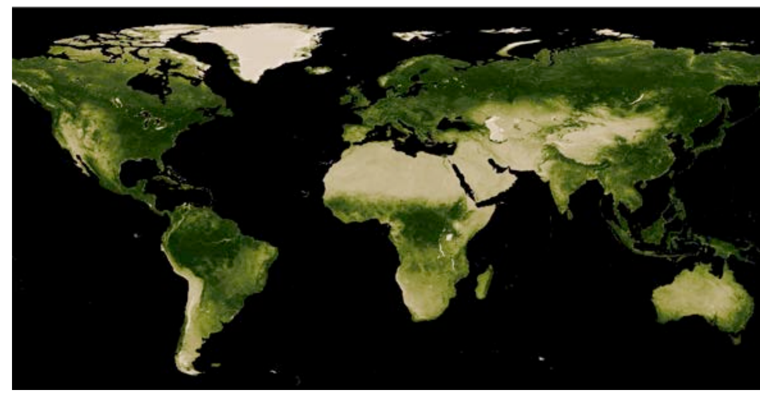
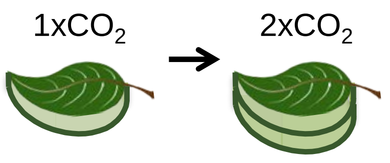
Plant leaf trait acclimation amplifies simulated warming in response to elevated carbon dioxide.



Marlies Kovenock[1] & Abigail L.S. Swann[2,1]
[1]Dept. of Biology, [2]Dept. of Atmospheric Sciences
University of Washington

Plant traits respond to CO_2

Δ Leaf Traits



Leaf mass per area increases

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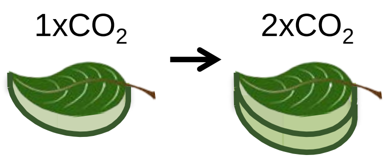

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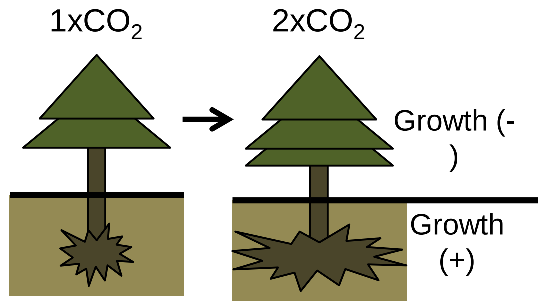

Root growth favored over leaf growth

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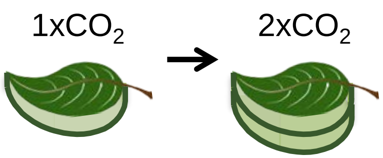

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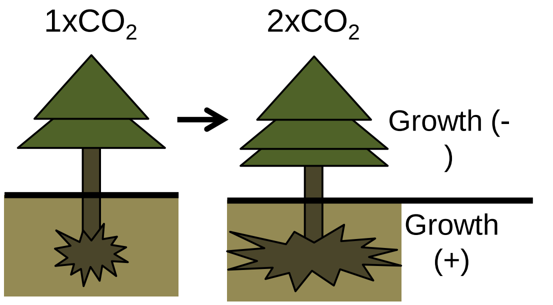

Root growth favored over leaf growth

Questions

- Are climate and the global carbon cycle altered by plant trait responses to elevated carbon dioxide?

Plant traits respond to CO_2

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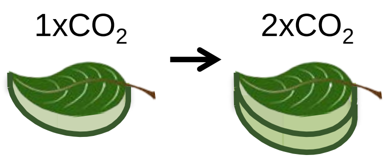

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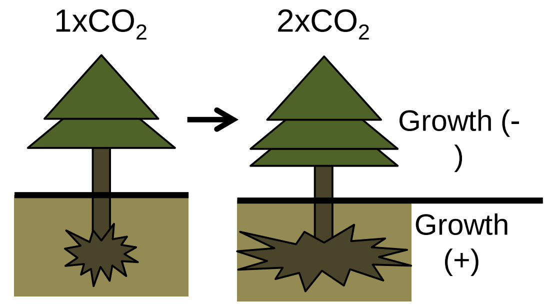

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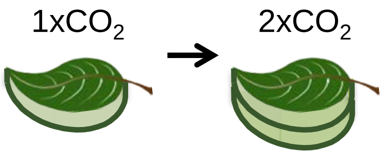

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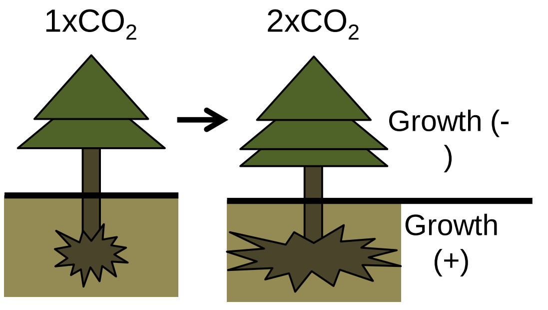

Root growth favored over leaf growth

Questions

- Are climate and the global carbon cycle altered by plant trait responses to elevated carbon dioxide?
- How large is the feedback? What are the mechanisms?
- Which plant trait responses have the largest influence?

