LADCO | LAKE MICHIGAN AIR DIRECTORS CONSORTIUM

# Trends in $PM_{2.5}$ and Ozone in the LADCO Region:

## With Estimated 2024 Values

Angie Dickens and Mark Janssen
LADCO Data Scientist & Emissions Director

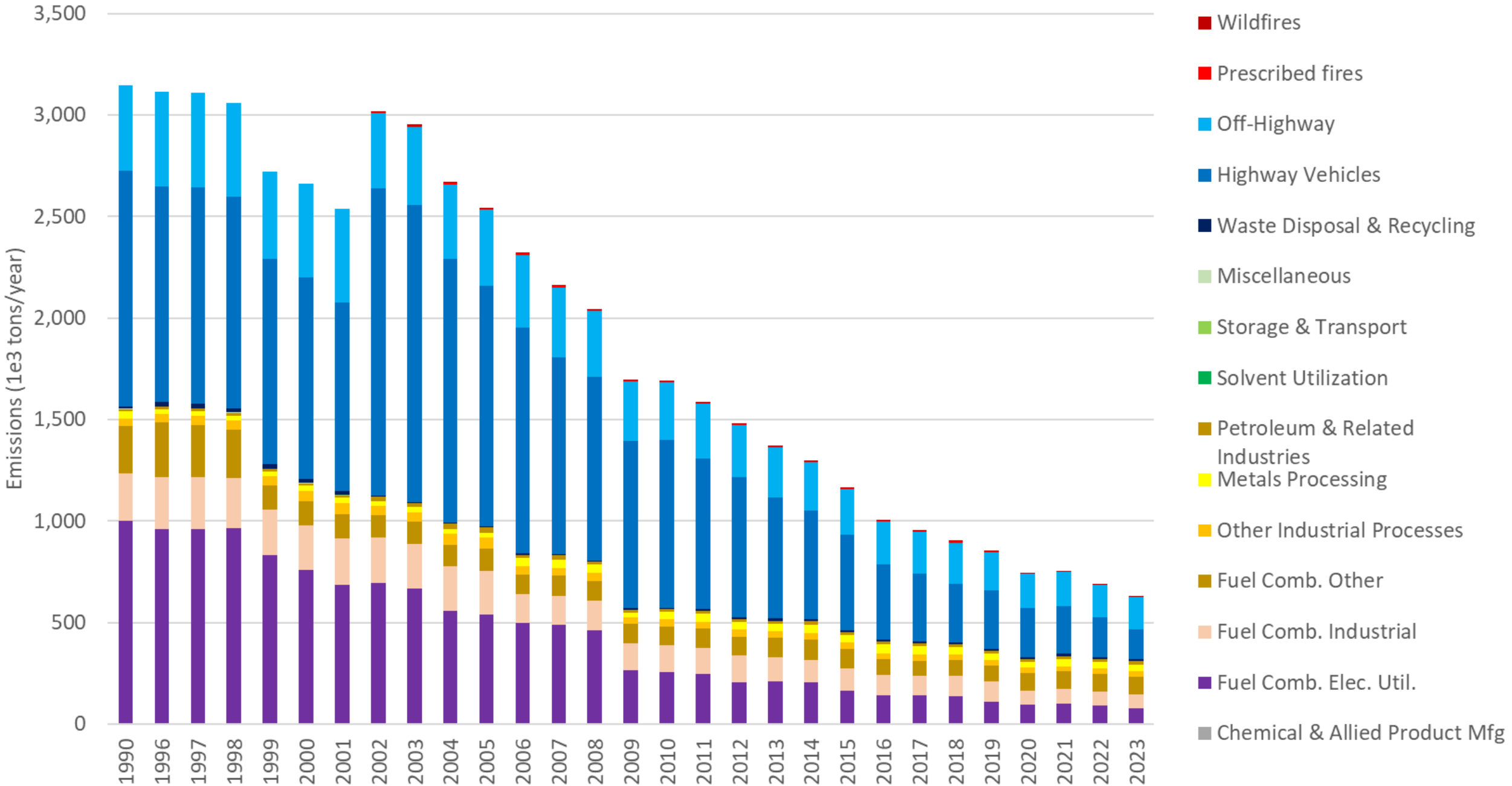
LADCO Business Meeting
September 25, 2024

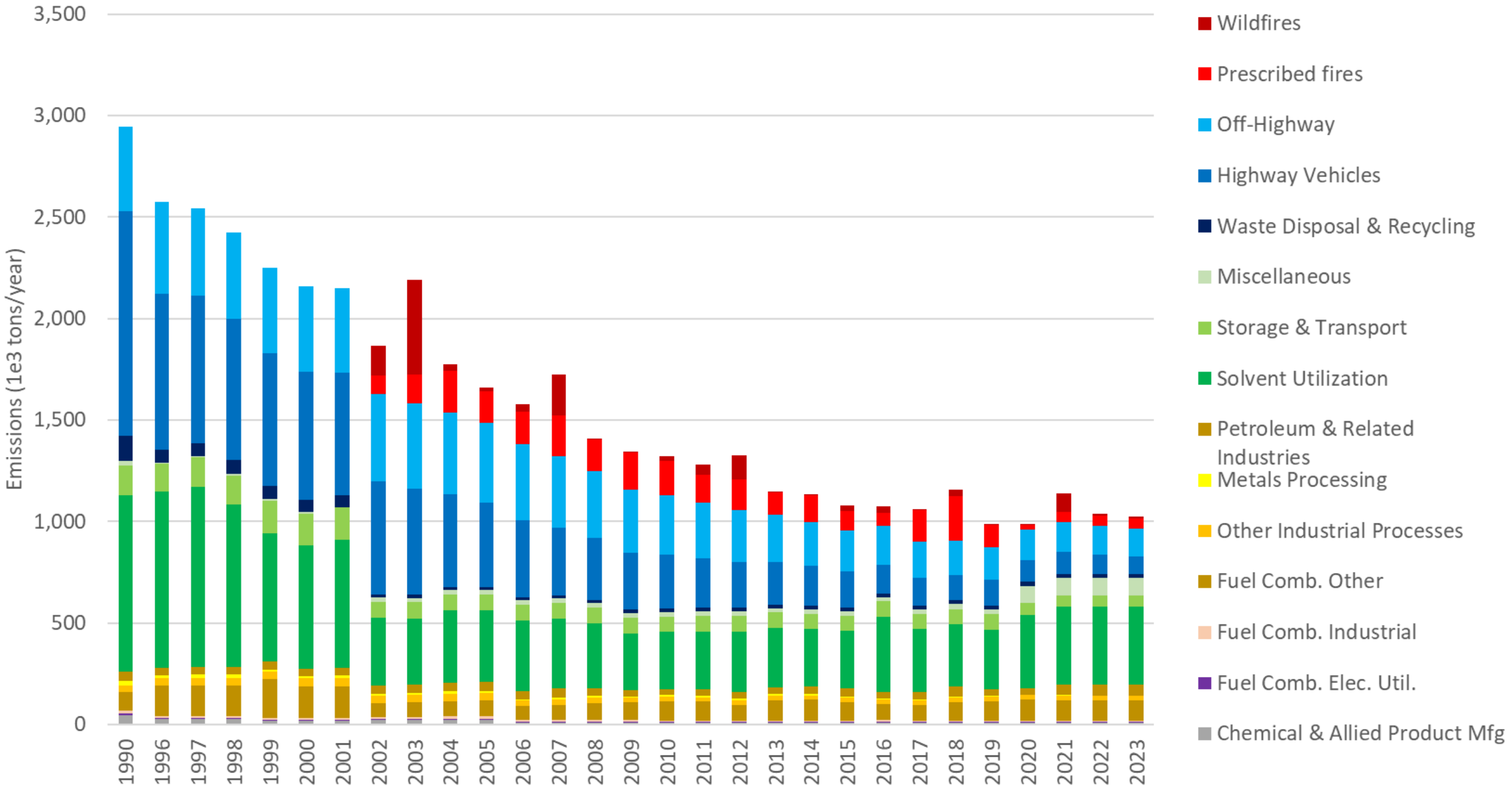
# The overall picture: A normal to clean air year

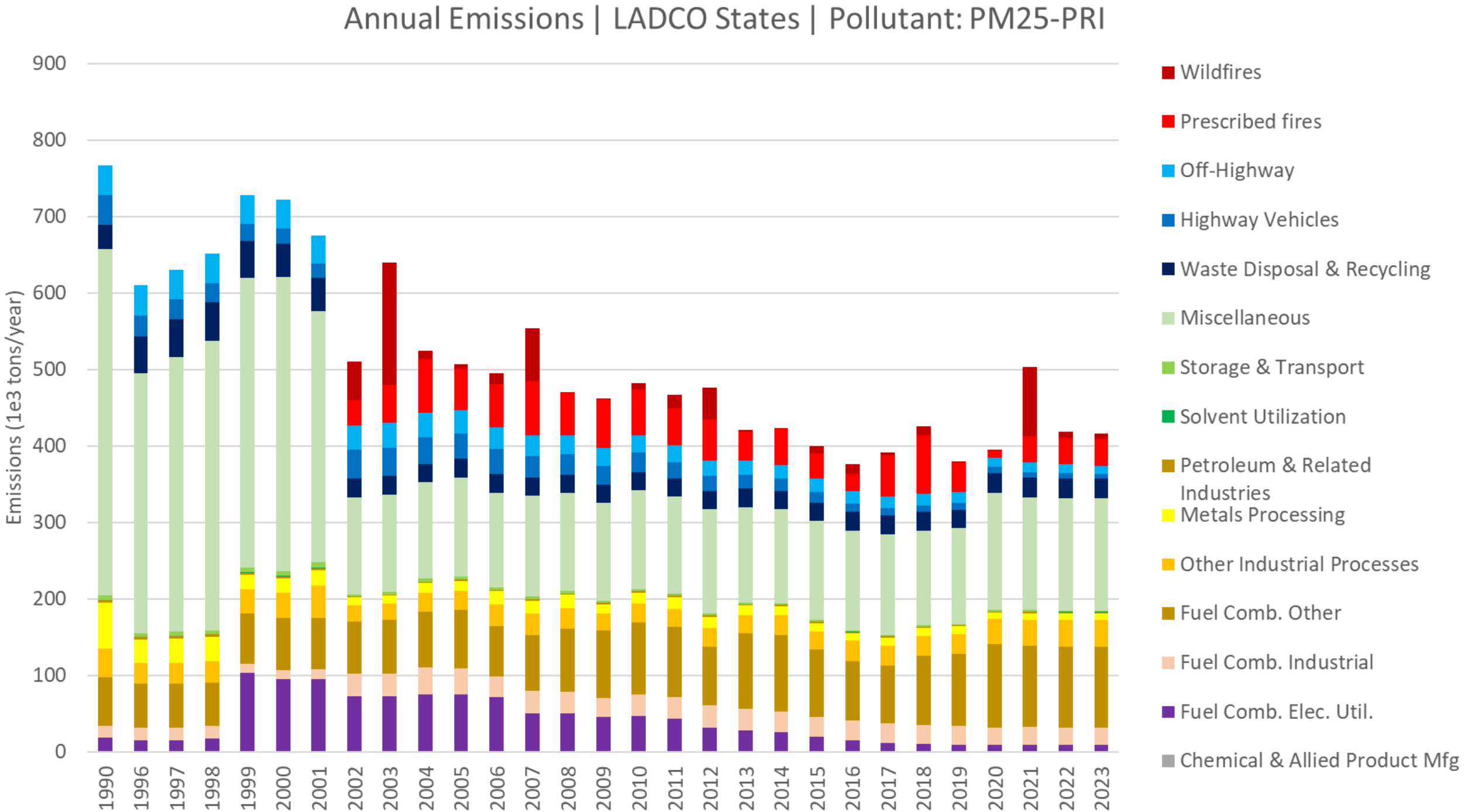
- Emissions trends
- $PM_{2.5}$ annual values & design values
  - Trends & distribution
- Ozone fourth-high values & design values
  - Drivers in 2024
  - Trends and distribution
  - Meteorological adjustment using CART
- Regional haze trends

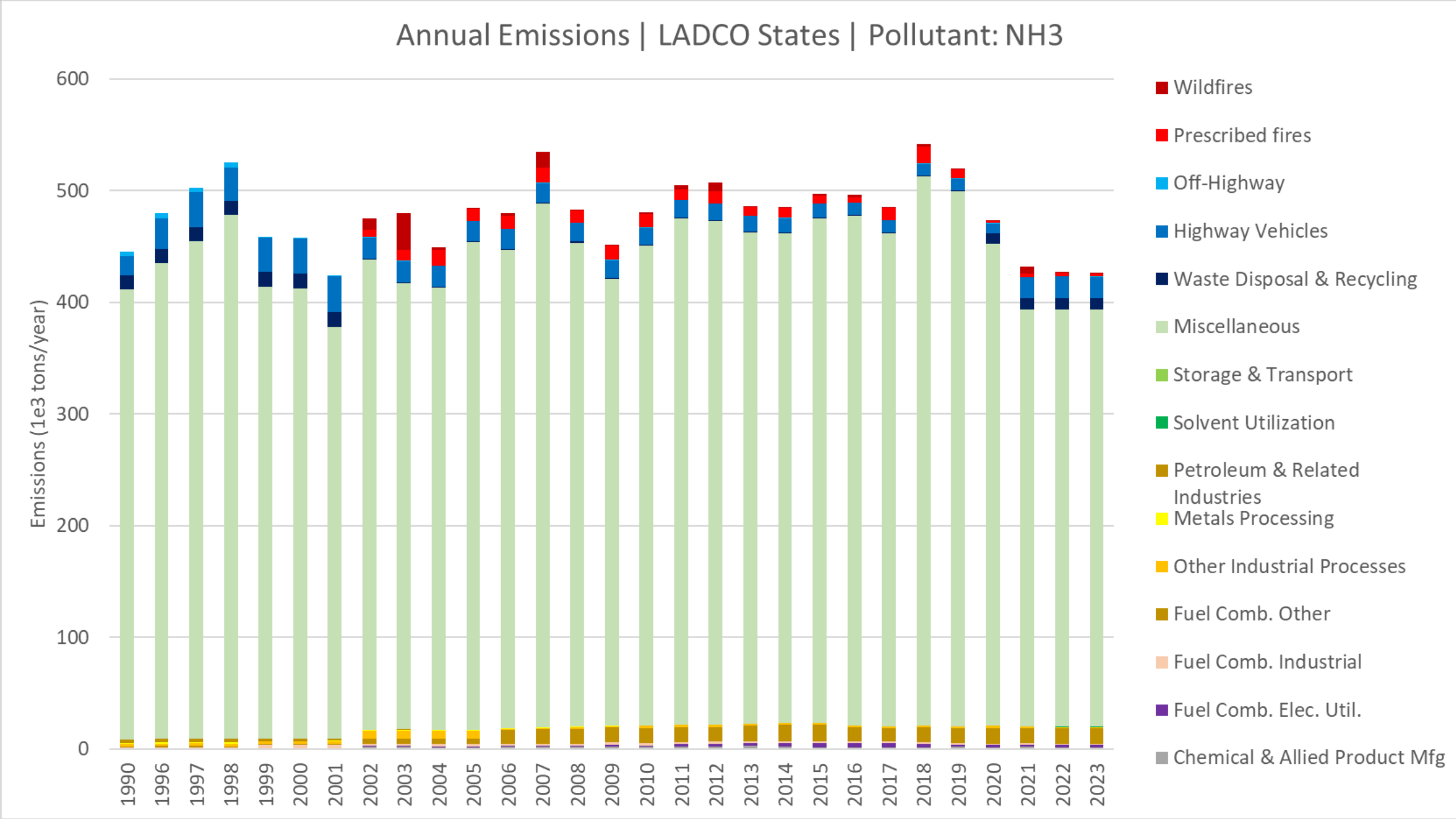


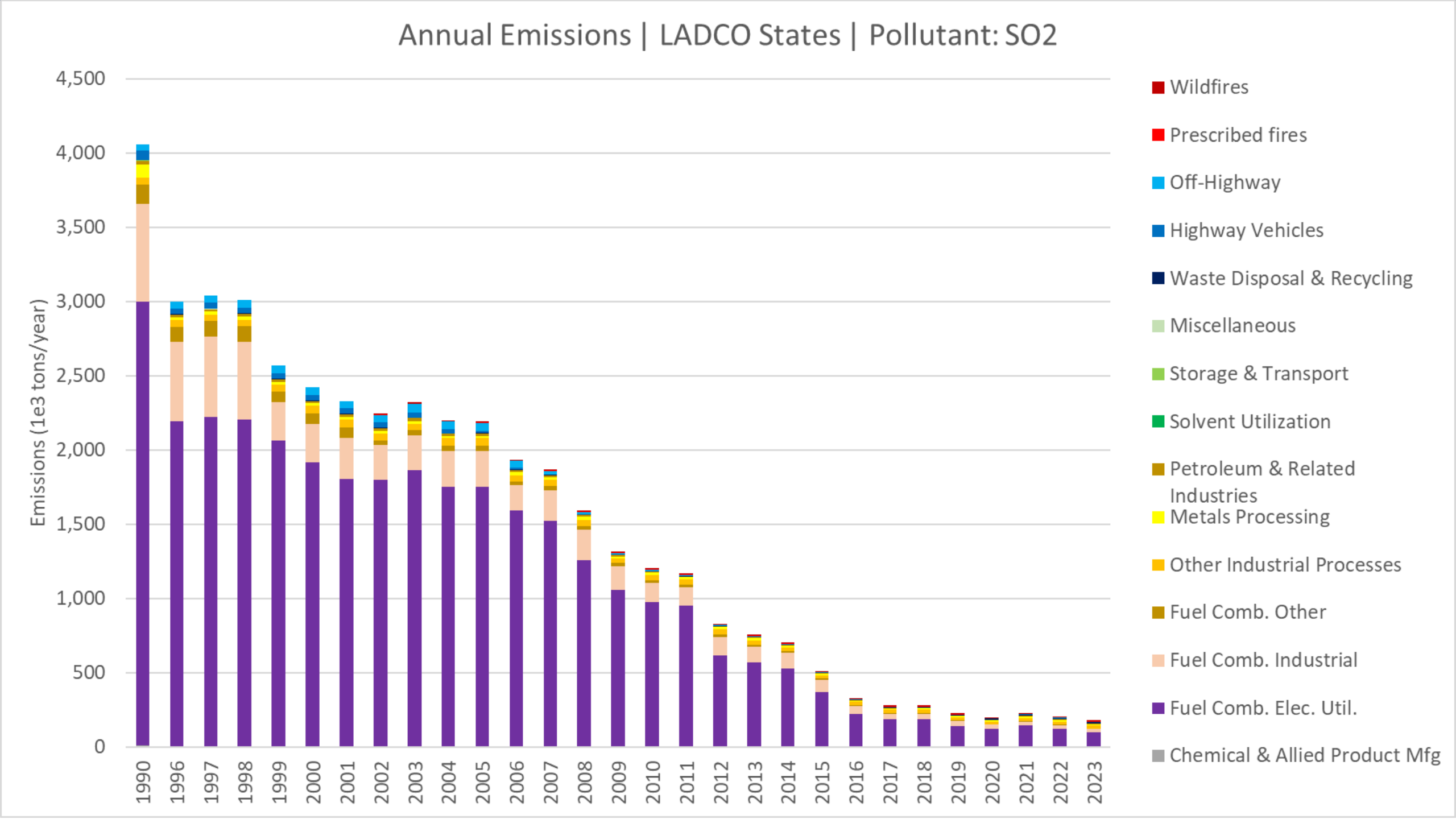
LADCO

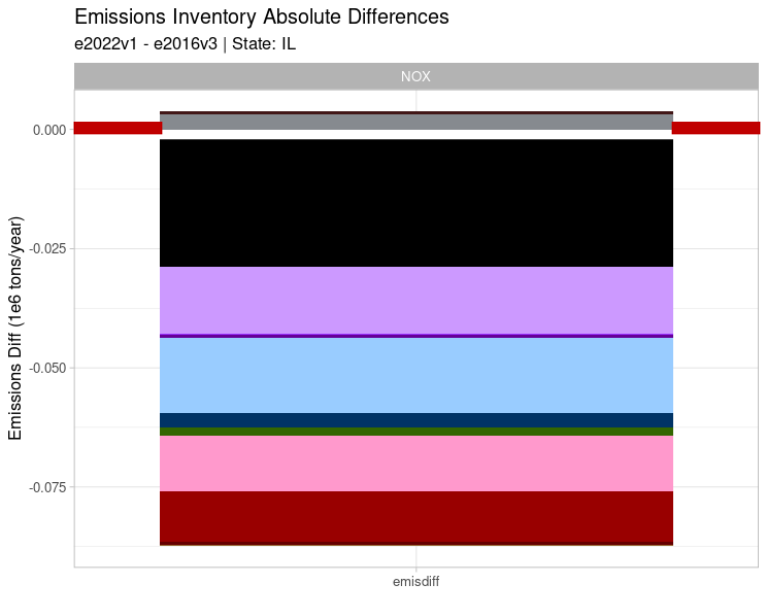

Annual Emissions | LADCO States | Pollutant: NOX
Emissions (1e3 tons/year)
3,500
3,000
2,500
2,000
1,500
1,000
500
0
1990
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
Wildfires
Prescribed fires
Off-Highway
Highway Vehicles
Waste Disposal & Recycling
Miscellaneous
Storage & Transport
Solvent Utilization
Petroleum & Related Industries
Metals Processing
Other Industrial Processes
Fuel Comb. Other
Fuel Comb. Industrial
Fuel Comb. Elec. Util.
Chemical & Allied Product Mfg

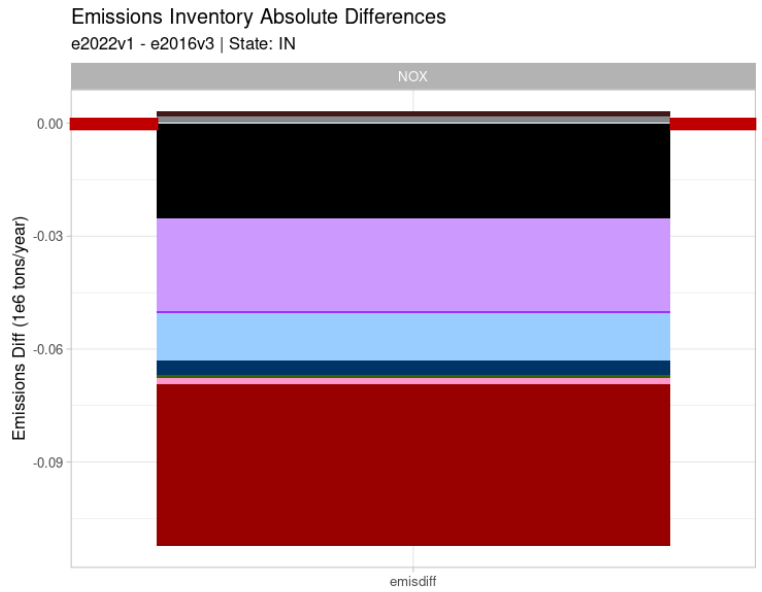

Annual Emissions | LADCO States | Pollutant: VOC
Emissions (1e3 tons/year)
3,500
3,000
2,500
2,000
1,500
1,000
500
0
1990
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
Wildfires
Prescribed fires
Off-Highway
Highway Vehicles
Waste Disposal & Recycling
Miscellaneous
Storage & Transport
Solvent Utilization
Petroleum & Related Industries
Metals Processing
Other Industrial Processes
Fuel Comb. Other
Fuel Comb. Industrial
Fuel Comb. Elec. Util.
Chemical & Allied Product Mfg

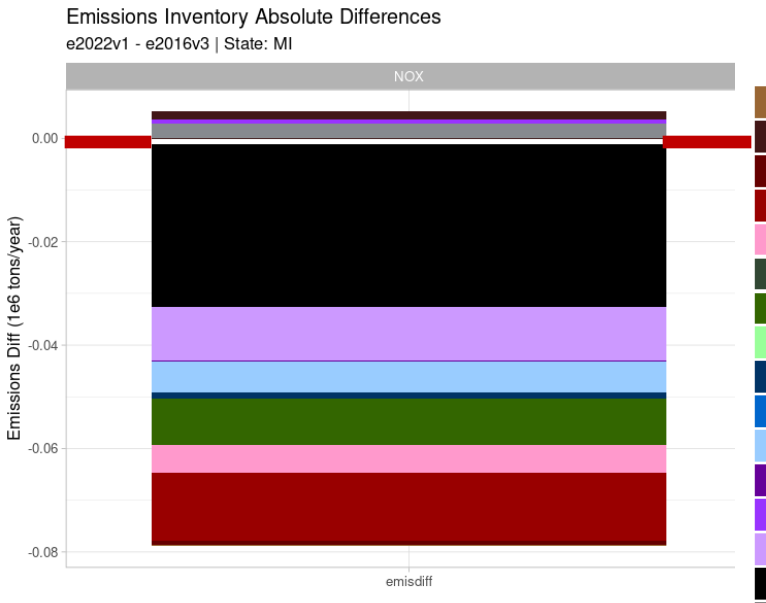

Annual Emissions | LADCO States | Pollutant: PM25-PRI
Emissions (1e3 tons/year)
900
800
700
600
500
400
300
200
100
0
1990
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
Wildfires
Prescribed fires
Off-Highway
Highway Vehicles
Waste Disposal & Recycling
Miscellaneous
Storage & Transport
Solvent Utilization
Petroleum & Related Industries
Metals Processing
Other Industrial Processes
Fuel Comb. Other
Fuel Comb. Industrial
Fuel Comb. Elec. Util.
Chemical & Allied Product Mfg


Annual Emissions | LADCO States | Pollutant: NH3
Emissions (1e3 tons/year)
600
500
400
300
200
100
0
1990
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
Wildfires
Prescribed fires
Off-Highway
Highway Vehicles
Waste Disposal & Recycling
Miscellaneous
Storage & Transport
Solvent Utilization
Petroleum & Related Industries
Metals Processing
Other Industrial Processes
Fuel Comb. Other
Fuel Comb. Industrial
Fuel Comb. Elec. Util.
Chemical & Allied Product Mfg

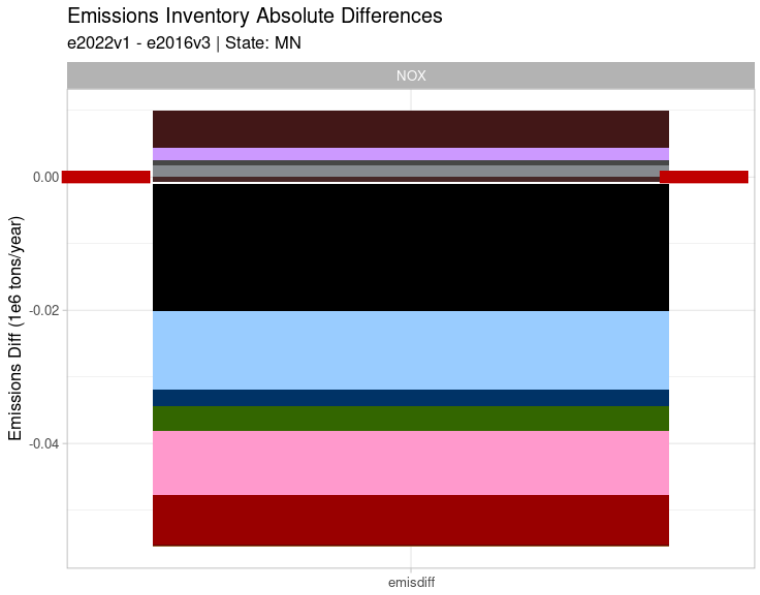

Annual Emissions | LADCO States | Pollutant: SO2
Emissions (1e3 tons/year)
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
1990
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
Wildfires
Prescribed fires
Off-Highway
Highway Vehicles
Waste Disposal & Recycling
Miscellaneous
Storage & Transport
Solvent Utilization
Petroleum & Related Industries
Metals Processing
Other Industrial Processes
Fuel Comb. Other
Fuel Comb. Industrial
Fuel Comb. Elec. Util.
Chemical & Allied Product Mfg

