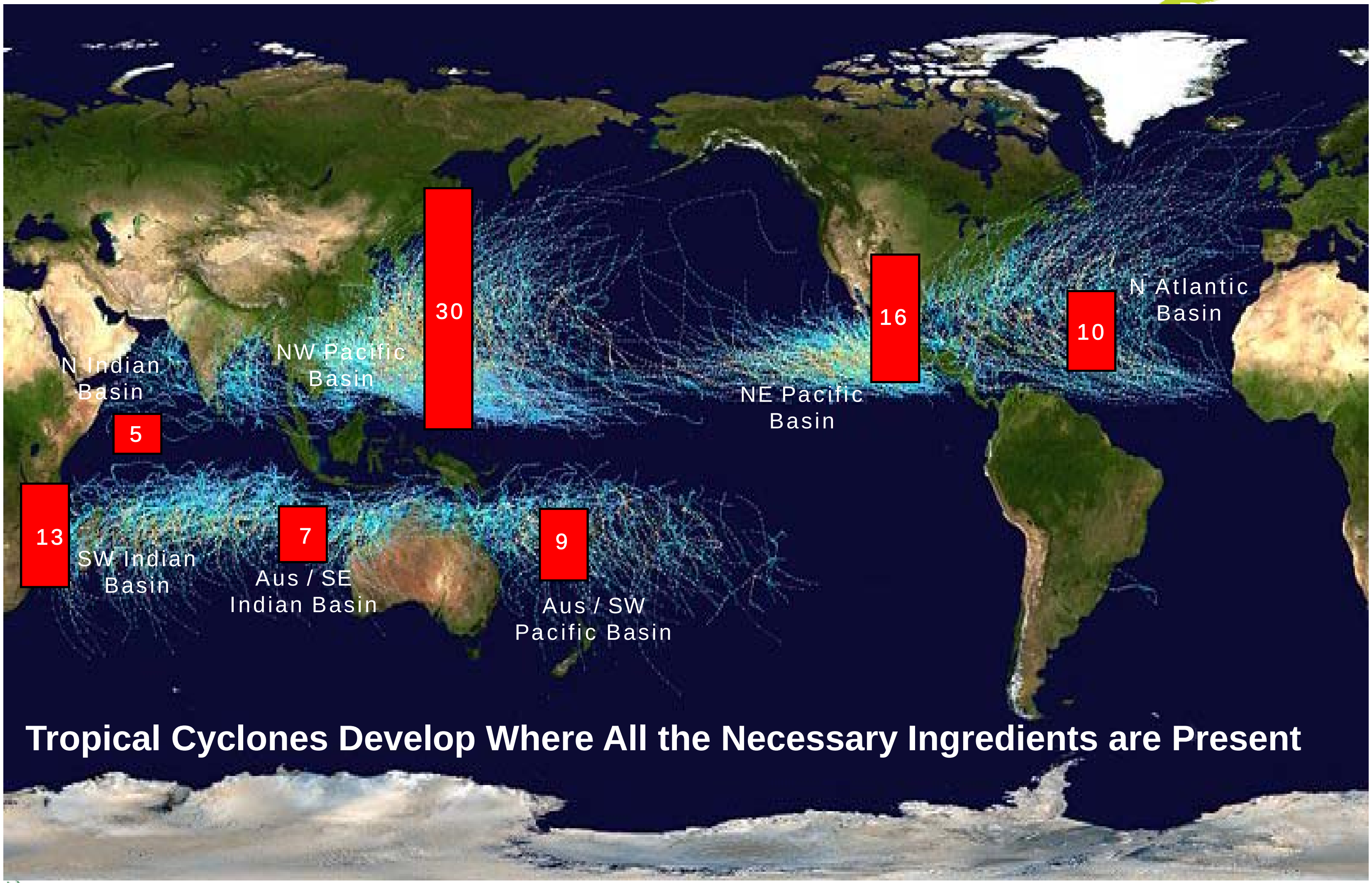
- Due to the low frequency of severe catastrophes, traditional actuarial methods may not be a good predictor of possible losses
- The constantly changing landscape of exposure data limits the usefulness of past loss experience
  - New properties continue to be built in areas of high hazard
  - Building materials and designs change
  - New structures may be more or less vulnerable to catastrophic events than the old ones
- Models should capture all possible events *before they occur* to ensure they provide an objective and stable view of risk over time

Catastrophe Modeling Framework



Hurricane

Average Tropical Cyclone Formation by Basin (Wind > 39 mph)



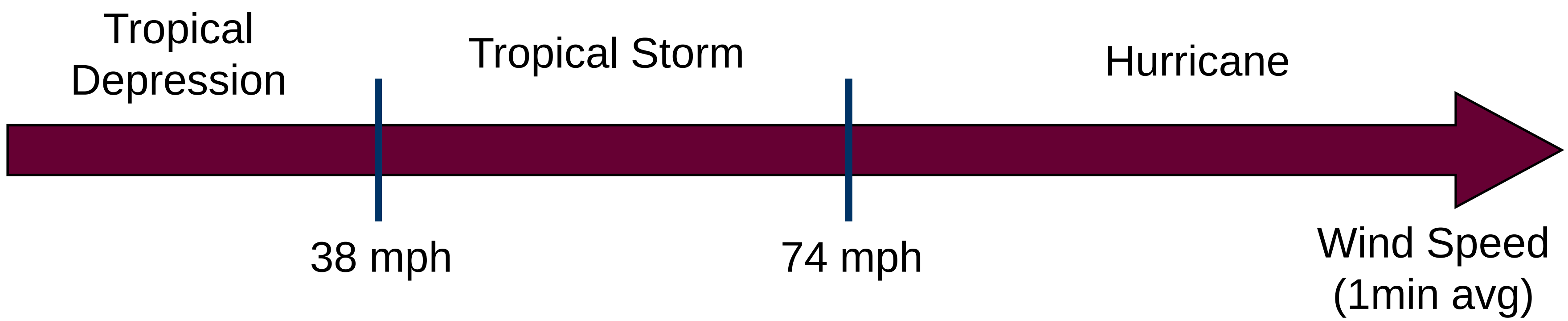
Hurricane

- **Tropical Cyclone:** warm-core, low pressure system that develops over tropical or subtropical waters and has a definite organized surface circulation

  - **Tropical Depression:** Tropical cyclone in which the maximum sustained surface wind speed (1-minute average) is 38 mph or less

  - **Tropical Storm:** Tropical cyclone in which the maximum sustained surface wind speed ranges from 39 mph to 73 mph

  - **Hurricane:** Tropical cyclone in which the maximum sustained surface wind is 74 mph or more



How Do These Mechanisms Affect Atlantic Hurricane Activity?

Mechanism	Increase Activity	Decrease Activity	Why?
Atlantic Sea Surface Temperature	Warm	Cool	A hurricane's main energy source is the heat and moisture of the ocean.
Vertical Wind Shear	Low	High	The shear created by varying surface and upper-level winds is destructive to hurricanes.
Upper Atmosphere Winds	Westerly	Easterly	Hurricanes are atmospheric engines, with inflow at their base and exhaust at their top. Upper-level winds affect a hurricane's ability to vent its outflow.
Atlantic Pressure Distribution	Bermuda High South and West	Bermuda High North and East	Pressure differences in the Atlantic influence the steering mechanism for hurricane tracks.

What Questions Are A Hurricane Model Designed to Answer?

- **Where are future hurricanes likely to occur?**
- **How intense are they likely to be?**
- **How frequently are they likely to occur?**
- **What is the wind associated with each potential hurricane?**
- **What is the property damage and insured losses associated with each potential hurricane?**

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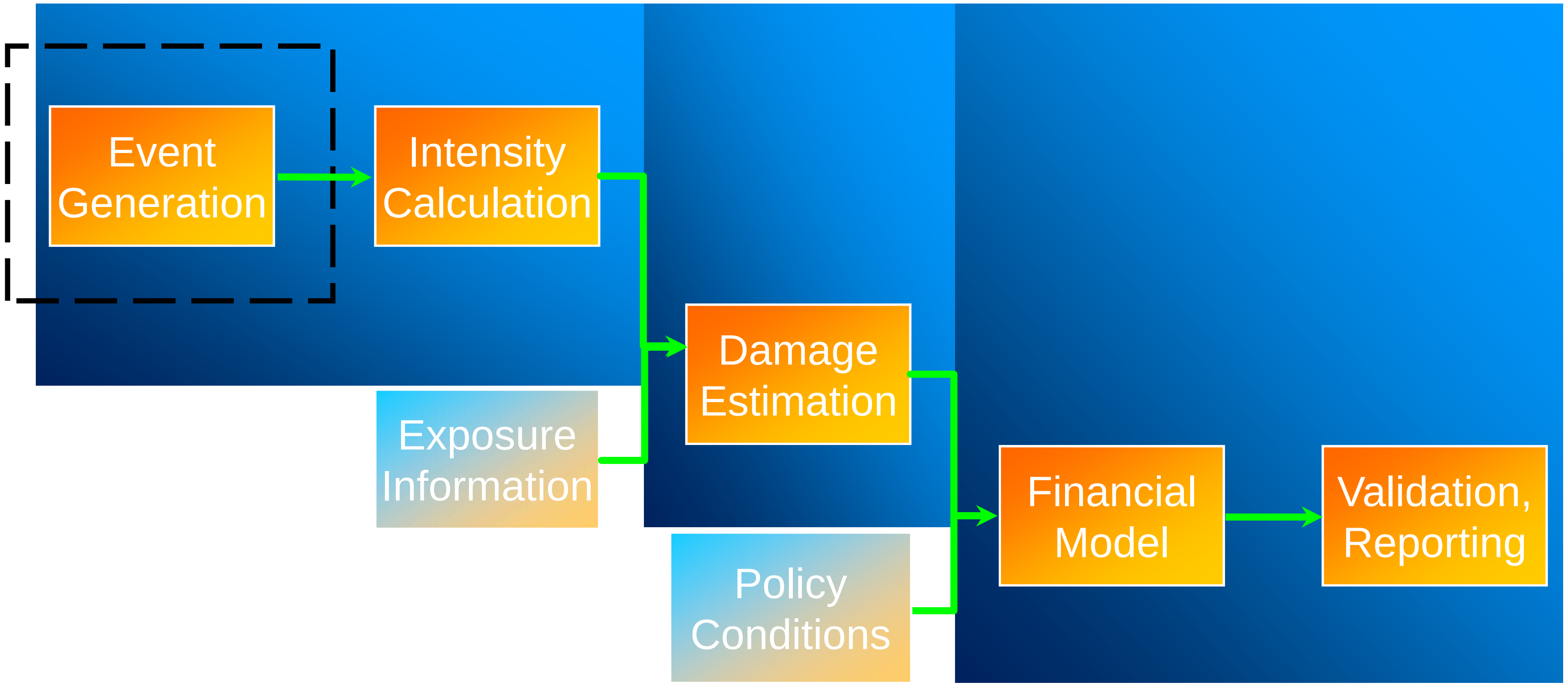
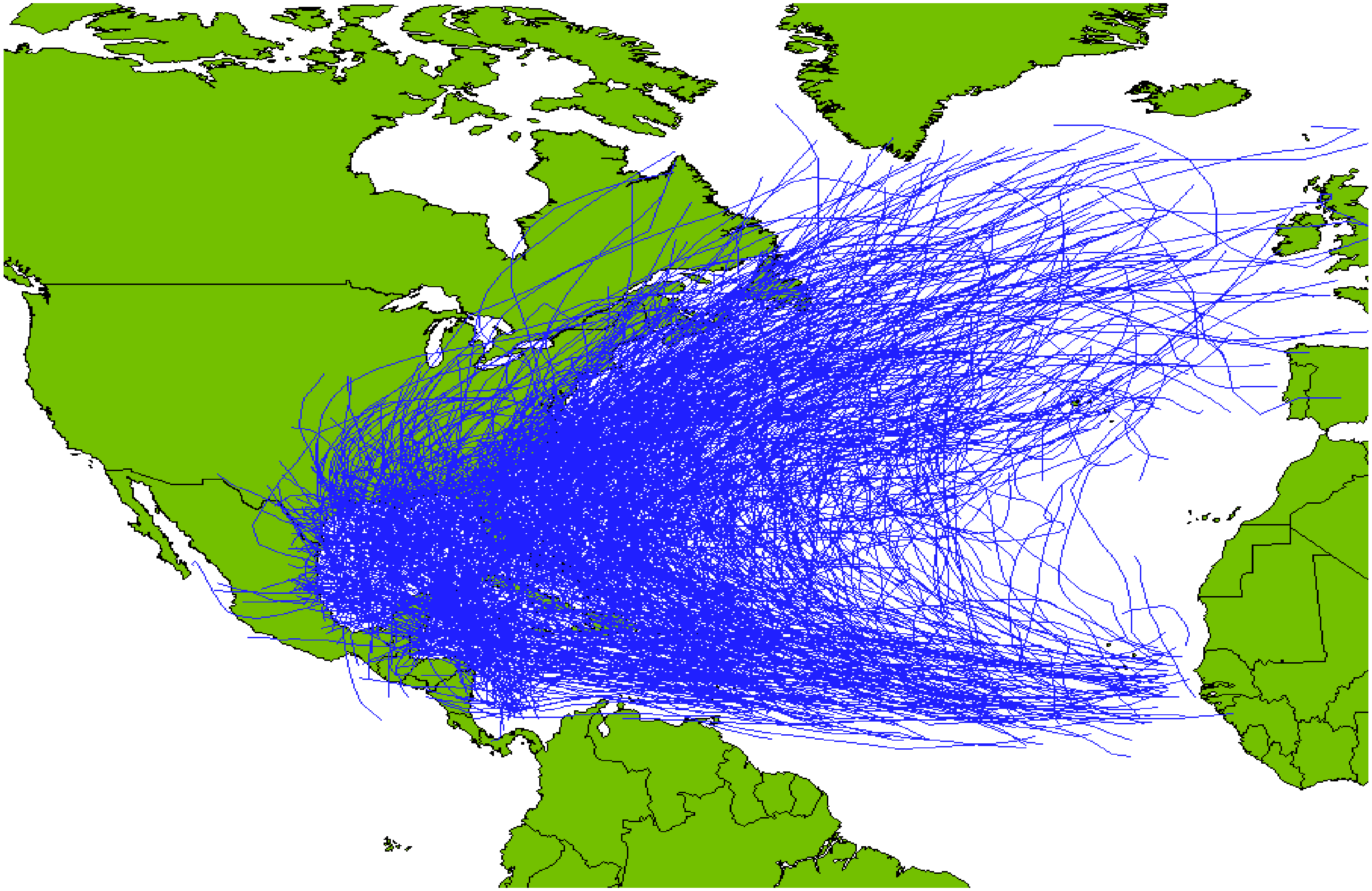
Catastrophe Modeling Framework



