CLIMATE RESPONSES TO PROGRESSIVE MID-LATITUDE AFFORESTATION

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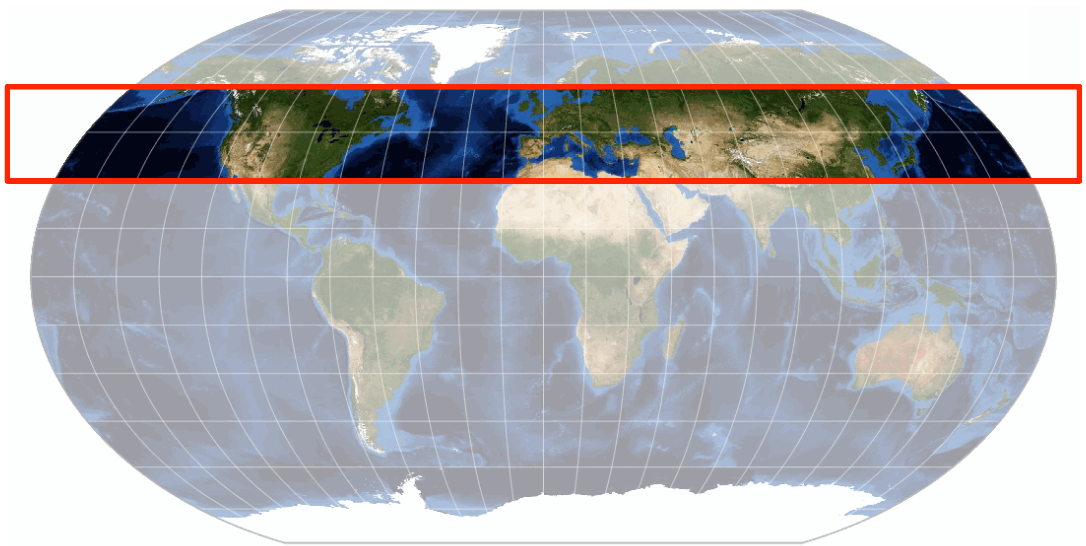
1. Global climate impacts of mid-latitude afforestation

2. How climate response scales with area of afforestation

- Mid-latitude afforestation drives local and remote shifts in cloud cover and energy transport
- Energy response scales linearly with the area of afforestation (precipitation doesn't)



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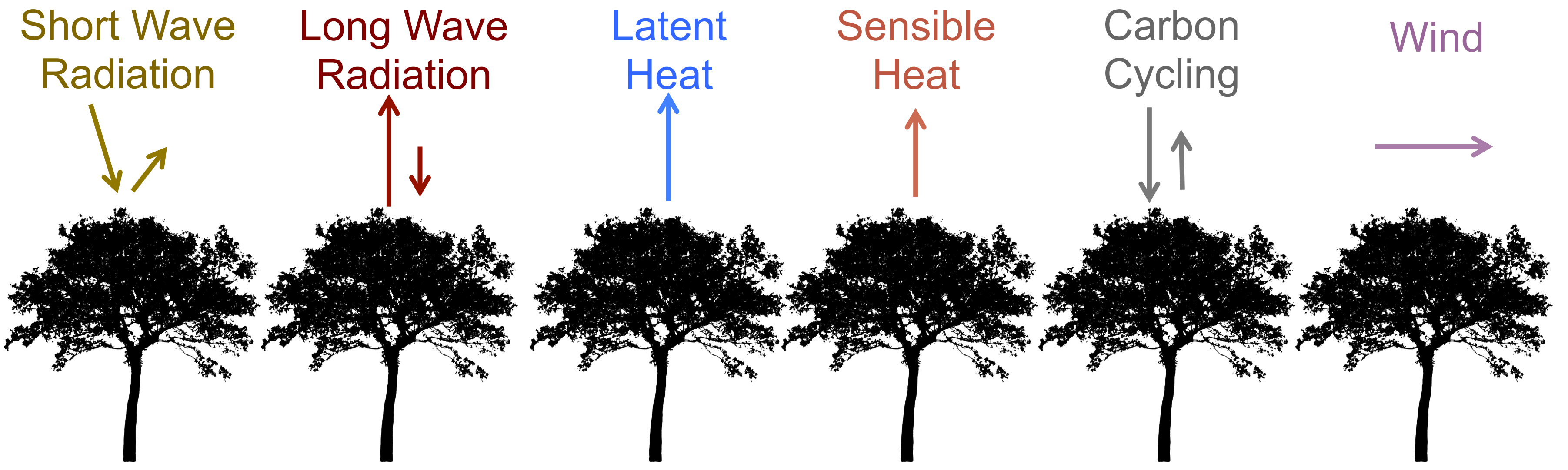

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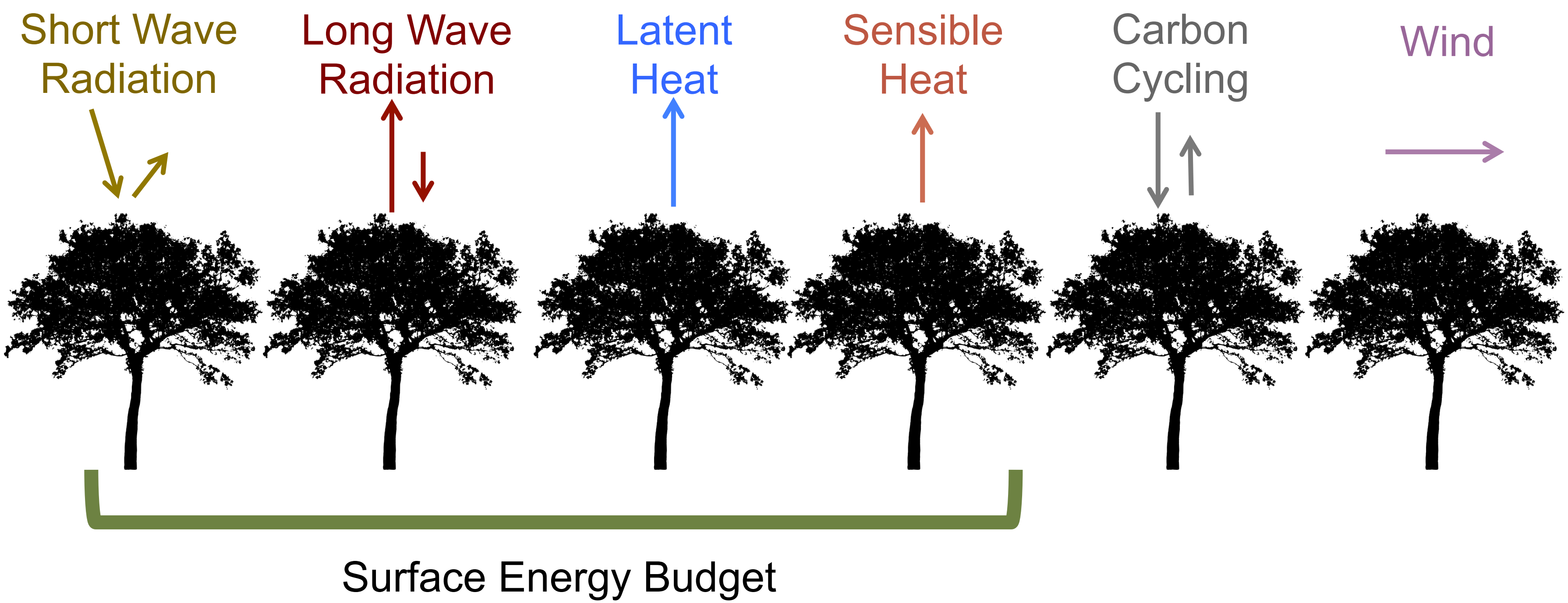

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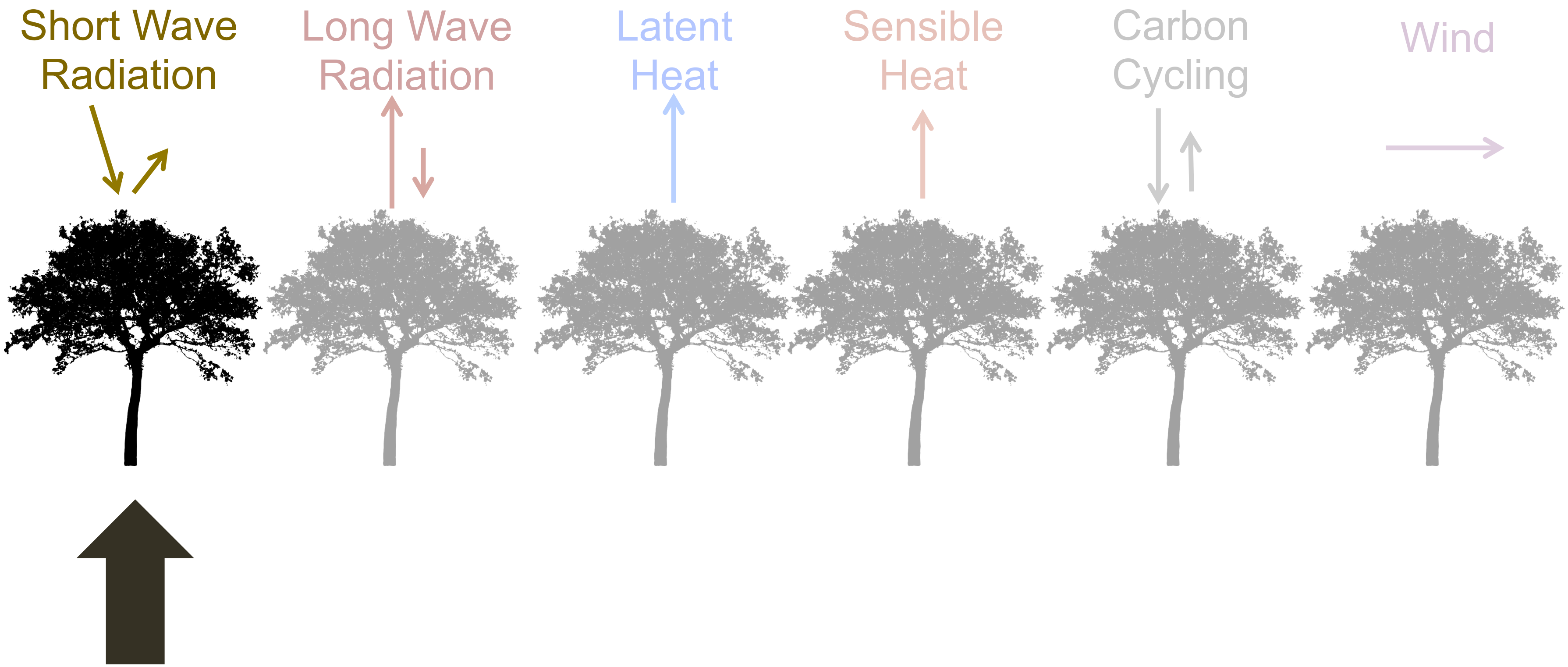

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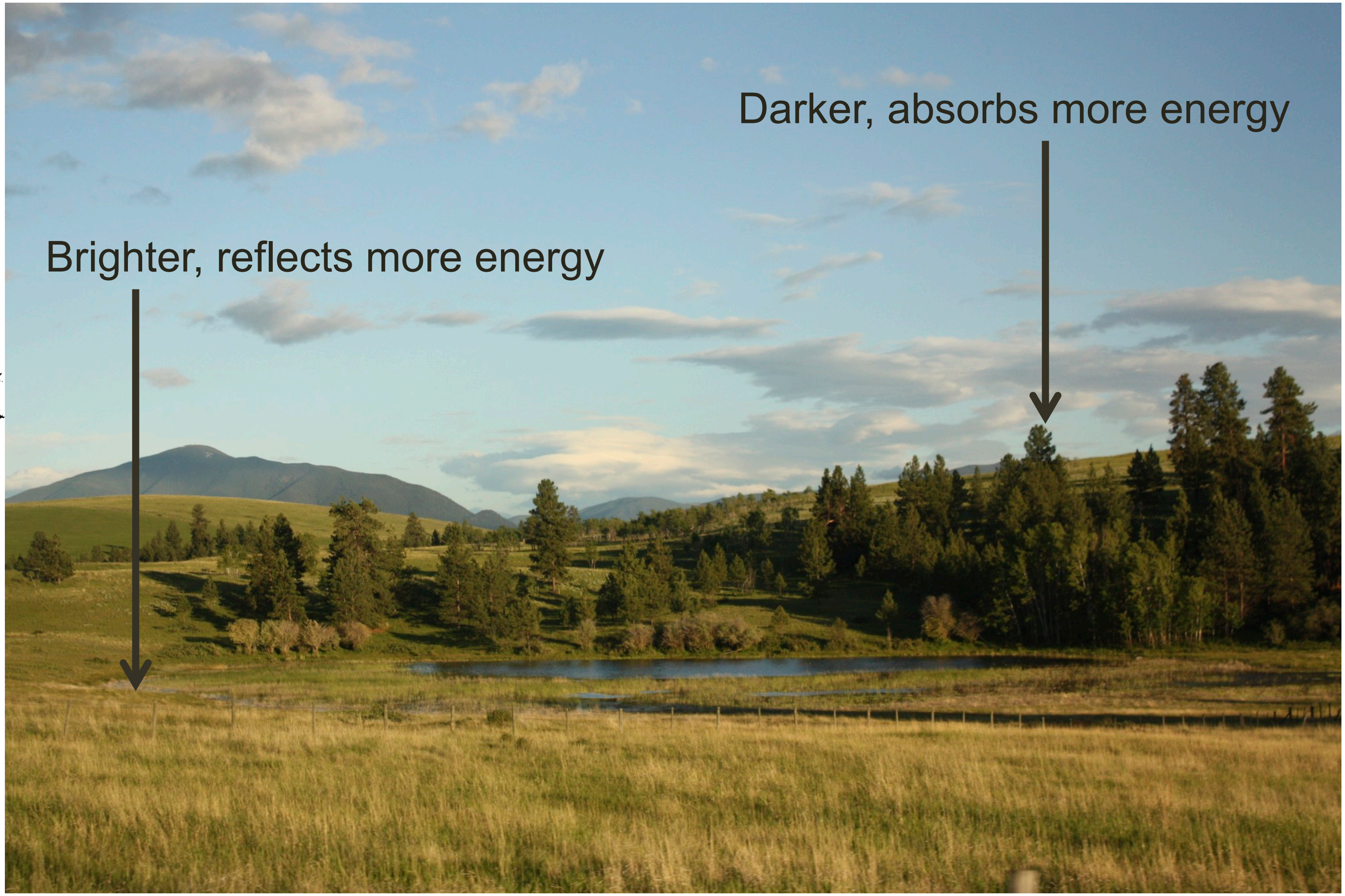

Climate impacts of vegetation change has been explored at two scales:

Regional (anthropogenic)

Scale:
tens to hundreds of thousands of km^2

Global/ Continental

Scale:
tens of millions of km^2

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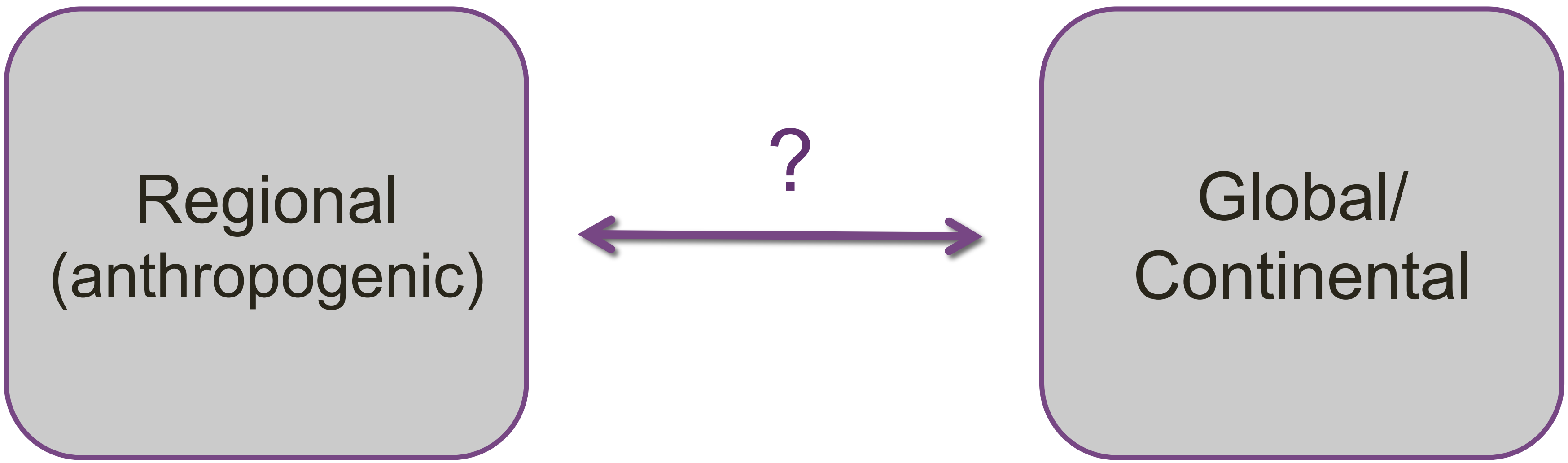

