

CESM Land Model Working Group – Example Simulating Land Cover Change and the Terrestrial Carbon Cycle in CCSM 4.0 for CMIP5

Peter Lawrence

Terrestrial Science Section

with Gordon Bonan, Sam Levis, Keith Oleson, David
Lawrence, Sean Swensen, Johan Feddema, and Erik
Kluzek

1. IPCC Assessment Report 5 – Land Cover Change

1. The next IPCC assessment report (AR5) modeling experiments are defined in the Coupled Model Inter-comparison Project phase 5 (CMIP5) protocol described in [*Taylor, et al., 2009*]
2. Land cover change is included in the CMIP5 protocol for the 1850 – 2005 Historical period and for the 2006 – 2100 Representative Concentration Pathway (RCP) periods
3. For each Historical and RCP period land use and land cover change are described through annual changes in four basic land units:
 - Primary Vegetation
 - Secondary Vegetation
 - Cropping
 - Pasture
4. Harvesting of biomass is also prescribed for both primary and secondary vegetation land units

2. CMIP5 GLM Historical and RCP Land Cover Change

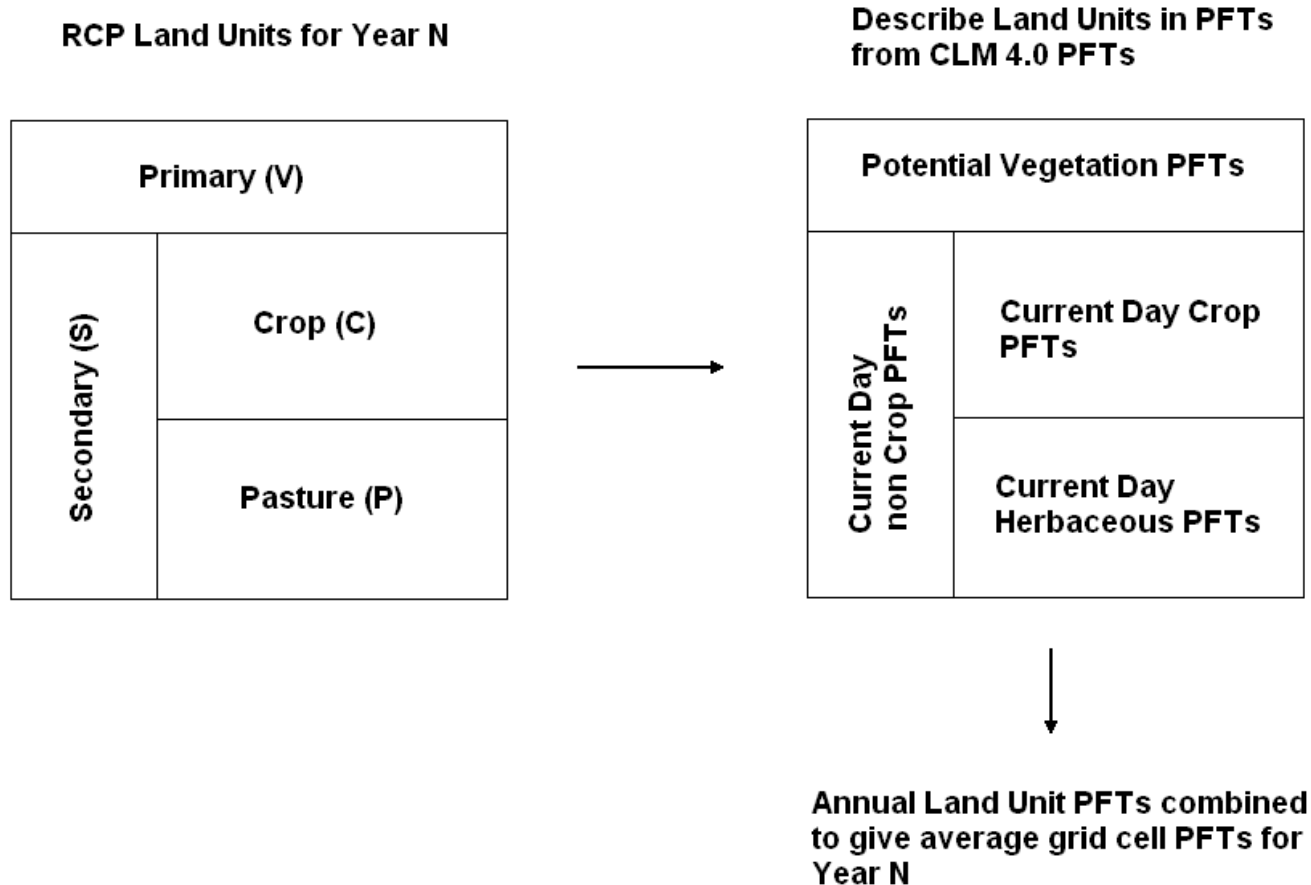
CMIP5 Cumulative Area of Land Cover Change for Historical and RCP Time Series (10^6 km²).

RCP Land Unit Vegetation Impact Scale: Best – 2nd Best – 2nd Worst – Worst

Time Series	Primary	Secondary	Crop	Pasture
Historical 1850-2005	-48.98	13.71	9.81	25.47
RCP 2.6 Image	-15.27	10.66	5.29	-0.67
RCP 4.5 MiniCAM	-12.05	20.71	-4.15	-4.52
RCP 6.0 AIM	-11.88	23.61	3.70	-15.42
RCP 8.5 Message	-19.01	12.79	2.77	3.44

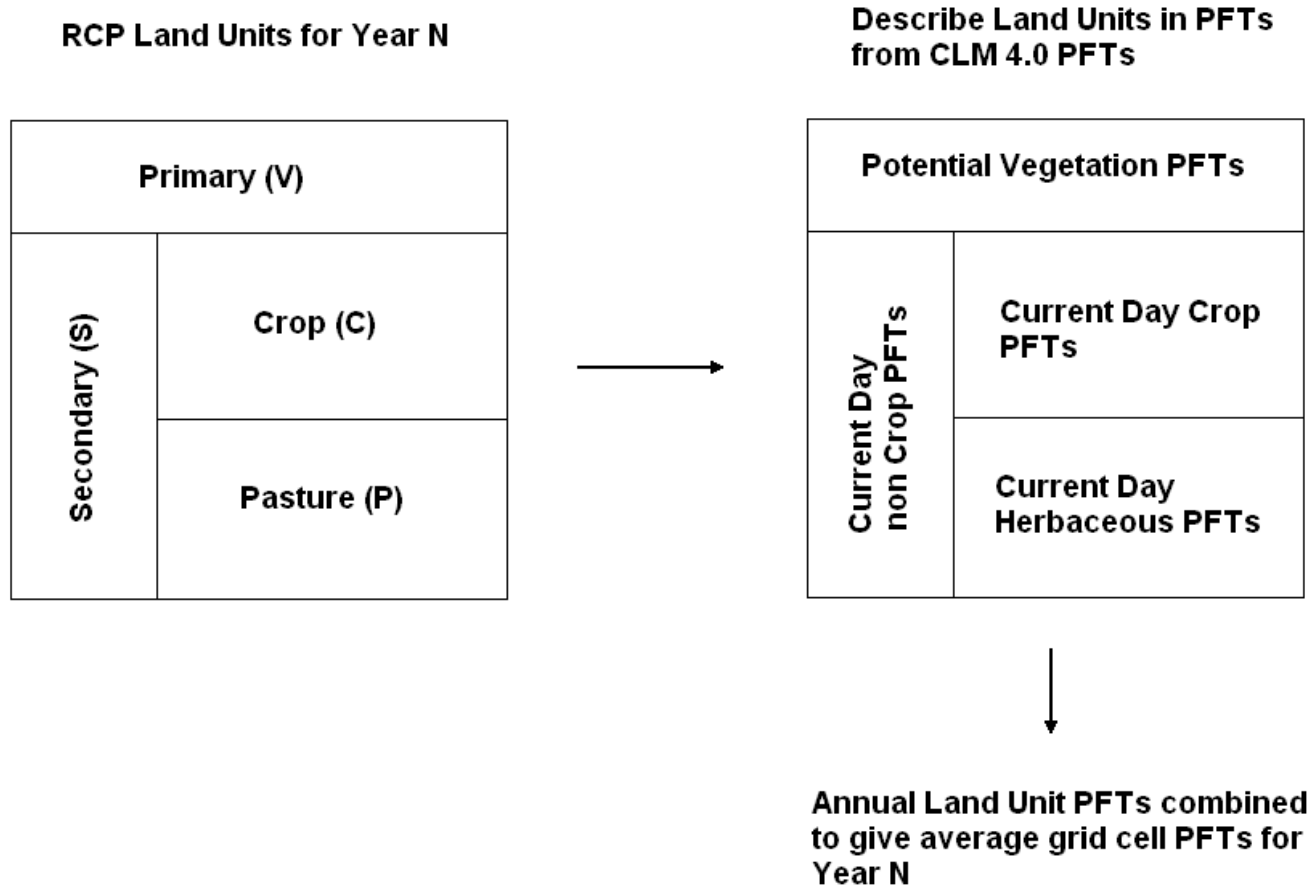
3. CMIP5 Transient Land Cover in CLM 4 PFTs Method

Firstly Crop PFT composition is directly specified from the Crop land unit fractional area.



