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AIR RESOURCES BOARD

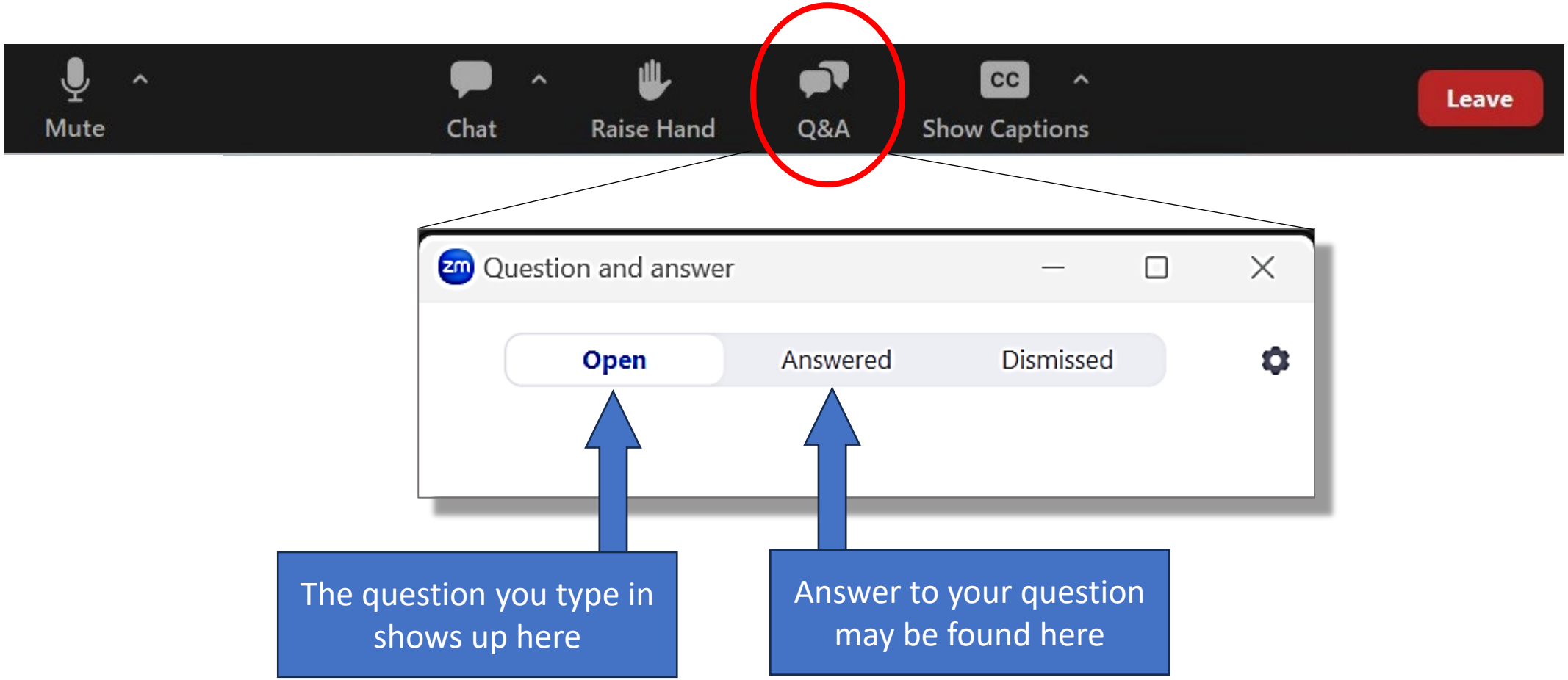
California Wildfire & Prescribed Fire Emission Inventory: Updates to Methodology & Data Sources

Public Webinar

October 16, 2025

Webinar Logistics

How to ask questions using the Q&A function



CARB

Overview

- **10:00**: Introduction *(5 min)*
- **10:05: Part A: Vegetation Burned in Wildfire** *(20 min)*
- **10:25**: Q&A *(10 min)*
- **10:35: Part B: Structures and Automobiles Burned in Wildfire** *(20 min)*
- **10:55**: Q&A *(10 min)*
- **11:05**: Break *(5 min)*
- **11:10: Part C: Prescribed Fire Activity & Emission Inventory** *(35 min)*
- **11:45**: Q&A *(10 min)*
- **11:55**: Wrap Up *(5 min)*

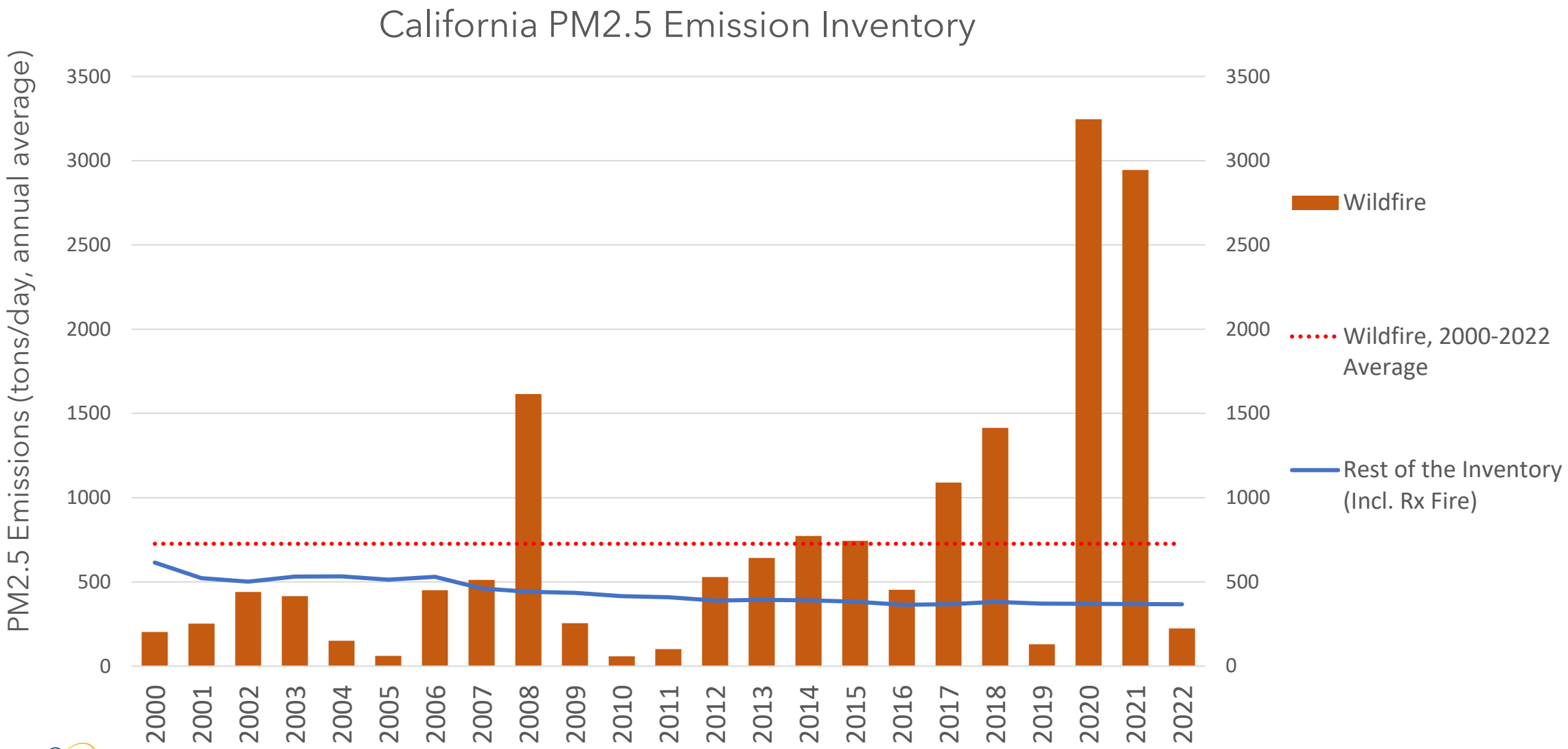
Scope of Inventory Update Covered in This Webinar

- **Today we will walk you through:**
  - Vegetation burned in wildfire
  - Structures and automobiles burned in wildfire
  - Prescribed fire for land management (e.g., hazardous fuel reduction)
- **This webinar does not cover:**
  - Ag burn: is being updated with 2023 activity data from air districts (Title 17 report); no change to methodology & data source
  - Residential backyard burning: is being updated as part of the area source inventory updates
  - Isolated structural/automobile fire incidents not burned in wildfire: update is in the works

Acronyms

- CARB: California Air Resources Board
- CAL FIRE: California Department of Forestry and Fire Protection
- FCCS: Fuels Characterization and Classification System
- FEDS: Fire Event Data Suite
- FOFEM: First Order Fire Effects Model
- NAAQS: National Ambient Air Quality Standard
- NEI: National Emission Inventory
- Rx Fire/Burn: Prescribed fire/burn
- US EPA: U.S. Environmental Protection Agency
- VIIRS: Visible Infrared Imaging Radiometer Suite
- WUI: Wildland Urban Interface

Most PM2.5 in California comes from wildfires



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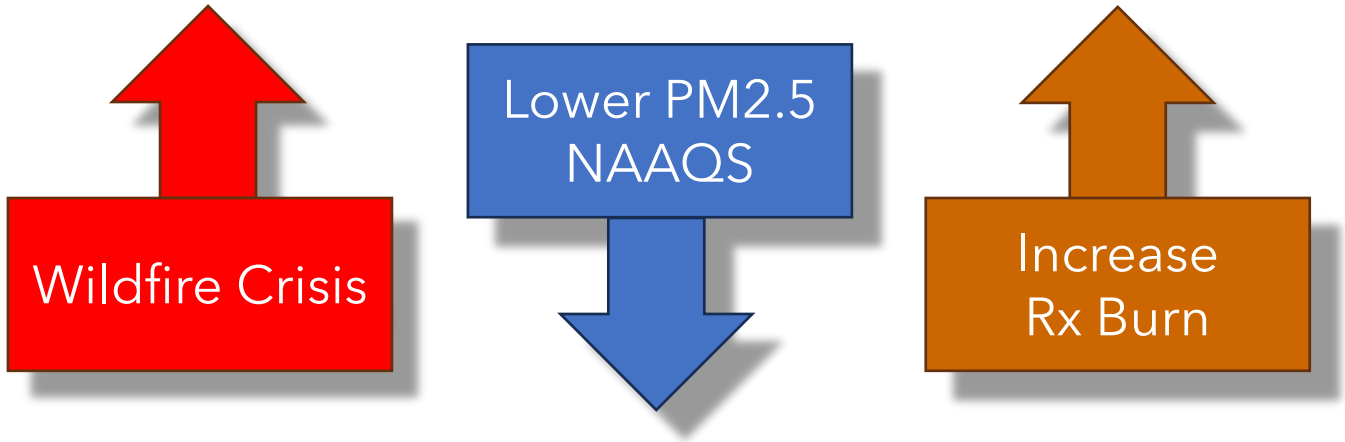
Need an event-based fire inventory and more accurate emission quantification



Need event info for:

- Exceptional events and flagging elevated air quality data
- Regional haze analysis
- State Implementation Plan modeling
- Understand wildfire & Rx fire's contribution to air quality impact
- US EPA's inventory

Event-Base Inventory: emissions are estimated for each date of fire event and shown by their explicit location.

In contrast, the current inventory is spatially-aggregated, and there is either no date info or the assumptions used in allocating emissions across date range may not be representative of what actually happened.

Emissions data must be…

- Consistent and transparent
- Accurate and reliable
- Accessible in a timely manner
- Powered by recent scientific advances
- Daily, event-based

… Introducing: CARB's new wildfire emissions inventory

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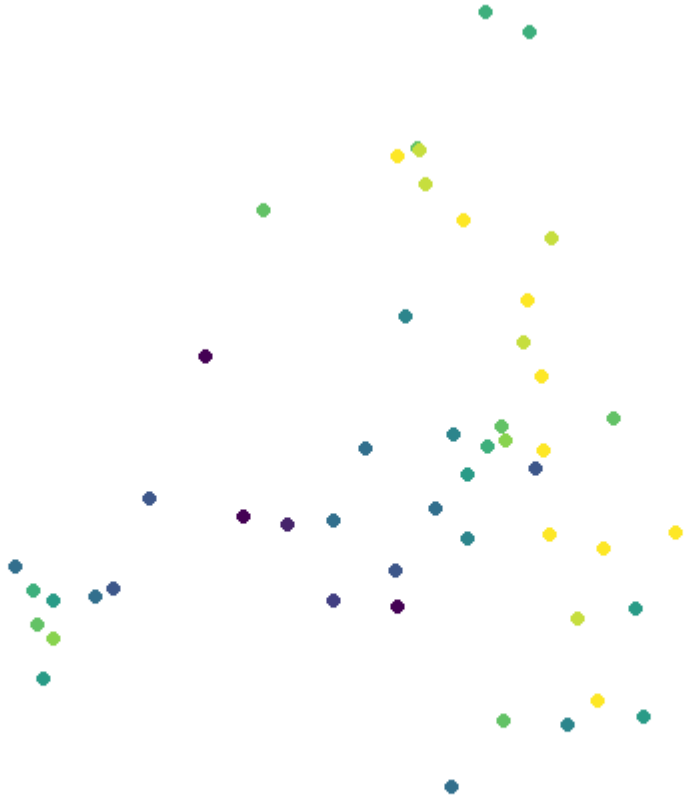
Part A

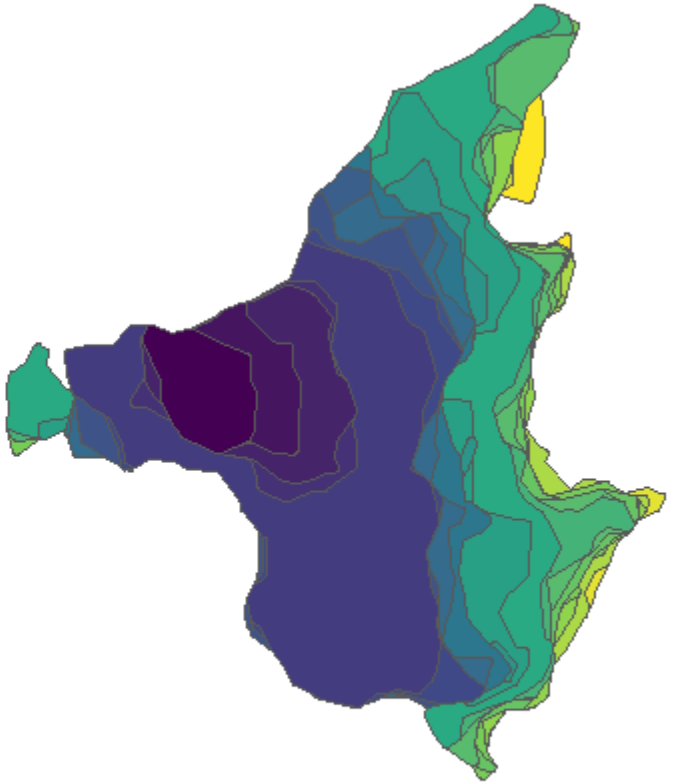
Emission Inventory of Vegetation Burned in Wildfire

*2022 Mosquito fire

Wildfire Emission Inventories

Past CARB methods	US EPA's NEI	New CARB methods





Wildfire Emission Inventories

	Past CARB methods	US EPA's NEI	New CARB methods
Basis of Rx Fire Activity	CALFIRE's wildfire geodatabase	Satellite detects supplemented by limited data from other fed/state government agencies	Combine CALFIRE's wildfire geodatabase + satellite detects
Latest consistent run	2001-2021	2021-2023	2015-2024
Data Latency*	6-7 months	2 years	6-7 months
Temporal Emission Info	Final bulk emissions	Daily emission estimates	Daily emission estimates
Emission Calculations	FOFEM: uses 30 m veg fuel data + fuel moisture	Consume: uses 120 m veg fuel data + fuel moisture, processed daily	FOFEM: uses 30 m veg fuel data + fuel moisture, processed daily, accounting for smoldering over multiple days
Spatial Representation	Polygon: final fire footprint	Points: centroids for each day of fire	Polygons: perimeters for each day of fire
Accuracy of Daily Burn Area	NA	Assumes certain acreage for each satellite detect point	Perimeters interpolated from satellite detects, closely match those from aircraft

* Data latency from the end of a calendar year.

Wildfire Emission Inventories (cont.)

