Highlights of the NOxSOx Secondary NAAQS R/EA

Presentation to CASAC

October 1, 2008

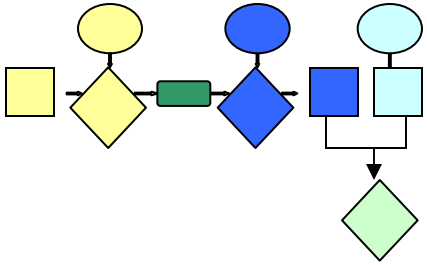
Office of Air Quality Planning and Standards

Health and Environmental Impacts Division

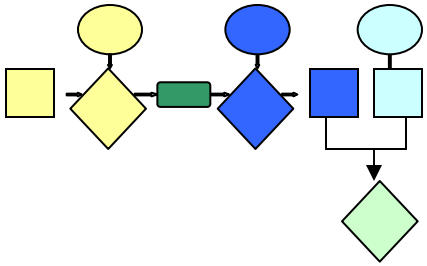
Air Quality Analysis Division

Office of Air Programs

Clean Air Markets Division

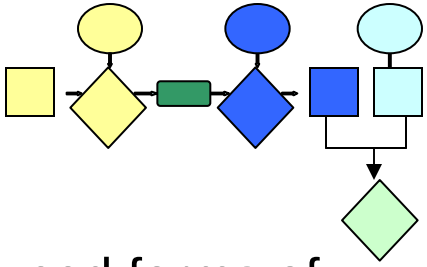


Purpose



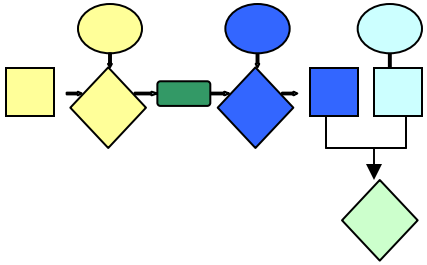
- Solicit feedback on EPA's first draft risk assessment for the NOx/SOx Secondary NAAQS review
  - Obtain guidance on the case study analyses and current risk assessment approach, and working structure for a secondary standard
  - Introduce some new material on policy-relevant interpretation of the science

In this review…



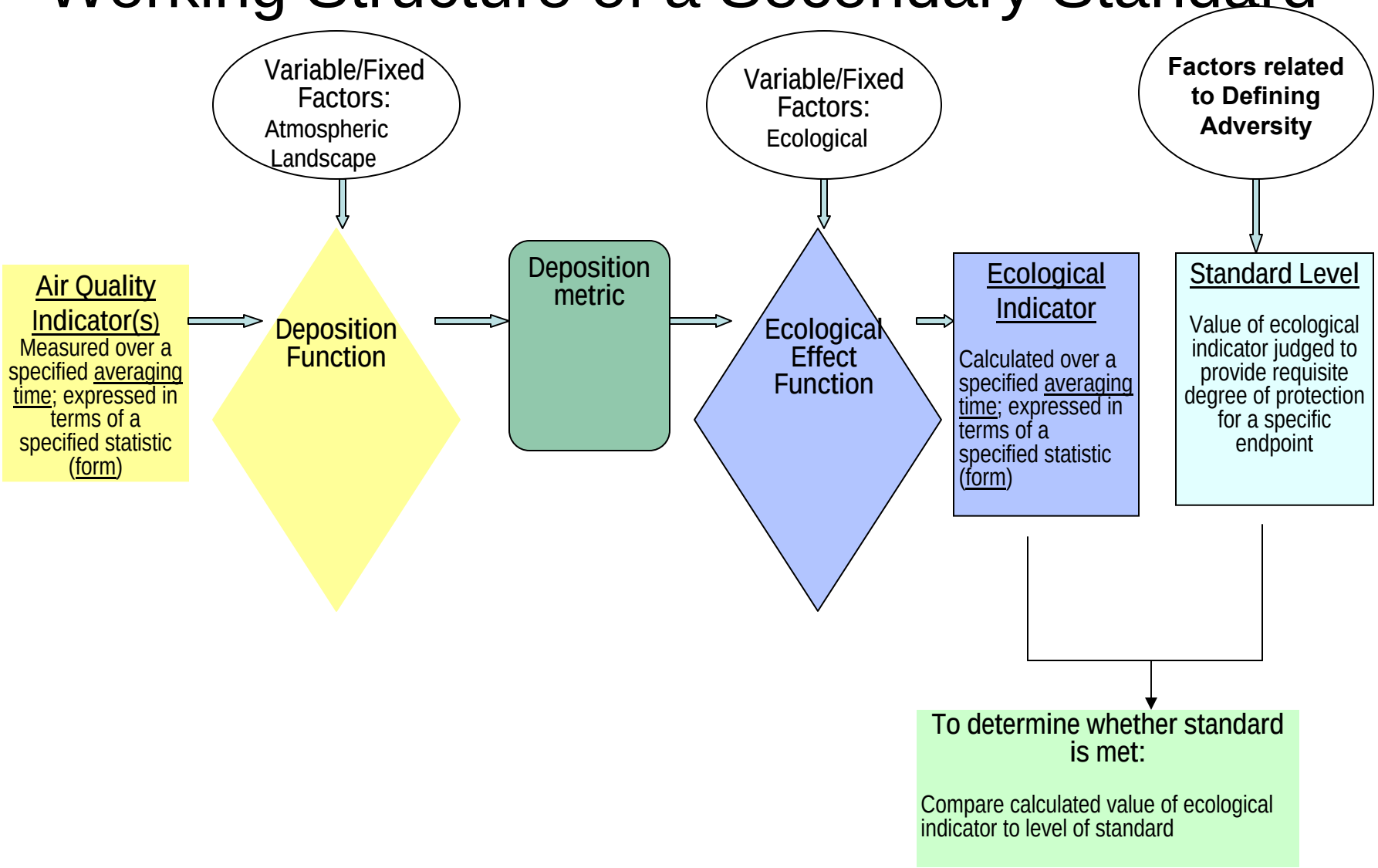
- Rationale, multi-pollutant approach, oxidized and reduced forms of nitrogen, policy-relevant questions (Ch 1)
- Overview of risk and exposure assessment, case study locations, effects, ecosystem services (Ch 2)
- Atmospheric analysis of spatial and temporal patterns of deposition; emissions and deposition relationships (Ch 3)
- Focus on environmental effects related to deposition of sulfur and reactive nitrogen into sensitive terrestrial and aquatic ecosystems
  - Acidification (Ch 4)
  - Nutrient Enrichment (Ch 5)
  - Additional Effects (Ch 6)
- Take a broad view of potential policy outcomes, after first evaluating relevant science and designing/conducting relevant assessments (Ch 7 & 8)

Complexities



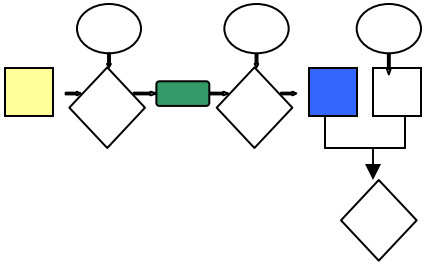
- Ecological effects linked to atmospheric concentrations of NOx and SOx through deposition of N and S
- Multi-pollutant, multi-source
- Many ecological endpoints
- Definition of adversity
- Many variables affect deposition rates and ecological effects
- Enhanced use of modeling and observational data of both ecological and atmospheric processes

Working Structure of a Secondary Standard

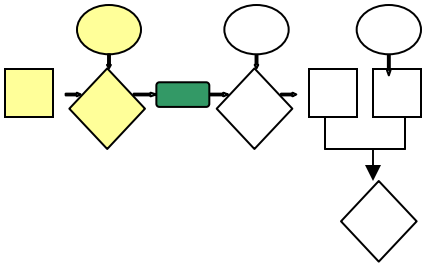


Key Concepts and Outline

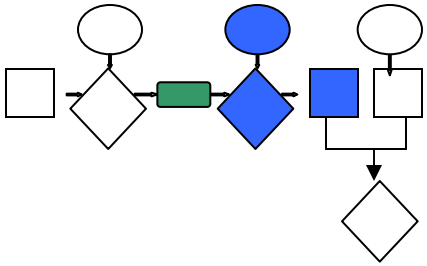
- Scientifically Sound Structure: *examines linkages between atmospheric concentrations of NOx and SOx, deposition of N and S, and ecological indicators*
  - Adirondacks Case Study Location
  - Ecological Effect of Aquatic Acidification



