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Biomass Burning Smoke: What is it and where does it come from?

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International Emissions Inventory Conference
September 26th, 2023
Seattle, WA

Smoke is everywhere

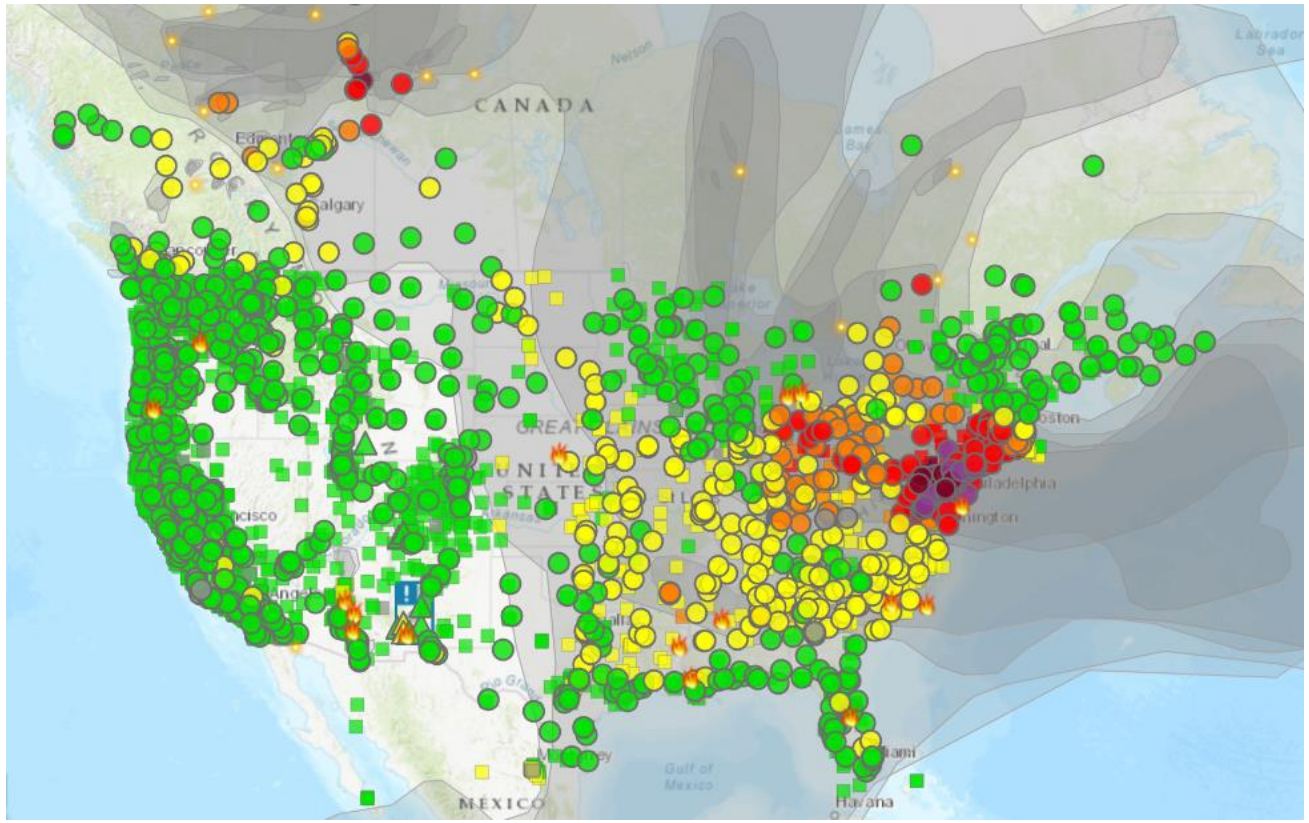
Los Angeles Times

LOG IN

Wildfire smoke has given New York the world's worst air quality. Californians have some tips

Buildings in Lower Manhattan in New York are partially obscured Tuesday by smoke from Canadian wildfires. (Angela Weiss / AFP via Getty Images)

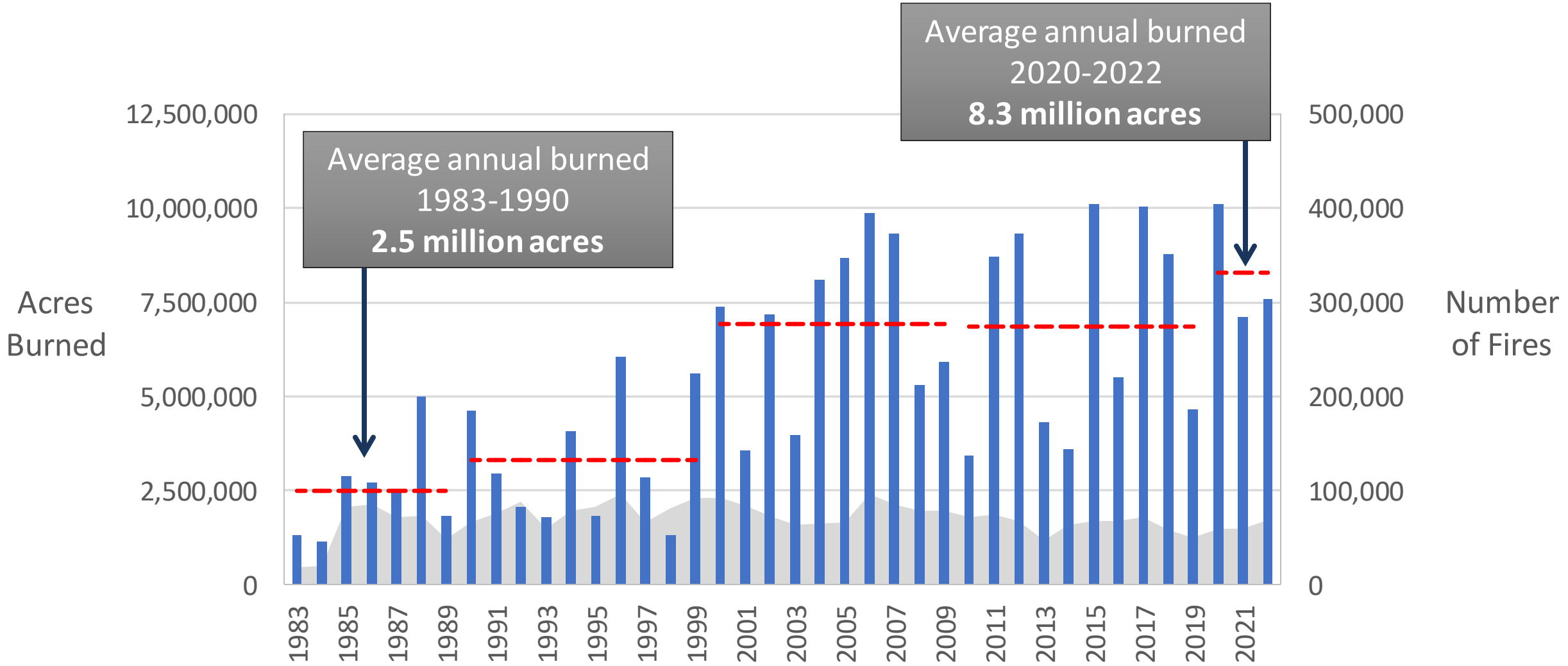
BY ALEXANDRA E. PETRI | STAFF WRITER



Record levels of wildfire smoke have been observed in areas that have not historically been impacted

