



# Observational Constraints on Terpene Oxidation During the GoAmazon 2014/5 Field Campaign using Speciated Measurements from SV-TAG

**Lindsay D. Yee**, Gabriel Isaacman-VanWertz, Rebecca A. Wernis, Nathan M. Kreisberg, Yingjun Liu, Karena A. McKinney, Suzane de Sá, Scot T. Martin, M. Elizabeth Alexander, Brett B. Palm, Weiwei Hu, Pedro Campuzano-Jost, Douglas A. Day, Jose L. Jimenez, Juarez Viegas, Stephen R. Springston, Florian Wurm, Joel F. Brito, Paulo Artaxo, Antonio Manzi, Luiz A. T. Machado, Karla Longo, Maria B. Oliveira, Rodrigo de Souza, Susanne V. Hering, Allen H. Goldstein

# Acknowledgements



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**UC Berkeley**  
Gabriel Isaacman-VanWertz, Rebecca Wernis, Allen Goldstein



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**Instituto Nacional de Pesquisas Espaciais**  
Luiz A. T. Machado, Karla Longo

**Harvard University**  
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# Green Ocean Amazon (GoAmazon) 2014/5



Terra MODIS Vegetation Index, NASA

*~80% of terpenoid emissions come from tropical trees,  
which cover about 18% of the global land surface*

*(Guenther et al., 2012)*

# Green Ocean Amazon (GoAmazon) 2014/5

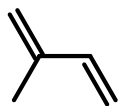


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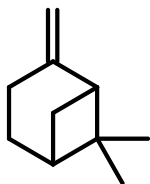
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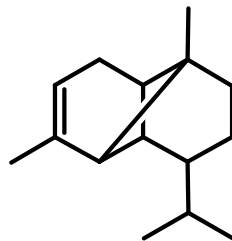
# Relevance of terpenes in oxygenated VOC and SOA formation



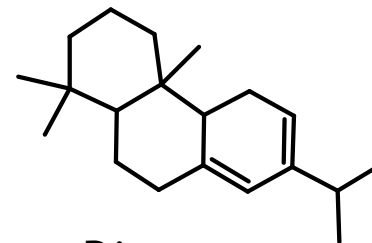
Isoprene  
 $C_5H_8$



Monoterpenes  
 $C_{10}H_{16}$



Sesquiterpenes  
 $C_{15}H_{24}$

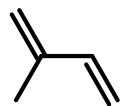


Diterpenes  
 $C_{20}H_{32}$

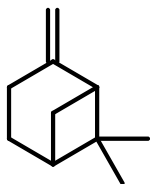




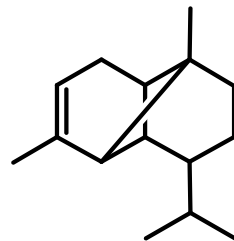
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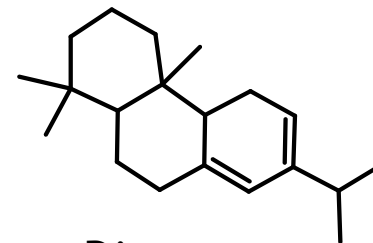
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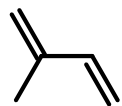
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Increasing reactivity and SOA yields

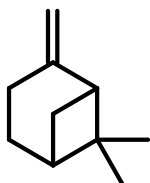
Level of scientific understanding



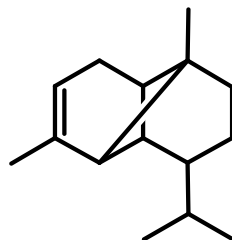
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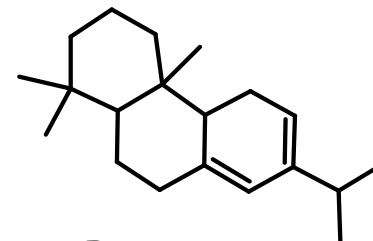
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Diterpenes  
 $C_{20}H_{32}$

Increasing reactivity and SOA yields

Level of scientific understanding

*Less to none known about oxidation products*

# Inconsistent data on relative prevalence of terpenes in emissions and plant tissue

	<i>n</i>	Isoprene [ $\mu\text{g g}^{-1} \text{h}^{-1}$ ]	Monoterpenes [ $\mu\text{g g}^{-1} \text{h}^{-1}$ ]	Sesquiterpenes [ $\mu\text{g g}^{-1} \text{h}^{-1}$ ]
Tropical plant species				
<i>Garcinia macrophylla</i>	3	16.83 ± 3.45	–	–
<i>Hevea brasiliensis</i>	3	–	21.33 ± 14.66	–
<i>Hevea guianensis</i>	2	–	9.45 ± 1.63	–
<i>Hevea spruceana</i> (v)	2	–	18.90 ± 16.26	–
<i>Hevea spruceana</i> (i)	3	–	52.50 ± 13.35	–
<i>Hura crepitans</i>	3	–	–	–
<i>Ocotea cymbarum</i>	3	–	–	–
<i>Pachira insignis</i>	3	12.13 ± 3.84	–	–
<i>Pouteria glomerata</i>	3	–	–	–
<i>Pseudobombax munguba</i>	3	–	–	–
<i>Scleronema micranthum</i>	3	–	0.35 ± 0.07	–
<i>Vatairea guianensis</i> (v)	2	63.20 ± 42.85	–	–
<i>Vatairea guianensis</i> (i)	2	47.20 ± 3.53	–	–
<i>Zygia jurana</i>	3	13.73 ± 8.78	–	–

Bracho-Nunez et al., 2013

# Inconsistent data on relative prevalence of terpenes in emissions and plant tissue

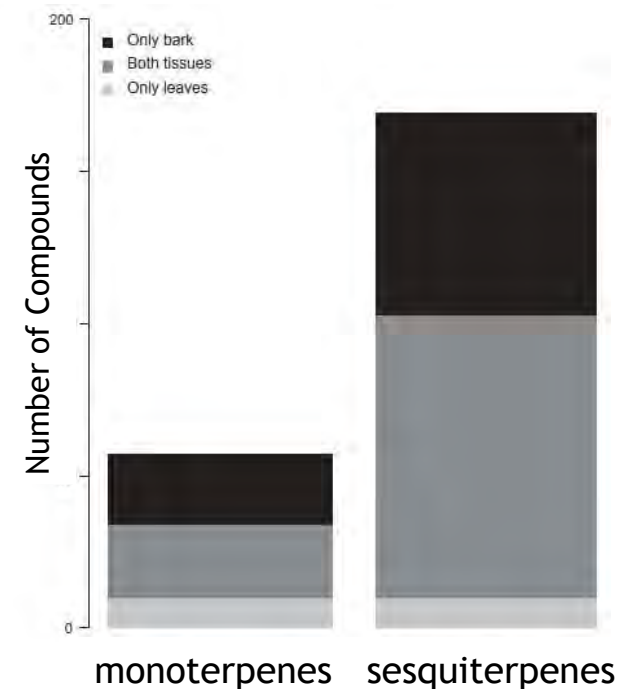


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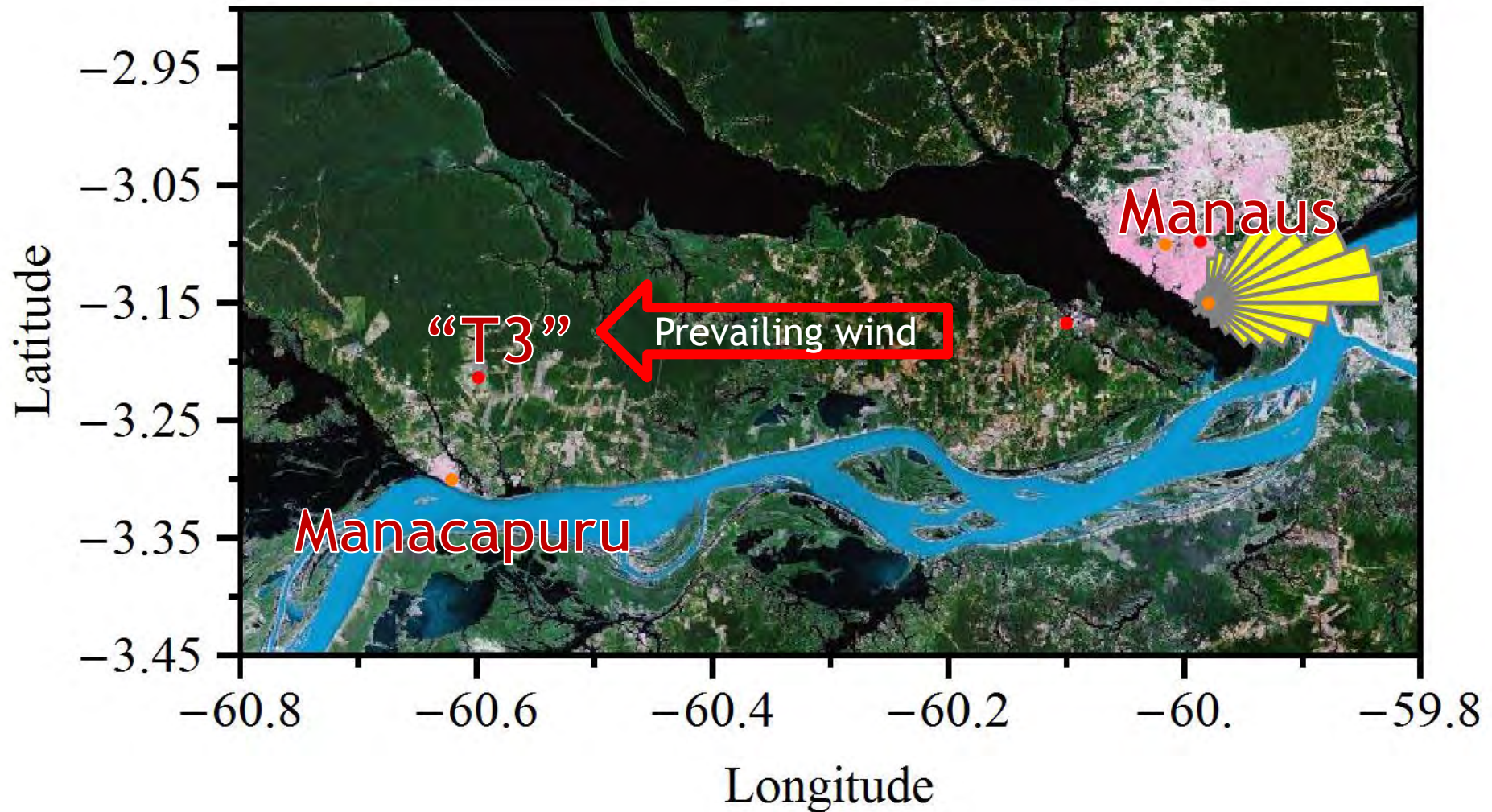
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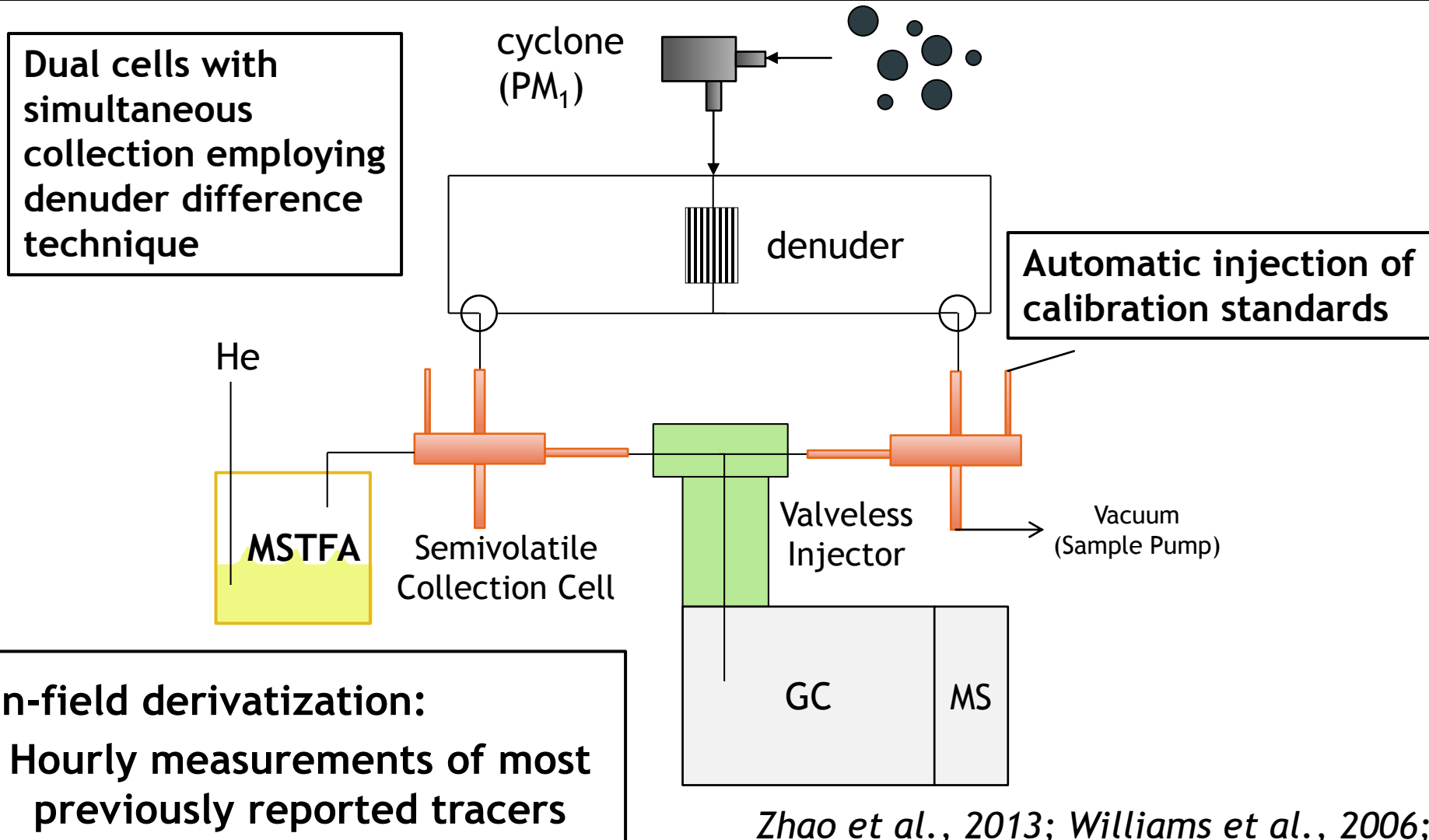
Adapted from Courtois et al, 2012

