Greenhouse gas policies influence climate via direct effects of land use change

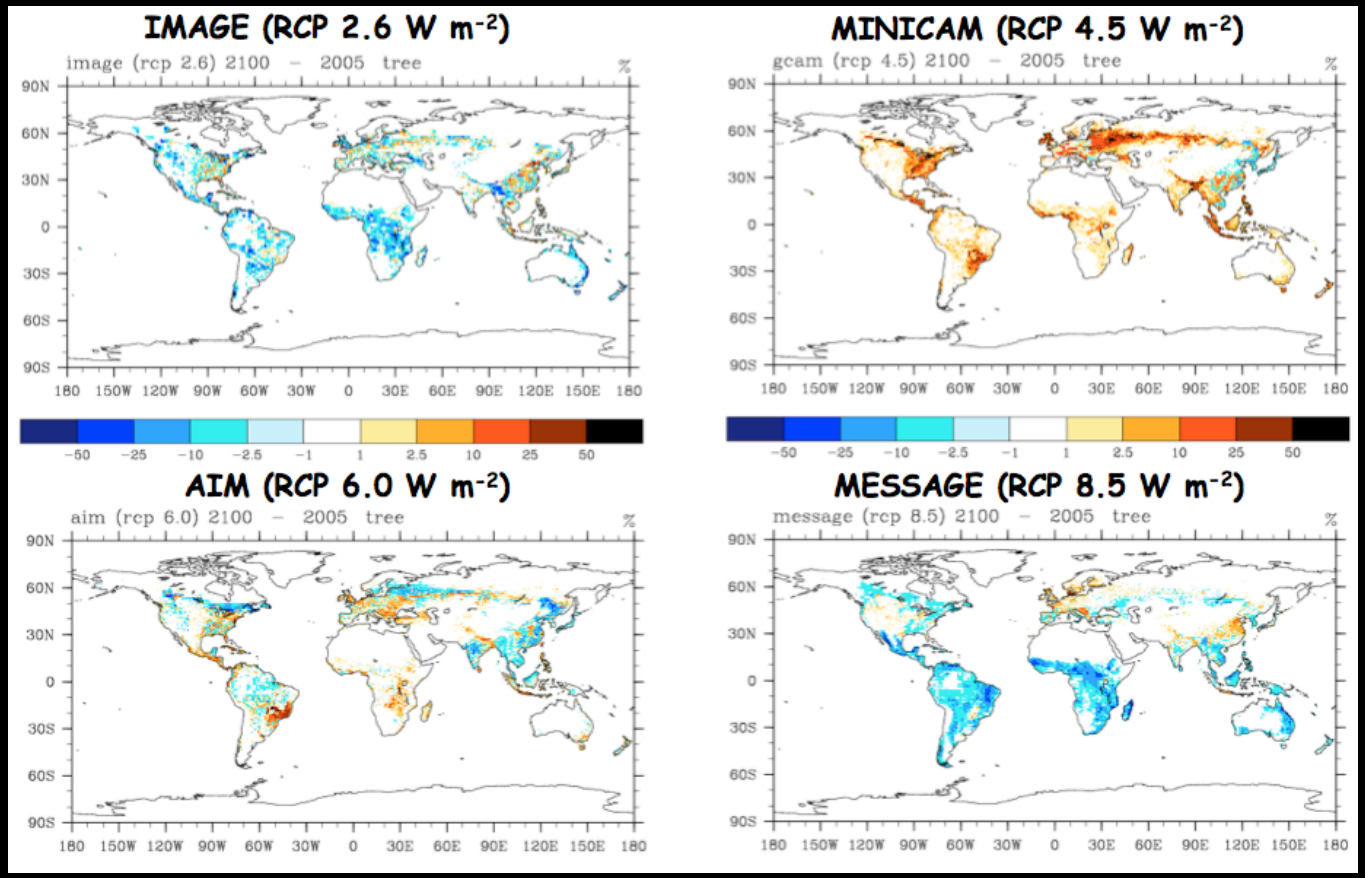
Andrew D Jones, Katherine Calvin, Anthony Janetos, William Collins, Jae Edmonds, Peter Thornton, Louise Chini, Allison Thompson, Margaret Torn, Jiafu Mao, Xiaoying Shi

UC Berkeley - LBNL - PNNL - Univ of Maryland - ORNL

Motivation

- New policies address GHG sources and sinks from land use change
- However, these policies (and the hypothetical ones modeled for IPCC) ignore biogeophysics
- Not clear whether plausible scenarios of future land use change induce significant biogeophysical climate perturbations
  - If so, not clear that radiative forcing metric is convenient or appropriate

Future Projections of Land Use Differ Widely



Lawrence, P. J., J. J. Feddema, G. B. Bonan, G. A. Meehl, B. C. O'Neill, S. Levis, D. M. Lawrence, K. W. Oleson, E. Kluzek, K. Lindsay, and P. E. Thornton (2011), Simulating the Biogeochemical and Biogeophysical Impacts of Transient Land Cover Change and Wood Harvest in the Community Climate System Model (CCSM4) from 1850 to 2100, *Journal of Climate*, in review.

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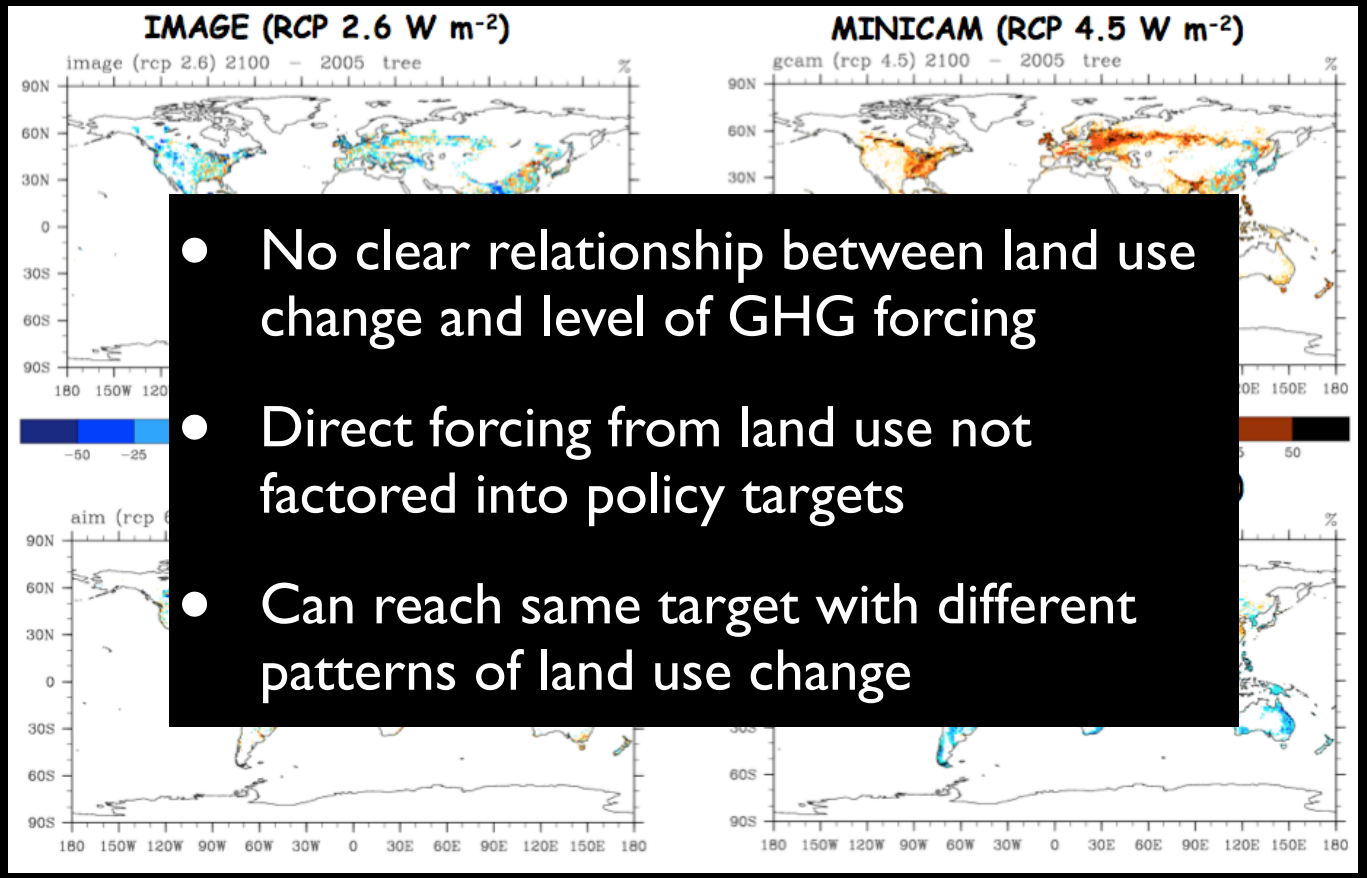
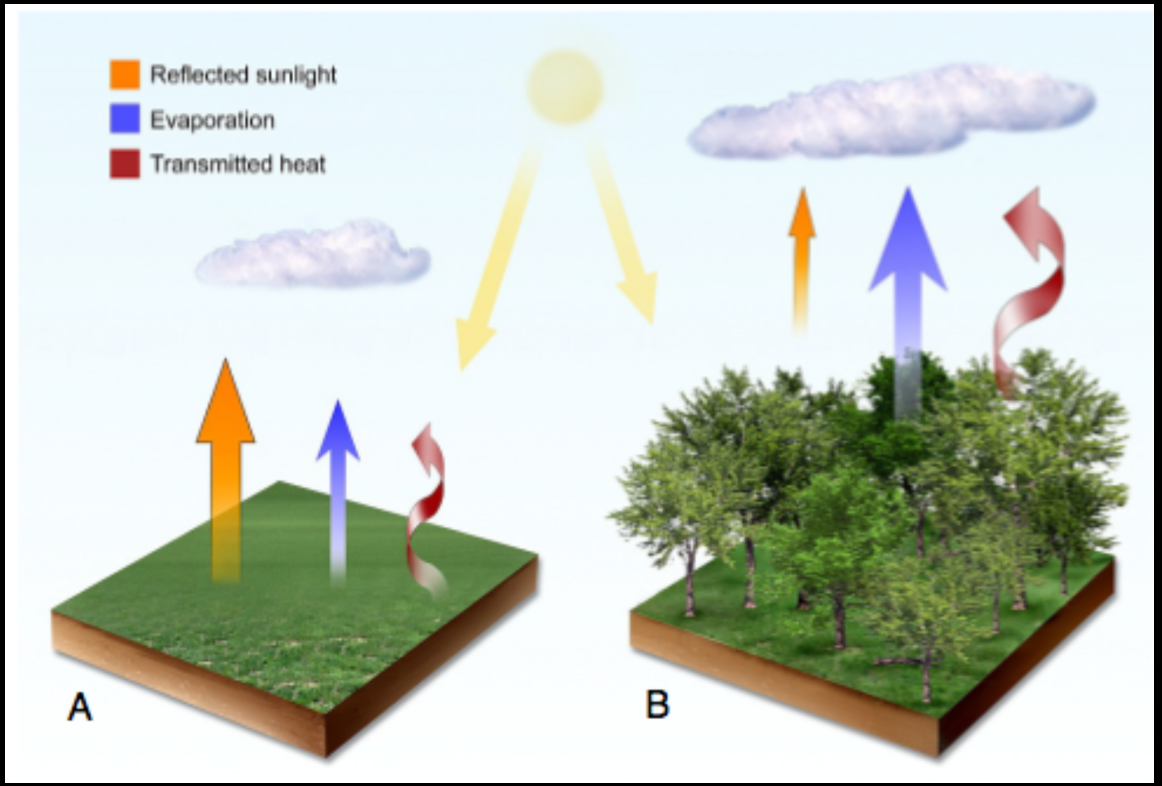