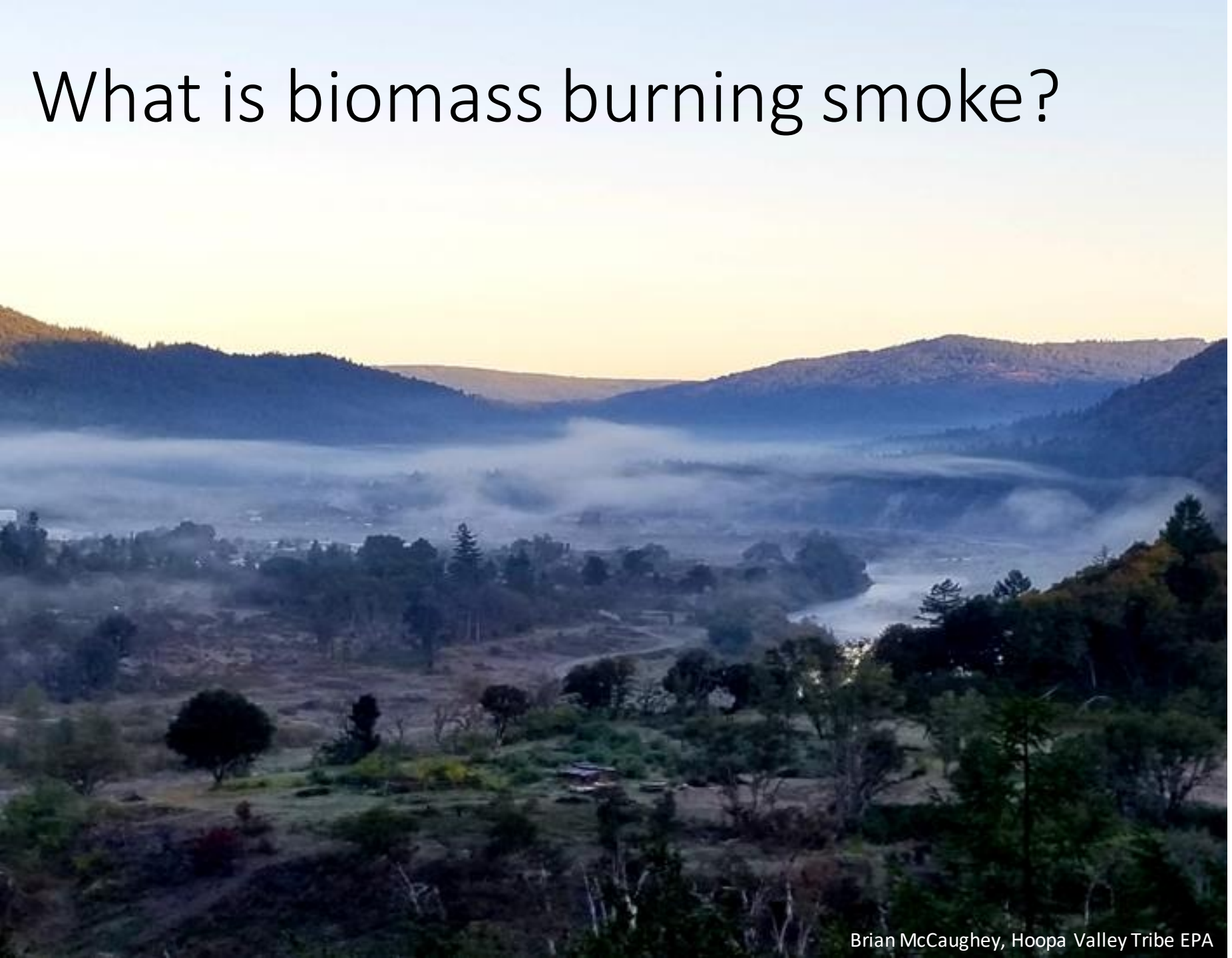
https://www.latimes.com/world-nation/story/2023-06-07/wildfire-smoke-canada-wildfires-east-coast-new-york-air-quality

In the US, the number of wildfires has not changed but burned area is increasing



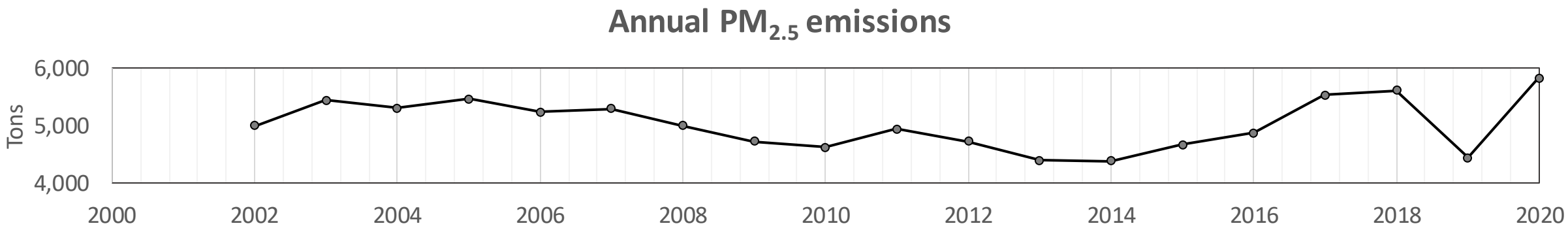
Adapted from https://www.nifc.gov/fireInfo/fireInfo_stats_totalFires.html

What is biomass burning smoke?



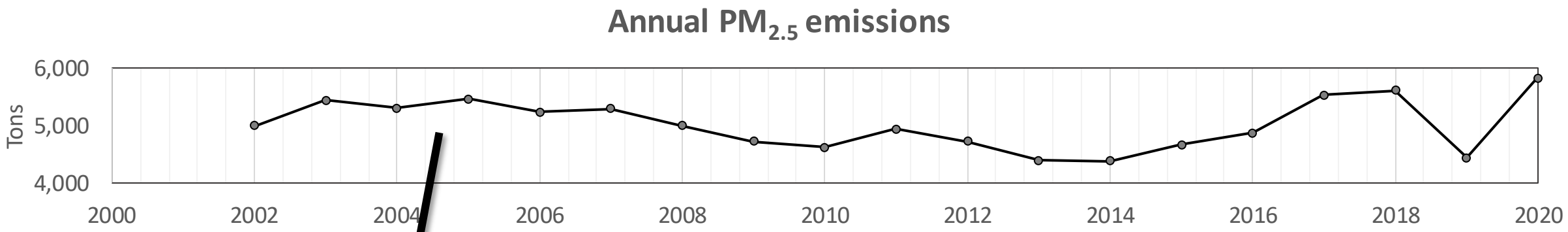
- **A complex mixture of major combustion products carbon dioxide (CO_2), water (H_2O), carbon monoxide (CO), and fine particulate matter ($PM_{2.5}$)**
- **There is also a wide range of hazardous air pollutants:**
  - Volatile organic compounds (VOCs)
  - Semi-volatile organic compounds (SVOCs)
  - Trace level toxics

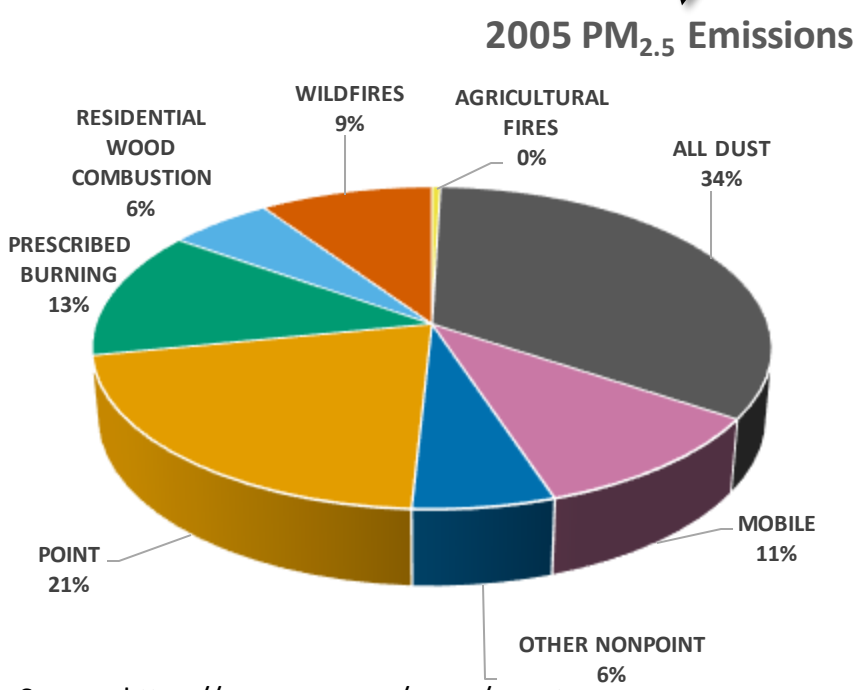
What is the overall $PM_{2.5}$ trend in the US?



Source: https://www.epa.gov/cmaq/equates

What are the trends for smoke?





