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Spatial Patterns and Temporal Trends of Mercury Wet Deposition in the Great Lakes Region

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Introduction

- Great Lakes multi-media Hg synthesis project
- Hg wet deposition is a primary loading of Hg to lakes and watersheds in the region and related to MeHg in fish and wildlife
- Different from previous evaluations of MDN data*
- Combine Hg data from MDN, Michigan Hg Monitoring Network, and Integrated Atmospheric Deposition Network (Canada) with precipitation data from Cooperative Weather Observer Networks (USA, Canada)

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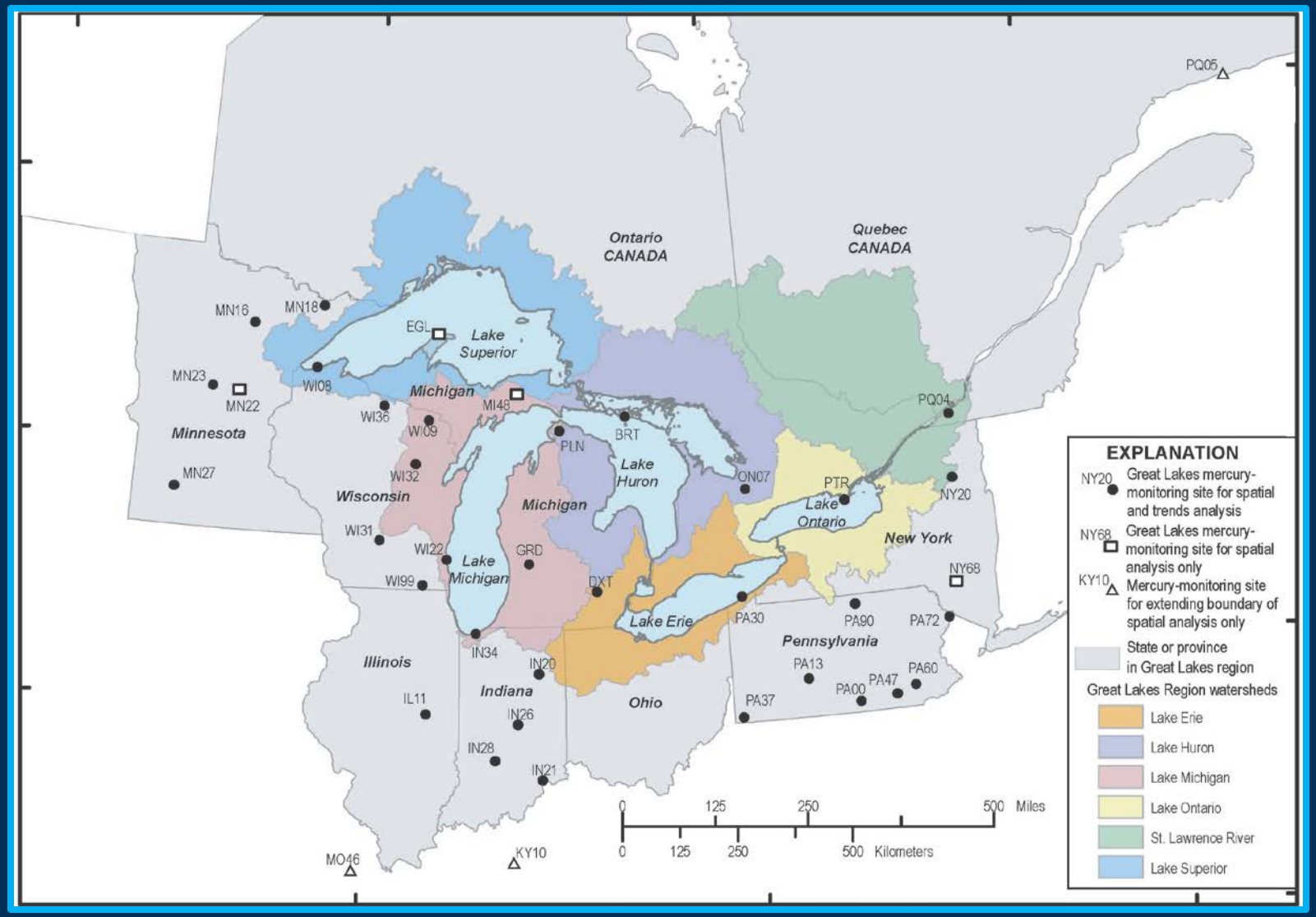
*Prestbo & Gay, 2009; Butler et al., 2007, Miller et al., 2005; Van Arsdale et al., 2005



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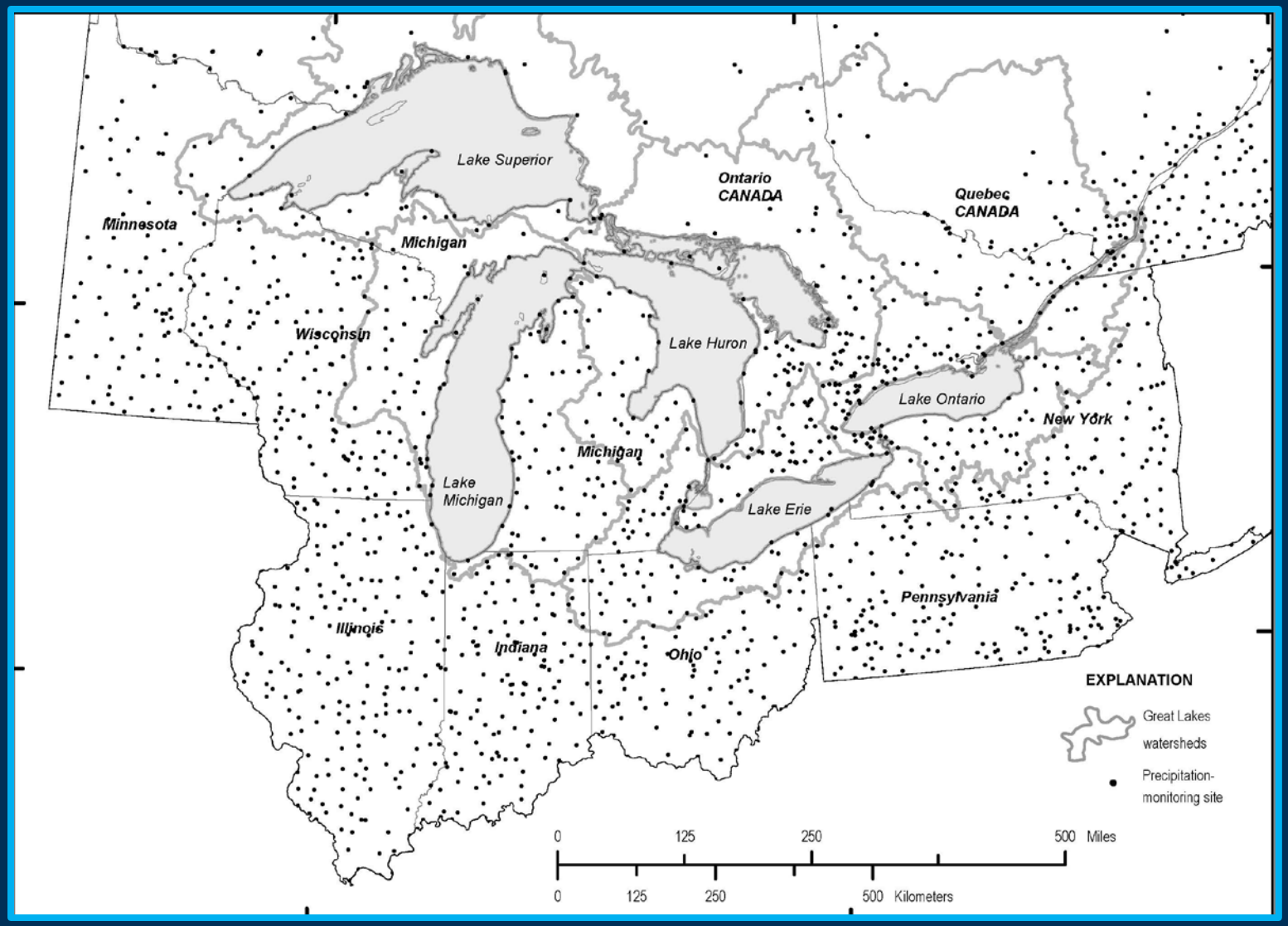
37 Hg sites with at least 75% complete data per year for 5 of 7 years, 2002-2008



