# Developing the Critical Loads and Target Loads of $SO_4^{2-}$, $NO_3^-$ and $NH_4^+$ in Watersheds of the Great Smoky Mountain National Park


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# Outline

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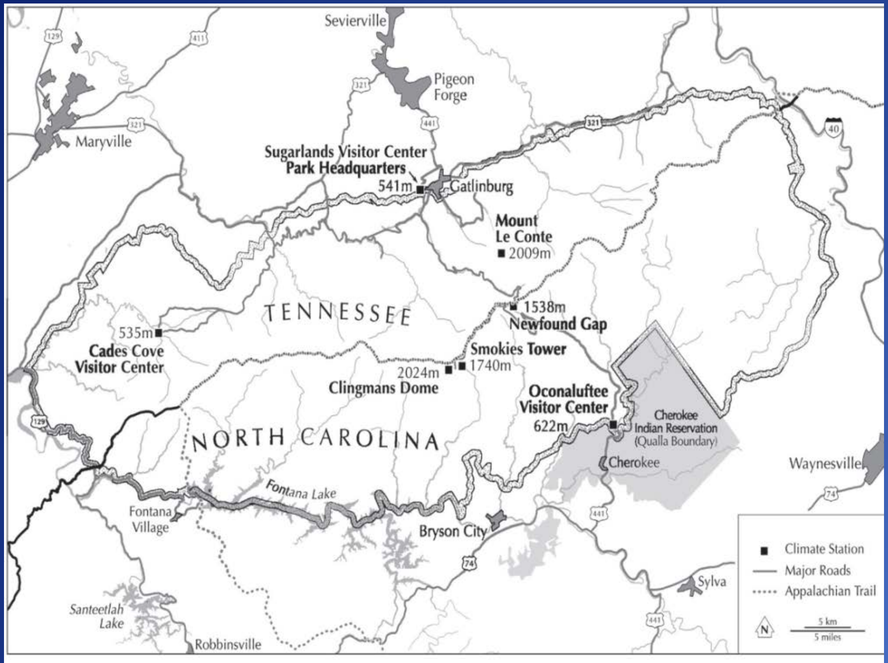
- Conclusions

# Great Smoky Mountain National Park (GSMNP)




# Objectives

- To assess the response of streams and soils to past and potential future changes in the acidic deposition.
- To establish the Target Loads (TL) and Critical Loads(CL) for N and S deposition in watersheds of the Great Smoky Mountain National Park (GSMNP).
- To explore the factors that control the critical loads in the GSMNP.
- Inform the Total Maximum Daily Load process.

