Biogenic volatile organic compound emissions from bamboo: Exploring patterns of diversity across species

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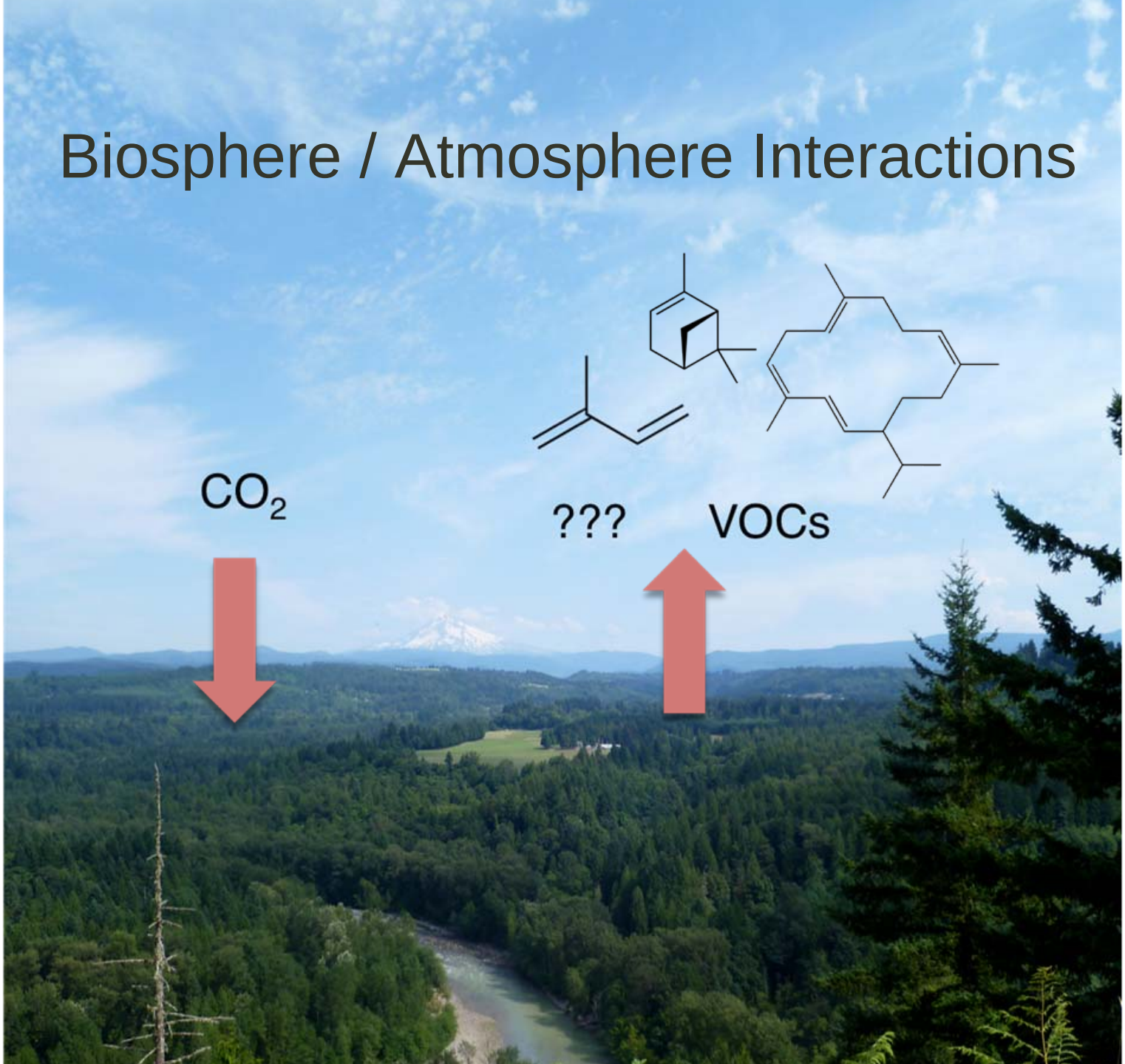
Biosphere / Atmosphere Interactions



Volatile: gaseous, reactive

Organic: carbon based

Compounds: molecules, chemicals

- VOCs have a big impact on the atmosphere
- 95%: Biogenic “B” VOCs
- 5%: Anthropogenic VOCs
- BVOCs are 2% of photosynthetic carbon

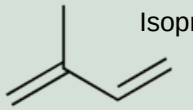
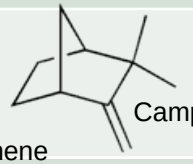
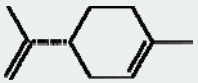
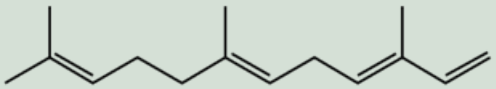
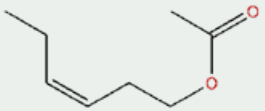
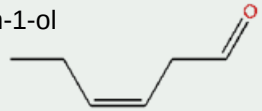
BVOCs impact Atmospheric Chemistry:

- Increase tropospheric ozone levels
  - Human health consequences
  - NO_x dependent
    - Higher in urban areas
    - Higher around combustion sources
- Form Secondary Organic Aerosols (SOA)
  - Create particles in air
  - Decrease visibility
- Influence air quality
- Indirectly effect global change

BVOCs have multiple Biological roles

- Function as plant-plant communication
- Defense compounds
- Recruitment for insect predators
- Protect against oxidative damage
- Metabolic overflow
- Increase under abiotic or biotic stress

BVOCs have diverse forms and functions

Compound	Structure	Function
Isoprene C_5H_8	 Isoprene	Heat, Drought stress
Monoterpenes $C_{10}H_{16}$	 (1R)-(+)-alpha-pinene  Camphene  Limonene	Signaling, Plant-insect interactions
Sesquiterpenes $C_{15}H_{24}$	 Alpha-farnesene	Signaling, Abiotic and biotic stress
Green Leaf Volatiles (Alkenes, Aldehydes, Alcohols, Acetate)	 (Z)-3-hexen-1-ol  (Z)-3-hexenyl-acetate  (Z)-3-hexenal	Released from wounded tissue, Signaling

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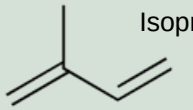
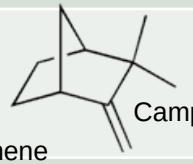
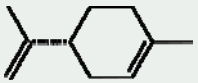
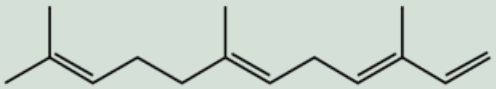
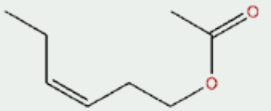
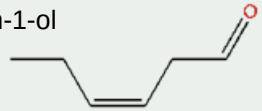
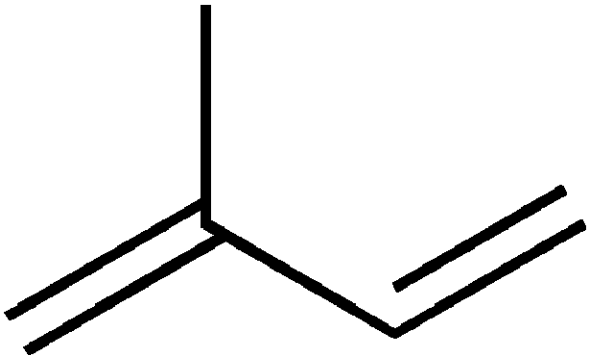
Isoprene C_5H_8	 Isoprene	Heat, Drought stress
Monoterpenes $C_{10}H_{16}$	 (1R)-(+)-alpha-pinene  Camphene  Limonene	Signaling, Plant-insect interactions
Sesquiterpenes $C_{15}H_{24}$	 Alpha-farnesene	Signaling, Abiotic and biotic stress
Green Leaf Volatiles (Alkenes, Aldehydes, Alcohols, Acetate)	 (Z)-3-hexen-1-ol  (Z)-3-hexenyl-acetate  (Z)-3-hexenal	Released from wounded tissue, Signaling