# Influence of the Manaus Plume



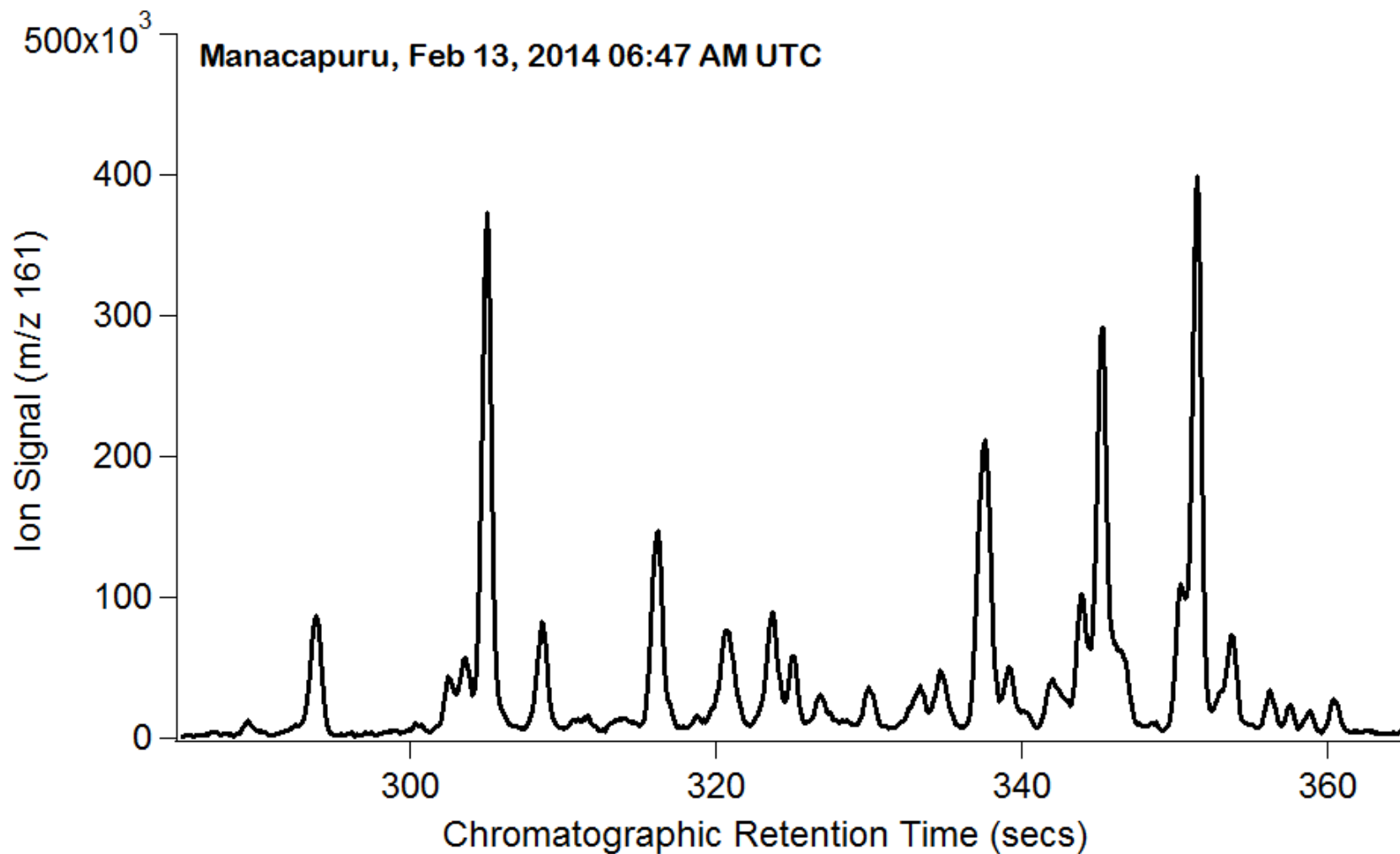
Adapted from GoAmazon White Paper

# Semivolatile Thermal Desorption Aerosol Gas Chromatograph (SV-TAG) with Derivatization

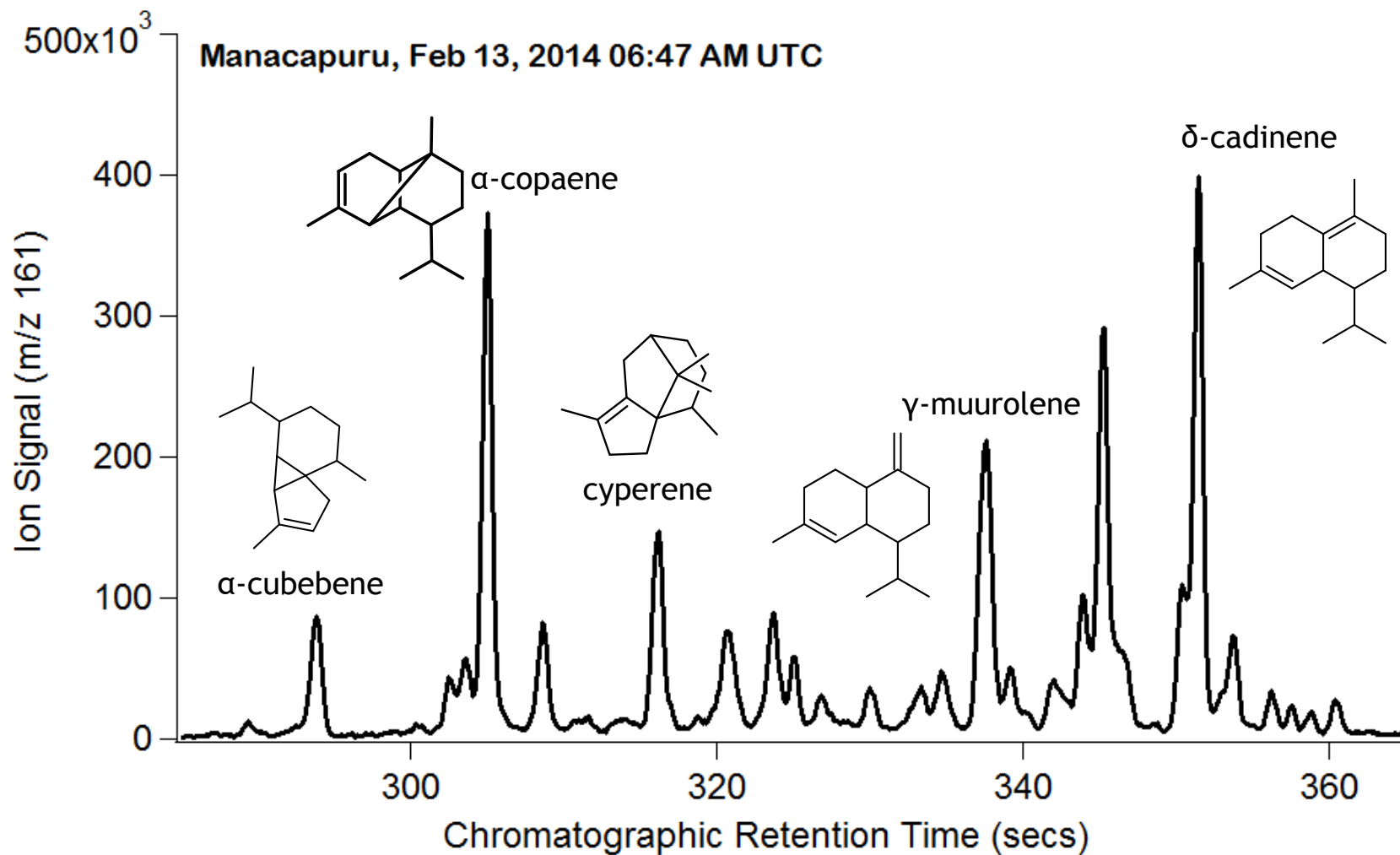


*Zhao et al., 2013; Williams et al., 2006; Kreisberg et al., 2009; Isaacman et al., 2014*

