Project Final Review

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

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University of New Hampshire

RTP, NC
October 28, 2008

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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, O_3, NO_x, hydrocarbons, and the oxidative capacity of the atmosphere.

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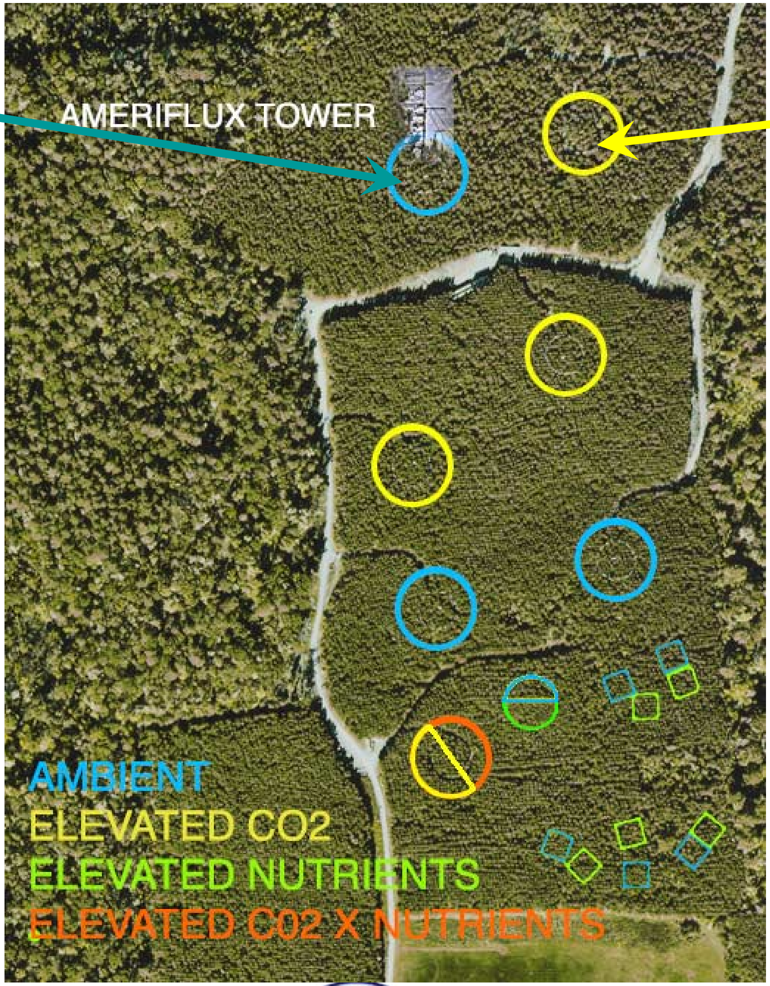
TRACK I: CO_2 ENRICHMENT RESEARCH – Measurements at the Duke Forest FACTS-I site

Ring 1
Ambient CO_2

Ring 2
Elevated CO_2
(Ambient+200 ppmv)



Measurements at Duke Forest

NMHCs
Halocarbons
Alkyl Nitrates
OVOCs
O_3
NO
CO_2
H_2O

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

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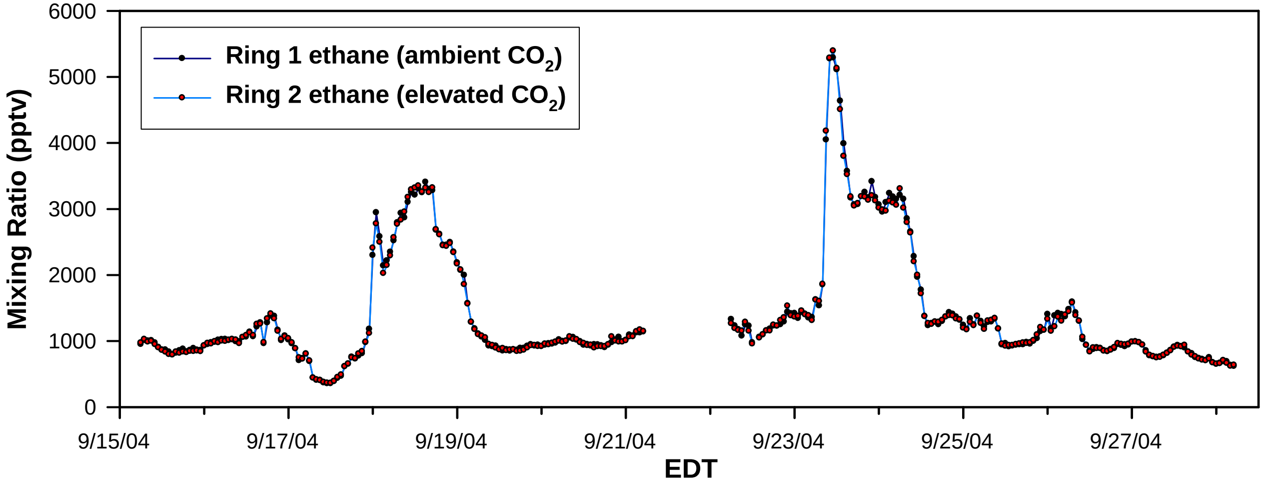
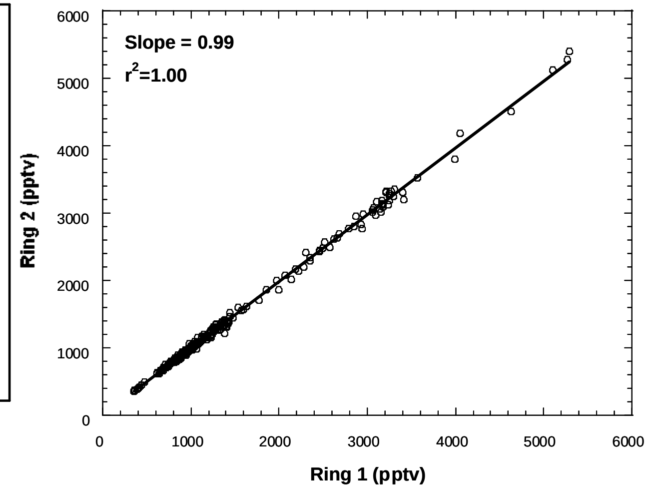
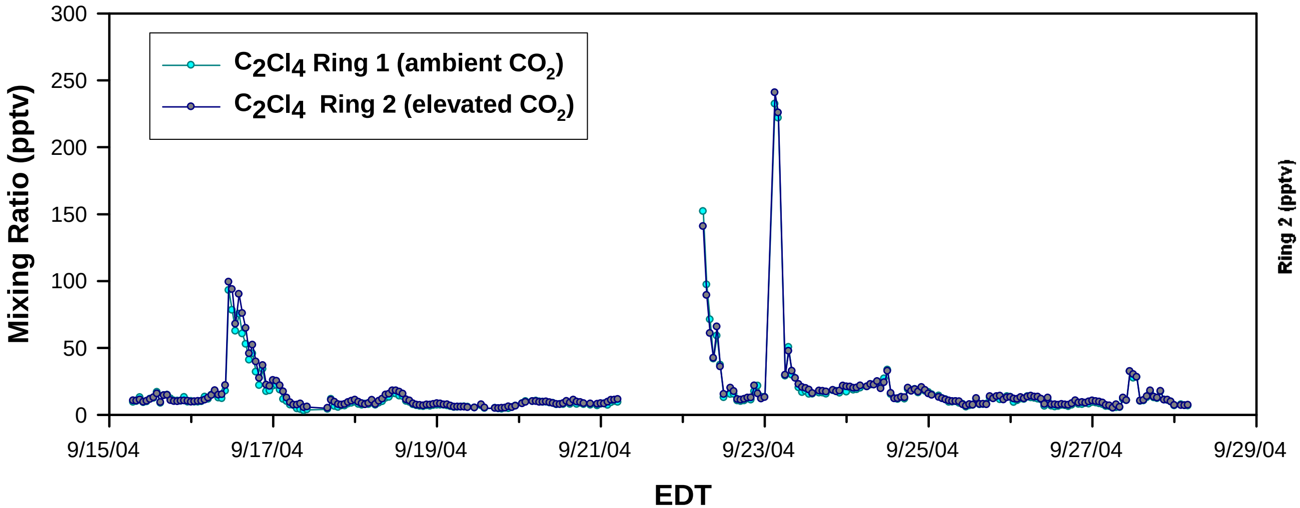
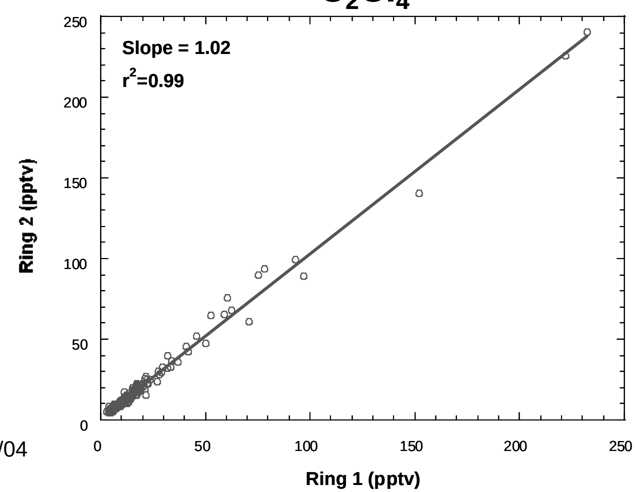