Isoprene is everywhere

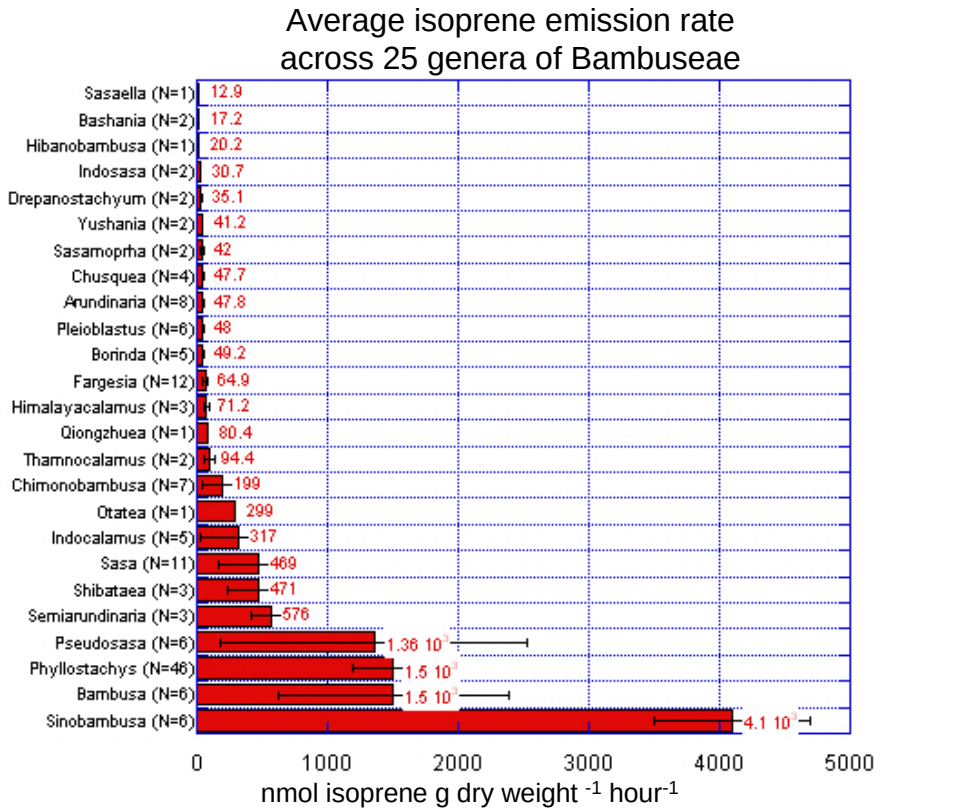


- Most abundant BVOC emitted
- Broad taxonomic distribution
  - Mosses, Kudzu, Eucalyptus, Poplar
- Increases during stress events
  - Aids in membrane stability
  - Acts as an antioxidant
- Plant taxa typically **do** or **do not** make isoprene
  - Bamboos are an exception

Bamboo: A novel system for BVOC studies

- Variable isoprene emission
- Diverse forms, many genera
- Few physiological studies
- Fewer BVOC studies

Isoprene emission in Bamboo: Extreme variation across genera and species



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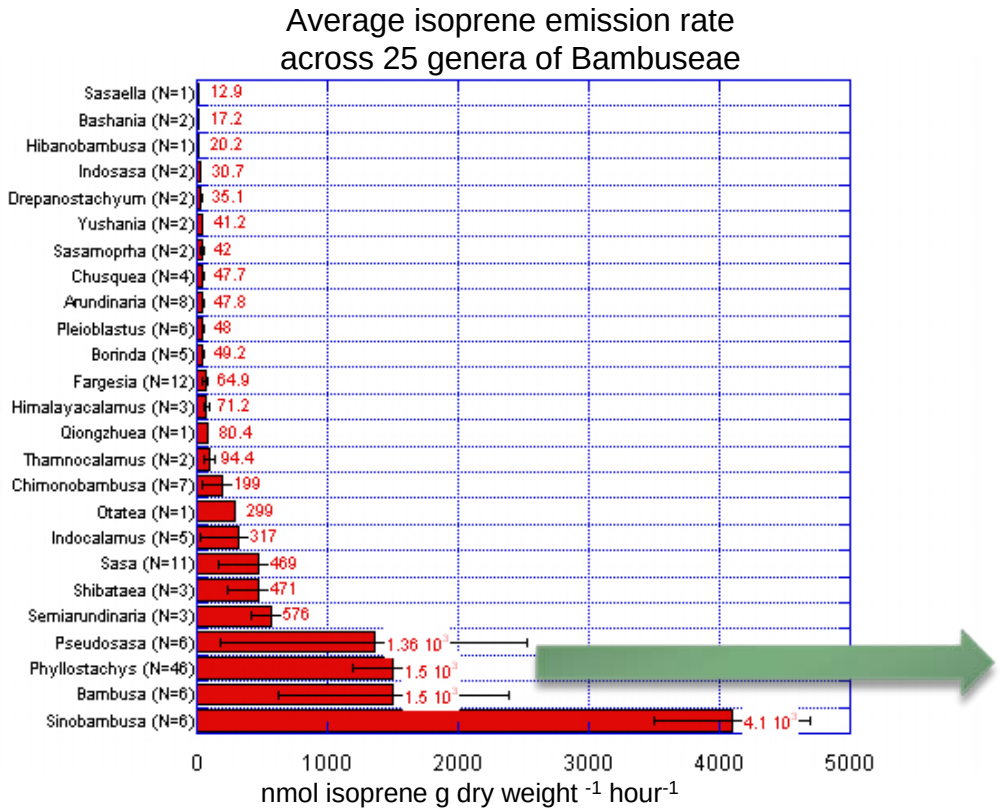
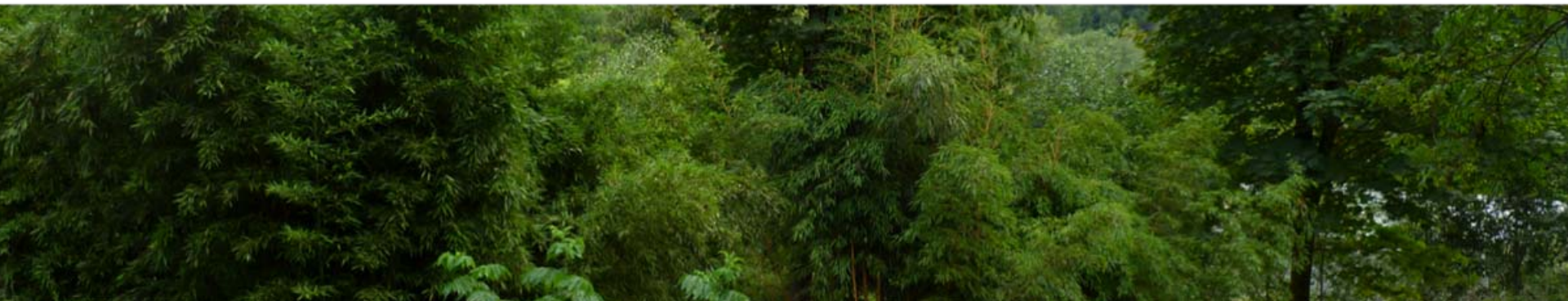
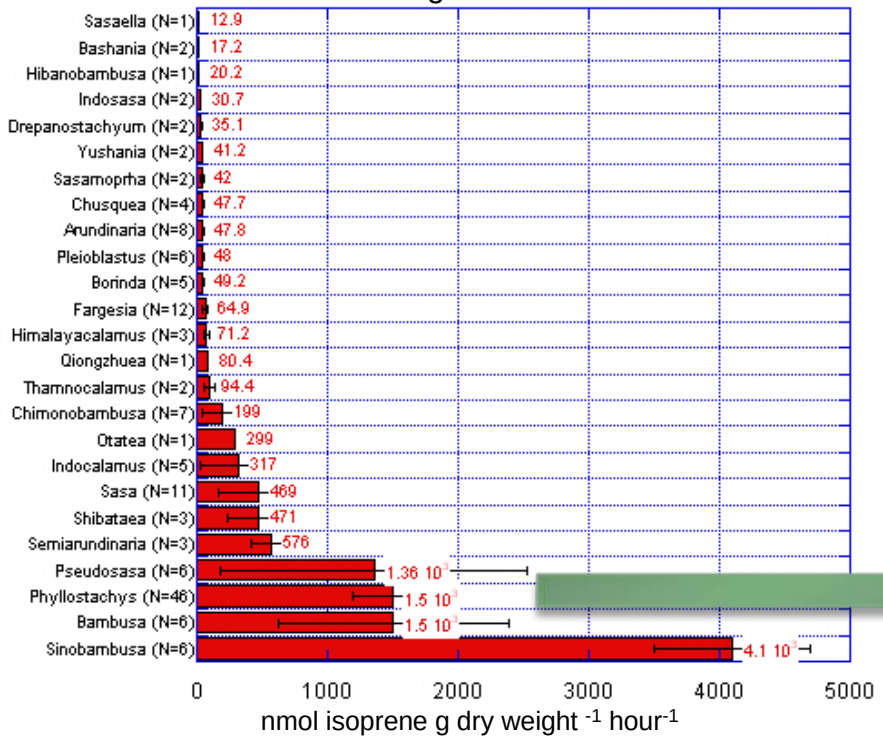


