The increasing importance of U.S. reduced nitrogen deposition

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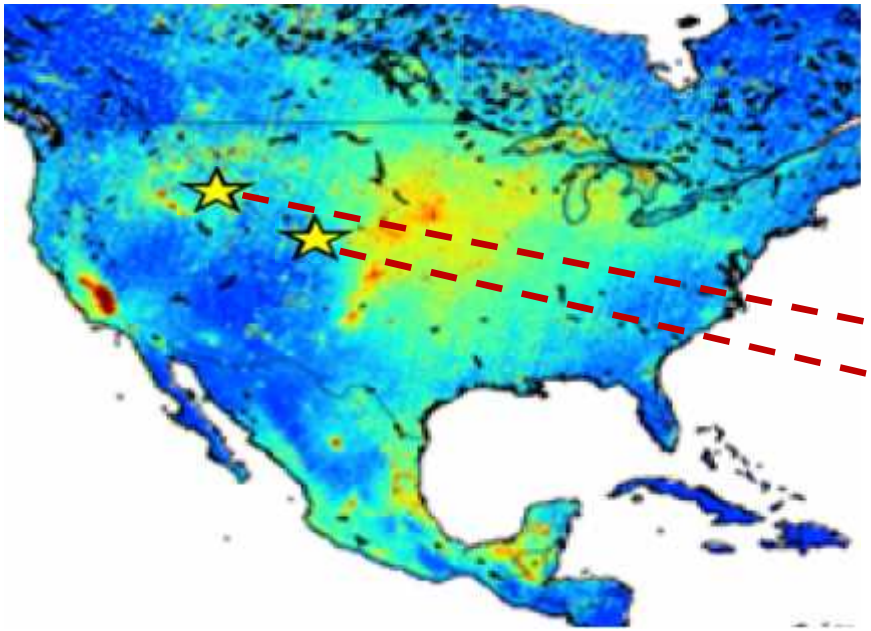
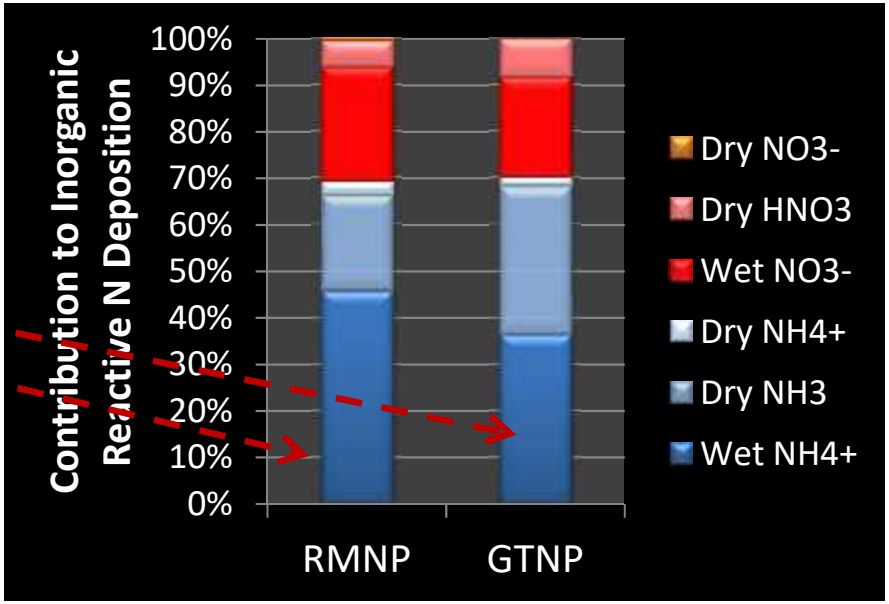
Rocky Mountain inorganic N deposition budgets



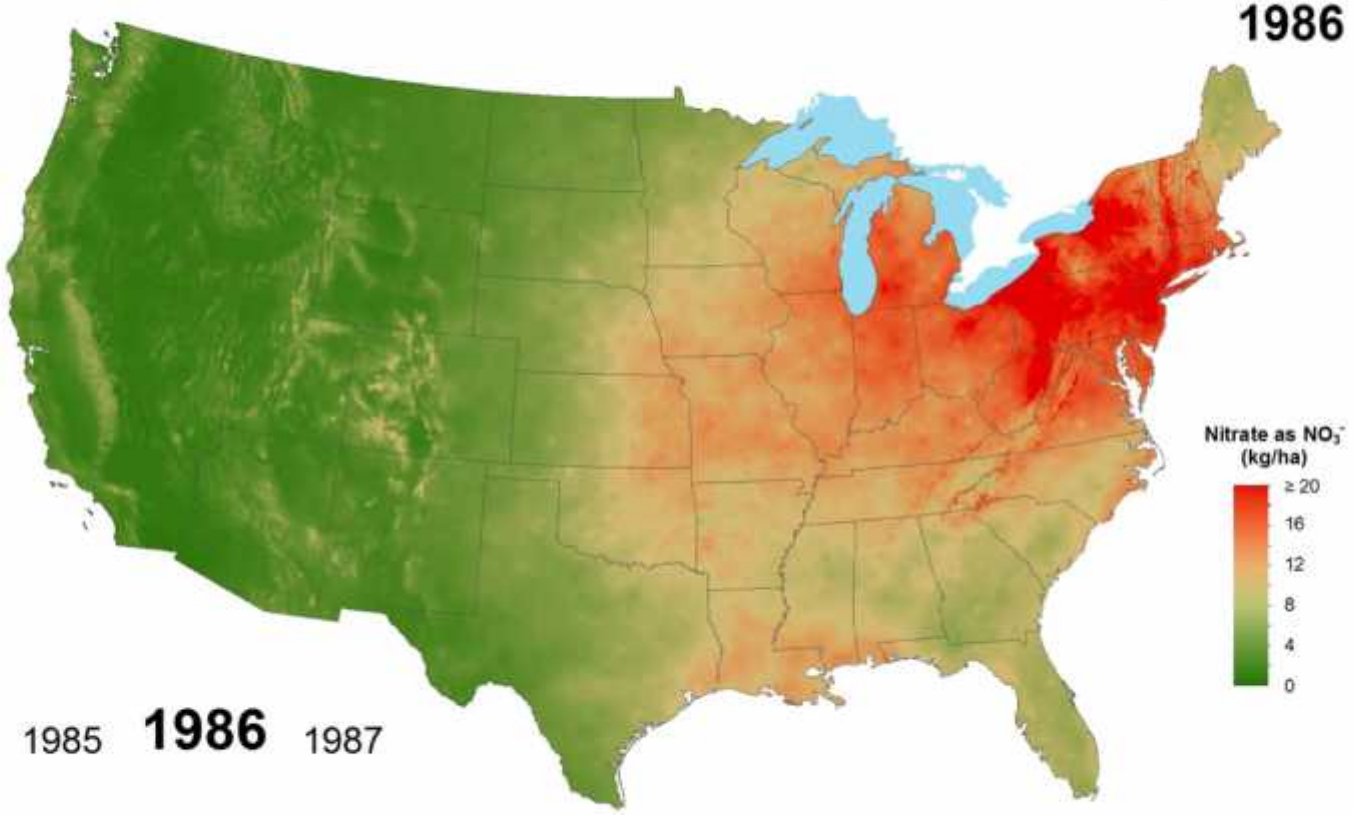
IASI satellite NH_3 (2008-2013)
M. Van Damme and J.W. Erisman