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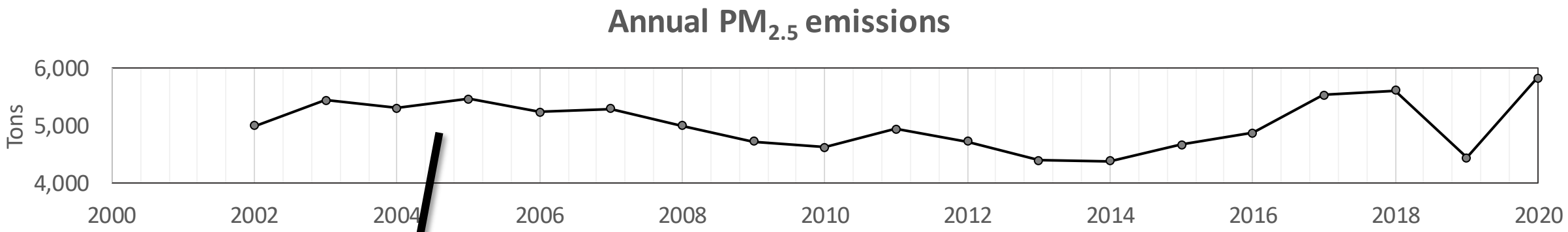
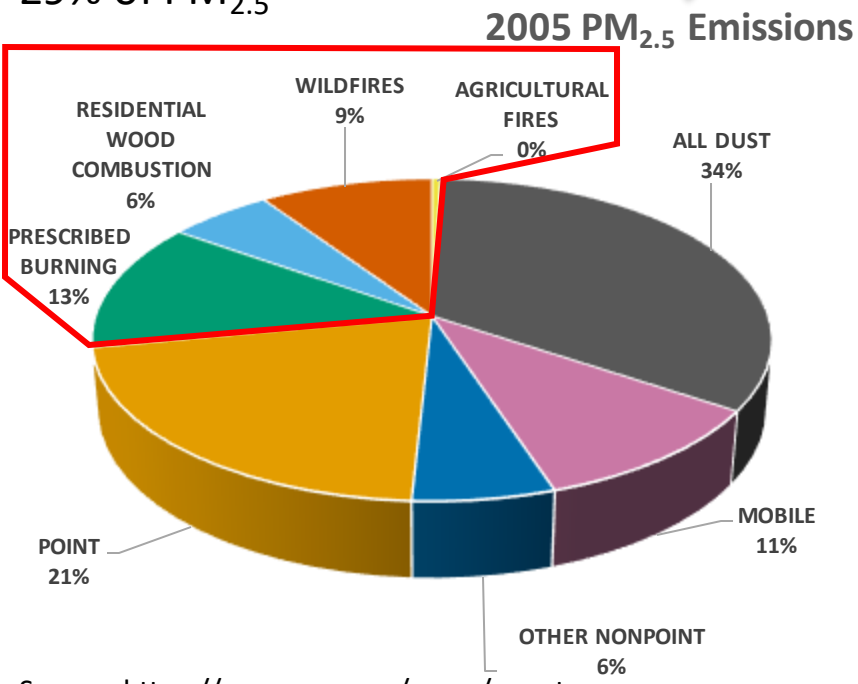


Biomass burning emits 29% of $PM_{2.5}$



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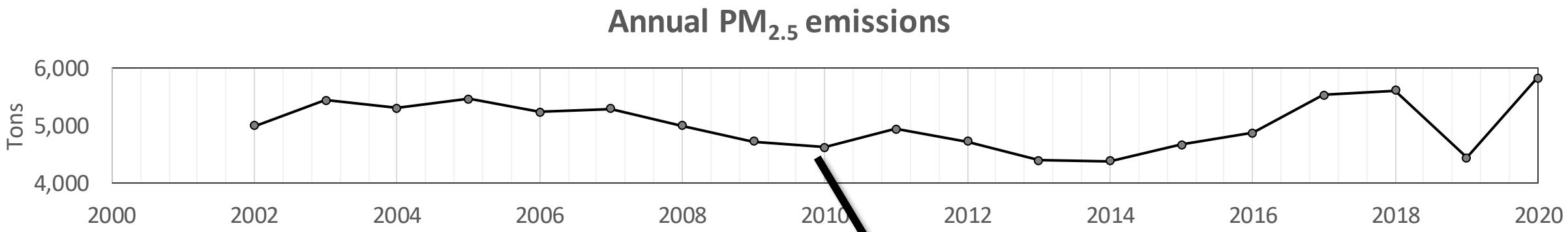

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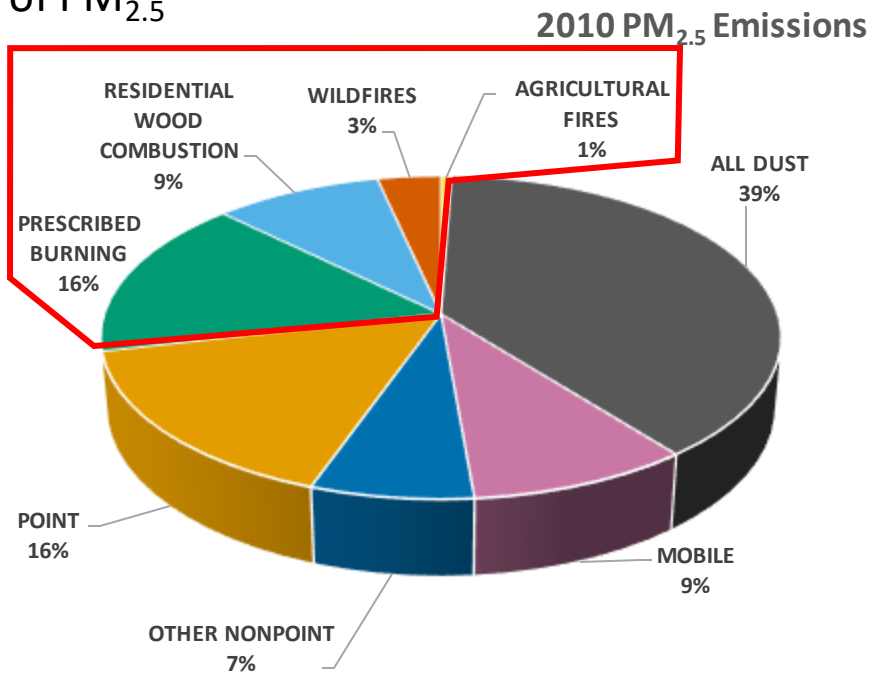