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1,541 precipitation sites with at least 75% complete data per year for 5 of 7 years

Methods

- Equivalence of sample collection and Hg analysis in three networks; Michigan network daily event data converted to weekly data
- GIS grid-map method for regional isopleths of annual Hg concentrations & annual precipitation
- High-resolution maps of annual Hg wet deposition for spatial patterns of annual means and net annual change (sum of interannual differences)
- Temporal trends in weekly data determined with Seasonal Kendall Trend Test and Seasonal Kendall Slope Estimator (for rate of change)

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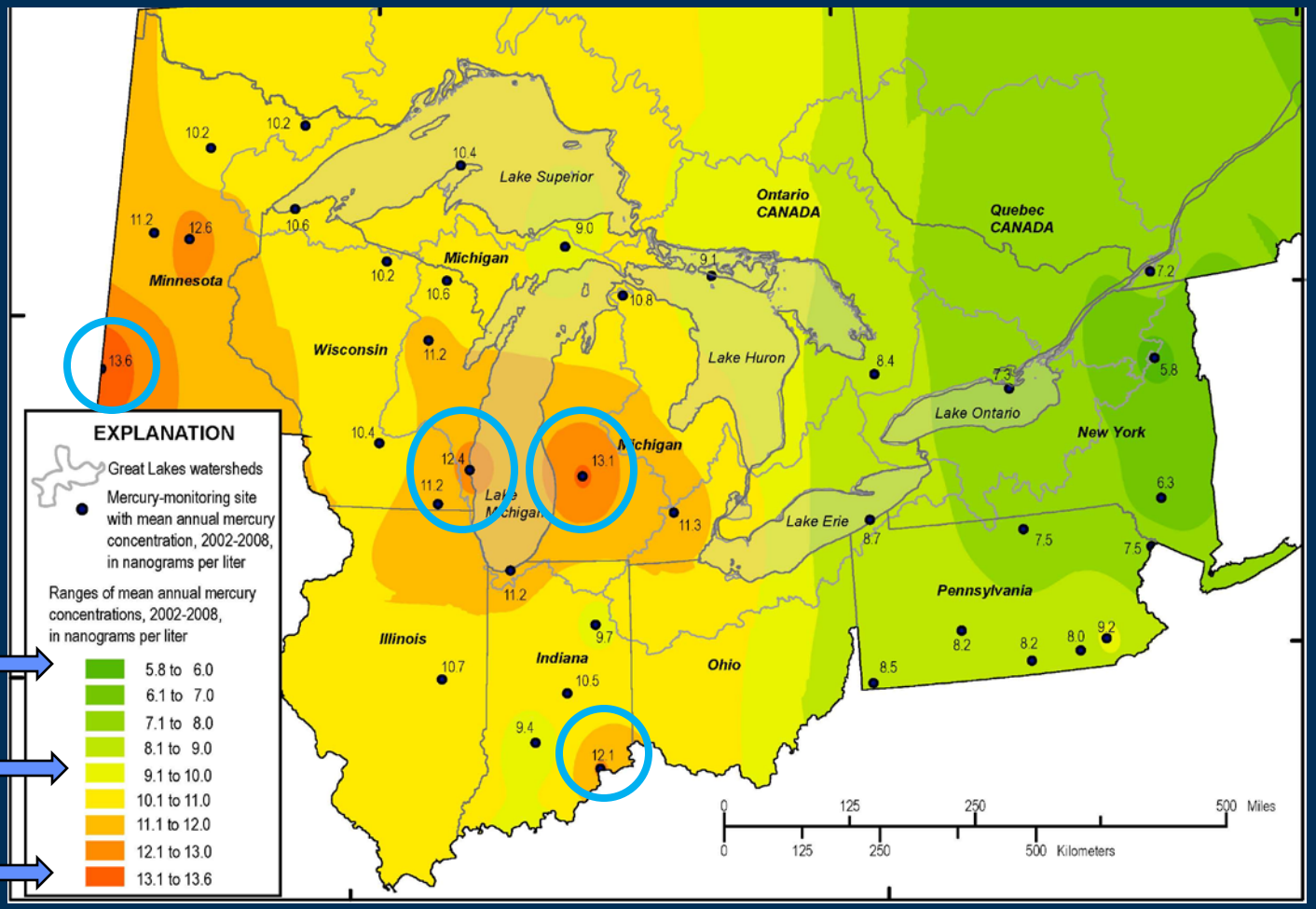
7-Year Mean Annual Hg Concentrations



Low

Median

High

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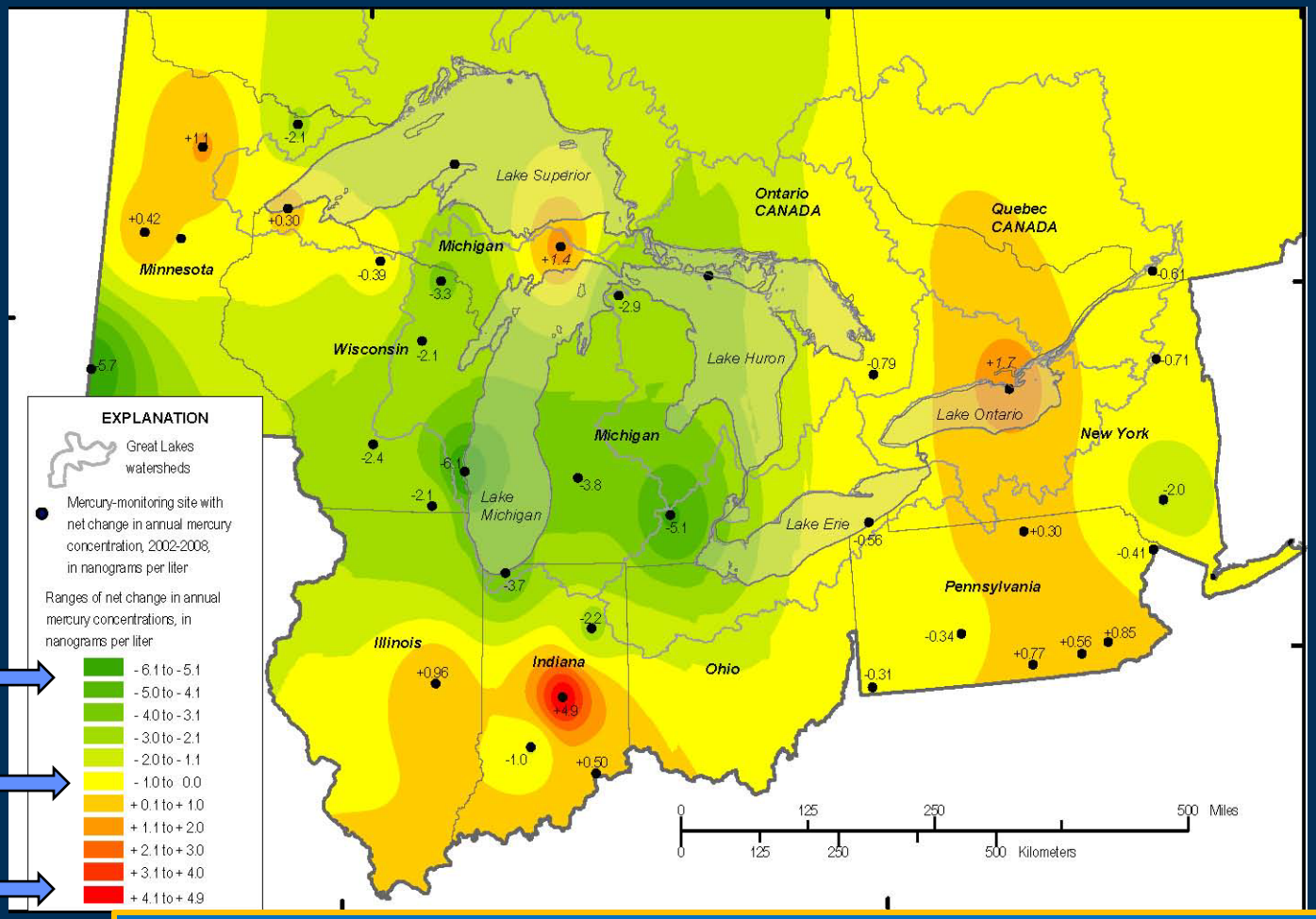
> 12 ng/L criterion 6 of 7 years in 4 states

