How does smoke change as it is carried away from the source?

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Thanks to these colleagues for their contributions to these remarks:

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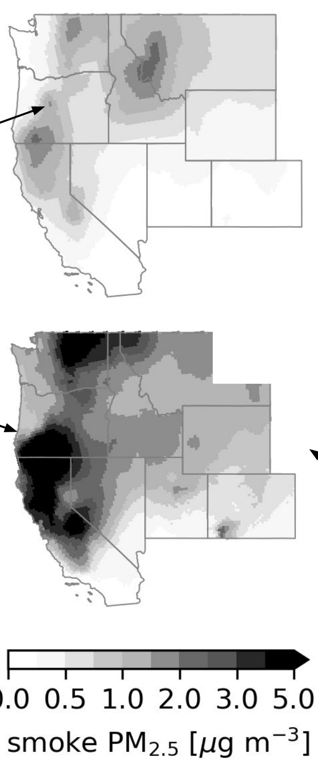
When we think of smoke, we first think of $PM_{2.5}$. Smoke makes the largest contribution to $PM_{2.5}$ in the Pacific Northwest and directly downwind.

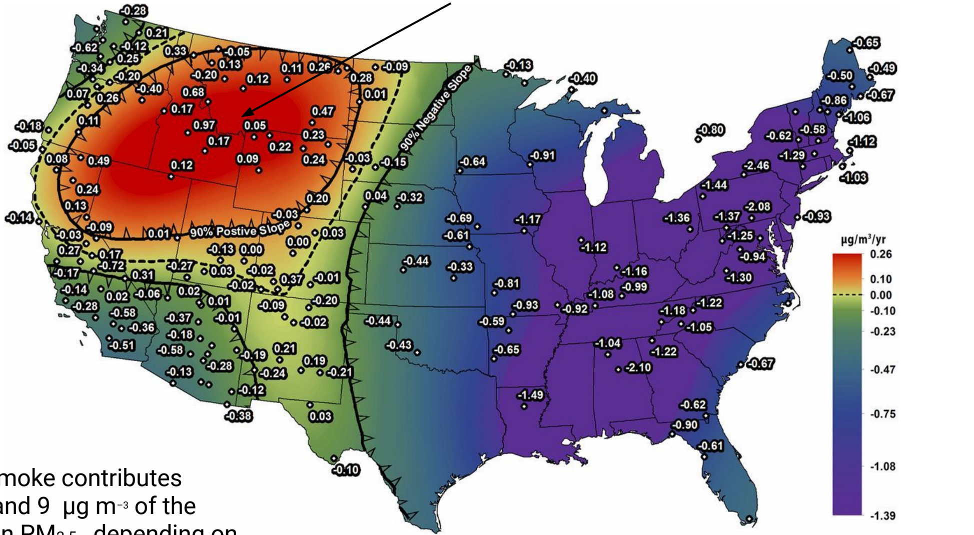
2006 - 2018 Average Annual Smoke Exposure

2018 as an Average Annual Smoke Exposure



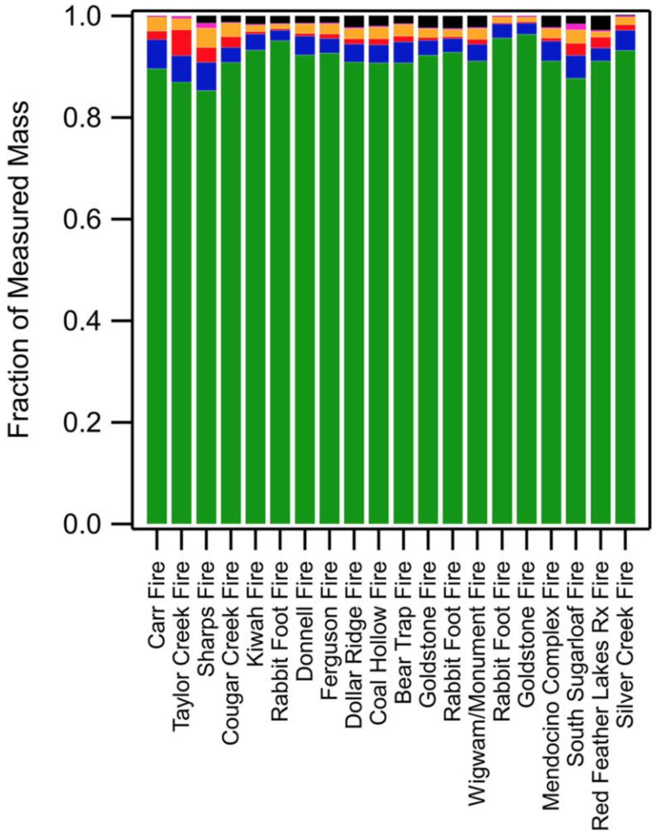
In the PNW smoke contributes between ~2 and 9 $\mu g\ m^{-3}$ of the summer-mean $PM_{2.5}$, depending on the year. In a high-fire year, this is ~70% of the $PM_{2.5}$.

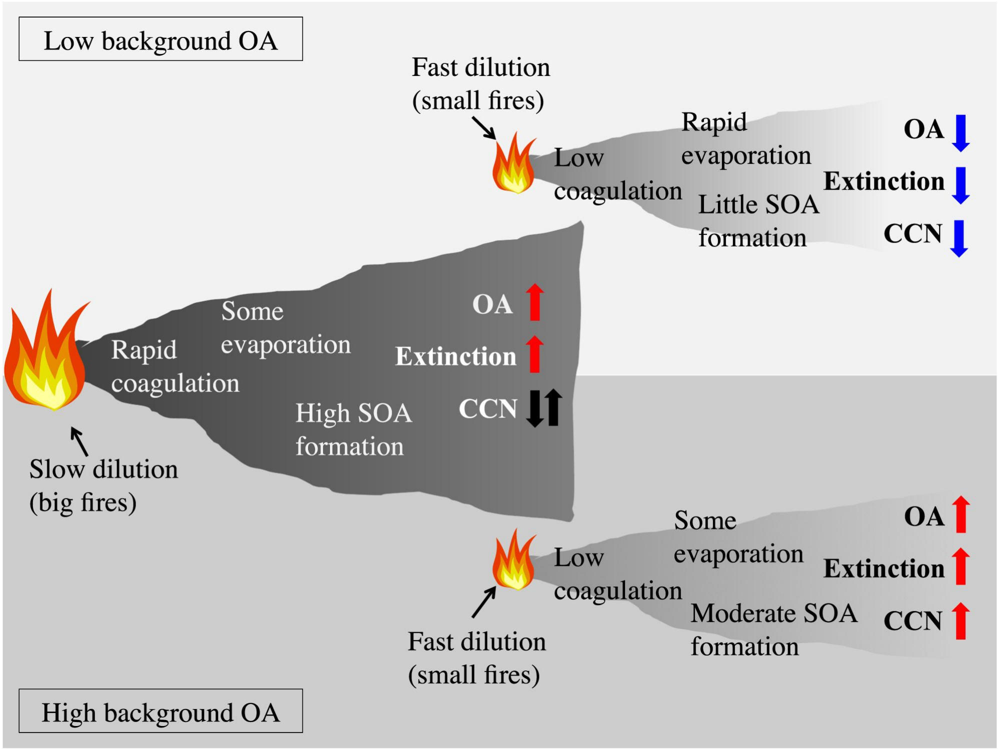
The positive trend in 98th quantile $PM_{2.5}$ is due to wildfire activity