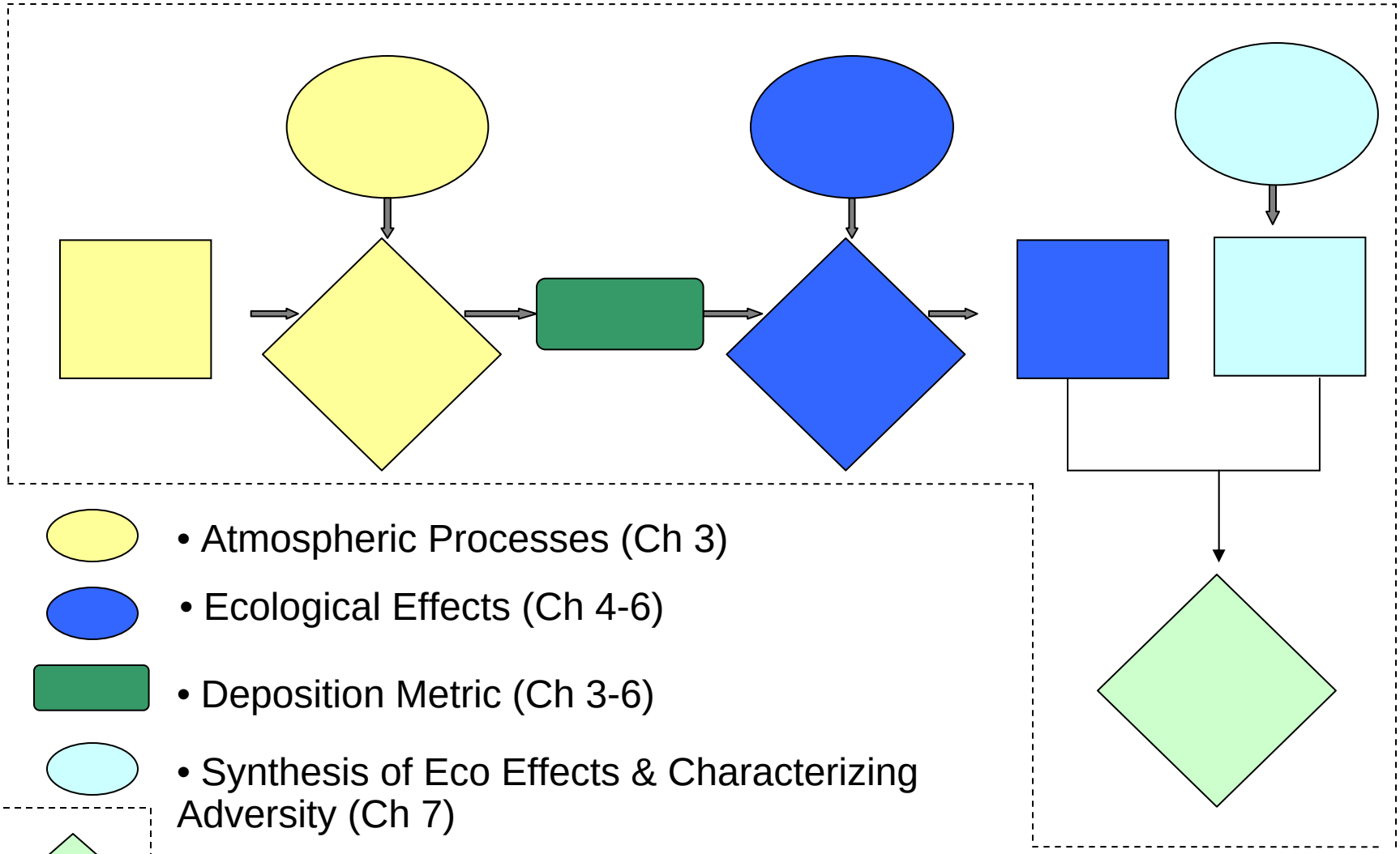
- Atmospheric Influences: *vary based on sources, transport, deposition, co-pollutants*
  - spatial and temporal characterization
  - emission and deposition relationships



- Ecological Influences: *reflect characteristics of ecological sensitivity (geology, weathering rates, soil thickness)*
  - Ecological Indicator: ANC
  - Relationship between ANC and deposition

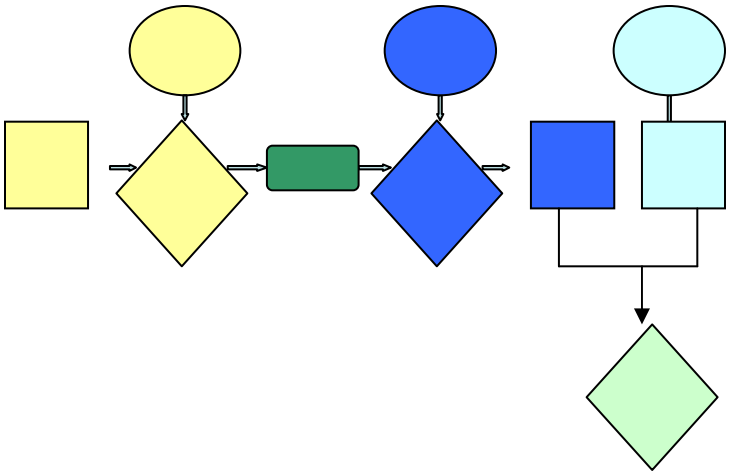


Second Draft Risk Assessment



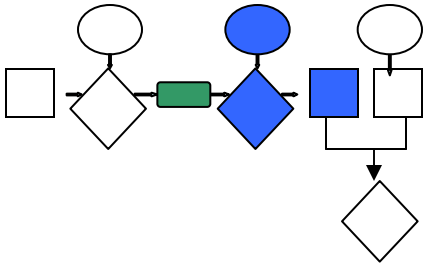
- Atmospheric Processes (Ch 3)
- Ecological Effects (Ch 4-6)
- Deposition Metric (Ch 3-6)
- Synthesis of Eco Effects & Characterizing Adversity (Ch 7)
- Statutory Interpretation: Structure of a Secondary Standard (Ch 8)

Illustrative Example



- Ecological Effect: Aquatic Acidification
- Case Study Location: Adirondacks

Ecological Effects and Indicators

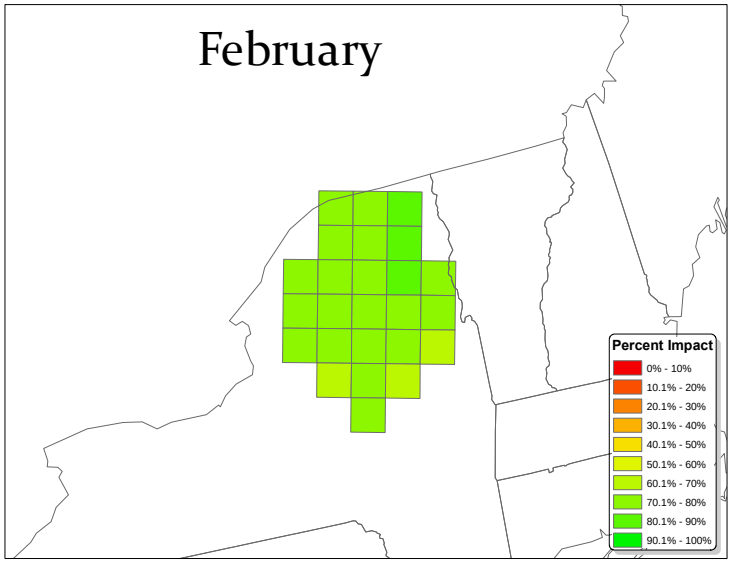


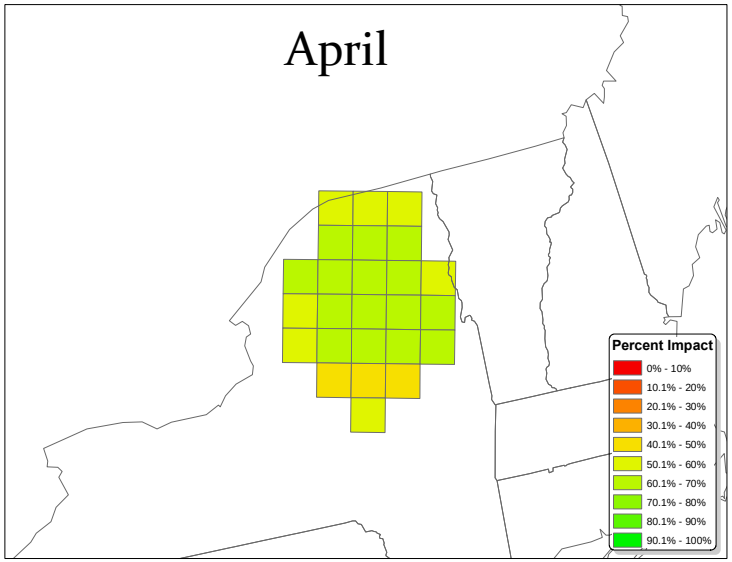
Targeted Effect area	Characteristics of Sensitivity (Variable Ecological Factors)	Ecological Indicator	Case Study Locations
Aquatic Acidification	geology, surface water flow, soil depth, weathering rates	Species richness, abundance, composition, **ANC**	Adirondack Mountains (NY) Blue Ridge Mountains, Shenandoah National Park (VA)
Terrestrial Acidification	geology, surface water flow, soil depth, weathering rates	Tree health Red spruce, sugar maple **ANC**	Kane Forest (Allegheny Plateau, PA) Hubbard Brook Experimental Forest (White Mountains, NH)
Aquatic Nutrient Enrichment	N-limited systems, presence of nitrogen in surface water, eutrophication status, nutrient criteria,	**Eutrophication Index (EI)**	Potomac River Basin, Chesapeake Bay Neuse River Basin, Pamlico Sound
Terrestrial Nutrient Enrichment	Presence of Acidophytic Lichens, anthropogenic land cover	**Species composition**	Coastal Sage Scrub and mixed conifer forest (San Bernadino and Sierra Nevada Mountain Ranges, California)

