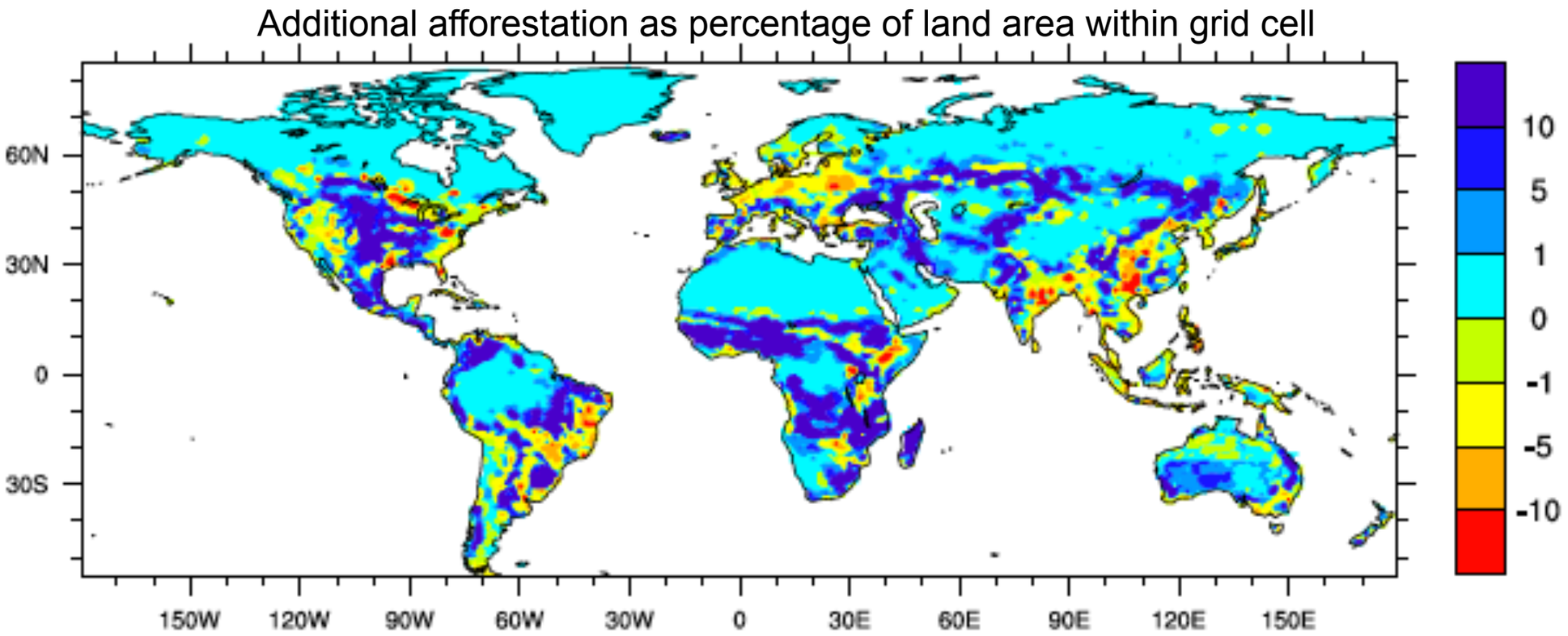
Coupling the land use decisions and carbon cycles of earth system and integrated assessment models



Alan Di Vittorio, Ben Bond-Lamberty, Louise Chini, Jiafu Mao, Kate Calvin, Andy Jones, Xiaoying Shi, Pralit Patel, John Truesdale, Anthony Craig, Bill Collins, Jae Edmonds, George Hurtt, Allison Thomson, Peter Thornton, Yuyu Zhao, Marcia Branstetter, Enhao Du, Jennifer Holm

DOE BER Climate Modeling PI Meeting
May 12-14, 2014

Main Points

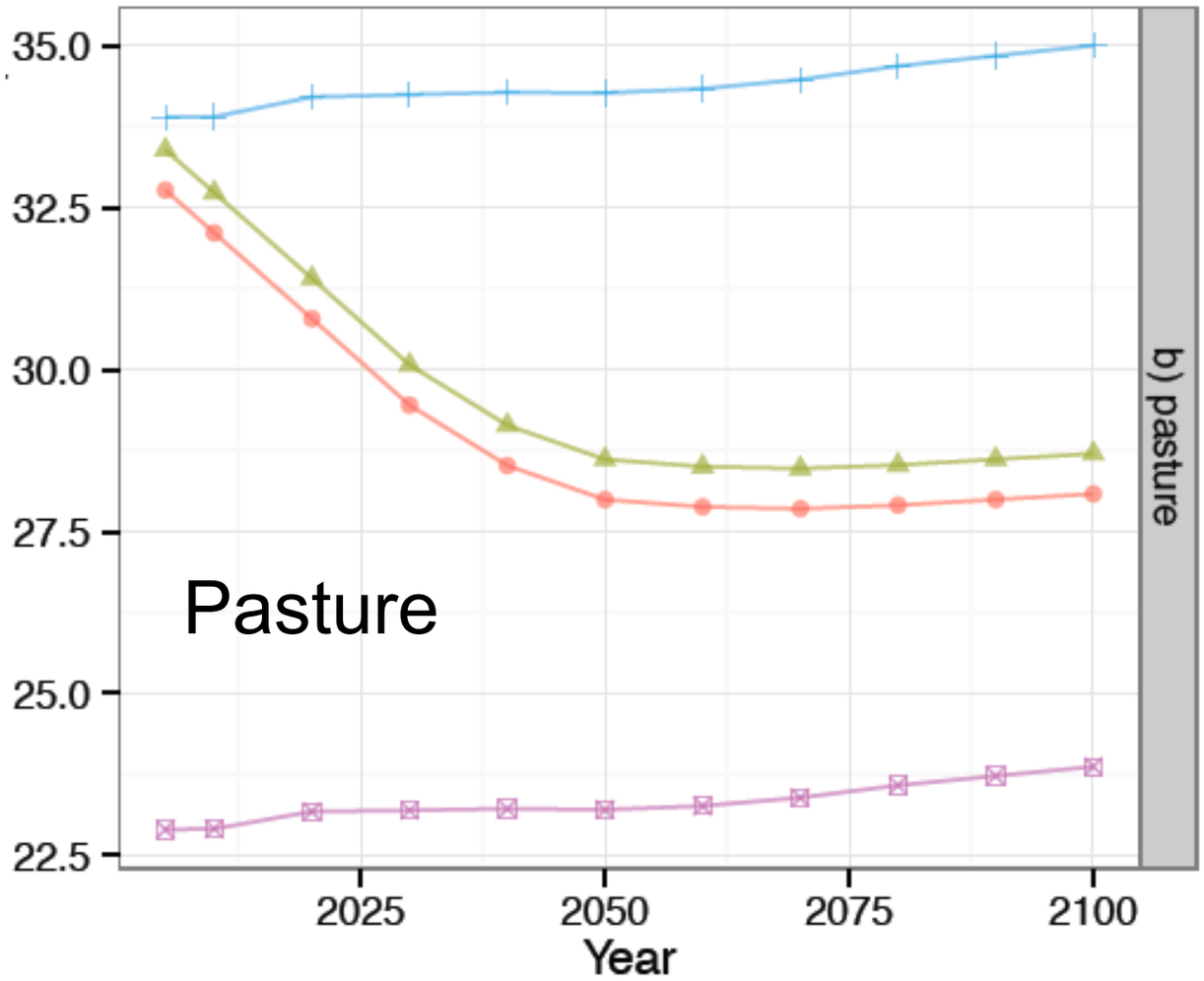
- We have successfully implemented 2-way land coupling between GCAM and CESM