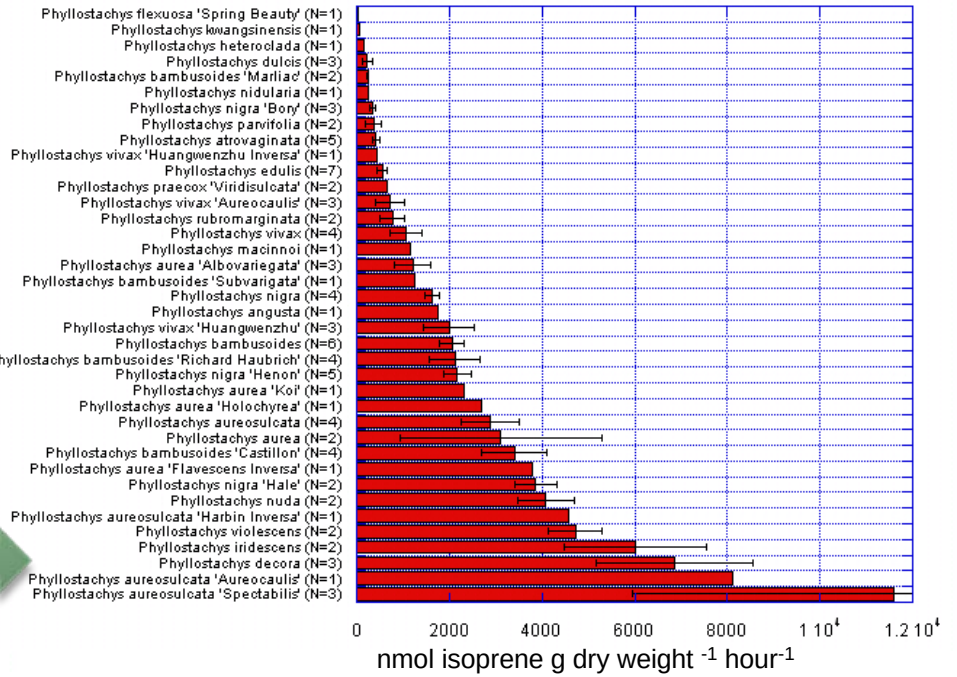


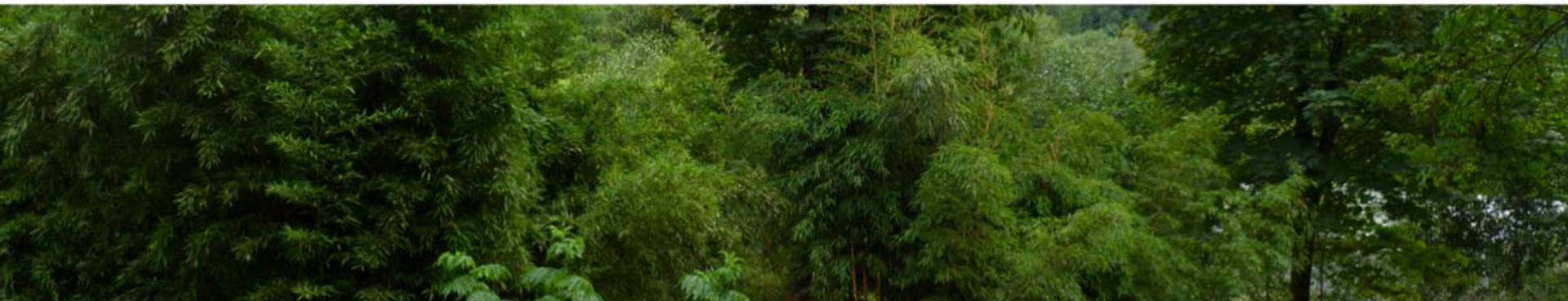
Isoprene emission in Bamboo: Extreme variation across genera and species

Average isoprene emission rate across 25 genera of Bambuseae



Average isoprene emission rate within a single genus, *Phyllostachys*



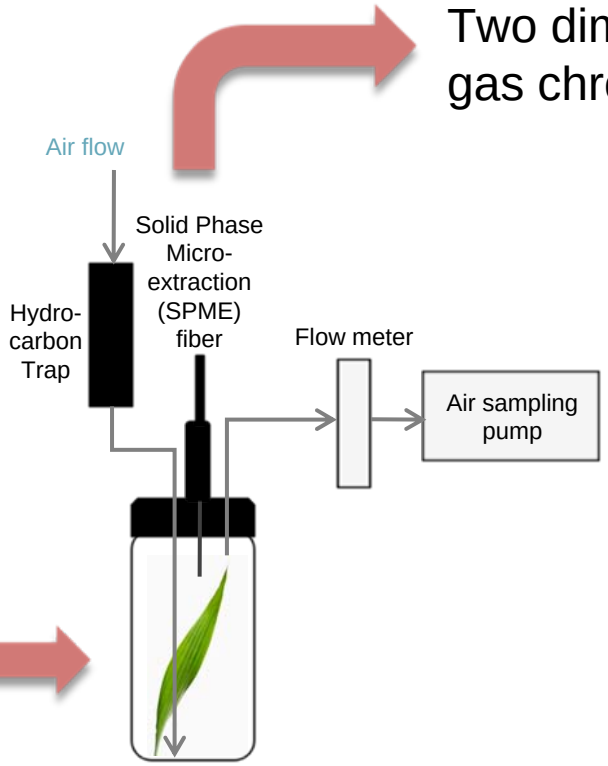


Central Questions: What about other BVOCs?

- How variable are BVOCs emissions within the Bambusoideae?
- Does isoprene emission influence the composition of other BVOCs?

