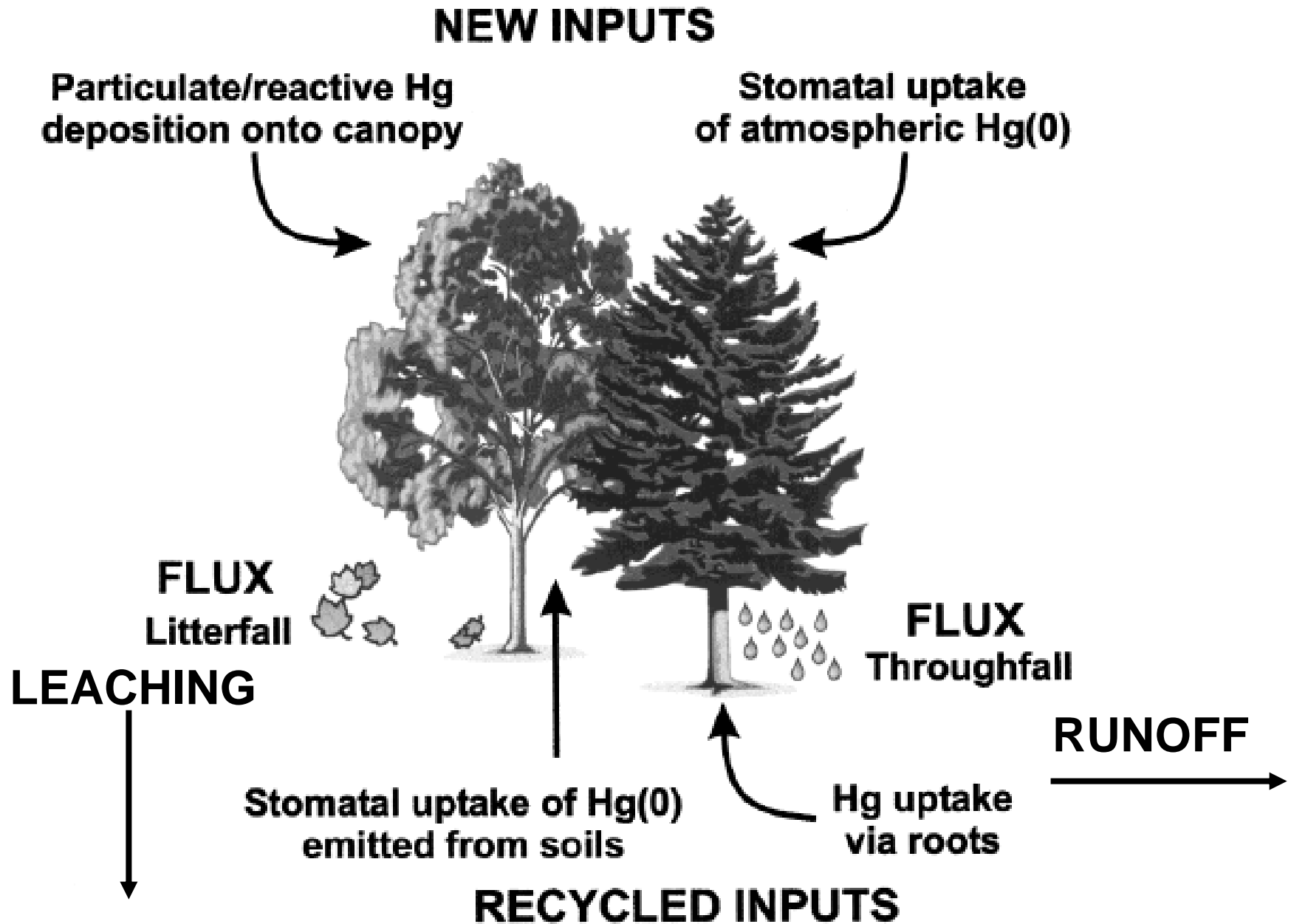# CO_2 effects on mercury cycling in two temperate forests

Sue Natali
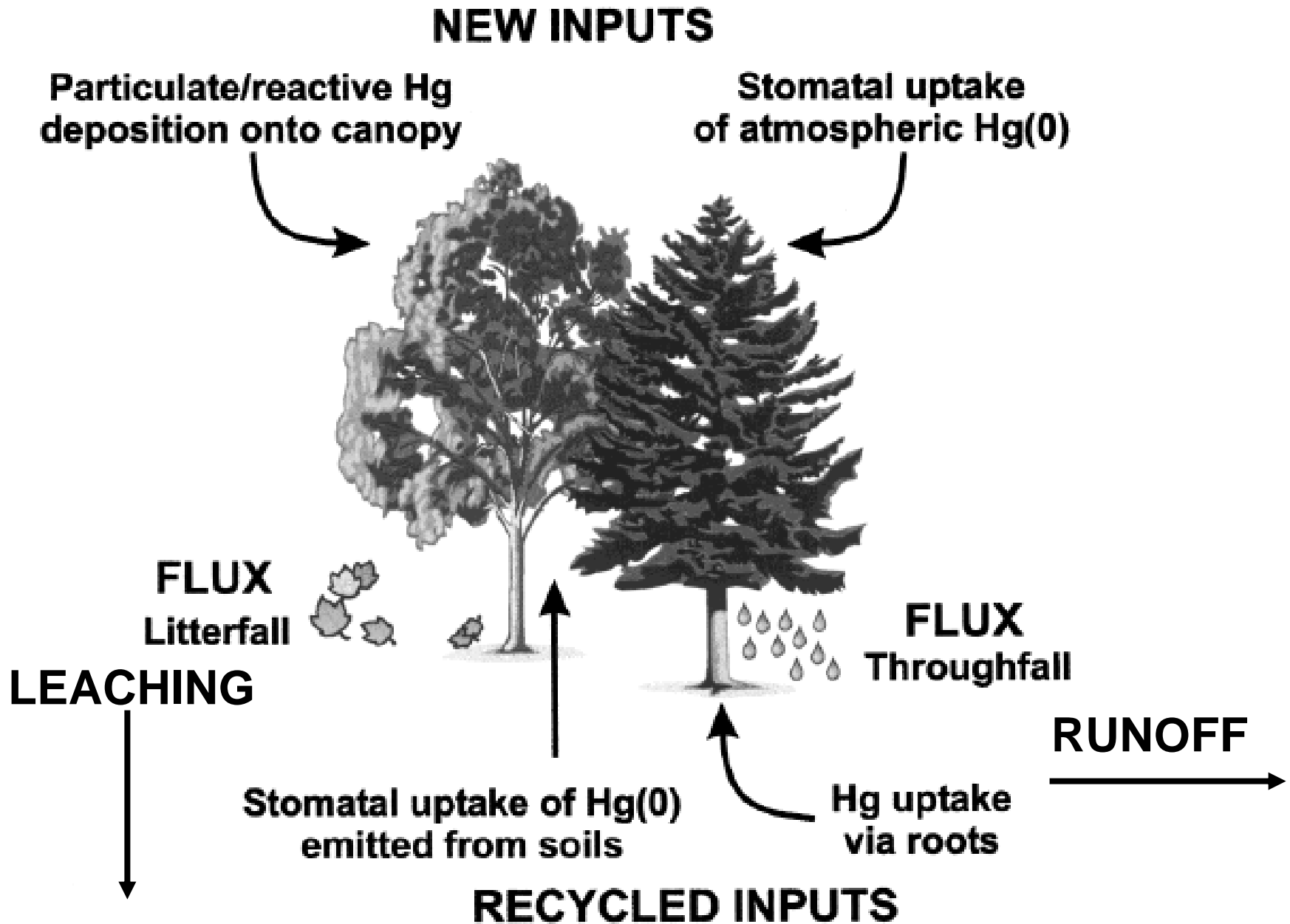State University of New York at Stony Brook

NEW INPUTS

Particulate/reactive Hg
deposition onto canopy

Stomatal uptake
of atmospheric Hg(0)

FLUX
Litterfall

LEACHING

FLUX
Throughfall

RUNOFF

Stomatal uptake of Hg(0)
emitted from soils

Hg uptake
via roots

RECYCLED INPUTS

Potential CO₂ effects

$$\text{Potential } CO_2 \text{ effects}$$

Adapted from:
St. Louis *et al.* 2001

NEW INPUTS

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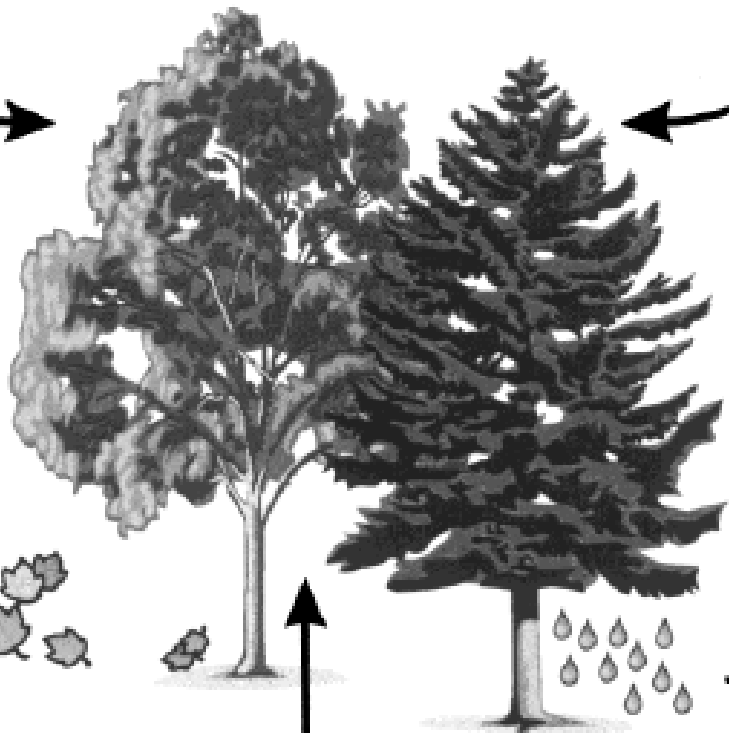
RECYCLED INPUTS

