How has air quality changed over time? What do we think air quality will look like in the future?

To the

Metropolitan Washington Air Quality Committee (MWAQC)

By

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February 22nd 2023, 12:00–2:00 pm

The Guilty Parties

Outline

Motivation

The good news

The rest of the story

What does the future hold?

Ongoing and future work

Motivation
The Lancet Commission on Pollution and Health, 2018

Pollution is the largest environmental cause of disease and premature death in the world today. Diseases caused by pollution were responsible for an estimated 9 million premature deaths in 2015 —16% of all deaths worldwide — three times more deaths than from AIDS, tuberculosis, and malaria combined, and 15 times more than from all wars and other forms of violence.

The good news

A policy of region-wide abatement has been highly successful in improving AQ on the regional scale.

Lead, Pb, a Criteria Pollutant

Toxic, leads to loss of mental acuity.

Limits: 0.15 µg/m^3 rolling three-month average.

Long gone from gasoline in the US.

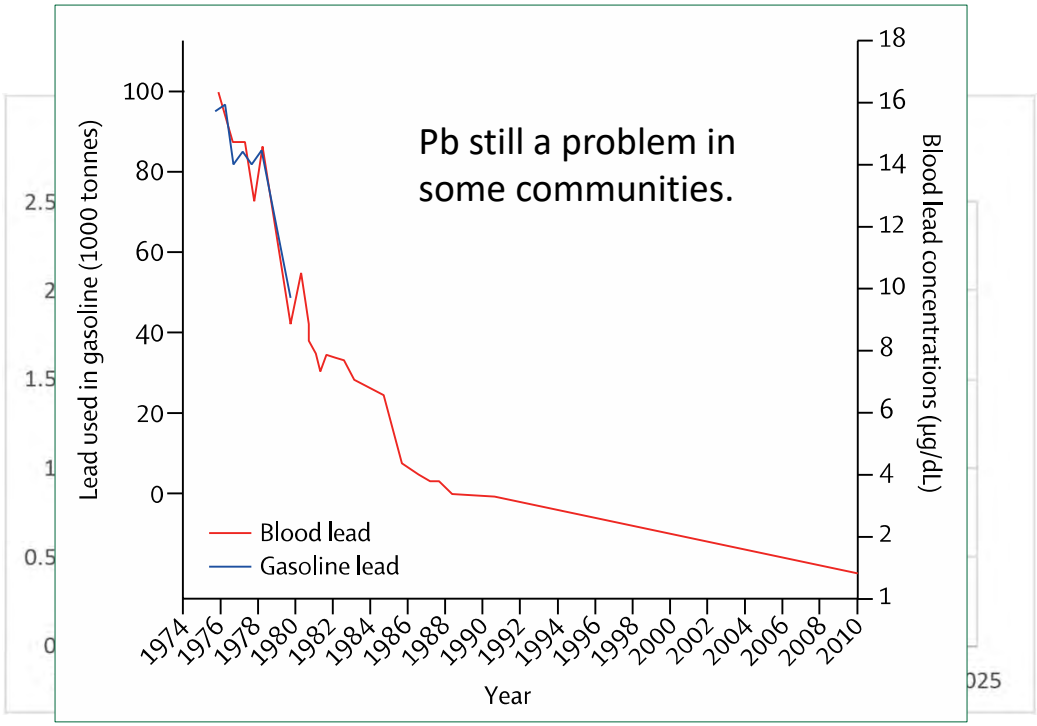
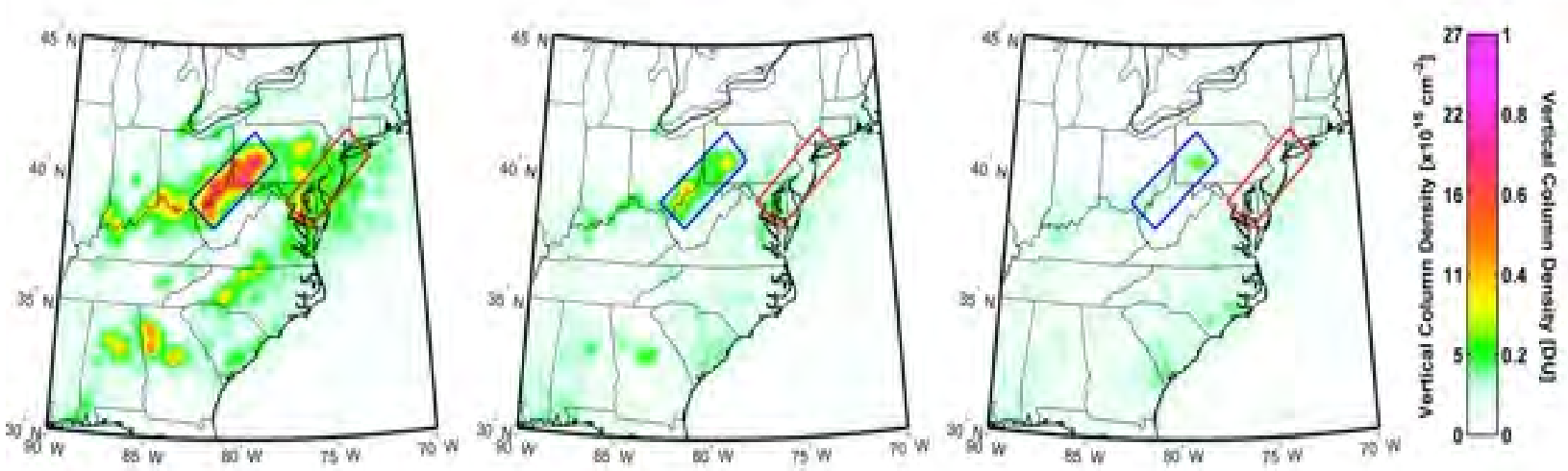


Figure 2: **Correlation between population mean blood concentration of lead and lead use in gasoline in the USA, 1974–91**

Taken from data that is publicly available from the Centers for Disease Control.

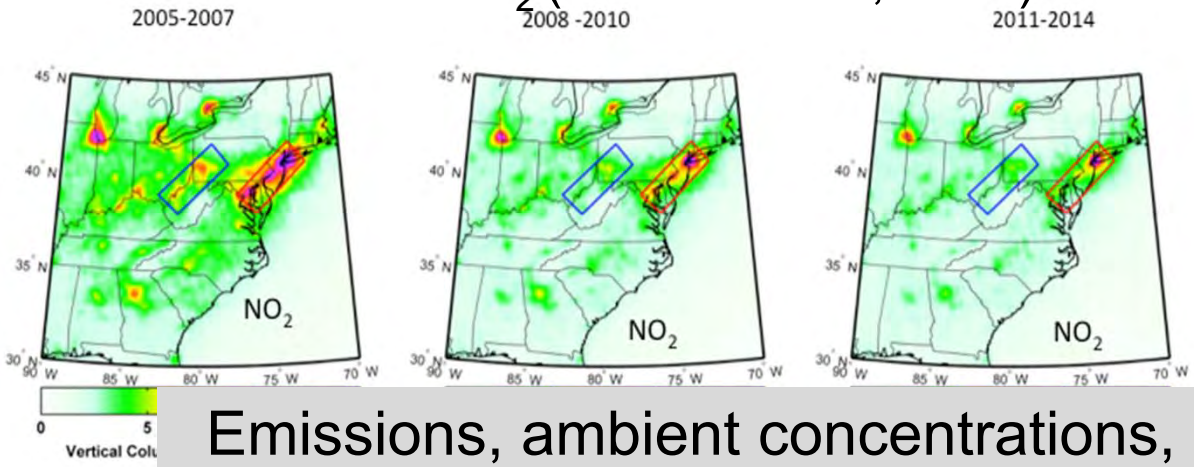
Sulfur emissions down and acid rain mostly solved.