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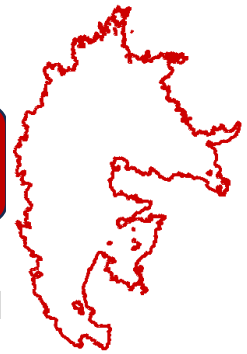
Final fire perimeter

Spatial, temporal info

Try to run FEDS (fireatlas module, Wildfire Tracking Lab, Chen et al. 2022)

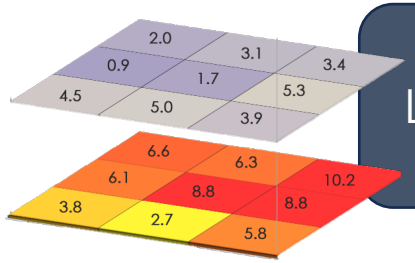
Daily perimeters available

Daily perimeters NOT available



Extract data for each daily perimeter

Extract data for final perimeter



gridMET 1000-hr fuel moisture, LANDFIRE FCCS fuelbeds (2014, 2016, 2020, 2023)

FOFEM FuelCalc (FUEL TREATMENT PLANNING TOOL / FIRST ORDER FIRE EFFECTS MODEL)

Run FOFEM (pyfofem module)

Export emissions and wildfire activity

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HOW DOES THE FEDS ALGORITHM WORK?

www.nasa.gov

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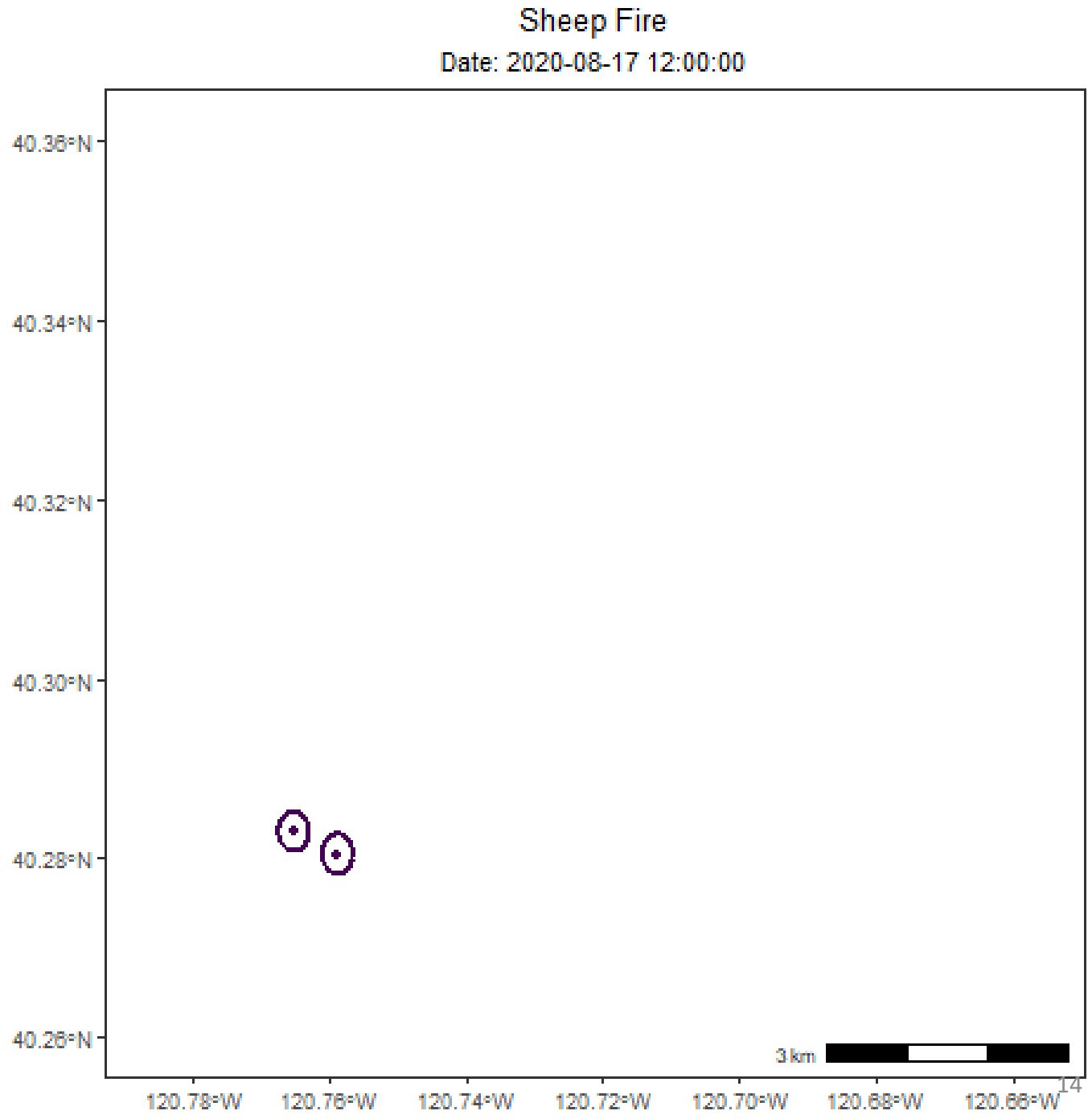
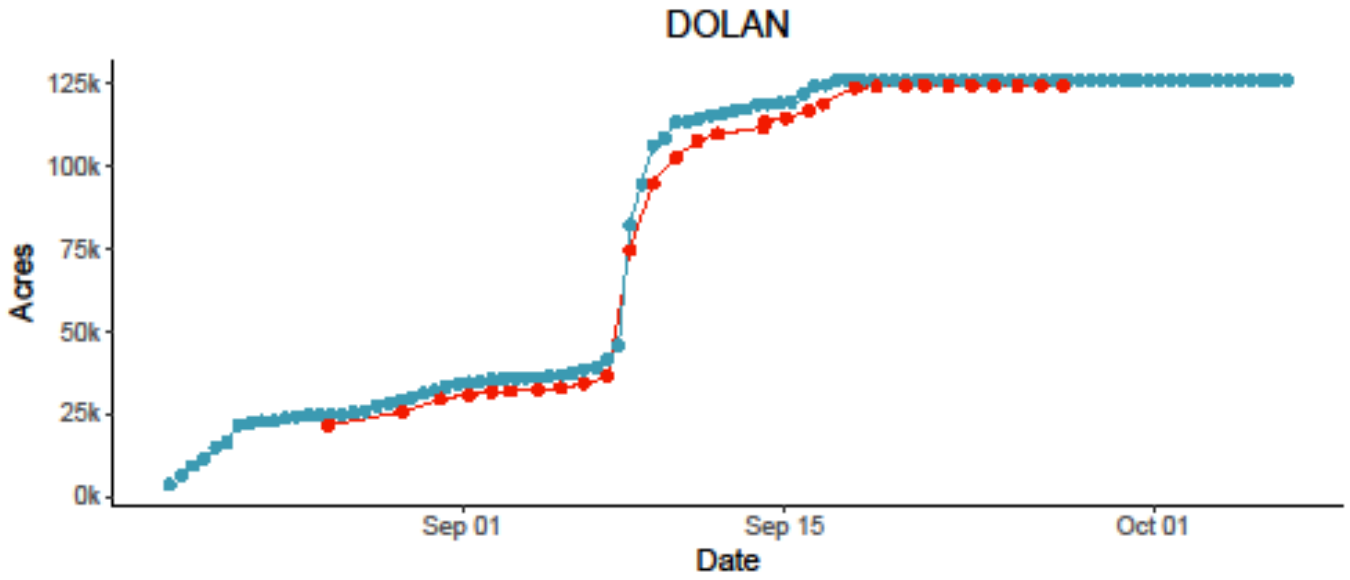
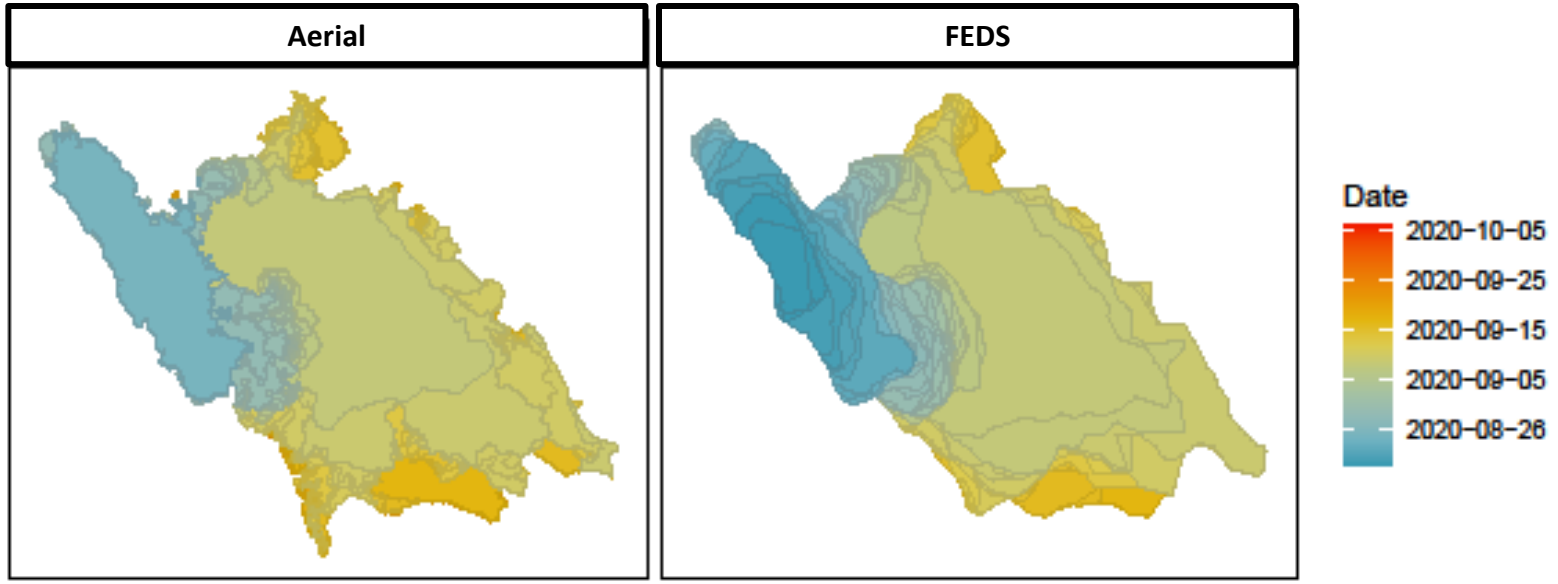


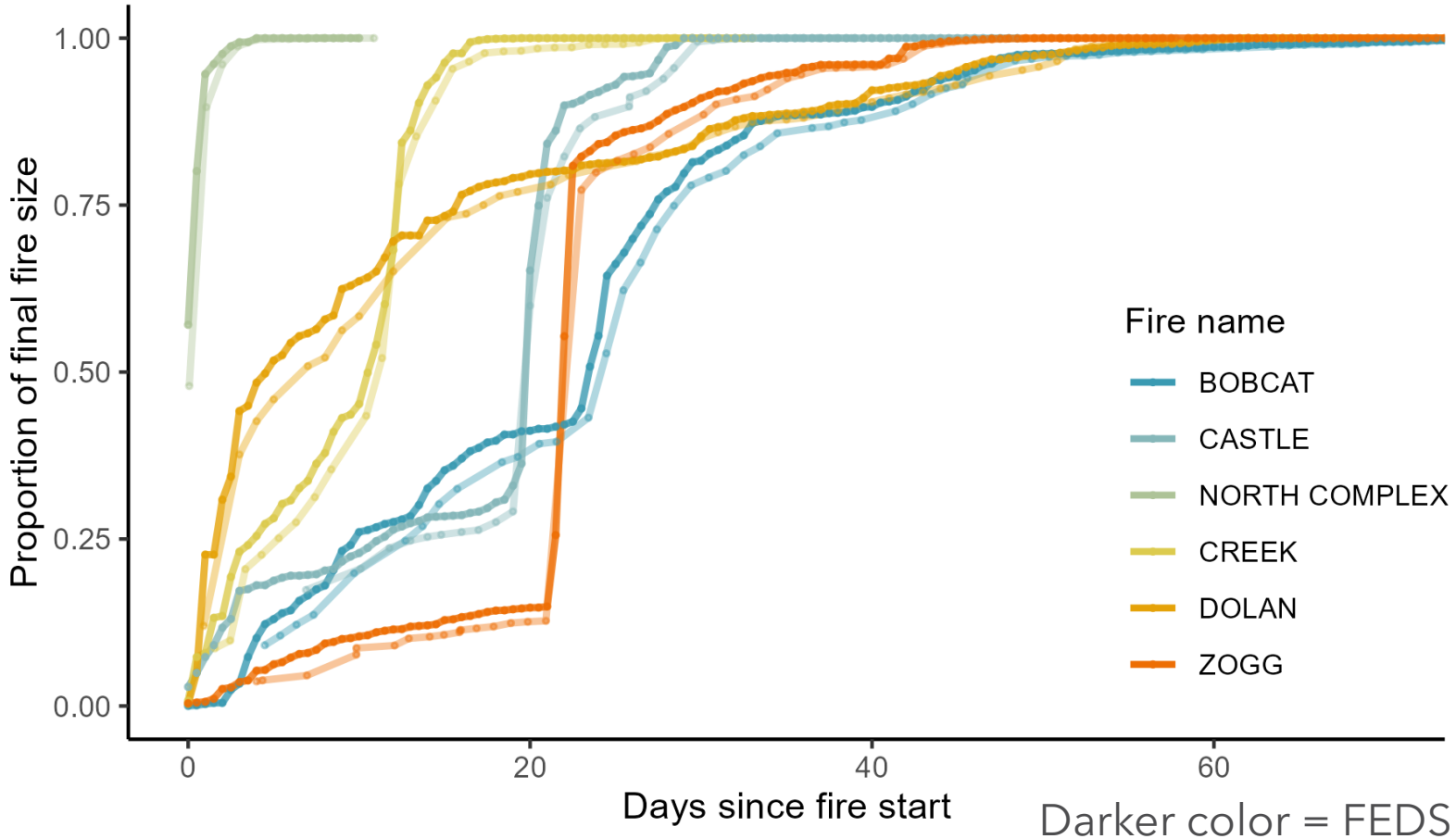
PERFORMANCE OF THE ALGORITHM





PERFORMANCE OF THE ALGORITHM

Several fires in 2020



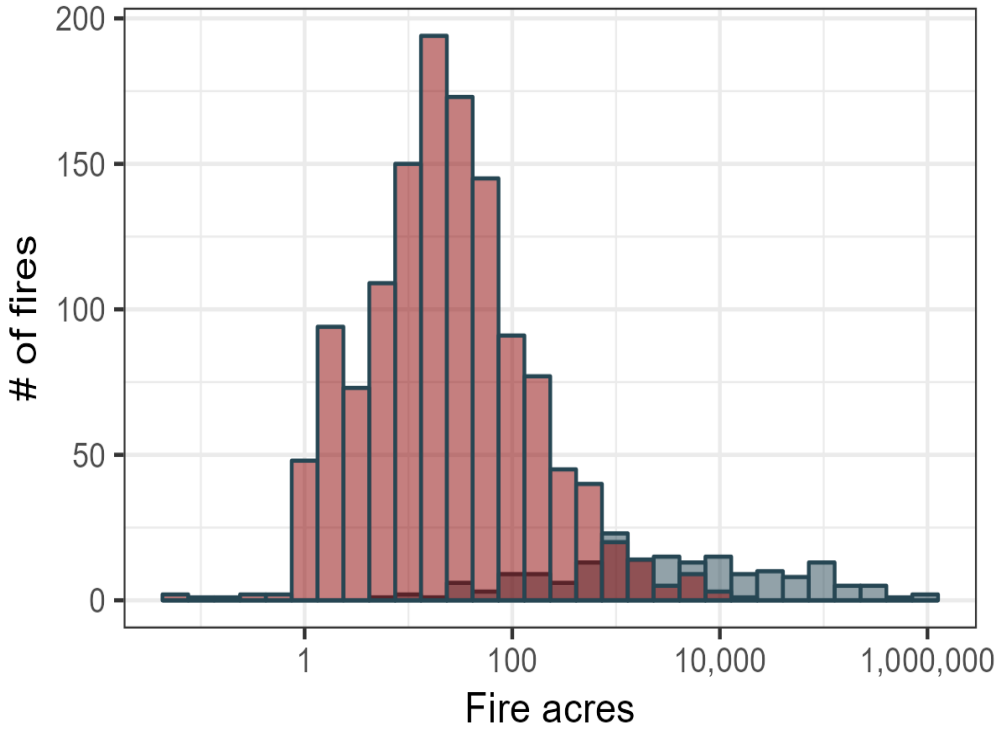
Darker color = FEDS
Lighter color = Aerial

How much of the inventory is based on the daily perimeters?

