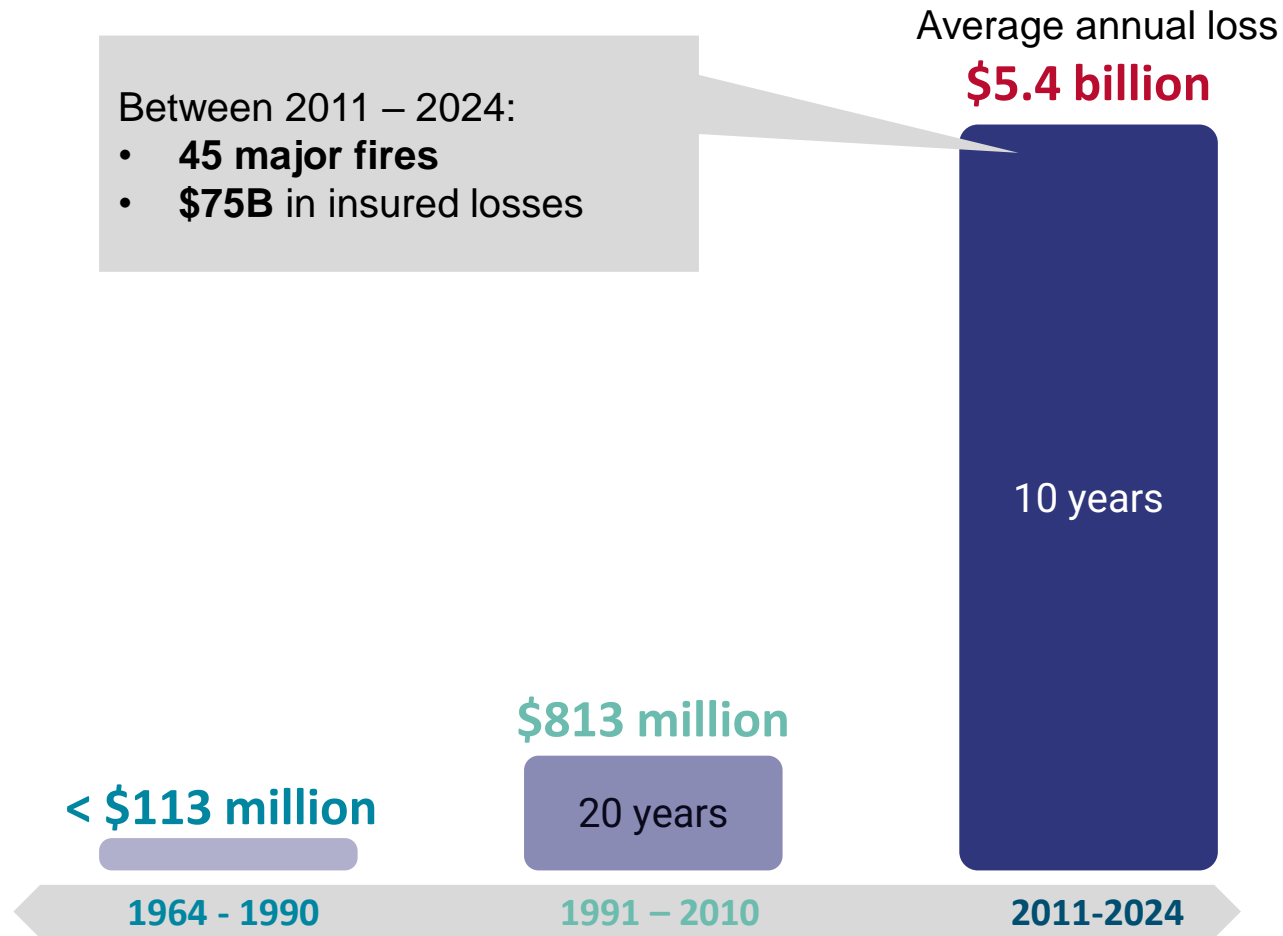


MOODY'S

Robert Muir-Wood
RMS: Chief Research Officer

Wildfire Risk Modelling
Moody's RMS
Sept 2024

Escalating Wildfire Severity – US Trends



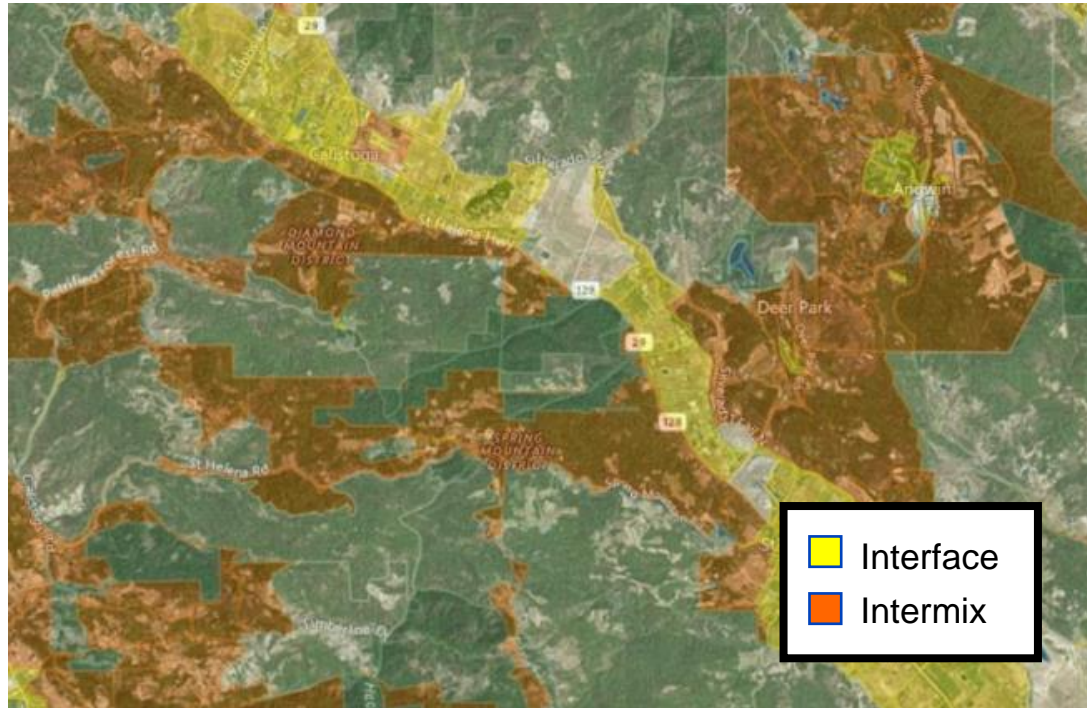
WHY?