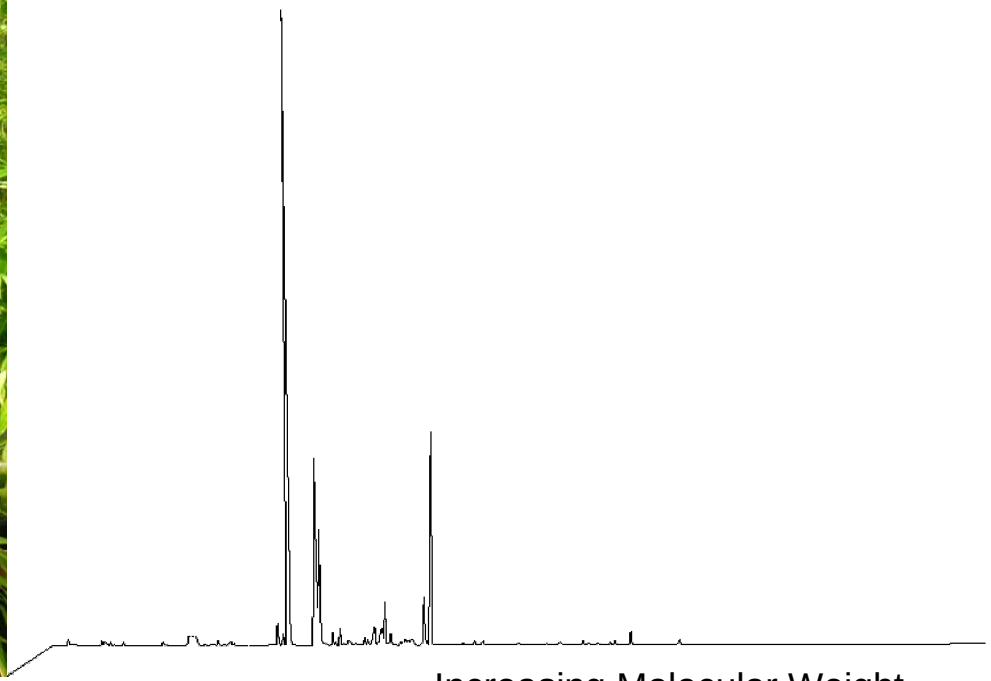
Genus species 'Cultivar'	Relative Isoprene Emission	Growth Form	Leaf Color	Subfamily
Arundo donax	**High**	Clumping	Variegated	Arundinoideae
Arundinaria gigantea	None	Running	Green	Bambusoideae
Bambusa ventricosa	**High**	Clumping	Green	Bambusoideae
Bambusa ventricosa 'Kimmei'	**High**	Clumping	Variegated	Bambusoideae
Fargesia rufa	None	Clumping	Green	Bambusoideae
Phyllostachys aurea	**High**	Running	Green	Bambusoideae
Phyllostachys edulis	None	Running	Green	Bambusoideae
Phyllostachys nigra	**High**	Running	Green	Bambusoideae
Pleioblastus chino	None	Running	Green	Bambusoideae
Pleioblastus chino 'Murakamianus'	None	Running	Variegated	Bambusoideae
Pleioblastus chino 'Vaginatus Variegatus'	None	Running	Variegated	Bambusoideae
Sasa kurilensis	None	Running	Green	Bambusoideae
Sasa kurliensis 'Simofuri'	**High**	Running	Variegated	Bambusoideae

Sampling Procedure



Sampling Procedure

Two dimensional
gas chromatography



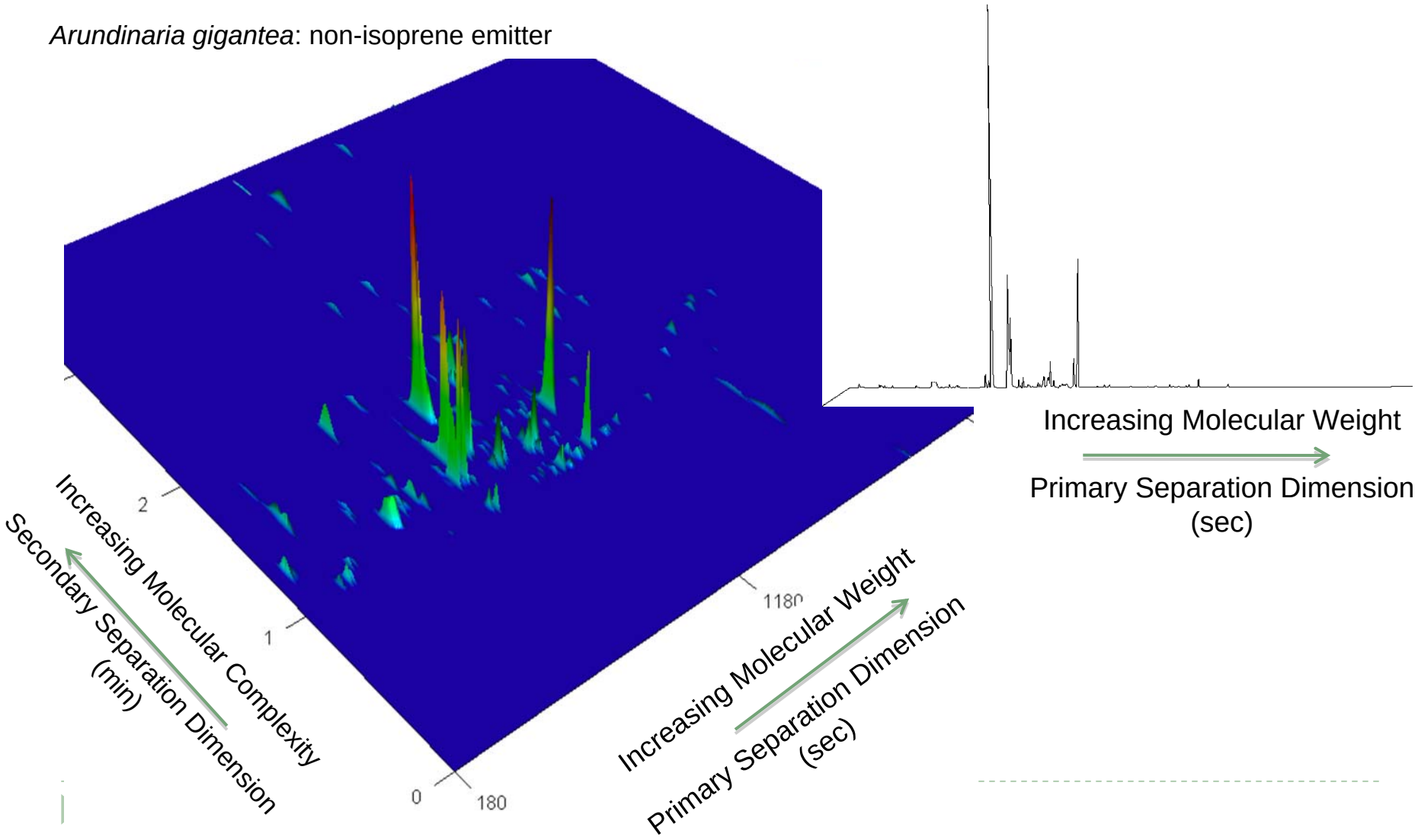
Increasing Molecular Weight

Primary Separation Dimension (sec)

GCxGC-TOFMS

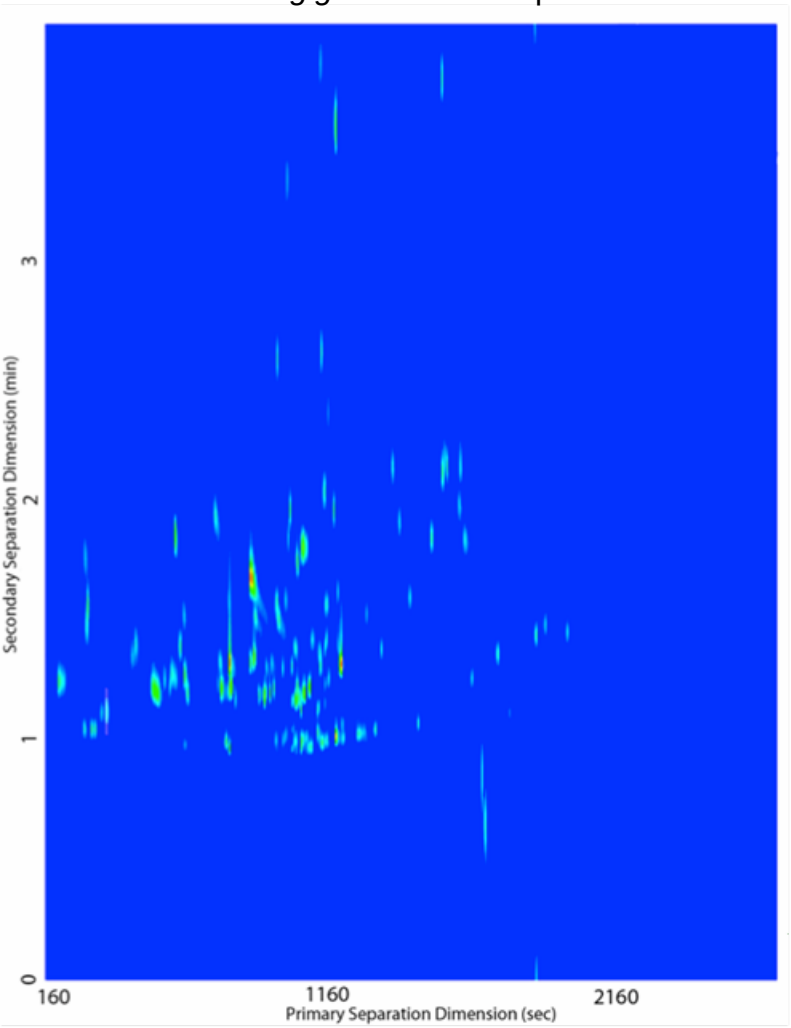
- Two-dimensional gas chromatography
- Time of flight mass spectrometry
- Leco Pegasus 4D GC × GC-TOFMS