7-Year Net Change in Annual Hg Concentrations



Low

Median

High

Median net change in region –0.4 ng/L
(Limit of measurement variability is 2 ng/L*)

*Wetherbee et al., 2007, co-located collectors study

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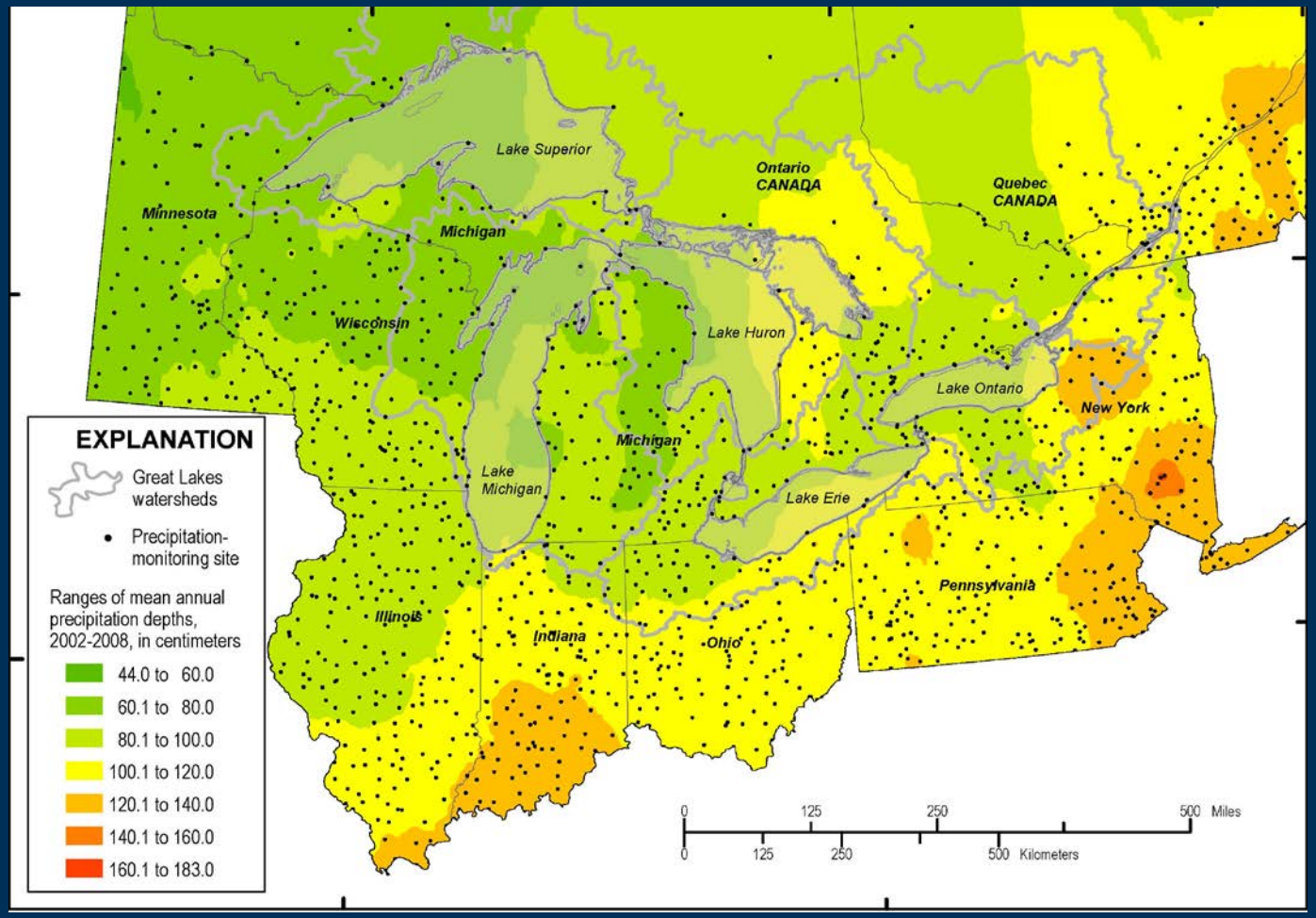
7-Year Mean Annual Precipitation Depths



