Oregon Wine Symposium

Evolving our Understanding of Smoke Exposure Impact

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Background Levels of Smoke Phenols in Unimpacted Oregon Wines

Cole Cerrato, Ph.D., Oregon State University

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Red Wines Smoke Sensory Characteristics*

- Ashy
- Medicinal
- Campfire
- Burnt
- Rubbery

2020 Wildfires caused >$3 billion impact!

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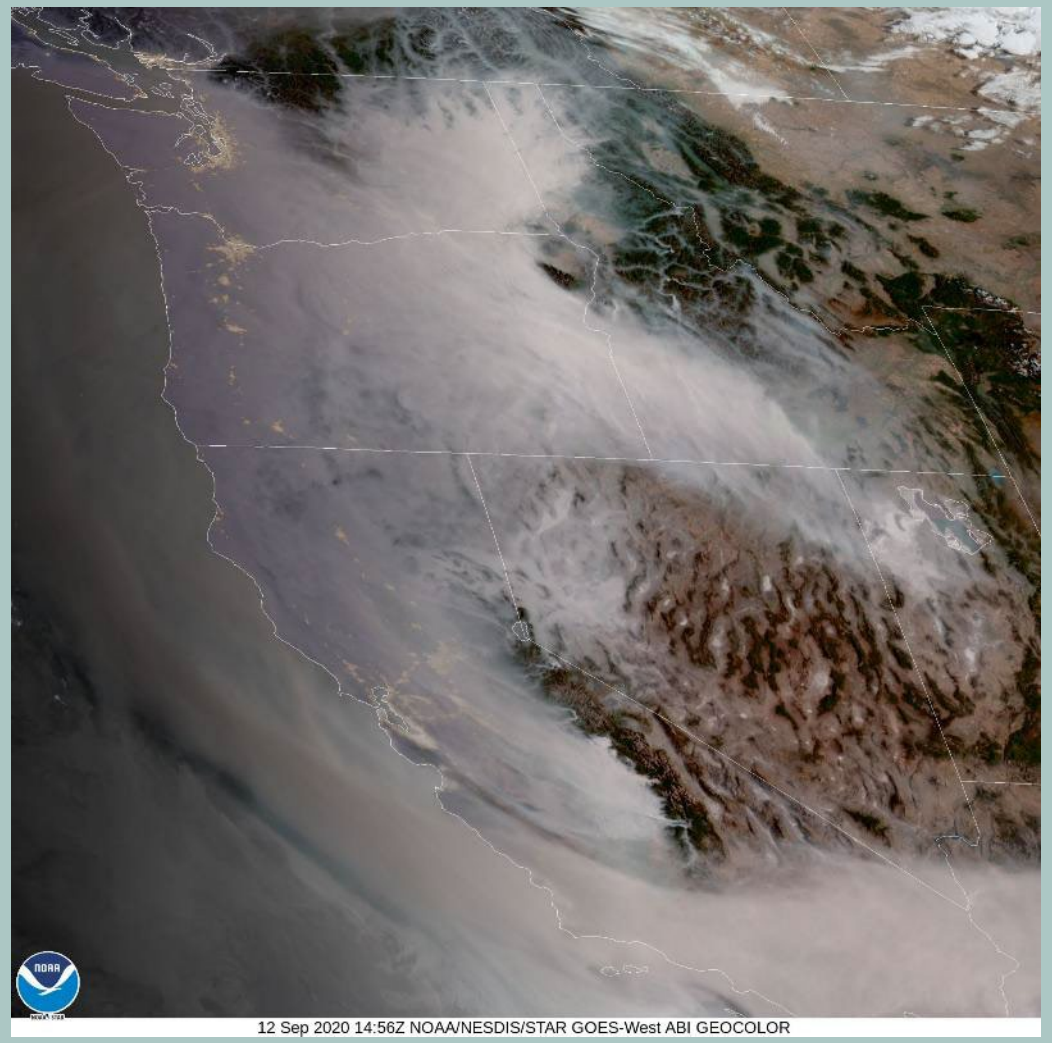
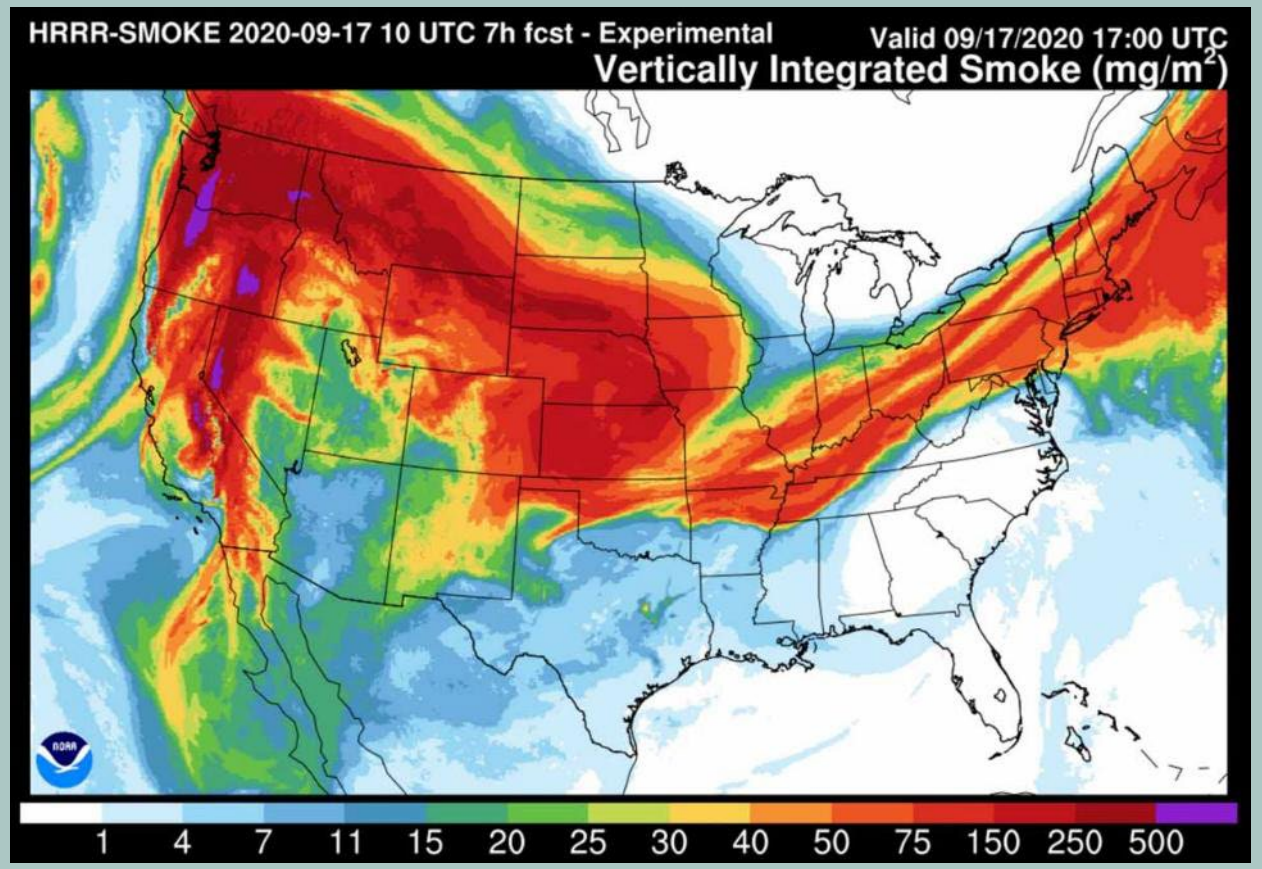
Graphic by: The Complex Science and Evolving Toll of Smoke Taint | Wine Enthusiast Magazine (winemag.com)





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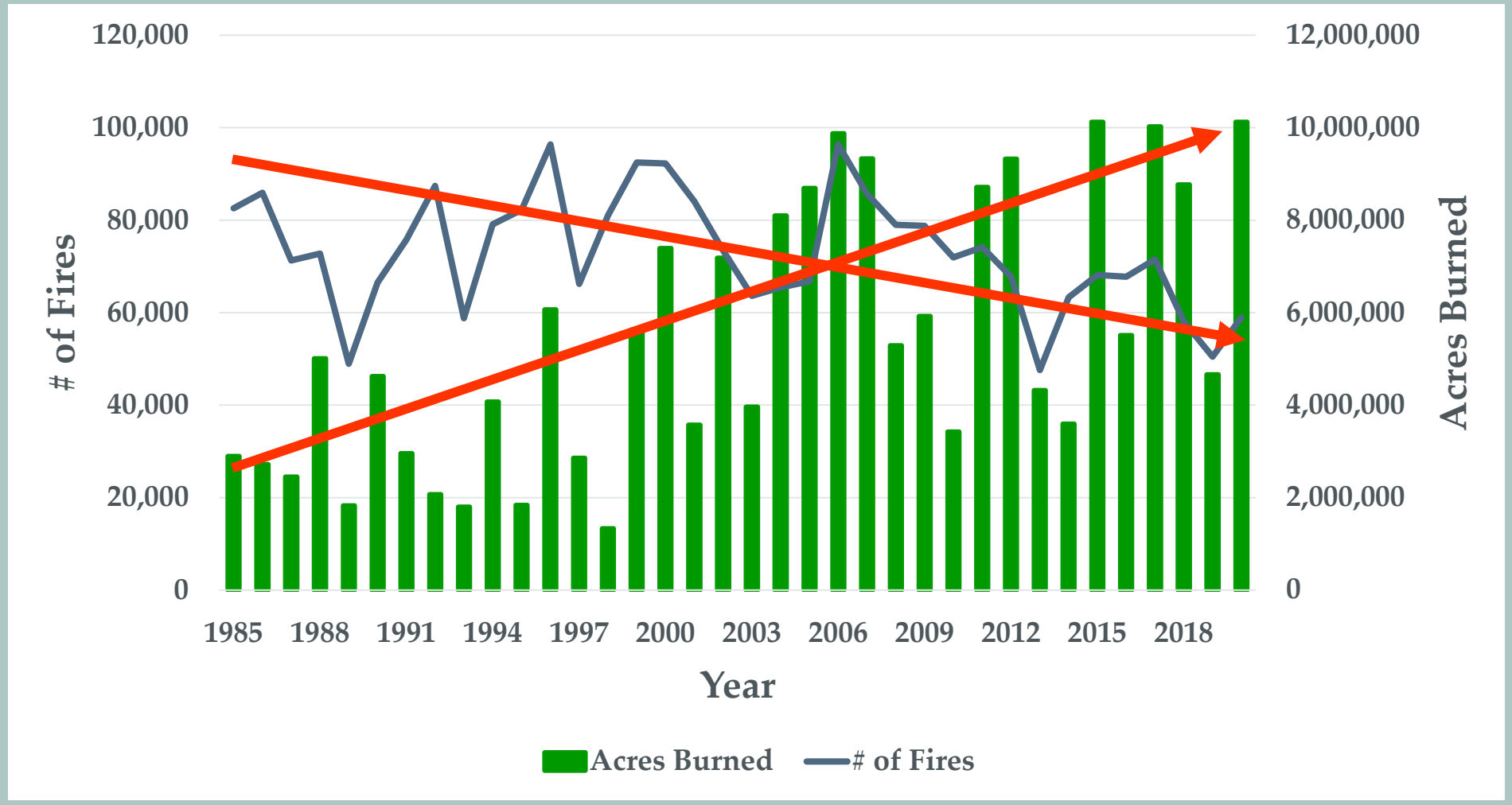

