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Comments to the CASAC Review Panel on the Draft Policy Assessment Documents for the Secondary NAAQS for SOx and NOx

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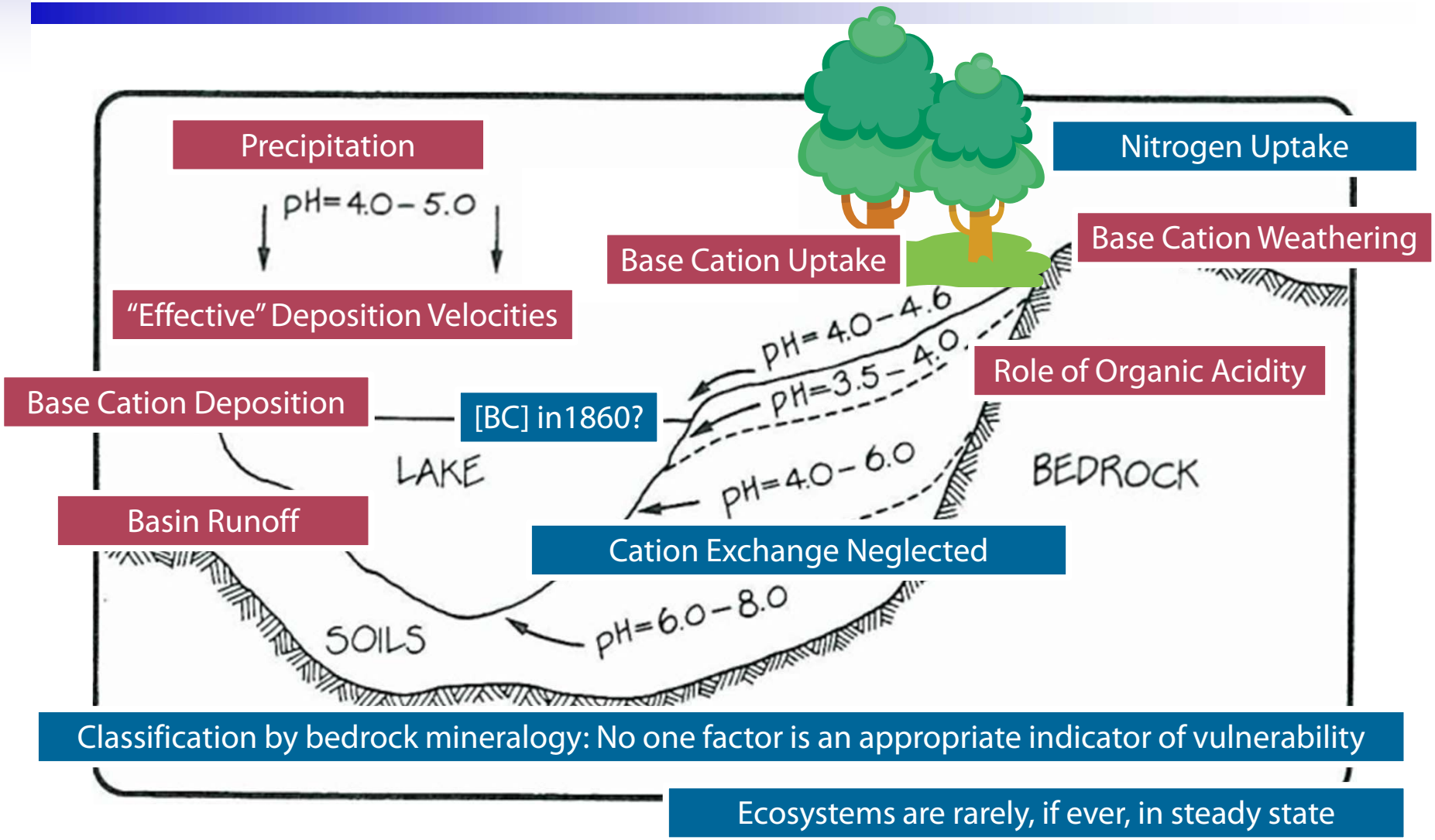
CASAC Review Panel Meeting
Research Triangle Park
October 6, 2010

Critical Processes



Classification by bedrock mineralogy: No one factor is an appropriate indicator of vulnerability

Ecosystems are rarely, if ever, in steady state

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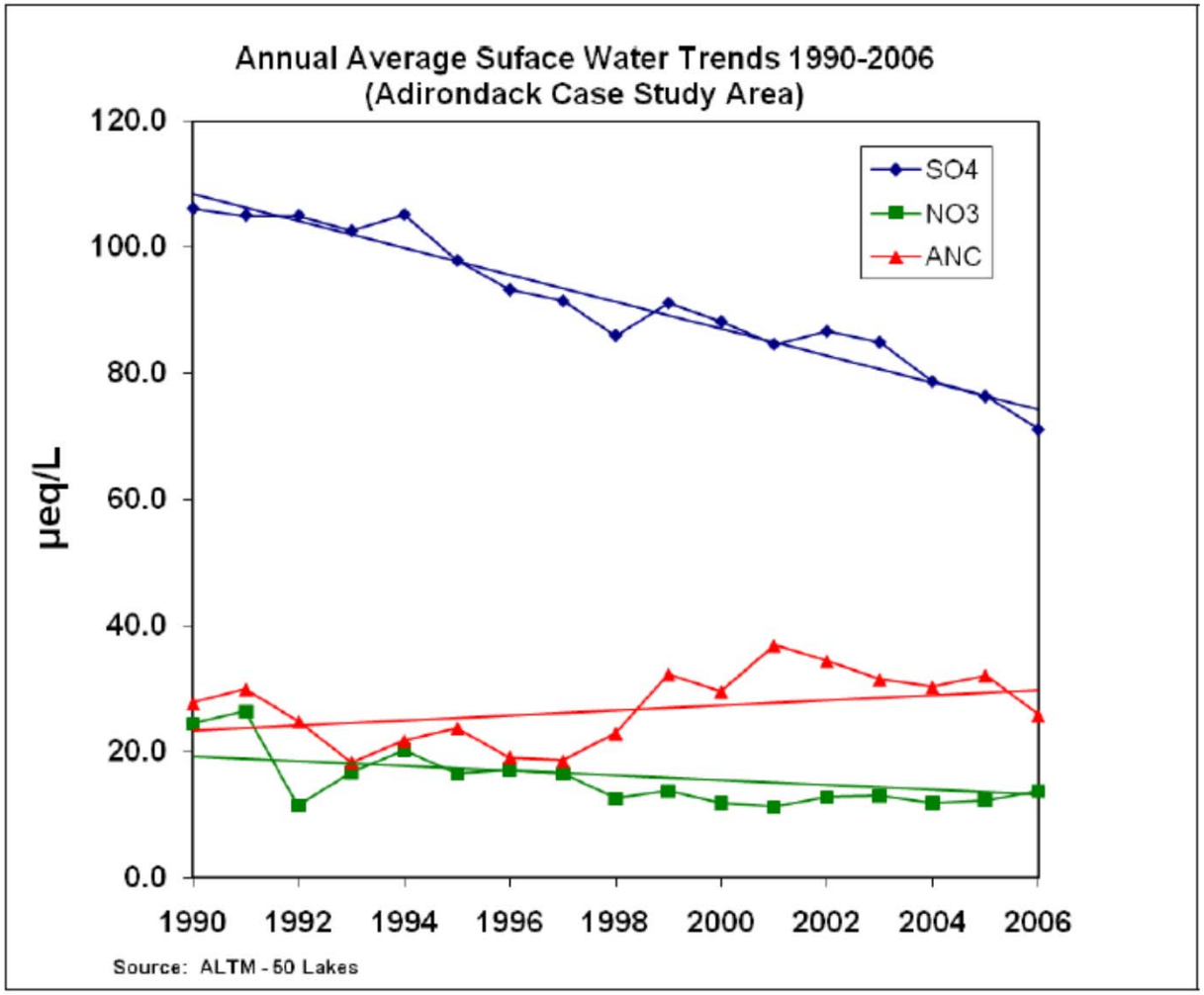
Comparable Adirondack Lake Solute Trends (Source: PAD)



