Continuous Monitoring of Pollution in the Nation's Precipitation

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USGS science for a changing world

National Atmospheric Deposition Program

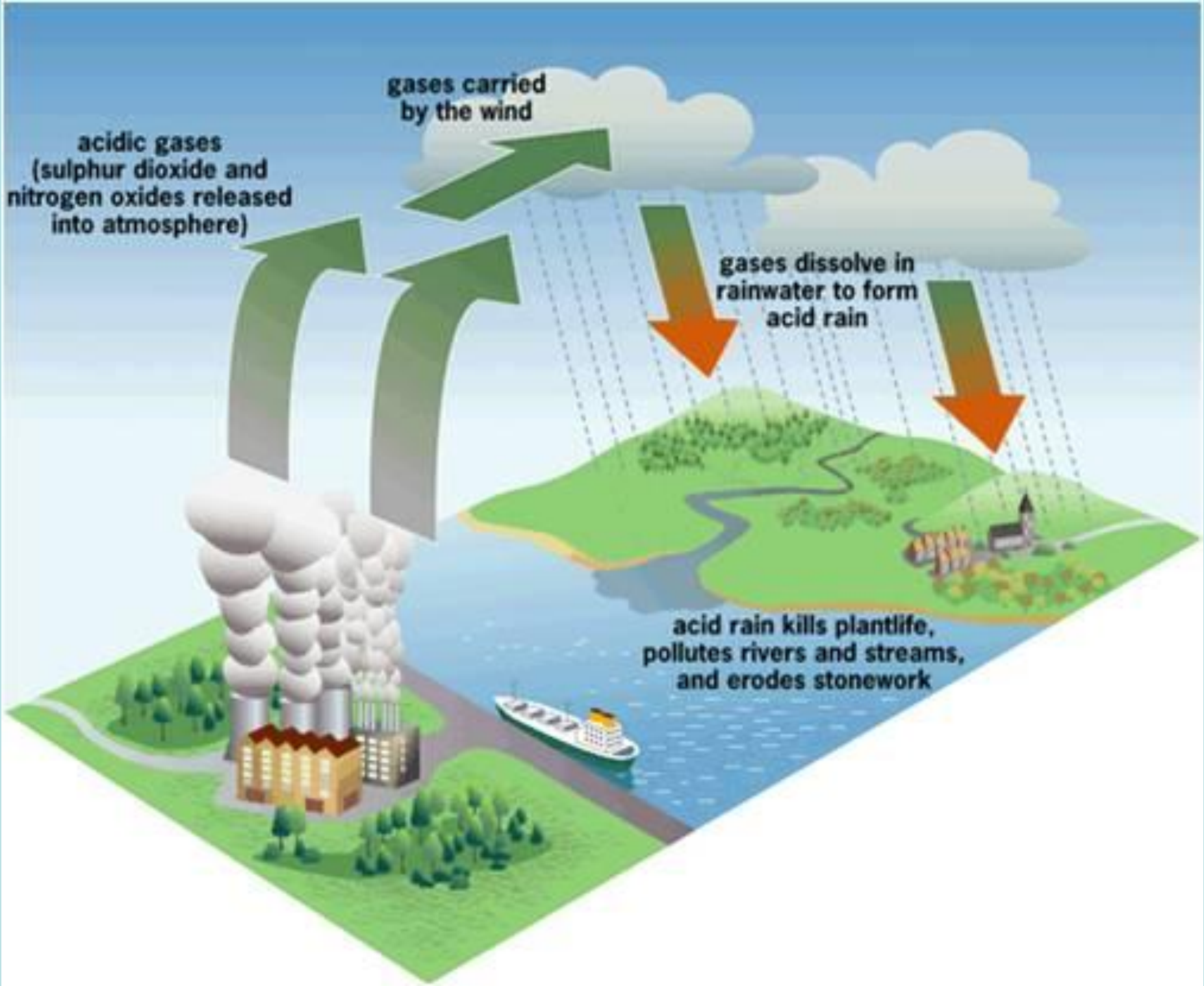
Topics

Brief overview:

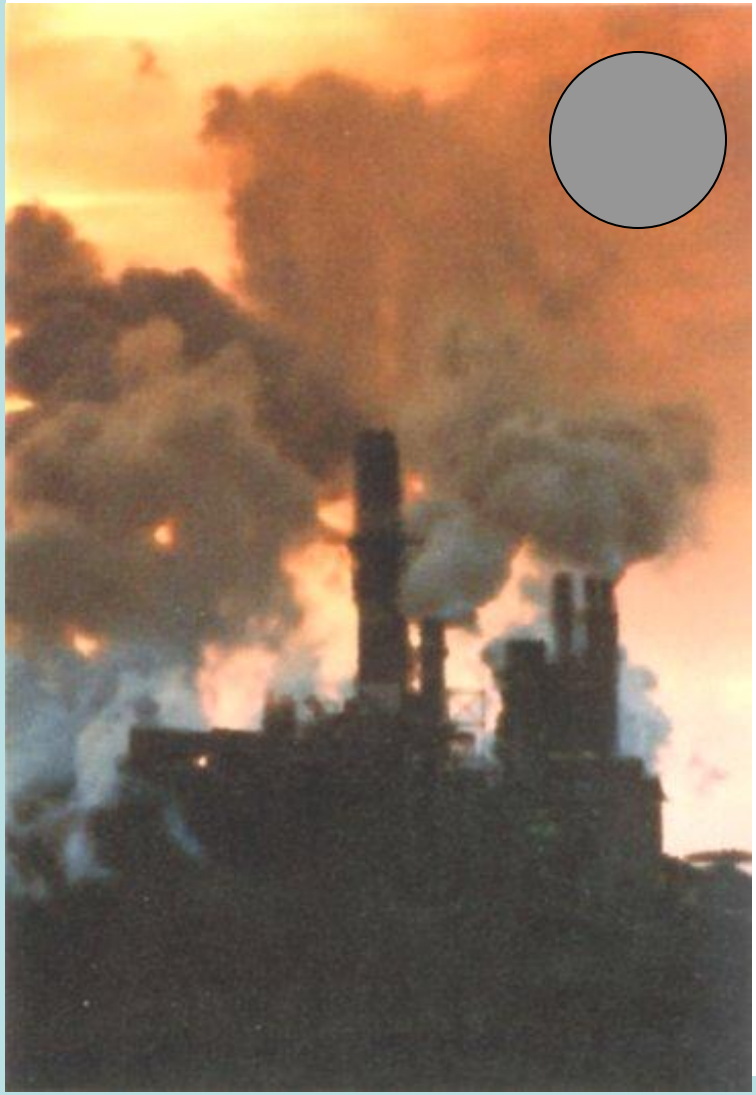
- What wet and dry deposition
- NADP and how we operate
- Review of results

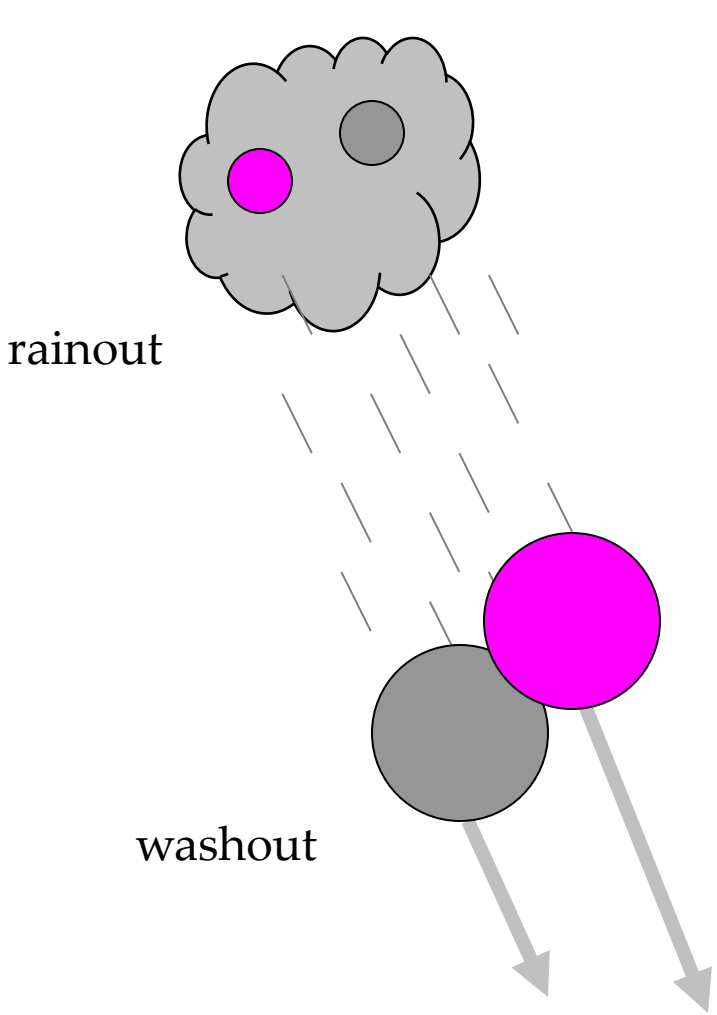
Marty Risch/USGS will cover specific mercury topics in Indiana

How Do Pollutants Get into Rain?


gases carried
by the wind
acidic gases
(sulphur dioxide and
nitrogen oxides released
into atmosphere)
gases dissolve in
rainwater to form
acid rain
acid rain kills plantlife,
pollutes rivers and streams,
and erodes stonework

Wet Deposition of Pollutants





Dry Deposition of Pollutants

- Solids and gases
  'fall' out of the atmosphere
- Very difficult to measure

- But you can estimate the rate of deposition

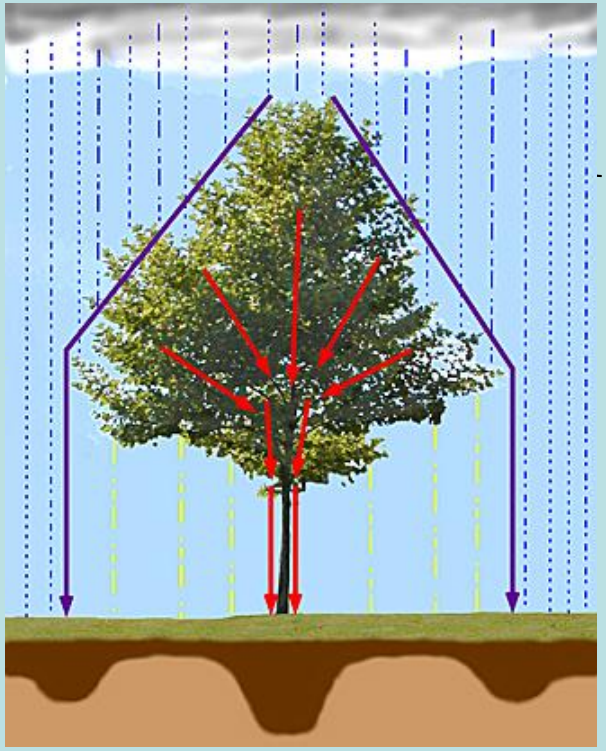
$$Flux = Conc\ X\ Deposition\ Velocity$$

$$F = C\ x\ Vd$$

Other Mass Movement Processes…

- Litterfall

- Throughfall

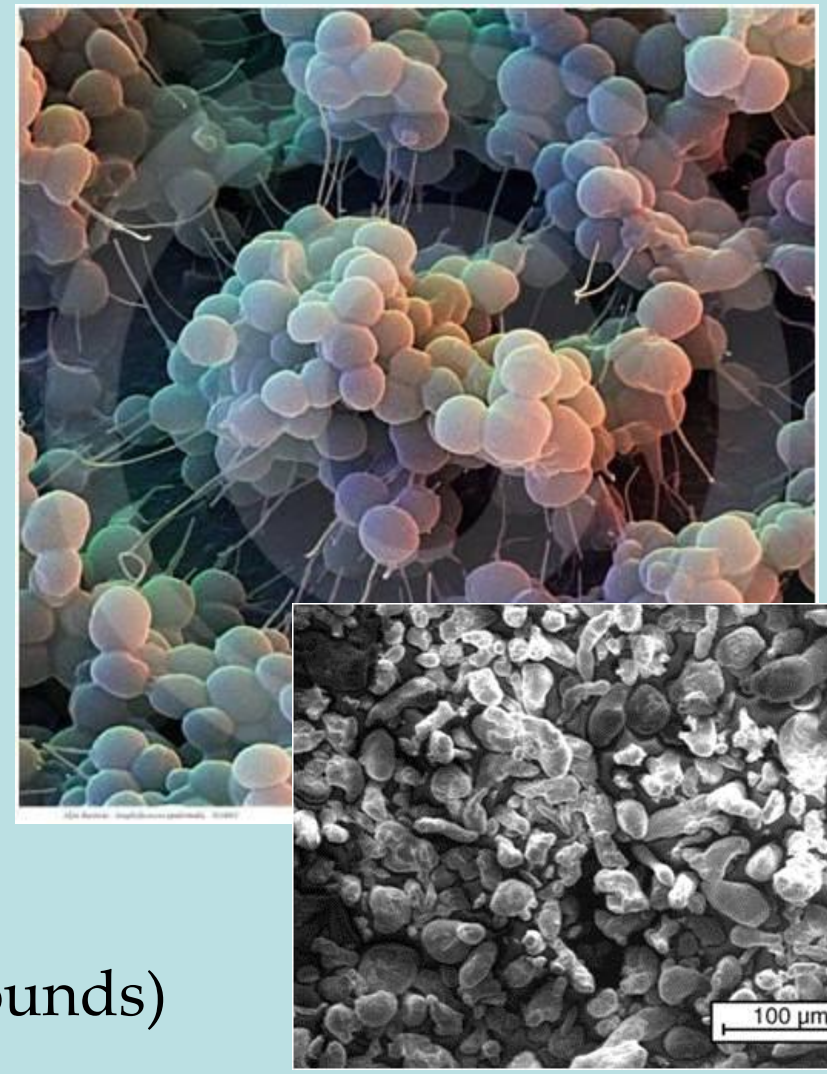


What Ecotoxics are in Precipitation?