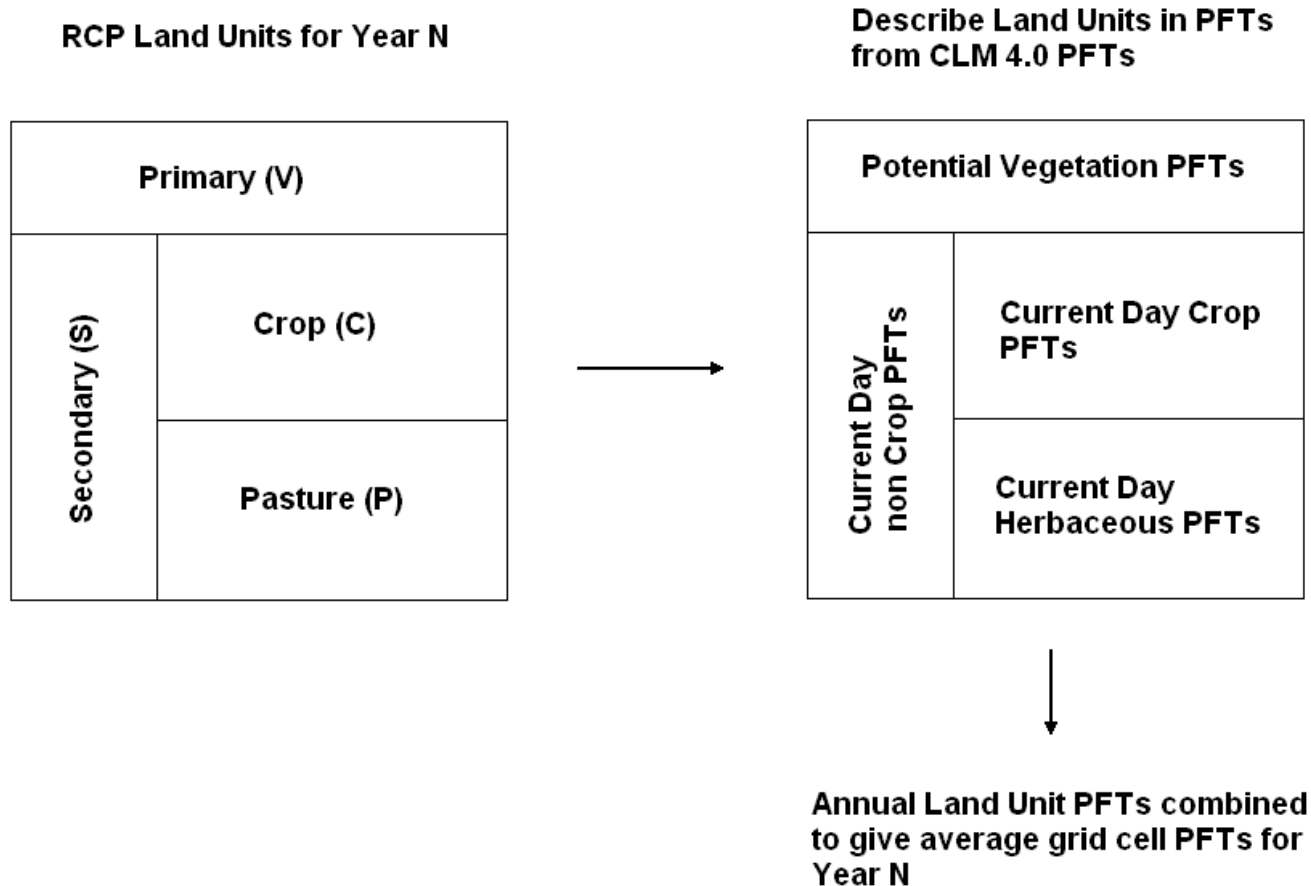
3. CMIP5 Transient Land Cover in CLM 4 PFTs Method

Secondly Pasture PFTs are assigned based on grass PFTs found in the potential vegetation and current day CLM4 land surface parameters scaled by the area of the Pasture land unit. Grass PFTs limited by Veg Frac



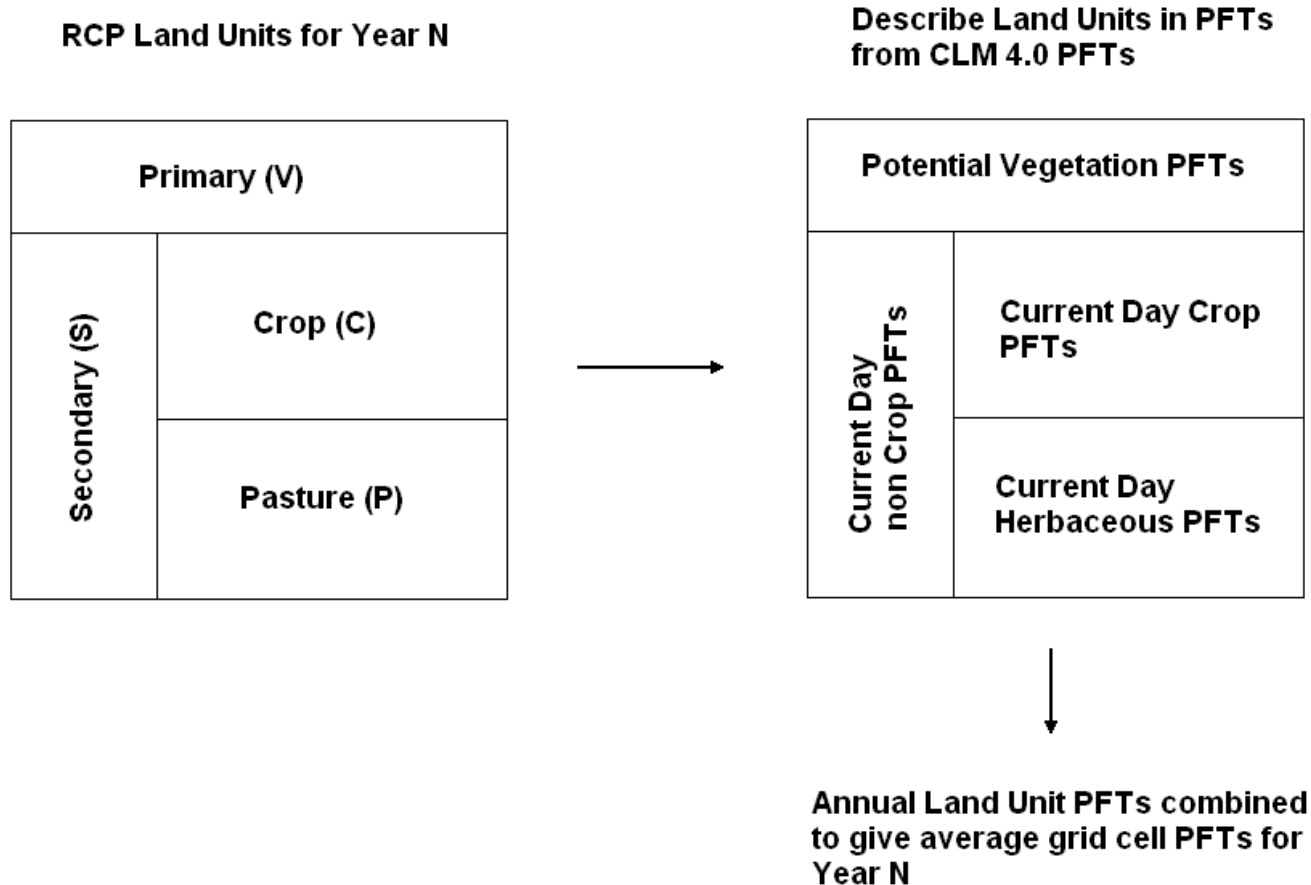
3. CMIP5 Transient Land Cover in CLM 4 PFTs Method

Thirdly Primary PFTs are assigned from potential vegetation PFTs scaled by the fractional area of the Primary land unit.



3. CMIP5 Transient Land Cover in CLM 4 PFTs Method

Finally Secondary PFTs are assigned from current day non-crop and non-pasture PFTs scaled by the fractional area of the Secondary unit.



3. CMIP5 Historical and RCP Land Cover Change PFTs

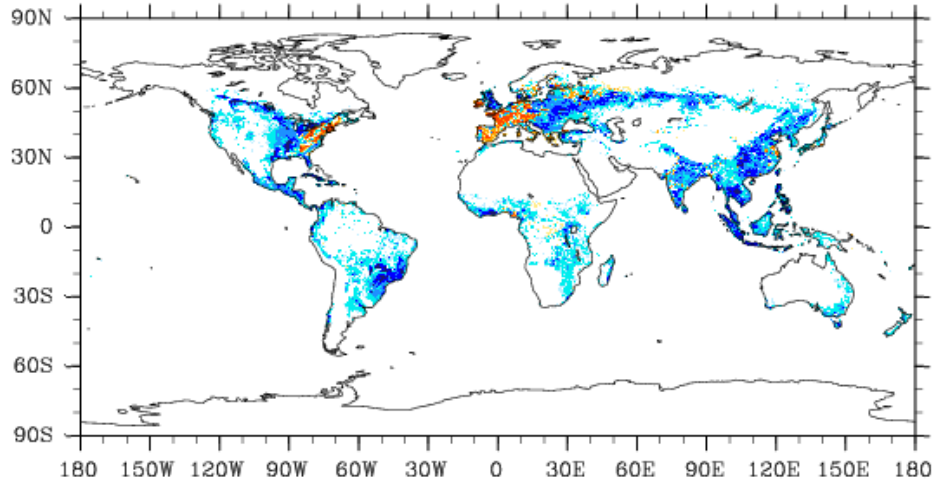
CMIP5 Total Area of Land Cover Change for Historical and RCP Time Series (10⁶ km²).

RCP PFT Vegetation Impact Scale: **Best** – 2nd **Best** – 2nd **Worst** – **Worst**

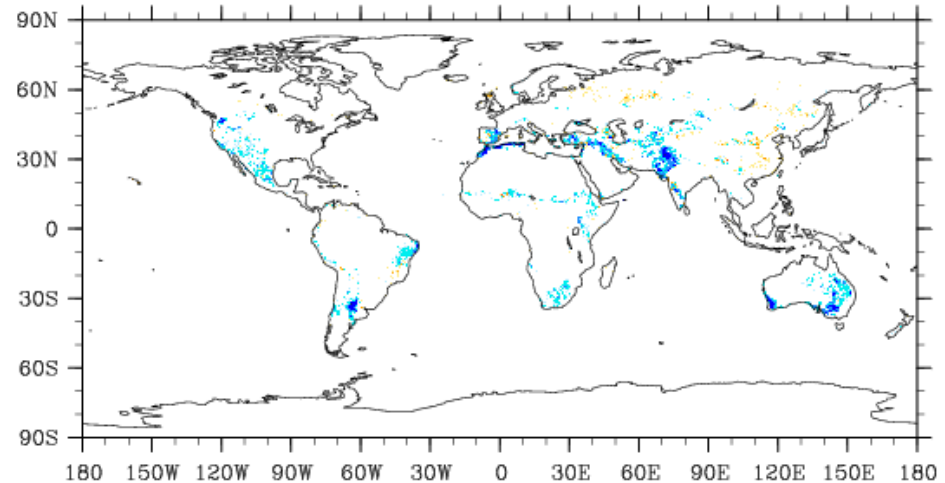
Time Series	Tree PFTs	Shrub PFTs	Crop PFTs	Grass PFTs
Historical 1850-2005	-5.53	-0.97	9.81	-3.25
RCP 2.6 Image	-2.68	-0.41	5.29	-2.10
RCP 4.5 MiniCAM	2.96	0.19	-4.15	0.99
RCP 6.0 AIM	-0.33	-0.31	3.70	-2.95
RCP 8.5 Message	-3.51	-0.10	2.77	0.85