Trends

- # of fires decreasing
- Area burned increasing

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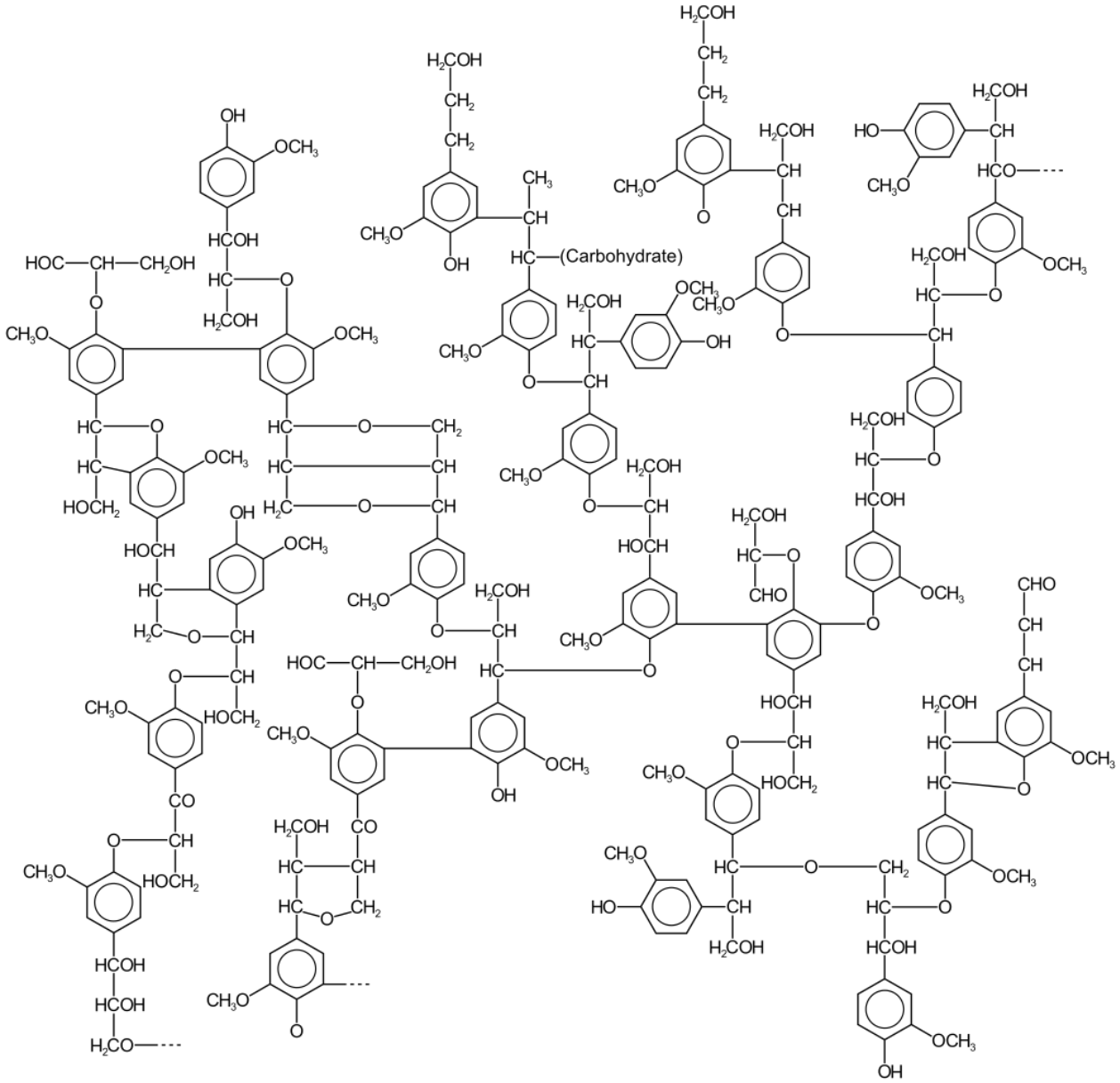
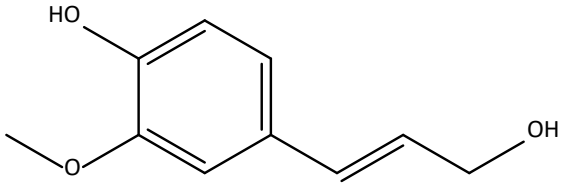
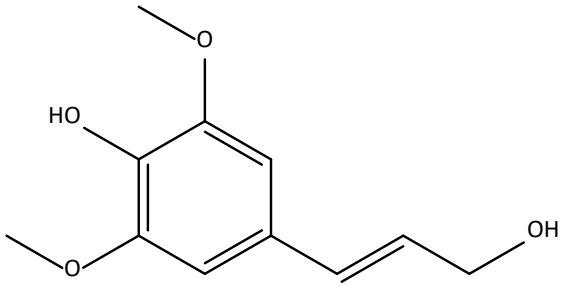
General Lignin Structure

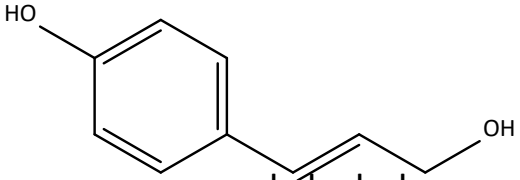




coniferyl alcohol



sinapyl alcohol



p-coumaryl alcohol

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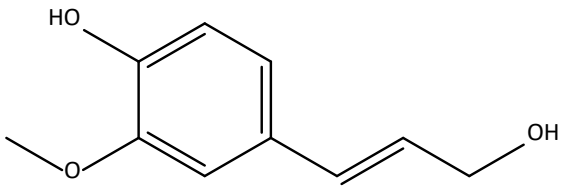
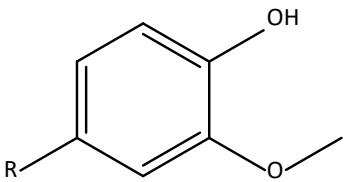
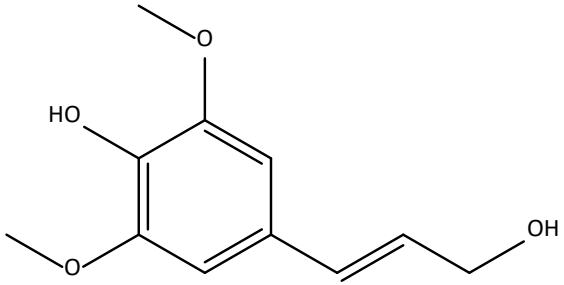


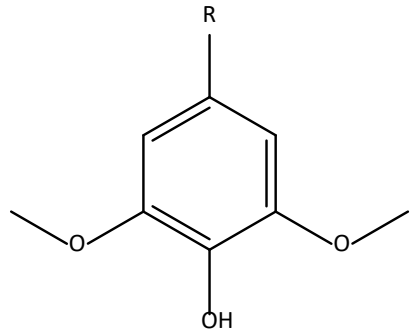
coniferyl alcohol



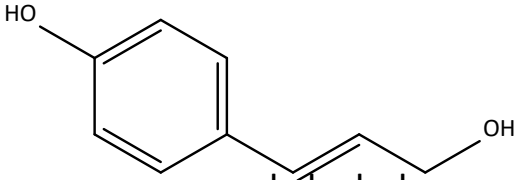
guaiacol



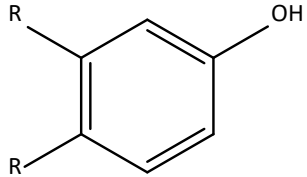
sinapyl alcohol



syringol



p-coumaryl alcohol



Phenols/Cresols

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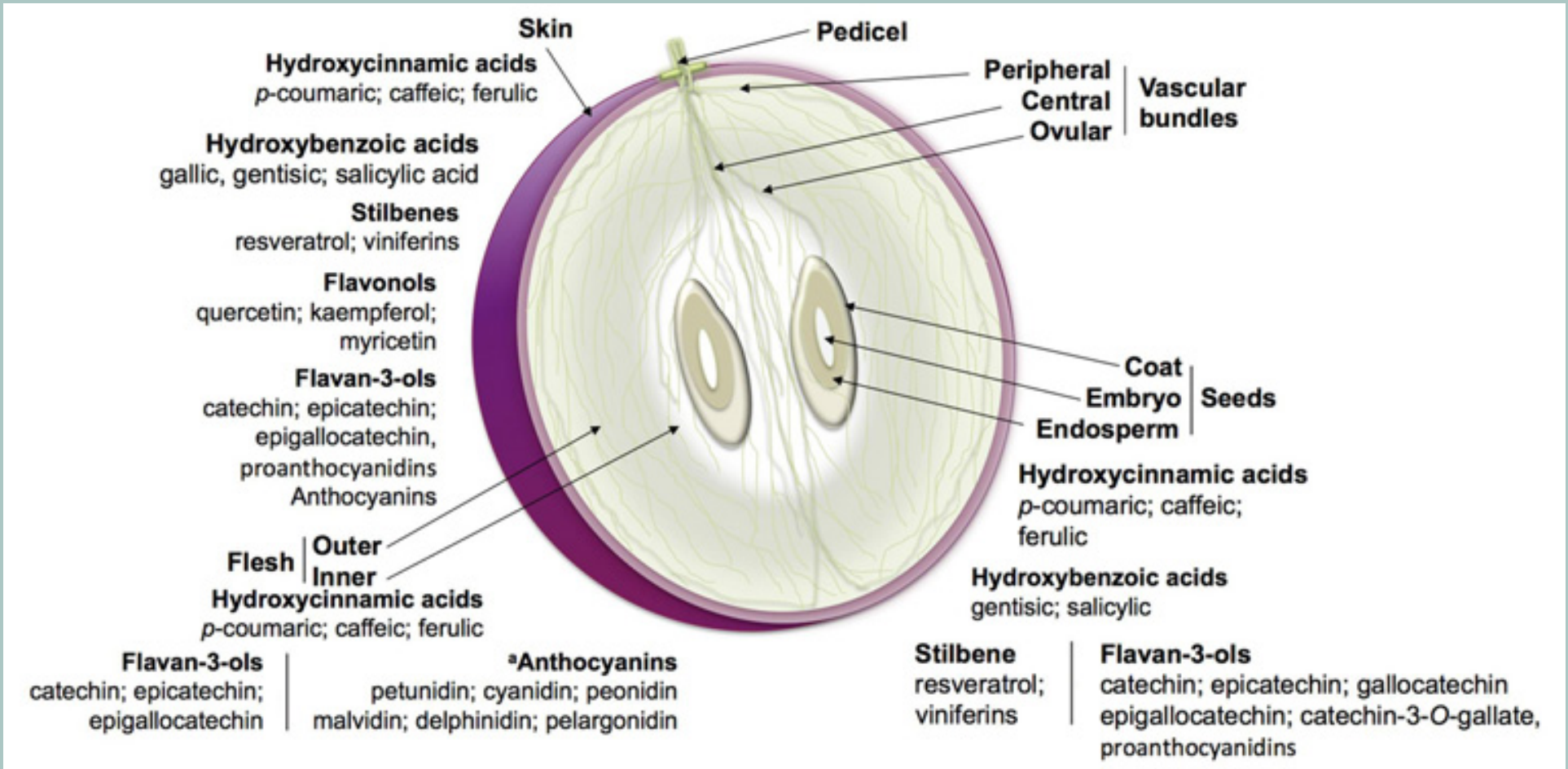

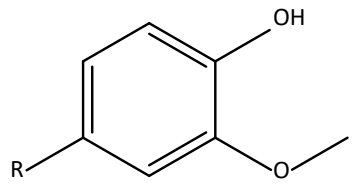

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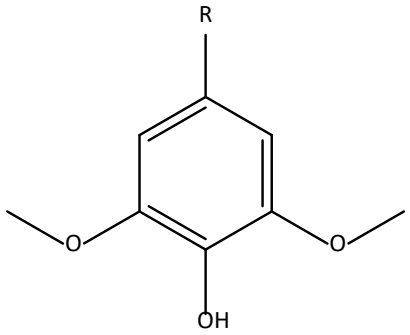
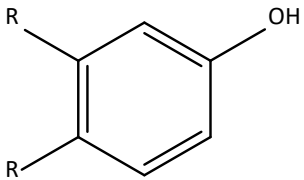


syringol



Phenols/Cresols

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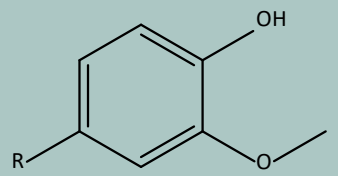
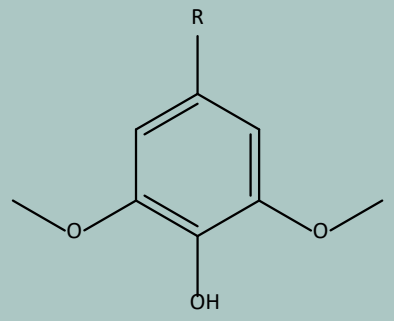


guaiacol



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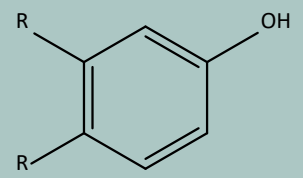
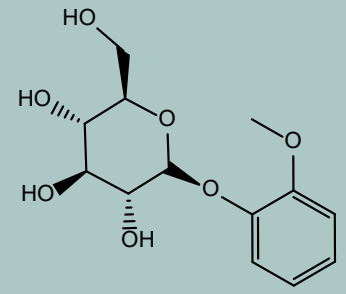
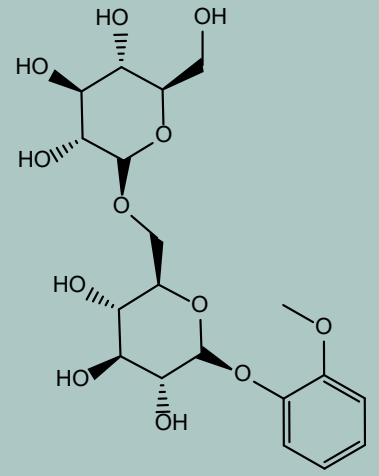


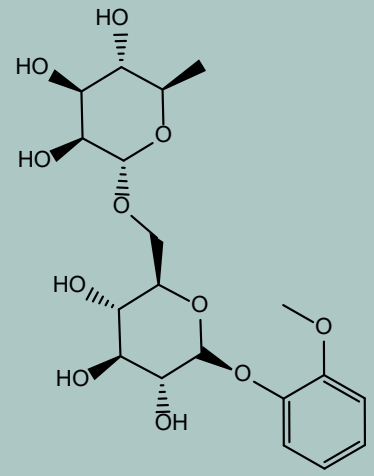
Phenols/Cresols



guaiacyl-^{B}-D-glucopyranoside



guaiacyl-^{B}-D-gentiobioside



guaiacyl-^{B}-D-rutinoside

Despite their higher concentrations after wildfire smoke exposures, the flavors imparted by these compounds aren't necessarily representative of smoked wine flavors when added directly

