NCAR Earth System Laboratory NESL

Land Cover Change in CLM4

Dr. Peter Lawrence

Project Scientist

Terrestrial Science Section
Climate and Global Dynamics Division

(With thanks to TSS group for their many contributions)

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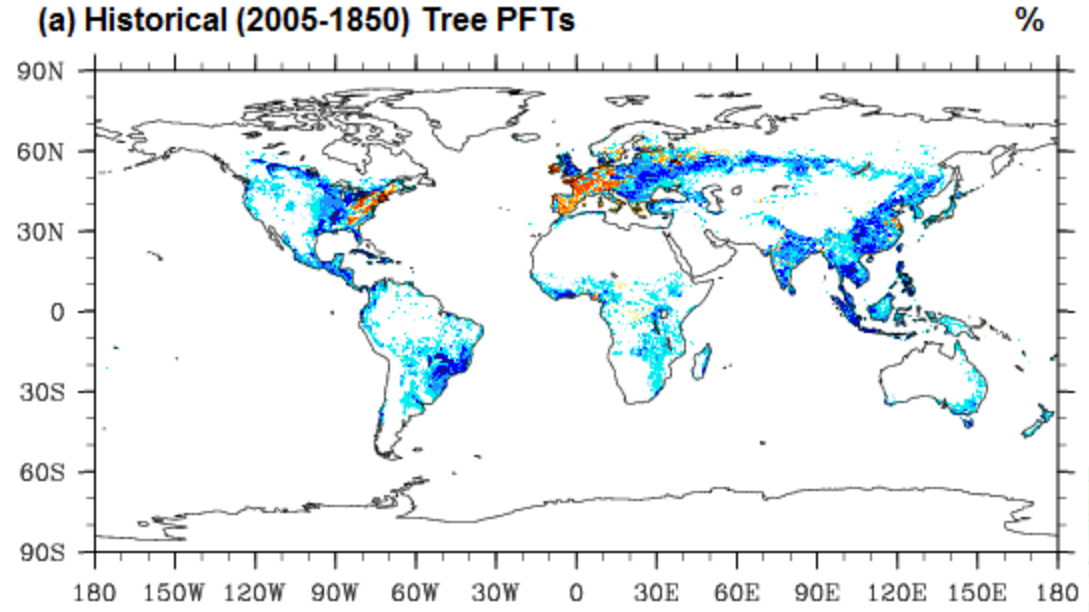
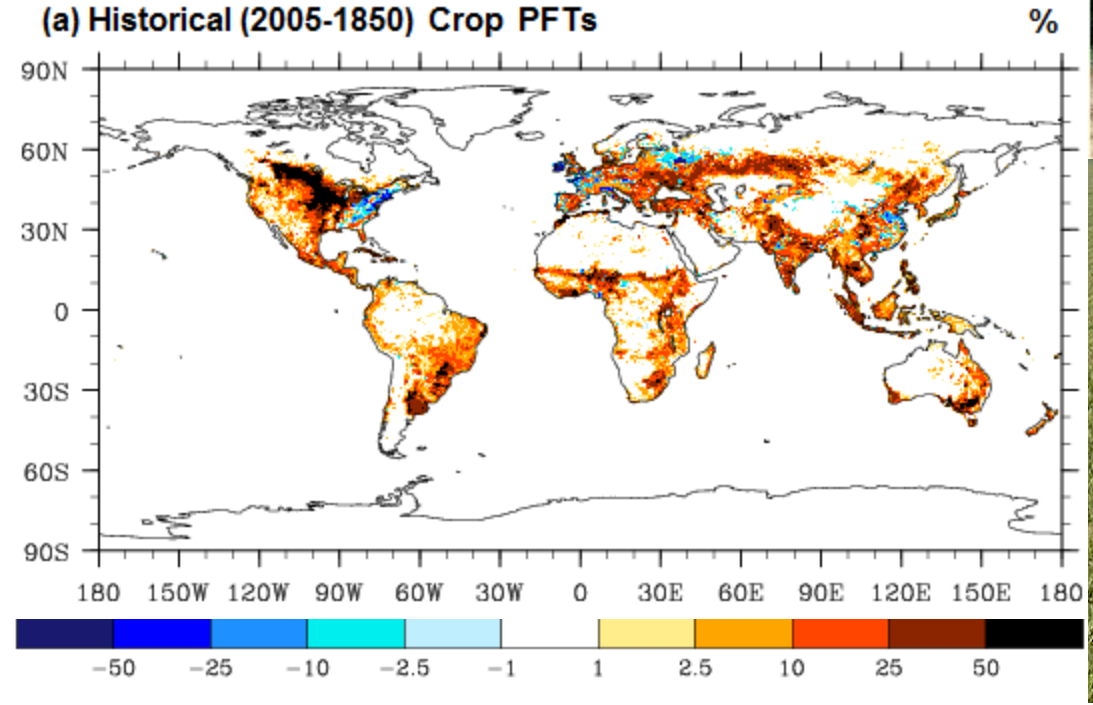
Land Cover Change, Cropping and Forests in CLM4



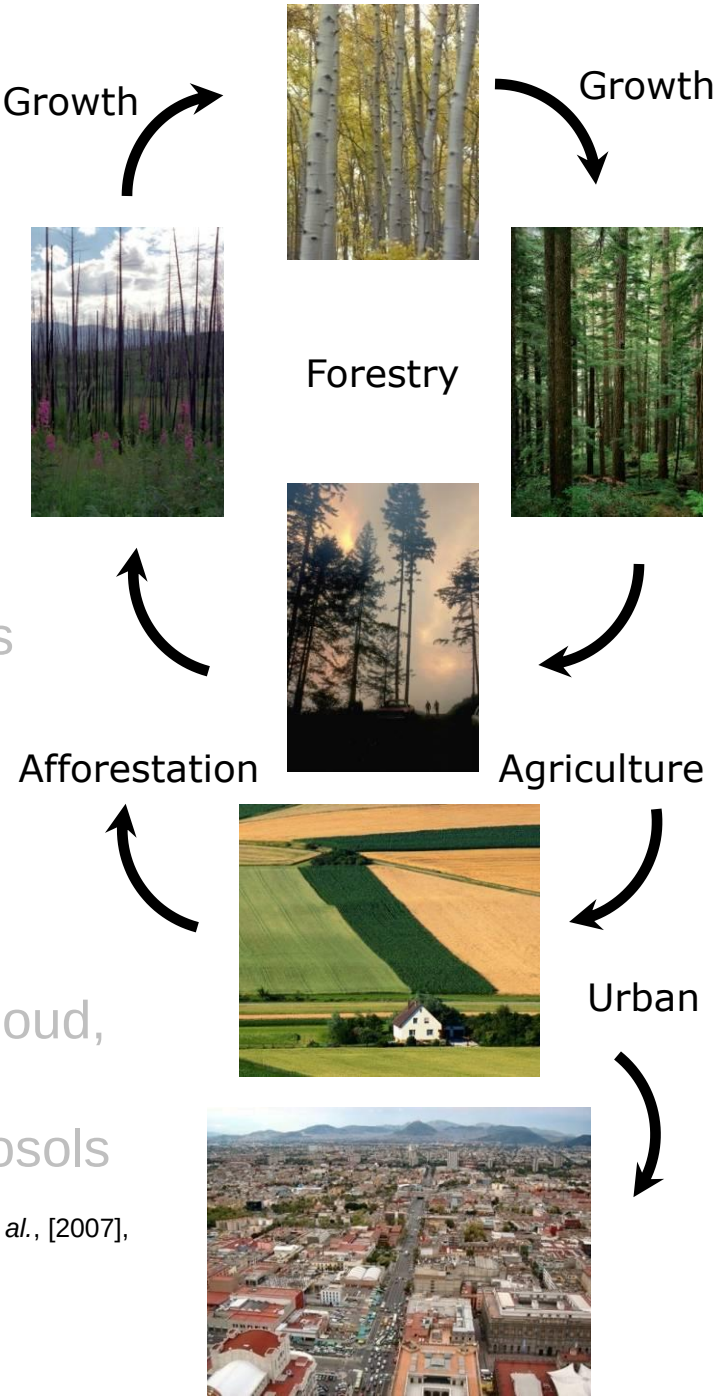


Human Land Cover Change

1. Direct Biogeophysical Impacts:
- Albedo – Radiation (Snow Interactions)
- Surface Hydrology (Irrigation)
- Surface Roughness

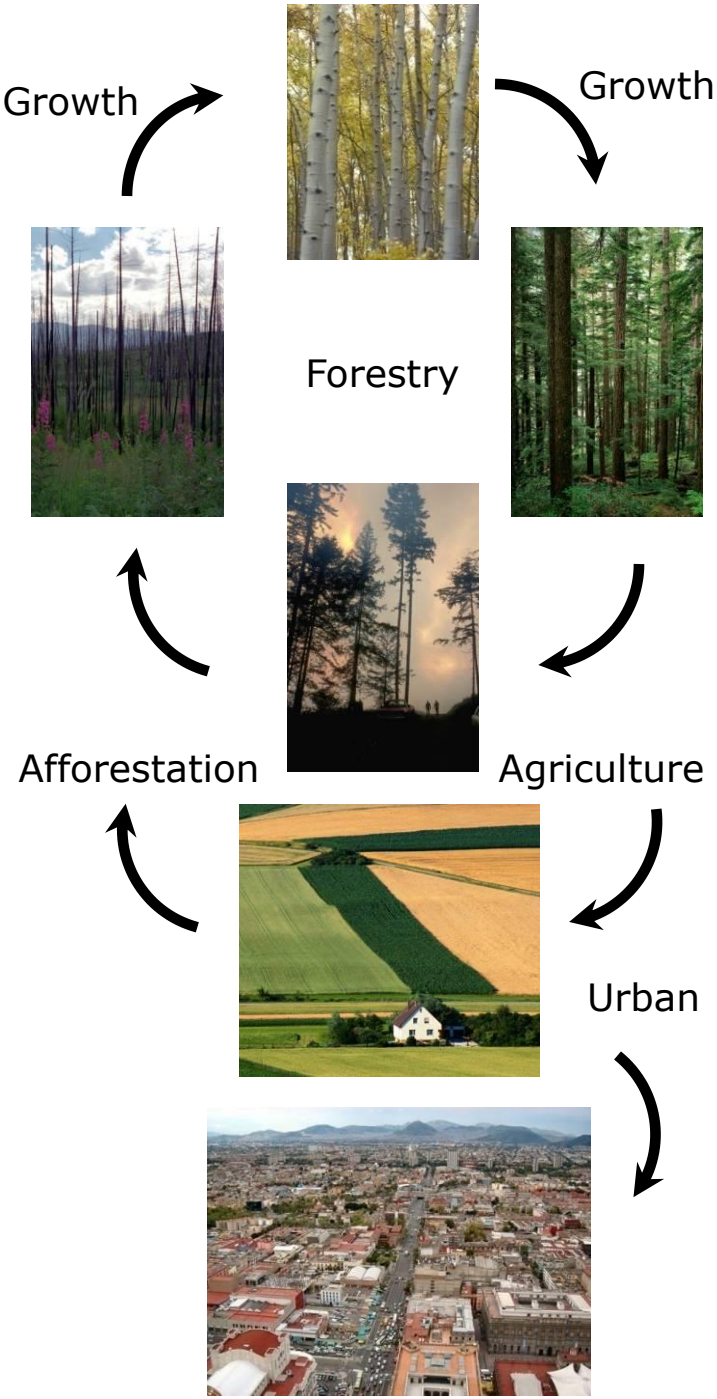
2. Direct Biogeochemical Impacts:
- Vegetation and Soil Carbon Fluxes from Conversion Natural -> Human systems
- Harvesting from Forestry and Agriculture

3. Indirect Impacts:
- Increased Photosynthesis through higher CO_2, Nitrogen, Phosphorus and Potassium
- Atmospheric Responses in Temperature, Cloud, Precipitation and Larger Scale Circulation
- Fire, Methane, Dust, Volatile Organics, Aerosols

