Emission Reductions Improve Air Quality

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Large, Widespread Emission Reductions, 1996 – 2016

NOx Emissions

Source: U.S. EPA trends inventory; Environment and Climate Change Canada air pollutant emission inventory
Mean Annual Ambient NO$_2$ Declined at NY Sites

All NY State NO$_2$ monitoring sites (N = 5 – 12 sites per year, ≥ 7 sites except 2012 & 2013)

Source: U.S. EPA Air Quality System (AQS) pre-generated data files
Ambient NO₂ Decline Tracked NOₓ Emissions

New York Botanical Garden/Pfizer Lab, Morrisania Center/IS52, Buffalo, Queens

r² = 0.97

Source: U.S. EPA Air Quality System (AQS) pre-generated data files
Nitrate Deposition (wet NO$_3$ + dry HNO$_3$ + dry pNO$_3$)
Deposition Tracked Regional NO$_x$ Emissions

Source: U.S. EPA Clean Air Status and Trends Network data

Implication: NO$_x$ sink is proportional to NO$_x$ emissions
Annual 4th-Highest Daily Peak 8-Hour O₃ Declined Rate of Decline ~ 1 ppbv per Year

All NY State O₃ monitoring sites (N = 22 – 38 sites per year, ≥ 30 since 1995)

Source: U.S. EPA Air Quality System (AQS) pre-generated data files
Max O₃ Values Declined Along with 75th – 95th Percentiles (Declining Toward ~40 – 50 ppbv)

Whiteface Mountain
O₃ Trends are Due to Emission Changes (Not to Trends in Weather)

https://www.epa.gov/air-trends/trends-ozone-adjusted-weather-conditions

Atmospheric Environment 41 (2007) 7127–7137
The effects of meteorology on ozone in urban areas and their use in assessing ozone trends
Louise Camalier, William Cox, Pat Dolwick
O₃ Trends are Modulated by Atmospheric Chemistry (Discussed in Next Presentation)

Regional NOₓ and VOC emissions declined together

Source: U.S. EPA trends inventory; Environment and Climate Change Canada
Large, Widespread \( \text{SO}_2 \) Emission Reductions

83% reduction, 1995 - 2015
Ambient SO₂ Declined with Regional and NY State SO₂ Emission Reductions

$r^2 = 0.94$
Multi-site Mean PM$_{2.5}$ SO$_4$ Tracked Regional (and NY) SO$_2$ Emissions

As a result of SO$_2$ emission reductions and ambient PM SO$_4$ decreases, aerosol composition and ion balance have changed.
Organic Matter (OM) and Elemental Carbon (EC) are Now a Larger Fraction of PM$_{2.5}$ Mass (OM = scaled OC)
Consistent Ratio of Organic Carbon (OC) to Elemental Carbon (EC) Over Time and Space

Excluding Bronx:
OC = 0.86 (± 0.04) + 1.66 (± 0.07) EC; p < 0.0001, r² = 0.90

The exception is Bronx pre-2010

Annual averages

Consistent OC/EC suggests similar sources and processes affect all sites
Mobile-Source PM and VOC Emissions Decreased

NY State on-road mobile source emissions determined from MOVES model

- 66% VOC decrease
- 70% OC decrease
- 72% EC decrease
PSP OC and EC Trends are (Sort of) Consistent with Mobile-Source PM$_{2.5}$ OC and EC Emission Reductions

Source: EPA trends inventory highway vehicles plus non-highway vehicles PM$_{2.5}$ emissions scaled by MOVES and SPECIATE ratios of OC and EC to PM$_{2.5}$ mass
Multiple Sources Contribute to PM$_{2.5}$ OC and EC (Biomass Burning, Mobile, Secondary, Fossil Fuel, Crustal)

Receptor model source apportionment of data from Pinnacle State Park, 2001 – 2015 (means of 1087 days)

OC source contributions include secondary as well as primary components.
Consistent PM Trends from Two Receptor Models

At Pinnacle State Park (PSP), biomass burning OC and EC increased as \( \text{SO}_4 \)-associated OC decreased.

**PCA = Principal Component Analysis**  
**PMF = Positive Matrix Factorization**
Biomass Burning PM Increases at PSP are Not Seen at Other Sites (Massiol et al., Atmos. Environ., 2019)
Diesel PM Contributions Decreased at Most Sites (Massiol et al., Atmos. Environ., 2019)
Questions?
Extra Slides
Comparison of NO\textsubscript{x} Emissions

![Bar chart showing comparison of NO\textsubscript{x} emissions over years]

- MOVES Default On-road
- NEI Highway
- EPA Trends Highway
- Xing et al. On-road

Year: 1999 to 2016
NO\textsubscript{x} Emissions (1000 metric tons)
Bronx EC Decline Compared with Ni Trends
Seasonal Variations of PCA and PMF Factors at PSP
Trends in OC Source Contributions at PSP

Fossil fuel combustion OC (μg m\(^{-3}\))

Crustal OC (μg m\(^{-3}\))

Non-SO\(_2\) Combustion OC (μg m\(^{-3}\))
Variation of OC Source Contributions with Morning Wind Direction
PMF fixes the OC/EC ratio for each factor so there is no standard error of the mean.