Time Dependency

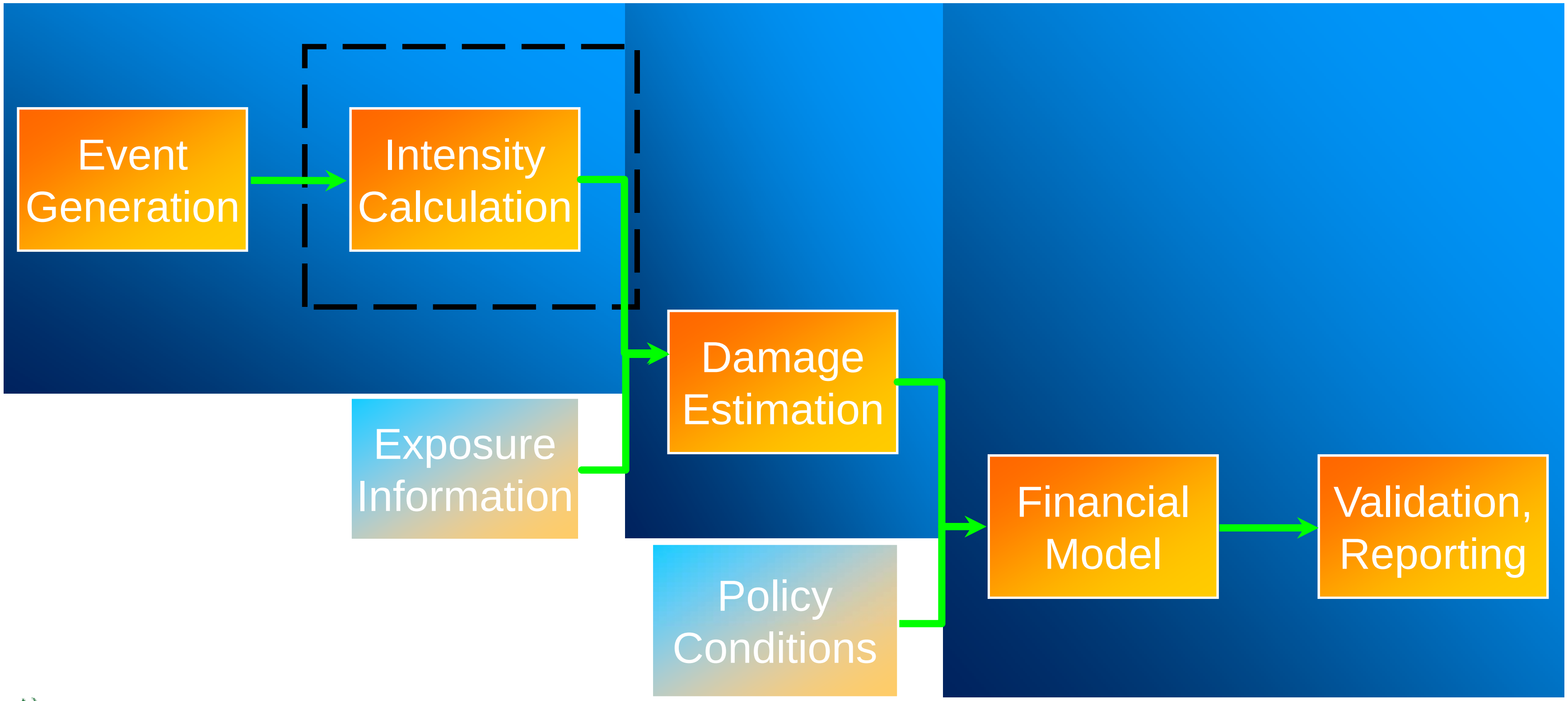
Historically, the estimation of the probability of earthquake occurrence has been based on “memoryless” Poissonian models in which the rate of occurrence for a given seismic source is assumed to be constant over time.

That is, the probability of occurrence does not depend on when the last similar earthquake occurred.

However, data suggests that while Poissonian models are adequate for estimating the probability of occurrence of earthquakes over a large region, for individual faults, the occurrence of large earthquakes are time dependent.

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.


Event Generation

Intensity Calculation

Damage Estimation

Exposure Information

Financial Model

Validation, Reporting

Policy Conditions

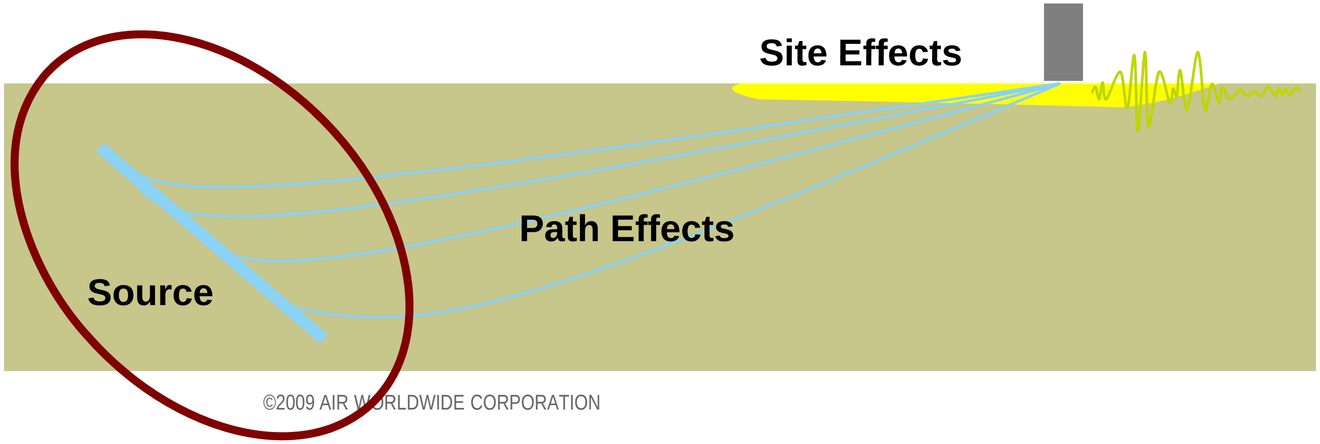
Empirically Derived Attenuation Relationships

- Attenuation relationships appropriate to each region mathematically describe the rate the rate of decay in ground motion with distance

log(Y) = c1 + c2*M + c3*(M_ref - M)^2 + (c4 + c5*M)*log(R) + c6*R
+ site effect + faulting mechanisms + ...

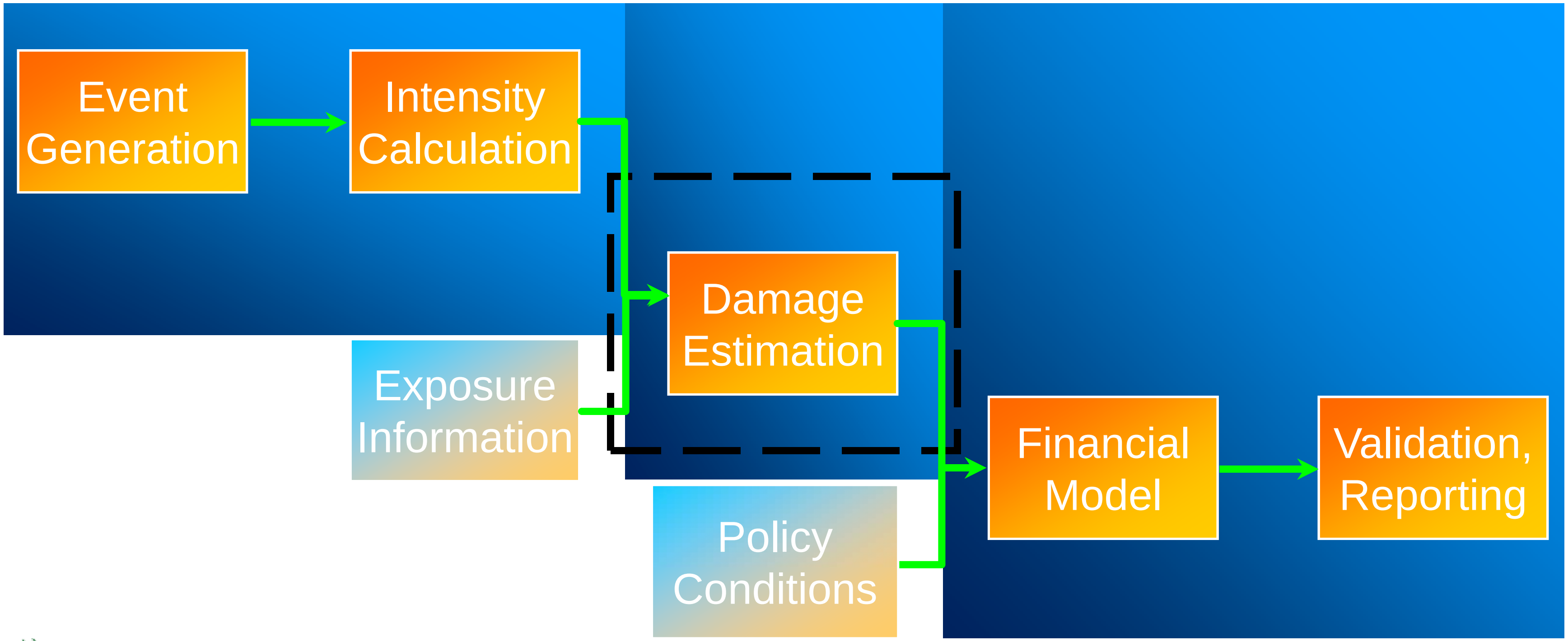
where

Y: **Ground motion or spectral values**
M: **Magnitude**
R: **Source - site distance**
c?: **Coefficients obtained empirically from the real or simulated ground motion 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 the local intensity to which they are exposed.


