Mid-Latitude Afforestation Experiments

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Changes in Arctic vegetation amplify high-latitude warming through the greenhouse effect

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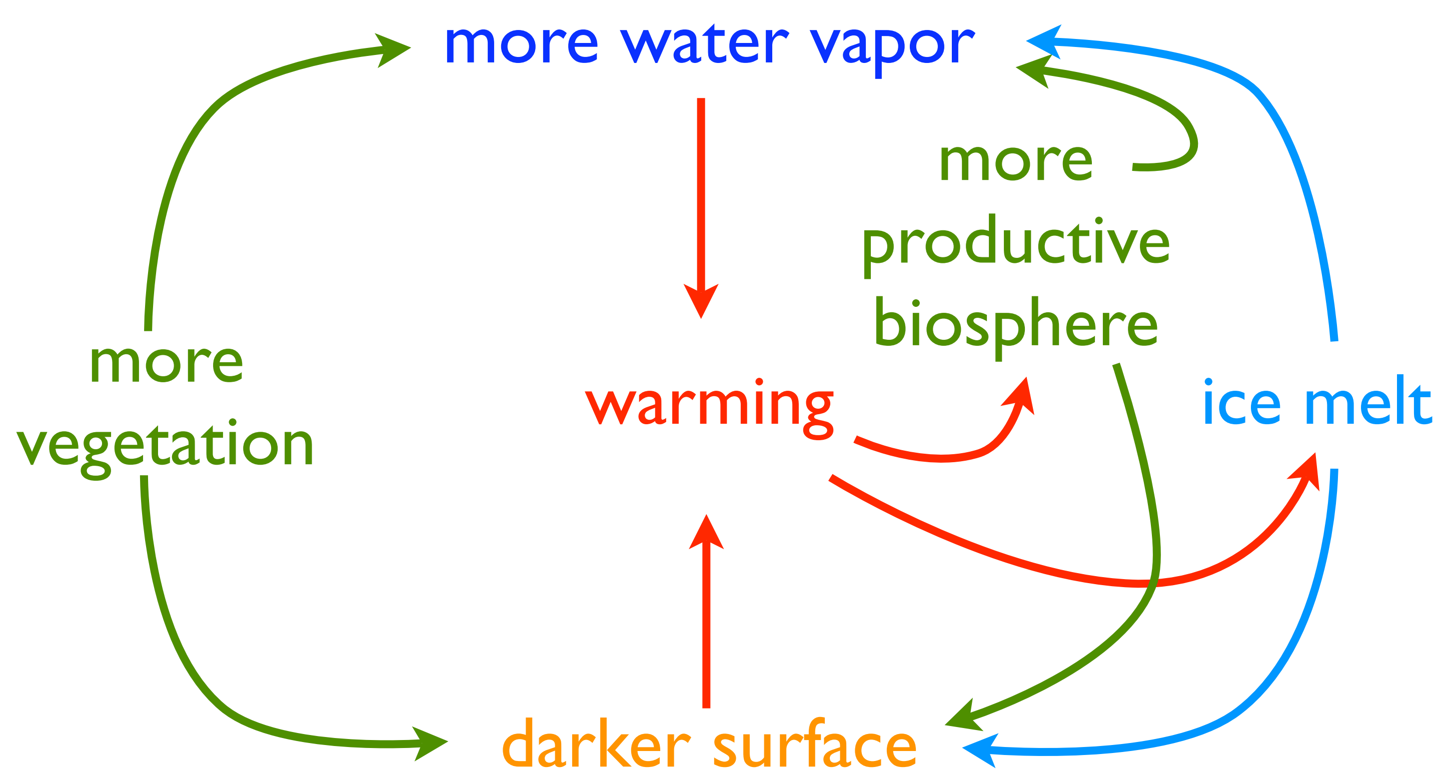
Contributed by Inez Y. Fung, December 4, 2009 (sent for review October 20, 2009)

Arctic climate is projected to change dramatically in the next 100 years and increases in temperature will likely lead to changes in the distribution and makeup of the Arctic biosphere. A largely deciduous ecosystem has been suggested as a possible landscape for future Arctic vegetation and is seen in paleo-records of warm times in the past. Here we use a global climate model with an interactive terrestrial biosphere to investigate the effects of adding deciduous trees on bare ground at high northern latitudes. We find that the top-of-atmosphere radiative imbalance from enhanced transpiration (associated with the expanded forest cover) is up to 1.5 times larger than the forcing due to albedo change from the forest. Furthermore, the greenhouse warming by additional water vapor melts sea-ice and triggers a positive feedback through changes in ocean albedo and evaporation. Land surface albedo change is considered to be the dominant mechanism by which trees directly modify climate at high-latitudes, but our findings suggest an additional mechanism through transpiration of water vapor and feedbacks from the ocean and sea-ice.

biosphere-atmosphere interaction | climate feedback | radiative forcing | sea-ice | deciduous



News Release

Printer-Friendly

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FOR IMMEDIATE RELEASE
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Poplar tree genome holds promise of breakthrough in biofuel research

JGI DOE JOINT GENOME INSTITUTE US DEPARTMENT OF ENERGY OFFICE OF SCIENCE

WALNUT CREEK, Calif. — Wood from a common tree may one day factor prominently in meeting transportation fuel needs, according to scientists whose research on the fast-growing poplar tree is featured on the cover of the Sept. 15 edition of the journal *Science*.

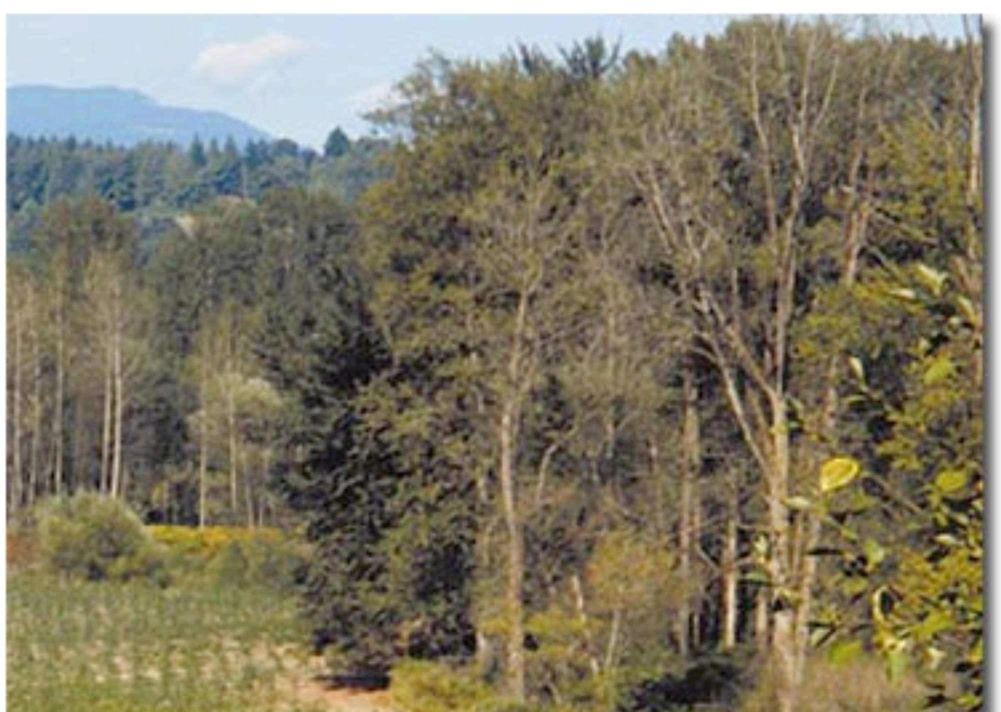
More Information

"The Genome of Black Cottonwood, *Populus trichocarpa*" (abstract)
Science, Sept. 15, 2006

"Poplar Tree Sequence Yields Genome Double Take"(subscription required)
Science, Sept. 15, 2006

International *Populus* Genome Consortium

DOE Joint Genome Institute



The North American black cottonwood *Populus trichocarpa*, a popular subject of commercial and ecological studies, was chosen as the first woody perennial plant to have its DNA sequence decoded by the DOE Joint Genome Institute because of its relatively compact genome, making it an ideal model system for

The article, highlighting the ana
first complete DNA sequence o
black cottonwood, or *Populus tr*
lays the groundwork that may le
development of trees as an idea
for a new generation of biofuels
cellulosic ethanol. The research
of a four-year scientific and tech
led by the U.S. Department of E
Genome Institute (DOE JGI) and
National Laboratory (ORNL) an
efforts of 34 institutions from aro
world, including the University o
Columbia and Genome Canada
Science Centre in Sweden; and
University in Belgium.

"Biofuels could provide a major
our energy needs by giving the
a homegrown, environmentally
alternative to imported oil," said
secretary for Science, Dr. Raym
Orbach. "Fine-tuning plants for
production is one of the keys to making
biofuels economically viable and cost-