Arundinaria gigantea: non-isoprene emitter

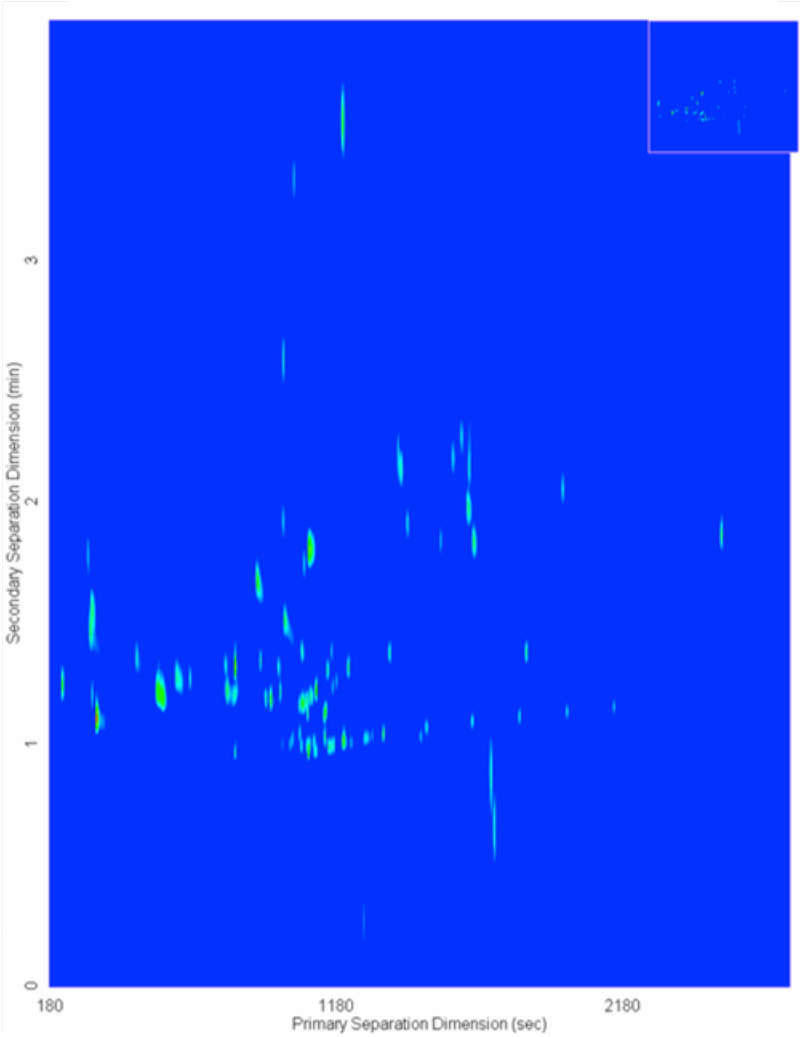


Difference in many compounds emitted by bamboos

Arundinaria gigantea: non-isoprene emitter



Bambusa ventricosa 'Kimmei': isoprene emitter



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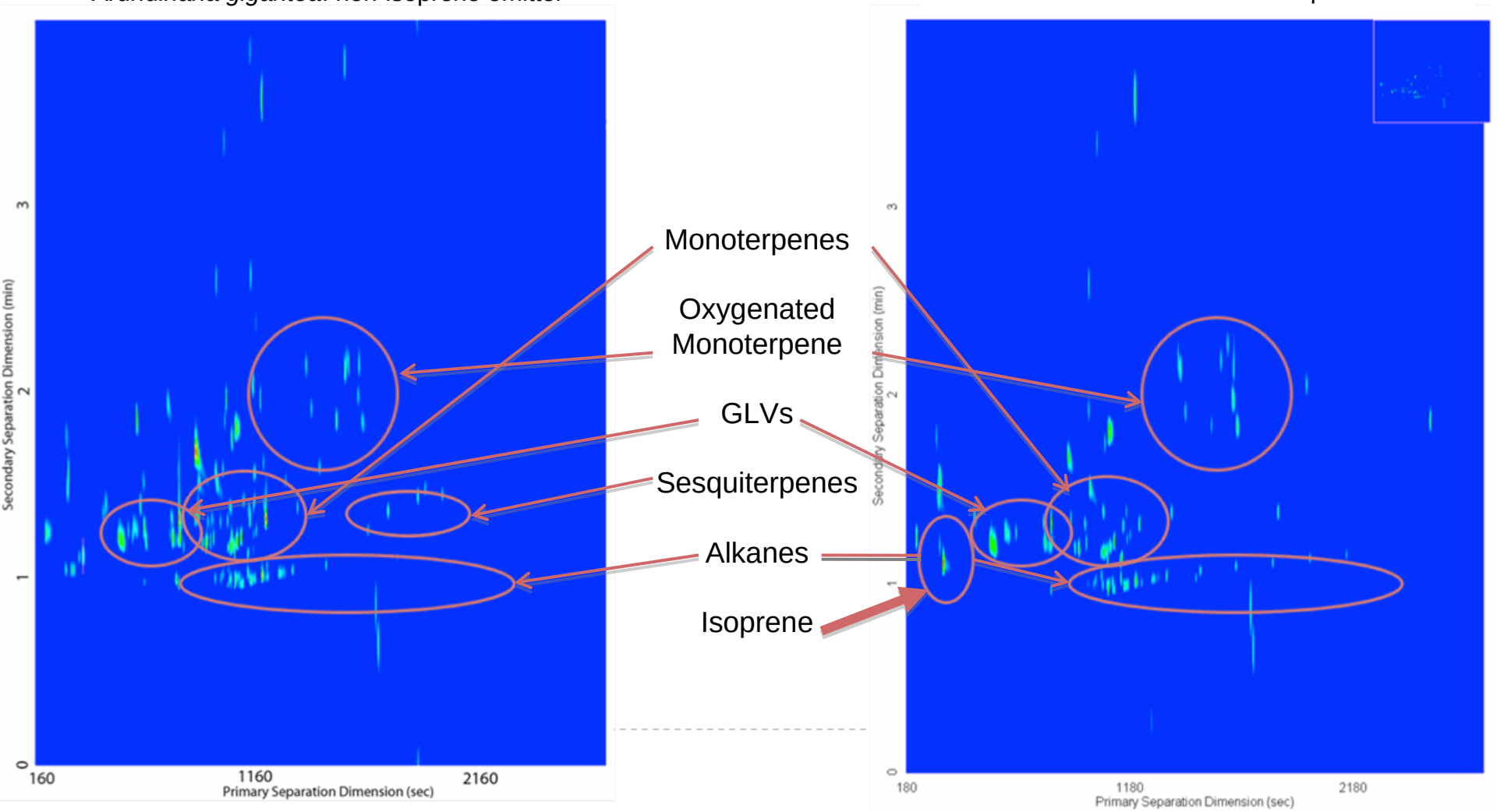
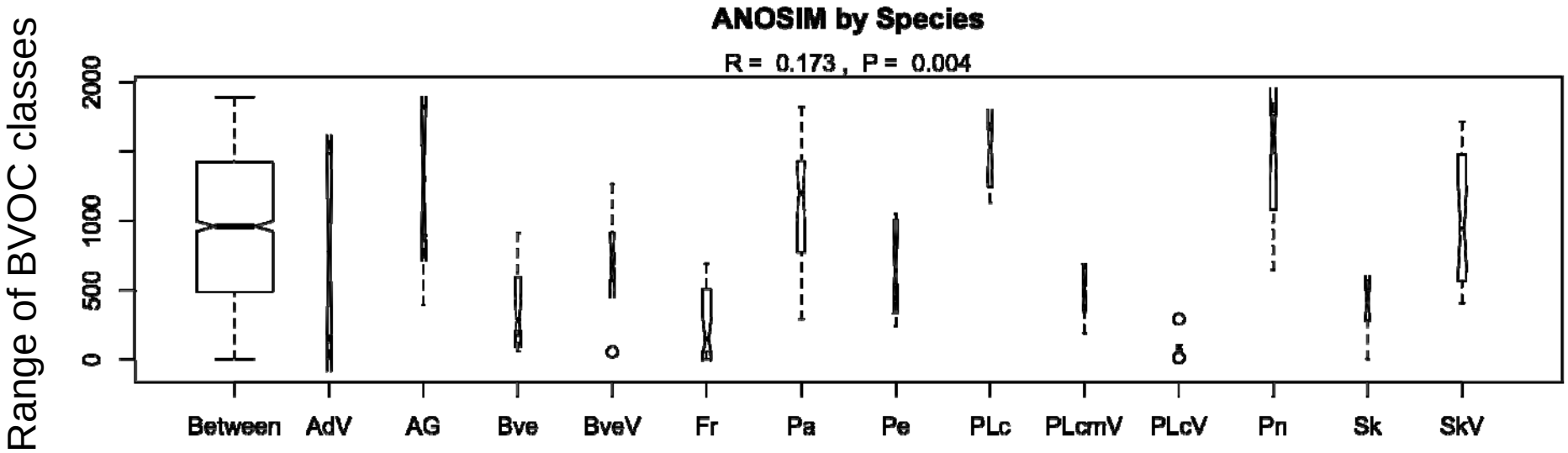