Plant traits respond to CO_2

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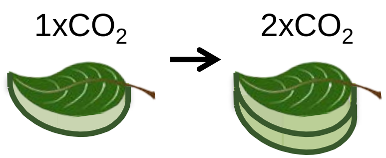

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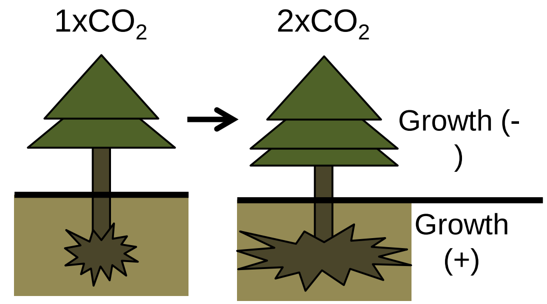

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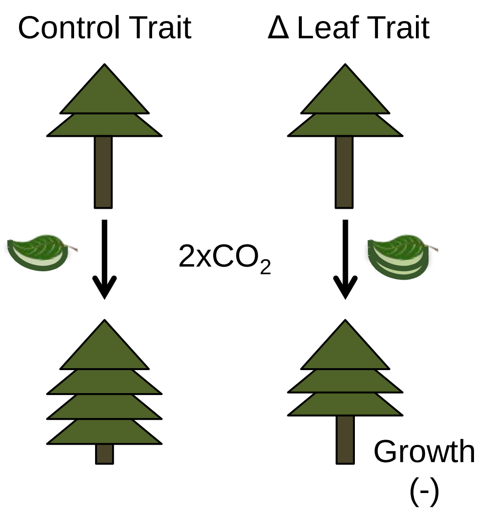
Δ Leaf Area Growth



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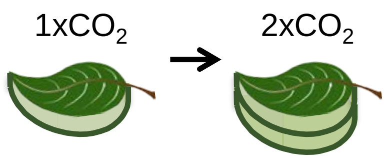

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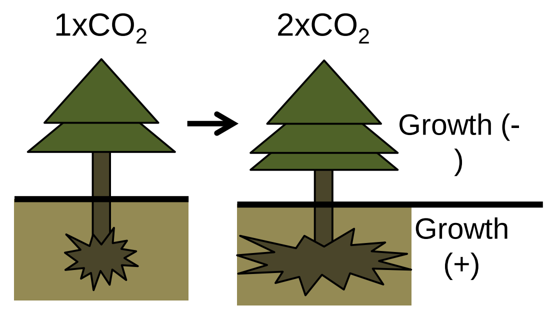

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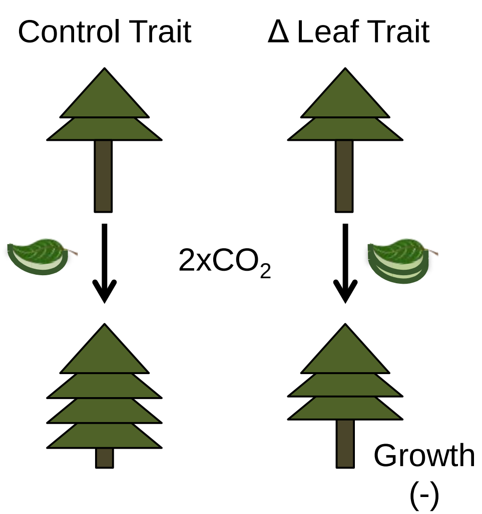
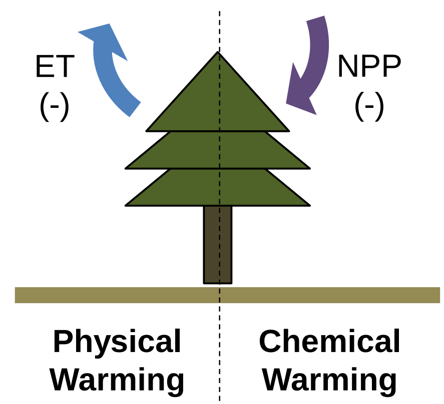


Δ Climate & Carbon Cycle



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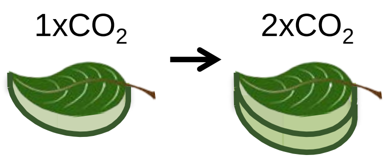

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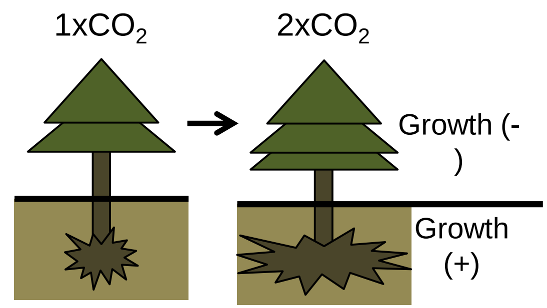

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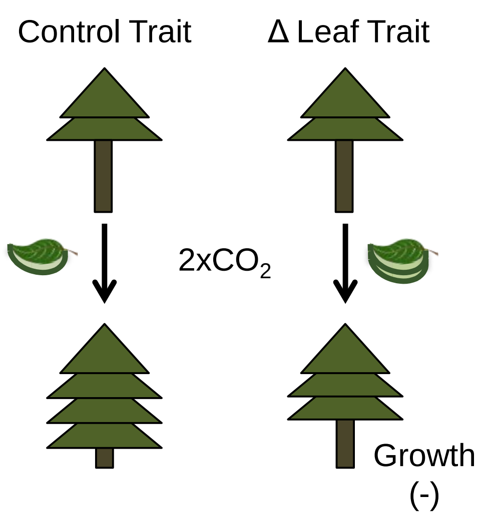