O'Dell et al. (2020); McClure et al. (2018)

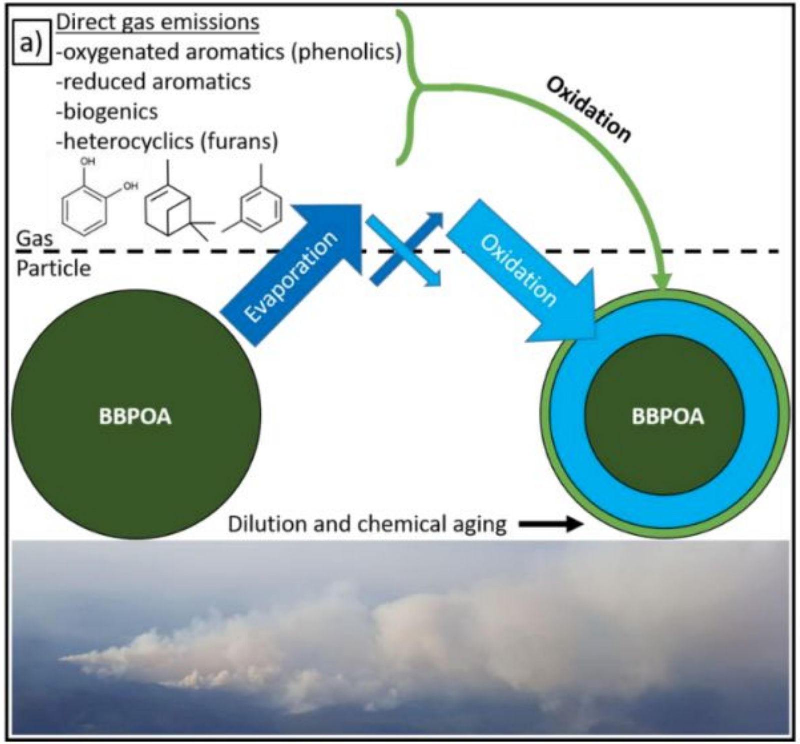
Organic aerosols (OA) dominate fine PM mass. Recent work shows the interplay between emissions and subsequent chemical and physical transformations for OA.

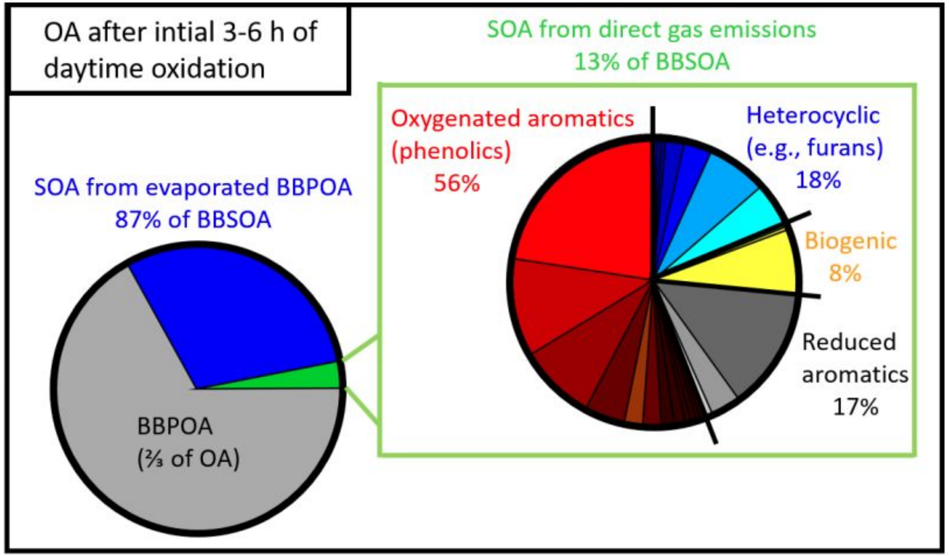




Garofalo et al. (2019); Hodshire et al. (2019);

Phenolics are important gas-phase emissions (small influence on OA mass, important for absorption); evaporated POA is the dominant source for SOA.

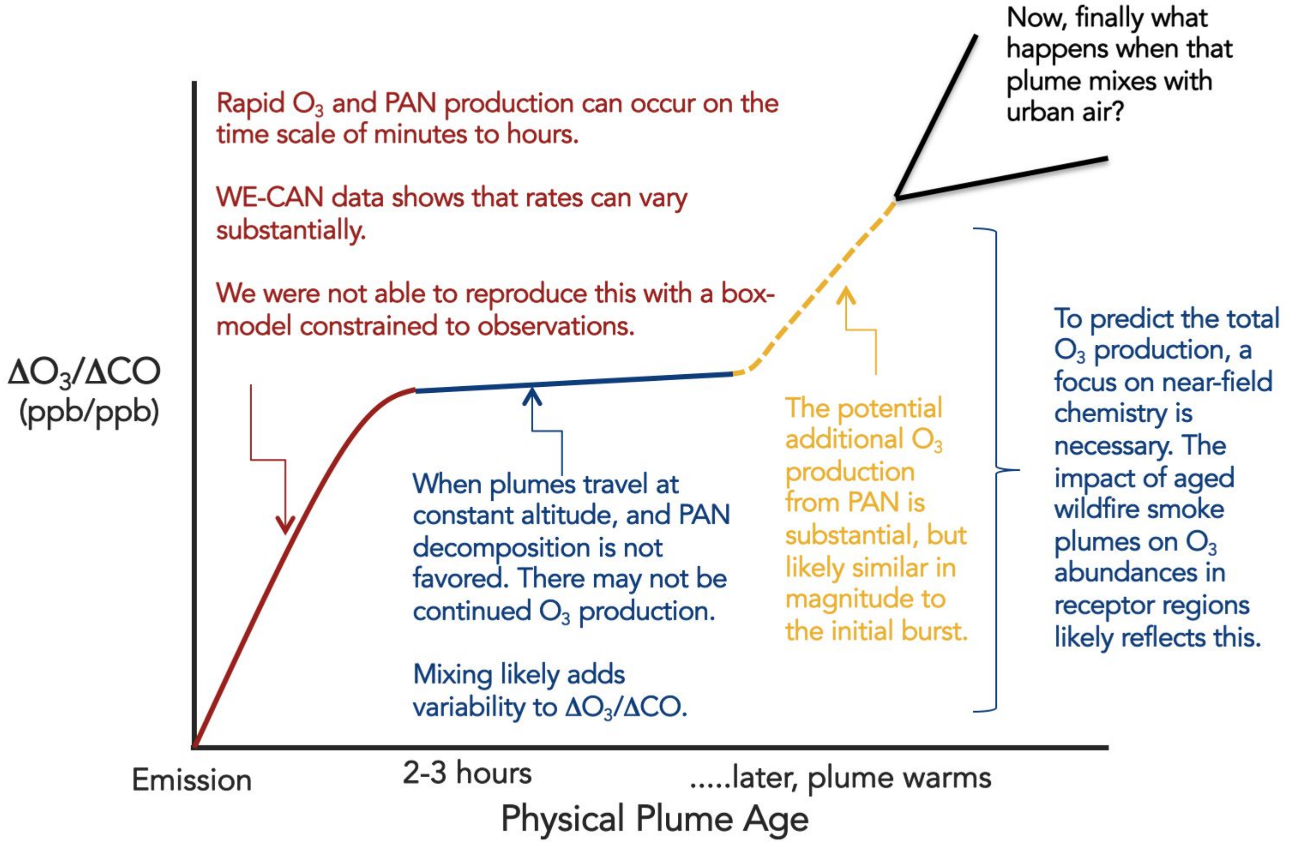




This study covers the period when large wildfire plumes dilute by a factor of 5 - 10 during the day.

