Listening to the flow:
Discoveries from wildland fire acoustics

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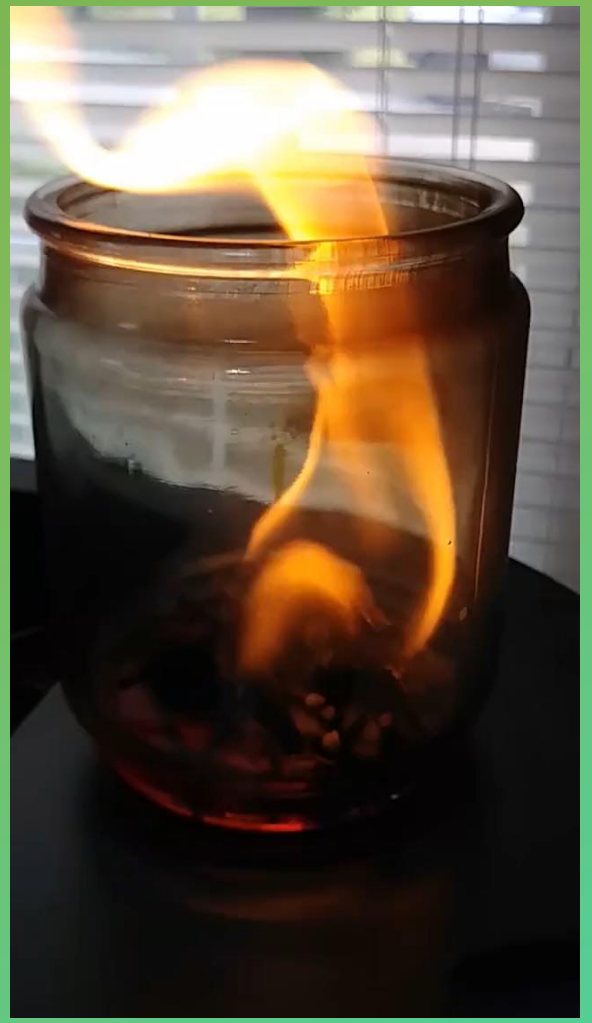
Introduction – Fire is...elusive?

FIRE

Our obsession with staring at hot soot…

H …that

Temp … changes, …ht,…



Introduction – Current measurement techniques

https://www.nesdis.noaa.gov/GOES-R-Series-Satellites

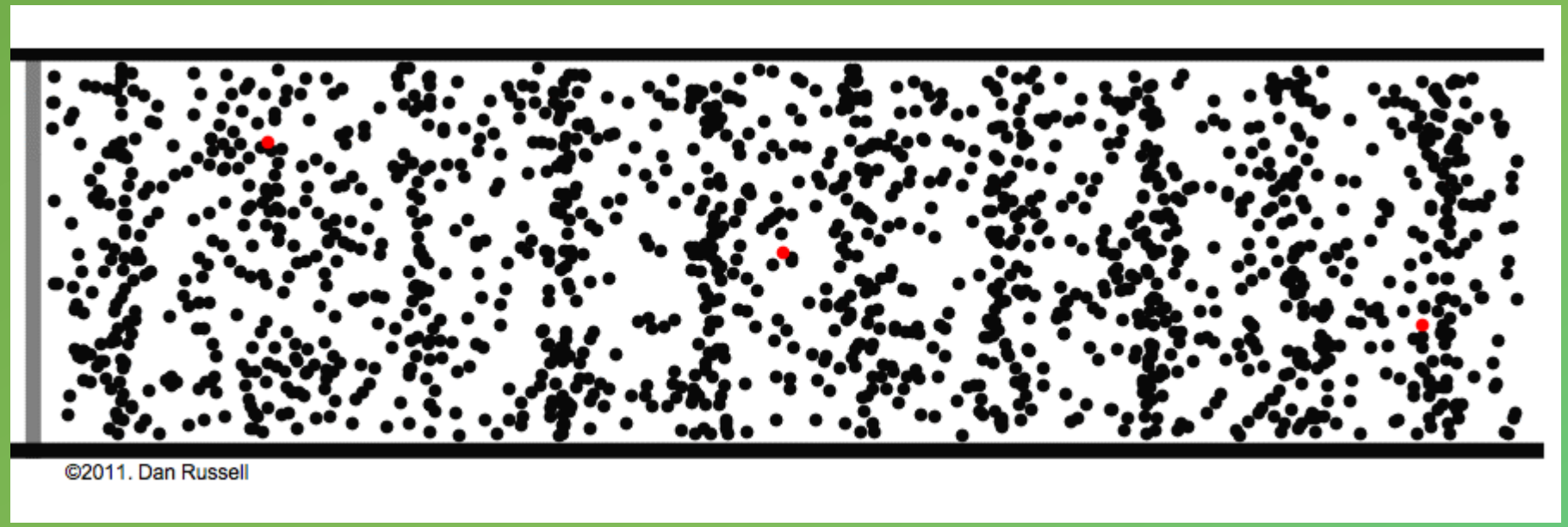
Introduction – What info do we get from sound?

Can combustion acoustics tell us anything?

In mechanical engineering, sound is a known byproduct of combustion that can lead to Thermo-acoustic instability

In forensics, gun shot acoustics are used to detect both timing and location of origin of the shooter(s) involved.

What is sound?



Introduction – Anecdote to Data

What is missing without sound?

Introduction – Anecdote to Data

What is missing without sound?

Can wildland fire acoustics tell us **more**?

We are naturally alert to Roaring and Crackling in fire

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Volume [Amplitude]

Timbre [Frequency signature]

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Volume [Amplitude]

Timbre [Frequency signature]

Number of Events [Impulse activity]

Can wildland fire acoustics tell us **more**?

We are naturally alert to Roaring and **Crackling** in fire

Fire observers intuitively respond to changes in

- Volume [Amplitude]
- Timbre [Frequency signature]
- Number of Events [Impulse activity]

Introduction – Acoustic Impulse Events


Image courtesy of The New York Times

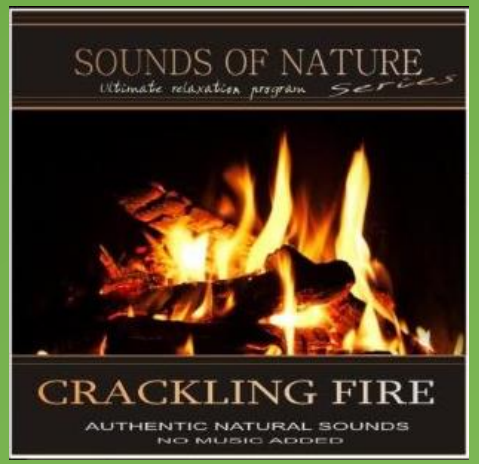



Image courtesy of Tenor


Image courtesy of Tenor

What is an Acoustic Impulse Event (AIE)?


Image courtesy of Giphy


Image courtesy of TheJobMouse.com

Introduction – Recent Efforts

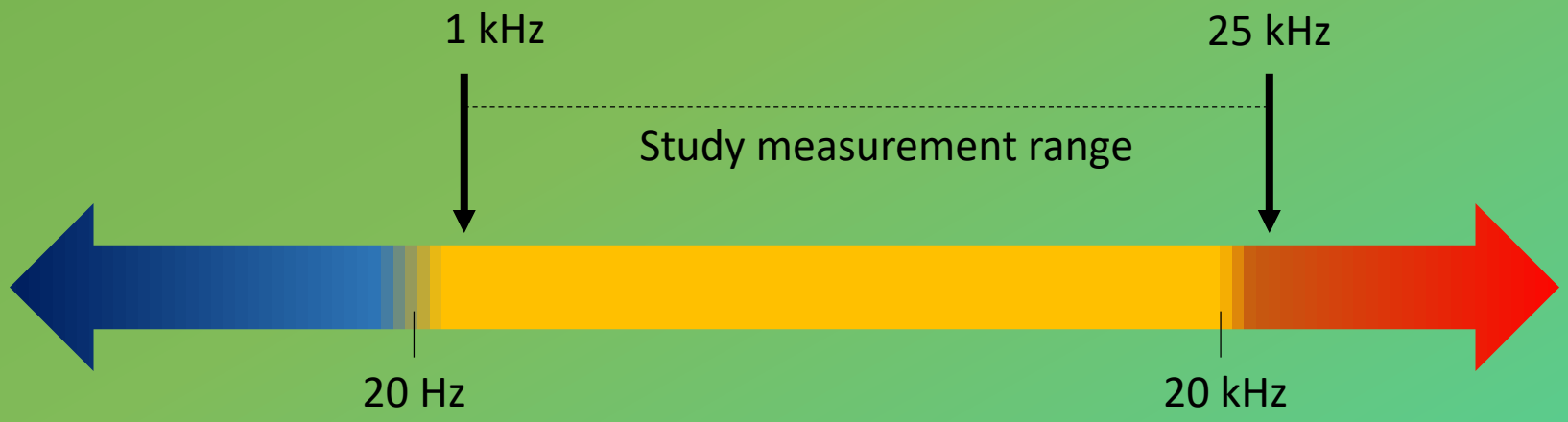
Our work has shown the crackling sound of burning vegetation contains a unique signature that indicates:

Species
Level of drought stress

Hypotheses:

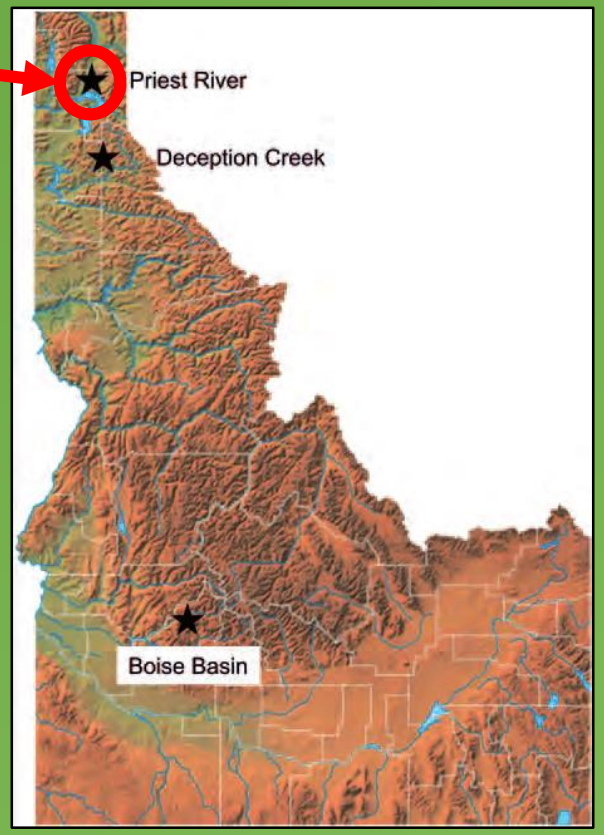
1. Acoustic Impulse Events (AIEs) that occur during burning of live vegetation **vary based on the plant species in mature plants.**

2. AIEs that occur during burning of live vegetation **vary based on age,** for a given species.



Methods

Methods – Field Study Design



- 6 different mature conifer species
- 3 trees sampled per species
- 2 branches collected per tree

Lodgpole pine
(Pinus contorta)

Ponderosa pine
(Pinus ponderosa)

Grand fir
(Abies grandis)

Western White pine
(Pinus monticola)

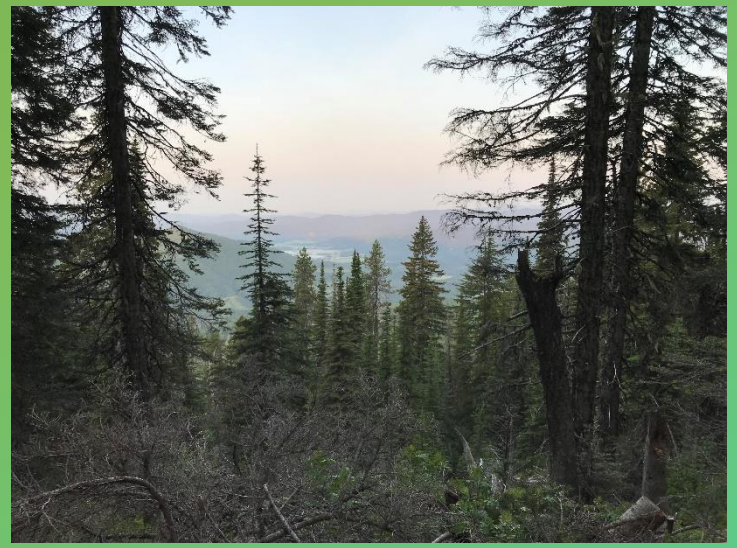
Engelmann spruce
(Picea engelmannii)

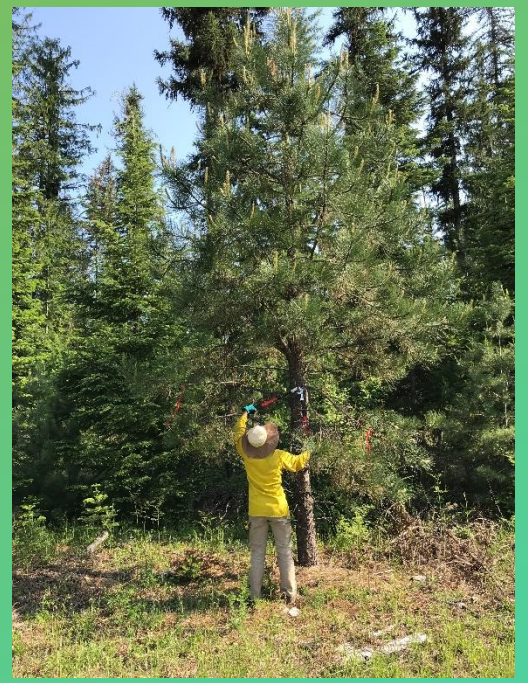
Douglas-fir
(Pseudotsuga)

Methods – Field study design

Fuels Prep:

- Predawn leaf water potentials were measured for each branch
- Branches were harvested the morning of the study
- Timing of branch burning randomized to reduce unaccounted for environmental effects
- Fuel moisture samples collected just prior to each burn
- Branch height above soil





Methods – Field study design

Burn Pit Setup:

- Rectangular pit measuring 110 cm X 65 cm X 15 cm
- Expanded steel grate suspended 5cm above floor of pit
- Charcoal briquettes used as quiet source of constant heat flux
- IR camera used to monitor charcoal

Methods – Field study design

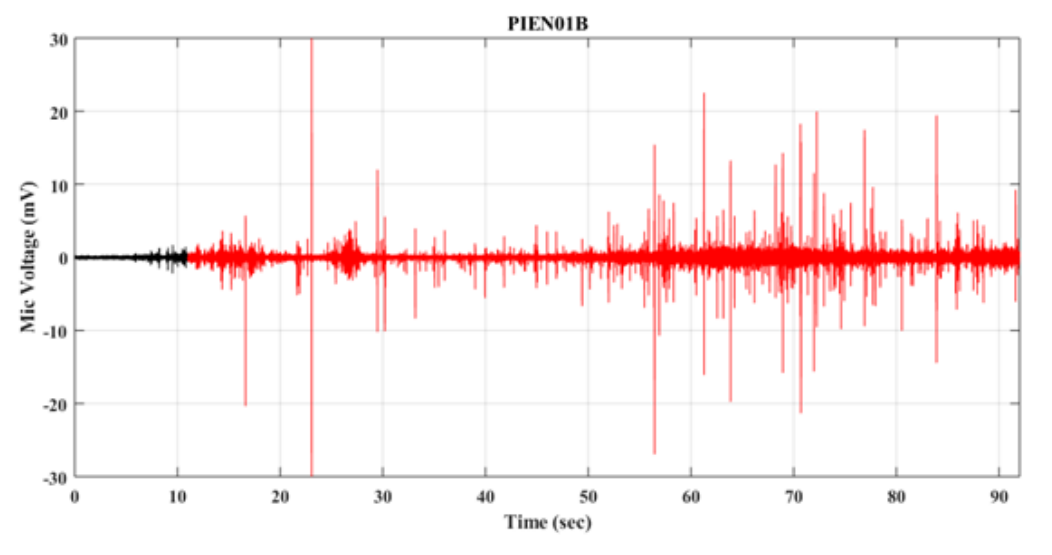
Microphone:

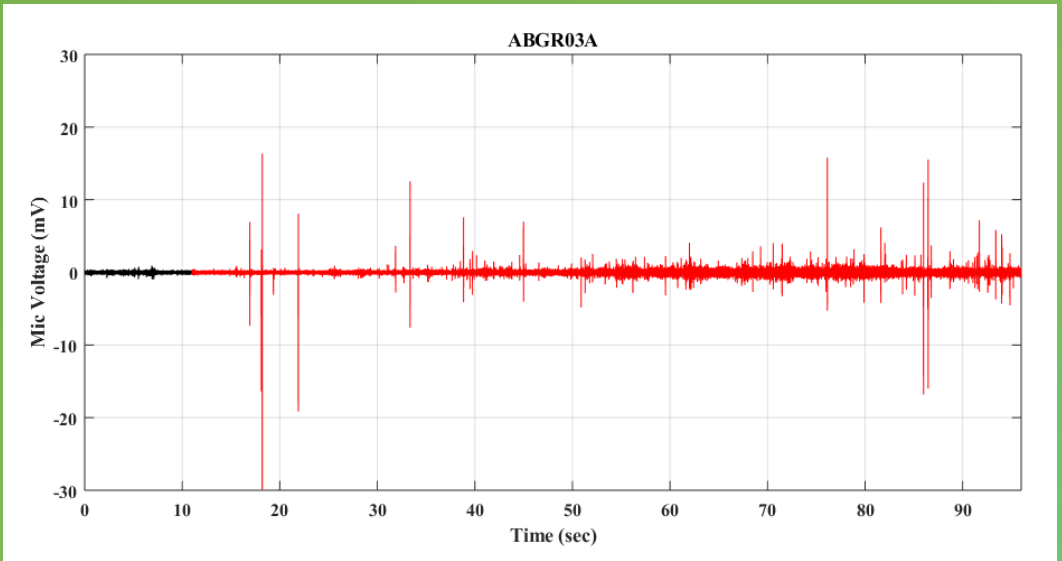
- ½” diameter pressure-response measurement microphone
- nominal sensitivity of 9 mV Pa^{-1}
- bandwidth 20 Hz - 25 kHz.
- 82 cm from center
- 42 cm from edge of pit
- ~35 cm above plane of fuel bed

