Thirty-two year retrospective of liming northern hardwoods on the Allegheny Plateau, PA: How long did it take the lime to dissolve and how long do the effects last?"

Scott Bailey, US Forest Service, Northern Research Station

- Barry Towers, PA DCNR, retired
- Lew Auchmoody NEFES, retired
- Dave Saf, NEFES, retired
- Harry Steele, NEFES, retired
- Ernie Wiltsie, NRS, retired
- Robert Long, NRS, retired
- Stephen Horsley, NRS, retired
- Brad Regester, PA DCNR
- Susan Stout, NRS, retired
- Don Eggen, PA DCNR

Study Design

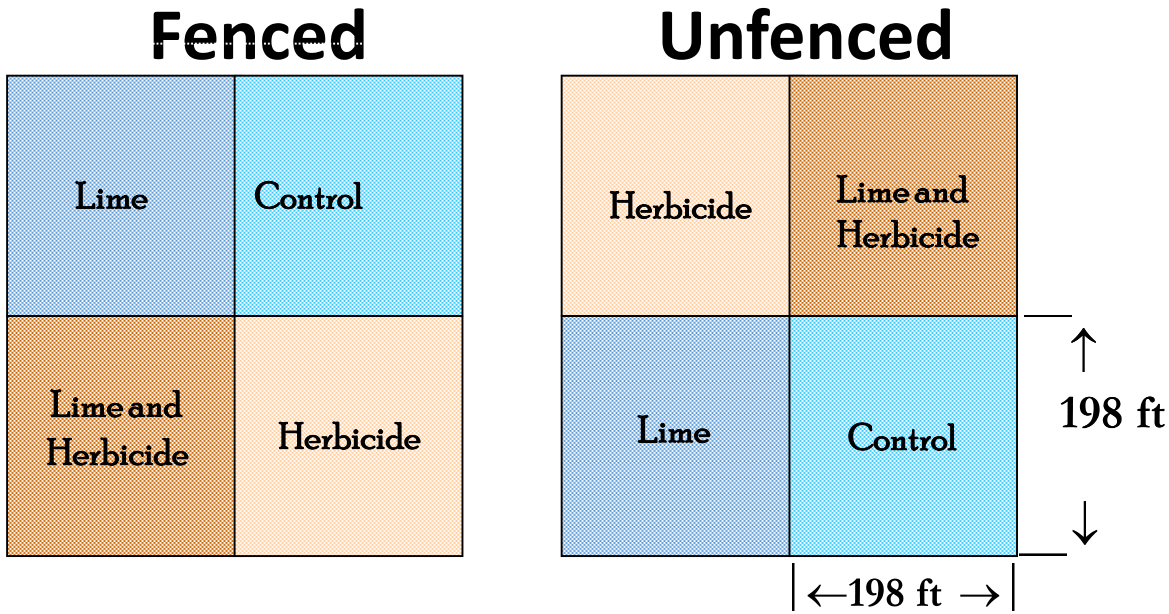
- Four replications on Susquehannock State Forest in Potter County—all on unglaciated soils
- Four treatments in a split plot design:

  Fencing—to exclude deer

  Herbicide– to reduce interfering plants

  Lime—to reduce soil acidity

  Lime + Herbicide



Lime Treatment

- **One-time application of dolomitic limestone at a rate of 22.4 Mg ha^{-1} or 10 tons/acre in 1985**
- **Stands thinned in winter 1985-1986**

Soils of the Allegheny Plateau

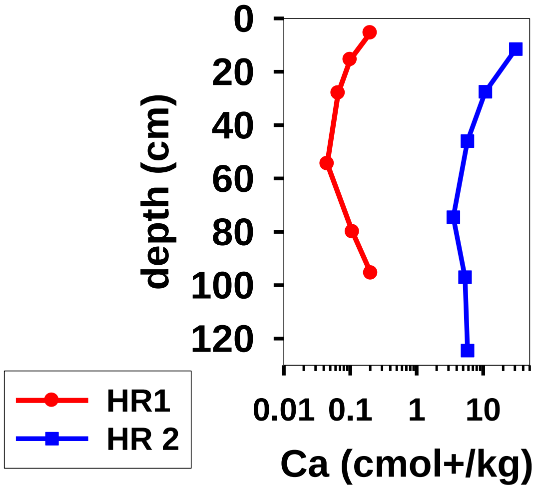
Grandparent Material: clastic sedimentary rocks

Unglaciated Plateau

Parent Materials: Residuum, Colluvium

Ultisols and Inceptisols

Total Ca content: 0.02 %



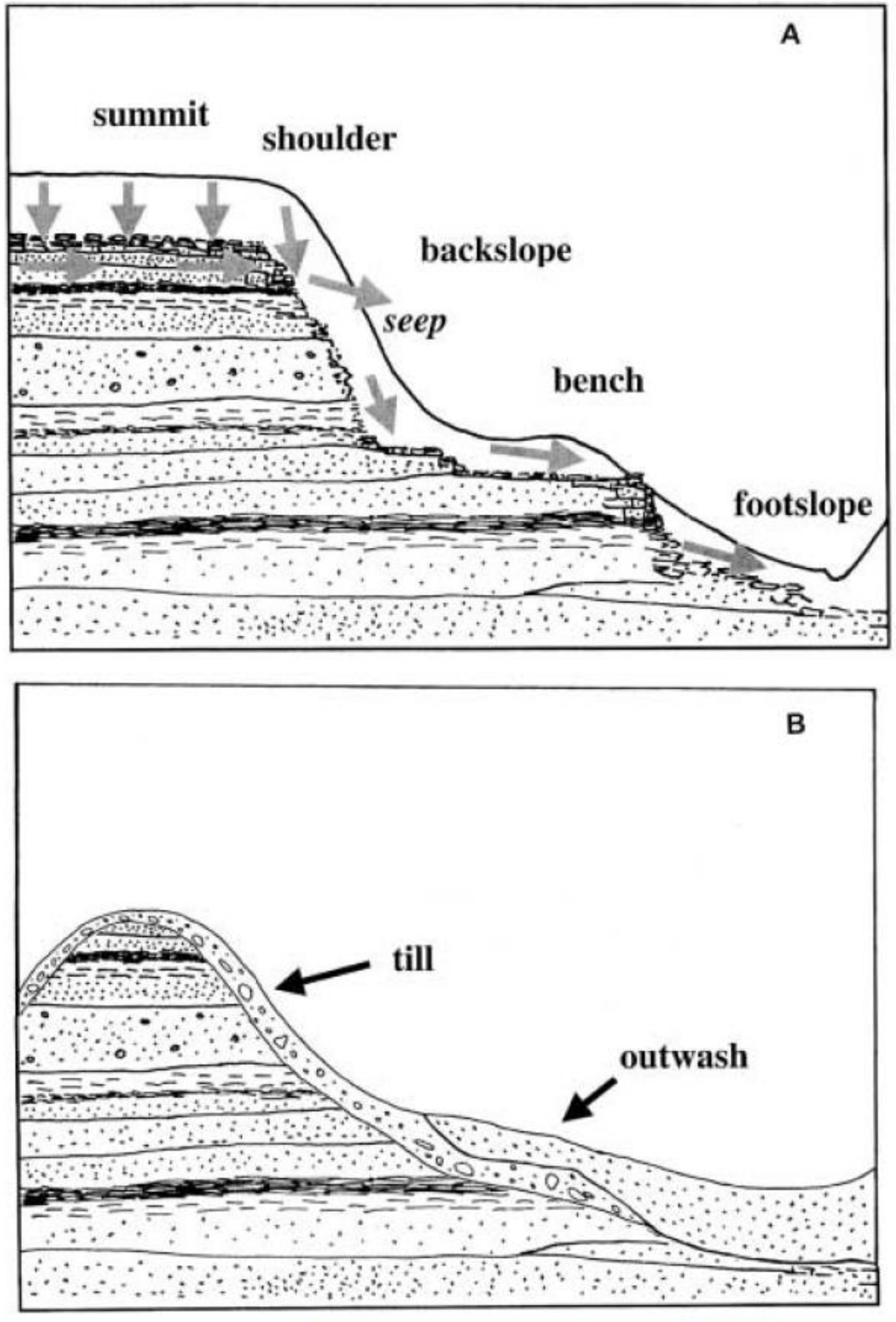
Glaciated Plateau

Parent Materials: Glacial Drift

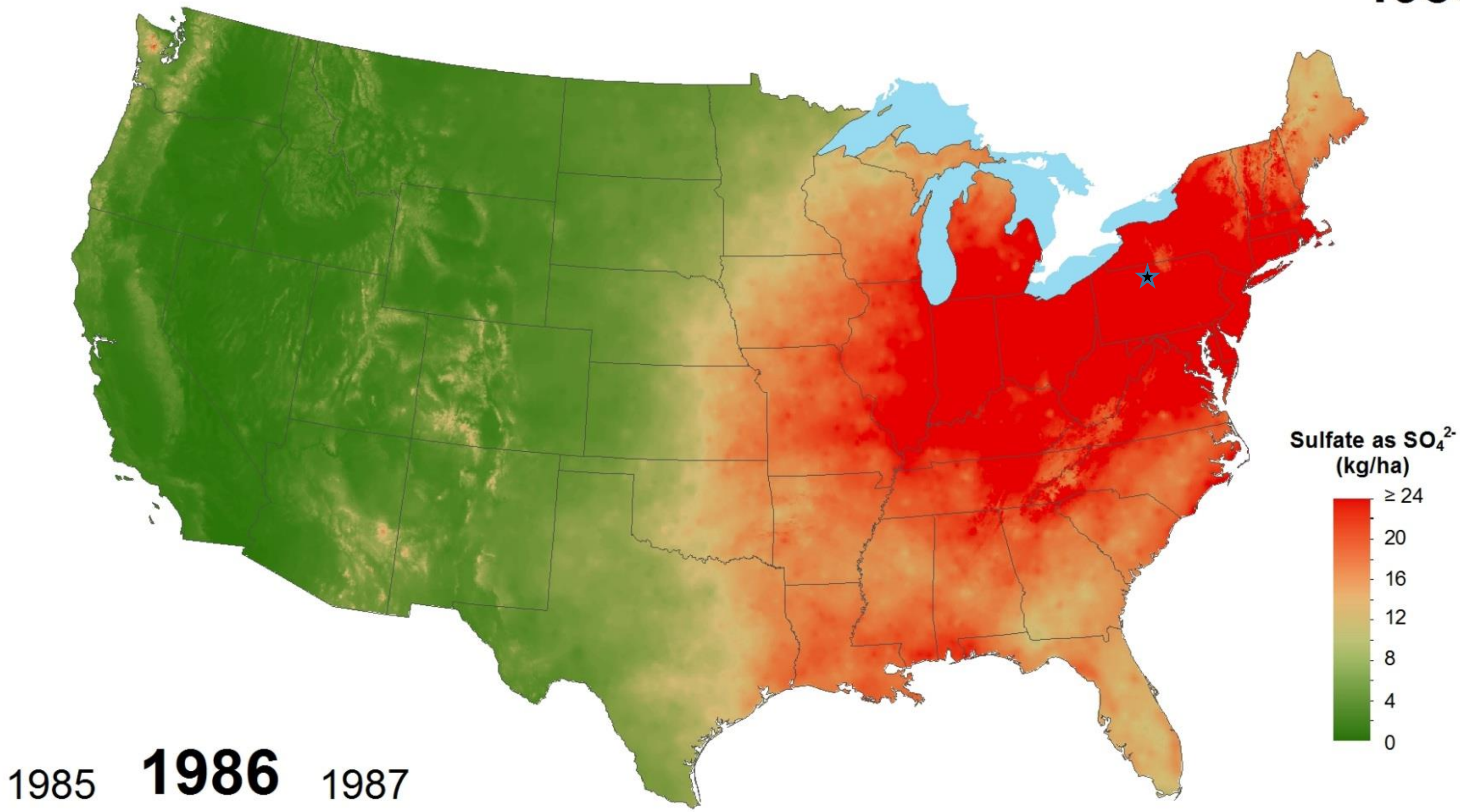
Inceptisols

Total Ca content: 1.0%

Bailey et al. 2004

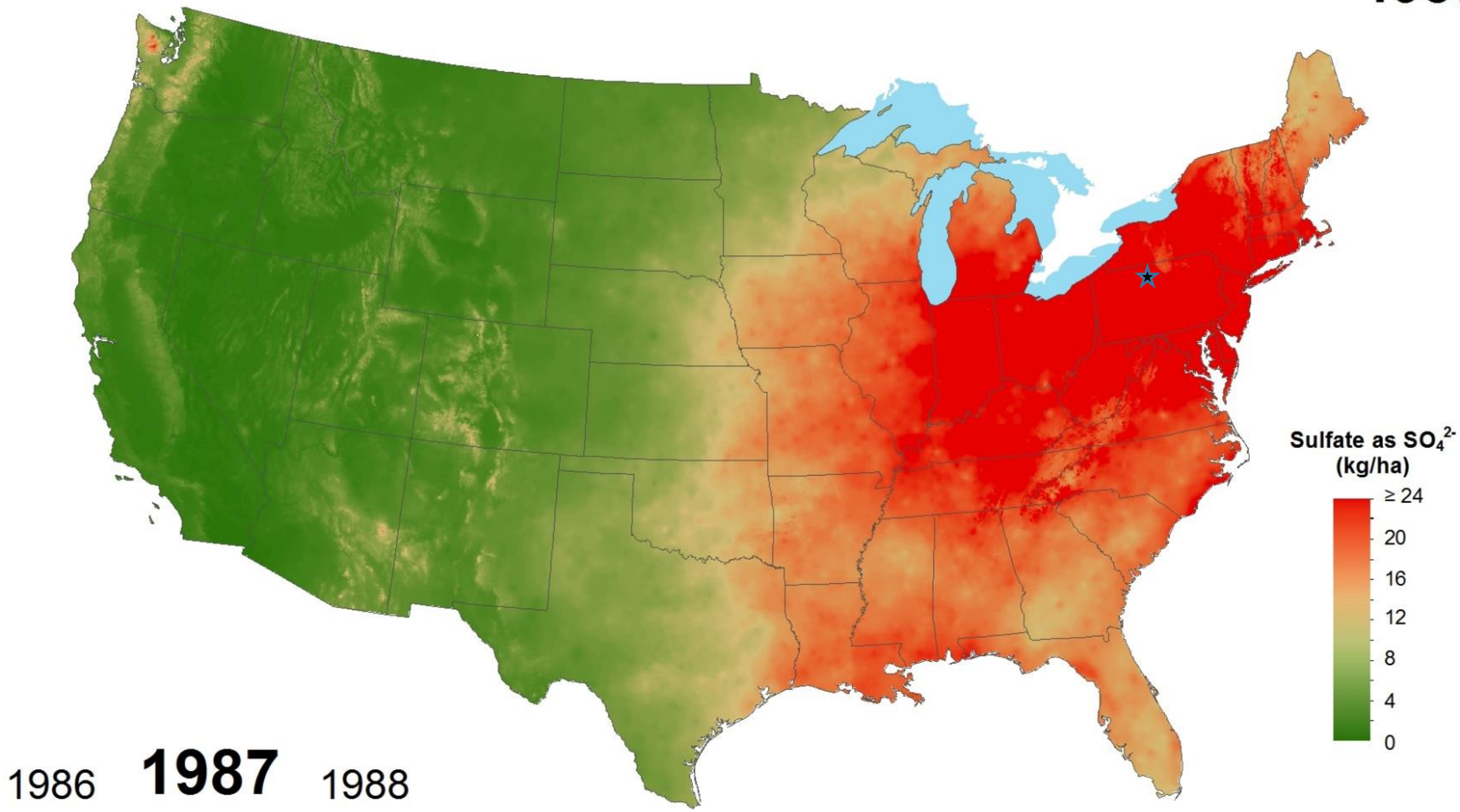


Sulfate ion wet deposition
1986



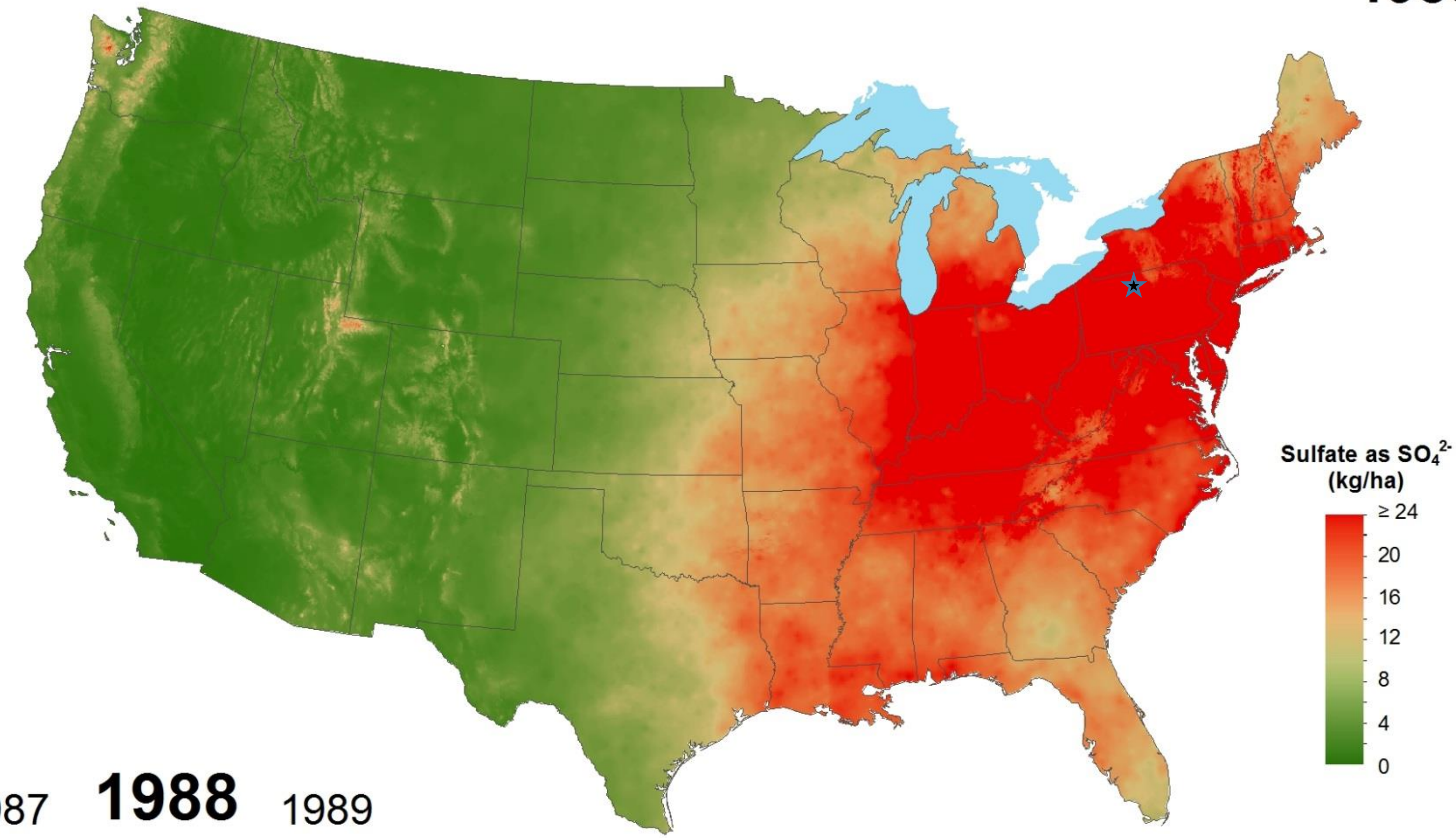
National Atmospheric Deposition Program/National Trends Network
http://nadp.isws.illinois.edu