Potential CO$_2$ effects

NEW INPUTS

Particulate/reactive Hg deposition onto canopy

Stomatal uptake of atmospheric Hg(0)

Leaf area

Stomatal conductance

FLUX Litterfall

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Stomatal uptake of Hg(0) emitted from soils

Hg uptake via roots

RECYCLED INPUTS

Potential CO$_2$ effects

Adapted from: St. Louis *et al.* 2001

NEW INPUTS

Particulate/reactive Hg deposition onto canopy

Stomatal uptake of atmospheric Hg(0)

litterfall biomass

TF volume & chemistry

FLUX Litterfall

FLUX Throughfall

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RECYCLED INPUTS

Potential CO₂ effects

Potential CO_2 effects

NEW INPUTS

Particulate/reactive Hg deposition onto canopy

Stomatal uptake of atmospheric Hg(0)

FLUX Litterfall

LEACHING

Altered soil properties

FLUX Throughfall

RUNOFF

Stomatal uptake of Hg(0) emitted from soils

Hg uptake via roots

RECYCLED INPUTS
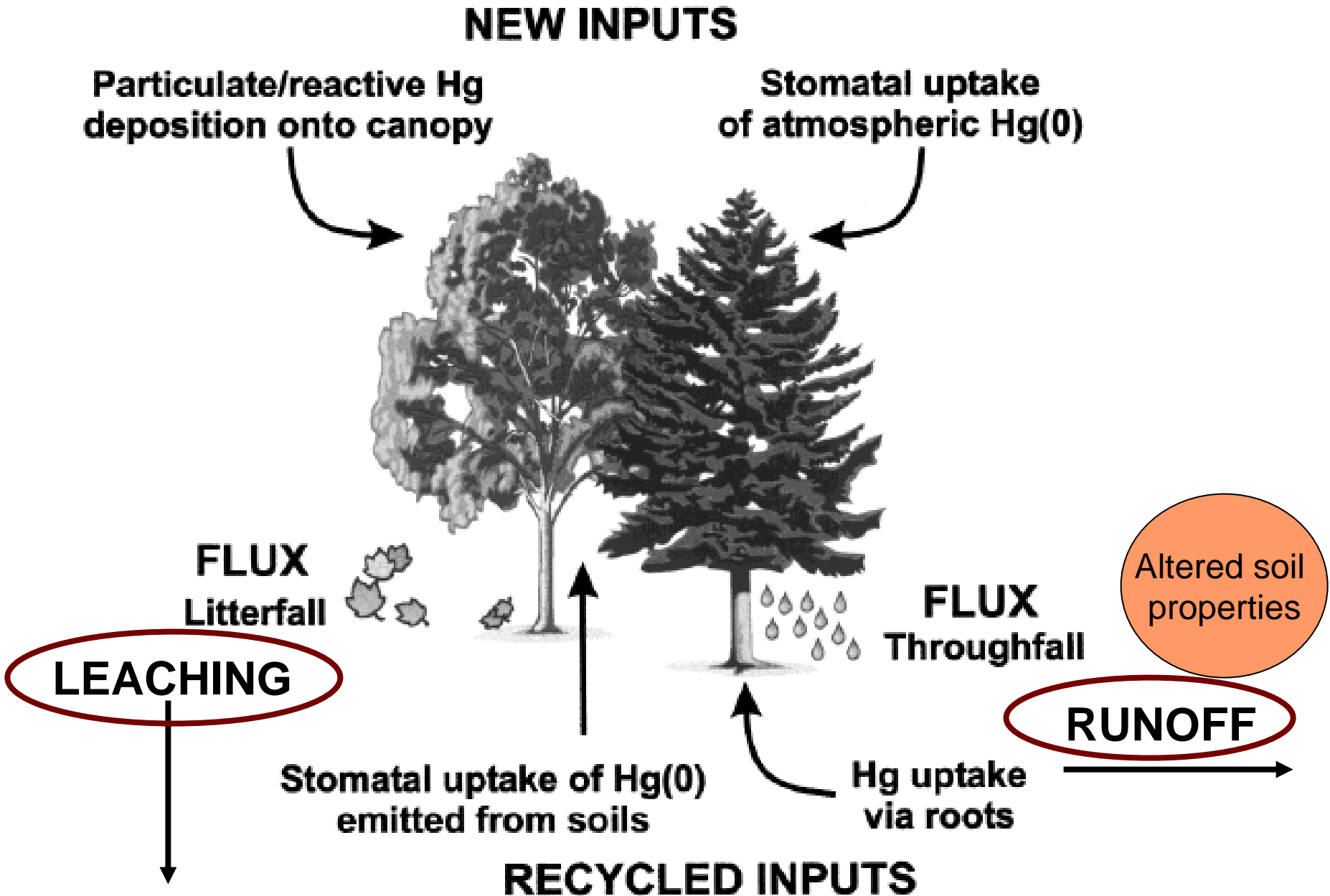
Potential CO_2 effects

Adapted from: St. Louis *et al.* 2001

NEW INPUTS

Particulate/reactive Hg deposition onto canopy

Stomatal uptake of atmospheric Hg(0)

Leaf area

Stomatal conductance

litterfall biomass

TF volume & chemistry

FLUX Litterfall
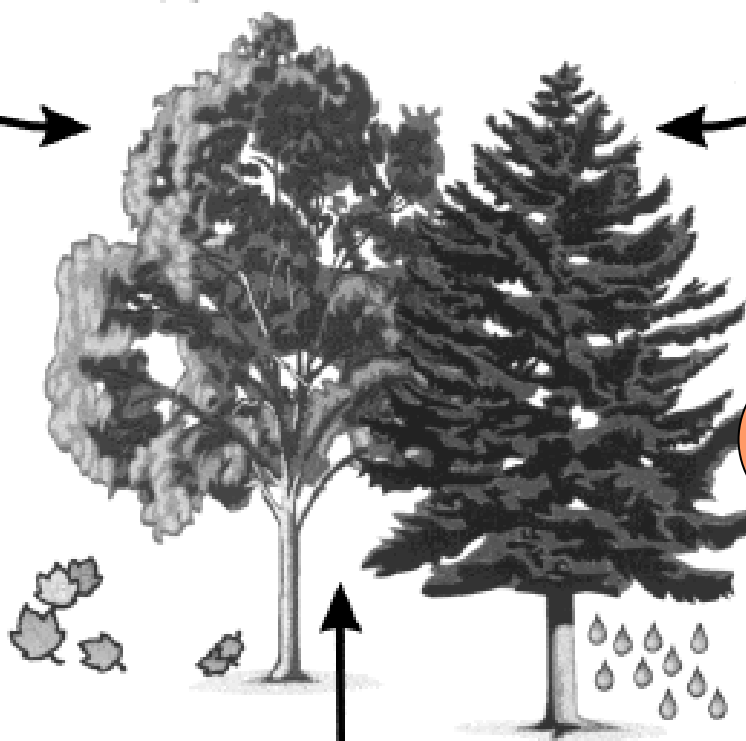
FLUX Throughfall

Altered soil properties

LEACHING

RUNOFF

Stomatal uptake of Hg(0) emitted from soils

Hg uptake via roots

RECYCLED INPUTS

Hypothesis

Elevated CO_2 will increase inputs of Hg into terrestrial systems and decrease losses, causing an **increase in Hg in forest soils.**
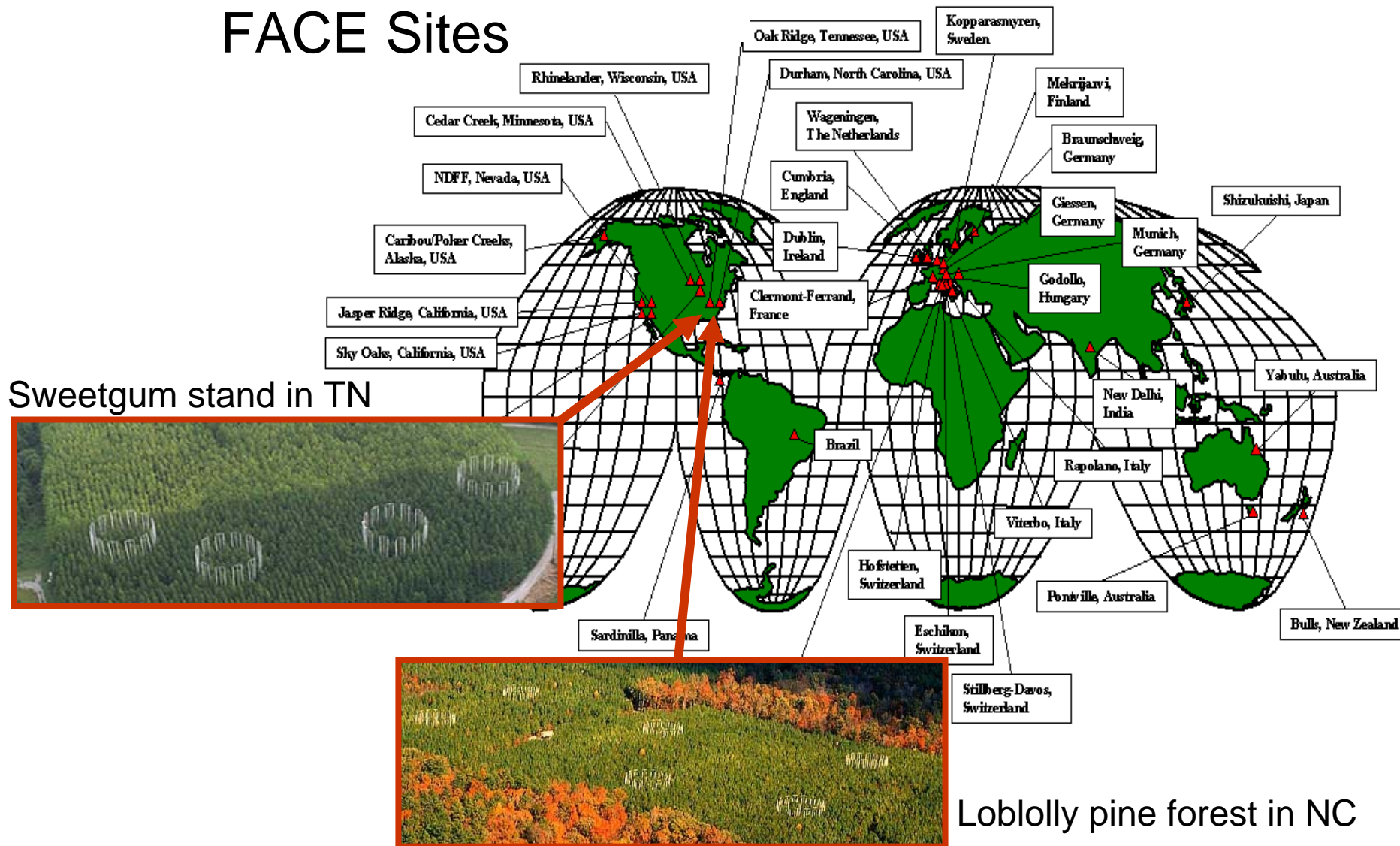
Questions

How will elevated CO_2 affect:

- Foliar Hg concentrations?