3. CMIP5 - Historical Land Cover Change – PFTs %area

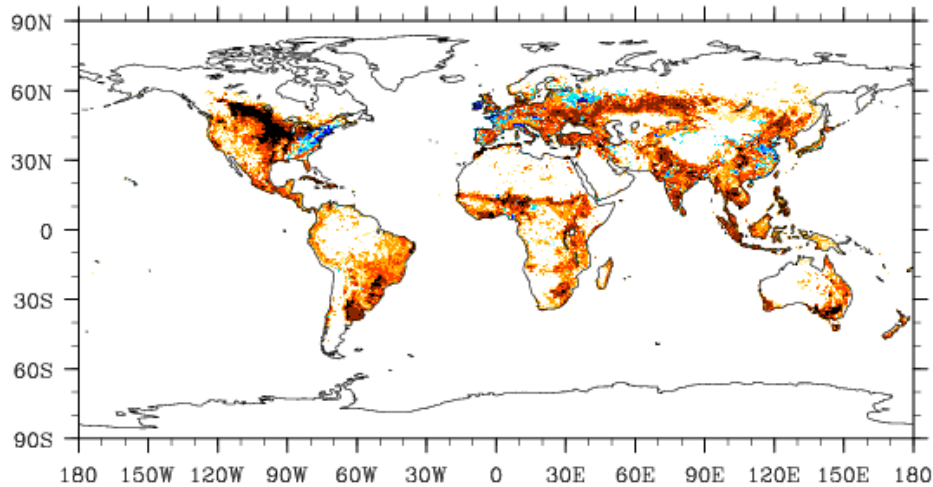
Historical (2005-1850) Tree PFTs



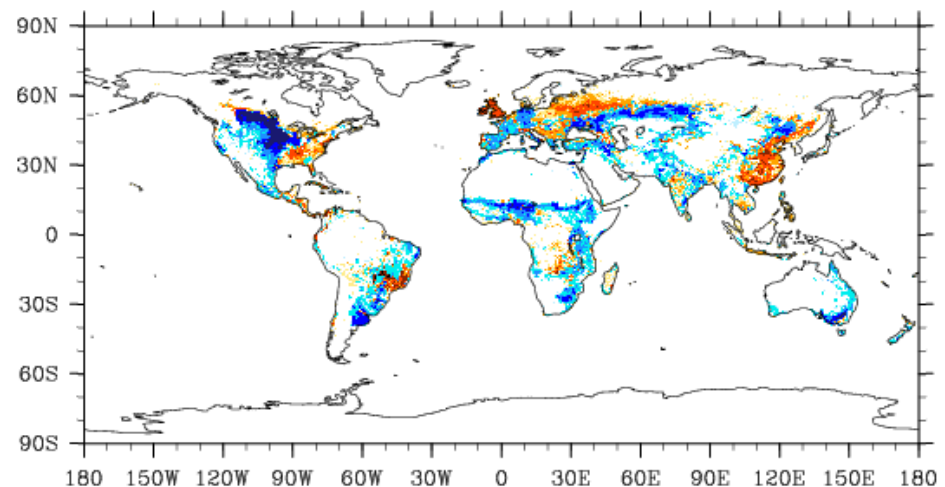
Historical (2005-1850) Shrub PFTs



Historical (2005-1850) Crop

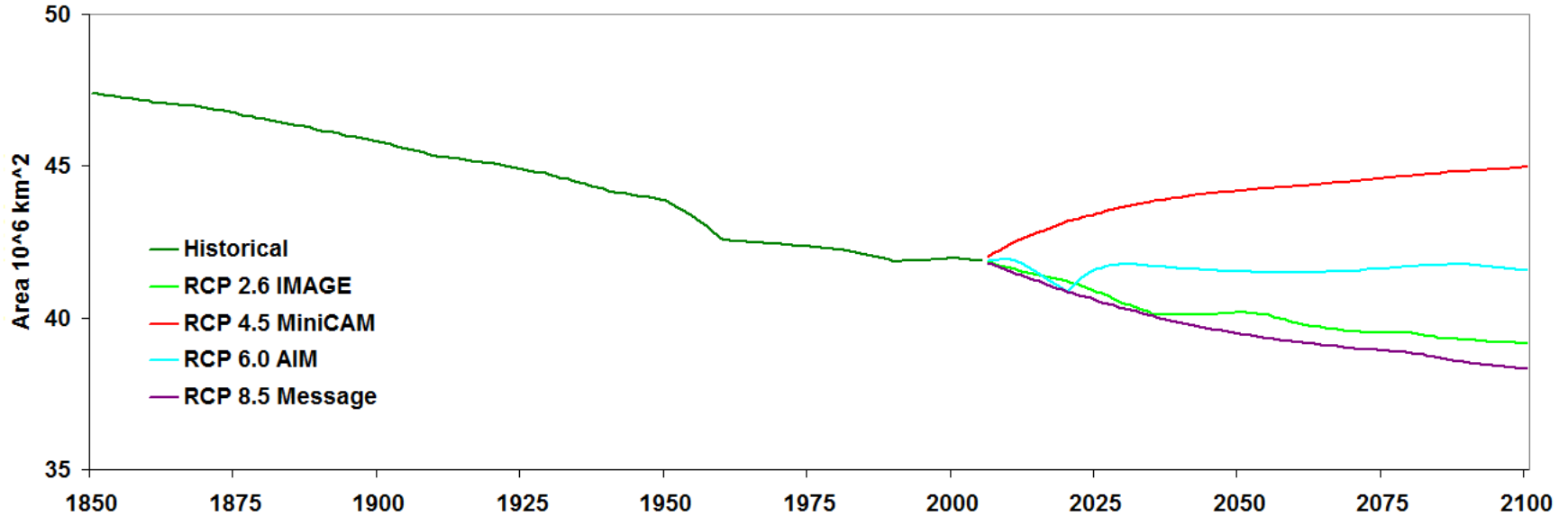


Historical (2005-1850) Grass PFTs

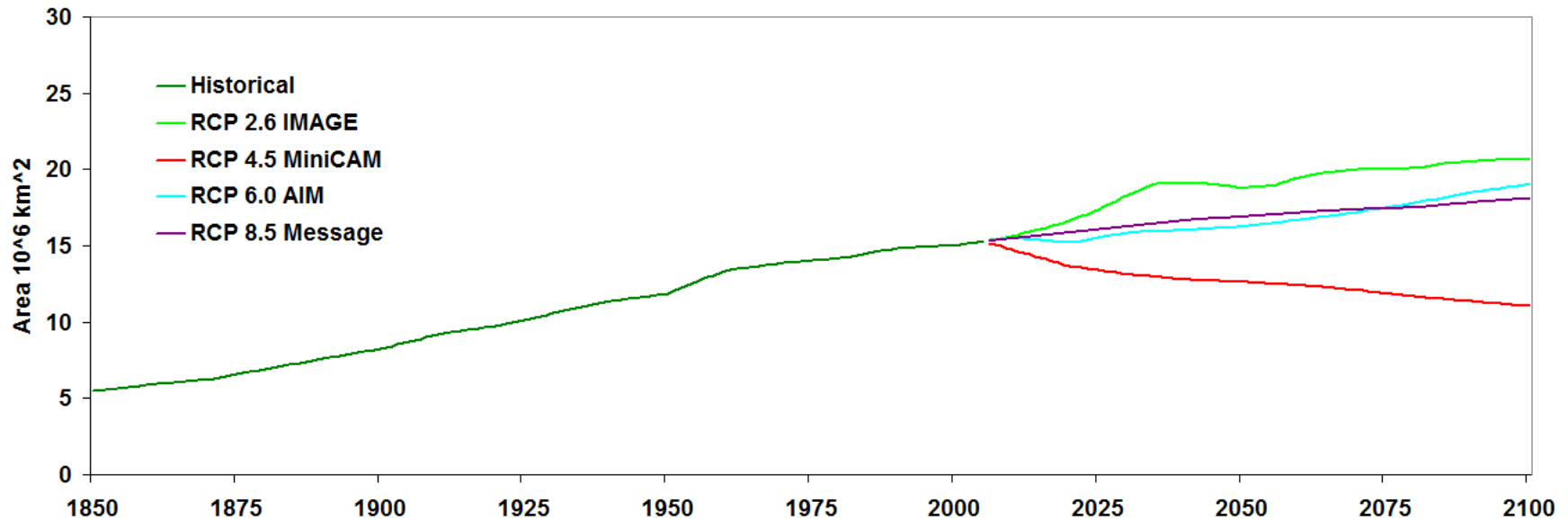


3. CMIP5 Transient Land Cover in CLM 4 PFTs

CMIP5 Total Global Tree PFT Area

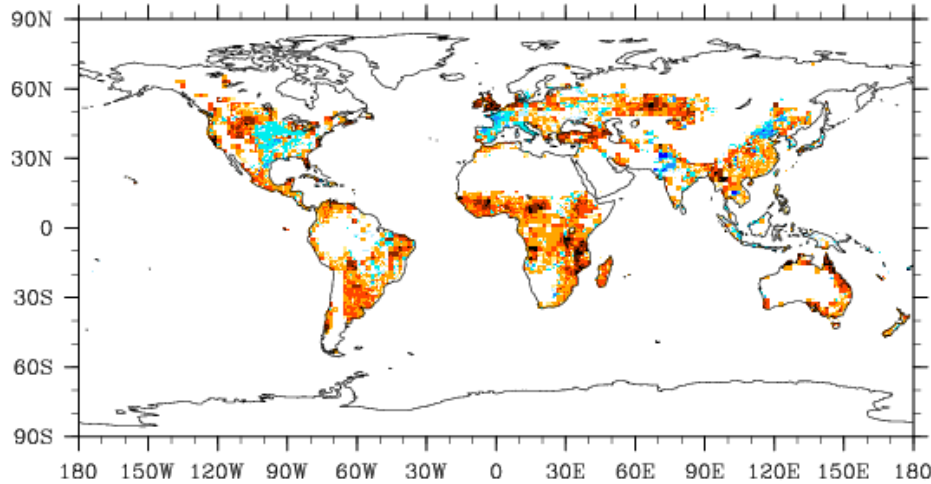


CMIP5 Total Global Crop PFT Area

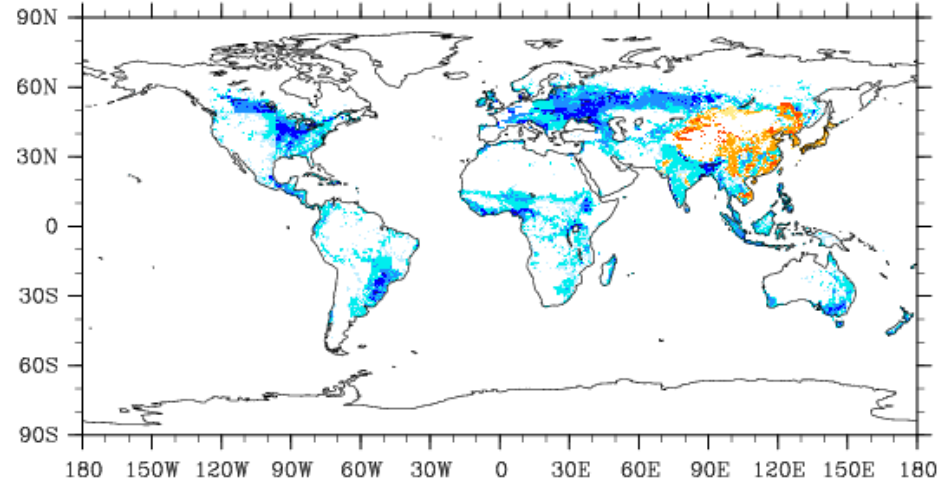


3. CMIP5 - RCP Land Cover Change PFTs – Crop %area

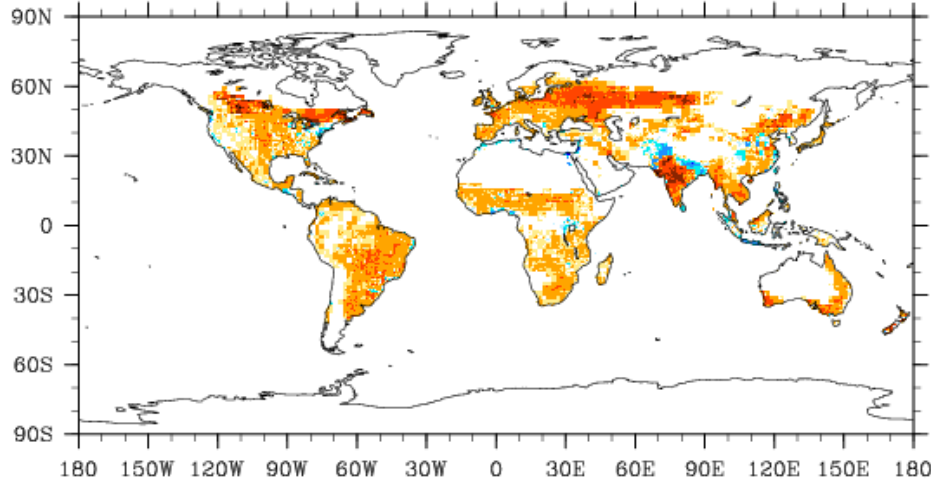
RCP 2.6 IMAGE (2100-2006) Crop



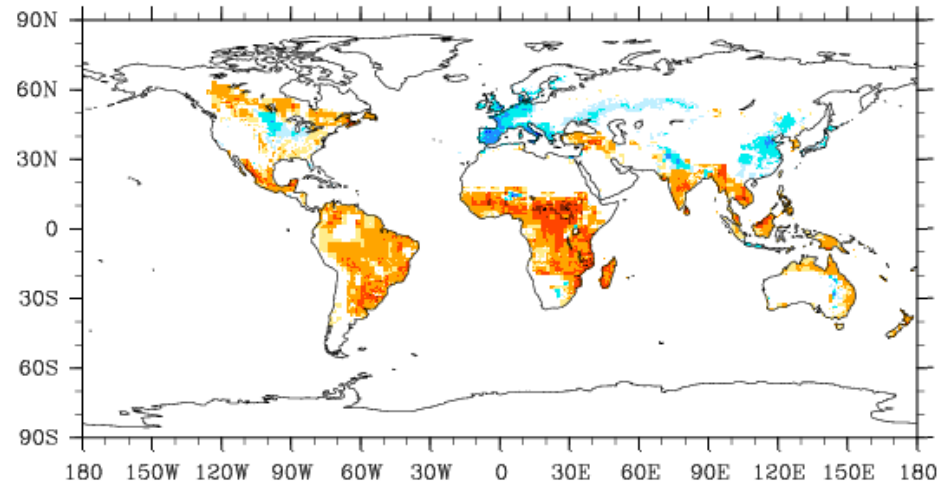
RCP 4.5 MiniCAM (2100-2006) Crop



RCP 6.0 AIM (2100-2006) Crop

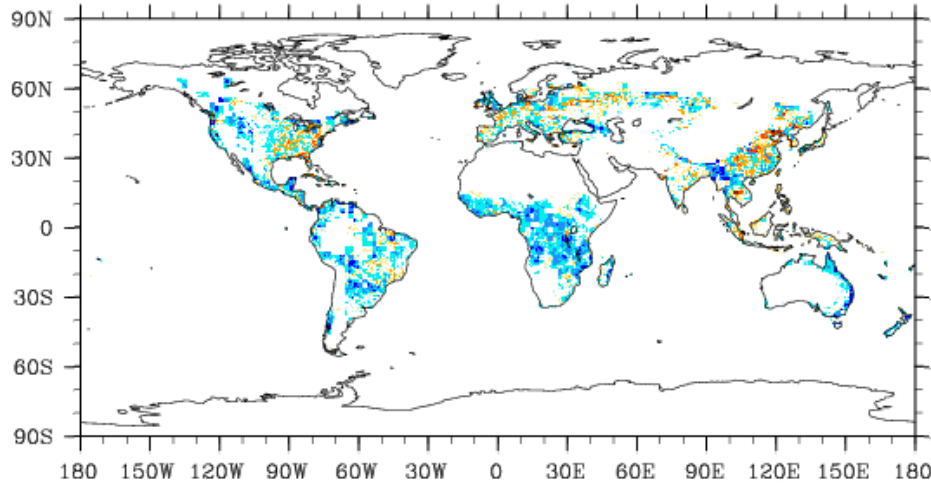


RCP 8.5 Message (2100-2006) Crop