- More houses in high risk areas
- Climate change
- Aggressive firefighting in 20th century → excessive burnable vegetation

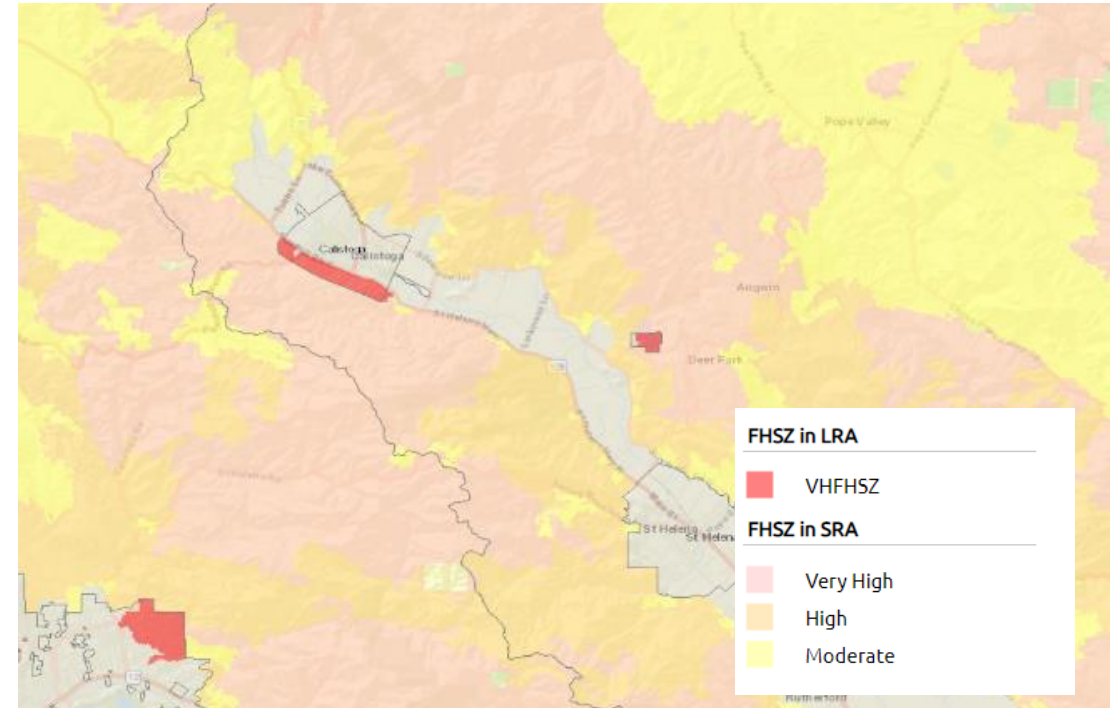
Average Annual Loss (AAL) from United States wildfires

Differentiating Risk Scores and Models

Wildland-Urban Interface/Intermix Around Napa, California



Cal FIRE Zoning



Intent of scoring is to bin risks in a relative way (e.g. on a scale from 1-10)

Simple mapping/scoring techniques and models that don't explicitly consider ember travel, smoke, and urban conflagration are no longer sufficient.

Also doesn't allow for quantifying absolute levels of risk. What does 'high' risk mean from a rating perspective? 3

Risk Scores vs. Prob. Models

Risk Scores are meant to help with risk selection. Risk relativities are useful when comparing two risks side by side. Output is typically a score in a range, for example on a scale of 1-10.

Probabilistic models can be used for a wide variety of use cases, including underwriting, risk transfer, and portfolio management. Output is a dollar loss and can be used from a location level all the way up to a portfolio-wide view.

Use Cases for Each Model Type



Capability	Risk Scores	Prob. Models
Risk Selection	✓	✓
Risk Relativities	✓	✓
Pricing		✓
Return Period Metrics		✓
Mitigation Features		✓
Portfolio Management		✓
Risk Transfer		✓

Catastrophe Models: Key Financial Metrics

Average Annual
Loss (AAL)

Loss Cost

OEP

AEP

- Expected mean loss from all events in a given year
- Also known as ‘annual pure premium’ required to cover modeled loss over time
- Calculated by sum-product of event mean loss and event frequency (rate):

$$\sum_{i=1}^{\text{Number of Events}} \text{Event Mean Loss}_i \times \text{Event Rate}_i$$

Catastrophe Models: Probabilistic Outputs

Average Annual
Loss (AAL)

Loss Cost

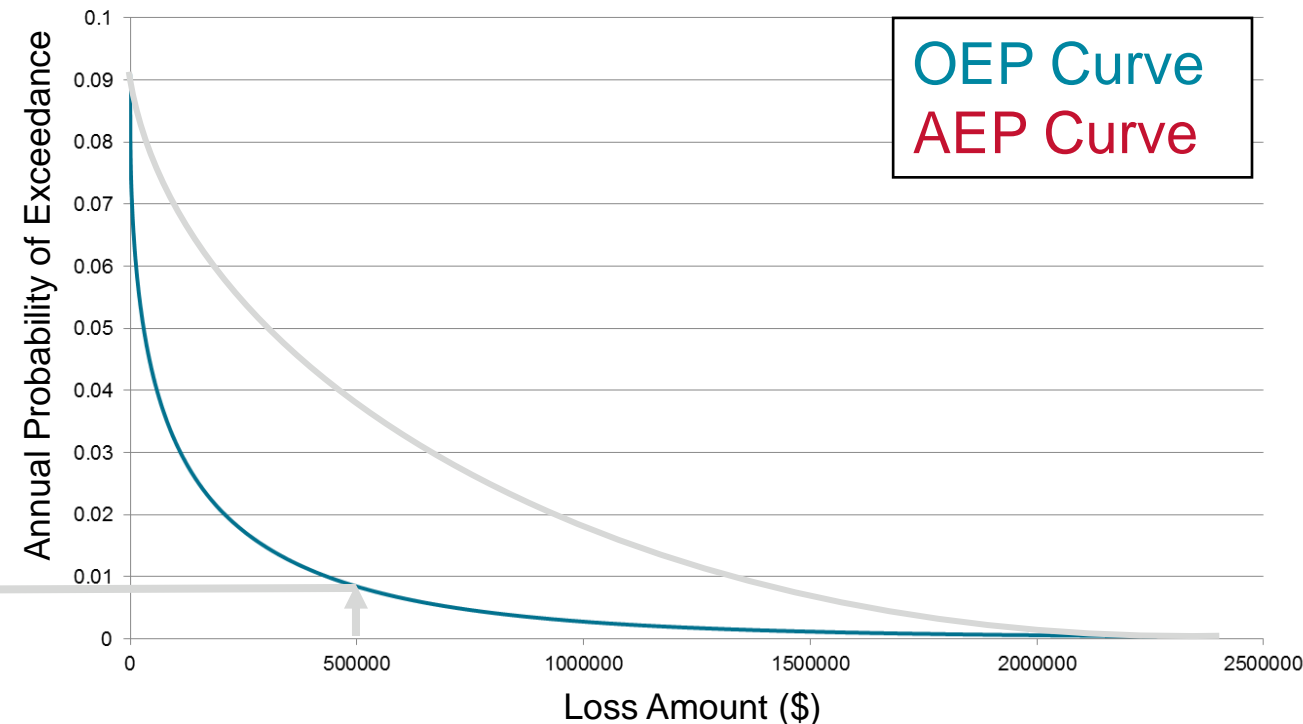
OEP

AEP

- Probability that losses from the **single largest occurrence in a year** will exceed a given threshold
- Each point represents a loss threshold and a probability of exceeding that threshold **for one event**

Q: What is the probability of any single event in a year exceeding \$500,000 in loss?

