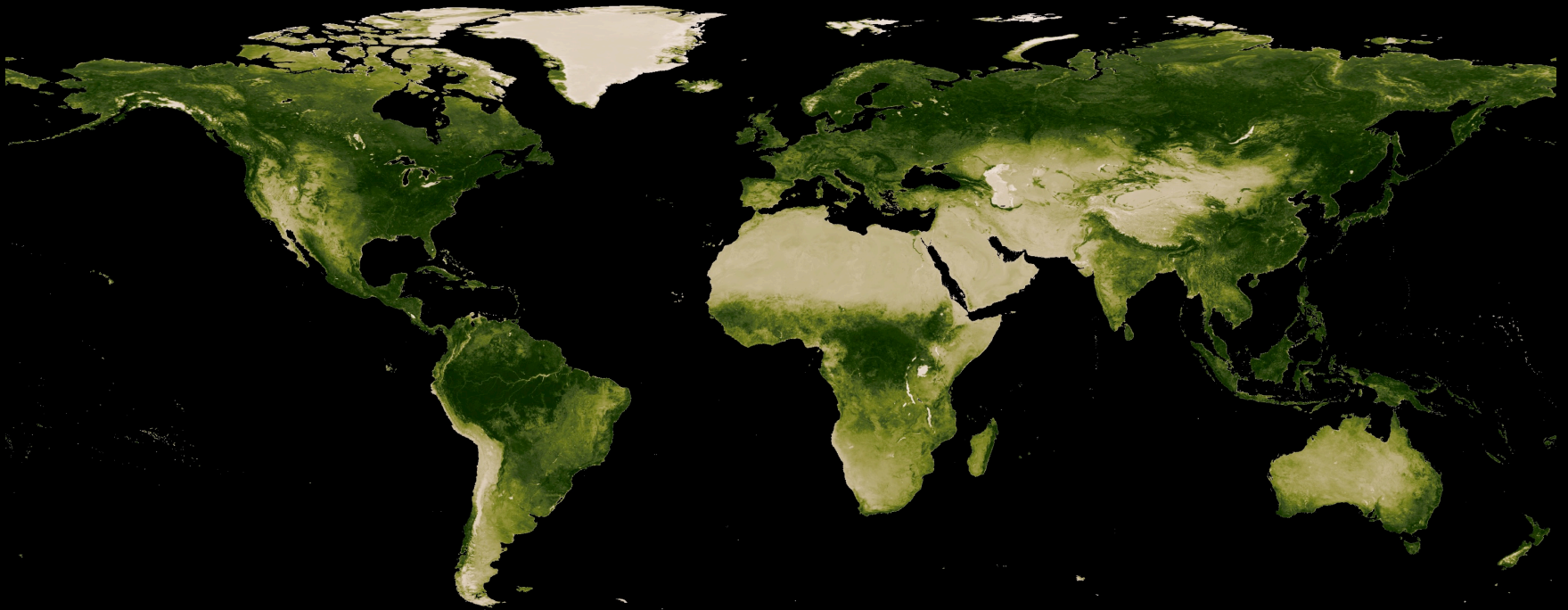


# **Climate Impacts of Plant Structural Acclimation in Response to Climate Change**

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**Marlies Kovenock<sup>1</sup>  
and Abigail L.S. Swann<sup>2,1</sup>**

**University of Washington**

**<sup>1</sup>Dept. of Biology, <sup>2</sup>Dept. of Atmospheric Sciences**

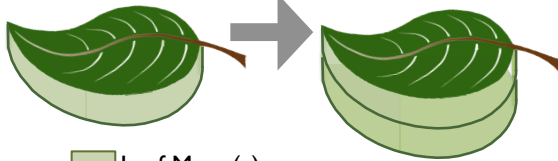
## $\Delta$ Plant Structure

Ambient CO<sub>2</sub>

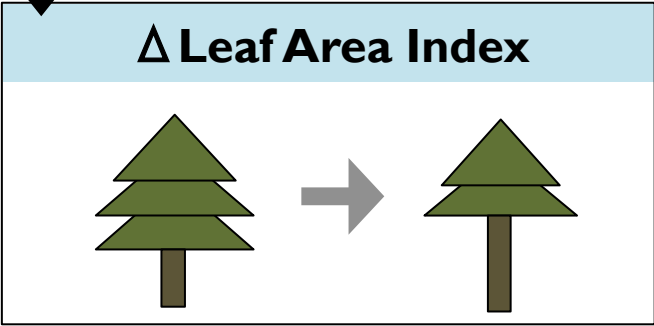
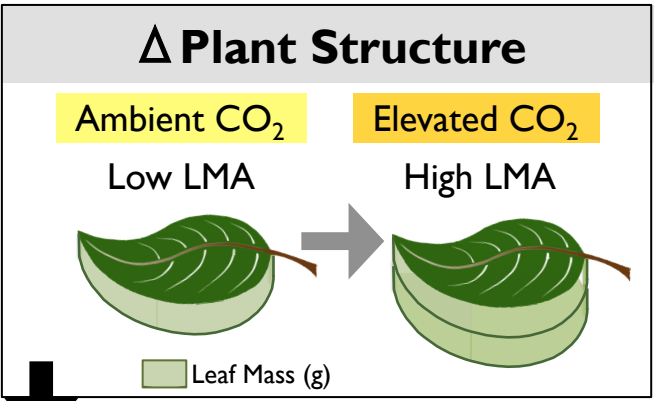
Elevated CO<sub>2</sub>

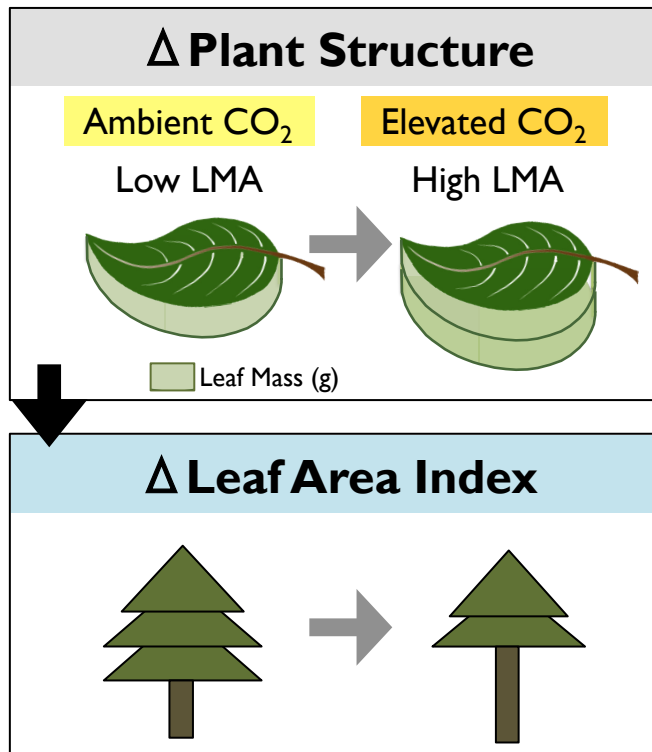
Low LMA

High LMA

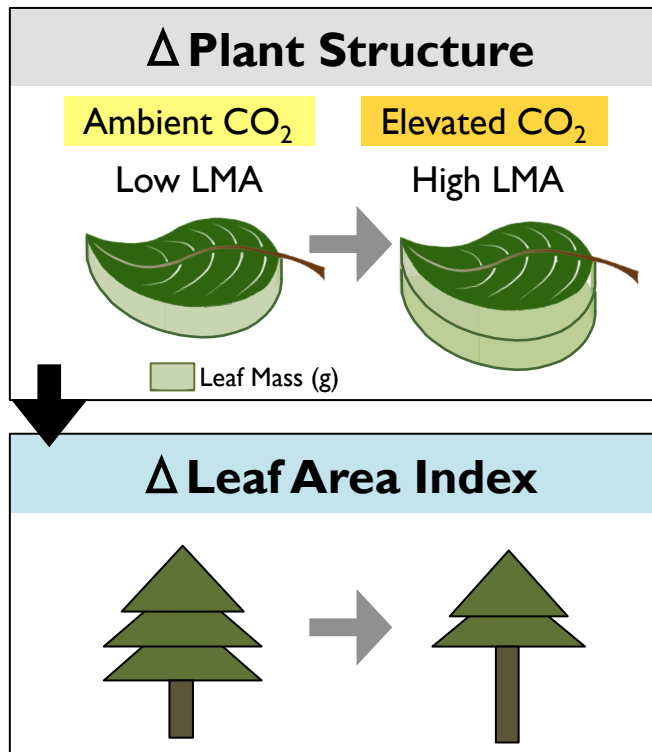


Leaf Mass (g)

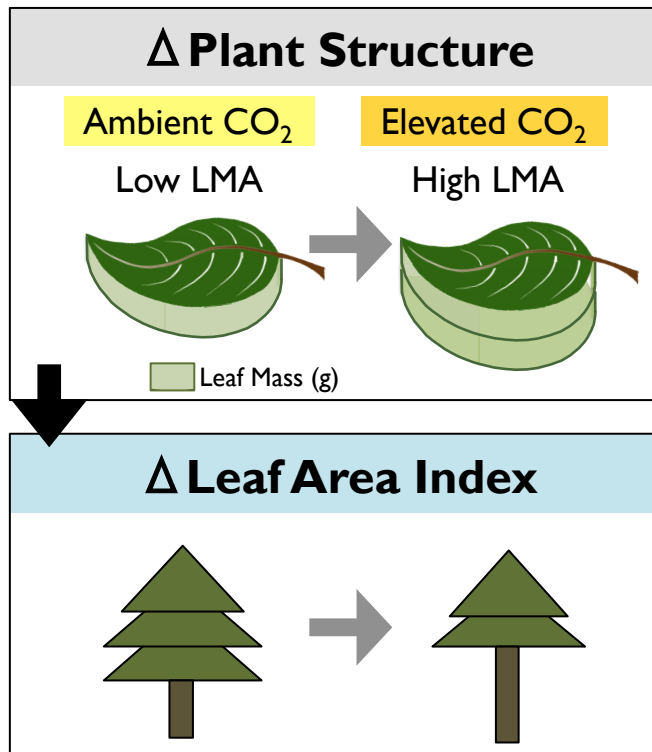




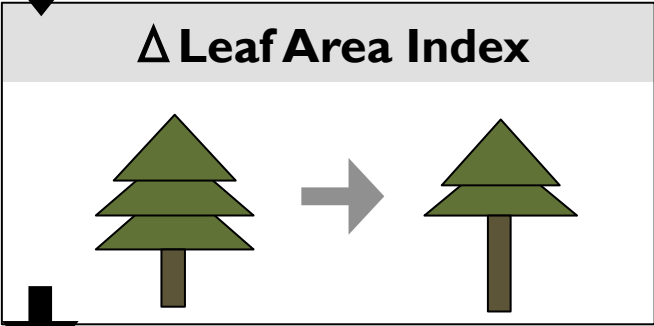
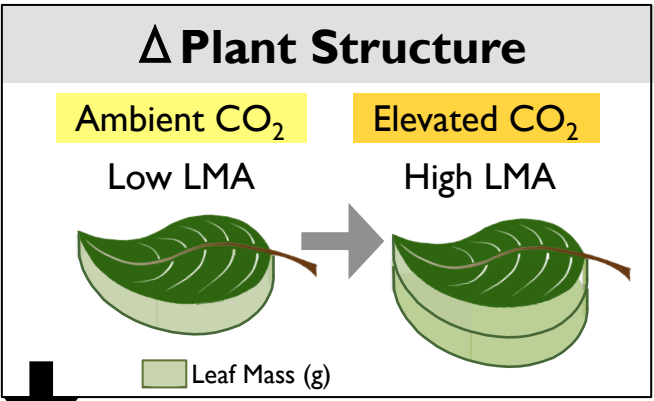
$$\text{Leaf Area Index} = \frac{e(\alpha \text{ Carbon}_{\text{Leaf}}) - I}{\alpha \text{ LMA}}$$



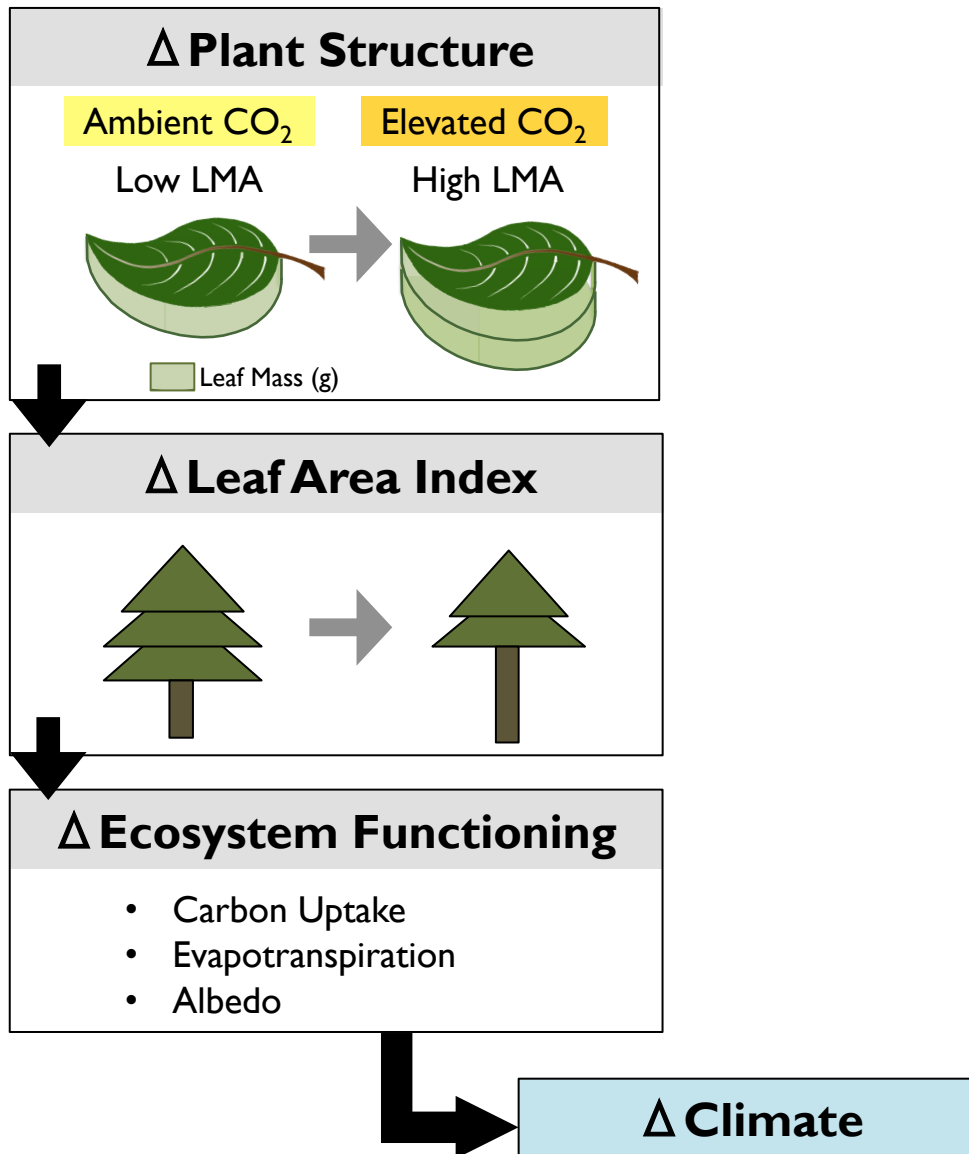
$$\text{Leaf Area Index} = \frac{e(\alpha \text{ Carbon}_{\text{Leaf}}) \cdot I}{\alpha \text{ LMA} \uparrow}$$