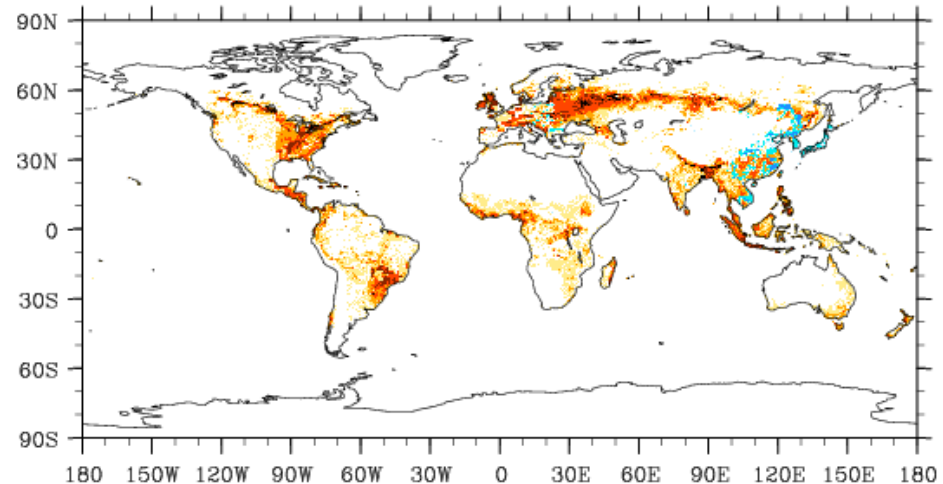


3. CMIP5 - RCP Land Cover Change PFTs – Trees %area

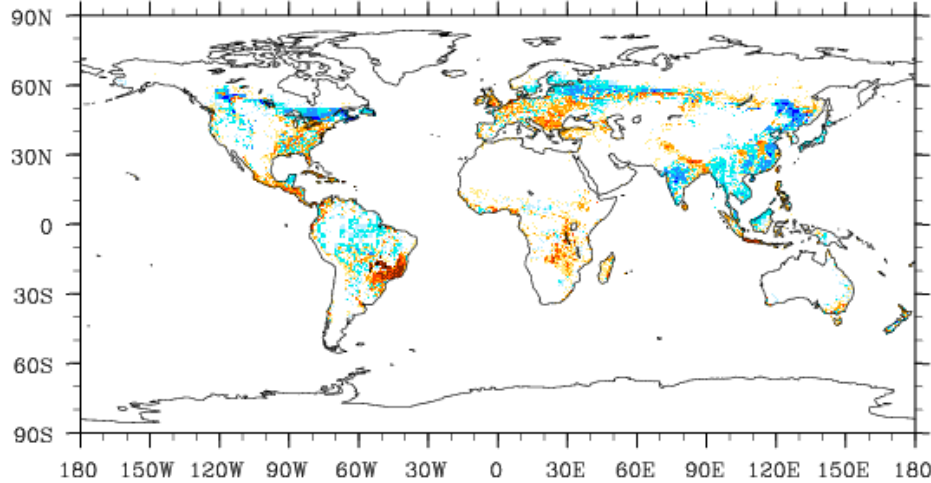
RCP 2.6 IMAGE (2100-2006) Tree PFTs



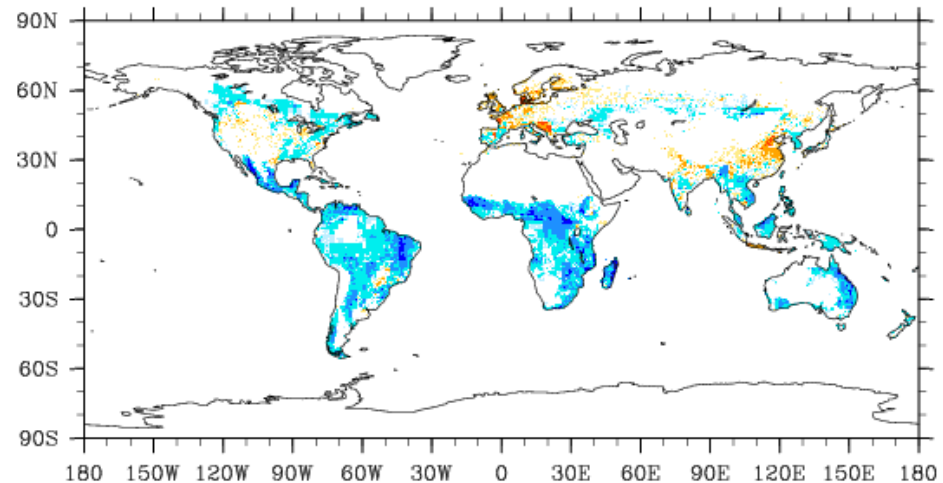
RCP 4.5 MiniCAM (2100-2006) Tree PFTs



RCP 6.0 AIM (2100-2006) Tree PFTs



RCP 8.5 Message (2100-2006) Tree PFTs



4. CMIP5 Primary and Secondary Wood Harvest

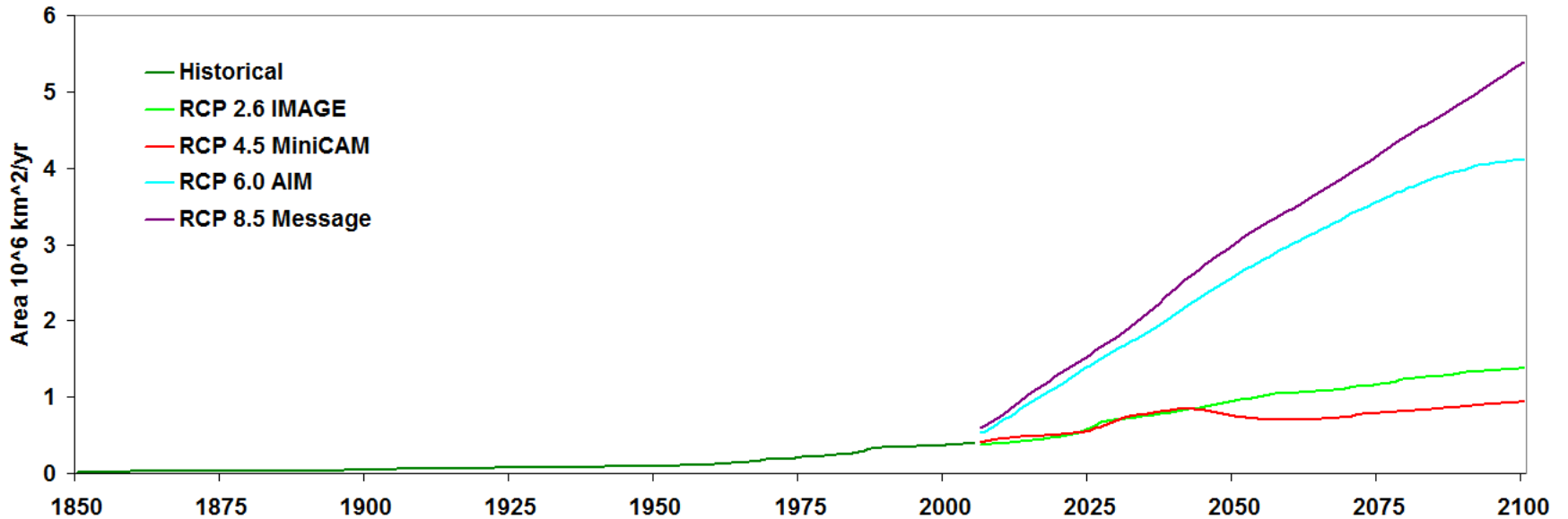
1. Primary and Secondary wood harvest are prescribed on the same 0.5 degree grid as the land use class transitions for each year.
2. For consistency with the land use transitions the area of land harvested is specified for each grid cell for each year
3. To ensure consistency with the wood products specified in the Integrated Assessment Models the amount of carbon harvested is also specified for each grid cell for each year.