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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
ΣC_A	126	87	-39
ΣC_B	151	117	-34

$\Sigma C_B / \Sigma C_A = 0.87$

MAGIC Model

Solute	1990	2006	Delta
SO_4^{2-}	115	68	-47
ANC	33	61	+28
NO_3^-	5	5	0
ΣC_A	120	75	-45
ΣC_B	153	134	-19

$\Sigma C_B / \Sigma C_A = 0.42$

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

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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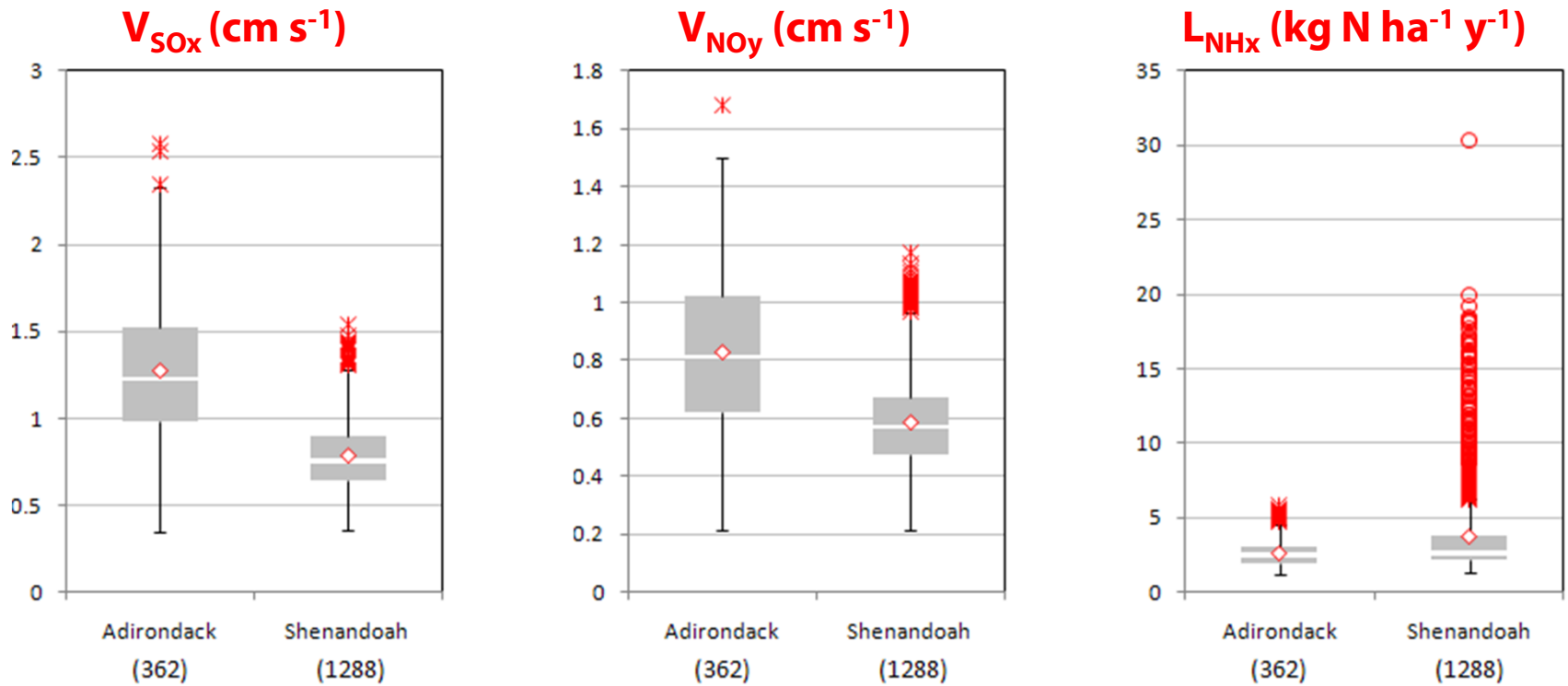
Variability in Effective Deposition Velocities (V_{SOx} and V_{NOy}) and NHx Loads

Spatial variability in a region (Adirondack and Shenandoah) including all simulations



Numbers in parentheses are number of data points.

For simplicity, V values are shown with units of effective deposition velocities; they are equivalent to the concentration-deposition transformation functions in the PAD.

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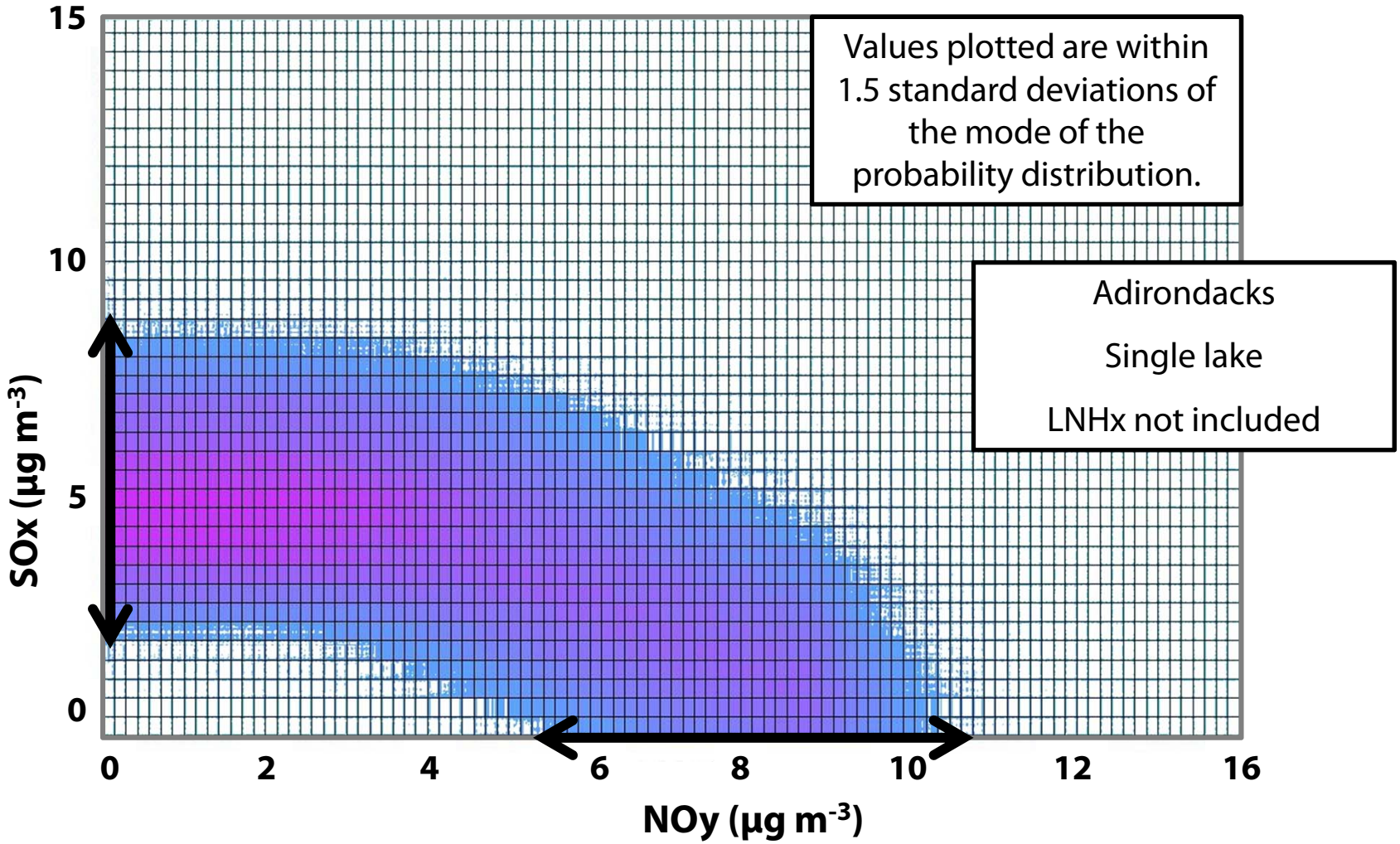
Uncertainty in Atmospheric Standards: Adirondack Example