- No clear relationship between land use change and level of GHG forcing
- Direct forcing from land use not factored into policy targets
- Can reach same target with different patterns of land use change

Lawrence, P. J., J. J. Feddema, G. B. Bonan, G. A. Meehl, B. C. O'Neill, S. Levis, D. M. Lawrence, K. W. Oleson, E. Kluzek, K. Lindsay, and P. E. Thornton (2011), Simulating the Biogeochemical and Biogeophysical Impacts of Transient Land Cover Change and Wood Harvest in the Community Climate System Model (CCSM4) from 1850 to 2100, *Journal of Climate*, in review.

Biogeophysical Effects of Land Use Change

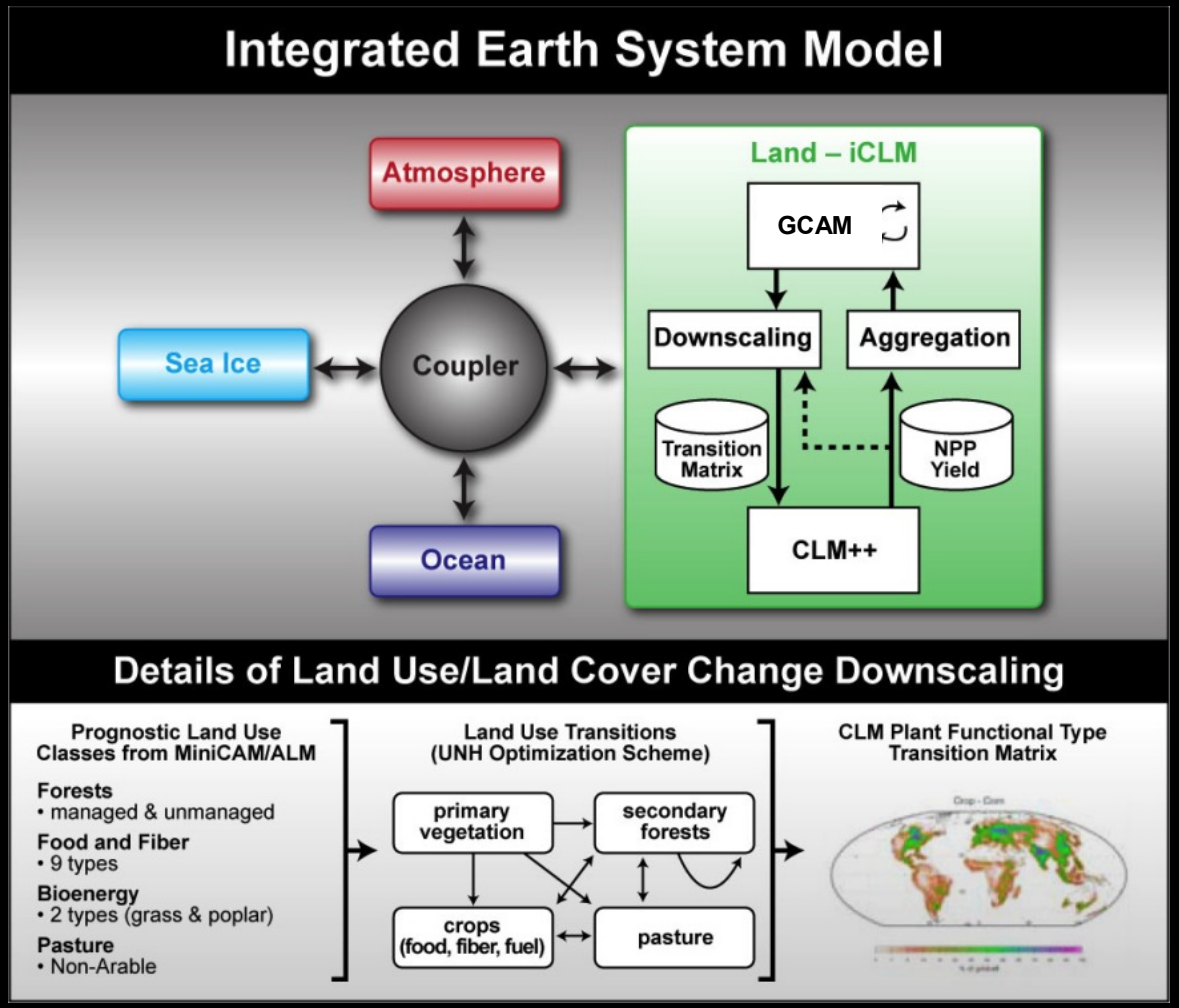


Source - Jackson et al. Environ. Res. Lett.3 (2008) 044006

Objectives

- Examine climate implications of two future scenarios of anthropogenic activity
  - Scenarios reach the same GHG forcing target with very different land use change.
- Use offline land and radiative transfer simulations to isolate forcing and feedback mechanisms operating in different regions

Do all RCP4.5 policies lead to same climate?



