A Tree's Response to Herbivory: Quantification of Biogenic Volatile Organic Compound Emissions

Giuliana Viglione, Celia Faiola, Tim VanReken

Laboratory for Atmospheric Research, Washington State University

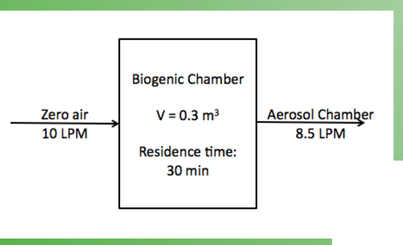
Abstract

Biogenic Volatile Organic Compounds (BVOCs) are a class of chemicals produced on a large scale by trees and other plants. BVOCs play a significant role in plant growth, defense, and communication; they are also emitted to the atmosphere, where, due to their high reactivity, they become an abundant source of Secondary Organic Aerosols (SOA). These emissions are known to vary in quantity and composition due to both biogenic and anthropogenic stressors. In this study, BVOC emissions from bristlecone pine saplings were quantified before and after an exogenous methyl jasmonate exposure stress treatment. Samples were collected from the biogenic chamber, where the trees were housed. The gaseous compounds were analyzed using a gas chromatograph coupled with a mass spectrometer and flame ionization detector (GC-MS-FID). The data collected were used to calculate the mixing ratios of different BVOCs in the chamber. By identifying the change in the composition and quantity of BVOCs emitted, a better picture can be formed of how potential future increases in herbivory (due to milder winters, etc.) will affect BVOCs. This in turn can provide more accurate predictions for modeling future climate change.

Objectives

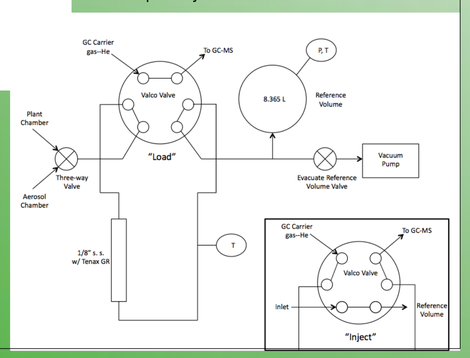
- Optimize, test, and characterize VOC sampling system
- Identify the major components of the emissions of bristlecone pine trees
- Determine the effect of exogenous methyl jasmonate exposure on the overall quantity of emissions of terpenes from bristlecone pine trees
- Analyze the changes in composition of terpene emissions from bristlecone pine trees before and after methyl jasmonate stress treatment

Experimental Setup



Above: A box model of the biogenic chamber. The chamber was kept at a positive pressure to avoid contamination of the air being sampled by air from the surroundings.

Below: A schematic detailing the configuration of the inlet system in both the sample "load" and sample "inject" modes.



Methods

1. Move saplings into biogenic chamber, allow to acclimate for at least 24 hours.
2. Valve in "load" position: draw air from biogenic chamber through sampling loop. BVOCs adsorb to the Tenax and air passes through to the reference volume.
3. Switch valve to "inject" position. Heat the trap to 230 °C for 90 seconds. Helium gas is pumped through the trap to purge it of VOCs, which are carried to the the GC-MS-FID.
4. The GC separated out the compounds, the MS was used to identify the compounds present in each sample, and the FID was used to quantify each compound.
5. Herbivory stress is simulated using exogenous methyl jasmonate exposure. Sampling proceeds in the same way.

Calculations

$$mol_{air} = \frac{P_{ref} * V_{ref}}{R * T_{ref}}$$

$$nmol_{terpene} = \frac{A_{terpene}}{Sens_{FID}} * \frac{1}{ECN}$$

$$Sens_{FID} = \frac{A_{C8}}{8 * MR_{C8}} * \frac{R * T_{ref}}{P_{ref} * V_{ref}}$$

$$MR_{C8} = 10^9 * \frac{IR_{C8} * \rho_{C8}}{10^3 * MW_{C8}} * \frac{1}{60} * \frac{R * T}{P * MF}$$