Benedict et al., 2013a,b

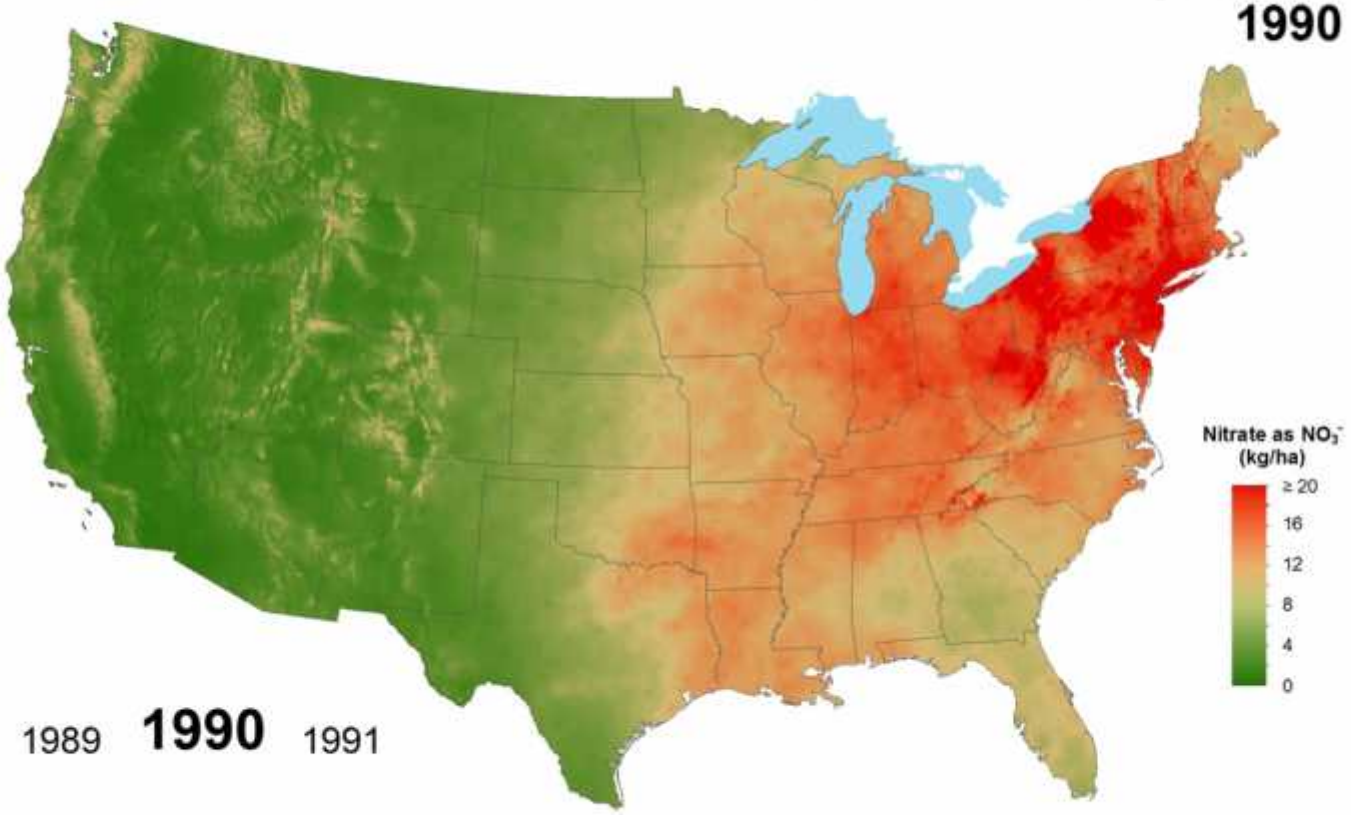
Historical changes in U.S. wet reactive N deposition

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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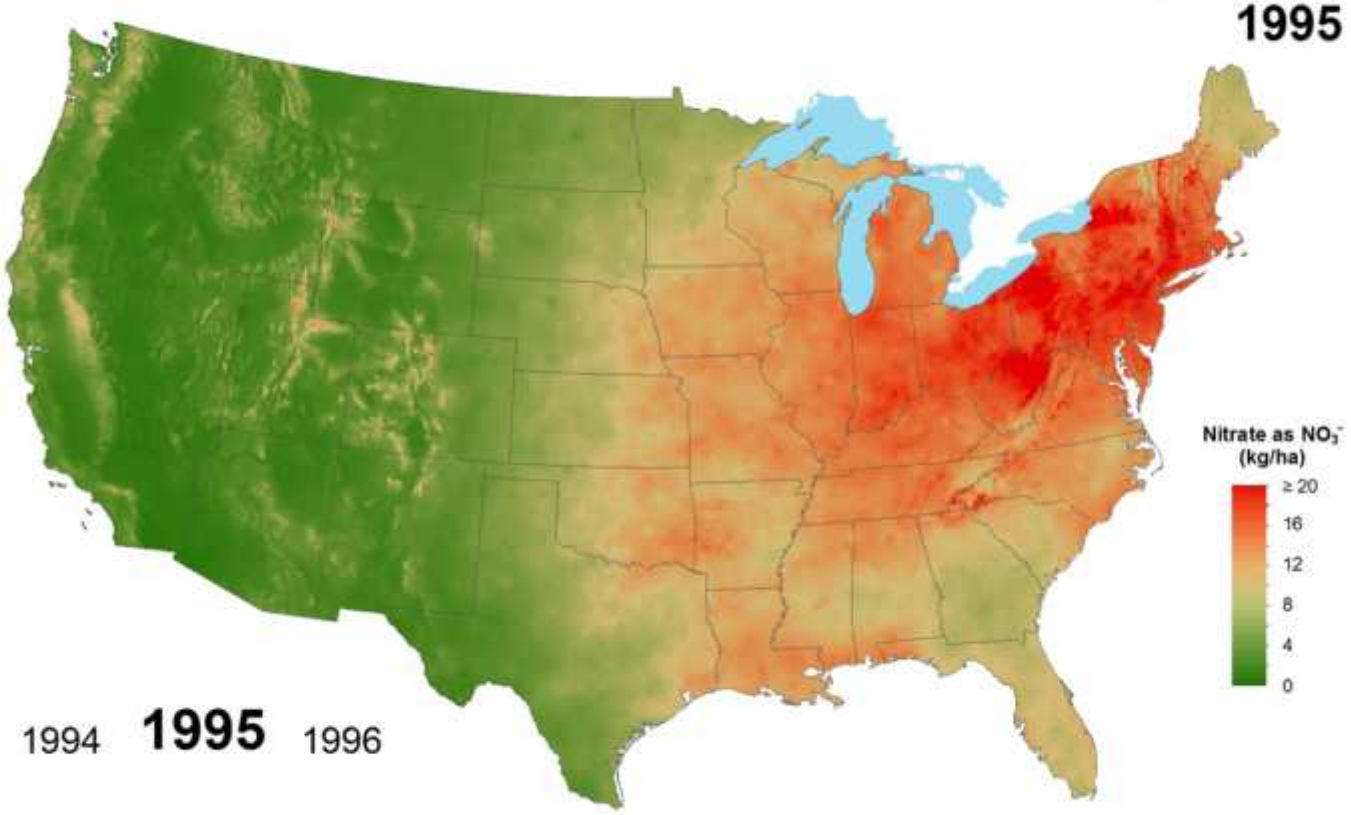
Nitrate ion wet deposition
1995



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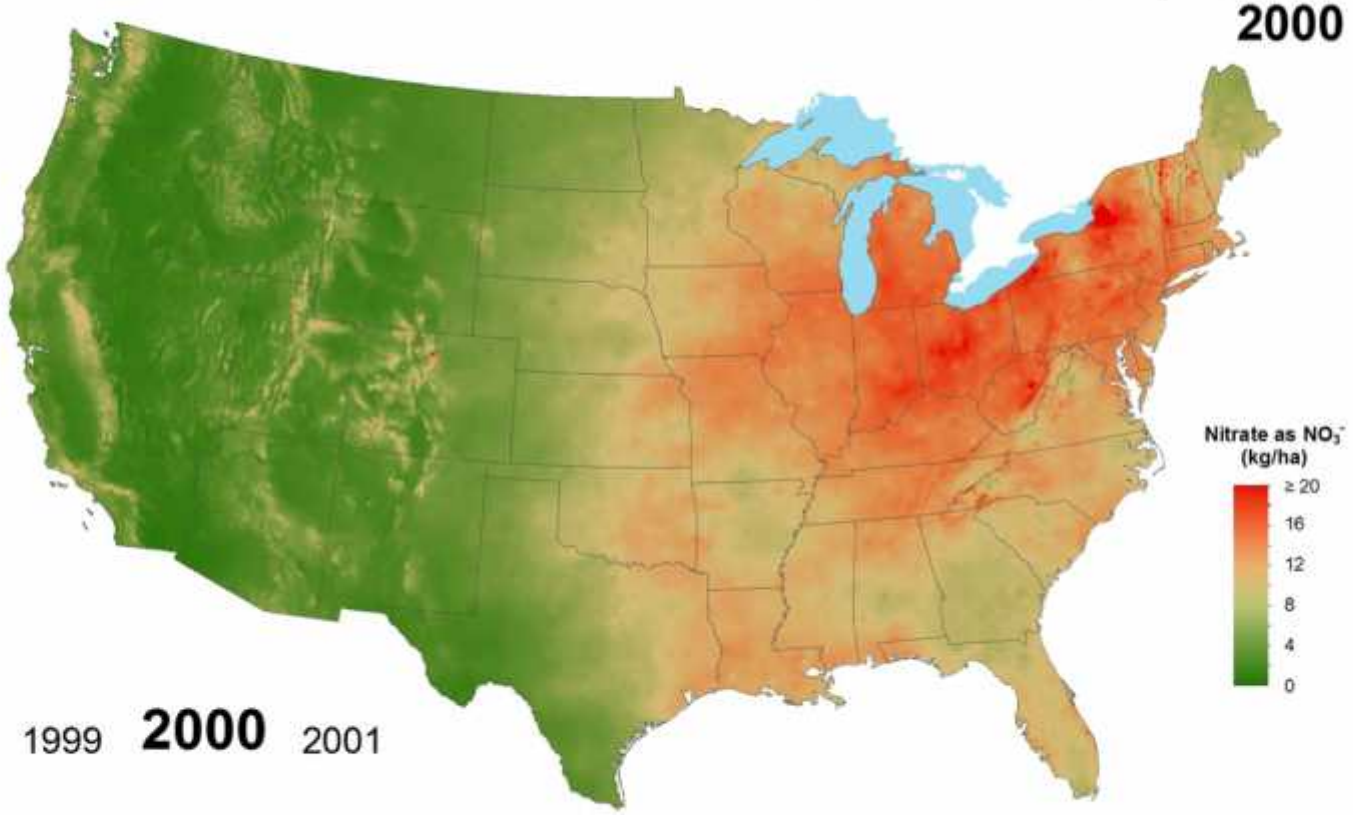
Nitrate ion wet deposition
2000