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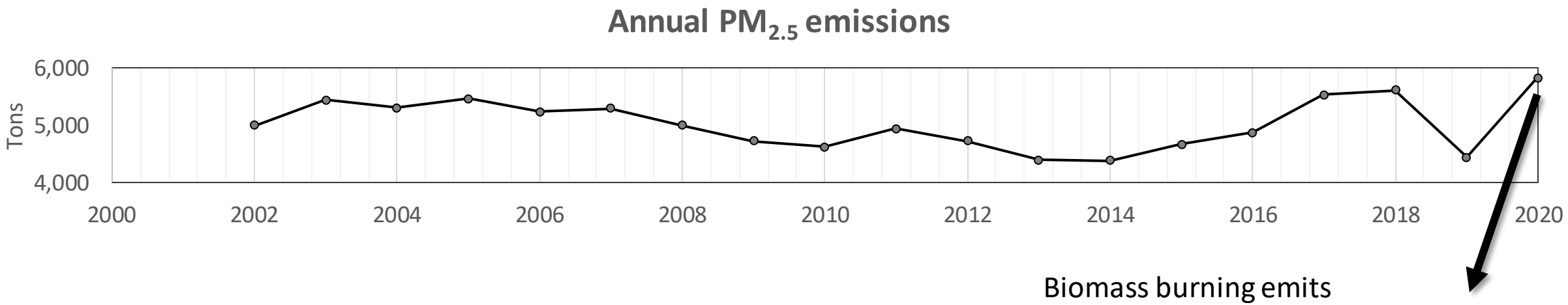
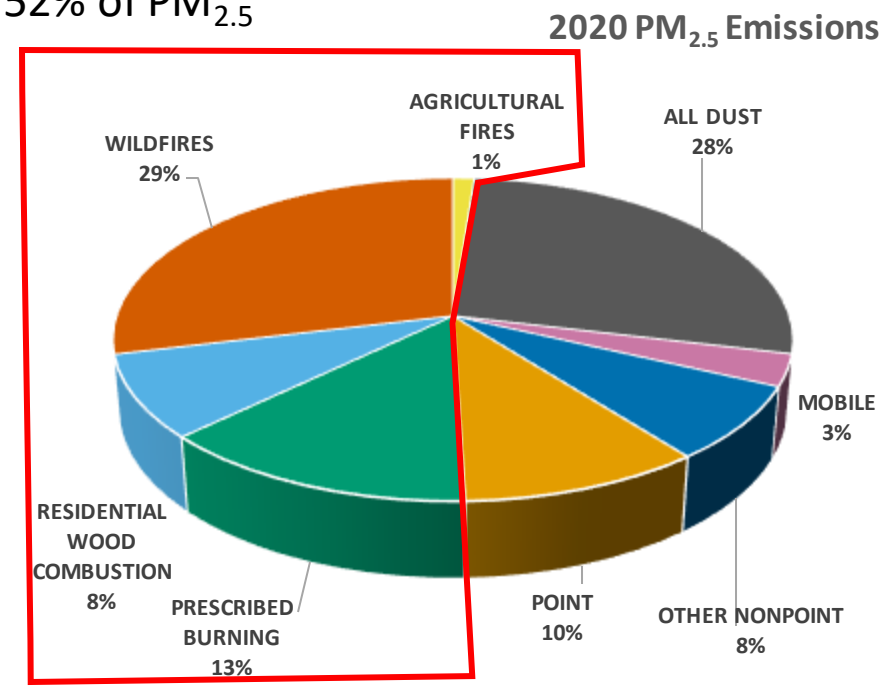
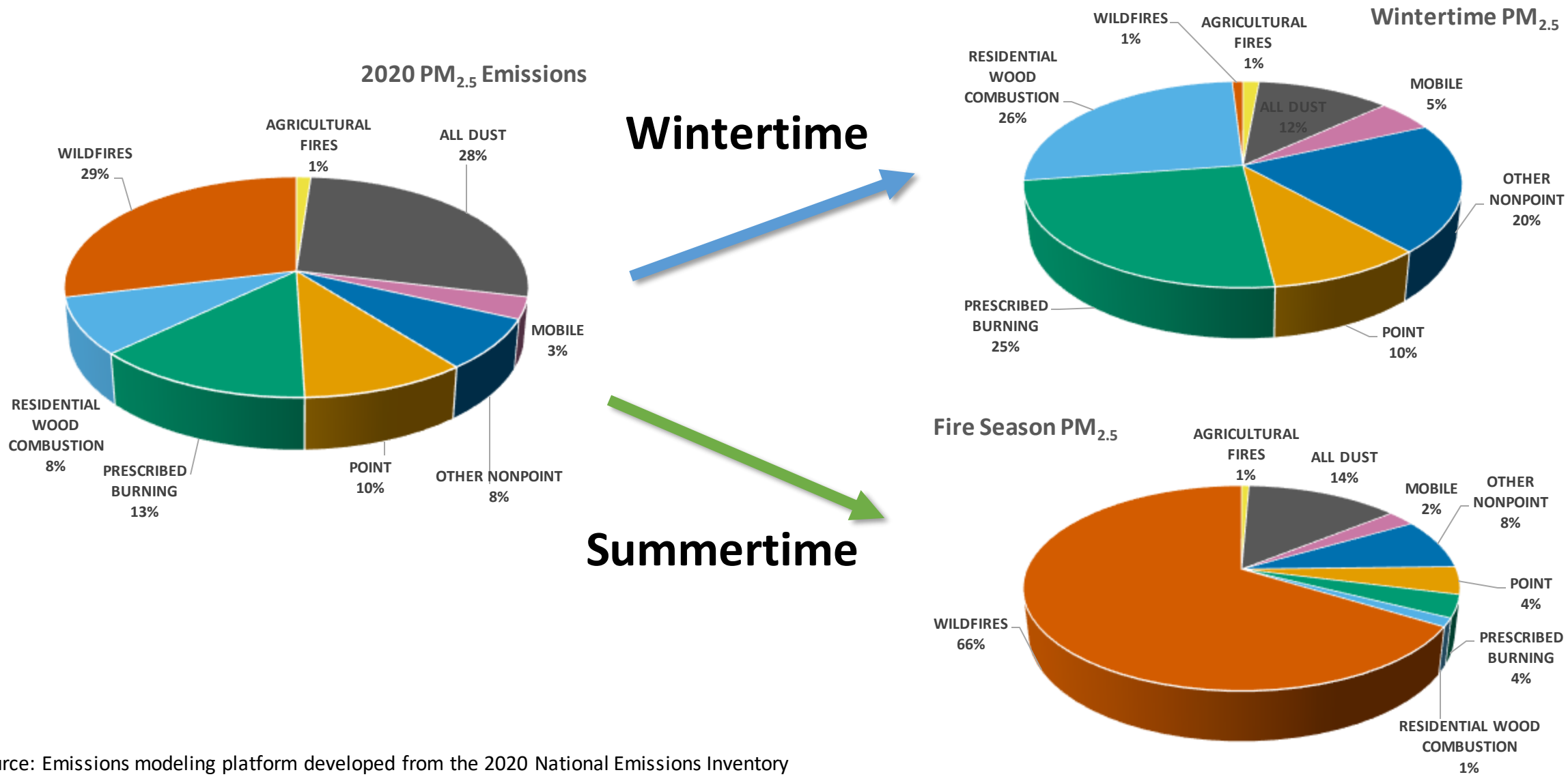


Biomass burning emits 52% of $PM_{2.5}$



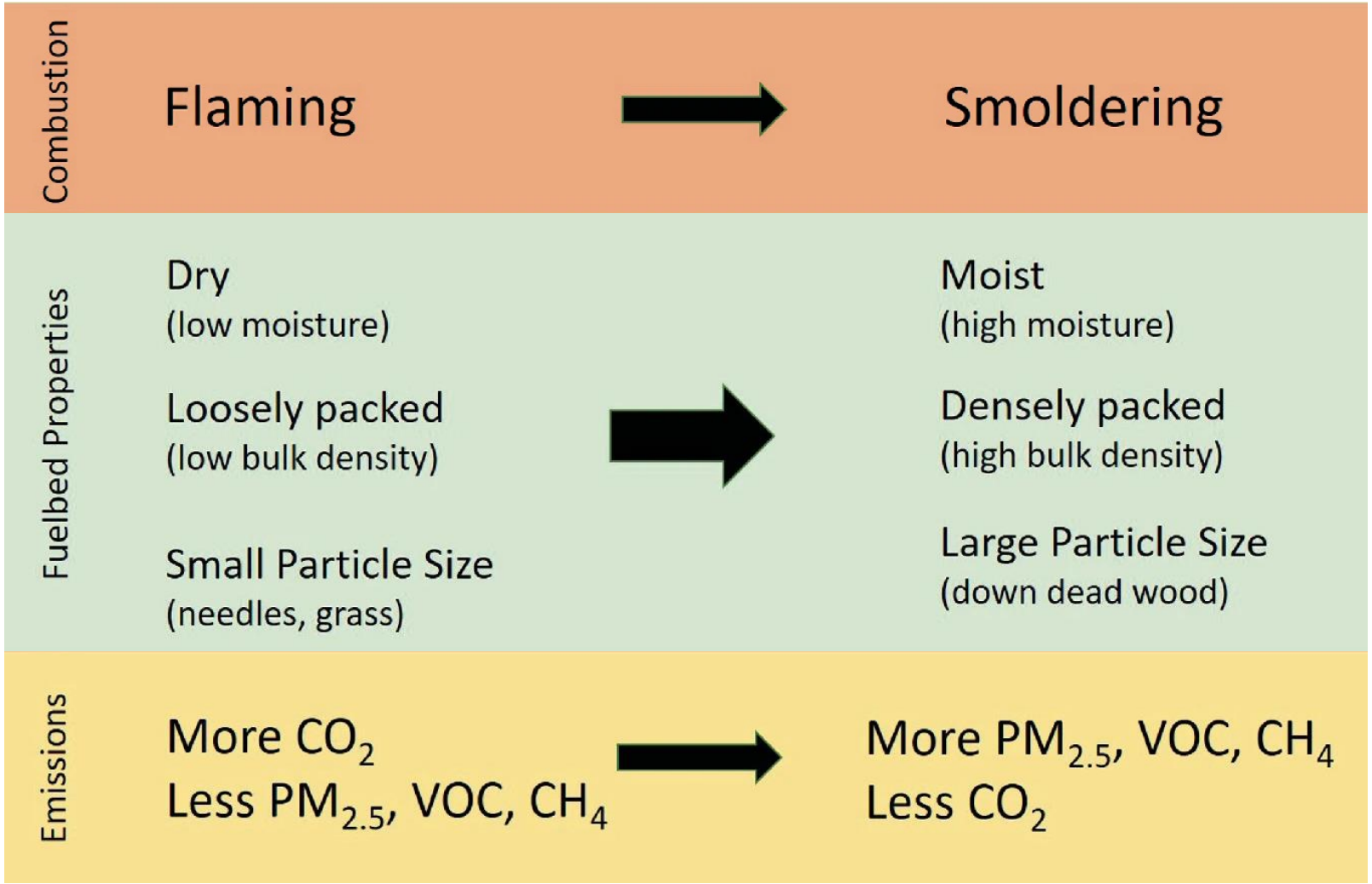
Source: https://www.epa.gov/cmaq/equates

Biomass burning emissions vary through the year



Source: Emissions modeling platform developed from the 2020 National Emissions Inventory
https://www.epa.gov/air-emissions-inventories/2020-national-emissions-inventory-nei-data