A: 0.009 = 0.9%
or 1 in 111 years

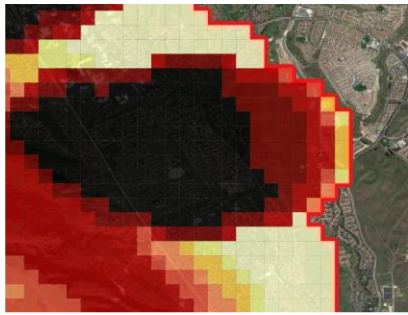


Catastrophe Modeling Framework



Stochastic Event Catalogue

Simulate wildfire scenarios for 50,000 versions of next year



Assess Hazard

Quantify spatial extent & intensity of heat, ember, smoke hazards using physical science models



Apply Exposure

Apply replacement value of properties at risk for structure, contents, and business interruption



Item	Value	Value	Value	Value	Value
1000	100.00	100.00	100.00	100.00	100.00
2000	200.00	200.00	200.00	200.00	200.00
3000	300.00	300.00	300.00	300.00	300.00
4000	400.00	400.00	400.00	400.00	400.00
5000	500.00	500.00	500.00	500.00	500.00
6000	600.00	600.00	600.00	600.00	600.00
7000	700.00	700.00	700.00	700.00	700.00
8000	800.00	800.00	800.00	800.00	800.00
9000	900.00	900.00	900.00	900.00	900.00
10000	1000.00	1000.00	1000.00	1000.00	1000.00

Calculate Damage

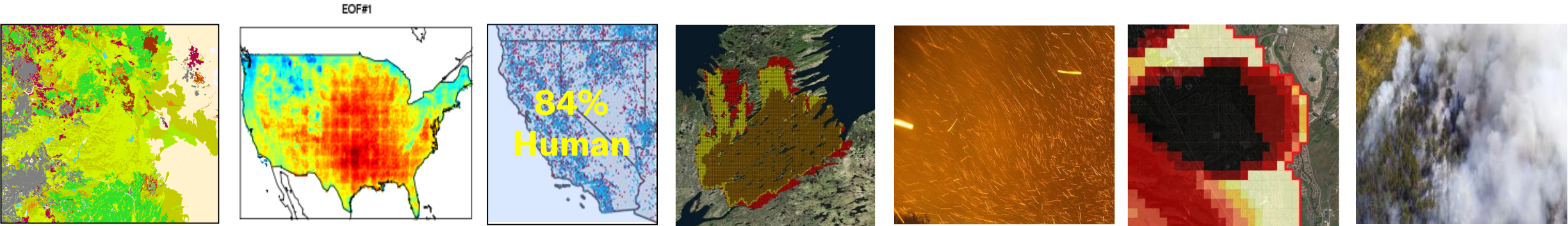
Estimate damage for different vulnerability classes based on material, height, occupancy, year built & mitigation measures



Quantify Financial Loss

Apply insurance terms & conditions to estimate loss to policy holder, insurer, reinsurer

Wildfire Hazard Modeling Framework



Topography
Surface Fuels
Forest Fuels

Dist. to
Vegetation

50,000-year
Climate
& Extreme
Weather
Simulations

Climate Change
“So-Far”

Simulate
Ignitions
considering
urbanization
patterns

Minimum
Travel Time
Algorithm
=
Realistic fire
durations

Ember
Transport
Modeling

Structure to
Structure
Spread
=
Next
Coffey Park

Smoke Footprints:

Emission and
Transport models

Up to 20% of loss

CONTRIBUTIONS FROM EMBERS

Without the presence of a flaming fire front, embers still attack and ignite structures.

No radiant heat component

Ember attack beyond flaming front



http://www.yakimaherald.com/photos_and_videos/news_photos/aerial-views-show-the-damage-caused-by-wenatchee-fire/collection_8c7e082e-1eb4-11e5-b423-af0885fd85cb.html

Urban Conflagration



Initiation of urban
conflagration

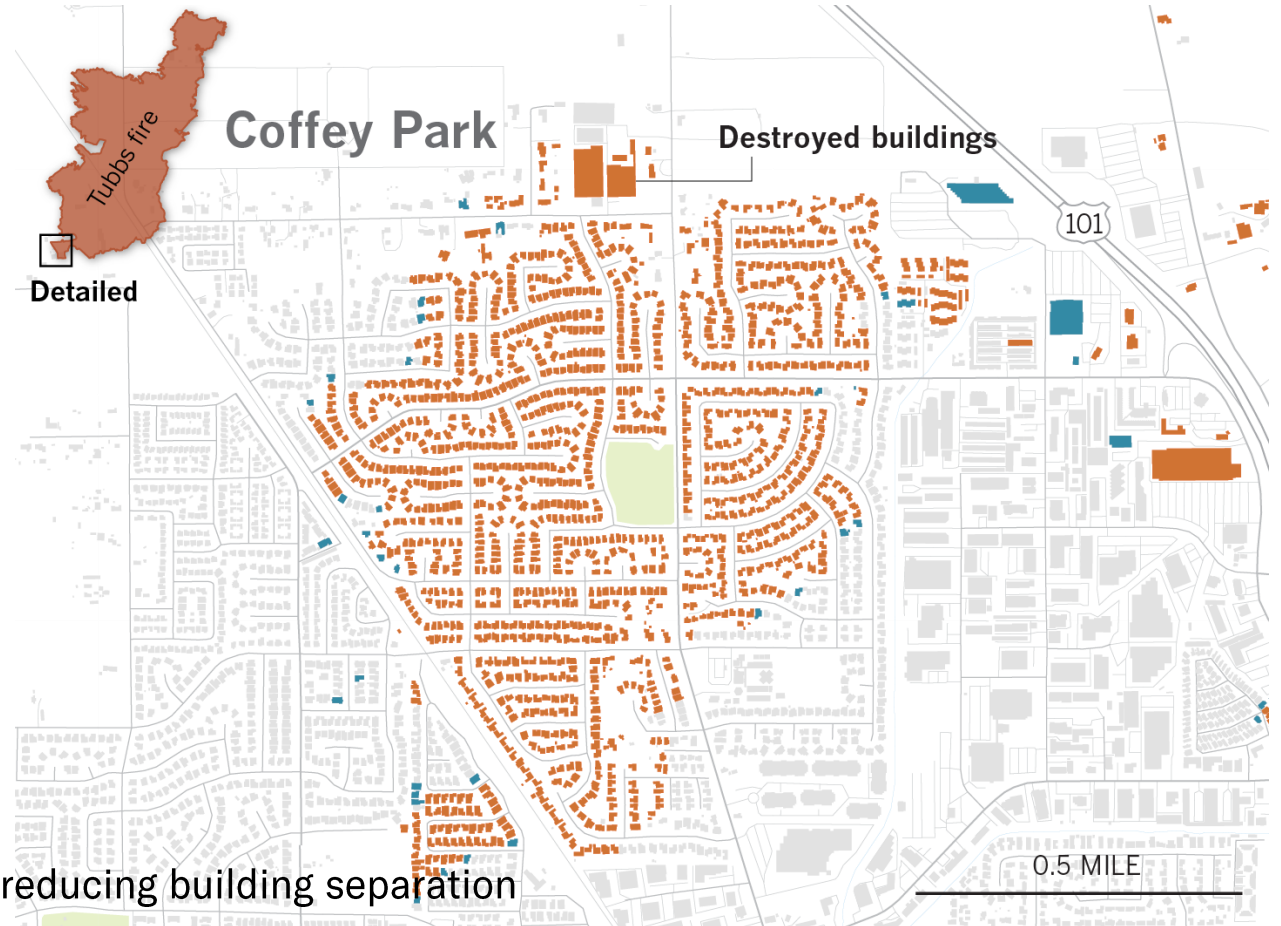
Function of:

- Population/Structure Density
- Extreme Weather
- Fuels
- Suppression assumptions

2 km

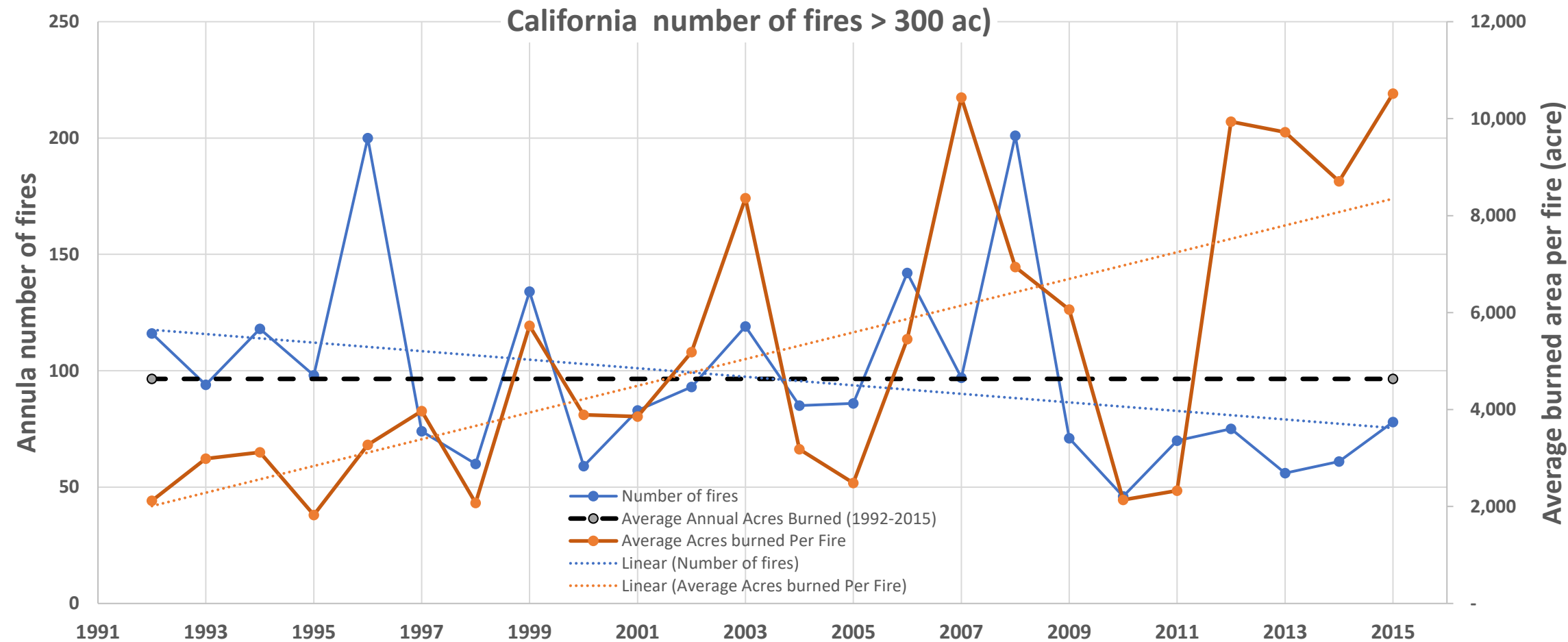
Modeled
conflagration
extent

October 2017 TUBBs Fire: Wildfire transitions into urban conflagration in Coffey Park, Santa Rosa



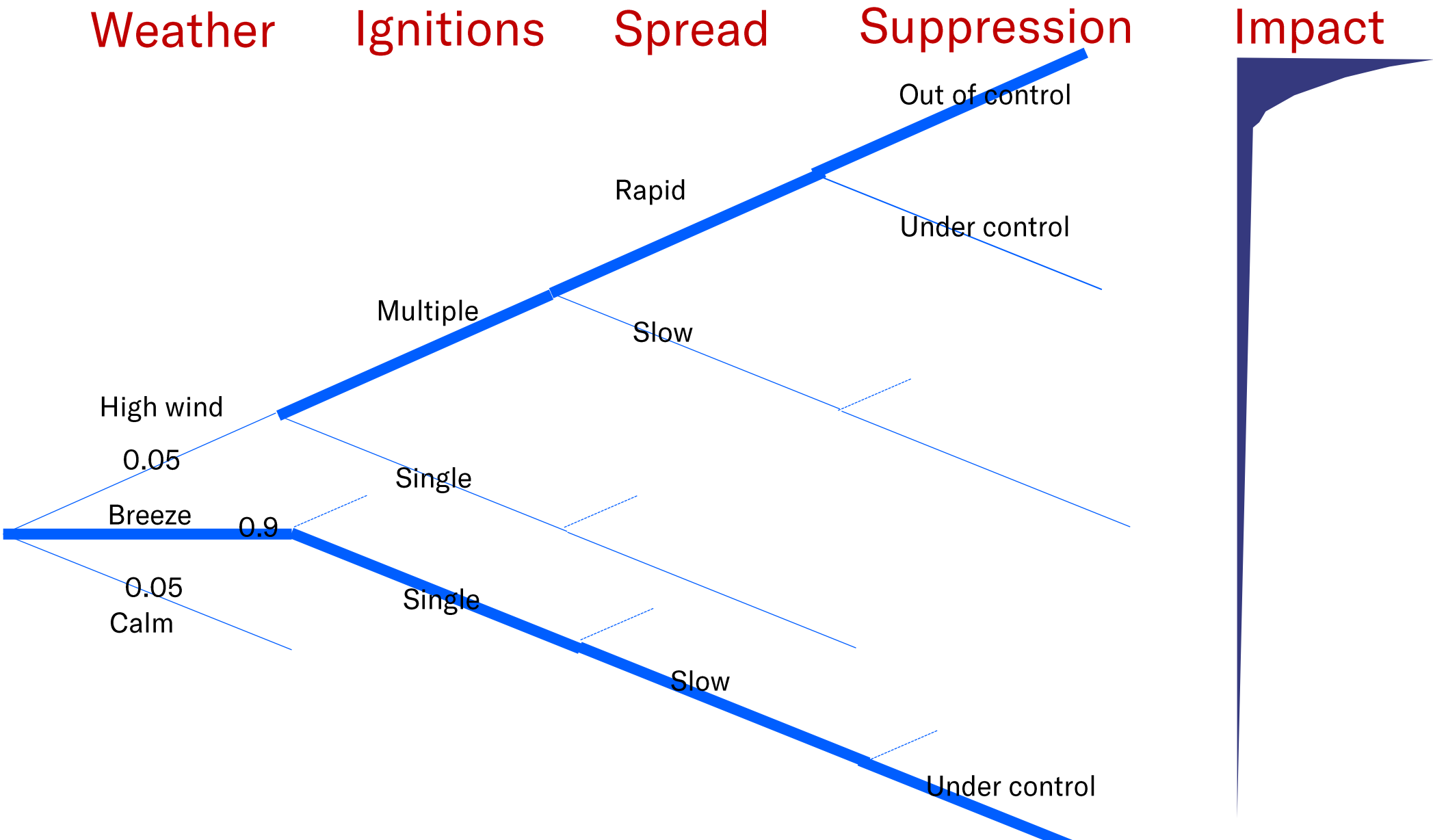
High land values mean buildings cover almost the whole plot, reducing building separation and raising the conflagration risk.