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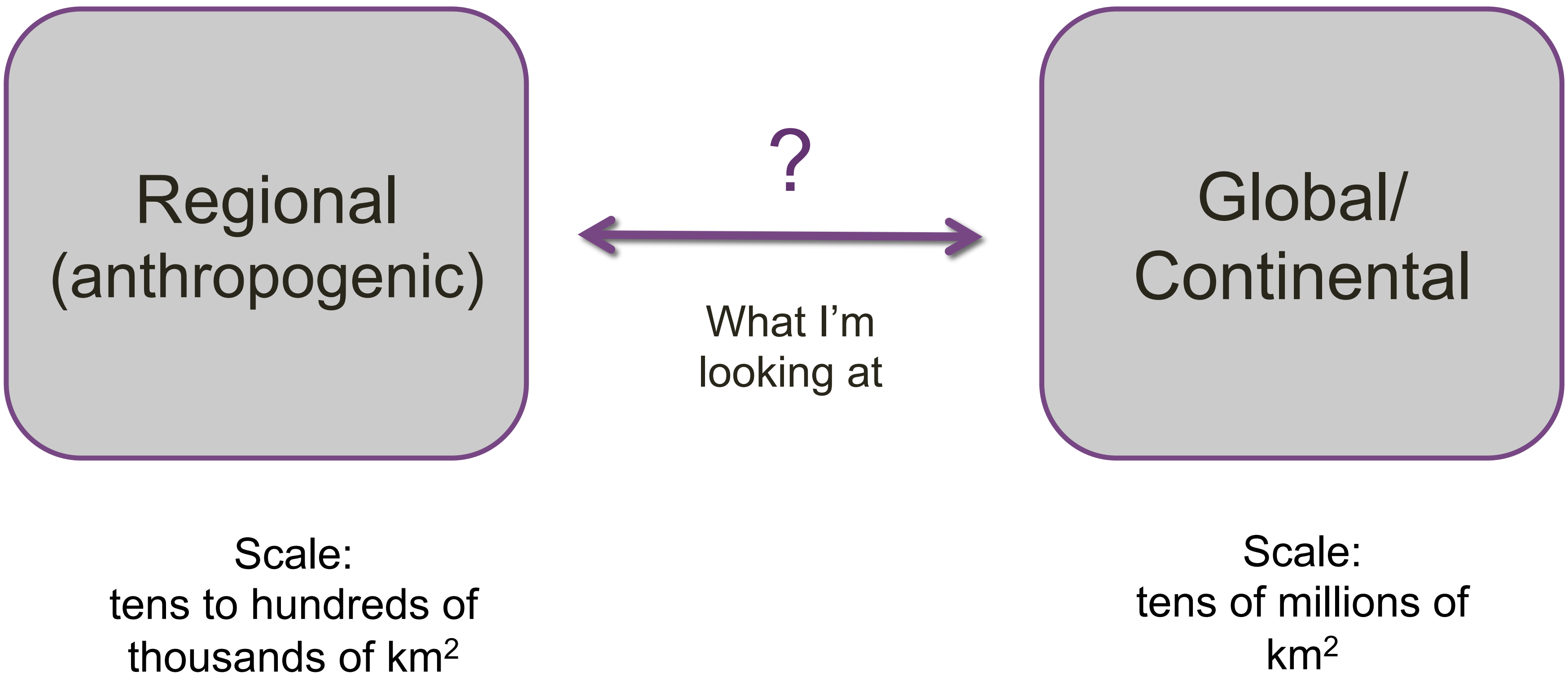

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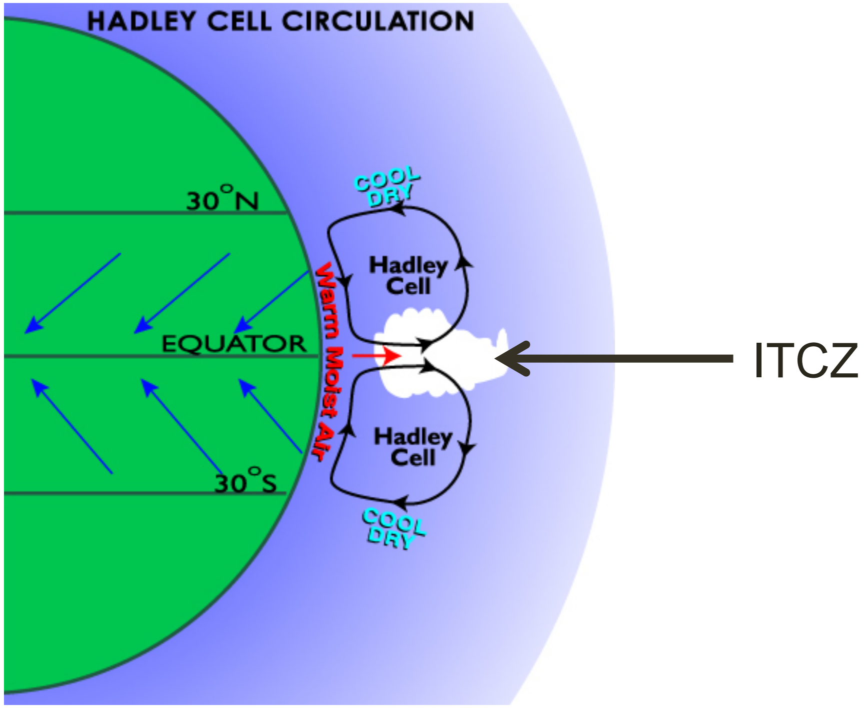

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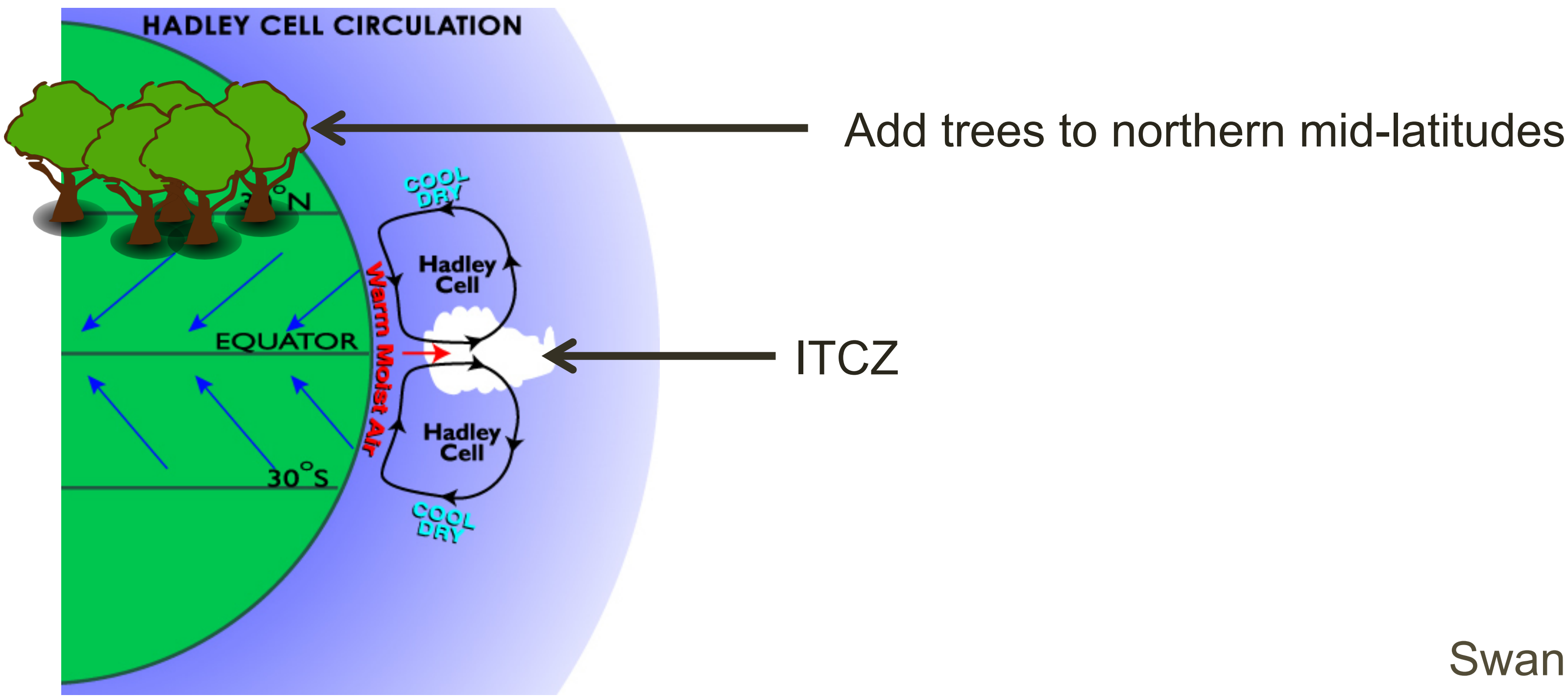

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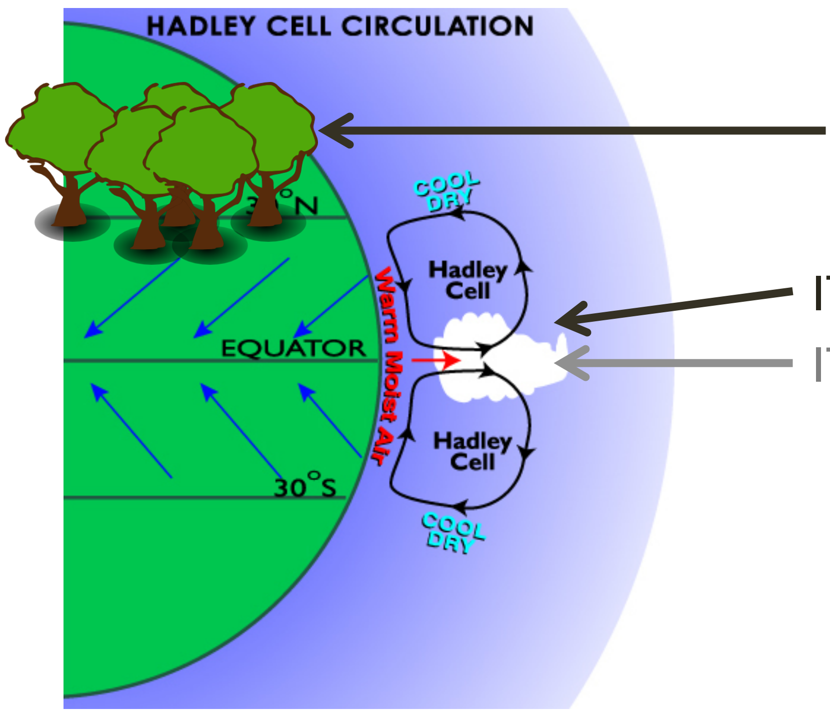

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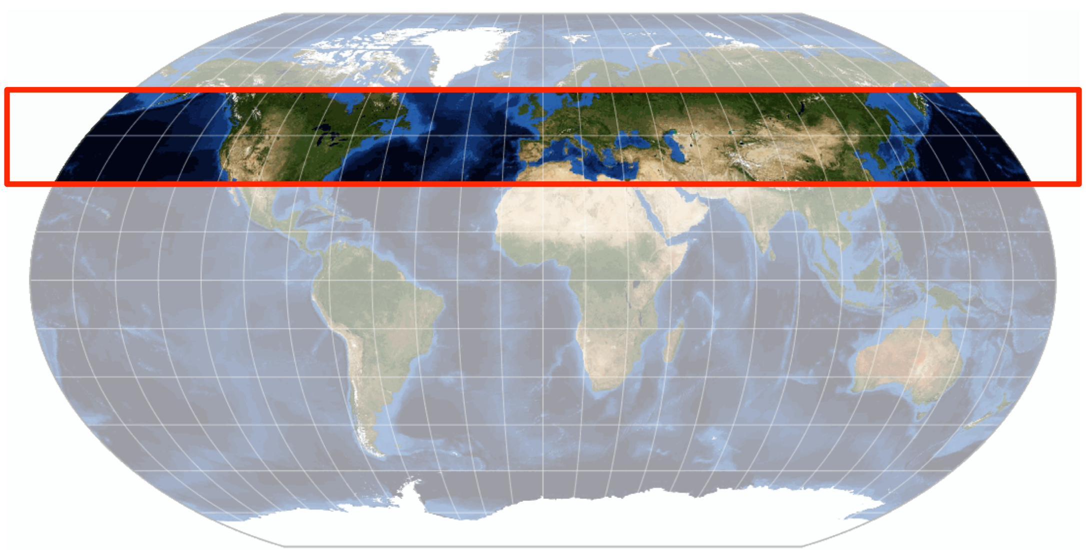

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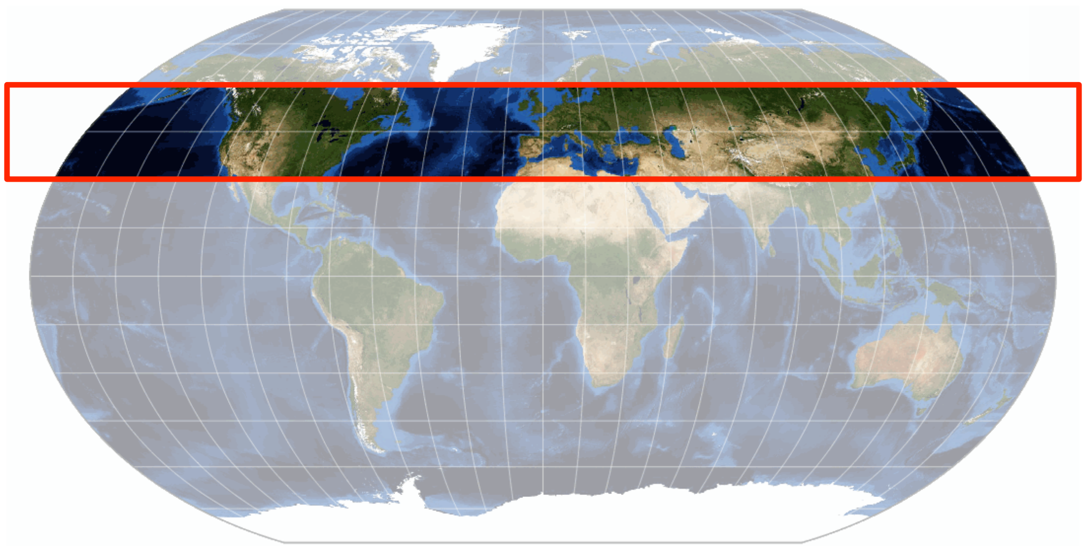