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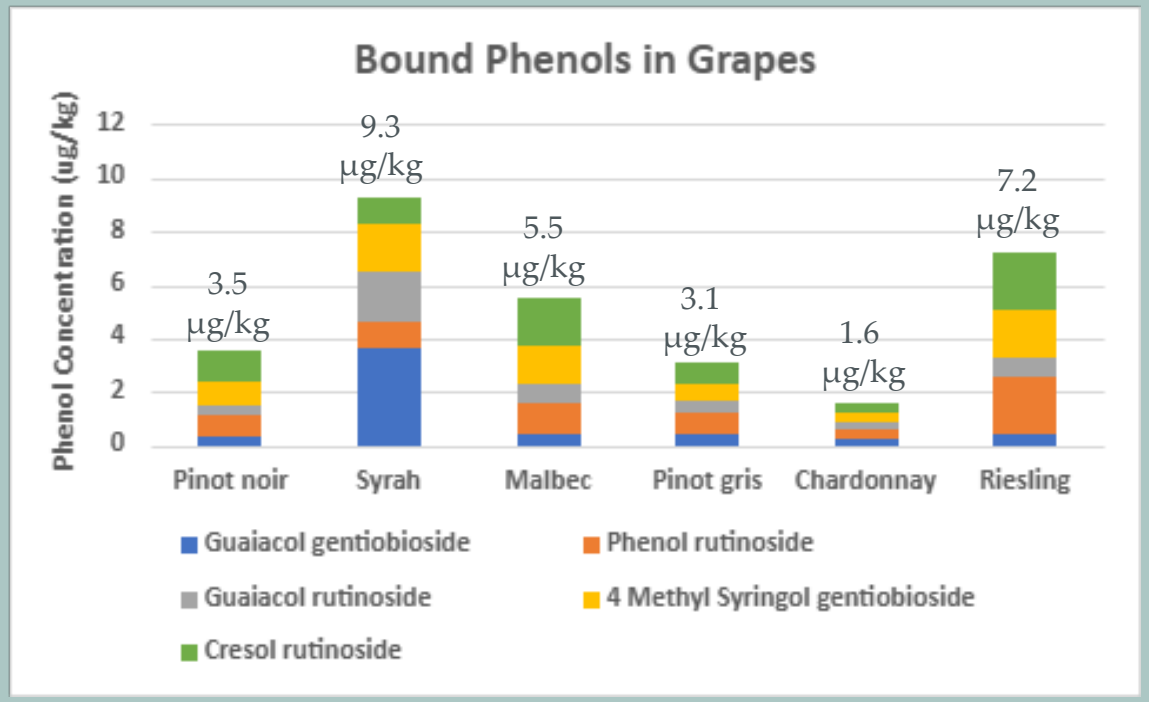
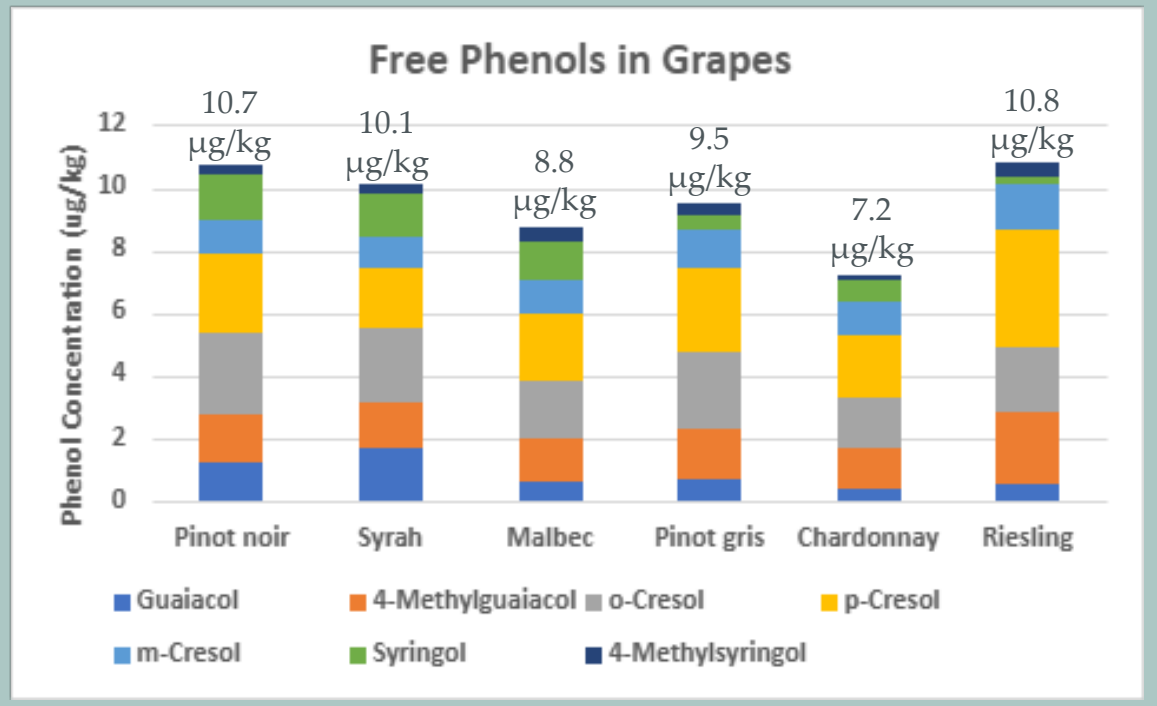
1. McKay, M., Bauer, F.F., Panzeri, V., Mokwena, L., and Buica, A. Profiling smoke tainted red wines: volatile phenols and aroma attributes. *South African Journal of Enology and Viticulture*. **2019.** 40(2). Doi: 10.21548/42-2-3270.
2. Wilkinson, K., Ristic, R., McNamara, I., Loveys, B., Jiang, WW., and Krstic, M. Evaluating the potential of smoke from Stubble burning to taint grapes and wine. *Molecules*. **2021.** Vol 26. Doi: 10.3390/molecules26247540

How much is too much smoke?: Background Phenols in Grapes





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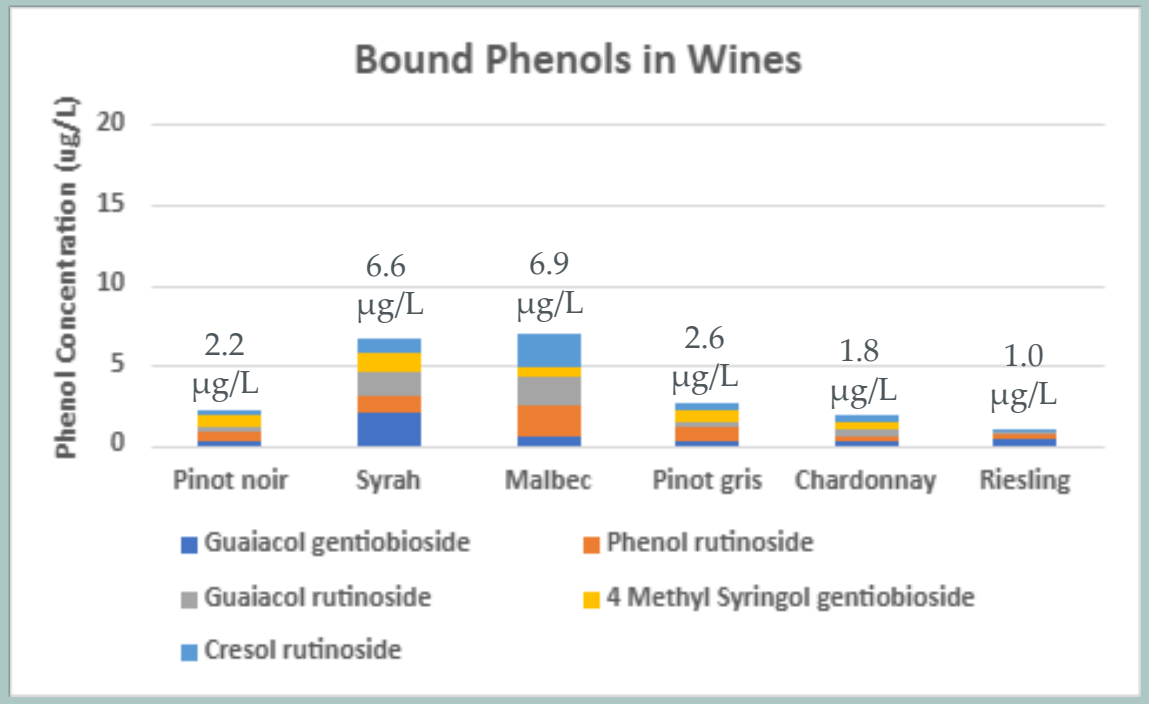
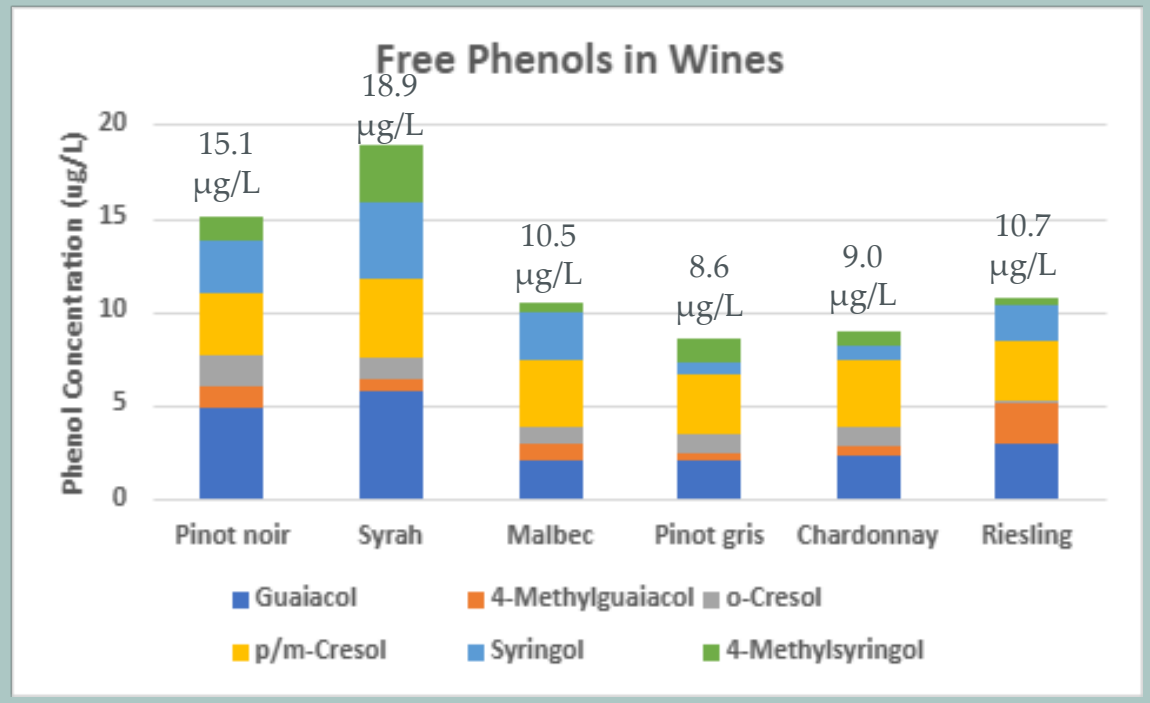
How much is too much smoke?: Background Phenols in Wines





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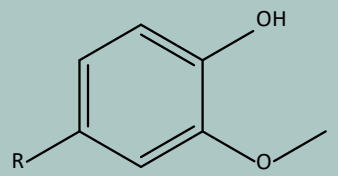
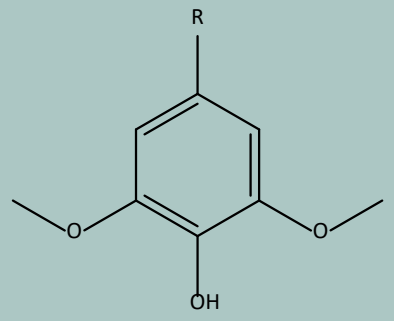
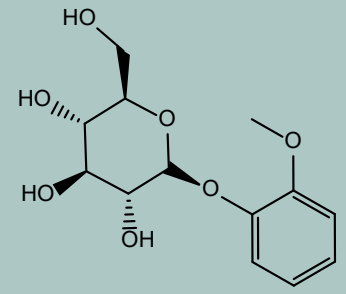


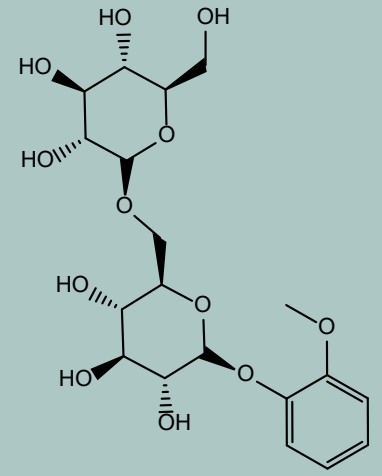
guaiacol



syringol



guaiacyl-^{B}-D-glucopyranoside



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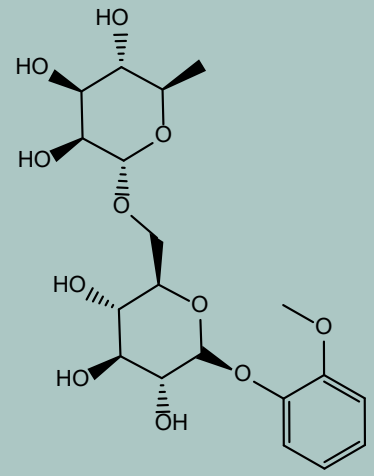

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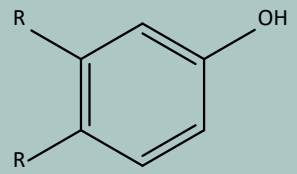

Phenols/Cresols

Data is the first step in understanding how much smoke is too much smoke. Knowing how much is naturally present, **we can start looking at how smoke duration and density might impact grapes in real-time!**

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1. McKay, M., Bauer, F.F., Panzeri, V., Mokwena, L., and Buica, A. Profiling smoke tainted red wines: volatile phenols and aroma attributes. *South African Journal of Enology and Viticulture*. **2019.** 40(2). Doi: 10.21548/42-2-3270.
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Wildfire Smoke Aging

