EPA STAR Grant:
Dynamic Air Quality Management-Progress Review Webinar
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Creating Building Blocks for a More Dynamic Air Quality Management Framework

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Acknowledgement

Thanks to Christian Hogrefe (U.S. EPA), principal scientist who collaborated with our research team under this co-operative agreement and to Sergey Napelenok for his contributions in resolving complier issues associated with the CMAQ-DDM computations.

Presentation Outline

- Research Objectives
- Description of CMAQ-DDM Computation Data Base
- O3 Sensitivity to EGU Peaking units
- Sensitivity analysis of predicted O_3 concentrations with respect to emission source categories and emission domains
- Summary of Findings
- Regional and hemispheric influences on northeastern US baseline carbon monoxide and ozone over 2001 – 2010
- The impact of emission reductions and transport on Hg° in Bronx, NY over 2008 – 2015
- Trends in northeastern U.S. background Hg°
- Summary of Findings

Research Objectives

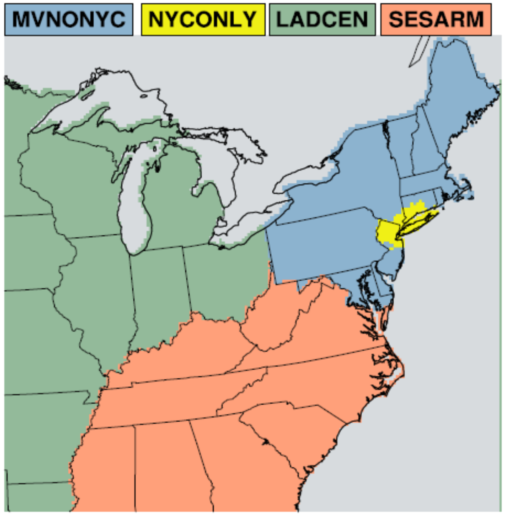
1) Develop a prototype system for providing real-time information on the contribution of short-term emission sources to air quality in relation to other source categories and the potential air quality benefits from episodic control measures.

2) Perform a comprehensive multi-pollutant air quality assessment that examine trends in pollutant concentrations versus emission controls, co-pollutant effects, and develop possible indicators that may aid in improved tracking of the effect of emission controls.

DDM computational database created from CMAQ, (running CMAQ-DDM), NOX, VOC, for O_3 sensitivity (May-Sep, 2007)

Emission Category	NYCONLY					MVNONYC					LADCEN					SESARM				
	May	Jun	Jul	Aug	Sep	May	Jun	Jul	Aug	Sep	May	Jun	Jul	Aug	Sep	May	Jun	Jul	Aug	Sep
1	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
2	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
3	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
4	x	x	x	x	x	x	x	x	x	x	no model runs					no model runs				
5	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
6	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
7	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
BC	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

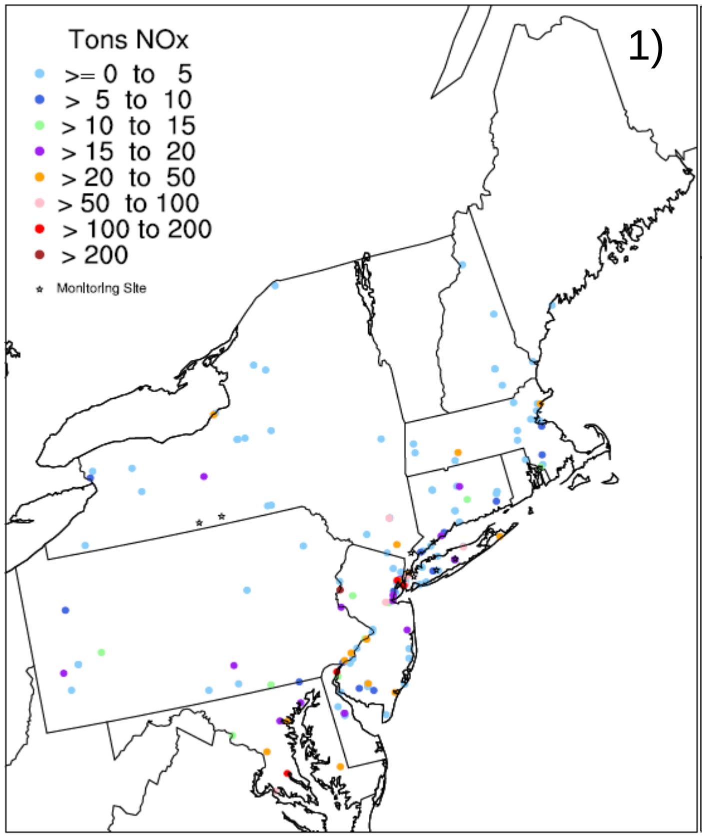
Computational production runs (above table) by emission category: 1) all anthropogenic emission sources; 2) mobile source emissions; 3) combined area and non-road emissions; 4) "peaking unit" electric generating unit (EGU) point sources emissions; 5) all EGU point sources emissions; 6) other point sources emissions; 7) biogenic emissions; and boundary conditions (BC) and the respective emission domains as shown on the right.

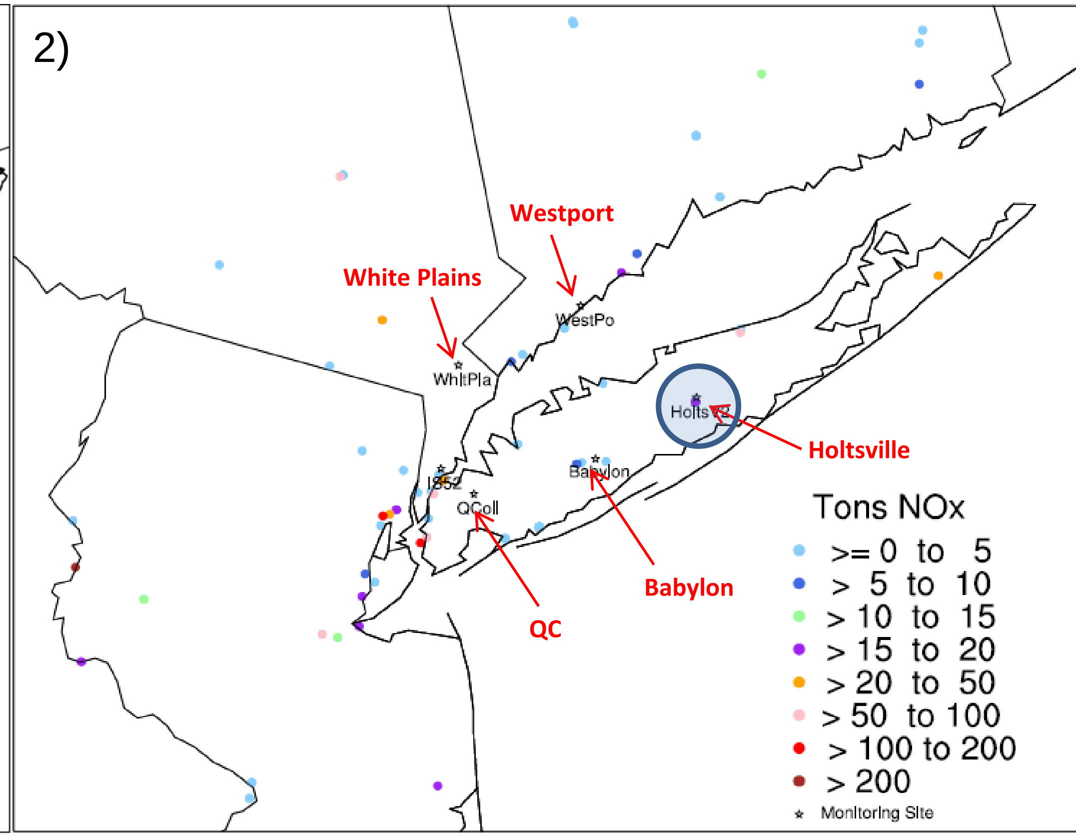


CMAQ-DDM 12-km modeling domain and emission regions

EGU/ PEAKING UNITS O_3 SENSITIVITY

Selected monitoring sites and locations of peaking units for sum of NO_x greater than 80 tons in MANEVU



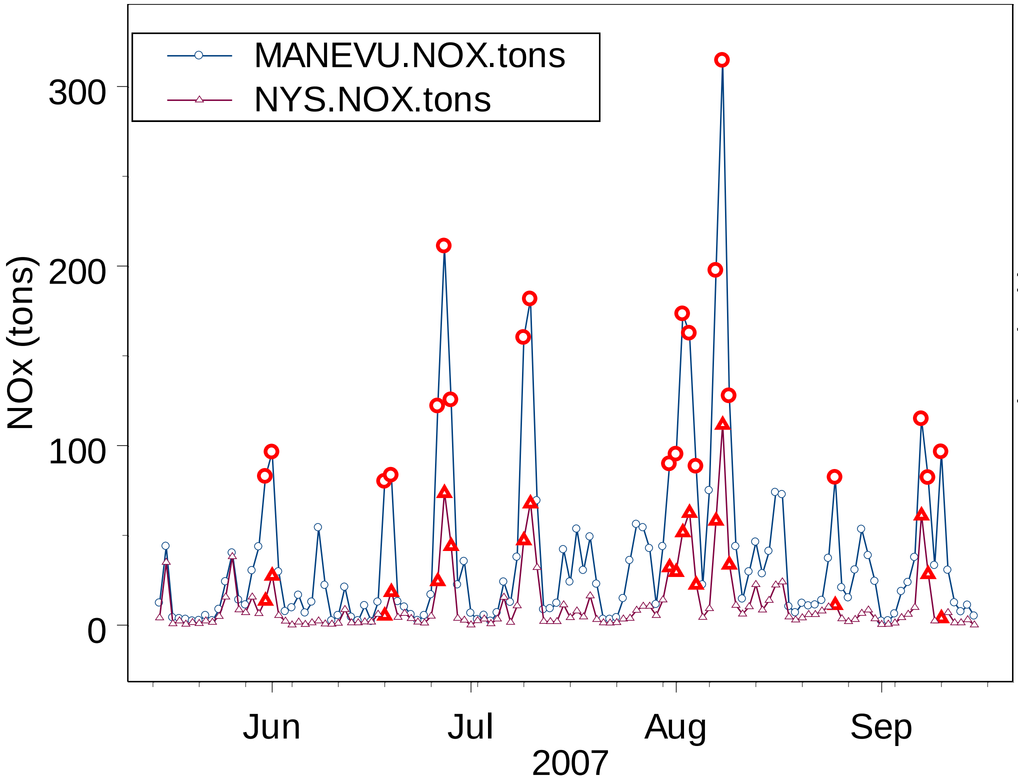


1) MANEVU region

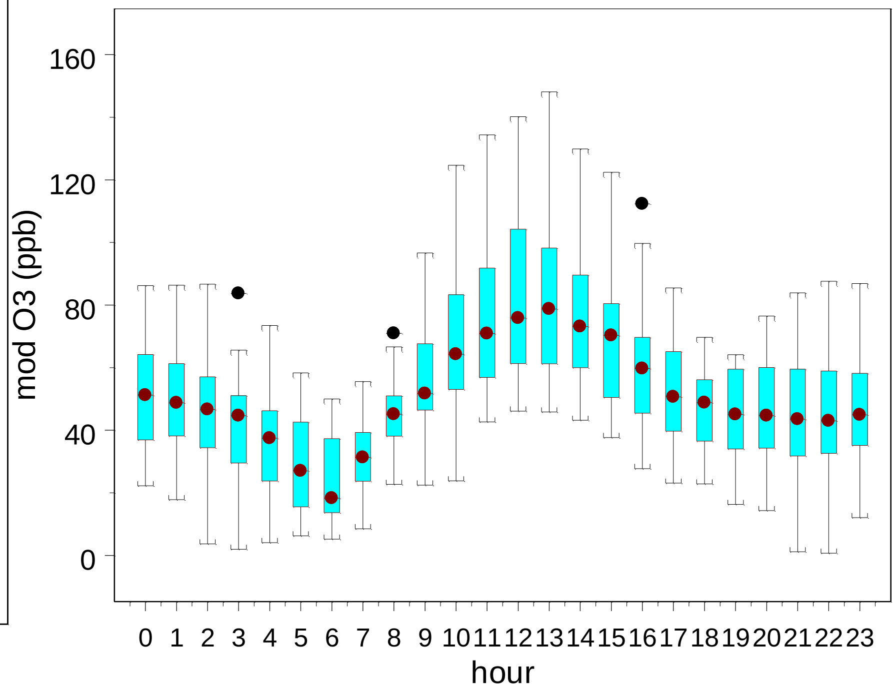
2) NYCONLY region

Yun et al. EM 2013

Peaking units high demand days (21 days) - Daily total NO_x from peaking units in MANEVU greater than 80 tons/day (Holtsville)