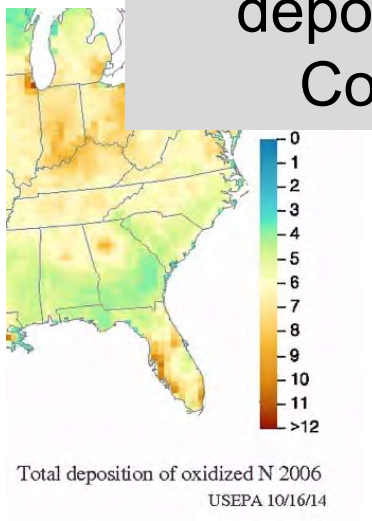
2006 2010 2014

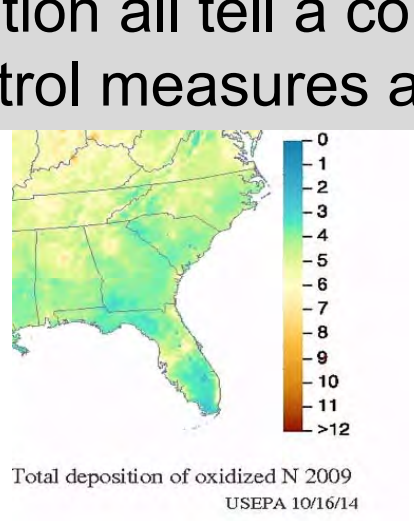
Satellite measured column SO_2 from Krotkov et al., ACPD 2016.

OMI NO_2 (Krotkov et al., 2005-2007, 2008 -2010, 2011-2014)

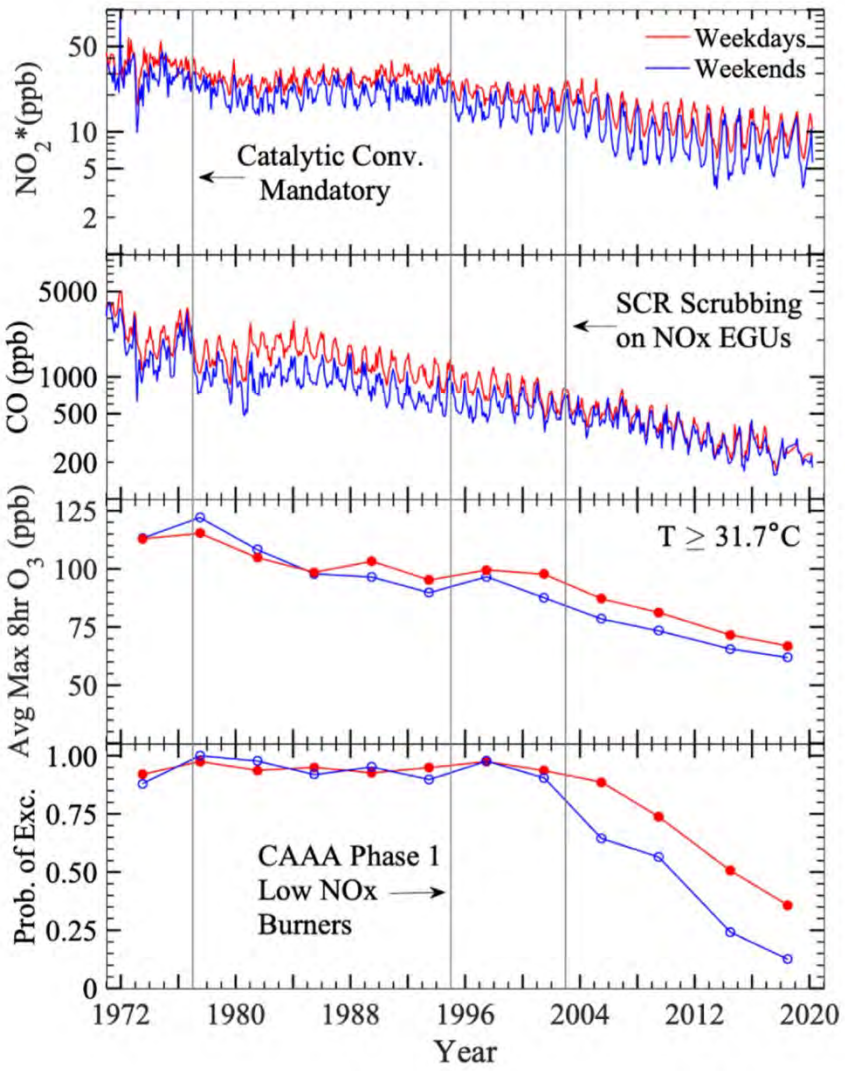


Emissions, ambient concentrations, and deposition all tell a consistent story. Control measures are working.





Total NOy deposition (EPA-NADP). Affects air and water quality.



Ozone Smog in the DMV

Observations: The Baltimore/Washington region suffered severe ozone for decades. NAAQS = 70 ppb.

Initial VOC & CO controls had little effect.

Policy-relevant science.

Region-wide NOx controls worked.

From Roberts et al., 2022.

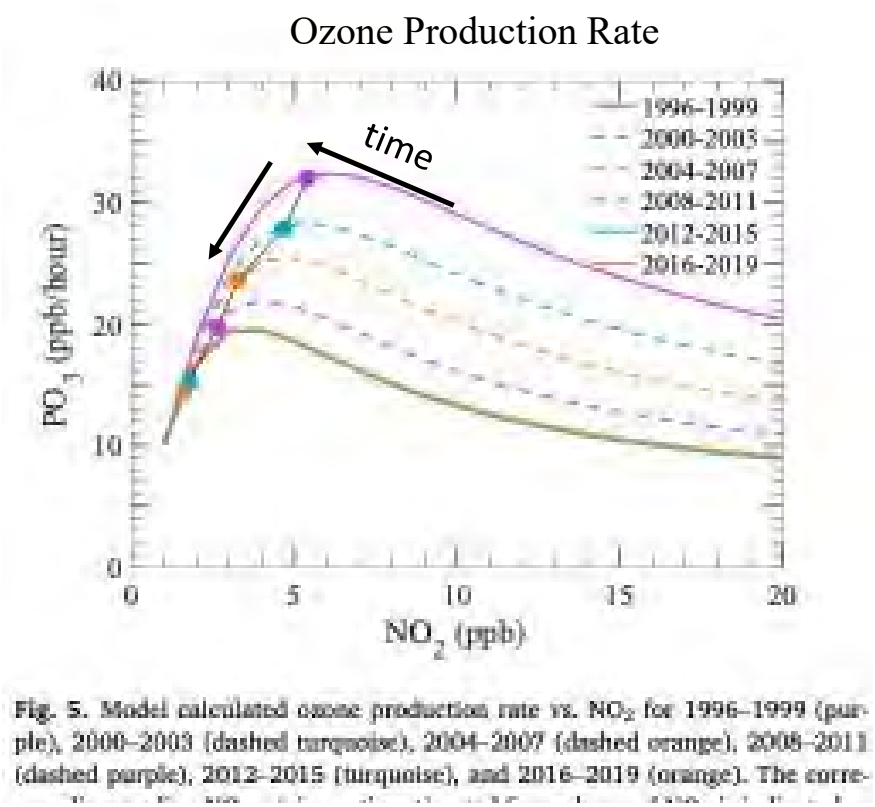


Fig. 5. Model calculated ozone production rate vs. NO_2 for 1996–1999 (purple), 2000–2003 (dashed turquoise), 2004–2007 (dashed orange), 2008–2011 (dashed purple), 2012–2015 (turquoise), and 2016–2019 (orange). The corre-

Roberts et al., 2022.