- Chemicals
  - Acids
  - Bases (NH_3^+)
  - Oxidants (Cl^-, Br^-, O_3, OH^- radicals)
  - Metals (arsenic, vanadium, strontium, chromium, etc.)
  - Organics (world of compounds)
  - Other inorganics/industrialized compounds
  - Radiological elements (alpha, beta, gamma)

What Ecotoxics are in Precipitation?

- Biological Elements
  - Bacteria
  - Viruses
  - Spores
  - fungi
- Physical Agents
  - Solids/particulates
  - Frozen water
  - Radiation (from compounds)



What is the National Atmospheric Deposition Program?

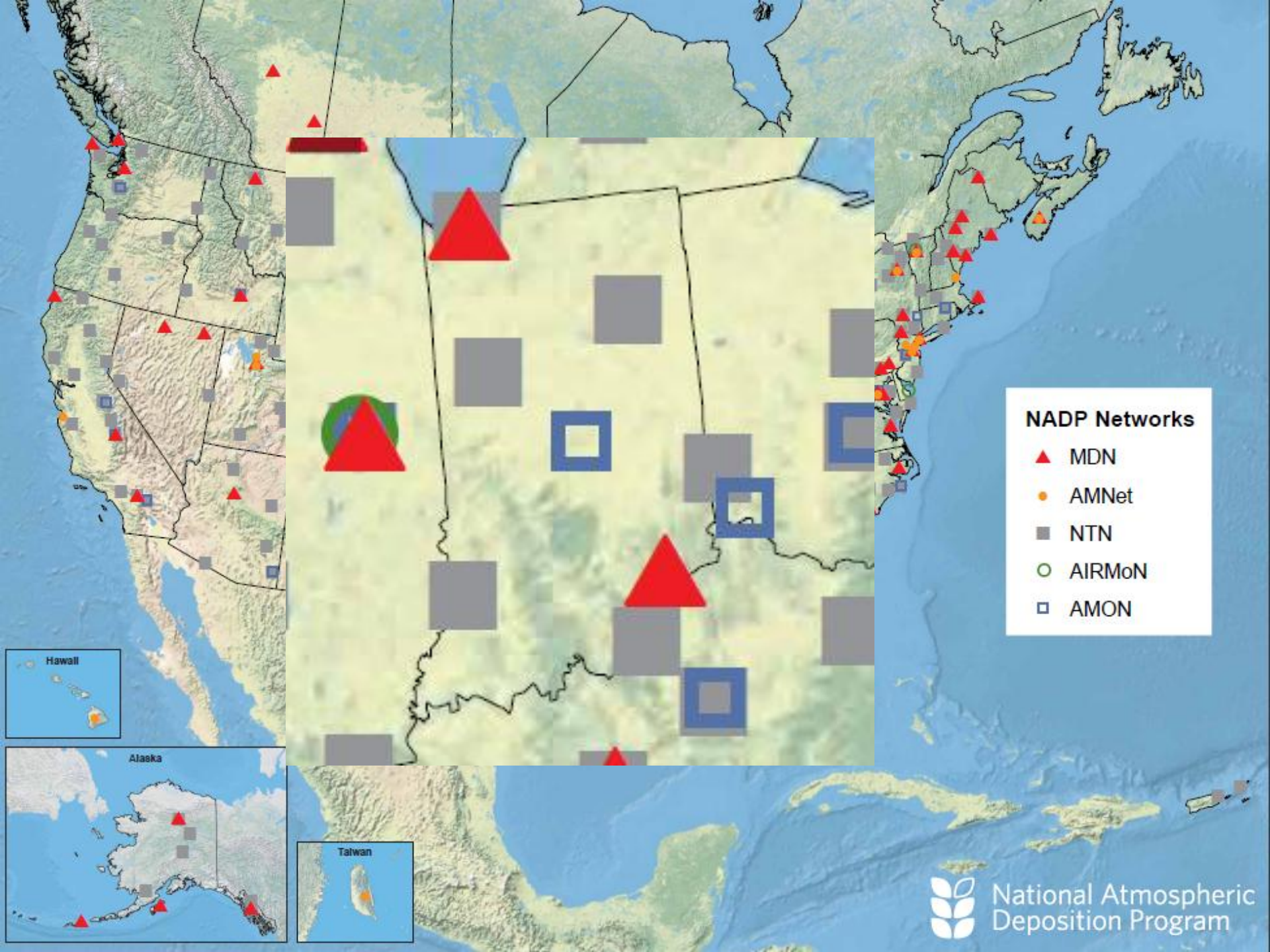
- A Cooperative Research Program *(Un. Of Illinois)*
  - Measure wet deposition of pollutants
  - We monitor the rate of pollution movement to the surface (dry deposition)
  - North America
    - US, Canada, and some in Mexico
    - Also Taiwan, South America, Hawaii
  - Owned and operated by our members
    - Decisions made by our members
    - Started in 1978, 35th year
  - "acid rain network"
  - Over 450,000 precipitation samples

NADP is Five Networks

- measure wet deposition of pollutants
  1. National Trends Network (NTN)
  2. Atmospheric Integrated Research Monitoring Network (AIRMON)
  3. Mercury Deposition Network (MDN)
- measure atmospheric concentrations (dry deposition)
  4. Atmospheric Mercury Network (AMNet)
  5. Ammonia Monitoring Network (AMoN)

NADP's Goal

To monitor the chemistry of precipitation (rain and snow) and in the atmosphere, as consistently and as accurately as we can, for long periods to determine changes over time (trends).


NADP Networks
MDN
AMNet
NTN
AIRMoN
AMON
Hawaii
Alaska
Taiwan
National Atmospheric Deposition Program

Who is NADP?

Some of our Funders

(100+ total agencies)

Federal Agency Members

Tribal Organizations

Universities

US States

Other Organizations

What Does NADP Measure?

Network #1: National Trends Network (NTN)

- **Collects one-week precipitation-only samples with NADP wet-dry collector**
- **Measures precipitation with gage**
- **Analyses**
  Acids
  Nutrients
  Base Cations

Species Measured by the NADP

acidic species

free acidity (or pH), sulfate, nitrate, chloride

nutrients

nitrate, ammonium, orthophosphate

earth crustal base cations

calcium, magnesium, potassium

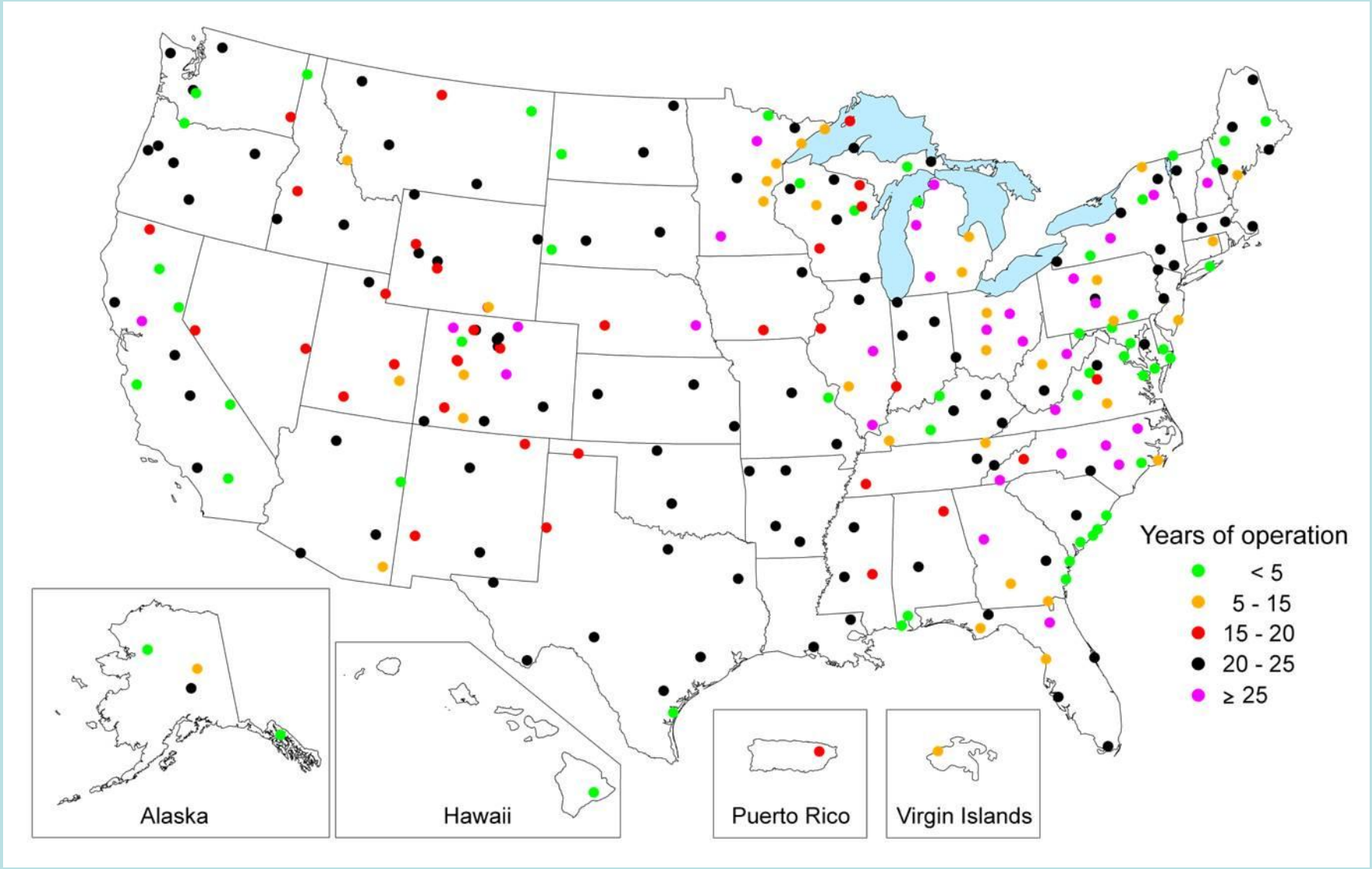
salts

sodium and chloride

heavy metals

mercury, trace metals (MDN)

National Trends Network (NTN)