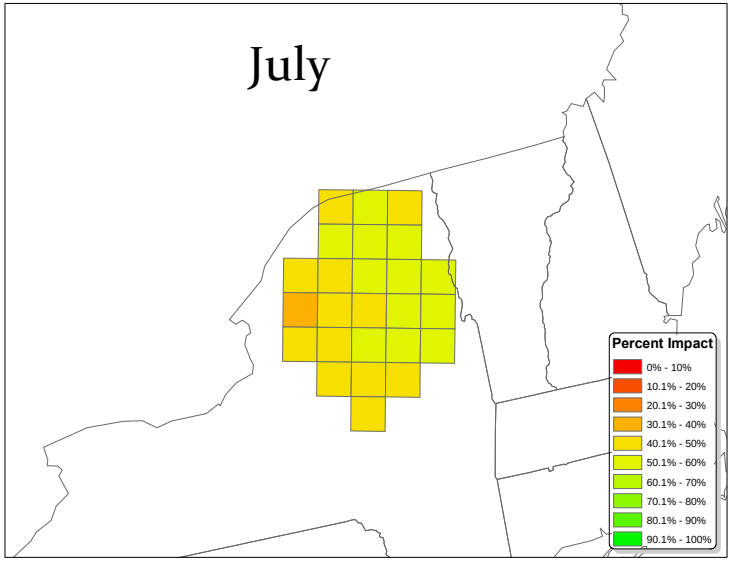
Role of NOx in N Deposition

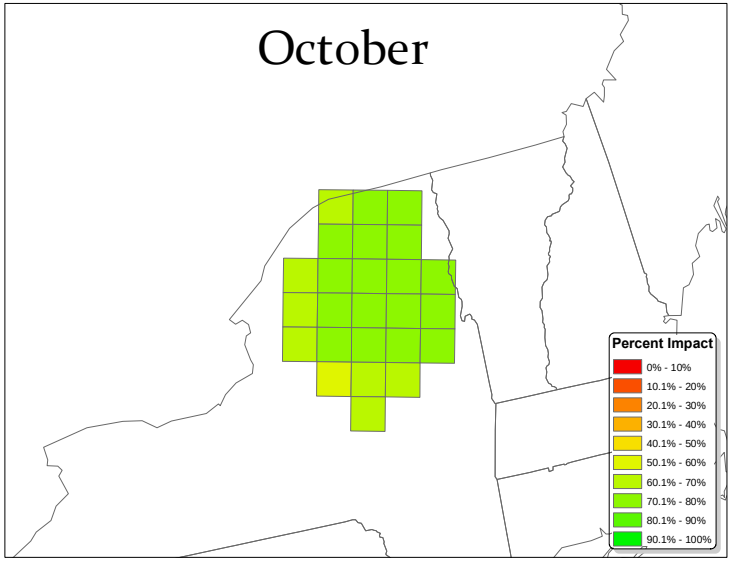
- Ecological effects are associated with total nitrogen. NOx contribution relative to ammonia and other sources of N is important.
- RSM analysis of N deposition for case studies indicates that NOx emissions play significant role in total N deposition.
- In some areas (e.g. Neuse Basin) NH3 plays lead role but NOx still important.
- In Western U.S., international emissions of NOx and NH3 contributing to total N but domestic emissions still dominant.
- RSM analysis supports addressing ambient NOx to reduce nitrogen related ecological impacts, and also supports the separation of total nitrogen into oxidized and reduced forms for the purposes of constructing ambient standards.

Contribution of Anthropogenic NOx Emssions to Total Nitrogen Deposition in the Adirondacks Case Study Area

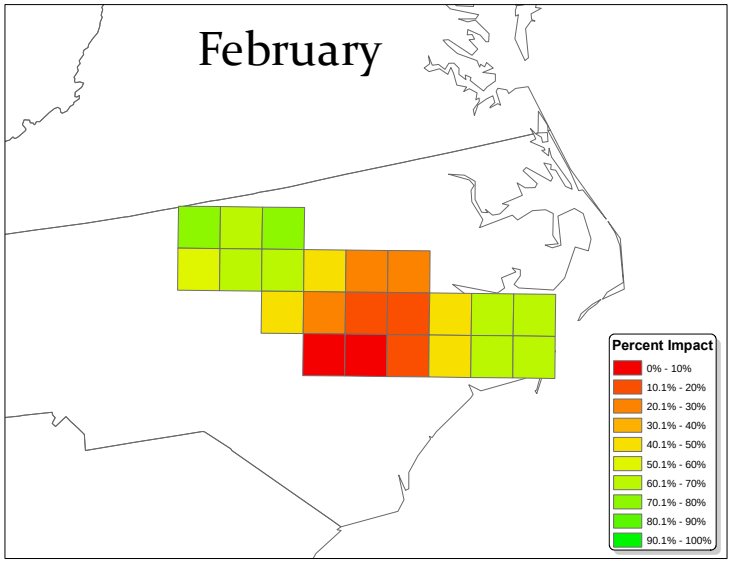


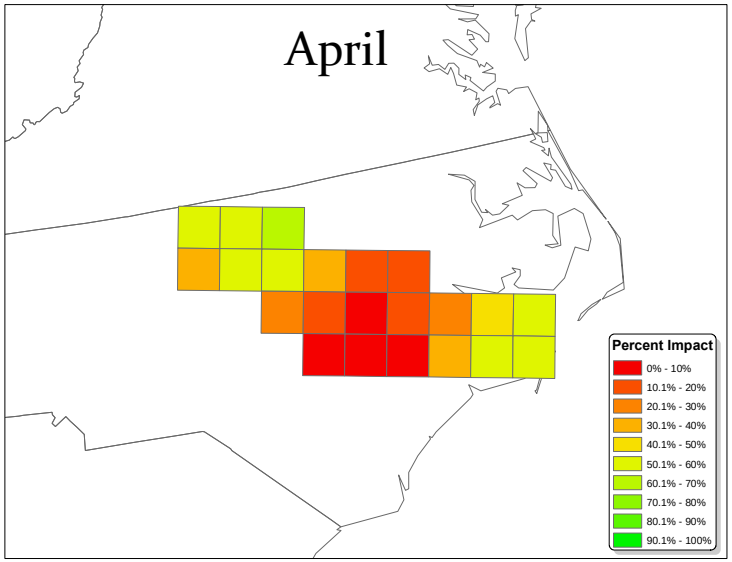


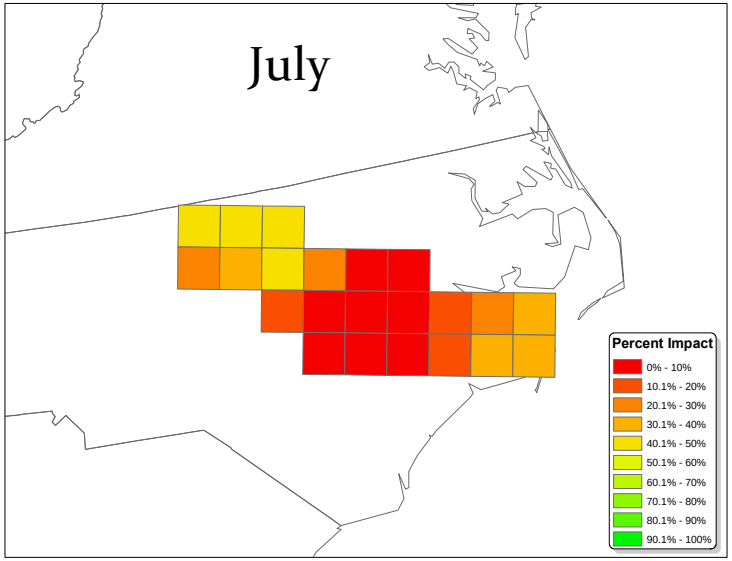


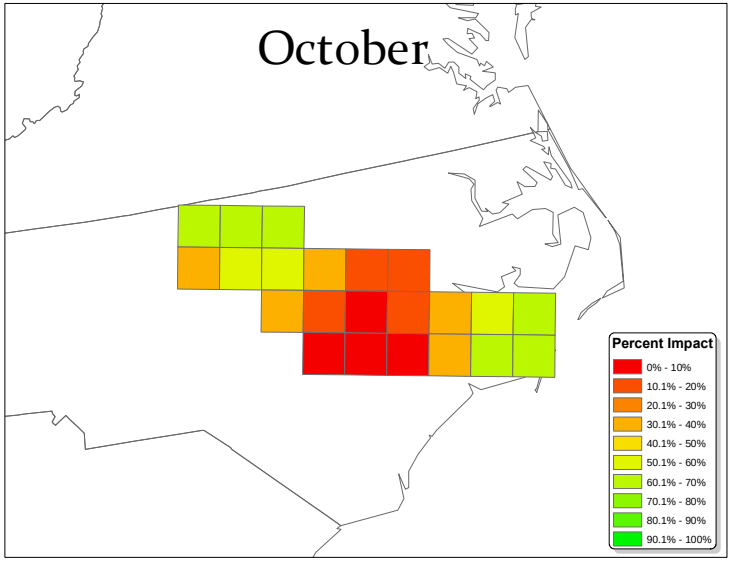


Contribution of Anthropogenic NOx Emissions to Total Nitrogen Deposition in the Neuse Case Study Area









Characterization of Deposition and Concentrations

- Purpose: Describe the magnitude, spatial gradients, and intra-annual and inter-annual variations in NOx and SOx in and near the Case Study Areas

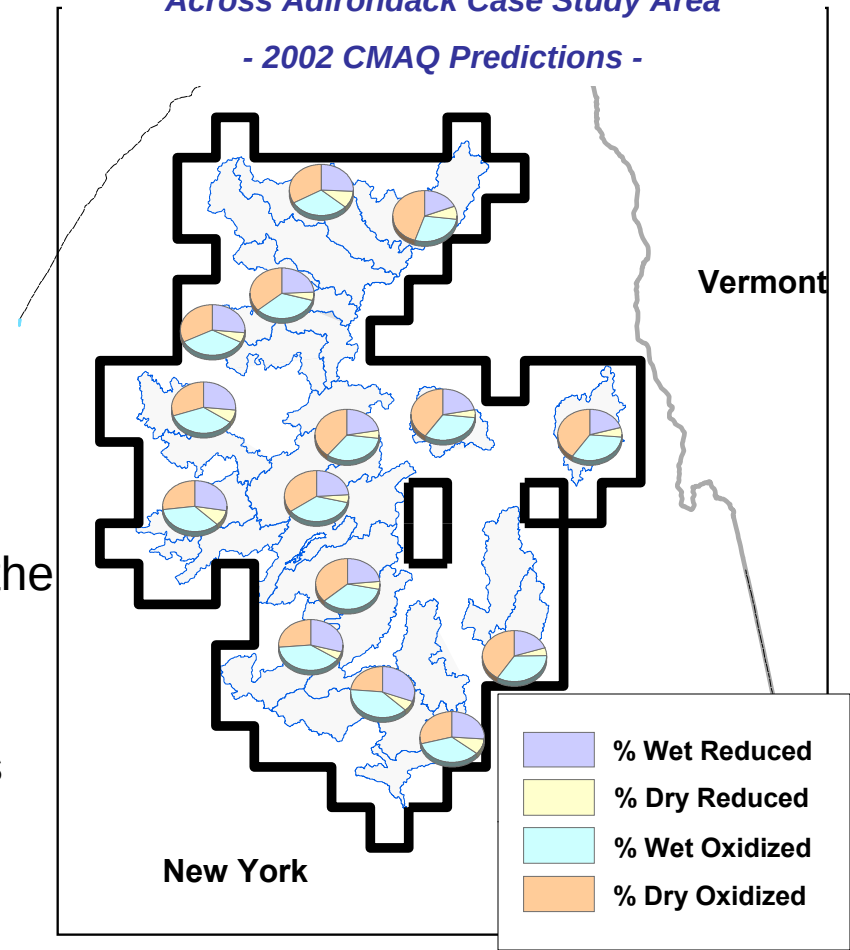
- Compare the relative amounts of…
  - wet vs dry deposition of N and S
  - oxidized vs reduced N deposition

