NAIC NATIONAL MEETING SUMMER 2021

Date: 7/2/21

Virtual Meeting
(in lieu of meeting at the 2021 Summer National Meeting)

CATASTROPHE RISK (E) SUBGROUP
Thursday, July 15, 2021
11:00 a.m. – 12:00 p.m. ET / 10:00 – 11:00 a.m. CT / 9:00 – 10:00 a.m. MT / 8:00 – 9:00 a.m. PT

ROLL CALL

Wanchin Chou, Chair	Connecticut	Halina Smosna	New York
Robert Ridenour, Vice Chair	Florida	Tom Botsko	Ohio
Laura Clements	California	Andrew Schallhorn	Oklahoma
Judy Mottar	Illinois	Will Davis	South Carolina
Gordon Hay	Nebraska	Miriam Fisk	Texas
Anna Krylova	New Mexico		

NAIC Support Staff: Eva Yeung

AGENDA

1. Consider Adoption of its June 1 and April 26 Minutes—*Wanchin Chou (CT)* — Attachment 1

2. Discuss its Working Agenda Items—*Wanchin Chou (CT)* — Attachment 2

3. Hear an Update from the Catastrophe Model Technical Review Ad Hoc Group —*Wanchin Chou (CT) and Halina Smosna (NY)*

4. Hear Presentation from AIR Worldwide Regarding Wildfire in the Western United States—*Jeffery S. Amthor, Ph.D. (AIR)* — Attachment 3

5. Discuss Any Other Matters Brought Before the Subgroup—*Wanchin Chou (CT)*

6. Adjournment

W:\National Meetings\2021\Summer\Agenda\tf\capadequacy\pcrbc\071521 cat risk agenda.docx

This page intentionally left blank.

Draft: 6/15/21

Catastrophe Risk (E) Subgroup
Virtual Meeting
June 1, 2021

The Catastrophe Risk (E) Subgroup of the Property and Casualty Risk-Based Capital (E) Working Group of the Capital Adequacy (E) Task Force met June 1, 2021. The following Subgroup members participated: Wanchin Chou, Chair (CT); Robert Ridenour, Vice Chair (FL); Laura Clements, Giovanni Muzzarelli, and Lynne Wehmueller (CA); Judy Mottar (IL); Gordon Hay (NE); Anna Krylova (NM); Halina Smosna and Sak-man Luk (NY); Tom Botsko (OH); Andrew Schallhorn (OK); and Miriam Fisk, Rebecca Armon and Monica Avila (TX).

1. Forwarded the Response to a Request for Proposed Changes to the P/C RBC Catastrophe Component

Mr. Chou said the Subgroup exposed the response to a request for proposed changes to the catastrophe risk component for a 30-day public comment period during its April 26 meeting. He stated that the Subgroup received no comments during the exposure period. Mr. Chou said the purpose of this response is to inform the Climate and Resiliency (EX) Task Force that due to the limited resources of the Subgroup, it is currently only focusing on developing the risk charge for the wildfire peril. However, the Subgroup plans to discuss the additional peril like flood when the models become more mature and with better underlined statistic in the future.

Ms. Clements made a motion, seconded by Ms. Mottar, to forward the response to the Climate and Resiliency (EX) Task Force. The motion passed unanimously.

2. Heard an Update from its Catastrophe Model Technical Review Ad Hoc Group

Ms. Wehmueller said the ad hoc group met on May 10 to: 1) discuss data input and financial impact questions and responses; 2) review questions for model assumptions; and 3) discuss a referral letter from the Subgroup. She stated that some of the responses from AIR to the wildfire model questions posed by the ad hoc group were quite comprehensive and explanatory, while others were limited and require follow-up. Ms. Wehmueller also said the questions posed by the ad hoc group covered all components of the wildfire model generation, including hazard, vulnerability and financial modules, as well as some general questions about the model inputs, updates, model strengths and opportunities for improvement. She said the ad hoc group noticed that a reference document of data sources for the model inputs provided by AIR indicated different data inputs were based on different time periods and levels of resolution. In addition, Ms. Wehmueller said the Subgroup and its ad hoc group will need to work with the NAIC Legal department to establish a data use agreement between them and AIR. Moreover, she stated that Mr. Chou urged the ad hoc group members to review the AIR wildfire model documentation and provide additional technical question for AIR during the last ad hoc group meeting. Lastly, she said Mr. Chou asked every member of the ad hoc group to review and provide comments for the response to a request for proposed changes to the property/casualty (P/C) risk-based capital (RBC) catastrophe component.

Mr. Chou said the data use agreement has been set up; it allows the ad hoc group to share data via closed meetings. He also stated that additional questions provided by the ad hoc group members were received last week. Mr. Chou said he plans to discuss and finalize all the question by the upcoming ad hoc group meeting to ensure AIR has enough time to respond by the Subgroup's next meeting.

3. Discussed the Possibility of Allowing Additional Third-Party Models or Adjustments to the Vendor Models

Mr. Chou said the Subgroup discussed the working agenda item to evaluate the possibility of allowing additional third-party models or adjustments to the vendor models to calculate the catastrophe model losses during the last virtual meeting. He stated that the Subgroup discussed the possibility of modifying the PR027 catastrophe risk instructions to accommodate the three different kinds of catastrophe (CAT) models that deviate from the vendor models: 1) internal CAT models; 2) vendor CAT models with adjustments or different weight; and 3) derivative models based on the vendor models. Mr. Chou asked the Subgroup members and interested parties to discuss: 1) the appropriateness to categorize the internal CAT models and derivative models based on the vendor models as internal models and vendor CAT models with adjustments or different weight as a modified vendor models; and 2) modifying the PR027 instructions based on the discussion. Mr. Botsko commented that the Subgroup should consider the following issues while discussing this item: 1) resource limitation from the state to review the internal models; and 2) how to validate the immature models. Ralph Blanchard (Travelers) asked the Subgroup to review

the current treatment of the second category—vendor CAT models with adjustments or different weight consistent with the current instructions. Scott Williamson (Reinsurance Association of America—RAA) said he thinks that the current PR027 instruction has addressed the treatment of the second category of the model. However, he asked the Subgroup to consider: 1) how to handle the proprietary type of models; and 2) developing a process for approving proprietary models. Mr. Chou said this is a complicated subject and that the Subgroup will take time to discuss during upcoming meetings.

Mr. Chou said the Subgroup will schedule another meeting in July to continue discussing all the outstanding issues.

Having no further business, the Catastrophe Risk (E) Subgroup adjourned.

W:\National Meetings\2021\Summer\TF\CapAdequacy\PCRBC\Att01_06-01propertycatsg.doc

Draft: 4/28/21

Catastrophe Risk (E) Subgroup
Virtual Meeting
April 26, 2021

The Catastrophe Risk (E) Subgroup of the Property and Casualty Risk-Based Capital (E) Working Group of the Capital Adequacy (E) Task Force met April 26, 2021. The following Subgroup members participated: Wanchin Chou, Chair, and Susan Andrews (CT); Robert Ridenour, Vice Chair (FL); Laura Clements, Giovanni Muzzarelli, Mitra Sanandajifar and Lynne Wehmueller (CA); Judy Mottar (IL); Gordon Hay (NE); Anna Krylova (NM); Gloria Huberman, Halina Smosna and Sak-man Luk (NY); Tom Botsko (OH); Andrew Schallhorn (OK), Will Davis (SC); and Miriam Fisk and Monica Avila (TX).

1. Exposed the Response to a Request for Proposed Changes to the P/C RBC Catastrophe Component

Mr. Chou said the Subgroup received a referral letter from the Climate and Resiliency (EX) Task Force on March 15. He said the Task Force recommended the Subgroup to consider: 1) expanding the current catastrophe framework to include other perils such as wildfire, flood and/or convection storms that may experience a greater tail risk under projected climate-related trends; 2) implementing two perils in the risk-based capital (RBC) framework by year-end 2022 if possible; 3) revising the current criteria for all commercial modelers that are allowed to be used; and 4) ensuring all modeling information is documented and made available to NAIC staff and lead state regulators.

