EPA
United States
Environmental Protection
Agency

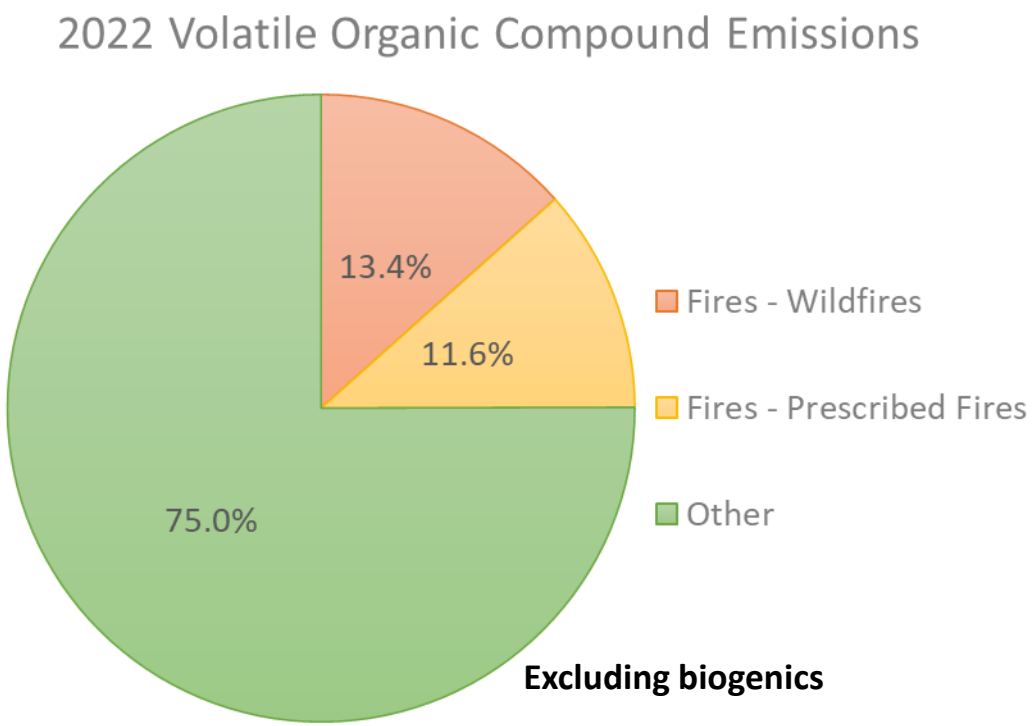
Gaseous Reactive Organic Compound Emissions Factors from Wildland Fires

United States Environmental Protection Agency
Office of Air and Radiation

September 17, 2025
Presentation to: Emissions Inventory Conference

Background

- Wildland fires are a significant source of gaseous reactive organic carbon emissions to the atmosphere.
  - In the 2022v1 Emissions Modeling Platform, there are > 3.5 million short tons of volatile organic compound (VOC) emitted.
- Current operational EPA methods leverage non-methane organic carbon (NMOC) emissions factors (EFs) from Urbanski, 2014. These NMOC EFs ignore unspeciated mass; which are measured emissions but not explicitly identified.
  - Studies suggest this unidentified mass includes significant intermediate volatile organic compound (IVOC) mass (Pye et al., 2024) → secondary organic aerosol precursors.



Urbanski, S., *Wildland fire emissions, carbon, and climate: Emission factors*. Forest Ecology and Management, 317, 51-60, 2014.

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Magnitude of Unspeciated Mass

Existing EFs

Total Measurements

Emissions Using Existing EFs

Description	NMOC EF [g/kg]	Unspeciated NMOC EF [g/kg]			2022v1 NMOC [tons]
SE Conifer	16.046	10.020	26.067	62%	645,414
Boreal	23.152	15.170	38.323	66%	35,053
Rx NW Conifer	26.975	18.360	45.336	68%	198,523
WF NW Conifer	33.874	25.680	59.556	76%	1,070,371
W Shrub	17.4988	7.140	24.639	41%	34,495
Grass	17.6451	7.140	24.785	40%	566,437
Residual CWD (Stumps and Logs)	45.25	39.650	84.825	88%	839,429
Residual Duff	61.6955	154.145	215.841	250%	

Unspeciated Mass

Percent Increase

Goal: leverage data from additional studies to characterize previously unidentified mass, with a focus on better representing the full volatility distribution (from less volatile species, such as IVOCs, to more volatile species, such as those typically reported) of gaseous wildland fire emissions.

