LADCO | LAKE MICHIGAN AIR DIRECTORS CONSORTIUM

Speciated $PM_{2.5}$ Concentrations and Emissions in the LADCO Region

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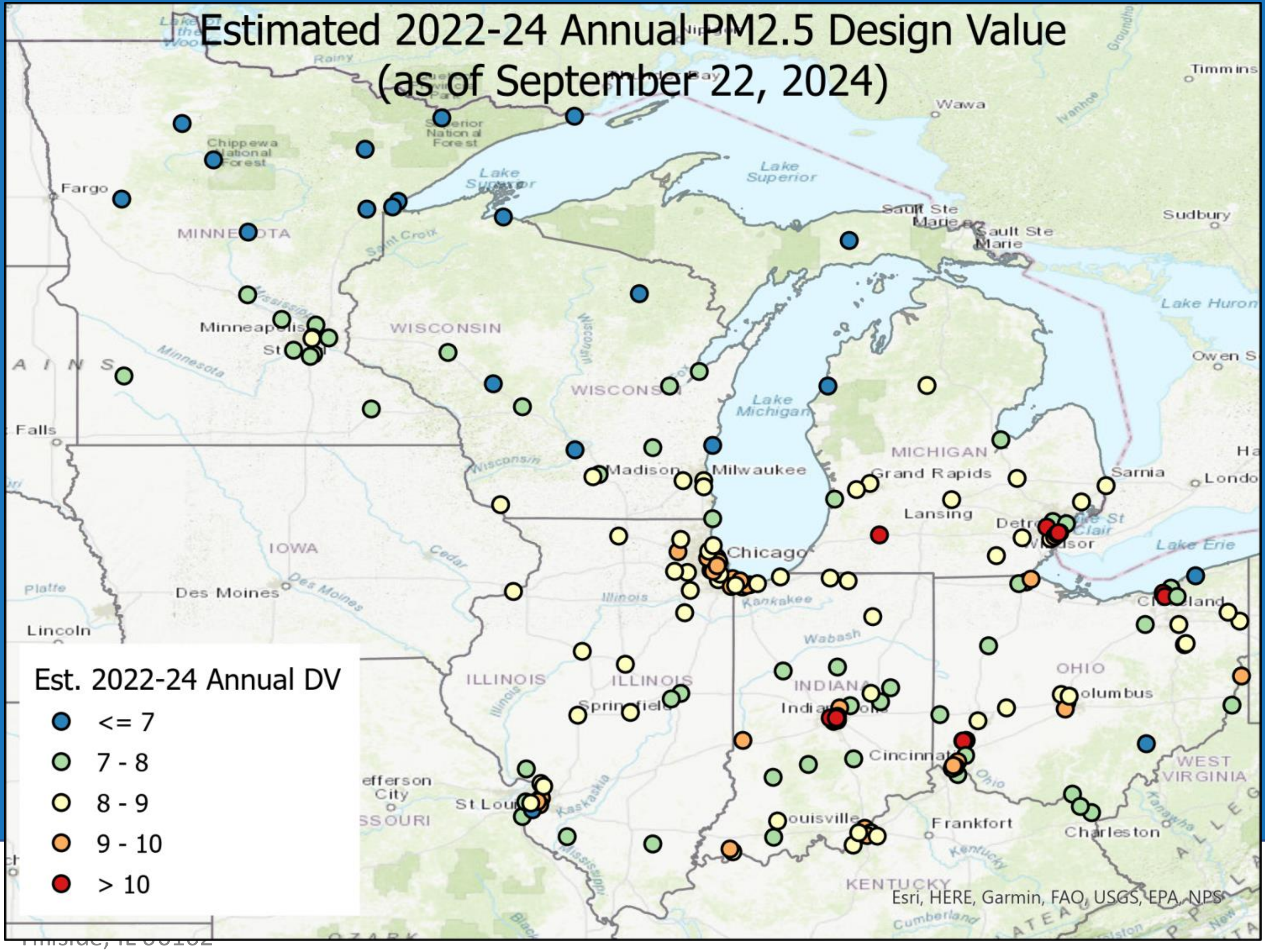
LADCO Data Scientist and Emissions Director

LADCO Business Meeting
September 26, 2024

PM$_{2.5}$ Design Values



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Driving Questions: Speciation Analysis

- Main question: what emissions controls will help states attain the new NAAQS?

- How has $PM_{2.5}$ speciation and seasonality changed over time?
  - What are the most important species/seasons currently?
- How has wildfire smoke contributed to $PM_{2.5}$ in the region?
  - What do trends look like without smoke?

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Approach

- Looked at speciated $PM_{2.5}$ data where available
- Combined data from IMPROVE and CSN Networks
  - Fairly complicated to do so (thanks to Margaret McCourtney!)
- Originally had grouped monitors together into clusters with similar composition and trends
- Here, I'm looking at trends within each high-$PM_{2.5}$ CBSA
  - Look at 6 major species
  - In 4 seasons
  - In 5 year groups (2001-2023)

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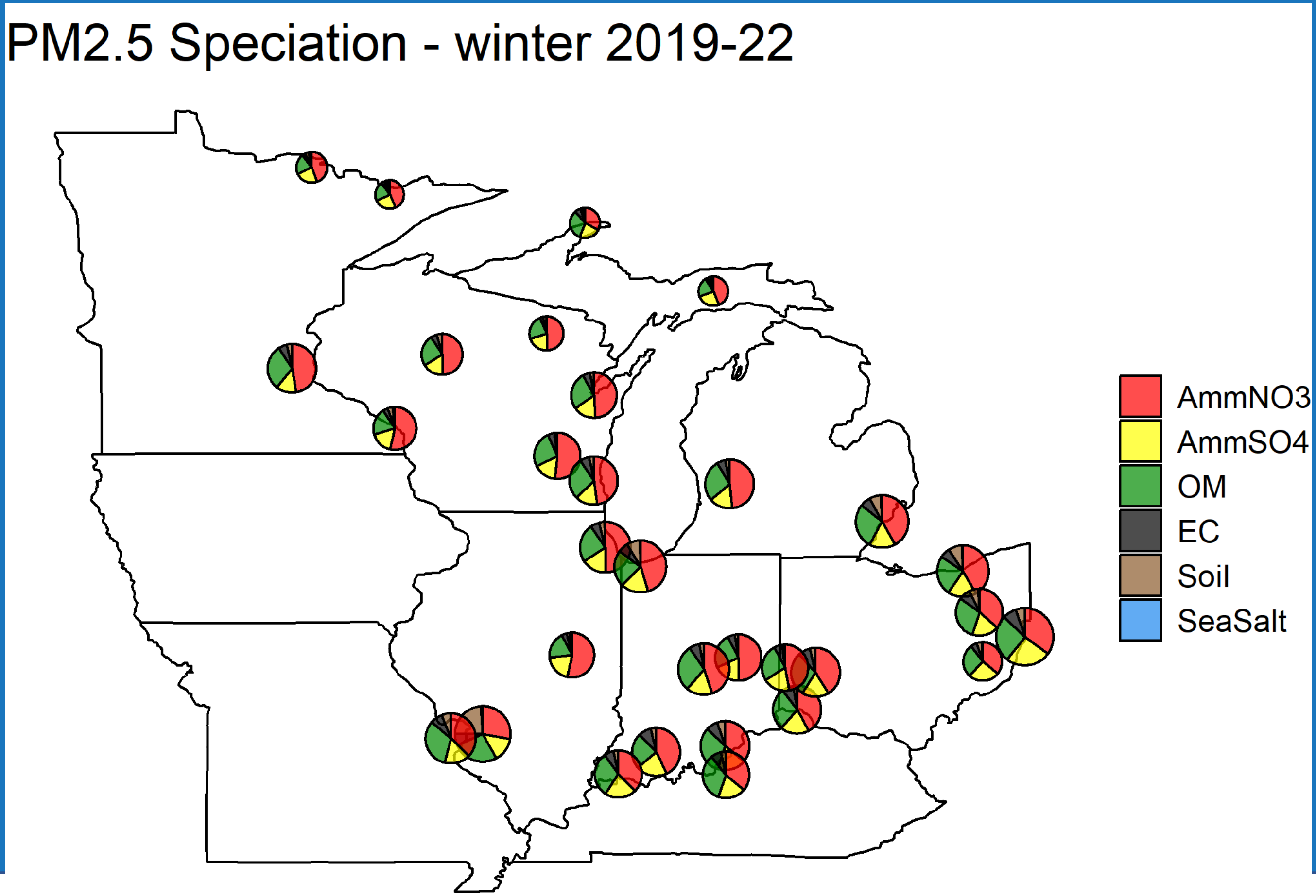
Current Status: Winter $PM_{2.5}$



- Winter $PM_{2.5}$ is (still) dominated by Ammonium Nitrate (AmmNO3)
  - Highest in northern states (except at the far northern IMPROVE sites)
- Concentrations similar in urban areas around the region
  - Northern cities ≈ southern cities
  - N/S cities > N/S rural
  - All >> Far north

All monitors in an urban area are combined into a mean value for plotting.

AmmNO3 = ammonium nitrate, AmmSO4 = ammonium sulfate, OM = organic matter, EC = elemental carbon

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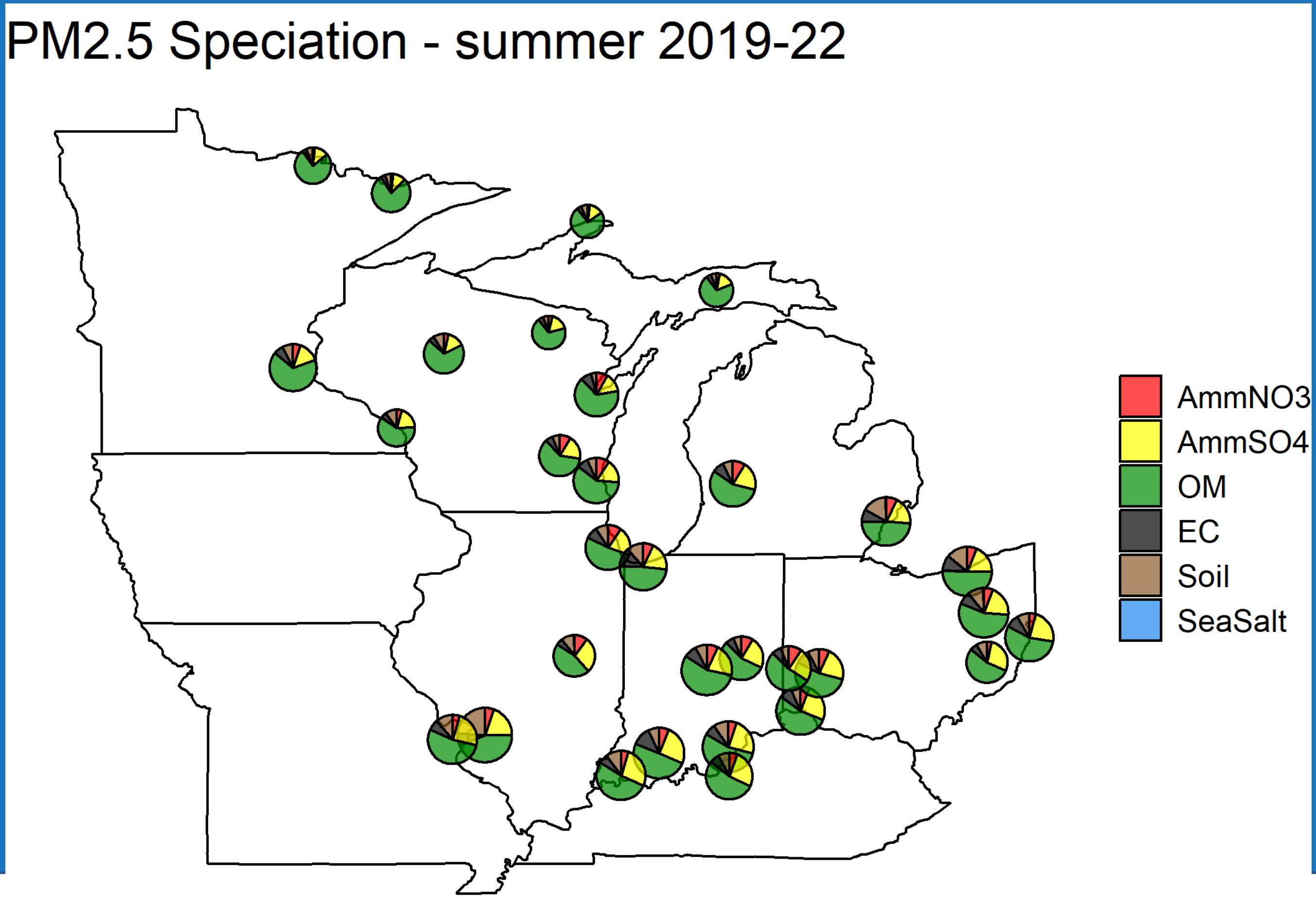
Current Status: Summer $PM_{2.5}$



- Summer $PM_{2.5}$ is now dominated by organic matter (OM, aka OC)
  - Highest proportion in northern states – primarily because they have less AmmSO4
- Concentrations are greatest in southern cities and decrease going north
  - Southern cities > others
  - Northern cities ≈ Rural south
    - All > Rural North > Far North

All monitors in an urban area are combined into a mean value for plotting.

AmmNO3 = ammonium nitrate, AmmSO4 = ammonium sulfate, OM = organic matter, EC = elemental carbon