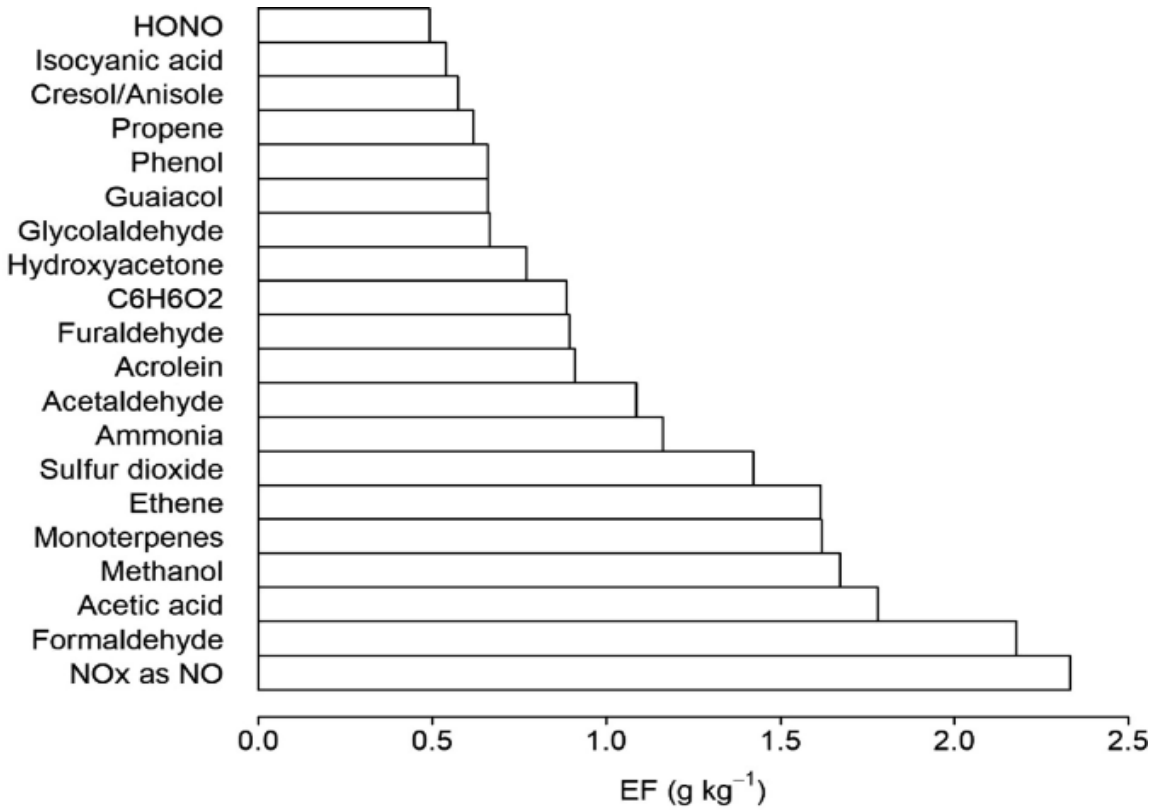
Fuel characteristics and combustion conditions determine emissions



Chapter 5 Emissions, Urbanski et al. https://doi.org/10.1007/978-3-030-87045-4_5

Large number of gases emitted from biomass burning

Example of most abundant gases emitted from burning of western conifers



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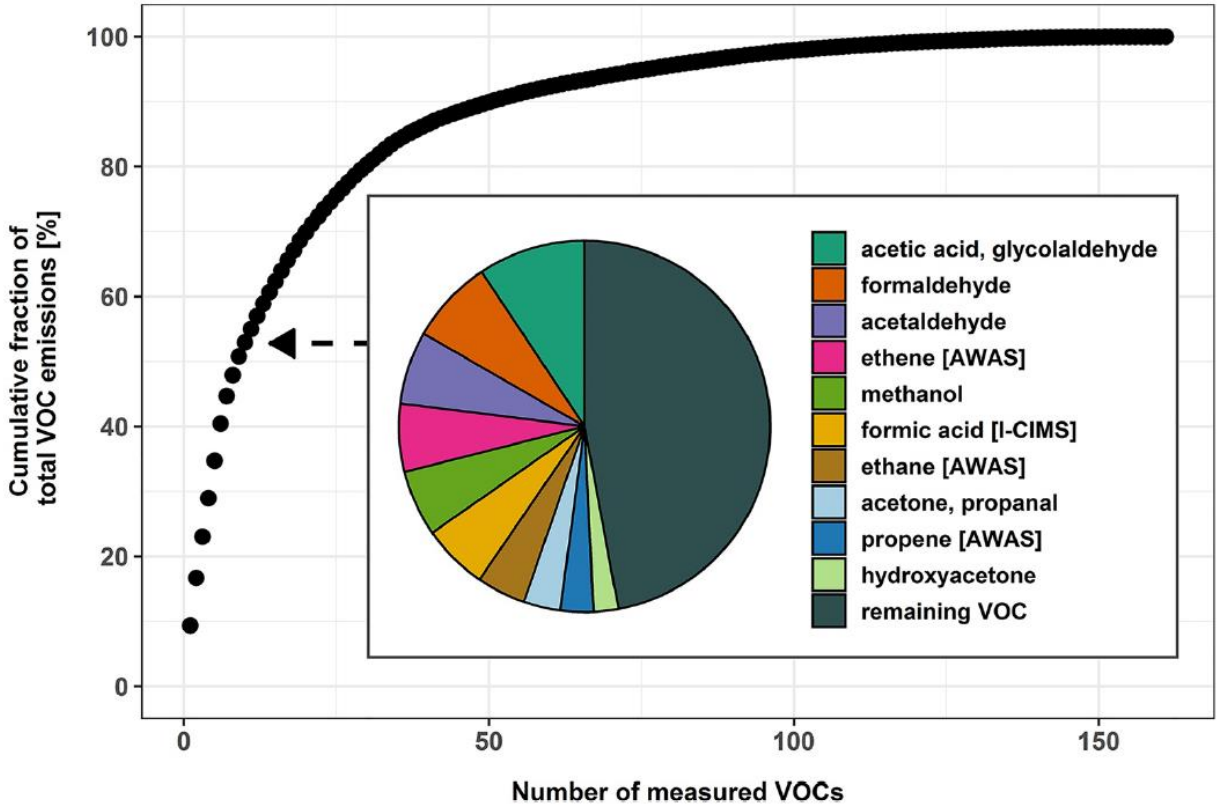
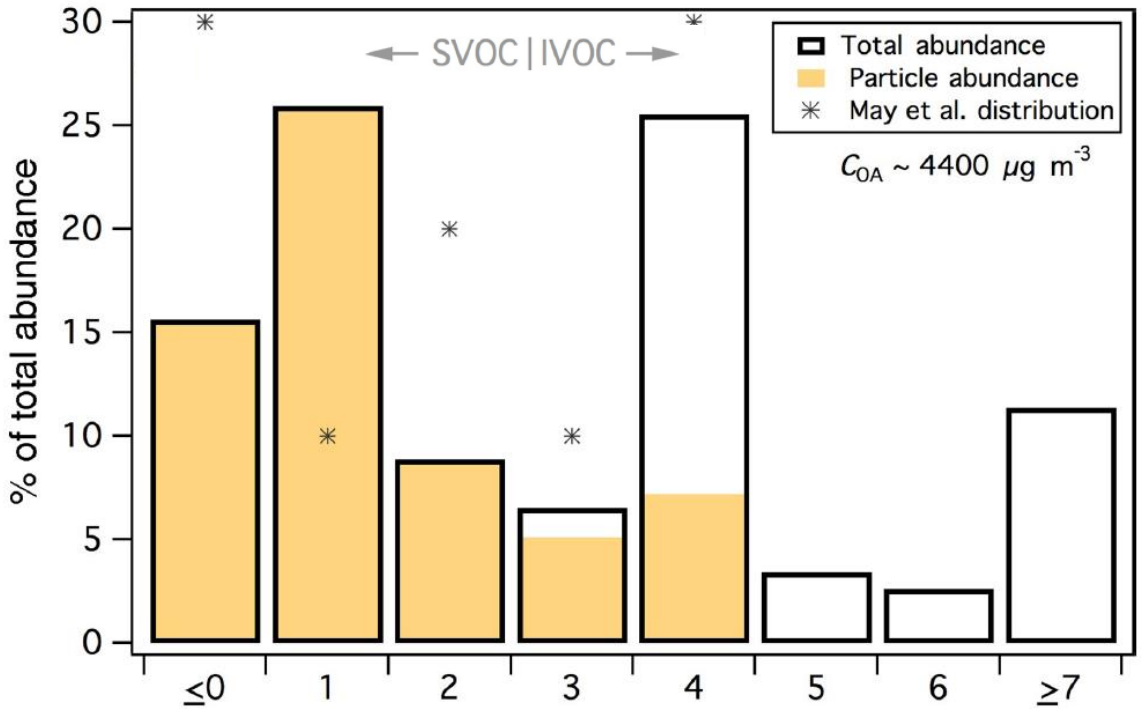


