Drought Impacts on Secondary Organic Aerosol, a Case Study in the Southeast United States

Tsinghua University

UNIVERSITY of HOUSTON

Georgia Tech

zhaozj14@mails.tsinghua.edu.cn

Zijian Zhao[1], Yuxuan Wang[1,2], Momei Qin[3], Yongtao Hu[3], Armistead G. Russell[3]

[1]*Department of Earth System Sciences, Tsinghua University, Beijing, China*

[2]*Department of Earth and Atmospheric Sciences, University of Houston, Houston, Texas, USA*

[3]*School of Civil and Environmental Engineering, Georgia Institute of Technology, Atlanta, Georgia, USA*

16th CMAS
UNC-Chapel Hill
Oct 23-25, 2017

Introduction

Drought has a widespread influence in the US and has been shown to be associated with higher surface pollution levels. A previous observational and modeling analysis indicated a large enhancement of organic aerosol in the southeastern US during the 2011 severe summer drought, but the causes for this enhancement are not well understood.

This study uses the Community Multiscale Air Quality (CMAQ) modeling system to understand the complex effects of drought on emissions, formation, and deposition of air pollutants in the southeast US, with a focus on secondary organic aerosol (SOA). Different model sensitivity simulations are carried out to calculate the SOA budget and quantify the perturbation of drought on deposition, emissions, and chemistry of SOA.

Data & Methodology

1. Model configuration

Model: the Community Multiscale Air Quality (CMAQ) modeling system v5.0.2 with additional updates

- ✓ SOA module: same as CMAQv4.7 Carlton et al. (2010)
- ✓ Isoprene SOA updates: Pye et al. (2013)
- ✓ Adjustment of emissions: Vasilakos et al. (2017, in draft)
- ✓ Monoterpene and multigenerational oxidation updates: Qin et al. (2017, in draft)

Simulation time: 2013 June (May 28th – June 30th, first 4 days as spin up)

Domain: US continent

Resolution: 36km

Input data:

- 2011/2013 meteorology field: May28-June30, simulated by WRF ARW v3.3.1, processed by MCIP v3.6
- 2013 emission field: May28-June30, processed by SMOKE v3.5.1

- ✓ **Dif_all** = Dif_BVOC + Dif_met = 2011 case – 2013 case
- ✓ **Dif_BVOC** = 2011 case - 2011_fixBVOC case
- ✓ **Dif_met** = 2011_fixBVOC case - 2013 case

Table 1. CMAQ simulation cases

Model Simulation	MET field	Emission (Anthropogenic)	Emission (Biogenic)	Descrip-tion
Case1: 2013	2013	Fixed of 2013 (NEI 2011)	BEIS3 2013	Wet year
Case2: 2011_fixBVOC	2011	Fixed of 2013 (NEI 2011)	BEIS3 2013	Drought year
Case3: 2011	2011	Fixed of 2013 (NEI 2011)	BEIS3 online 2011	Drought year