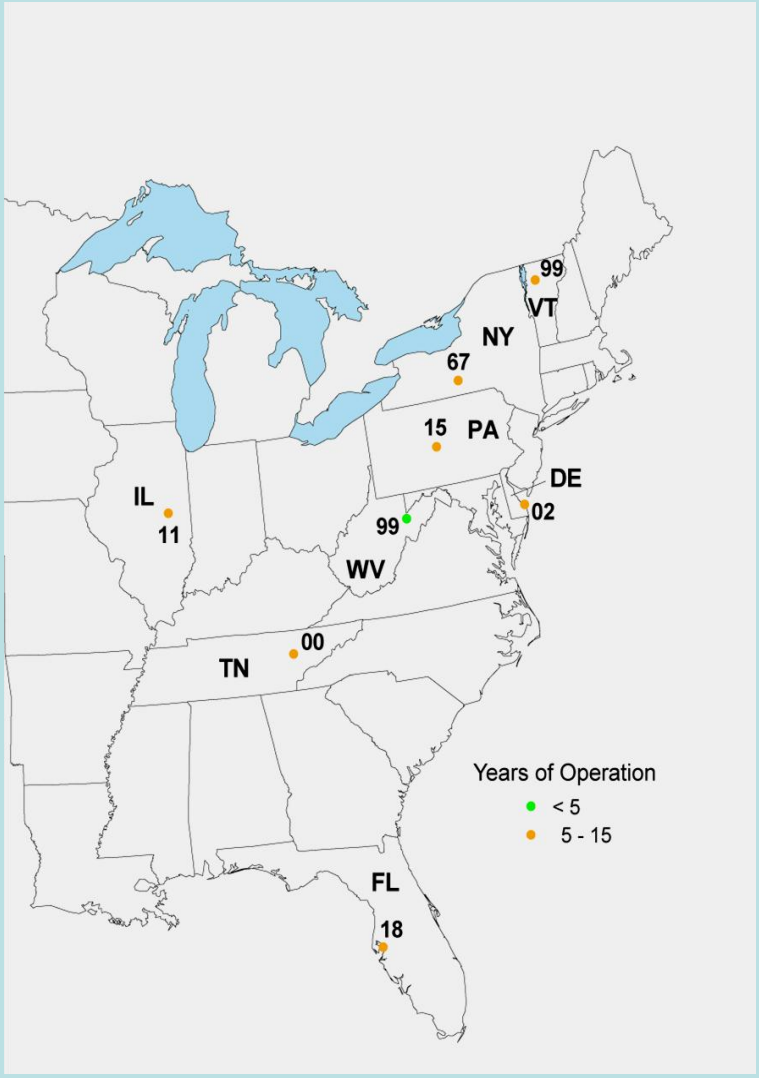
NTN NV05
Great Basin National Park

NTN IL11
Bondville, IL

AIRMoN PA15
Penn State Univ., PA

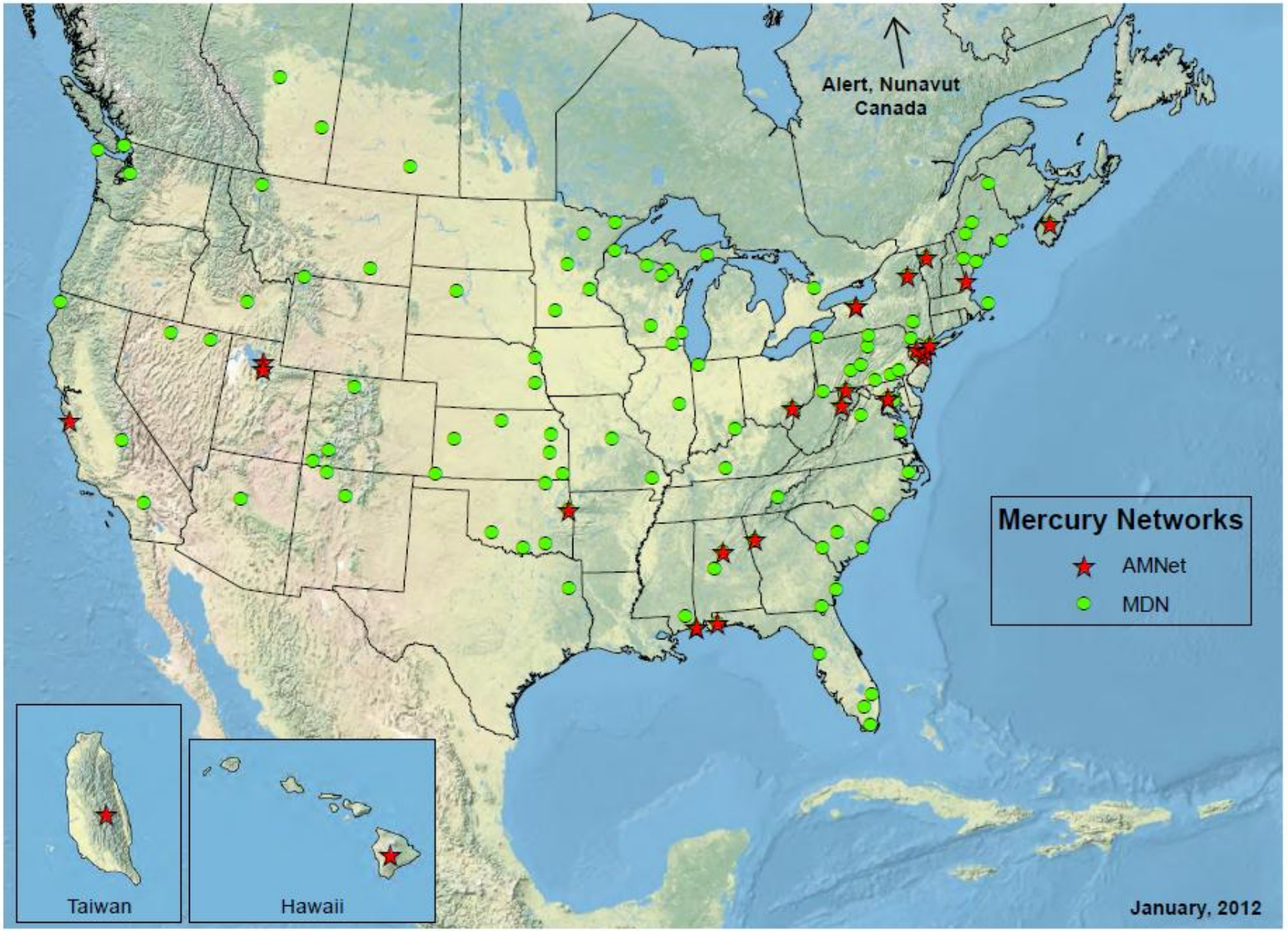
MDN FL11
Everglades N.P., FL

Network #2: Atmospheric Integrated Research Monitoring Network (AIRMoN)



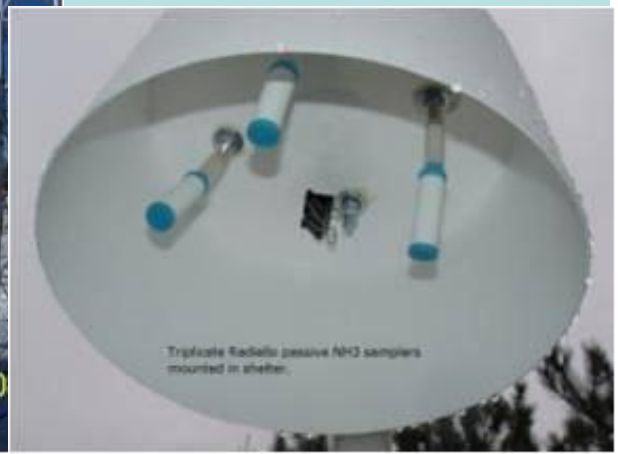
- Very similar to NTN, but collects daily when precipitation occurs
- Measures precipitation with NWS “stick gage”
- Measures same analytes as NTN
- Samples refrigerated from collection until analysis

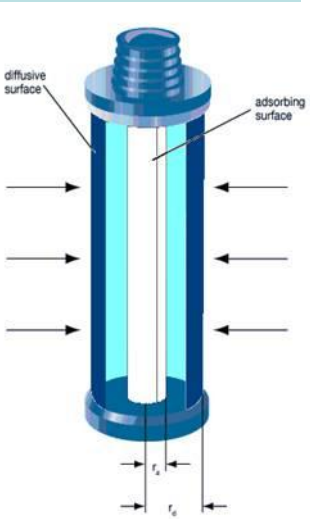
Networks #3& 5: Mercury Deposition (MDN & AMNet)

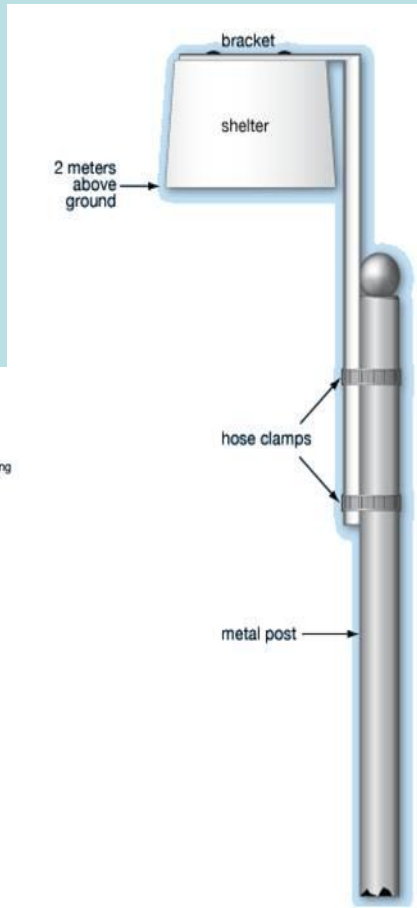


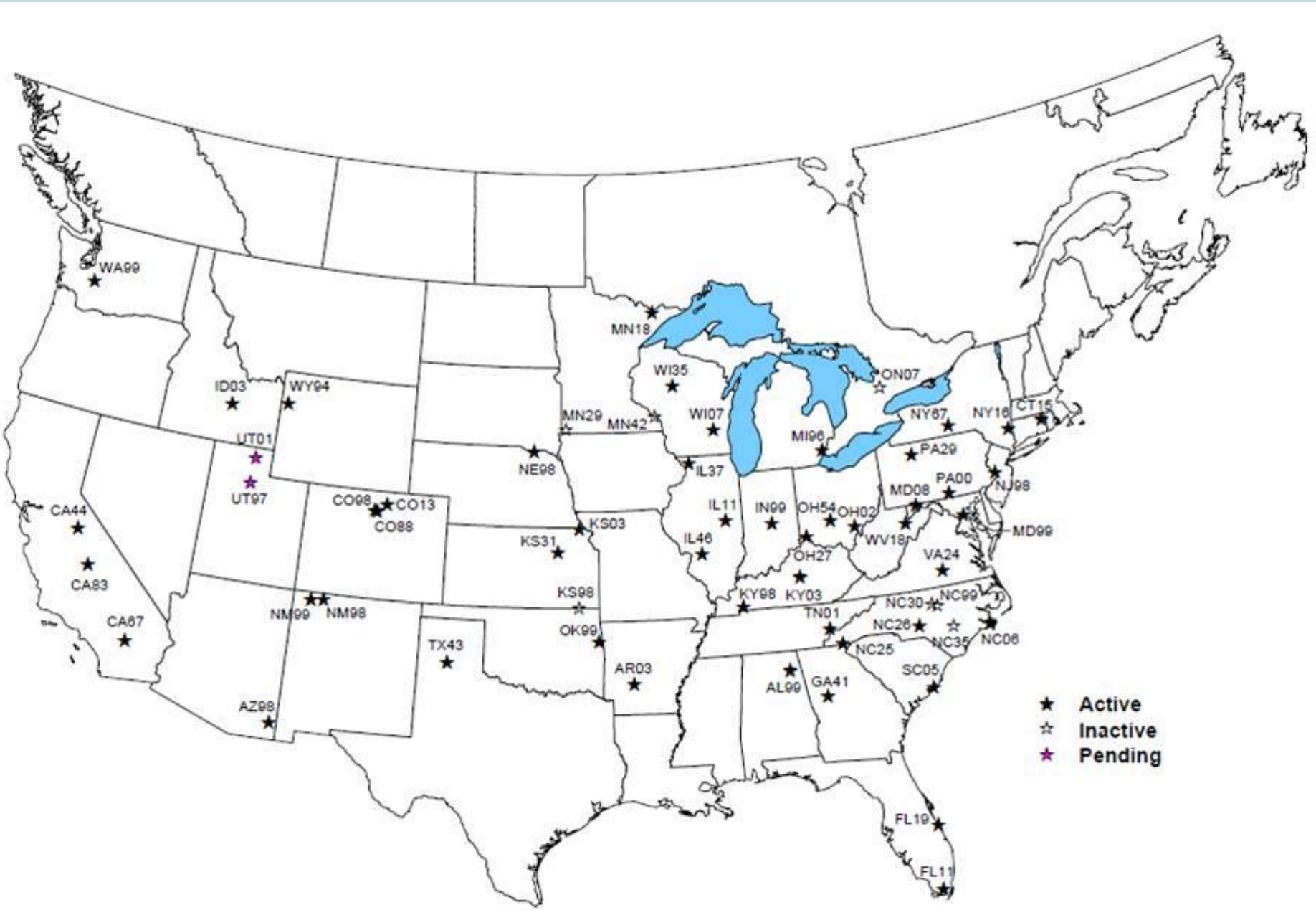
Network #4: Ammonia Monitoring Network (AMoN)

- Measure atmospheric concentrations of ammonia
- Passive samplers
- Low cost, 2 week integrated sample








WA99
ID03
WY94
UT01
UT97
CA44
CA83
CA67
AZ98
NM99
NM98
CO99
CO13
CO88
NE98
KS03
KS31
KS98
OK99
TX43
AR03
MN18
MN29
MN42
WI35
WI07
IL37
IL11
IL46
IN99
MI96
ON07
OH54
OH02
OH27
KY98
KY03
TN01
AL99
GA41
NC30
NC99
NC26
NC35
NC25
NC06
SC05
FL19
FL11
NY67
NY16
CT15
PA29
PA00
NJ98
MD08
MD99
WV18
VA24
Active
Inactive
Pending

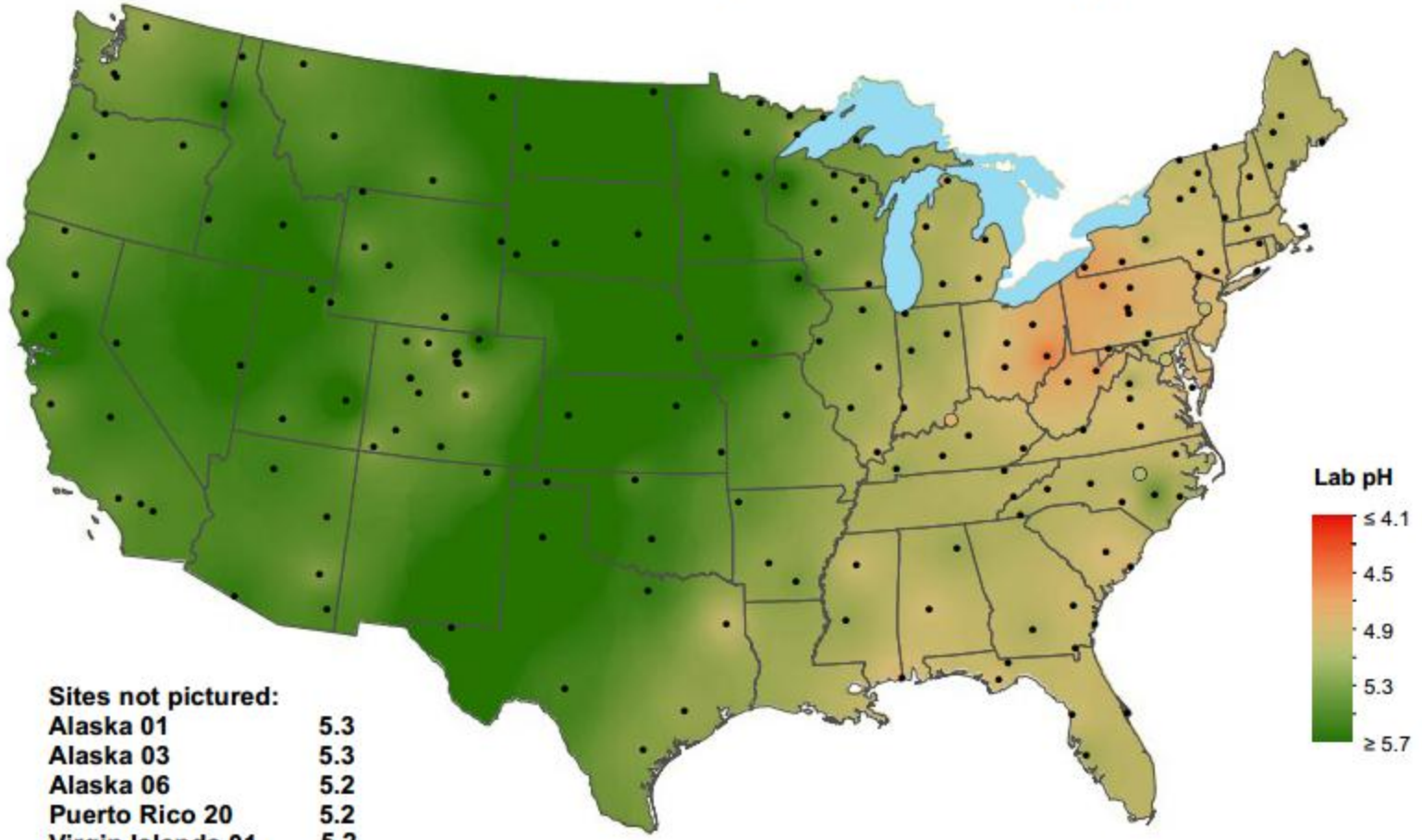
All of this information
(including data)
is on the web

http://nadp.isws.illinois.edu

So……

what are we finding?