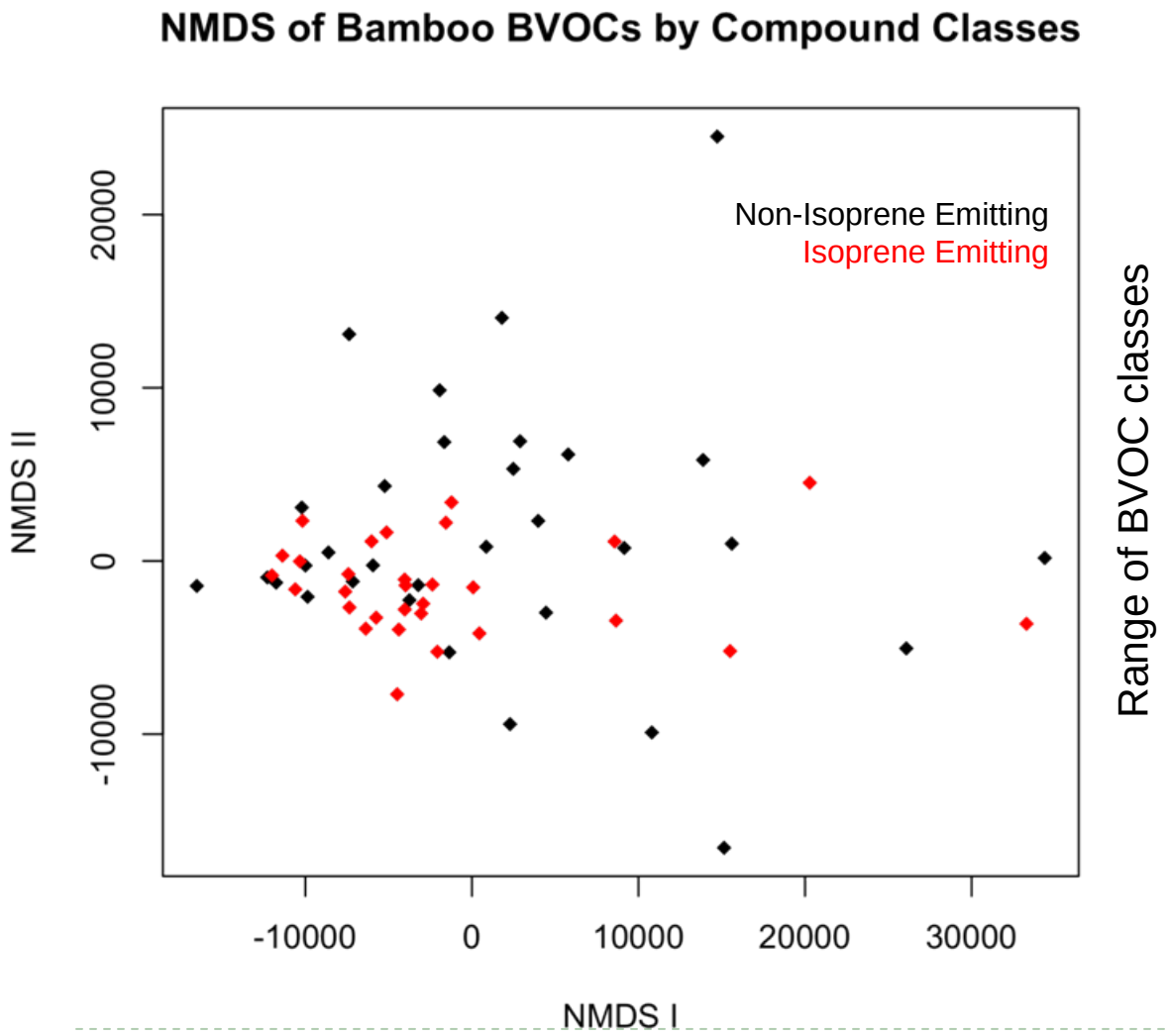
No difference in number of compounds emitted by isoprene emitting bamboos

Genus species ‘Cultivar’	Average number of compounds (n=4)	Isoprene emitting
Bambusa ventricosa	**75**	←
Bambusa ventricosa 'Kimmei'	**105**	←
Sasa kurilensis	117	
Fargesia rufa	123	
Arundinaria gigantea	140	
Arundo donax	**141**	←
Phyllostachys aurea	**150**	←
Phyllostachys edulis	154	
Sasa kurliensis ‘Simofuri’	**156**	←
Pleioblastus chino	169	
Pleioblastus chino ‘Murakamianus’	176	
Phyllostachys nigra	**195**	←
Pleioblastus chino ‘Vaginatus Variegatus’	196	