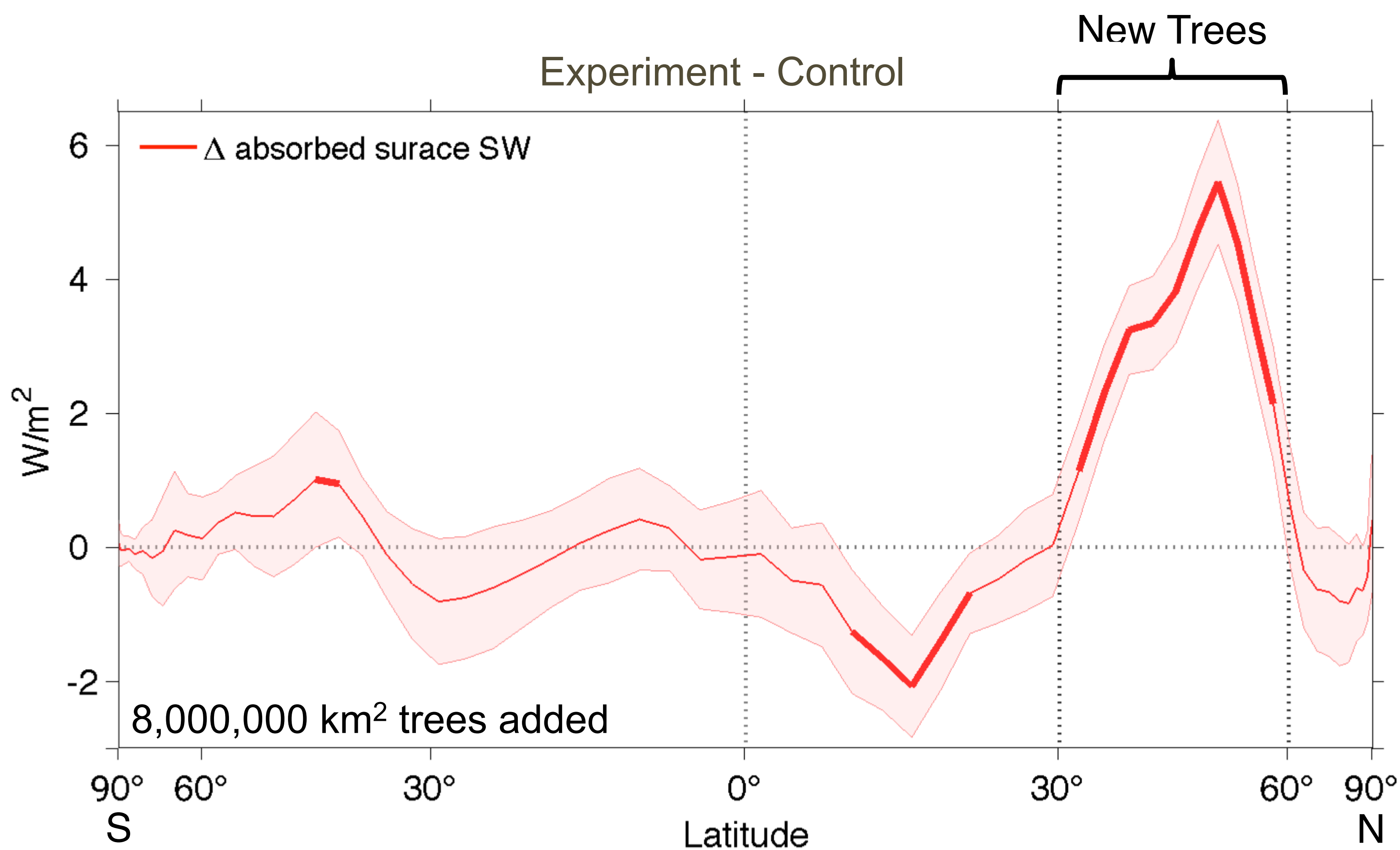
Model:
CAM 3.0, CLM 3.5, CASA' Carbon Cycle, slab ocean, fixed atm CO_2 (350 ppm)

Experiments: 50 years
Control: 100 years

RESULTS

1. Energy & cloud response to mid-latitude afforestation
2. How the response scales with different areas of afforestation

Change in solar energy absorbed at the surface



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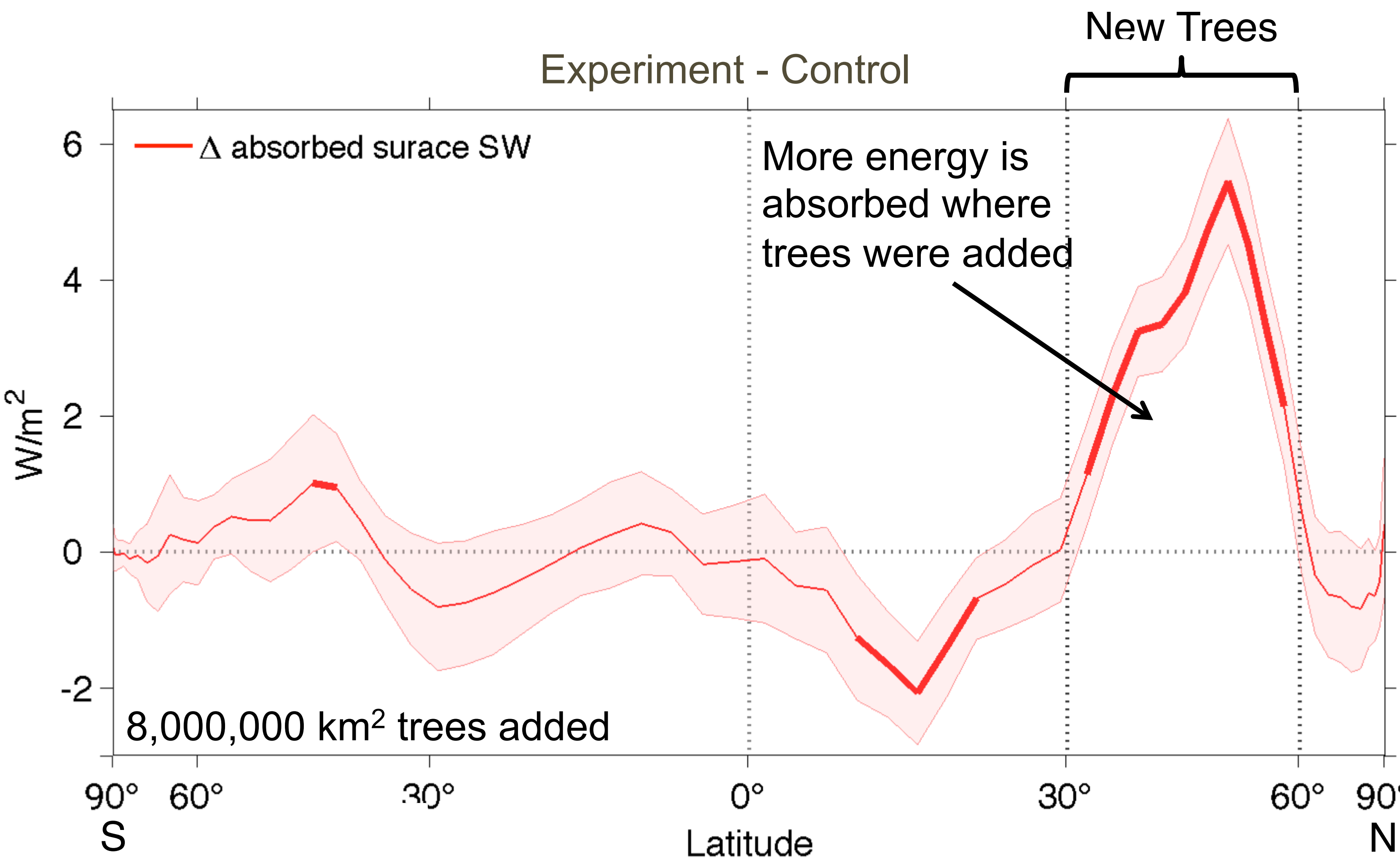

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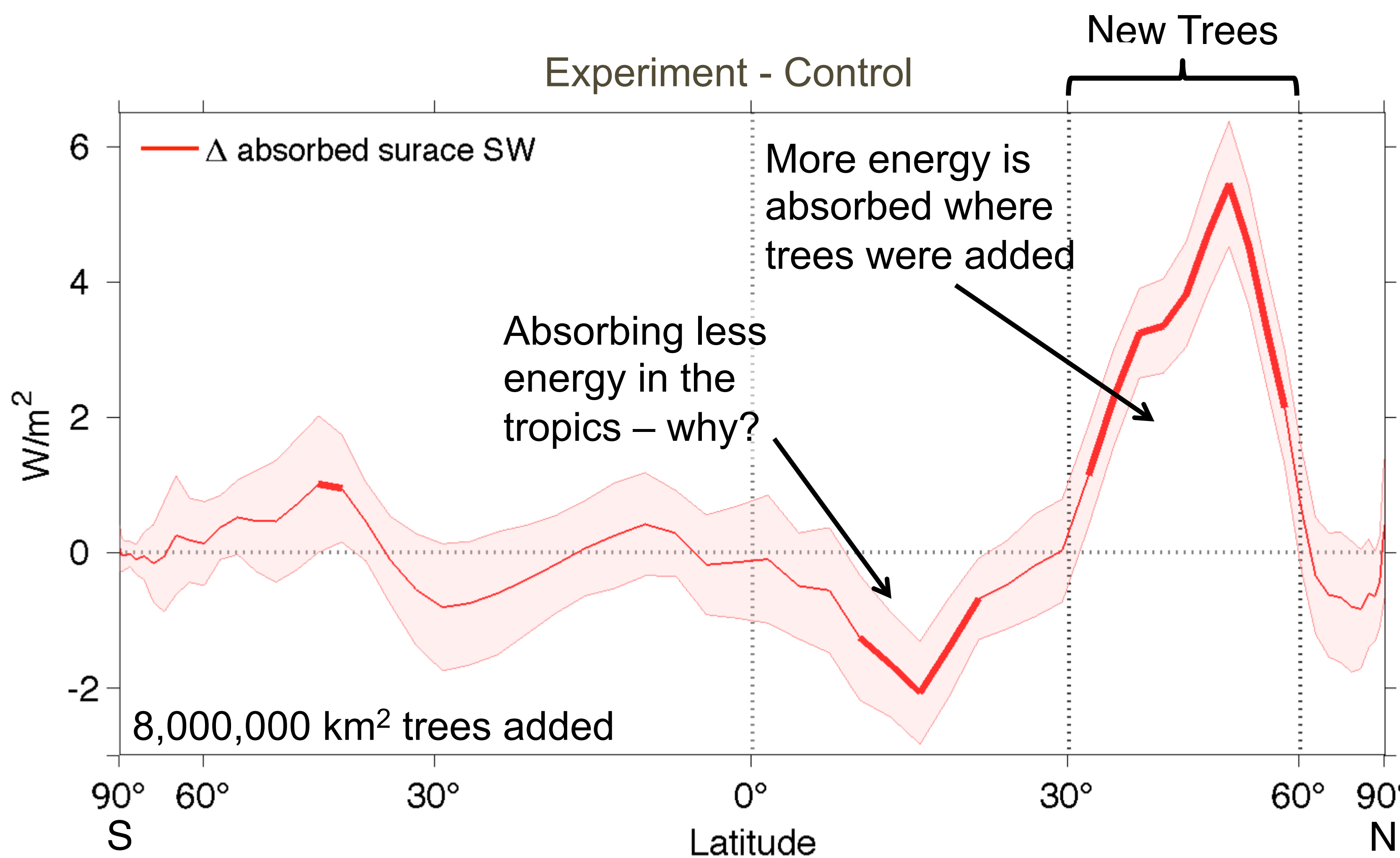
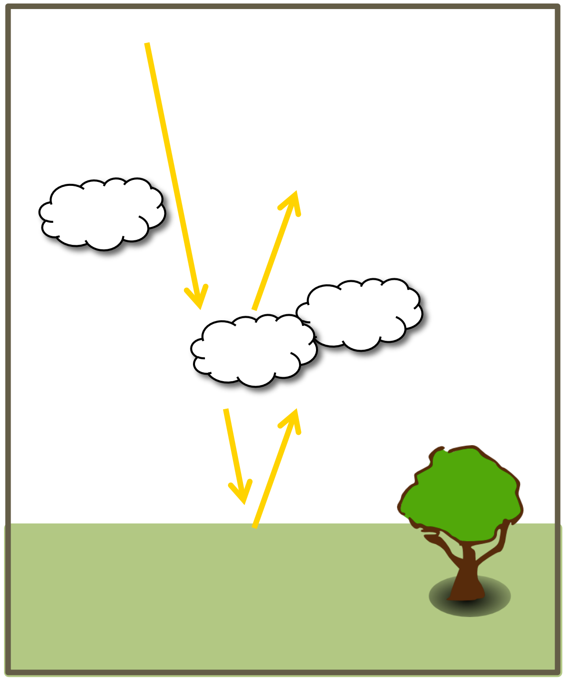
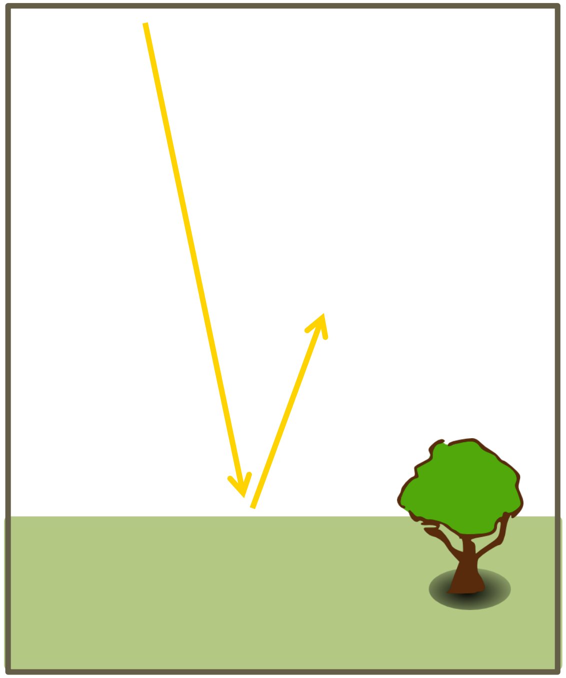