Hydrogen ion concentration as pH from measurments made at the Central Analytical Laboratory, 2011

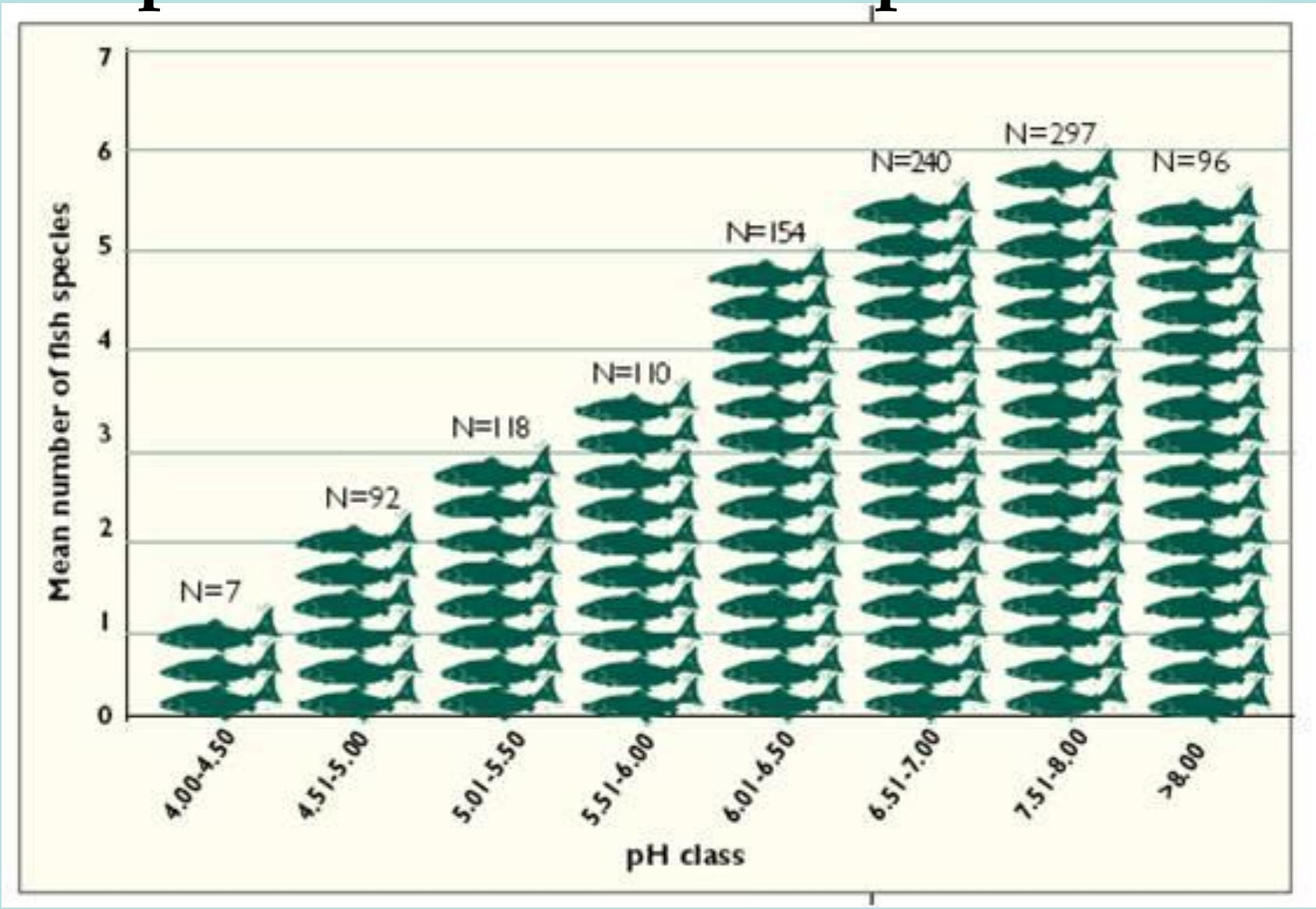


Sites not pictured:

Alaska 01	**5.3**
Alaska 03	**5.3**
Alaska 06	**5.2**
Puerto Rico 20	**5.2**
Virgin Islands 01	**5.2**

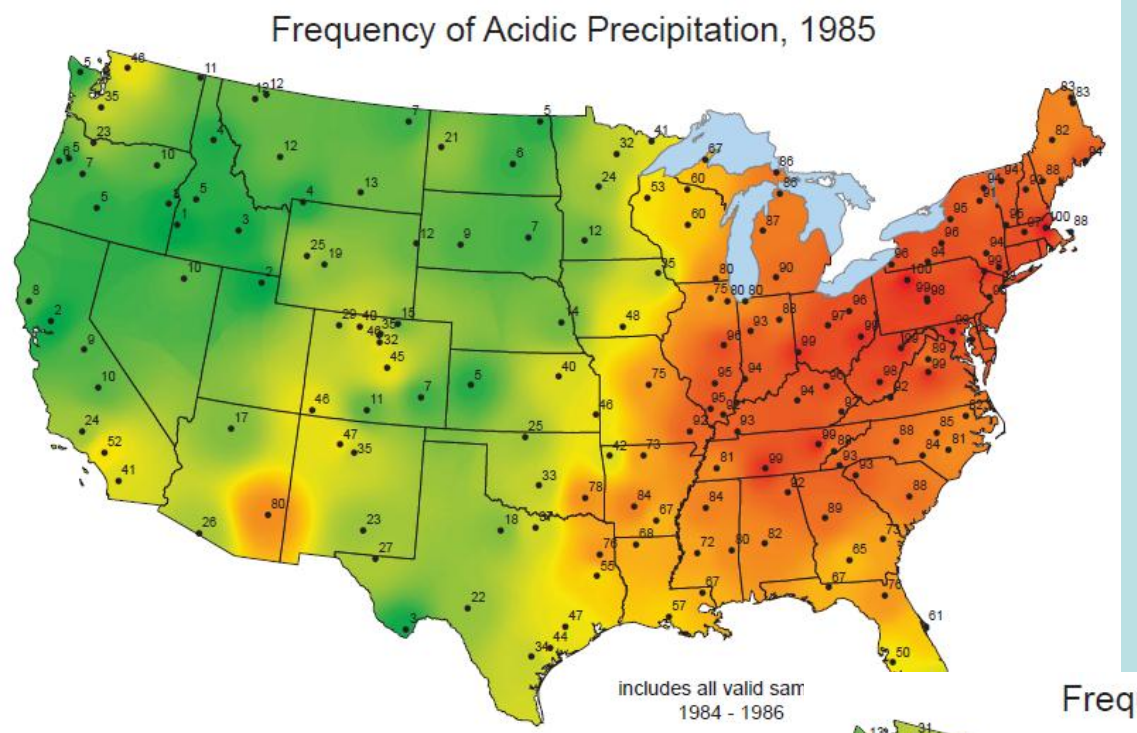
National Atmospheric Deposition Program/National Trends Network
http://nadp.isws.illinois.edu

pH Effects on Fish Population

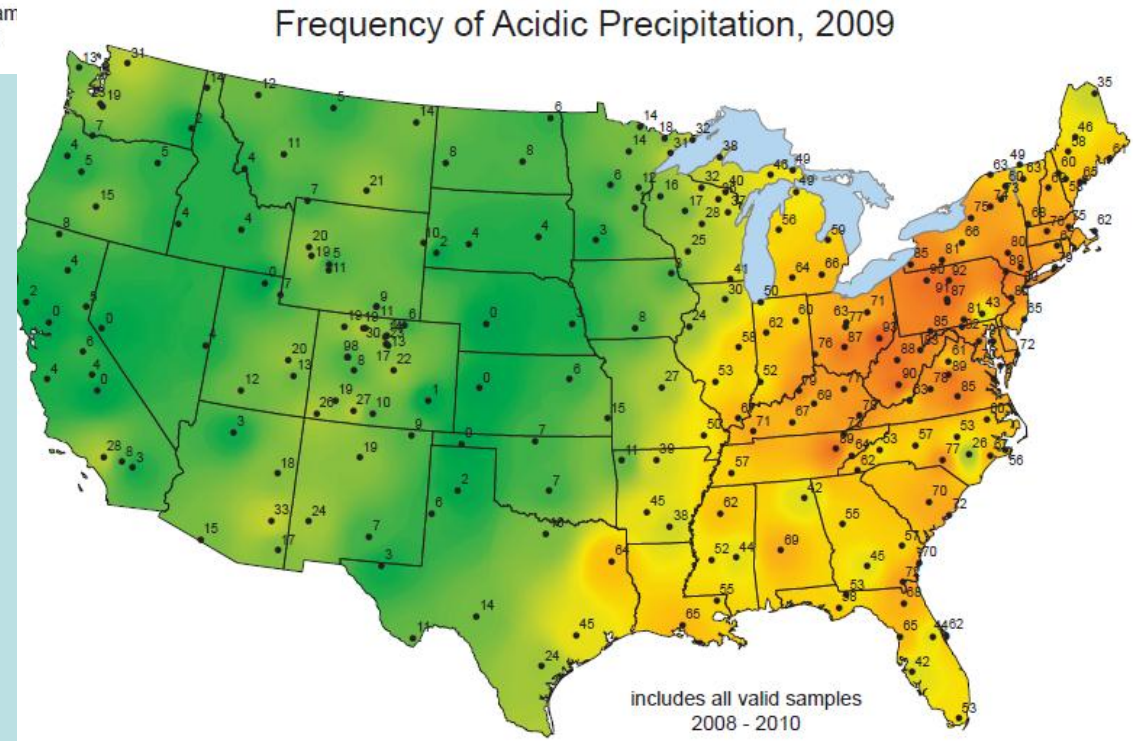


Source: HBRF, *Acid Rain Revisited*, 2001

Damage to Forests



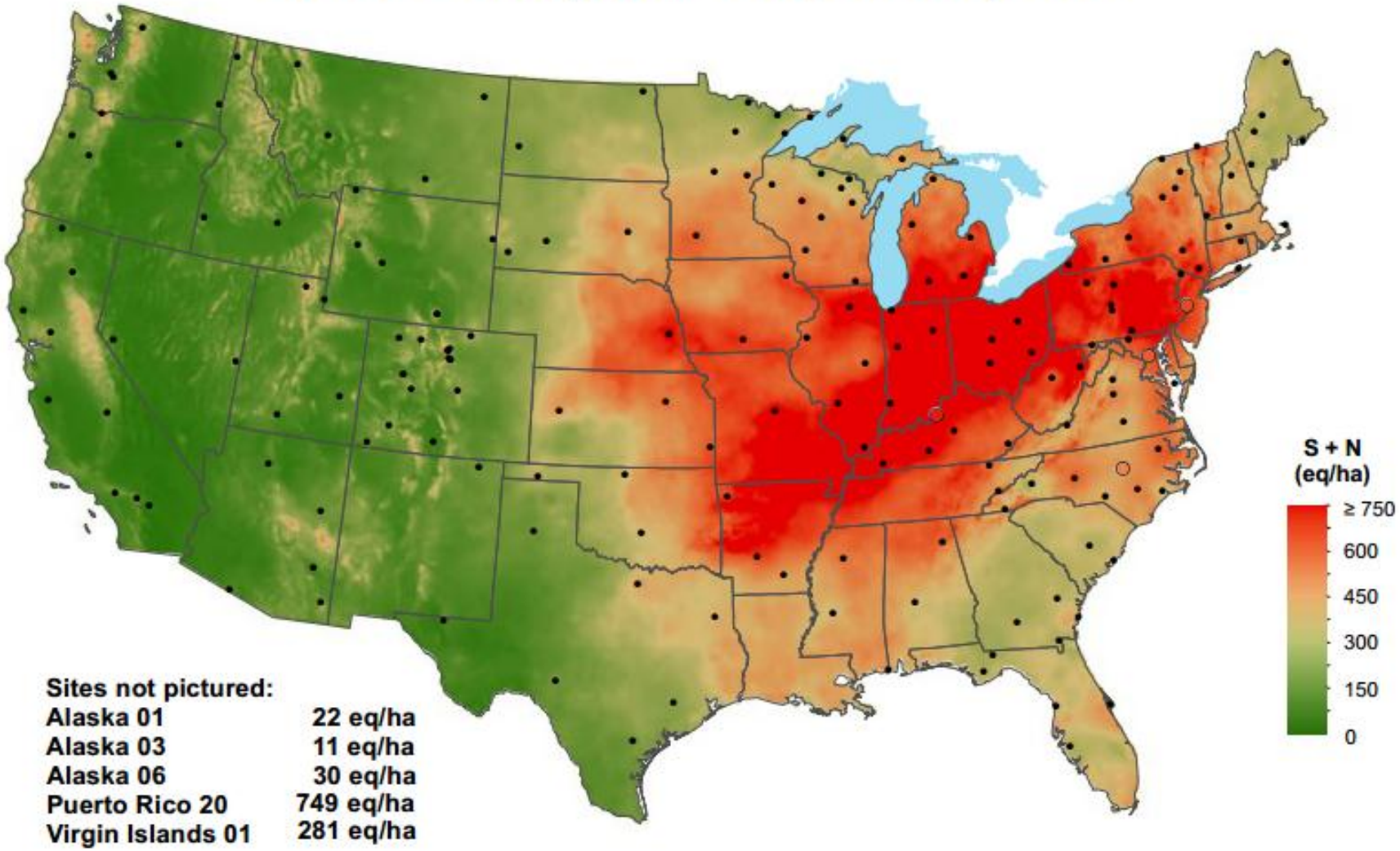
"Acid Rain" is still an issue.