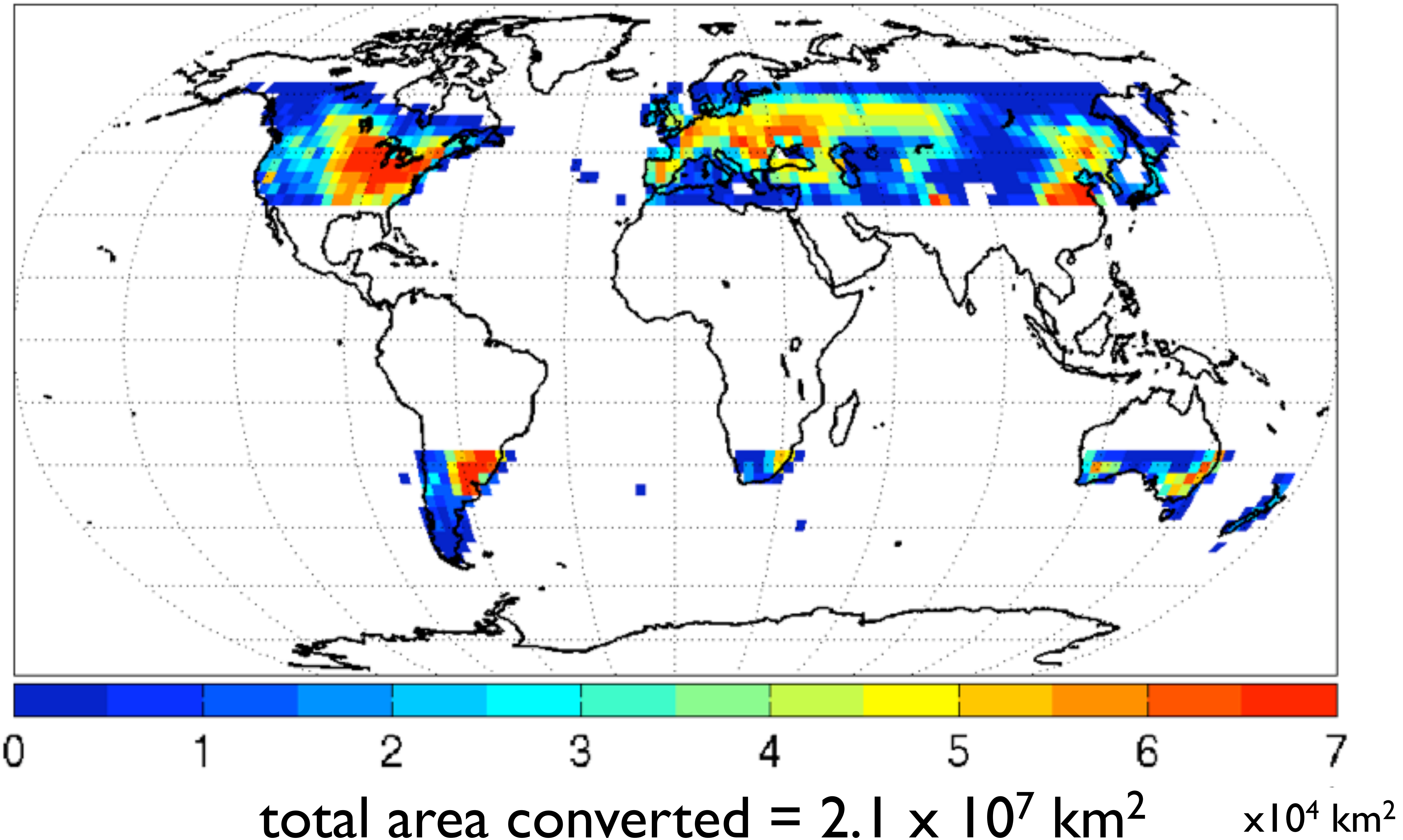
Mid Latitude Afforestation Experiments

model set up:
CAM 3 + CLM 3.5 + CASA'
slab ocean model
30 year runs, ave of last 20

convert all
C3 grass + crop =>Broad-leaf deciduous trees

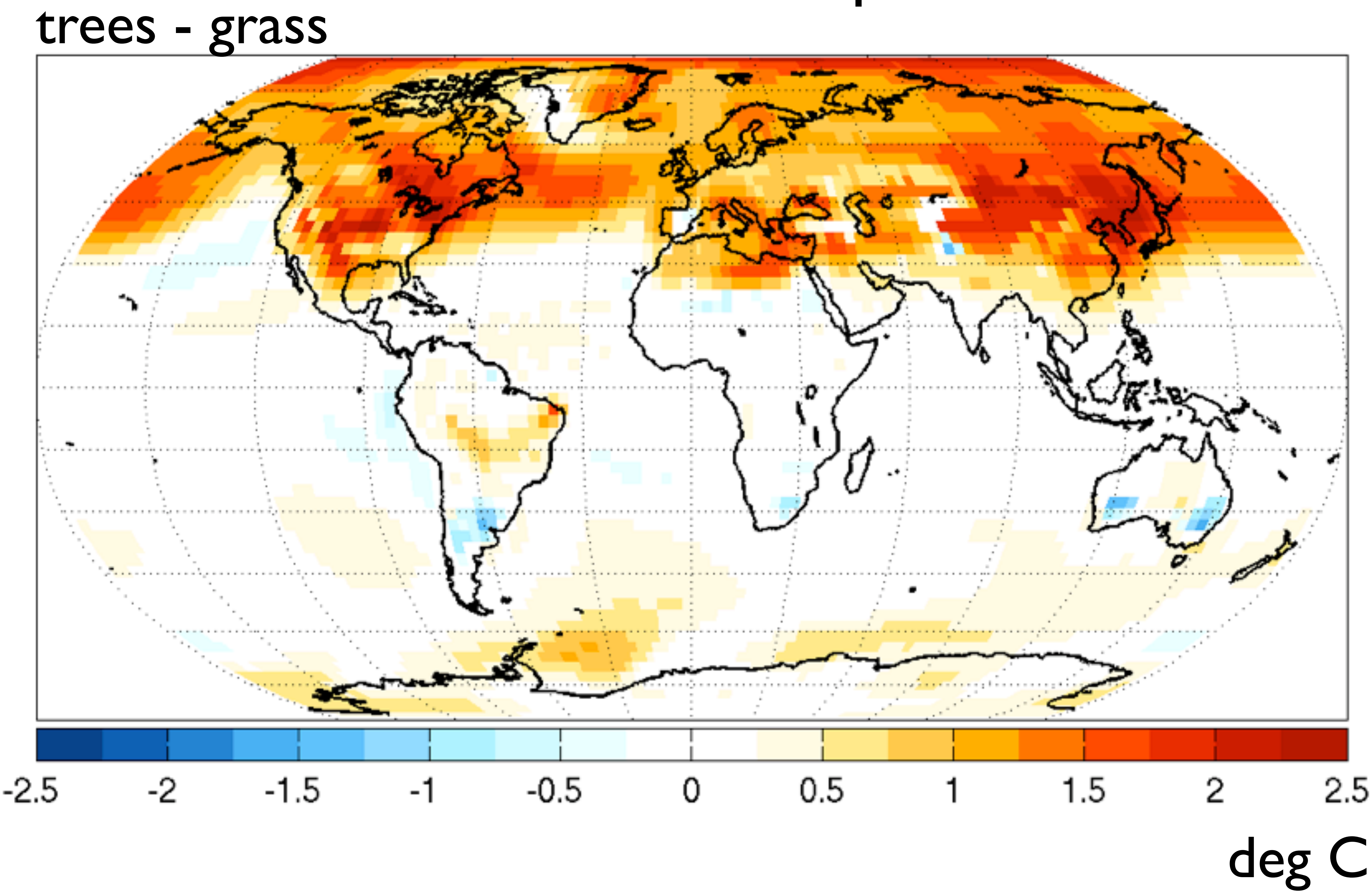
CASA' provides prognostic leaf area & biogeochem