- Based on modeled and measured data
  - National Air Deposition Network (NADP) wet deposition
  - CMAQ wet and dry deposition

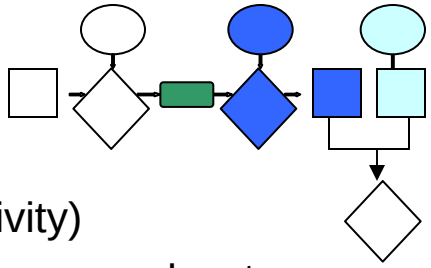
- Example: Of the total annual N deposition in the Adirondacks……
  - oxidized N dominates over reduced N (~ 70% vs 30%)
  - relative amount of wet vs dry oxidized N varies across the region
  - total wet deposition dominates over dry deposition (~60% vs 40%)

Example: Relative Amount of Wet / Dry, Oxidized / Reduced Nitrogen Deposition Across Adirondack Case Study Area

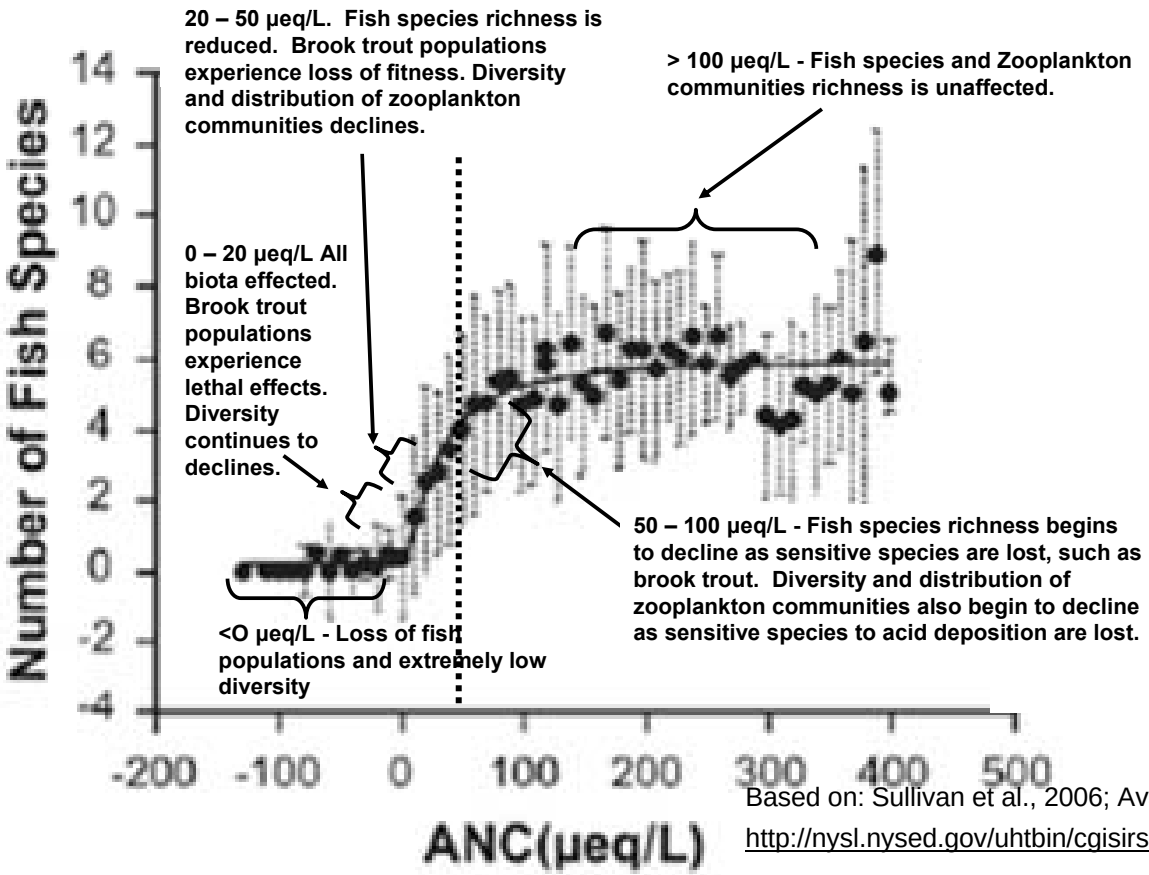
- 2002 CMAQ Predictions -



Aquatic Acidification

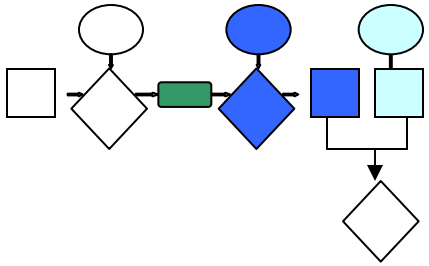


- Case Study Areas: Adirondacks and Shenandoahs (sensitivity)
- 2002 CMAQ predicted dry deposition coupled with NADP measured wet deposition, MAGIC model
- Ecological Indicator: Acid Neutralizing Capacity (ANC)
- Ecosystem Services: Fisheries, recreation, food, natural habitat, tourism



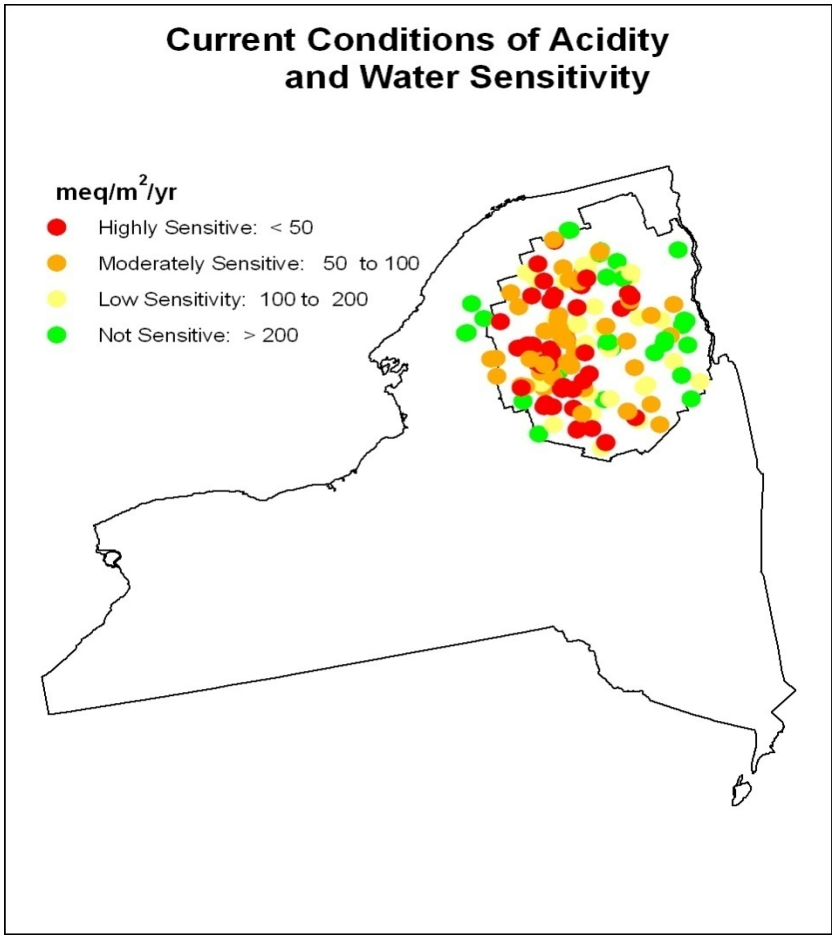
Based on: Sullivan et al., 2006; Available: http://nysl.nysed.gov/uhtbin/cgisirsi/Qcwd6NzFby/NYSL/138650099/8/429847

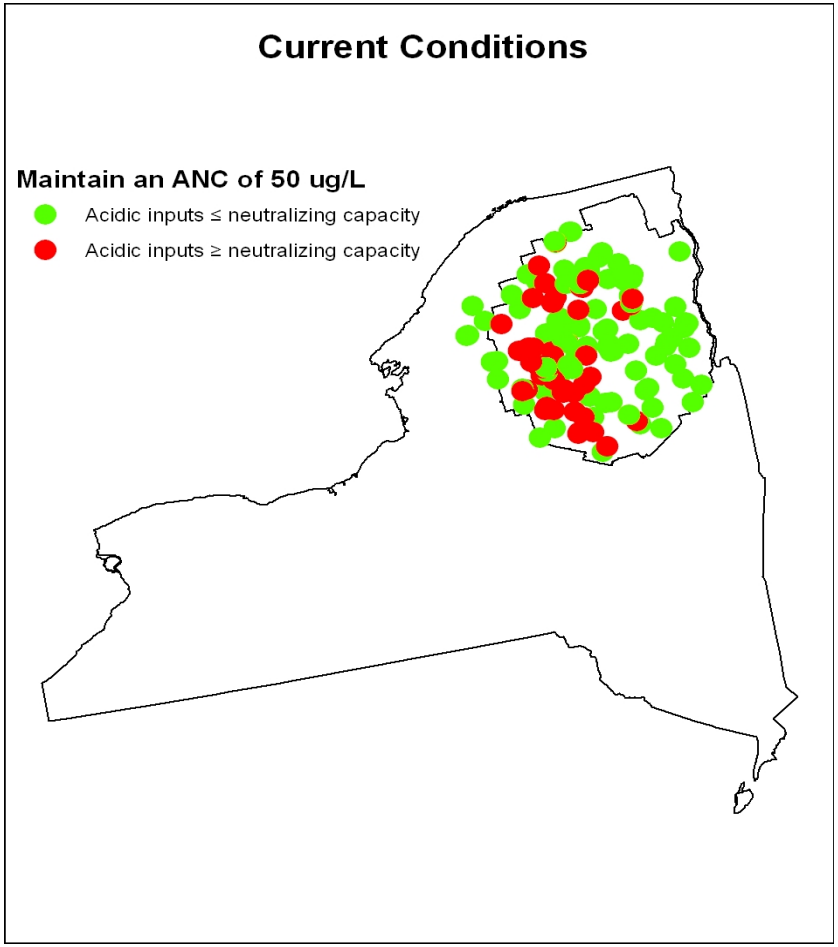
Preliminary Current Conditions Results for the Adirondacks