number v AREA of California FIRES



Source: Short, Karen C. 2017. Spatial wildfire occurrence data for the United States, 1992-2015, USDA Forest Service, Missoula Fire Science Laboratory

Fire-following windstorm logic tree



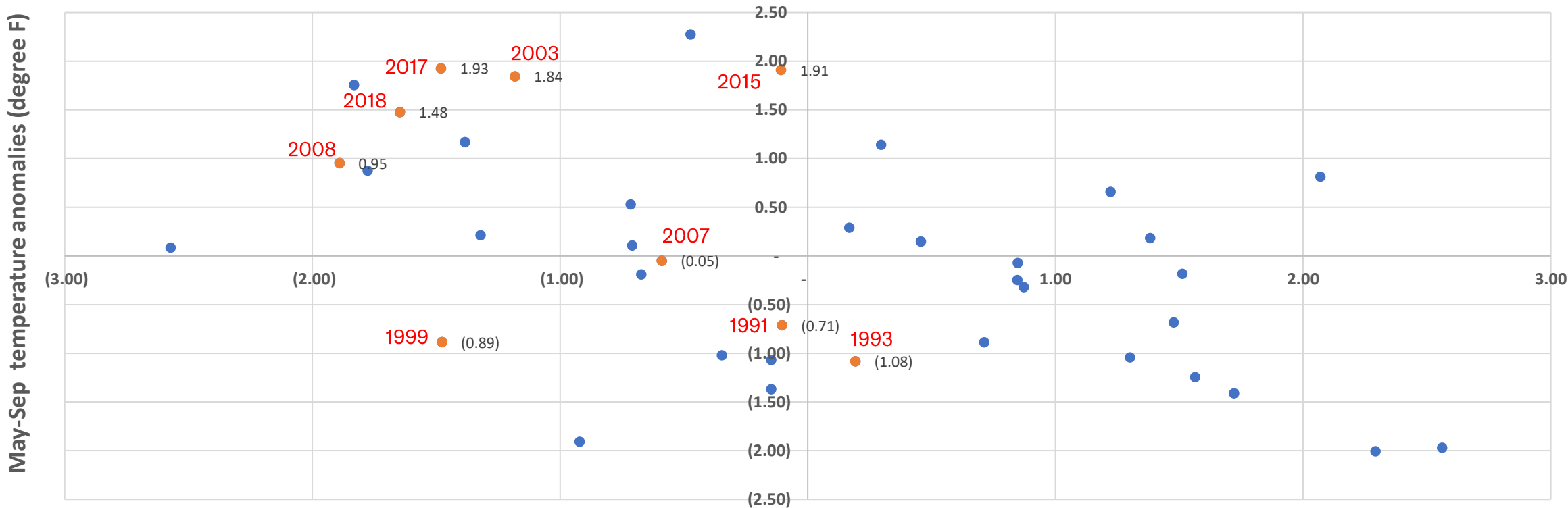
Years with loss > \$1B (may-oct) (anomalies vs 1980-2018)

1991,1993,1999, 2003, 2007, 2008, 2013, 2017, 2018

Dry, Hot

California

Wet, Hot



Dry, Cold

May-Oct precipitation anomalies (in)

Wet, Cold

Increasing precipitation volatility in twenty-first-century California

Daniel L. Swain^{1,2*}, Baird Langenbrunner^{3,4}, J. David Neelin³ and Alex Hall³