grass + crops => deciduous trees



total area converted = 2.1×10^7 km^2

Delta Near Surf. Temperature

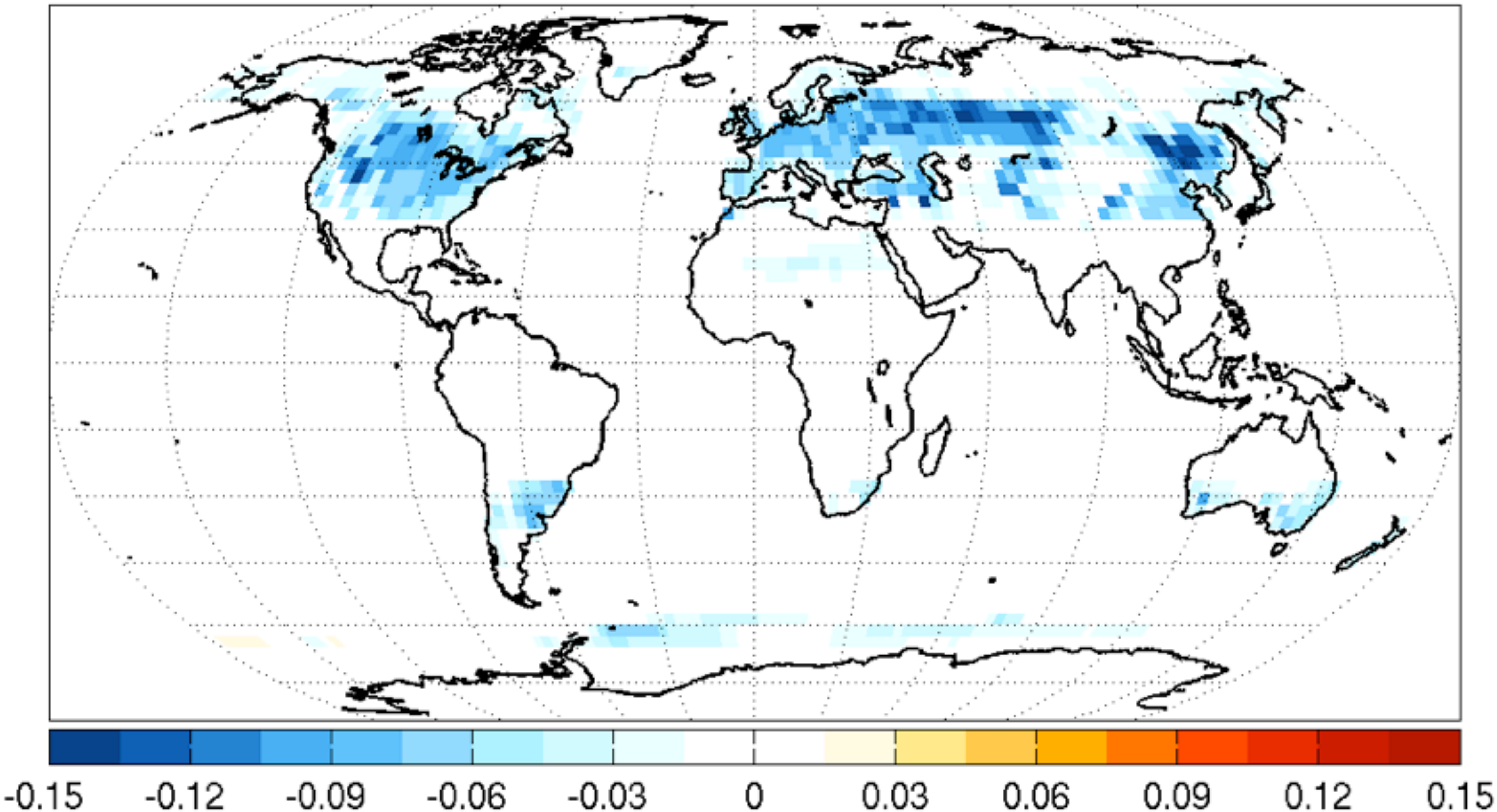


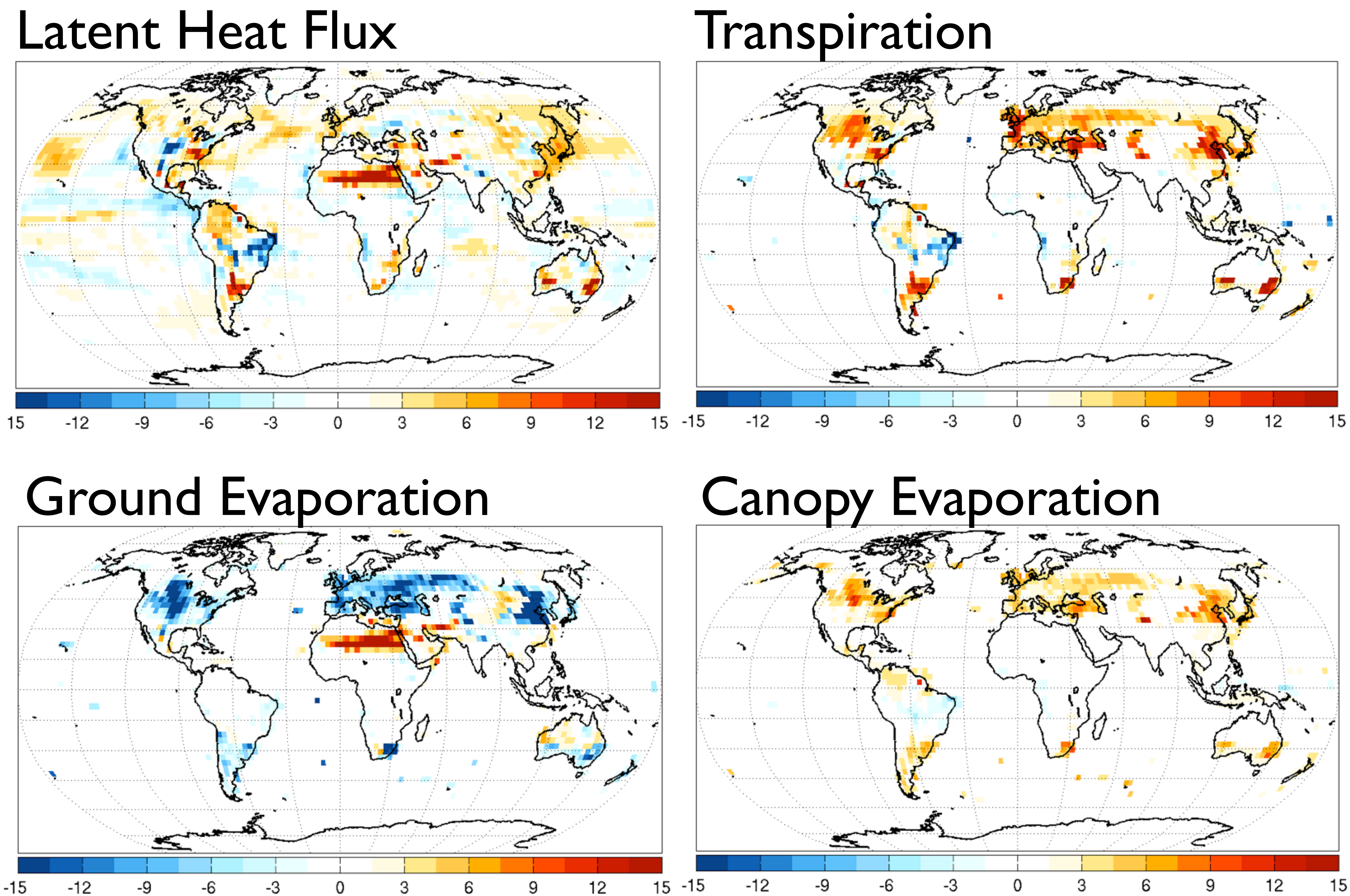
grass vs. deciduous trees

- trees are darker than grass
- trees are taller than grass
- higher productivity =>higher transpiration
- total latent heat flux difference?

Delta Albedo

trees - grass





trees - grass

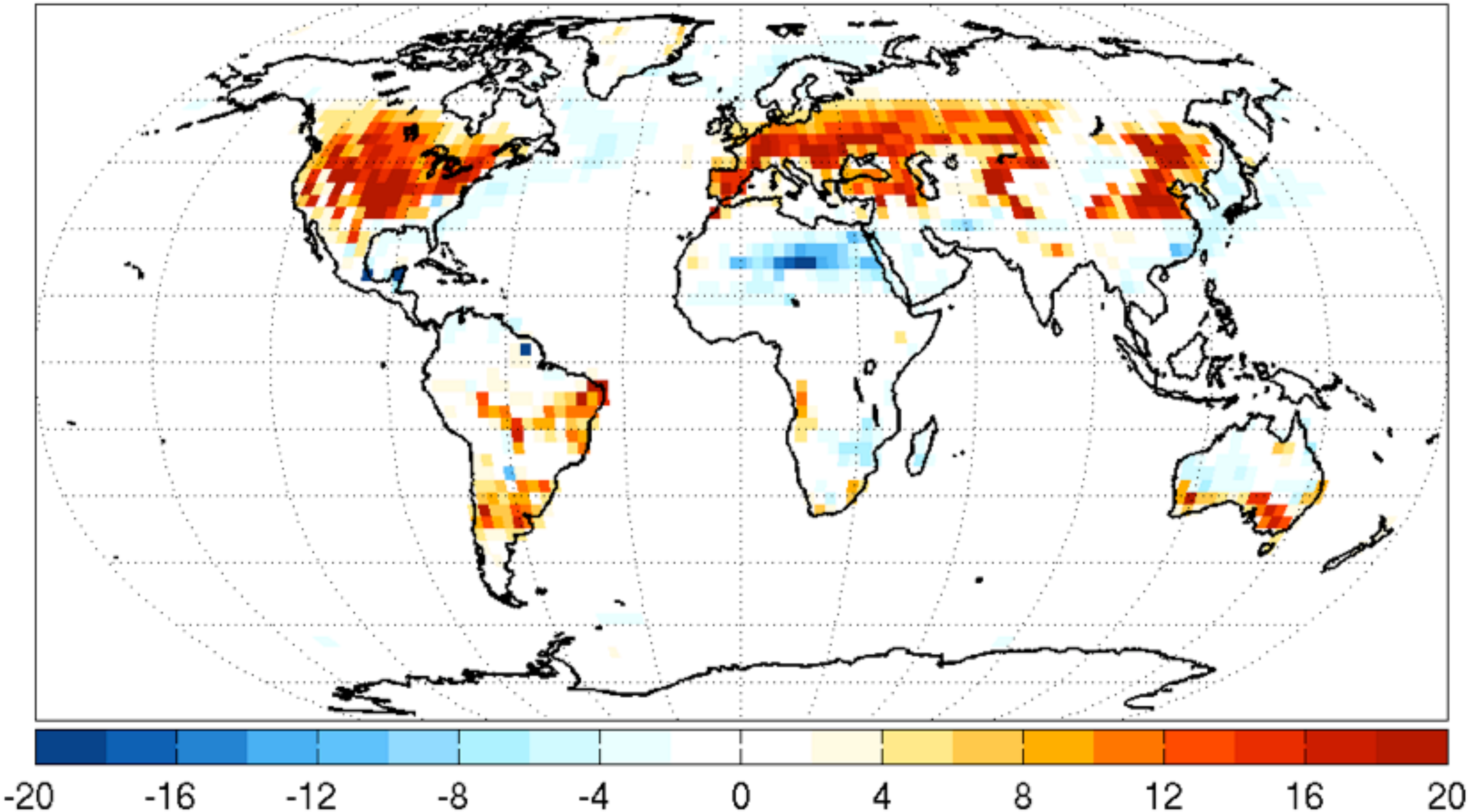
Wm^{-2}

Impact on the Hydrologic Cycle

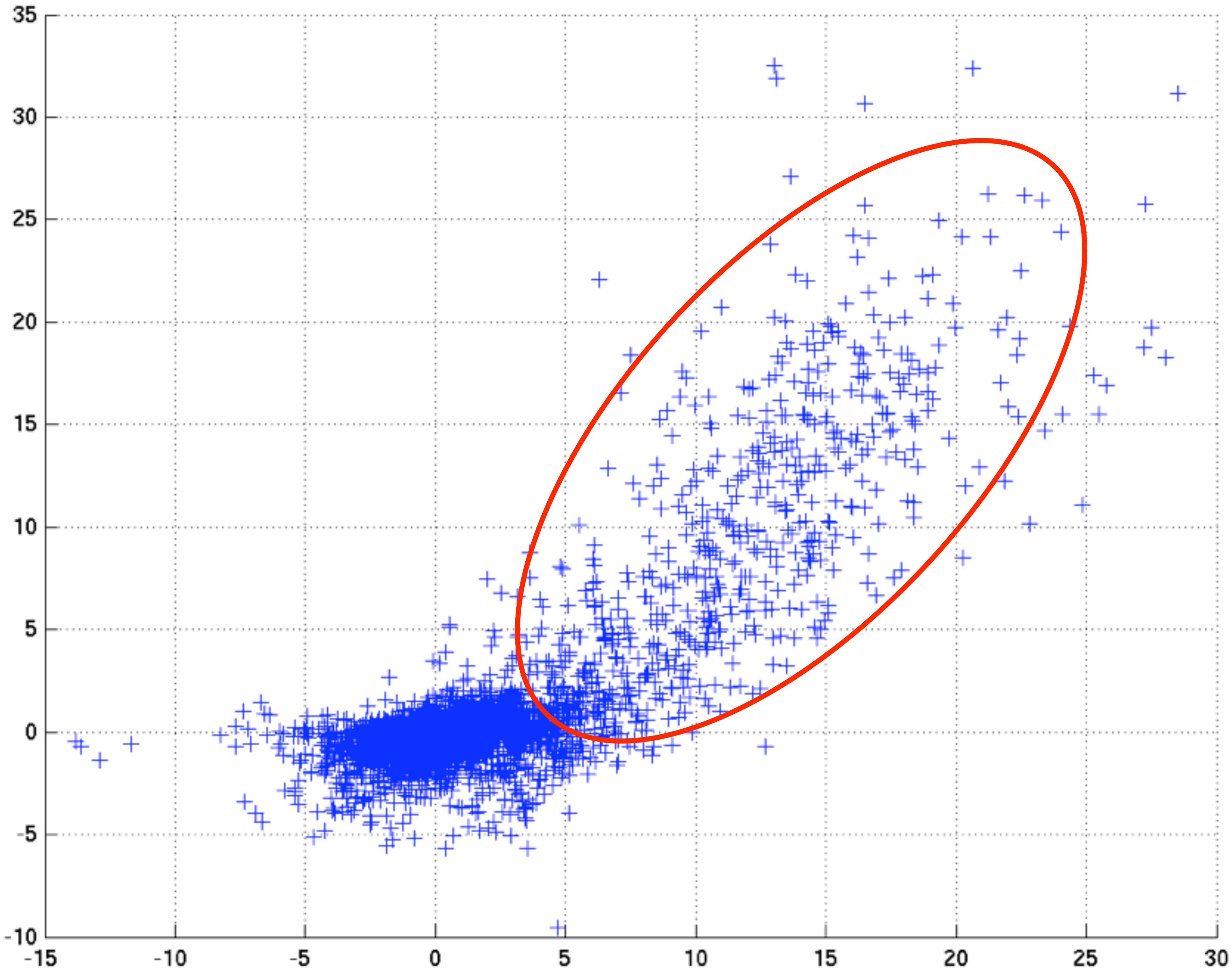
- latent heat flux somewhat difficult to interpret
- looks like transpiration is balanced by ground evap so the net lhflx is near zero
- precipitation follows latent heat flux + circulation changes