# Approach: the criterion of choosing different sites in GSMNP

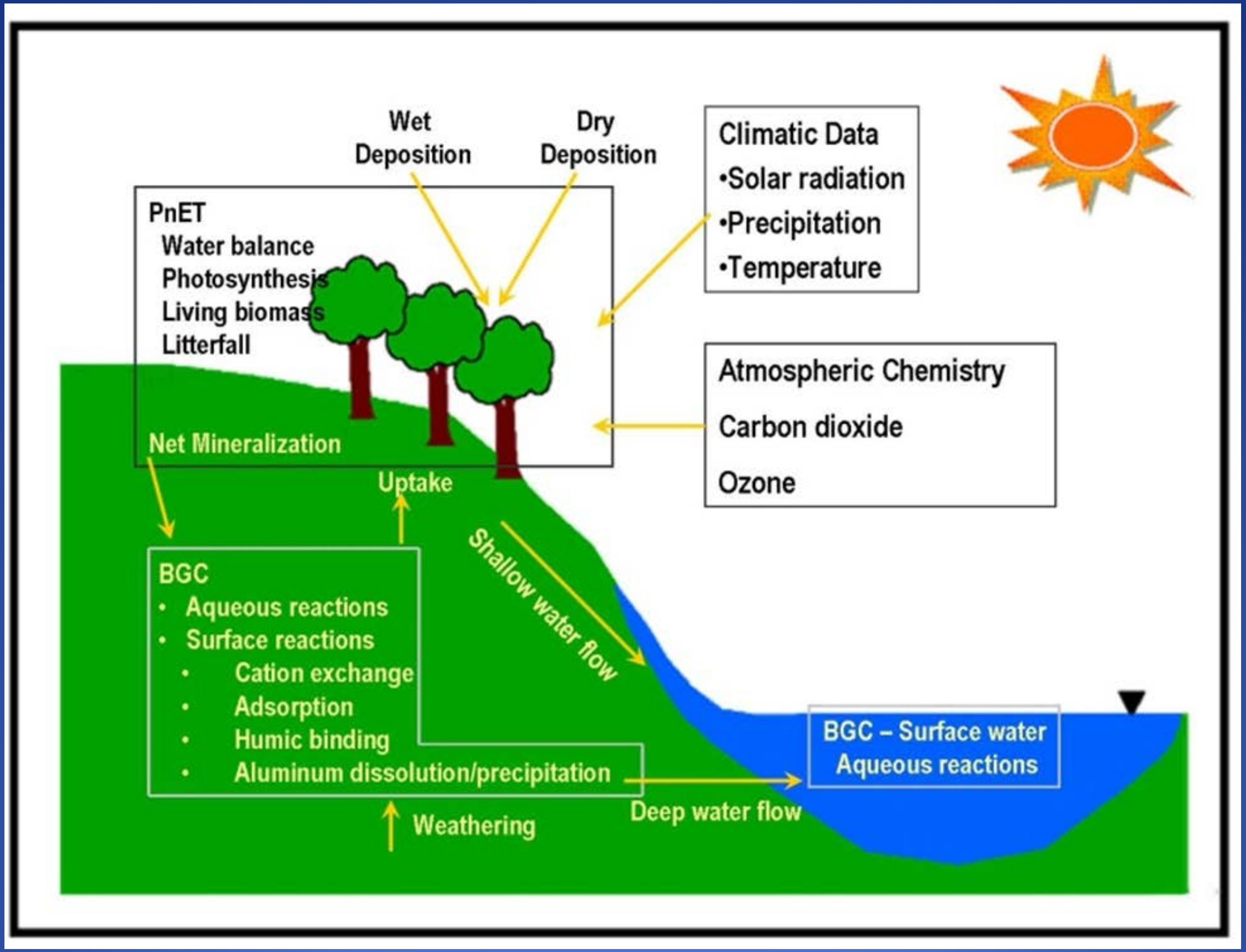
Study sites in block units

| Block | Basin Area | Elevation | Anakeesta |
|---|---|---|---|
| 1 | 1-10 $km^2$ | <1000m | >10% |
| 2 | 1-10$km^2$ | >1000m | >10% |
| 3 | 1-10$km^2$ | <1000m | None |
| 4 | 1-10$km^2$ | >1000m | None |
| 5 | 10$km^2$-20 $km^2$ | <1000m | >10% |
| 6 | 10$km^{2-}$20 $km^2$ | >1000m | >10% |
| 7 | 10 $km^2$-20$km^2$ | <1000m | None |
| 8 | 10 $km^2$-20 $km^2$ | >1000m | None |

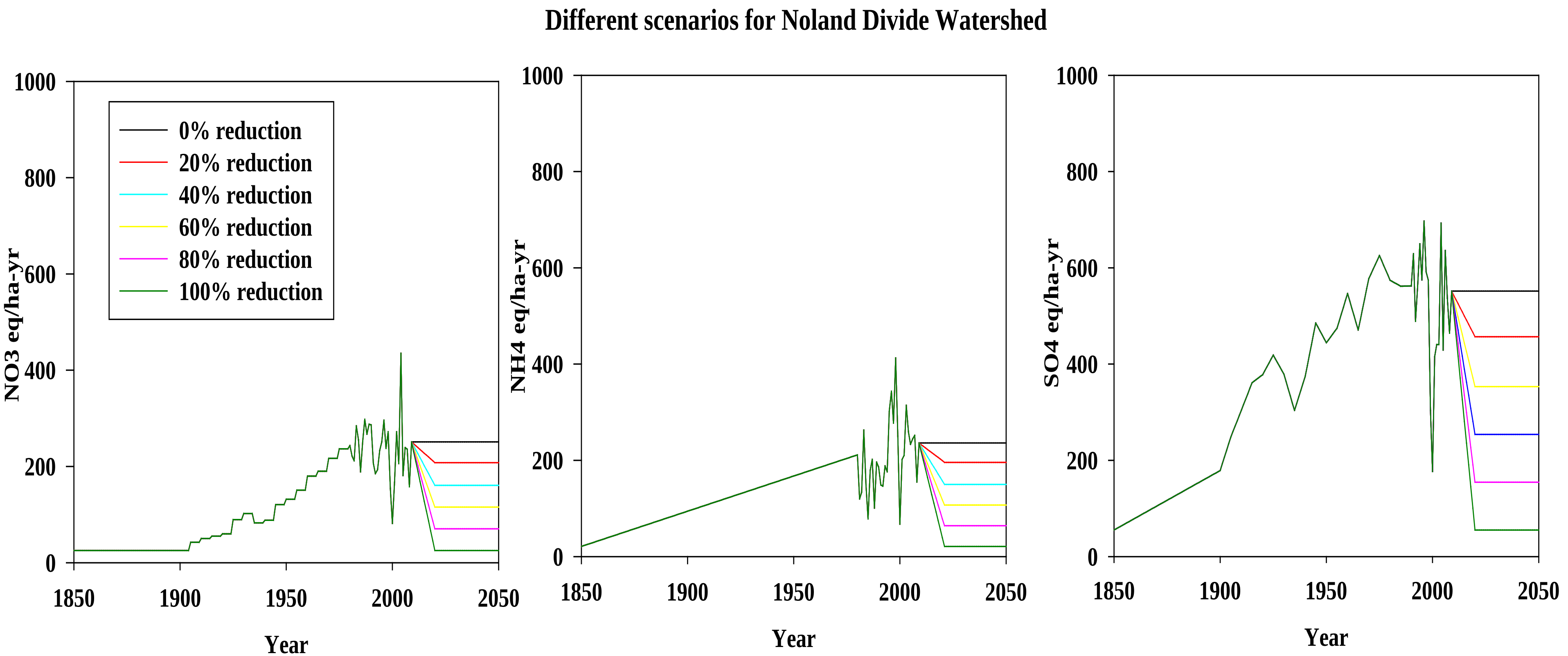
# Physical and chemical characteristics of different sites

