

Targeting Houston’s ozone: How sector-specific emissions drive spatiotemporal sensitivity

Evan Couzo¹, Colin O’Hagerty², Alejandro Valencia³, Yafang Guo³, Kenneth Craig³, William Vizuite²

¹ Grinnell College, Chemistry Department, Grinnell, Iowa 50112, United States

5 ² University of North Carolina Chapel Hill, Environmental Sciences & Engineering Department, Chapel Hill, North Carolina 27599, United States

³ Spheros Environmental, Denver, Colorado 80204, United States

Correspondence to: William Vizuite (vizuite@unc.edu)

Supplement

10 **Supplemental Table 1. Top 10 Houston-Galveston-Brazoria (HGB) modeling days by monitor for the 2019 modeling platform.**

Site	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
BAYP	9-Jun	1-Aug	1-Jun	12-Jun	5-Oct	3-Aug	15-Aug	31-Aug	2-Aug	26-Jul
BYTE	1-Jun	9-Jun	16-Aug	6-Sep	2-Jun	3-Aug	14-Jun	5-Sep	9-Apr	26-Jul
CLTN	9-Jun	1-Jun	3-Aug	12-Jun	6-Sep	5-Oct	31-Aug	1-Aug	15-Aug	26-Jul
CNR2	16-Aug	14-Jun	5-Sep	5-May	6-Sep	1-Jun	3-Jun	2-Jun	24-Jul	6-Apr
DRPK	9-Jun	1-Jun	3-Aug	12-Jun	5-Oct	14-Aug	6-Sep	2-Aug	15-Aug	9-Apr
GALV	15-Aug	13-Jun	12-Jun	5-Oct	8-Jun	6-Sep	1-Sep	14-Jun	25-Apr	13-Apr
HALC	1-Jun	9-Jun	5-Sep	6-Sep	16-Aug	3-Aug	5-May	14-Jun	12-Jun	2-Jun
HCHV	1-Jun	9-Jun	6-Sep	3-Aug	16-Aug	5-Sep	14-Jun	12-Jun	10-Jul	5-Oct
HCQA	9-Jun	12-Jun	5-Oct	15-Aug	31-Aug	2-Aug	1-Jun	3-Aug	11-Jun	1-Aug

Site	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
HLAA	9-Jun	5-Sep	1-Jun	6-Sep	3-Aug	15-Aug	5-Oct	26-Jul	26-Sep	5-May
HNWA	5-Sep	6-Sep	24-Jul	5-May	16-Aug	15-May	9-Jun	26-Sep	15-Aug	5-Oct
HOEA	9-Jun	1-Jun	3-Aug	6-Sep	12-Jun	5-Oct	5-Sep	31-Aug	14-Jun	26-Jul
HSMA	9-Jun	12-Jun	1-Jun	5-Oct	3-Aug	15-Aug	2-Aug	14-Aug	31-Aug	6-Sep
HWAA	9-Jun	1-Jun	6-Sep	5-Sep	3-Aug	12-Jun	16-Aug	5-May	11-Jul	26-Jul
LKJK	13-Jun	12-Jun	1-Sep	13-Apr	11-Jul	5-Oct	26-Apr	14-Jun	12-May	15-Aug
MACP	12-Jun	5-Oct	9-Jun	15-Aug	2-Aug	31-Aug	1-Sep	13-Jun	14-Aug	25-Jul
PRKP	9-Jun	1-Jun	3-Aug	12-Jun	5-Oct	15-Aug	31-Aug	6-Sep	1-Aug	2-Aug
SBFP	1-Jun	9-Jun	12-Jun	14-Aug	3-Aug	15-Aug	9-Apr	14-Jun	6-Sep	2-Aug
SHWH	9-Jun	1-Aug	26-Jul	5-Oct	1-Jun	15-Aug	6-Sep	2-Aug	31-Aug	12-Jun

Supplemental Table 2. Unique model days for the 2019 Comprehensive Air Quality Model with Extensions (CAMx) Higher-Order Decoupled Direct Method (HDDM) episode. These 34 days represent the top 10 highest maximum daily 8-hour average (MDA8) Tropospheric ozone (O₃) days at the nonattainment monitors. Days marked with an asterisk were removed from the domain-wide analysis (see Sect. 2 for more detail).