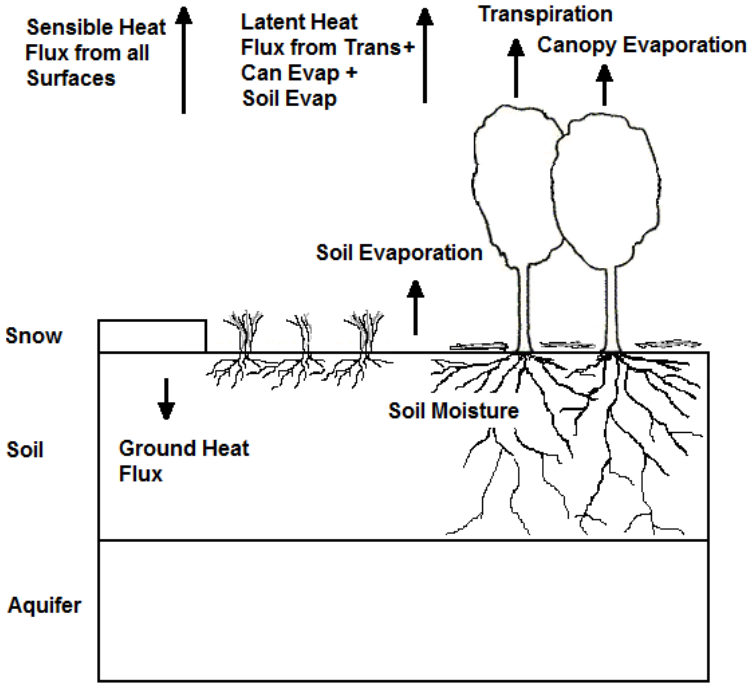


Lawrence et al., [2011]*, Lawrence and Chase*, [2010], *Feddema, et al.*, [2005], *Findell, et al.*, [2007], *IPCC*, [2007], *Bonan*, [2008], and *Canadell, et al.*, [2007]

Land Cover Change



CLM4 Heat Fluxes



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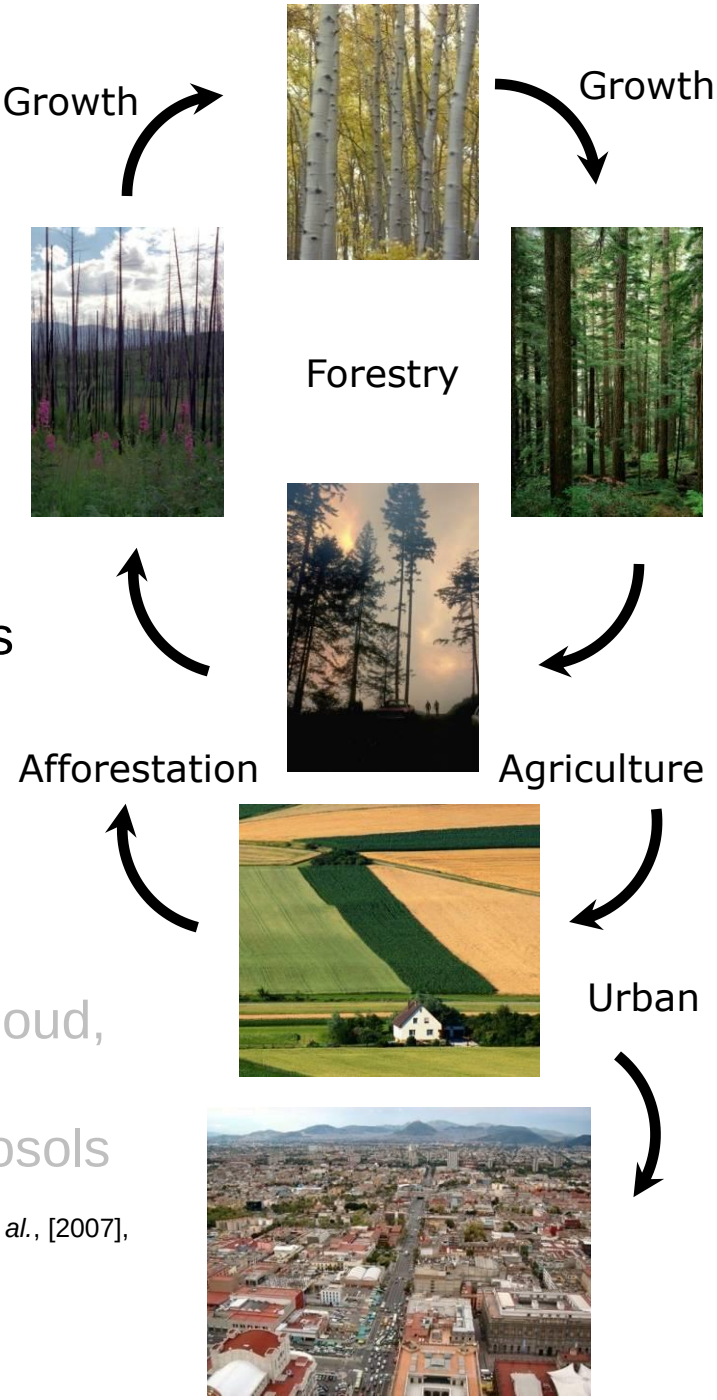

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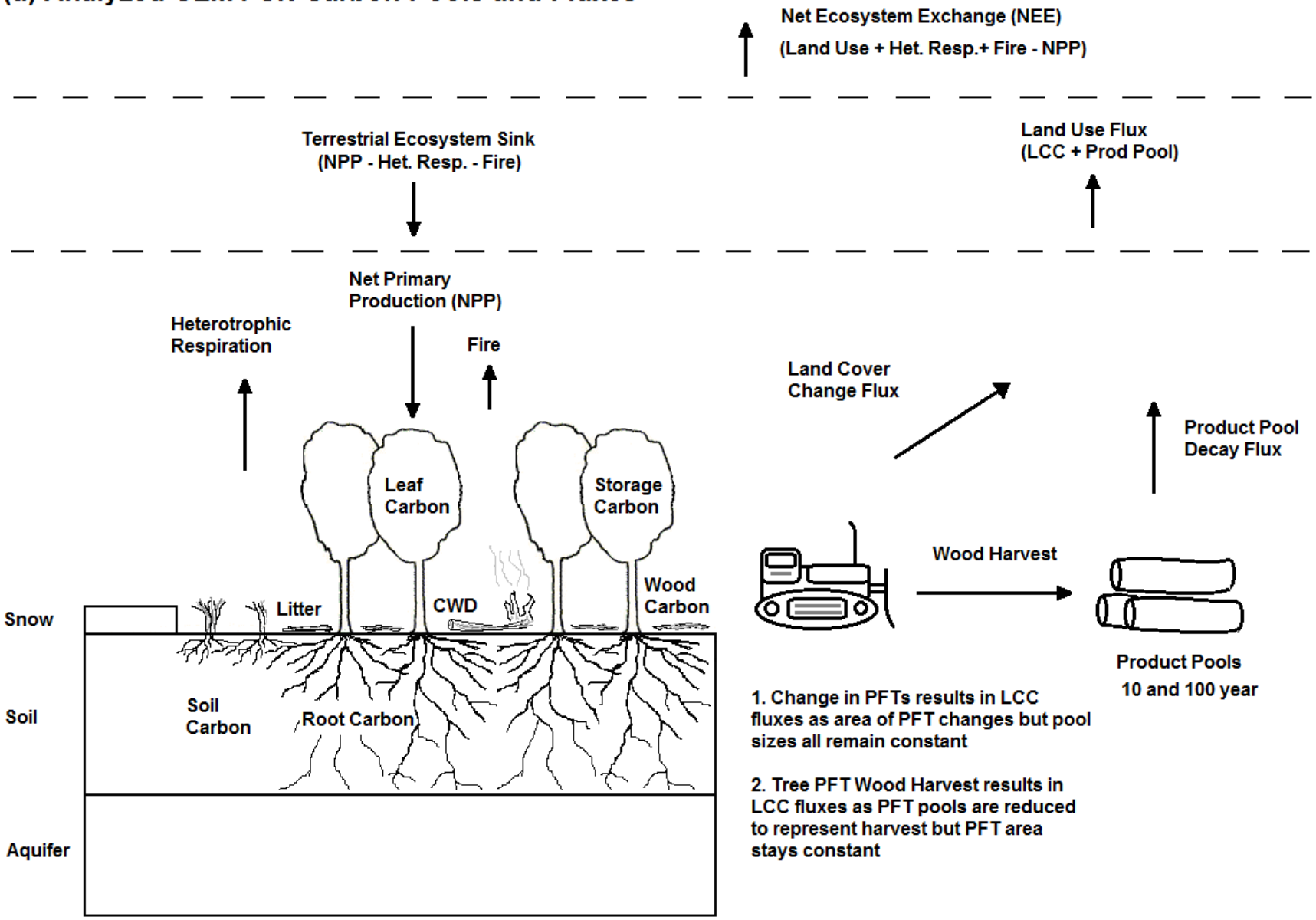
Land Cover Change in (CLM4 CN)

(a) Analyzed CLM4 CN Carbon Pools and Fluxes



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

** CWD = Coarse Woody Debris

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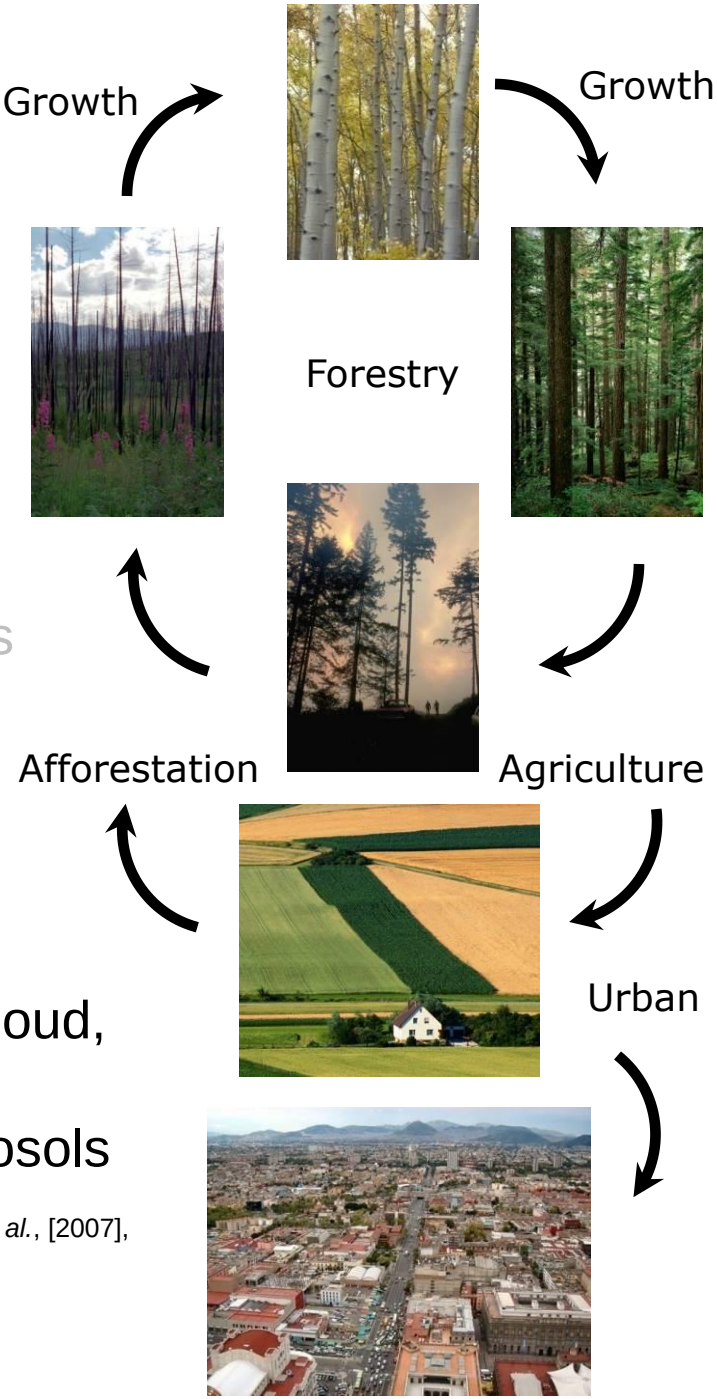

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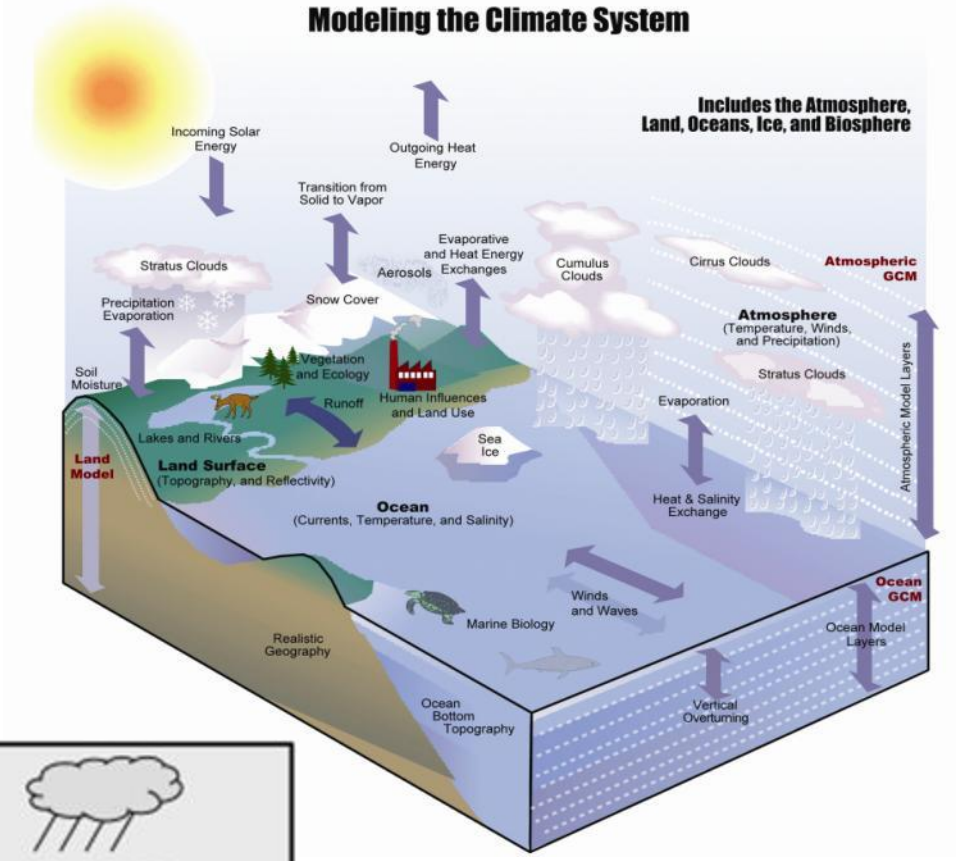
Land Cover Change in the Climate System: Using the Community Earth System Model (CESM)