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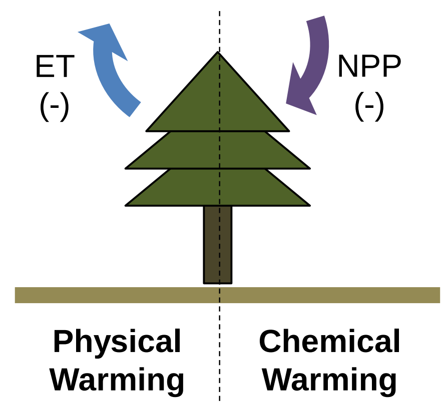
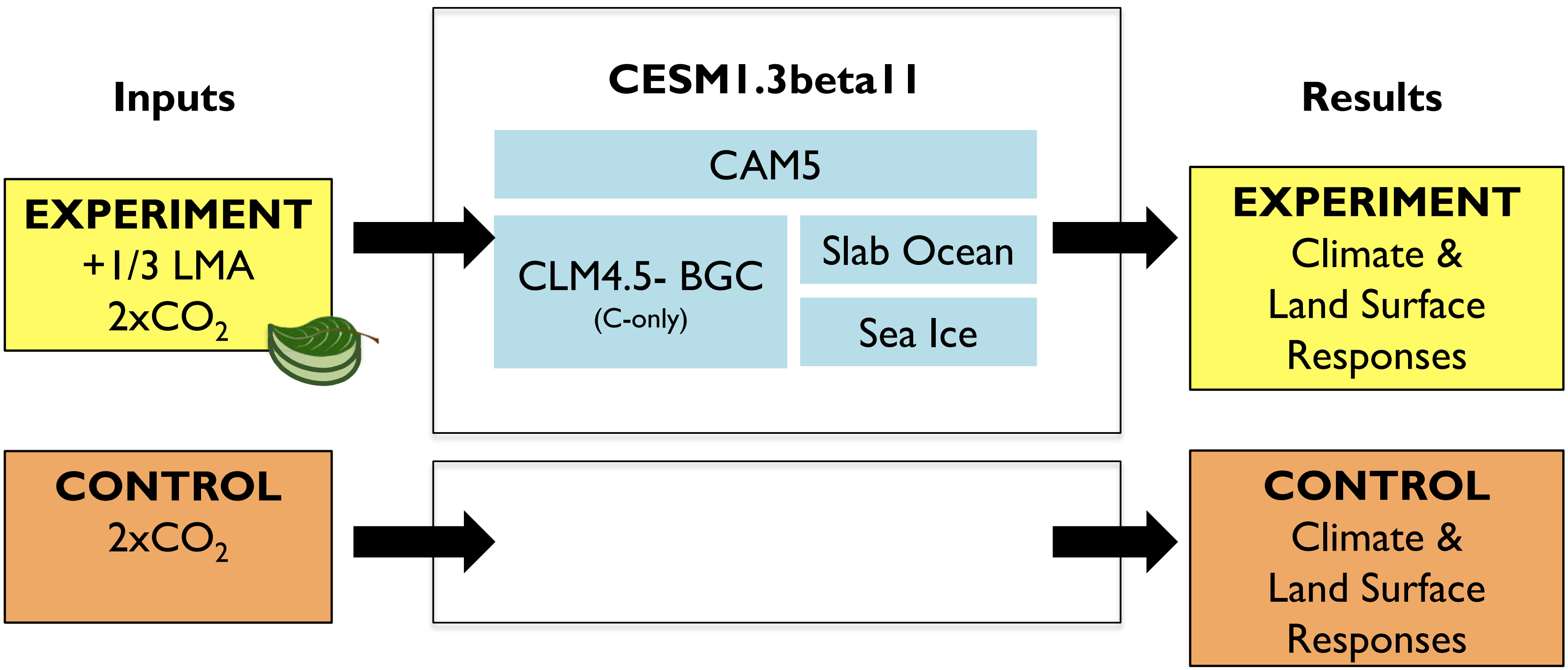


Testing leaf acclimation impact on climate



Increasing Leaf mass per area in CLM4.5-BGC

- Large, observationally constrained[1] **increase in leaf mass per area: +1/3**

[1] Poorter et al. 2009, *New Phytol;* [2]Oleson et al. 2013*, CLM Tech Notes*

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- We tested increased and **no change in photosynthetic rates**.

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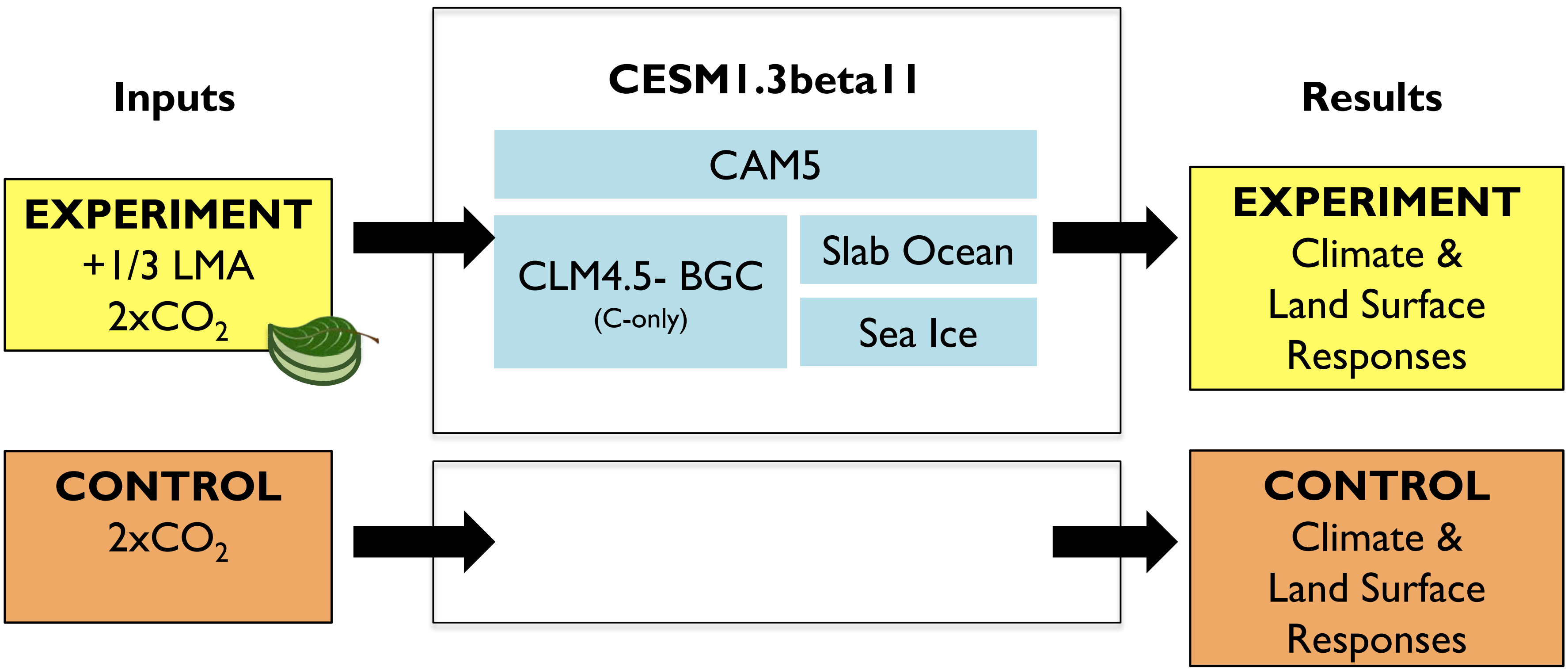
Testing leaf acclimation impact on climate