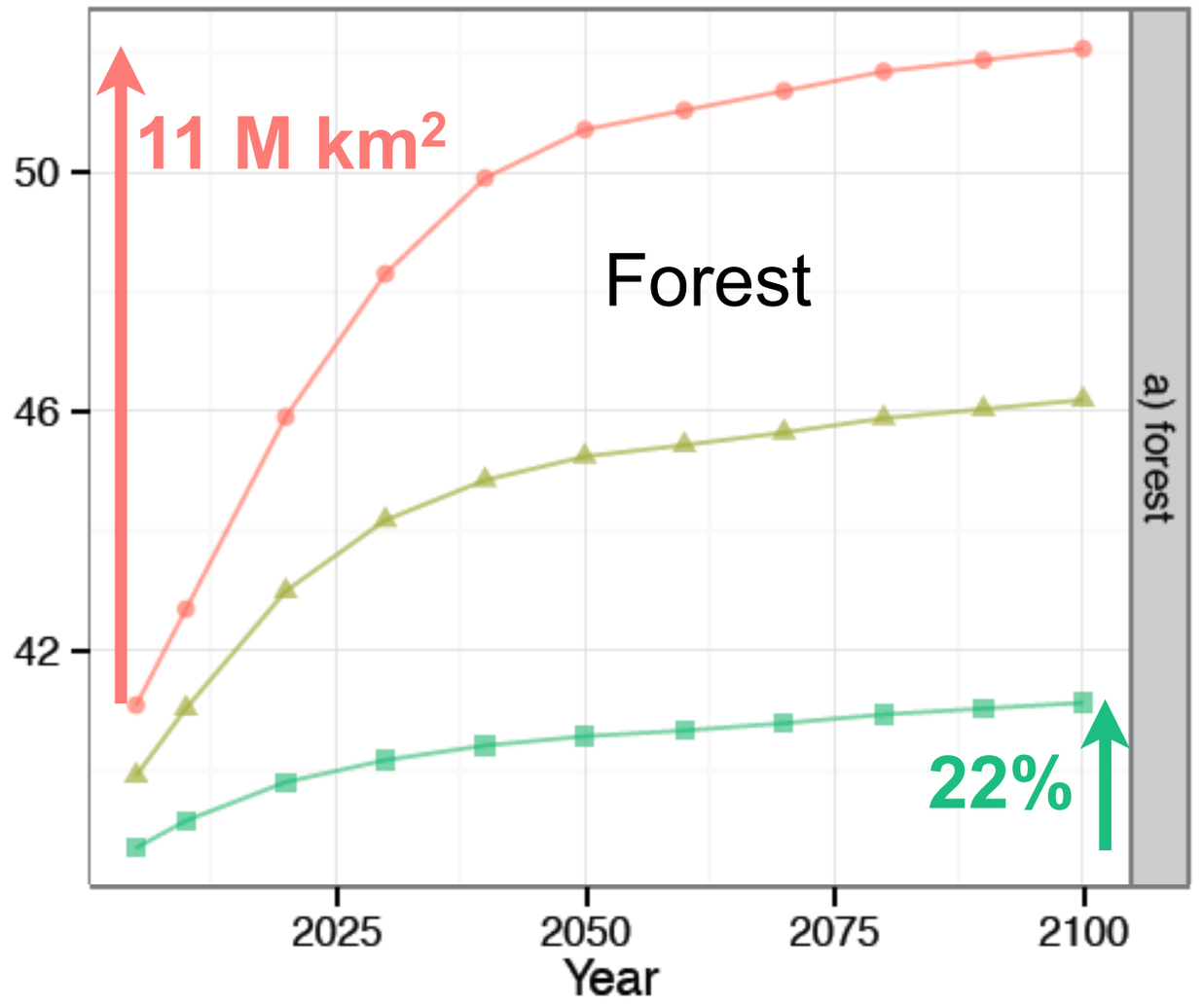
- Climate feedback from CESM to GCAM is robust

- Inconsistencies in land cover effectively change the scenario passed from GCAM to CESM and significantly affect the global carbon cycle
  - Extremely challenging problem
  - Similar inconsistencies exist for other CMIP5 models
  - Not necessarily limited to RCP4.5
  - iESM needs land constancy and a single carbon cycle