Mr. Chou said a response to the referral letter was drafted earlier. It stated that the Subgroup is focusing on developing the risk charge for the wildfire peril only due to the limited resources and modeling information for other perils. He said the Subgroup plans to discuss the additional perils such as flood when the model becomes more mature with better underlying statistics in the near future. Mr. Chou also indicated that the Subgroup is only the assessor, not the reviewer of the model. However, he said the Subgroup will take the appropriate time and steps to understand the models and assign an appropriate charge to each additional peril. Mr. Chou asked all the interested parties to review the draft response and submit comments during the exposure period. Any received comments will be discussed during an upcoming meeting.

The Subgroup agreed to expose the response to a request for proposed changes to the property/casualty (P/C) RBC catastrophe component for a 30-day public comment period ending May 25.

2. Heard an Update from its Catastrophe Model Technical Review Ad Hoc Group

Mr. Chou said an ad hoc group to conduct a more in-depth review on different wildfire models was established earlier this month. He emphasized that the goal of this ad hoc group is not trying to approve the models. Rather, it is to perform a more in-depth technical study of different model assumptions, limitations and impact analysis in the upcoming months and ultimately provide a proper risk charge recommendation to the Subgroup for consideration. Ms. Smosna said the ad hoc group met for the first time early this month to discuss: 1) the development history of the current earthquake and hurricane risk charges; and 2) the possibility of developing an action plan to achieve phase 2 through phase 4 of wildfire model review phases. She also stated that the ad hoc group thinks that gaining some understanding on Florida's catastrophe modeling approval process will be a good starting point to address this issue.

Mr. Ridenour said the Florida Commission on Hurricane Loss Projection Methodology (Florida Commission) establishes standards for model review every two years. Its hurricane loss projection methodology is based on certain switches being applied and a specific version of the model. He also stated that the Florida Commission approval process is only used in Florida; it is not something approved for NAIC purposes. Mr. Chou finally said that the ad hoc group will meet once a month until a proper wildfire charge is developed. He encouraged all interested parties to submit comments or questions to the ad hoc group for further discussion.

3. Discussed the Possibility of Allowing Additional Third-Party Models or Adjustments to the Vendor Models

Mr. Chou said the working agenda item to evaluate the possibility of allowing additional third-party models or adjustments to the vendor models to calculate the catastrophe model losses was created in December 2019. He stated that the Subgroup discussed three different kinds of catastrophe (CAT) models that deviate from the vendor models: 1) internal CAT models; 2) vendor CAT models with adjustments or different weight; and 3) derivative models based on the vendor models at the Spring National Meeting.

Scott Williamson (Reinsurance Association of America—RAA) commented that the Subgroup should consider developing a basic approval process if the Subgroup decided to rely on models in order to ensure the use of models are consistent and comparable across companies. Ralph Blanchard (Travelers) said Subgroup decided earlier that a company should use the same data, modeling and assumptions that the insurer uses in its own internal catastrophe risk management process. Mr. Chou said unlike earthquake and hurricane models, wildfire models do not have consistent assumptions and switches. The Subgroup will need to take the appropriate time and steps to understand them. Mr. Chou said that valuable information will be able to assist the Subgroup on developing the instructions in the future. He then encouraged all the interested parties to provide input on revising the RBC catastrophe risk charge instructions on PR027.

Mr. Chou said the Subgroup will schedule another meeting in May to continue discussing all the outstanding issues.

Having no further business, the Catastrophe Risk (E) Subgroup adjourned.

W:\National Meetings\2021\Summer\TF\CapAdequacy\PCRBC\Att01_04-26propertycatsg.doc

CAPITAL ADEQUACY (E) TASK FORCE
WORKING AGENDA ITEMS FOR CALENDAR YEAR 2021

2021 #	Owner	2021 Priority	Expected Completion Date	Working Agenda Item	Source	Comments	Date Added to Agenda
				Carry-Over Items Currently being Addressed – P&C RBC			
9	Cat Risk SG	1		Continue development of RBC formula revisions to include a risk charge based on catastrophe model output:			
			Year-end 2022 or later	a) Evaluate other catastrophe risks for possible inclusion in the charge - determine whether to recommend developing charges for any additional perils, and which perils or perils those should be.	Referral from the Climate and Resiliency Task Force. March 2021	4/26/21 - The SG expose the referral for a 30-day exposure period. **6/1/21 - The SG forwarded the response to the Climate and Resiliency Task Force.**	4/26/2021
14	Cat Risk SG	1	Year-end **2022** or later	Evaluate the possibility of allowing additional third party models or adjustments to the vendor models to calculate the cat model losses		**7/15/21 - The SG is continue evaluating this item.**	12/6/2019
17	Cat Risk SG	1	2021 Spring Meeting	Modify instructions to PR027 Interrogatories that clarify how insurers with no gross exposure to earthquake or hurricane should complete the interrogatories		10/27/20 - expose the propsal for 30 day comment period **3/8/21 - The SG adopted the proposal 2020-08-CR at the Spring National Meeting.**	10/19/2020
~~18~~	~~P&C RBC WG/Cat Risk SG~~	~~1~~	~~2021 Spring Meeting~~	~~Remove the embedded 3% operational risk component contained in the reinsurance contingent credit risk factor of Rcat~~		~~10/27/20 - expose the propsal for 35 day comment period~~ **3/8/21 - The SG and P/C RBC WG adopted the proposal 2020-11-CR at the Spring National Meeting.**	~~10/27/2020~~
19	Cat Risk SG	1	2022 Spring Meeting or later	Implement Wildfire Peril in the Rcat component (For Informational Purpose Only)		**7/15/21 - The SG is continue studying this item.**	3/8/2021

W:\QA\CADTF\ Working Agenda 2021 as of 04/29/2021xls

This page intentionally left blank.

Wildfire in the Western United States

Jeffrey S. Amthor, Ph.D.
AIR Worldwide

AIR

Wildfires (aka wildland fires)

420,000,000 years … and counting

- Charcoal in fossil records
- ‘Shortly’ after appearance of land plants
- First **forests** developed 380,000,000 years ago
- Fire ‘amount’ related to atmospheric oxygen concentration (in range of 13–35%)

[Reviewed by A.C. Scott & I.J. Glasspool (2006) Proc. Natl. Acad. Sci. 103, 10861]

AIR

Recent development: Wildland-Urban Interface (WUI)

"The Wildland-Urban Interface (WUI) is defined as the **location where structures and [human] communities meet or intermingle with undeveloped wildland.**"

[National Institute of Standards and Technology, U.S. Dept. of Commerce]

"The wildland urban interface is an area where **human made structures and infrastructure…are in or adjacent to areas prone to wildfire**."

[National Research Council (2011)]

AIR

Wildland-Urban Interface (WUI)

Human development in the WUI

- Increases number of fires: more people → more fires (to a point)
- Increases risk to lives and structures **per fire**: exposure higher
- Has been rapid in recent decades, and is expected to remain rapid

U.S. WUI	1990	2010	Change
Houses	30,800,000	43,400,000	+41 %
Land area (km^2)	581,000	770,000	+33 %

[*Source:* Radeloff *et al*. (2018) *Proceedings of the National Academy of Sciences* 115: 3314-3319]