Over the hump!

- Things can get worse before they get better.
- Nonlinearities in ozone chemistry.
- Small action on NOx now means big improvement in smog.

More good news

International Journal of Chronic Obstructive Pulmonary Disease, 2014.

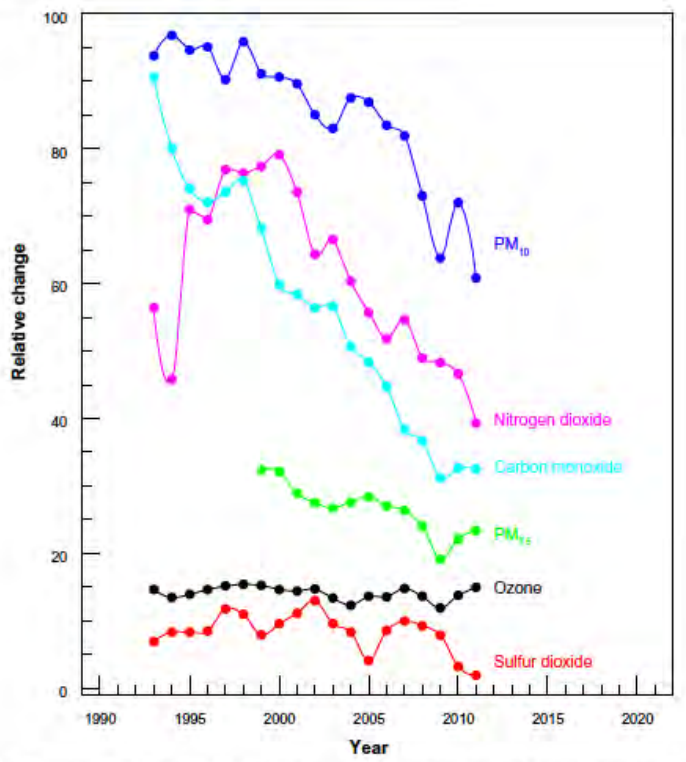


Figure 1 Levels of six air pollutants in North Carolina, 1993–2011. Individual pollutants were placed onto a single graph by utilizing arbitrary units to enable a collective visualization of the trends.
Abbreviation: PM, particulate matter.

Results: Decline in emphysema deaths was associated with decreasing levels of SO_2 and CO in the air, decline in asthma deaths–with lower SO_2, CO, and PM_{10} levels, and decline in pneumonia deaths–with lower levels of SO_2. Sensitivity analyses were performed to study potential effects

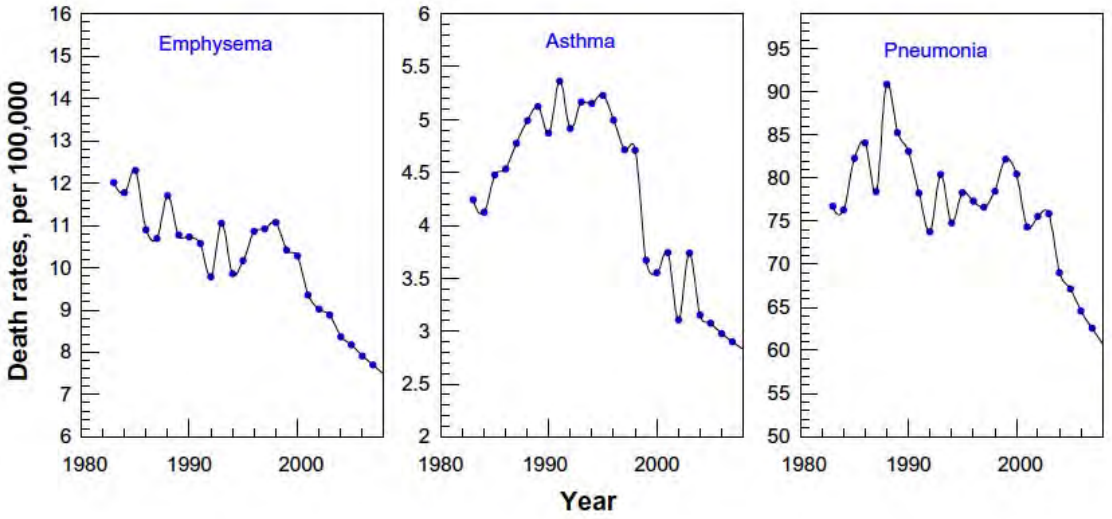


Figure 3 Trends in death rates for emphysema, asthma, and pneumonia in North Carolina, 1983–2010. Mortality rates were age-adjusted to the 2000 North Carolina population.

What does the future hold?