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Appendix

1. Table of Simulations used in the evaluation of V and L values
   - Different meteorological modeling years
   - Different atmospheric models
   - Grid Resolution: Coarse grid vs. fine grid
   - Emission Year: Different emissions year
2. Definition of the Box and Whisker Plots used in this presentation
3. Illustration of Adirondack and Shenandoah regions
4. Spatial variability within a region (Adirondack and Shenandoah) for individual simulations
5. Scenario variability for fixed points in space
6. Monte Carlo parameters
7. Explanation of Proof on CV Lower Bound

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Currently Available Regional Annual Modeling Outputs

Study	Model	Emiss/Met Years	Domain 1		Domain 2		Domain 3	
			km	Local	km	Local	km	Local
VISTAS	CMAQ V4.5.1 SOAmods	2002/2002 2009/2002 2012/2002 2018/2002	36	CONUS	12	SE US		
UBAQS	CMAQ V4.6	2005/2005 2006/2006 2012/2005 2012/2006	36	CONUS	12	UT-CO		
EPRI	CMAQ AMSTERDAM	2002/2002			12	E US		
FCAQTF	CAMx V4.51	2018/2005	36	CONUS	12	SW US	4	4Corners
General	CAMx V5.21	2005/2005 2006/2006	36	CONUS				

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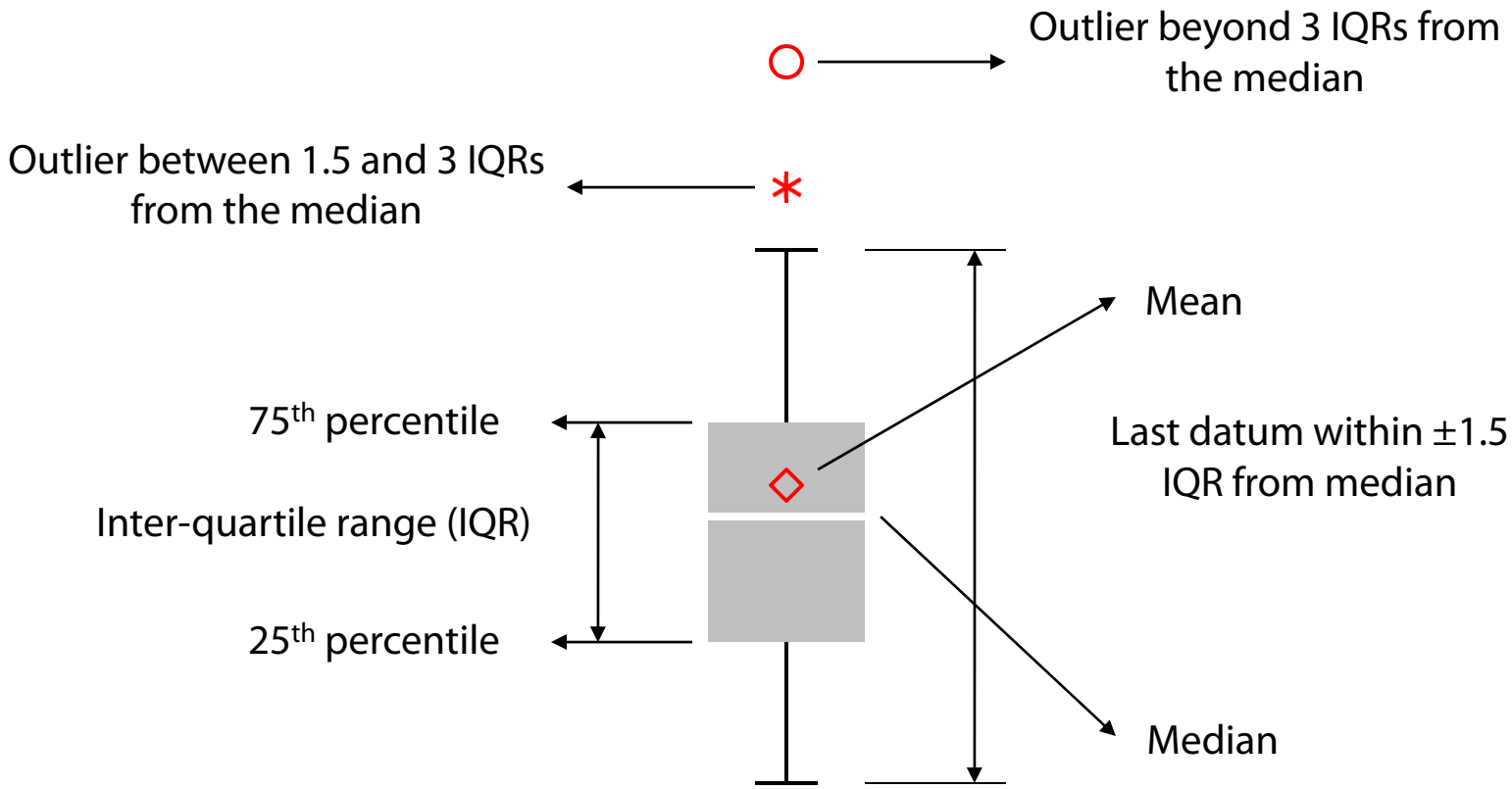
Box and Whisker Plot Definition



