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Comments on the Final Policy Assessment Document EPA Review of the Secondary NAAQS for SOx and NOx

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Chapel Hill, NC

EPRI Review of Secondary NAAQS for SOx and NOx

- **Multipollutant:**
  - Addresses SOx and NOx (gases and particles) jointly
- **Multimedia:**
  - Control of air emissions to address aquatic acidification attributed to atmospheric acid deposition
- **Models:**
  - Relies heavily on atmospheric and aquatic models to develop a new parameter, the Aquatic Acidification Index (AAI)

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Elements of the Standard

- **Indicators:**
  - SOx: sum of SO_2 and SO_4^{2-}
  - NOy: sum of NO + NO_2 + HNO_3 + NO_3^- + all other forms of oxidized nitrogen (inorganic and organic) in gas and particles
- **Level:**
  - Based on the "ecological indicator" of Acid Neutralizing Capacity (ANC); EPA staff suggests values in the range of 20-75 μeq L^{-1}
- **Averaging Time:** 3-5 years
- **Form:** Aquatic Acidification Index

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Aquatic Acidification Index (AAI)

- **AAI = F1 – F2 – F3[NOy] – F4[SOx]**

- $F1 = ANC_{lim} + CL_r/Q_r$
- $F2 = NHx/Q_r$
- $F3 = TNOy/Q_r$
- $F4 = TSOx/Q_r$

- ANC_{lim} is the limiting ("target") ANC
- NHx is the wet and dry deposition of reduced nitrogen, taken as sum of NH_3 and NH_4^+ deposition loads from the CMAQ air quality model spatially averaged over an ecoregion
- CL_r is the representative critical load, assuming a Steady-State Water Chemistry (SSWC) model, calculated as the value to protect a certain percentile of waterbodies in an ecoregion with sufficient data for critical load calculations
- Q_r is the representative hydrologic run-off rate, calculated as the median of all waterbodies with data in an ecoregion
- TSOx and TNOy are the transference ratios that convert annual ambient air concentrations of SOx and NOy to annual deposition loads of SOx and NOy, respectively, also derived from the CMAQ model spatially averaged over an ecoregion

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Conceptual Framework Part 1

- Divide the country into regions: **EPA staff has selected Omernik Level III ecoregions**
- Classify ecoregions as acid-sensitive and non-acid sensitive **based on EPA staff criteria:**
  - Sensitive ecoregions are those with **1%** of waterbodies with measurements of **ANC < 100 μeq L^{-1}** and **5%** of waterbodies with measurements of **ANC < 200 μeq L^{-1}**
  - **The sensitivity of this screening process is not shown in the PAD**

- Set a limiting ("target") ANC (ANC_{lim}): **ANC_{lim} is a decision of the Administrator**
- Calculate critical loads for each waterbody having sufficient data using **steady state** assumptions

- Use the critical load at a certain percentile of the distribution in AAI equation: CL_r
  - Percentiles from 70th to 90th suggested by EPA staff for acid sensitive regions
  - Median (50th percentile) suggested by EPA staff for non-acid-sensitive regions
  - **These percentiles of protection are also a decision of the Administrator**

- Calculate F1 for each ecoregion using the regional median runoff rate: Qr
- Note that population of waterbodies that are used to determine sensitivity are likely different than those used to calculate CL_r and Q_r.

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Conceptual Framework Part 2

- Calculate F2, a value for annual reduced nitrogen (ammonia and ammonium) total (wet and dry) deposition load from CMAQ air quality model, spatially averaged across the ecoregions: (NHx)
  - EPA is considering alternative estimation methods for the NHx deposition load

- Calculate F3 and F4, transference ratios (effective deposition velocities): annual aggregate, wet + dry, deposition load of all species of SOx or NOy ÷ annual aggregate concentrations of all species of SOx or NOy, respectively; data obtained from the CMAQ air quality model, spatially averaged across the ecoregions (TSOx and TNOy)

- Calculate AAI by using these values and measured annual atmospheric concentrations of SOx and NOy averaged over 3-5 years
  - **The details of spatial and temporal averaging for CL_r, Q_r, NHx, TSOx and TNOy are unclear**

- **Ecoregions where AAI < ANC_{lim} are designated as non-attainment**

- How the standard will be implemented (i.e., who is responsible for a non-attainment area) remains unclear as EPA considers this and other important questions to be out of the scope of the standard setting process.

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Conceptual Framework: General Observation

- The proposed elements of the standard
  - are unconstrained due to a lack of data availability,
  - introduce concepts that have not been thoroughly tested by the scientific community,
  - exhibit an overreliance on aquatic and atmospheric models that have not been evaluated with a rigor commensurate with the significance of their anticipated use within a nationwide standard, and
  - fail to objectively recognize key fundamentals in the science of aquatic acidification.

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Overarching Issues

- Regionalization, Spatial Aggregation and Data Representativeness
- Use of a Steady State Approach for Critical Load Calculations
- ANC as an Indicator of Ecosystem Health
- Aquatic and Atmospheric Models
- Uncertainty of the Aquatic Acidification Index
- **Within each of these issues there are a number of specific concerns**

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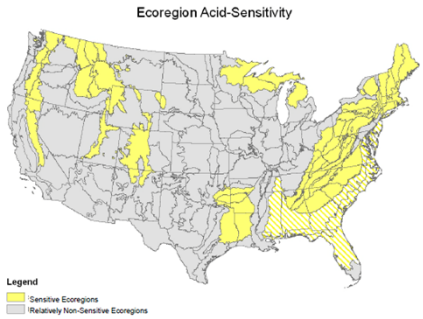
Regionalization: Ecoregions



- 29 acid-sensitive ecoregions screened in; ultimately 4 excluded because deposition reduction needed would be too large.
- Regionalization is disparate and mostly emphasizes vegetation differences, not key water-quality or limnological variables
- Overly broad definition of acid-sensitive regions
- EPA is using median Q and mean TSOx and TNOy, even for dissimilar areas spanning large distances and elevation differences.
- Mixing of disparate areas: some ecoregions will be assigned very low critical loads because, in fact, they are a mix of non-sensitive and very sensitive areas.

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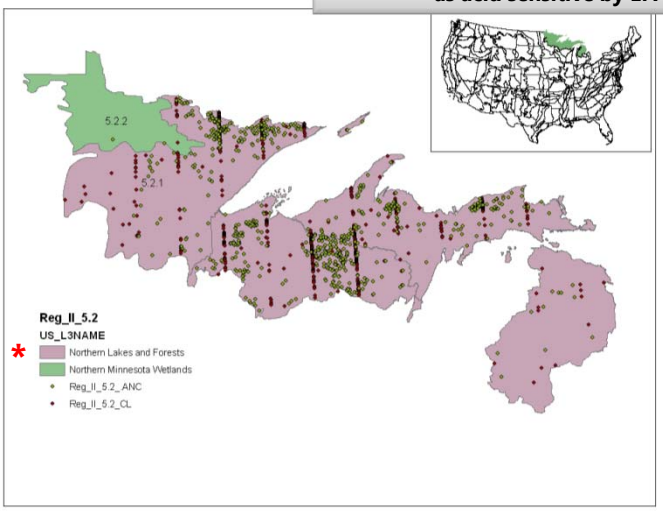
Ecoregion 5.2.1 and.2

Ecoregions highlighted in RED are classified as acid sensitive by EPA



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Ecoregions 5.3.1 and .3

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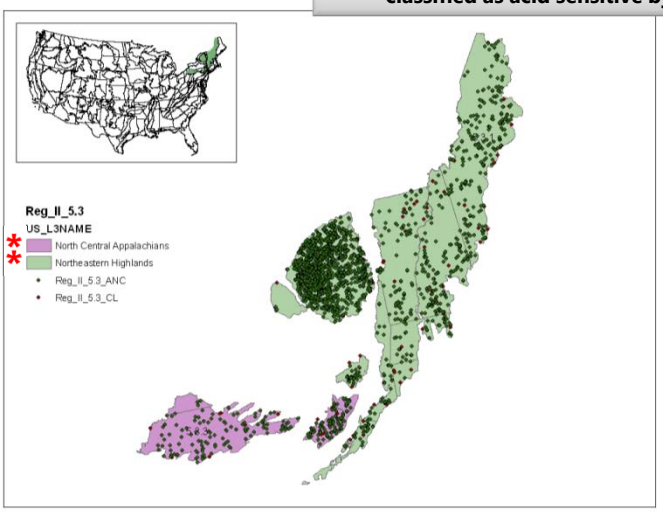

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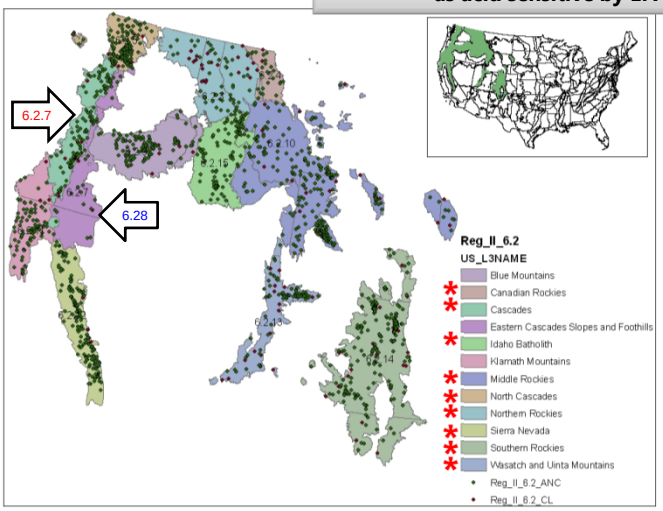
Ecoregions 6.2.3, .4, .5, .7, .8, .9, .10, .11, .12, .13, .14 and .15