North Atlantic Tropical Cyclone Tracks Since 1900



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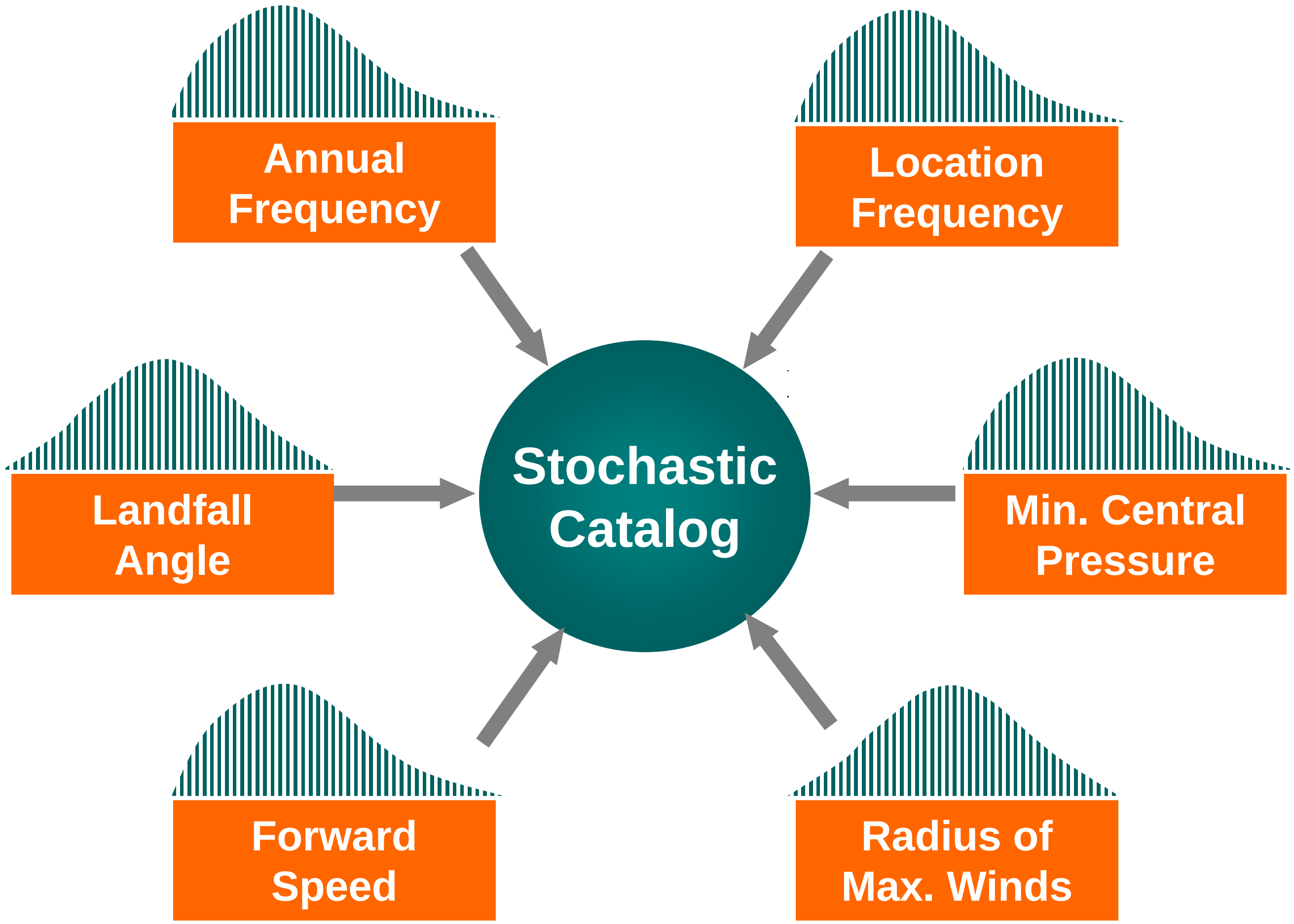
Landfall Characteristics: How Intense? How Big? How Fast Moving?



Sample Stochastic Hurricane Catalog Output

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	29.689	-93.713	9	20	18
8	7	204	1	1	39	987	76	32.937	-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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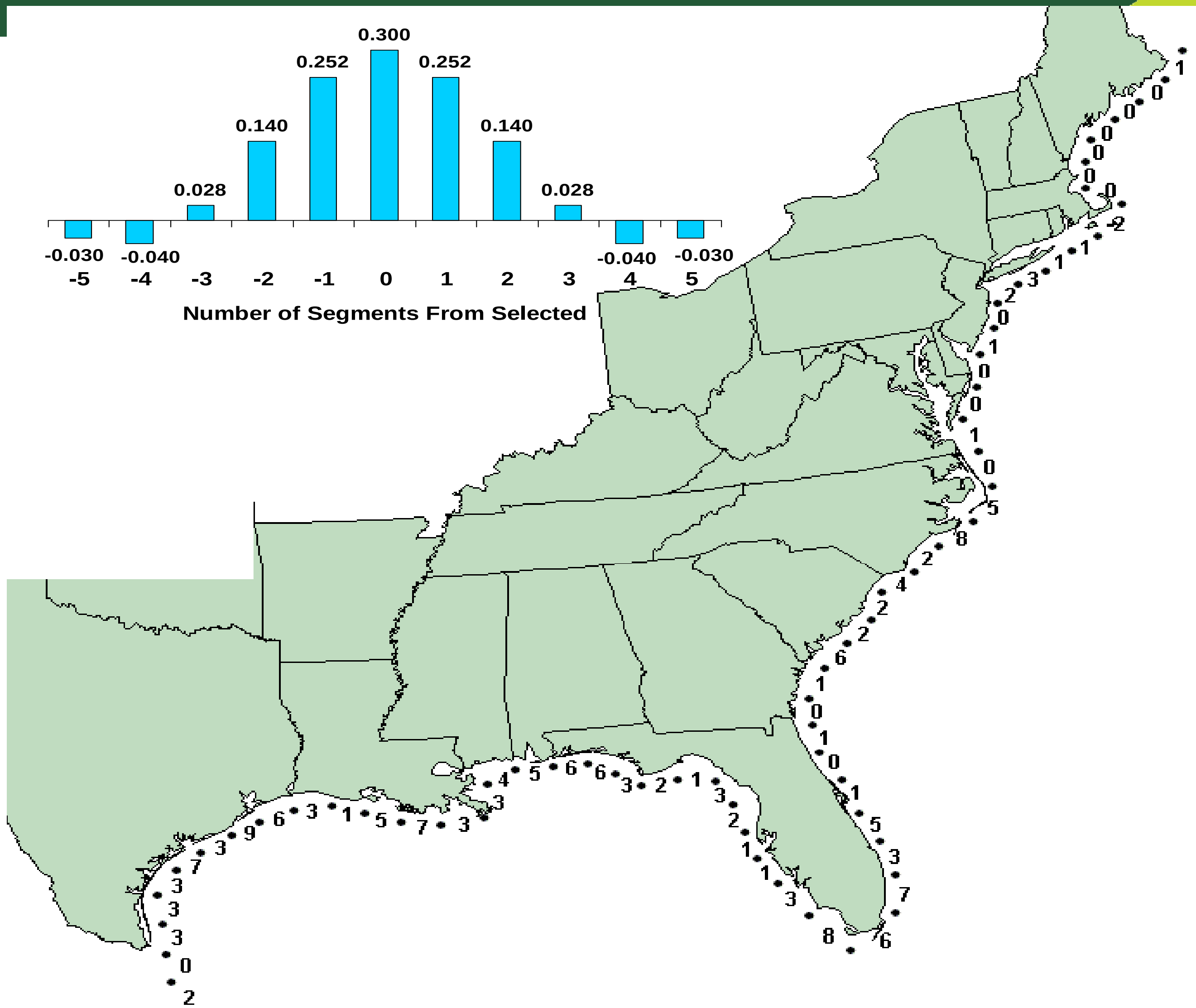
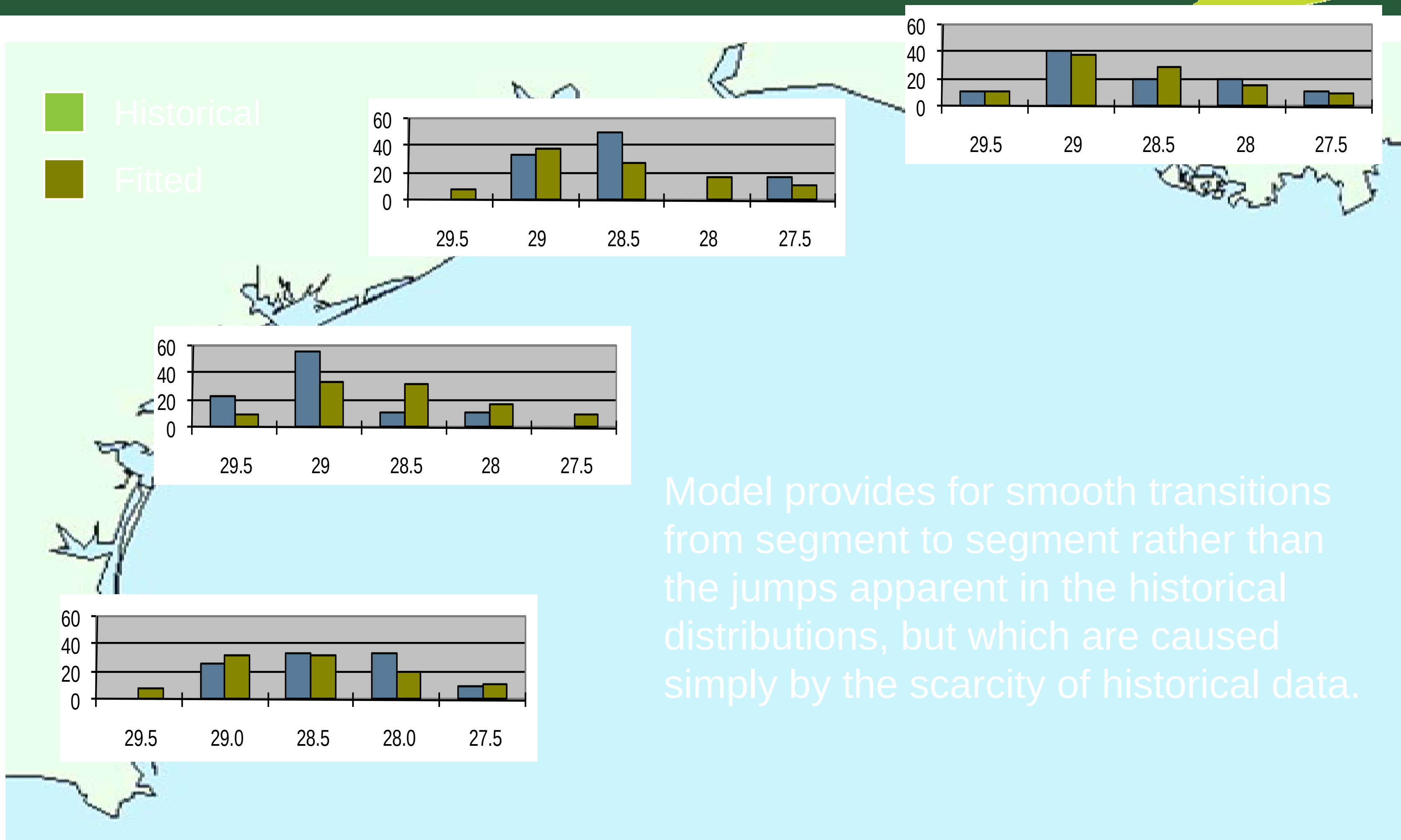
Estimating Hurricane Locational Frequencies



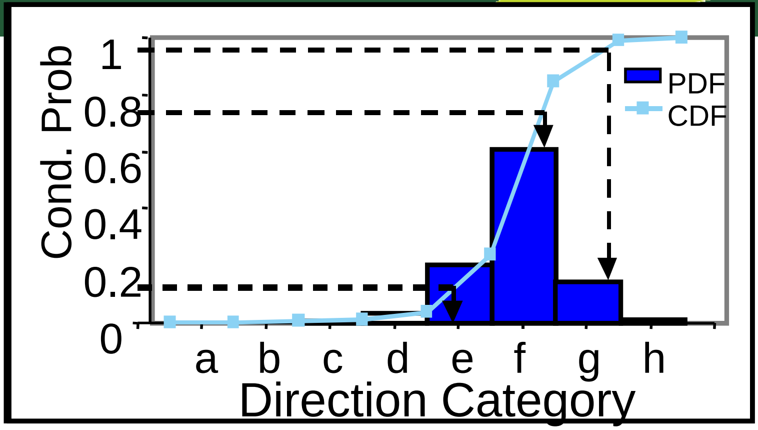
Estimating Storm Intensity by Landfall Location

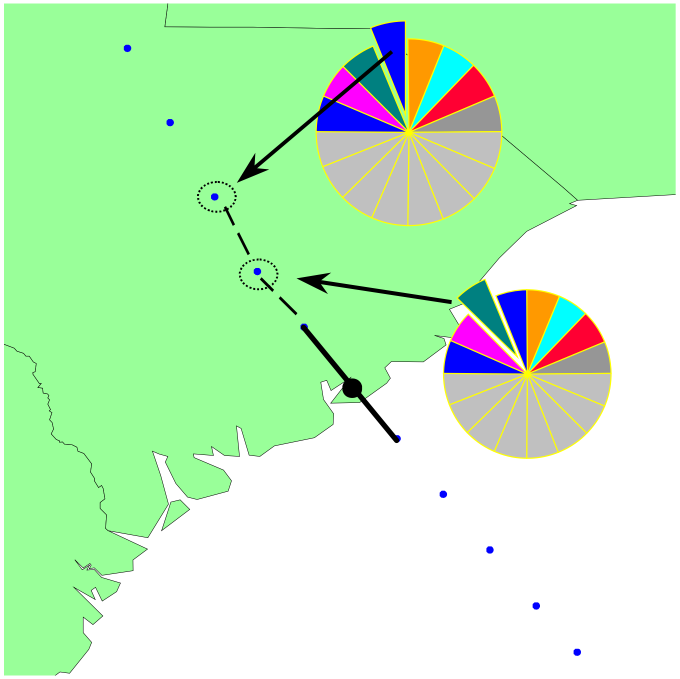


Model provides for smooth transitions from segment to segment rather than the jumps apparent in the historical distributions, but which are caused simply by the scarcity of historical data.