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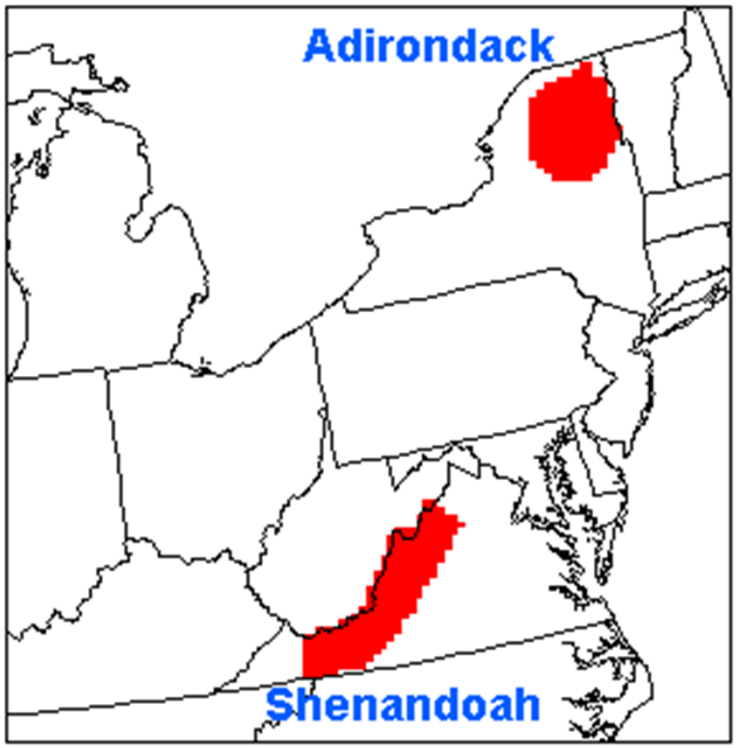
Variability in Effective Deposition (V) Values: Concentration-Deposition Functions



# of grid cells for Adirondack

- 18 (36-km resolution)
- 164 (12-km resolution)

# of grid cells for Shenandoah

- 23 (36-km resolution)
- 207 (12-km resolution)

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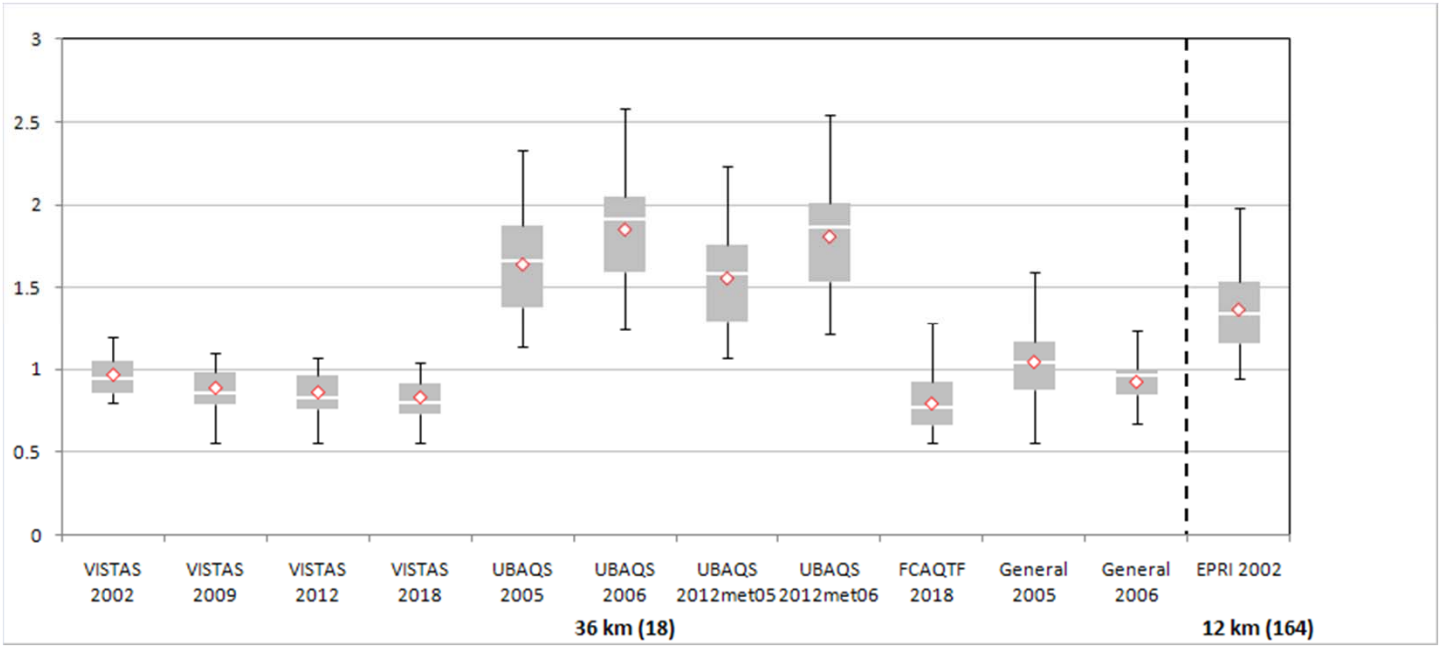
Variability – Case Study Areas

Spatial-Only Variability

V_{SOx} (cm s^{-1})

Adirondack



Numbers in parentheses are number of data.

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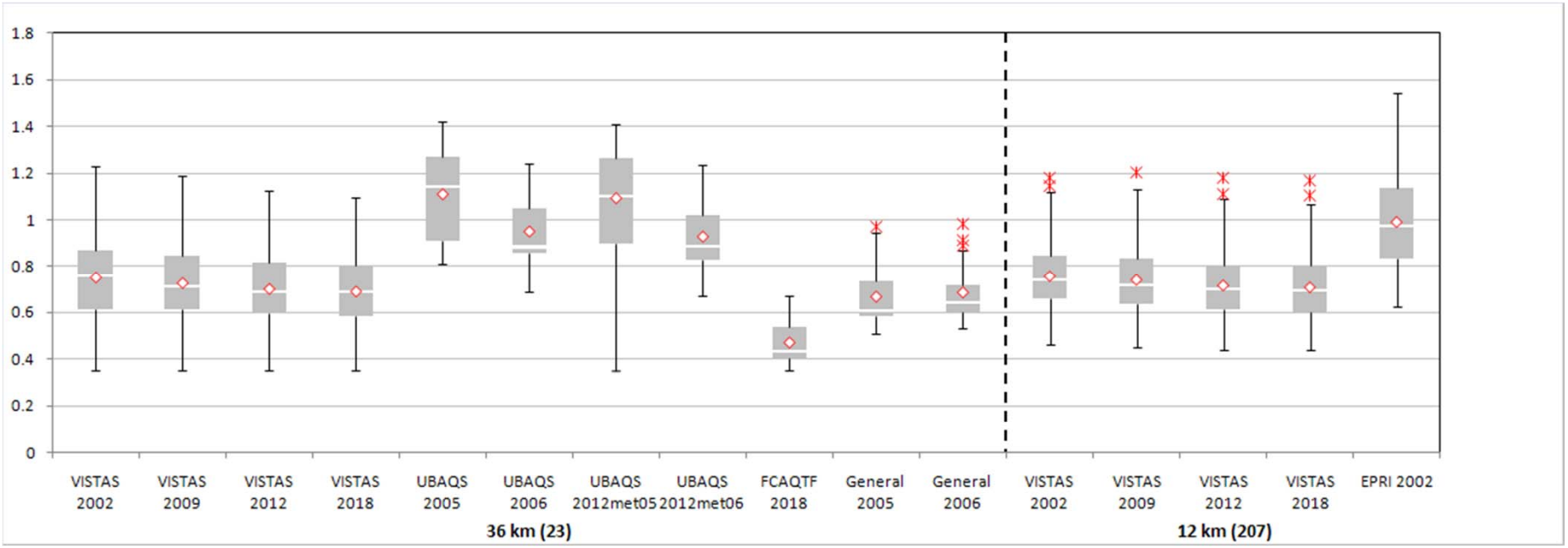
Variability – Case Study Areas