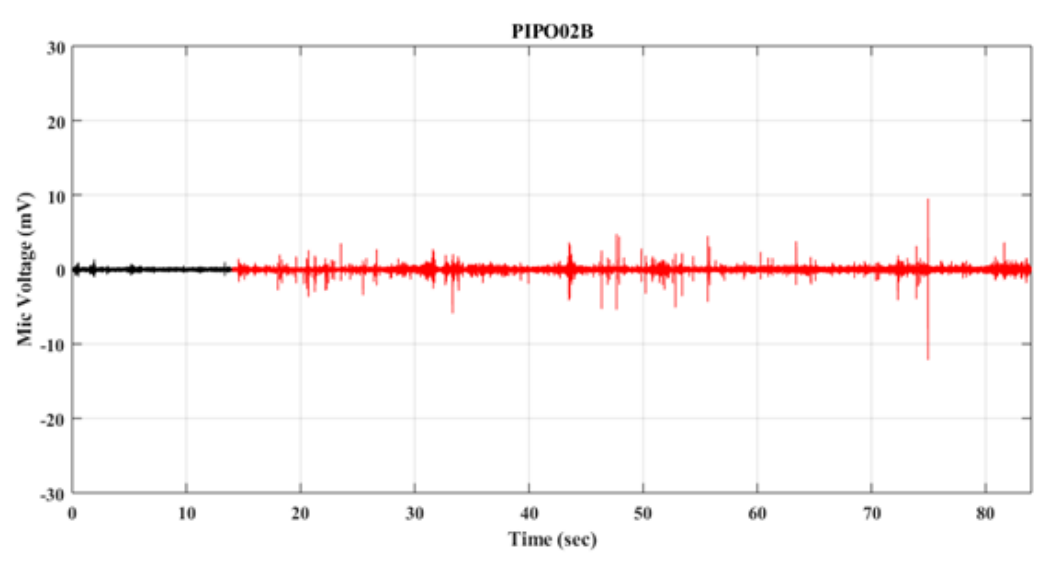
The microphone signal:

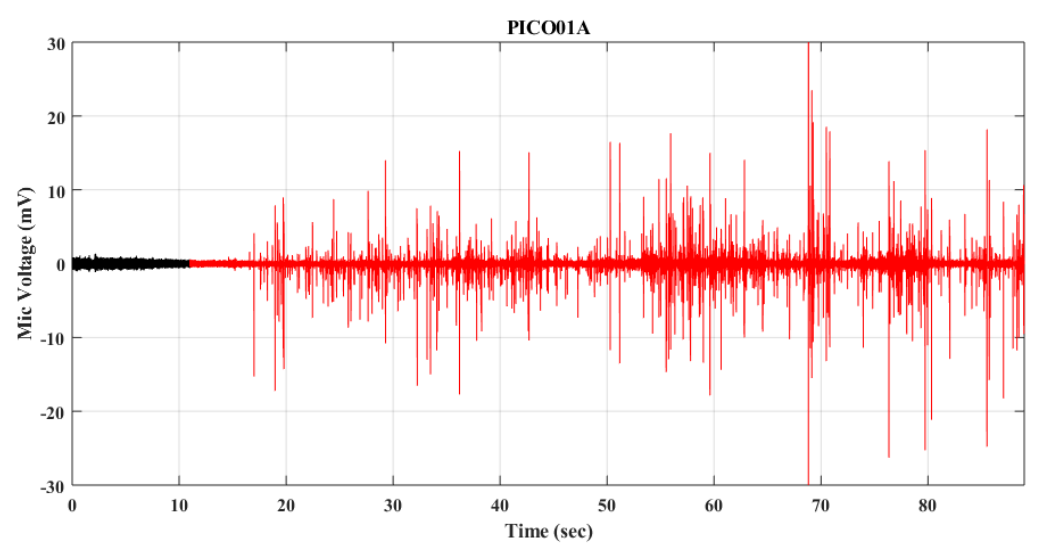
- alias-filtered
- amplified
- digitized at a rate of 50 kHz with 12 bit resolution

Methods – Time-series data



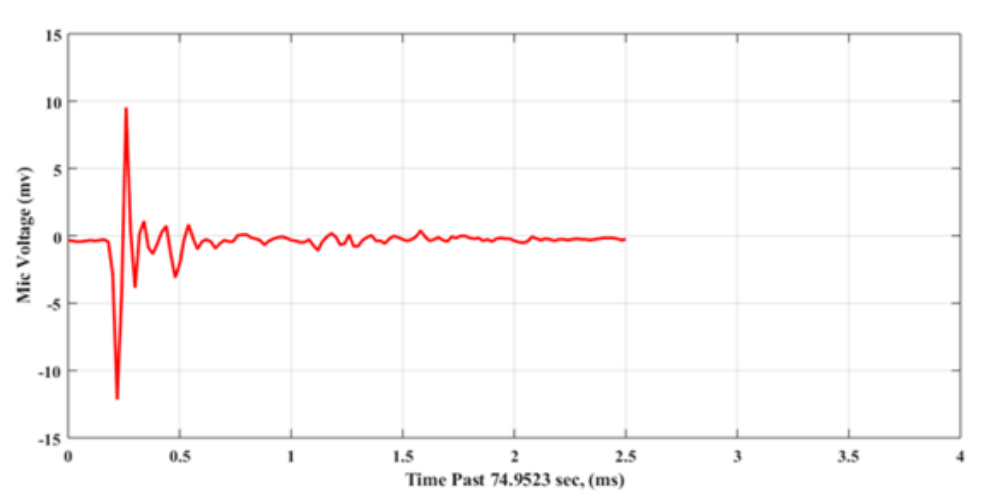


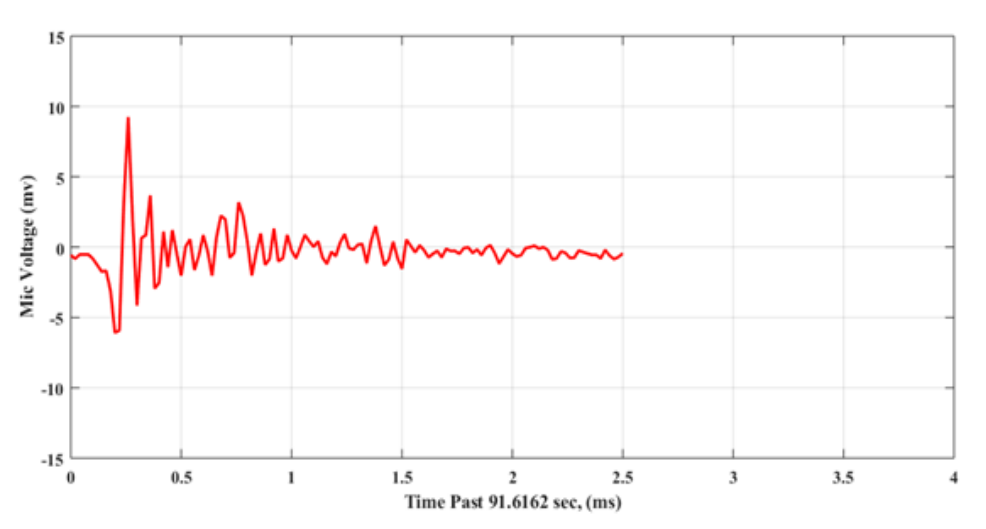




Methods – Data analysis

Individual ruptures were extracted

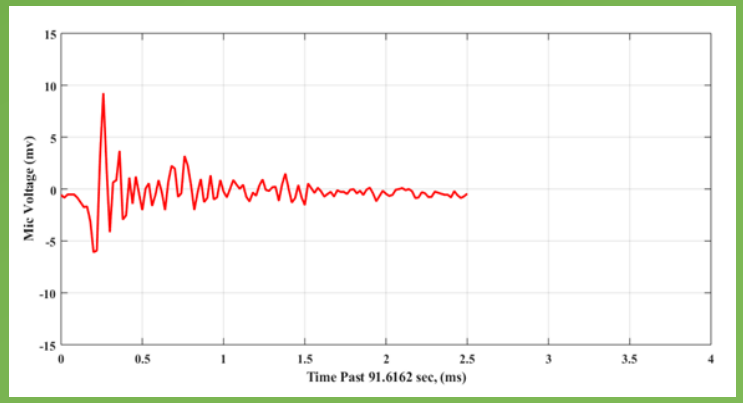


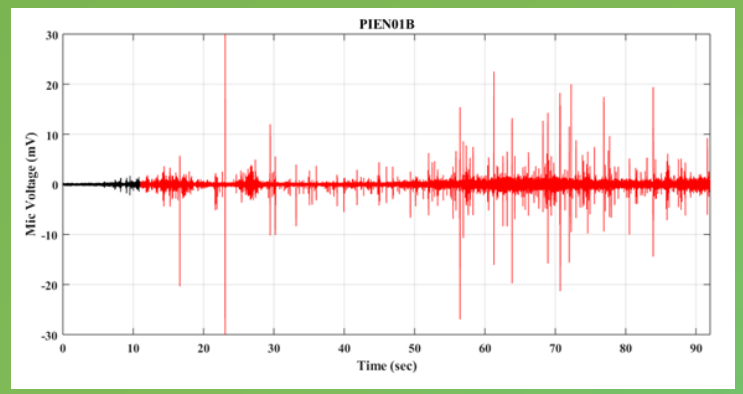


Total AIEs by species	
Douglas-fir	208
Engelmann spruce	228
Ponderosa Pine	118
Lodgepole Pine	448
Grand Fir	194

Methods – Data analysis

$$\text{AIE Normalized Spectrum} = \frac{1}{N}\sum_{i=1}^{N}\left[\frac{\text{Power @ ea. Frequency}}{\text{Total Power for duration of seedling combustion}}\right]$$