5. CMIP5 Wood Harvest in CLM 4 PFTs

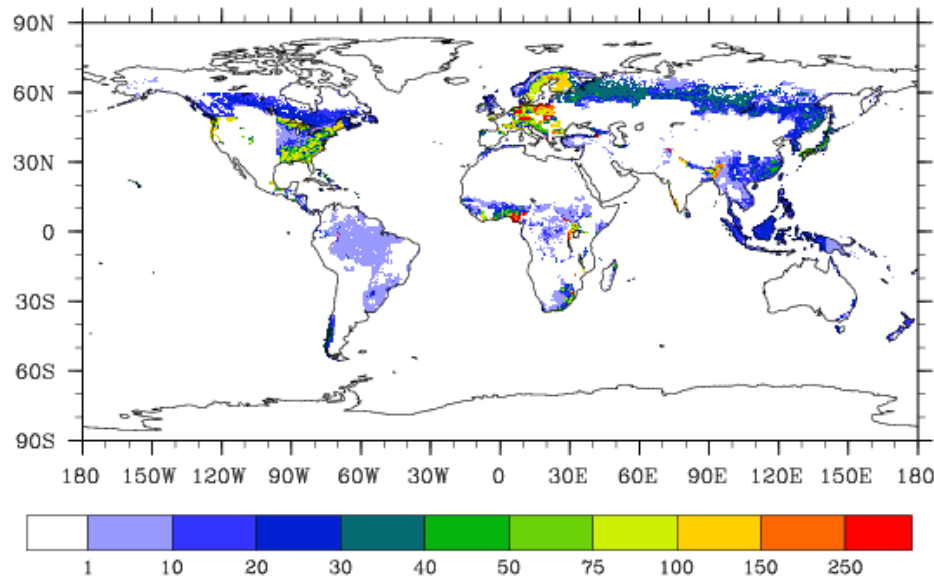
1. Annual tree PFT harvest parameters are calculated for CLM4 based on the harvest area information of the CMIP5 time series
2. The area values are combined with the transient tree PFT values for each grid cell for year giving a tree PFT harvest fraction
3. The GLM area values are therefore prescribed directly in CLM4 normalized to Tree PFT values.

5. CMIP5 Historical and RCP Tree PFT Harvest

CMIP5 Total Global Annual Tree PFT Harvest Area

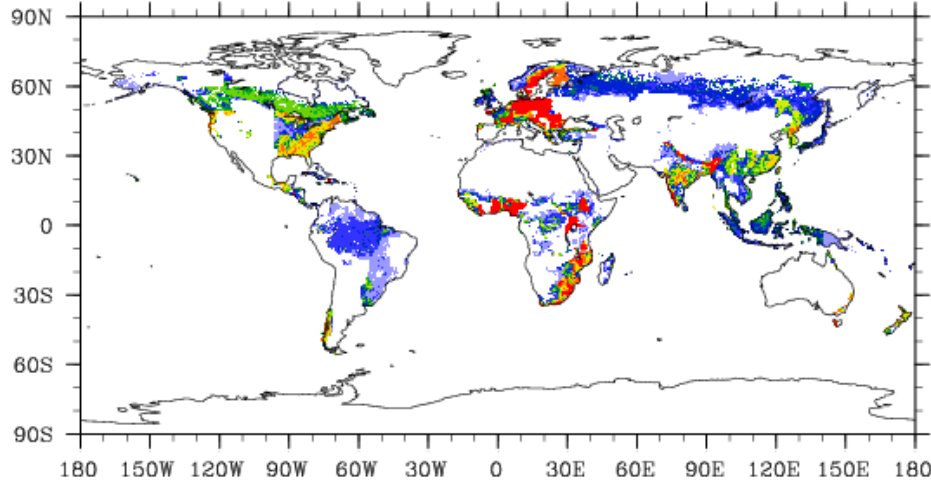


Historical (2005-1850) Tree PFT Harvest

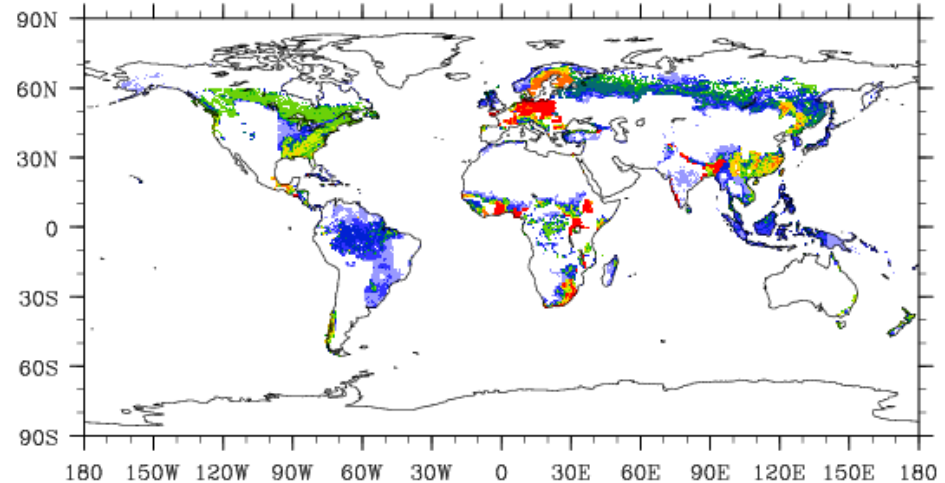


5. CMIP5 - RCP Land Cover Change Tree PFT Harvest %

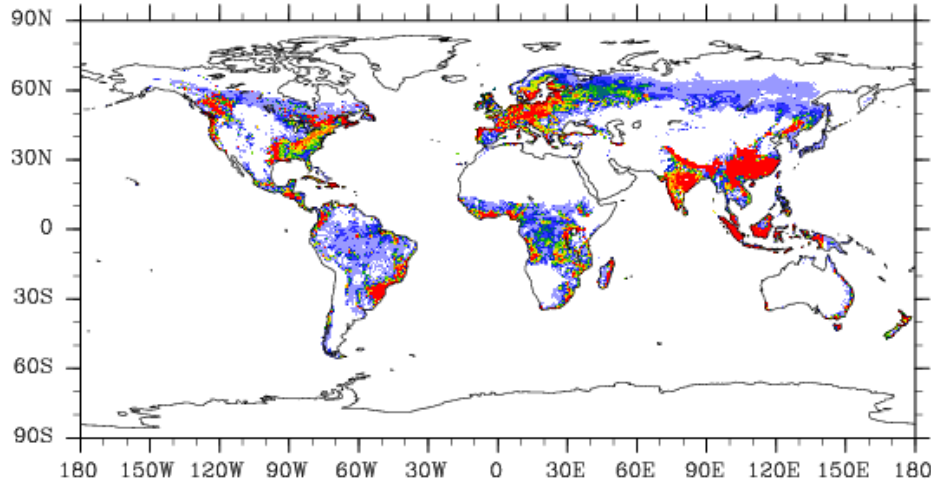
RCP 2.6 IMAGE (2100-2006) Tree PFT Harvest



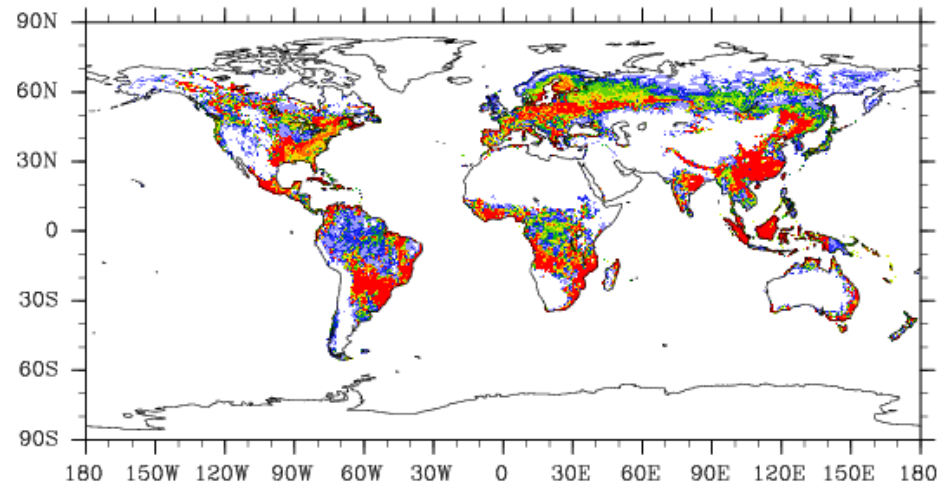
RCP 4.5 MiniCAM (2100-2006) Tree PFT Harvest



