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Mercury Deposition in the Great Lakes Region

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MPCA 2023 Statewide Mercury TMDL Meeting
September 21, 2023

wq-iw4-02k7

LADCO Report on Mercury

- Technical report: Mercury Deposition in the Great Lakes
  - Released June 2023
  - https://www.ladco.org/wp-content/uploads/Projects/Mercury/Mercury-deposition-in-the-Great-Lakes-Report-2023_FINAL-CLEAN.pdf
- Examines amounts and trends in wet and dry (litterfall) deposition of mercury in the Great Lakes states
  - MN, WI, MI, IL, IN, OH
  - Also looks at emissions trends and trends in atmospheric concentrations (where available)
  - Based on data from the National Atmospheric Deposition Program (NADP)
  - Interprets data using published research studies

Outline

- The mercury cycle and monitoring networks
- Mercury emissions trends
- Atmospheric mercury concentrations
- Mercury deposition trends
  - Wet deposition
  - Dry deposition (litterfall)
- Insights into sources of mercury in the region

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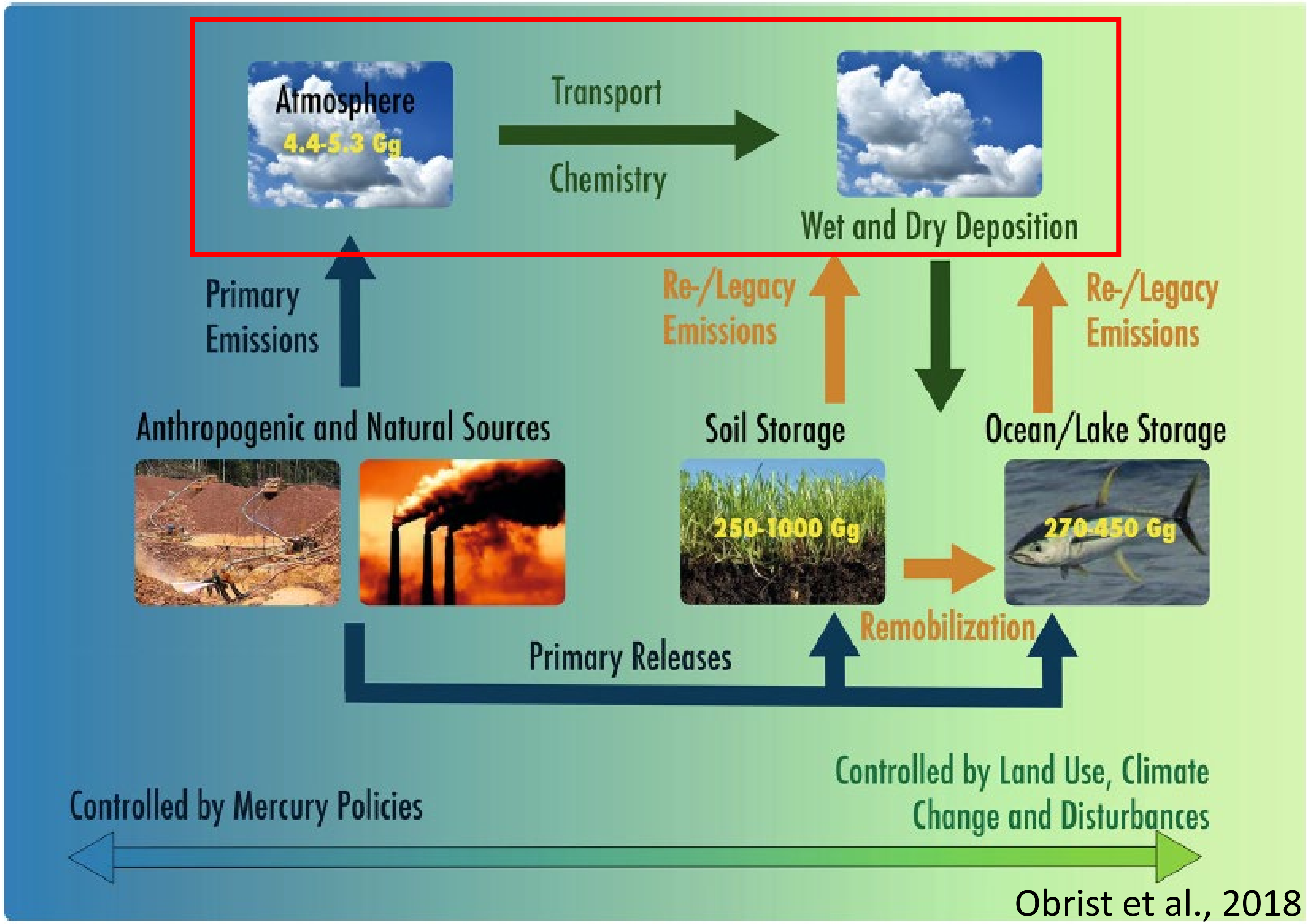
The Mercury Cycle



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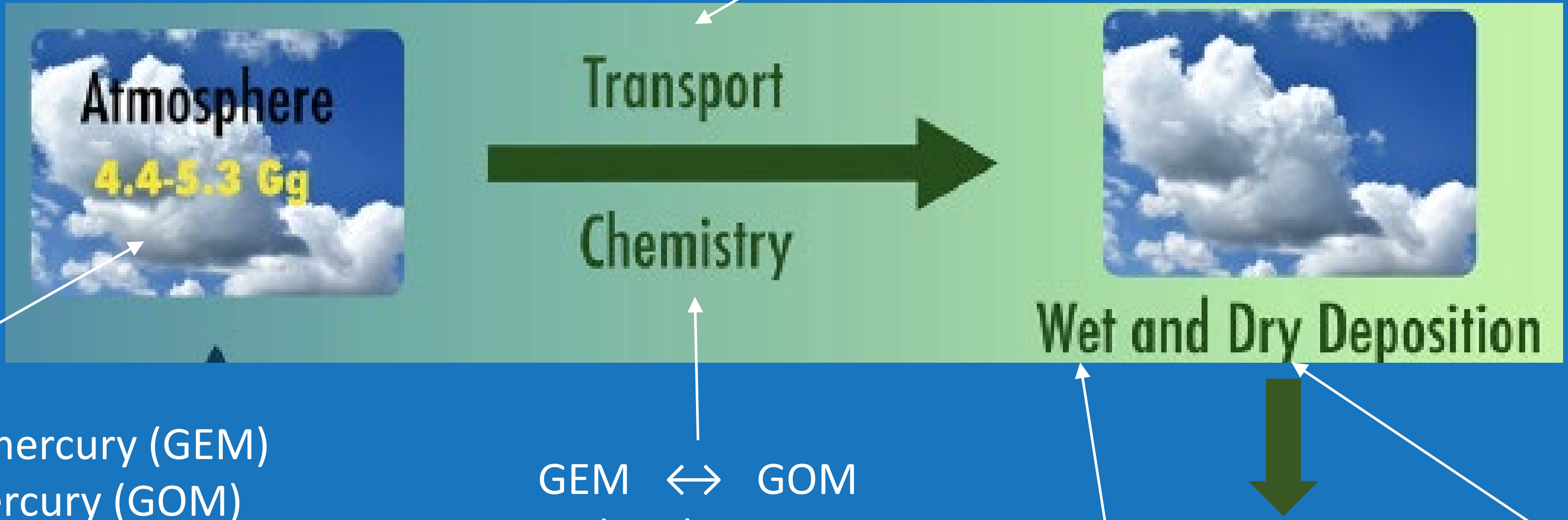
The Mercury Cycle

Local, regional, continental, global



Gaseous elemental mercury (GEM)
Gaseous oxidized mercury (GOM)
Particle-bound mercury (PBM)

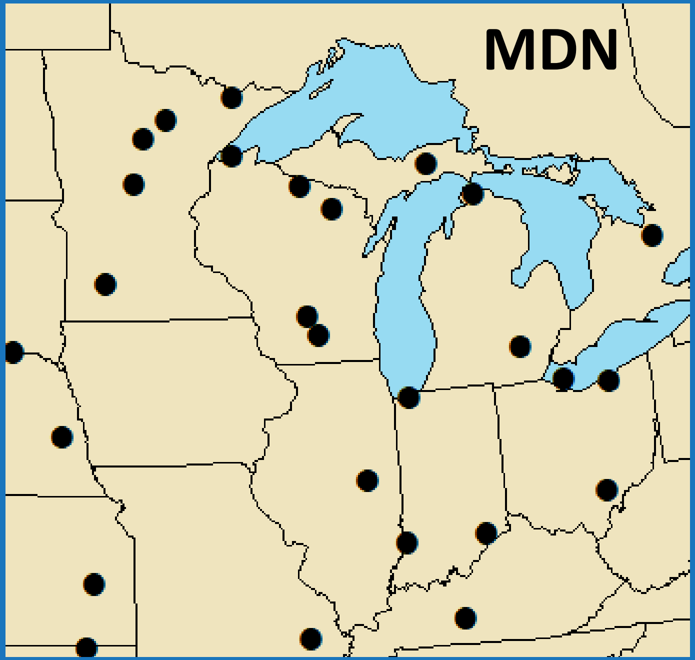
GEM ↔ GOM
GOM dissolves in water
GOM ↔ PBM