Delta Sensible Heat Flux

trees - grass



Sensible Heat fluxes balance SW absorbed



delta Sensible Heat

delta SW absorbed

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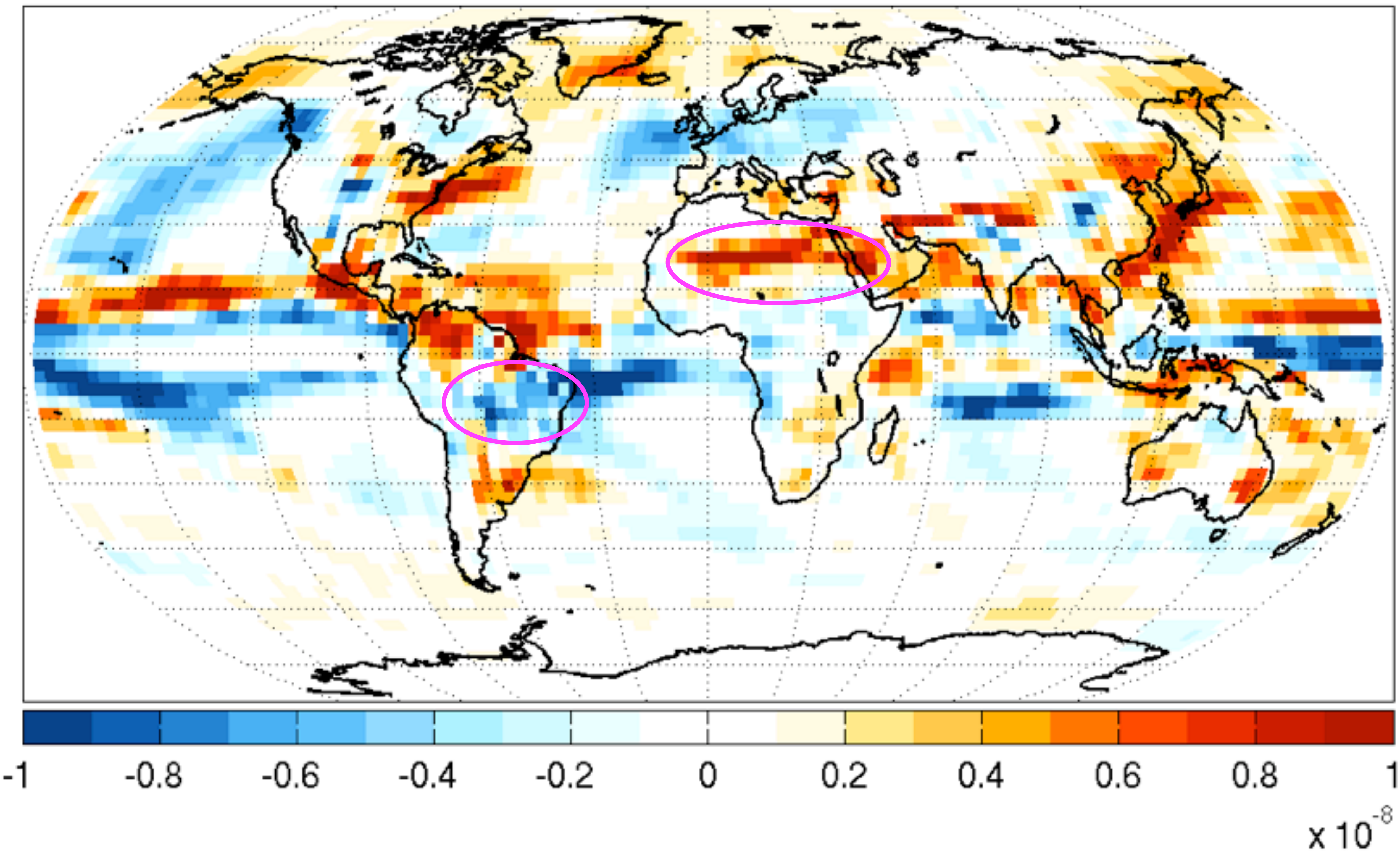
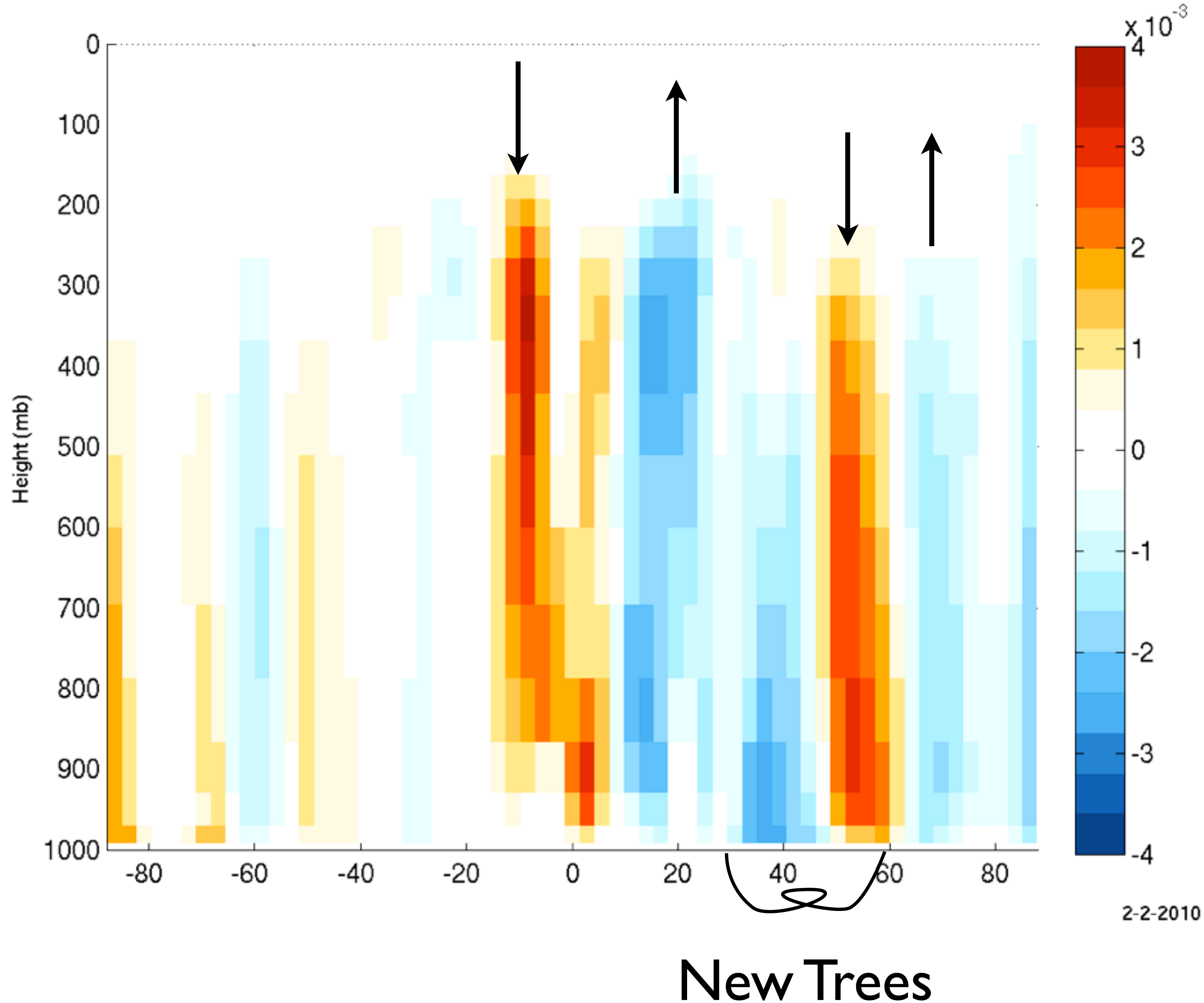
Delta Precipitation