Significant difference in BVOC composition across species



Leaf BVOC composition varies with isoprene emission



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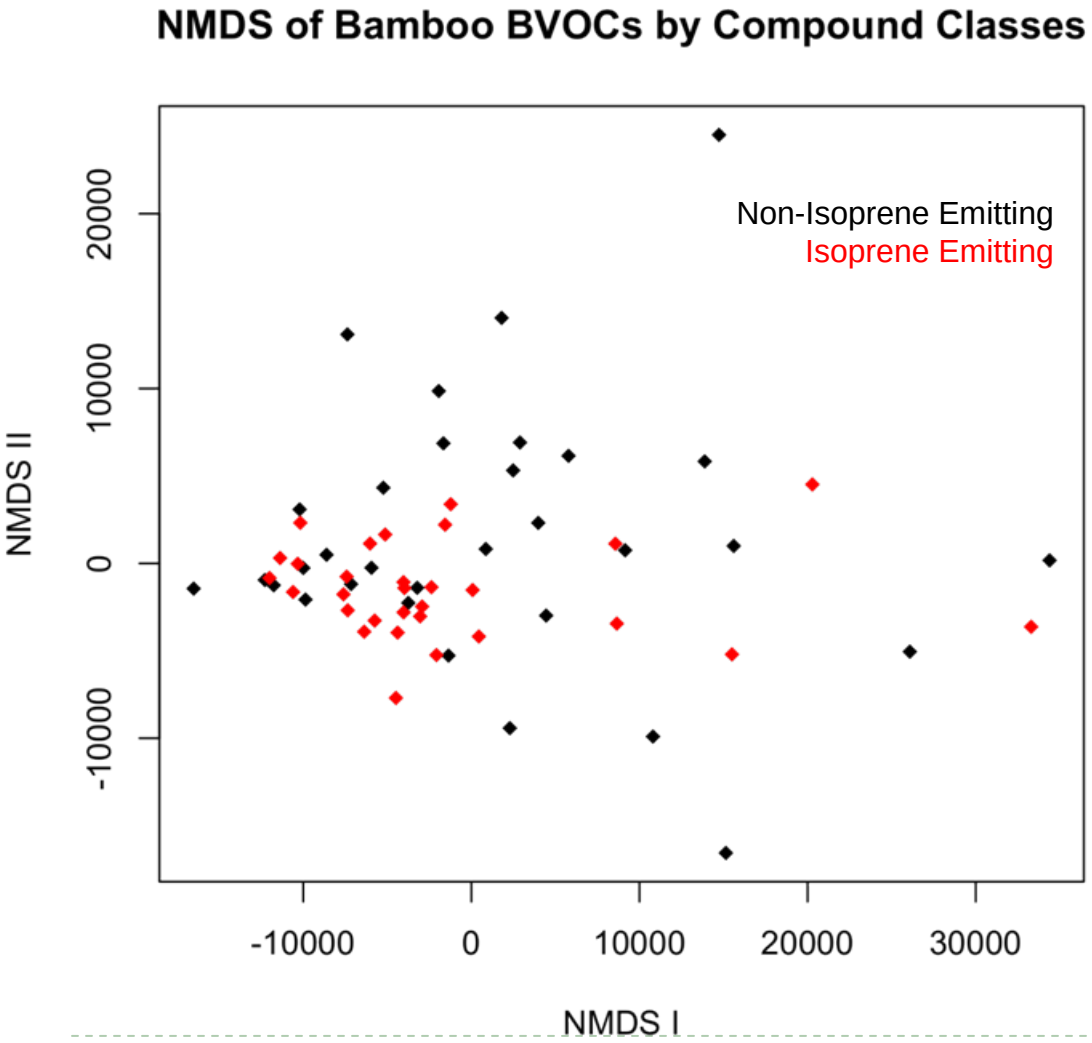
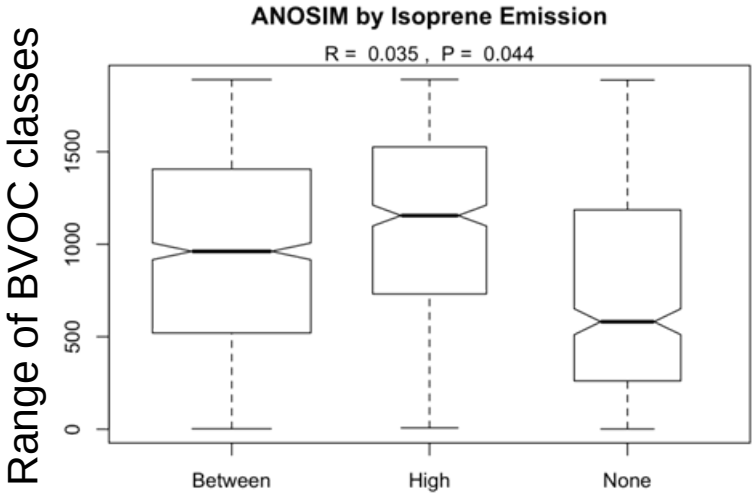
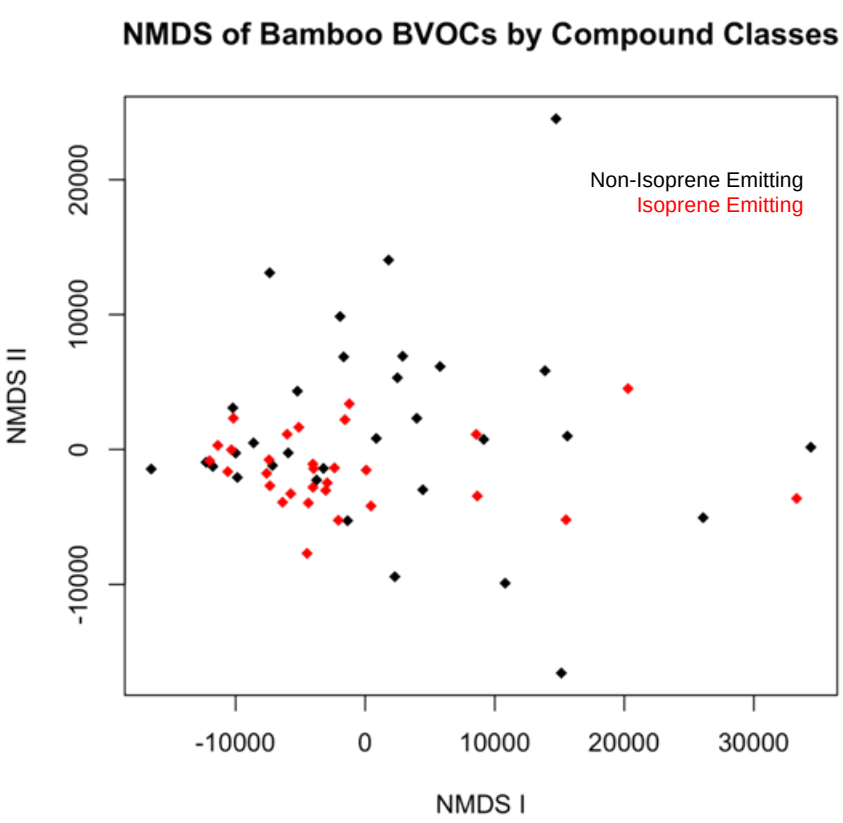
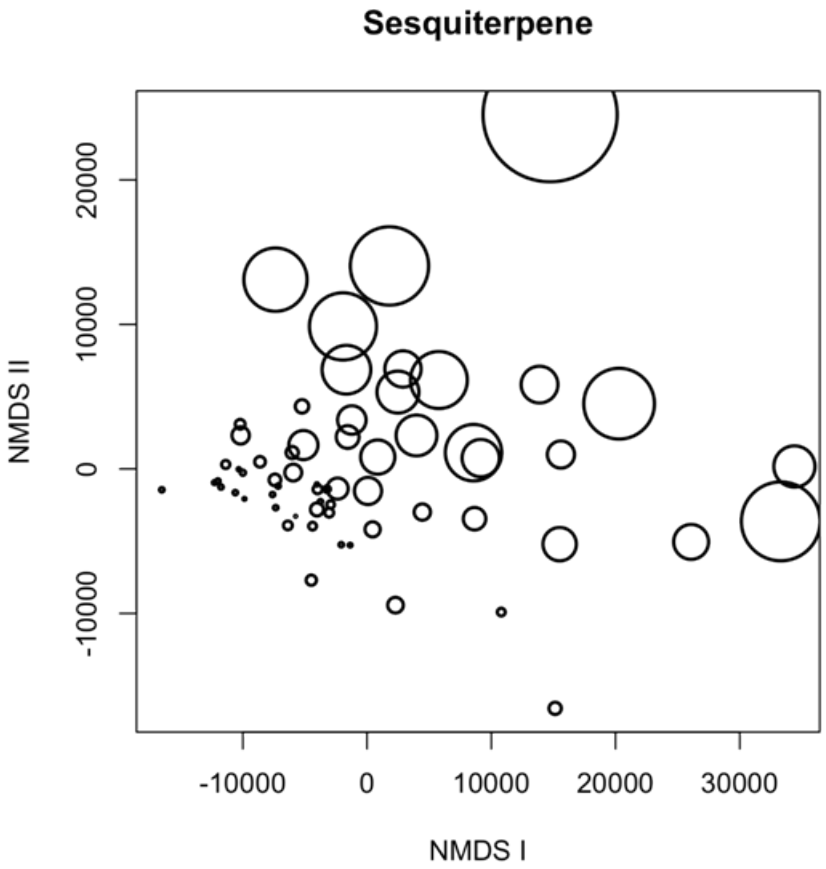