# >20 Sesquiterpenes in ambient

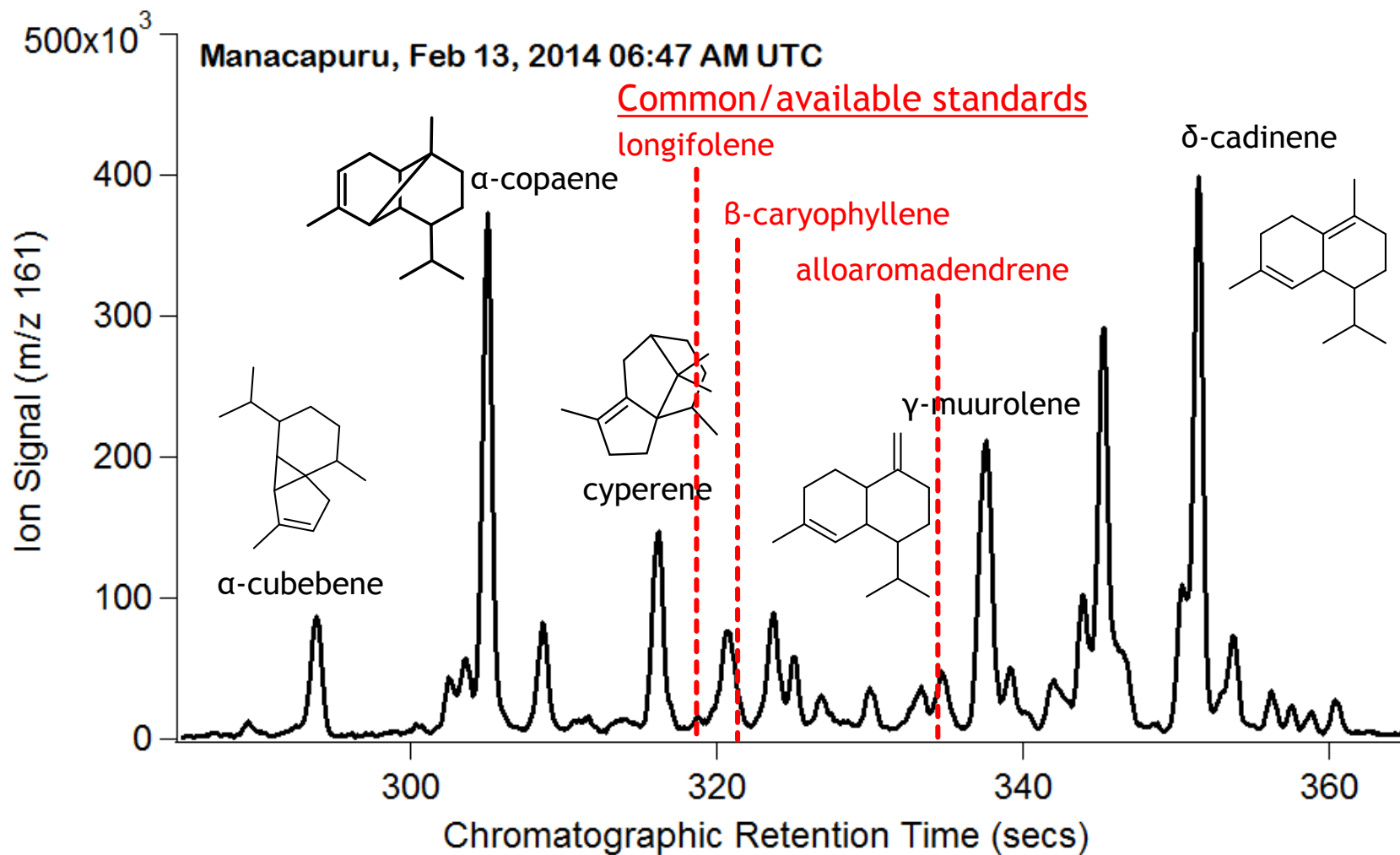


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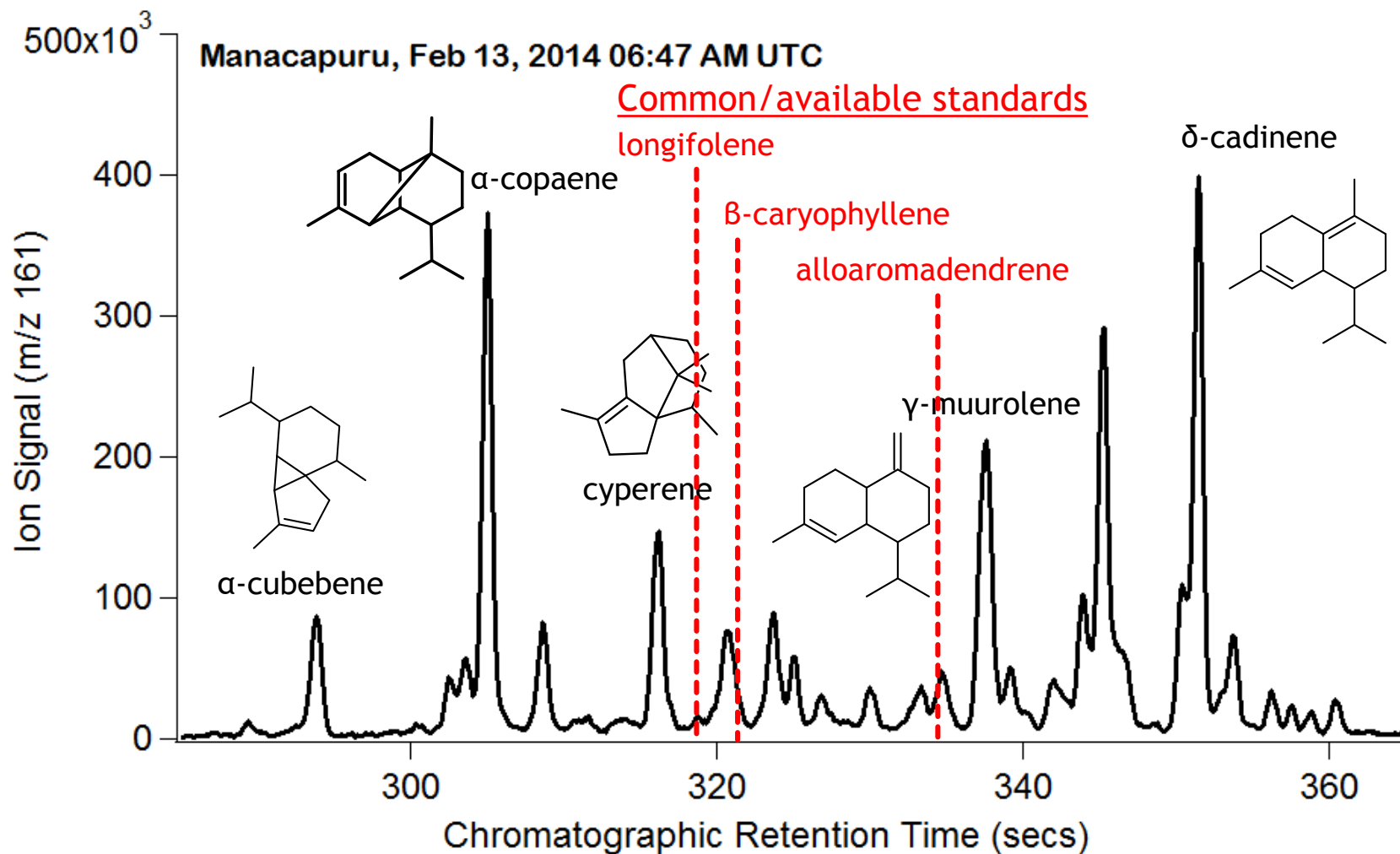




# >20 Sesquiterpenes in ambient



# >20 Sesquiterpenes in ambient



*Very few of these have been studied by atmospheric chemists in terms of kinetics or SOA production.*

# “Authentic” standards

## Copaiba Essential Oil



### Copaiba Essential Oil uses:

- Relieves pain
- Muscle aches
- Arthritis
- Heals insect bites
- Sore throat
- Urinary disorders
- Skin disorders
- Depression
- Anxiety
- Inflammation
- Bronchitis
- Urinary tract problems
- Stomach ulcers



### **Did you know???**

Copaiba is the only essential oil tapped directly from the tree and is not distilled.