- VOC emissions are dominated by oxygenated compounds
- Emissions depend on combustion conditions

Permar et al. 2021 doi:10.1029/2020JD033838

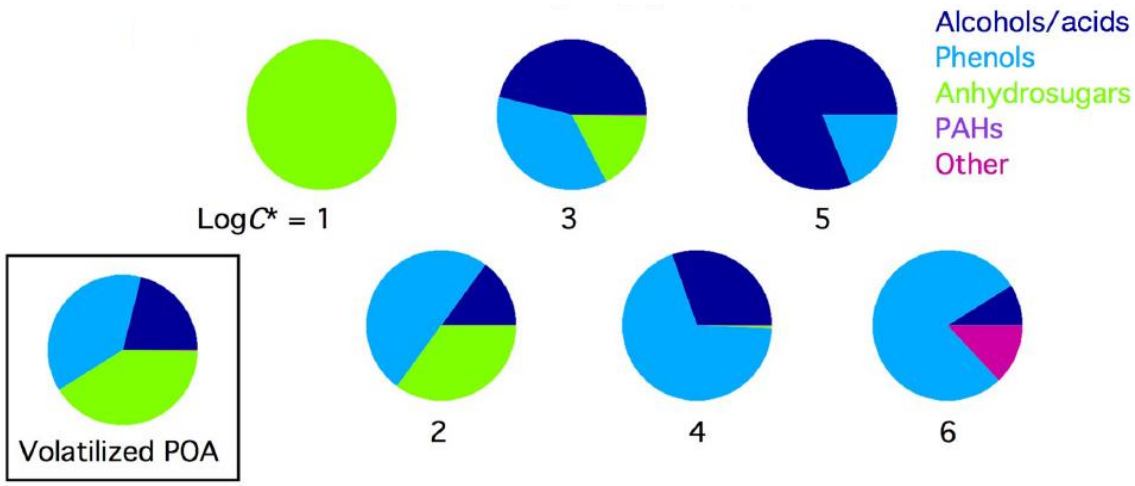
Wide range of semi and intermediate volatile compounds



PM ⟷ VOC

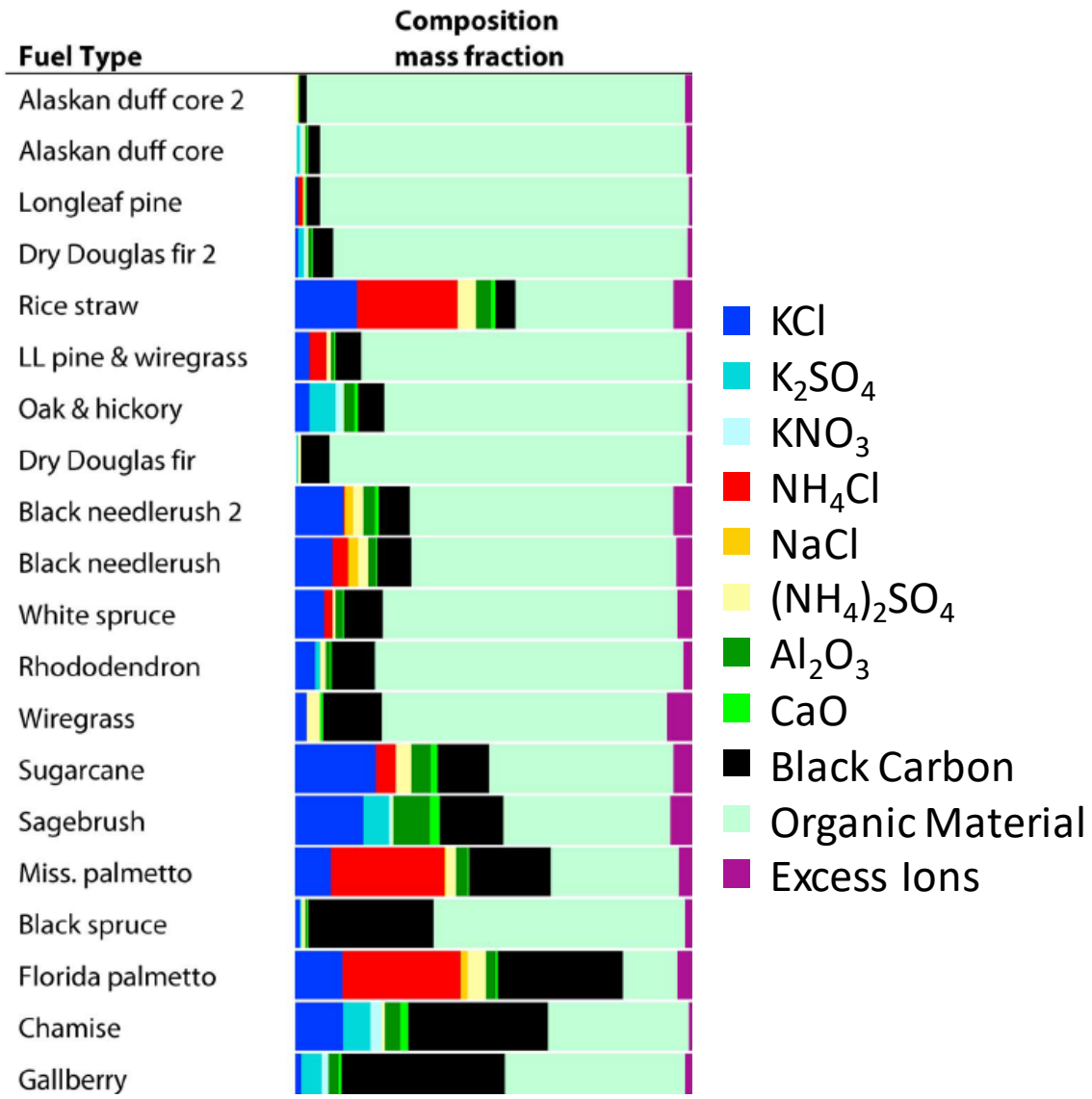
Volatility of organics

Composition of these intermediate organics (IVOCs)



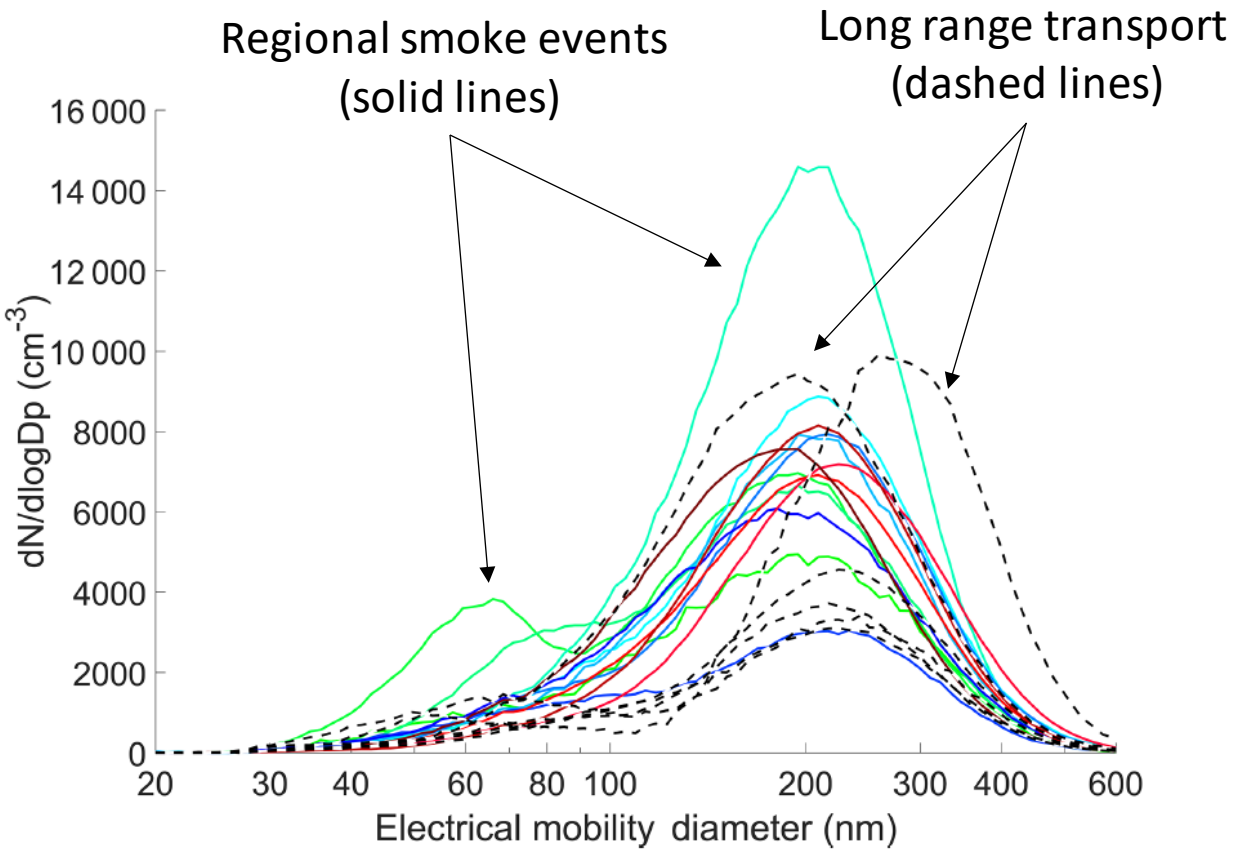
Hatch et al. 2018 doi:10.5194/acp-18-17801-2018