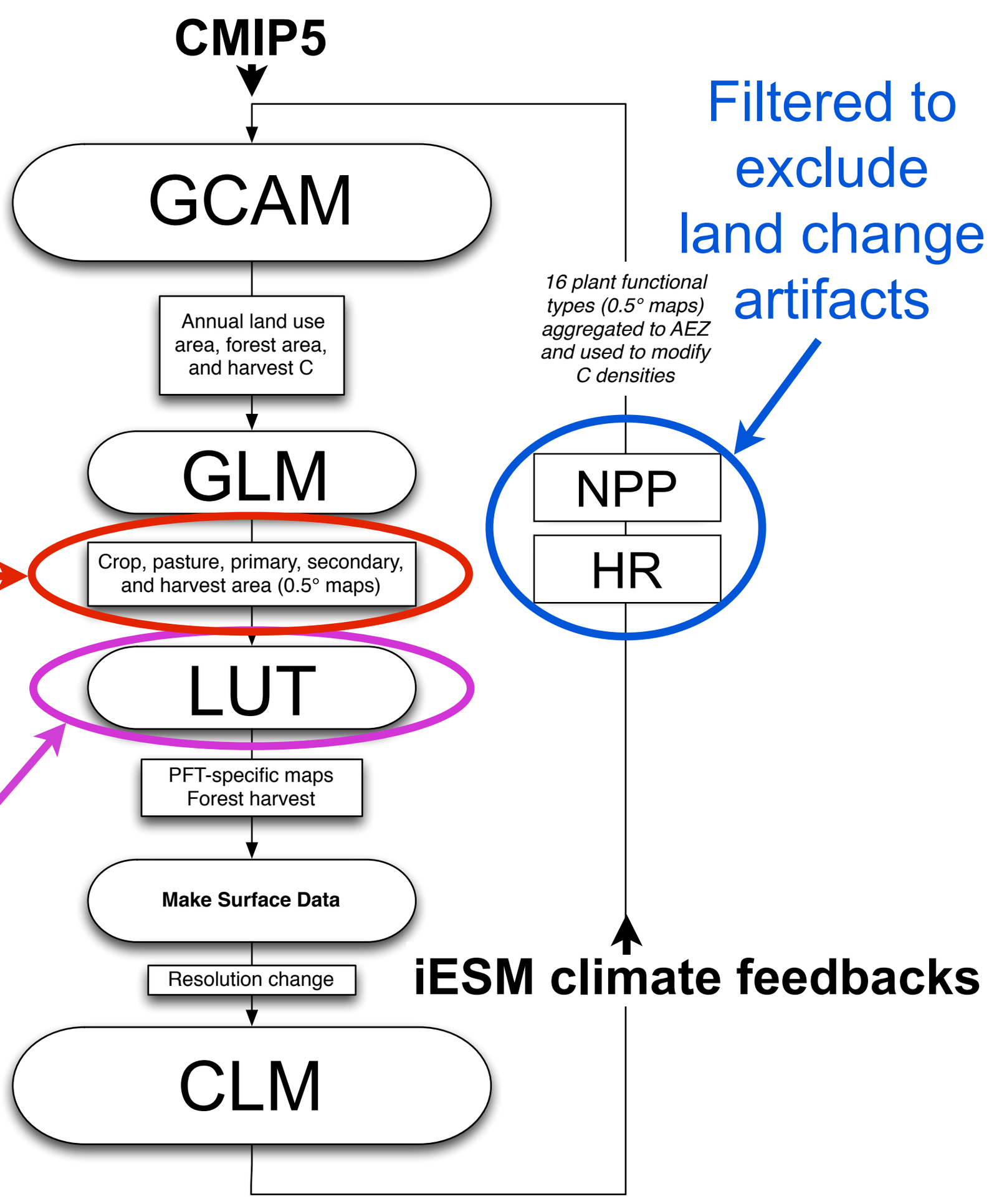
3

CMIP5 RCP4.5 global area (million km^2)





