

US EPA ARCHIVE DOCUMENT

Project Review

A Coupled Measurement-Modeling Approach to Improve Biogenic Emission Estimates: Application to Future Air Quality Assessments

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RTP, NC
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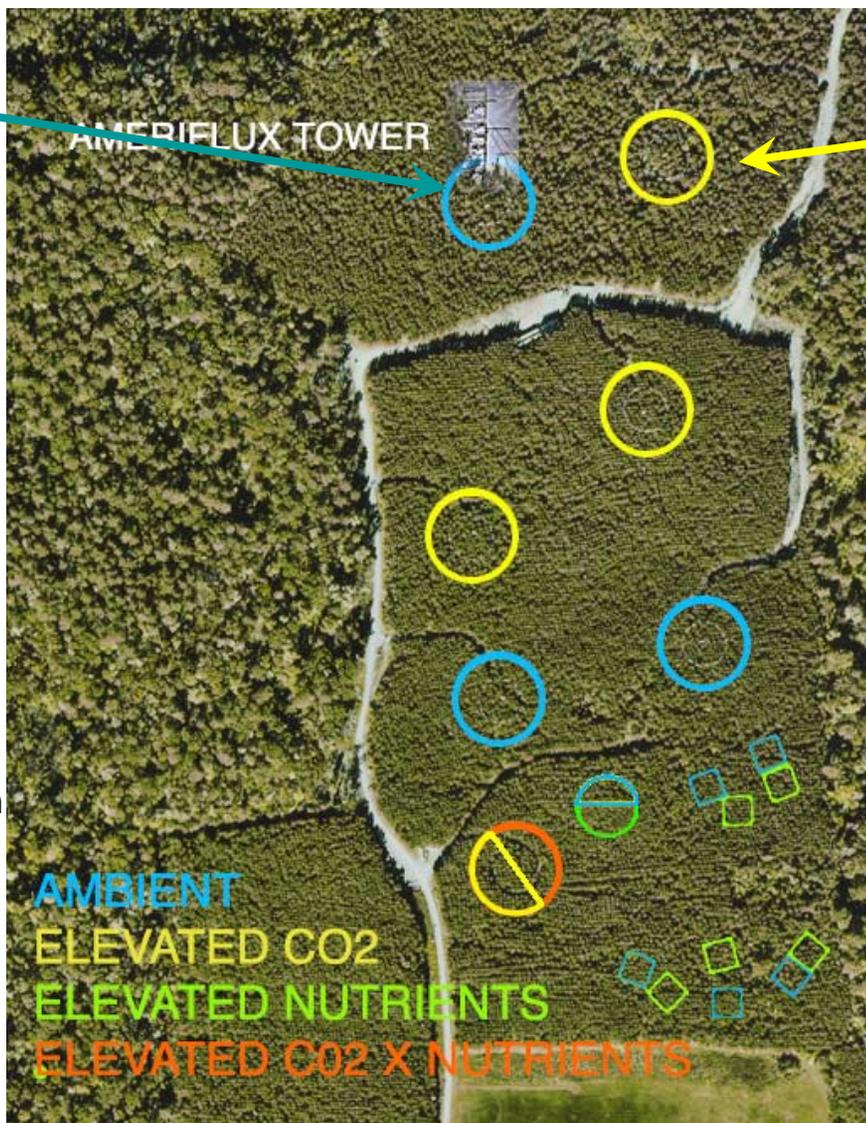
Objectives

- To predict changes in climate that influence biogenic emissions and air quality.
- To quantify the impact of climate change on plant ecosystem composition.
- To estimate the impact of a changing plant ecosystem on biogenic emissions.
- To estimate the impact of changes in regional climate and plant ecosystem on aerosol loading, O₃, NO_x, hydrocarbons, and the oxidative capacity of the atmosphere.

TRACK I: CO₂ ENRICHMENT RESEARCH – Measurements at the Duke Forest FACTS-I site

Ring 1
Ambient CO₂

Ring 2
Elevated CO₂
(Ambient+200 ppmv)



Measurements at Duke Forest

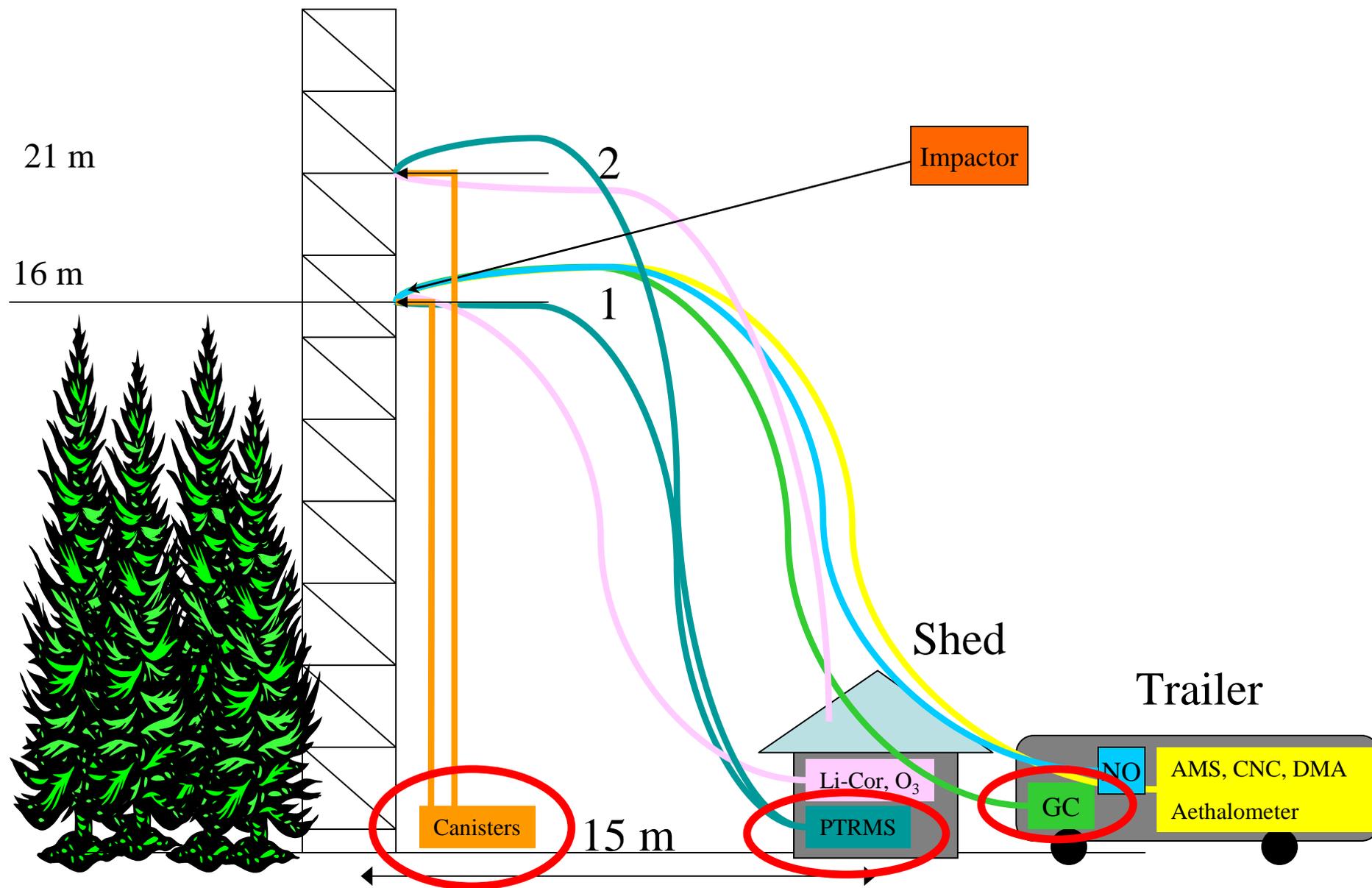
NMHCs
Halocarbons
Alkyl Nitrates
OVOCs
O₃
NO
CO₂
H₂O

SOA & POA – number density,
size distribution and composition
(AMS, CN, filters)
Black Carbon
Met Data

3 Field Campaigns

1. Canopy:
September 2004
2. Vegetation and
Soil: June 2005
3. Soil:
September 2005

Trace Gas Measurements: September 2004



Vegetation Flux Measurements: June 2005



Loblolly Pine
(*Pinus taeda*)