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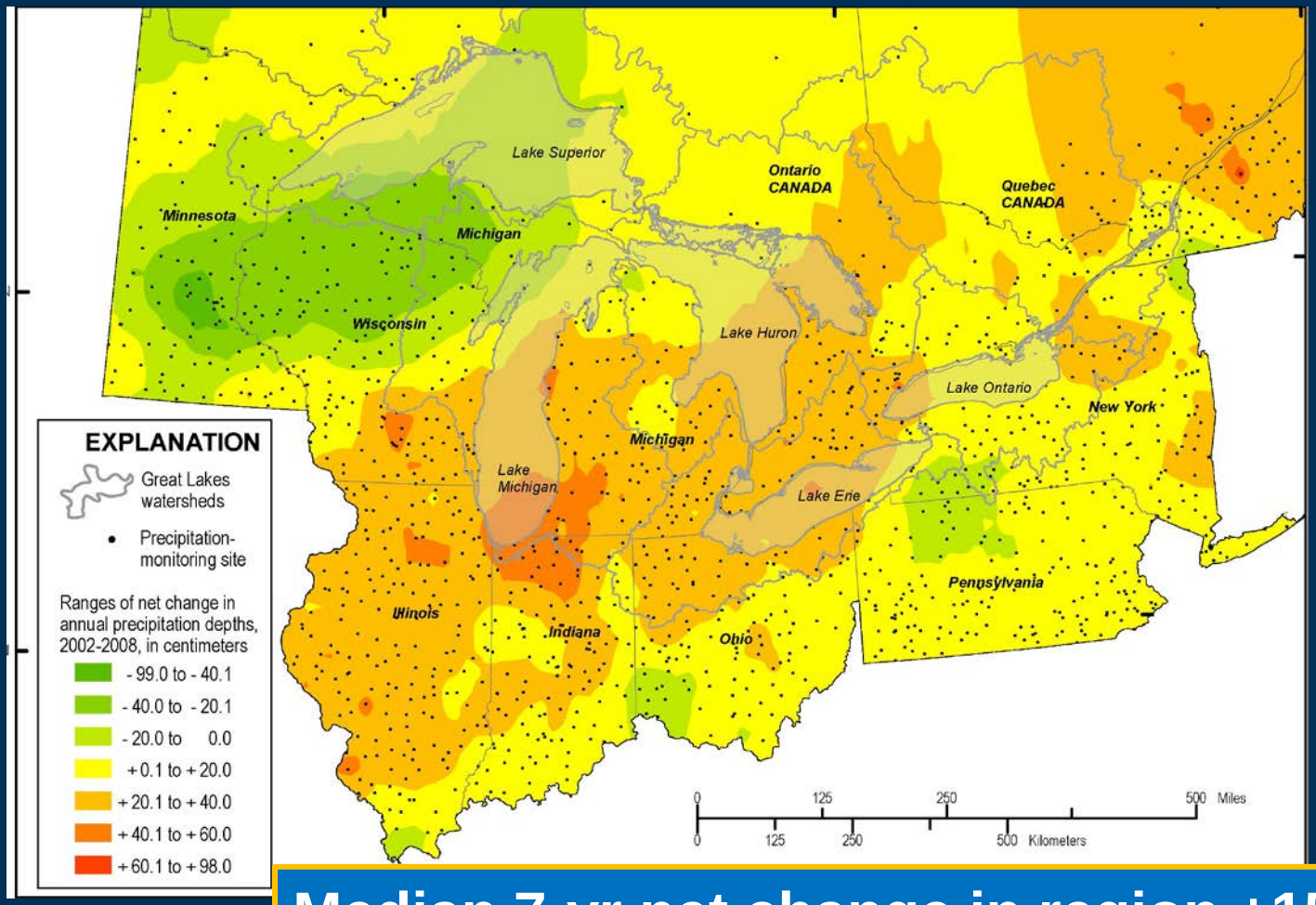
Median annual precipitation depth in the region was 99 cm

7-Year Net Change in Annual Precipitation Depths



Median 7-yr net change in region +15 cm

total +10.7 cm (1955-2004, Hodgins et al., 2007)

+11.4 cm IN; +10.4 cm MI (112 yrs, MRCC, 2010)

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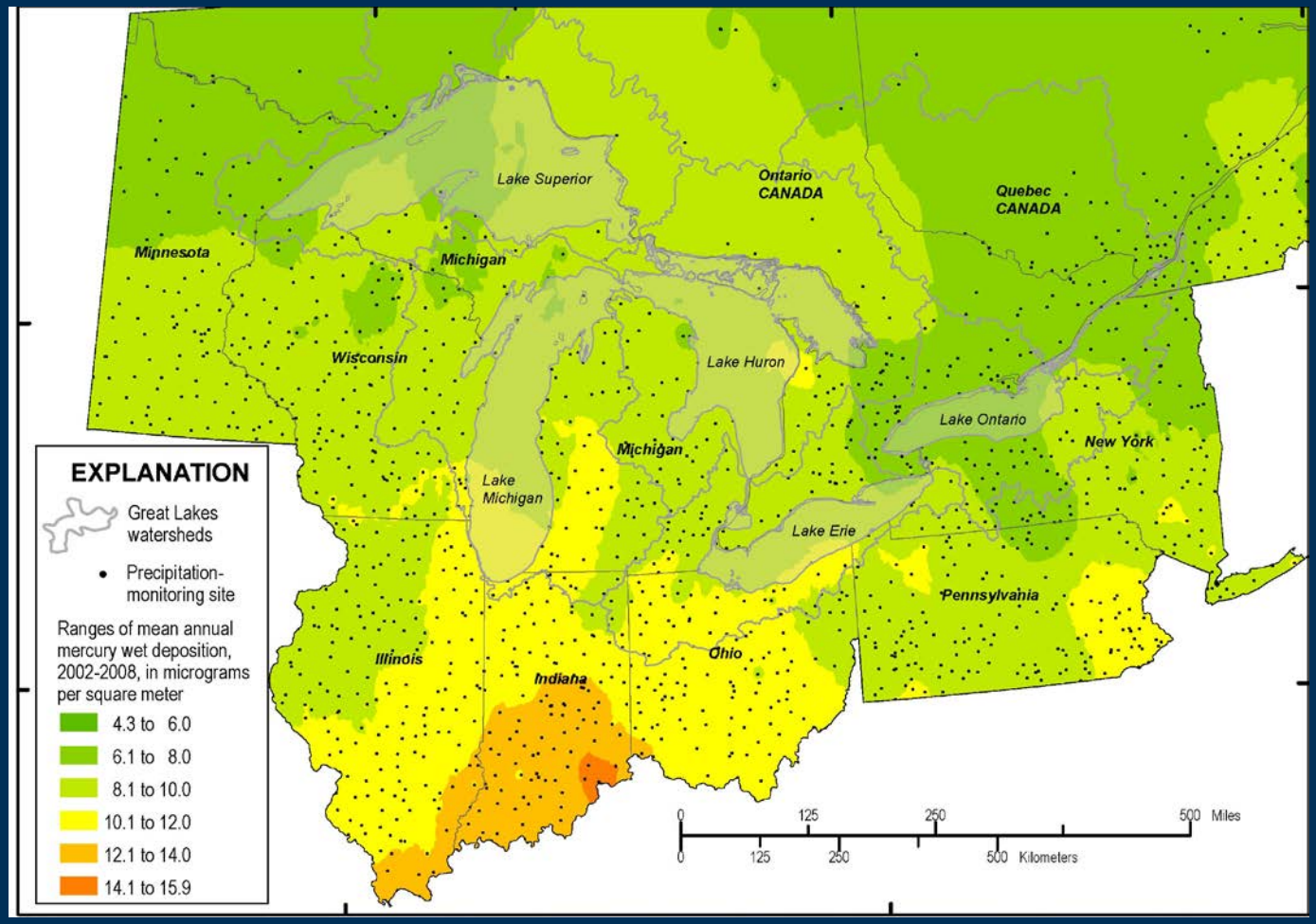
7-Year Mean Annual Hg Wet Deposition