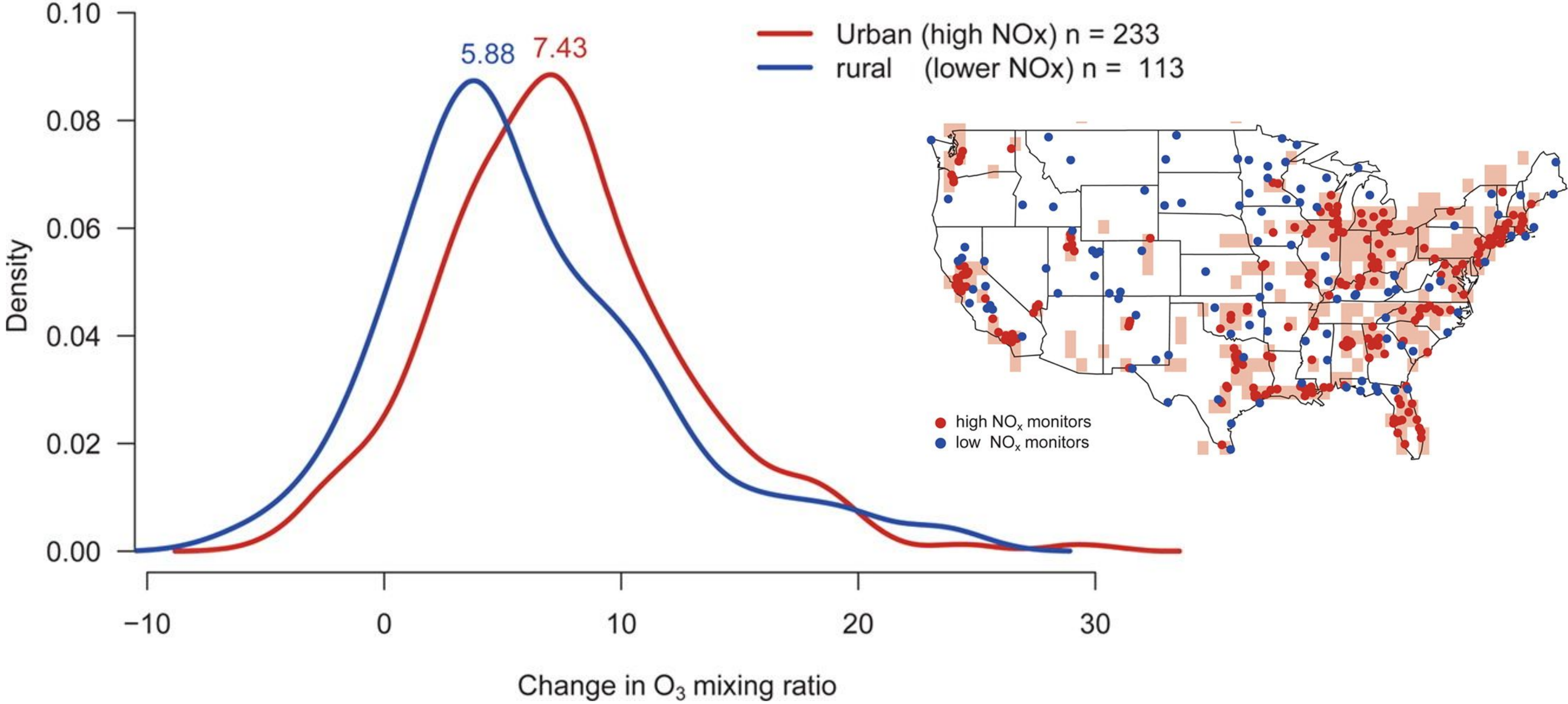
Palm et al (in revision, PNAS)

O_3 is often produced in smoke plumes, but there are different timescales and environmental conditions to consider.



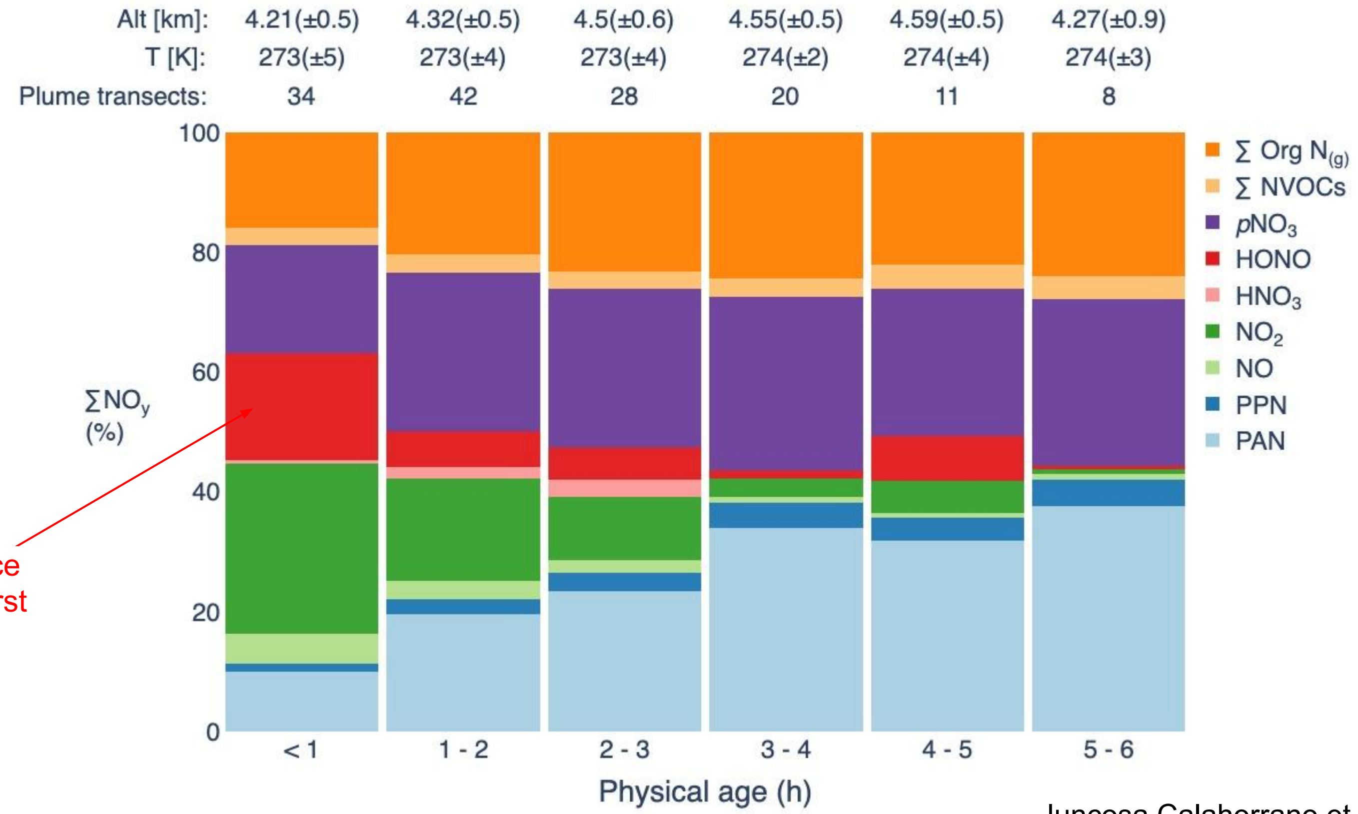
Fischer et al. (in prep)