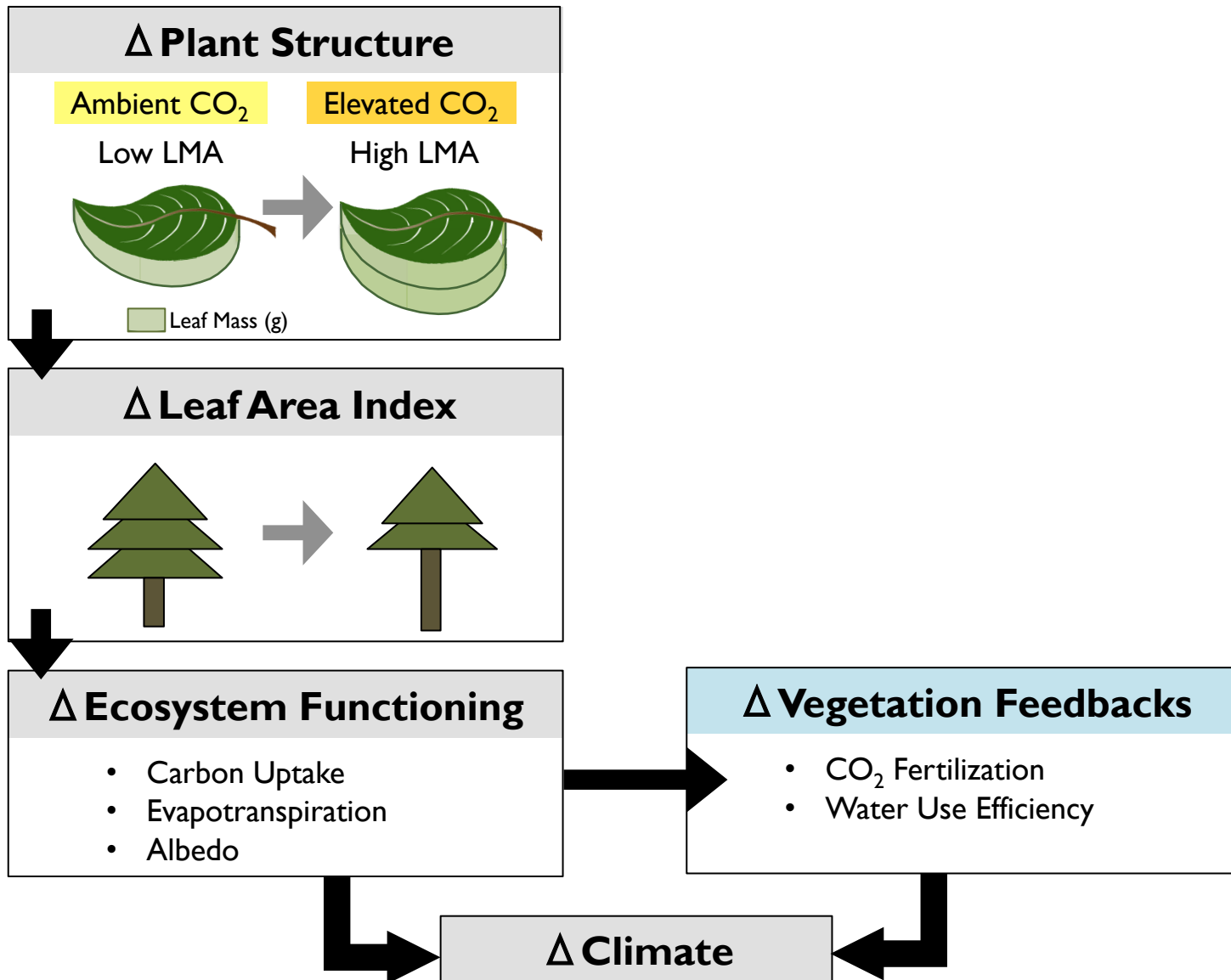
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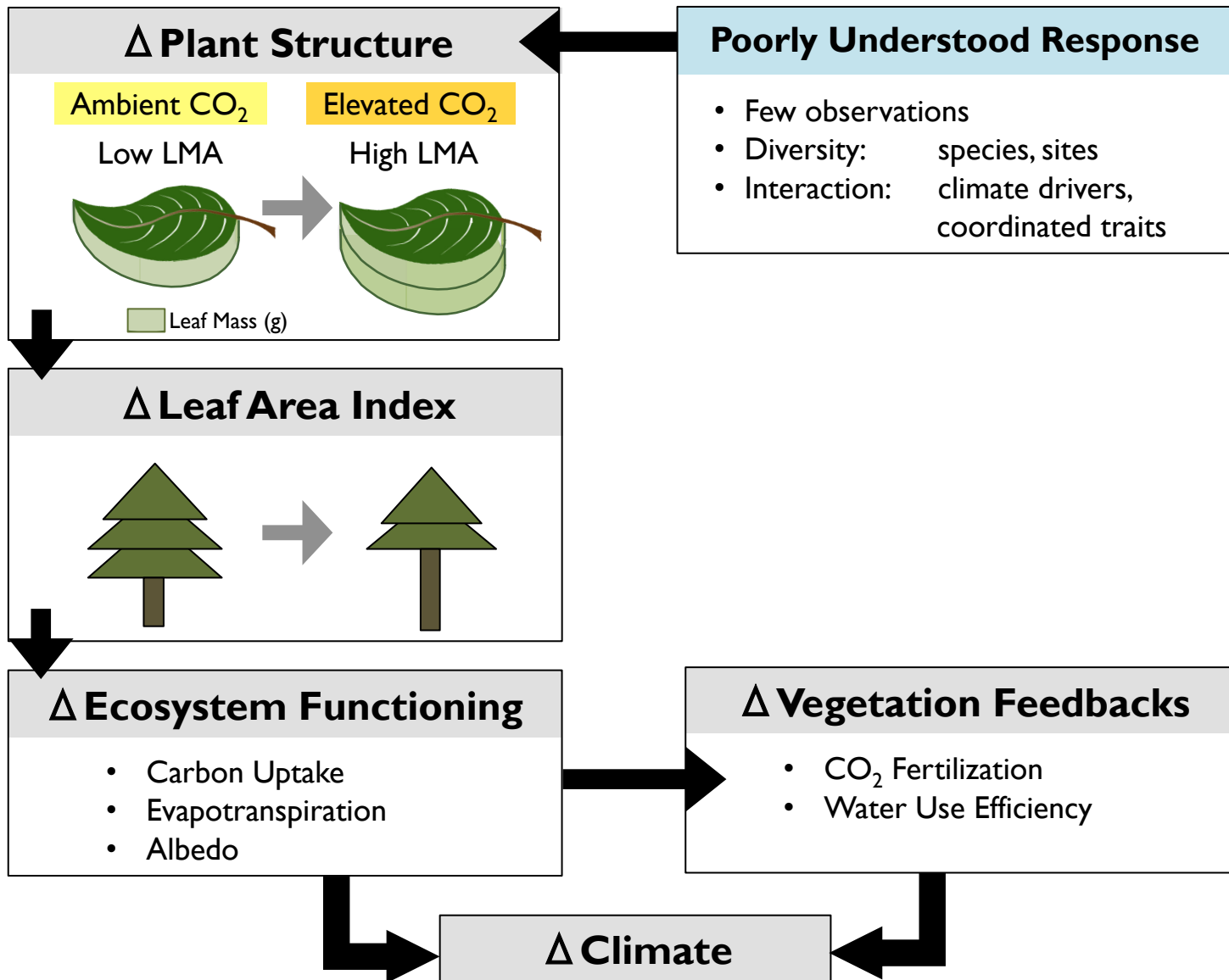


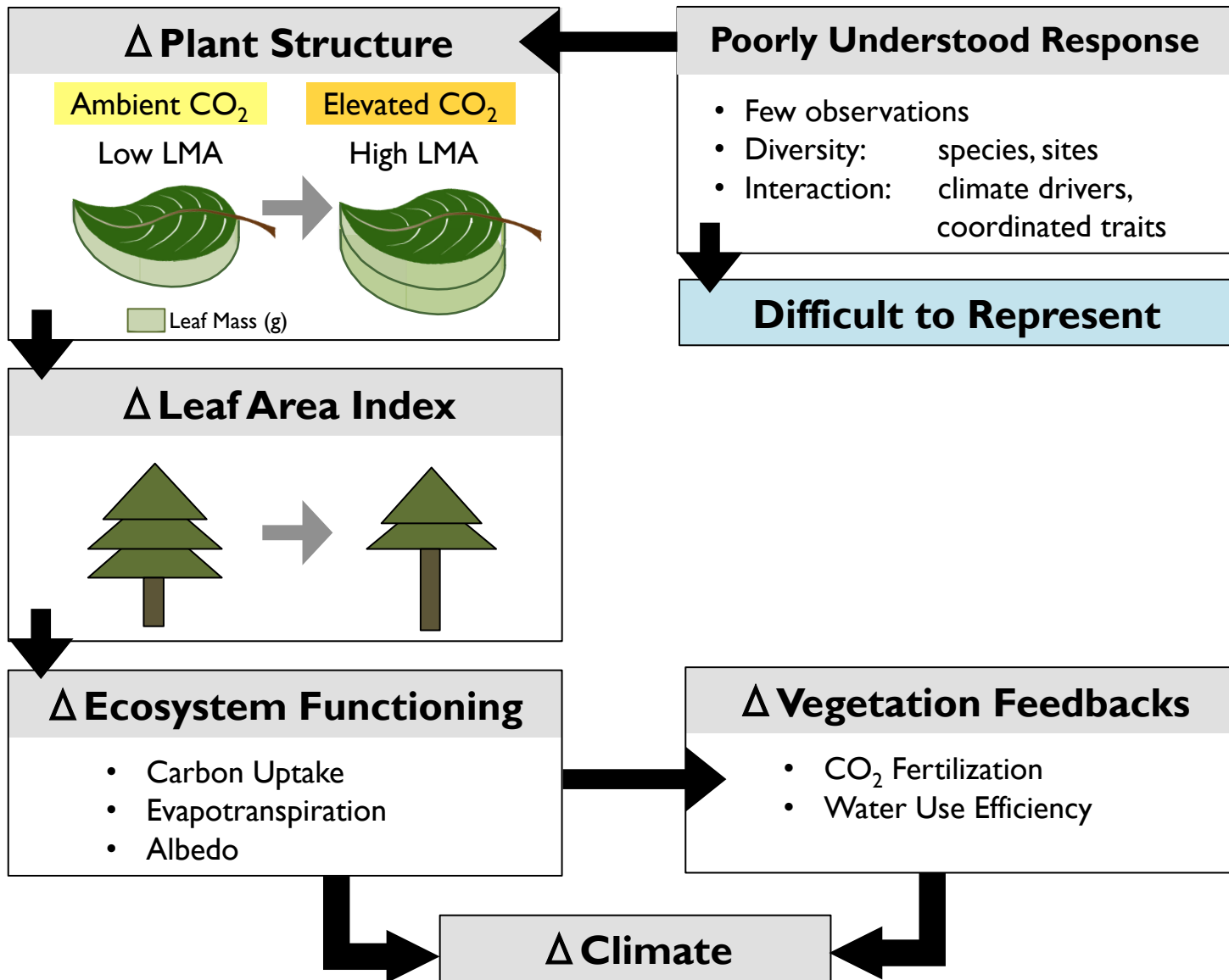
- ### Δ Ecosystem Functioning
- Carbon Uptake
  - Evapotranspiration
  - Albedo