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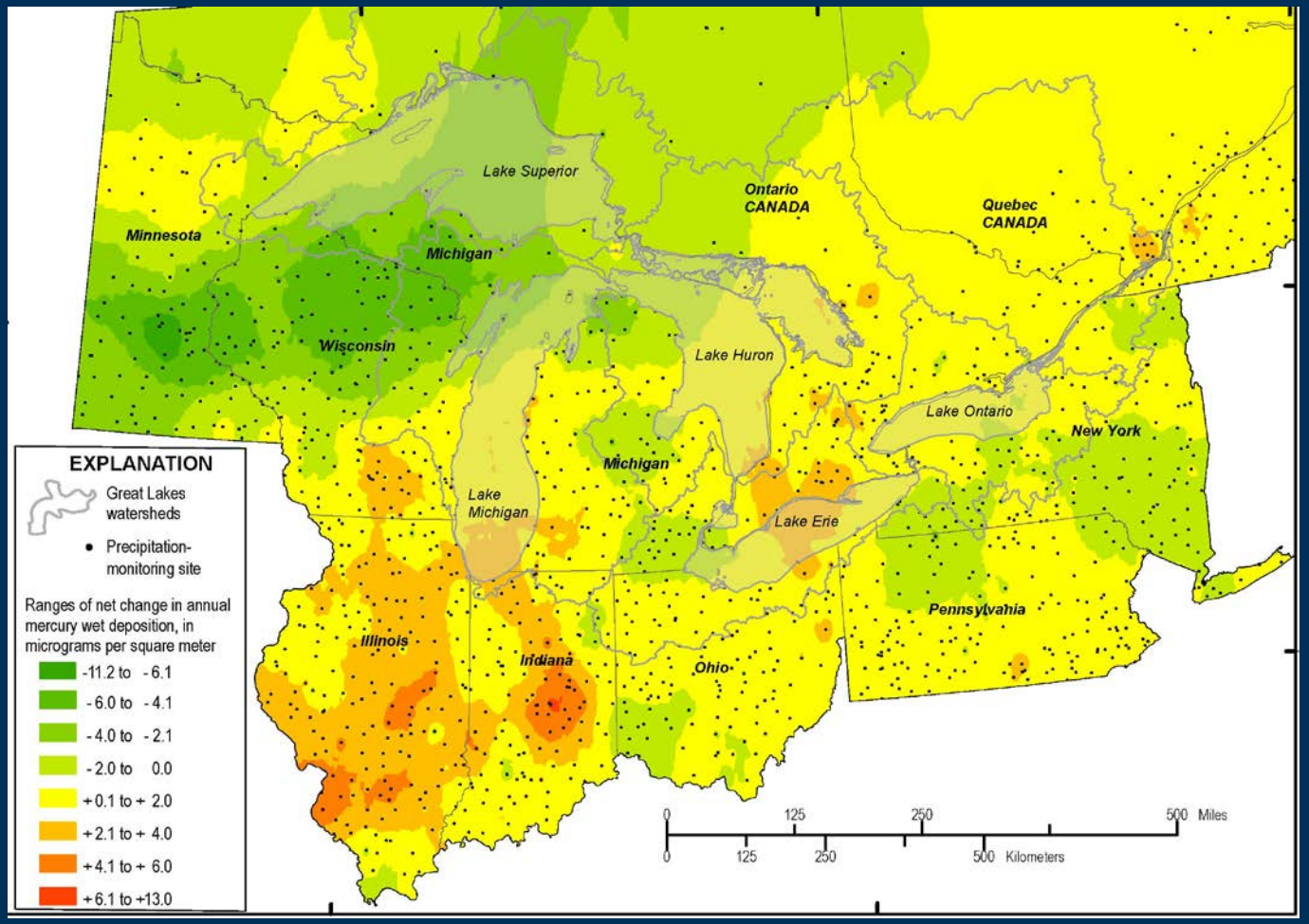
Median annual Hg wet deposition in the region was 9.2 μg/m²

7-Year Net Change in Annual Hg Wet Deposition



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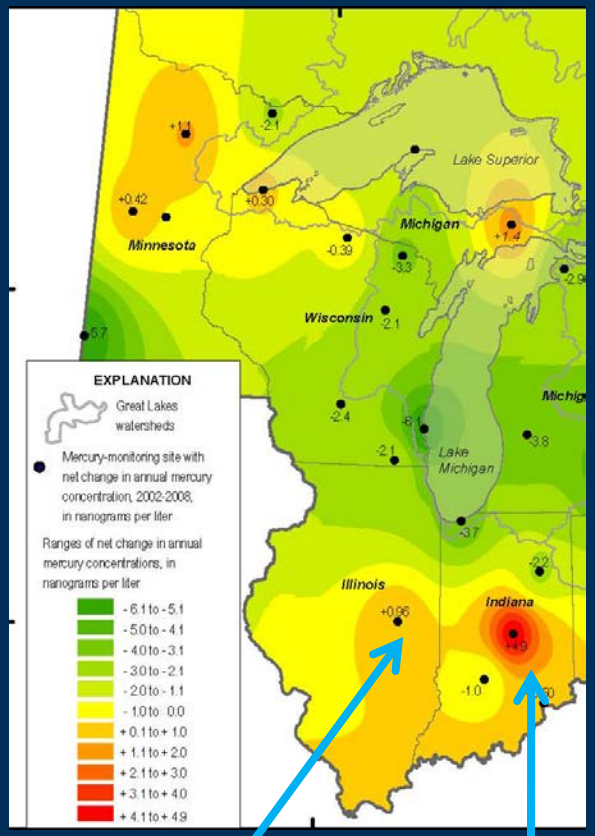
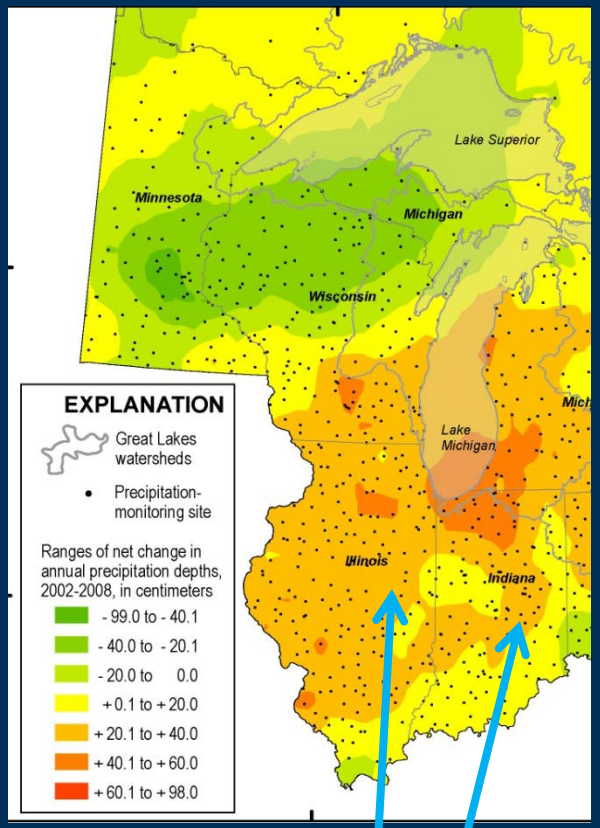
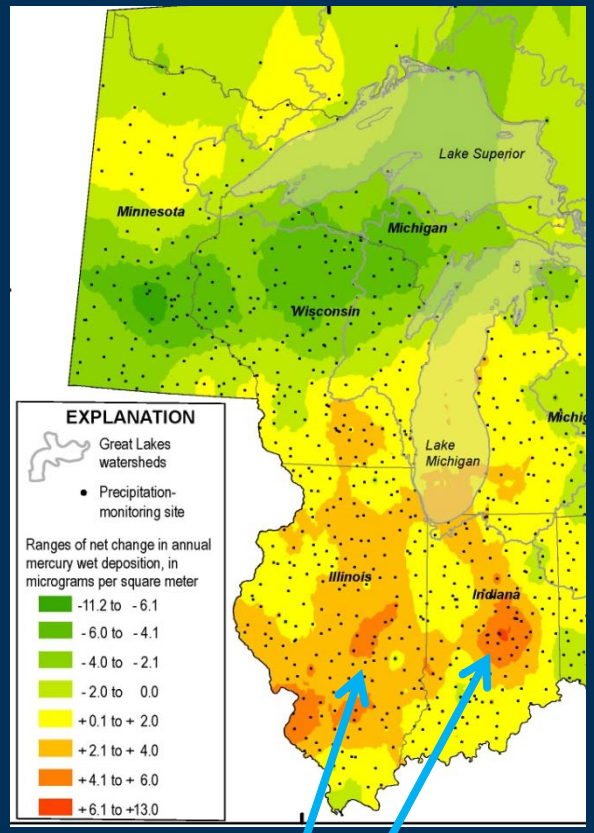
Median net change in region was +0.7 μg/m²

1) Local increases of Hg concentration, precipitation depths, and Hg wet deposition







