Modeling feedbacks and interactions between the land, climate, and human systems in the Community Land Model (CLM4): Successes and further research needs

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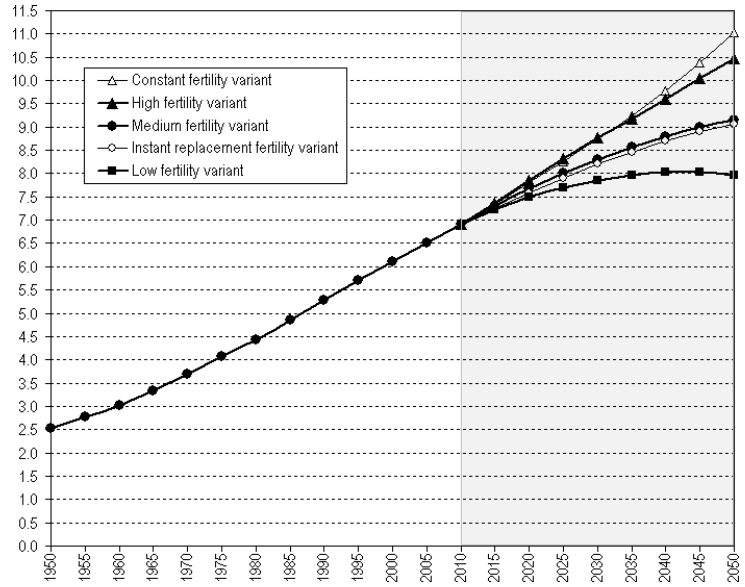
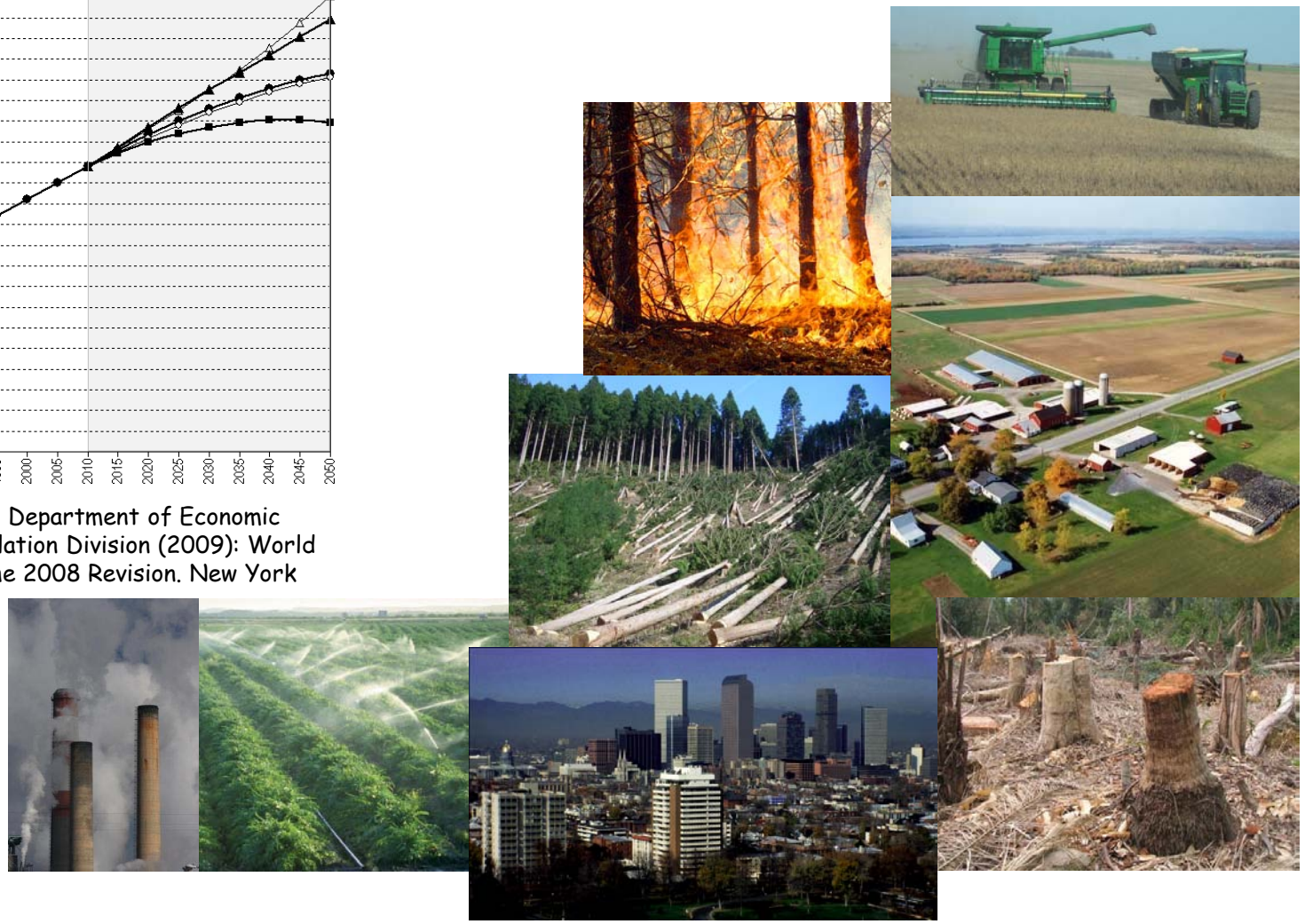
The Anthropocene