Tom Jobson: Professor, Dept. Civil & Environmental Engineering, WSU, Pullman

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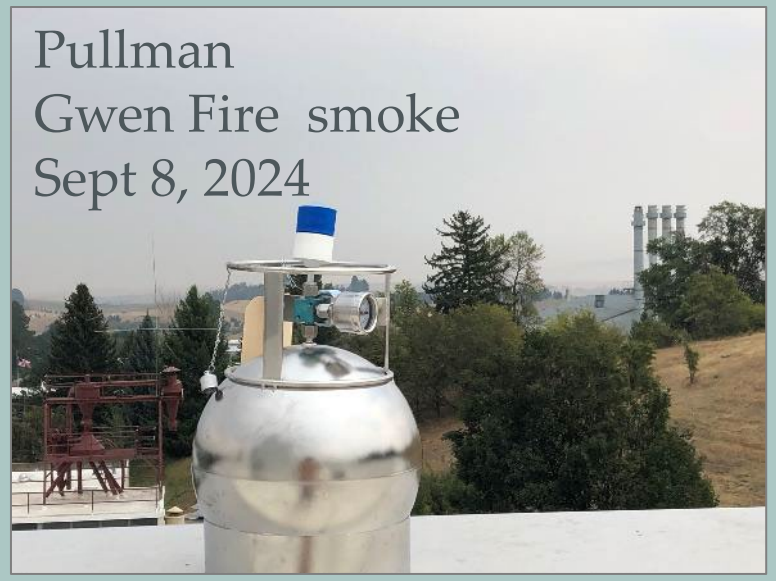
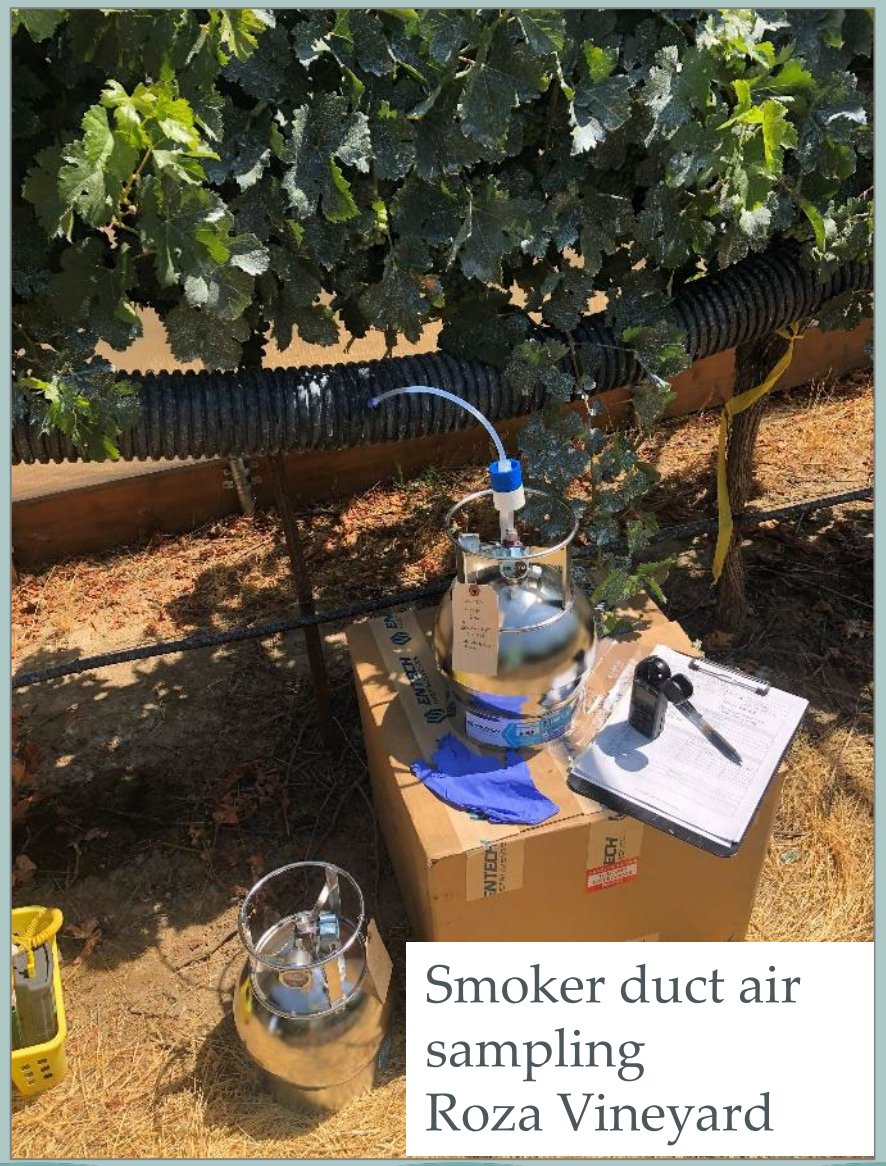
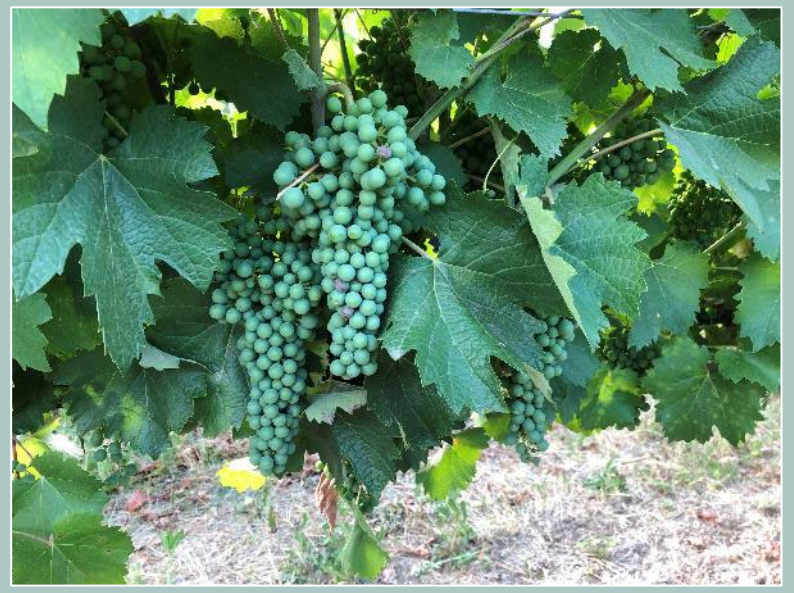
Wildfire Smoke



Roza Vineyard smoker



Smoker duct air sampling Roza Vineyard



Smoke is a mixture of organic particles and gases.

We know “fresh” smoke produces grape taint.

Does older smoke cause problems?

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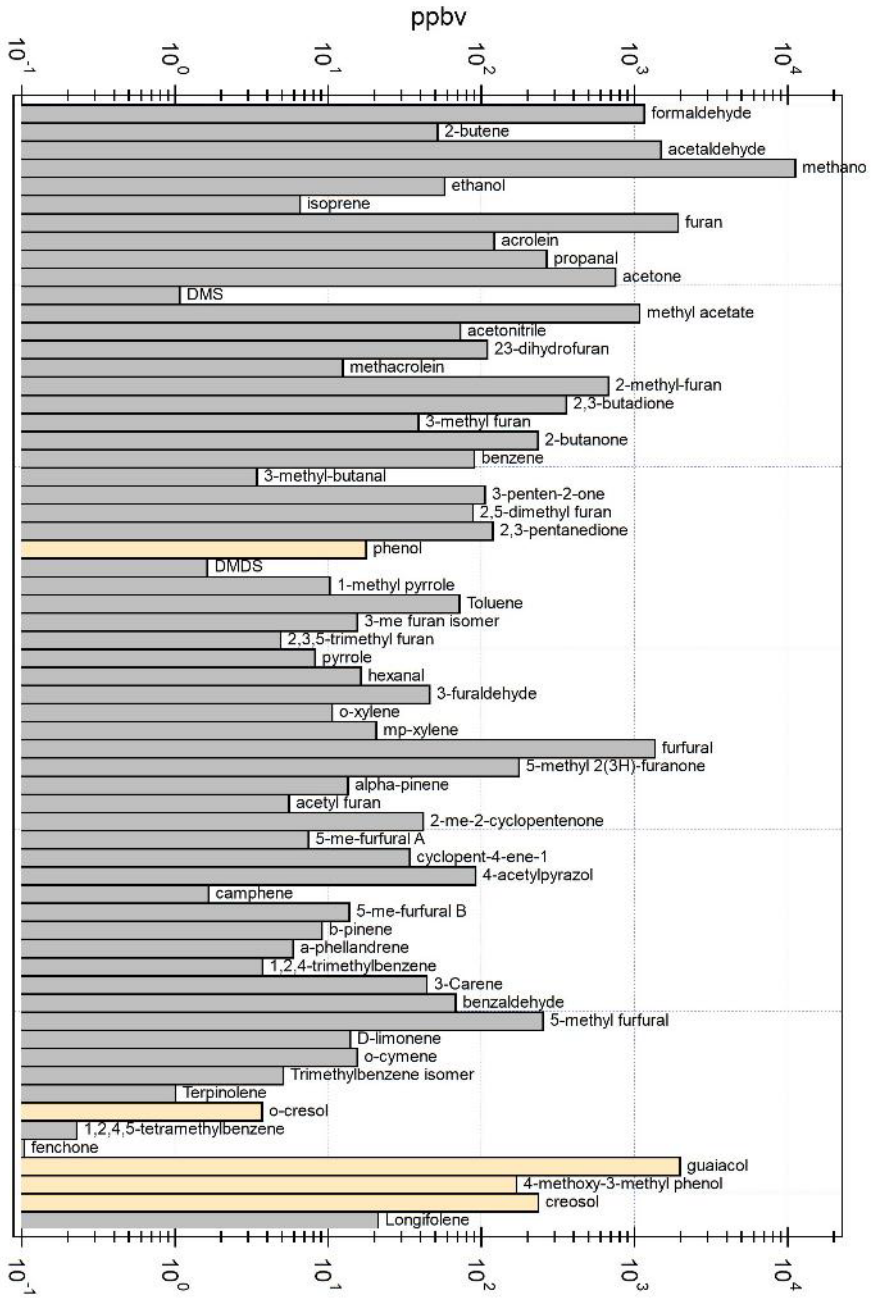
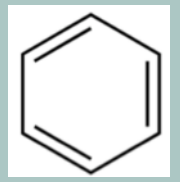
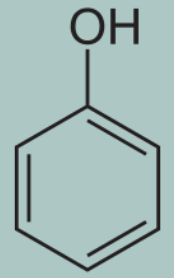


Fresh Smoke sample. Most abundant volatile organic gases identified from WSU Roza Vineyard smoker (air sample from pellet smoker).

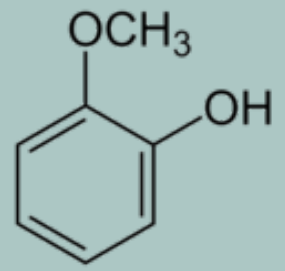
Yellow shaded bars indicate known smoke taint compounds.



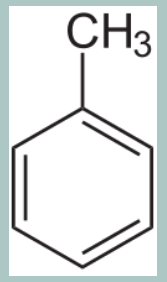
benzene



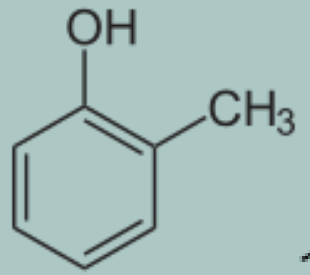
phenol



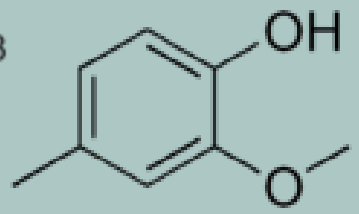
guaiacol



toluene



o-cresol



creosol

Phenolic compounds have large emission rates from wood combustion.

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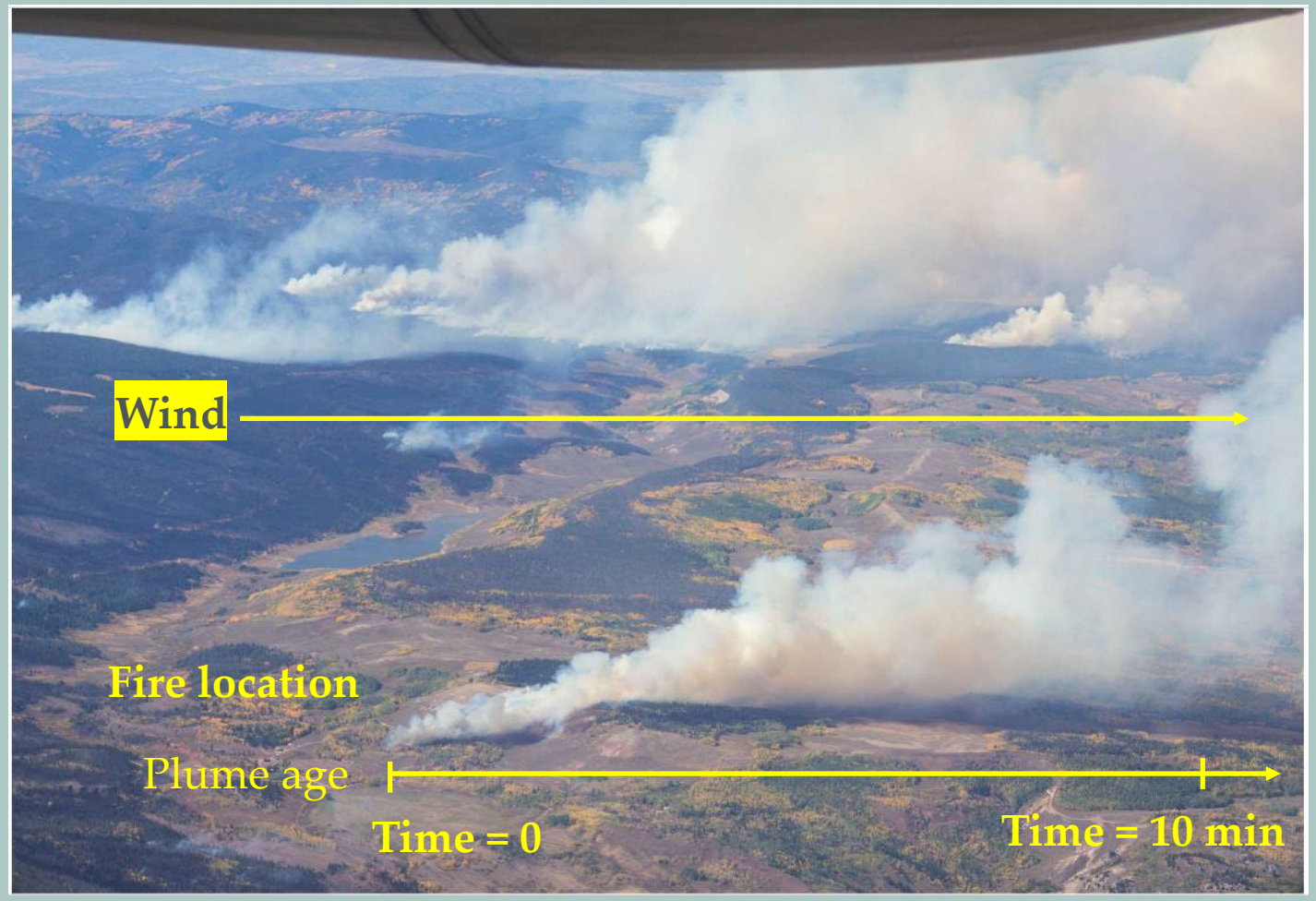
Wildfire Smoke Aging – what does this mean?