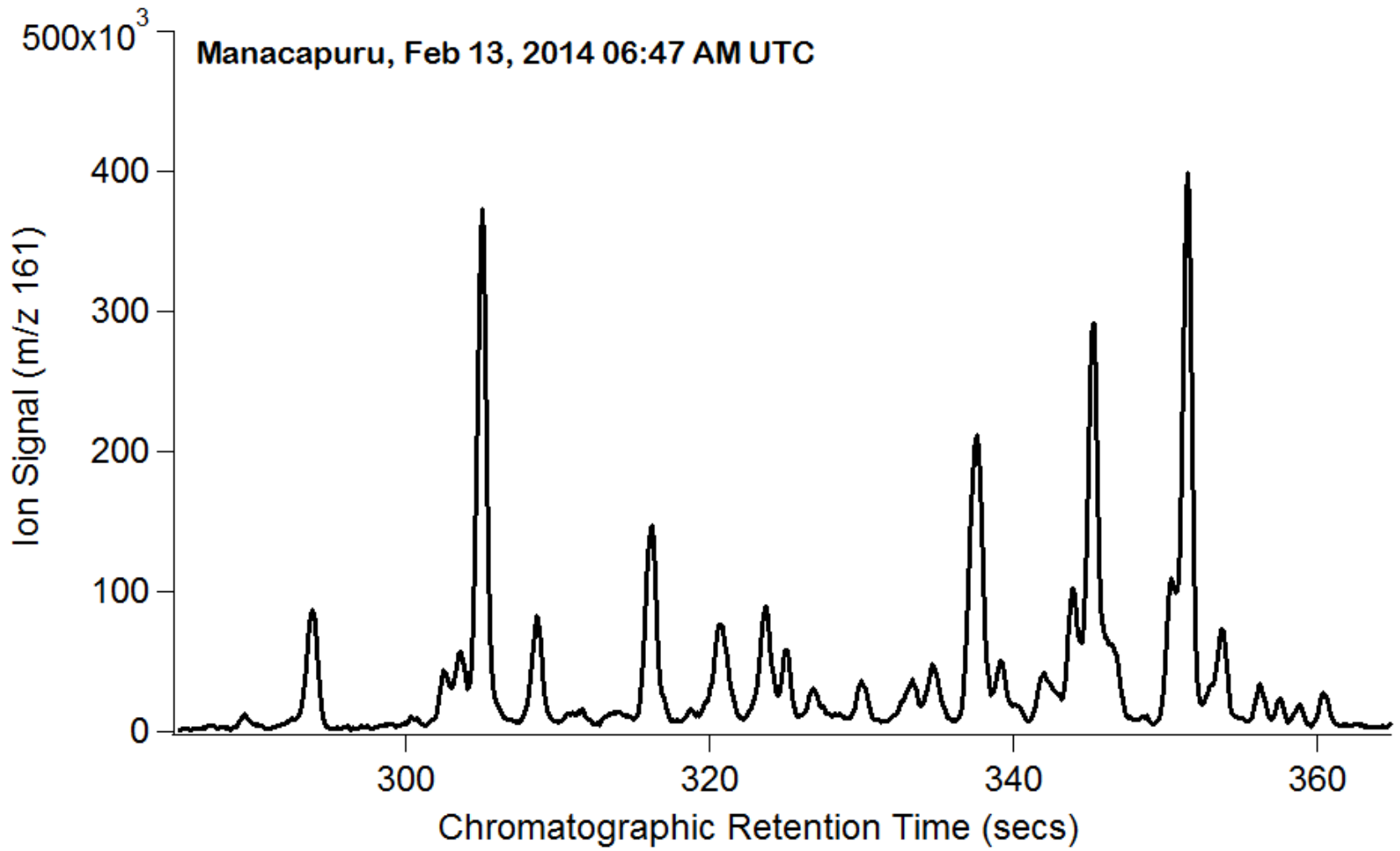
### **How to Use:**

- Directly inhale
- Apply topically
- Diffuse
- Dietary supplement

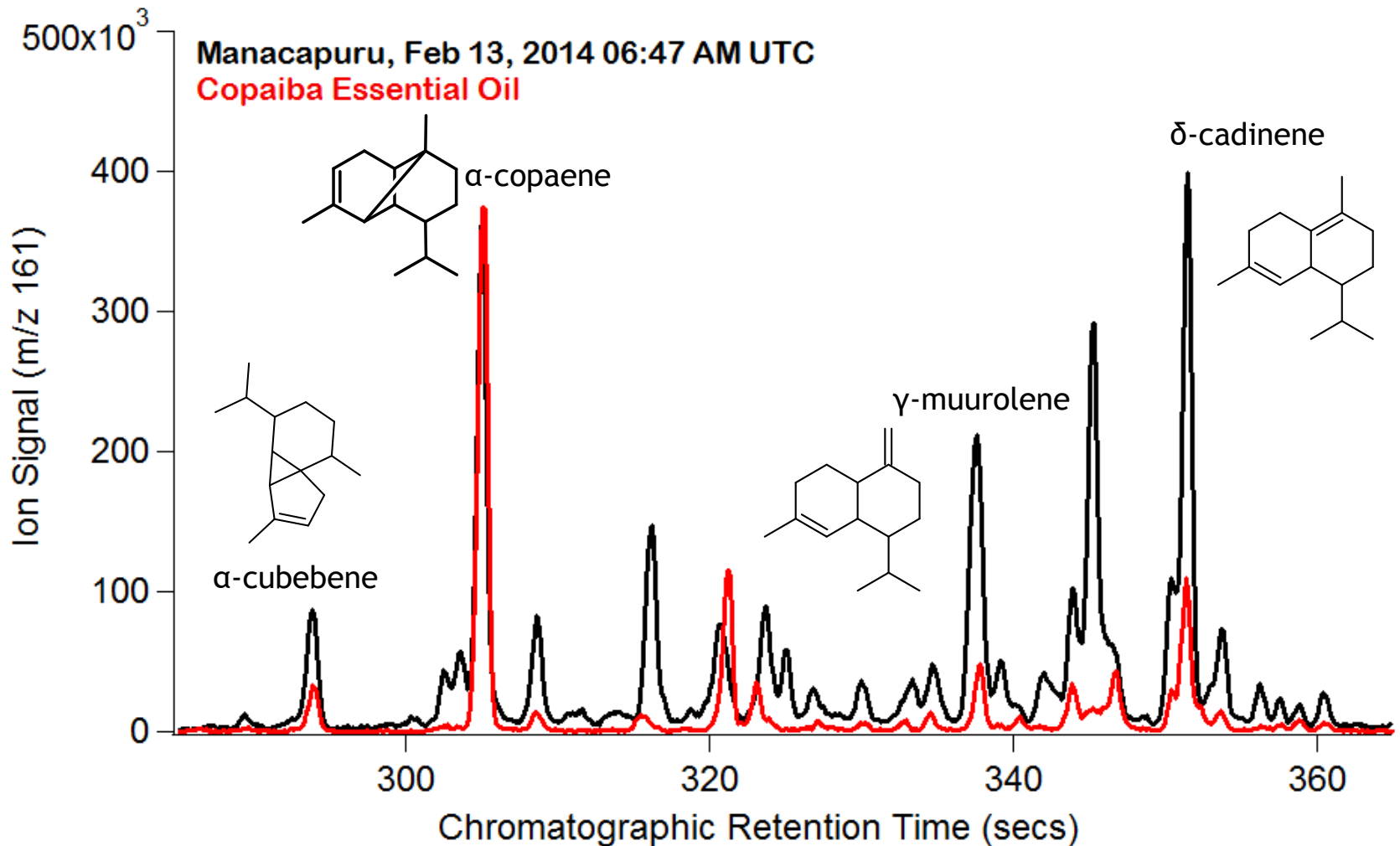
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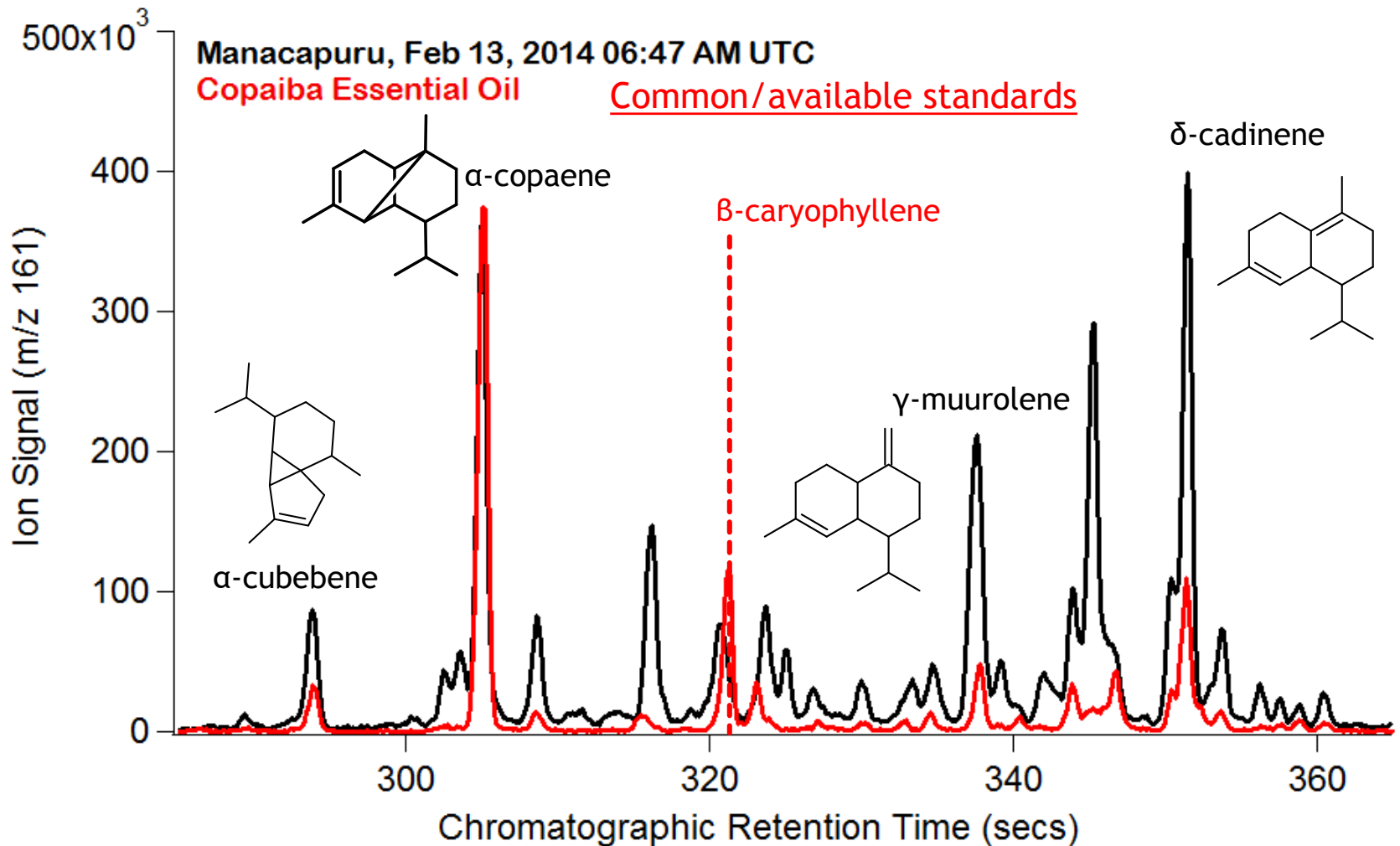
# Does ambient SQT composition compare to that of copaiba oil?