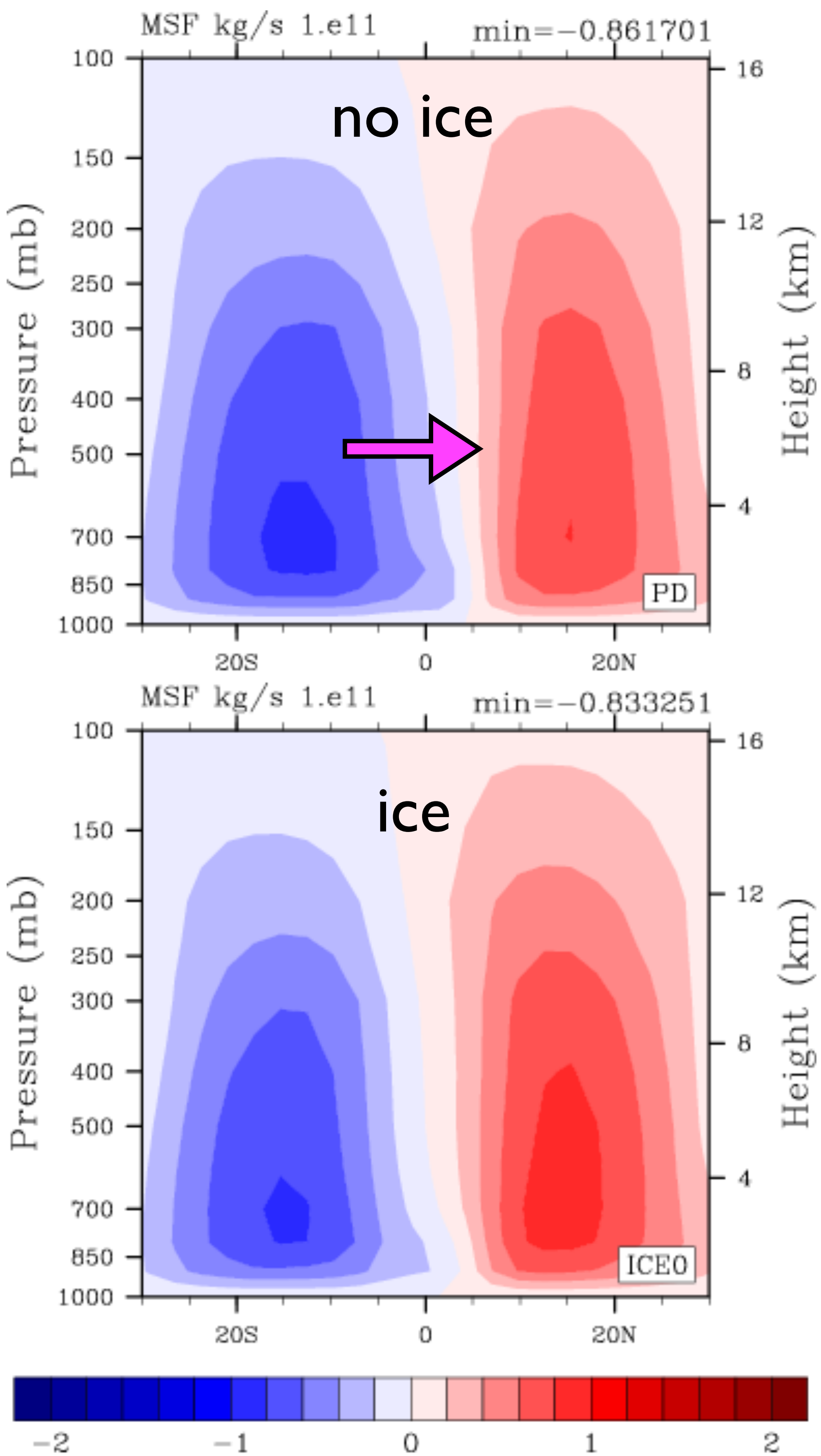
trees - grass



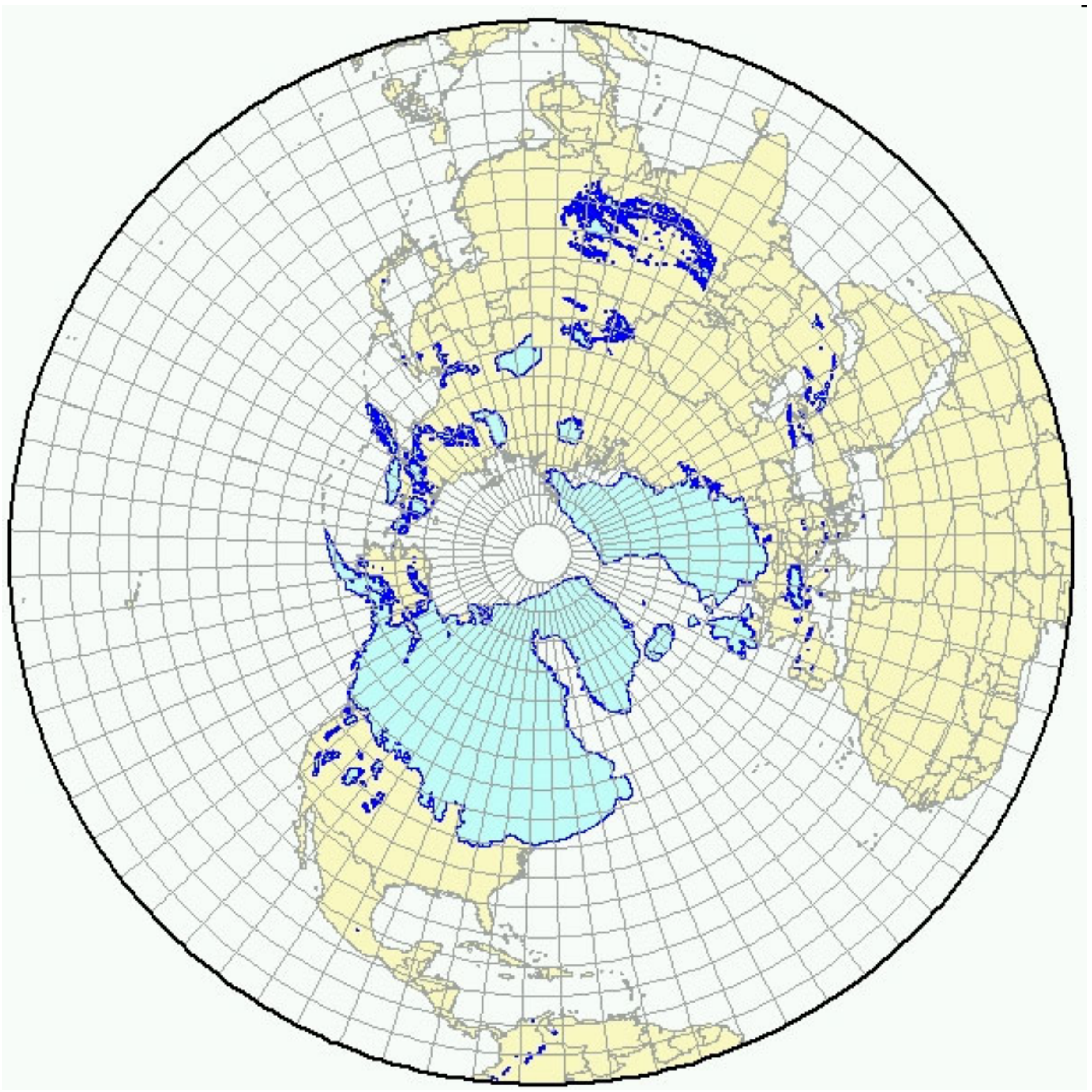
Hadley cell moves north towards trees



Hadley cell moves south with glaciation

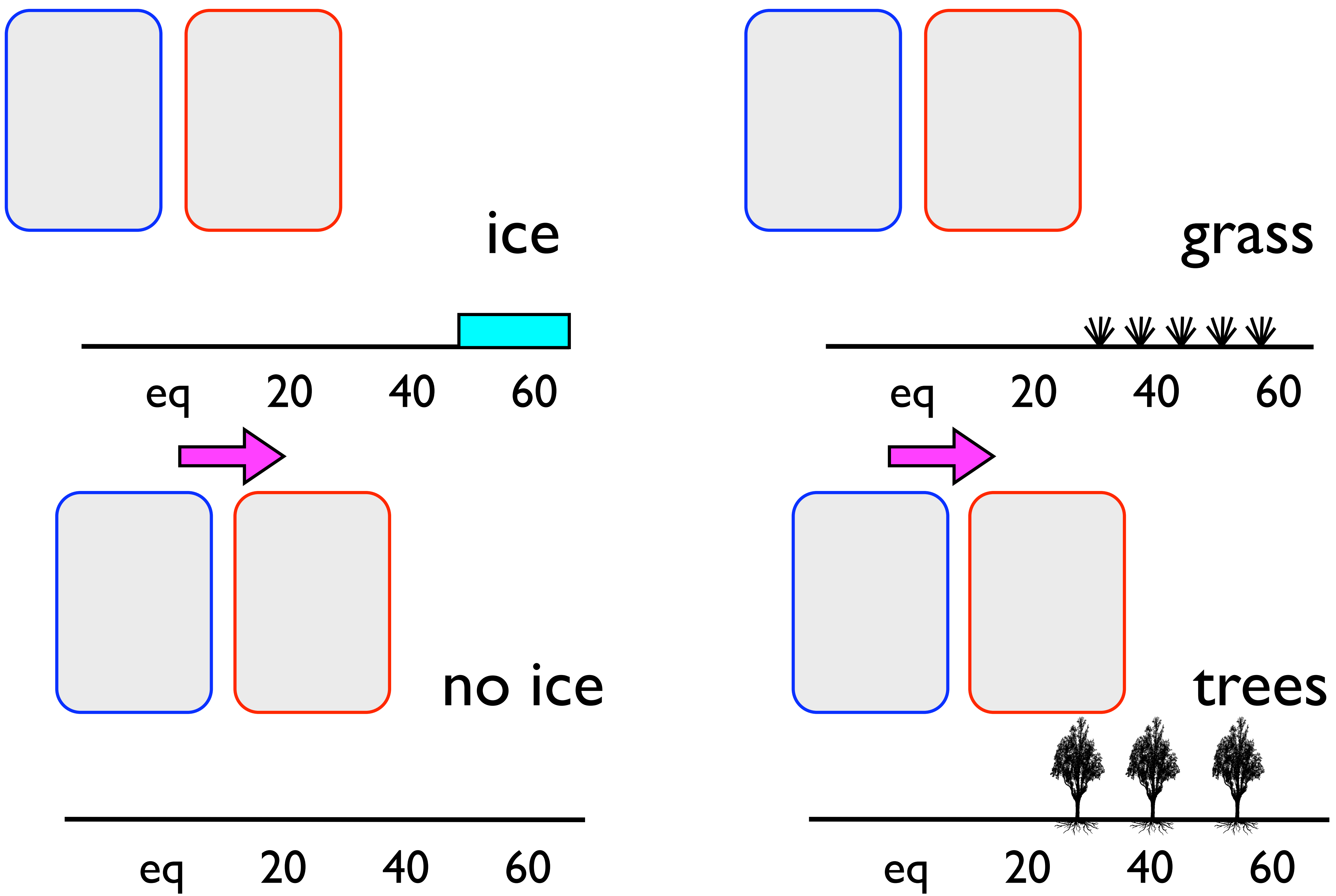


Ice sheet location

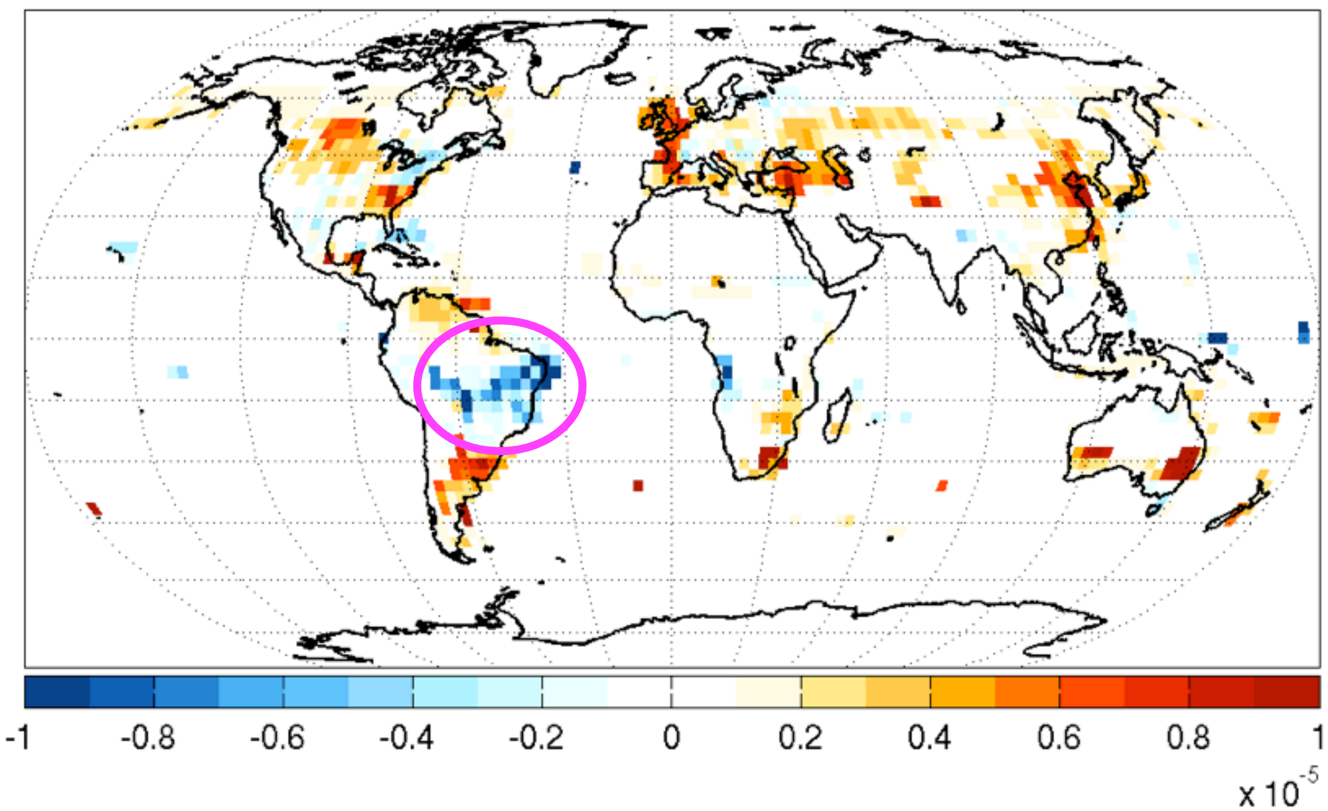


Lee and Chiang, 2010 (in prep)