Credit: Silver Creek Fire, CO
J.R. Pierce &

Age of a smoke plume can be defined by the time it takes for wind to blow smoke from the source to the receptor (i.e. winery).

Age = the smoke transport time.

We can use the terms “fresh” smoke and “aged smoke”.

Transport times can be complicated by merging of plumes from different sources.

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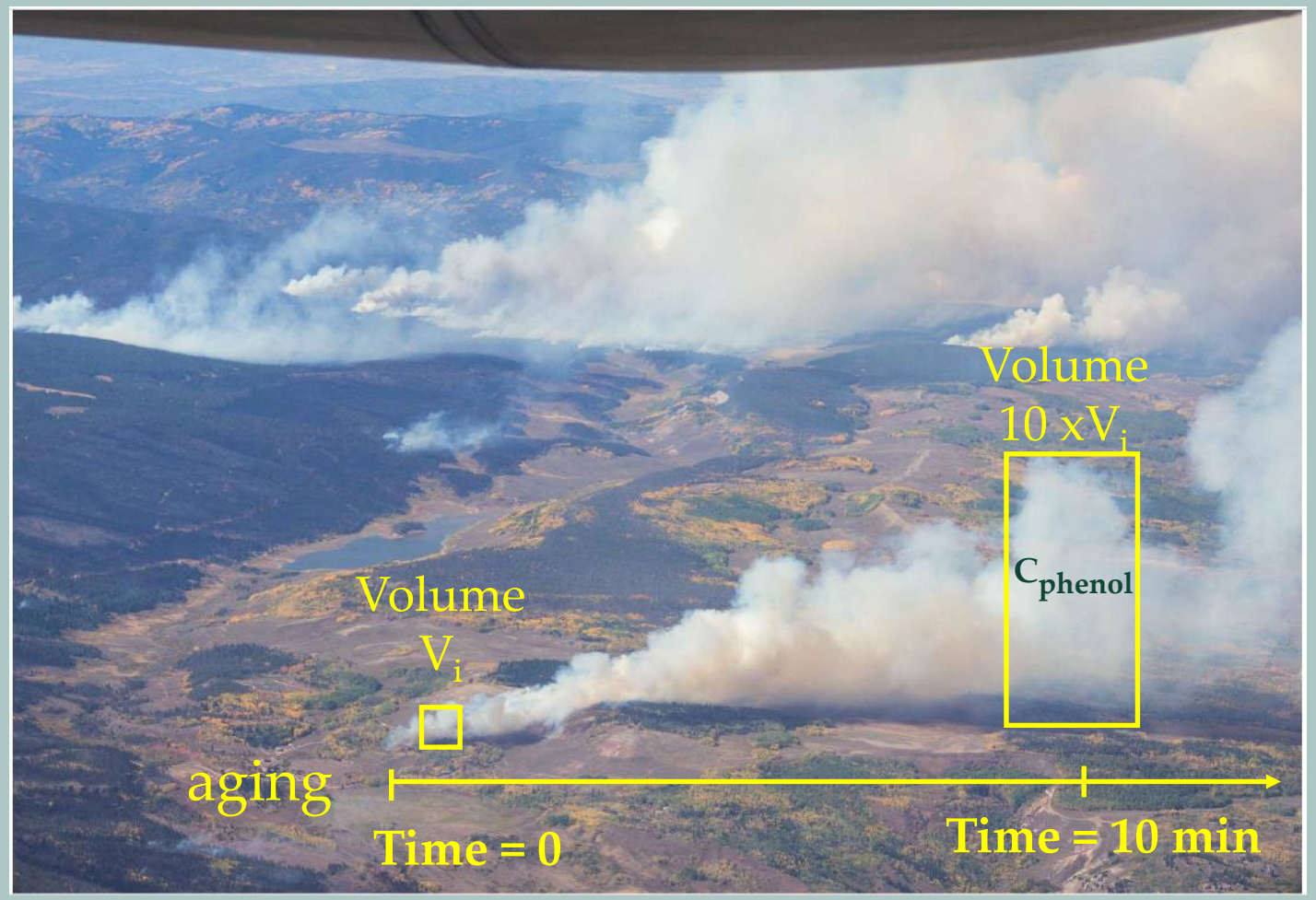
1. Smoke dispersion



Anecdotal evidence suggests that "fresh smoke" is more problematic for grape taint.

What happens during aging?

1. Plume disperses and **dilution** with clean air lowers concentrations of organic vapors and particles ($PM_{2.5}$) that comprise the smoke.

We want to know the dose received at the vineyard.

$$\text{phenol dose (ng)} = \left(\begin{array}{c}\text{concentration}\\ \text{of phenol in}\\ \text{the air}\end{array}\right) \times \left(\begin{array}{c}\text{exposure}\\ \text{time}\end{array}\right) \times \left(\begin{array}{c}\text{uptake}\\ \text{efficiency}\\ \text{into grape}\end{array}\right)$$

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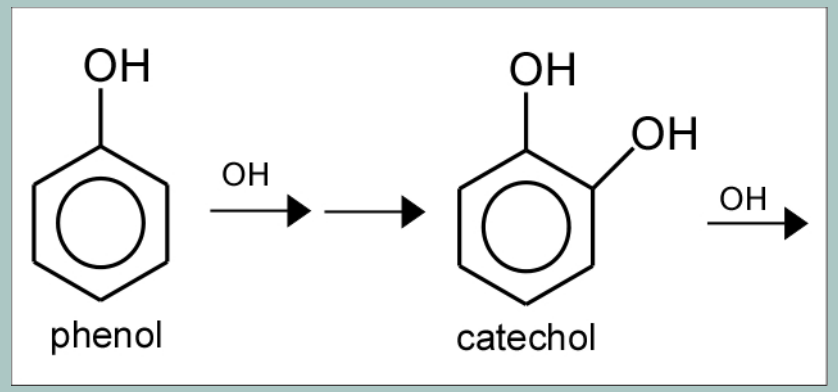
2. Photochemical Aging in Sunlight is Important



The UV radiation in sunlight causes chemical reactions that create the OH radical.

OH radical is a powerful oxidizer.

2. Organic vapors are oxidized in the **daytime** (by hydroxyl radical (OH) & ozone) as plume travels downwind.

OH oxidation rates are very fast in fresh wildfire plumes (first couple of hours)!

How long does phenol last in the plume?

Characterized by a chemical lifetime (like radioactive decay and half-life). Exponential decay.

$$\text{lifetime (hours)} : \tau = \frac{1}{k_{OH}\ \text{OH}}$$

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Estimated photochemical lifetimes – ball park values

Compound	OH rate constant (k_{OH} : cm^3 $molecule^{-1}$ s^{-1})	Lifetime (hours) assuming OH = 5×10^6 molecules cm^{-3})
phenol	2.7×10^{-11}	2.1
o-cresol	4.1×10^{-11}	1.4
m-cresol	5.9×10^{-11}	0.9
p-cresol	5.0×10^{-11}	1.1
guaiacol	7.5×10^{-11}	0.7
catechol	10.4×10^{-11}	0.5
benzene	0.12×10^{-11}	46
toluene	0.64×10^{-11}	8.7

Phenol lifetime could be ~2 hours.

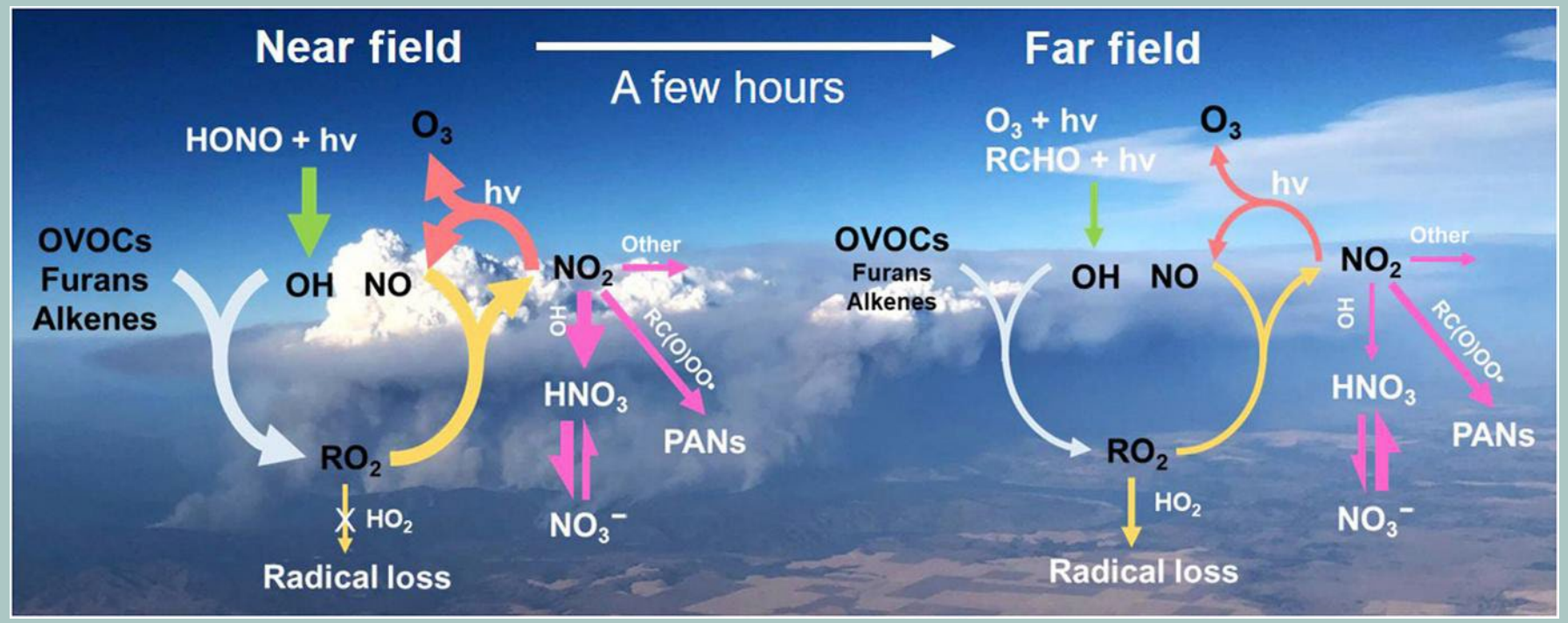
This means:
63% oxidized in 2 hours,
86% oxidized in 4 hours.

HO concentrations in plumes not directly measured. Inferred from chemical transport models and measured decay rates of VOCs.

Wildfire Smoke Aging – rapid oxidation of phenolic compounds

Fresh Smoke

Aged Smoke



Lu Xu et al., Science, 2021

Fresh smoke is **very photochemcially active** because of HONO (nitrous acid) emissions from the fire.

Phenolic smoke taint compounds will be rapidly oxidized by the OH radical in the first few hours.

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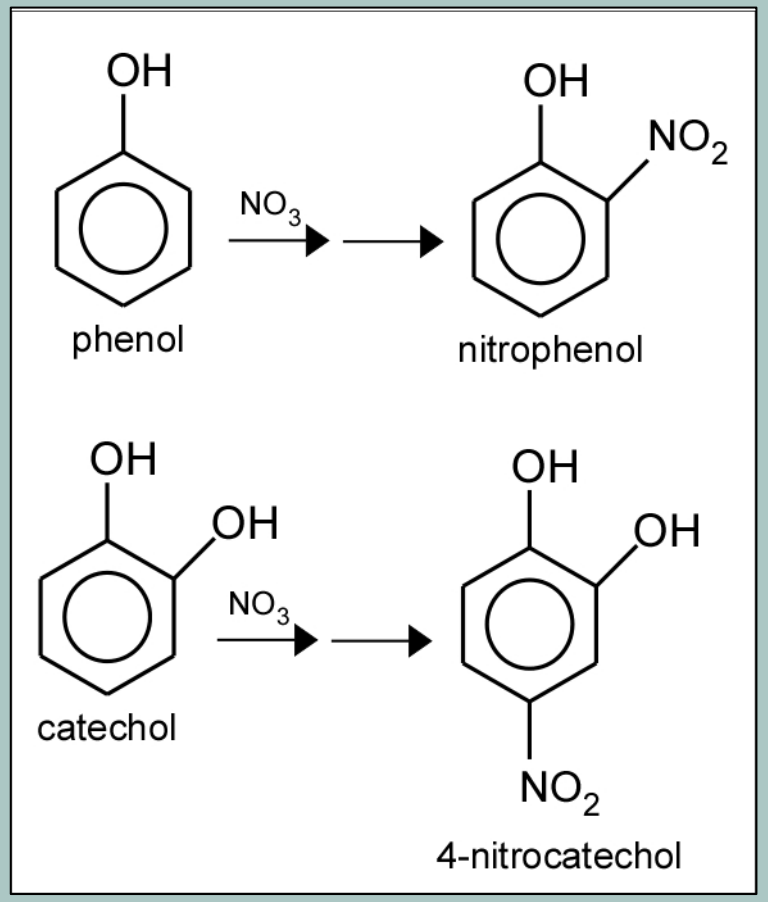
3. Chemical oxidation at night by the nitrate radical



What happens at night (no sunlight to make OH)?