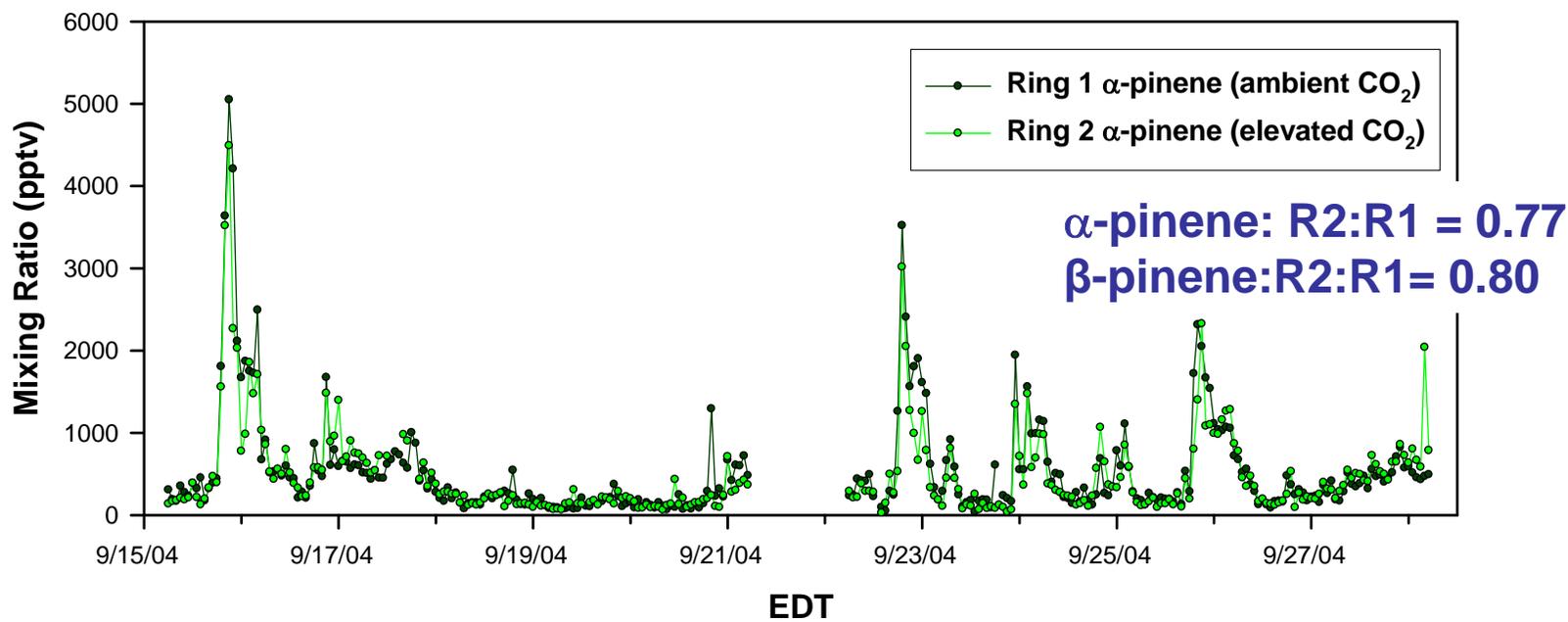
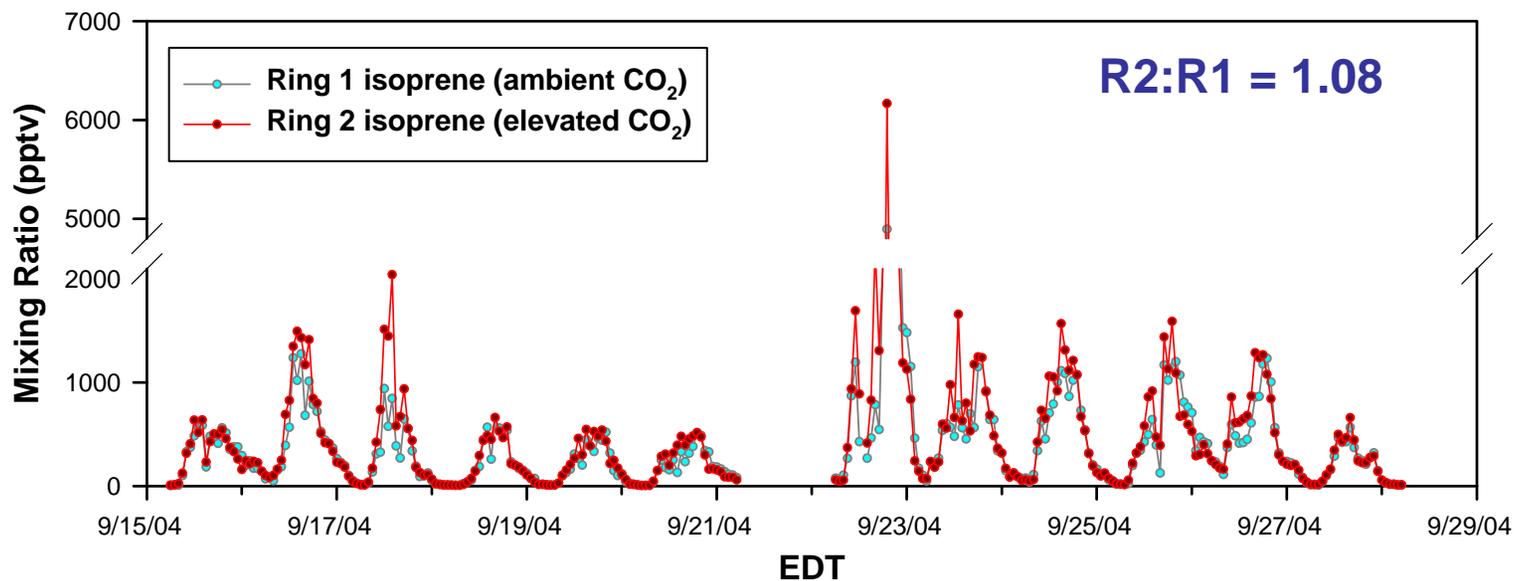
Branch enclosure
measurements made
every 2 hours over 2 day
period for each species.

Sweet Gum
(*Liquidambar styraciflua*)