Sulfate ($SO_4^{=}$) Deposition Animation

Anion most associated with combustion and acid rain
Deposition over time (kg per hectare per year)

Sulfur + Nitrogen wet deposition, 2011

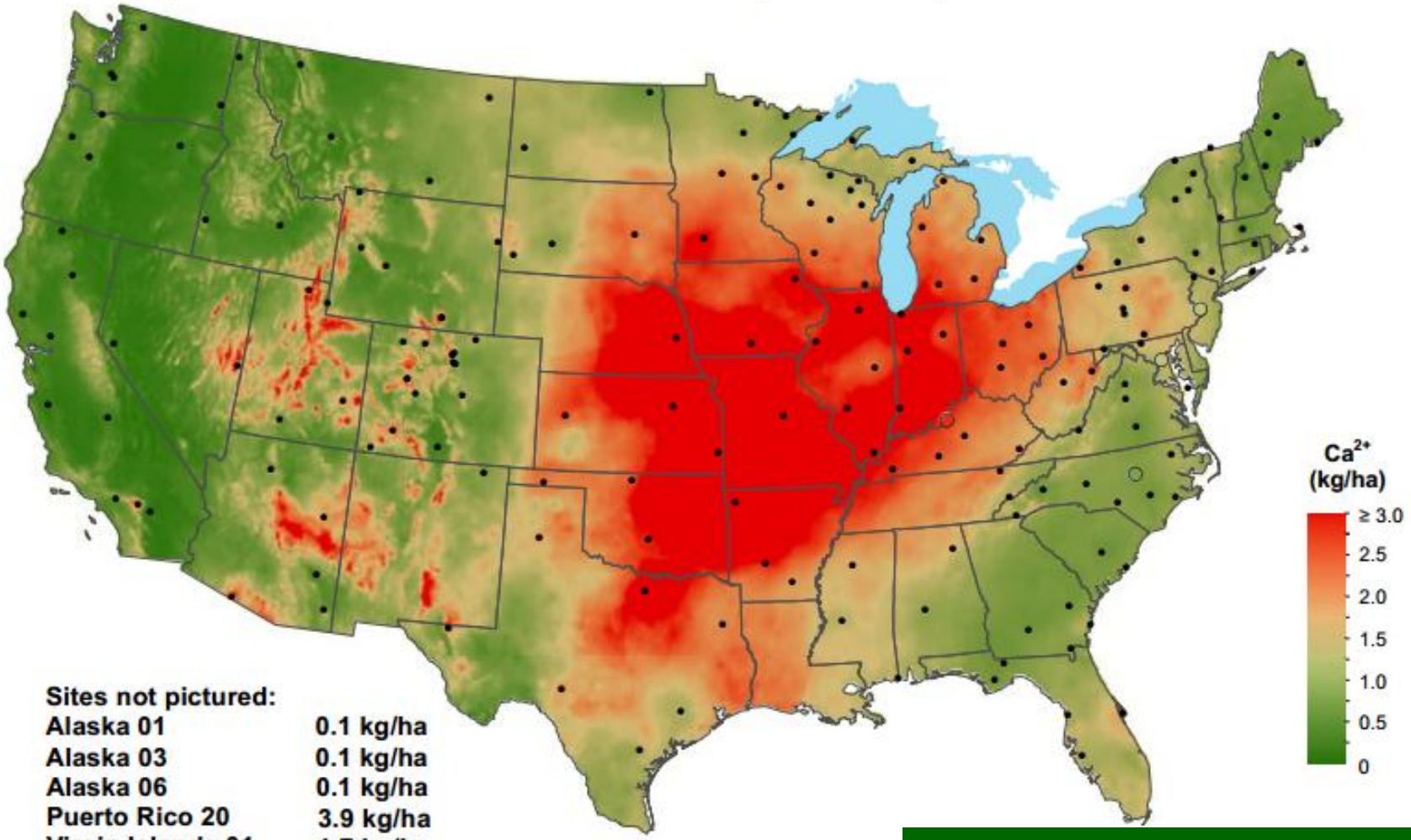


Sites not pictured:

Alaska 01	22 eq/ha
Alaska 03	11 eq/ha
Alaska 06	30 eq/ha
Puerto Rico 20	749 eq/ha
Virgin Islands 01	281 eq/ha

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

Calcium ion wet deposition, 2011



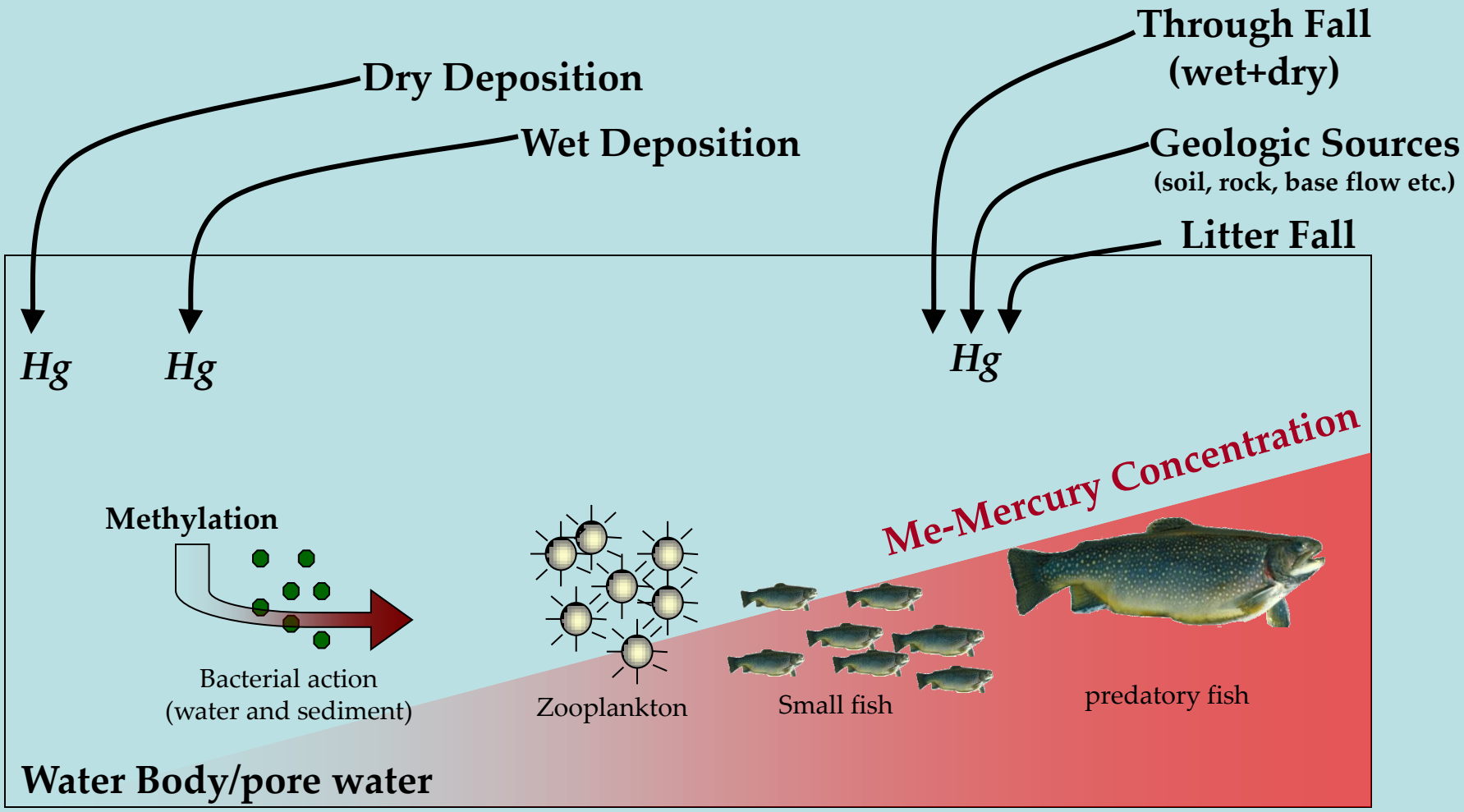
Sites not pictured:

Alaska 01	**0.1 kg/ha**
Alaska 03	**0.1 kg/ha**
Alaska 06	**0.1 kg/ha**
Puerto Rico 20	**3.9 kg/ha**
Virgin Islands 01	**1.7 kg/ha**

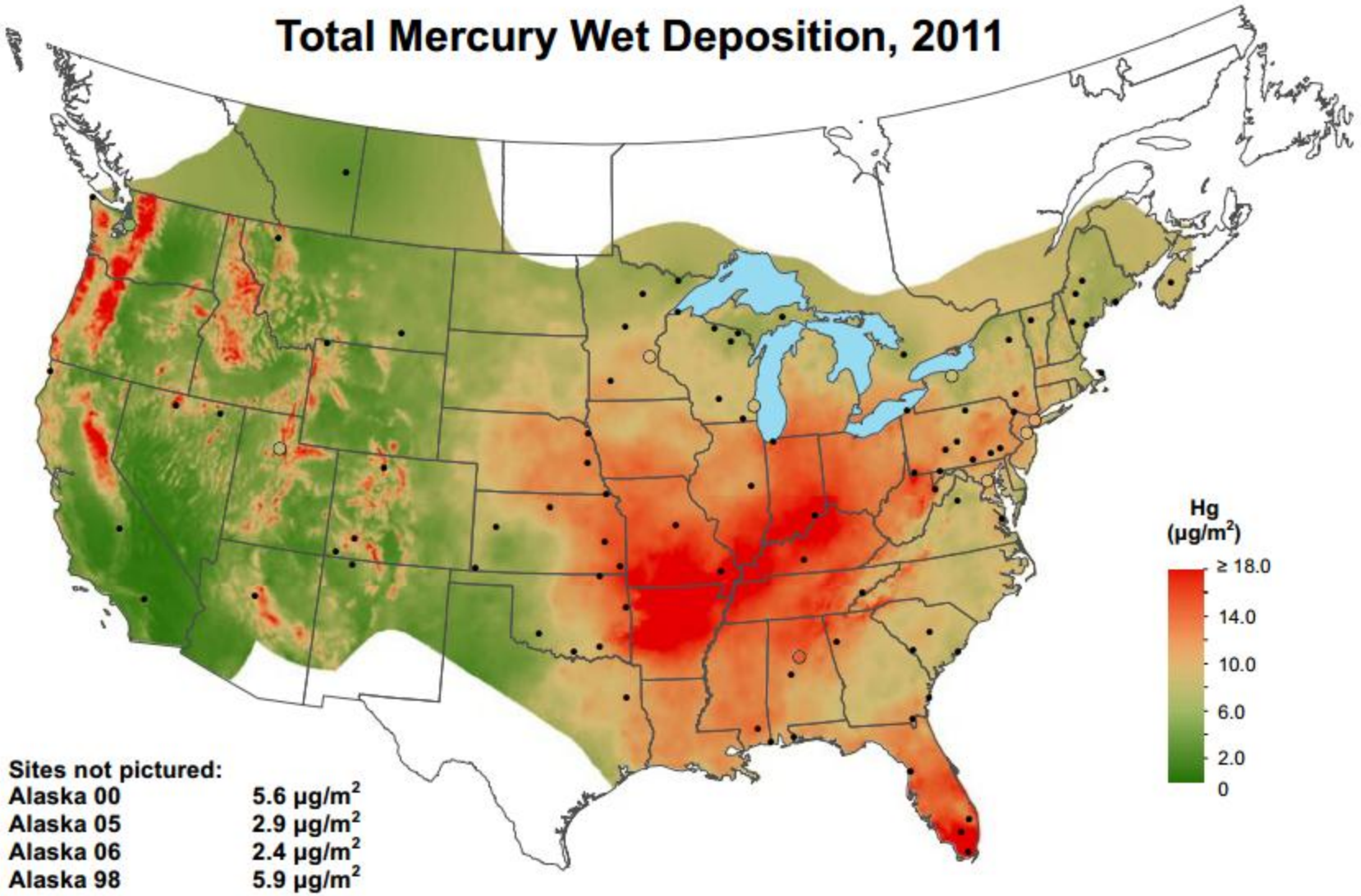
National Atmospheric Deposition Program/National Trends Network
http://nadp.isws.illinois.edu