iESM land coupling

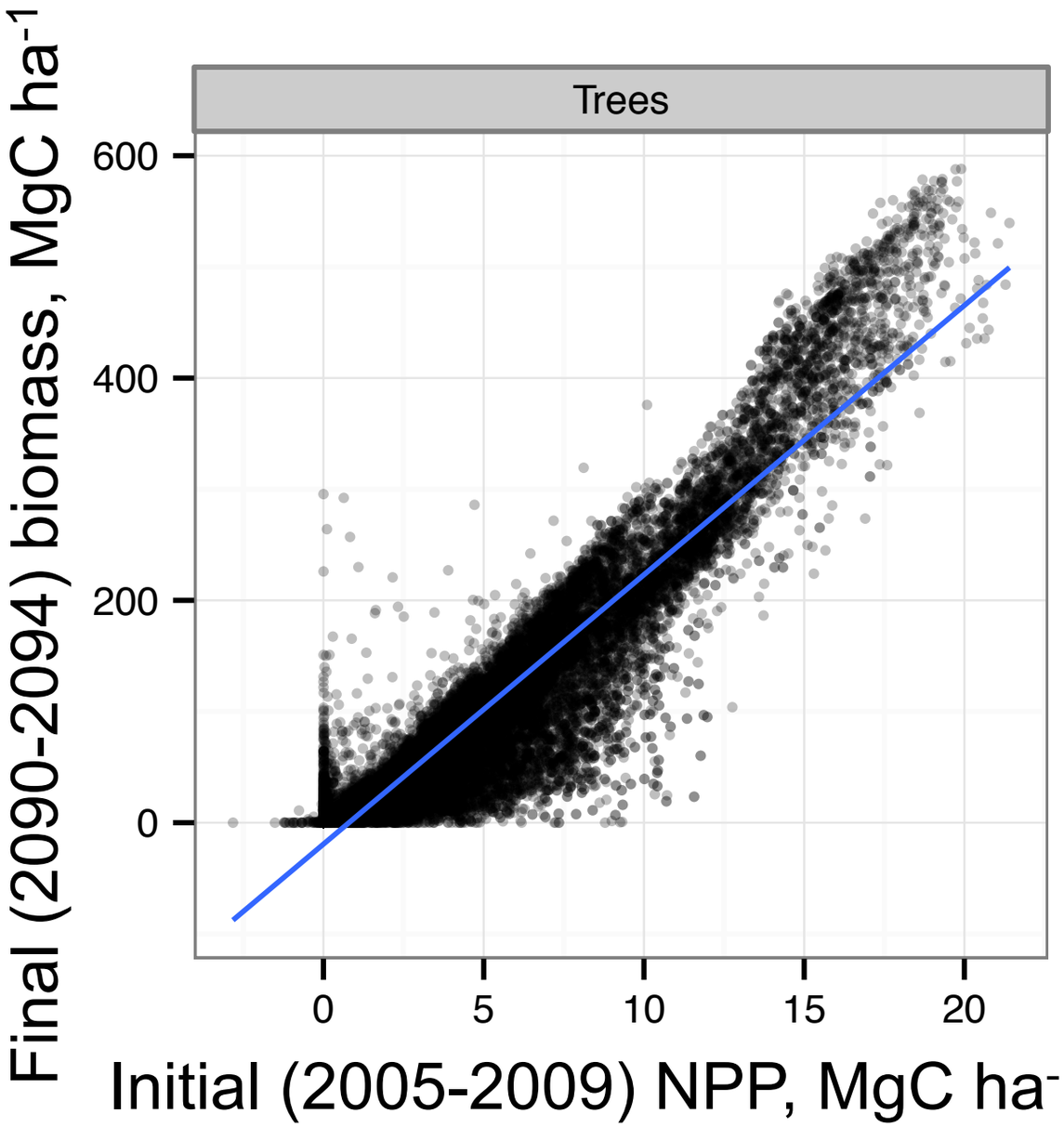


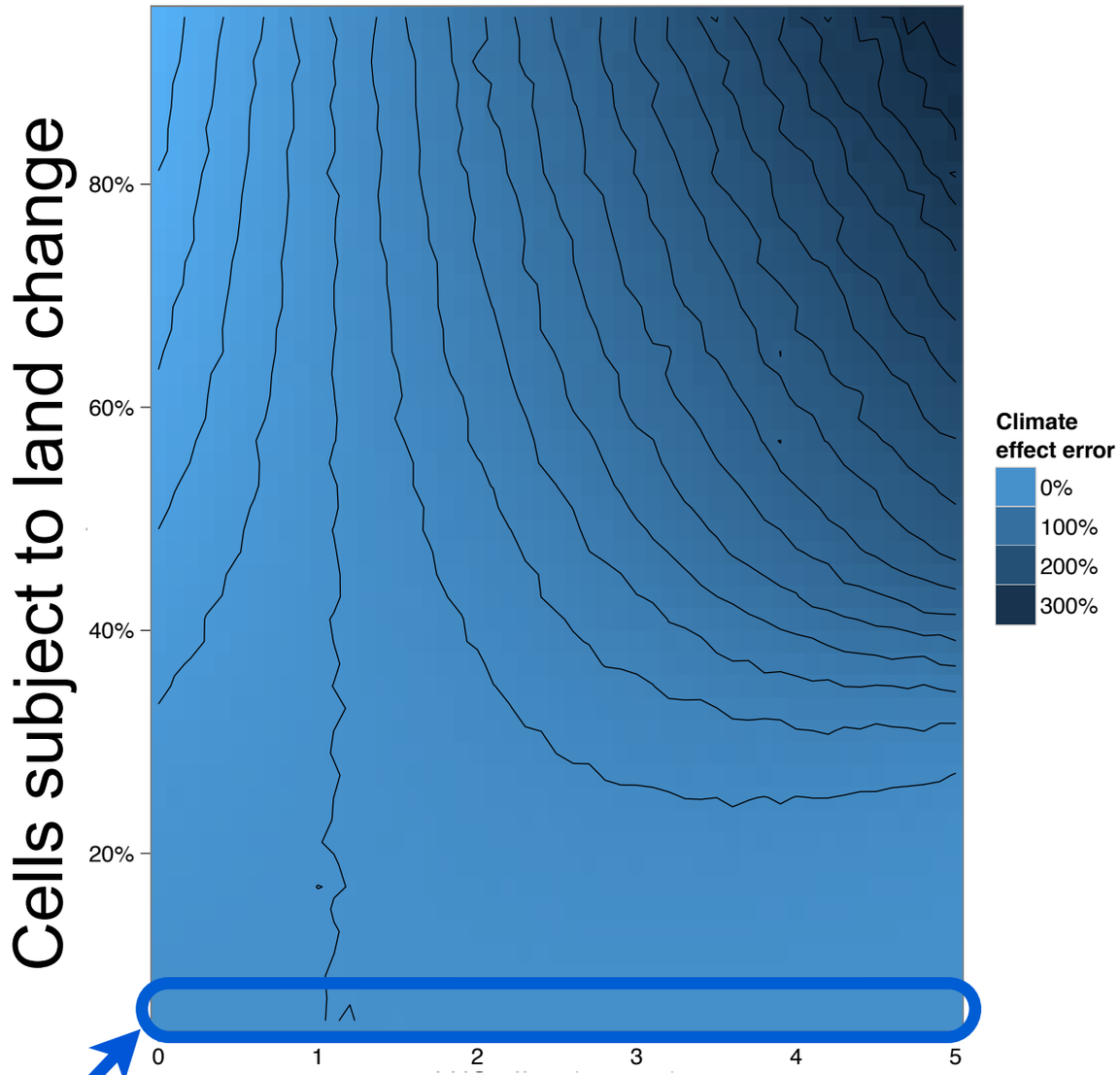
No land cover info!
Only crop, pasture, primary, secondary

New Land Use Translator (LUT)

