United States Environmental Protection Agency

Secondary NAAQS for Oxides of Nitrogen and Sulfur

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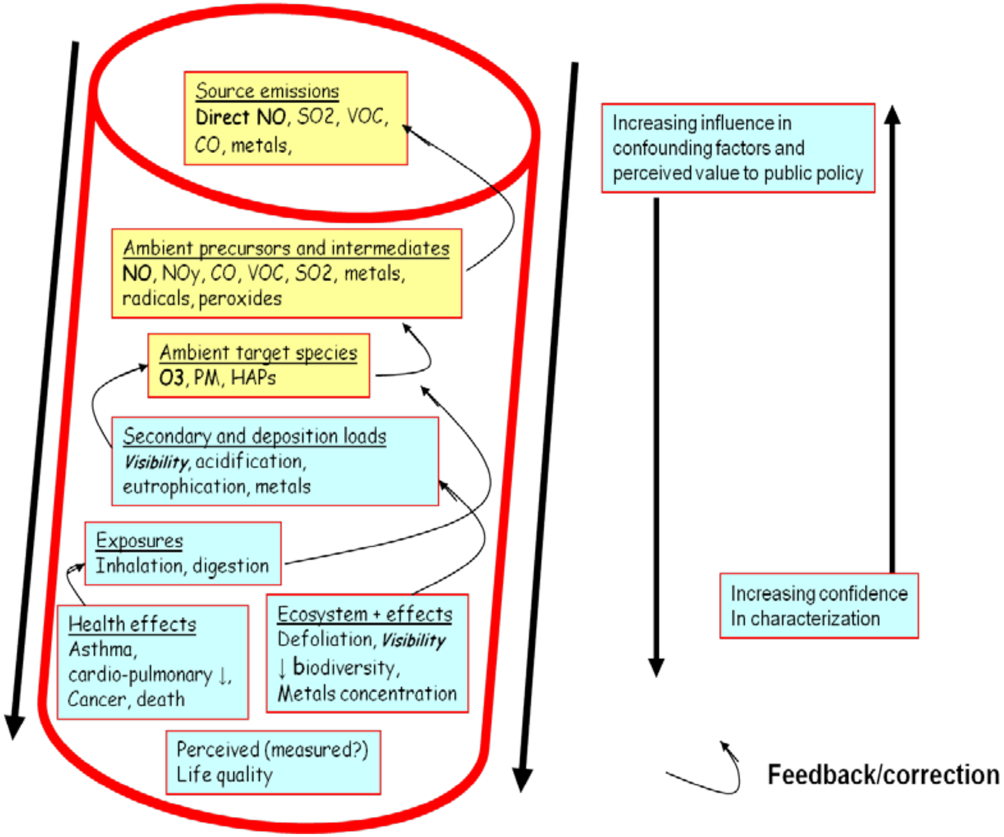
Case study on the Nexus of multiple pollutants, multiple environmental media, multiple models, observations, science, policy and politics

Office of Research and Development
National Center for Environmental Assessment

Roles of emissions and air quality based rules

- Emissions based rules (MACT, BACT, CAIR, MATS, ***Title IV*** (acid rain))
  - objective to reduce emissions, recognizing directional benefits but without a requirement to confirm benefits downstream
- Air quality based rules (NAAQS)
  - Objective is to reduce ambient air levels that associate with direct heath (human and environmental) outcomes
  - Built in iterative review of assessment of science and adequacy to enable modification



Source emissions
Direct NO, SO2, VOC, CO, metals,

Ambient precursors and intermediates
NO, NOy, CO, VOC, SO2, metals, radicals, peroxides

Ambient target species
O3, PM, HAPs

Secondary and deposition loads
Visibility, acidification, eutrophication, metals

Exposures
Inhalation, digestion

Health effects
Asthma, cardio-pulmonary ↓, Cancer, death

Ecosystem + effects
Defoliation, ***Visibility***
↓ biodiversity, Metals concentration

Perceived (measured?) Life quality

Increasing influence in confounding factors and perceived value to public policy

Increasing confidence In characterization

Feedback/correction

Background

- Since review initiated in 2006, EPA has completed the following milestones in conducting a review of the secondary standards for oxides of N and S :
  - Integrated Science Assessment (ISA, 2008)
  - Risk and Exposure Assessment (REA, 2009)
  - Staff Policy Assessment (PA, 2011)