| | Elevation (m) | Watershed areas($km^2$) | Disturbance | Vegetation | $NO_3^-$ (μeq/L) | ANC (μeq/L) |
|---|---|---|---|---|---|---|
| Noland Divide | 1798 | 0.174 | Balsam Woolly Adelgid | SF | 44.3 | 4.3 |
| Cannon Creek | 751 | 4.19 | Land disturbance | HD | 20.6 | 17.1 |
| Cosby Creek | 783 | 5.78 | Land disturbance | HD | 38.2 | 36.8 |
| Goshen Prong | 1046 | 7.29 | Logging | HD | 21.2 | 19.3 |
| Indian Camp Creek | 1205 | 6.31 | Land disturbance | HD | 42.1 | 16.9 |
| Left Prong Anthony | 909 | 1.61 | None | SF | 23.4 | 35.4 |
| Lost Bottom | 1000 | 5.15 | Land disturbance | HD | 7.7 | 59.2 |
| Mill Creek | 545 | 10.92 | Land disturbance | HD | 56.1 | 17.0 |
| Pretty Hollow | 903 | 11.18 | Land disturbance | HD | 16.6 | 46.1 |
| Sugar Fork | 780 | 2.14 | Land disturbance | HD | 3.7 | 86.3 |
| Thunderhead | 664 | 11.26 | Fire | HD | 14.4 | 33.2 |
| Walker Camp | 1386 | 4.24 | None | HD | 38.0 | -13.3 |