Wet deposition
- Mostly GOM & PBM

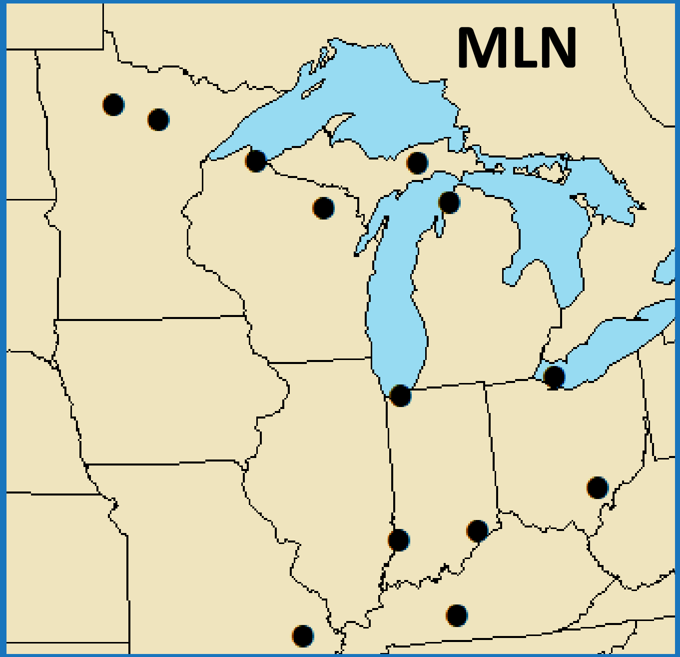
Dry deposition
- Mostly GEM
- 75% via litterfall

Obrist et al., 2018

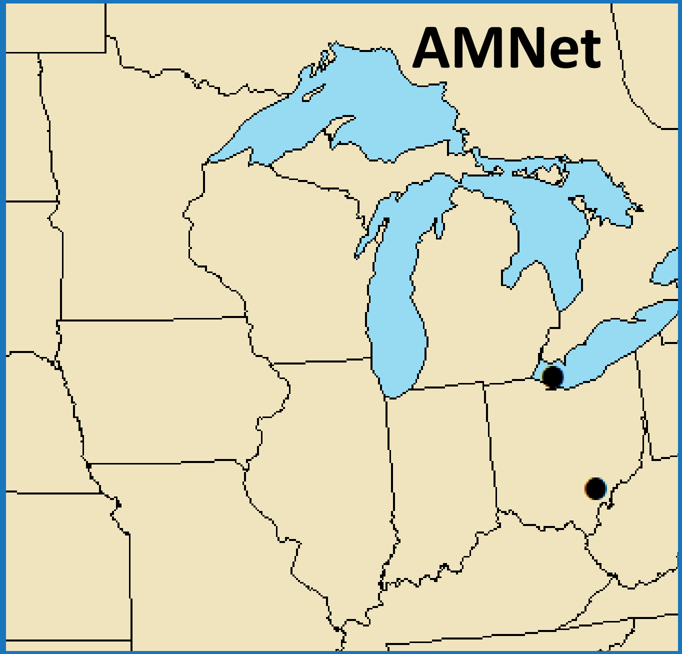
National Atmospheric Deposition Network (NADP) Sites



Mercury Deposition Network
- Measures wet deposition
- Most extensive network
- Longest record

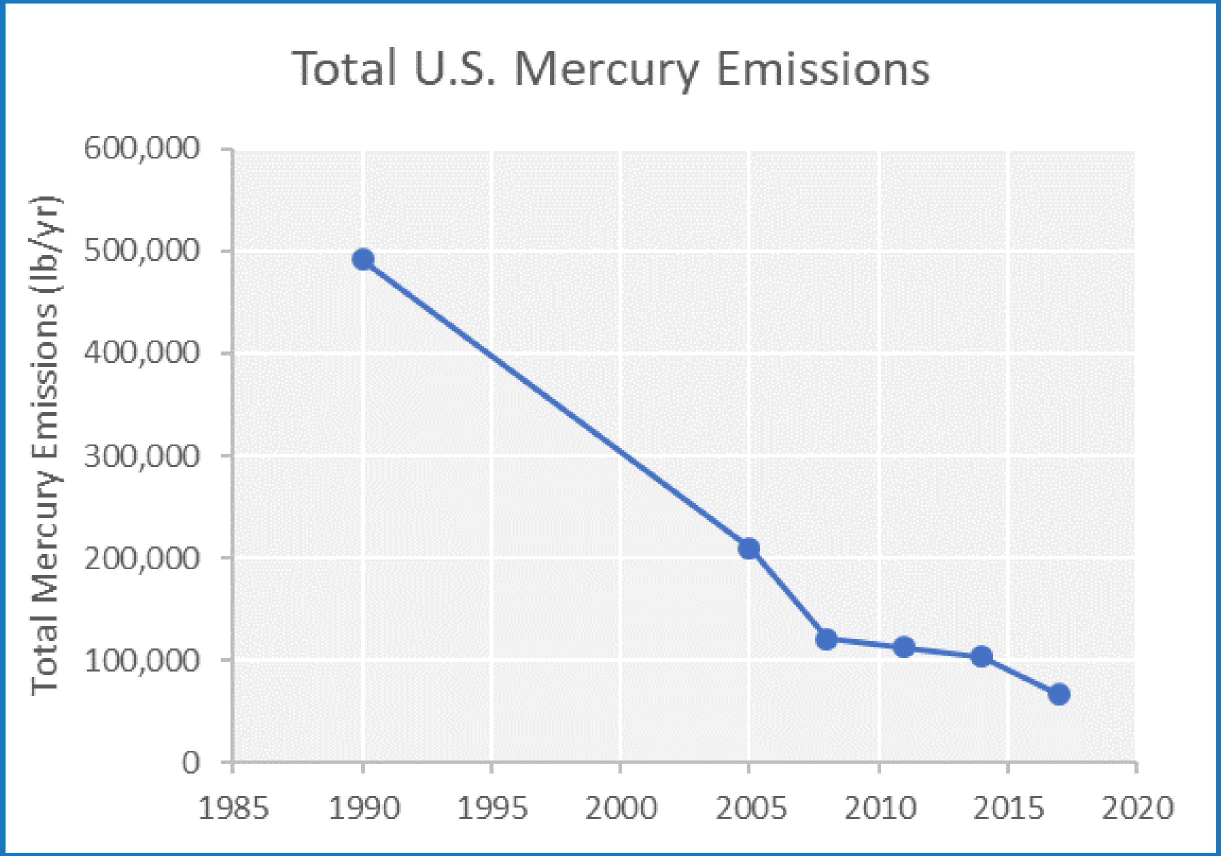


Mercury Litterfall Network
- Measures dry deposition
- Intermediate coverage



Atmospheric Mercury Network
- Measures gaseous or particulate forms
- Very sparse network

Mercury Emissions



Decreased by 87% from U.S. sources

- Reductions from a variety of sources, particularly:
    - Chlor-alkali plants
    - Coal combustion

Global emissions trends are less certain

- Likely increased at least through 2013
- No consensus on direction or magnitude

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Data: National Emissions Inventory (NEI) as reported in Brigham et al. (2021)