Population of the world, 1950-2050, according to different projection variants (in billion)

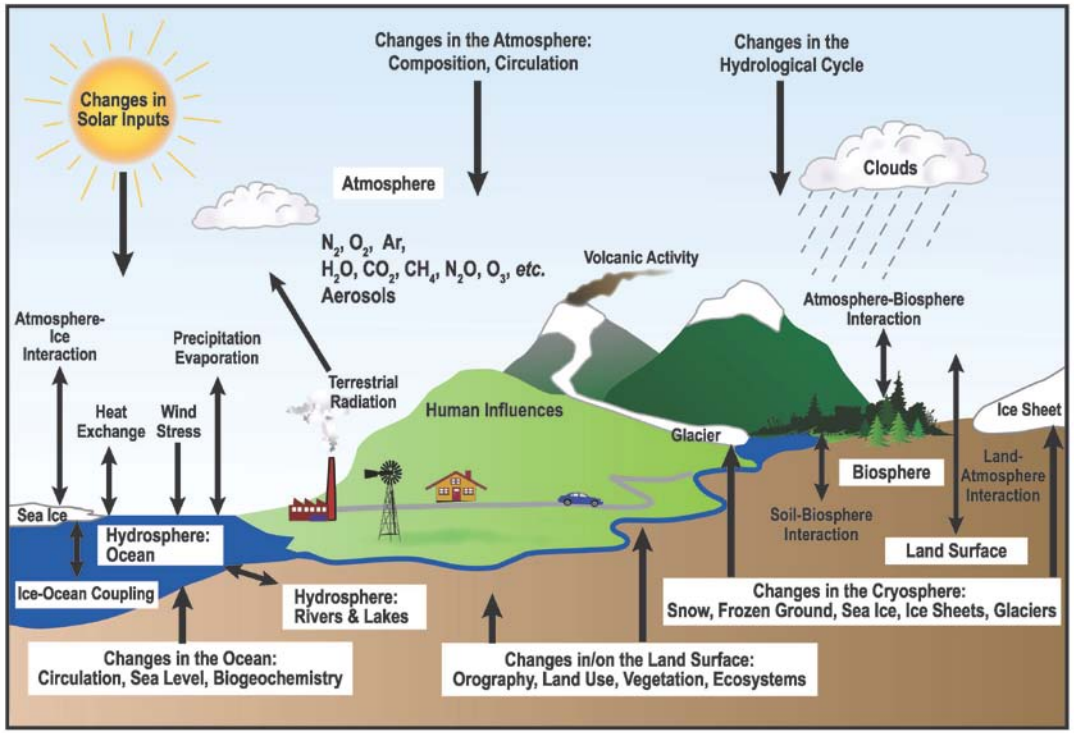


Source: United Nations, Department of Economic and Social Affairs, Population Division (2009): World Population Prospects: The 2008 Revision. New York

Human activities (agriculture, deforestation, urbanization) and their effects on climate, water resources, and biogeochemical cycles