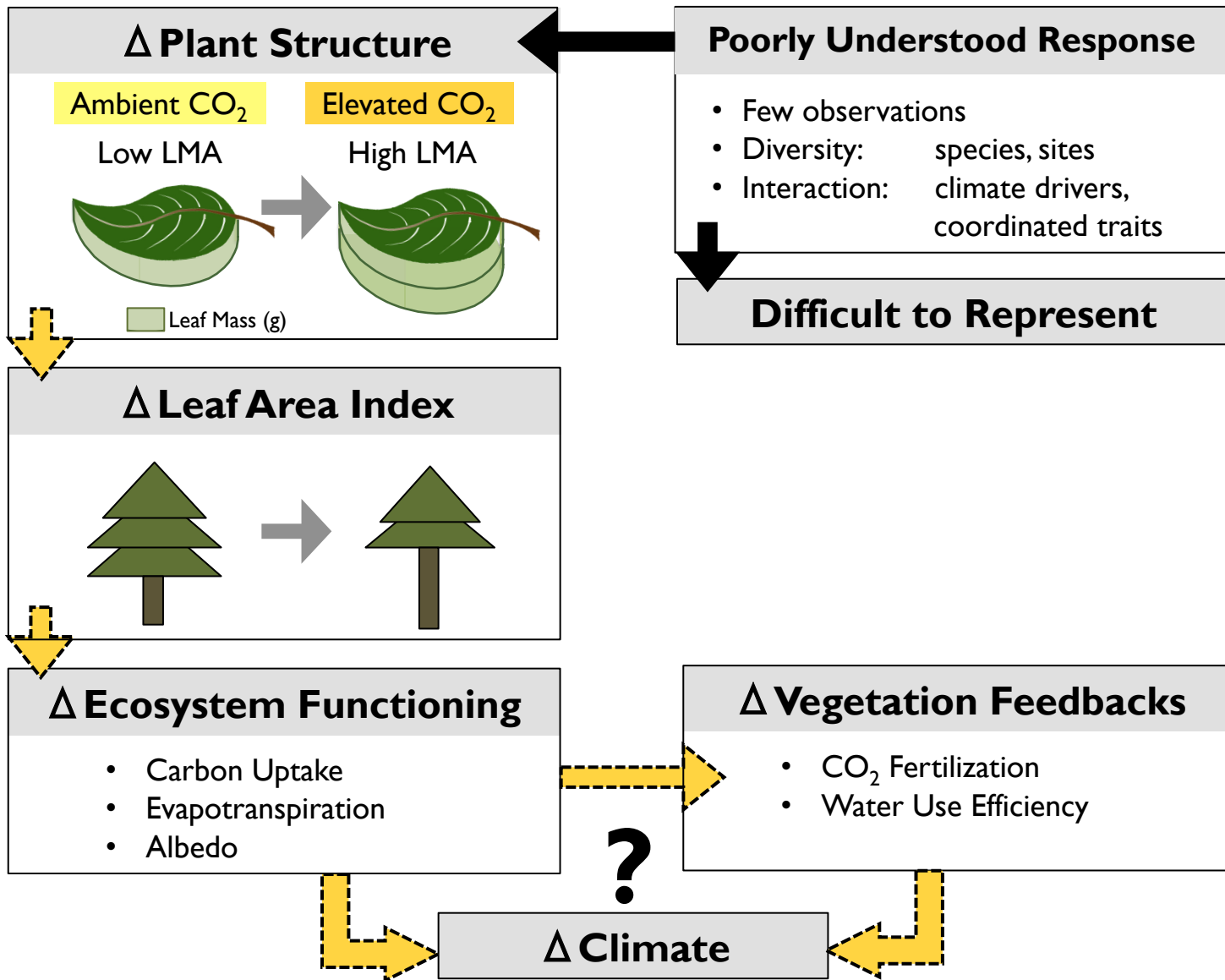


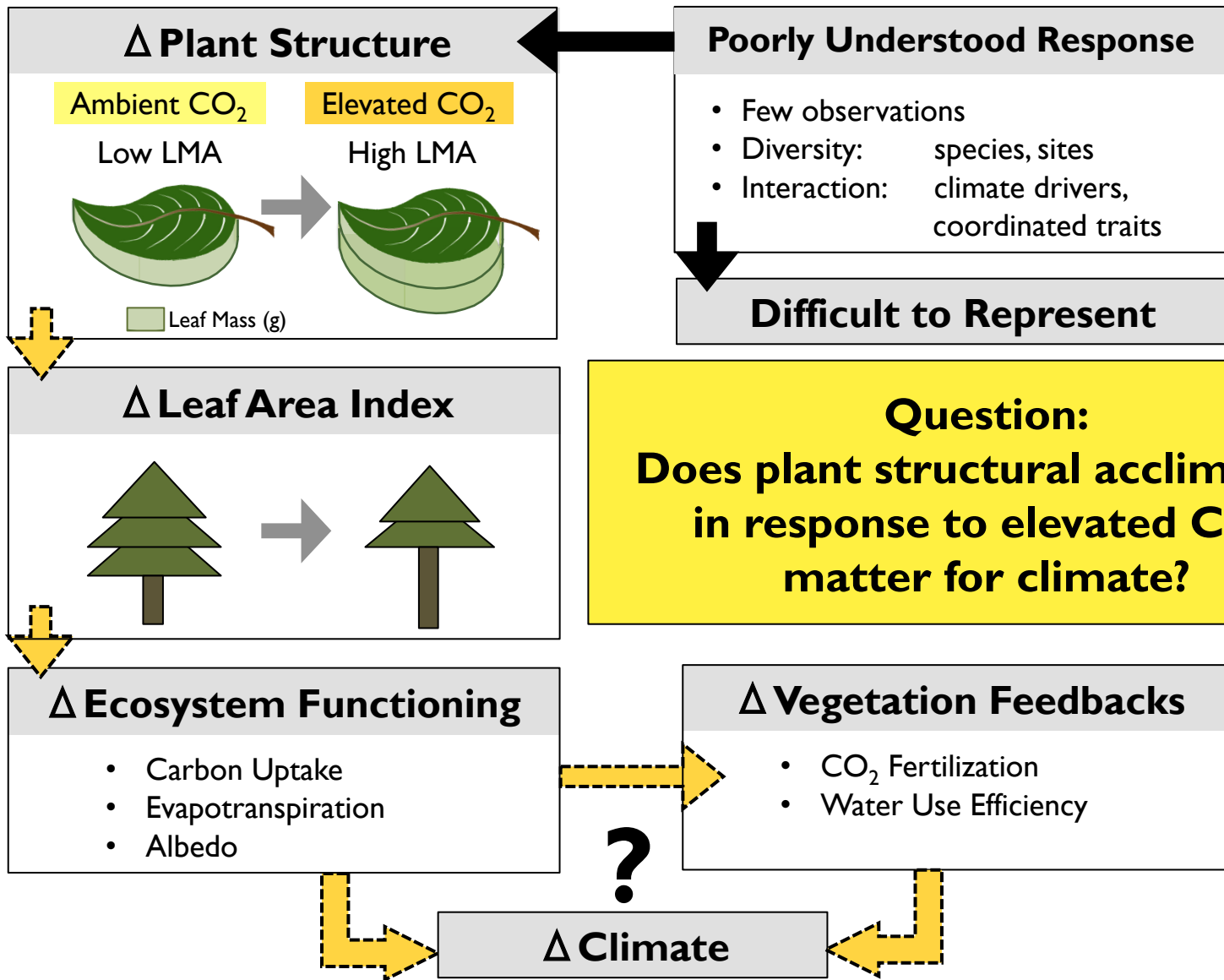




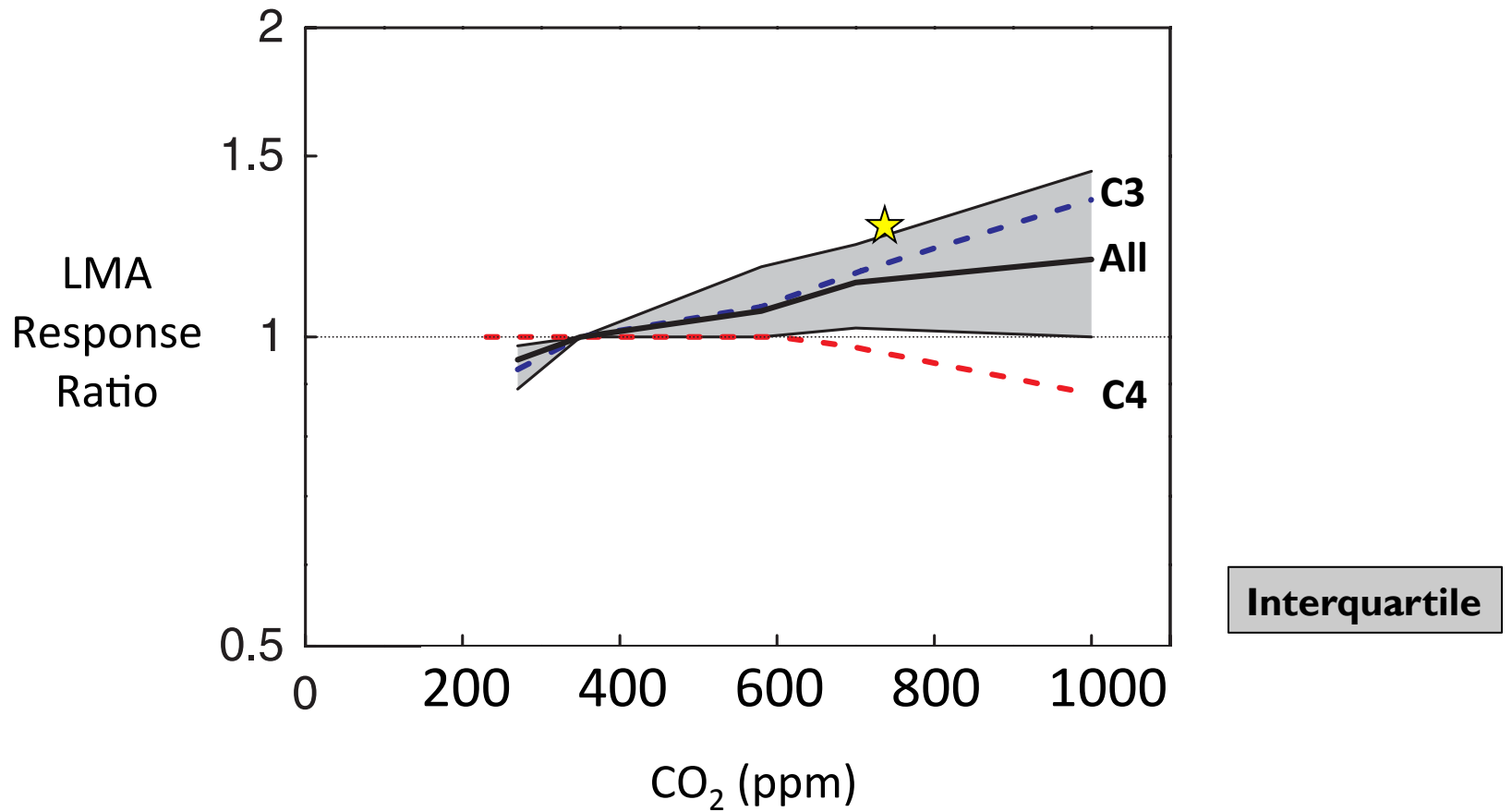




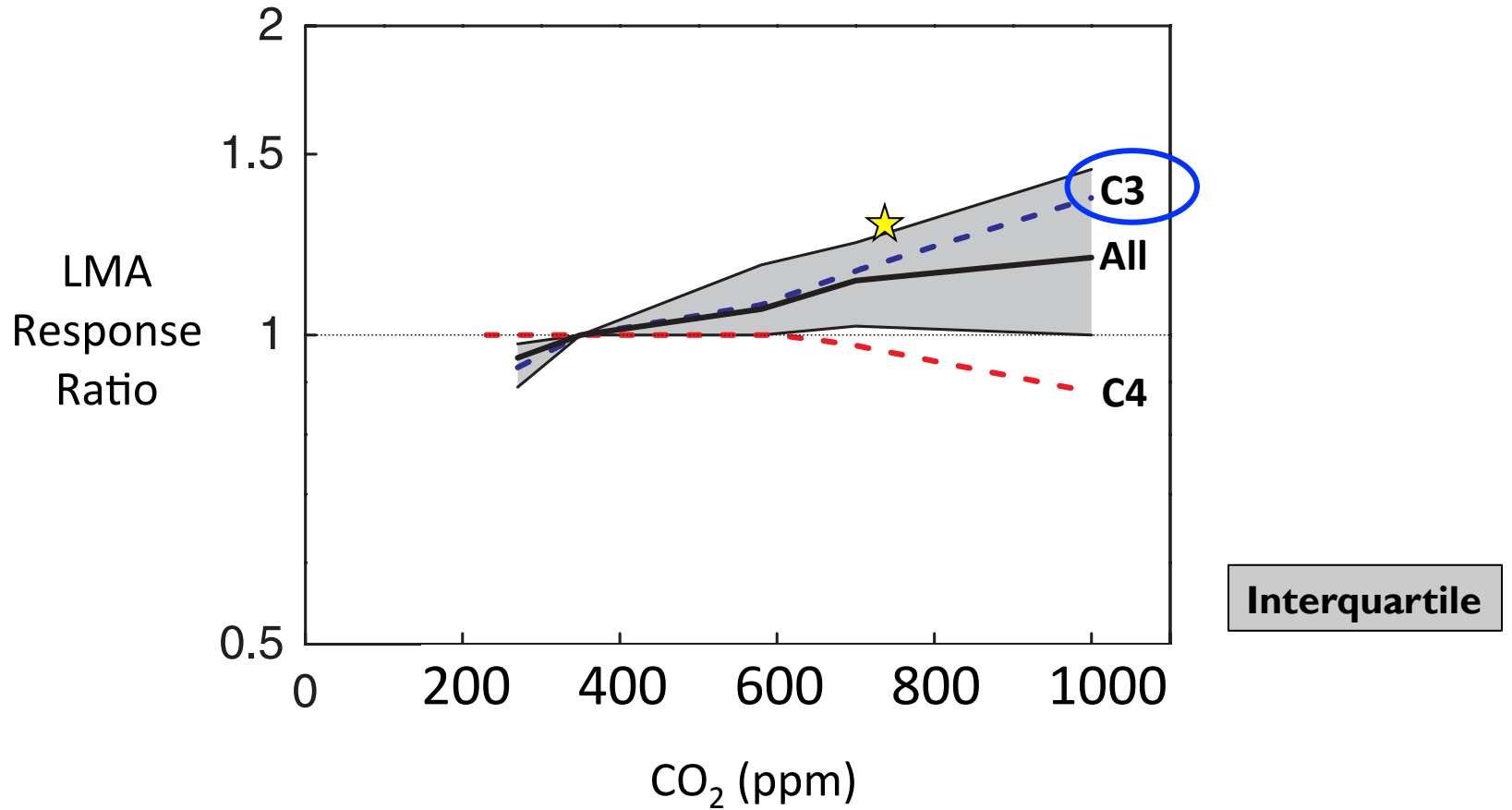




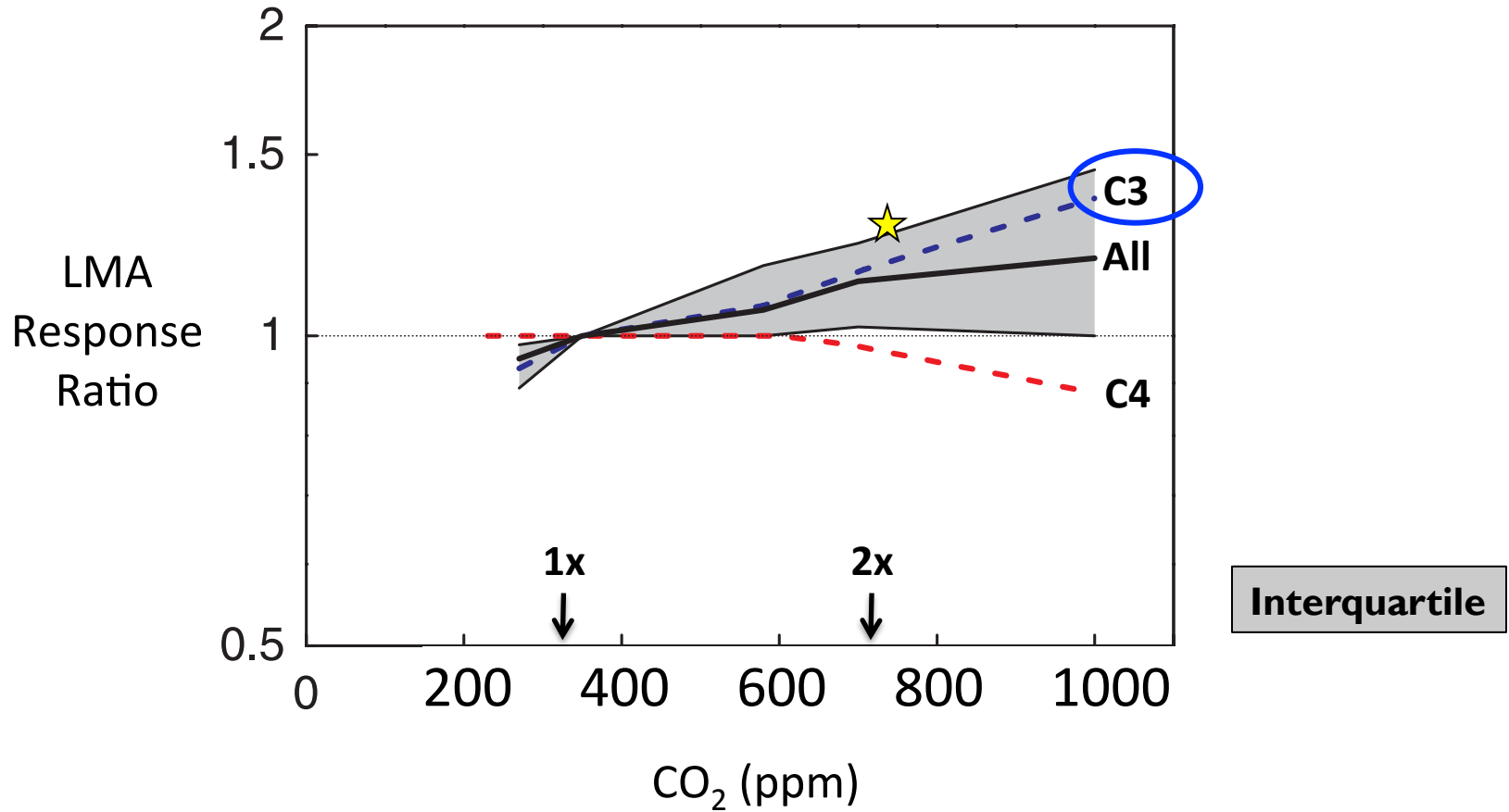
# Test large but plausible acclimation: +1/3 LMA in all C3 plants