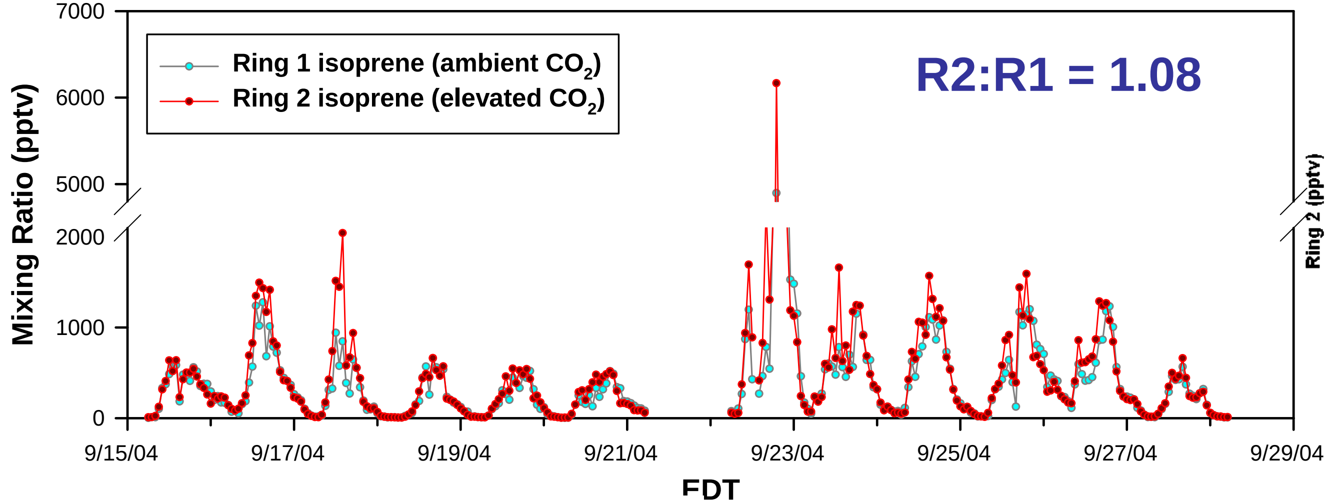
Ethane



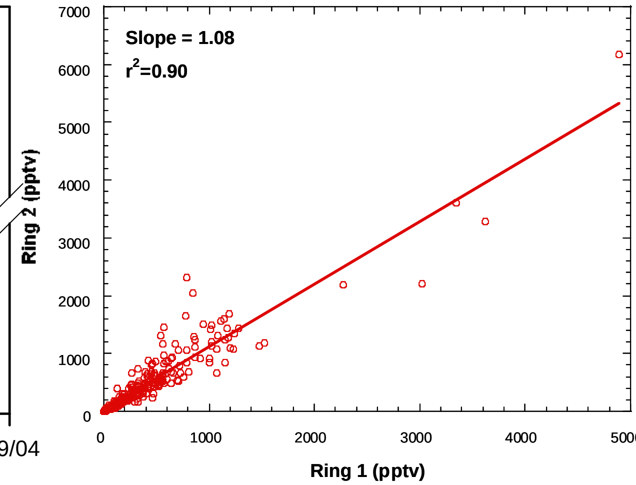


C_2Cl_4

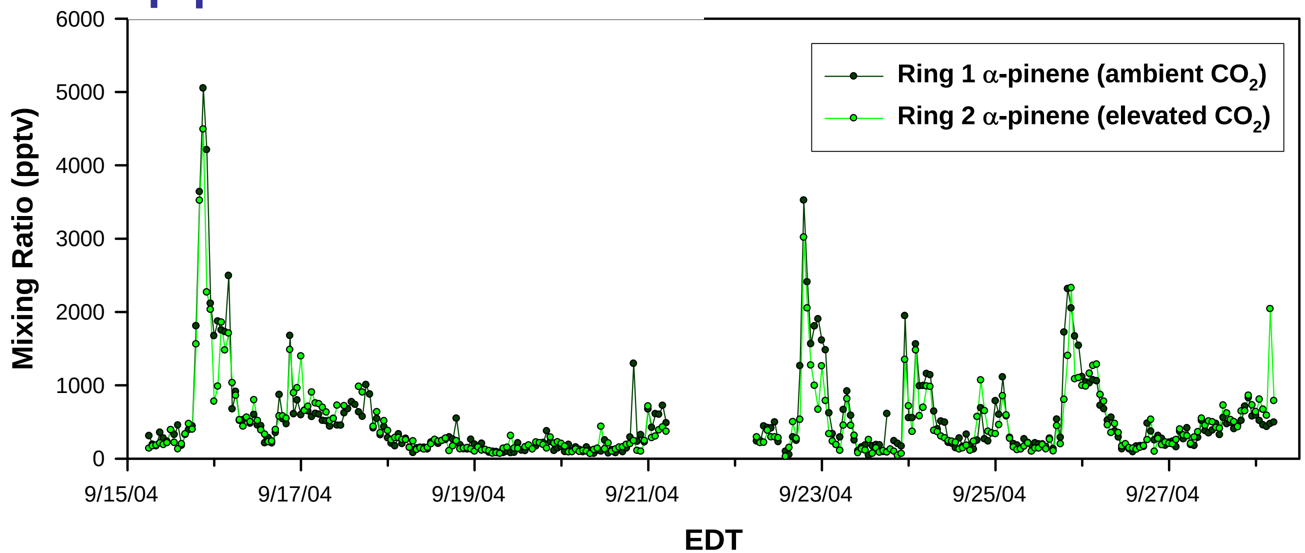




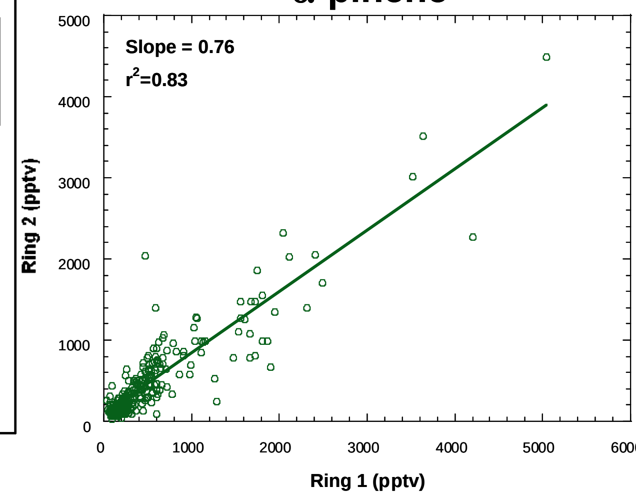
Isoprene



α-pinene: R2:R1 = 0.77
β-pinene:R2:R1= 0.80



α-pinene



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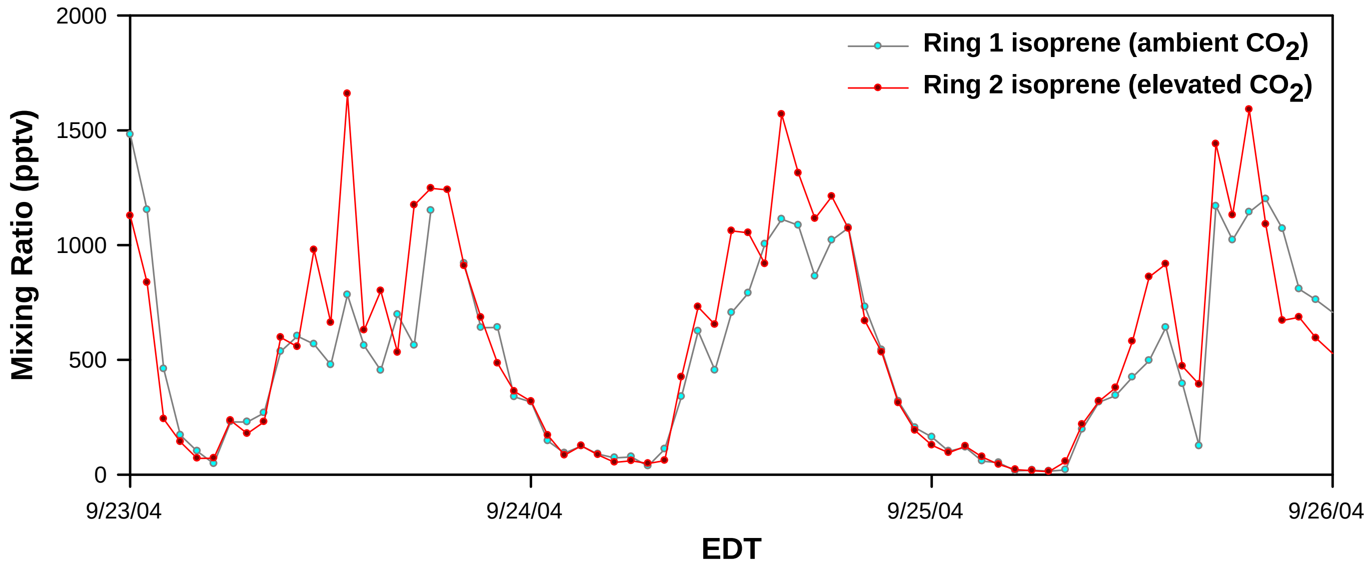

Isoprene	9/23/04 11am-6pm Average Mixing Ratio (pptv)	9/24/04 11am-6pm Average Mixing Ratio (pptv)
Ring 1 Ambient CO_2	657 (± 80)	880 (± 79)
Ring 2 Elevated CO_2	960 (± 135)	1112 (± 96)
Ring 2/Ring1	1.46	1.26

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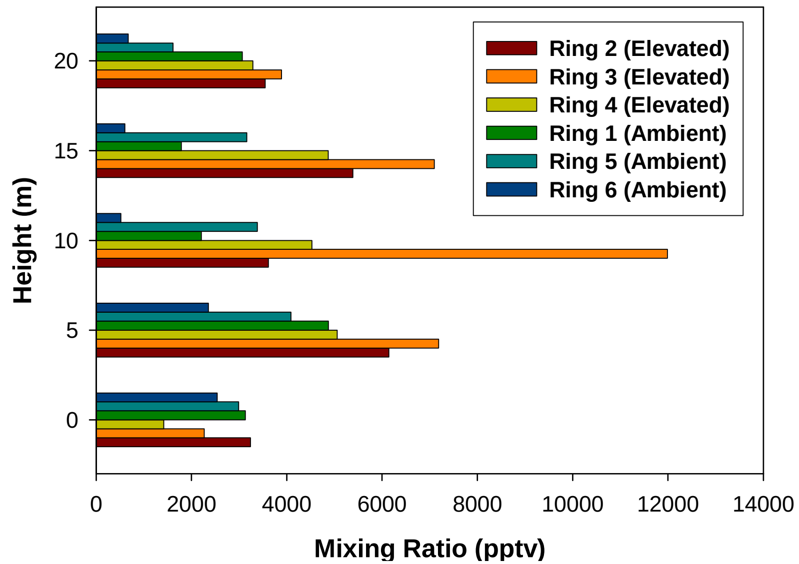
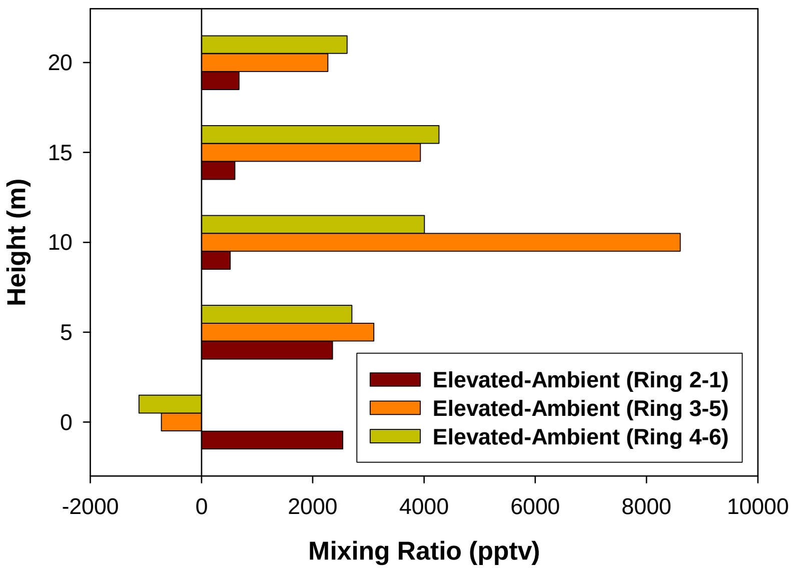
Isoprene

June 5, 2005 16:00 (EDT)





Comprehensive vertical profiles Rings 1-6 confirm elevated isoprene in elevated CO_2 environment.

Difference betw Rings: 1 & 2, 3 & 5, and 4 & 6.
All rings exhibit similar differences
Rules out that:

1) vegetation distributions betw rings biasing results
2) results are fortuitous.

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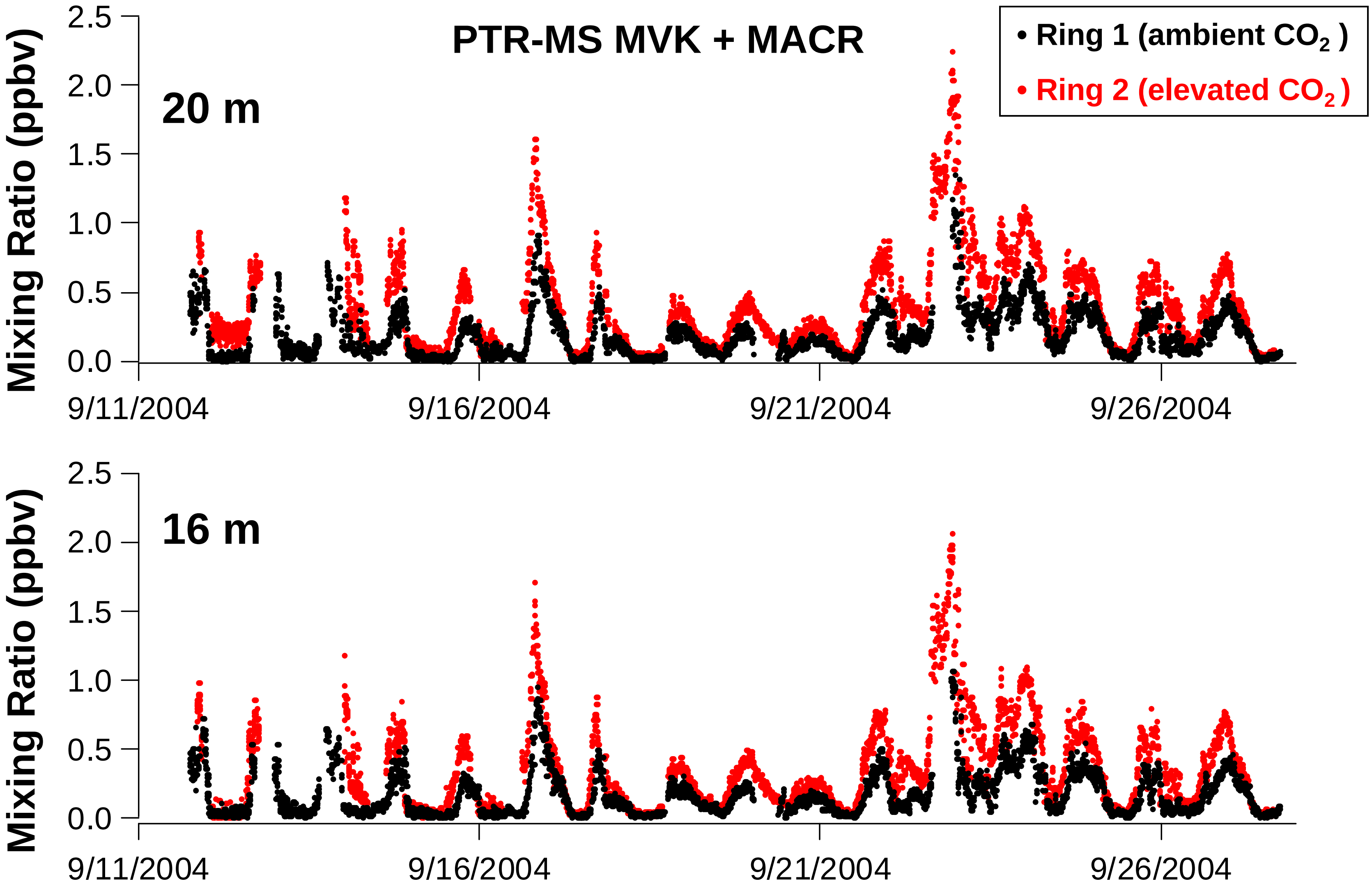