Spatial-Only Variability

V_{SOx} (cm s^{-1})

Shenandoah



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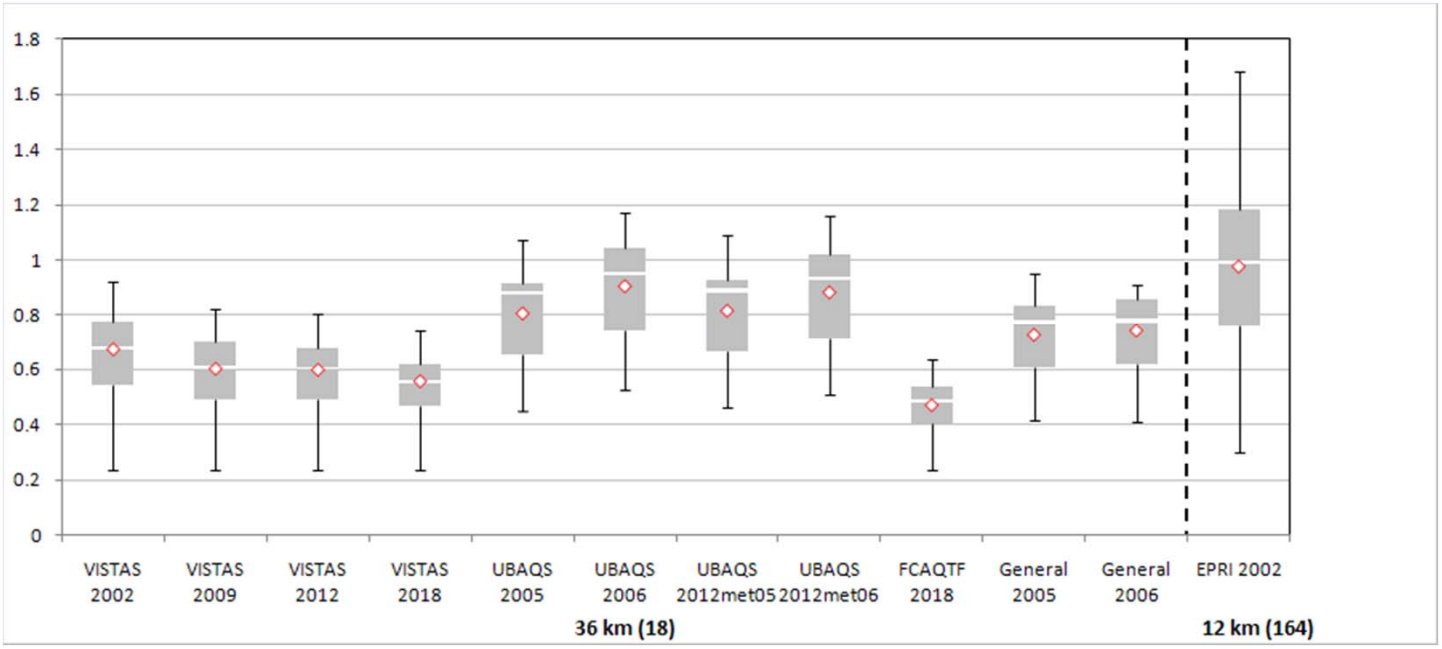
Variability – Case Study Areas

Spatial-Only Variability

V_{NOy} (cm s^{-1})

Adirondack



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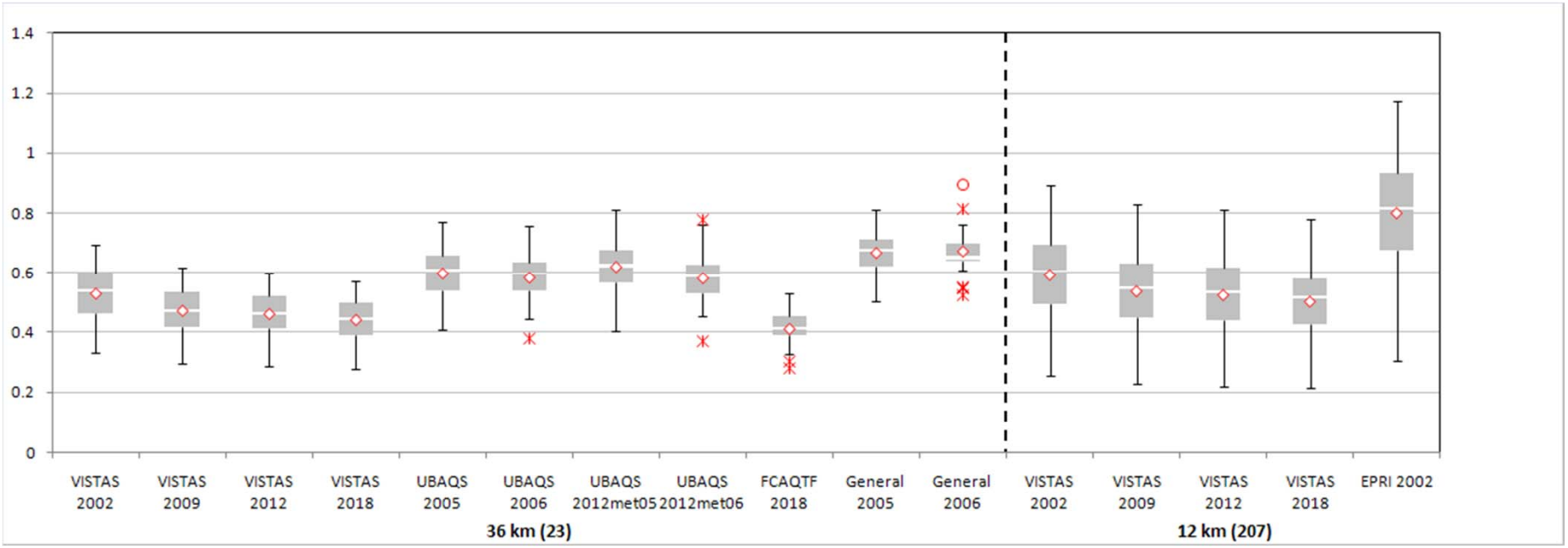
Variability – Case Study Areas

Spatial-Only Variability

V_{NOy} (cm s^{-1})