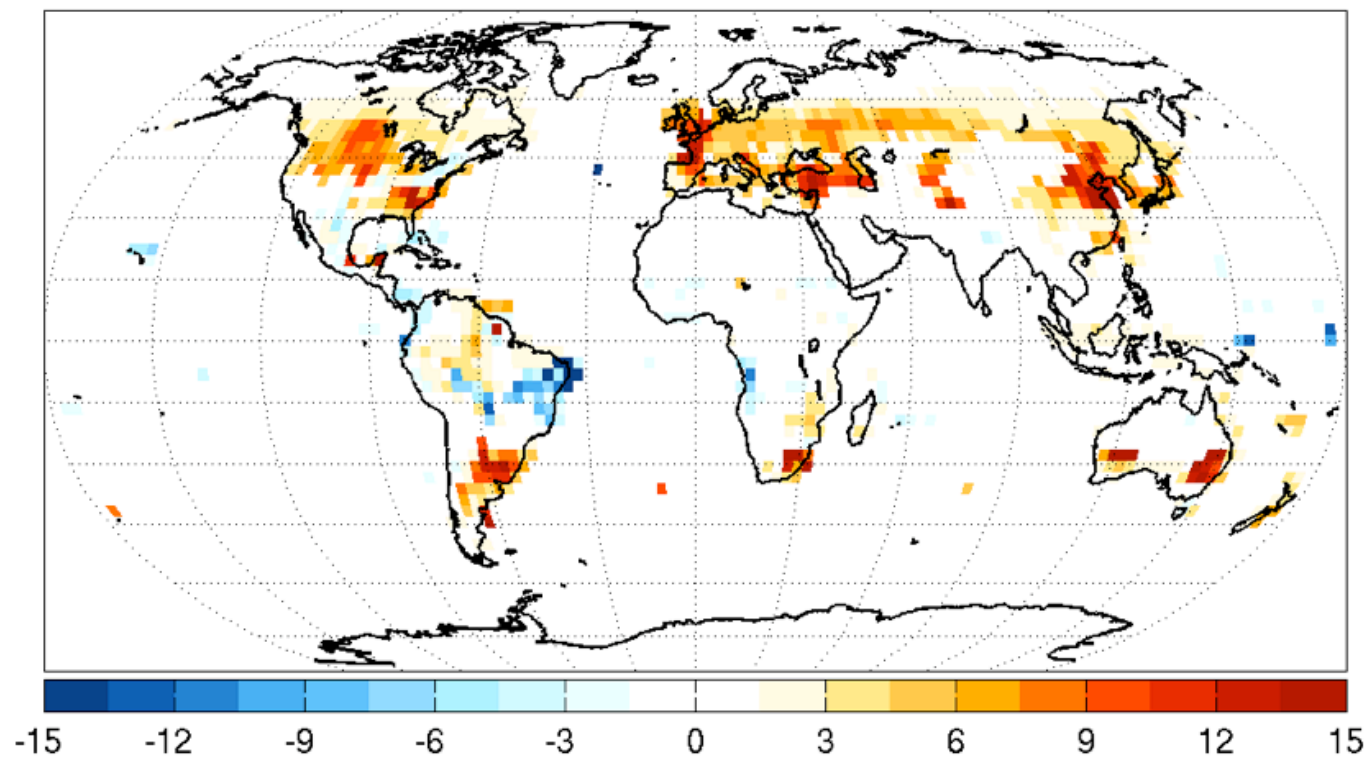
Hadley cell moves towards low albedo



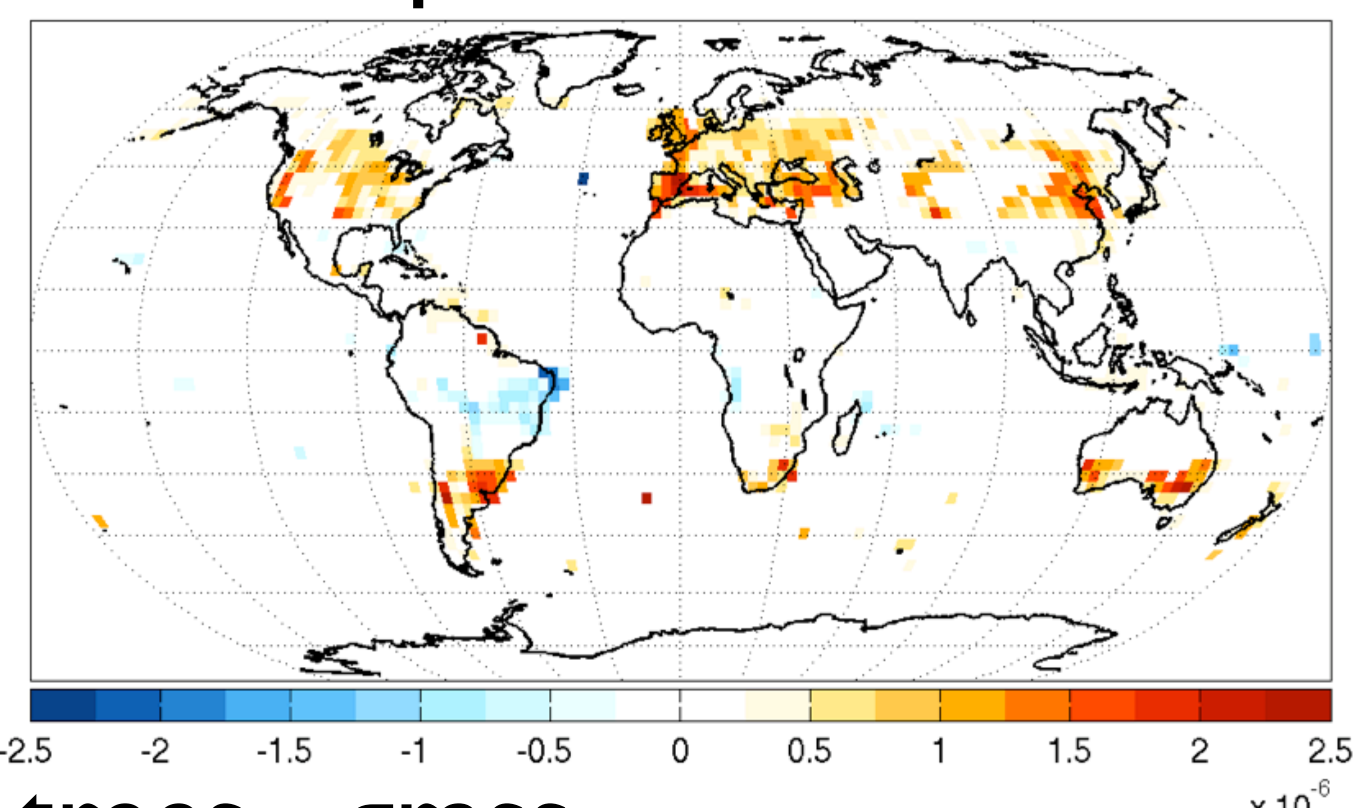
Net Primary Production



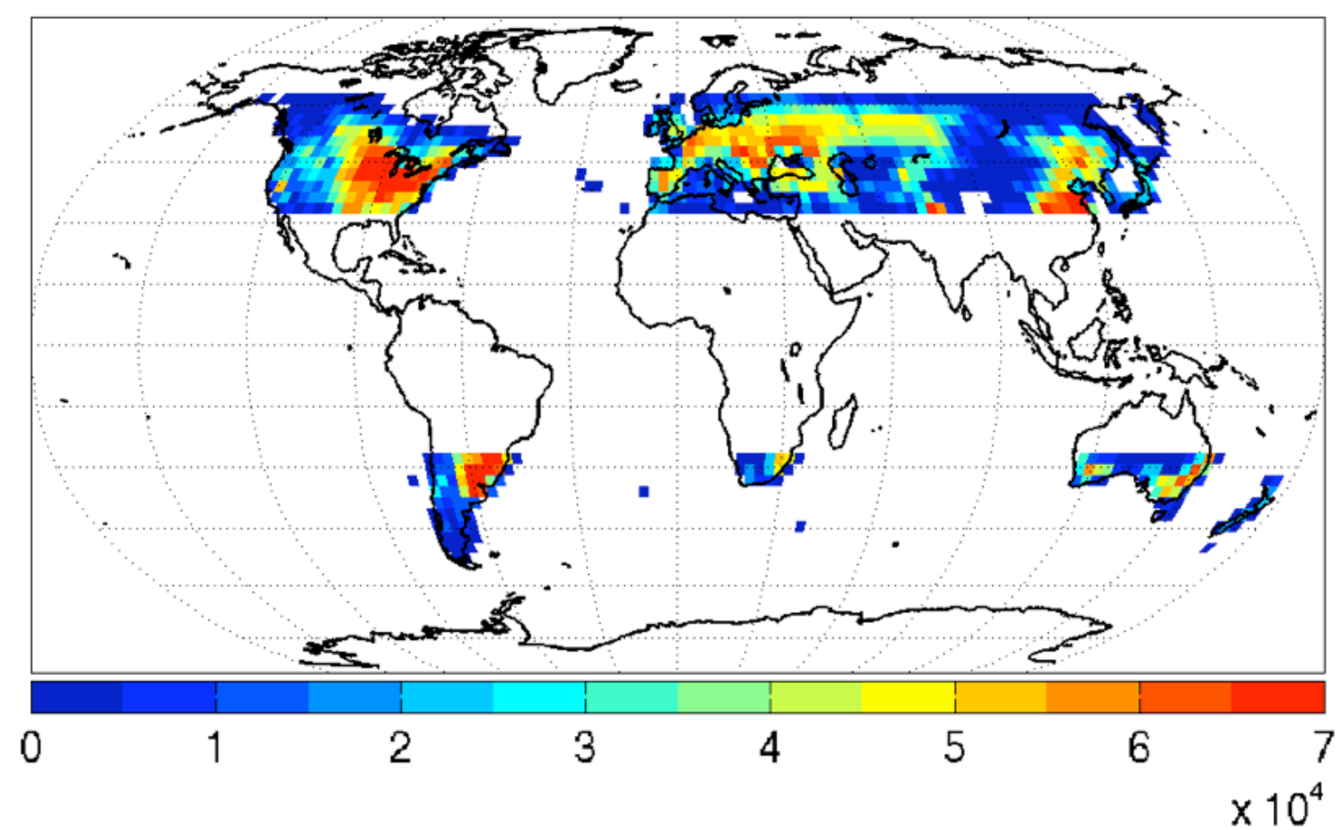
Transpiration



Soil Respiration



New Trees



trees - grass

grass + crops => deciduous trees

- ITCZ shifts north
- Amazon dries and productivity decreases
- Sahel region and lower Sahara get wetter - could support plants (no dgvm in these runs)

large changes in mid latitude land cover can have global effects

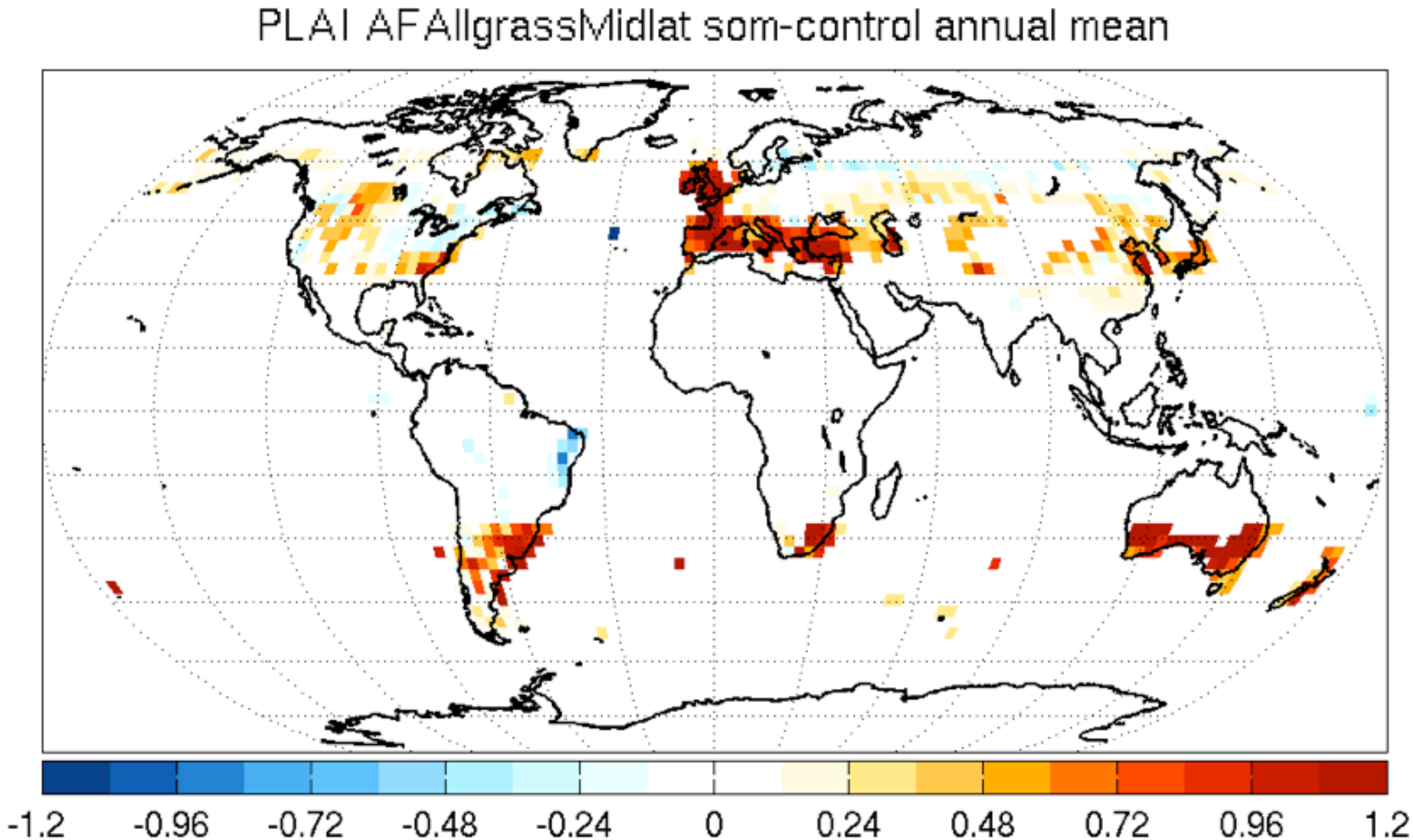
end

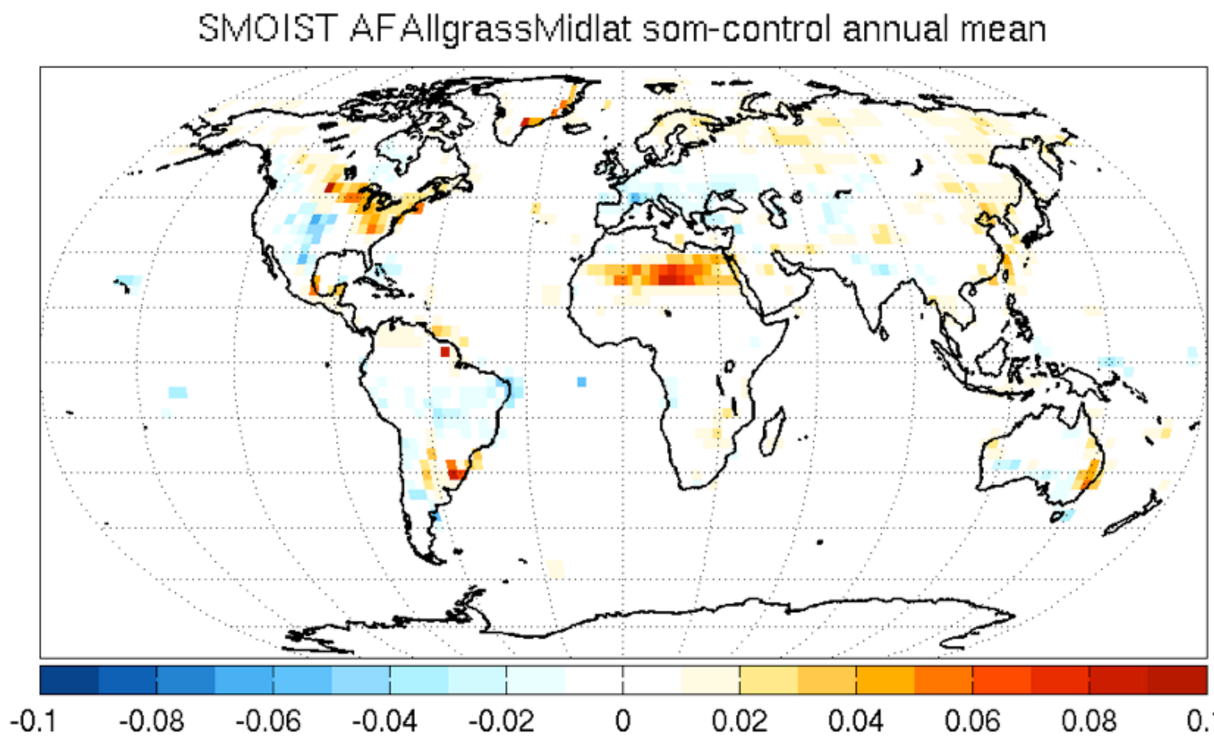
AFAllgrassMidlat

Mid Latitude mean

Month	Variable Name	Units	SOM					
			Land			Ocean		
Annual Mean			μ	Δ	p	μ	Δ	p
	Surf. Air Temp.	K	281.38	1.15	**0.0000**	284.10	0.47	**0.0474**
	Water Vapor	kgm^{-2}	13.42	1.02	**0.0005**	17.43	0.55	**0.0228**
	Low Cloud	fraction	0.29	-0.02	0.6143	0.54	0.00	0.9273
	Albedo	albedo	0.22	-0.05	**0.0003**	0.07	0.00	0.9678