In 1992 EPA predicted NOx Emissions

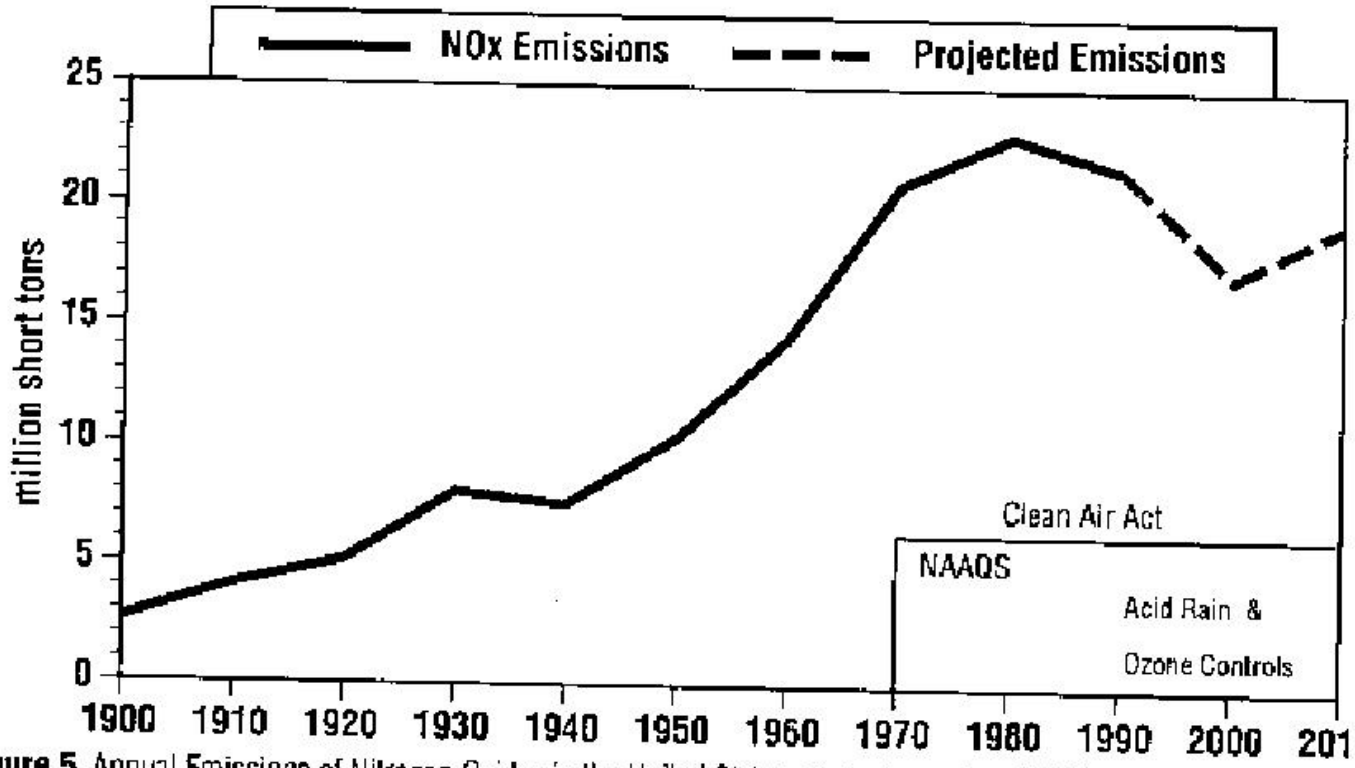


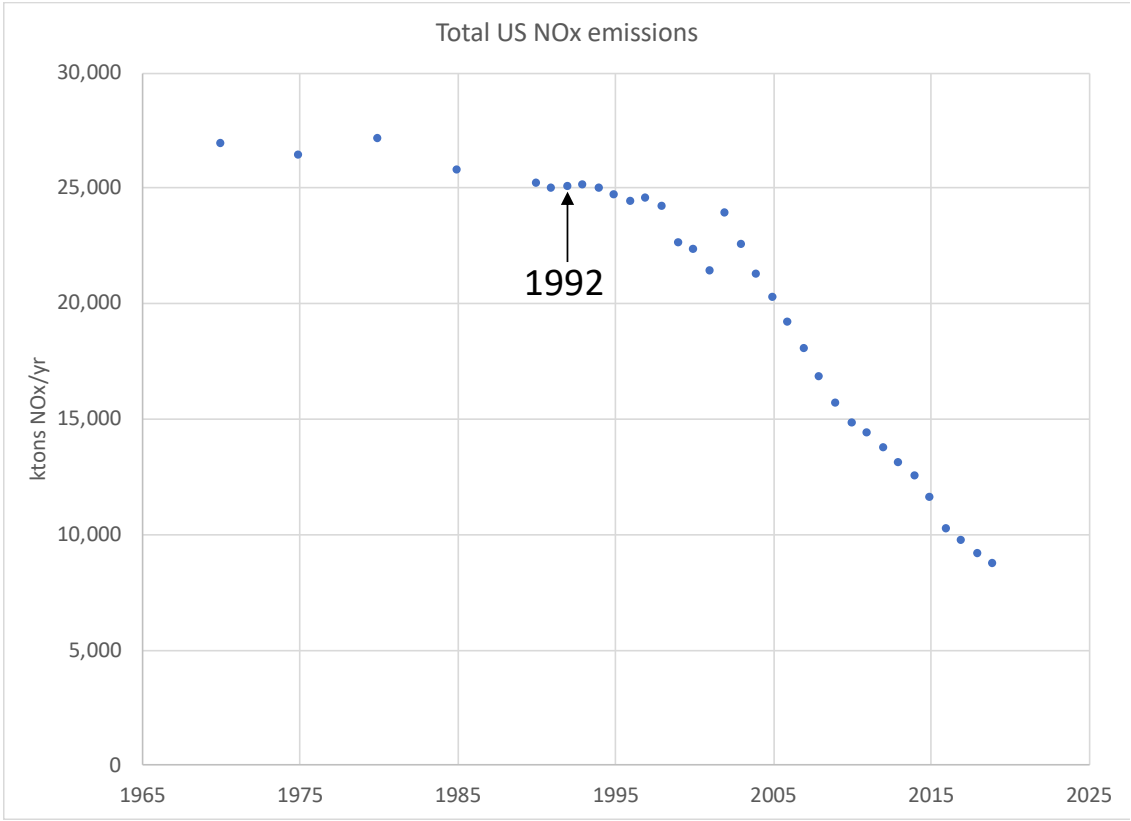
Figure 5 Annual Emissions of Nitrogen Oxides in the United States. Emissions since 1970 have been controlled under the Clean Air Act and its Amendments. Emissions in the 21st century will depend on many factors including regulations and their implementation, fuel use, economic conditions, technology developments, and implementation. There is no national cap on the emissions of nitrogen oxides. (*Data source: National Air Pollutant Emission Estimates 1940-1990, EPA*)
NAAQS - National Ambient Air Quality Standards

The future is hard to predict. What really happened? National Emission Trends

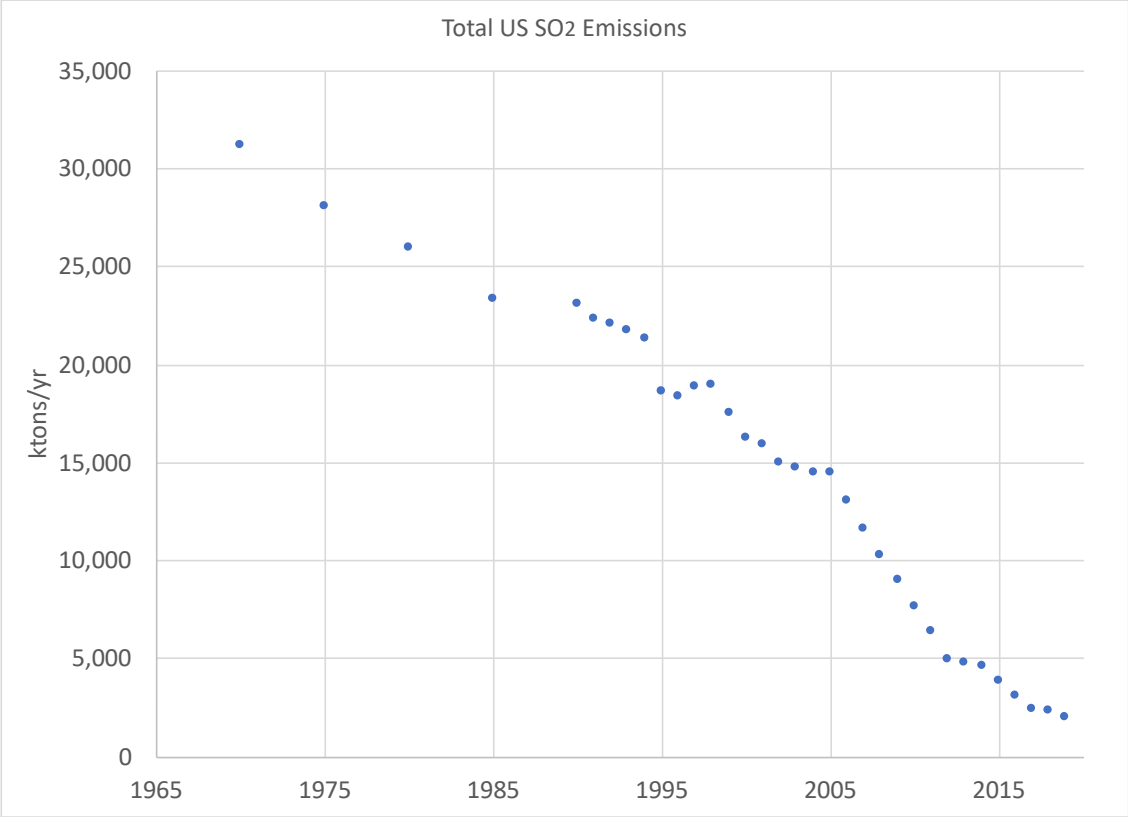
http://www.epa.gov/ttn/chief/trends/index.html

What really happened?

EPA's reported NOx Emissions.