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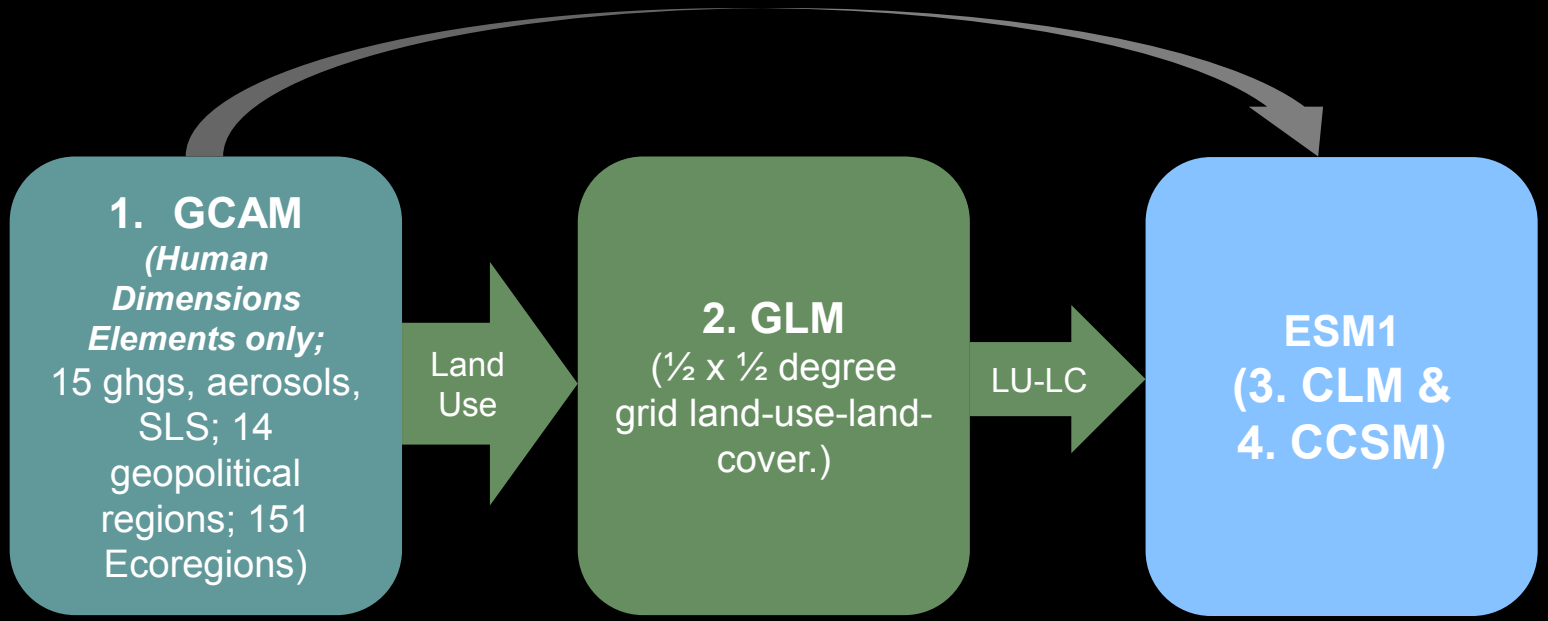

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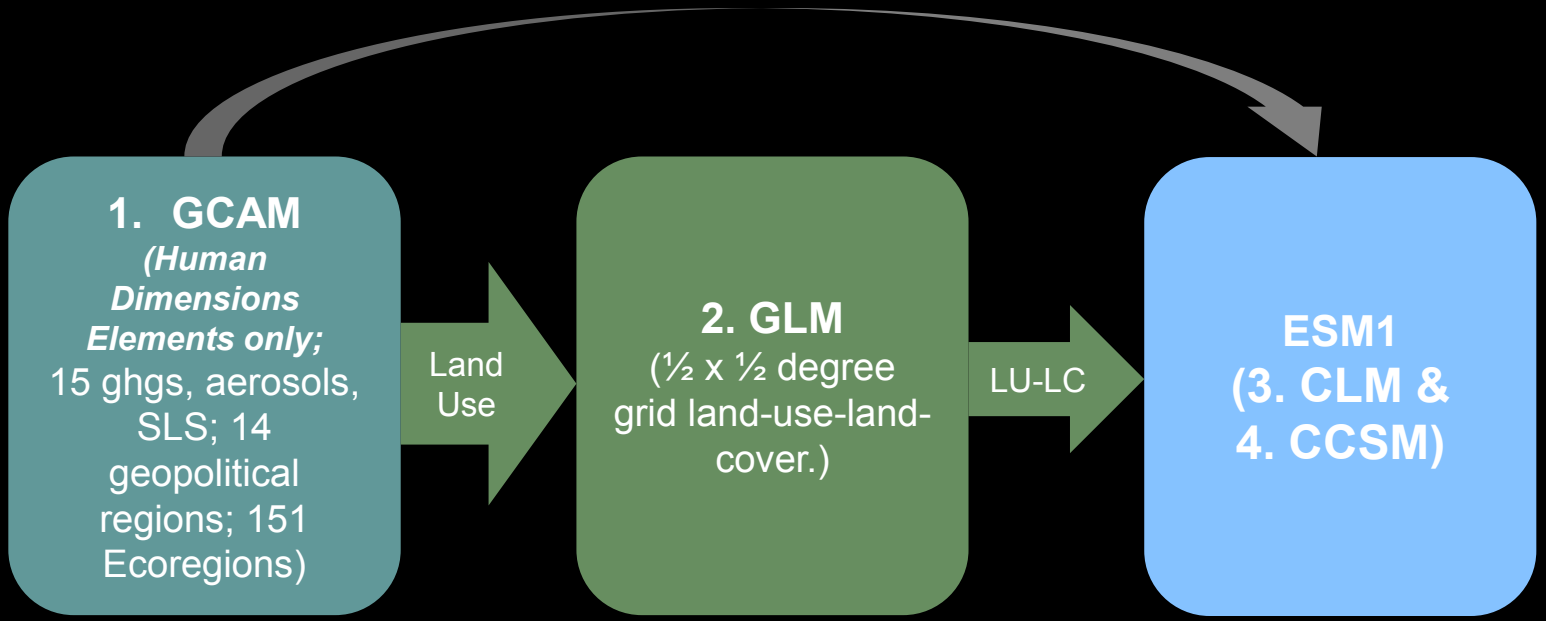


Two Scenarios: 2005-2100

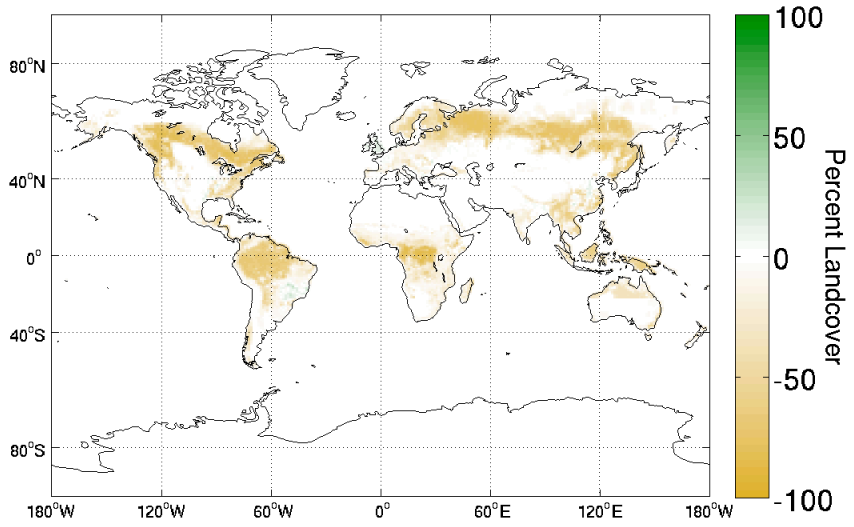
- RCP4.5 UCT (x6 ensemble)
- RCP4.5 FFICT (x1 ensemble)
  - Biofuel and crop expansion
  - ~50% forest cover loss

- Fully-Coupled Transient
- 1 degree resolution
- CN model active
- Simple crop model