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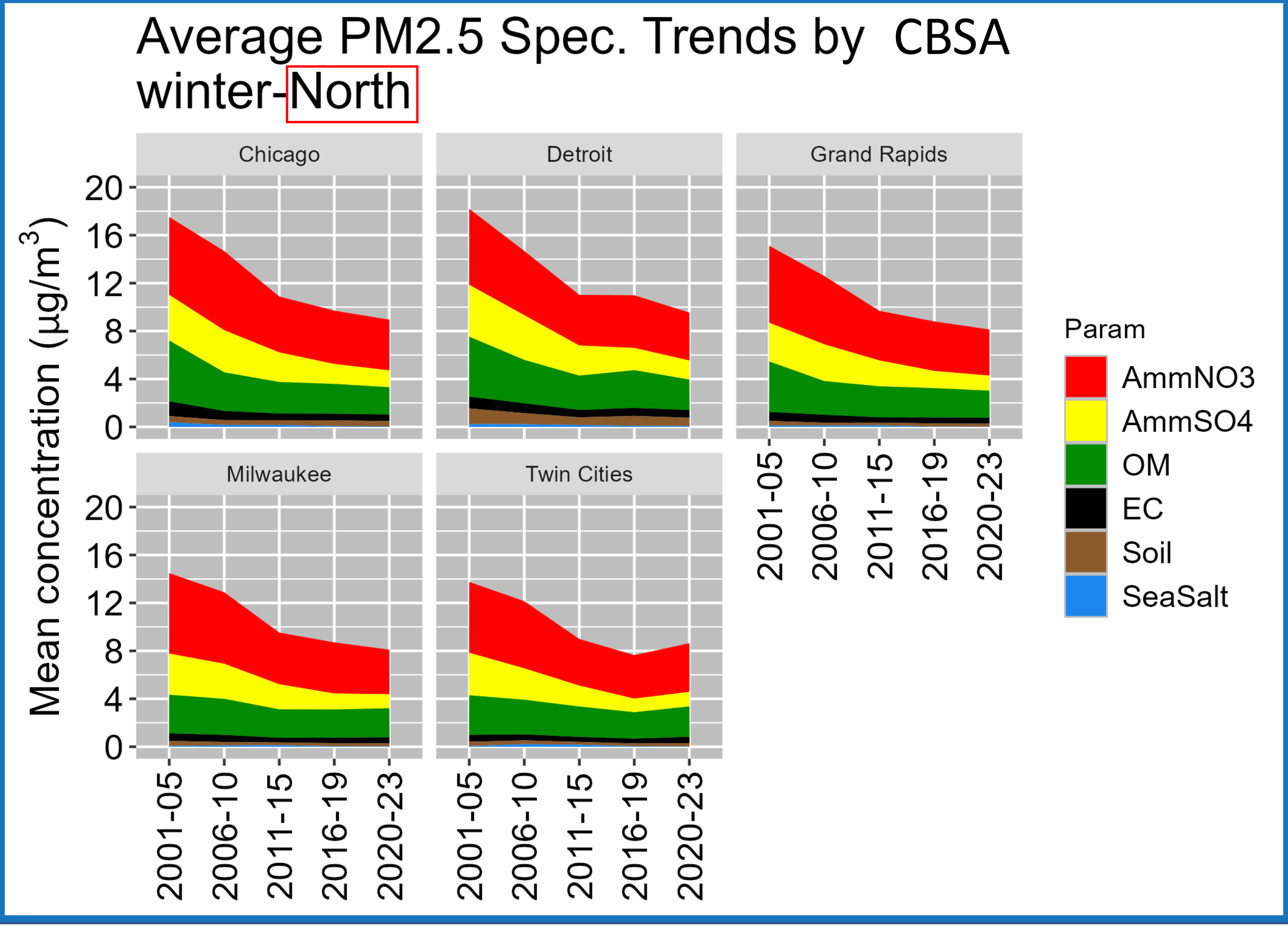
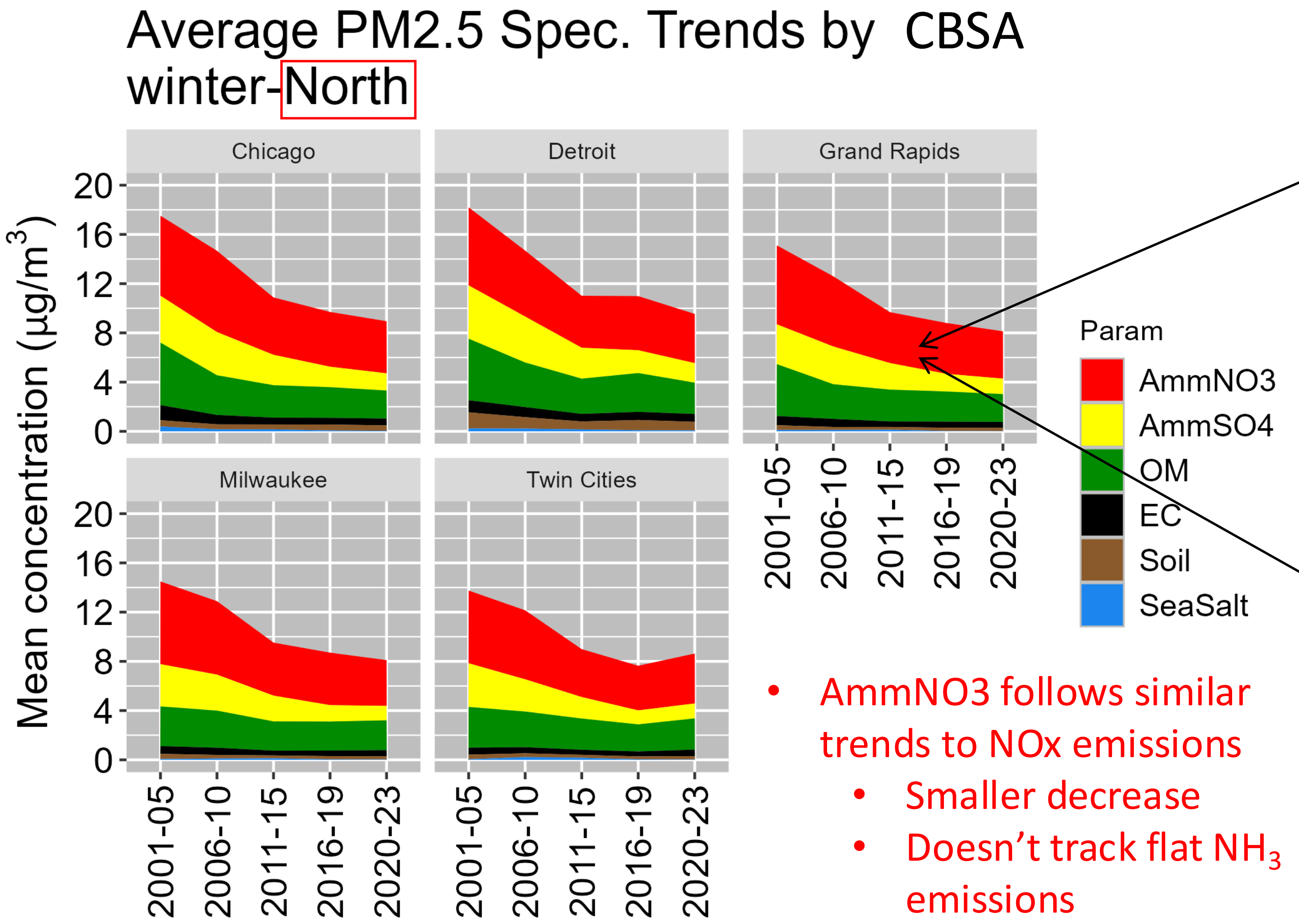
Trends over time: Winter Speciated $PM_{2.5}$



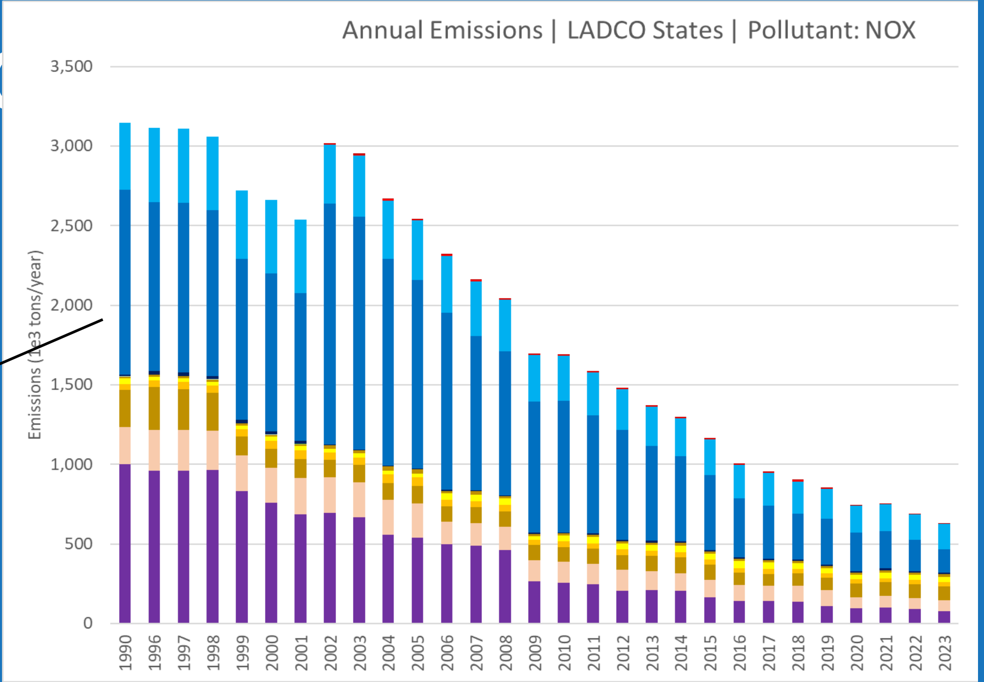
- Reductions in both AmmNO3 and AmmSO4
- Smaller reductions in OM
- Overall composition hasn't changed that much

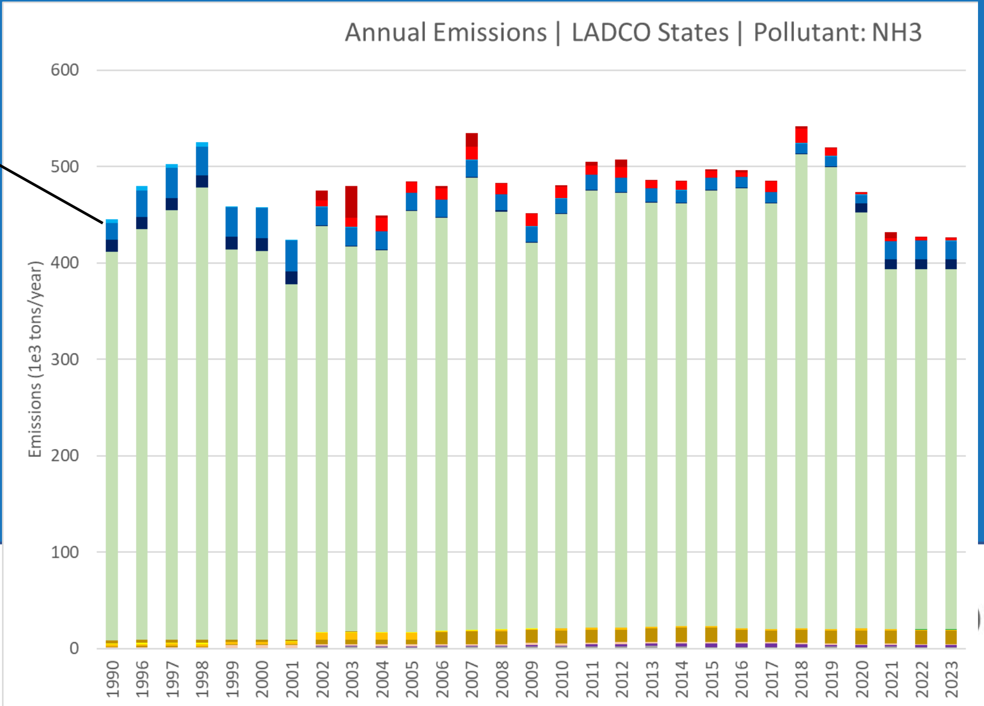
See Appendix for trends by species

Trends over time: Winter Spec

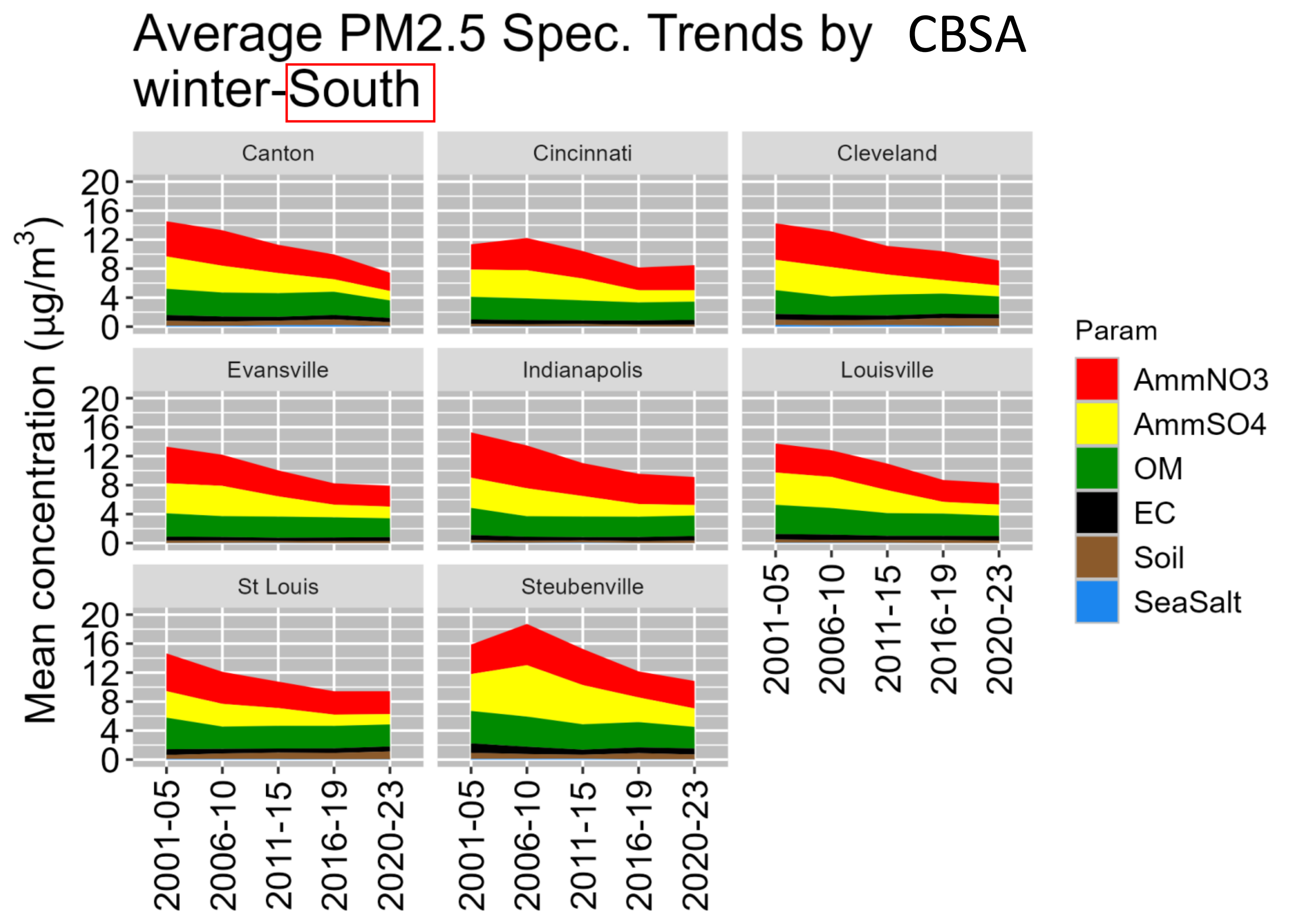


- AmmNO3 follows similar trends to NOx emissions
  - Smaller decrease
  - Doesn't track flat NH_3 emissions





Trends over time: Winter Speciated $PM_{2.5}$



- Similar trends to northern sites
  - Less AmmNO3 overall

See Appendix for trends by species

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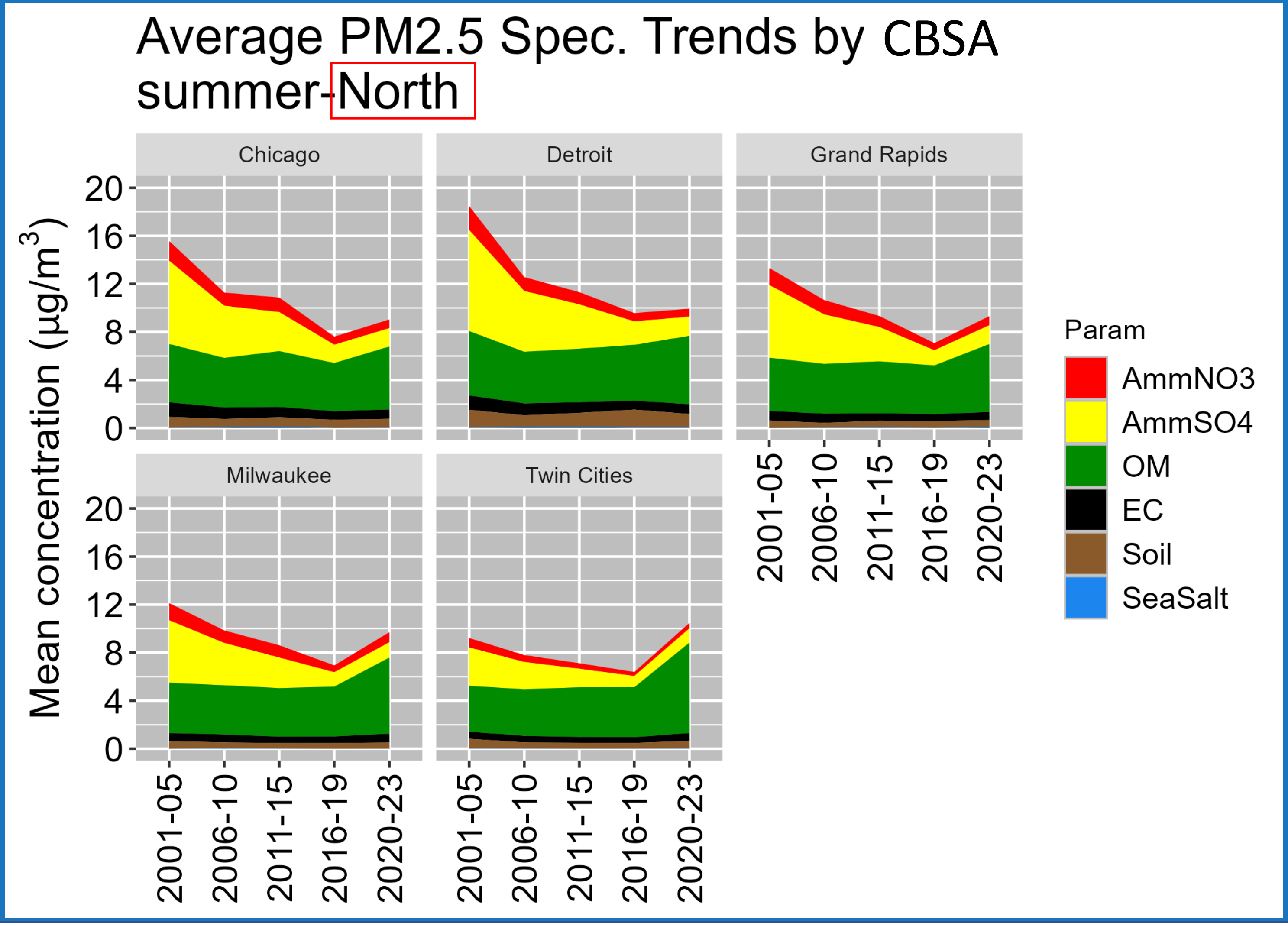
Trends over time: Summer Speciated $PM_{2.5}$