Sulfate ion wet deposition
1987



National Atmospheric Deposition Program/National Trends Network
http://nadp.isws.illinois.edu

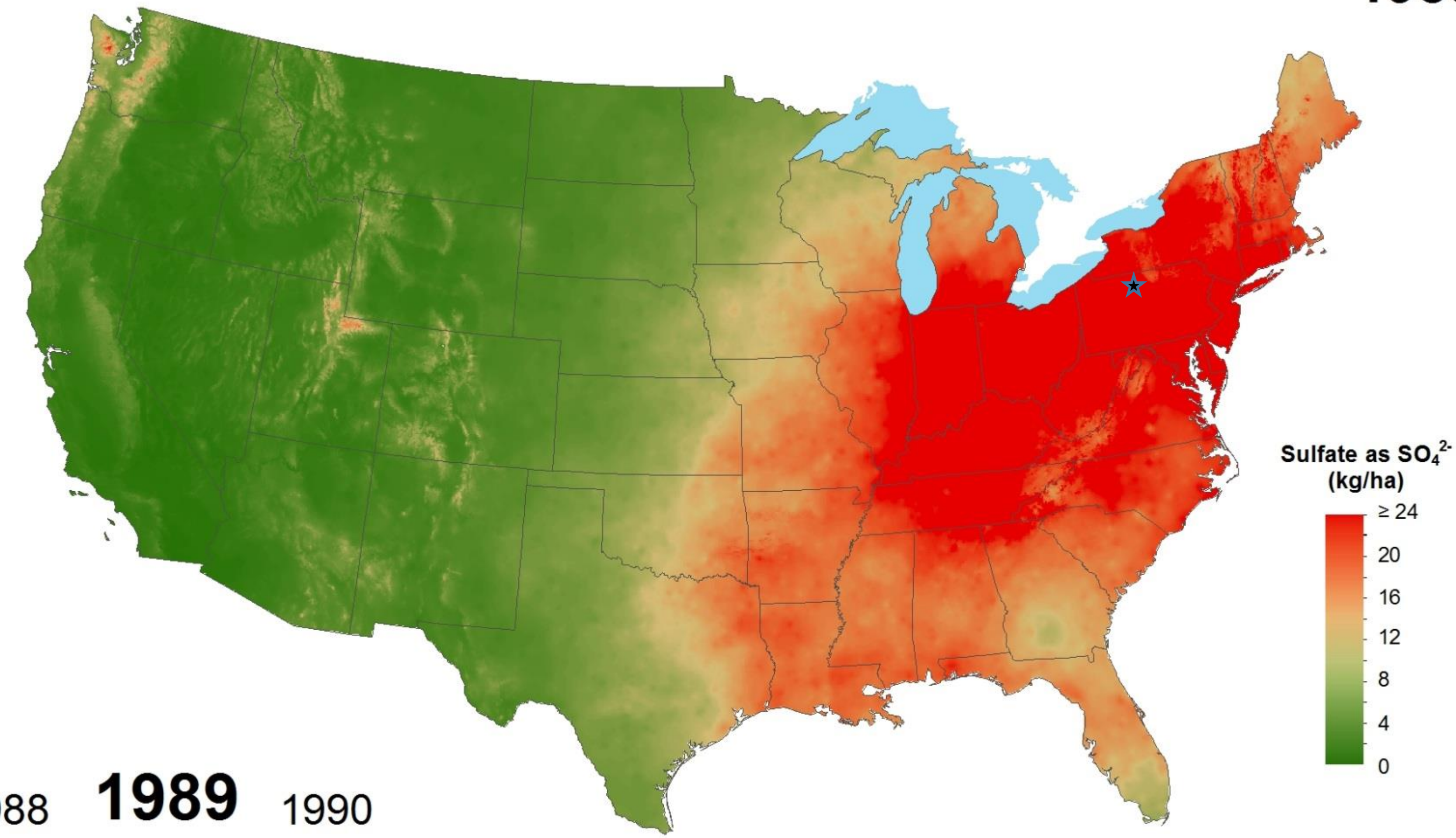
Sulfate ion wet deposition
1988



1987 **1988** 1989

National Atmospheric Deposition Program/National Trends Network
http://nadp.isws.illinois.edu

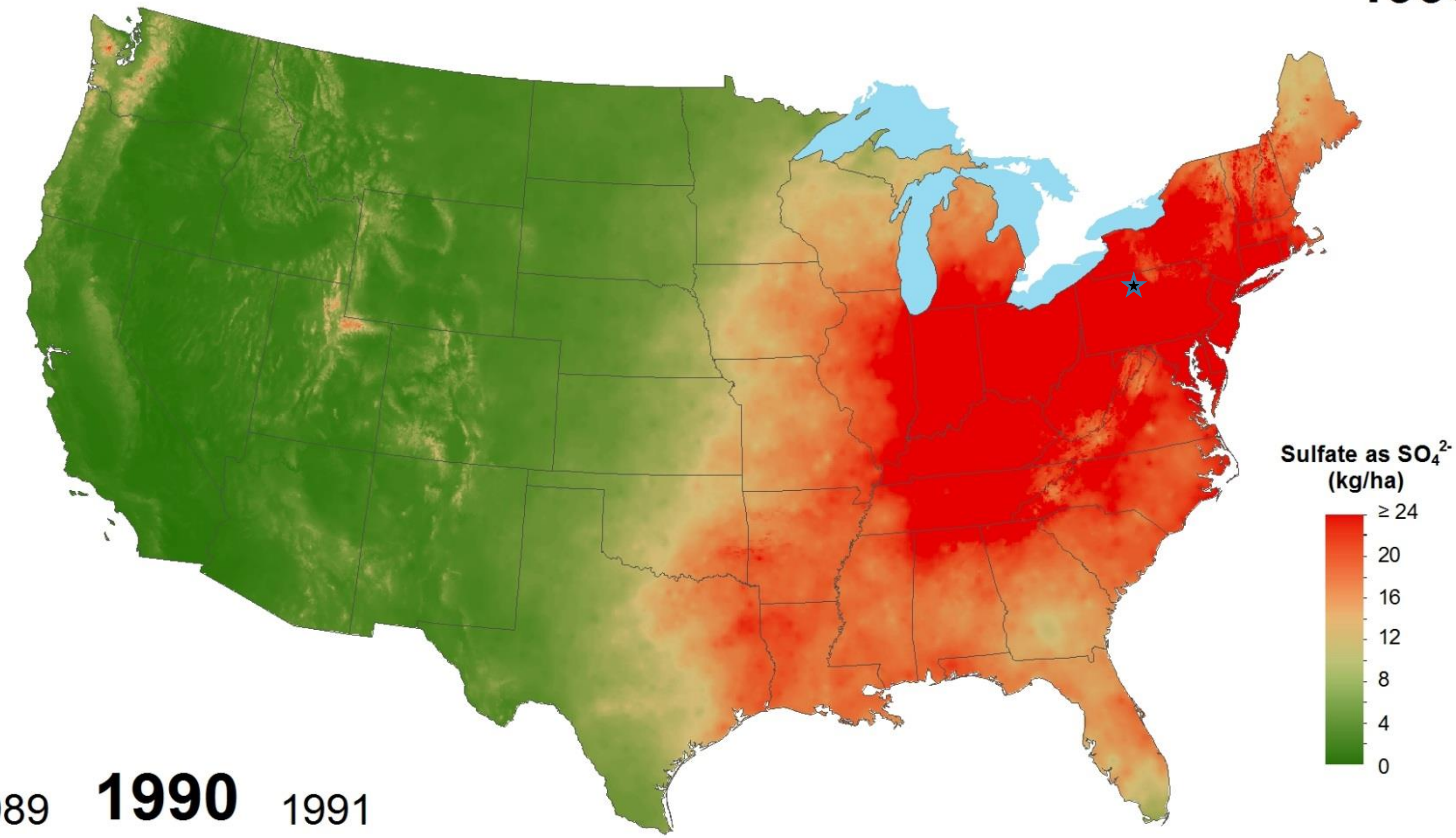
Sulfate ion wet deposition
1989



1988 **1989** 1990

National Atmospheric Deposition Program/National Trends Network
http://nadp.isws.illinois.edu

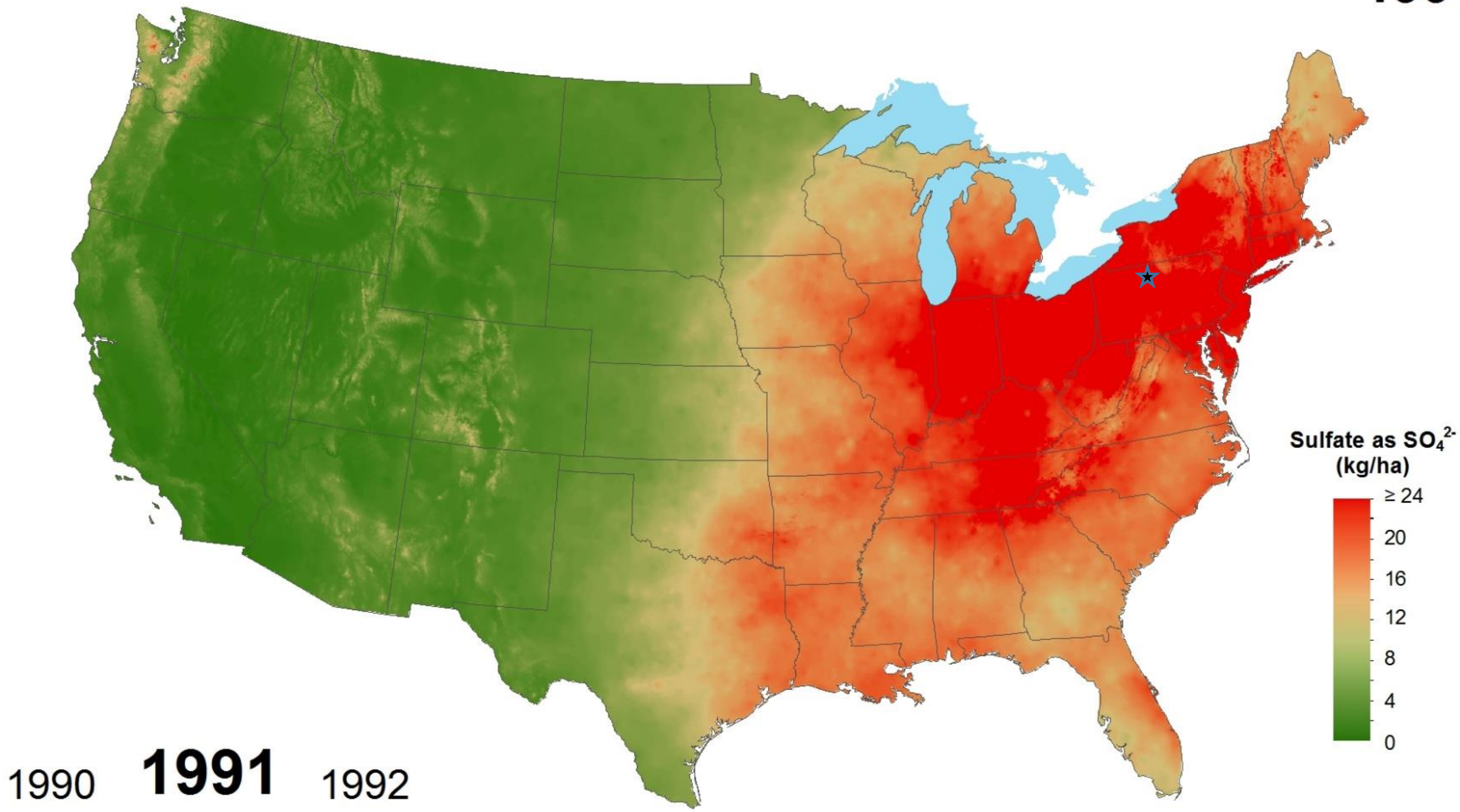
Sulfate ion wet deposition
1990



1989 **1990** 1991

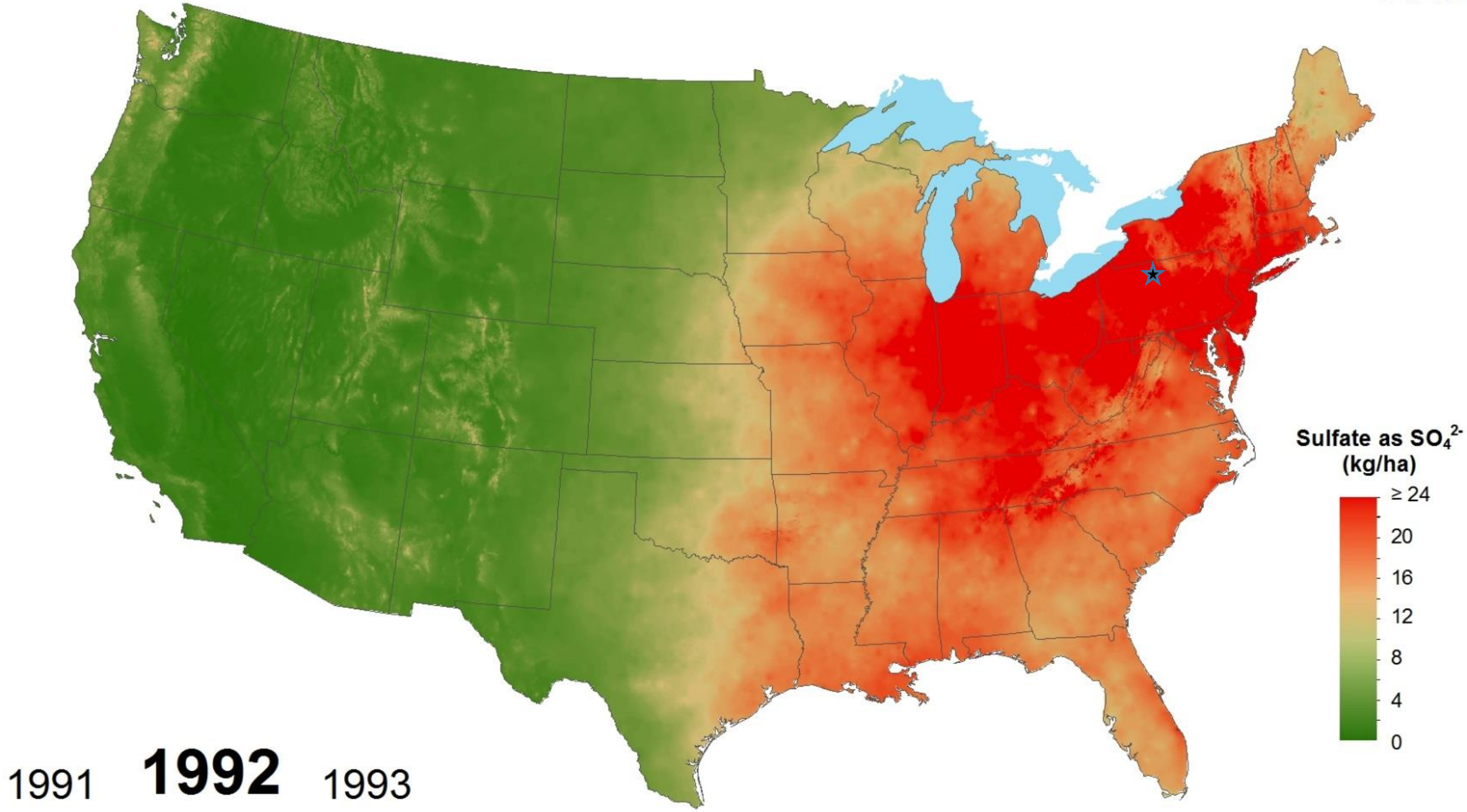
National Atmospheric Deposition Program/National Trends Network
http://nadp.isws.illinois.edu

Sulfate ion wet deposition
1991



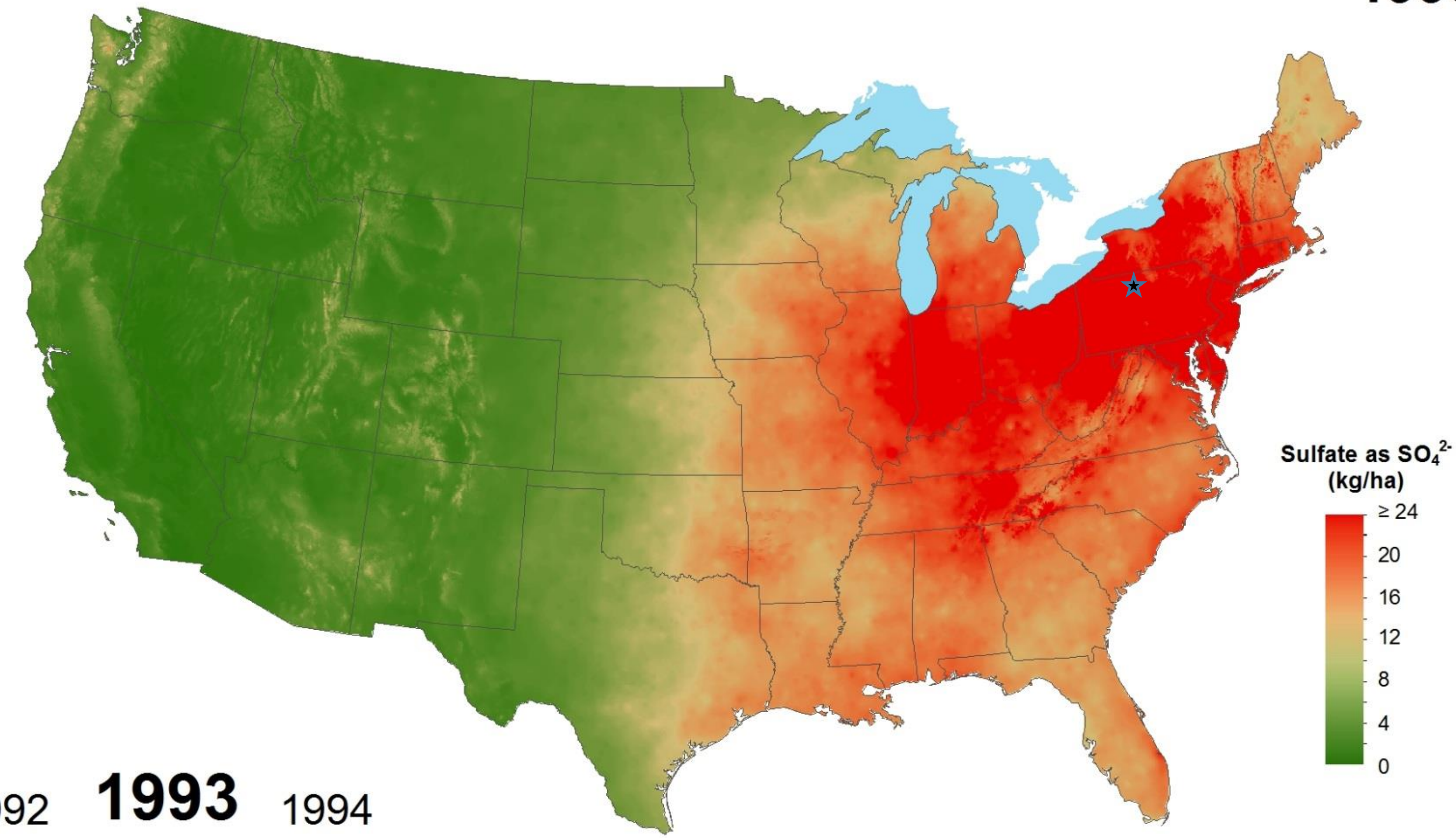
National Atmospheric Deposition Program/National Trends Network
http://nadp.isws.illinois.edu