- Resulting in:
  - Reaffirming existing secondary stnds. Related to gaseous exposure and vegetation harm
  - Emphasis on deposition related effects – aquatic and terrestrial acidification, nutrient enrichment
  - Focus on aquatic acidification and development of aquatic acidifcation index (AAI) as the basis for a new ecologically relevant standard

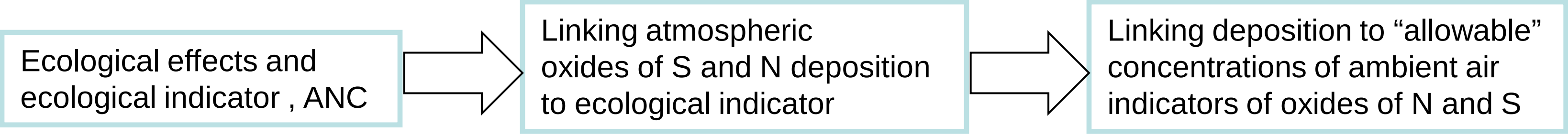
[first review independent from primary standards; multiple pollutant, and multiple media]

Background, cont.

- On July 12, 2011 EPA proposed/stated
  - To retain existing secondary standards
  - Current standards afford inadequate protection from deposition effectse
  - Not to forward an *AAI based standard*
  - Set the secondary stnds. equivalent to the 1-hr primary standards for NO_2 and SO_2
  - Conduct a pilot studies field program in 3-5 ecoregions
    - *Unique collaboration opportunity*

- Under a court ordered schedule to sign final rule by March 20, 2012
  - Includes an extension of 18 months granted by the plaintiffs on the basis that we needed more time to develop an ecologically relevant standard

Conceptual model an aquatic acidification standard



Ecological effects and ecological indicator , ANC

Linking atmospheric oxides of S and N deposition to ecological indicator

Linking deposition to “allowable” concentrations of ambient air indicators of oxides of N and S

- Unlike most other NAAQS that are based on the direct relationship between pollutant concentrations in the air and effects on health or welfare, this standard necessarily involves multiple linkages, since aquatic effects are not directly related to concentrations of oxides of N and S in the ambient air
- Linkage between *ecological effects and deposition* of oxides of N and S is characterized by critical load modeling
- Linkage between *deposition and air concentrations* of oxides of N and S is characterized by atmospheric modeling that translates emissions of N and S into ambient concentrations and deposition
- Model also takes into account deposition of N from reduced forms of nitrogen (e.g., ammonia) that contributes to the aquatic effects but is not part of the “criteria” pollutants addressed by this standard

What is the Aquatic Acidification Index (AAI)?

- AAI is the expected long term ANC sustained by a representative set of water bodies for a given atmospheric state of ambient concentrations of oxides of N and S, given:
  - known deposition rate of reduced nitrogen (NHx)
  - representative steady state critical load estimates
    - Implying knowledge of biogeochemistry and hydrological attributes

Derivation of the AAI

- Starting with a modified version that incorporates attributes of SSWC and FAB steady state models
  - CL= $(BC_0^* - ANClim)Q + Neco$
    - Where Neco represents all N loss terms (uptake, denitrification, immobilization); estimated as N deposition – NO_3 leaching (not strictly ss)
    - $BC_0^* = [BC^*]_t - F([AA]_t^* - [AA]_0^*)$, based on water quality data
    - National water quality data base of over 9,000 water bodies (J. Lynch)
  - Step 1 – separate Cl deposition into oxidized S,N, and NHx deposition components
  - Step 2 - represent deposition of oxidized N and S in terms of concentration – deposition velocity relationships
  - Step 3 – Convert deposition exceedances to concentration exceedance
  - Step 4- rearrange terms to relate potential ANC as a function of concentrations of oxides of S and N

Form of the standard

Aquatic Acidification Index (AAI) $= F_1 - F_2 - F_3\,[NOy] - F_4\,[SOx]$

$$AAI = (ANClim + CL_r/Q_r) - NHxdep/Q_r - T_{NOy}\,[NOy]/Q_r - T_{SOx}[SOx]/Q_r$$