Wildfire smoke impacts O_3 in both urban and rural locations. Across the U.S. the average increase in O_3 on a smoke-impacted day is ~6 ppbv.



Brey et al. (2016)

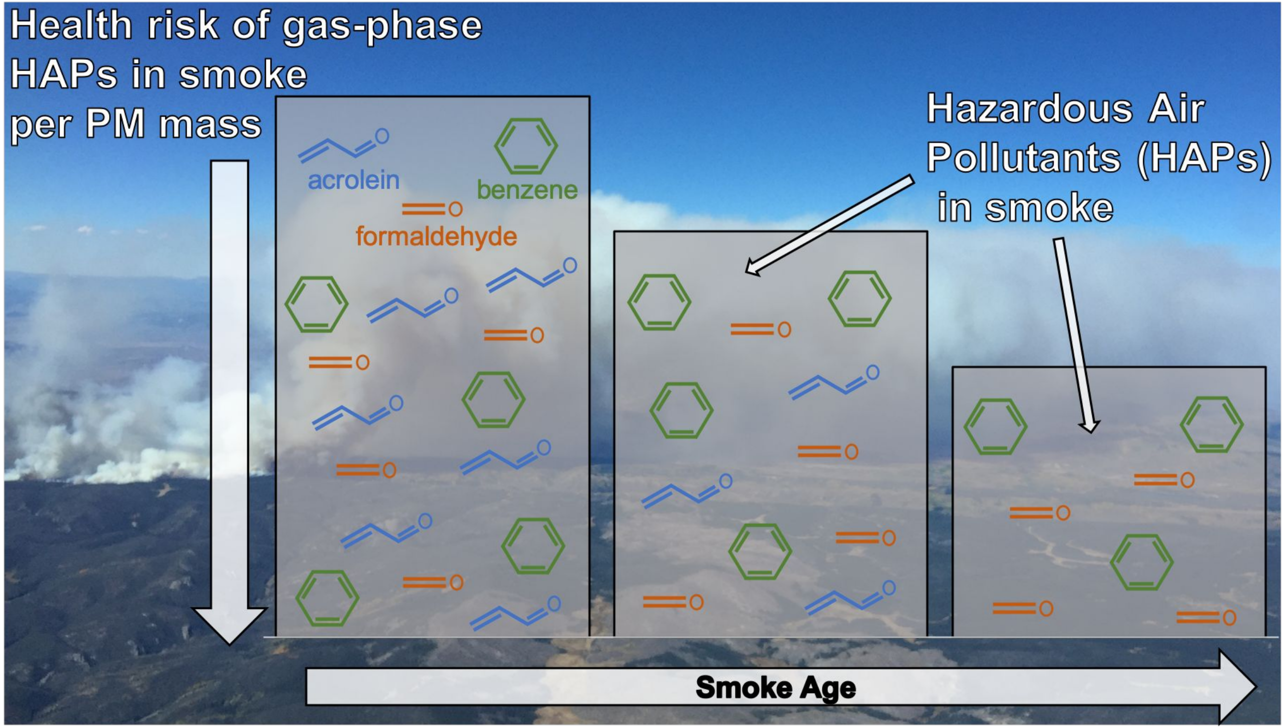
Highly relevant to O_3 in large smoke plumes, we now have a more complete view of daytime NO_y partitioning for the first ~6 hours of evolution.



HONO is the dominant source of OH for the first few hours
Peng et al. (2020)

Juncosa Calahorrano et al. (in revision, JGR)

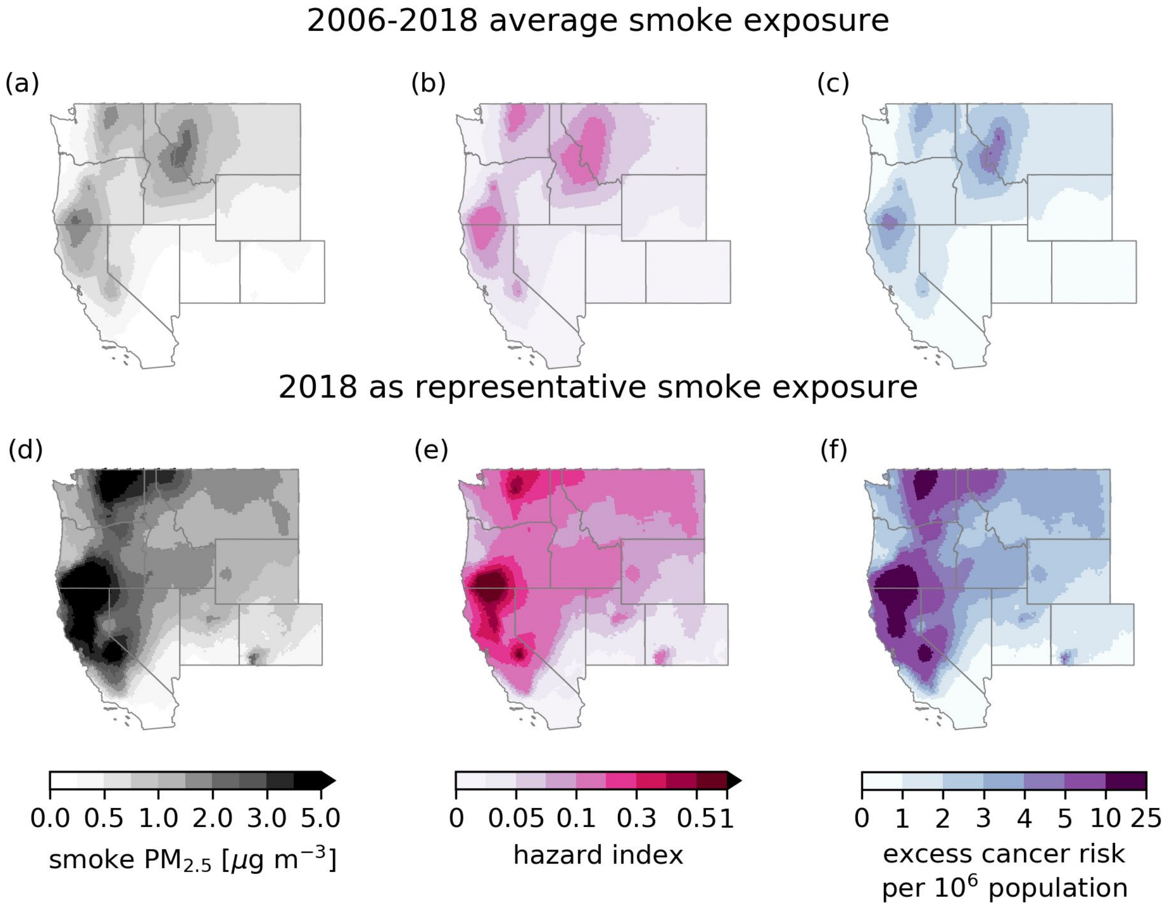
Moving beyond $PM_{2.5}$ and O_3: Acrolein, formaldehyde, benzene, and HCN are likely the dominant contributors to gas-phase HAPs risk.