Event Generation

Intensity Calculation

Damage Estimation

Exposure Information

Policy Conditions

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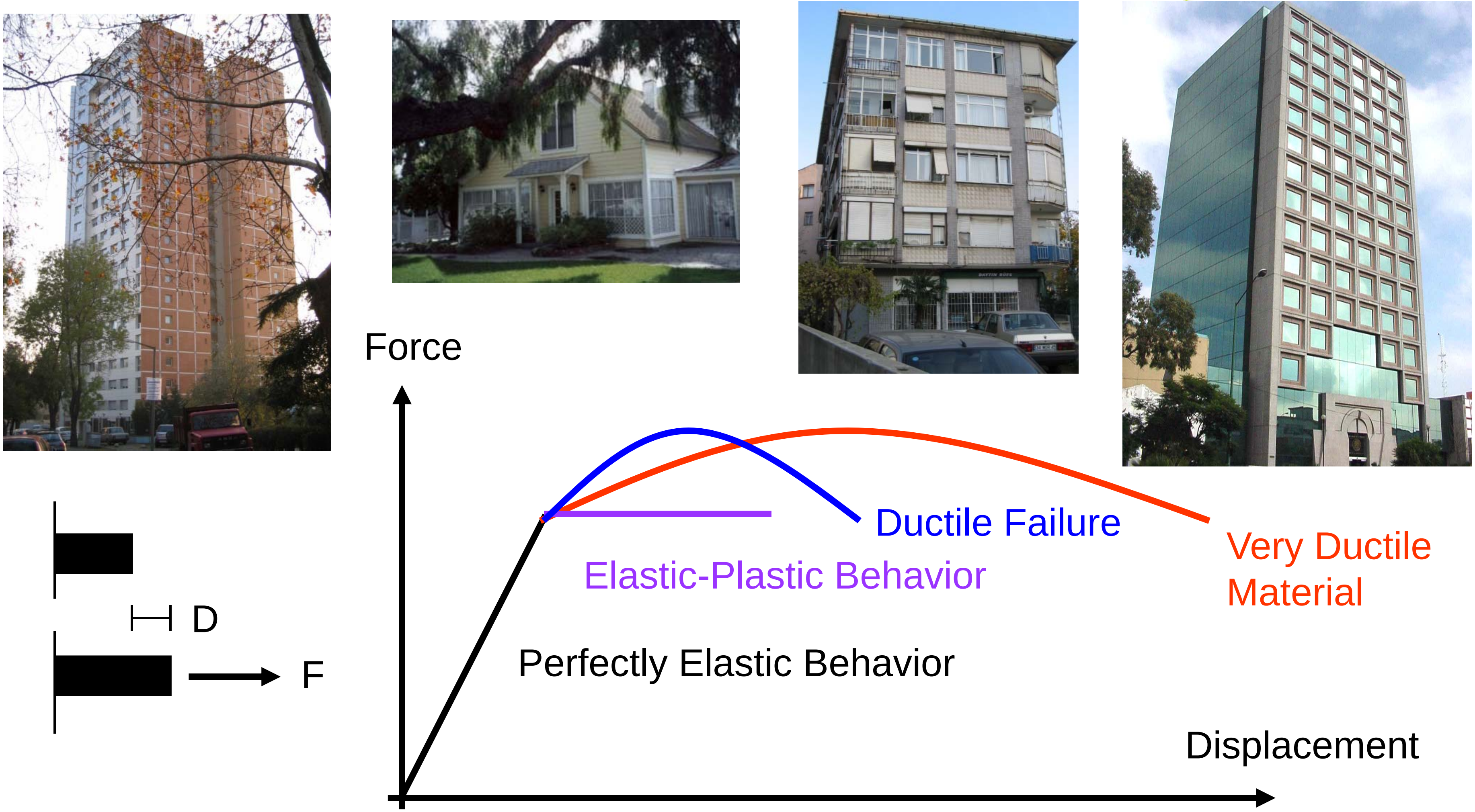
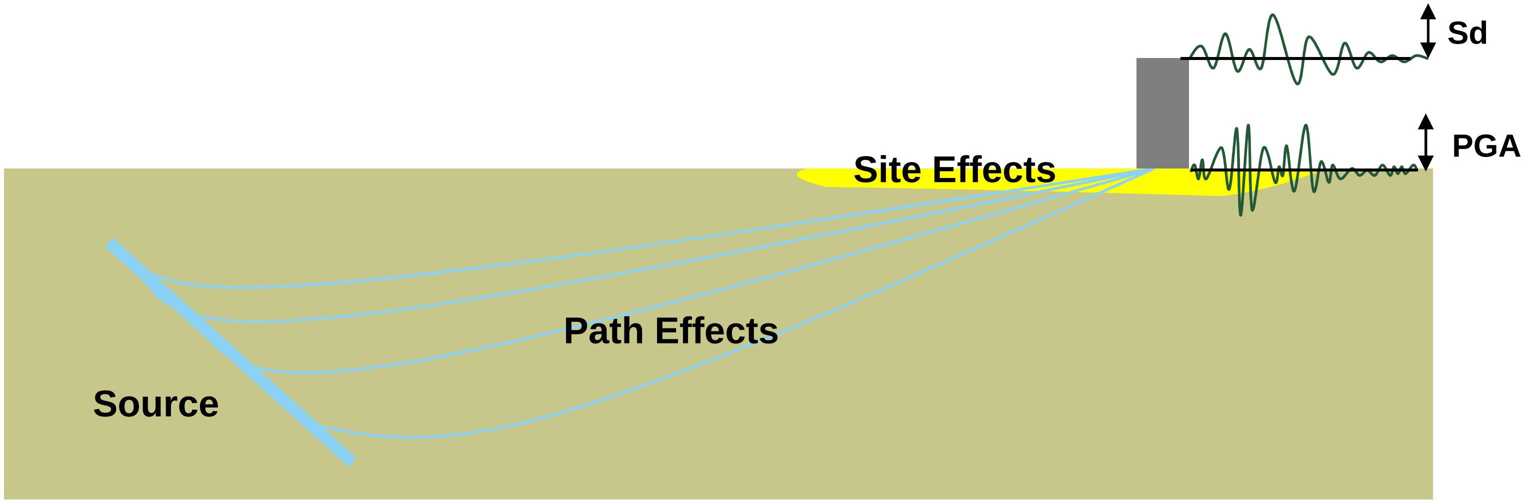
Validation, Reporting

Different Properties of Materials Result in Different Behaviors



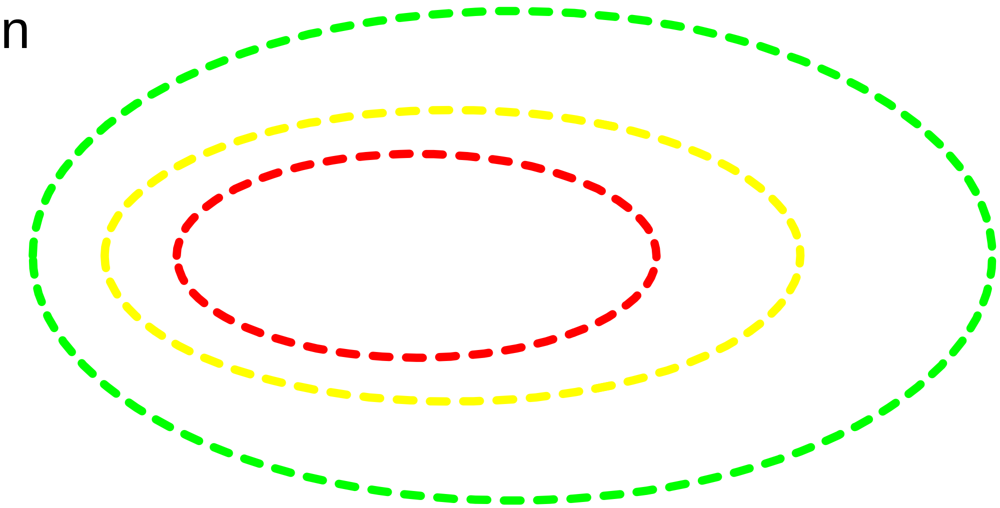
What Variable Correlates with Damage?

- Spectral ordinates (acceleration, displacement) measure the *response of the building* at the time of earthquake
- Spectral ordinates depend on both the earthquake (ground motion) *and* building characteristics
- Why is PGA only not a good predictor of damage? **Because it does not take into account the properties of the building!**



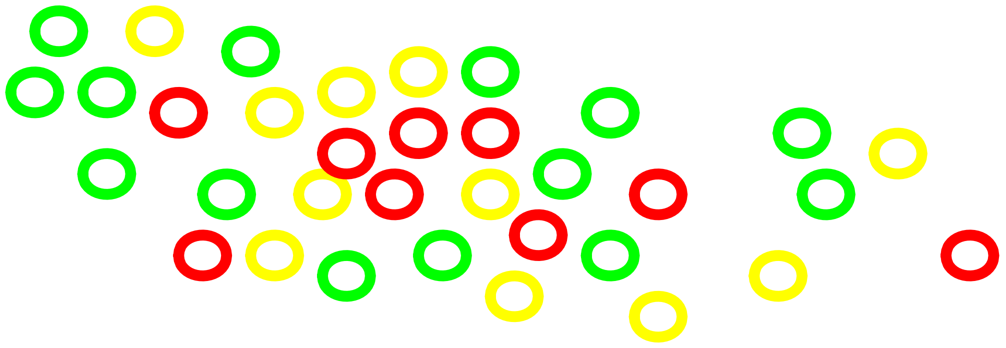
Damage Footprints with MMI vs. Sd

Since intensity is not dependent on building properties, the damage footprints coincide with hazard levels, but not with damage



Based on MMI

Since Sd is explicitly dependent on building properties, the damage footprints represent more accurately the actual damage sustained

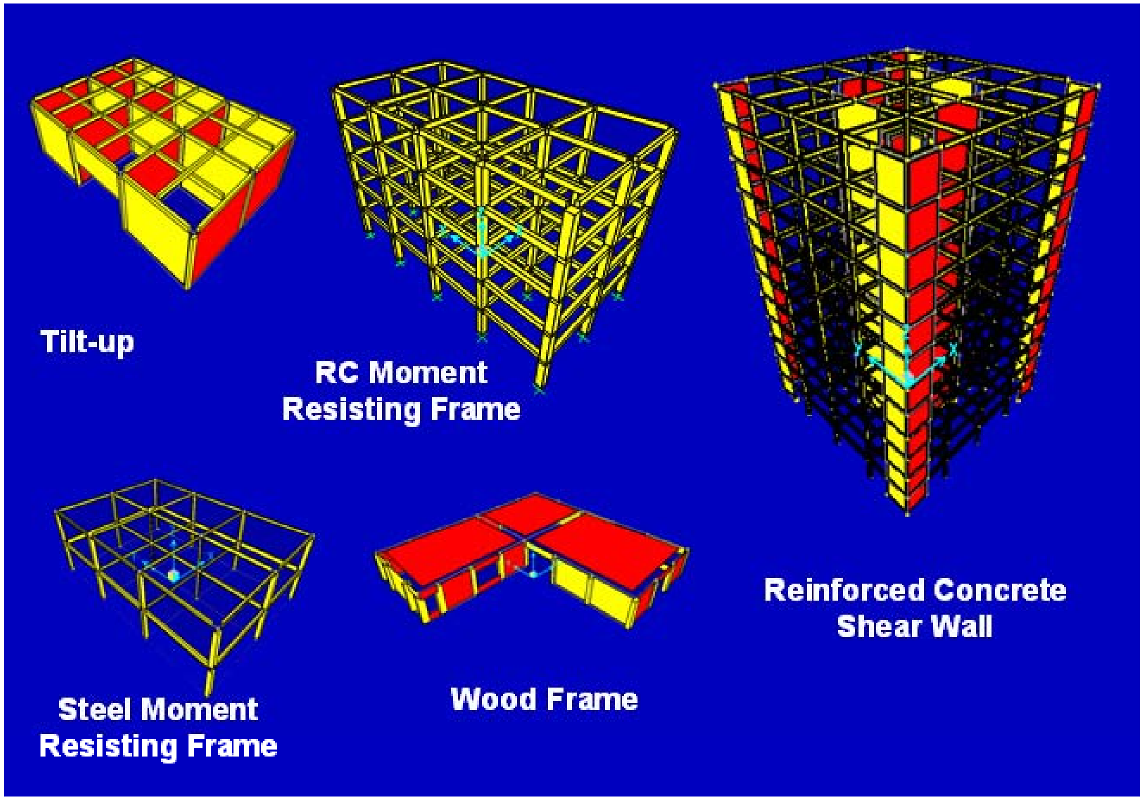


Based on S_d

Conceptualizing the Building Classes

- Each building class in the inventory is associated with a characteristic typical geometry and set of material properties as a first approach to estimate its behavior in an earthquake scenario.

- Steel
  - Moment Resisting Frame
  - Braced Frame
- Reinforced Concrete
  - Moment Resisting Frame
  - Shear Wall
- Pre-Cast Concrete
  - Moment Resisting Frame
  - Shear Wall
  - Tilt-Up



A History of Earthquakes and Seismic Codes

1900 1925 1950 1975 2000

1906 San Francisco

1925 Santa Barbara

1933 Long Beach

1971 San Fernando

1994 Northridge

UBC 1927

- First seismic deign provision

UBC 1949

- introduced national seismic hazard map for the first time

UBC 1976

- included more stringent design requirements based on the work of SEAOC

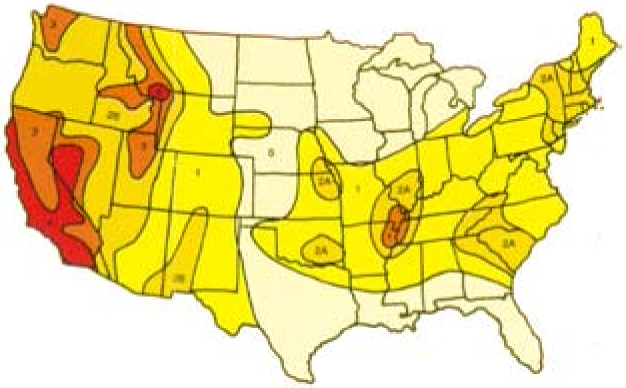
IBC 2000

- used contours of design ground motion rather than a numbered zonation map

Performance-based design

- define multiple target performance levels, which are expected not to be exceeded, when the building is subjected to earthquake of specified intensity

Firstly introduced in 1949, this version is from 1991



2000

Fire Following Earthquake

- Fire Following is a secondary peril that may be triggered by an earthquake event if the disruption of gas pipes or electric wiring, for instance, result in ignitions that evolve into fires.