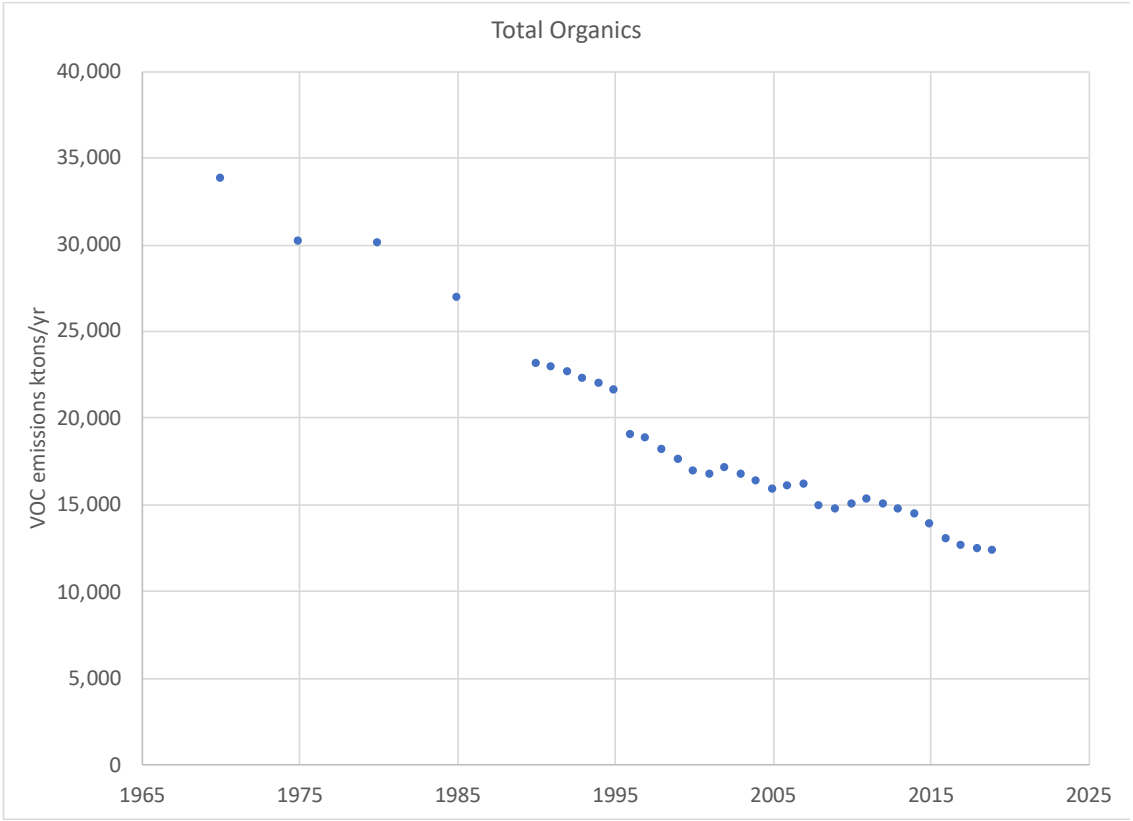


What really happened?
National SO2 Emission Trends

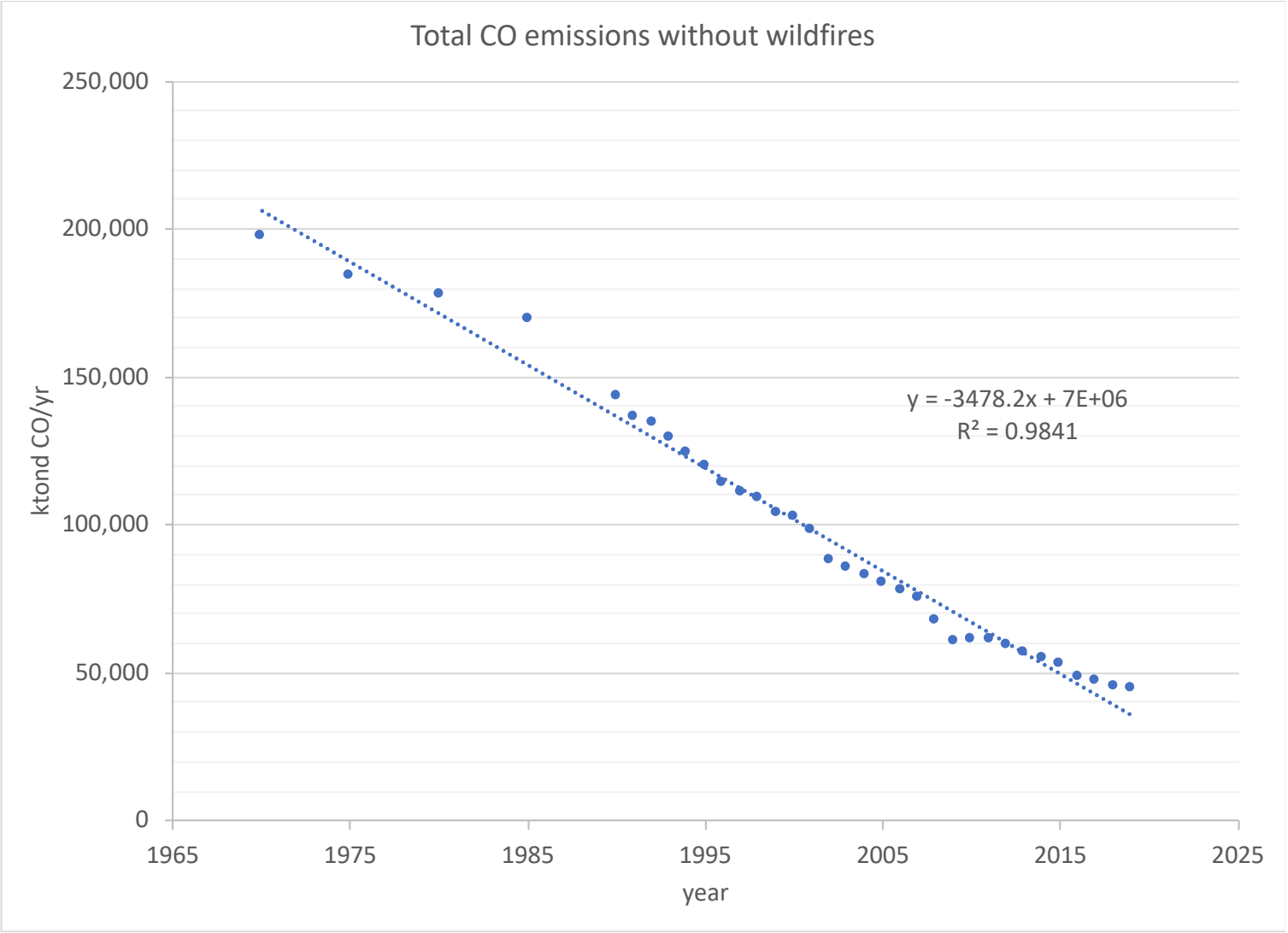


https://www.epa.gov/air-emissions-inventories/air-pollutant-emissions-trends-data