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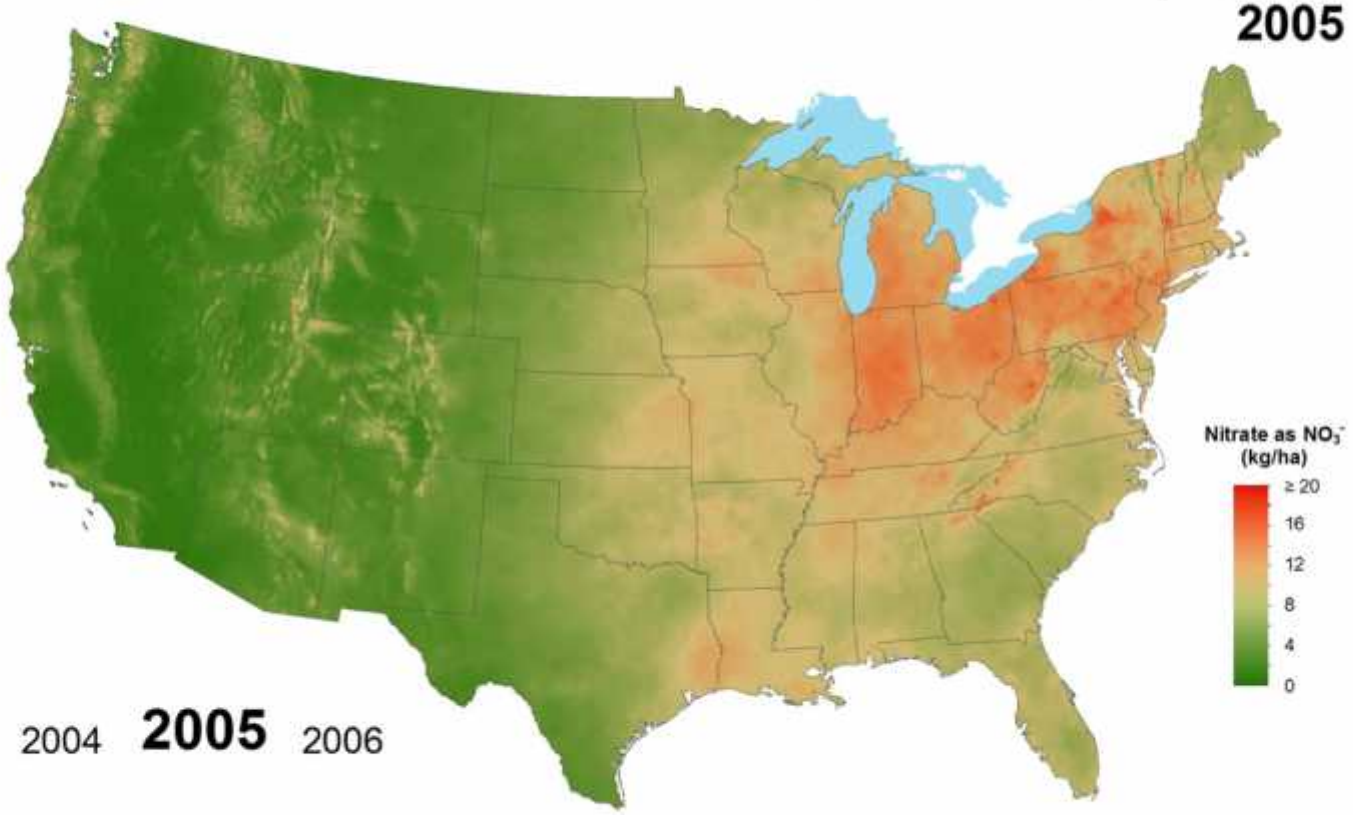
Nitrate ion wet deposition
2005



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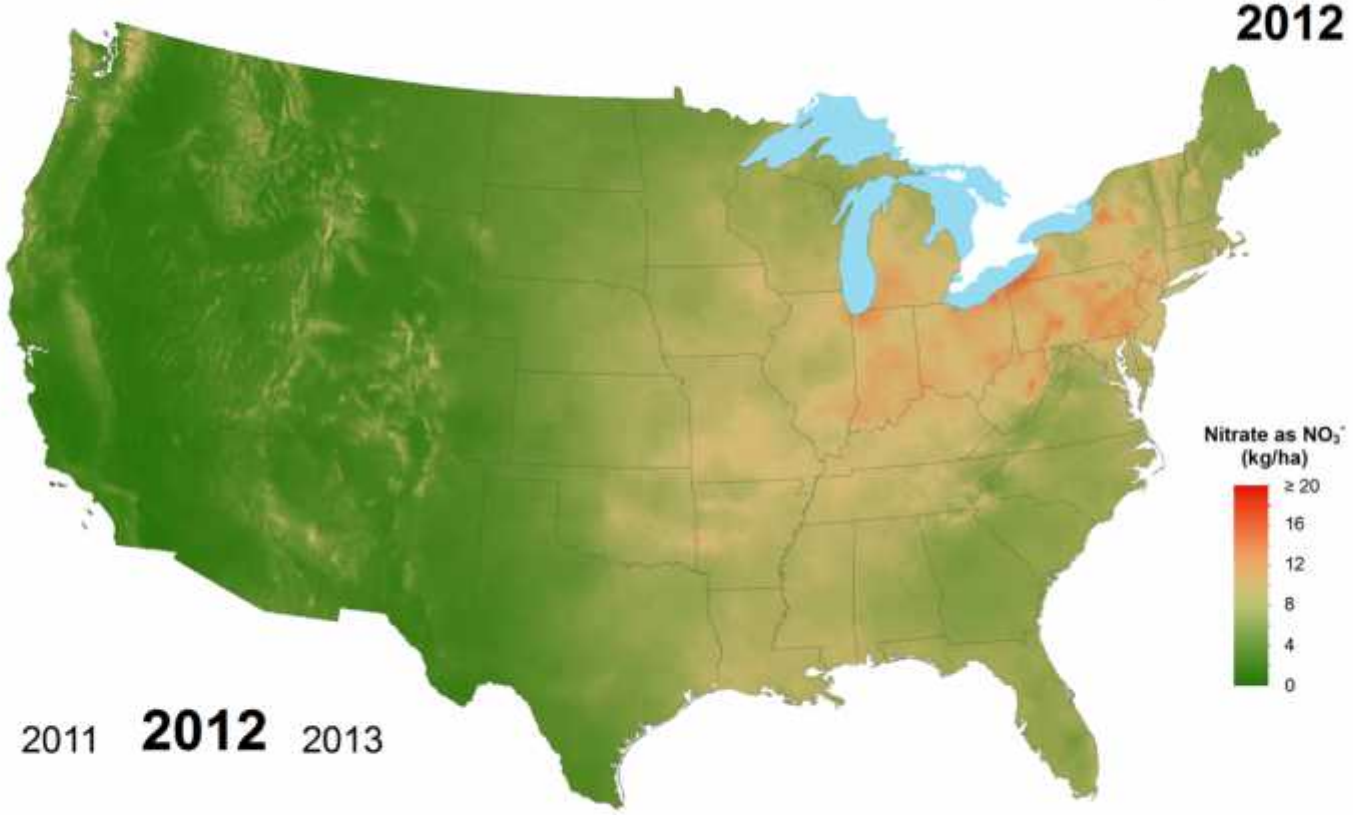
Nitrate ion wet deposition
2012