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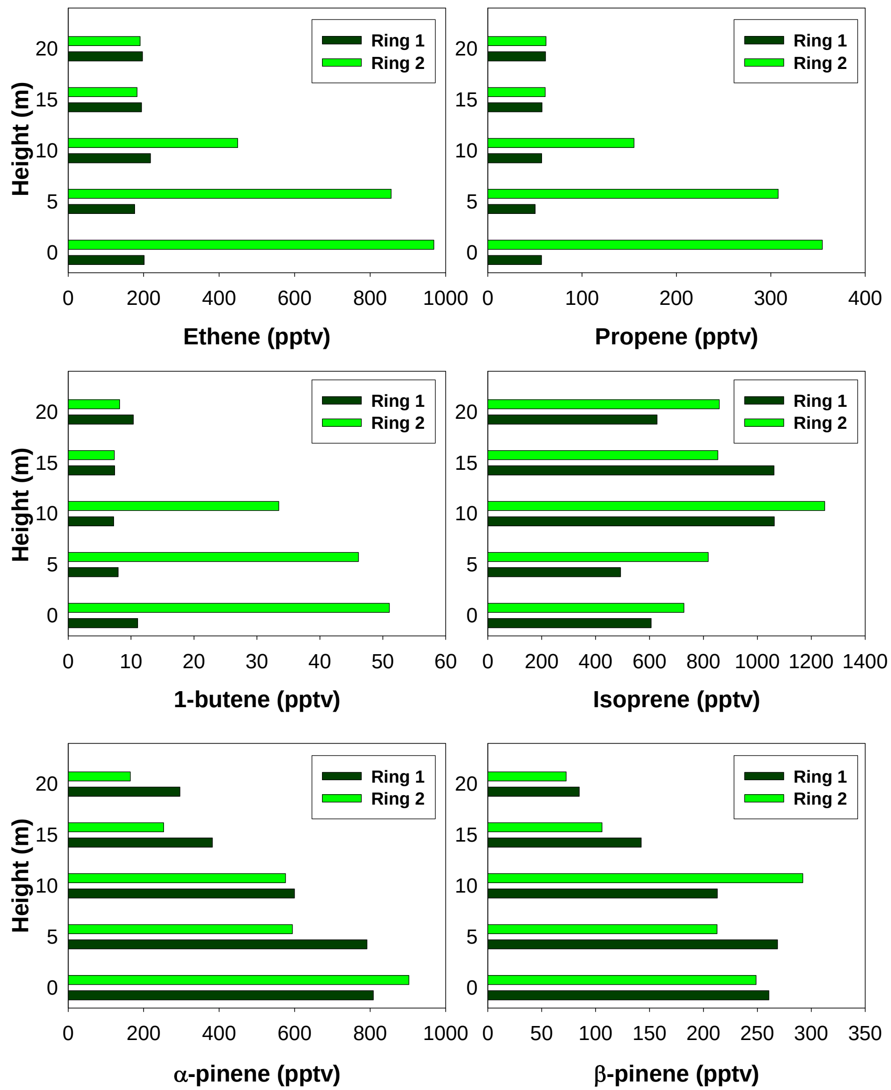

- Below-canopy profiles of a suite of VOCs measured.
- Source of reactive alkenes in the lower forest canopy/soil in the elevated CO_2 ring.
- Some uptake of isoprene near the surface.

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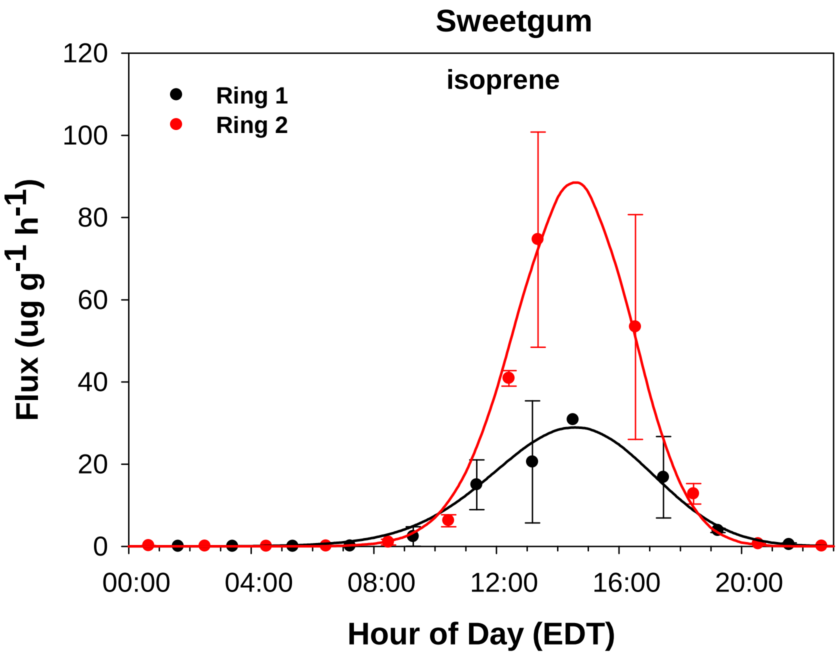
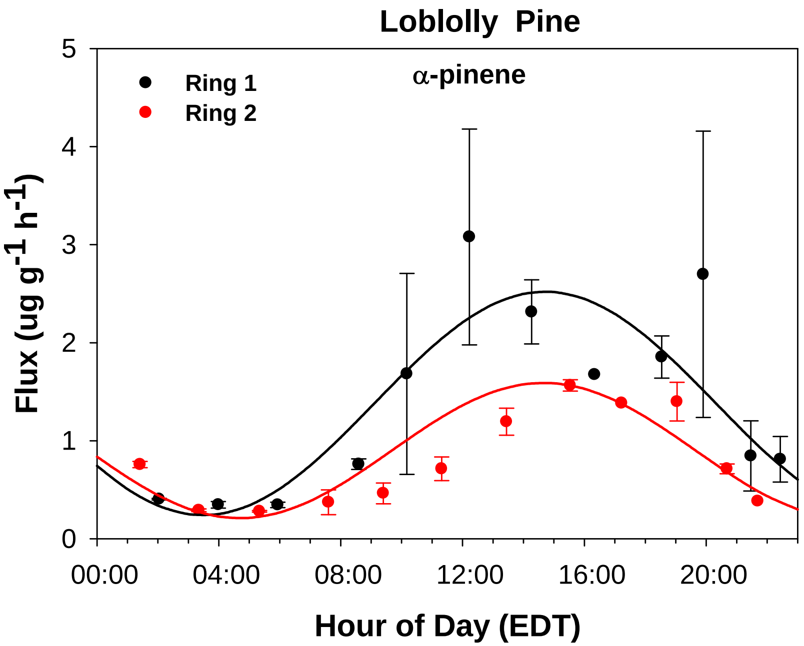
Emission Fluxes





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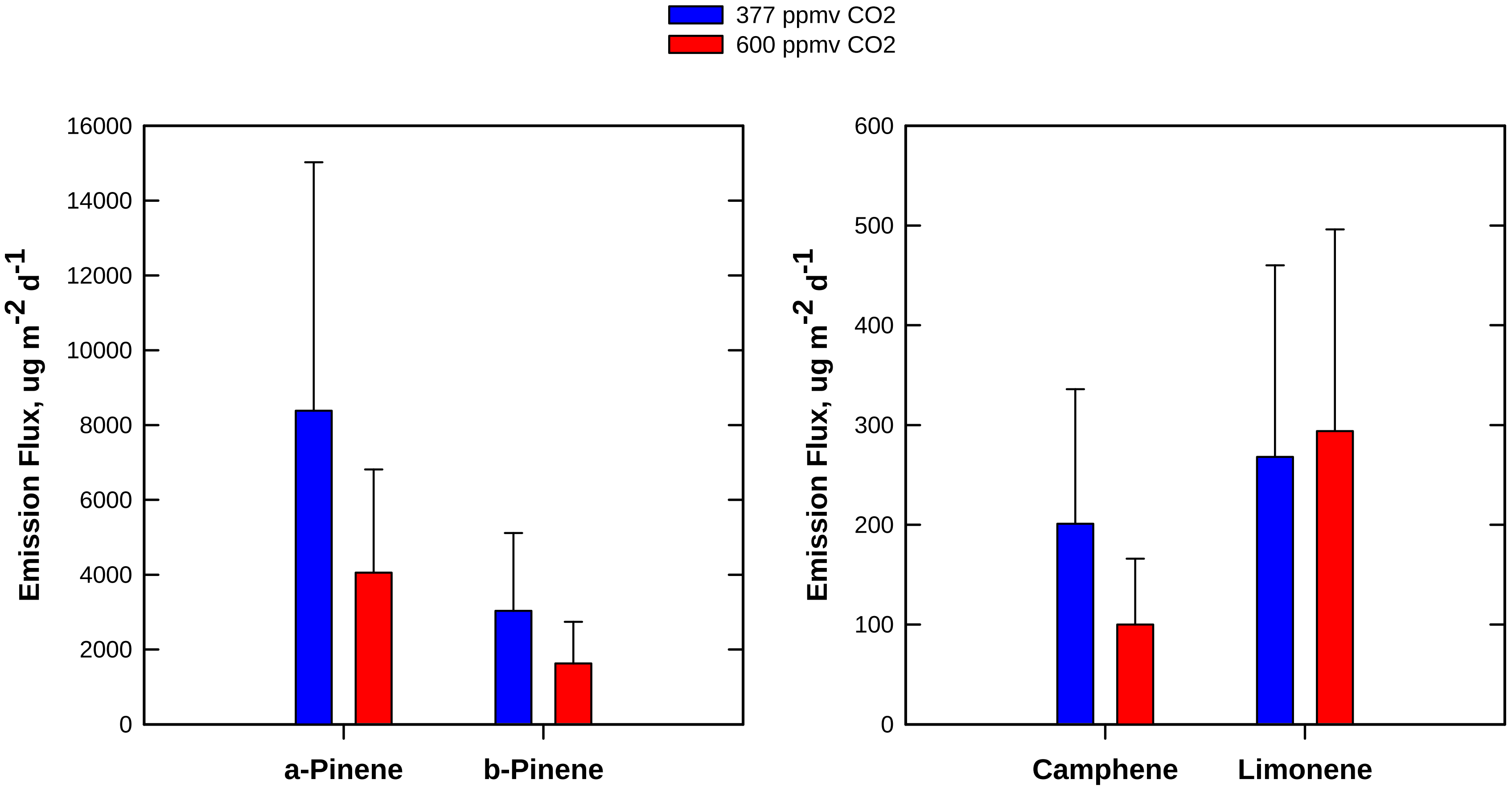
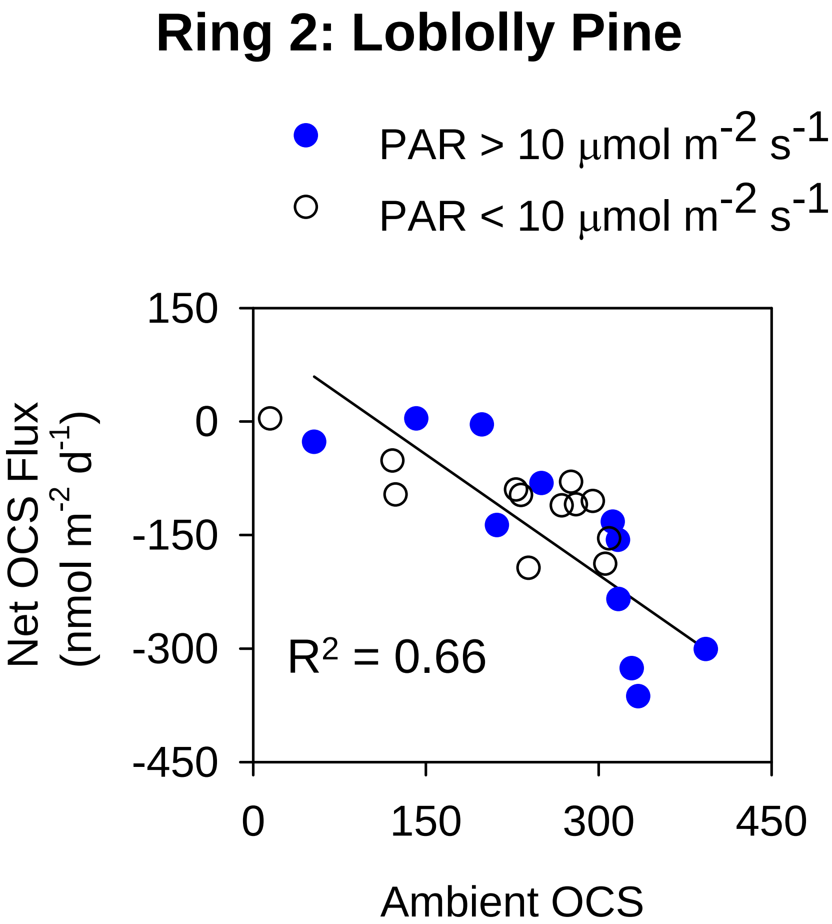
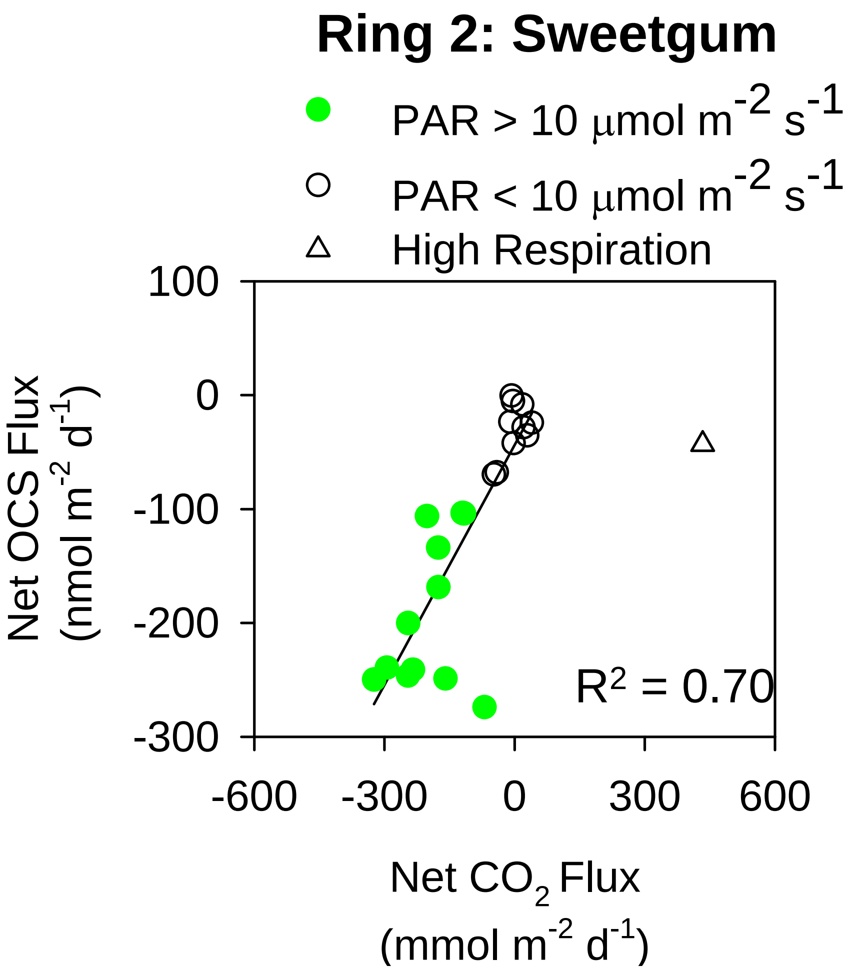
Duke Forest - Loblolly Pine