•Amount of acidity a lake can neutralize and still maintain and ANC of 50

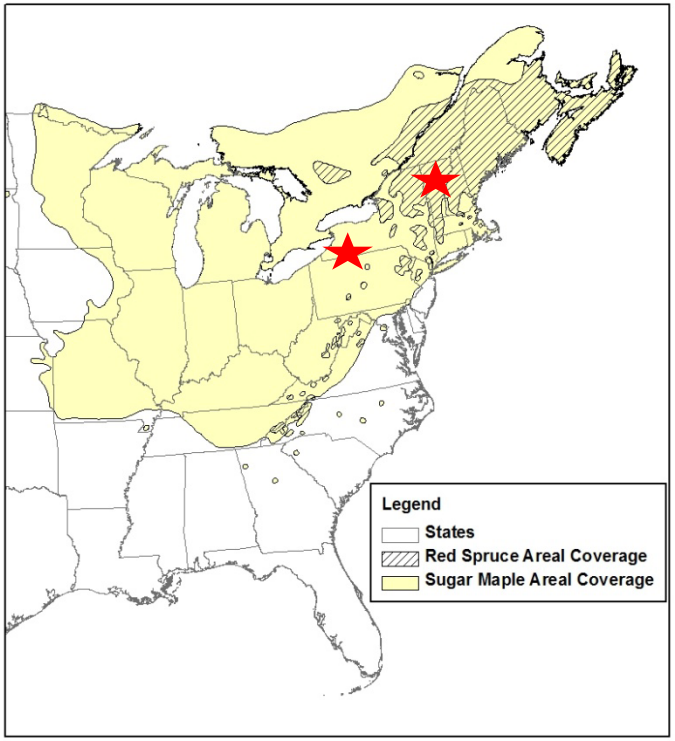
•Lakes that are receiving more acidity than they can neutralize





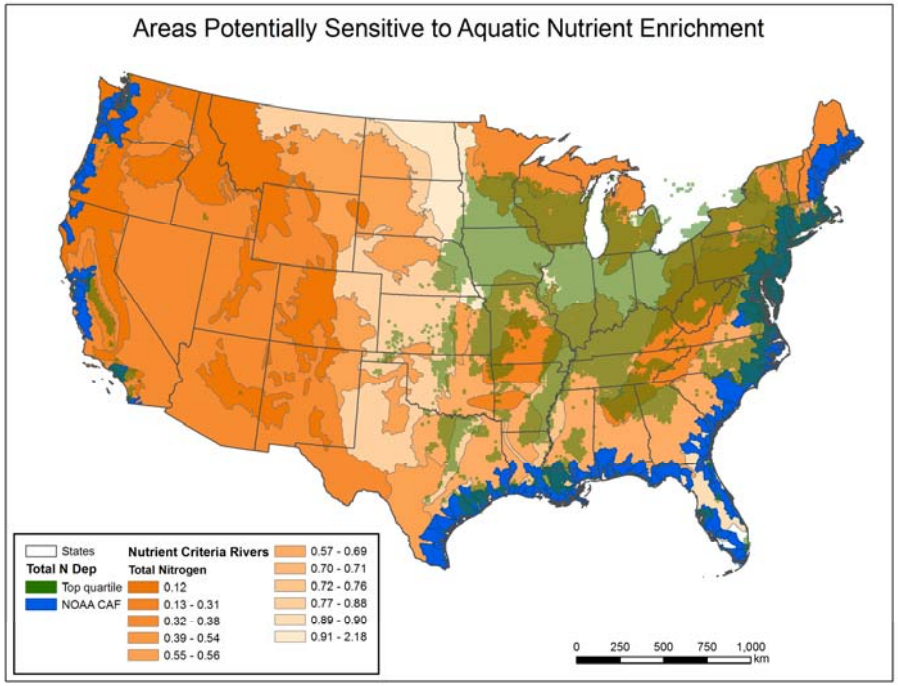
Terrestrial Acidification

- Case Studies:
  - Sugar Maple: Kane Experimental Forest in PA
  - Red Spruce: Hubbard Brook Experimental Forest in NH
- Model deposition effects on acid neutralizing capacity of forest soil
- Results expected early fall
- Ecosystem services: food, natural habitat, tourism

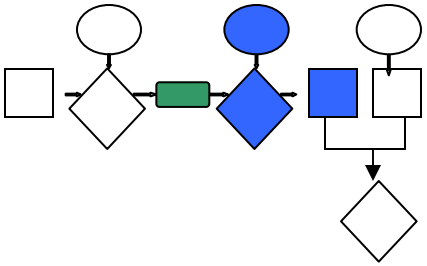


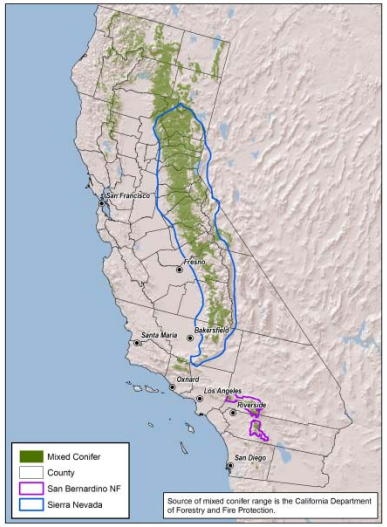
Aquatic Nutrient Enrichment

- Model how changes to nitrogen deposition affect the eutrophication index in an estuary
  - Deposition Data
    - Dry deposition from CMAQ model
    - Wet deposition from NADP
  - Watershed Fate and Transport model(SPARROW)
  - NOAA Eutrophication Index
- Case Study Areas:
  - Potomac River (Chesapeake Bay)
  - Neuse River (Pamlico Sound)
- Results expected early fall
- Ecosystem Services: fisheries, recreation, tourism