2011 **2012** 2013

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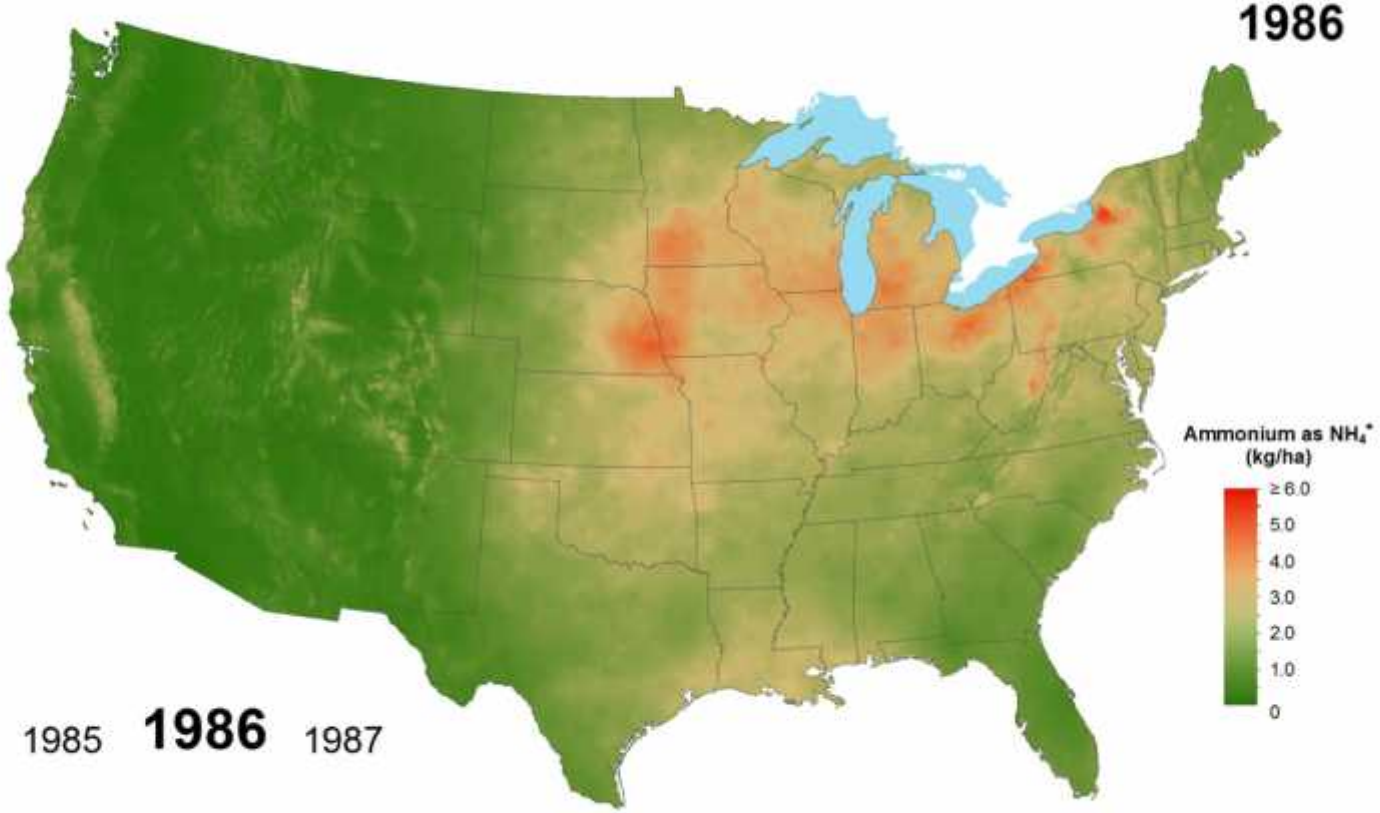
Changes in NO_x emissions

Ammonium ion wet deposition
1986



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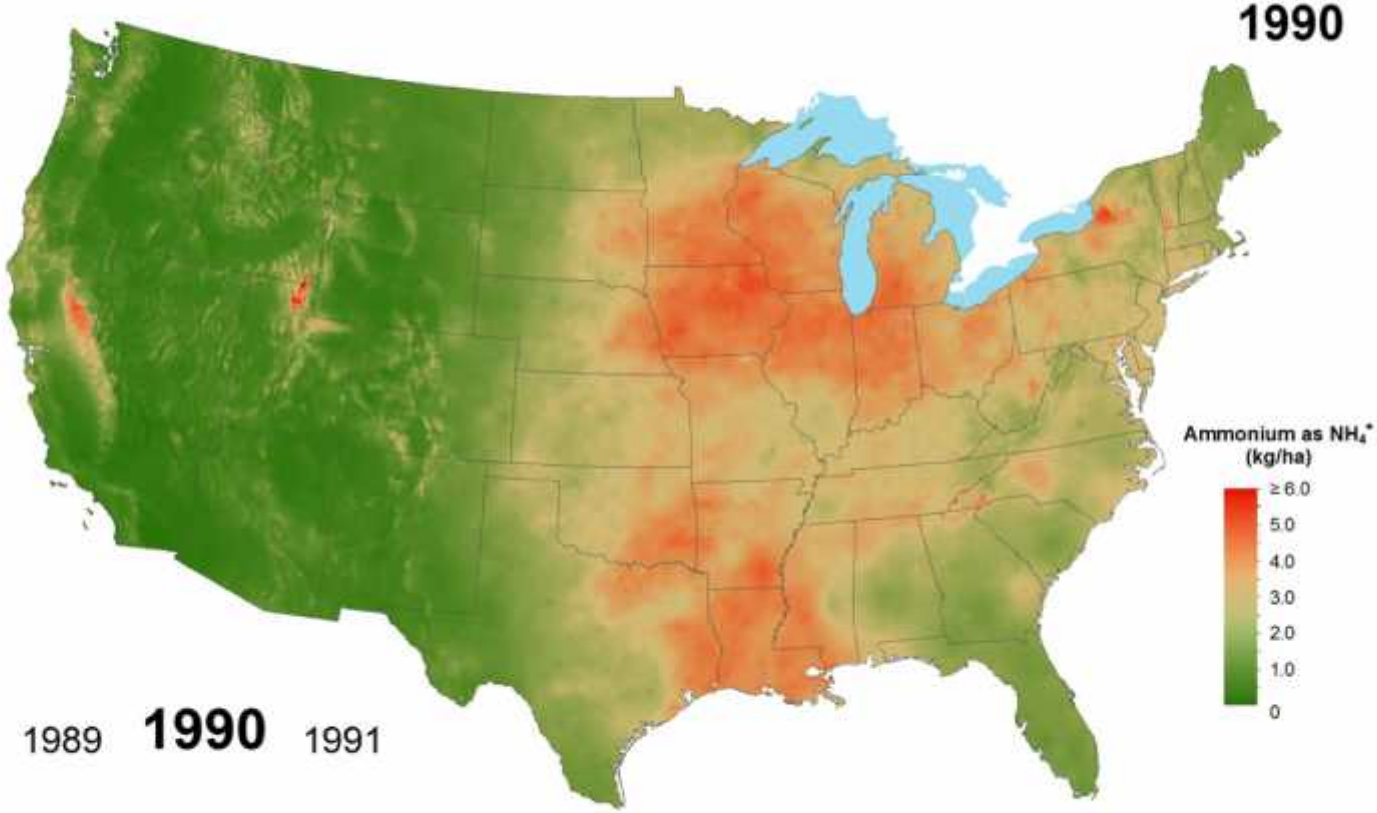
Ammonium ion wet deposition
1990



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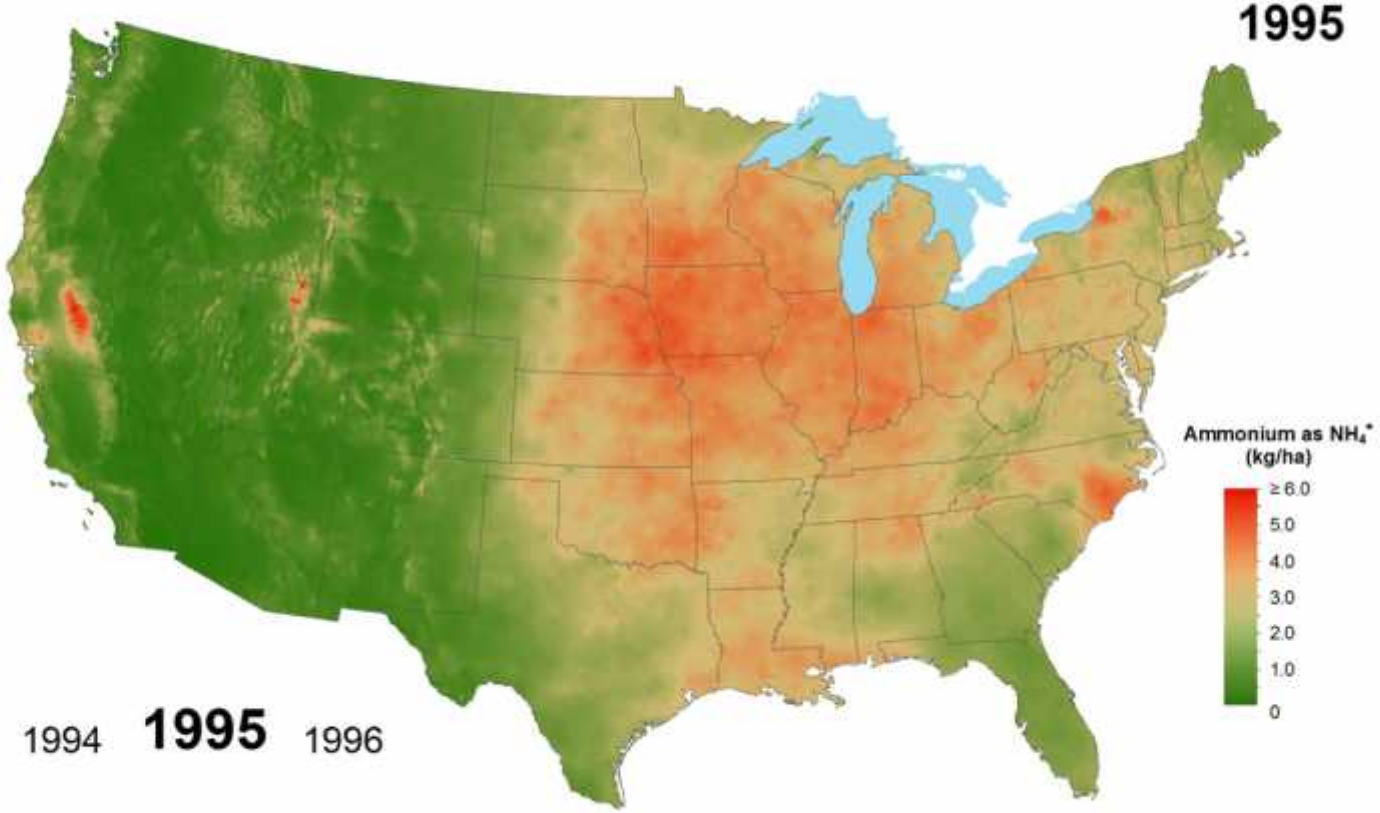
Ammonium ion wet deposition
1995