	Latent Heat	Wm^{-2}	33.99	1.57	**0.0469**	70.31	0.81	0.1595
	Sensible Heat	Wm^{-2}	28.38	7.84	**0.0000**	14.88	-0.18	0.6933
	Ice Fraction	fraction	na	na	na	0.00	0.00	0.9536
	Precipitation	$10^{-8}m\ s^{-1}$	1.99	0.03	1.0000	3.13	0.00	1.0000
	Eff. Water Import	$kg\ s^{-1}$	na	na	na	-4570.21	-80.07	**0.0000**
	Transpiration	Wm^{-2}	10.22	3.70	**0.0000**	9999.00	na	na
JJA								
	Surf. Air Temp.	K	292.63	1.65	**0.0000**	284.37	0.49	**0.0194**
	Water Vapor	kgm^{-2}	20.21	1.76	**0.0000**	18.42	0.62	**0.0223**
	Low Cloud	fraction	0.18	-0.03	0.5117	0.56	0.00	0.9400
	Albedo	albedo	0.18	-0.04	**0.0106**	0.08	0.00	0.9679
	Latent Heat	Wm^{-2}	60.58	1.38	0.0743	66.55	1.04	0.0766
	Sensible Heat	Wm^{-2}	45.78	14.43	**0.0000**	13.64	-0.04	0.9127
	Ice Fraction	fraction	na	0.00	na	0.00	0.00	0.9767
	Precipitation	$10^{-8}m\ s^{-1}$	0.00	0.00	1.0000	3.16	0.00	1.0000
	Eff. Water Import	$kg\ s^{-1}$	na	0.00	na	-4870.59	-82.93	**0.0000**
	Transpiration	Wm^{-2}	23.03	6.29	**0.0000**	9999.00	na	na