Add trees when cropland and pasture areas are reduced

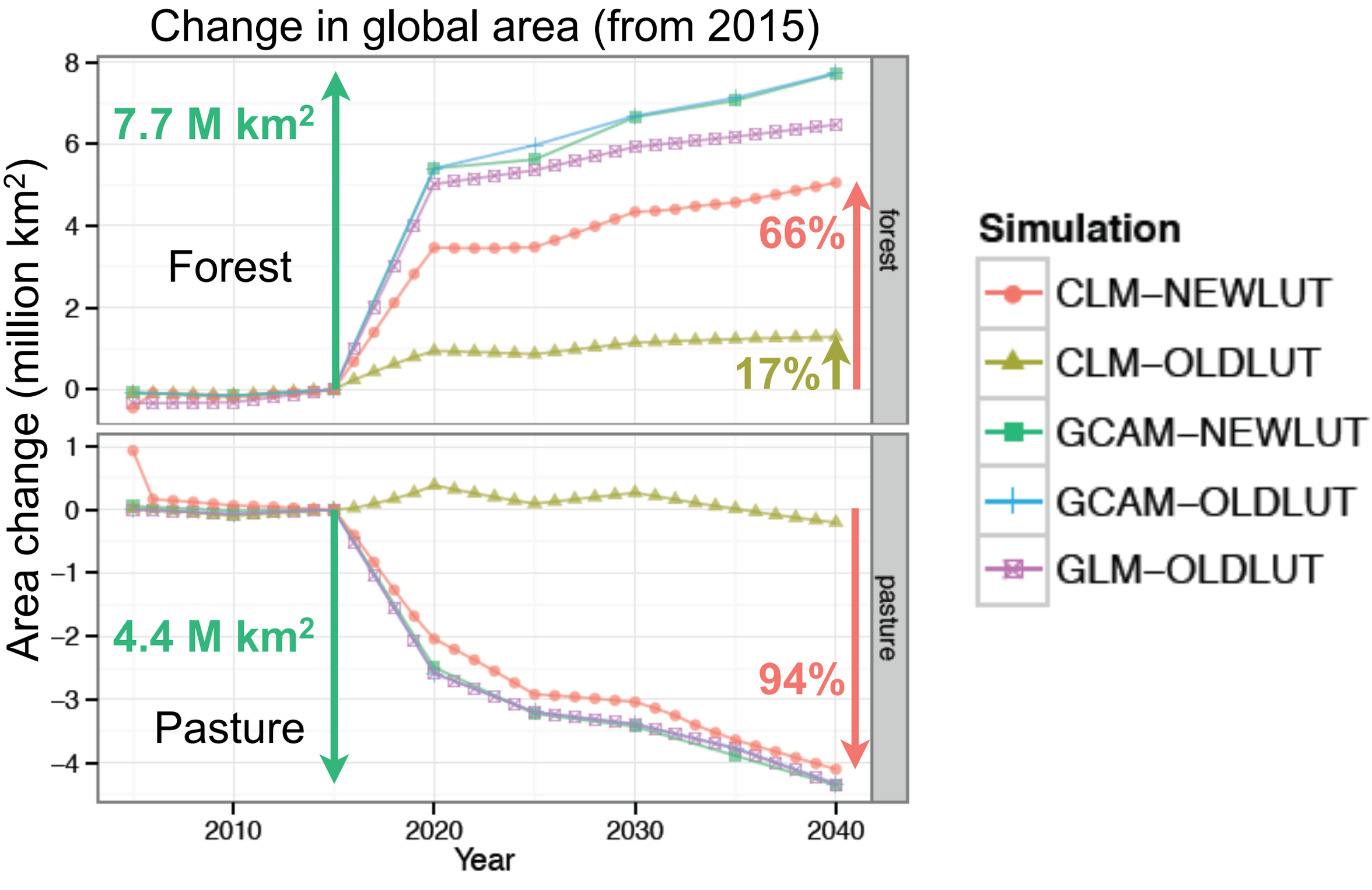
Robust climate feedback implementation





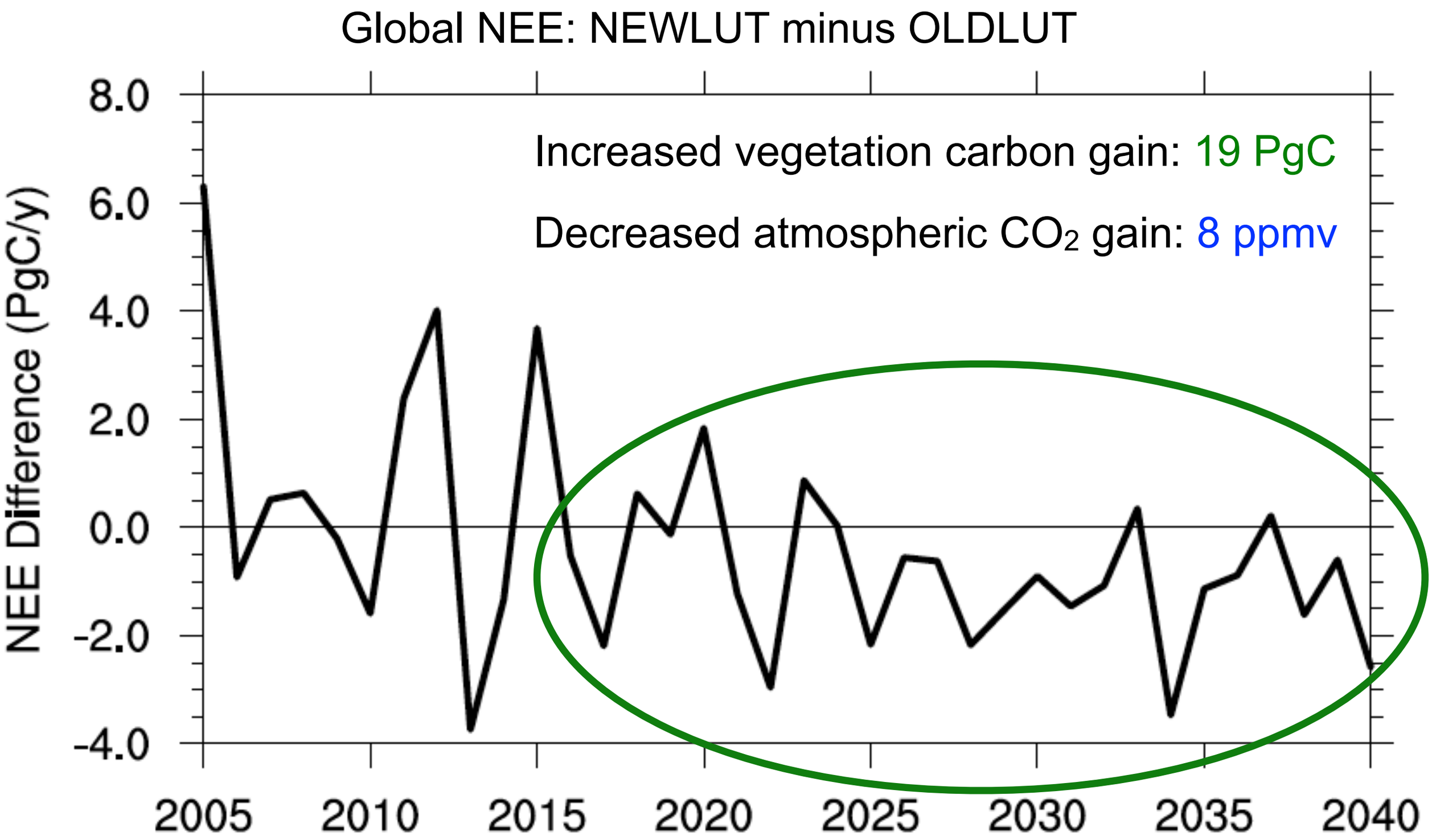
iESM cells removed

iESM transmits 66% of the afforestation to CLM



8

Additional land C uptake due to afforestation



Summary

- iESM successfully implements 2-way land coupling between GCAM and CESM

- Robust climate feedback implementation
  - GCAM (potential) vs CESM (actual) carbon

- Land cover inconsistencies across models significantly affect the global carbon cycle
  - CESM-only modification helps, but not sufficient
    - ~60 out of 100 PgC increase in veg. carbon
    - ~25 out of 40 ppmv decrease in atm. CO_2

- Land cover inconsistencies alter the prescribed scenario

Thank you!