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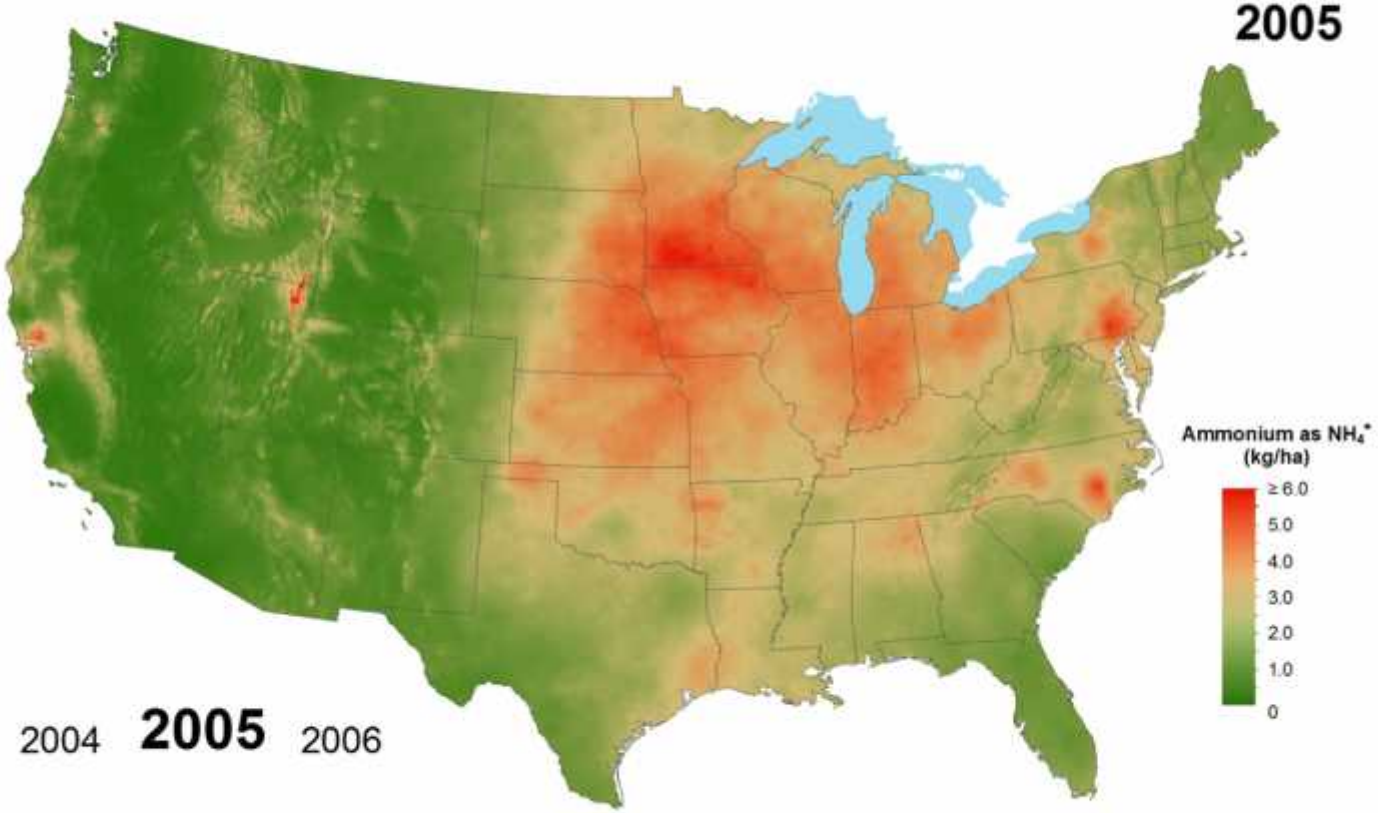
Ammonium ion wet deposition
2005



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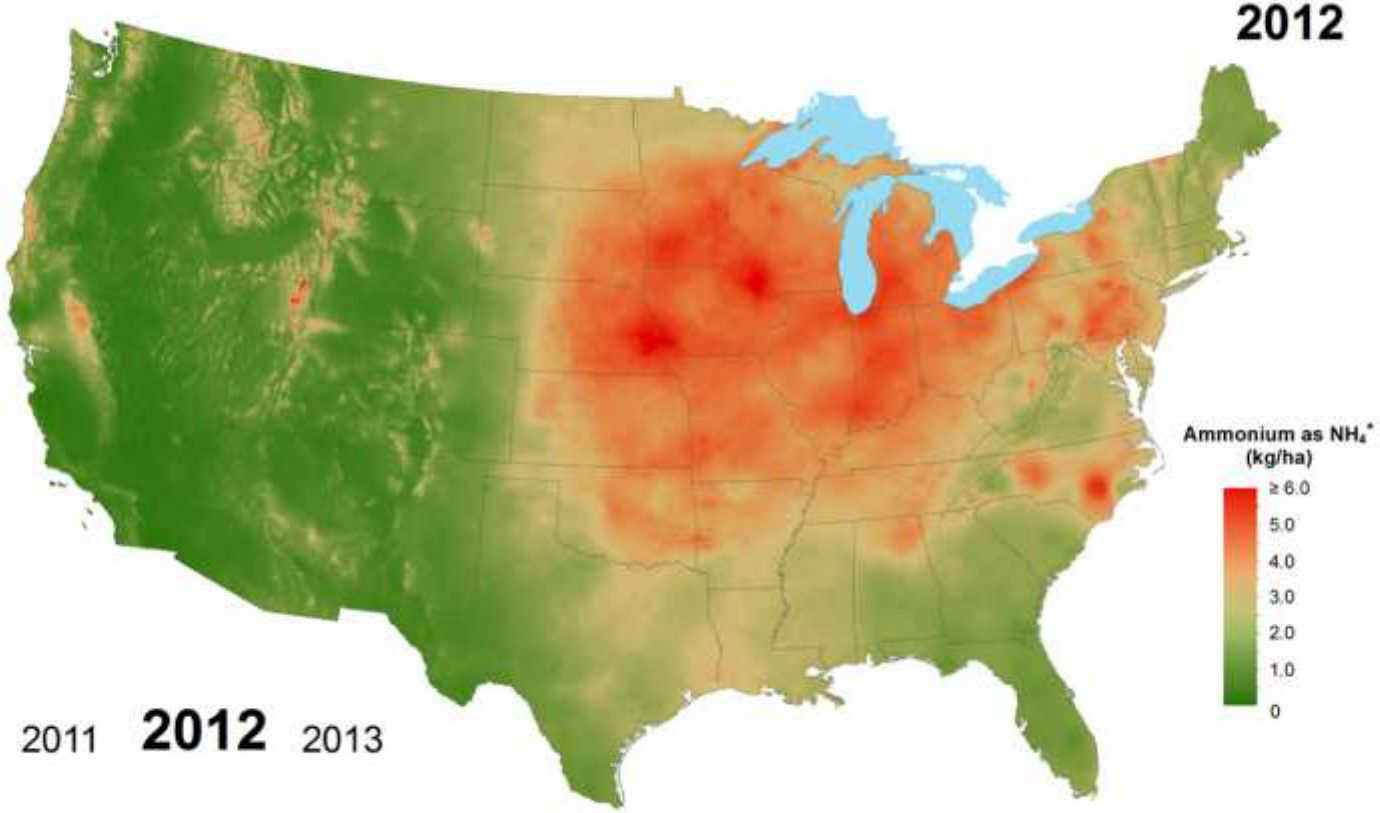
Ammonium ion wet deposition
2012