- Large reductions in AmmSO4
- OM is steady to increasing
- Shift from mostly AmmSO4 to mostly OM
- Other components are very small

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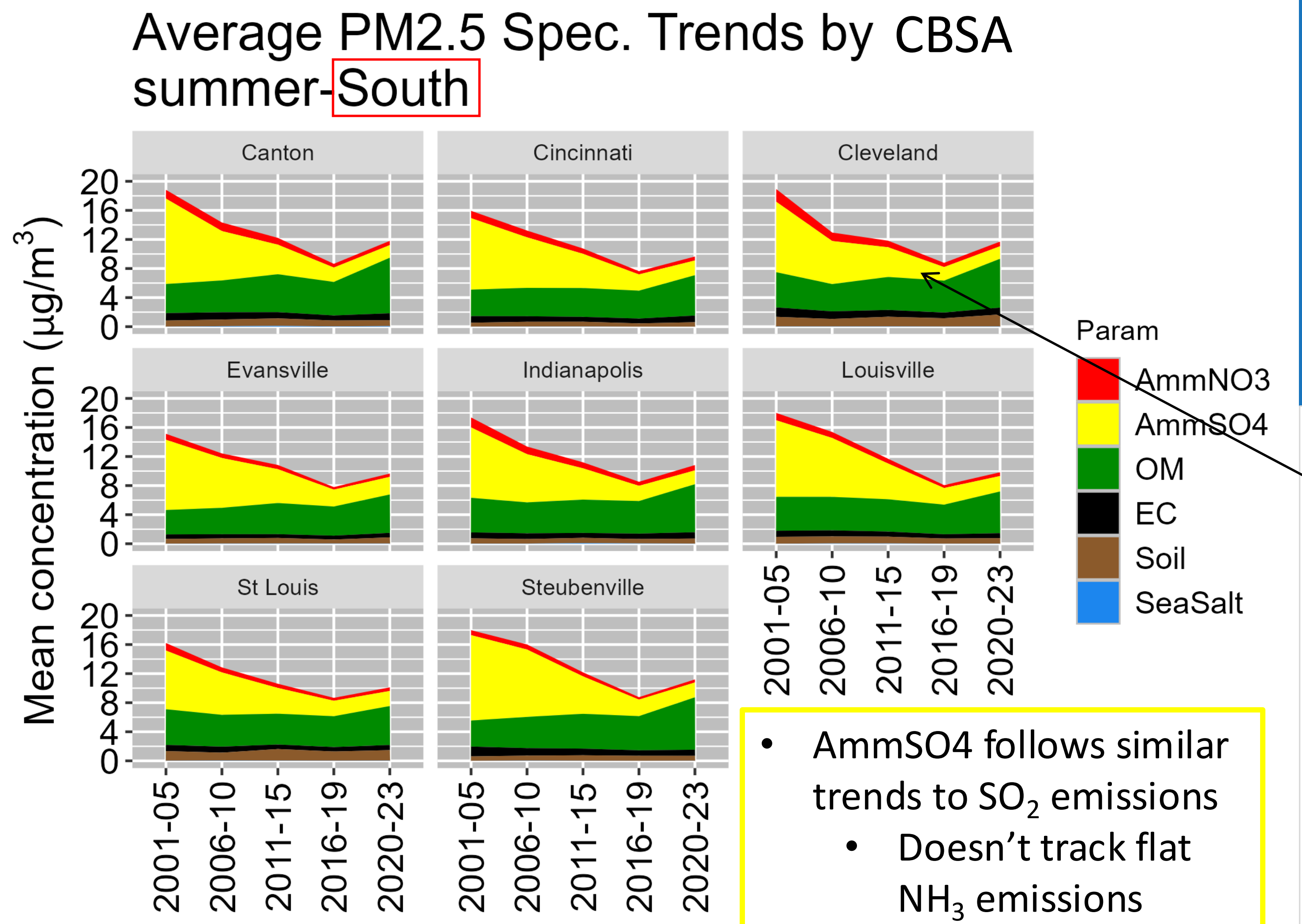
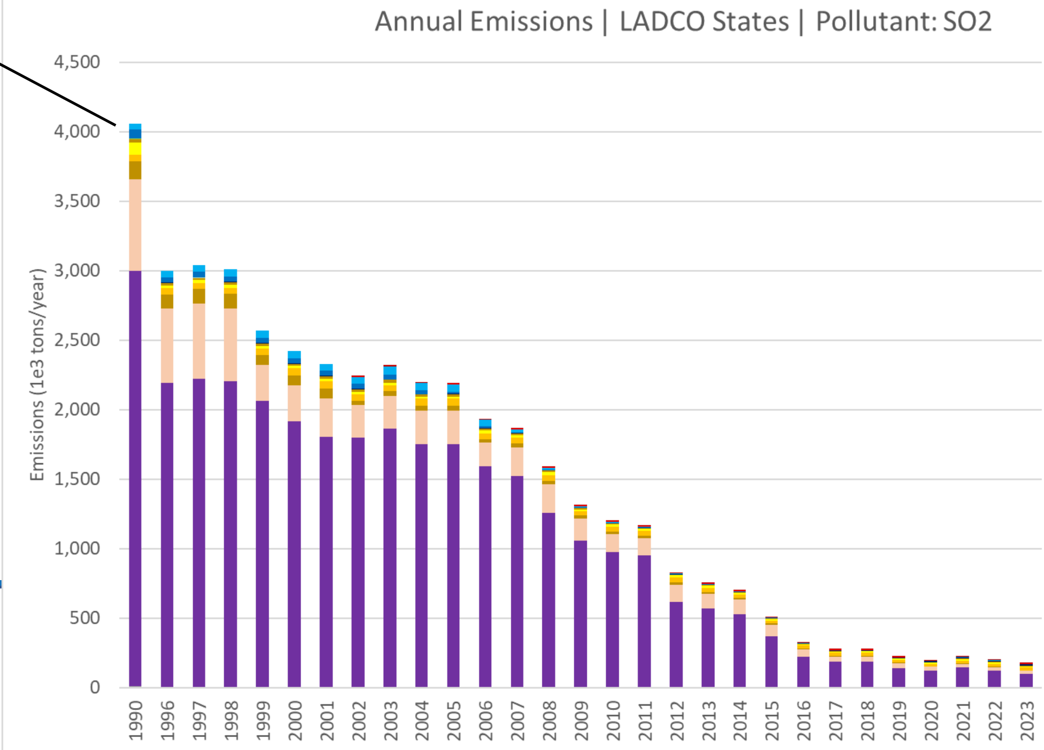
Trends over time: Summer Speciated $PM_{2.5}$



- Similar trends to in the North
- Even larger reductions in AmmSO4 than in the north

See Appendix for trends by species



- AmmSO4 follows similar trends to SO_2 emissions
  - Doesn't track flat NH_3 emissions
- Similar size decrease to SO_2 emissions

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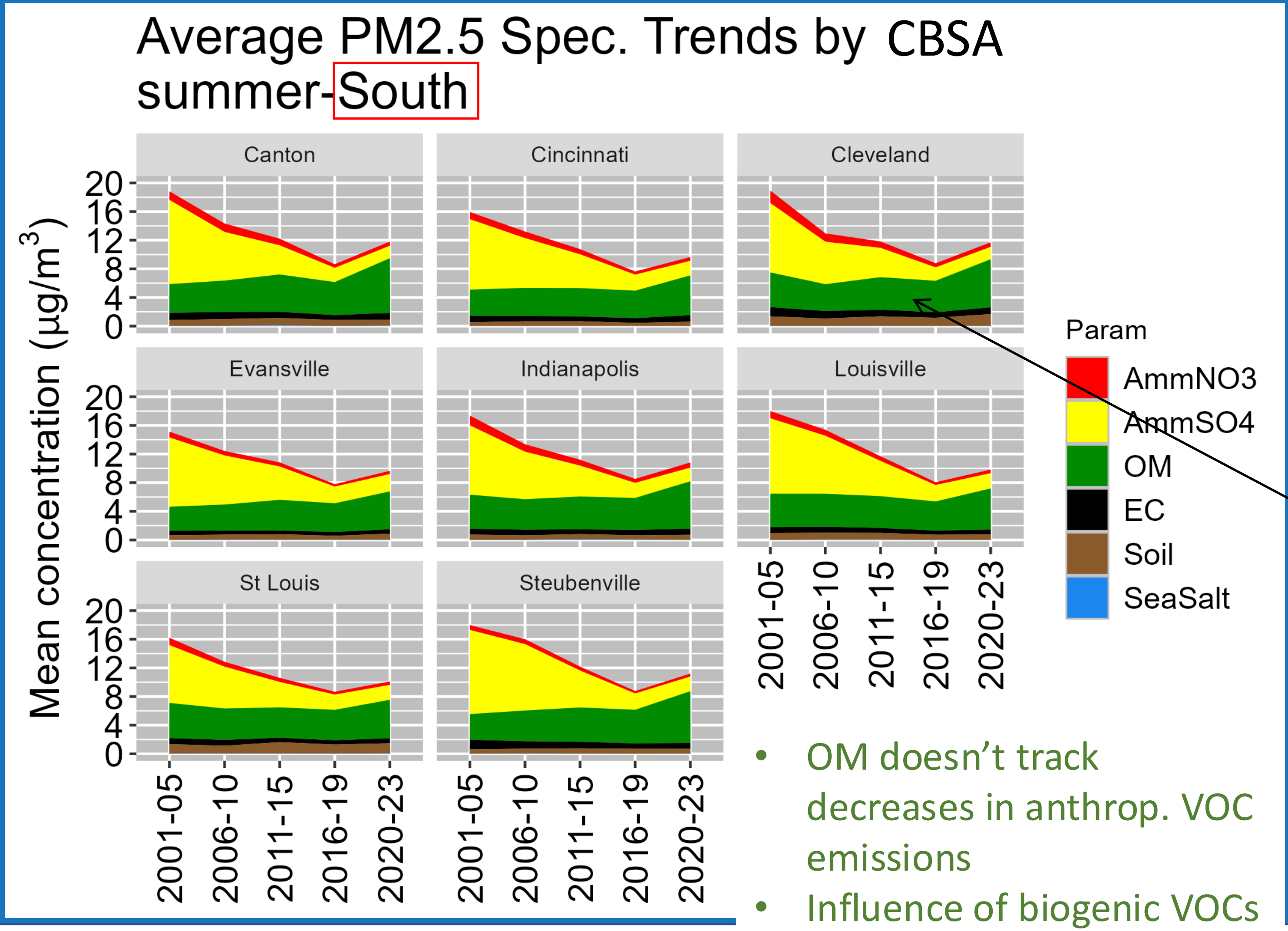
Trends over time: Summer Speciated $PM_{2.5}$



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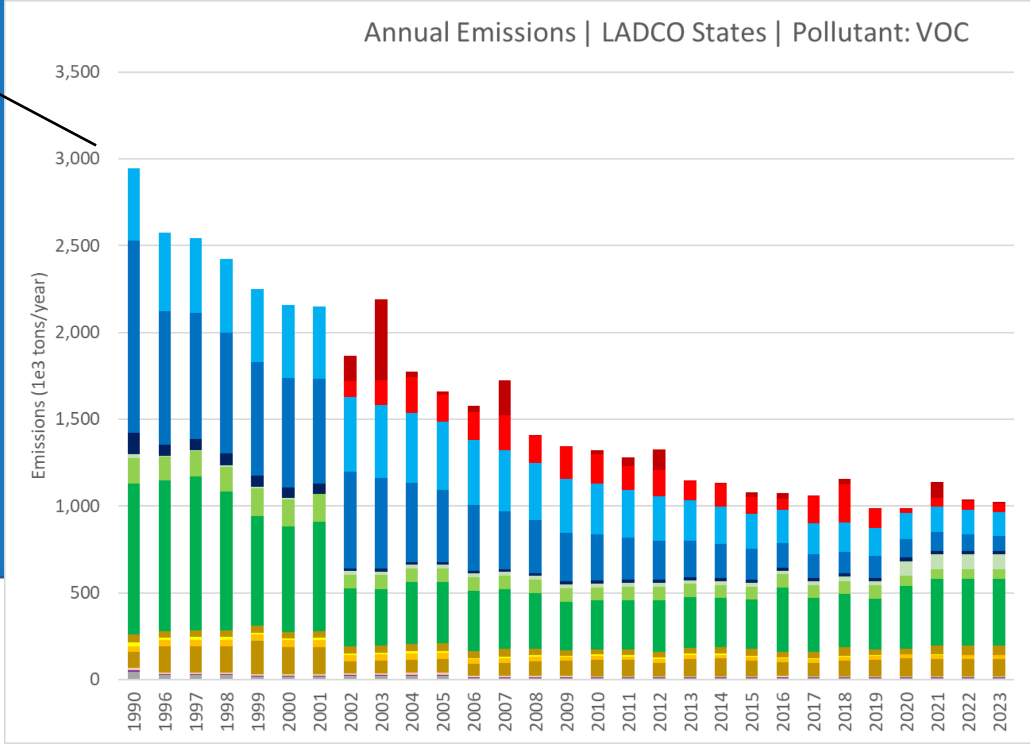

- OM doesn't track decreases in anthrop. VOC emissions
- Influence of biogenic VOCs & smoke