Organic vapors are oxidized by the NO_3 (nitrate) radical.

At night and twilight:

$NO + O_3 \rightarrow NO_2$

$NO_2 + O_3 \rightarrow NO_3 + O_2$

Oxidation by NO_3 has also been found to be very fast in fresh wildfire plumes in the twilight hours.

Products of oxidation accrete onto existing particles in the plume - nitrocatechols found in $PM_{2.5}$.

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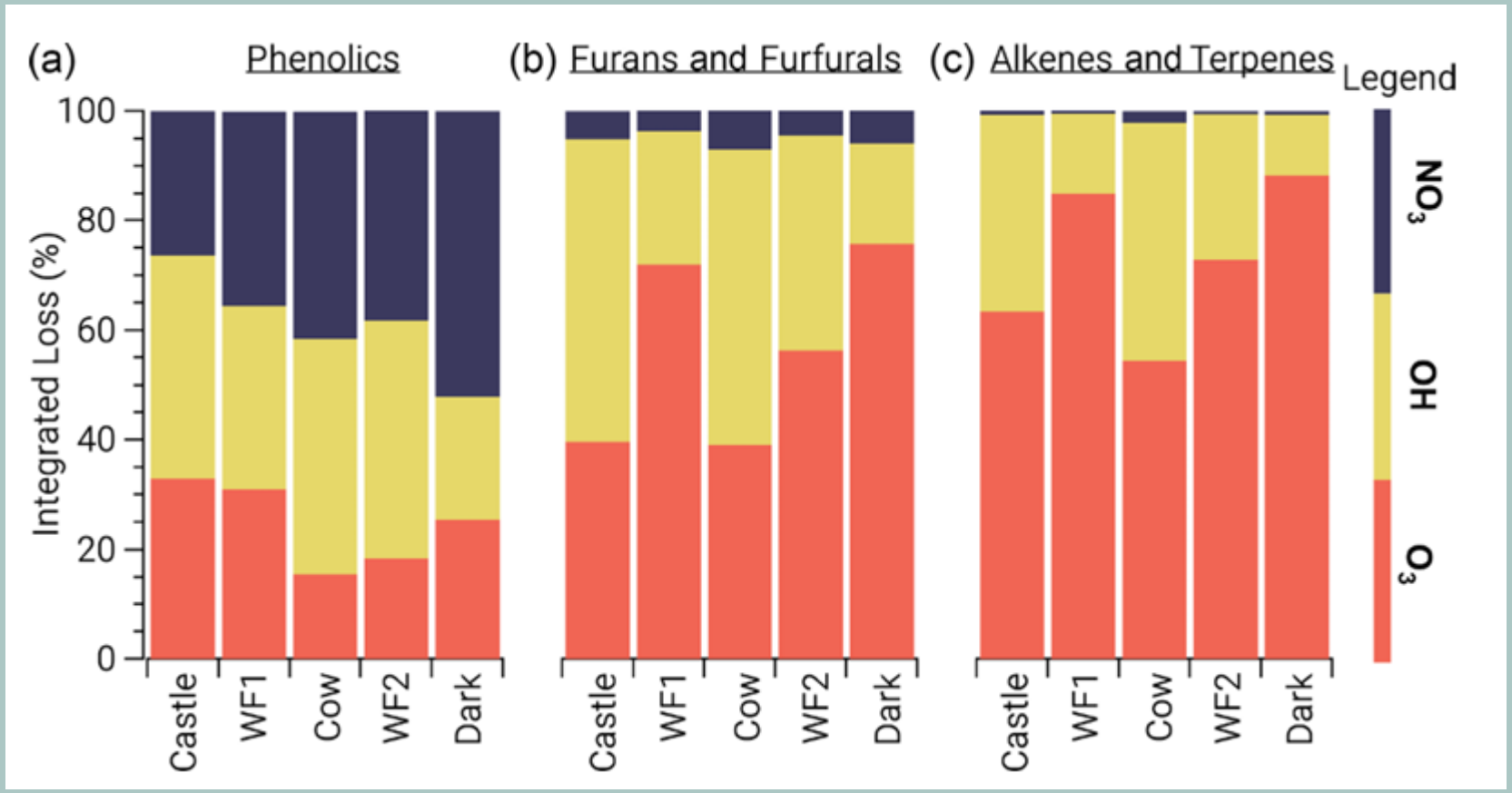
Nitrate radical

Twilight and nighttime data from wildfire plume transects



Decker et al., ACP, 2021

NO_3 radical oxidation of phenolic compounds as important as OH radical at twilight.

Likely nighttime chemical loss important too.

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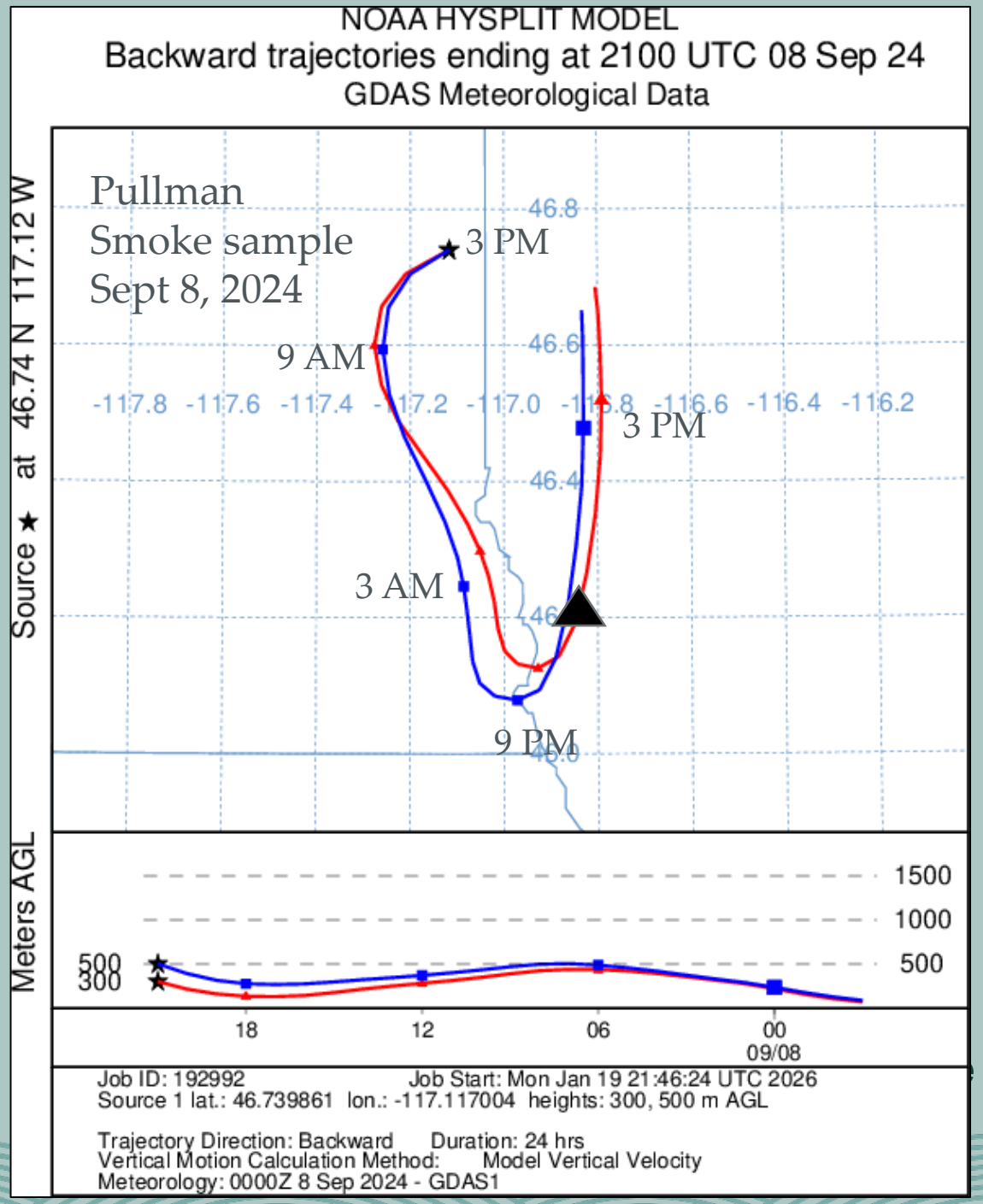
Transport Times

Publicly available trajectory calculation from NOAA Air Resources Lab: HySplit Model

- Gwen Fire, Sept 2024
  Destroyed Colter Creek Winery
  Grass + brush fire
  30,000 acres over 14 days.

18 + hours of transport –
air sample was "clean" of VOCs
but lots of $PM_{2.5}$.



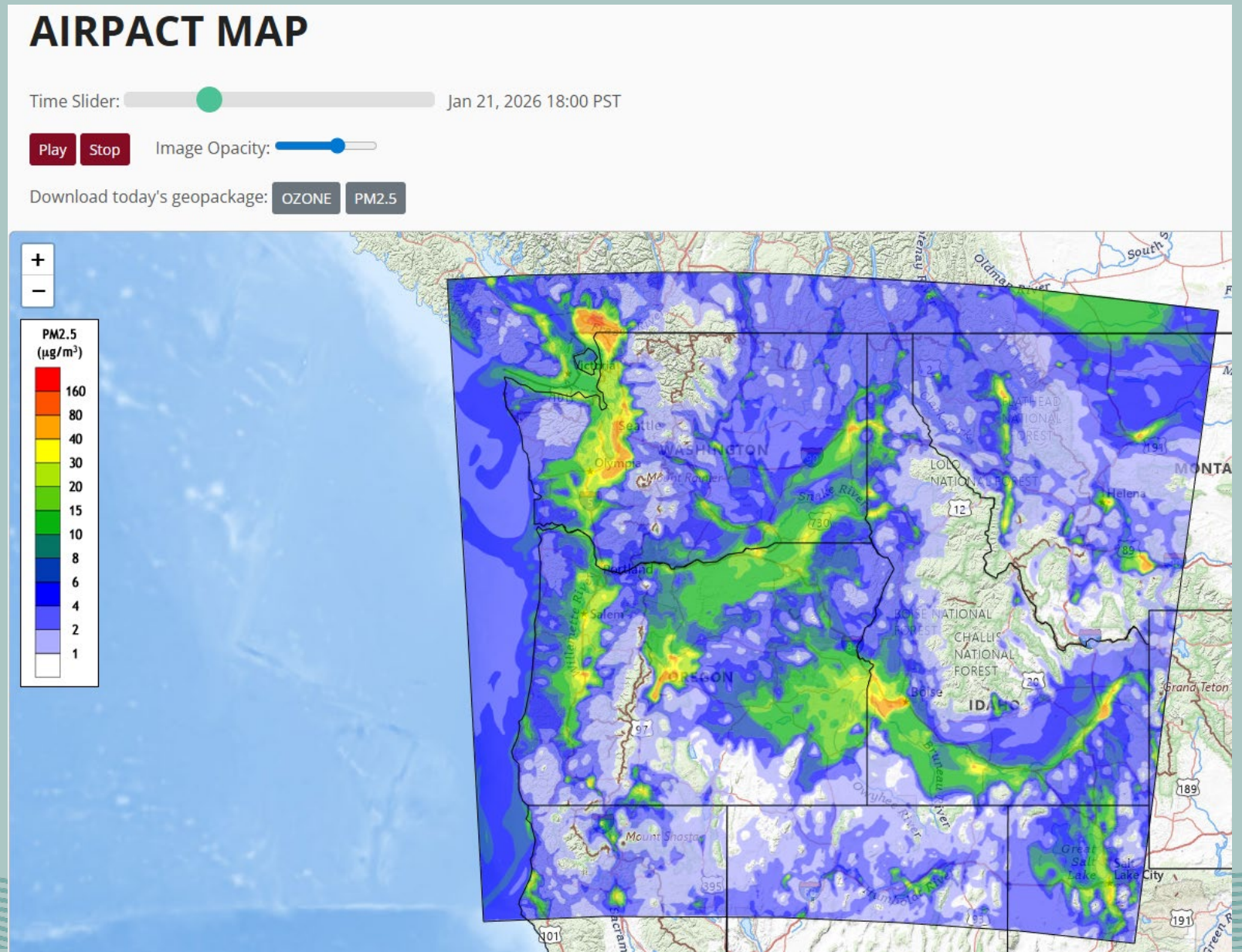
Chemical Transport Forecast Model

WSU Laboratory for Atmospheric Research operates a chemical forecast model called AIRPACT-5.

Provides hourly forecast of pollution for PNW for 36 hour period.

Gets wildfire location data and predicts PM2.5 and chemical transport.

www.airpact.wsu.edu



Summary

Aircraft based sampling of wildfire plumes has demonstrated rapid daytime gas-phase oxidation of emitted phenolics (known grape taint compounds) in first few hours of plume transport time.

If I had to bet on this:
Only “fresh” smoke less than 4 to 5 hours old has the potential to be a problem for vineyards.

Is grape taint caused by exposure to gases, particles, or both?

Acknowledgements

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  Opinions are the authors and not USDA.

