Sensitivity of Ozone to Peaking Units versus All EGU Point and Mobile Source Emissions using CMAQ DDM

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Background

•There is a robust correlation between ambient temperature, energy load, and electric generating unit (EGU) point sources emissions.[1] On days of high energy demand, which are associated with high ambient temperatures, additional generators are operated for power generation. These units are referred to as "peaking units". The peaking unit NO_x emissions can contribute significantly to total EGU NO_x emissions and air quality on those high temperature days. In this study we characterize the sensitivity of ozone concentrations to peaking EGU units compared to all EGU units and mobile source emissions in the Mid-Atlantic/Northeast Visibility Union (MANEVU) region using the direct decoupled method (DDM), sensitivity analysis technique for the Community Multiscale Air Quality (CMAQ) model. CMAQ DDM v.4.7.1 simulated ozone sensitivities from baseline 2007 emissions were used to project ozone air quality in 2011 based on anticipated ozone precursor emission changes. The results from this study will help characterize air quality impacts from these sources and support policy decisions for air quality management.

Objectives

•Estimate the effect of emissions changes in mobile sources and EGU point sources on ozone concentrations based on historic emissions changes from 2007 to 2011

•Analyze peaking unit contributions to ozone air quality in NY

Modeling System and Approach

•CMAQ DDM v4.7.1 with Carbon Bond 05 (gas phase) and AERO5 (aerosol) chemistry
•2007 MARAMA V3 emissions inventory
•12-km modeling domain, as illustrated in Figure 1
•Study period of 5/15/2007 to 9/15/2007

•CMAQ DDM simulations to compute O_3 sensitivity to NO_x and VOC precursor emission changes in the following emission categories:

1) all anthropogenic emission sources
2) mobile source emissions
3) "peaking unit" EGU point sources emissions
4) all EGU point sources emissions

•Spatially, sensitivity fields are calculated separately for emissions from the following regions:

1) NYC only area (NYCONLY)
2) MANEVU region except NYC (MVNONYC)
3) southeastern US region (SESARM)
4) rest of the modeling domain (LADCEN) to distinguish sensitivities from local vs. regional emissions. Figure 1 shows our modeling domain and emissions sensitivity regions.

• DDM calculates 1st order sensitivities of ozone to changes in NO_x and VOC from each emission source category and each region as listed above.

•We grouped hourly O_3 sensitivity data (5/15 – 9/15/2007) based on daily max 8 hour average O_3 into the following categories: 10 worst days, >=75 ppb, 50-75 ppb, and <50 ppb, as well as 21 days when daily total NO_x emissions from all peaking units in the MANEVU region were greater than 80 tons per day. Figure 2 illustrates daily total NO_x emissions from all peaking units in the MANEVU and NYS region, highlighting 21 days with NO_x emissions greater than 80 tons. Figure 3 shows selected ozone monitoring sites and locations of peaking units operating during those 21 days (193 locations) with 21-day total NO_x emissions.

•Based on 2007 MARAMA V3 and 2011 EPA V1 inventories, we used the following emissions changes for our case study: MVNONYC/NYCONLY NO_x(-30%) and VOC(-20%), SESARM NO_x(-30%) and VOC(+40%), and LADCEN NO_x(-15%) and VOC(+15%).

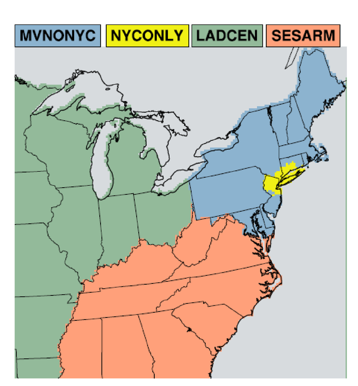

Figure 1. 12-km Modeling Domain and Emission Sensitivity Regions

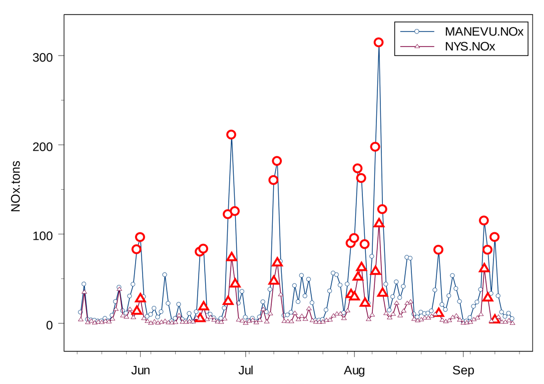

Figure 2. Daily total NO_x emissions from all peaking units (5/15-9/15/2007) (21 days exceeding 80 tons/day)