RCP 6.0 AIM (2100-2006) Tree PFT Harvest

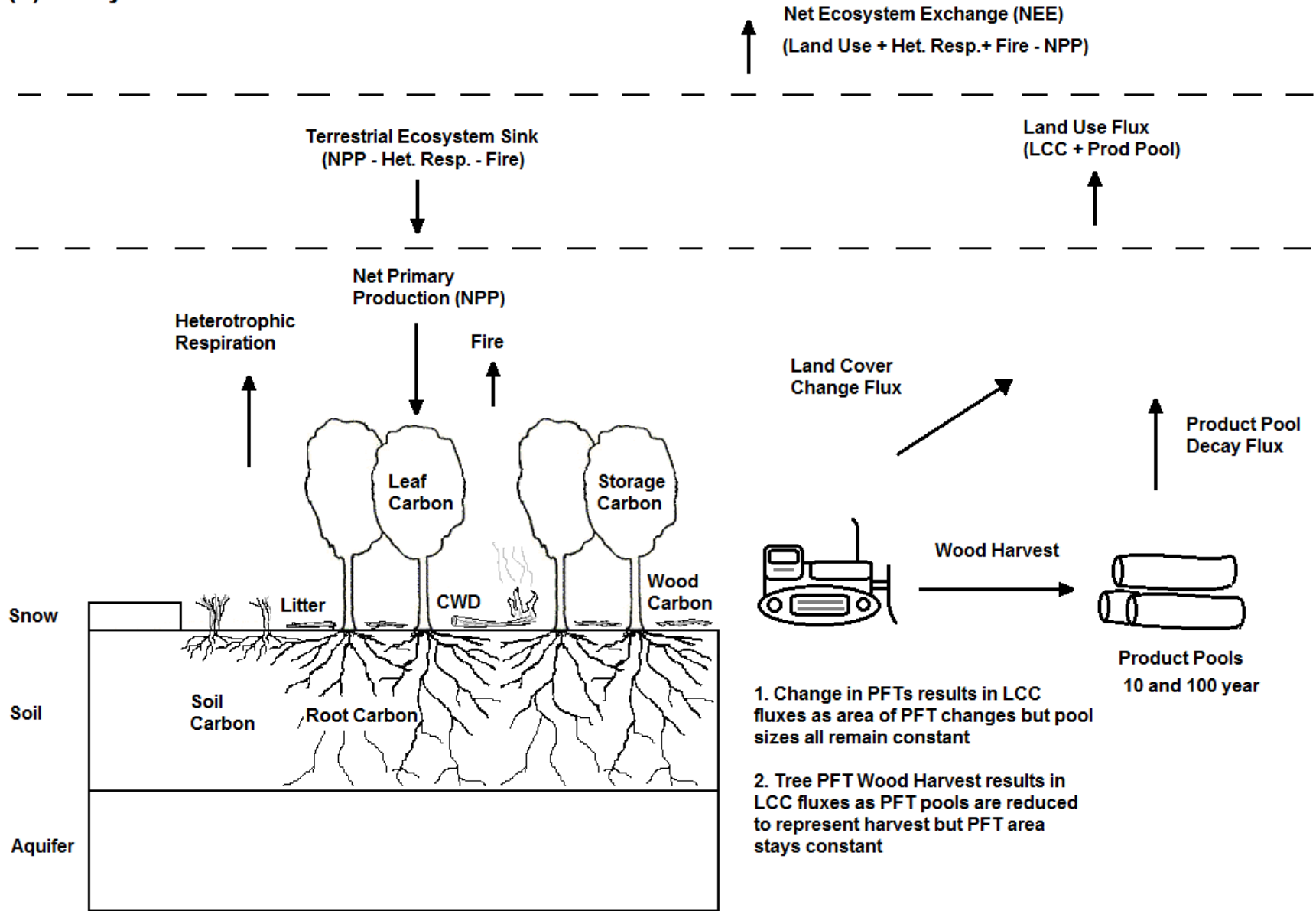


RCP 8.5 Message (2100-2006) Tree PFT Harvest



6. Land Cover Change in (CLM4 CN)

(a) Analyzed CLM4 CN Carbon Pools and Fluxes



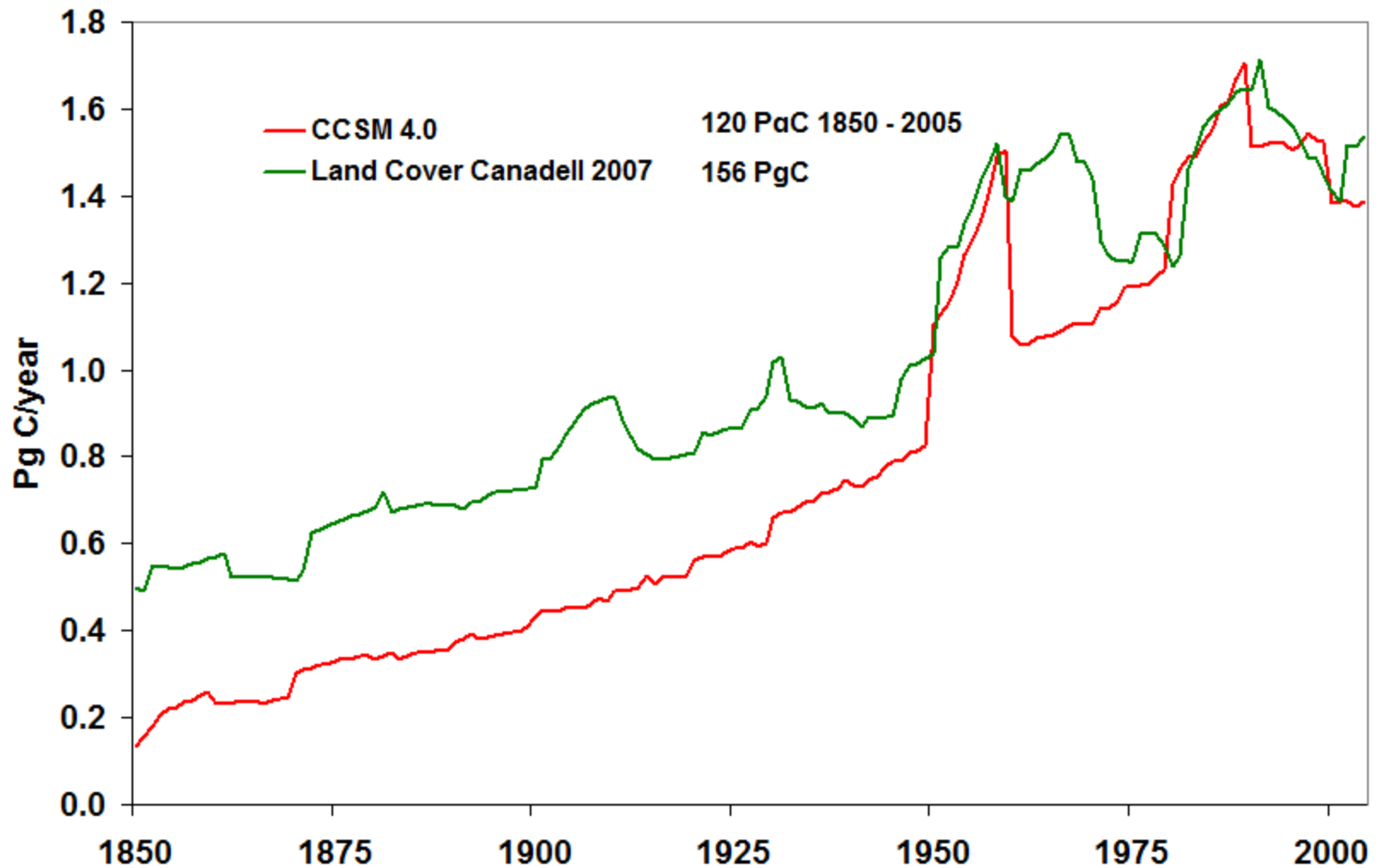
1. Change in PFTs results in LCC fluxes as area of PFT changes but pool sizes all remain constant
2. Tree PFT Wood Harvest results in LCC fluxes as PFT pools are reduced to represent harvest but PFT area stays constant

* Ecosystem Carbon = Leaf + Wood + Root + Storage + Litter + Coarse Woody Debris + Soil Carbon

** CWD = Coarse Woody Debris

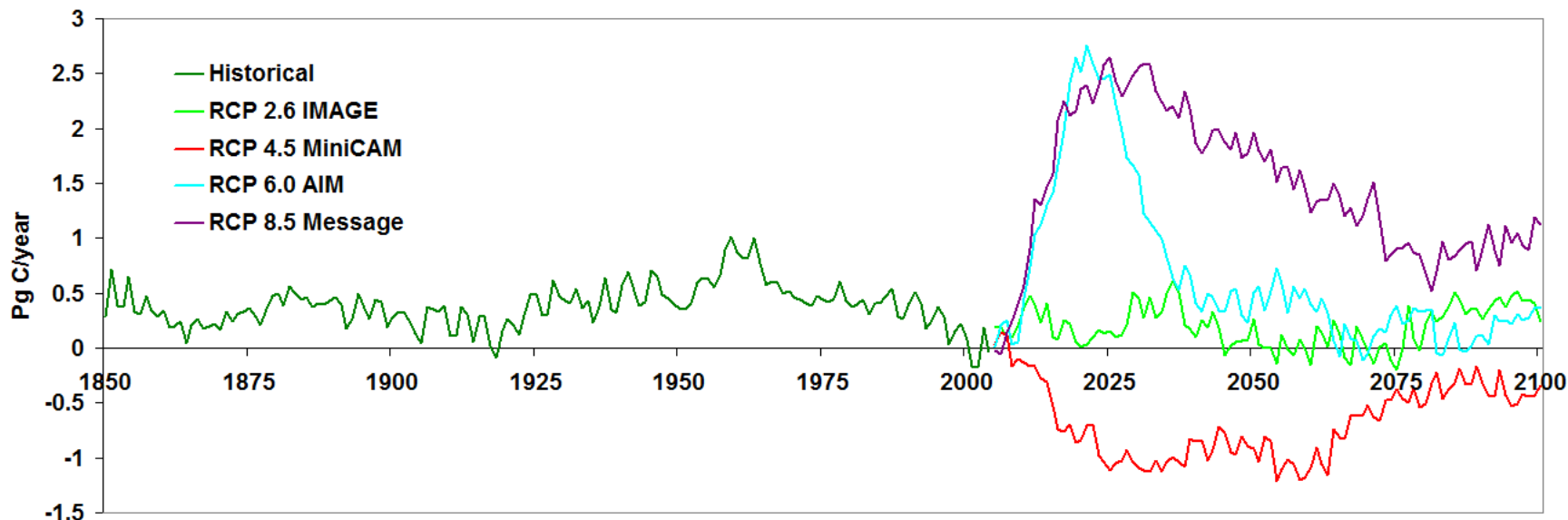
6. LCC in CCSM 4 – Coupled Climate & Prescribed CO₂