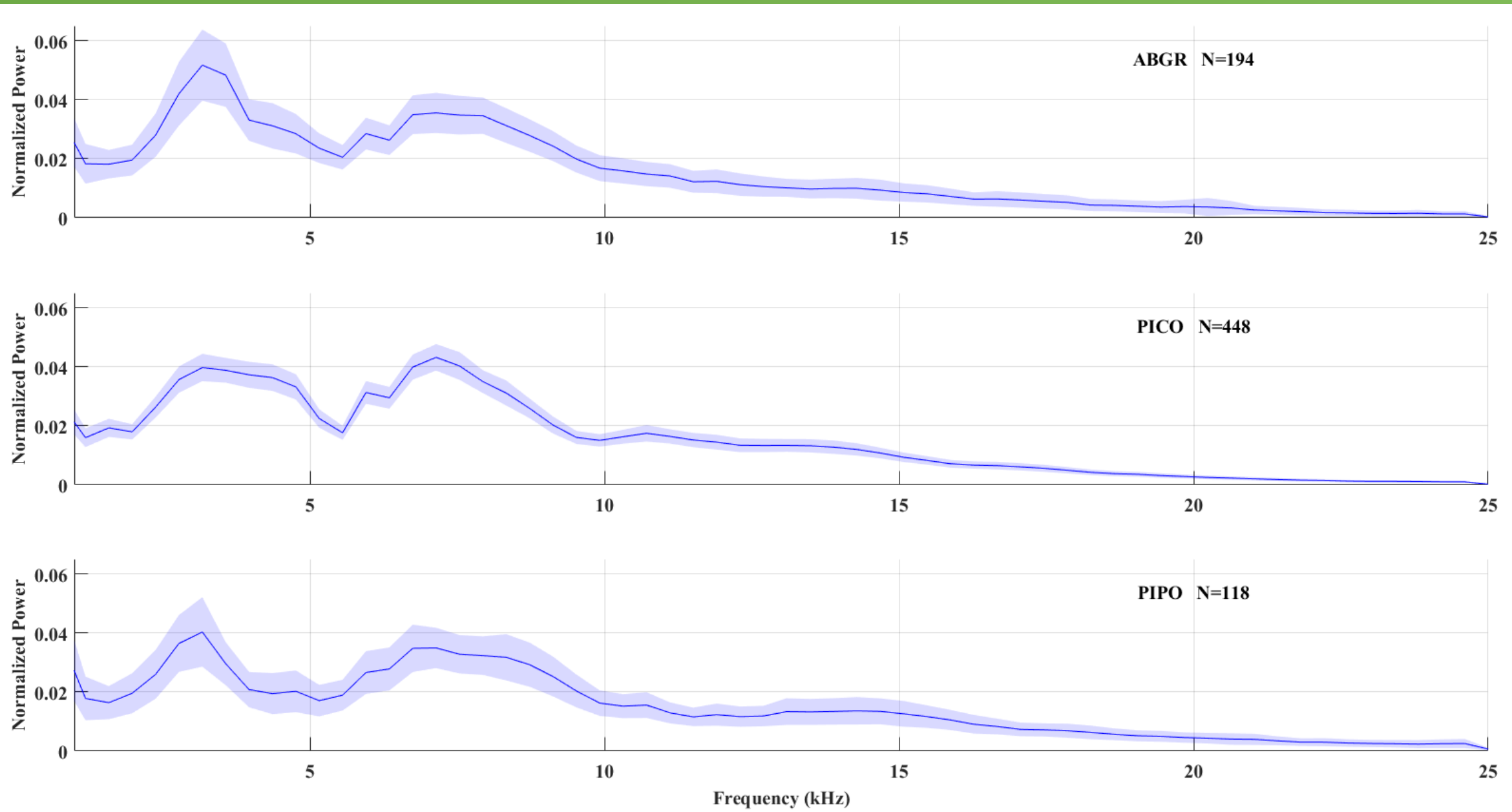


Calculated:

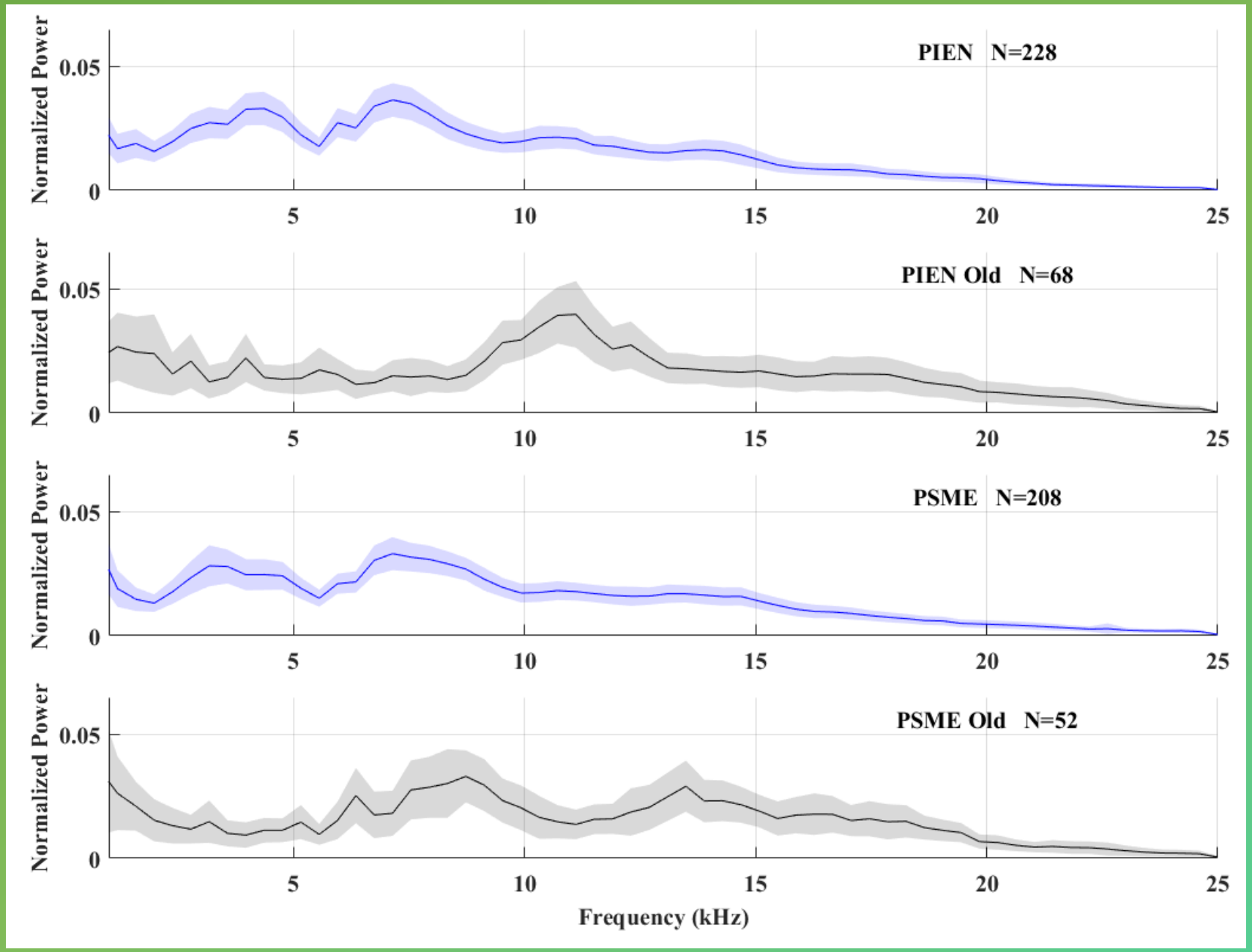
1. average normalized spectrum for each species and age group
2. Difference of means between species and age
3. Quantile confidence intervals (98%)

Results

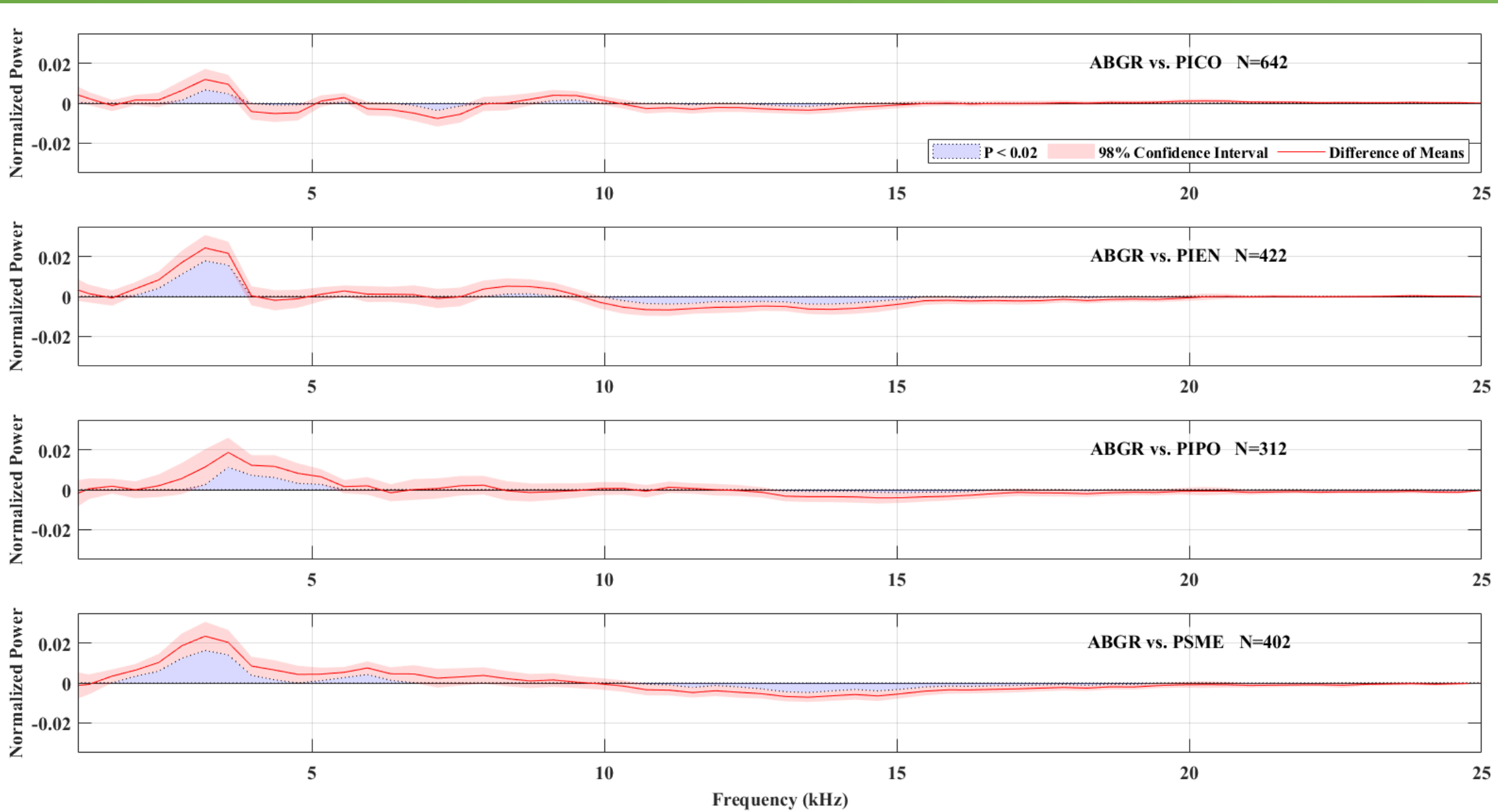
Results – Normalized AIE Spectrum: Species