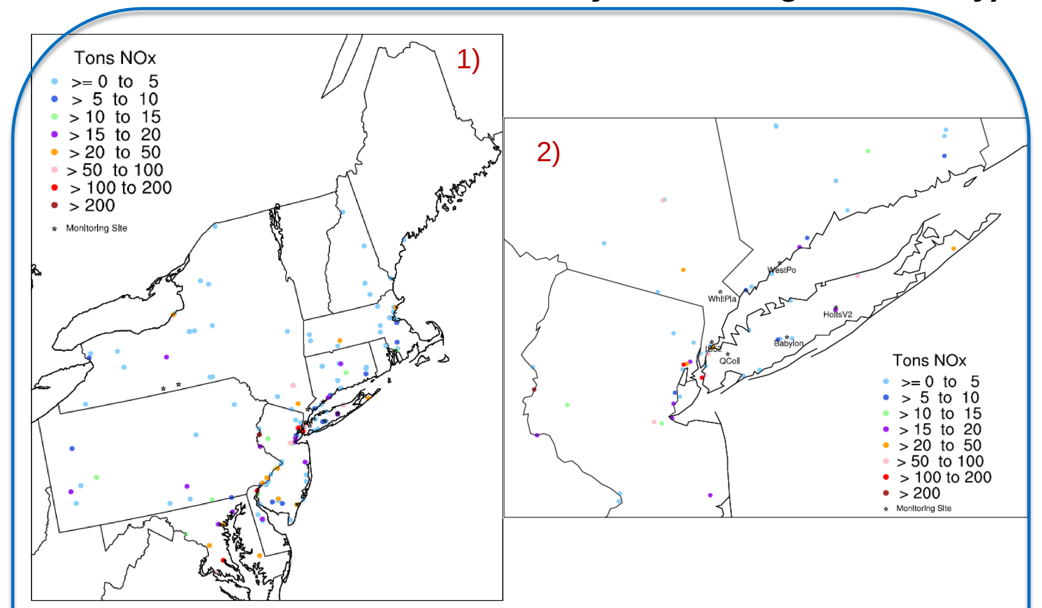

Figure 3. Selected monitoring sites and locations of peaking units for sum of NO_x greater than 80 tons in MANEVU:
1) MANEVU region 2) NYCONLY region

Results

Example site: Holtsville, Babylon, NY Botanical Garden (NYBG) Pfizer lab, and Queens College (QC) in NY

(New York-N. New Jersey-Long Island, NY-NJ-CT 8 hour ozone nonattainment areas (2008 standard))

Sensitivity Regions and Pollutants:
a) MVNONYC NOX b) MVNONYC VOC
c) NYCONLY NOX d) NYCONLY VOC