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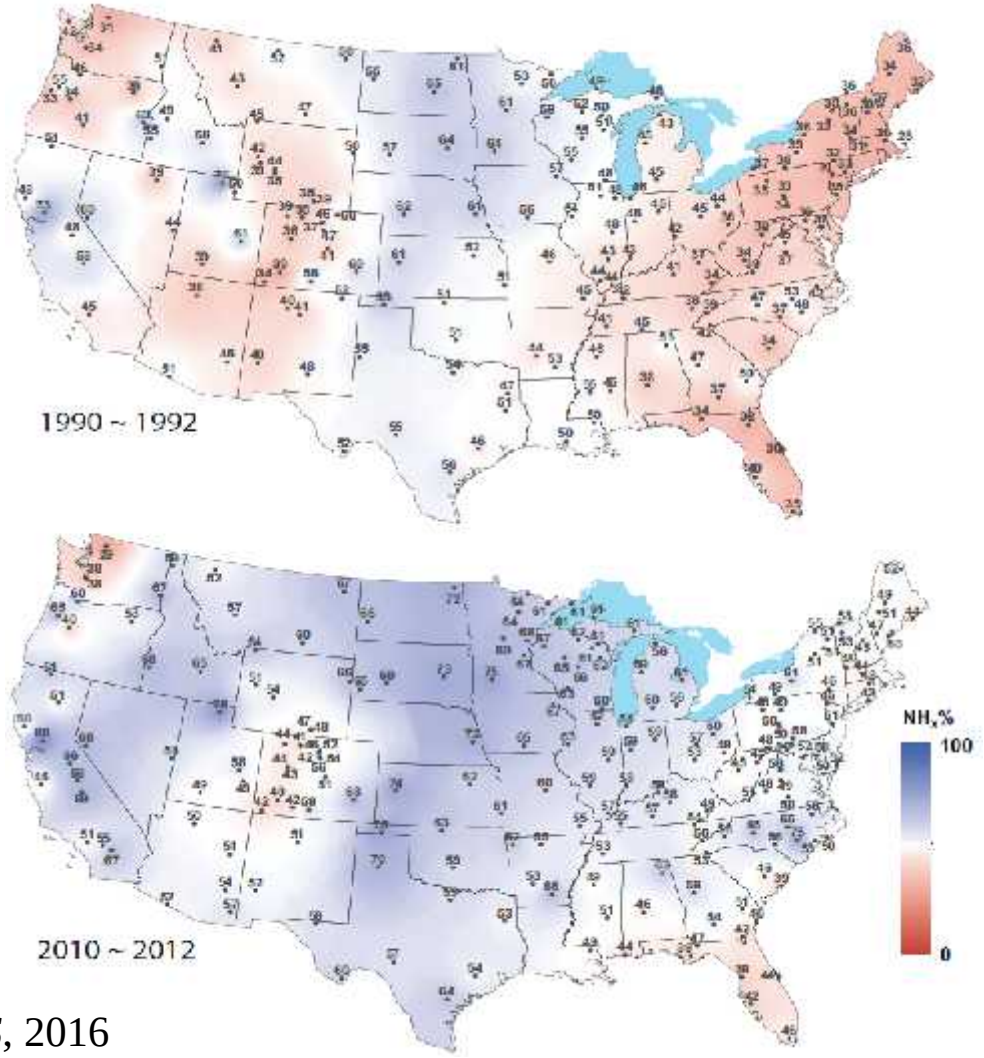
NH_4^+ % of wet inorganic N dep

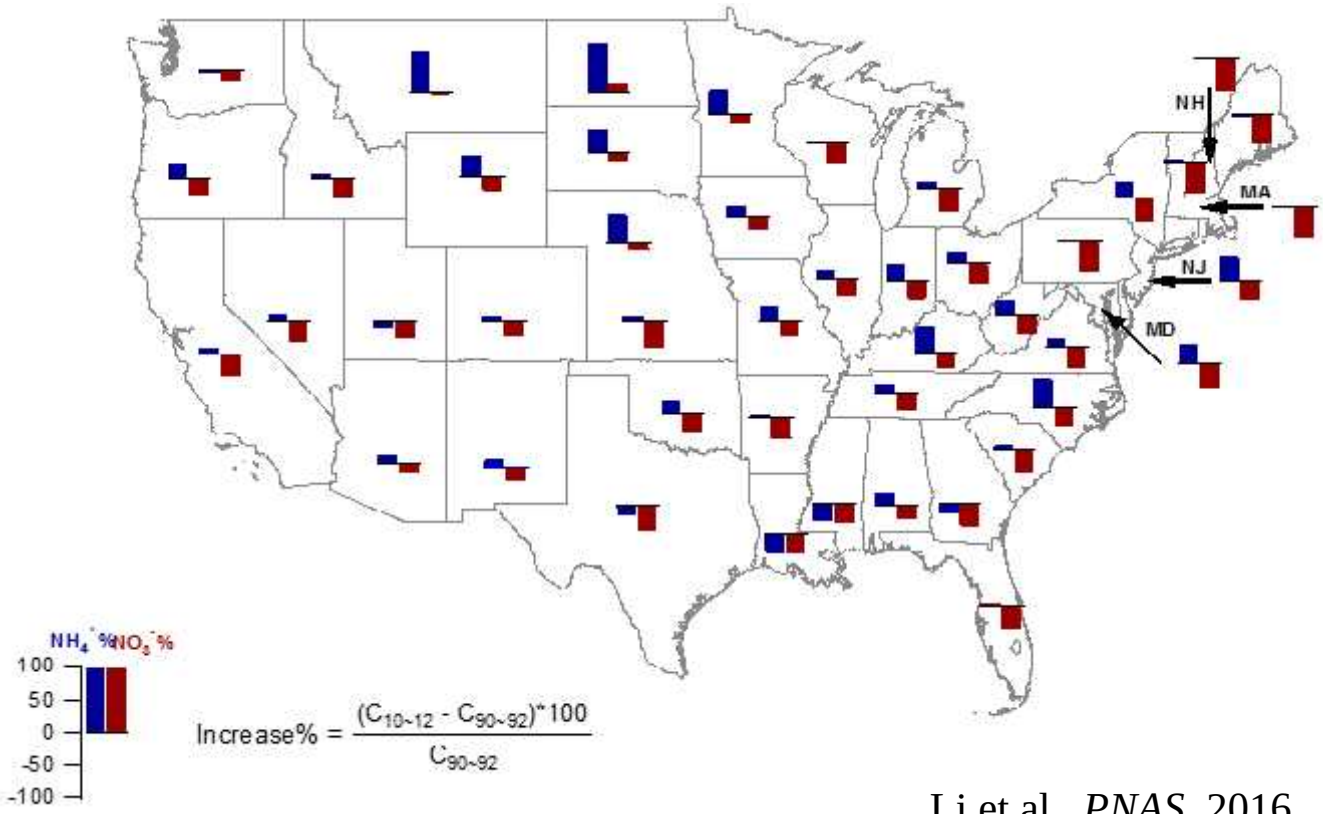
- NO_3^- dominated U.S. wet N dep in 70s and 80s
- NH_4^+ now comprises > 50% of wet inorganic nitrogen deposition across most of the U.S.



Li et al., *PNAS*, 2016

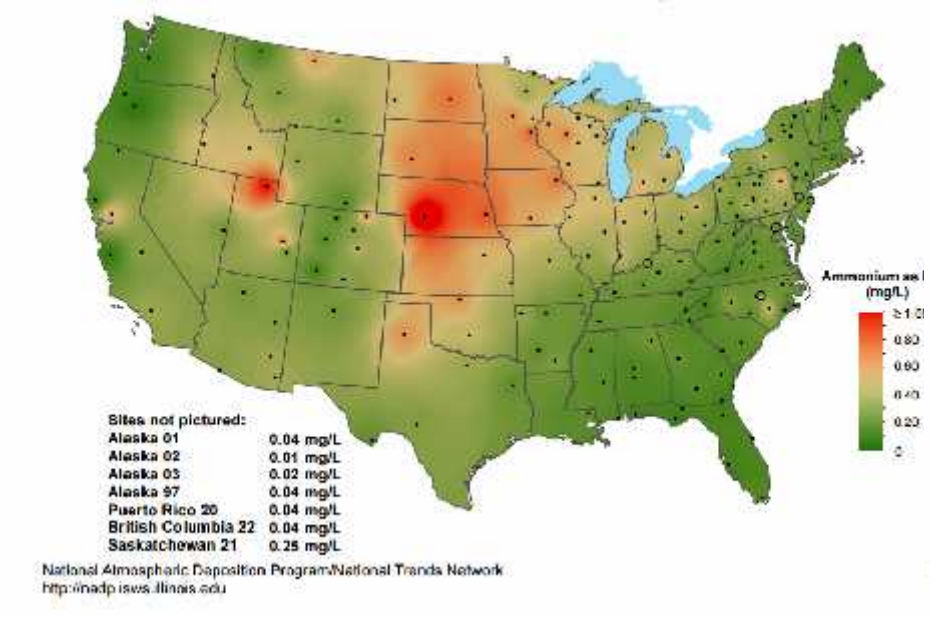
Changes in precipitation N

- 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^+?