- WSU Roza Vineyard smoke experiments led by Prof. Tom Collins, WSU Wine Research Center

- Canister sample analysis by Rhonda Skaggs

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Smoke Perception in Wine: What and When

Jillian Thrall, Oregon State University MS Student

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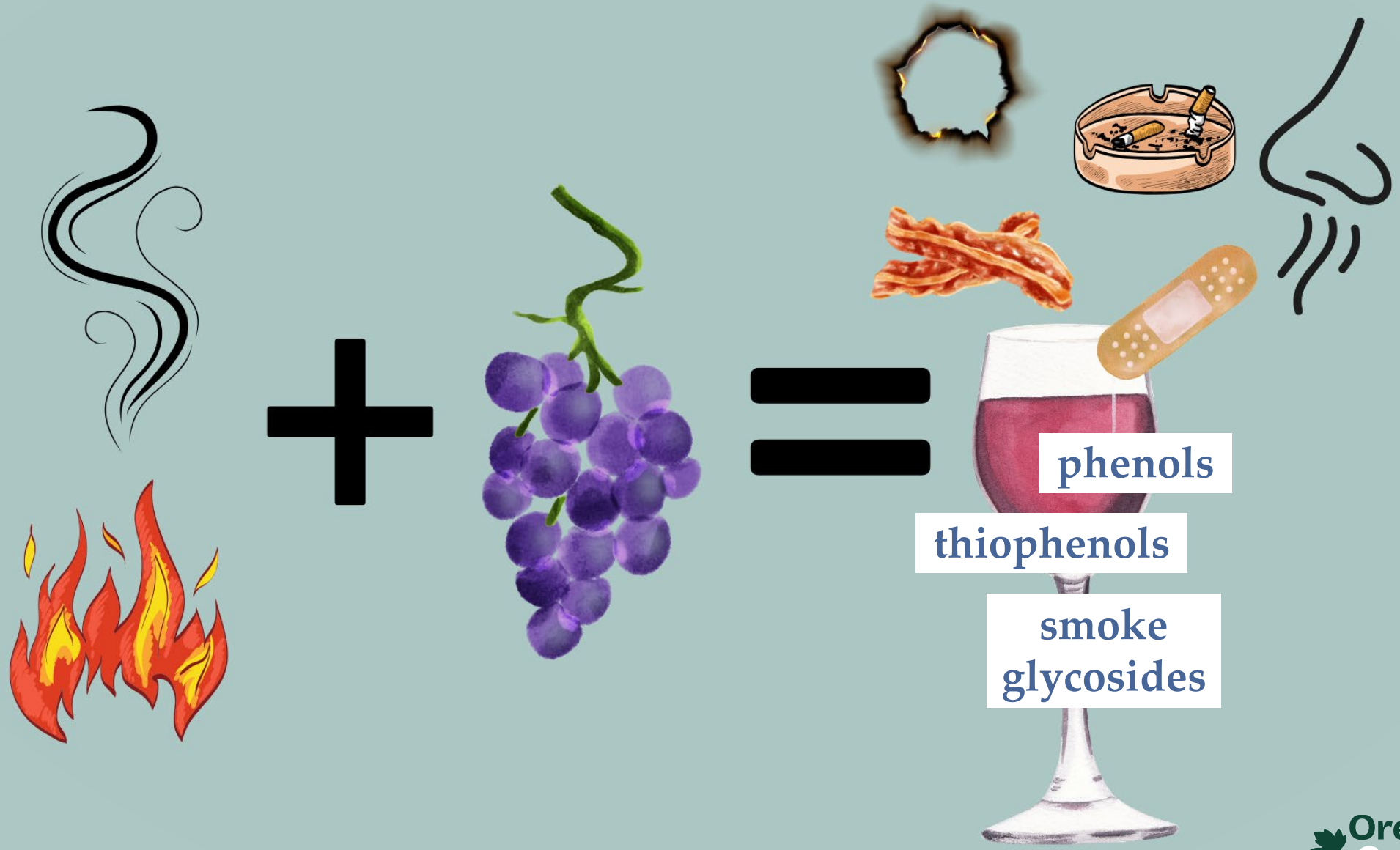

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Smoke Perception in Wine

What do we smell/taste, and when?

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Three-fold approach:

1. Phenol interactions

2. Phenol + thiol thresholds

3. Phenols + thiols + smoke-glycosides

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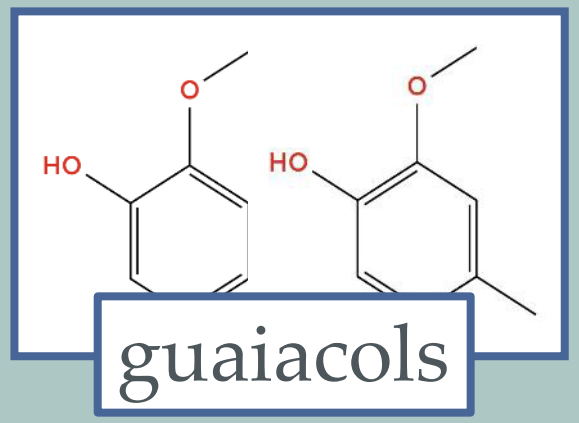
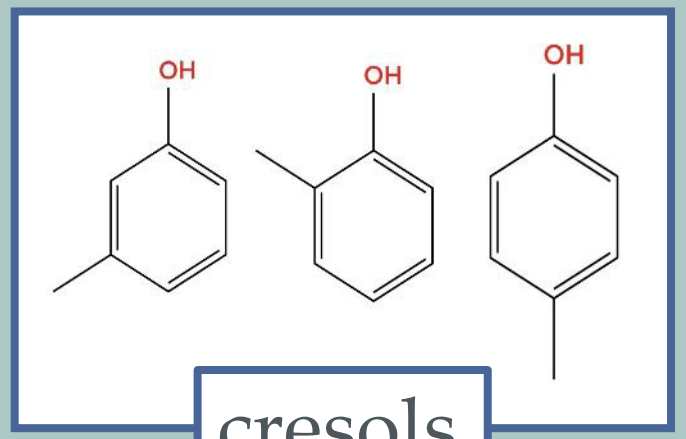
Smoke phenols



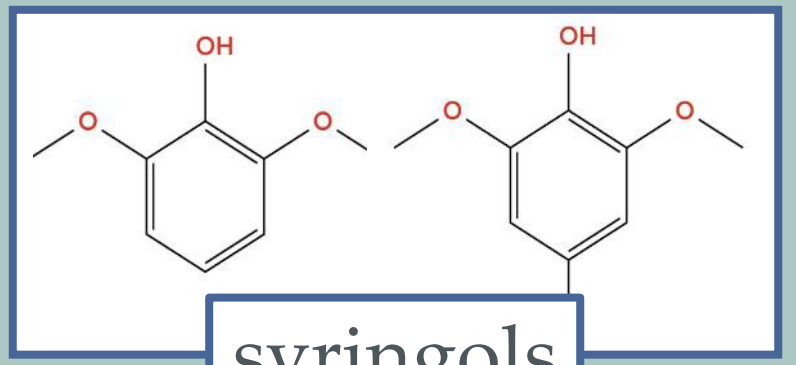
guaiacols

+



cresols

+



syringols

≠

…so what's going on?

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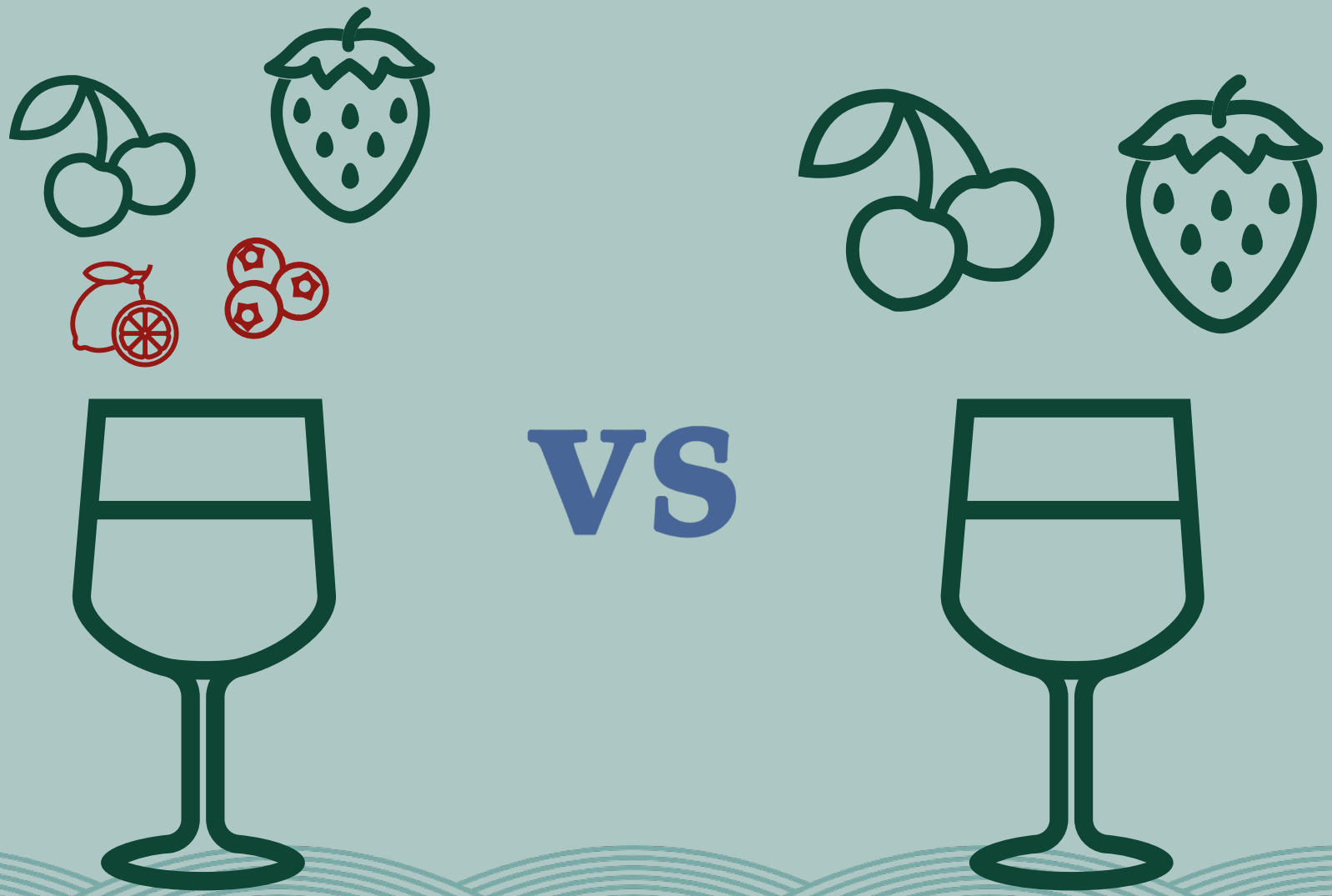
Matrix interactions & sub-threshold behavior



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Three Comparisons

1

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Three Comparisons

2

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Three Comparisons

Bonus question: does the base wine matter?

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“Describe the aroma”

Pinot Noir

Cabernet Sauvignon

Varying concentrations of G:C:S

Spice	Red Jam	Medicinal
Red Fruit	Black Jam	Ashy
Dark Fruit	Oak	Liquid Smoke
Chemical	Vanilla	Musty

Smoke

Liquid

None

Extreme

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Three Comparisons

1

NO DIFFERENCE IN PERCEPTION between treatments with same total phenol concentration

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Three Comparisons

2

PN: Significant difference at **3.3x increase** in total phenol

CS: Significant difference at **4.0x increase** in total phenol

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CS: Significant difference at **4.0x increase** in total phenol

25 µg/L

100 µg/L

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Three Comparisons

3

No significant difference between treatments with and without syringols

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Three Comparisons

Bonus question: does the base wine matter?

PN: Significant difference at **3.3x increase** in total phenol

CS: Significant difference at **4.0x increase** in total phenol

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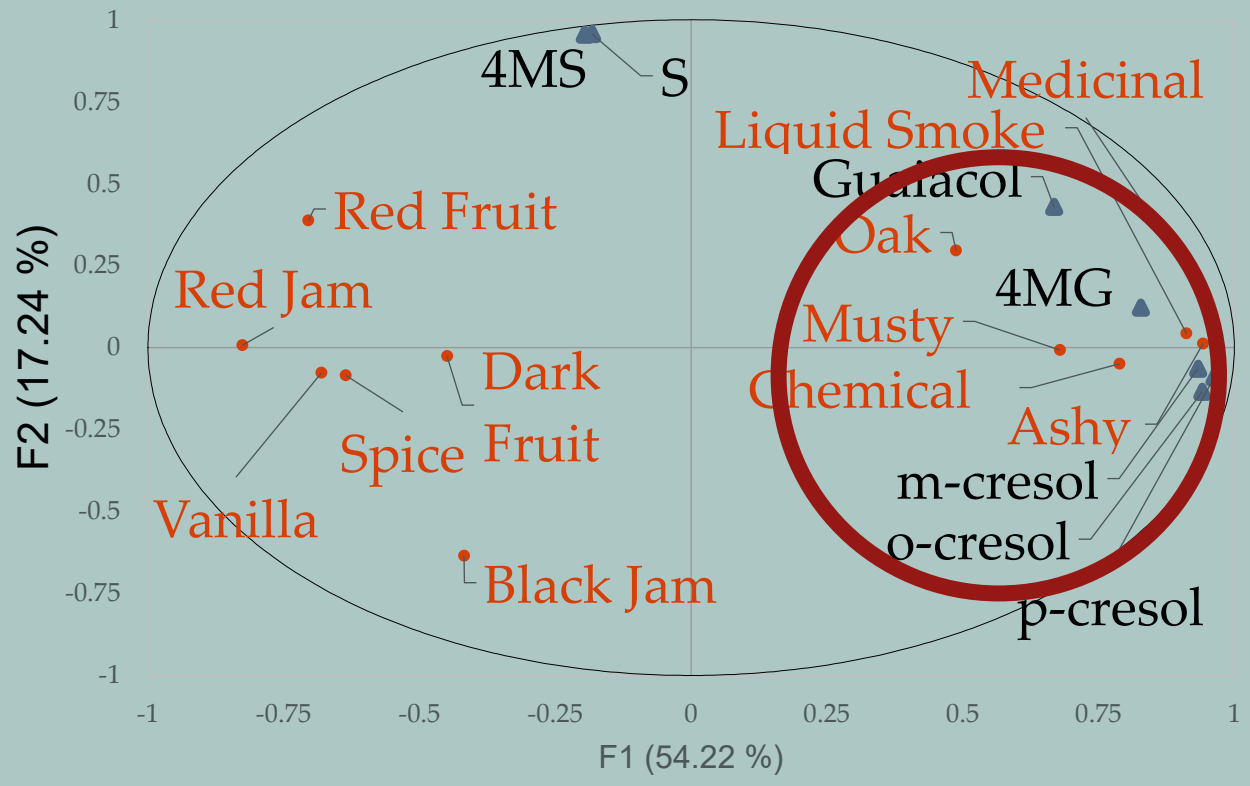