Sulfate ion wet deposition
1992



National Atmospheric Deposition Program/National Trends Network
http://nadp.isws.illinois.edu

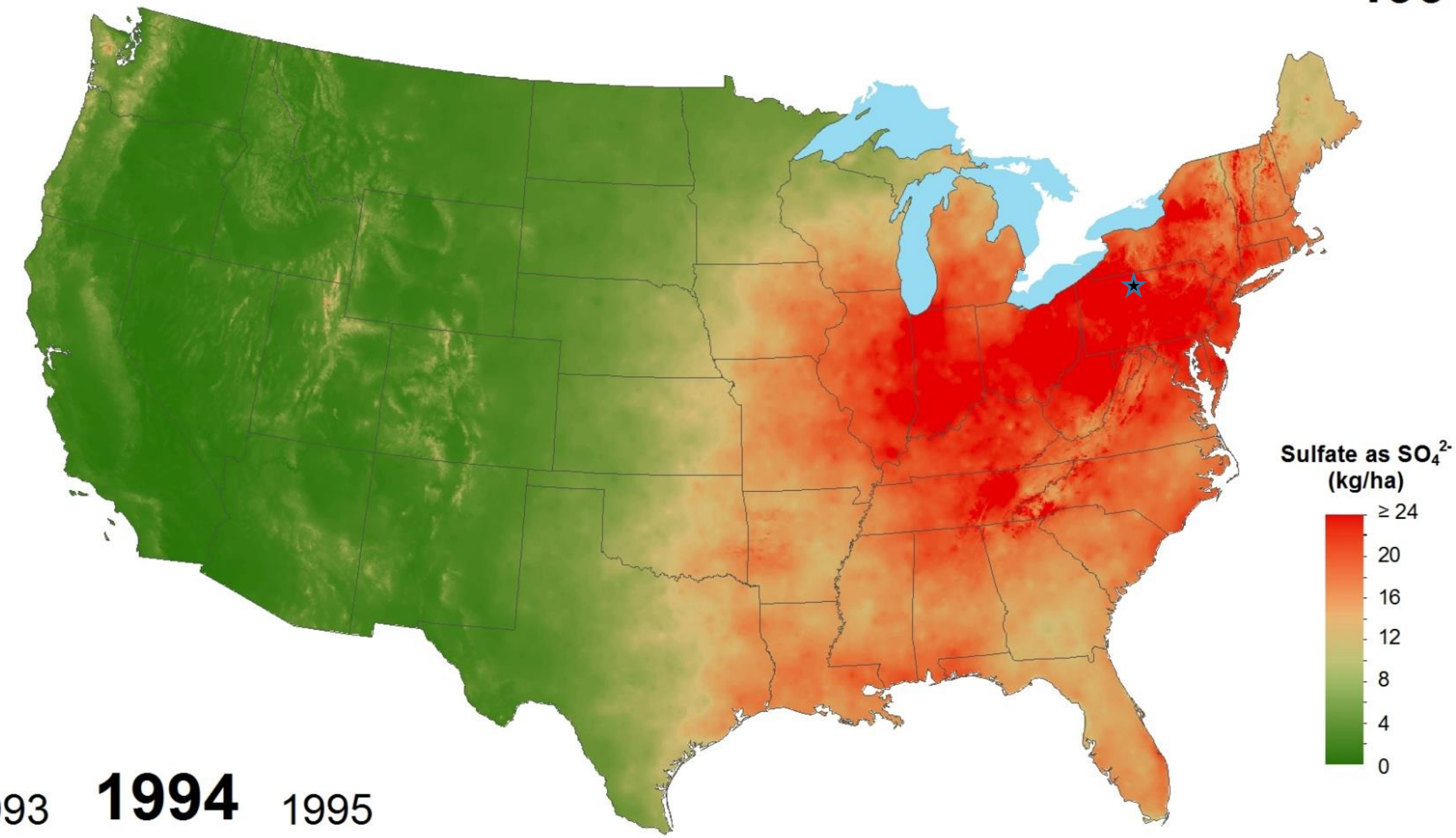
Sulfate ion wet deposition
1993



1992 **1993** 1994

National Atmospheric Deposition Program/National Trends Network
http://nadp.isws.illinois.edu

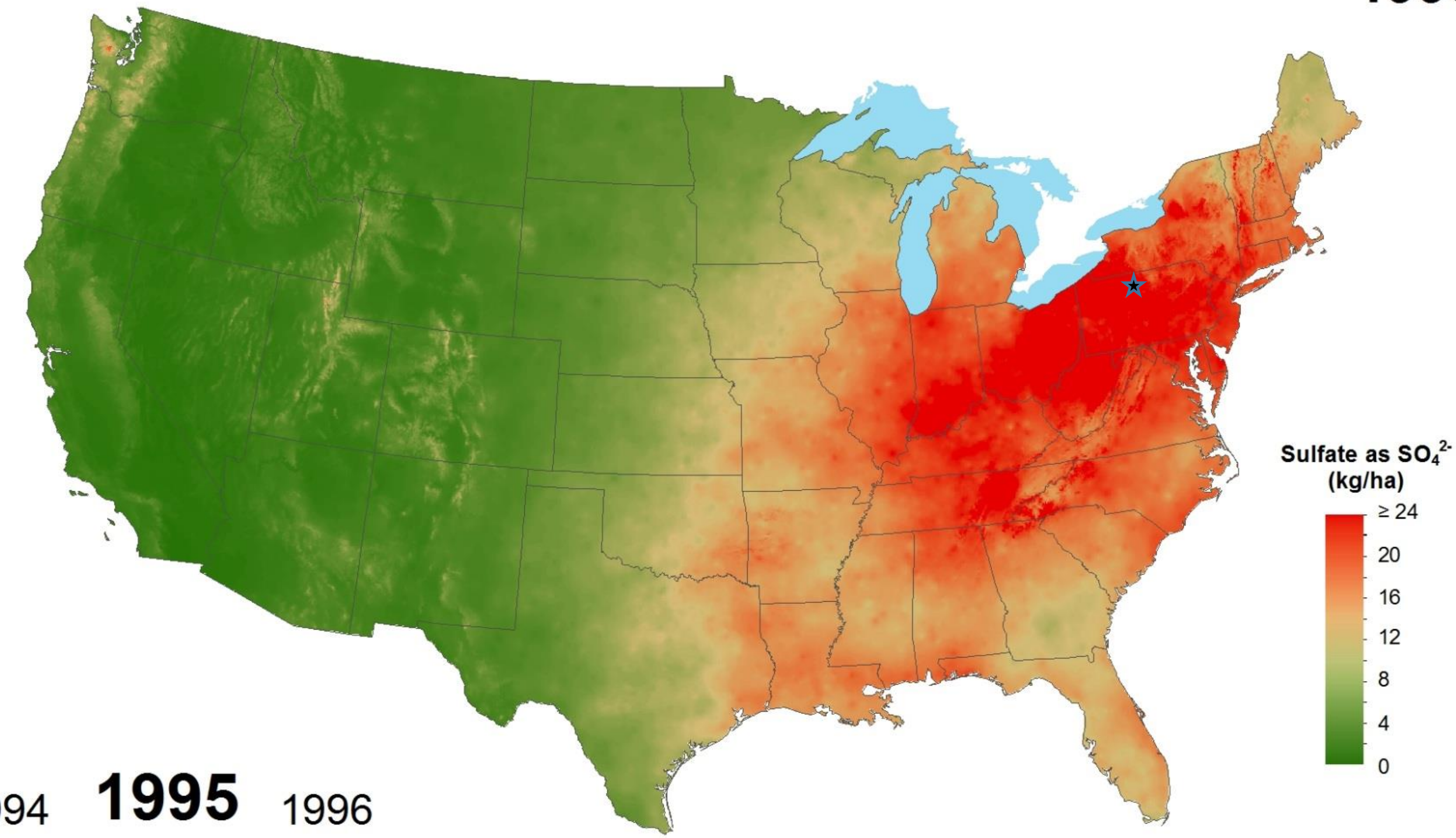
Sulfate ion wet deposition
1994



1993 **1994** 1995

National Atmospheric Deposition Program/National Trends Network
http://nadp.isws.illinois.edu

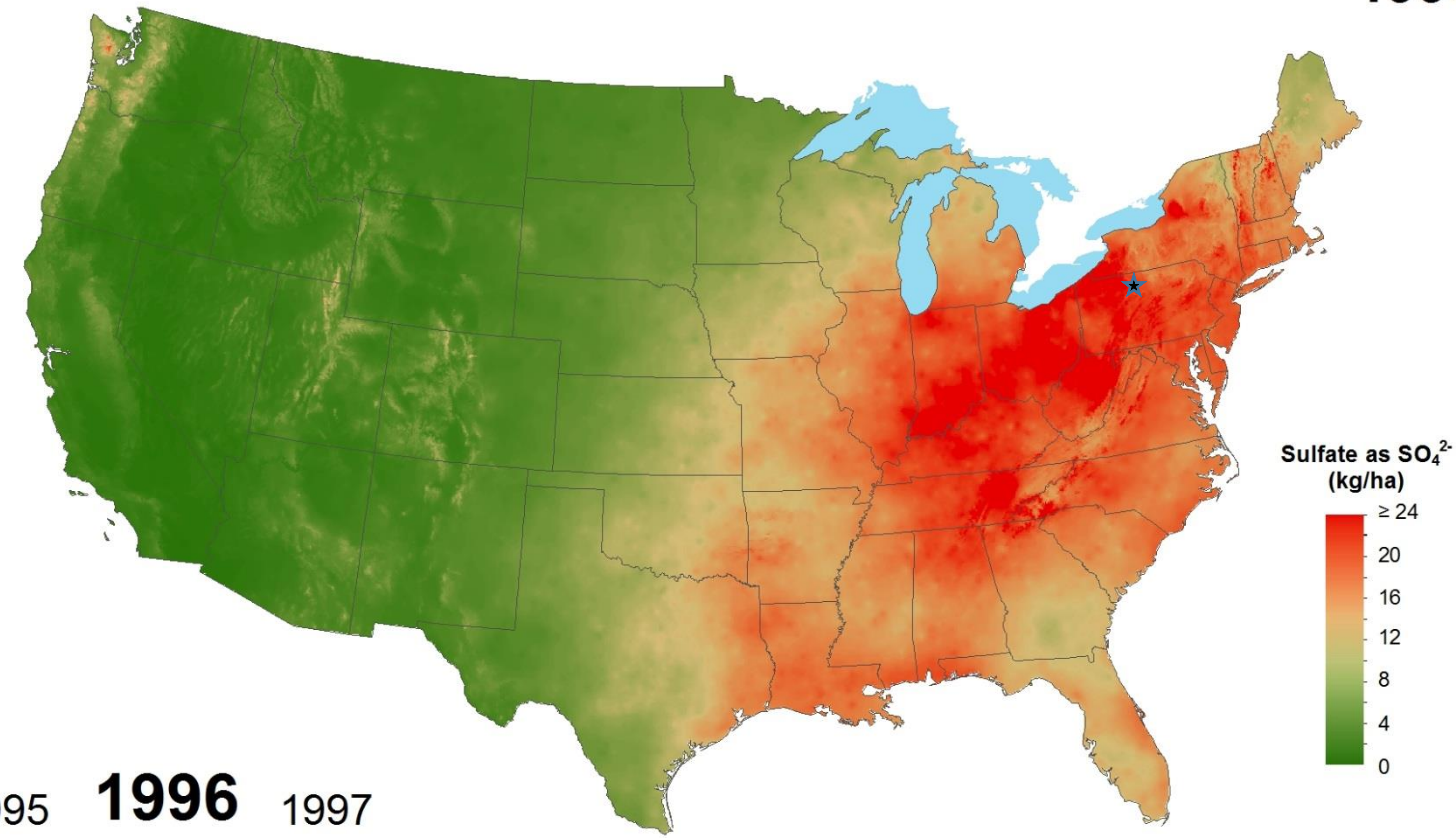
Sulfate ion wet deposition
1995



1994 **1995** 1996

National Atmospheric Deposition Program/National Trends Network
http://nadp.isws.illinois.edu

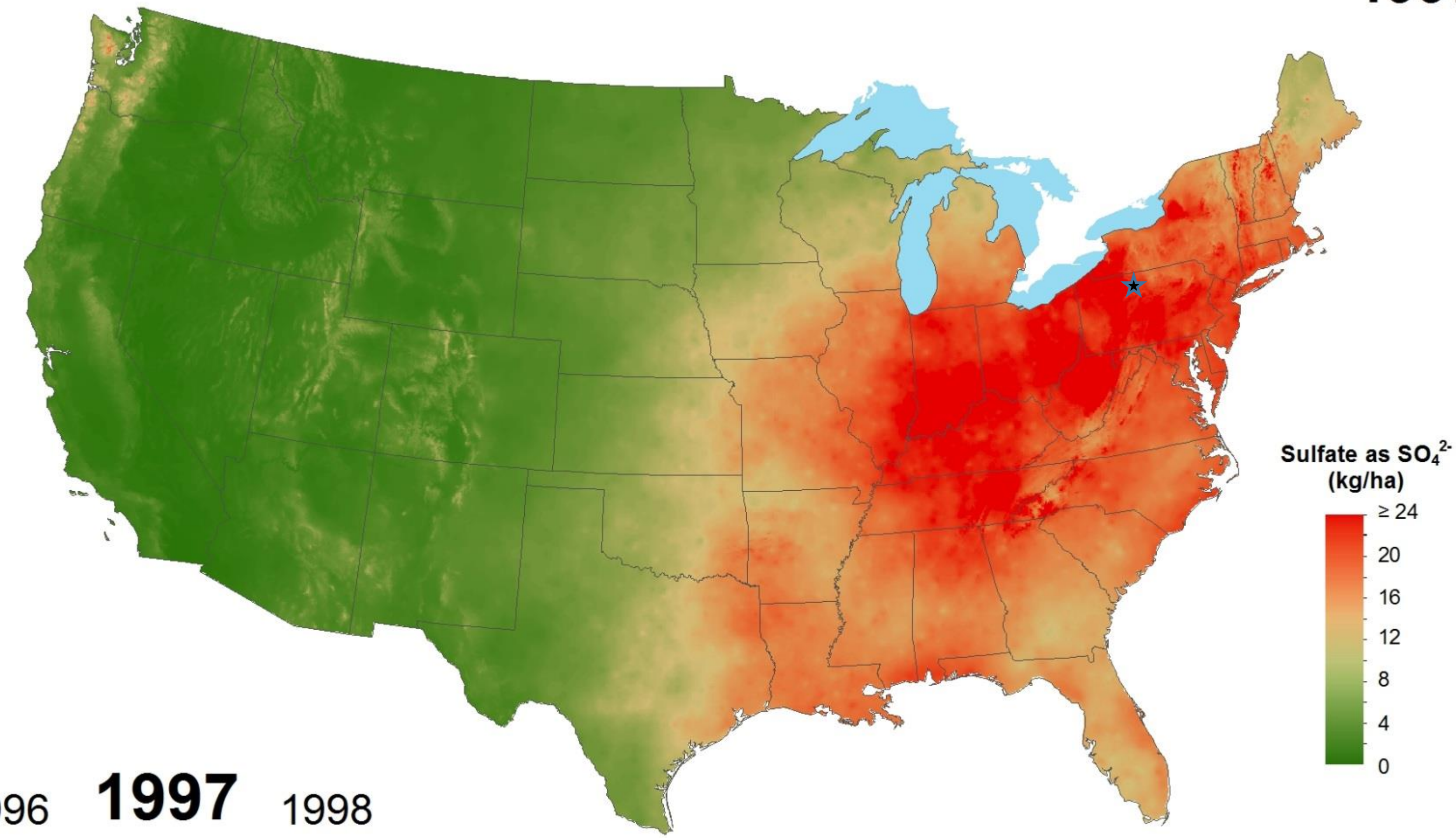
Sulfate ion wet deposition
1996



1995 **1996** 1997

National Atmospheric Deposition Program/National Trends Network
http://nadp.isws.illinois.edu