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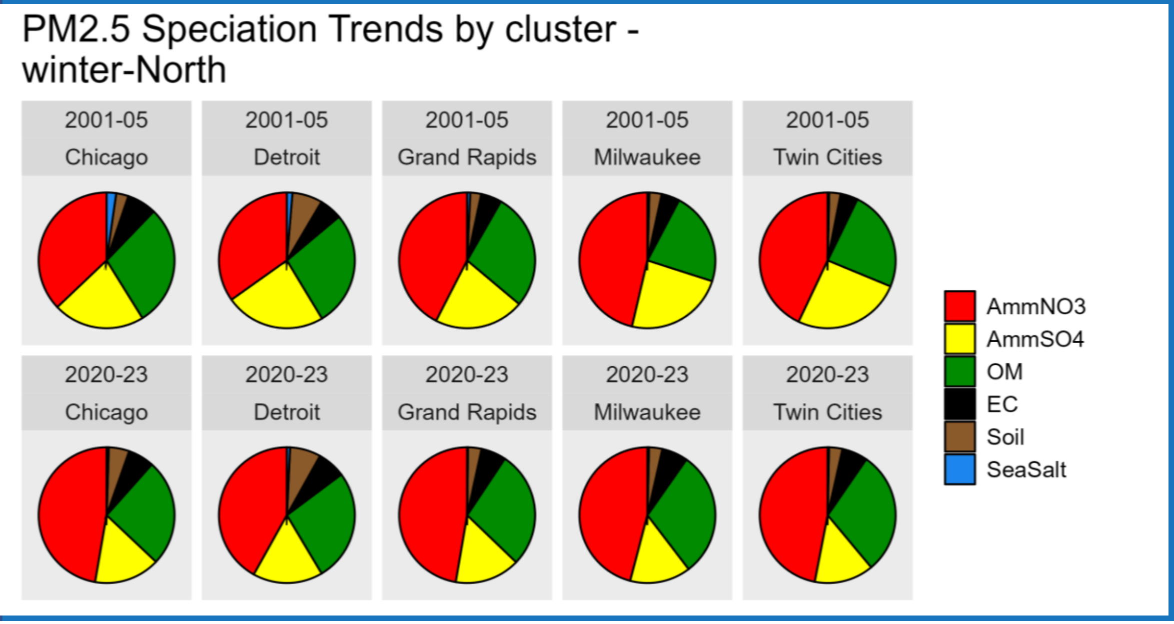
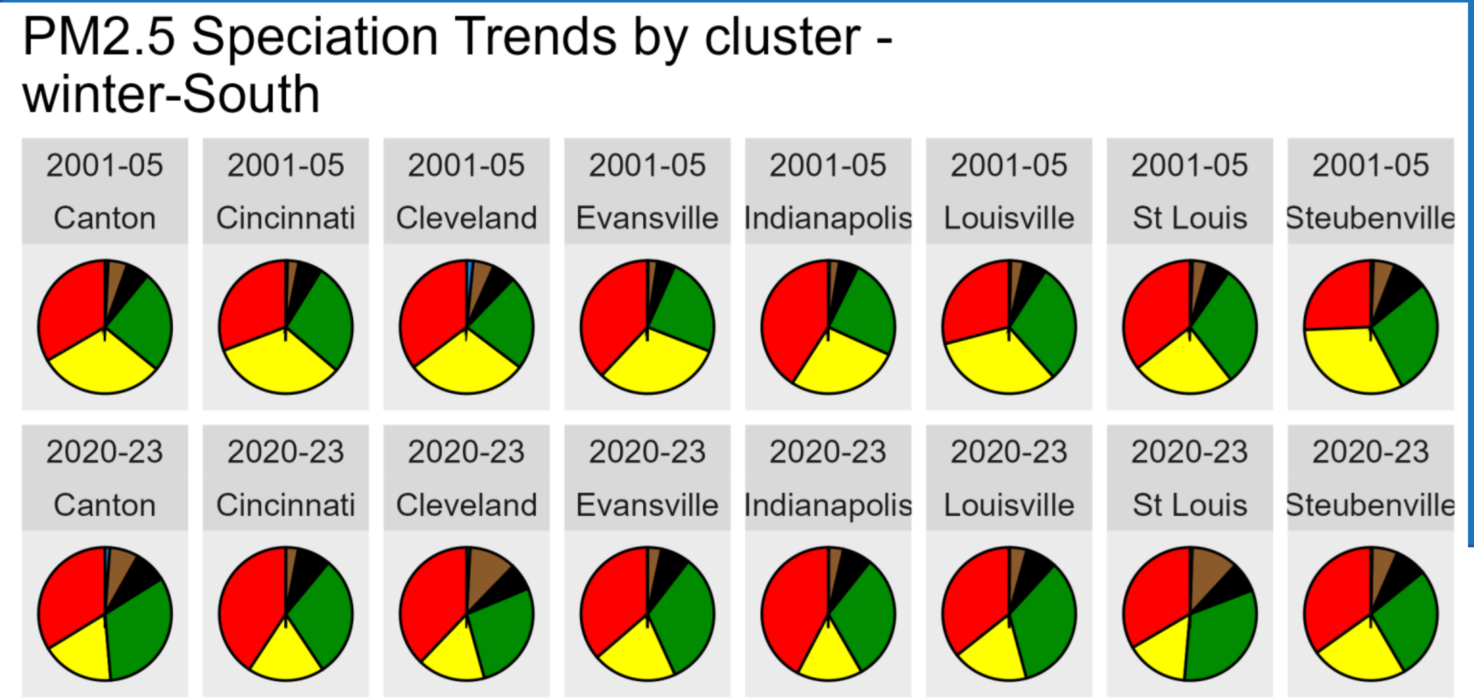
Trends over time Summary





- Winter composition isn't that different
    - Relatively more AmmNO3 and less AmmSO4

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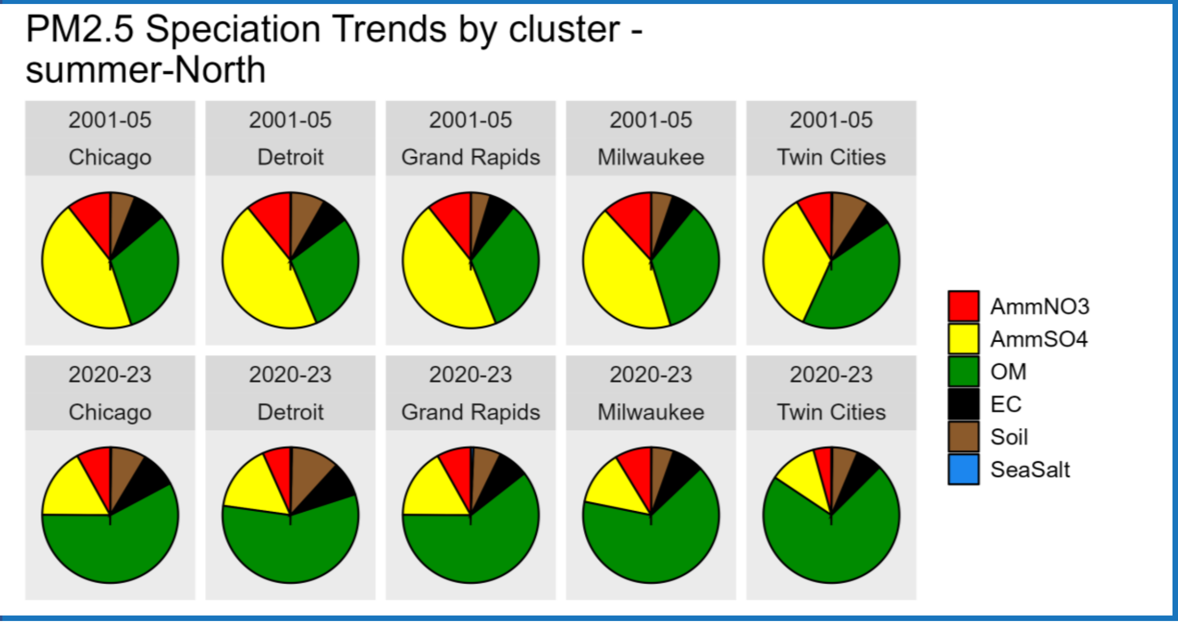
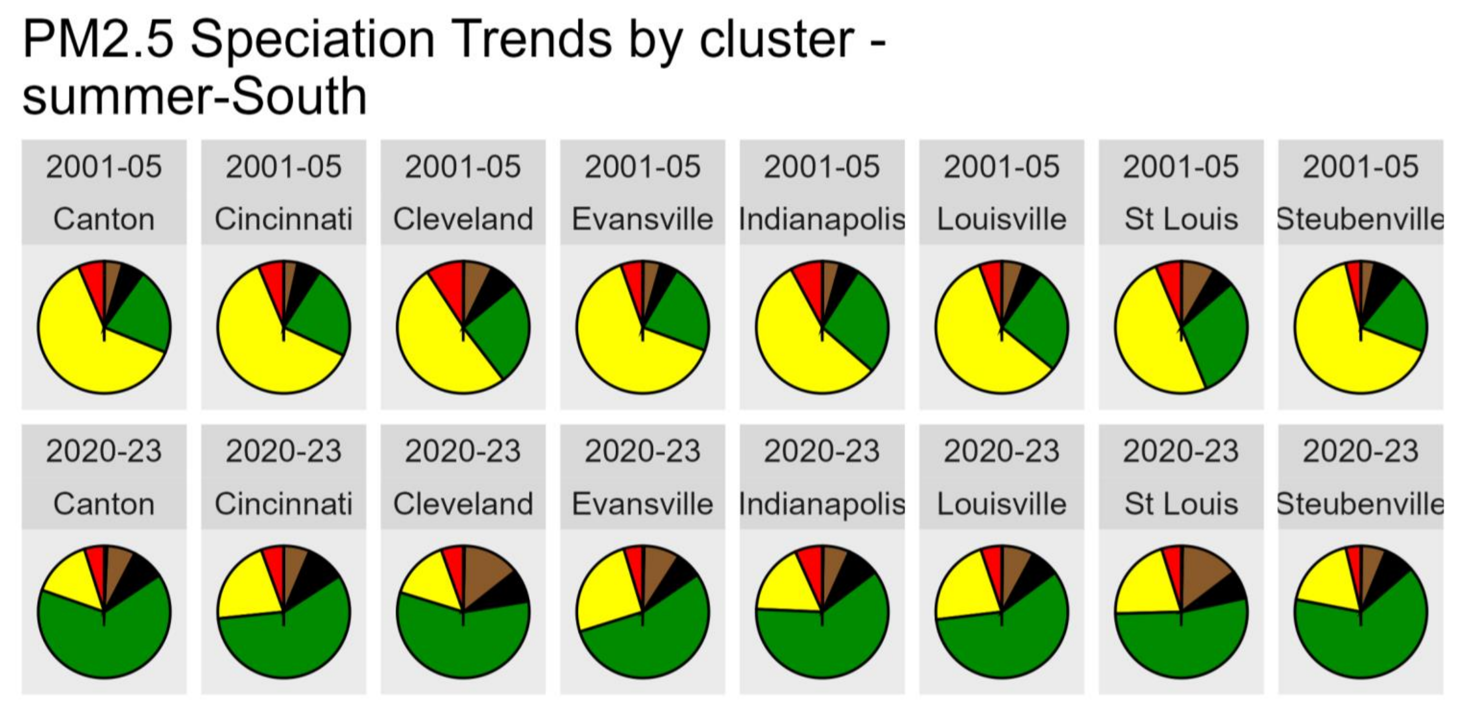
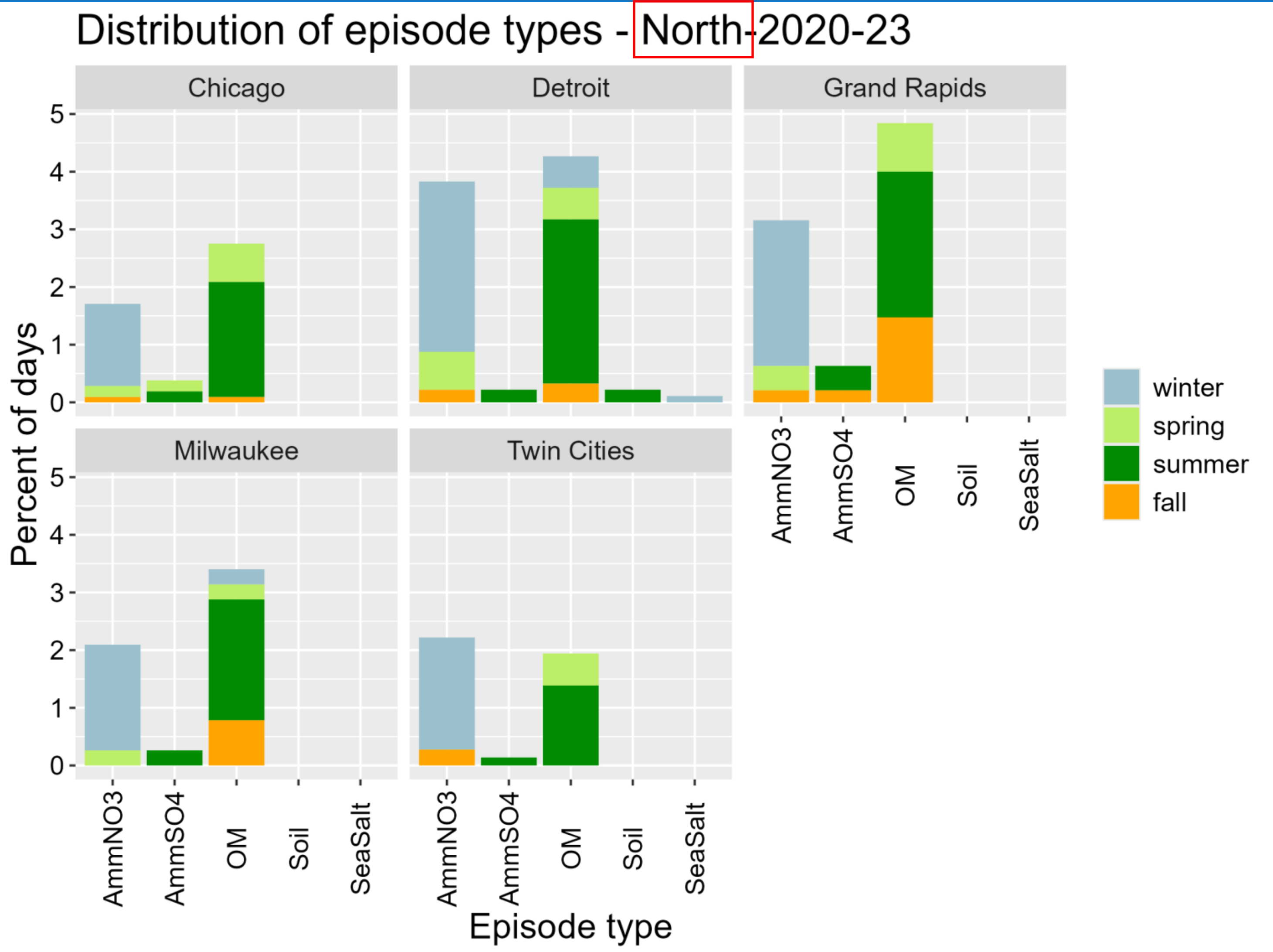
Trends over time Summary





