# The increasing importance of U.S. reduced nitrogen deposition


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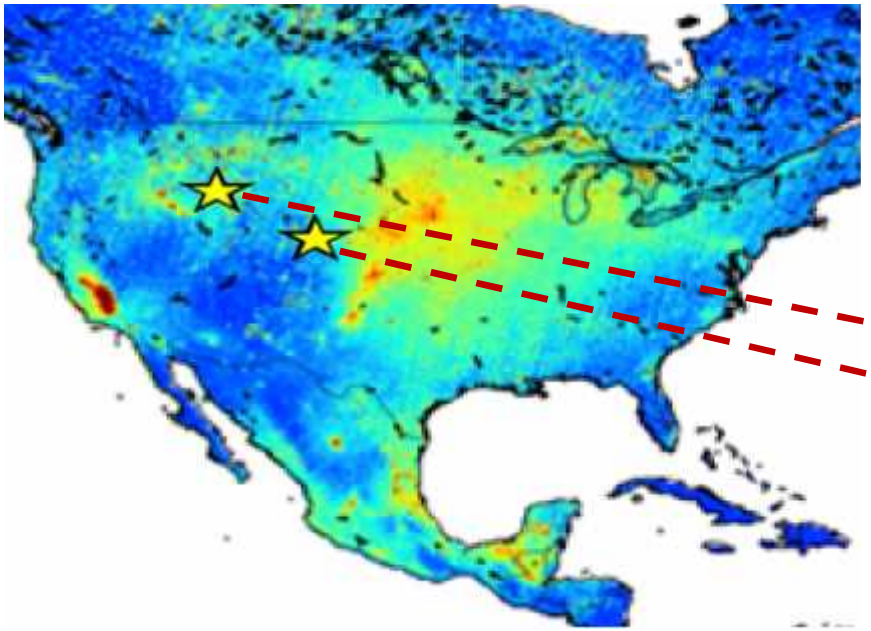
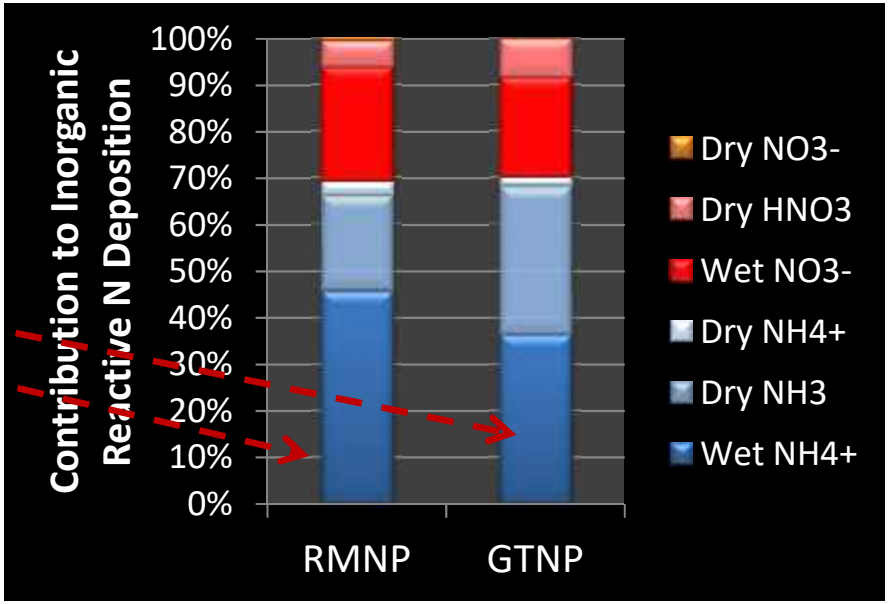
[3]United States Environmental Protection Agency

[4]Illinois State Water Survey

# Rocky Mountain inorganic N deposition budgets



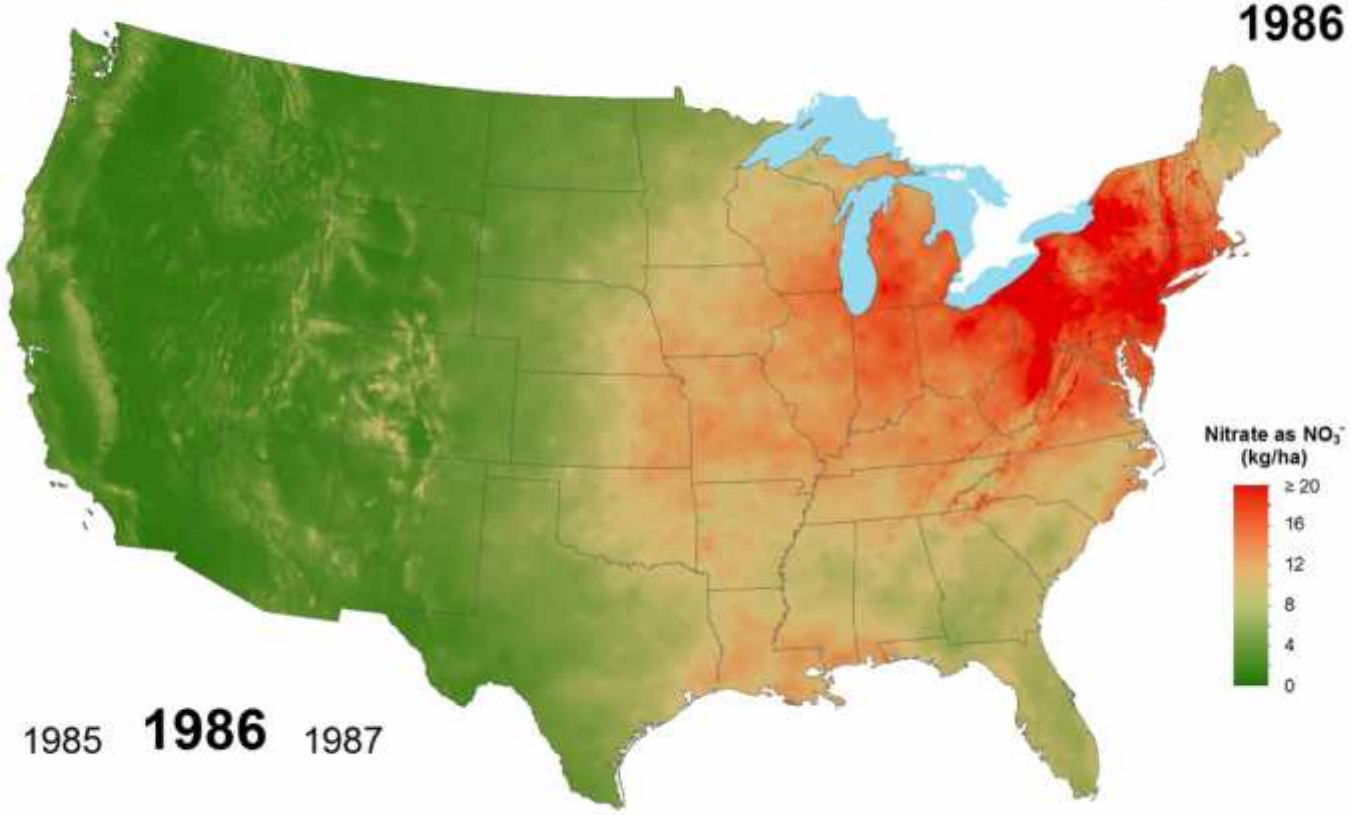
IASI satellite $NH_3$ (2008-2013)
M. Van Damme and J.W. Erisman