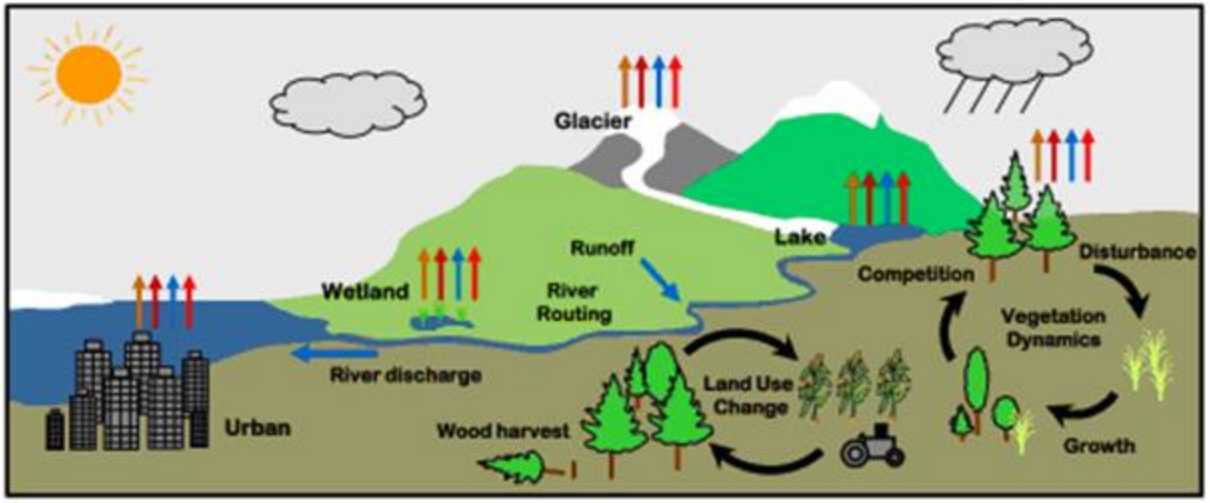
Global Environmental and Climate Change from the Land Surface in CESM:

- Solar Radiation heating the land surface through snow, ice, vegetation, soils and cities

- Changes in the water stored and returned to the atmosphere and oceans

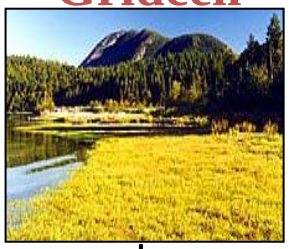
- Changes in the carbon and nutrient cycles between the land, the atmosphere, and the oceans





Land Cover Change in the CLM4 subgrid tiling

Gridcell



Landunit





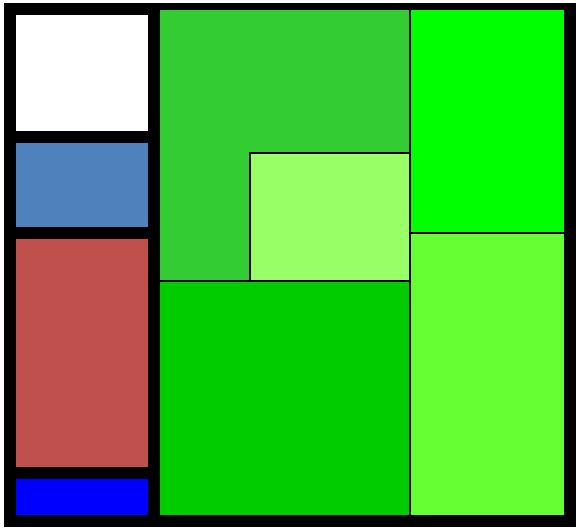
Glacier **Wetland** **Vegetated** **Lake** **Urban**

Columns

Soil Type 1

PFTs



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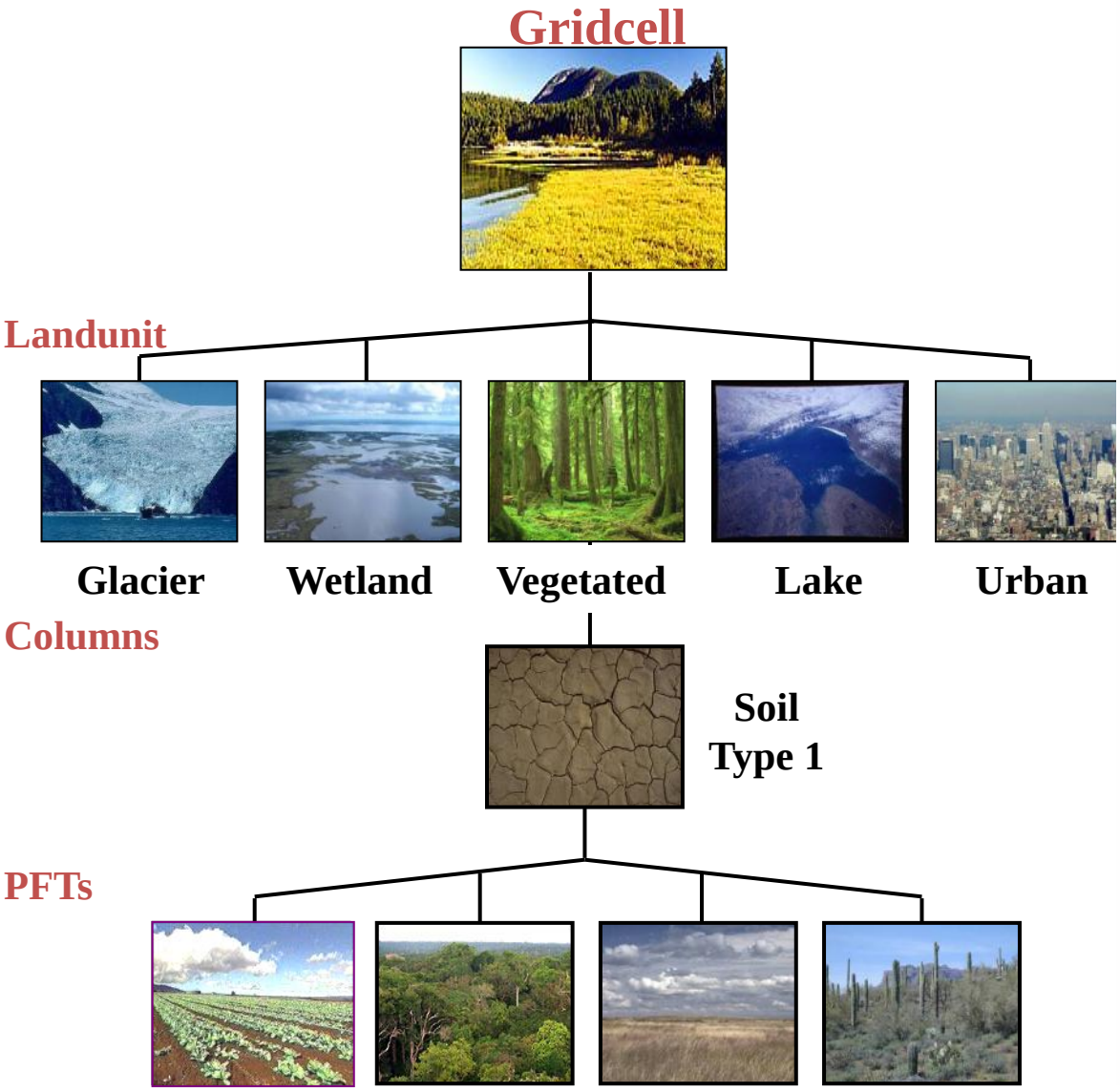


Plant Functional Types:

0. Bare

Tree:

1. Needleleaf Evergreen, Temperate
2. Needleleaf Evergreen, Boreal
3. Needleleaf Deciduous, Boreal
4. Broadleaf Evergreen, Tropical
5. Broadleaf Evergreen, Temperate
6. Broadleaf Deciduous, Tropical
7. Broadleaf Deciduous, Temperate
8. Broadleaf Deciduous, Boreal

Herbaceous / Understorey:

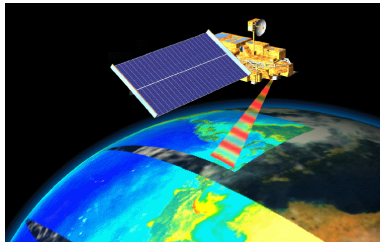
9. Broadleaf Evergreen Shrub, Temperate
10. Broadleaf Deciduous Shrub, Temperate
11. Broadleaf Deciduous Shrub, Boreal
12. C3 Arctic Grass
13. C3 non-Arctic Grass
14. C4 Grass
15. Crop

Land Cover Change impacts through changes in Plant Functional Type Parameters

- Optical properties (visible and near-infrared):
  - Leaf angle
  - Leaf reflectance
  - Stem reflectance
  - Leaf transmittance
  - Stem transmittance

- Morphological properties:
  - Leaf area index (annual cycle)
  - Stem area index (annual cycle)
  - Leaf dimension
  - Roughness length/displacement height
  - Canopy height
  - Root distribution
- Photosynthetic parameters:
  - specific leaf area (m^2 leaf area g^{-1} C)
  - m (slope of conductance-photosynthesis relationship)

Mapping Current Day CLM PFTs from MODIS at 0.05 degrees



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MODIS Vegetation Continuous Fields
(tree%,herbaceous%, bare%)

MODIS Land Cover
(IGBP Classes for Shrub% and Grass%)

Ramankutty (2008) Cropping 2000
(Crop %)

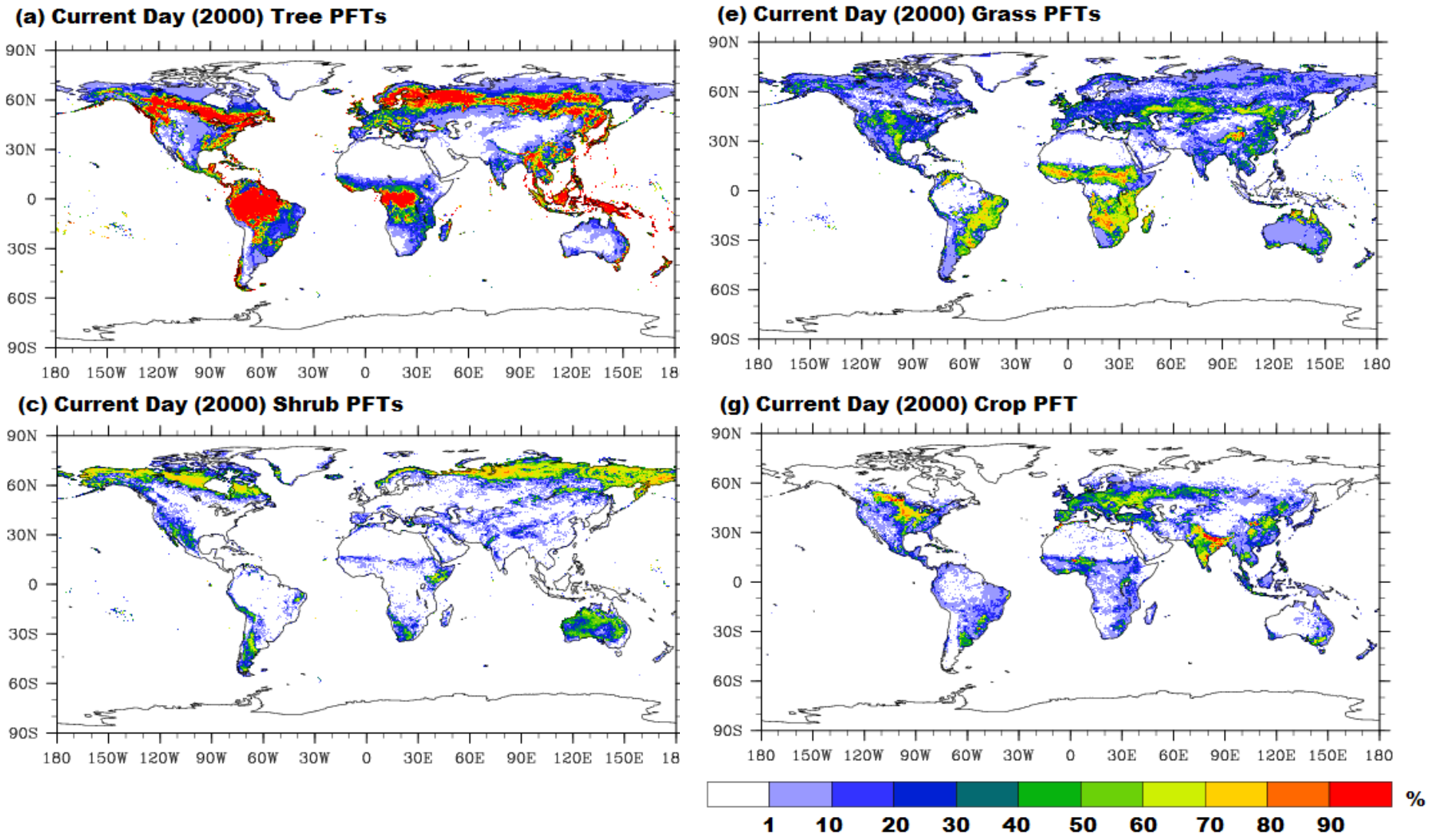
AVHRR Continuous Fields Tree Cover
(Needle%, Broad%, Evergreen%, Decid%)