2. Meteorology of drought

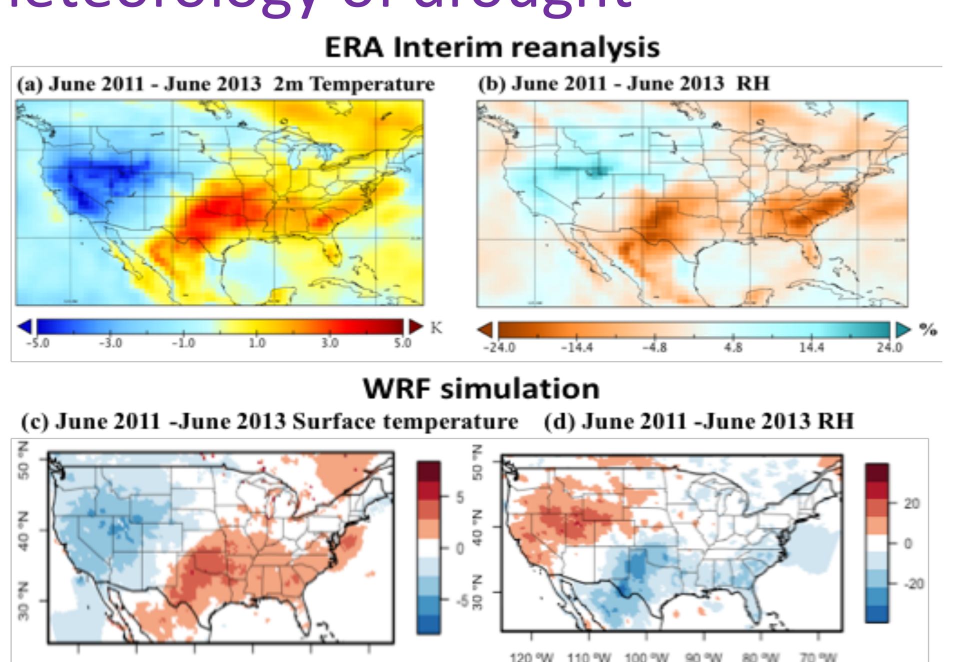
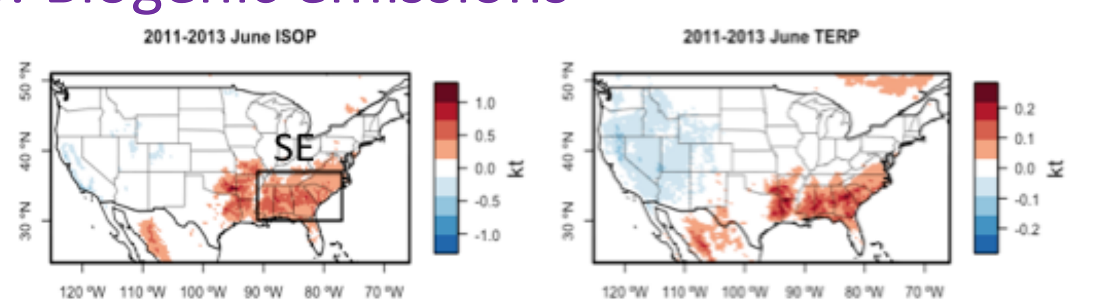


Figure 1. Differences in monthly (a)(c) temperature and (b)(d) relative humidity between June 2011 and June 2013. Data are from ERA Interim reanalysis dataset and WRF ARW v3.3.1 simulations.

3. Biogenic emissions



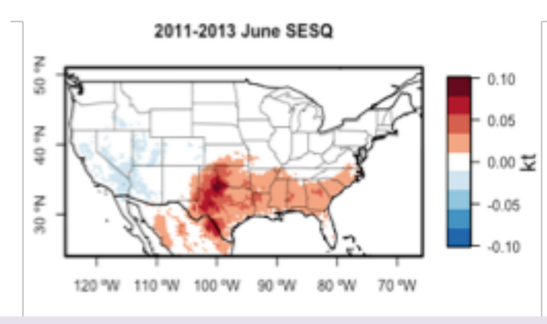


Figure 2. Differences in monthly biogenic emissions of (a) isoprene, (b) monoterpenes, and (c) sesquiterpenes in BEIS3 between June 2011 and June 2013.