Benedict et al., 2013a,b

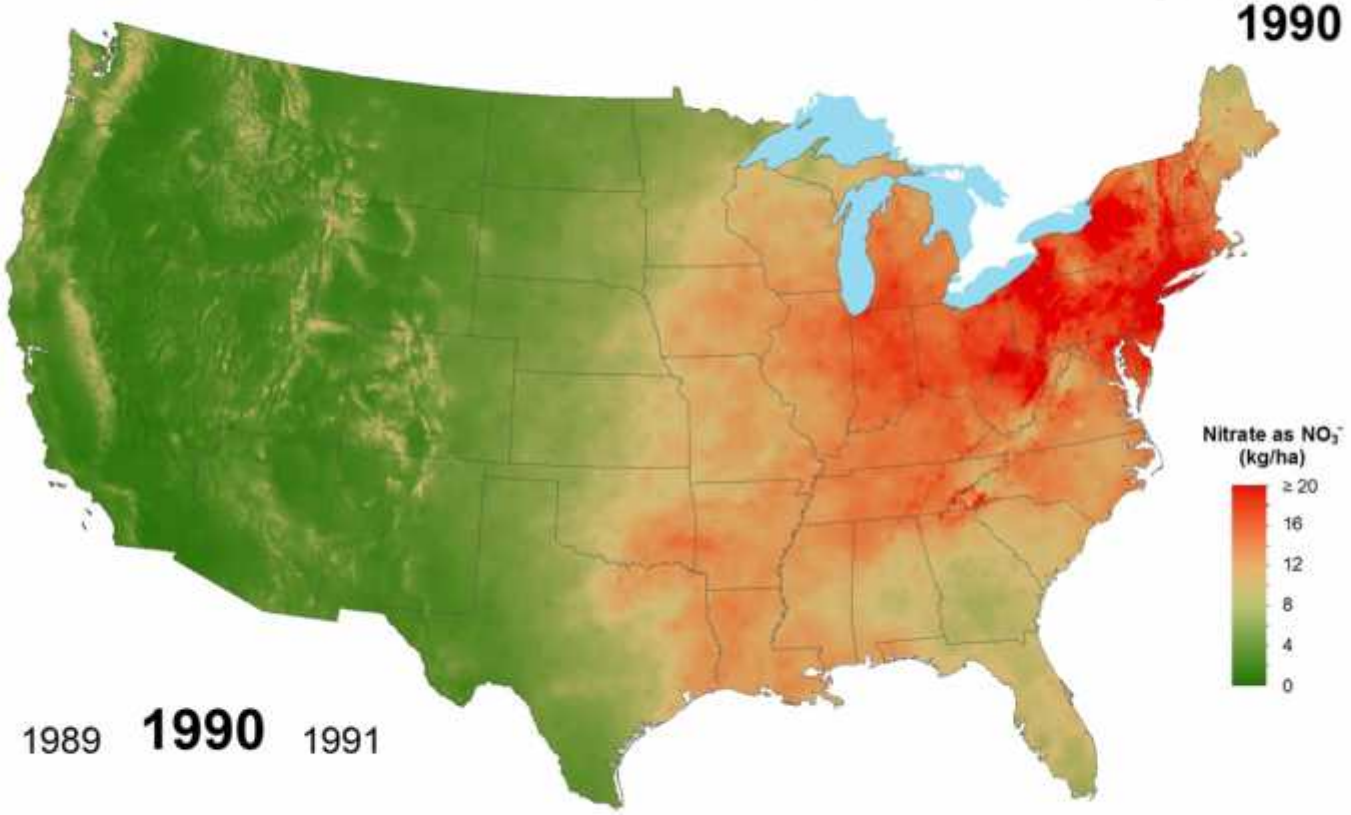
# Historical changes in U.S. wet reactive N deposition

# Nitrate ion wet deposition
# 1986




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

# Nitrate ion wet deposition
# 1990

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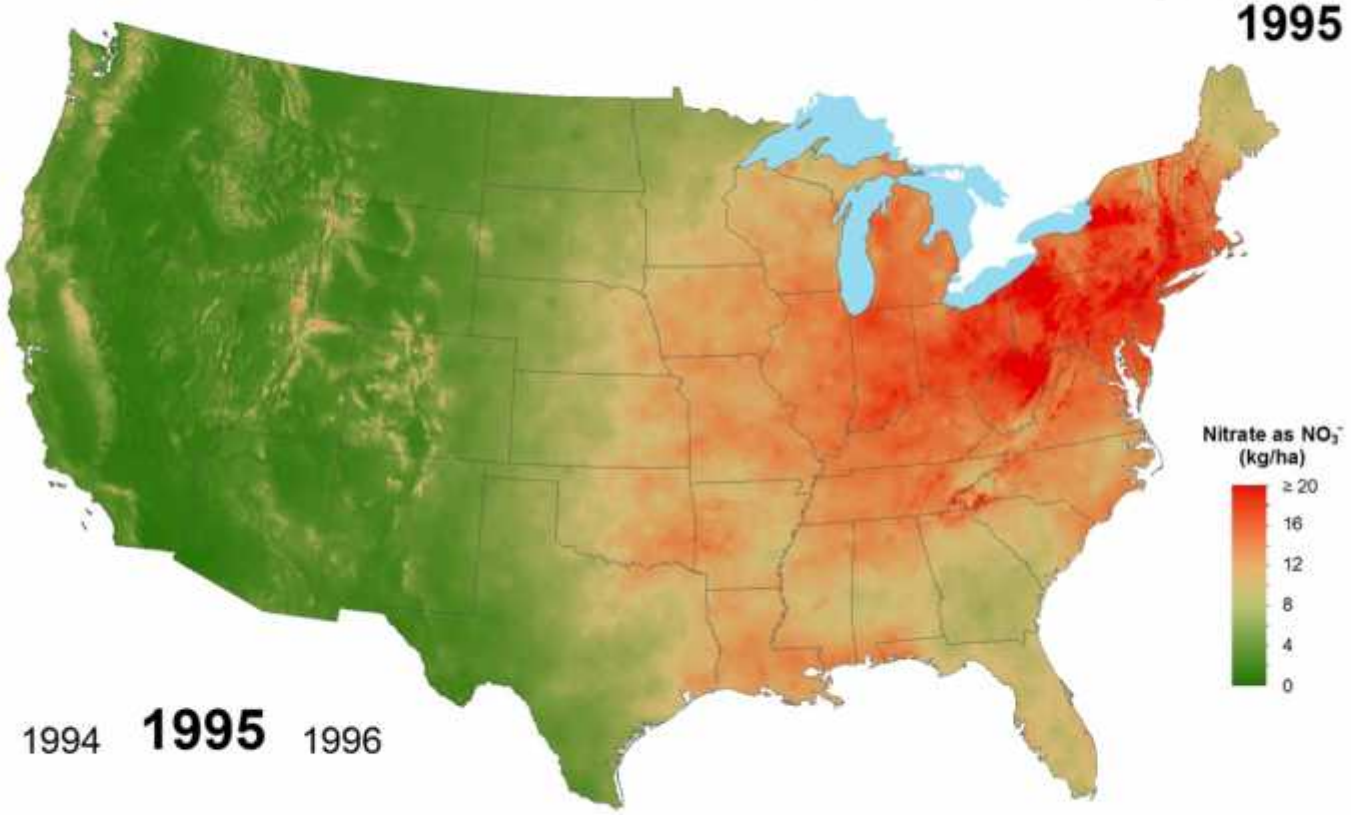
# 1995

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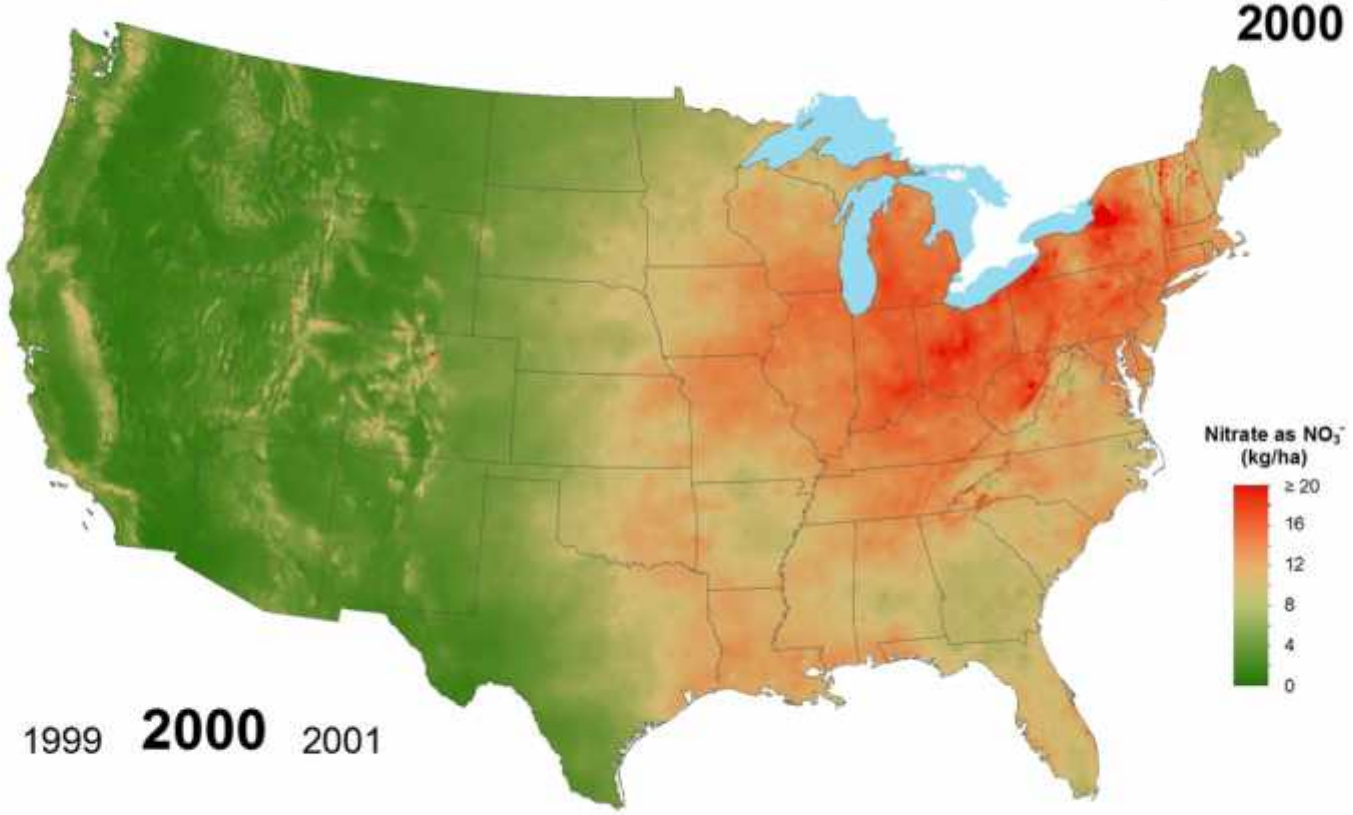
# Nitrate ion wet deposition
# 2000