Figures are from:

Di Vittorio et al. (2014, in review). From land use to land cover: Restoring the afforestation signal in a coupled integrated assessment - earth system model and the implications for CMIP5 RCP simulations. *Biogeosciences Discussions (available soon)*.

Bond-Lamberty et al. (2014, in review). Coupling earth system and integrated assessment models: The problem of steady state. *Geoscientific Model Development Discussions, doi:10.5194/gmdd-7-1499-2014*.

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100 yrs of Anthropogenic Emissions

IPCC AR5

Economic Model (GCAM)

100 yrs of Land Use Change

Land Use Change Model (GLM)

Earth System Model (CESM)

5 yrs of Land Use Change

5 yrs of Vegetation Productivity

Current

5 yrs of Anthropogenic Emissions

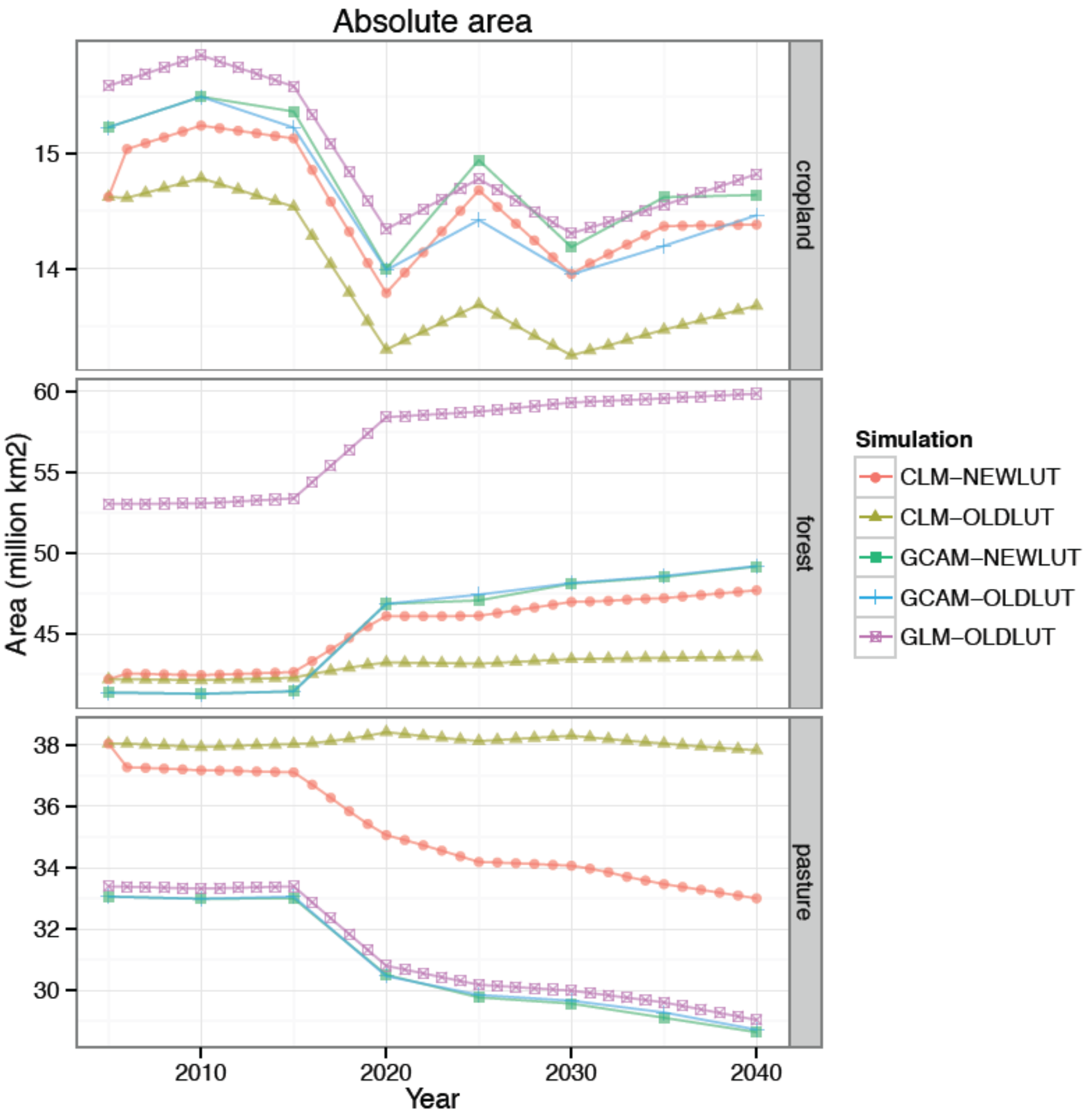
5 yrs Temperature and CO_2 concentrations