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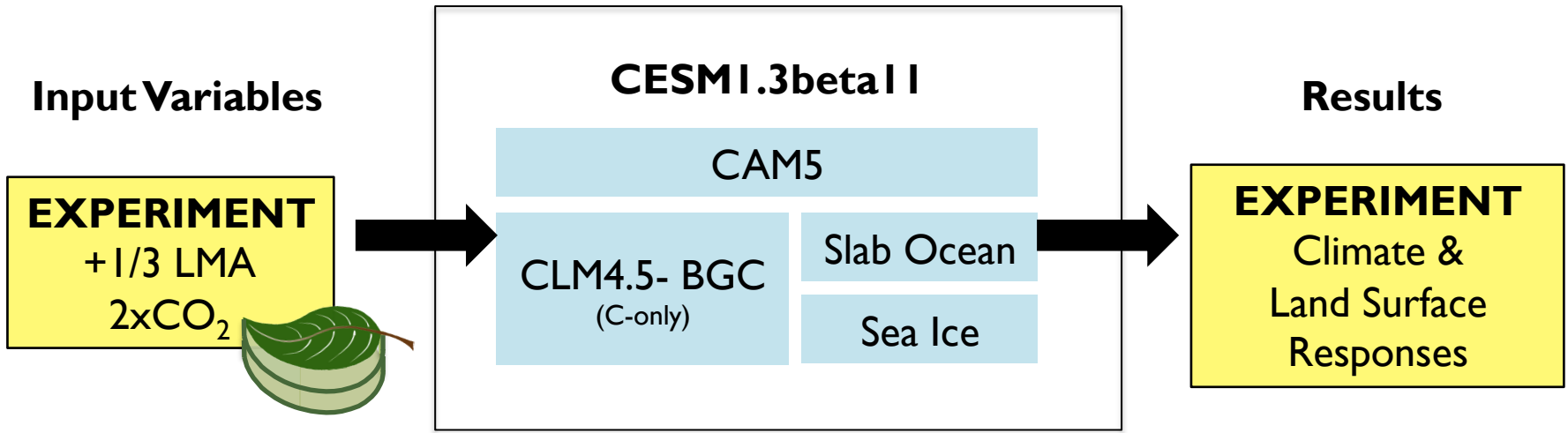


# Test large but plausible acclimation: +1/3 LMA in all C3 plants

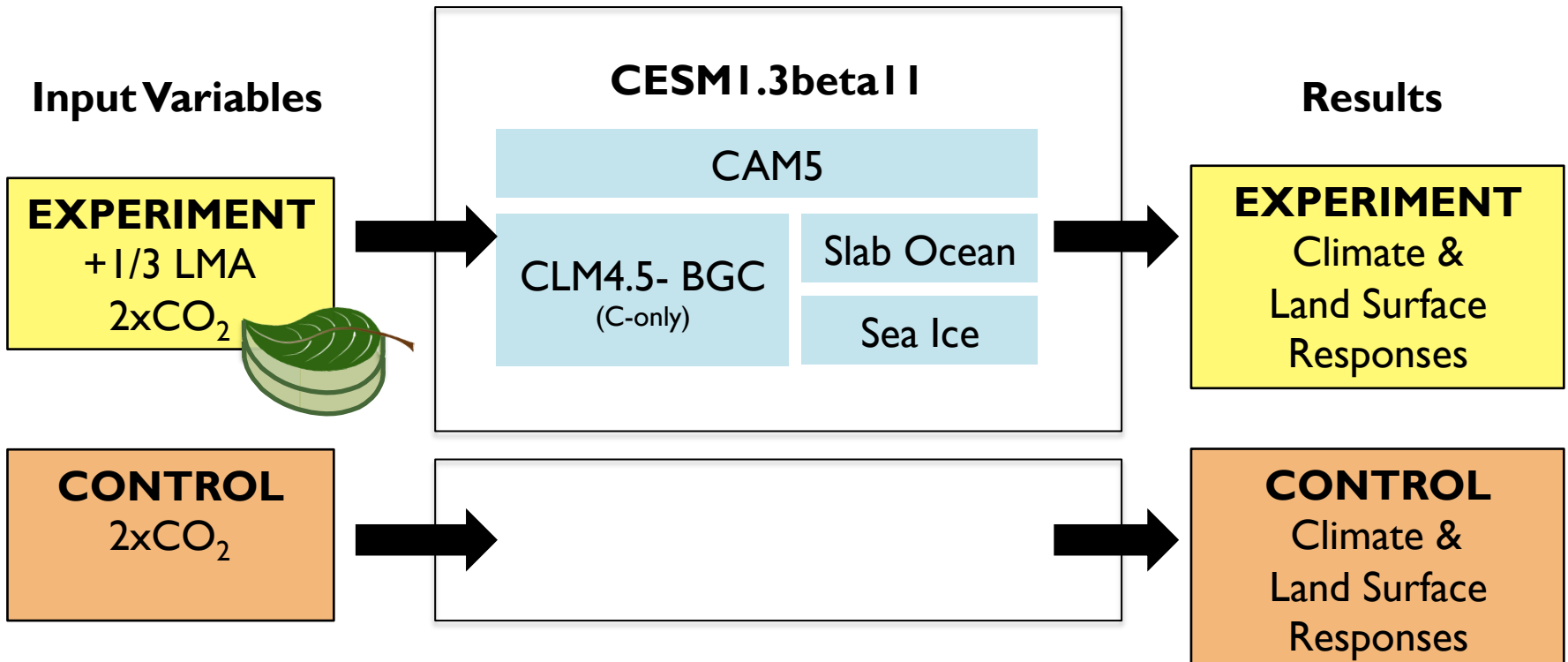




# Simulations



# Simulations



85 year runs.  
Results calculated from last 65 years.

# Implementation of +1/3 LMA in CESM

- CLM4.5BGC parameter  $SLA_0 = 1/LMA_0$

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Oleson and Lawrence (2013)

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Oleson and Lawrence (2013)

- We tested increased photosynthetic rates

# Implementation of +1/3 LMA in CESM

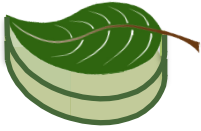
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$$V_{\text{cmax25}} = \frac{\alpha LMA_0}{C:N_{\text{Leaf}}} \begin{matrix} \uparrow \\ \uparrow \end{matrix} \quad (\text{Eqn. 8.17 \& 8.18})$$

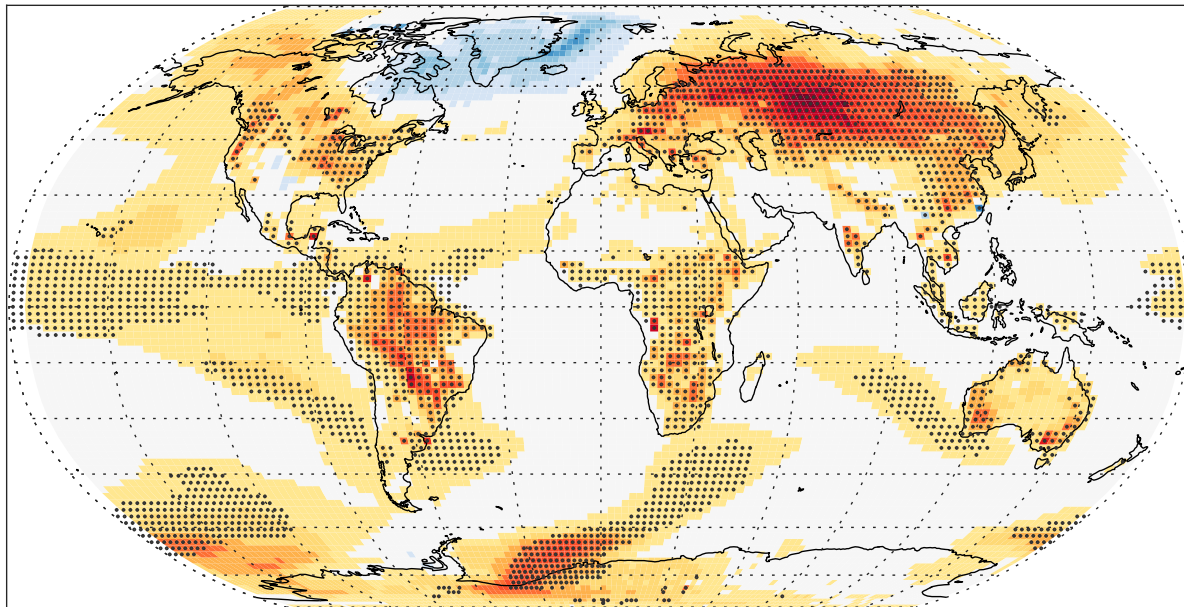
Oleson and Lawrence (2013)

- We tested increased and no change in photosynthetic rates.

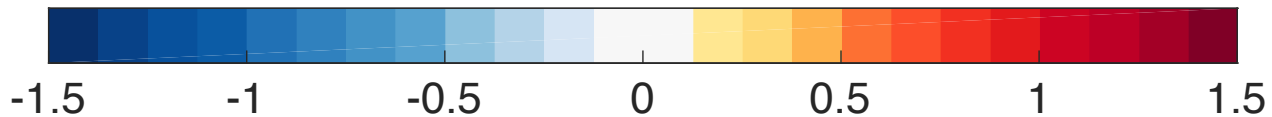


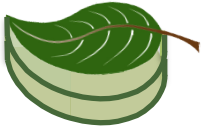


# Physical warming over land +0.3°C globally

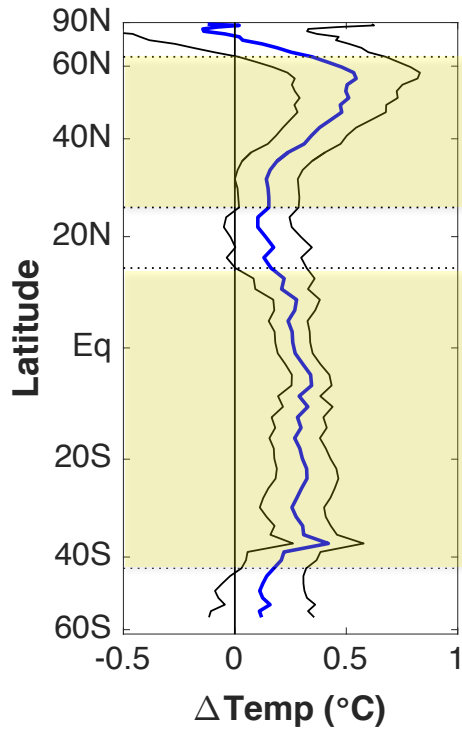


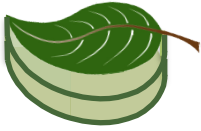
$\Delta$  Annual Mean Temperature (Exp-Ctrl)