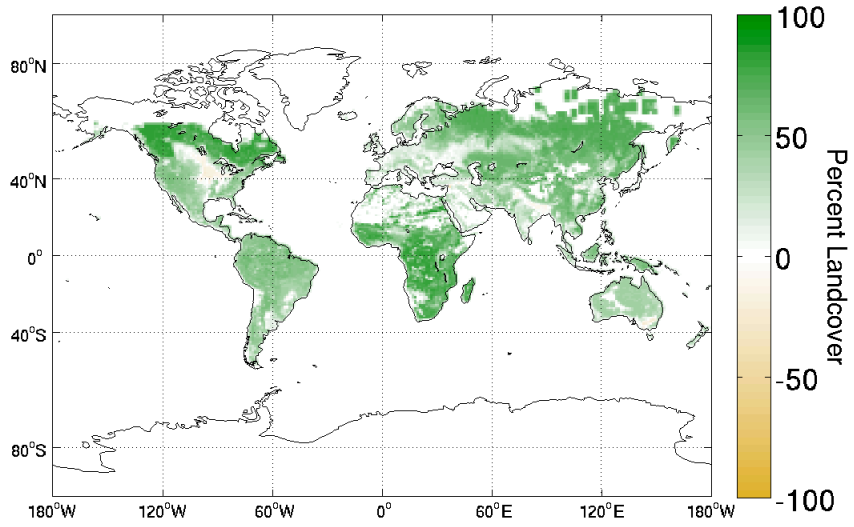
Fossil Only Tax → Deforestation

Change in Landcover from 2005 to 2100

FFICT: Change in Forest Cover



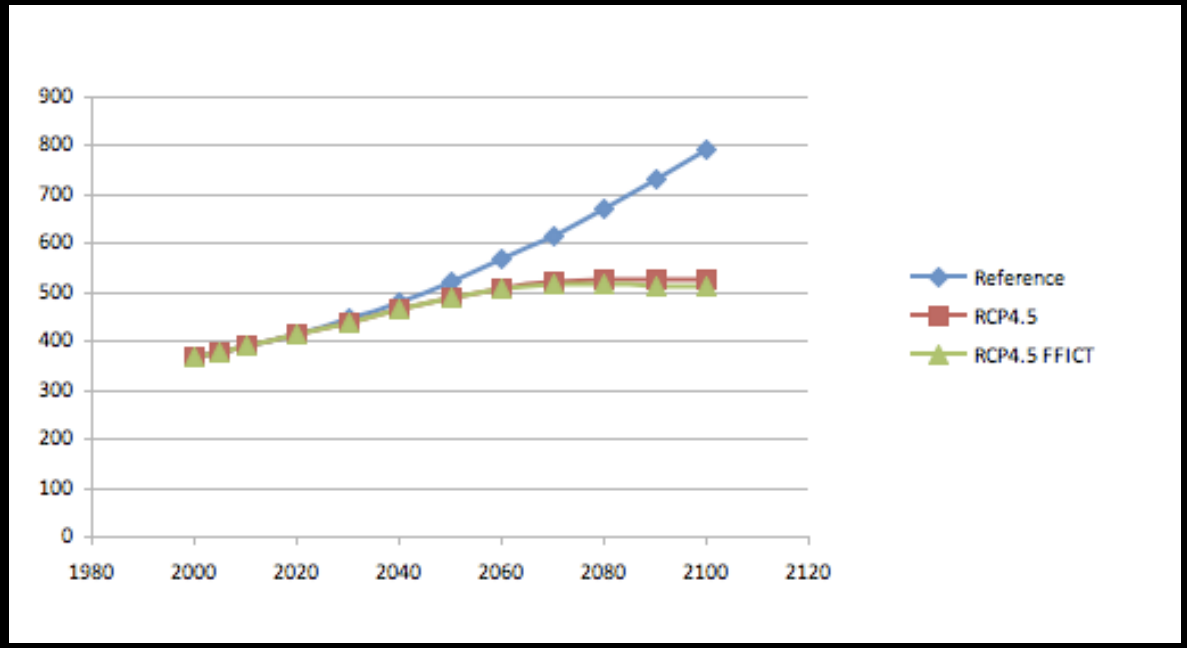
FFICT: Change in Crop Cover



50% Forest Conversion to Bioenergy & Croplands

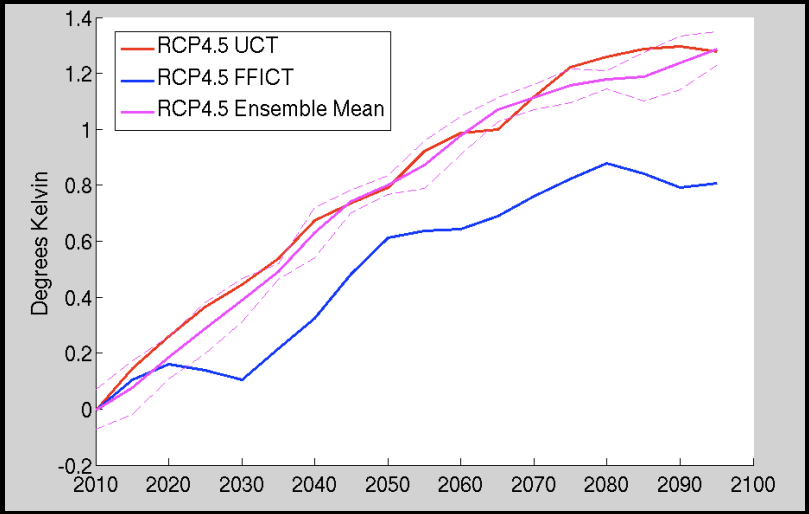
CO2 Concentration

ppm



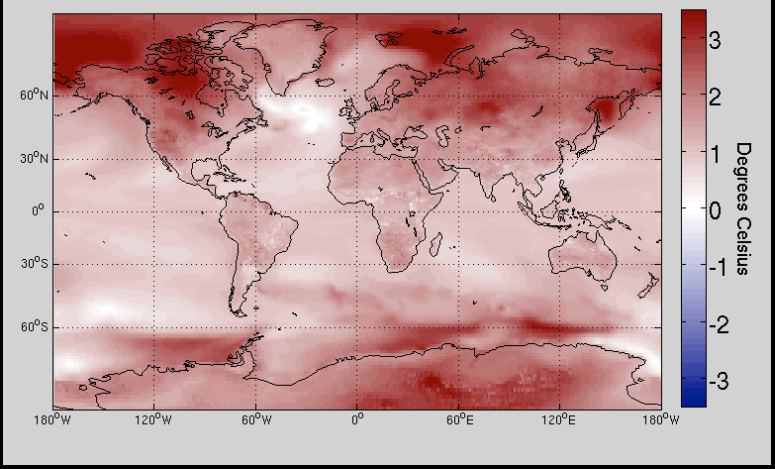
year

Global Mean Temp Change

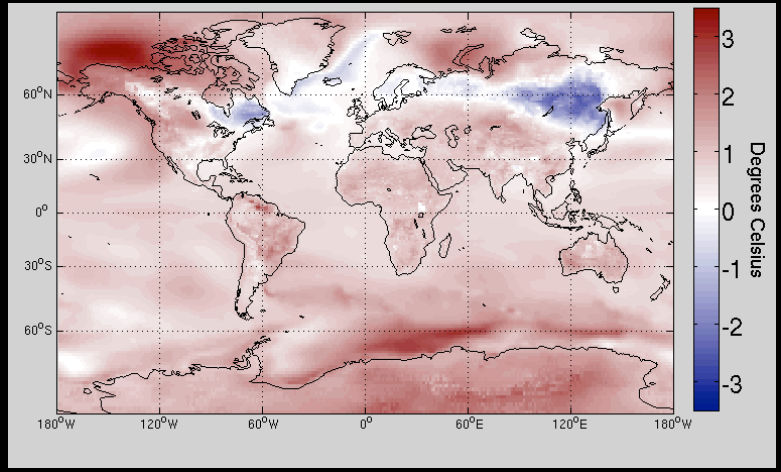


Temperature change from first (2005-2015) to last (2091-2100) decade

RCP4.5 UCT



RCP4.5 FFICT

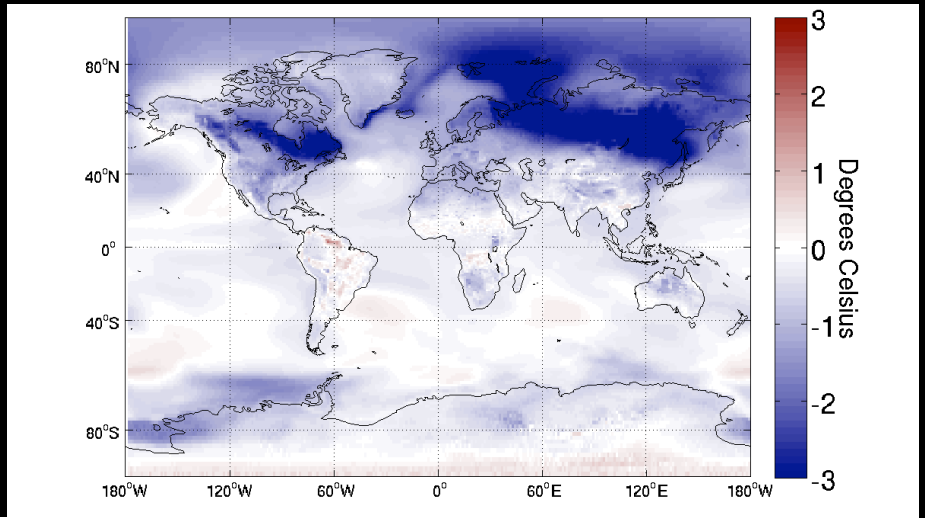


Temperature difference *FFICT-UCT*

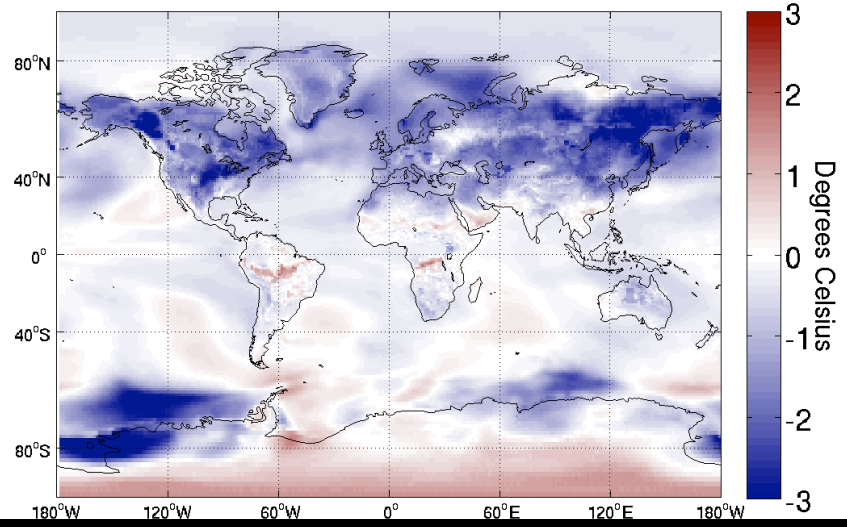
(decadal mean, 2090-2100)