Mercury Deposition

Bioaccumulation of Methyl Mercury



Total Mercury Wet Deposition, 2011

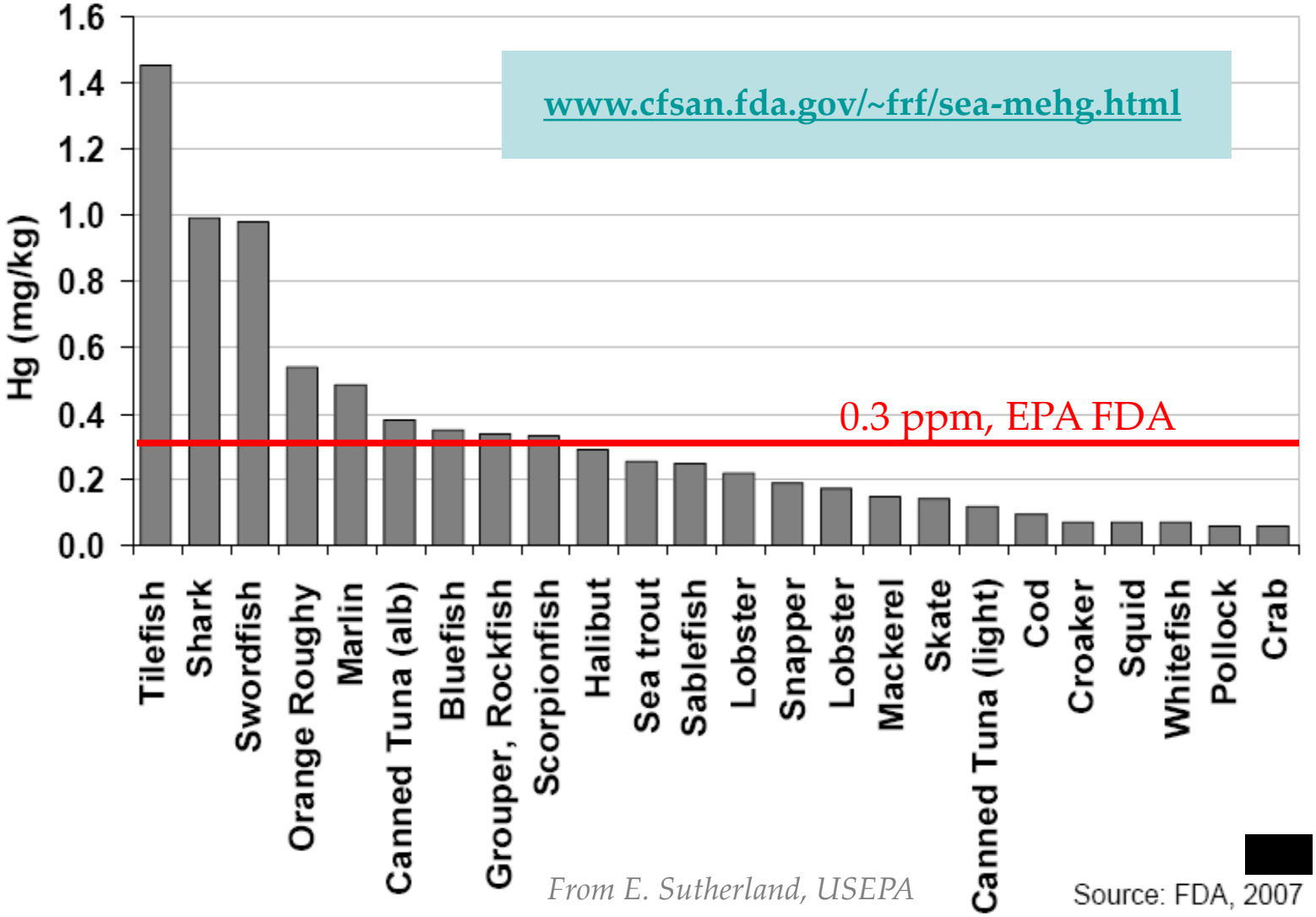


Sites not pictured:

Alaska 00	**5.6 µg/m²**
Alaska 05	**2.9 µg/m²**
Alaska 06	**2.4 µg/m²**
Alaska 98	**5.9 µg/m²**

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

FDA Reported National Hg Values



From E. Sutherland, USEPA

Many Sources of Atmospheric Mercury

- Coal combustion
- Incineration
  - Medical
  - Trash
  - Cremation
- Industrial emissions (chlor-alkali)
- Cement production (Hg in lime)
- Mining
  - Hg use in gold and silver mining (amalgam formation)
  - Mining for Hg
  - taconite
- Automobile Recycling
- Mercury in Landfills
  - Fluorescent lamps
  - dental amalgams (also in sewers)
  - Thermometers
  - Batteries
  - Discarded electrical switches
- Others will surface
  - Other carbon fossil fuels (gas/oil/diesel)?

- Volcanoes (St. Helens)
- Naturally enriched ores/soils
  - Plate tectonic boundaries
  - Cinnabar (HgS), taconite, others
- Soils and rocks (0.08 to 0.5 ppm in crust)
- Evaporation
  - Soils
  - Fresh water and Oceans
- Natural forest fires
  - Tree bark (wood fire places)
  - soils

- Volatilization from rocks?

- Wind Blown reintroduction
  - Mine tailings
  - Industrial contaminated soils

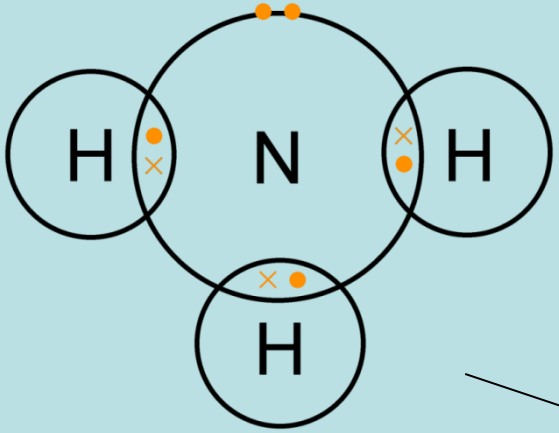
- Evolving Gases
  - Mines, industrial areas
  - Waste facilities (municipal in particular)
  - Out of soil

Marty will be covering more here….

Ammonia Deposition

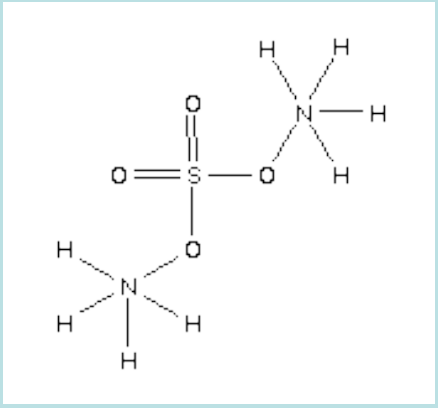
Ammonium (NH_4^+)

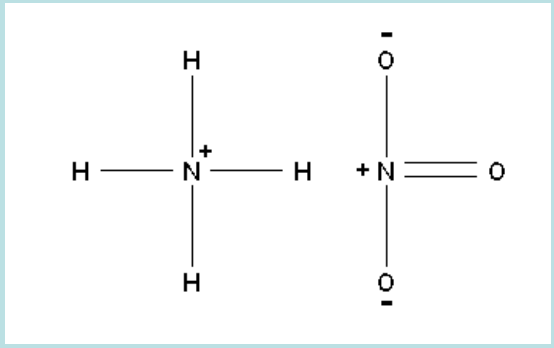
Why Measure?
NH3 is very Reactive, Forms Particulates, Nitrogen Addition