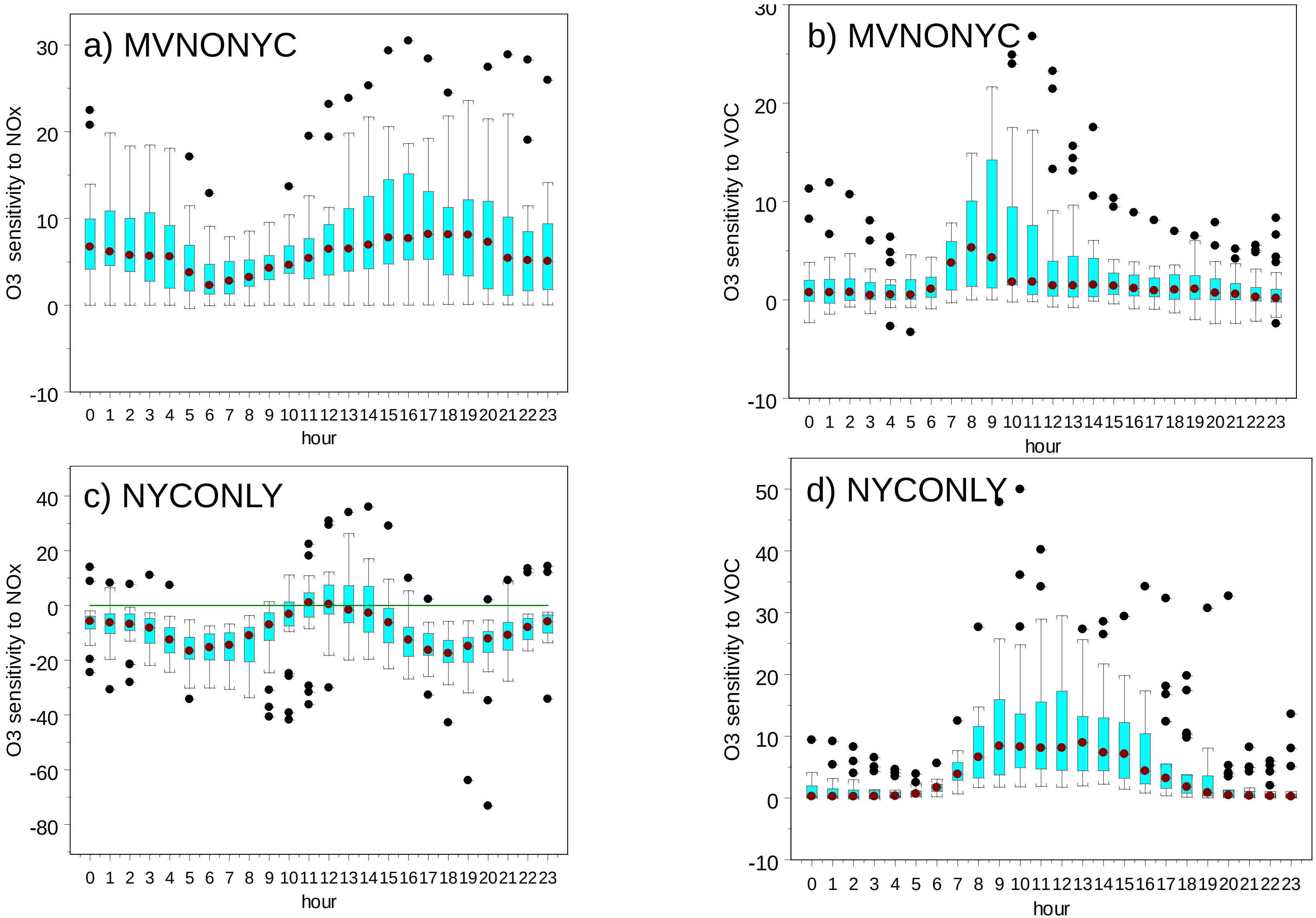


Daily total NO_x emissions from all peaking units (5/15-9/15/2007) (21 days exceeding 80 tons/day)

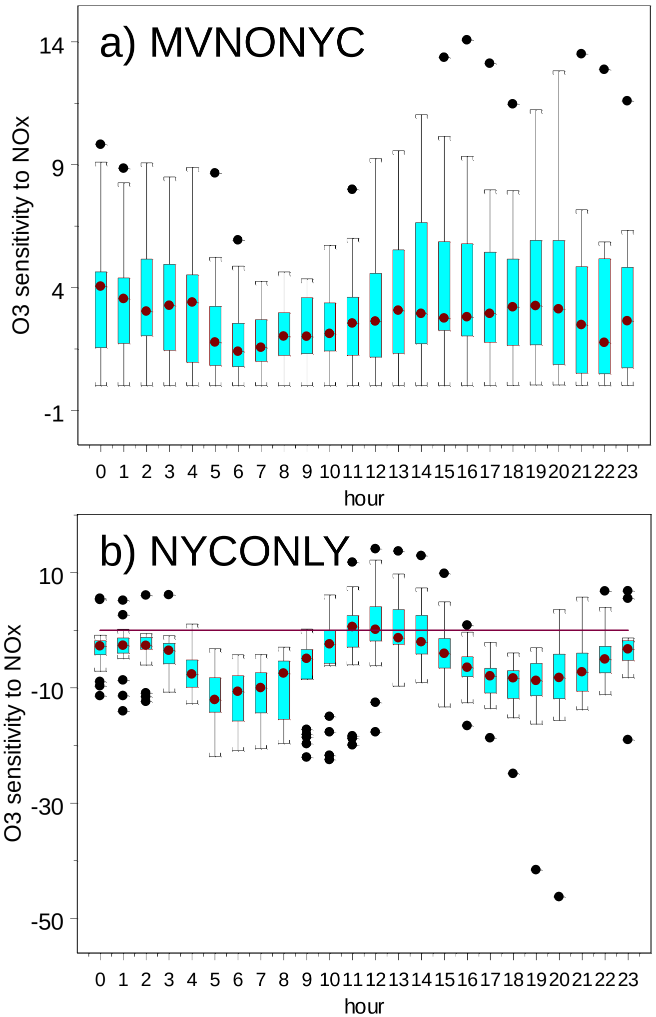


Modeled O_3 hourly distribution (21 days exceeding 80 tons/day)

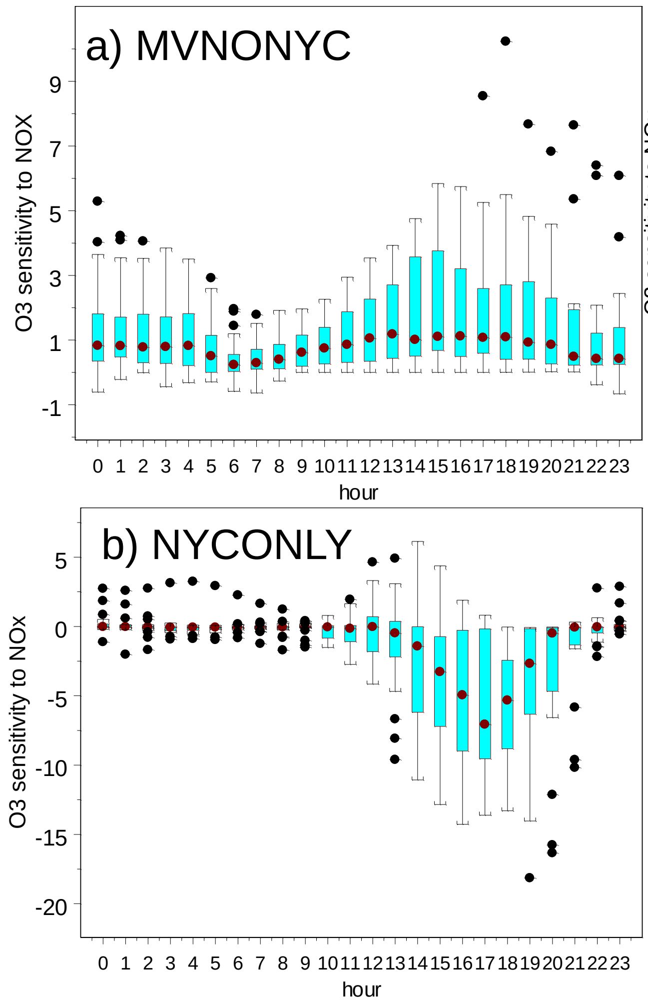
O_3 sensitivity to NOx/VOC emissions from all sources at Holtsville (21 days)



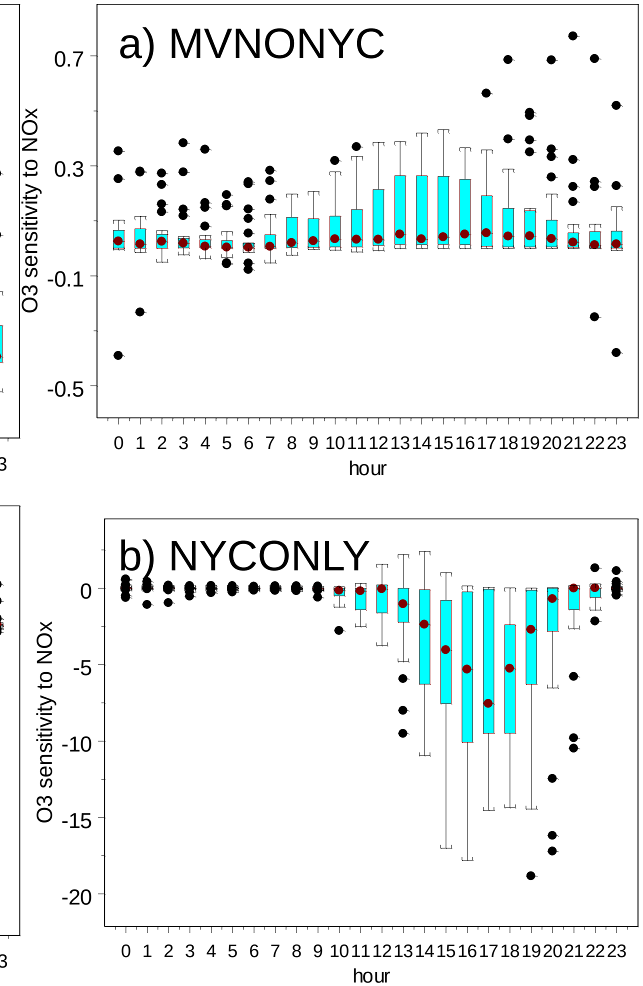
O_3 sensitivity to NOx emissions at Holtsville (21 days)