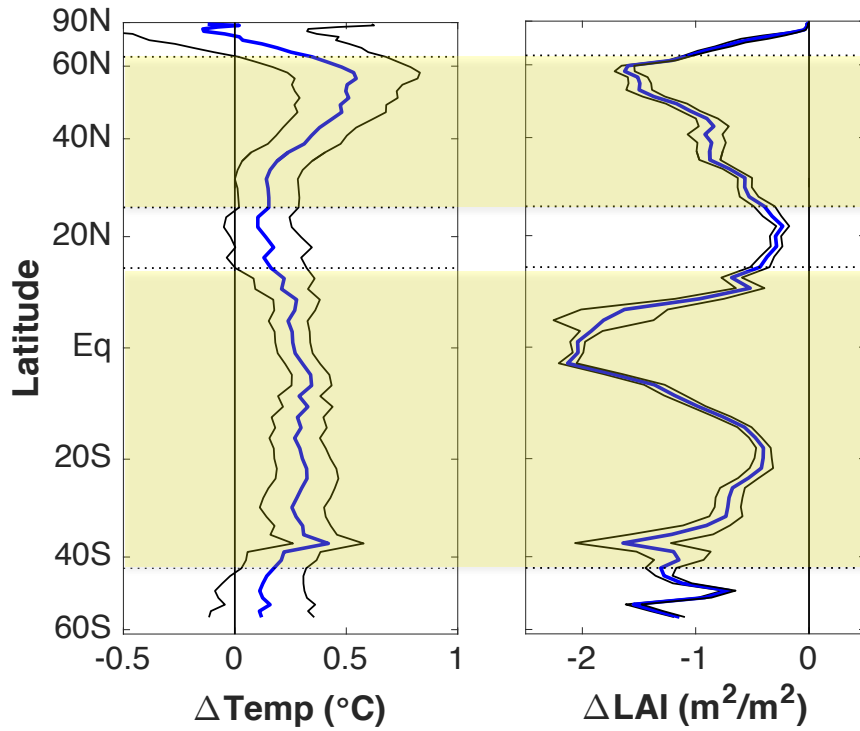


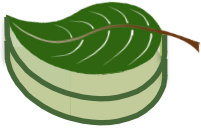
# Warming



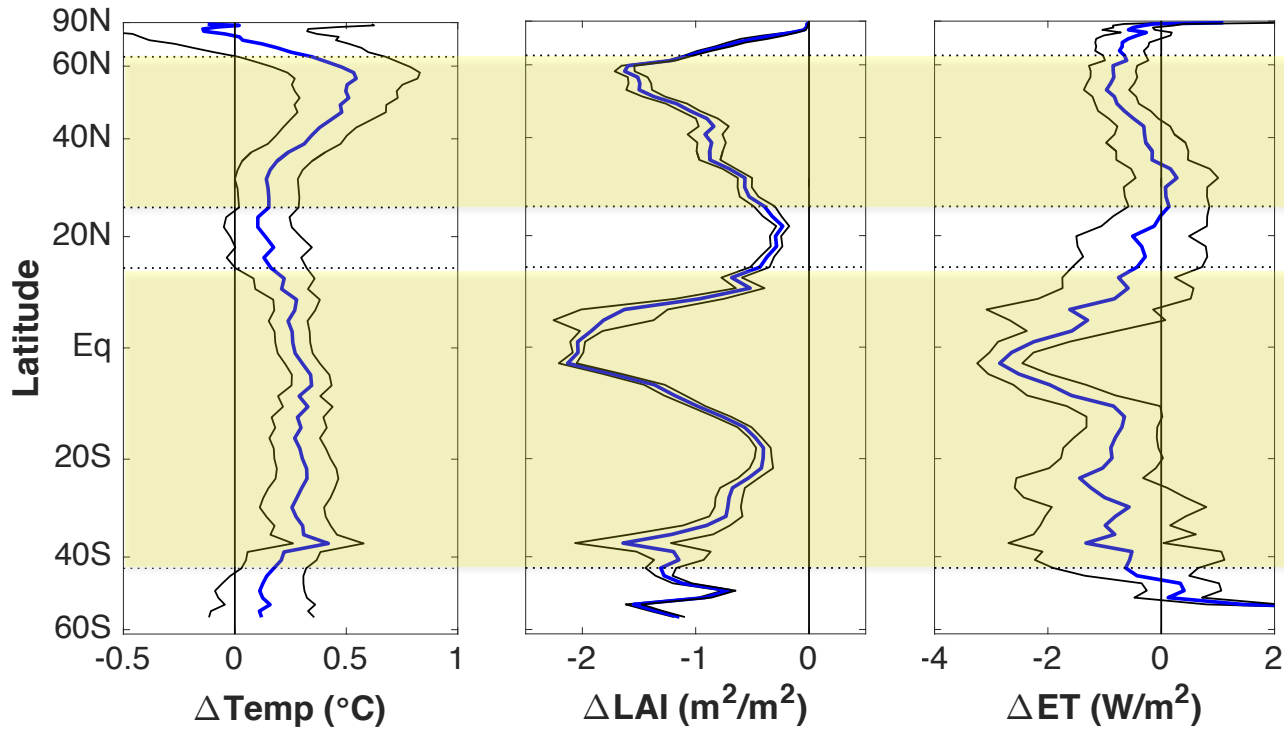


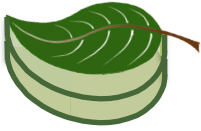
# Warming due to ↓ LAI



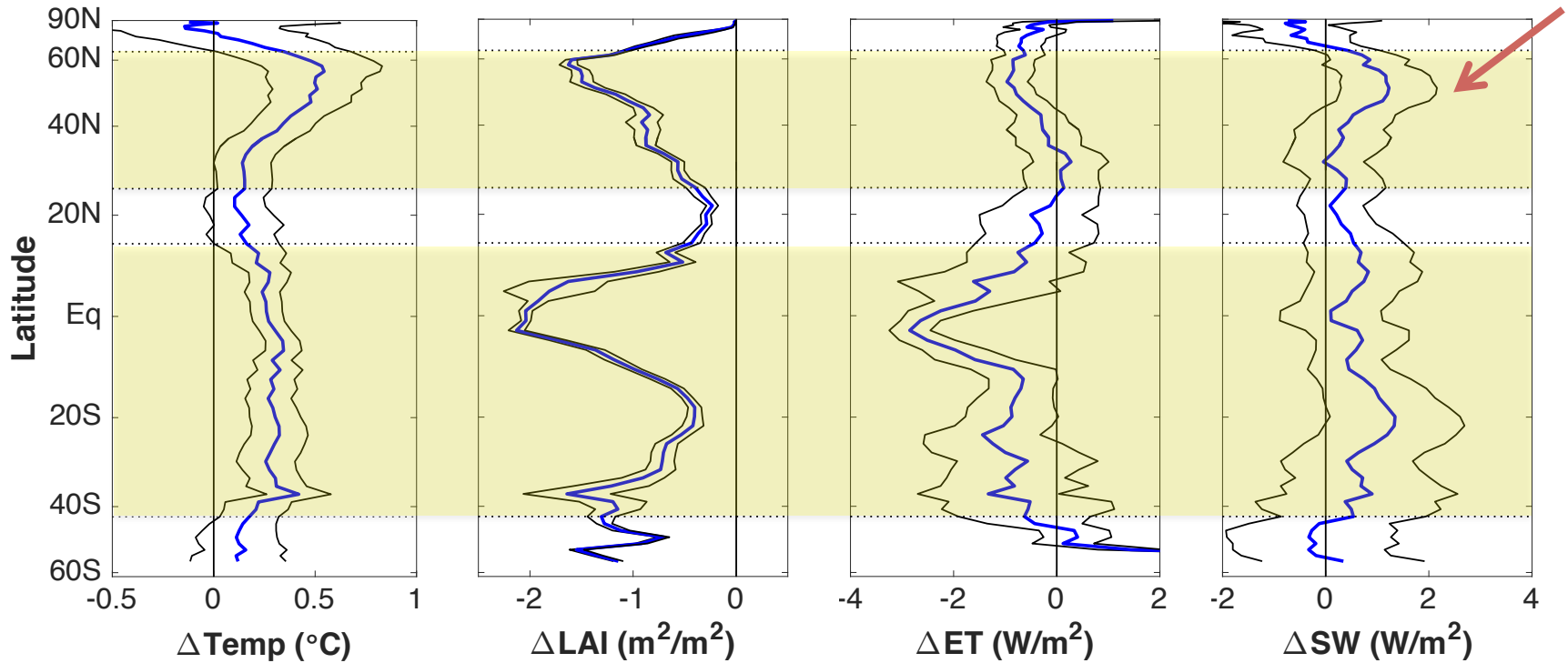


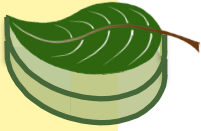
# Warming due to $\downarrow$ LAI, $\downarrow$ ET



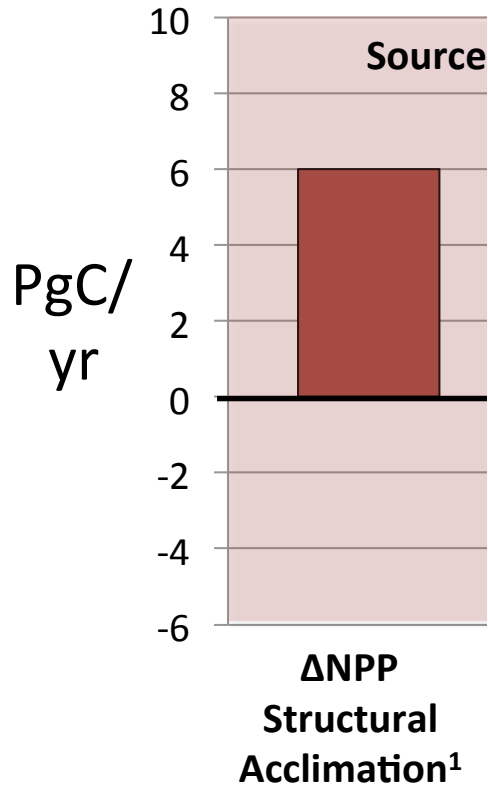


Warming due to  $\downarrow$  LAI,  $\downarrow$  ET,  $\uparrow$  Solar Absorbed

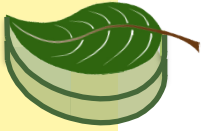




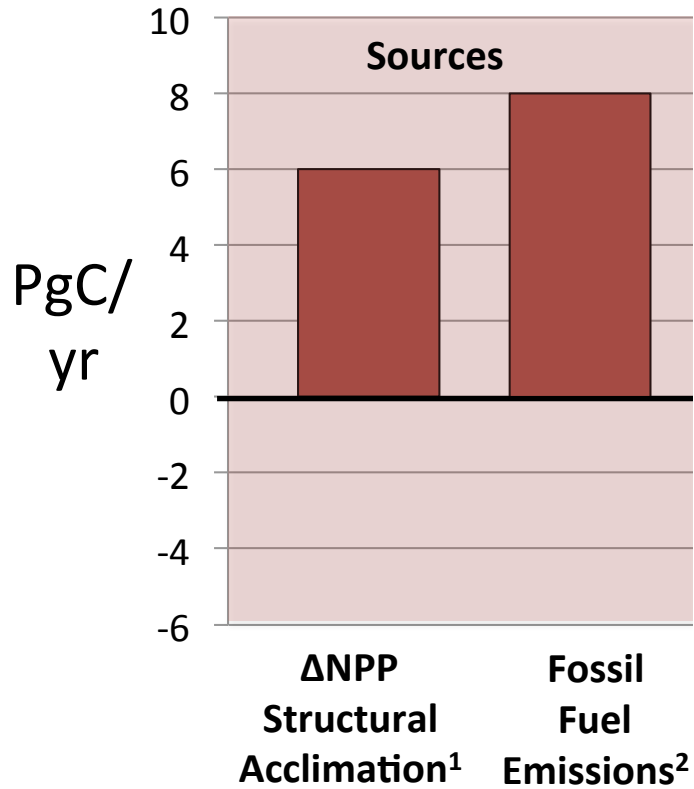
# Additional Warming due to ↓ Carbon Uptake



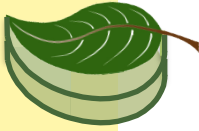
<sup>1</sup>Kovenock and Swann *in prep*



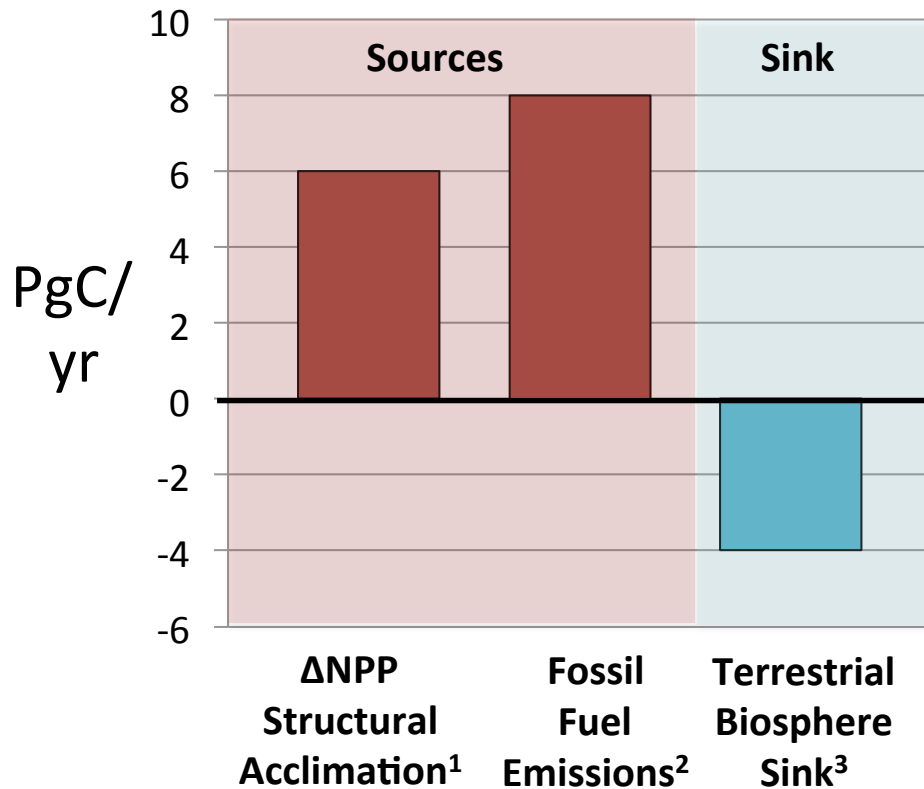
# Additional Warming due to ↓ Carbon Uptake



<sup>1</sup>Kovenock and Swann *in prep*, <sup>2</sup>Ciais et al. 2013

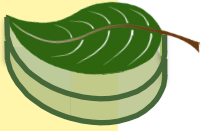


# Additional Warming due to ↓ Carbon Uptake

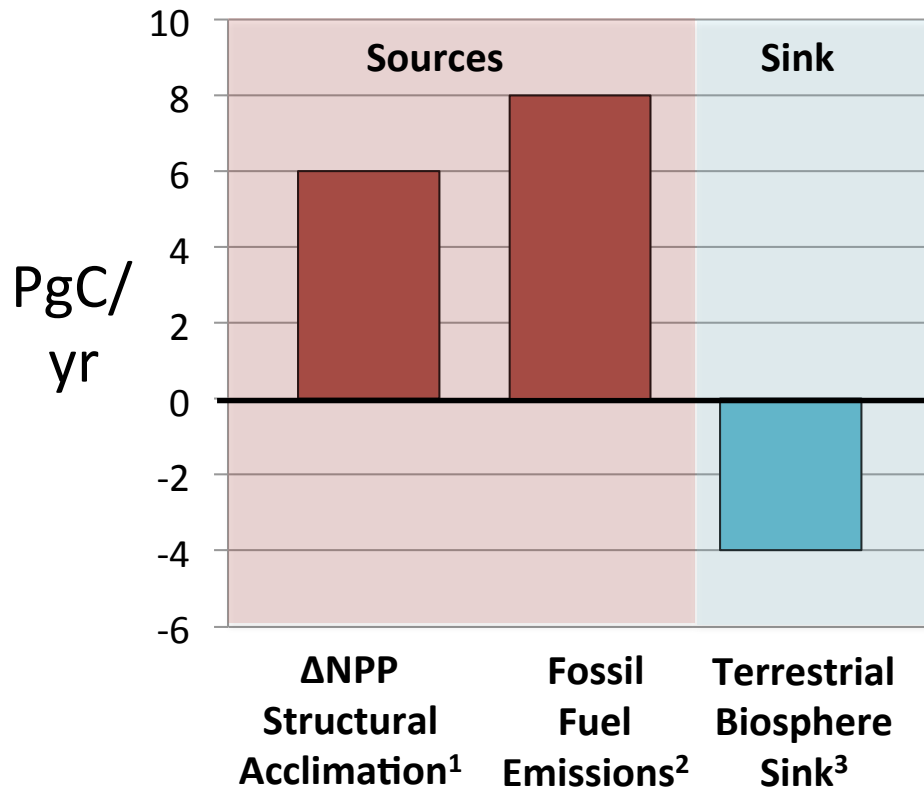


<sup>1</sup>Kovenock and Swann *in prep*, <sup>2</sup>Ciais et al. 2013, <sup>3</sup>Global Carbon Project