50% Forest loss

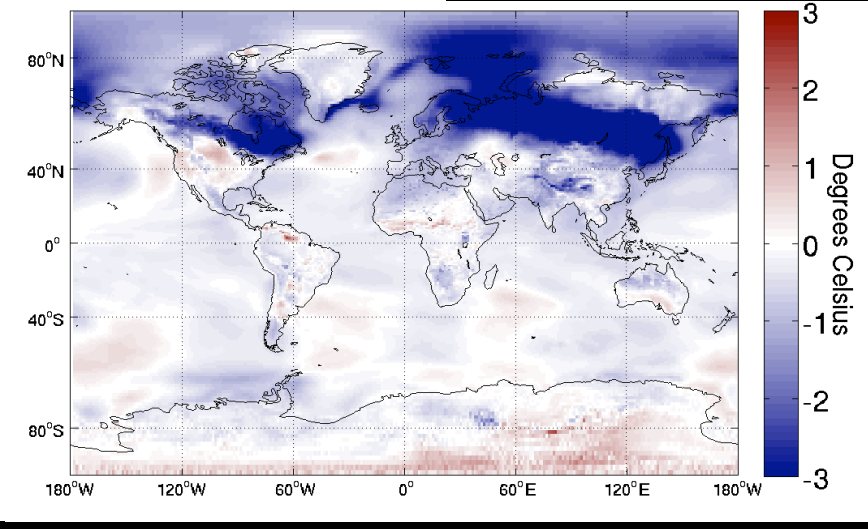
Annual Mean



NH Summer

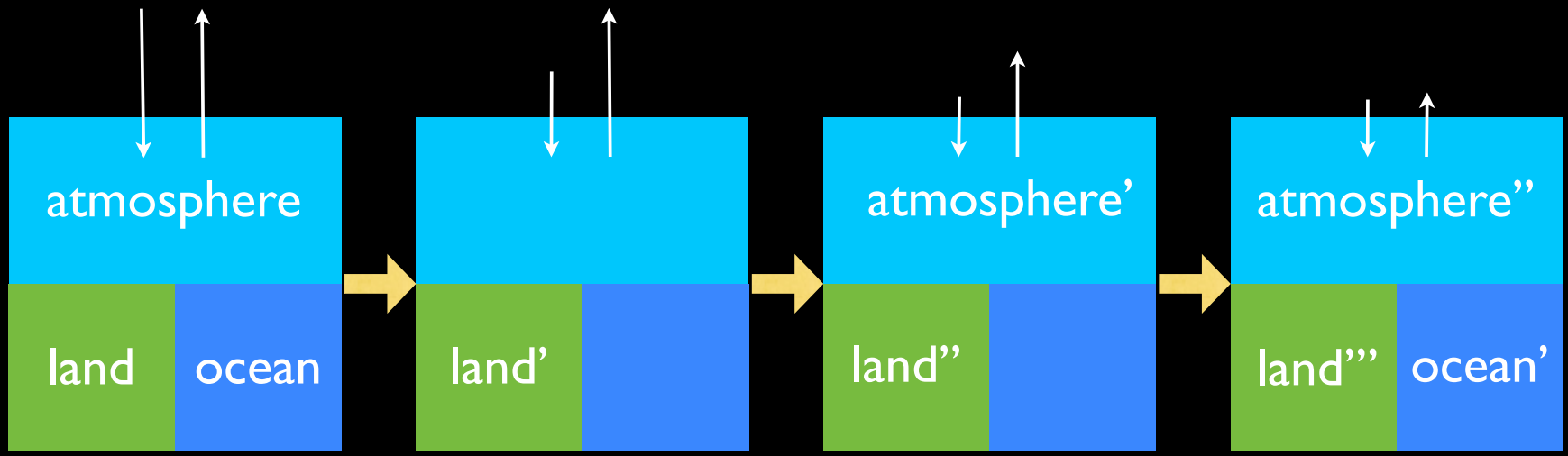


NH Winter

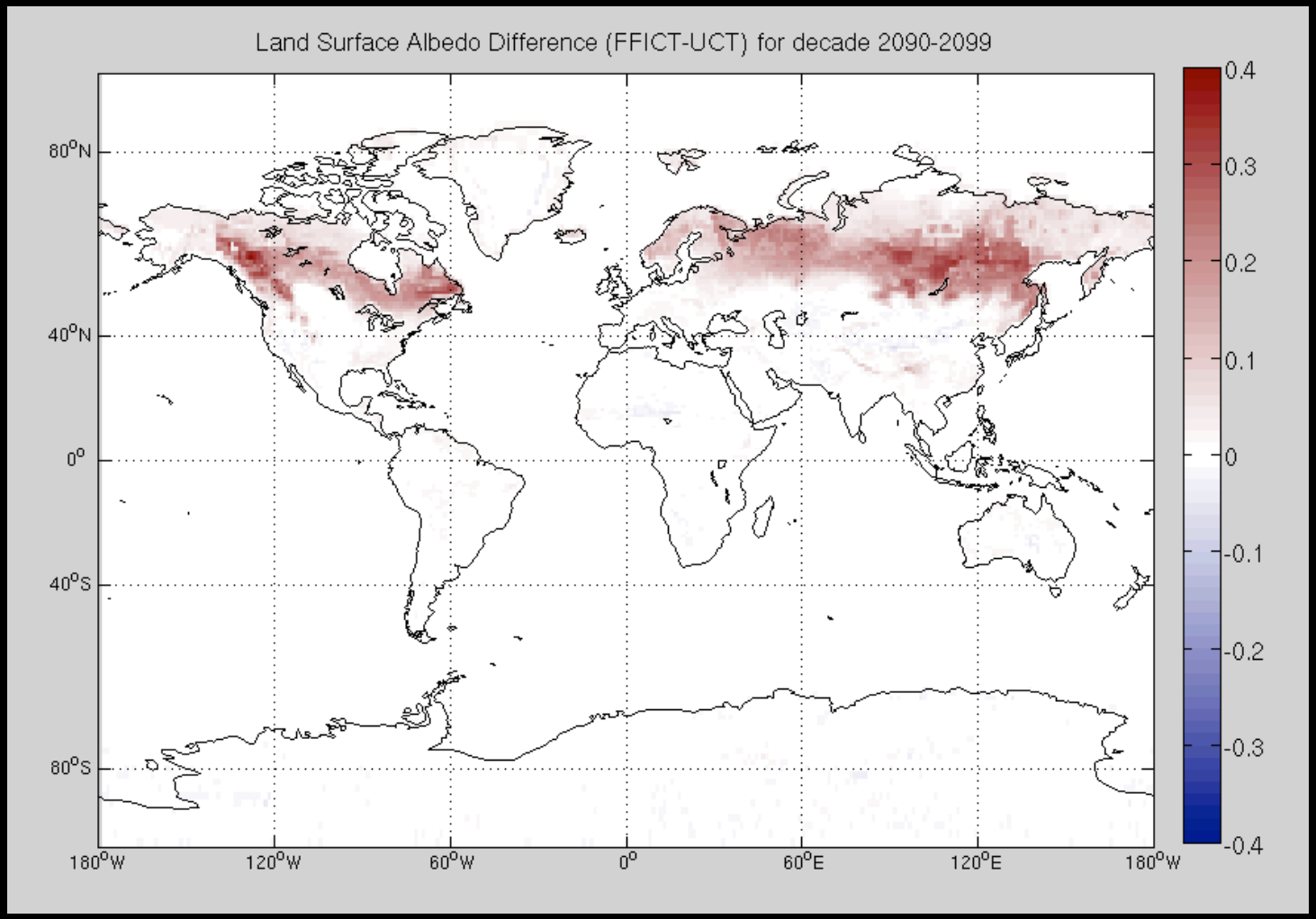


What drives the regional differences?