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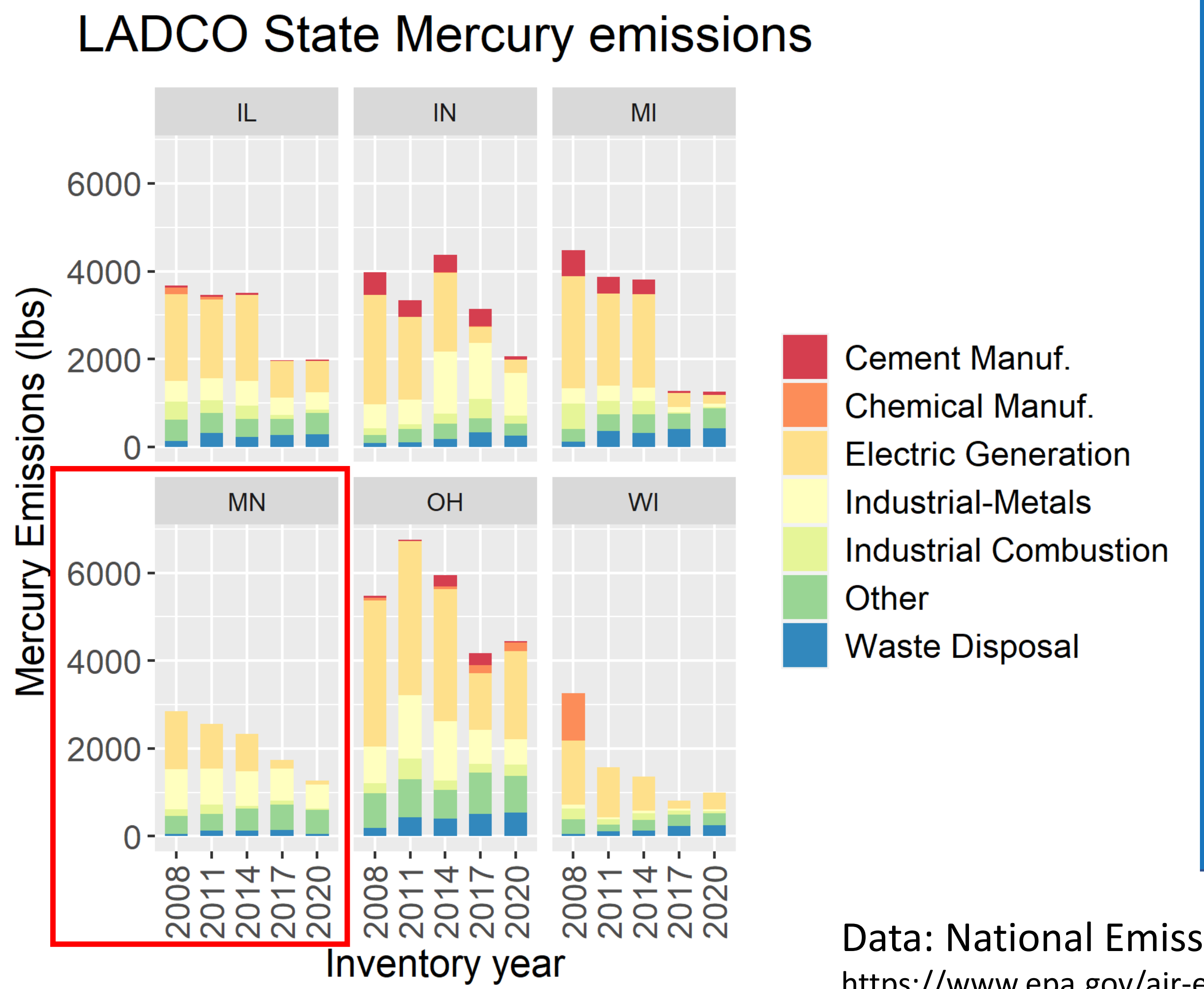
Mercury Emissions



Reductions of 19% (OH) to 72% (MI) since 2008

- Largest reductions from Electricity Generation

Minnesota: 55% reductions

- Most reductions from Electricity Generation

Data: National Emissions Inventory (NEI)
https://www.epa.gov/air-emissions-inventories/national-emissions-inventory-nei

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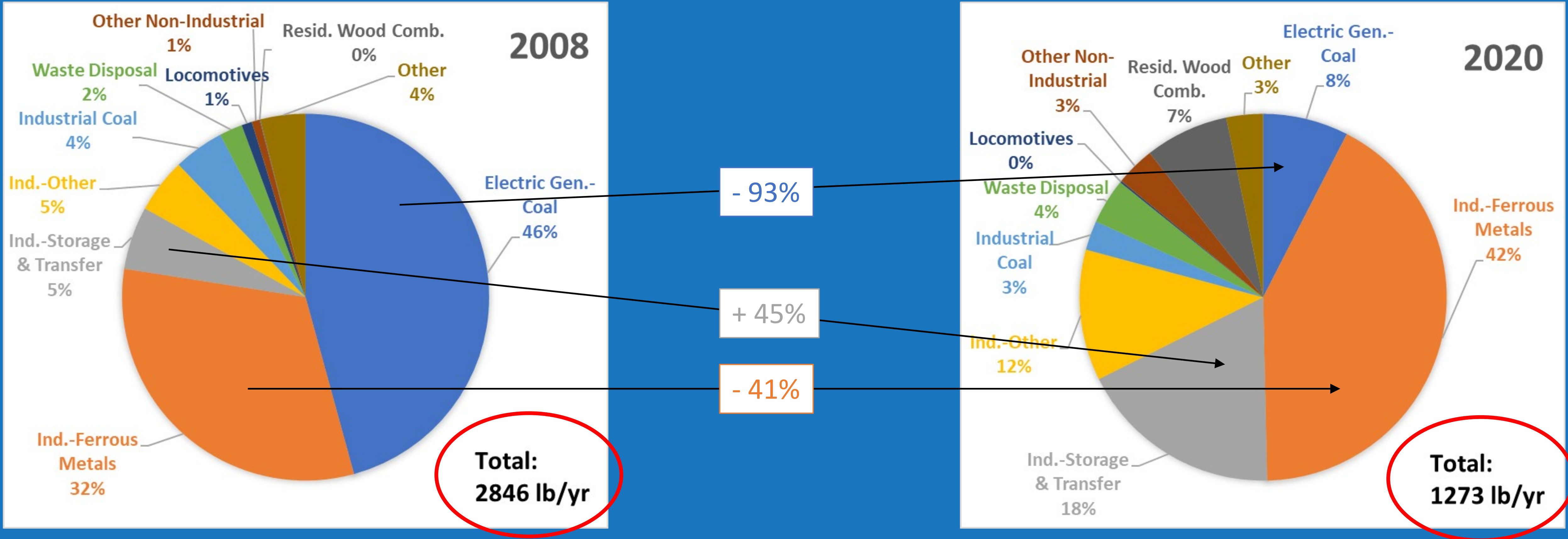
Mercury Emissions from MN Sources



Largest source: electricity generation with coal → Largest source: ferrous metals industry

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Data: National Emissions Inventory (NEI)
https://www.epa.gov/air-emissions-inventories/national-emissions-inventory-nei

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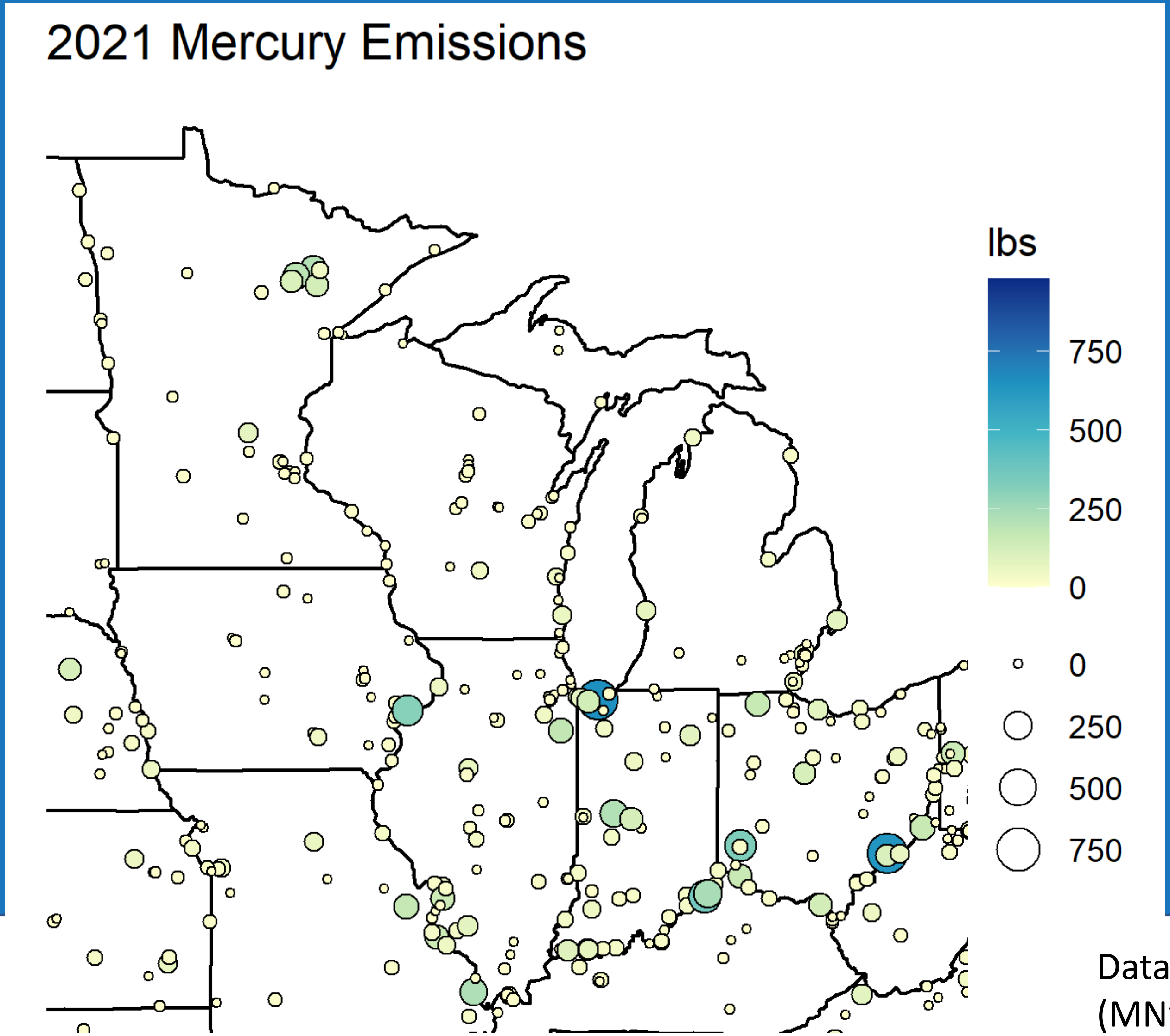
Mercury Emissions from Point Sources