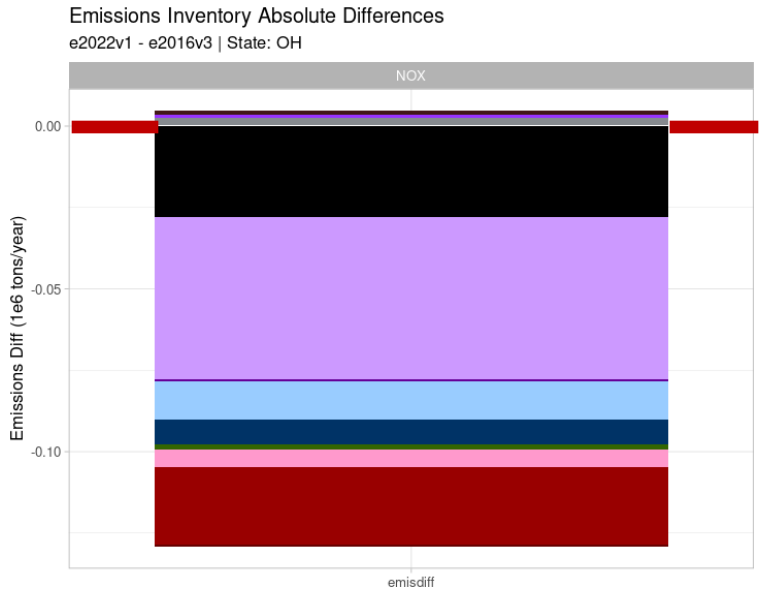

Emissions Inventory Absolute Differences
e2022v1 - e2016v3 | State: IL
NOX
0.000
-0.025
-0.050
-0.075
Emissions Diff (1e6 tons/year)
emisdiff

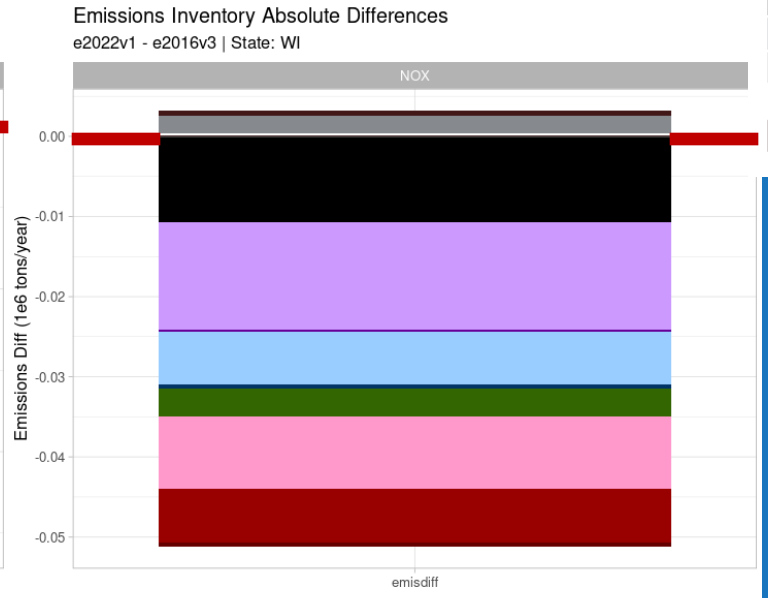

Emissions Inventory Absolute Differences
e2022v1 - e2016v3 | State: IN
NOX
0.00
-0.03
-0.06
-0.09
Emissions Diff (1e6 tons/year)
emisdiff


Emissions Inventory Absolute Differences
e2022v1 - e2016v3 | State: MI
NOX
0.00
-0.02
-0.04
-0.06
-0.08
Emissions Diff (1e6 tons/year)
emisdiff

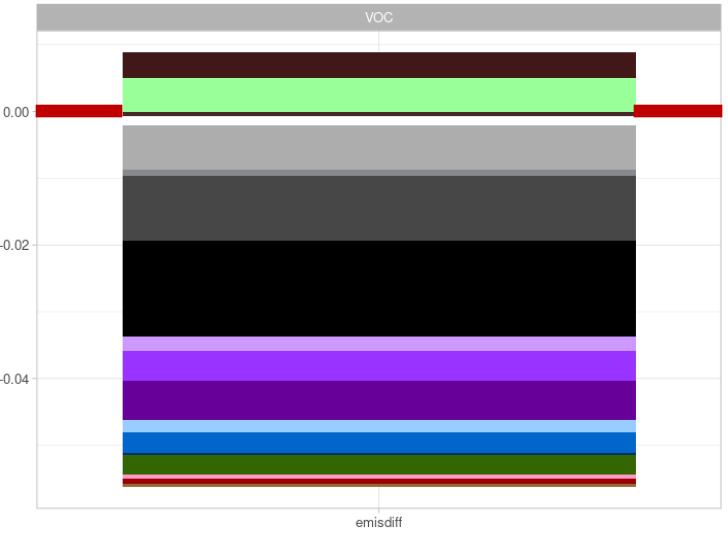

Aircraft
Commercial / Inst
Commercial Marine Vessels
Electric Generation
Fuel Comb - Industrial
Fugitive dust
Industrial Processes
Livestock
Locomotives
Miscellaneous
Nonroad diesel
Nonroad gas + other
Oil and Gas
Onroad Heavy Duty
Onroad Light Duty
Prescribed and Ag Fires
Residential
Solvents
Waste disposal
Wildfires


Emissions Inventory Absolute Differences
e2022v1 - e2016v3 | State: MN
NOX
0.00
-0.02
-0.04
Emissions Diff (1e6 tons/year)
emisdiff

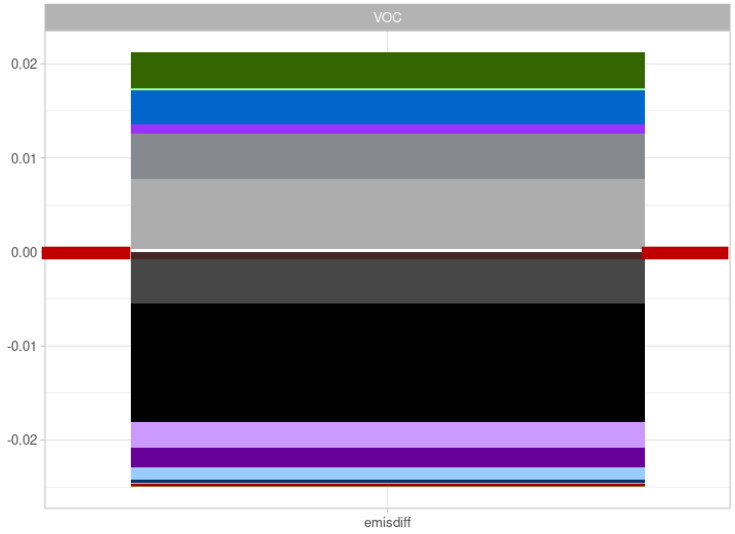

Emissions Inventory Absolute Differences
e2022v1 - e2016v3 | State: OH
NOX
0.00
-0.05
-0.10
Emissions Diff (1e6 tons/year)
emisdiff


Emissions Inventory Absolute Differences
e2022v1 - e2016v3 | State: WI
NOX
0.00
-0.01
-0.02
-0.03
-0.04
-0.05
Emissions Diff (1e6 tons/year)
emisdiff

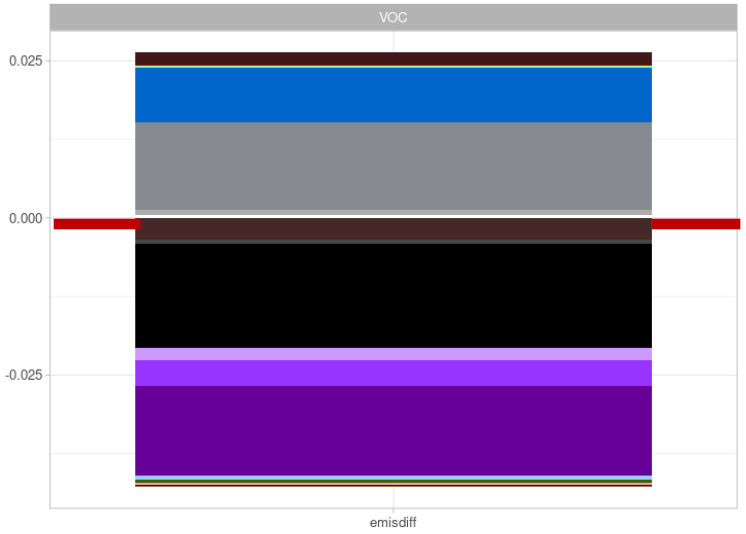
IL




IN

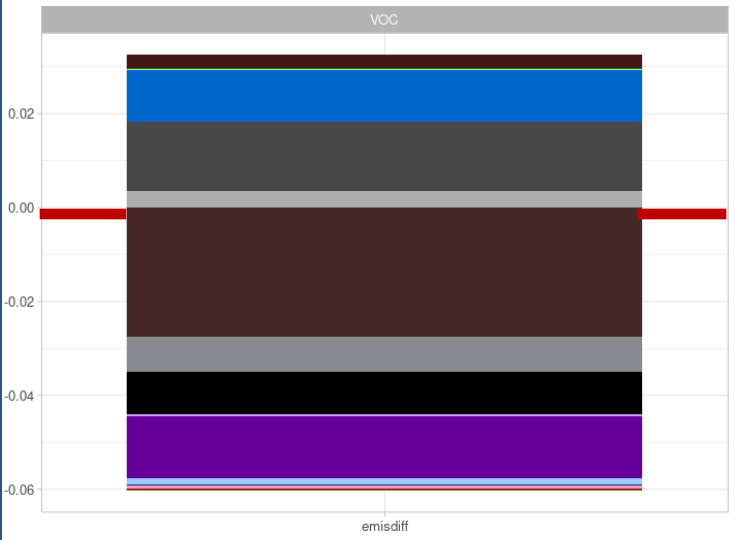



MI

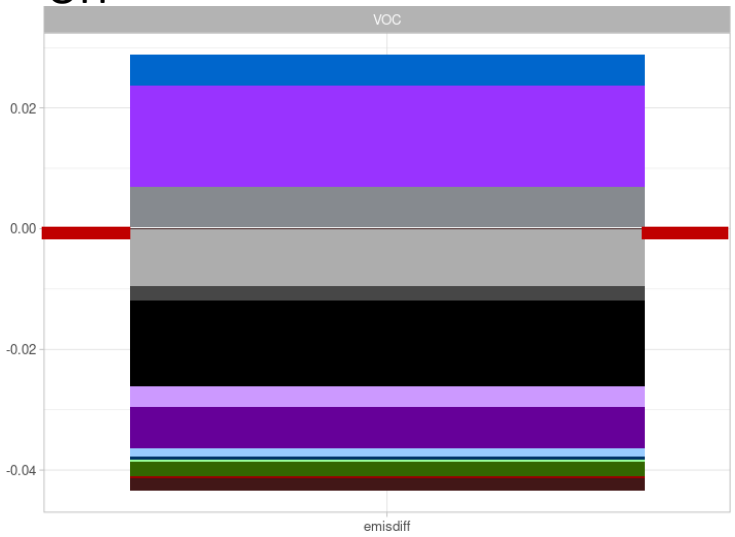



Aircraft
Commercial / Inst
Commercial Marine Vessels
Electric Generation
Fuel Comb - Industrial
Fugitive dust
Industrial Processes
Livestock
Locomotives
Miscellaneous
Nonroad diesel
Nonroad gas + other
Oil and Gas
Onroad Heavy Duty
Onroad Light Duty
Prescribed and Ag Fires
Residential
Solvents
Waste disposal
Wildfires

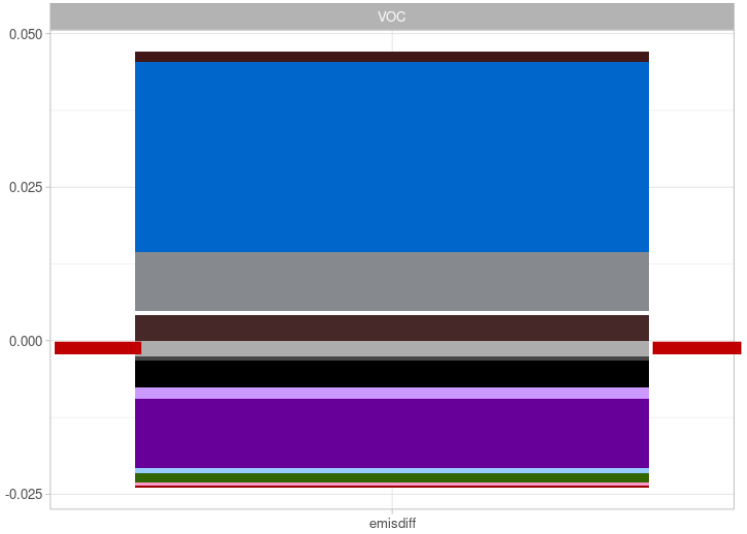
MN



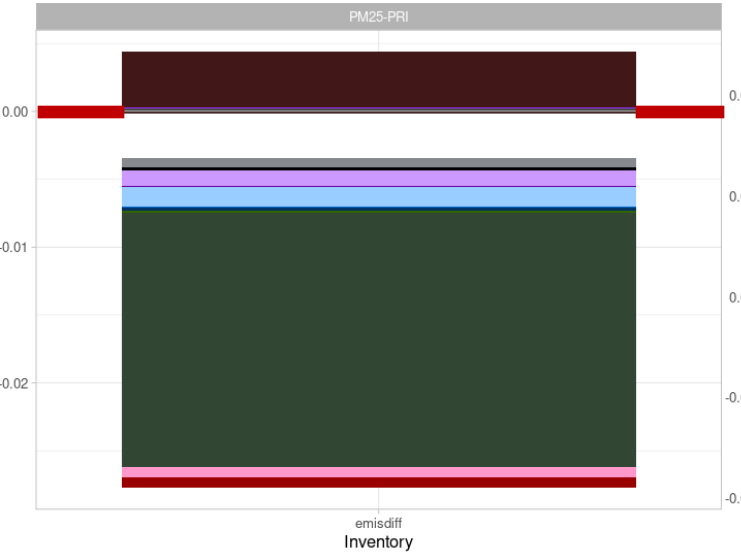

OH



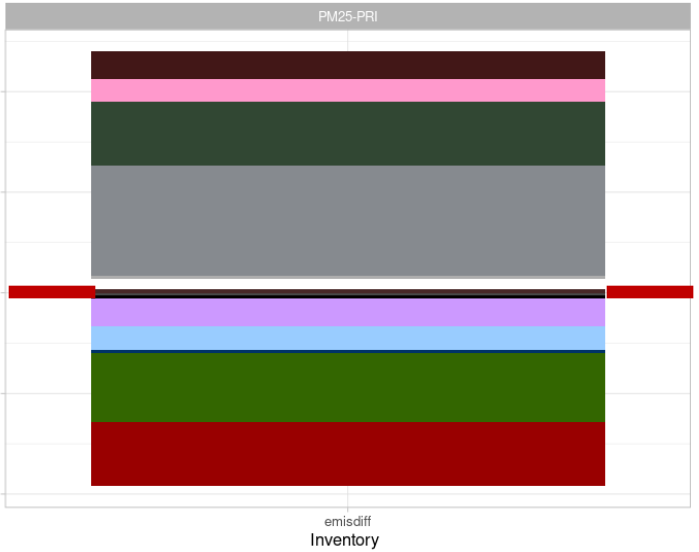

WI



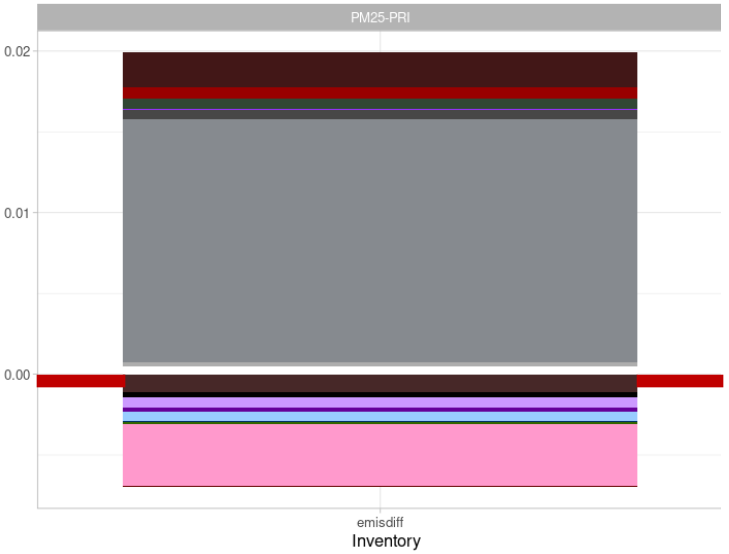
IL




IN

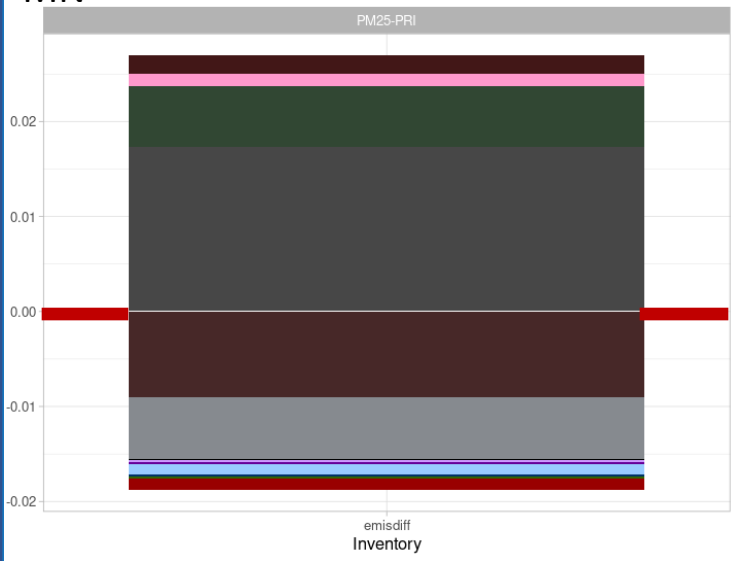



MI

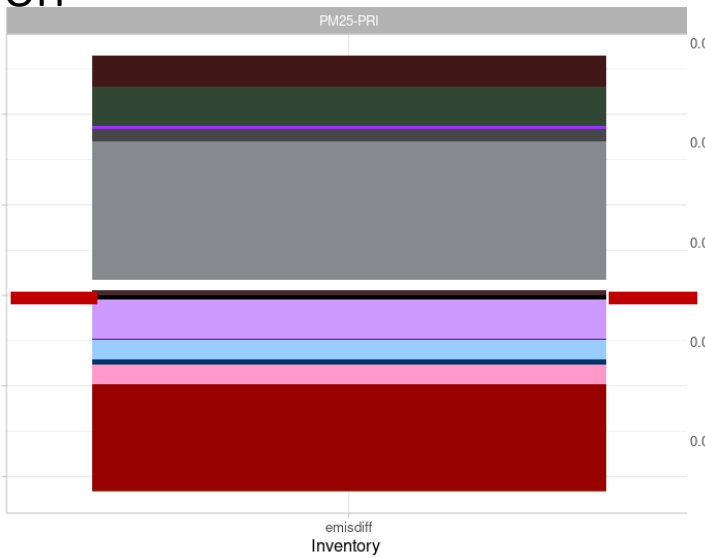




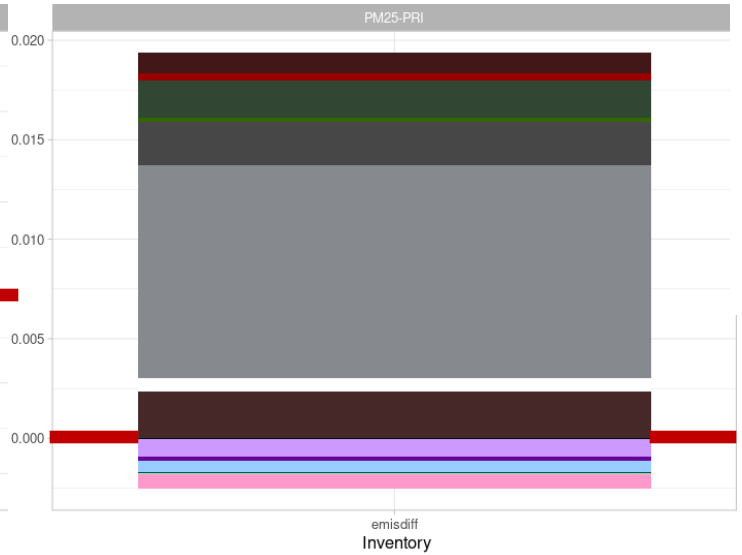
MN




OH



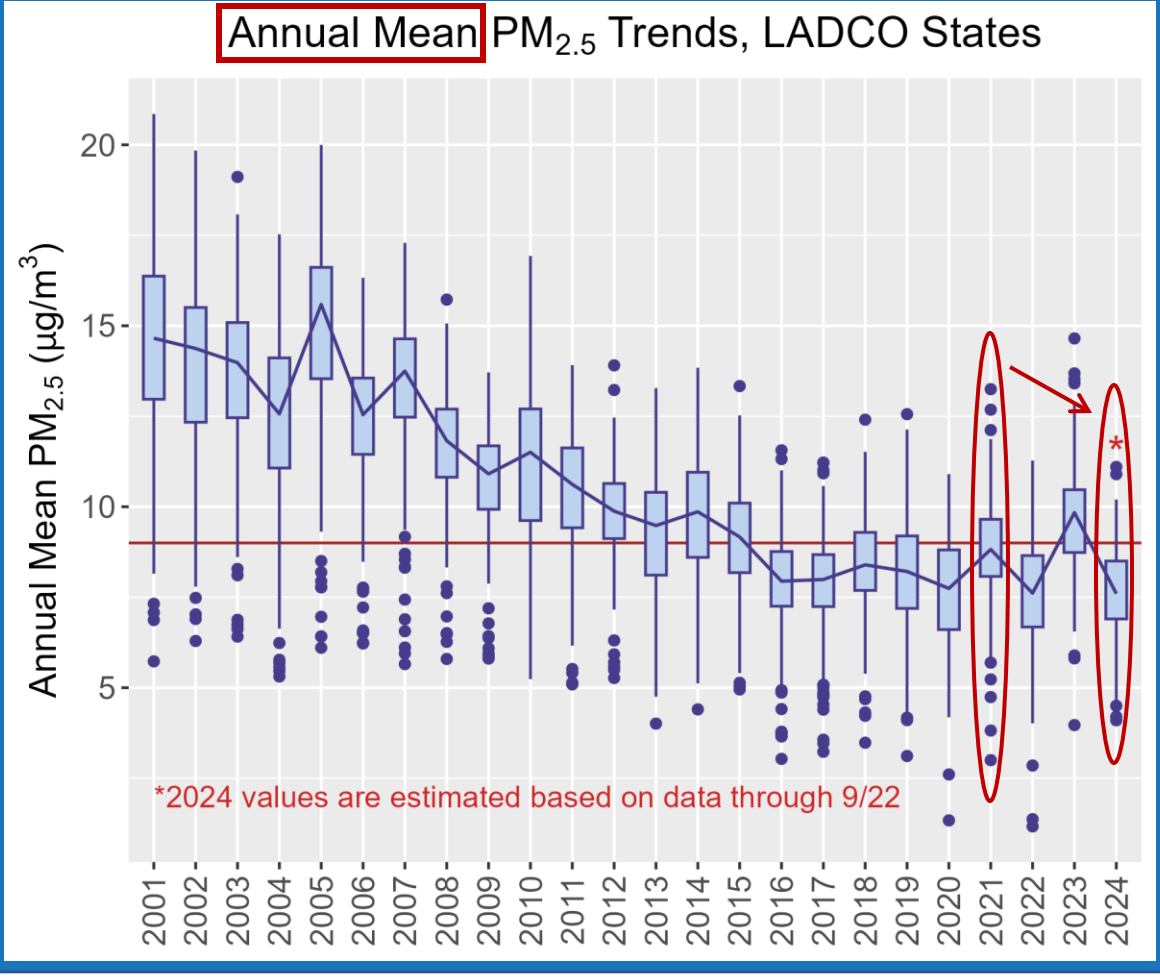

WI

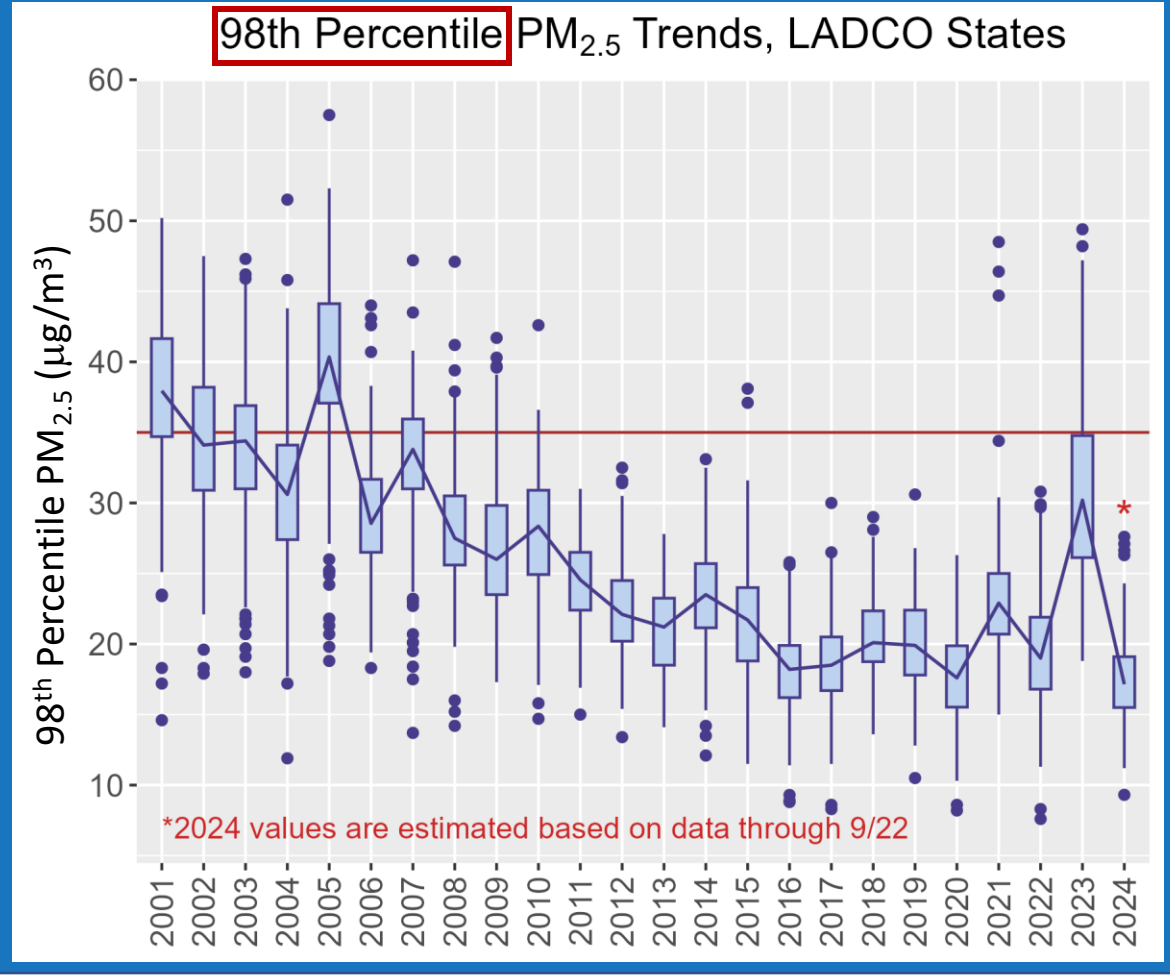


# Estimated 2024 $PM_{2.5}$ Values

- Used draft monitoring concentrations through September 22nd
- Use Annual Mean concentrations for 2022 and 2023
- For 2024 (in progress):
  - Use AQS data when available (3-9 months at this point)
  - If not, use AirNow Tech data when available (for continuous monitors)
  - If neither is available, use historical monthly concentrations
    - Estimate three values: minimum, mean, maximum using 2019-2023 data (5 years)
      - Exclude June 2023 because it was such an outlier
    - Minimum (maximum, mean) uses the minimum (maximum, mean) monthly value from the previous 5 years
    - Gives an idea of the likely range of design values