Ecoregions highlighted in RED are classified as acid sensitive by EPA



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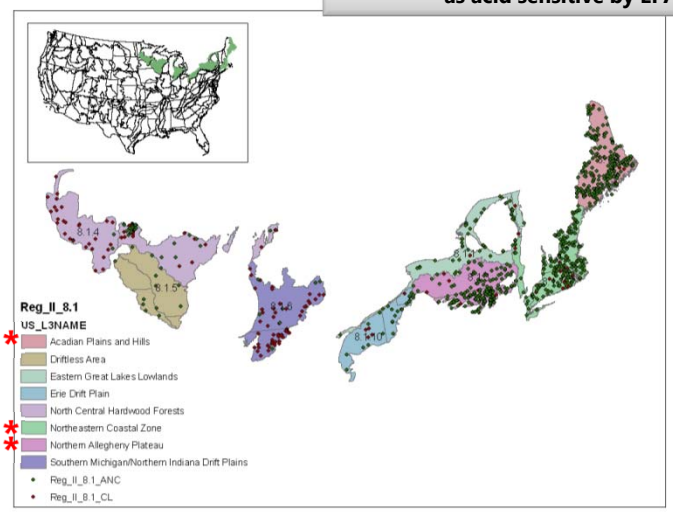
Ecoregions 8.1.1, .3, .4, .5, .6, .7, .8 and .10

Ecoregions highlighted in RED are classified as acid sensitive by EPA



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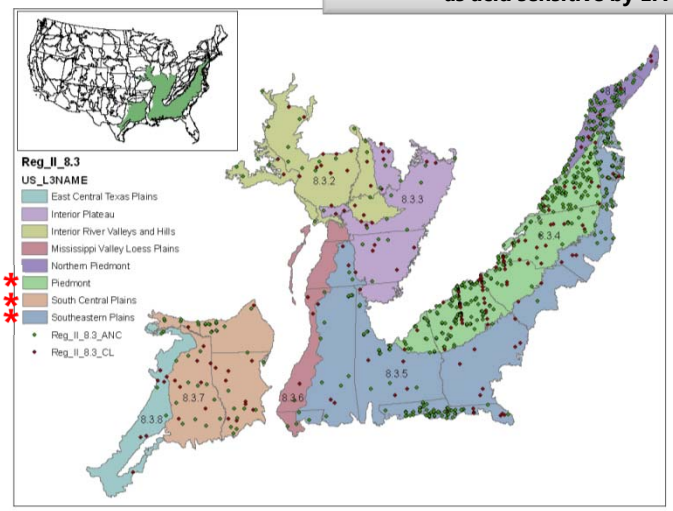
Ecoregions 8.3.1, .2, .3, .4, .5, .6, and .7

Ecoregions highlighted in RED are classified as acid sensitive by EPA



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Ecoregions 8.5.1, .2, .3 and .4

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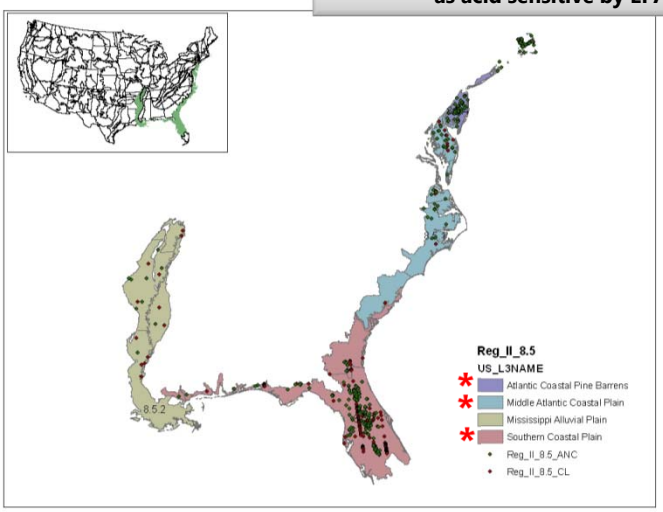

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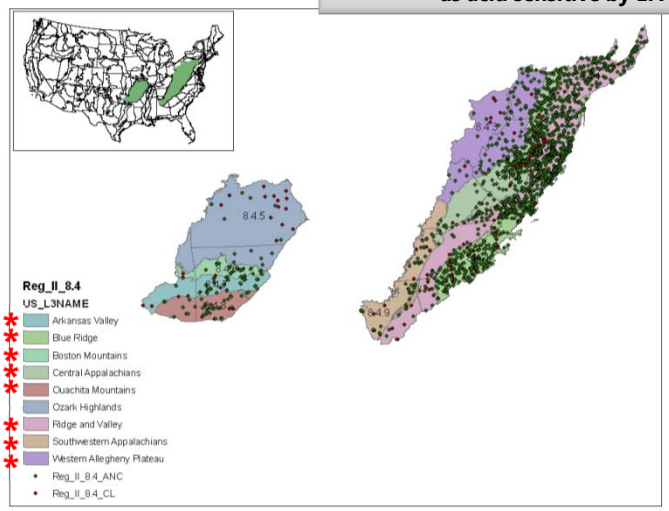
Ecoregions 8.4.1, .2, .3, .4, .5, .6, .7, .8 and .9

Ecoregions highlighted in RED are classified as acid sensitive by EPA



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Level III is too broad; Level IV is of limited use.

- Even Omernik Level IV ecoregions are limited in their usefulness.
- Sullivan, TJ; Webb, JR; Snyder, KU; Herlihy, AT; Cosby, BJ. Spatial Distribution of Acid-sensitive and Acid-impacted Streams in Relation to Watershed Features in the Southern Appalachian Mountains. *Water, Air and Soil Pollution, 182*, 57-71, 2007. (Emphases and bracketed clarifications added.)
- *There were 13 [Level IV] ecoregions within the SAMI region that were represented by more than 25 sample locations. Most of those contained at least one acidic (9 of 13 [Level IV] ecoregions) and ANC 0 to 20 μeq L^{-1} (12 of 13 [Level IV] ecoregions) stream and each occupied less than 7% of the [Southern Appalachian Mountains Initiative] SAMI domain.* ***The [Level IV] ecoregion designation was therefore of limited utility as a classification parameter to be added to geologic sensitivity.*** *Nevertheless, only four [Level IV] ecoregions (Forested Hills and Mountains, 69a; Southern Sandstone Ridges, 67h; Trap Rock and Conglomerate Uplands, 66b; and Northern Sandstone Ridges, 67c) contained* ***81% of the known acidic streams and 66% of the known streams having ANC < 20 μeq L^{-1} in the SAMI domain, and these four [Level IV] ecoregions only occupied 13% of the region.***
- Results of this study indicate that, at the broad regional scale, acidic and low-ANC streams are strongly associated with **watershed lithology [represented by % siliceous bedrock in watershed]**. Other important variables associated with acid-sensitivity include **elevation, % forested watershed, and watershed area.** These relationships allow identification of subregions where acid-sensitive streams are most numerous.

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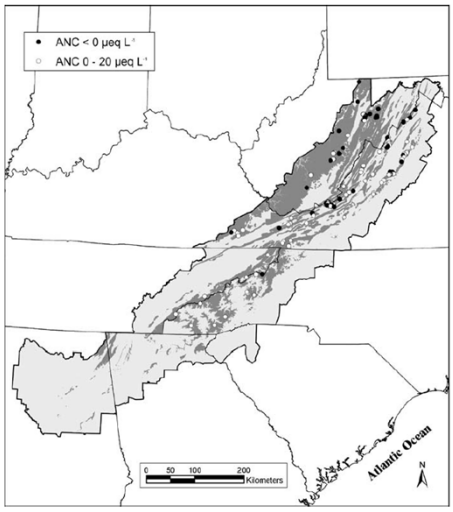
Regional Interspersion of Sensitive and Non-Sensitive Regions

Fig. 4 Final area delimited by the acidification sensitivity classification scheme within the SAMI study area. The *darkly shaded area* includes the siliceous geologic sensitivity class surrounded by a 750 m buffer. In addition, all areas less than 400 m elevation have been deleted and areas greater than 1,000 m elevation have been added. The area thus circumscribed includes 95% of the known acidic streams and 88% of the known streams having ANC ≤20 μeq l^{-1} within the region. Furthermore, all known streams having ANC ≤20 μeq l^{-1} are in close proximity to the final mapped area



The Southern Appalachians are a marbled assembly of siliciclastic, granitic and basaltic watersheds.