Willmott and Matsuura Climate
(Air Temperature, Precipitation)

MODIS Monthly LAI
(Monthly LAI for C3/C4 Grass Growing Months)

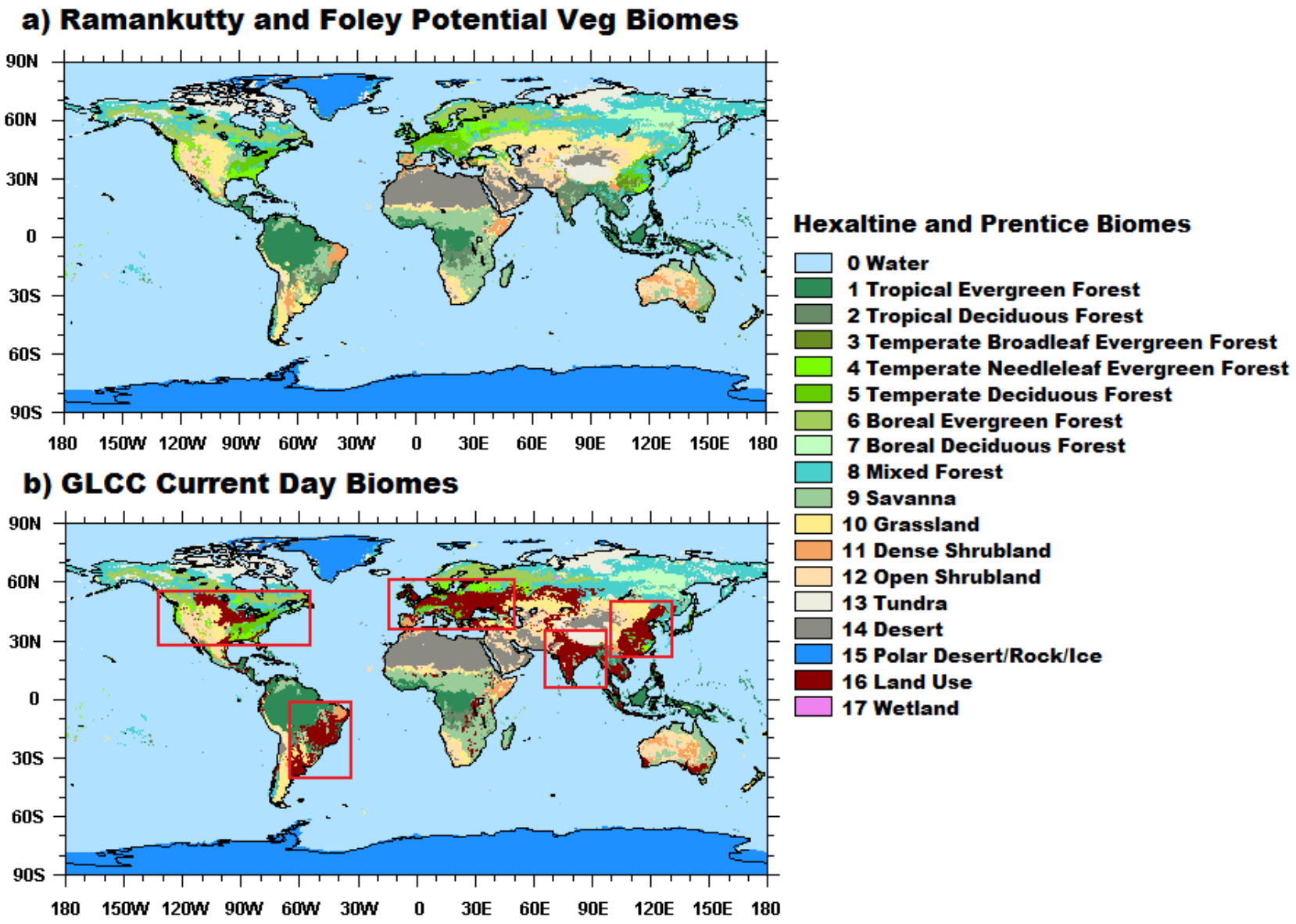
Lawrence and Chase (2007)

Mapping Current Day CLM PFTs from MODIS at 0.05 degrees



Lawrence and Chase, 2007

Generating Potential Vegetation CLM PFTs from Biomes



Lawrence and Chase (2010)

Transient 1850 – 2100 Land Cover Change in CLM

1. Land cover change and wood harvest were included in the Coupled Model Intercomparison Project phase 5 (CMIP5) climate simulations performed by NCAR to inform the latest United Nations – Intergovernmental Panel on Climate Change (UN IPCC) Assessment Report 5 (AR5).

2. The CMIP5 protocol prescribed values for the 1850 – 2005 Historical period and for four different 2006 – 2100 Representative Concentration Pathway (RCP) periods. (Extensions back to 850 AD)

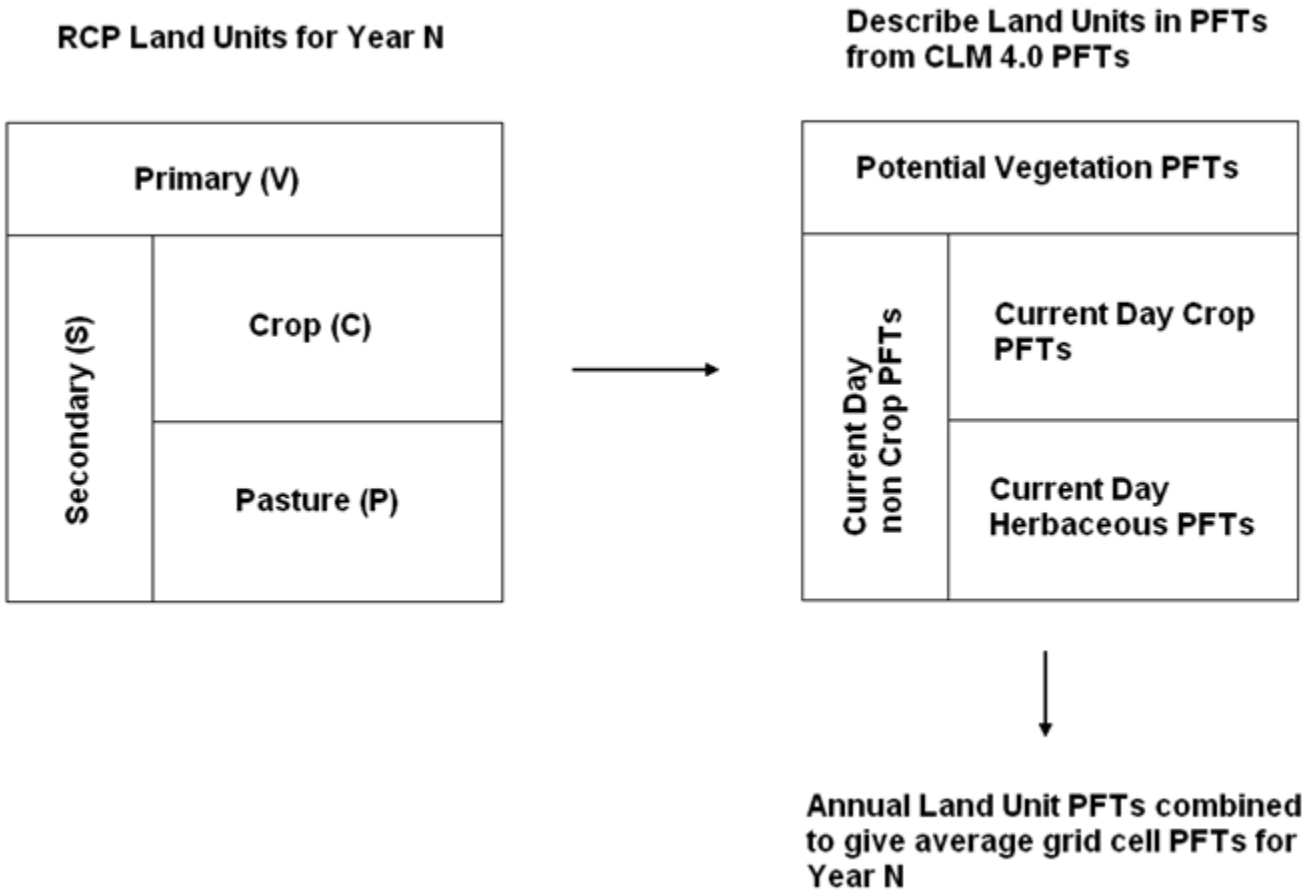
3. For each Historical and RCP period land use and land cover change are described through annual changes in four basic land units:

   - Primary Vegetation (Prior to Human Disturbance)
   - Secondary Vegetation (Disturbed then abandoned or managed)
   - Cropping
   - Pasture (Grazing Lands)

4. Harvesting of woody biomass is also prescribed for both primary and secondary vegetation land units

CMIP5 Transient Land Cover in CLM 4 PFTs Method

A time series of annual PFT tile mosaics is generated from the annual CMIP5 Land Cover Classes by combining them with the Current Day and Potential Vegetation PFTs that were previously mapped from satellite and bioclimatic modeling.