O_3 sensitivity to mobile source emissions

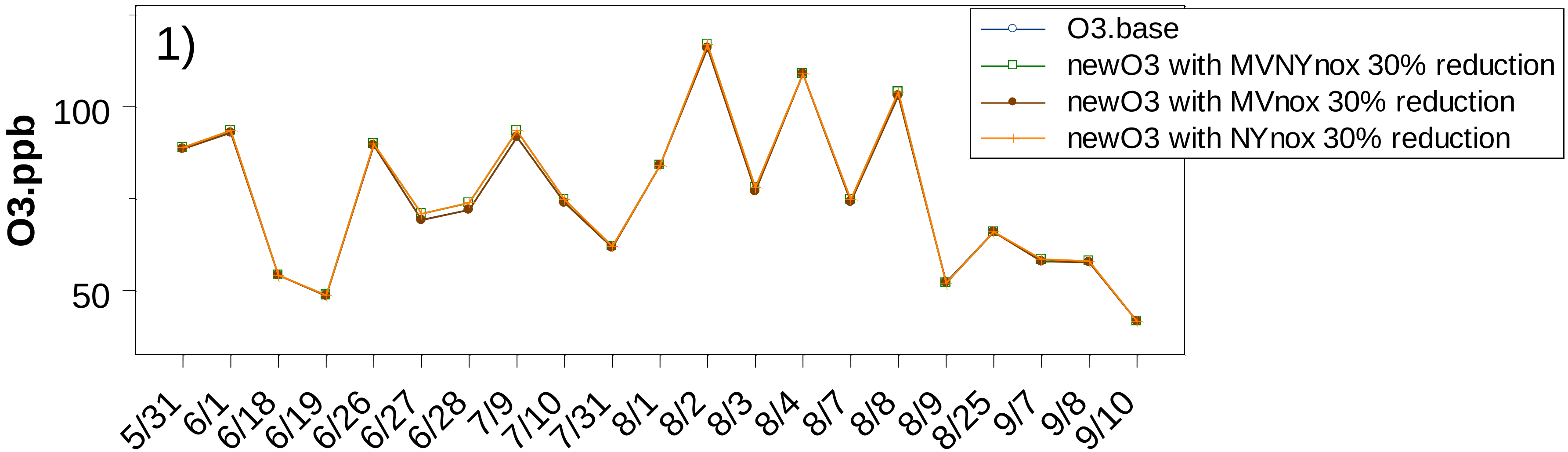


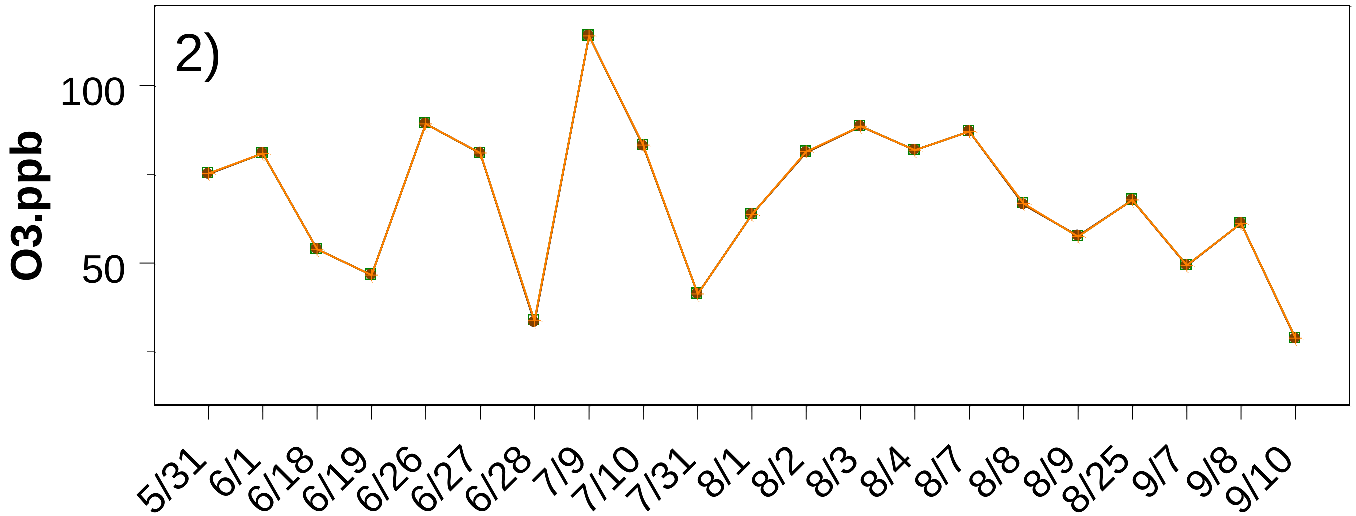
O_3 sensitivity to all EGU source emissions



O_3 sensitivity to peaking EGU source emissions

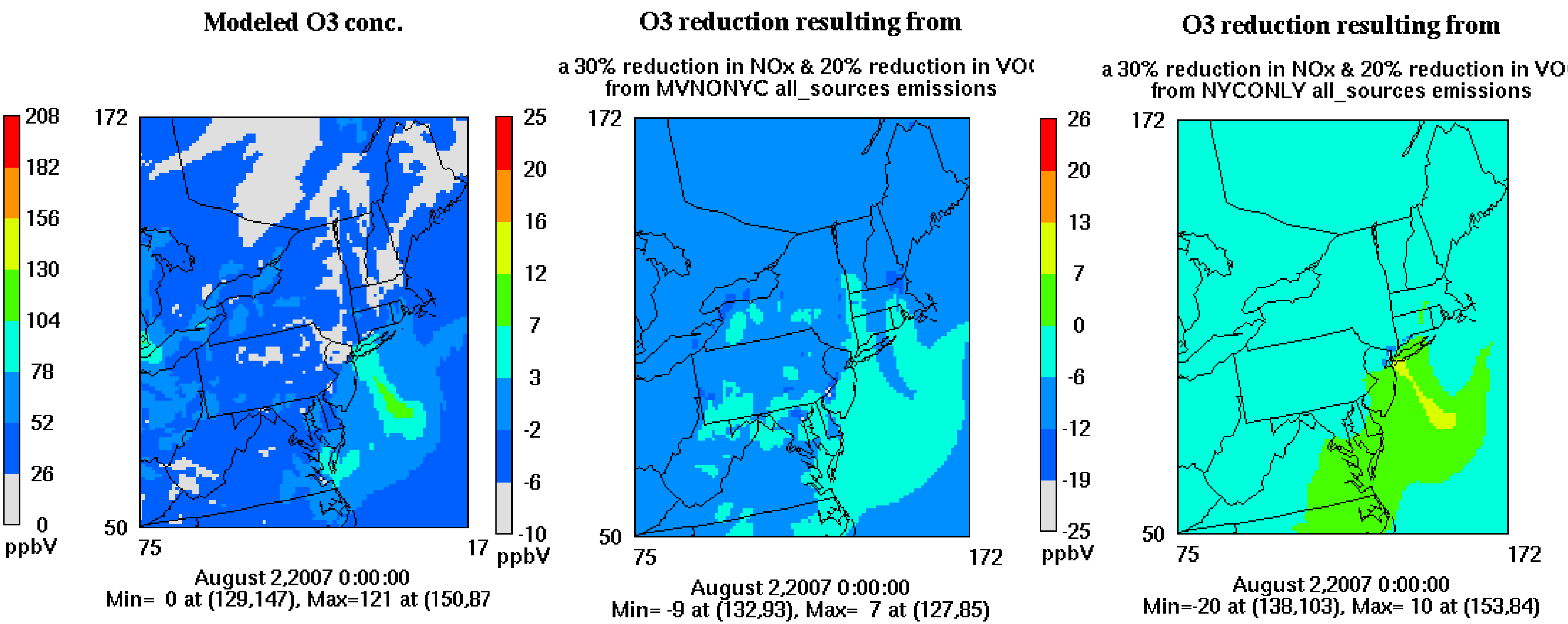
Daily max 8hr avg. O_3 (base) and new daily max 8hr avg O_3 for each emission/region (peaking unit sources) change scenario: 1) Holtsville 2) Queens College



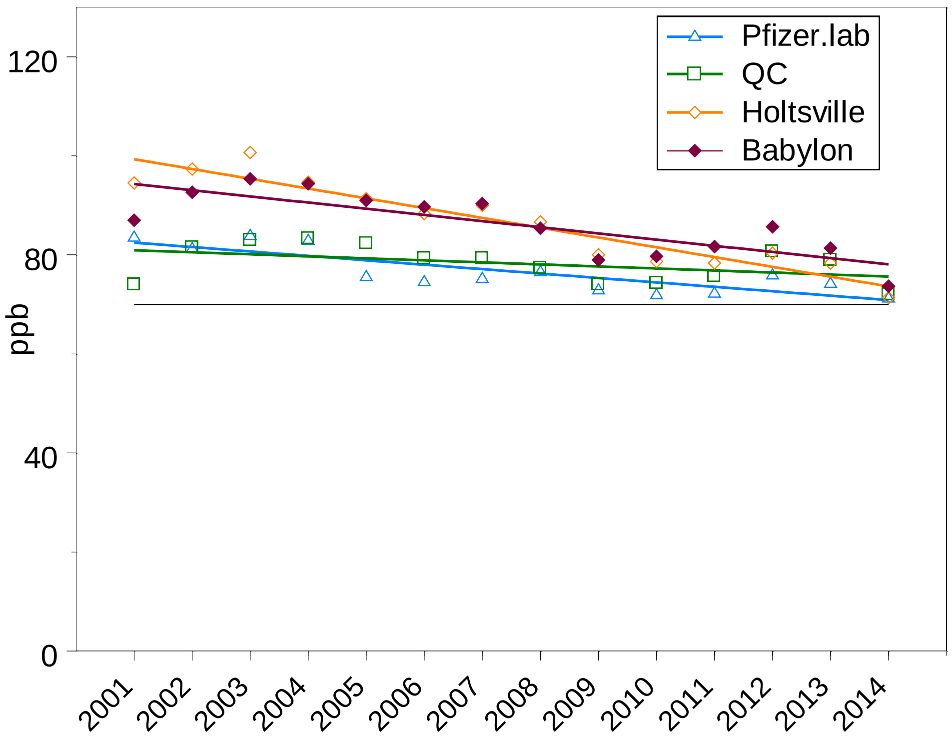


SENSITIVITY ANALYSIS OF PREDICTED O_3 CONCENTRATIONS WITH RESPECT TO EMISSION SOURCE CATEGORIES AND EMISSION DOMAINS

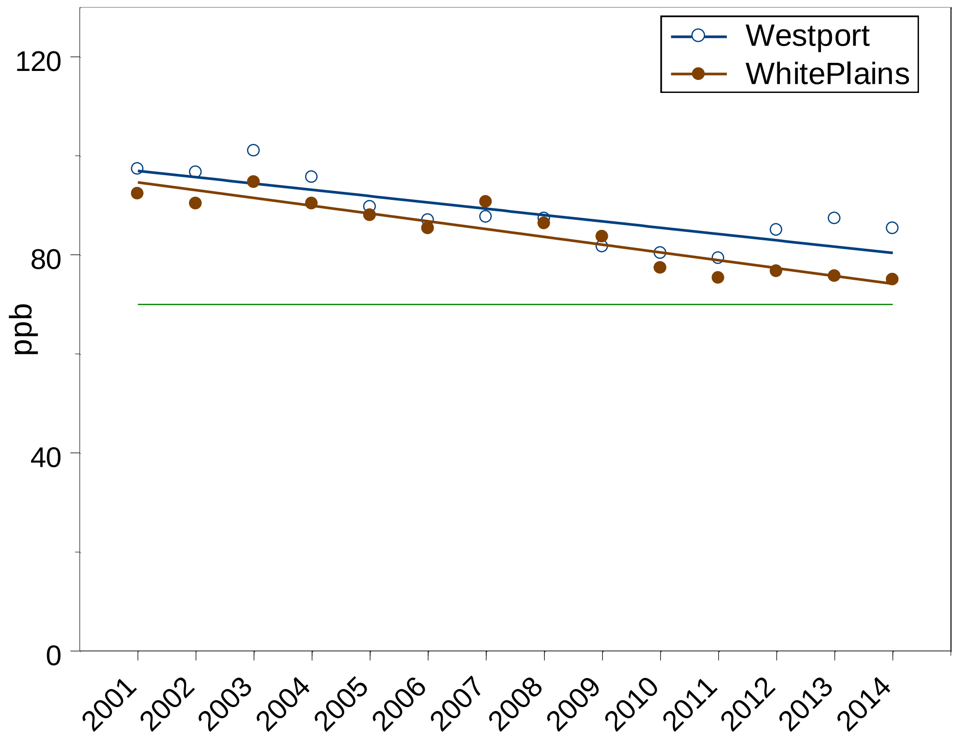
8/2/2007


Modeled O3 conc.
208
182
156
130
104
78
52
26
0
ppbV
172
50
75
17
August 2,2007 0:00:00
Min= 0 at (129,147), Max=121 at (150,87
O3 reduction resulting from
a 30% reduction in NOx & 20% reduction in VO
from MVNONYC all_sources emissions
25
20
16
12
7
3
-2
-6
-10
ppbV
172
50
75
172
August 2,2007 0:00:00
Min= -9 at (132,93), Max= 7 at (127,85)
O3 reduction resulting from
a 30% reduction in NOx & 20% reduction in VOC
from NYCONLY all_sources emissions
26
20
13
7
0
-6
-12
-19
-25
ppbV
172
50
75
172
August 2,2007 0:00:00
Min=-20 at (138,103), Max= 10 at (153,84)

3 year moving average of 4th highest daily max 8 hour average O_3 at monitoring sites