Conditional Probability Matrices Determine Storm Track Direction

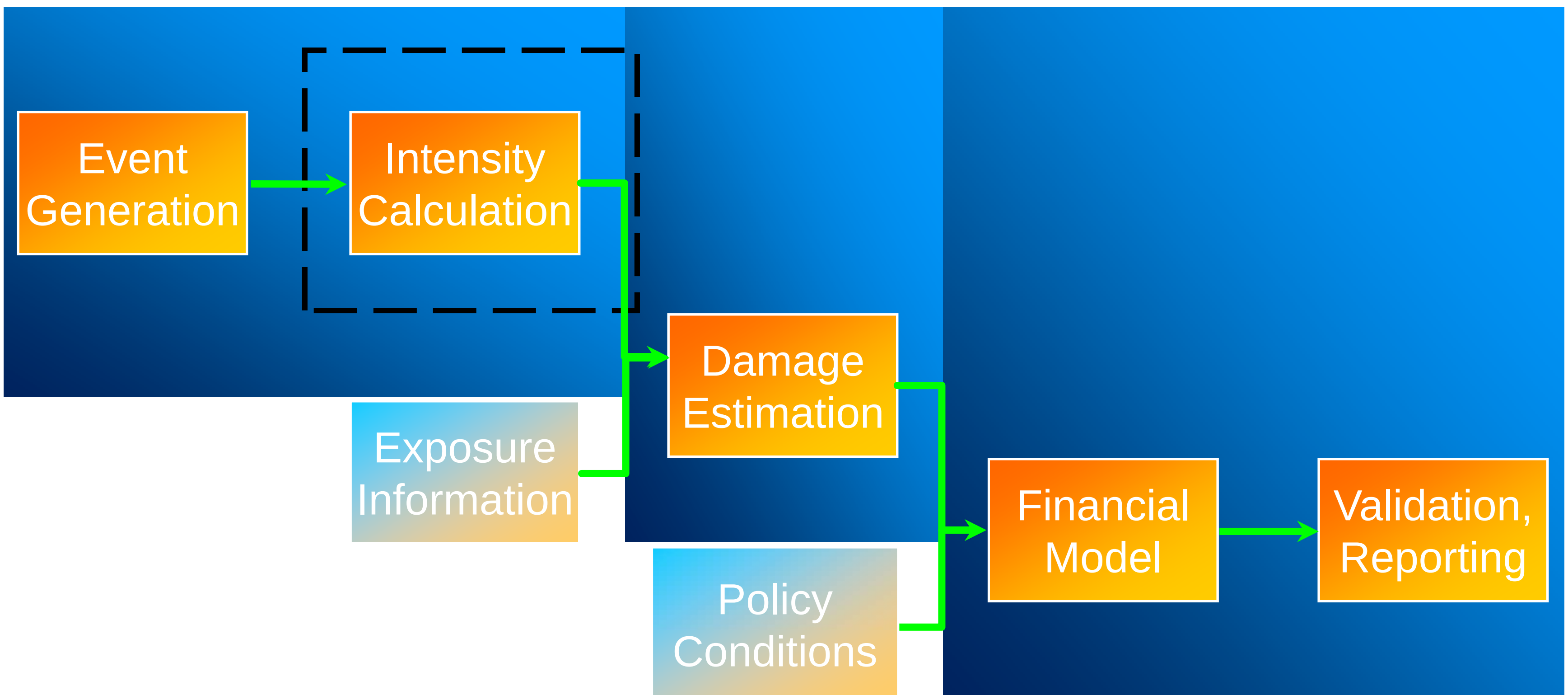
- Conditional probabilities based on the tracks of more than 900 historical Atlantic tropical cyclones, both landfalling and nonlandfalling
- Matrices answer the question: "If the direction of the current storm heading to is a, what is the probability that its next heading will be a, b, c, d, etc.?"
- For each given storm arrival, this matrix specifies the probability of all possible outgoing directions



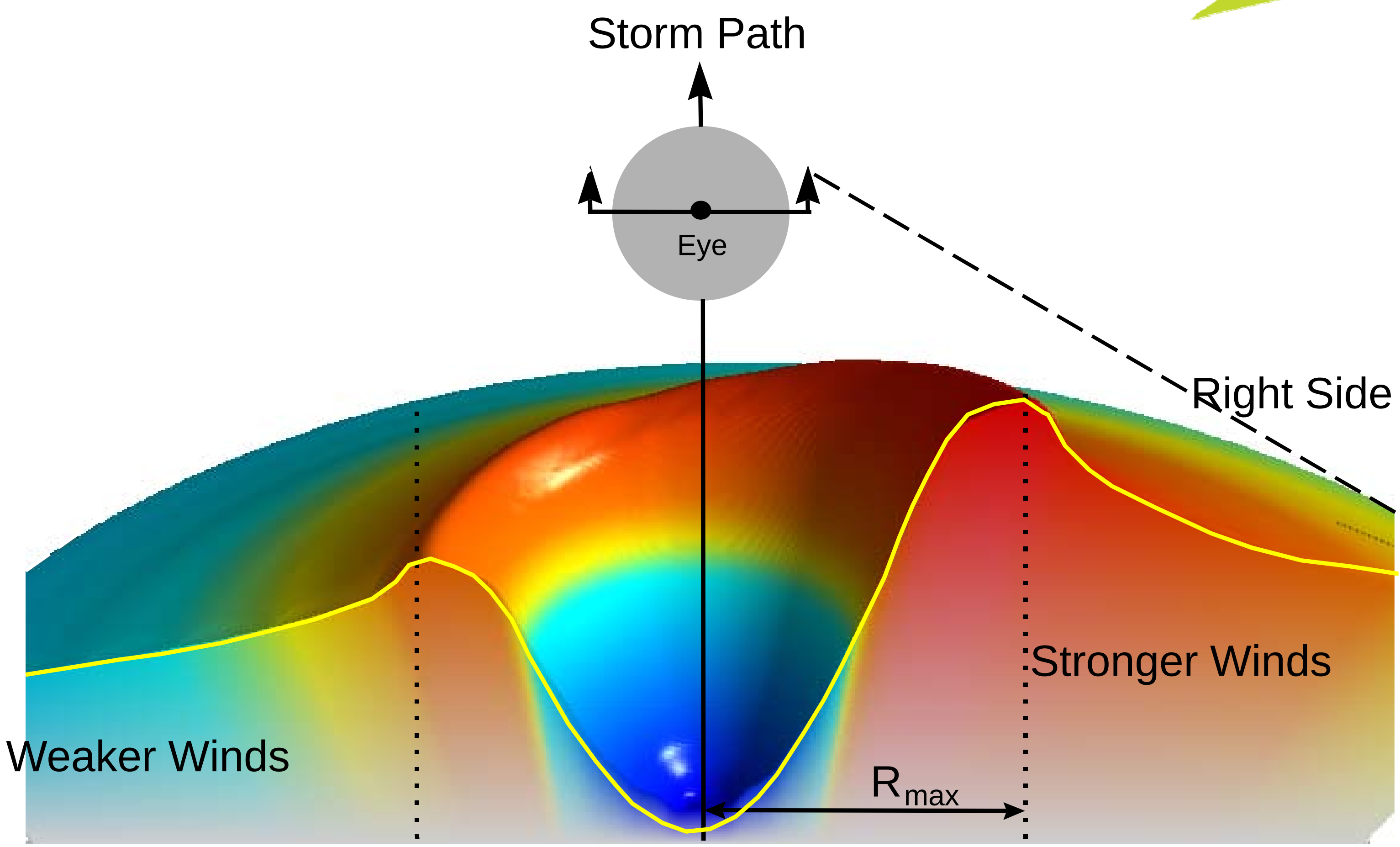


Local Intensity Calculation

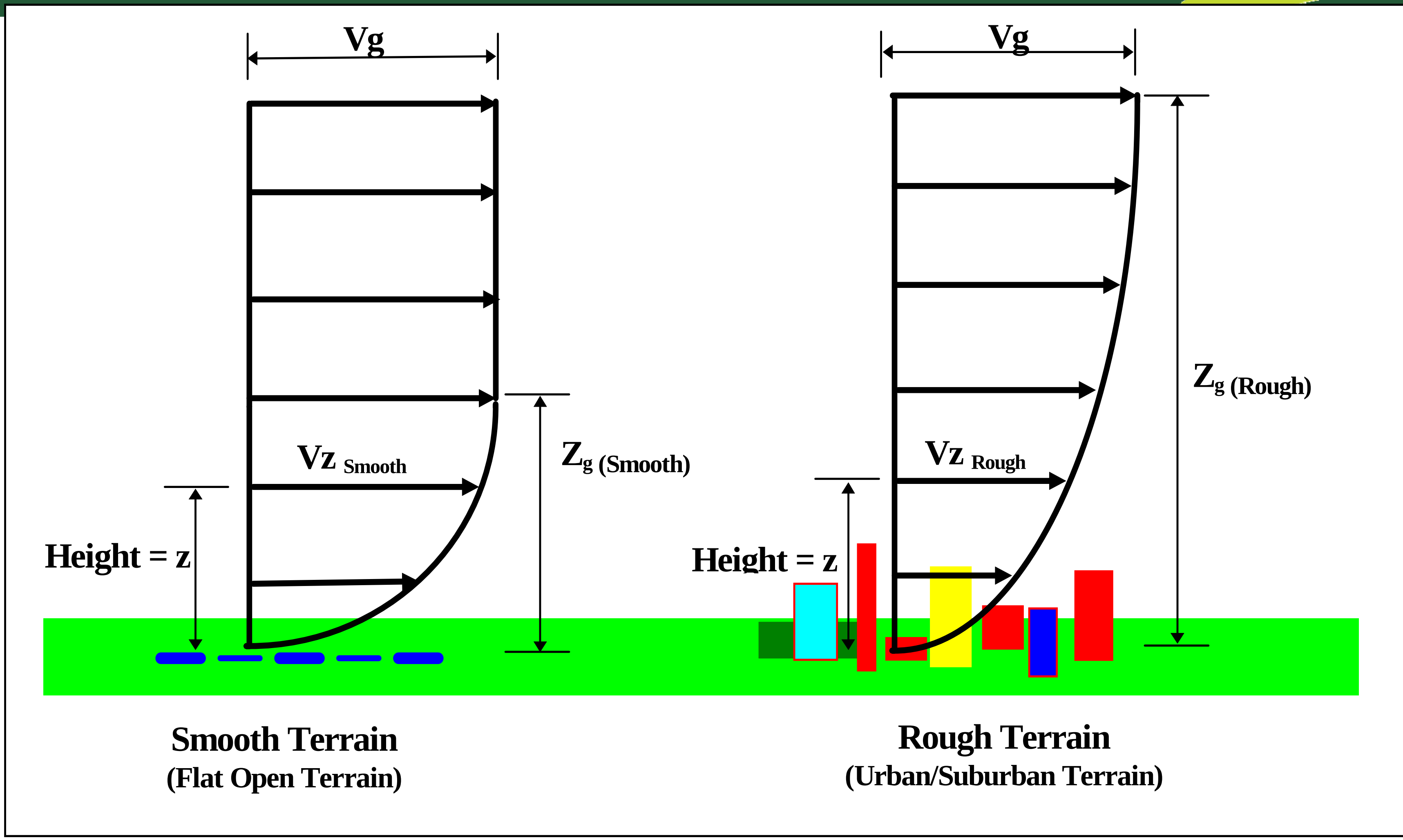
- Once the model probabilistically generates the characteristics of each simulated event, it propagates the event across the affected area. For each site within the affected area, local intensity is estimated.