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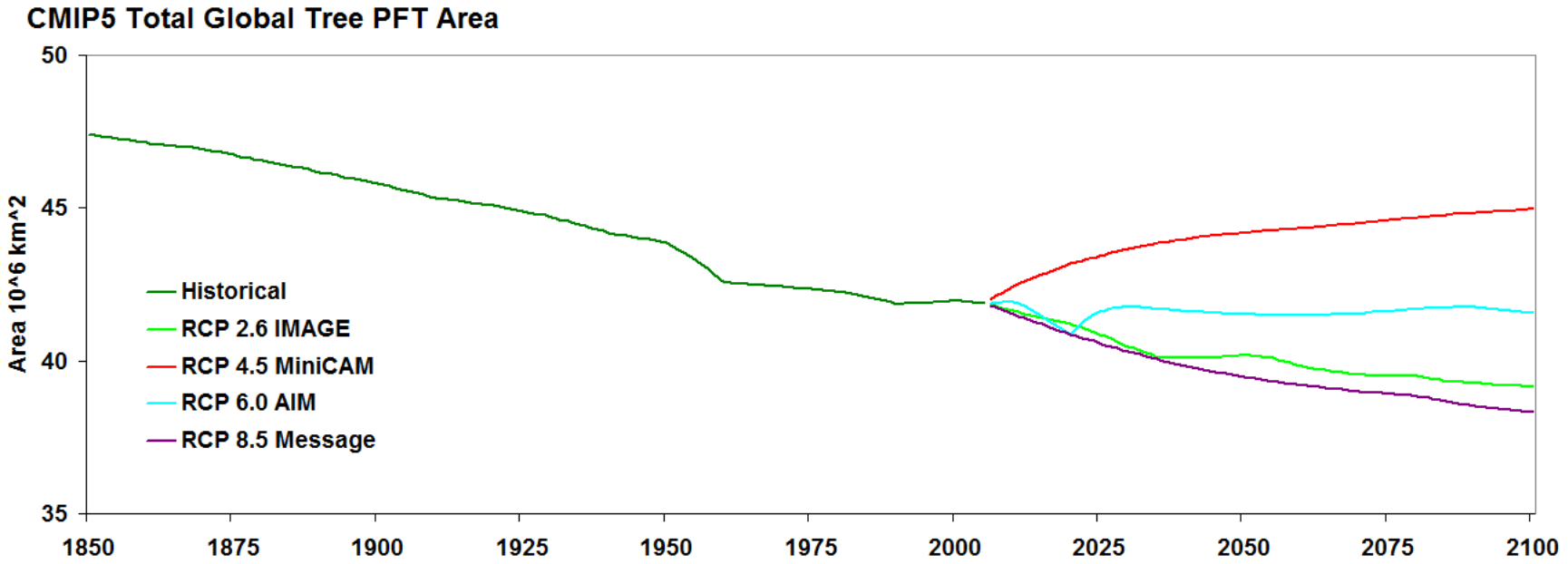
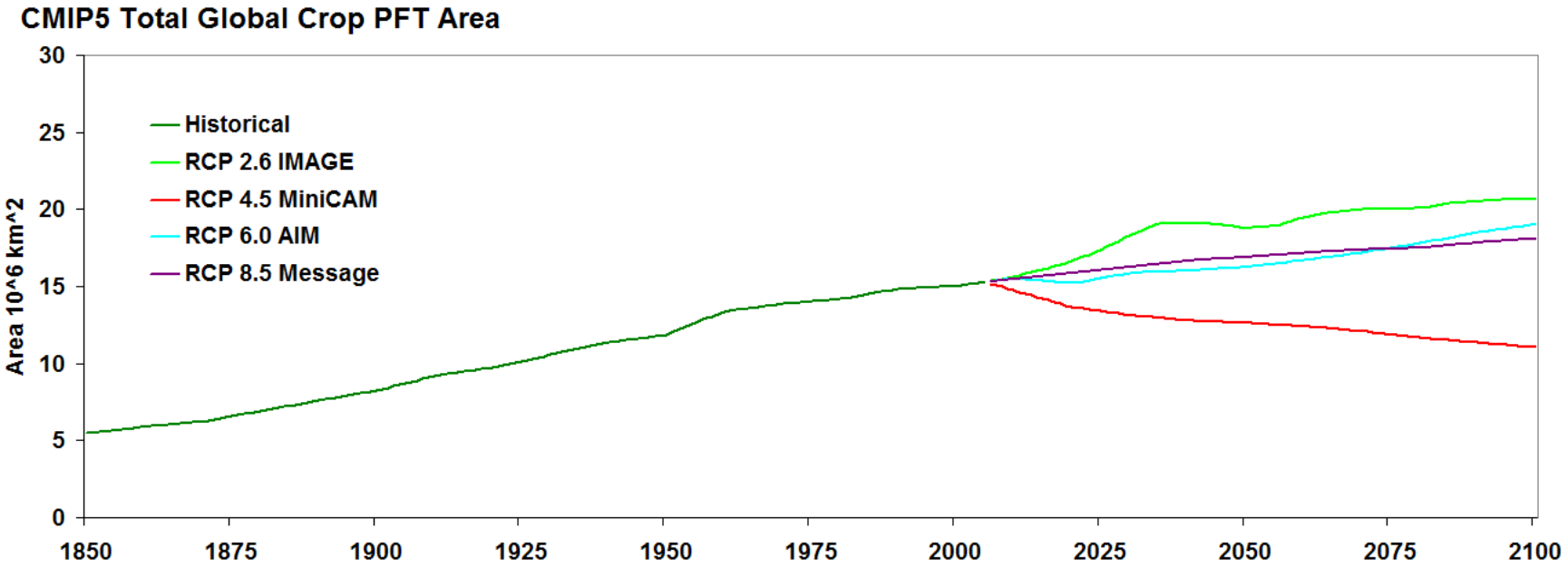
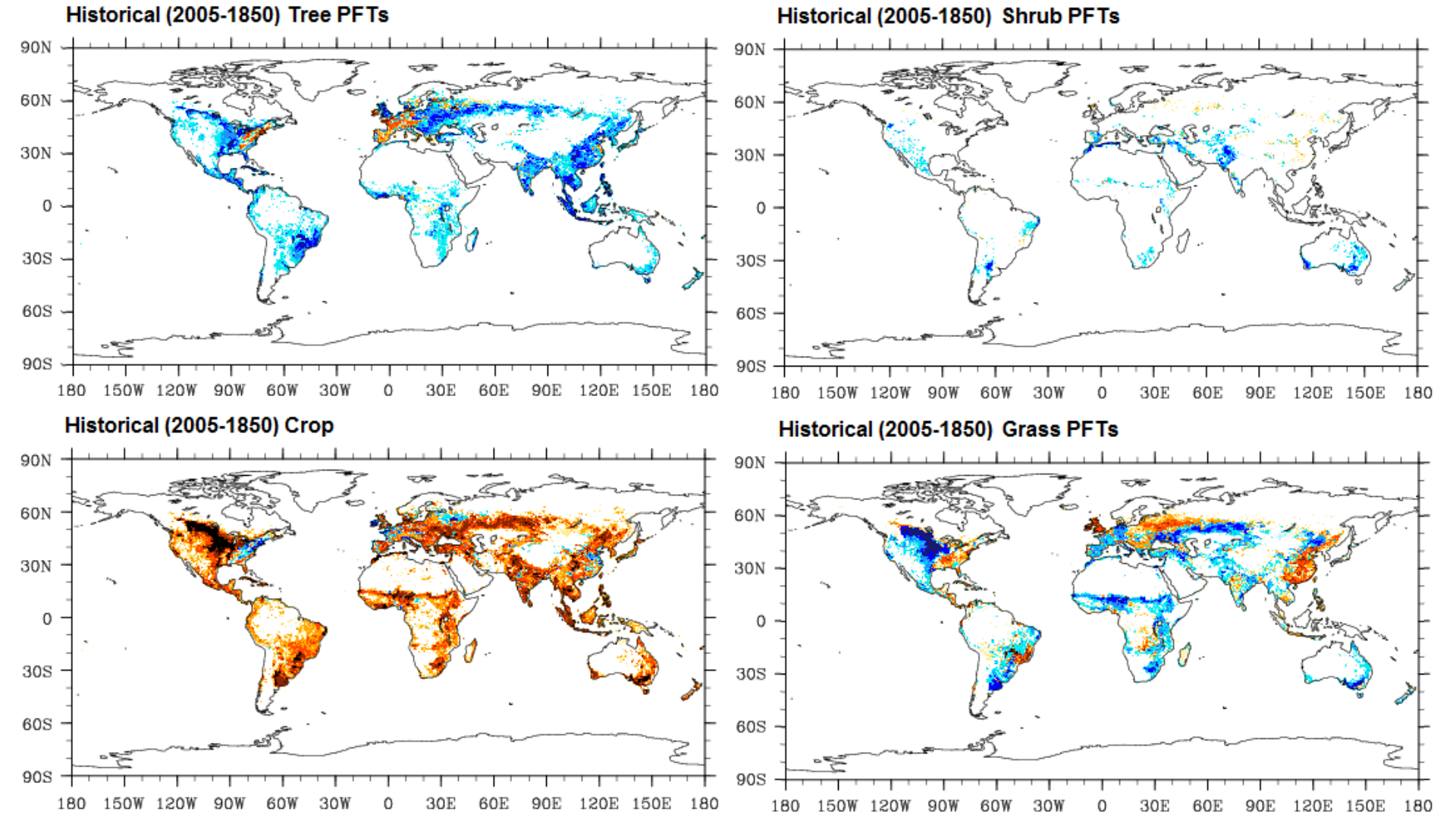
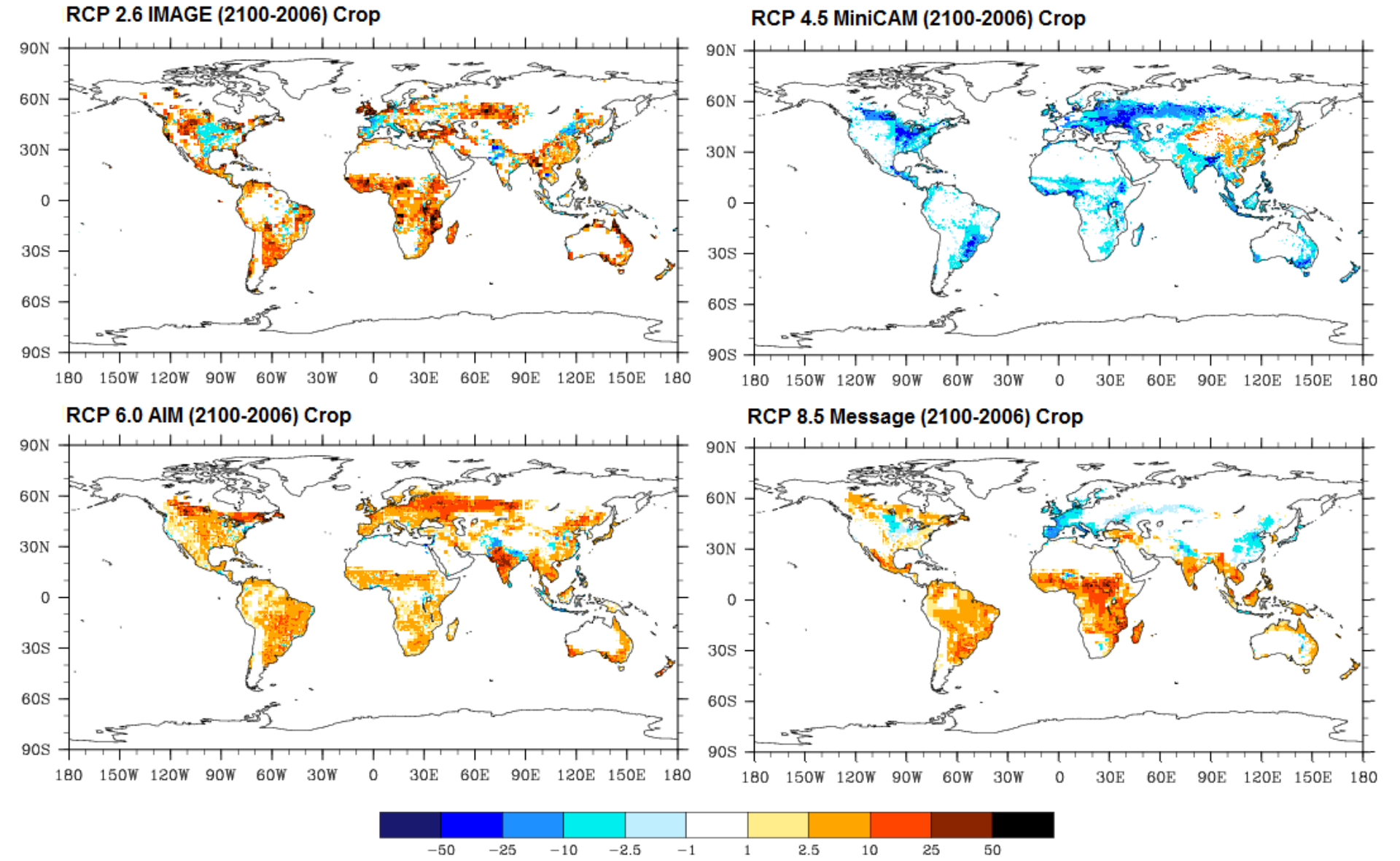