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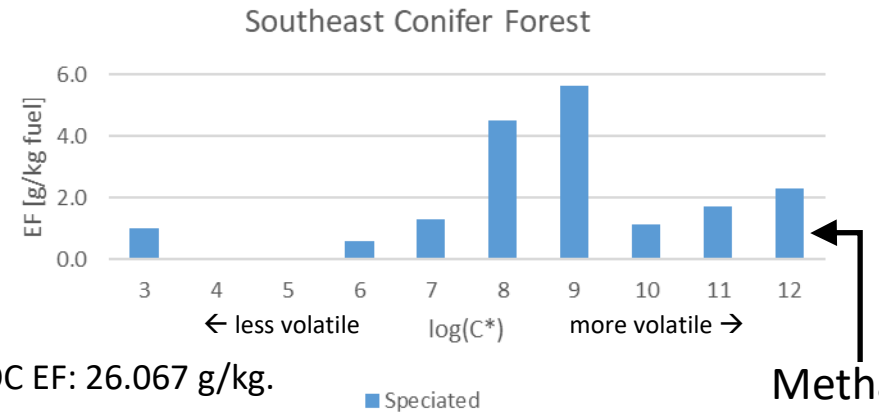
Emissions Factors from: Urbanski, S., *Wildland fire emissions, carbon, and climate: Emission factors*. Forest Ecology and Management, 317, 51-60, 2014.

Volatility Distributions of Emissions

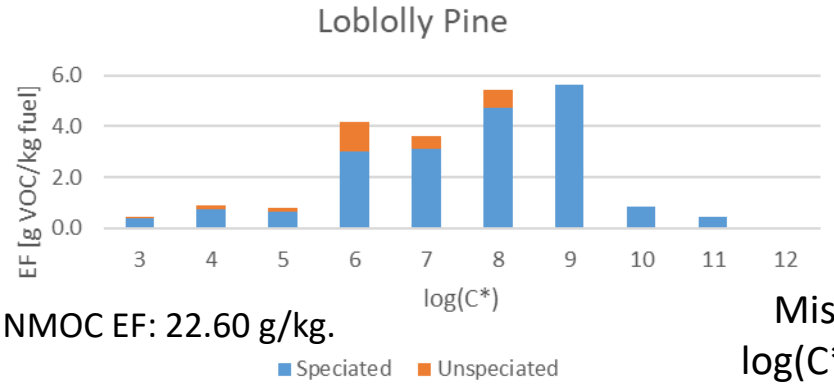
Urbanski, 2014: volatility distribution of speciated mass.



Total NMOC EF: 26.067 g/kg.

Methane

Koss et al., 2018: volatility distribution of all mass.



Total NMOC EF: 22.60 g/kg.

Missing mass in log(C*) 10/11 bins?

- Koss et al., 2018 reports an ionic formula and molecular weight of “unknown” species, which provides information on approximate volatility.
- Koss et al., 2018 is reasonably consistent with Urbanski, 2014 in the moderate volatility log(C*) bins.
- Can we blend the studies?

Koss, A., et. al., *Non-methane organic gas emissions from biomass burning: identification, quantification, and emission factors from PTR-ToF during the FIREX 2016 laboratory experiment*. ACP, 18, 3299-3319, 2018.