Results

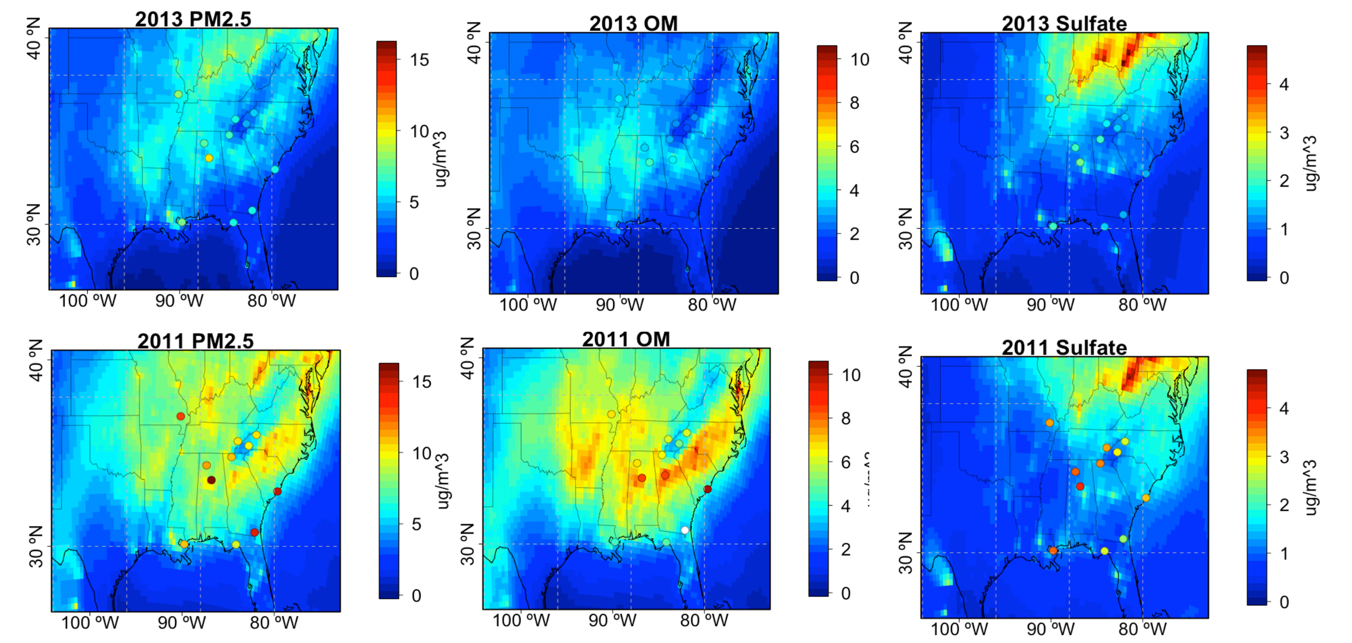


Figure 3. Monthly mean surface $PM_{2.5}$, OM, and sulfate concentrations in 2011 and 2013 over Southeast US from CMAQ model simulations and IMPROVE observations.

Observations

Table 2. Surface $PM_{2.5}$ concentrations from observations of IMPROVE sites over the Southeast US during June 2011 and June 2013.

	June 2011		June 2013		Dif 2011-2013	
μg/m^3	mean	% of mean $PM_{2.5}$	mean	% of mean $PM_{2.5}$	mean	% of mean $PM_{2.5}$
$PM_{2.5}$	11.73	100.0%	6.87	100.0%	4.86	100.0%
OM	6.84	58.3%	2.79	40.6%	4.06	83.4%
Sulfate	3.22	27.4%	1.78	26.0%	1.44	29.6%
Nitrate	0.24	2.1%	0.24	3.4%	0.004	0.1%
EC	0.48	4.1%	0.25	3.6%	0.23	4.8%
Others	0.95	8.1%	1.81	26.4%	-0.87	-17.9%

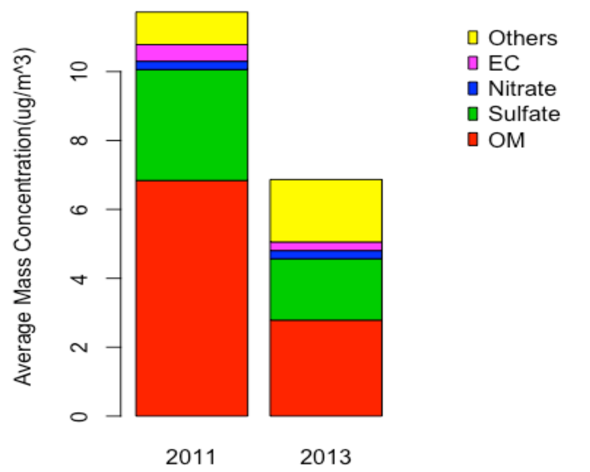


Figure 4. Observed monthly mean $PM_{2.5}$ by species averaged over the IMPROVE surface site locations in the Southeast US during June 2011 and June 2013.