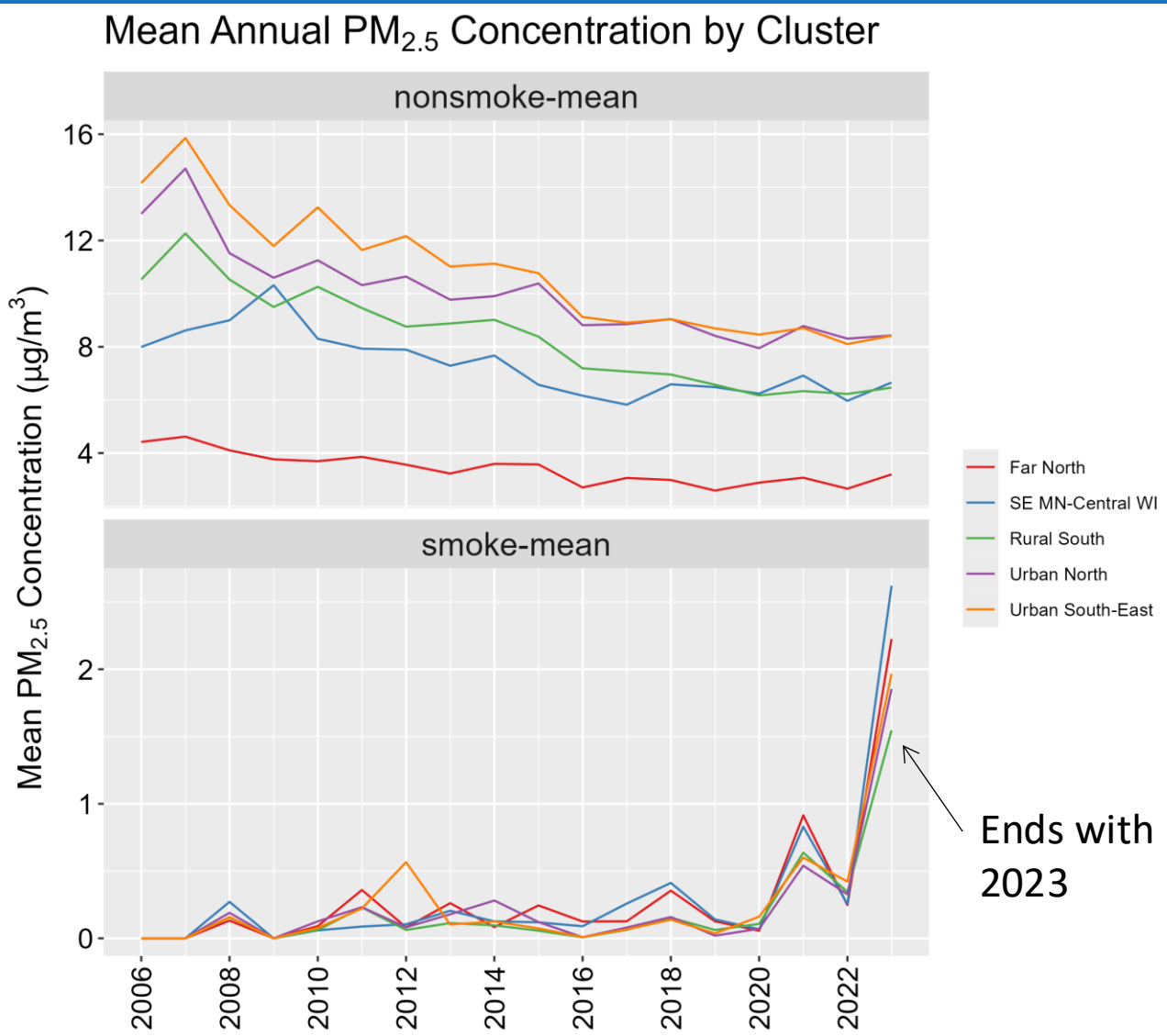
# Estimated 2024 $PM_{2.5}$ Values




LADCO

# Impact of smoke on trends




Determined amount of smoke on a given day

- = $PM_{2.5\text{-daily}} - (\text{Mean } PM_{2.5} + 1 \text{ stdev})_{\text{nonsmoke-days-month}}$
- When smoke in satellite column (HMS smoke)
- Method adapted from Childs et al. (2022) *ES&T* and Burke et al. (2023) *Nature*

Appears that without smoke impacts, $PM_{2.5}$ trends would be relatively flat



LADCO

# Range of Estimated 2022-2024 $PM_{2.5}$ DVs

CBSAs with 2021-23 DVs > 9 µg/m³

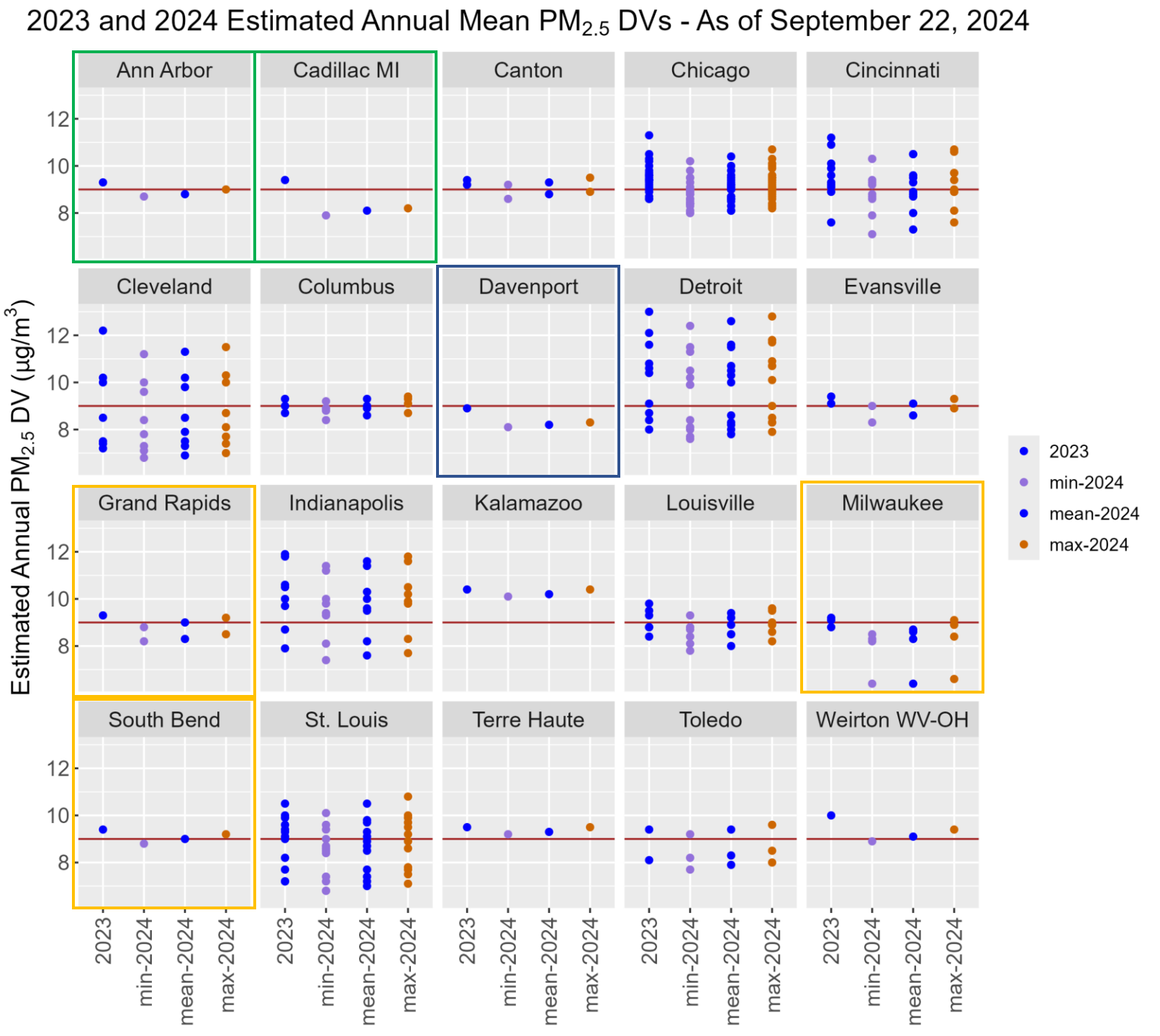
Davenport/Rock Island has corrected 2021-23 DV < 9 µg/m³

Cadillac & Ann Arbor MI almost certainly will have 2022-24 DVs < 9 µg/m³

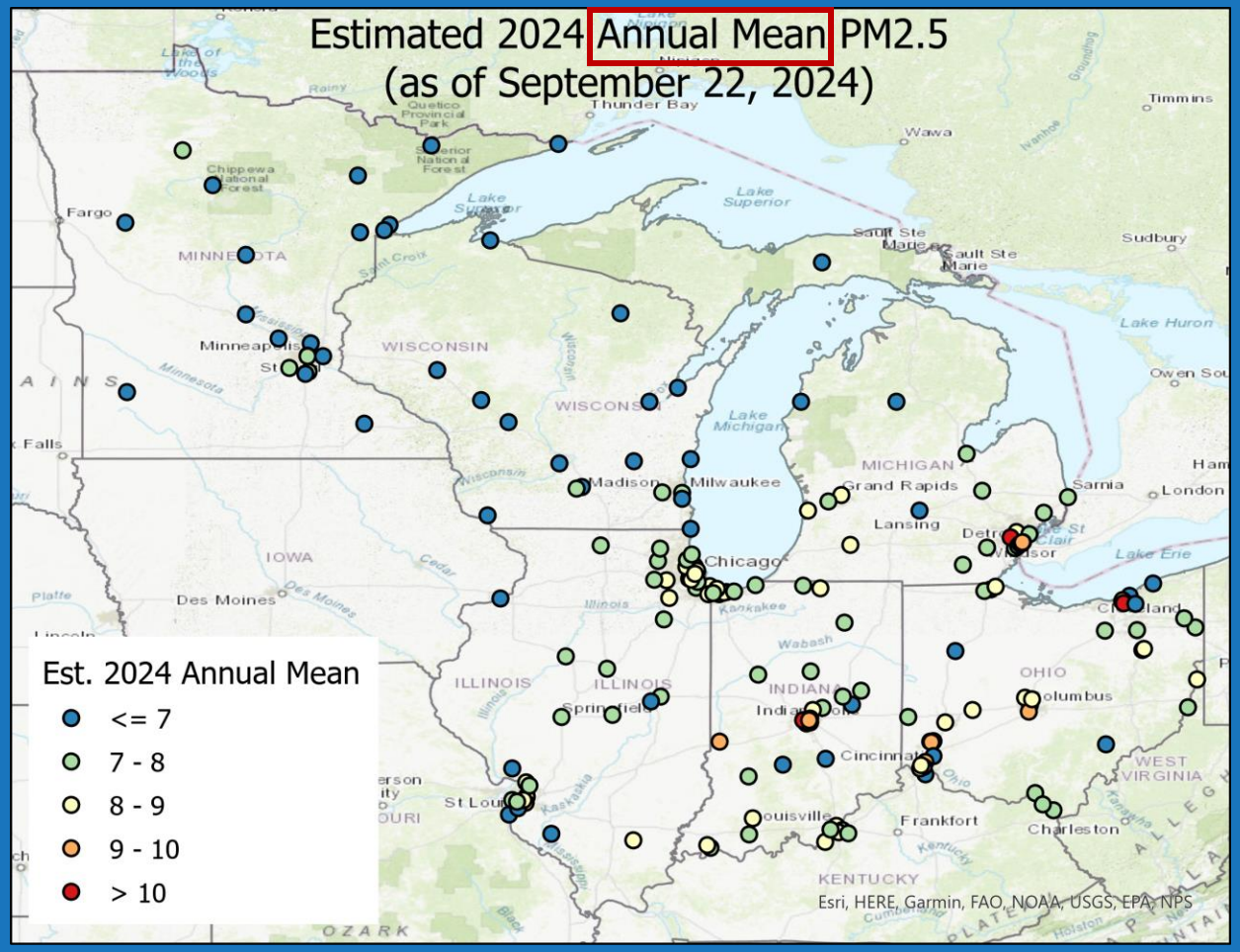
Several other areas have estimated mean DVs at or below 9 µg/m³ but maximum DVs > 9 µg/m³

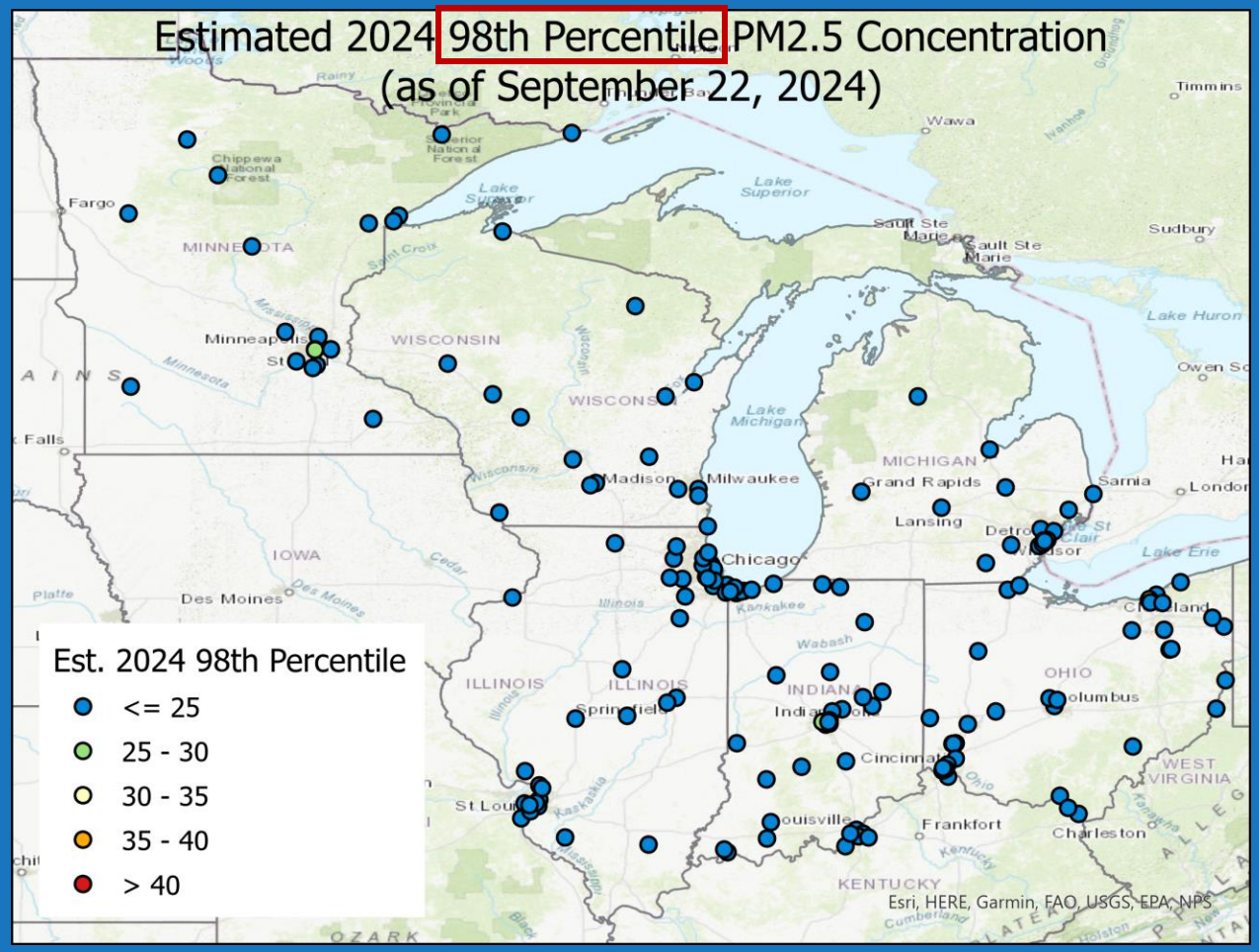
- Likely will be okay, but maybe not, depending on $PM_{2.5}$ levels the rest of this year
- Grand Rapids, Milwaukee, and South Bend

Other areas will almost certainly have DVs > 9 µg/m³



# Estimated 2024 $PM_{2.5}$ Values

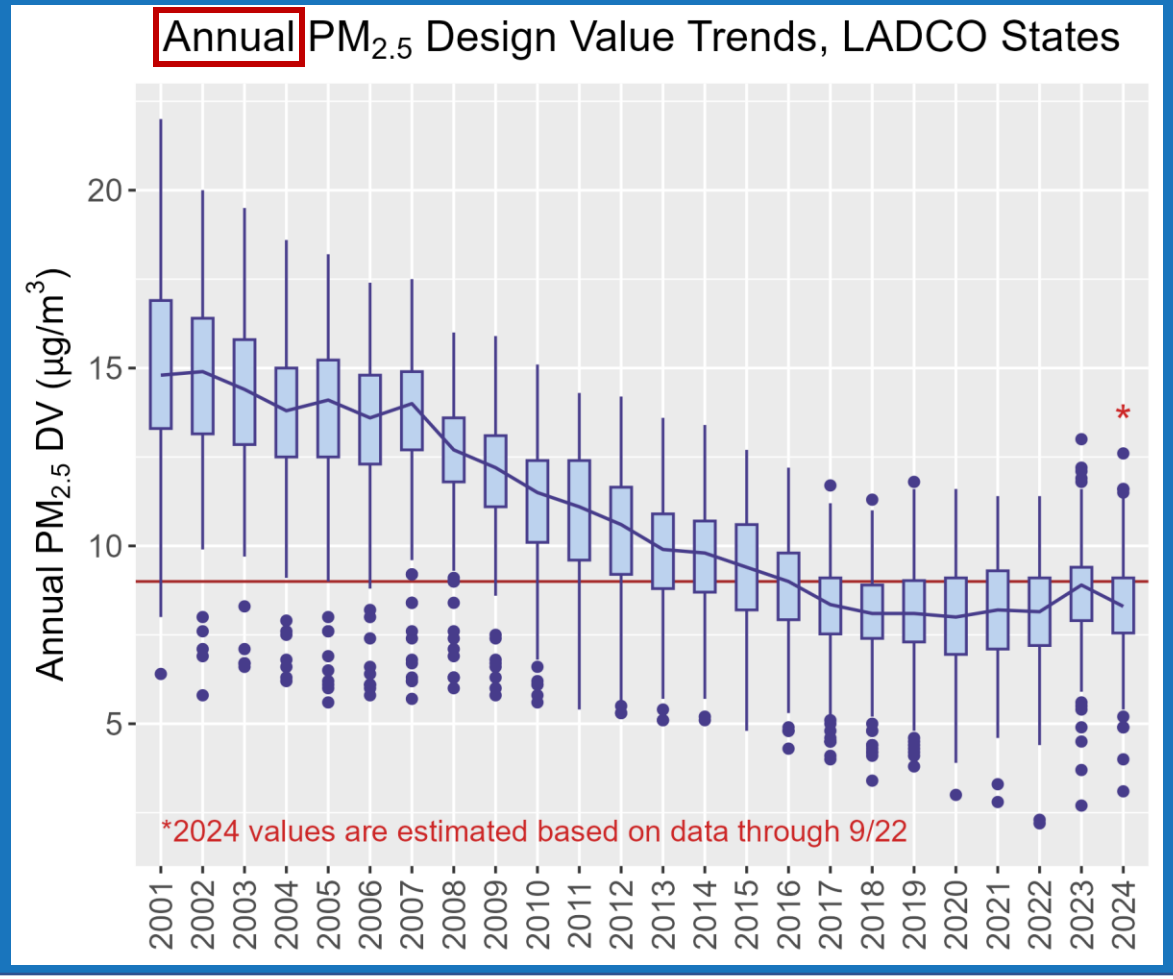


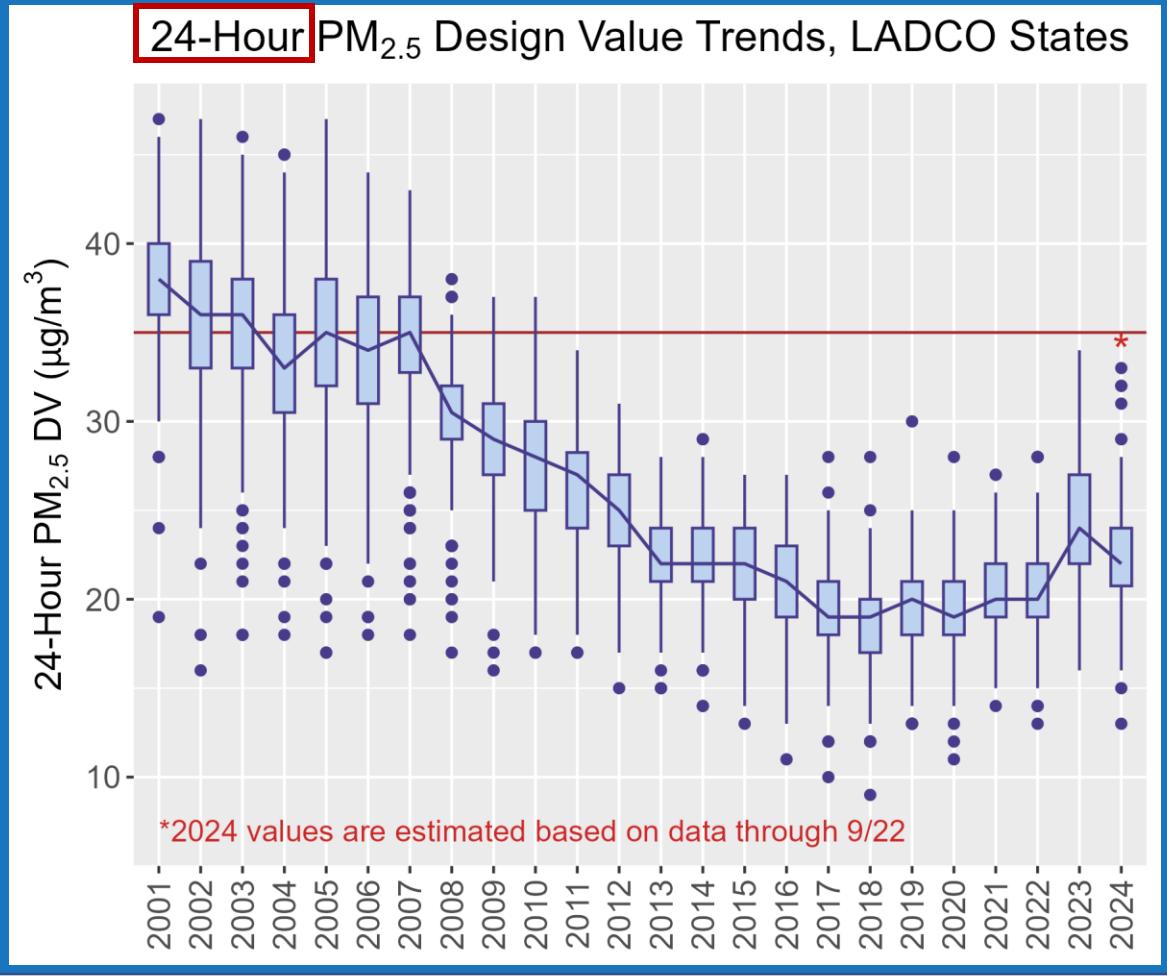




Annual: peak values in southern/eastern urban areas

All values are very low

# Estimated 2022-2024 $PM_{2.5}$ Design Values



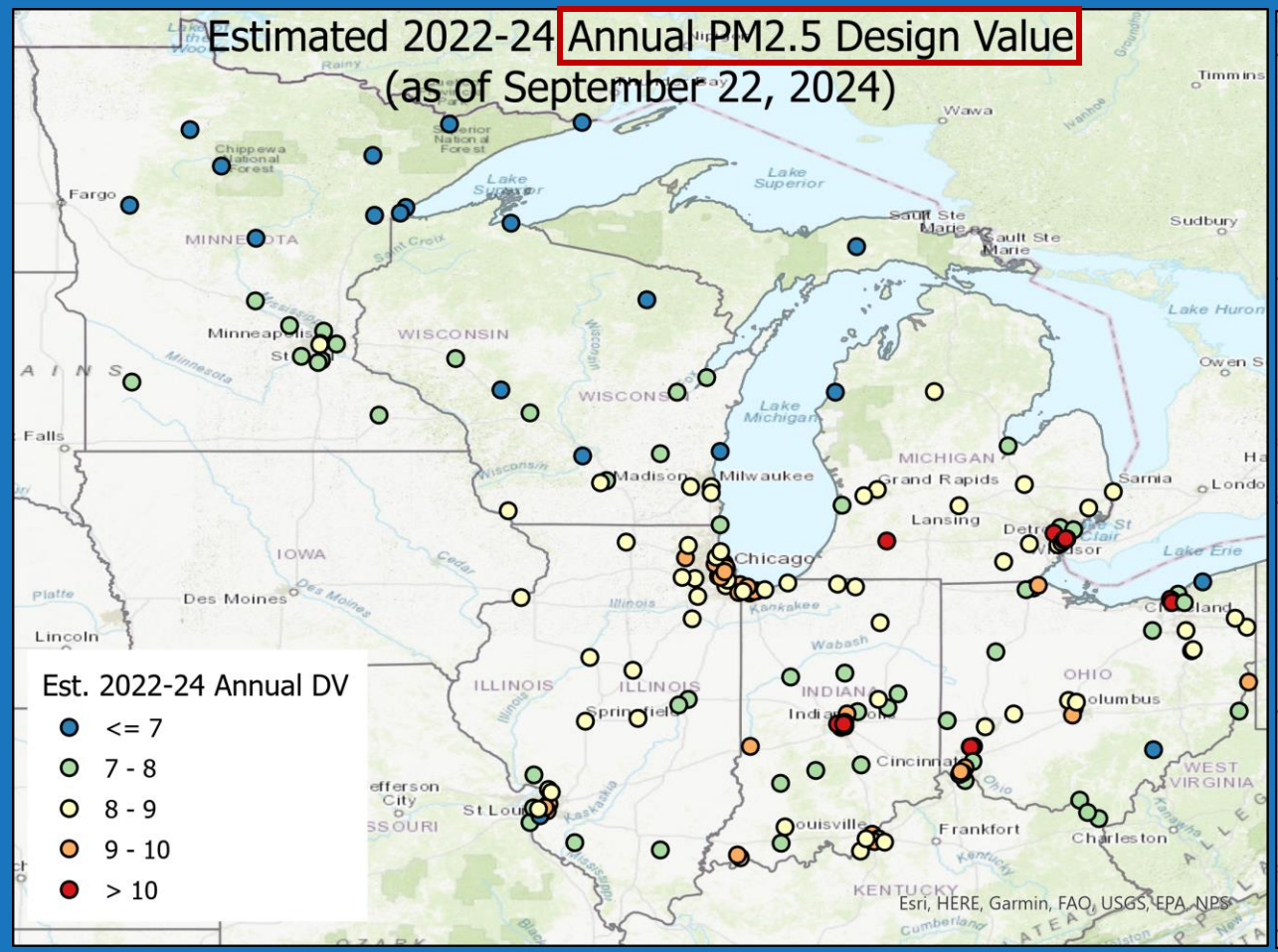



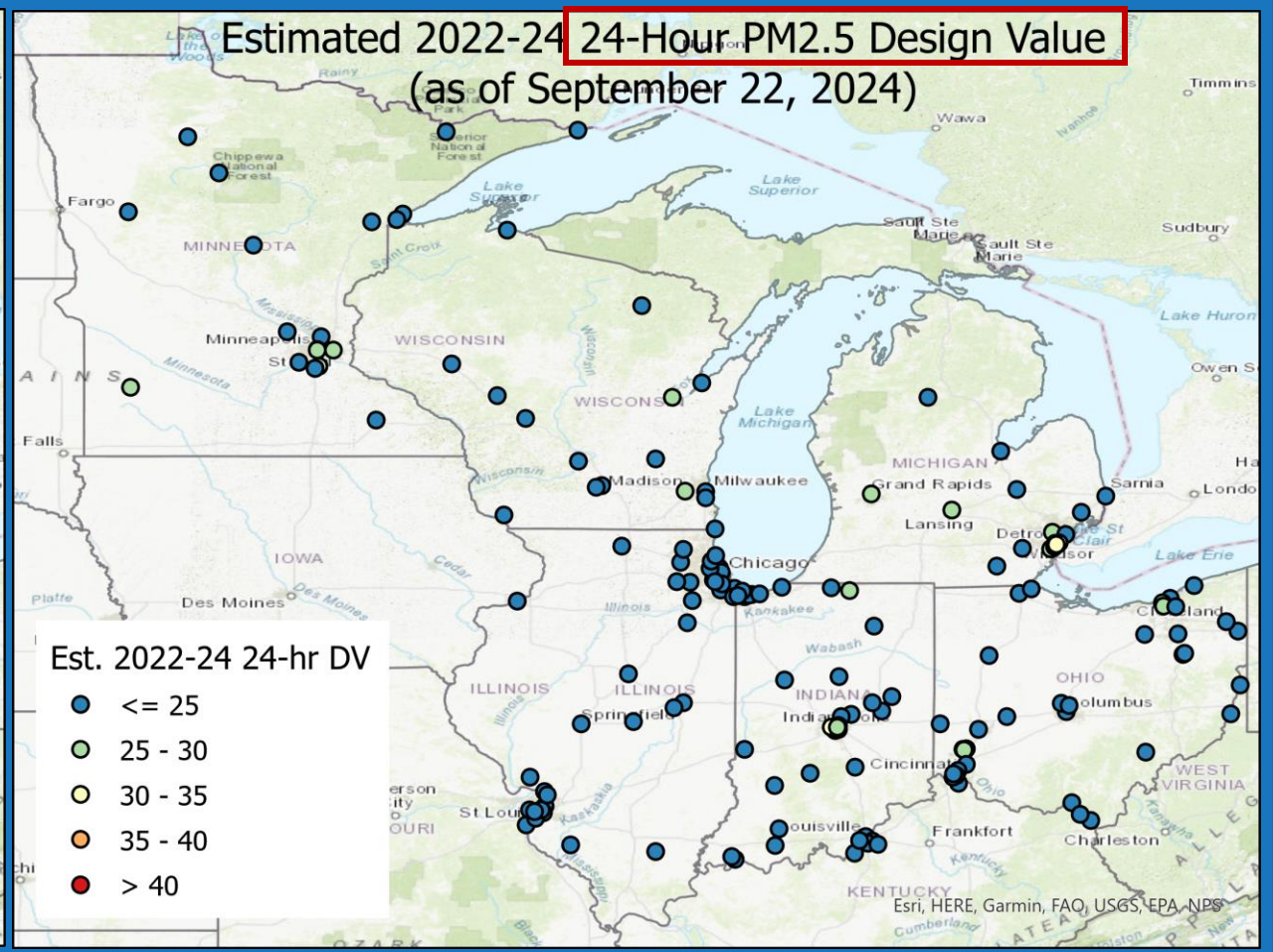

Design values are lower than for 2021-23
Many (~ 25%) are still over the NAAQS

All design values are below the NAAQS

LADCO

# Estimated 2022-2024 $PM_{2.5}$ Design Values



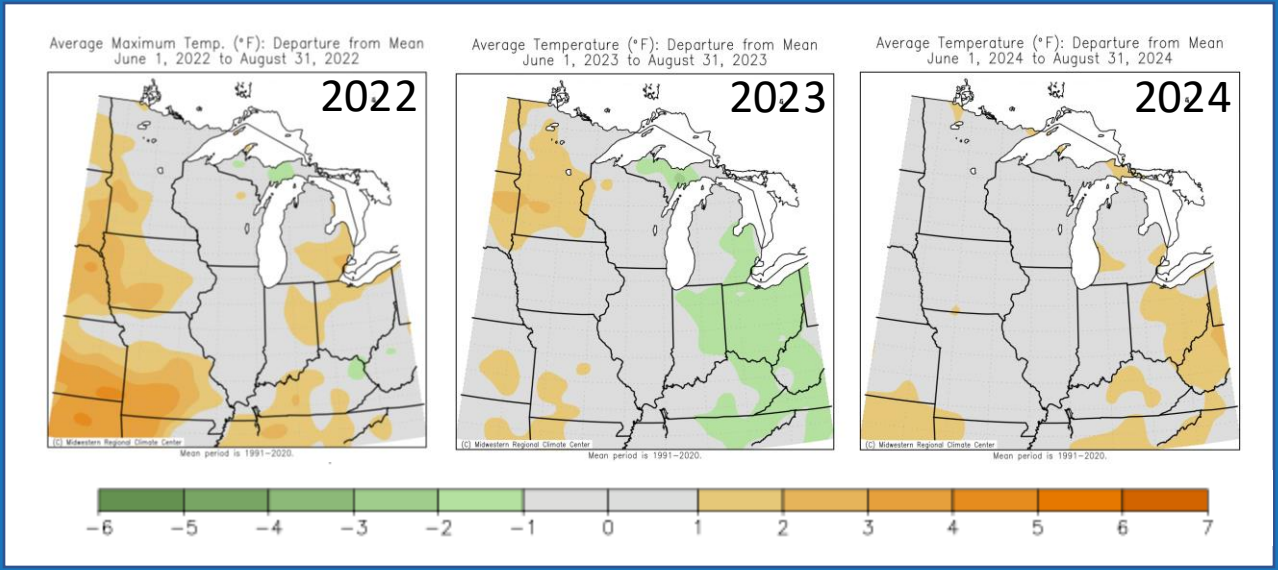

Annual: peak values in urban areas in east:

- Indianapolis, Cincinnati, Detroit, Kalamazoo, & Cleveland

All values are well below the level of the NAAQS

# Ozone: Major Drivers

## June-August Temperatures:

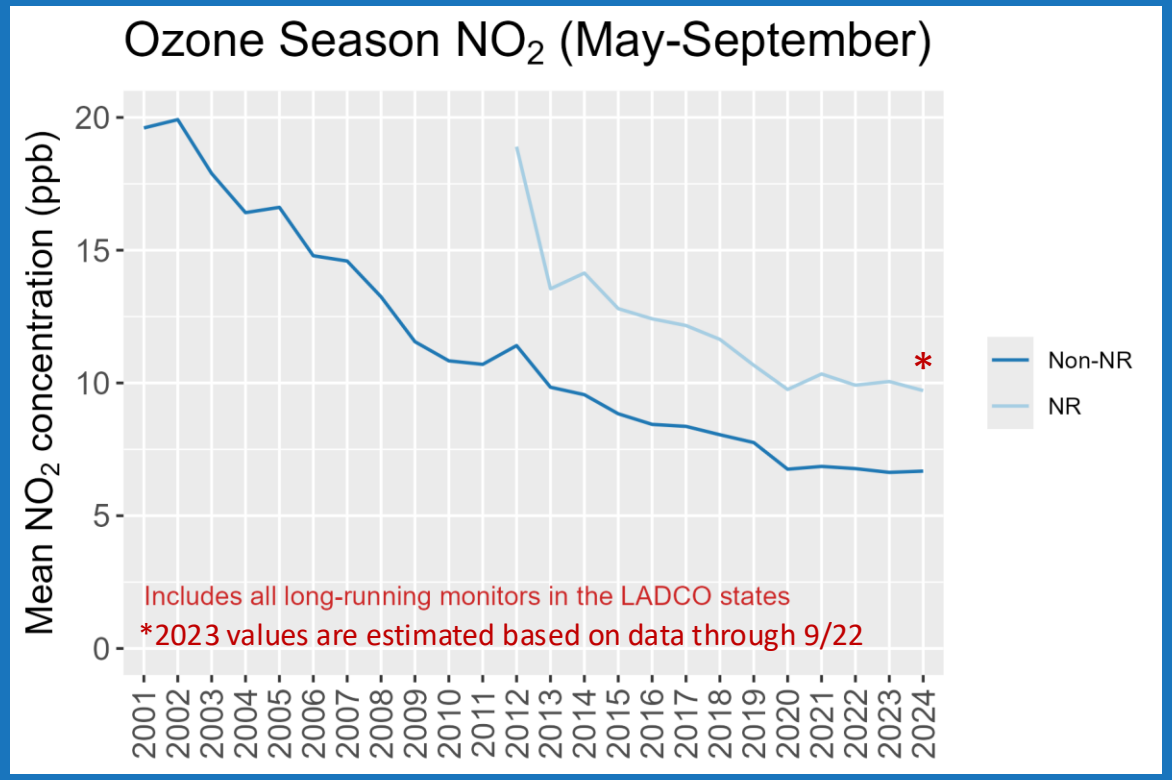



Average temperatures across almost the whole region

LADCO

# Ozone: Major Drivers

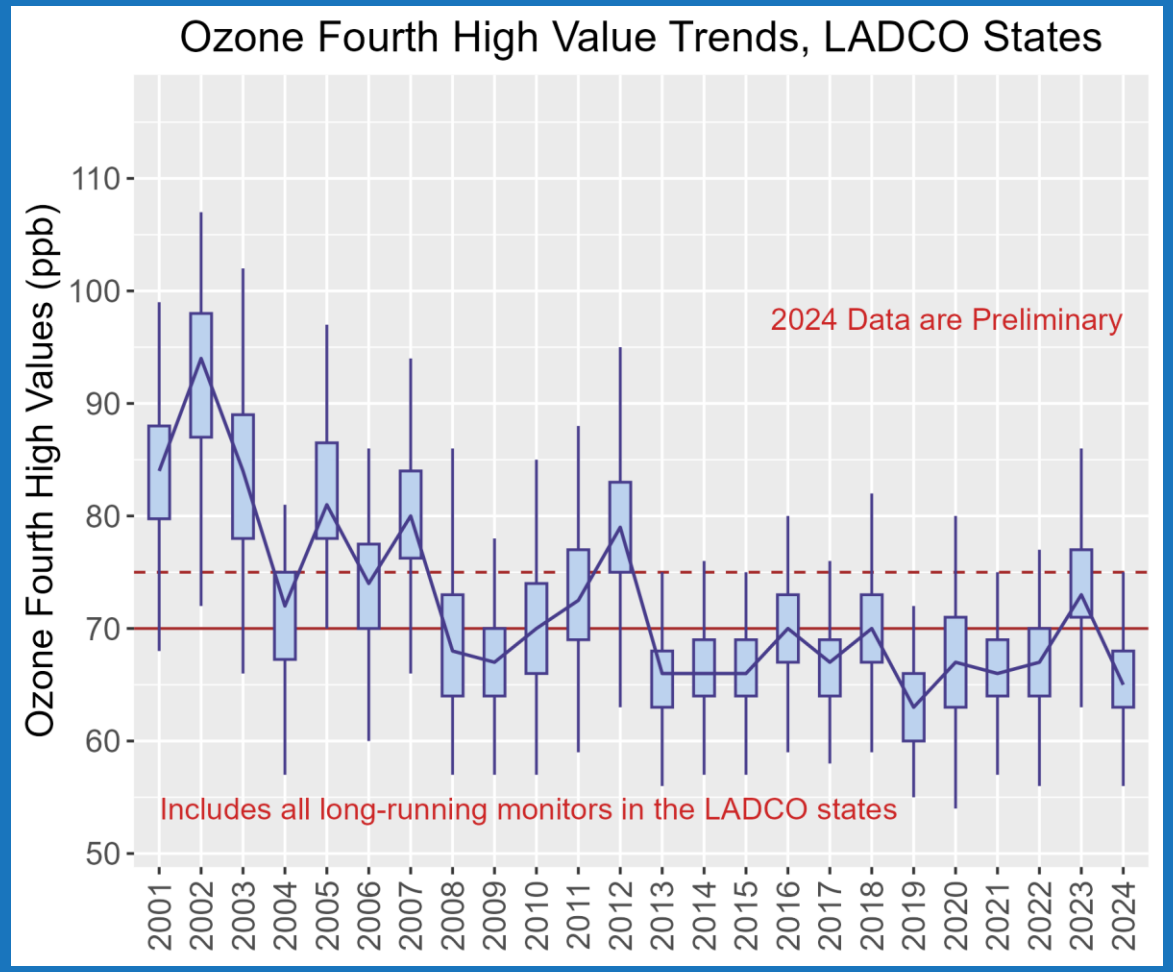
## Monitored $NO_2$ Concentrations:




$NO_2$ has only decreased very slightly since 2020

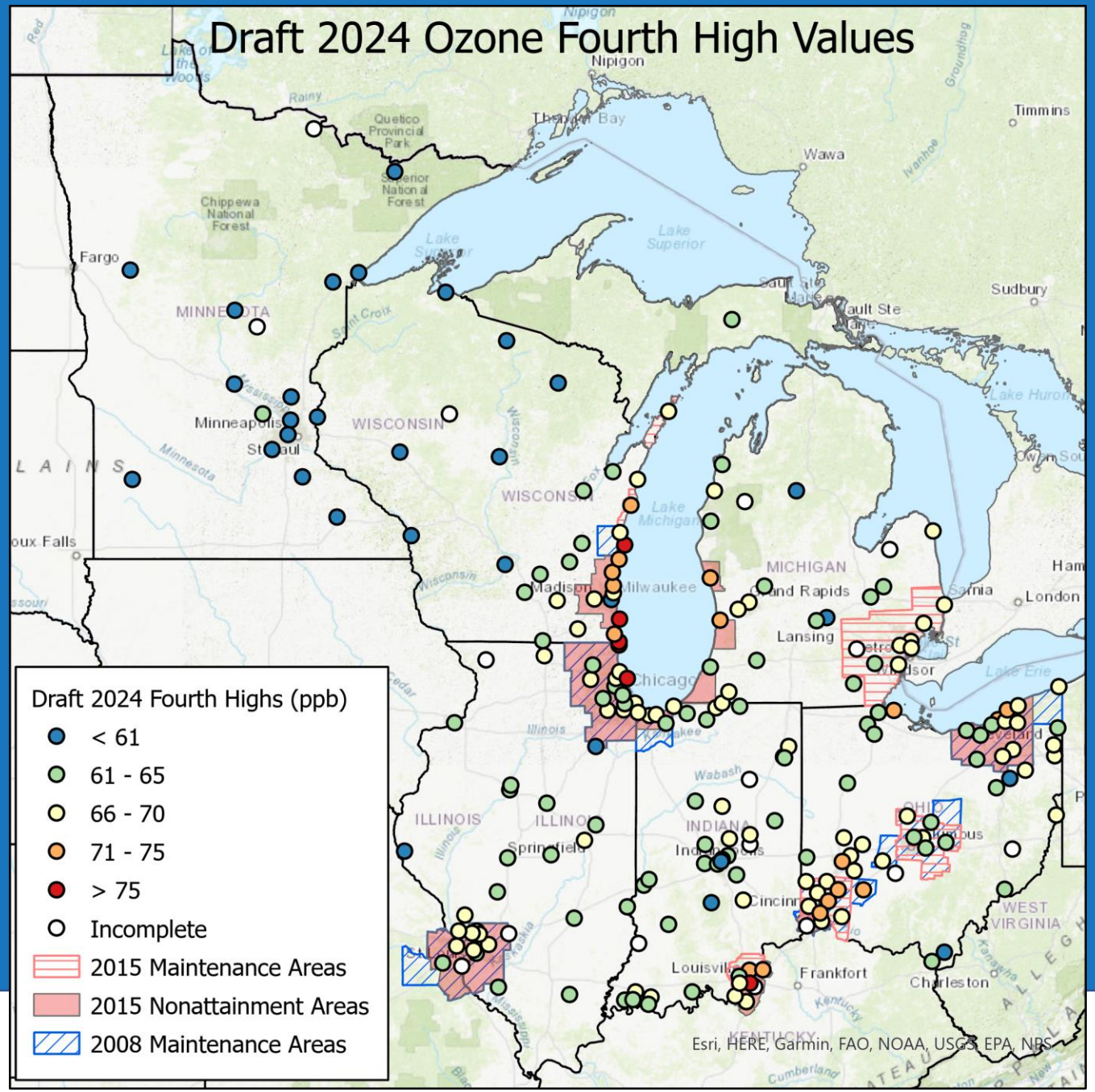
→ Not helping ozone decrease

# Current 2024 Ozone Fourth High Values




Fourth high ozone values were the second-lowest observed in the last few decades

LADCO

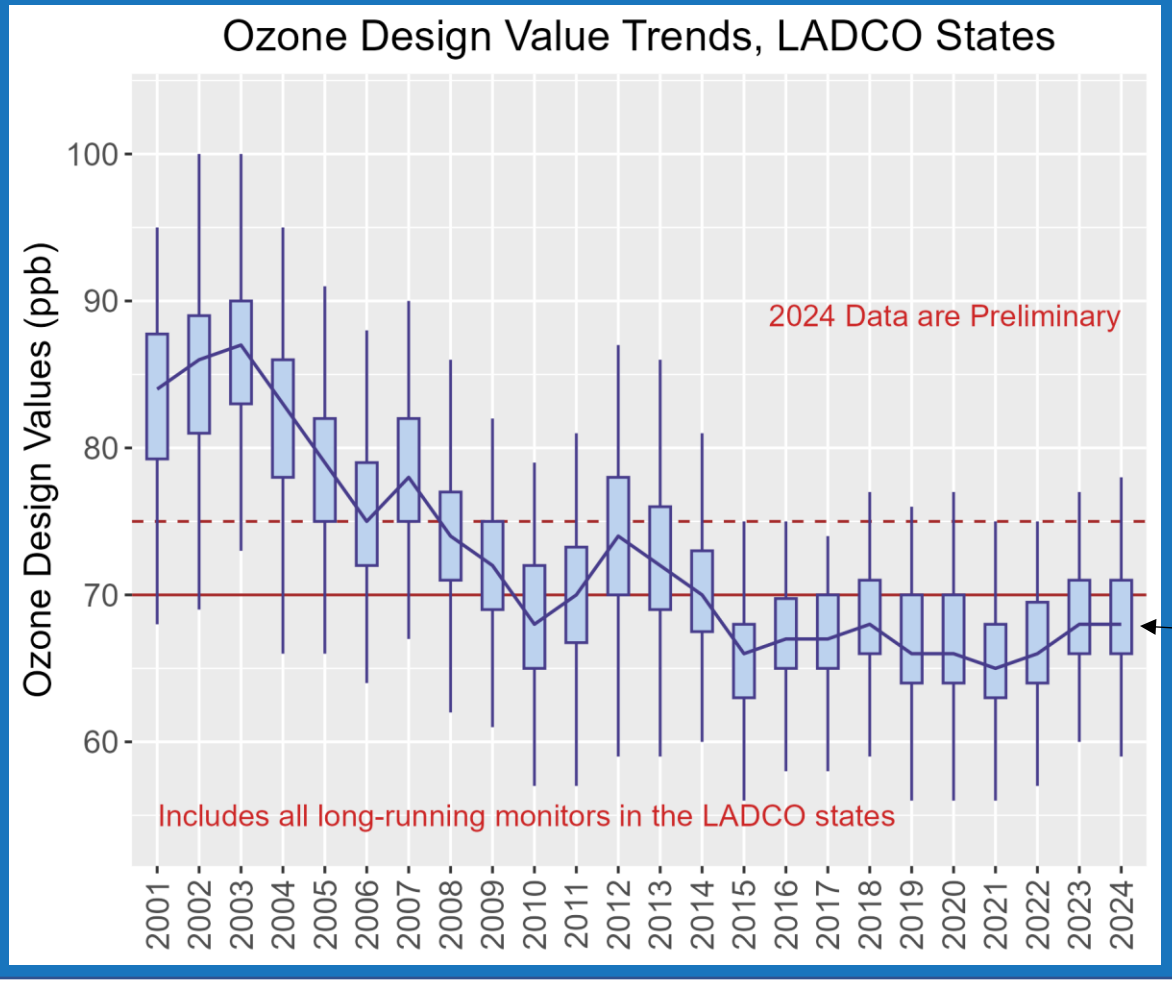



# Current 2024 Ozone Fourth High Values

- Fairly low in much of the region
- Very high/high in the classic locations on Lake Michigan
- High in southern areas: Louisville & Cincinnati
- Unusually low in most of Chicago (except northern lakeshore monitors)
- High monitors in Cleveland and Toledo

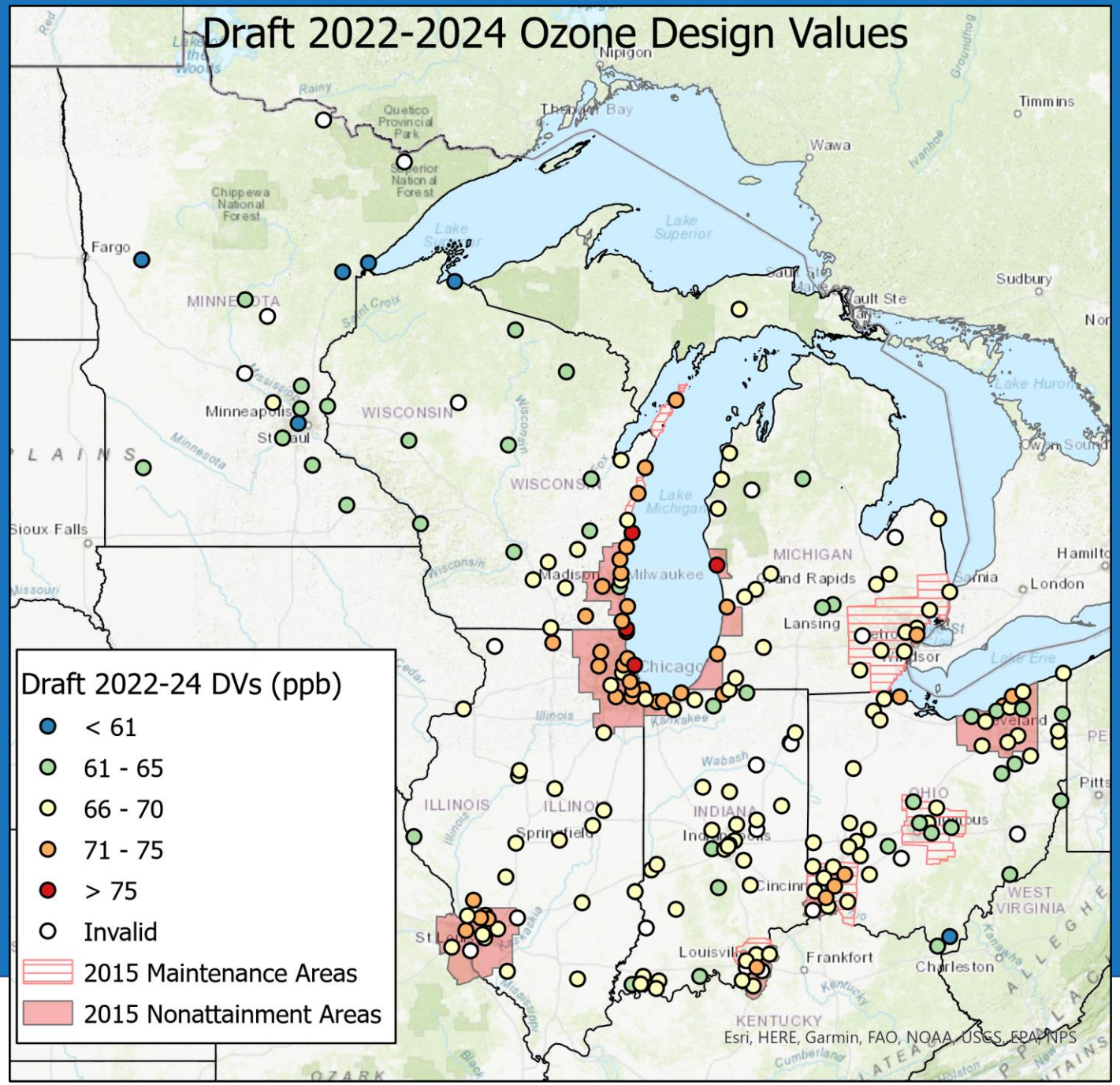
LADCO

# Current 2022-2024 Ozone Design Values




Overall, similar DVs to 2021-23

LADCO




# Current 2022-2024 Ozone Design Values

- Much higher than 2024 fourth highs because 2023 was so high
- Mostly follow typical spatial patterns

Additional $PM_{2.5}$ and Ozone trends figures by nonattainment area are in the Appendix

LADCO

# Meteorological Adjustment of Ozone via CART

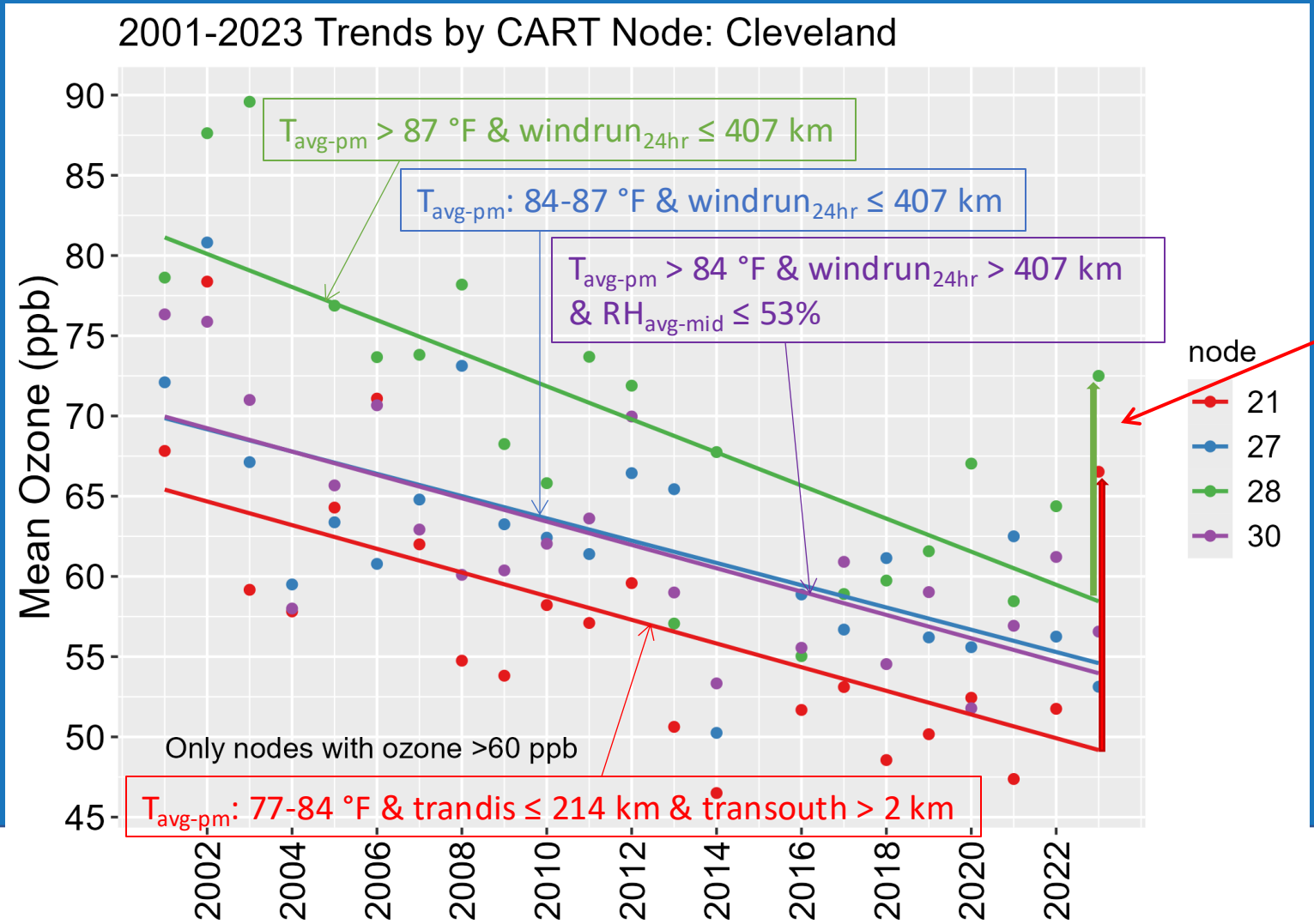
- CART is a statistical tool to classify data
- Used to determine meteorological conditions on high-ozone days
- Examine trends in ozone on meteorologically similar days
  - Allows examination of trends in ozone as a result of non-meteorological factors, such as emissions changes
- Applied CART to data from 2001-2023

- Will develop a report with the complete analysis



LADCO

# CART – Cleveland




Almost all areas: continued reductions in $O_3$ on $O_3$-conducive days

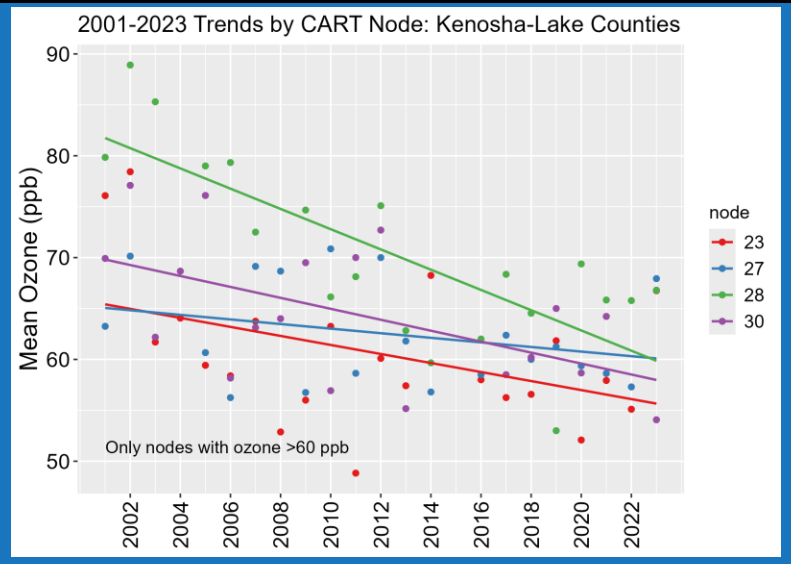
Most high-$O_3$ nodes show a spike in 2023