1. Max 8hr avg O_3, 10 worst days (Holtsville)

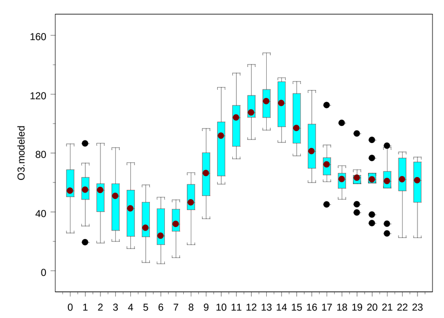

Figure 4-1. O_3 hourly distribution

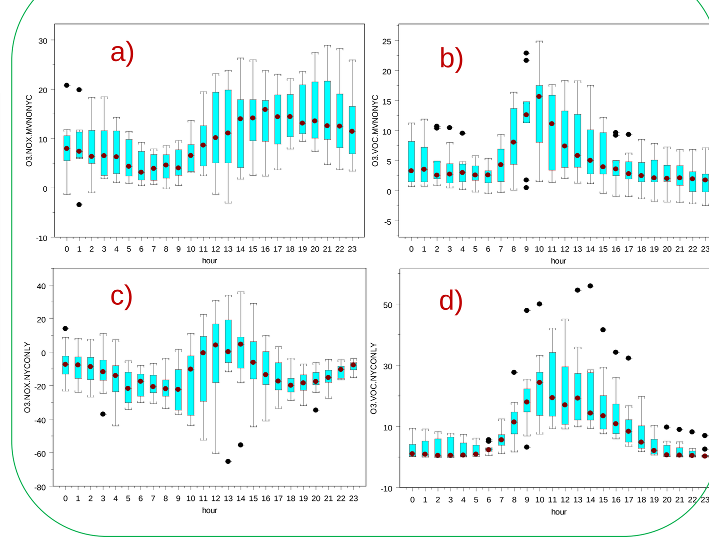

Figure 4-2. O_3 sensitivity to ALL source emissions

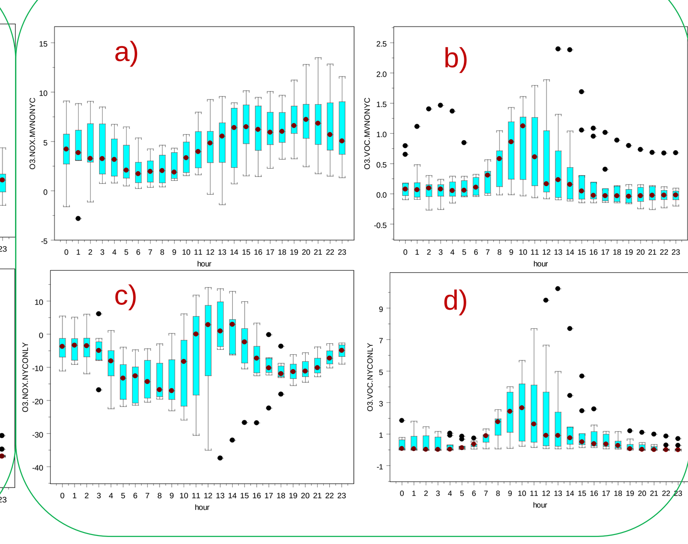

Figure 4-3. O_3 sensitivity to mobile source emissions

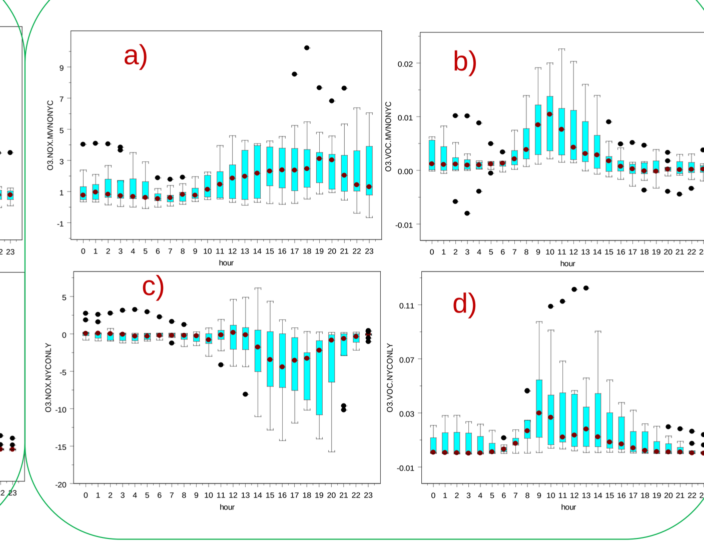

Figure 4-4. O_3 sensitivity to all EGU source emissions

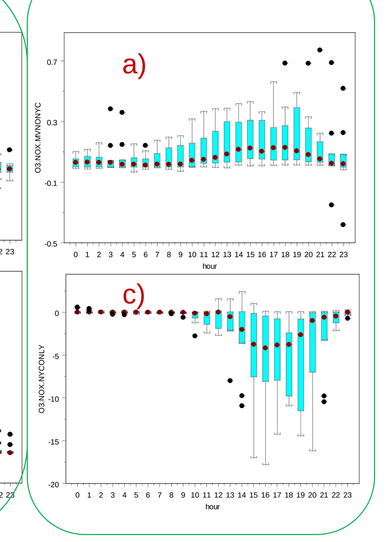