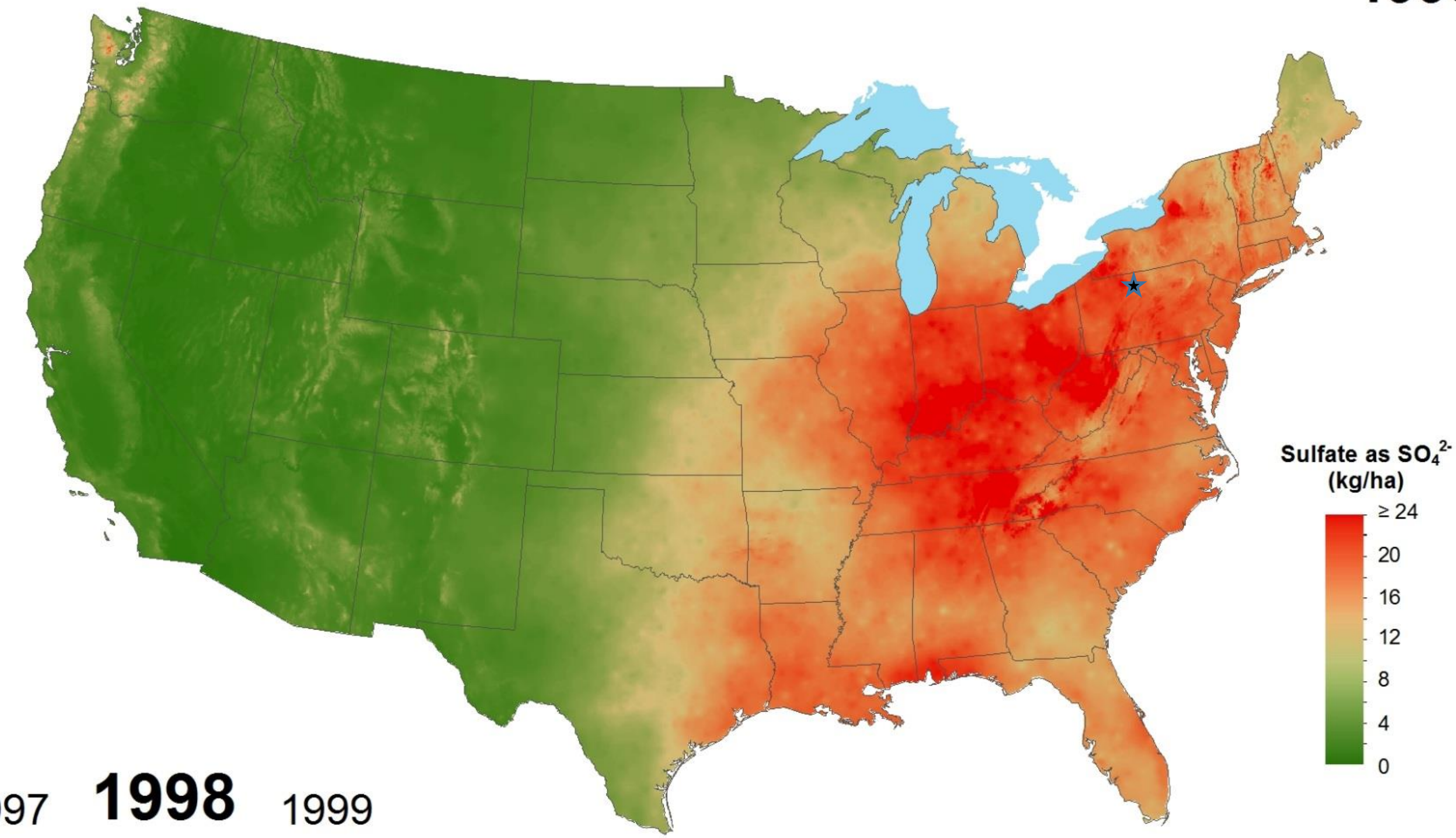
Sulfate ion wet deposition
1997



1996 **1997** 1998

National Atmospheric Deposition Program/National Trends Network
http://nadp.isws.illinois.edu

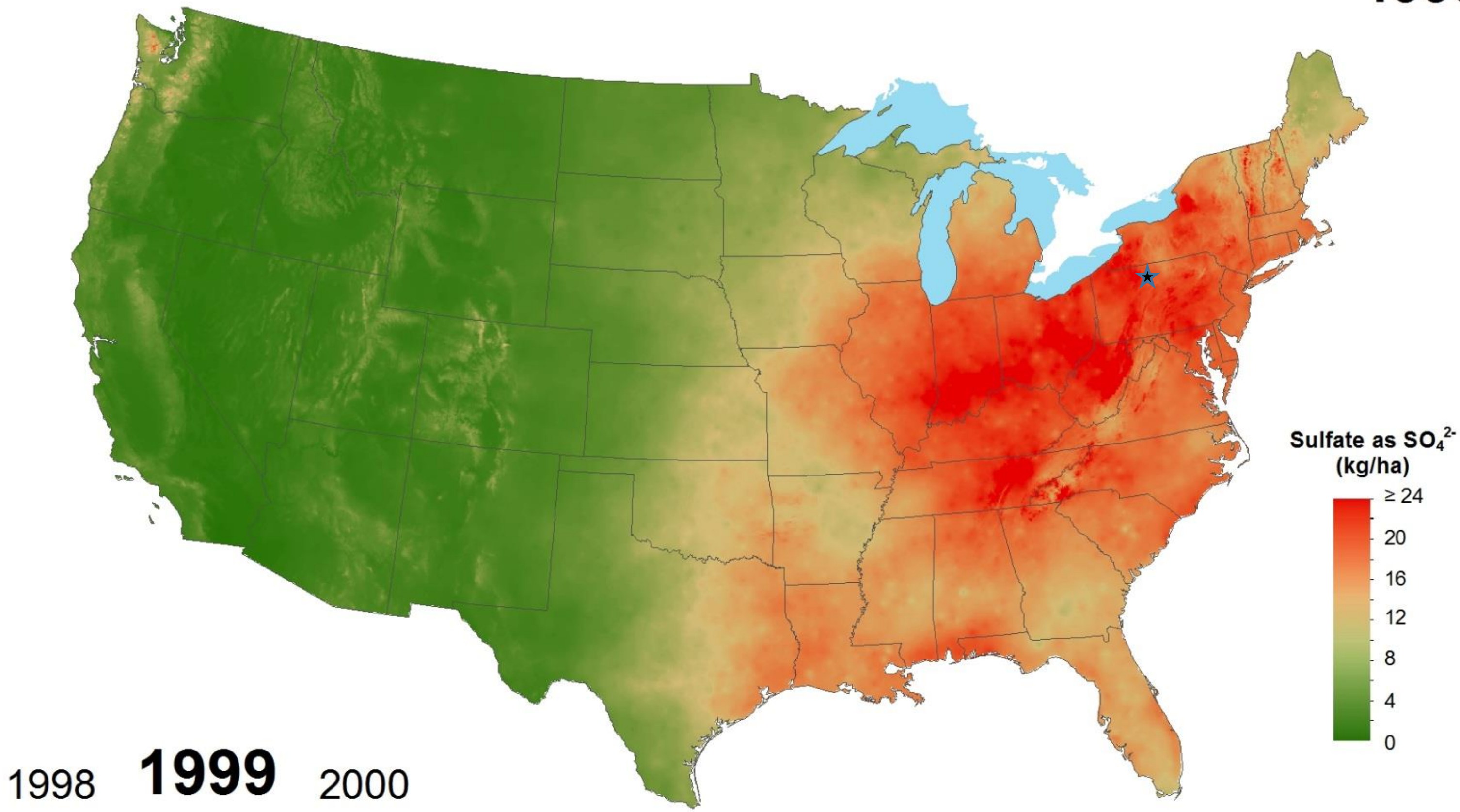
Sulfate ion wet deposition
1998



1997 **1998** 1999

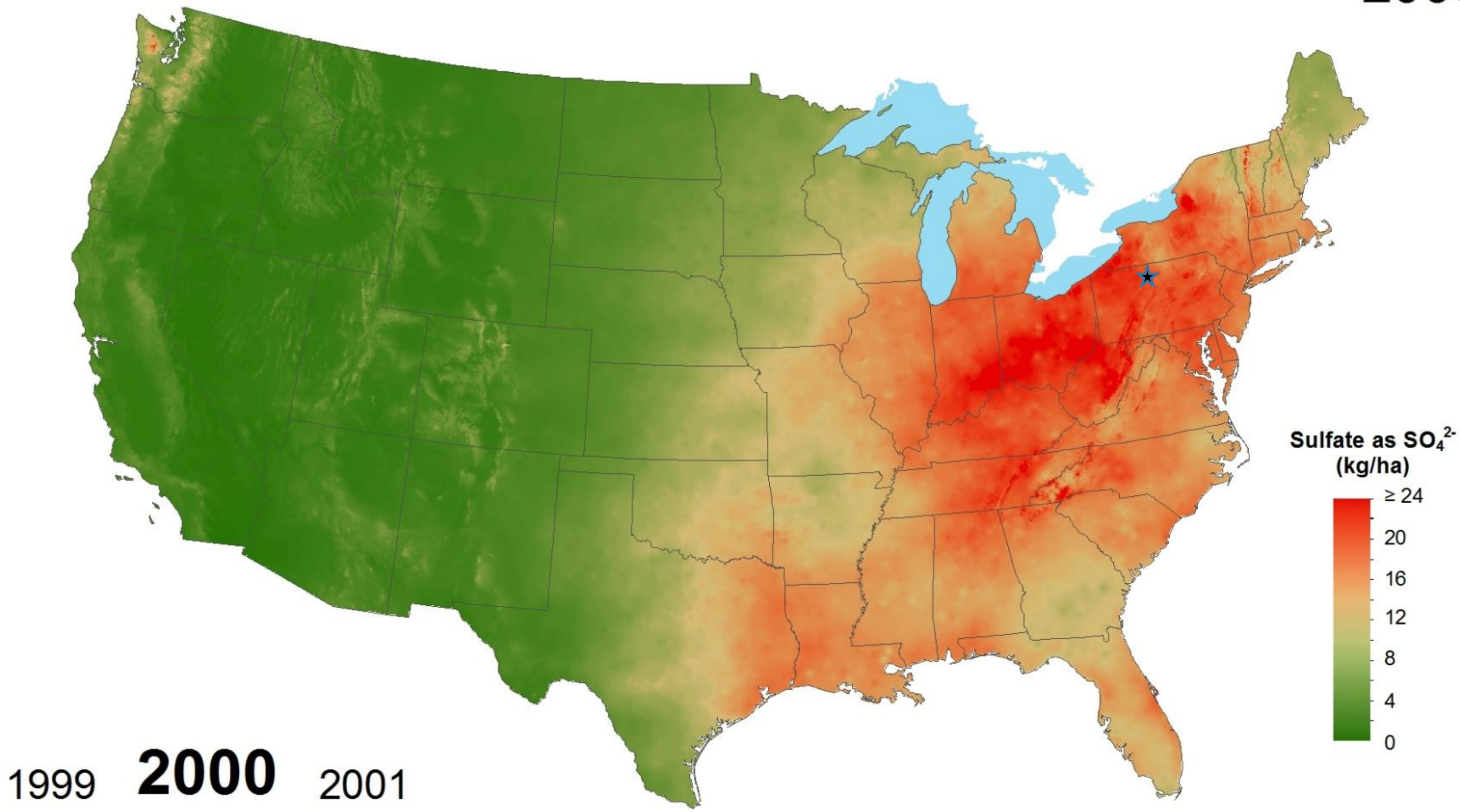
National Atmospheric Deposition Program/National Trends Network
http://nadp.isws.illinois.edu

Sulfate ion wet deposition
1999



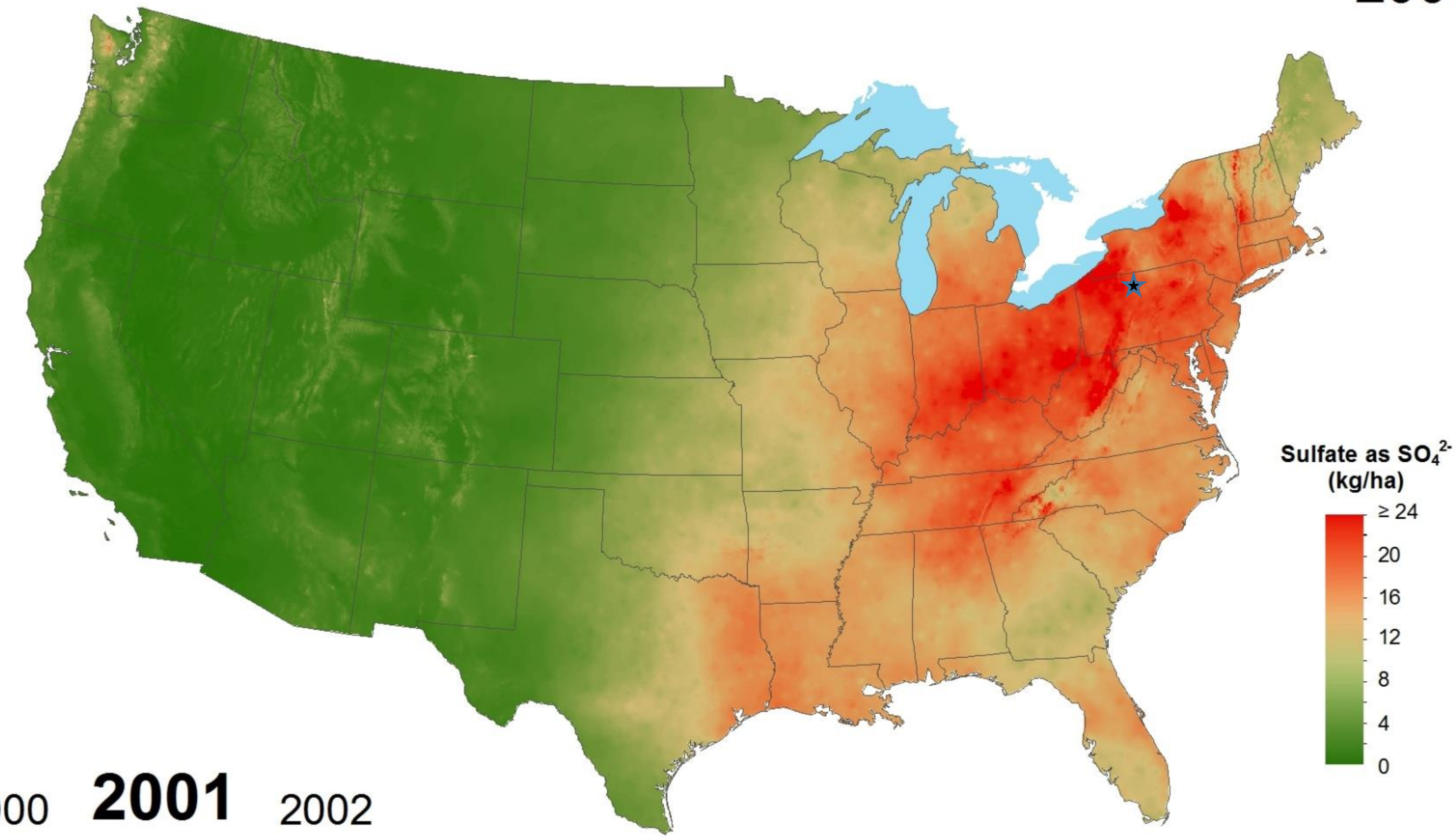
National Atmospheric Deposition Program/National Trends Network
http://nadp.isws.illinois.edu

Sulfate ion wet deposition
2000



National Atmospheric Deposition Program/National Trends Network
http://nadp.isws.illinois.edu

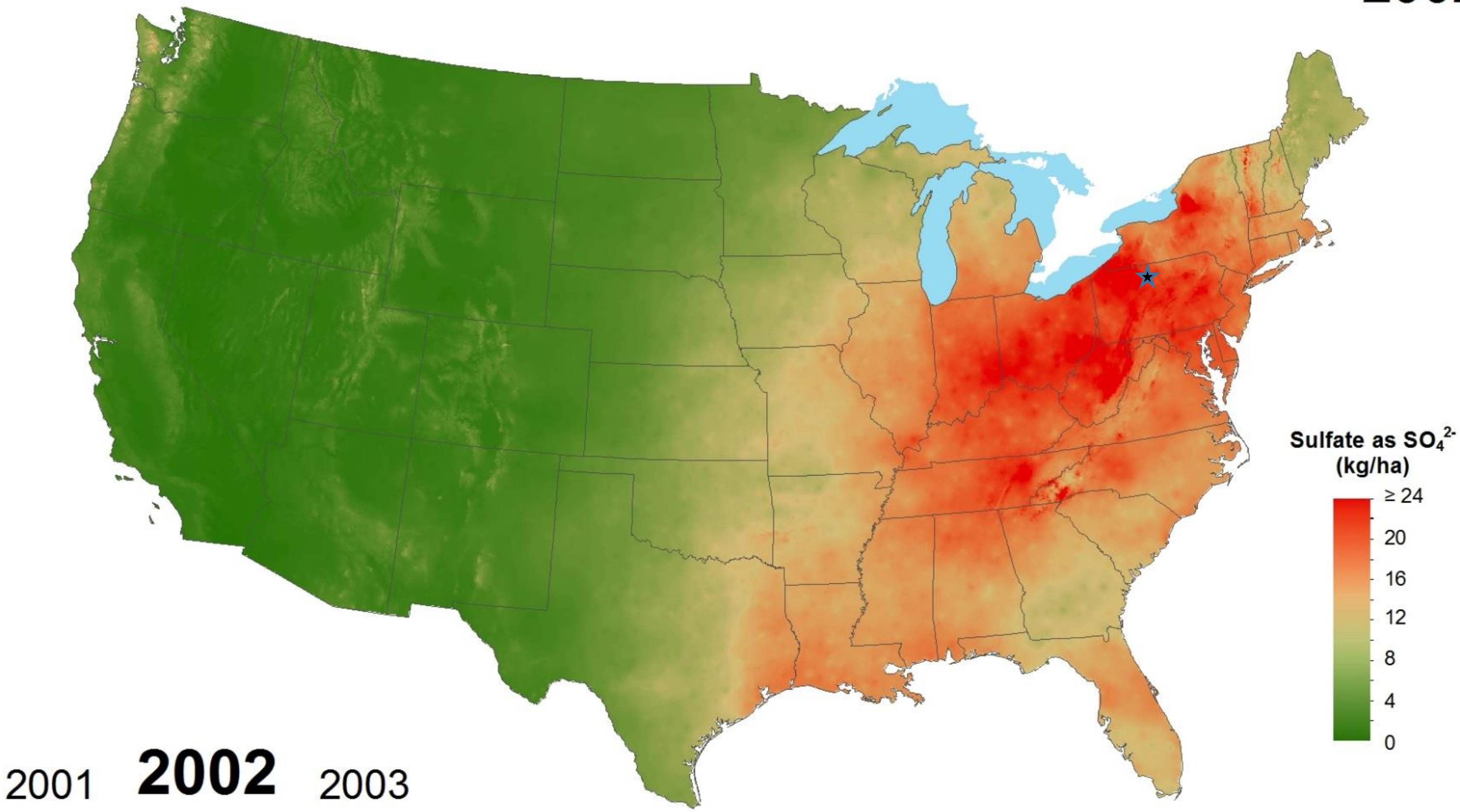
Sulfate ion wet deposition
2001



2000 **2001** 2002

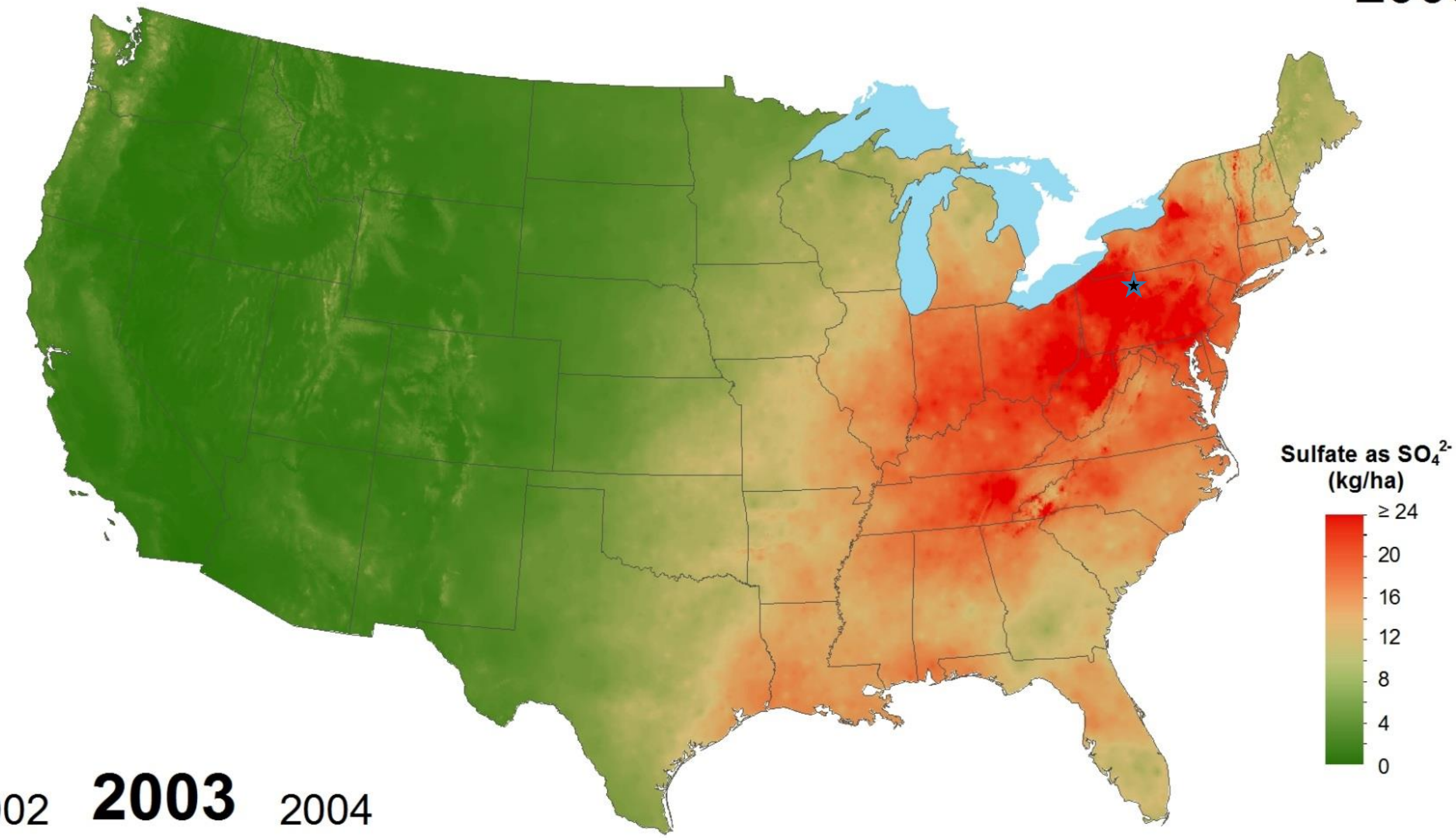
National Atmospheric Deposition Program/National Trends Network
http://nadp.isws.illinois.edu