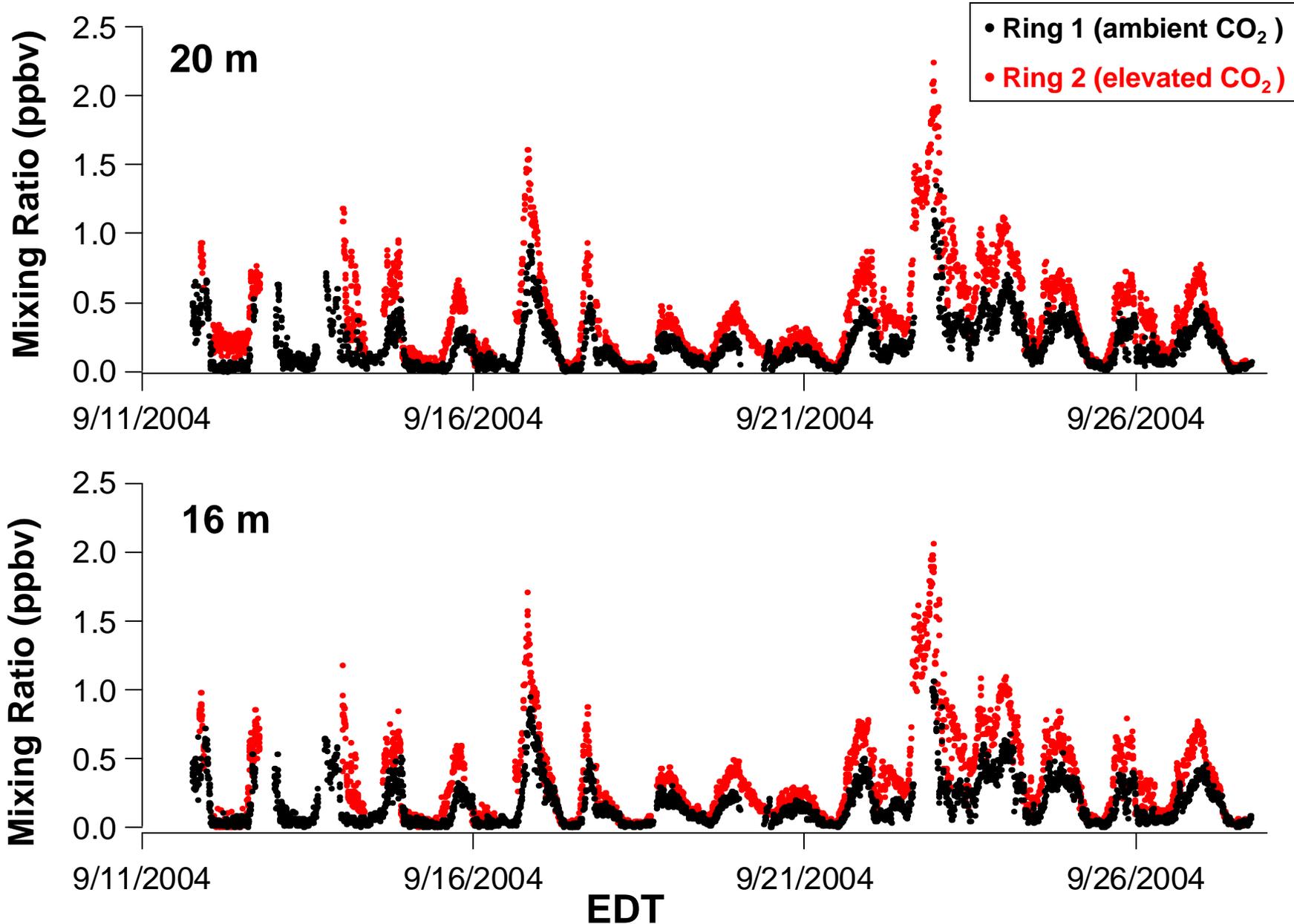


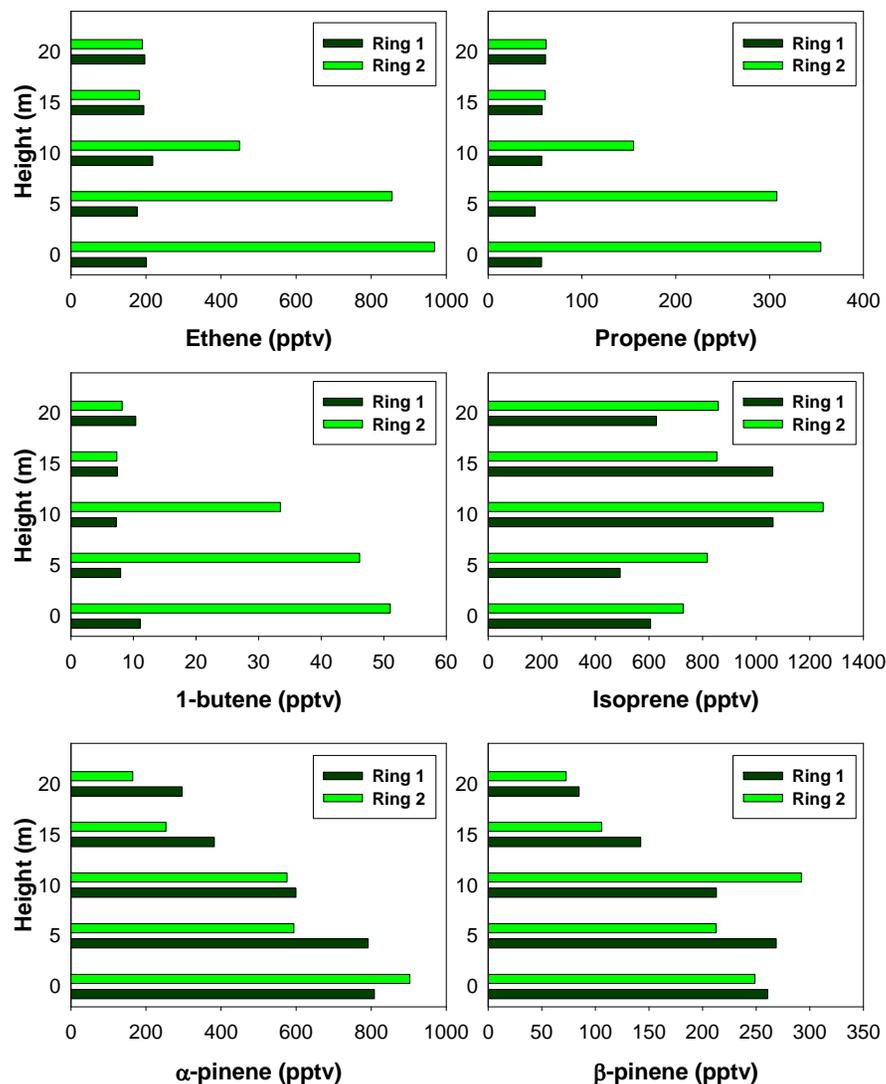
Soil Fluxes: June and September 2005



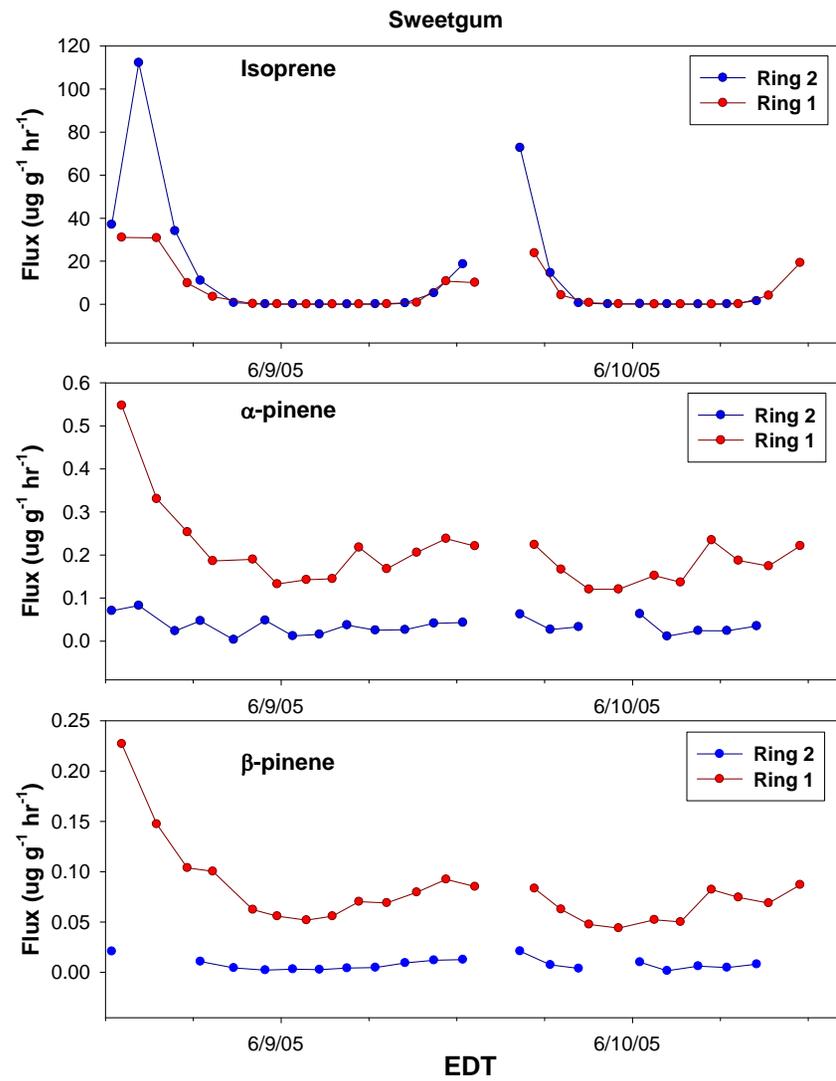
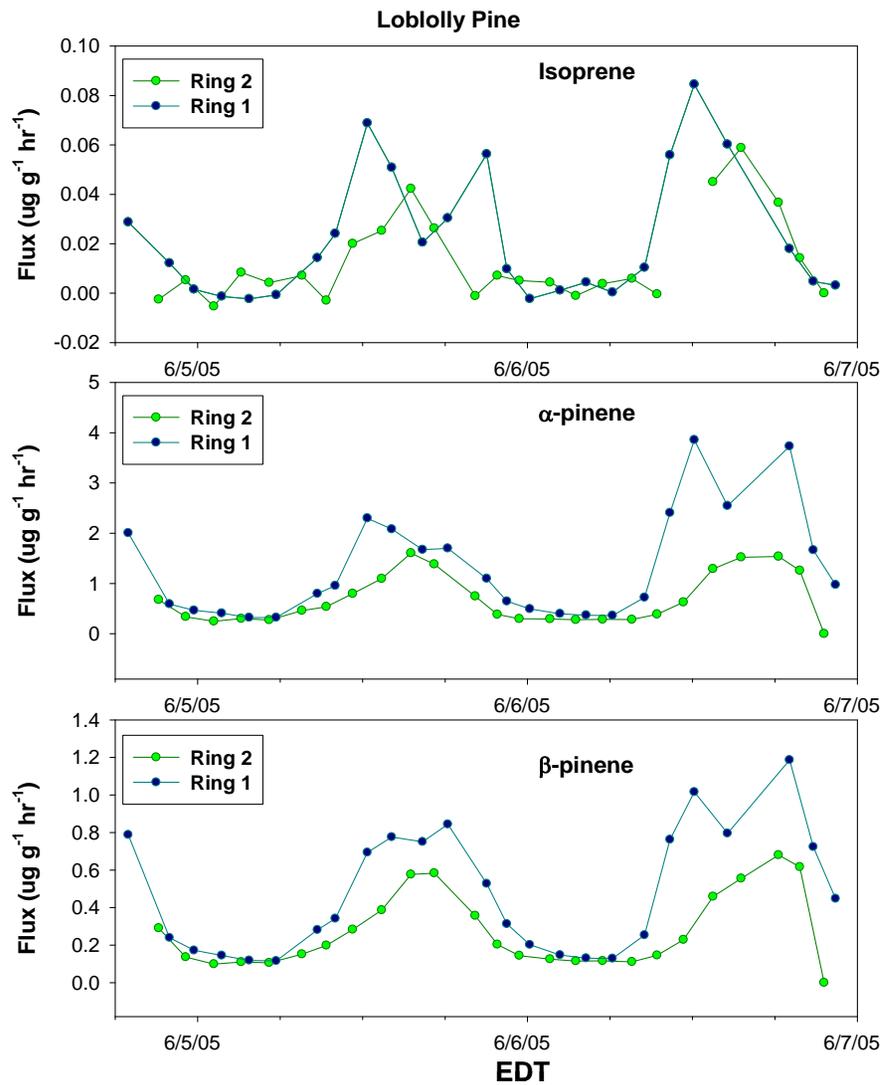