Windfield Cross Section

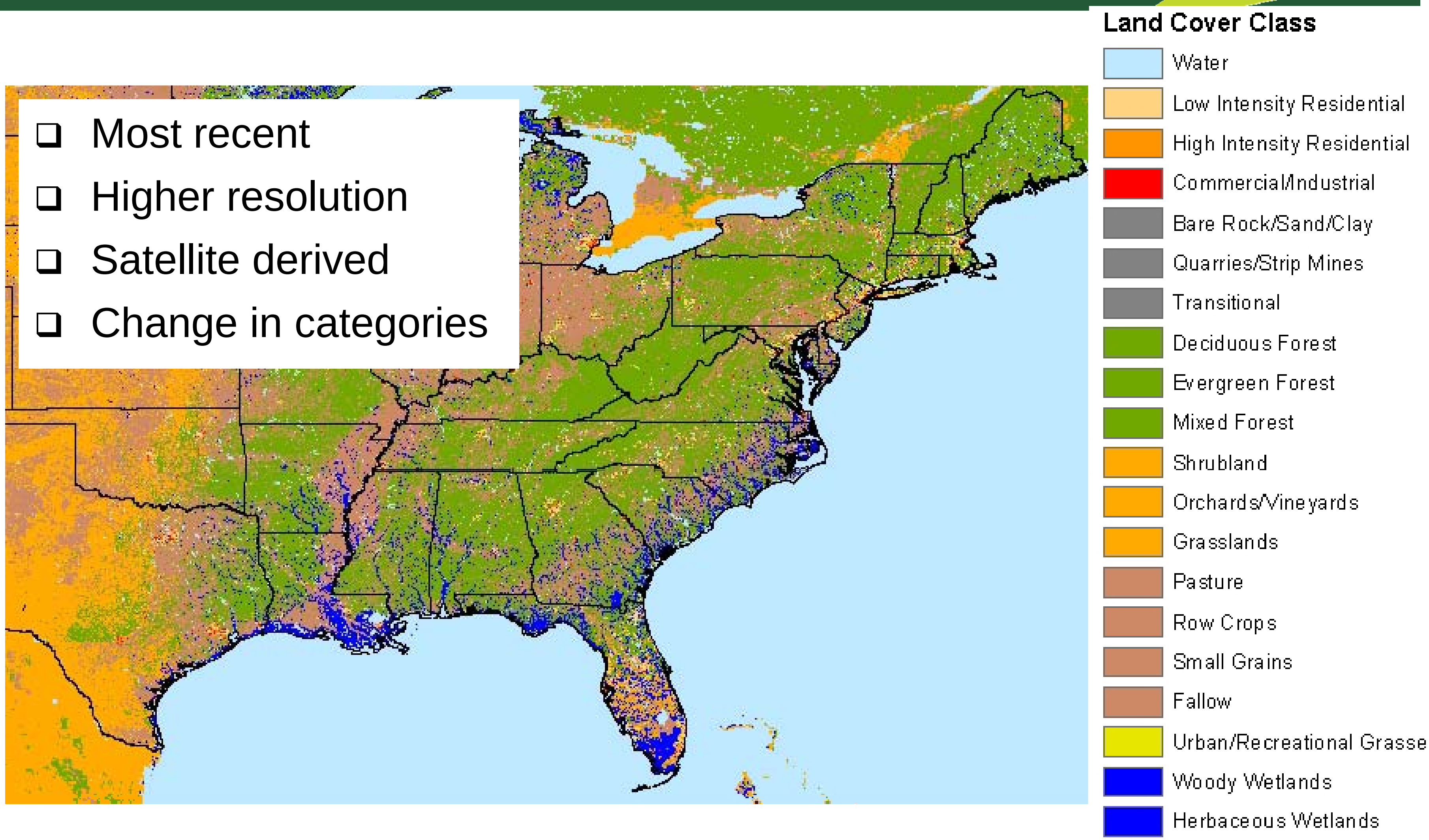


Terrain Effects on Wind Velocity Profiles

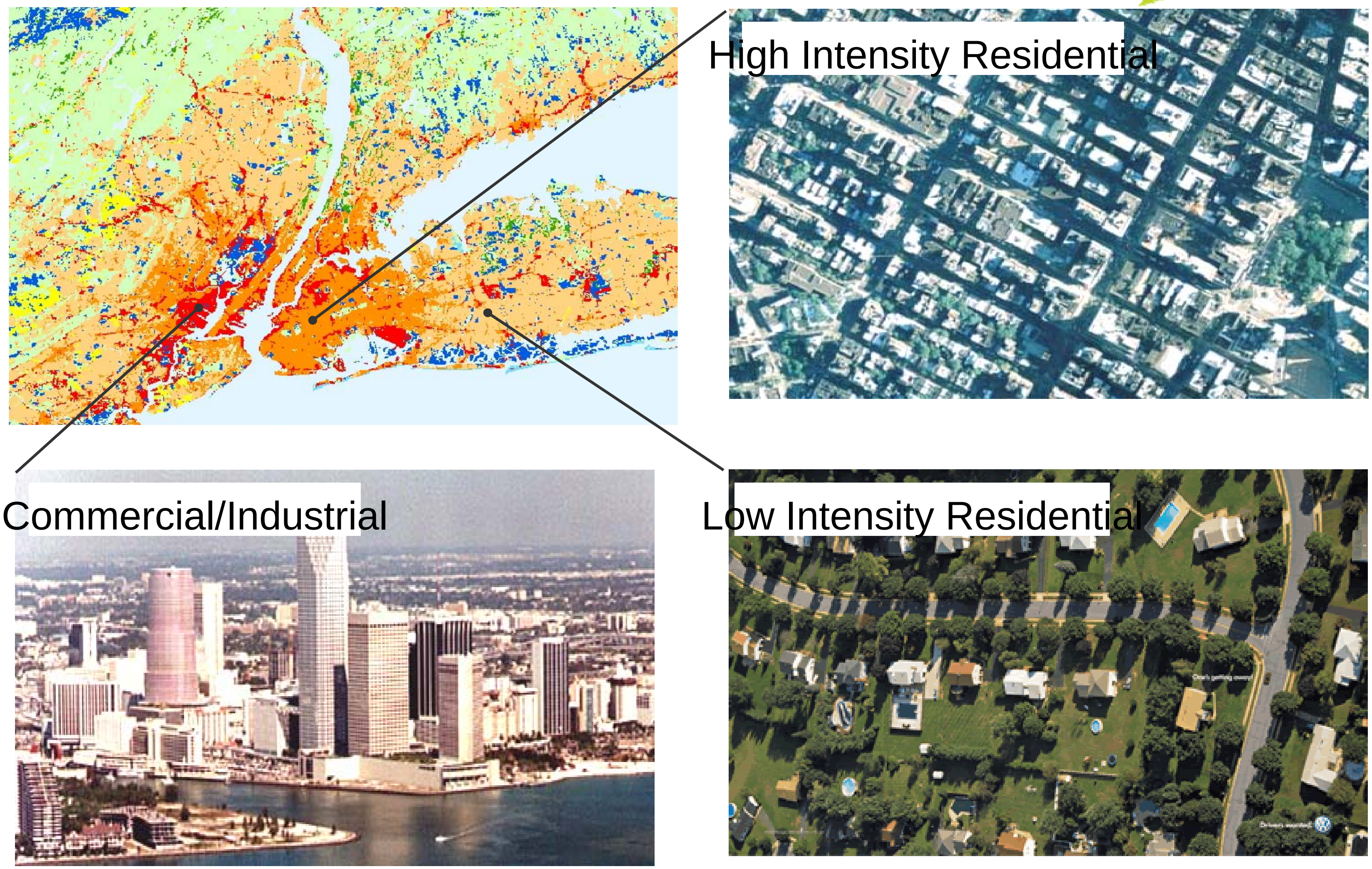


High Resolution Land Use / Land Cover Data

- ❑ Most recent
- ❑ Higher resolution
- ❑ Satellite derived
- ❑ Change in categories