Almost all large* sources in the region are in the metals industry:

- Steel plants
- Other metal processing facilities (Mn & Al)
- Taconite facilities
- (One coking plant)

Electricity generating units have lower emissions as a result of regulations and shutdowns

**Large sources emitted >100 lb Hg in 2021*

Data: EPA's Toxics Release Inventory except for MN (MN's point source air emissions inventory)

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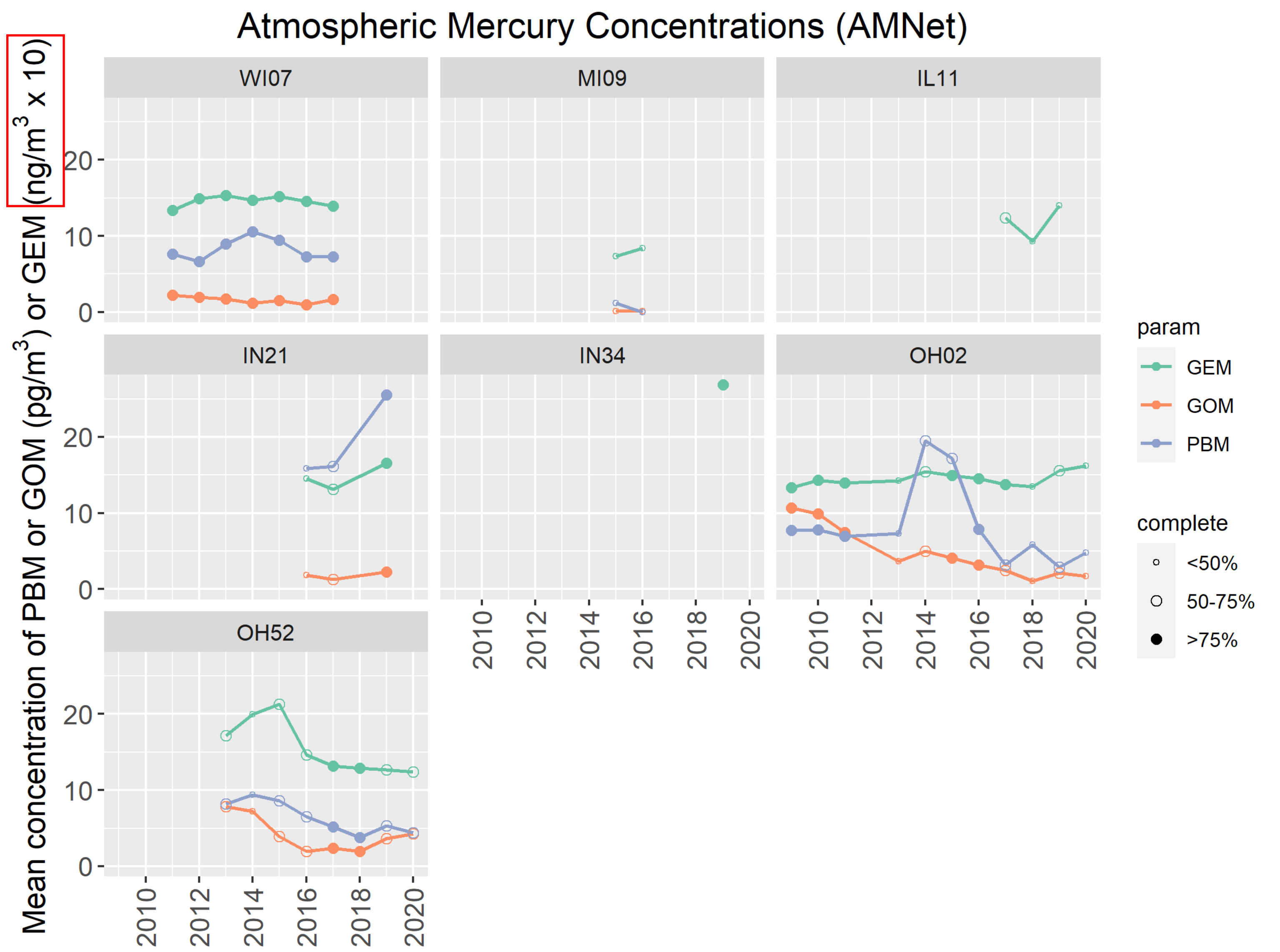
Atmospheric Concentrations of Mercury

- GEM, GOM, and PBM
- Very sparse data in space and time
- Many years have incomplete data → Less representative

Atmospheric Concentrations of Mercury

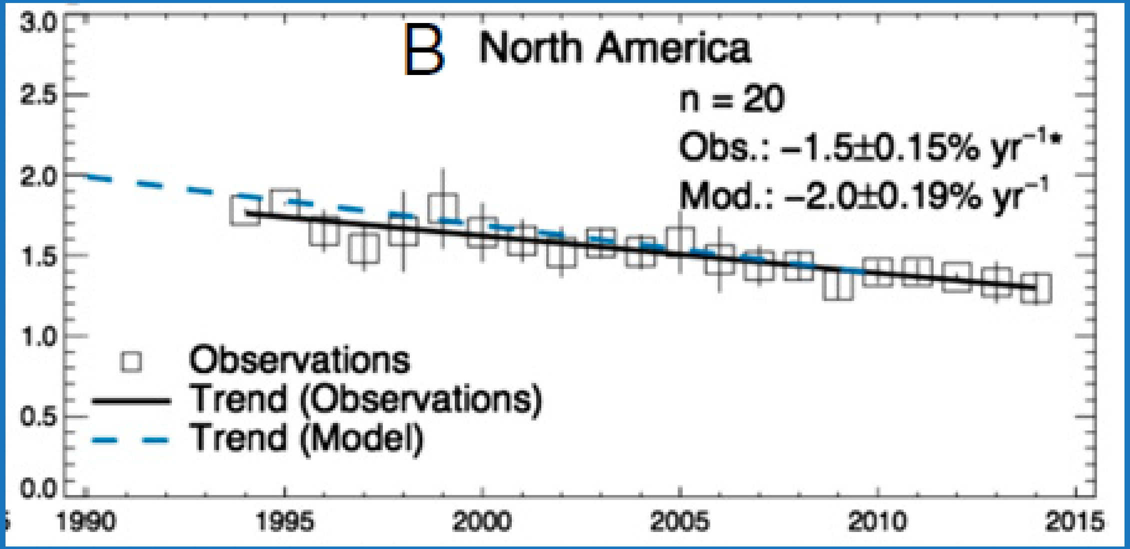


- GEM is >100 x as abundant as GOM or PBM (nanograms vs picograms)

- Focus on sites with more complete data
- GEM similar at all sites with no obvious trends
- GOM lower in Wisconsin (WI07) than in Ohio (OH02)
    - GOM seems to be decreasing at both sites
- PBM: no clear spatial or temporal trends