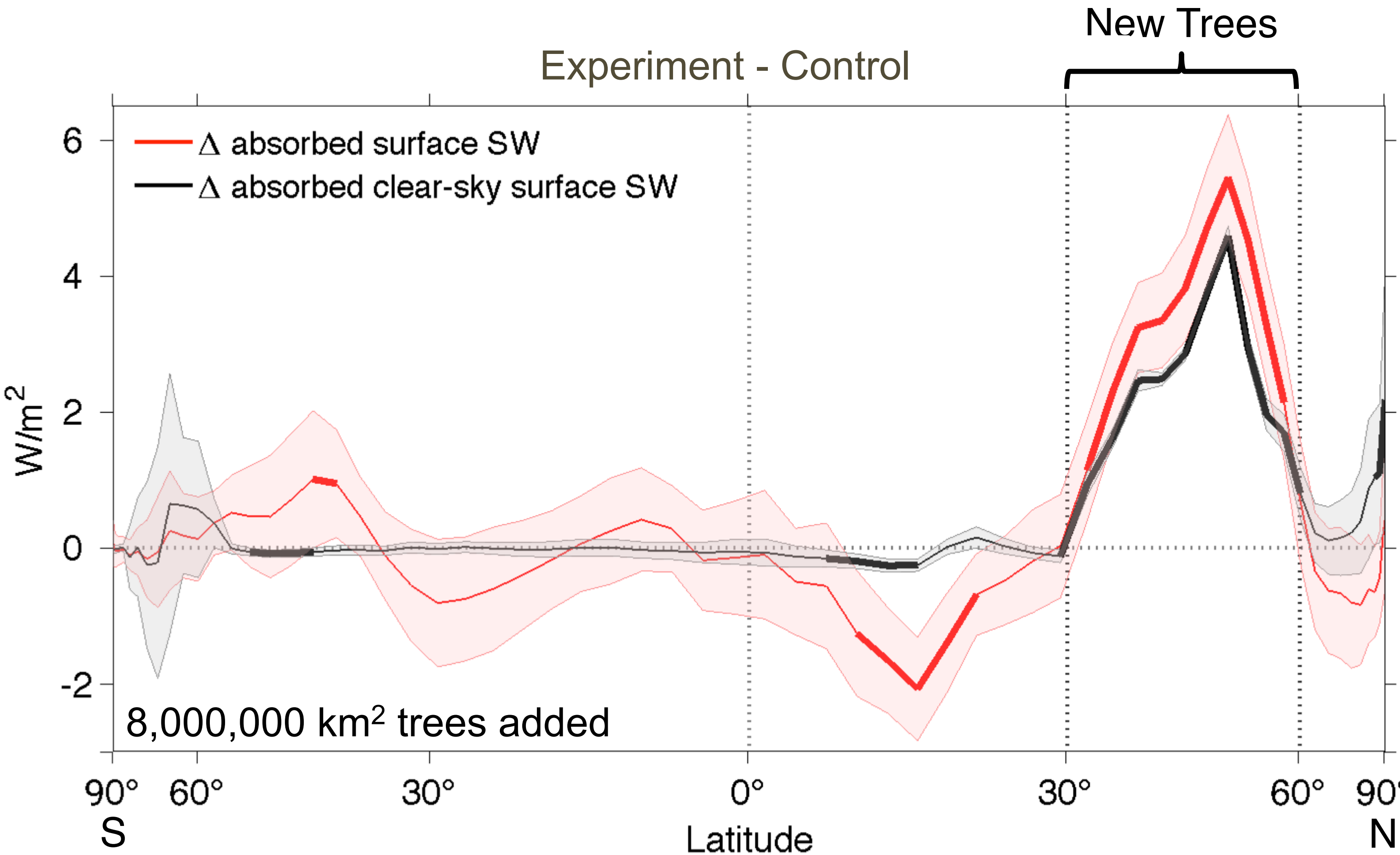
Full-sky surface radiation



Clear-sky surface radiation



Tropics don't have a change in energy absorption under cloud-free conditions



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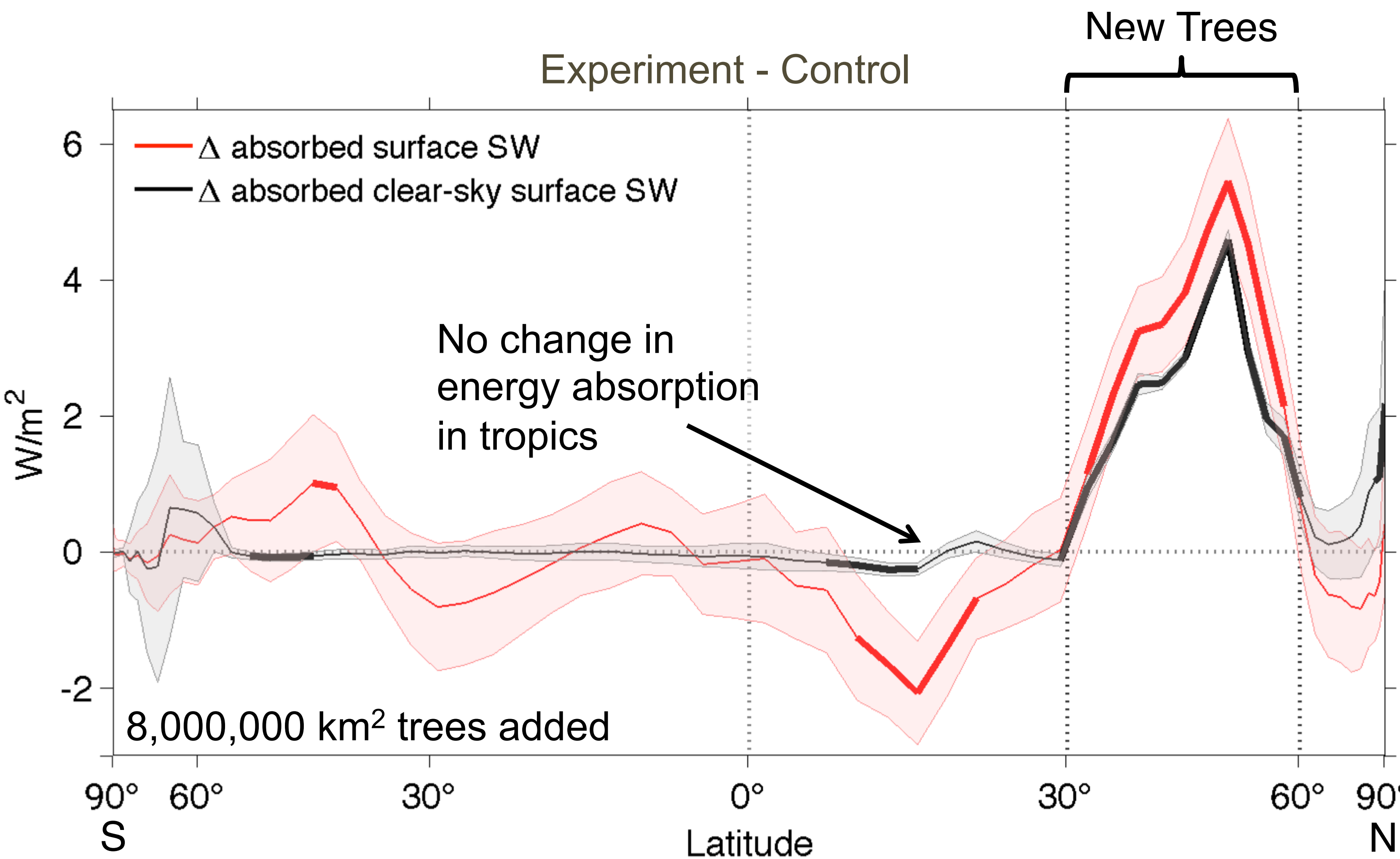

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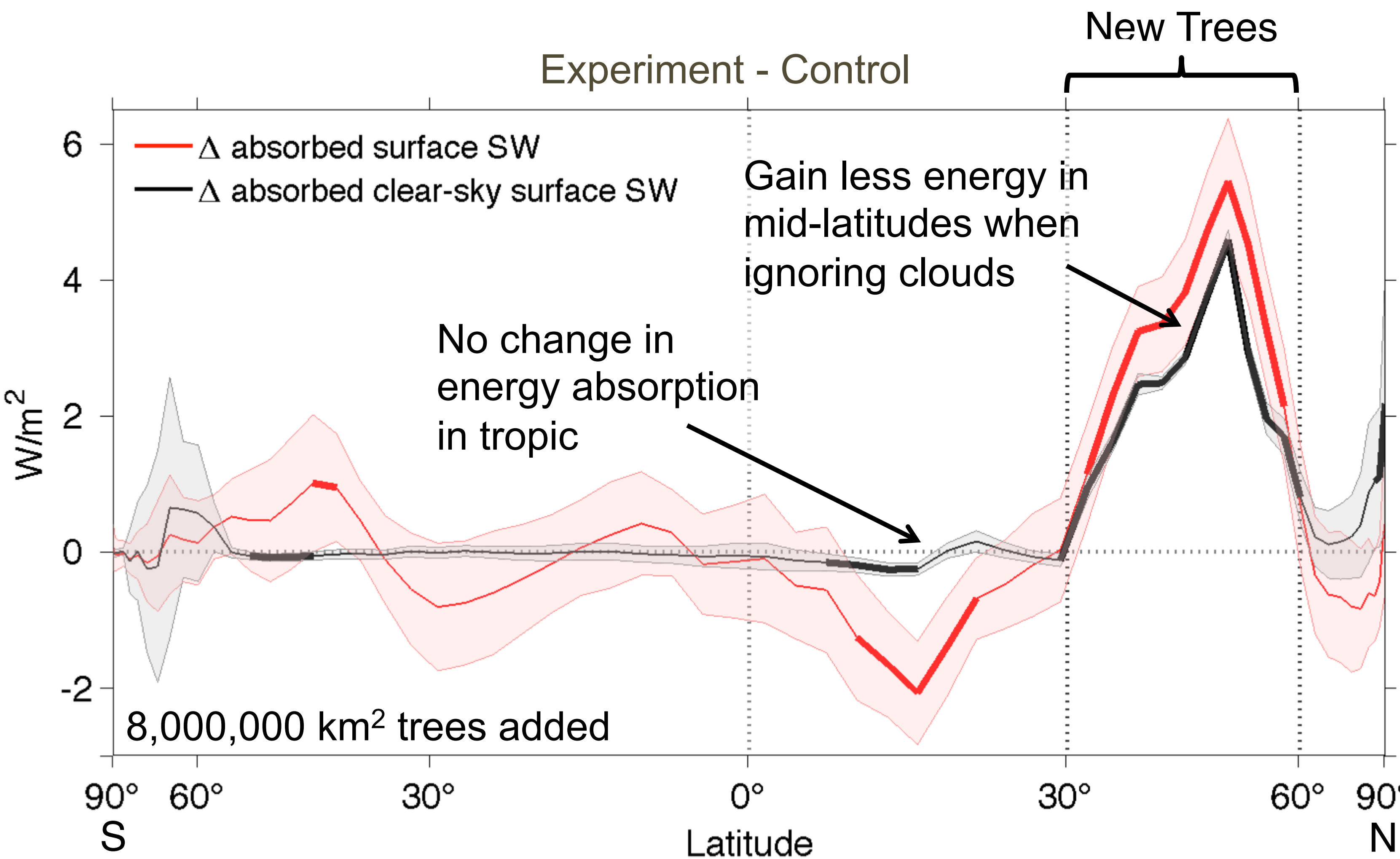
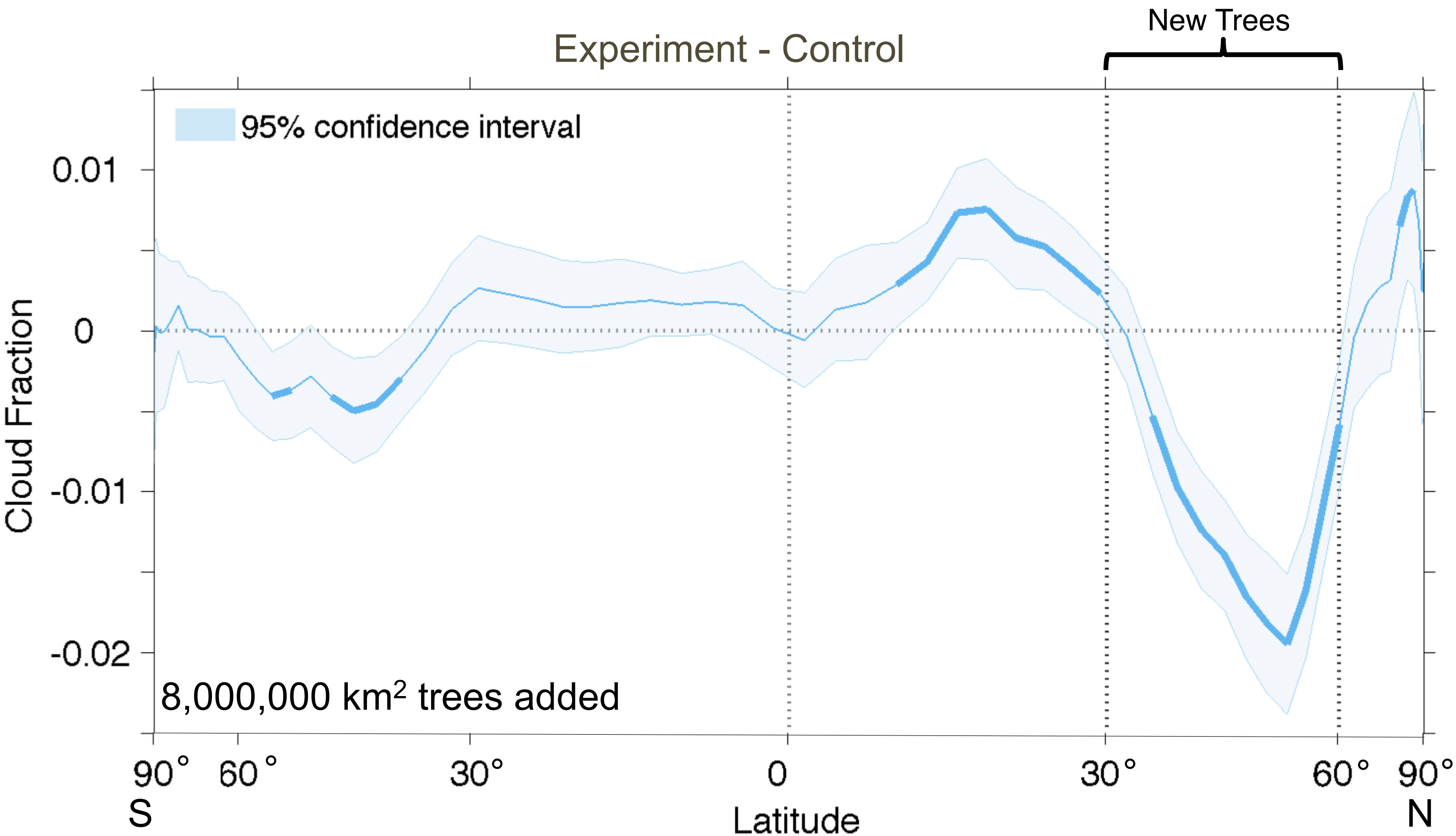


Change in low cloud cover matches change in tropical energy absorption



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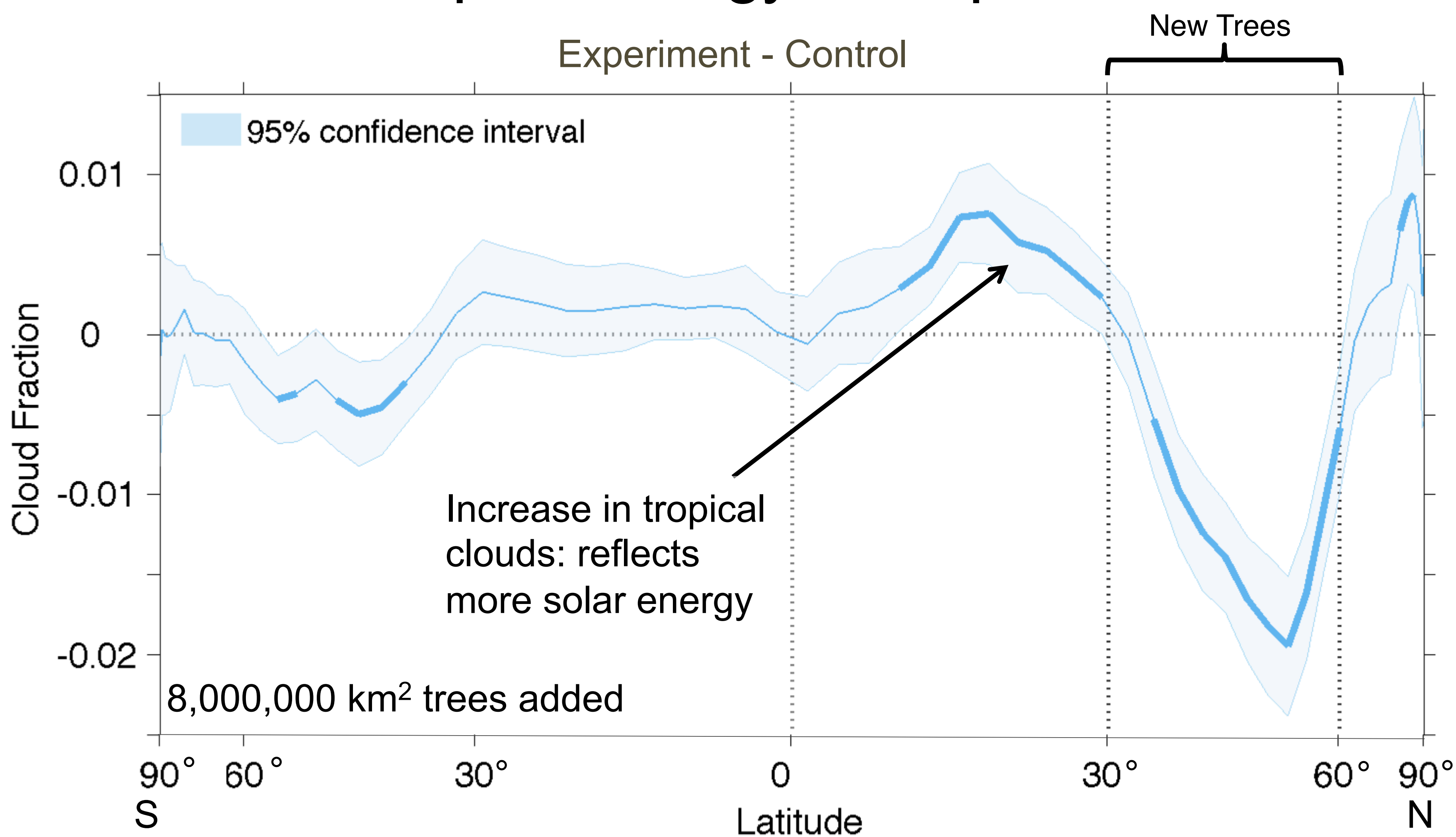