OCS uptake is tree species-dependent: ambient OCS level for Loblolly pine and net CO_2 flux for sweetgum. ***White et al*., 2008, ACPD, in review**

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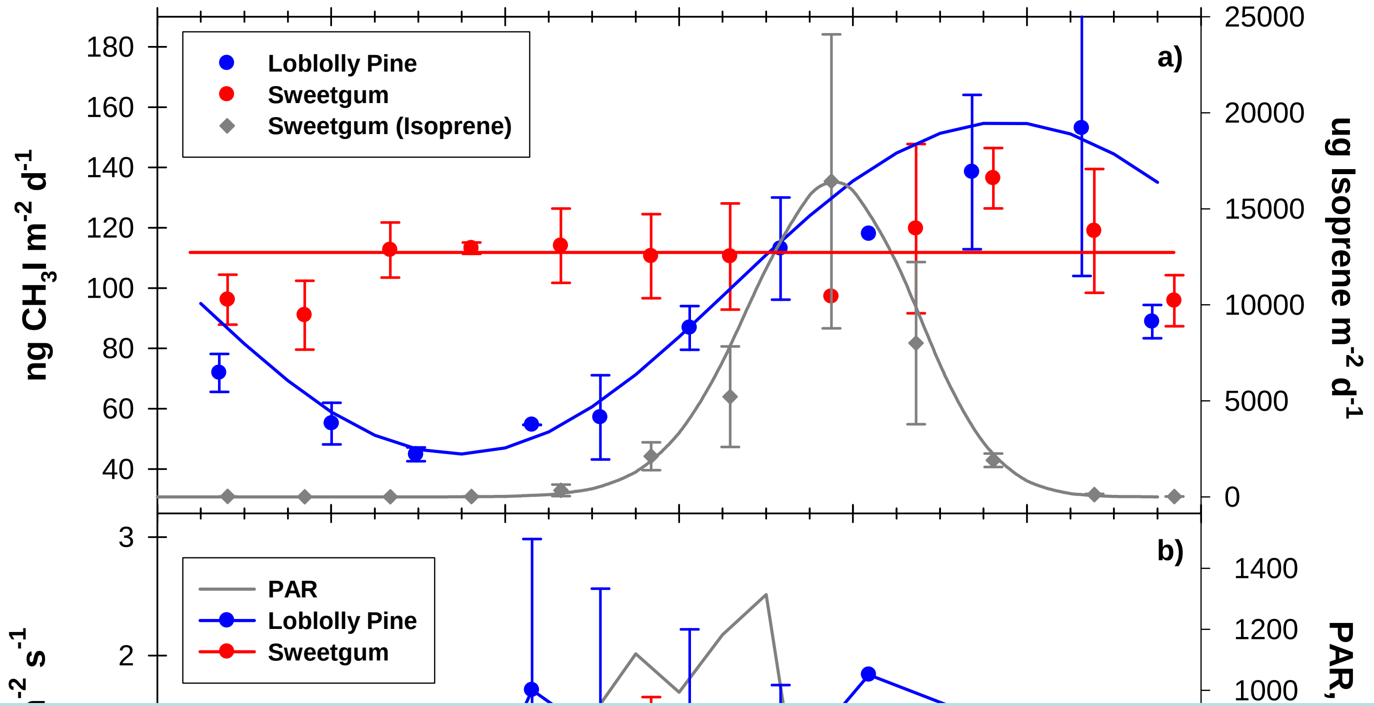

Emissions of CH_3I from the two tree species were comparable, but with a distinct diurnal cycle from Loblolly Pine and none from Sweetgum (emission not stomatally driven).

The average CH_3I flux from mid-latitude vegetation and soils similar in magnitude to previous estimates of the oceanic source strength.

Sive *et al.* [2007], GRL

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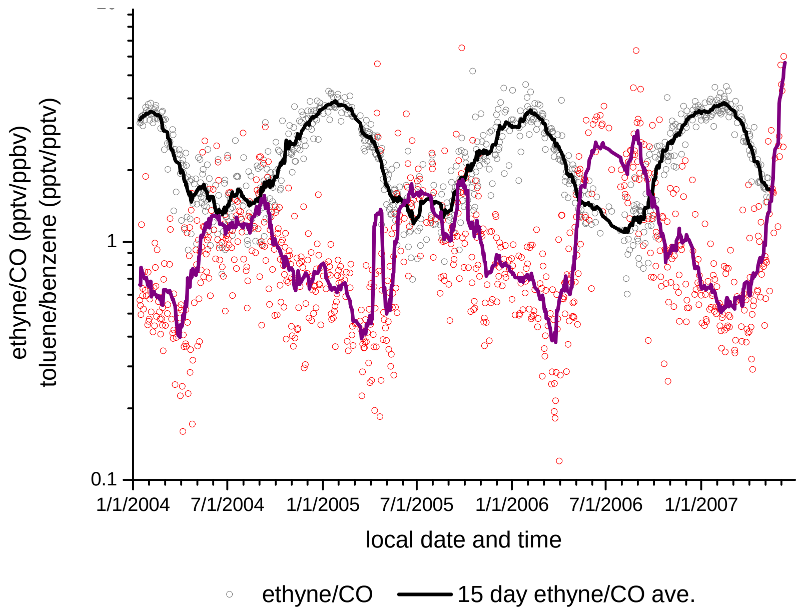
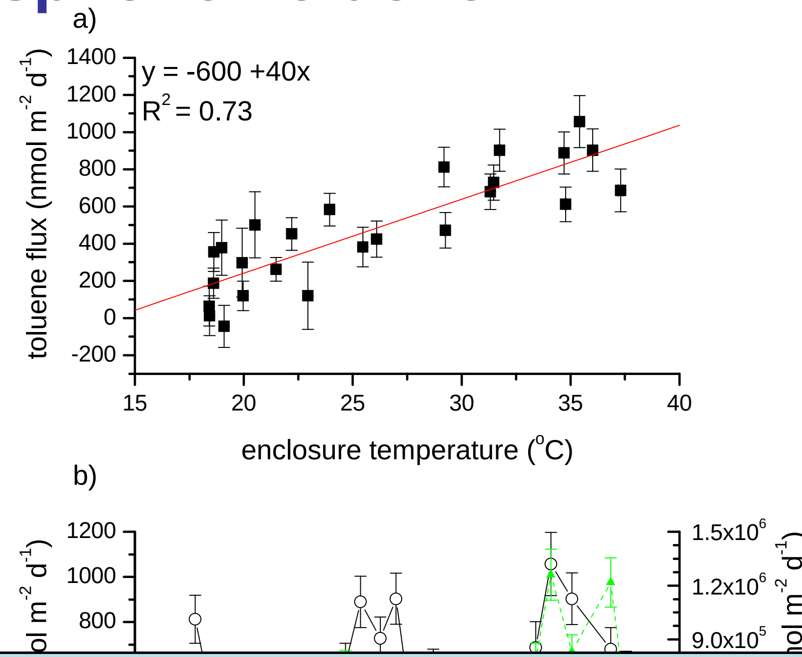
Biogenic Emissions ares a Significant Source of Summertime Atmospheric Toluene





Year	Toluene from Fuel Evaporation (pptv d^{-1})	Toluene from Crop Plant Emissions (pptv d^{-1})	Toluene from Pine Tree Emissions (pptv d^{-1})	Summer Toluene Enhancement (pptv d^{-1})
2004	22 ±7	5 ±0.3	12 ±7	21 ±6
2005	16 ±6	5 ±0.3	12 ±7	43 ±9
2006	30 ±10	5 ±0.3	12 ±7	50 ±10