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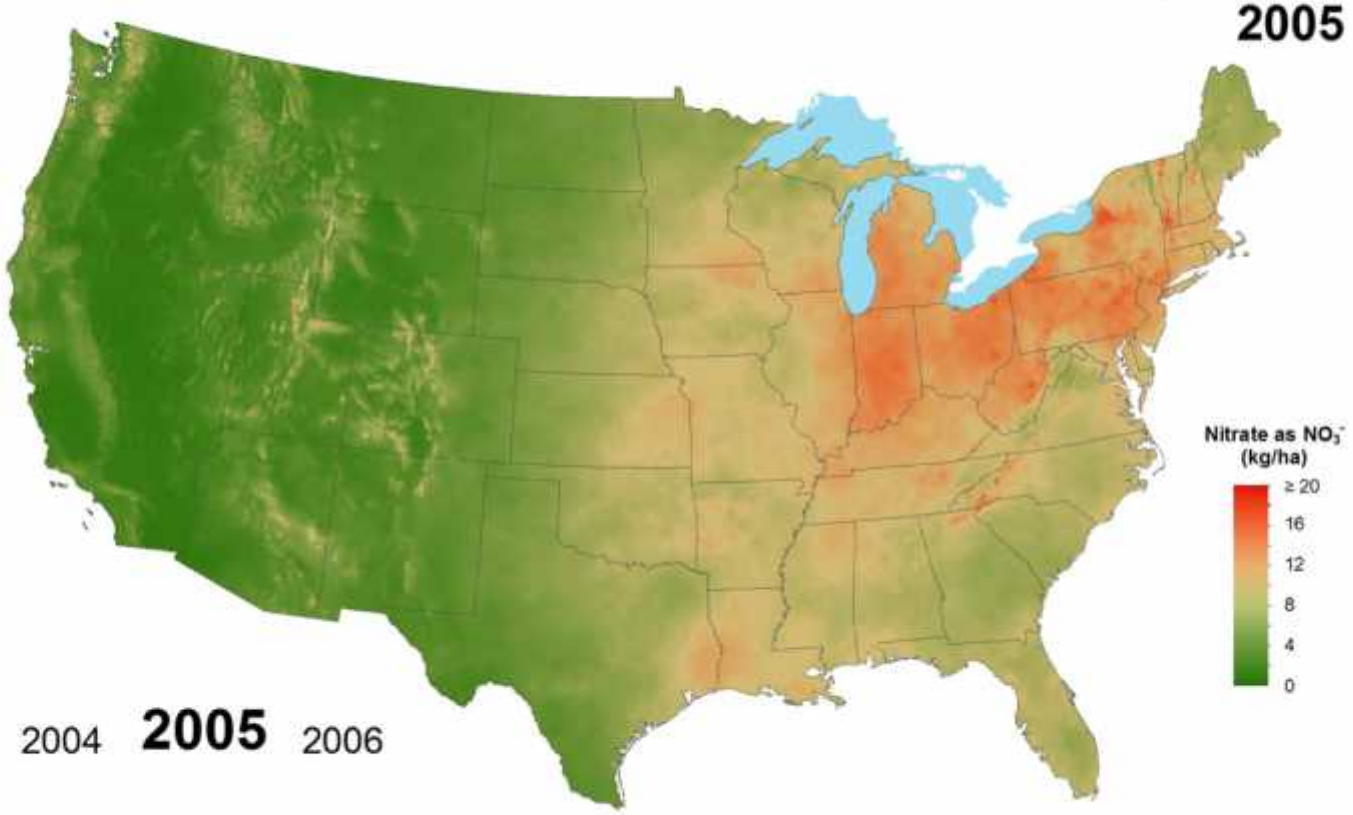
# Nitrate ion wet deposition
# 2005

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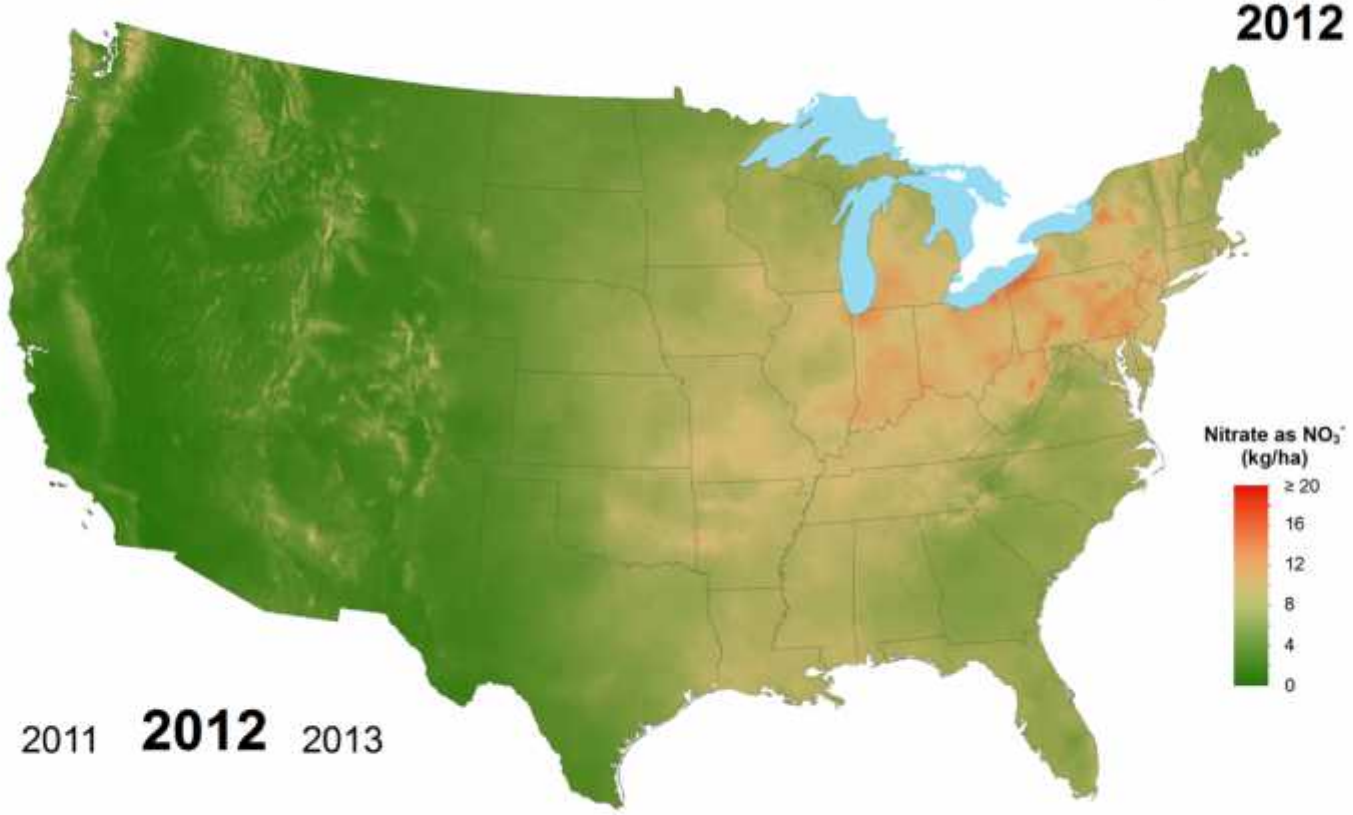
# Nitrate ion wet deposition
# 2012