Figure 4-5. O_3 sensitivity to peaking EGU source emissions

2. Max 8hr avg O_3, 50 - 75 ppb (Holtsville)

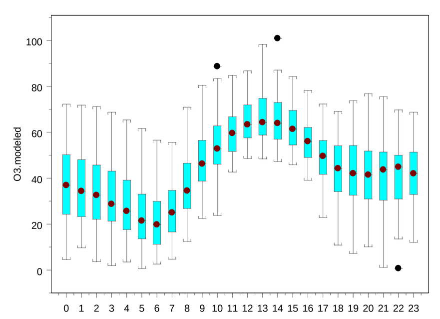

Figure 5-1. O_3 hourly distribution

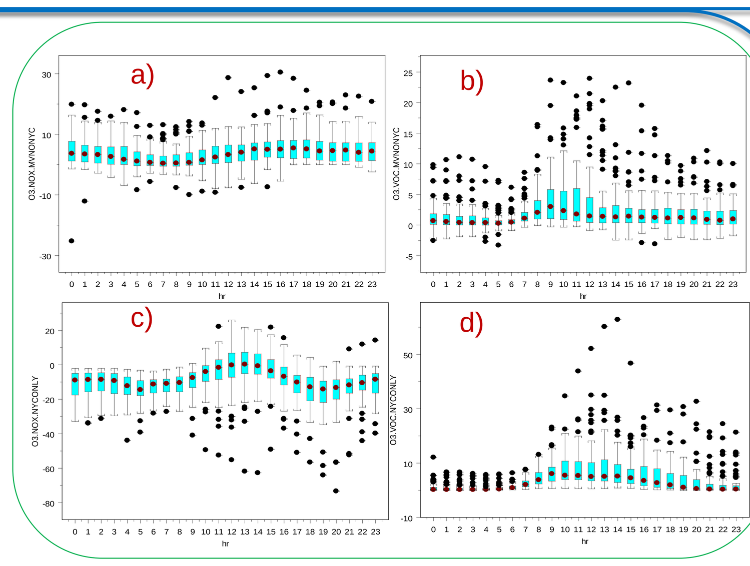

Figure 5-2. O_3 sensitivity to ALL source emissions

Table 1. O_3 reductions (ppb) associated with each emission change scenario on selected sites in NY for 10 max 8hr average O_3 worst days