The ratios between acute, chronic noncancer, and chronic cancer HAPs health risk and PM in smoke decrease with smoke age.

O’Dell et al. (2020)

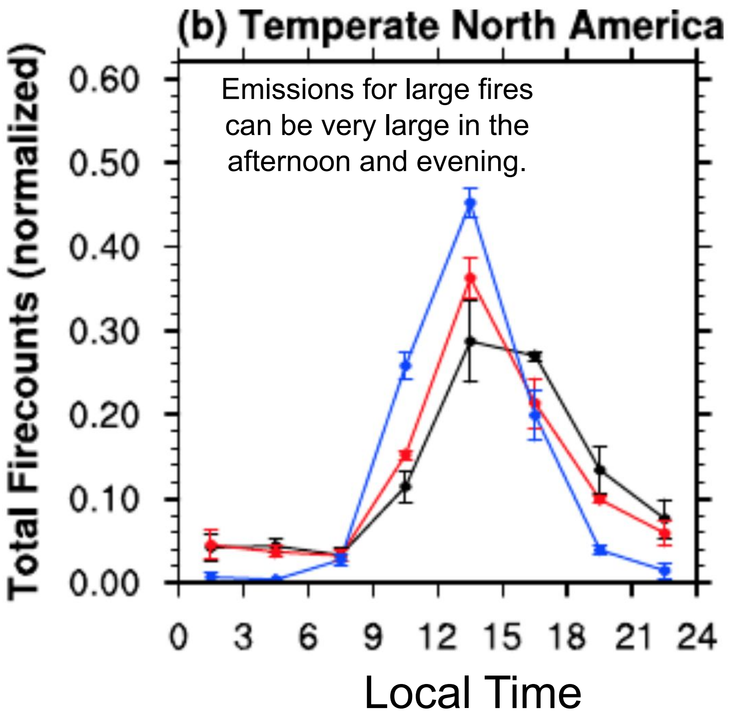
A cancer risk of 1 per 10^6 is used to identify locations and pollutants of concern. Heavily fire-prone regions exceed this threshold (mainly due to HCHO).



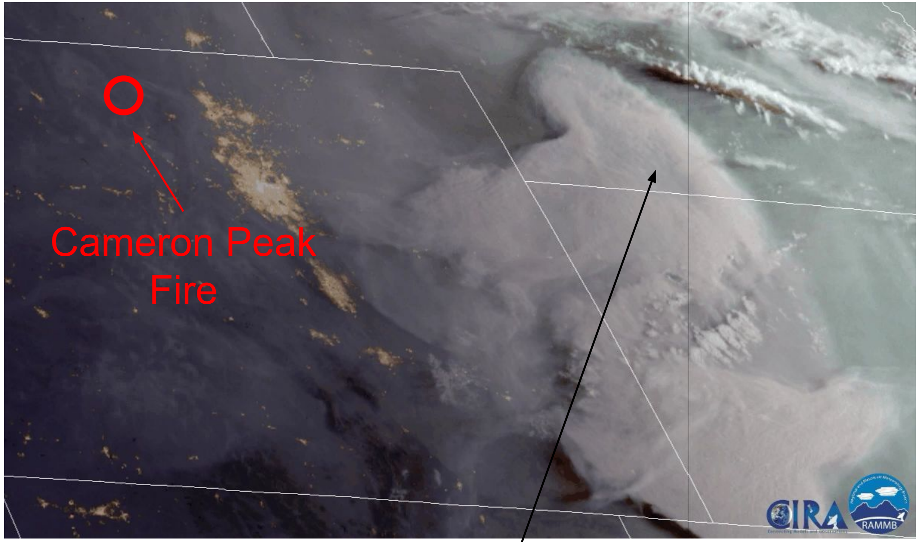
A hazard index of 1 is used as the threshold to indicate a potential health risk. Although smoke-specific hazard indices are below this value, the smoke HAPs may combine with other HAPs sources, or other air pollutants, to increase overall risks.

O'Dell et al. (2020)

To understand the full lifecycle of smoke,
we also need to consider what happens overnight.

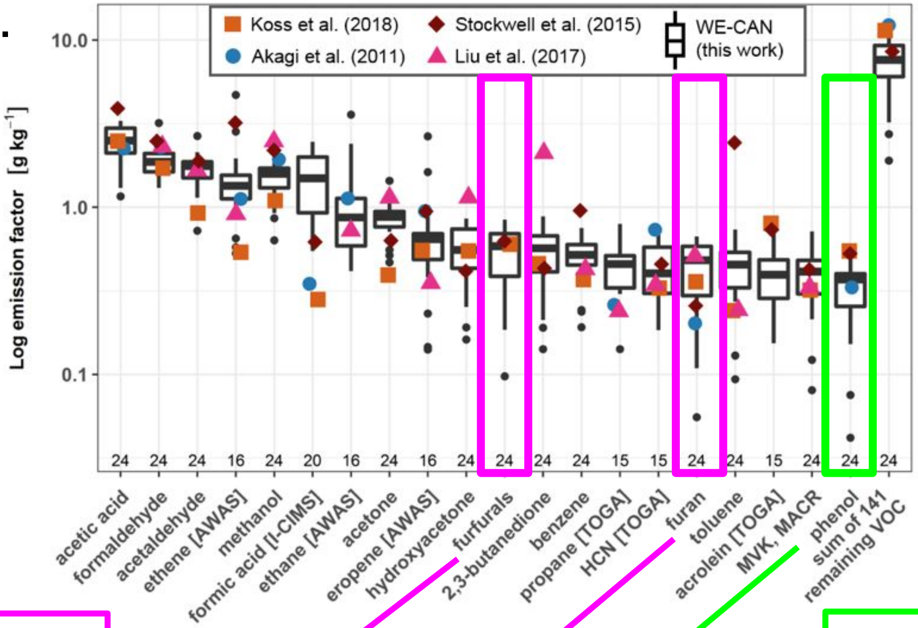


Mu et al. (2011)



Cameron Peak Fire Smoke Plume
Image from 9/7/20
Thanks to Steve Brown and CIRA

Chemical evolution differs at night when the roles of NO_3 and O_3 can increase.