2011 **2012** 2013

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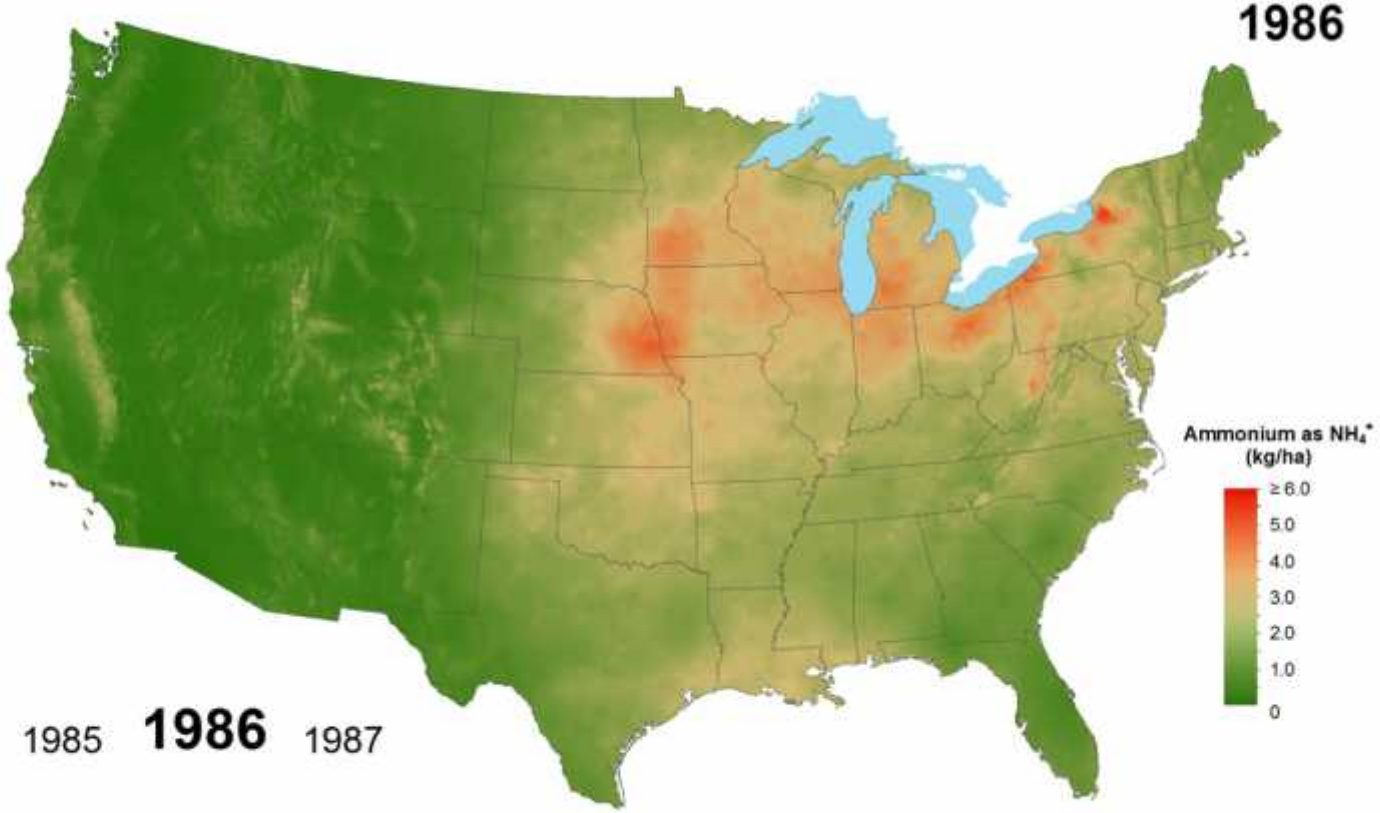
# Changes in $NO_x$ emissions

# Ammonium ion wet deposition
## 1986

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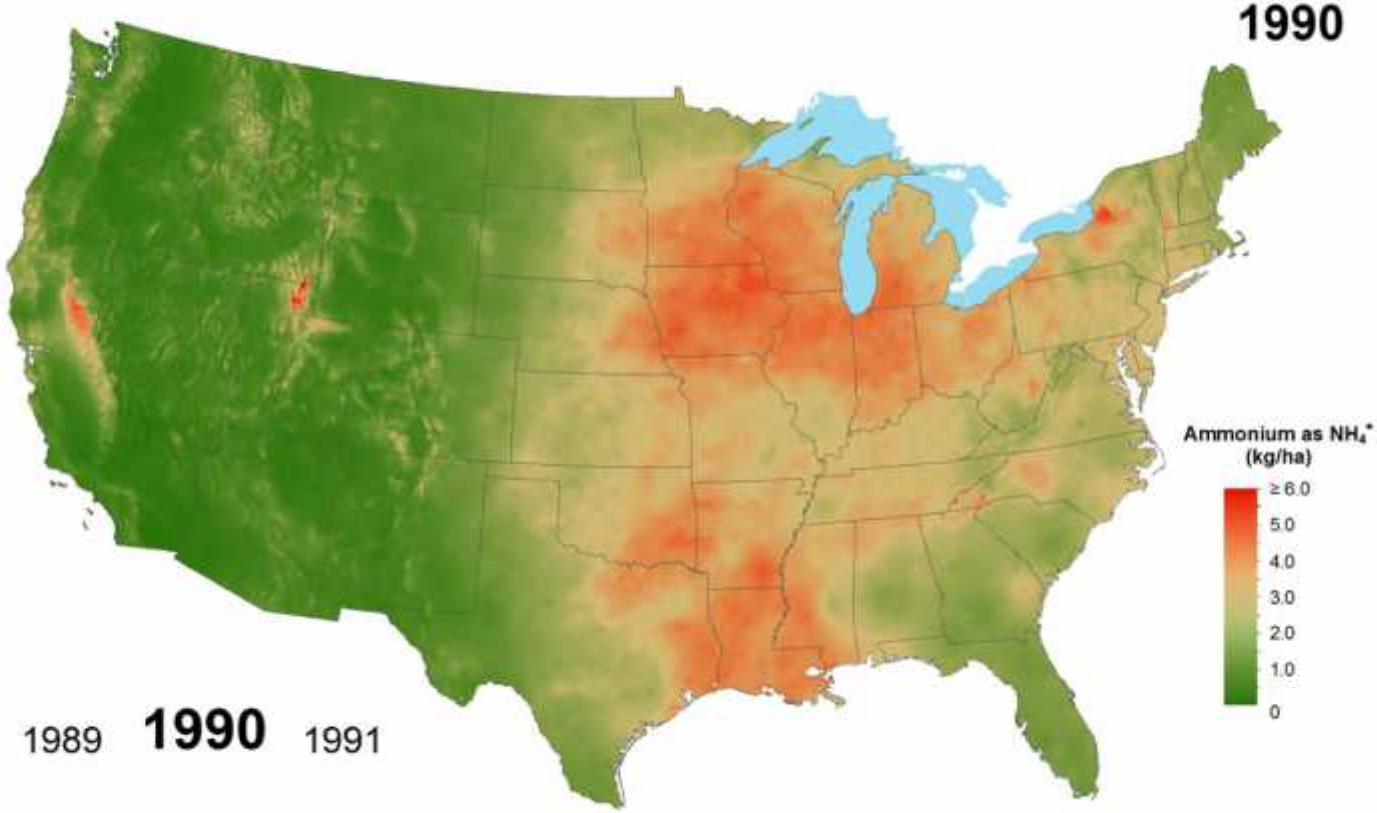
# Ammonium ion wet deposition
# 1990

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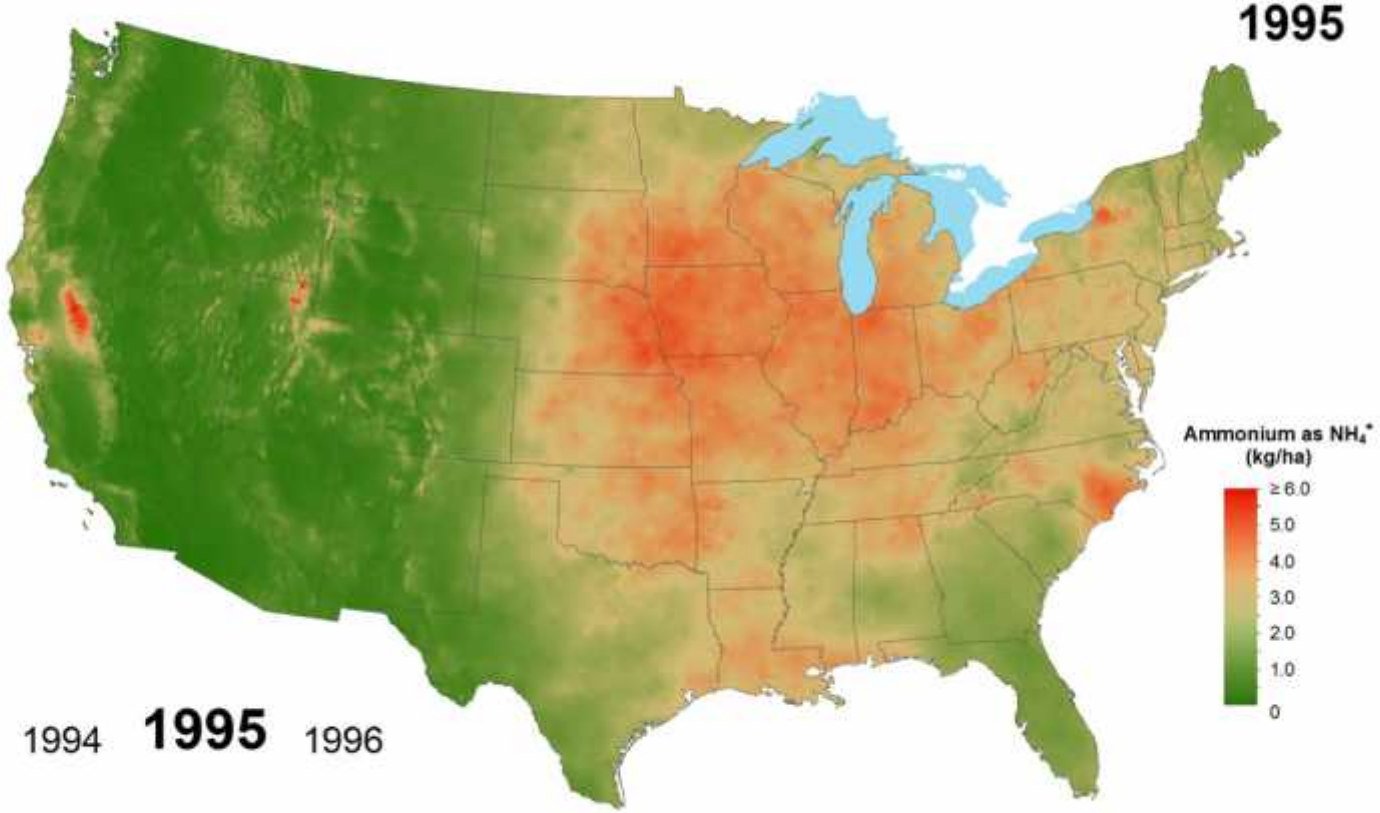
# Ammonium ion wet deposition
## 1995