- Components of the form:
  - AAI : calculated ANC expected to result *over time* from deposition associated with monitored NOy and SOx concentrations
  - $F_1 = (ANClim + CL_r/Q_r)$
    - natural ability of an ecosystem to neutralize deposition
    - $CL_r = (BC_0^{*} - ANClim)Q_{wb}$
    - Q_r = median runoff rate of sampled water bodies
  - F_2 = NHx deposition/Q_r
    - reduced nitrogen (ammonia gas and ammonium ion) deposition
  - F_3, F_4 are transference ratios; T_{SOx} = SOx deposition/[SOx]; T_{NOy} = Noy deposition/NOy
    - factors that convert measured NOy and SOx in the ambient air to NOy and SOx deposition

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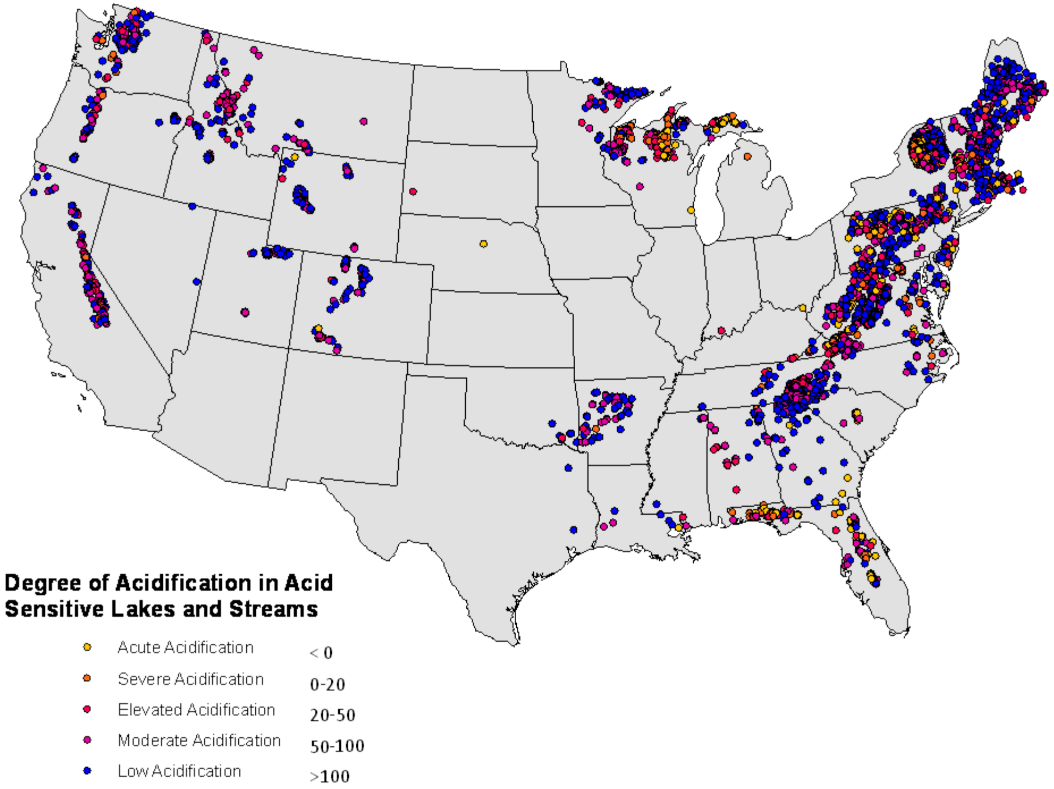
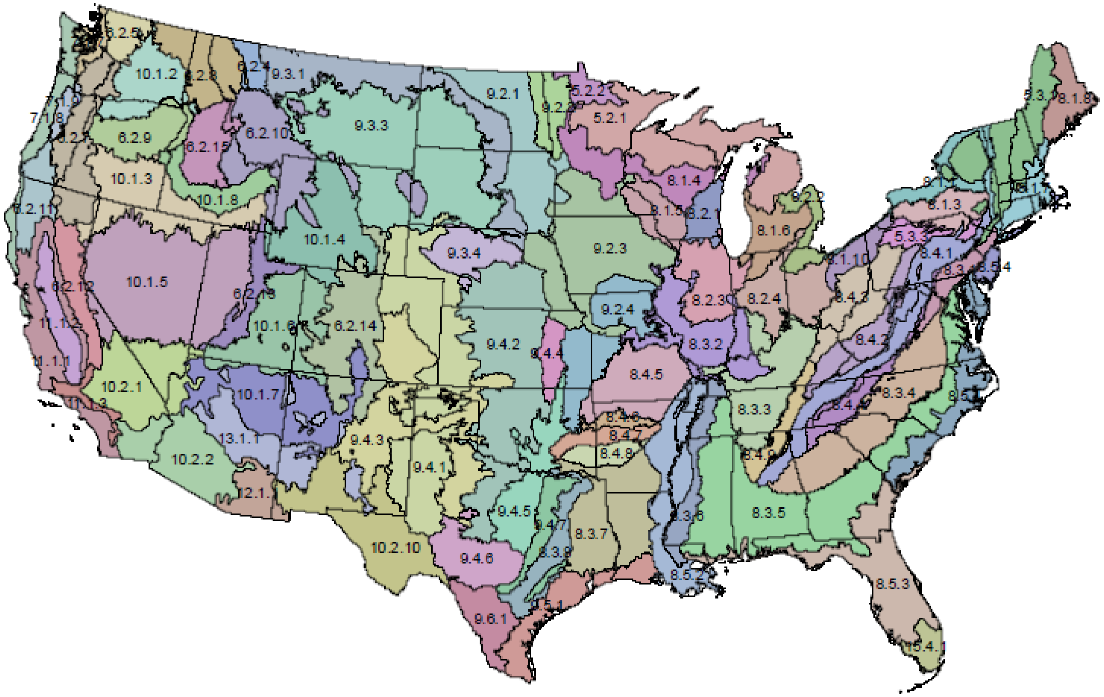
Regional Sensitivity to Acidification