Biomass burning particles are also complex



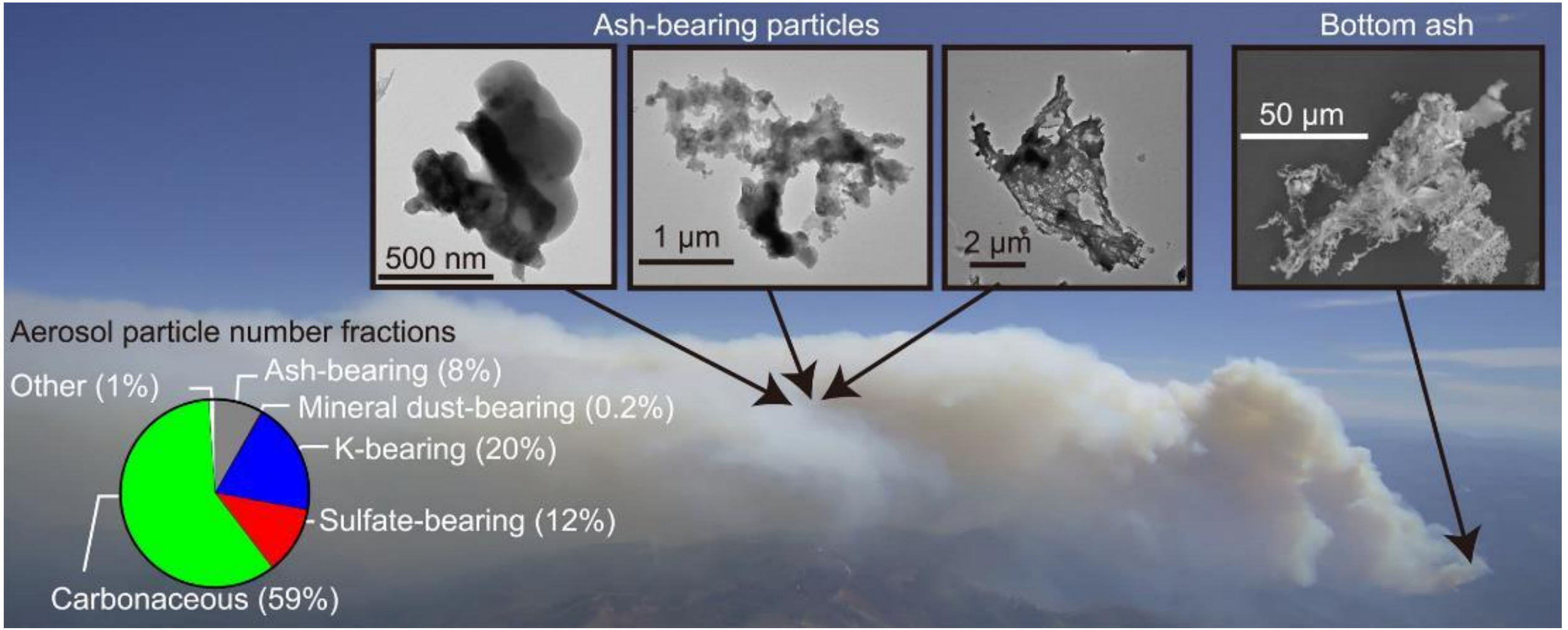
Levin et al. 2010 0, doi:10.1029/2009JD013601

Wildfire Smoke Size Distributions



Laing et al. 2016 doi:10.5194/acp-16-15185-2016

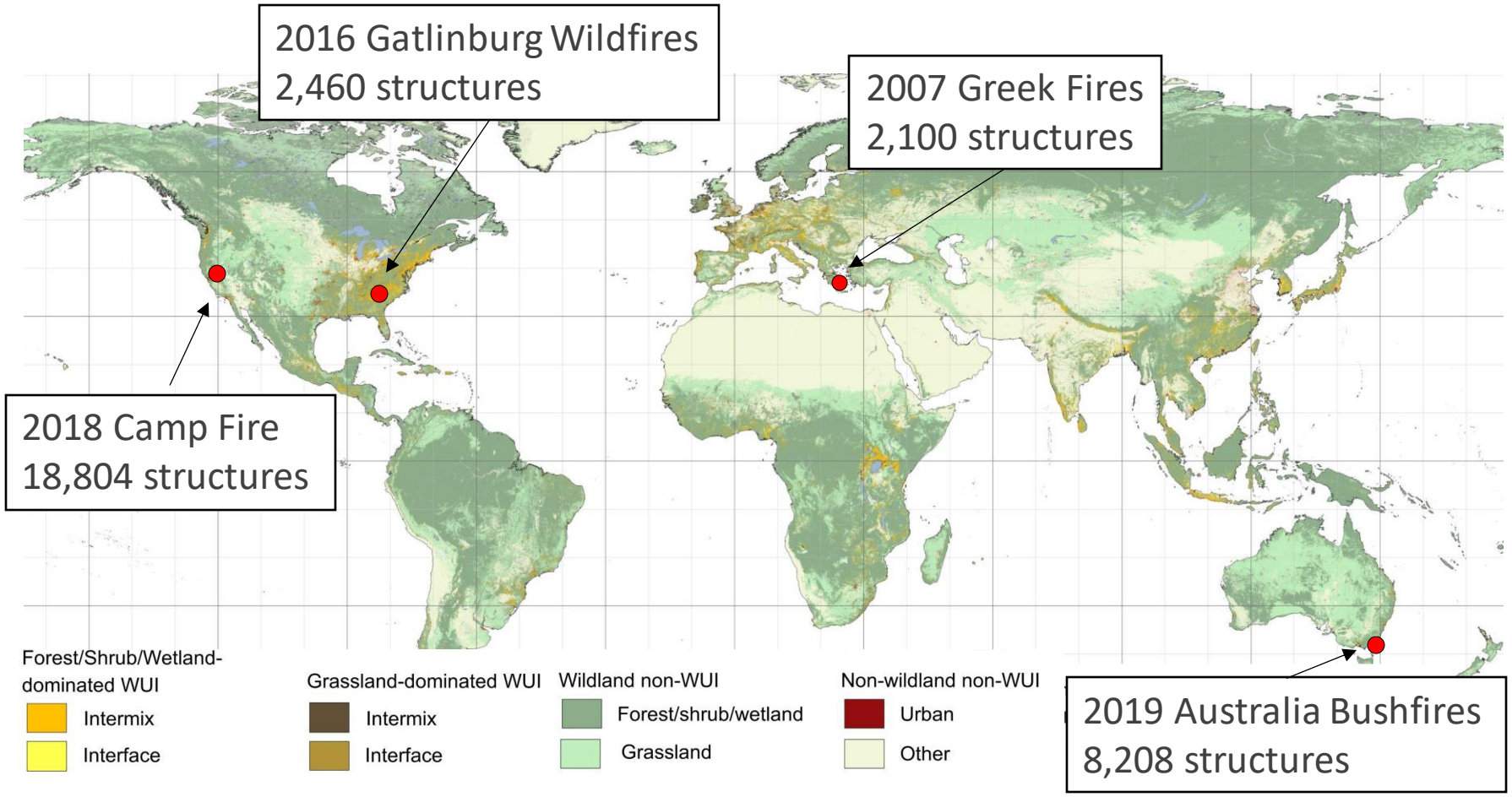
Ash is also a concern for wildfires



Adachi et al. 2022 doi:10.1029/2021JD035657

Wildfires are also burning structures in the wildland urban interface (WUI)

2023 Lahaina wildfire
2,200 structures



https://silvis.forest.wisc.edu/globalwui/

Method to estimate structure fire emissions

$$E_x = A \times B \times F \times EF_x$$

- Fire specific speciated emissions
  - Not resolved by day
  - Limited spatial resolution

- Number of structures burned
  - State counts
  - ICS 209* incident status summaries
- Number of vehicles burned
  - Recycling statistics
  - Insurance database