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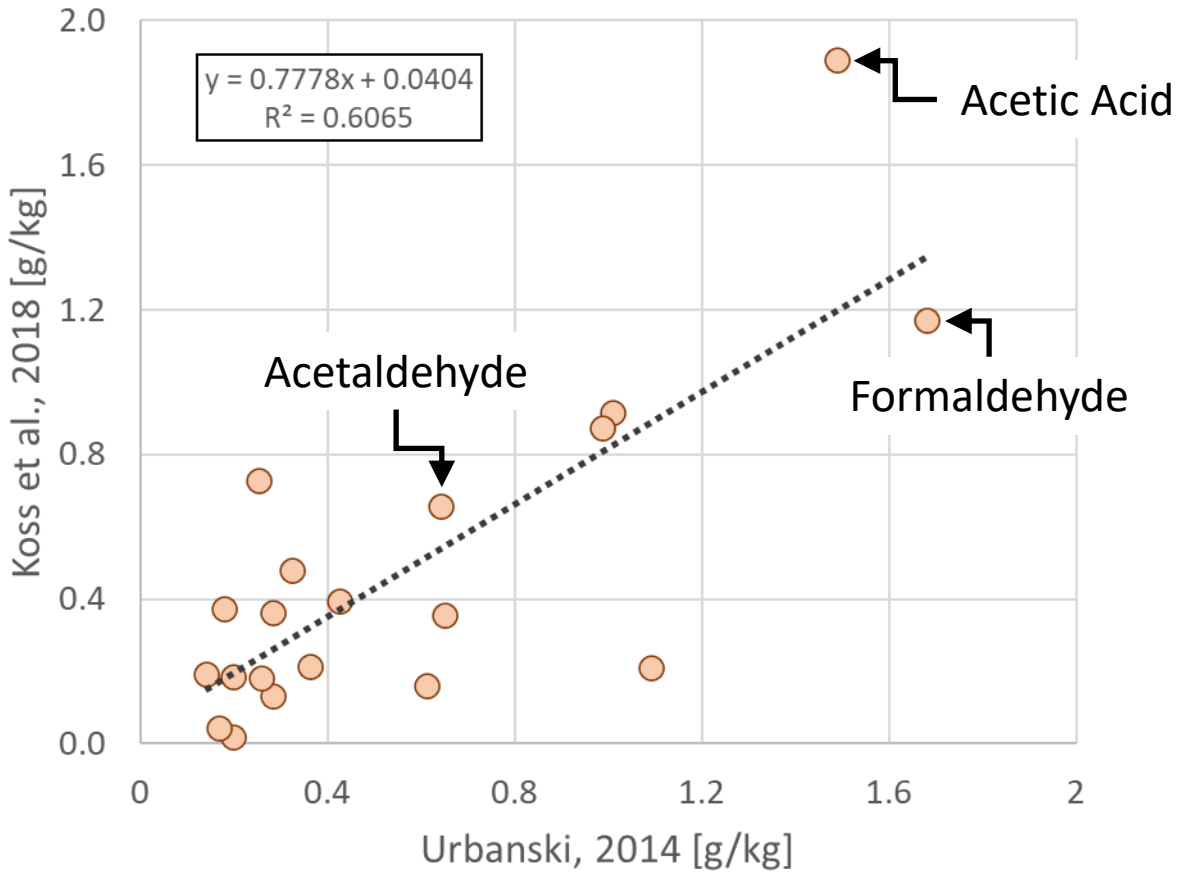
Explicit Compound Comparison



Comparison of 20 most abundantly emitted, explicit compounds reported by Urbanski, 2014 (conifer forest) to similar species reported by Koss et al., 2018 (loblolly pine).

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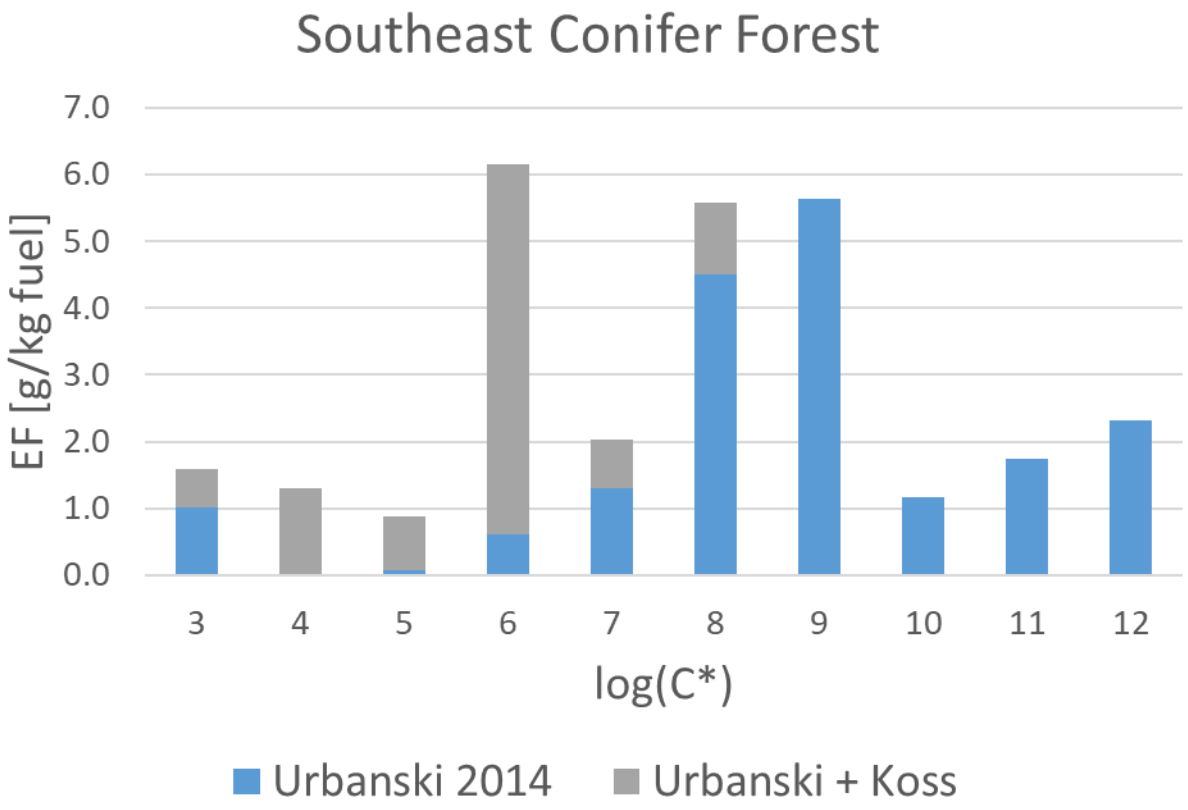
Leveraging Multiple Studies to Fill Gaps