Sulfate ion wet deposition
2002



National Atmospheric Deposition Program/National Trends Network
http://nadp.isws.illinois.edu

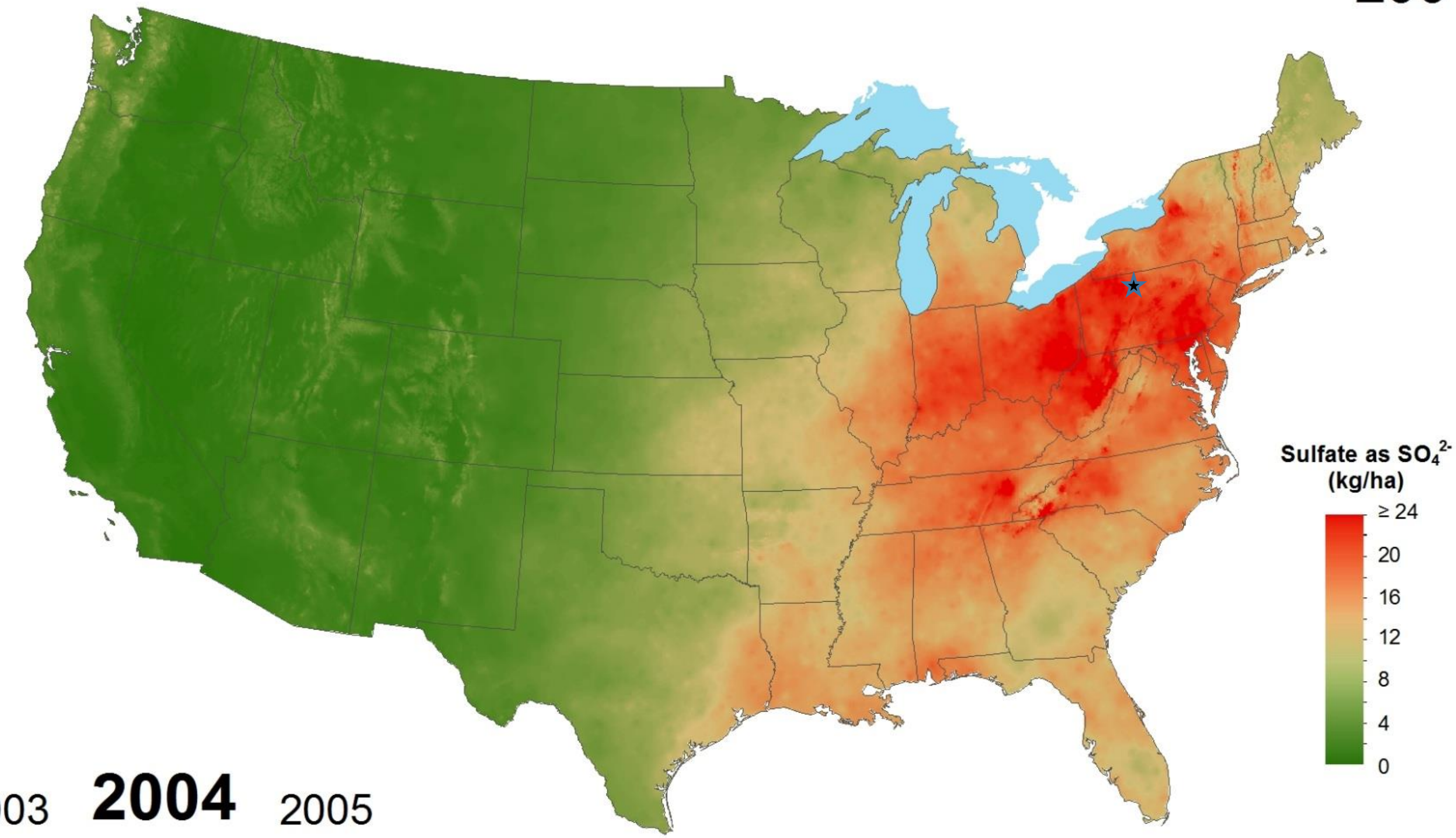
Sulfate ion wet deposition 2003



2002 **2003** 2004

National Atmospheric Deposition Program/National Trends Network
http://nadp.isws.illinois.edu

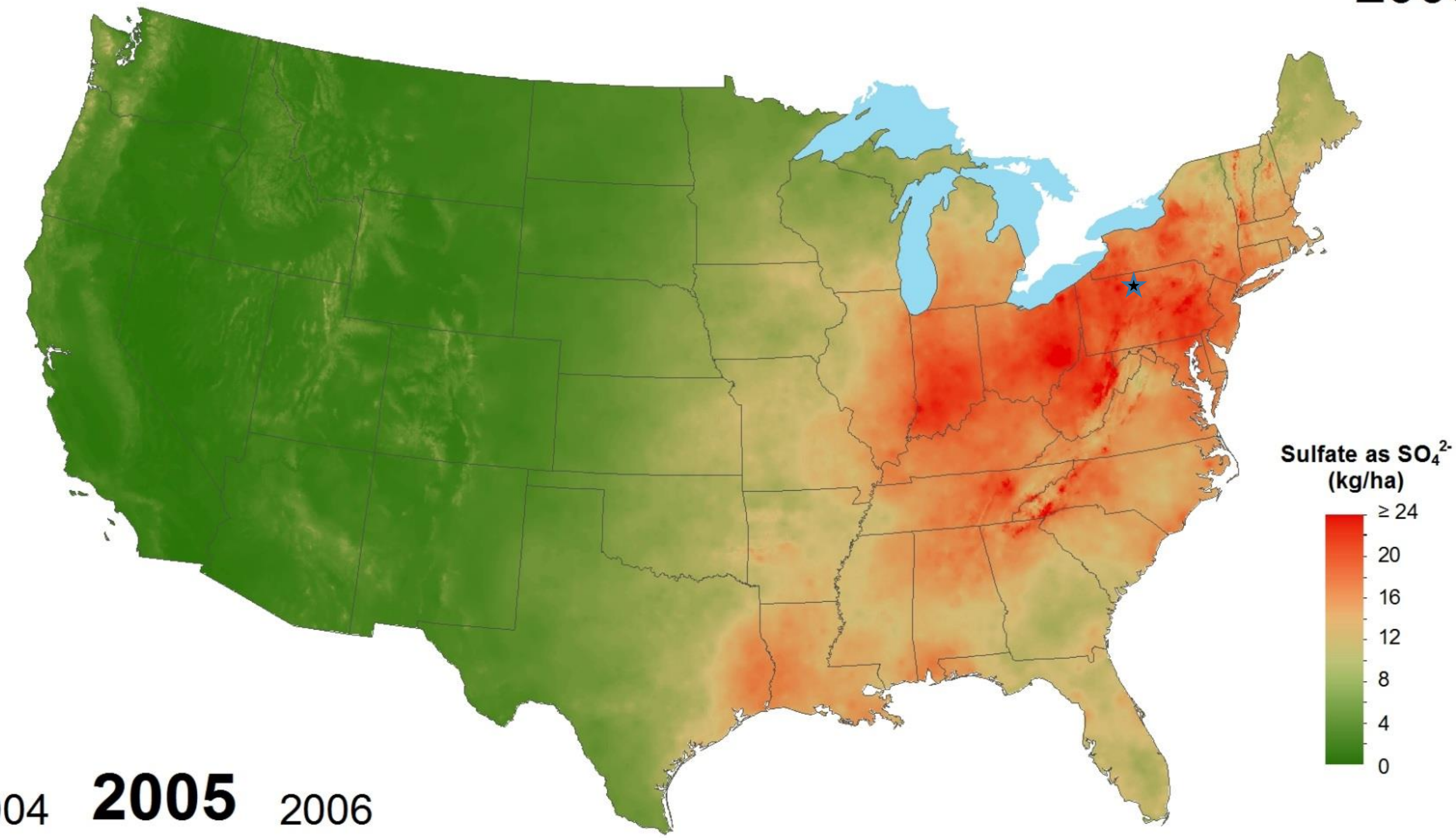
Sulfate ion wet deposition 2004



2003 **2004** 2005

National Atmospheric Deposition Program/National Trends Network
http://nadp.isws.illinois.edu

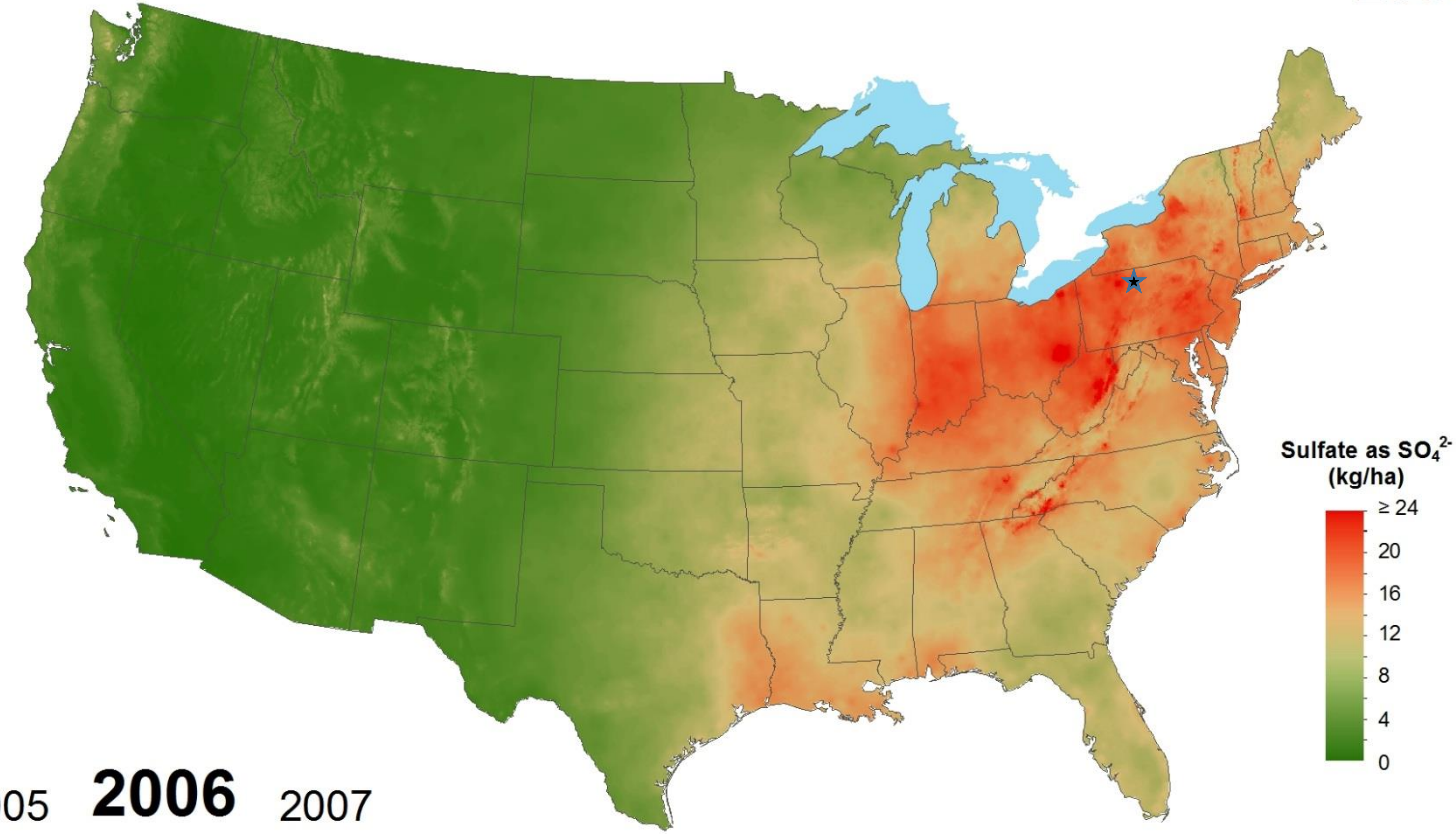
Sulfate ion wet deposition
2005



2004 **2005** 2006

National Atmospheric Deposition Program/National Trends Network
http://nadp.isws.illinois.edu

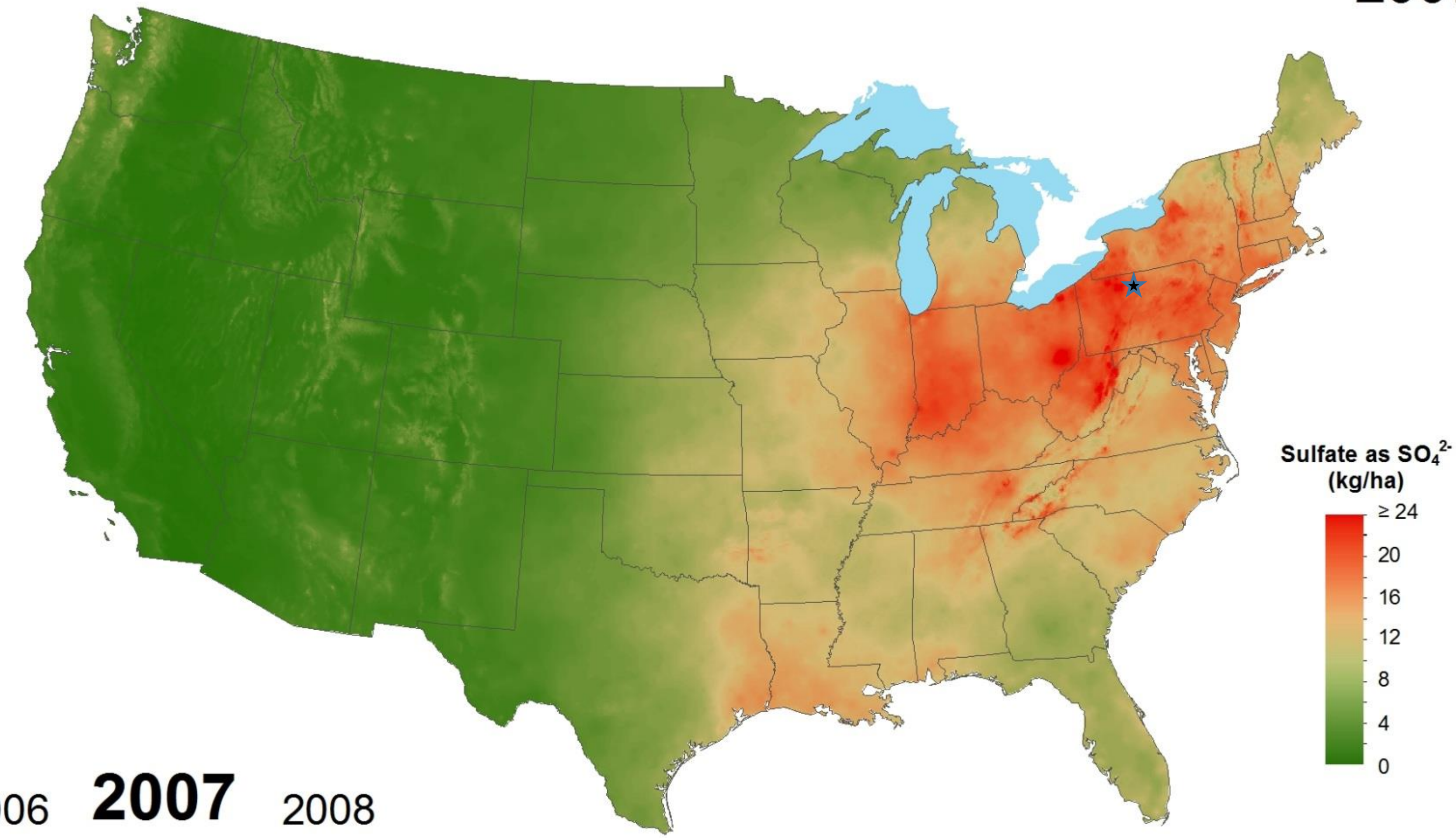
Sulfate ion wet deposition
2006



2005 **2006** 2007

National Atmospheric Deposition Program/National Trends Network
http://nadp.isws.illinois.edu