# Approach

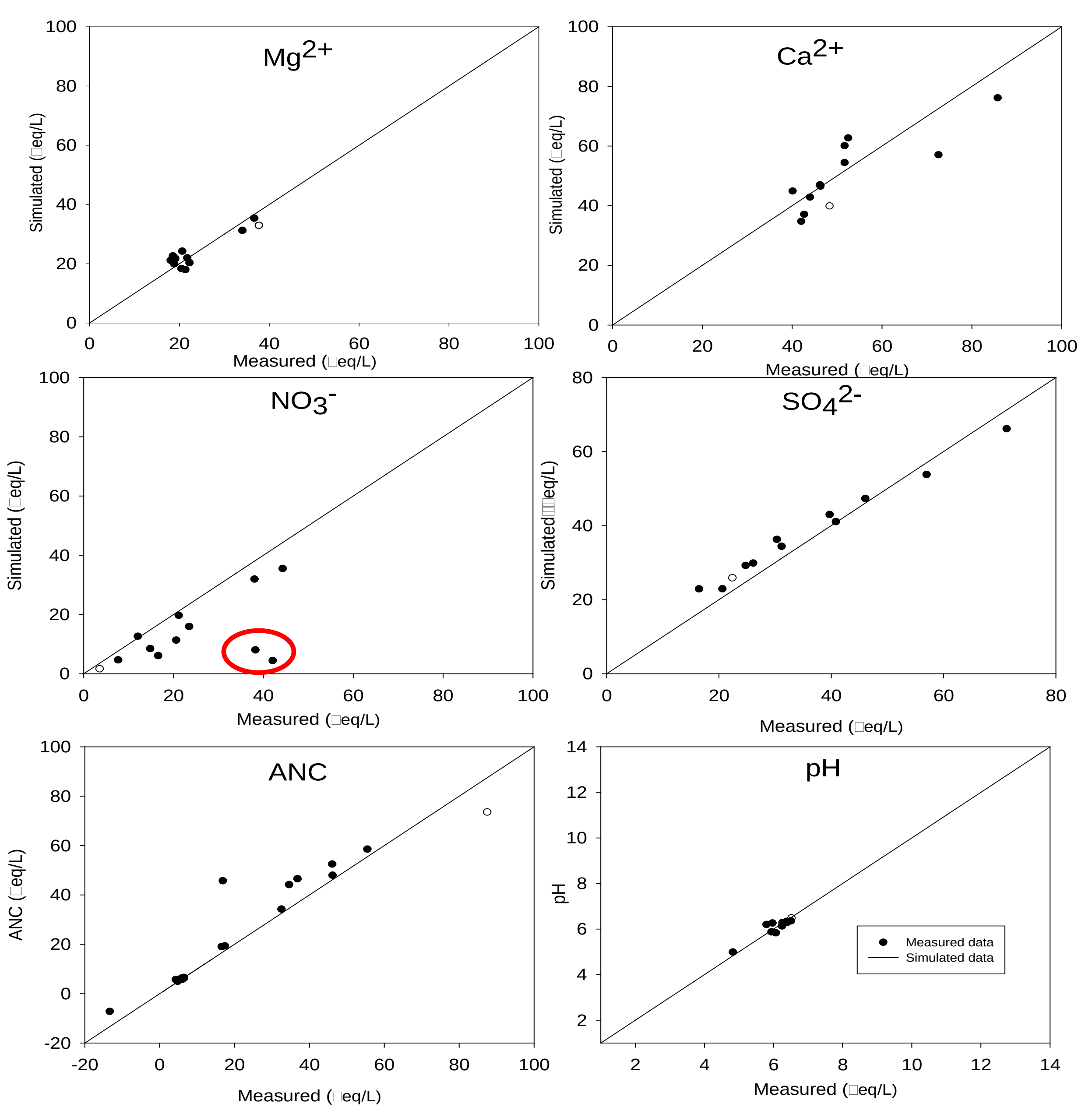

Wet Deposition
Dry Deposition
Climatic Data
•Solar radiation
•Precipitation
•Temperature
PnET
Water balance
Photosynthesis
Living biomass
Litterfall
Atmospheric Chemistry
Carbon dioxide
Ozone
Net Mineralization
Uptake
Shallow water flow
BGC
• Aqueous reactions
• Surface reactions
• Cation exchange
• Adsorption
• Humic binding
• Aluminum dissolution/precipitation
BGC – Surface water
Aqueous reactions
Weathering
Deep water flow

# Approach

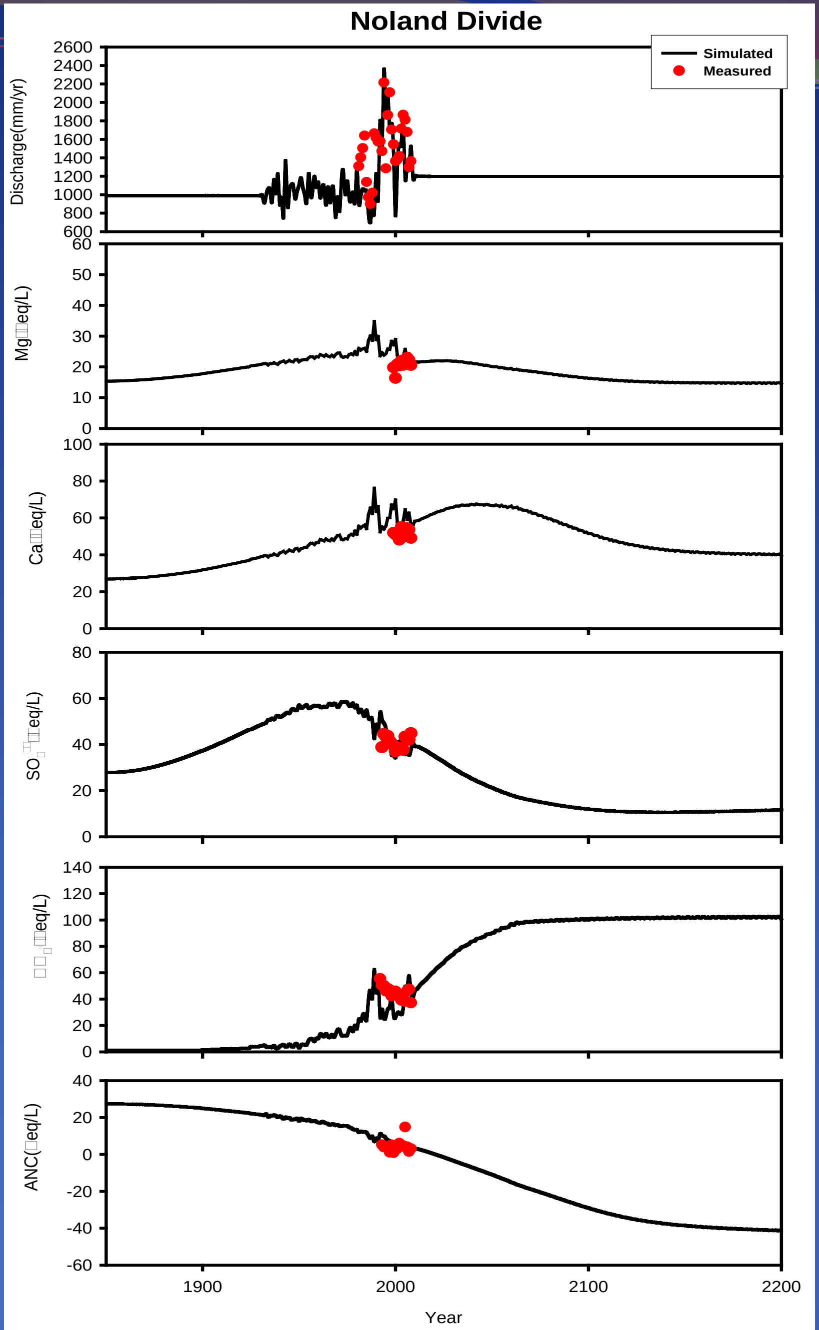


Different scenarios for Noland Divide Watershed
0% reduction
20% reduction
40% reduction
60% reduction
80% reduction
100% reduction
NO3 eq/ha-yr
NH4 eq/ha-yr
SO4 eq/ha-yr
Year
0
200
400
600
800
1000
1850
1900
1950
2000
2050

