

# Linking ammonia emission reduction and air concentrations and depositions of reduced nitrogen in Europe

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## Outline

- Background of this (trends) study
- Results previous trends study
  - Data on emissions and concentrations/depositions
  - Conclusions drawn
- What happened since that study?
  - Did it bring new insights?

## Background of this trends study

- Builds on previous study by Sutton et al. (2000)
  - Background document for the UN/ECE Ammonia Expert Group (AEG)
- Reason for update of the 'old' study
  - Additional 5 years of information
  - New studies on emission/concentration/deposition relations
- Input to new background document to be presented at the December meeting of UN/ECE AEG

## Why is this study important?

- Emission/transport/deposition of reduced nitrogen ( $\text{NH}_x$ ;  $\text{NH}_3$  and  $\text{NH}_4^+$ ) will eventually lead to eutrophication and acidification of ecosystems and contribute to local air quality
- Recognizing this, together with the transboundary nature of the problem, the UN/ECE developed protocols on:
  - Limiting  $\text{NH}_3$  emissions
  - Reducing  $\text{SO}_2$ ,  $\text{NO}_x$  and VOC concentrations
  - Setting national emission ceilings to be reached in 2010 (Gothenburg Protocol, 1999)
- In parallel: European Union agreed on the 'National Emissions Ceilings Directive (NECD)', setting targets for e.g.  $\text{NH}_3$  emissions binding in European Law.

## Why is this important ? (II)

- Evidence needed for effective  $\text{NH}_3$  emission reduction:
  - Achievable
  - Measurable
- $\text{NH}_3$  emissions mainly from agricultural sources, thus:
  - Abating  $\text{NH}_3$  will be in agricultural sector
    - Reduction in animal numbers
    - Reducing fertilizer consumption
    - Implementing technical measures
- Since reducing sector activity was not an option, there is a need to demonstrate the effectiveness of technical measures

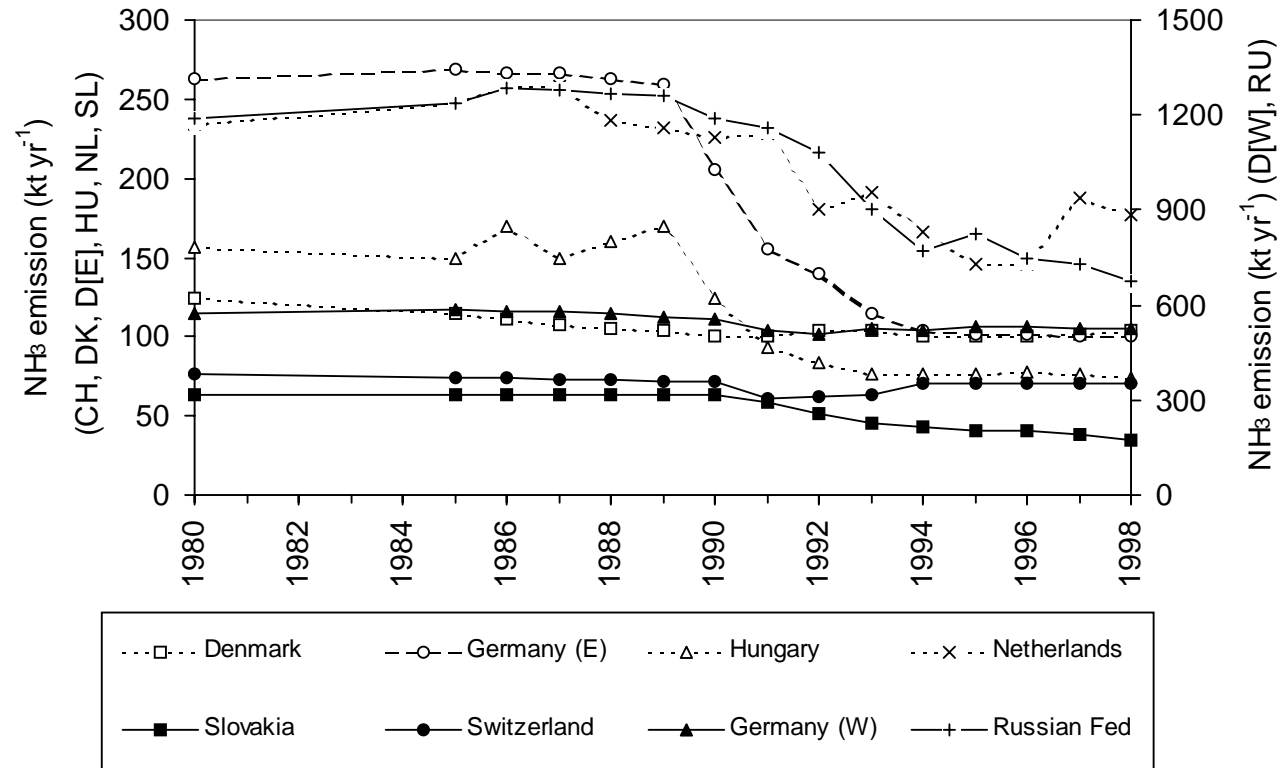
## Challenges

- Quantify the link between  $\text{NH}_3$  emission changes and monitored atmospheric  $\text{NH}_x$  in situations where emissions have definitely changed
  - Note: not only  $\text{NH}_x$  issue. Many questions regarding linearity between  $\text{SO}_2$  and  $\text{NO}_x$  emissions and  $\text{NH}_x$  concentrations
- Assess the effectiveness of  $\text{NH}_3$  emission abatement policies

## What has been done?

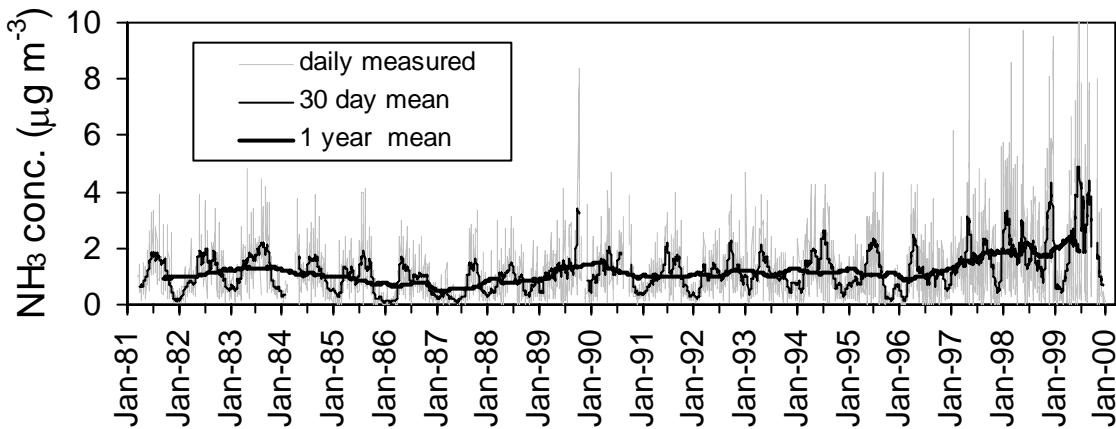
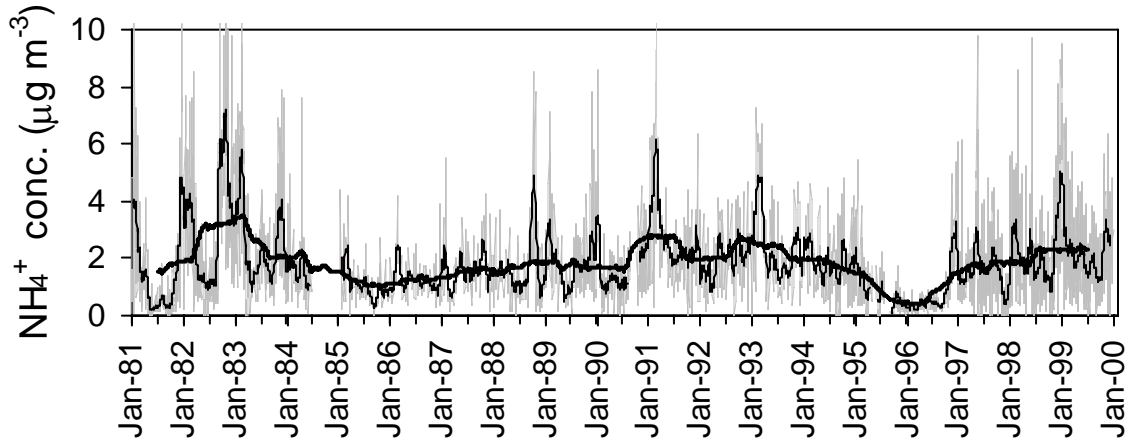
- 2000 trends study brought together information about the link between  $\text{NH}_3$  emission and measurements (concentration and deposition) from different case studies:
  - link between agr. sector activity and atm.  $\text{NH}_x$ 
    - Hungary, Slovakia, Former East & West Germany, Russia, Switzerland & North Carolina
  - link between  $\text{NH}_3$  emission abatement and atm.  $\text{NH}_x$ 
    - Netherlands
    - Denmark

# Emissions: are they true?

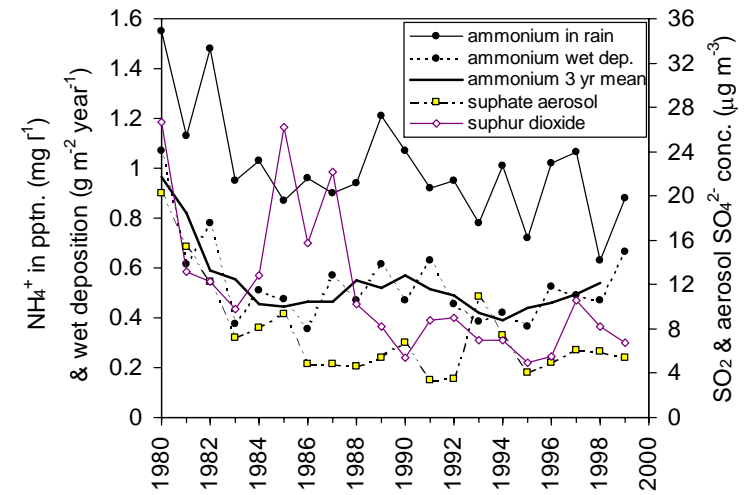




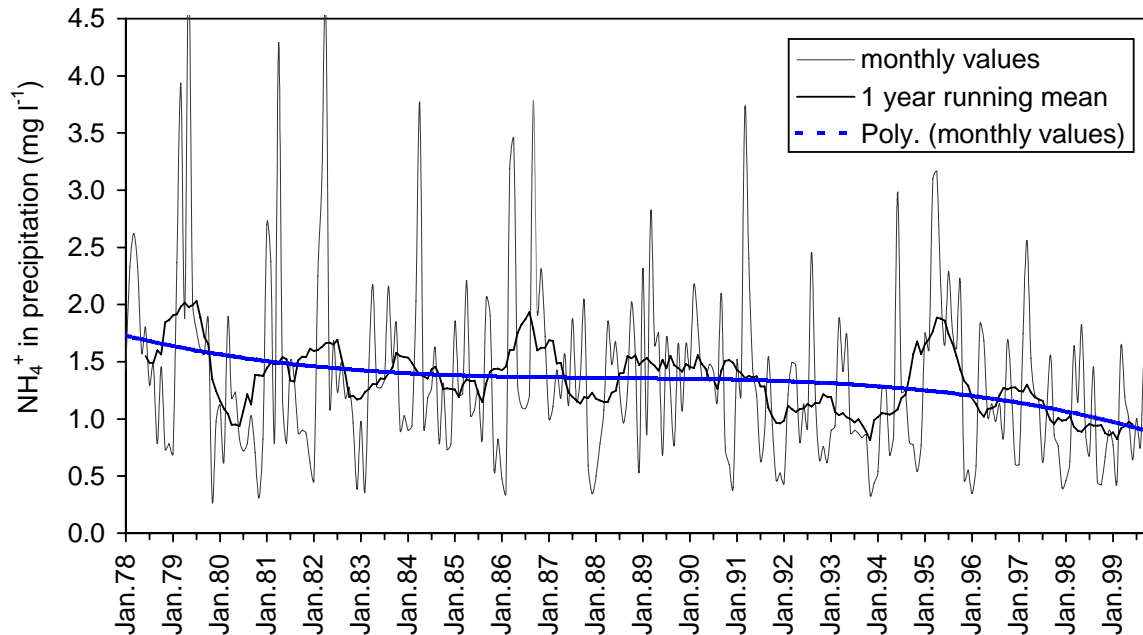
# Hungary



- 53% emission reduction
- no clear trend in either  $\text{NH}_4$  or  $\text{NH}_3$

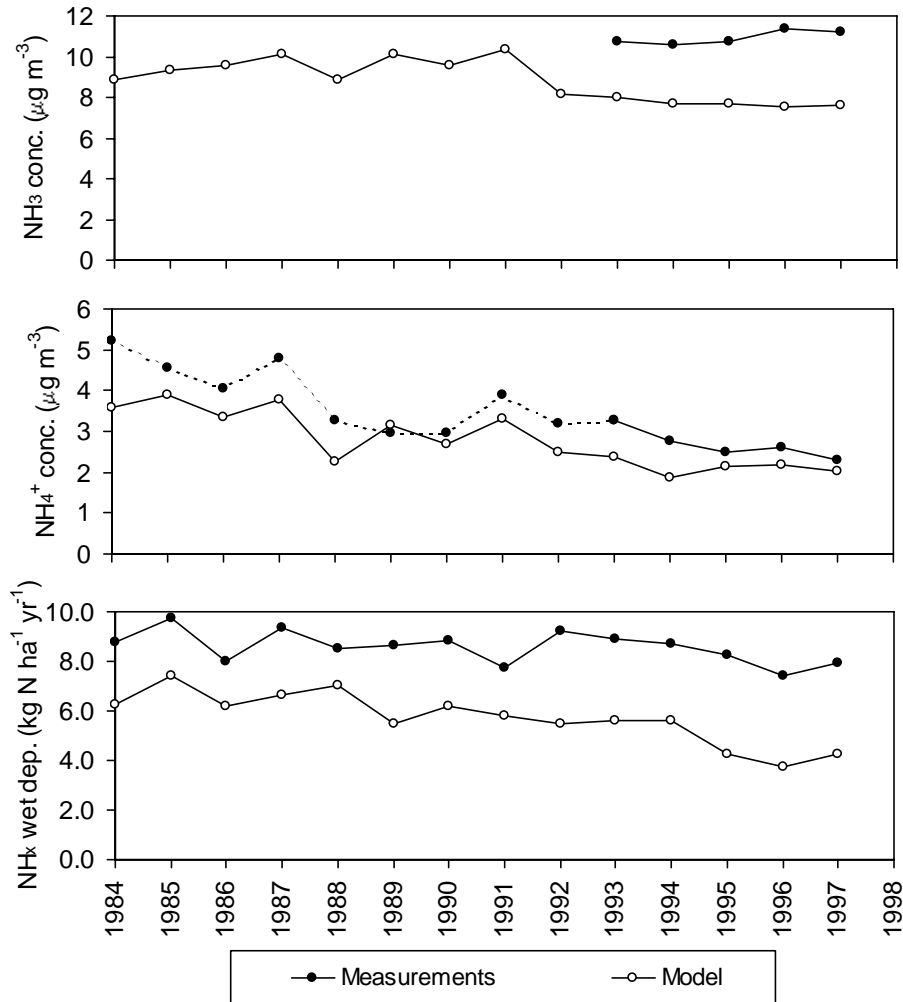


# Slovakia



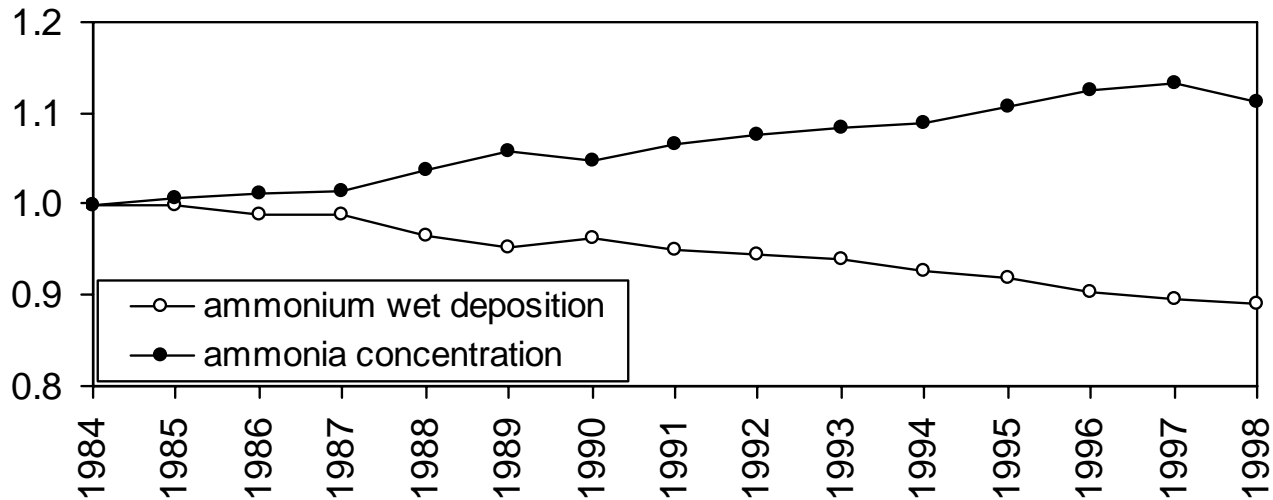
- 44% emission reduction
- ~20% reduction of  $\text{NH}_4$  between 1990-1999

# Netherlands



- 35% emission reduction
- 10% reduction NH<sub>4</sub> wd
- 29% reduction NH<sub>4</sub> aerosol
- Again: part of the explanation - parallel changes in SO<sub>2</sub> and NO<sub>x</sub> emission
- But also: overestimation of effectiveness of measures

## Netherlands – effect of changing SO<sub>2</sub> and NO<sub>x</sub>



- 1984 SO<sub>2</sub> and NO<sub>x</sub> emissions and actual emissions
- increase in NH<sub>3</sub> conc. and decrease in NH<sub>4</sub> wd