# Several sesquiterpenes in ambient also in copaiba essential oil

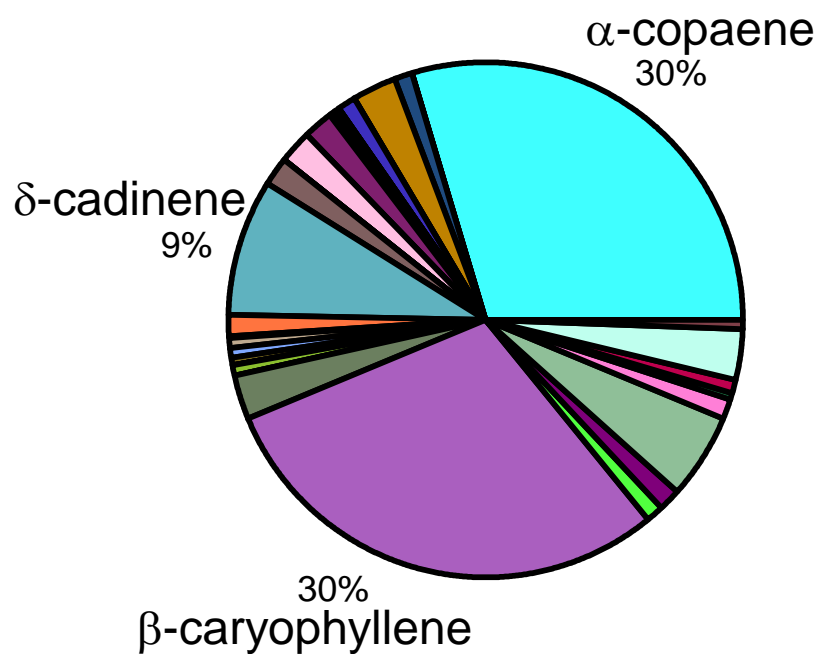


# Several sesquiterpenes in ambient also in copaiba essential oil



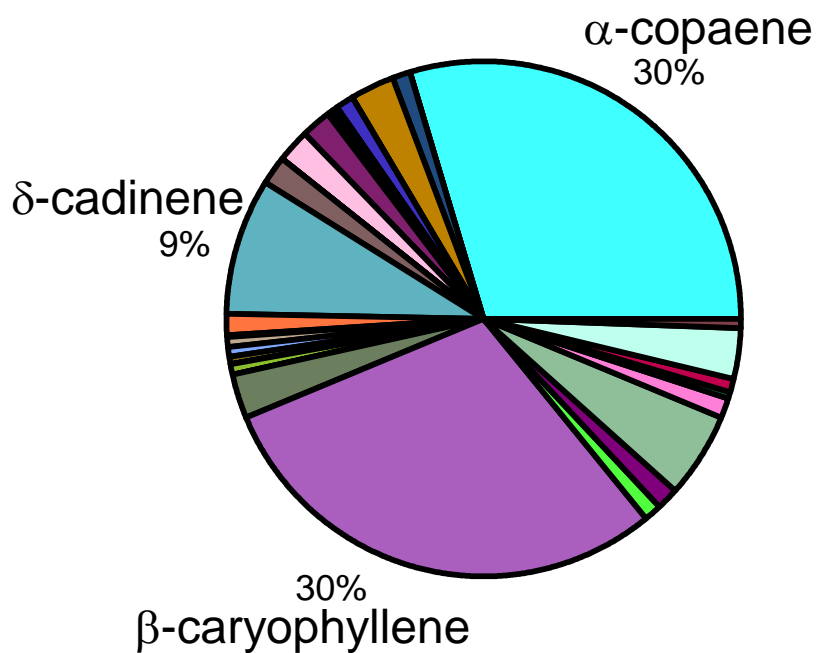
# Sesquiterpenes composition

## Copaiba Essential Oil

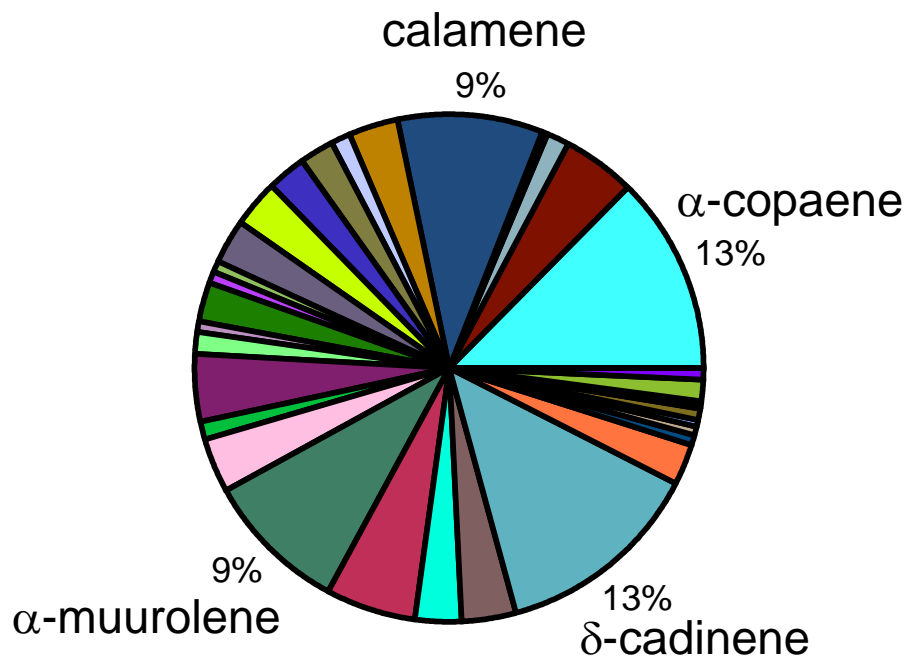


# Sesquiterpenes composition

Copaiba Essential Oil



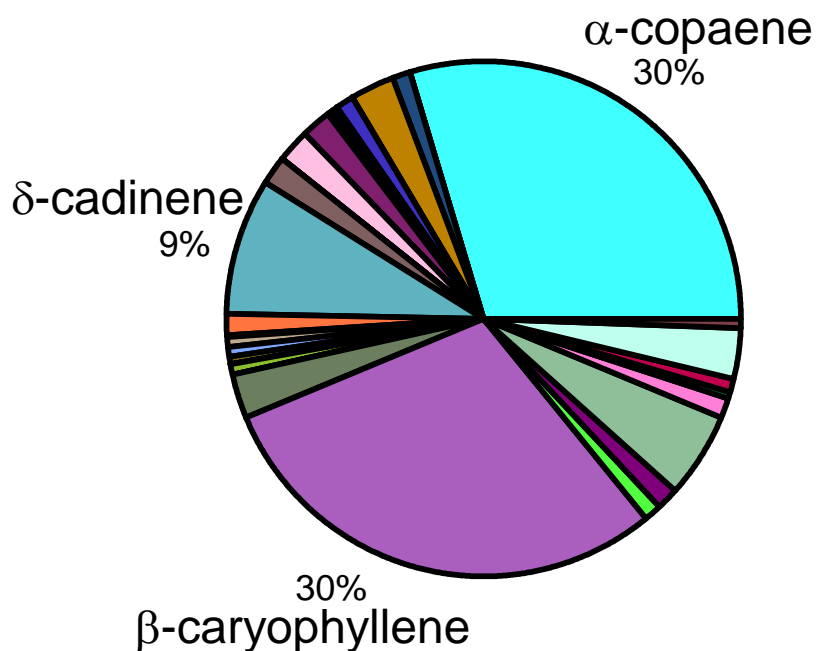
Full ambient composition



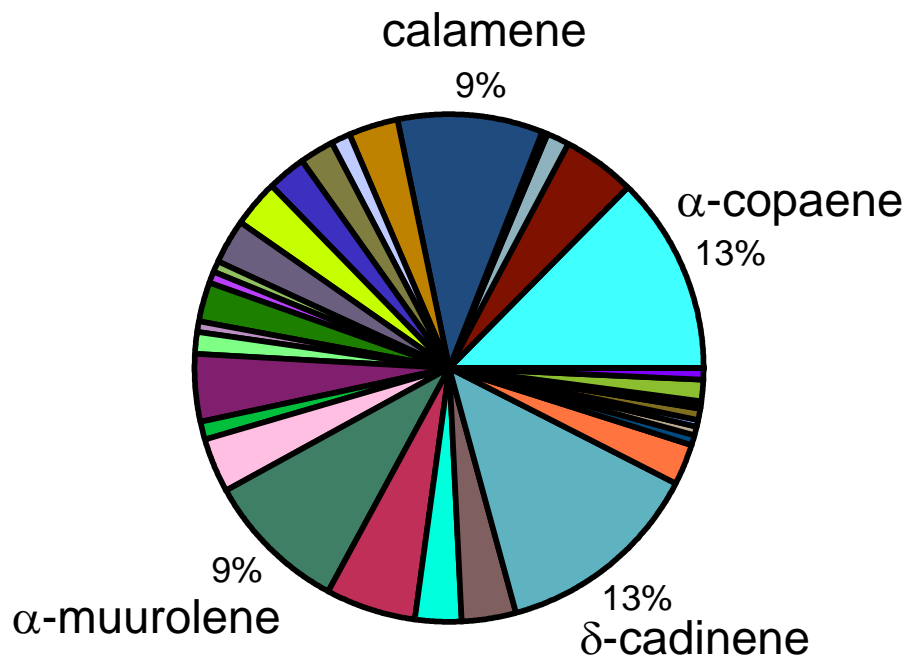


# Sesquiterpenes composition

Copaiba Essential Oil

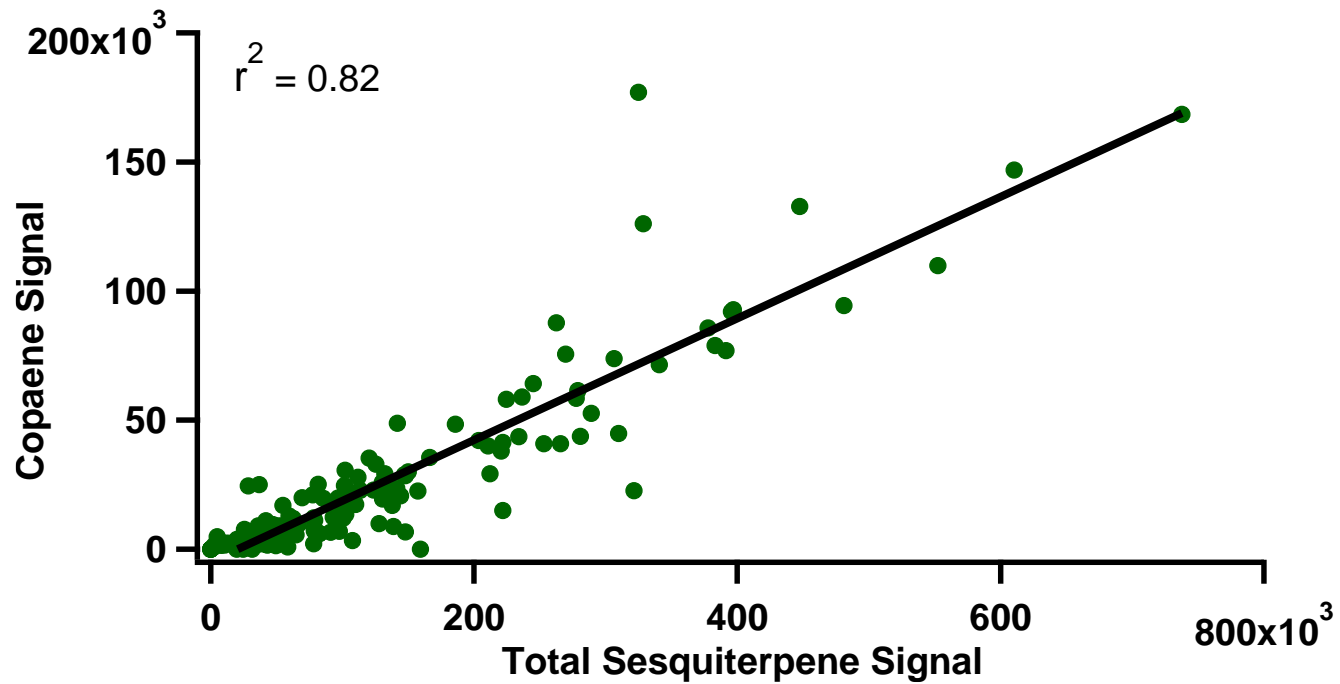


Full ambient composition

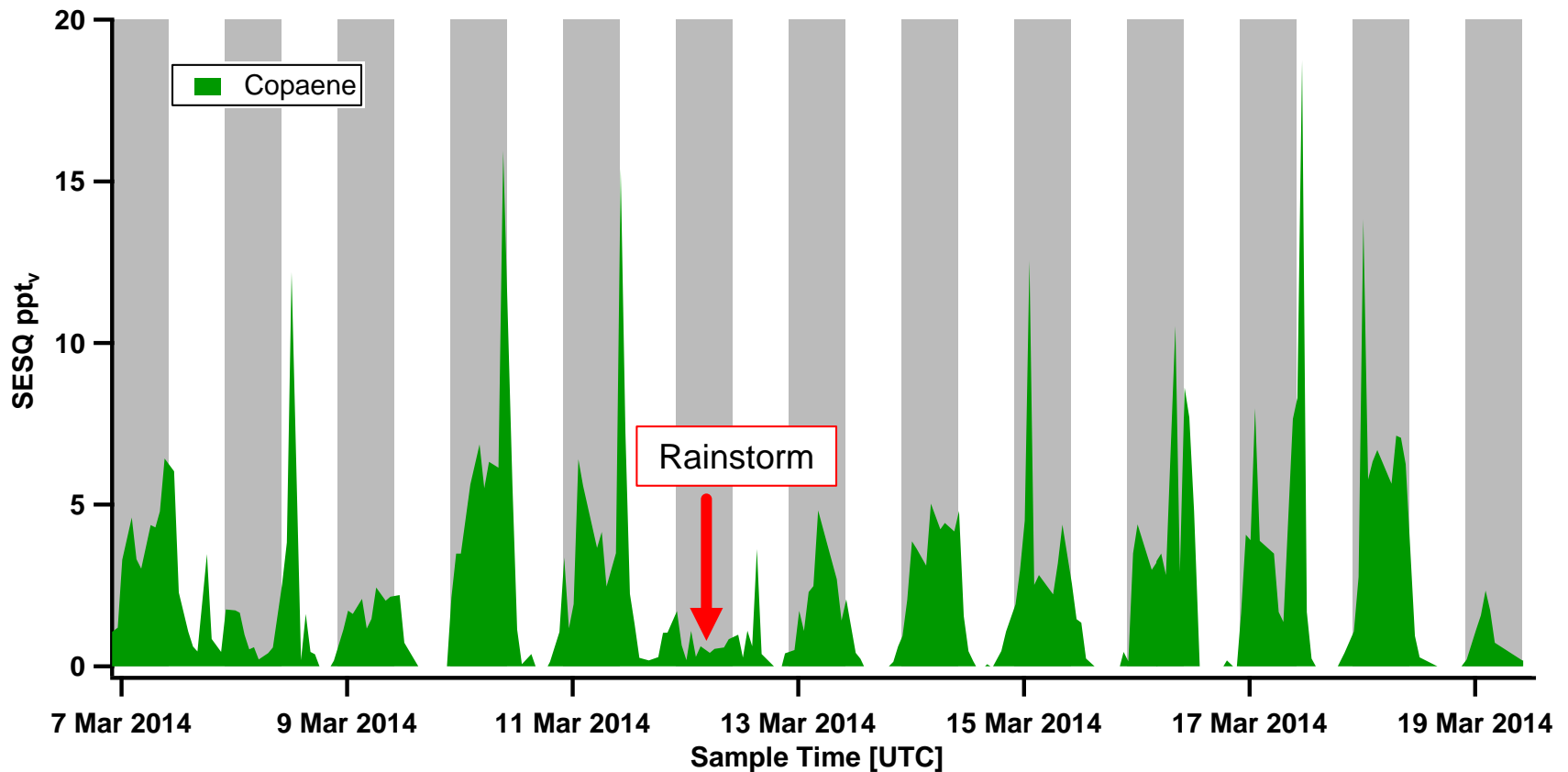


At 20 ppb O<sub>3</sub>: β-caryophyllene  $\tau_{O_3} < 3$  mins  
α-copaene  $\tau_{O_3} = 3.3$  hrs