Pfizer lab, QC, Holtsville, and Babylon in New York

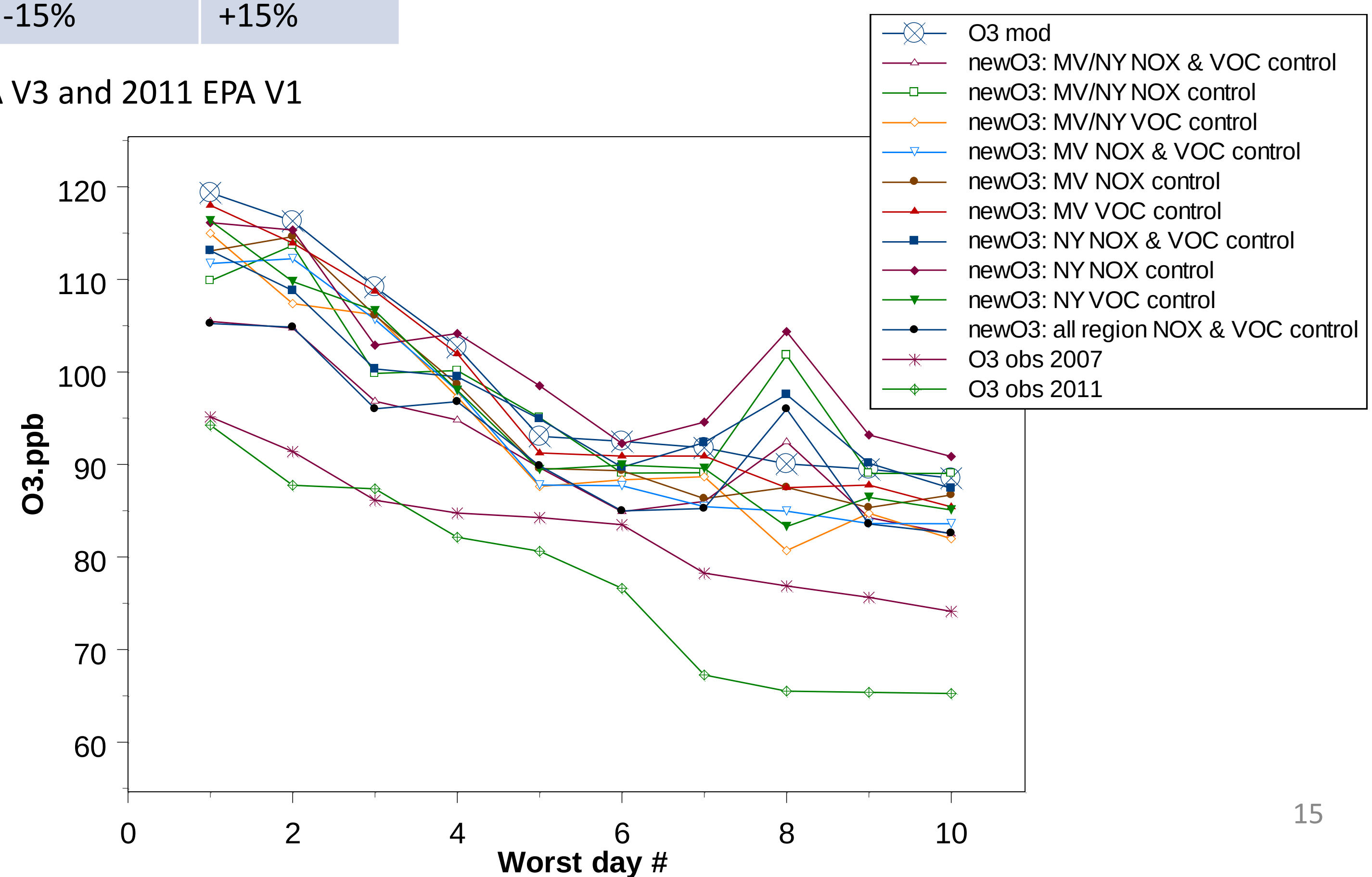


White Plains and Westport

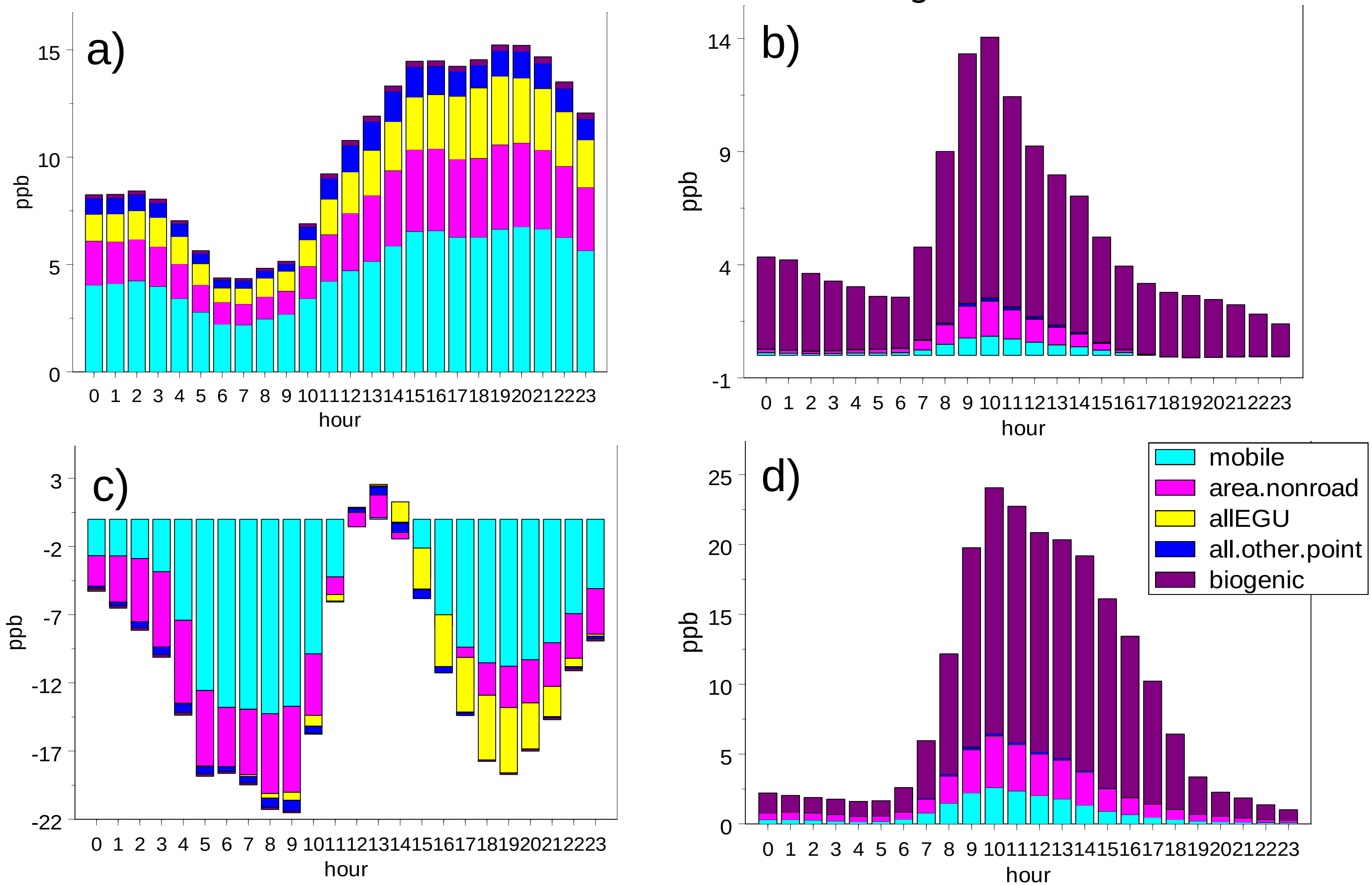
Daily max 8 hour average O_3 (base) of 10 worst days and new daily max 8 hour average O_3 for each emission/region (all sources) change scenario at the Holtsville site

Emission domain	NO_X	VOC
MVNONYC/NYCONLY	-30%	-20%
SESARM	-30%	+40%
LADCEN	-15%	+15%

based on 2007 MARAMA V3 and 2011 EPA V1 inventories

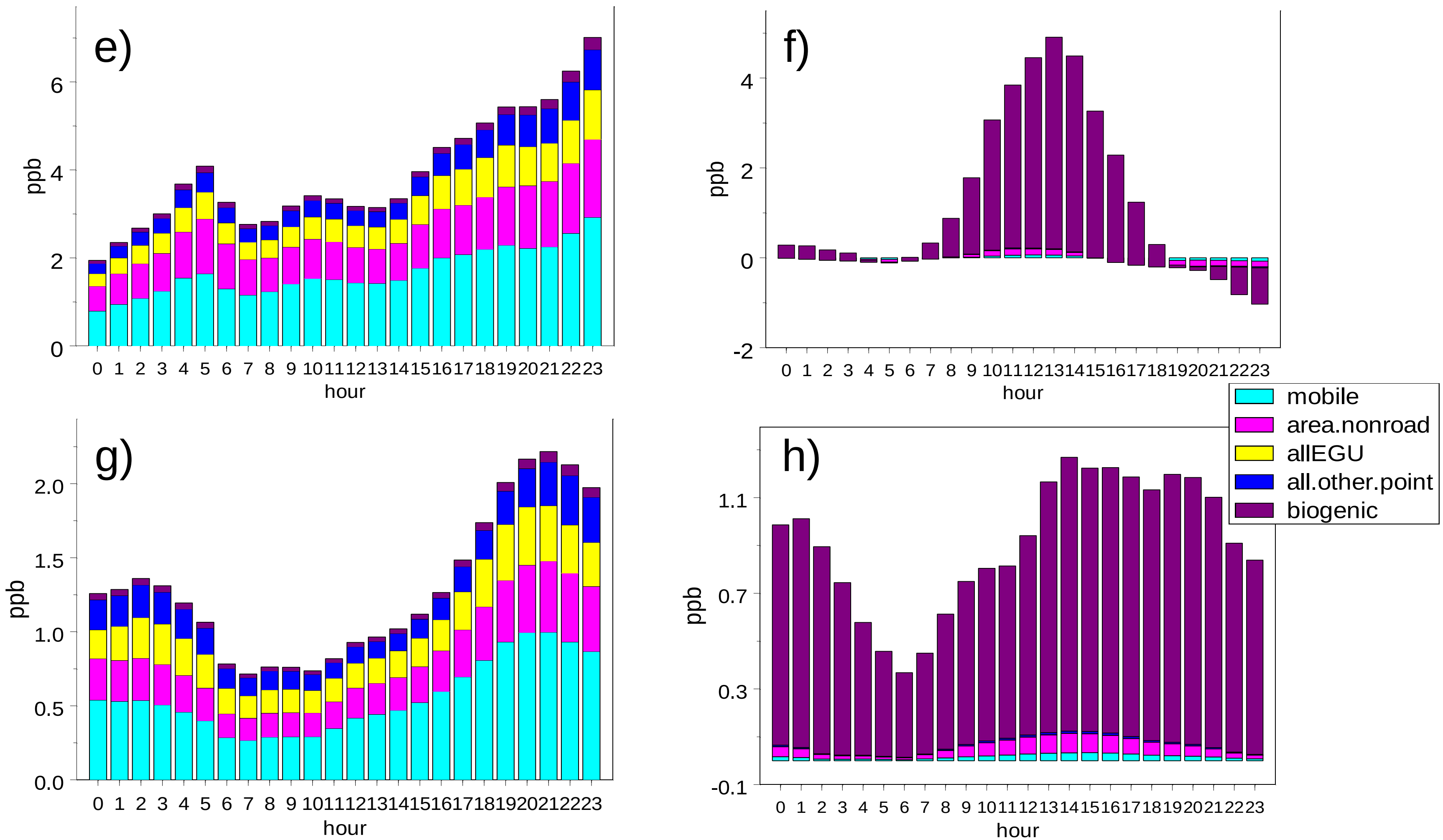


Hourly average distributions of O_3 sensitivity to emissions/regions at the Holtsville site for 10 worst days of daily max 8 hour average O_3



a) NOx from the MVNONYC region
b) VOC from the MVNONYC region
c) NOx from the NYCONLY region
d) VOC from the NYCONLY region