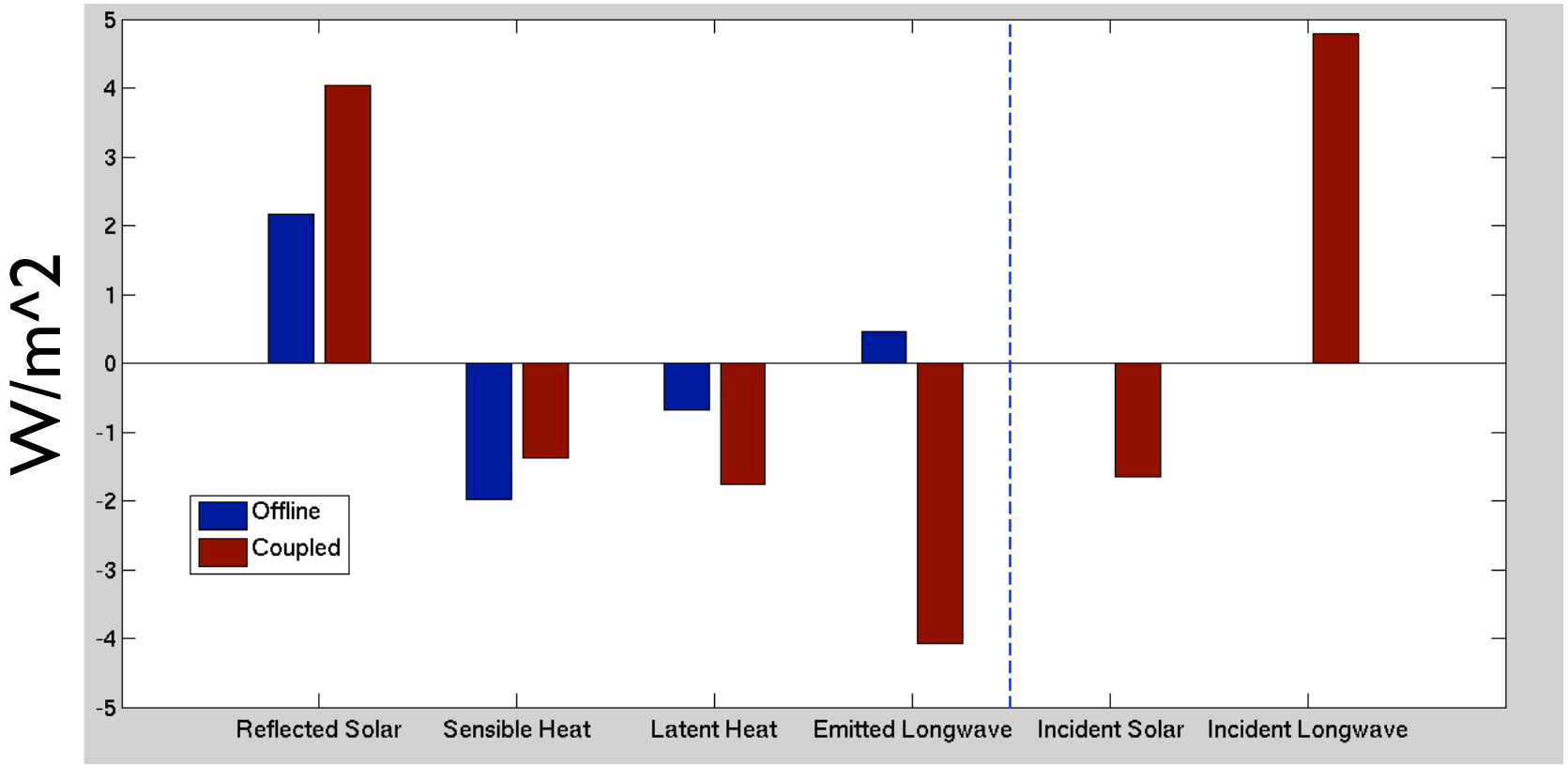
Forcing vs. Feedback



Surface Albedo difference *FFICT-UCT*
(decadal mean, 2090-2100)

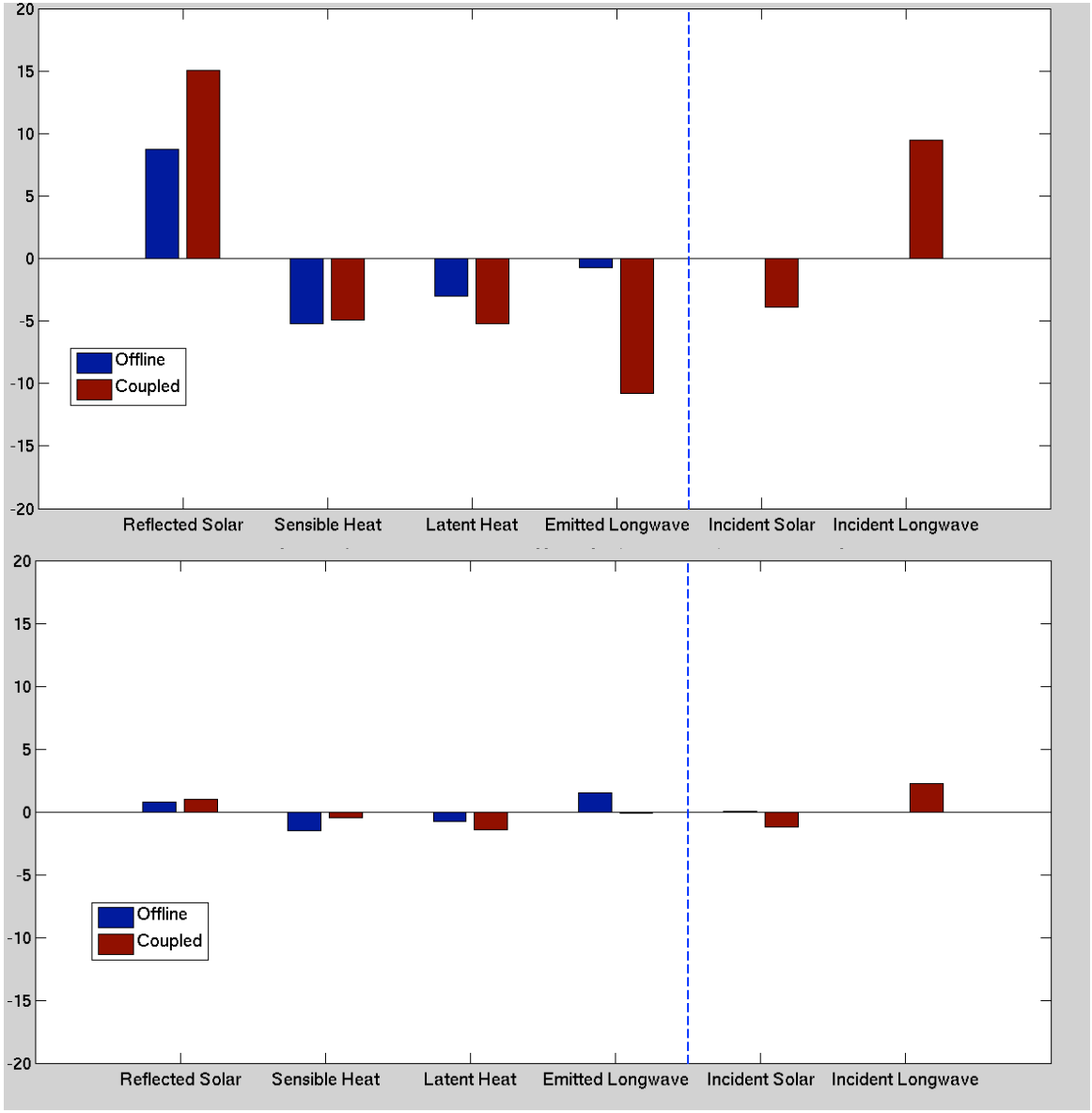


Global Surface Energy Budget Changes
(FFICT-UCT, decadal mean, 2090-2100)



Regional Land Surface Energy Budget Changes

(FFICT-UCT, decadal mean, 2090-2100)

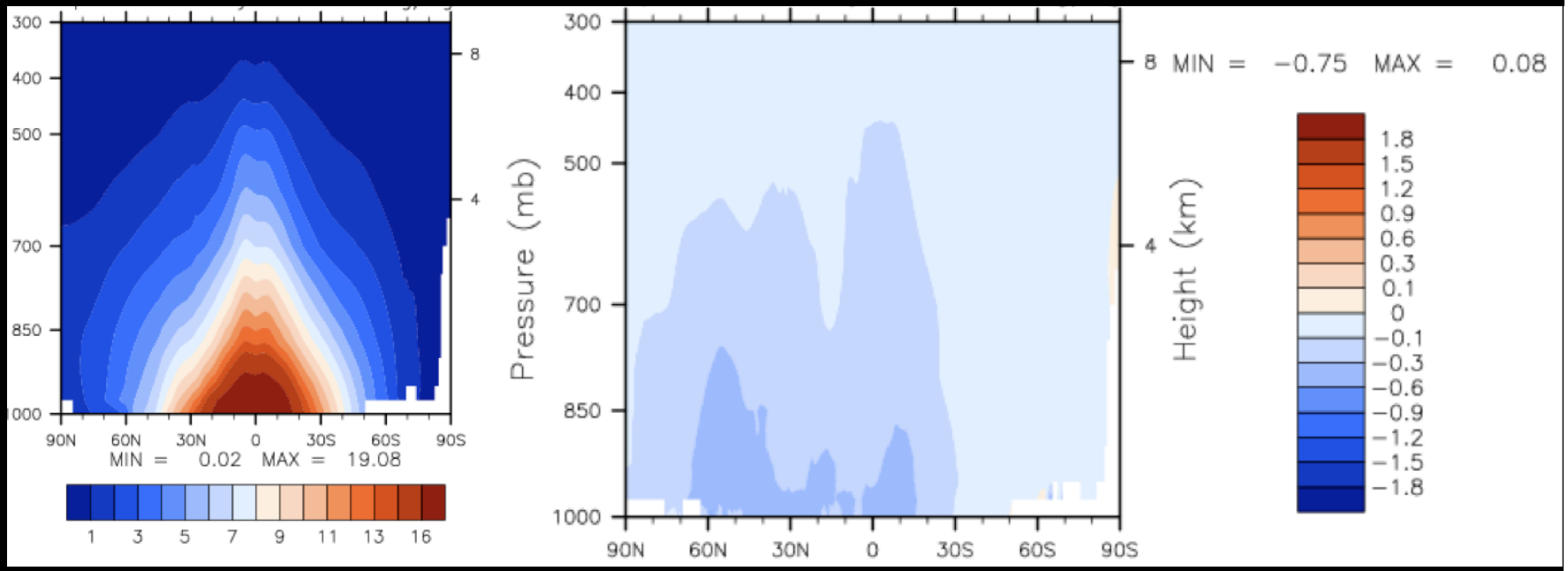


Water Vapor Differences
(decadal mean, 2090-2100)

baseline (UCT)