				O3 reductions associated with each emission changes scenario															
				MVNY	MVNY	MVNY	MV	MV	MV	NY	NY	NY	SE	SE	SE	LAD	LAD	LAD	allreg
site	site ID		base O3	nox.voc	nox	voc	nox.voc	nox	voc	nox.voc	nox	voc	nox.voc	nox	voc	nox.voc	nox	voc	nox.voc
All sources emissions																			
Babylon	361030002	**mean**	**99.8**	**4.6**	**-2.9**	**7.5**	**5.8**	**3.3**	**2.4**	**-1.1**	**-6.2**	**5.1**	**-0.5**	**1.4**	**-1.9**	**0.0**	**0.3**	**-0.3**	**4.2**
		SD	6.5	4.0	7.1	4.1	2.6	1.8	1.6	5.5	7.0	2.8	1.3	1.5	1.6	0.2	0.4	0.2	4.4
Holtsville	361030009	**mean**	**99.3**	**7.1**	**1.6**	**5.5**	**5.2**	**3.6**	**1.7**	**1.9**	**-1.9**	**3.8**	**-0.3**	**1.0**	**-1.4**	**0.0**	**0.2**	**-0.2**	**6.8**
		SD	11.7	4.8	6.0	2.2	1.2	1.5	0.9	4.9	5.5	1.6	1.4	0.9	1.8	0.1	0.2	0.1	5.7
NYBG	360050133	**mean**	**90.0**	**-0.1**	**-8.3**	**8.3**	**4.1**	**2.2**	**1.9**	**-4.1**	**-10.5**	**6.4**	**-1.1**	**1.4**	**-2.6**	**0.0**	**0.2**	**-0.2**	**-1.2**
		SD	3.5	2.2	5.1	3.8	1.7	1.1	1.4	3.7	5.3	2.6	2.0	1.3	2.5	0.1	0.2	0.2	4.0
QC	360810124	**mean**	**90.0**	**0.4**	**-6.2**	**6.6**	**4.8**	**3.0**	**1.8**	**-4.4**	**-9.2**	**4.8**	**0.1**	**1.5**	**-1.3**	**-0.1**	**0.4**	**-0.4**	**0.5**
		SD	10.9	2.9	4.7	3.0	1.9	1.6	0.9	3.3	4.4	2.3	1.8	1.6	1.2	0.4	0.4	0.4	4.0
Mobile sources emissions																			
Babylon	361030002	**mean**	**99.8**	**-2.3**	**-3.1**	**0.7**	**1.6**	**1.5**	**0.1**	**-4.0**	**-4.6**	**0.6**	**0.6**	**0.6**	**0.0**	**0.1**	**0.1**	**0.0**	**-1.6**
		SD	6.5	3.4	3.9	0.5	0.9	0.8	0.1	3.6	4.0	0.5	0.7	0.7	0.0	0.2	0.2	0.0	3.6
Holtsville	361030009	**mean**	**99.3**	**0.5**	**0.1**	**0.4**	**1.7**	**1.6**	**0.1**	**-1.2**	**-1.5**	**0.3**	**0.5**	**0.5**	**0.0**	**0.1**	**0.1**	**0.0**	**1.1**
		SD	11.7	2.7	3.1	0.4	0.4	0.4	0.1	2.7	3.0	0.3	0.4	0.5	0.0	0.1	0.1	0.0	2.6
NYBG	360050133	**mean**	**90.0**	**-4.2**	**-4.9**	**0.7**	**1.1**	**1.0**	**0.1**	**-5.3**	**-6.0**	**0.6**	**0.7**	**0.7**	**0.0**	**0.1**	**0.1**	**0.0**	**-3.5**
		SD	3.5	2.4	2.7	0.4	0.6	0.5	0.0	2.6	2.8	0.4	0.7	0.7	0.0	0.1	0.1	0.0	2.8
QC	360810124	**mean**	**90.0**	**-4.5**	**-5.0**	**0.6**	**1.3**	**1.3**	**0.1**	**-5.8**	**-6.3**	**0.5**	**0.7**	**0.7**	**0.0**	**0.2**	**0.2**	**0.0**	**-3.6**
		SD	10.9	2.8	3.0	0.3	0.7	0.7	0.0	2.8	3.0	0.3	0.8	0.8	0.0	0.2	0.2	0.0	3.2
All EGU point sources emissions																			
Babylon	361030002	**mean**	**99.8**	**0.5**	**0.5**	**0.0**	**0.7**	**0.7**	**0.0**	**-0.1**	**-0.1**	**0.0**	**0.2**	**0.2**	**0.0**	**0.0**	**0.0**	**0.0**	**0.8**
		SD	6.5	0.8	0.9	0.0	0.4	0.4	0.0	0.7	0.7	0.0	0.2	0.2	0.0	0.0	0.0	0.0	1.0
Holtsville	361030009	**mean**	**99.3**	**0.1**	**0.1**	**0.0**	**0.6**	**0.6**	**0.0**	**-0.5**	**-0.5**	**0.0**	**0.2**	**0.2**	**0.0**	**0.0**	**0.0**	**0.0**	**0.3**
		SD	11.7	0.8	0.8	0.0	0.3	0.4	0.0	0.8	0.8	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.8
NYBG	360050133	**mean**	**90.0**	**-0.3**	**-0.3**	**0.0**	**0.4**	**0.4**	**0.0**	**-0.7**	**-0.7**	**0.0**	**0.2**	**0.2**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
		SD	3.5	0.7	0.7	0.0	0.3	0.3	0.0	0.8	0.8	0.0	0.2	0.2	0.0	0.0	0.0	0.0	0.8
QC	360810124	**mean**	**90.0**	**0.1**	**0.1**	**0.0**	**0.6**	**0.6**	**0.0**	**-0.5**	**-0.5**	**0.0**	**0.3**	**0.3**	**0.0**	**0.1**	**0.1**	**0.0**	**0.4**
		SD	10.9	0.8	0.8	0.0	0.4	0.4	0.0	0.6	0.6	0.0	0.2	0.2	0.0	0.0	0.0	0.0	0.9

MVNY: (MVNONYC & NYCONLY) MV: (MVNONYC) NY: (NYCONLY) SE: (SESARM) LAD: (LADCEN) allreg: (ALL REGIONS)