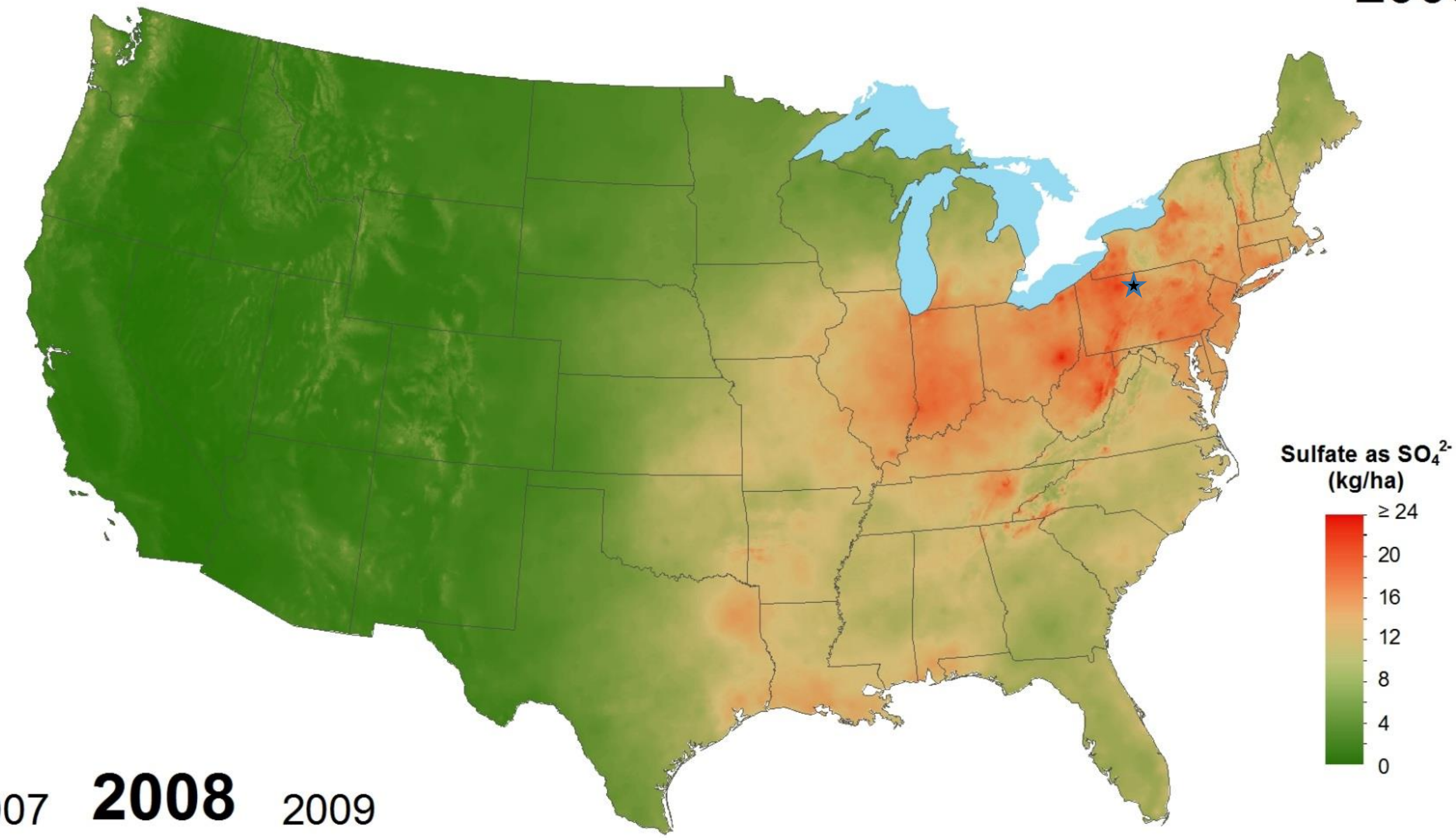
Sulfate ion wet deposition
2007



2006 **2007** 2008

National Atmospheric Deposition Program/National Trends Network
http://nadp.isws.illinois.edu

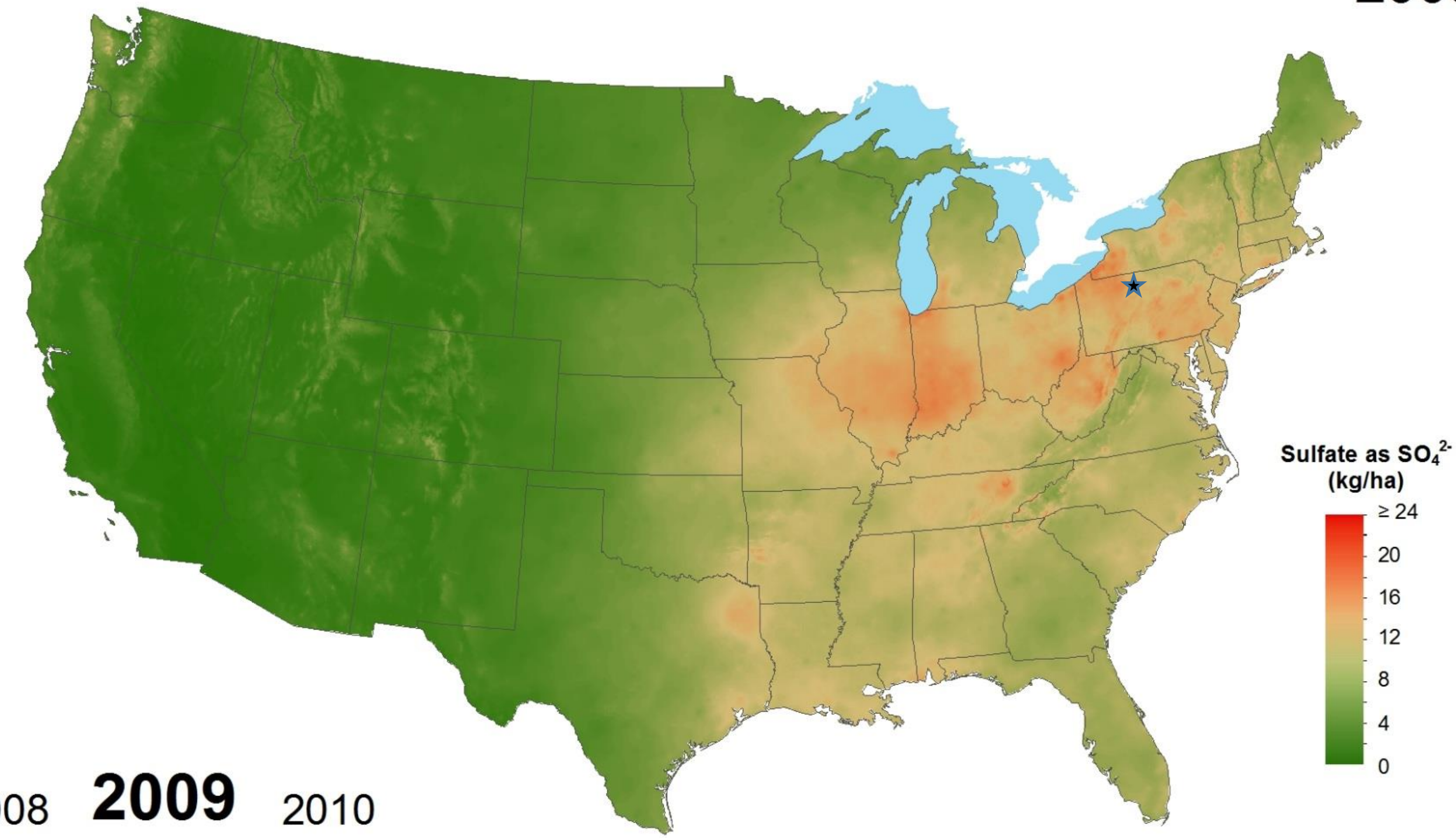
Sulfate ion wet deposition 2008



2007 **2008** 2009

National Atmospheric Deposition Program/National Trends Network
http://nadp.isws.illinois.edu

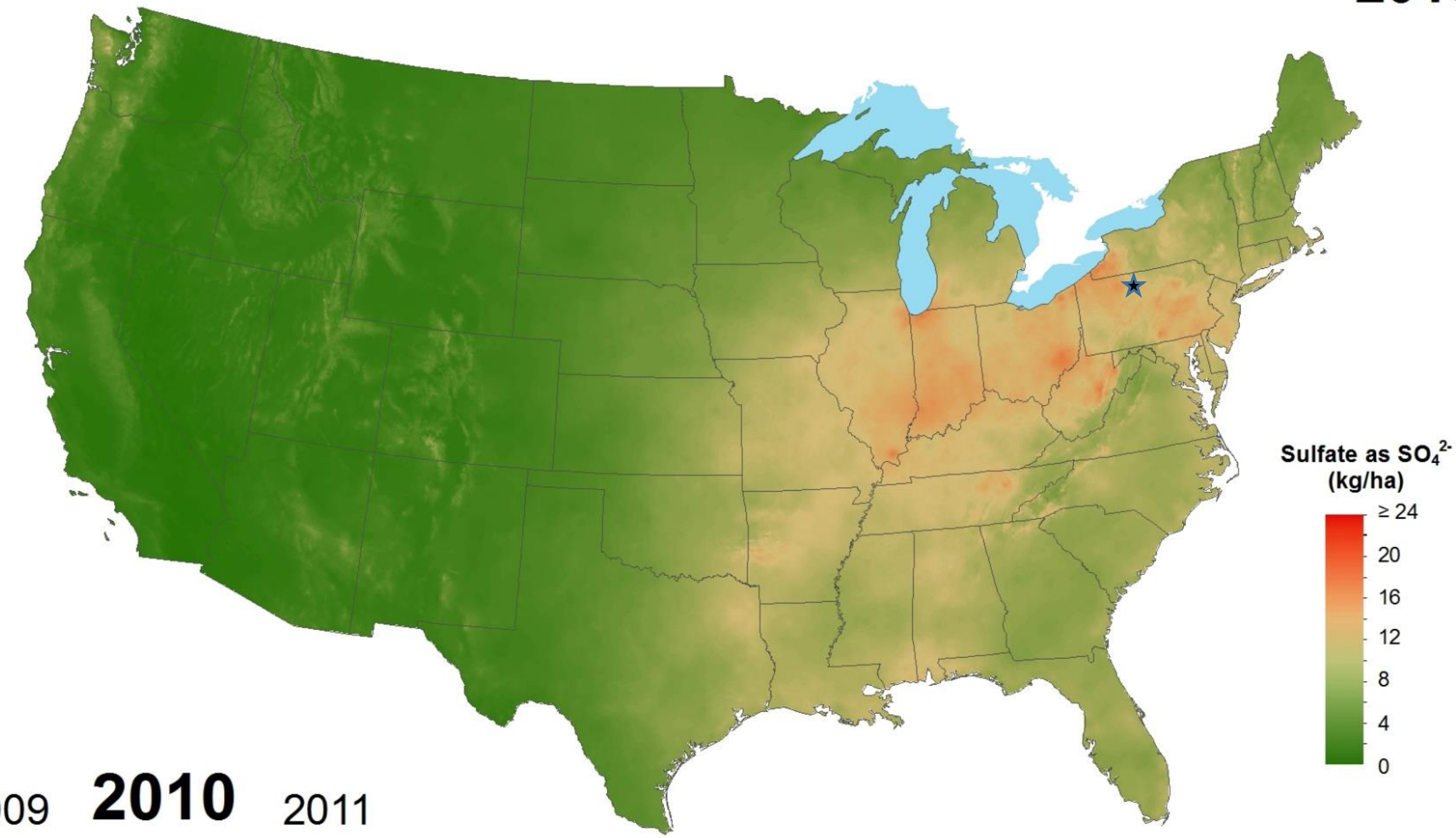
Sulfate ion wet deposition
2009



2008 **2009** 2010

National Atmospheric Deposition Program/National Trends Network
http://nadp.isws.illinois.edu

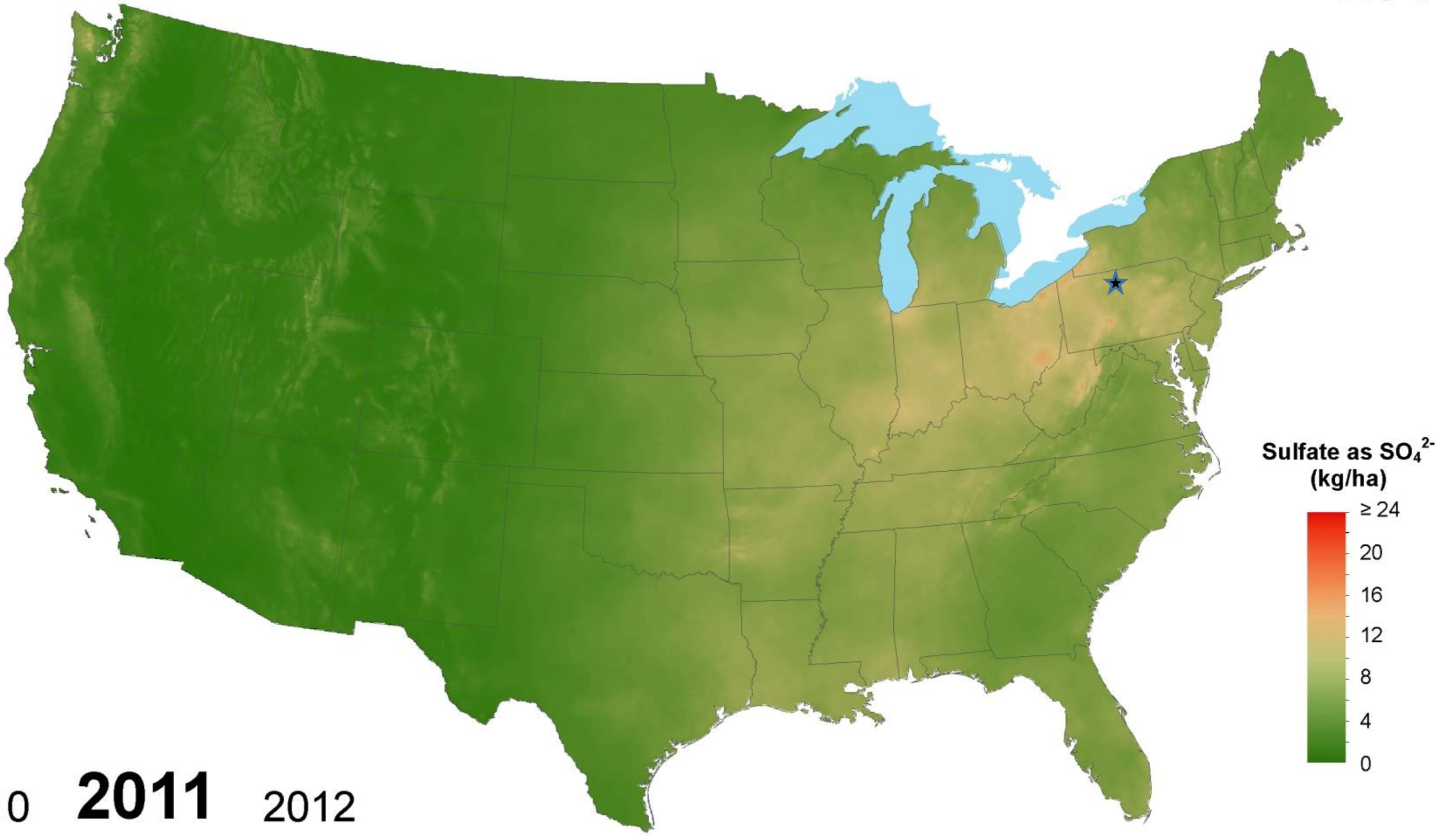
Sulfate ion wet deposition
2010



2009 **2010** 2011

National Atmospheric Deposition Program/National Trends Network
http://nadp.isws.illinois.edu

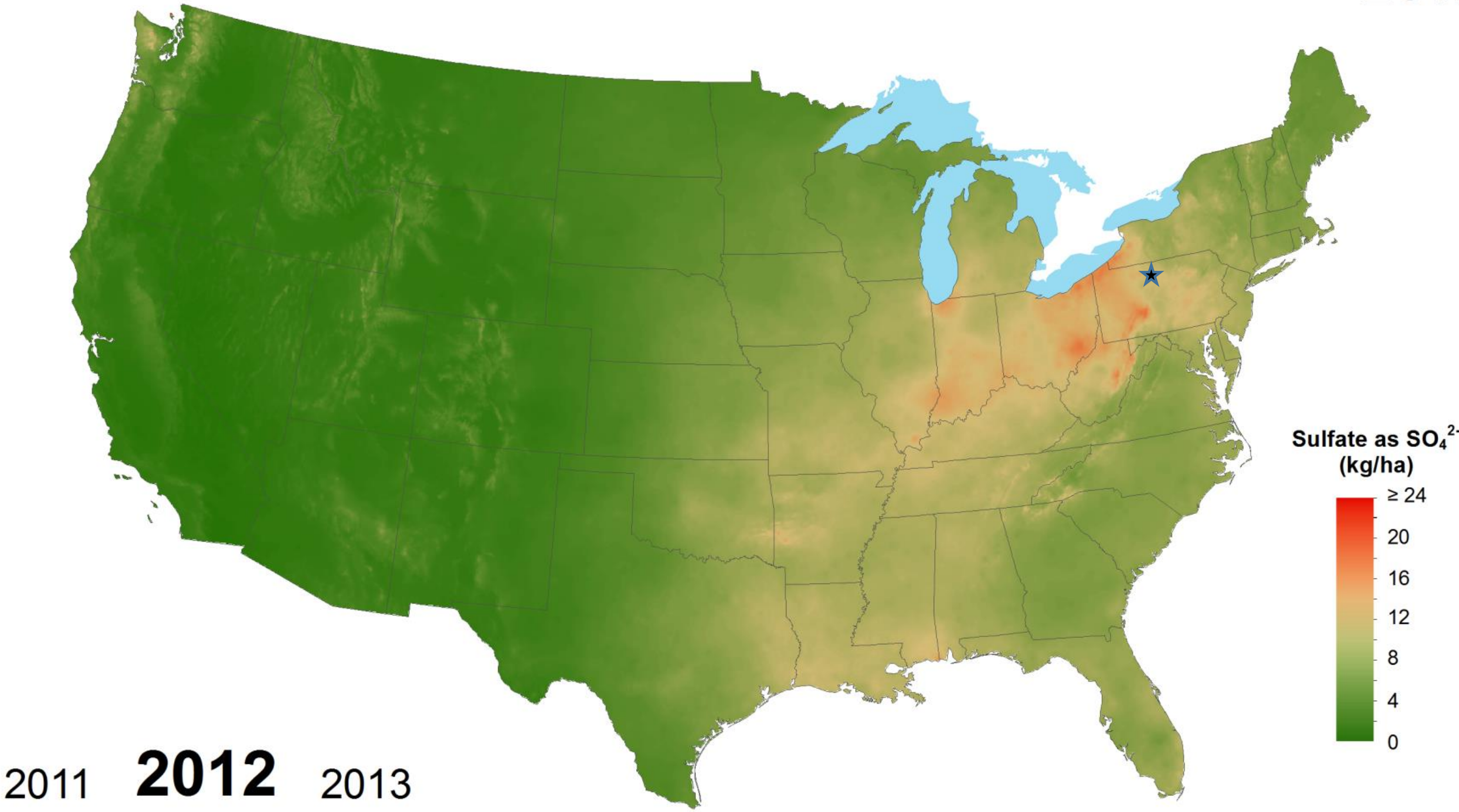
Sulfate ion wet deposition
2011



2010 **2011** 2012

National Atmospheric Deposition Program/National Trends Network
http://nadp.isws.illinois.edu