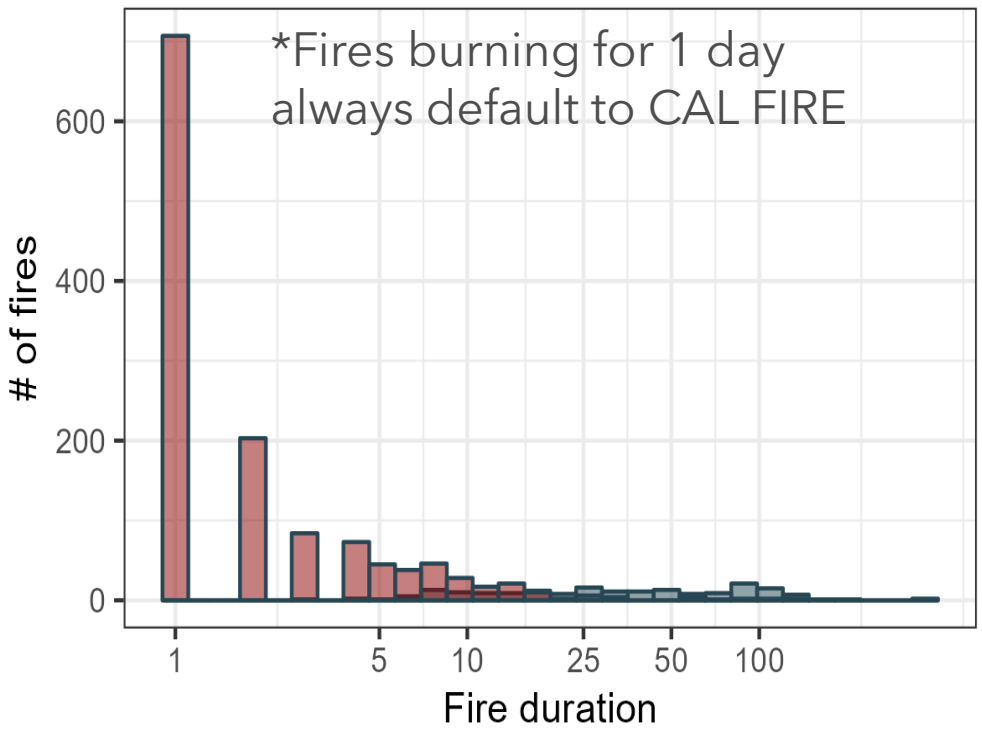
12% of wildfires (2020-2023) rely on FEDS*

FEDS accounts for:
-97% burned acres
-99% fuel consumed
-99% PM emissions

CAL FIRE median size = 22 acres
FEDS median size = 2866 acres



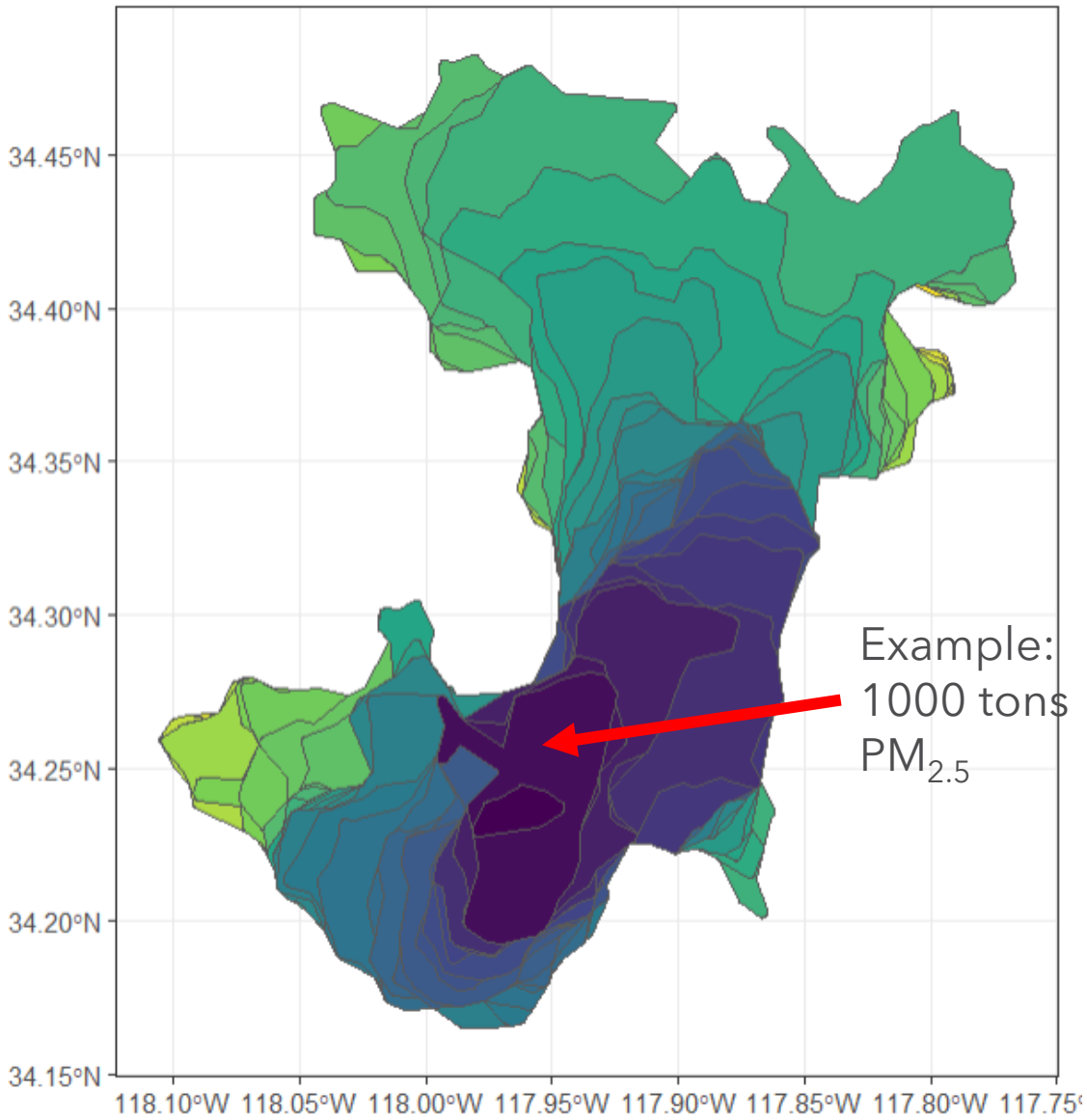
~2/3 of fires last 1-2 days



FEDS CAL FIRE

Smoldering Emissions Details

- FOFEM returns total bulk emissions for each day's polygon
- In reality, emissions are emitted over an unknown timeframe: hours to days
- Use Fire Radiative Power (FRP) of VIIRS detects to empirically distribute emissions over time



Smoldering Emissions Details (cont.)

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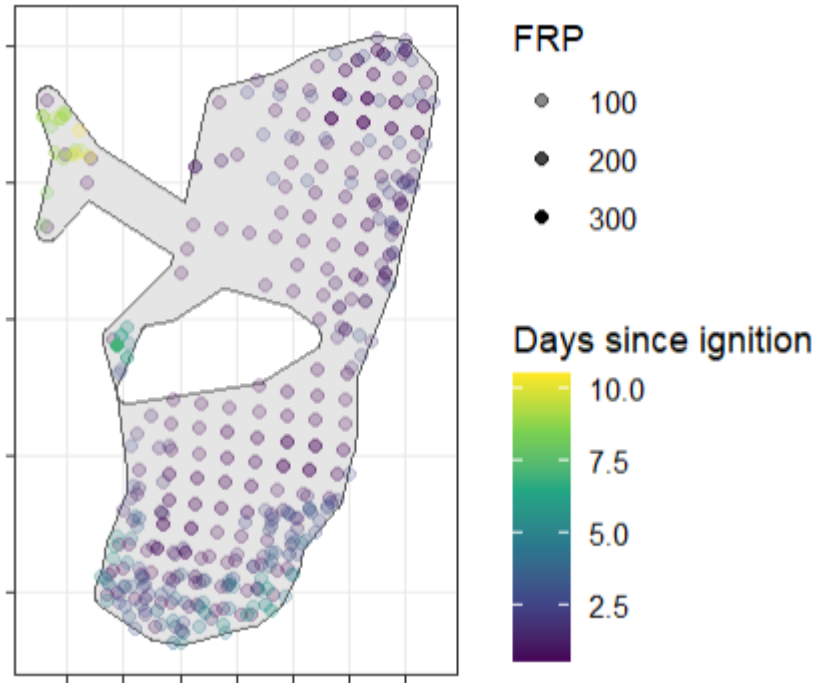

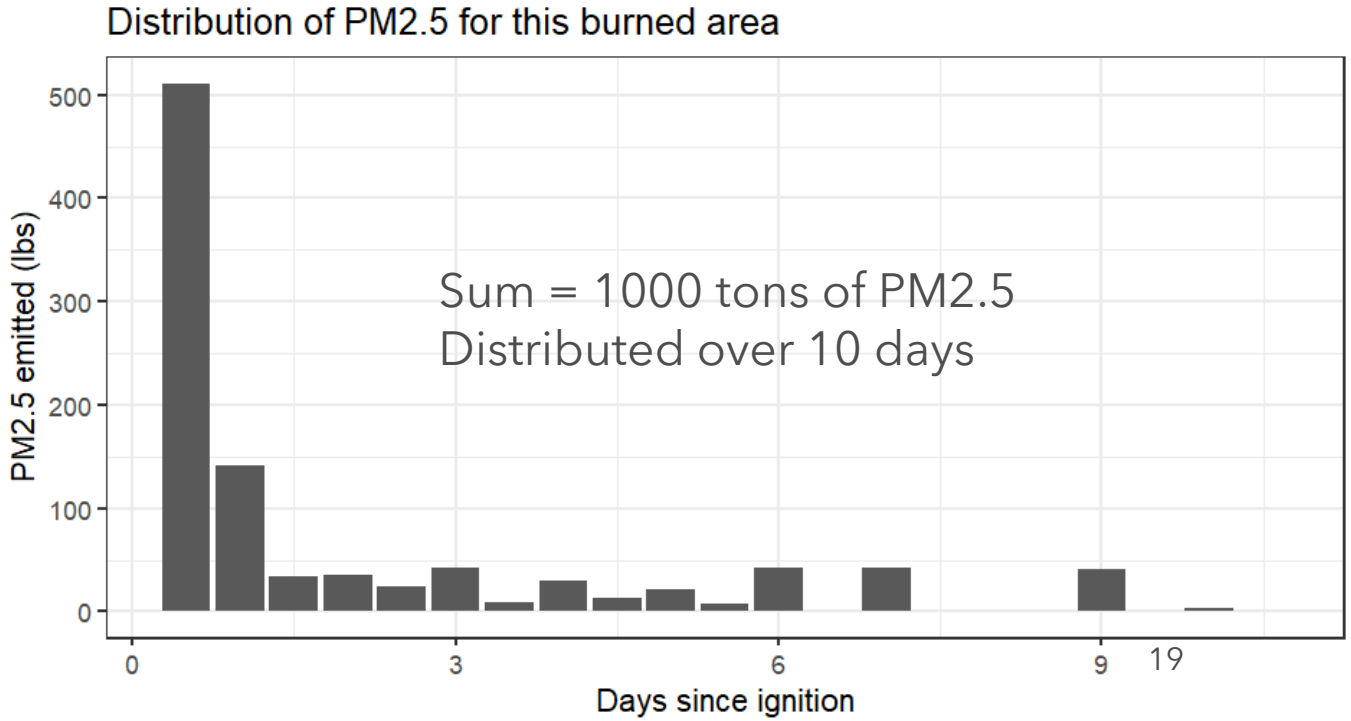

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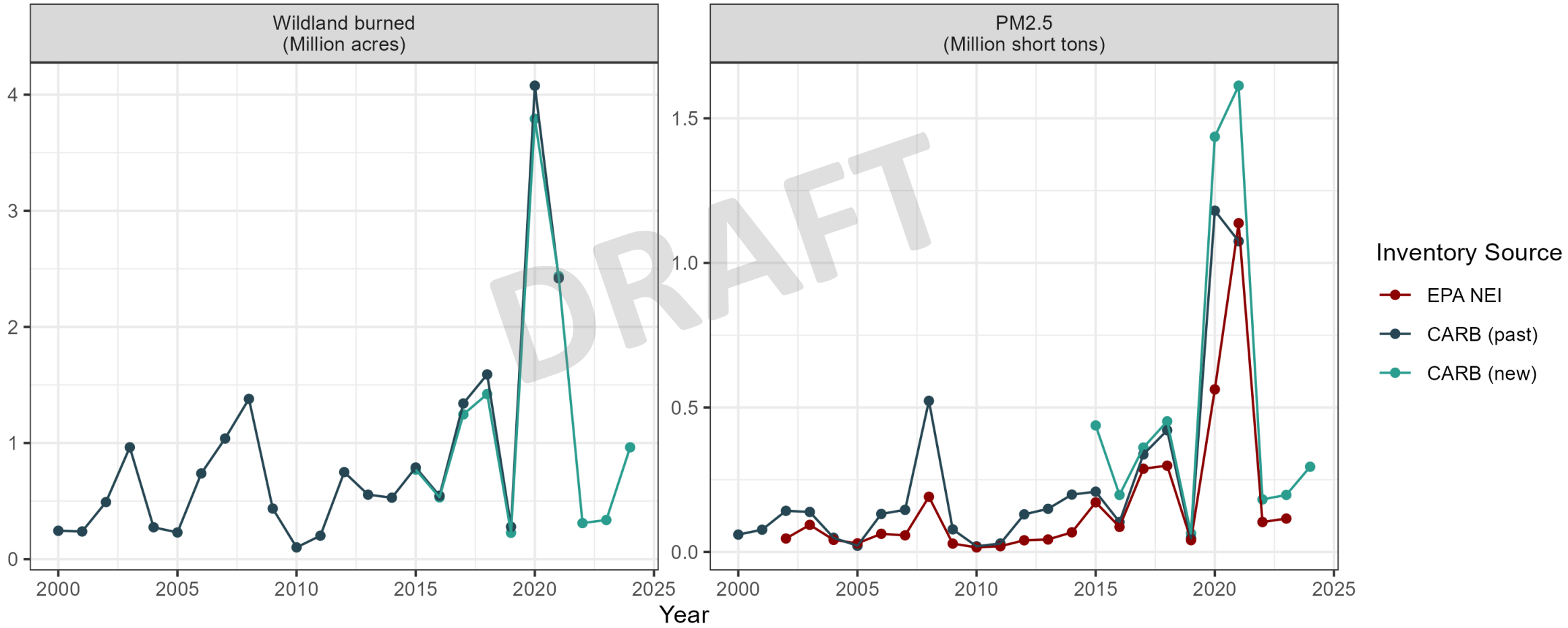
How does this inventory compare to others?