Results – Normalized AIE Spectrum: Species and Age



Results – Difference in Means: Species



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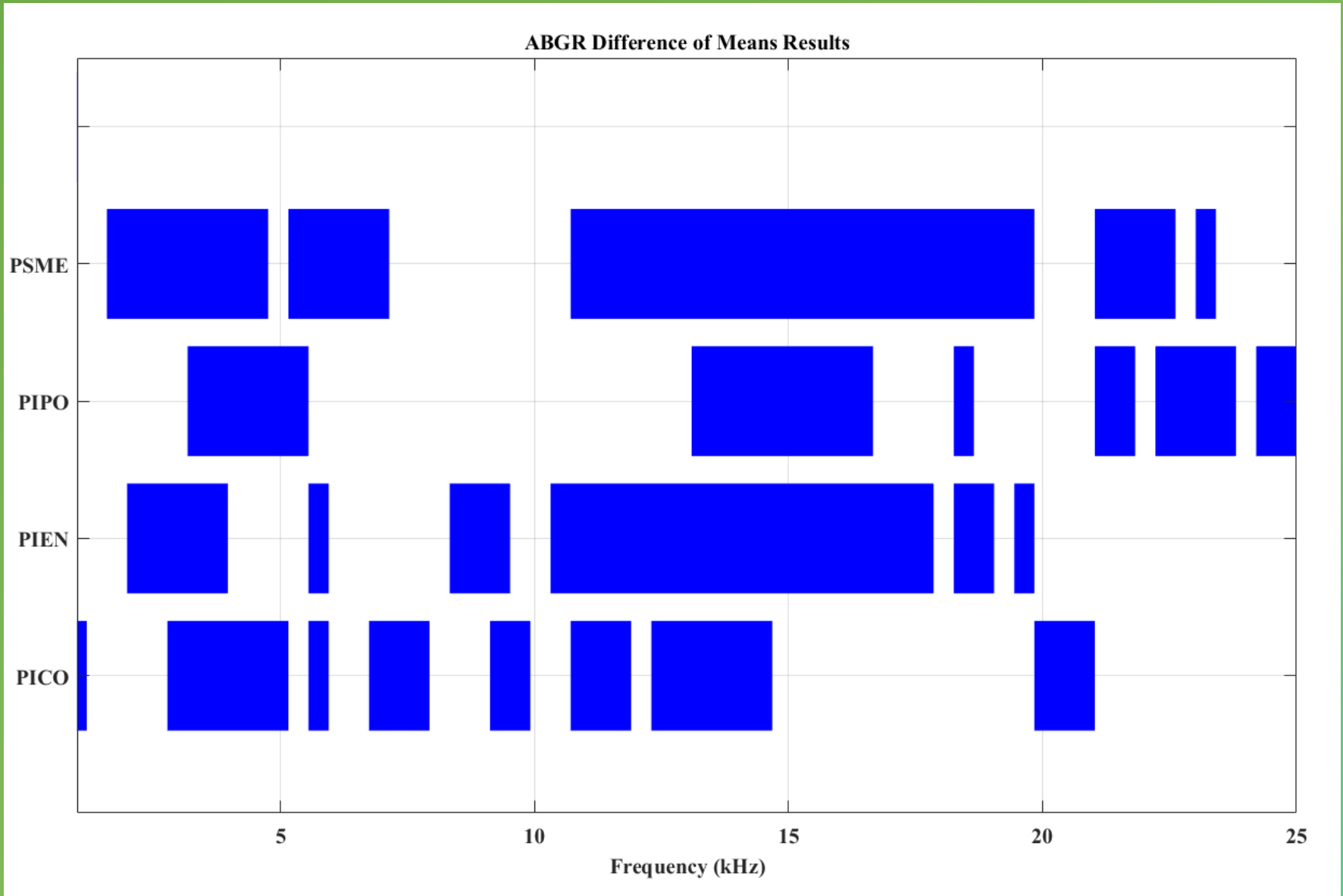
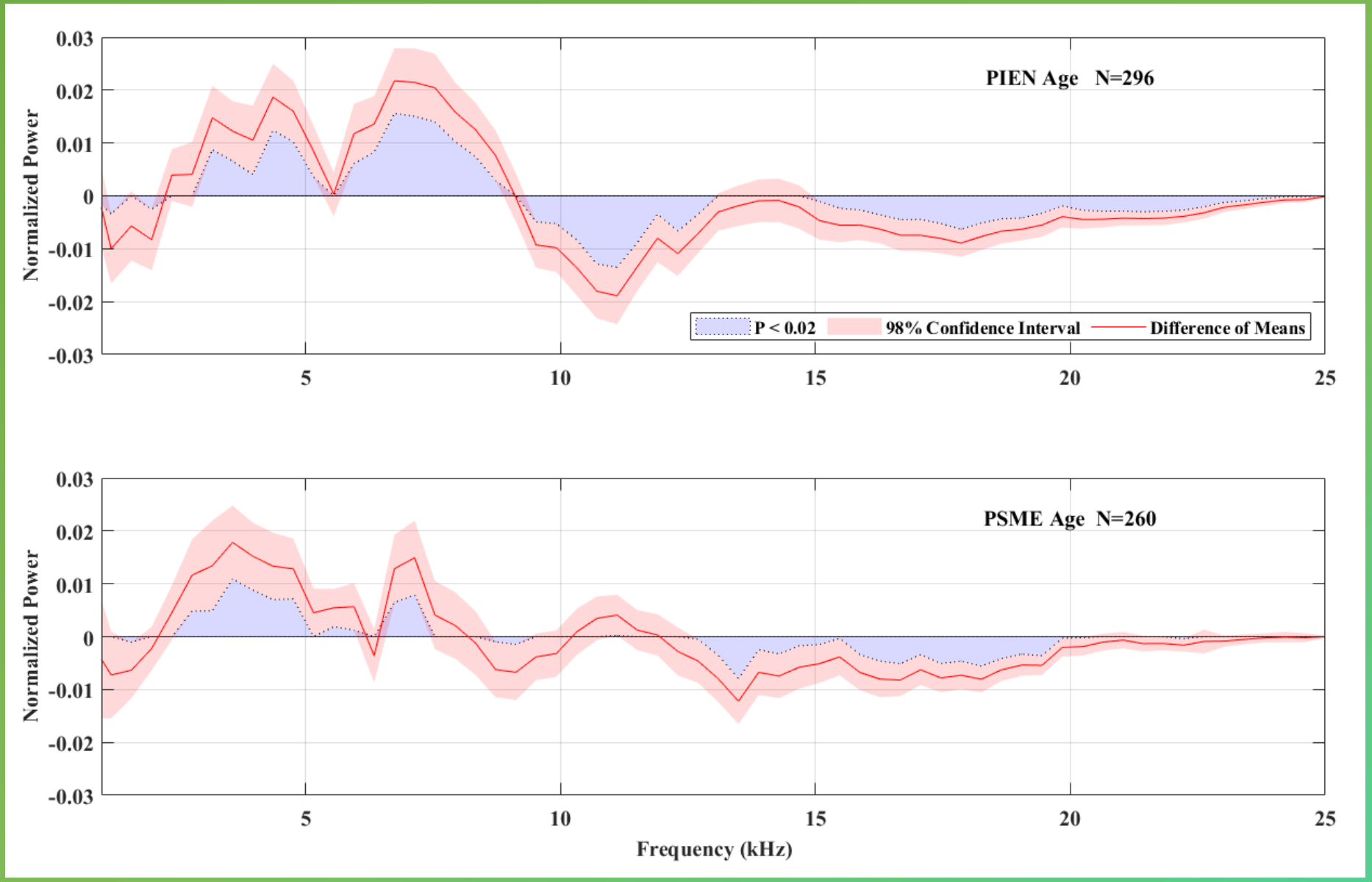