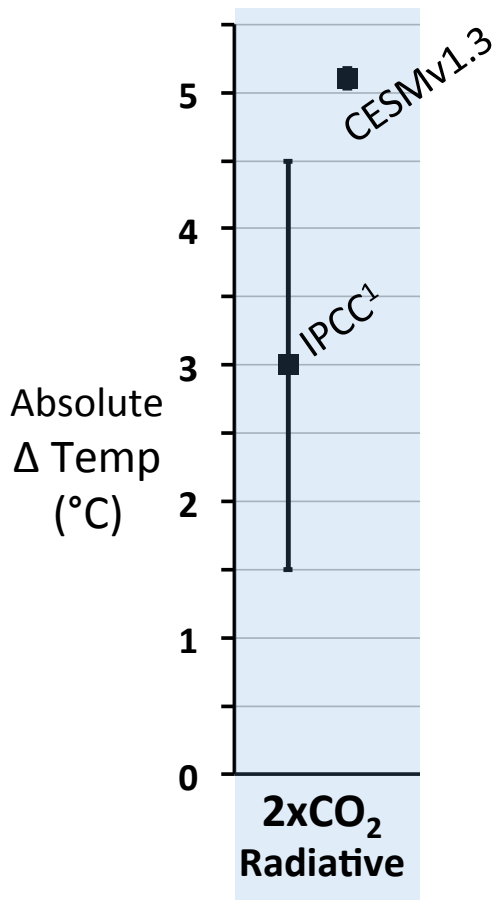
# Additional Warming due to ↓ Carbon Uptake



Back of Envelope  
Calculation:  
**+0.2 to +0.9 °C**  
over century  
(including ocean buffering)

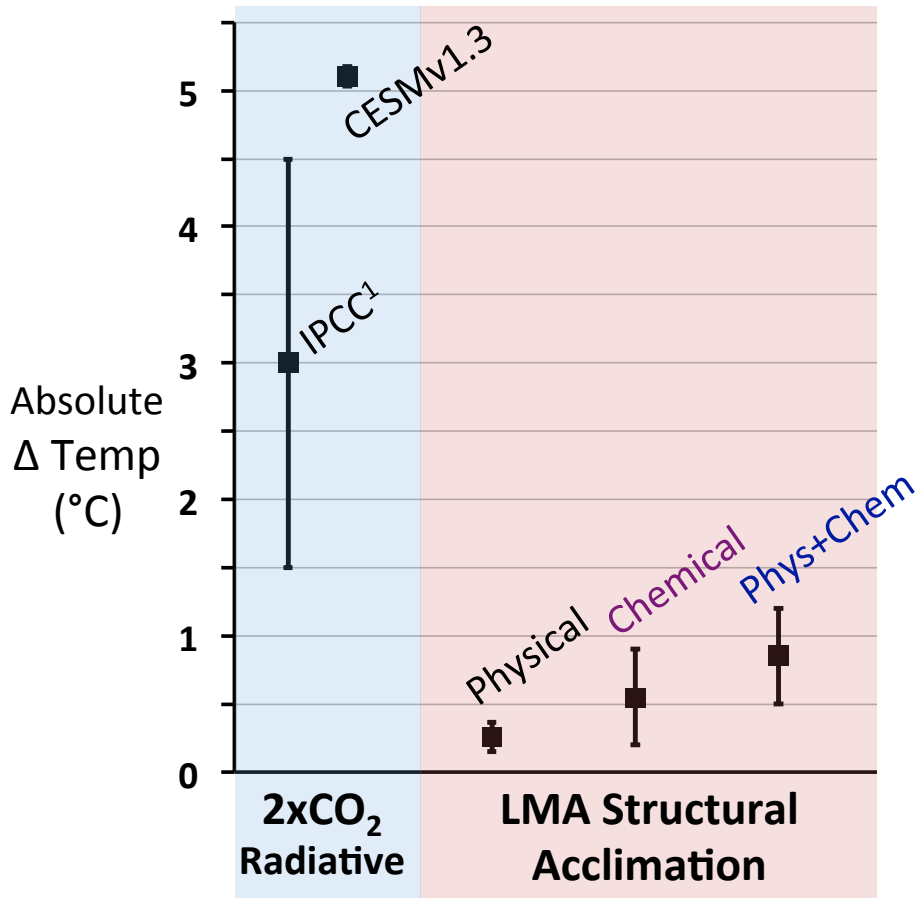
<sup>1</sup>Kovenock and Swann *in prep*, <sup>2</sup>Ciais et al. 2013, <sup>3</sup>Global Carbon Project

# Comparison of Temperature Changes



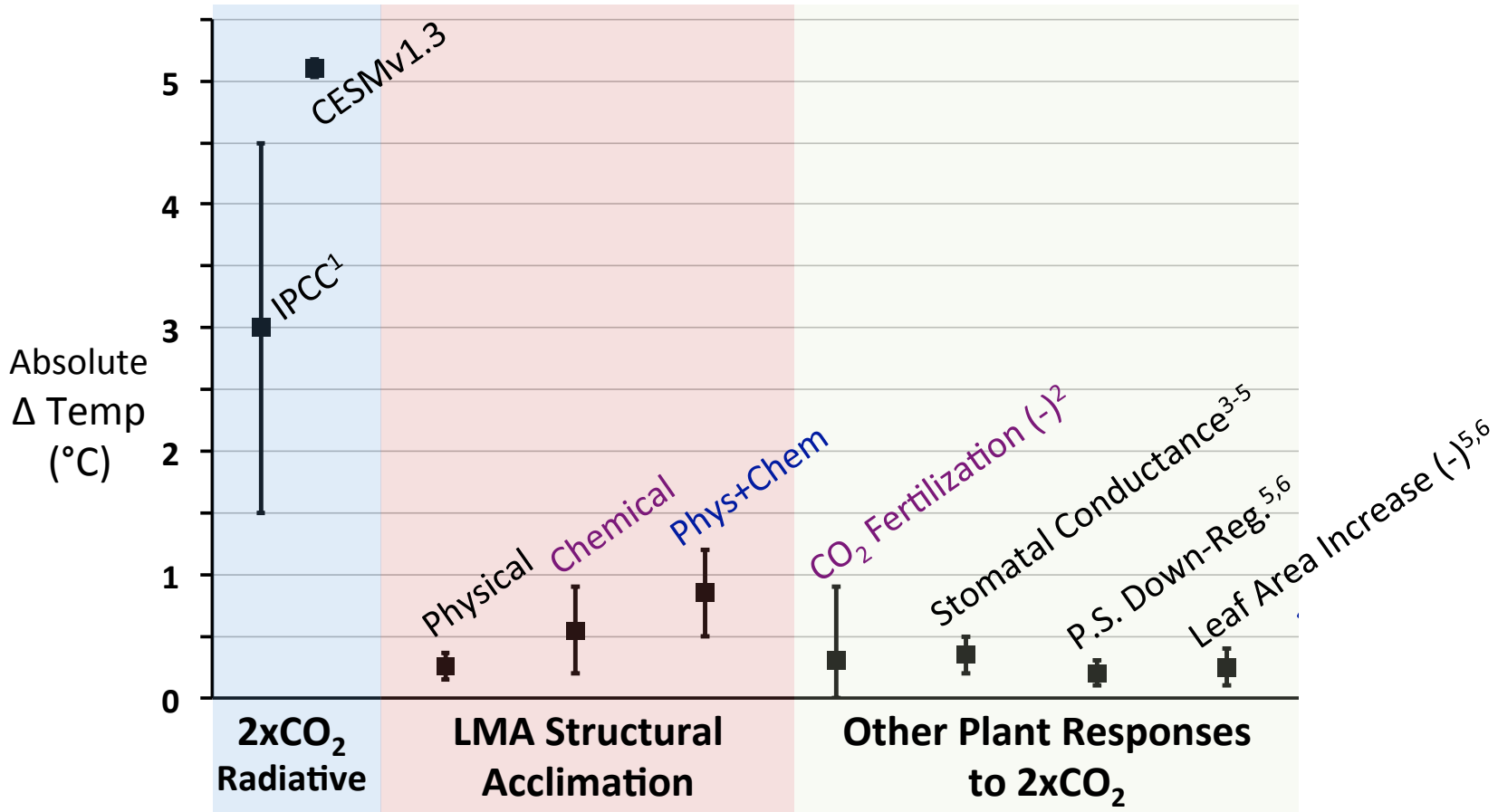
<sup>1</sup> IPCC AR5, <sup>2</sup> Estimated from Arora et al. 2013, <sup>3</sup> Cao et al. 2010, <sup>4</sup> Sellers et al. 1996, <sup>5</sup> Pu and Dickinson 2012, <sup>6</sup> Bounoua et al. 2010, <sup>7</sup> Pongratz et al. 2010, <sup>8</sup> Davin et al. 2010.

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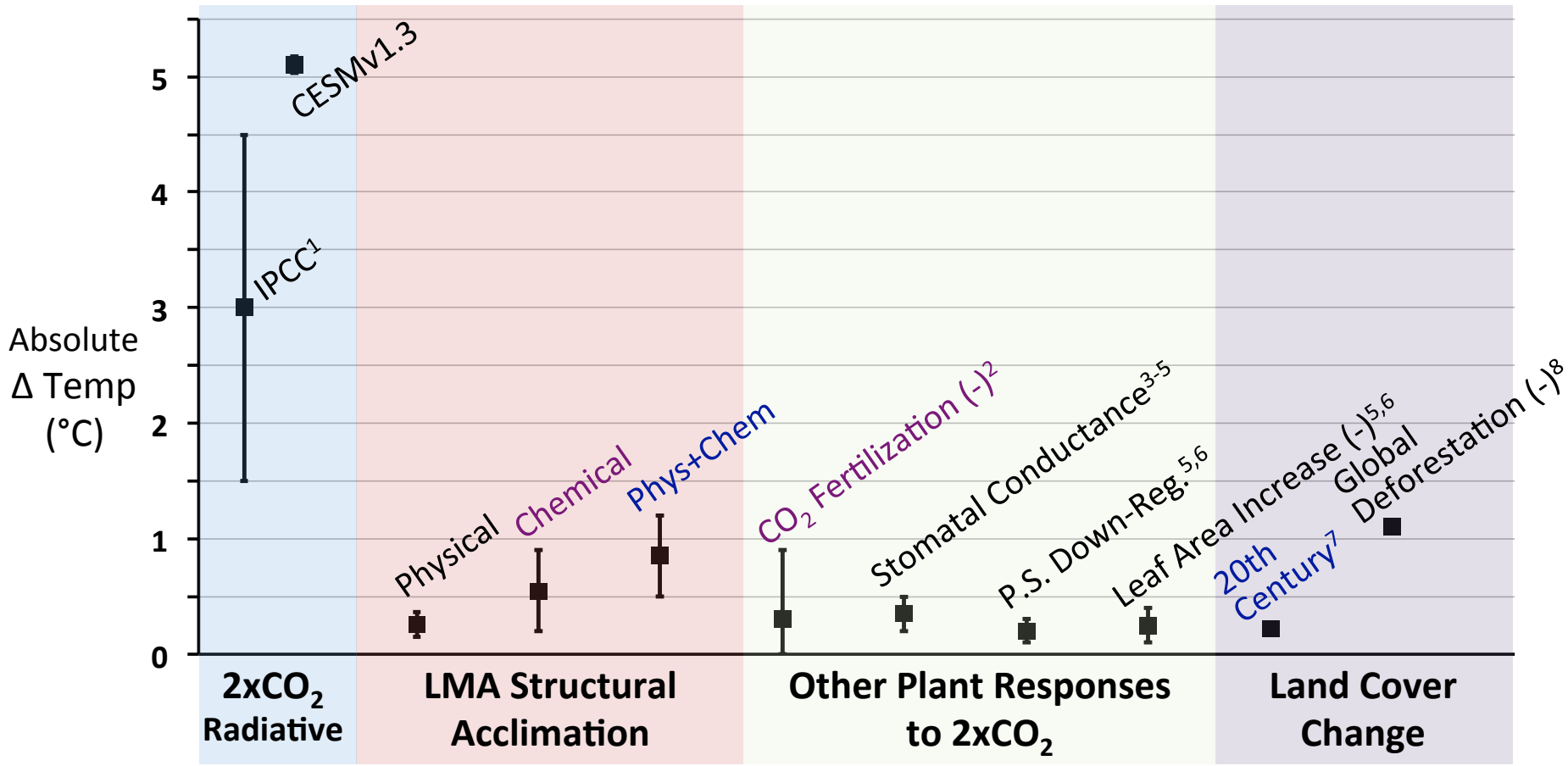
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# Conclusions

LMA structural acclimation in response to  $\text{CO}_2$  has *significant climate impacts* in CESM.