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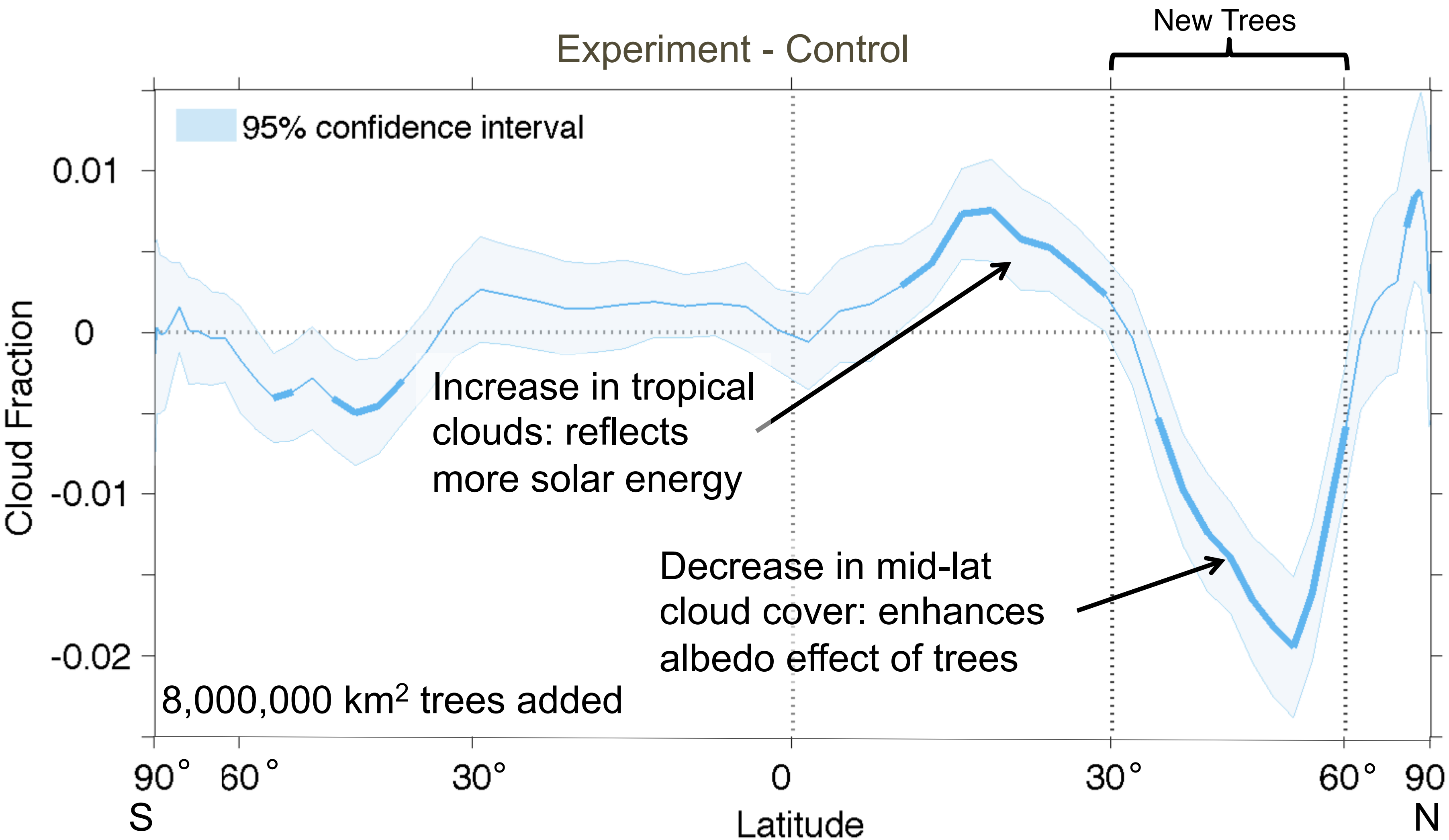
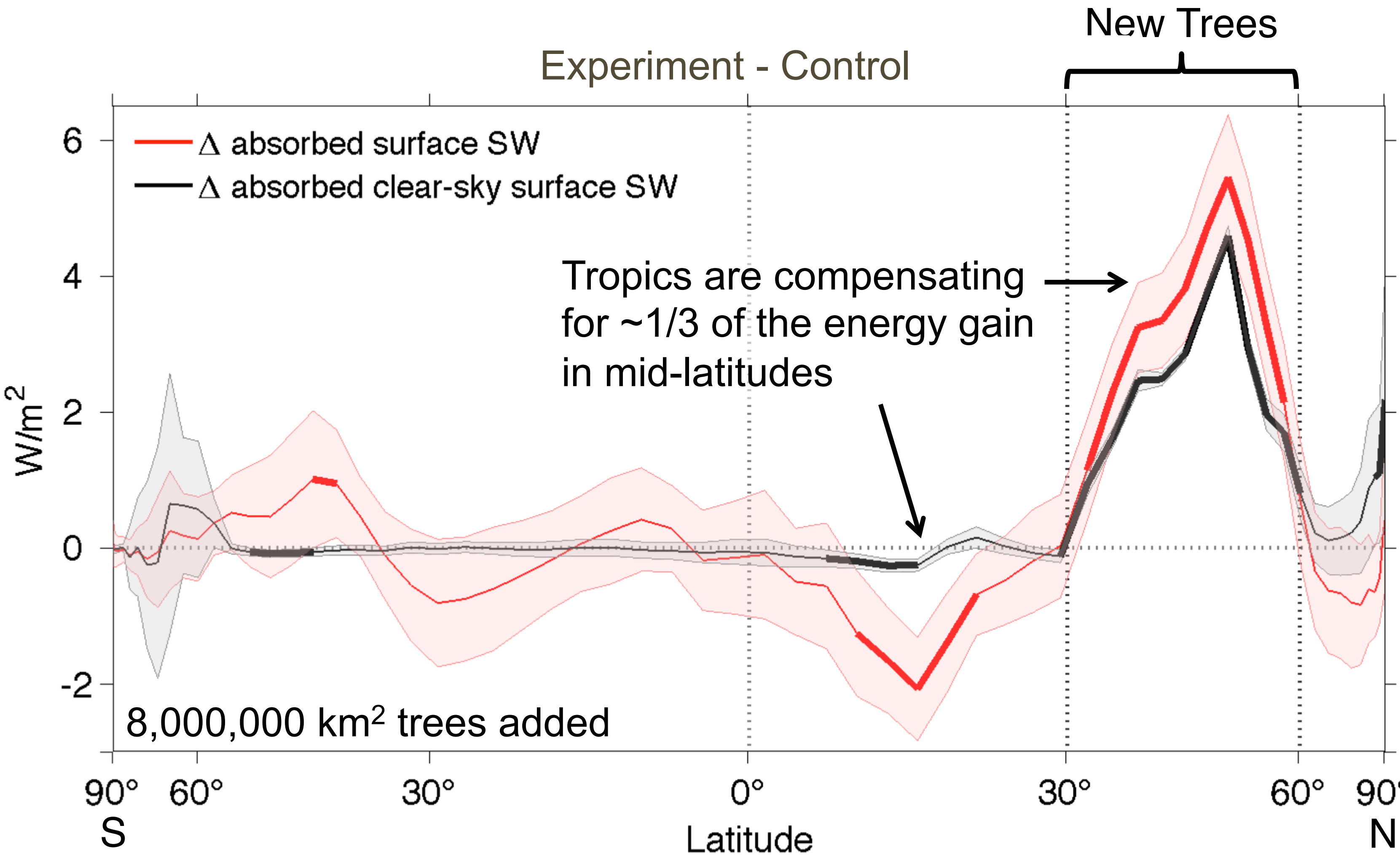


Overall energy gain in the northern hemisphere due to afforestation



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Impacts of afforestation on the energy budget

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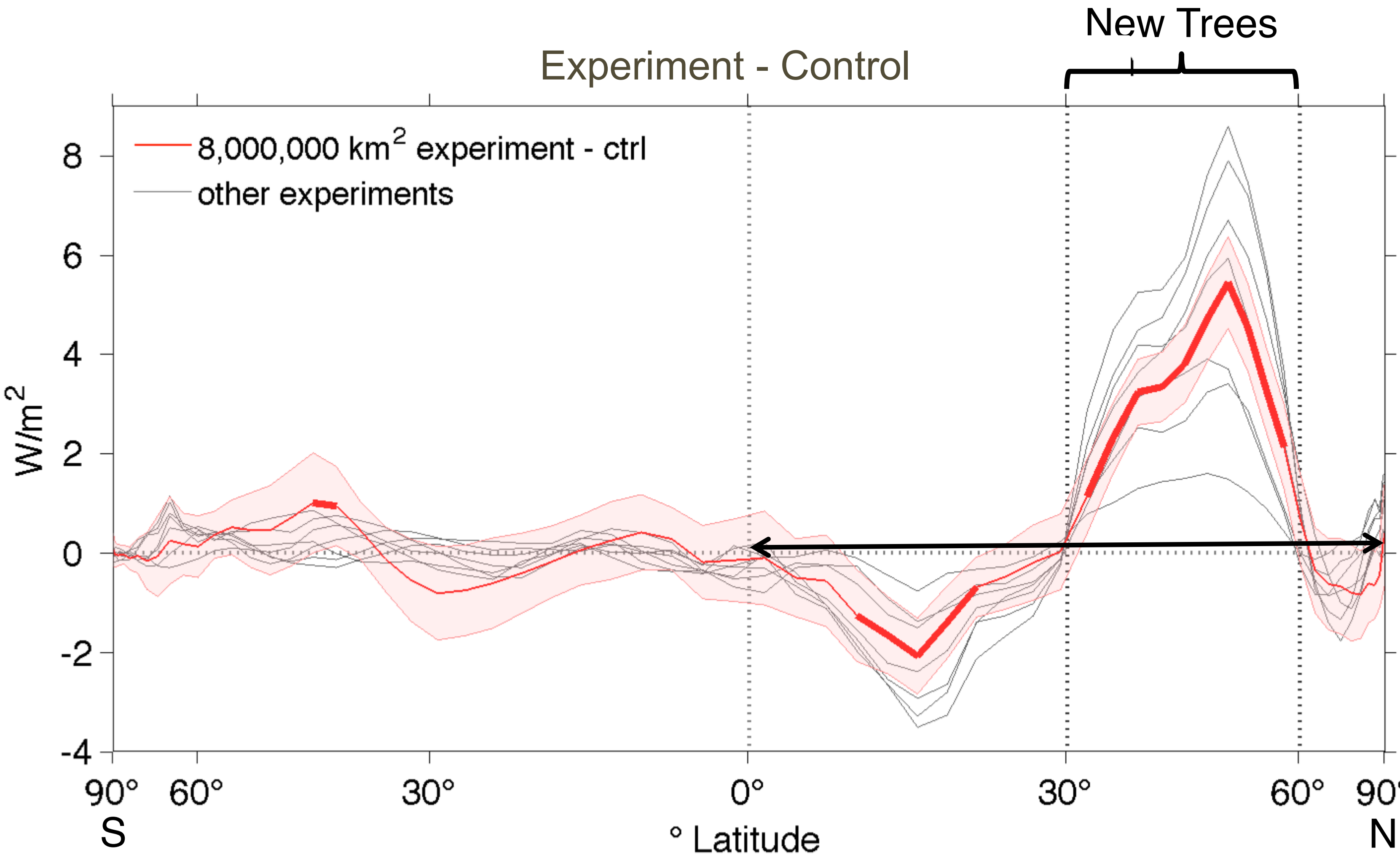
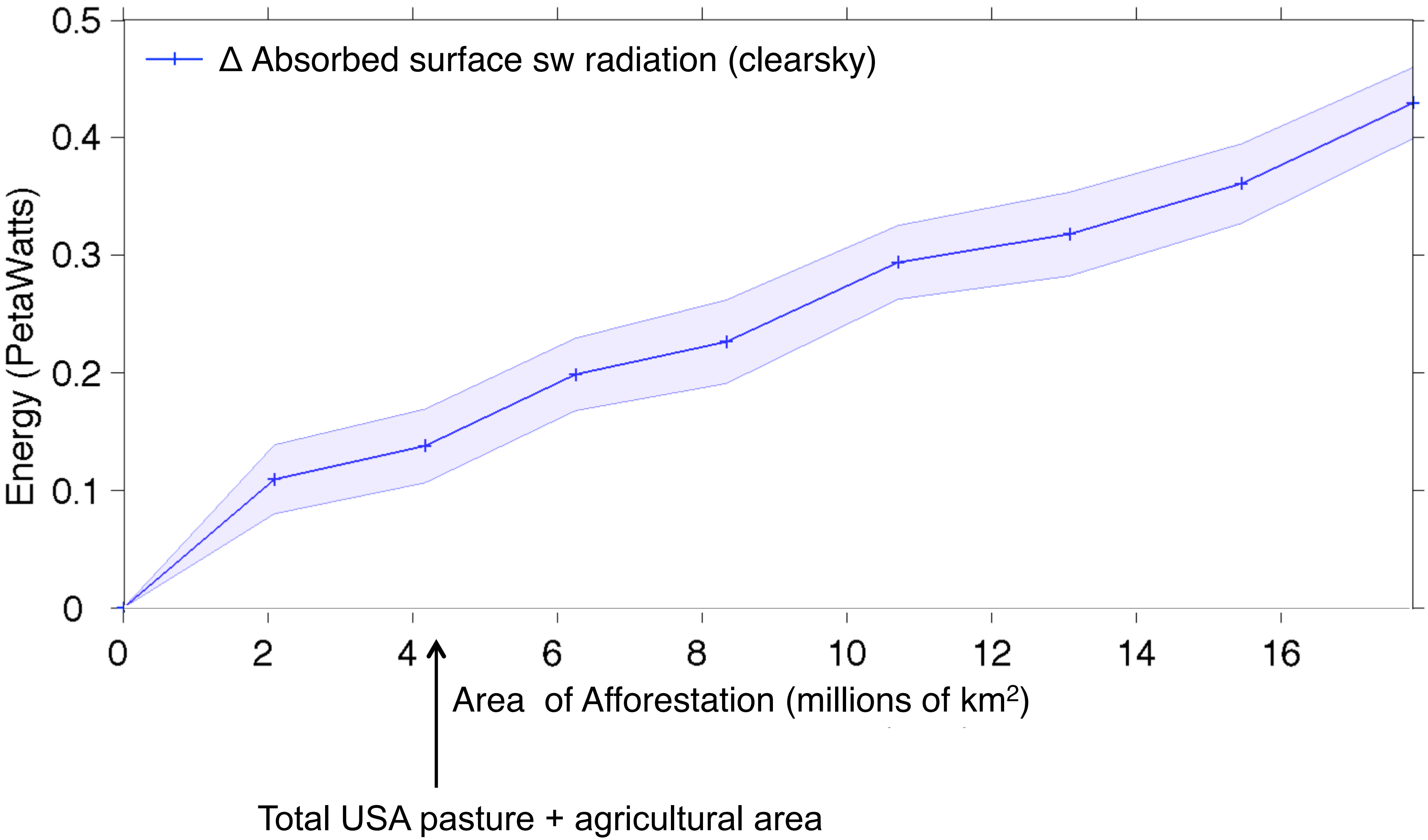
Net gain of energy in northern hemisphere is ~1/3 smaller because of tropical cloud response.



Increase in absorbed solar energy scales linearly with area of new trees.



Energy imbalance between hemispheres

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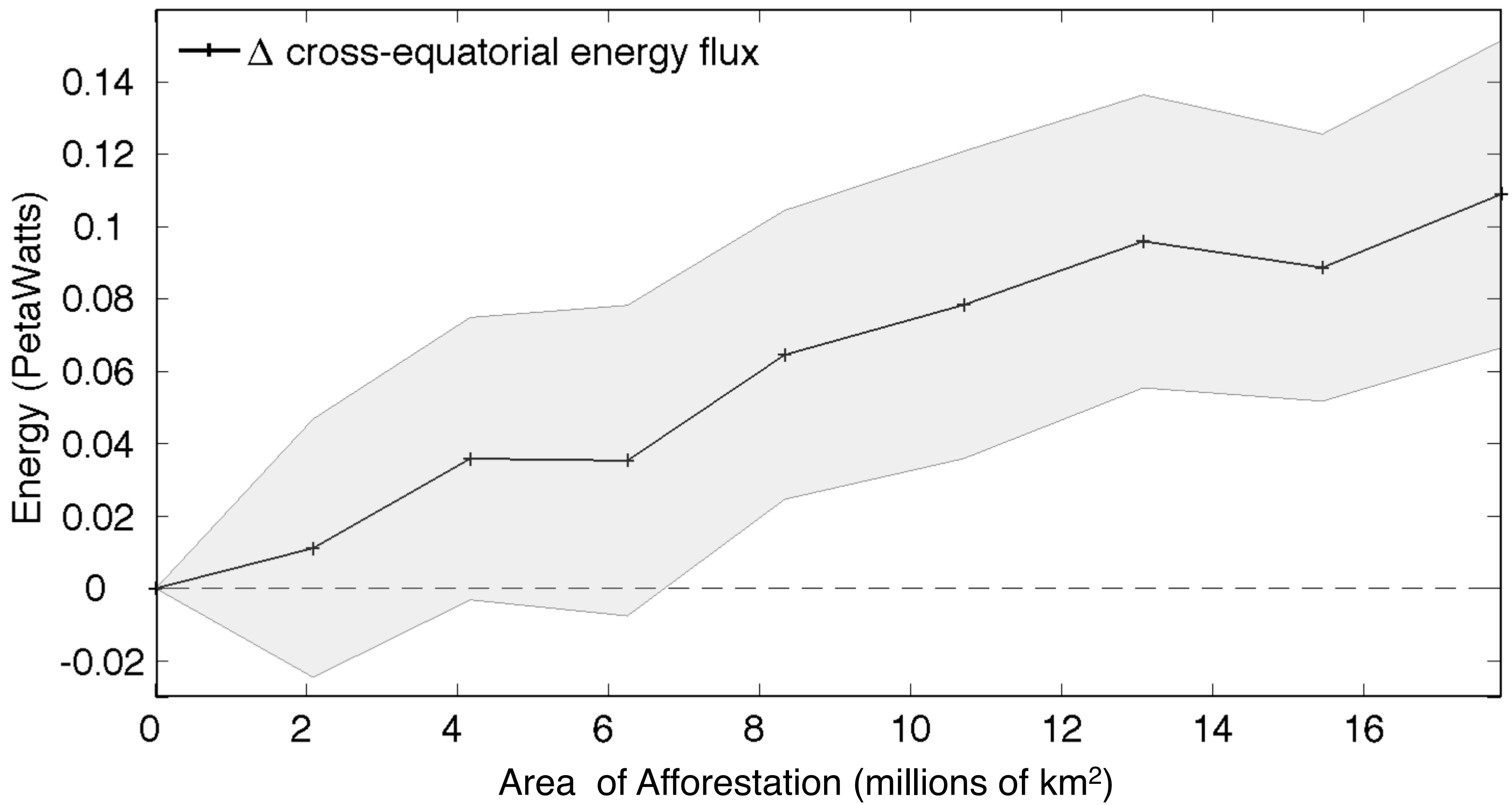
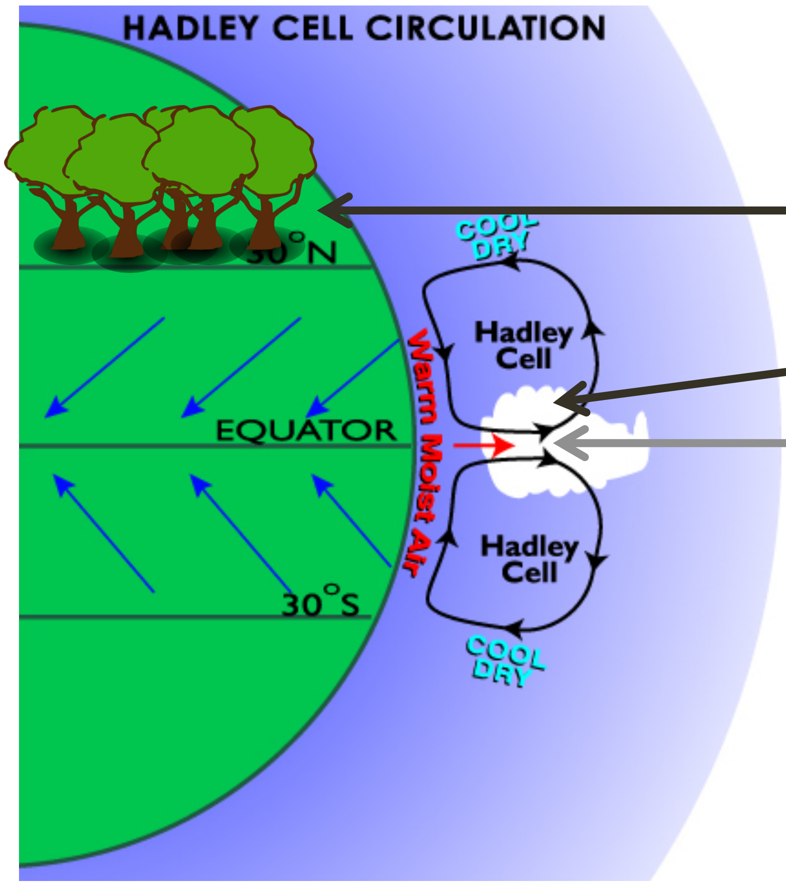
Shift in energy transport