EPA's reported VOC emissions



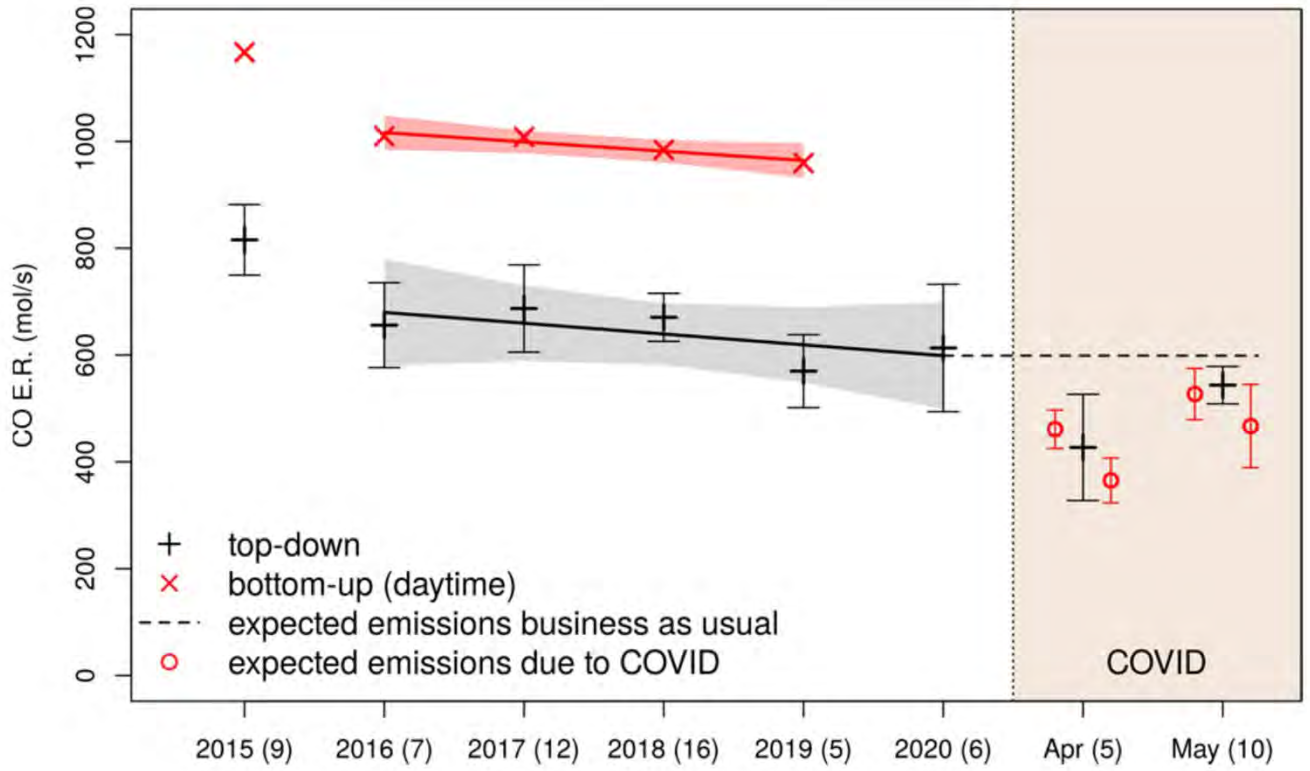
EPA's reported CO emissions




N7675E

Aircraft observations show how Carbon Monoxide (CO) fell.

Lopez-Coto et al., 2022.



Better observations
Better models
Better policy
Better air quality

What does the future hold?

- Attainment for NAAQS
- Cleaner air from
  - Electric vehicles
  - Complete conversion from coal to natural gas for electricity
  - Renewables.
- But
  - More people
  - More vehicle miles traveled
  - More industry
  - More agriculture.
  - Warming climate

Will a hotter DMV mean more ozone?
Models are doing OK, so...
Yes – but not if NOx goes down enough (Hembeck et al., 2022).

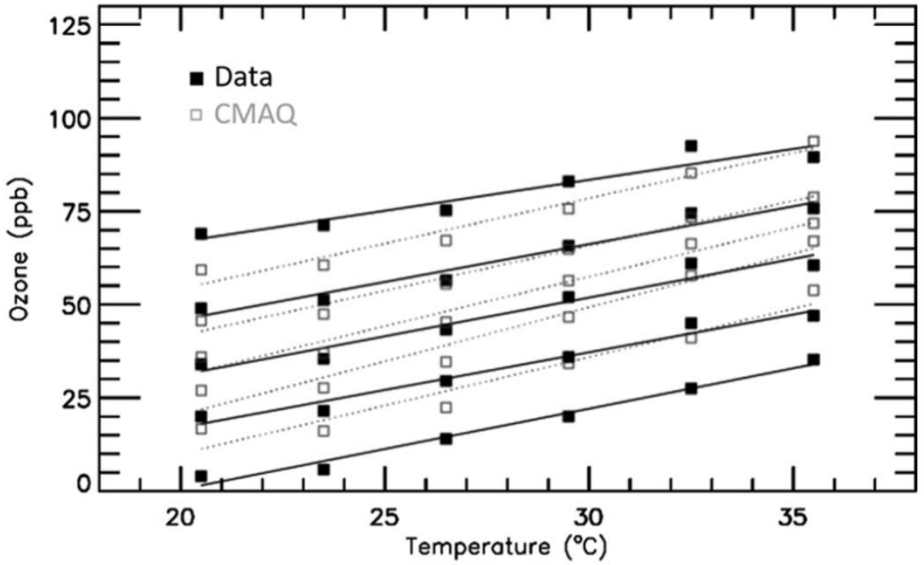
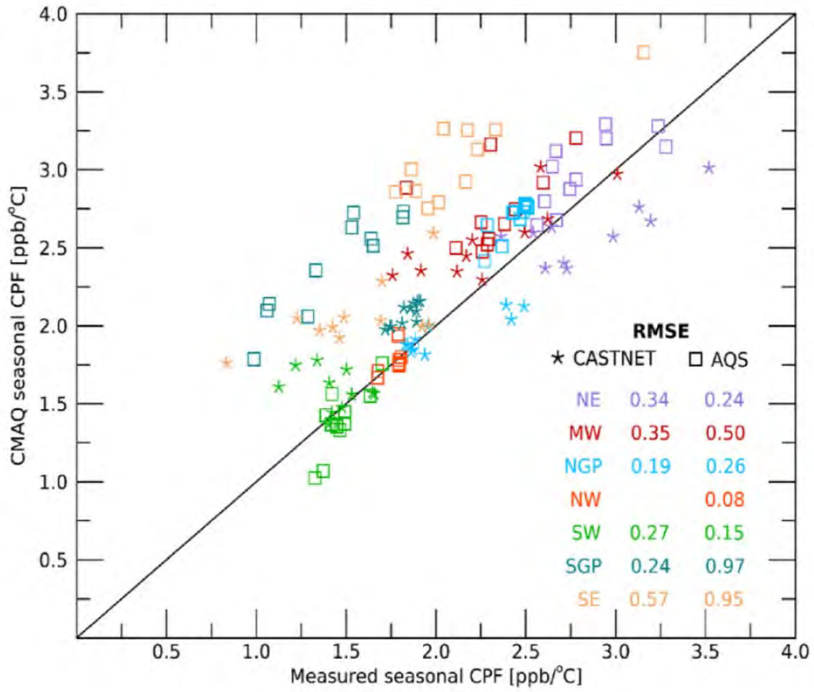


Fig. 3. Ozone vs. temperature plotted in 3 °C temperature bins across the range 19–37 °C for the 5th, 25th, 50th, 75th, and 95th percentiles (black and gray



Climate Penalty Factor
Measured (X axis) and modeled (Y axis)

The rest of the story

- If air is so much cleaner, why do we still have high morbidity and mortality associated with AQ?