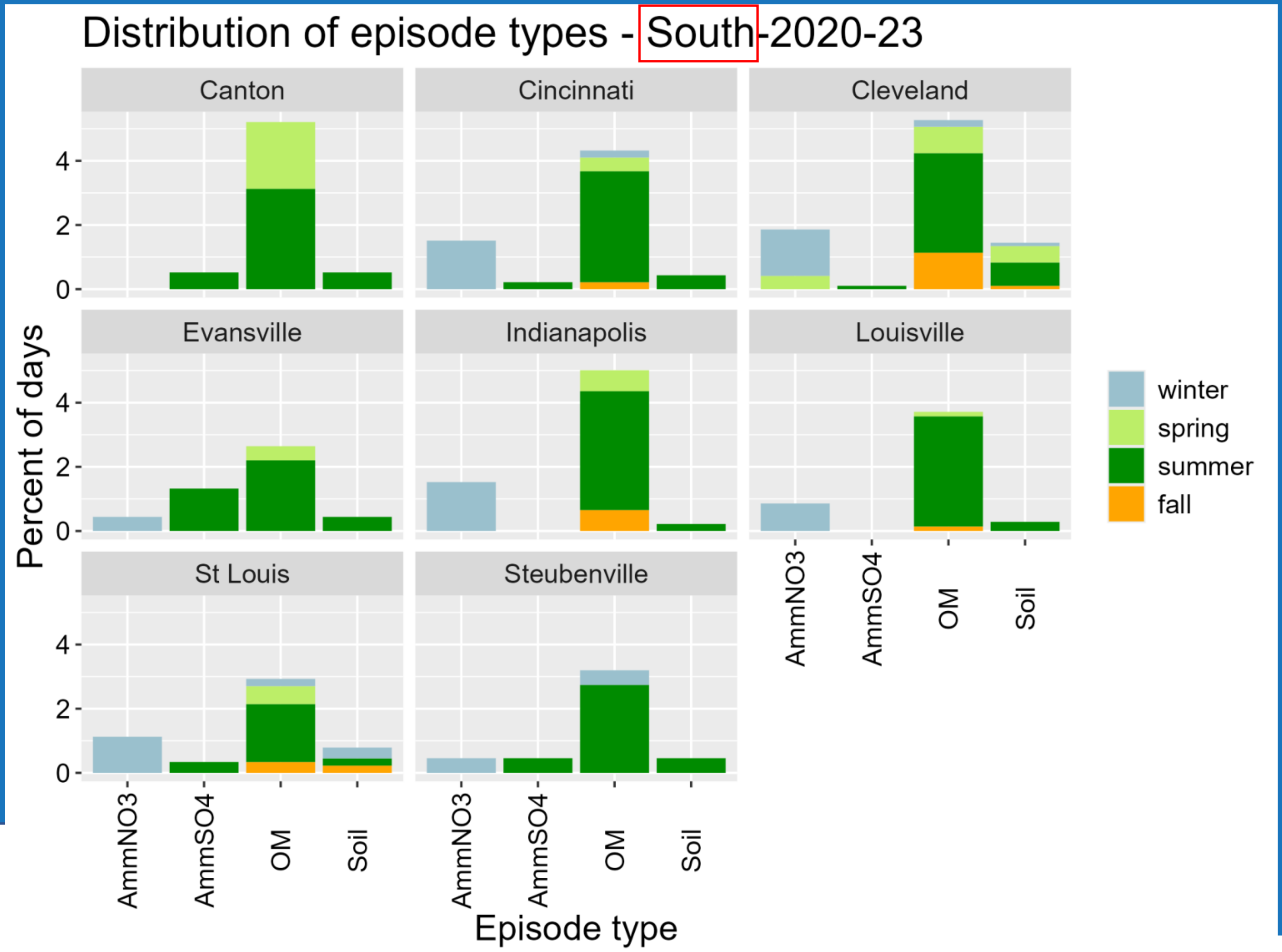
- Summer composition is very different
  - Much less AmmSO4 and much more OM (relatively)
    - OM concentrations actually roughly steady but other components have decreased

Drivers of $PM_{2.5}$ Episodes



- Episodes = days with 24-hour $PM_{2.5}$ > 17.5 ug/m^3 (half the daily NAAQS)
  - Look at major component on episode days
- Current period:
  - Winter AmmNO3 and summer OM events are important in all areas
  - More OM events than AmmNO3 events → smoke?
    - Will look into this
- → Controlling winter AmmNO3 will be important!
  - Likely an easier target than OM, which is impacted by biogenic emissions as well as smoke

Drivers of $PM_{2.5}$ Episodes

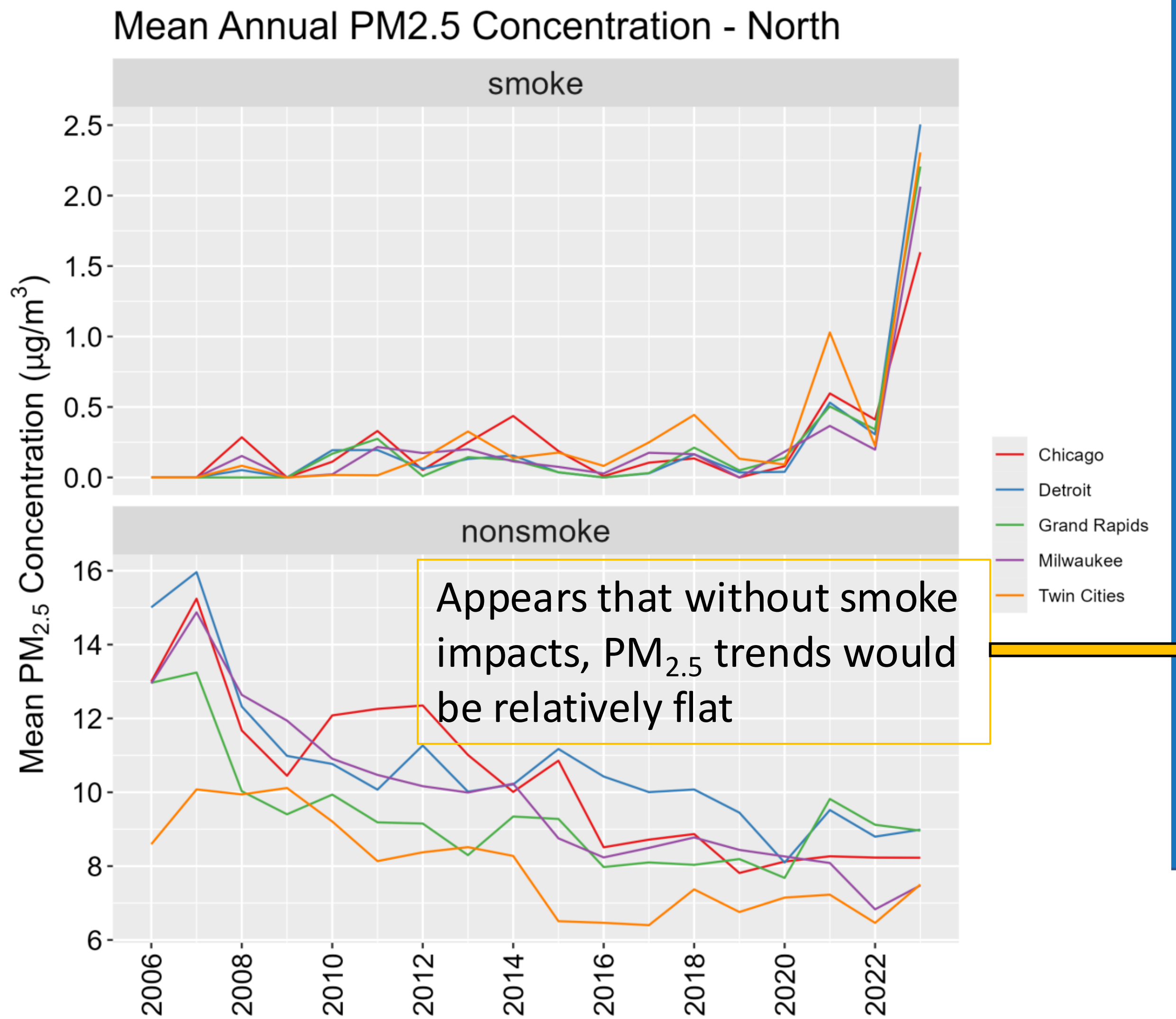


- Current period:
  - Most episodes are summer OM
  - Winter AmmNO3 contributes in almost all areas
  - AmmSO4 still contributes

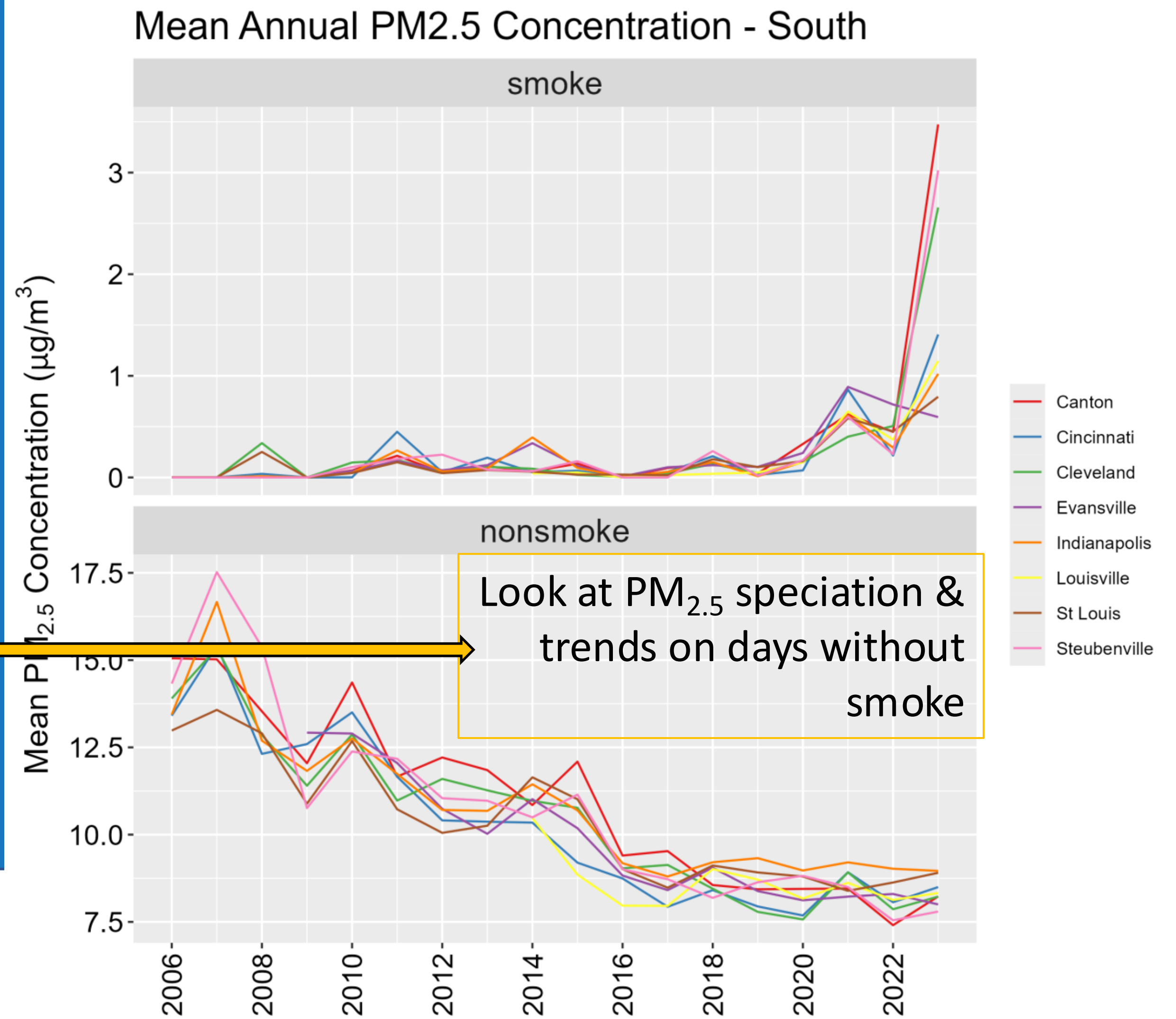
Smoke Impacts

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*



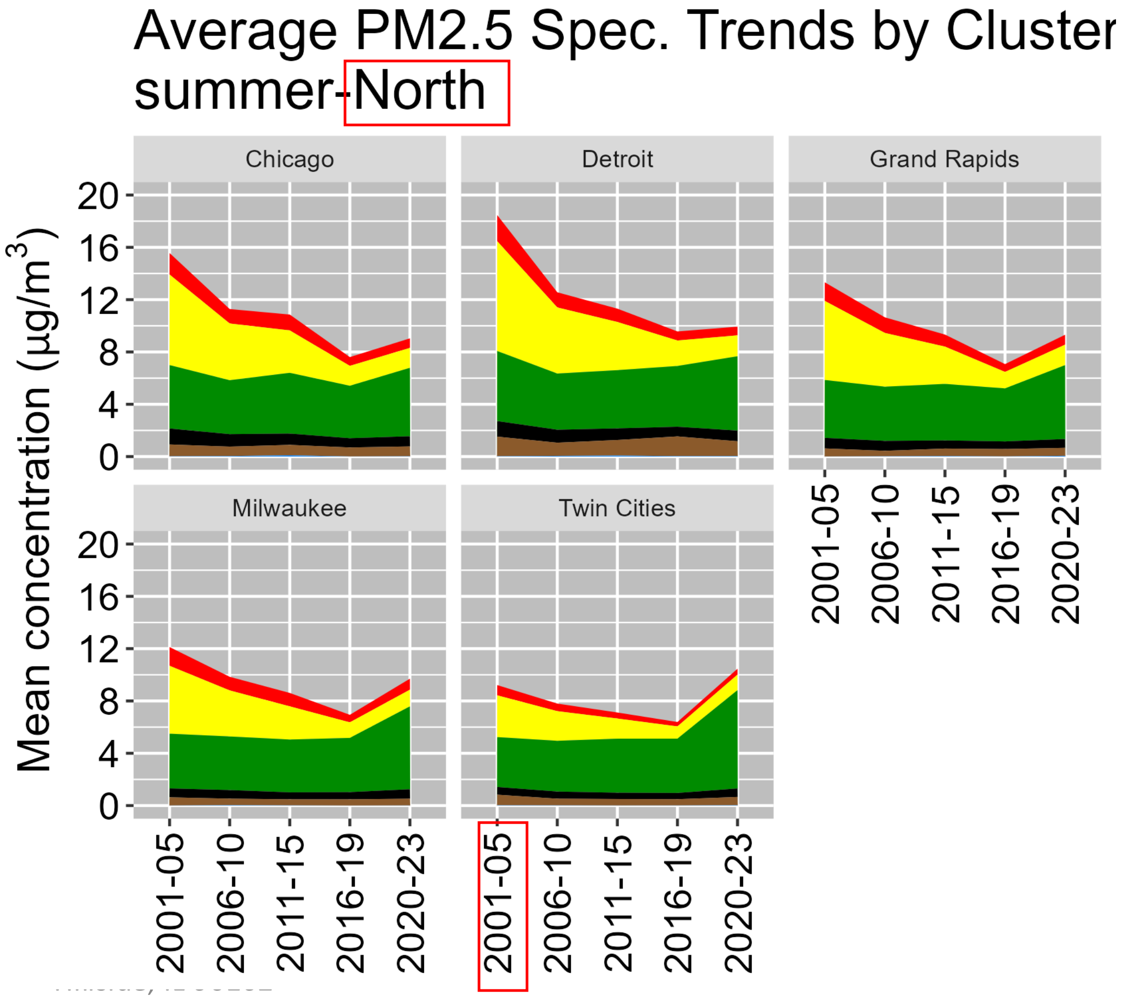
Appears that without smoke impacts, $PM_{2.5}$ trends would be relatively flat