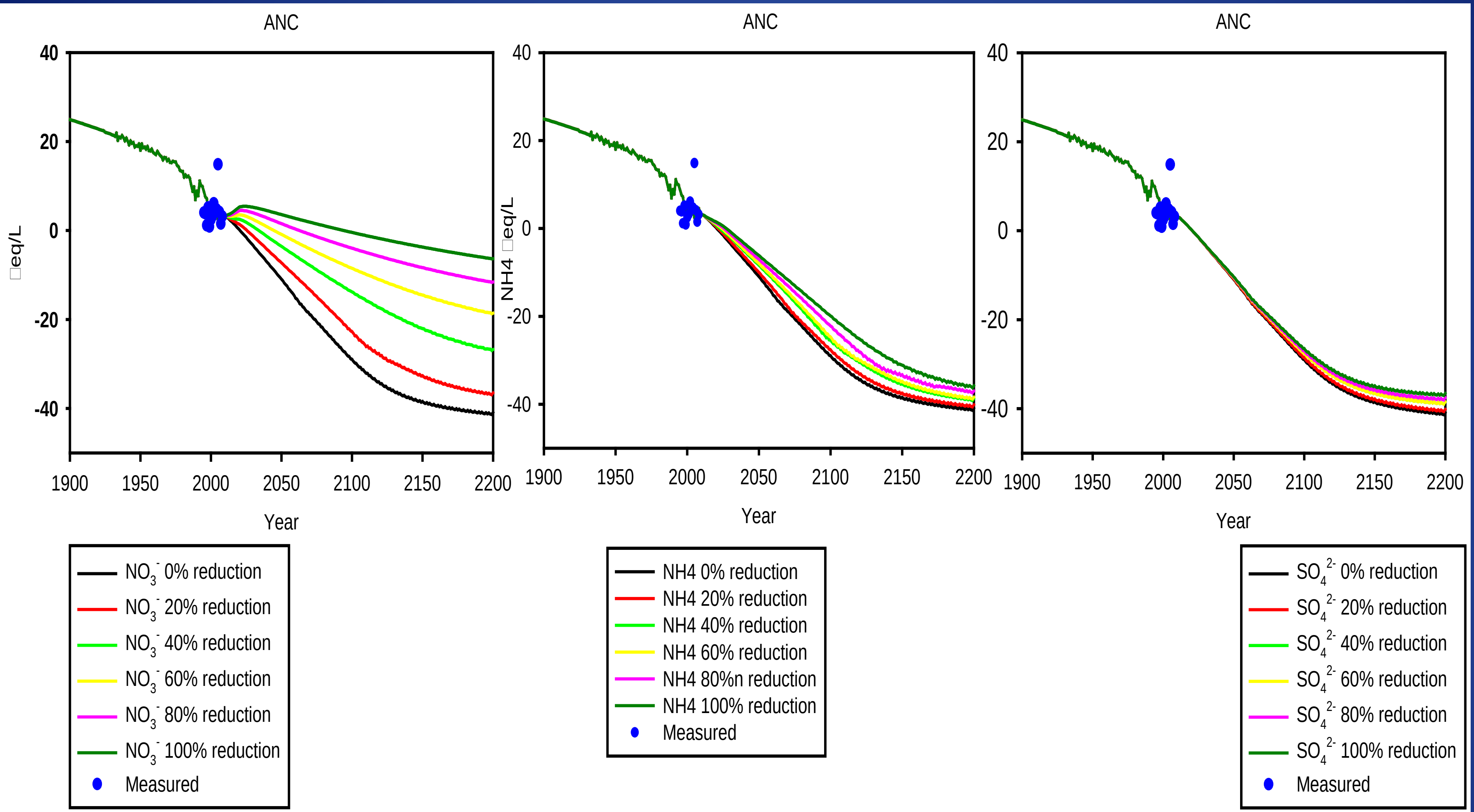
# Results: Model Performance



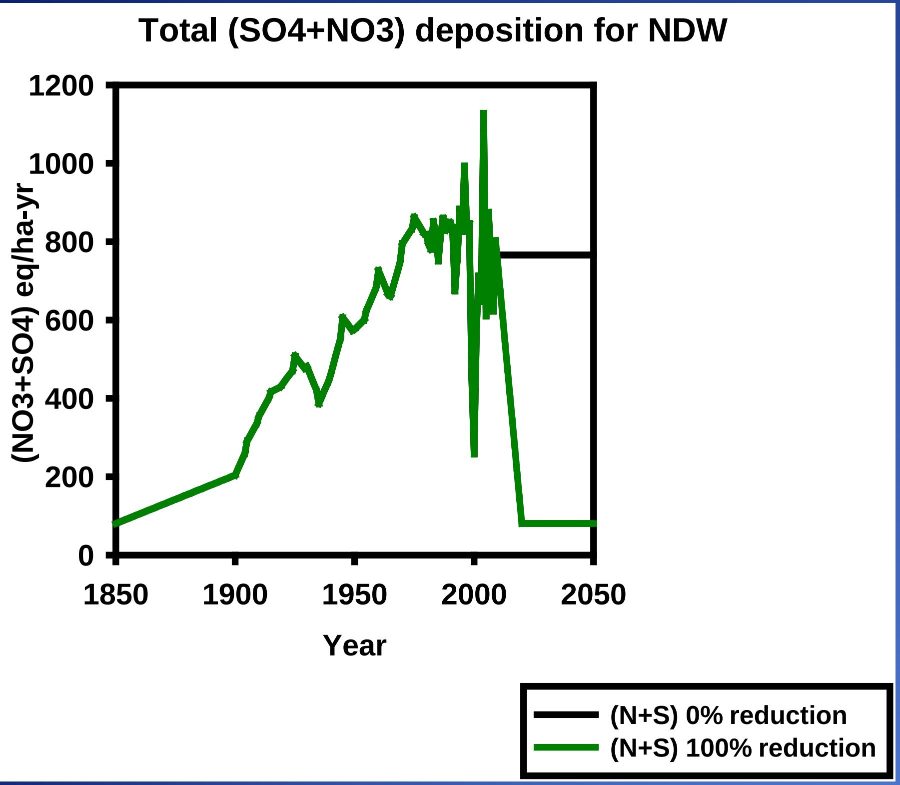
# Results:


Noland Divide
Simulated
Measured
Discharge(mm/yr)
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
60
50
40
30
20
10
0
100
80
60
40
20
0
80
60
40