Atmospheric Concentrations of Mercury

Published GEM Trends

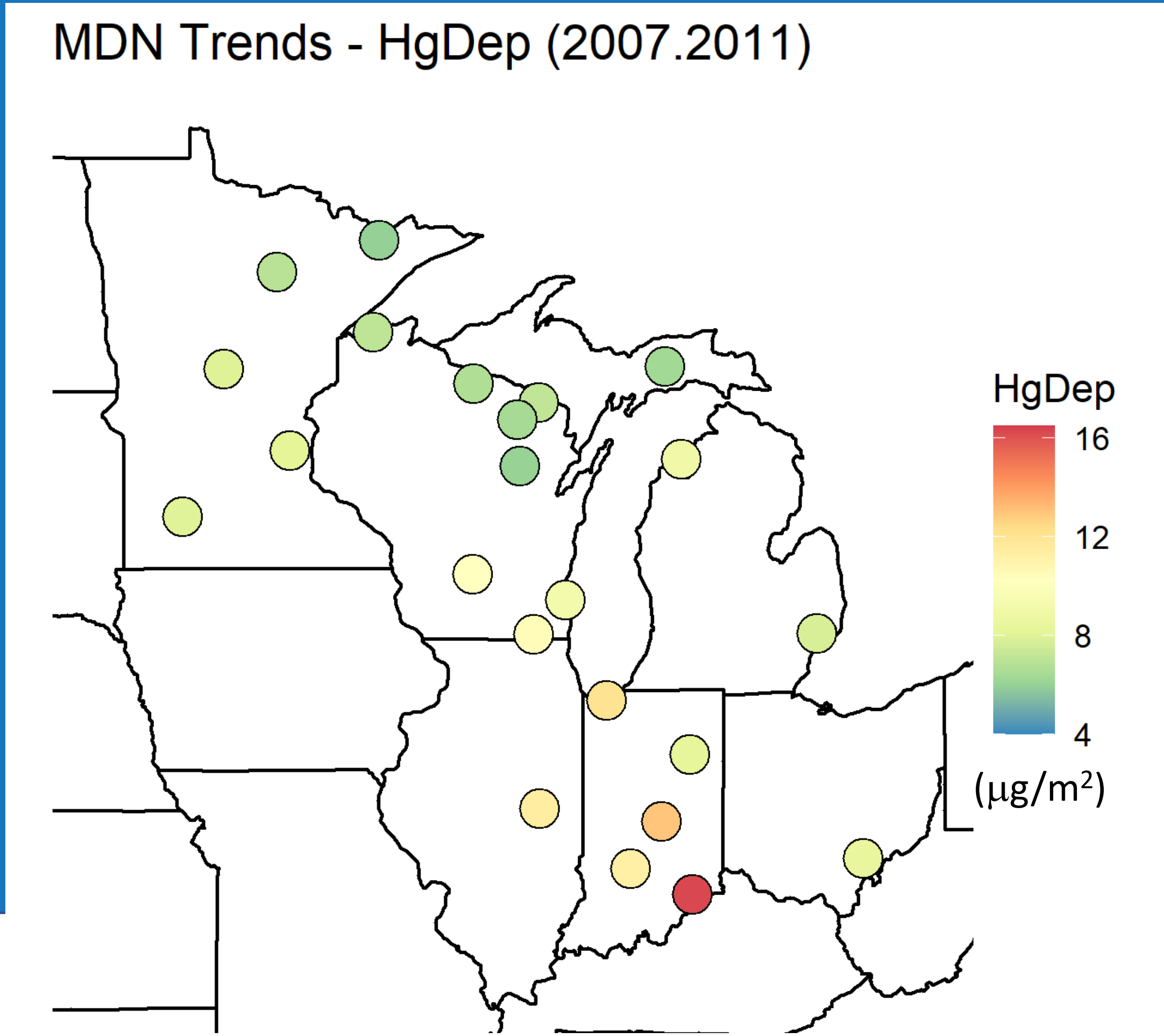


Zhang et al. (2016)

In contrast:

- North American GEM decreased 1.2 to 2.1% per year from 1990 to 2013 (Zhang et al., 2016)
    - May not see this in the Great Lakes region because decreases have slowed or because of the sparsity of sampling sites
- Atmospheric mercury concentrations have been increasing in East Asia (Obrist et al., 2018)

Wet Deposition of Mercury

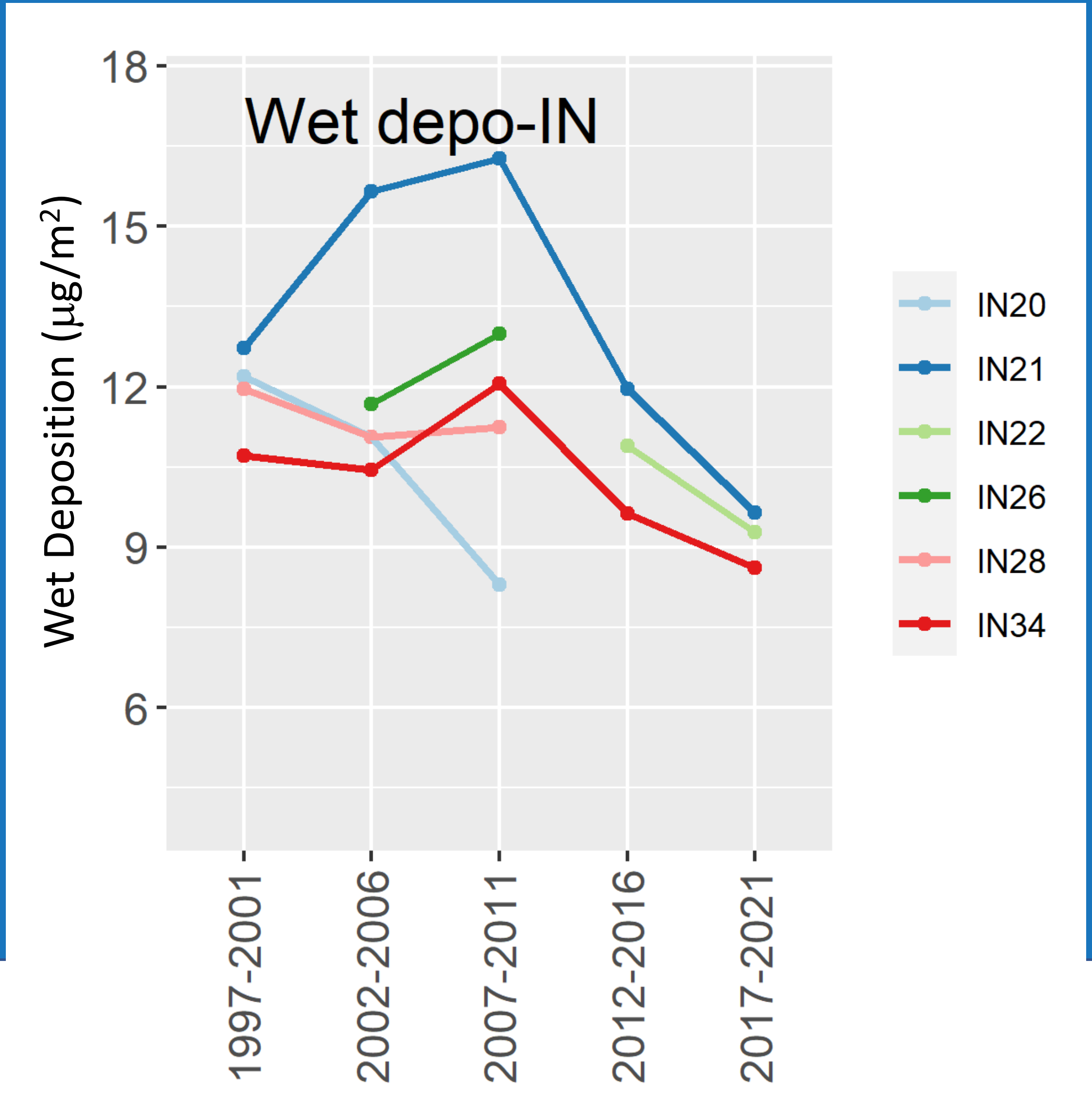


Wet deposition is greater in the southern part of the region

- Likely due to greater precipitation in southern areas (Risch and Kenski, 2018)
- Also: larger point sources of mercury in the southern states

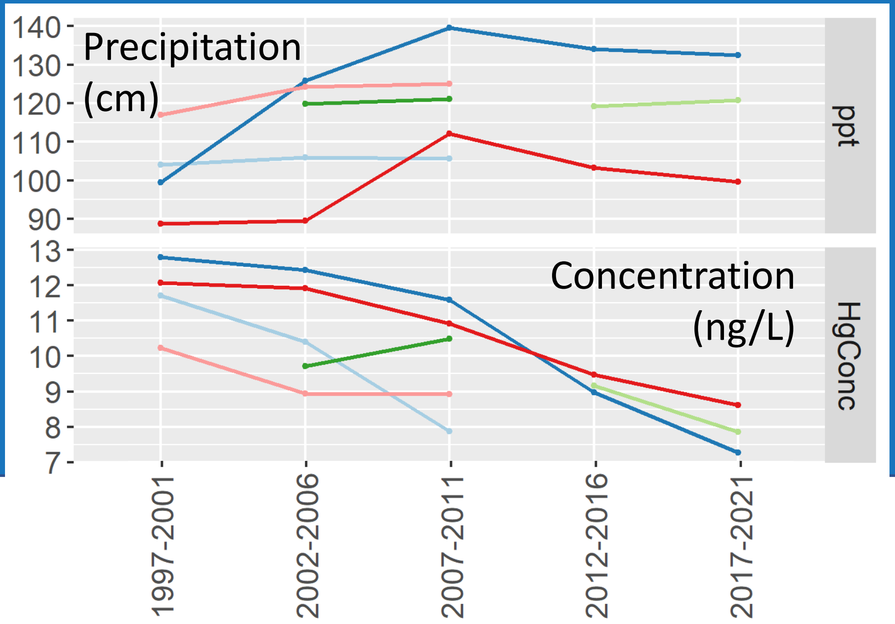
Variation within the region suggests a role for local and regional emissions sources, as well as global emissions

Wet Deposition of Mercury



<u>Southern states</u> (IN as example):

- Wet deposition has been decreasing for at least the last 15 years
  - Largest reductions in the Ohio River Valley (IN21)
  - Steady reductions in mercury concentrations and unclear trends in precipitation
  - Mercury concentration reductions appear to be driving deposition decreases
    - Likely due to decreased local and regional emissions