NATURE CLIMATE CHANGE | VOL 8 |
MAY 2018 | 427–433

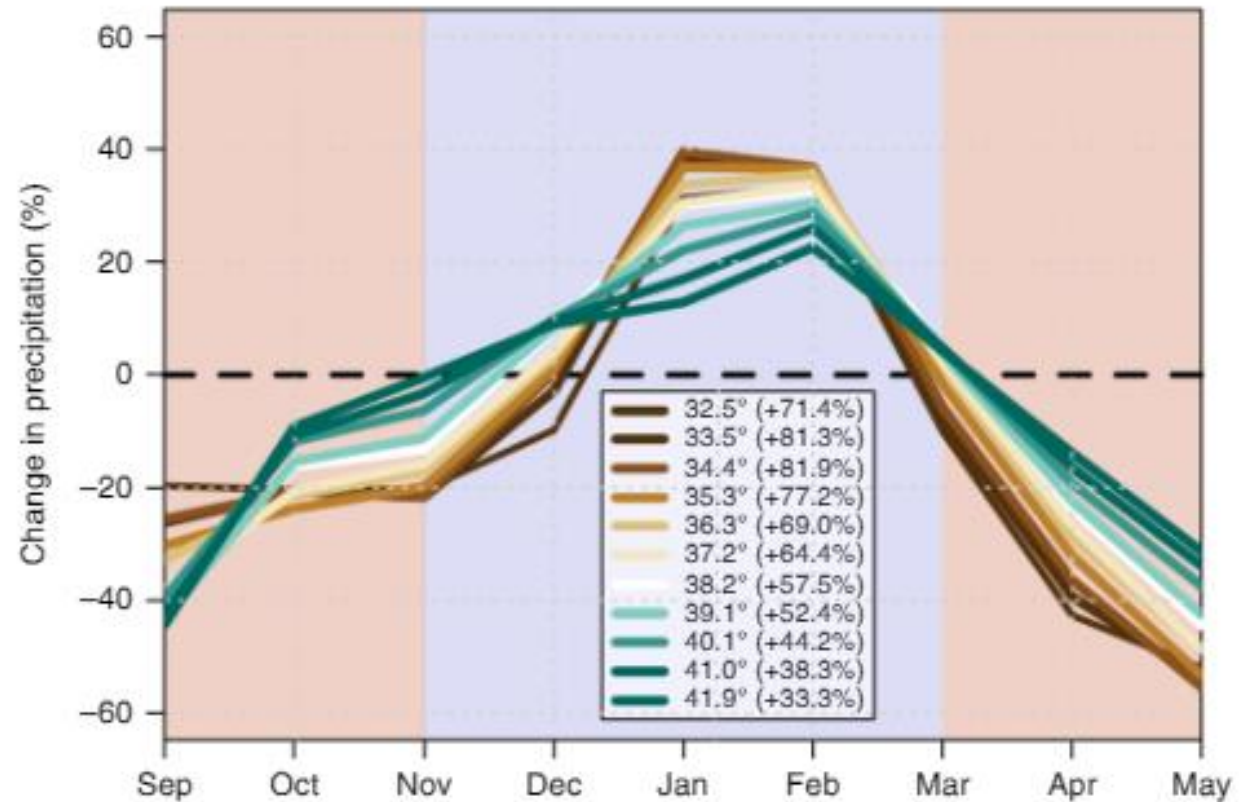
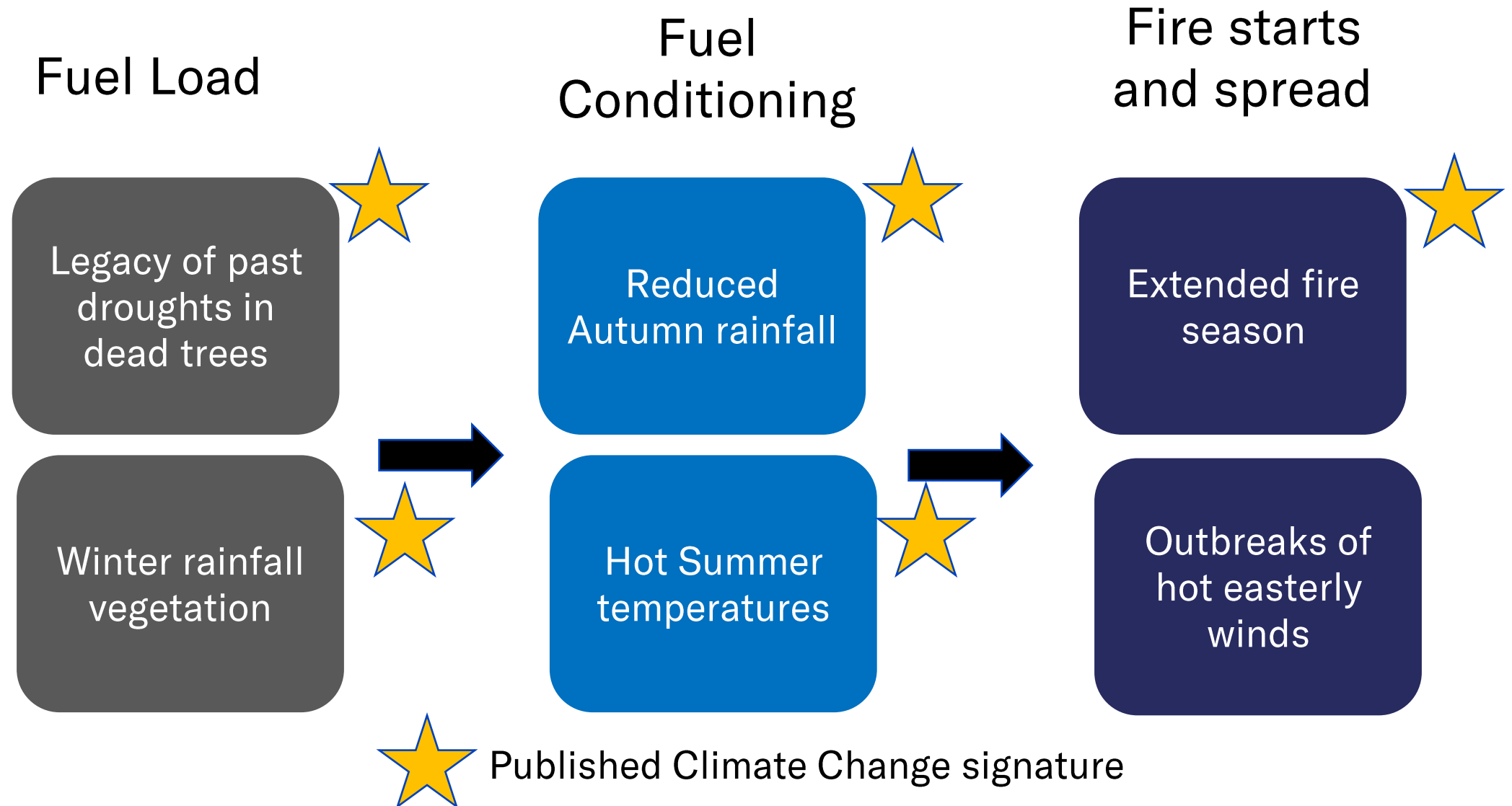


Fig. 5 | Shifts in precipitation seasonality. Relative changes in CESM-LENS monthly mean precipitation at the end of the twenty-first century

Climate change and wildfire – the accelerants



An aerial photograph of a residential neighborhood with many houses and trees. In the background, a large fire is burning on a hill, with thick black smoke rising into the sky. The fire is bright yellow and orange, contrasting with the dark smoke and the greenery of the neighborhood.

Exploring mitigation options using the risk model

Building code

Vegetation clearance

Neighbouring properties?

Utility equipment hardening?

Wind forecast power cuts?

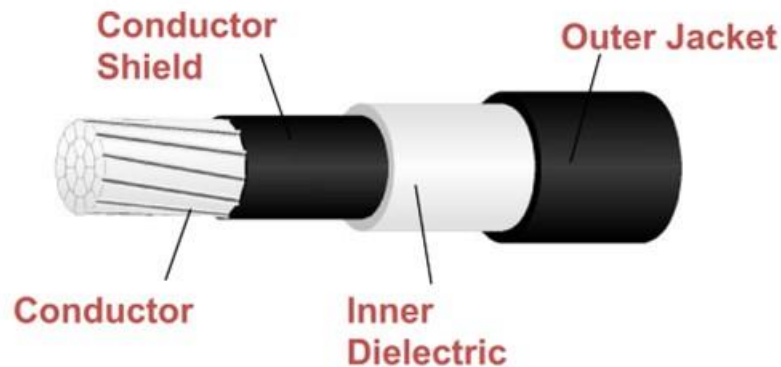
Learning from Partnerships with Utilities

- Utility companies investing Billions of \$ to harden their power networks
 - Prevent/reduce ignitions causing major wildfires
- Moody's RMS partnered with several Utility companies
 - To understand & evaluate impact of various mitigations
 - To help quantify risk reduction due to network hardening & PSPS