Delta Prognostic LAI





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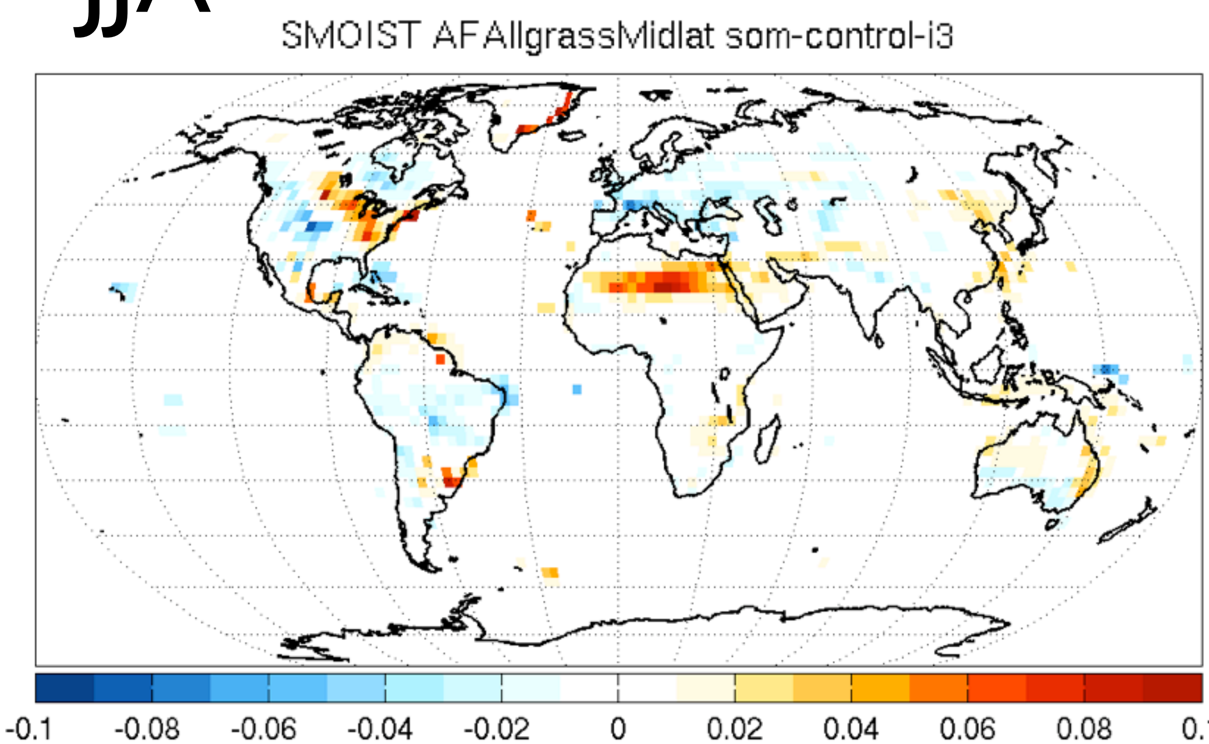
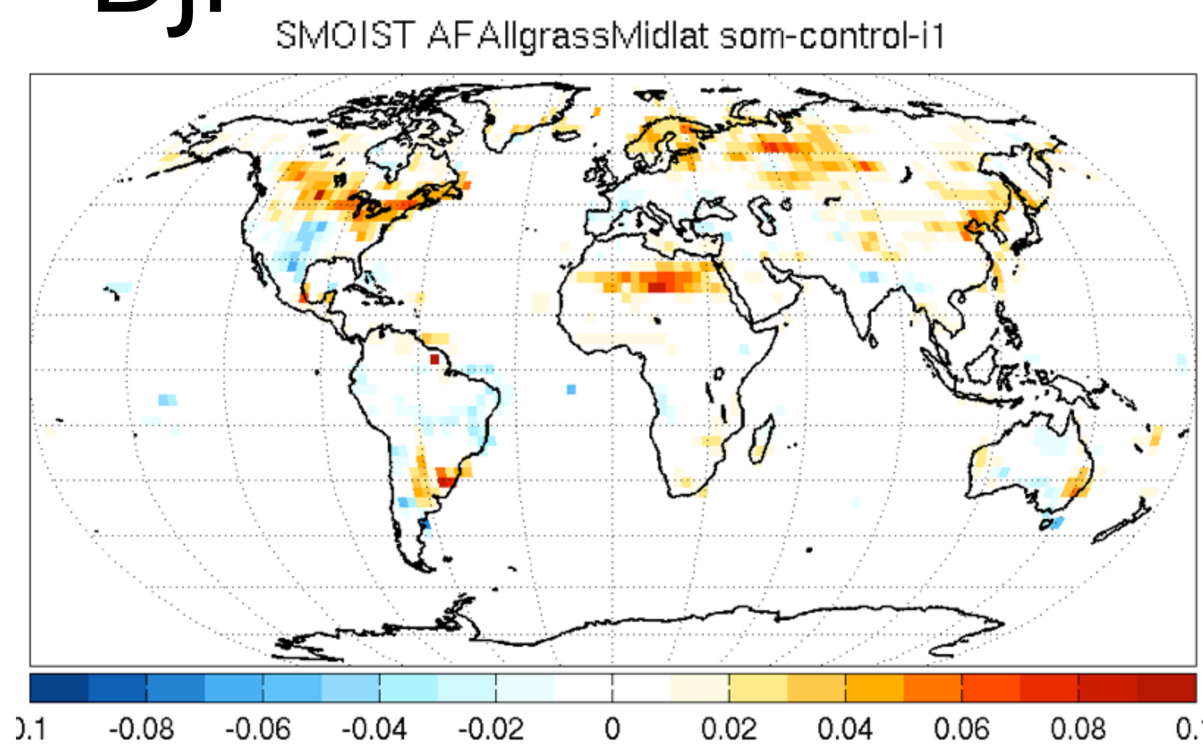


DJF



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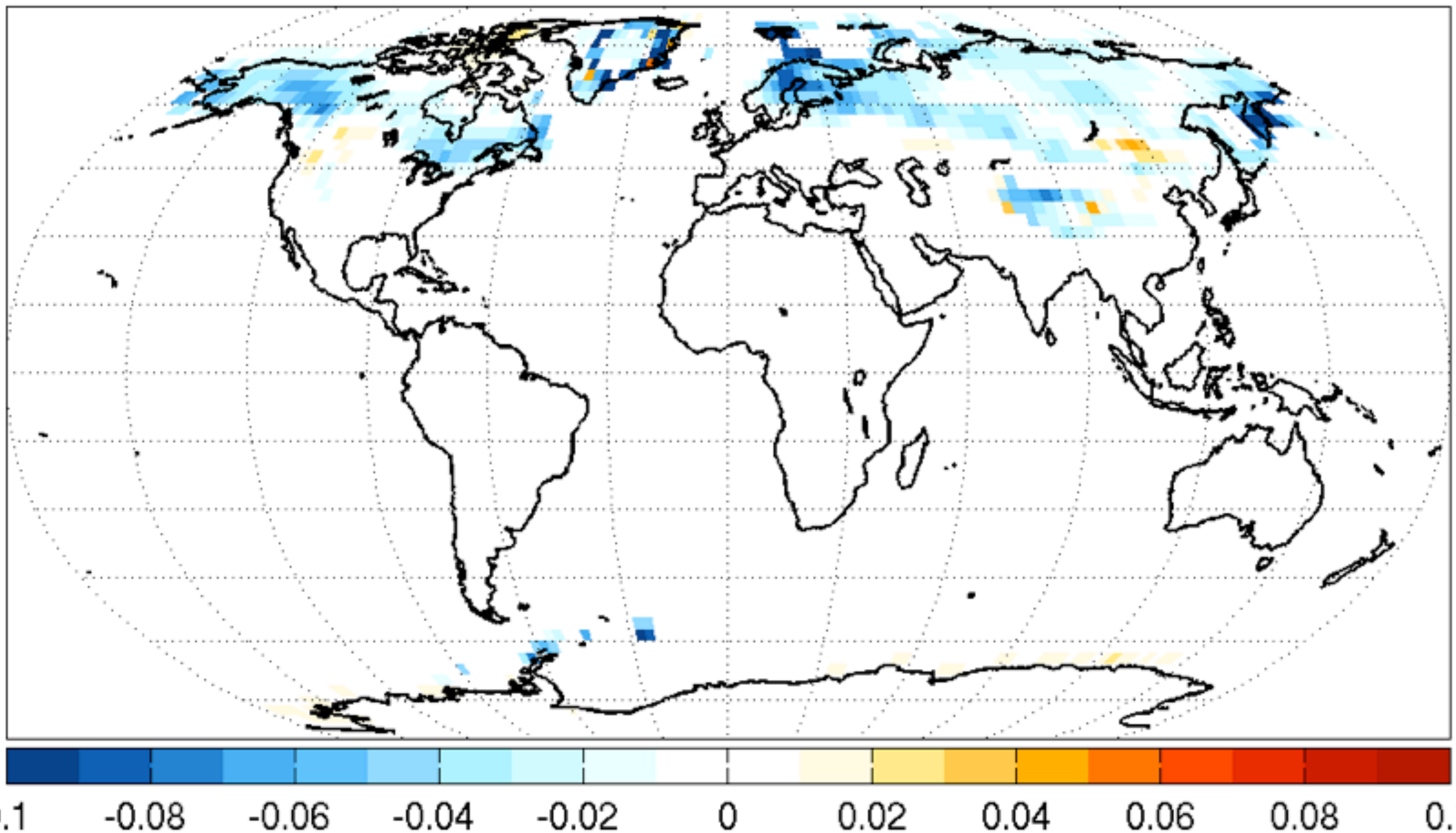
FSNO AFAllgrassMidlat som-control annual mean



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