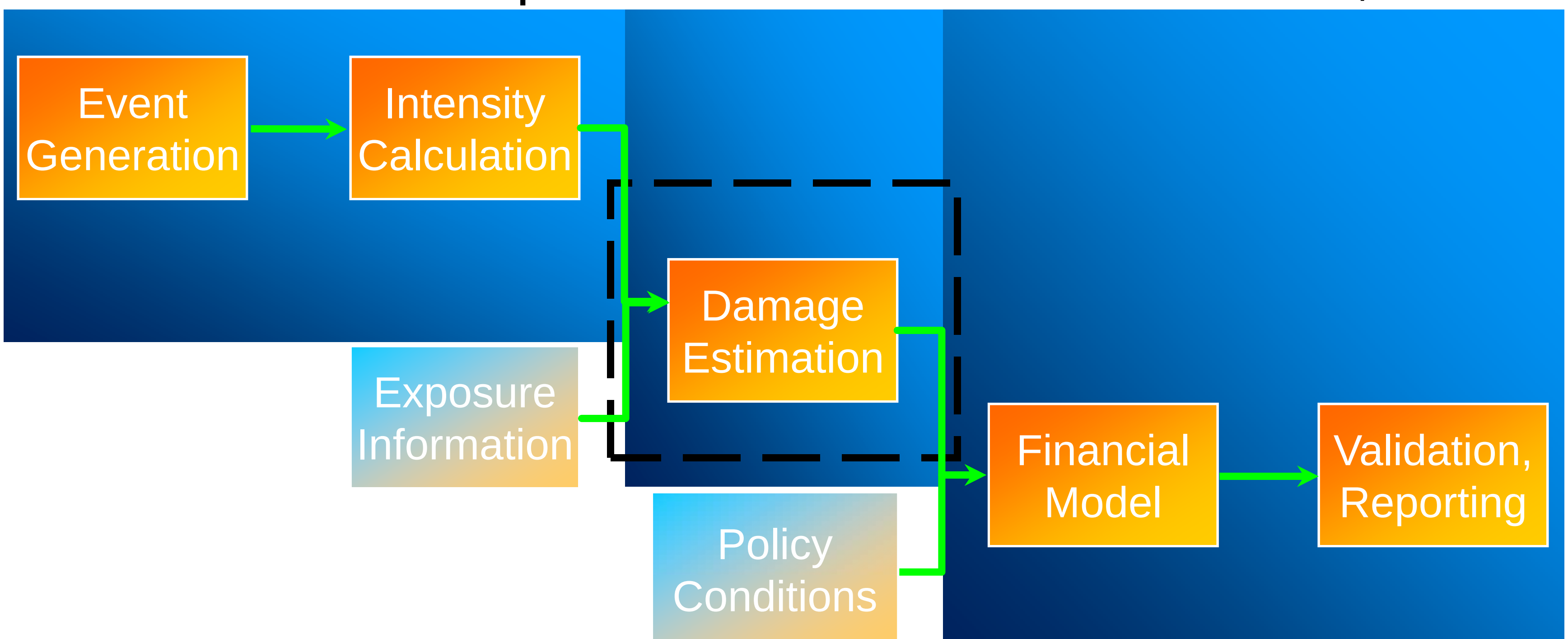


Examples of High Resolution Land Use Data

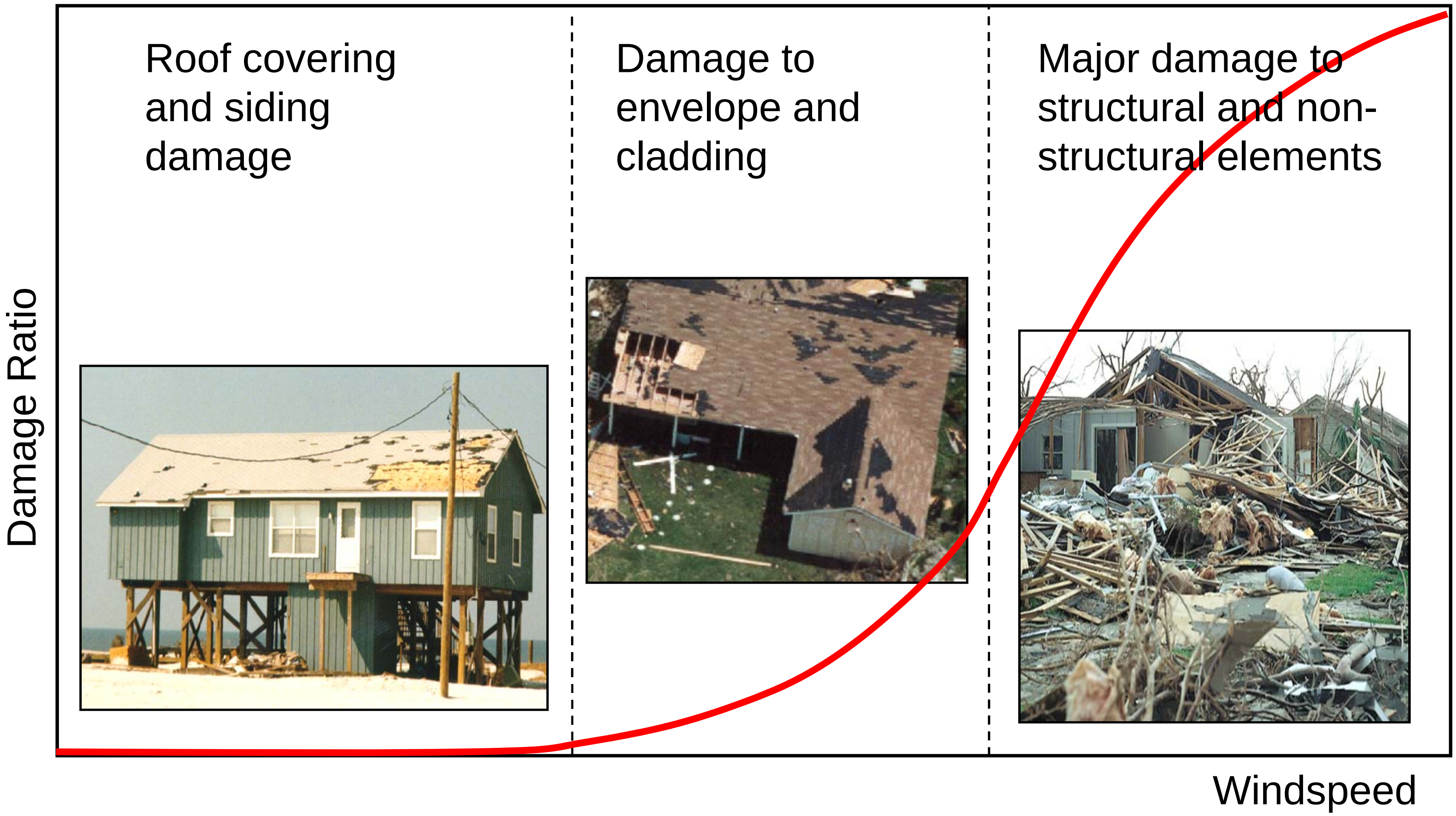


Damage Calculation

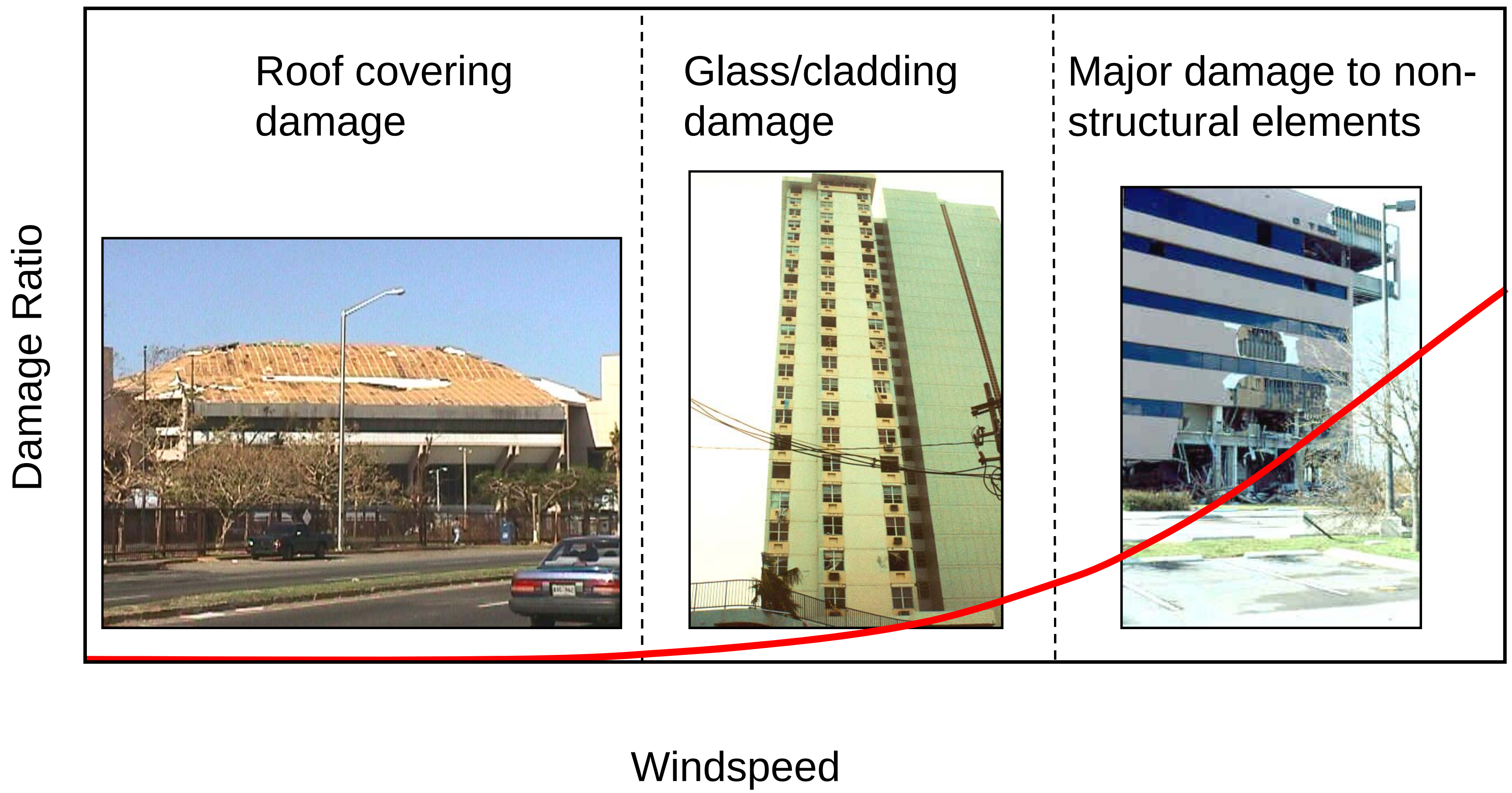
- The model employs mathematical functions called “damageability relationships” that describe the interaction between buildings, including both their structural and nonstructural components as well as their contents, and



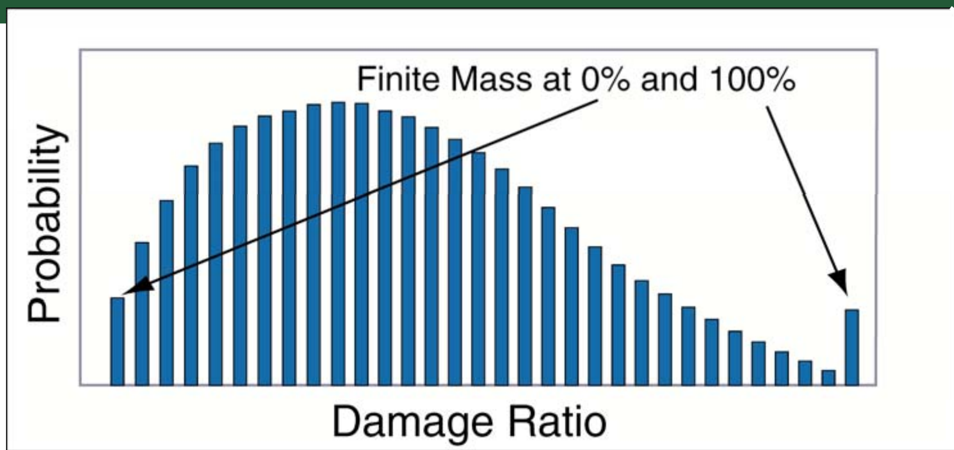
Vulnerability Function - Residential Wood Frame

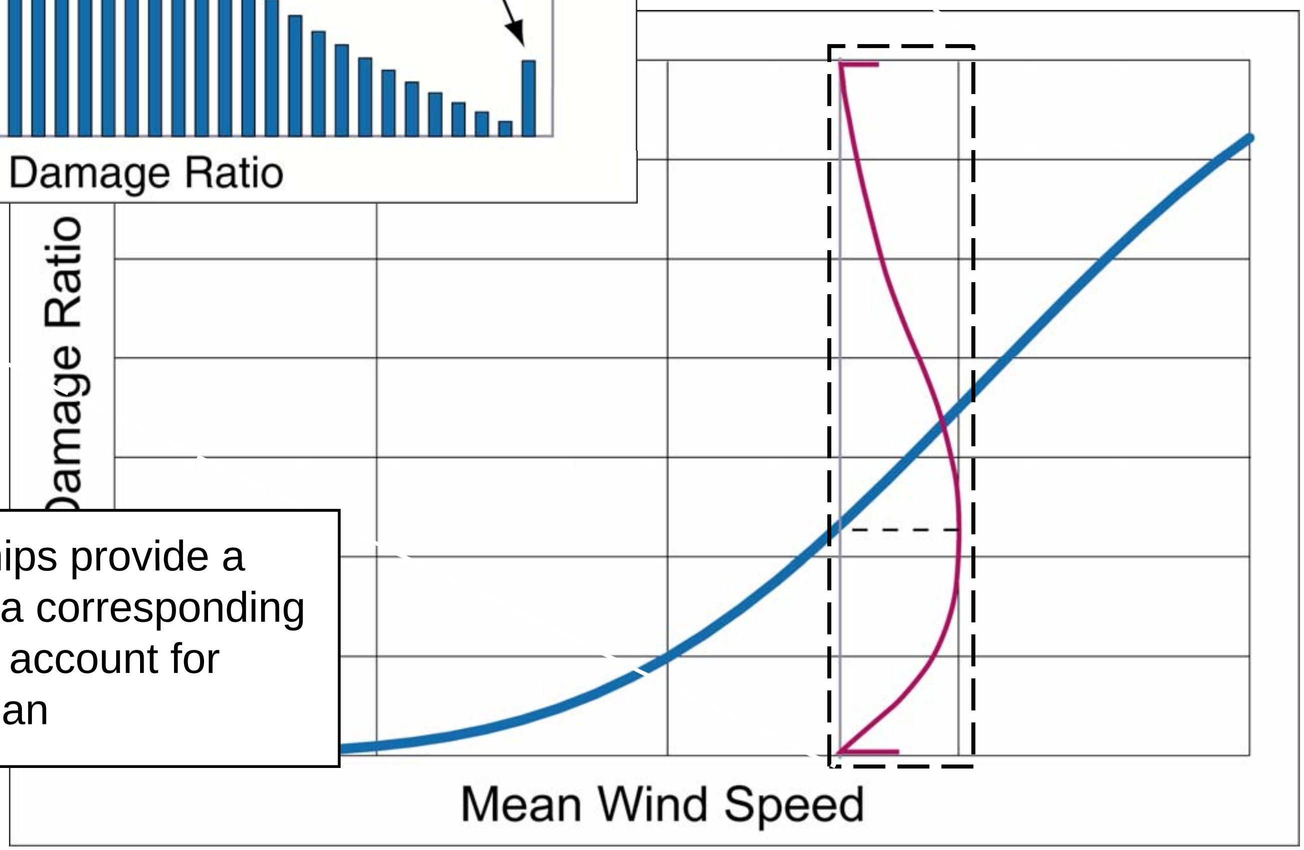


Vulnerability Function - Reinforced Concrete and Steel Frame



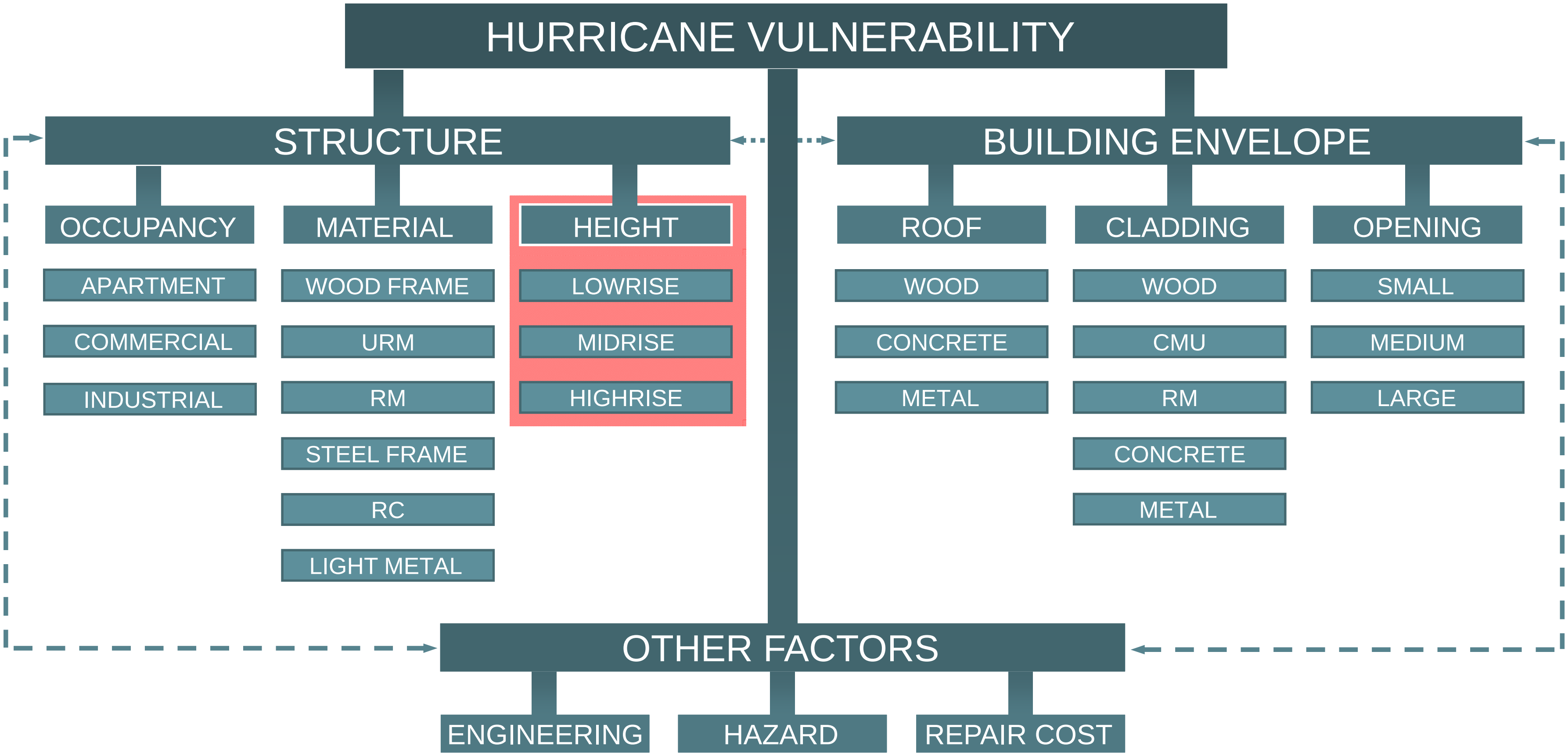
Variability in Damage for Individual Buildings



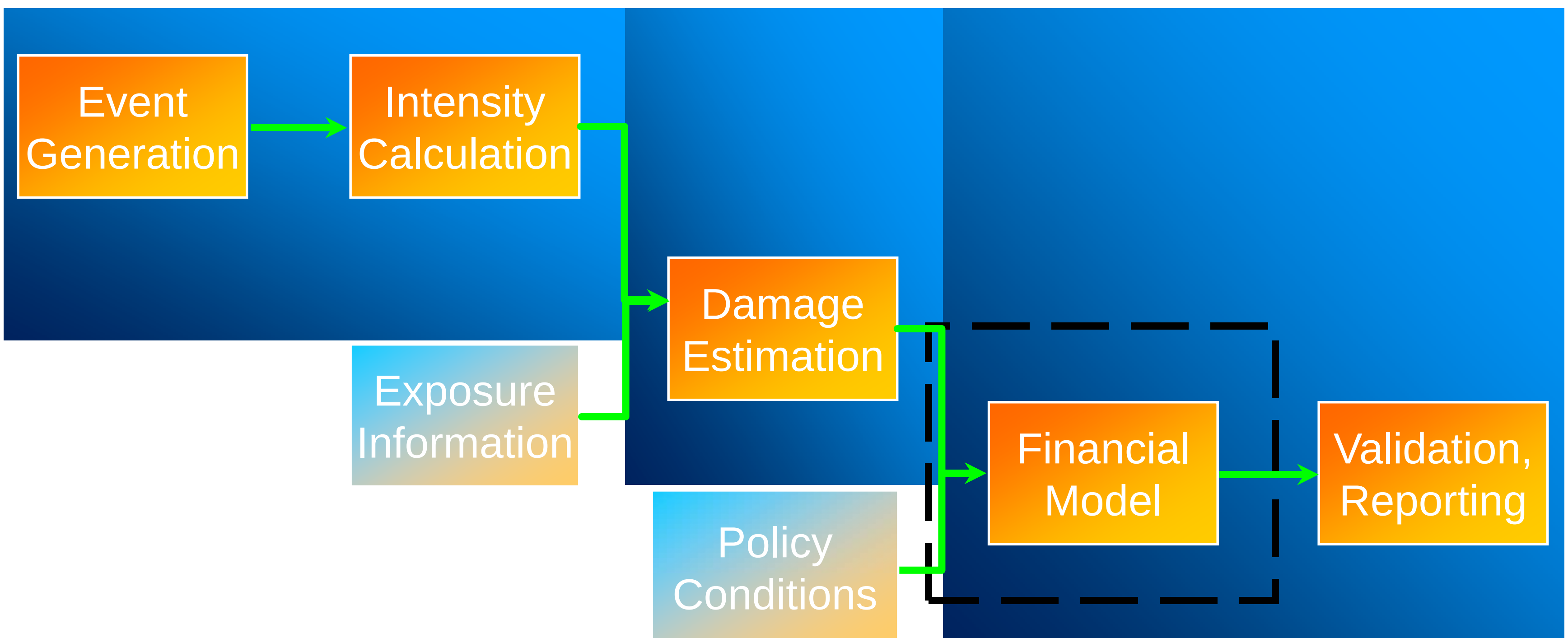


Damageability relationships provide a mean damage ratio and a corresponding probability distribution to account for variability around the mean