Sulfate ion wet deposition
2012

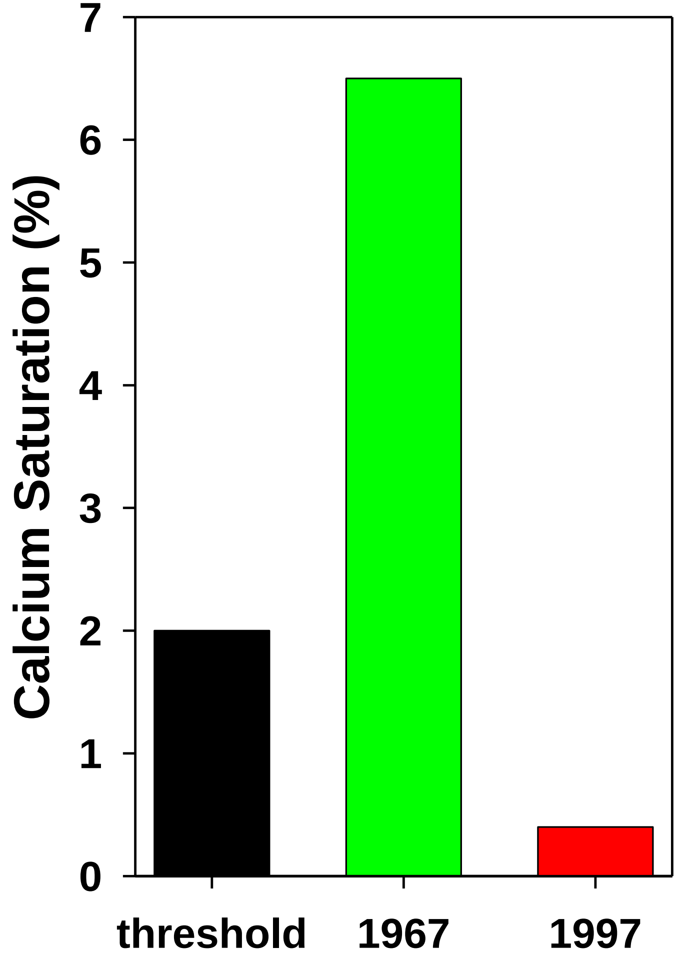


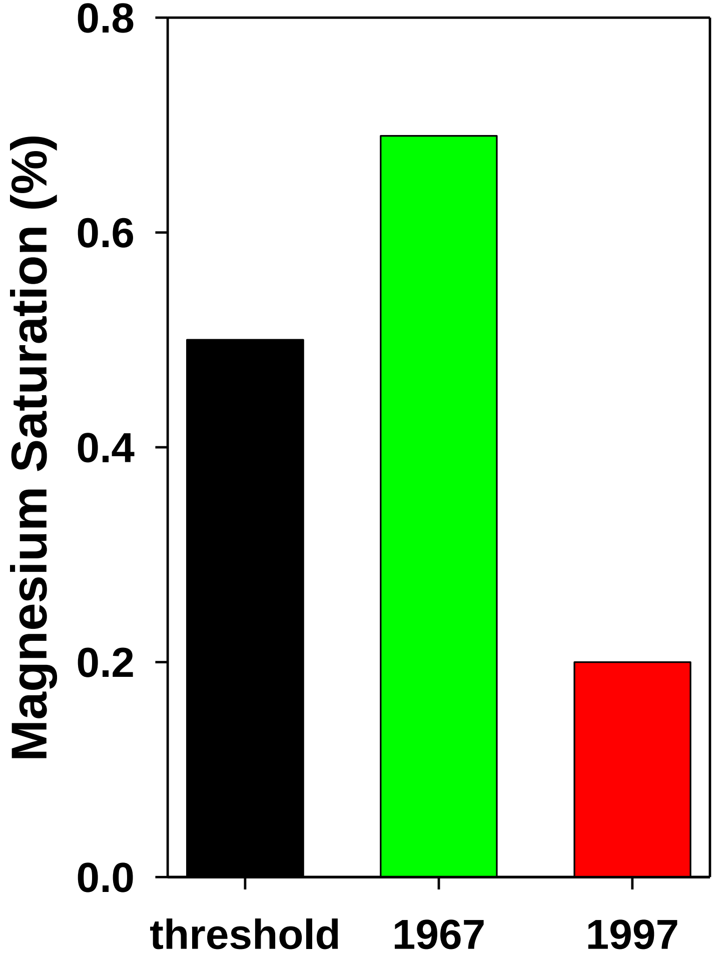
National Atmospheric Deposition Program/National Trends Network
http://nadp.isws.illinois.edu

Sugar Maple Decline

Measured chemistry in upper B horizon

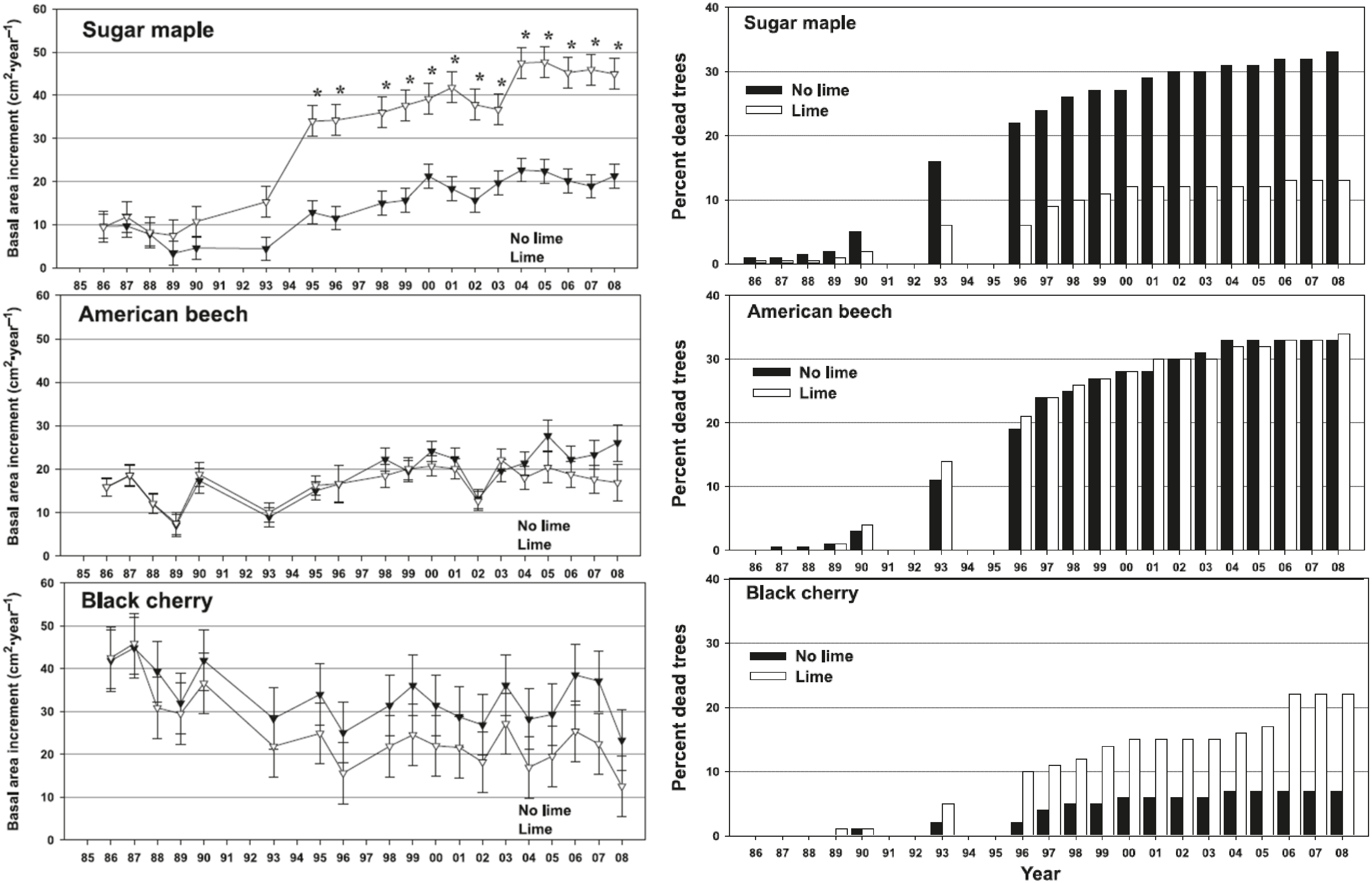
1967 & 1997 vs. proposed health thresholds





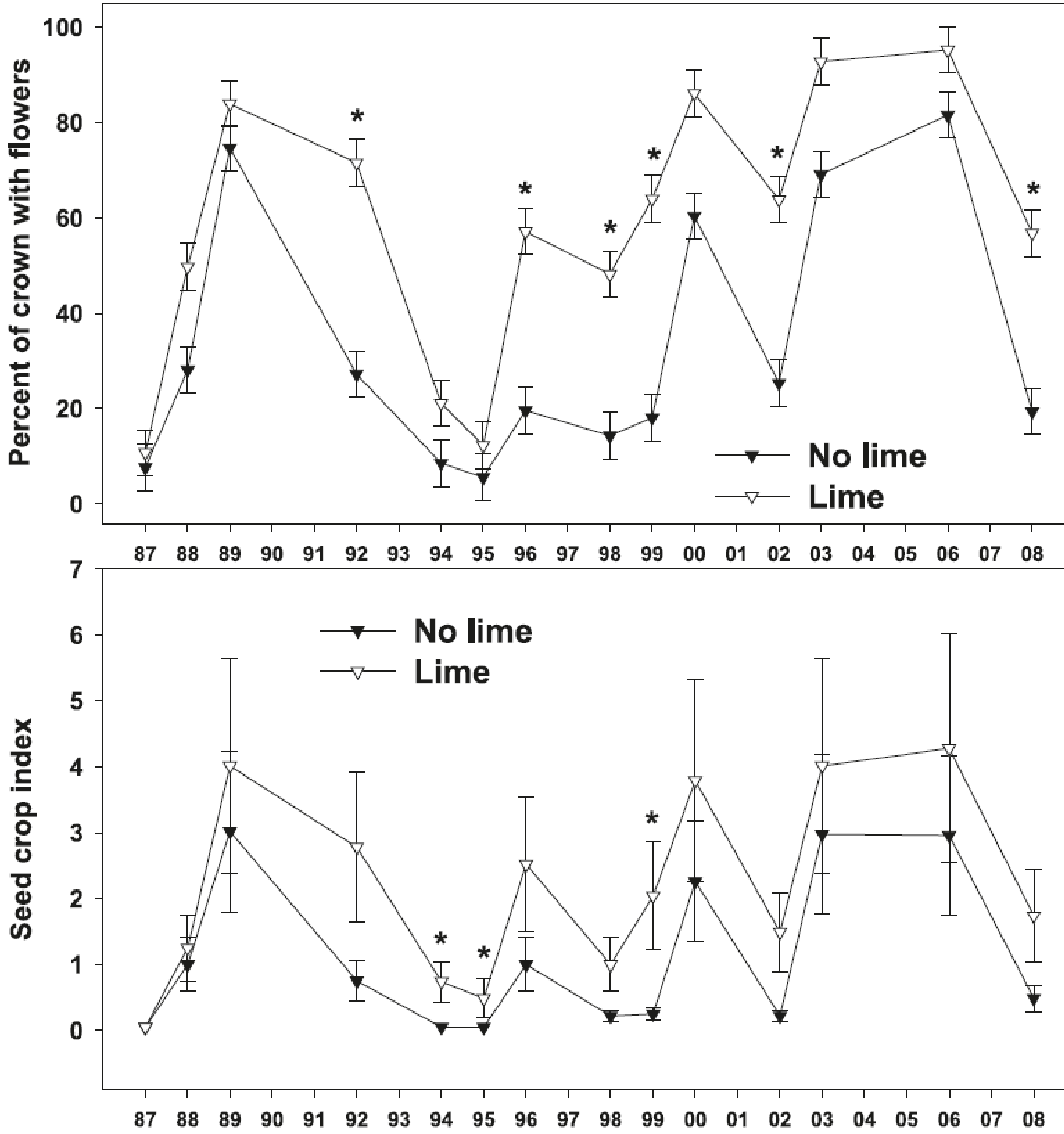
Bailey et al. 2005

Differential Response: S. Maple – Beech – Blk Cherry



Long et al. 2011

Responses: Sugar Maple Reproduction



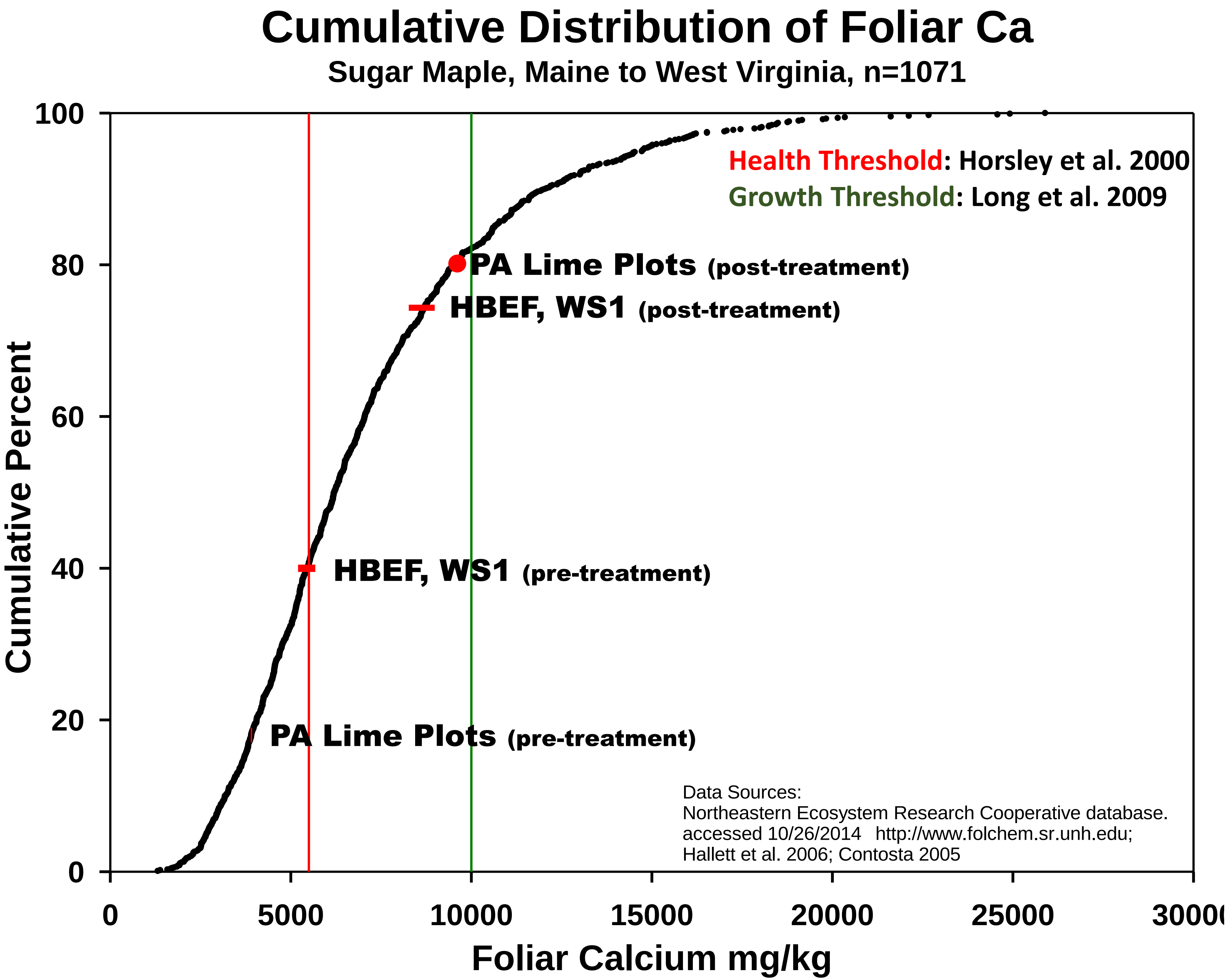
Long et al. 2011

Foliar Chemistry: Sugar Maple

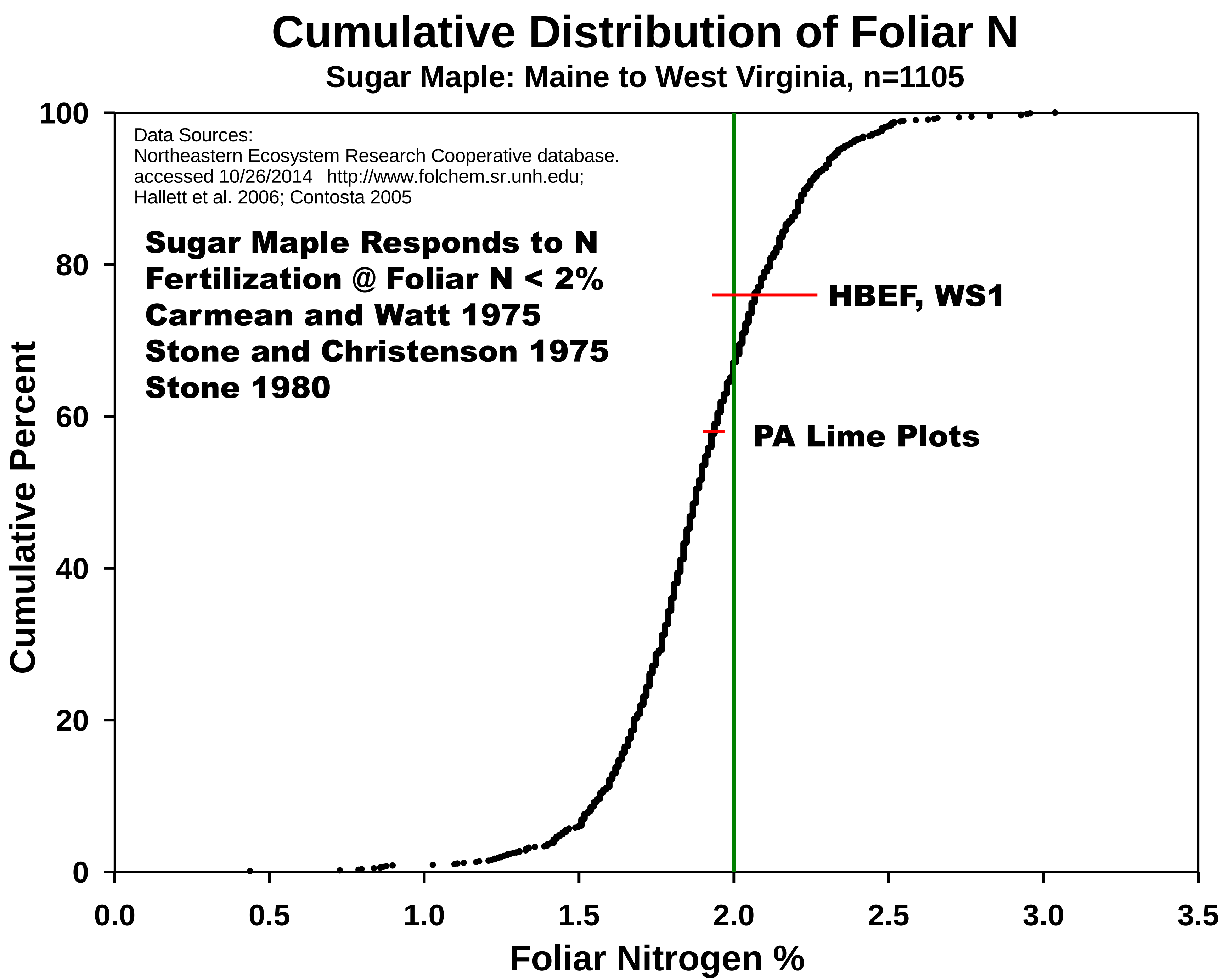
Element	Lime	No Lime	Healthy Range*
Ca	8777	4031	5000-21900
Mg	2655	617	1100-4000
K	4811	7136	5500-10400
N	15584	16005	16000-23300
Al	25	38	32-60
Mn	1148	2548	632-1630