$$MR_{terpene} = \frac{nmol_{terpene}}{mol_{air}}$$

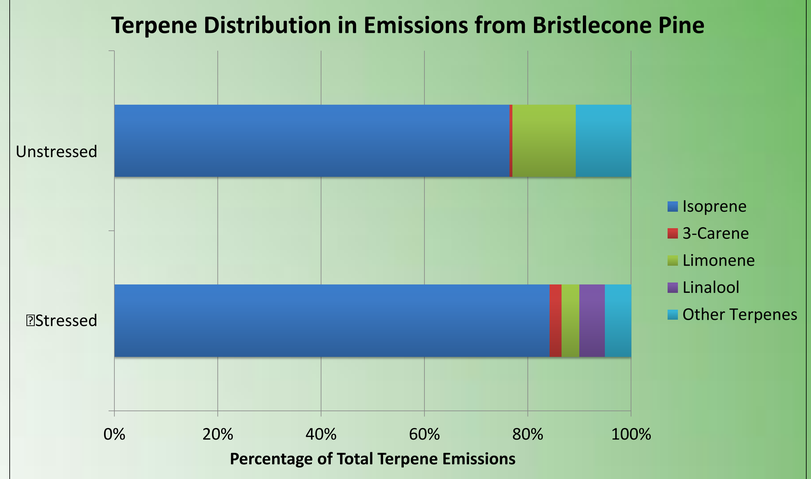
P_{ref} = Reference Volume Pressure
V_{ref} = Reference Volume
R = Gas constant
T_{ref} = Reference Volume Temperature
A = Area of FID peak
$Sens_{FID}$ = FID Sensitivity
ECN = Effective Carbon Number
MR = Mixing Ratio
IR = Infusion Rate
ρ = Density
MW = Molecular Weight
MF = Molar flow

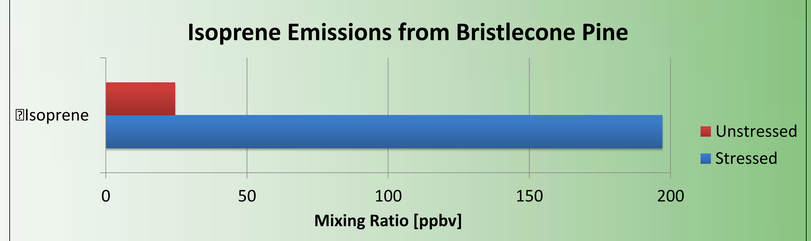
- Moles of air were calculated using the ideal gas law and temperature and pressure readings from the reference volume.
- FID Sensitivity is calculated using an external standard by comparing the amount of n-octane "seen" by the FID to the amount of n-octane injected. This is used to correct for the emissions that are not detected by the FID.
- Since the strength of the FID signal is determined by the number of carbons in and the complexity of each compound, an effective carbon number is used to calculate the moles of the compound from the integrated area.

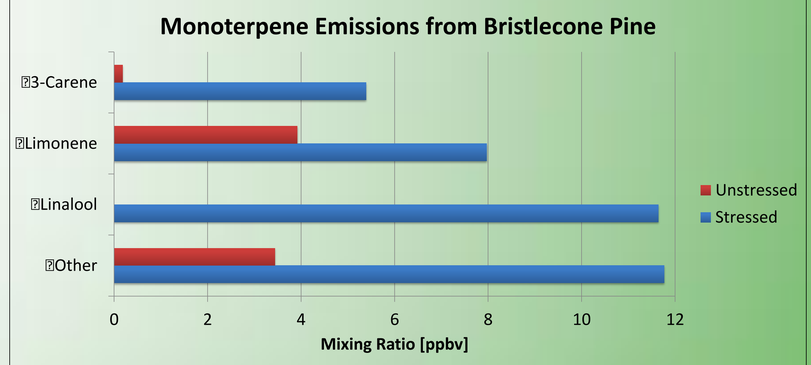
Terpenes Identified

Baseline		*Stressed*	
3-carene	fenchone	3-carene	camphene
α-phellandrene	isoprene	α-phellandrene	eucalyptol
α-pinene	limonene	α-pinene	isoprene
β-pinene	o-cymene	α-terpinene	limonene
β-trans-ocimene	p-cymene	α-thujene	linalool
camphene	styrene	β-myrcene	o-cymene
camphor	terpinolene	β-phellandrene	p-cymene
eucalyptol		β-pinene	styrene
		β-trans-ocimene	terpinolene

Results







Conclusions

- Under standard conditions, isoprene and limonene are the two major components of emissions from bristlecone pine.
- After the methyl jasmonate stress treatment, the major components of the pine emissions were isoprene, 3-carene, limonene, and linalool.
- Exogenous methyl jasmonate exposure increased total terpene emissions from bristlecone pine by a factor of 7. In addition, each run of the baseline experiment showed 15 terpenes, while the stressed experiments showed 18.
- Future work to be done includes varying the species of tree tested and changing the type of stress applied – for example, exposure to increased ozone, increased temperature, and physical harm.

Acknowledgements

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