AIR

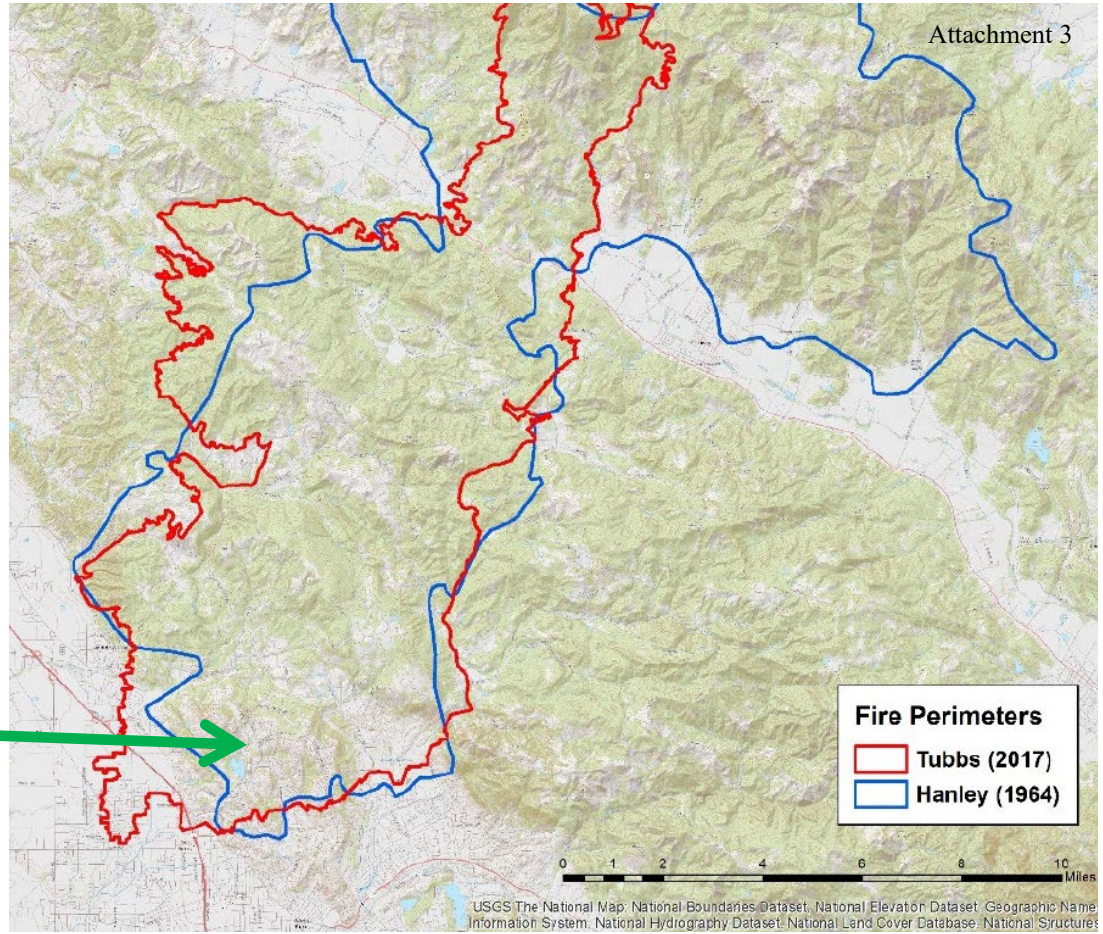
“Same” fire, different time

Hanley Fire (1964)

- Inconsequential (to humans) — no houses

Tubbs Fire (2017)

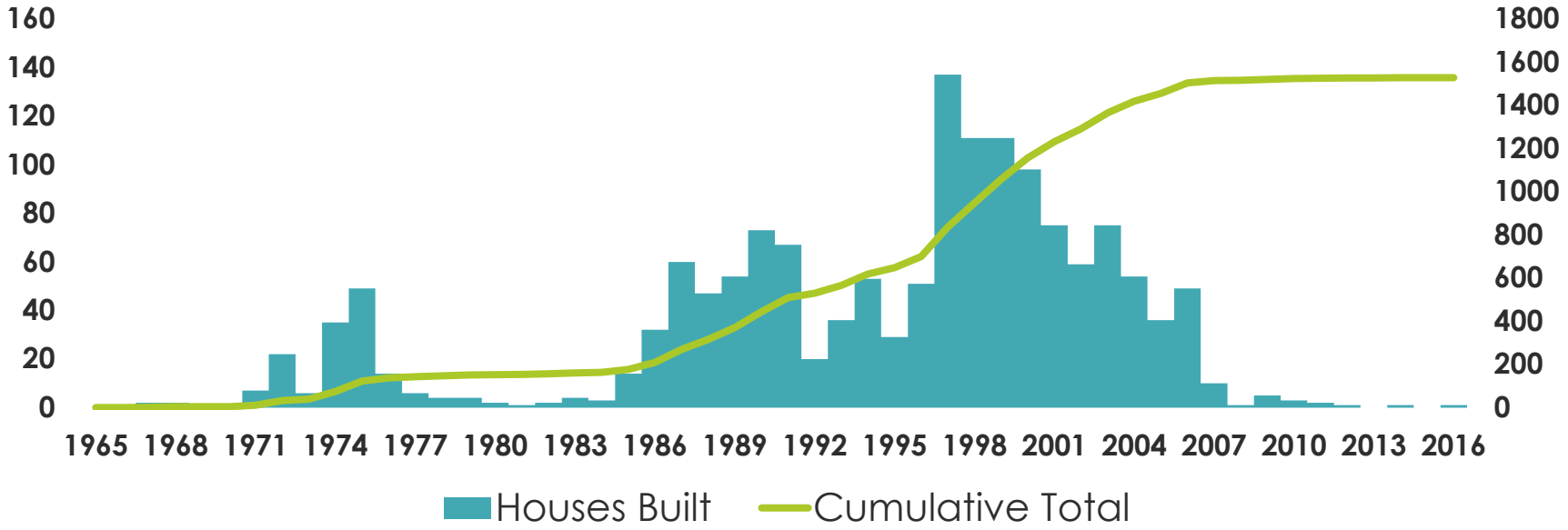
- **Second** most destructive fire in California history
- **Fourth** most deadly
- Burned Fountaingrove area of Santa Rosa (north of San Francisco)
- ‘Hurricane-force’ winds



AIR

The hazard existed in 1964; the risk came later

Houses built in Fountaingrove, 1965–2016



[*Data source:* Sagara & Kanik (2018) *Built to burn*. revealnews.org/article/built-to-burn/]

AIR

Development in previous fire footprints: many examples

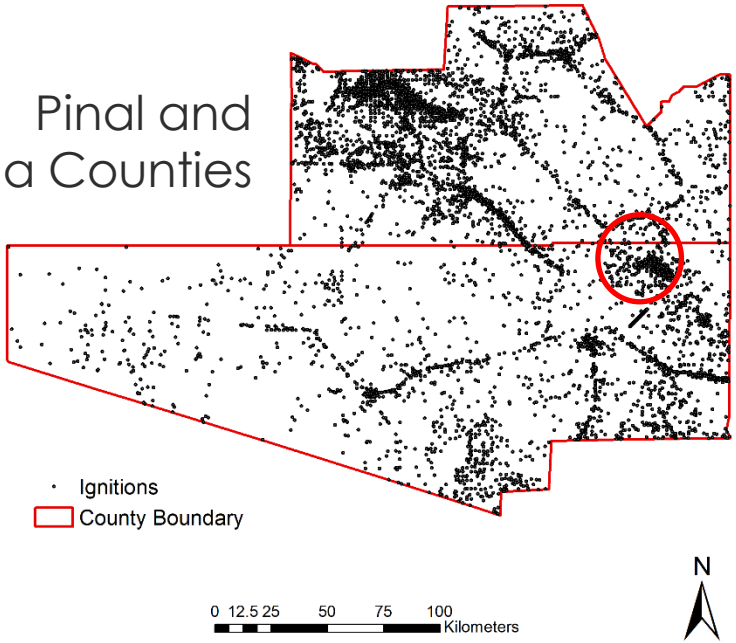
Perimeter of 1993 SoCal wildfire, with significant development afterward