- Litter Hg concentrations?

- Total Hg litter inputs?

- Soil Hg concentrations?

- Total mass of Hg in soils?

*F*ree *A*ir *C*arbon *E*nrichment
FACE Sites

Oak Ridge, Tennessee, USA

Kopparasmyren, Sweden

Rhinelander, Wisconsin, USA

Durham, North Carolina, USA

Melrrijanvi, Finland

Cedar Creek, Minnesota, USA

Wageningen, The Netherlands

Braunschweig, Germany

NDFF, Nevada, USA

Cumbria, England

Giessen, Germany

Shizukuishi, Japan

Caribou/Poker Creeks, Alaska, USA

Dublin, Ireland

Munich, Germany

Jasper Ridge, California, USA

Clermont-Ferrand, France

Godollo, Hungary

Sky Oaks, California, USA

Yabulu, Australia

Sweetgum stand in TN

New Delhi, India

Brazil

Rapolano, Italy

Viterbo, Italy

Hofstetten, Switzerland

Pontville, Australia

Sardinilla, Panama

Eschikon, Switzerland

Bulls, New Zealand

Stillberg-Davos, Switzerland

Loblolly pine forest in NC

Samples collected from ambient and enriched CO_2 (~ambient + 200ppmv) plots

	Duke	**ORNL**
Location	Orange County, NC	Roane County, TN
Lat-long	35°58'N, 79°05'W	35°54'N, 84°20'W
Annual T	15.5° C	13.9° C
Annual rain	1140 mm	1371 mm
Planted	1983	1988
FACE start	1996	1998
CO_2 treatment	A: ~ 382ppmv E: ~ 582ppmv	A: ~ 393ppmv E: ~ 544ppmv
Plot size	30 m diameter	25 m diameter
Soil type	Hapludalf	Aquic Hapludult
Soil pH	~ 5.3 (water)	~ 4.8 (water)
Canopy	*Pinus taeda* +	*Liquidambar styraciflua*

Sampling

FOLIAGE

- Three replicates from low (10-12m), mid (12-14m) and upper (14-16m) canopy

- Mature fully-expanded *L. styraciflua* (Sweetgum) leaves at both sites

- Current/0-yr and 1-yr *P. taeda* (loblolly pine) needles at Duke

- Freshly fallen litter from forest floor at ORNL

- Senescent leaves from trees at Duke

Sampling

SOIL

- Collected with soil corer, lined with plastic liners

- Top 20 cm, separated into 5 cm increments

- Replicates pooled for chemical analyses

Samples collected and handled using trace metal clean techniques

Chemical analyses

<u>Hg:</u>

- digested in HNO_3 and H_2O_2
- analyzed by ICP-MS

<u>Soil organic matter (SOM):</u> % loss-on-ignition

<u>pH:</u> 1:1 soil in distilled water and in .01M CaCl

<u>Soil bulk density:</u> soil dry wt/volume

<u>Litter biomass:</u> 2004(Duke)/2005(ORNL) litter baskets
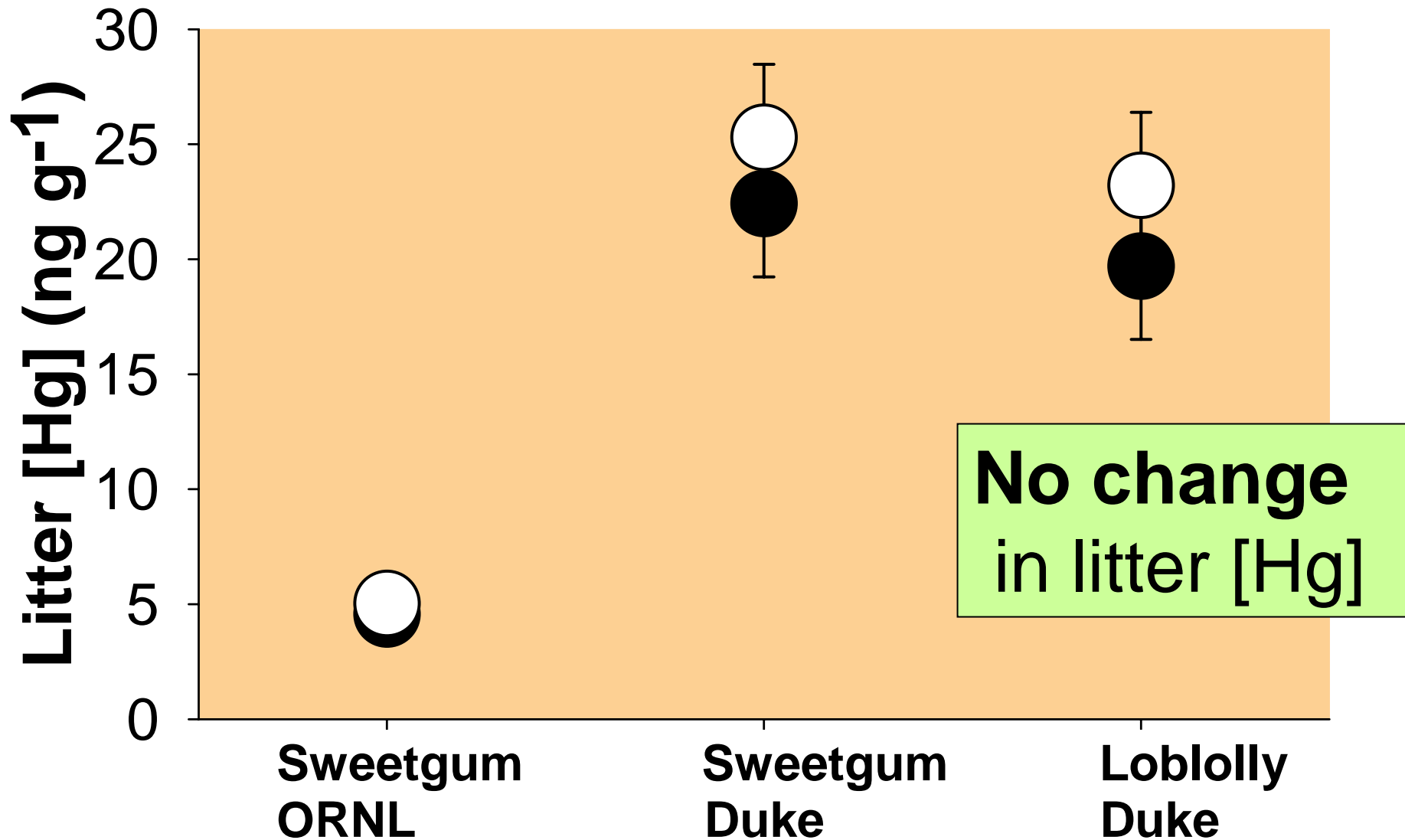
Questions

How will elevated CO_2 affect:

- **Foliar Hg concentrations?**

- Litter Hg concentrations?

- Total Hg litter inputs?

- Soil Hg concentrations?

- Total mass of Hg in soils?

CO$_2$ effects on leaf [Hg]

ORNL: Sweetgum

No change in sweetgum [Hg] at ORNL

Leaf Hg (ng g^{-1})

Ambient   Elevated

CO$_2$: NS

CO$_2$ effects on leaf [Hg]

Leaf Hg (ng g^{-1})

Duke: Sweetgum

No change in sweetgum [Hg] at Duke

Ambient   **Elevated**

CO$_2$: NS
Site: p=.018

CO$_2$ effects on leaf [Hg]

Duke: Loblolly pine

Leaf Hg (ng g^{-1})