Furans and furfurals

Oxidized mostly by O_3 or OH

Dominant reactions:

1. O_3 + 2,5-dimethylfuran
2. OH + furanone

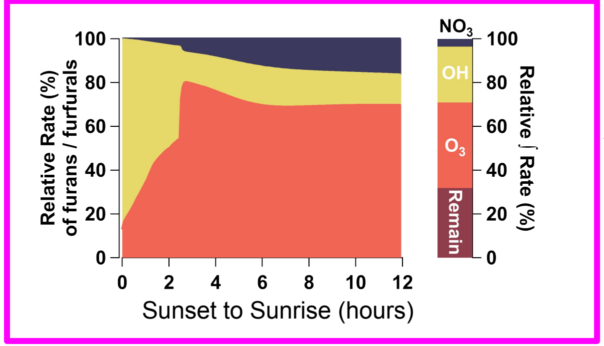
0 - 30% remain at sunrise

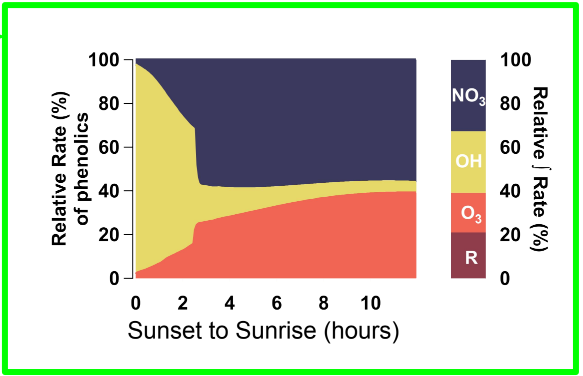
Phenolics

Oxidized mostly by NO_3 or O_3

Catechol and methylcatechol account for 58-77% of phenolic + NO_3 oxidation.

0-20% remain at sunrise

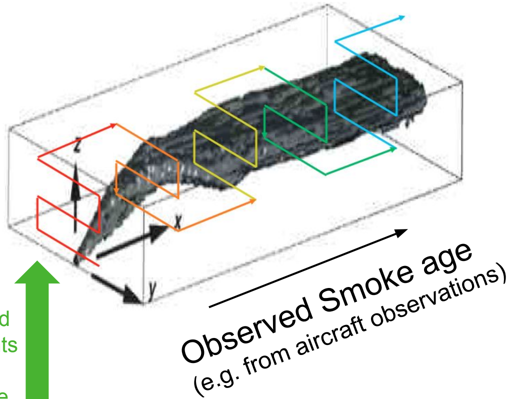




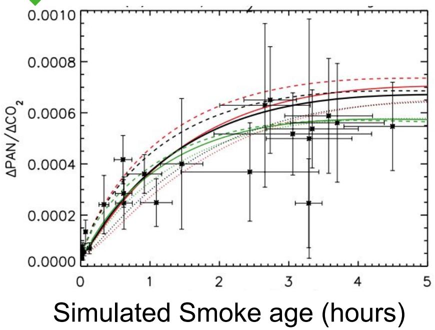
Permar et al. (in review, JGR)

Decker et al. (in prep)

Are our models capturing transformations? Connections between process-level observations and plume-scale models are strong, but links to CTMs are weak.

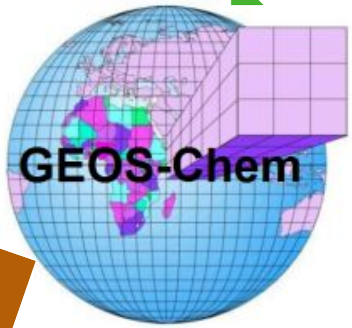


Iteration and improvements are at the plume-scale now.

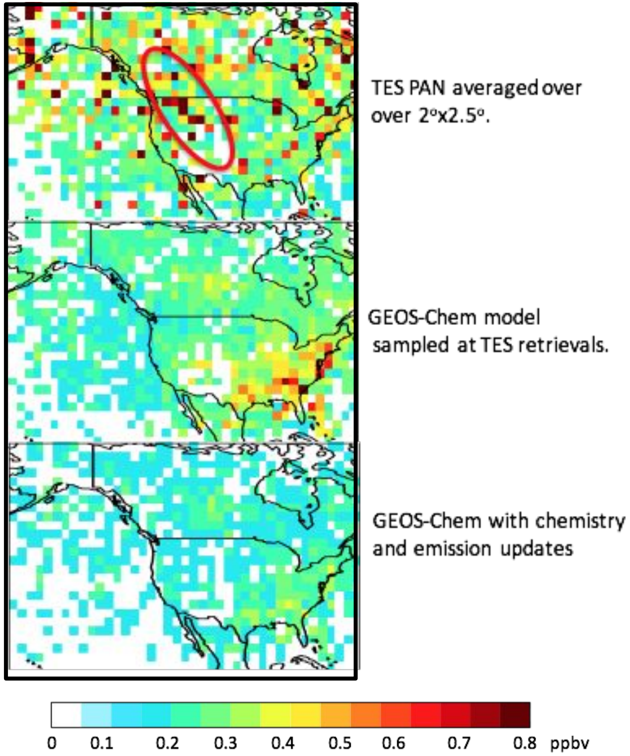


Alvarado et al. (2015; in press)

Strong ties to satellites and long-term observations shows us problems, but not solutions for smoke plumes. Updates may not apply to smoke.



Significant work is needed here. Global (and regional) models are not capturing smoke adequately because of resolution, emissions timing and injection, lack of species, and mis-represented (or missing) mechanisms.



Summary / Overview Thoughts:

Smoke is a national air quality concern for multiple pollutants.

- PM contribution relatively solid, maximum in PNW.
- Relevant O_3 chemistry needs work.
- Understanding of HAPs is emerging.