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Public Data Package

Our website will be updated soon with the following information

- Wildfire emissions and activity dataset for 2015-2024
  - Full dataset and summary-level tables in spreadsheet format
- Documentation: technical documentation, data dictionary, open-source code
- Provide the public with ways to explore the data

Acknowledgment

Special thanks to:

FEDS development team

- NASA Goddard Space Flight Center (Tess McCabe, Zeb Becker, Eli Orland, Doug Morton)
- UC Irvine (Yang Chen)
- Development Seed (Greg Corradini)
- Element 84 (Julia Signell)

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Emission Inventory of Vegetation Burned in Wildfire

Q&A

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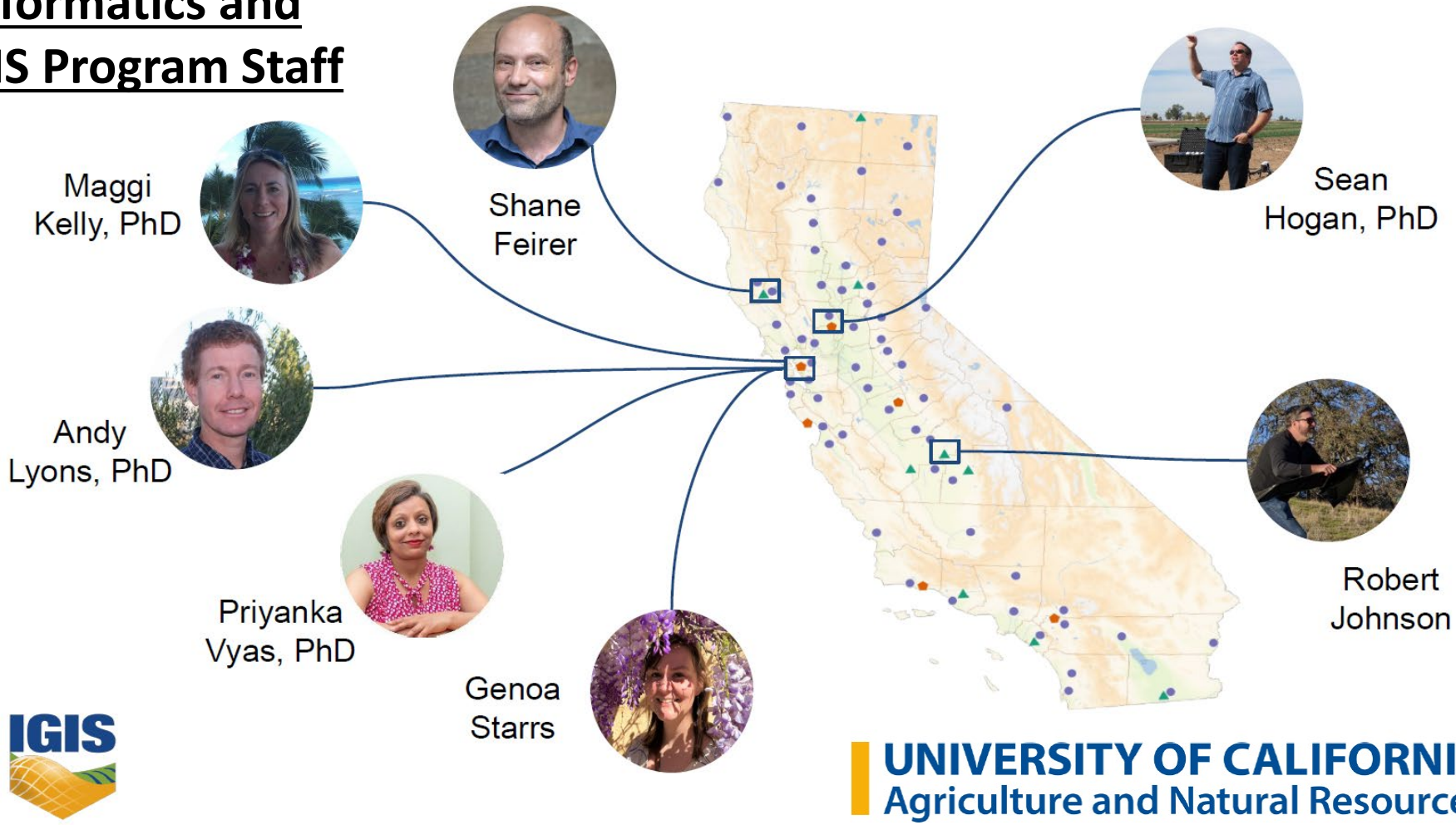
Part B

Emission Inventory of Structures & Automobiles Burned in Wildfire

Acknowledgments

Informatics and GIS Program Staff



IGIS

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Project Objective

- Create a spatially explicit methodology to estimate emissions from structures damaged or impacted by wildfire statewide.
- Improve the emissions estimation process by integrating **structure-specific data** from the **real-world structures impacted by wildfire**, such as square footage and building materials.
- Incorporate emission factors from recent research.

Structure Emissions Estimation

(Frame Load + Contents Load) x Consumption Factor (%) x Emissions Factor

Structure Emissions Estimation

(Frame Load + Contents Load) x Consumption Factor (%) x Emissions Factor

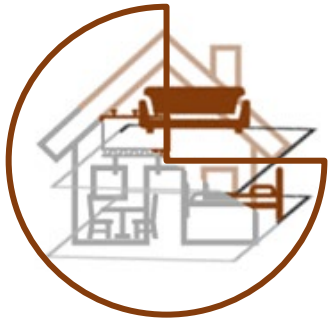
How much material is in a structure?

Frame factor (lbs/sq ft) + Contents factor (lbs/sq ft)

Multiply by square footage = lbs of material per sq ft of fuel in the structure.

Structure Emissions Estimation

(Frame Load + Contents Load) x Consumption Factor (%) x Emissions Factor



How much material was consumed by fire?

Multiply fuel load from structure by the percent consumed.
A structure with 1000 lbs of frame and contents consumed 80% would be 800 lbs of consumed material that would produce emissions.

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Structure Emissions Estimation (cont.)

(Frame Load + Contents Load) x Consumption Factor (%) x Emissions Factor

What quantity of pollutants are released when that material burns?

Emissions factors are used to estimate how much of a pollutant species is produced per unit (lbs, tons, kgs) of material consumed.

Key Assumptions

CARB Previous Estimate Done in 1999

- Use California Fire Incident Reporting System data to estimate average structure and content material burned
- Estimates 7.3% of structure burns
- Average CA home size: 1649 sq ft
- 7.91 lbs contents per sq ft
- Loading factor: 1.23 tons/fire
- Emission factors for pollutant species:
- TOG, CO, NOx, SOx, PM

New Assumptions Based on Holder et al. 2022

- Meta analysis of emissions estimation in the wildland urban interface
- Average structure and content material burned
- Estimate 80% of structure burns
- Average WUI home size: 2150 sq ft
- 5.87 lbs contents per sq ft
- Loading factor: 39.72 tons/fire
- Many, many emissions factors for pollutant species

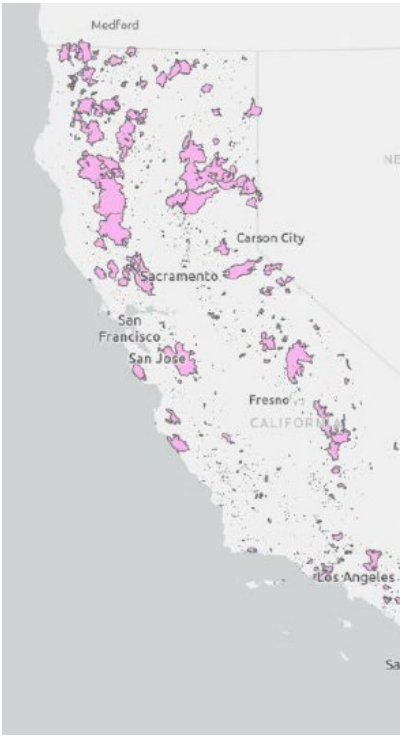
Data Sources

CAL FIRE DINS

Parcel Data & Building Footprints

WFIGS Fire Perimeters

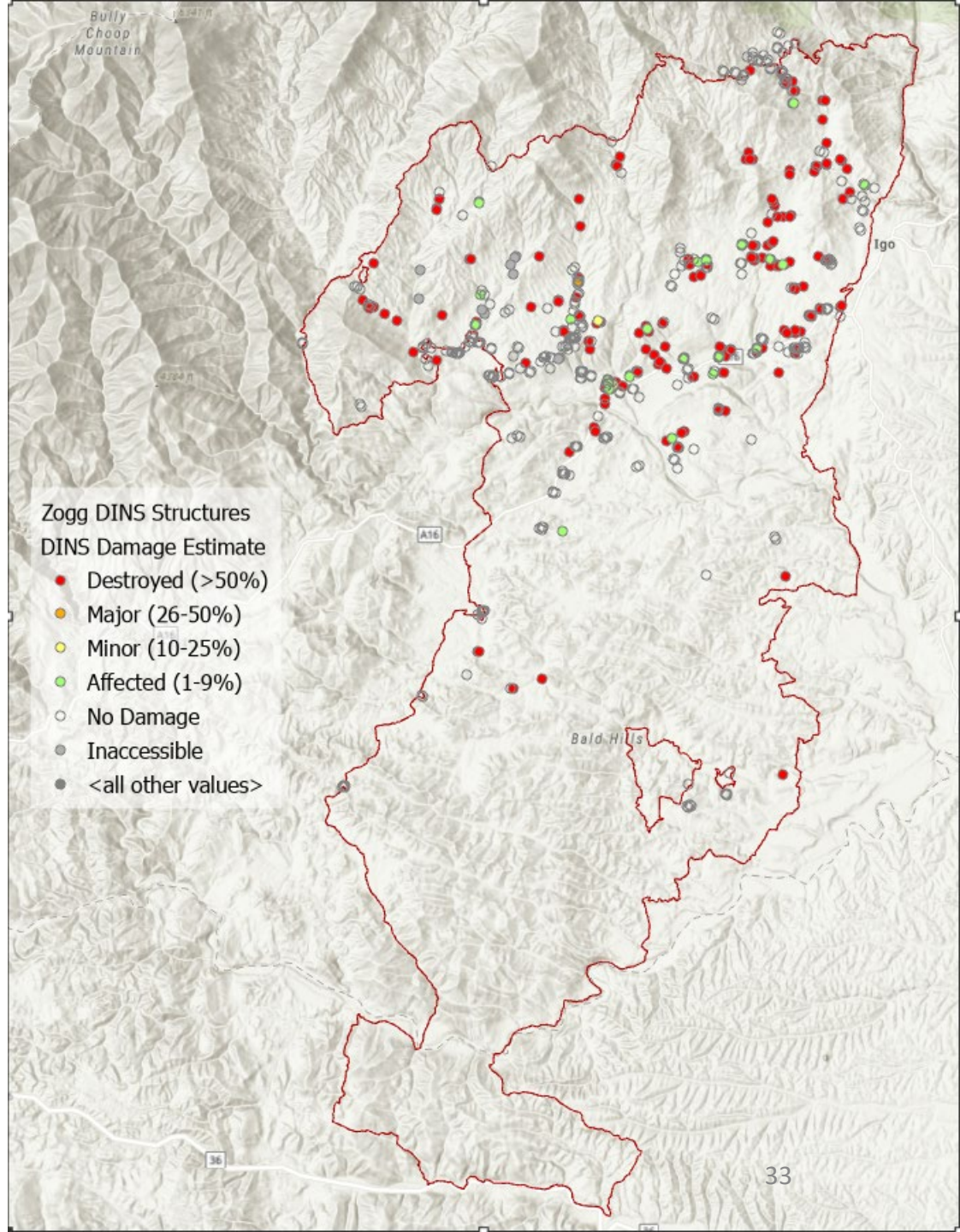
FRAP Fire Perimeters



Key Datasets: the new inventory integrates updated data from five publicly available datasets. Statewide parcel data (not publicly available) is also integrated.

CAL FIRE Damage Inspection Data (DINS)

- Collected on the ground by damage inspectors
- Curated by CAL FIRE / State Fire Marshal's office
- Statewide
- Database updated annually (January)
- Each structure is a point with identifiers and key attributes (parcel number, address, incident, structure type)
- Damage reported in ranges—see image on right
- **Does not currently include square footage data for structures**



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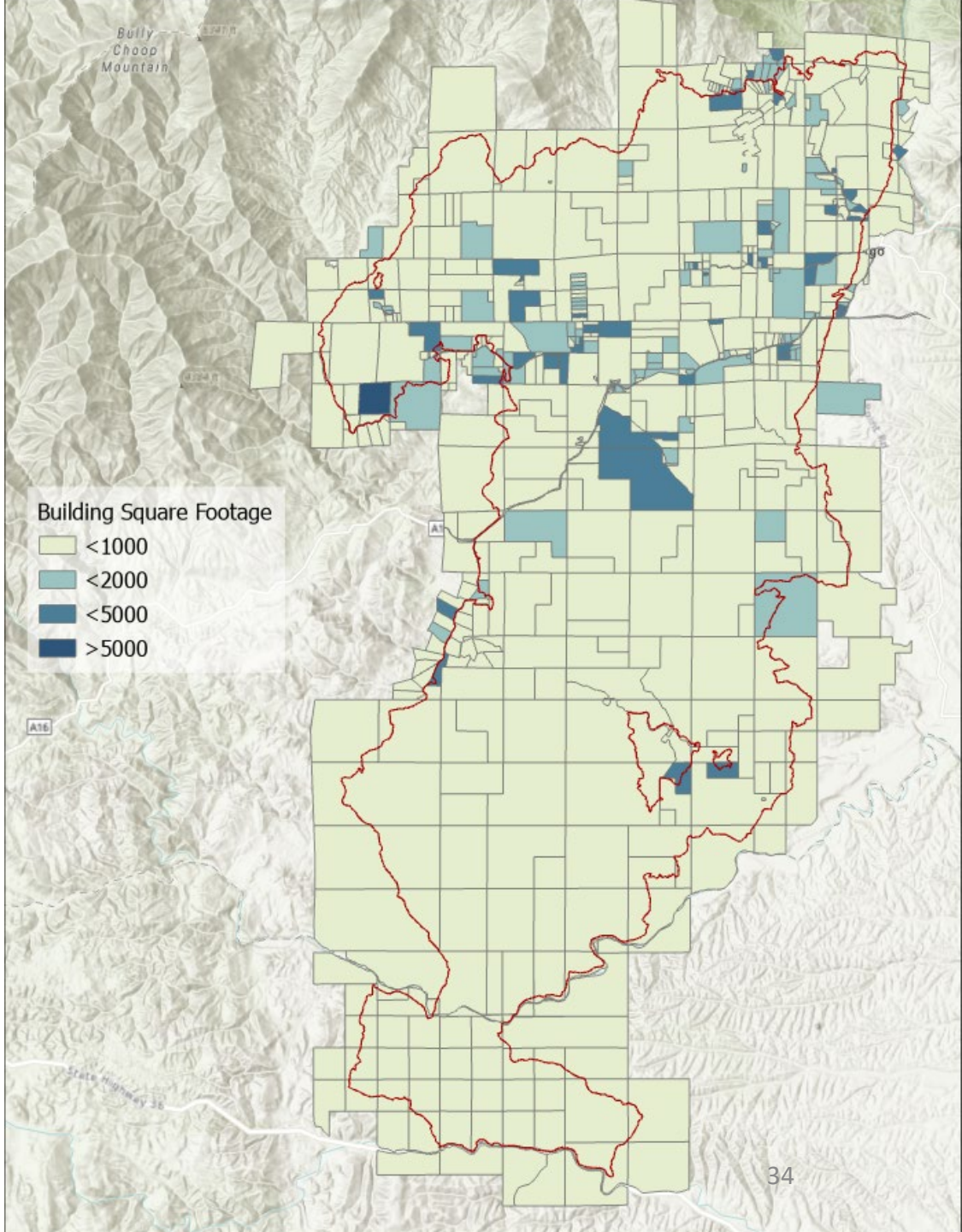
Parcel Data

- Quarterly parcel data acquired through Lightbox
- Records vary county to county, but generally include building square footage.
- Includes additional identifiers (parcel number, address)
- Use/zoning information
- Additional information that may be useful in the future
- Cons: May be multiple structures per parcel, not regularly updated or missing information, and differences by county.