15

12

9

6

3

0

Ambient   **Elevated**
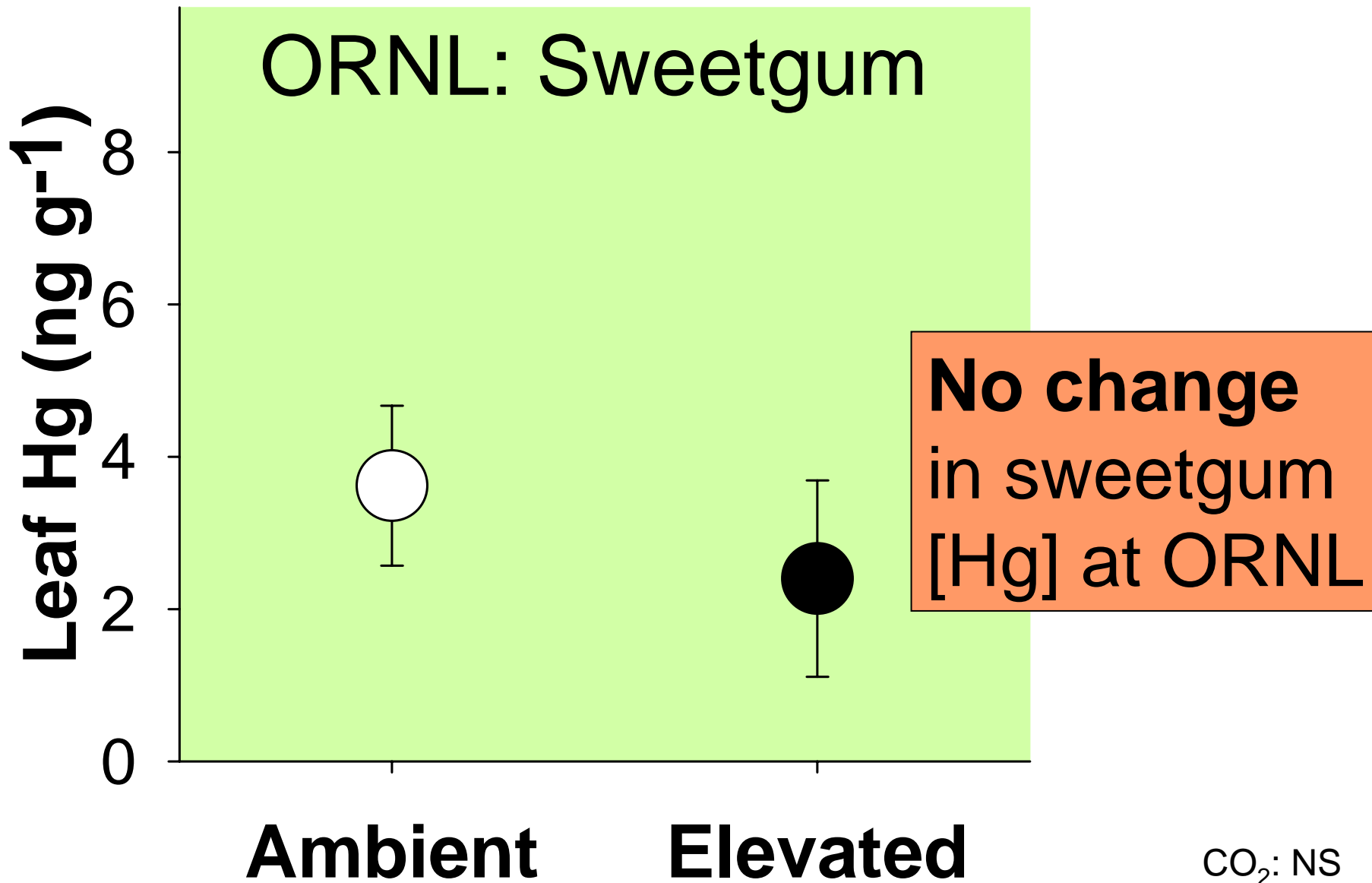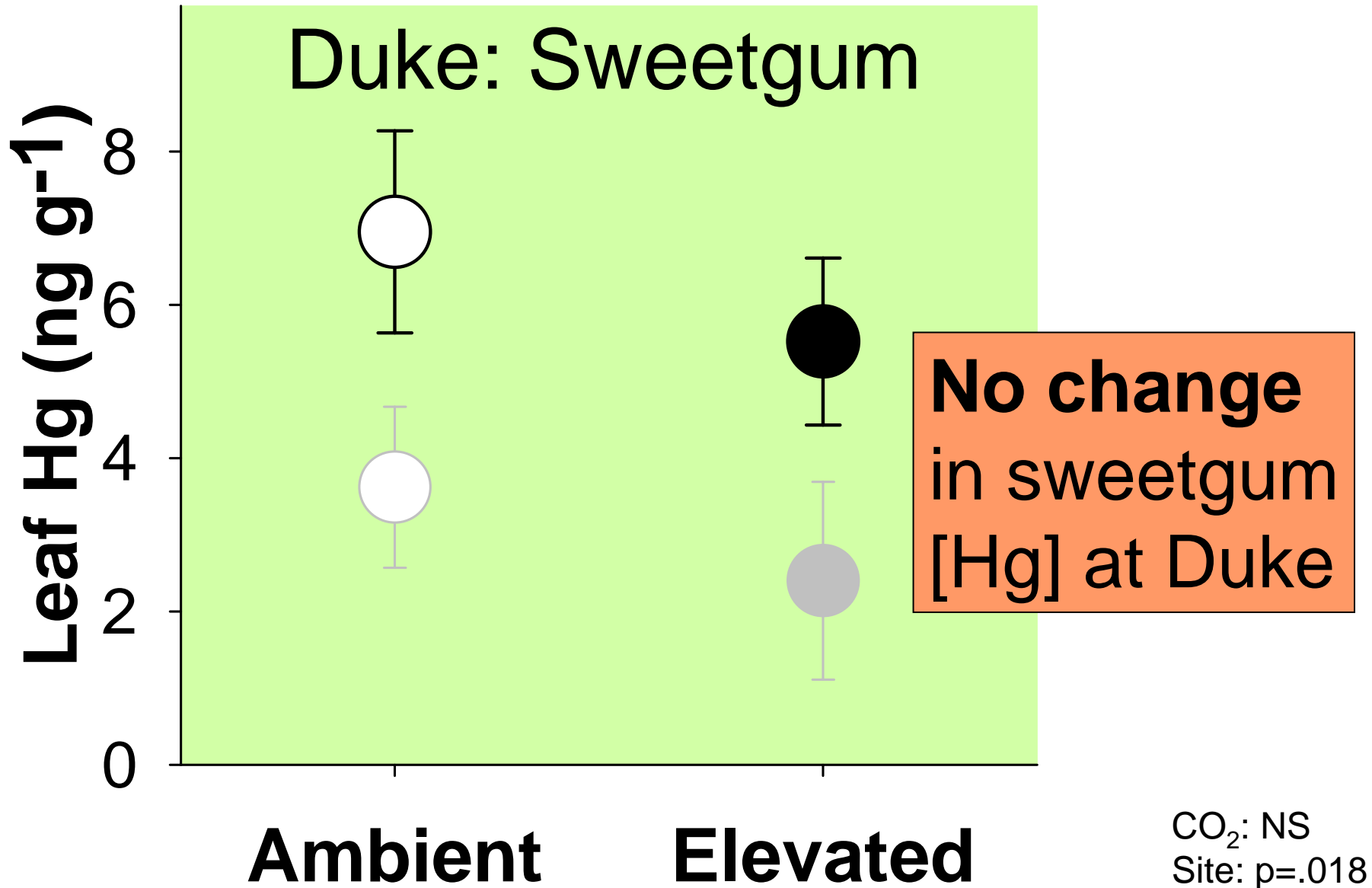
DECREASE in loblolly pine [Hg]
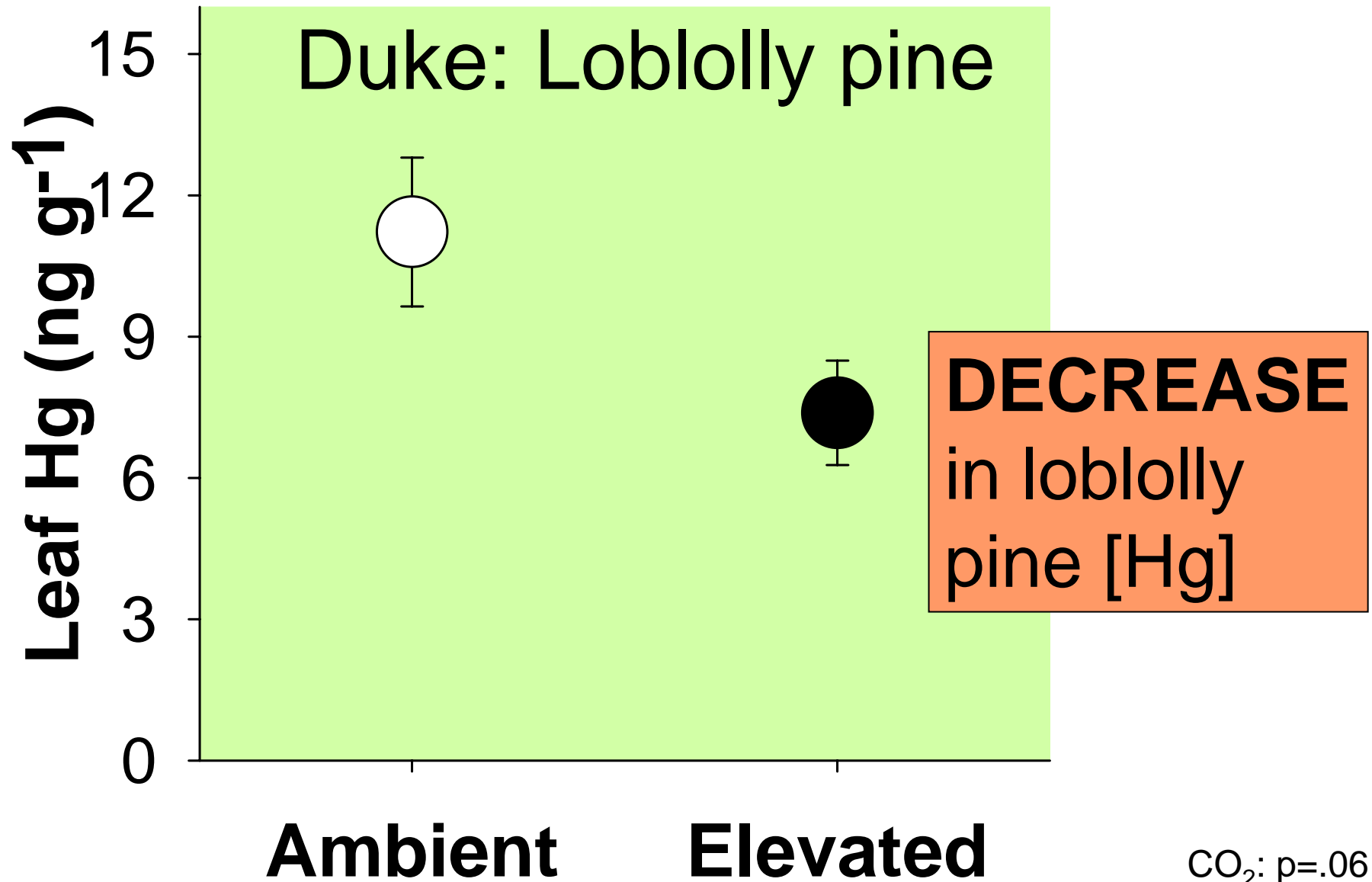
CO$_2$: p=.06