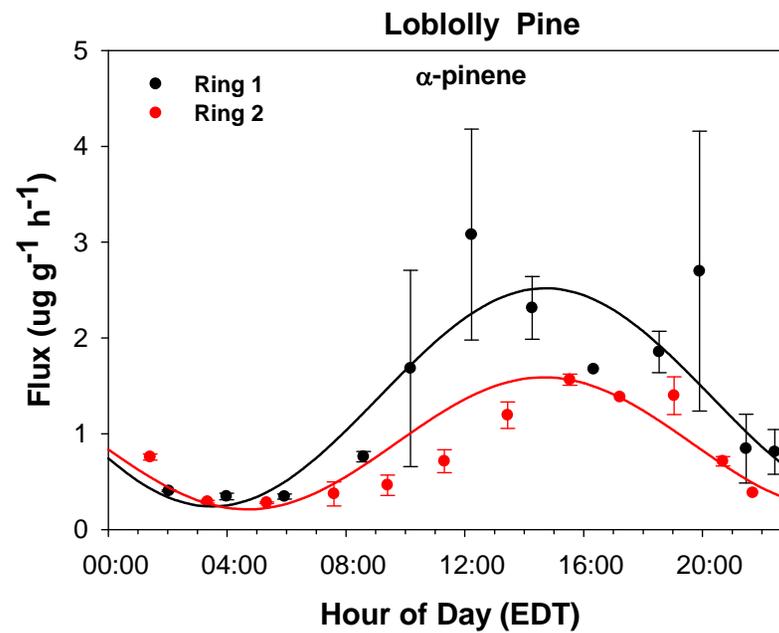
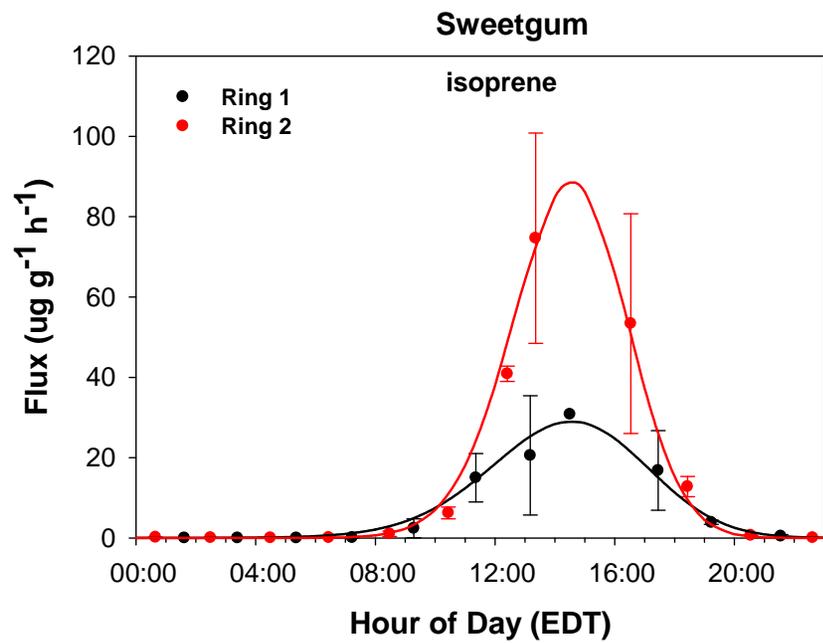
PTR-MS MVK + MACR





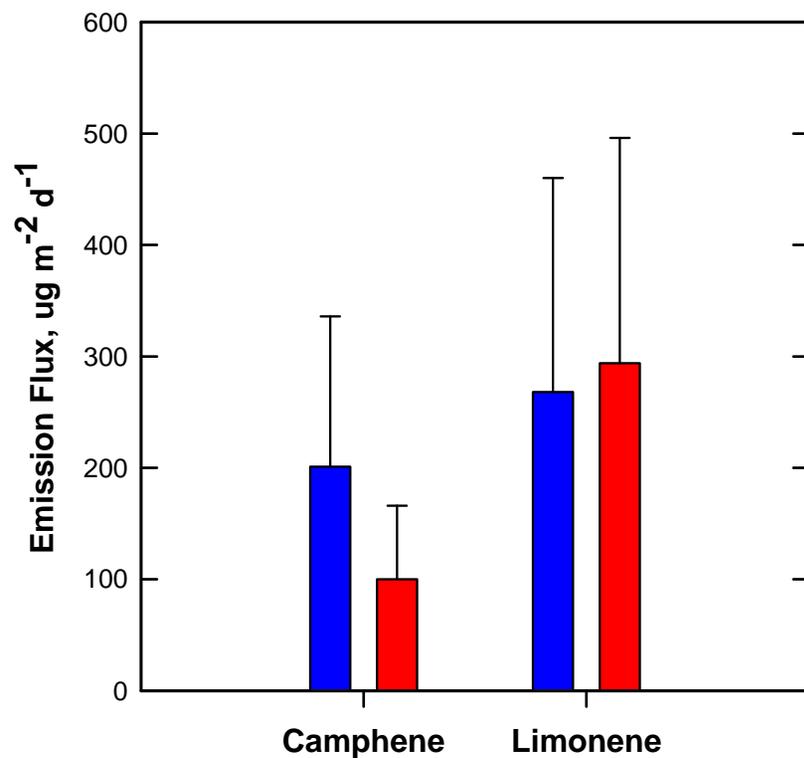
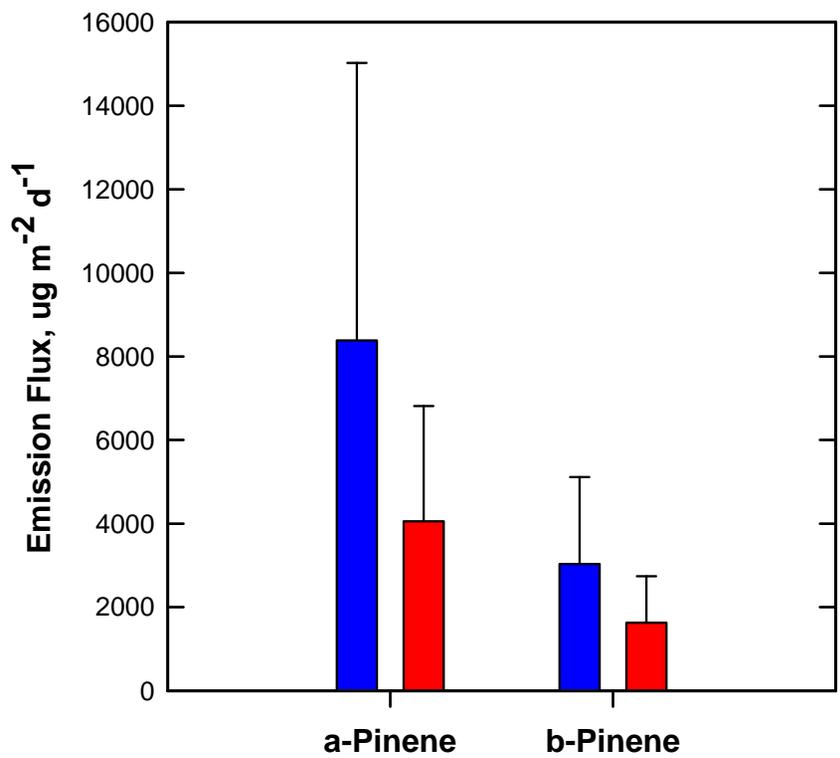
- Below-canopy profiles of a suite of VOCs measured.
- Source of reactive alkenes in the lower forest canopy/soil in the elevated CO₂ ring.
- Some uptake of isoprene near the surface.
- Possible soil emissions of terpenes.