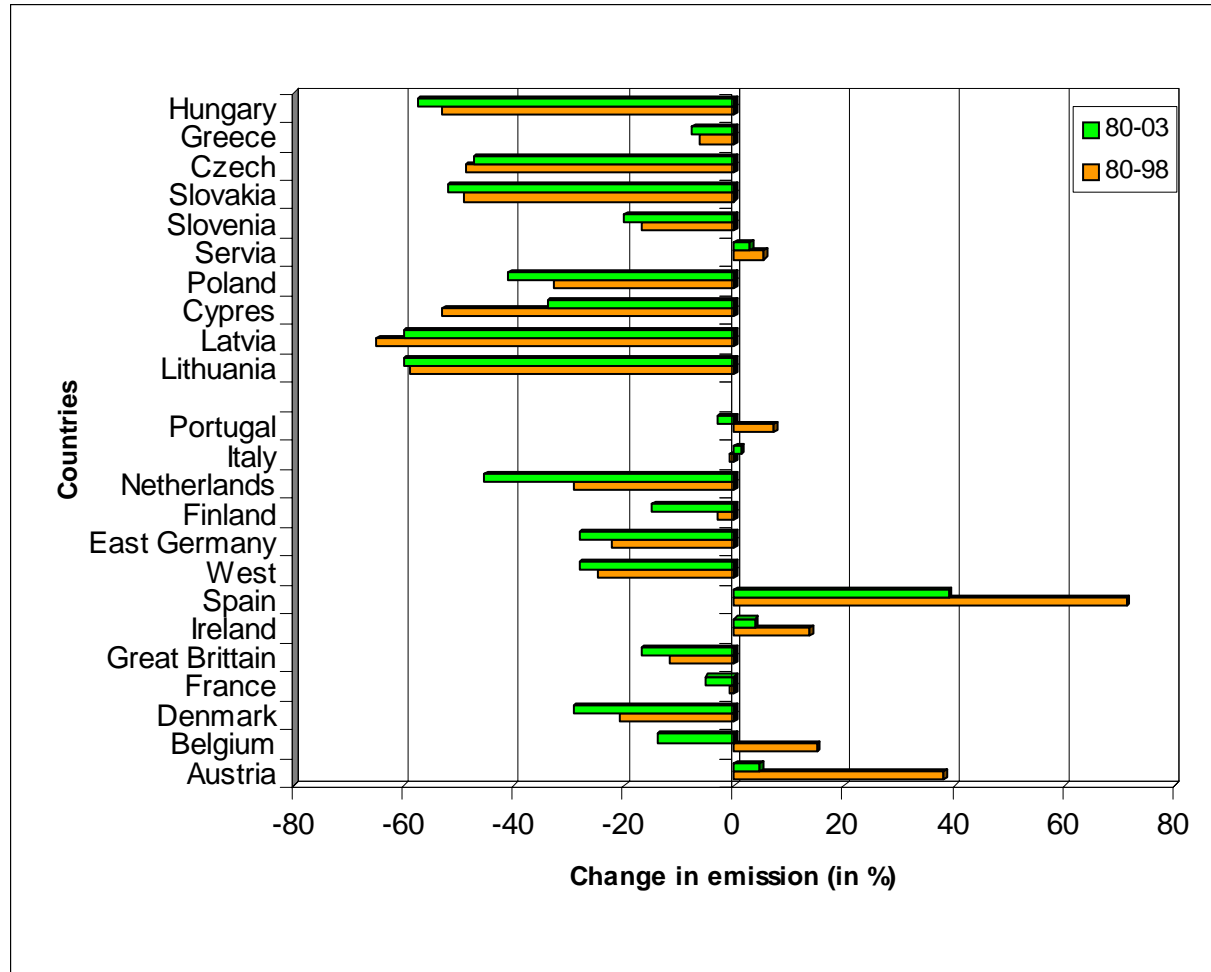
## Overall conclusions

- many difficulties involved in evaluating changes in  $\text{NH}_3$  emissions by using monitoring networks
  - need for long time series
  - interaction with other components ( $\text{SO}_2$  &  $\text{NO}_x$ )
  - models used not always 'complete'
- caution when measured values do not follow expectations:
  - limitations in the models
  - limitations in the monitoring
  - ineffectiveness of the abatement techniques

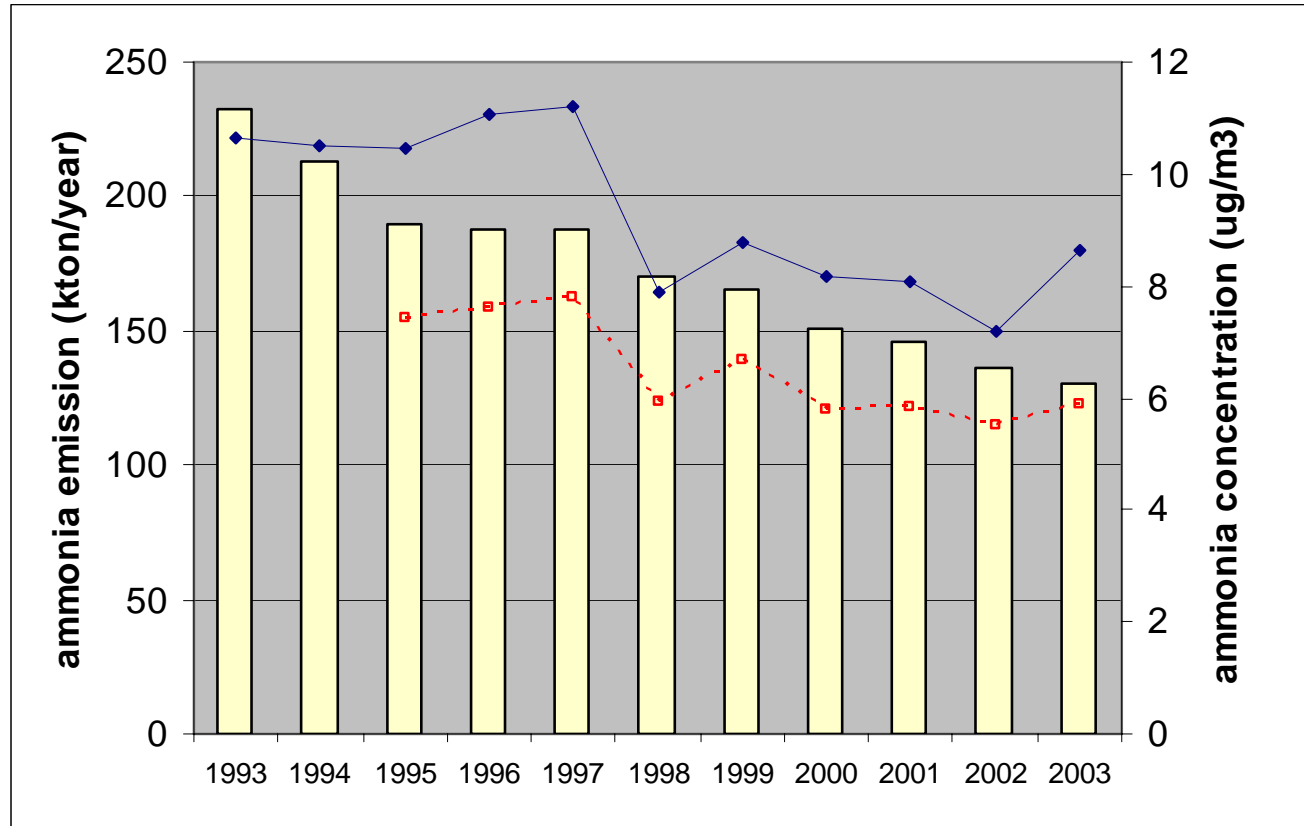
## What happened since?

- Ongoing discussion on trends (in relation with meeting the NECD targets)
  - Additional measuring programmes
  - Evaluating/updating models
    - Emissions
    - Transport/deposition
- Updated information; 5 additional years
  - Emissions
  - Concentrations/depositions
- New studies
  - United Kingdom
  - Netherlands
  - EMEP

# Updated EMEP emissions for Europe

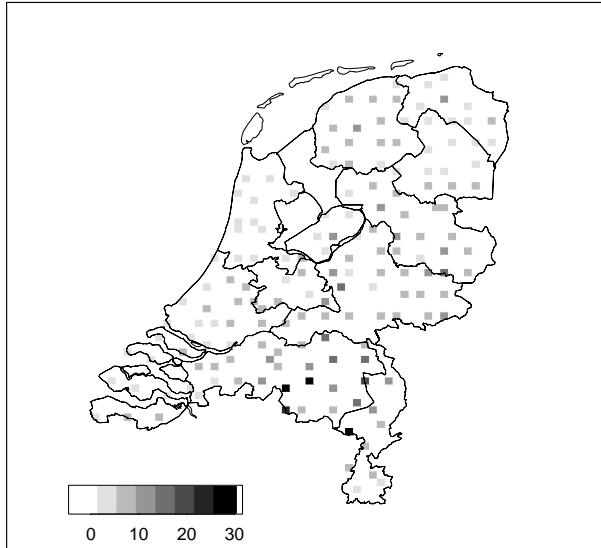


# The Netherlands



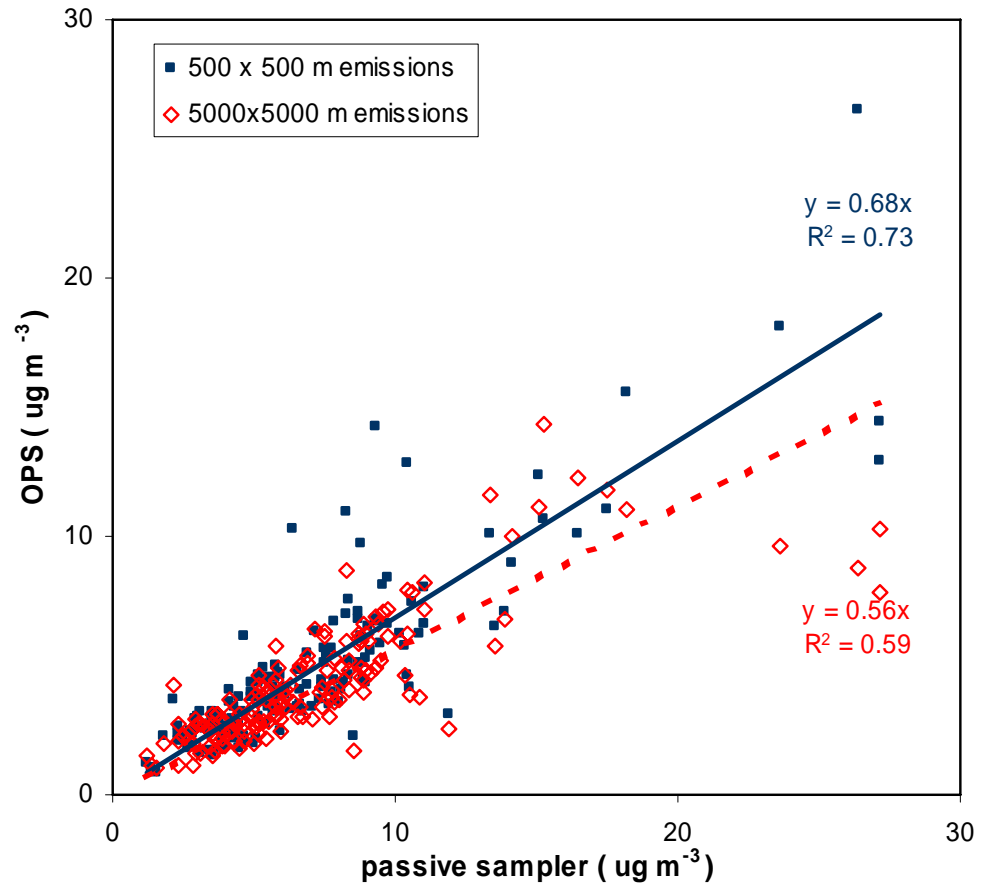


# The Netherlands (II)



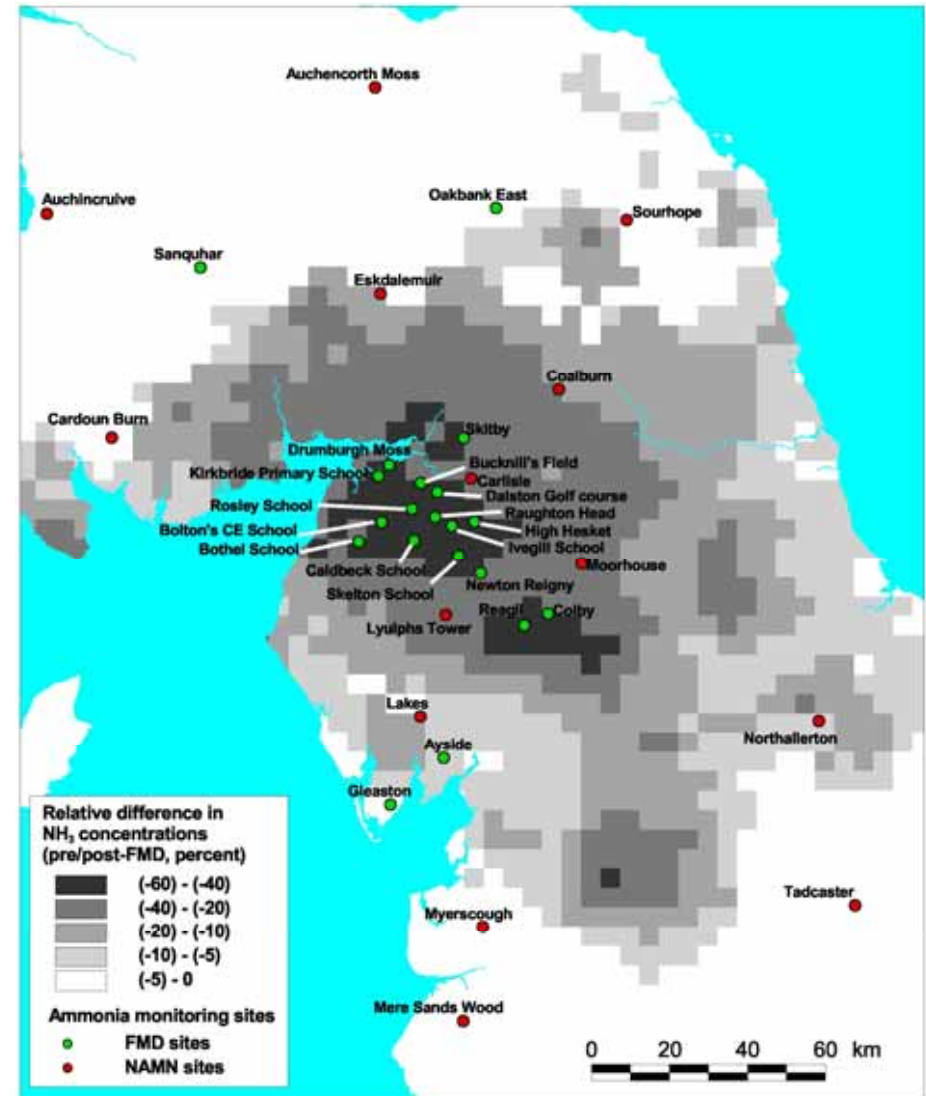
30 % difference

- Emission uncertainties
- Dry deposition parameterization

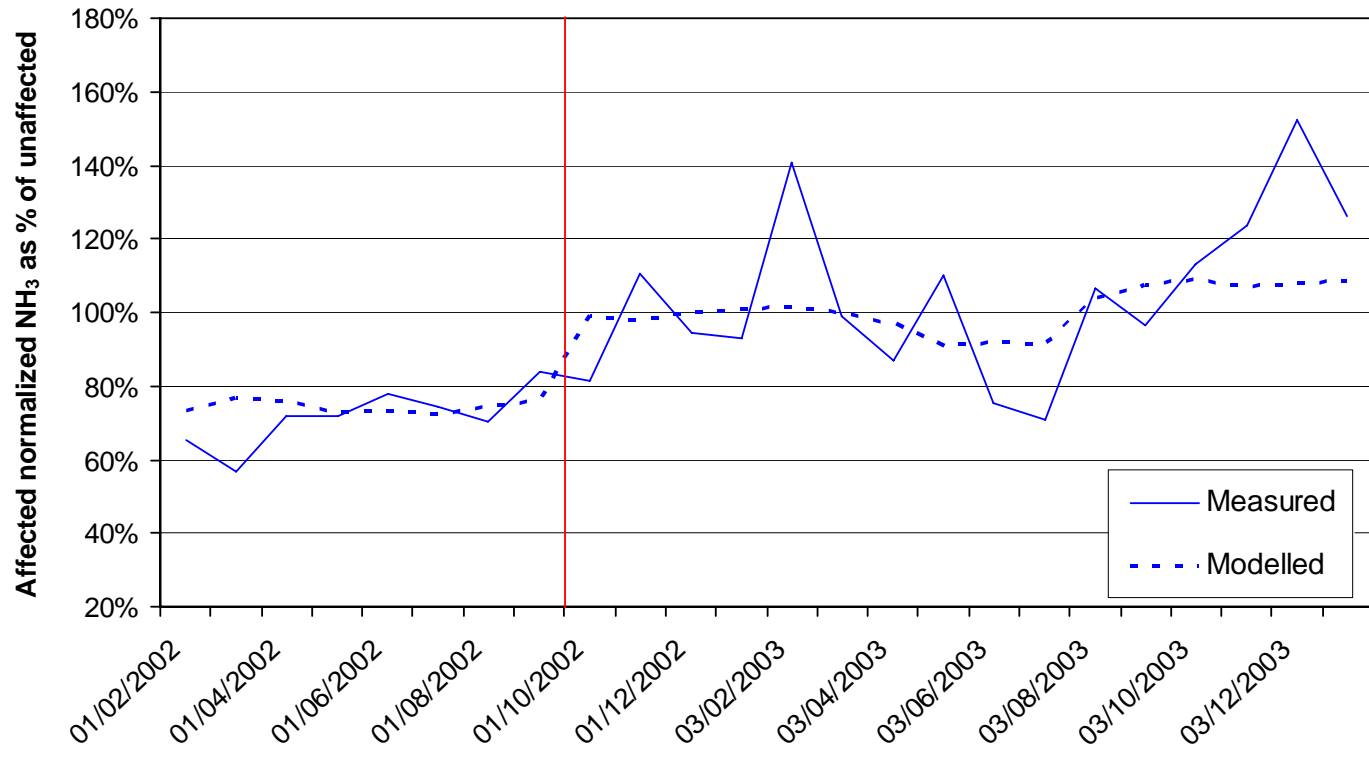
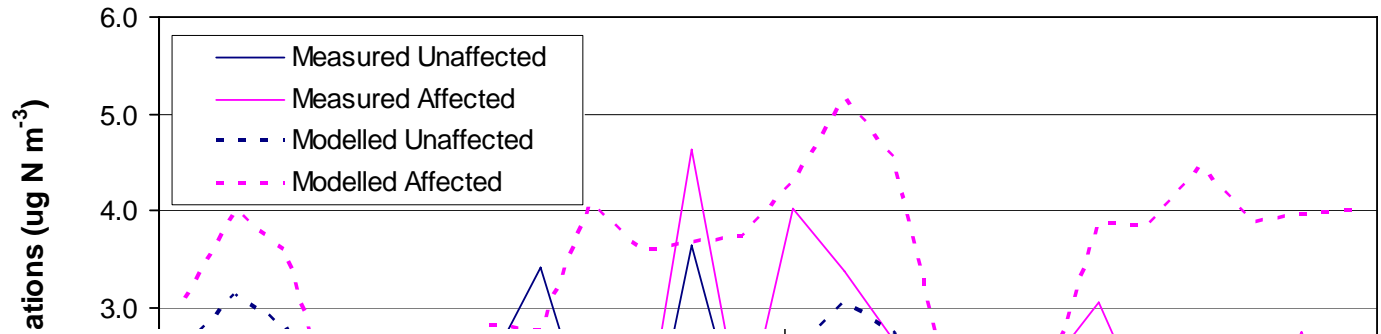


# United Kingdom

- Question to be answered:
  - Can we detect  $\text{NH}_3$  emission changes after the outbreak of foot & mouth disease?
- Study motivated by Dutch & E. European experience of difficulty to see trends following emission reductions