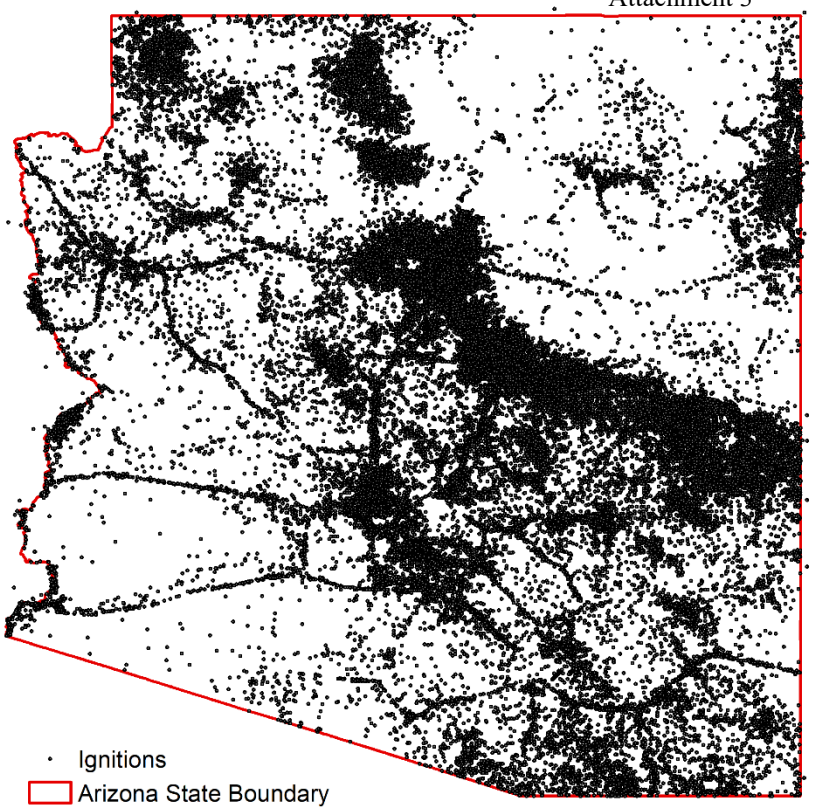
- Will "same" fire re-occur?
- Would/will it be prevented or suppressed?

AIR

Humans and wildfire ignitions often co-located

Pinal and Pima Counties





Data Source: Short, Karen C. 2017. Spatial wildfire occurrence data for the United States, 1992-2015 [FPA_FOD_20170508]. 4th Edition. Fort Collins, CO: Forest Service Research Data Archive. https://doi.org/10.2737/RDS-2013-0009.4

Fire Occurrence Database

71,586 ignitions (1992–2015)

Even where human impacts are obvious…dry lightning

Top (south): **Bighorn Fire** Cause: **lightning** (10 PM 6/5/20), Santa Catalina Mountains, **120,000 acres burned**

Illegal drone flights in area halted aircraft suppression, possibly resulting in increased area burned

Bottom (north): **Tortolita Fire** Cause: **lightning** (9 PM 6/5/20), Tortolita Mountains, **3,140 acres burned**

Photo taken morning 6/9/20 looking SSE

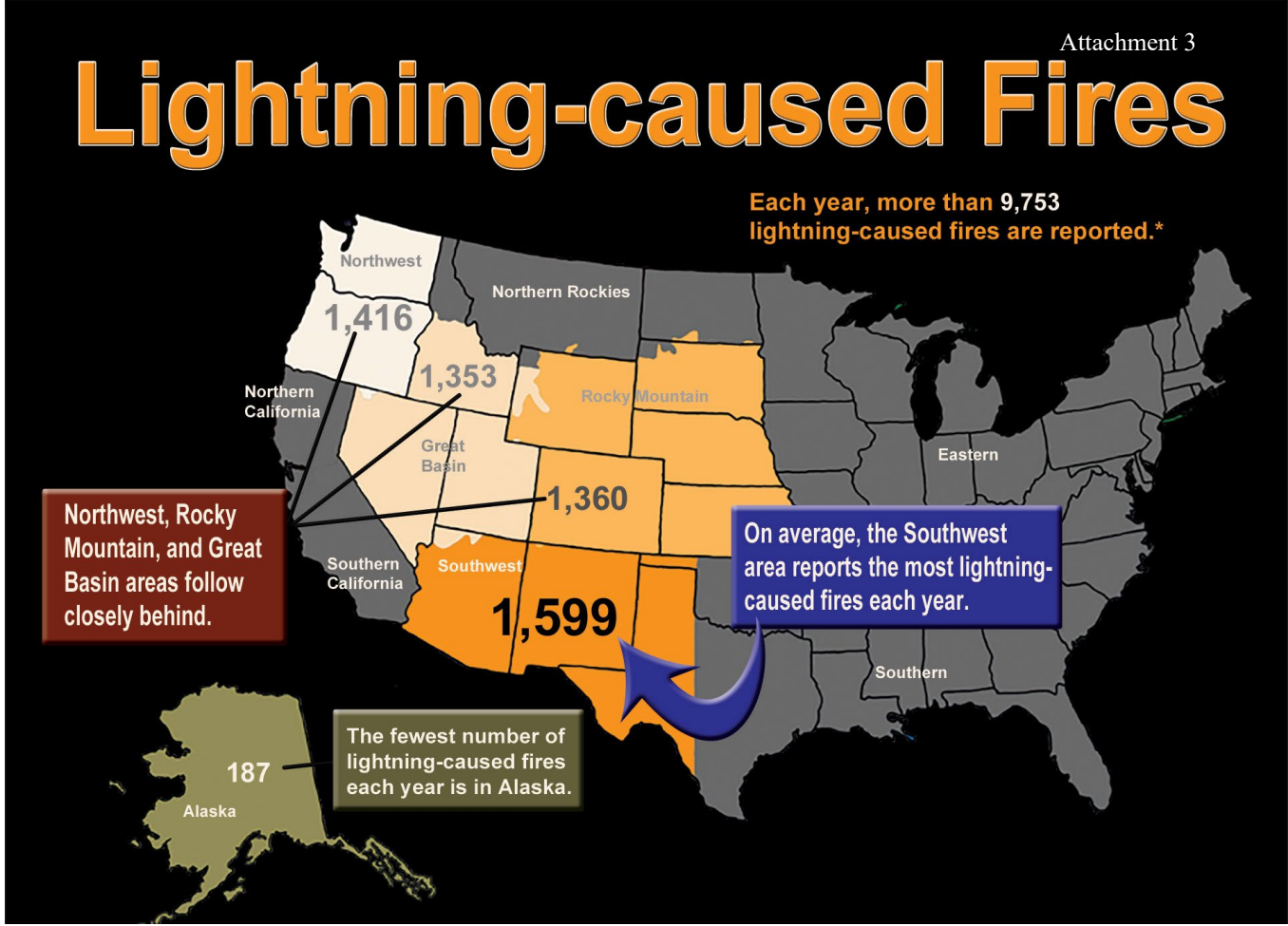
InciWeb-Incident Information System [inciweb.nwcg.gov]