***White et al.*, 2008, ACP**

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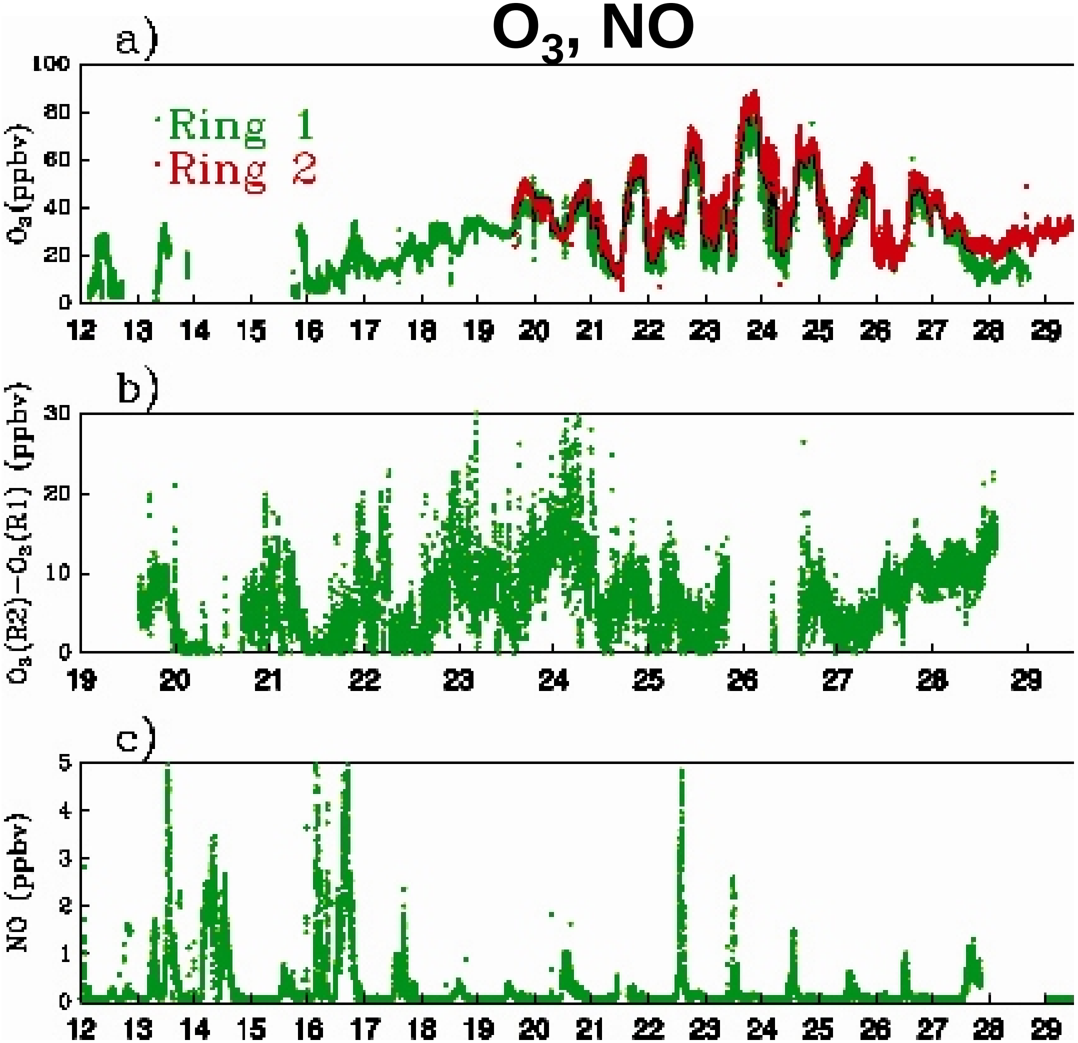
O_3, NO



Days in September

R2-R1:

6.4±5.5 ppbv

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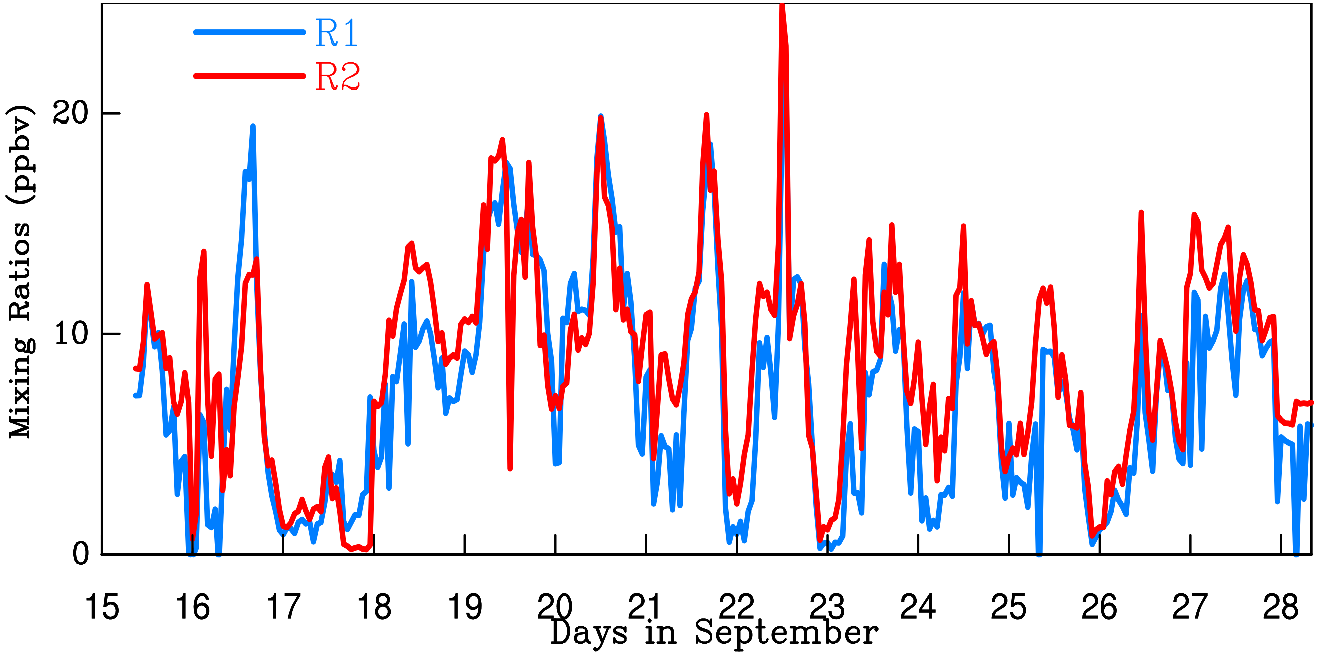
MM Simulated O_3 Mixing Ratios



1. Box model results show that O_3 levels in Ring 2 were increased by 2.4 ppbv±2.0 ppbv on average.
2. Ozone uptake by vegetation was increased in Ring 2 by 0.5±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 O_3 increases in Ring 2. Compounds are missing from our VOC measurements that likely contributed to O_3 production. ***Mao et al.*, 2008, to be submitted to ACP**

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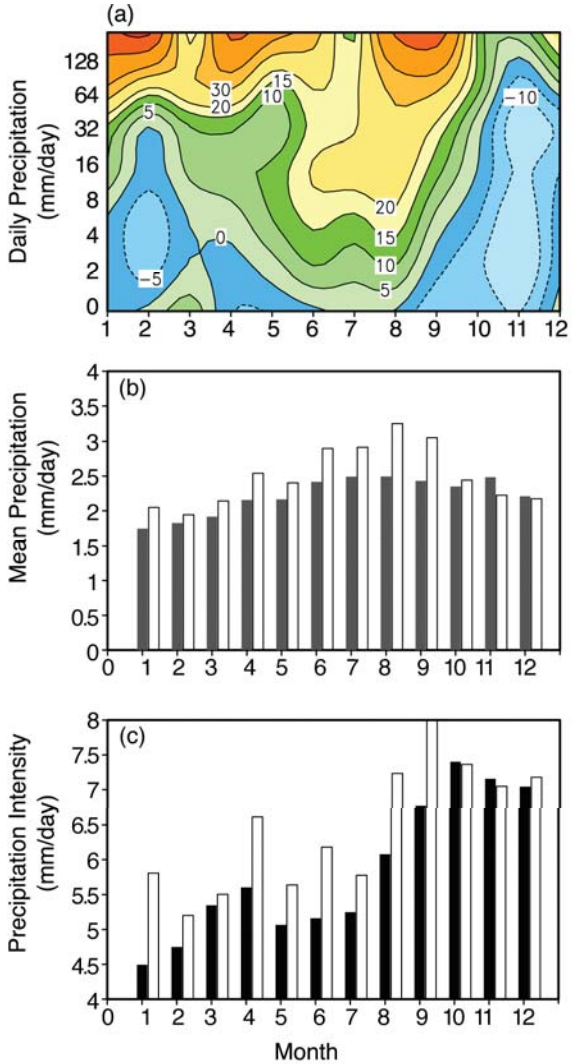
TRACK II – Regional Climate and Air Quality Assessment



<u>For a future climate with doubled CO_2:</u>

1. More convective precipitation with 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], GRL**

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CMAQ OA Module Improvement

Species	Data points	Mean observation (μg m^{-3})	Mean prediction (μg 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], JGR

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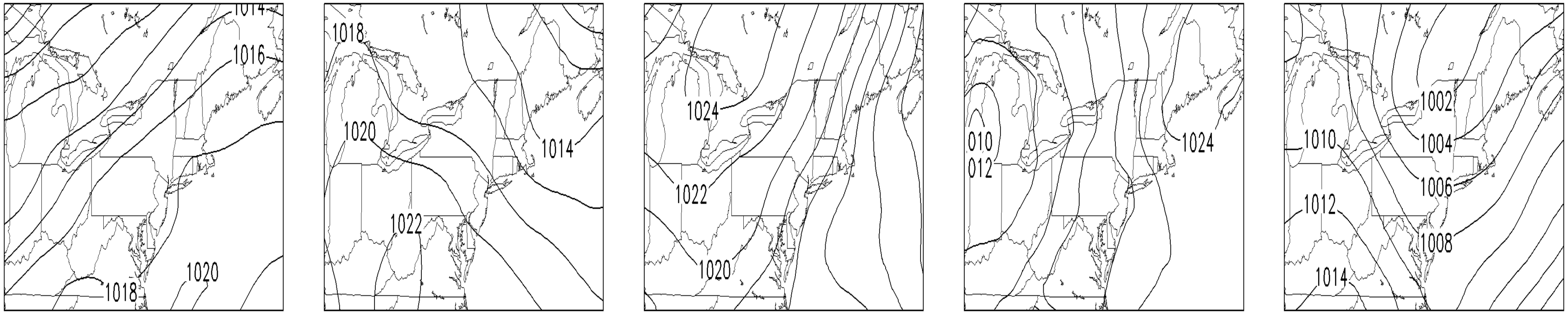
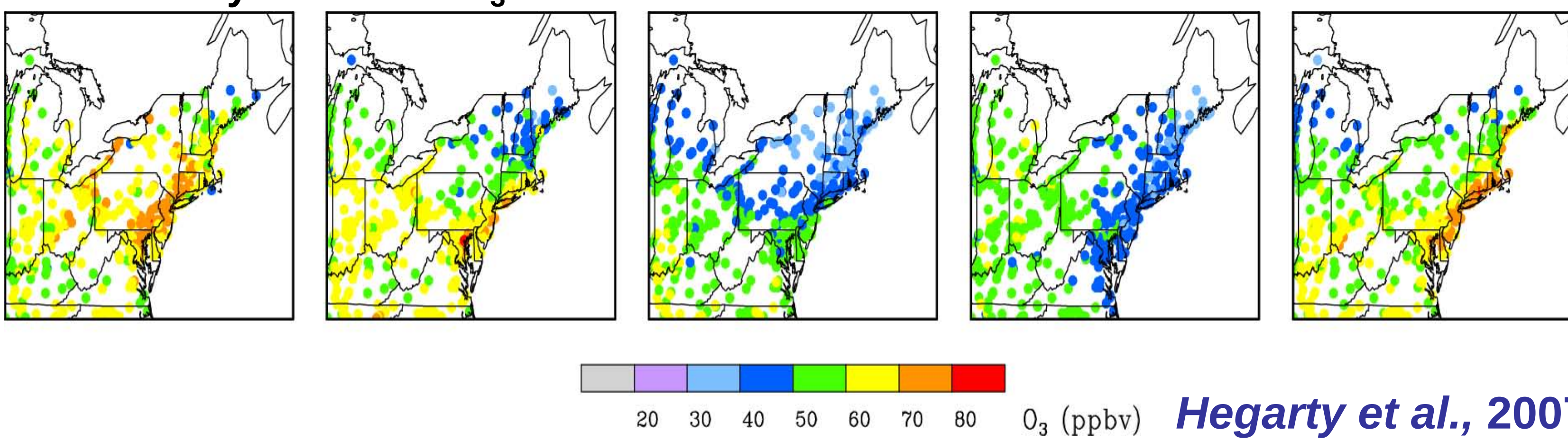
2000 – 2004 Summertime Air Quality

Map Types - Sea Level Pressure (mb)