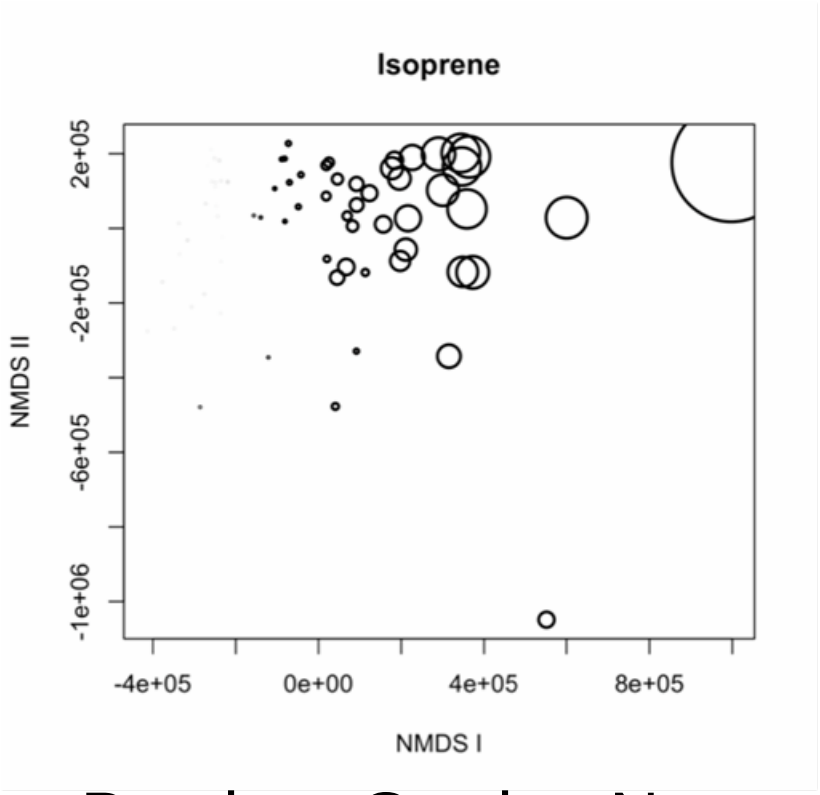


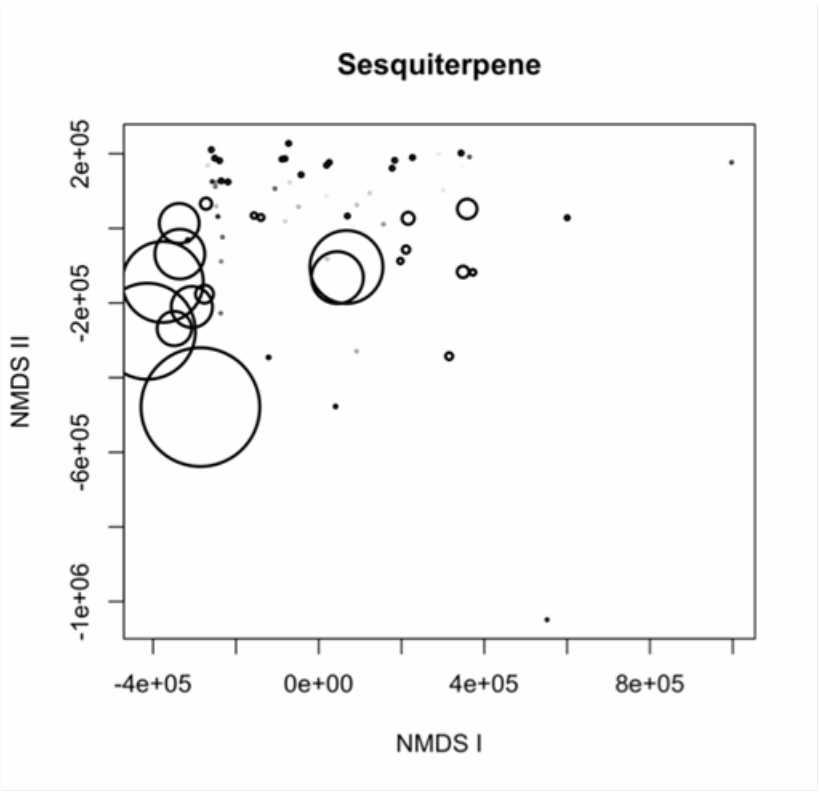
Low isoprene emitting bamboos emit more sesquiterpenes





Field study verifies greenhouse results: Lower isoprene = higher sesquiterpene



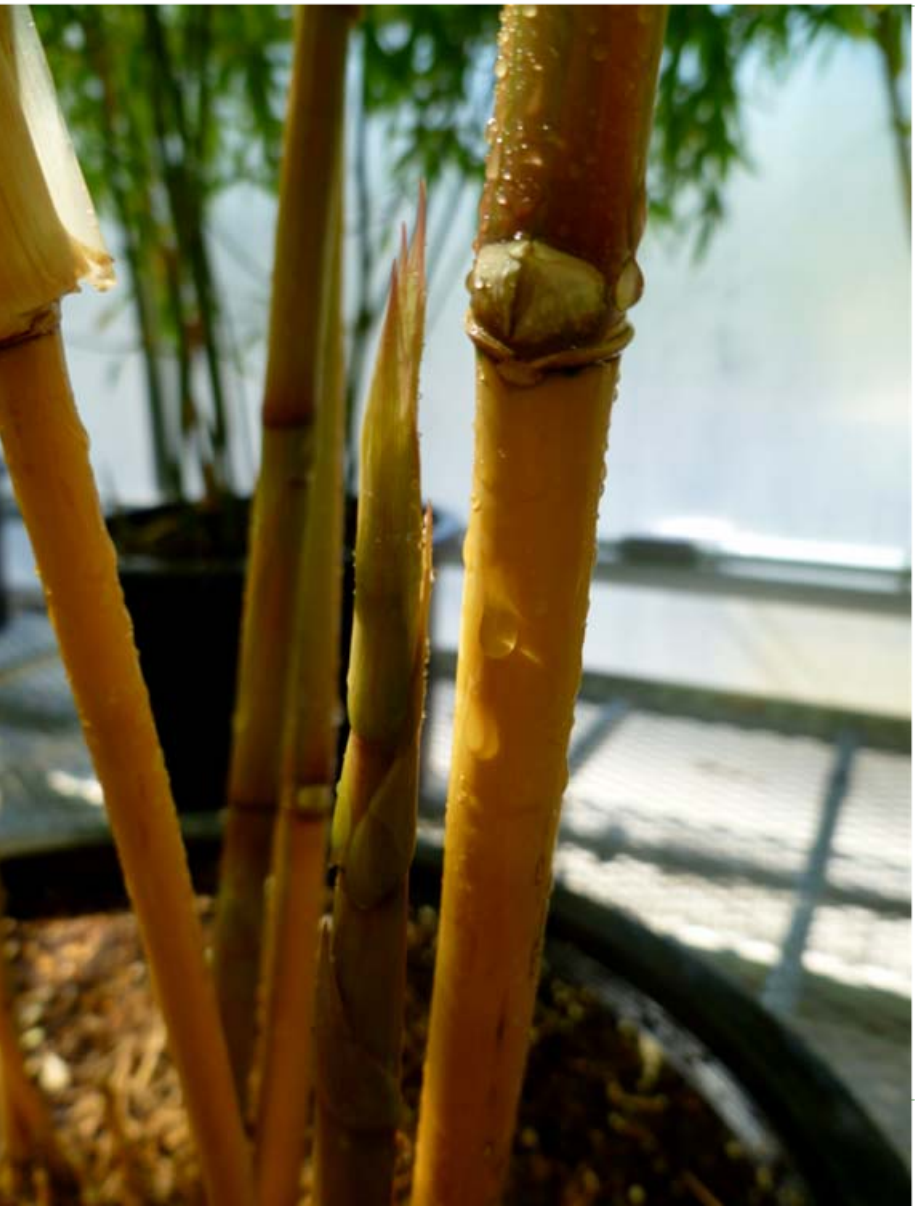


- Bamboo Garden Nursery
- 16 different species, 12 genera
  - Phylogenetically diverse
  - Isoprene emission across entire range

Sesquiterpene / Isoprene shift means different:

- Biochemistry
  - May influence other aspects of physiology
- Ecological roles
  - Less insect recruitment?
- Strategies of stress protection
- Atmospheric fates
  - Isoprene = ozone
  - Sesquiterpenes = SOA particles

Conclusions



- Bamboo emissions are not all equal
- Vast diversity of BVOCs in Bamboos
  - BVOC emissions not predicted by genus alone
  - Variation in BVOC emission is tied to isoprene production
- Bamboos may impact air quality differently
  - Species matters
  - Placement matters
  - Amount matters

Acknowledgements

- Todd Rosenstiel, PSU Biology
- Ned Jaquith, Bamboo Garden Nursery
- Noah Bell and Bamboo Garden Nursery Staff
- Jim Pankow, PSU Chemistry
- Pankow Group
  - Wentai Luo
  - Lorne Isabel
- Sarah Eppley, PSU Biology
- Eppley/Rosenstiel lab members