Extra energy in northern hemisphere drives shift in cross-equatorial energy flux



Change in cross-equatorial energy flux implies a change in the Hadley circulation



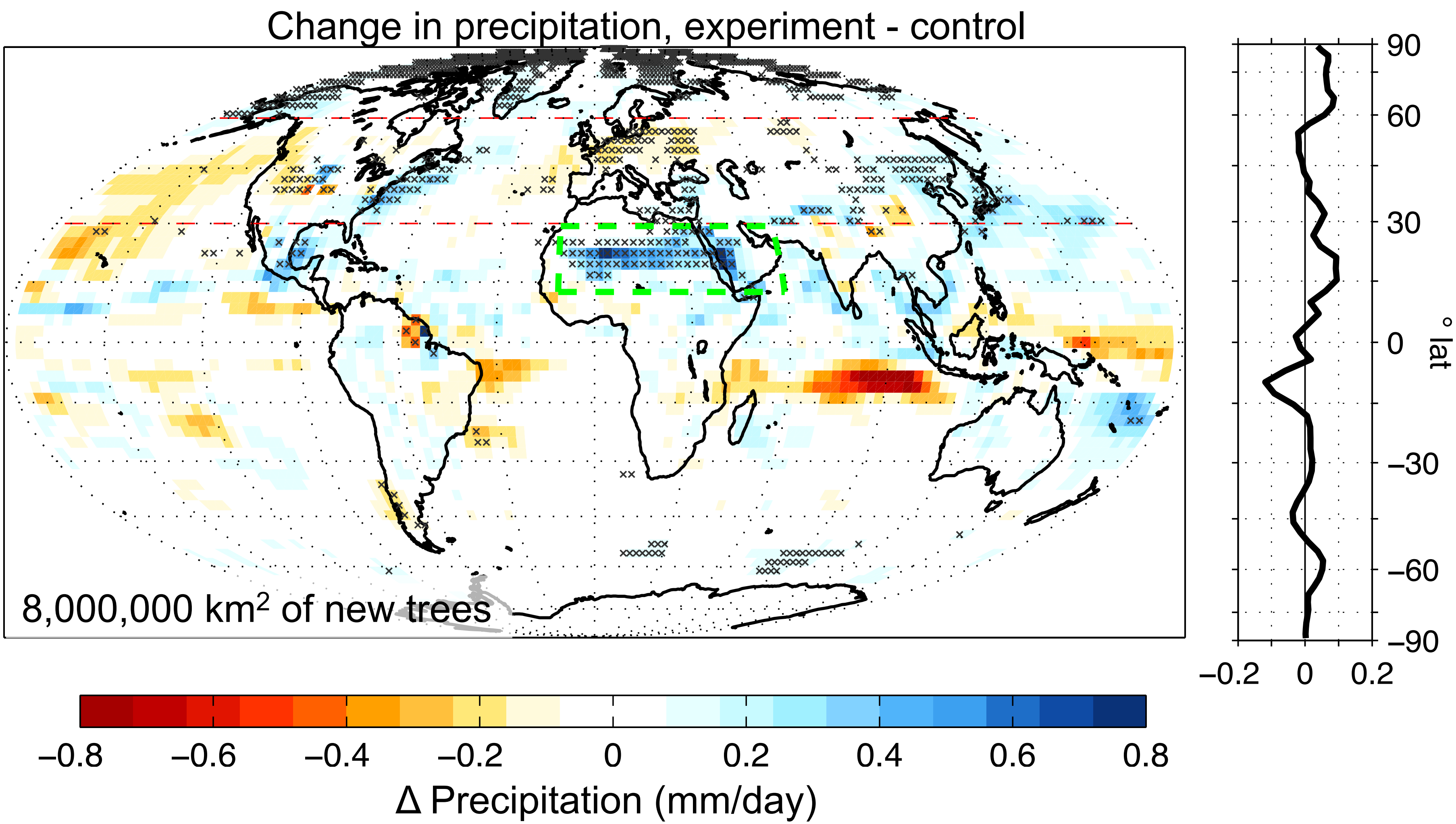
Add trees to northern mid-latitudes

ITCZ shifts northward

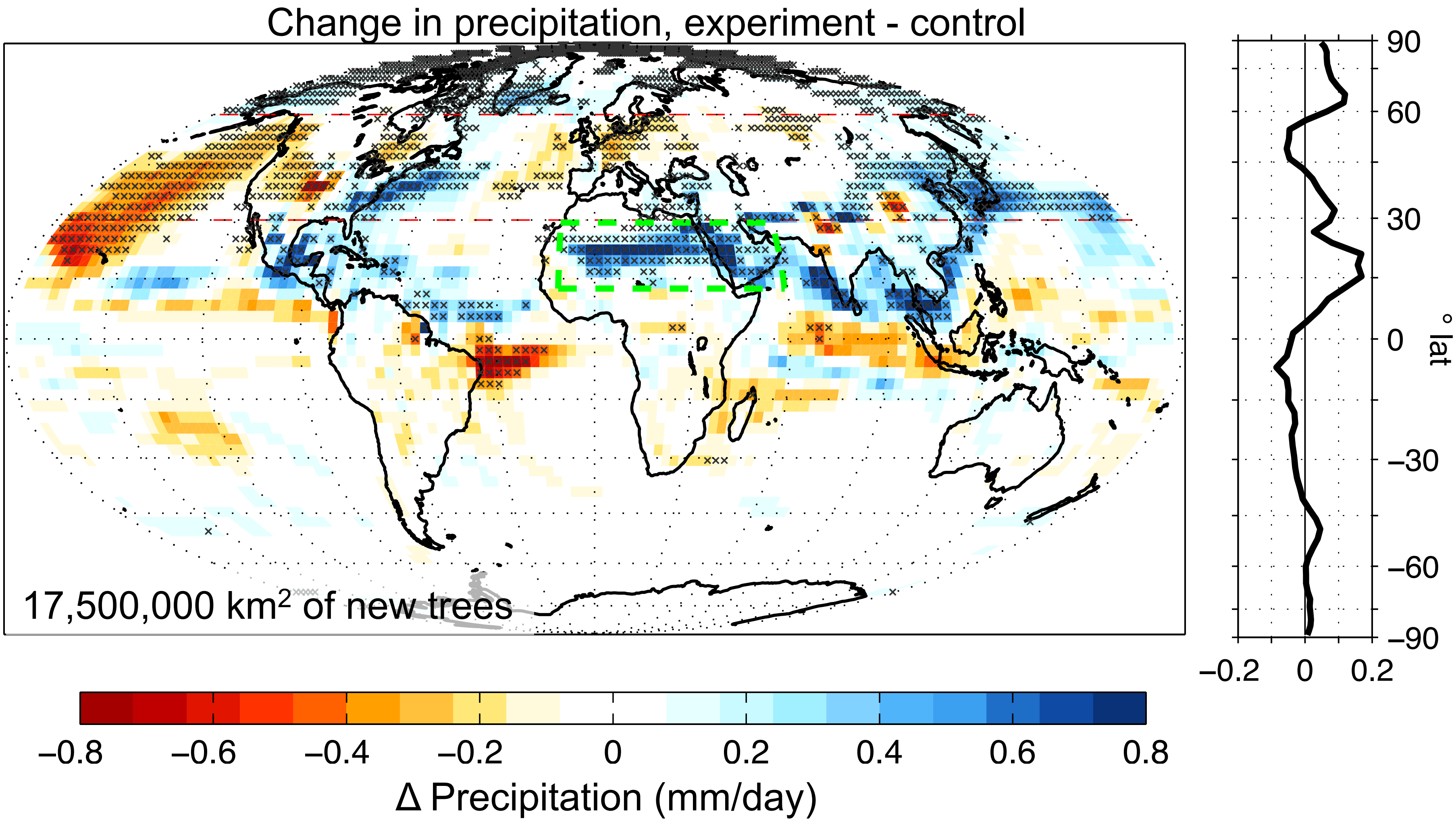
ITCZ

Swann 2012

Despite the shift in energy transport, we don't see a zonal shift in the ITCZ in weaker experiments



Big increase in precipitation over the Sahara – up to 400 mm/year. That's enough to support grass in the Sahara.



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Circulation response to incrementally larger areas of afforestation

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- Changes in energy transport are linear
- Precipitation response is **not** linear; changes in rain over the Sahara are large enough to support vegetation.

Questions?

Carbon Effects

- Most forced run: ~18,000,000 km^2 trees
- Net land uptake of ~228 PgC (this is big: total land carbon sink is on order of 2000 PgC)
- 228 PgC = 107 ppm CO_2
- BUT ocean buffering will release CO_2 in response, so the net effect on atmospheric [CO_2] is ~50 ppm (~6 ppm per experiment – not that dramatic compared to anthropogenic emissions).

Anthropogenic land use comparison:

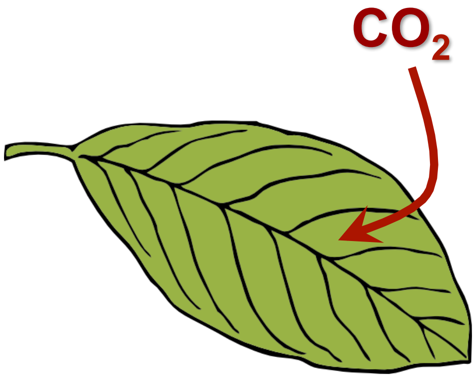
- ~ 1,940,000 km^2 of agriculture in USA
- ~ 2,480,000 km^2 grazing

Source:
EPA
(http://www.epa.gov/agriculture/ag101/landuse.html)

Climate impacts of global changes in vegetation

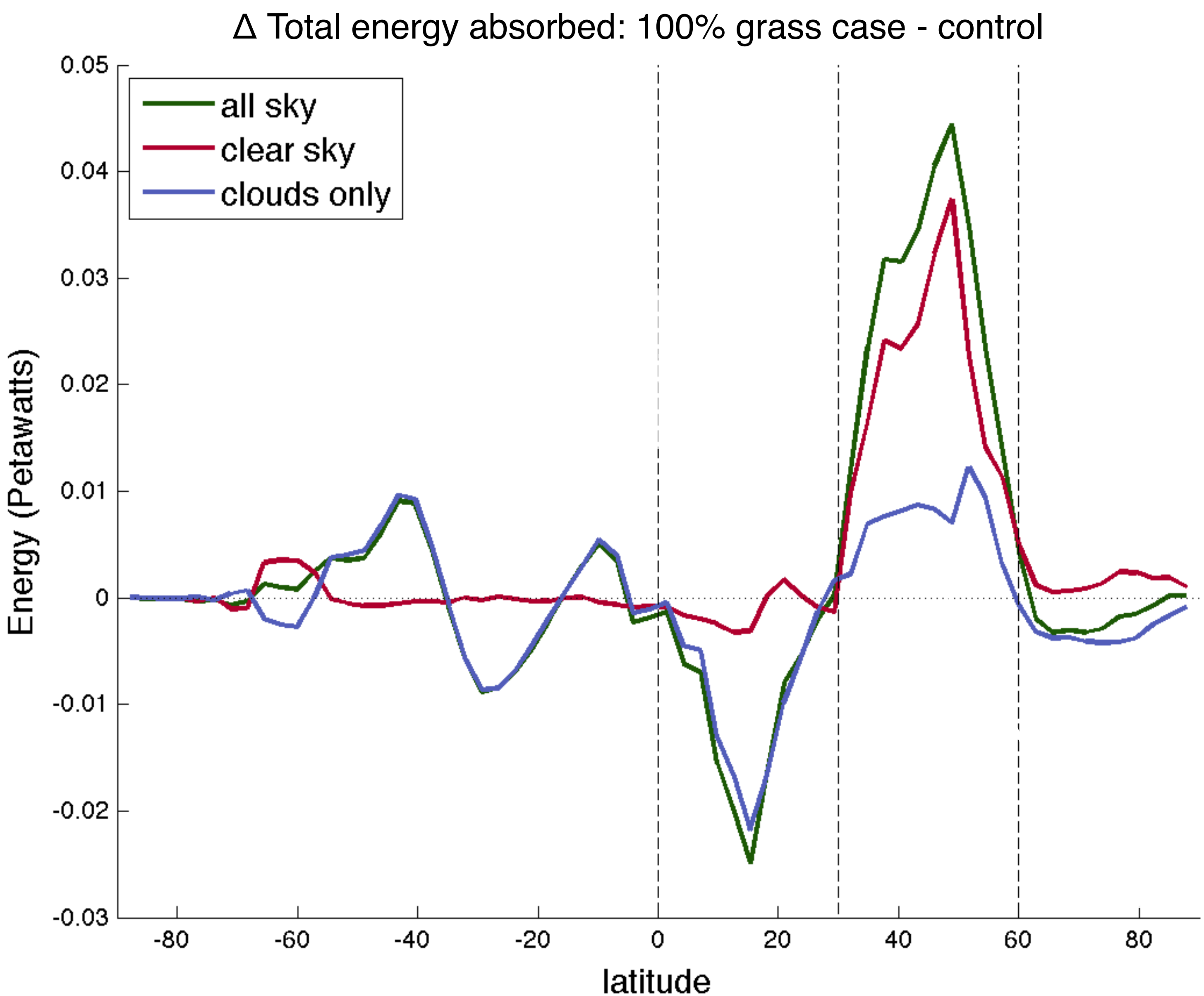
- Deforestation cools global temperatures (on global scales)
- Afforestation warms global temperatures

- Albedo effect dominates carbon-cycle effect
  - Global deforestation leads to cooling even though it releases a lot of carbon.



Bala et al., 2007; Bathiany et al. 2010

How much do the clouds compensate?