Results – Difference in Means: Age



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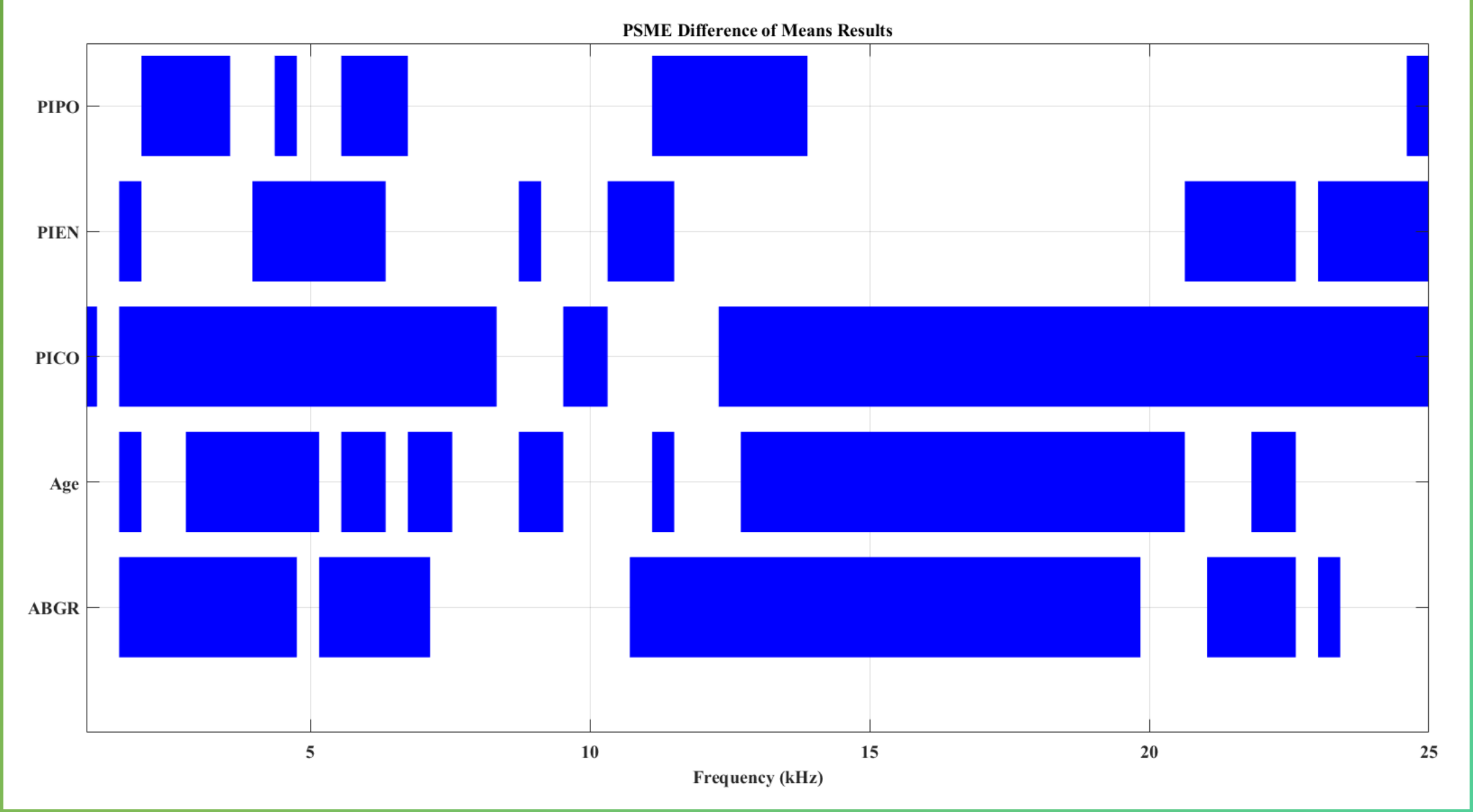

Conclusions

Conclusions – Hypotheses revisited

Hypotheses:

1. Acoustic Impulse Events (AIEs) that occur during burning of live vegetation **vary uniquely based on the plant species and age.**

    - To determine the structure of potentially significantly unique rupture signatures, non-parametric statistics will explored further
    - To determine the influence of heat flux, heat sources of varying intensity will be explored with a common fuel

Ongoing Work

Ongoing work – What are the ruptures?

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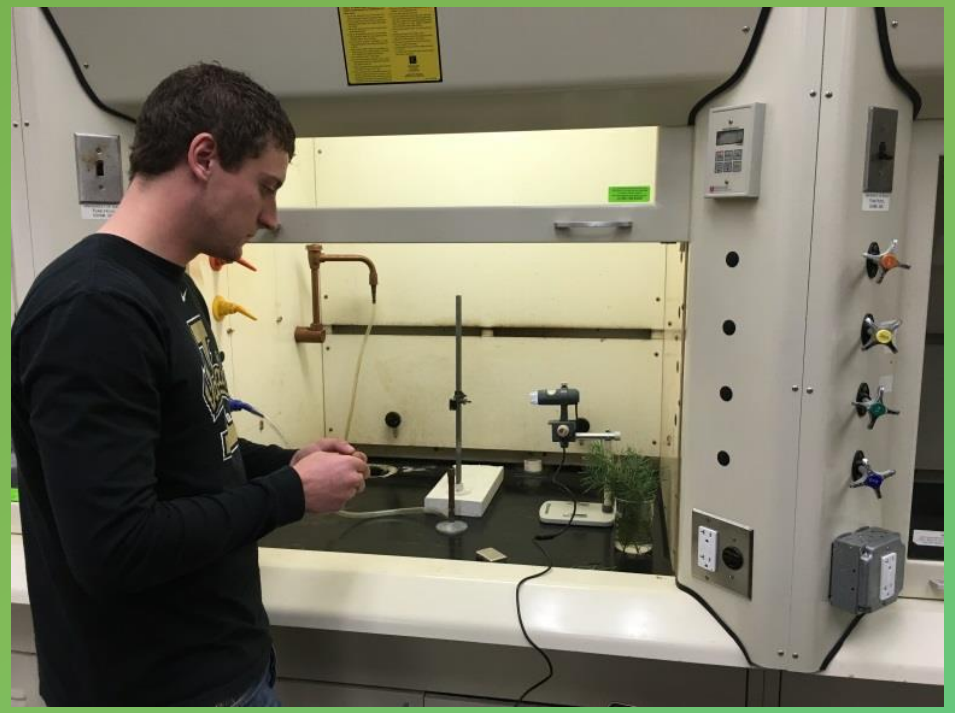
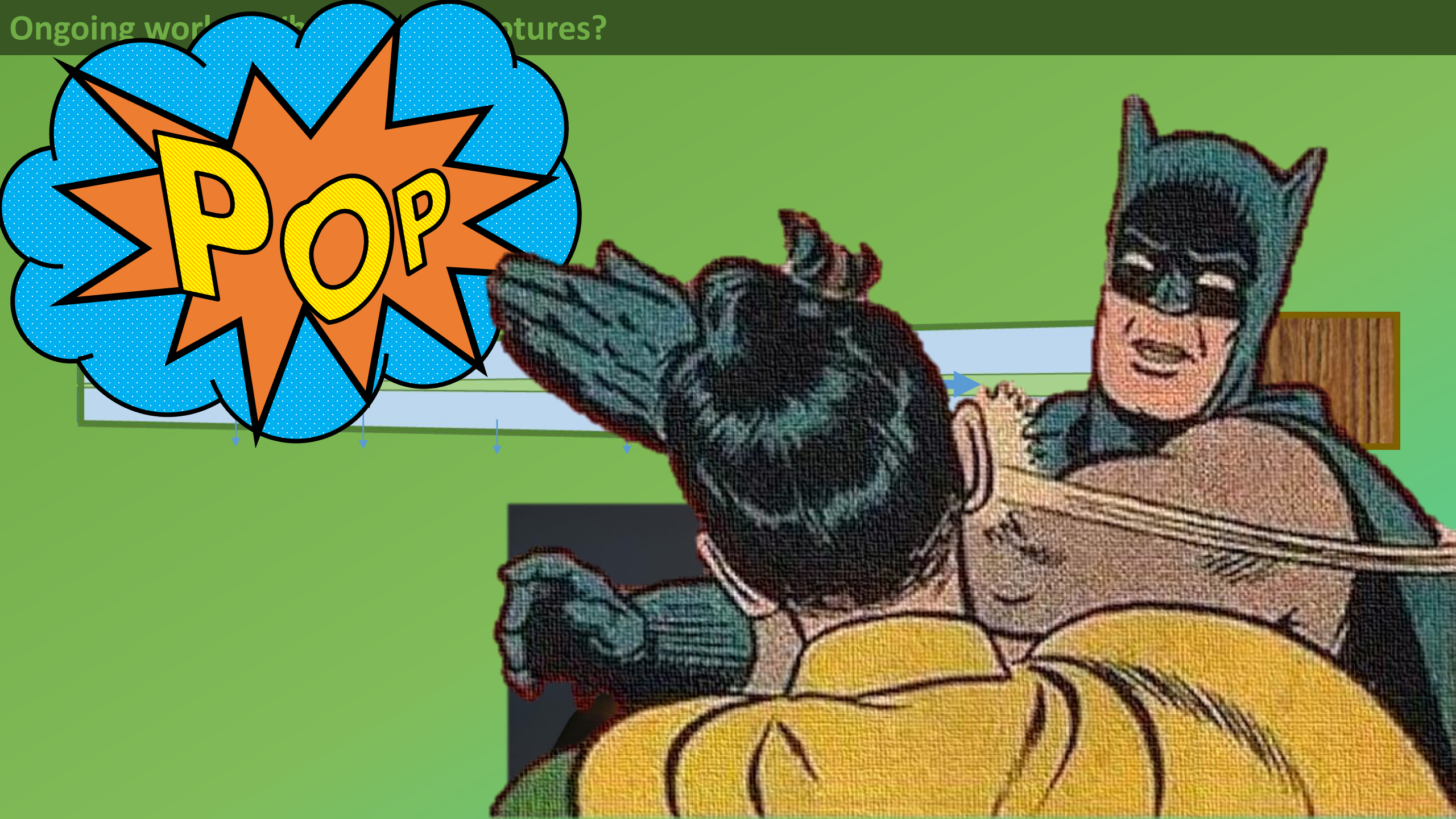


Ongoing work… …tures?