- Ecosystem sensitivity varies across the nation, predominantly due to variability of geologic material (bedrock and soils) which buffers acidifying deposition.
- *Focus of this secondary standard is on aquatic systems located in relatively pristine, rural environments – typically, high elevation clear water bodies supporting trout fisheries*
- Map based on water quality data available through EPA monitoring programs

Defining appropriate ecoregions

- Omernik Ecoregion III classification scheme (developed in the 1980s by EPA) divides the U.S. into ecologically relevant regions (84 regions cover the continental U.S.)
  - Based on common vegetation, geology, soils, and hydrological characteristics



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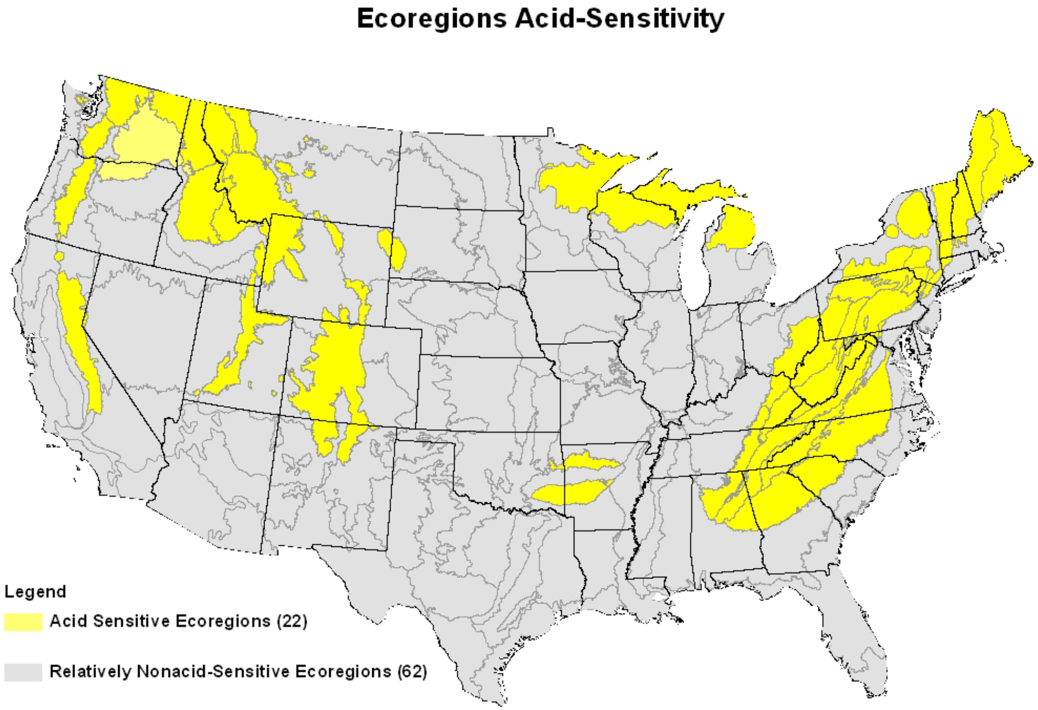
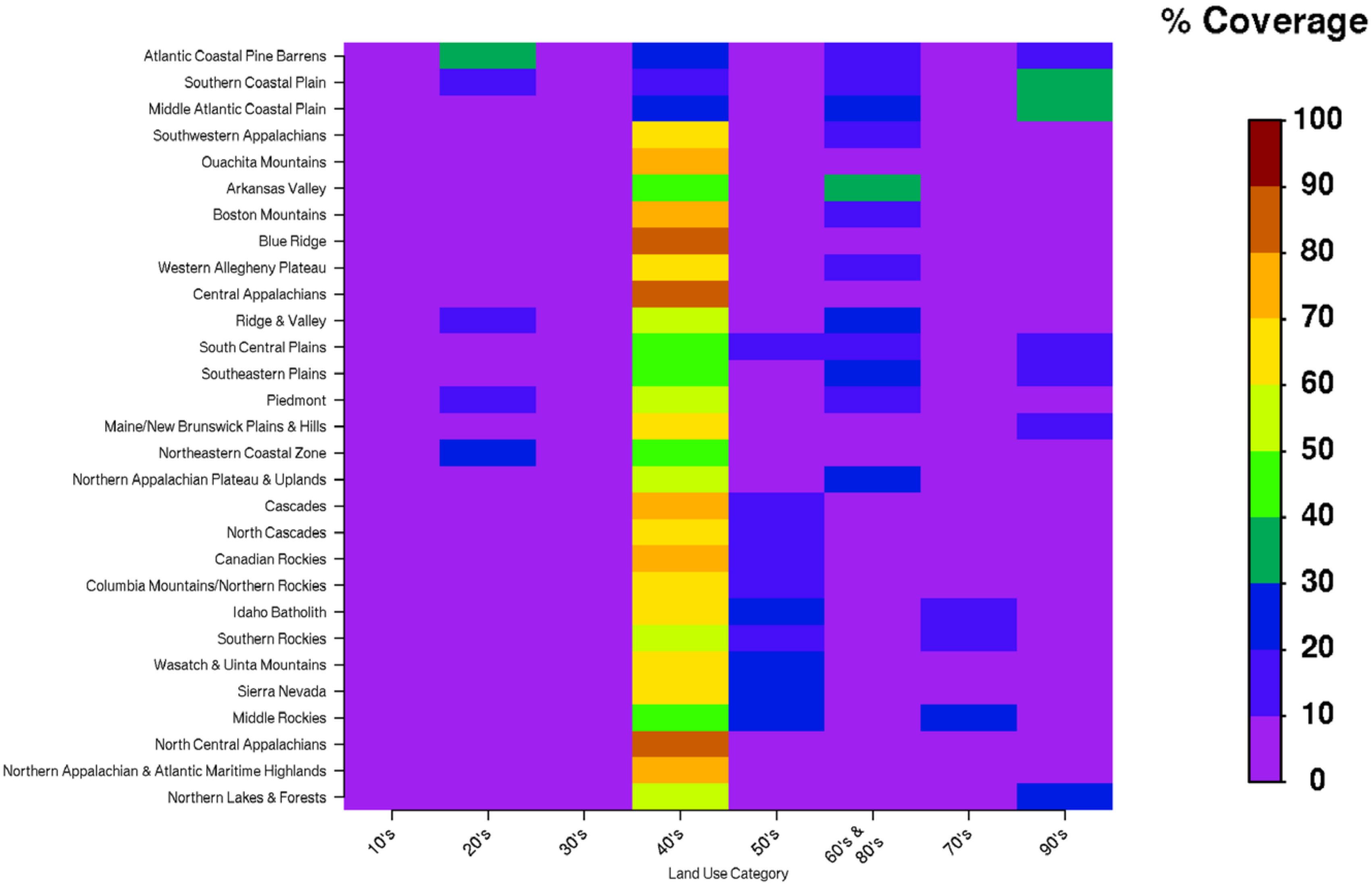
Acid sensitive and non-sensitive ecoregions