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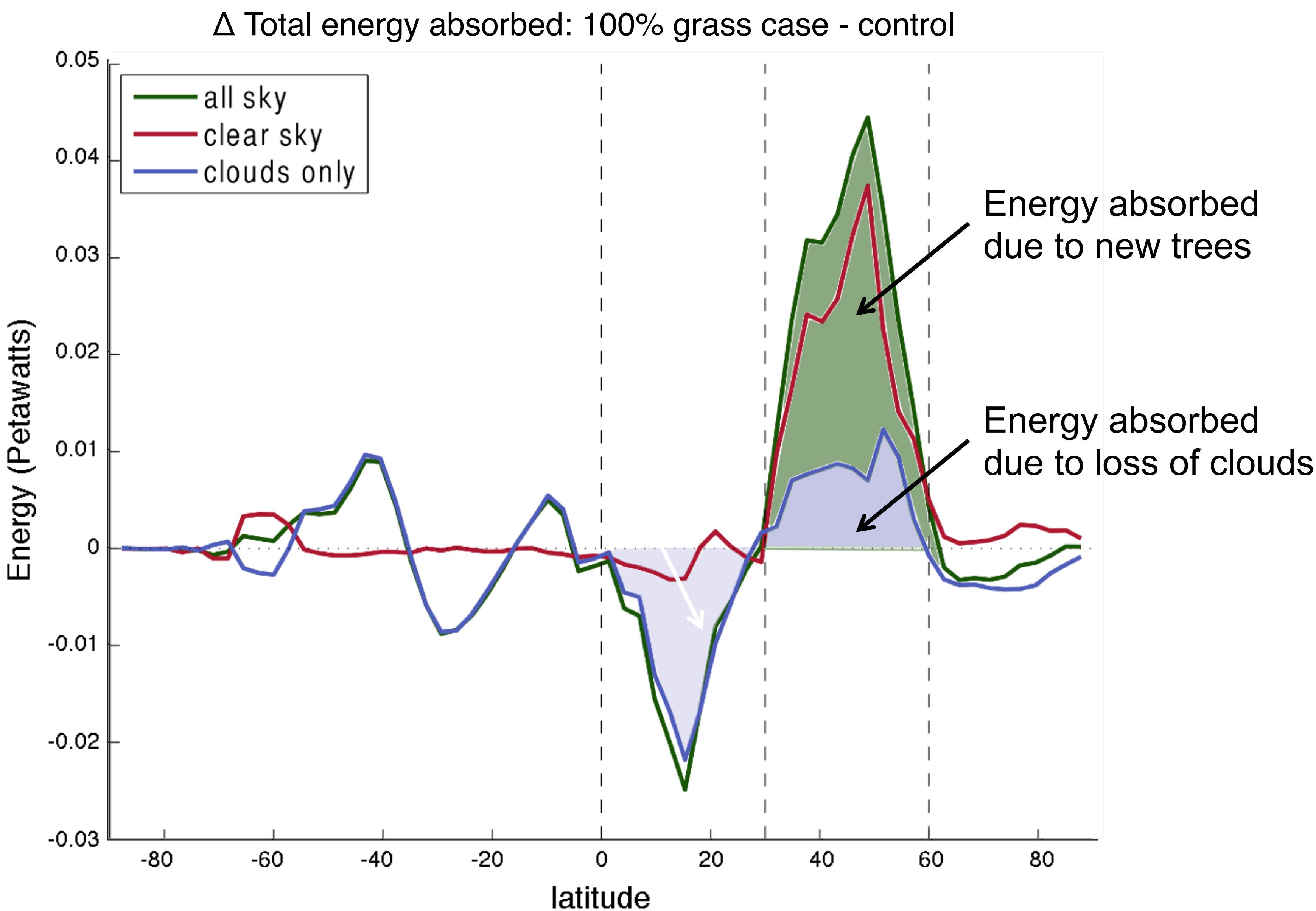
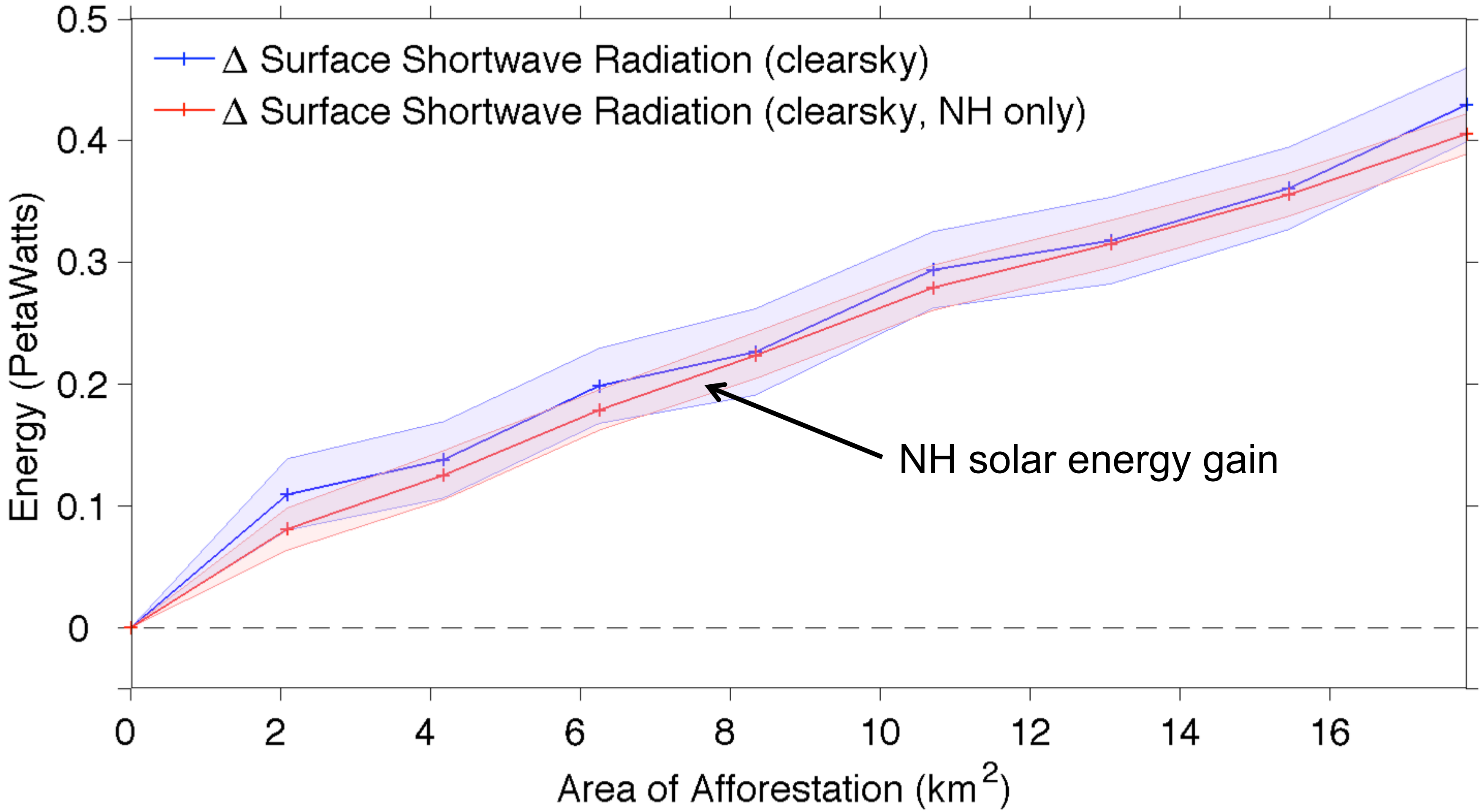
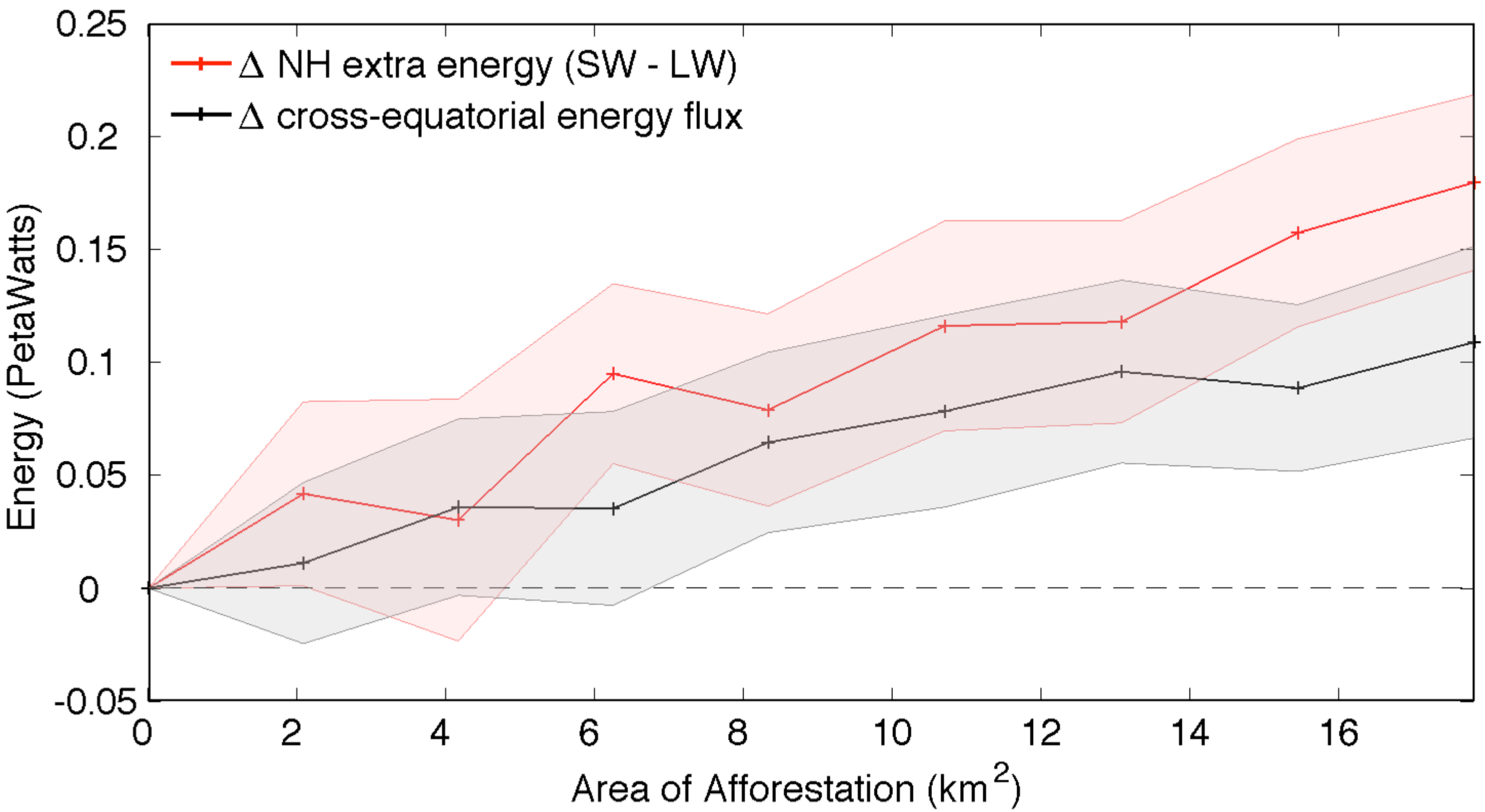


Increase in absorbed solar energy scales linearly with area of new trees.

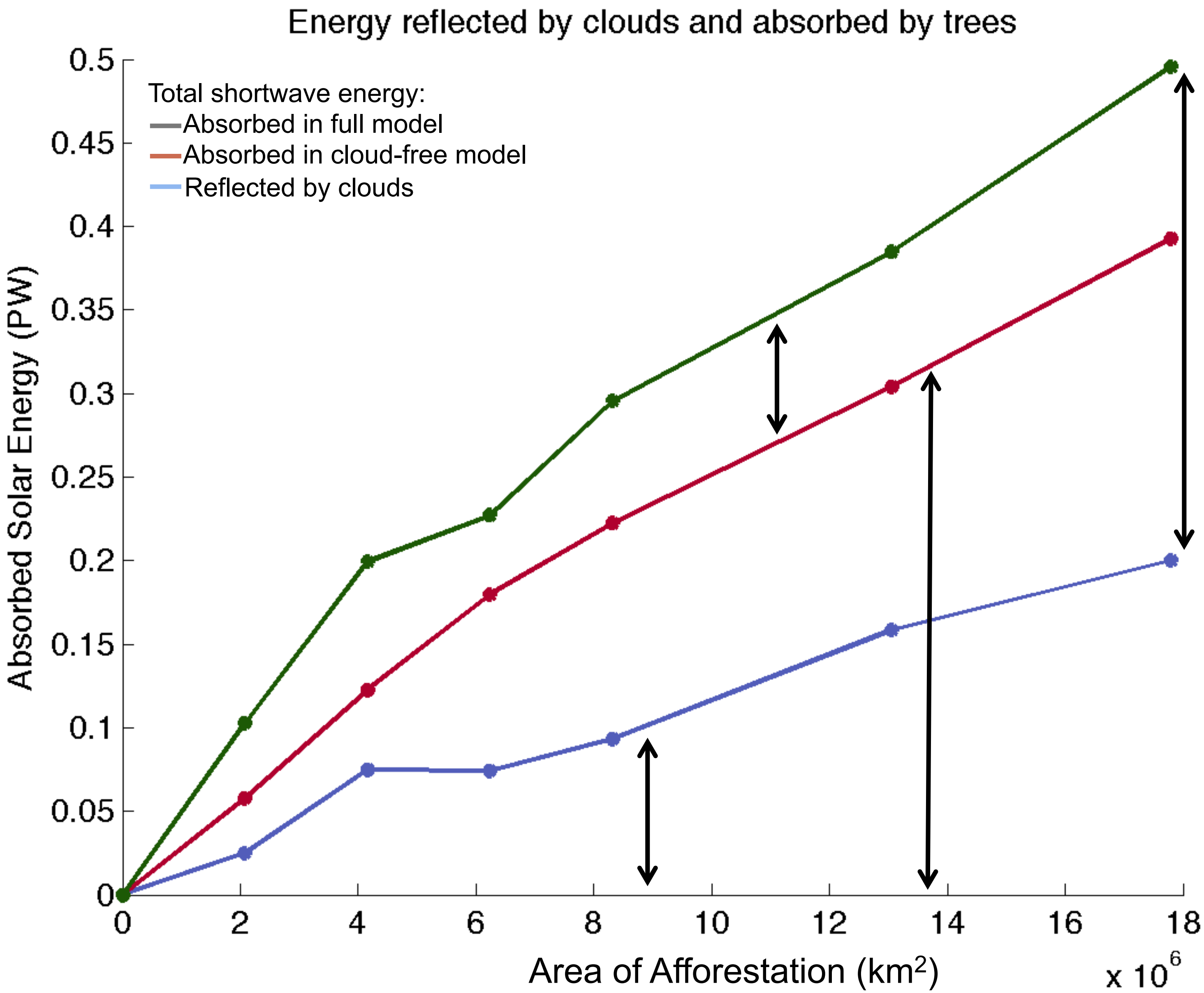


Increased energy in northern hemisphere scales linearly with area of added trees

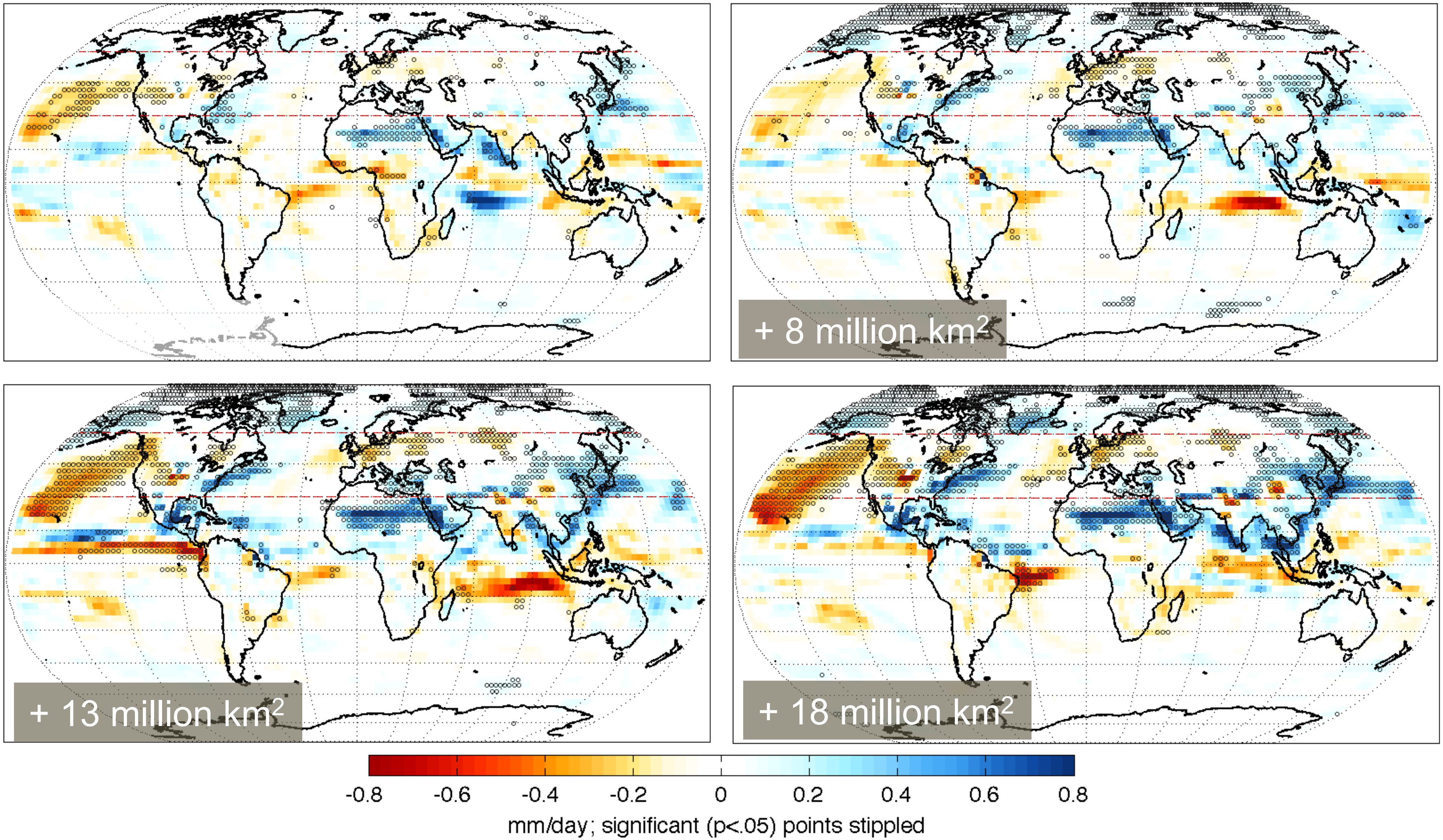


Northern hemisphere energy gain = Total shortwave radiation absorbed by NH − Total longwave radiation lost by NH