The Community Earth System Model



(IPCC 2007)

Earth system models use mathematical formulas to simulate the **physical**, **chemical**, and **biological** processes that drive Earth's atmosphere, hydrosphere, biosphere, and geosphere

A typical Earth system model consists of coupled models of the **atmosphere**, **ocean**, **sea ice**, and **land**

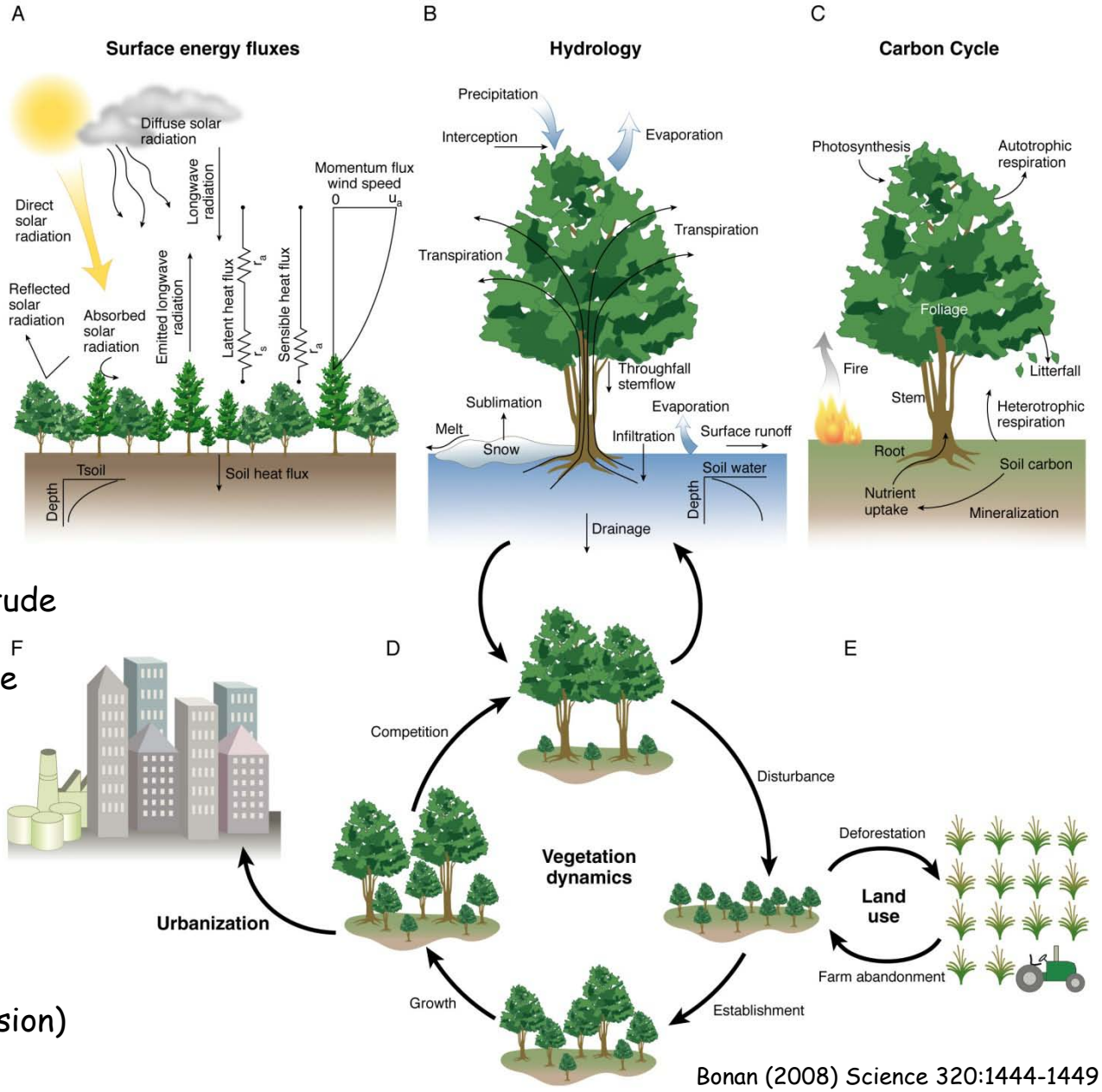
Land is represented by its **ecosystems**, **watersheds**, **people**, and **socioeconomic** drivers of environmental change