Sullivan, TJ; et al.. Spatial Distribution of Acid-sensitive and Acid-impacted Streams in Relation to Watershed Features in the Southern Appalachian Mountains. *Water, Air and Soil Pollution, 182*, 57-71, 2007

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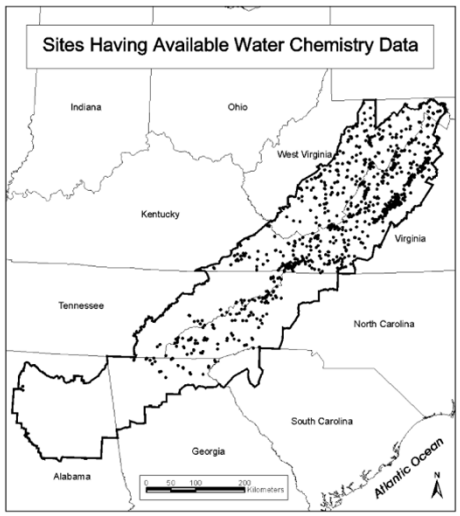
Regionalization: Representativeness of Data

Fig. 2 Water chemistry sampling sites used for evaluation of landscape classification. The SAMI region boundary and state boundaries are also shown



The Southern Appalachians area marbled assembly of siliciclastic, granitic and basaltic watersheds.

And waterbodies with available data are not representative of the overall region but rather are preferentially located in the more sensitive regions.

Sullivan, TJ; et al.. Spatial Distribution of Acid-sensitive and Acid-impacted Streams in Relation to Watershed Features in the Southern Appalachian Mountains. *Water, Air and Soil Pollution, 182*, 57-71, 2007

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Regionalization: Representativeness of Data

The STREAM SITE NUMBER distribution is not representative of the STREAM LENGTH distribution

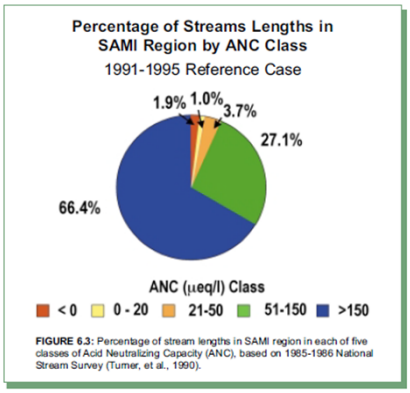

FIGURE 6.3: Percentage of stream lengths in SAMI region in each of five classes of Acid Neutralizing Capacity (ANC), based on 1985-1986 National Stream Survey (Turner, et al., 1990).

Southern Appalachian Mountain Initiative, Final Report. Based on Turner, R.S., et al. 1990. *Watershed and Lake Processes Affecting Surface Water Acid-Base Chemistry.* Report 10. In: *National Acid Precipitation Assessment Program, Acidic Deposition: State of Science and Technology. Volume II.*
National Acid Precipitation Assessment Program, Washington, D.C.

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Regionalization: Representativeness of Data

- Concerns exist even with the Adirondack data.
- Sullivan, TJ; Cosby, BJ; Herlihy, AT; Driscoll, CT; Fernandez, IJ; McDonnell, TC; Boylen, CW; Nierzwicki-Bauer, SA; Snyder, KU. Assessment of the Extent to Which Intensively-studied Lakes are Representative of the Adirondack Region and Response to Future Changes in Acidic Deposition. *Water, Air and Soil Pollution, 185,* 279-291, 2007.
    - *Based on modeling results reported here for the lakes that were studied, ALTM and AEAP modeling results appear to be well-distributed across a gradient of highly acid-sensitive conditions.* ***They are not, however, representative of the overall population of Adirondack lakes, or even the subset of Adirondack lakes that includes those having ANC ≤ 200 µeq L^{-1}.*** *In particular, the ALTM and AEAP monitoring lakes having the longest records of monitoring data represent a group of lakes that largely receive high S deposition and exhibit a high degree of sensitivity to chemical change in response to acidic deposition.*
- EPA has not provided the data to evaluate the representativeness of waterbodies in their selected regionalization scheme. Just 10 waterbodies—regardless of their characteristics, such as size, elevation, soil depth, and a host of other limnological, hydrological and geographical parameters—is all that is needed to create a distribution for assessing an ecoregion.
- It is important that these data become available and that the **VINTAGE** of the data be clearly stated.

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Regionalization: Representativeness of Data

Ecoregion	Num. of Lakes	Total Area	% Number	% Area	Mean; Median; Std. Dev.; Geo Std. Dev.	Vintage; Source
All						
ANC data						
ANC data; ANC<100						
CL data						
CL data; ANC<100						

Ecoregion	Num. of Stream Segments	Total Length	% Number	% Length	Mean; Median; Std. Dev.; Geo Std. Dev.	Vintage; Source
All						
ANC data						
ANC data; ANC<100						
CL data						
CL data; ANC<100						

Basic data such as these are not provided by EPA. Some of this information may be covered in figures, but it is not tabulated or summarized in this fashion.

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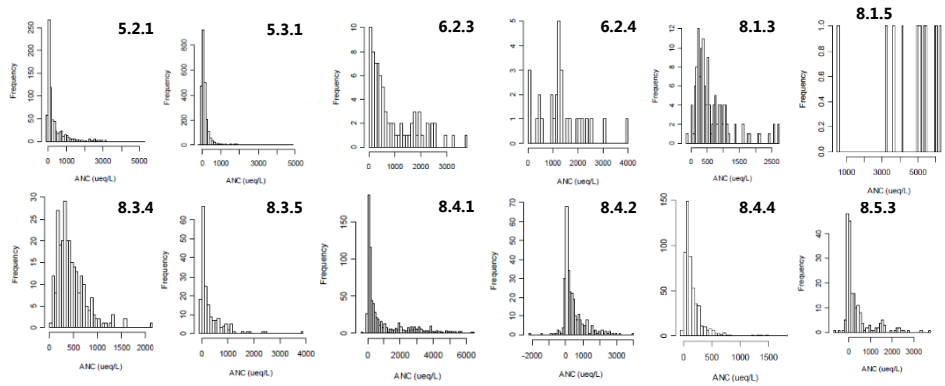
Regionalization: Representativeness of Data

- In the final version of the PAD dated February 4, 2011, EPA added a series of plots showing the distribution of variables ANC, Q, $[BC]_0$*, SO_4^{2-}, NO_3^-, DOC. These can help us illustrate the problems with data representativeness. **Please note changes in the scales of both axes.**



\Without a table as in the previous slide, **we know little about the actual meaning of these distributions** relative to the entire population (**or any sub-populations**) of waterbodies in their respective ecoregions.

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Critical Loads: Background

- Steady-State Water Chemistry Model
  - $CL = ([BC]_0^* - ANC_{lim})\ Q + N_{eco}$

- BC_0^* = Preacidification Base Cation Input = $BC_w + BC_{dep}^* - BC_u = BC_t - BC_i$
  - Conditions in 1850; never measured

- BC_t: Present Day BC levels
- BC_i: BC input due to ion exchange

- BC_0^*: EPA staff proposes two different calculation methods:
  - Henriksen F-factor approach
  - Model of Acidification of Groundwater in Catchments (MAGIC) Model

- N_{eco}: Nitrogen uptake by ecosystem
  - EPA proposes two different calculation methods
  - Both are also too simplistic (addressed in detail in EPRI Comments on Second Draft PAD)

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BC_0*: Preacidification Base Cation Input

- EPA states that MAGIC is the preferred approach
  - MAGIC fails at reproducing long-term changes; underestimates BC_i, present-day BC input due to ion exchange
- However, it appears that EPA is data-limited and will need to apply the Henriksen F-factor approach in most regions
  - The F factors, based on Norwegian data, are too low for the U.S.

- $[BC_0]^* = [BC]_t - [BC]_i = [BC]_t - F \times ([SO_4^{2-}]_t - [SO_4^{2-}]_0 + [NO_3^-]_t - [NO_3^-]_0)$
- $F = \sin\left(\frac{\pi}{2}\,[BC]_t/S\right)$, where **S=400 µeq L^{-1} (value for Norway, Brakke et al., 1990)**
- $[SO_4^{2-}]_0 = 15 + 0.16 \times [BC]_t$ (µeq L^{-1}, equation for Ontario, Canada, Henriksen et al., 2002)
- $[NO_3^-]_0 = 0$ (assumed)
- Subscript $_t$ = today; Subscript $_0$ = preindustrial/preacidification

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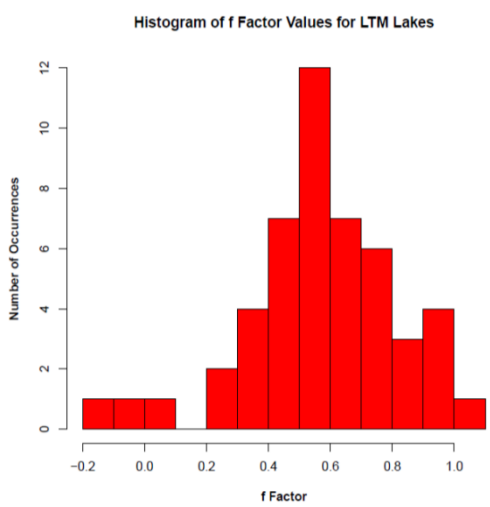
Critical Loads F-Factor



EPA states that the "F" factor values are between 0.2 and 0.4 for the Adirondacks.