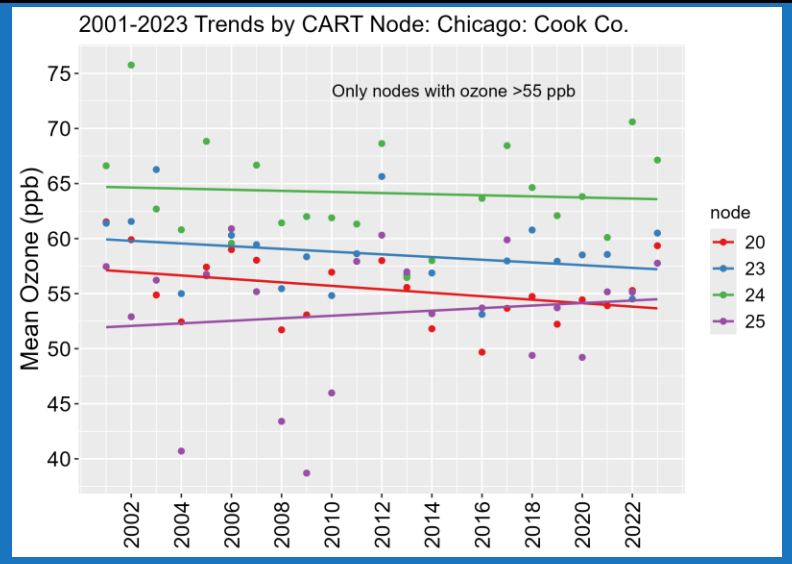
- Presumably due to smoke enhancement

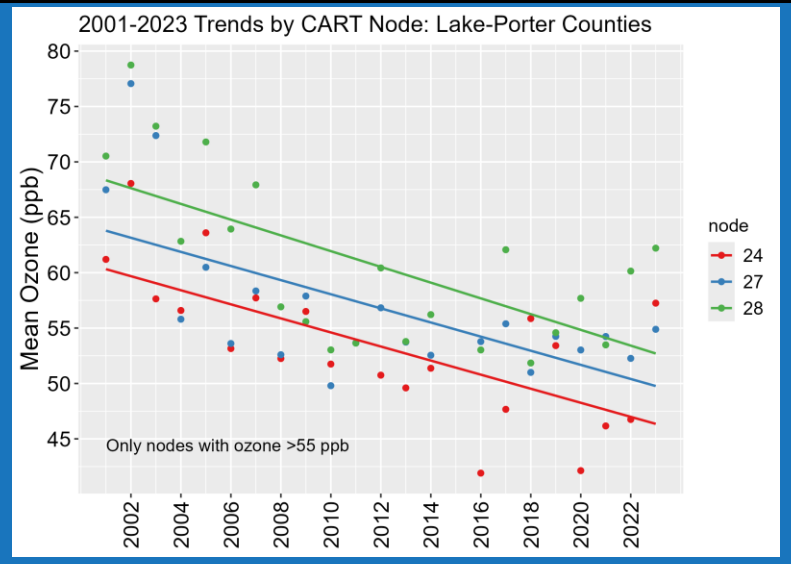


LADCO

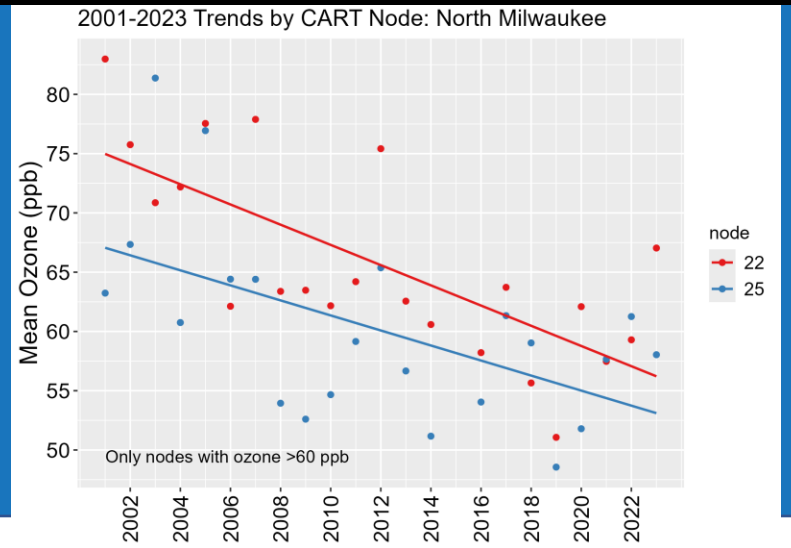
# CART – Urban Nonattainment Areas

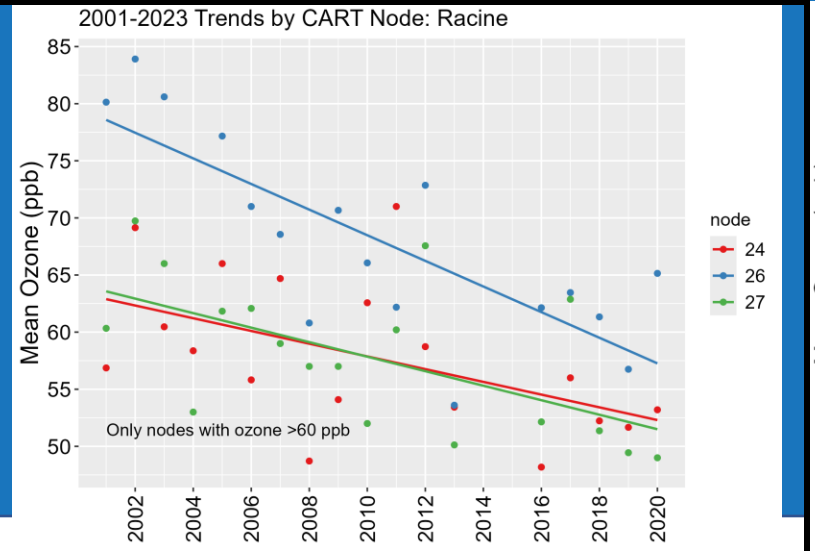


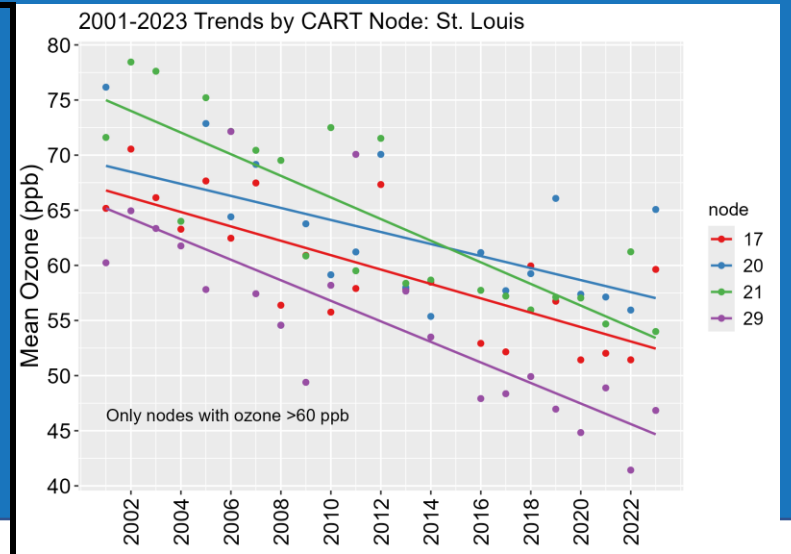




CHICAGO



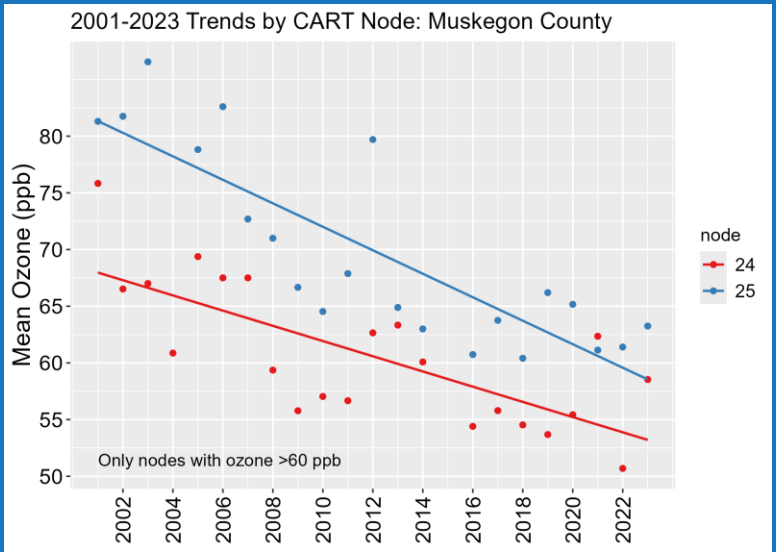



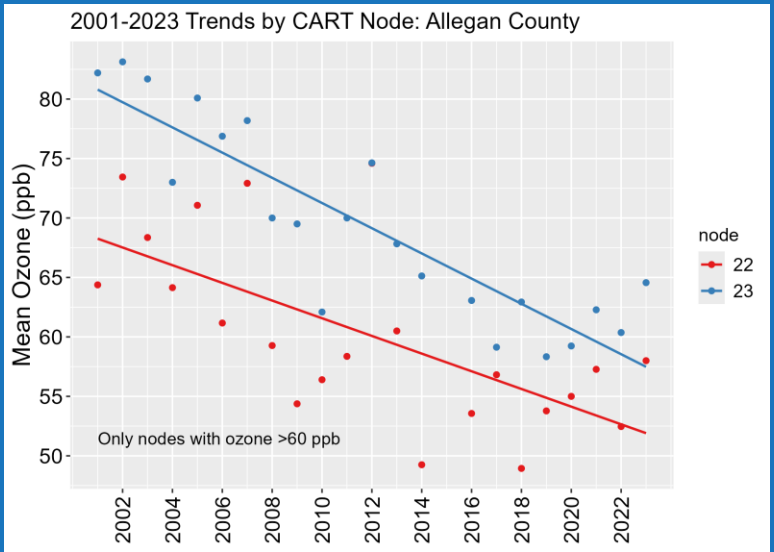

MILWAUKEE

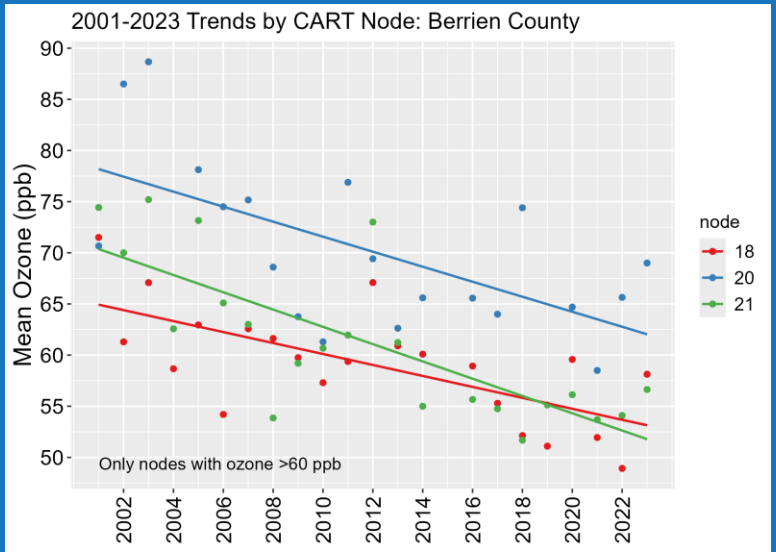


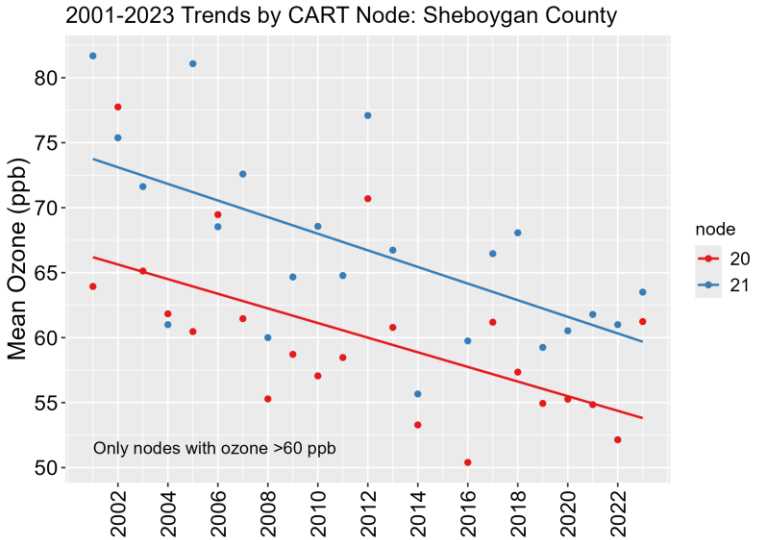
LADCO

# CART – Rural Lake MI Nonattainment Areas



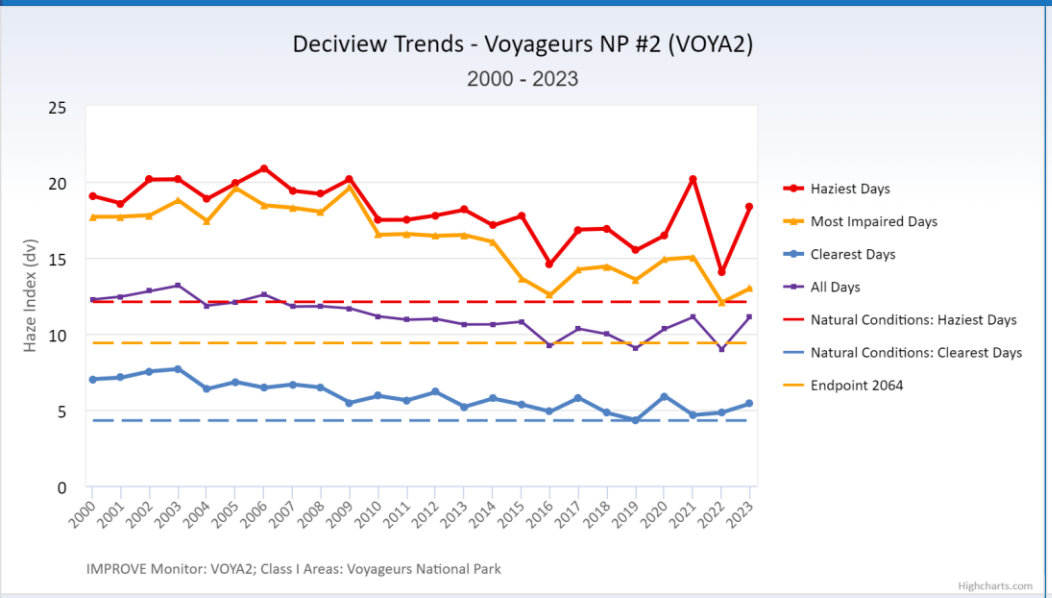



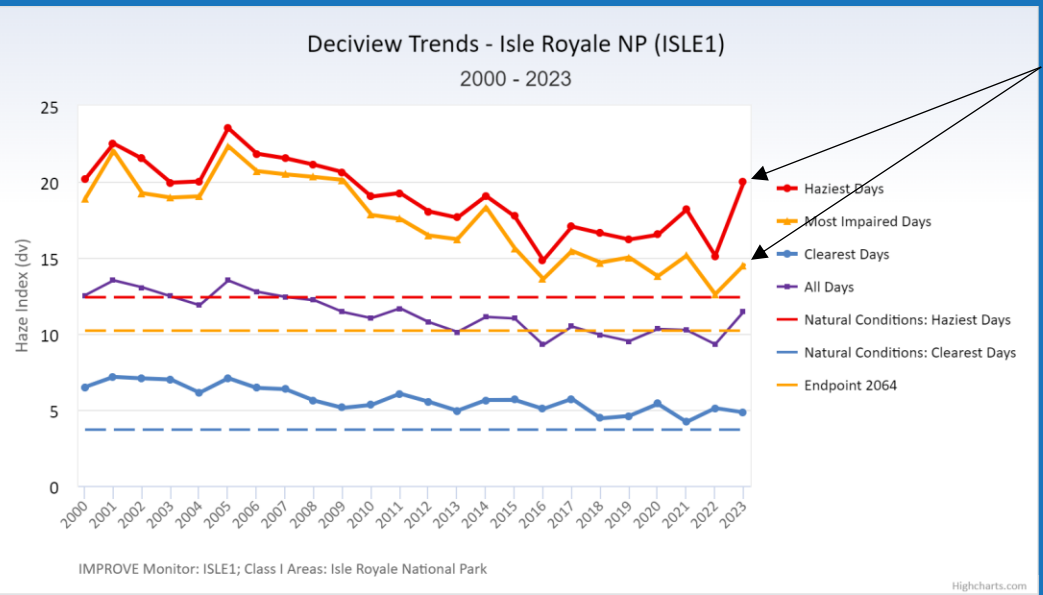



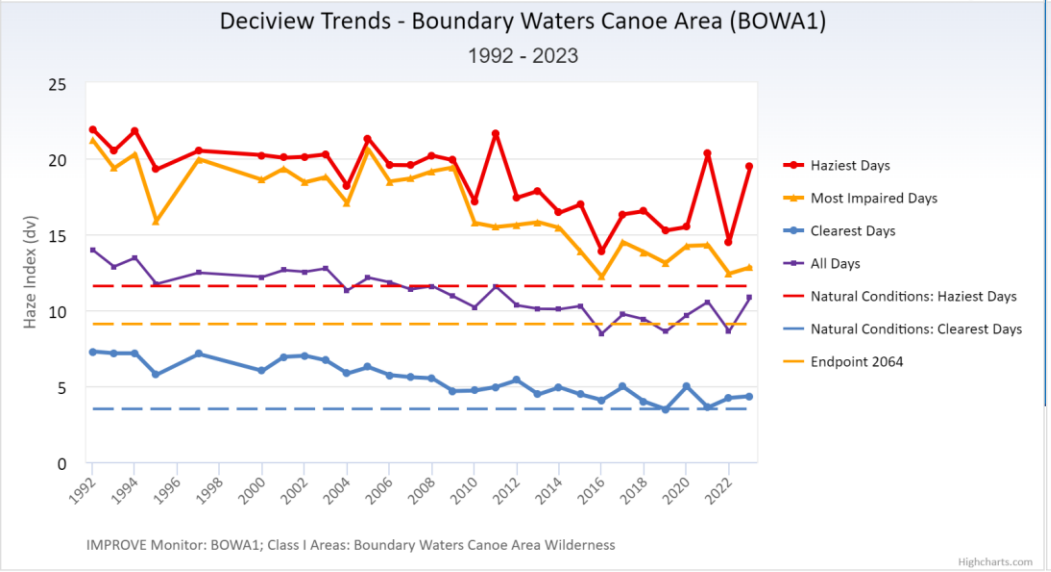



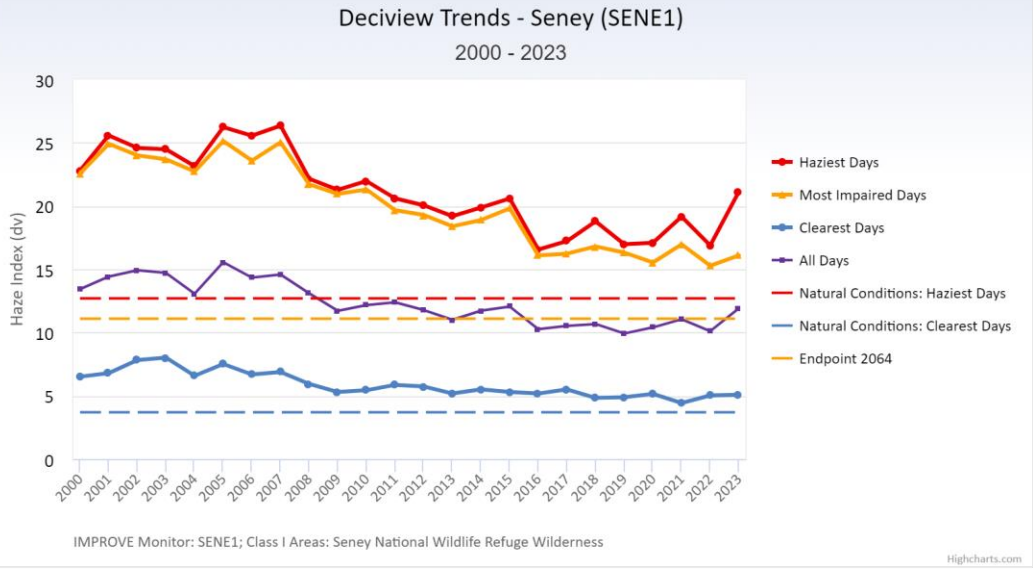

Additional plots are available in the appendix

# Regional Haze – Through 2023




See smoke in haziest days but not much in most impaired days

- Haze generally continues decreasing
- Decreases are slower than before
- Appears sites will meet endpoints by 2064 if decreases continue



LADCO

# Conclusions

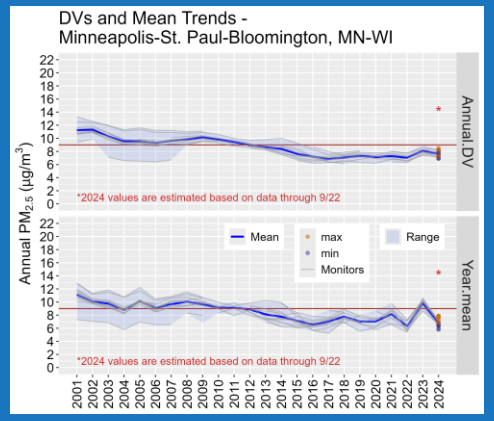
- Emissions reductions are slowing
  - Impacts of large national rules won't be felt until the end of the decade

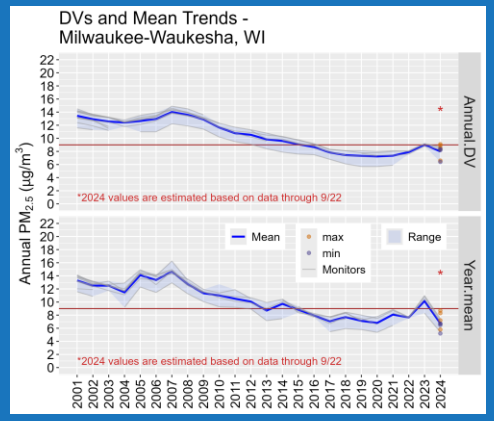
- 2024 was a relatively clean year for air quality in the region (so far)
  - Didn't have a lot of smoke transported into the region (although there was some)
  - Average temperatures
  - Stable $NO_2$ concentrations

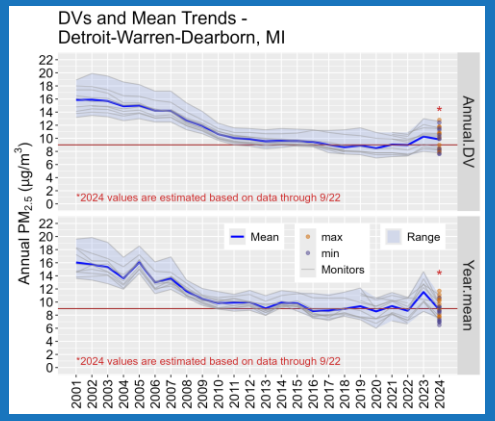

Questions?

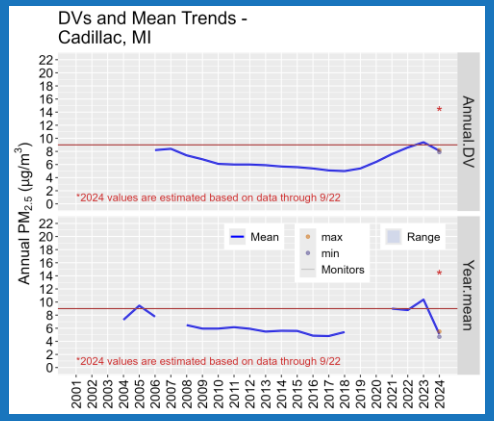
# APPENDIX

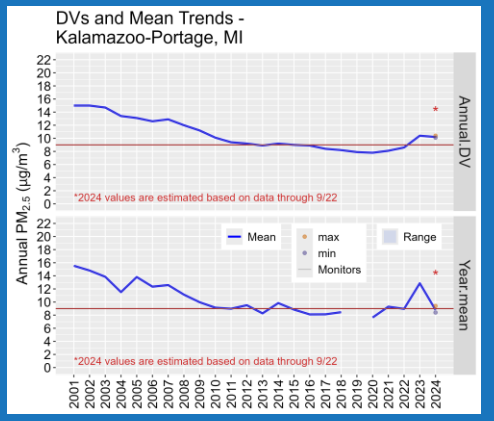
# Annual $PM_{2.5}$ Trends by CBSA: Northern States + Northern IL

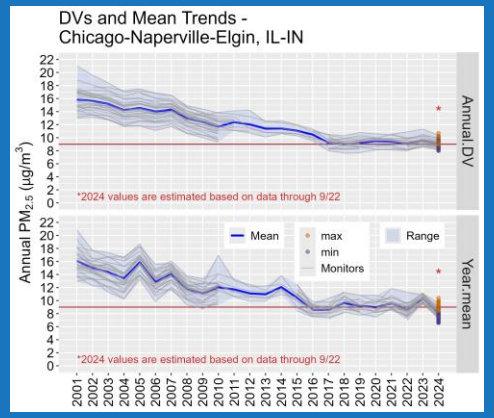


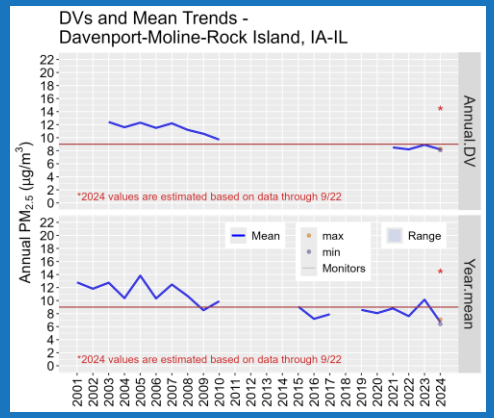



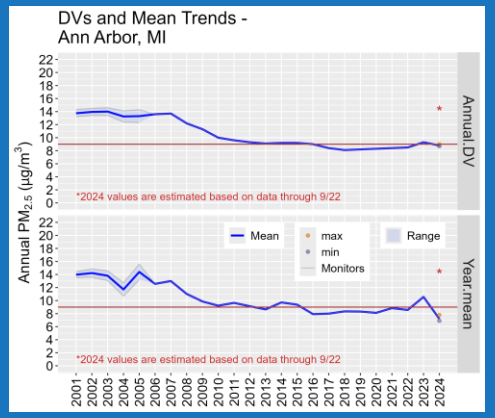



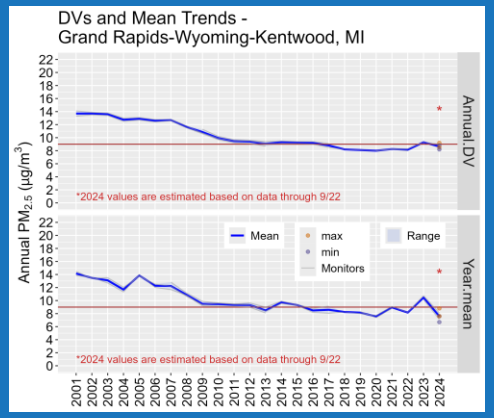



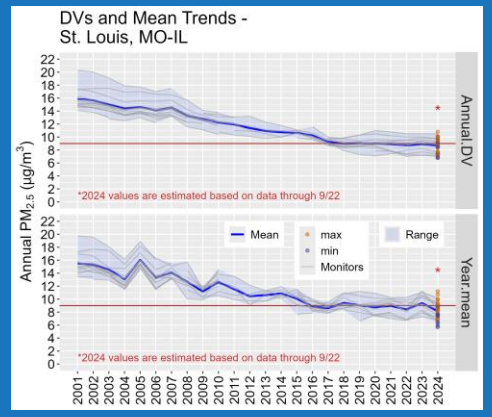

4415 West Harrison St., Suite 548
Hillside, IL 60162

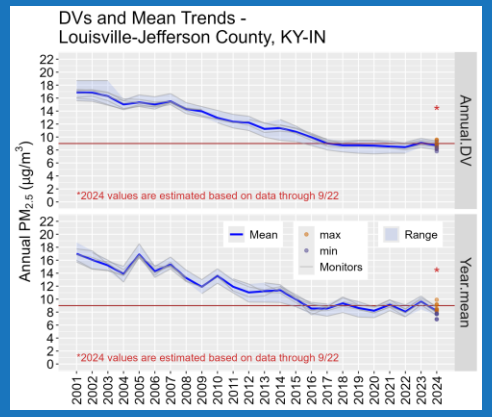
LADCO also has design value-only plots.