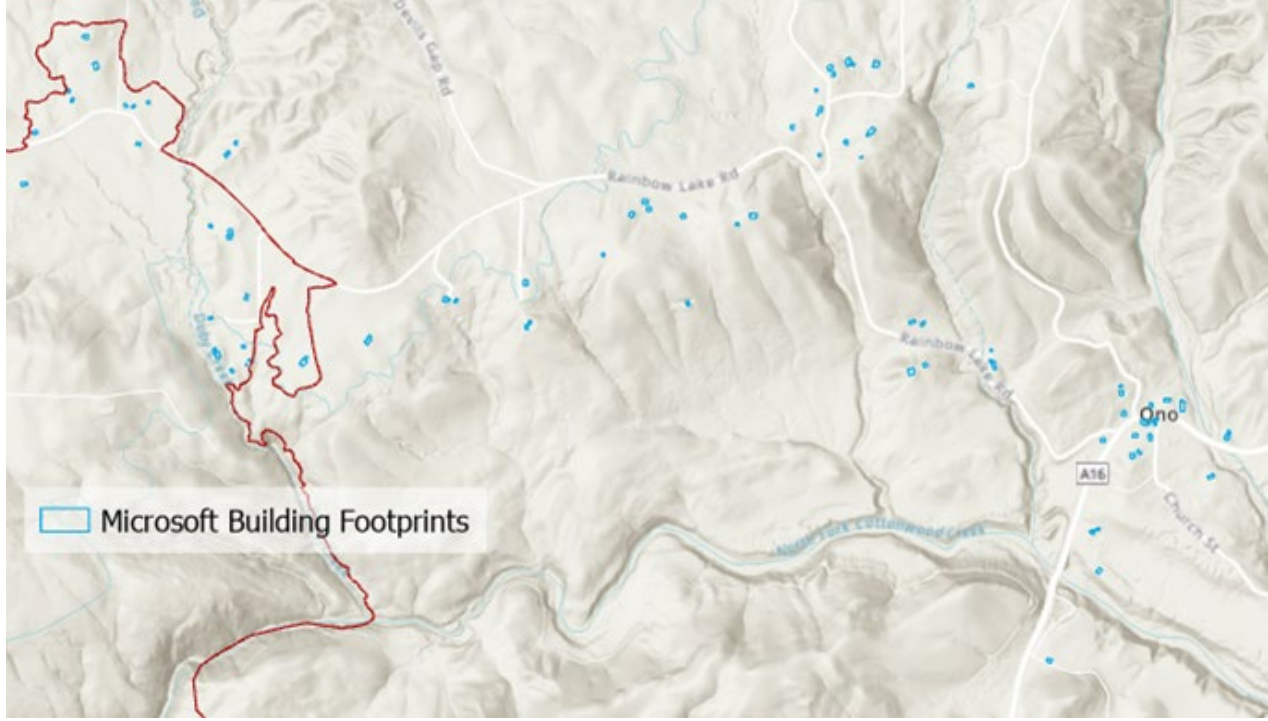
Building Footprints

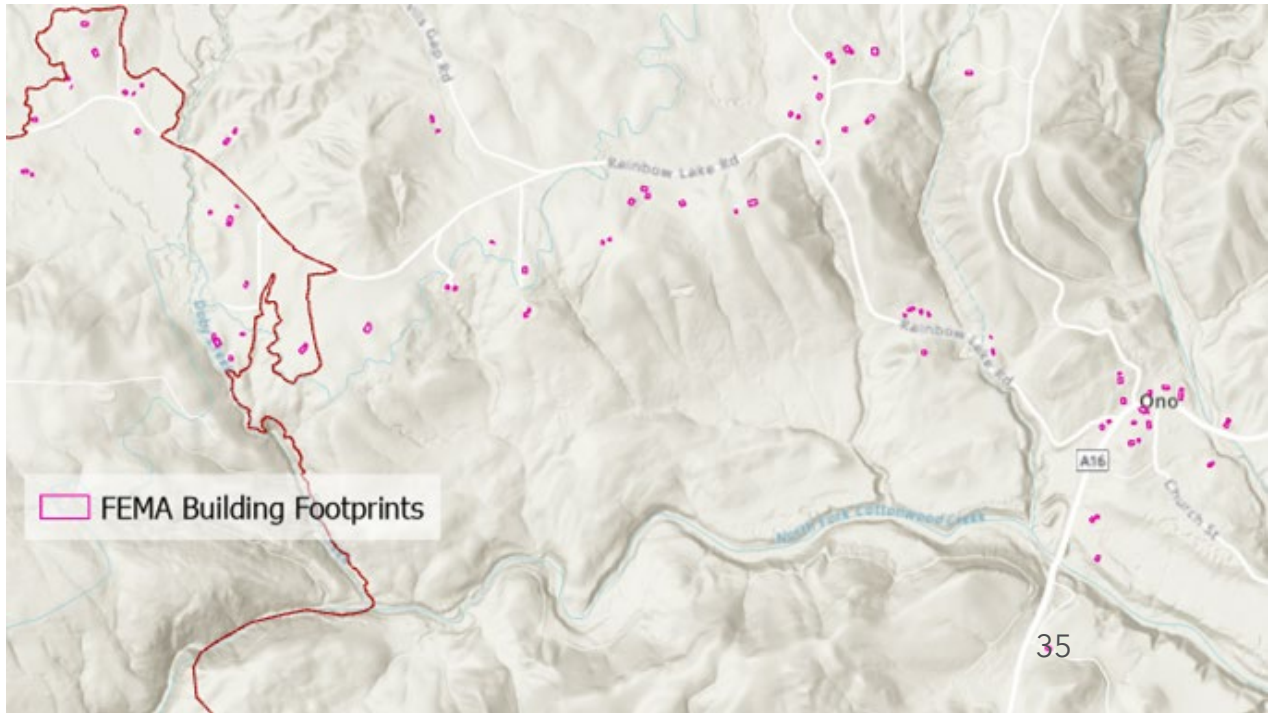
Microsoft:

- Microsoft produces free footprints based on data from 2019-2020 for most of CA, the rest averaging 2012.
- Main disadvantage– No scheduled version updates (not temporally explicit)

FEMA:

- Footprints for all structures greater than 450 square feet in the USA
- May be more info on structures added in the future.





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Assumptions When Building Square Footage Unavailable

- Used footprint and other location-based data to estimate square footage where parcel data square footage was not available OR likely referred to a different structure.
- Parameters used:
  - Year built
  - Elevation
  - Average value
  - Development density class (single, multi, etc)

Estimating Emissions of Automobiles Burned per Wildfire

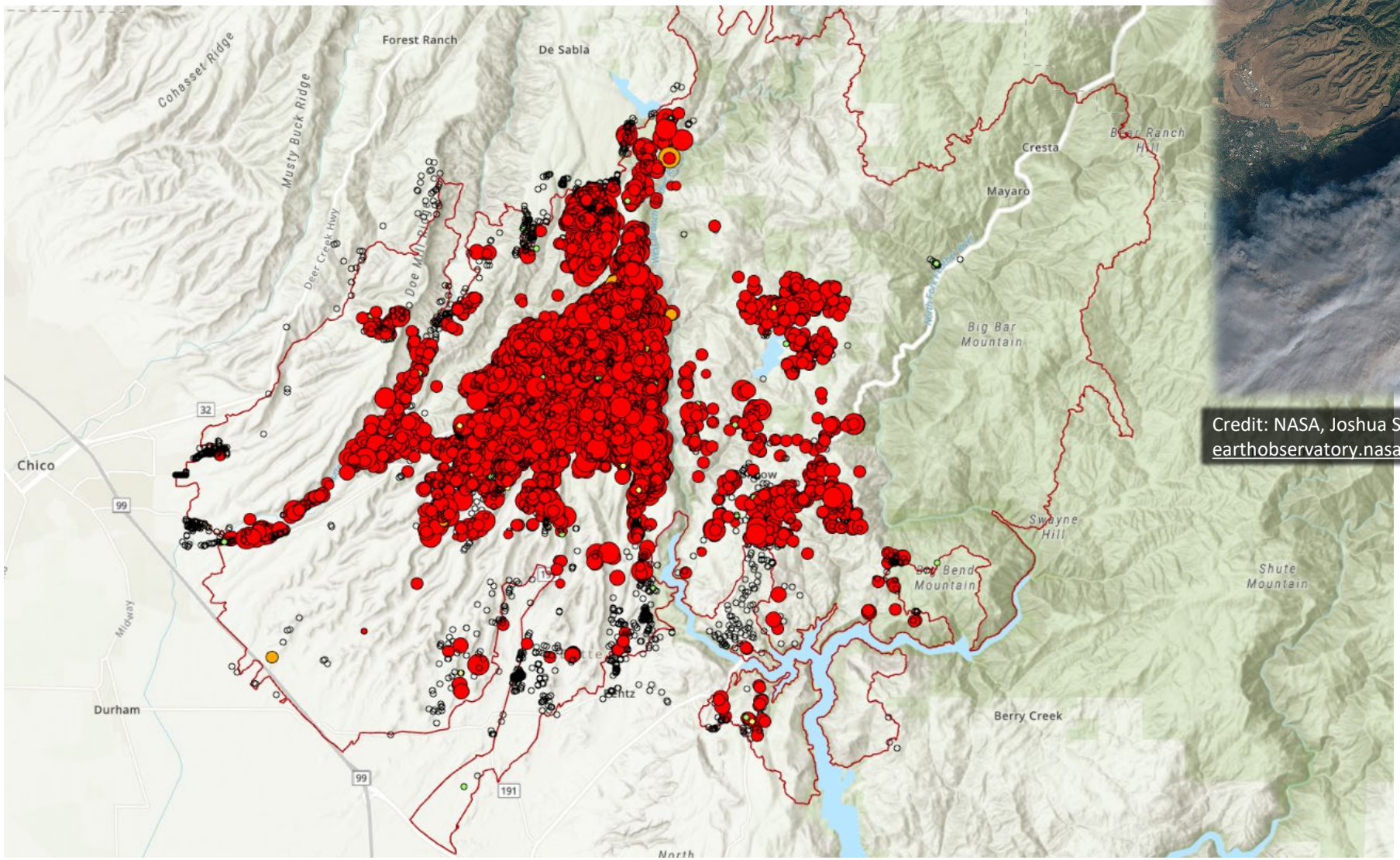
- No database of burned automobiles available
- Without an activity inventory, use assumptions in Holder et al. (2022) to estimate bulk emissions for each fire; estimate is not spatial
  - Average number of vehicles per structure = 1.44
  - Mass of burnable materials in an average vehicle = 461 kg

Combustible vehicle loading x Emission Factor

Number of structures burned
x 1.44 vehicles per structure
x 461 kg/vehicle of combustible mass

$\times$ EF_i

Example: Camp Fire (2018)



Credit: NASA, Joshua Stevens
earthobservatory.nasa.gov/images/144225/camp-fire-rages-in-california

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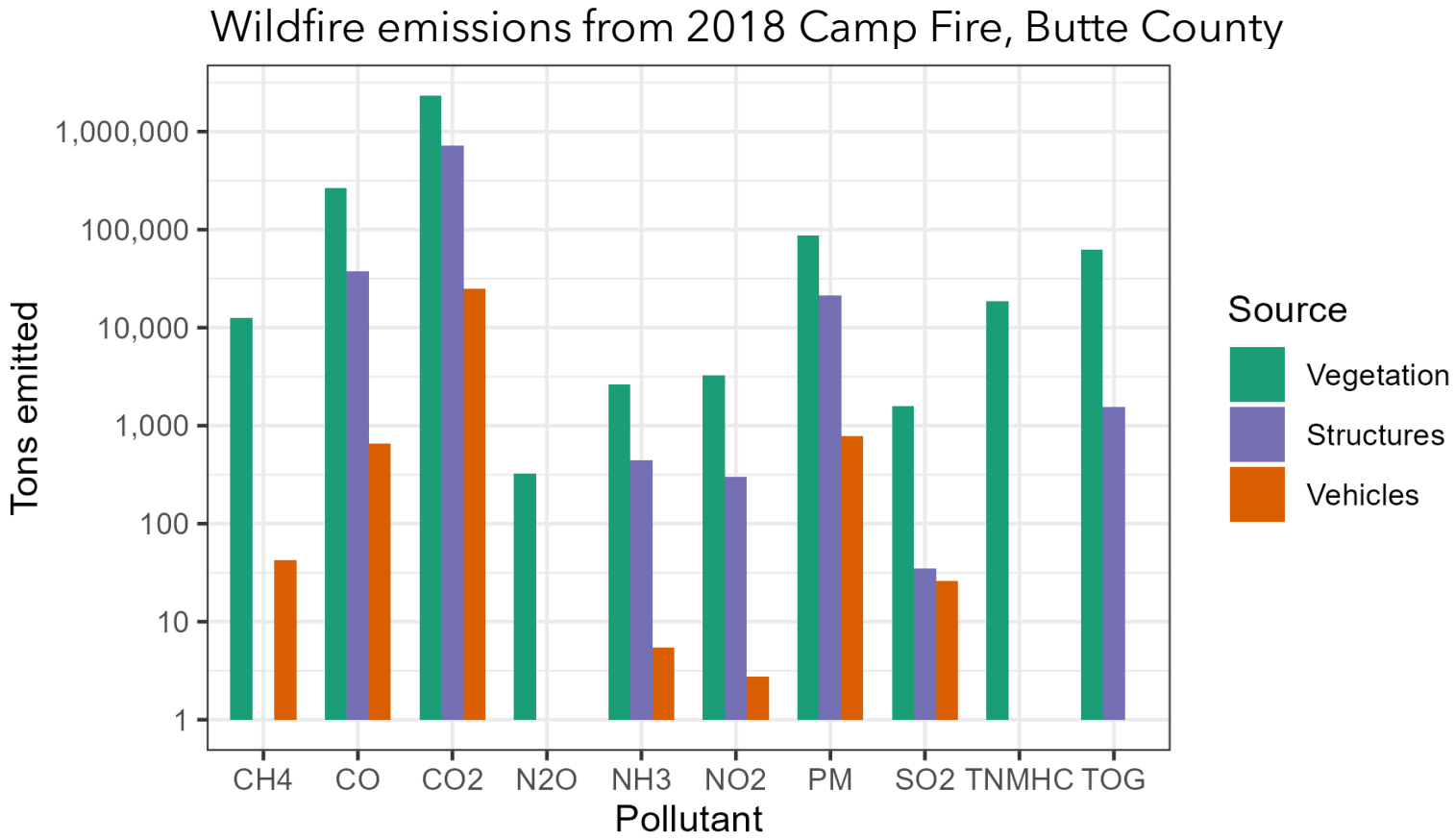
Example: Camp Fire (2018)

Damage Class	Count	Fraction
No Damage	4,066	17%
Affected (1-9%)	626	3%
Minor (10-25%)	101	<1%
Major (26-50%)	27	<1%
Destroyed (>50%)	18,804	80%

Inventory Outputs:

- Aggregated emissions report
- Detailed emissions report (by structu
  - Spatial
  - Tabular
- Vehicle emissions



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Emission Inventory of Structures/Automobiles Burned in Wildfire

Q&A

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5-Minute Break

Please return at 11:05

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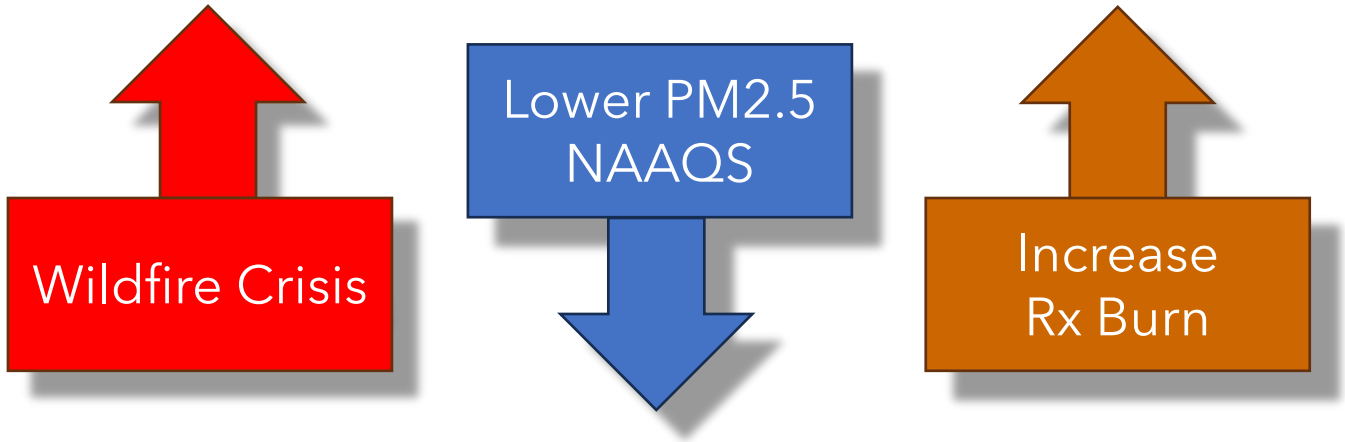
Part C

Prescribed Fire Activity & Emission Inventory

Outline

1. Background:
    - Motivations, previous methodology, new/improved activity datasets
2. Key Elements of Inventory Revamp
3. Activity Inventory
    - Reconciliation and integration of several government agency datasets and satellite data
    - Draft results
4. Emission Inventory
    - Emission estimation methodology & assumptions
    - Draft results

As Rx fire becomes more important, we need an event-based fire inventory and more accurate emission quantification



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Previous Methodology

- Not an event-based inventory
- **Emission estimation method:** FOFEM model, documentation
  - No pile burn specific methodology
- **Activity data:** Rx burn polygons in CAL FIRE's (updated annually) Fire Perimeters geo-database
  - Historically captured most activity compared to other similar datasets
  - Not intended for capturing all Rx fire activities in CA nor for emission inventory purpose
  - Not event-specific: date ranges instead of actual burn date; no info to distinguish unburned area
- If an Air District included their own Rx fire emission estimates in their annual emission inventory submittal to CARB, used Air District's inventory

New/Improved Activity Datasets

New/improved Rx fire activity datasets in recent years enable a more complete/accurate inventory

- **Air District (AD) Data** (need reconciliation):
  - Prescribed Fire Information & Reporting System (PFIRS): more participation now than a decade ago
  - CA Air Pollution Control Officers Association's (CAPCOA) quarterly compilation for grant program
- **Land Management Agencies** (LMA): increase effort on collecting activity data and improving data detail/completeness
- **CA Wildfire & Forest Resilience Task Force** (WFR TF or TF): Interagency Treatment Tracking System (ITS) compiled data from state/federal agencies' databases
- **Satellite data:** advancement in spatial resolution & temporal coverage for fire detection and land surface change

New Event-Based Inventory

Emissions are shown by each event, each date, & geospatial location.