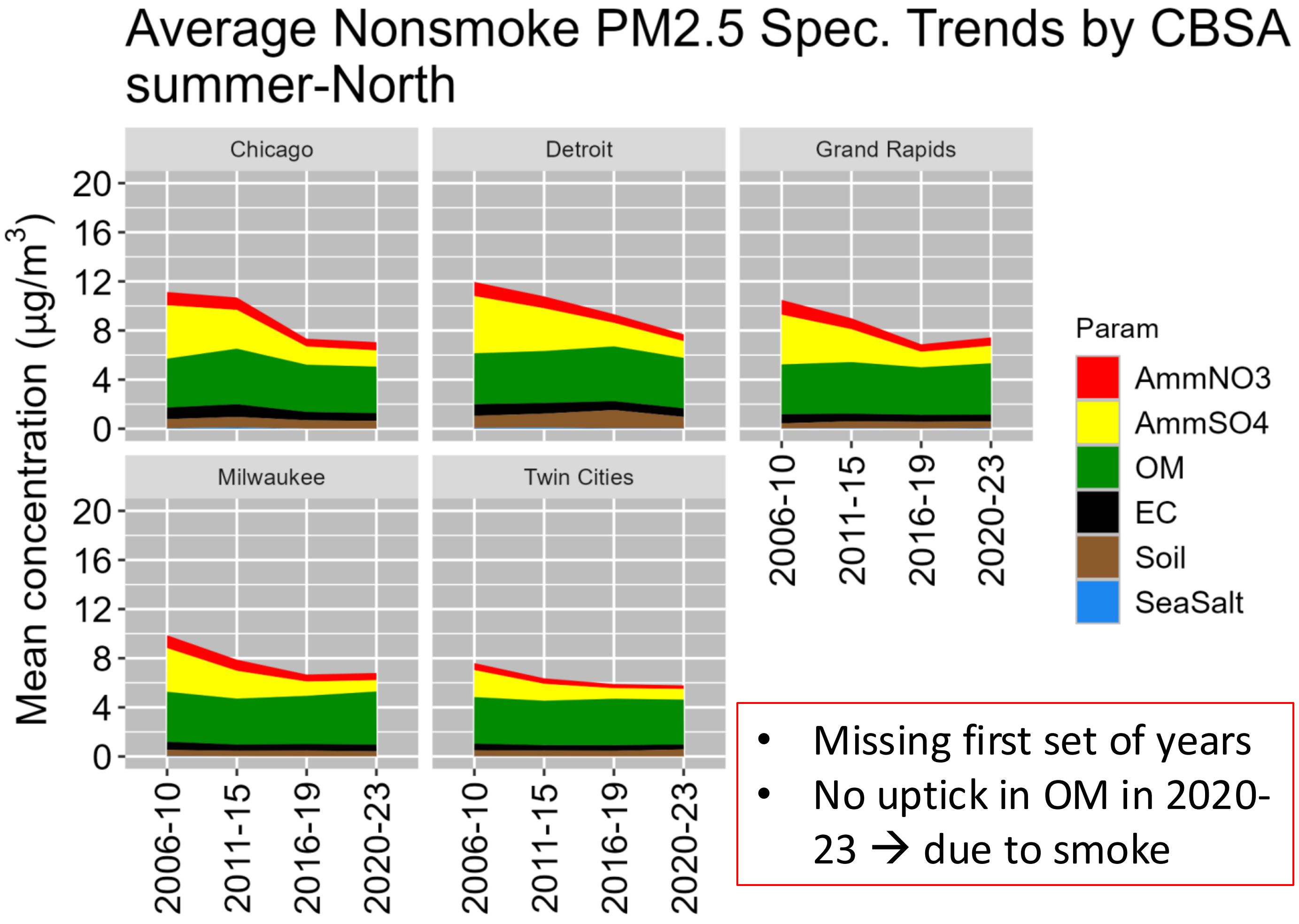


Look at $PM_{2.5}$ speciation & trends on days without smoke

Smoke Impacts

All Days → **Smoke-Free Days Only**

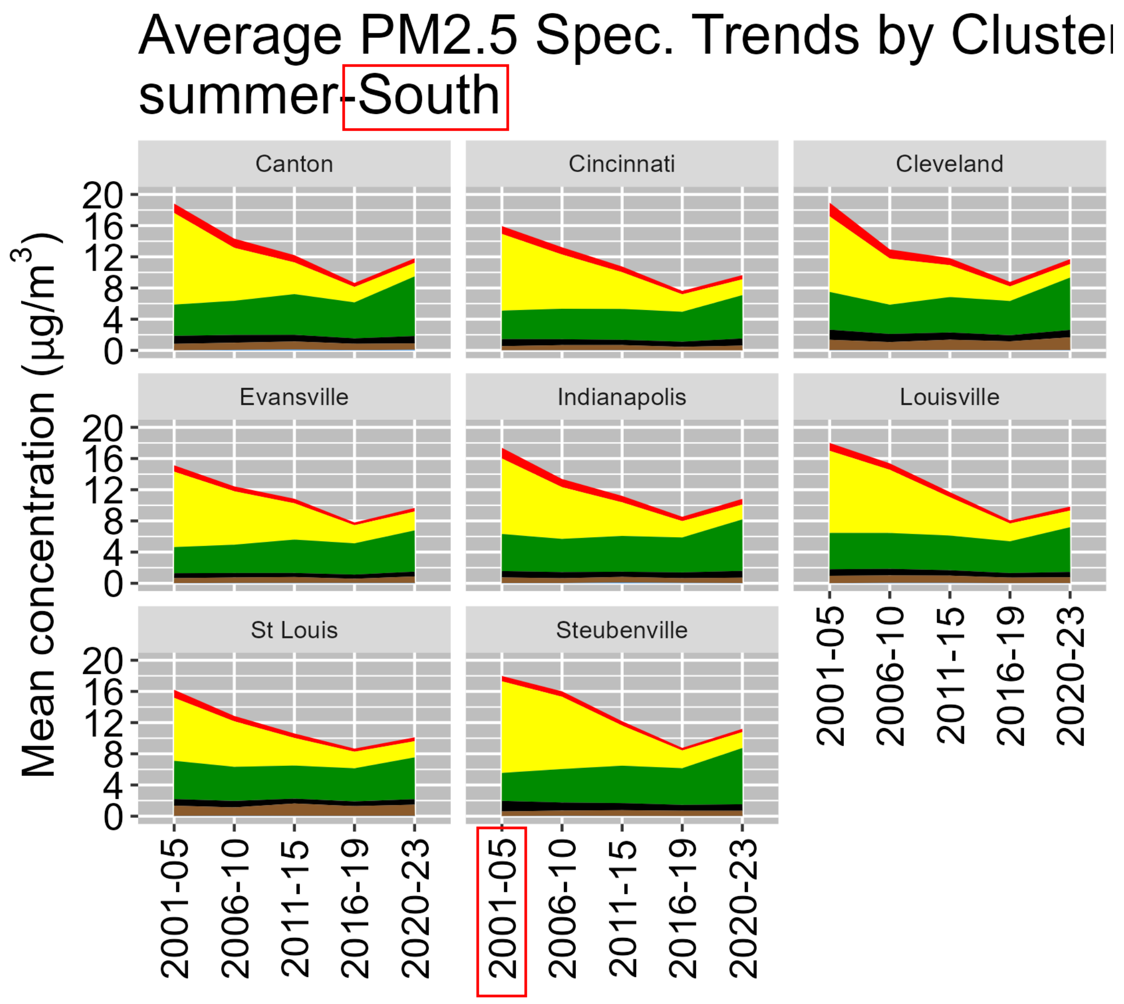


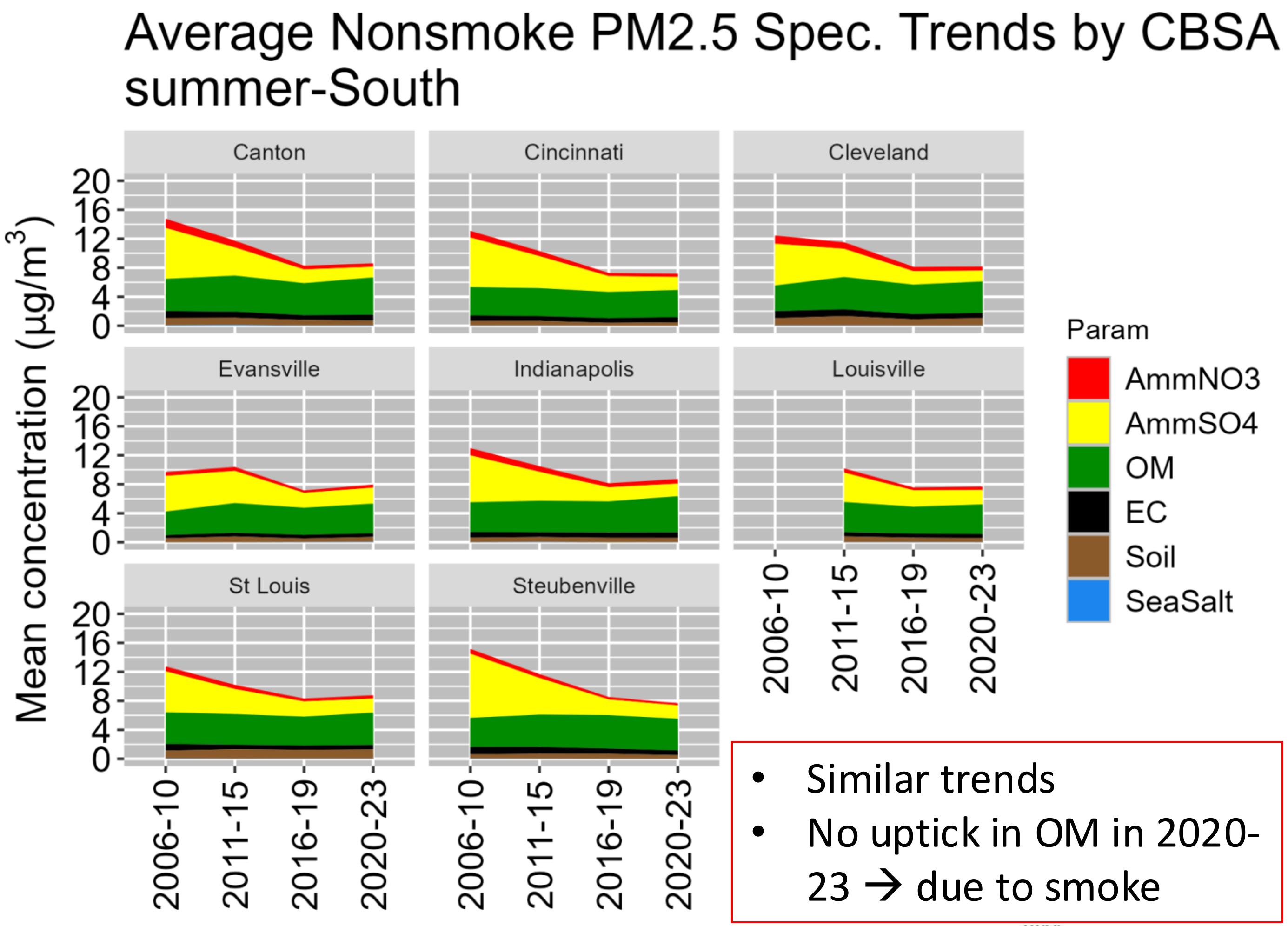


- Missing first set of years
- No uptick in OM in 2020-23 → due to smoke

Smoke Impacts

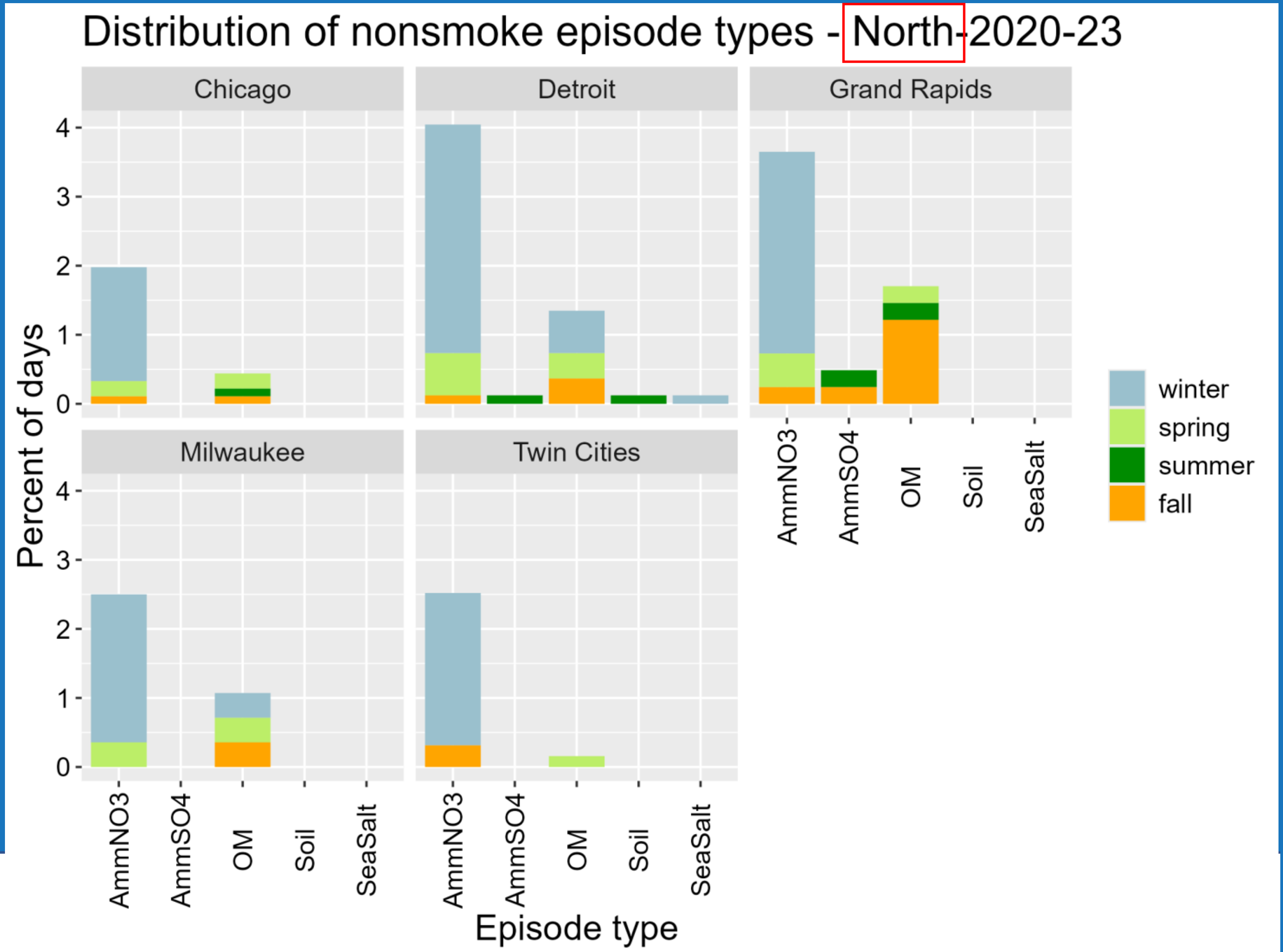
All Days → **Smoke-Free Days Only**





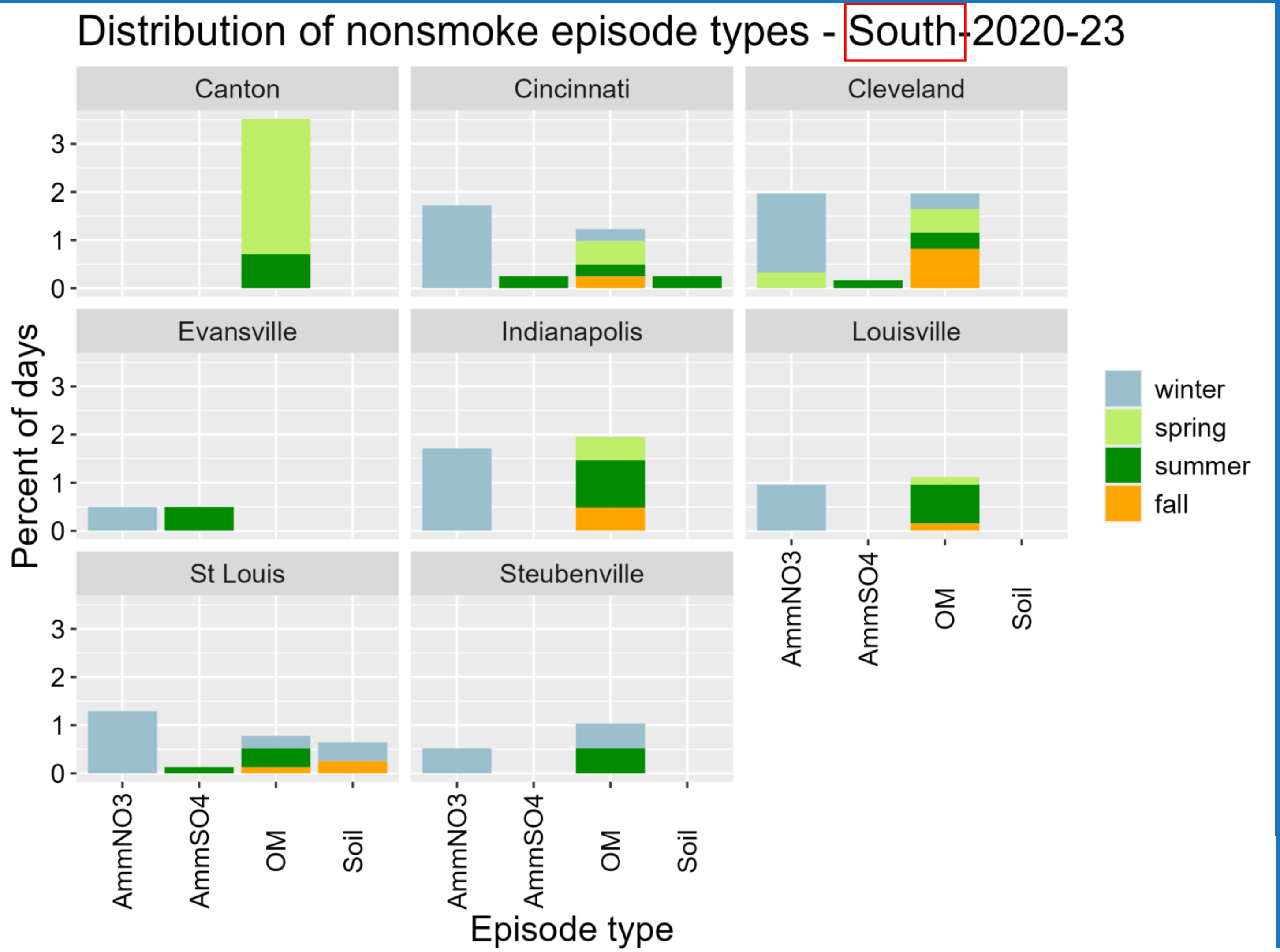
- Similar trends
- No uptick in OM in 2020-23 → due to smoke