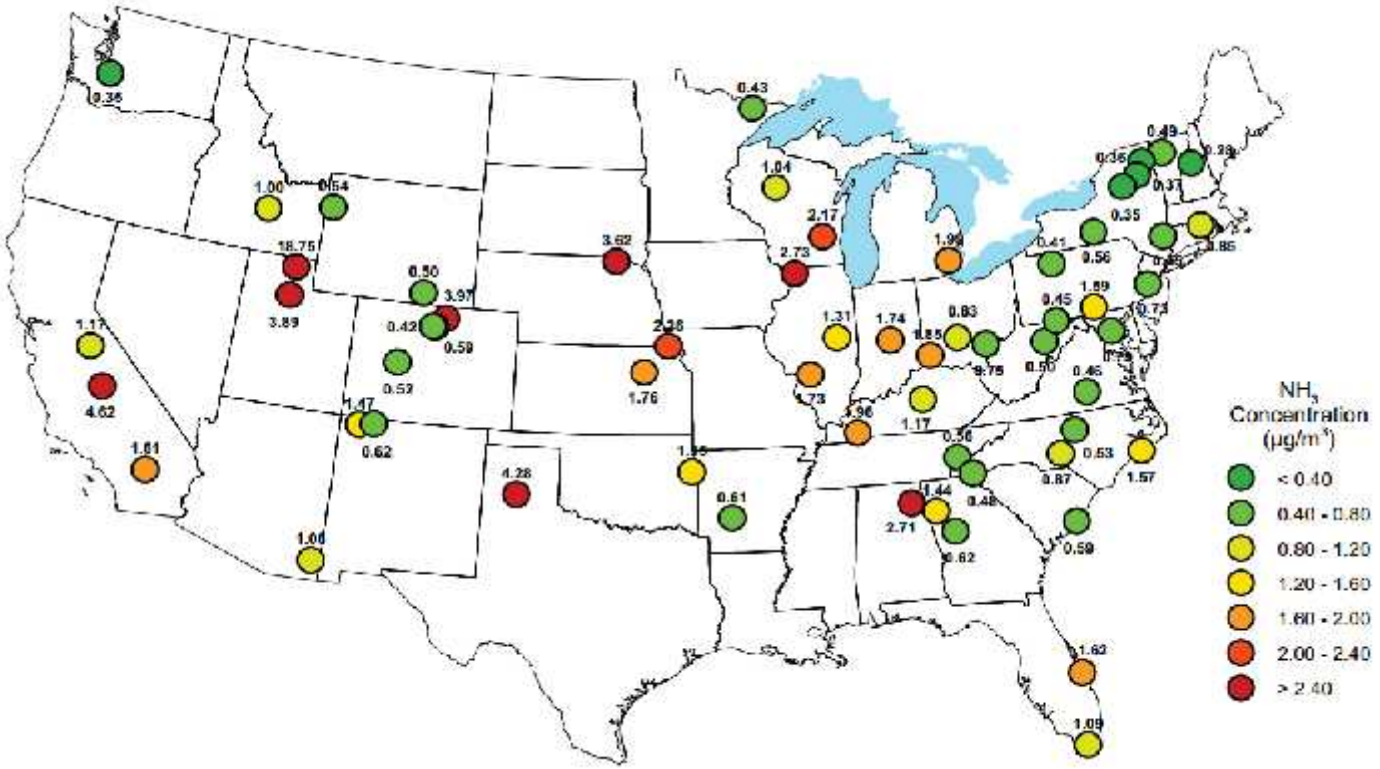


NADP wet deposition of NO_3- and NH_4^+

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

New NADP AMoN Network

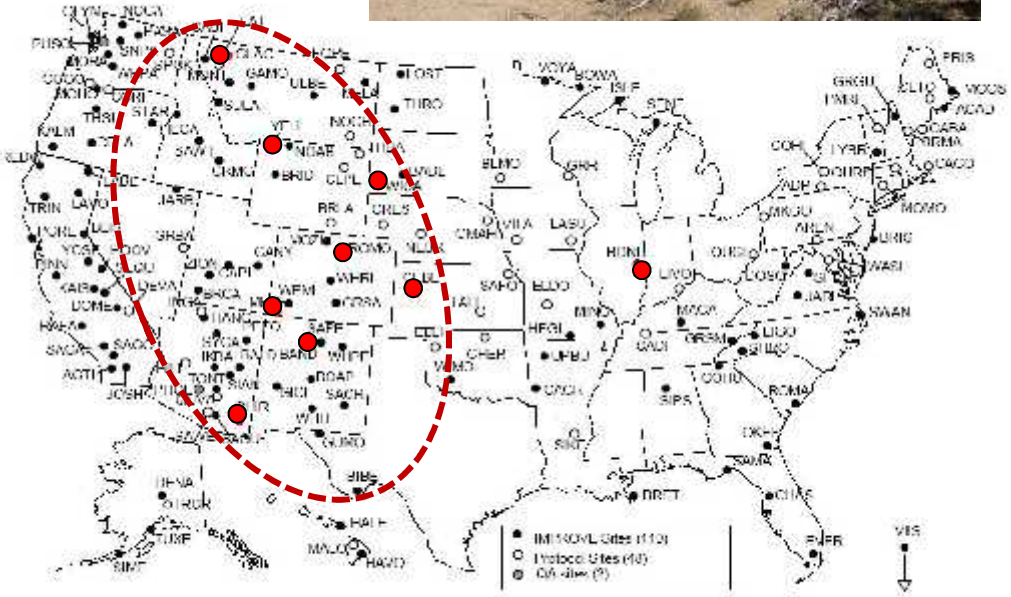
Bi-weekly Radiello passive sampler measurements of gaseous NH_3



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



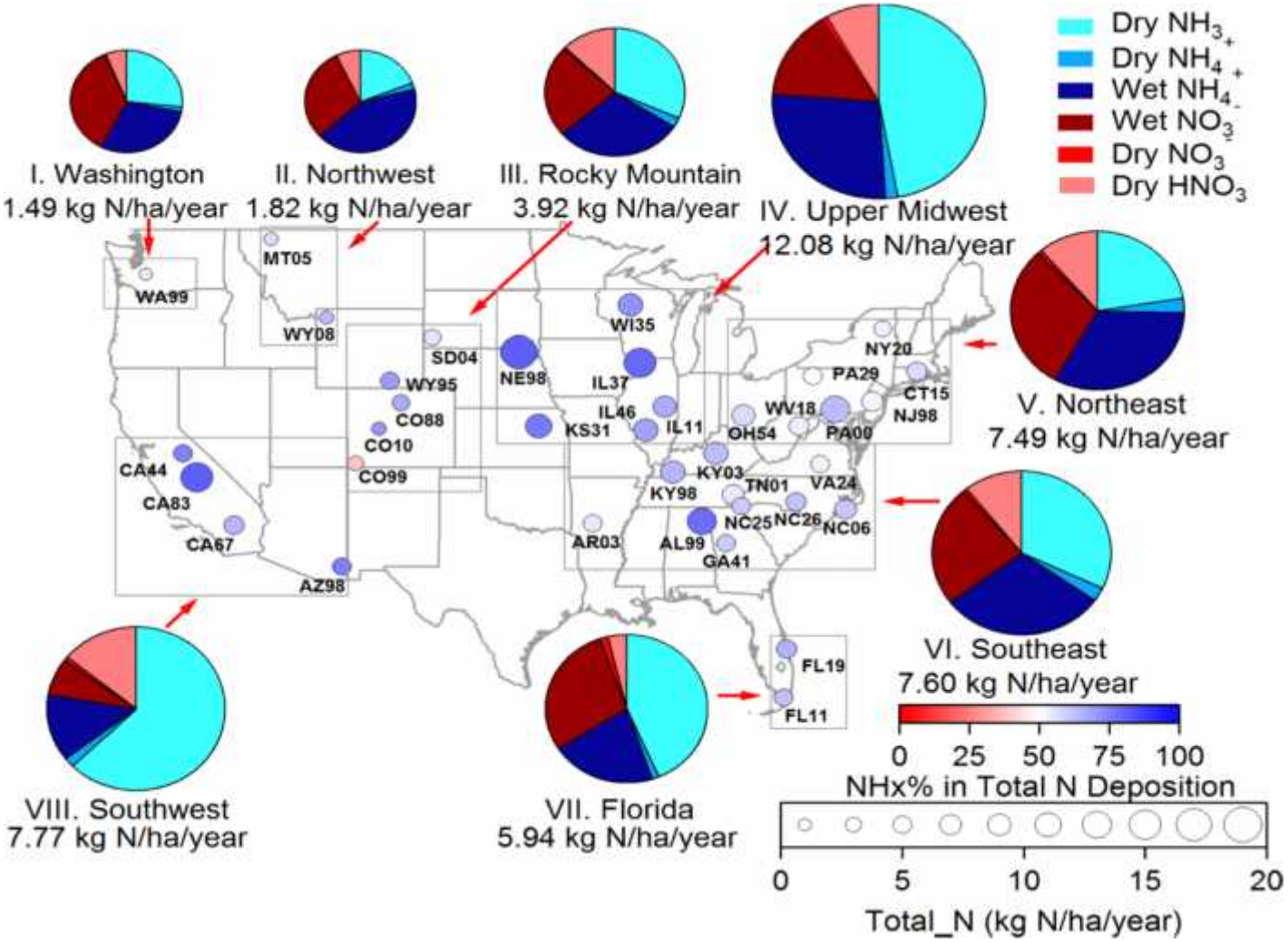
What fraction of total reactive N deposition comes from NH_3/NH_4^+?