Model

Table 3. Surface $PM_{2.5}$ concentrations from CMAQ model simulation cases over the Southeast US during June.

Case	2011		2011_fixBVOC		2013		Dif_all		Dif_BVOC		Dif_met	
μg/m^3	mean	% of mean $PM_{2.5}$	mean	% of mean $PM_{2.5}$	mean	% of mean $PM_{2.5}$	mean	% of mean $PM_{2.5}$	mean	% of Dif_all	mean	% of Dif_all
$PM_{2.5}$	7.27	100 %	5.53	100 %	4.21	100%	3.06	100%	1.74	57%	1.32	43%
OM	5.32	73%	3.53	64%	2.61	62%	2.71	88%	1.79	66%	0.92	34%
Sulfate	1.28	18%	1.32	24%	1.05	25%	0.24	8%	-0.04	-16%	0.27	116%
Nitrate	0.007	0.1%	0.009	0.2%	0.01	0.2%	-0.002	-0.1%	-0.001	44%	-0.001	56%
Ammonium	0.31	4.3%	0.32	5.8%	0.25	5.9%	0.07	2.1%	-0.005	-8%	0.07	108%
EC	0.1	1.4%	0.1	1.8%	0.08	2.0%	0.02	0.5%	0	0%	0.02	100%
Others	0.26	3.5%	0.25	4.6%	0.21	5.0%	0.04	1.4%	0.002	5%	0.04	95%

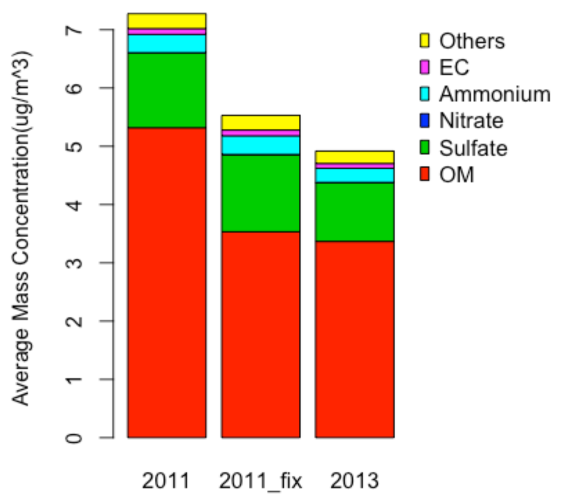


Figure 5. CMAQ simulated monthly mean $PM_{2.5}$ by species averaged over the Southeast US of three simulation cases during June 2013.

Conclusion

- Effects of enhanced biogenic emission and meteorology on $PM_{2.5}$ concentrations:
  - ➢ $PM_{2.5}$ concentrations increase by 73% in the drought case, from 4.2 μg/m^3 to 7.3 μg /m^3.
  - ➢ Nearly 88% and 8% of the total $PM_{2.5}$ increase can be attributed to the increase of OM and sulfate.
- Effects of enhanced biogenic emission on $PM_{2.5}$ concentrations:
  - ➢ 57% of the $PM_{2.5}$ increase is due to the enhanced biogenic emissions, which supplied sufficient BVOCs for BSOA formation.
- Effects of meteorology on $PM_{2.5}$ concentrations (meteorological effects include wet scavenging effects):
  - ➢ 43% of the $PM_{2.5}$ increase is related to the meteorology of drought.
  - ➢ OM and sulfate respectively contribute 70% and 21% of the $PM_{2.5}$ increase from meteorology effects.
- All of the sulfate increase in drought is caused by meteorology changes, not the biogenic emission.
- 66% of the OM increase in drought is driven by biogenic emission changes.
- 34% of the OM increase in drought is associated with meteorology changes.