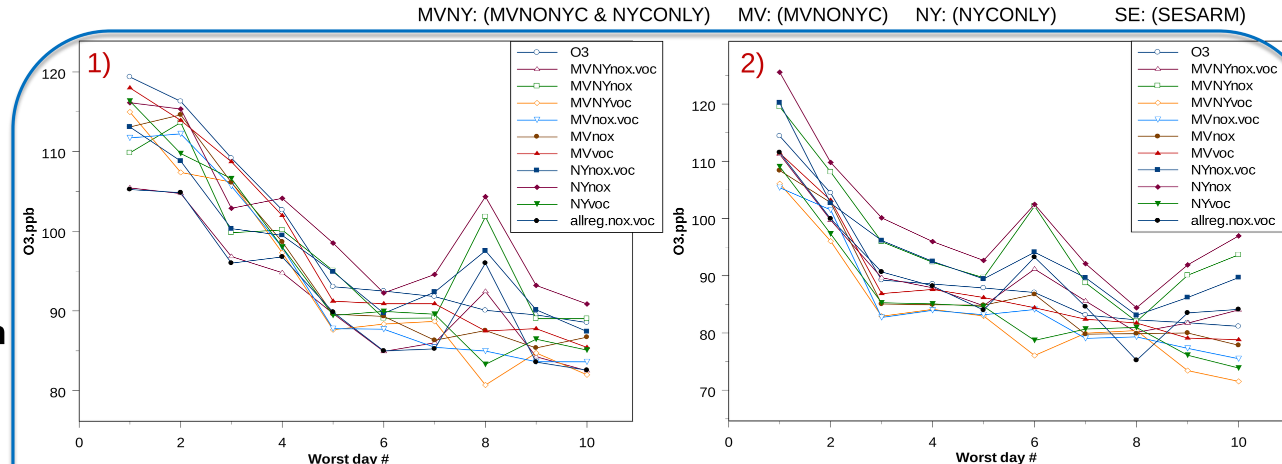

Figure 6. Daily max 8hr avg O_3 (base) of 10 worst days and new daily max 8hr avg O_3 for each emission/region (all sources) change scenario:
1) Holtsville 2) QC

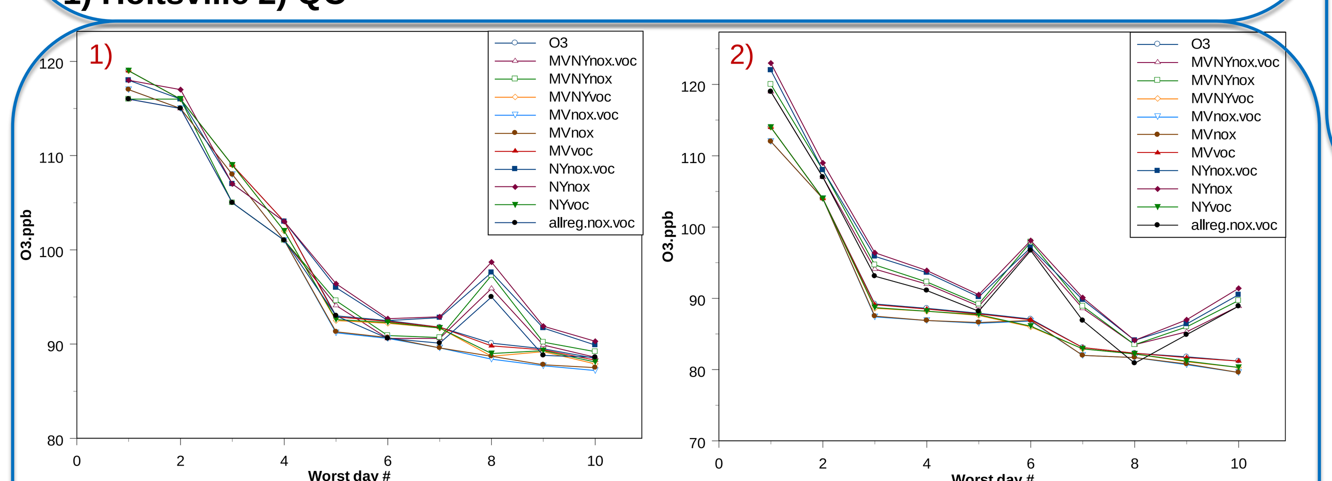

Figure 7. Daily max 8hr avg O_3 (base) of 10 worst days and new daily max 8hr avg O_3 for each emission/region (mobile sources) change scenario:
1) Holtsville 2) QC

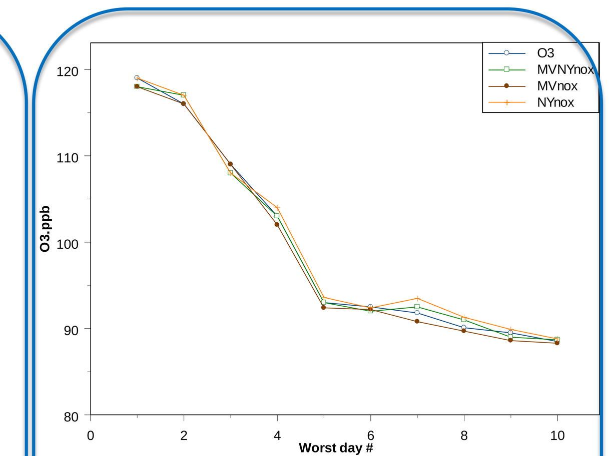

Figure 8. Daily max 8hr avg O_3 (base) of 10 worst days and new daily max 8hr avg O_3 for each emission/region (all EGU sources) change scenario (Holtsville)