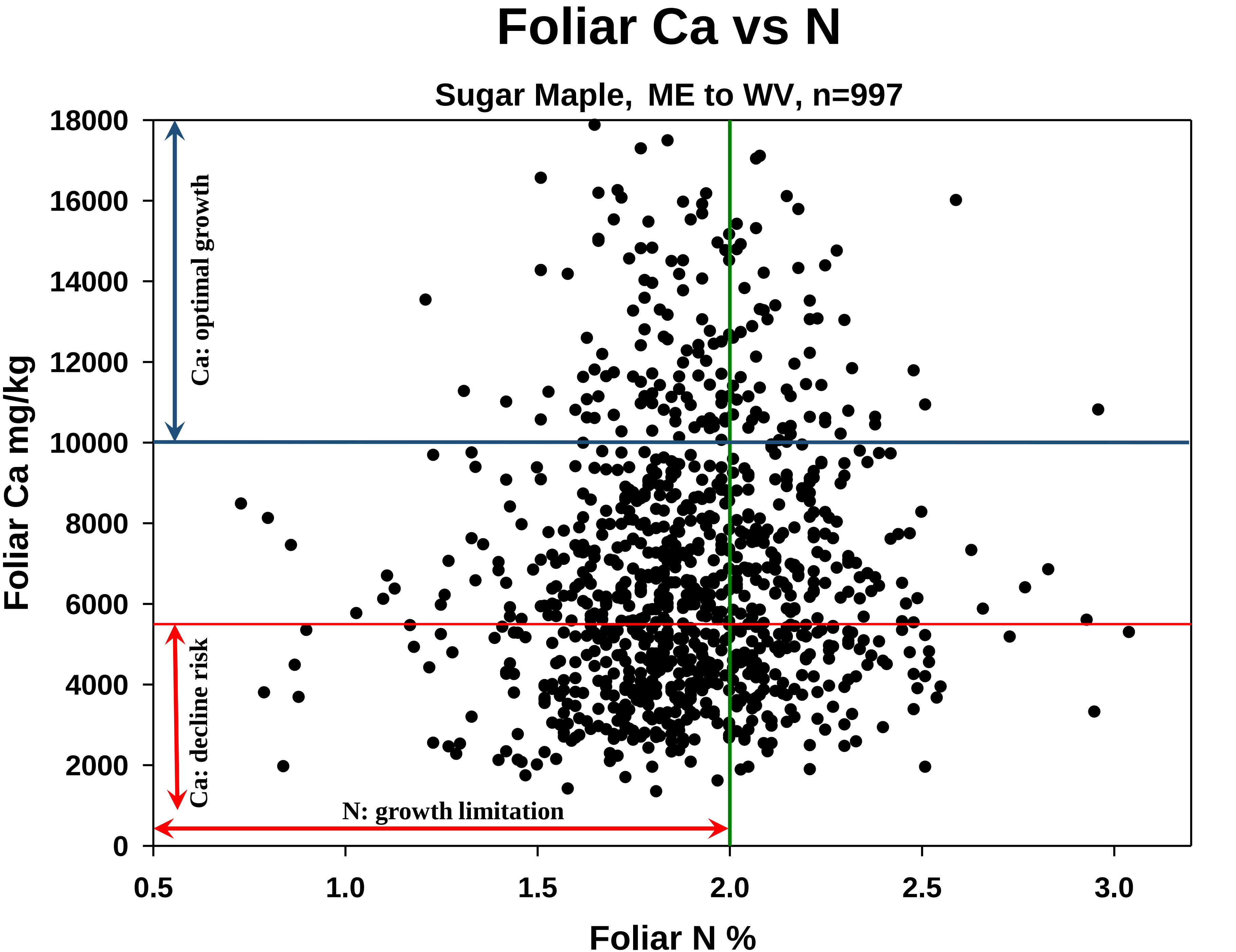
***From Kolb and McCormick, 1993. Can. J. Forest Research. 23:2395-2402.**

Long et al. 2011



Cumulative Distribution of Foliar Ca
Sugar Maple, Maine to West Virginia, n=1071
Health Threshold: Horsley et al. 2000
Growth Threshold: Long et al. 2009
PA Lime Plots (post-treatment)
HBEF, WS1 (post-treatment)
HBEF, WS1 (pre-treatment)
PA Lime Plots (pre-treatment)
Data Sources:
Northeastern Ecosystem Research Cooperative database.
accessed 10/26/2014 http://www.folchem.sr.unh.edu;
Hallett et al. 2006; Contosta 2005
Cumulative Percent
Foliar Calcium mg/kg
0
20
40
60
80
100
0
5000
10000
15000
20000
25000


Cumulative Distribution of Foliar N
Sugar Maple: Maine to West Virginia, n=1105
Data Sources:
Northeastern Ecosystem Research Cooperative database.
accessed 10/26/2014 http://www.folchem.sr.unh.edu;
Hallett et al. 2006; Contosta 2005
Sugar Maple Responds to N
Fertilization @ Foliar N < 2%
Carmean and Watt 1975
Stone and Christenson 1975
Stone 1980
HBEF, WS1
PA Lime Plots
Cumulative Percent
0
20
40
60
80
100
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
Foliar Nitrogen %



Foliar Ca vs N
Sugar Maple, ME to WV, n=997
Foliar Ca mg/kg
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
Ca: optimal growth
Ca: decline risk
N: growth limitation
0.5
1.0
1.5
2.0
2.5
3.0
Foliar N %

Lime Study Soil Chemistry

Soils sampled by 5 cm increments to 15 cm:

1986-1989

1993

1996

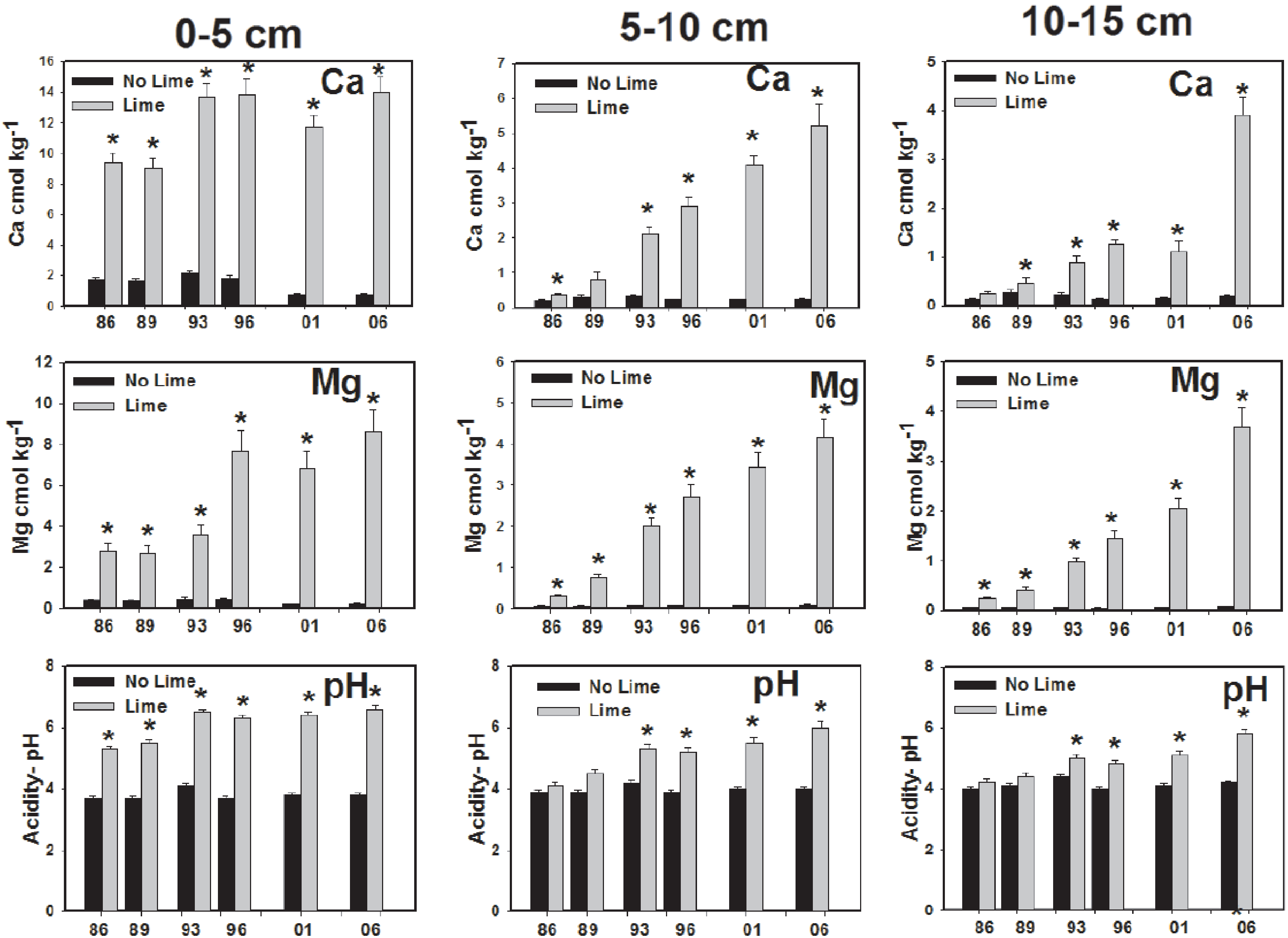
2001

2006*

2016*

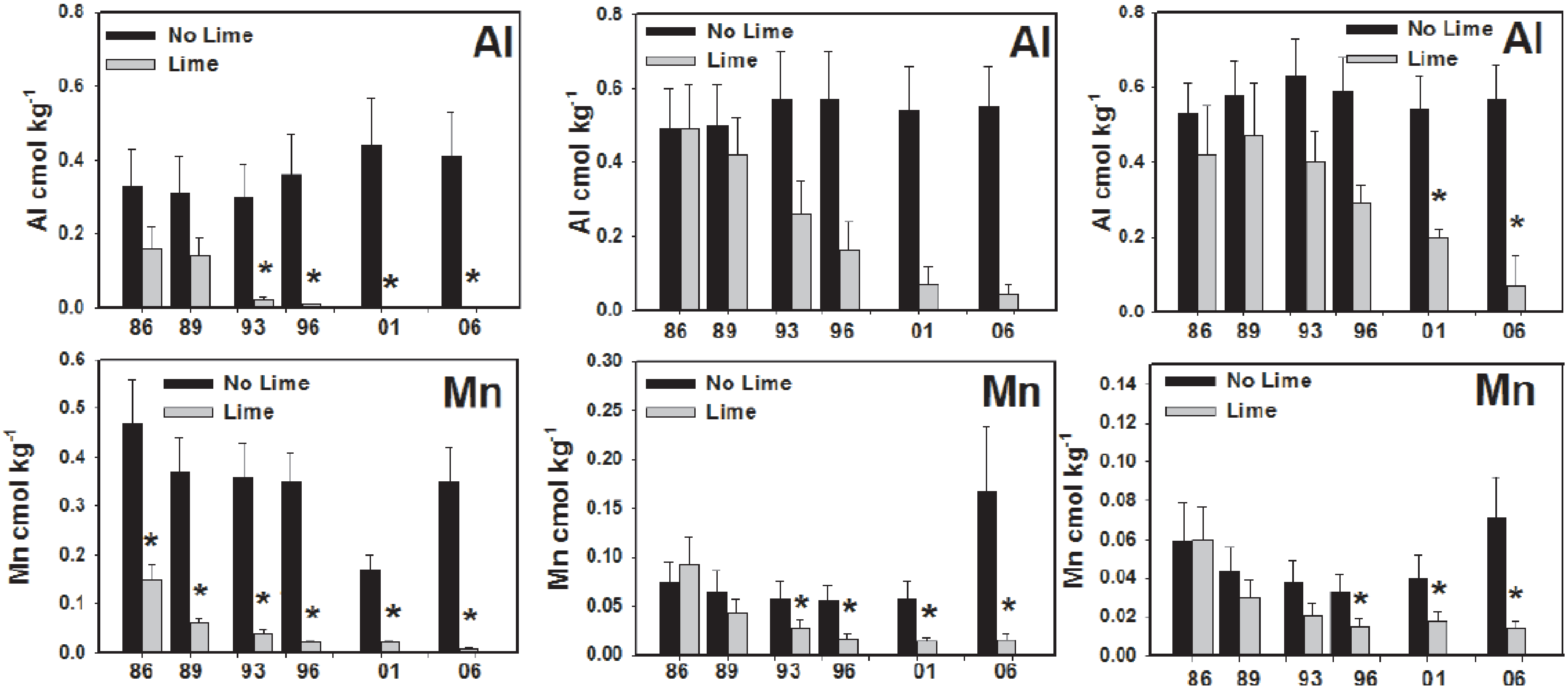
*** and 15-30 cm, 30-45 cm**

Soil Responses



Long et al. 2015

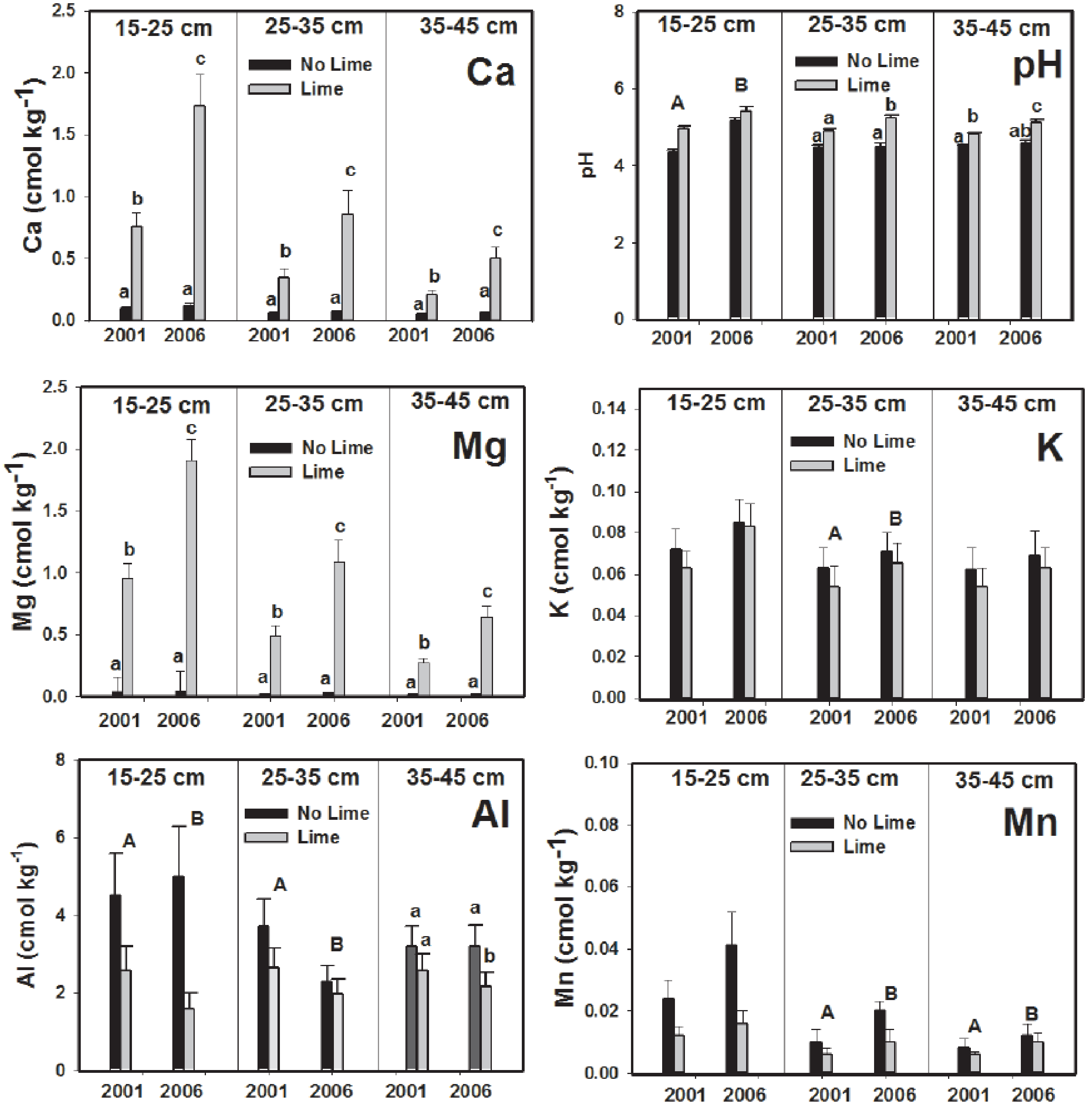
More Soil Responses



Long et al. 2015

Still More Soil Results:

Digging a Little Deeper



Long et al. 2015

How Long Did the Lime Take to Dissolve? 1985 treatment; 2001 detection

- **The lime content (calcium carbonate equivalent) ranged from 0.3 to 7.2% in the 0- to 5-cm layer, and from 0 to 0.4% in the 5- to 10-cm layer.**

- **Only three of the 5- to 10-cm sampled layers had a detectable amount of lime remaining. No lime was detected in the 10- to 15-cm layers.**

- **The amount of undissolved lime left on the plots in 2001 was 3 kg ha^{-1} (0.3 g m^{-2}) or about 0.01% of the original application.**

Long et al. 2015

Lime Study Results

- **The response to lime was species specific**
  - **Sugar maple responded positively**
  - **Black cherry responded negatively**
  - **American beech showed no response**
- **It took ~17 years for all of the lime to dissolve.**
- **Extractable soil chemistry changes increased for at least 21 years and then stabilized for at least 10 more years.**