Using actual Adirondacks data, the range in "F" is much larger, with the mode near 0.6.

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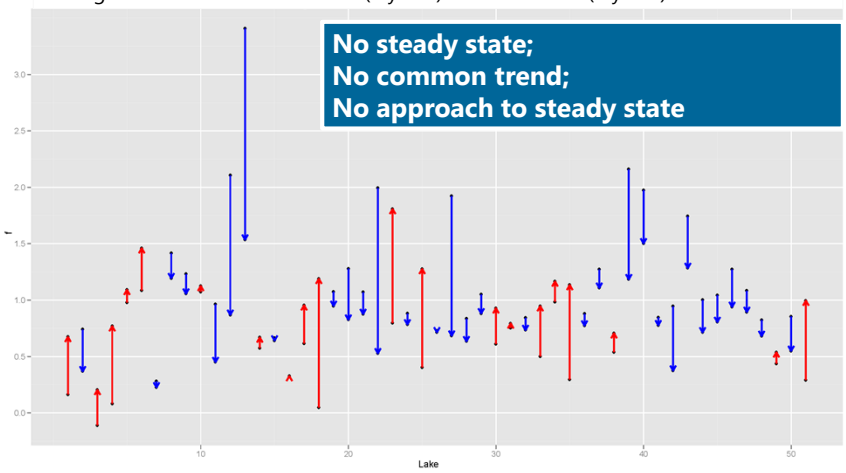
Critical Loads F-Factor: Changes on Decadal Scales

Changes in F factor from first half (9 years) to second half (9 years) of ALTM data set



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Critical Loads: MAGIC

- In its model performance evaluation of MAGIC, EPA shows the fit of MAGIC to the calibration data for 44 Adirondack Lakes and 60 Shenandoah streams.
- By definition, the results of the MAGIC model are **"calibrated"** to fit these data.
- EPA in the REA only shows the model performance to
  - **Two (2)** Adirondack lakes and
  - **Two (2)** Shenandoah streams.
- **Model performance for the other 100 waterbodies in the combined dataset should be presented**

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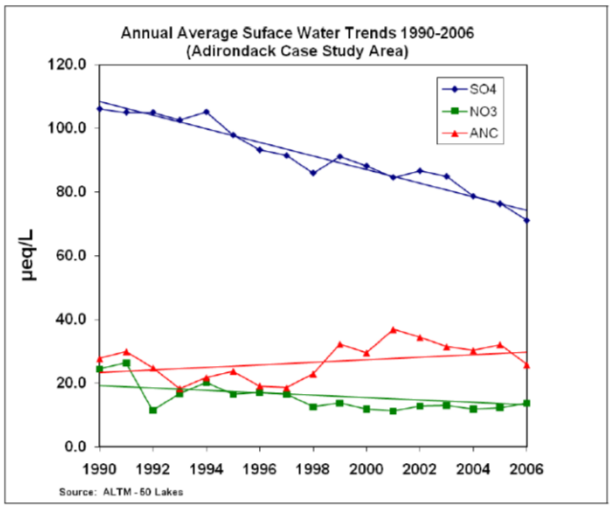
Comparable Adirondack Lake Solute Trends (Source: PAD)



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Changes in Solute Concentration in Adirondack Lakes, 1990-2006, Measured vs. MAGIC

Measured

Solute	1990	2006	Delta
SO_4^{2-}	107	73	-34
ANC	25	30	+5
NO_3^-	19	14	-5
$\sum C_A$	126	87	-39
$\sum C_B$	151	117	-34

$\sum C_B / \sum C_A = 0.87$

MAGIC

Solute	1990	2006	Delta
SO_4^{2-}	115	68	-47
ANC	33	61	+28
NO_3^-	5	5	0
$\sum C_A$	120	75	-45
$\sum C_B$	153	134	-19

$\sum C_B / \sum C_A = 0.42$

here, $\sum C_A = SO_4^{2-} + NO_3^-$

A similar comparison for the Shenandoah area shows MAGIC having some trends in the wrong direction, bringing into question the use of MAGIC to extrapolate forward from 150 years in the past

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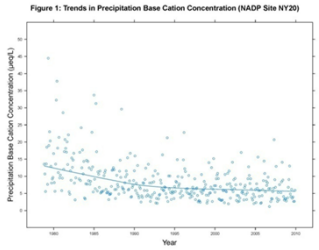
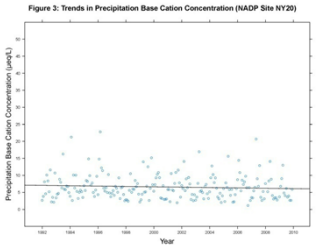
On Time Lags and Base Cations in Precipitation

- First discussed in October presentation to CASAC: little ANC increase for >50 percent reduction in emissions. EPA indicated that this observation could be due to a time lag in the Adirondack system.
- We found no evidence of lag in Adirondacks through data analyses and modeling. These analyses and model results were submitted to the EPA Docket and presented to EPA.
- EPA then responded that the lag could be due to decreases in base cations in precipitation.





- Base cation wet deposition decreased from 1979 to 1992 by 10.5 µeq L^{-1}; however, over the last 18 years (1992 to 2009) the slope of the best fit line is not significantly different from zero.
- Model simulation results of these small decreases shows negligible response in surface water quality.

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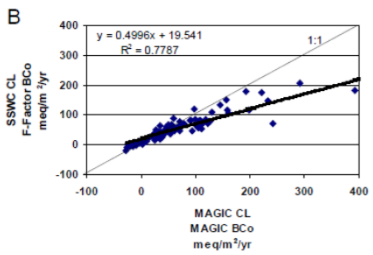
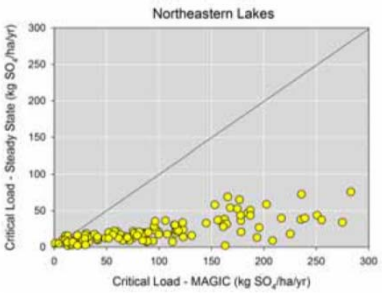
Critical Loads: MAGIC v. SSWC

- MAGIC consistently produces higher (less-stringent) critical loads than the Henriksen F-factor approach
- EPA explains the effect by discussing the "average" difference (which is influenced by the higher number of data points on the lower end of the distribution) rather than the trend (**slope of 0.5,** intercept 20)
- Other studies have shown this departure (even at low CLs) more clearly



Policy Assessment Document, v2011-Jan-14, Appendix B



Multiagency Workshop on Critical Loads, Final Report

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Atmospheric Models

- EPA has failed to perform a robust evaluation matching the time scale of model output to the time scale of the measurements.
- EPA is proposing to use mean transference ratios. Whereas, EPA notes the spatial variability in NHx loads could be large and even opens the possibility for more-refined processes for defining these NHx loads, the variability that exists in TSOx and TNOy (e.g., important variability with elevation) is not considered.
- These ratios can span a broad range of values, particularly in regions that traverse long distances crossing a wide range of latitudes, have considerable elevation gradients, or have their meteorology influenced by orographic effects.
- The distribution of transference ratios is imperative to understanding the distribution of critical loads as we will explain in our final overarching comment.
- Even in exploring the robustness of the "mean" transference ratios, EPA has limited itself to only two examples; this is not enough. In Figure F.15, EPA shows the inverse of the transference ratios which *visually* suppresses the variability shown in later figures.

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Domain-Averaged Time Series from EPA Monthly SO_4^{2-}

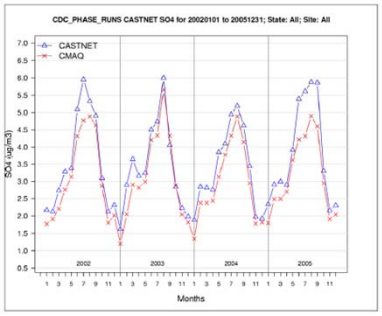

Figure F-5. 2002–2005 Domain-wide average SO_4^{2-} predicted concentrations and observations by month at CASTNet Sites in the eastern domain(note, units are in actual mass for SO_4, including oxygen) .

- EPA shows "domain-wide averaged" time series comparisons instead of mapping model performance to actual sites.
- For example, in the maps on the following slides we can observe that domain averaging will lead to compensation of errors by combining regions of overprediction with regions of underprediction.
- Temporal and spatial aggregation must be avoided in model performance evaluations.