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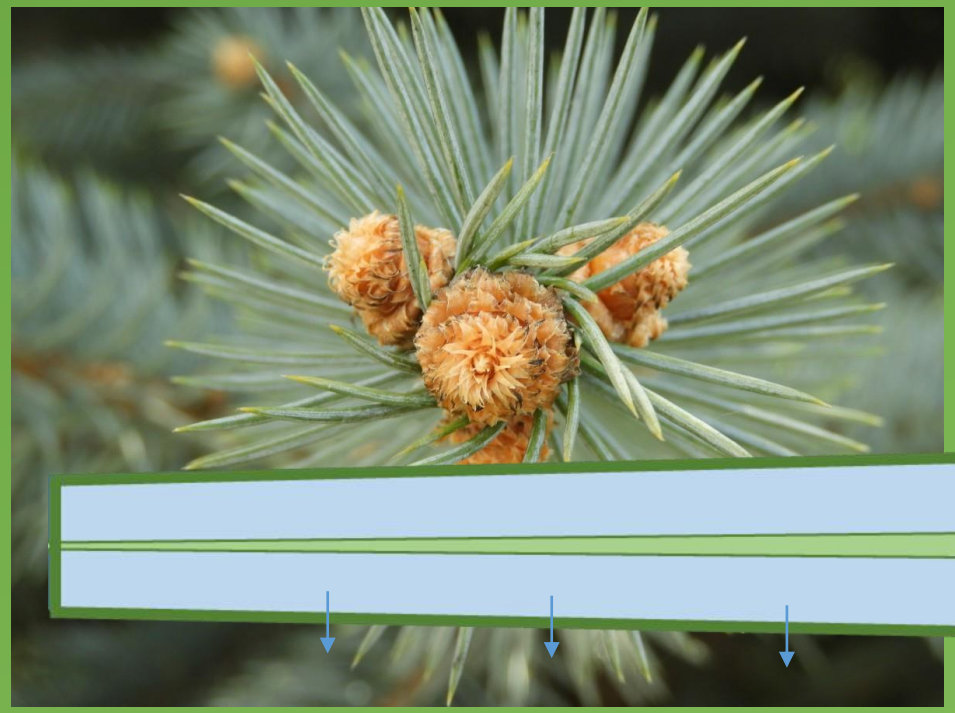

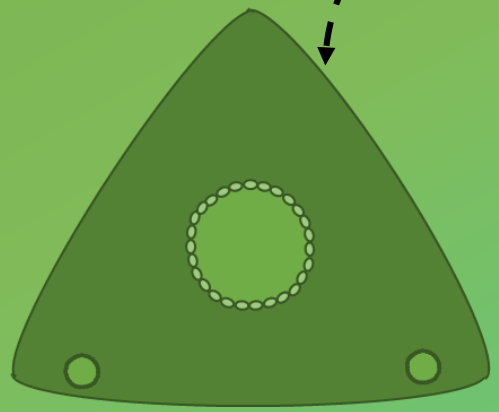

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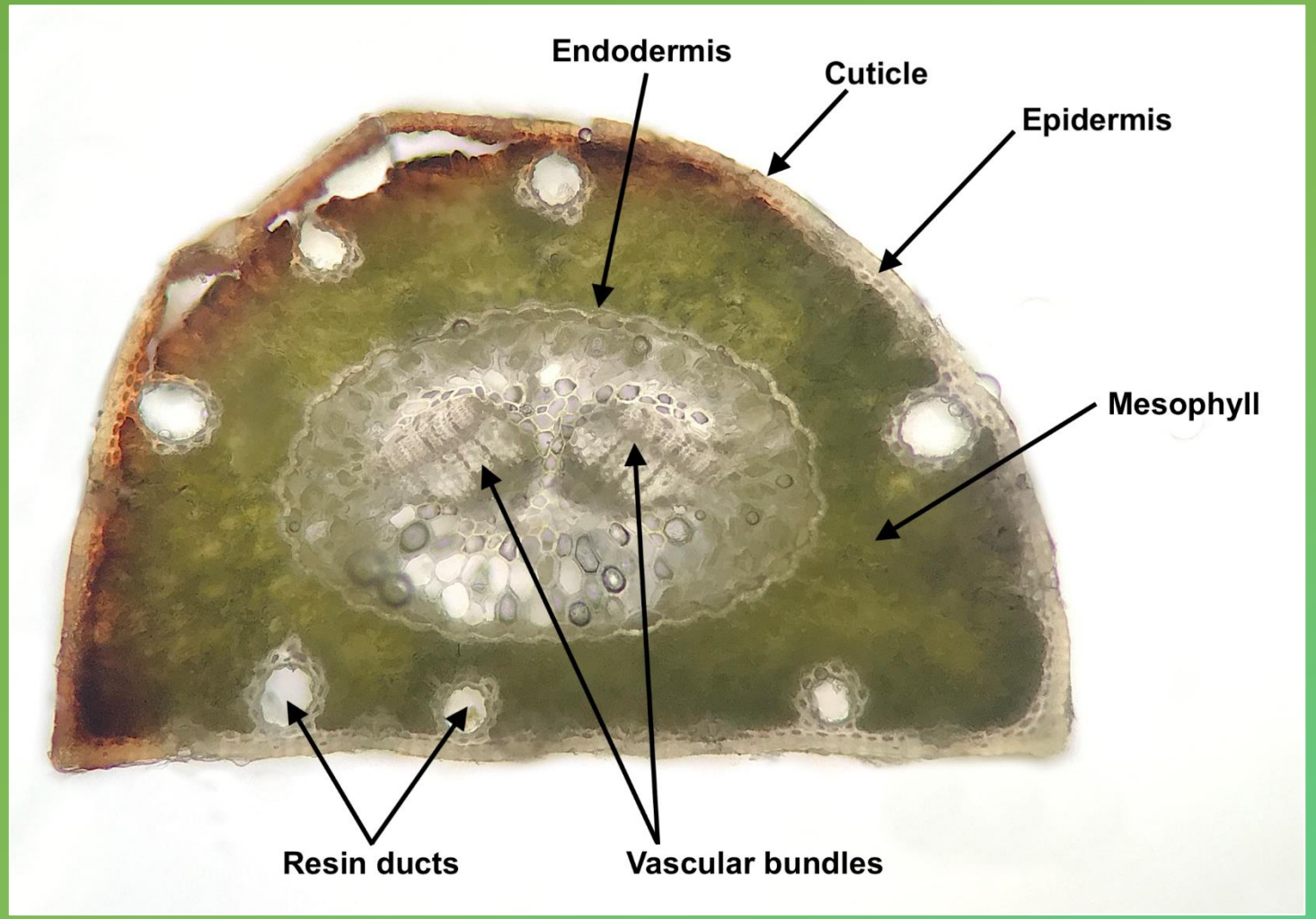


Ongoing work – What are the ruptures?

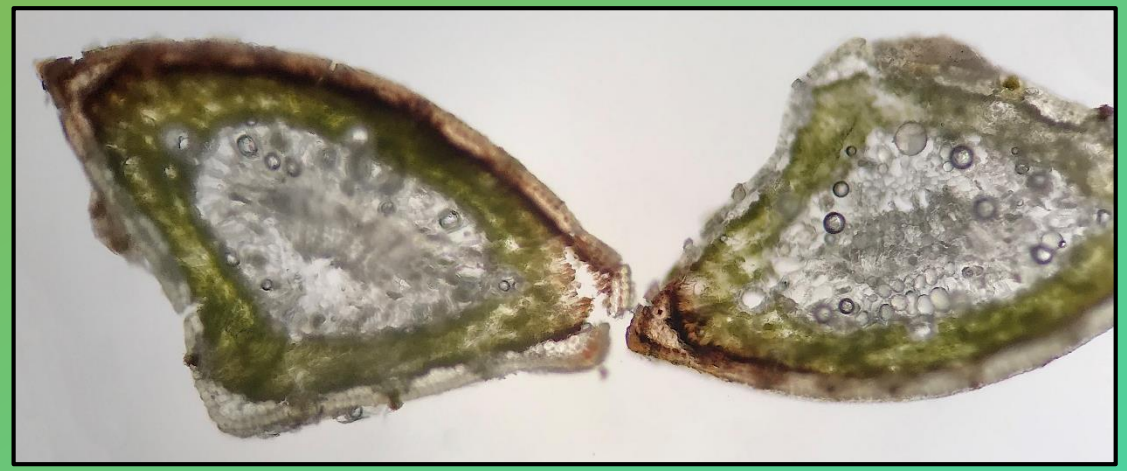
Grand fir

Douglas-fir

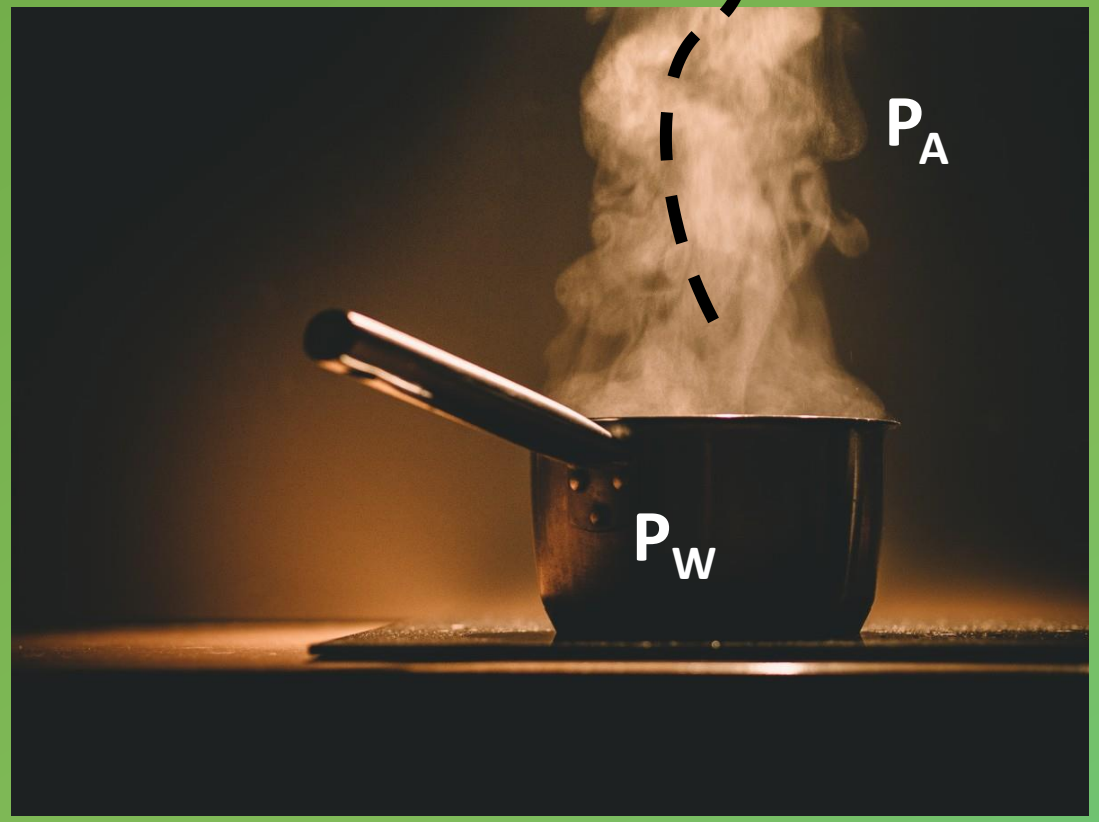
Ongoing work – What are the ruptures?