Pine needle age effect

Duke: Loblolly pine

Leaf Hg (ng g^{-1})

LOWER [Hg] in 0-yr needles
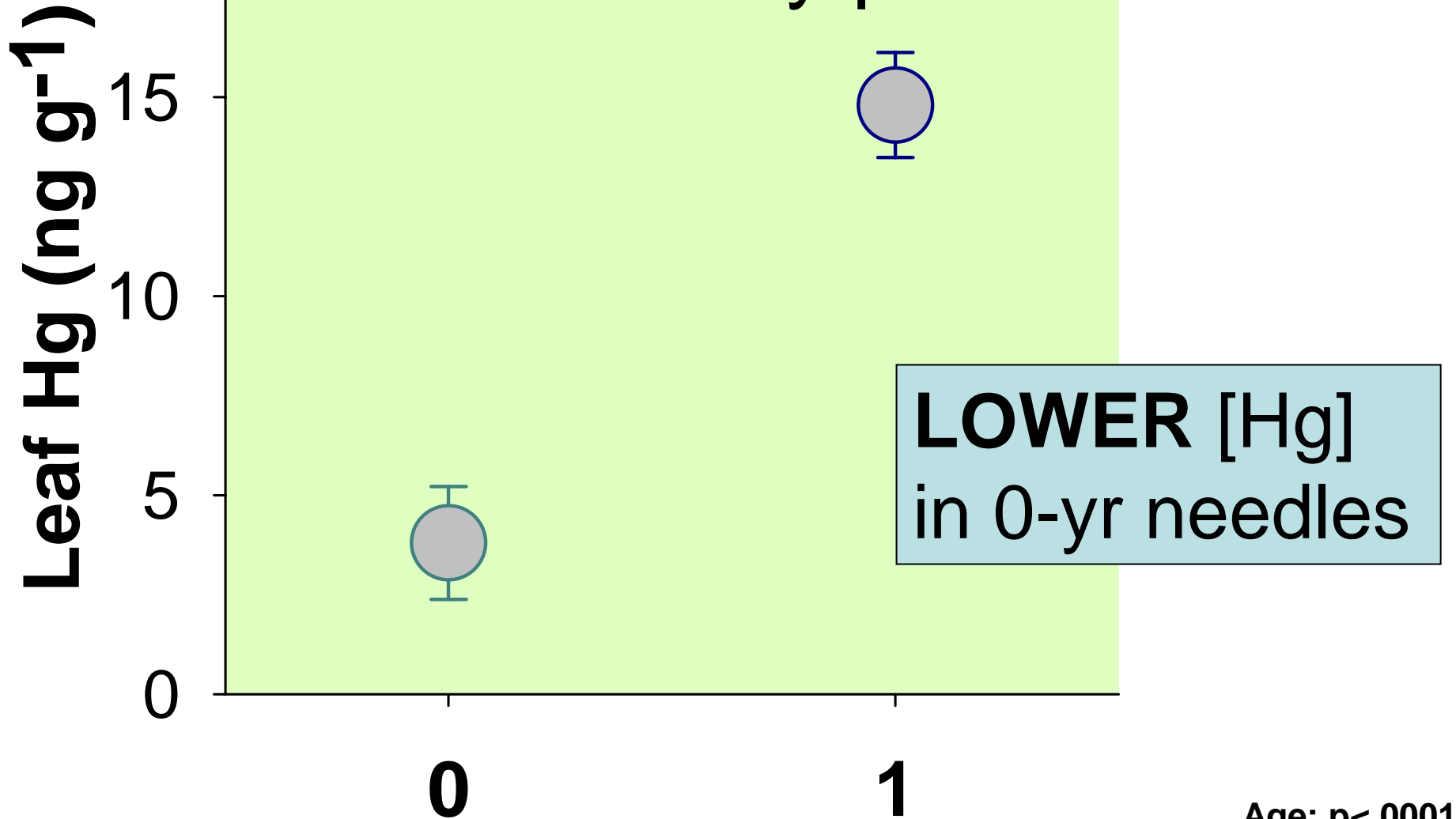
Age: p<.0001

CO$_2$ effects on leaf [Hg]

DECREASED [Hg] in 1-yr leaves only

Duke: Loblolly pine

Age: p<.0001

Duke: Loblolly pine
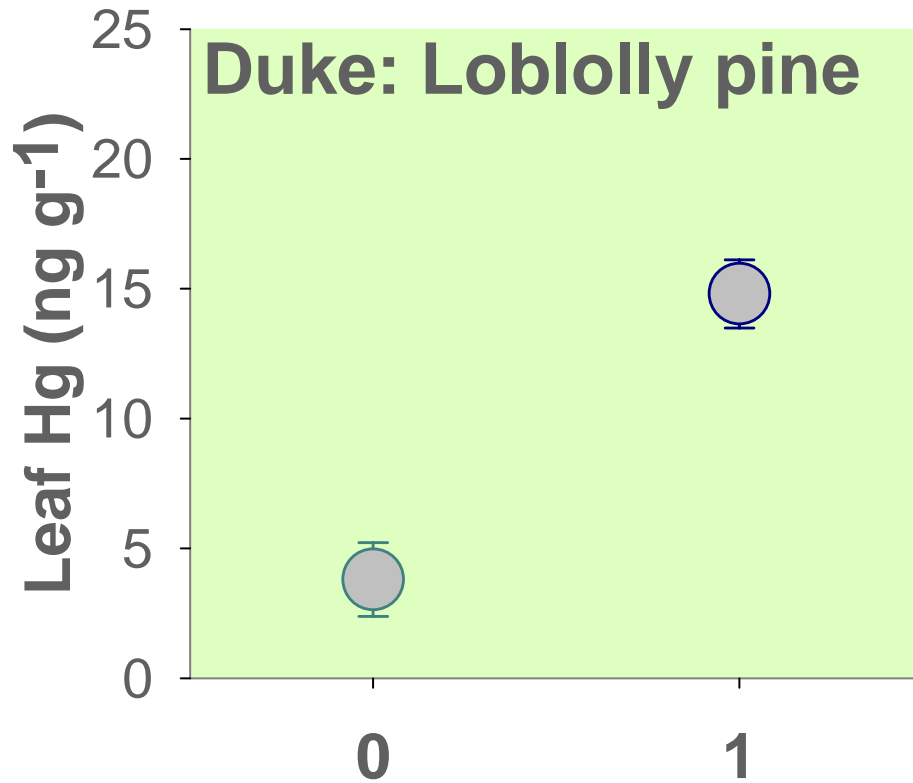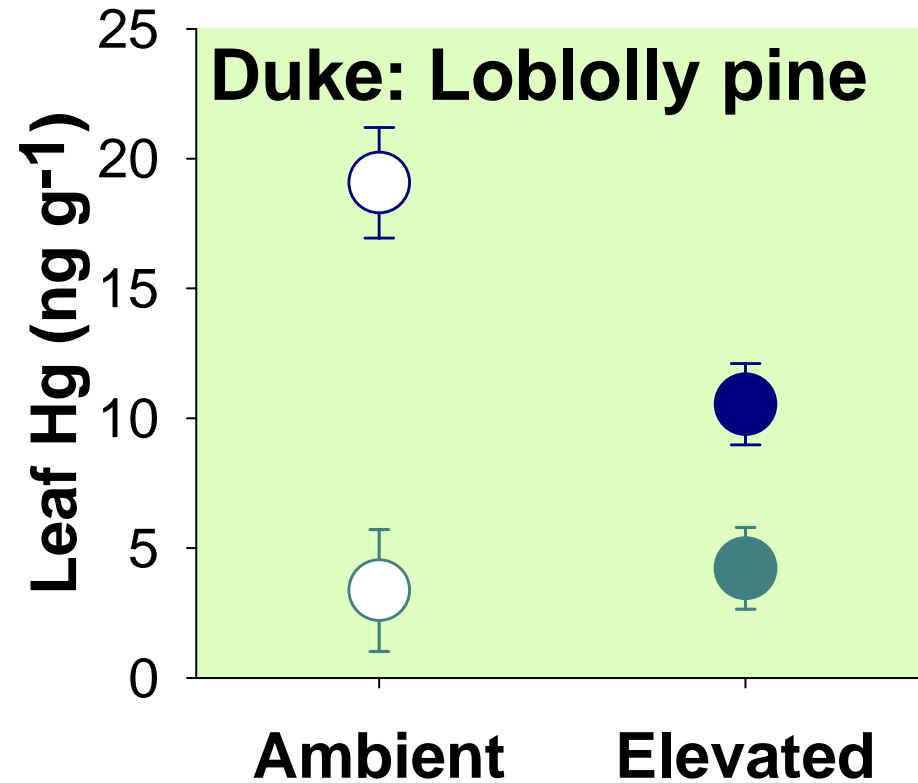
Age * CO$_2$: p=.03

Questions

How will elevated CO_2 affect:

- **Foliar Hg concentrations? ↓ or NC**

- Litter Hg concentrations?