Shenandoah



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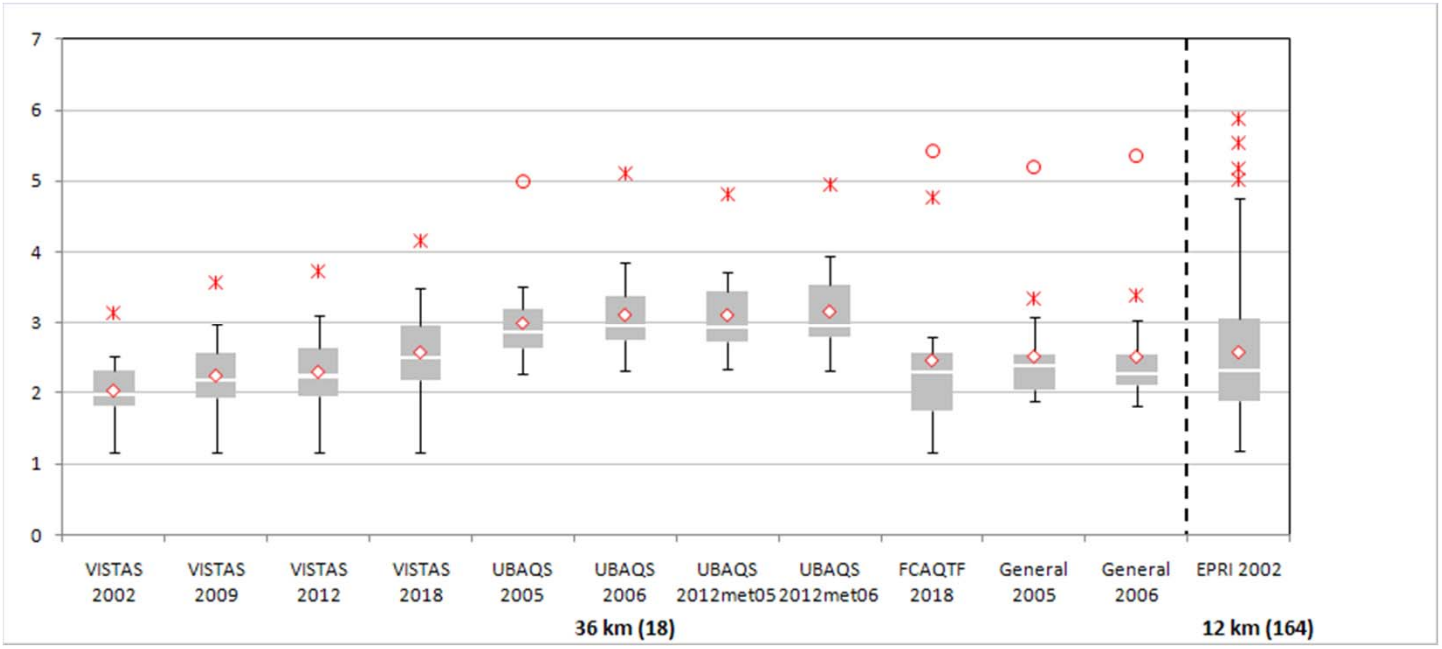
Variability – Case Study Areas

Spatial-Only Variability

L_{NHx} (kg N ha^{-1} y^{-1})

Adirondack



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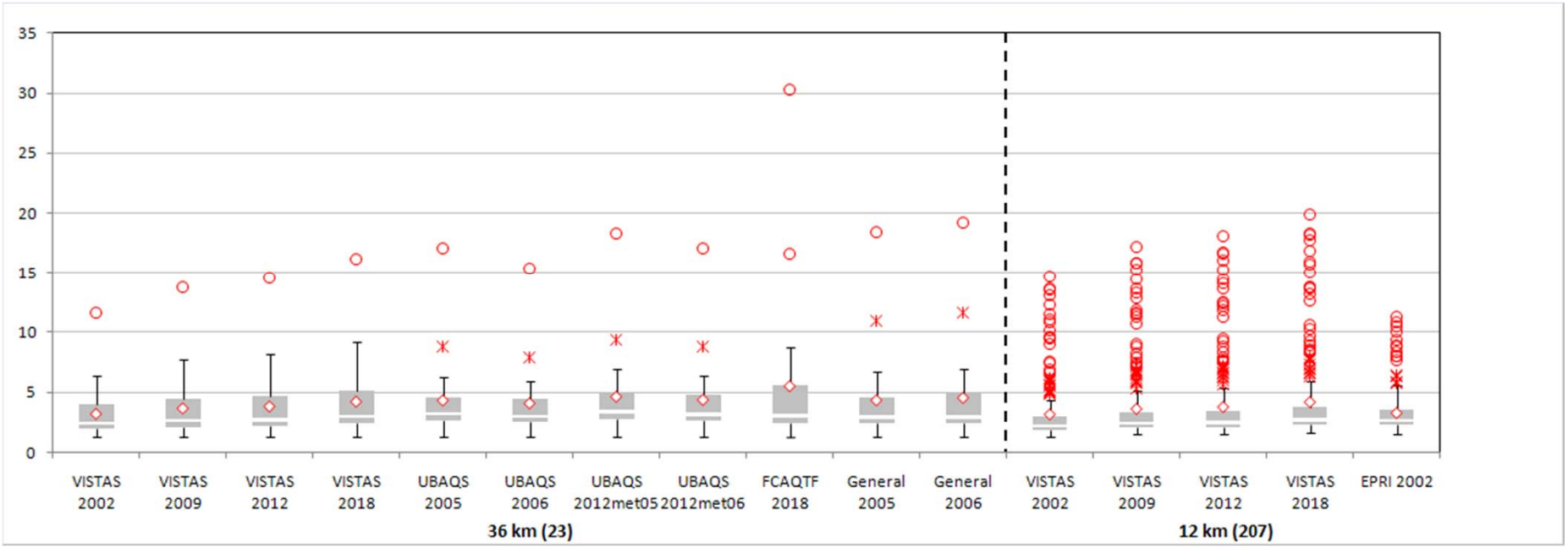
Variability – Case Study Areas

Spatial-Only Variability

L_{NHx} (kg N ha^{-1} y^{-1})

Shenandoah



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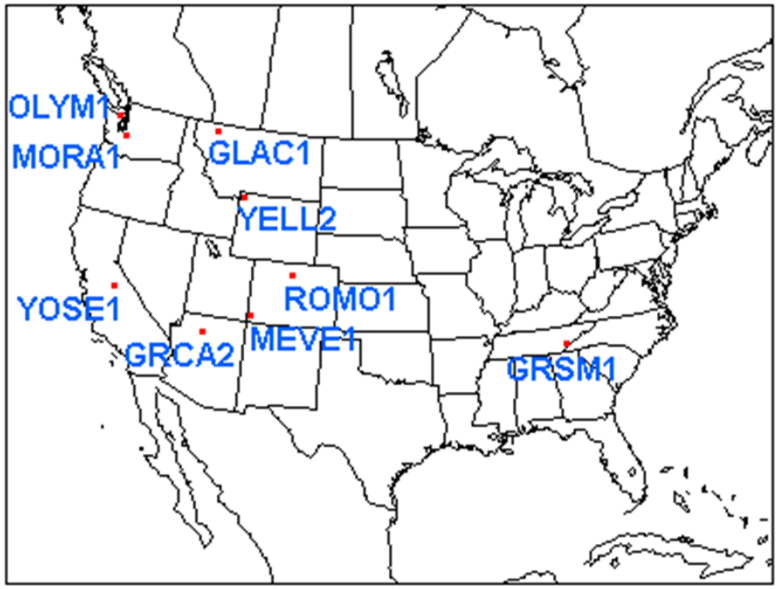
Variability – IMPROVE Monitoring Sites

Scenario-Only Variability

Single grid cell for each monitoring site



Olympic NP (OLYM1); Mount Rainier NP (MORA1); Yosemite NP (YOSE1); Grand Canyon NP (GRCA2); Glacier NP (GLAC1); Yellowstone NP (YELL2); Rocky Mountain NP (ROMO1); Mesa Verde NP (MEVE1); Great Smoky Mountains NP (GRSM1).