Red Pine

Long Leaf Pine



$P_W = P_A$



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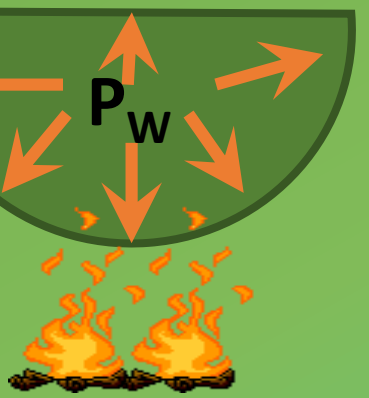
$P_W > P_A$



Ongoing work – Wait…there's more!

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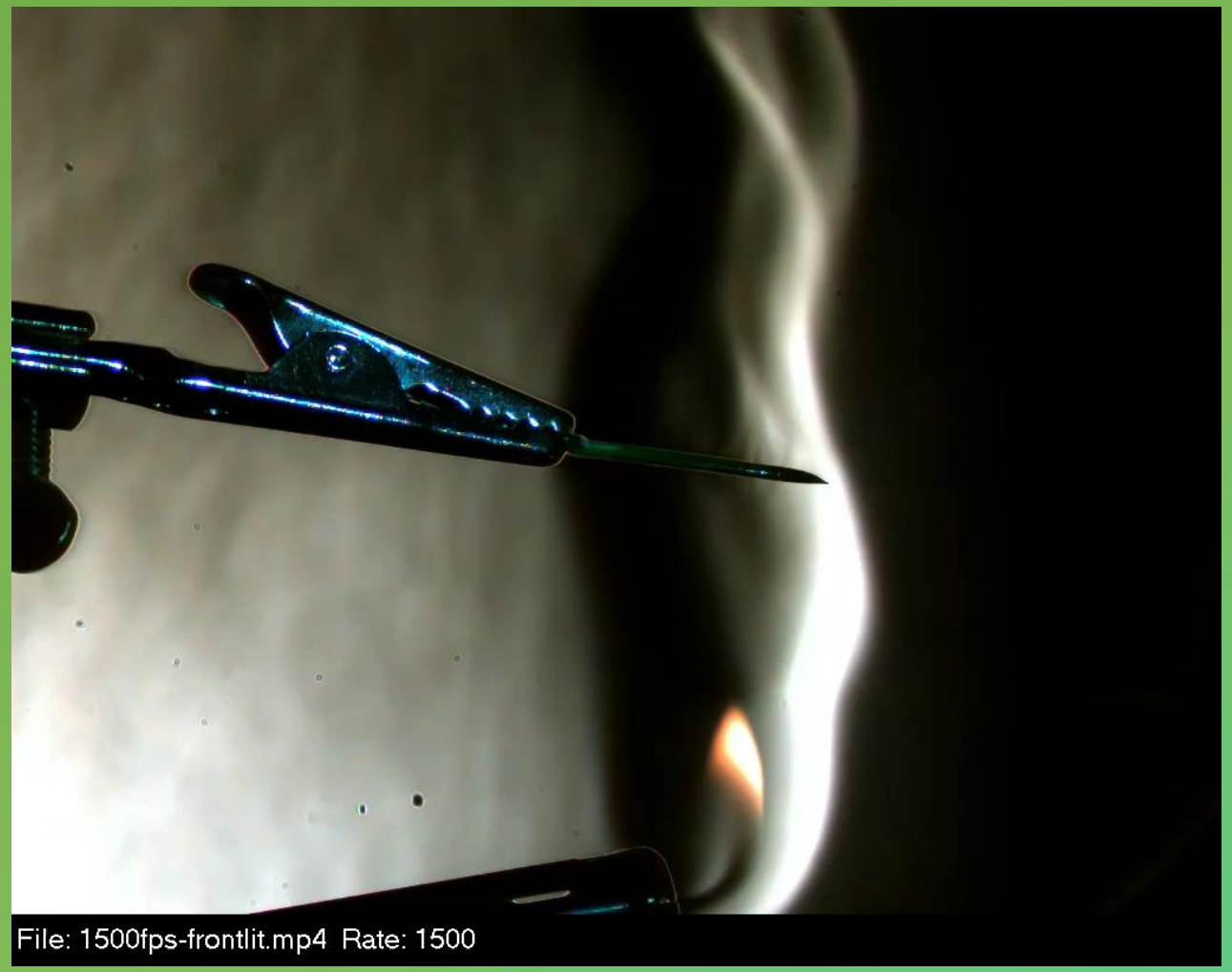

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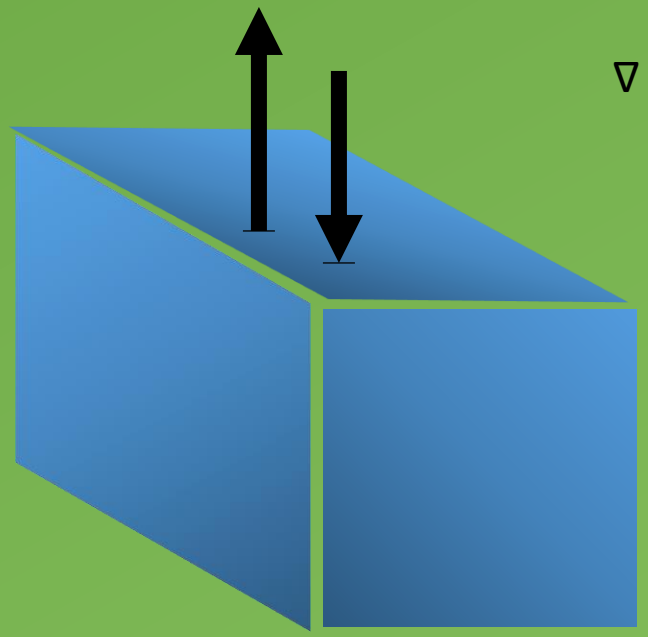
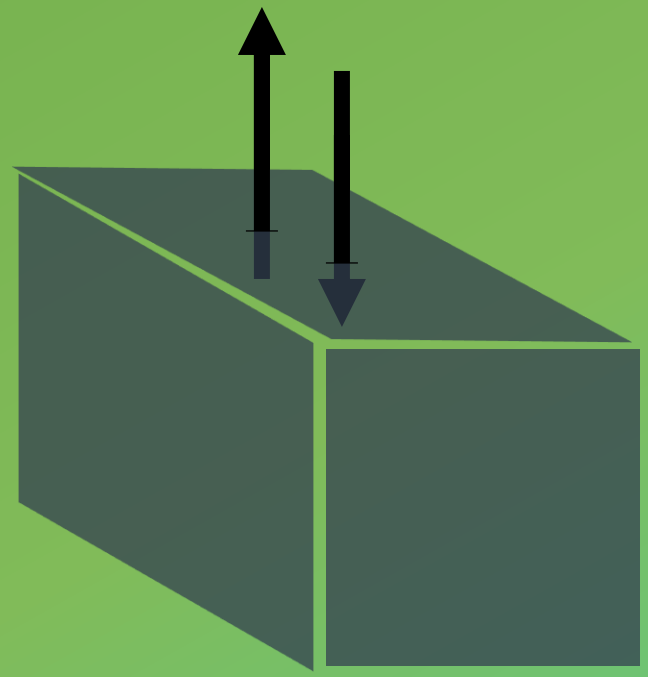
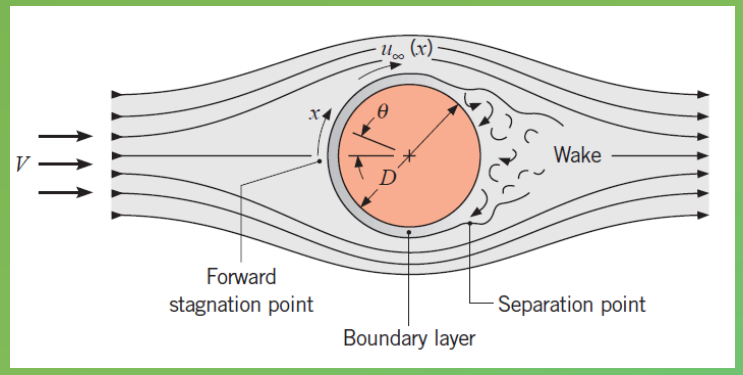


$\nabla (Q , L_V, V_w)$





W. Carpenter, (2016) External Flow: drag and Lift, http://slideplayer.com/slide/10651981/

Ongoing work – What we know

Water likely dominant material jetting from conifer needles tested

Jet is influencing the local boundary layer of the rupturing needle

Microscopy images indicate origin of the jet likely mesophyll

Ongoing work – Next Steps

Ongoing work

- Collect and analyze the rupture material content
- Evaluate spatial extent of rupture phenomena
- Quantify jet flow characteristics

Ongoing work – Next Steps

Acknowledgments

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