April	May	June	July	August	September	October
4/6	5/5	6/1	7/10	8/1	9/1	10/5
4/9	5/12	6/2	7/11	8/2	9/5	--
4/13*	5/15	6/3	7/24*	8/3	9/6	--
4/25	--	6/8	7/25	8/14	9/26	--
4/26*	--	6/9	7/26	8/15	--	--

--	--	6/11	--	8/16	--	--
--	--	6/12	--	8/31	--	--
--	--	6/13	--	--	--	--
--	--	6/14	--	--	--	--

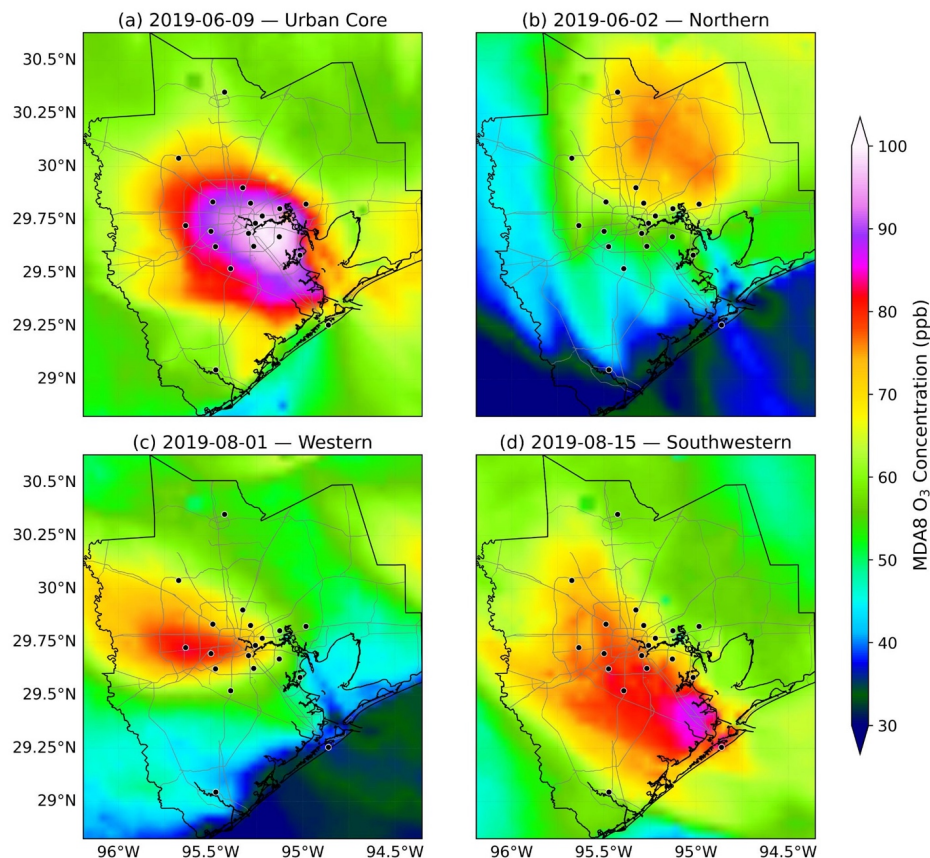
Supplemental Table 3. Summary statistics for Higher-Order Decoupled Direct Method (HDDM) sensitivities (ppb) to nitrogen oxide (NOx) and volatile organic compound (VOC) source groups when VOC emissions are doubled (i.e., the 2xVOC scenario). Sensitivities were extracted from high tropospheric ozone (O₃) plumes between 10:00 AM and the hour after model-predicted maximum O₃ concentrations on 31 high O₃ days. A description of plume identification is provided in Sect. 2. HDDM sensitivities to a given emitted precursor (e.g., NOx) are defined as the maximum ozone change achieved with a 100% reduction in that precursor with a 0% reduction in the other precursor (e.g., VOC).

Summary Statistics for HDDM Sensitivity to NOx and VOC Source Groups Across all High Ozone Days for Doubled VOC Emissions (2xVOC Scenario)					
Source Category	Mean	Median	Maximum	Minimum	Standard Deviation
Non-EGU VOC	5.52	4.07	23.39	0.00	5.08
Non-EGU NOx	3.40	3.42	12.27	-14.47	3.49
Area VOC	2.22	2.02	10.61	0.00	1.61
Marine NOx	1.81	2.07	7.95	-9.03	2.11
On-Road NOx	1.57	1.39	6.28	-2.99	1.62
Non-Road NOx	0.87	0.82	3.57	-1.65	0.95
EGU NOx	0.75	0.55	4.22	-2.22	1.02
Area NOx	0.67	0.67	2.29	-1.11	0.72
Off-Road NOx	0.57	0.46	3.00	-1.30	0.72
Non-Road VOC	0.35	0.31	1.25	0.00	0.23