The model provides a comprehensive understanding of the processes by which people and ecosystems **feed back**, **adapt to**, and **mitigate** global environmental change

The Community Land Model

Fluxes of energy, water, and carbon and the dynamical processes that alter these fluxes

Oleson et al. (2010) NCAR/TN-478+STR



Spatial scale

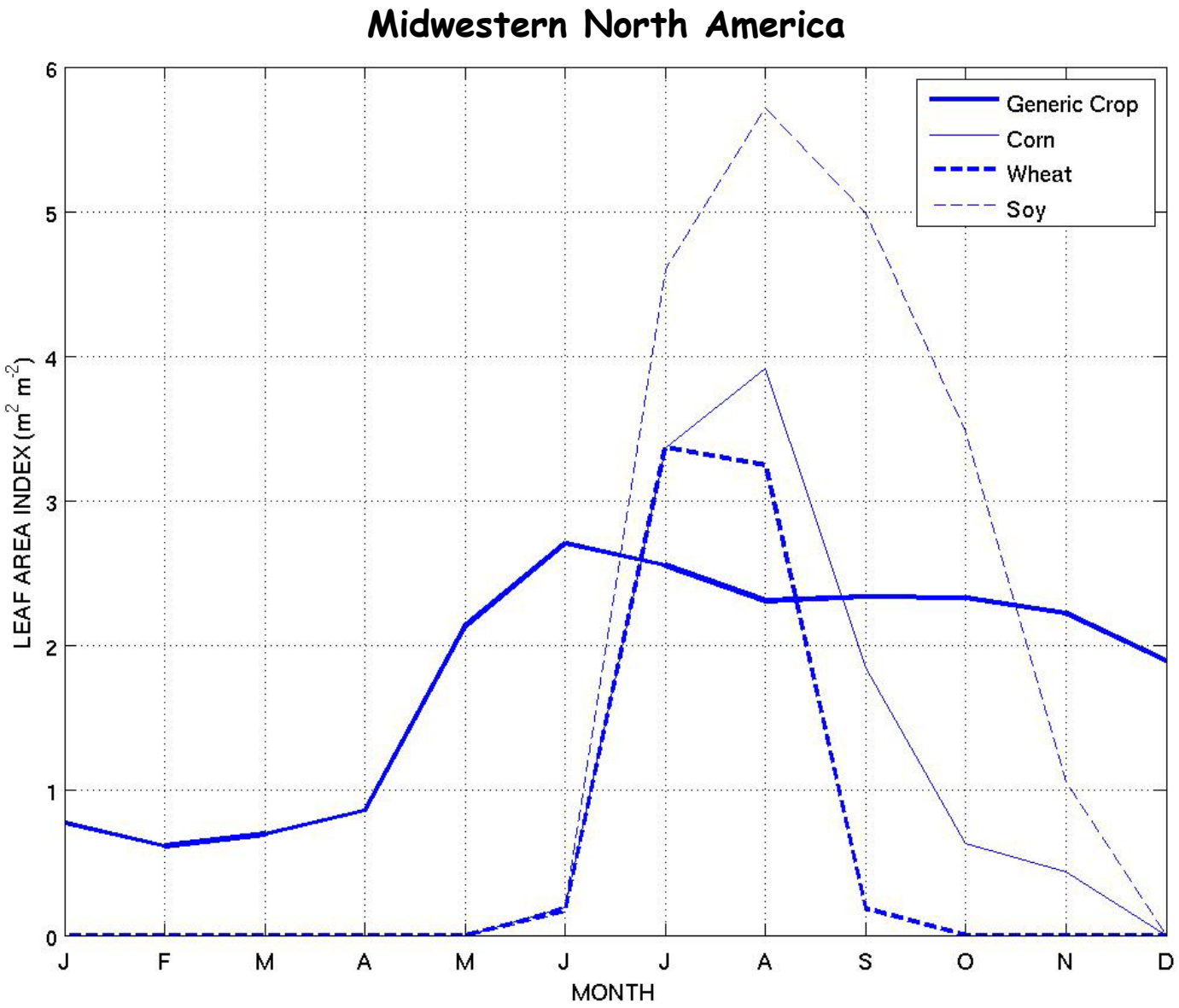
- 1.25° longitude × 0.9375° latitude (288 × 192 grid)
- 2.5° longitude × 1.875° latitude (144 × 96 grid)