- What if we leveraged the IVOCs and "Unknowns" from Koss et al., 2018 to speciate the "unspeciated" mass in Urbanski, 2014?
- The total NMOC EF would end up as 26.067 g/kg, as reported in Urbanski, 2014, and the explicit species from Urbanski, 2014 would not change.



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Filling the gaps for all emissions factors

Description	Leveraged Dataset		Leveraged Dataset	
SE Conifer	Urbanski, 2014	Prescribed fire southeast conifer forest	Koss et al., 2018	Loblolly Pine
Boreal	Urbanski, 2014	Wildfire boreal forest	Koss et al., 2018	Douglas Fir, Subalpine Fir
Rx NW Conifer	Urbanski, 2014	Prescribed fire northwest conifer forest	Koss et al., 2018	Ponderosa Pine, Lodgepole Pine, Engelmann Spruce, Jeffrey Pine
WF NW Conifer	Urbanski, 2014	Wildfire northwest conifer forest	Koss et al., 2018	
W Shrub	Yokelson et al., 2013	Semiarid Shrublands	--	--
Grass	Aurell et al., 2023	Flint Hills	Koss et al., 2018	Bear Grass, Rice Straw
Residual CWD	Urbanski, 2014	Stumps and Logs	--	--
Residual Duff	Yokelson et al., 2013	Organic Soil	--	--

Yokelson, R.J., et al., *Coupling field and laboratory measurements to estimate the emission factors of identified and unidentified trace gases for prescribed fires*. ACP, 13, 89-116, 2013.
Aurell, J., et al., *Seasonal emission factors from rangeland prescribed burns in the Kansas Flint Hills grasslands*. Atmo. Env., 304, 2023.