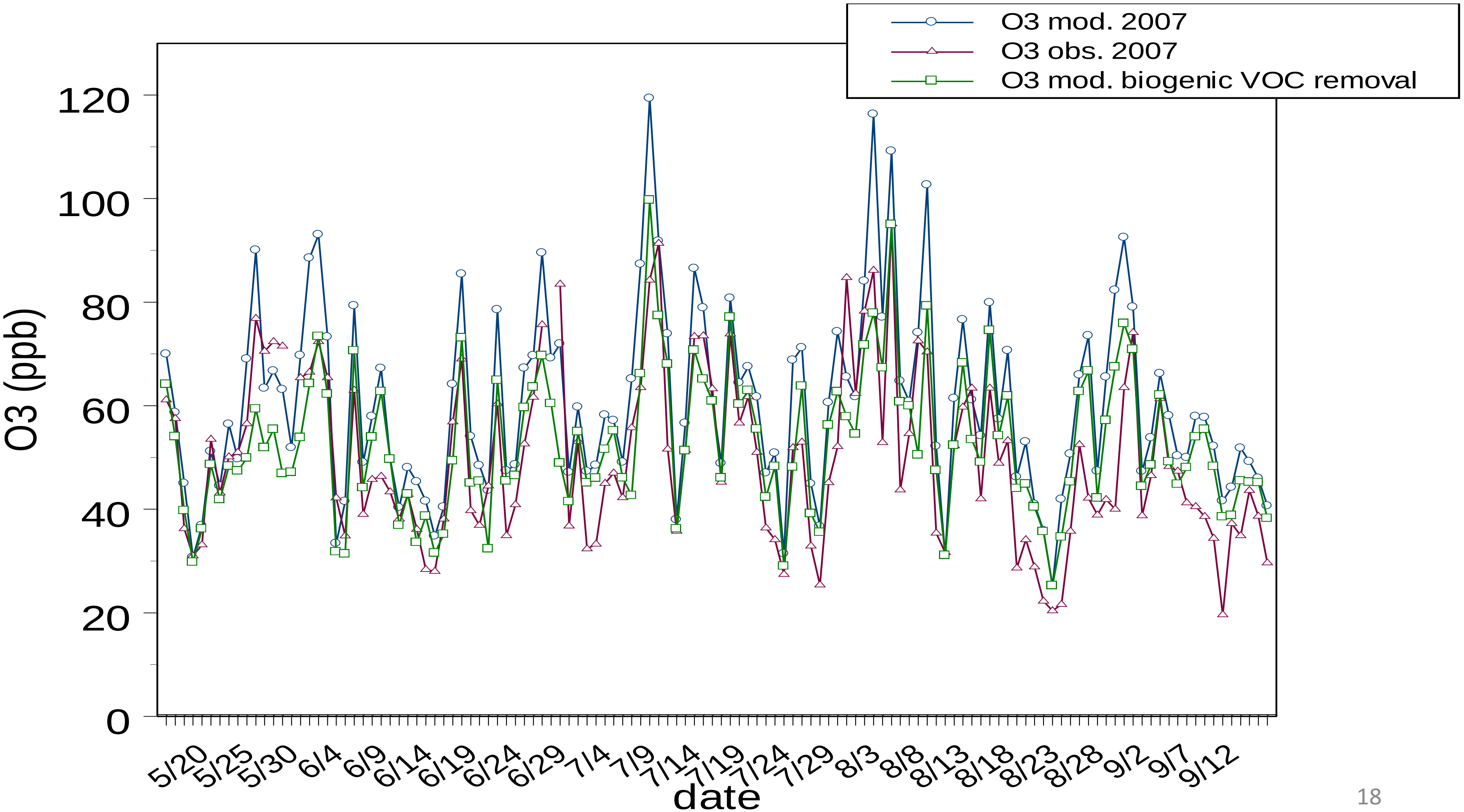
Hourly average distributions of O_3 sensitivity to emissions/regions at the Holtsville site for 10 worst days of daily max 8 hour average O_3



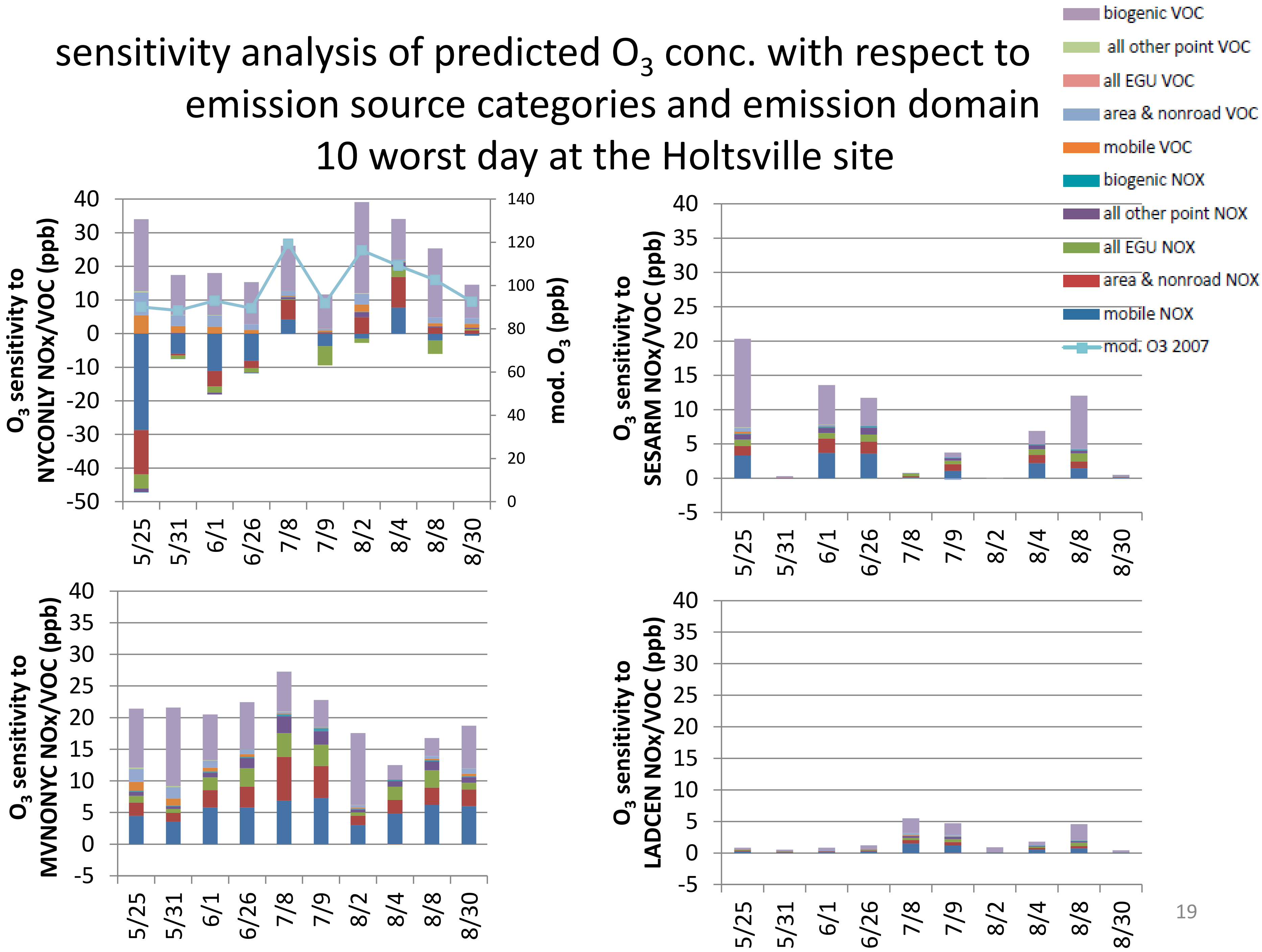
e) NOx from the SESARM region
g) NOx from the LADCEN region

f) VOC from the SESARM region
h) VOC from the LADCEN region

Daily max 8hr average O_3 with biogenic (MANEVU) VOC removal



sensitivity analysis of predicted O_3 conc. with respect to emission source categories and emission domain 10 worst day at the Holtsville site



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

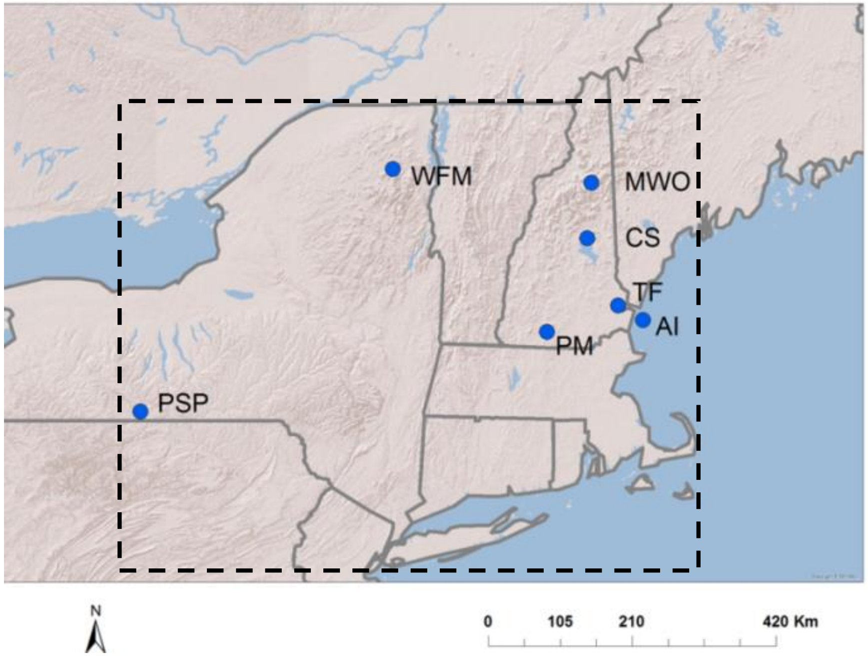
Summary Findings

- The CMAQ-DDM Computation Data Base provides exceptional data mining opportunities for assessing air quality management options.
- NOx emissions from EGU peaking units can be estimated for real-time operational AQ forecasts, but their impact on modeled ozone production is small.
- Modeled 2007 ozone concentrations for the 10 worst ozone days are over predicted by as much as 20 ppb at monitoring sites downwind of NYC.
- Sensitivity analysis of predicted O_3 concentrations with respect to source emission categories indicates a substantial contribution from biogenic VOC emissions which warrants further study.

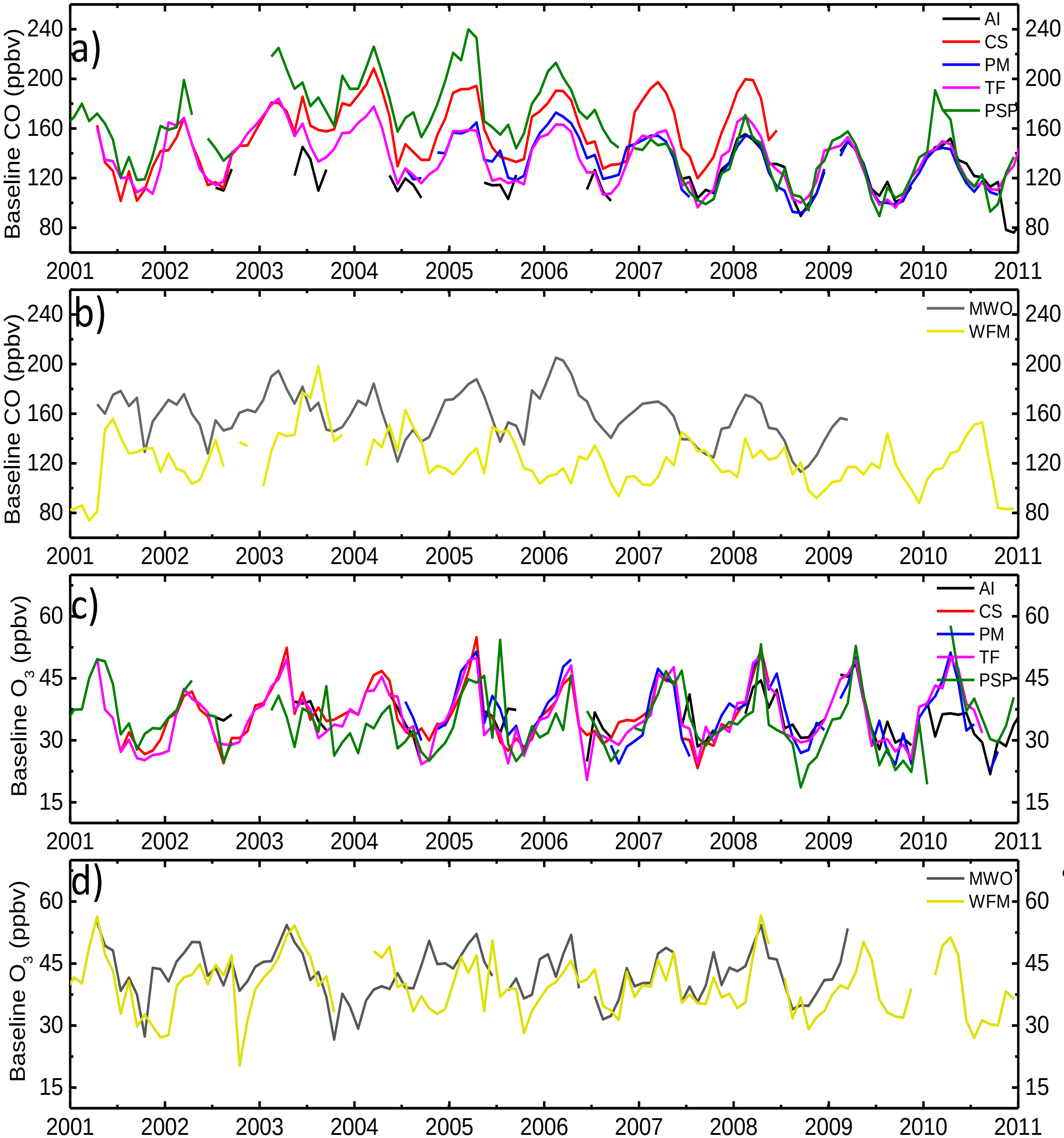
Regional and Hemispheric Influences on Northeastern US Baseline Carbon Monoxide and Ozone over 2001 – 2010

Impacts of increasing Asian emissions, NO_x emissions from the Northeast Urban corridor, global biomass burning emissions, and meteorological conditions (incl. cyclone activity, AO, and NAO) were found to be major factors influencing the baseline ozone and CO in the Northeastern US.