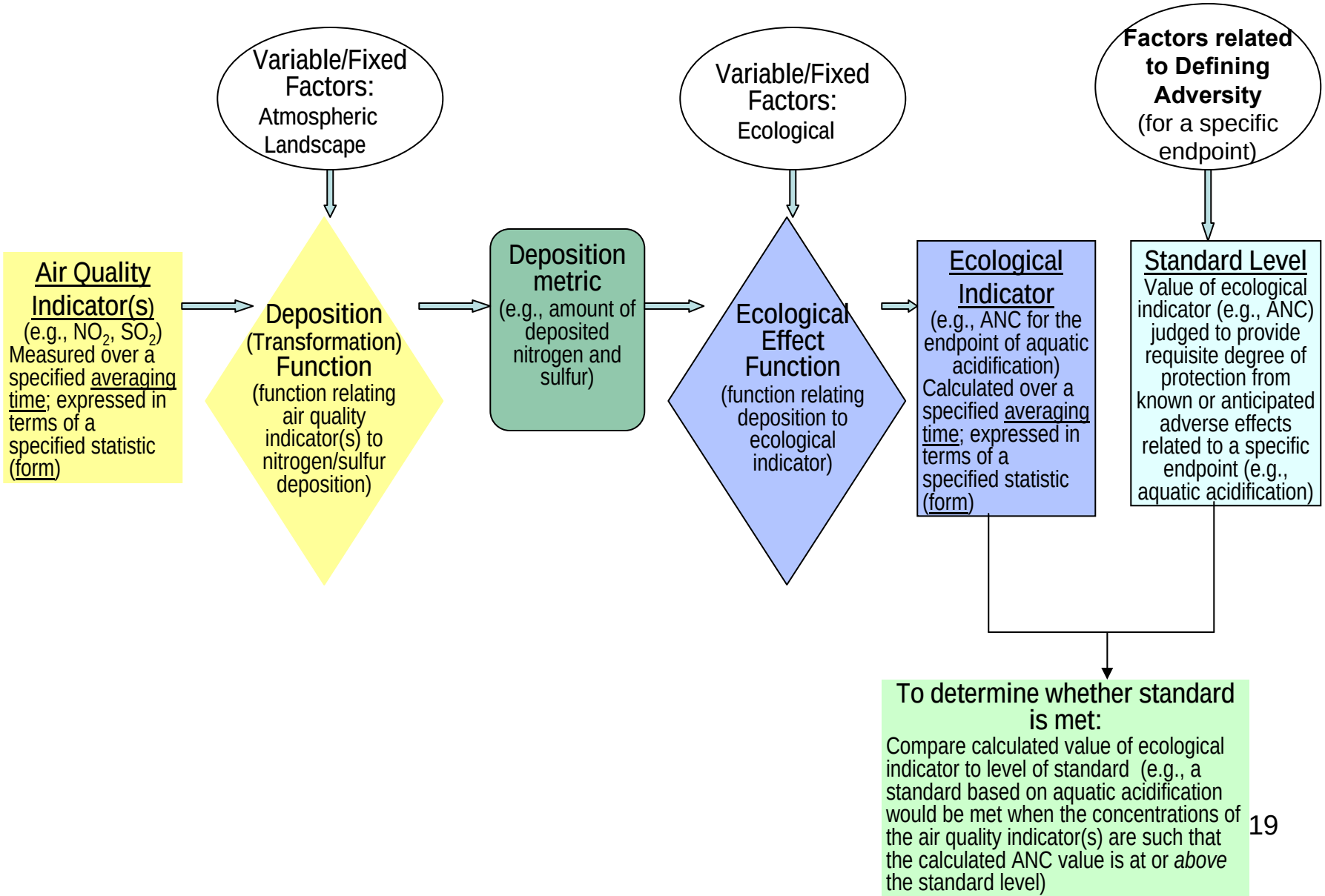
Terrestrial Nutrient Enrichment



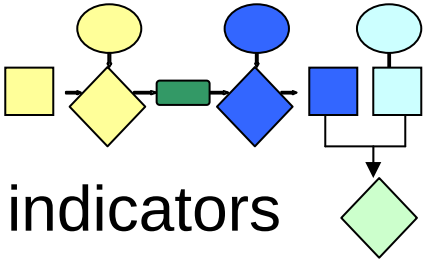


- Coastal Sage Scrub
  - Nitrogen deposition believed to enhance invasive grasses and increase fire threat
  - Habitat for threatened and endangered species
  - Developing a conceptual model to estimate effects from various loadings
- Mixed Conifer Forests in San Bernardino and Sierra Nevada Mountains
  - Decreased root biomass in Ponderosa Pine
  - Nitrate leaching due to soil saturation
  - Declines in sensitive lichen species
  - Analyzing loads versus effect levels from research reports
- Ecosystem Services: biodiversity, water quality, timber, recreation, fire hazard mitigation
- Results expected early fall

Challenges for Translating these Concepts into a Secondary Standard

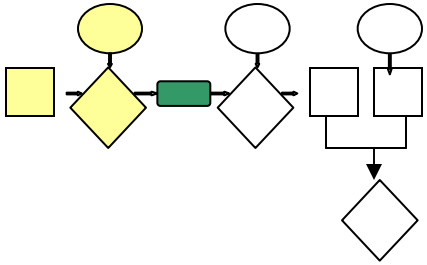


Conceptual Model



- Set of linked functions translating atmospheric indicators (NOx and SOx) to an ecological indicator that expresses the potential for deposition of nitrogen and sulfur to acidify an ecosystem
- Two parts to this system of functions:
  - deposition transformation function, which transforms ambient atmospheric concentrations (the atmospheric indicators) into a deposition metric
  - ecological effect function which converts the deposition metric to an ecological indicator (ANC) by adjusting for levels of other ecological factors that contribute to ANC
- The atmospheric levels of NOx and SOx that satisfy a particular level of ecosystem protection are those concentrations that lead to a deposition which achieves a given ANC.

Mathematical Representation: Deposition Transformation Function



(1) $S_D = f_S(NO_x, SO_x \mid Z)$

$N_D = f_N(NO_x, SO_x \mid Z)$

S_D is sulfur deposition,

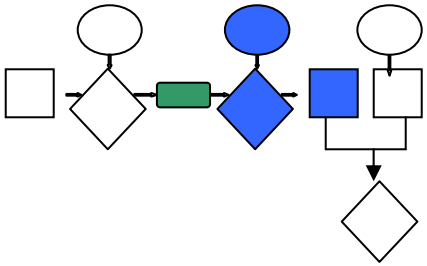
N_D is nitrogen deposition,

Z is a vector of parameters affecting deposition of ambient SO_x and NO_x (primarily determinants of deposition velocities),

f_S is a function relating S_D to ambient concentrations of NO_x and SO_x, given Z,

f_N is a function relating N_D to ambient concentrations of NO_x and SO_x, given Z.

Mathematical Representation: Ecological Effect Function



$$(2) \qquad I = ANC = g(\cdot) - S_D - N_D$$

I is an ecological indicator

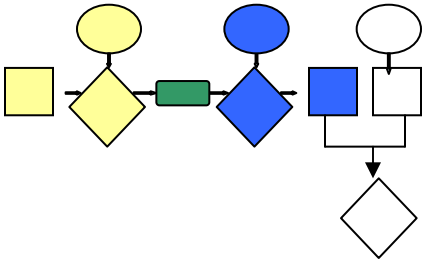
ANC is the indicator for protection against acidification

g(·) is a series of non-atmospheric environmental factors (e.g., runoff, weathering rates, geology, etc.), and NHx

S_D is sulfur deposition

N_D is nitrogen deposition

Mathematical Representation: Putting It All Together



By substituting (1) into (2), the ecological indicator I can be described in terms of ambient atmospheric NOx and SOx concentrations:

$$(3) \qquad I = g(\cdot) - f_S(NO_x, SO_x \mid Z) - f_N(NO_x, SO_x \mid Z)$$

The Role of Adversity

(4) $I^* = ANC_{limit} = g(\cdot) - DL(S) - DL(N)$

·When the Administrator selects a level of effect that is determined to be adverse to public welfare, that then determines the ANC_{limit} which defines the standard, I*

·ANC_{limit} is the limit for ANC necessary to provide a particular level of protections for biota in an ecosystem,

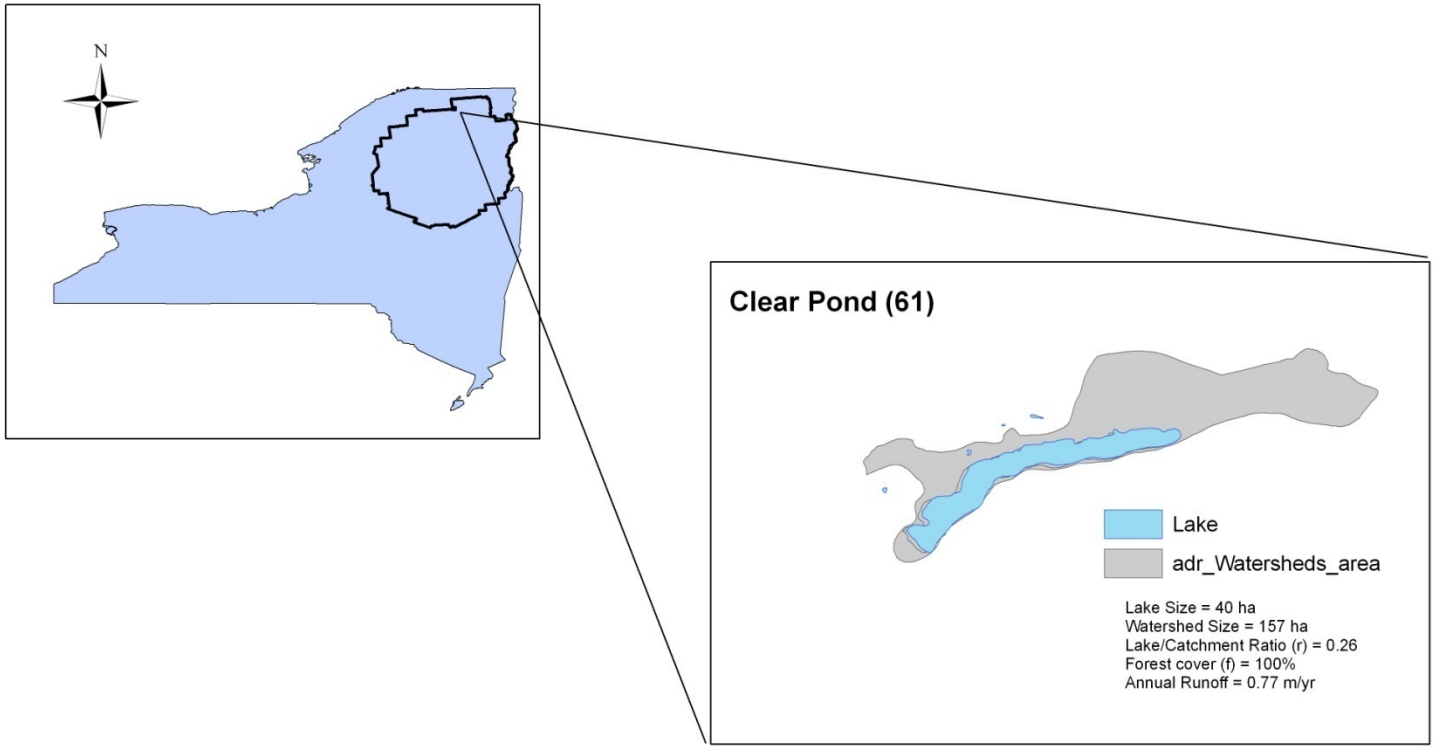
·DL(S) is the depositional load of S associated with ANC_{limit},

·DL(N) is the depositional load of N associated with ANC_{limit}

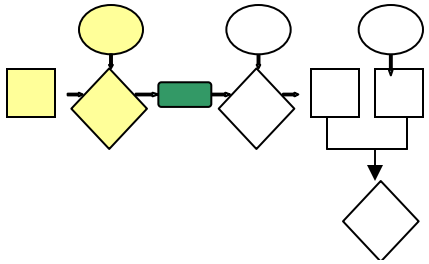
·Referring to equation 3, the point where adverse effects occur are when f_S and f_N are large enough to cause the ANC to fall below the ANC_{limit} value. This occurs when $f_S + f_N \geq DL(S) + DL(N)$ for a particular location.