3. Peaking units high demand days (21 days)

Daily total NO_x from peaking units in MANEVU greater than 80 tons

(Holtsville)

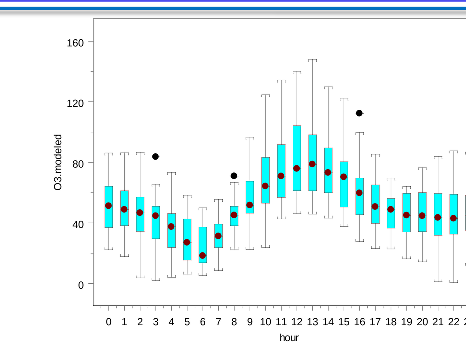

Figure 9-1. O_3 hourly distribution

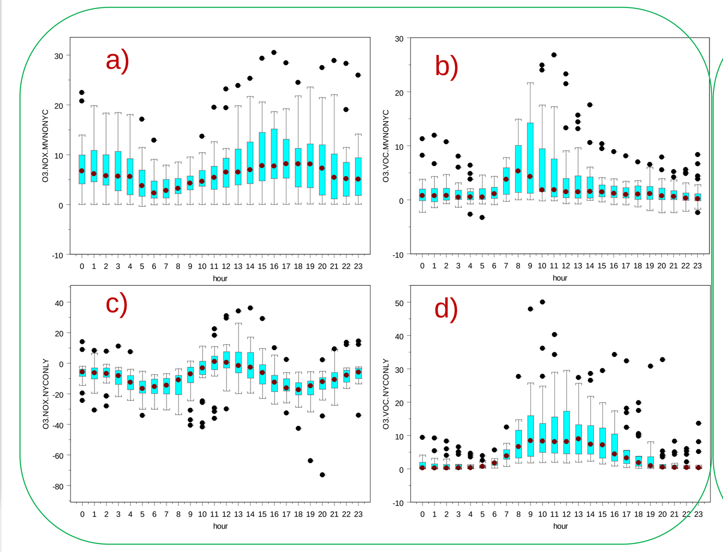

Figure 9-2. O_3 sensitivity to ALL source emissions

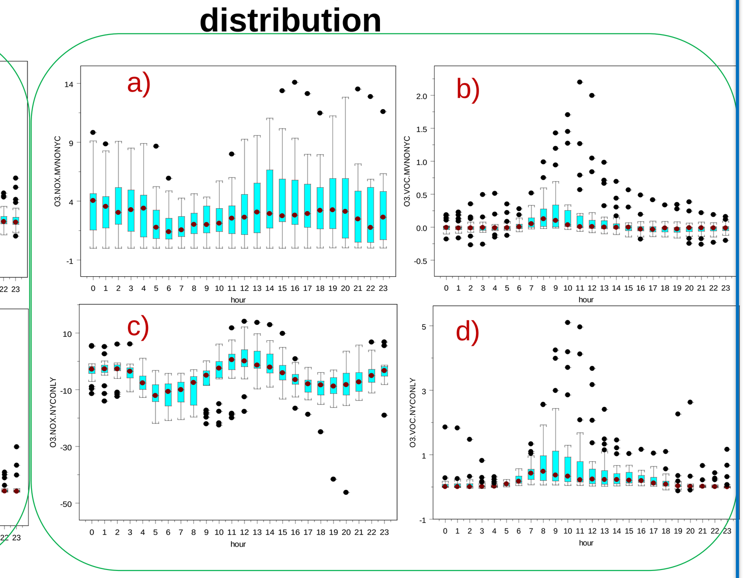

Figure 9-3. O_3 sensitivity to mobile source emissions

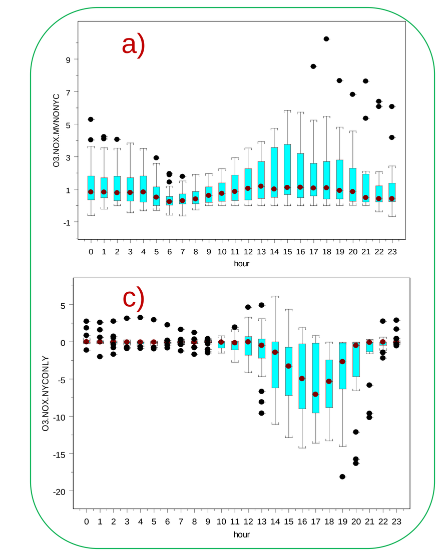

Figure 9-4. O_3 sensitivity to all EGU source emissions

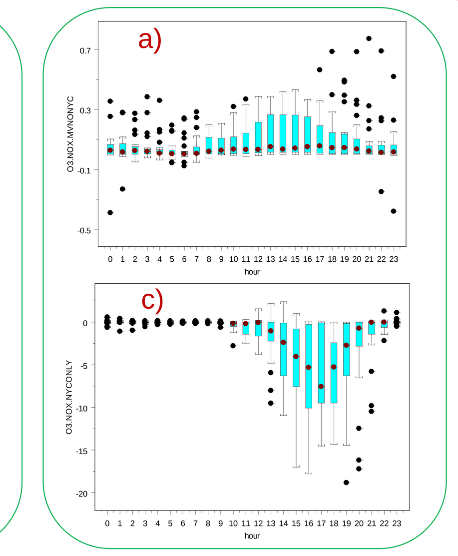

Figure 9-5. O_3 sensitivity to peaking EGU source emissions

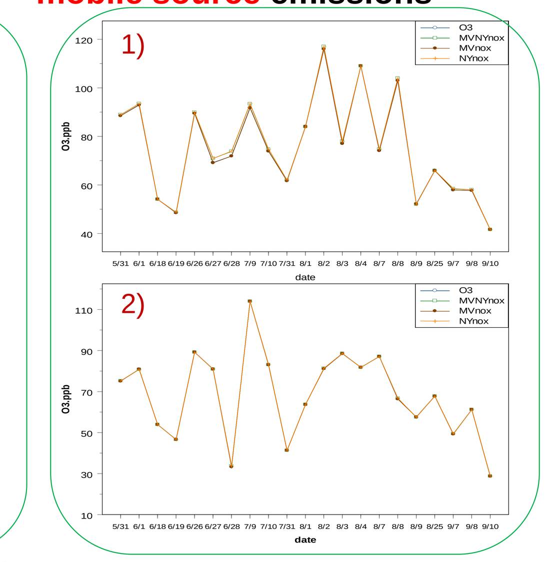

Figure 9-6. Daily max 8hr avg O_3 (base) and new daily max 8hr avg O_3 for each emission/region (peaking unit sources) change scenario:
1) Holtsville 2) QC

Summary

•O_3 sensitivities at the Holtsville site show diurnal patterns for the MVNONYC and NYCONLY emissions, but no distinct diurnal patterns in the SESARM and LADCEN emissions cases (not shown). The group (>=75 ppb) has a similar characteristic to the 10 worst day group (not shown).
•Diurnal patterns of O_3 sensitivities are less pronounced in the groups: 50-75 ppb and <50ppb (not shown).
•Emissions from the SESARM and LADCEN regions less contribute to O_3 in NY, compared to emission from the MVNONYC and NYCONLY regions.