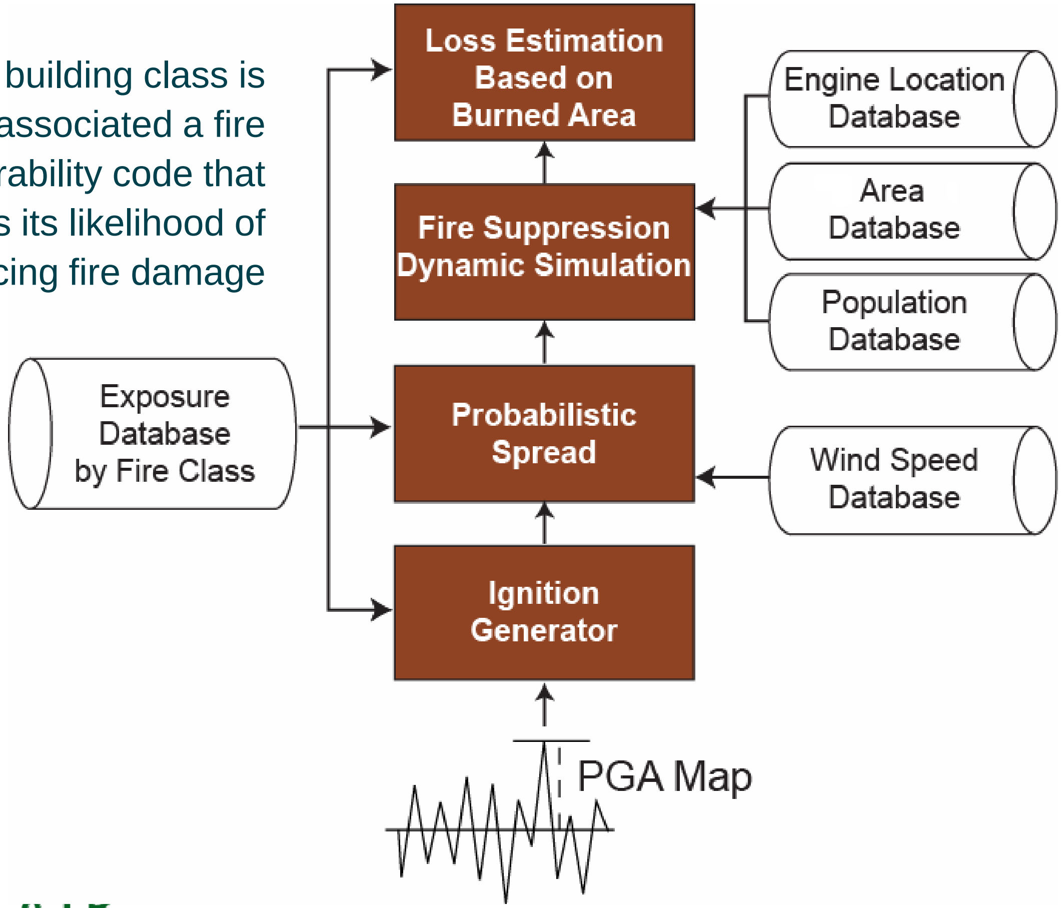
San Francisco, 1906

Northridge, 1994

Primary Model Components in Fire Damage Estimation

- Fire Following is modeled through a set of steps that take into account the probability of ignition generation, fire spread and fire suppression by emergency units.

Each building class is associated a fire vulnerability code that describes its likelihood of experiencing fire damage



A dynamic simulation is used to estimate the time needed for emergency units to respond to a fire emergency and control the spread

Environmental factors such as wind speed and direction play a role in determining the potential of the fire to spread in specific areas

Severe Thunderstorm

AIR's Definition of a Severe Thunderstorm Event Follows the National Weather Service Standard

- A severe thunderstorm produces at least one of the following
  - A tornado or funnel cloud
  - Hail at least 0.75 inch in diameter
  - Straight-line winds of at least 50 knots (58mph)
- A single occurrence of tornado, hail or straight-line winds is defined as a micro event
- A macro event is a collection of physically consistent micro events

Severe Thunderstorms in the U.S.

The Great Plains region of the U.S. is the most prone to the kinds of storms that produce hail, tornadoes, or damaging straight-line winds:

- Cool upper-level air, the continental air mass, is funneled down the east side of the Rocky Mountains;
- The land between the Rocky Mountains and the Appalachian range is mostly flat and so does not impede airflow;
- Warm moist air from the Gulf of Mexico, the maritime air mass, flows inland at the surface.

Losses From Severe Thunderstorms Can Be Significant

United States Severe Thunderstorm Losses (1998-2007)

Year	Period	States	Occurrence Loss ($M)	Aggregate Loss ($M)
2007	Mar 1 - 2	AL, GA	500	3,570
2006	Apr 13 - 15	IA, IL, IN, WI	1,850	8,098
2005	May 21 - 27	AL, FL, GA, MS, NC, TX, VA	655	2,829
2004	May 21 - 27	IA, IL, IN, KY, MI, MO, NC, NE, NY,OH, PA, SC, WI, WV	805	3,405
2003	May 2 - 11	AR, GA, IA, IL, IN, KS, KY, MI, MO, NE, OH, OK, SC, TN, TX, VA	3,100	5,100
2002	Apr 27 – May 3	AR, GA, IL, IN, KS, KY, MD, MO, MS, NC, NY, OH, PA, TN, TX, VA, WV	1,675	4,400
2001	Apr 6 - 12	AR, CO, IA, IL, IN, KS, KY, MI, MN, MO, NE, OH, OK, PA, TX, WI	2,200	4,765
2000	Mar 28 - 29	LA, TX	520	3,215
1999	May 3 - 7	AL, AR, FL, GA, IL, IN, KS, KY, LA, MO, MS, NC, NE, OH, OK, SC, TN, TX	1,485	4,626
1998	May 15 - 16	IA, MN	1,345	6,005

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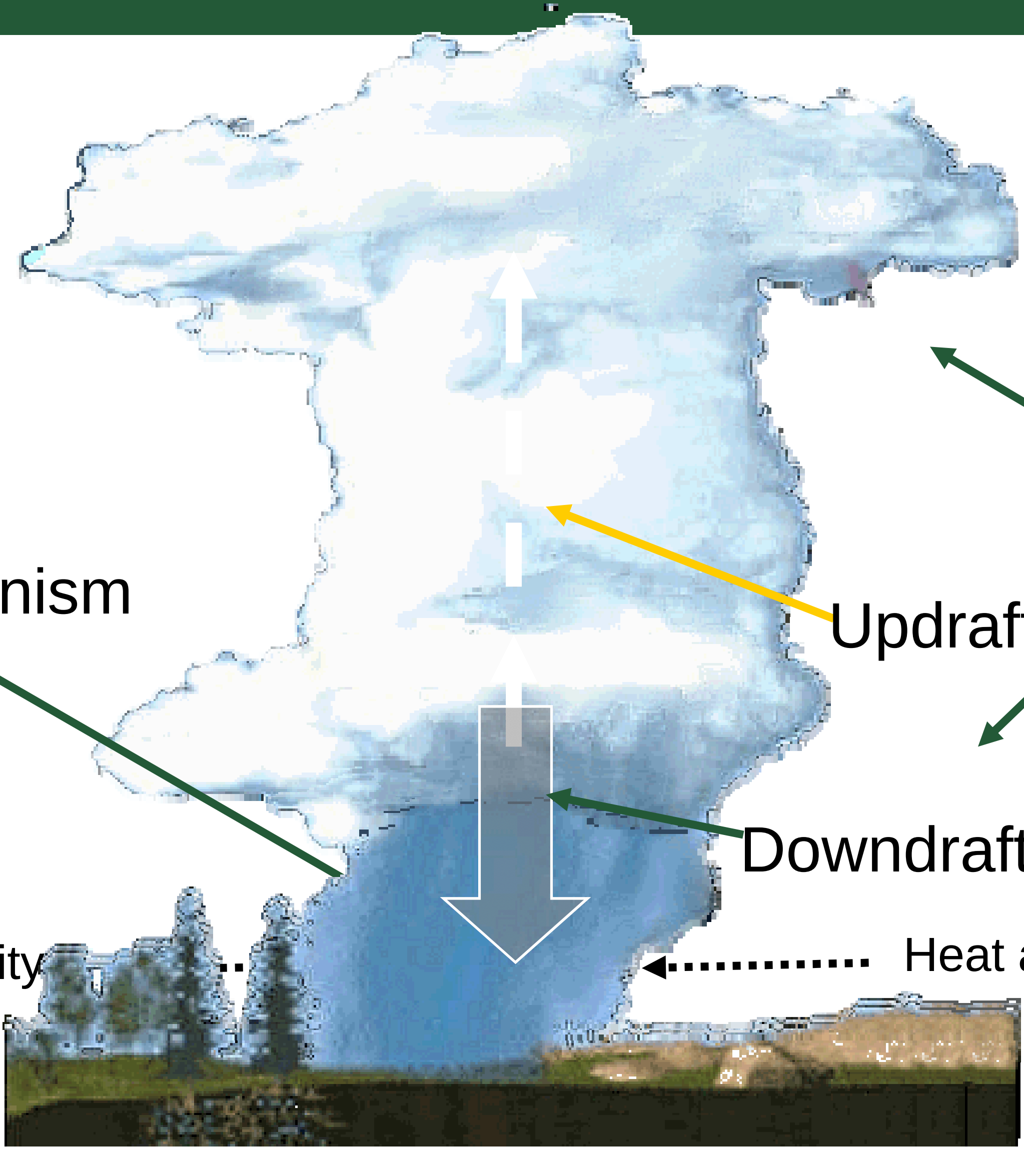
Thunderstorms Form in Unstable Atmospheric Conditions



Instability:

Cold, dry above warm humid air

Updraft

Lifting Mechanism

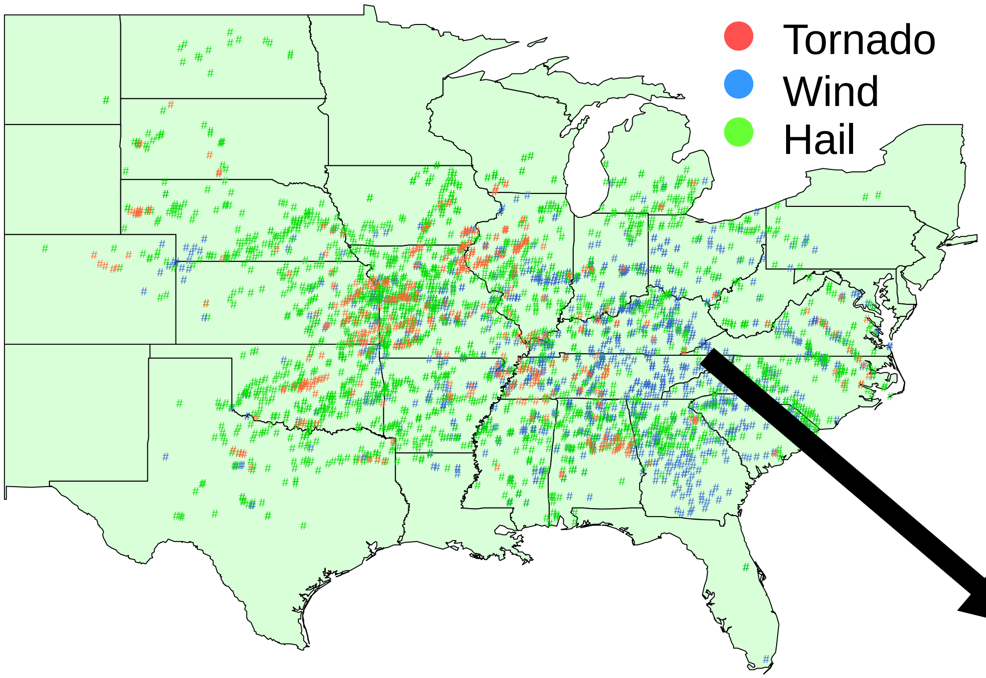
- Fronts
- Topography
- Convection

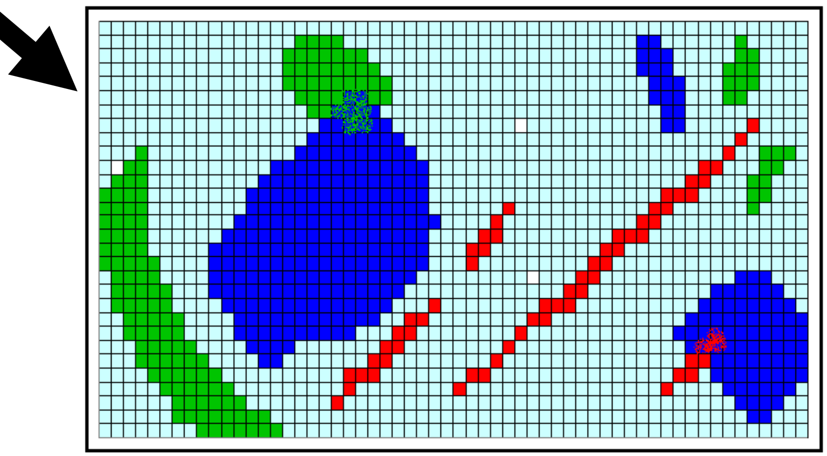
Downdraft

Heat and Humidity

Heat and Humidity

How Does the Severe Thunderstorm Model Integrate Information?