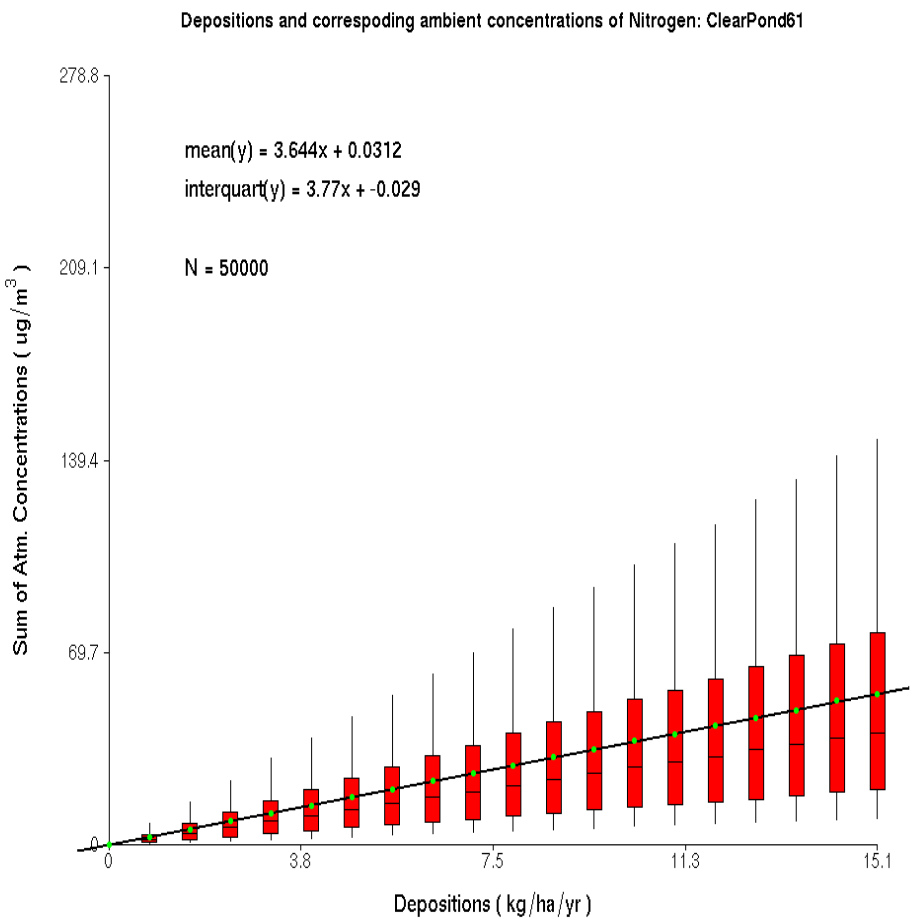
DL(S) and DL(N) are jointly determined by the equation $ANC_{limit} = g(\cdot) - DL(S) - DL(N)$, there is no unique solution

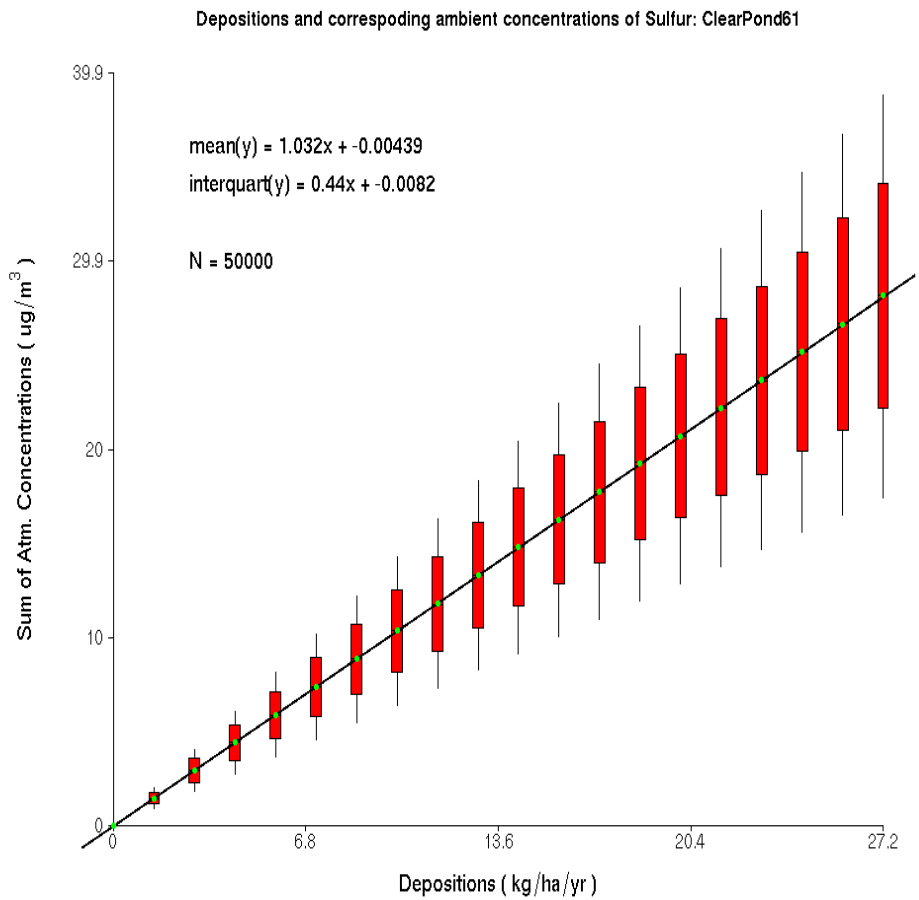
Calculating an Indicator Based Standard: Adirondacks Example



Concentration to Deposition Functions



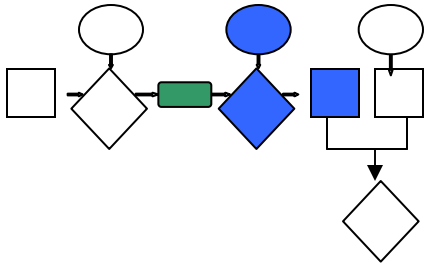




$$Dep_N = (v_{NO} \cdot C_{NO} \cdot m_{NO}) + (v_{NO_2} \cdot C_{NO_2} \cdot m_{NO_2}) + (v_{HNO_3} \cdot C_{HNO_3} \cdot m_{HNO_3}) + (v_{Nitr} \cdot C_{Nitr} \cdot m_{Nitr})$$

$$Dep_S = (v_{SO_2} \cdot C_{SO_2} \cdot m_{SO_2}) + (v_{Sulf} \cdot C_{Sulf} \cdot m_{Sulf})$$

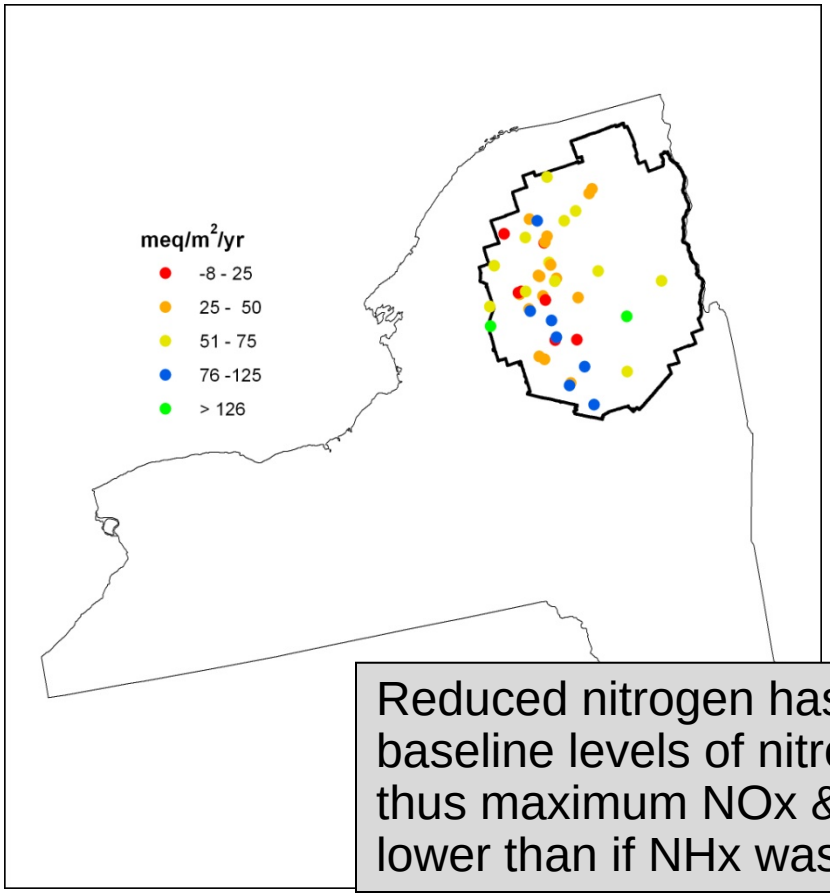
Ecological Effect Function



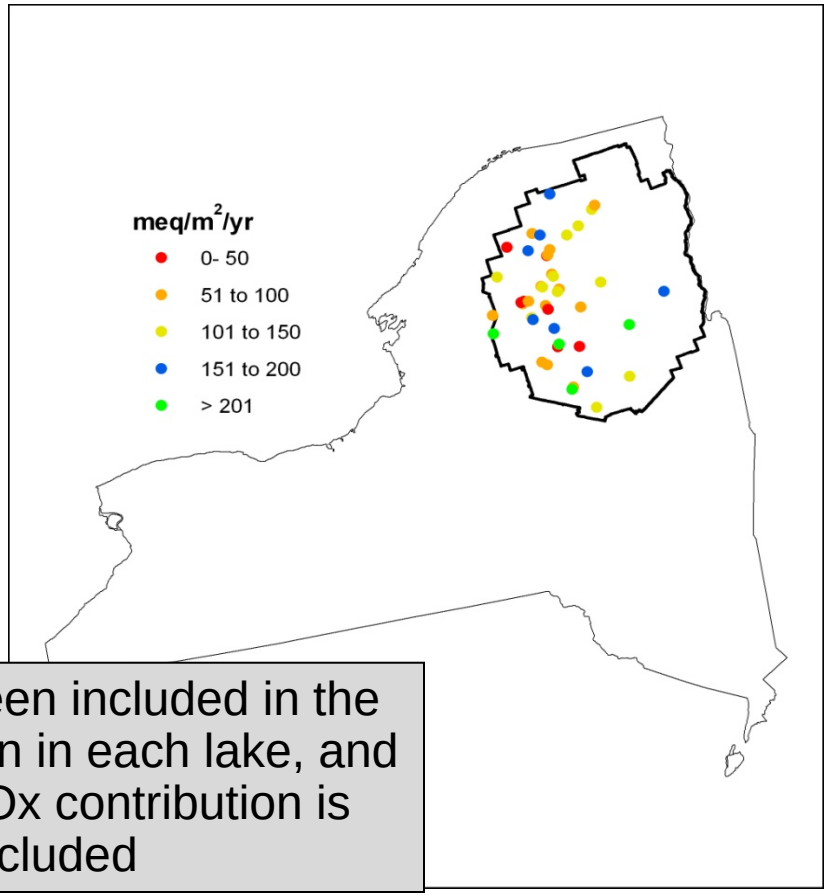
- Environmental parameters
  - lake area (ha)
  - catchment area (ha)
  - the amount of forest area in the catchment (*f*)
  - annual runoff (m/y)
- Catchment removal of N and S is calculated based on a combination of modeled and measured data
- Leaching export (NO_3 and SO_4) level will determine the ANC level
- Resulting charge balance gives the maximum deposition from ambient atmospheric NOx and SOx that will give a minimum level of ANC