Recent major advances in smoke evolution include:

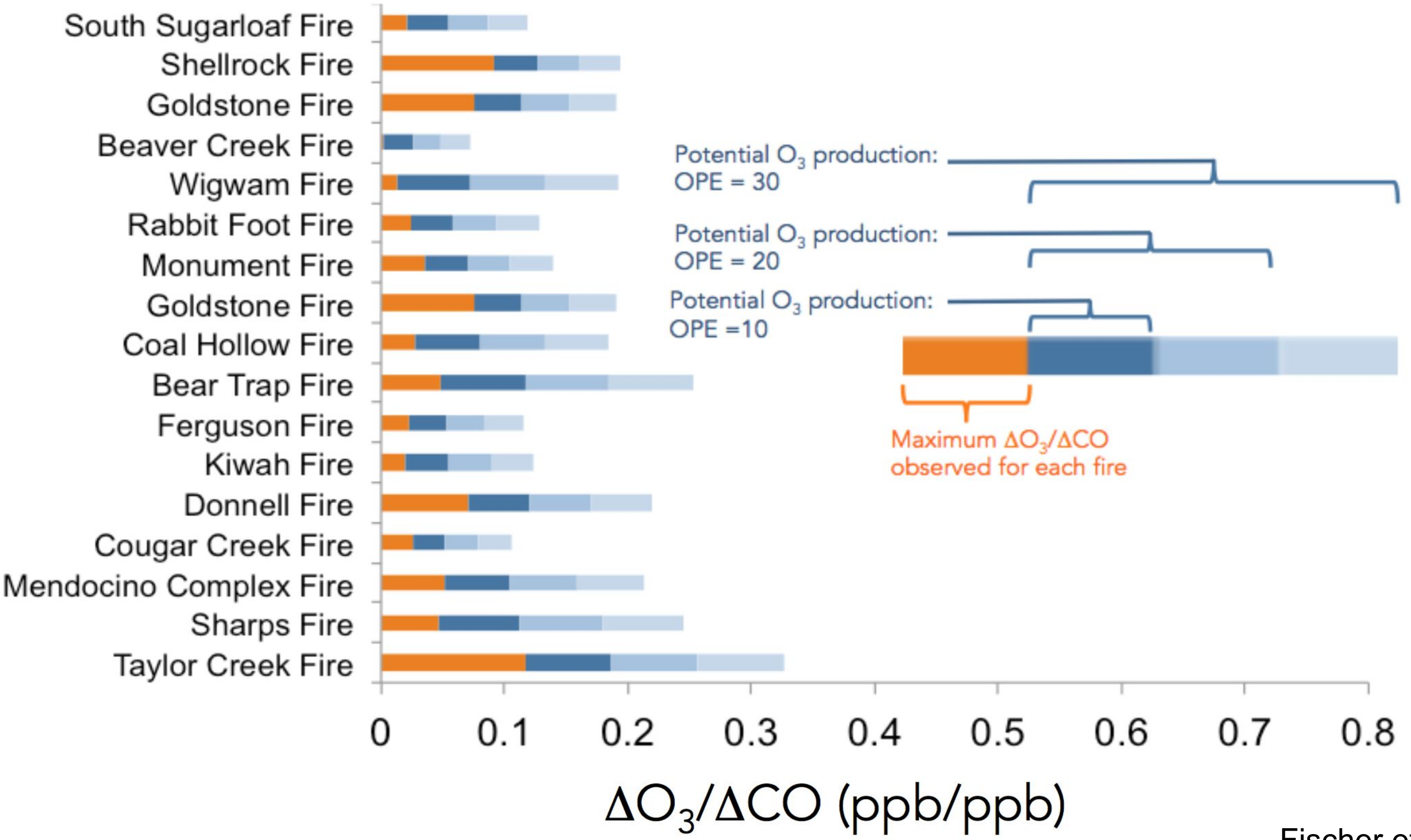
- The chemical evolution of OA.
- Daytime radical sources
- Nighttime chemistry is still a frontier due to under-sampling/study.

Plume-scale models are improving and can be improved/validated with new data.

- Connections to regional/global models are still lacking.
- Health-centric simplifications may be possible.

Extra Slides

When compared to the potential O_3 from PAN decomposition, the initial bursts of O_3 production likely account for a significant portion of total O_3 production in smoke plumes.



Fischer et al. (in prep)

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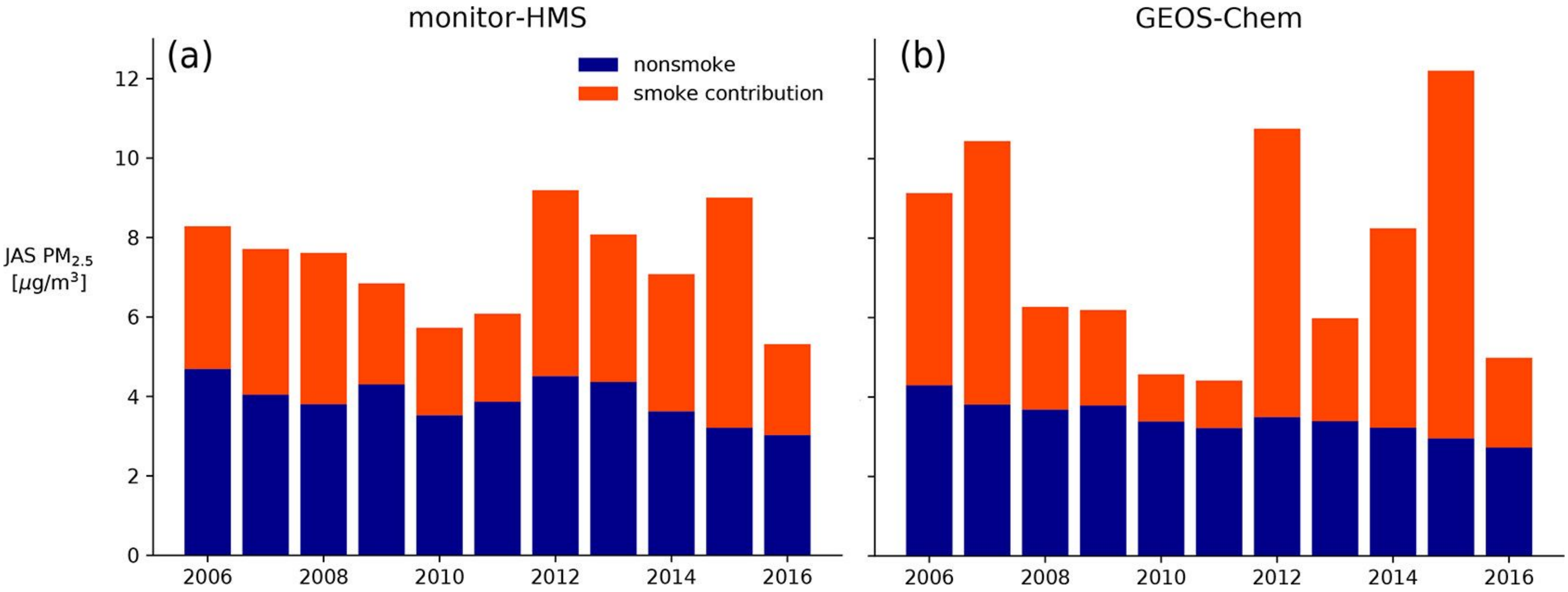
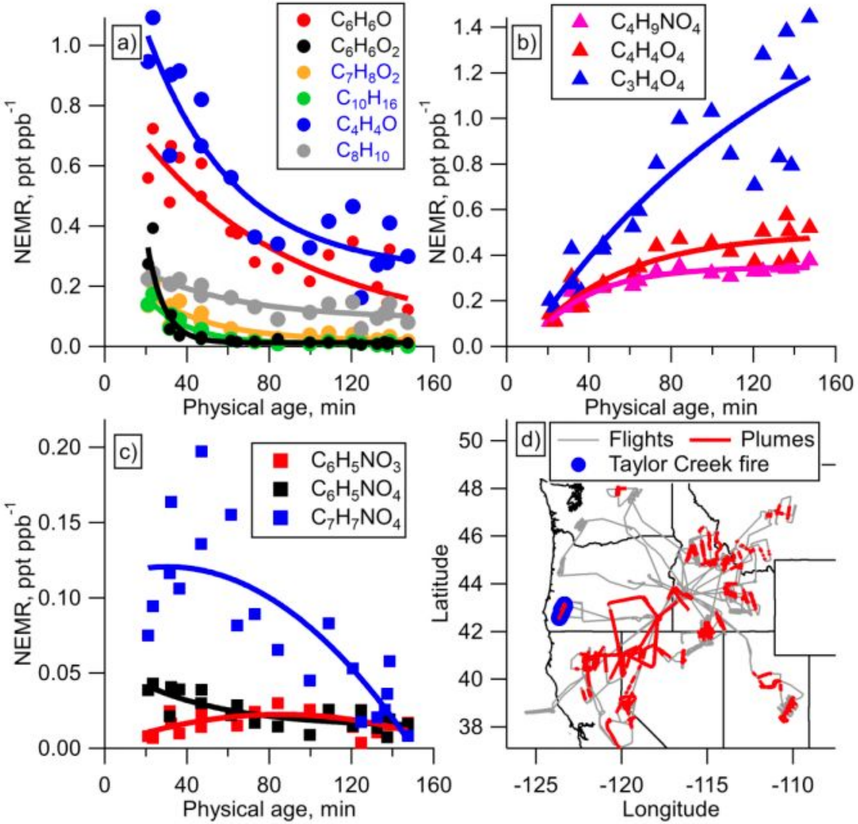
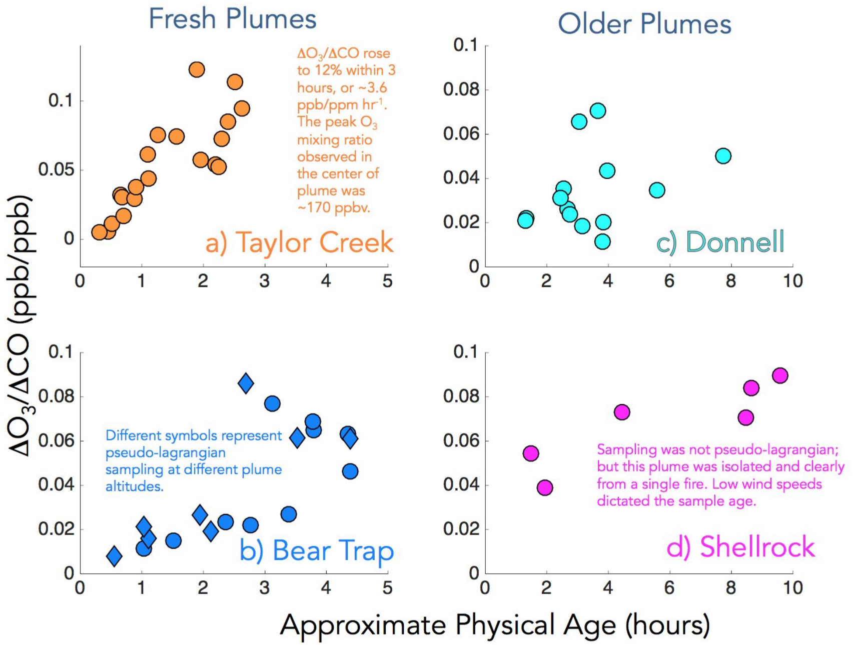