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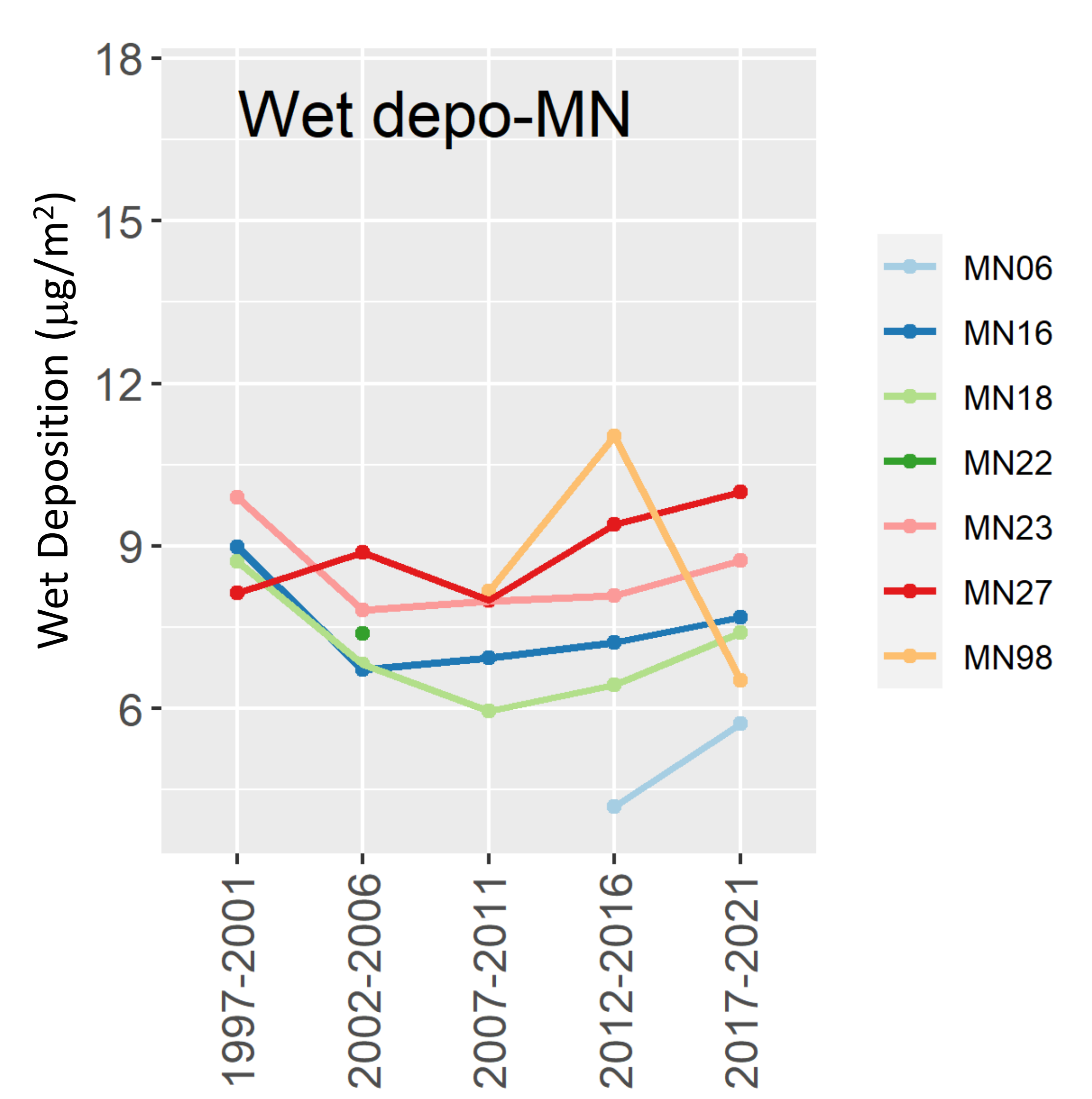
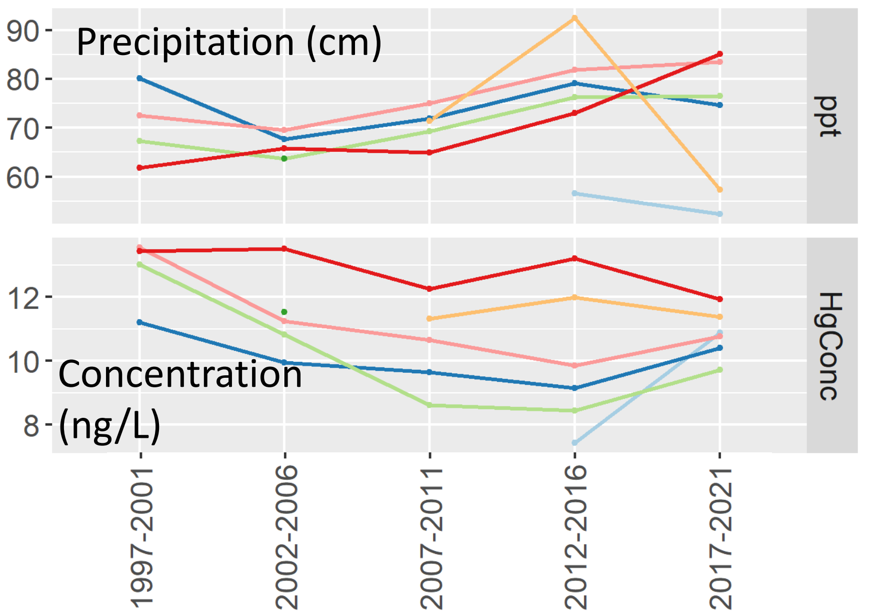
Wet Deposition of Mercury



Northern states (MN as example):

- Wet deposition is flat to increasing
  - Increasing most consistently in MN
  - Mercury rainwater concentrations have mostly decreased but not as clearly as in the south
  - Precipitation has increased
    - Increased deposition likely primarily due to increased precipitation
  - Contrasted with earlier decreases at these sites