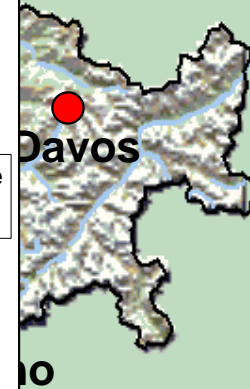


# UK (II)

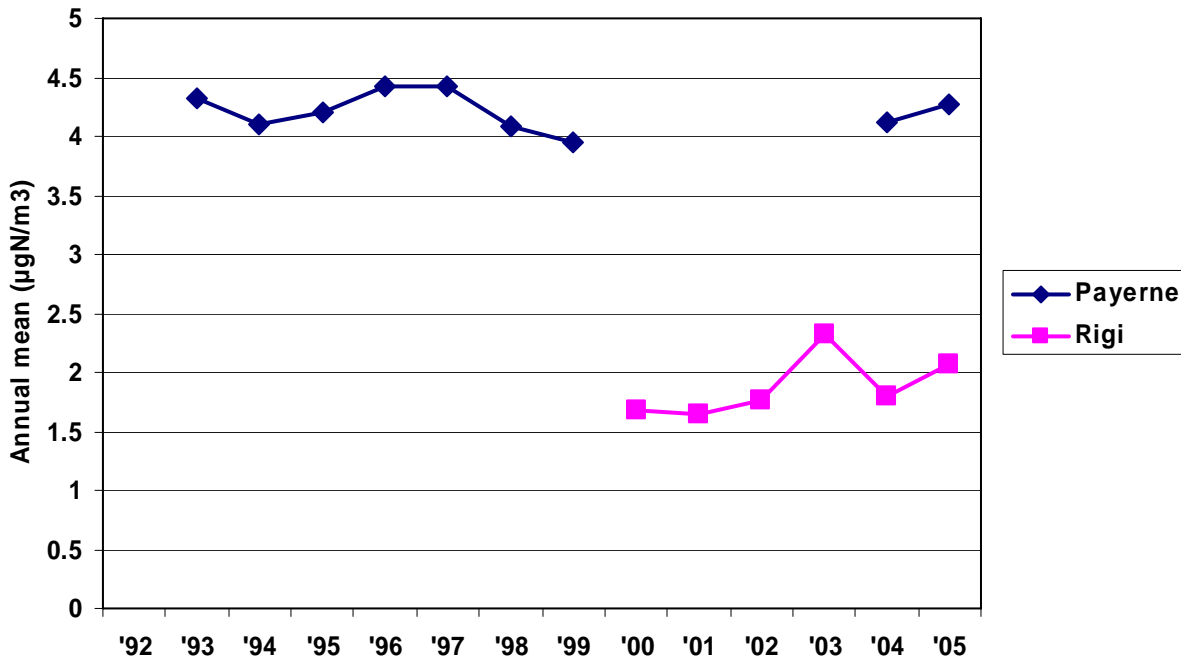


- Trend was detected:
  - Only by comparing affected and unaffected sites simultaneously

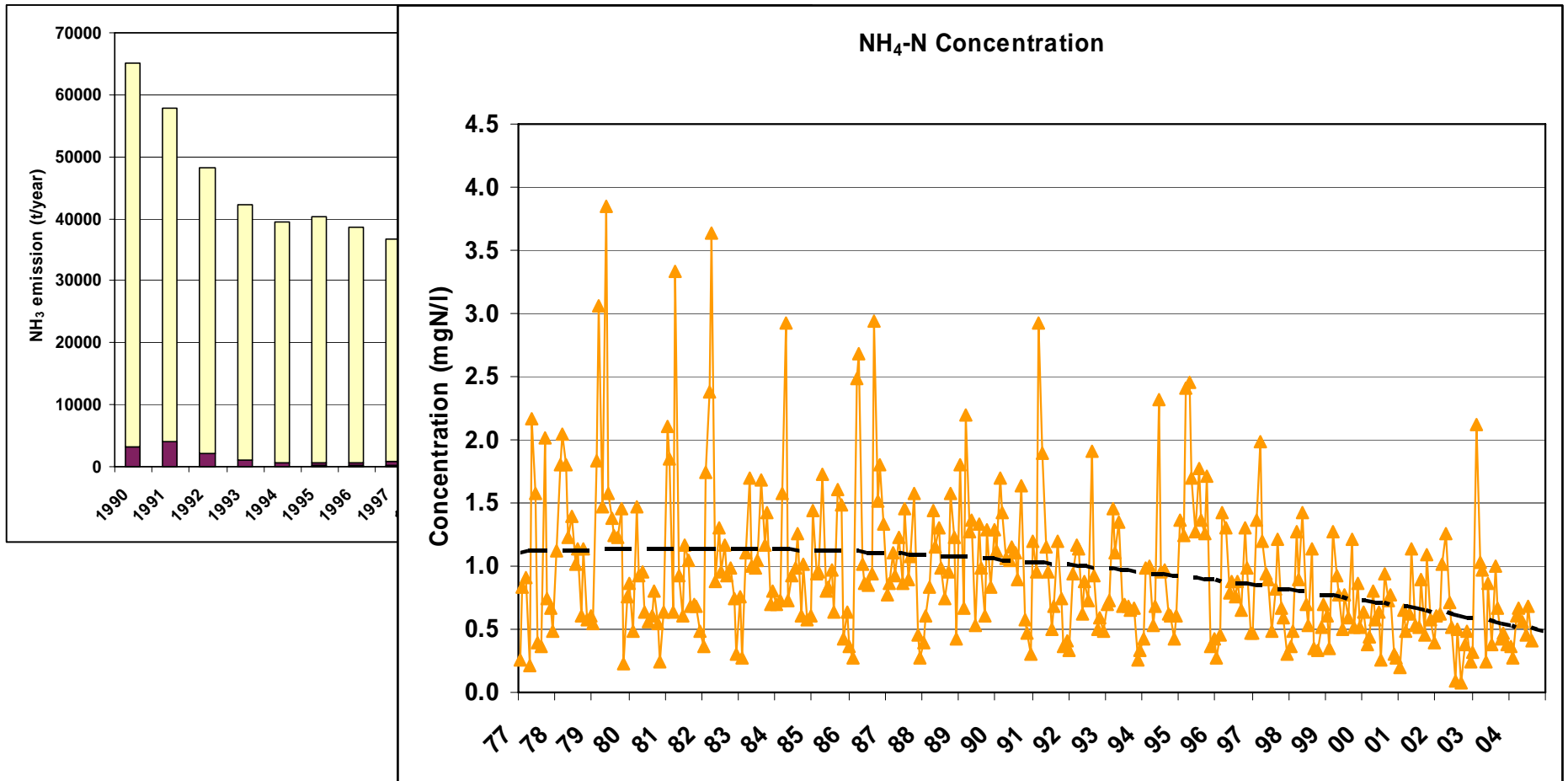
# Switzerland



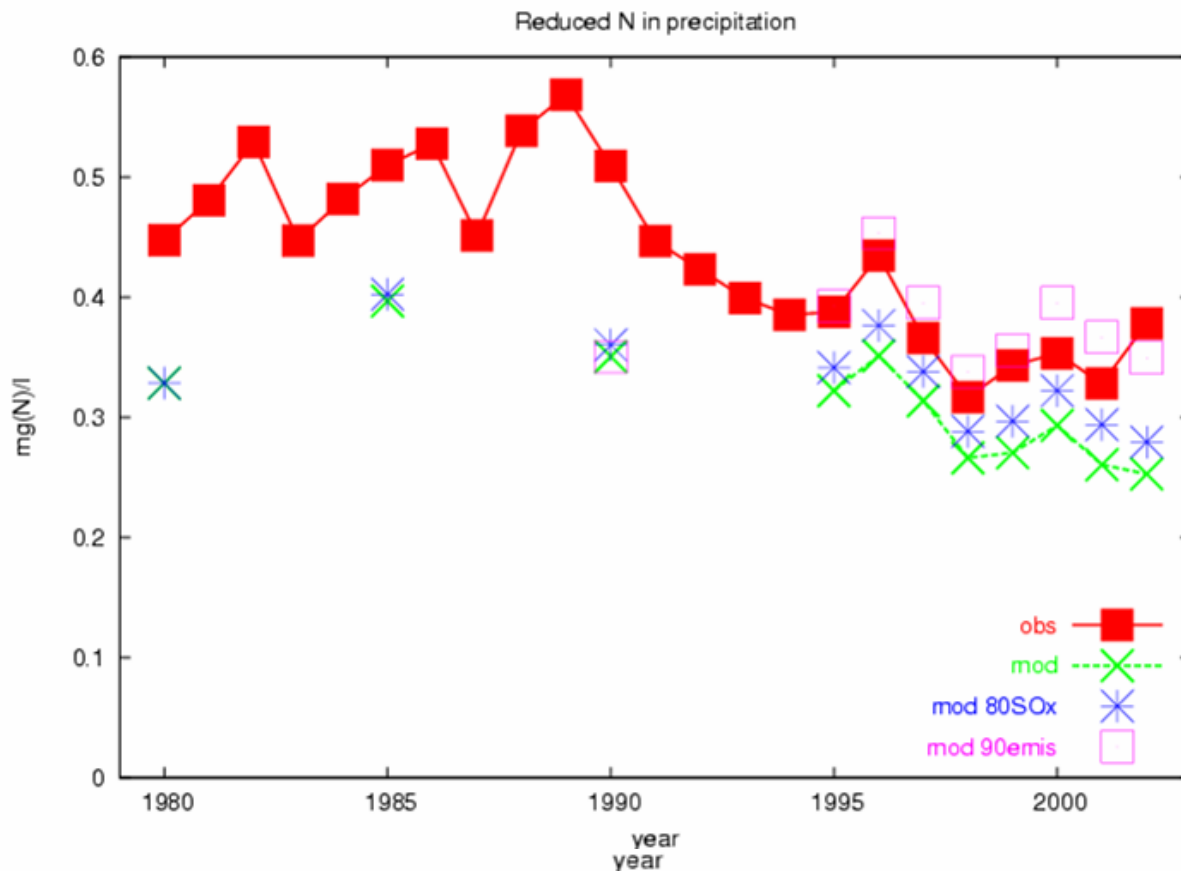
NH<sub>4</sub>+NH<sub>3</sub> Concentrations



# Slovak Republic



# EMEP - Europe

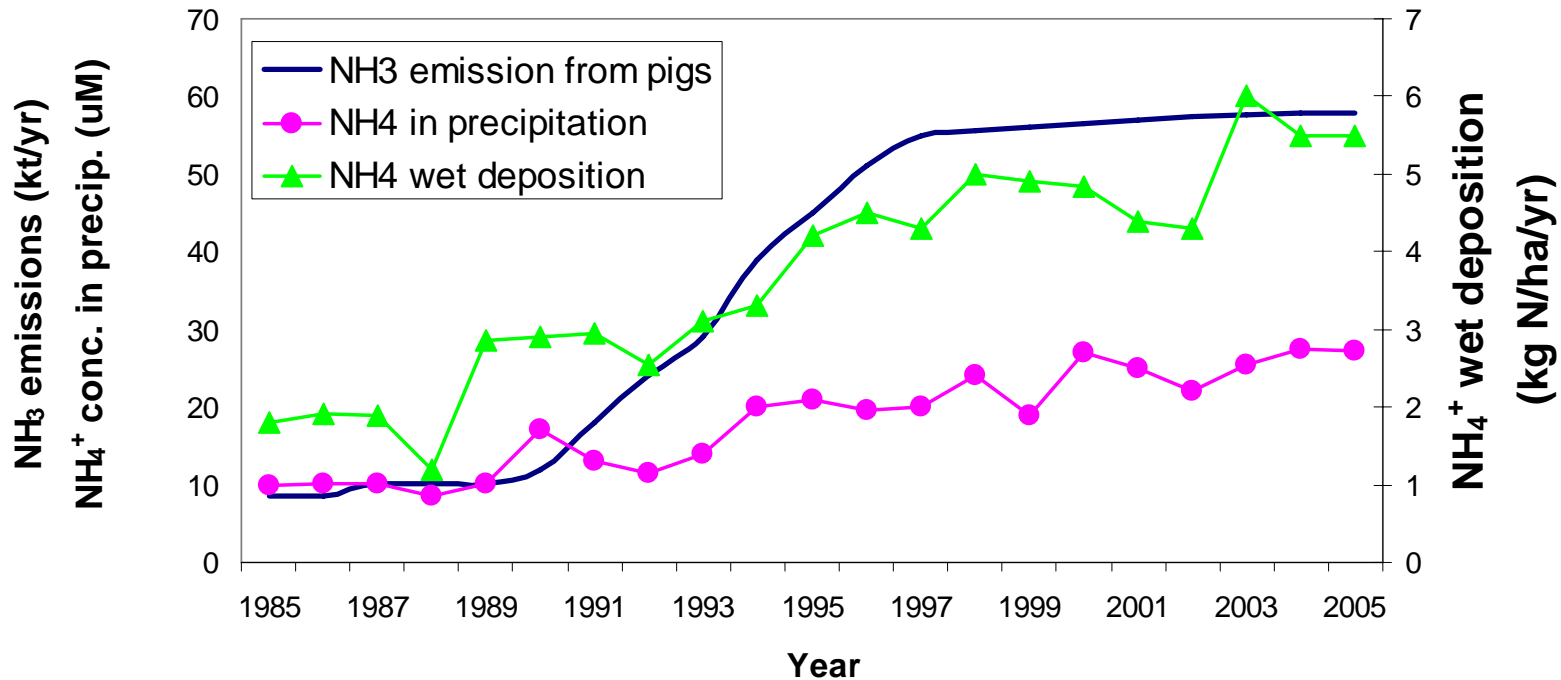


$\text{NH}_3 + \text{NH}_4^+$  decrease more as a consequence of  $\text{SO}_x$  reductions

Less effect on conc. in precip:  
less scavenging of  $\text{NH}_4^+$   
compensated by more of  $\text{NH}_3$

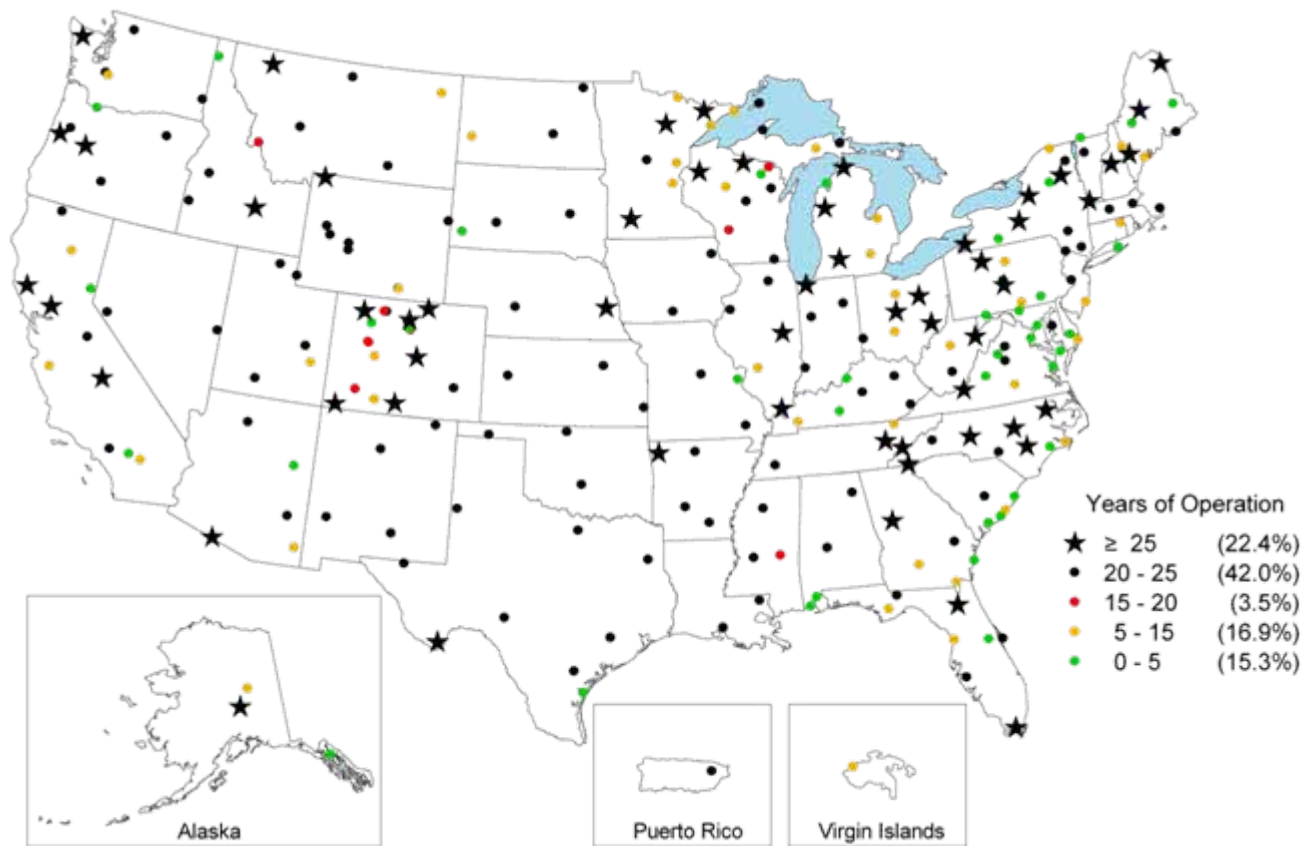
Tendency for air concentrations to decrease more than wet depositions— model predicts this to be caused by the  $\text{SO}_2$  emission reductions

# USA – North Carolina

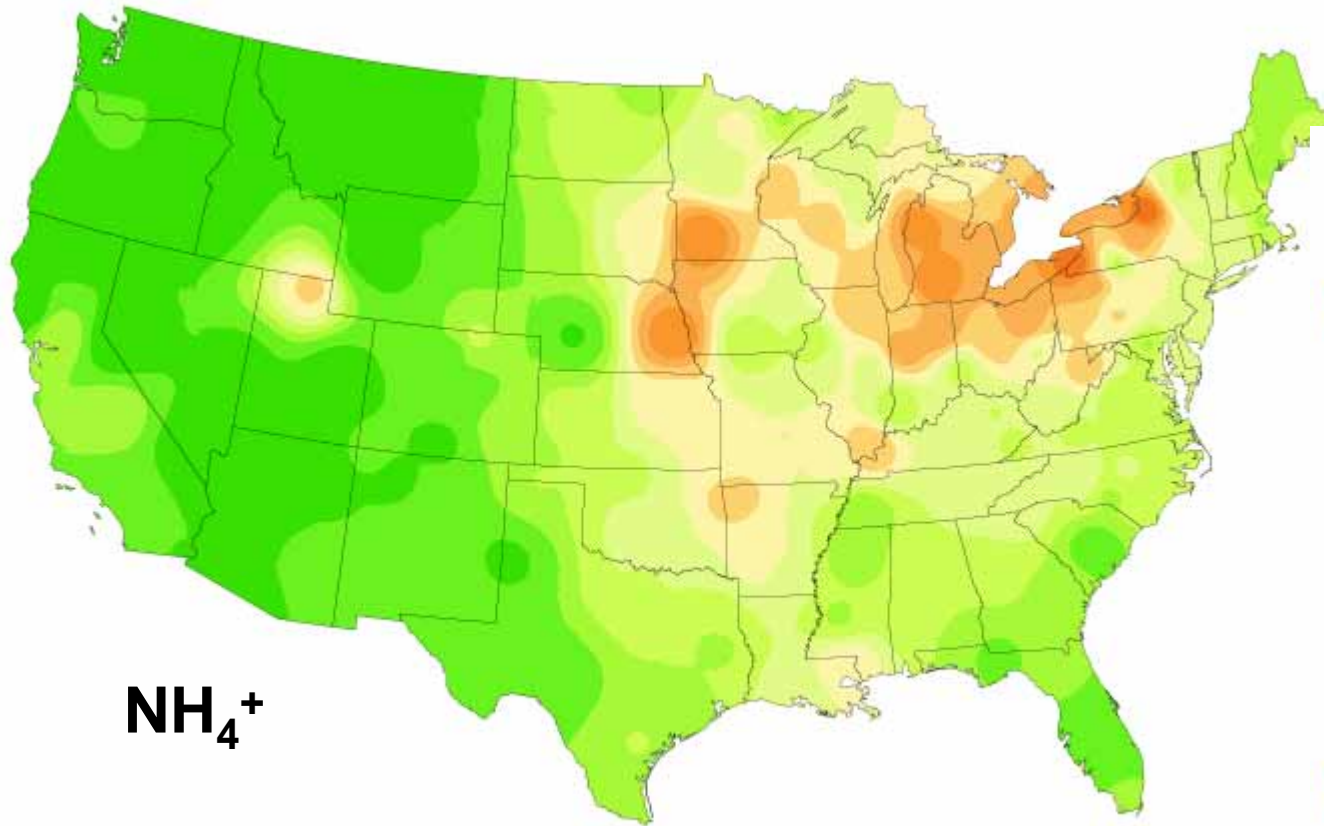


Comparison of NH<sub>3</sub> emissions in the coastal plain region of North Carolina, USA, against NH<sub>4</sub><sup>+</sup> precipitation concentrations and wet deposition at the NADP monitoring site NC35 in Sampson County (Aneja et al., 2006)