Spacer Cables



Covered Conductors

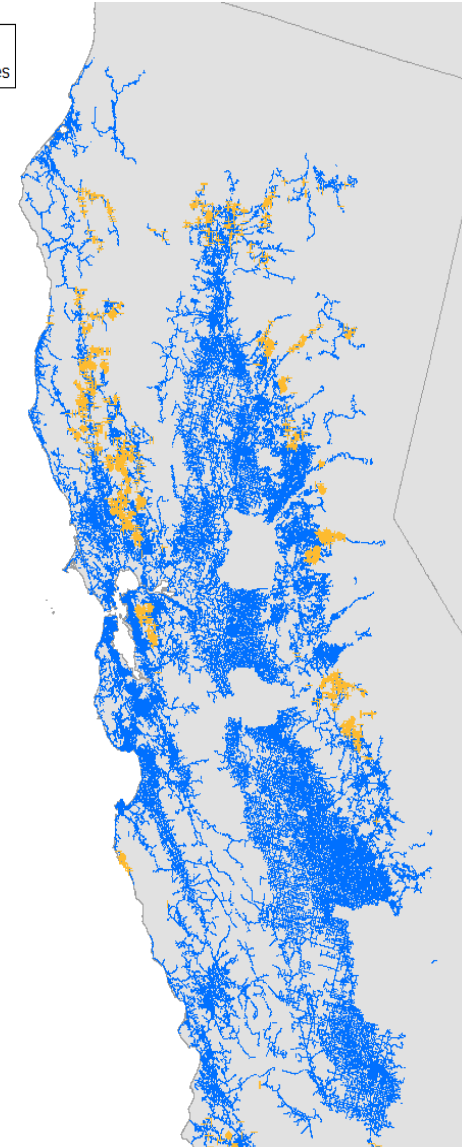


Tree Trimming



Public Safety Power Shut-off (PSPS)

Enhanced Powerline Safety System/Fast Curve

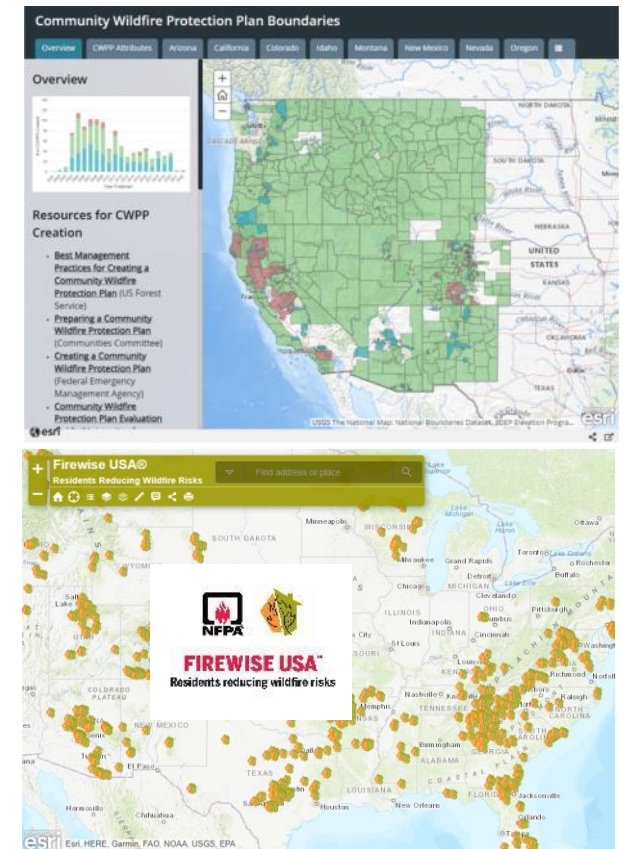


Community-level Preparedness

California DOI requires mandatory credit for community level mitigation

Some programs include:

- NFPA Firewise USA Program
- Fire Risk Reduction California
- Wildfire Adapted Partnership, Southwest Colorado Fire Adapted Communities



- Moody's is working closely with IBHS to understand future IBHS Wildfire Prepared Community and intended changes
- U.S. Wildfire HD Model v2.0 will include explicit consideration for community-level mitigation



Upper Deerwood Case Study

Applying the Moody's wildfire climate-conditioned catastrophe model to a high wildfire risk California suburb, Upper Deerwood (pictured below), the analysis explores present-day and future exposure to wildfire using loss cost and average annual loss (AAL) metrics under various Representative Concentration Pathways (RCPs). AAL, representing the average of potential losses in a given year, is a key metric in this analysis complemented by loss cost, which is defined as the average annual loss per \$1,000 insured coverage. In addition to exploring alternate RCPs and time horizons, different scenarios are considered, including the hardening of building structures and community expansion of defensible space to reduce proximal fuel and local burn probabilities. The climate change scenarios shown for the Upper Deerwood community are not necessarily representative of broader climate change impact estimates for Northern California or the United States. Variations in wildfire behavior, local and regional responses to climate change, and property vulnerability, including adherence to local building codes, can lead to differing climate risk outlooks depending on the location of an individual property or portfolio of properties.