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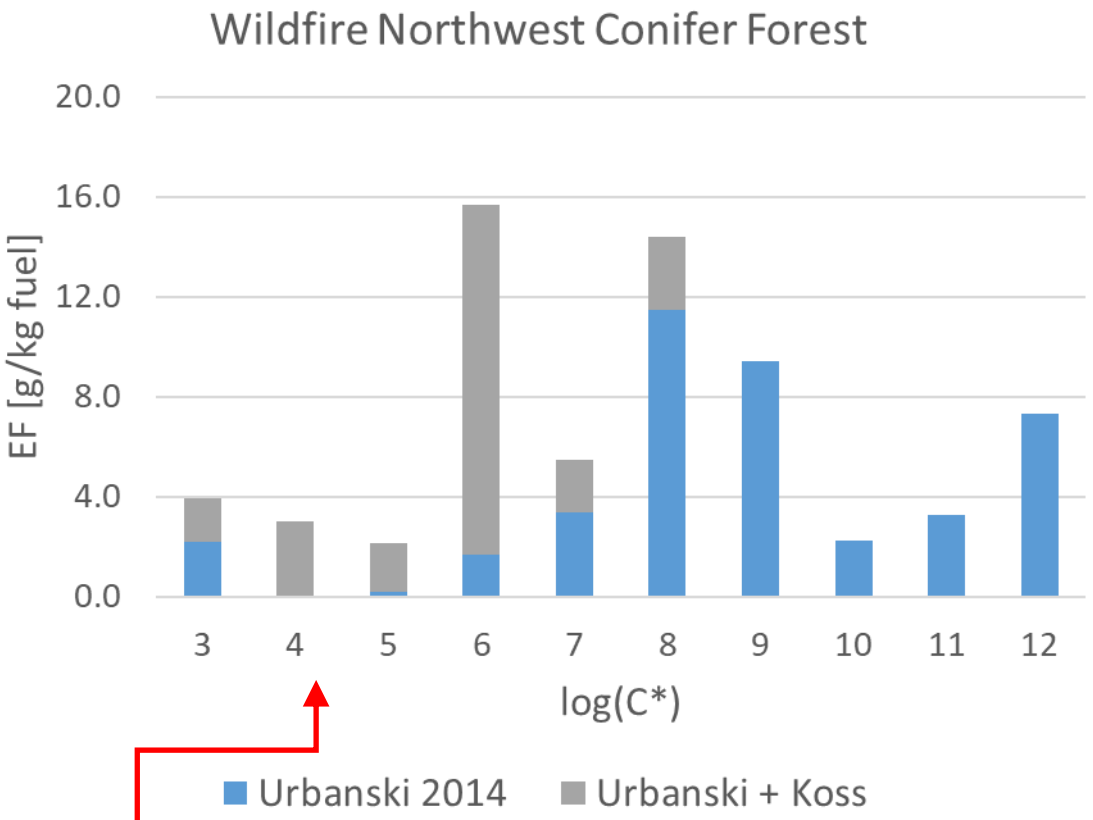
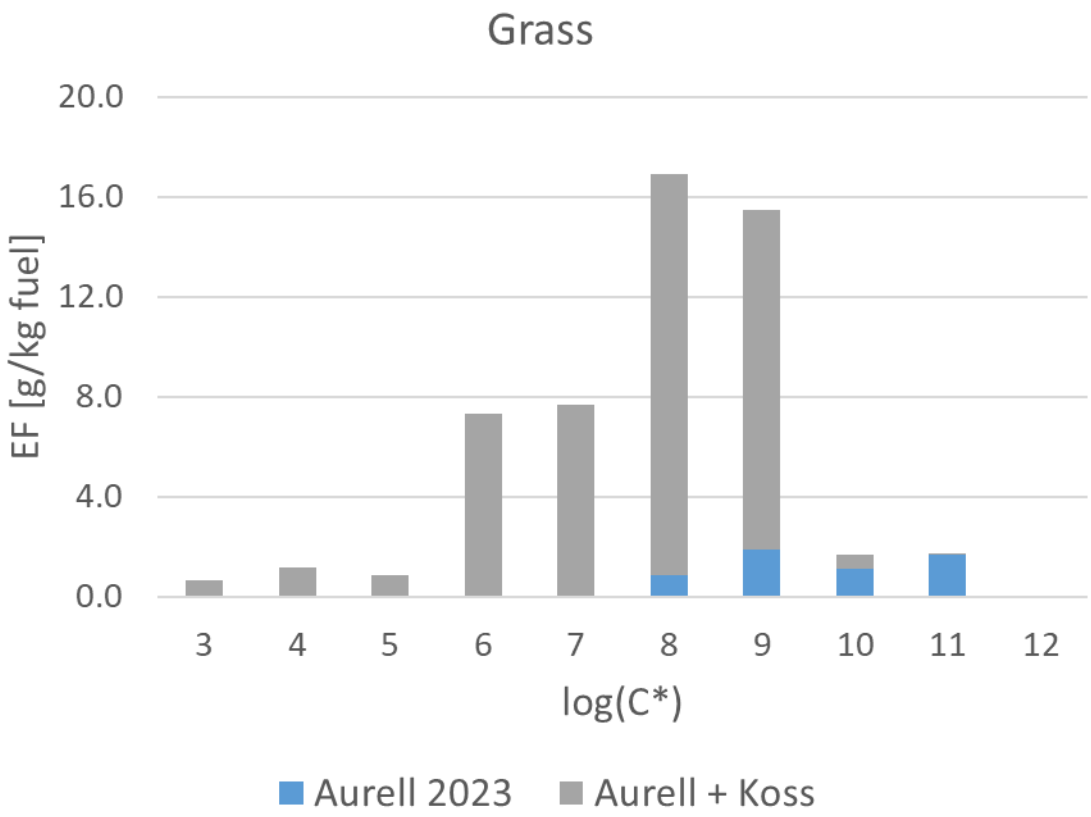
Emissions Factor Updates





Note the drop-off for emissions in the log(C*) bins < 6. Are the measurements missing lower volatility mass?