- While the standard would apply nationwide, categorizing ecoregions as relatively acid-sensitive (22 areas) or non-sensitive (~62 areas) serves to identify areas that will benefit most from reductions in NOy and SOx deposition (similar to “susceptible populations” for health-based standards)
- Categorization based on water quality data and land use categories (naturally acidic and managed areas categorized as relatively non-sensitive)



2006 NLCD land use data by ECO III



Dev

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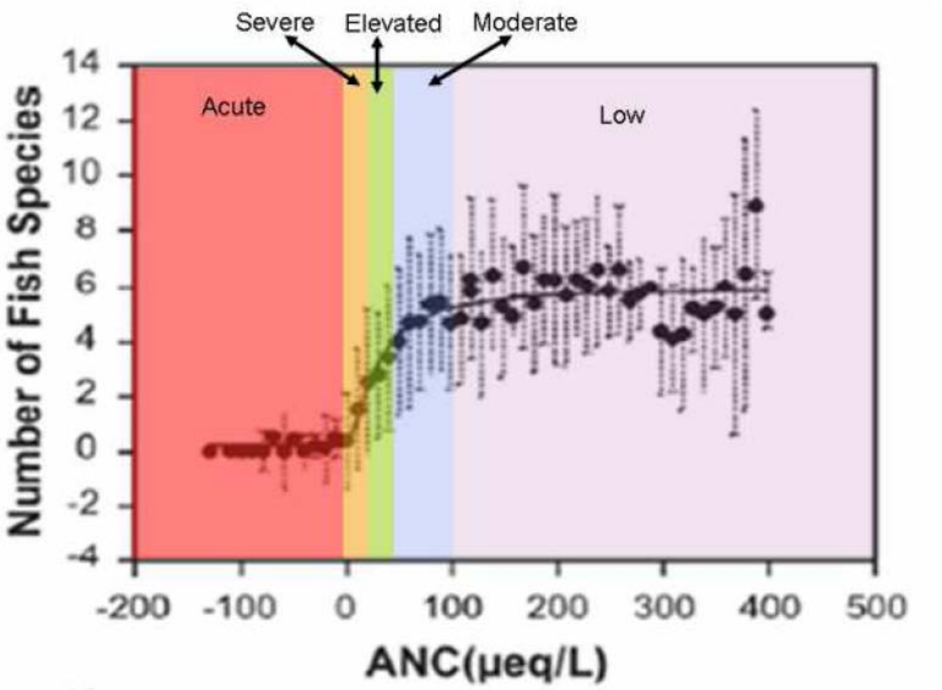
Ecoregion-specific factors (F1 – F4)

- Each ecoregion has a unique set of factors, F1 – F4, based on data averaged across the ecoregion
  - F1 is determined based on selecting a representative critical load of sampled water bodies for each ecoregion
    - For acid sensitive regions, a representative critical load is defined in terms of a specific percentile of the distribution of critical loads that have been calculated for each ecoregion
      - Use of a higher percentile (e.g., 90th percentile) would be more protective than a lower percentile (e.g., 70th percentile)
    - For relatively non acid-sensitive ecoregions, consider using a national default critical load based on averaging the 50th percentile values from all such ecoregions
      - This different approach is intended to avoid potential for over protection in relatively non acid-sensitive ecoregions
  - F2, F3, and F4 are based on CMAQ (Community Multi-scale Air Quality Model) modeling, which translates emissions of N and S into ambient concentrations and deposition
- EPA would calculate and codify (as part of NAAQS rulemaking) F values for each ecoregion and provide tables – update every 5 year
  - Logically build off of the National critical load data base effort and new CMAQ simulations

Level of the standard

- Policy Assessment focused on a range of values from 20 – 75 µeq/L
  - Range would afford some degree of protection from long-term, chronic aquatic acidification
  - Upper part of range would afford:
    - Added protection for episodic acidification (e.g., spring snowmelt)
    - Shorter time frame for some water bodies to reach a target ANC