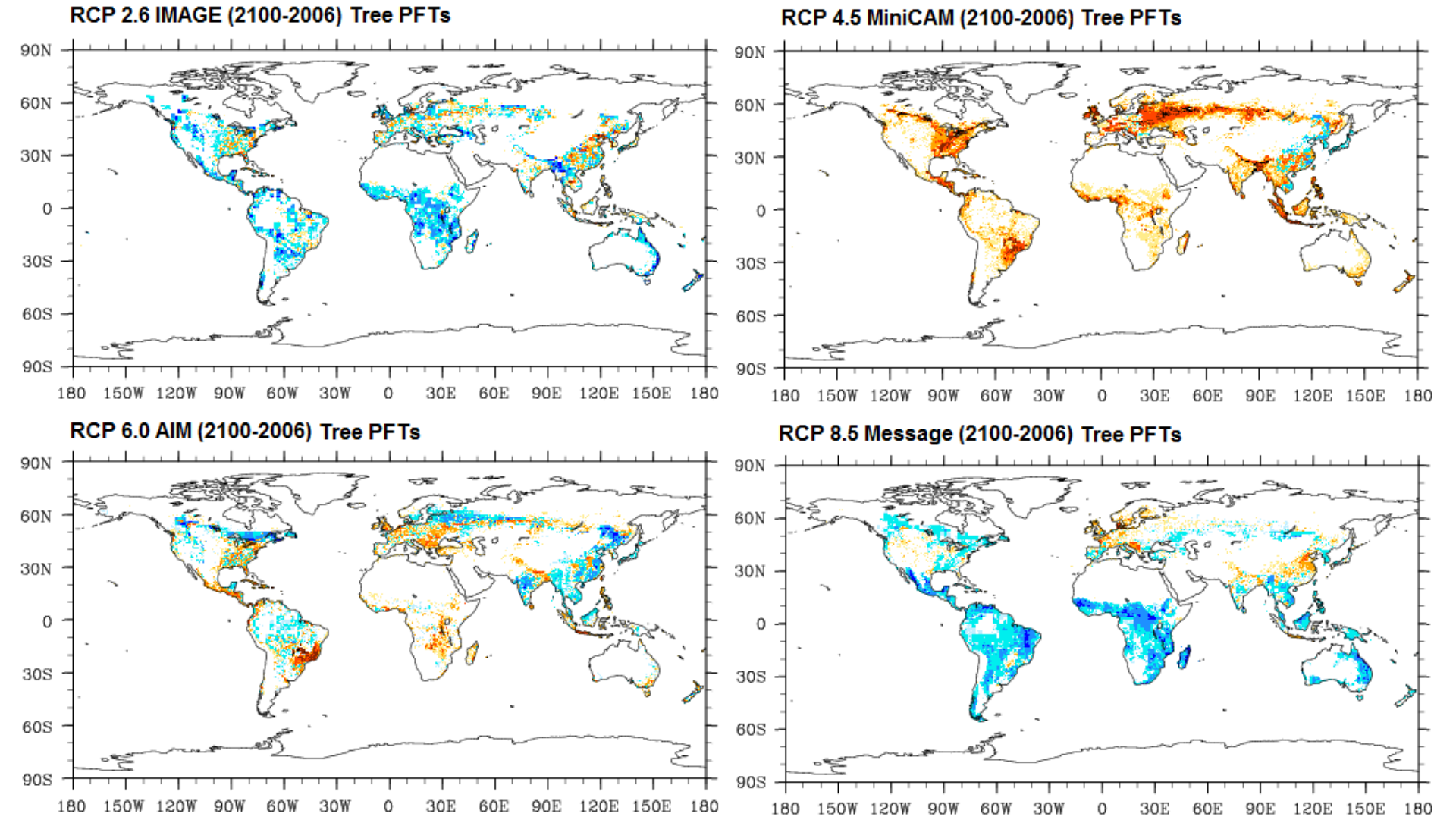
CMIP5 - Historical Land Cover Change – PFTs %area



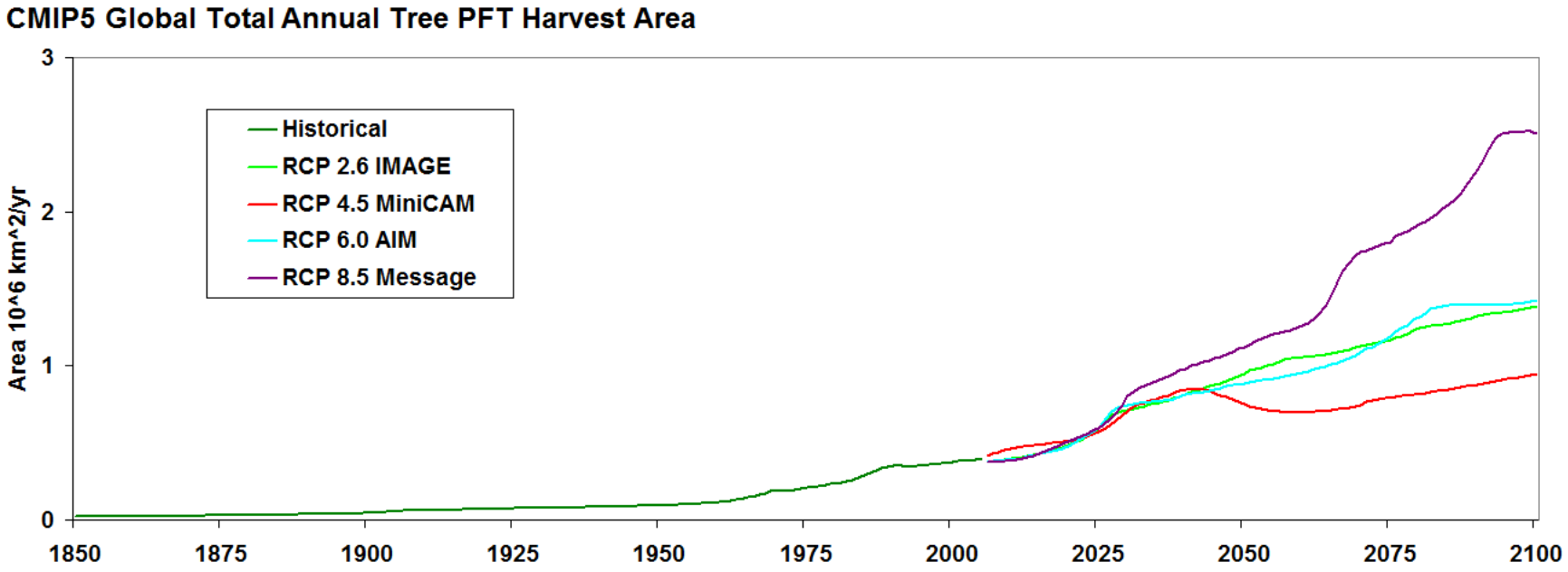
CMIP5 - RCP Land Cover Change PFTs – Crop %area

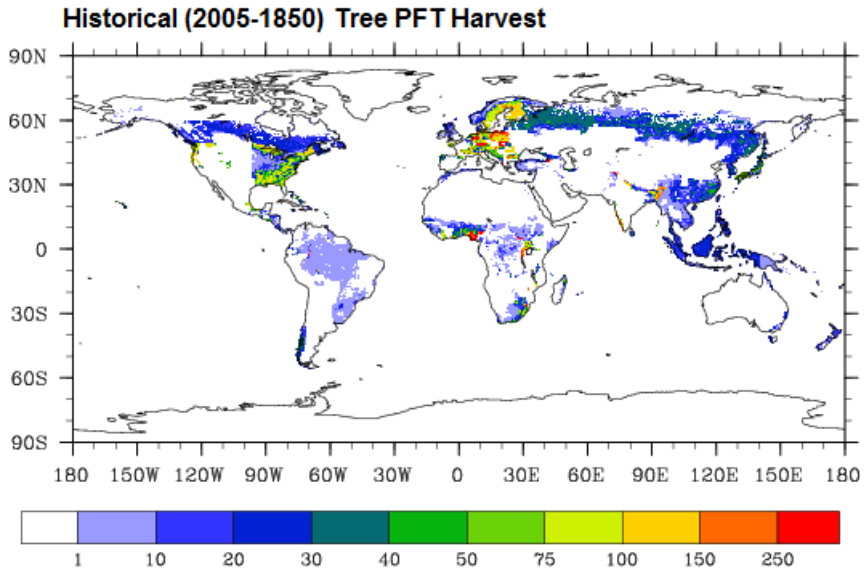


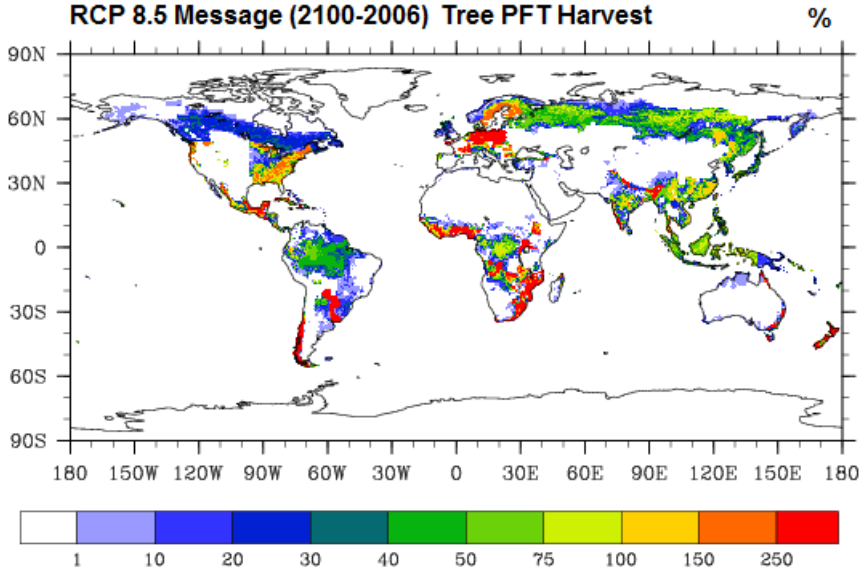
CMIP5 - RCP Land Cover Change PFTs – Trees %area



CMIP5 Historical and RCP Tree PFT Harvest







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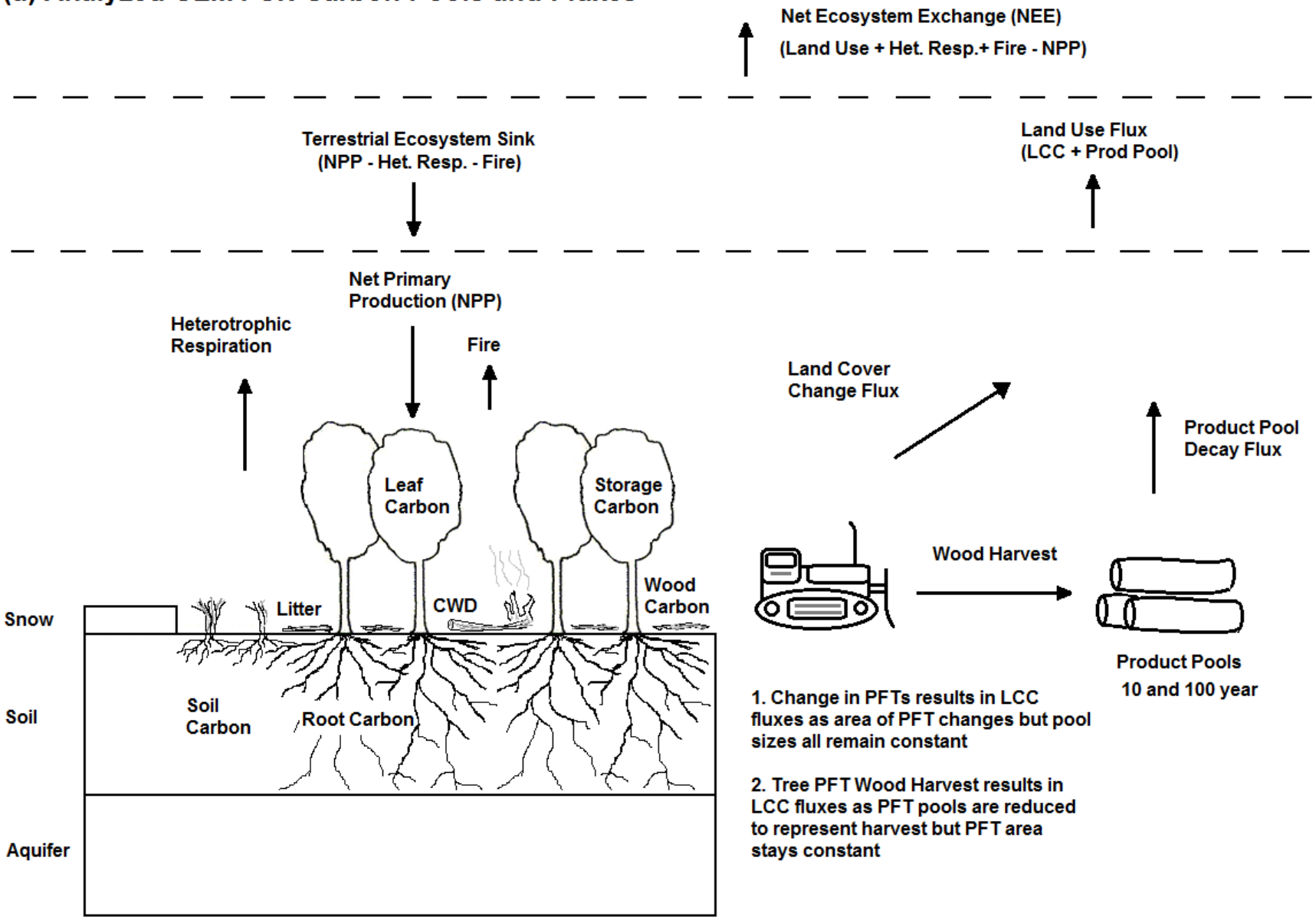