O'Dell et al. (2019)

WE-CAN measurements show rapid (minutes to hours) chemical transformations with implications for OA mass and properties and O_3 formation.





Palm et al. (under revision); Fischer et al. (in prep)

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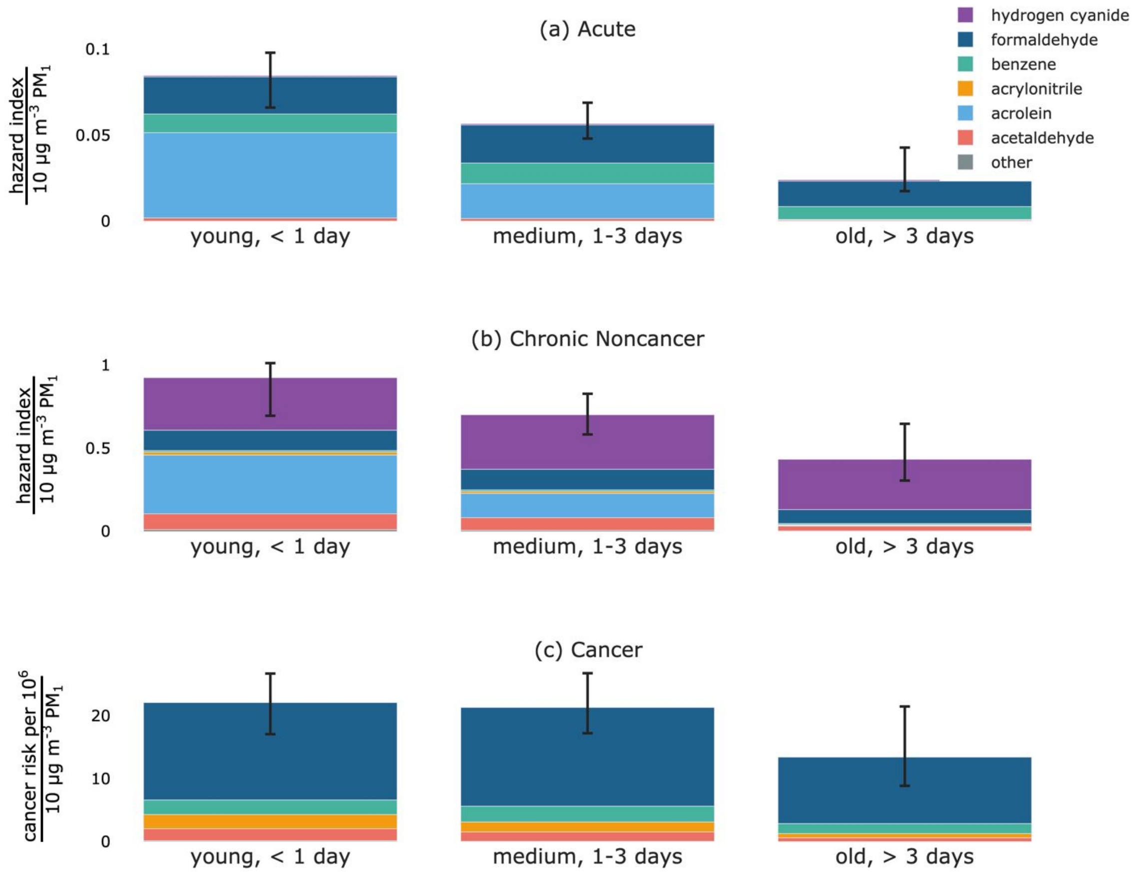

O'Dell et al. (2020)