- Estimates of typical American fuel loads
  - Mean home area (2,150 ft^2)
  - 98% of the structure is 'Wood'
  - 3% of the structure is 'Other stuff'

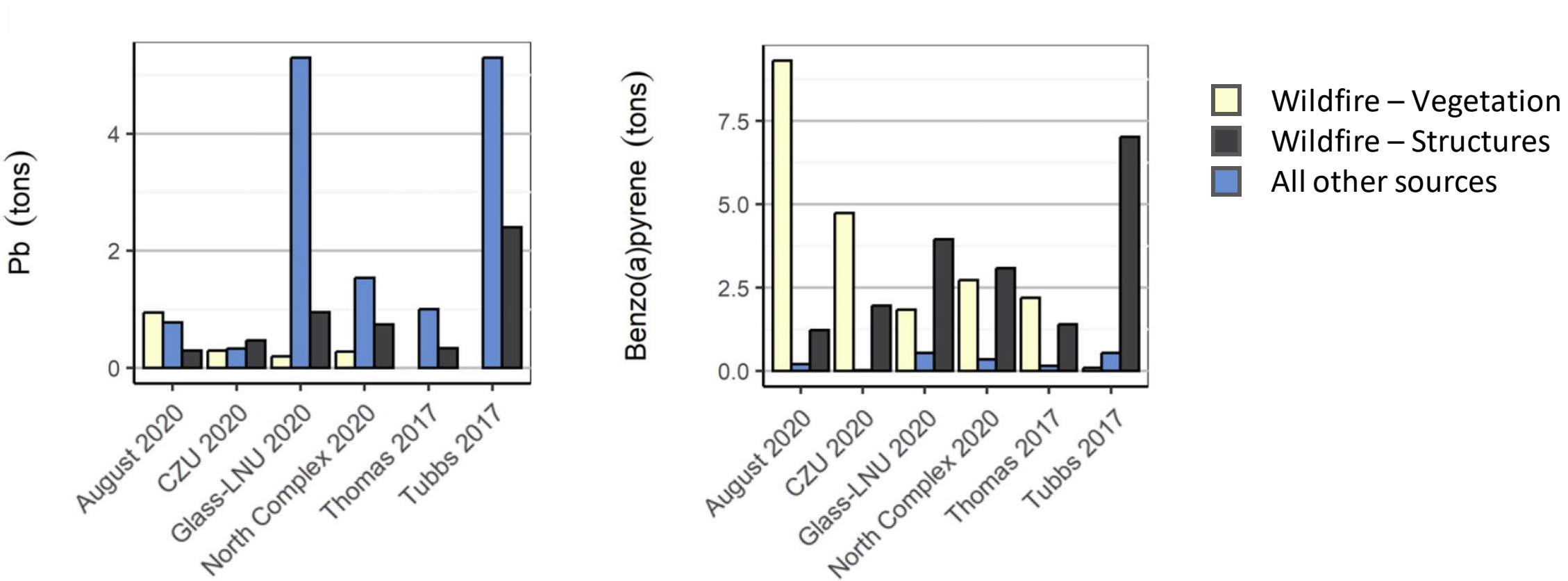
- 80% of the combustible mass assumed for wildfire conditions

- Emission factors for all species lumped by 'Wood' and 'Other stuff'
- Median of factors derived from bench and pilot scale urban material fires

Holder et al. 2023 doi.org/10.1093/pnasnexus/pgad186

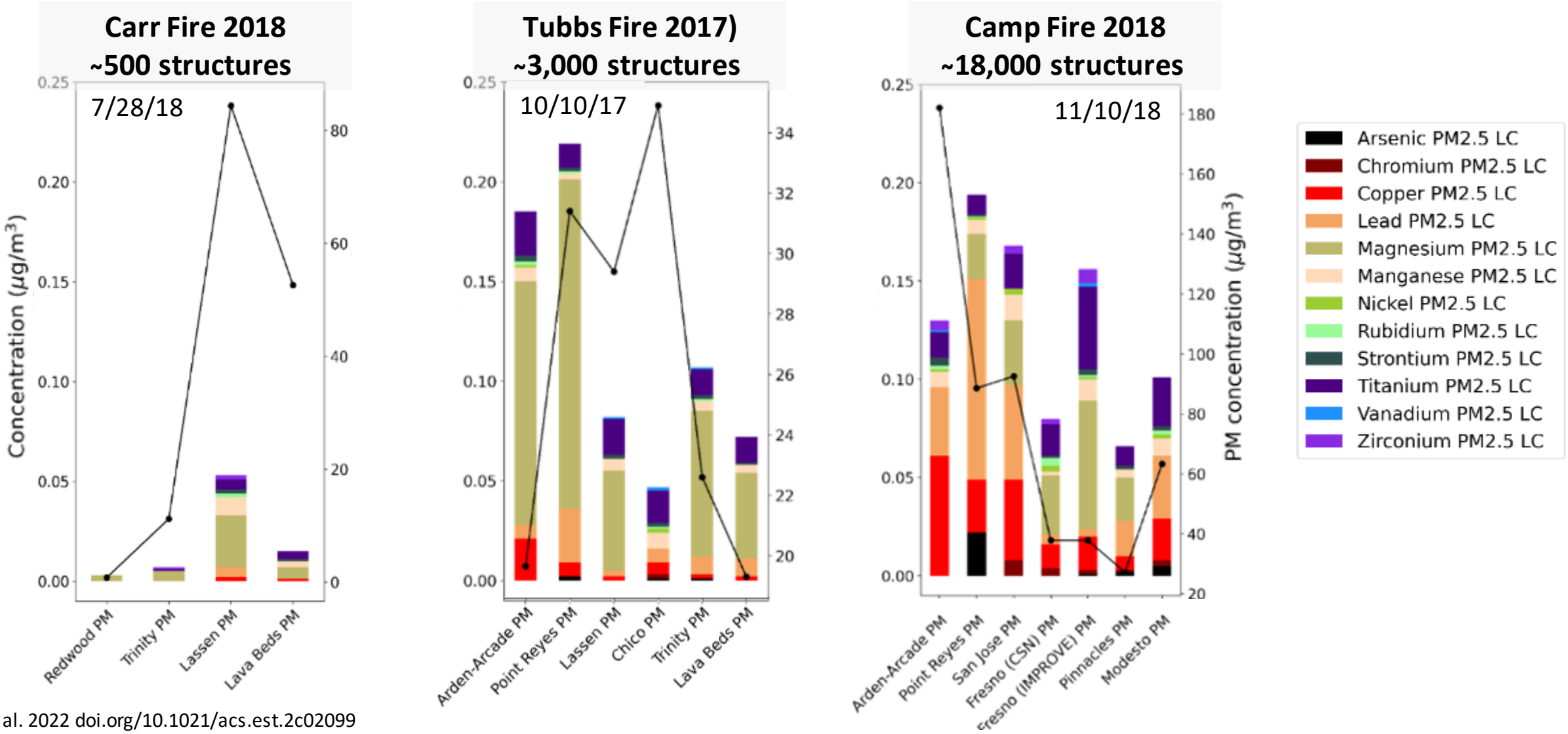
* Incident Command System (ICS); ICS 209 Incident status summary

Recent wildland urban interface fires emit substantial amounts of toxic compounds



Holder et al. 2023 doi.org/10.1093/pnasnexus/pgad186

Metals may be an emissions fingerprint for burning structures



Boaggio et al. 2022 doi.org/10.1021/acs.est.2c02099

Looking forward, what are the research needs for biomass burning inventories?

- Improved activity and emissions data:
  - Comprehensive prescribed fire reporting to keep pace with expected large increases in prescribed fire programs
  - Information on residential wood combustion activity such as types of devices, wood species and condition, duration and type of operation
  - Information on real-world residential wood combustion emissions
  - Update inventories to reflect recent research on wildfire emissions
- Accounting for WUI fires in hazardous air pollutant inventories
- More chemical speciation data for all sources/conditions especially for hazardous air pollutants (even at trace level)
- Better understanding of the climate impacts on biomass burning activity, emissions, and feedbacks

In summary

- Biomass burning emissions are a major source of air pollution
  - Wildfires, prescribed fires, and woodstoves are the predominant sources of $PM_{2.5}$ in the US
  - Wildfires are increasing in magnitude as is their contribution to US emissions
  - Climate change is expected to alter global wildfire patterns
- Biomass burning emissions are a complex mixture
  - Emissions are dominated by oxygenated organic molecules
  - PM is primarily < 1 µm and organic, with a wide variety of trace elements
  - Wildland urban interface fires likely emit more toxic compounds than vegetative fires

Boaggio et al. 2022 doi.org/10.1021/acs.est.2c02099

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EPA NEI Team
EPA EQUATES Team

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