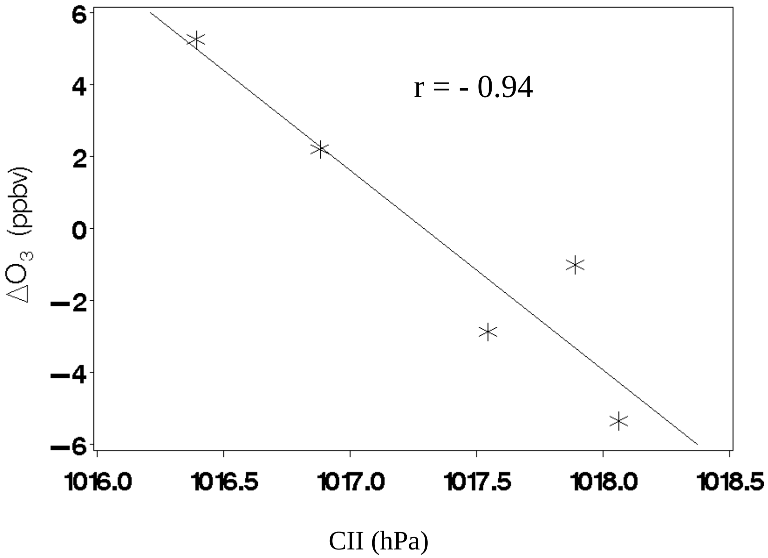


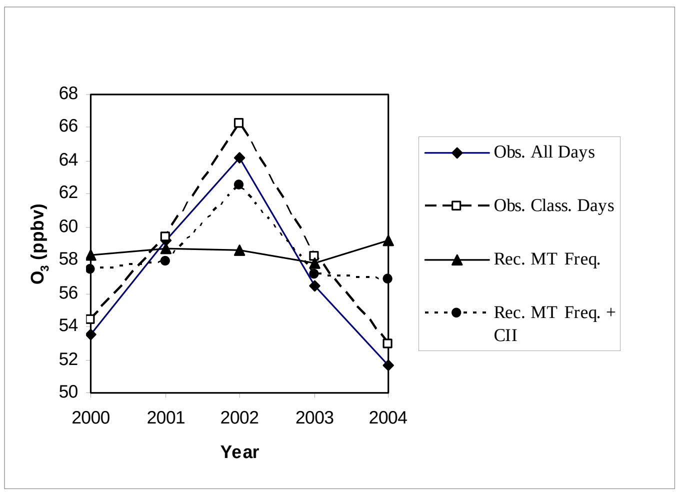
Mean Daily Maximum O_3



***Hegarty et al.*, 2007, JGR**

Interannual Variability Reconstruction





Map Type III

Regression Analysis

Reconstruction of summer O_3 level based on map type frequency and intensity reproduced **46%** of interannual variability

$$\overline{\overline{O}}_{3m} = \sum_{k=1}^{5} \left(\overline{O}_{3k} + \Delta O_{3km} \right) F_{km}$$

O_{3k} - mean per map type ***k***

ΔO_{3km} - O_3 perturbation from CII

F_{km} - Frequency per map type ***k*** per year ***m***

Hegarty et al., 2007

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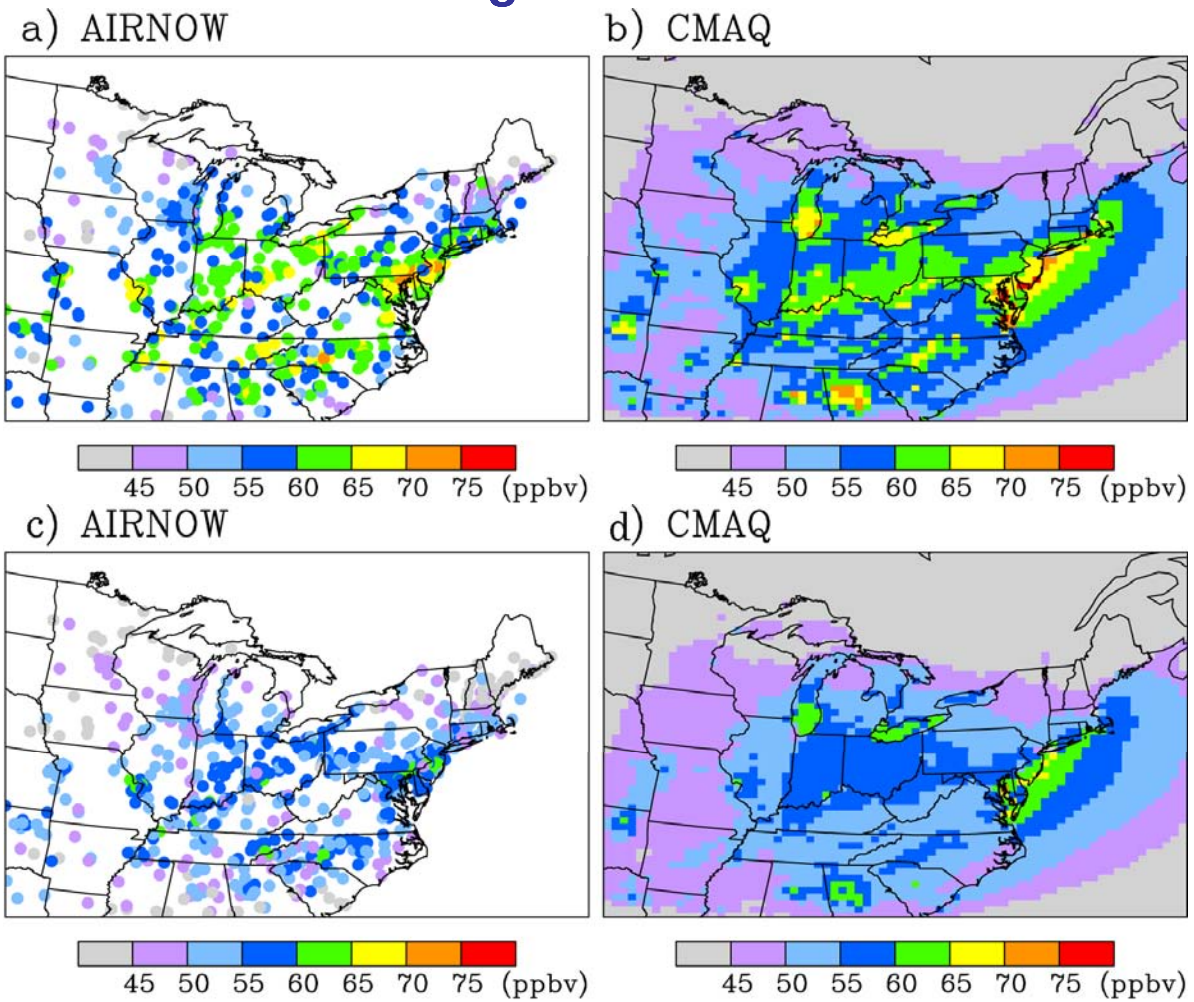
Surface 1h (a,b) and 8h (c,d) O_3 Daily Maximums Averaged over 2001-2005



1-hr

8-hr

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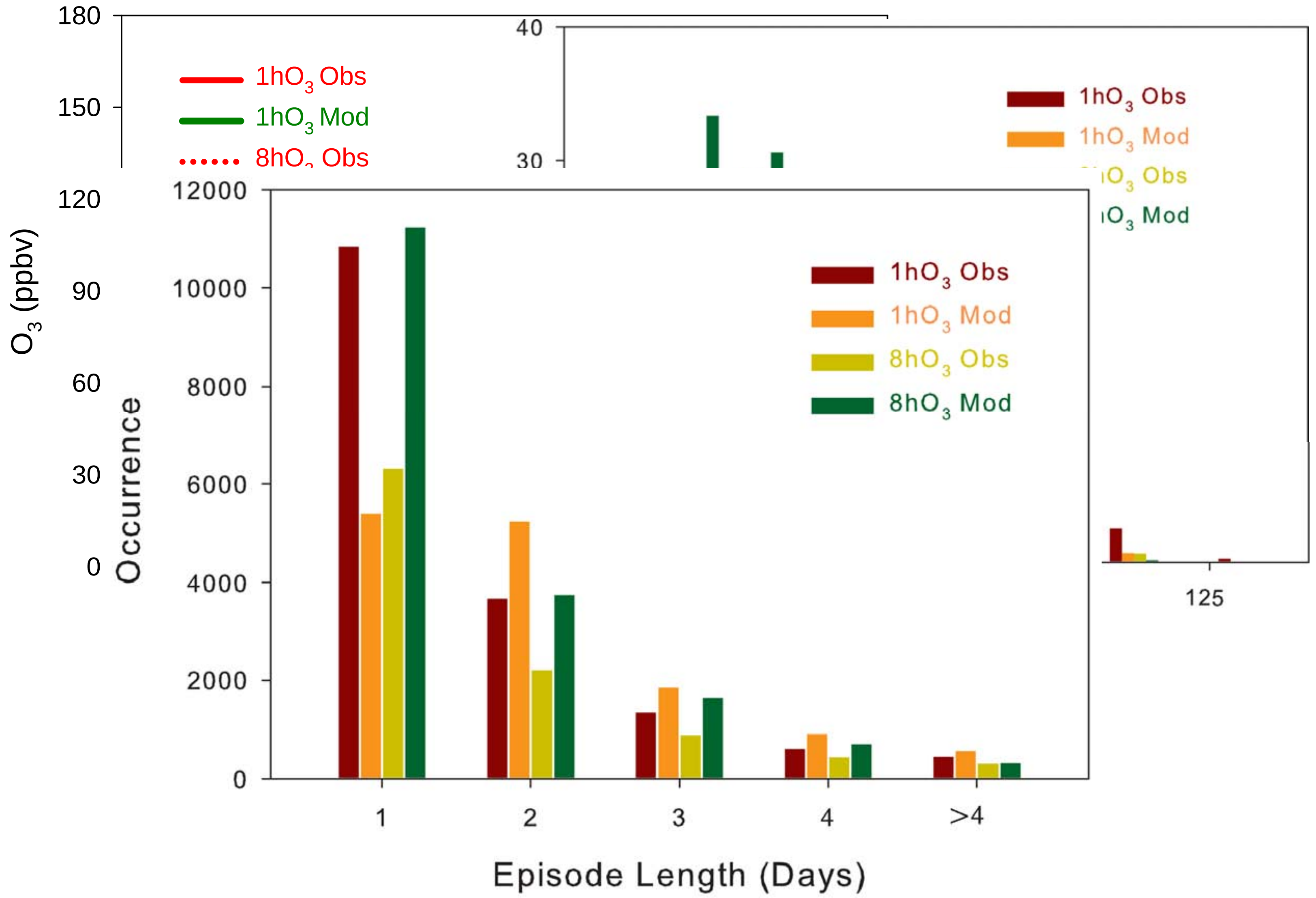
Comparison of Domain Averaged Observed and Modeled 1h-O_3 Daily Maxima

	Sample #	$\overline{OBS - MOD} \pm \sigma$	$\overline{OBS}$	$\overline{MOD}$	RMSE	AINDEX	R
2001	55718	2.3±17	62	60	17	68	0.48
2002	56223	5.5±18	65	60	19	66	0.53
2003	57300	1.7±15	59	57	15	70	0.52
2004	55984	-3.6±15	52	56	15	64	0.46
2005	56505	-2.5±17	58	61	17	71	0.51
Total	282371	0.7±17	59	59	17	69	0.51

8h-O_3 Daily Maxima

	Sample #	$\overline{OBS - MOD} \pm \sigma$	$\overline{OBS}$	$\overline{MOD}$	RMSE	AINDEX	R
2001	55718	1.8±14	55	53	14	73	0.58
2002	56223	3.4±16	58	54	16	69	0.56
2003	57300	-0.3±14	52	52	14	69	0.52
2004	55984	-4.7±13	46	51	13	65	0.51
2005	56505	-3.2±14	52	55	14	73	0.57
Total	282371	-0.6±14	52	53	14	71	0.54