AIR

Fraction of U.S. wildfires during 2001–2019: 14%

Fraction of area burned: 60%

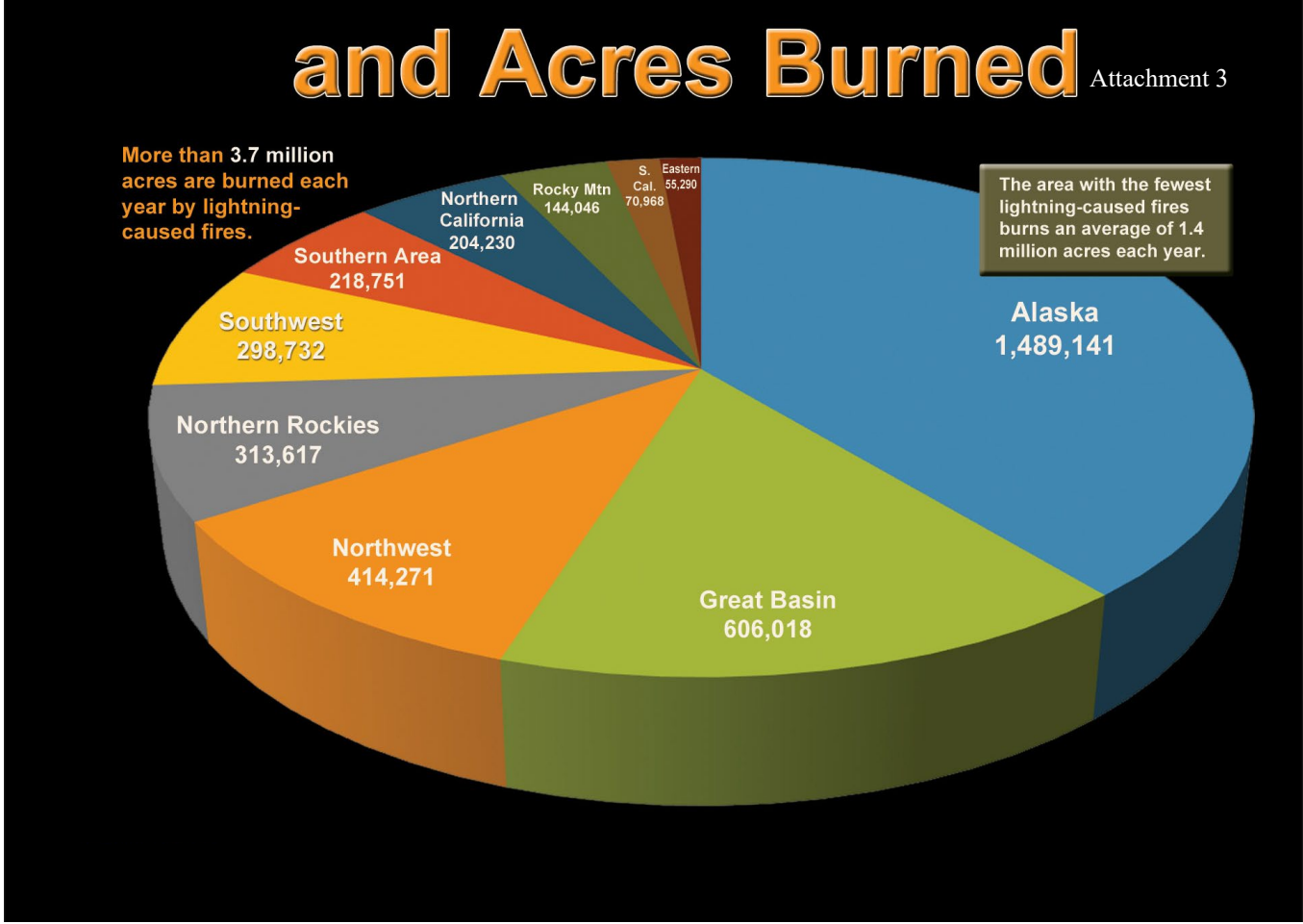
Note small **number** of lightning-caused fires in Alaska



[Image source: National Interagency Fire Center]

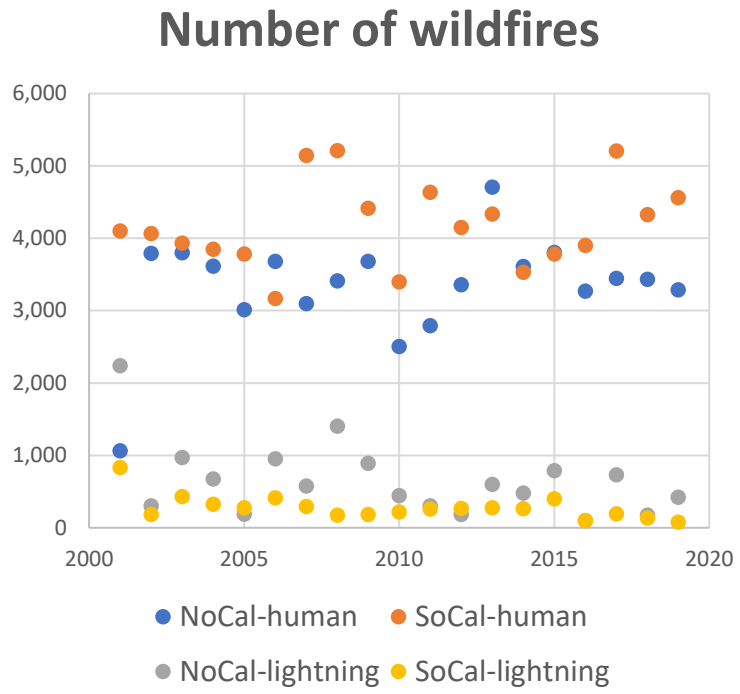
Lightning-caused fires are large in lightly populated regions

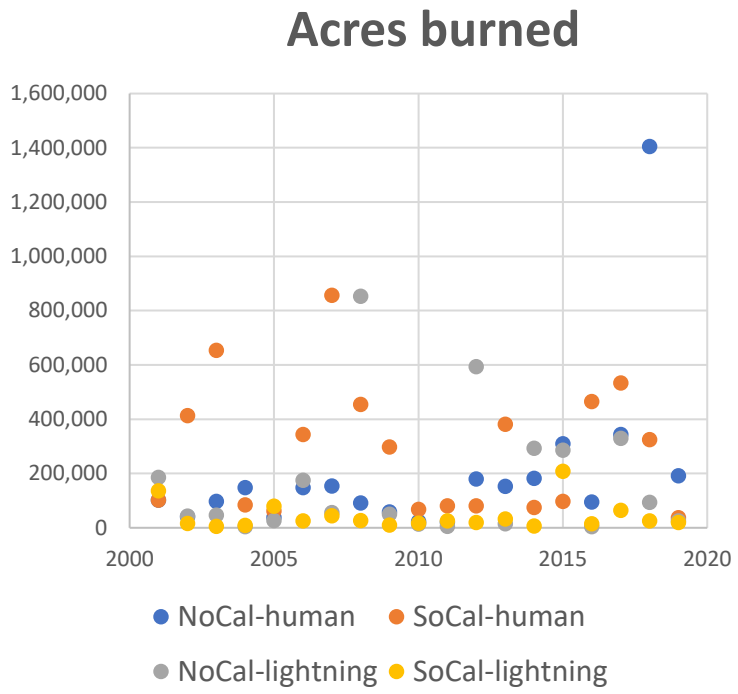
Area burned does not generally correspond to property loss



[Image source: National Interagency Fire Center]

Recent California wildfires: lightning *vs.* human-caused

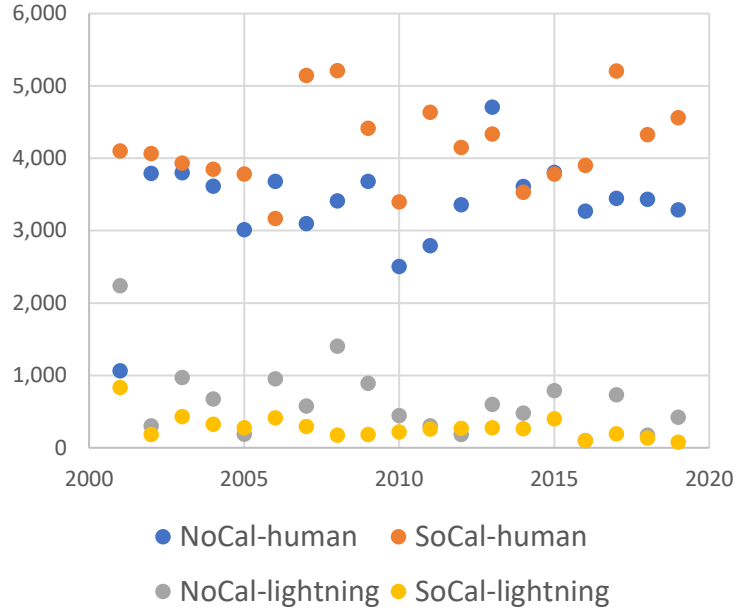




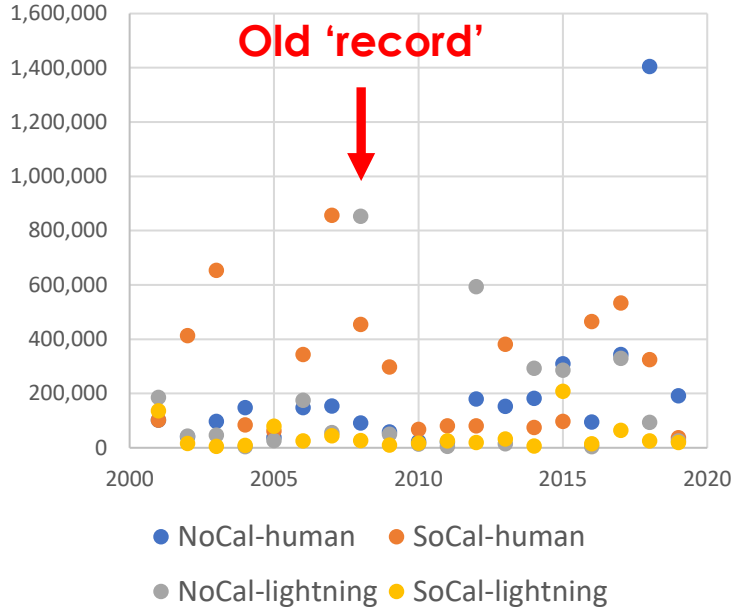
Recent California wildfires: lightning *vs.* human-caused