Alternative Standards

- Level and form together determine the degree of protection afforded by standard

- Alternative levels (*20 – 75 µeq/l*) and forms (F1 based on *70th to 90th percentile*) were assessed in terms of whether acid-sensitive ecoregions would likely not meet alternative standards
    - Anticipate that all non acid-sensitive ecoregions would meet this range of standards

Results – by ANC level and percentile

Least protective
ANC = 20; 70 %

	70th	75th	80th	85th	90th
ANC20 4 5 5 8 13	N.Central App. Ridge and Valley Central App. Blue Ridge	N.Central App. Ridge and Valley Central App. Blue Ridge SW App.	N.Central App. Ridge and Valley Central App. Blue Ridge SW App.	N.Central App. Ridge and Valley Central App. Blue Ridge SW App. W. Allegeheny N. Lakes Boston mtns.	N. Highlands(Adks) N.Central App. Ridge and Valley Central App. Blue Ridge SW App. W. Allegeheny Piedmont Boston mtns. Ouachita mtns. N. Lakes Sierre Nevada Cascades
ANC35 5 5 9 11 13	N.Central App. Ridge and Valley Central App. Blue Ridge SW App.	N.Central App. Ridge and Valley Central App. Blue Ridge SW App.	N. Highlands(Adks) N.Central App. Ridge and Valley Central App. Blue Ridge SW App. Boston Mtns. N. Lakes Sierre Nevada	N. Highlands(Adks) N.Central App. Ridge and Valley Central App. Blue Ridge SW App. W. Allegheny Boston Mtns. N. Lakes Sierre Nevada Cascades	N. Highlands(Adks) N.Central App. Ridge and Valley Central App. Blue Ridge SW App. W. Allegheny Piedmont Boston mtns. Ouachita mtns. N. Lakes Sierre Nevada Cascades
ANC50 6 8 11 14 15	N.Central App. Ridge and Valley Central App. Blue Ridge SW App. Sierre Nevada	N. Highlands(Adks) N.Central App. Ridge and Valley Central App. Blue Ridge SW App. N. Lakes Sierre Nevada	N. Highlands(Adks) N.Central App. Ridge and Valley Central App. Blue Ridge SW App. W. Allegheny Boston mtns. N. Lakes Sierre Nevada Idaho Batholith	N. Highlands(Adks) N.Central App. Ridge and Valley Central App. Blue Ridge SW App. W. Allegheny Piedmont Boston mtns. Ouachita mtns. N. Lakes Sierre Nevada Cascades Idaho Batholith	N. Highlands(Adks) Maine/N.B. Hills N.Central App. Ridge and Valley Central App. Blue Ridge SW App. W. Allegheny Piedmont Boston mtns. Ouachita mtns. N. Lakes Sierre Nevada Cascades Idaho Batholith
ANC75 10 11 14 15 22	N. Highlands(Adks) N.Central App. Ridge and Valley Central App. Blue Ridge SW App. Boston Mtns N. Lakes Sierra Nevada Idaho Batholith	N. Highlands(Adks) N.Central App. Ridge and Valley Central App. Blue Ridge SW App. Boston Mtns N. Lakes Sierra Nevada Cascades Idaho Batholith	N. Highlands(Adks) Maine/N.B. Hills N.Central App. Ridge and Valley Central App. Blue Ridge SW App. W. Allegheny Piedmont Boston Mtns N. Lakes Sierra Nevada Cascades Idaho Batholith	N. Highlands(Adks) Maine/N.B. Hills N.Central App. Ridge and Valley Central App. Blue Ridge SW App. W. Allegheny Piedmont Boston Mtns Ouachita mtns. N. Lakes Sierra Nevada Cascades Idaho Batholith	N. Highlands(Adks) Maine/N.B. Hills N.Central App. Ridge and Valley Central App. Blue Ridge SW App. W. Allegheny N. App plateau Piedmont Boston Mtns Ouachita mtns. N. Lakes Sierra Nevada Cascades Idaho Batholith Canadian Rockies N. Rockies M. Rockies S. Rockies N. Cascades Wastach/Uinta mtns

🟥 northeast mtns., 🟦 central/southern Appalachians, 🟨 southern Piedmont, 🟩 Ozark region, ■ northern midwest Lakes, ▨ western mountains