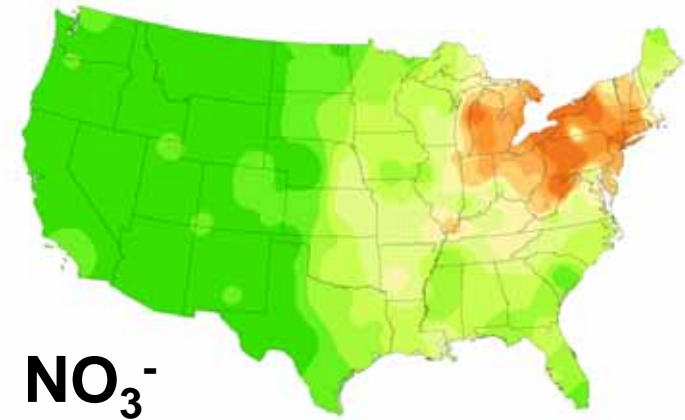
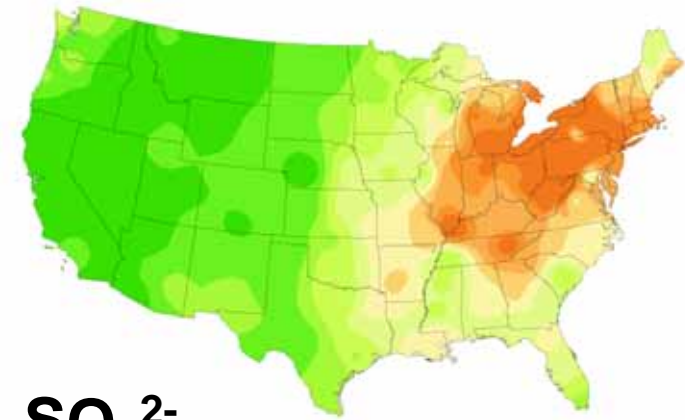
# USA – National Trends Network (NTN)

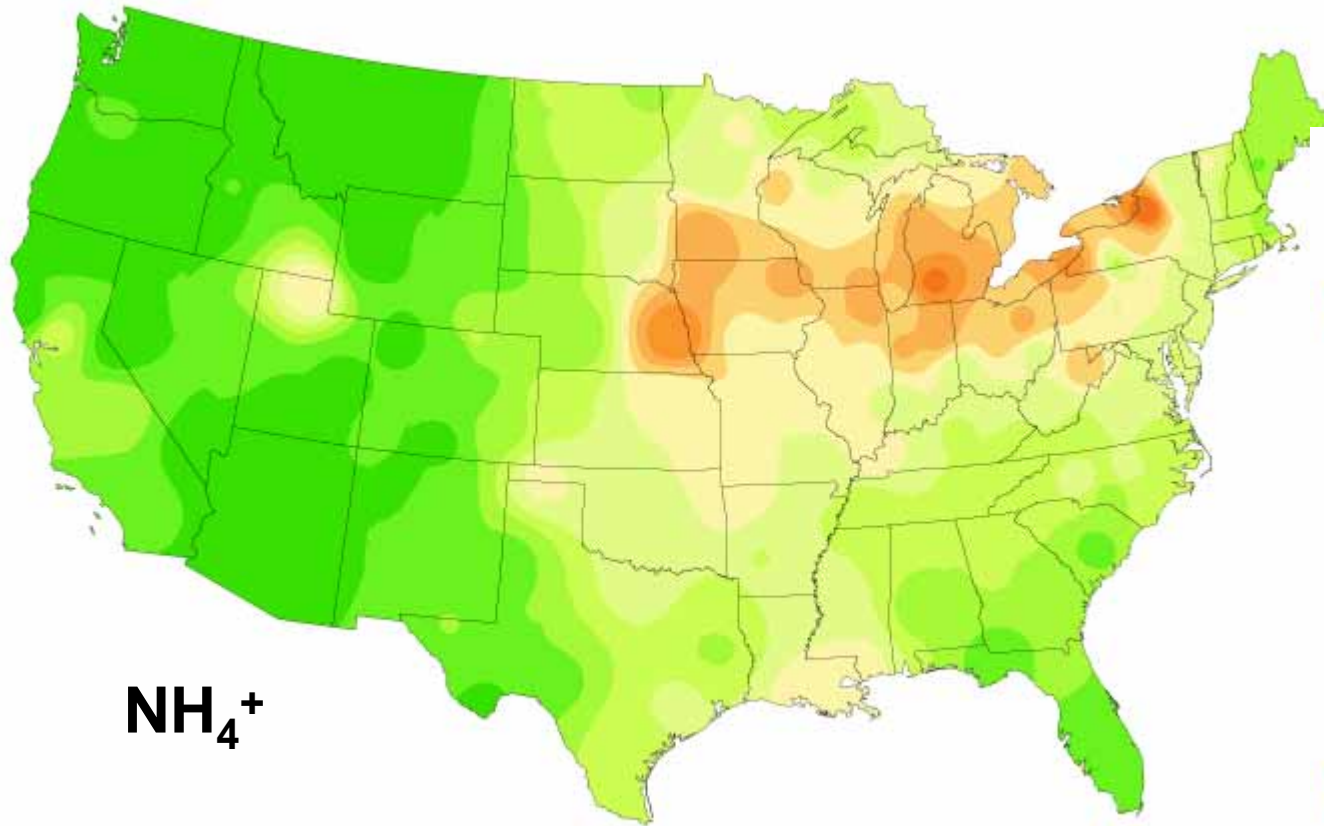






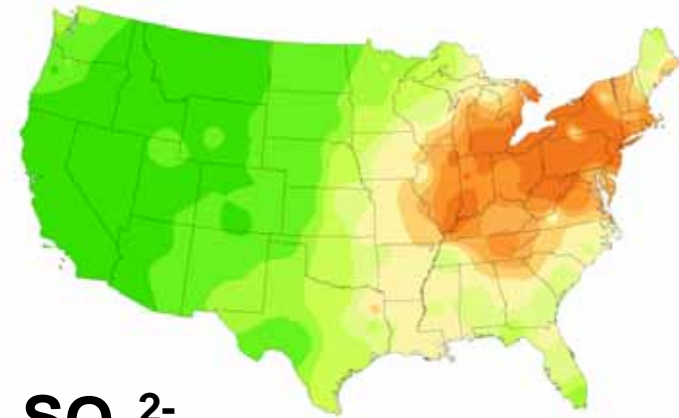
1984 **1985** 1986



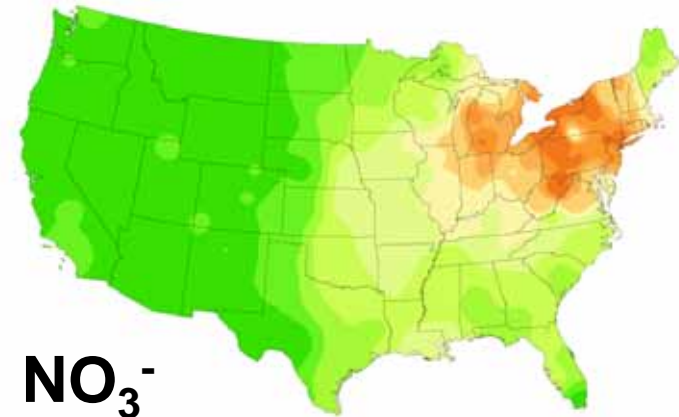


$\text{NH}_4^+$

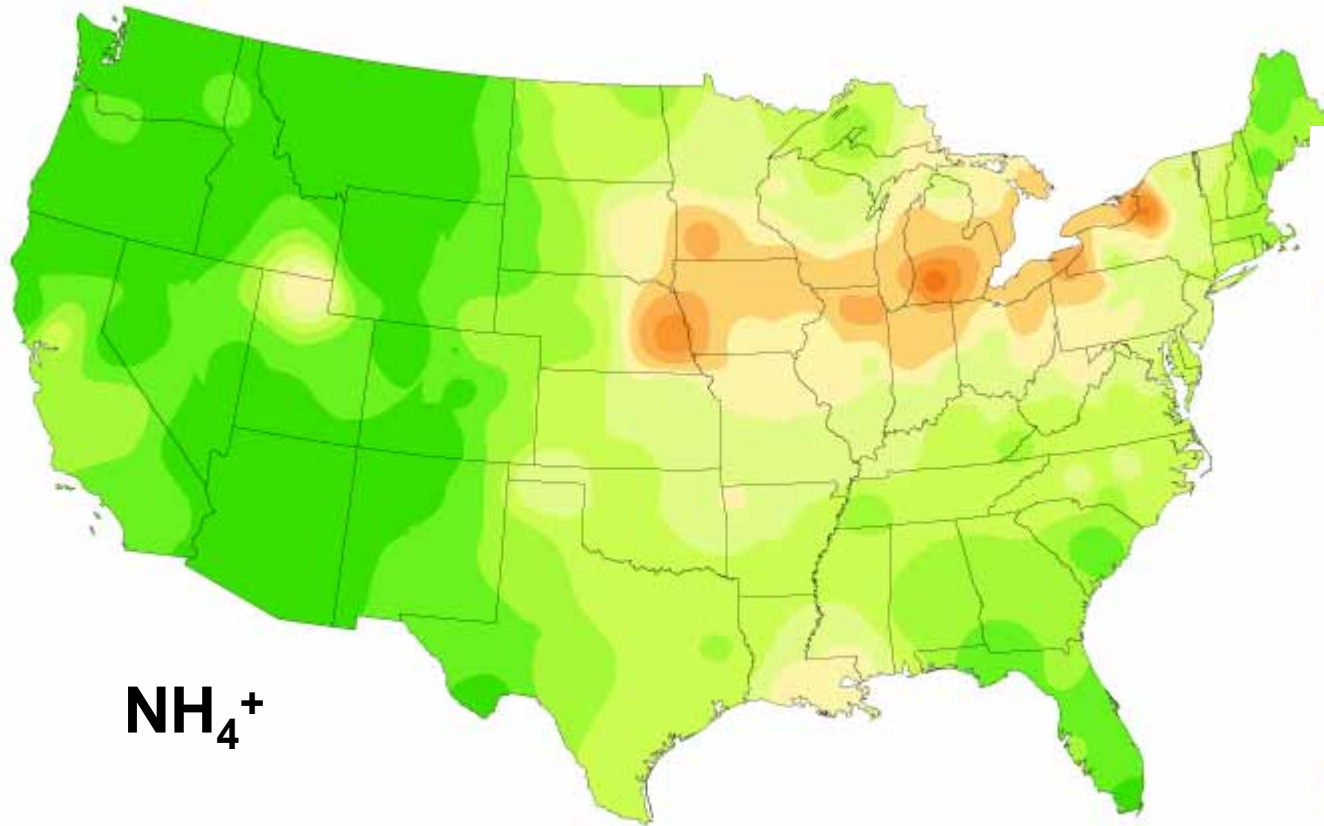
1985 **1986** 1987



$\text{SO}_4^{2-}$

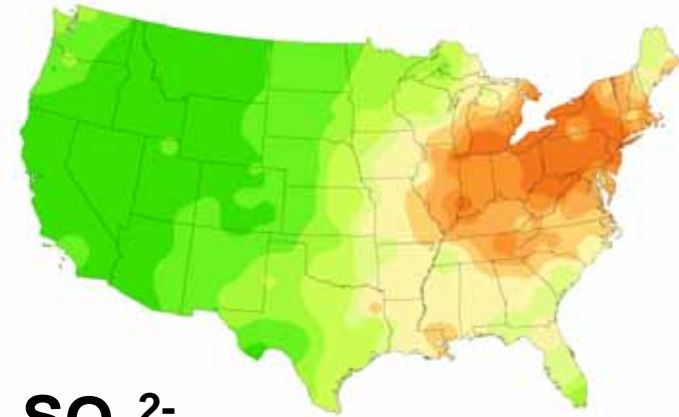


$\text{NO}_3^-$

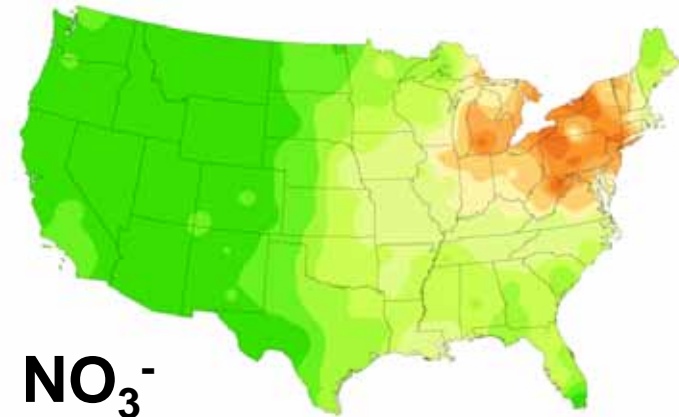


$\text{NH}_4^+$

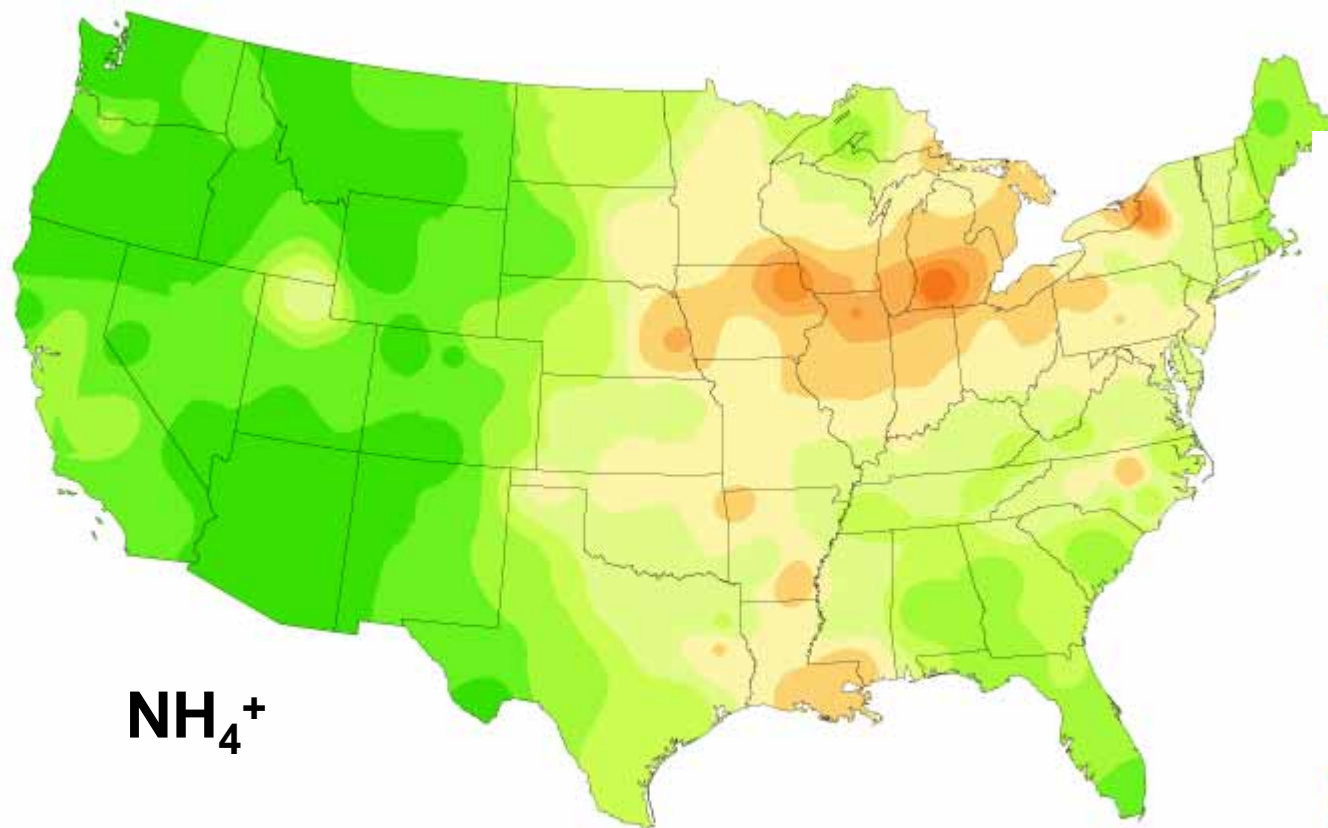
1986 **1987** 1988



$\text{SO}_4^{2-}$

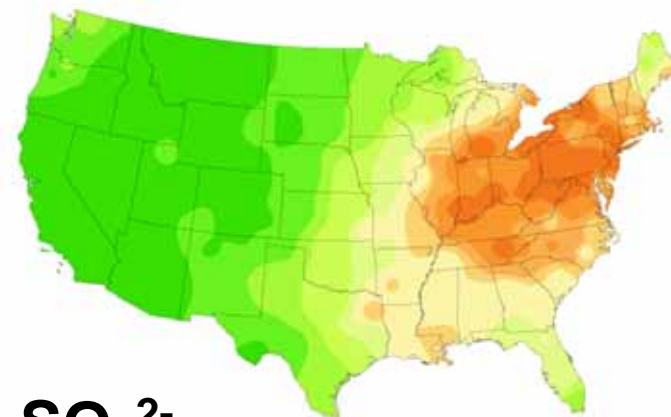


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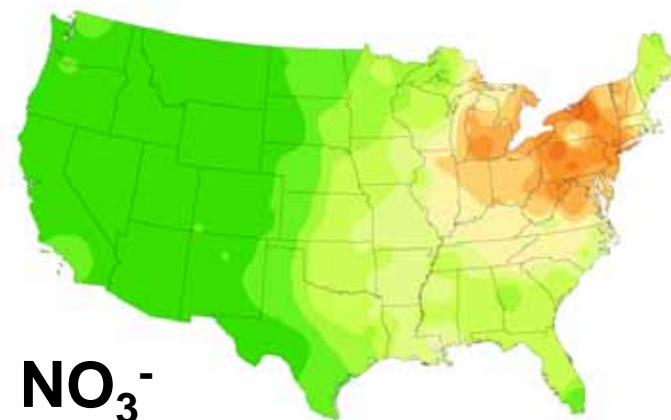