Then there was 2020: more than 2,000,000 NoCal acres burned in lightning-caused fires

Number of wildfires



Acres burned



AIR

Forest structure in Bitterroot National Forest **1909**

Prior to aggressive Forest Service fire suppression

Fire scars in trees indicated fire return period of about 7 years (average in the period 1600–1900)

U.S. Forest Service

Forest structure in Bitterroot National Forest **1979**

Attachment 3

Same camera location after 70 years of fire exclusion

Much greater potential for hot, intense fire

U.S. Forest Service

Human-introduced invasive species, e.g., buffelgrass

Normally sparse vegetation

- Gaps filled w/buffelgrass
- Highly flammable
- Greater fire intensity can kill Saguaro, which normally sees cooler fires

National Park Service

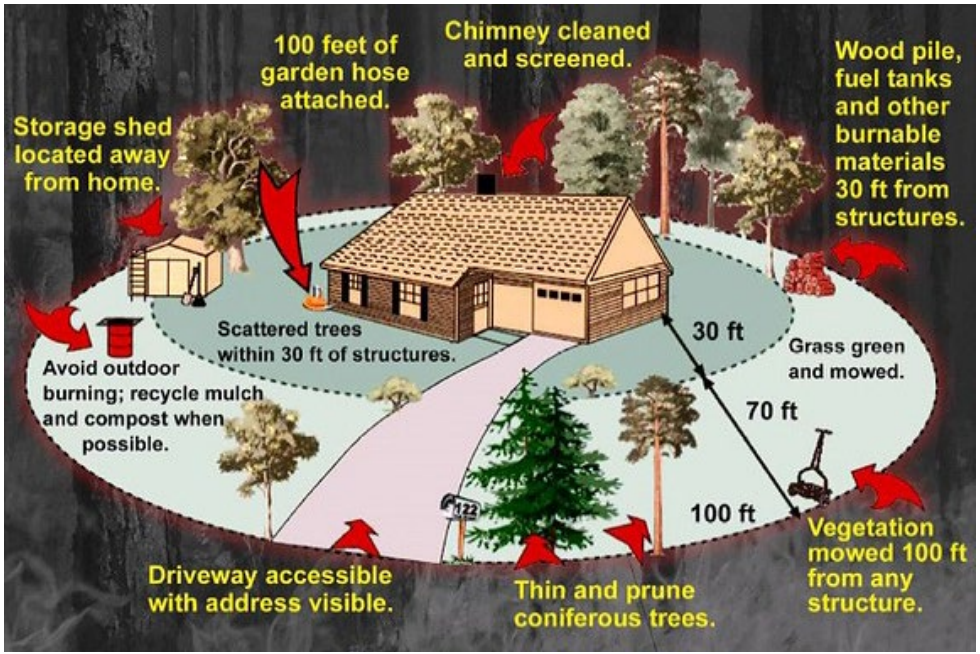
AIR

Risk to property can be reduced

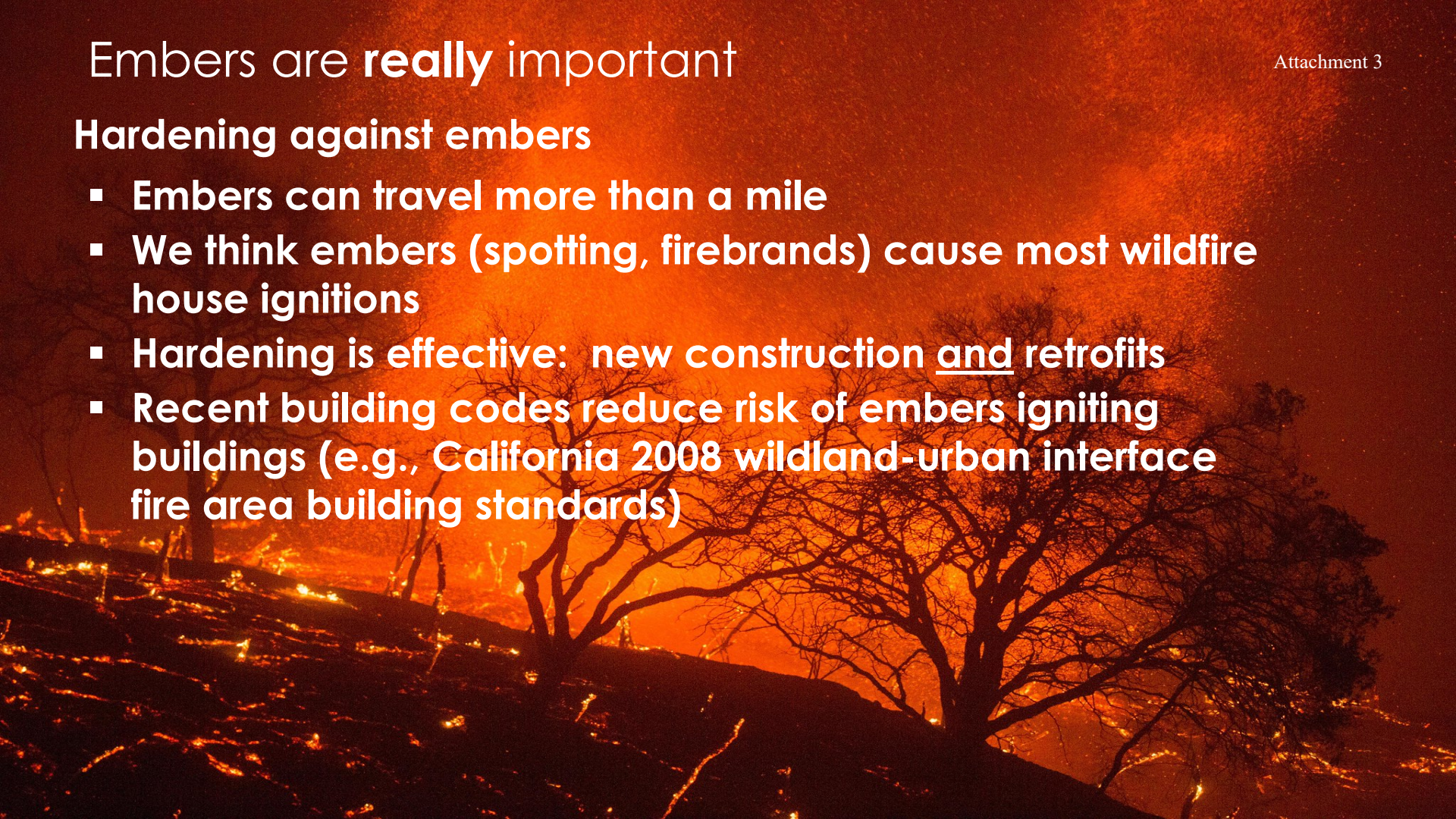
Defensible space

- Reduce fuel around buildings
- Reduce fuel "ladders" around buildings
- It's the law in California for homes in State Responsibility Area (SRA) lands
  - Maintain a defensible space buffer of at least 100 feet around buildings (or to the property line) by clearing, and maintaining clearance, of flammable vegetation
  - **Effectiveness requires compliance**

Image source: USDA



Embers are **really** important



Hardening against embers

- Embers can travel more than a mile
- We think embers (spotting, firebrands) cause most wildfire house ignitions
- Hardening is effective: new construction and retrofits
- Recent building codes reduce risk of embers igniting buildings (e.g., California 2008 wildland-urban interface fire area building standards)

Grass Valley Fire

October 22, 2007 (San Bernardino Mountains)

House-to-house spread from circled home

[Source: USDA Forest Service R5-TP-026b, 2008]