Temporal scale

- 30-minute coupling with atmosphere
- Seasonal-to-interannual (phenology)
- Decadal-to-century climate (disturbance, land use, succession)
- Paleoclimate (biogeography)

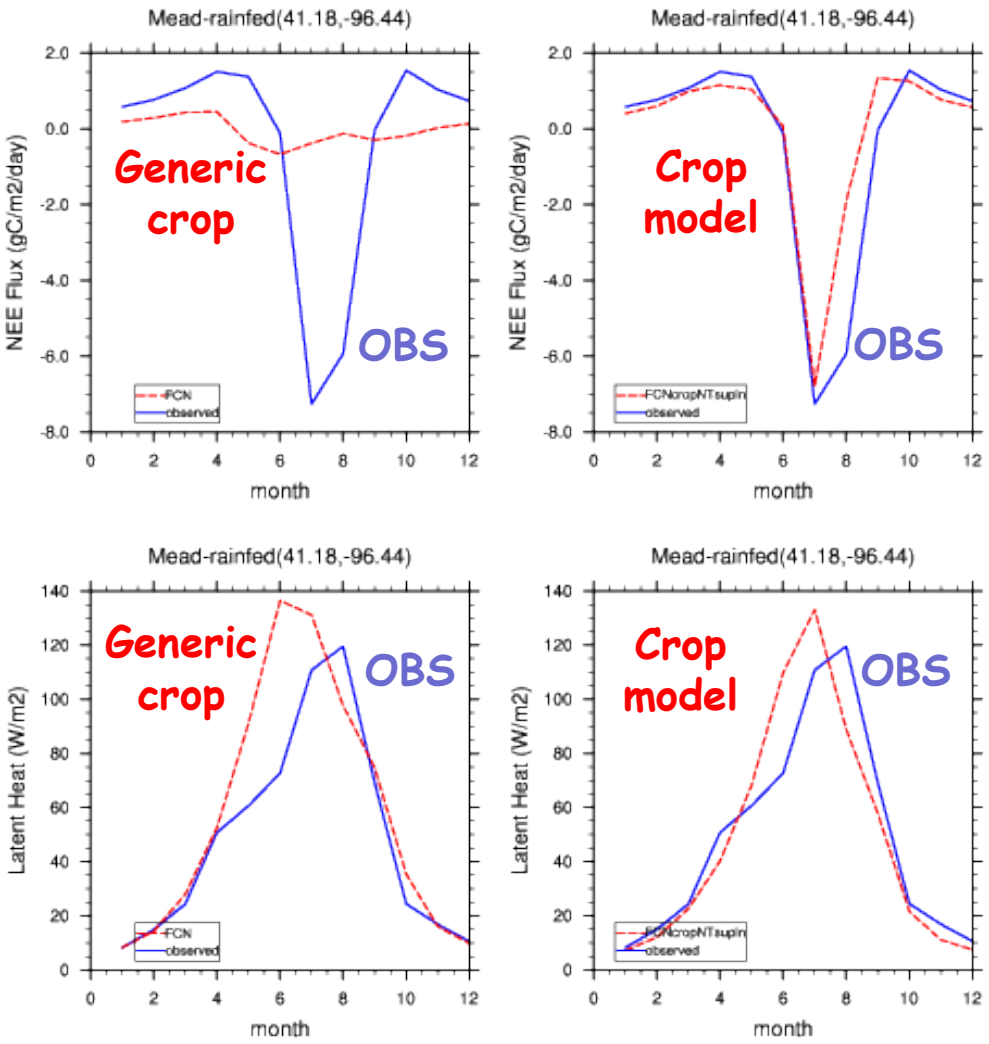