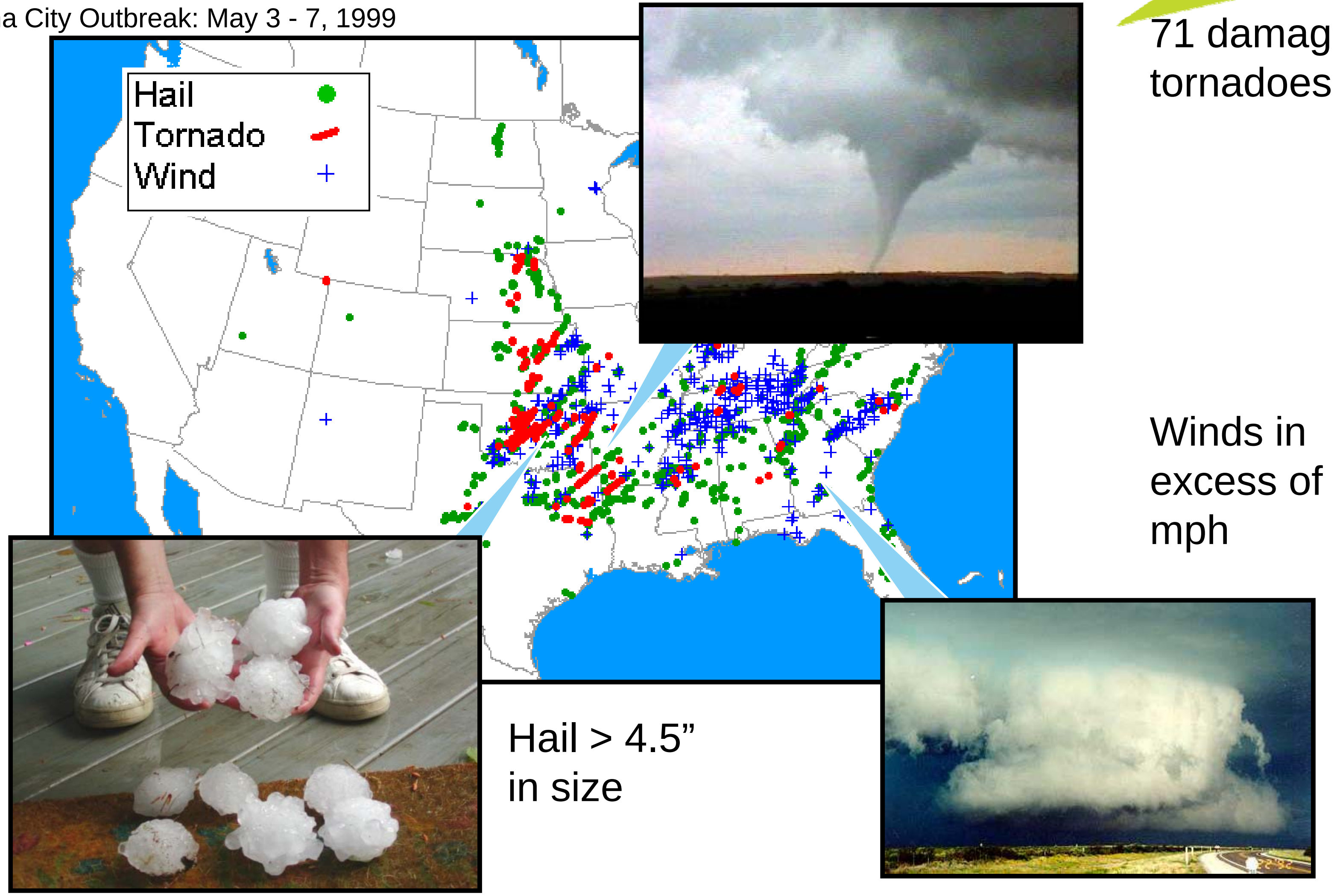




By computing intensity and loss on a high resolution grid, the model captures the highly localized effects of microevents.

Macro Events Are Comprised of Clusters of Micro Events Within the Same Weather Pattern

Oklahoma City Outbreak: May 3 - 7, 1999

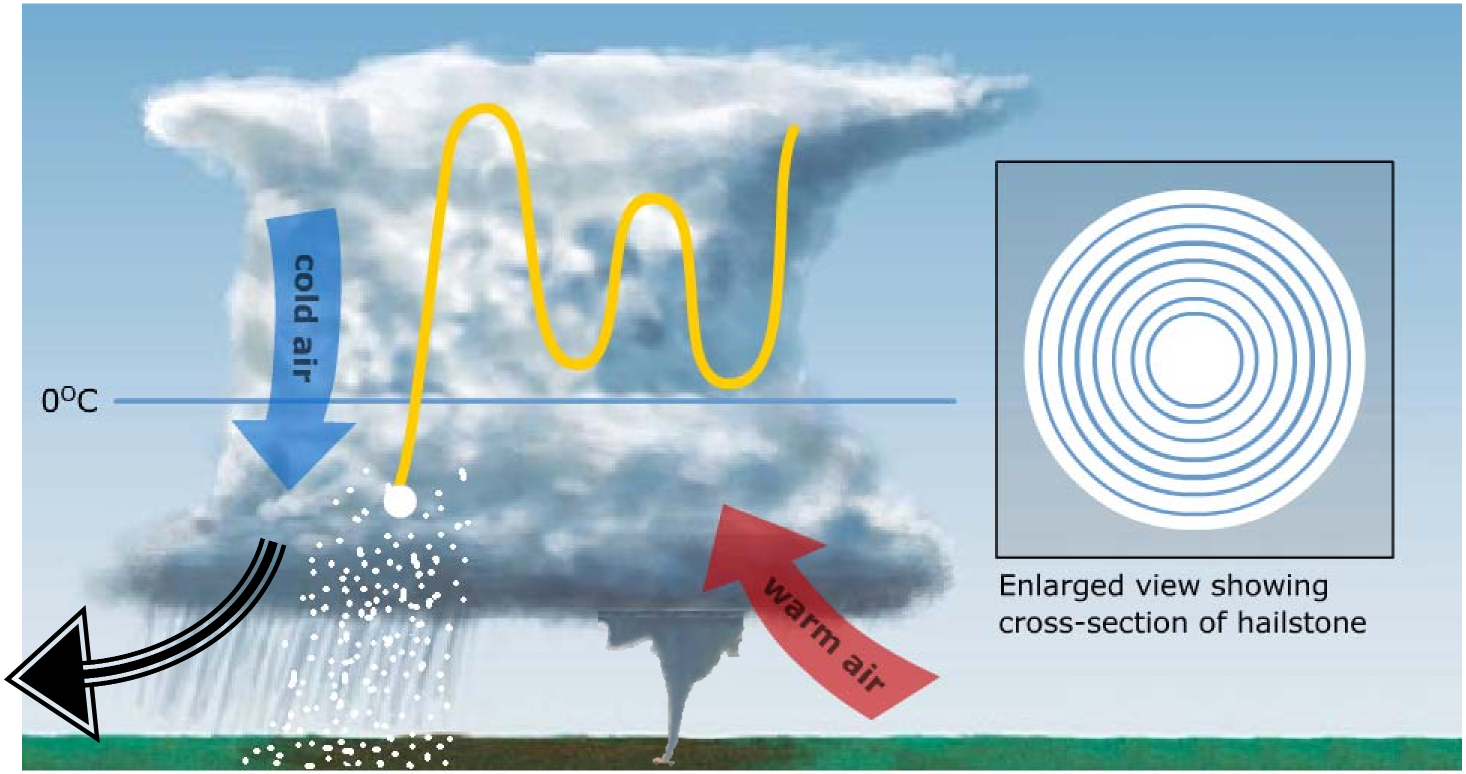


71 damaging tornadoes

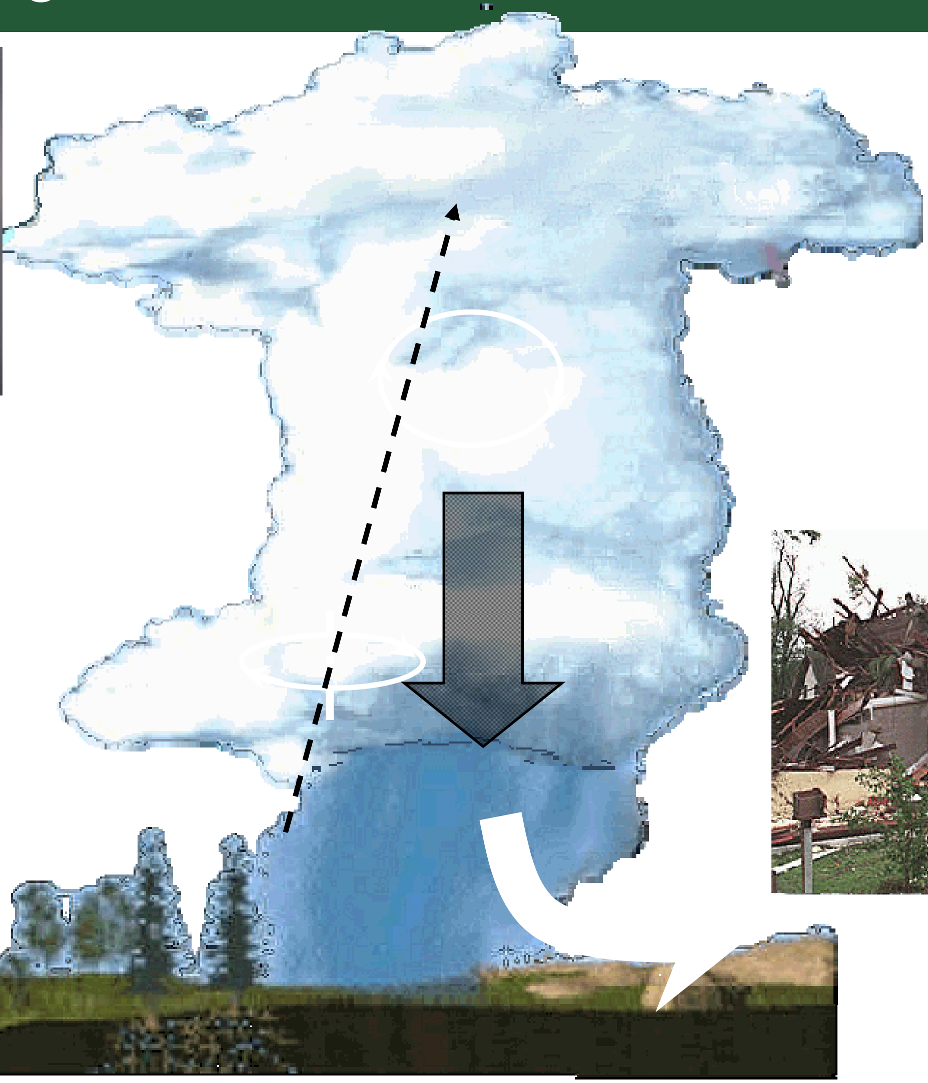
Winds in excess of 100 mph

Hail > 4.5” in size

Scale of Microevents in a Severe Thunderstorm

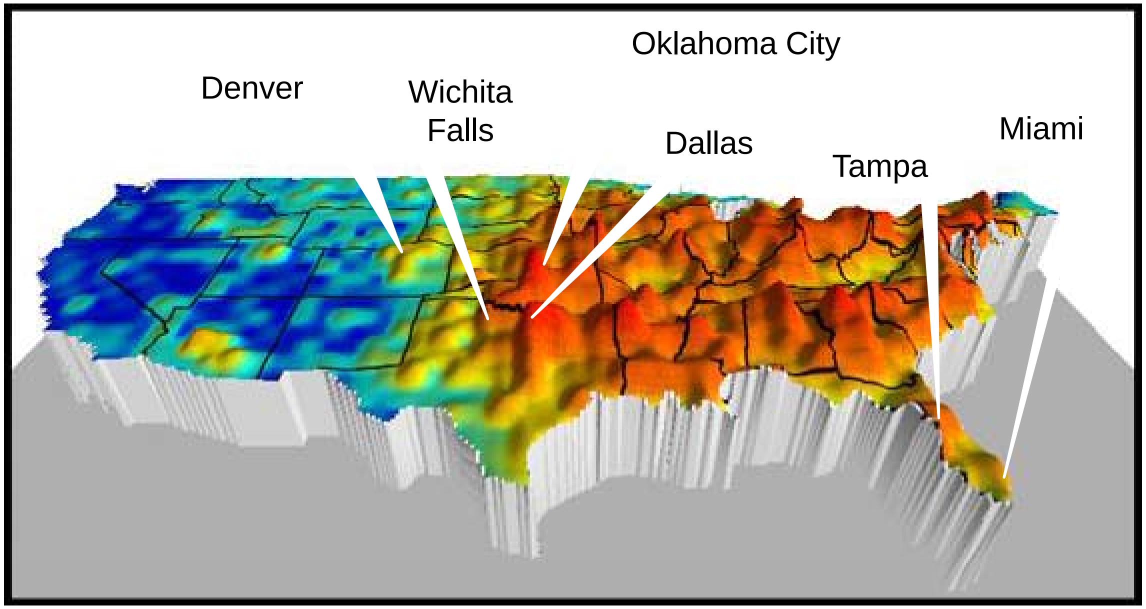


Severe Thunderstorms Can Generate Hail, Tornadoes, and Extreme Straight-line Winds