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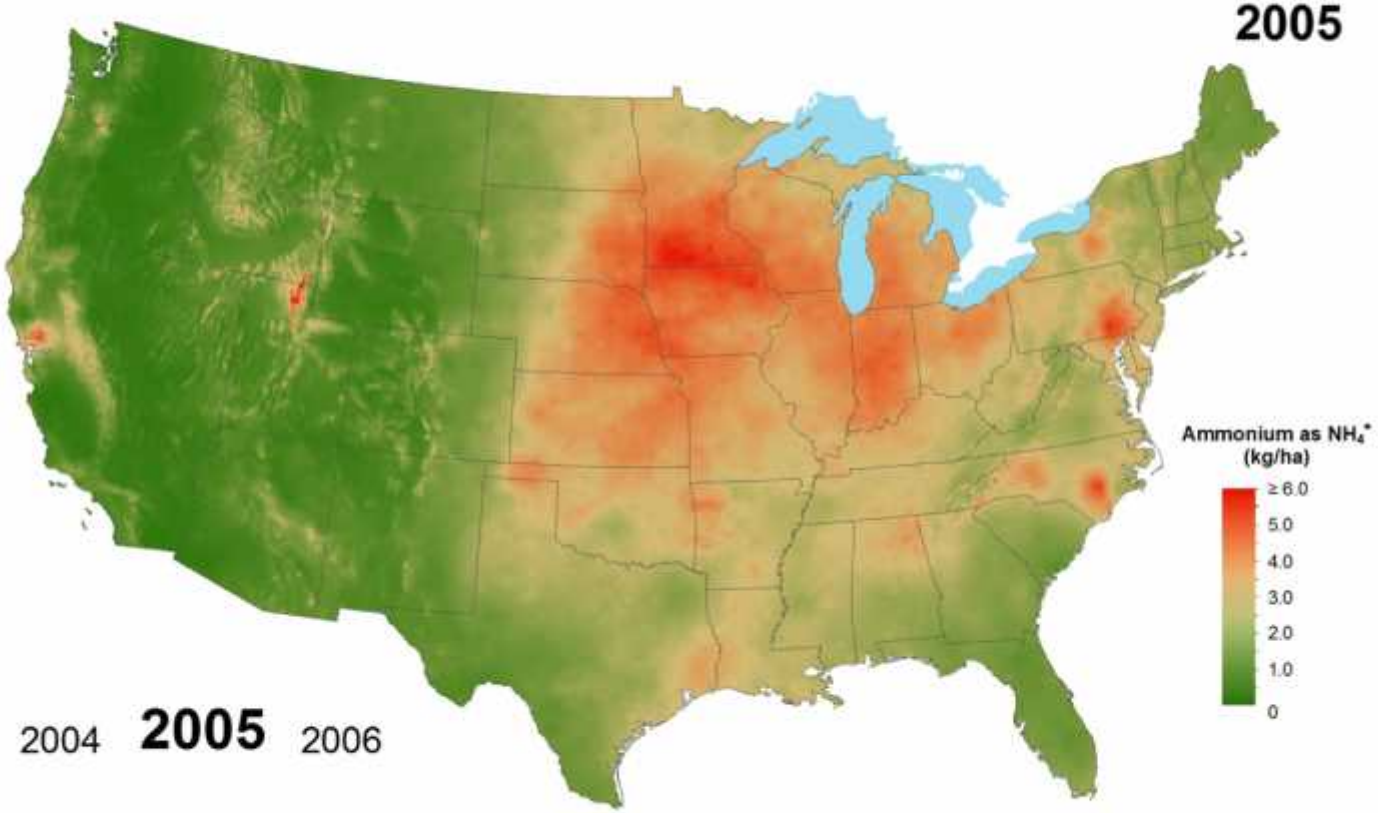
# Ammonium ion wet deposition
# 2005




National Atmospheric Deposition Program/National Trends Network
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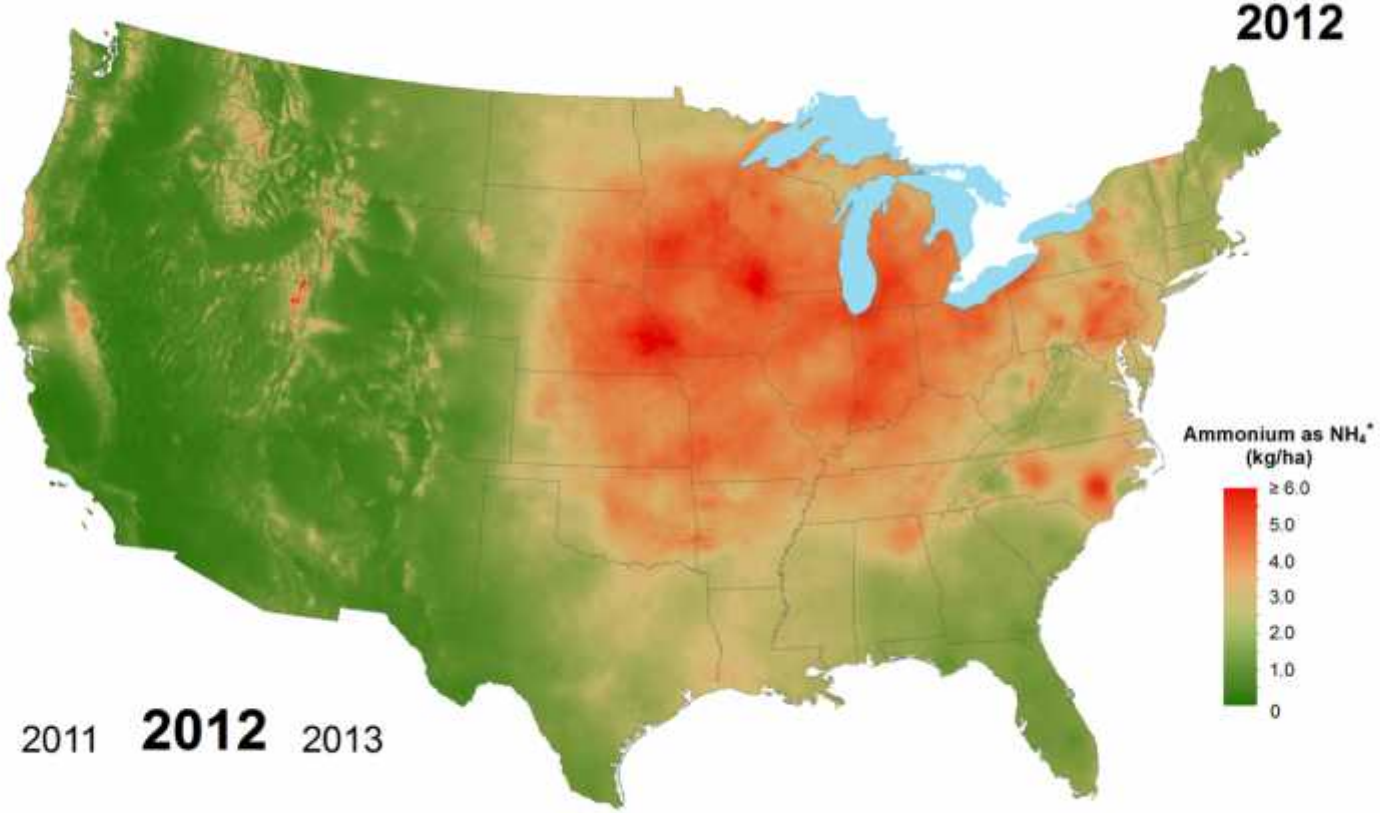
# Ammonium ion wet deposition
# 2012