Leaf acclimation enhances physical warming over land (+0.3°C)

Zonal Annual Mean Change (LMA Exp. – CC Control)

90N
65N
40N
20N
Eq
20S
40S
60S (a)
-0.5 0 0.5 1

Kovenock & Swann, submitted

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Zonal Annual Mean Change (LMA Exp. – CC Control)

90N
65N
40N
20N
Eq
20S
40S
60S

(a)
-0.5 0 0.5 1

(b)
-3 -2 -1 0

Kovenock & Swann, submitted

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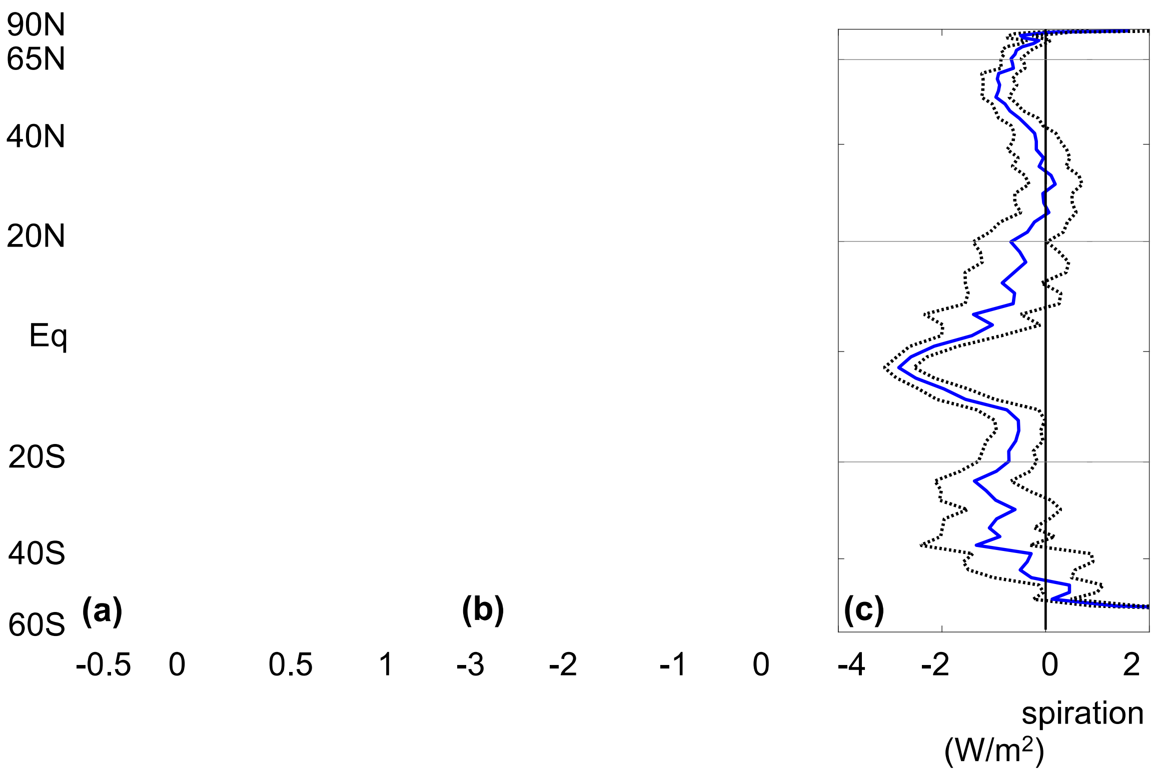