Global Land Use and Land Cover Change Carbon Fluxes

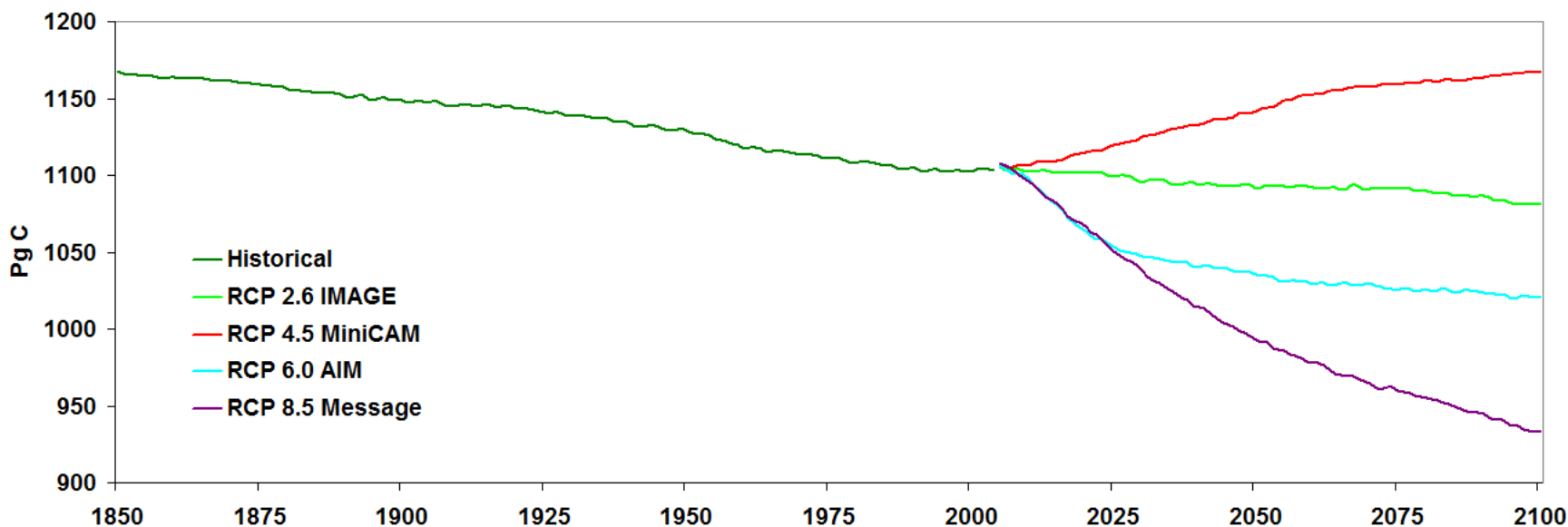


6. LCC in CCSM 4 – Coupled Climate & Prescribed CO2

CCSM 4.0 Net Ecosystem Exchange (NEE) - 10 year smoothed (Including Land Use Flux)

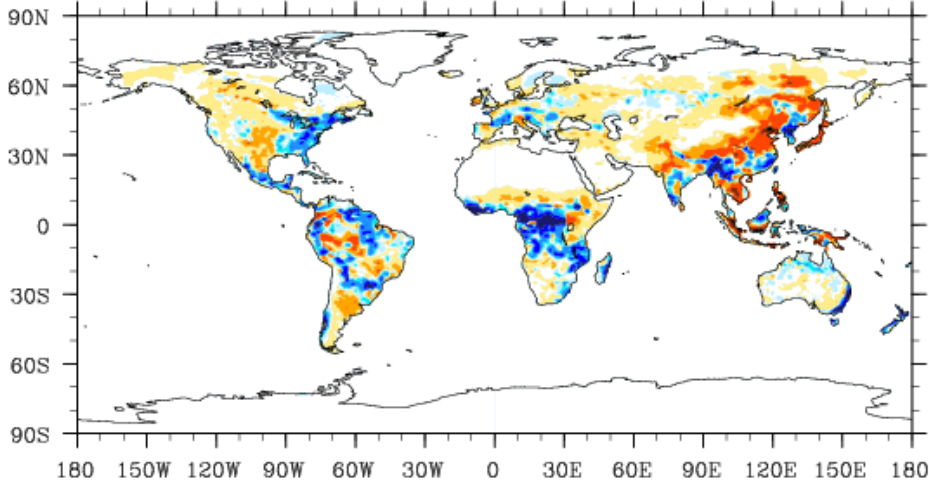


CCSM 4.0 Global All of Ecosystem Carbon (Excluding Product Pools)

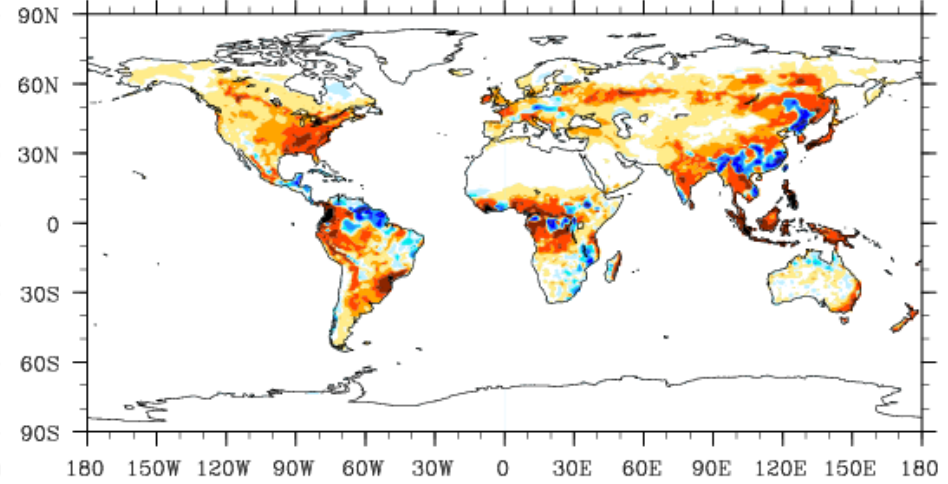


6. LCC in CCSM 4 – Coupled Climate & Prescribed CO2

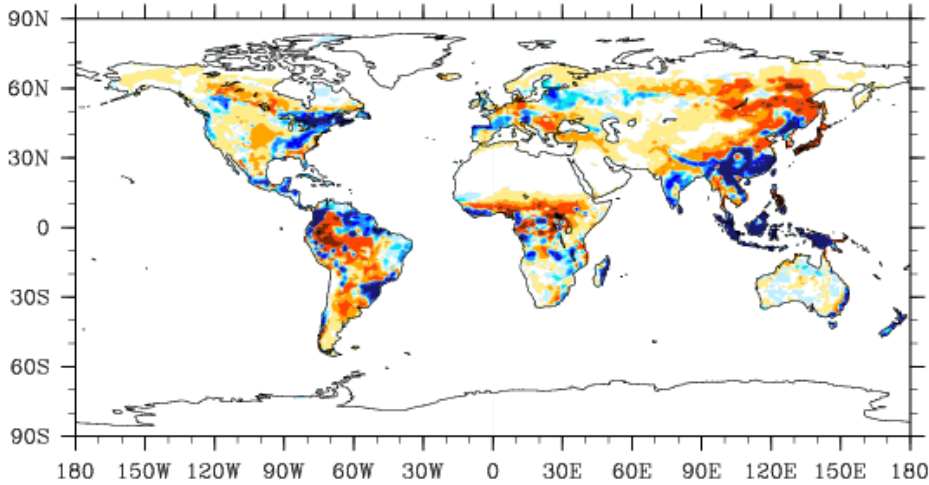
RCP 2.6 IMAGE (2100-2006) All of Ecosystem Carbon gC/m^2



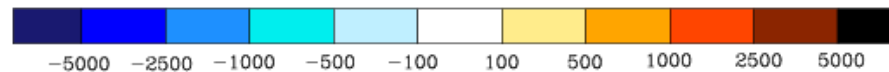
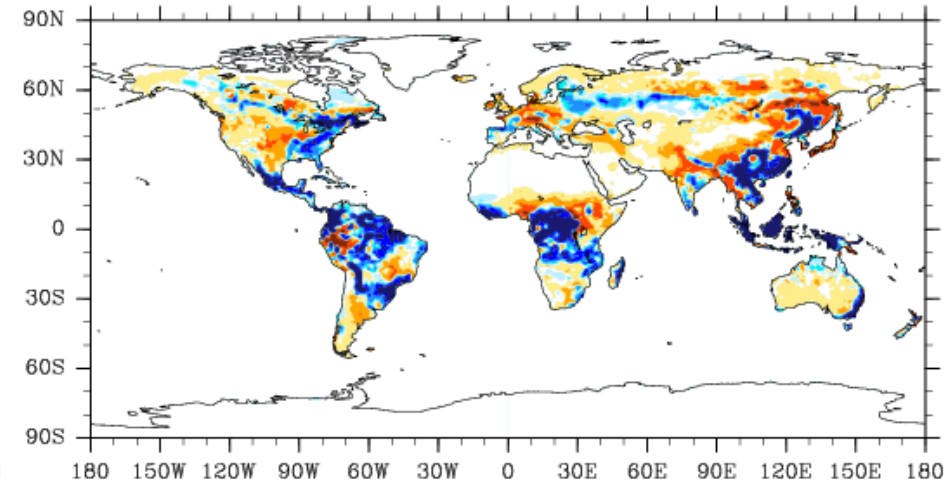
RCP 4.5 MiniCAM (2100-2006) All of Ecosystem Carbon gC/m^2