An Observational Bias Exists in the Reporting of Severe Thunderstorms

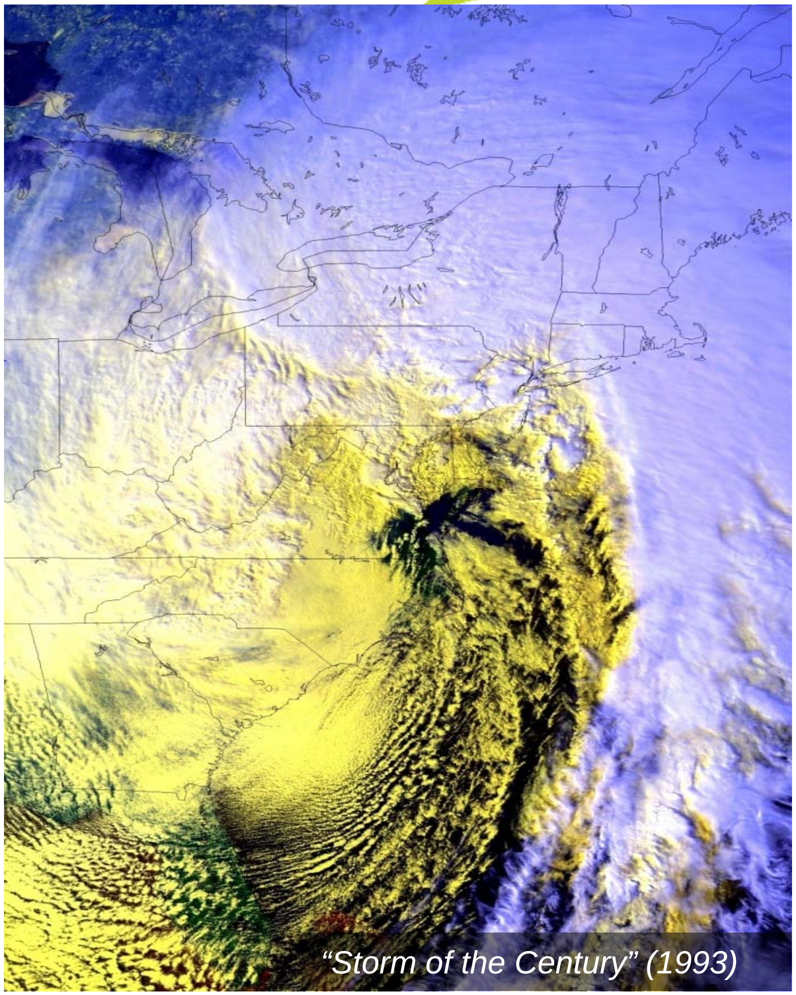
- ☐ In the U.S. each year there are an average of
  - 1,200-1,500 tornado reports
  - 8,000-12,000 severe straight-line wind reports
  - 7,000-10,000 hail reports



Winter Storm

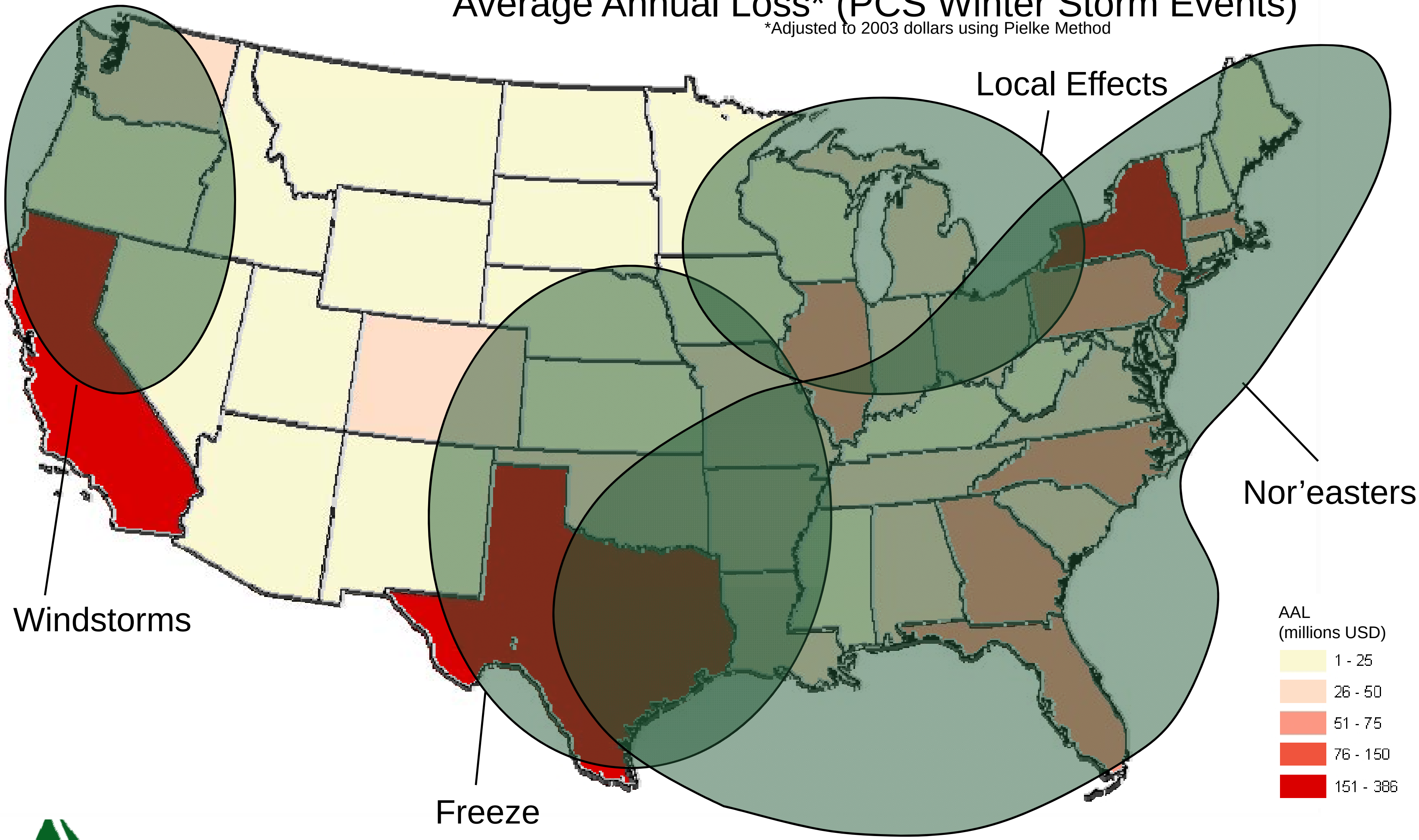
Winter Storms in North America

- Winter storms in North America are the main source of extreme weather in the winter months
- North American winter storms include important “sub-perils” of wind, precipitation, and temperature
- Virtually the entire U.S. is impacted by these storms
- Accumulation of vulnerability over the course of a season can lead to loss not necessarily associated with a single event



“Storm of the Century” (1993)

Regional Loss Experience from Winter Storms



Average Annual Loss* (PCS Winter Storm Events)

*Adjusted to 2003 dollars using Pielke Method

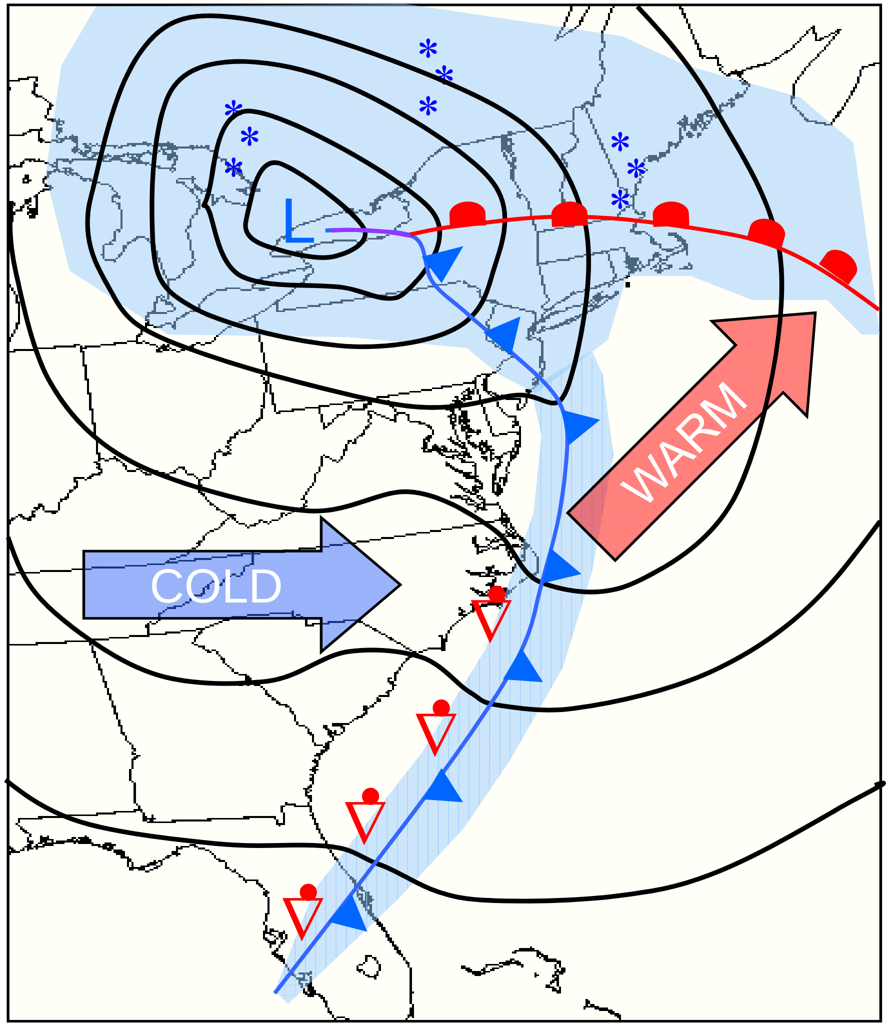
Sources of Winter Storm Damage

Wind: damage to roof, envelope, cladding due to wind loads on building

Freeze: water damage due to bursting pipes

Snow/Ice: roof collapse due to snow load, drifting, ice dams, accumulation on trees and power lines

Anatomy of a Winter Storm



- AIR event definition
  - Location: Within the contiguous US and/or Canada
  - Time: Occurring during the timeframe of October 1st to April 1st
  - Type: Region of low pressure and cyclonic rotation
  - Intensity: Winds or snow somewhere within the system in excess of *50 mph* and *1 inch*, respectively
- Captures severe thunderstorm activity that occurs in conjunction with the winter storm – usually initiated by a trailing front

Modeling Sub-perils in 3-D

- Modeling of each sub-peril requires full understanding of 3-dimensional storm structure
  - Wind gusts: the strongest winds in an ETC are closely tied to the three-dimensional structure of the event
  - Snow load: snowfall intensity is related to “surface convergence” and “moisture availability”, a fundamentally 3-D process
  - Temperature: transport of cold temperatures from the polar latitudes varies based on the dynamics of each storm
- Numerical Weather Prediction (NWP) is the right tool
  - Models interaction and feedback between the surface and the air aloft, factors which play a key role in all winter storms
  - Incorporates all known physics about the atmosphere including extremely complex processes (e.g., cloud microphysics)
  - Runs at high resolution (space and time) to pick up locally intense winds, precipitation, and temperature

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Stochastic Storm Catalog

- NWP model used to simulate events
  - Perturbing NWP models' initial conditions produces a realistic range of outcomes
  - By applying equally likely perturbations, physical model produces a full spectrum of storms
- Stochastic catalog contains over 60,000 winter storms
  - 60% east coast storms
  - 40% west coast and cross-country storms
- Snow melt model sets existing ground load for snow
  - Simulates snow load remaining since last winter storm event
  - Explicitly incorporates vulnerability associated with "serial clustering"