- Total Hg litter inputs?
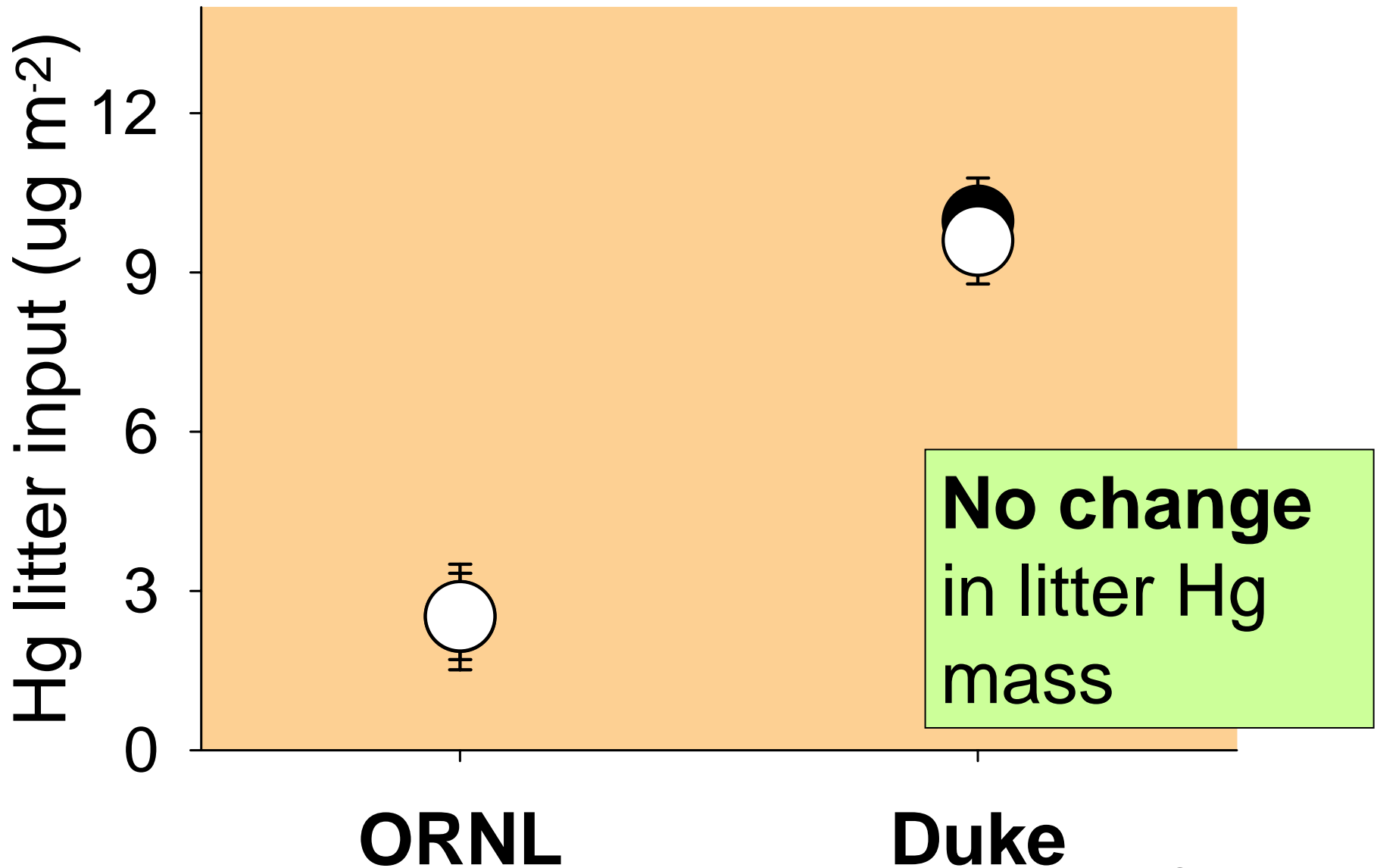
- Soil Hg concentrations?

- Total mass of Hg in soils?

Questions

How will elevated CO_2 affect:

- **Foliar Hg concentrations? ↓ or NC**

- **Litter Hg concentrations?**

- Total Hg litter inputs?

- Soil Hg concentrations?

- Total mass of Hg in soils?

CO$_2$ effects on litter [Hg]

Questions

How will elevated CO_2 affect:

- **Foliar Hg concentrations? ↓ or NC**

- **Litter Hg concentrations? NC**

- Total Hg litter inputs?

- Soil Hg concentrations?

- Total mass of Hg in soils?

Questions

How will elevated CO_2 affect:

- **Foliar Hg concentrations? ↓ or NC**

- **Litter Hg concentrations? NC**

- **Total Hg litter inputs?**

- Soil Hg concentrations?

- Total mass of Hg in soils?

CO$_2$ effects on total Hg litter inputs

Hg litter input (ug m^{-2})

No change in litter Hg mass

ORNL   Duke

Site: p<.0001

Questions

How will elevated CO_2 affect:

- **Foliar Hg concentrations? ↓ or NC**

- **Litter Hg concentrations? NC**

- **Total Hg litter inputs?**   **NC**

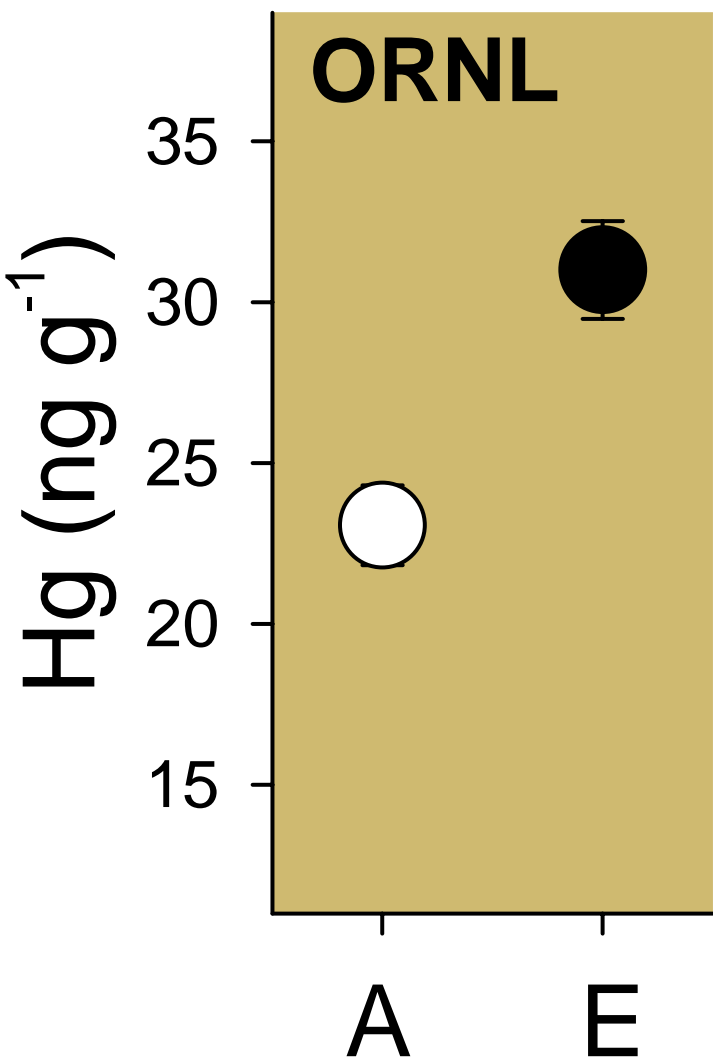- Soil Hg concentrations?

- Total mass of Hg in soils?

Questions

How will elevated CO_2 affect:

- Foliar Hg concentrations? ↓ or NC

- Litter Hg concentrations? NC

- Total Hg litter inputs?   NC

- **Soil Hg concentrations?**

- Total mass of Hg in soils?

CO$_2$ effects on soil [Hg]
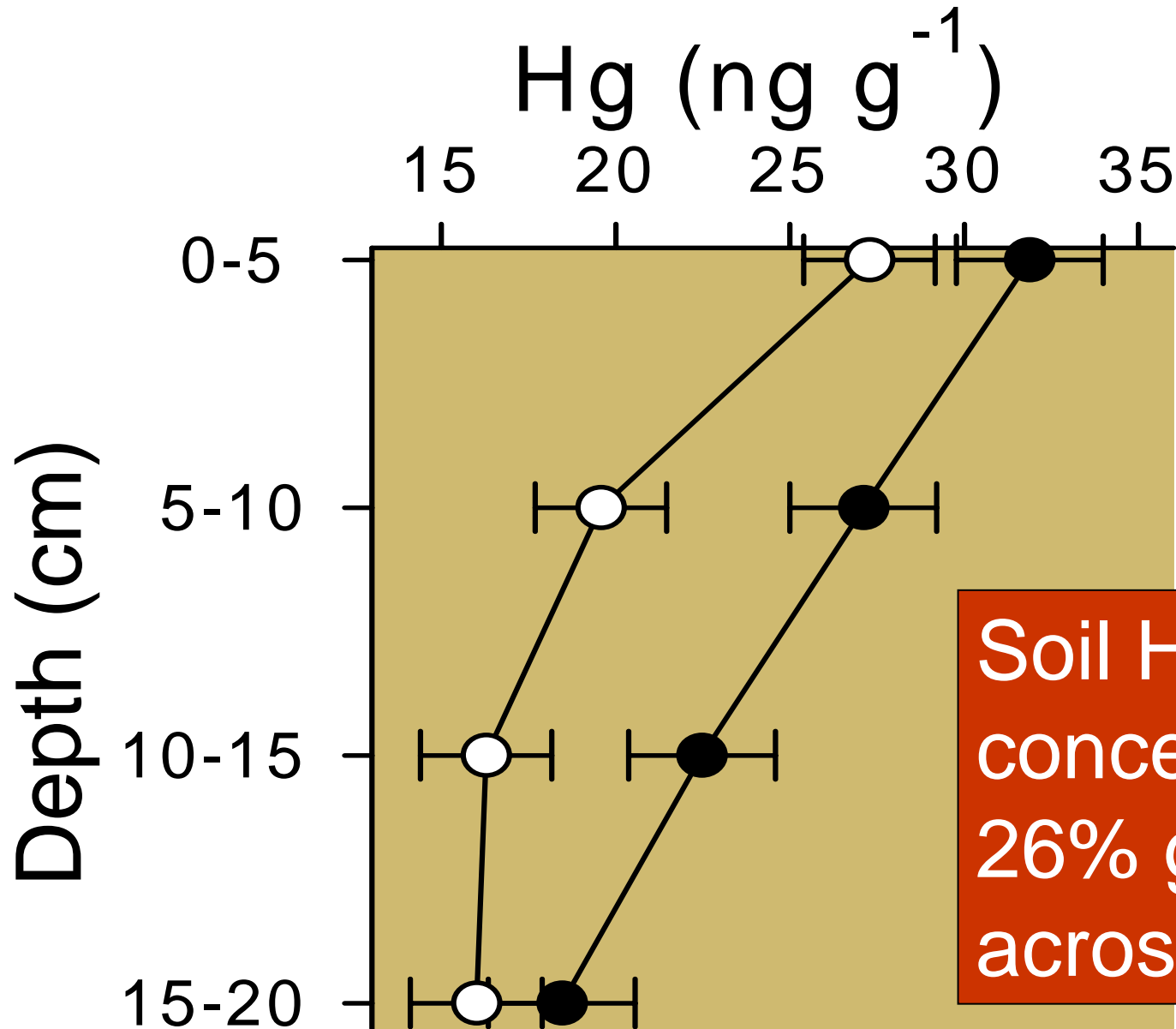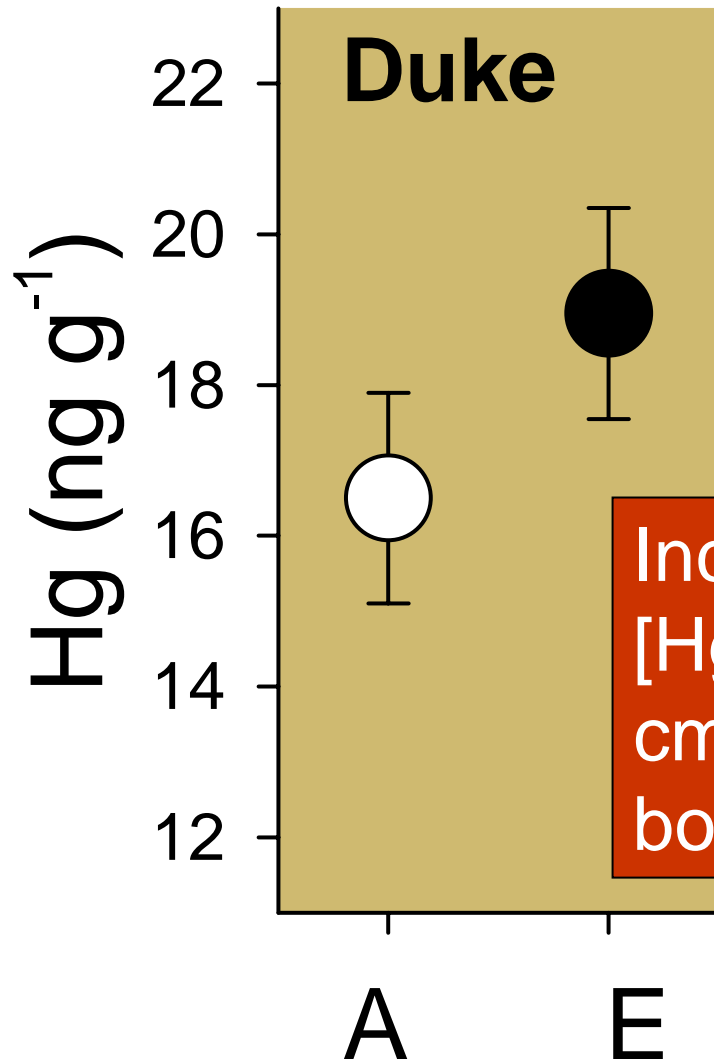
Hg (ng g^{-1})