	Past Inventory Method	Event-Based Method
 **When?**	• **Temporal info** may not reflect actual burn dates • Data were **not event** specific	• **Daily emissions** reflect actual burn activity • Data represent specific **daily event**
 **Where?**	• Spatially aggregated to **large project areas** or **county level** • Limited land management activity data	• **Treatment or activity level** • Expanded land management activity data • More agencies' databases are included
 **What?**	• All prescribed fire modeled as broadcast burn.	• All prescribed fire is modeled using one of three pathways (broadcast, pile, and ACI)

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Information that guides an event-based inventory

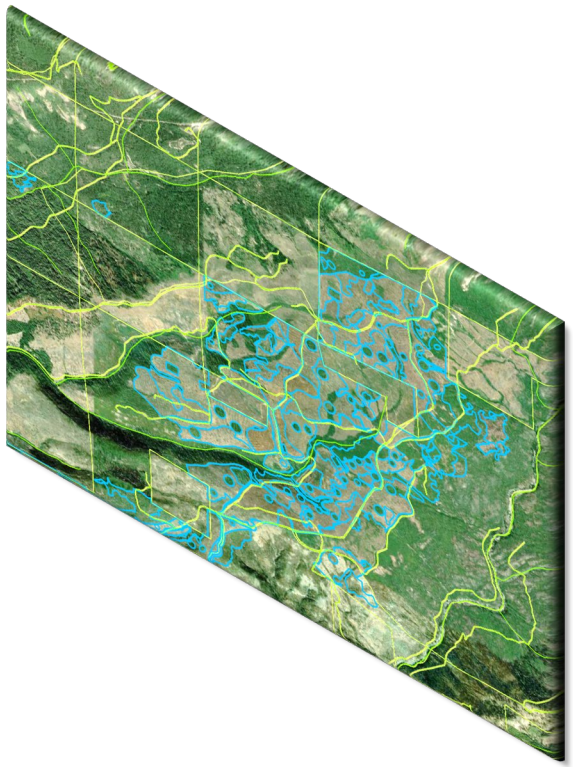
Primary Information

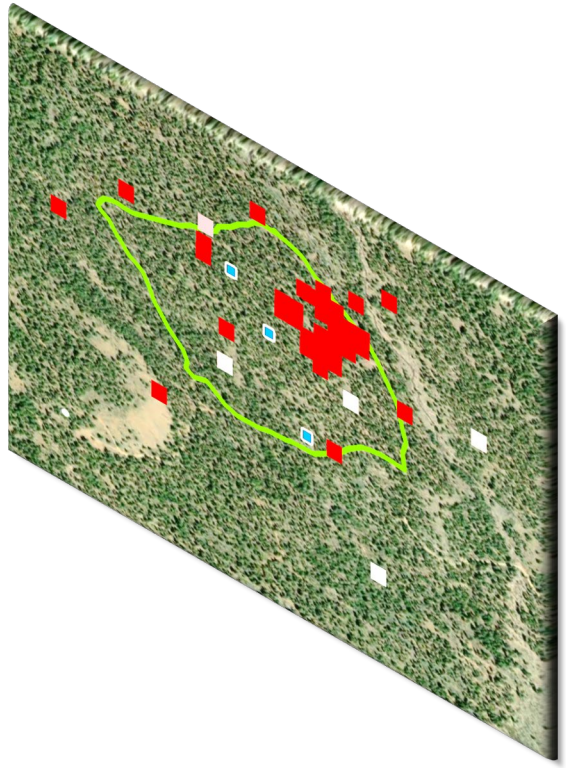
Air District Data:
Tables that record approved burns including PFIRS and Air District records

Land Management Agencies:
Spatial data that provide tracking of activities on the landscape, specifically pile and broadcast burning

Supplemental Information

Satellite data products:
Spatial data that collects frequent information about timing and duration of fire on California's landscape.





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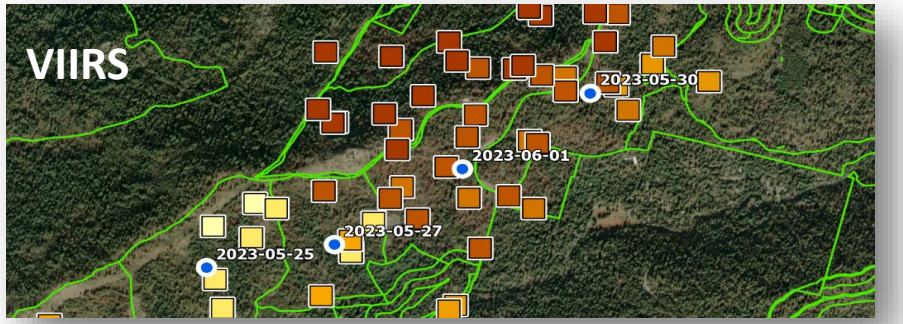
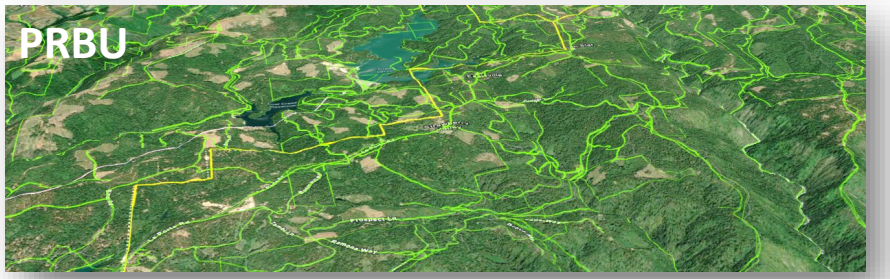
Additional info will supplement PFIRS & other Air District data

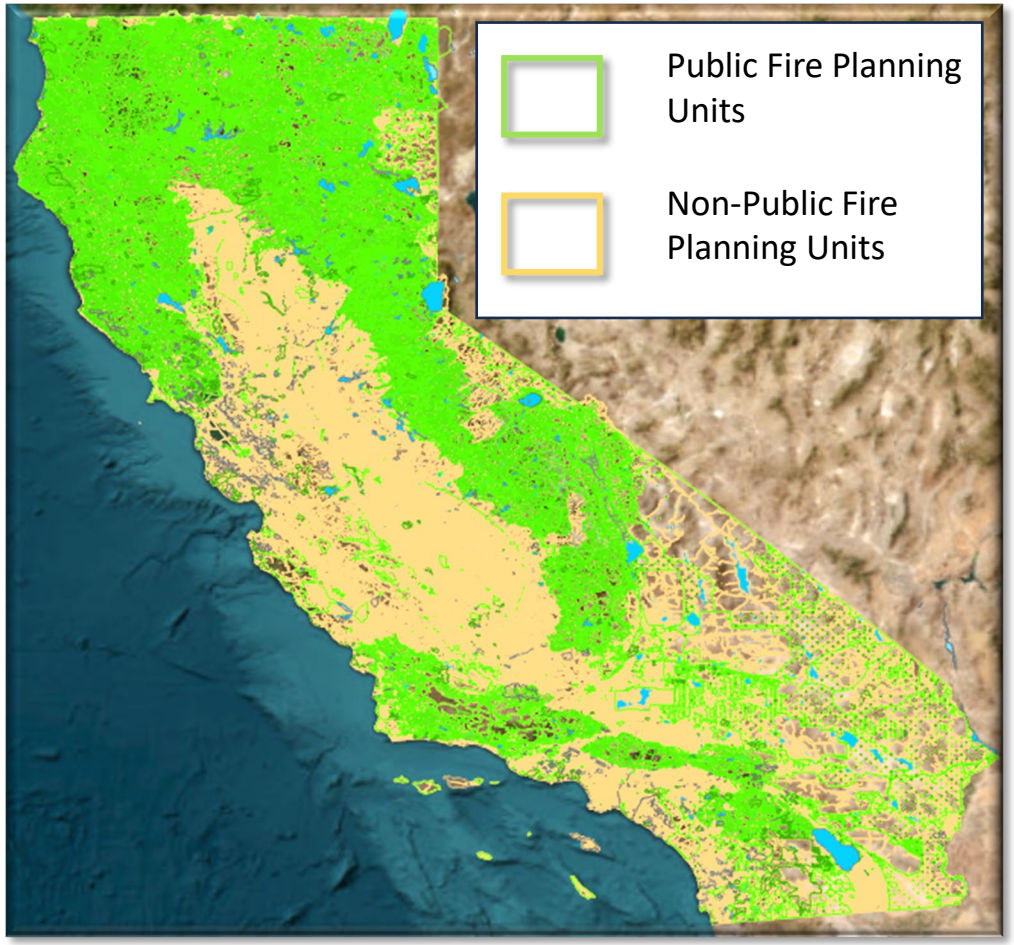


VIIRS thermal detections– A satellite product that shows when a fire occurred in a unit.



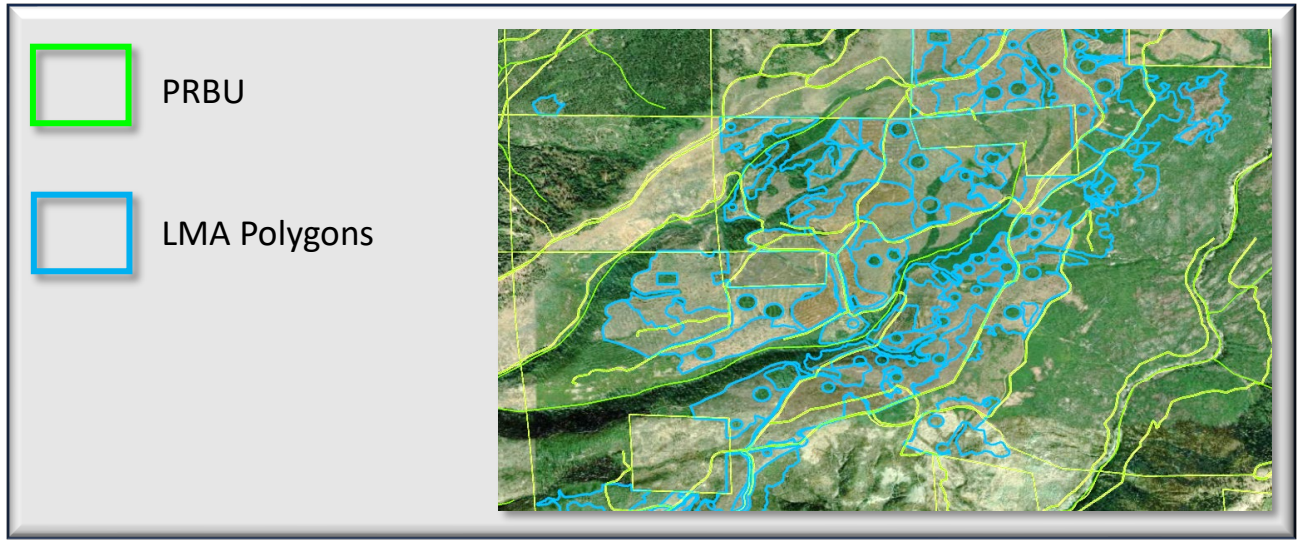
Potential RxFire Burn Unit (PRBU) – A uniform Statewide database that divides the state into prescribed fire scaled units.

Key Elements of the Revamp: Potential Prescribed Fire Unit (PRBU)



Potential Prescribed Burn Unit Map (PRBU)

- Foundation of an events-based inventory
- Pre-load PFIRS with veg. fuels, previous treatments, terrain, location, and agency
- Additional CARB benefits: evaluating emissions trade-offs and carbon tracking
- Multi-agency, common, and uniform spatial tracking system



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Our source data for the inventory: Primary government records before reconciliation

PFIRS
(burn decisions)
6263 records

CAPCOA
(quarterly reports)
4330 records

Task Force ITS
(activity data)
2185 records

12,778 government records
to evaluate and reconcile

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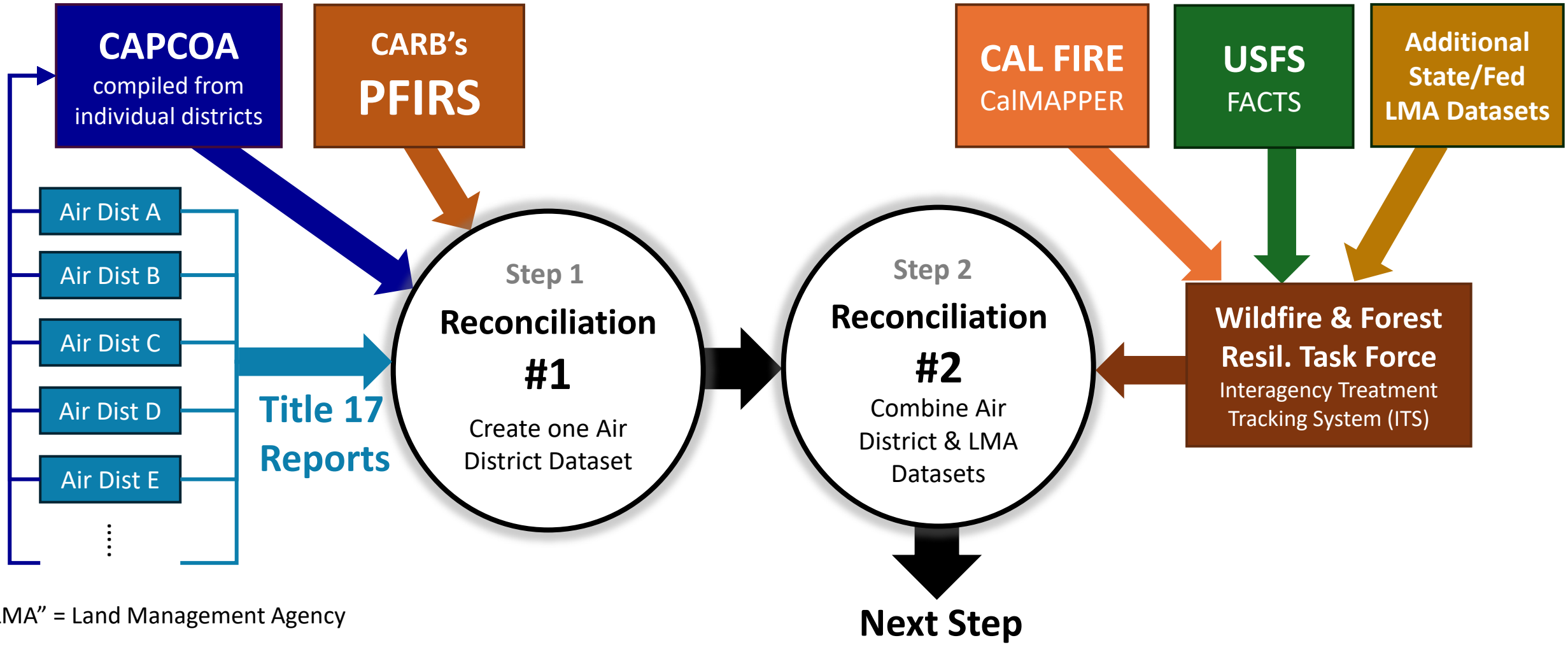
Activity Data Reconciliation Principles