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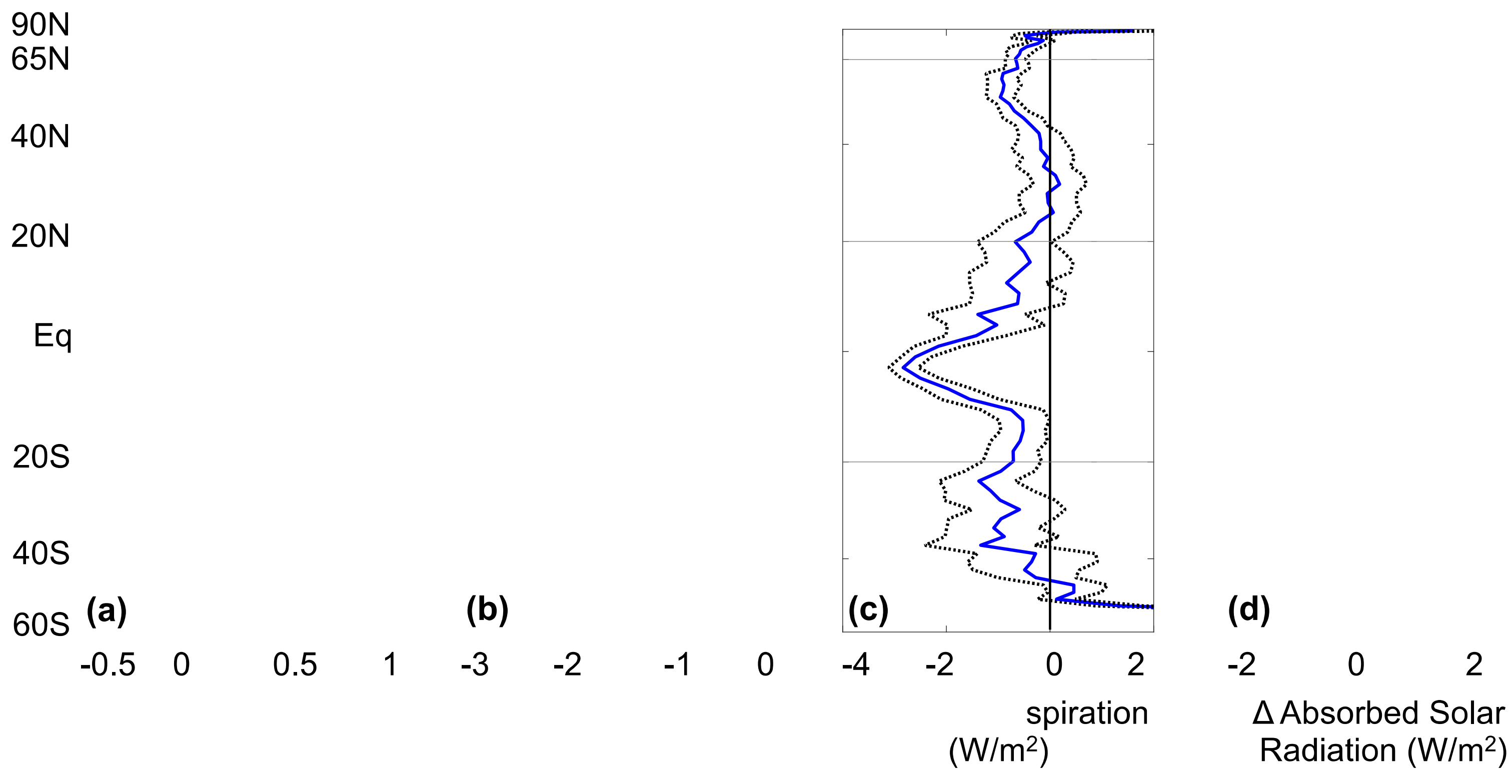

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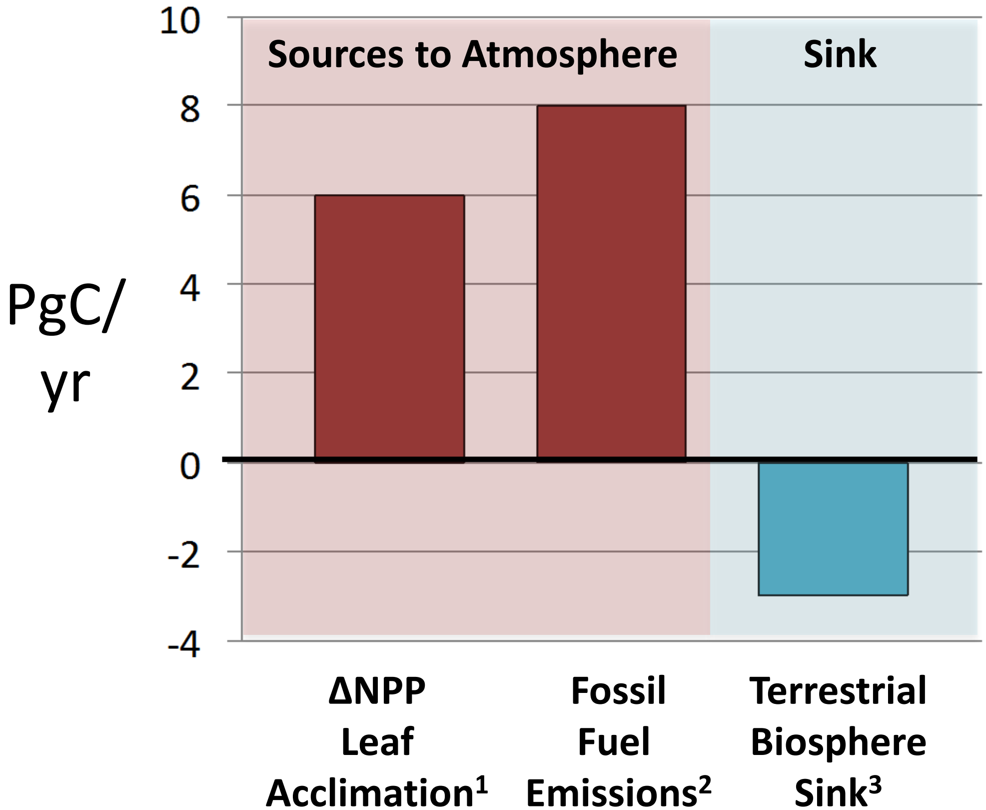
Additional chemical warming from reduced NPP growth (-6 PgC/yr)