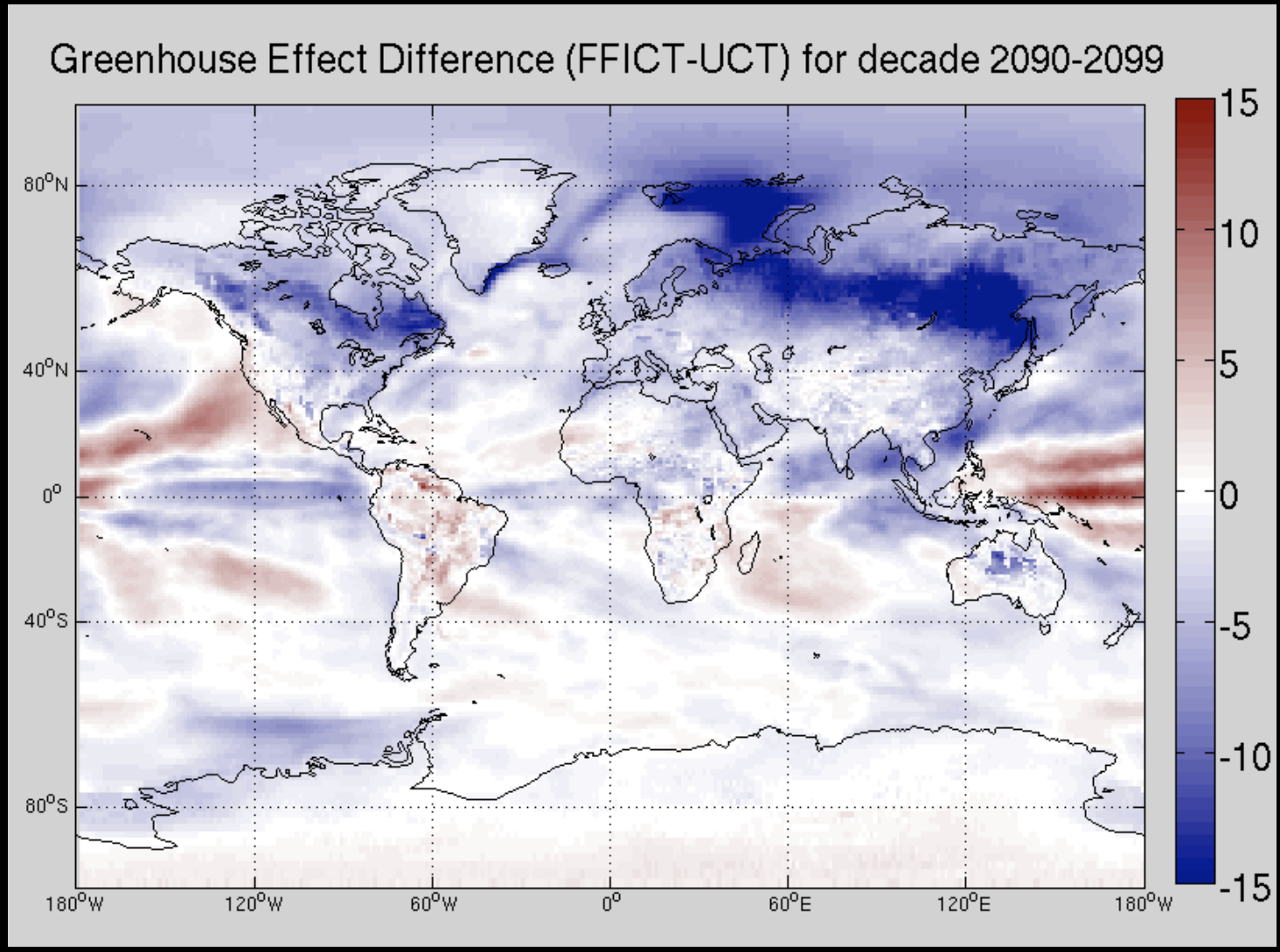
difference (FFICT-UCT)

pressure (mb)

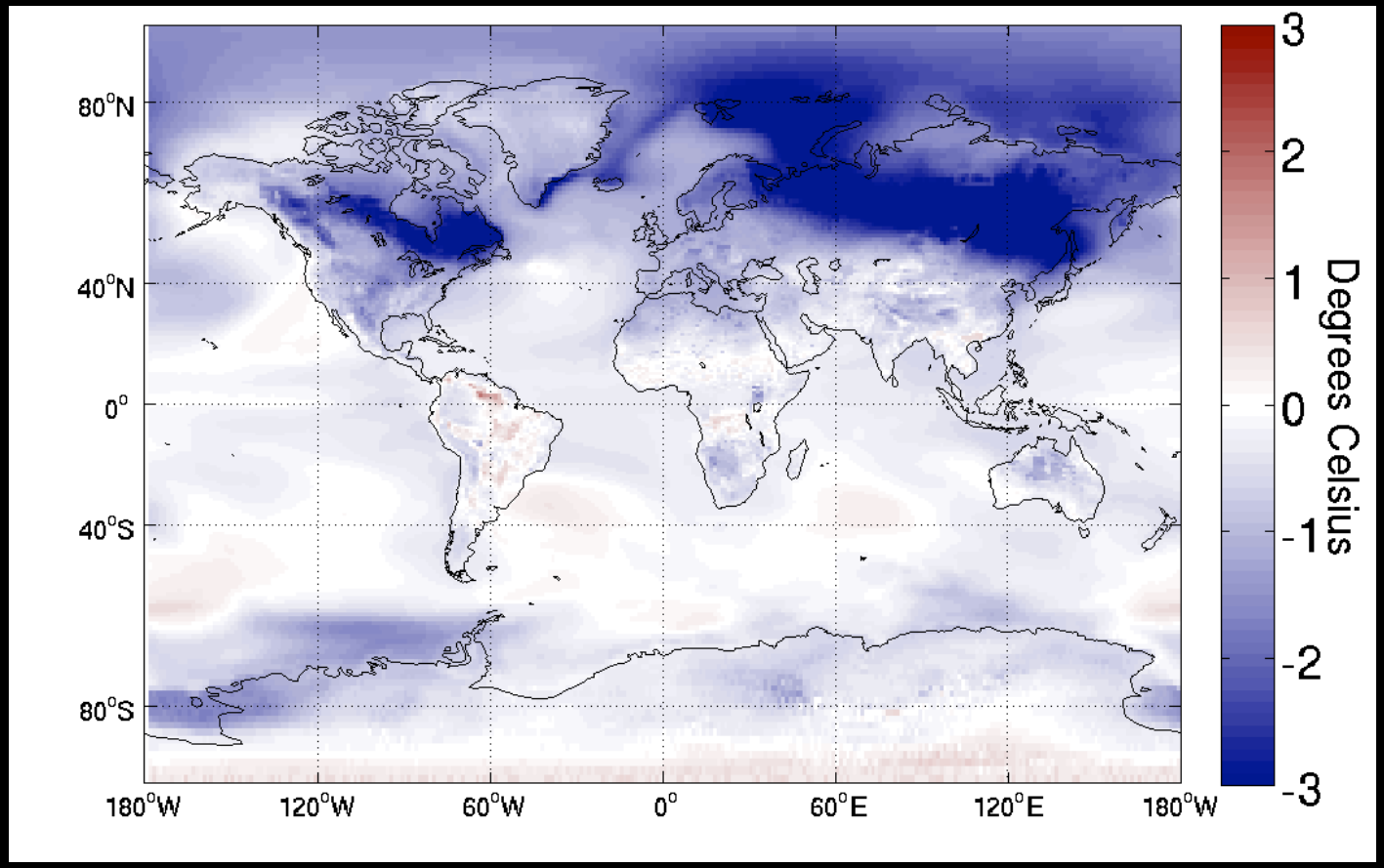


latitude

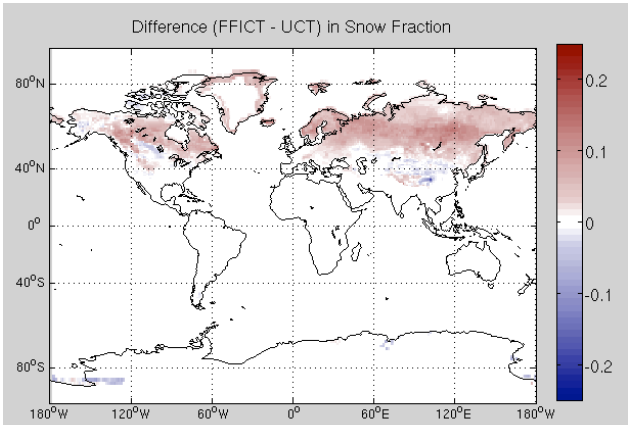
latitude


Greenhouse Effect Difference (FFICT-UCT) for decade 2090-2099
80°N
40°N
0°
40°S
80°S
180°W
120°W
60°W
0°
60°E
120°E
180°W
15
10
5
0
-5
-10
-15
W / m2