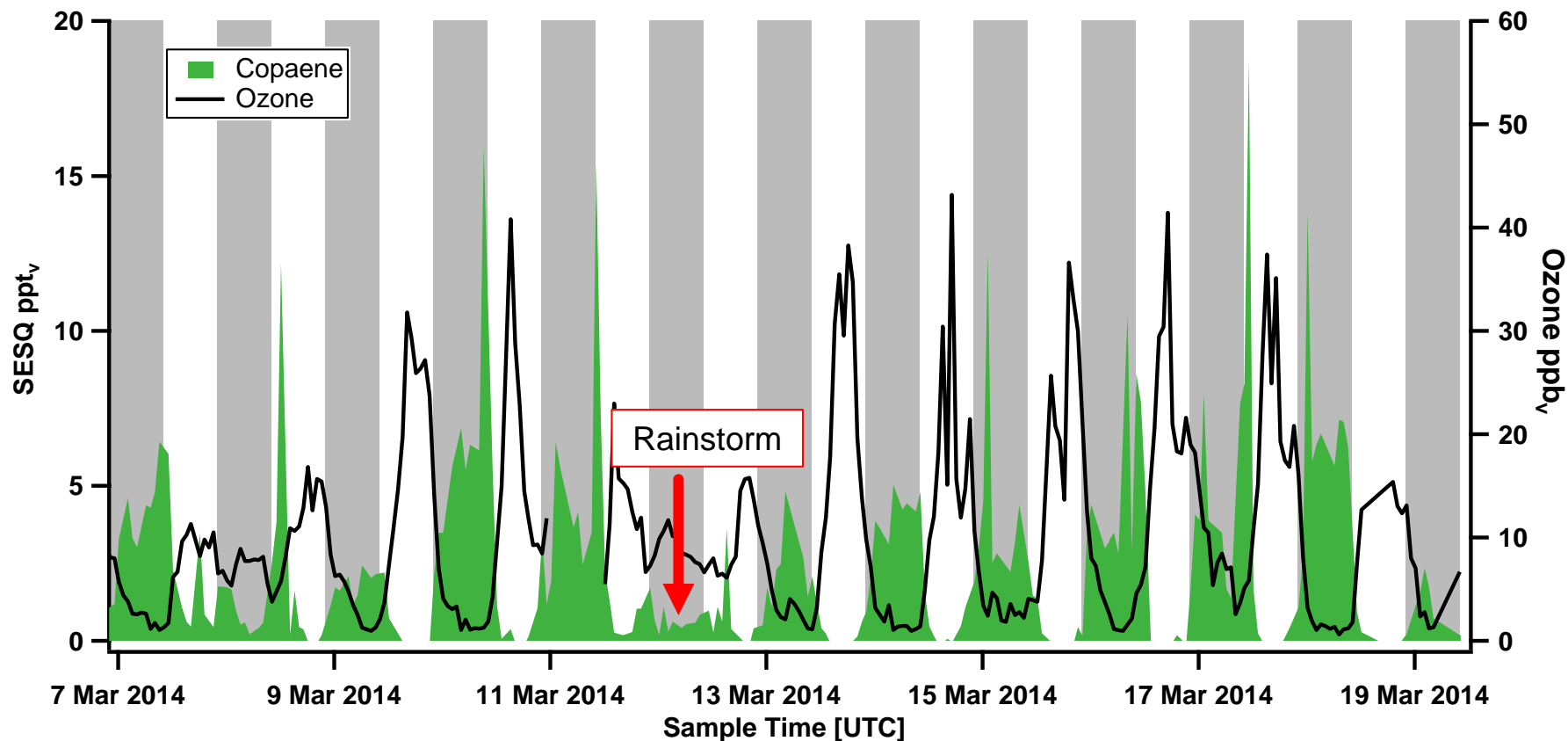
# Copaene as indicator for total sesquiterpenes



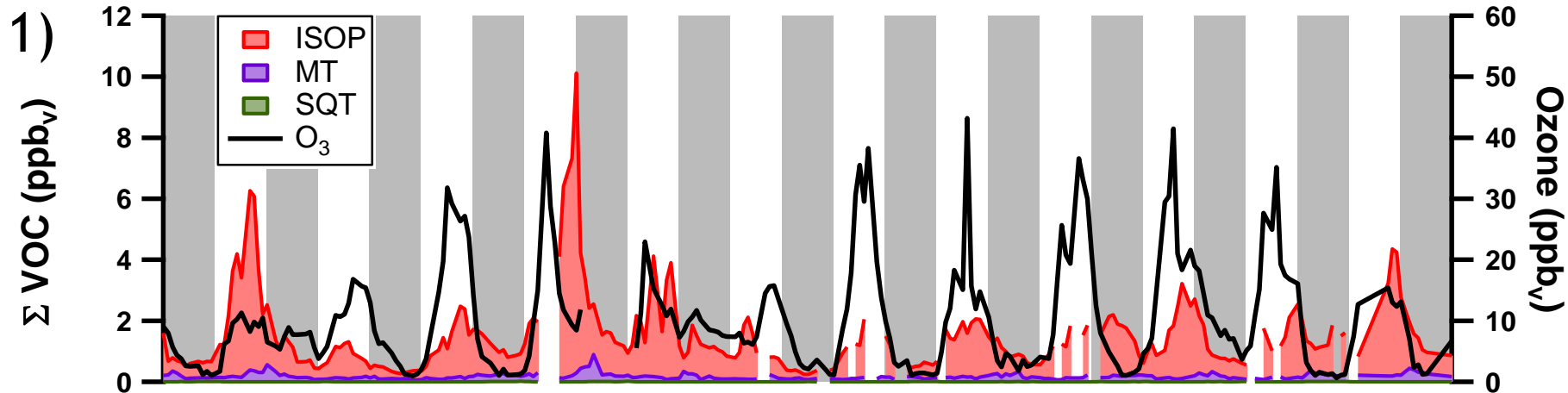
# Sesquiterpenes: high at night, very low in daytime