20
0
140
120
100
80
60
40
20
0
40
20
0
-20
-40
-60
ANC(eq/L)
1900
2000
2100
2200
Year

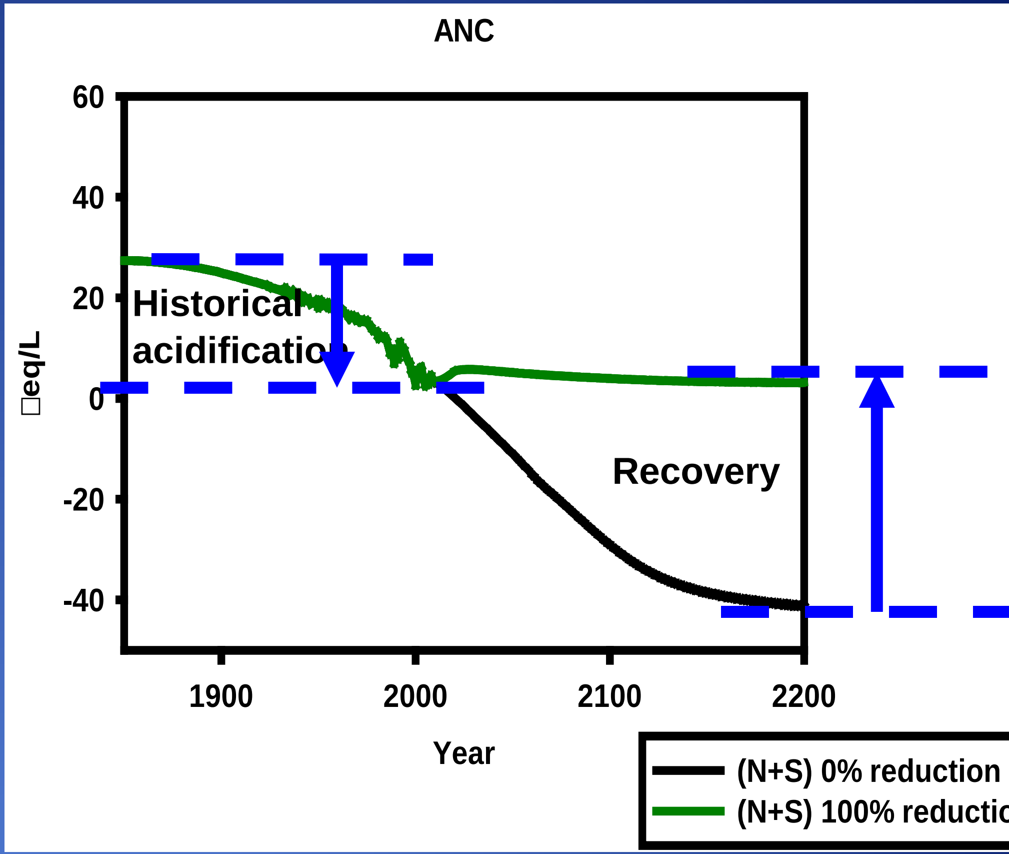
# Result: Predictions of future response of stream ANC to different scenarios of nitrate, ammonium and sulfate deposition in Noland Divide Watershed