Baseline: Monthly 10th percentile values of CO; the median value of the ozone data corresponding to CO < monthly 10th percentile.



Zhou et al., 2016, acpd

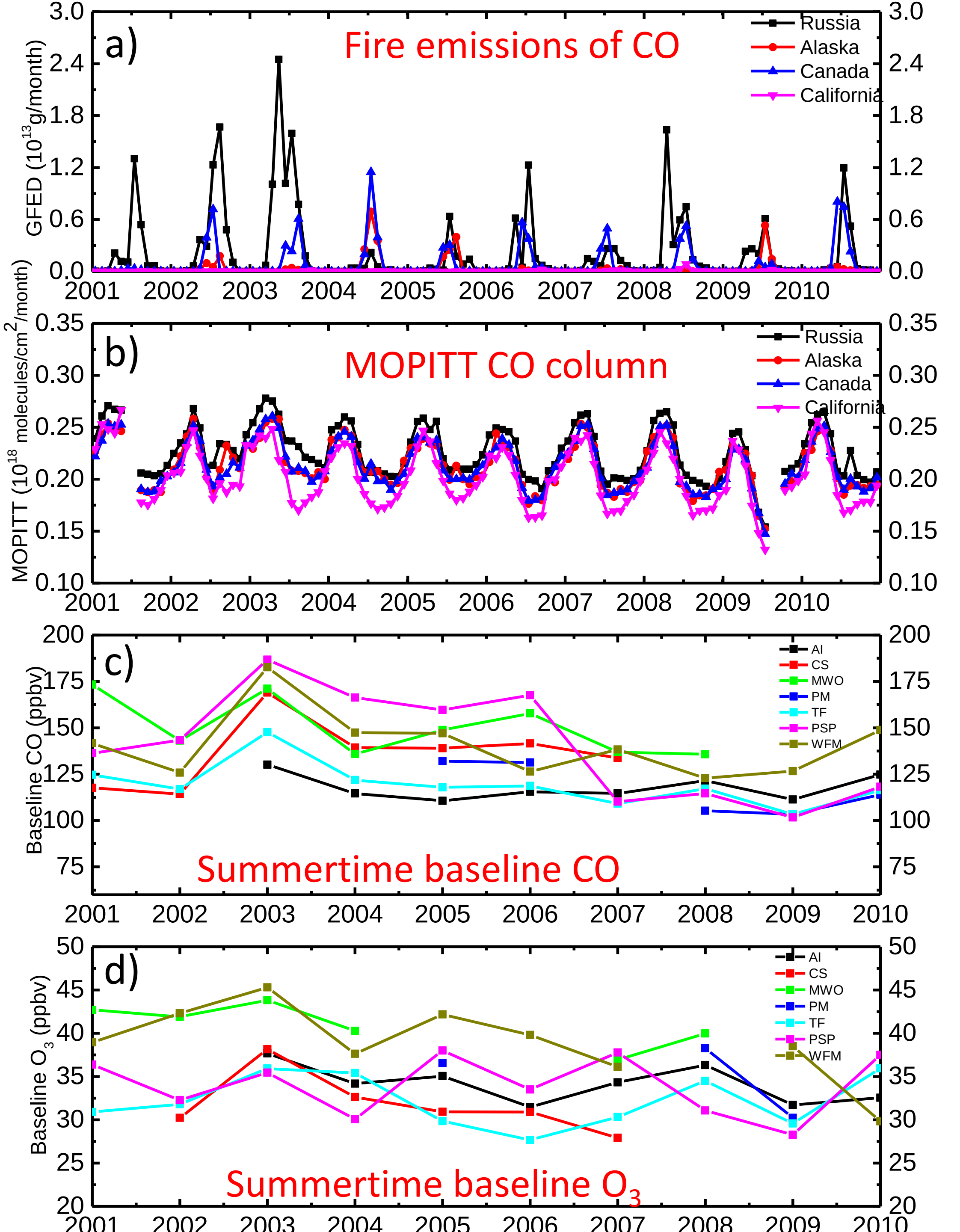


Zhou et al., 2016, acpd

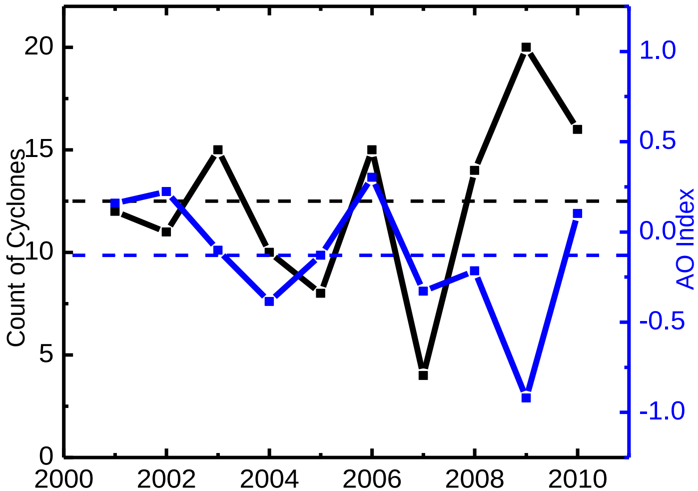
- **Decreasing trends in baseline CO at most sites, −4.3 to −2.5 ppbv yr^{-1}**
- **Insignificant trends in baseline CO at high elevation sites in spring and winter due possibly to decreasing US emissions and increasing Asian emissions.**
- **No overall significant trends in baseline O_3 due possibly to worldwide increasing NOx and constant CH_4 in the 2000s**
- **TF was the only site with increasing baseline O_3 at significant rates in spring and winter over 2001–2010, likely a result of NOx emission reductions in the Northeast.**

- **Siberian and Canadian forest fires contributed 37% & 22%, respectively, to summertime baseline CO variability over 2001-2010**

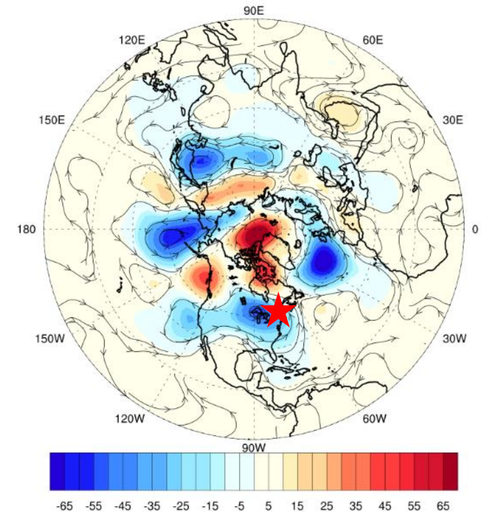
- **Decreasing biomass burning emissions in Russia likely contributed to decreasing baseline CO and O_3 in summer.**



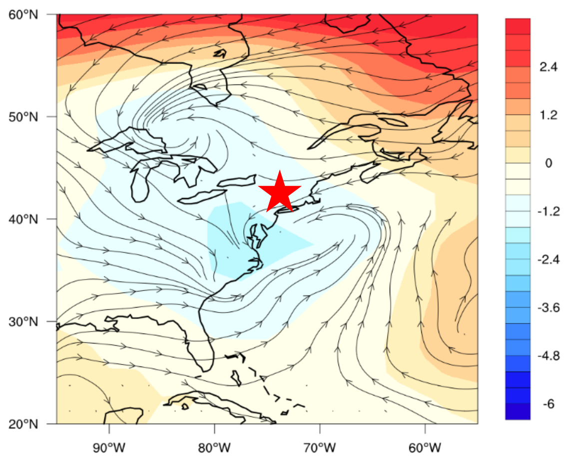
Impact of cyclone activity and Arctic Oscillation



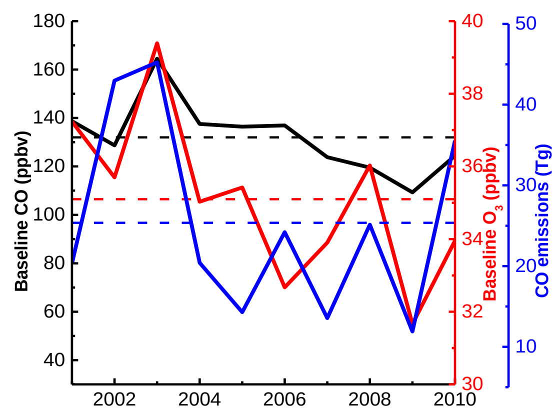
A case in point was summer 2009 with the largest cyclone count (20) and the strongest negative AO phase (−0.92) of the decade



Unusually strong northeasterly



Lowest fire emissions in summer 2009

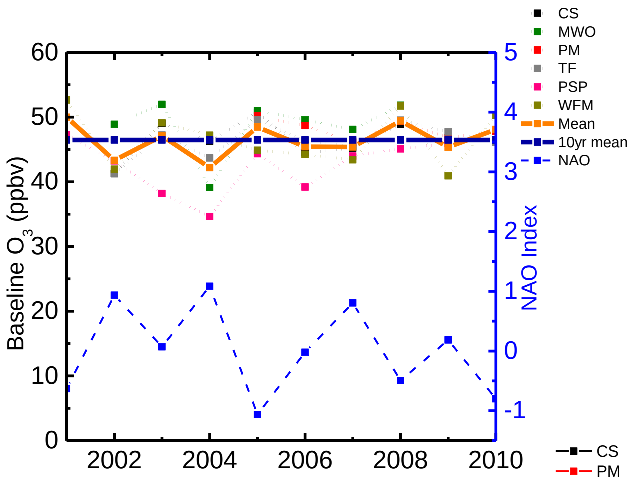


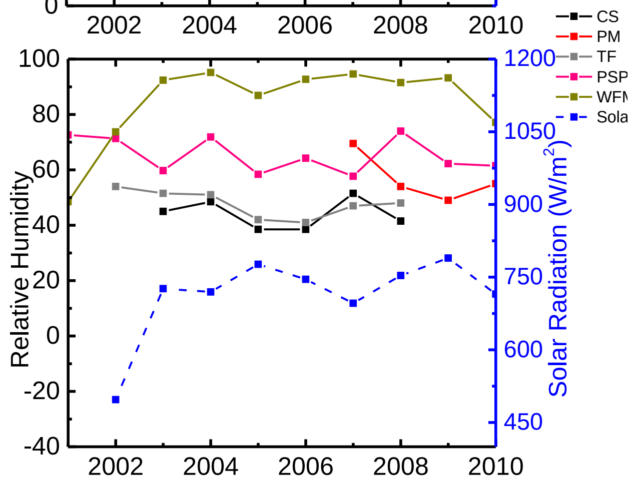
The effect of biomass burning may dominate over AO and cyclone activity during some summers (e.g., 2003), while the two worked in concert during others (e.g., 2009).

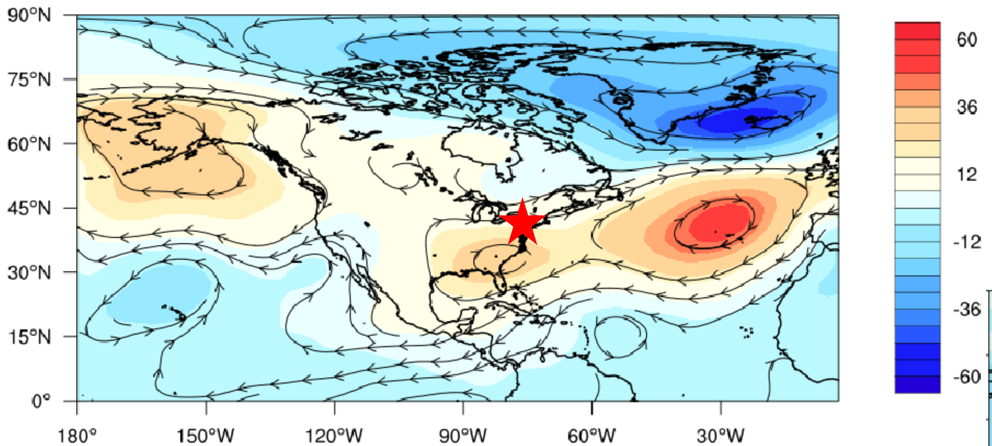
Impact of NAO in spring (March and April)

Negative correlation between springtime baseline O_3 and NAO

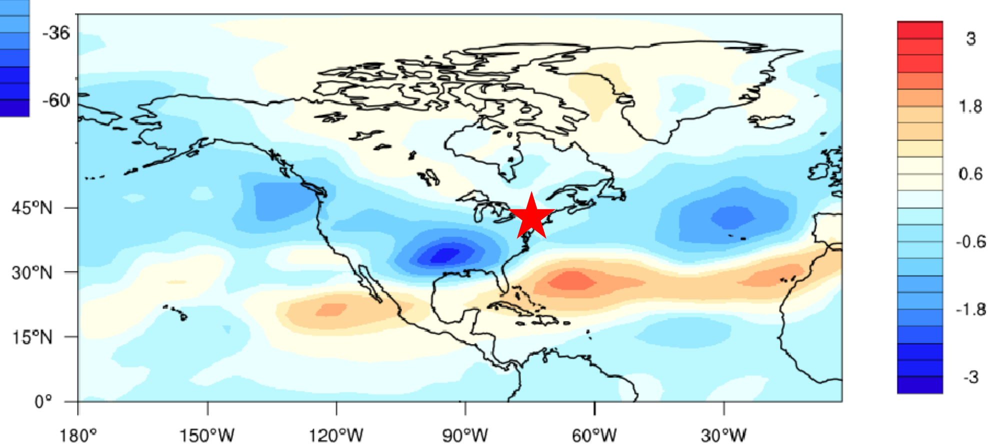
Lower NE US baseline O_3 linked to positive NAO with less solar radiation flux, weakened stratospheric intrusion, and intensified continental export.