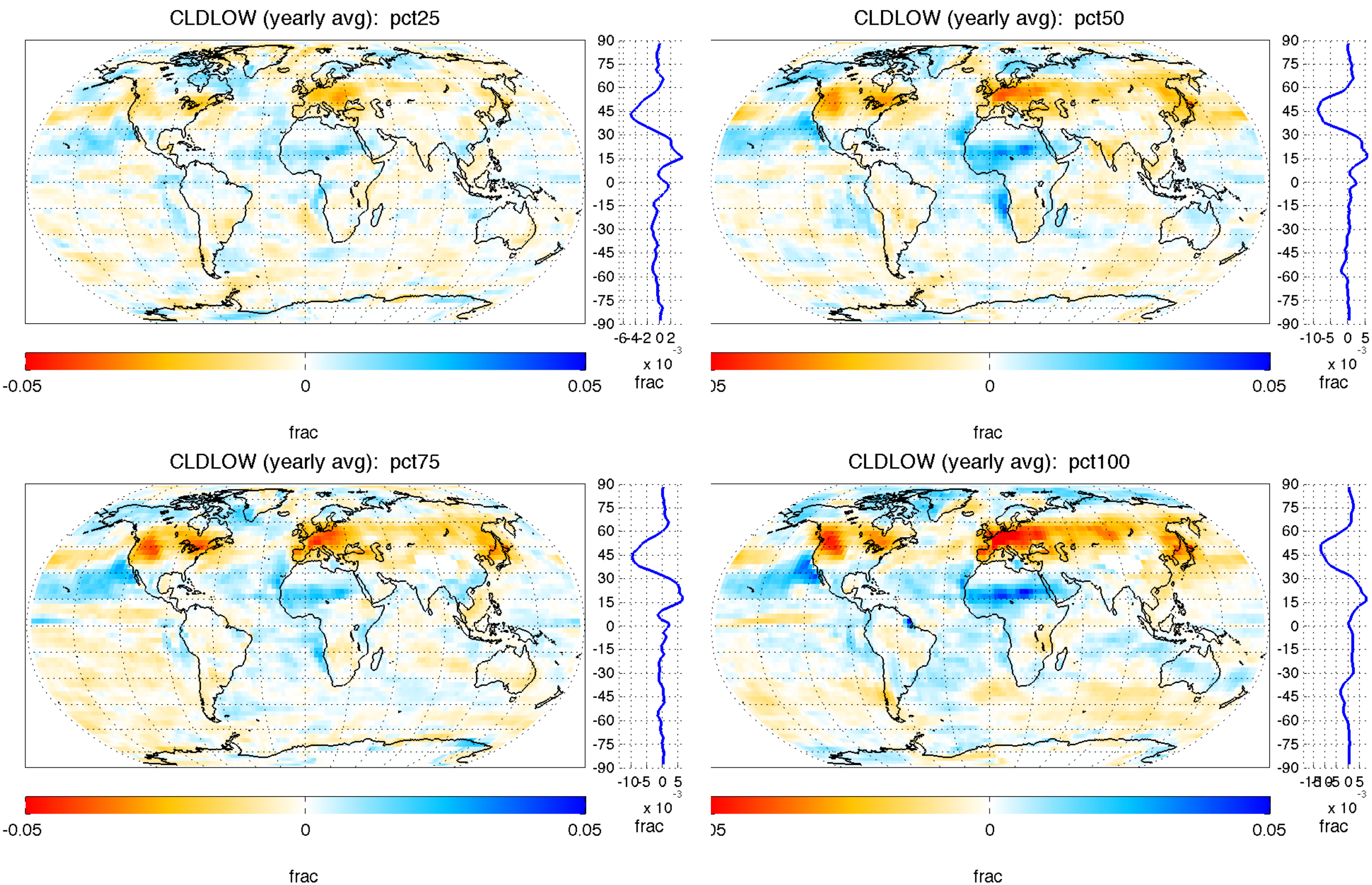
New clouds reflect ~1/3 of the energy new trees add



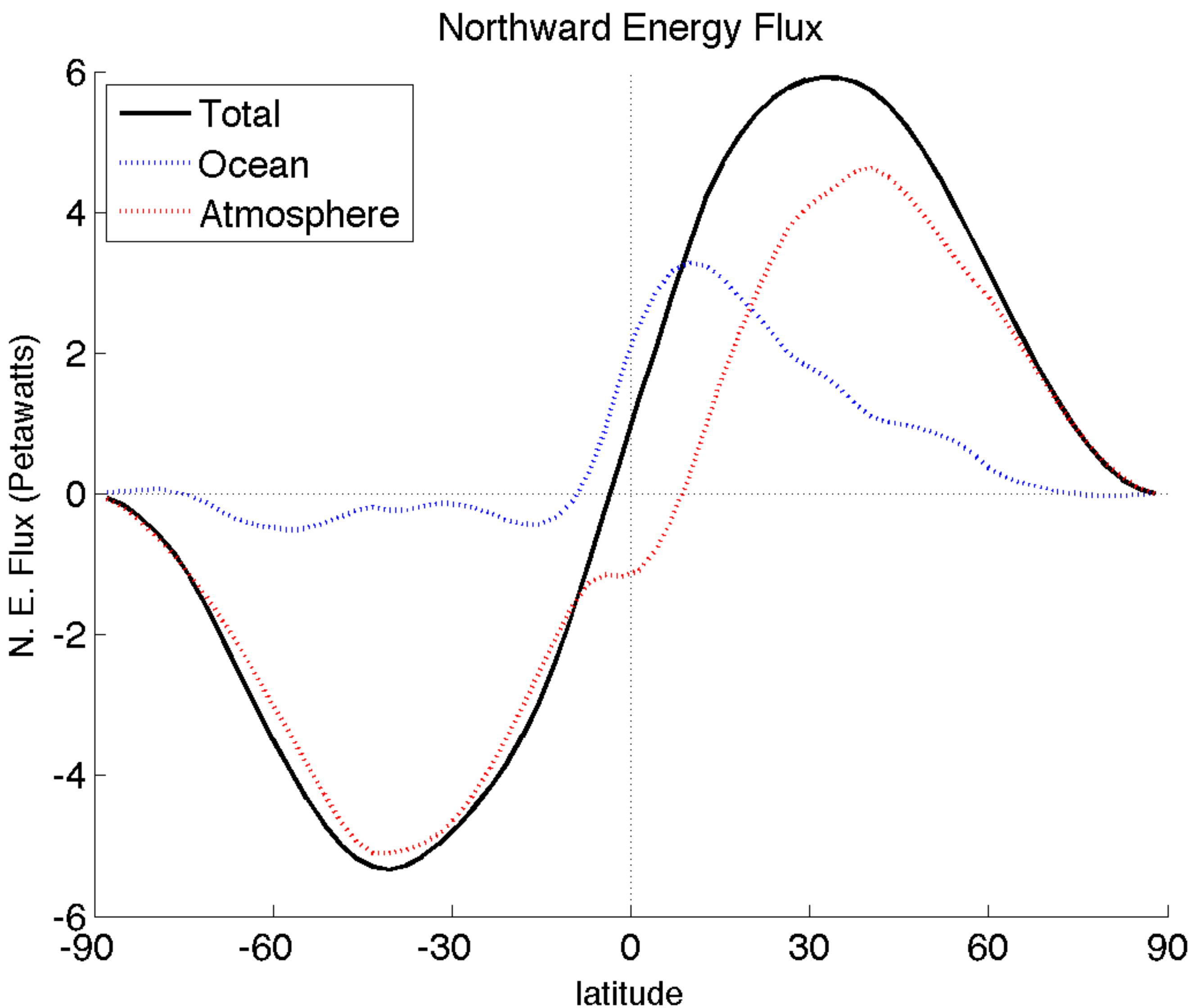
Precipitation ↑ over the Sahara in all cases; ITCZ slower to respond



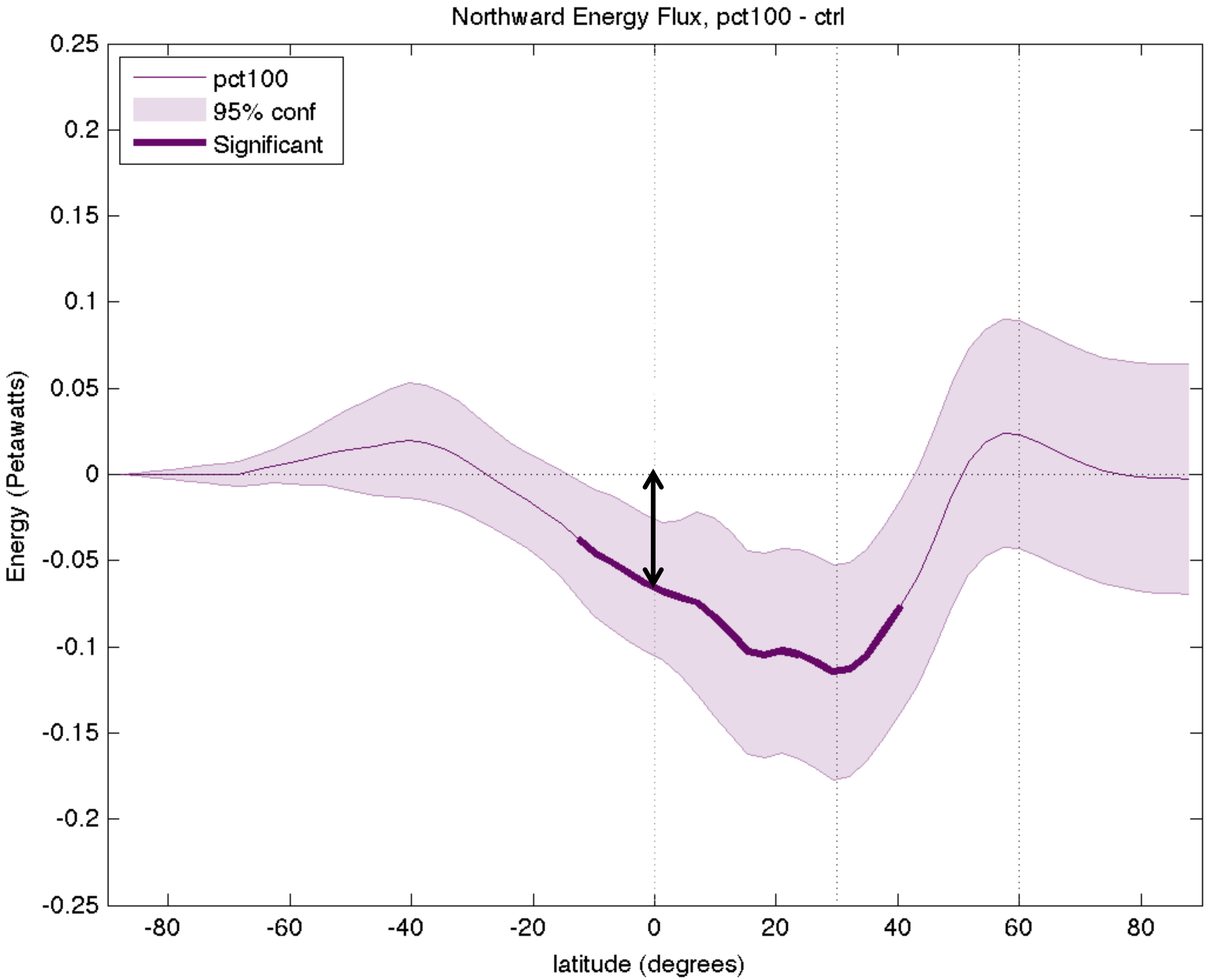
Low Cloud Fraction



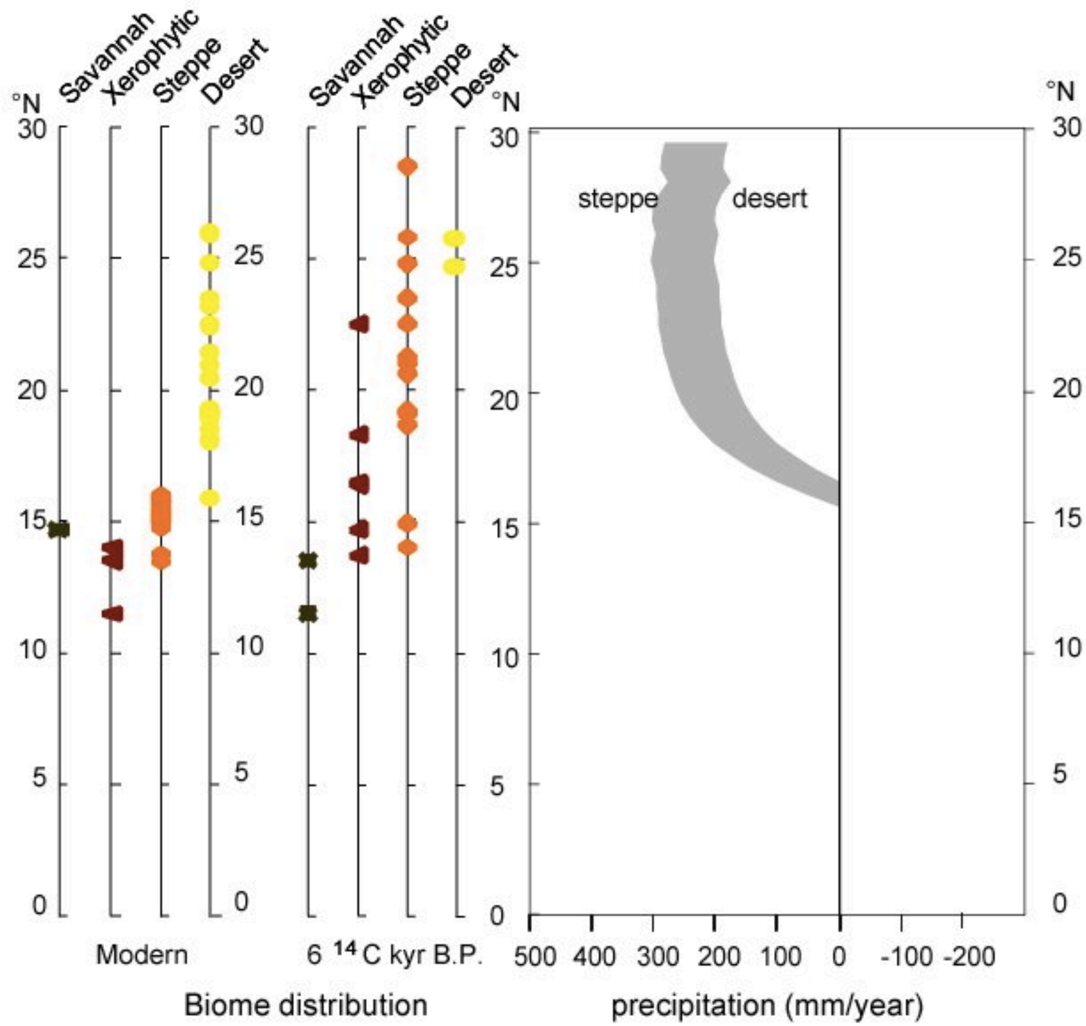
Northward energy flux broken into atmos+ocn components. Atmos "energy equator" *is* north of the equator, as we would expect from the ITCZ.



Δ Northward Energy Transport



Changes in precip are on order of 1mm/day max, or about 30 cm/year. This *is* enough to produce a change along the southern edge of the Sahara



PMIP, Joussaume et al. (1999)