↑ LMA causes ↓ leaf area index  
because ↑ carbon cost of leaf area

↑ physical warming: ↓ ET, ↑ SW

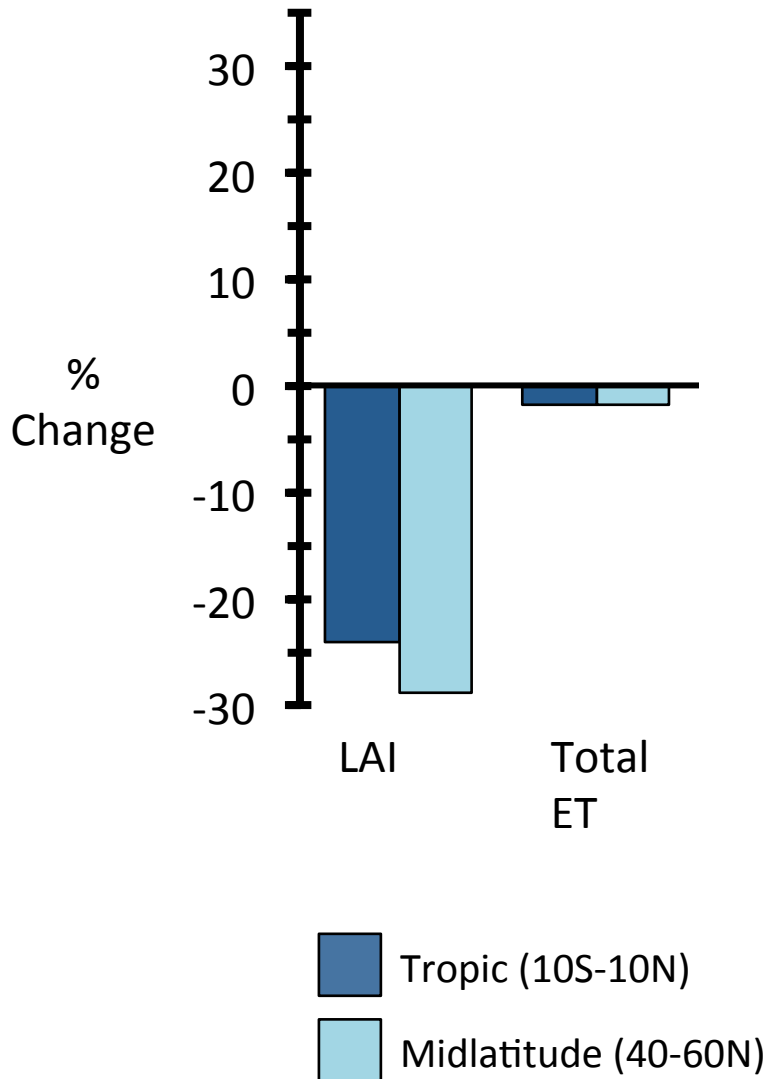
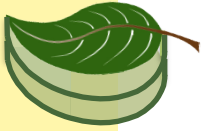
↑ chemical warming: ↓ NPP

## Caveats & Future Research

Climate impacts of LMA acclimation  
could be influenced by:

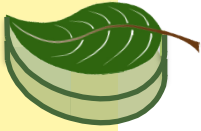
- other climate drivers of LMA acclimation
- other concurrent changes in carbon allocation
- LMA acclimation effects on competition

# Does leaf area decrease explain lower ET?

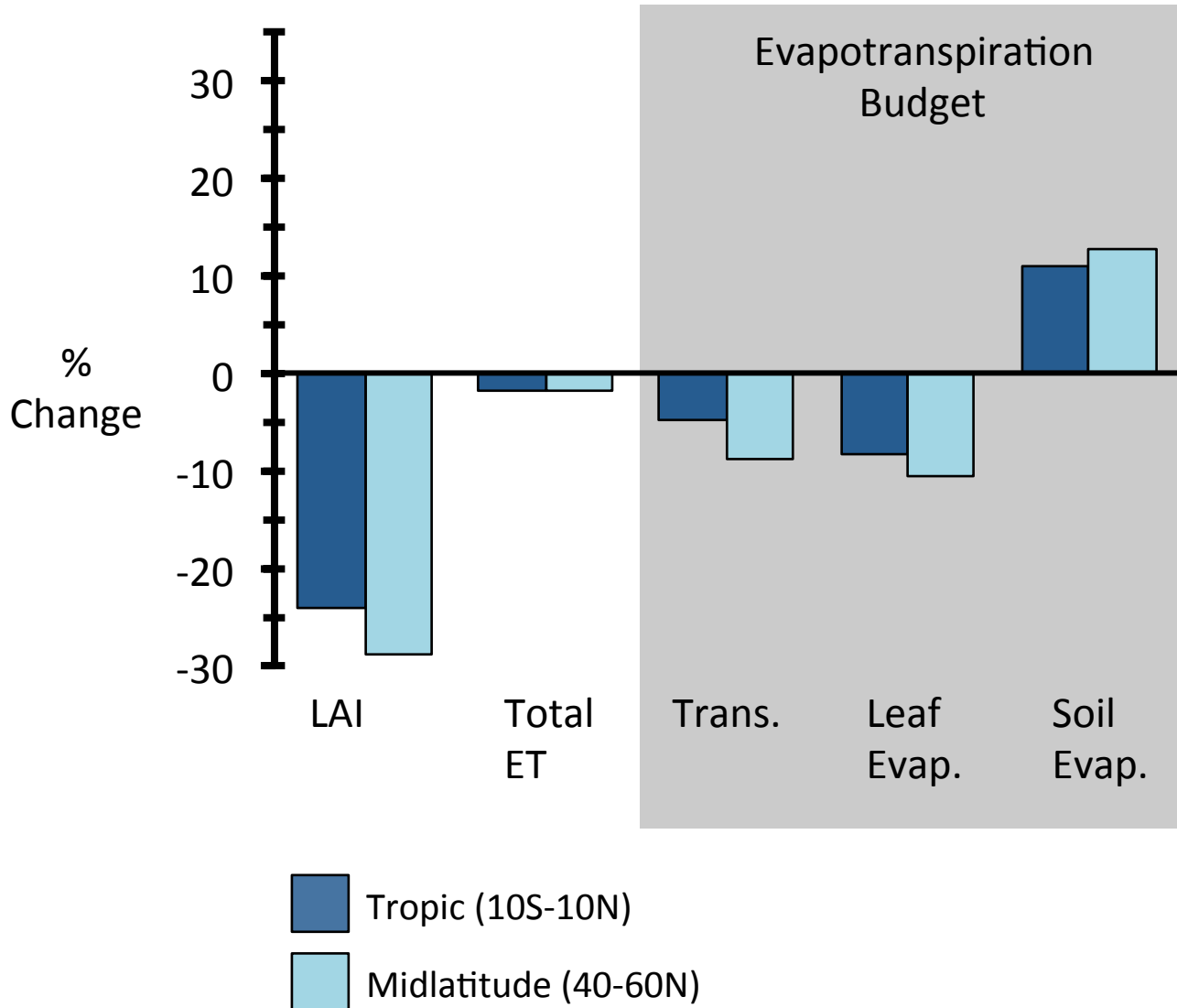




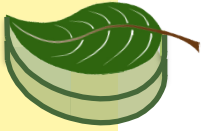
# Moderating Mechanism #1



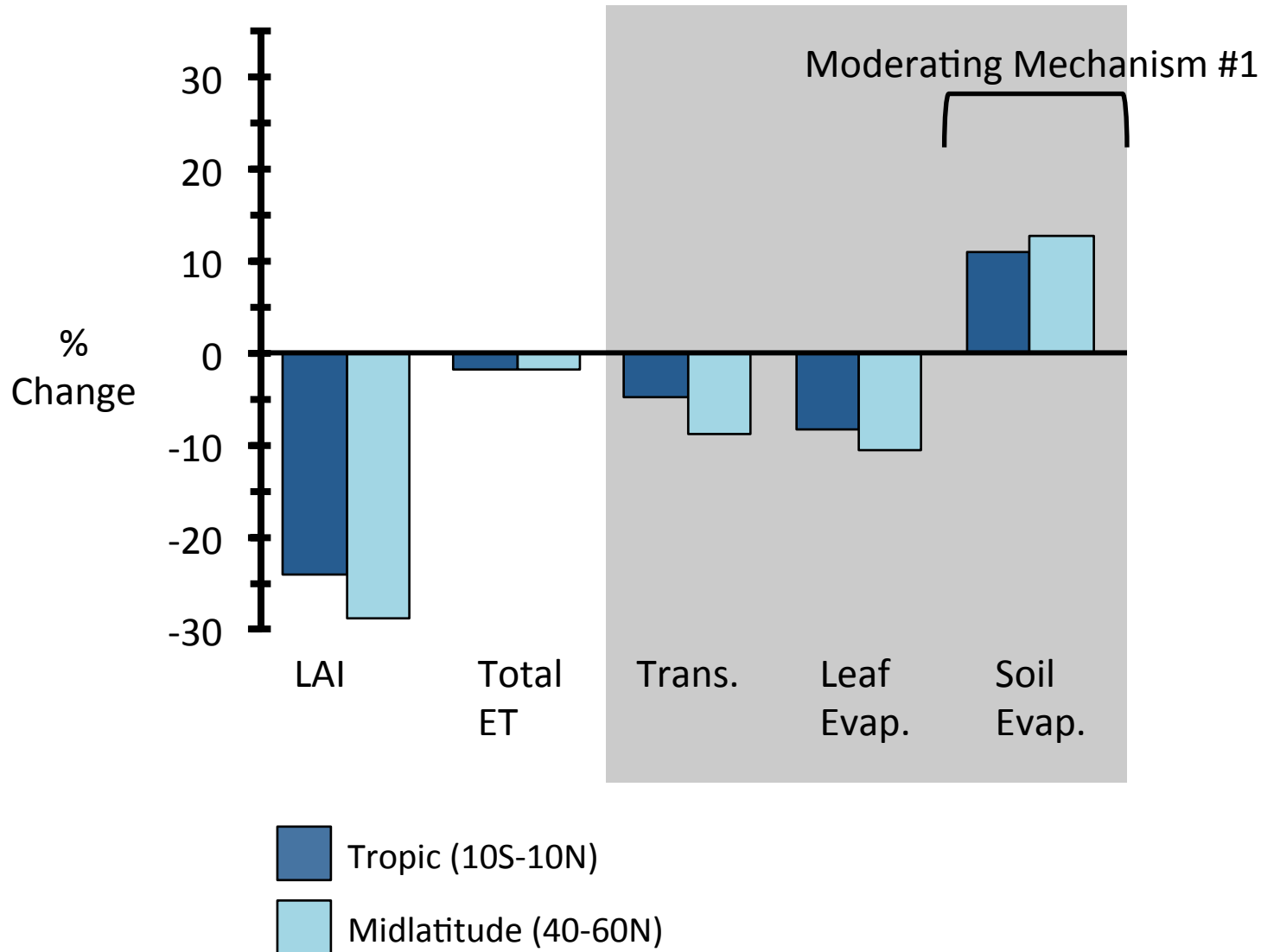
↑ Soil evaporation partially compensates



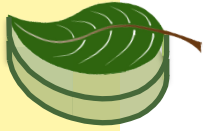
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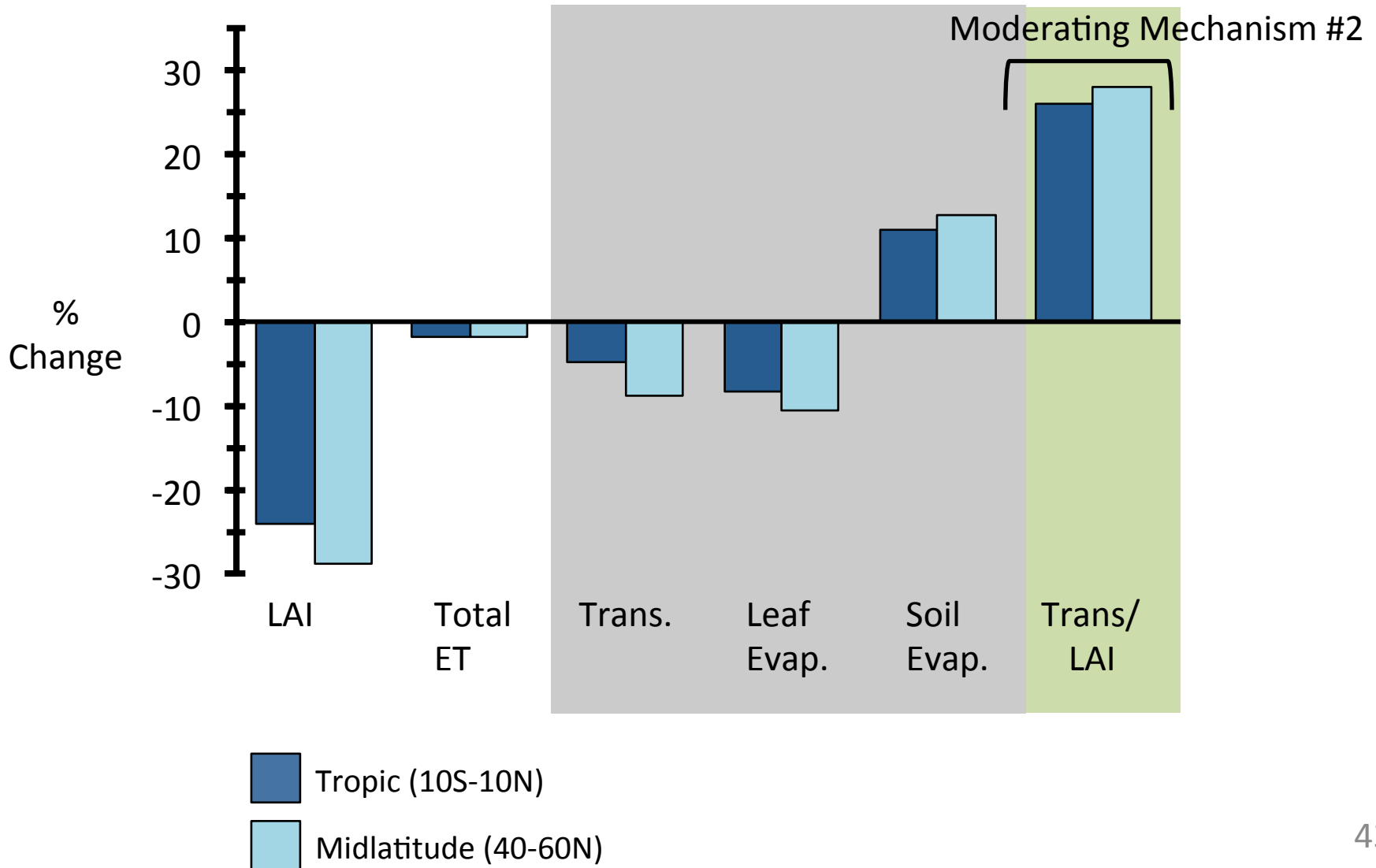
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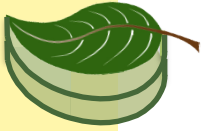