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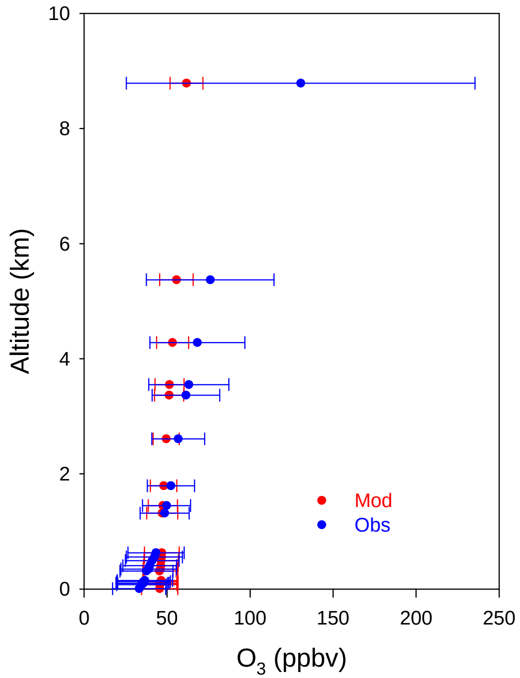
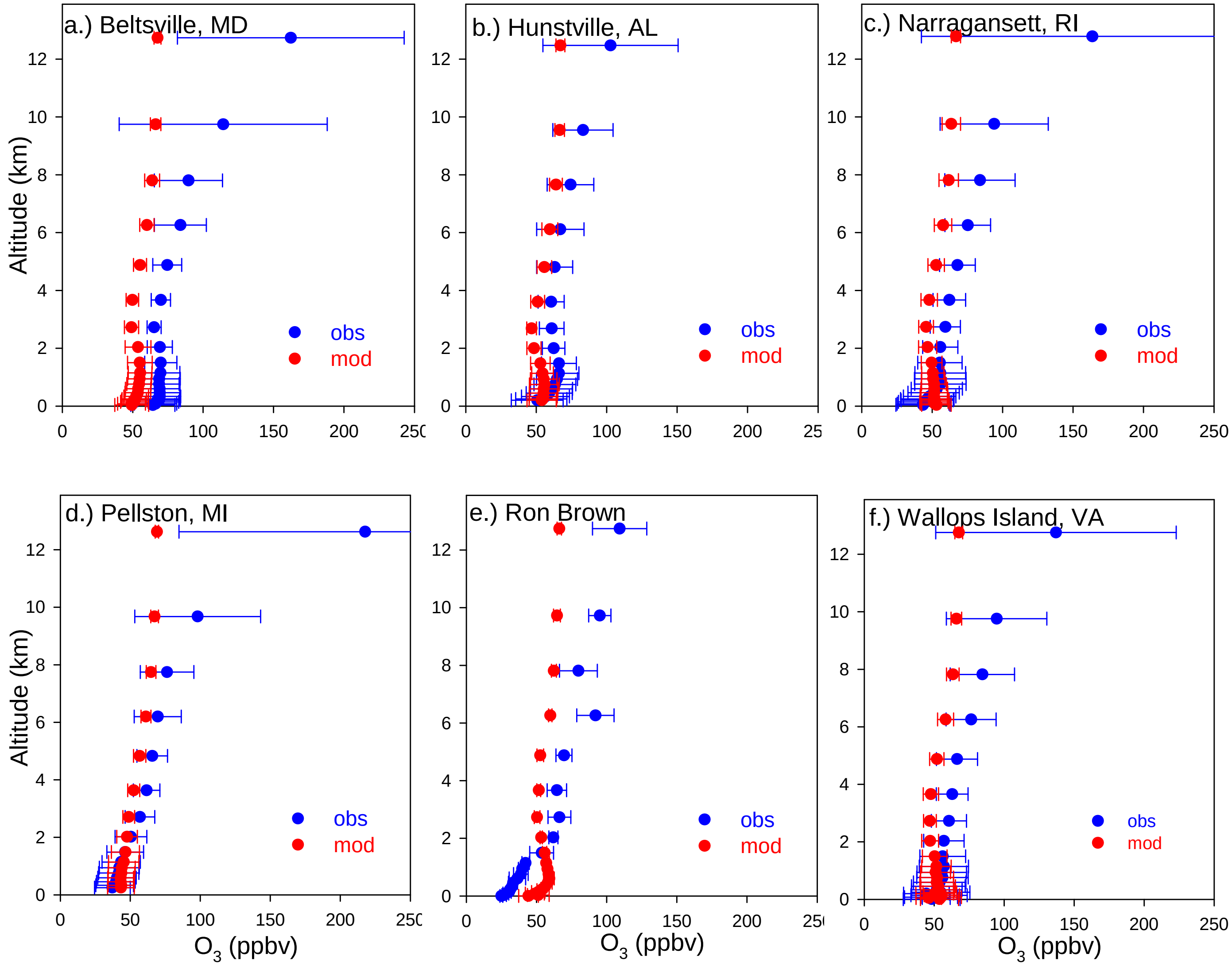
Example: IONS Ozonesonde vs. Model

Average over all sites





Future Climate Change and Its Impact on Air Quality

Future Projection of Global and US Anthropogenic 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**
NOx (OECD90)	13	18	**38**

Case Scenarios

	Present (Case 1)	Future (Case 2)	Future (Case 3)	Future (Case 4)	Future (Case 5)
Climate	P	F	P	F	F
Emissions	P	F	F	P-Einv, F-Bio	P
BC	P	P	P	P	P

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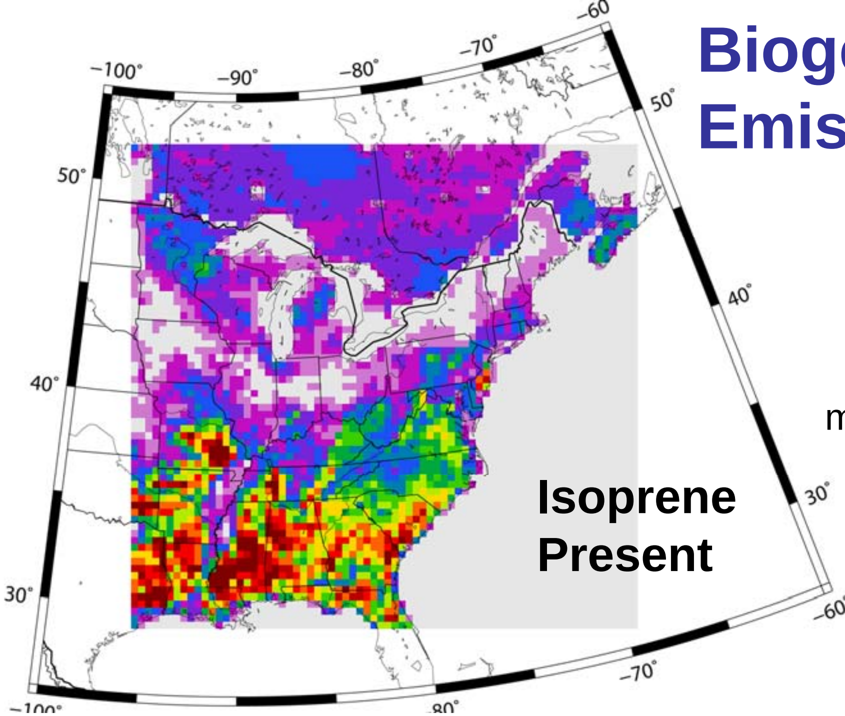
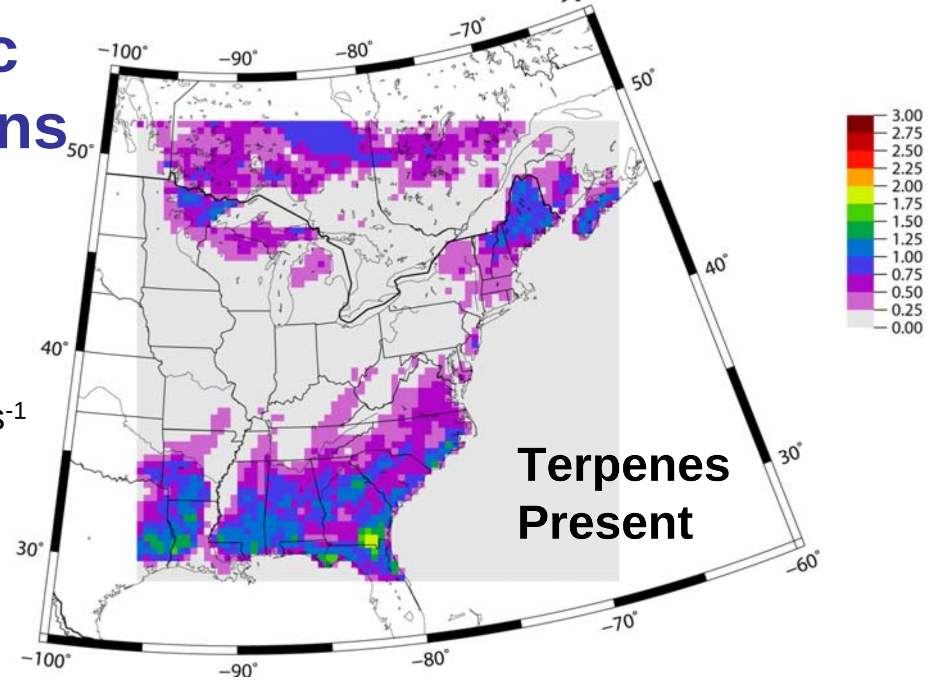
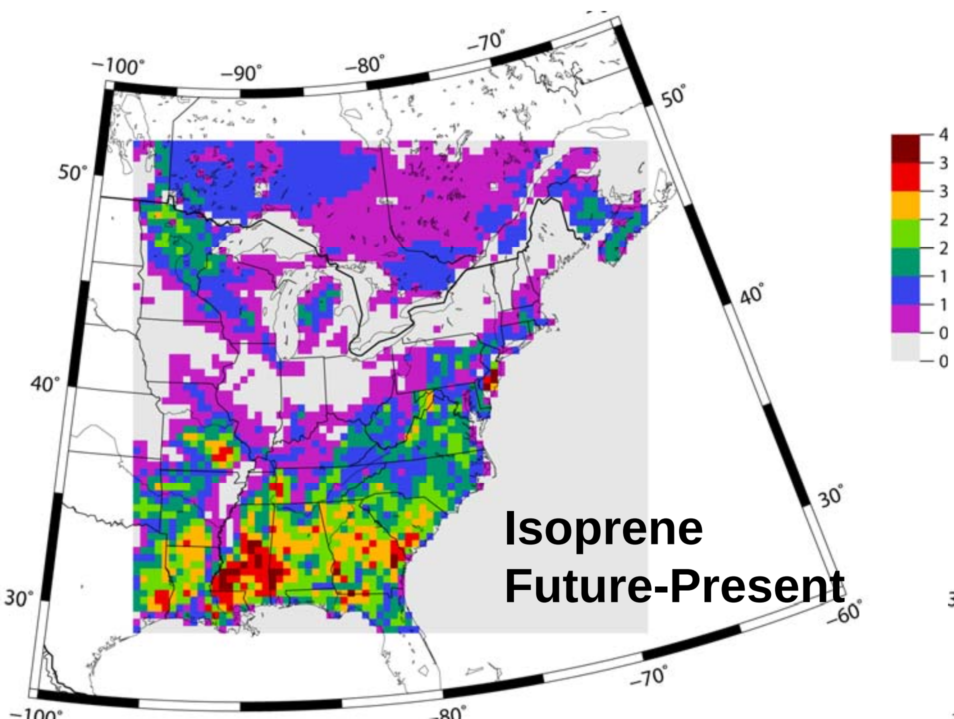
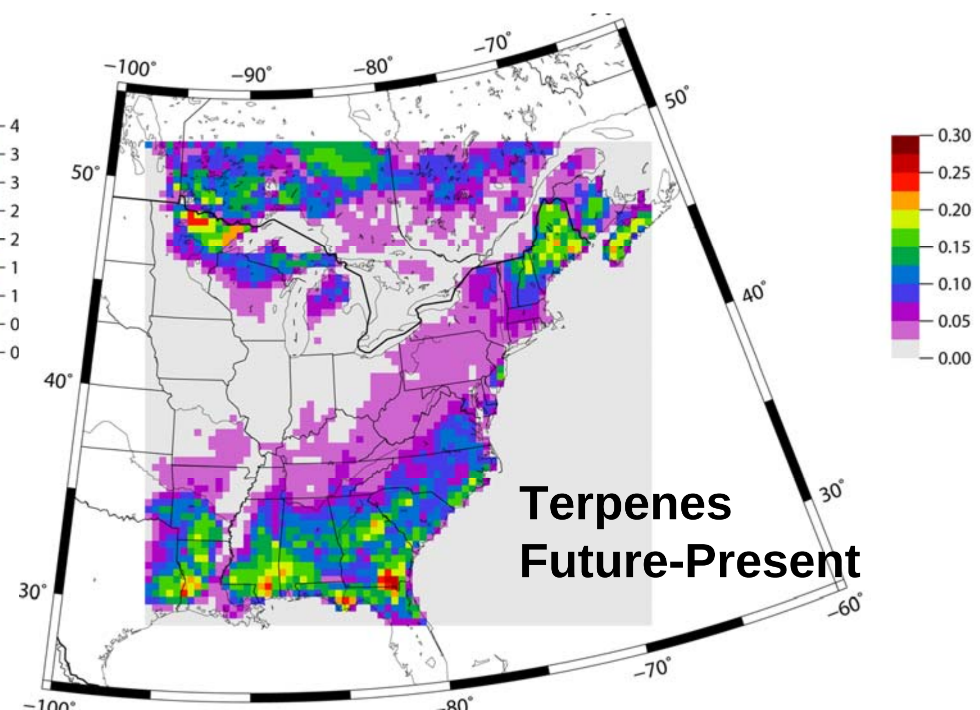
Biogenic Emissions