Drivers of $PM_{2.5}$ Episodes on Nonsmoke Days



- On days without smoke:
  - Winter AmmNO3 is responsible for most of the episodes
  - OM still contributes
    - From many seasons, not just summer
- → Demonstrates that winter AmmNO3 is the dominant controllable type of $PM_{2.5}$ in the north

Drivers of $PM_{2.5}$ Episodes on Nonsmoke Days



- On days without smoke:
  - Roughly evenly split between winter AmmNO3 and OM (all seasons) in most areas
- → AmmNO3 is also important in the south

Important question: What is controlling winter Ammonium Nitrate?

- Can be sensitive to either ammonia or nitrate (NOx emissions)
  - Impacts what emissions controls will lower $PM_{2.5}$
- Initial analysis suggests it's nitrate-sensitive (NOx-sensitive)
  - Suggests controlling winter NOx emissions is the best route to lower winter $PM_{2.5}$
  - Consistent with findings in other parts of the country
- Will continue to explore this question

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Future work

- Read more of the scientific literature & past regional studies
- Explore meteorological drivers of $PM_{2.5}$ formation/transport
  - Apply CART and/or GAM
- Examine impacts of past emissions controls on $PM_{2.5}$ concentrations and composition

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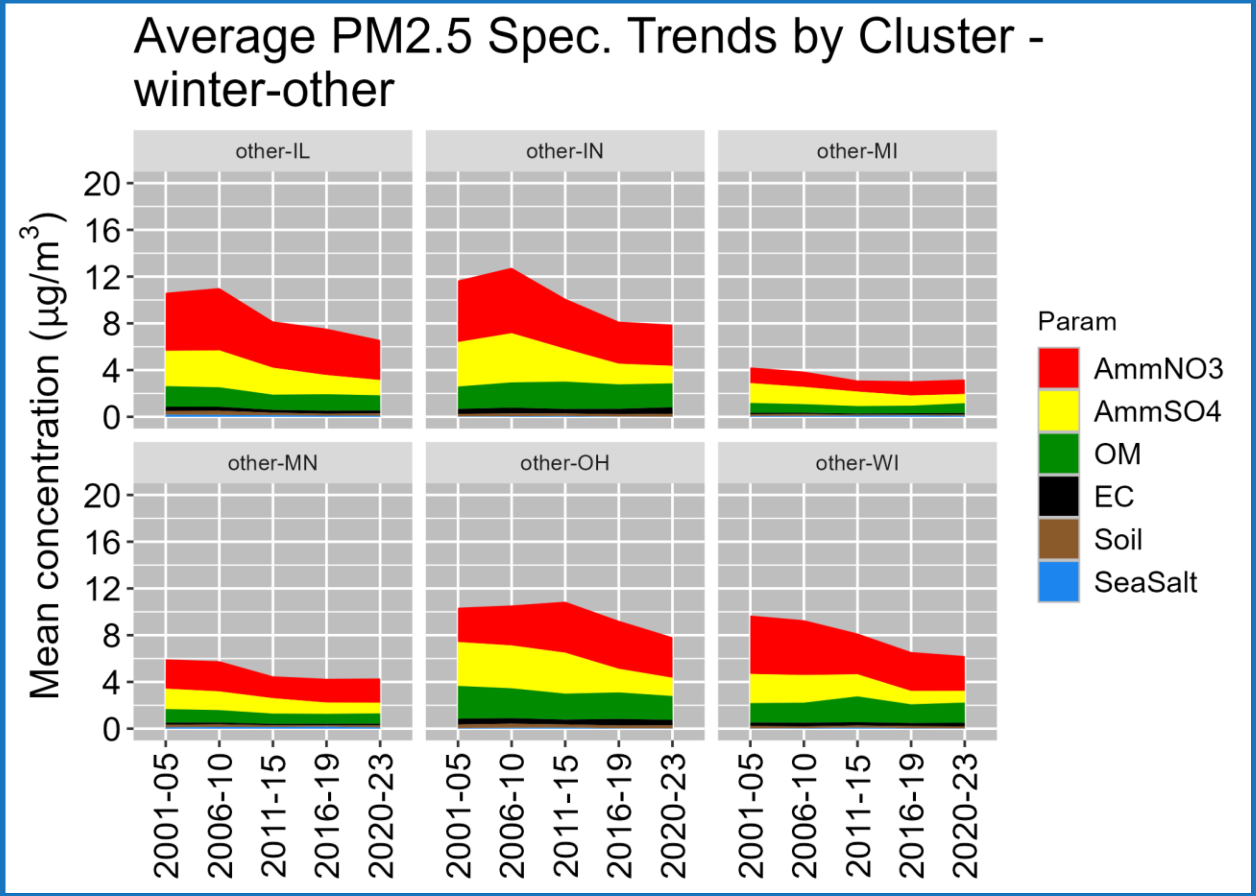
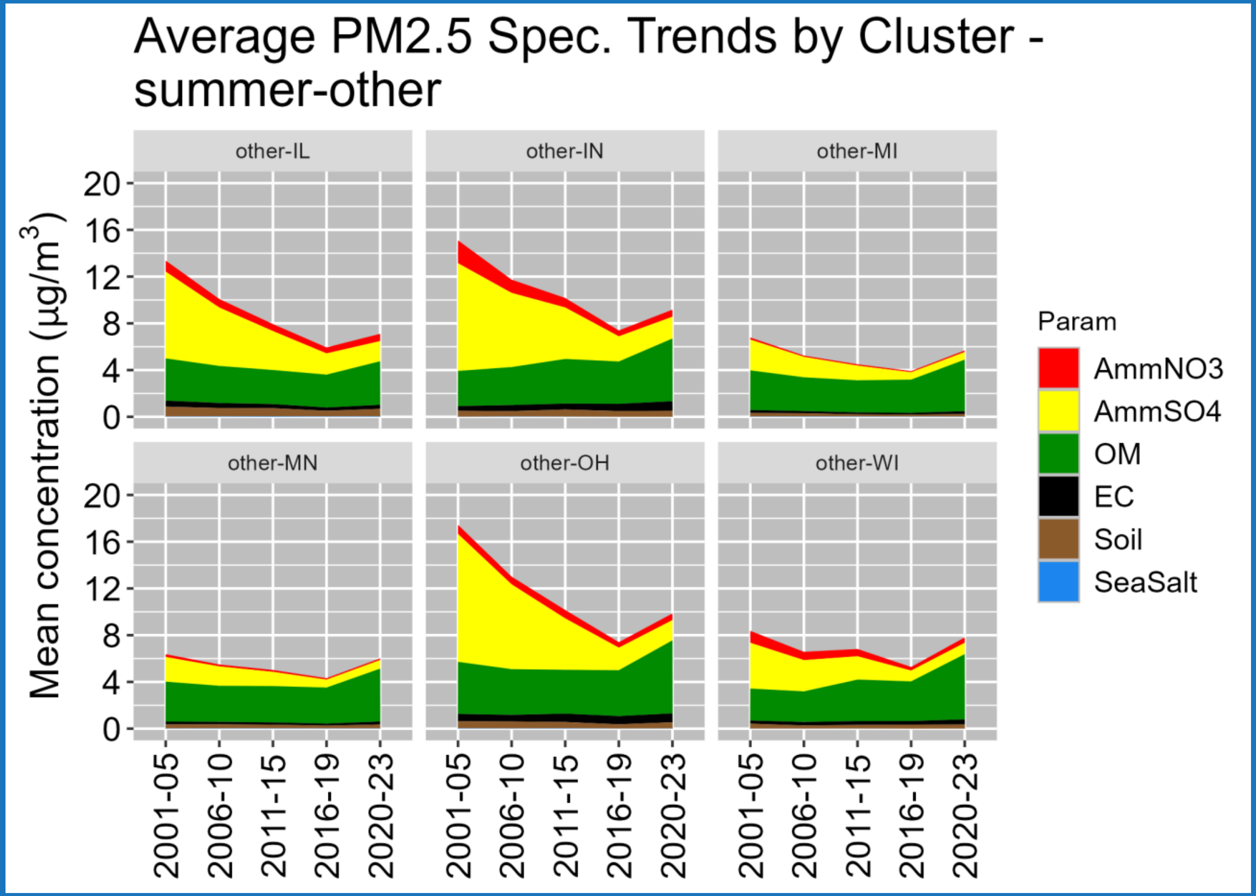
Thank you!

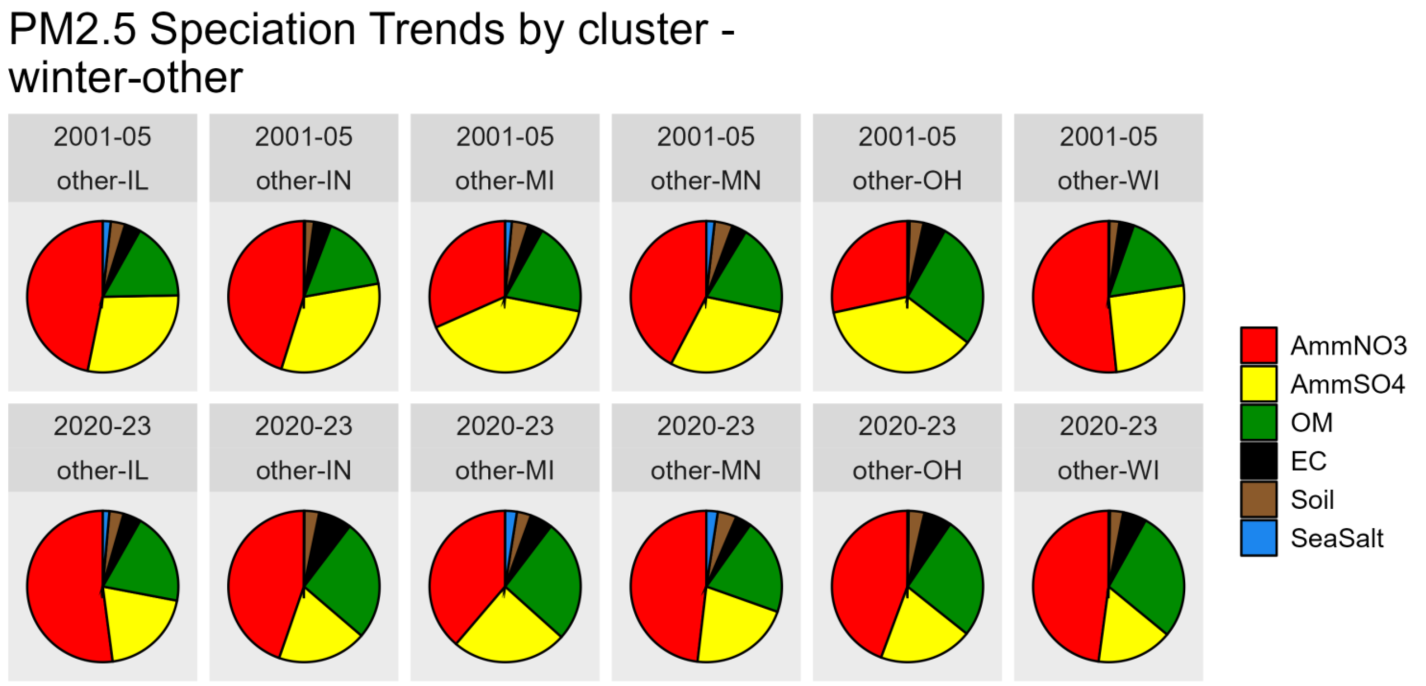
Questions?

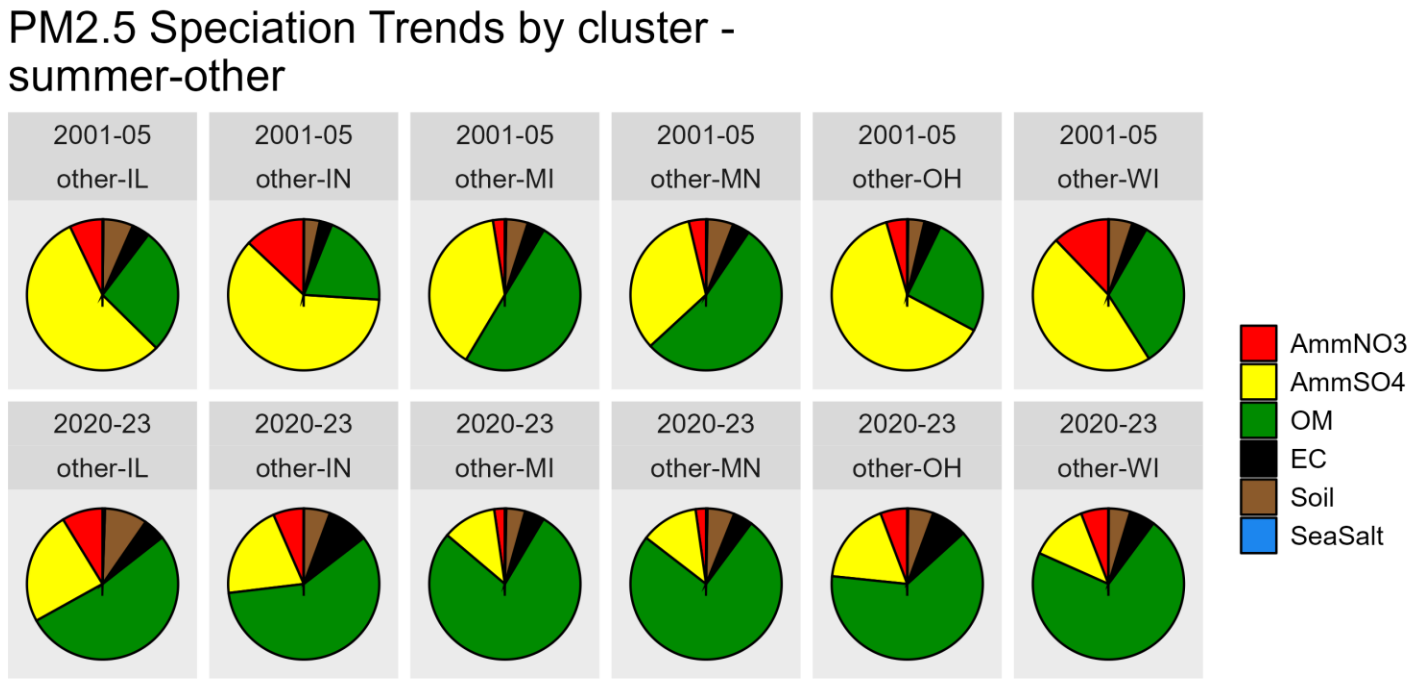
Trends over time: Speciated $PM_{2.5}$ – Other Areas