National Atmospheric Deposition Program/National Trends Network
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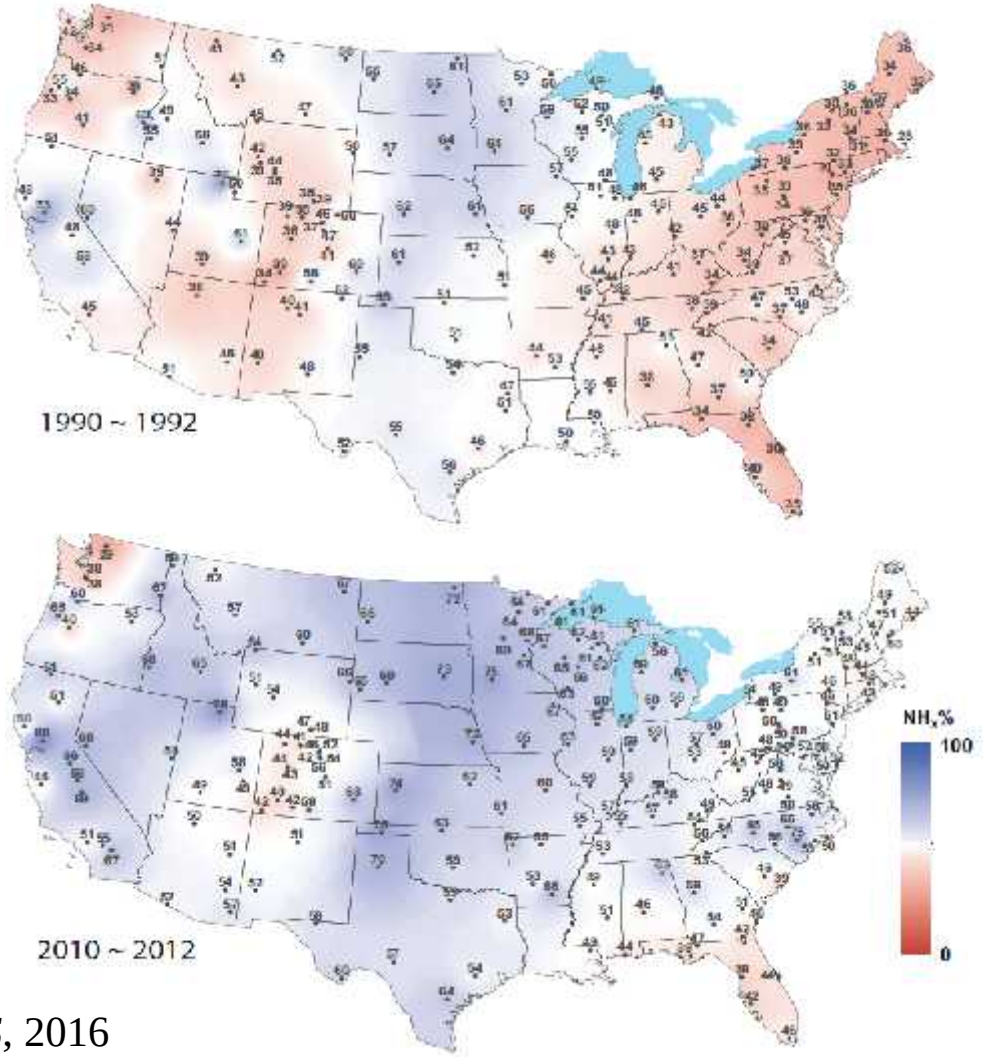
# $NH_4^+$ % of wet inorganic N dep

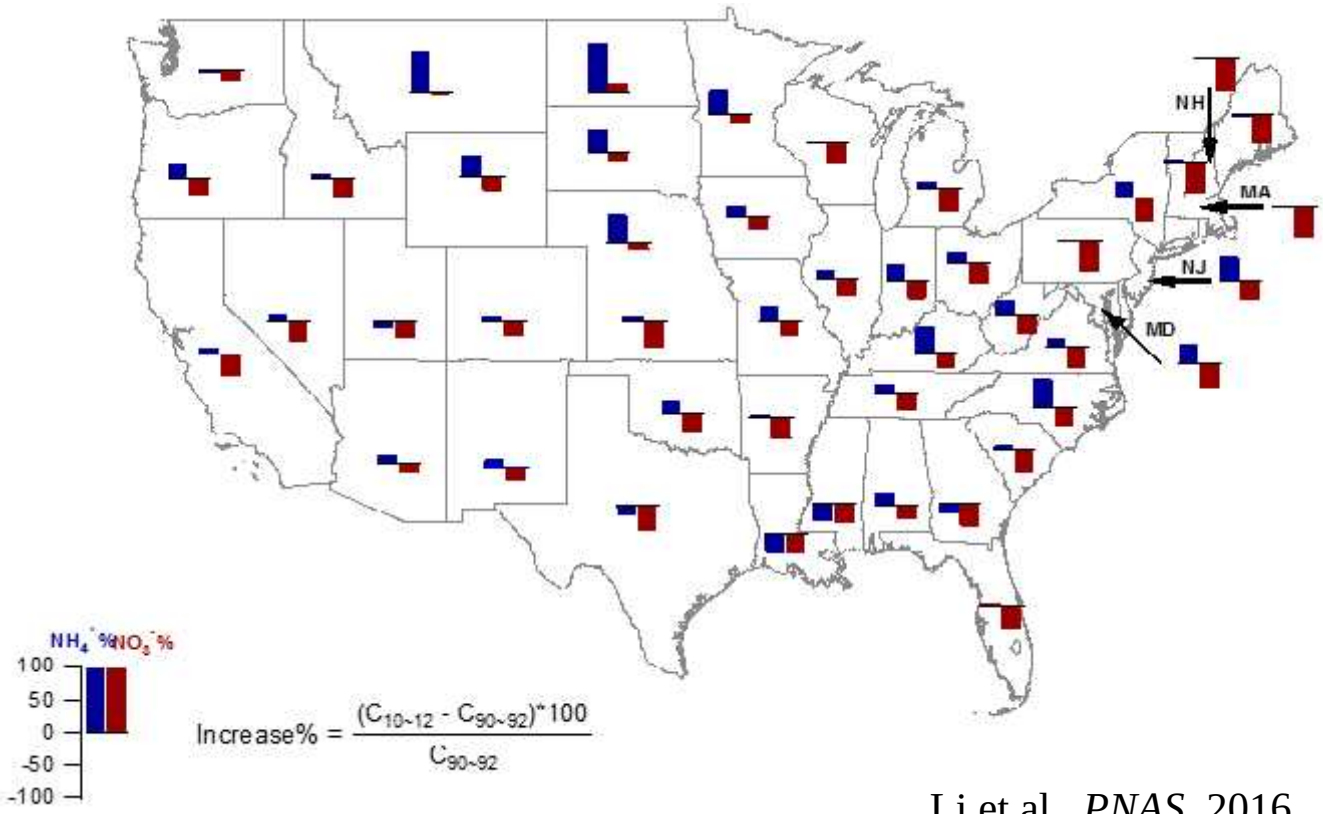
- $NO_3^-$ dominated U.S. wet N dep in 70s and 80s
- $NH_4^+$ now comprises > 50% of wet inorganic nitrogen deposition across most of the U.S.




Li et al., *PNAS*, 2016

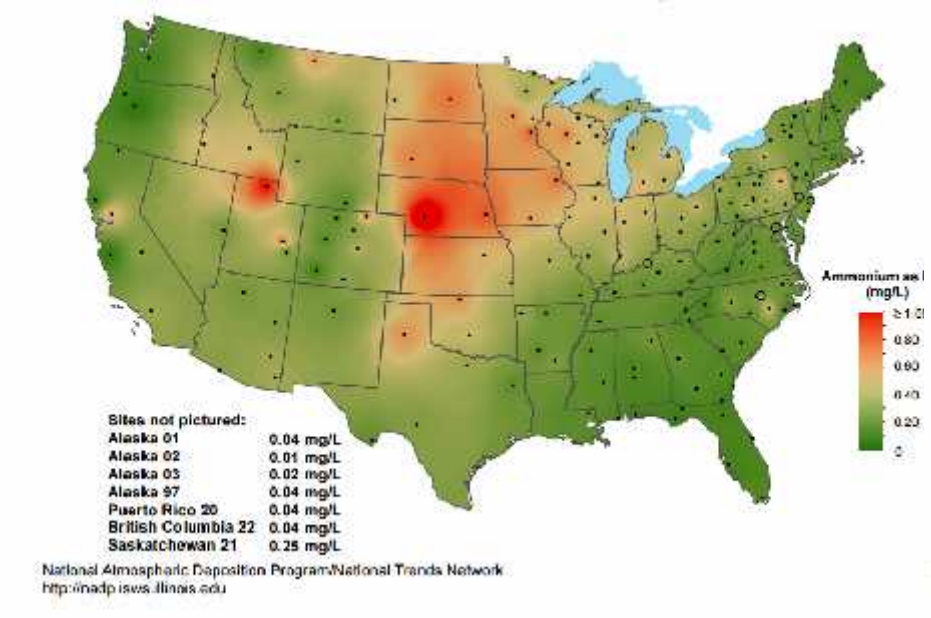
# Changes in precipitation N

- In all but one state, $NO_3^-$ wet deposition fluxes decreased (average 29%)
- In 37 of 45 states, $NH_4^+$ wet deposition fluxes increased (average 22%)