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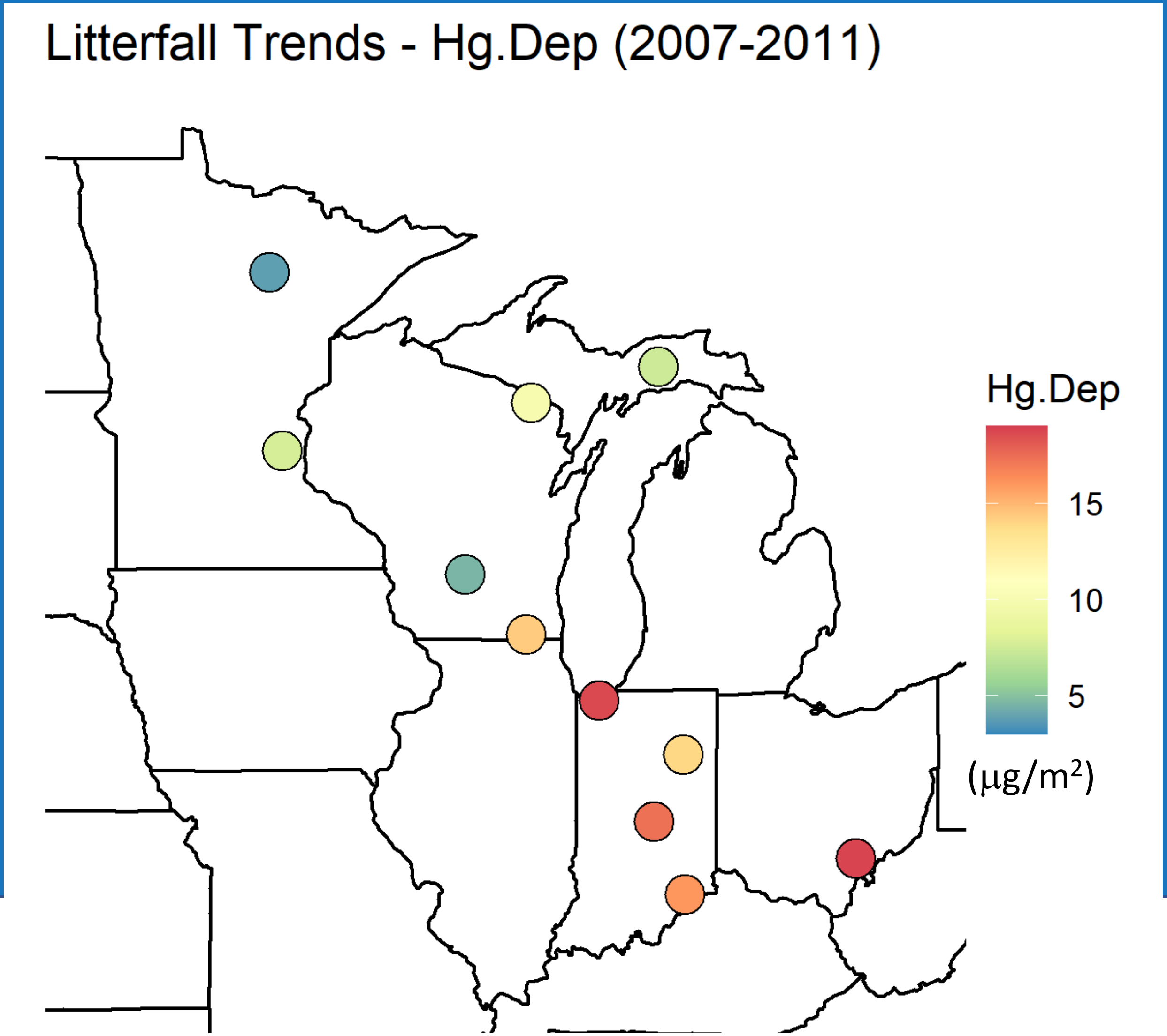
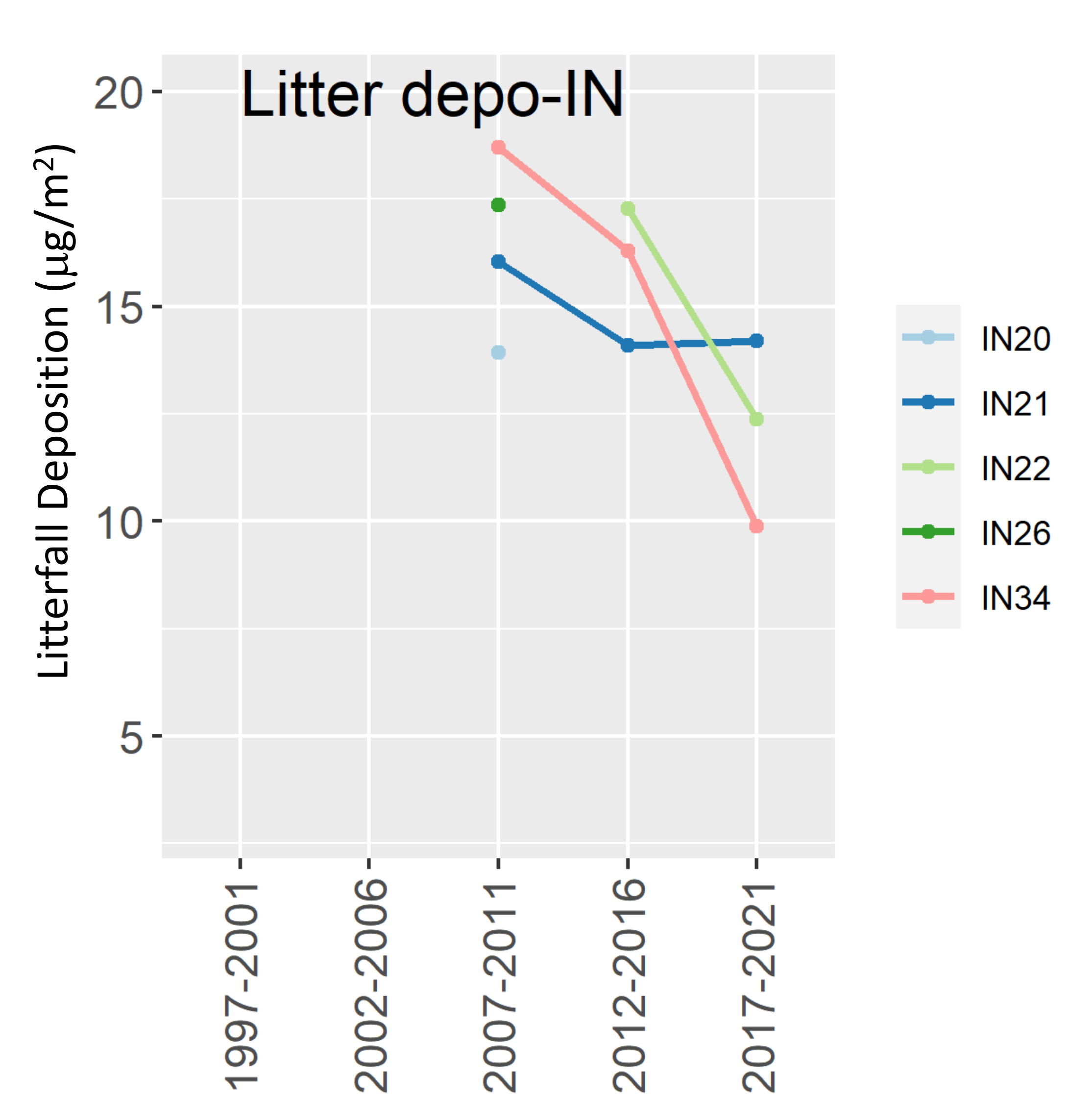
Dry (Litterfall) Deposition of Mercury



Dry deposition is greater in the southern part of the region

- Similar patterns to wet deposition

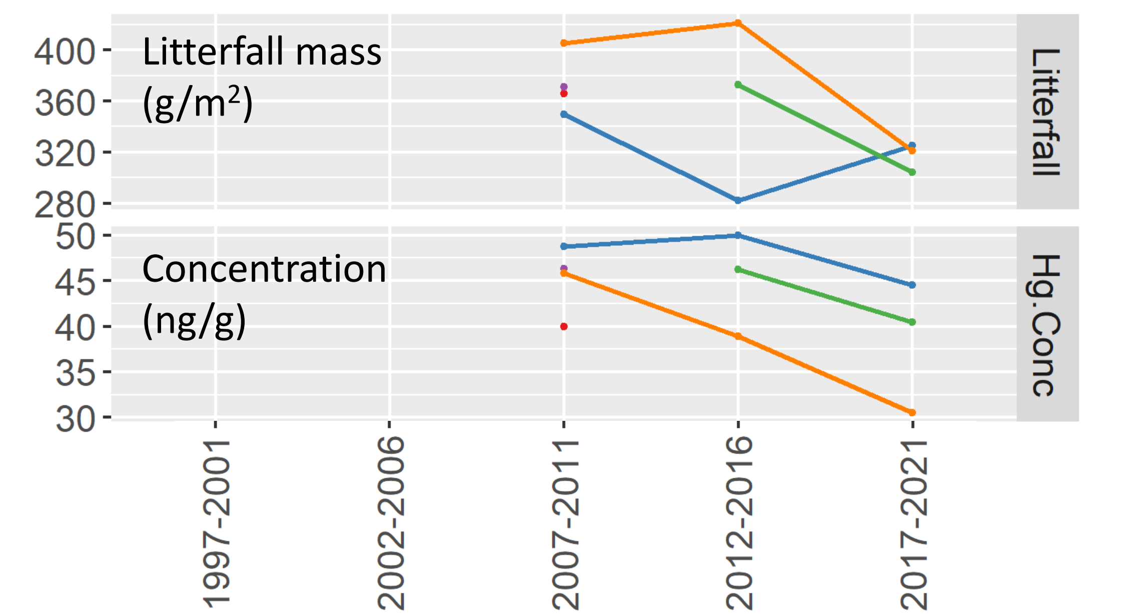
Dry (Litterfall) Deposition of Mercury



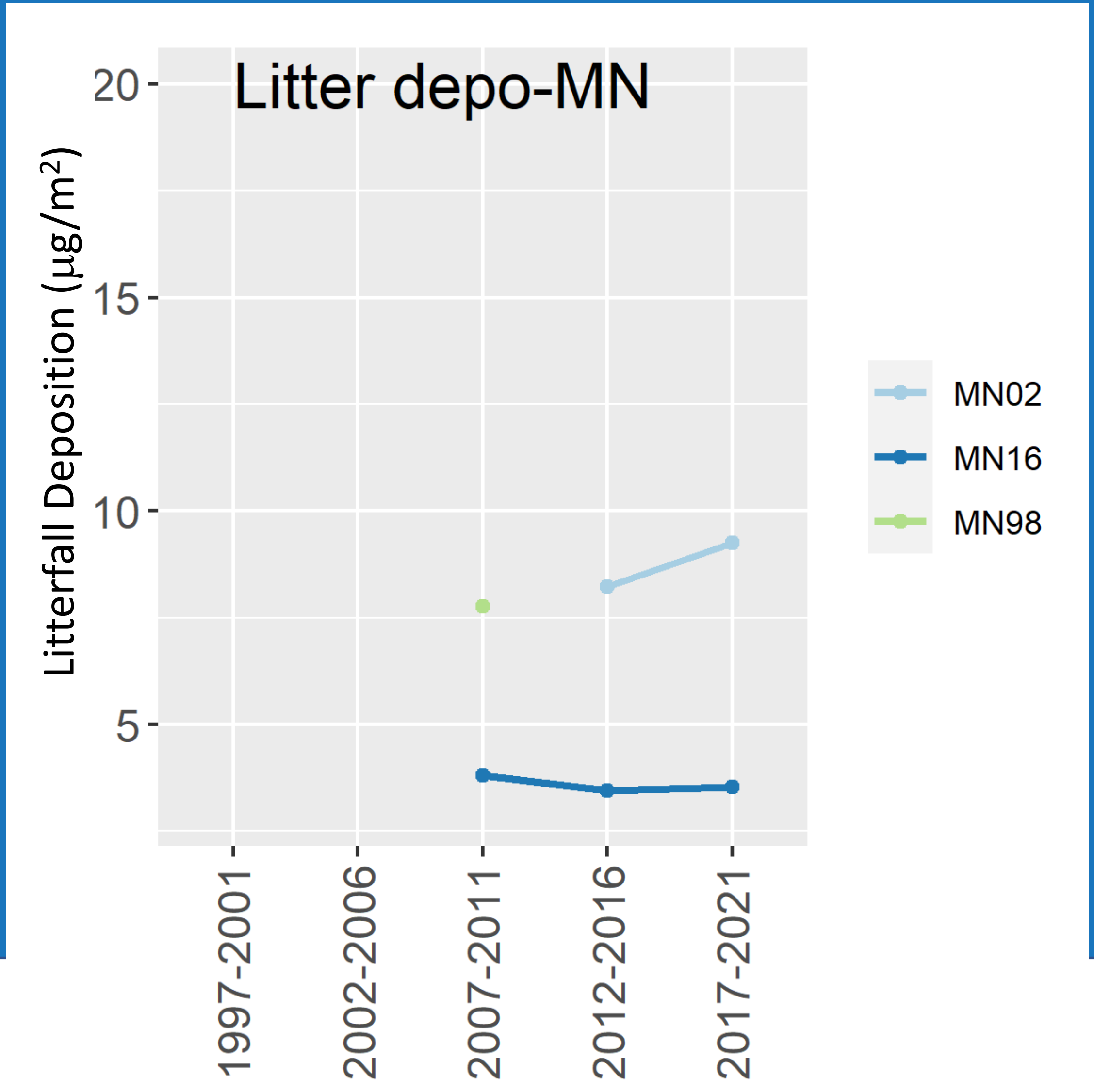
Shorter and less complete records than for wet deposition