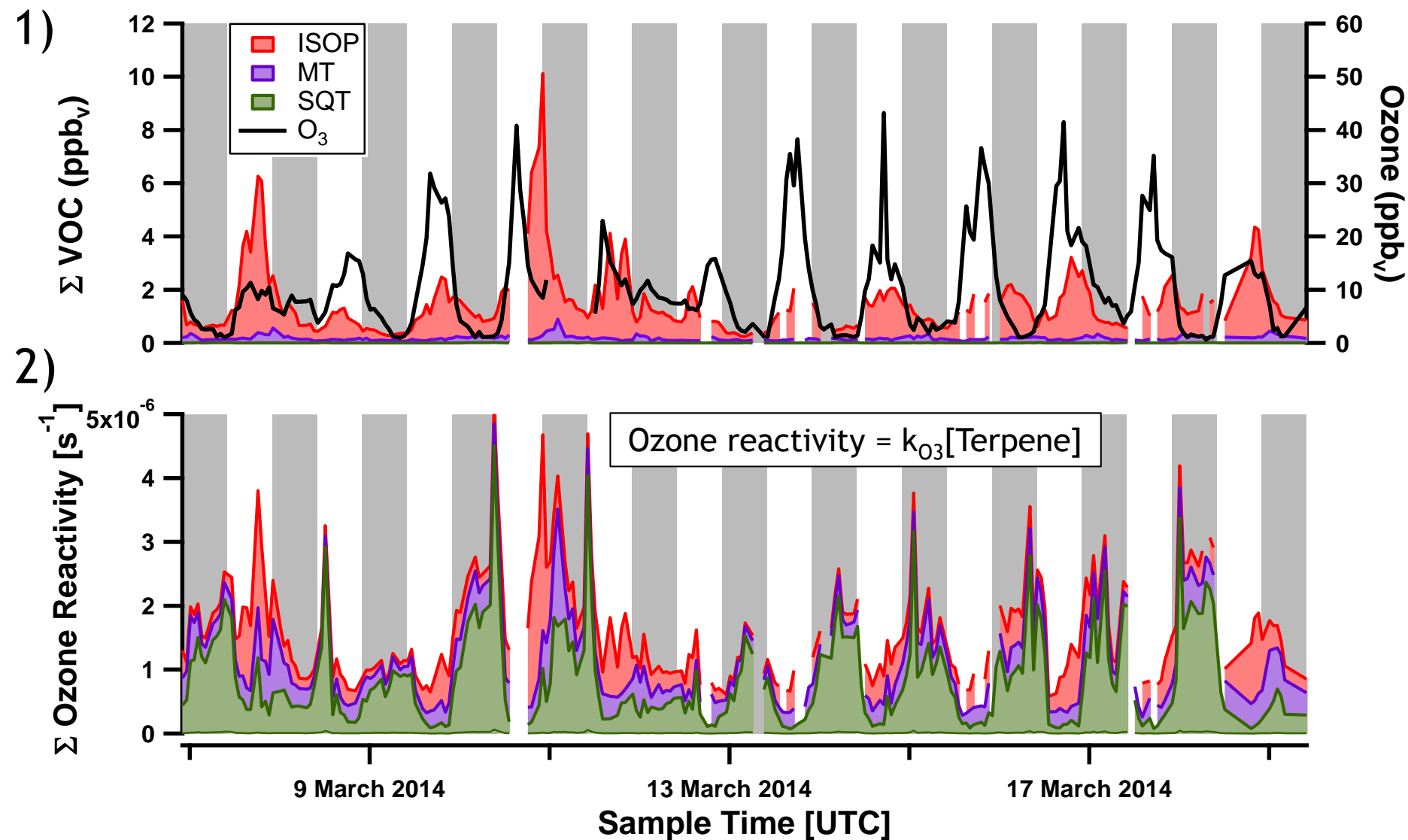
# Sesquiterpenes modulated by ozone



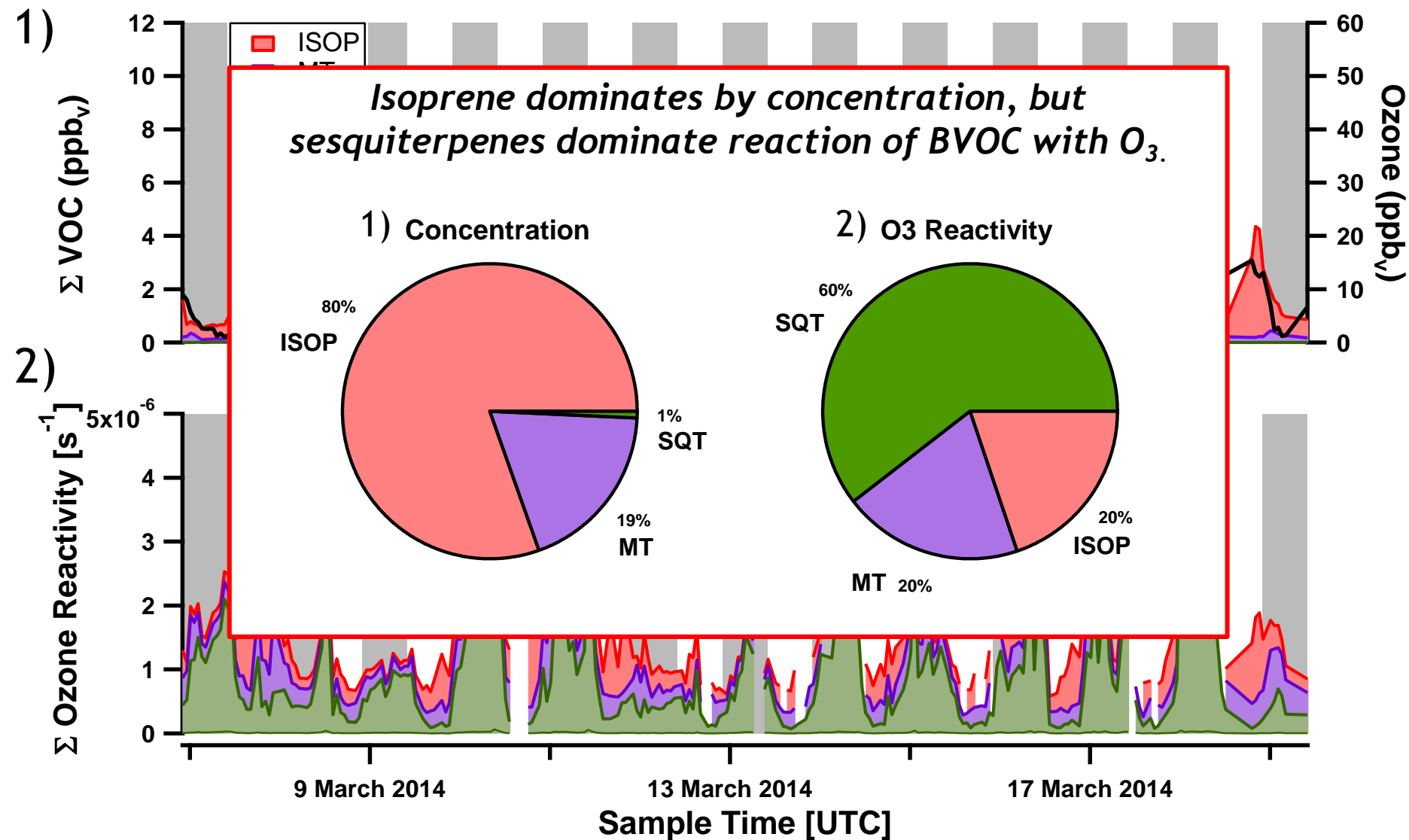
# 1) Conc. Isop > MT > SQT



## 2) Ozone reactivity $SQT > MT > ISOP$

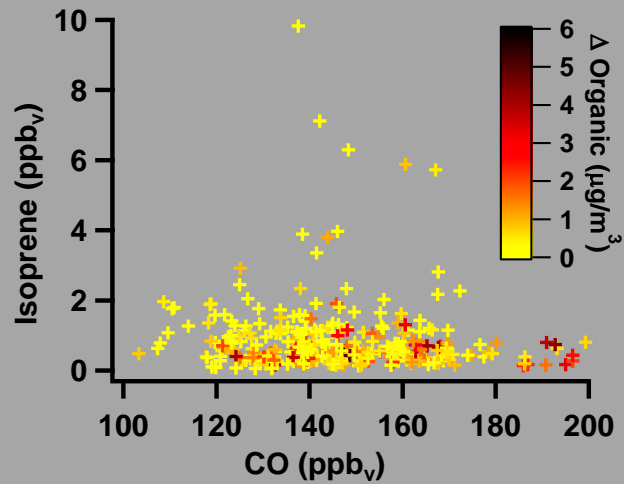


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# Organic aerosol enhancement by BVOC and CO

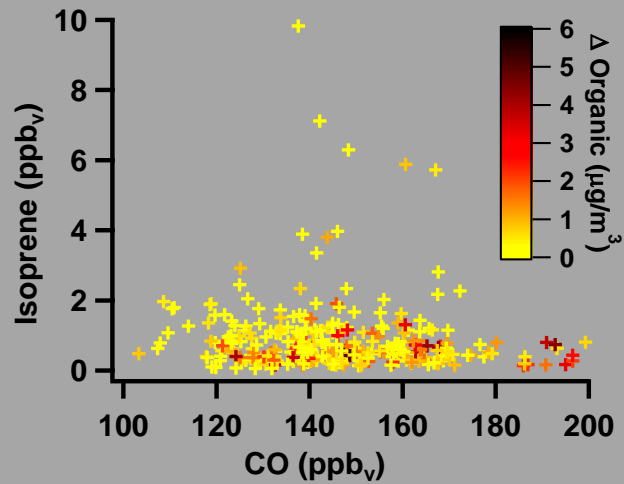
## Isoprene



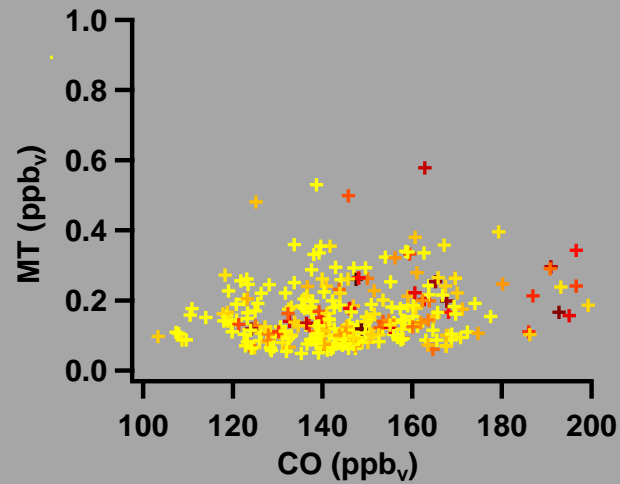


# Organic aerosol enhancement by BVOC and CO

## Isoprene

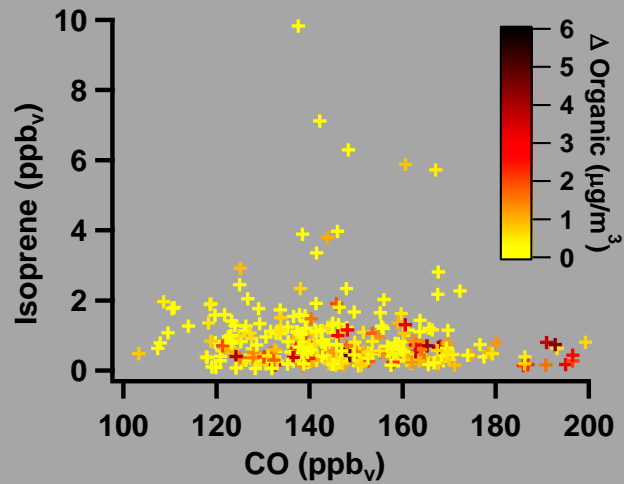


## Monoterpenes

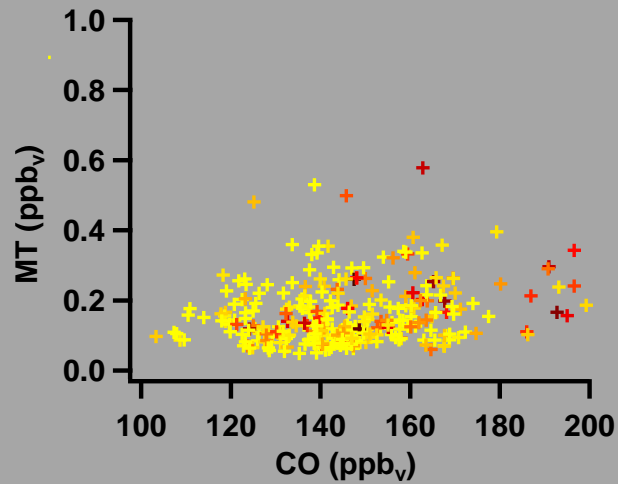


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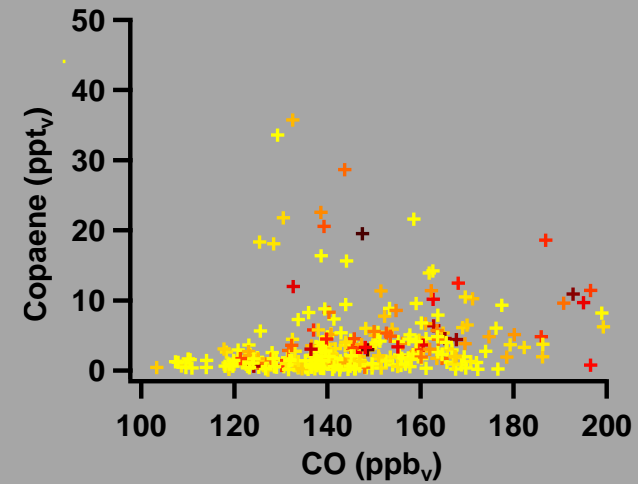
## Isoprene



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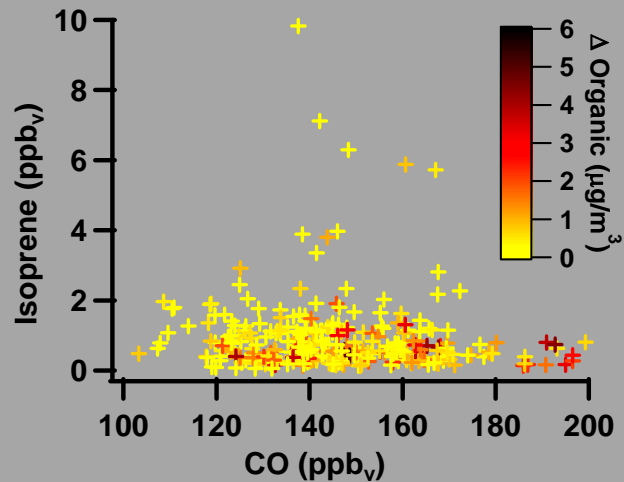


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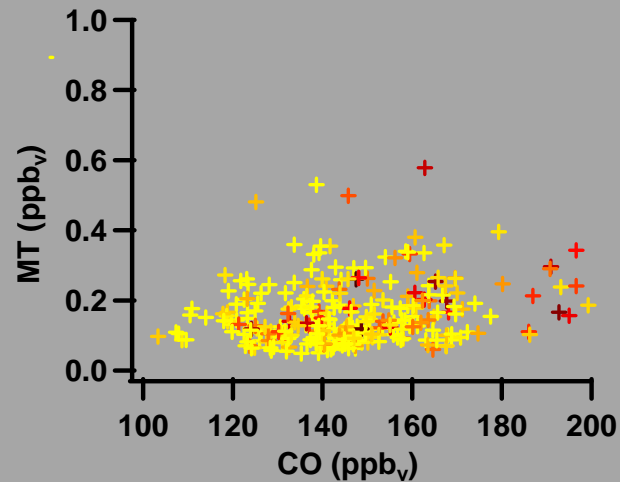