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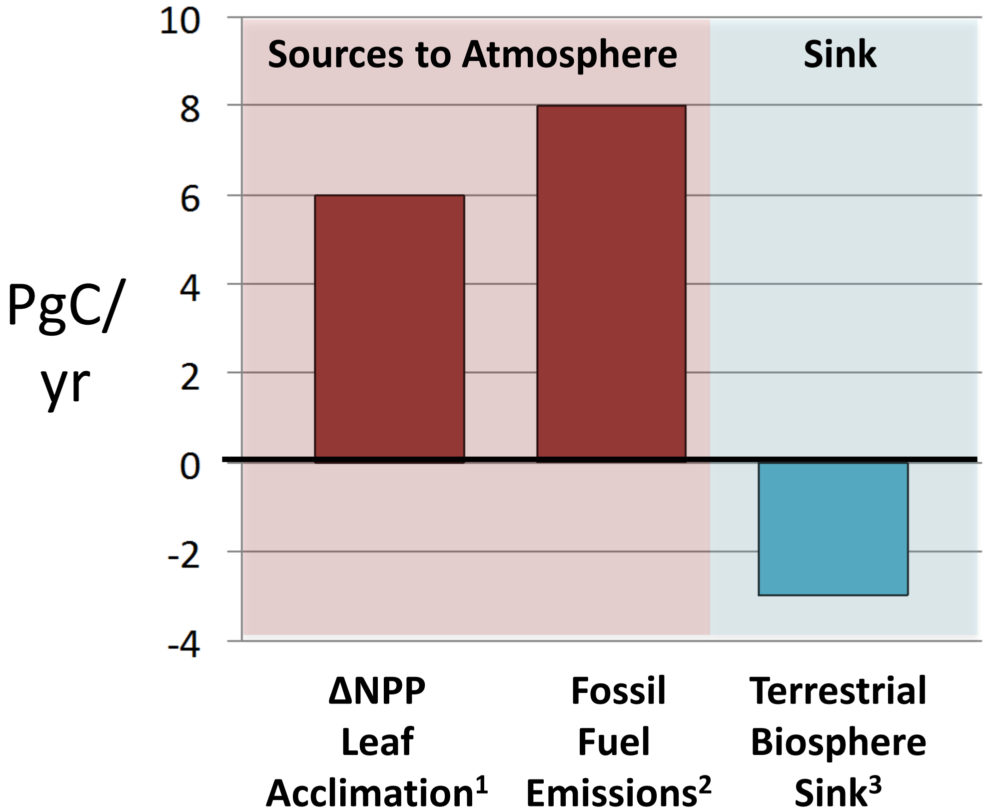

Chemical Warming

back-of-envelope estimate:

+0.1 to +1.0 °C

over century

(including ocean buffering)

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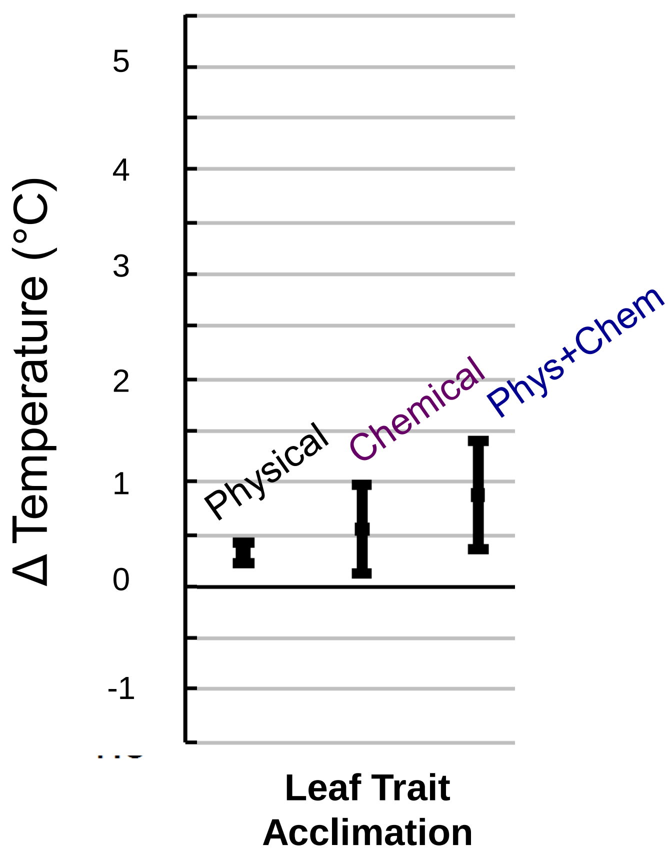
Warming due to Leaf Acclimation of comparable magnitude to other climate forcings



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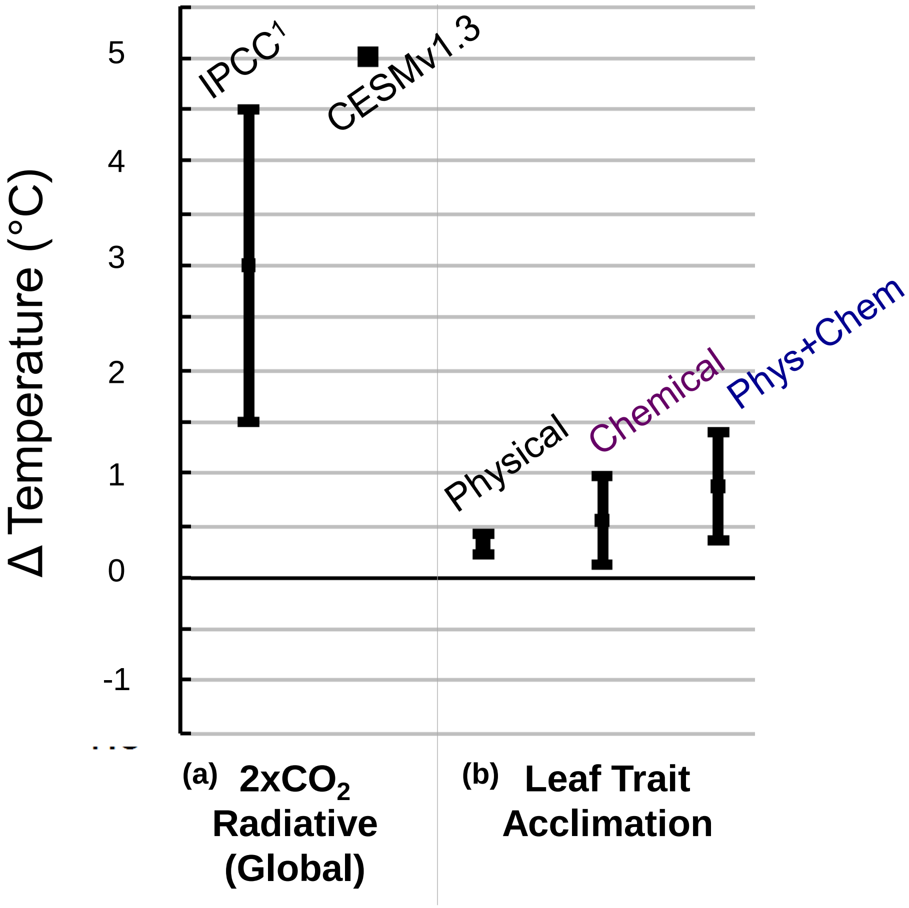