44 Adirondack Lakes

Maximum Deposition of Sulfur from Ambient Atmospheric SOx for an ANC of 50



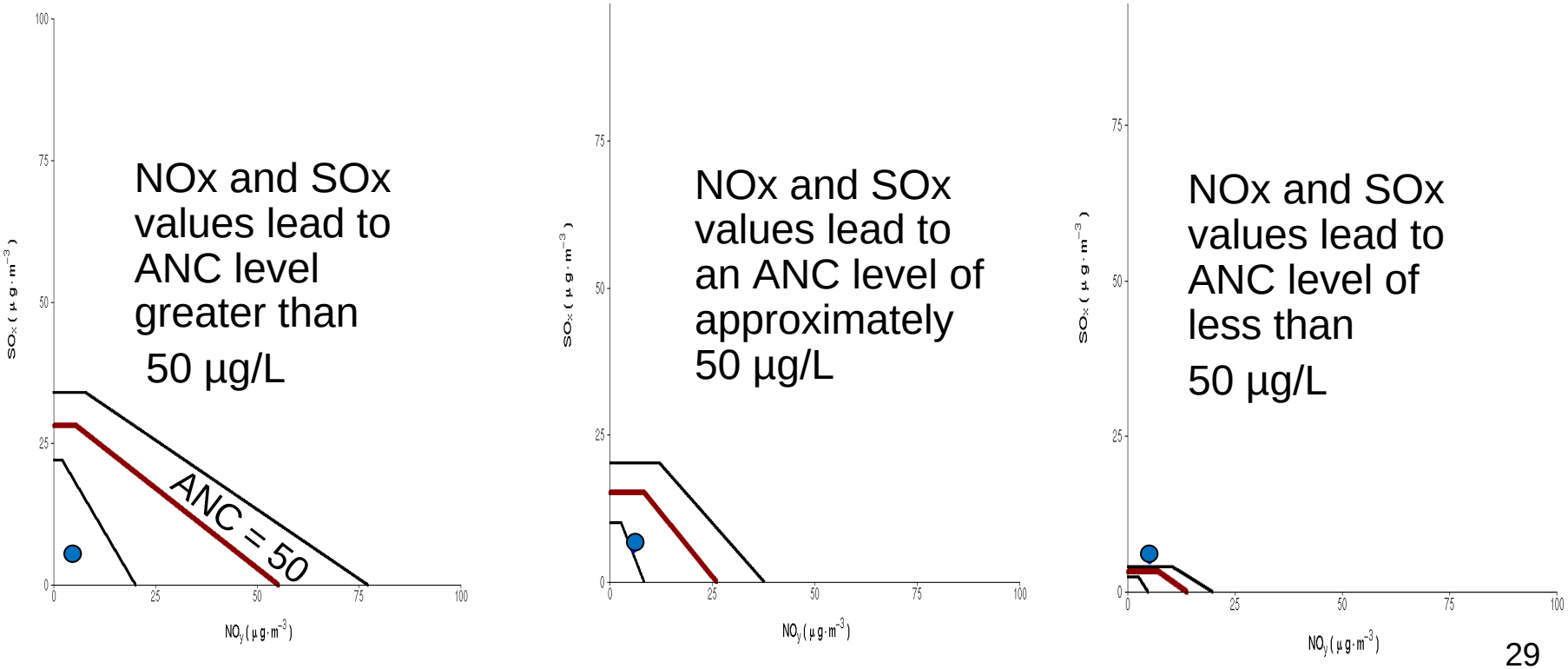
Maximum Deposition of Oxidized Nitrogen from Ambient Atmospheric NOx for an ANC of 50



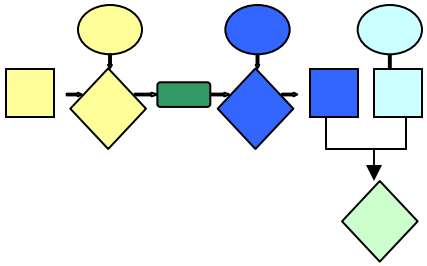
Reduced nitrogen has been included in the baseline levels of nitrogen in each lake, and thus maximum NOx & SOx contribution is lower than if NHx was excluded

Putting It All Together: Comparing Atmospheric Concentrations of NOx and SOx and ANC levels

- Contours represent combinations of NOx and SOx that yield an ANC value of 50
- Black boundary lines indicate the range of possible combinations given variability in the atmospheric concentrations of different NOx and SOx species
- Blue dots show the current 2002 CMAQ modeled combinations of NOx and SOx

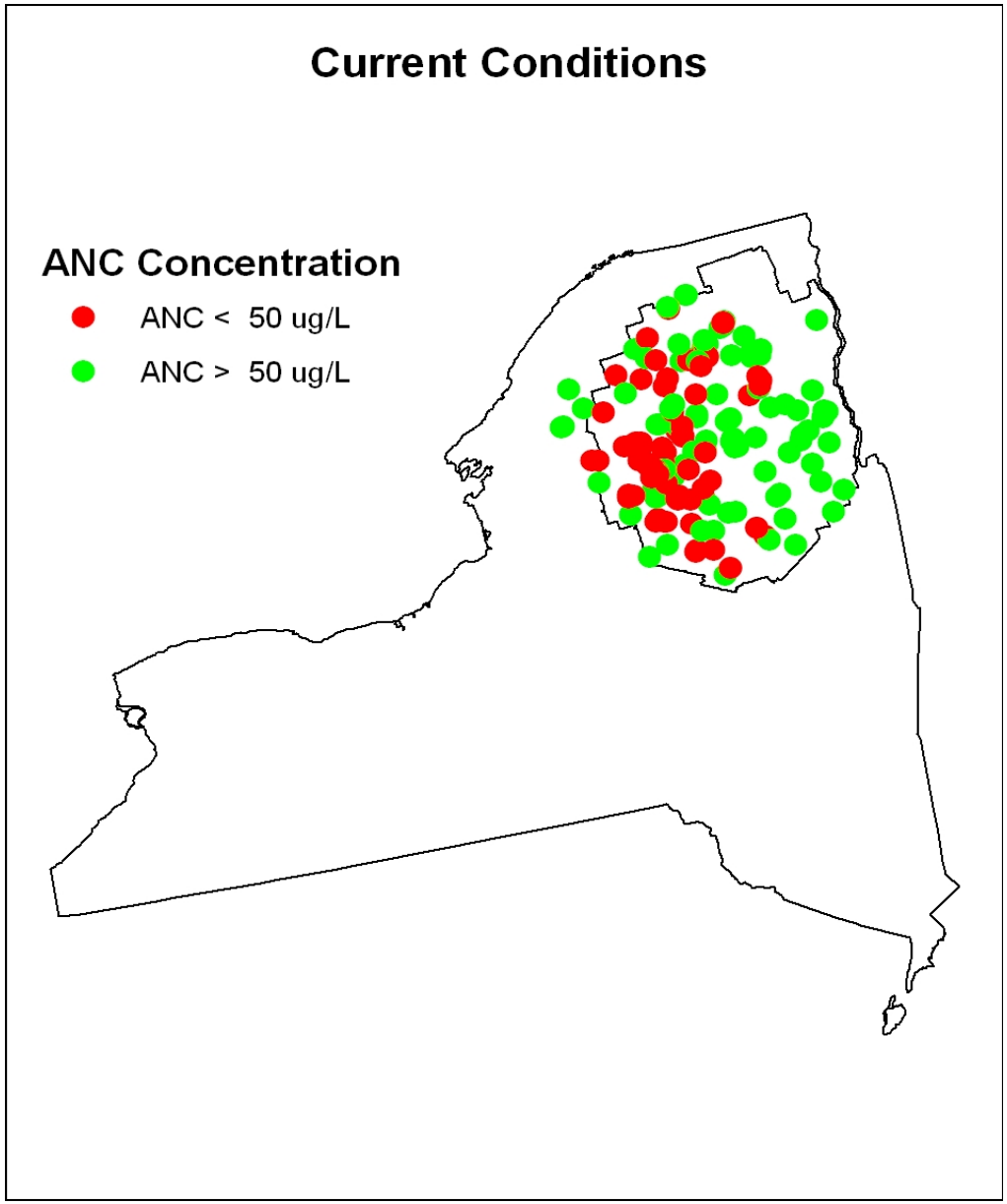


Next Steps



- Continue case study analyses
- Develop additional functions linking ambient NOx and SOx and ecological indicators for other endpoints (terrestrial acidification, aquatic and terrestrial nutrient enrichment)
- Examine how ecological indicators and ecosystem services can be used to define adversity
- Evaluate impacts and risks under alternative levels of standards

Appendix


Current Conditions
ANC Concentration
ANC < 50 ug/L
ANC > 50 ug/L