Li et al., *PNAS*, 2016

# What fraction of total reactive N deposition comes from $NH_3/NH_4^+$?

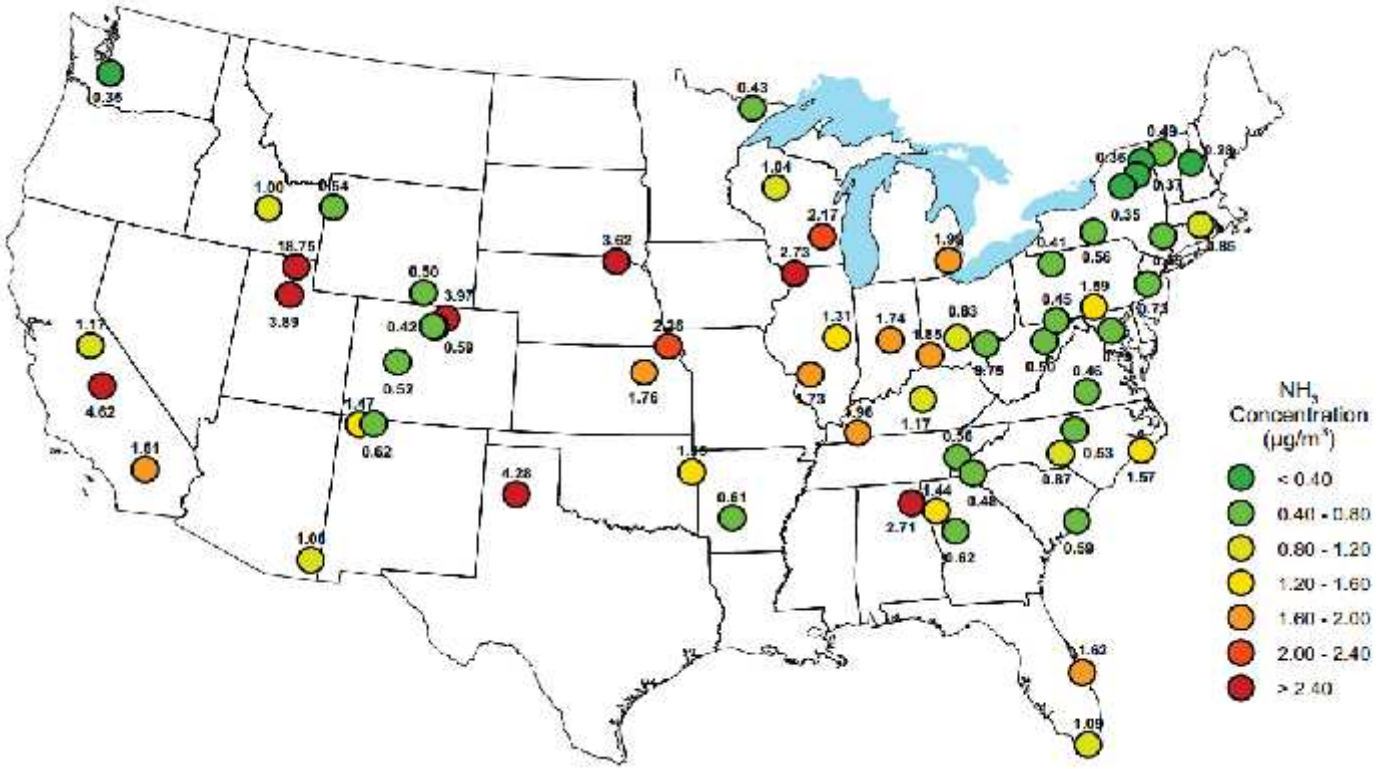



NADP wet deposition of $NO_3$- and $NH_4^+$


CASTNet dry deposition of $HNO_3$, $NO_3$-, and $NH_4^+$

# New NADP AMoN Network

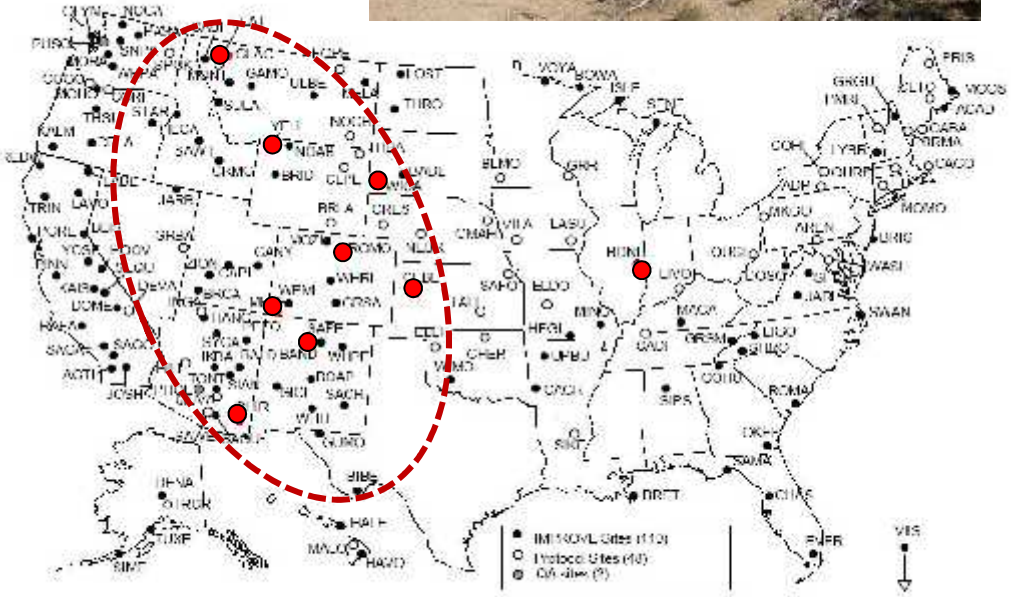
Bi-weekly Radiello passive sampler measurements of gaseous $NH_3$




NADP 2013 Annual Summary

# Pilot IMPROVE $NH_x$ network

- Rocky Mountain focus
  - 9 sites, 1-in-3 day sampling
  - 4/2011 - 8/2012
- Single phosphorous acid-coated filter to capture particulate $NH_4^+$ + gaseous $NH_3$



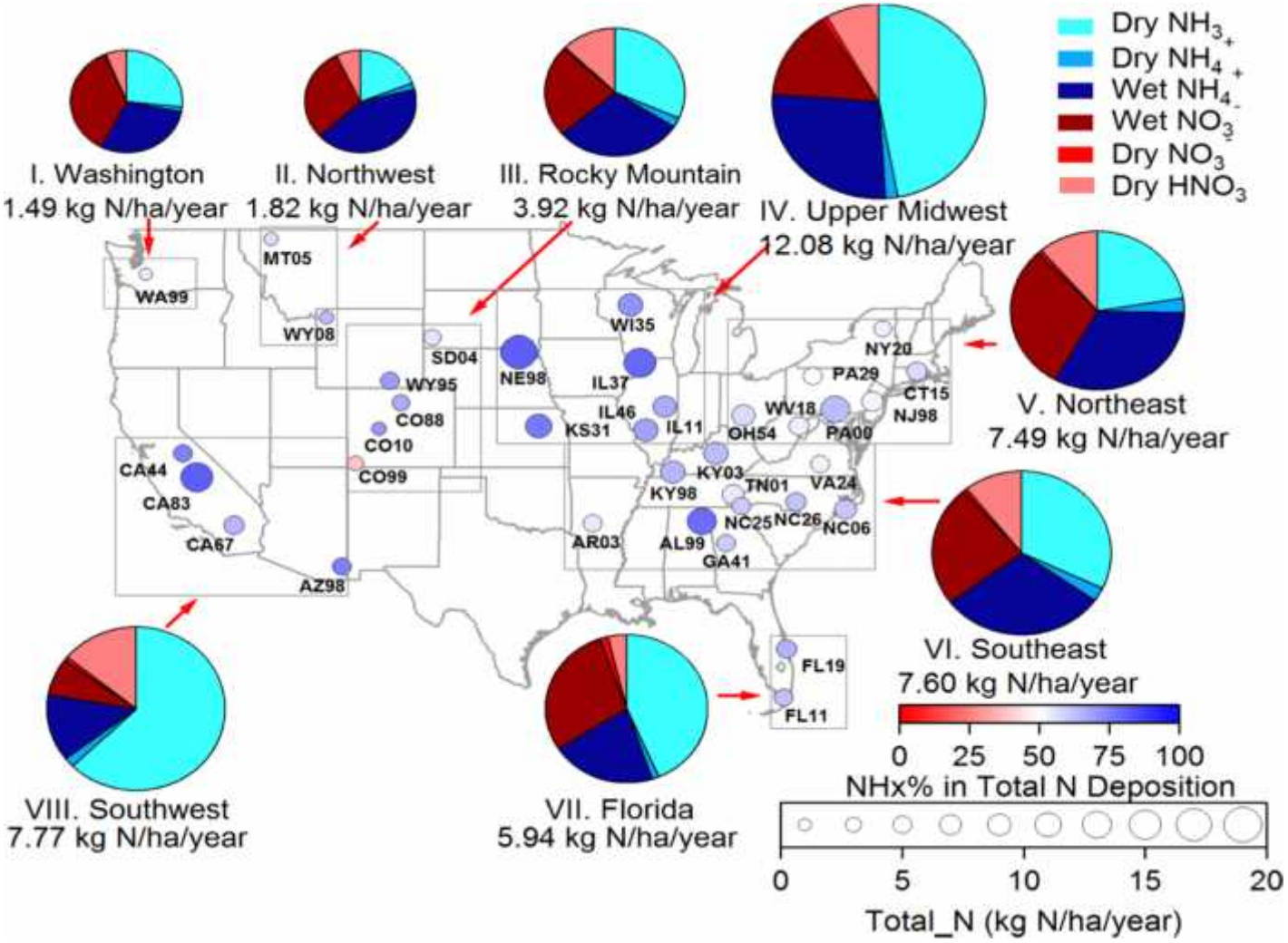
# What fraction of total reactive N deposition comes from $NH_3/NH_4^+$?