AIR

Grass Valley Fire house destruction data

October 22, 2007	# houses
Completely burned (destroyed)	174
Partially burned	25
Total houses burned	**199**
Surface fire and/or **ember** ignitions	71 (36%)
Crown fire (tree canopy flames)	6 (3%)
House-to-house spread (structure flames or embers)	**122 (61%)**

Source: USDA Forest Service R5-TP-026b, 2008

AIR

GIGAFIRE: today's term for a **million acre** fire*

Wildfire Today headline (October 26, 2018):

Bushfire in Australia burns over 2 million acres, becoming a "gigafire"

*In the language of science, '**mega**' means million (e.g., 1 megagram is 1,000,000 grams) and '**giga**' means billion (e.g., 1 gigameter is 1,000,000,000 meters), but '**megafire**' was already in use to describe fires of 100,000 acres or more

AIR

GIGAFIRE: today's term for a **million acre** fire*

Wildfire Today headline (October 26, 2018):

Bushfire in Australia burns over 2 million acres, becoming a "gigafire"

August Complex fire N. California

- **Lightning-caused** ignitions August 16–17, 2020
- **38 separate fires**
- **1,032,648 acres** (equivalent to ca. 40 × 40 mile square; ca. 1% of California)
- Structures destroyed: 935 [Cal Fire]
- Human fatalities: 1 (a firefighter)

*In the language of science, '**mega**' means million (e.g., 1 megagram is 1,000,000 grams) and '**giga**' means billion (e.g., 1 gigameter is 1,000,000,000 meters), but '**megafire**' was already in use to describe fires of 100,000 acres or more

AIR

GIGAFIRE: is it **new** to N. America?

Historic fire	Acres (million)	Date(s)	Fatalities	Associated factors
Miramichi Fire (NB, ME)	**3–4**	Oct 7-8, 1825	160	Drought, heat, strong winds, logging & forest clearing
Great Fire of 1845 (OR)	**1.5**	1845		Drought, heat, strong winds
Peshtigo Fire (WI, MI)	**1.2–1.5**	Oct 8-9, 1871	1,200–2,500	Drought, heat, strong winds, logging & forest clearing
Great Michigan Fire (MI)	**2.5**	Oct 8, 1871	200	Drought, heat, strong winds, logging & forest clearing
Thumb Fire (MI)	**1.0** (stopped by Lake Huron?)	Sep 4-6, 1881	282	Drought, heat, strong winds, logging & forest clearing
Great Fire of 1898 (NC, SC)	**3.0**	Feb, 1898	14	Drought, strong winds, logging (slash)
Great Fire of 1910 (ID, MT, WA, BC)	**3.0**	Aug 20-21, 1910	85-87	Drought, heat, strong winds, logging & forest clearing
Great Fire of 1919 (AB, SK)	**5**	May, 1919	13	Drought, strong winds
Chinchaga Fire (AB, BC)	**3.5–4.9**	Jun-Oct, 1950	-0-	Strong winds

AIR

Climate change likely increasing area burned

Projected change in area burned in western ecosystems corresponding to **global warming of 1°C** relative to 1950–2003 median annual area burned. [*National Research Council* (2011) http://nap.edu/12877]

Ecosystem	Δ burned area
Cascade mixed forest	+428 %
N. Rocky forest	+241 %
Mid Rocky steppe-forest	+515 %
S. Rocky steppe-forest	+656 %
Intermountain semi-desert / desert	+283 %
Great Plains & Palouse dry steppe	+393 %
Intermountain semi-desert	+111 %

Ecosystem	Δ burned area
Sierran steppe-mixed forest	+312 %
NV-UT montane semidesert	+73 %
Sonoran-Mojave desert	+74 %
Chihuahuan desert	+323 %
AZ-NM montane semidesert	+382 %
Colorado Plateau semi-desert	+470 %

AIR

Stochastic wildfire modeling for risk assessment

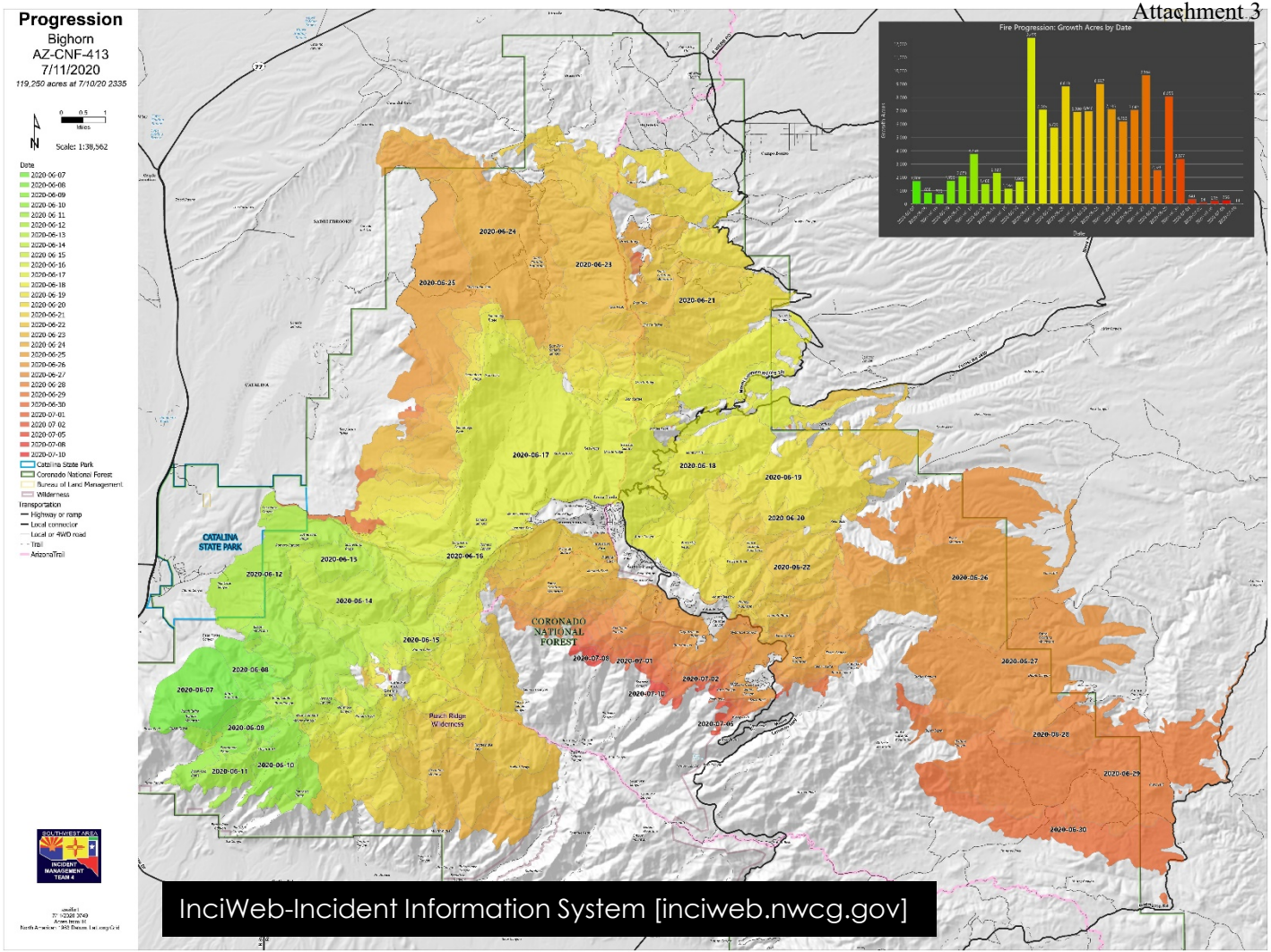
AIR

Modeling goal is realistic fires

Exact matches impossible

Large stochastic fire catalogs used to provide robust view of possibilities and probabilities:

- 10,000 years
- 100,000 years



InciWeb-Incident Information System [inciweb.nwcg.gov]

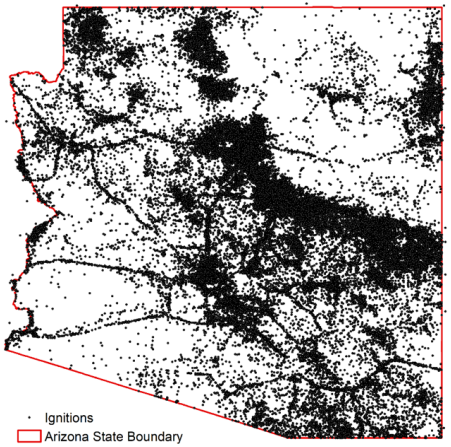
Wildfire modeling begins with ignition

History is a guide: what were relationships between ignitions and their causes?