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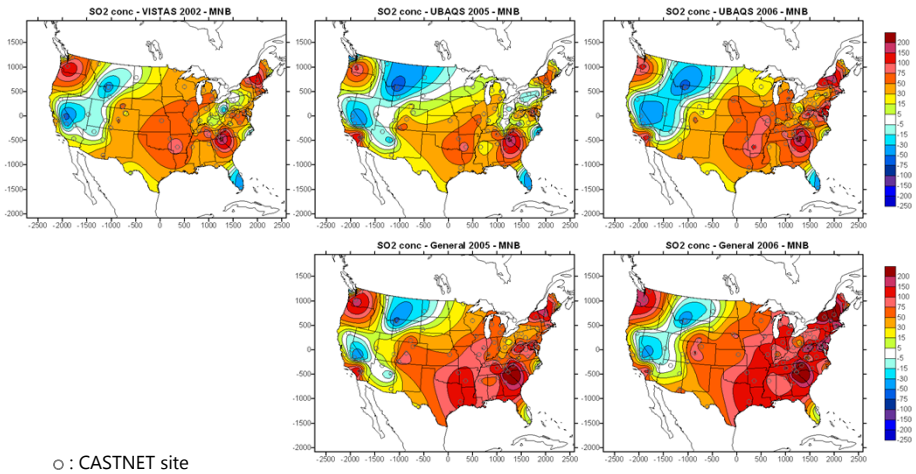
Weekly Average SO_2 Concentration Mean Normalized Bias (%)



○ : CASTNET site

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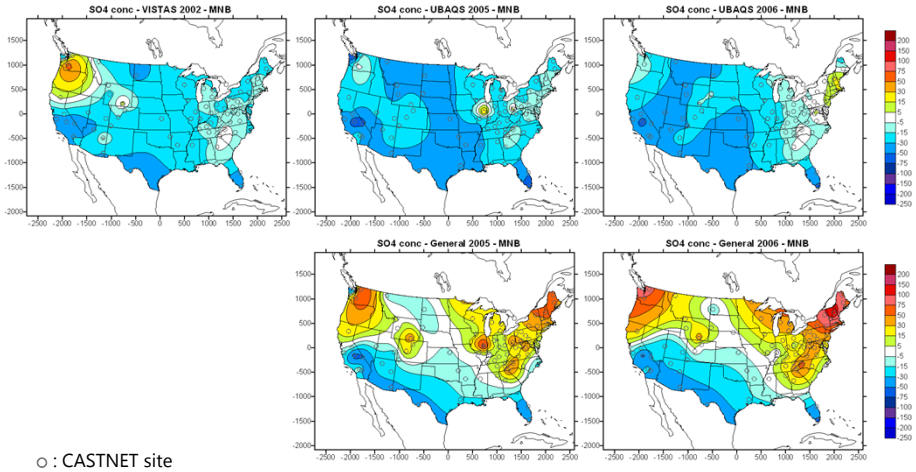
Weekly Average SO_4^{2-} Concentration Mean Normalized Bias (%)



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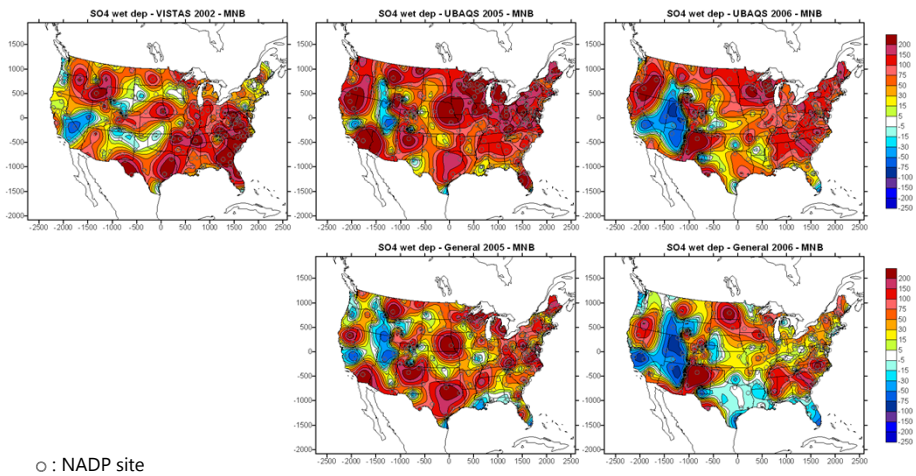
Weekly Total SO_4^{2-} Wet Deposition Mean Normalized Bias (%)



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Domain-Averaged Time Series from EPA Monthly TNO_3

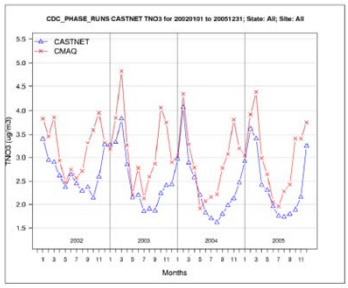

Figure F-6. 2002–2005 Domain-wide average TNO_3 predicted concentrations and observations by month at CASTNet sites in the eastern domain (note, units are in actual mass for NO_3, including oxygen).

- EPA shows "domain-wide averaged" time series comparisons instead of mapping model performance to actual sites.
- For example, in the maps on the following slides we can observe that domain averaging will lead to compensation of errors by combining regions of overprediction with regions of underprediction.
- Temporal and spatial aggregation must be avoided in model performance evaluations.

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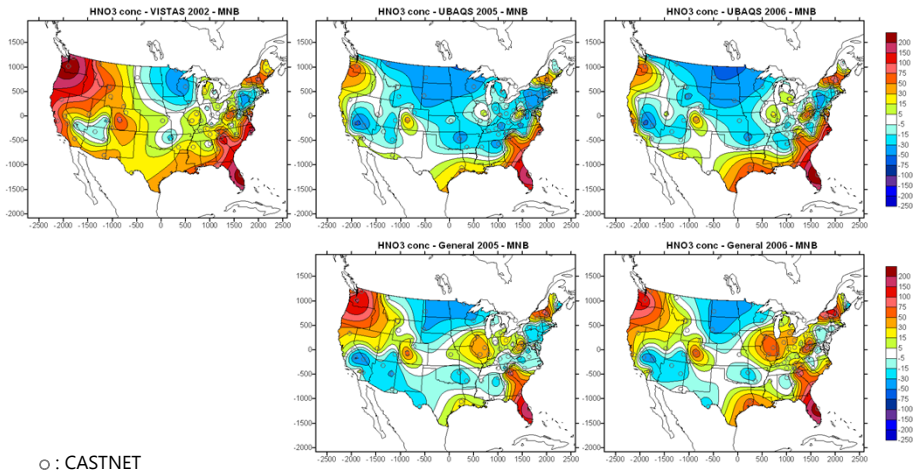
Weekly Average HNO_3 Concentration Mean Normalized Bias (%)



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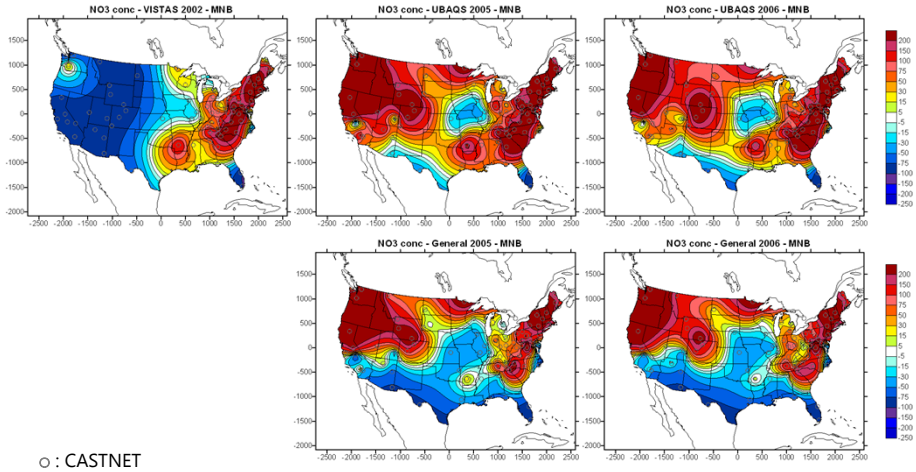
Weekly Average NO_3^- Concentration Mean Normalized Bias (%)



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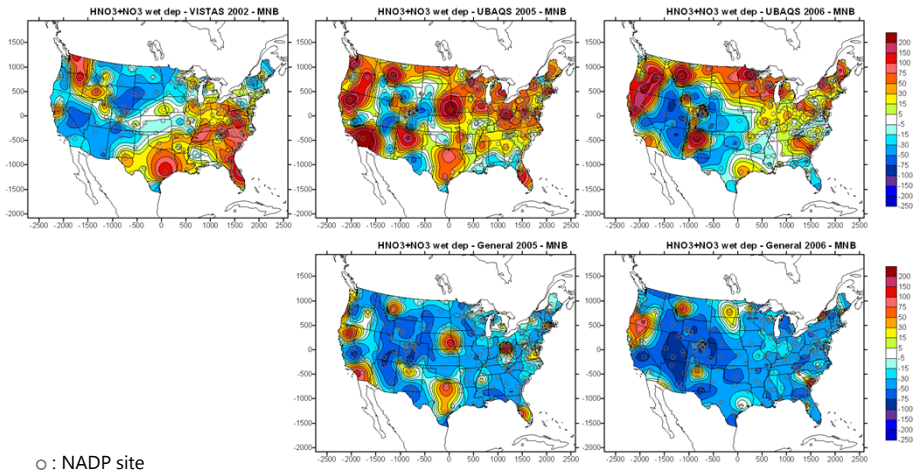
Weekly Total $HNO_3+NO_3^-$ Wet Deposition Mean Normalized Bias (%)