Use NADP wet deposition + CASTNet observations/MLM model dry deposition + new AMoN and IMPROVE $NH_x$ network measurements for $NH_3$ concentrations

- Estimate $NH_3$ deposition $V_d$ from scaled MLM $HNO_3$ $V_d$ (factor of 0.7)
- Check against bidirectional flux model with single dominant vegetation type

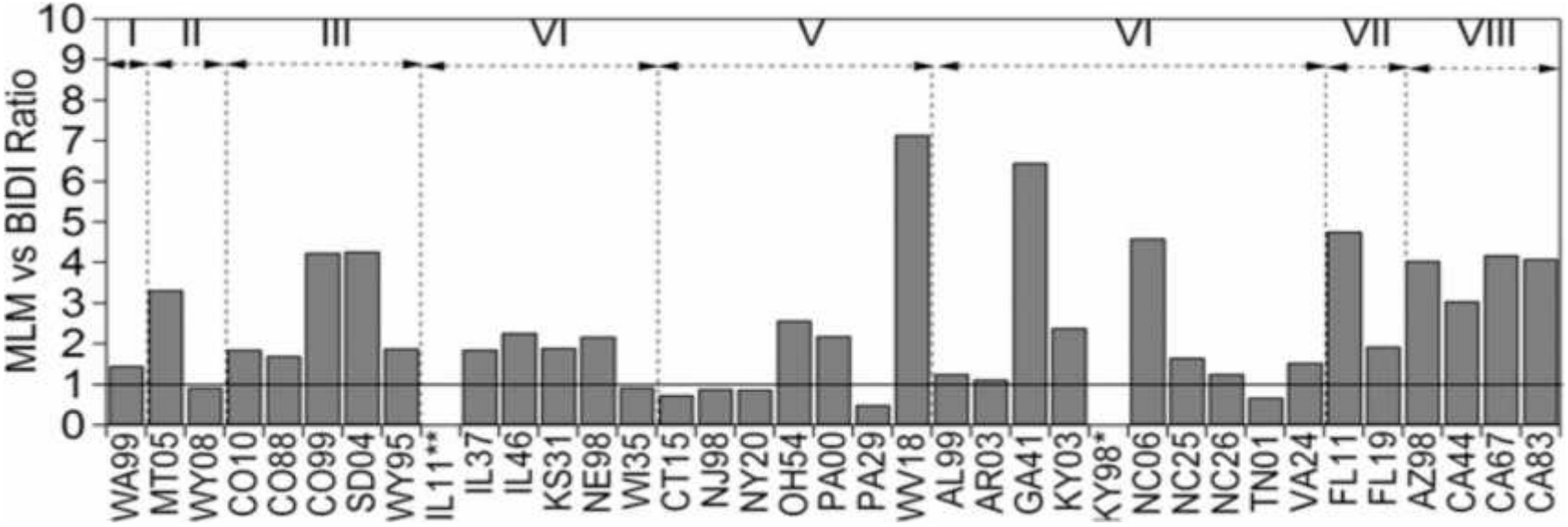
Determine balance of reduced and oxidized total (wet + dry) deposition at 37 U.S. locations

$NH_x$ comprises majority of total inorganic nitrogen deposition across U.S.




Li et al., *PNAS*, 2016

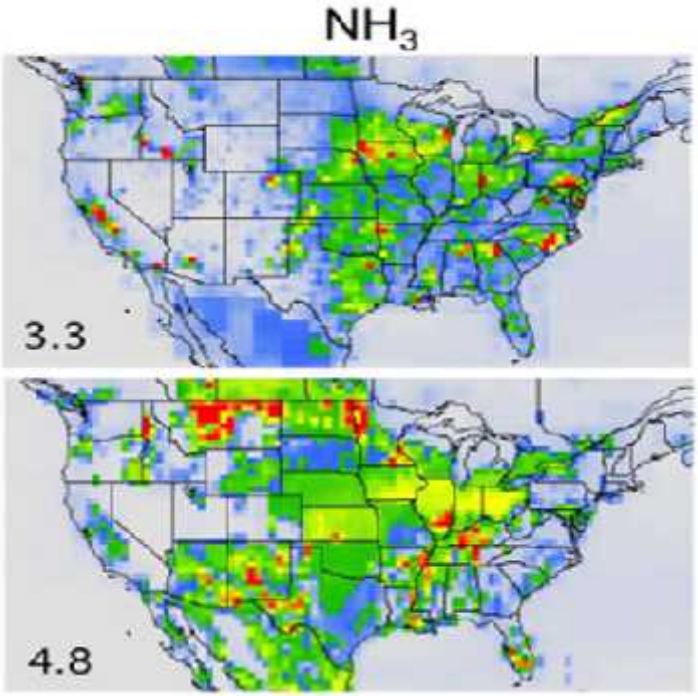
# Scaled MLM vs. bidi $NH_3$ deposition comparison




Li et al., *PNAS*, 2016

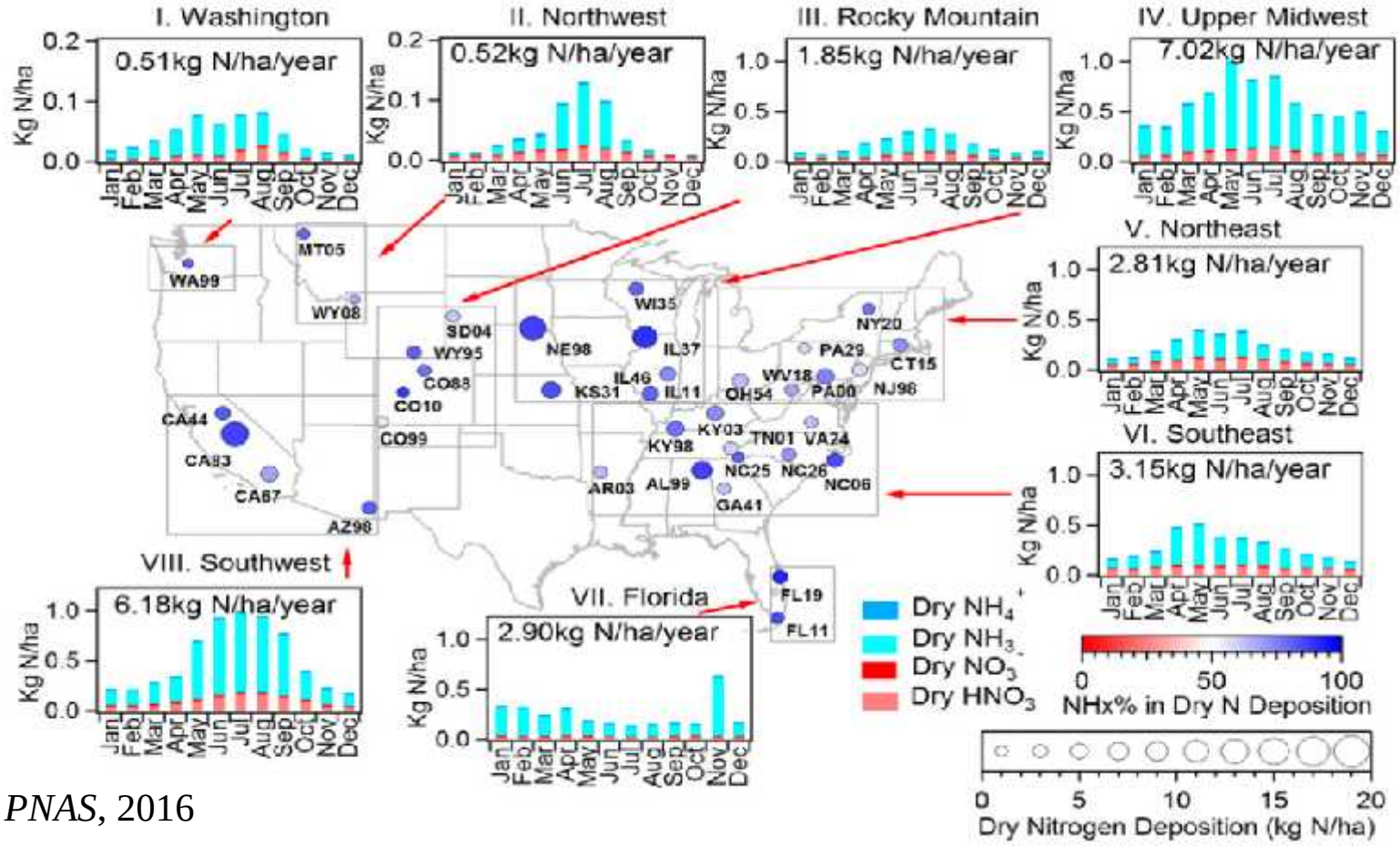
# Summary

- As $NO_x$ emissions have decreased, $NH_4^+$ has become the majority component of U.S. N wet deposition
- Recent $NH_3$ monitoring permits new view of U.S. dry deposition of oxidized and reduced N
  - Reduced N dominates inorganic N dry and total dep budgets
  - Need additional research to improve bidirectional flux characterization
- Future emissions projections suggest continued growth in the reduced N fraction of U.S. N deposition




Ellis et al. (2013)
$NH_3$ emissions for 2006 (top)
& 2050 (bottom)

# $NH_x$ comprises majority of U.S. inorganic nitrogen dry deposition




Li et al., *PNAS*, 2016