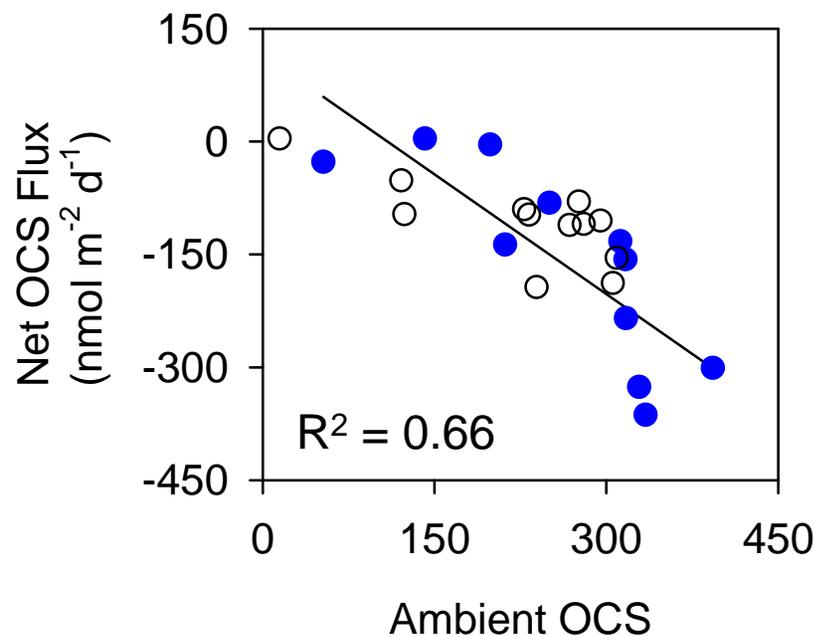
Duke Forest - Loblolly Pine

377 ppmv CO2
600 ppmv CO2

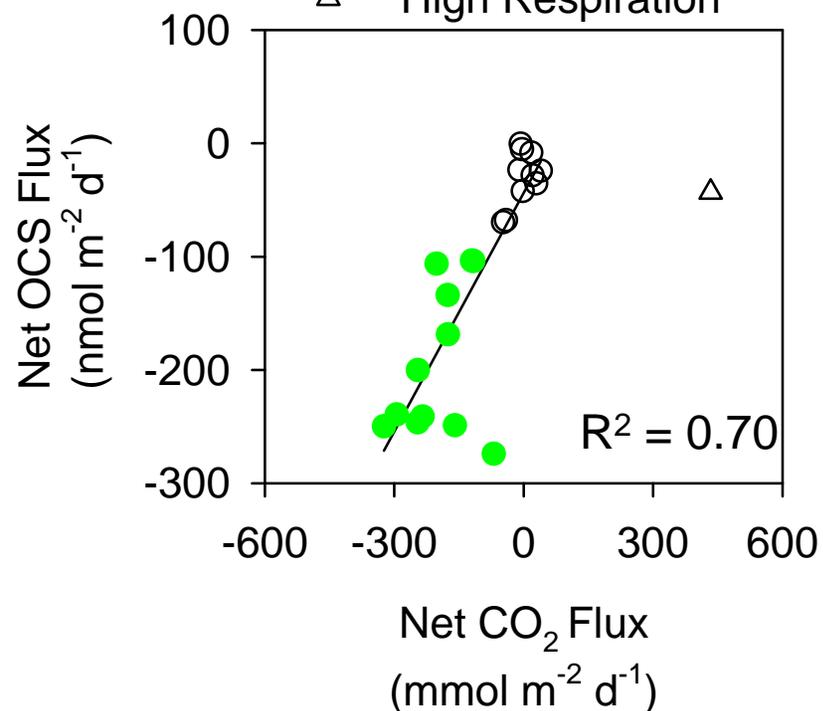


Ring 2: Loblolly Pine

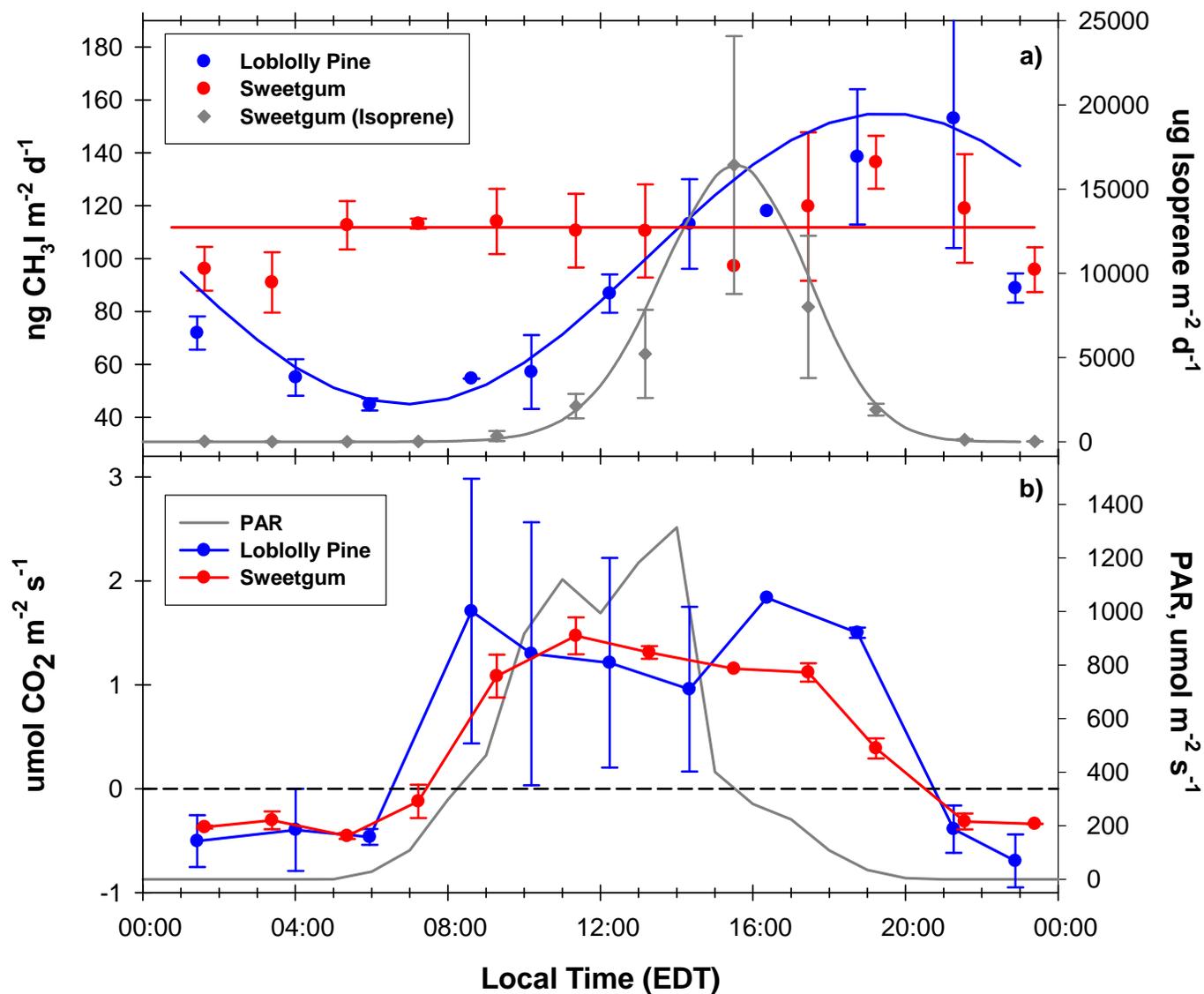
- PAR > 10 $\mu\text{mol m}^{-2} \text{s}^{-1}$
- PAR < 10 $\mu\text{mol m}^{-2} \text{s}^{-1}$

**Ring 2: Sweetgum**

- PAR > 10 $\mu\text{mol m}^{-2} \text{s}^{-1}$
- PAR < 10 $\mu\text{mol m}^{-2} \text{s}^{-1}$
- △ High Respiration



OCS uptake is tree species-dependent: ambient OCS level for Loblolly pine and net CO_2 flux for sweetgum.



Emissions of CH_3I from the two tree species were comparable, but with a distinct diurnal cycle from Loblolly Pine and none from Sweetgum (emission not stomatally driven). *Sive et al. [2007]*

Key Points from Vegetation and Soil Flux Measurements

Loblolly Pine

Emission fluxes of α -pinene, β -pinene, & camphene ~50% lower under enhanced CO₂ conditions ($p = 0.01$).

OCS uptake is tree species dependent: it increases with the ambient OCS level.

Sweetgum

β -pinene emission flux ~200% lower under enhanced CO₂ conditions ($p = 0.01$).

OCS uptake is tree species dependent: it decreases with enhanced CO₂.

*Limonene emission fluxes were not significantly different between the two CO₂ environments for either tree species.

*Terrestrial vegetation and soils make a significant contribution to CH₃I regional and global budgets.

*CO₂ enrichment does not have a significant effect on CH₃Cl or CH₃Br exchange.

Soil

Wide spatial and temporal variability in soil fluxes.

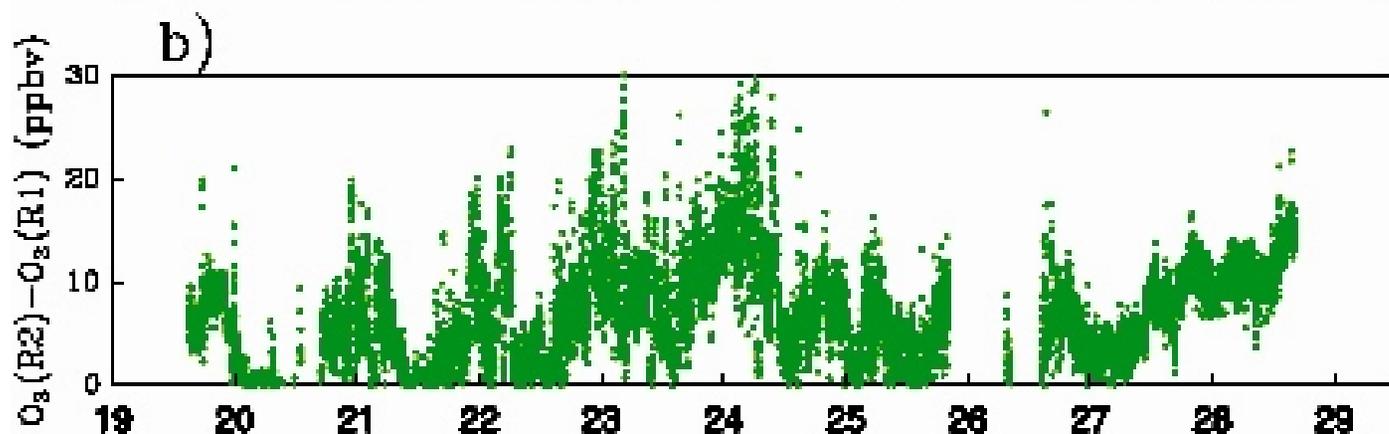
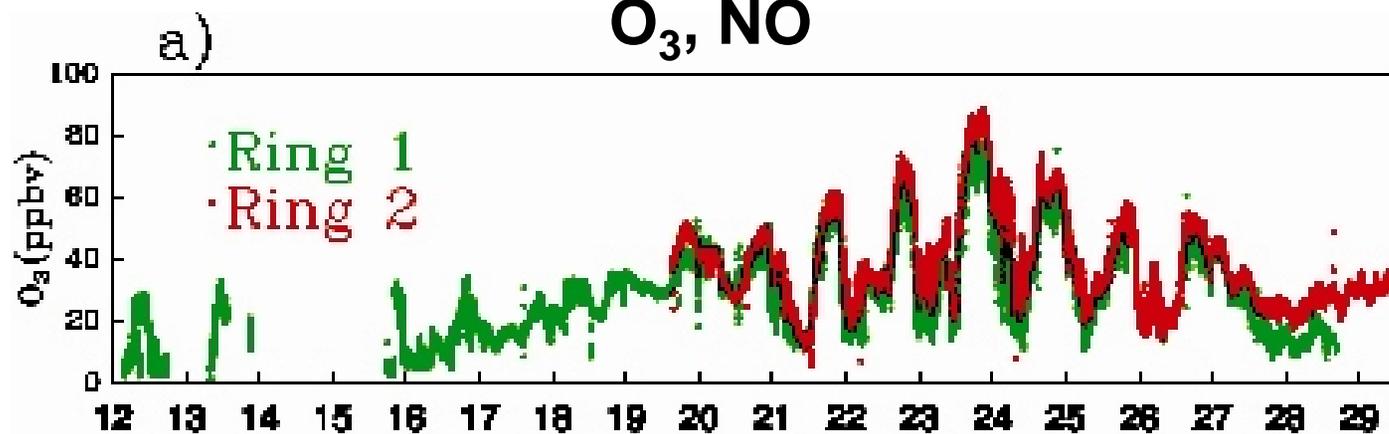
Propane & camphene emissions fluxes were ~150% higher from wet (soaked) compared to dry soils.

β-pinene emission was equal to its flux from Sweetgum (10% of Loblolly).