Southern states (IN as example):

- Clear decreases in litterfall deposition
  - Mercury concentrations decreased
  - Litterfall mass also decreased at some sites
  - Likely driven by decreased local/regional emissions

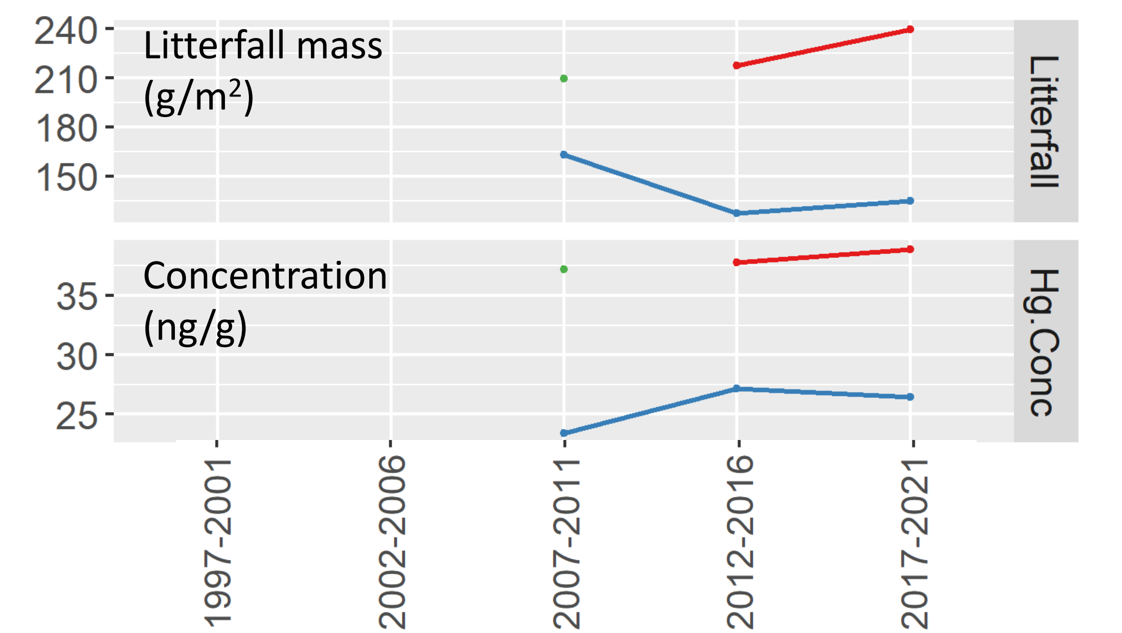


Dry (Litterfall) Deposition of Mercury



Northern states (MN as example):

- Litterfall deposition is flat relatively steady over the last 15 years
- Litterfall mass and mercury concentrations are also steady



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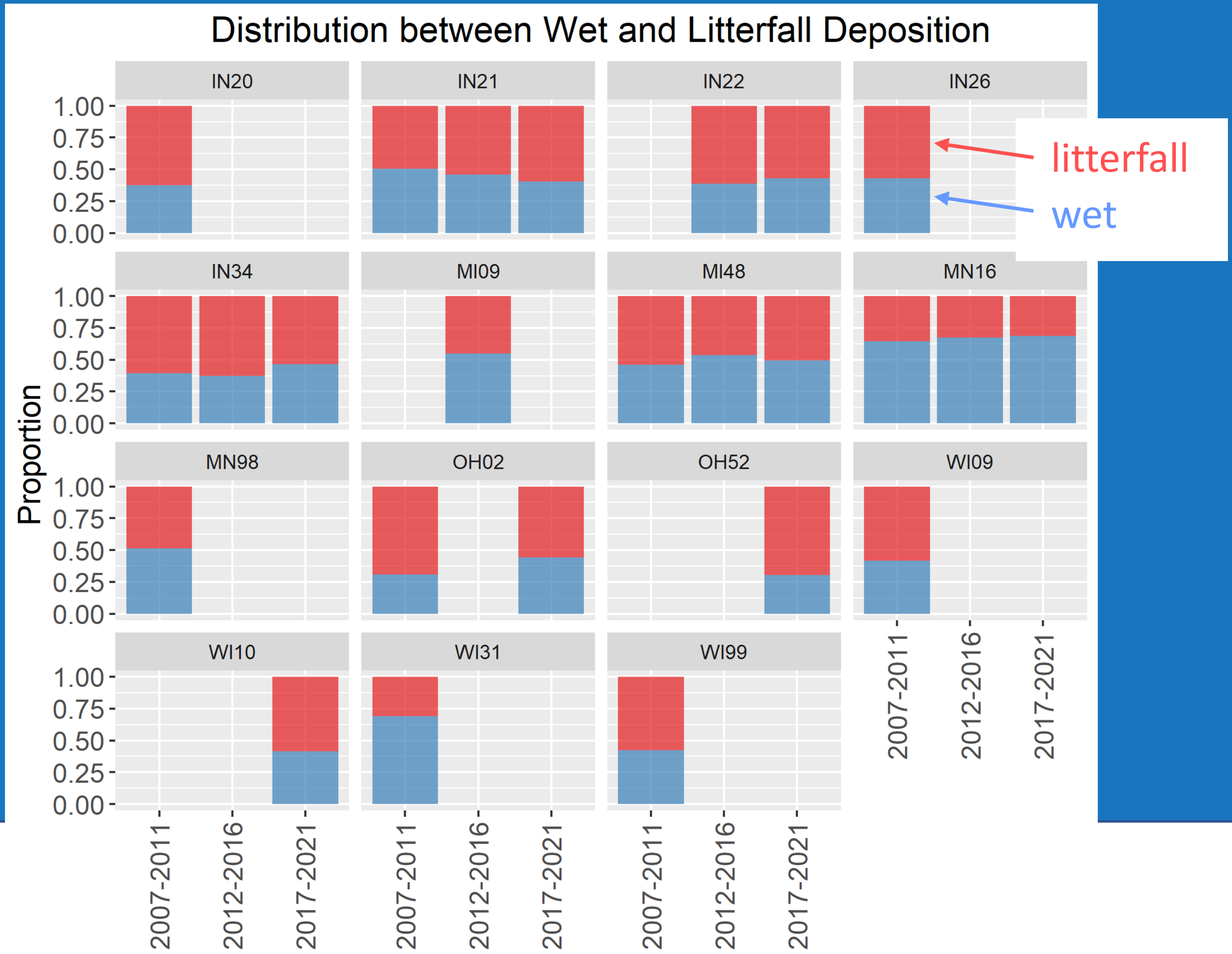
Comparison of Wet & Litterfall Deposition



Generally similar contributions from both litterfall and wet deposition

- Both types of deposition are important
- Litterfall seems more important at southern sites
- Wet deposition is more important at some northern sites (MN16 & WI31) but not at others

No clear trends over time

Sources of Mercury in the Region

- Based on this analysis and literature studies
- Contributions from local and regional sources are important
  - In addition to continental and global sources
  - Evidence: decreases in Hg concentrations and deposition while global emissions are steady or increasing
  - Southern Great Lakes region:
    - Reductions occurred when major local/regional emissions sources (e.g. EGUs) were installing controls or shutting down
    - Heavy influence from local emissions
  - Northern Great Lakes region:
    - Mixed influence from local, regional, and global sources
    - Previous decreases linked to local emissions reductions (Engstrom et al., 2007)
    - Also influenced by increased precipitation → increased wet deposition

Conclusions

- Both litterfall and wet deposition of mercury are highest in southern areas
  - Near the most/largest sources
- Wet deposition is strongly decreasing in the south but weakly increasing in the north
  - Led to decreases in regional differences over time
- Litterfall deposition is decreasing in the south but trends are unclear in the north

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Thank you!

Questions?

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References

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