# Results:

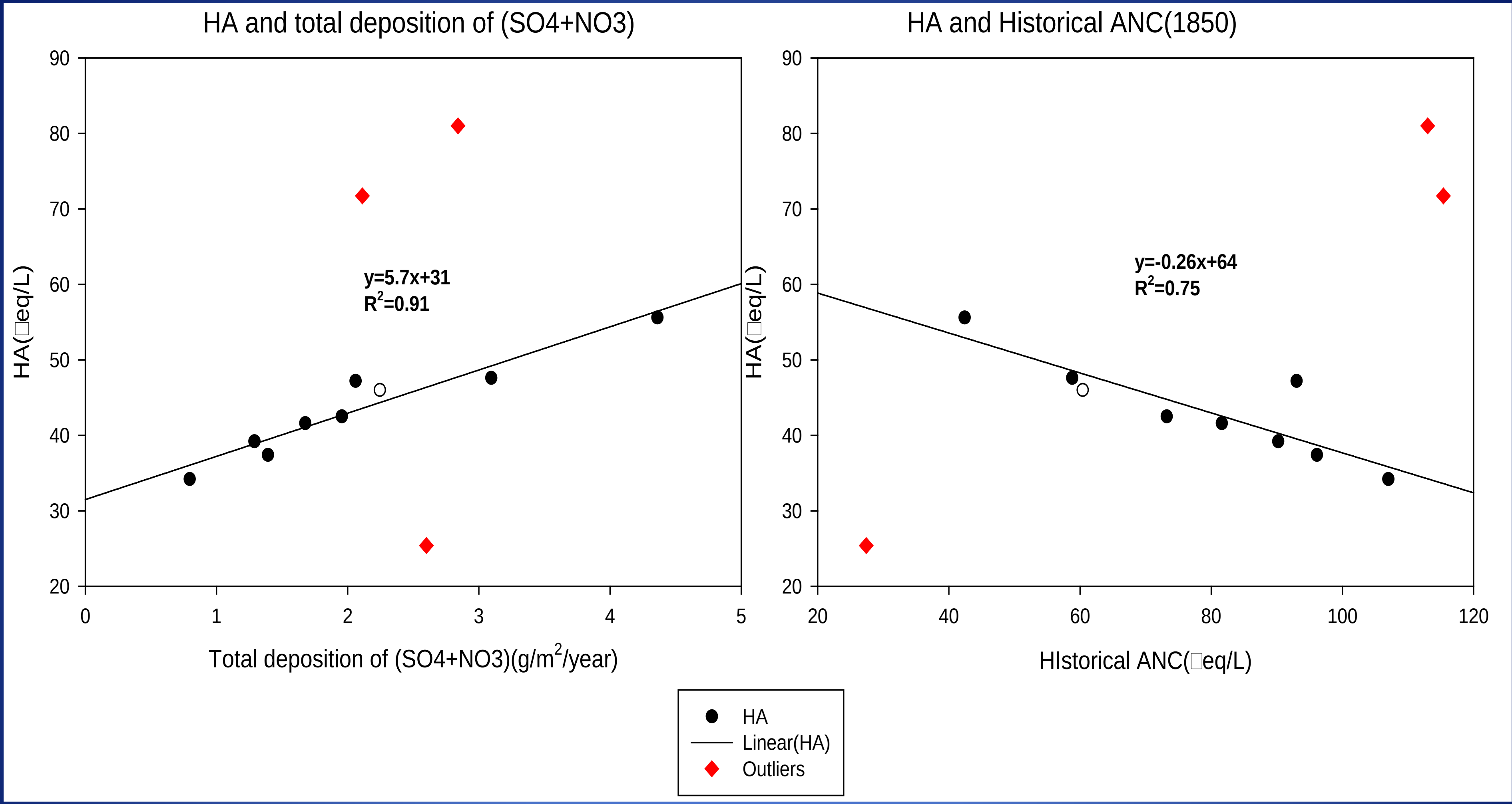


Total (SO4+NO3) deposition for NDW
1200
1000
800
600
400
200
0
(NO3+SO4) eq/ha-yr
1850
1900
1950
2000
2050
Year
(N+S) 0% reduction
(N+S) 100% reduction