Soil Hg concentration 26% greater across sites!

CO$_2$ effects on soil [Hg]

Potential CO$_2$ effects

Adapted from:
St. Louis *et al.* 2001

NEW INPUTS

Particulate/reactive Hg deposition onto canopy

Stomatal uptake of atmospheric Hg(0)

Leaf area

Stomatal conductance

litterfall biomass

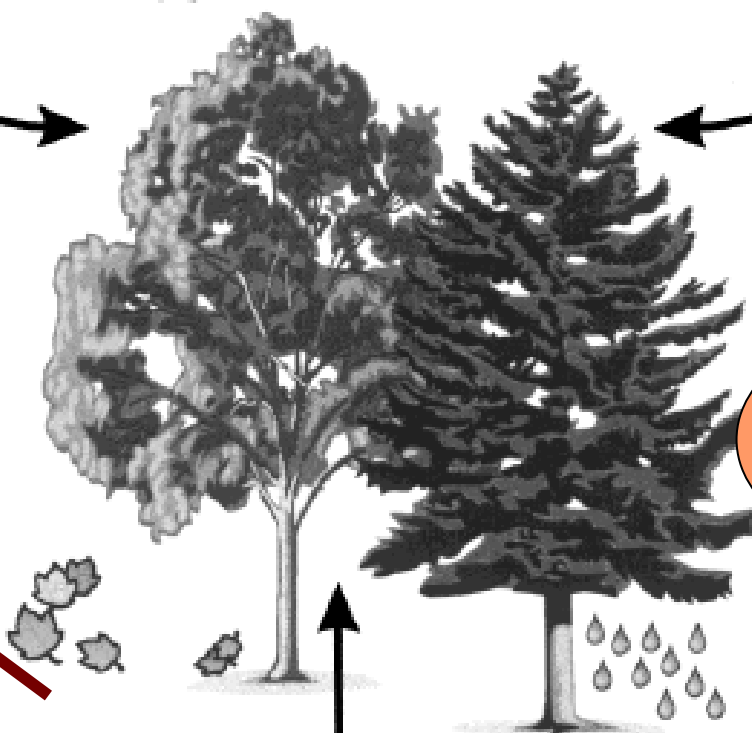TF volume & chemistry

FLUX Litterfall

Altered soil properties

LEACHING

FLUX Throughfall

RUNOFF

Stomatal uptake of Hg(0) emitted from soils

Hg uptake via roots

RECYCLED INPUTS

What mediates CO$_2$ effects?

Soil Hg correlated with SOM at both sites

* p<0.05

What mediates CO$_2$ effects?

Soil Hg correlated with pH at Duke

ORNL

Duke *
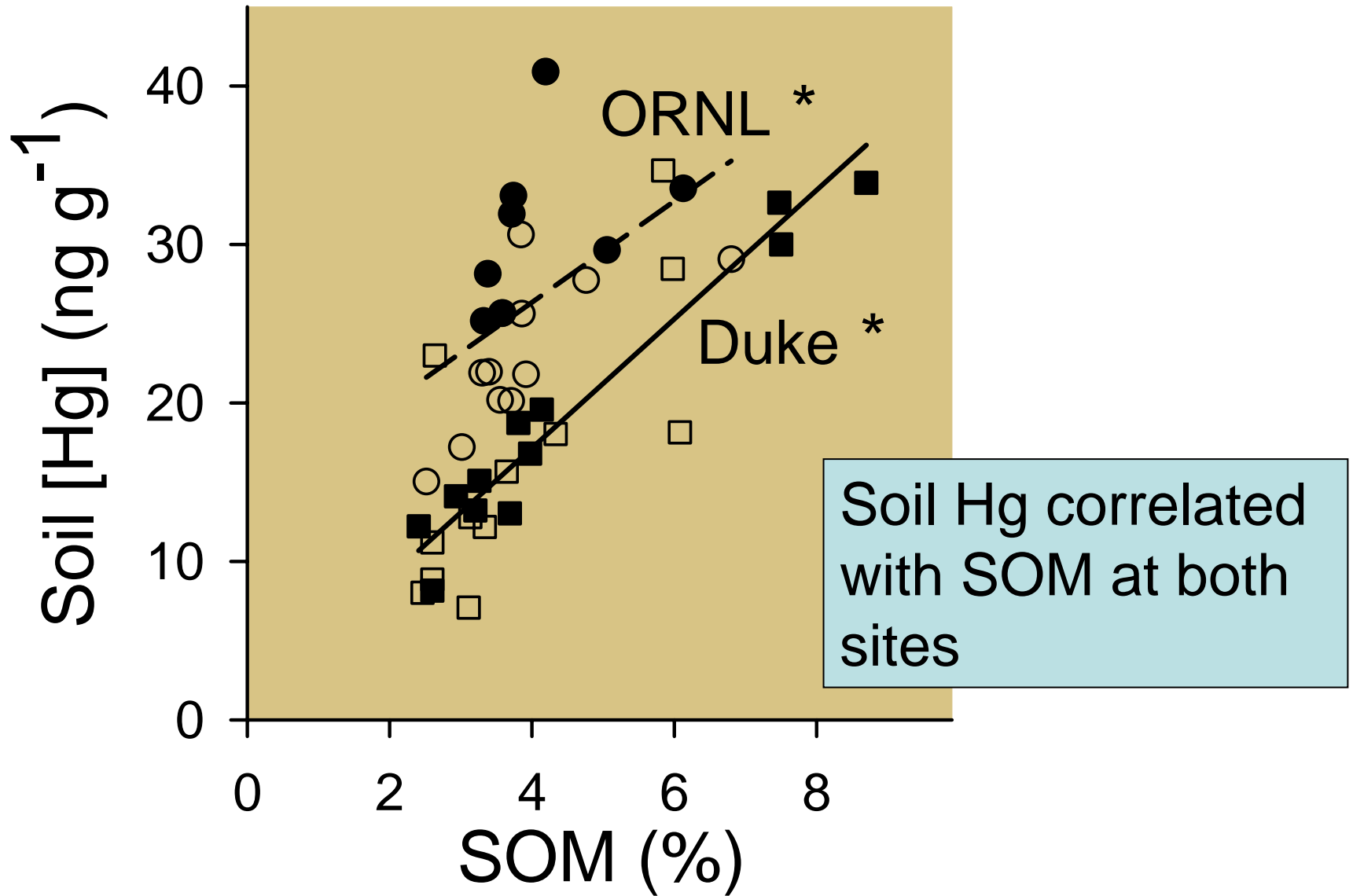
* p<0.05
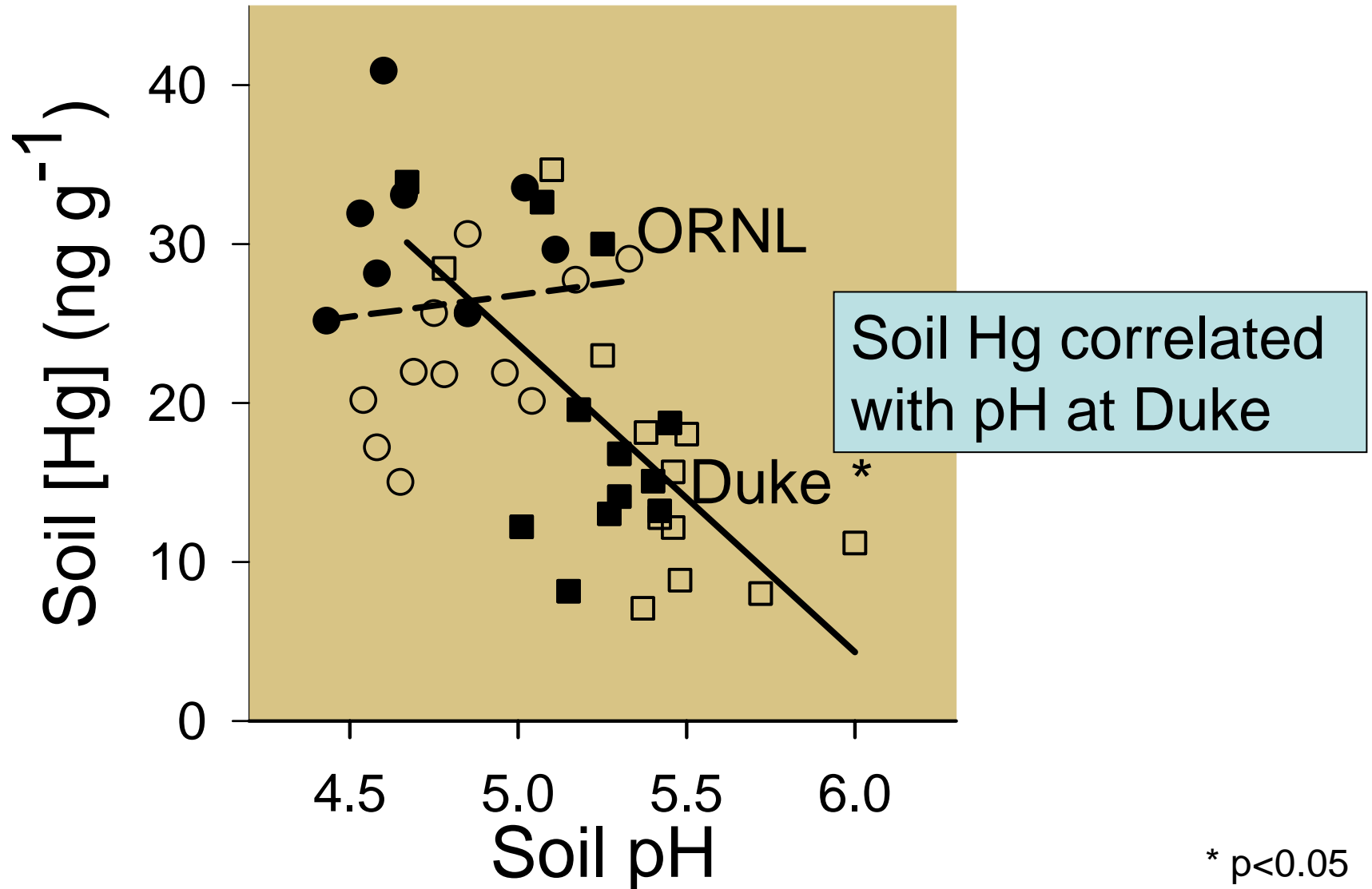
SOM and pH explain 68% of the variation in soil [Hg] across sites