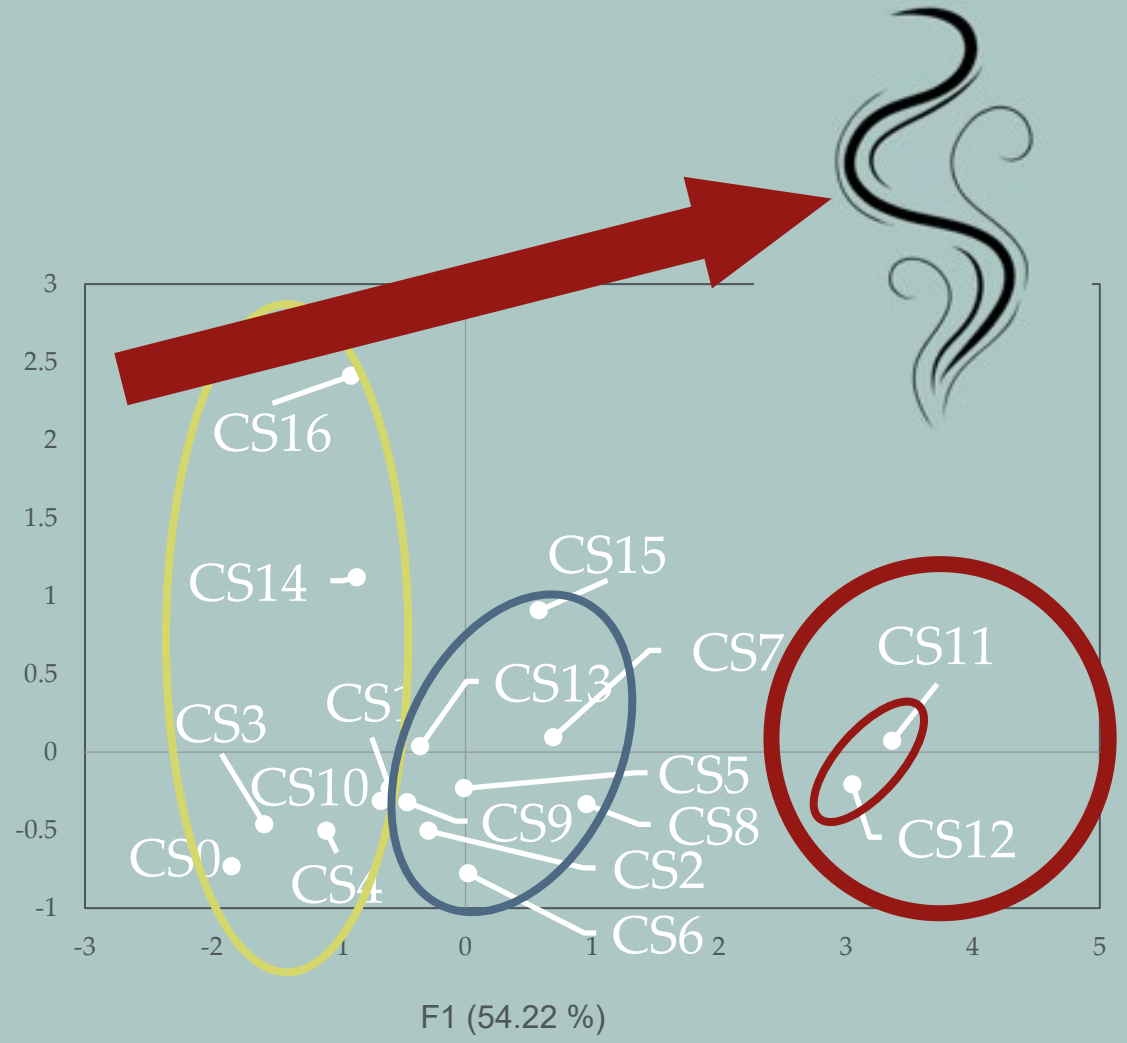

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What does this mean for winemakers?

- Total phenol concentration determines aroma quality – not G:C
- Syringols did not contribute to aroma quality
- Wine styles differ in their smoke phenol perception limits based on their base matrix (volatile and non-volatile compounds)

LIMITATIONS OF APPLICATION

Aroma only!

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Three-fold approach:

1. Phenol interactions

2. Phenol + thiol thresholds

3. Phenols + thiols + smoke glycosides

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Thiophenol Ashy Recognition Thresholds

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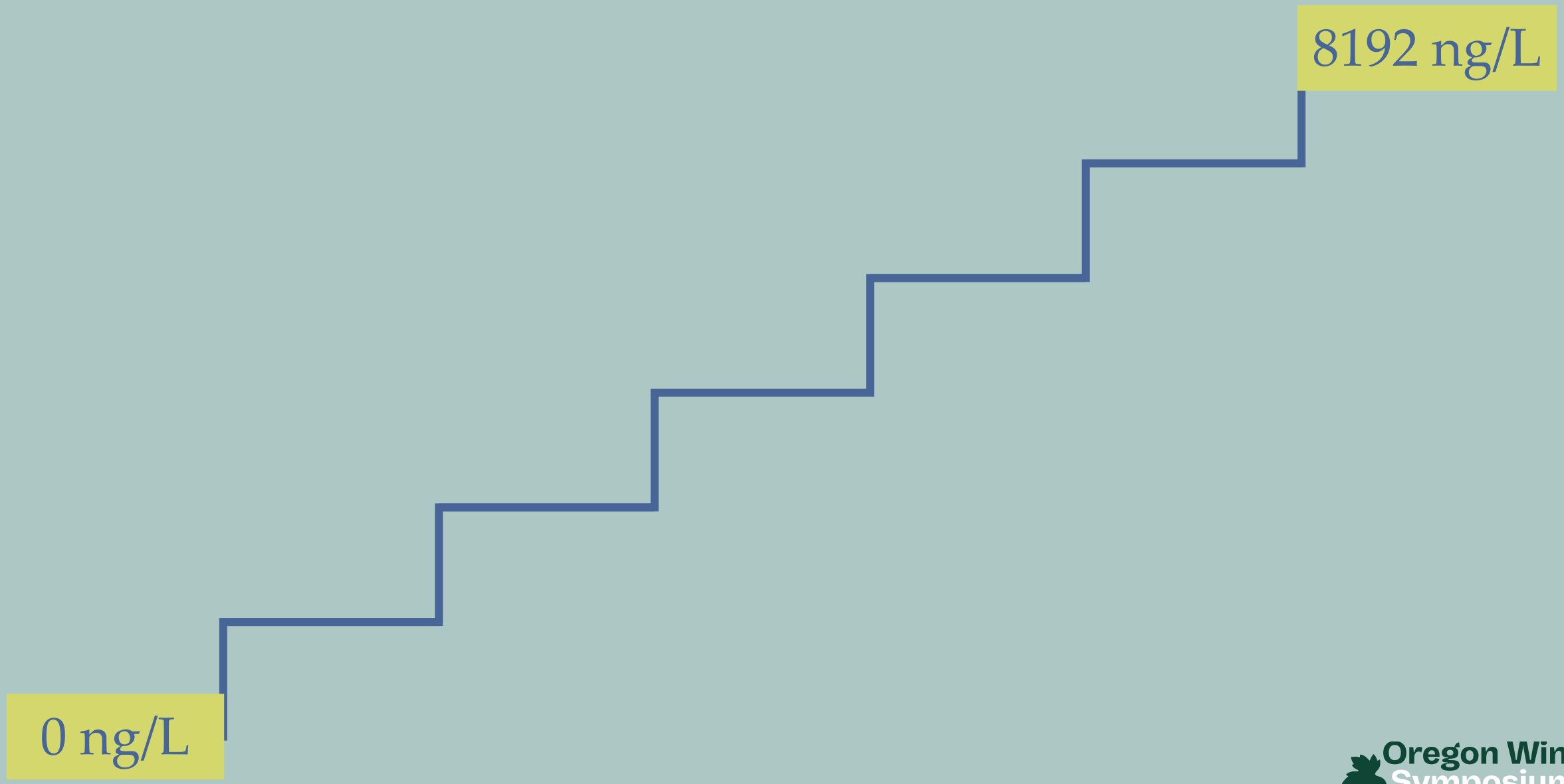
“Is it ashy?”

Pinot Noir
Cabernet Sauvignon
Syrah
Riesling

105 µg/L phenols

Thiols



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“Is it ashy?”

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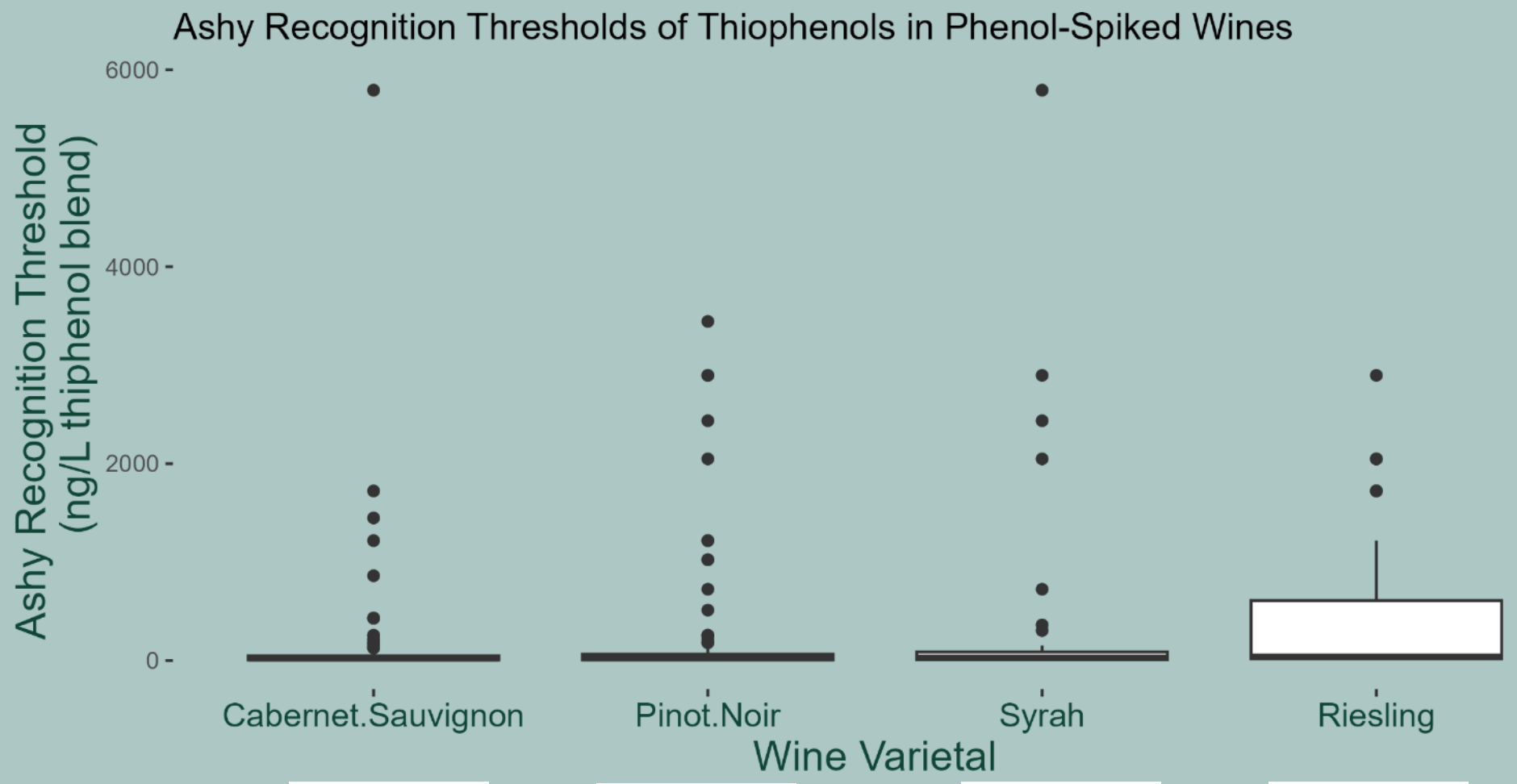
Thiol Threshold Results



21 ng/L	23 ng/L	37 ng/L	76 ng/L

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Three-fold approach:

1. Phenol interactions

2. Phenol + thiol thresholds

3. Phenols + thiols + smoke glycosides

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Future study

Food grade smoke glycoside extractions pending

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	P	T	G
P	phenols		
T	phenols + thiols	thiols	
G	phenols + glycosides	thiols + glycosides	glycosides

phenols + thiols + glycosides

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Thank you!

- Dr. Elizabeth Tomasino
- Camilla Sartori
- Tomasino Lab group
- OWRI
- Chateau Ste Michelle
- WSU Wine Science Center
- UC Davis

- My many panelists!

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