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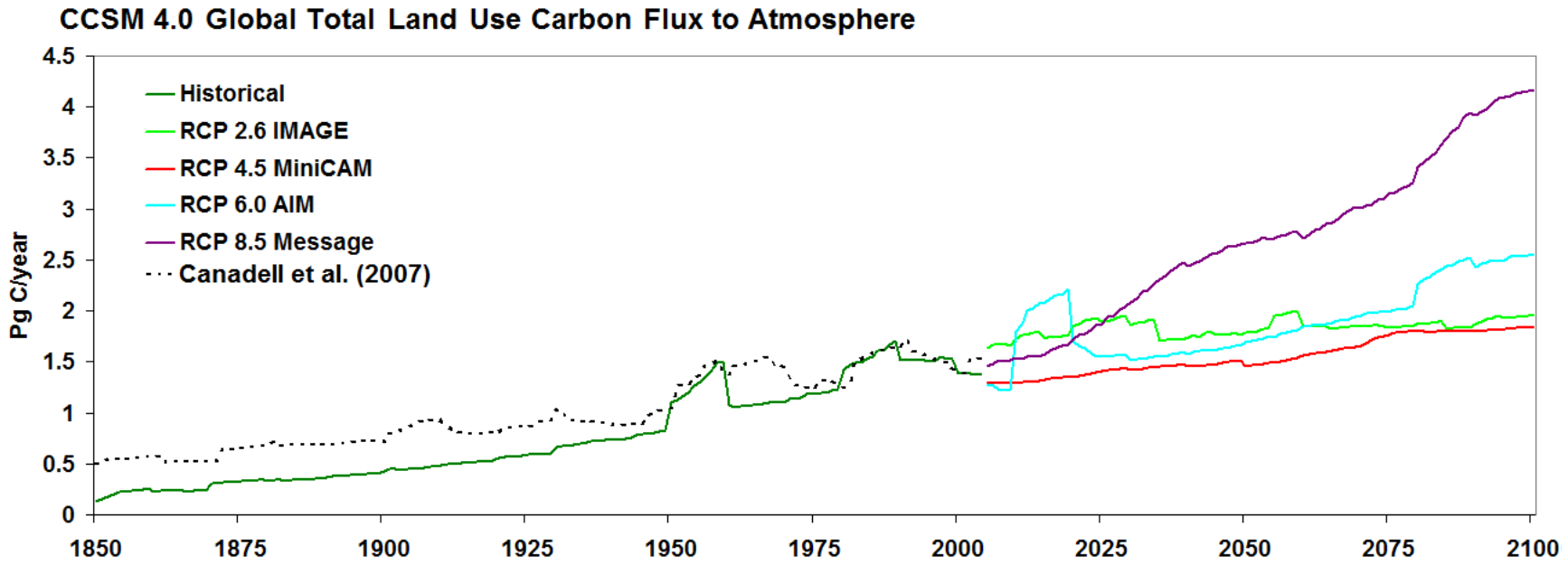
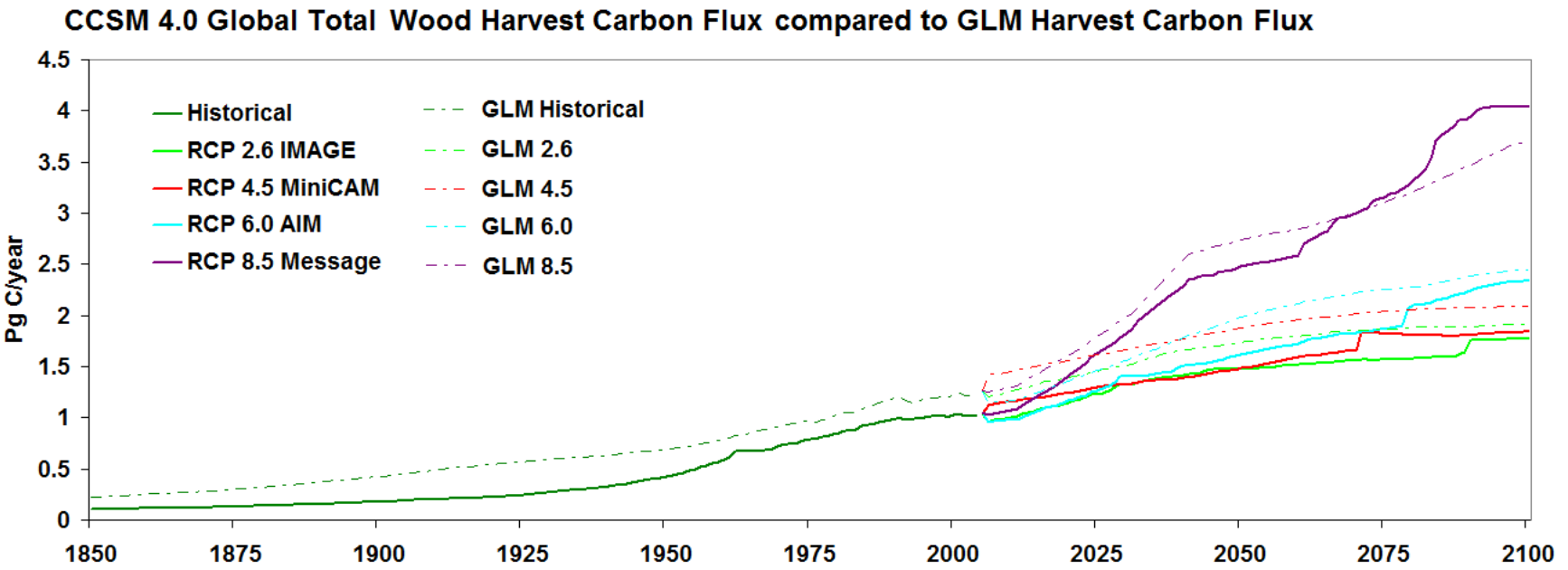
LCC in CESM – Coupled Climate & Prescribed CO2





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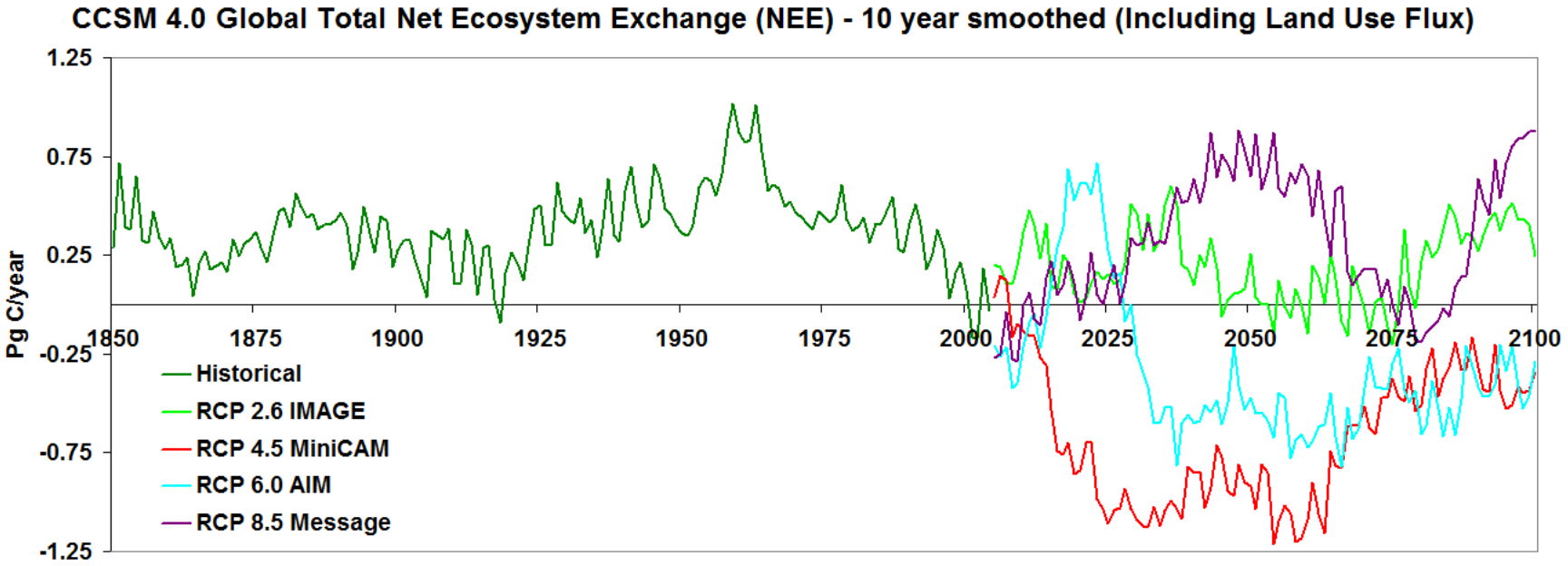