$\text{NH}_4^+$

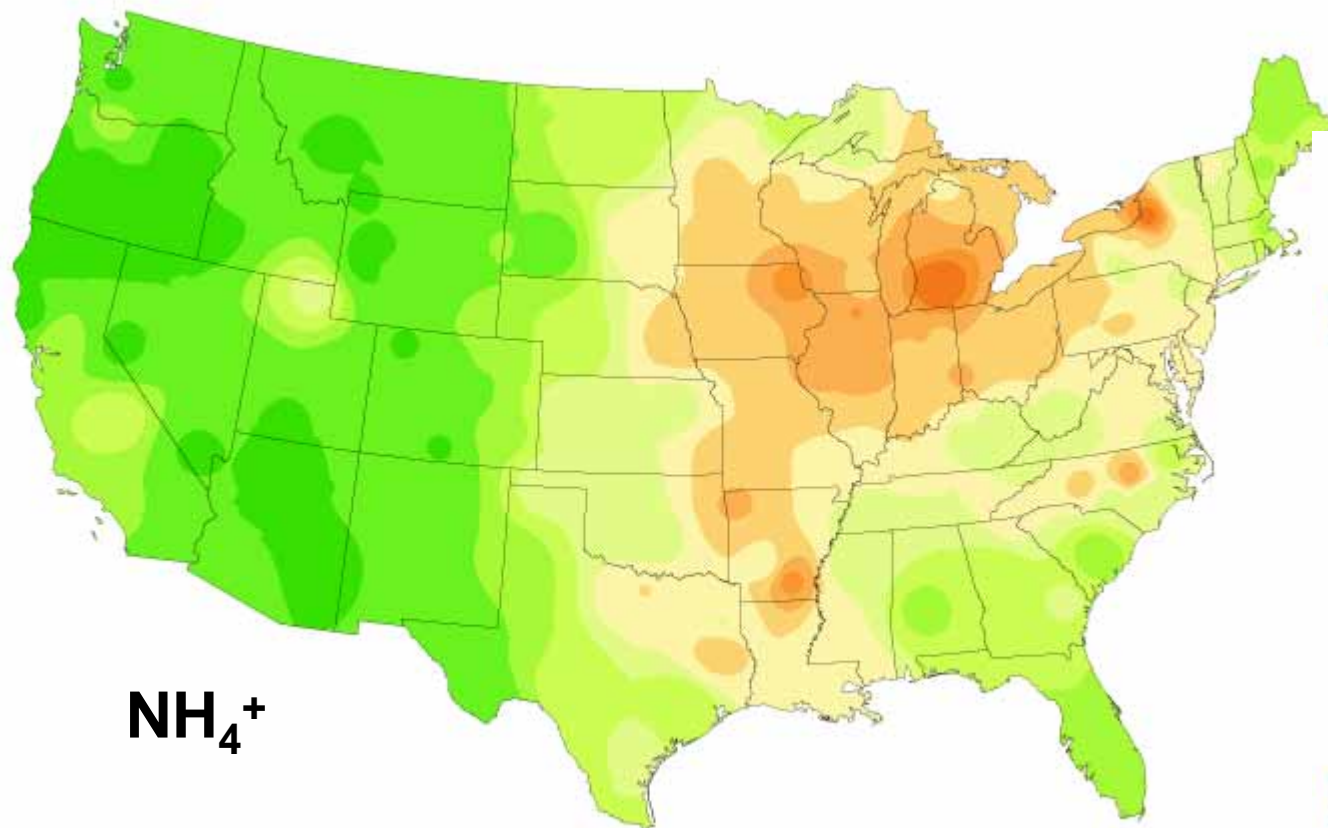
1987 **1988** 1989



$\text{SO}_4^{2-}$

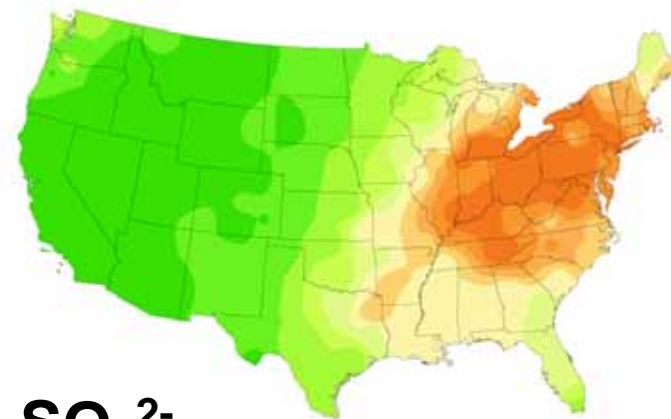


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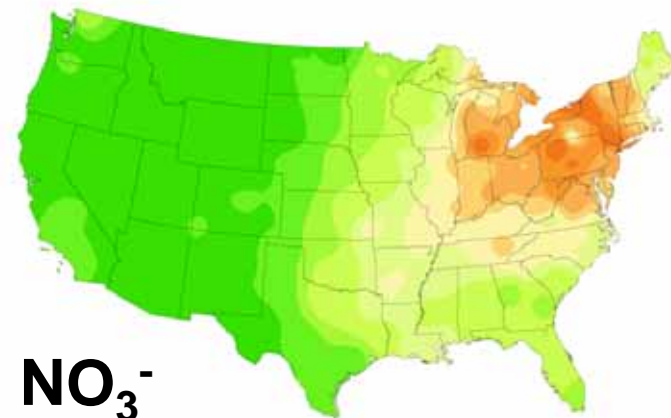


$\text{NH}_4^+$

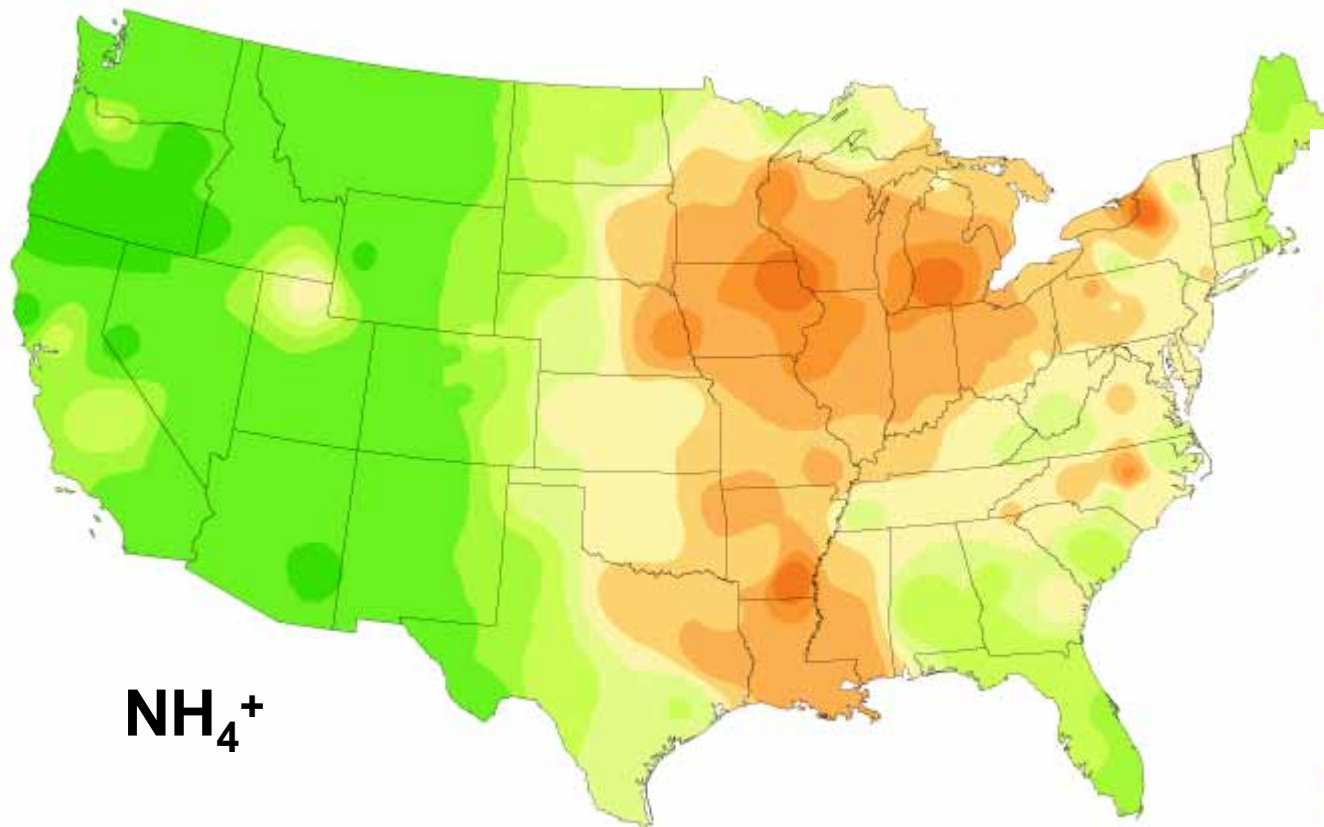
1988 **1989** 1990



$\text{SO}_4^{2-}$

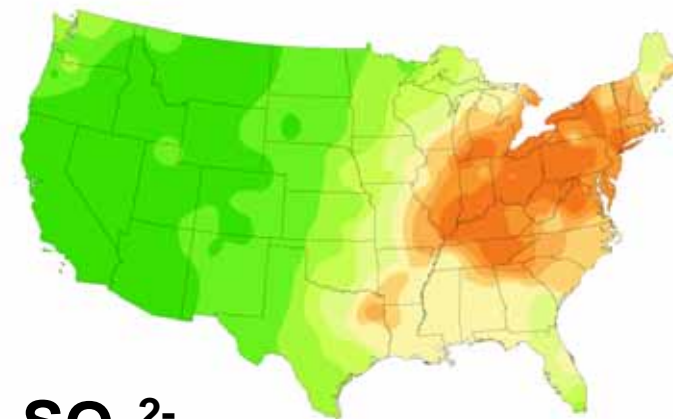


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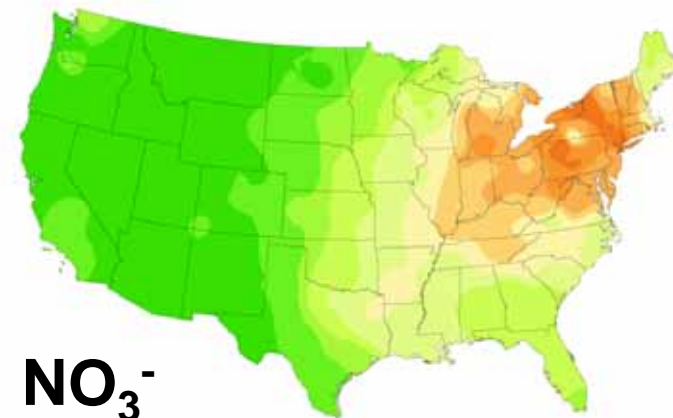


$\text{NH}_4^+$

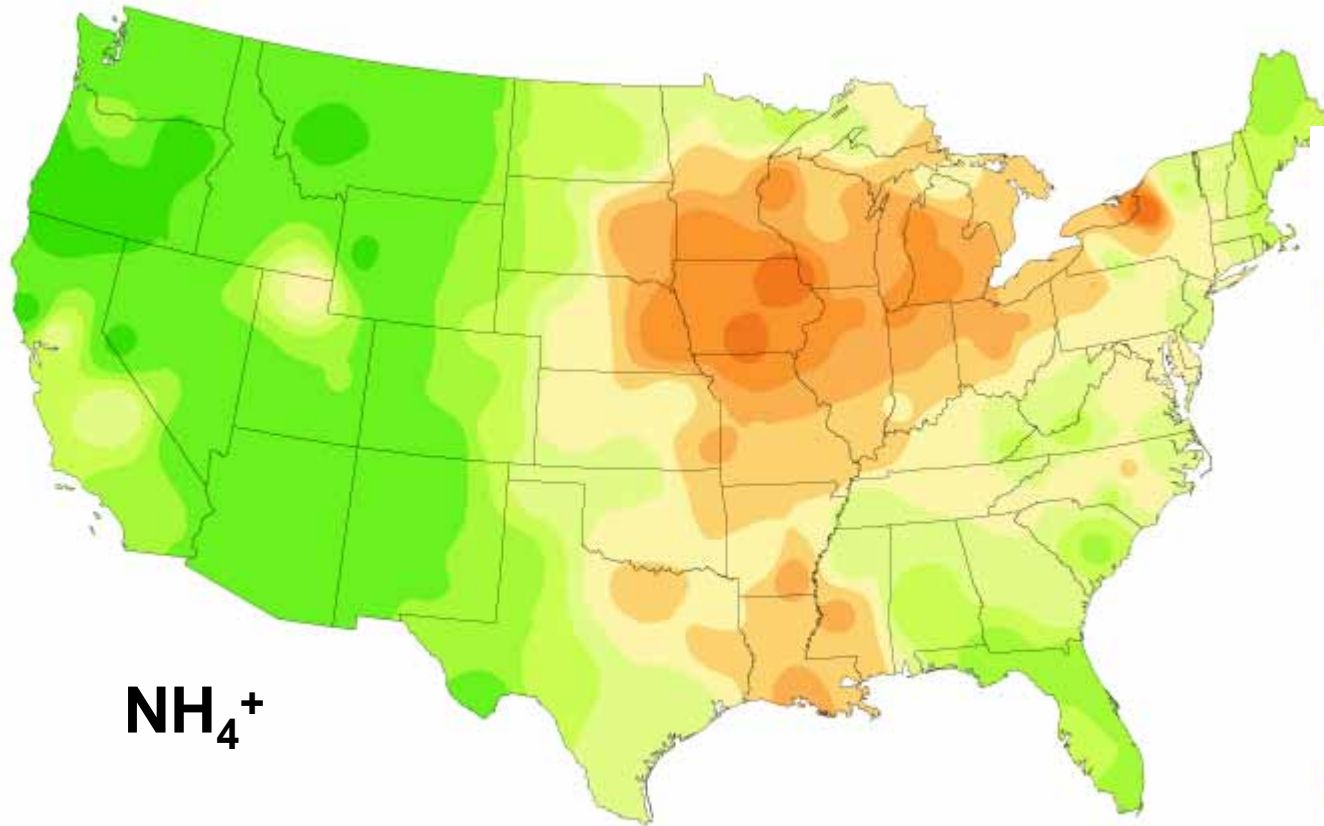
1989 **1990** 1991



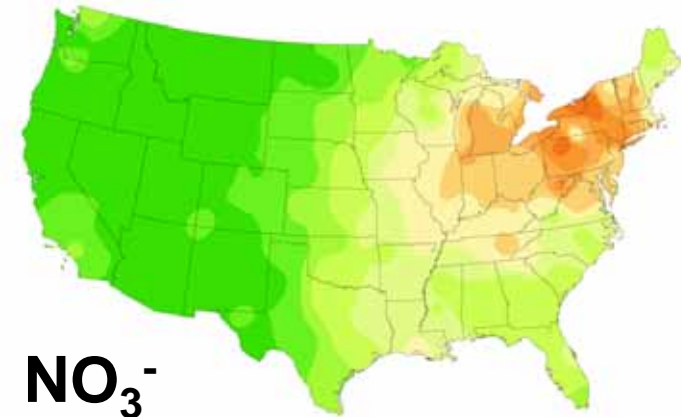
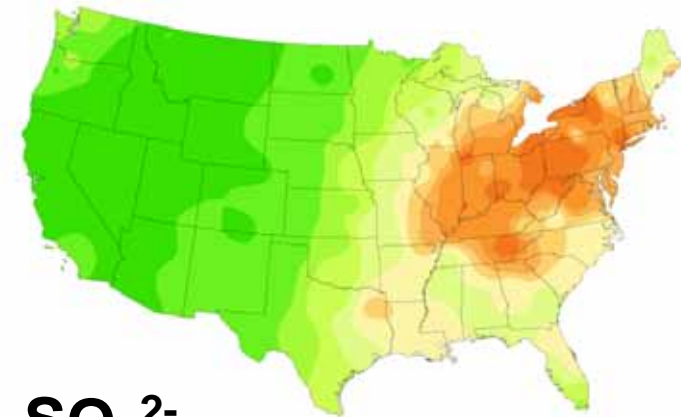
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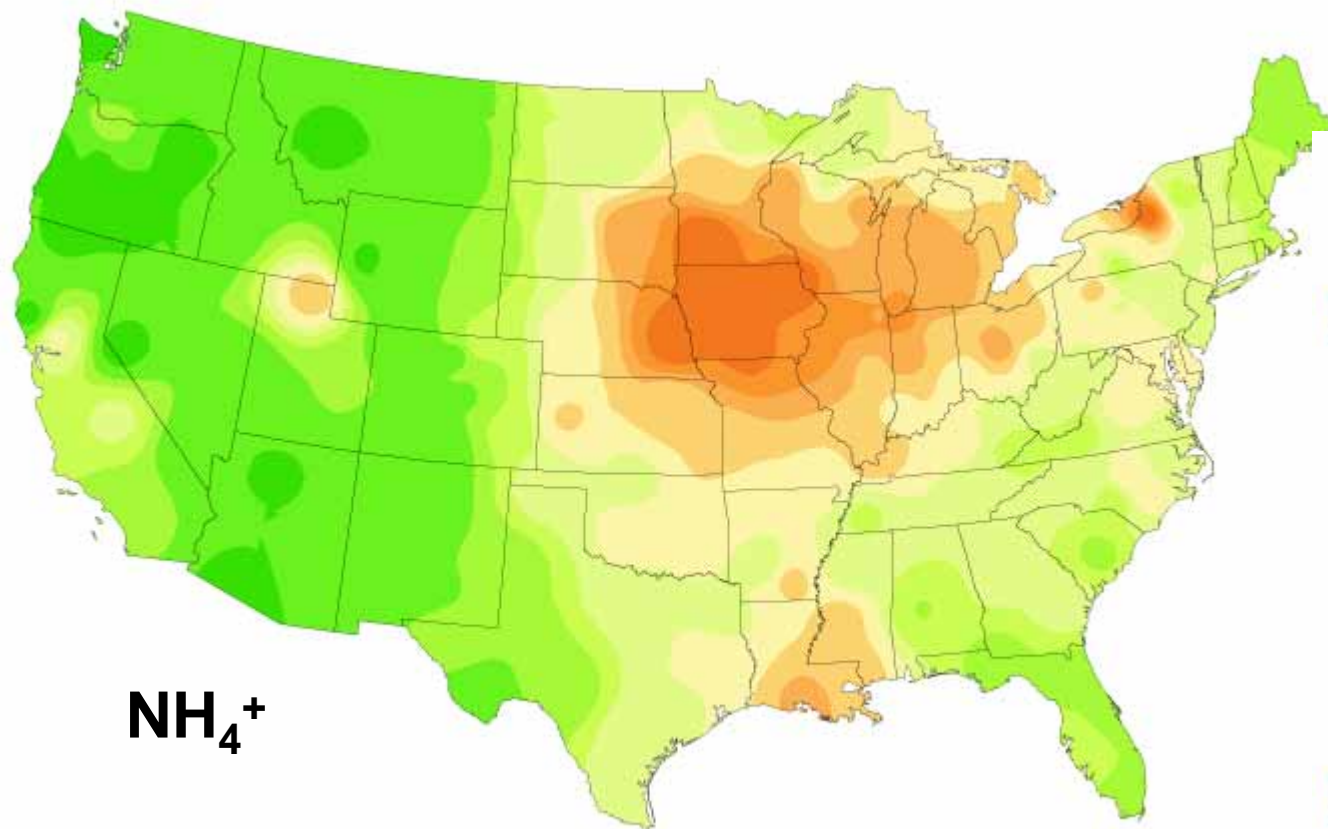


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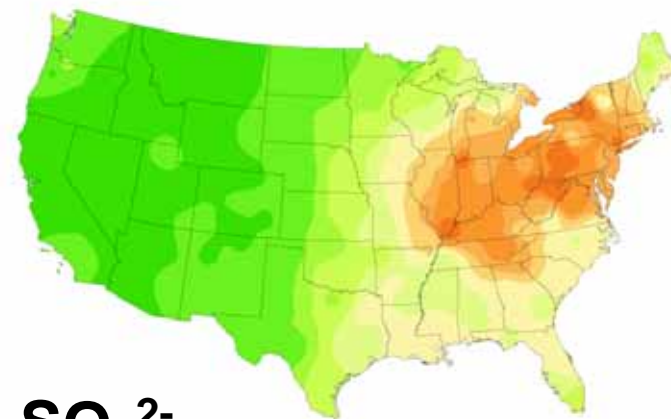
1990 **1991** 1992