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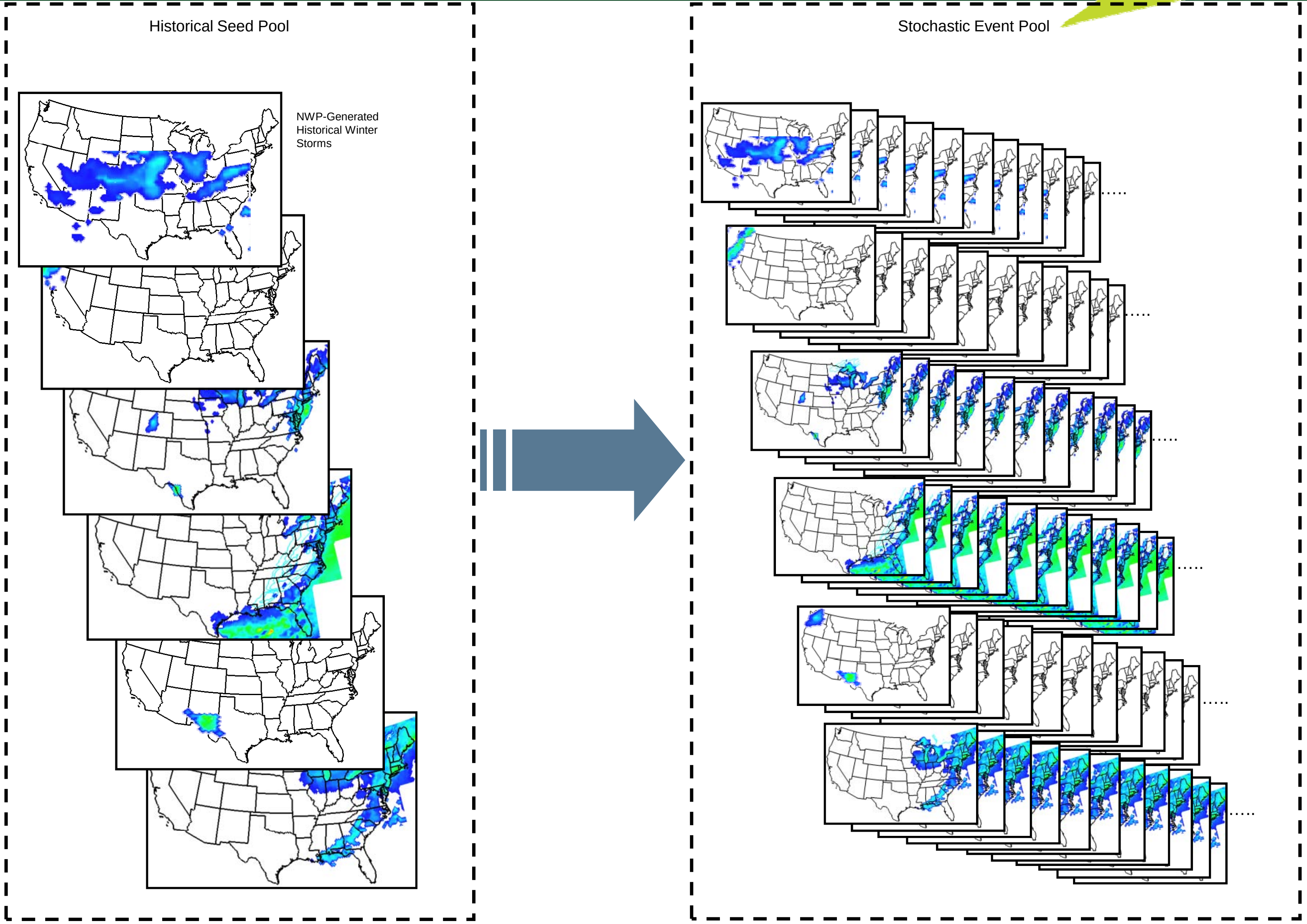
A Large Set, or Ensemble, of Potential Storms is Generated by Repeatedly Perturbing the Initial Conditions of Historical Storms by Small, but Equally Likely Amounts

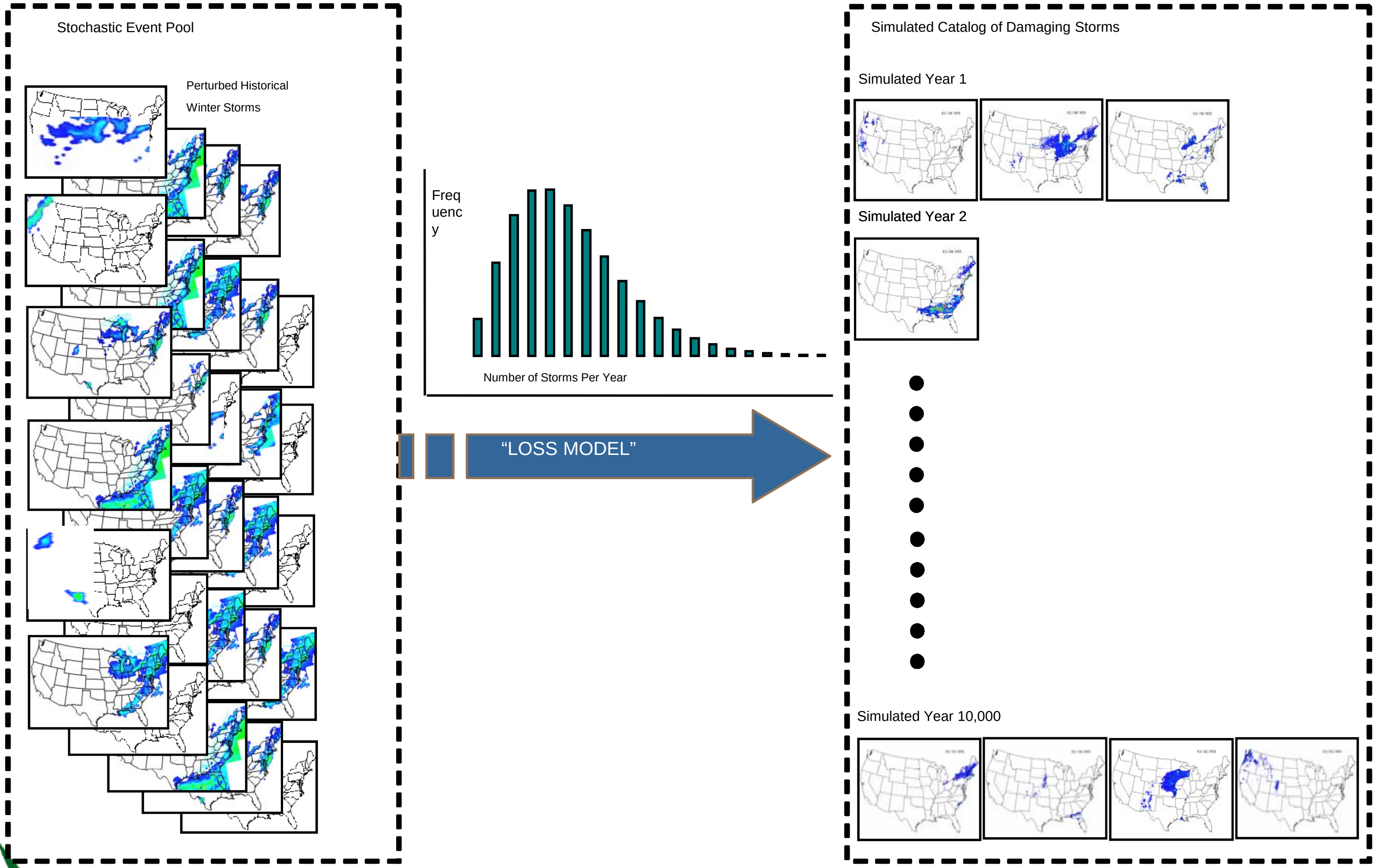


Historical Seed Pool

NWP-Generated
Historical Winter
Storms

Stochastic Event Pool

The Stochastic Catalog is Created by Drawing from the Stochastic Storm Pool Using a Negative Binomial Distribution



Stochastic Event Pool

Perturbed Historical Winter Storms

"LOSS MODEL"