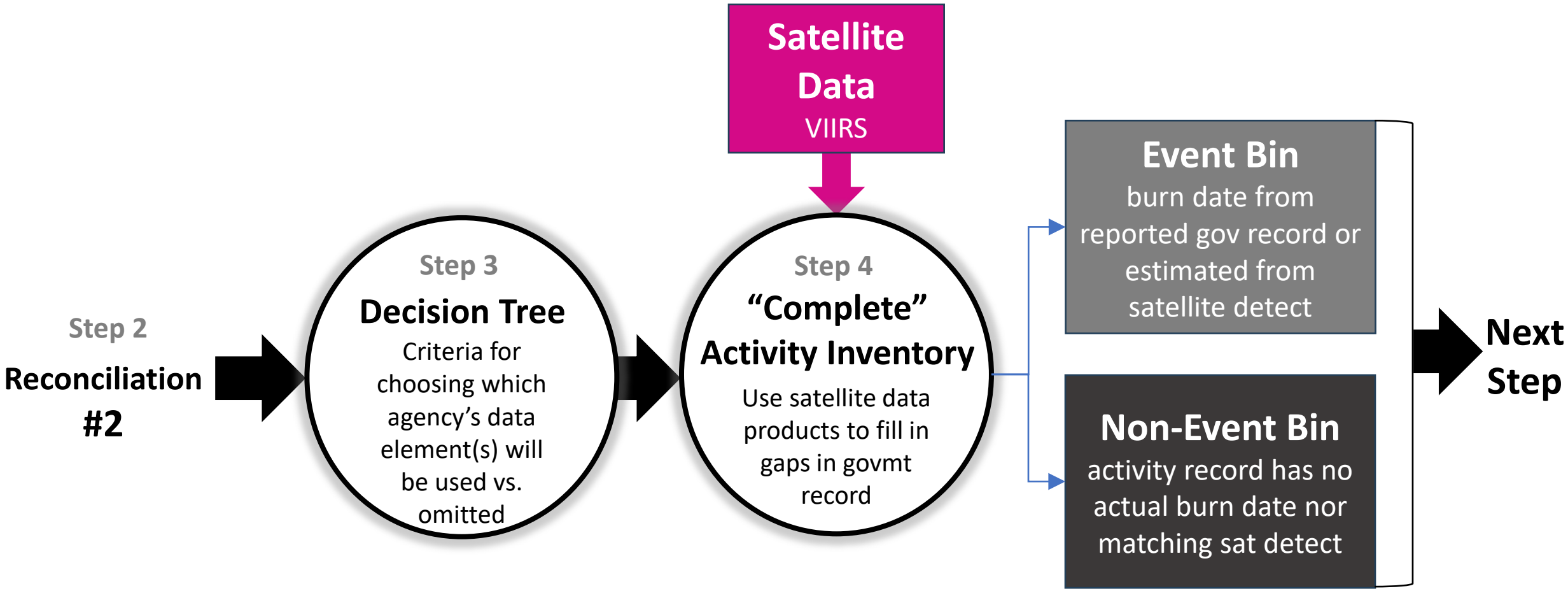
1. Utilize government records from data partner agencies as much as feasible, after excluding double/triple counting and records with non-remediable data issues:
    i. The activity data collected by air districts & CAPCOA
    ii. The info that land managers entered into PFIRS
    iii. LMA's own records of the work they did (ITS database)
2. Use best available science to fill in certain gaps (e.g., fuel type & consumption, emission factors) in estimating emissions
3. However, we will <u>not</u> make up event info such as date, the quantity of activities, what was done, and the location

Significant reconciliation effort is required to piece together a complete activity dataset without double/triple counting

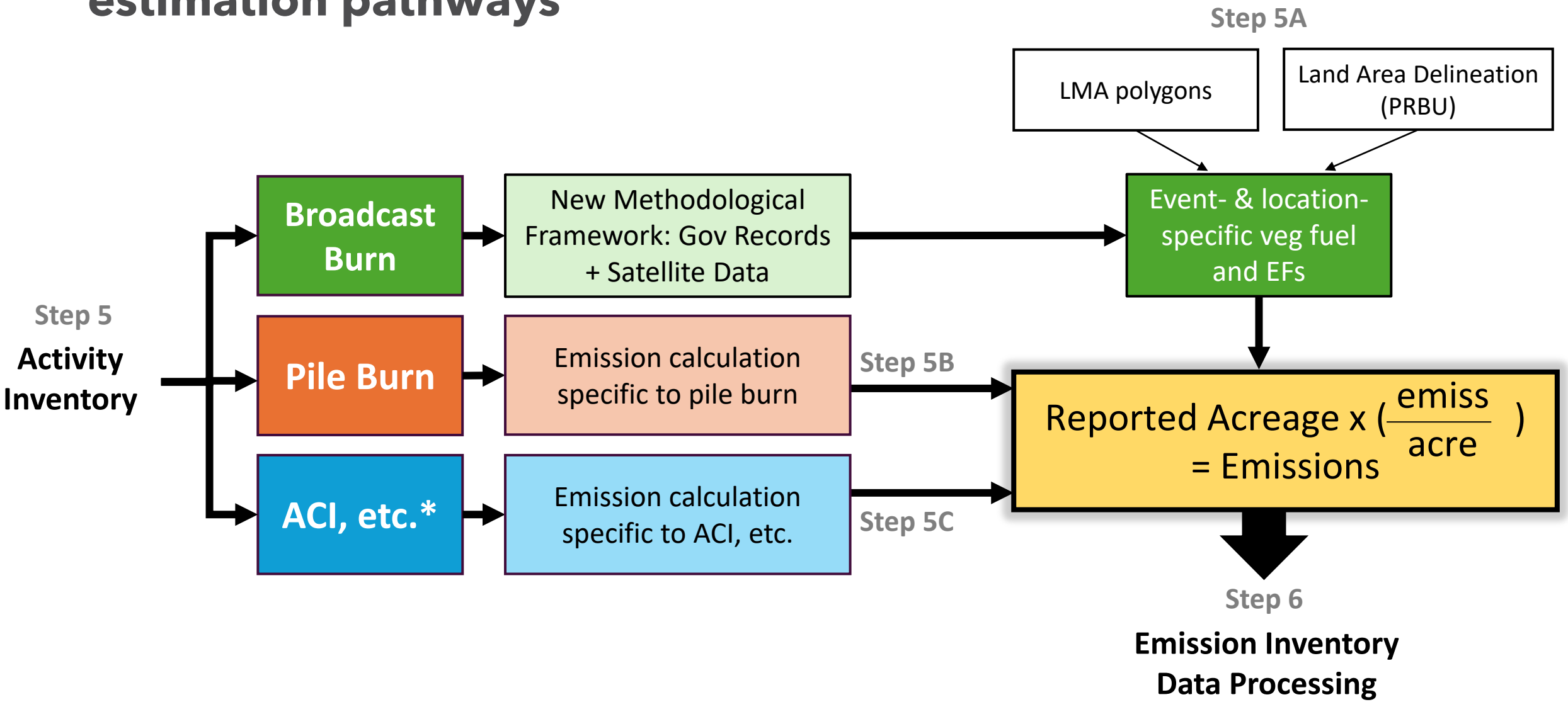


"LMA" = Land Management Agency

Criteria for deciding which agency's info to use in various data discrepancy scenarios. Use available satellite data to fill in gaps in burn date.

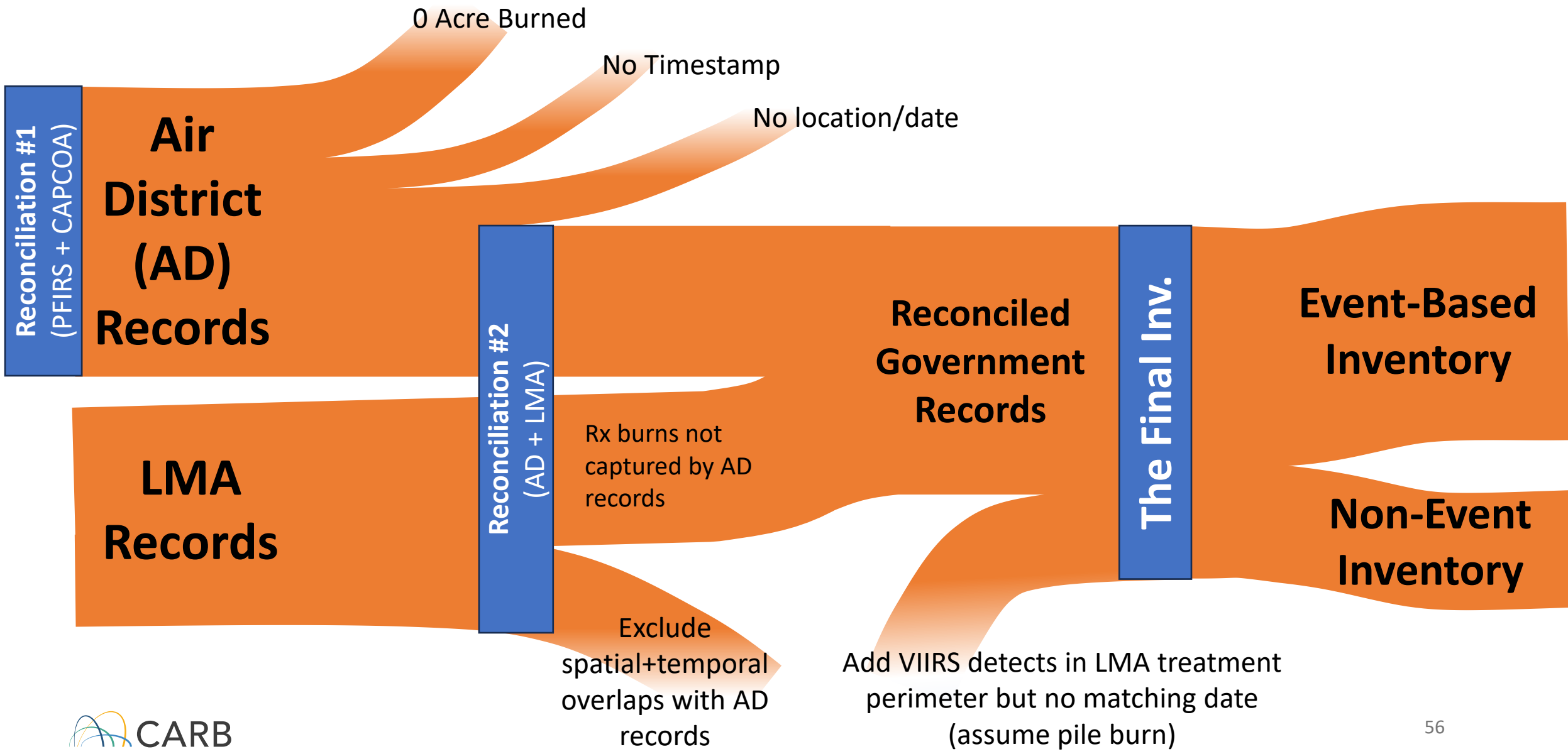


Rx burn activity records will be segregated into 3 emission estimation pathways



*"ACI, etc." = Air Curtain Incinerator (ACI), carbonizer, and other similar technologies that burners are using as alternatives to conventional pile burn.

The data that consist the final inventory after reconciliation



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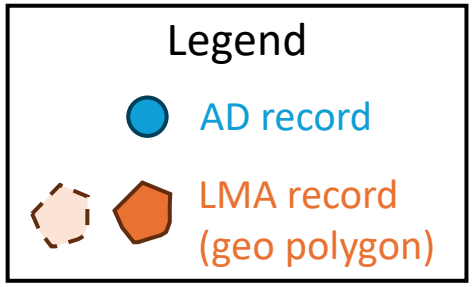
Reconciling LMA records with Air District records using 30-day temporal buffer

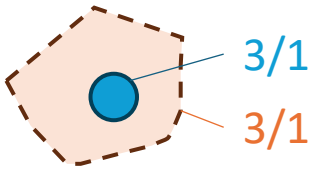


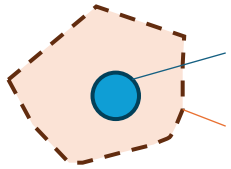
Spatial+Temporal Match

Use AD record; omit LMA record

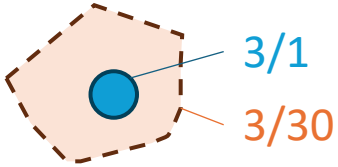
(All 4 examples: 1 burn date = 3/1)

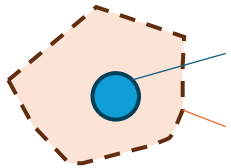
Dates matched





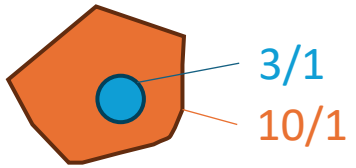
Date discrepancy is ≤30 days: consider them matched



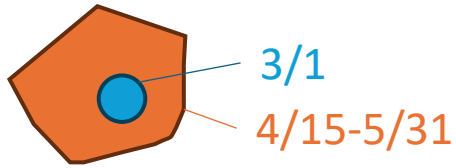


Spatial Match but No Temporal Match

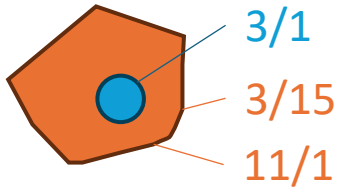
Treat AD & LMA records as separate burns



2 burns



2 burns
but the LMA record is “non-event”

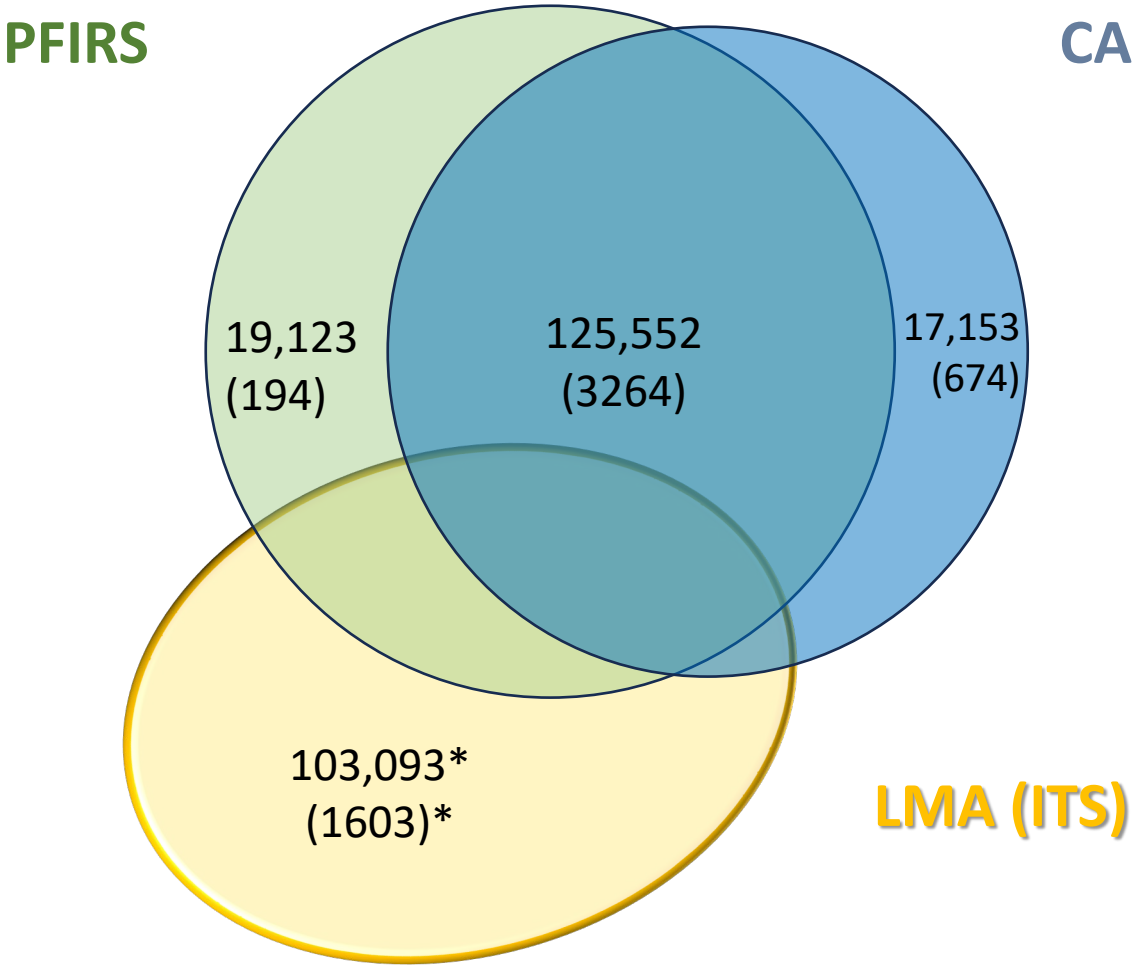


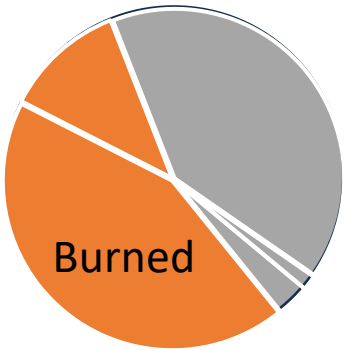
2 burns
3/15 is omitted due to 30-day buffer
11/1 is a separate burn

⚠ Potentially missing burn dates and overestimating emissions/day

Result of Reconciliation of All Included Government Records

2023 Rx Burn Records (DRAFT)*
Total: 264,921 acres
(5735 records)





* Numbers include LMA records that do not spatially+temporally match AD records, and LMA records that are being treated as separate burn in the inventory due to no temporal match (but there may be spatial association).