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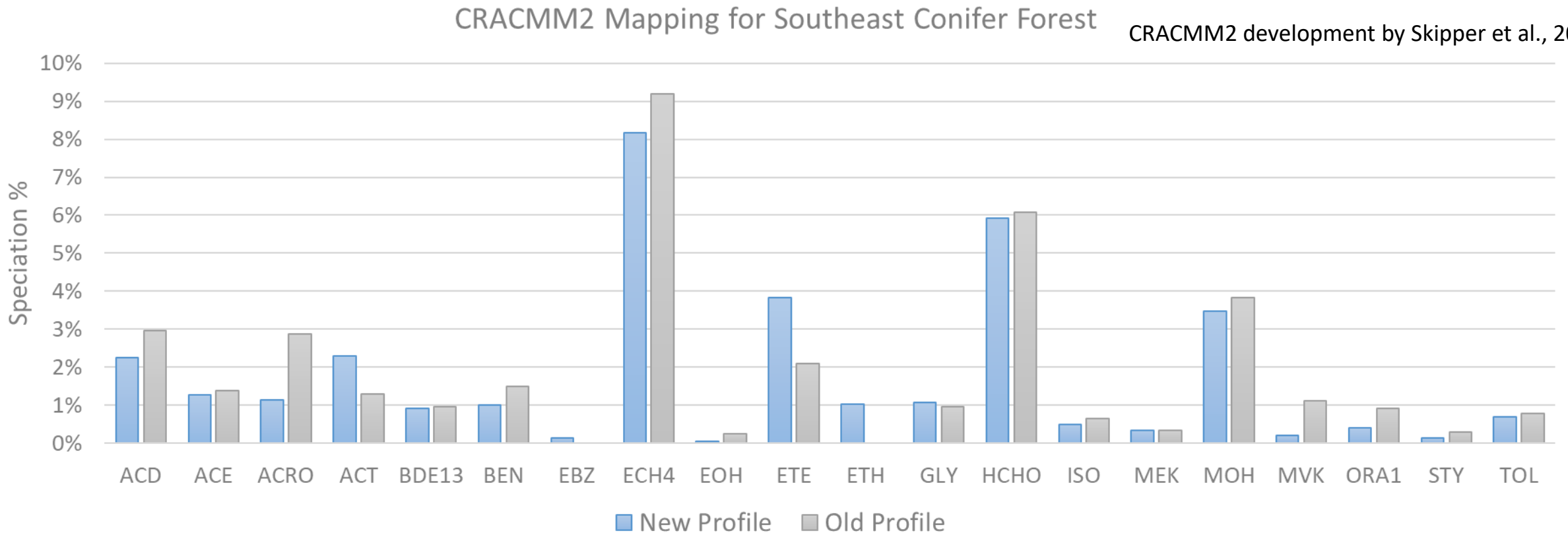
Speciation Impacts

CRACMM2 development by Skipper et al., 2024



These are all explicit species in the CRACMM2 chemical mechanism. There are not a lot of speciation changes for these species. Note that the “Old Profile” is currently used for all wildland fire emissions, whereas the “New Profile” is specific to SE Conifer Forests.