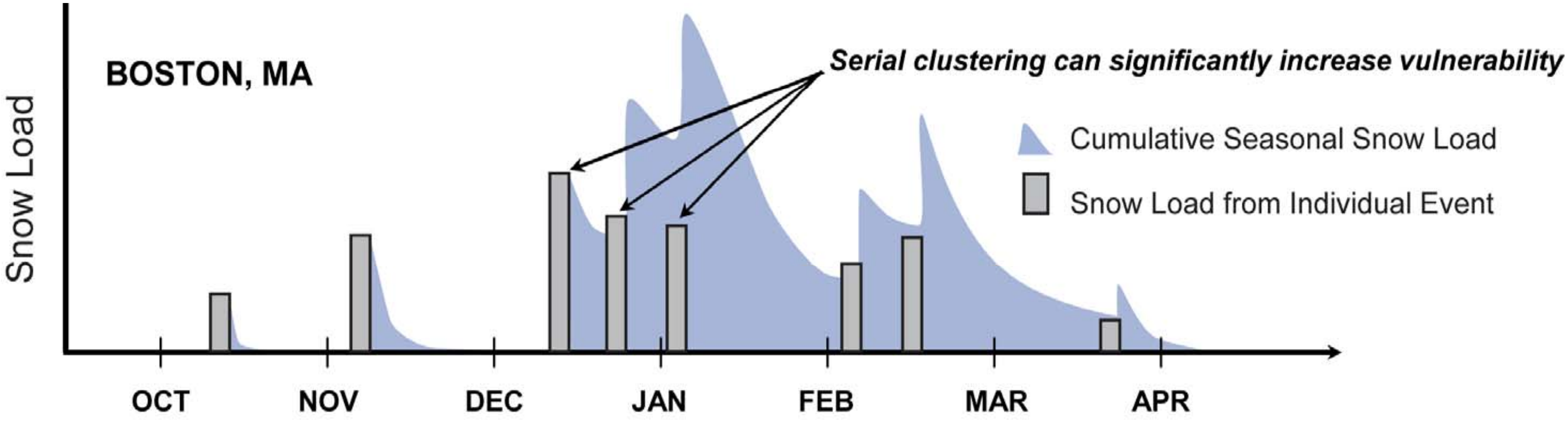
Simulated Catalog of Damaging Storms

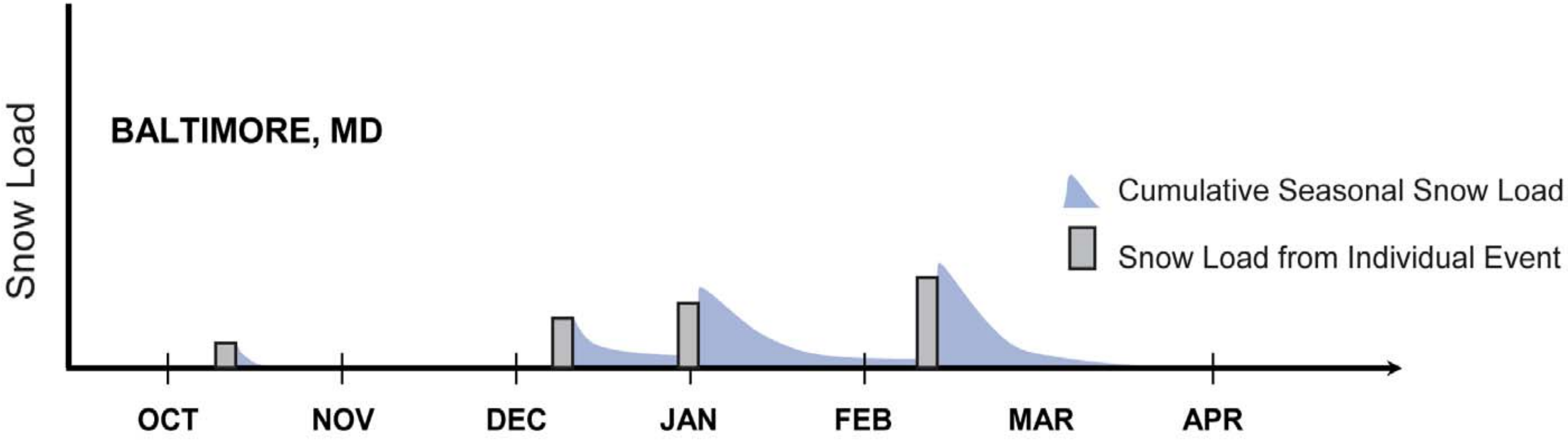
Simulated Year 1

Simulated Year 2

Simulated Year 10,000

Snow Melt Module Generates Cumulative Ground Load Conditions throughout a Season





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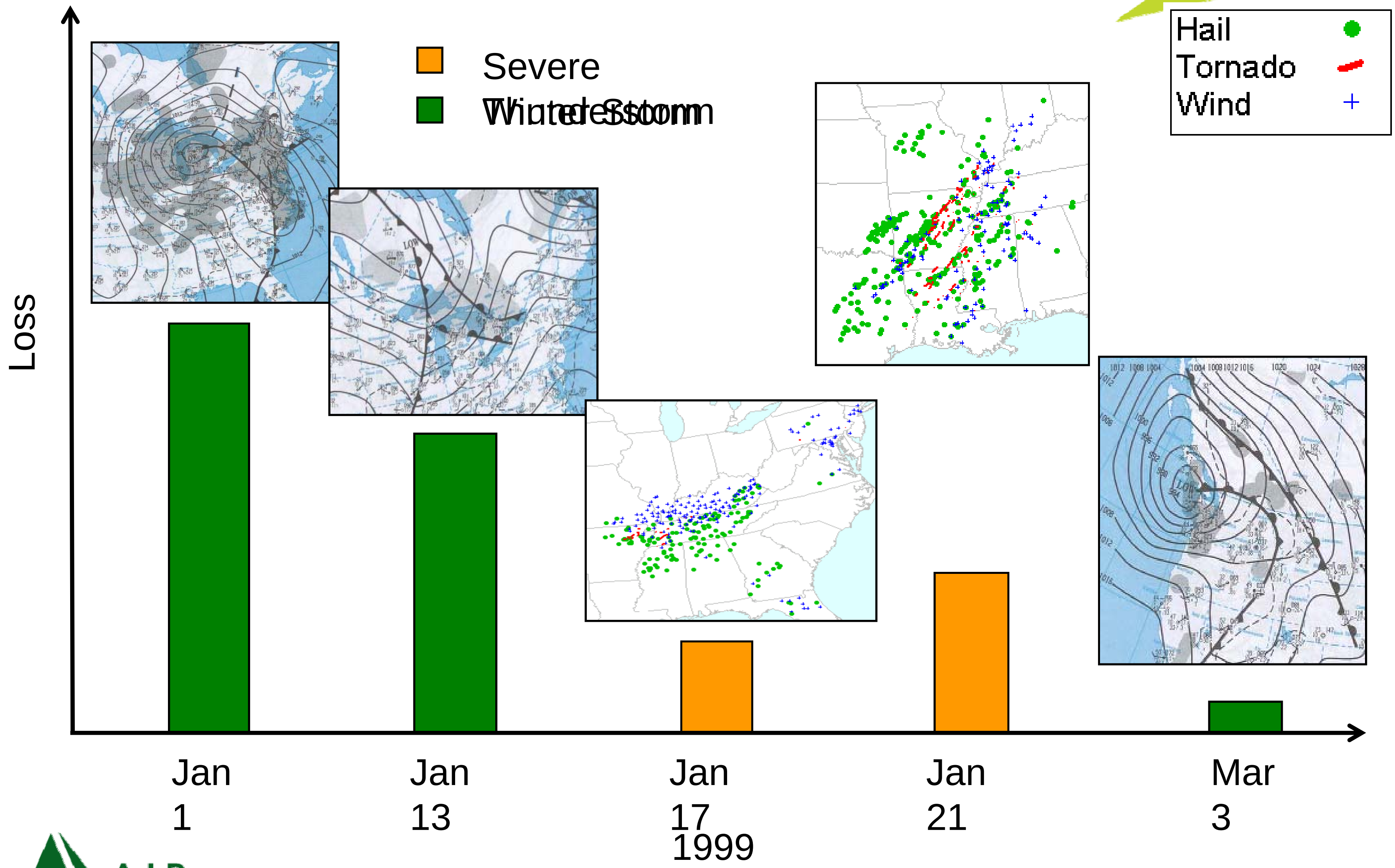
A Typical Winter Season



Wildfire

Wildfire Peril

Cause	Various natural and manmade
Frequency of Occurrence	High
Area at Risk	Wildland Urban Interface
Fire Behavior	Ignitions followed by fire spread in wildland vegetation
Severity of Tail Losses	Moderate

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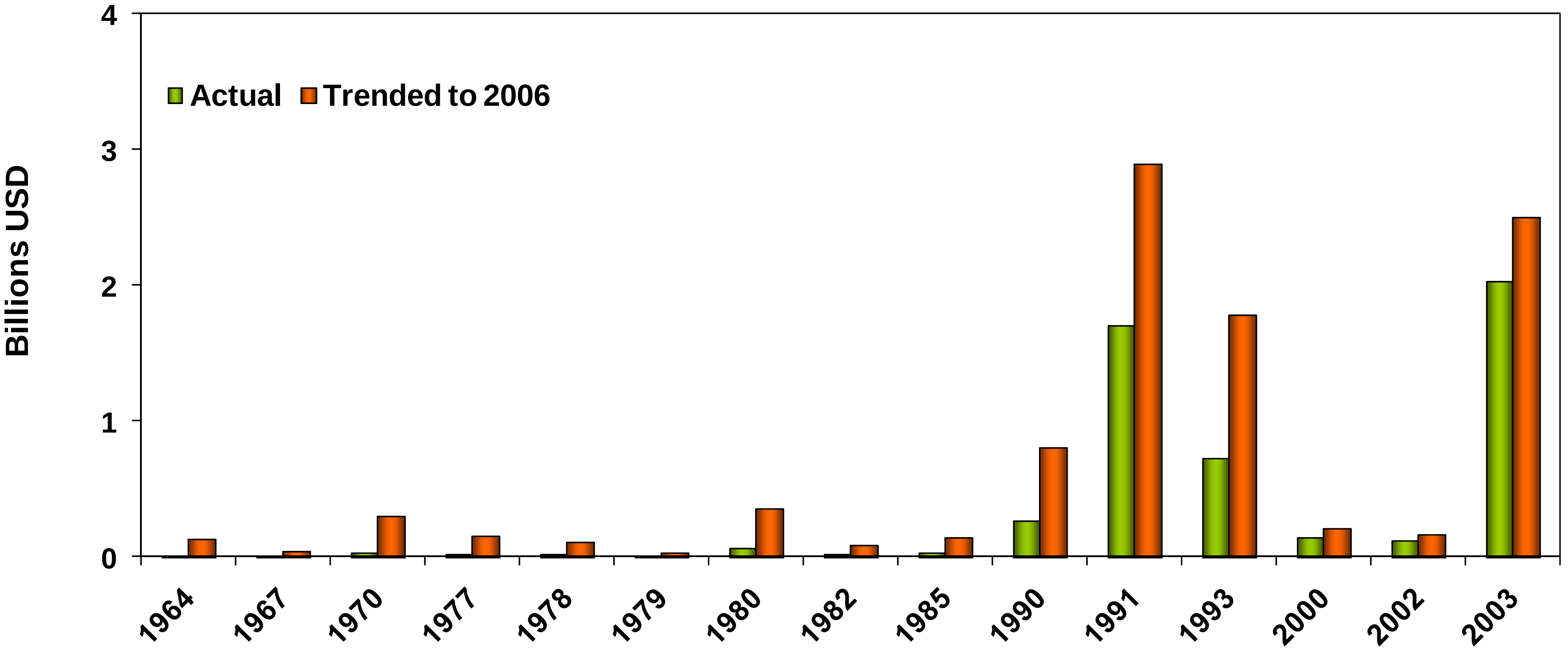
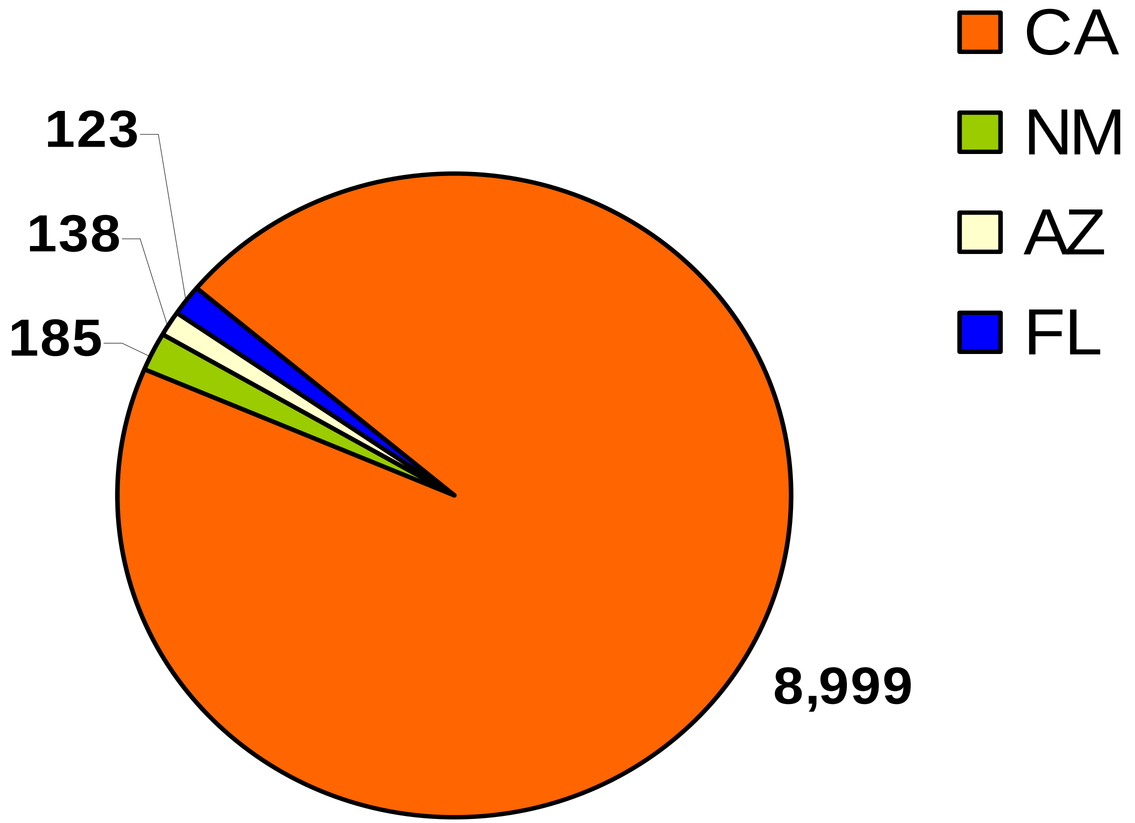
Why Should You Should Be Concerned About Wildfires?

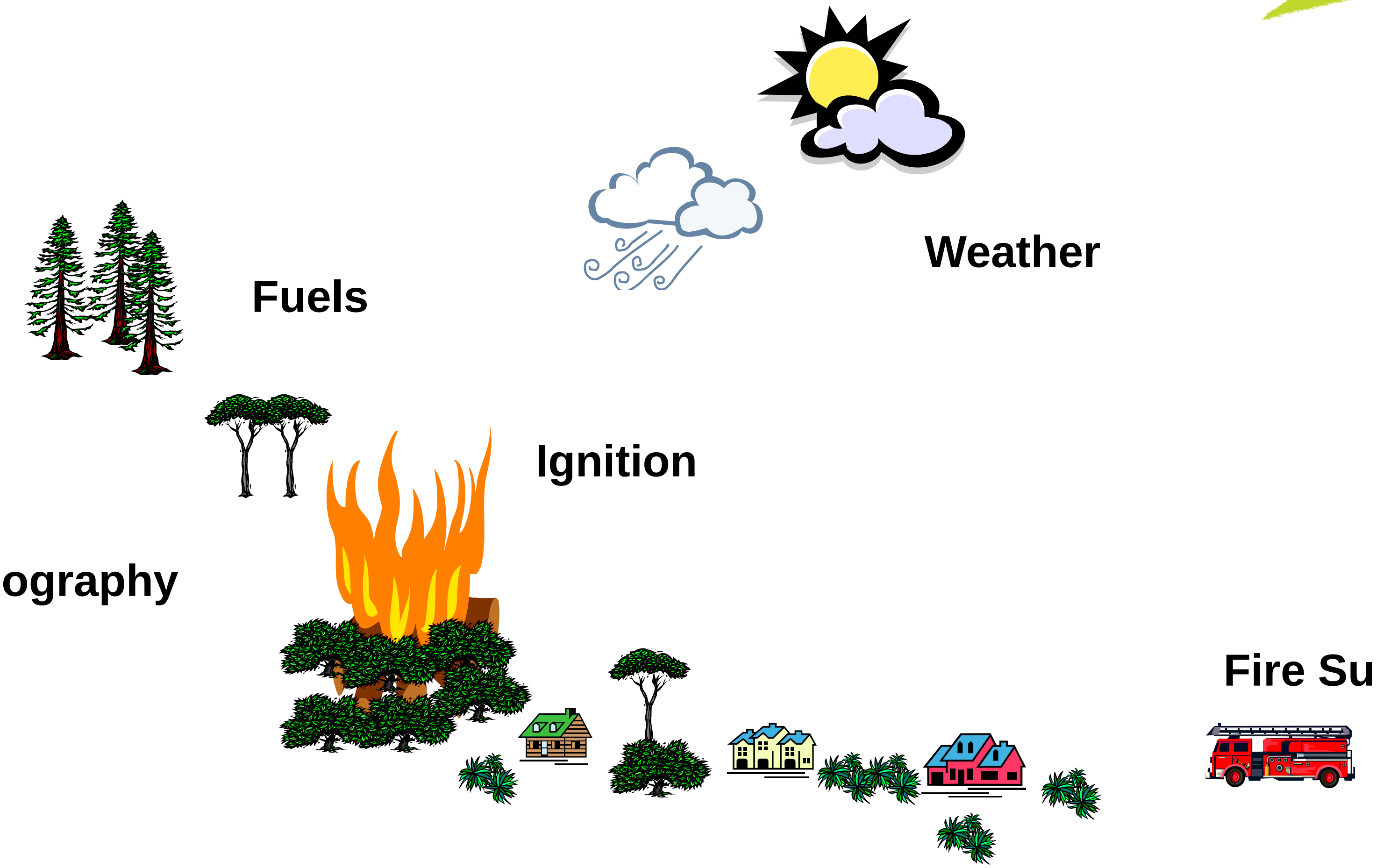


Historical Losses by State 1964 – 2003 (Millions USD)