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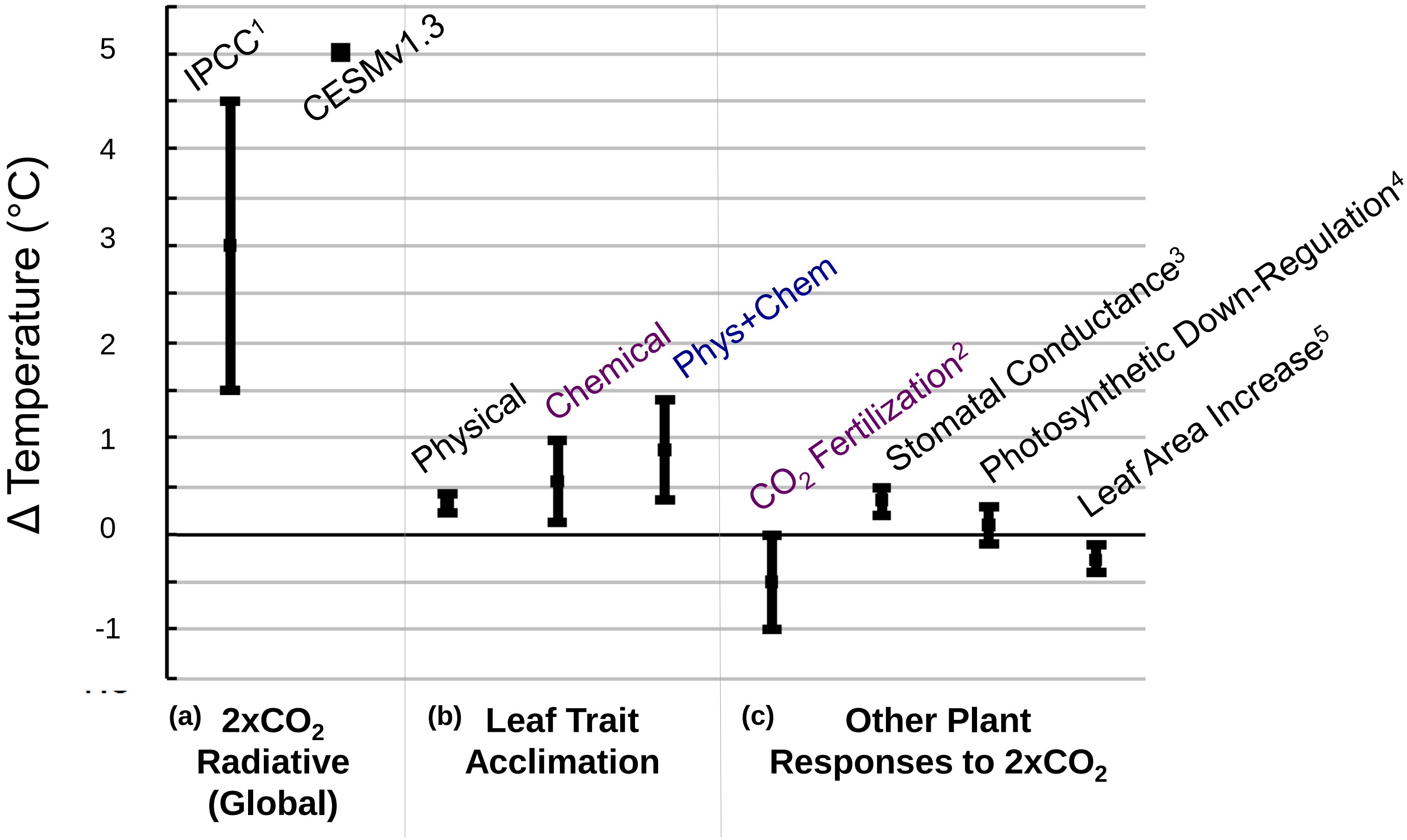