Hurricane Component Vulnerability Model



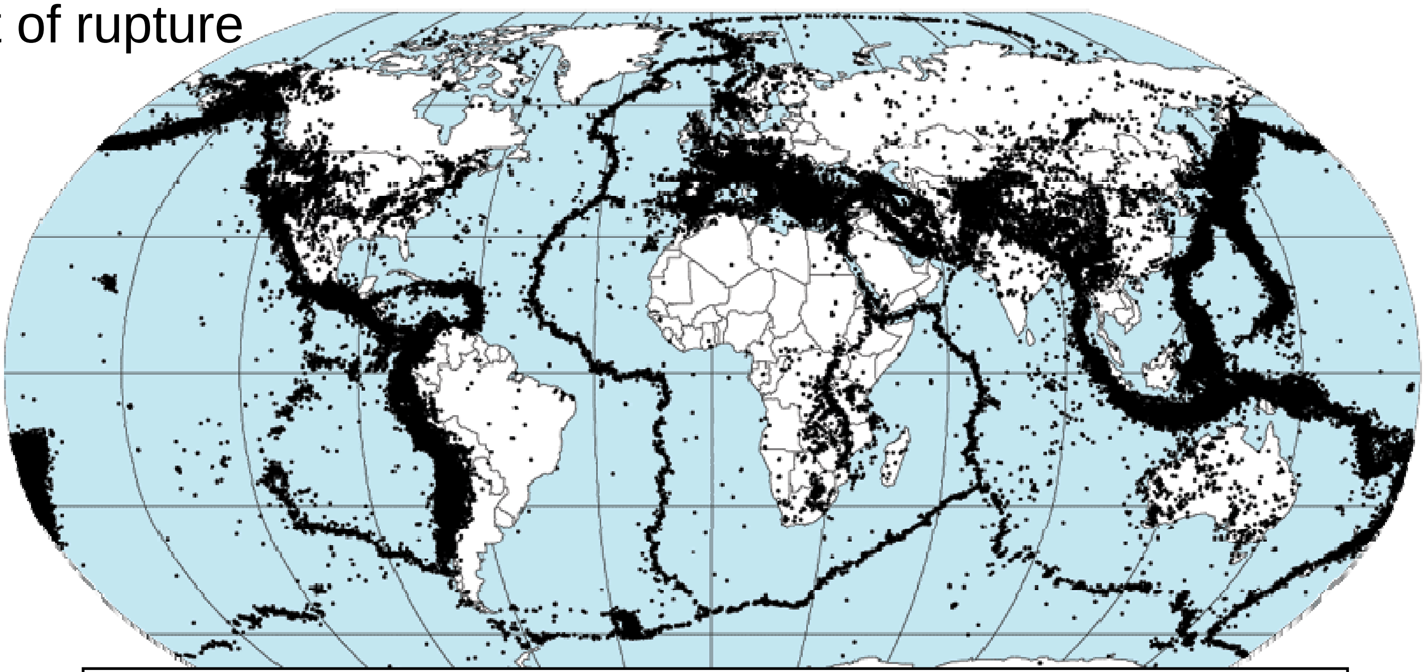
Financial Model



Earthquake

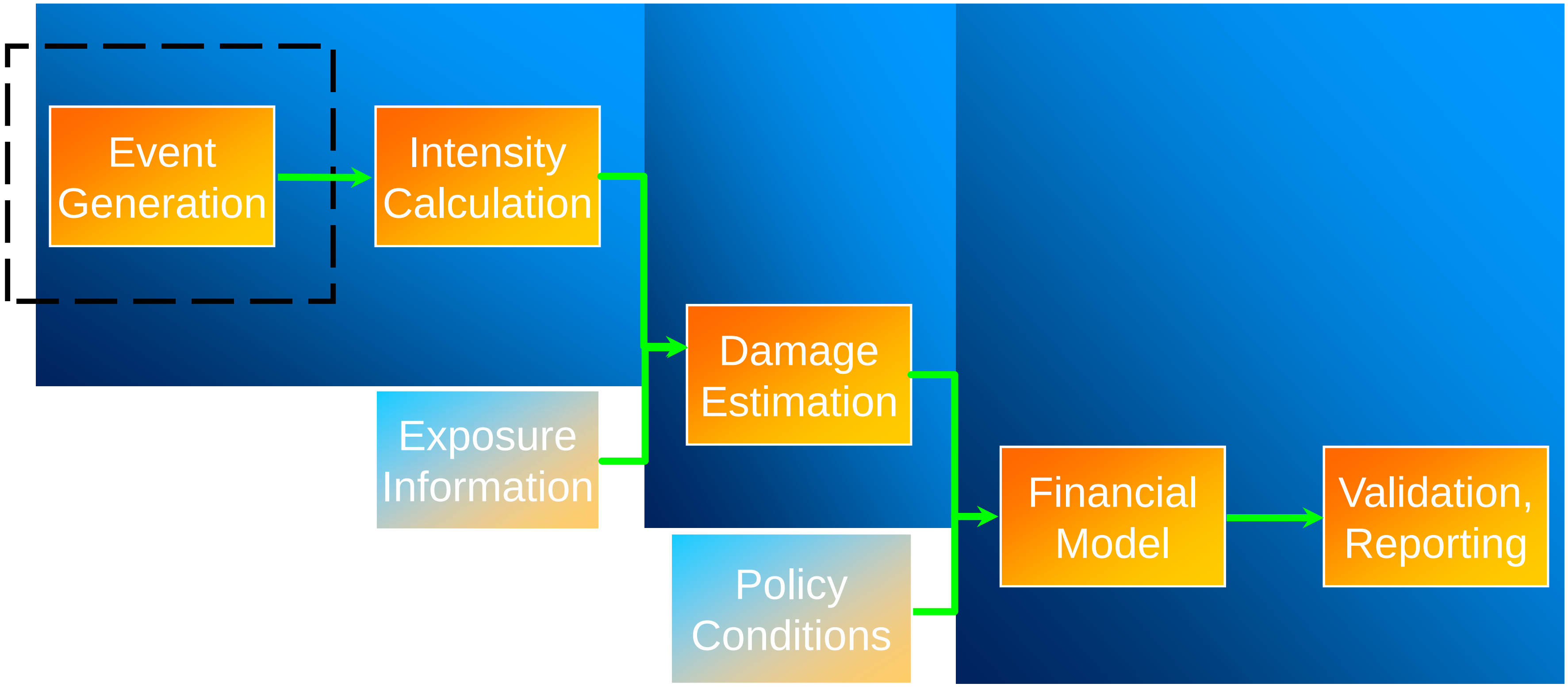
What Is An Earthquake?

A rapid, relative displacement of the rock on either side of a fracture, or fault, in the interior of the solid earth; the energy released produces seismic waves that radiate outward in all directions from the initial point of rupture

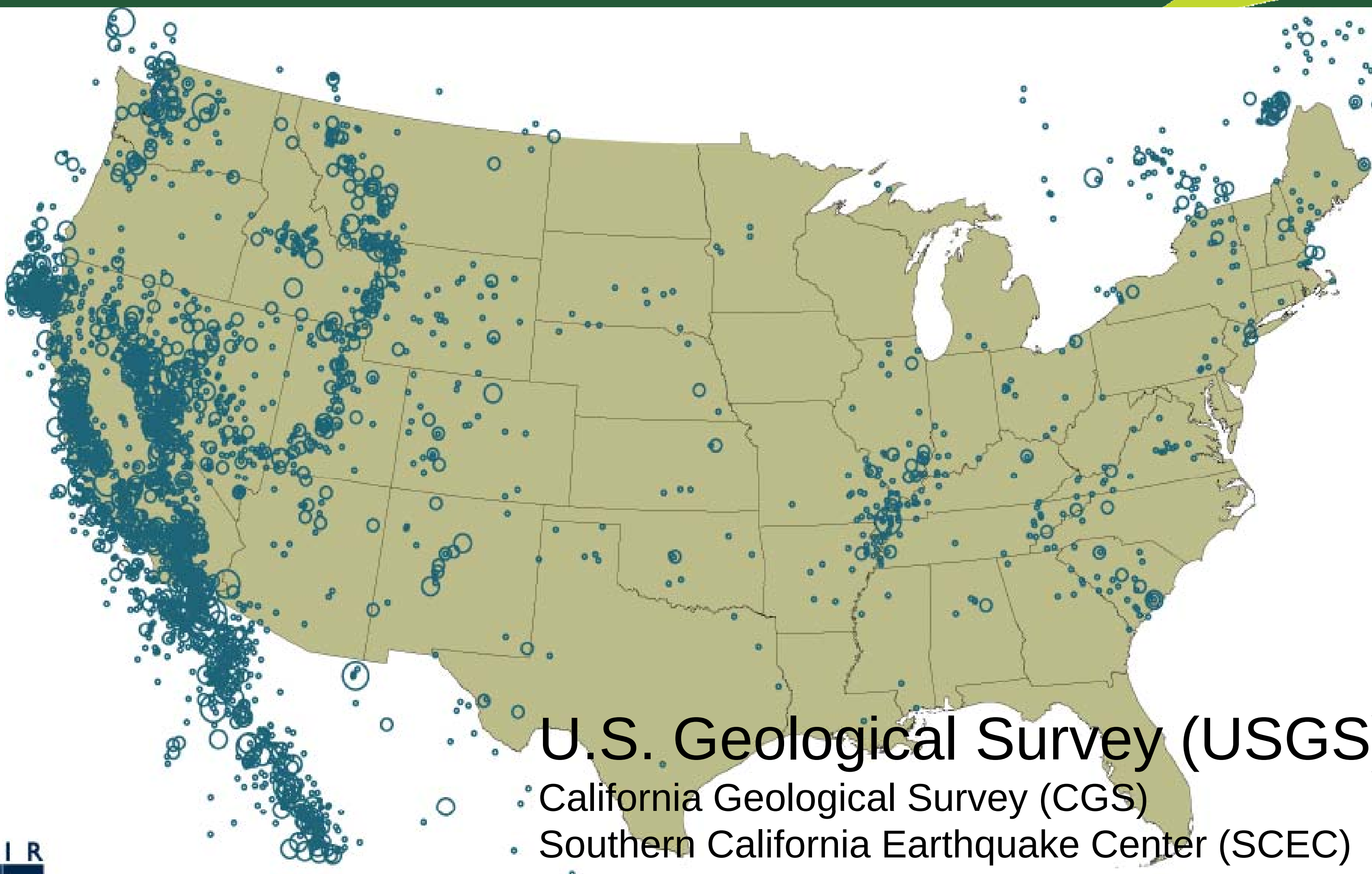


Ninety percent of the world's earthquakes occur along plate boundaries

Catastrophe Modeling Framework



Historical Data Is the Starting Point of Seismic Hazard Analysis



U.S. Geological Survey (USGS)

California Geological Survey (CGS)

Southern California Earthquake Center (SCEC)

Historical, Paleoseismic and GPS Data Determine Where, When and How Earthquakes Occur

WHERE

WHEN

HOW

↔

- Historical records
- Paleo-seismic studies →
  - Trenching
  - Carbon dating
  - Fault geometry exploration
- GPS measurements →
  - Deformation and slip rates
  - Stress calculations
- Numerical modeling

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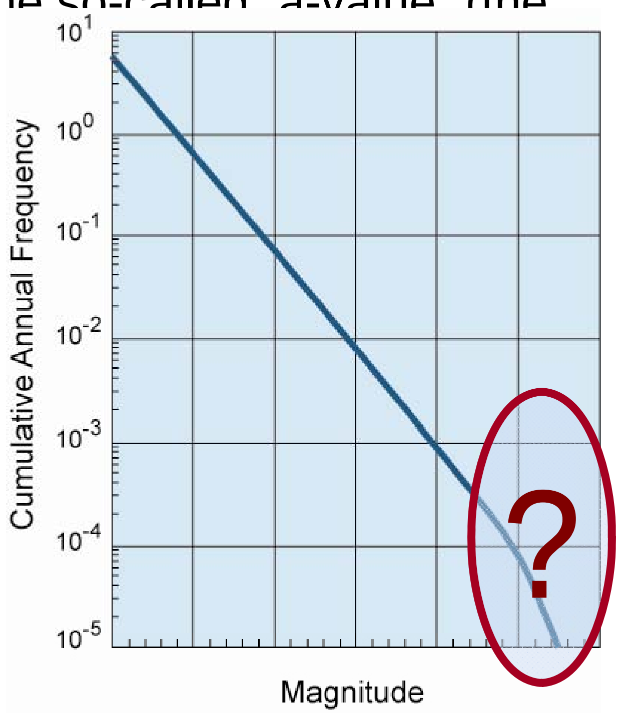
Fitting the Historical Data to the Gutenberg Richter Relationship

- The Gutenberg-Richter (GR) distribution is an empirical relationship between the frequency and magnitude of earthquakes
- The GR relationship is described by two parameters
  - An occurrence rate of earthquakes of magnitude greater than or equal to some reference magnitude, characterized by the so-called “a-value” (the y-intercept)
  - A “b-value” representing the rate at which the log of the cumulative annual frequency of earthquakes decreases as the magnitude increases (the slope)

But how do you estimate the frequency of very large events, when there are so few in the historical record?