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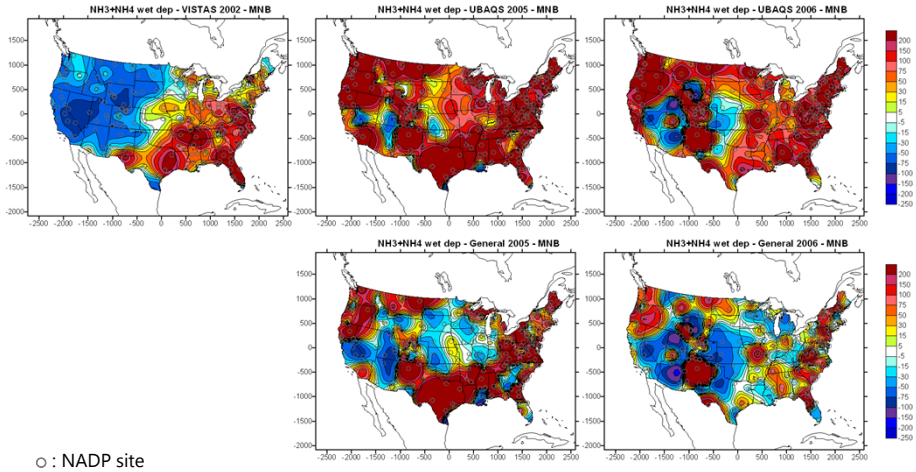
Weekly Total $NH_3+NH_4^+$ Wet Deposition Mean Normalized Bias (%)



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Atmospheric Models: PRISM Adjustments and Bias Corrections

- In the discussion, EPA makes the assessment that combining model and measurement data in the AAI would be inconsistent and that it is favorable to only proceed with one approach, ultimately choosing to employ model data.
- However, EPA addresses concerns over model performance for wet deposition by applying adjustments based on precipitation data through the PRISM model and then proceeds to support a step of adjusting these results with bias-correction factors.
- This appears to contradict EPA's previous statements of maintaining consistency across the use of modeling data, i.e., prior statements about not combining measured and modeled data in development of the transference ratios.
- In fact, the consequences of applying PRISM corrections to wet-deposition data alone and not to concentrations or dry deposition values (and how to address those) have not been explored. This leads to a conceptual disconnect: a lack of mass balance between the model and the "adjusted and bias-corrected" wet deposition values.

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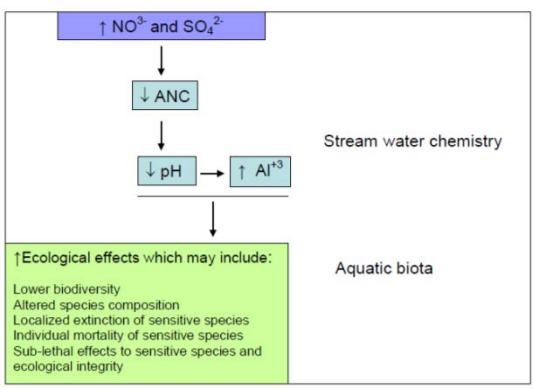
True Ecological Indicators: pH or Al_{im}



Source: EPA

- EPA recognizes the true sensitivity of aquatic species to pH and inorganic monomeric aluminum (Al_{im}), as shown in their figure from the PAD.
- EPA even states that the toxicity of lakes has a causal relationship to pH and Al_{im} and that ANC *per se* does not cause adverse impacts to aquatic habitats.

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Scientific Concerns with EPA's Indicator

- EPA proposes to use an ecological indicator, ANC, on the basis that ANC is more convenient to implement within a standard and not on its adequacy as a universal indicator of aquatic ecosystem viability and health. ANC alone is inappropriate.
- With appropriate information, the relationships between ANC, pH and [Al_{im}] can be calculated for waterbodies and the influence of SOx, NOy and NHx deposition on these variables can be determined.
- The argument that mass conservation is critical to a standard is not scientific and conflicts with the nature of existing standards.
  - The fact that ANC maintains mass balance is a property of the parameter, not a scientific requirement for an indicator.
  - For example, ozone (O_3) is formed through highly non-linear reactions of ambient VOC and NOx, as well as O_2 and H_2O as **reagents,** and does not have a mass-balance relationship with the emissions of its controlled precursors (VOC and NOx).
  - Another example of a non-mass-conservative standard are temperature-based discharge standards to protect aquatic habitats. Ultimately, one should target the indicator(s) most closely related to the causative agent(s).

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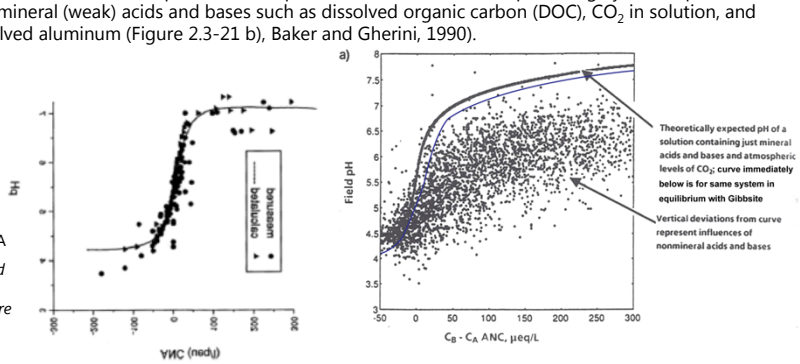
Relation of ANC with pH is NOT Universal

- Moreover, the relationship of ANC with pH is not universal and it depends highly on the presence of non-mineral (weak) acids and bases such as dissolved organic carbon (DOC), CO_2 in solution, and dissolved aluminum (Figure 2.3-21 b), Baker and Gherini, 1990).

Source: EPA

Flipped and rotated to match figure on right.



- Fish populations have been shown to thrive in regions with low ANC when inorganic monomeric aluminum concentrations are low.
- This comment has been raised on various occasions. In fact, EPA provides only limited illustrations of ANC and aquatic viability and bases essentially all of their conclusions on the observations in the Adirondack lakes and Shenandoah streams, instead of providing data for the rest of the U.S.

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Response of Fish Species

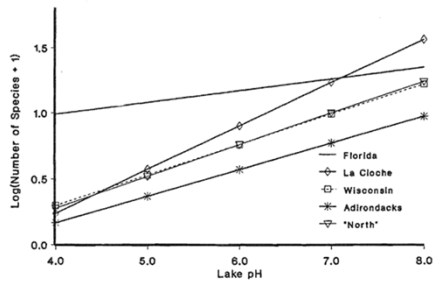

FIG. 1. Regression lines for number of fish species vs. pH for Florida, Wisconsin (Rahel 1982), La Cloche (Harvey 1975), Adirondack Mountain (Adirondack Lake Survey Corp. 1989) lakes, and the merged north-temperate data "North." All are significant ($P \approx 0.05$). F: $Y = 0.09$ (pH) + 0.63; $R^2 = 0.33$. C: $Y = 0.33$ (pH) − 1.08; $R^2 = 0.35$. W: $Y = 0.23$ (pH) − 0.62; $R^2 = 0.50$. NY: $Y = 0.20$ (pH) − 0.63; $R^2 = 0.43$. N: $Y = 0.24$ (pH) − 0.68; $R^2 = 0.38$.

- Fish respond to Al_{im} and to a certain extent to pH, but only incidentally to ANC.
- EPA used comparisons of number of species to ANC for Adirondacks and Shenandoah areas.
- Correlation of number of species to pH is NOT identical in different regions. The relationship to ANC is even more disparate.
- Other factors important, e.g. temperature, diet, spawning habitat.

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Shenandoah N. Park: Fish in Sensitive Habitats (SNP:FISH): Not Acidic → > 50 μeq L^{-1}

Table 1. Brook trout stream categories, ANC classes, and ANC thresholds for brook trout responses to acidification in forested headwater catchments in western Virginia (Bulger et al. 1999).

Brook trout stream category	ANC class	ANC range (μequiv·L^{-1})	Brook trout response
Suitable	Not acidic	>50	Reproducing brook trout populations expected where habitat suitable
Indeterminate	Indeterminate	20–50	Extremely sensitive to acidification; brook trout response variable
Marginal	Episodically acidic	0–20	Sublethal and (or) lethal effects on brook trout possible
Unsuitable	Chronically acidic	<0	Lethal effects on brook trout probable

SNP:FISH
Shenandoah National Park:
Fish In Sensitive Habitats
Project Final Report, Volumes I-IV

A.J. Bulger, B.J. Cosby, C.A. Dolloff,
K.N. Eshleman, J.R. Webb, J.N. Galloway

http://www.nps.gov/nero/science/FINAL/Shen%20Fish/Shen%20Fish.htm

Bulger, A.J.; Cosby, B.J.; Webb, J.R. Current, reconstructed past, and projected future status of brook trout (*Salvelinus fontinalis*) streams in Virginia. *Canadian Journal of Fisheries and Aquatic Sciences 57*, 1515–1523, 2000.