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▨ western mountains

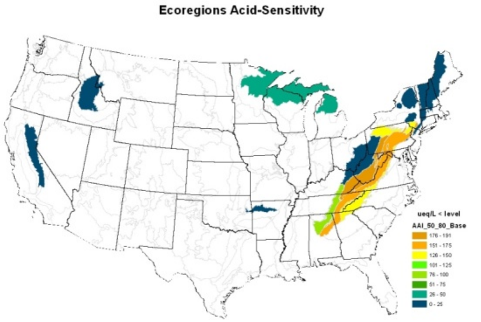
Most protective
ANC =75; 90 %

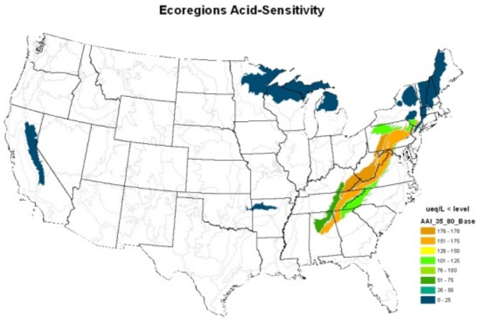
Ecoregions not likely to meet alternative standards

ANC 50, 80%

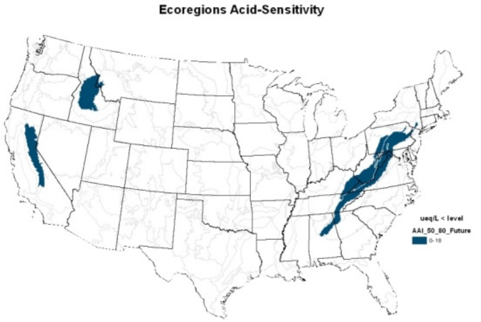
ANC 35, 80%

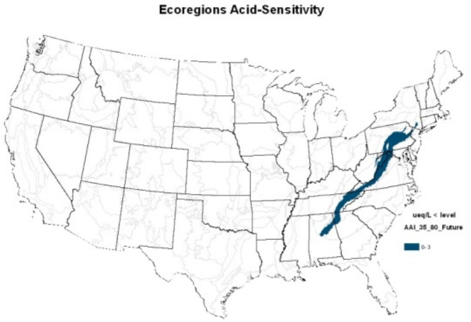
2005





Policy assessment results
Emissions sensitivity run:
42% and 48% SOx, NOx reduction





2016 projection
39% NOx and 73% SOx reductions

Conclusions

- AAI formulation is consistent with current understanding of adversity and expected future response
- Role of nitrogen, particularly NHx, increases (over time) relative to sulfur
  - western based aquatic acidification gradually displaces Eastern U.S. aquatic acidification?
- Data base enrichment – air, terrestrial and aquatic media will reduce uncertainties, and identify new ones

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Additional Slides

Critical Load modeling to AAI

AAI equation is derived from the CL expression by (1)separating out NHx, (2) defining a deposition exceedance, (3) defining an ANClim exceedance, (4) translating an ANClim exceedance to a calculated AAI as the air quality/deposition below that to achieve and ANClim:

1) $CL\ (N + S) = ([BC]_0^* - [ANC_{lim}])Q + Neco = [NOy]T_{NOy} + [SOx]T_{SOx} + NHx;$

note: T's are aggregated deposition velocities

2) $DEPex = [NOy]T_{NOy} + [SOx]T_{SOx} + NHx - CL$

3) $ANClim_{ex} = DEPex/Q_r = \{[NOy]T_{NOy} + [SOx]T_{SOx} + NHx - CL\}/Q_r$

note: Qr is a representative runoff rate to balance units

4) $ANCcalc = ANClim - \{[NOy]T_{NOy} + [SOx]T_{SOx} + NHx - CL\}/Q_r$

Rearranging:

$$AAI = (ANClim + CL_r/Q_r) - NHxdep/Q_r - T_{NOy}[NOy]/Q_r - T_{SOx}[SOx]/Q_r$$

Condition Ndep < Neco, $CL\ (N + S) = ([BC]_0^* - [ANC_{lim}])Q$ *and NHx and* $T_{NOy} = 0$