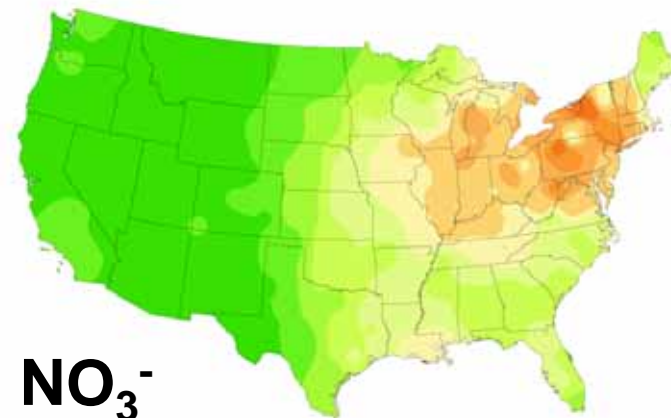


$\text{NH}_4^+$

1991 **1992** 1993

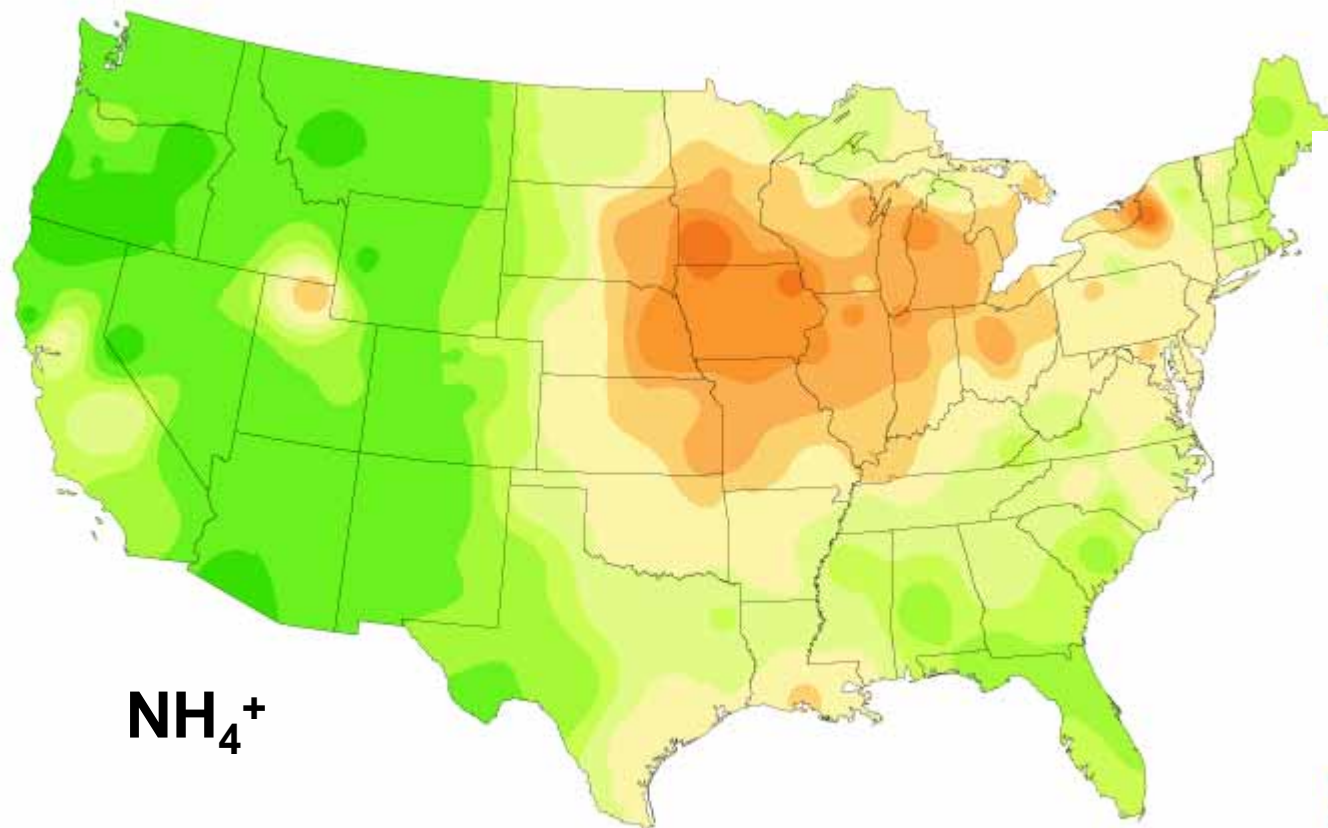


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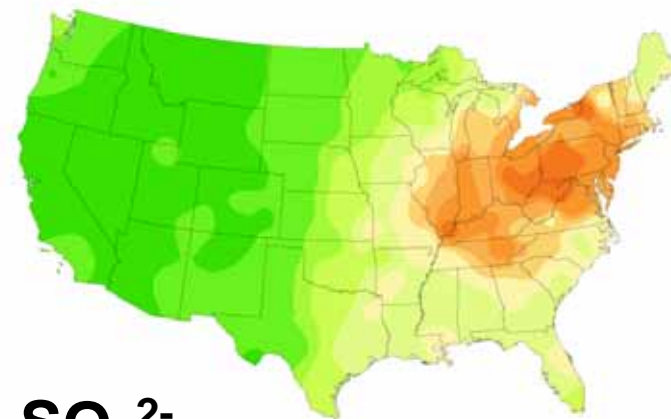
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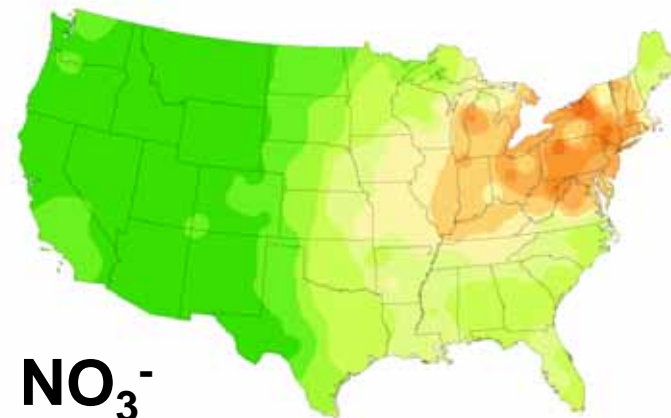


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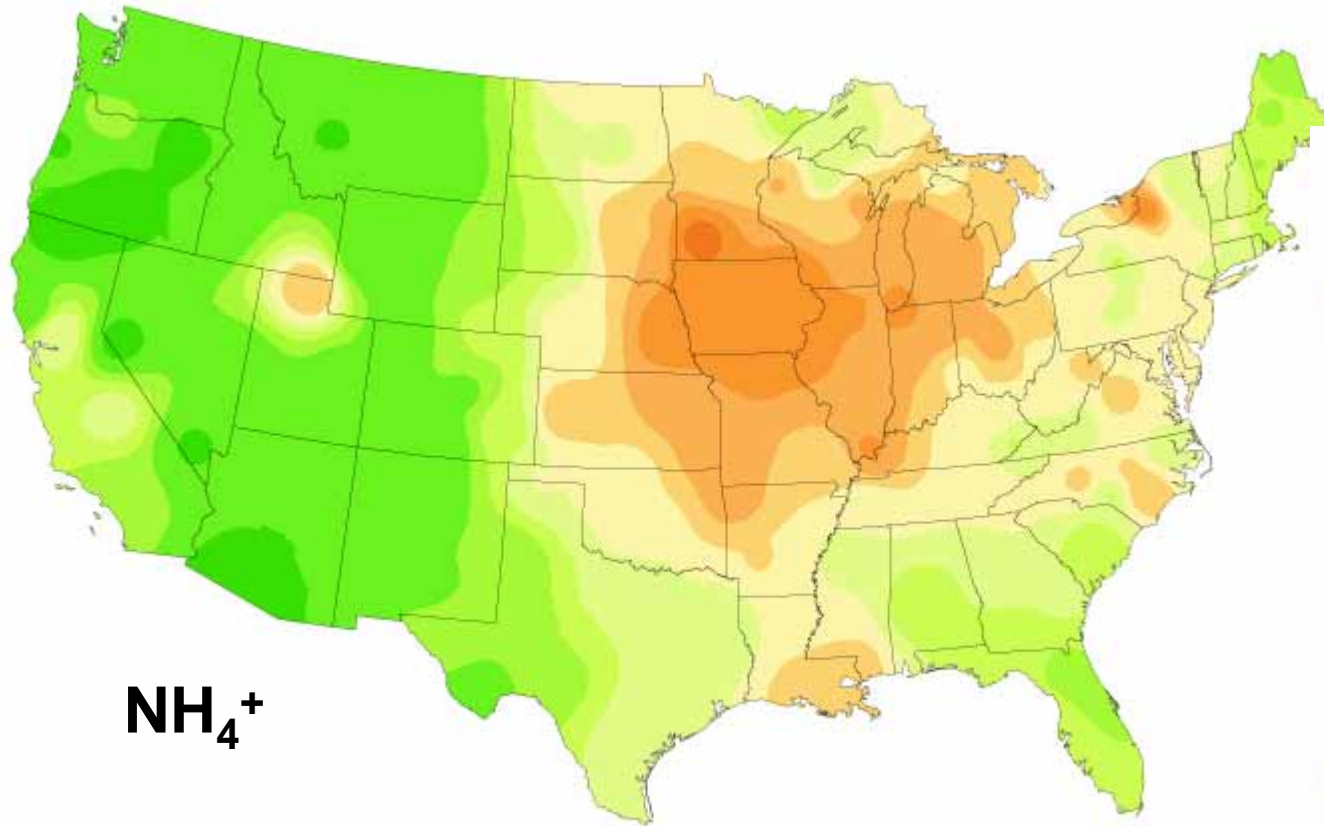
1992 **1993** 1994



$\text{SO}_4^{2-}$

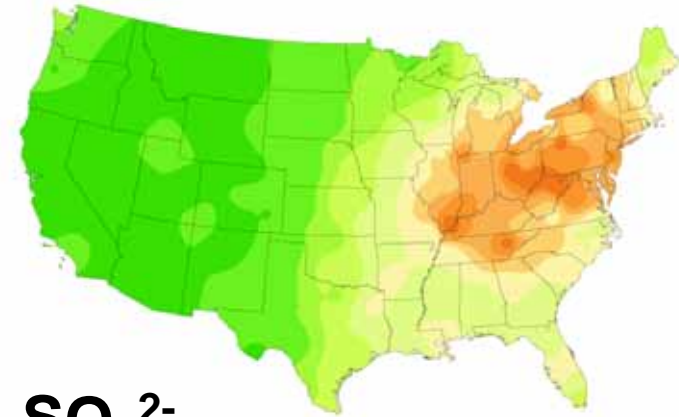


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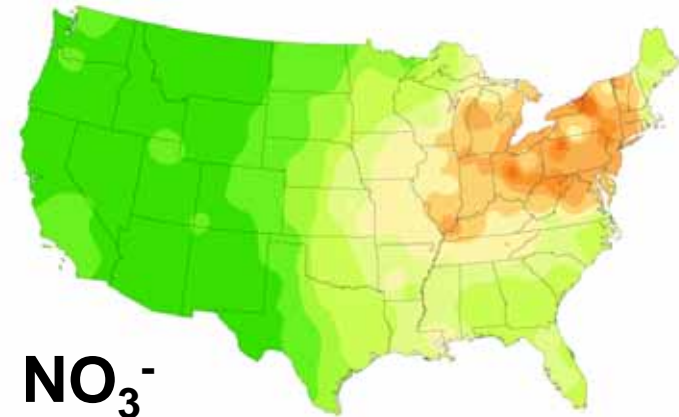


$\text{NH}_4^+$

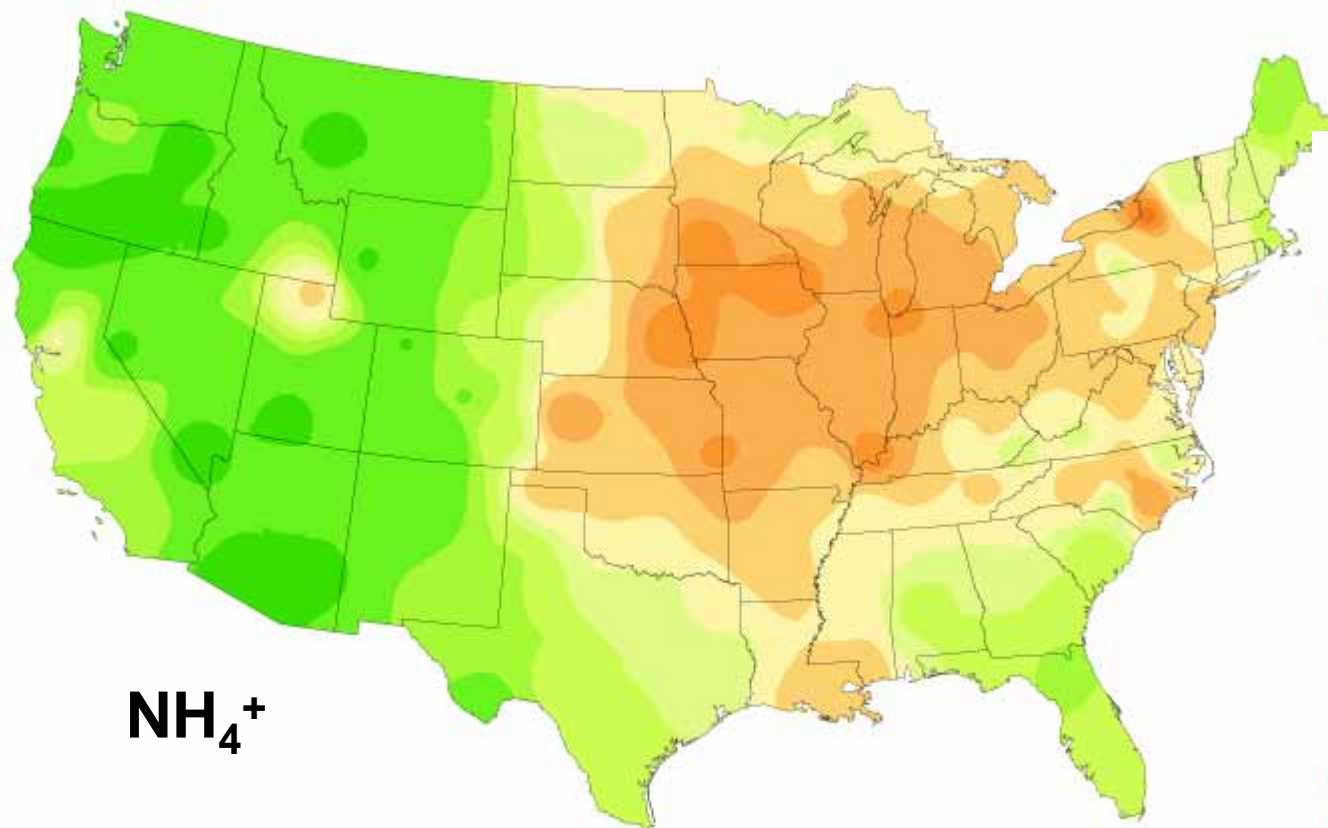
1993 **1994** 1995



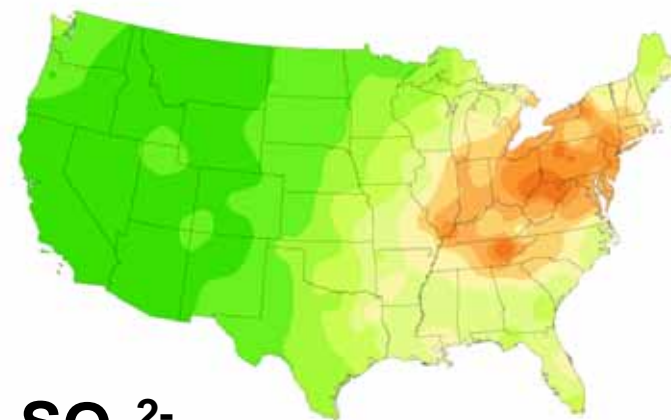
$\text{SO}_4^{2-}$



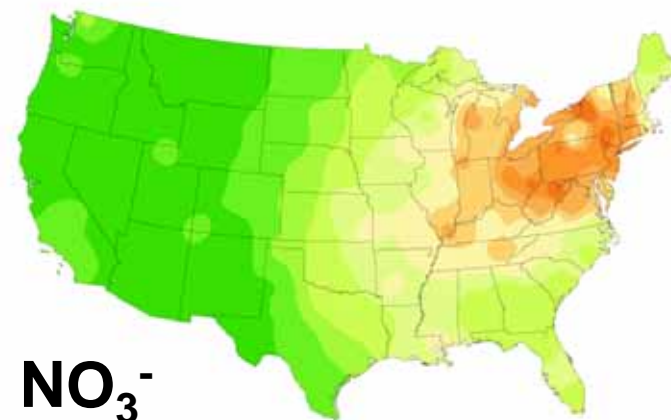
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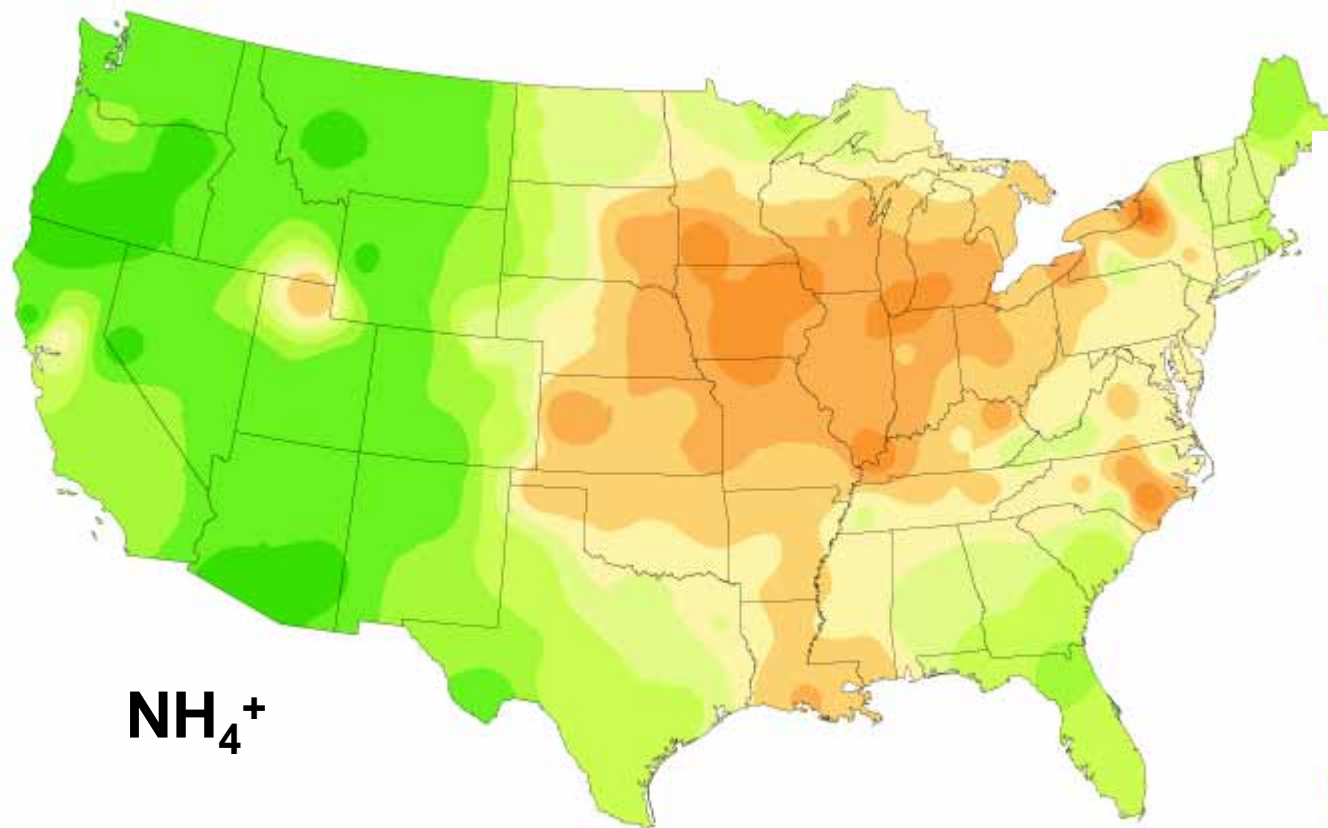
1994 **1995** 1996