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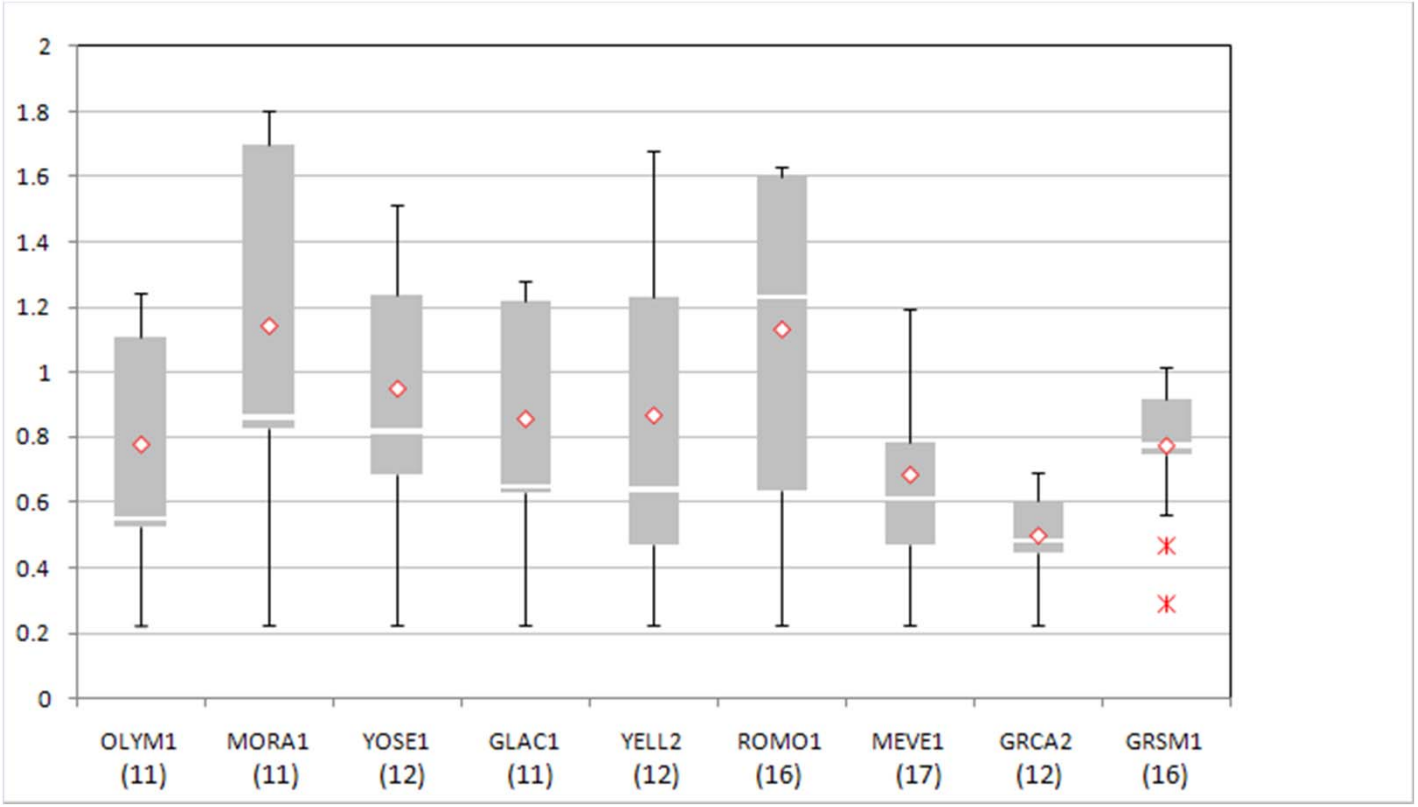
Variability – IMPROVE Monitoring Sites

Scenario-Only Variability

VSOx (cm s^{-1})



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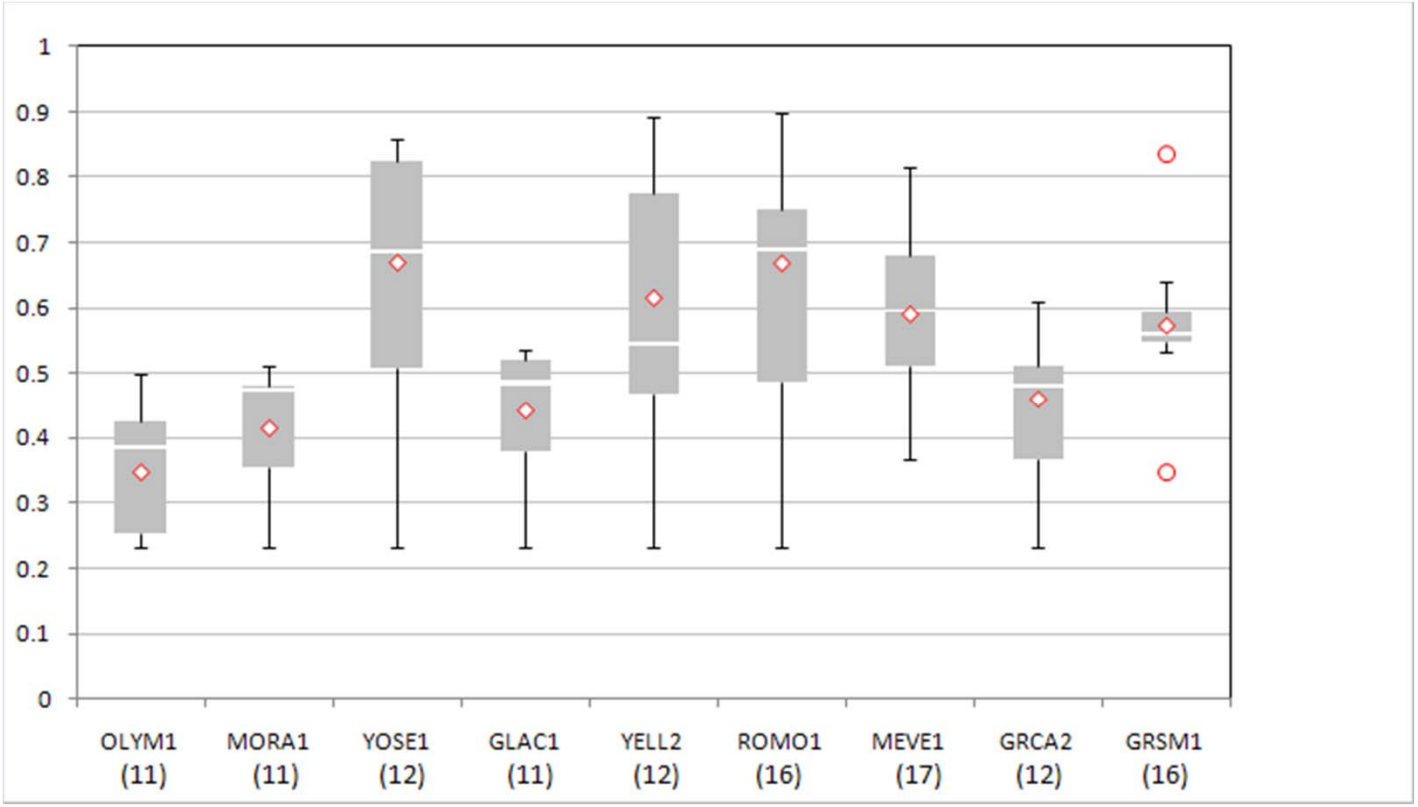
Variability – IMPROVE Monitoring Sites