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

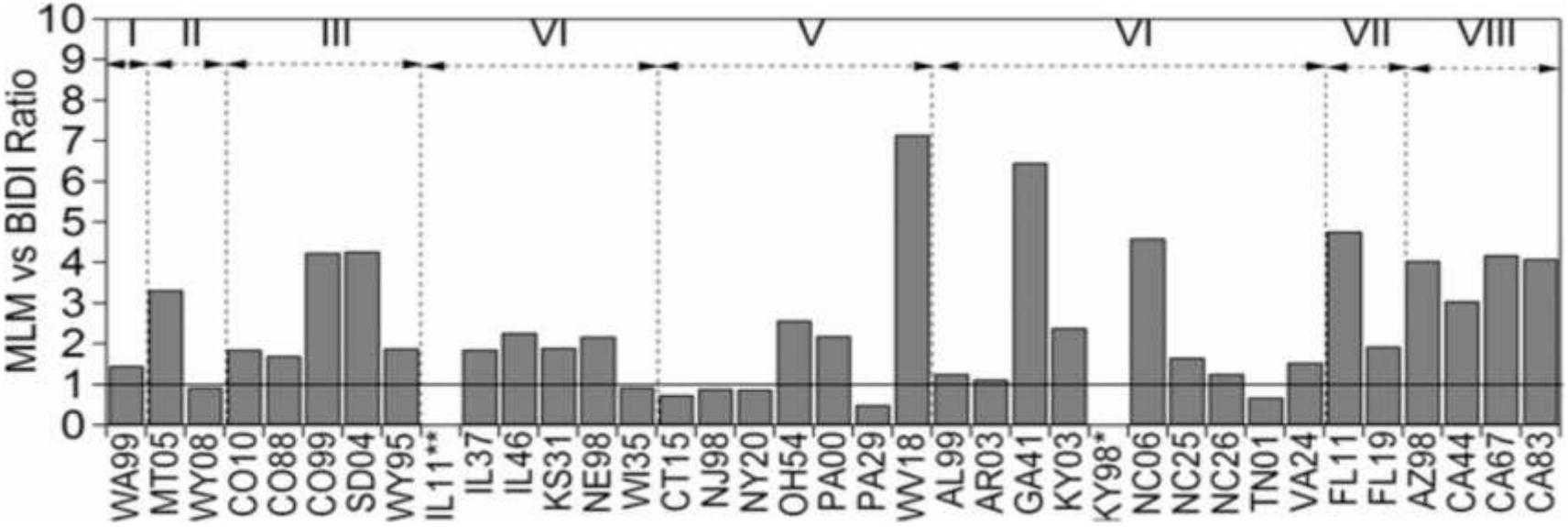
Determine balance of reduced and oxidized total (wet + dry) deposition at 37 U.S. locations

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



Li et al., *PNAS*, 2016

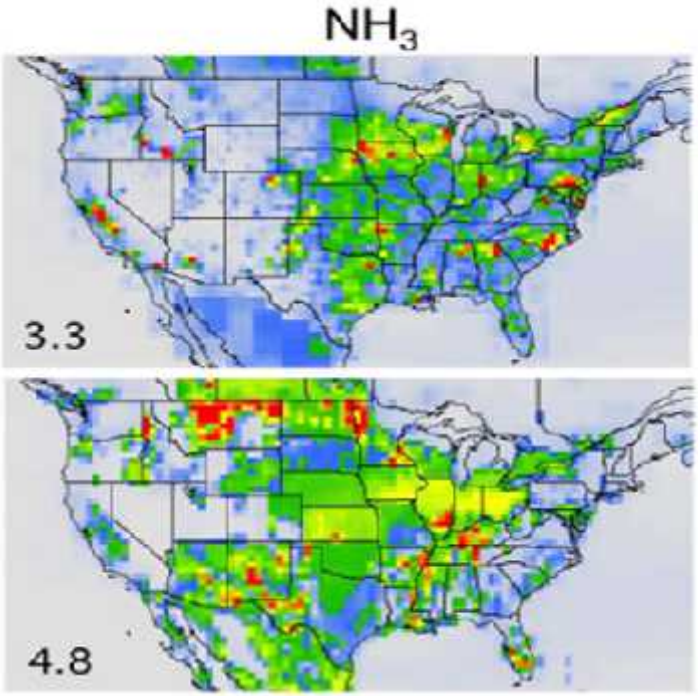
Scaled MLM vs. bidi NH_3 deposition comparison



Li et al., *PNAS*, 2016

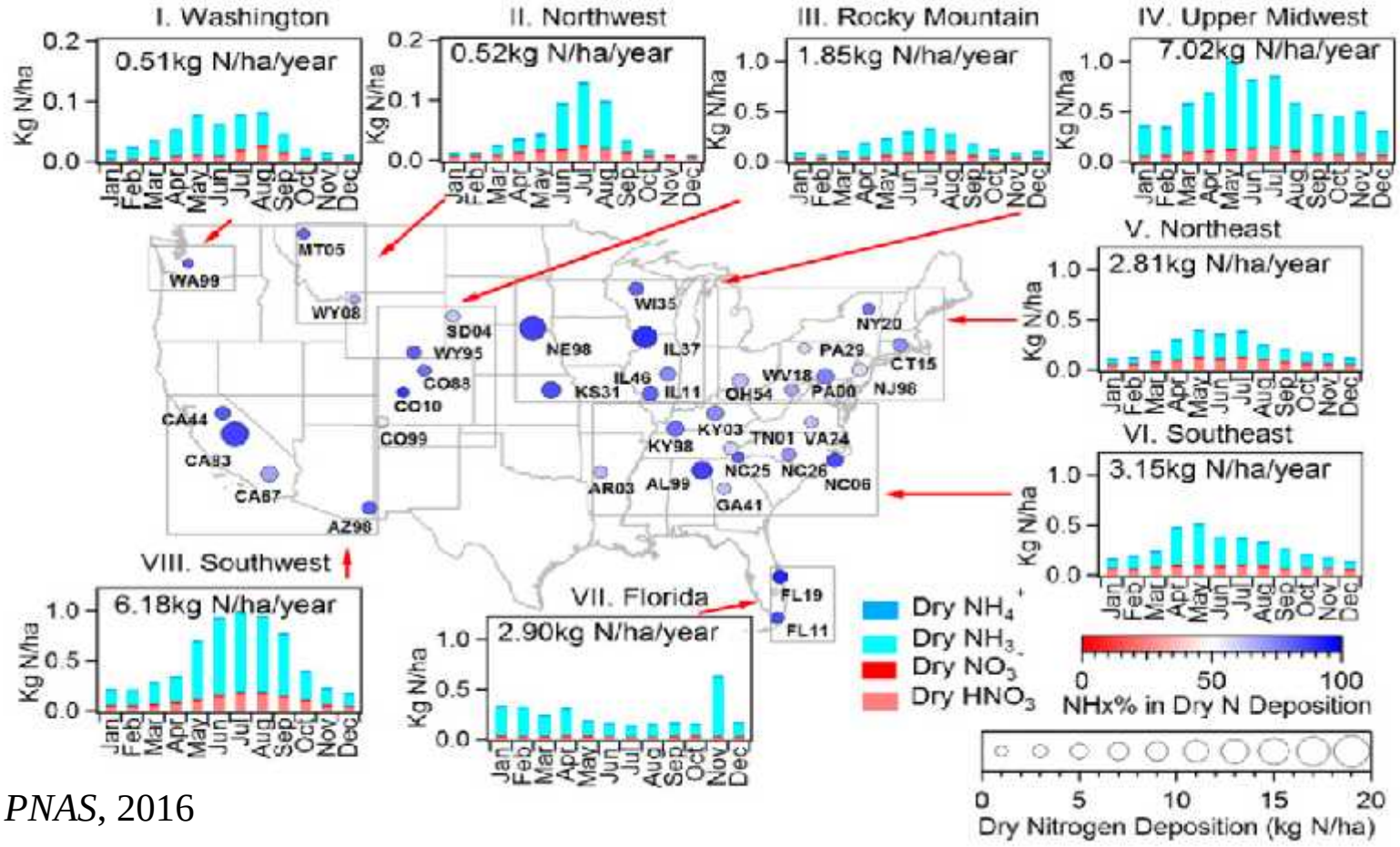
Summary

- 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