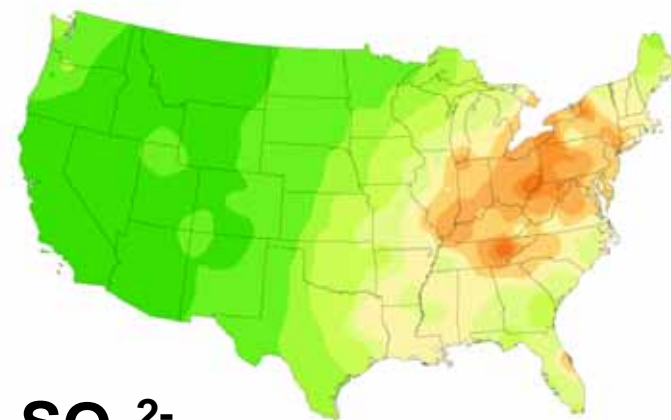
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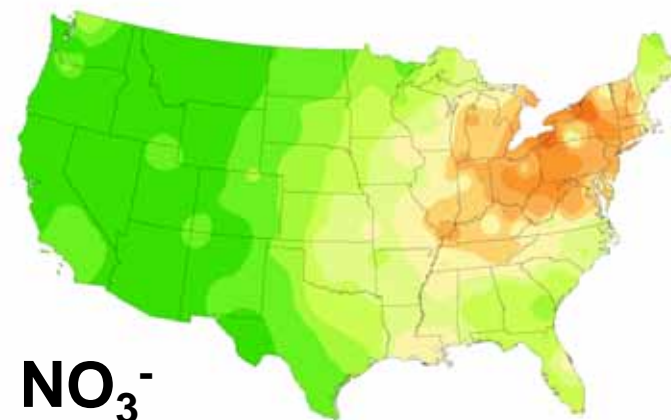
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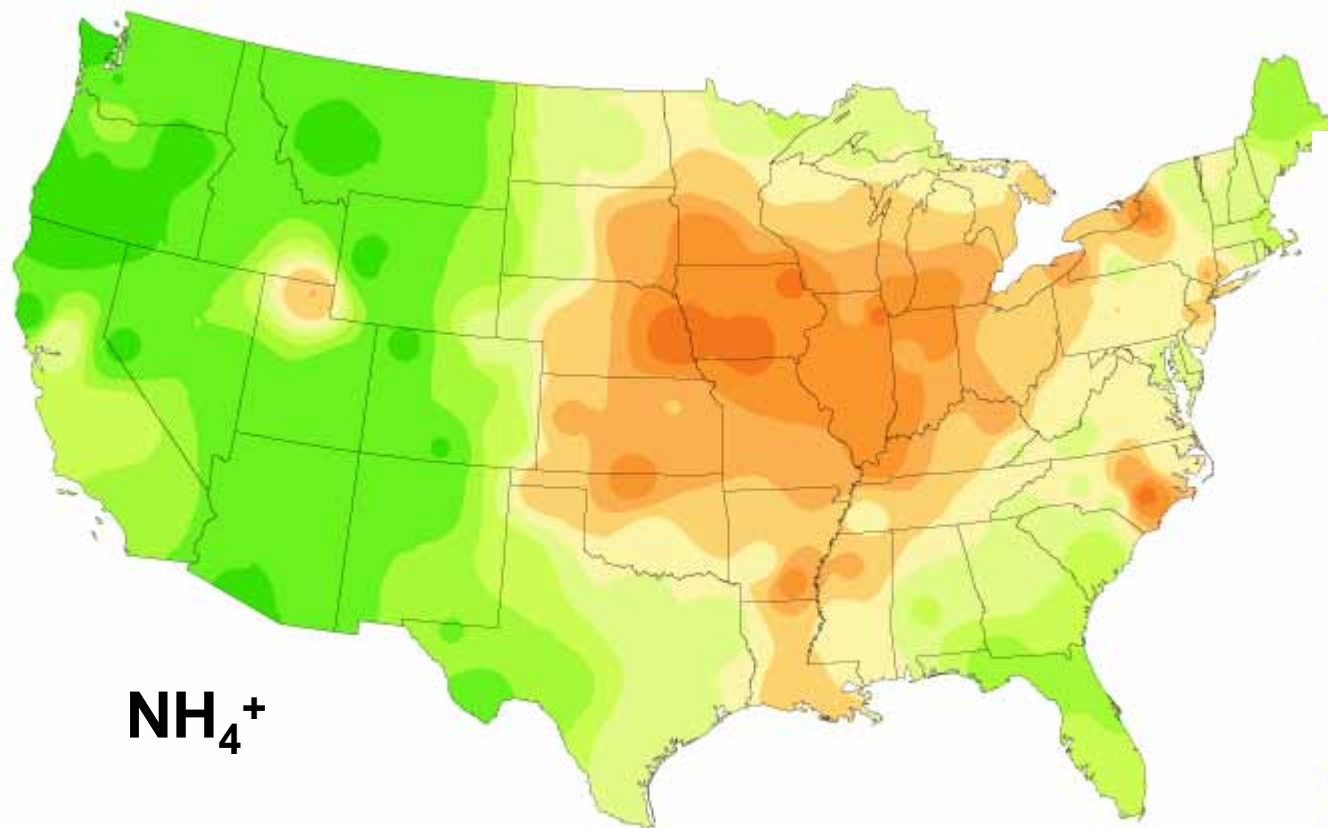
1995 **1996** 1997



$\text{SO}_4^{2-}$

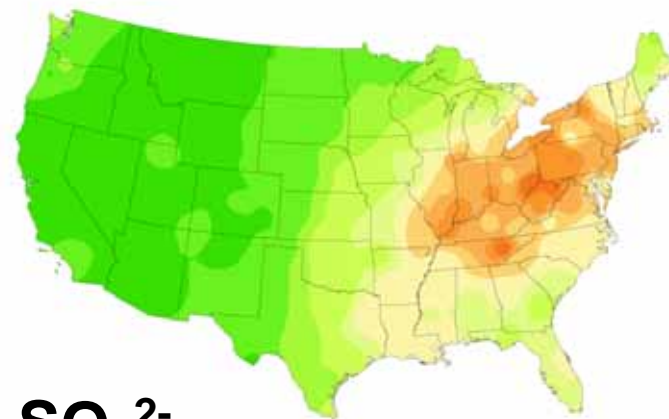


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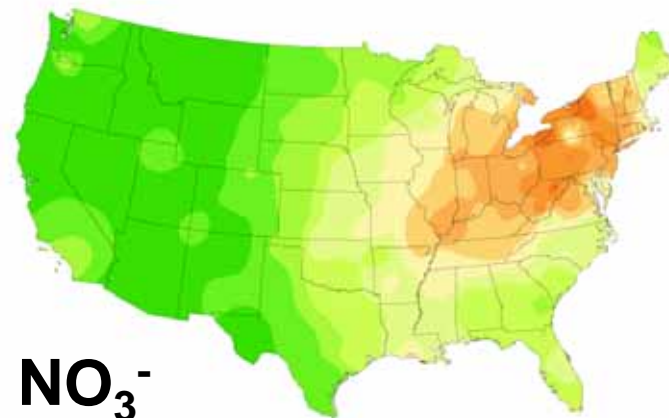


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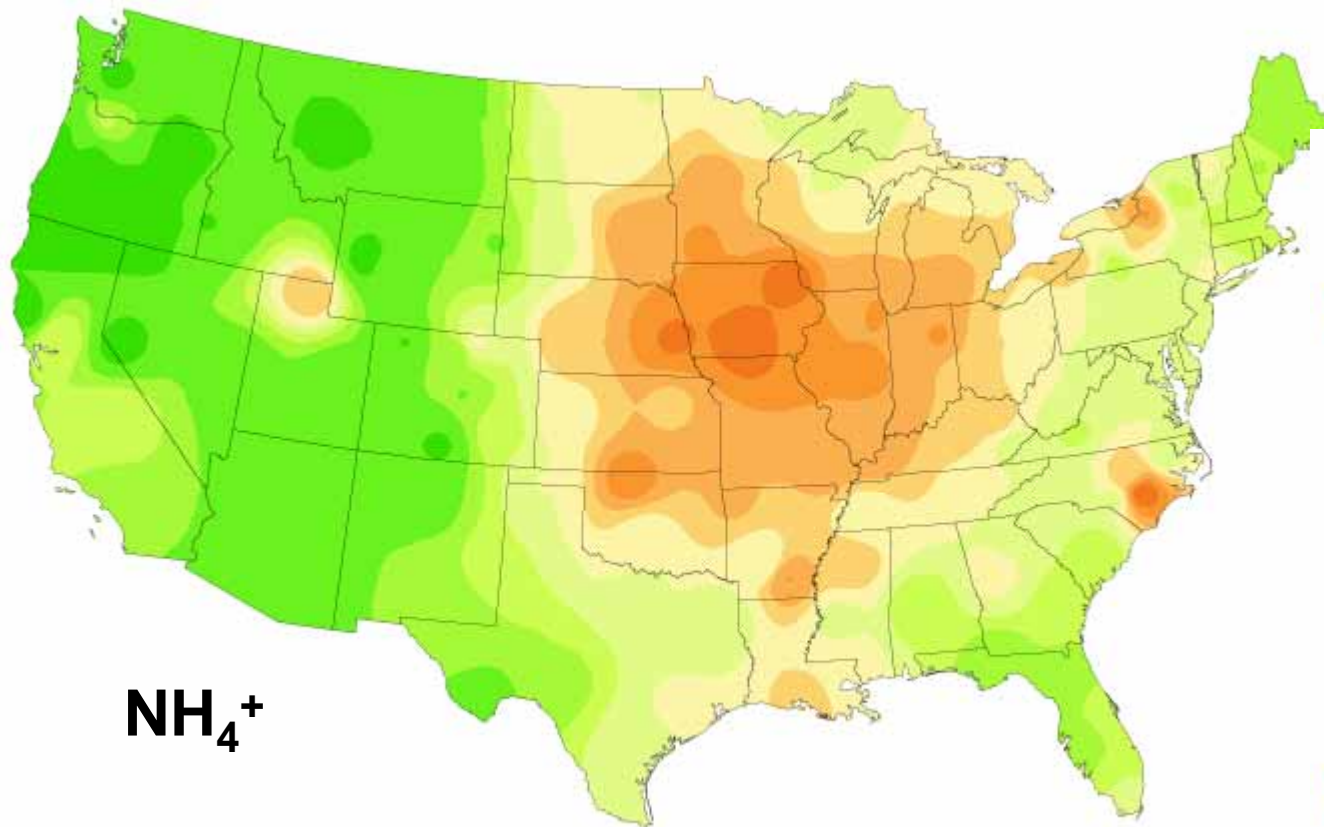
1996 **1997** 1998



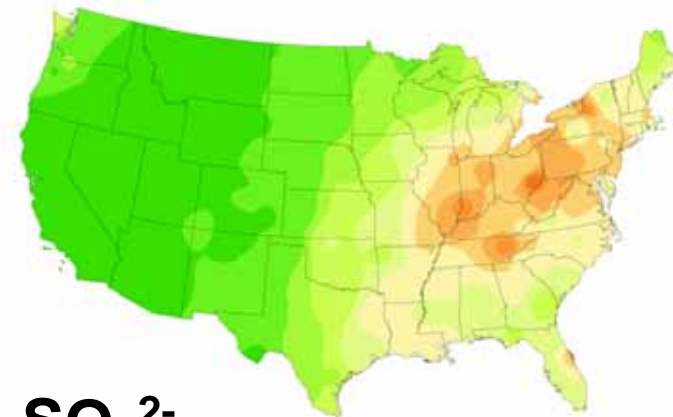
$\text{SO}_4^{2-}$



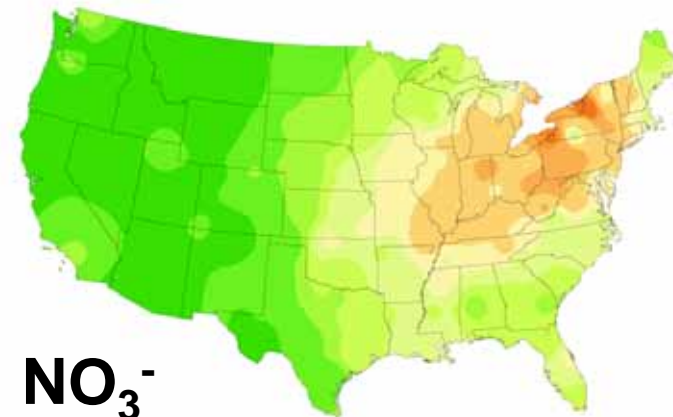
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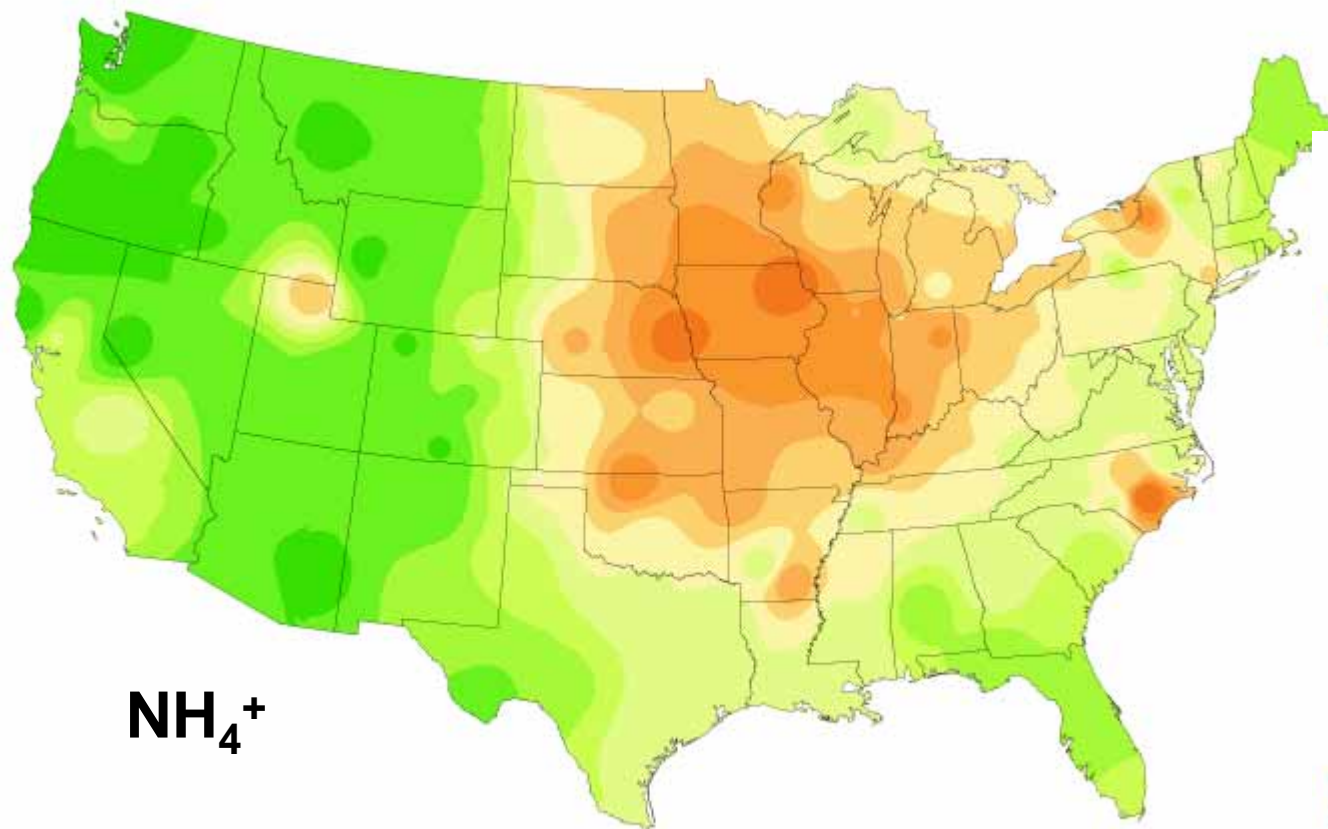
1997 **1998** 1999



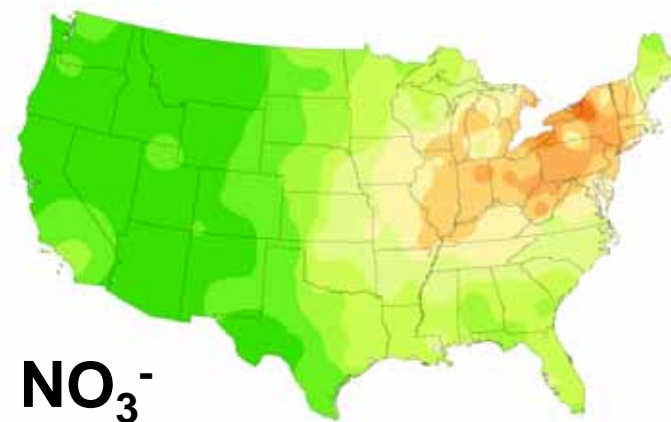
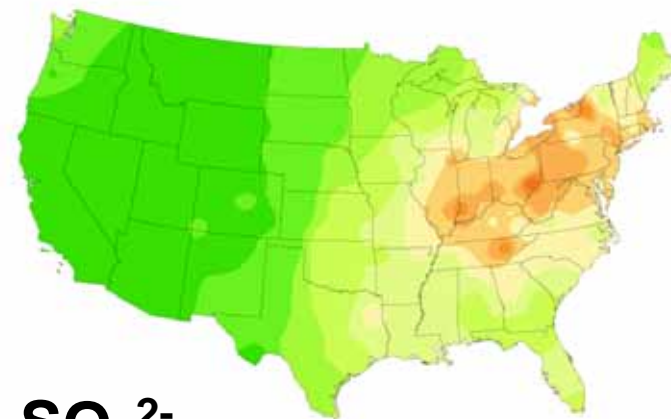
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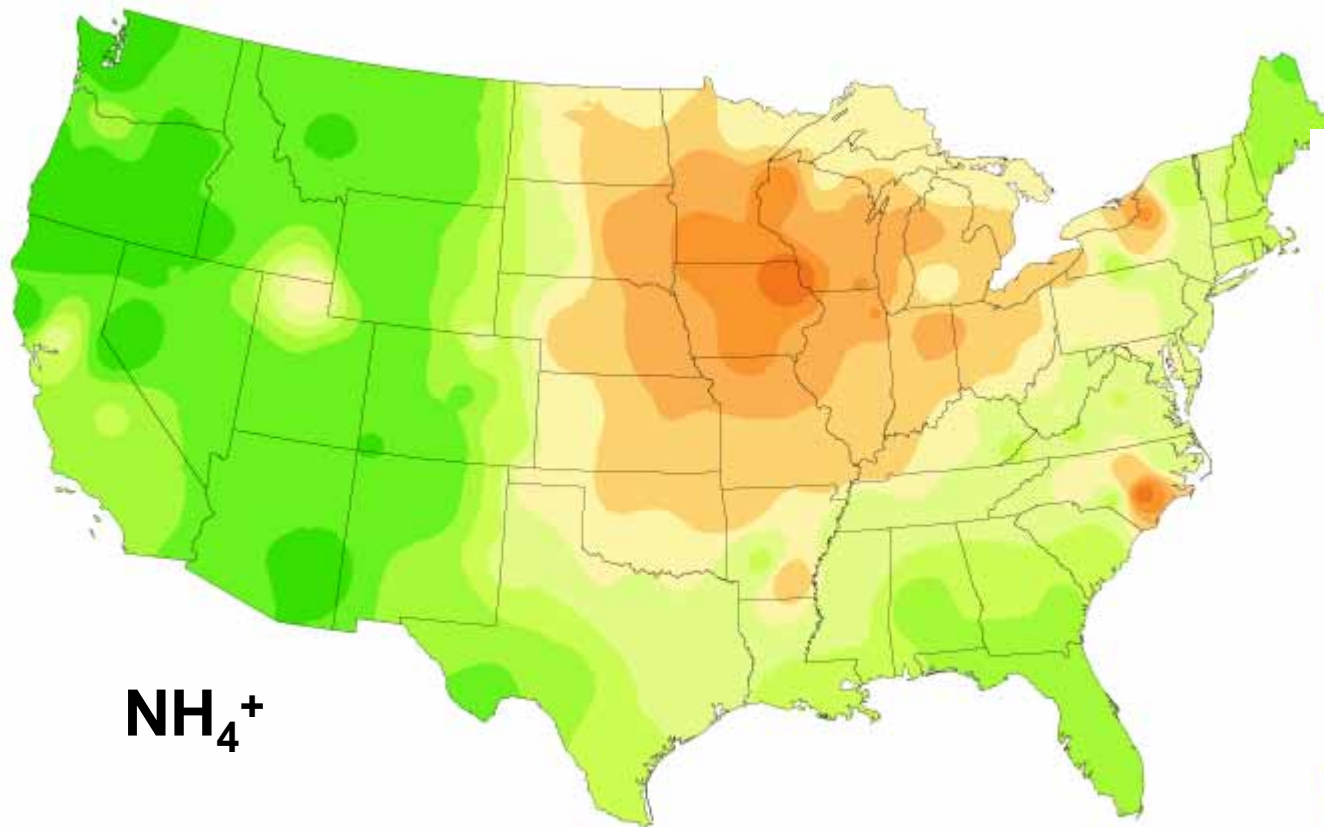