Scenario-Only Variability

V_{NOy} (cm s^{-1})



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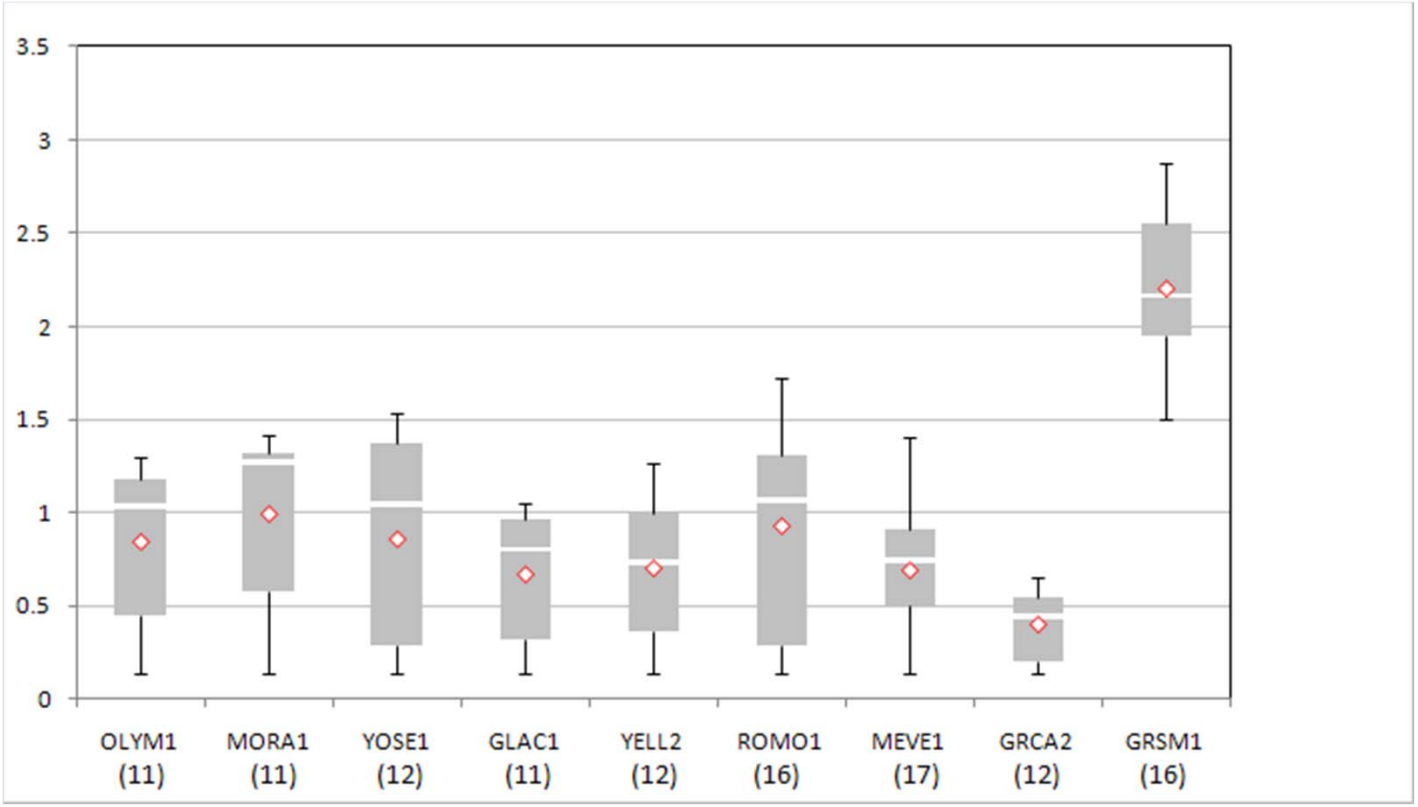
Variability – IMPROVE Monitoring Sites

Scenario-Only Variability

L_{NHx} (kg N ha^{-1} y^{-1})



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Uncertainty in Atmospheric Standards: Adirondack Example

Parameters used in the Monte Carlo Simulations

Variable	Mean	Std.Dev.	Units.
BC_0*	150	95	$\mu eq\ L^{-1}$
Q	0.5	0.2	$m\ y^{-1}$
N_{eco}	63.95	30	$meq\ m^{-2}\ y^{-1}$
V_{SOx}	1.25	0.25	$cm\ s^{-1}$
V_{NOy}	0.82	0.2	$cm\ s^{-1}$
L_{NHx}	20.4	8	$meq\ m^{-2}\ y^{-1}$

L_{NHx} was not used in the Monte Carlo simulations and is only shown for reference.

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Explanation of Proof on CV Lower Bound

$$\mathrm{CL}(A) = (Q + \varepsilon_1)\left([\mathrm{BC}_0^*] + \varepsilon_2 - [\mathrm{ANC}]_{\mathrm{lim}}\right)$$

This is the equation for critical load from EPA's PA with error terms added (the epsilons) to Q and BC_0^* to represent uncertainty

$$\mathrm{V}[\mathrm{CL}(A)] = \left([\mathrm{BC}_0^*] - [\mathrm{ANC}]_{\mathrm{lim}}\right)^2 \mathrm{V}[\varepsilon_1] + Q^2 \cdot \mathrm{V}[\varepsilon_2] + \mathrm{V}[\varepsilon_1 \varepsilon_2]$$

Take the variance of the above expression and expand

$$\mathrm{V}[\mathrm{CL}(A)] \geq \left([\mathrm{BC}_0^*] - [\mathrm{ANC}]_{\mathrm{lim}}\right)^2 \mathrm{V}[\varepsilon_1]$$

Variance is positive by definition, so omitting the last two terms above gives this inequality

$$\frac{\sqrt{\mathrm{V}[\mathrm{CL}(A)]}}{\mathrm{E}[\mathrm{CL}(A)]} = \mathrm{CV}[\mathrm{CL}(A)] \geq \frac{\sqrt{\left([\mathrm{BC}_0^*] - [\mathrm{ANC}]_{\mathrm{lim}}\right)^2 \mathrm{V}[\varepsilon_1]}}{Q\left([\mathrm{BC}_0^*] - [\mathrm{ANC}]_{\mathrm{lim}}\right)}$$

CV is standard deviation (square root of variance) over expected value. This is just expressing the above variance as a CV

$$\mathrm{CV}[\mathrm{CL}(A)] \geq \frac{\sqrt{\left([\mathrm{BC}_0^*] - [\mathrm{ANC}]_{\mathrm{lim}}\right)^2 Q^2 (\mathrm{CV}[\mathrm{Q}])^2}}{Q\left([\mathrm{BC}_0^*] - [\mathrm{ANC}]_{\mathrm{lim}}\right)} = \mathrm{CV}[Q]$$

This expresses var(e_1) in terms of Q, giving CV(CL) in terms of CV(Q)

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