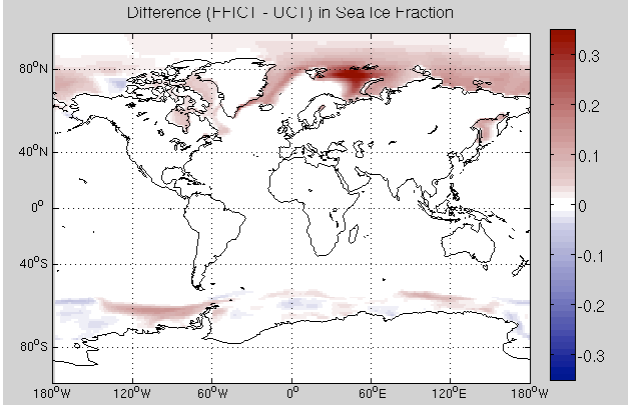
Temperature difference *FFICT-UCT*
(decadal mean, 2090-2100)



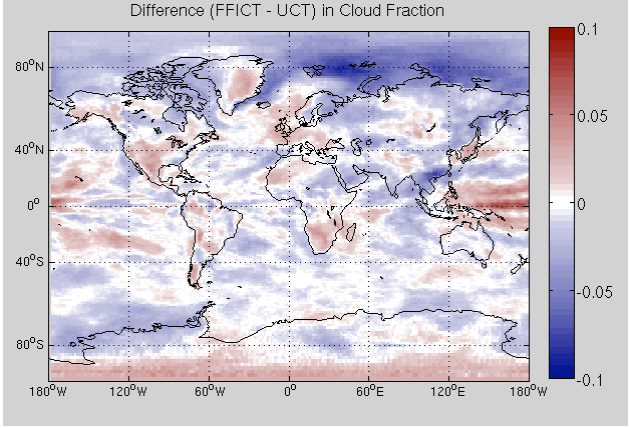
Snow Fraction



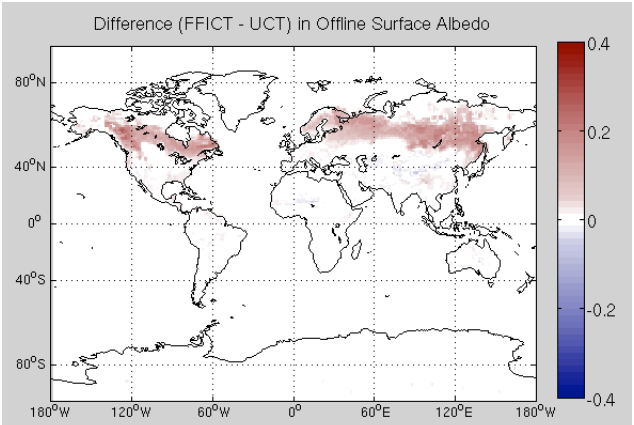
Sea Ice



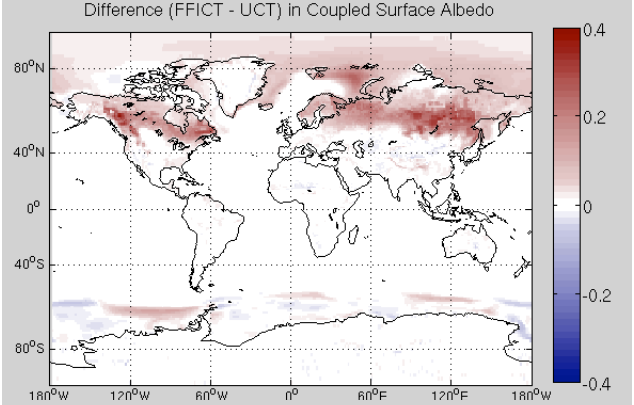
Clouds



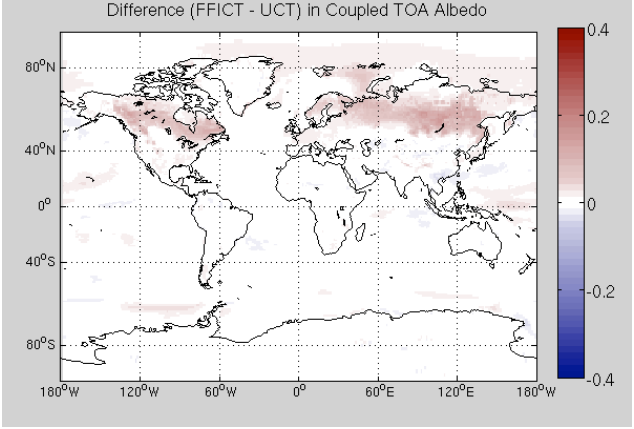
Offline Surface Albedo



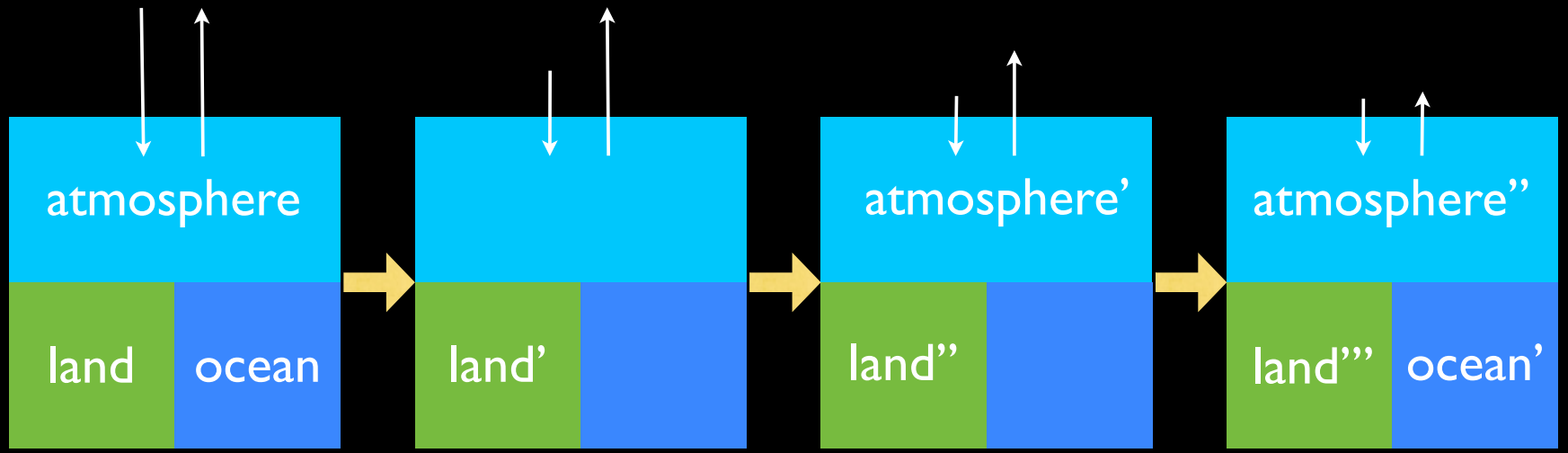
Coupled Surface Albedo



Coupled TOA Albedo



What is the radiative forcing from land use change?



~ -1 W/m^2

Conclusions / Discussion

- Neither the magnitude nor spatial pattern of future warming is explained by GHG forcing alone
  - Land use is a critical consideration in understanding the outcomes of climate policy
  - CMIP protocol may need to be revised
- GHG warming may expand the range of agriculture northward, but forest clearing will reverse the trend
- Although boreal deforestation leads to a cooler climate in 2100, forest clearing should not be confused with reduced GHG emissions

Before you go home and cut down a tree...

- We assume a perfect carbon market that compensates for all changes in terrestrial carbon stocks
  - In reality biogeophysical changes will be accompanied by biogeochemical ones
- The cooling effect of boreal trees is highly regional
  - If you care about Himalayan glacial melt, landcover change in Siberia will probably not help
- Although more difficult to detect, we suspect changes in atmospheric circulation and precipitation as well