In Progress

Water Demand

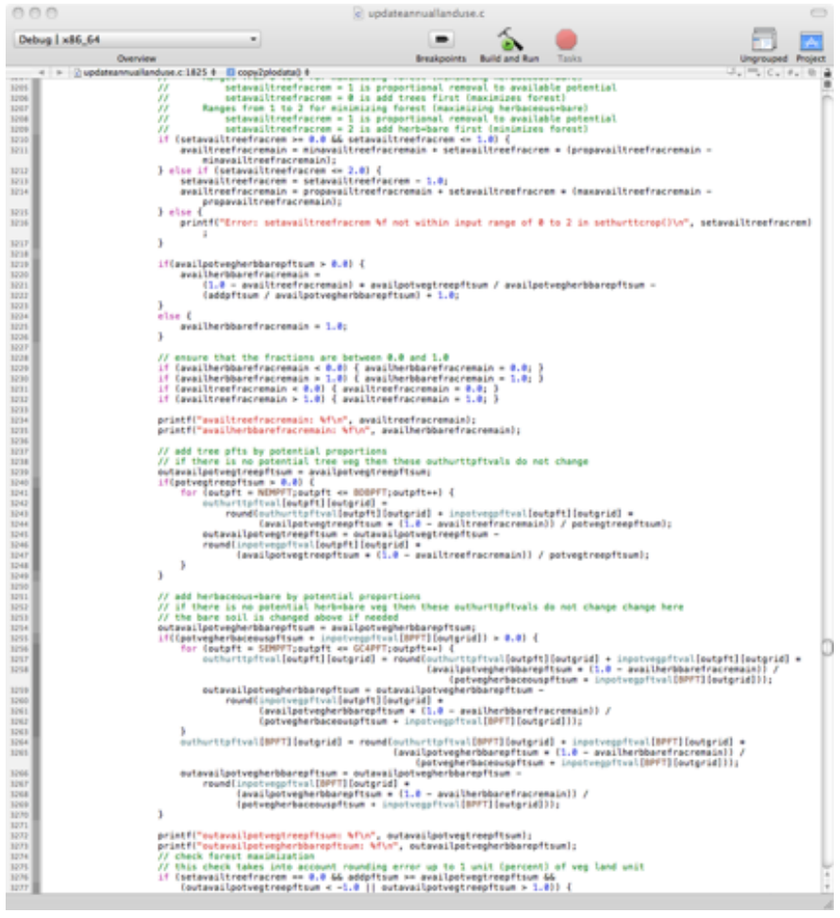
Water Supply

Planned


Absolute area
cropland
forest
pasture
Area (million km2)
15
14
60
55
50
45
38
36
34
32
30
2010
2020
2030
2040
Year
Simulation
CLM–NEWLUT
CLM–OLDLUT
GCAM–NEWLUT
GCAM–OLDLUT
GLM–OLDLUT

In the context of the integrated Earth System Model (iESM)

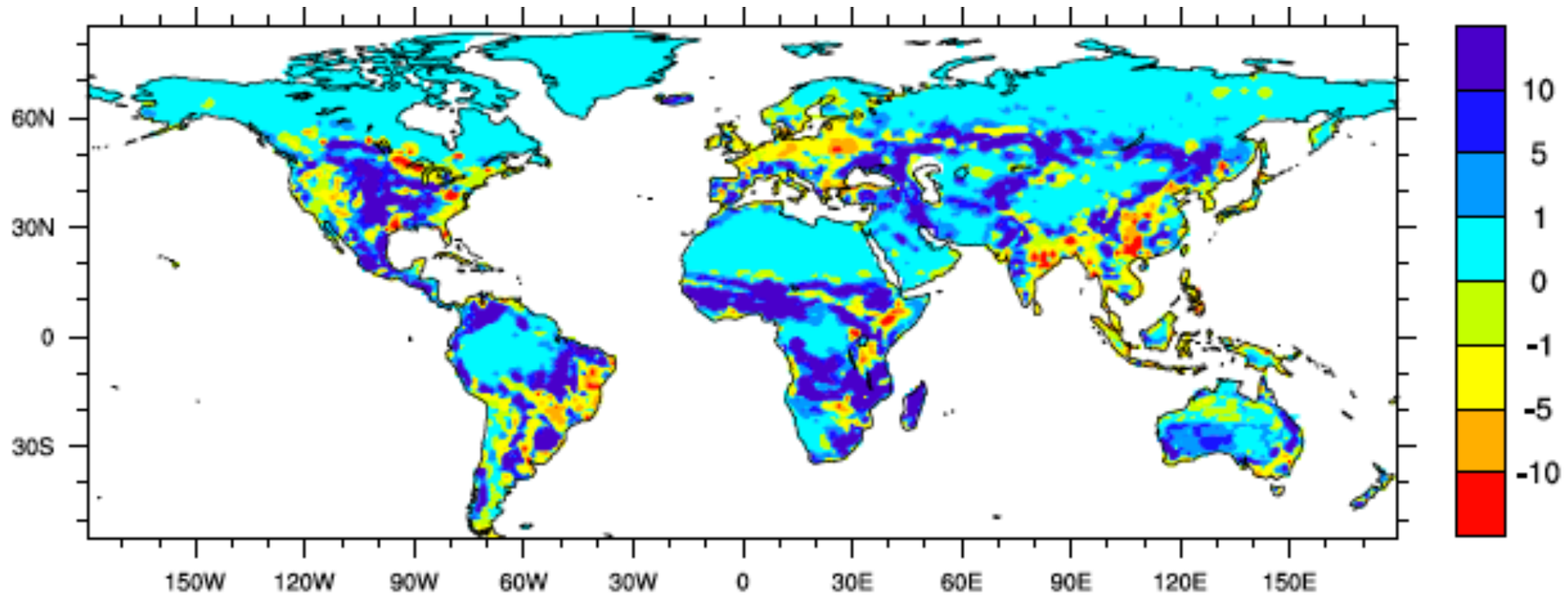
To what extent can we restore the RCP4.5 afforestation solely within CLM/CESM?



How does restored afforestation affect the carbon cycle and climate?