Source: PCS

Anatomy of a Wildfire – Key Factors



Weather

Fuels

Ignition

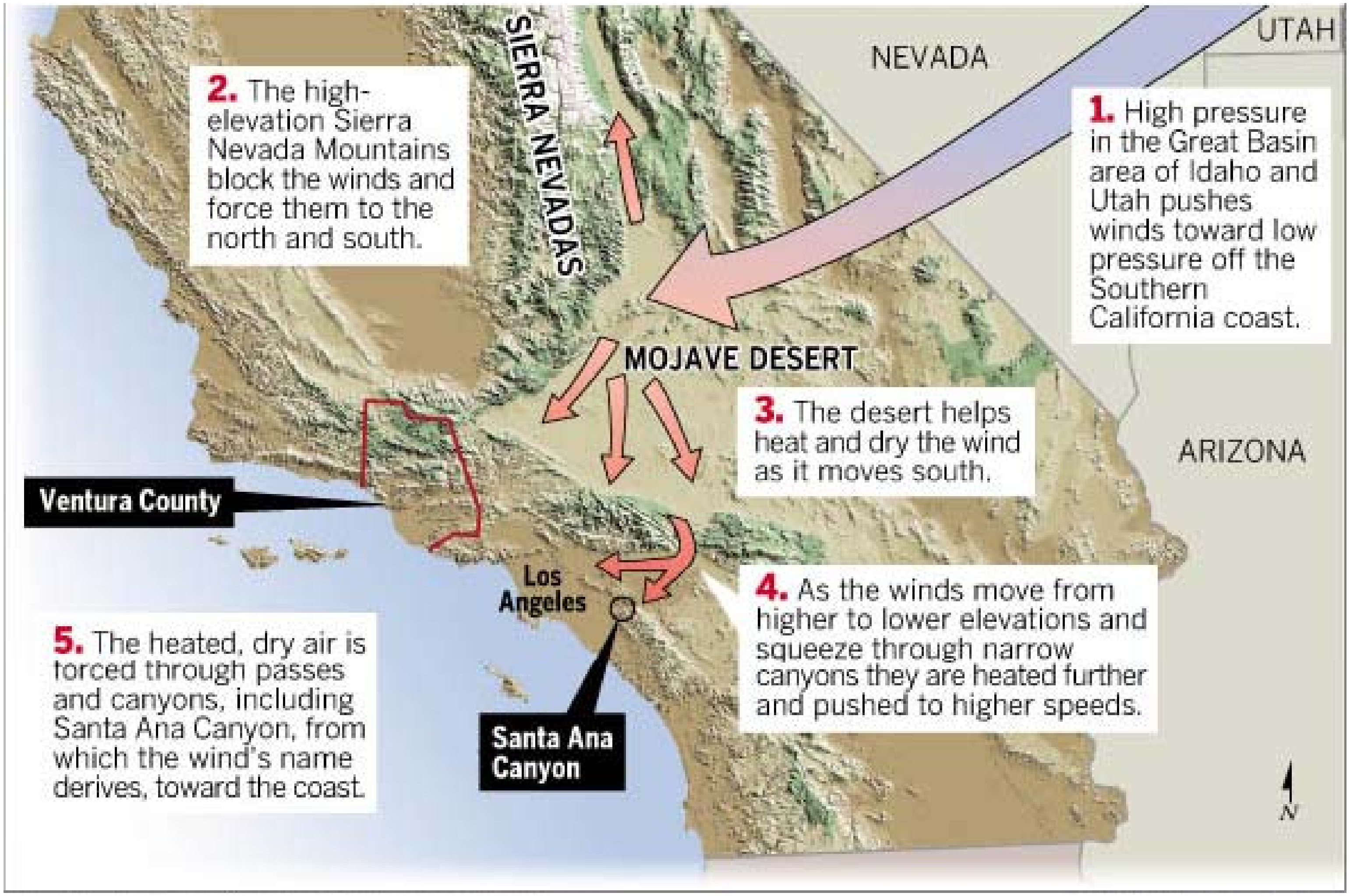
Topography

Fire Suppression

Topography

- Since heat rises, fuels located immediately upslope from a wildfire will be dried and preheated, allowing the fire to spread more rapidly
- Extreme slopes impede fire suppression activities
- Slope and aspect also influence wind and sun exposure

Weather – Special Consideration for Santa Ana Winds



1. High pressure in the Great Basin area of Idaho and Utah pushes winds toward low pressure off the Southern California coast.

2. The high-elevation Sierra Nevada Mountains block the winds and force them to the north and south.

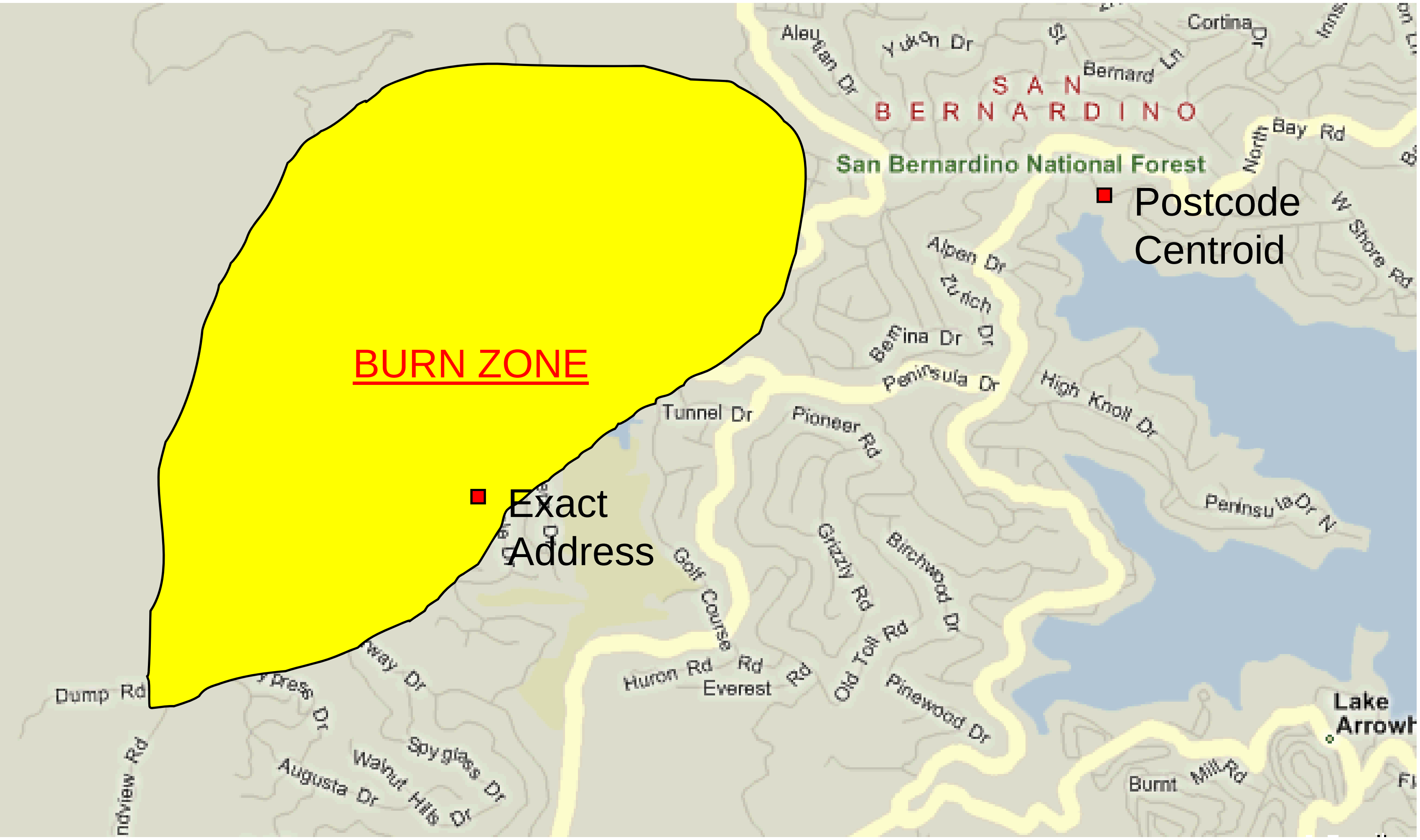
3. The desert helps heat and dry the wind as it moves south.

4. As the winds move from higher to lower elevations and squeeze through narrow canyons they are heated further and pushed to higher speeds.

5. The heated, dry air is forced through passes and canyons, including Santa Ana Canyon, from which the wind's name derives, toward the coast.

Source: UCLA and UC San Diego

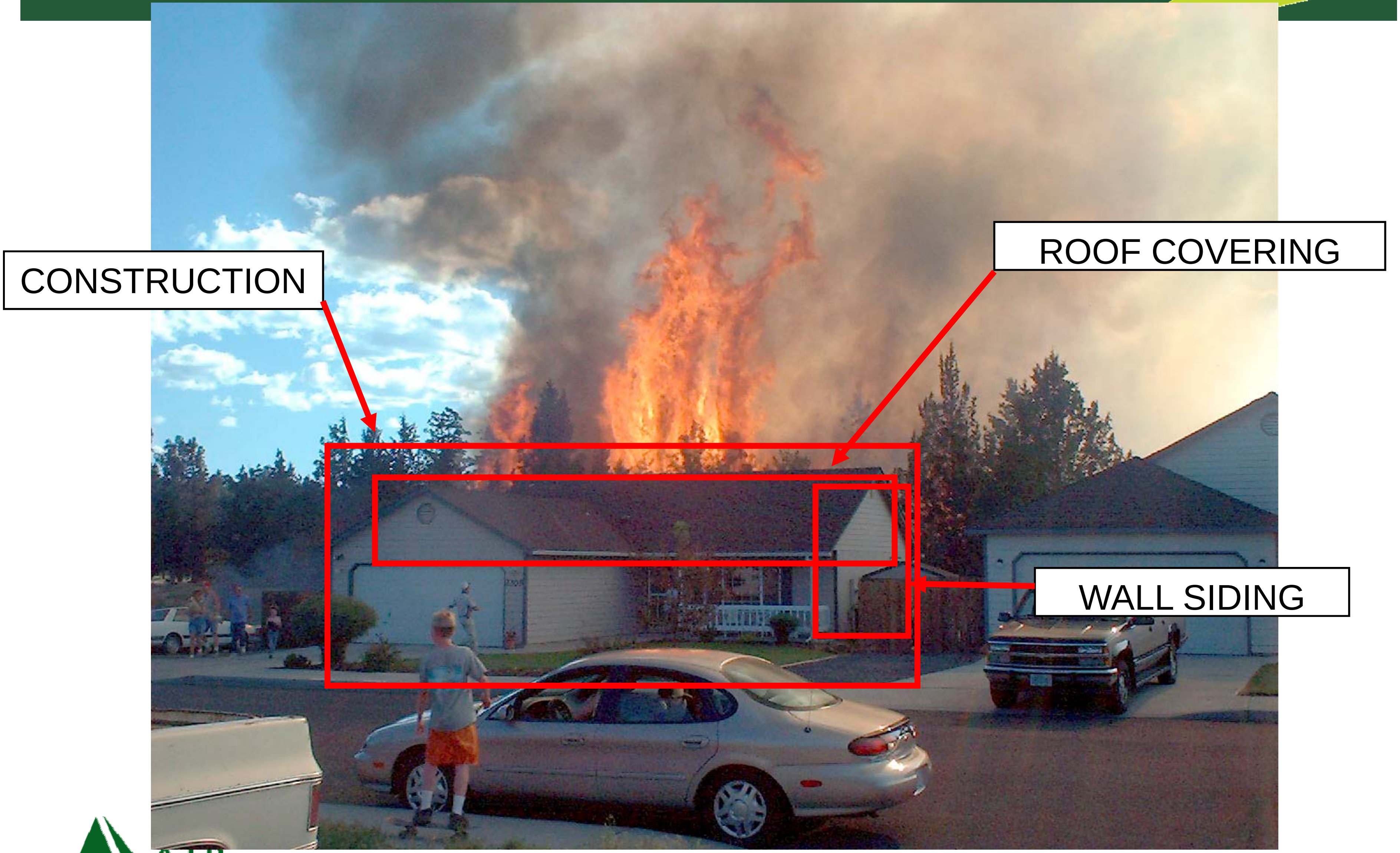
Exact Address is Essential for Accurate Results



Key Model Variables

1. Annual Frequency
2. Fire Location
3. Fire Size
4. Seasonal Distribution

Accurate Construction Characteristics Are Essential



Relative Vulnerability of Roof and Siding Materials

Low

Moderate

High

Low

Moderate

Don’t Ask