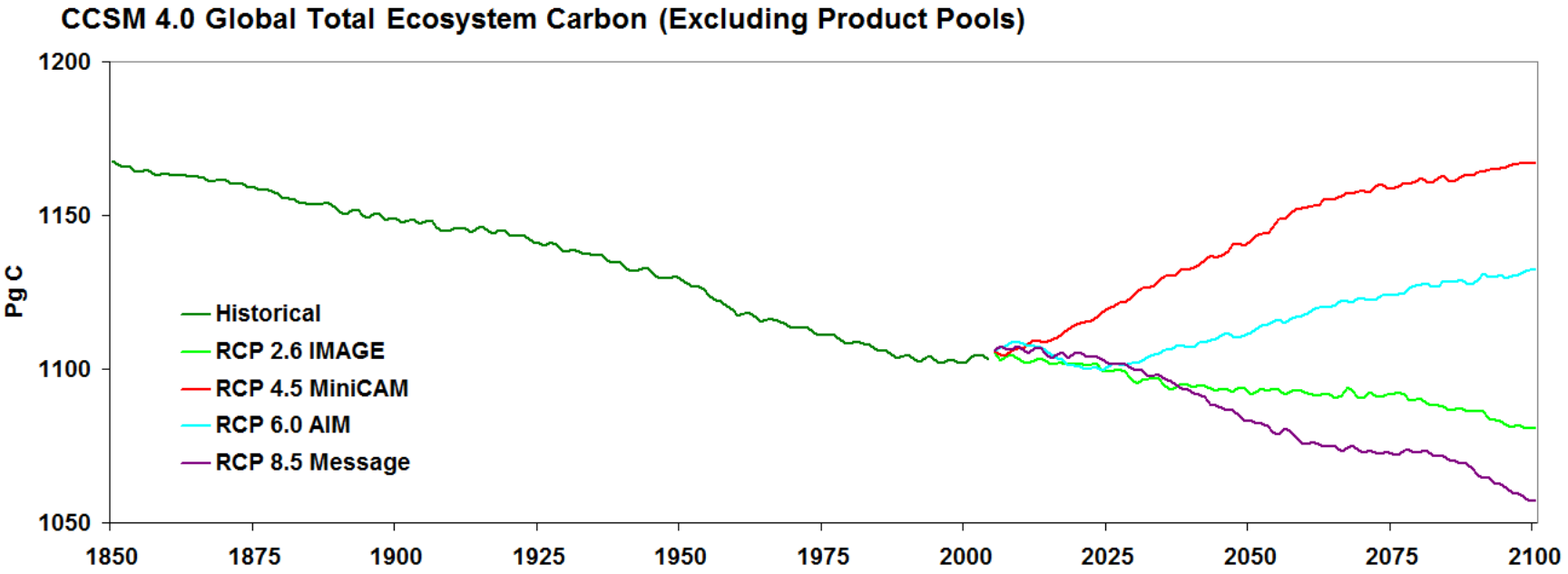

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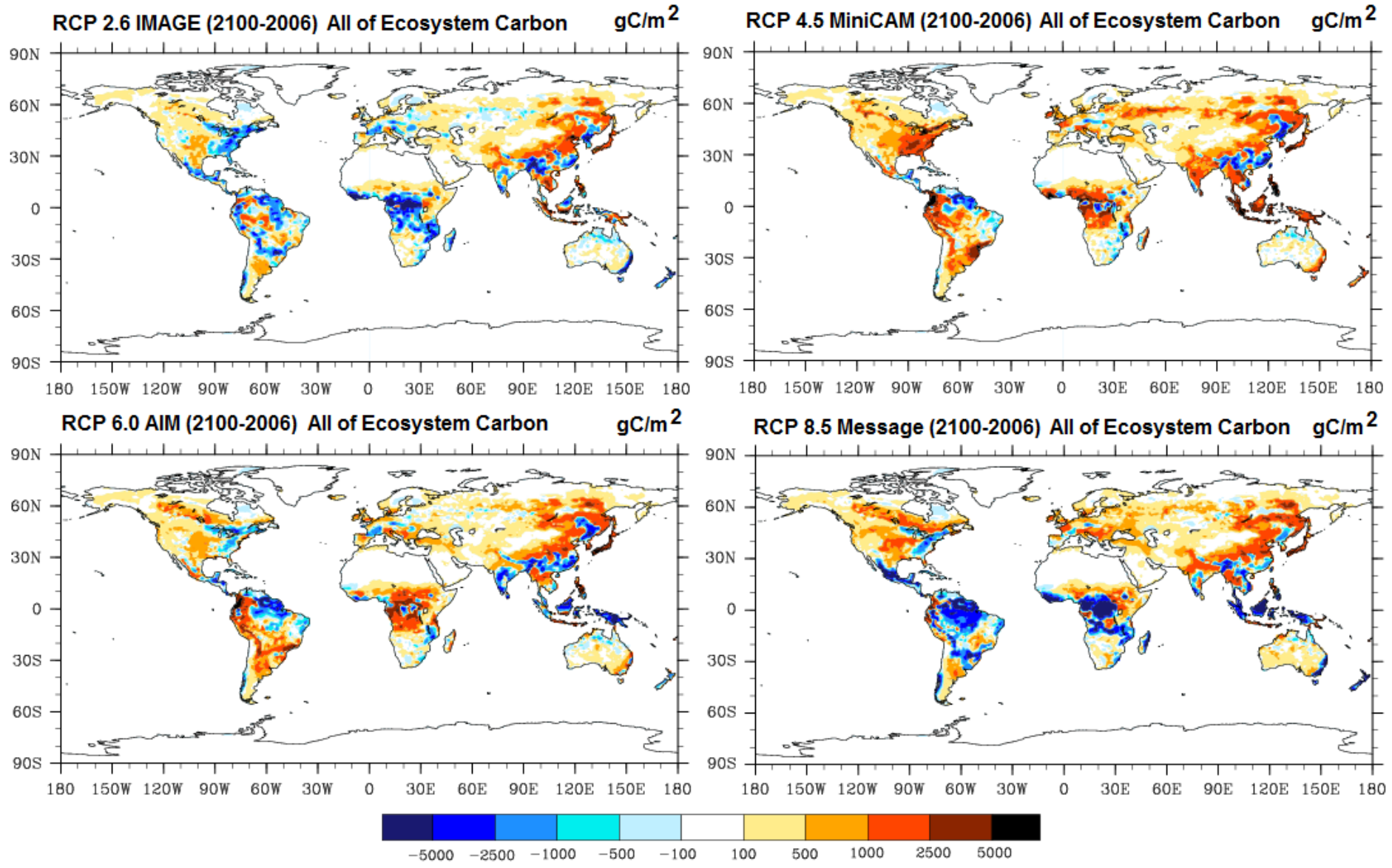
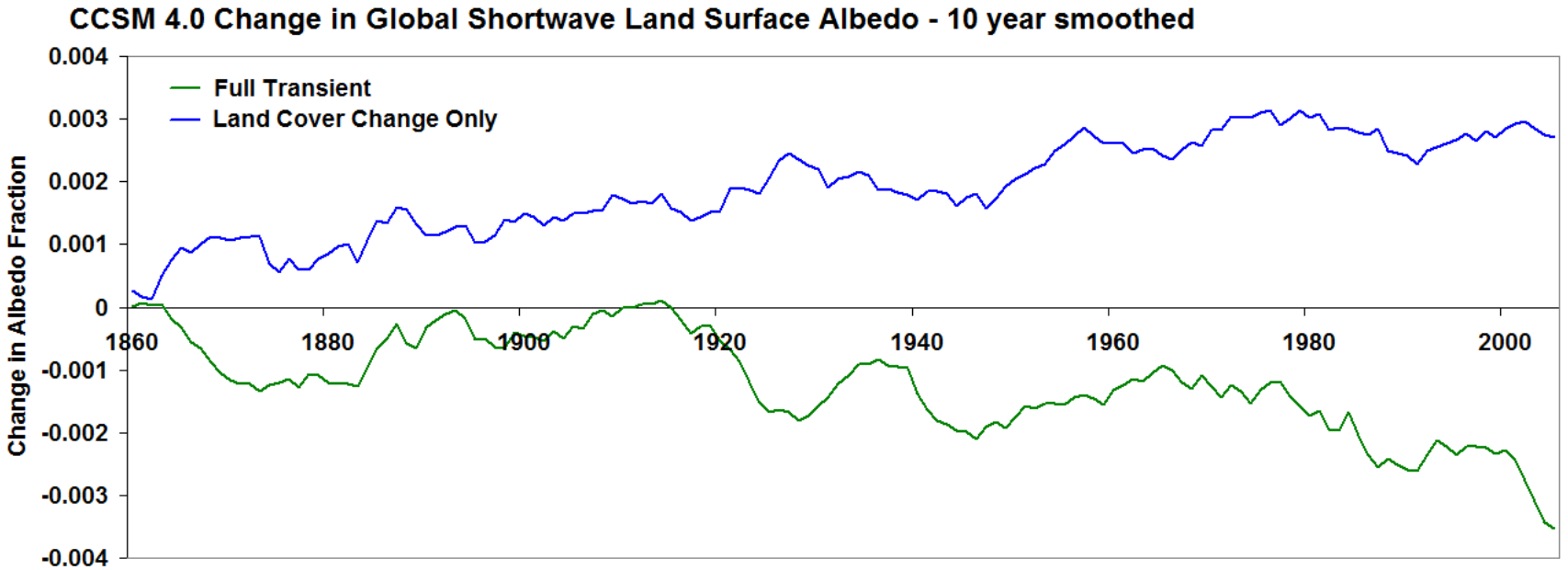
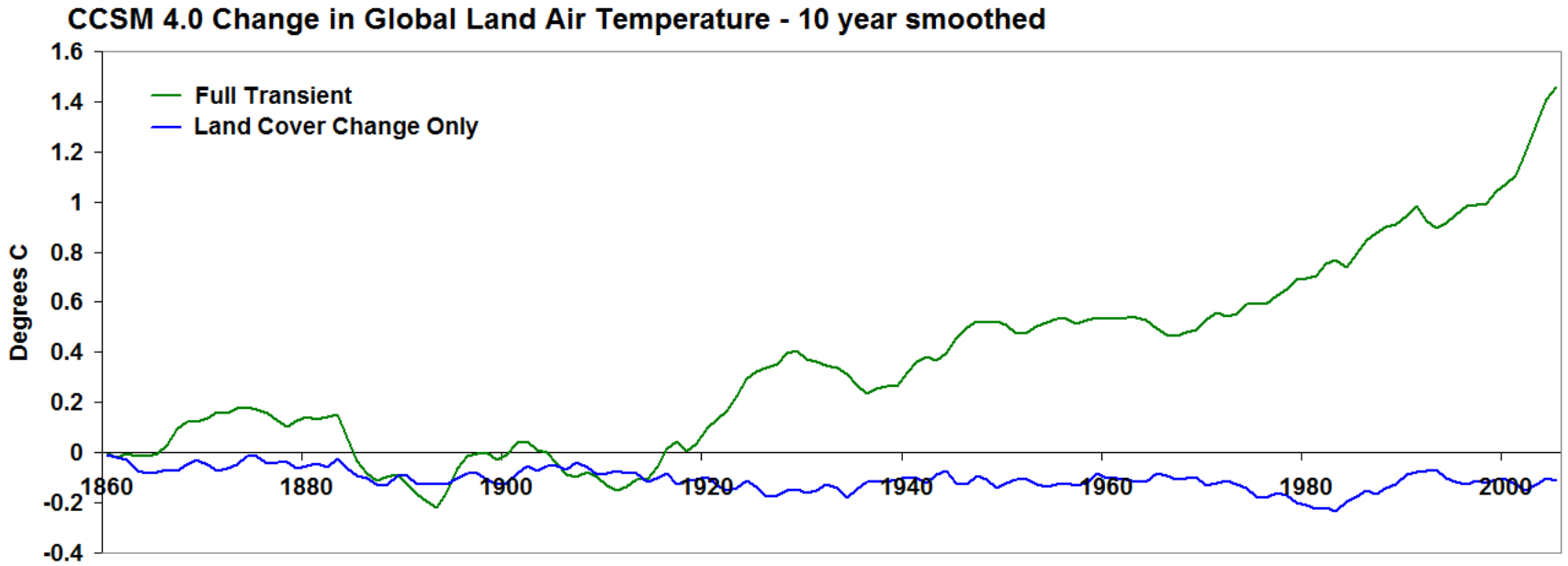


CESM – Historical Full Transient vs Land Cover Change





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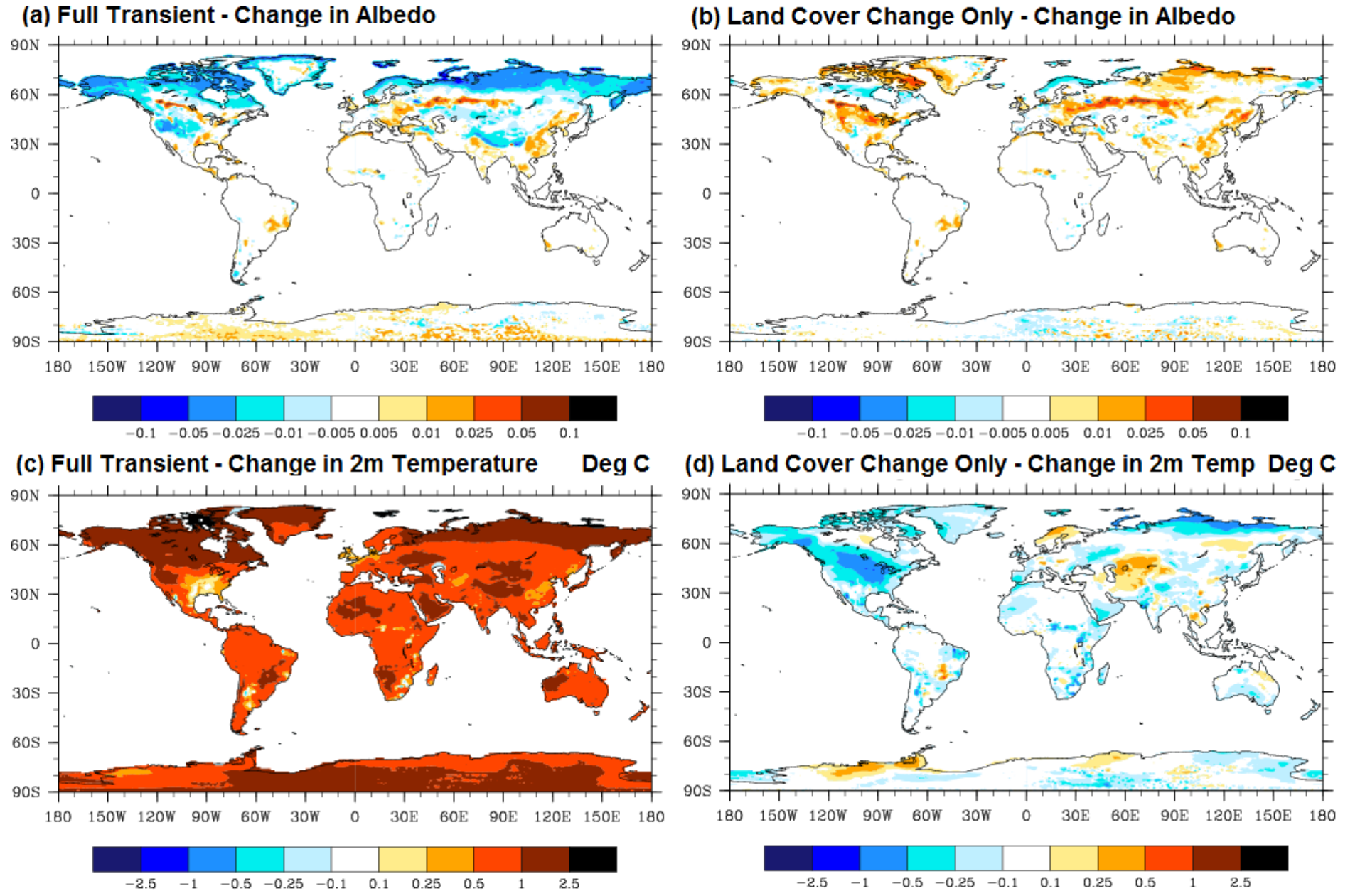

Summary Land Cover Change in CLM4 and CESM

1. Transient CLM4 Land Cover Change is specified as changes in PFTs and wood harvest from the CMIP5 historical and RCP trajectories combined with current day MODIS vegetation and bioclimatically modeled potential vegetation. (1850 – 2100)

2. CLM4 takes these changes in PFTs and wood harvest to change surface fluxes of energy, moisture and carbon. This impacts surface climate and biochemistry as well as larger scale atmospheric processes and chemistry.

3. The future RCP simulations demonstrated that land use can be an effective management tool for carbon. RCP 4.5 resulted in an increase of 64.3 PgC in land carbon through reforestation which offset increasing wood harvest and other land use fluxes.

4. RCP 8.5 on the other hand resulted in a loss of -49.0 PgC of ecosystem carbon