Bonan (2008) Science 320:1444-1449

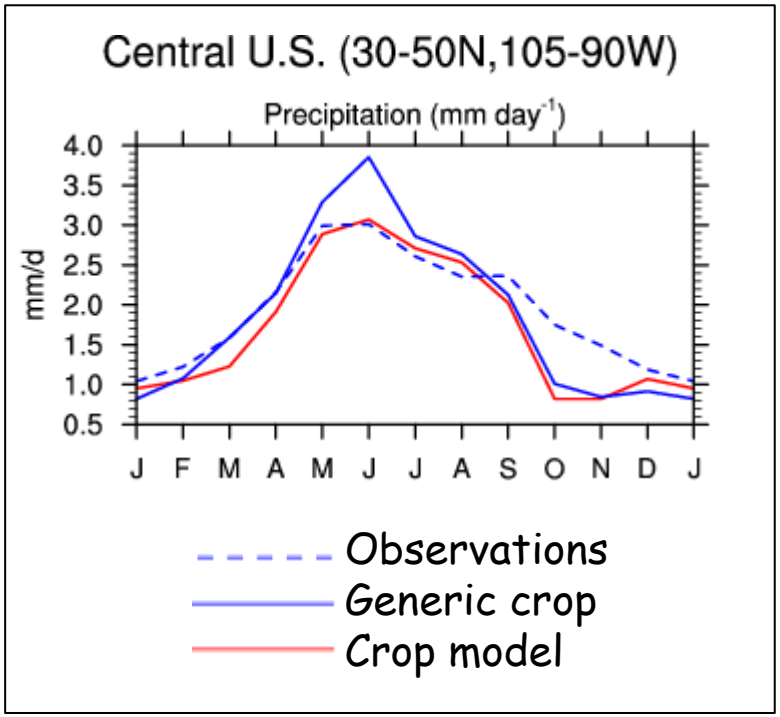
Crop model improves leaf area phenology



(Sam Levis, NCAR)

Crop model improves surface fluxes and climate





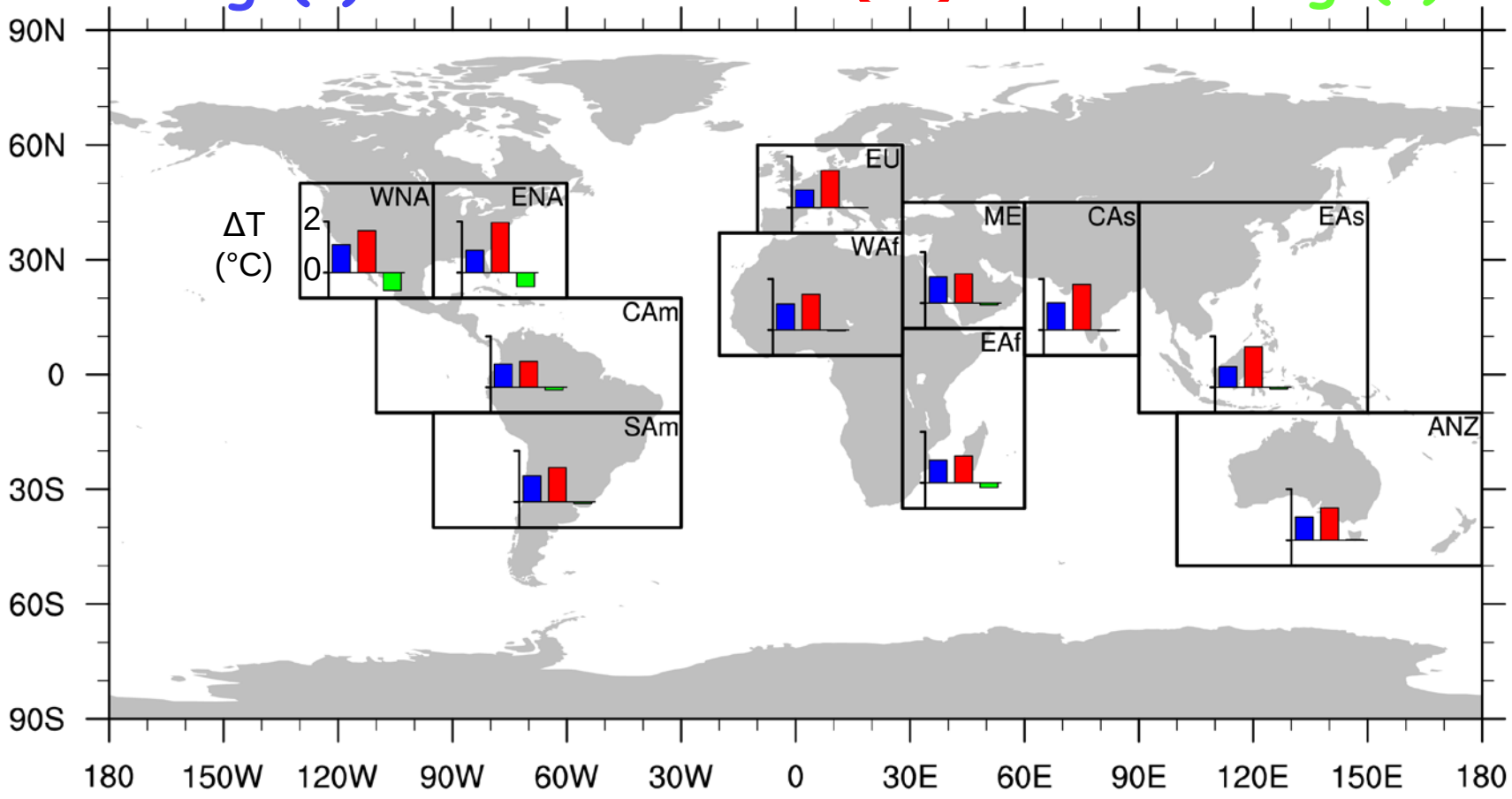
(Sam Levis, NCAR)