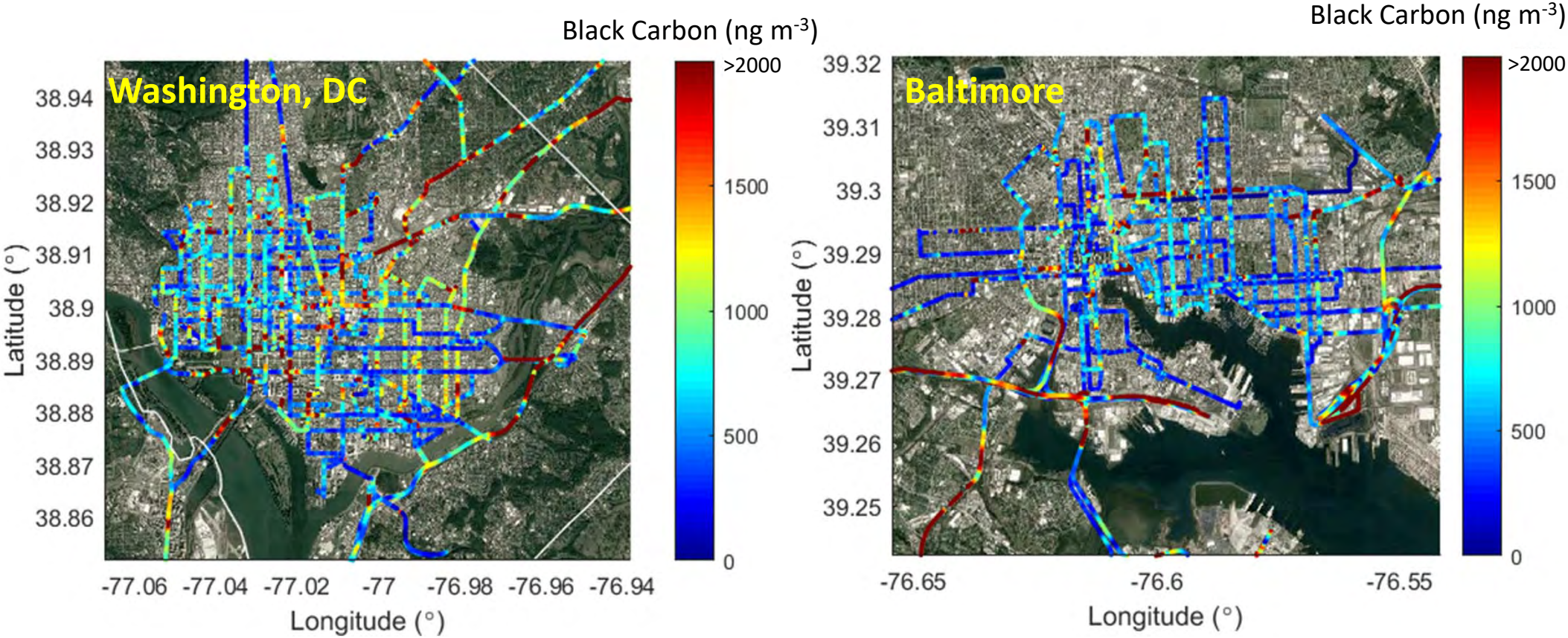
NOAAs ARC
Air Resources Car

Measurement Suite:

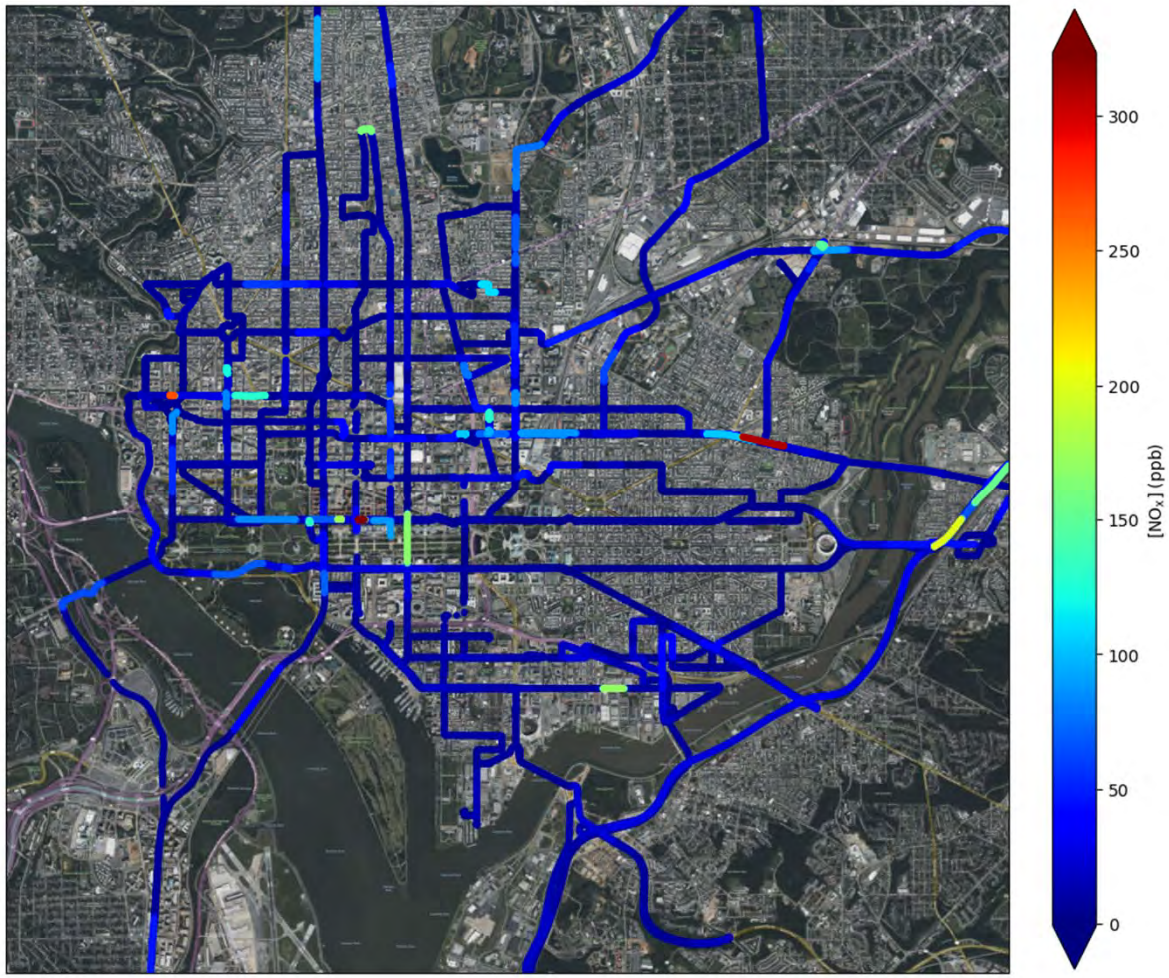
(1) Picarro 2401-m for $CO_2/CH_4/CO/H_2O$
(2) Teledyne T500U CAPS NO_2 analyzer
(3) Teledyne U500 CAPS NO-NO_2-NOx analyzer
(4) AE43 Aethalometer for black carbon
(5) Aeris ethane analyzer
(6) Met: T/RH/3-D wind

Black Carbon in DC and Baltimore

NAAQS for PM2.5 = 10 μgm^{-3} but 0.5 μgm^{-3} causes morbidity.