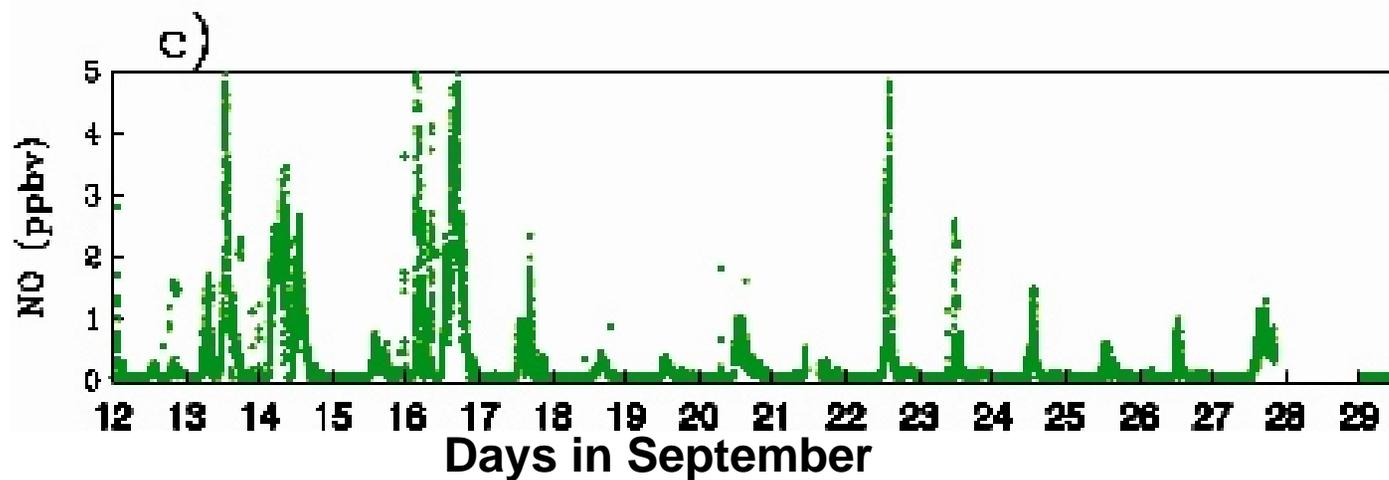
Soils were both a net source and sink of CH₃Br and CH₃Cl.

No significant difference for any trace gas between the present versus future CO₂ conditions.

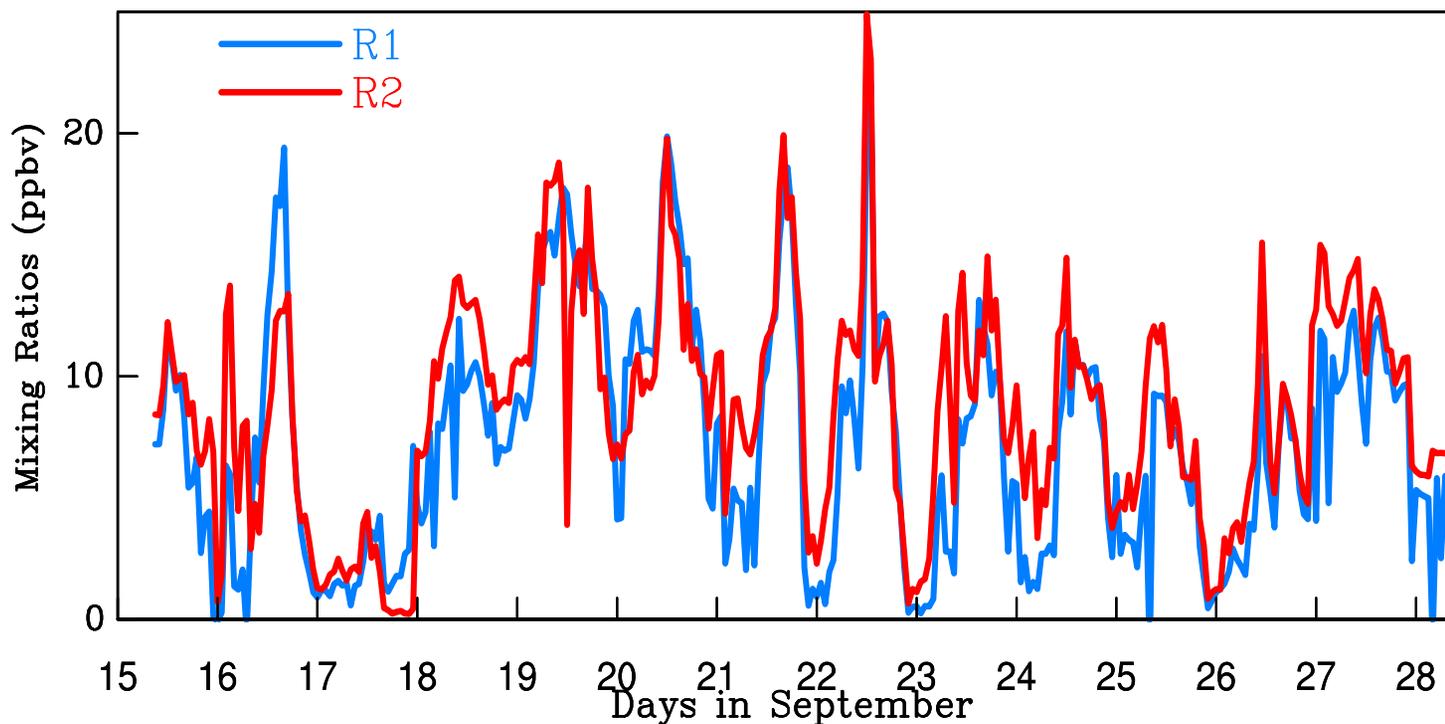
O₃, NO



R2-R1:
6.4±5.5 ppbv



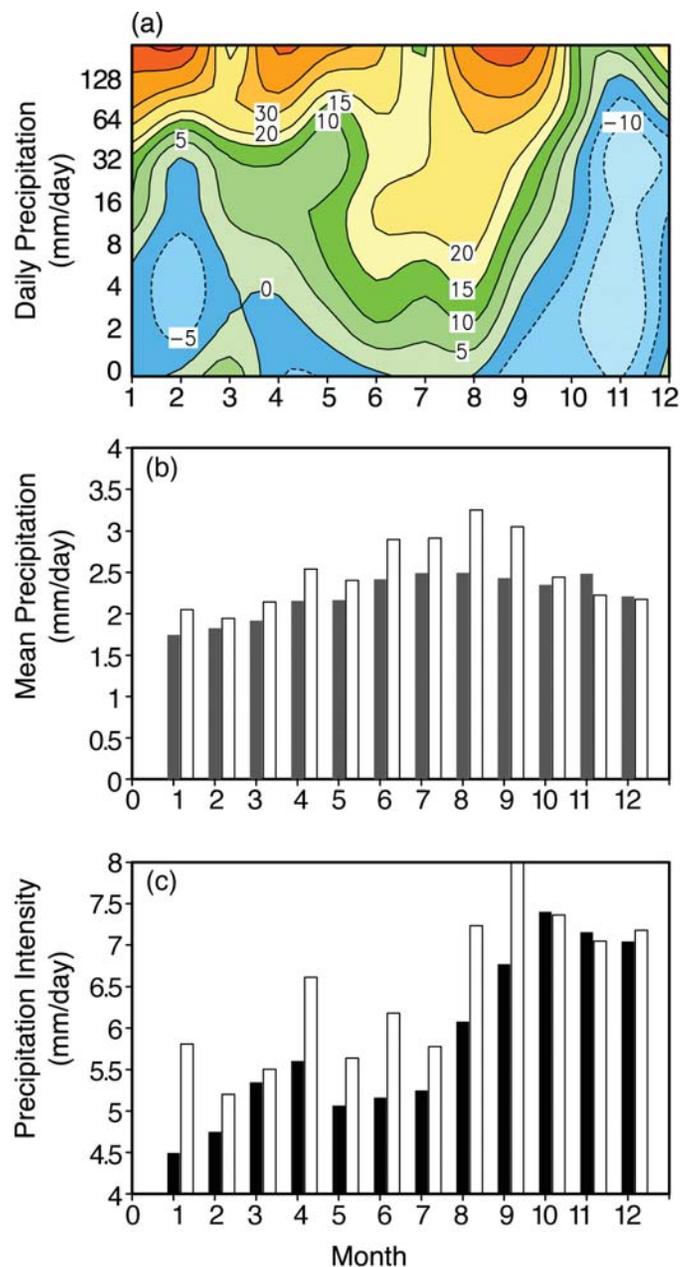
MM Simulated O₃ Mixing Ratios



1. Box model results show that O₃ levels in Ring 2 were increased by 2.4 ppbv \pm 2.0 ppbv on average.
2. Ozone uptake by vegetation was increased in Ring 2 by 0.5 \pm 0.3 ppbv hr⁻¹ on average compared to Ring 1 using the sap flux measurements.
3. Overall, model only captured 37% of the observed O₃ increases in Ring 2. Compounds are missing from our VOC measurements that likely contributed to O₃ production.

Mao et al. [2007]

TRACK II – Regional Climate and Air Quality Assessment



For a future climate with doubled CO₂:

1. More convective precipitation, with a higher intensity across the U.S.
2. Heavy precipitation events should become more frequent, and be distributed over fewer days with larger daily amounts.
3. The mean length of the drying period should increase from 1.78 days at present to 1.92 days, and the domain-wide maximum extended from 34 to 40 days.
4. The probability of flooding and droughts should increase in the future.