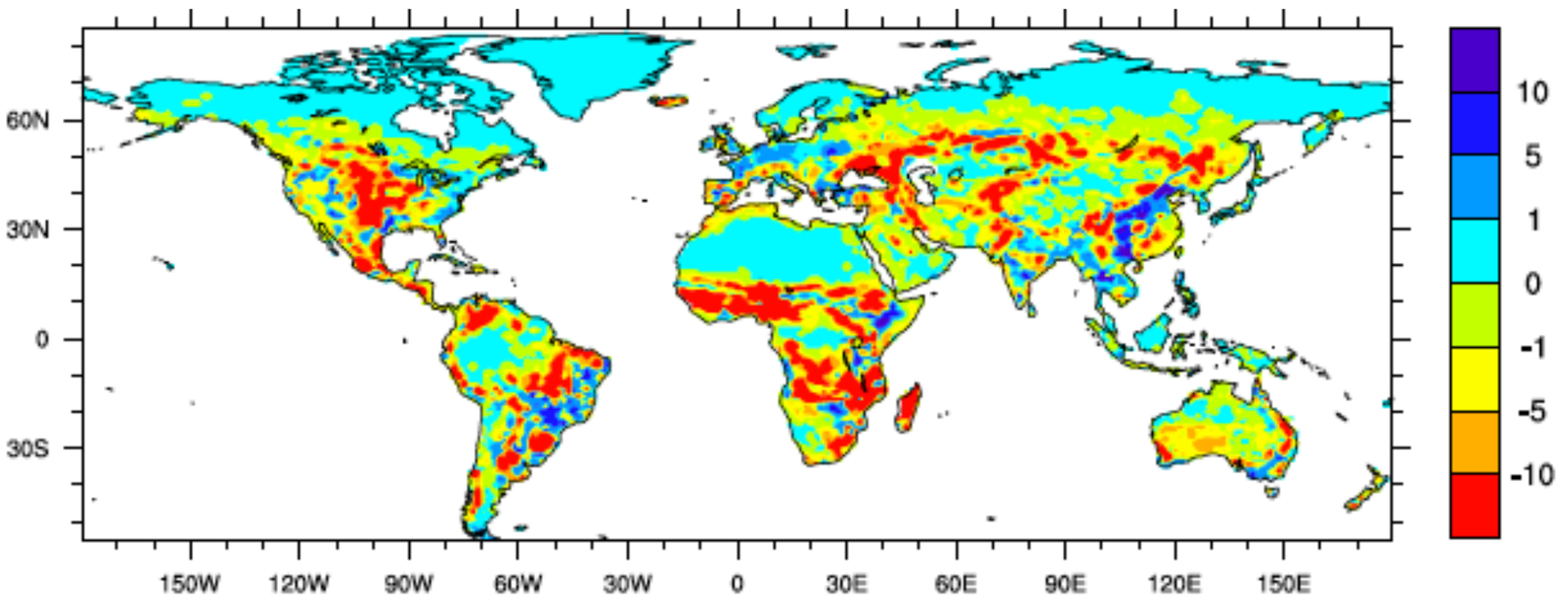
Most new trees replace shrubs and grass

Difference in tree PFT area (2040)



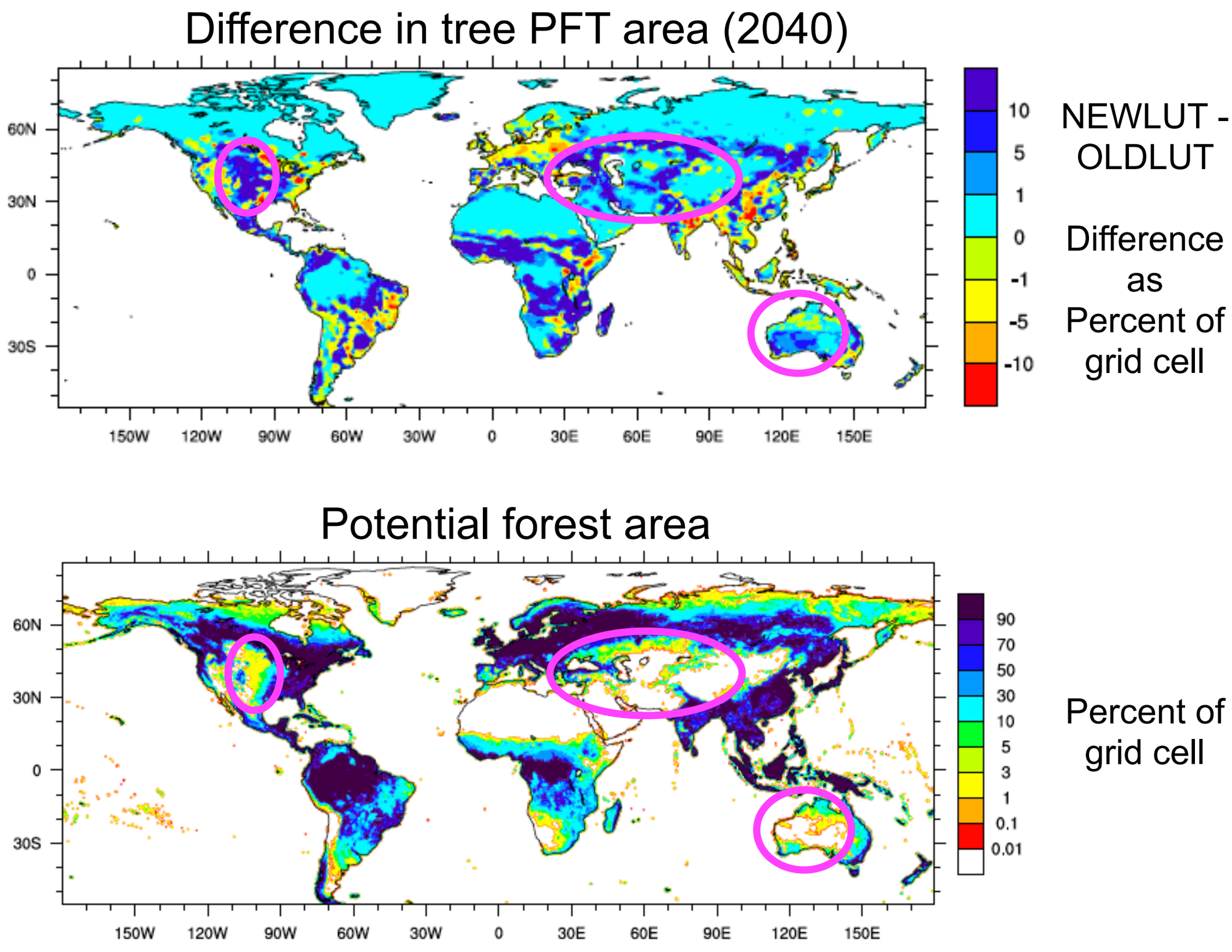
NEWLUT - OLDLUT

Difference in shrub and grass PFT area (2040)



Difference as Percent of grid cell

Not always coincident with potential forest



iESM veg carbon and atmospheric CO_2