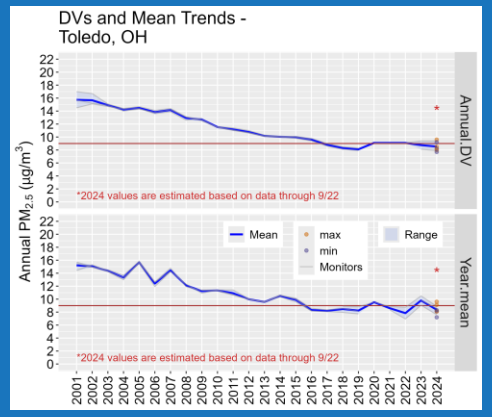


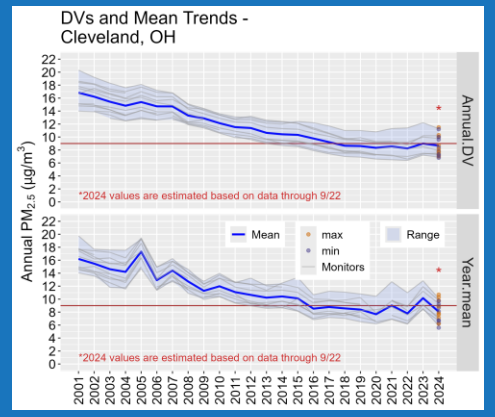
LADCO

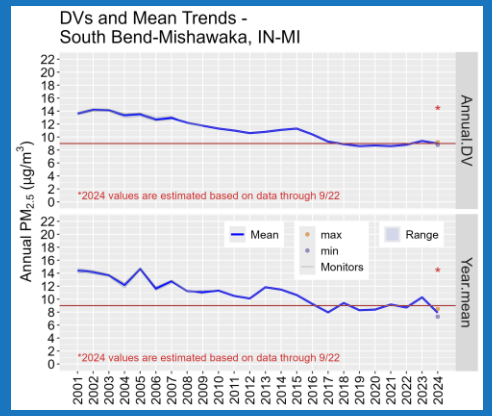
# Annual $PM_{2.5}$ Trends by CBSA: Southern Areas

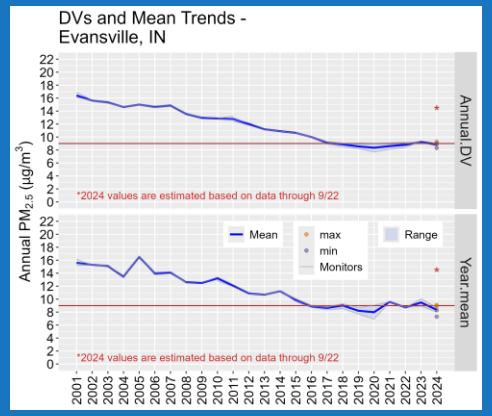


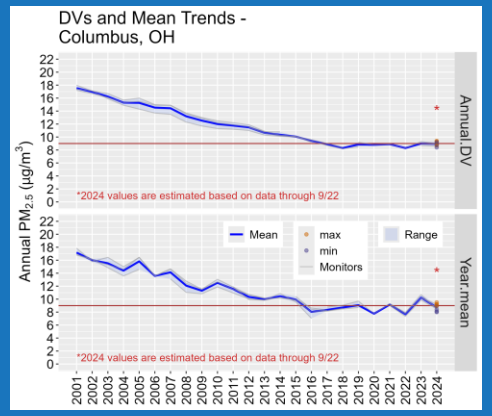



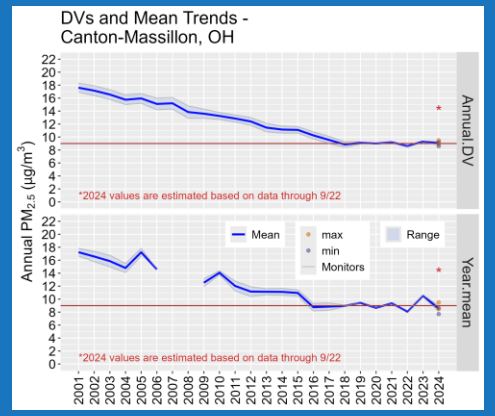



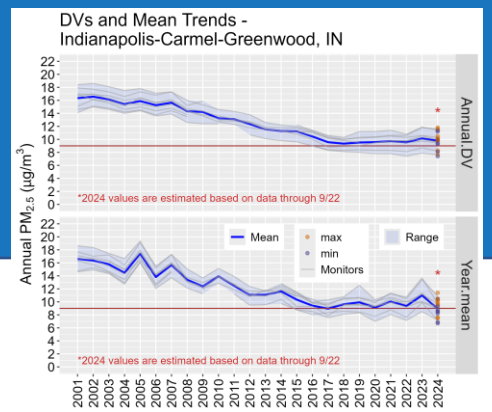



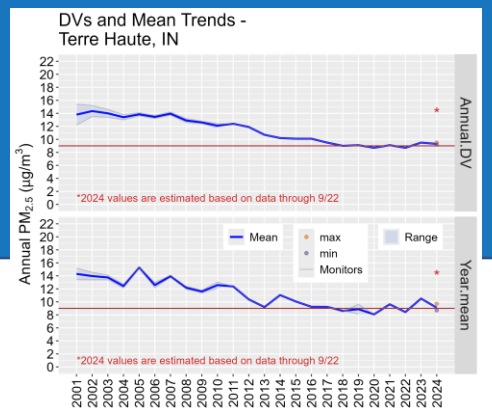



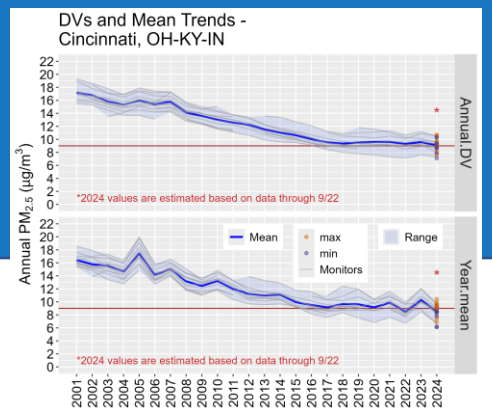



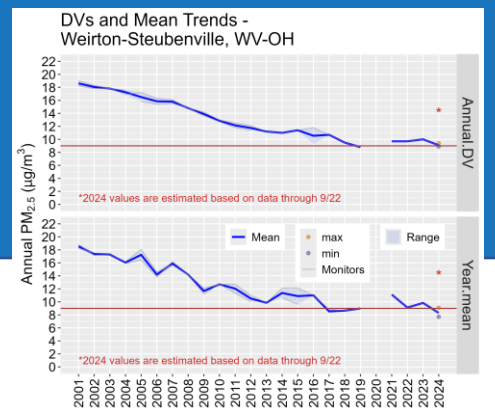



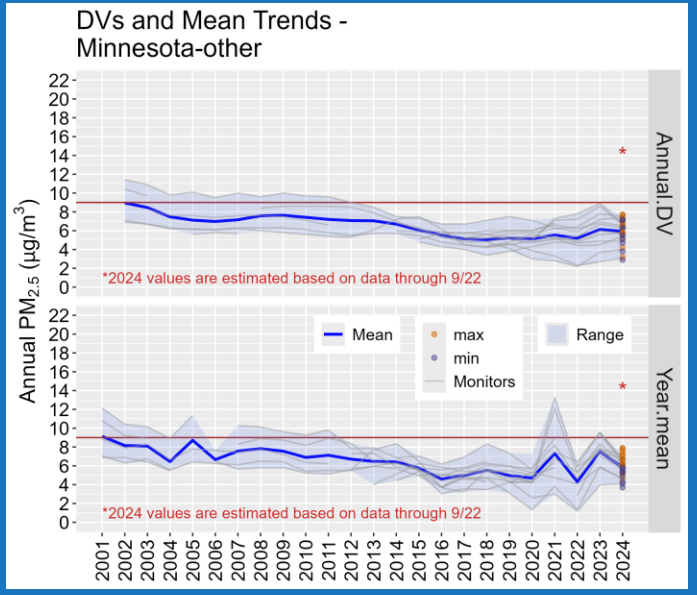



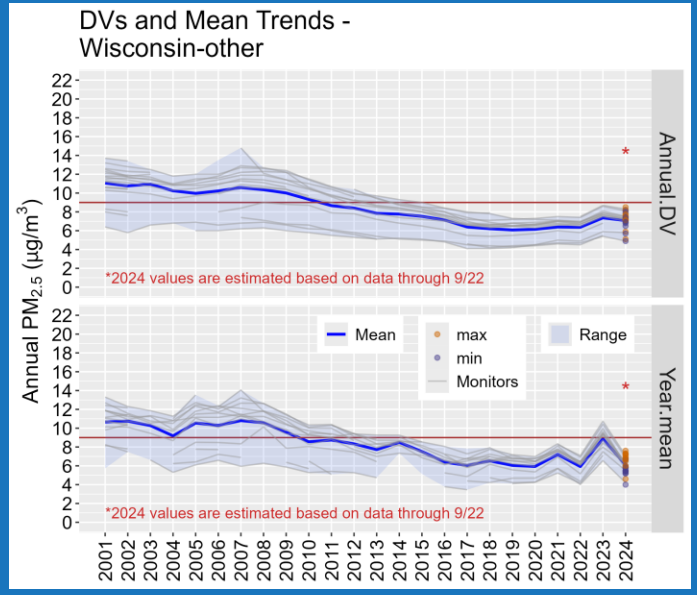



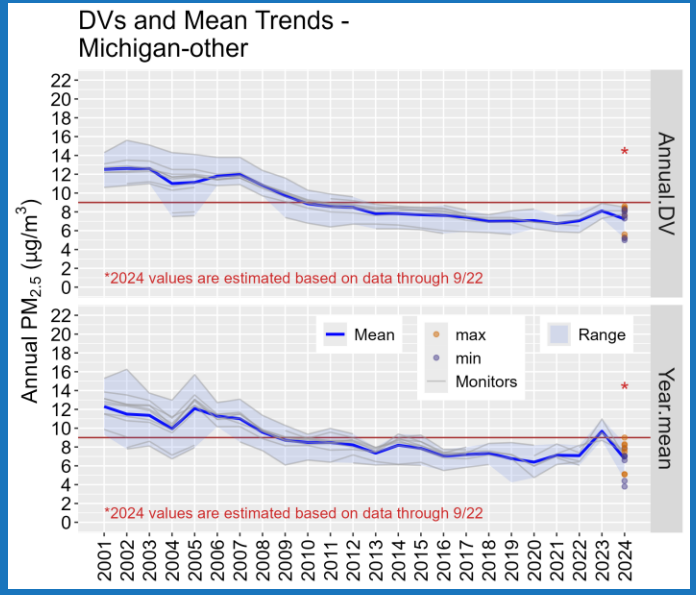


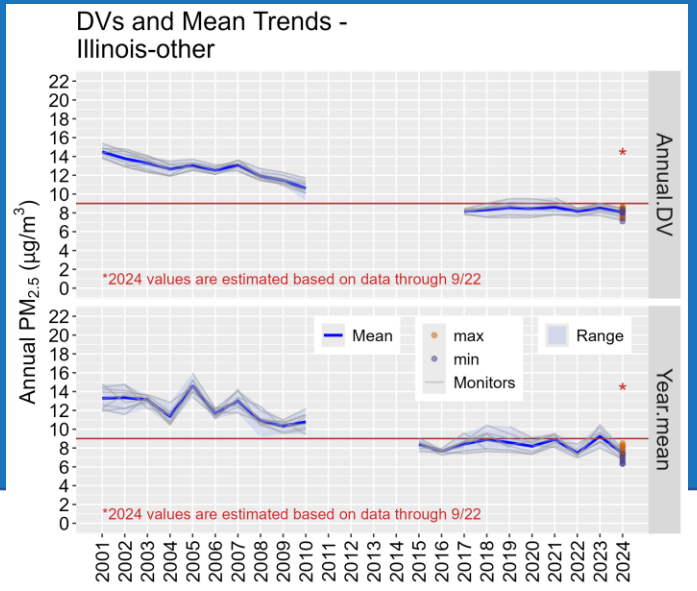

LADCO

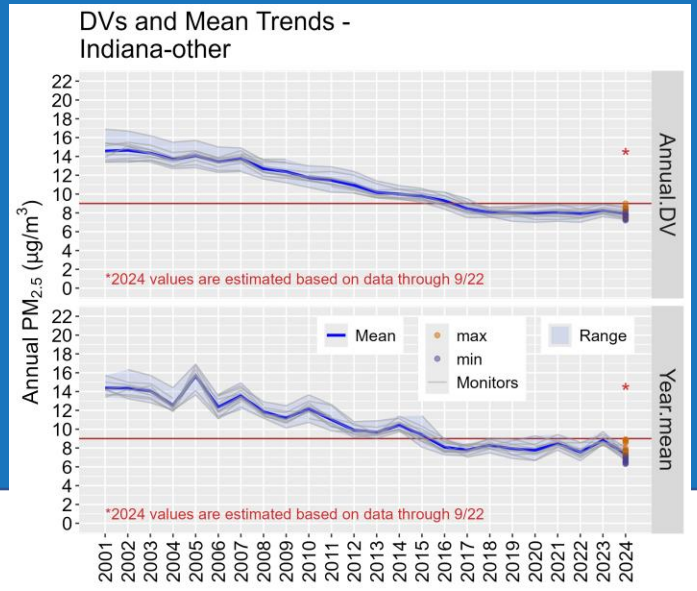
# Annual $PM_{2.5}$ Trends by CBSA: Other Areas

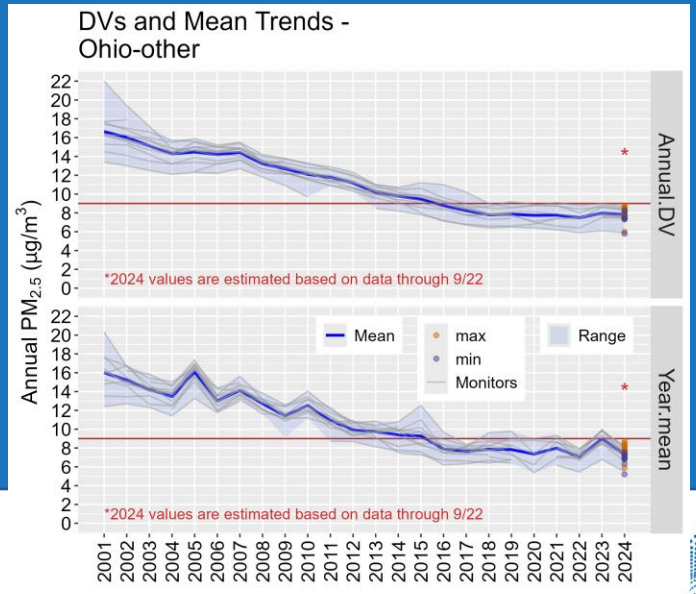


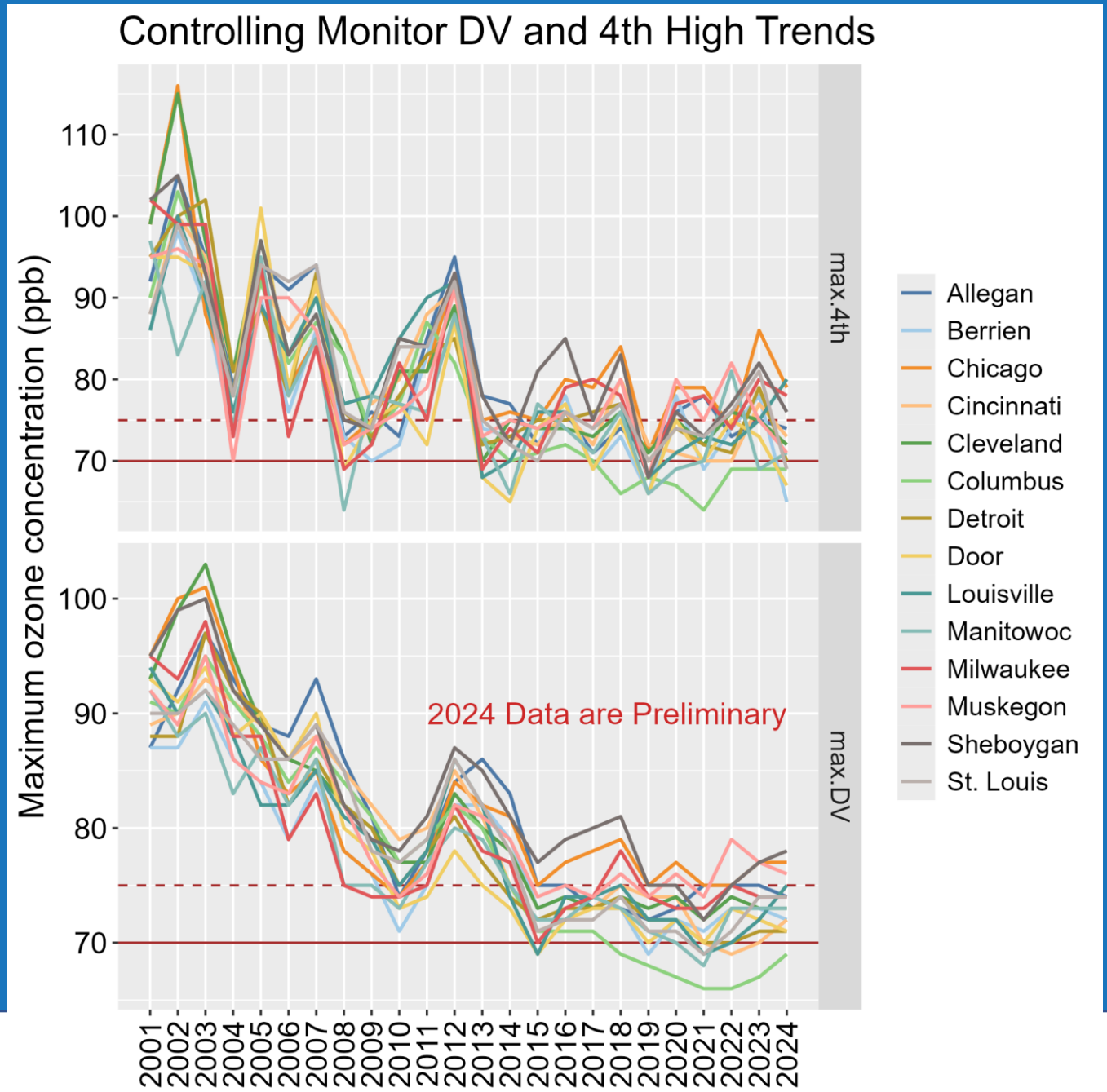



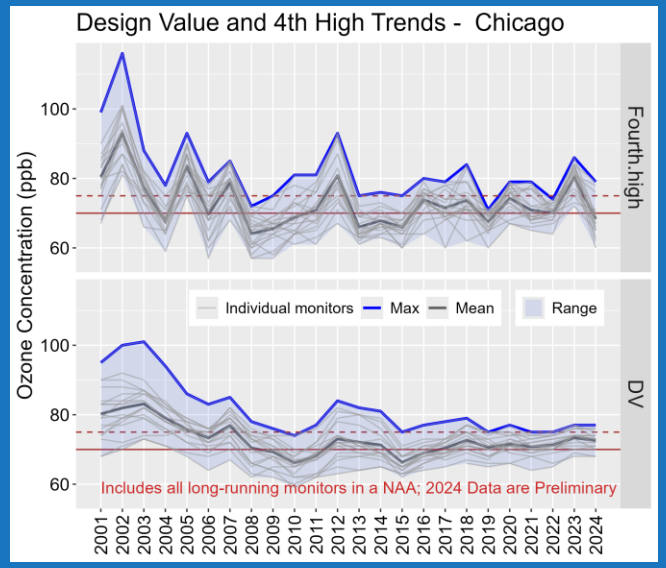



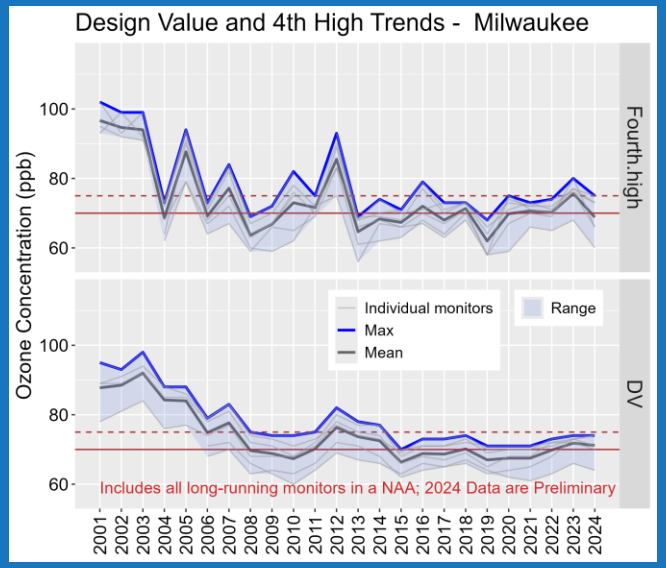

LADCO

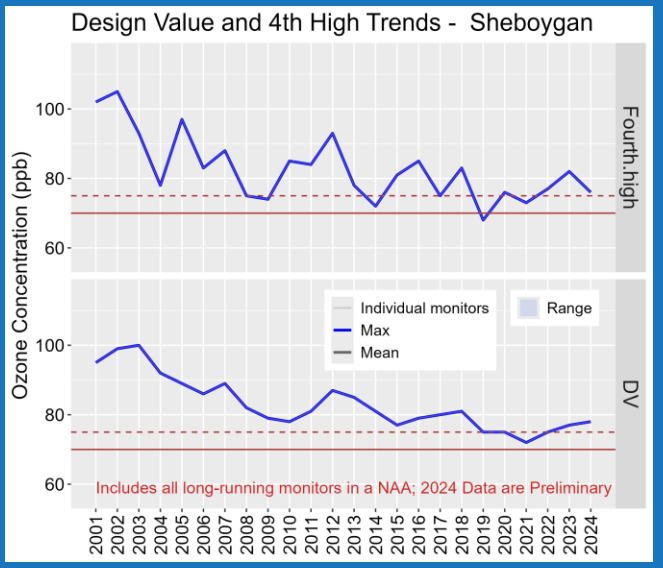
# Ozone

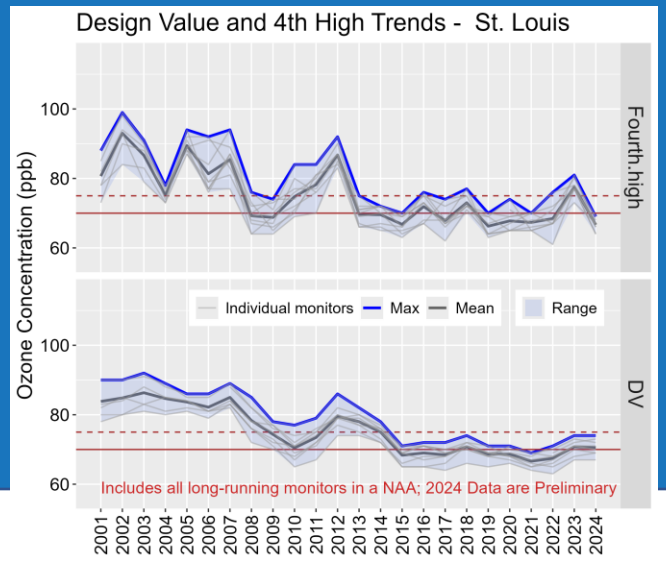

Controlling Monitor DV and 4th High Trends
Maximum ozone concentration (ppb)
110
100
90
80
70
max.4th
100
90
80
70
max.DV
2024 Data are Preliminary
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
Allegan
Berrien
Chicago
Cincinnati
Cleveland
Columbus
Detroit
Door
Louisville
Manitowoc
Milwaukee
Muskegon
Sheboygan
St. Louis