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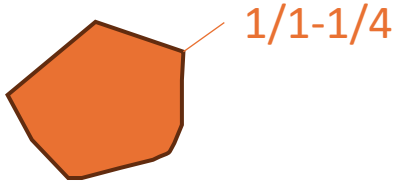
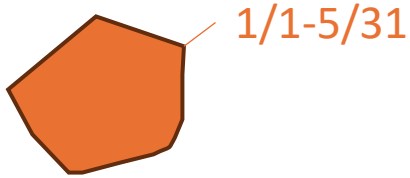
Leveraging satellite fire detect (VIIRS) in allocating emissions to different dates

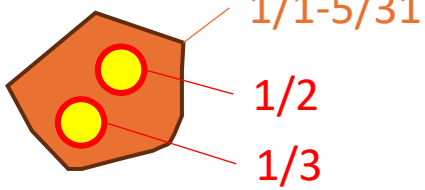
Legend
- VIIRS detect
- LMA record (geo polygon)



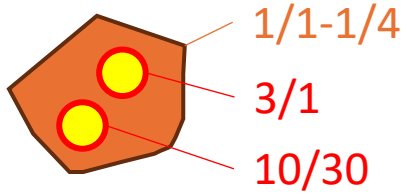
Date range is ≤5 days, no VIIRS: Evenly distribute emissions over 4 days: 1/1-1/4



Date range is >5 days, no VIIRS: "Non-Event" inventory



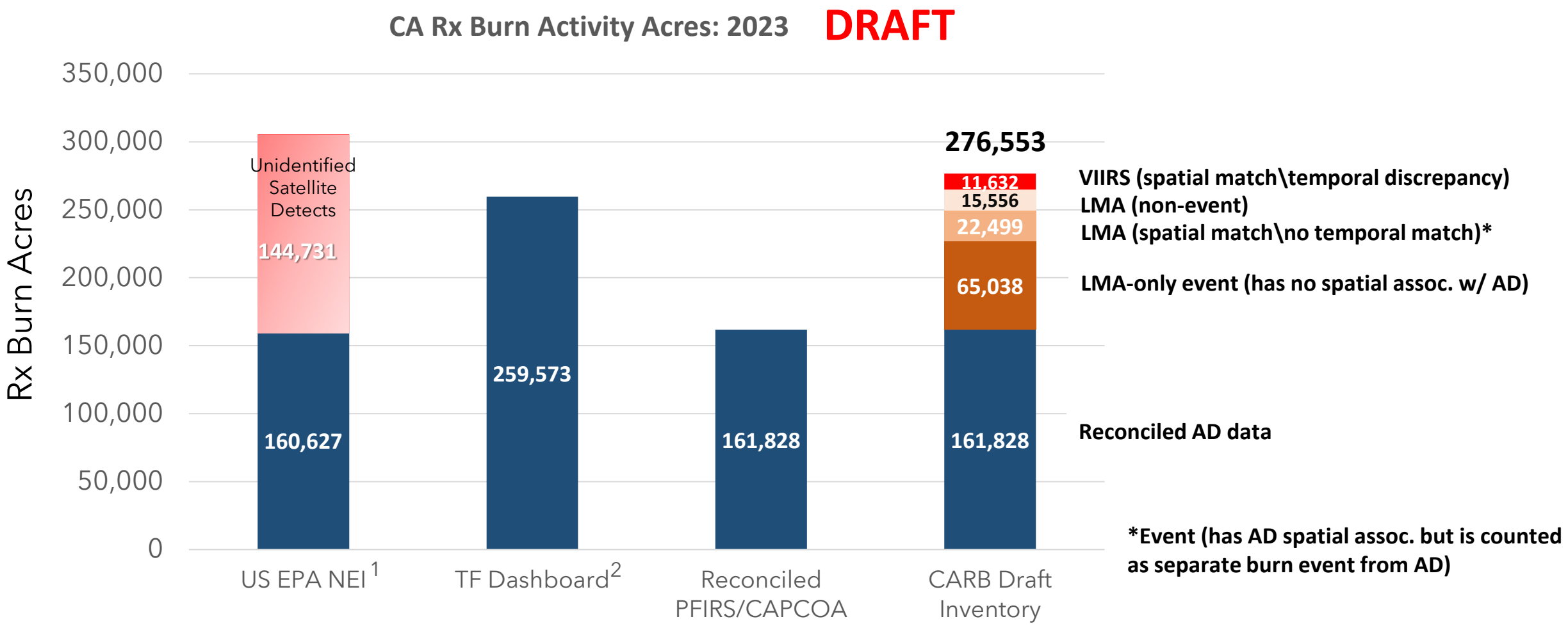
Use VIIRS detect dates when available: Evenly distribute total emissions to 2 dates:1/2 & 1/3



6 burn dates:
1/1-1/4: evenly distribute emissions over 4 days.
3/1 & 10/30: unreported burn, assume pile burn.

⚠ Potentially missing burn dates and overestimating emissions/day

How much Rx burn was done in 2023?



[1] In the NEI, US EPA does not include unidentified satellite detects in California.

[2] Task Force Dashboard focuses on the Rx burns conducted by state/federal agencies; it also includes some industrial timber companies and planned treatment burned in wildfire, latter of which CARB's Rx fire inventory does not include.

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Estimating Emissions

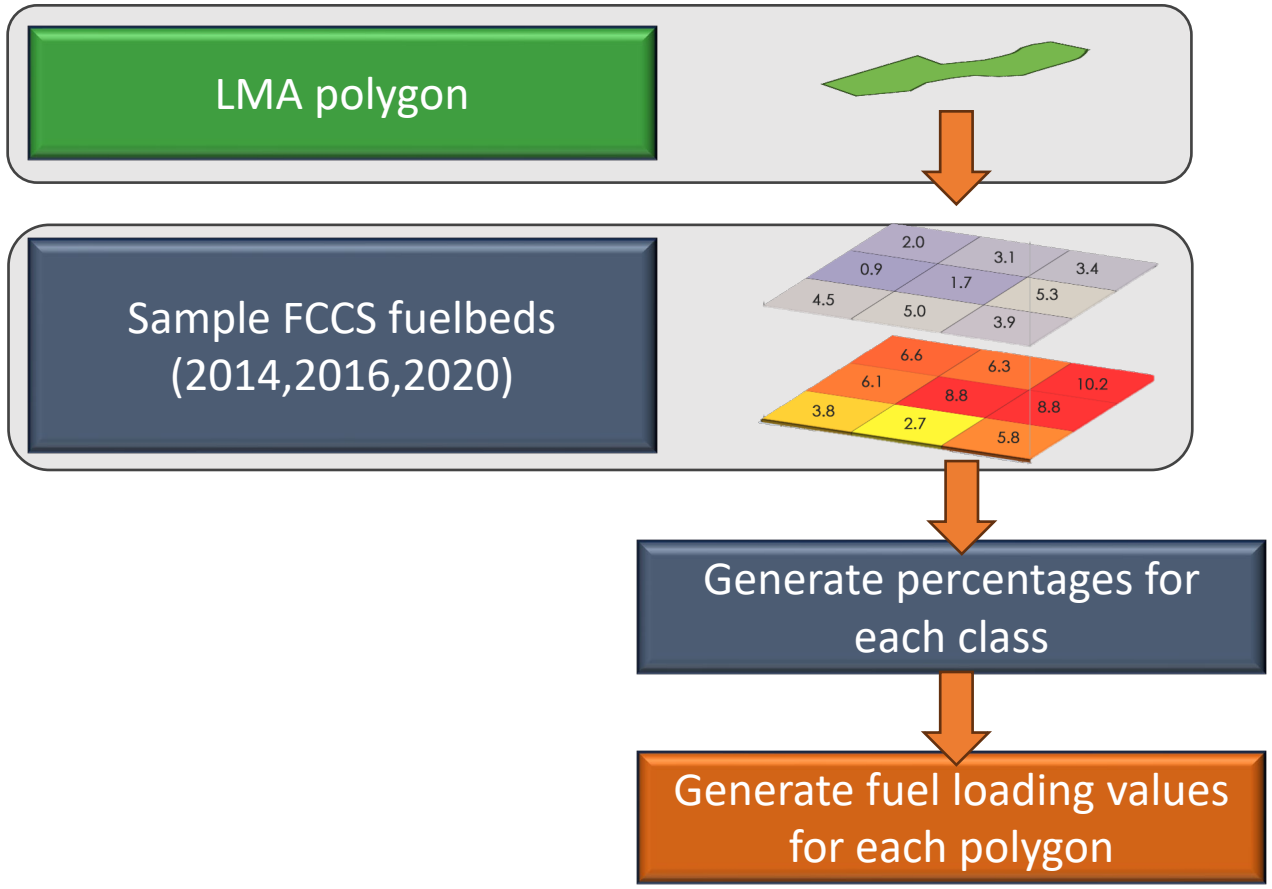
Emissions (lbs) = Fuel Quantity (tons) x Emission Factor (lbs/ton-fuel)

Estimating Fuel Quantity:

- **Broadcast Burn**: Burner Reported Acres x Fuel Loading (tons/acre) x Fuel Consumption Factor (%)
- **Pile Burn (Open Burn or ACI):**
  - If burner reported tons and acre: calculate from reported values
  - If tons is missing: We assume 6.74 tons per acre based on averages from Air District data.
  - If acre is missing: We drop the record from the inventory.
- **Satellite Fire Detects** Assumed to be Unidentified Pile Burn– Assumptions:
  - 23.5 acres from average acres for pile burn from 2023 Air District data.
  - We assume 6.74 tons per acre based on averages from Air District data.

Broadcast Burn: Fuel Loading Assumptions

Fuels Characteristic Classification System (Prichard et al. 2019; General Technical Report PNW-GTR-972)



Broadcast Burn: Consumption Assumptions

Based on average fuel moistures between 12-16%

Fuel Component	Avg. Consumption (%)	Notes
Litter	75–90%	Usually nearly fully consumed unless moisture is high.
Duff	20–40%	Duff smolders, highly sensitive to duff moisture; often little consumption in Rx burns.
Depth Reduction (Duff Depth)	0.2–0.6 in.	Average duff depth reduction per burn.
Shrub	70–90%	High consumption if shrubs are cured or dead; live moisture reduces this.
Herbaceous	80–95%	Usually consumed completely if cured; <50% if green.
1-hr fuels	90–100%	Nearly all fine fuels consumed.
10-hr fuels	60–80%	Partial; depends on moisture, flame length.
100-hr fuels	20–50%	Often only surface-charred or partially consumed in Rx burns.
1000-hr (3–9" sound, 3–9" rotten)	Sound: 10–20% Rotten: 30–60%	Rotten wood burns more readily; sound wood rarely consumed in prescribed conditions.

Broadcast Burn: Emissions Factors

Accessed from the extended emissions factors described in FOFEM. Required the emissions factors to include flaming and smoldering.

Flaming

Type	PM10	PM2.5	CH4	CO	CO2	SO2	NH3	NMOC	N20	NOx as NO
Western Forest	45.5	38.7	10.7	231.0	3515.6	2.3	3.4	59.3	1.1	4.5
Shrubland	18.3	15.5	8.1	162.8	3682.8	1.5	3.3	38.5	0.3	4.8
Grassland	22.0	18.7	4.3	134.2	3751.0	1.5	3.3	38.8	0.2	4.8

Smoldering

Type	PM10	PM2.5	CH4	CO	CO2	SO2	NH3	NMOC	N20	NOx as NO
Western Forest	44.0	33.0	22.0	310.0	3430.0	1.1	44.0	5.5	3.3	1.1
Shrubland	16.0	12.0	7.0	100.0	1580.0	0.4	15.0	1.5	1.5	0.3
Grassland	12.0	8.0	5.0	80.0	1600.0	0.3	10.0	1.0	1.0	0.2

FOFEM User Guide Lutes, D. (2020). FOFEM 6.7: First Order Fire Effects Model, USFS, page 86

Pile Burn: Emissions Factors

Accessed from the Smoke Emissions Reference Application (SERA). Required the emissions factors to include flaming and smoldering.

Flaming

Type	PM10	PM2.5	CH4	CO	CO2	SO2	NH3	NMOC	N20	NOx as NO
Conifer	12.6	11.7	5.6	103.8	3403.0	0.1	1.1	39.5	0.3	2.3
Hardwood	7.8	7.3	2.8	80.0	3369.9	0.4	0.6	13.4	0.3	4.3

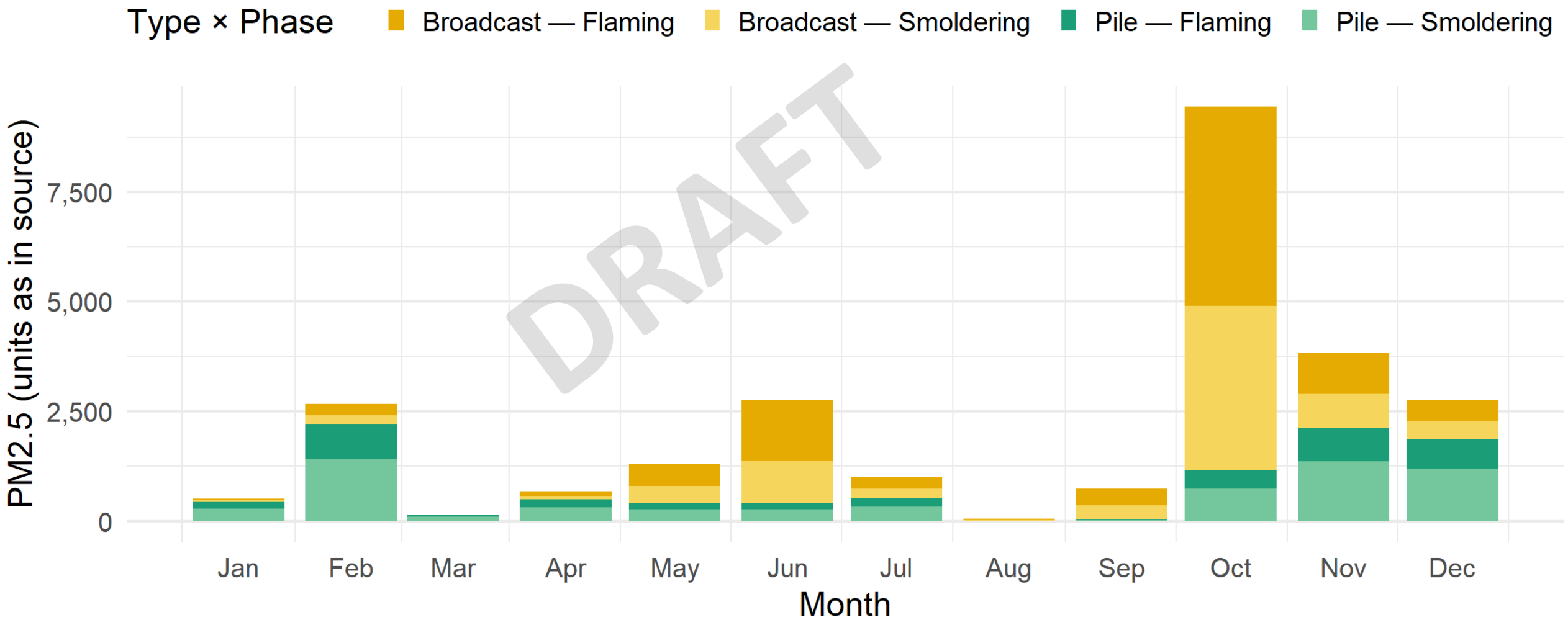
Smoldering

Type	PM10	PM2.5	CH4	CO	CO2	SO2	NH3	NMOC	N20	NOx as NO
Conifer	30.2	18.1	20.3	247.8	3101.9	0.1	57.3	1.1	3.8	0.3
Hardwood	18.8	17.4	10.3	191.1	3070.9	0.4	19.5	1.1	7.1	0.3

Smoke Emissions Reference Application (SERA)

PM2.5 Emissions Estimates for 2023

Monthly Statewide PM2.5 (Flaming + Smoldering)



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CALIFORNIA
AIR RESOURCES BOARD

Prescribed Fire
Activity and Emission Inventory

Q&A

Wrap Up

- **2025 inventory cycle:** data release in Q4 of 2025
- **On-going :**
  - Incorporate more years as activity data become available
  - Continually explore additional inventory refinements
  - We welcome your suggestions any time as we continue to build upon this work and refine the inventory

Contact Info

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- Eric.Rowell@arb.ca.gov

Lisa Rosenthal, Wildfire Inventory Specialist

- *available only until Oct 21, 2025; please contact Anny Huang for questions about wildfire inventory*

Program Webpage:

- https://ww2.arb.ca.gov/wildfire-emissions