Chen et al. [2005]

CMAQ OA Module Improvement Replacing SORGAM with MPMPO

Date (EST)	Data points	Mean Observation ($\mu\text{g m}^{-3}$)	Mean Prediction ($\mu\text{g m}^{-3}$)		MNGE		MNB	
			CACM /MPMPO	CB4 /SORGAM	CACM /MPMPO	CB4 /SORGAM	CACM /MPMPO	CB4 /SORGAM
08/03/2004	117	20.1	14.6	14.7	0.37	0.37	-0.23	-0.22
08/04/2004	117	21.0	15.1	15.3	0.38	0.39	-0.25	-0.24

Species	Data points	Mean observation ($\mu\text{g m}^{-3}$)	Mean prediction ($\mu\text{g m}^{-3}$)		Mean normalized gross error (MNGE)		Mean normalized bias (MNB)	
			CACM /MPMPO	CB4 /SORGAM	CACM /MPMPO	CB4 /SORGAM	CACM /MPMPO	CB4 /SORGAM
PM _{2.5}	45	16.70	13.70	14.10	0.33	0.36	-0.17	-0.15
Sulfate	44	7.13	7.98	8.55	0.52	0.60	0.32	0.39
Nitrate	44	0.28	0.19	0.18	1.34	1.23	-0.06	-0.03
Ammonium	15	2.73	2.74	2.71	0.14	0.15	0.03	0.02
EC	44	0.80	0.39	0.39	0.52	0.52	-0.45	-0.45
OC	44	3.82	1.26	1.18	0.66	0.69	-0.66	-0.69

Chen et al. [2006]

Future Climate Change and Its Impact on Air Quality

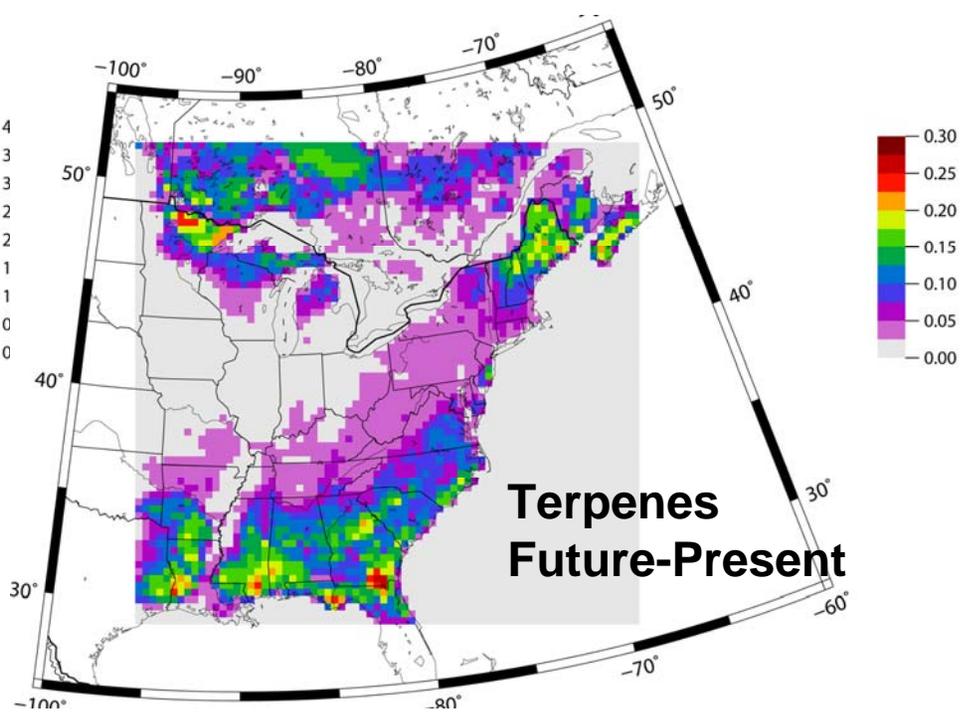
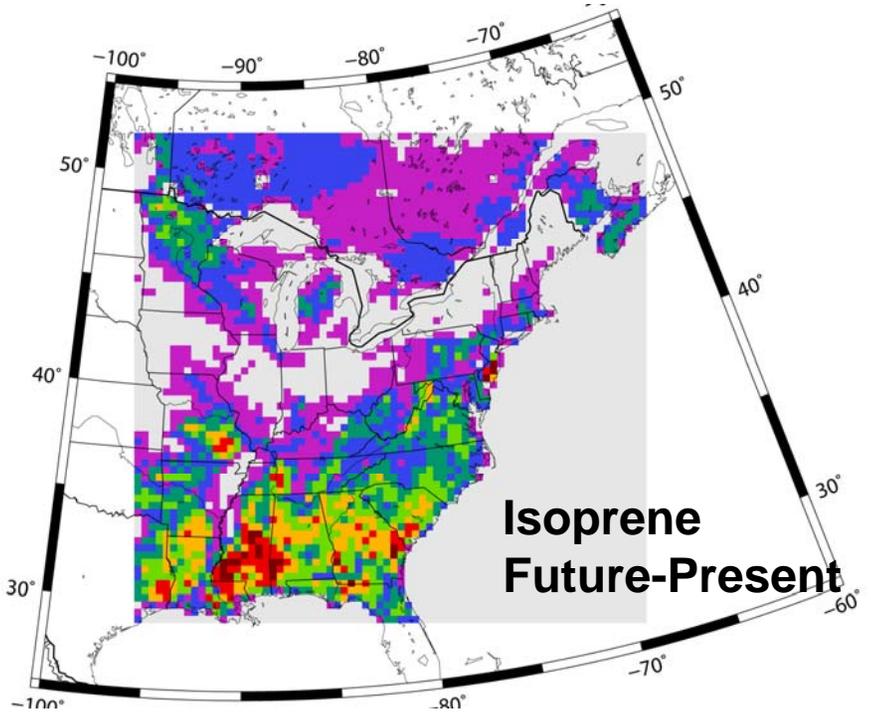
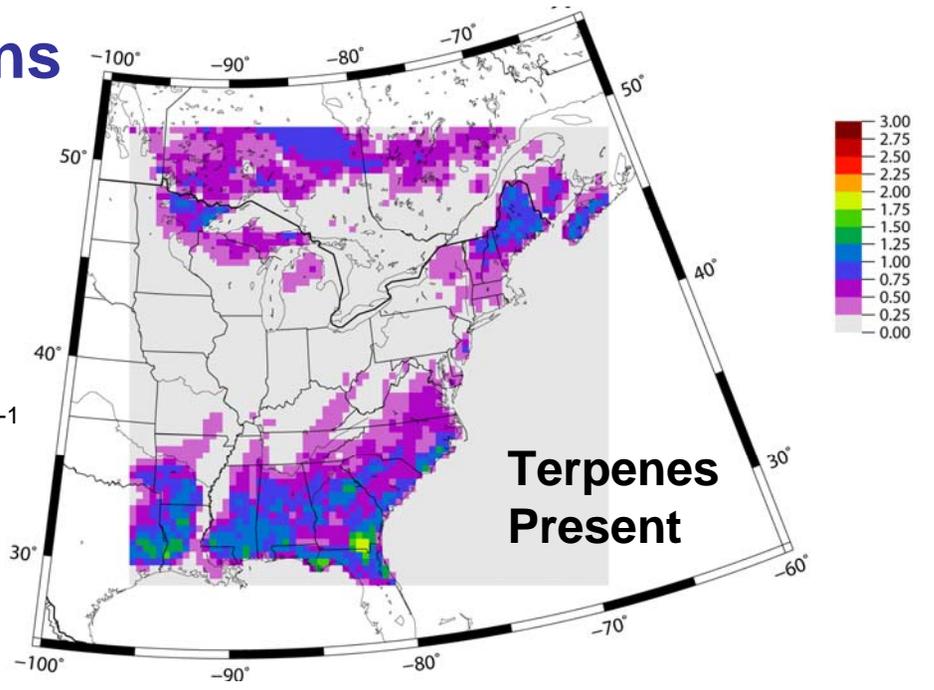
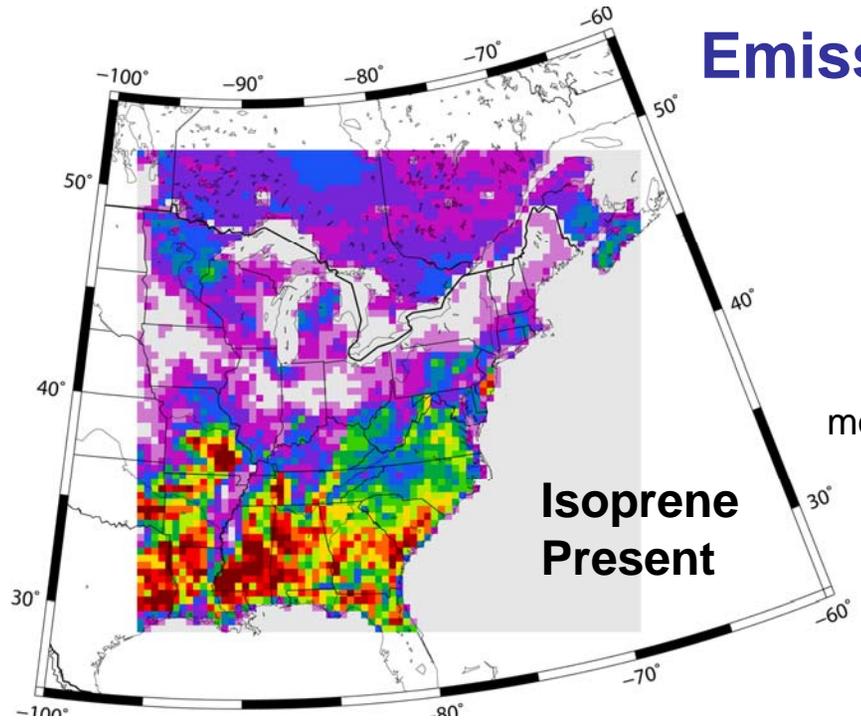
Future Projection of Global and US Emissions