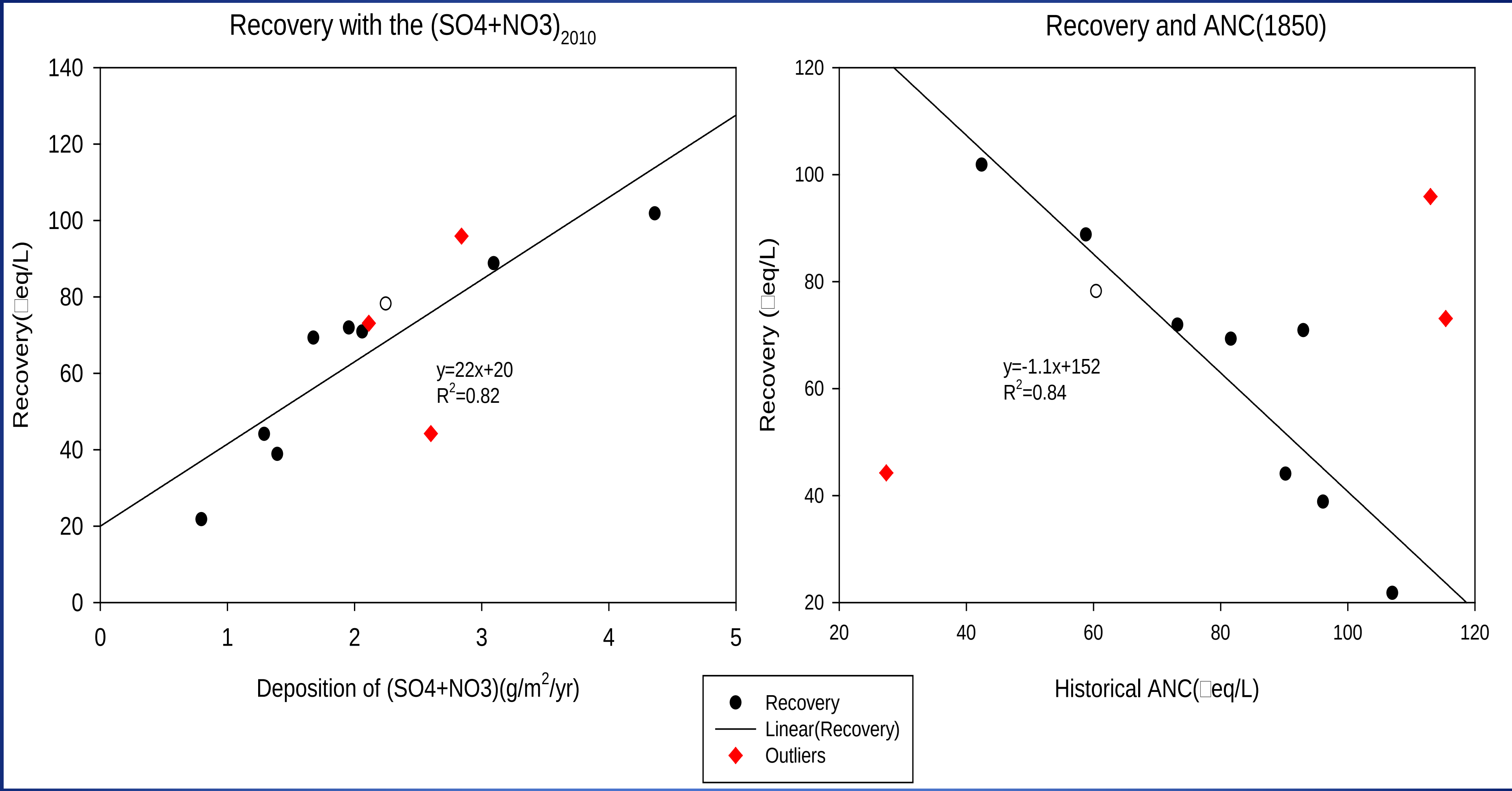



ANC
60
40
20
0
-20
-40
□eq/L
Historical
acidification
Recovery
1900
2000
2100
2200
Year
(N+S) 0% reduction
(N+S) 100% reductio

# Historical Acidification(HA)



# Recovery



Recovery with the (SO4+NO3)2010
Recovery(□eq/L)
140
120
100
80
60
40
20
0
0
1
2
3
4
5
y=22x+20
R2=0.82
Deposition of (SO4+NO3)(g/m2/yr)
Recovery and ANC(1850)
Recovery (□eq/L)
120
100
80
60
40
20
40
60
80
100
120
y=-1.1x+152
R2=0.84
Historical ANC(□eq/L)
Recovery
Linear(Recovery)
Outliers

# How does the recovery of GSMNP compare with Adirondack watersheds?

| Recovery / Regions | Target load(2050) | | Critical load(2200) | |
|---|---|---|---|---|
| | $\frac{\Delta ANC(\mu eq.L^{-1})}{\Delta SO_4^{2-}(eq.ha^{-1})}$ | $\frac{\Delta ANC(\mu eq.L^{-1})}{\Delta NO_3^{-}(eq.ha^{-1})}$ | $\frac{\Delta ANC(\mu eq.L^{-1})}{\Delta SO_4^{2-}(eq.ha^{-1})}$ | $\frac{\Delta ANC(\mu eq.L^{-1})}{\Delta NO_3^{-}(eq.ha^{-1})}$ |
| Adirondack | 0.06(±0.02) | -0.02(±0.01) | 0.12(±0.04) | 0.01(±0.018) |
| GSMNP | 0.03(±0.01) | 0.07(±0.03) | 0.06(±0.01) | 0.19(±0.04) |

# Conclusions

- The stream ANC in the GSMNP increases to a greater extent in response to $NO_3^-$ decreases than with $SO_4^{2-}$ or $NH_4^+$ decreases.
- There is a strong relationship between historical acidification with changes in $NO_3^-$ and $SO_4^{2-}$ deposition and historical ANC (1850).

# Conclusions

- Comparison between GSMNP and the Adirondacks suggests that surface water ANC responds more to changes in $SO_4^{2-}$ deposition in Adirondacks, but more to changes in $NO_3^-$ deposition in the GSMNP.

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