Ivy City recorded BC up to 35 μg m^{-3} (Northcross et al., 2019)



NOAA's ARC

Measured NOx in Washington, DC

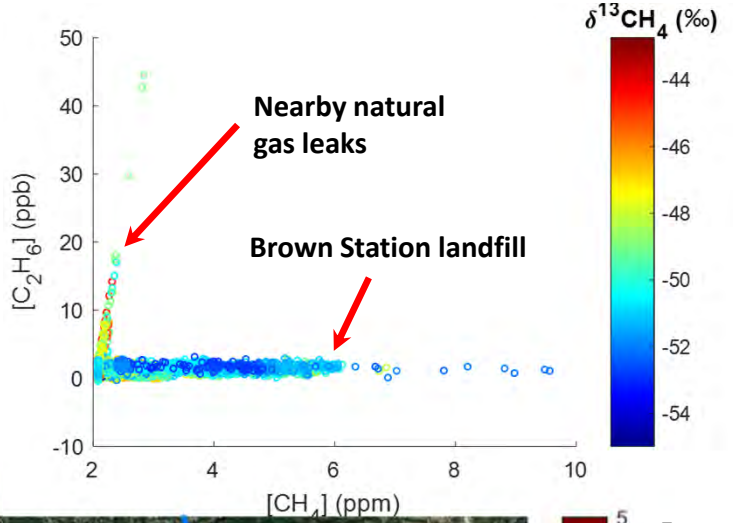
On-Road measurements of pollutants in the Baltimore/Washington area. 2022

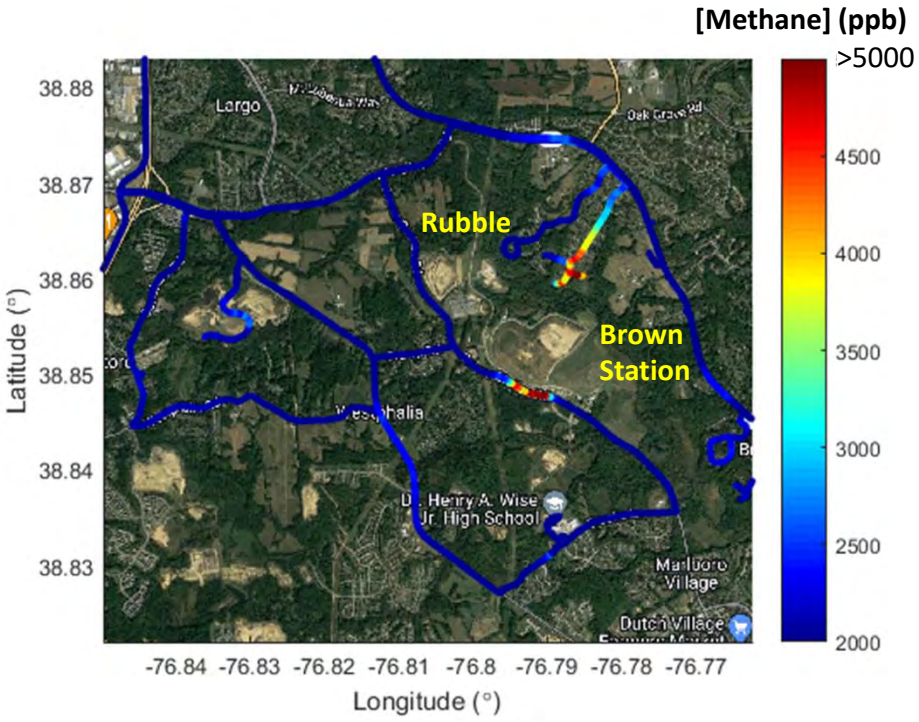
	BC (μgm^{-3})	NOx (ppb)
Min	7.20	0.03
5th percentile	165.20	1.29
25th perccentile	342.30	3.80
Median	**570.00**	**7.41**
75th percentile	1008.38	19.55
95th percentile	3365.02	87.25
99th percentile	10671.73	267.98
Max	132245.70	971.39

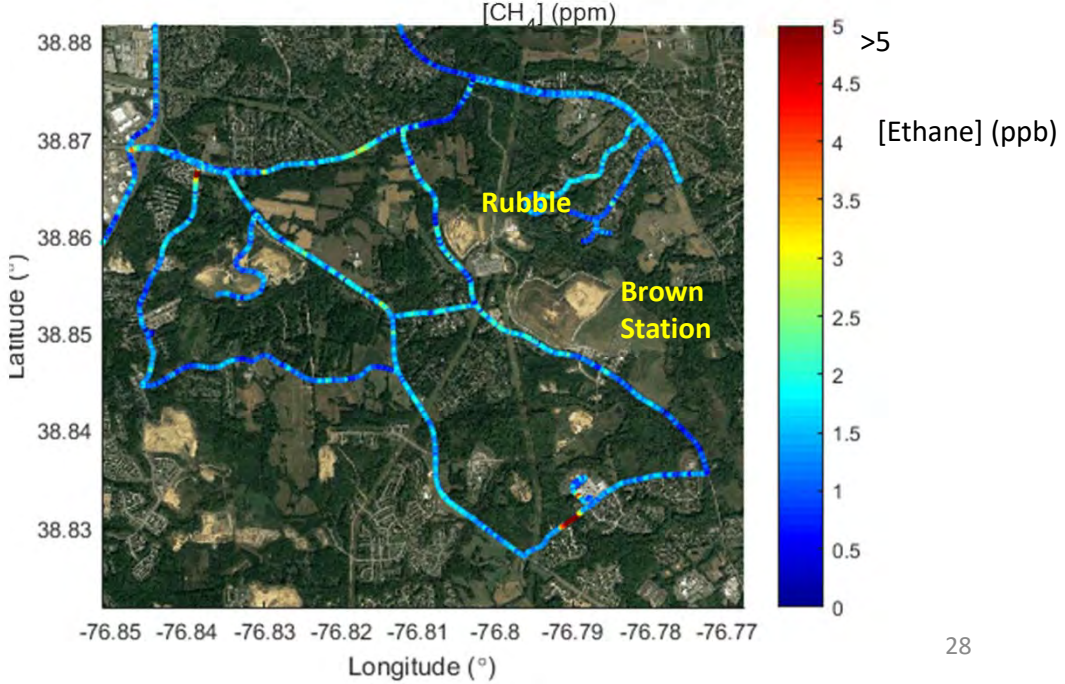
Methane emissions were underestimated.

Landfills may be low hanging fruit for emissions reductions.

(Now working with Brown Station municipal waste landfill and rubble landfill, NIST, NOAA, MDE)







Findings

- A policy of region-wide abatement has been highly successful in improving AQ on the regional scale.
- A warming climate will make attainment harder.
- Greenhouse gas emissions need verification.
- PM2.5 and O_3 are widely–spread, secondary pollutants; attainment of the NAAQS does not ensure safe levels of pollution for all.
- On-road measurements in Balt/Wash show:
  - > 3% of the readings for NOx exceed the EPA 1-hr NO_2 standard of 100 ppb.
  - > 75% of the readings exceed 1.0 $\mu g\ m^{-3}$ Black Carbon – associated with impaired cognition.
  - > 1% of the readings exceed 10 $\mu g\ m^{-3}$ Black Carbon (WHO suggested limit for PM2.5).

Future work

- Measurements and models to determine exposure, evaluate emissions inventories, and identify major sources of short-lived pollutants and greenhouse gases.
- Evaluate GHG emissions and meet goals (accountability).
- Focus on micro-scale (EPA grants): Neighborhoods with high concentrations of poor and nonwhite residence suffer disproportionately from air pollution: **Environmental Justice.**
- Primary pollutants s.a. PM10.
- NAAQS may be tightened but may also be revised (BC?).

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YEAR IN CHEMISTRY 2019

RESEARCH OF THE YEAR

Our understanding of air pollution's health effects deepened

Gut check: 2019 saw microbiome mysteries unraveled

PFAS pollution solutions moved forward

Chemists made industrial synthesis greener

Sensational syntheses of 2019

2019's top chemistry research, by the numbers

TOP NEWS STORIES OF THE YEAR

MOLECULES OF THE YEAR

DELIGHTS OF THE YEAR

CH FOR IN 2020

4/5

Research of the Year

POLLUTION

Our understanding of air pollution's health effects deepened

A wave of studies tied air pollution to an expanding range of adverse health effects

by ***Katherine Bourzac***

October 2019 EPA's CASAC fails to tighten PM standard.

Dec. 2019. EPA's CASAC fails to tighten O_3 standard.

"But I have promises to keep
And miles to go before I sleep."
R. Frost

Extra slides