Do pH and SOM mediate CO_2 effects on soil [Hg]?

Effect	ANOVA	ANCOVA pH-SOM covariates
	P	P
CO_2	**<0.05**	
CO_2 * Site	NS	

Do pH and SOM mediate CO_2 effects on soil [Hg]?

Effect	ANOVA	ANCOVA pH-SOM covariates
	P	P
CO_2	**<0.05**	NS
CO_2 * Site	NS	

Do pH and SOM mediate CO_2 effects on soil [Hg]?

Effect	ANOVA	ANCOVA pH-SOM covariates
	P	P
CO_2	**<0.05**	NS
CO_2 * Site	NS	**<0.05**

Do pH and SOM mediate CO_2 effects on soil [Hg]?

Effect	ANOVA	ANCOVA pH-SOM covariates
	P	P
CO_2	**<0.05**	NS
CO_2 * Site	NS	**<0.05**

Perhaps, but additional mechanism at ORNL

Questions

How will elevated CO_2 affect:

- **Foliar Hg concentrations? ↓ or NC**

- **Litter Hg concentrations? NC**

- **Total Hg litter inputs?   NC**

- **Soil Hg concentrations?   ↑**
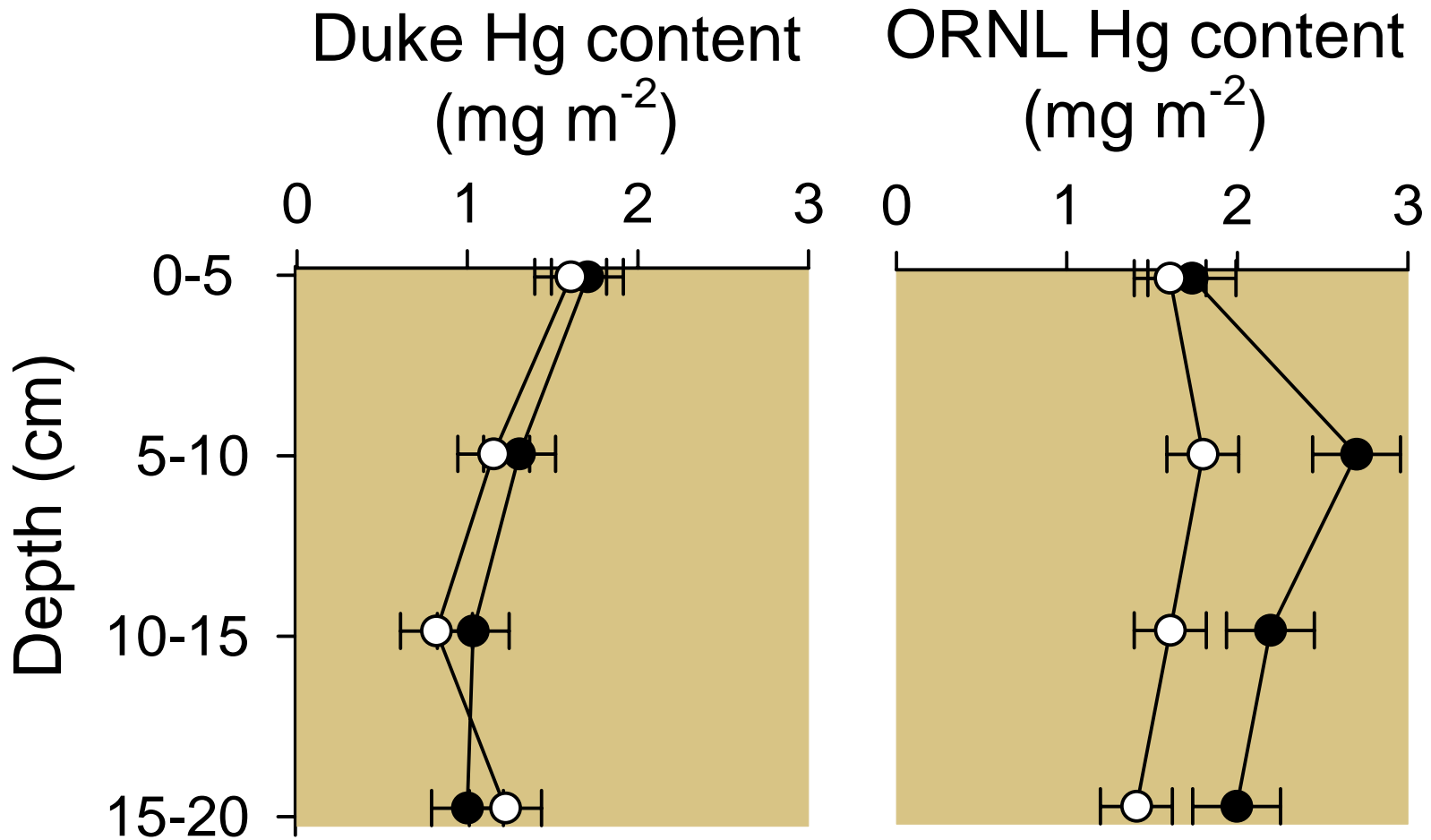
- **Total mass of Hg in soils?**

Questions

How will elevated CO_2 affect:

- **Foliar Hg concentrations? ↓ or NC**

- **Litter Hg concentrations? NC**

- **Total Hg litter inputs?   NC**

- **Soil Hg concentrations?   ↑**

- **Total mass of Hg in soils?**

CO$_2$ effects on total soil Hg content

Soil Hg mass 22% greater across sites, but significantly greater only at ORNL

Questions

How will elevated CO_2 affect:

- **Foliar Hg concentrations?** **↓ or NC**

- **Litter Hg concentrations?** **NC**

- **Total Hg litter inputs?** **NC**

- **Soil Hg concentrations?** **↑**

- **Total mass of Hg in soils?** **↑ or NC**

Hypothesis

Elevated CO_2 will increase inputs of Hg into terrestrial systems and decrease losses, causing an **increase in Hg in forest soils.**

Elevated CO_2 ***is*** **increasing Hg in forest soils.**

But data do not support hypothesis of increased inputs.

Implications

Elevated soil [Hg] may result in:

- greater pulsed inputs to freshwater systems

- decreased decomposition and microbial diversity

- increased Hg volatilization from soils

- increased methyl mercury in surface runoff water

Future plans

- Measure throughfall inputs

- Determine losses in runoff and volatile emissions

- Increase sampling throughout season/year

- Measure other soil parameters—such as S and metal (Fe, Al, Mn) hydroxides

- Expand to other CO_2 experimental sites

Acknowledgements

SUNYSB:

Advisors: Manuel Lerdau & Sergio Sañudo-Wilhelmy

and lab members

FACE:

Rich Norby, Colleen Iversen, Adrien Finzi, Ram Oren, David Cooley, Robert Nettles