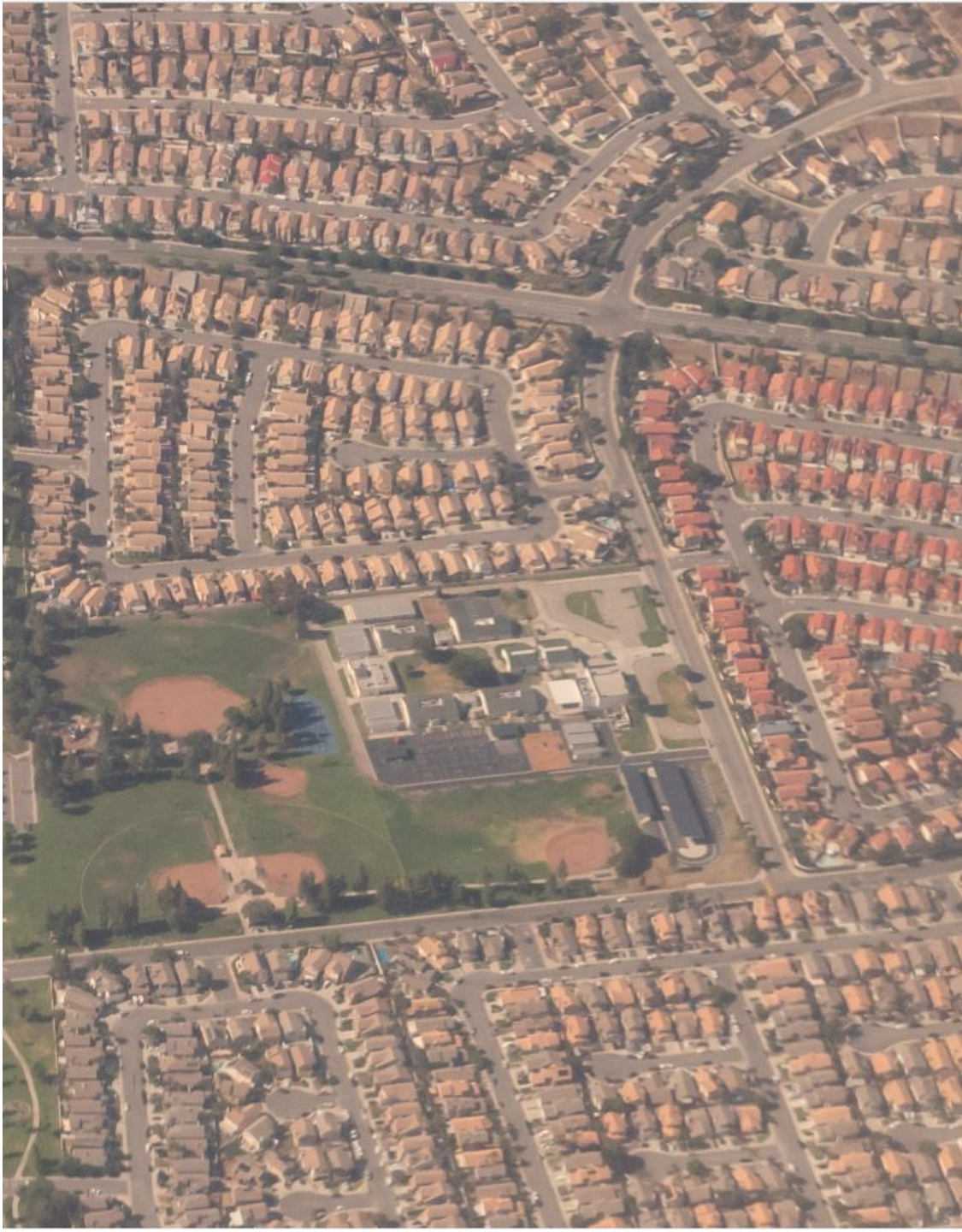


Figure 1. Upper Deerwood suburb pictured on the left in map view and aerial on

Upper Deerwood Loss Cost per \$1,000 Insured Value³

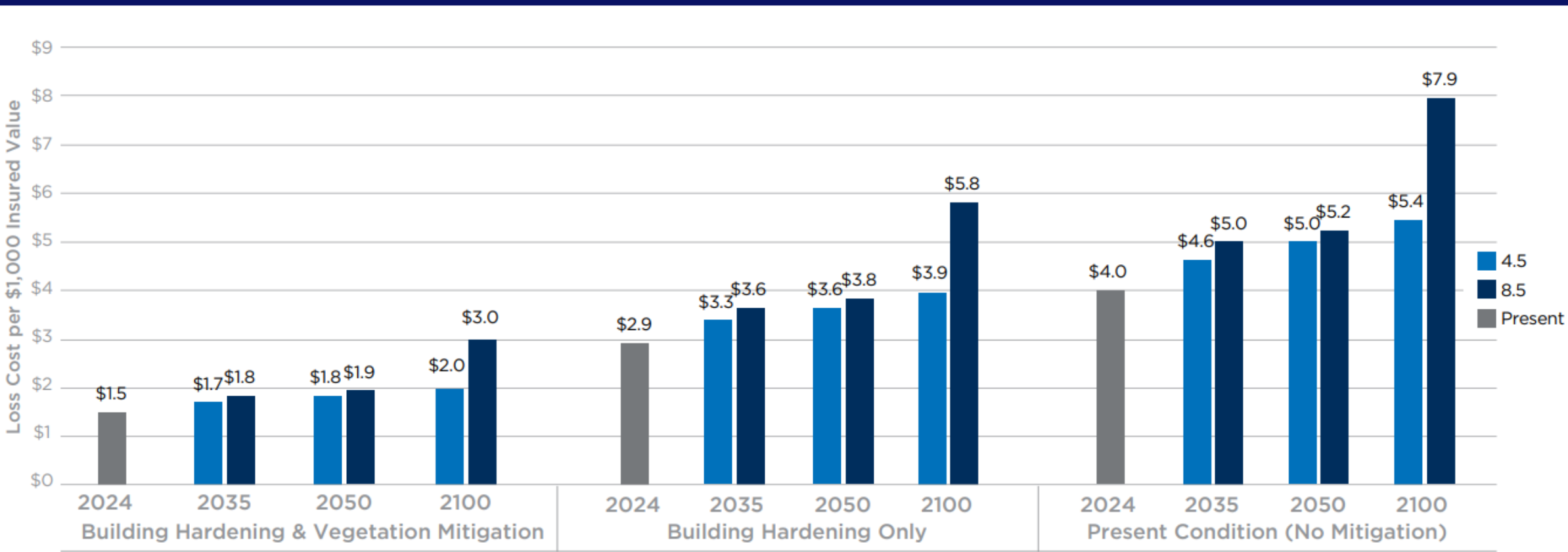


Figure 3: Shown left to right are increasingly less mitigated scenarios' plotted in terms of their loss cost per insured \$1000. Notional property values are assumed to be \$789,000 per property, with present day AAL under 2100 RCP 8.5 calculated to be \$10,931 per property.

² <https://www.rms.com/offer/wildfire-mitigation>

³ The climate risk metrics shown for the Upper Deerwood community are not necessarily representative of broader estimates for Northern California or the United States.

U.S. Wildfire risk trends - Summary

Wildfire Risk Still Evolving

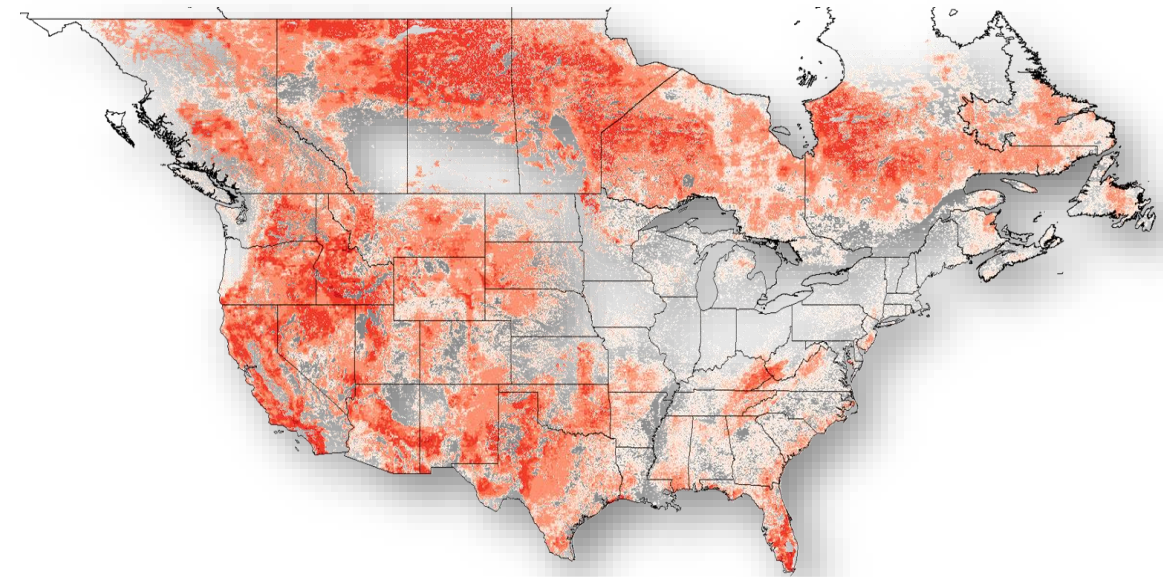
- **Non-stationary trends** in climate, fuel, fire behavior
- Climate Variability vs. **Climate Change** impact so far

Human Influence on Wildfire Hazard

- Ignitions (**PSPS & network hardening** impacts, awareness)
- **Fire suppression** (\$, preparedness)
- **Vegetation management** & tree mortality
- **Exposure** growth (WUI re-zoning)

Changing Market Forces

- Community & property-level **mitigation**
- **Regulatory measures** expanding coverage
- Coverage affordability, **under-insurance**, rising costs



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