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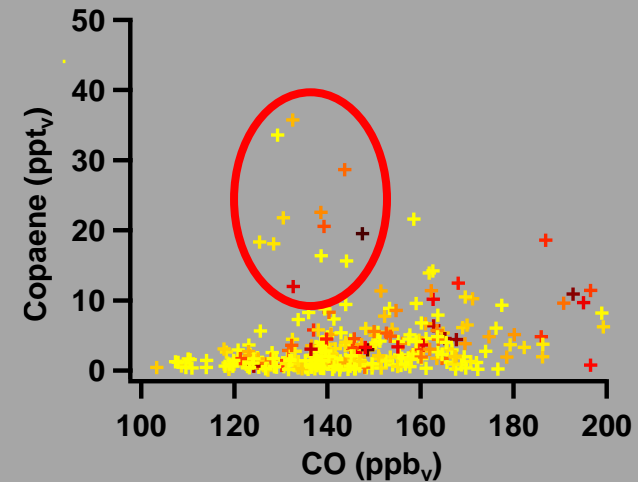
Isoprene



Monoterpenes



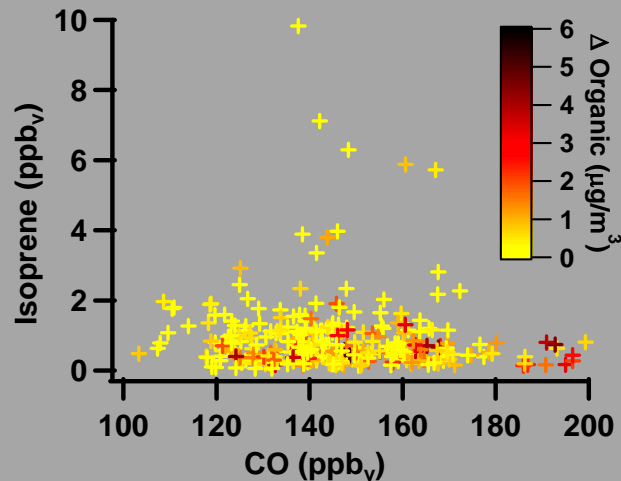
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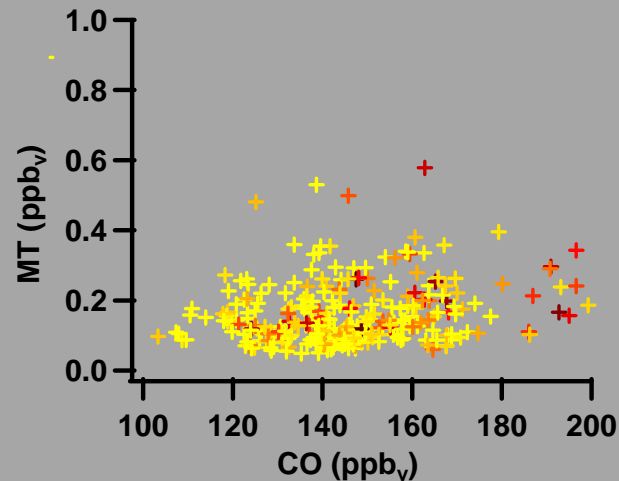
*High SQTs accompany enhanced organic production.*

# Organic aerosol enhancement by BVOC and CO

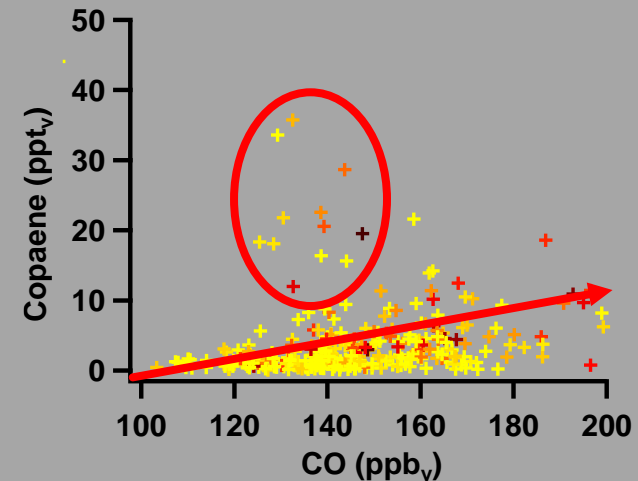
Isoprene



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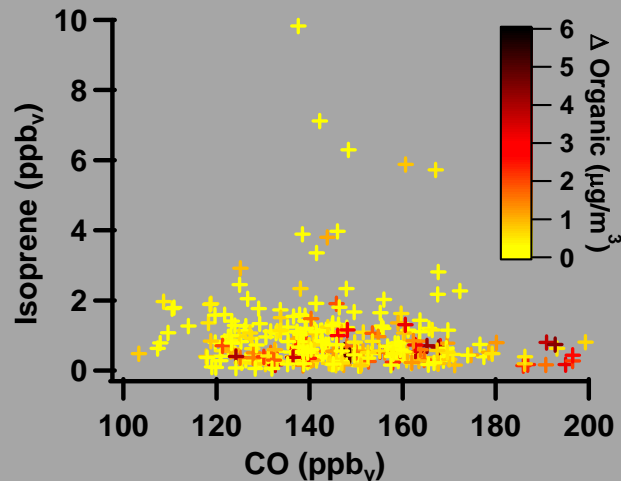
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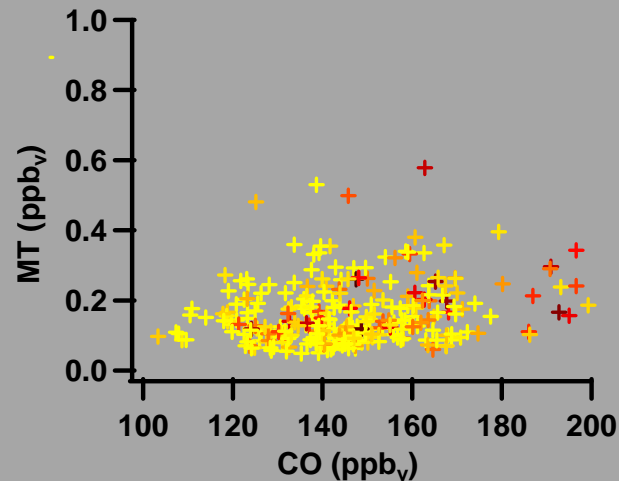
***High SQTs accompany enhanced organic production.  
High SQTs + High CO result in higher OFR enhancements.***

# Organic aerosol enhancement by BVOC and CO

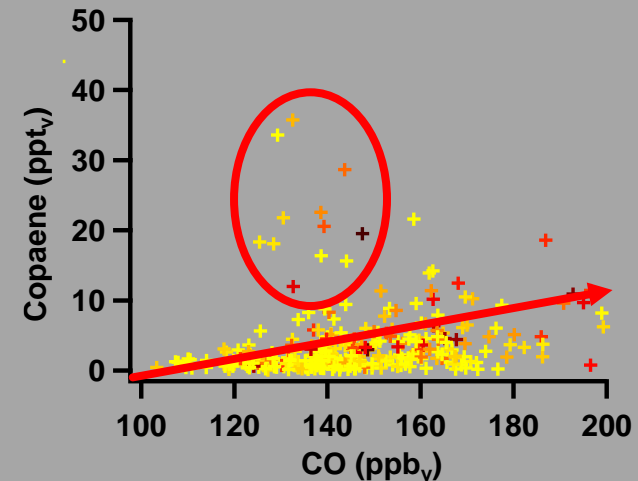
Isoprene



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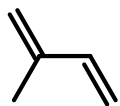


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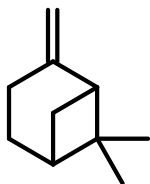


*High SQTs accompany enhanced organic production.  
High SQTs + High CO result in higher OFR enhancements.  
What chemical differences affect this?*

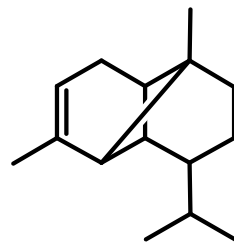
# Conclusions and *Future Work*



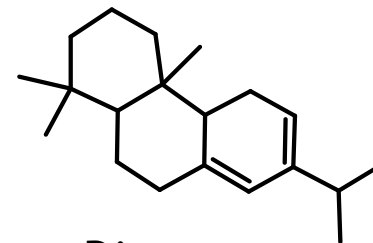
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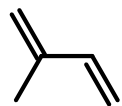


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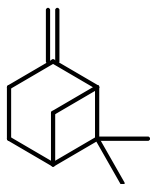


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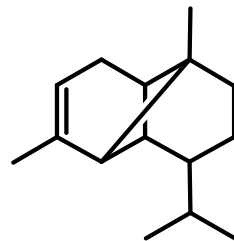
# Conclusions and *Future Work*



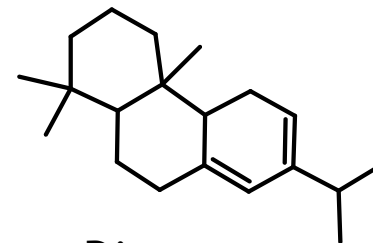
Isoprene  
 $C_5H_8$



Monoterpenes  
 $C_{10}H_{16}$



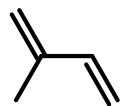
Sesquiterpenes  
 $C_{15}H_{24}$



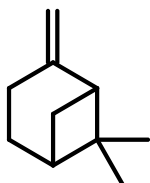
Diterpenes  
 $C_{20}H_{32}$

← Increasing concentration in the Amazon

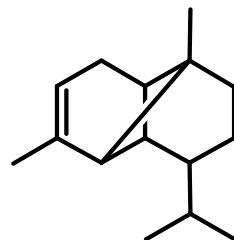
# Conclusions and *Future Work*



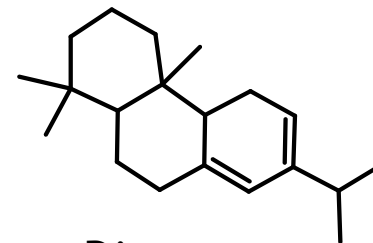
Isoprene  
 $C_5H_8$



Monoterpenes  
 $C_{10}H_{16}$



Sesquiterpenes  
 $C_{15}H_{24}$



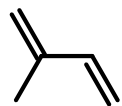
Diterpenes  
 $C_{20}H_{32}$

← Increasing concentration in the Amazon

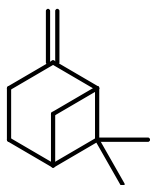
Increasing reactivity and chemical diversity →



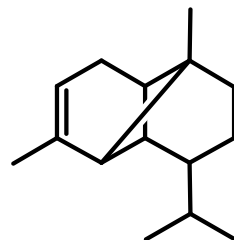
# Conclusions and *Future Work*



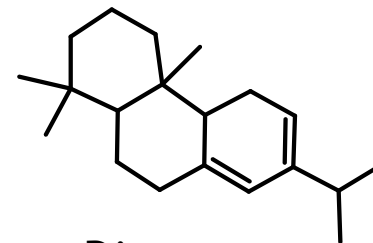
Isoprene  
 $C_5H_8$



Monoterpenes  
 $C_{10}H_{16}$



Sesquiterpenes  
 $C_{15}H_{24}$



Diterpenes  
 $C_{20}H_{32}$

← Increasing concentration in the Amazon

Increasing reactivity and chemical diversity →

← Increasing contribution to ambient SOA formation? →