+1 to +2 ng/L
+2 to +4 ng/L

+20 to +40 cm

+4 to +6 µg/m²

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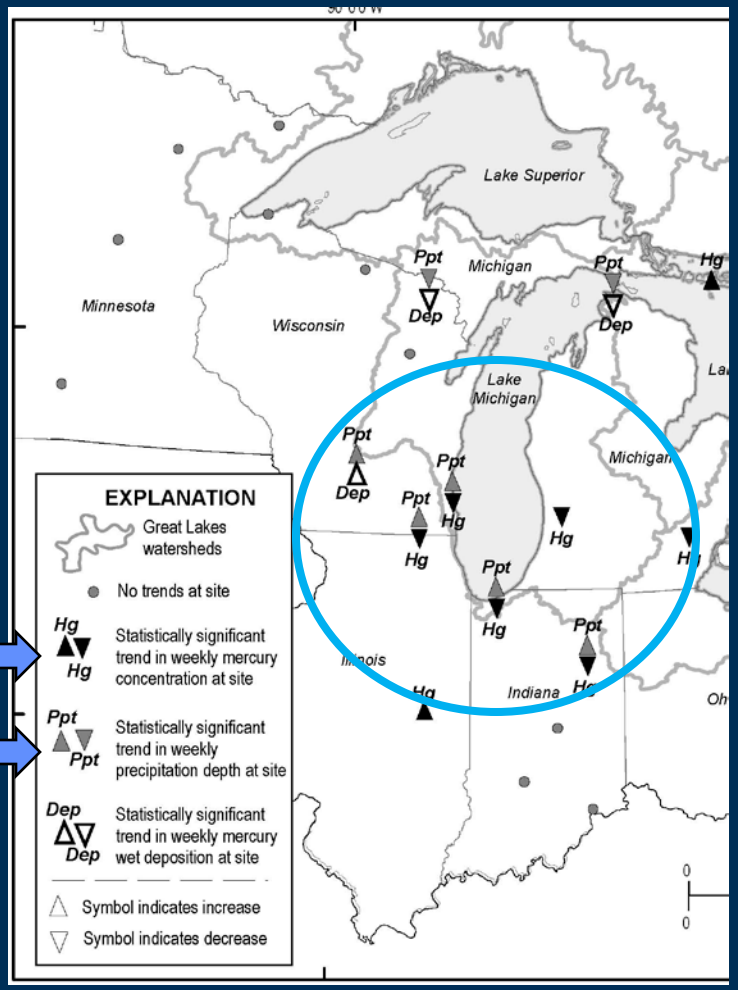
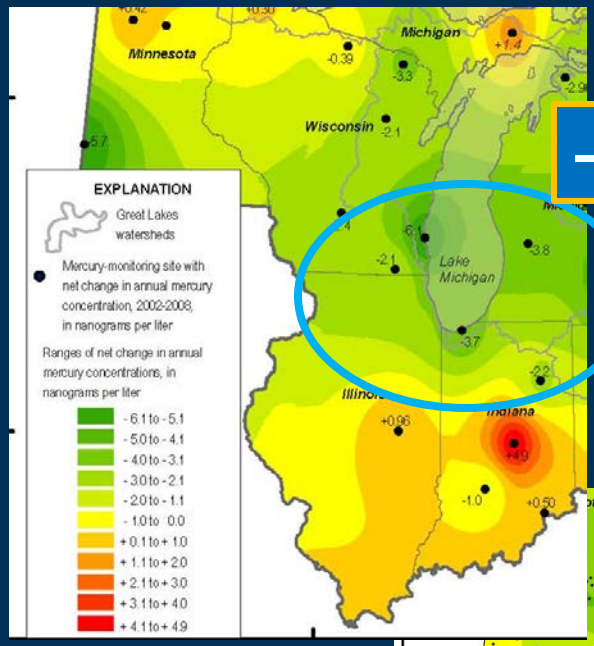
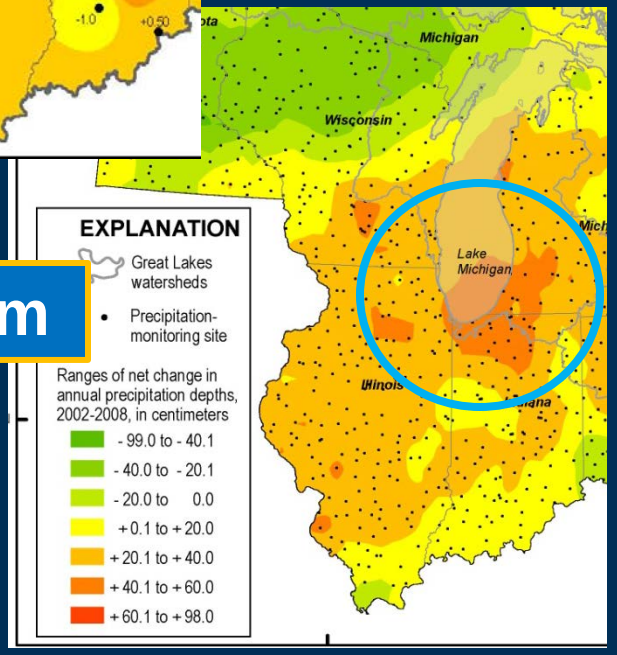
2) Local trends of decreasing Hg concentrations and increasing precipitation depths