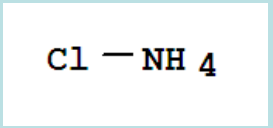
Other compounds

Ammonium sulfate



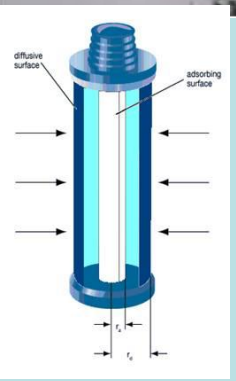


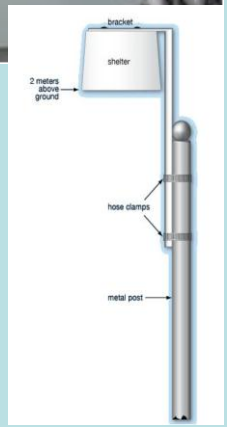
Ammonium nitrate



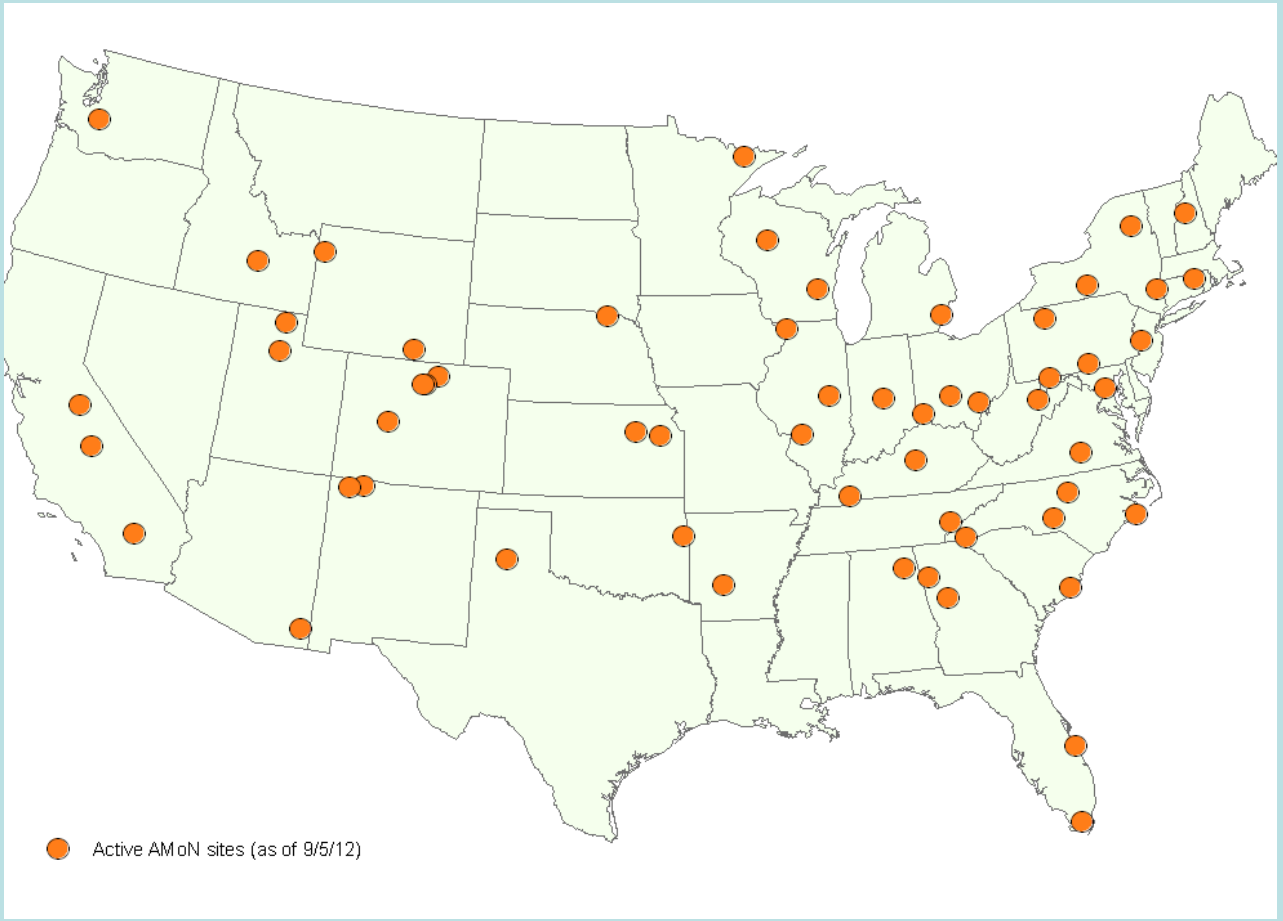
Ammonium chloride

AMoN Network Sites





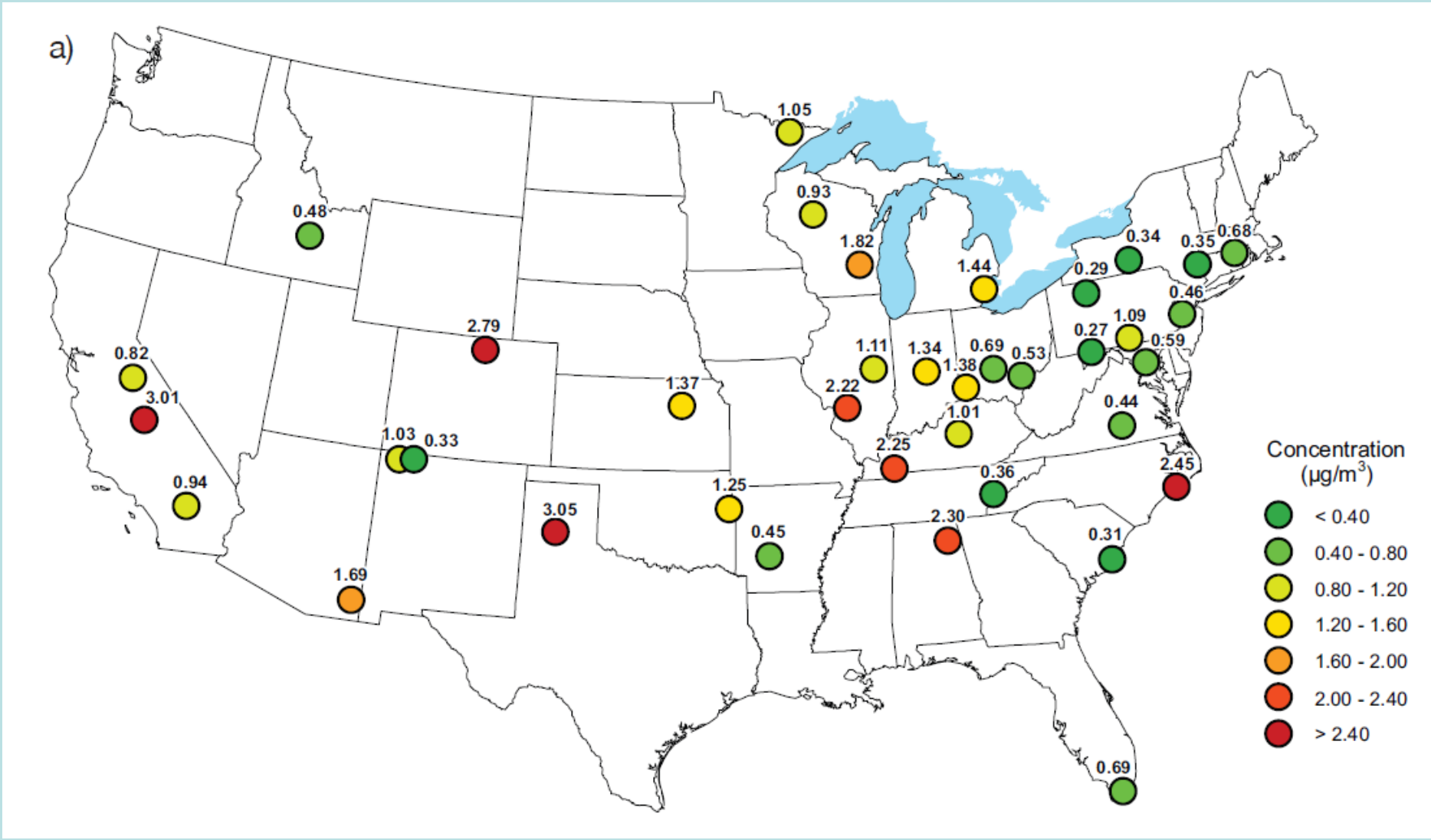
- 58 sites



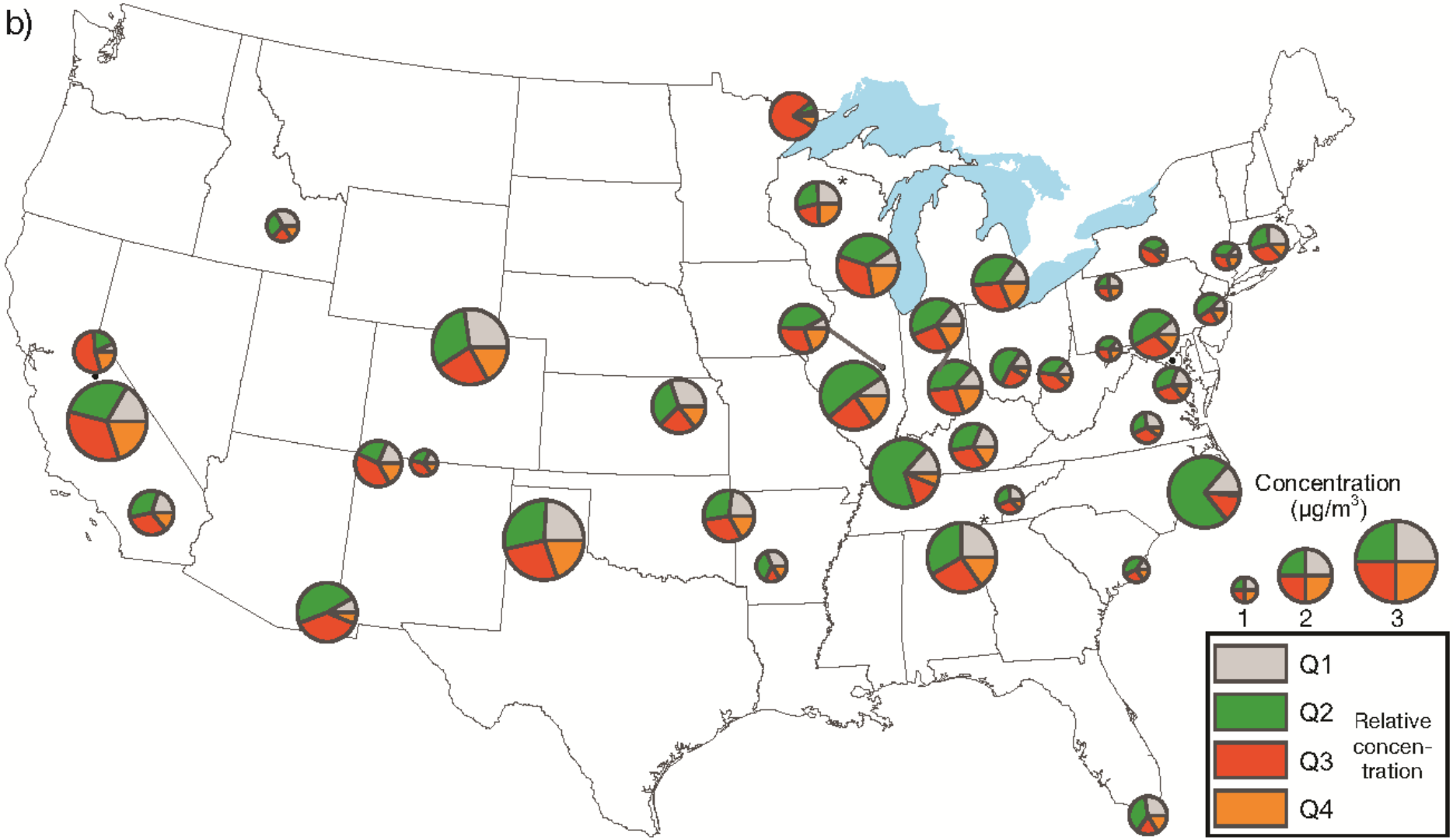

20 12:22AM


01/09/2008

2011 Annual Average Concentration

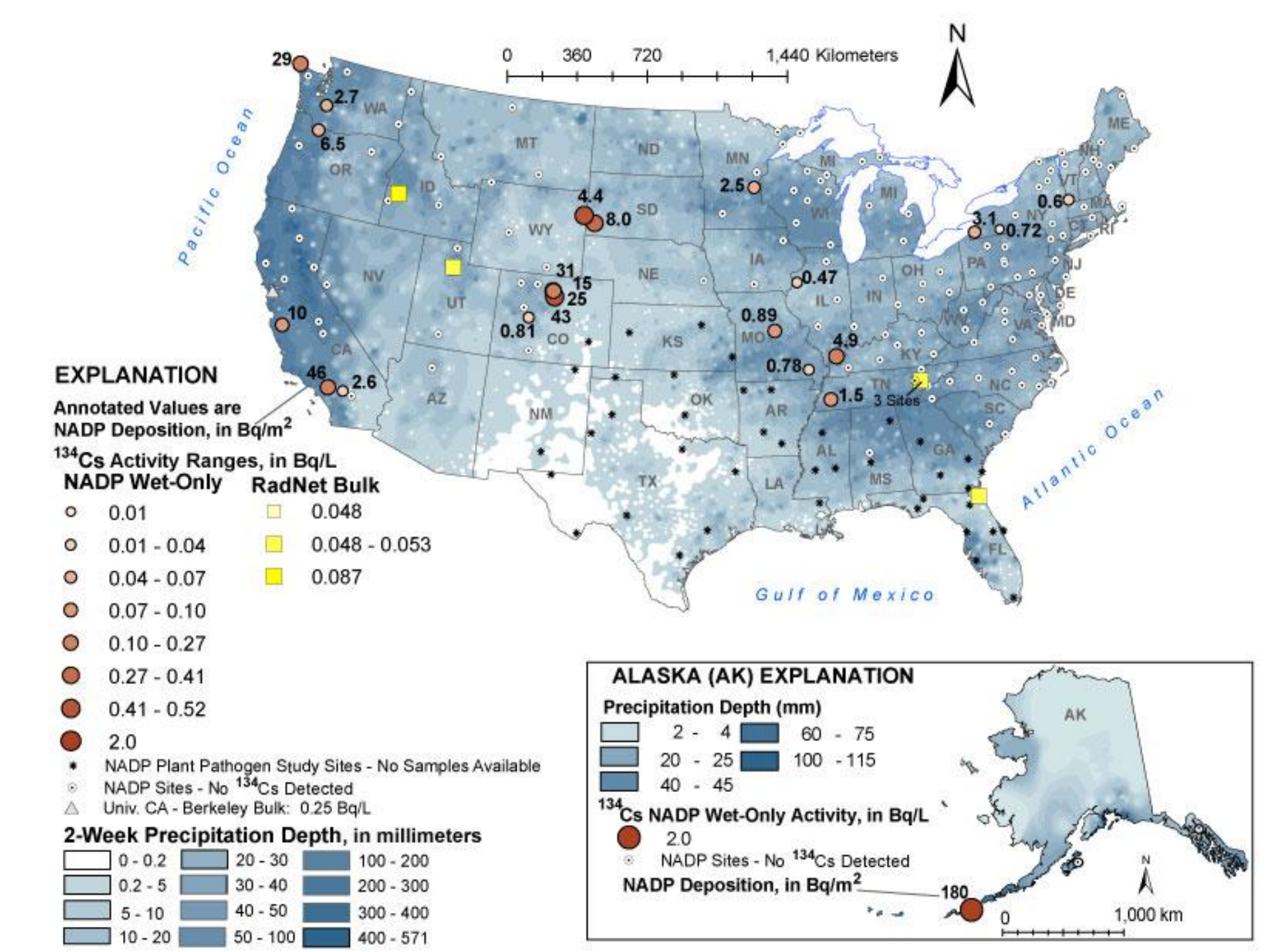


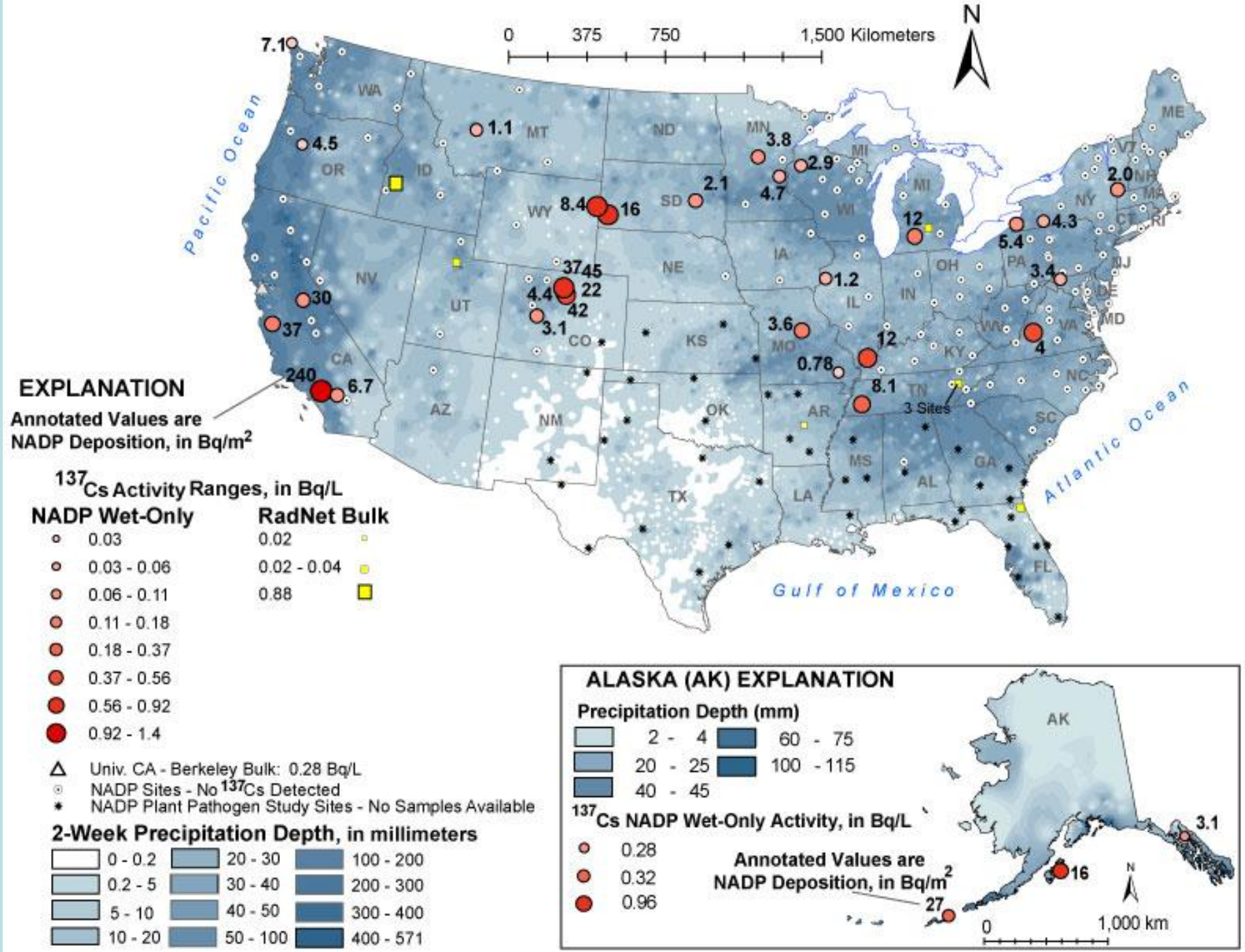
2011 Quarterly Average Concentration

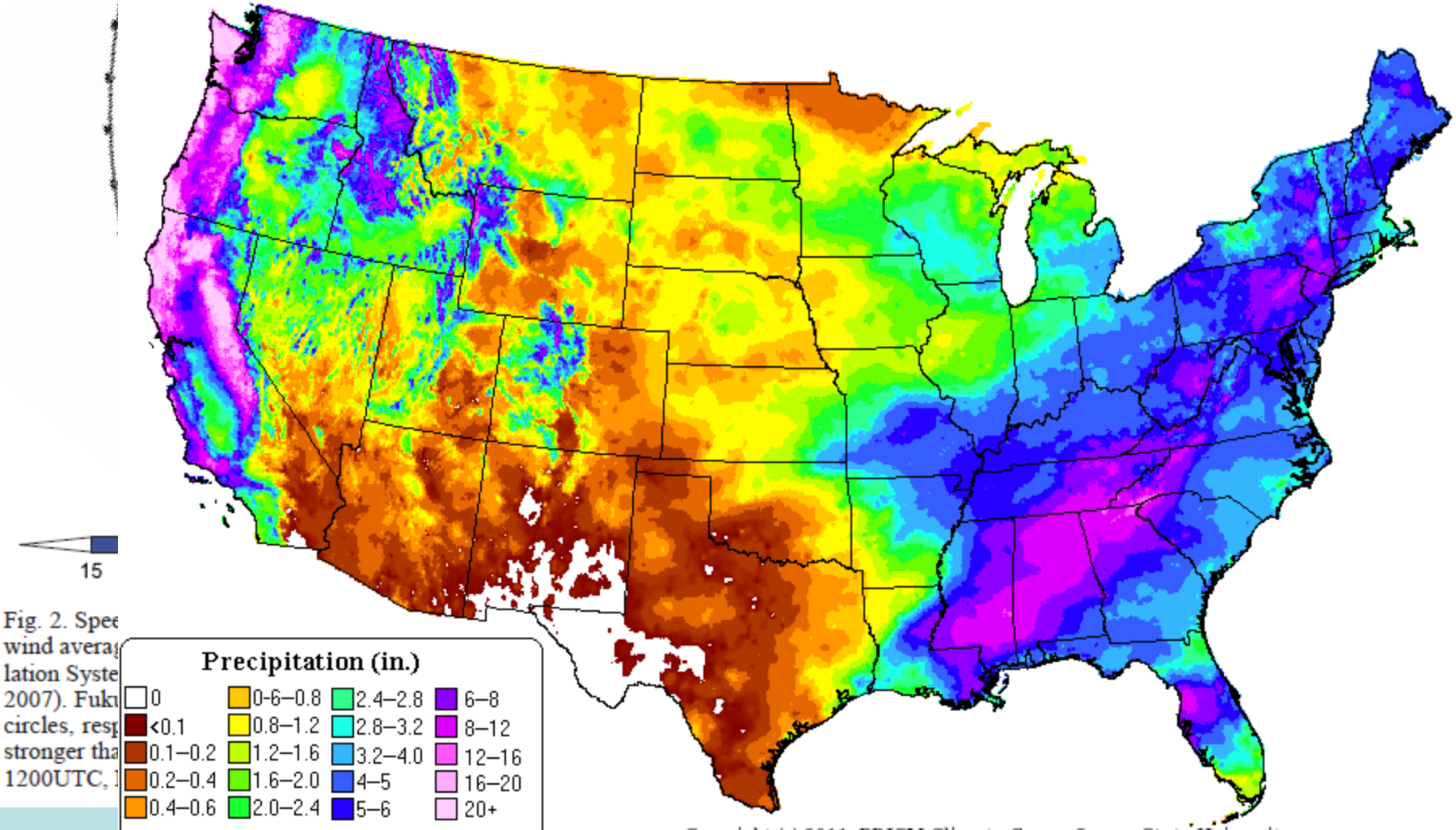


Radiation Deposition

NADP Monitoring Observations During Fukushima Accident


0 360 720 1,440 Kilometers
N
Pacific Ocean
Atlantic Ocean
Gulf of Mexico
WA
OR
CA
ID
NV
MT
WY
UT
AZ
CO
NM
ND
SD
NE
KS
OK
TX
MN
IA
MO
AR
LA
WI
IL
MS
MI
IN
KY
TN
AL
OH
WV
GA
FL
SC
NC
VA
PA
NY
MD
DE
NJ
CT
RI
MA
VT
NH
ME
29
2.7
6.5
10
46
2.6
4.4
8.0
31
15
25
43
0.81
2.5
0.47
0.89
4.9
0.78
1.5
3 Sites
3.1
0.72
0.6
EXPLANATION
Annotated Values are NADP Deposition, in Bq/m2
134Cs Activity Ranges, in Bq/L
NADP Wet-Only
0.01
0.01 - 0.04
0.04 - 0.07
0.07 - 0.10
0.10 - 0.27
0.27 - 0.41
0.41 - 0.52
2.0
RadNet Bulk
0.048
0.048 - 0.053
0.087
NADP Plant Pathogen Study Sites - No Samples Available
NADP Sites - No 134Cs Detected
Univ. CA - Berkeley Bulk: 0.25 Bq/L
2-Week Precipitation Depth, in millimeters
0 - 0.2
0.2 - 5
5 - 10
10 - 20
20 - 30
30 - 40
40 - 50
50 - 100
100 - 200
200 - 300
300 - 400
400 - 571
ALASKA (AK) EXPLANATION
Precipitation Depth (mm)
2 - 4
20 - 25
40 - 45
60 - 75
100 - 115
134Cs NADP Wet-Only Activity, in Bq/L
2.0
NADP Sites - No 134Cs Detected
NADP Deposition, in Bq/m2
180
AK
N
0
1,000 km


0 375 750 1,500 Kilometers
N
Pacific Ocean
Atlantic Ocean
Gulf of Mexico
7.1
4.5
1.1
3.8
2.9
4.7
2.1
8.4
16
2.0
12
4.3
5.4
3.4
1.2
37
45
22
42
4.4
3.1
30
37
3.6
12
4
0.78
8.1
240
6.7
3 Sites
WA
OR
CA
ID
NV
MT
WY
UT
AZ
CO
NM
ND
SD
NE
KS
OK
TX
MN
IA
MO
AR
LA