- Fuel type, amount
- Weather/moisture
- Human population/activity
- … [powerlines]

What is the functional form of those relationships?

$$P(\text{ignition}) = f(\text{fuel, weather, humans, …})$$

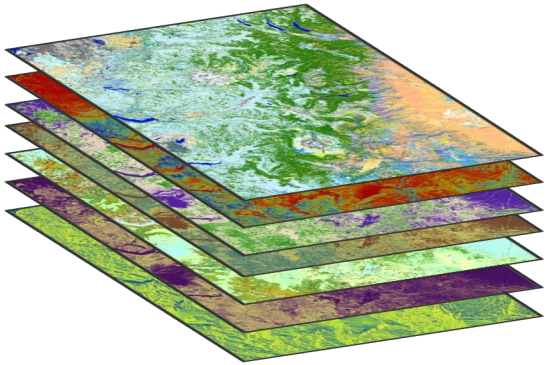


Application to the present

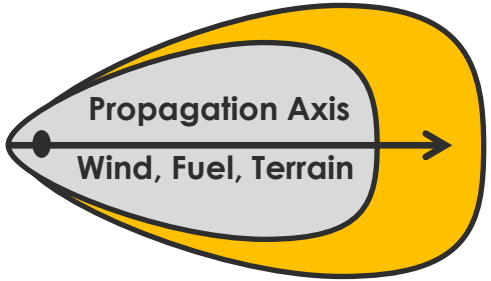
$$P(\text{ignition}_{\text{current}}) = f(\text{fuel}_{\text{current}}, \text{weather}_{\text{current}}, \text{humans}_{\text{current}}, \ldots)$$

AIR

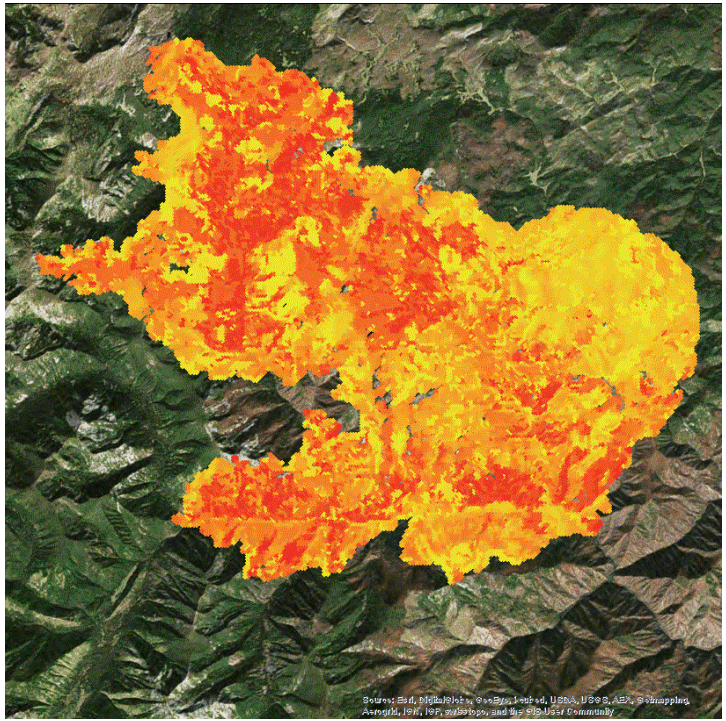
Physically based processes for simulating fire spread



Fuel Type / Amount
Slope
Aspect
Canopy Height
Canopy Cover
Base Height
Vegetation Bulk Density



Head of Fire



AIR

Modeling challenge: will suppression be successful?

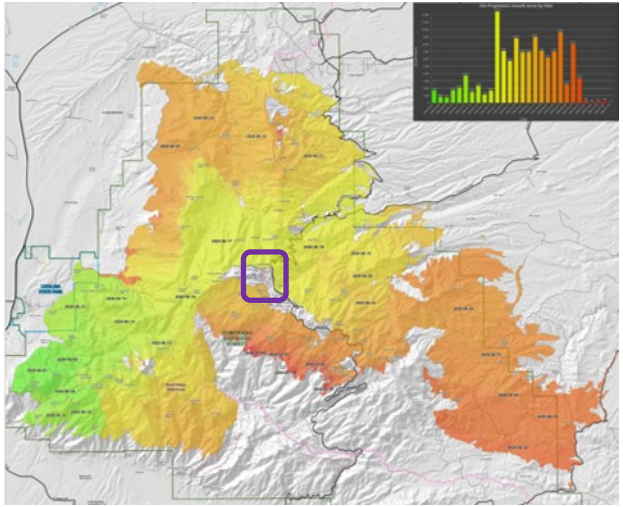
Attachment 3

Aspen (2003)

Monitoring Trends in Burn Severity (MTBS) (www.mtbs.gov)

Jun 17–Jul 12, 2003
Cause: hiker smoking
Area: 84,750 acres
Buildings destroyed: **340**

Bighorn (2020)



InciWeb-Incident Information System [inciweb.nwcg.gov]

Jun 05–Jul 14, 2020
Cause: lightning
Area: 119,600 acres
Buildings destroyed: **NONE**

AIR

Key modeling challenges / needs / realities

Reality is stochastic

- Future fires cannot be precisely predicted
- Structure ignitions depend on fine details (often unknown)
- Large stochastic fire catalogs important (tail risk)

Model data layers are critical, must be kept

- Up-to-date
- Comprehensive
- Accurate

History is a valuable guide, but…

- …it was then; this is now
- Trends must be accommodated — climate variability and change

AIR

Data sources: pre-1951 N. American 'gigafires'

- **Miramichi Fire**: www.cbc.ca/news/canada/new-brunswick/nb-author-great-miramichi-fire-remember-1.5751761; www.fireengineering.com/leadership/the-miramichi-fire-of-1825/#gref
- **Great Fire of 1845**: www.nifc.gov/fireInfo/fireInfo_stats_histSigFires.html; cliffhanger76.tripod.com/c2sea/fire/index.html#:~:targetText=c2seaTRAIL%20%2D%20Corvallis%2C%20Oregon%20to%20the,The%20Great%20Fire%20of%201845&targetText=The%20north%20half%20of%20Lincoln,Sheridan%20Sun%20journeyed%20to%20Woods
- **Peshtigo Fire**: www.weather.gov/grb/peshtigofire2; www.peshtigofiremuseum.com/; www.pbs.org/wgbh/americanexperience/features/burn-worst-fires/
- **Great Michigan Fire**: project.geo.msu.edu/geogmich/fires.html
- **Thumb Fire**: project.geo.msu.edu/geogmich/fires.html; www.nifc.gov/fireInfo/fireInfo_stats_histSigFires.html; earth.org/worst-wildfires-in-us-history/
- **Great Fire of 1898**: J. Hairr (2002) The Great Fire of 1898. *Our State*, 70(5): 24–25
- **Great Fire of 1910 (Big Burn)**: www.nifc.gov/fireInfo/fireInfo_stats_histSigFires.html; www.pbs.org/wgbh/americanexperience/features/burn-worst-fires/
- **Great Fire of 1919**: P.J. Murphy, C. Tymstra, M. Massie (2015) The Great Fire of 1919. *Forest History Today*. 21: 22-30
- **Chinchaga Fire**: C. Tymstra (2015) *The Chinchaga Firestorm: When the Moon and Sun Turned Blue*. University of Alberta Press

AIR

No part of this presentation may be copied or redistributed without the prior written consent of AIR.

This material was used exclusively as an exhibit to an oral presentation. It may not be, nor should it be relied on as reflecting, a complete record of the discussion.