–2 to –4 ng/L



+20 to +60 cm

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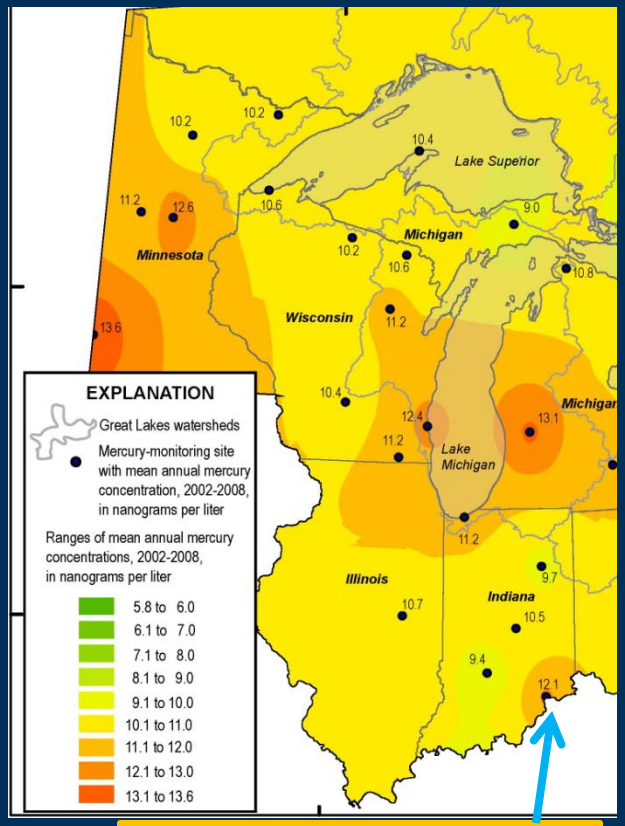
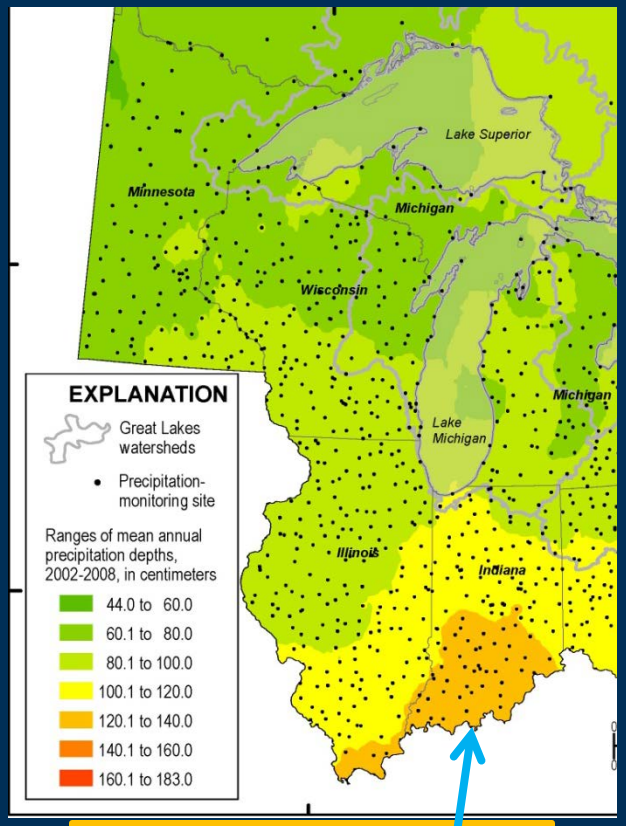
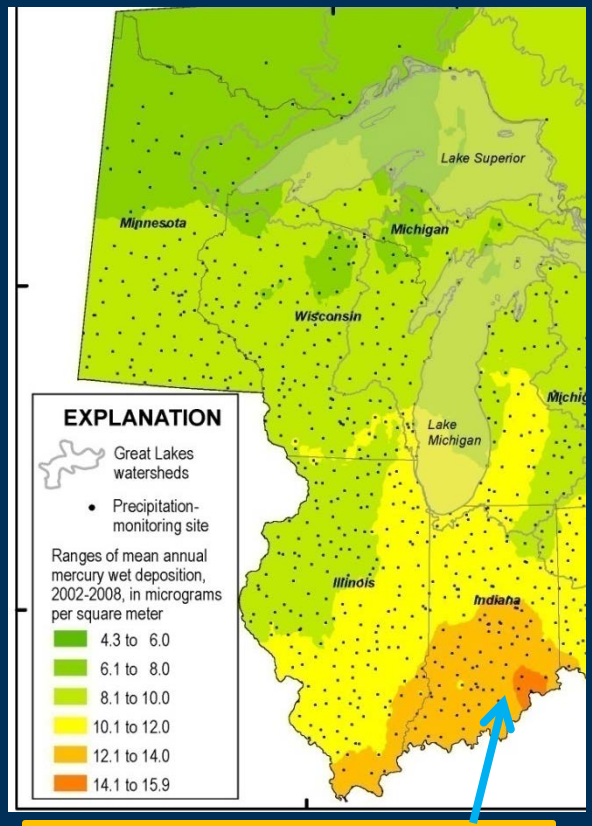
3) Areas of high Hg concentrations, precipitation depths, and Hg wet deposition



11 to 12 ng/L



120 to 140 cm



12 to 15.9 μg/m²

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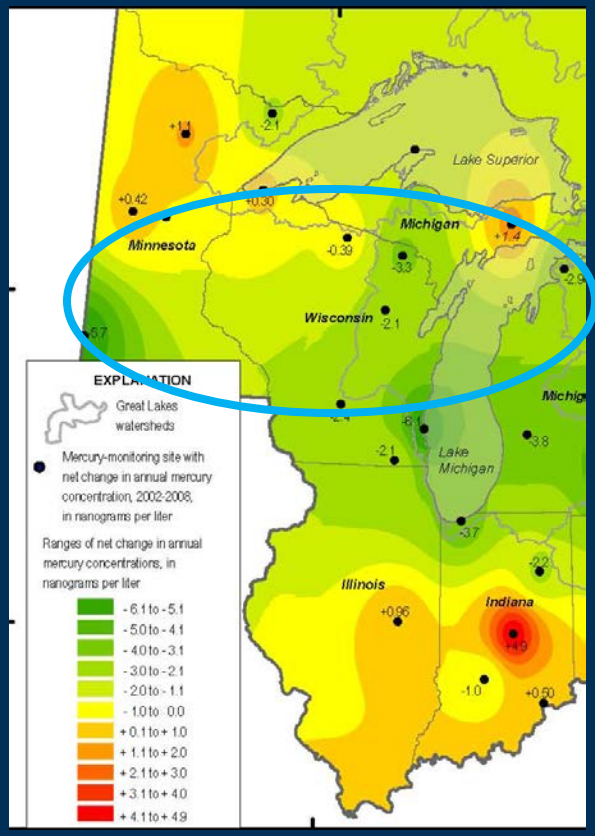
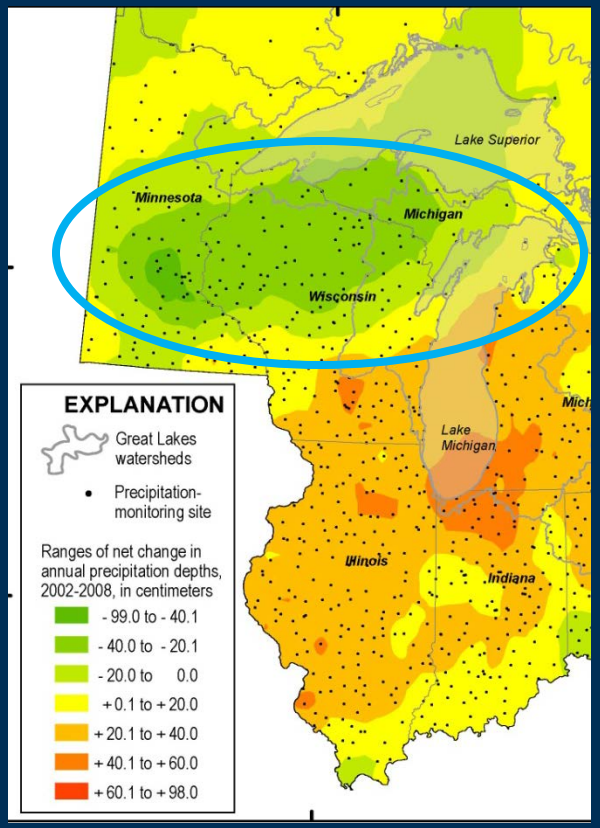
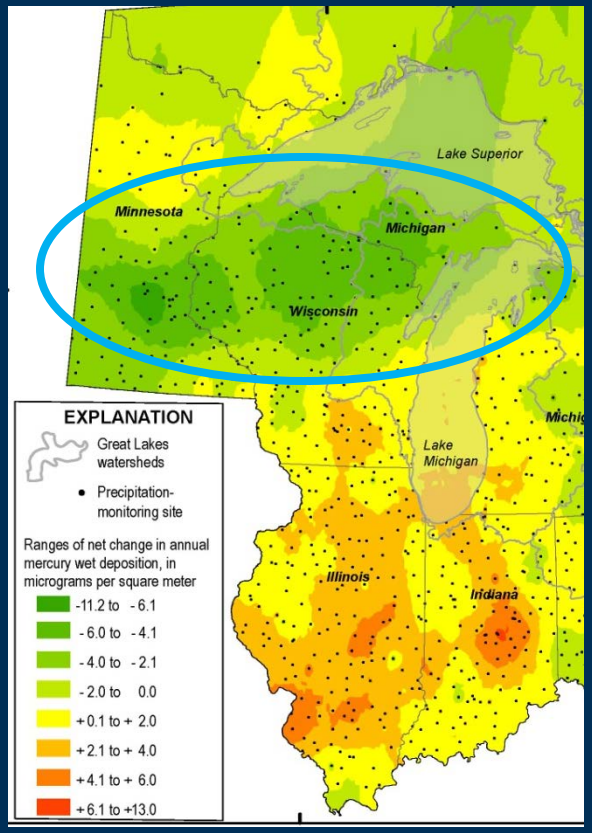
4) Local decreases in Hg concentrations, precipitation depths, and Hg wet deposition