PV

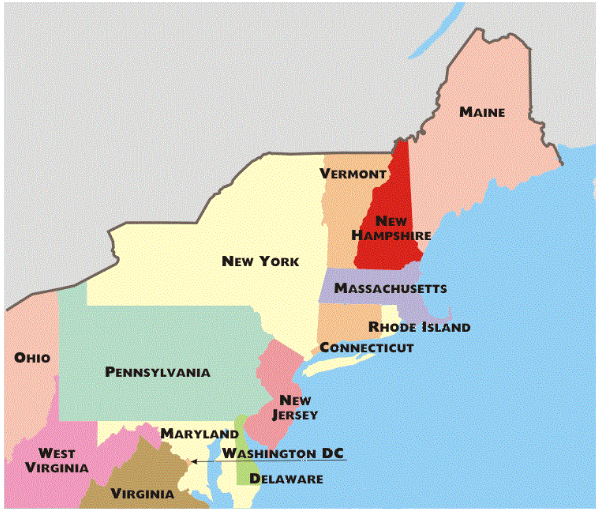


The Impact of Regional Transport and Emission Reductions on Hg° in Bronx, NY over 2008 – 2015

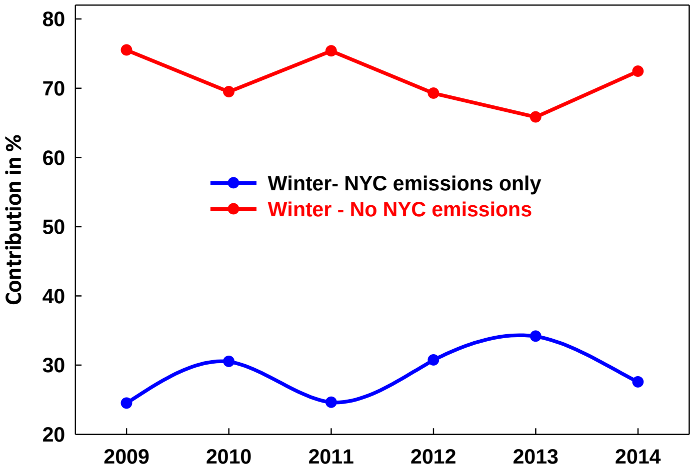
- Regional contributions to NYC ambient concentrations of Hg were estimated to be more than a factor of two larger than the local using the HYSPLIT dispersion model simulations.

- The effect of Hg emission reductions can be obscured by interannual variability in circulation.

a)



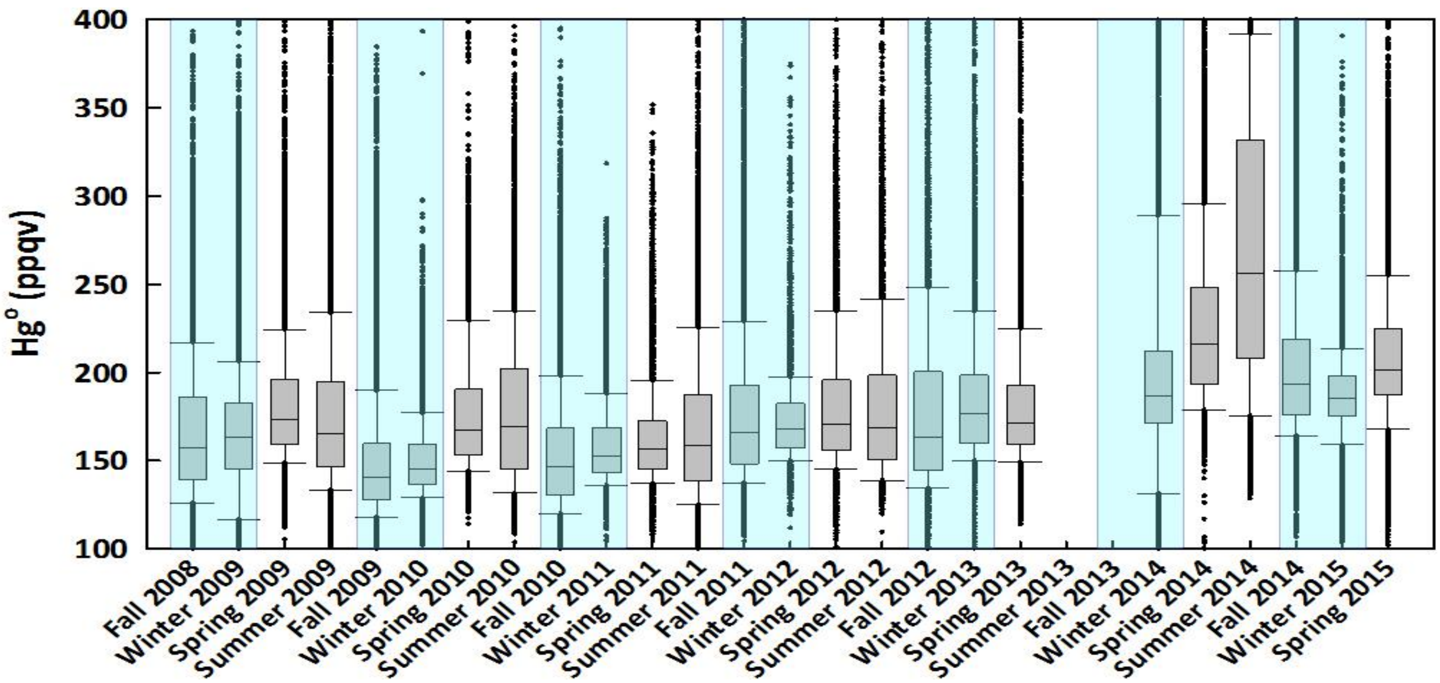
b)



Mercury emissions (lbs)

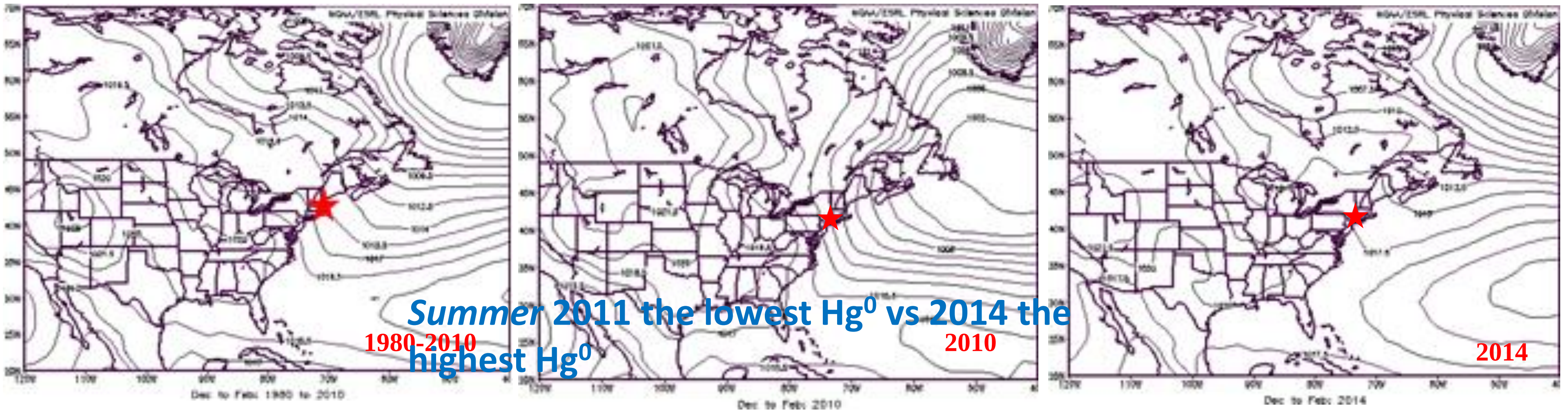
	2008	2011	Notes
NYC	165	199	Increases in misc. & waste ; little decrease in fuel comb
E US	64124	55187	Major decreases in fuel combustion

Emission changes not reflected in temporal variability in GEM concentrations



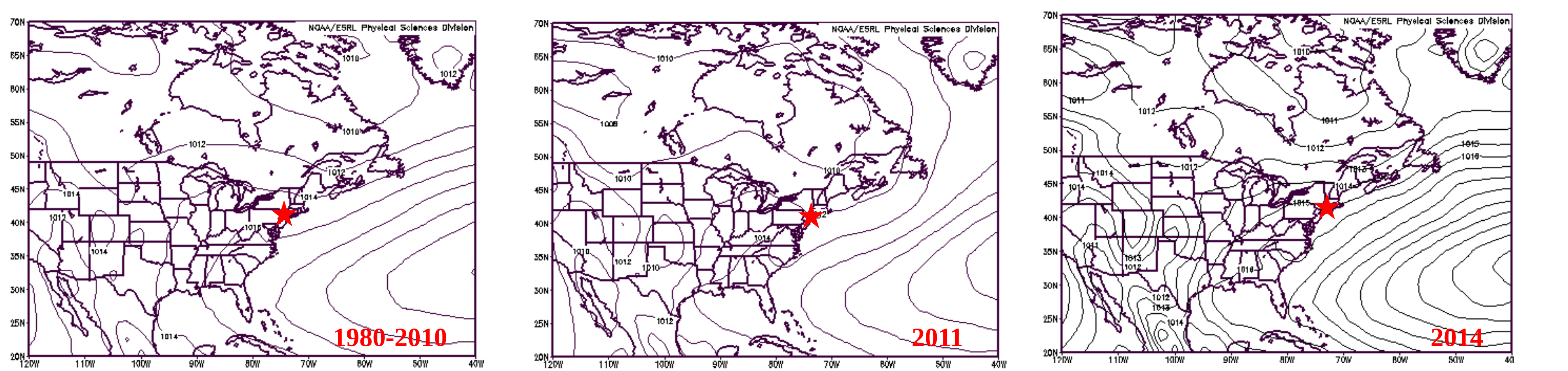
- The 2009 – 2010 annual cycles not reproduced in the other years.
- Lowest warm season concentrations in 2011 disrupted the 2009-2010 annual cycles
- Largest concentrations in 2014, in both cool and warm seasons

Winter 2010 the lowest Hg^0 vs 2014 the highest Hg^0 largely associated with the interannual variability in circulation patterns



Summer 2011 the lowest Hg^0 vs 2014 the highest Hg^0

Summer 2011 the lowest Hg^0 vs 2014 the highest Hg^0



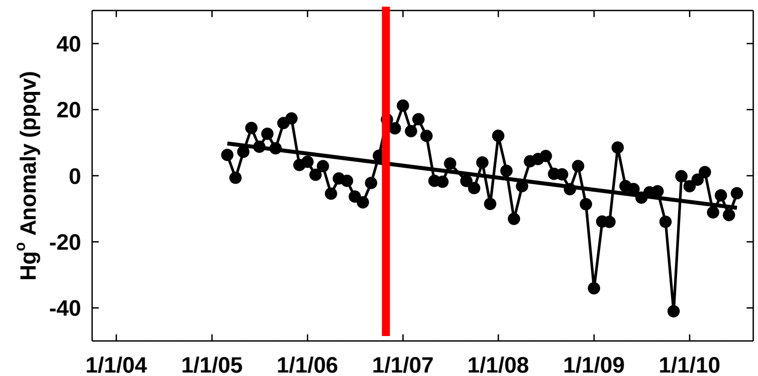
Trends in Northeastern U.S. Background Hg°

- A decreasing trend of 3.8±0.9 ppqv yr^{-1} found at an elevated rural site (Pac Monadnock), possibly associated with decreasing anthropogenic emission in North America.
- Changes in ecosystems could disrupt this decreasing trend .