•NO_x emissions from NYCONLY show negative O_3 sensitivity due to NO_x titration, therefore NO_x emissions reductions in NY could cause O_3 increases.
•O_3 predictions at the same location could vary from emission control scenario to scenario and from day to day.
•O_3 sensitivities to emissions vary from site to site.
•The QC site shows bigger O_3 sensitivities to mobile source emissions, compared to the Holtsville site.
•O_3 sensitivity to all EGU sources is small, compared to mobile sources.
•O_3 sensitivity to peaking EGU source emissions in NY is minimal even on high demand operating days.
•Quantifying temporal and spatial variations of the sensitivity fields from our model simulations will provide air quality managers with information on how the efficacy of certain control measures may vary from episode to episode, thus introducing a dynamic aspect into the process of developing emission control strategies aimed at meeting the NAAQS.

References

1. Yun, J., P. Doraiswamy, C. Hogrefe, E. Zalewsky, W. Hao, J.-Y. Ku, M. Beauharnois, and K. L. Demerjian (2013). Developing Real-Time Emissions Estimates for Enhanced Air Quality Forecasting, Environmental Management, November, pp.22-27.

Acknowledgements

This work was funded by U.S. EPA's STAR program. We would like to acknowledge Christian Hogrefe (U.S. EPA) for his comments and suggestions on this work and Sergey Napelenok (U.S. EPA) for his help with resolving computational issues with the CMAQ-DDM code.