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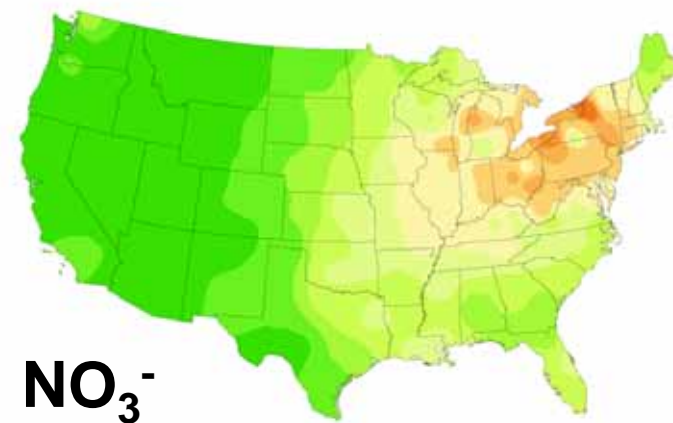
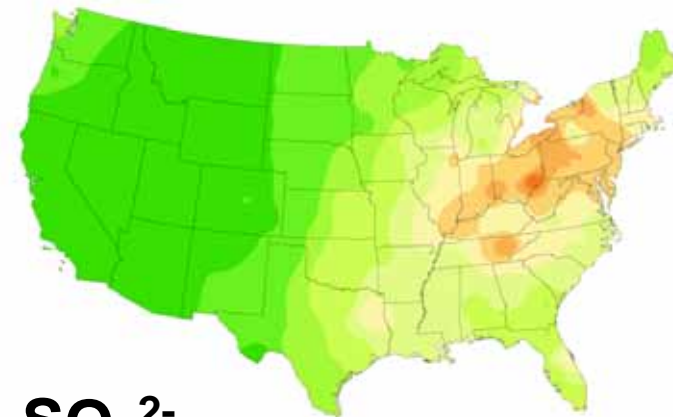


1998 **1999** 2000

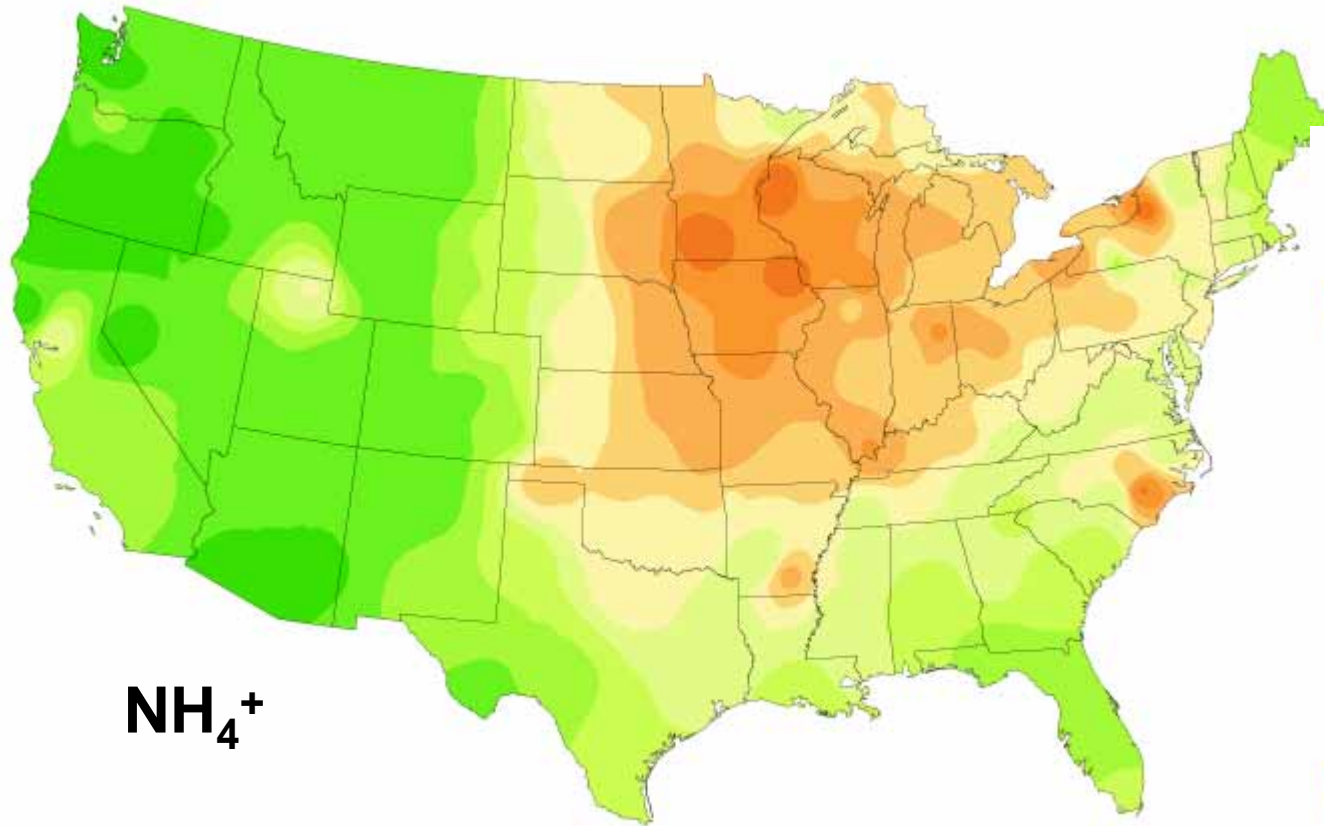




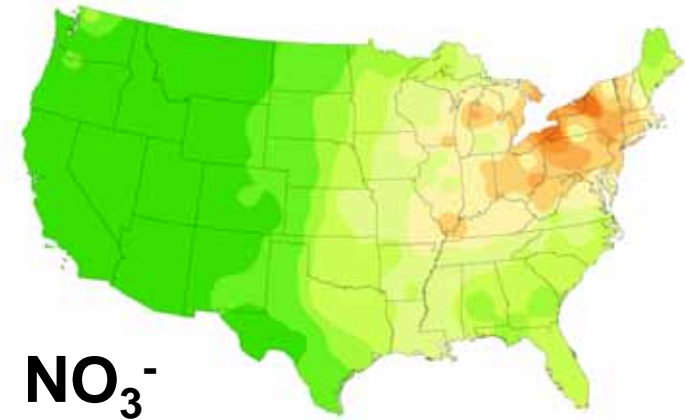
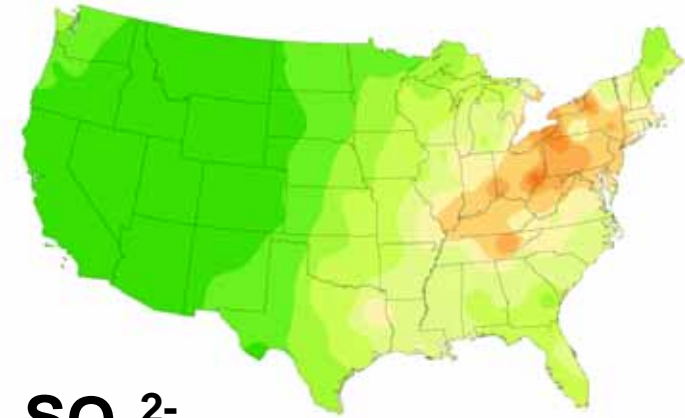
1999 **2000** 2001

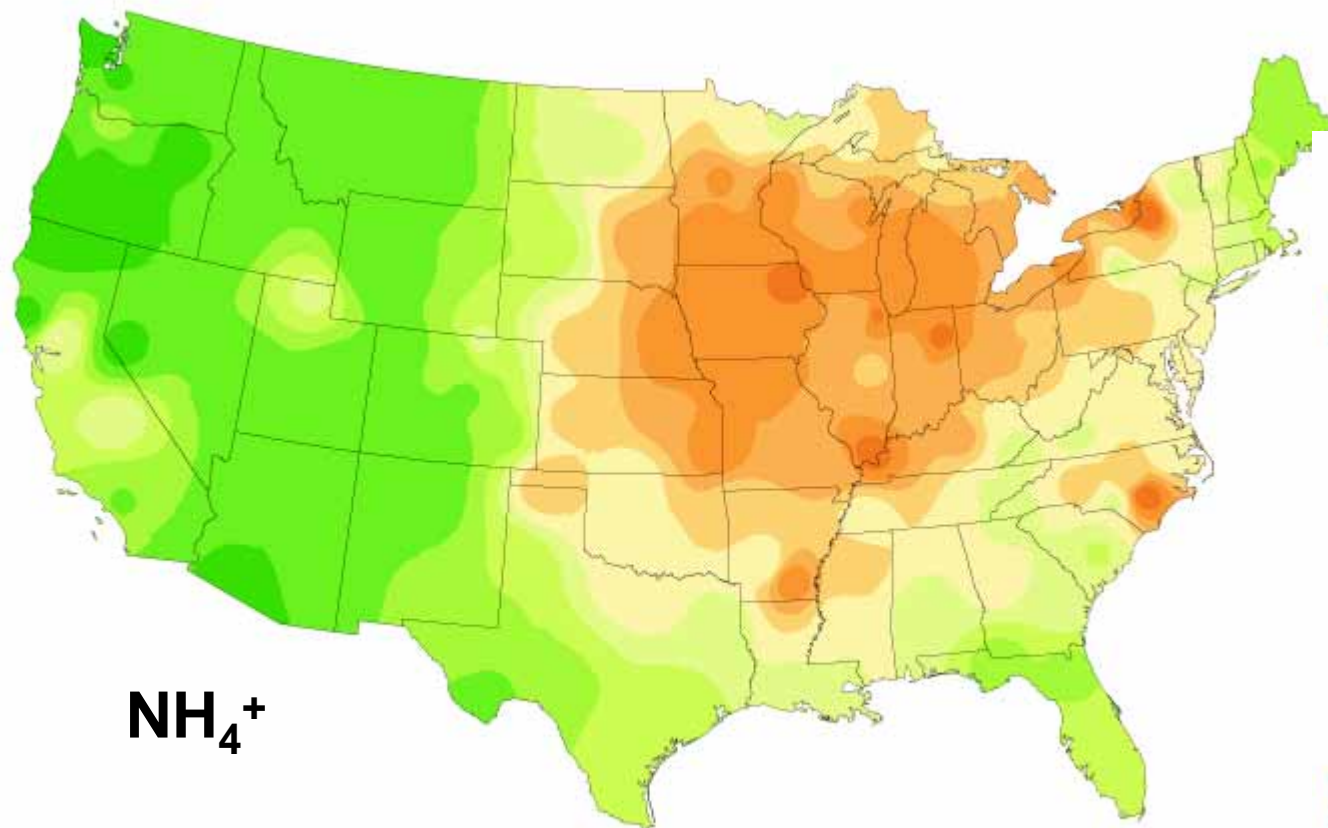




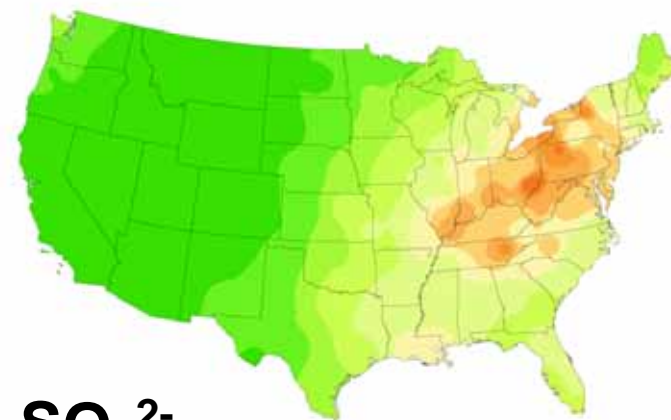


2000 **2001** 2002

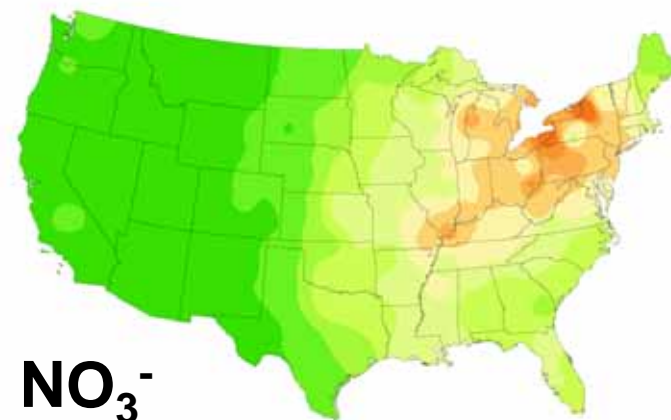




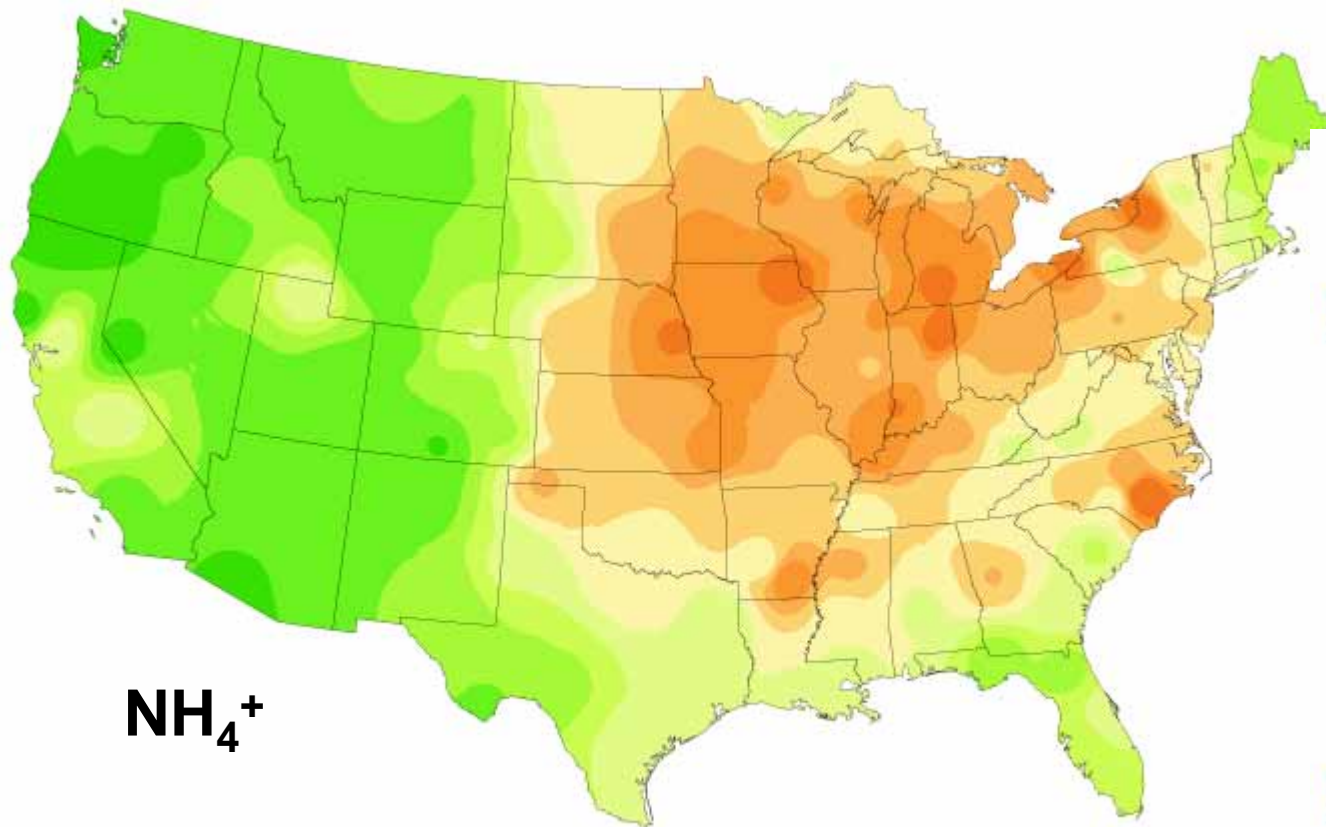
2001 **2002** 2003



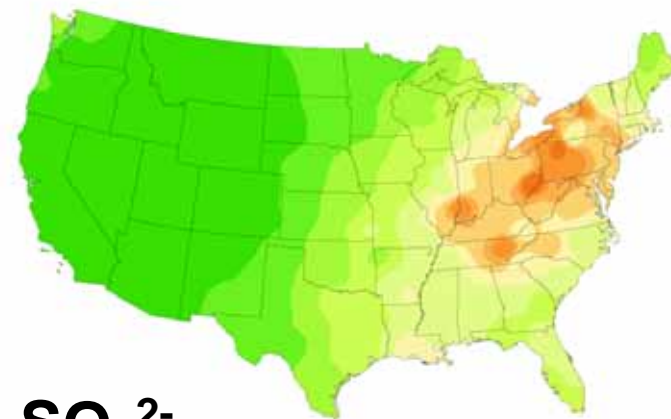
$\text{SO}_4^{2-}$



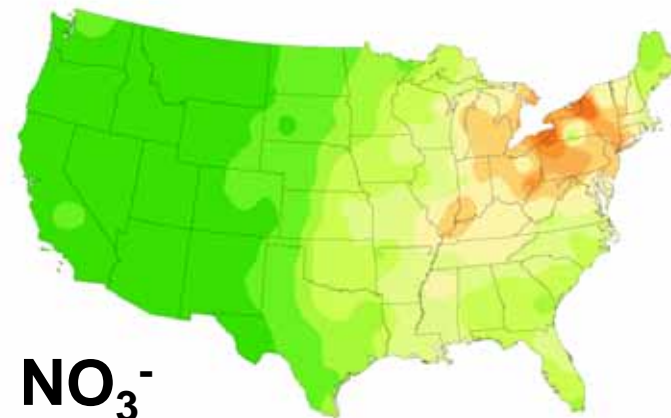
$\text{NO}_3^-$



2002 **2003** 2004



$\text{SO}_4^{2-}$



$\text{NO}_3^-$

## Overall

- Much effort put in trying to get a grip on the linkages between emissions and concentration
- New studies (again) showed relevance of having insight in:
  - Adequate emission estimates
  - Adequate model parameterizations
  - Need for long-term good quality measurements
    - in contrasting areas (evaluating abatement measures)
- If all this can be brought together, valuable evaluations on the effectiveness of  $\text{NH}_3$  abatement measures can indeed be made
- However, further discussion needed on reasons behind observed (lack of) trends in emissions and concentrations

## UN/ECE Expert Group on Ammonia

**4 – 6 December 2006, Edinburgh (UK)**

- Datasets on trends of  $\text{NH}_x$  still welcome, to be included in the background document
  - Not only Europe; also other experiences are needed to get the full picture
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