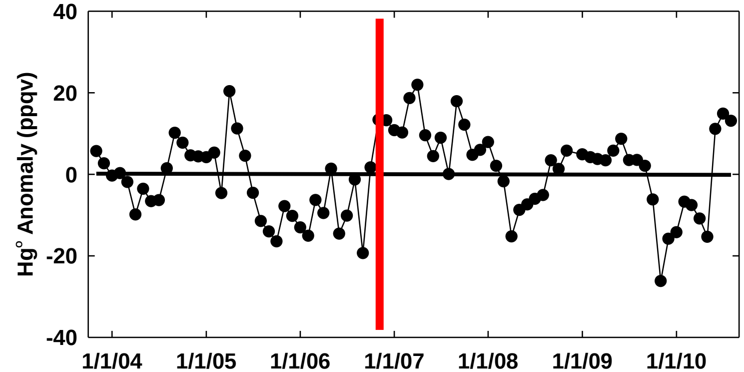
1. Thompson Farm – TF, Durham, NH, sea level
2. Pack Monadnock – PM, Peterborough, NH, 700 asl
3. Huntington Wildlife Forest – HWF, Adirondacks, NY, 510 m asl

- A decreasing trend of 3.8±0.9 ppqv yr^{-1} at PM, compared to Mace Head (3.1±1.1 ppqv yr^{-1}), Cape Point (3.8±0.6 ppqv yr^{-1}), and mid-latitude Canadian sites (~2.6-3.9 ppqv yr^{-1}).
- At TF, an abrupt increase in the fall of 2006 resulted in no trends over 2003 – 2010.
- HWF, no trend was observed over February 2006 – August 2013.

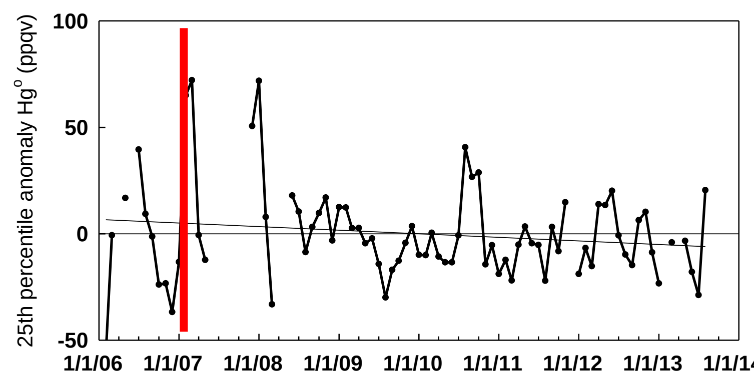
a) PM



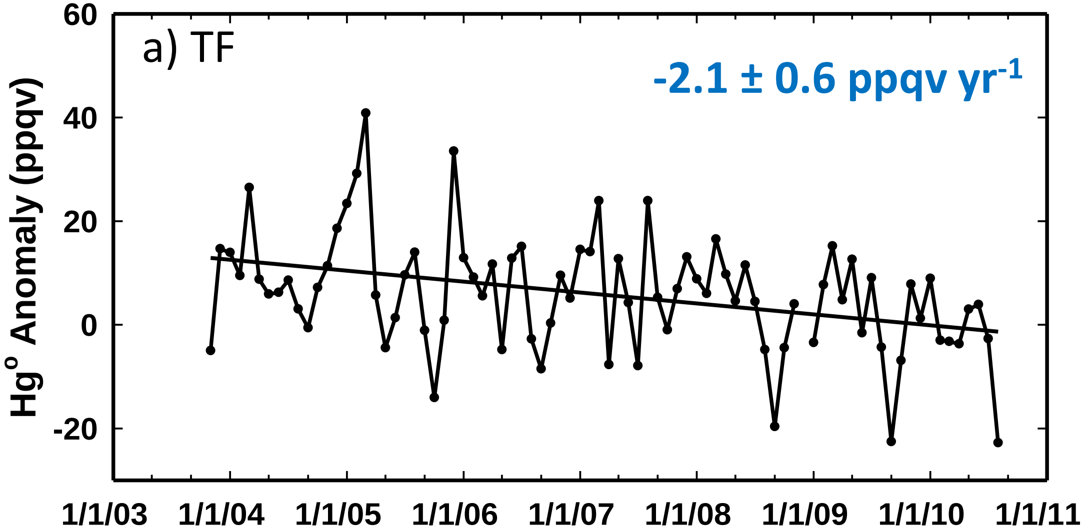
b) TF

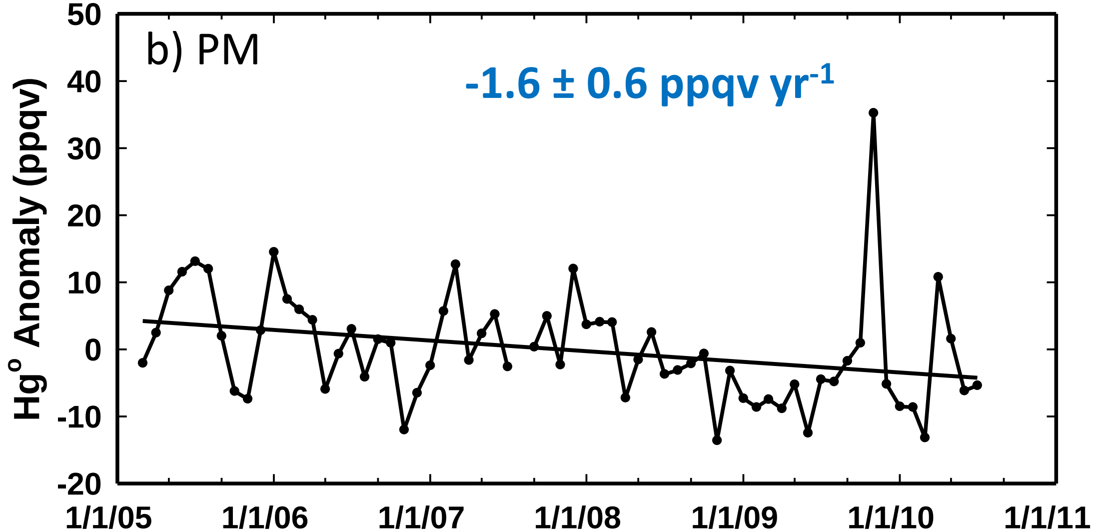


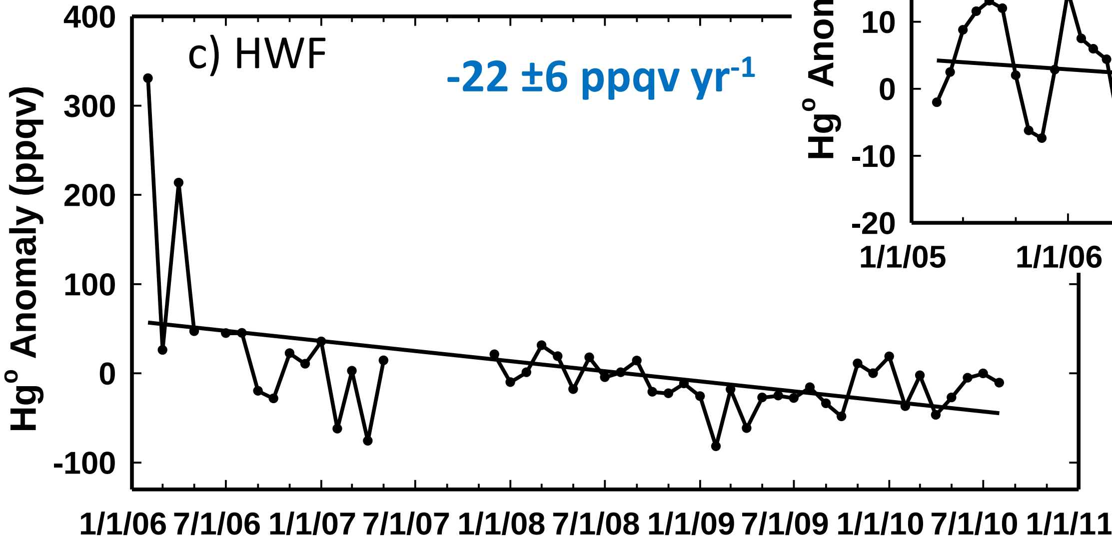
c) HWF



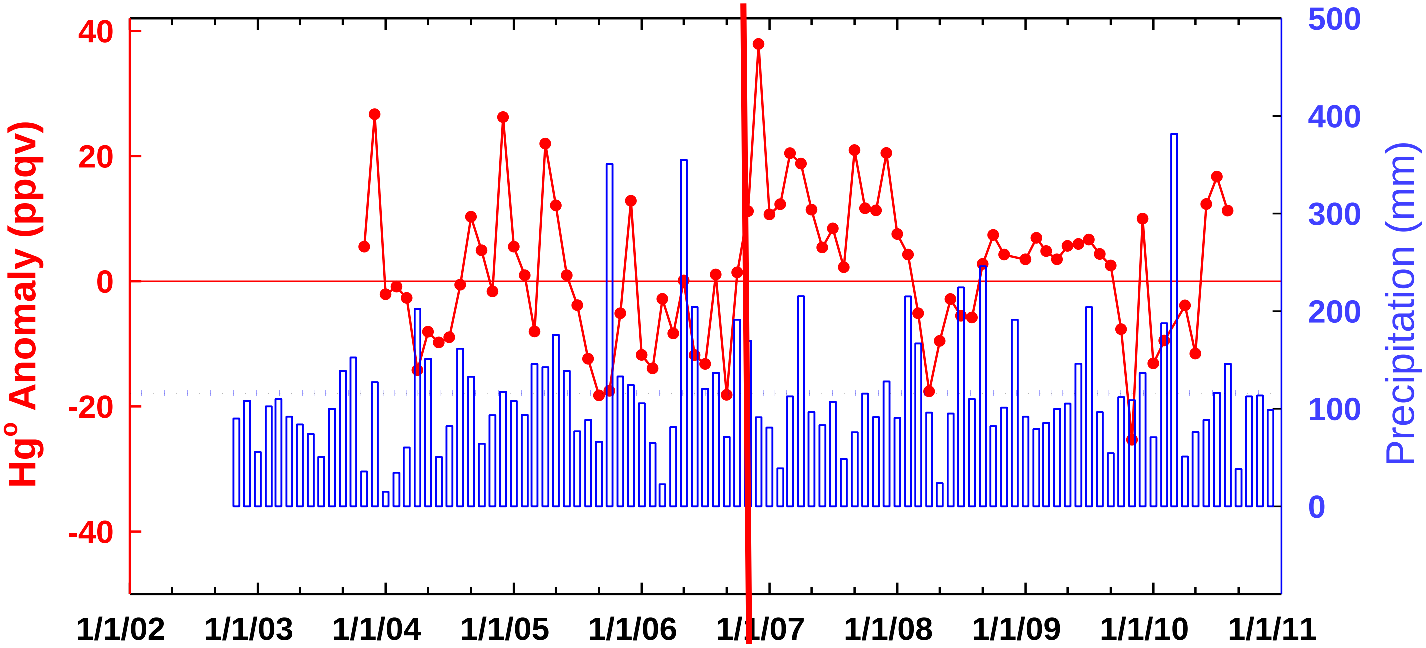
Anthropogenic Contribution estimated from the measurement data







TF Background GEM vs. Precipitation



- Abundant precipitation in the senescence months in 2006 followed by a lack of snow in the following winter in the northeastern U.S.

- An examination of long-term soil moisture data for a northeastern site (Lye Brook, NY) suggested soils to be the driest in the year of 2007 during the decade of 2001 – 2011.

Summary Findings

- Major factors influencing Northeastern US baseline ozone and CO include: 1) increasing Asian emissions; 2) decreasing NO_x emissions in the Northeast Urban corridor; 3) global biomass burning emissions; and 4) meteorological conditions (incl. cyclone activity, AO, and NAO).
- Regional contributions to NYC ambient concentrations of Hg were more than a factor of two larger than local contributions; the effect of emission reductions can be obscured by interannual variability in circulation.
- A decreasing Hg trend of 3.8±0.9 ppqv yr^{-1} found at a southern New England elevated rural site, in agreement with trends in background locations, is possibly associated with decreasing anthropogenic emissions in North America. Changes in ecosystems could disrupt this decreasing trend.

Thanks for your attention