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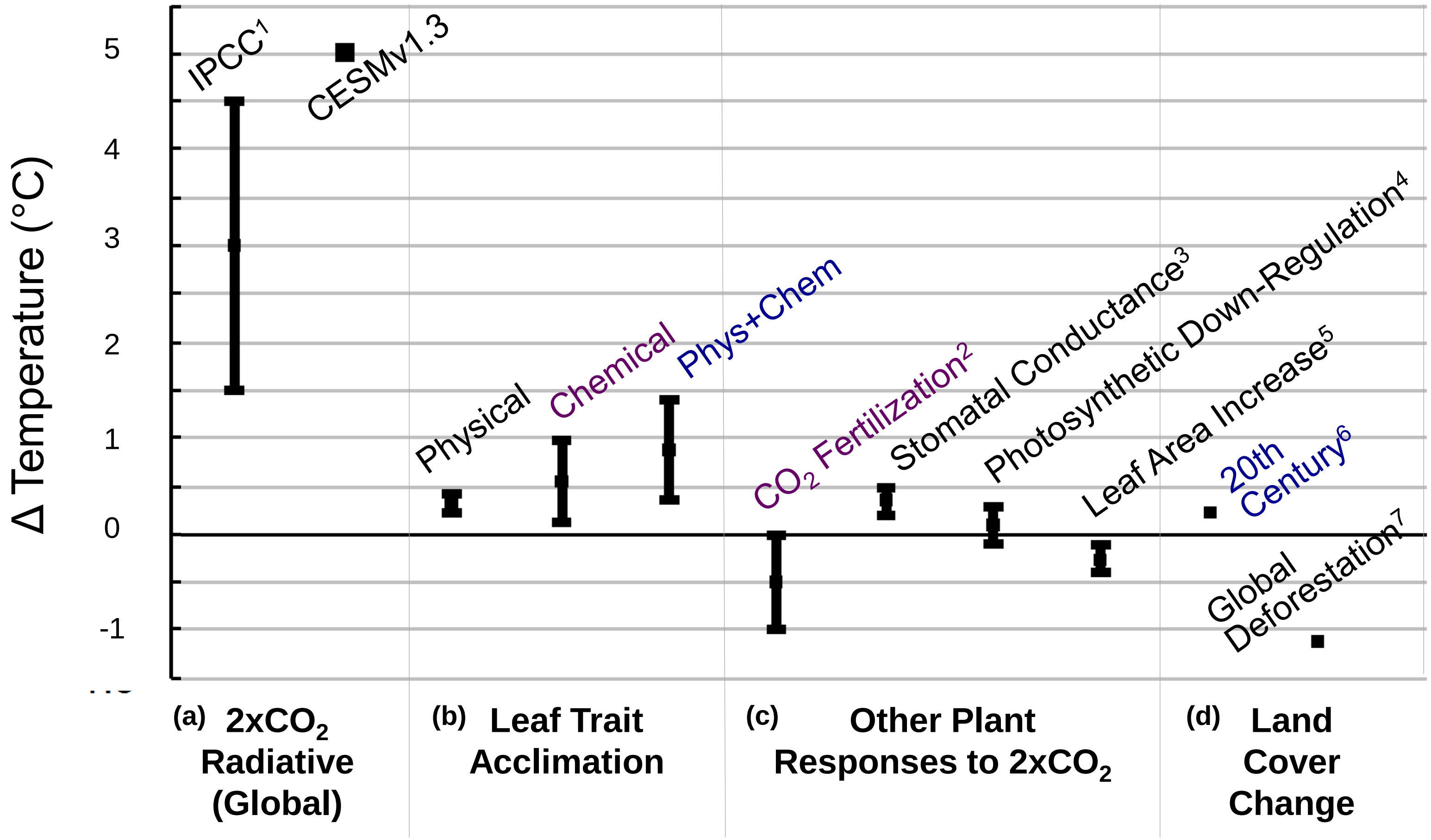

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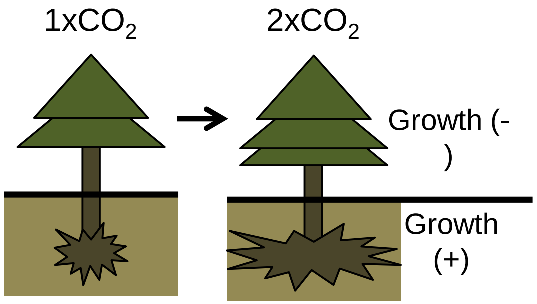
Next: Root response enhances warming?

Δ Root Traits



Root growth favored over leaf growth

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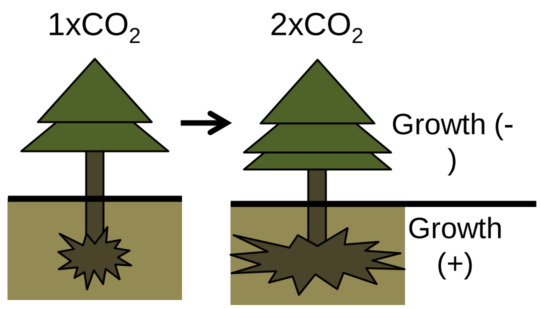

Root growth favored over leaf growth

Meta-analysis of Observations[1]:

Root:Shoot ratio

responds to elevated CO_2 :

+23% in forests

+13% in grasses

[1] Luo et al. 2006, *Ecology*

Implement Root Response in CLM5

1. **Change carbon allocation**

   fine root : leaf & stem : leaf

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Reduce Leaf Area Index
-5 to -10%

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$$\text{root conductance} = \frac{\text{max conductance} * \text{fraction} * \text{root area index}}{\text{root length} + \text{depth}}$$

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↑ (fine root : leaf)

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Implement Root Response in CLM5

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fine root : leaf & stem : leaf

2. Change root functioning

Increase Root Conductance
+20%

↑ root conductance = $\frac{\text{max conductance * fraction * root area index}}{\text{root length + depth}}$

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↑ (fine root : leaf)

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Implement Root Response in CLM5

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fine root : leaf & stem : leaf

Reduce Leaf Area Index
-5 to -10%

2. Change root functioning

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↑ root conductance = $\frac{\text{max conductance * fraction * root area index}}{\text{root length + depth}}$

↑ root area index = (stem + leaf area) * fine root : leaf * root fraction

↑ (fine root : leaf)

potential leaf area = f(control allocation parameters) → (stem + leaf area)

Take Home Points

- Plant trait response significantly impacts climate & carbon cycle response to elevated CO_2.

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- More information or questions: kovenock@uw.edu

Overview schematic for leaf trait response