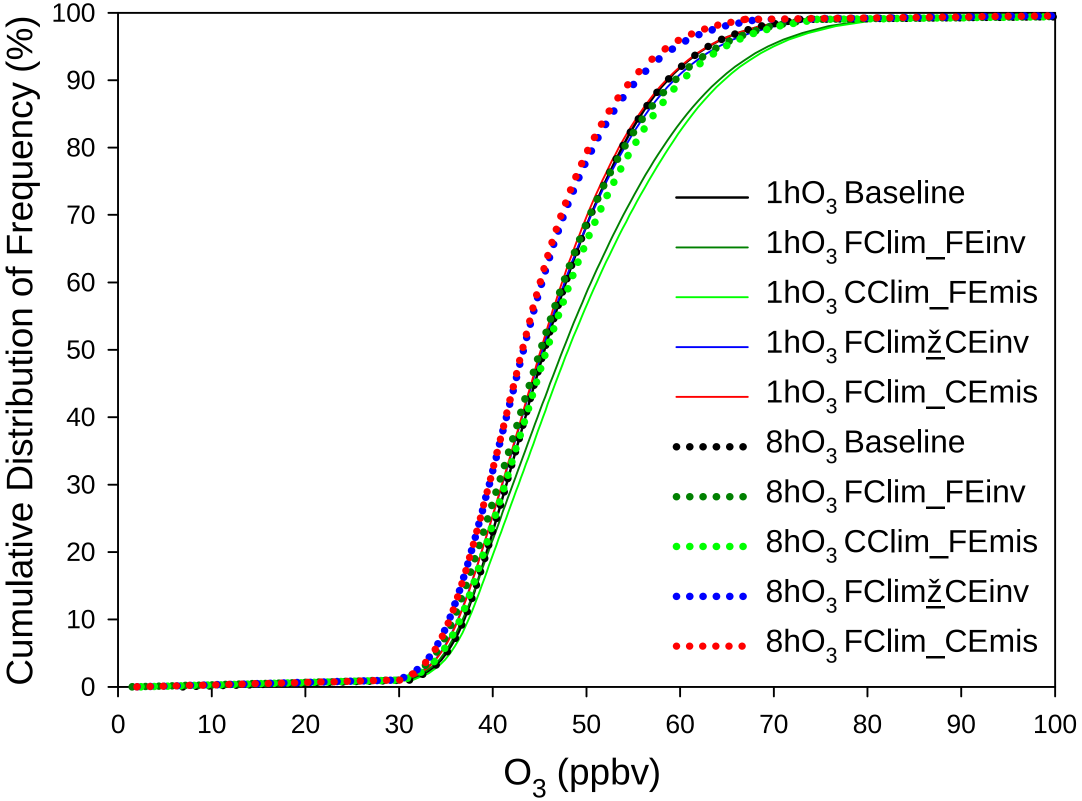






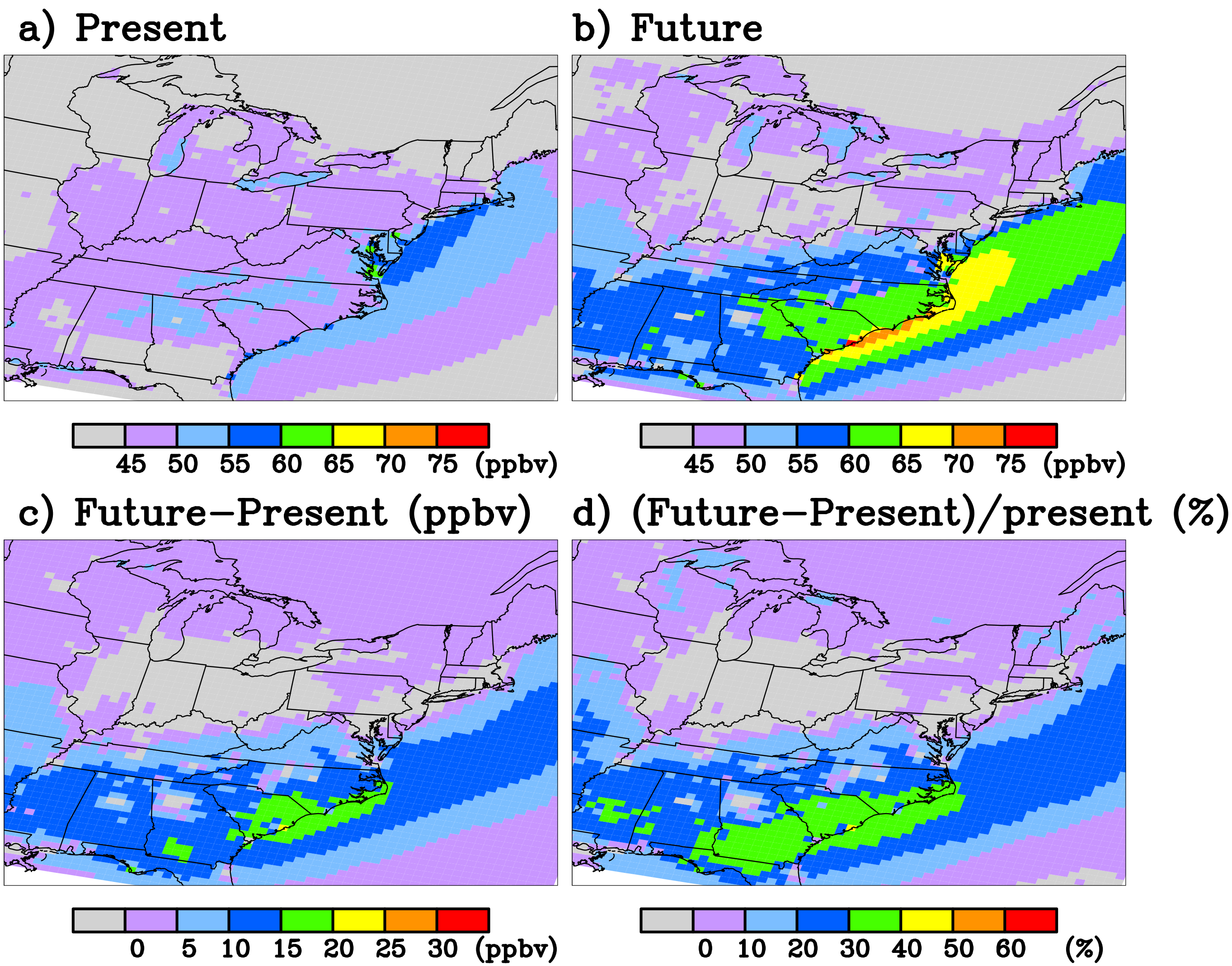


Daily Maximum 1h- and 8h-O_3

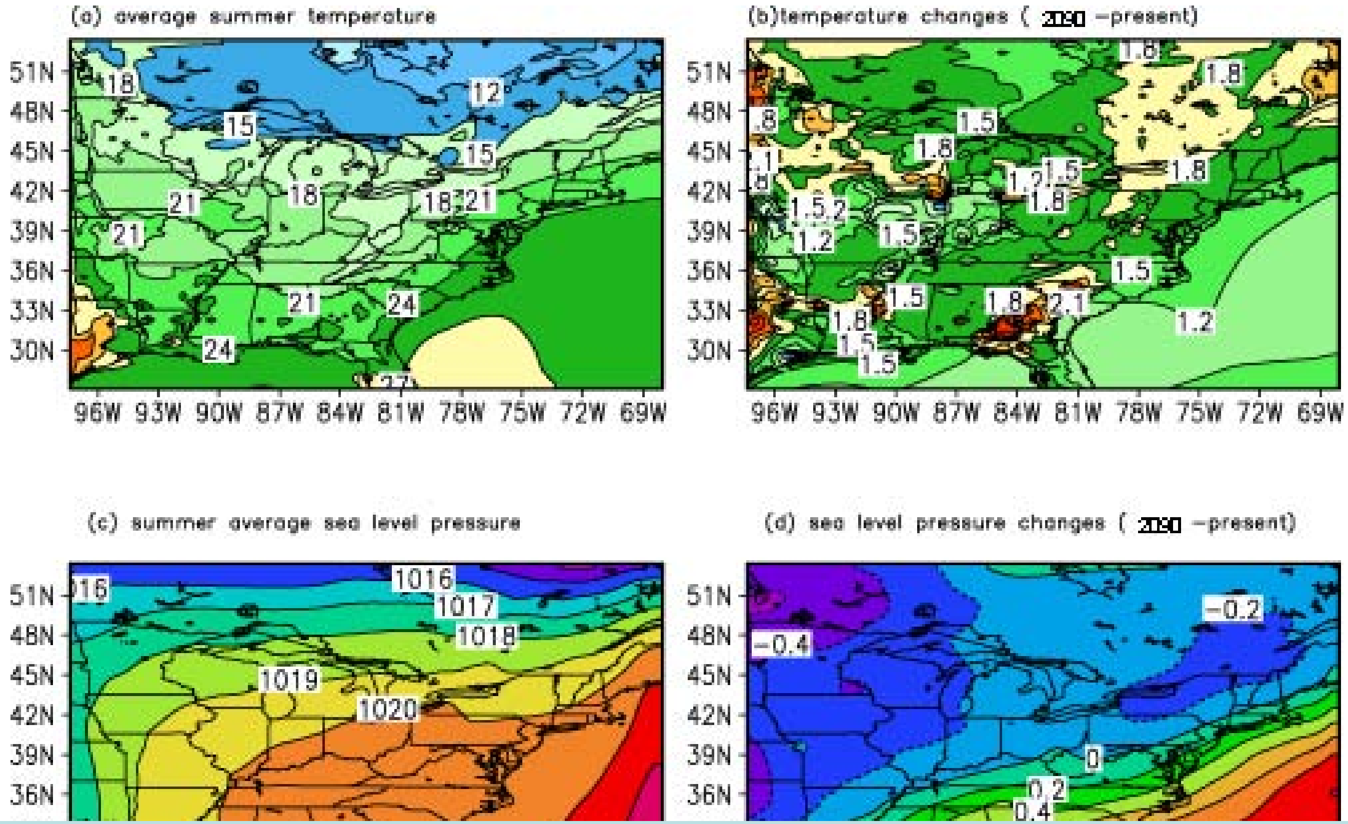


	Present (Case 1)	Future (Case 2)	Future (Case 3)	Future (Case 4)	Future (Case 5)
Median	31/60	25/66	28/67	30/64	29/62
4th highest	41/91	40/99	41/101	40/93	40/89
2.5th	13/44	9/46	9/45	14/45	14/45
25th	25/54	19/58	21/59	24/56	24/55
75th	37/71	33/79	37/78	36/75	36/71
97.5th	41/96	40/103	41/108	40/99	40/93

Seasonal Mean Daily Maximum 8h-O_3 Levels



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.

Publications

- Chen, M., H. Mao, and R. Talbot (2005), Changes in precipitation characteristics over North America for doubled CO_2, *Geophys. Res. Lett., 32*, L19716, doi:10.1029/ 2005GL024535*.*
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- Hegarty, J., H. Mao, and R. Talbot (2007), Relationships between circulations patterns and surface ozone over the northeastern United States, *J. Geophys. Res.*, *112,* D14306, doi:10.1029/2006JD008170.
- Chen, J., H. Mao, R.W. Talbot, and R.J. Griffin (2006), Application of the CACM and MPMPO modules using the CMAQ model for the Eastern United States, *J. Geophys. Res.,111,* D23S25, doi:10.1029/2006JD007603.
- Sive, B. C., R. K. Varner, H. Mao, D. R. Blake, O. W. Wingenter, and R. Talbot (2007), A large terrestrial source of methyl iodide, *Geophys. Res. Lett., 34*, L17808, doi:10.1029/2007GL030528.
- Sive, B. C., R. K. Varner, L. C. Nielsen, R. S. Russo, Y. Zhou, M. L. White, A. Csakai, P. Beckman, J. Ambrose, O. W. Wingenter, H. Mao and R. Talbot (2006), Isoprene and monoterpene emissions in ambient and future CO_2 environments, in preparation for submission to *Atmos. Chem. Phys*.

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Continued

- White, M. L., B. C. Sive, R. K. Varner, R. S. Russo, Y. Zhou, A. Csakai, P. Beckman, J. Ambrose, O. W. Wingenter, H. Mao and R. Talbot (2008a), Methyl halides and OCS exchange with soil and trees at the Duke Forest FACE site, Chapel Hill, NC, ACPD, in review.
- White, M. L., et al. (2008b): Are Biogenic Emissions a Significant Source in Summertime Toluene Enhancements in the Rural Northeast? ACPD, in review*.*
- Chen, M. et al., (2008), Characteristics Climate Change Patterns over Regions of Upwind Pollutants Sources and Their Impact on Regional Air Quality over New England, in preparation for submission to *J. Geophys. Res.*
- Mao, H., R. Talbot, B. Sive, R. Varner, M. Chen, R. Oren, and H.-S. Kim (2008a), Enhanced O_3 in an elevated CO_2 environment, in preparation for submission to *Atmos. Chem. Phys.*
- Mao, H., M. Chen, and R. Talbot (2008b), Air quality assessment for the northeastern United States, in preparation for submission to *Atmos. Chem. Phys*.
- Mao, H., M. Chen, and R. Talbot (2008c), Present and future air quality assessment for the northeastern United States, in preparation for submission to *Atmos. Chem. Phys*.

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Acknowledgement

- Laura Cottrell
- Pieter Beckman
- Tod Hagan
- All graduate students and technicians from Climate Change Research Center who participated in the project.

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