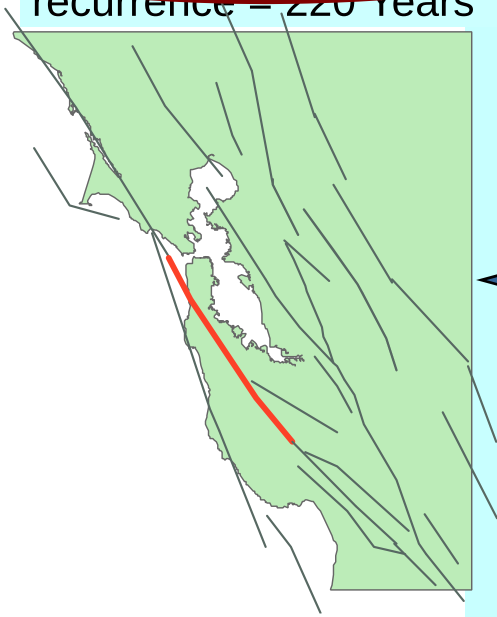
And is there some maximum magnitude?

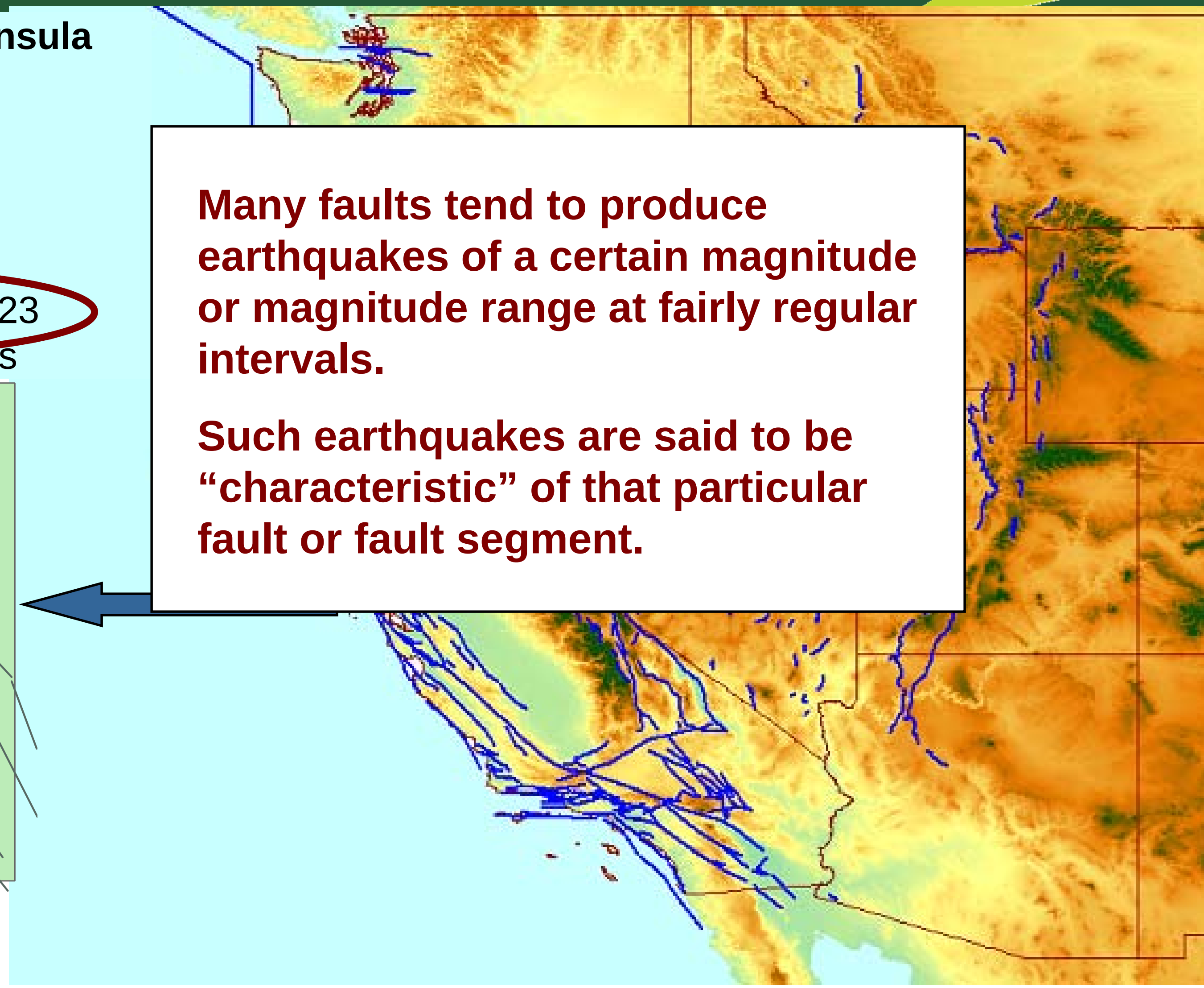


The USGS Provides Detailed Data on Faults in the Western U.S.

San Andreas Peninsula Segment

L = 85 km
W = 13 km
dip = 90°
slip rate = 17 mm/yr
Characteristic M_W = 7.23
recurrence = 220 Years





Many faults tend to produce earthquakes of a certain magnitude or magnitude range at fairly regular intervals.

Such earthquakes are said to be "characteristic" of that particular fault or fault segment.

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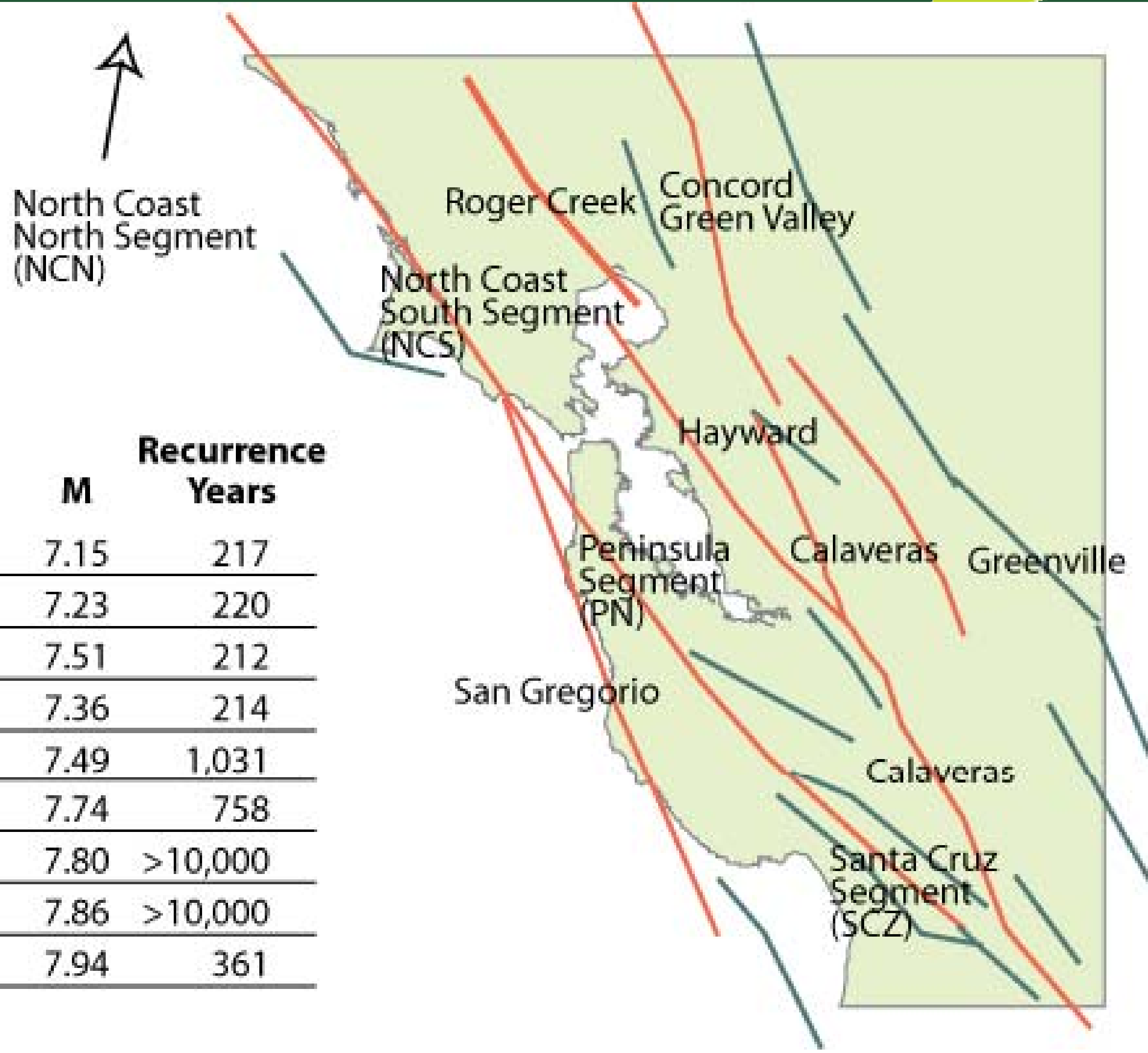
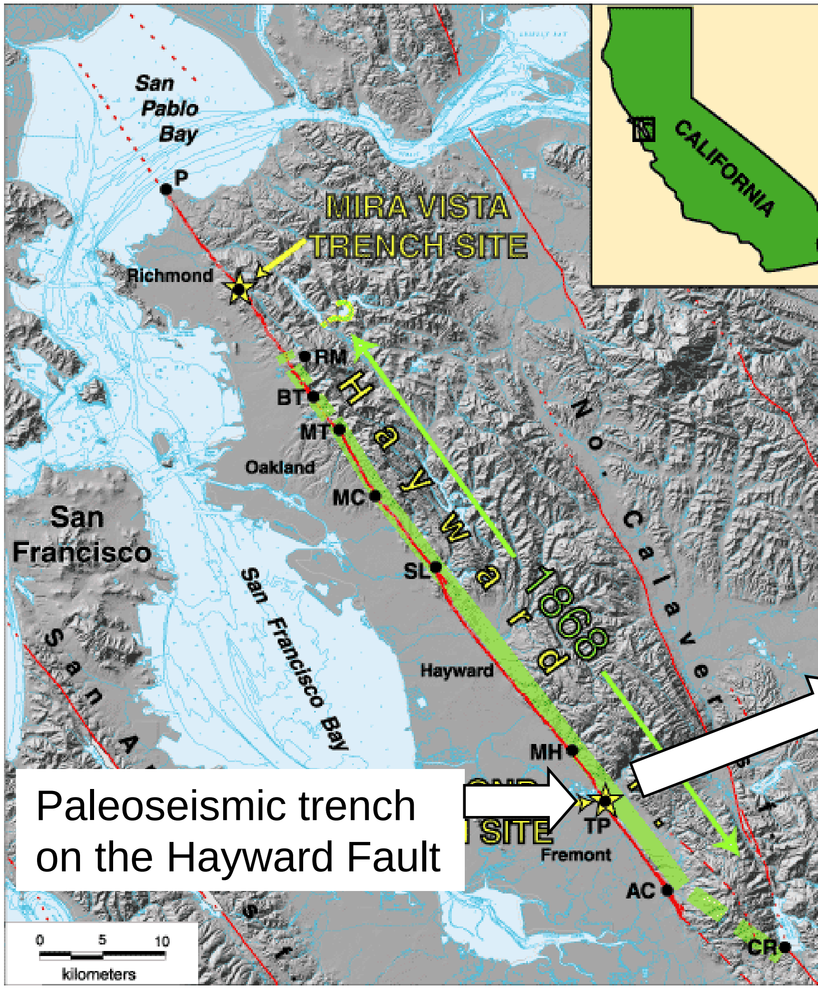
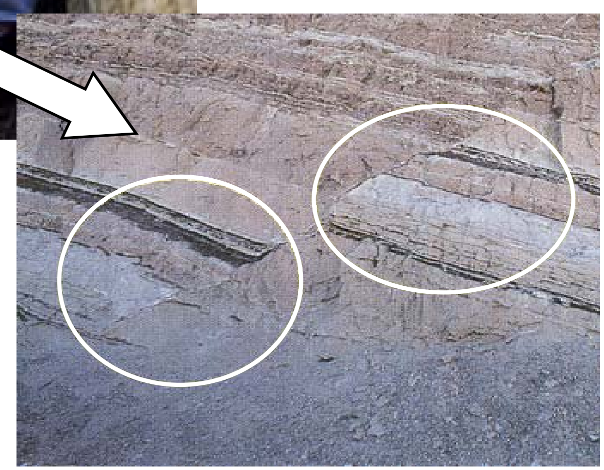
The Rupture of One Fault or Fault Segment Can Trigger the Rupture of Nearby Faults



San Andreas Fault Segment	M	Recurrence Years
SCZ	7.15	217
PN	7.23	220
NCS	7.51	212
NCN	7.36	214
SCZ + PN	7.49	1,031
NCS + NCN	7.74	758
SCZ + PN + NCS	7.80	>10,000
PN + NCS + NCN	7.86	>10,000
SCZ +PN + NCS + NCN	7.94	361