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Shenandoah N. Park: Fish in Sensitive Habitats (SNP:FISH): Response of Blacknose Dace

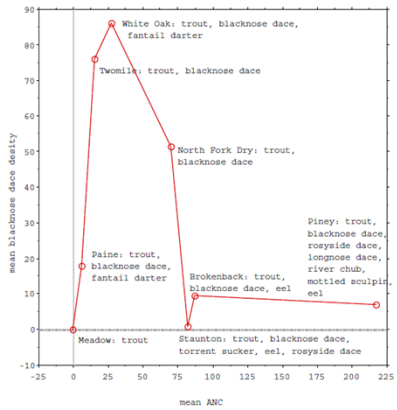

Figure E-4. Blacknose dace density (number of individuals per 100 m^2 of habitat) in the FISH project's three intensive and five extensive streams, versus mean ANC. Other fish species present in each stream are shown after the stream name on the graph.

SNP:FISH
Shenandoah National Park:
Fish In Sensitive Habitats
Project Final Report, Volumes I-IV

A.J. Bulger, B.J. Cosby, C.A. Dolloff,
K.N. Eshleman, J.R. Webb, J.N. Galloway

http://www.nps.gov/nero/science/FINAL/Shen%20Fish/Shen%20Fish.htm

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Introduction to Uncertainty Analysis

- **AAI = F1 – F2 – F3[NOy] – F4[SOx]**
- $F1 = ANC_{lim} + CL_r/Q_r$; $F2 = NHx/Q_r$; $F3 = TNOy/Q_r$; $F4 = TSOx/Q_r$
- $CL_r = ([BC]_0{}^*{}_{\%p} - ANC_{lim})\ Q_{\%p} + N_{eco,\%p}$
- $AAI = ANC_{lim} + \{ [BC]_0{}^*{}_{\%p} - ANC_{lim})\ Q_{\%p} + N_{eco,\%p} - NHx - TNOy[NOy] - TSOx[SOx] \}/\ Q_r$
- $AAI \times Q_r = ANC_{lim} \times Q_r - ANC_{lim} \times Q_{\%p} + [BC]_0{}^*{}_{\%p} \times Q_{\%p} - NHx - TNOy[NOy] - TSOx[SOx]$
- Attainment reached when AAI = $ANC_{lim.}$ Simplifying and rearranging:
- $TNOy[NOy] + TSOx[SOx] = ([BC]_0{}^*{}_{\%p} - ANC_{lim}) \times Q_{\%p} - NHx + N_{eco,\%p}$
- Q, $[BC]_0$* and Neco must represent the uncertainty in the parameters of the specific "representative critical load" at the percentile of protection: %p

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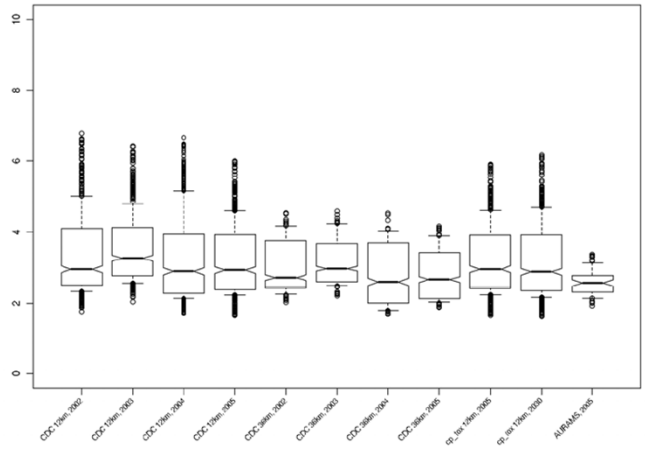
Transference Ratios for NOy from EPA



Units:

kg ha^{-1} y^{-1} μg^{-1} m^3

Divide by 3.1536 to convert to cm s^{-1}

Figure F-20. Modeled generated T_{NOy} ratios in the Adirondacks area showing CMAQ 12 and 36 km values 2002 – 2005 and AURAMS 2005.

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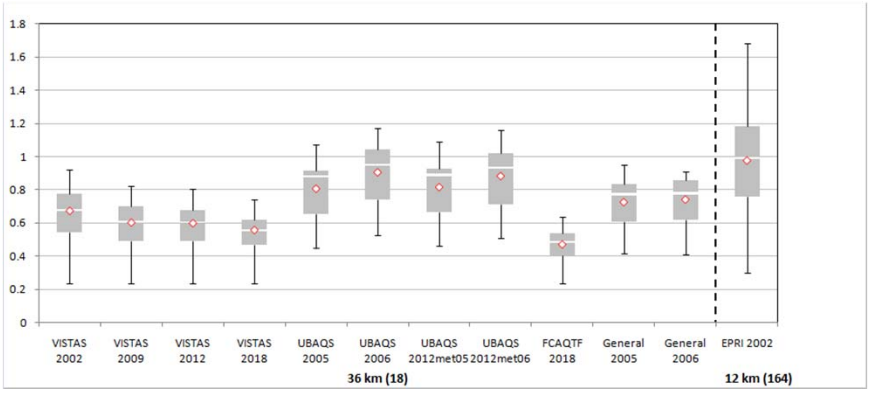
Transference Ratios for NOy from EPRI

Units: cm s^{-1}; multiply by 3.1536 to convert to kg ha^{-1} y^{-1} μg^{-1} m^3 (i.e., 10^7 m y^{-1})



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Transference Ratios for SOx from EPA

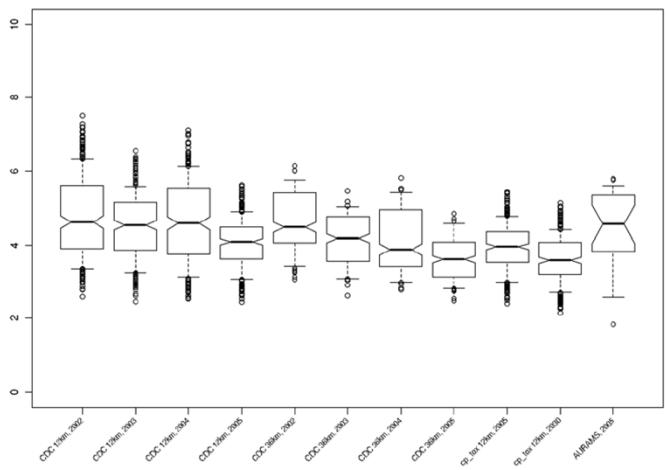

Figure F-21. Modeled generated T_{SOx} ratios in the Adirondacks area showing CMAQ 12 and 36 km values 2002 – 2005 and AURAMS 2005.

Units:

kg ha^{-1} y^{-1} μg^{-1} m^3

Divide by 3.1536 to convert to cm s^{-1}

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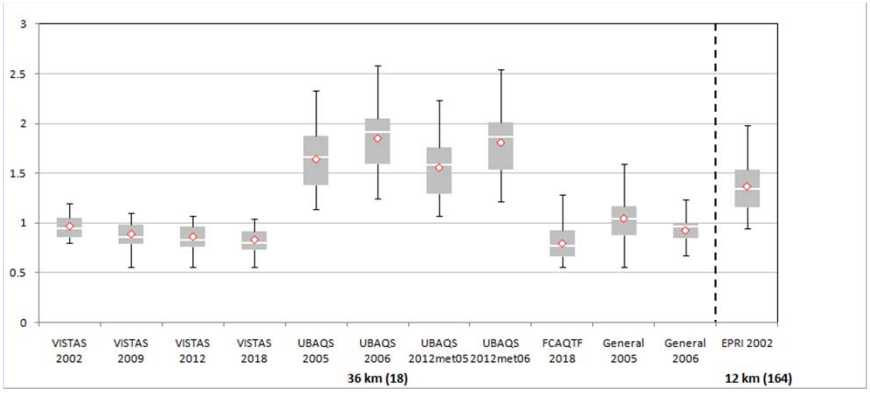
Transference Ratios for SOx from EPRI

Units: cm s^{-1}; multiply by 3.1536 to convert to kg ha^{-1} y^{-1} μg^{-1} m^3 (i.e., 10^7 m y^{-1})



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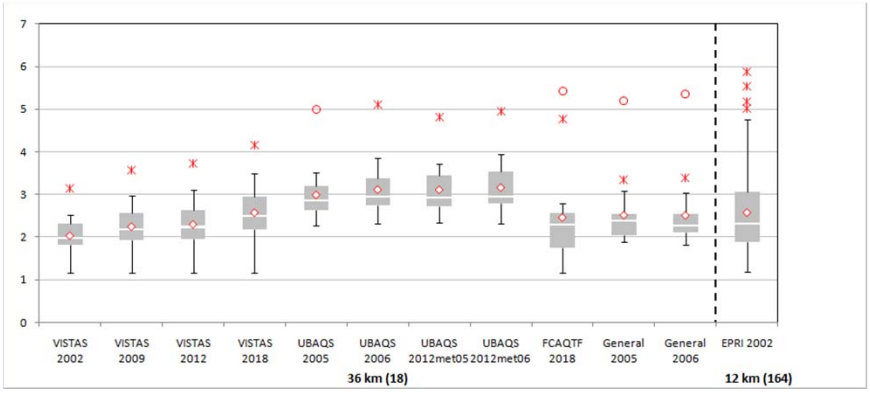
NHx Deposition Loads from EPRI



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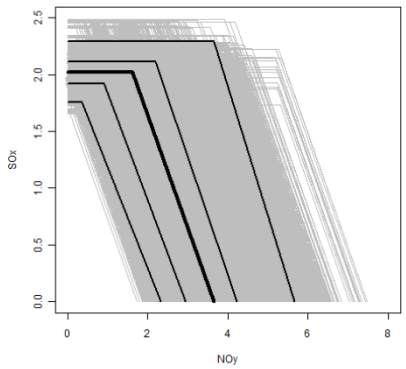
EPA's Monte Carlo Uncertainty Analysis

- Appendix G of the policy assessment document presents a "cumulative uncertainty analysis" of the AAI equation



- The distributions and conclusions presented are based on questionable "bootstrapping" techniques that lack clarity in their explanation (see next slides).
- EPA fails to clearly define their parameters.
- Ultimately, even the final distribution plot is suspect since one can solve for the "nominal trade-off curve". This curve is shifted low. We do note that the figure, as much of the appendices, does not show units.