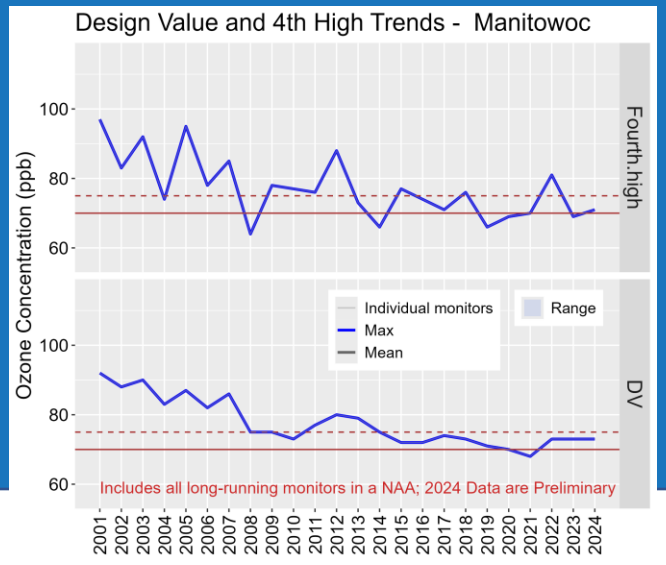
# Ozone Trends by Area: WI & IL

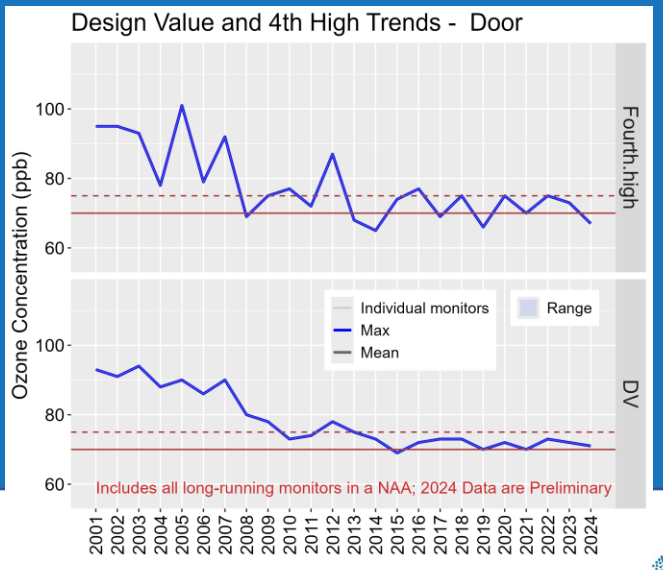


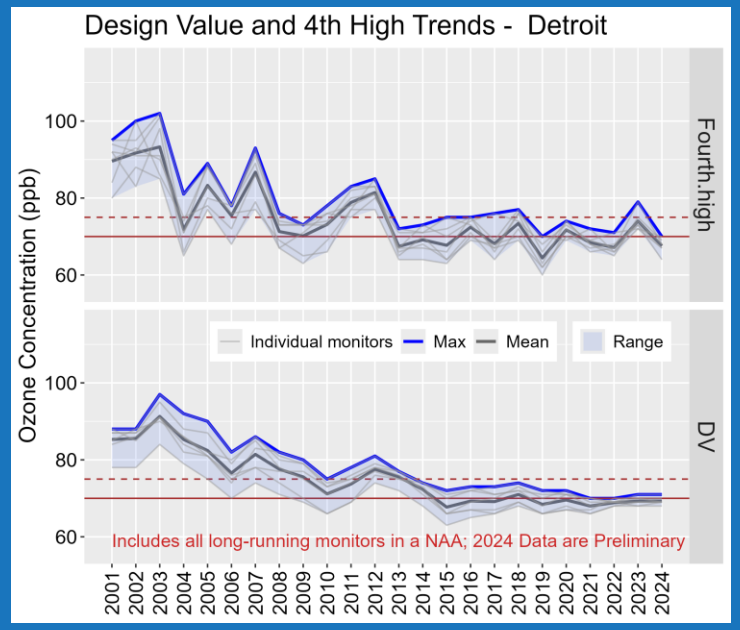



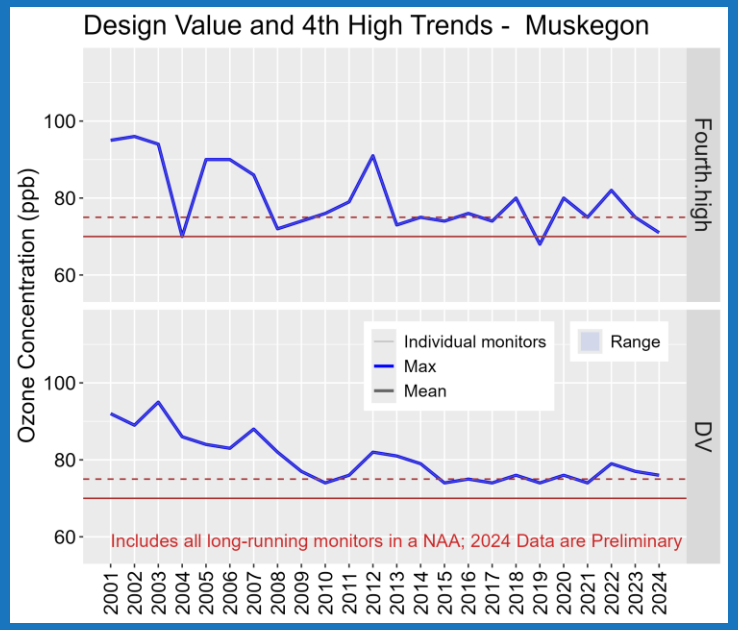



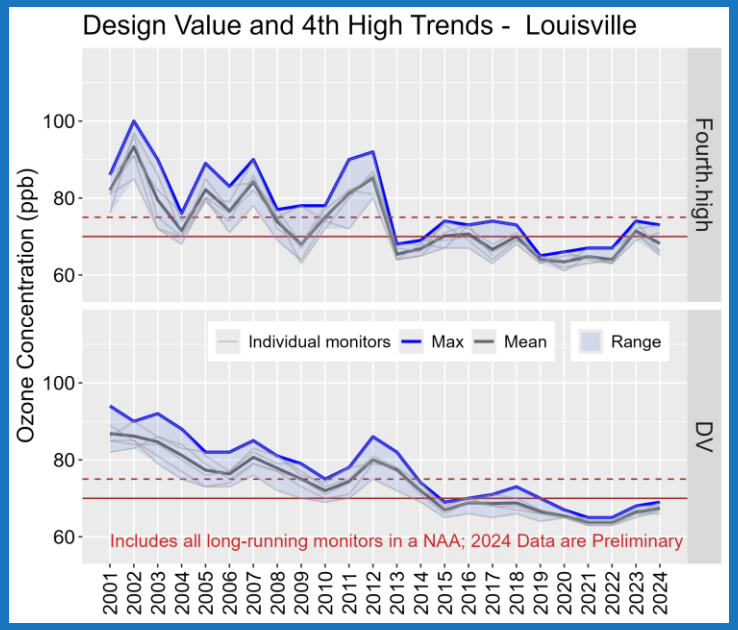



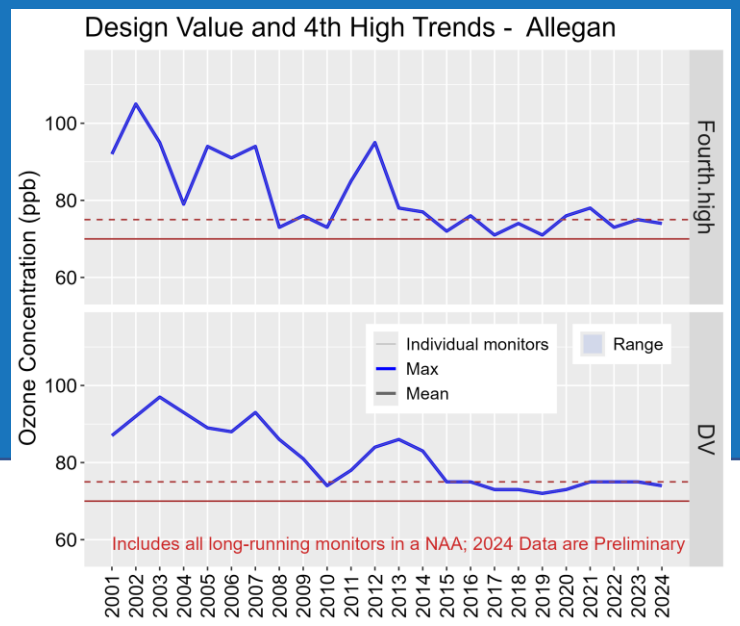

LADCO

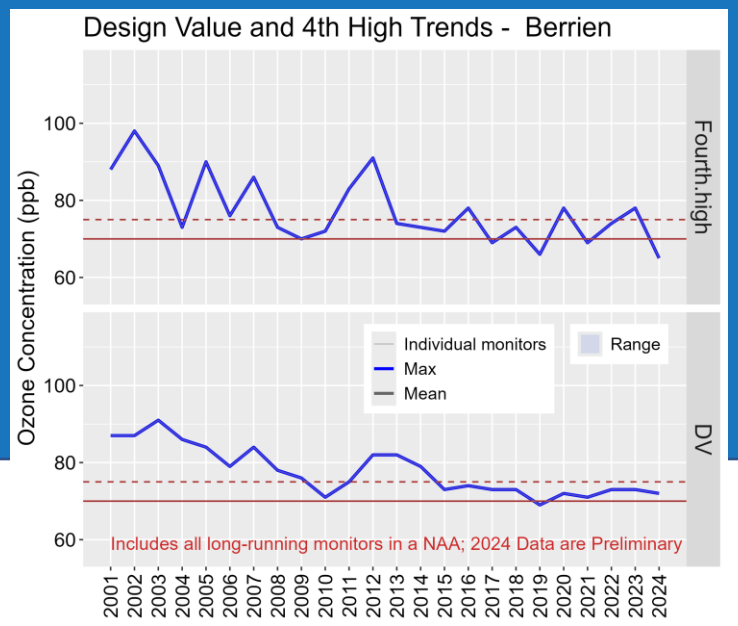
# Ozone Trends by Area: MI & IN



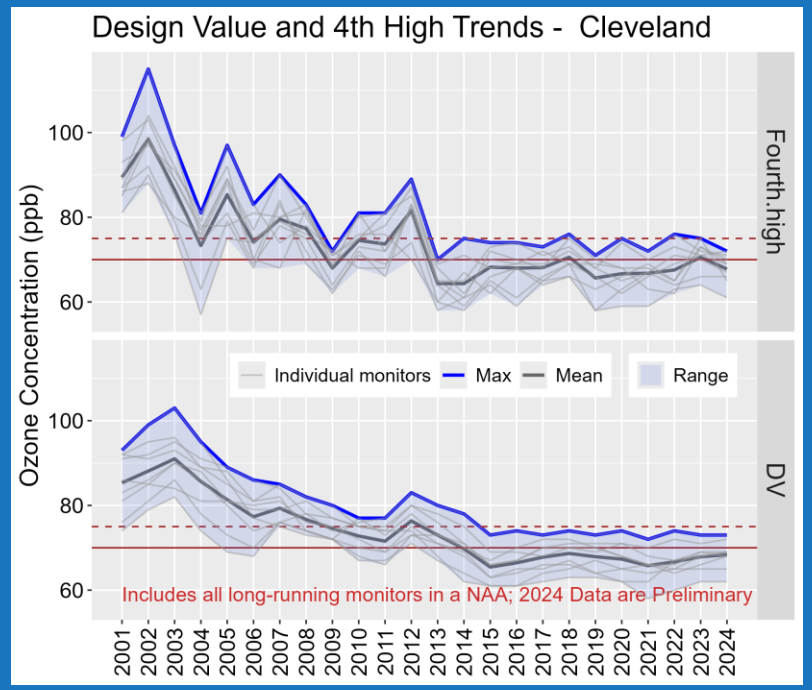



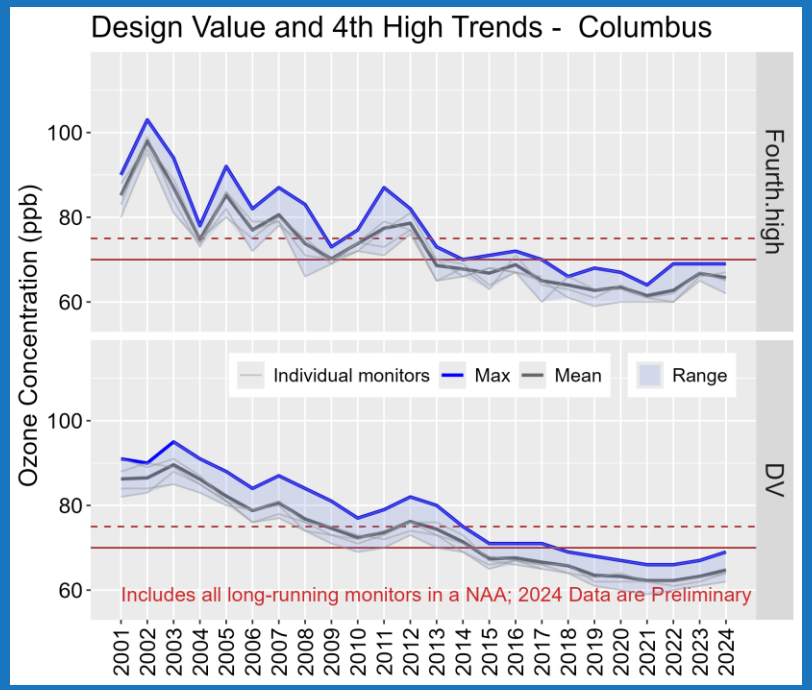



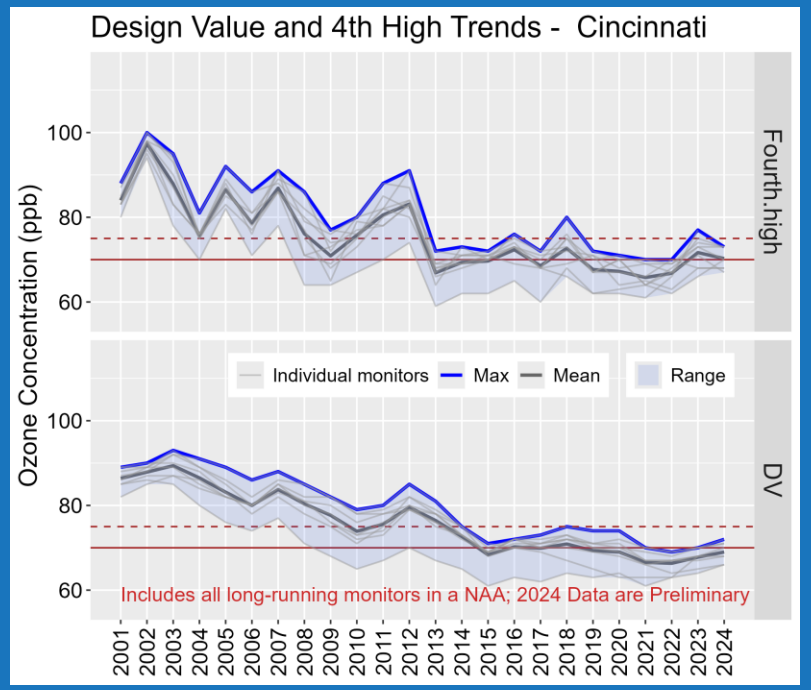



LADCO

# Ozone Trends by Area: OH



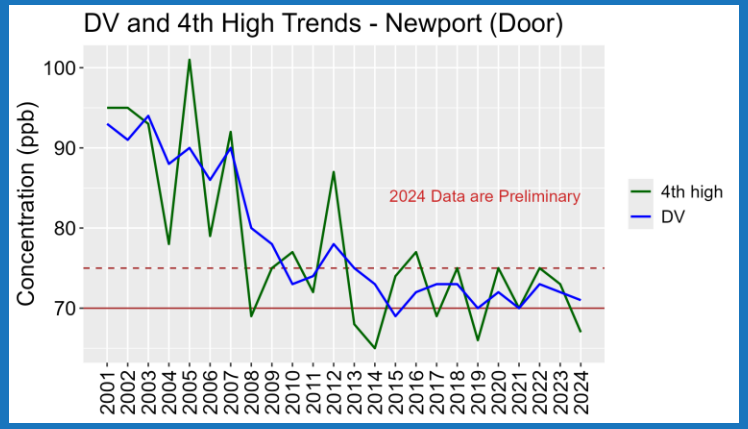

4415 West Harrison St., Suite 548
Hillside, IL 60162

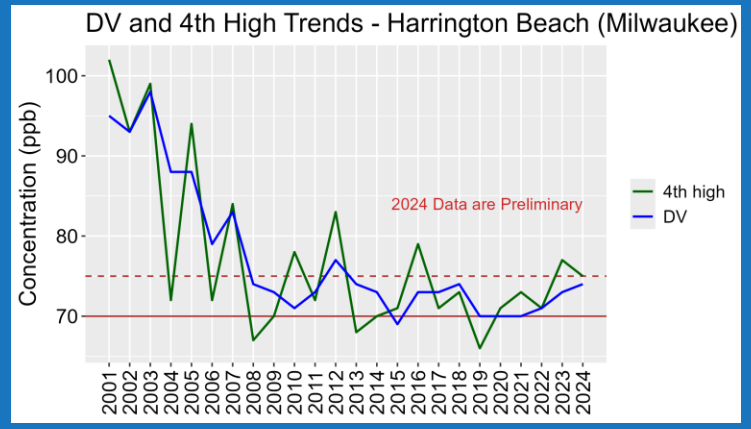
LADCO additional plots of ozone fourth highs and design values.

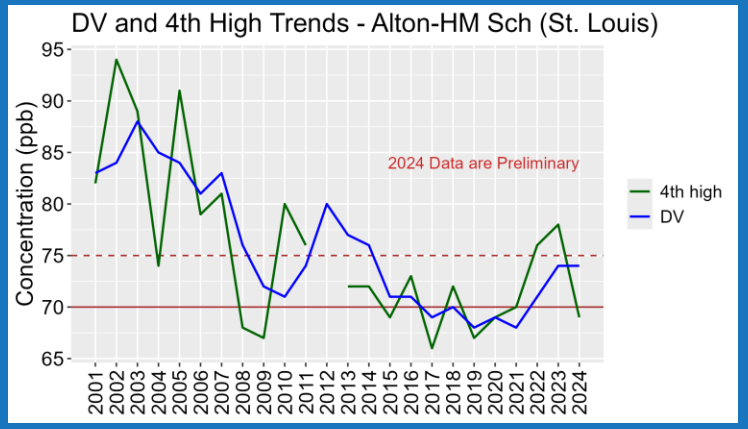


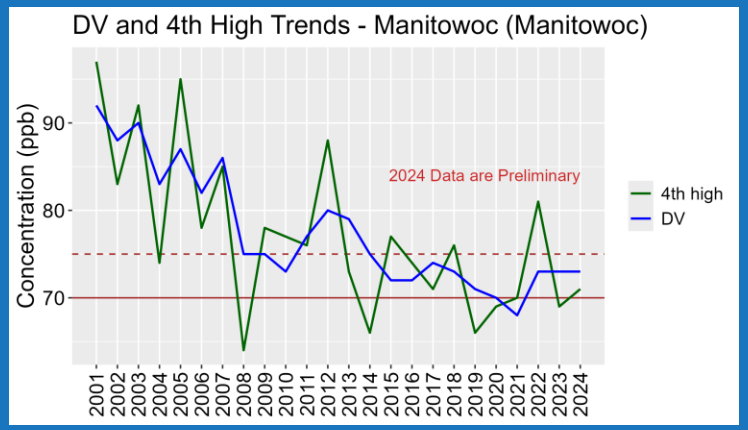
LADCO

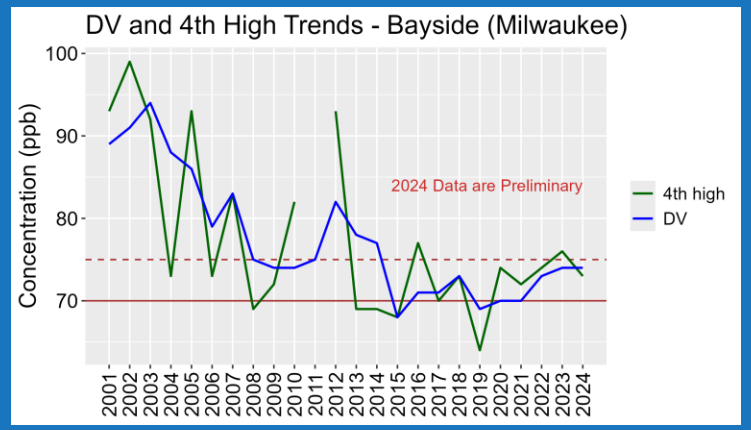
# Ozone Trends at Peak Monitors: WI & IL

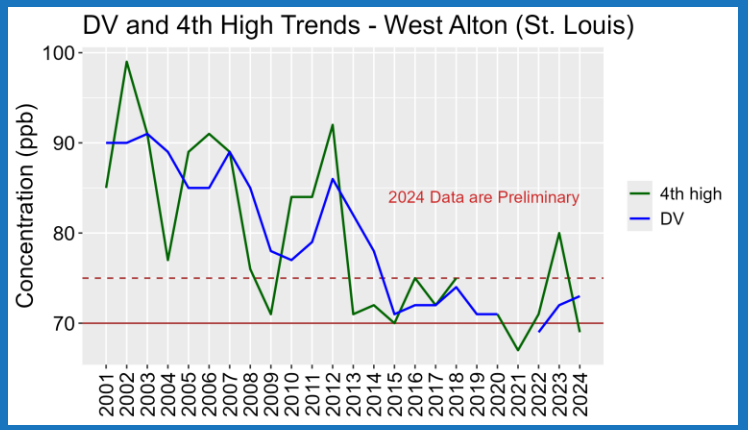


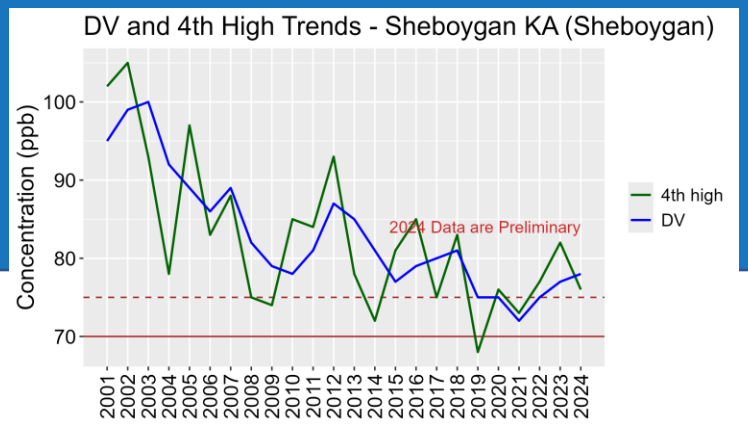



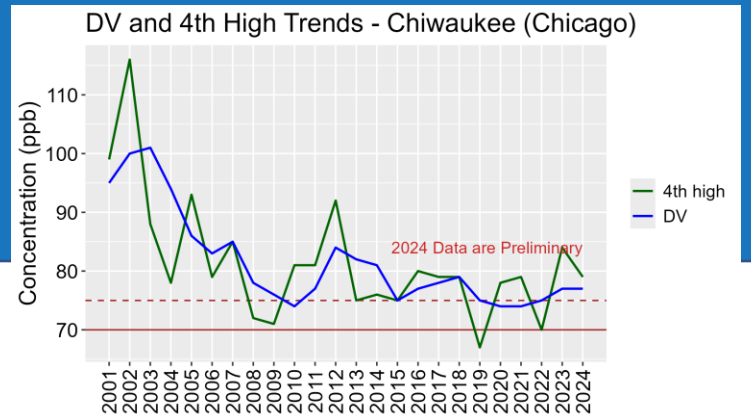



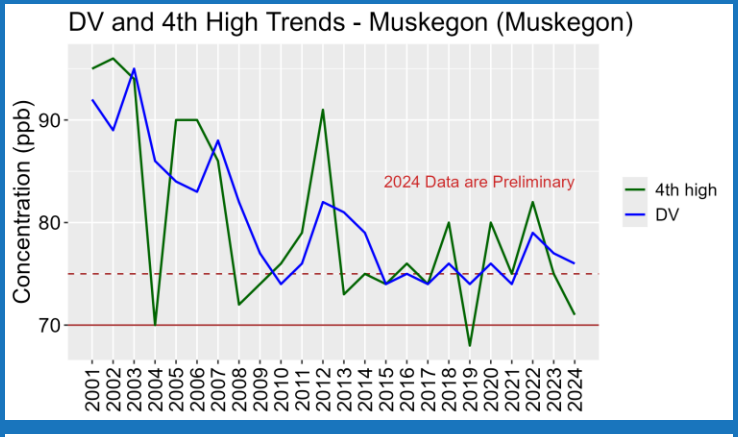



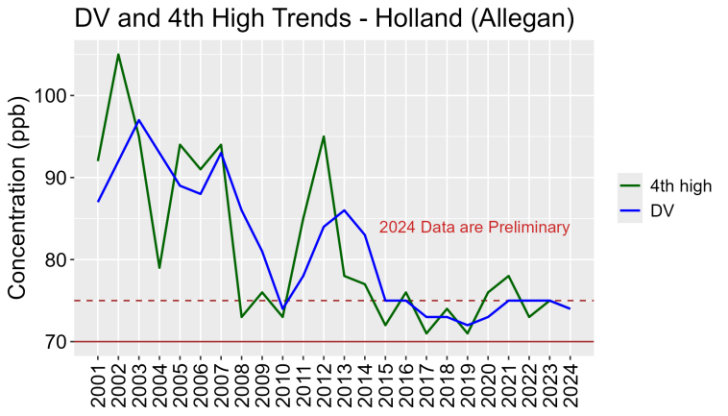



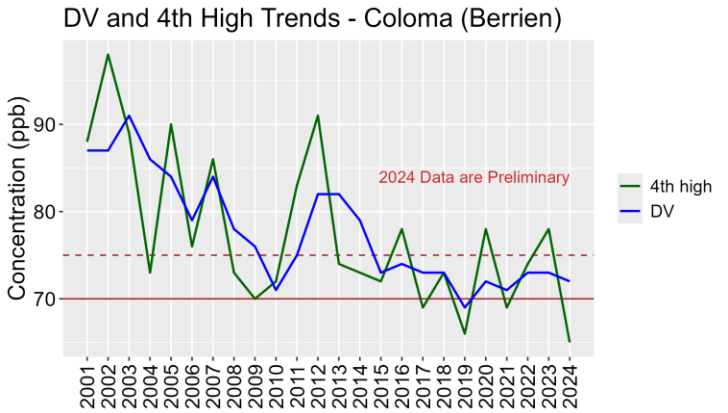



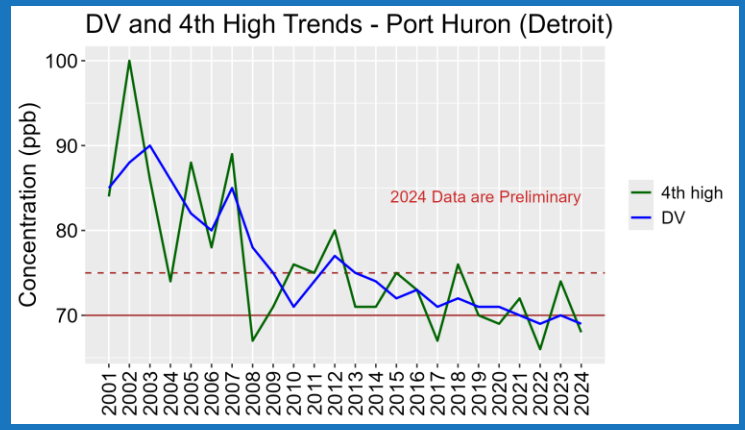

LADCO

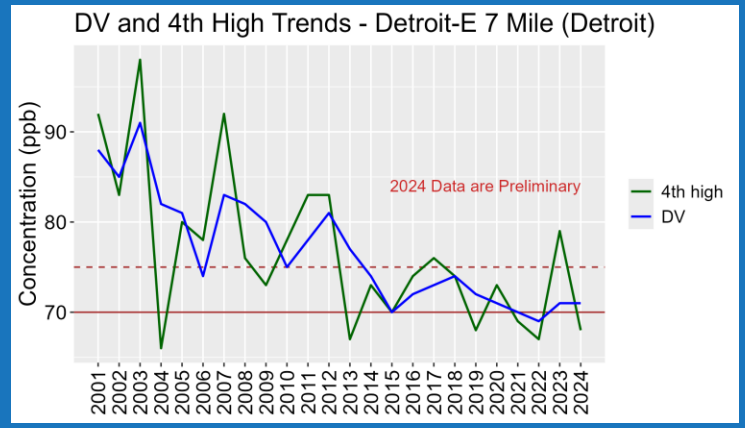
# Ozone Trends at Peak Monitors: MI & IN