IPCC A2	2000	2090	Change (%)
VOCs (Tg yr ⁻¹)	141	309	120
NO _x (Tg(N) yr ⁻¹)	32	98	207
VOCs (OECD90)	40	52	29
NO _x (OECD90)	13	18	38

Simulations

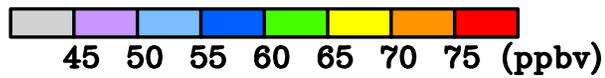
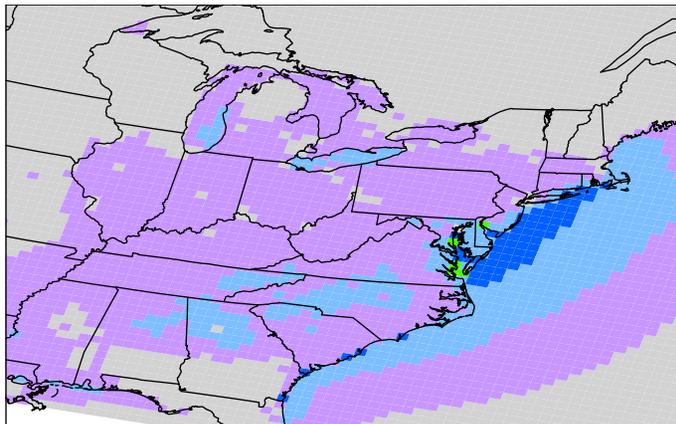
	Present	Future-F1	Future-F2	Future-F3	Future-F4
Climate	P	F	F	F	P
Emissions	P	F	F	P	F
BC	P	F	P	F	F

Emissions

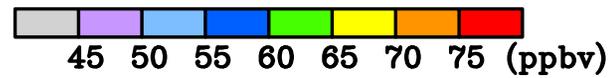
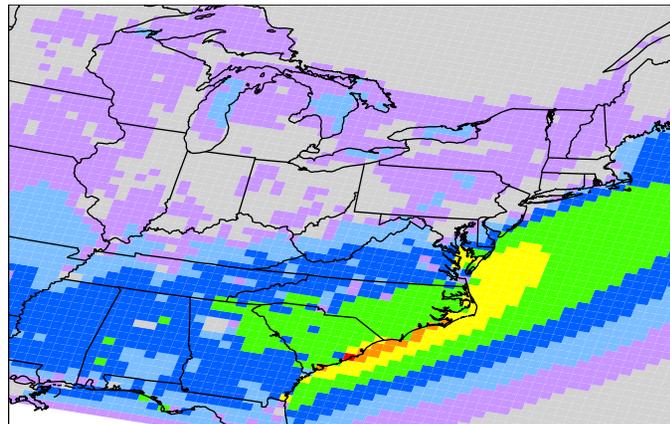


Seasonal Mean Daily Maximum 8h-O₃ Levels

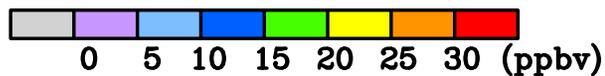
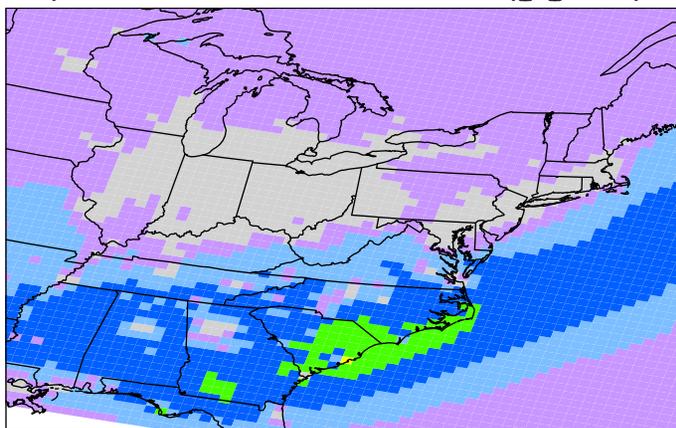
a) Present



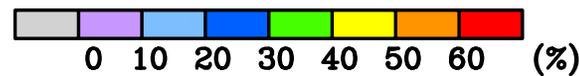
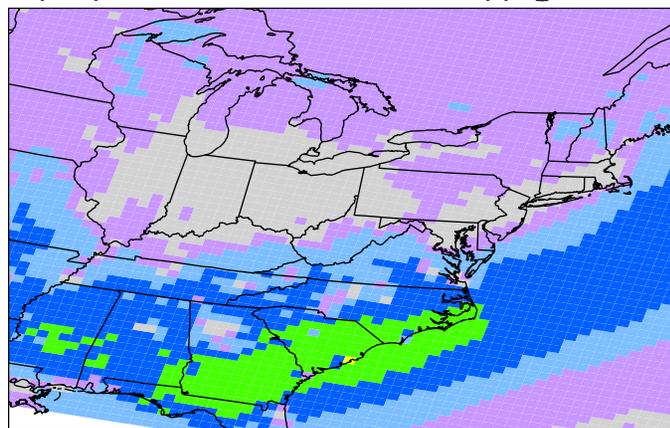
b) Future



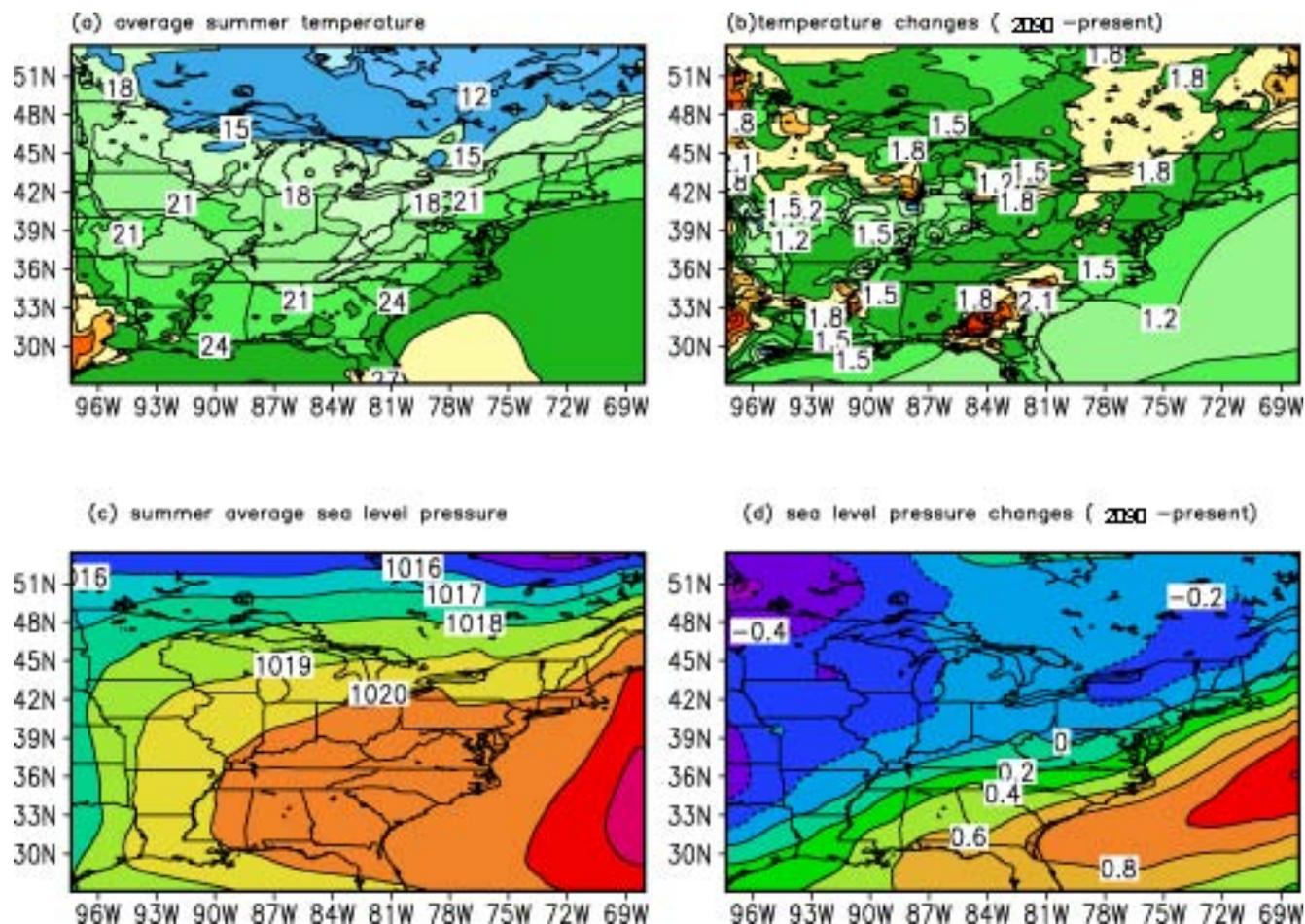
c) Future-Present (ppbv)



d) (Future-Present)/present (%)



Average Mean Temperature and Surface Pressure Levels



The area of largest increases in O_3 coincides with that of positive pressure changes in spite of uniform increases in anthropogenic O_3 precursors.

Future Work

- Estimate the changes in O₃ by implementing the changes in measured biogenic emissions into the air quality modeling system.
- Complete the remaining scenarios for future climate and air quality assessment.
- Quantify the impact of climate change-induced vegetation shifts on biogenic emissions with subsequent effect on air quality.



Acknowledgement

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- Peiter Beckman
- Tod Hagen
- All graduate students and technicians from Climate Change Research Center that participated in the project.