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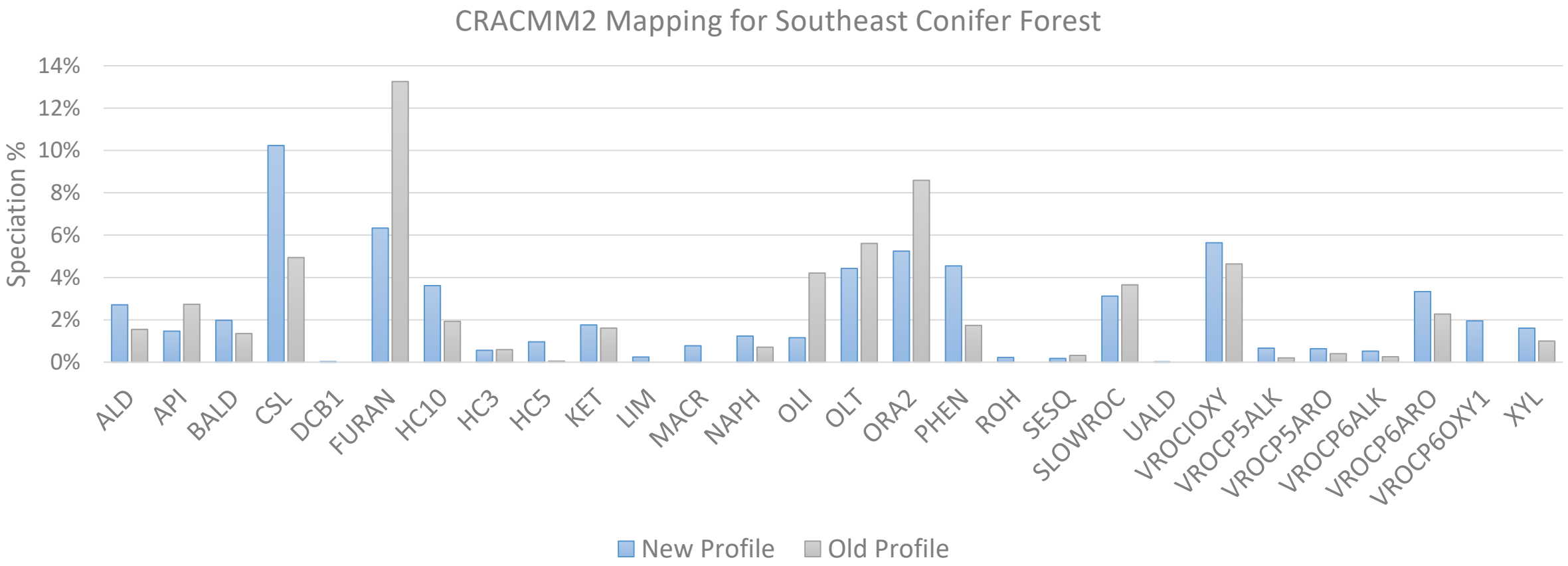
Speciation Impacts



These are all lumped species in the CRACMM2 chemical mechanism. There are some large changes for species that represent IVOCs.