Trends over time: Speciated $PM_{2.5}$ – Other Areas





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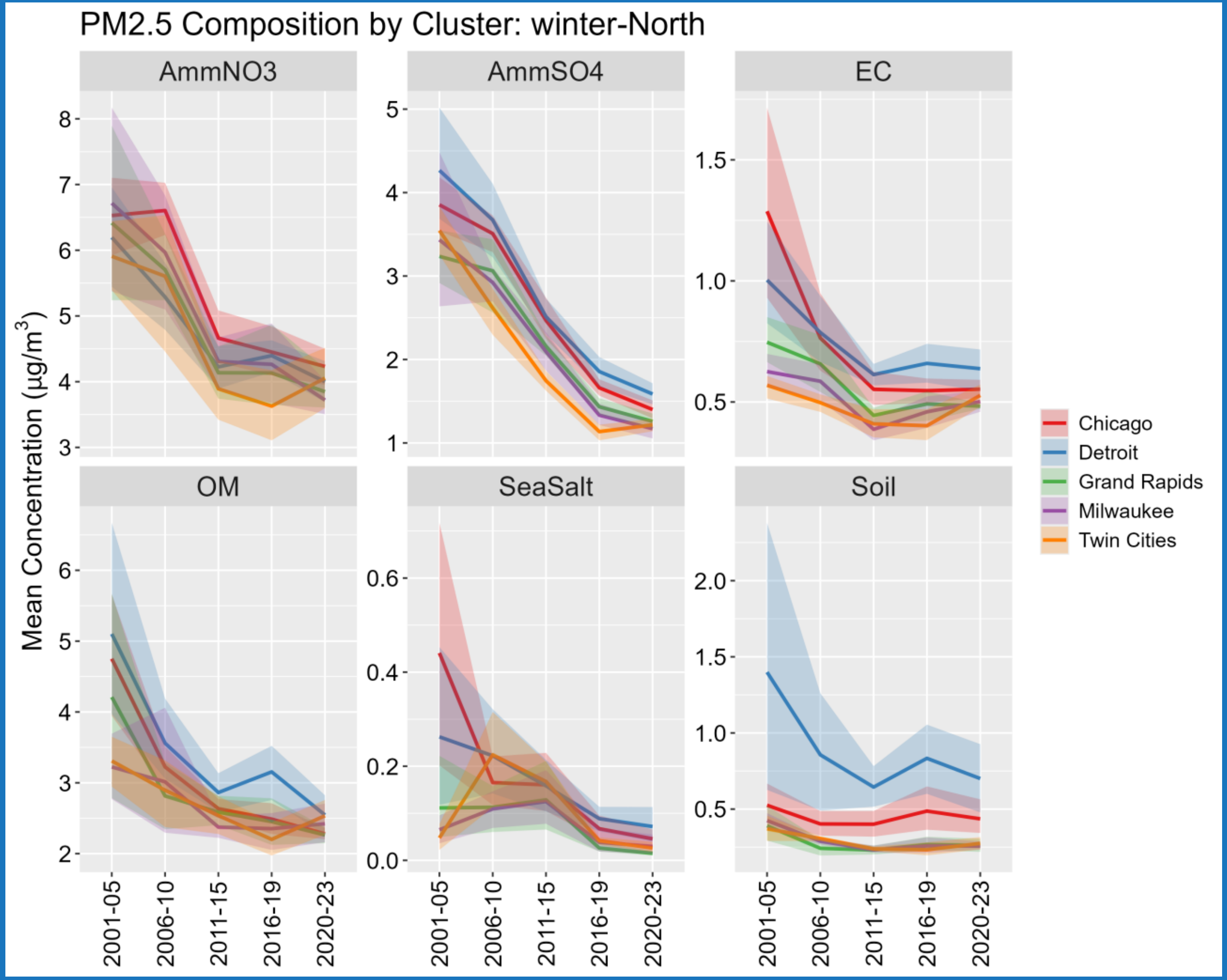
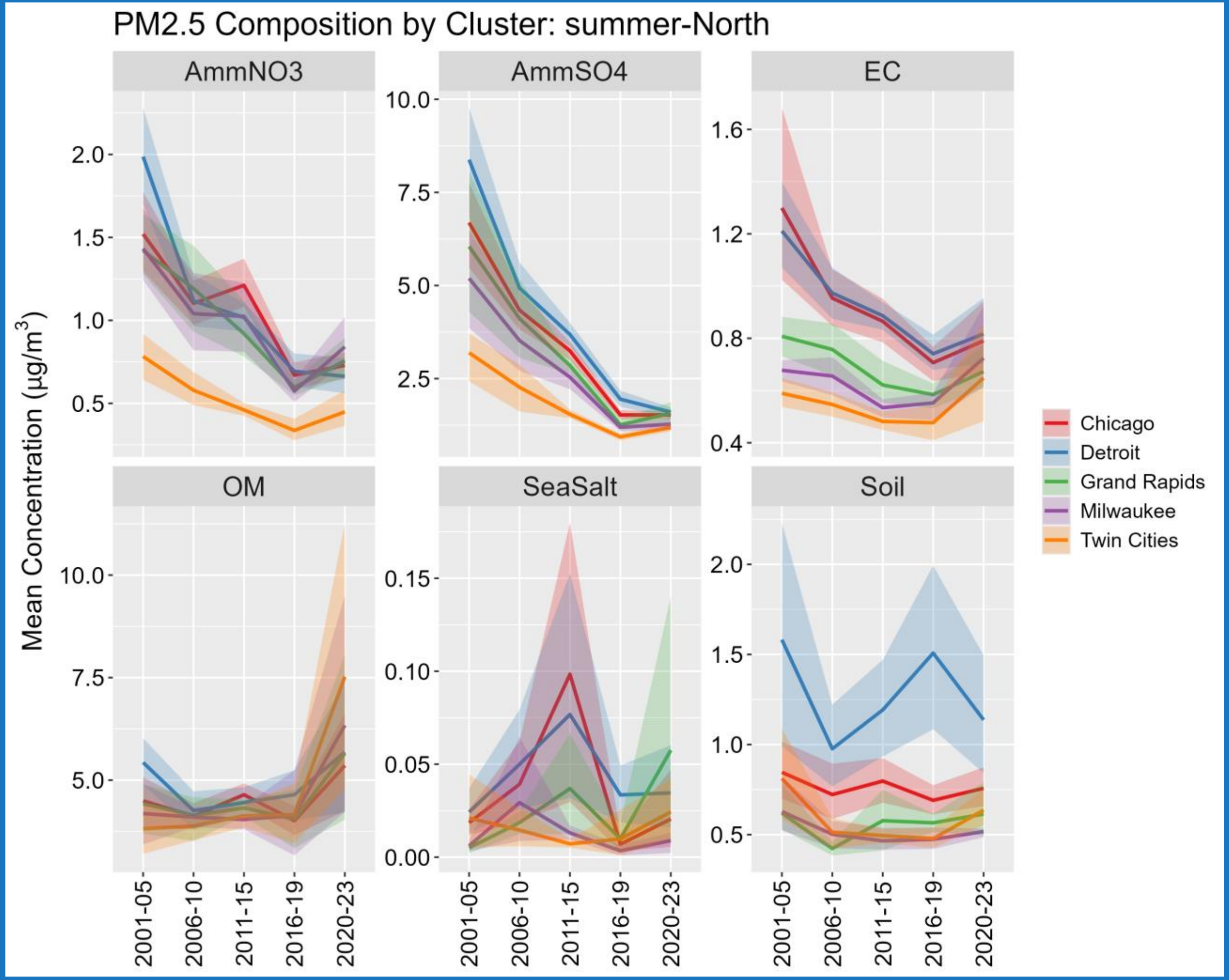
Trends over time: Individual Species





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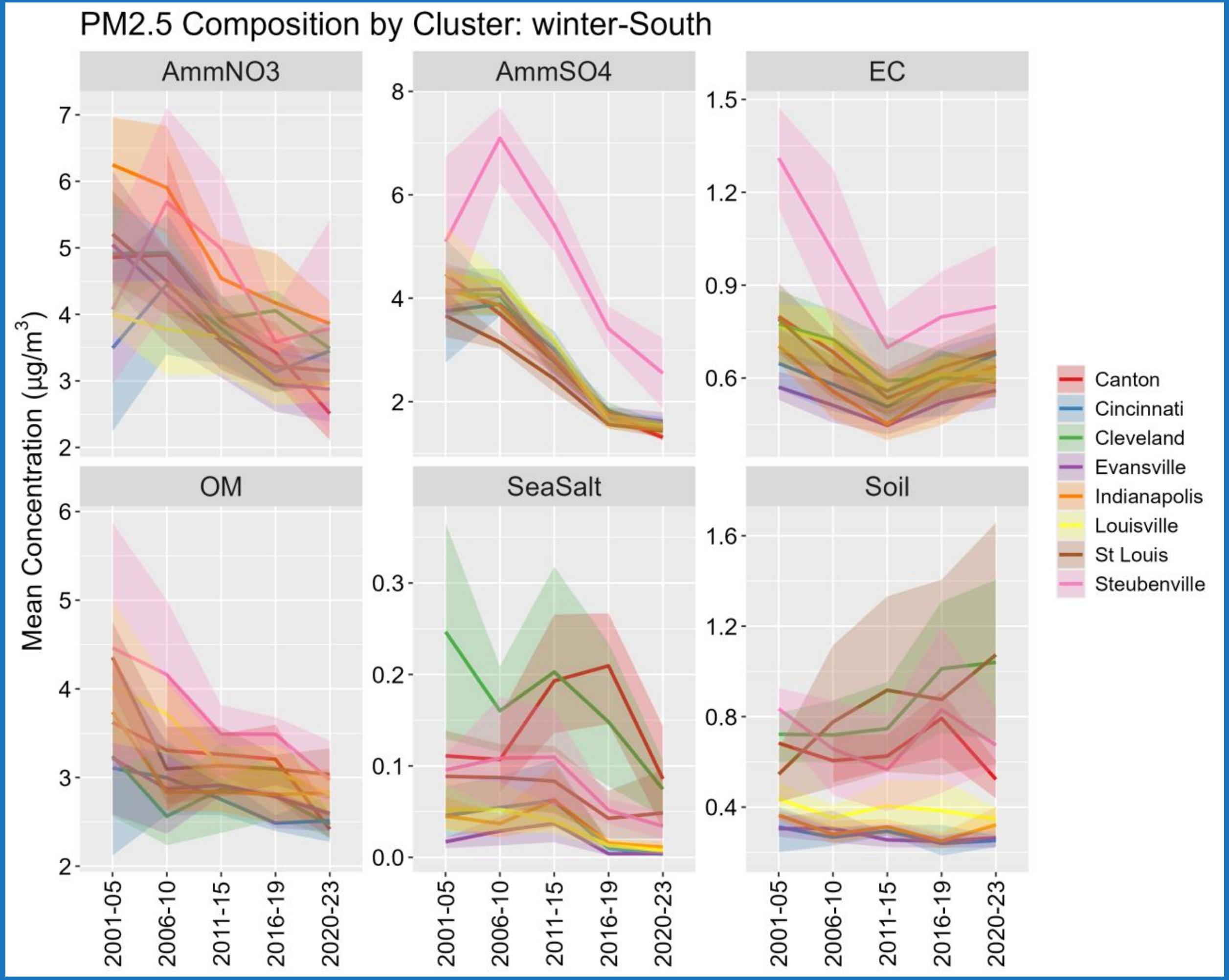

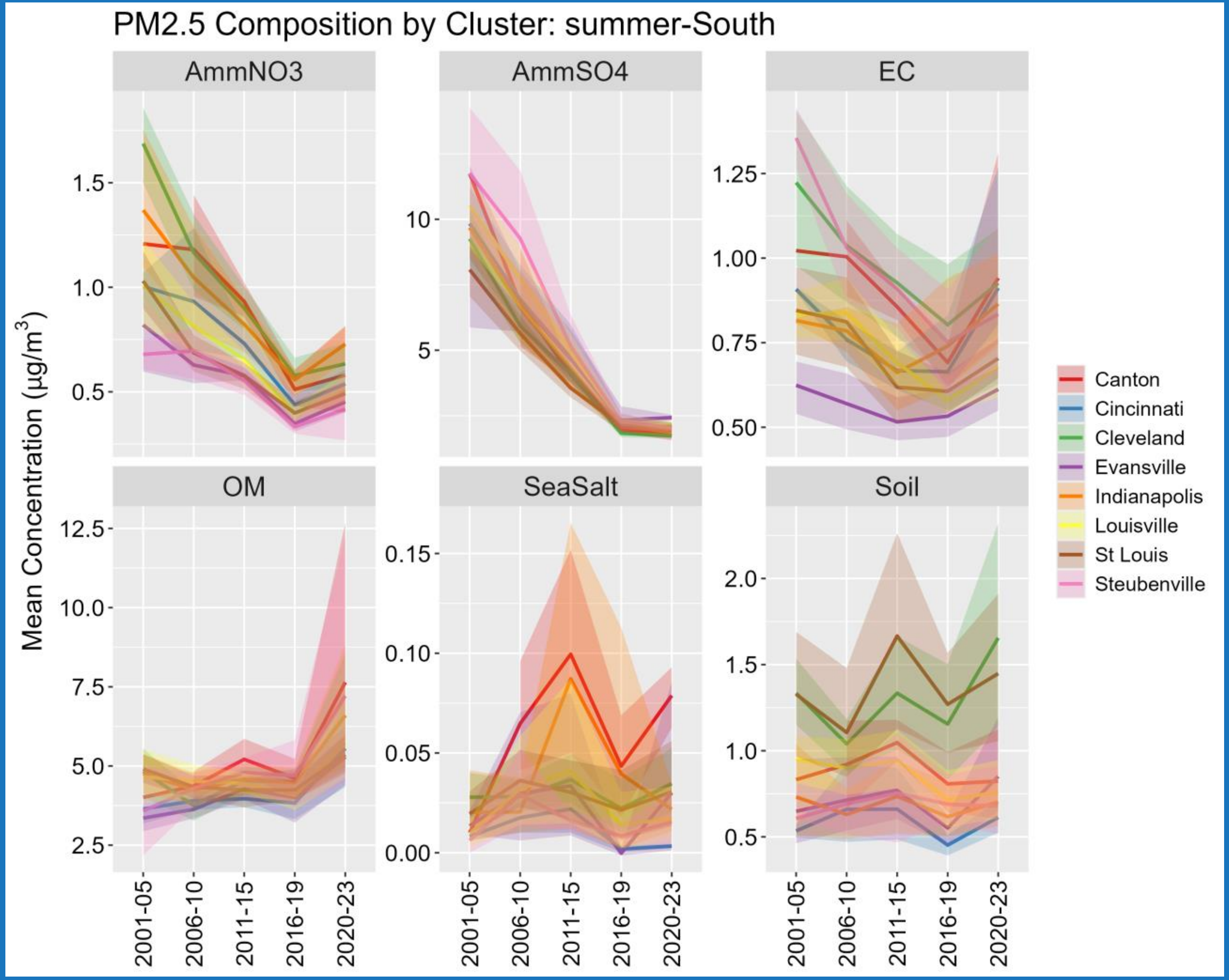

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Trends over time: Individual Species