WI
IL
MS
MI
IN
KY
TN
AL
OH
WV
GA
FL
SC
NC
VA
PA
NY
ME
VT
NH
MA
CT
RI
NJ
DE
MD
EXPLANATION
Annotated Values are
NADP Deposition, in Bq/m2
137Cs Activity Ranges, in Bq/L
NADP Wet-Only
0.03
0.03 - 0.06
0.06 - 0.11
0.11 - 0.18
0.18 - 0.37
0.37 - 0.56
0.56 - 0.92
0.92 - 1.4
RadNet Bulk
0.02
0.02 - 0.04
0.88
Univ. CA - Berkeley Bulk: 0.28 Bq/L
NADP Sites - No 137Cs Detected
NADP Plant Pathogen Study Sites - No Samples Available
2-Week Precipitation Depth, in millimeters
0 - 0.2
0.2 - 5
5 - 10
10 - 20
20 - 30
30 - 40
40 - 50
50 - 100
100 - 200
200 - 300
300 - 400
400 - 571
ALASKA (AK) EXPLANATION
Precipitation Depth (mm)
2 - 4
20 - 25
40 - 45
60 - 75
100 - 115
137Cs NADP Wet-Only Activity, in Bq/L
0.28
0.32
0.96
Annotated Values are
NADP Deposition, in Bq/m2
27
16
3.1
AK
N
0
1,000 km



15

Fig. 2. Spee
wind averag
lation Syste
2007). Fuku
circles, resp
stronger tha
1200UTC,

Results in Context

- Detectable ^{131}I, ^{134}Cs, & ^{137}Cs

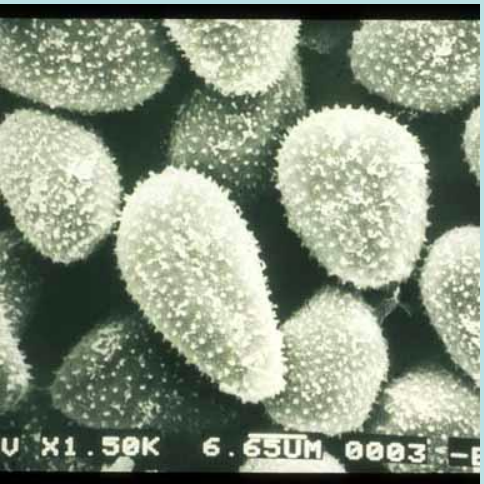
  20% of sampled locations.

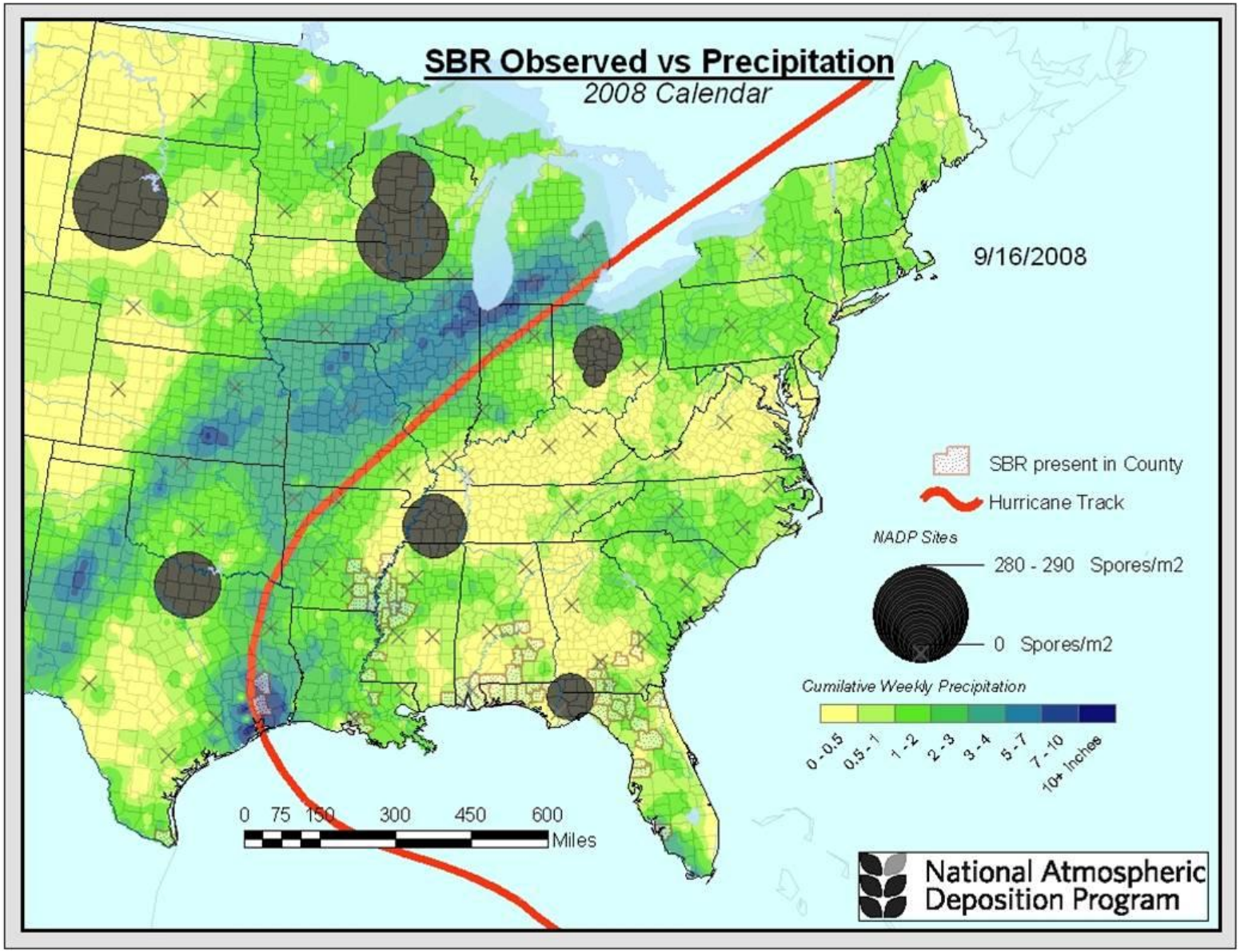
- Maximum ^{137}Cs deposition:

  ~ 3%-10% additional radioactivity to that present in a common m^2 of soil (5 cm deep).

- Maximum NADP-measured 137Cs (240 Bq/m^2)
  - ~ 17% of the NYC and Birmingham deposition (1,400 Bq/m2) during atmospheric nuclear testing in 1963.

Soybean Rust Deposition




SBR Observed vs Precipitation
2008 Calendar
9/16/2008
SBR present in County
Hurricane Track
NADP Sites
280 - 290 Spores/m2
0 Spores/m2
Cumulative Weekly Precipitation
0 - 0.5
0.5 - 1
1 - 2
2 - 3
3 - 4
5 - 7
7 - 10
10+ Inches
0 75 150 300 450 600
Miles
National Atmospheric Deposition Program

All of this information
(including data)
is on the web

http://nadp.isws.illinois.edu/amon

And NADP is open to all

Continuous Monitoring of Pollution in the Nation's Precipitation

David A. Gay

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National Atmospheric Deposition Program