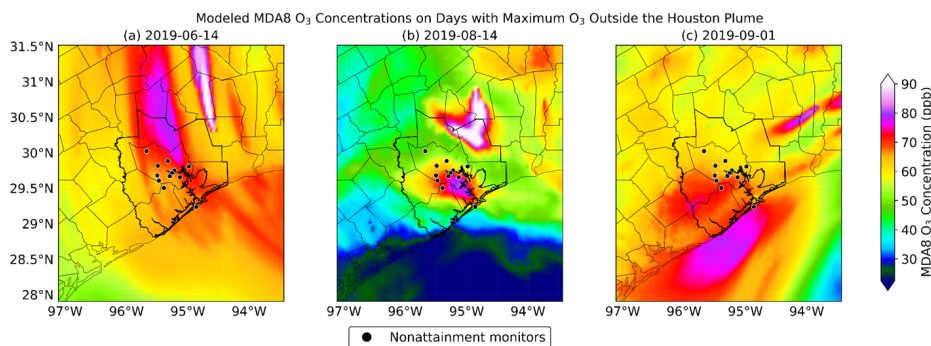
On-Road VOC	0.23	0.20	1.17	0.00	0.19
Marine VOC	0.11	0.09	0.47	0.00	0.10
Oil and Gas VOC	0.06	0.04	0.33	0.00	0.05
Off-Road VOC	0.04	0.03	0.34	0.00	0.03
Oil and Gas NOx	0.01	0.01	0.10	-0.04	0.02
EGU VOC	0.01	0.01	0.04	0.00	0.01

Note: EGU = electric generating unit

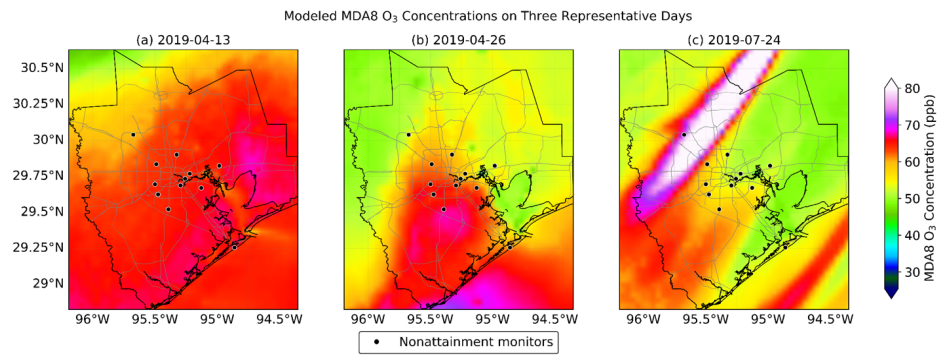
MDA8 O₃ Concentrations on Four Representative Houston Days



Supplemental Figure 1. Modeled maximum daily 8-hour average (MDA8) tropospheric ozone (O₃) concentrations on four days indicative of (a) urban core, (b) northern, (c) western, and (d) southwestern plume patterns. Black dots show the nonattainment monitors, and the black border outlines the Houston-Galveston-Brazoria (HGB) nonattainment area.



Supplemental Figure 2. Modeled maximum daily 8-hour average (MDA8) tropospheric ozone (O₃) concentrations on (a) 14 June, (b) 14 August, and (c) 1 September. Maximum O₃ occurs outside of the Houston-Galveston-Brazoria (HGB) region. While these days were included in the overall analysis, the analysis region was constrained to exclude the non-HGB high O₃ plumes. Black dots show the nonattainment monitors, and the black border outlines the HGB nonattainment area.



Supplemental Figure 3. Modeled maximum daily 8-hour average (MDA8) tropospheric ozone (O₃) concentrations on (a) 13 April, (b) 26 April, and (c) 24 July. These days were excluded from the overall analysis because the high O₃ plumes originate outside of the modeling domain. Two of these days are included in individual monitor analyses, however. 13 April was a top 10 O₃ day at GALV (far southeast), and 24 July was a top 10 O₃ day at HNWA (far northwest). Black dots show the nonattainment monitors, and the black border outlines the HGB nonattainment area.