RCP 6.0 AIM (2100-2006) All of Ecosystem Carbon gC/m^2

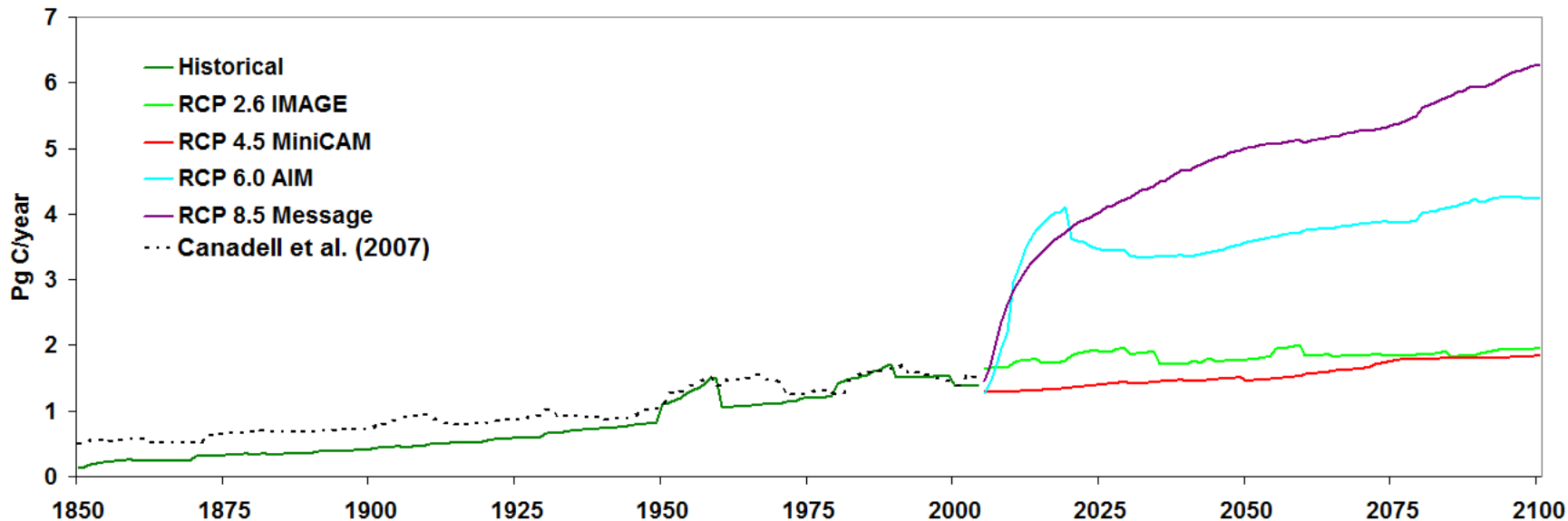


RCP 8.5 Message (2100-2006) All of Ecosystem Carbon gC/m^2

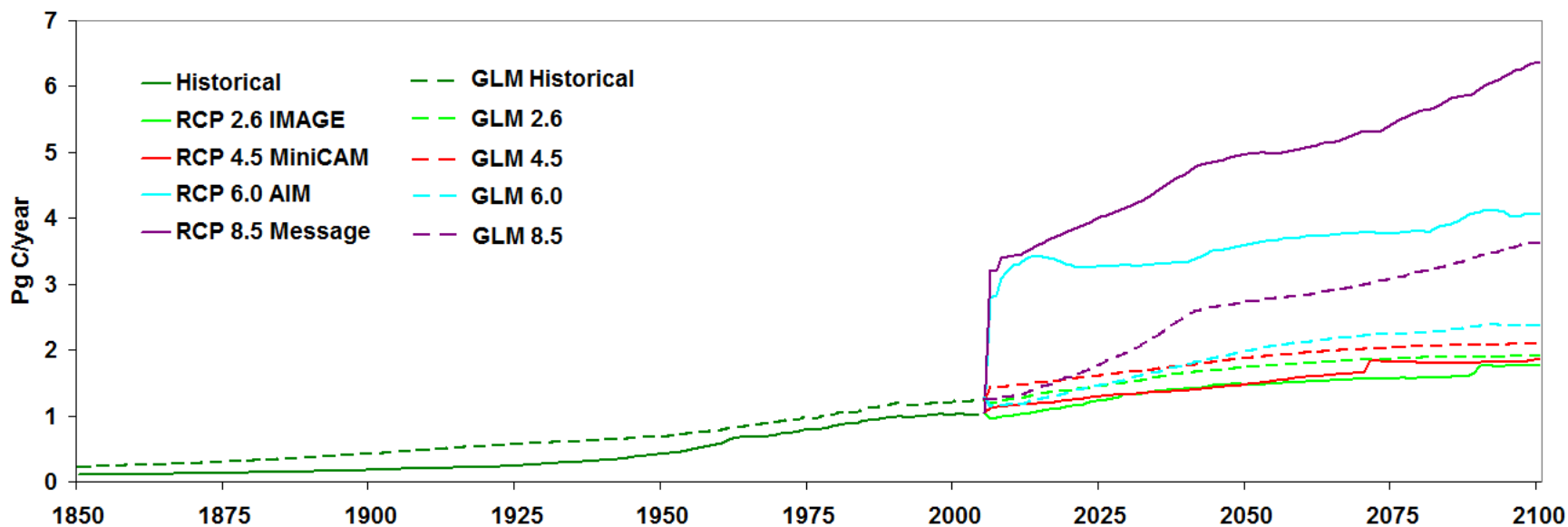


7. LCC in CCSM 4 – Coupled Climate & Prescribed CO2

CCSM 4.0 Global Land Use and Land Cover Change Flux to Atmosphere

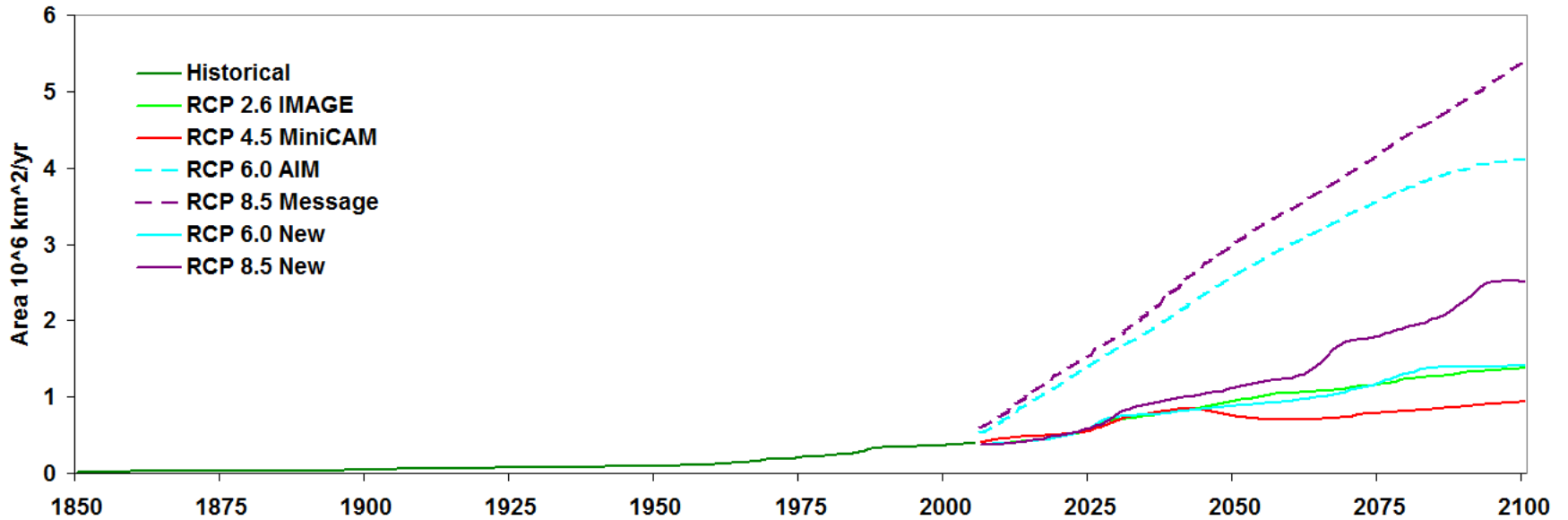


CCSM 4.0 Global Wood Harvest Carbon compared to GLM Harvest Carbon

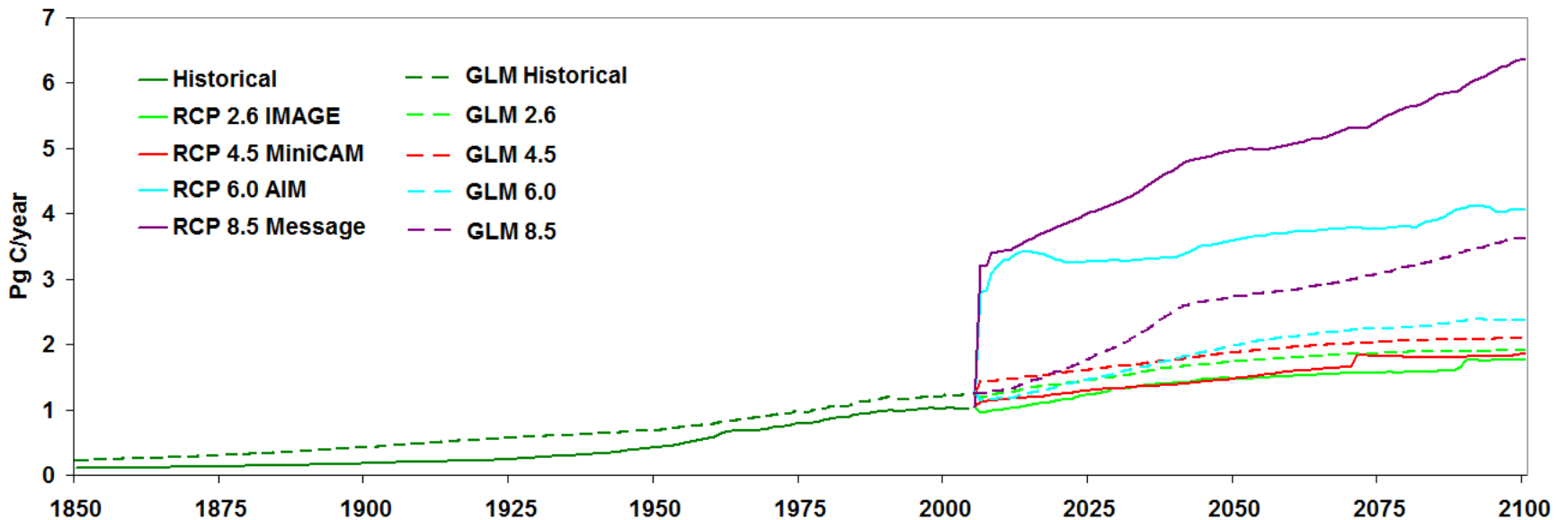


7. LCC in CCSM 4 – Coupled Climate & Prescribed CO2

CMIP5 Total Global Annual Tree PFT Harvest Area



CCSM 4.0 Global Wood Harvest Carbon compared to GLM Harvest Carbon



8. Conclusions

1. Land Working Group involves the collaboration of many groups at NCAR, DOE Labs and University community
2. Land Working Group projects are indivisibly linked to other many other working groups
3. CCSM 4 (CESM 1.0) provides a global carbon climate model with CLM 4.0 including Land Cover Change and Harvesting
4. CMIP5 historical and RCP Land Cover Change and Harvesting has been described in CLM4 parameters for all experiments
5. CCSM 4 simulates carbon fluxes in good agreement with other global estimates of Land Cover Change and Forestry however more work required to understand wood harvest