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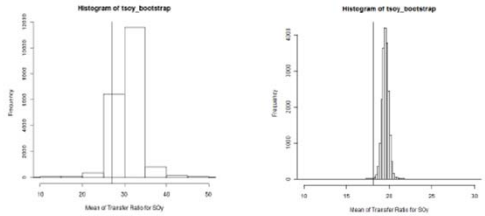
Distribution of T Ratios

Numerator = "Mean Annual Deposition" with 75% uncertainty (unclear what this means)

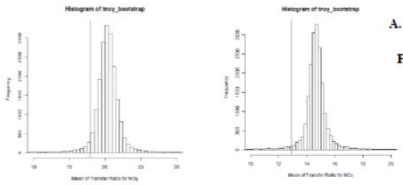
÷

Denominator= "Mean Annual Concentration" with 25% uncertainty (unclear what this means)



A. B.

Figure G-4. Bootstrap distribution of mean sulfur transference ratios (Tsox) for Regions 5.3.1 (A) and 9.3.3 (B)



A. B.

Figure G-3. Bootstrap distribution of mean nitrogen transference ratios (Tnoy) for Regions 5.3.1 (A) and 9.3.3 (B)

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Uncertainty Discussion Part 1

- EPA is focusing on the uncertainty of the average parameters. In fact, the variability of the values in the region also affect the "certainty" **of the standard**.
- Uncertainty and variability are indeed two different concepts. However, the variability in the parameters must be included in an uncertainty analysis due to the design of the AAI equation.
- For example, if an ecoregion with 10 monitors were to add 2 new monitors, the location of existing monitors and the choice of location of the two new monitors could have a tremendous impact on the **new average value of any given parameter** due to the extent of the variability in the ecoregion (particularly due to comments earlier on the lack of representativeness in the waterbody distribution).
- The extent by which the new "mean" values, **as well as the representative critical load,** could change must be assessed when there is high variability in the data and a lack of clearly defined representativeness in the waterbody population.

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Uncertainty Discussion Part 2

- It is appropriate to use the distribution of the actual individual parameters, such as TSOx and TNOy, in every ecoregion.
- With an increasing level of homogeneity in an ecoregion, the impact of variability diminishes. It is at this moment that the "certainty" of the standard is influenced by the uncertainty in the measurements or estimations of the AAI parameters.
- EPA's uncertainty analysis essentially ignores the impact of variability to the standard by assuming the "average" condition and defining **fixed** levels of uncertainty for the "average" parameters. The actual details of EPA's technique are not clear.

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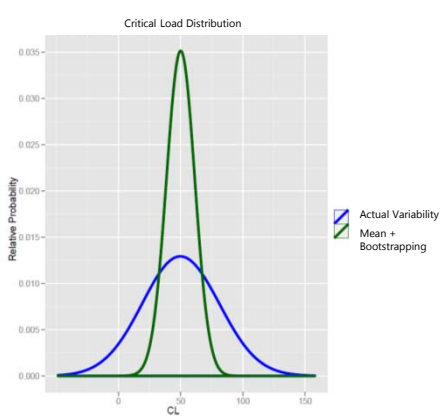
Distribution of CLs: Average Parameters with Bootstrapping vs. Variability of the Parameters



- The distribution of EPA's uncertainty of the average values with bootstrapping is much tighter (i.e., there is less spread), but it is important to understand that no information has been gained:
  - this distribution represents waterbodies that do not exist, i.e., a distribution of waterbodies that vary around mean limnological parameters;
  - the uncertainty of the ACTUAL critical load distribution has not been reduced and has been obscured by EPA in this analysis;
  - we are not aware of the details of EPA's "bootstrapping" or the statistical parameters of the distributions of the key variables.

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Introduction to EPRI Uncertainty

- $TNOy[NOy] + TSOx[SOx] = ([BC]_0{}^*{}_{\%p} - ANC_{lim}) \times Q_{\%p} - NHx + N_{eco,\%p}$
- Q, $[BC]_0{}^*$ and Neco must represent the uncertainty in the parameters of the specific "representative critical load" at the percentile of protection: %p
- EPRI originally performed this analysis with the parameters represented by normal distributions.
- This resulted in some of the probability occurring in non-physical space. By integrating the probability of the physical space alone, the analysis resulted in considerable skew.
- EPRI has redone the analysis using log-normally distributed variables reflecting the nature of these environmental parameters.
- This reduces (but does not eliminate) the skew of the resulting probability space.

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Uncertainty Analysis: Monte Carlo Simulation

- **Equation:** $(TNOy \times [NOy]) + (TSOx \times [SOx]) = Q \times (BC_0 - ANC_{lim}) + N_{eco} - NHx$
- **Number of Simulations:** 30,000
- **Independent, Fixed Variable:** ANC_{lim} = 50 μeq L^{-1}
- **Independent, Log-Normally Distributed Random Variables**

Variable	Geometric Mean, e^{μ}	Geo. Std. Deviation, e^{σ}
BC_0	225 μeq L^{-1}	0.637
Q	0.62 m y^{-1}	1.137
Neco	52 meq m^{-2} y^{-1}	1.351
NHx	17.9 meq m^{-2} y^{-1}	1.480
TSOx	1.75 cm s^{-1}	1.422
TNOy	0.82 cm s^{-1}	1.307

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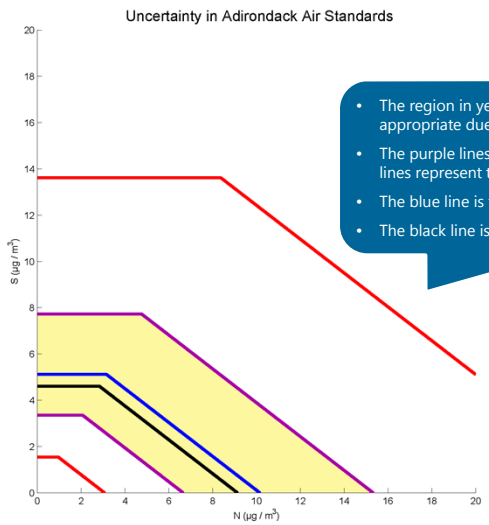
Monte Carlo Results



- The region in yellow represents the 50% confidence interval; appropriate due to inclusion of variability.
- The purple lines represent the 25th and 75th percentiles; the red lines represent the 5th and 95th percentiles.
- The blue line is the median.
- The black line is the nominal trade-off curve.

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Monte Carlo Conclusions

- Conclusions from Monte Carlo analysis
  - The 50% confidence interval centered around the median of the probability distribution is an appropriate representation of the impact of uncertainty and variability.
  - The nominal tradeoff curve (calculated using mean values) is moderately skewed from this median.
  - Also, the probability space is not symmetrical.
  - Even in the Adirondacks, certainly the one region in the U.S. with the most abundant available data, the uncertainty in the tradeoff curve is large.
    - Lack of data in other regions does not imply that the uncertainty is smaller or larger.
    - The situation is that the uncertainty is undefined or unknown.
    - The inclusion of variability in the uncertainty analysis is important to the design of the standard **based on the distribution of the variables themselves.**

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An Analysis of Interannual Variability of the AAI is Necessary to the Informing the Standard

- On page 7-53 of the PAD, EPA states that it does not have modeling results to explore multiyear-averaging (and therefore inter-annual variability) in the AAI.
- EPA also states lack of consecutive year modeling of CMAQ as an example, which would be important since they have based their analysis of the AAI by using CMAQ values rather than observed data.
- However, in the appendices it shows results from the CMAQ model from 2002-2005 in an analysis of the variability of transference ratios and also presents results for 2006 modeling applications in the PRISM discussion.
- This analysis is critical to understanding the variability in the AAI and is a significant omission to the Policy Assessment Document.

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Conclusions: Secondary NAAQS for SOx and NOx

- EPA is proposing a joint NAAQS for SOx and NOx to address aquatic acidification attributed to atmospheric deposition.
- However, EPA has failed to address concerns on five overarching issues:
  - Regionalization, spatial aggregation and data representativeness
  - Use of steady state assumptions for calculation of critical loads
  - Use of aquatic and atmospheric models in the standard-setting process
  - Inadequacy of ANC alone as an indicator of aquatic ecosystem health
  - Appropriate methods for estimating uncertainty and variability
- There are too many unresolved scientific issues that do not support the proposed methodology in its current form at the present time

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