# Moderating Mechanism #2

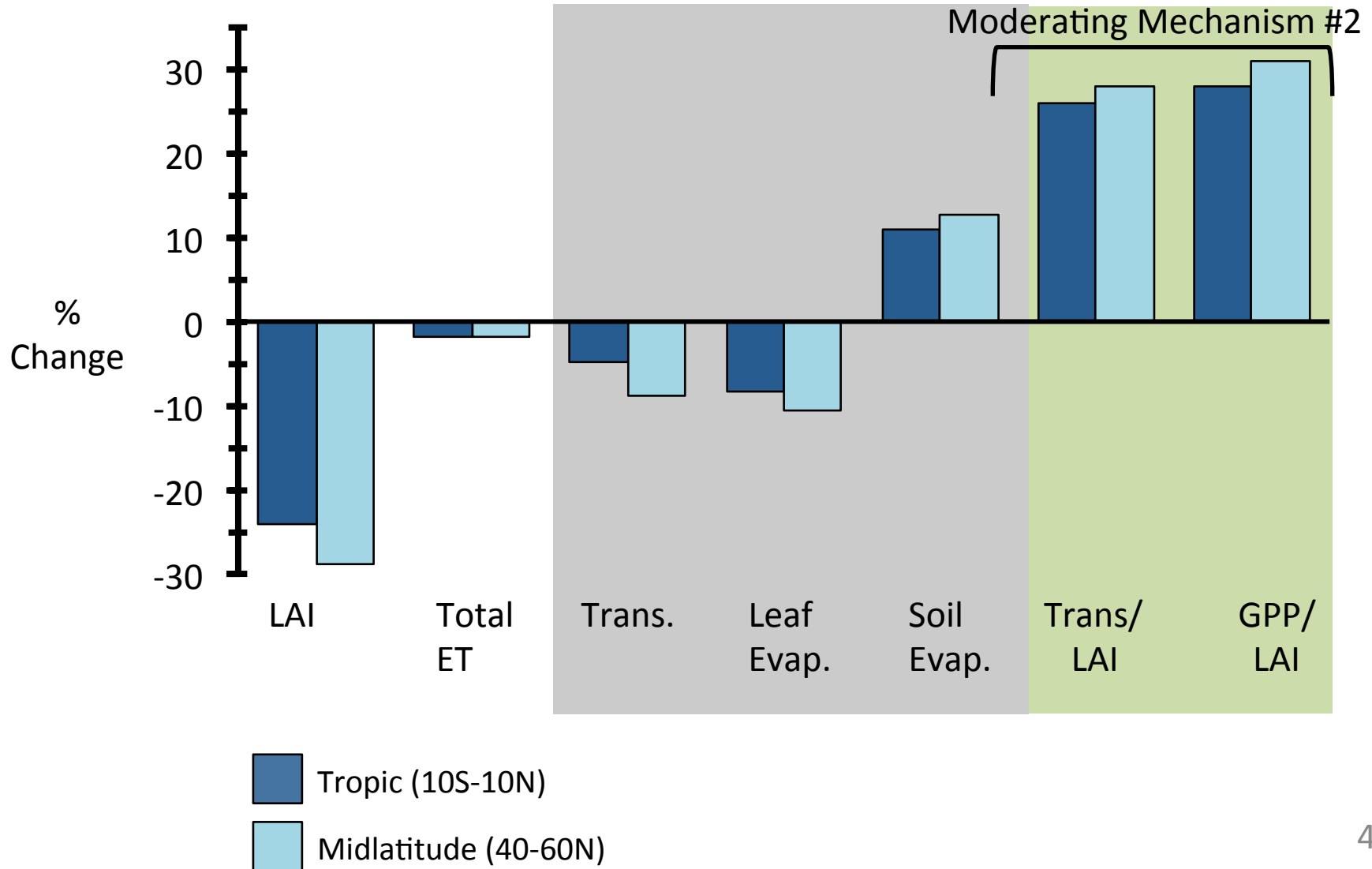


## ↑ Transpiration per Leaf Area Index

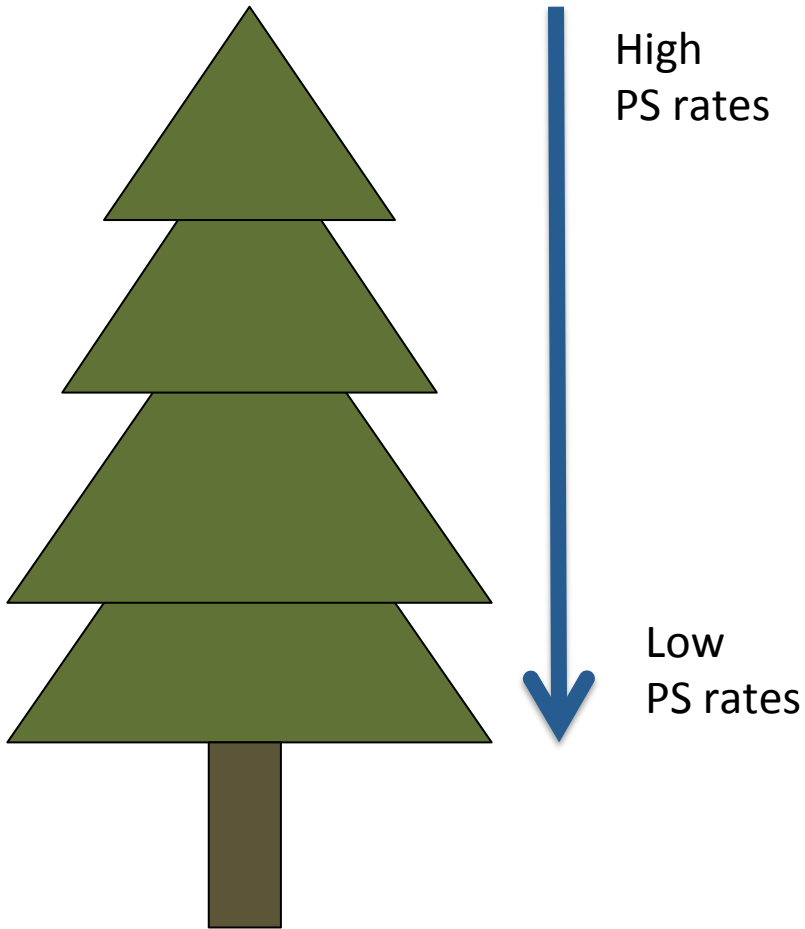




↑ Productivity per leaf area index  
Drives ↑ Transpiration per leaf area index

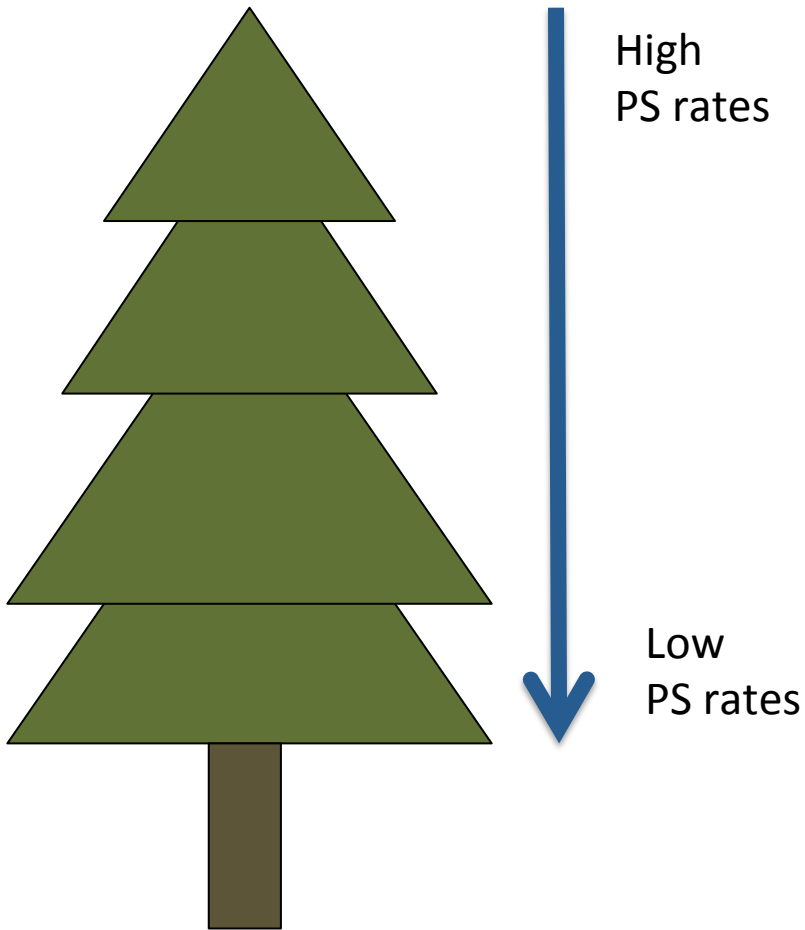


↑ Productivity per leaf area  
due to ↓ leaf area index



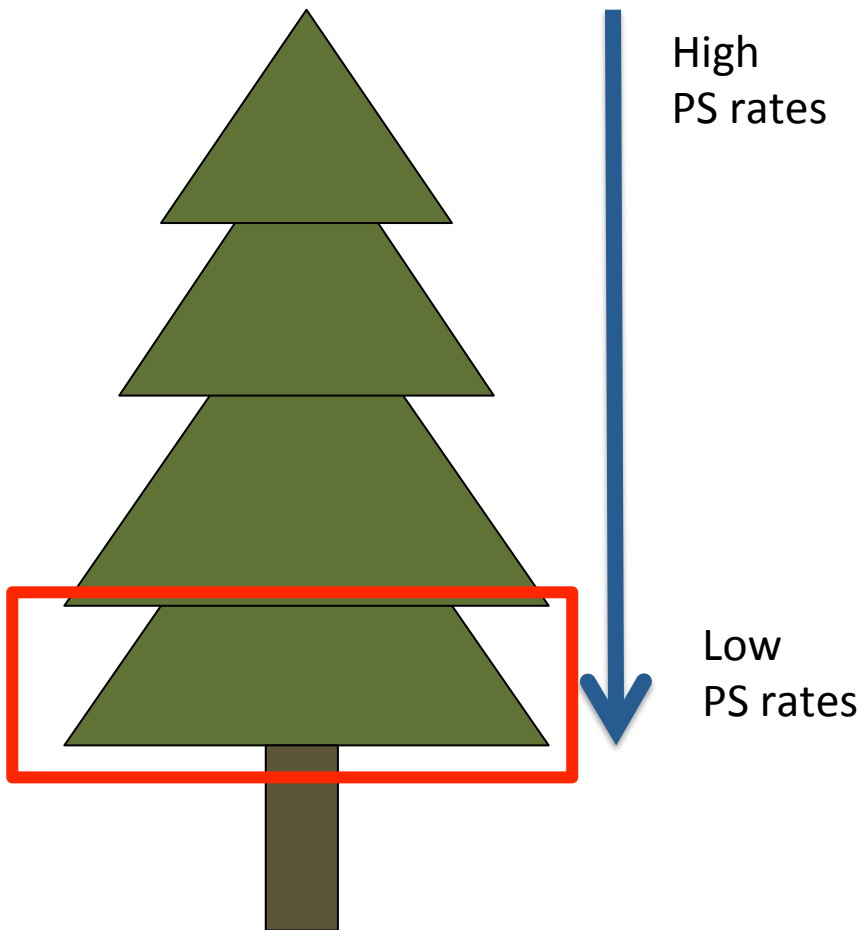
- Exponential decay of photosynthesis rates

↑ Productivity per leaf area  
due to ↓ leaf area index



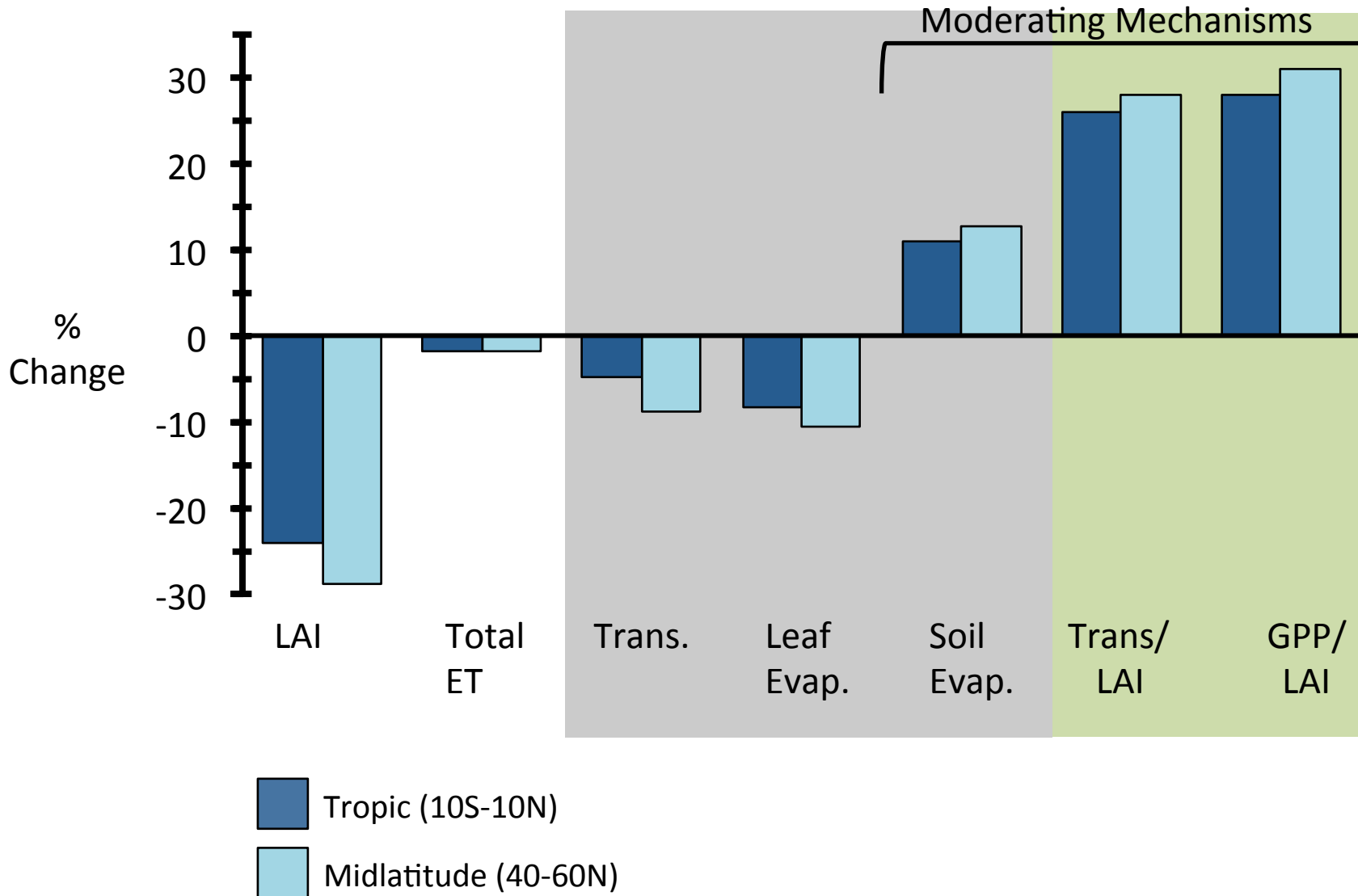
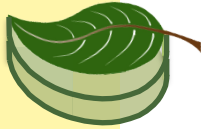
- Exponential decay of photosynthesis rates
- Lower leaves less productive

# ↑ Productivity per leaf area due to ↓ leaf area index



- Exponential decay of photosynthesis rates
- Lower leaves less productive
- Removing less productive leaves  
↑ productivity/leaf area

# ↓ Total Evapotranspiration due to Leaf Area despite moderating mechanisms





# LMA increased in all C3 plants.