–2 to –3 ng/L

– 20 to –40 cm

– 4 to – 6 μg/m²

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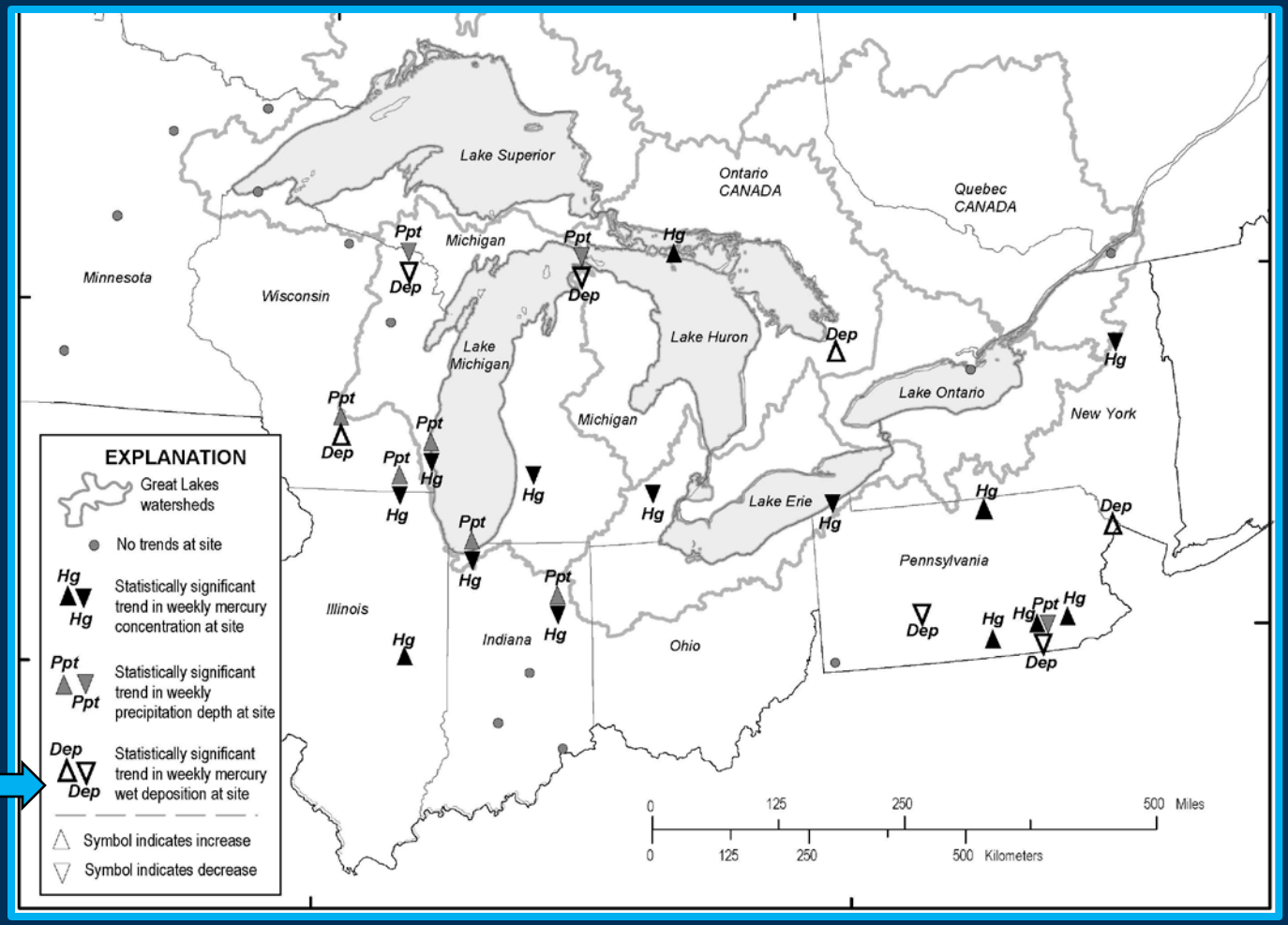
Trends in weekly Hg concentrations and Hg wet deposition do not correspond in location/direction; No regional trend in Hg wet deposition



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Summary and Footnote

- Regionally: small decrease in Hg concentration, real increase in precipitation; Hg wet deposition largely unchanged in 7 years.
- Localized differences, changes, and trends.
- No overlapping patterns or trends of decreasing Hg concentration and decreasing Hg deposition likely associated with decreases in Hg emissions.
- Number of MDN sites in Great Lakes region declining or closed in 2012: IN, OH, MI, Ontario, maybe WI; no changes MN, PA, & IL

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Spatial patterns and temporal trends in mercury concentrations, precipitation depths, and mercury wet deposition in the North American Great Lakes region, 2002–2008

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ABSTRACT

Annual and weekly mercury (Hg) concentrations, precipitation depths, and Hg wet deposition in the Great Lakes region were analyzed by using data from 5 monitoring networks in the USA and Canada for a 2002–2008 study period. High-resolution maps of calculated annual data, 7-year mean data, and net interannual change for the study period were prepared to assess spatial patterns. Areas with 7-year mean annual Hg concentrations higher than the 12 ng per liter water-quality criterion were mapped in 4 states. Temporal trends in measured weekly data were determined statistically. Monitoring sites with significant 7-year trends in weekly Hg wet deposition were spatially separated and were not sites with trends in weekly Hg concentration. During 2002–2008, Hg wet deposition was found to be unchanged in the Great Lakes region and its subregions. Any small decreases in Hg concentration apparently were offset by increases in precipitation.

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1. Introduction

Mercury (Hg) in aquatic ecosystems is a public-health concern and a threat to wildlife because it accumulates and magnifies to unsafe levels in aquatic food chains. Much of the Hg in aquatic ecosystems is introduced by atmospheric deposition, largely from Hg emissions to the atmosphere from human activity (Madison Declaration on Mercury Pollution, 2007). Currently, 100 percent of the Great Lakes and their connecting waters and the 8 USA states and 2 Canadian provinces in the North American Great Lakes region (hereafter, the Great Lakes region) have fish-consumption advisories because of unsafe Hg levels (Ontario Ministry of the Environment, 2009; Québec Ministère de l'Environnement, 2010; U.S. Environmental Protection Agency, 2009).

Atmospheric Hg can be transported to aquatic or terrestrial ecosystems in wet deposition through rainout from clouds and washout from the air. Mercury has been detected in precipitation throughout North America since monitoring began in 1996 (National Atmospheric Deposition Program, 2010; Prestbo and Gay, 2009; Sweet and Prestbo, 1999), and Hg concentrations in precipitation often exceed the water-quality criterion for a continuous freshwater concentration (12 ng per liter, ng/L; U.S. Environmental Protection Agency, 1999).

Previous investigations of Hg in precipitation in the USA and Canada have included monitoring sites in the Great Lakes region. At least 8 studies included Hg-monitoring data from sites in the Great Lakes region during 1993–2005. Sweet and Prestbo (1999) summarized data from as many as 30 sites in the Mercury Deposition Network (MDN) of the National Atmospheric Deposition Program (NADP) in North America for 1995–1998. Landis et al. (2002) investigated Hg wet deposition from 5 sites surrounding Lake Michigan as part of the Lake Michigan Mass Balance Study for

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