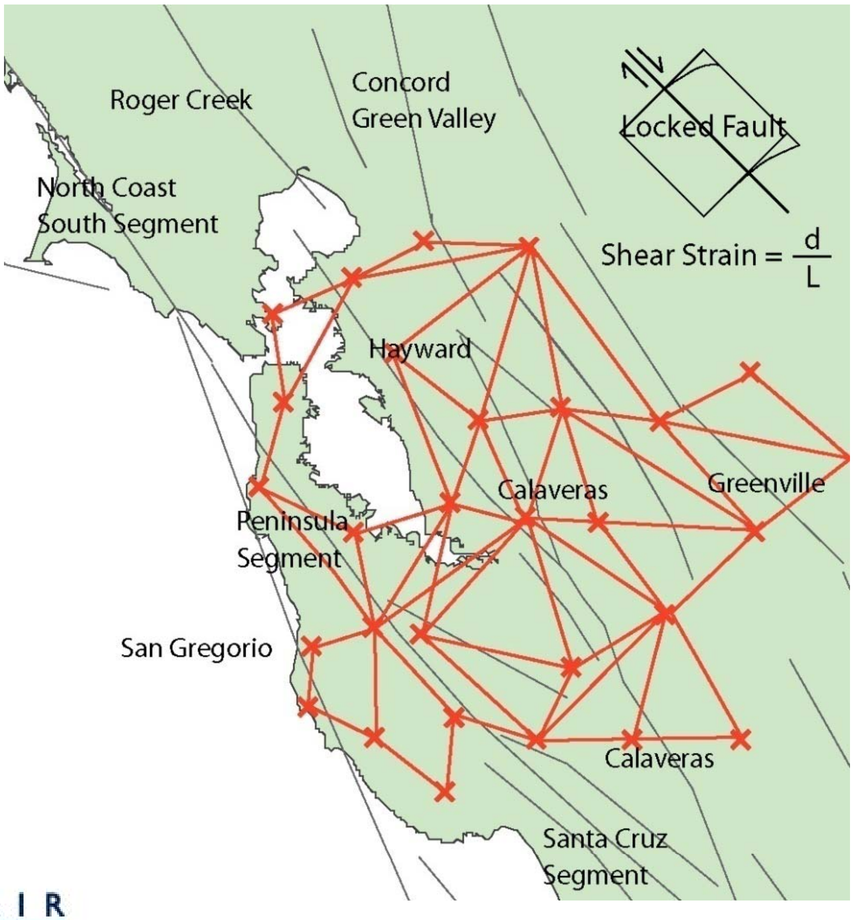
Fault Trenching Reveals Offsets in Rock and Soil Layers; Carbon Dating Provides Information on Recurrence Rates

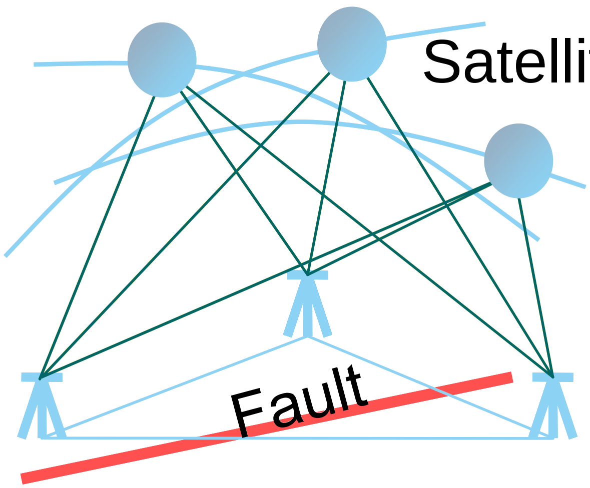




Global Positioning System (GPS) is Now the Dominant Technology for Tectonic Studies

Land Survey Stations in San Francisco Bay Area



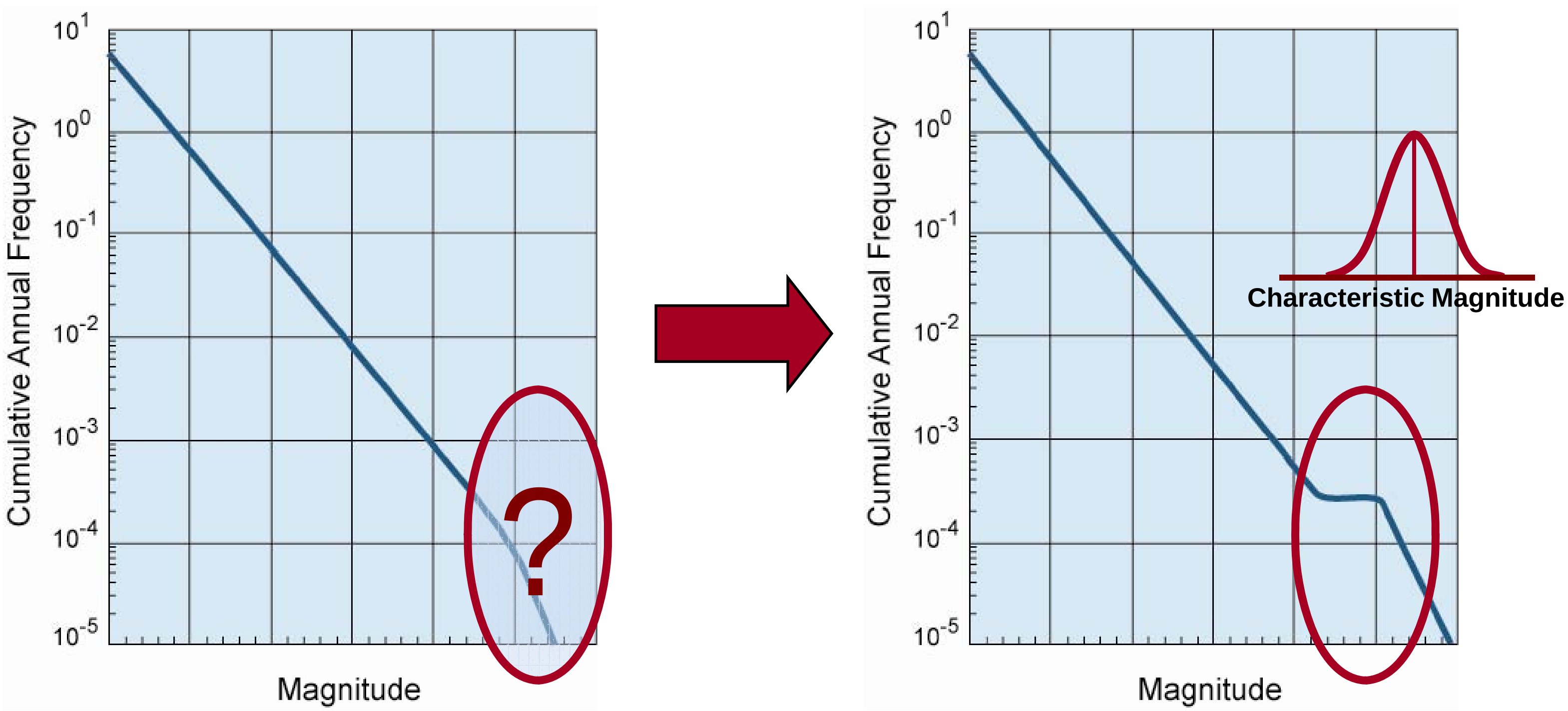


- Each satellite broadcasts radio signals with two different wavelengths
- A position on the earth can be located by recording and processing signals from three satellites with known orbits
- Relative locations of stations are used for horizontal and vertical land survey

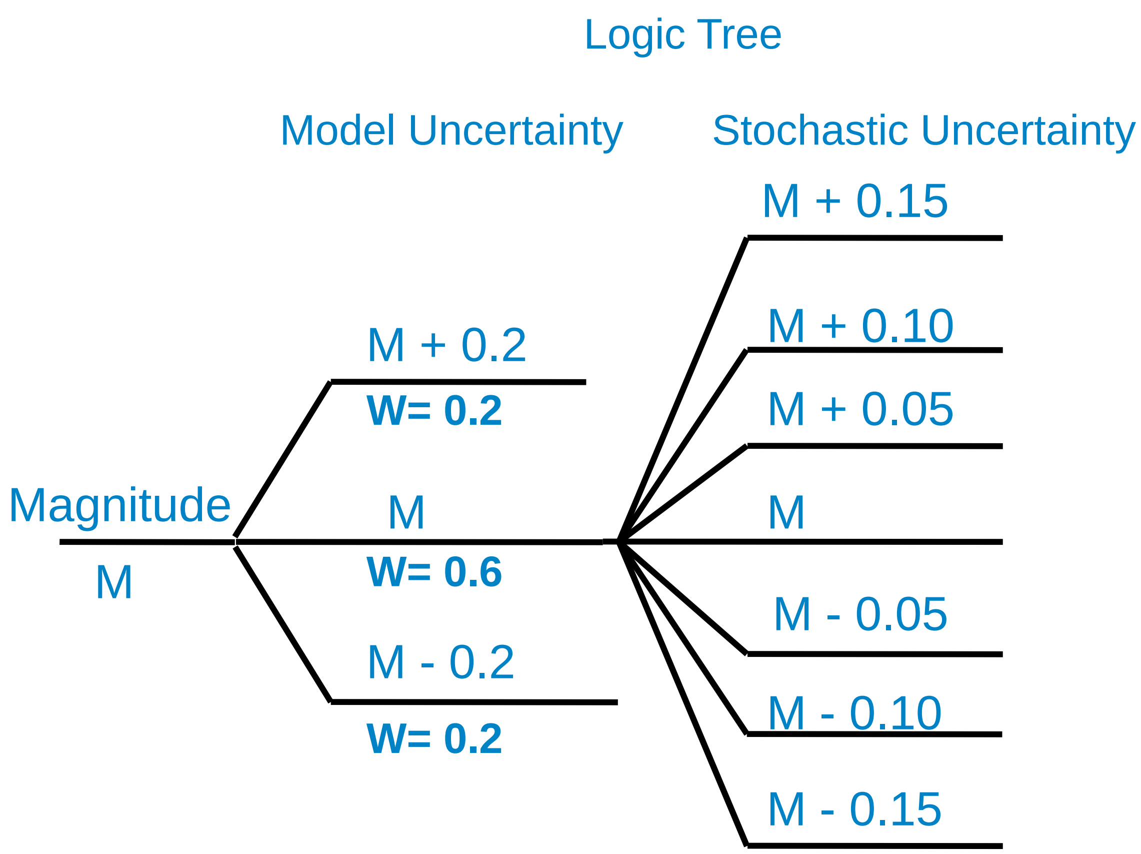
Putting It All Together: Fault And Regional Seismicity Parameters are Constructed from Historical, Paleoseismic, and GPS Data

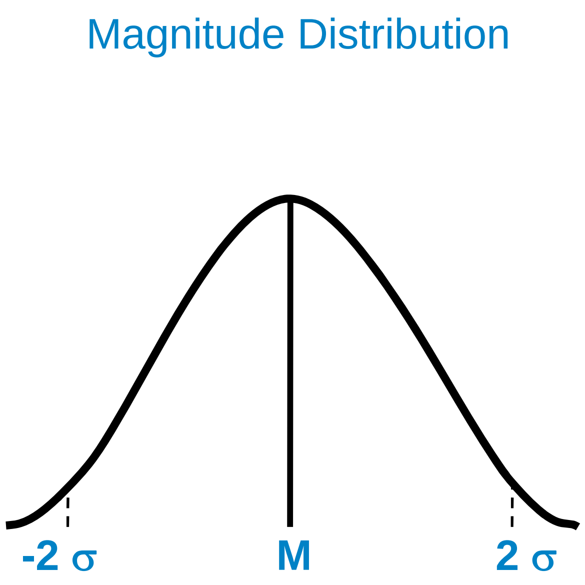
Time horizon for each data type:

- Historical catalog ~ 150 yrs
- Paleoseismic ~ ‘000s yrs
- Geodetic ~ Current



USGS Uses a Logic Tree to Characterize the Uncertainty in Magnitude of Faults in the Western U.S.





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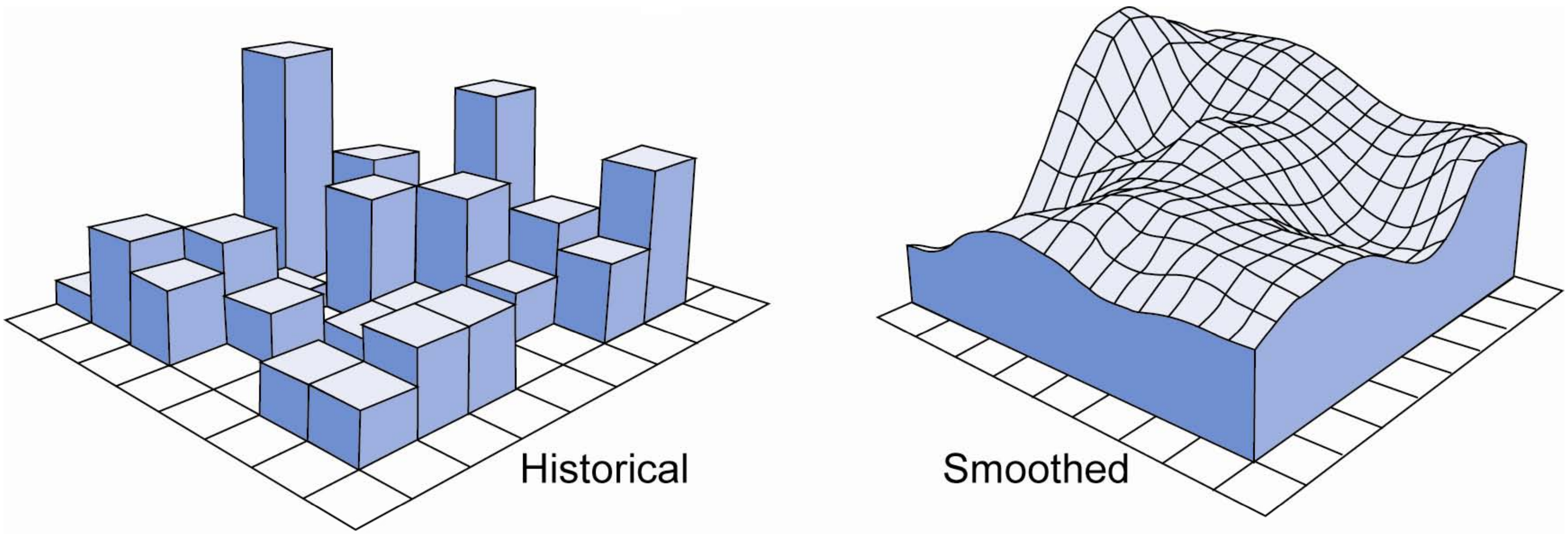
Background Seismicity

- Smoothed background seismicity allows for earthquakes to occur where there is no historical record, ensuring full spatial coverage



Other Important Modeled Earthquake Parameters