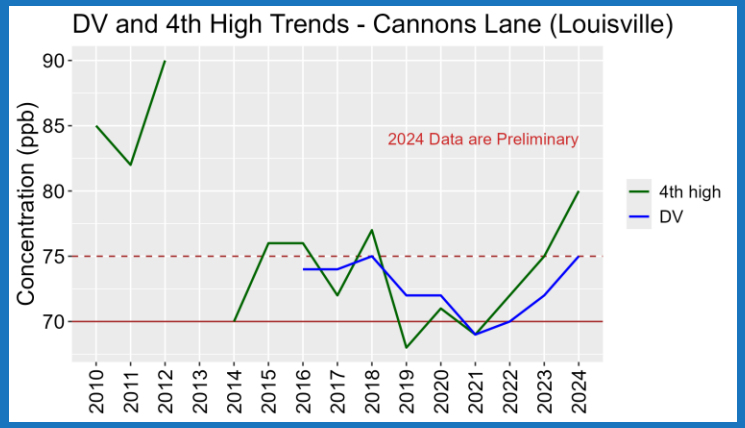


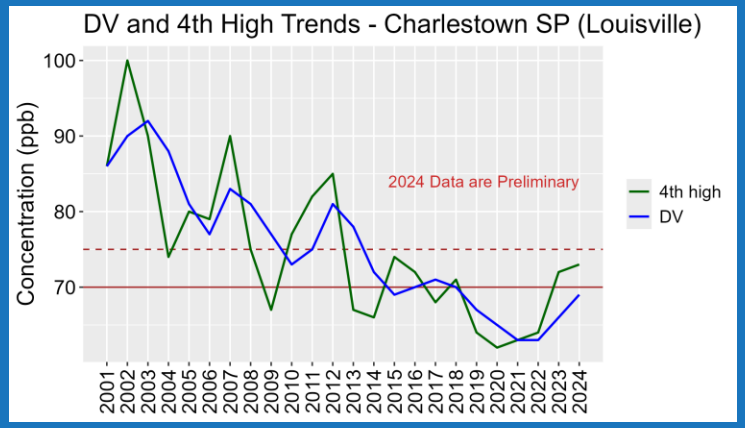



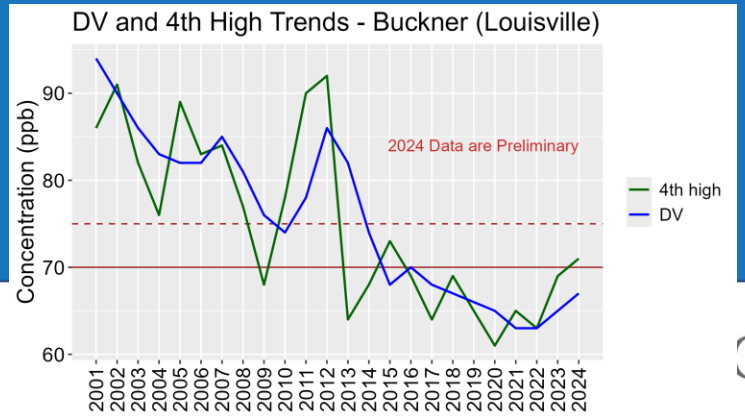



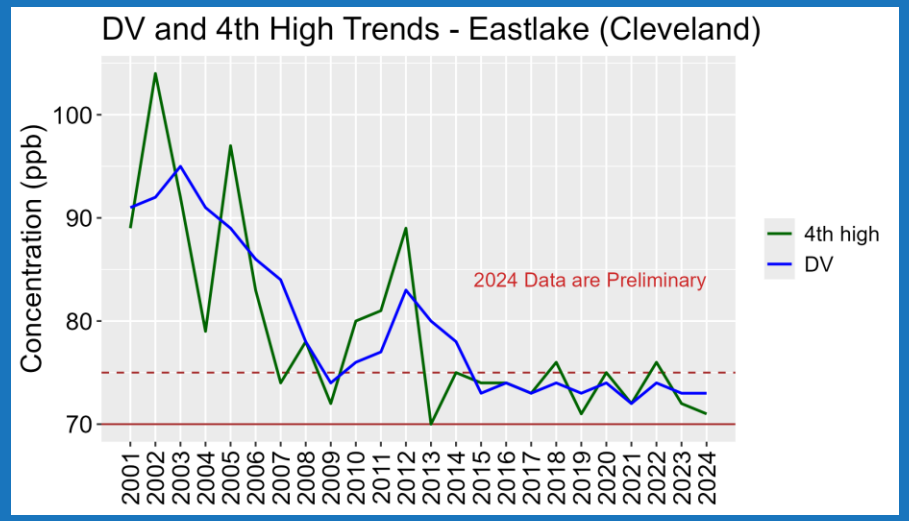



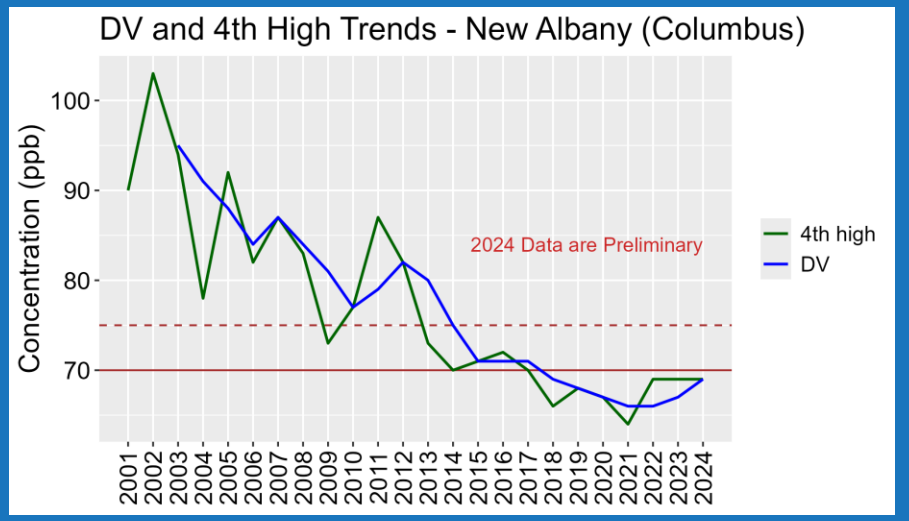



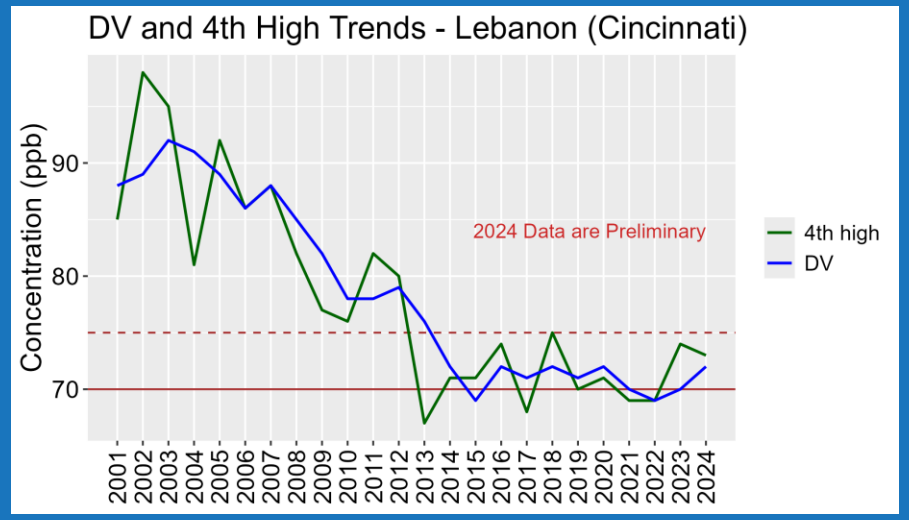



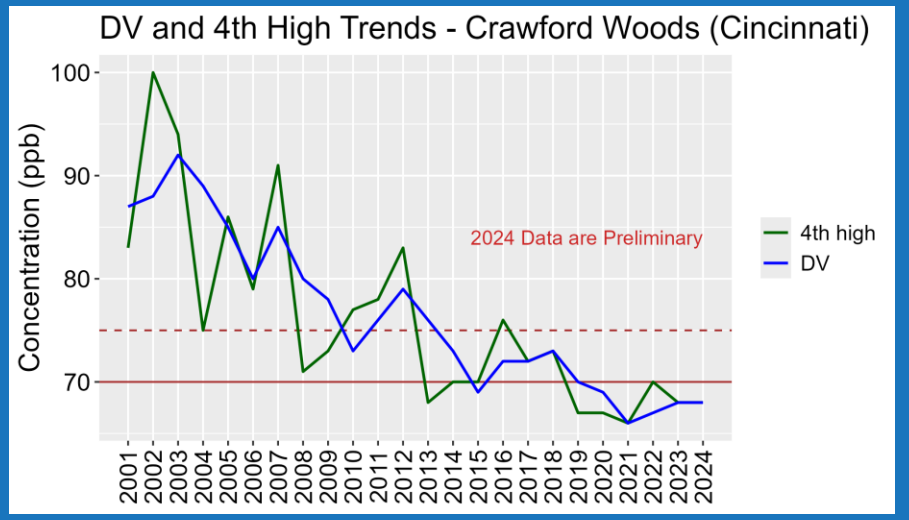



# Ozone Trends at Peak Monitors: OH

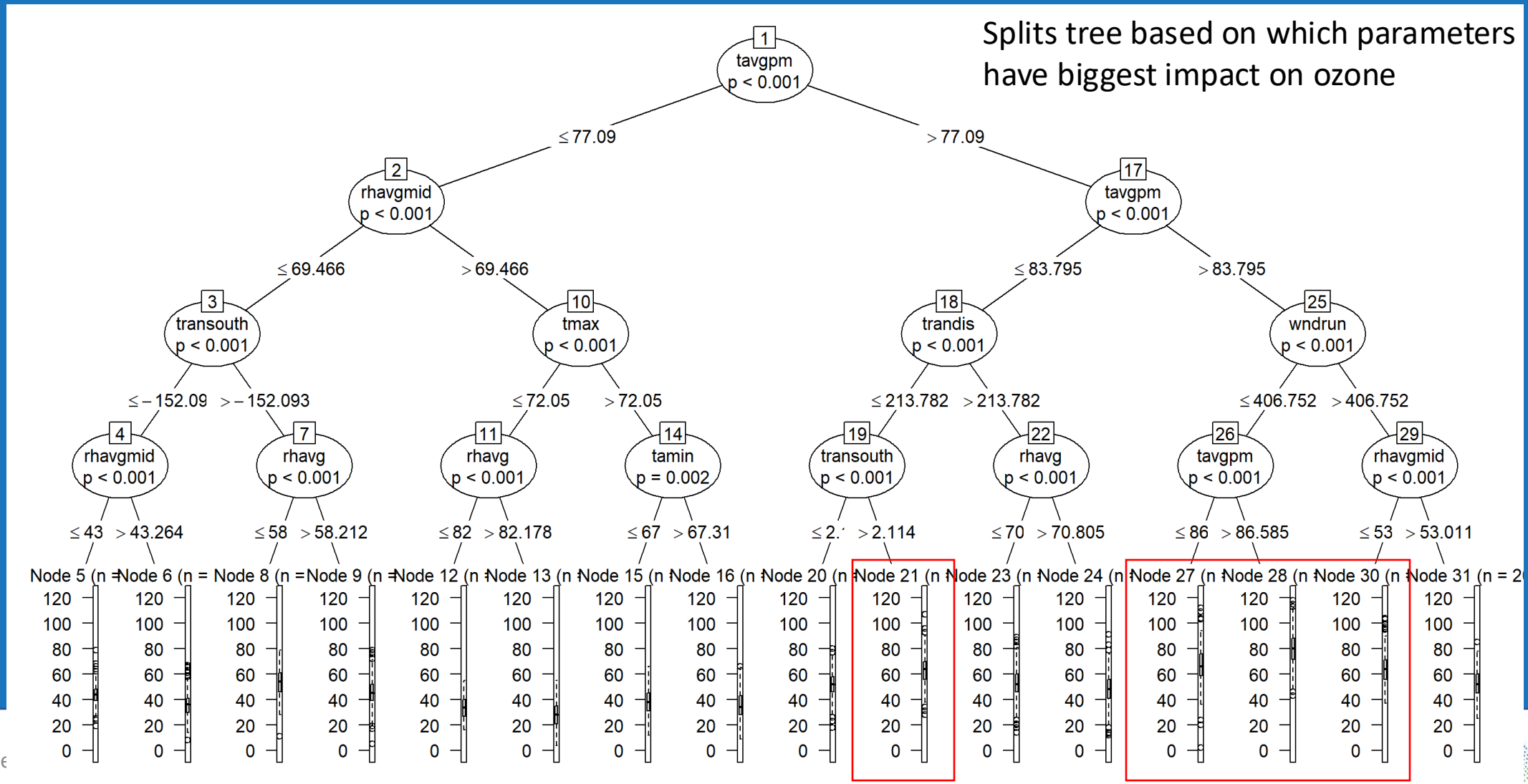


# CART – Cleveland

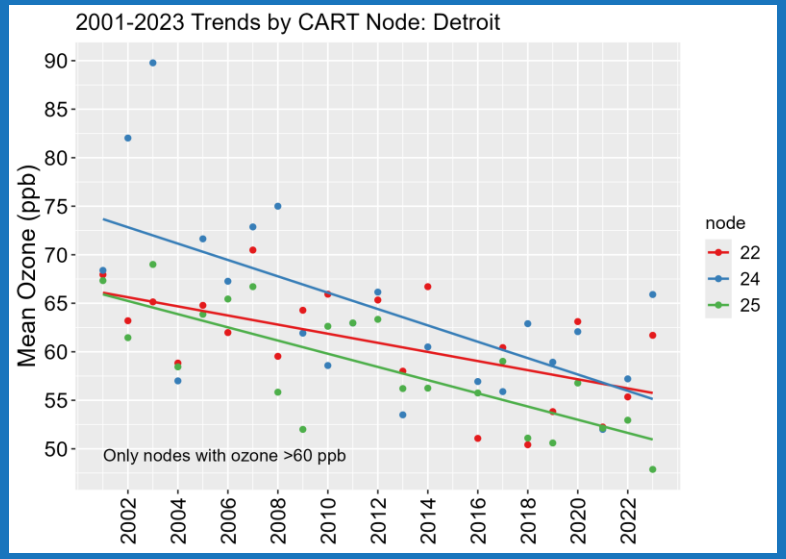


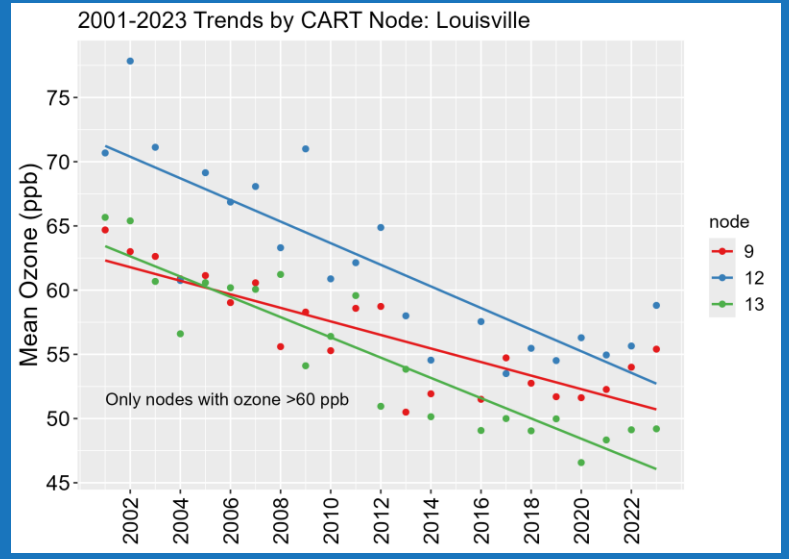

High-$O_3$ nodes (mean > 60 ppb)

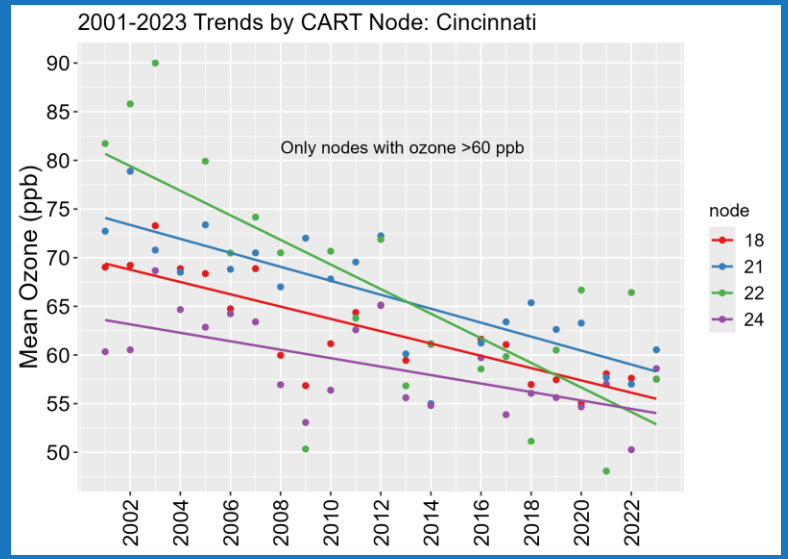


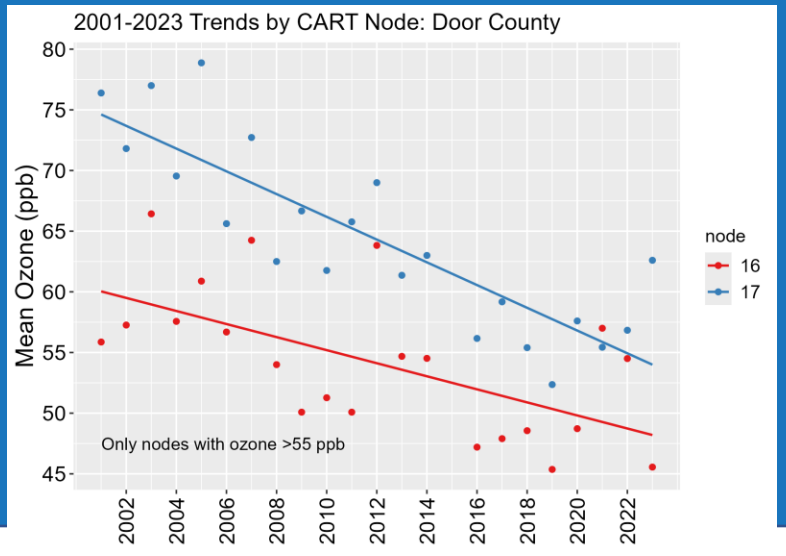
LADCO

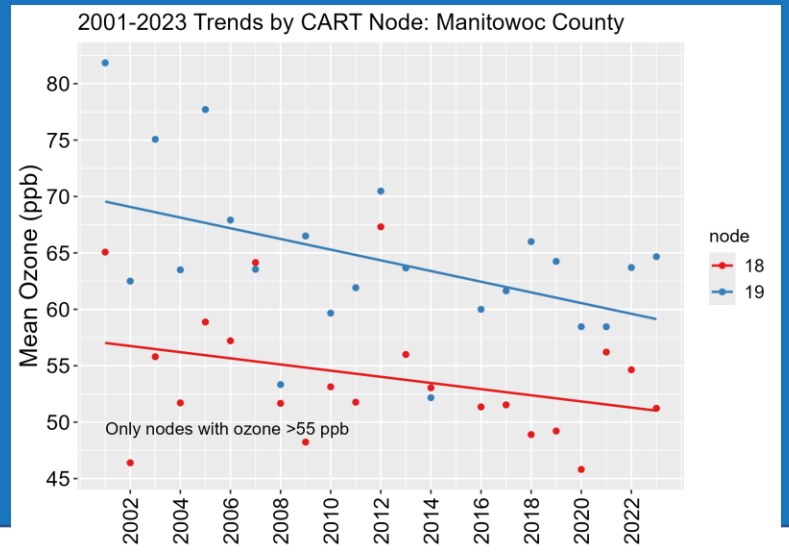
# CART Trends: Maintenance areas (& Milwaukee downtown)

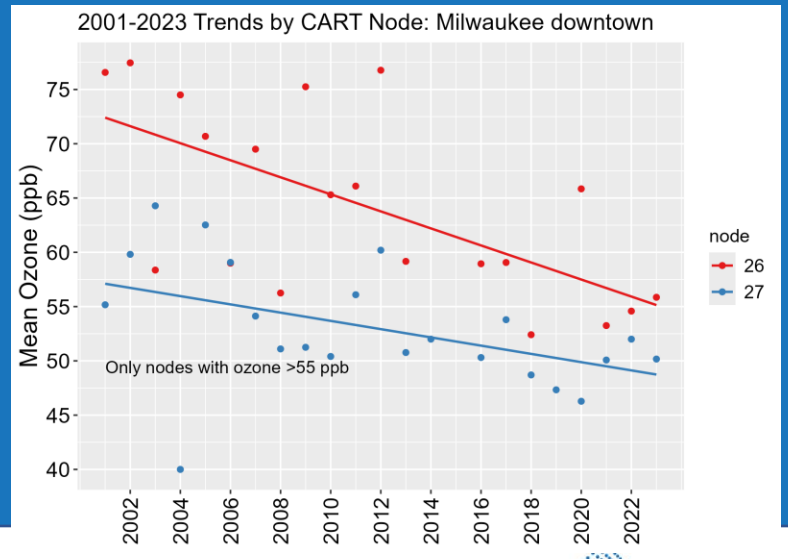


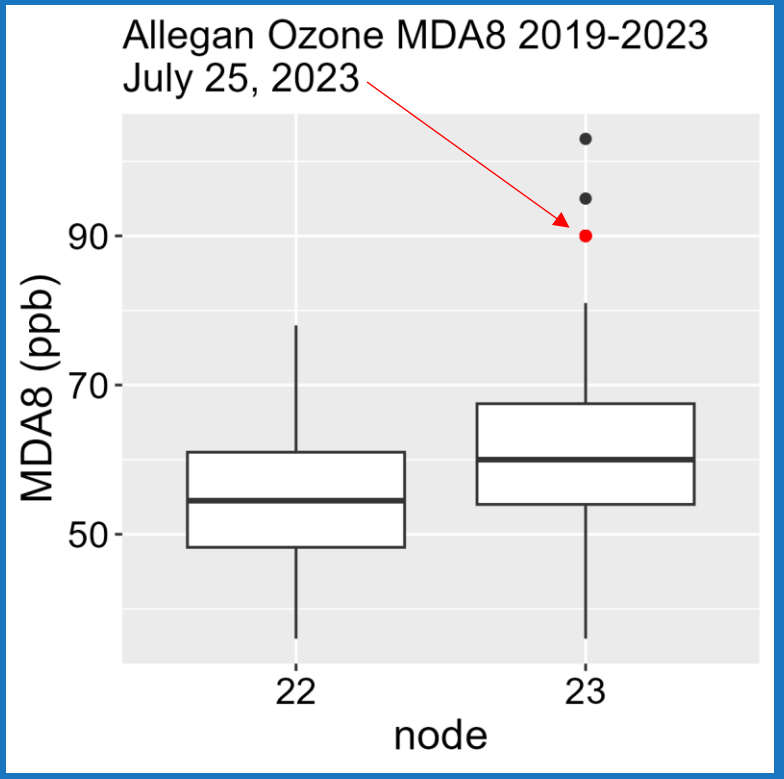

4415 West Harrison St., Suite 548
Hillside, IL 60162

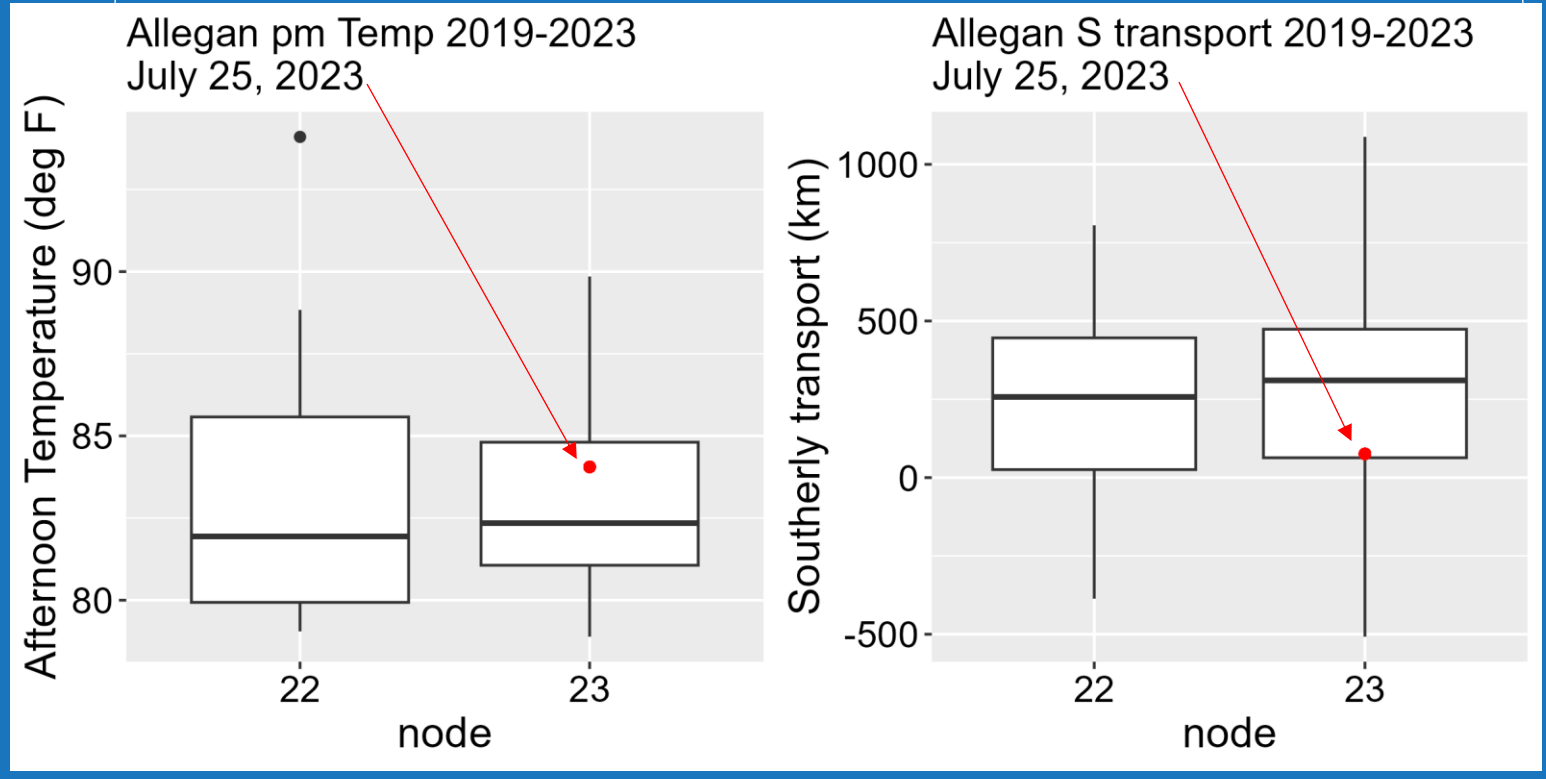


LADCO

# CART – Application to Similar-Day Analysis

Two most important met factors




July 25, 2023 had extraordinarily high ozone but the meteorology was "normal" for that type of day

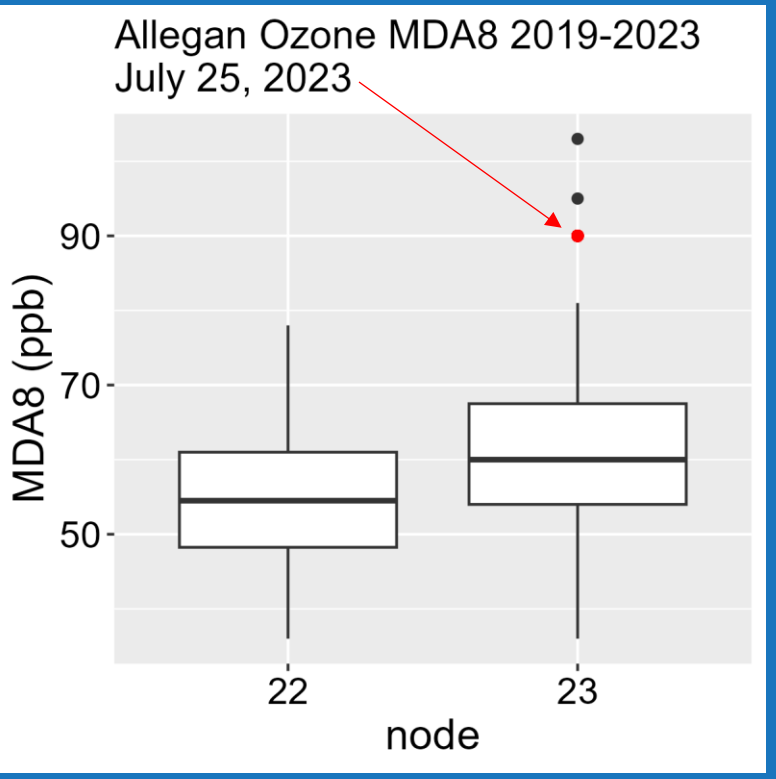
→ Strong support for importance of smoke enhancement of ozone formation

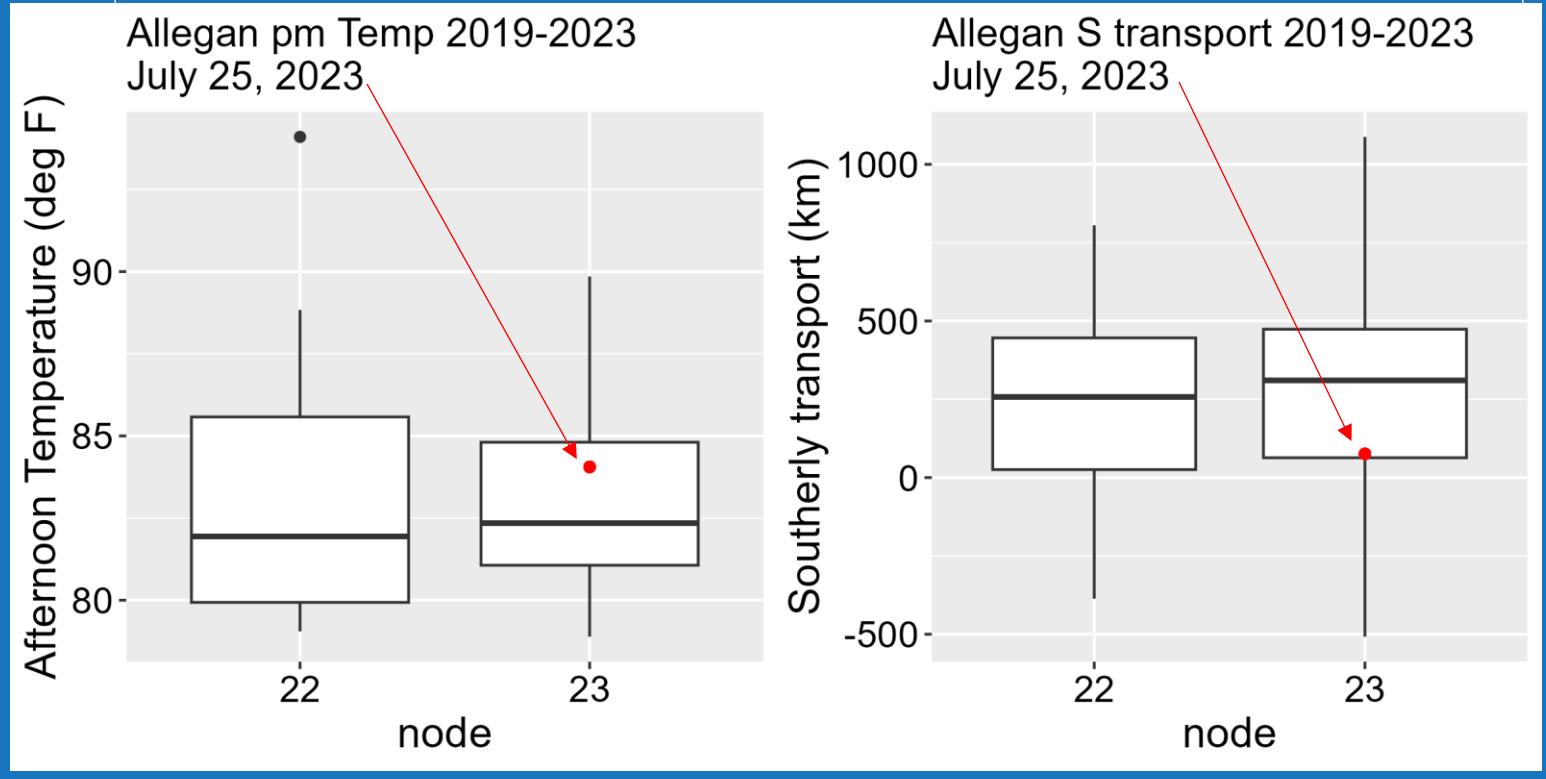
Two higher-$O_3$ points were June 20 and 21, 2022, 4-5 days after a Tier 1 $PM_{2.5}$ smoke day (from AZ/NM)

LADCO

# CART – Application to Similar-Day Analysis

Two most important met factors




Probably could use this analysis to support exceptional events demonstrations for ozone

- Challenge: meteorological data generally isn't available until spring/summer of the following year
- Planning to look into new ways of doing CART or similar analysis: may have less of a delay

LADCO