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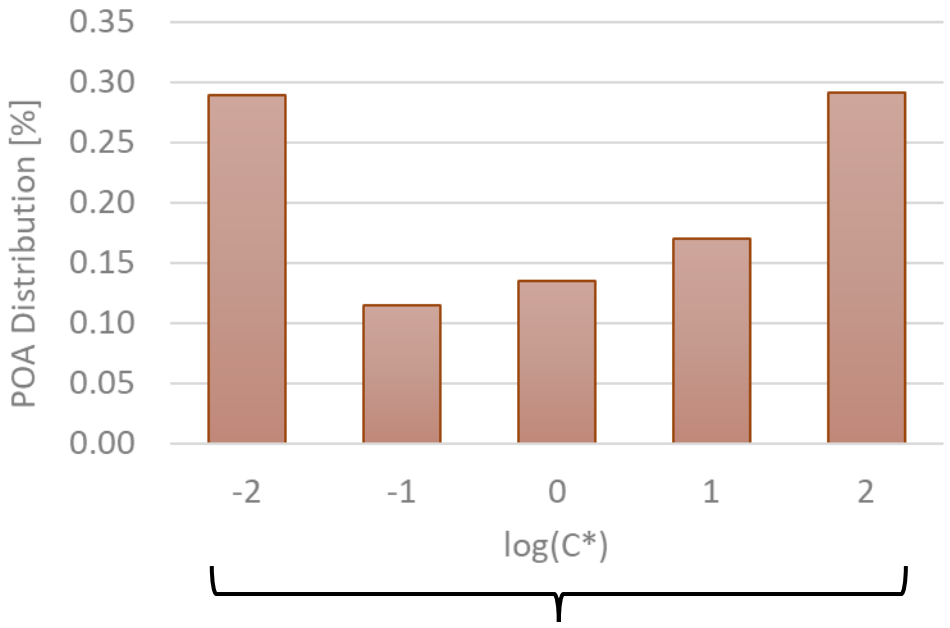
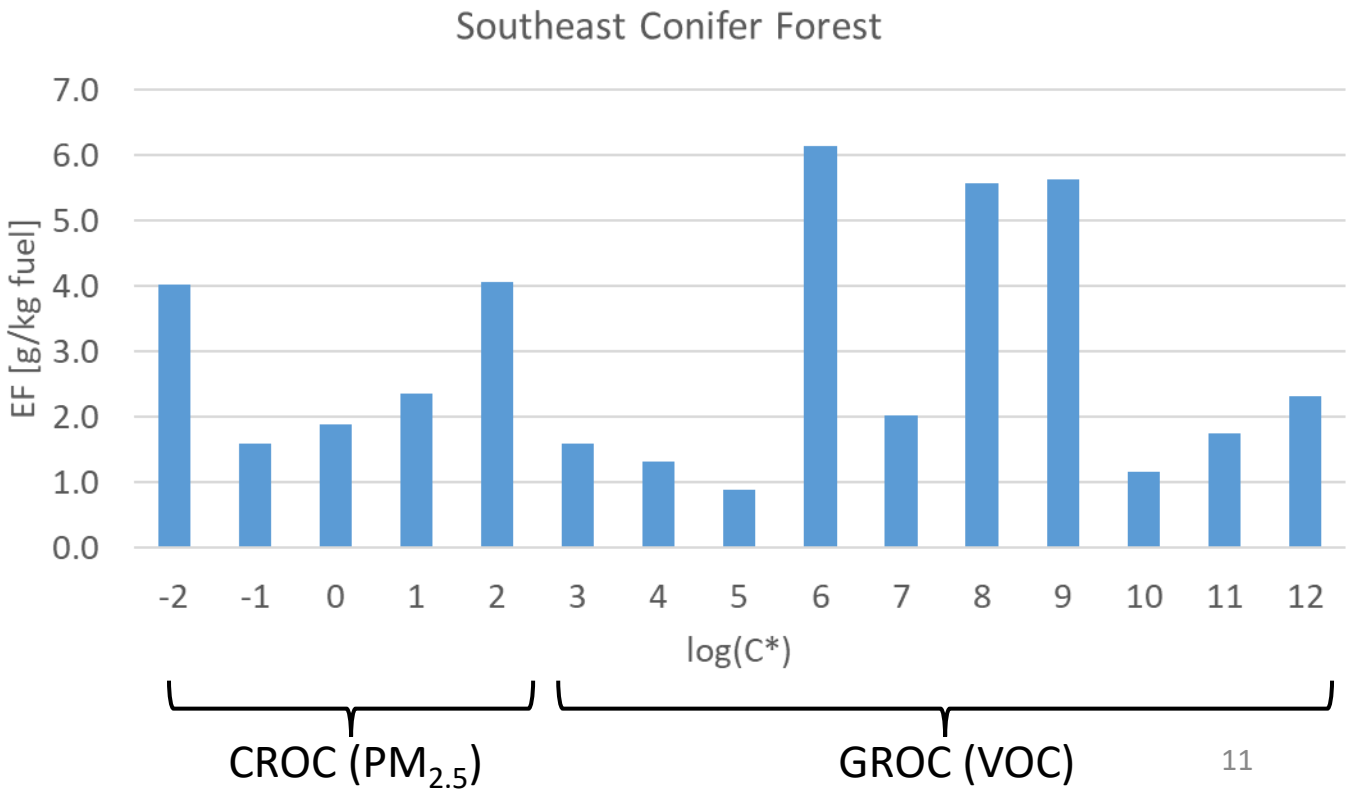
Future Considerations

- Ideally, we have organic emissions that span all relevant volatilities.
  - Condensible Reactive Organic Carbon: $\log(C^*) \leq 2$
  - Gaseous Reactive Organic Carbon: $3 \leq \log(C^*)$



These types of assumptions are applied regardless in new chemical mechanisms (e.g., CRACMM)



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Conclusions and Next Steps

- In the 2022v1 EMP, wildland fires are ~25% of all VOC emissions.
  - The current operational emissions factors ignore measured, yet unspeciated mass.
- Newer studies report speciation that provides greater chemical detail.
  - We can leverage data from additional studies to characterize previously unidentified mass.
  - For 2023, a moderate fire year, updated emissions factors that reflect this unidentified mass increase US wildland fire VOC emissions from **~3.1M tons to ~5.4M tons**.
- Follow on work could include air quality modeling sensitivity simulations and continued chemical mechanism updates to better represent aging of wildland fire emissions.