The urban heat island

Rural climate change(*)

Present-day urban heat island(**)

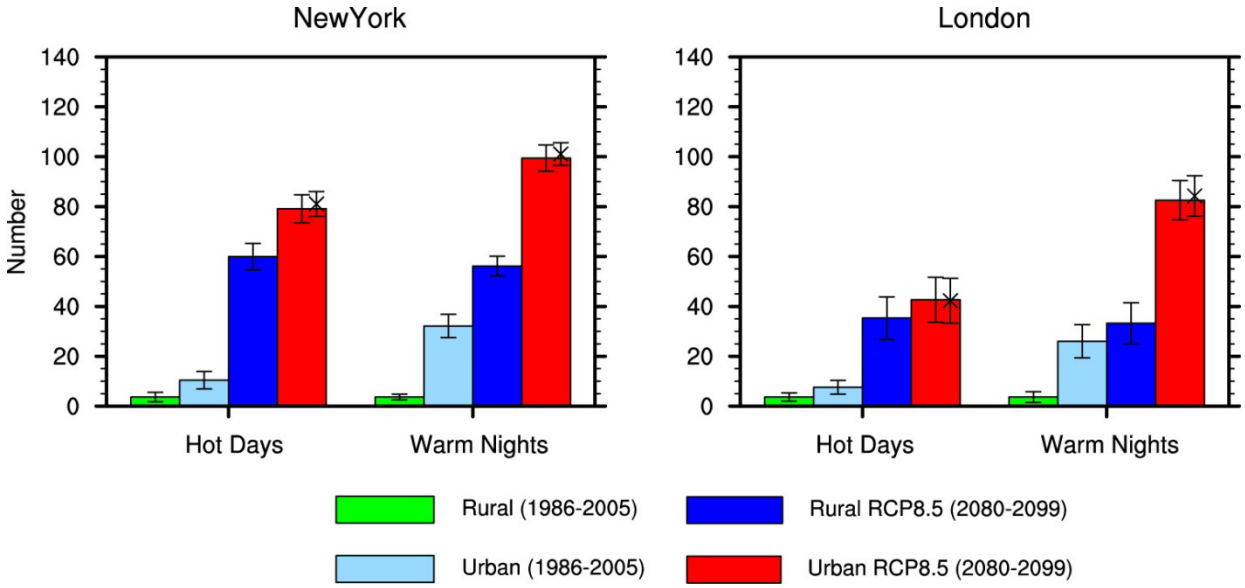
Rural landcover change(*)



(*) Present-day (1986-2005) minus pre-industrial (1850-1869) temperature change
(**) Present-day urban minus rural temperature difference

(Keith Oleson, NCAR)

Urban climates differ from rural climates



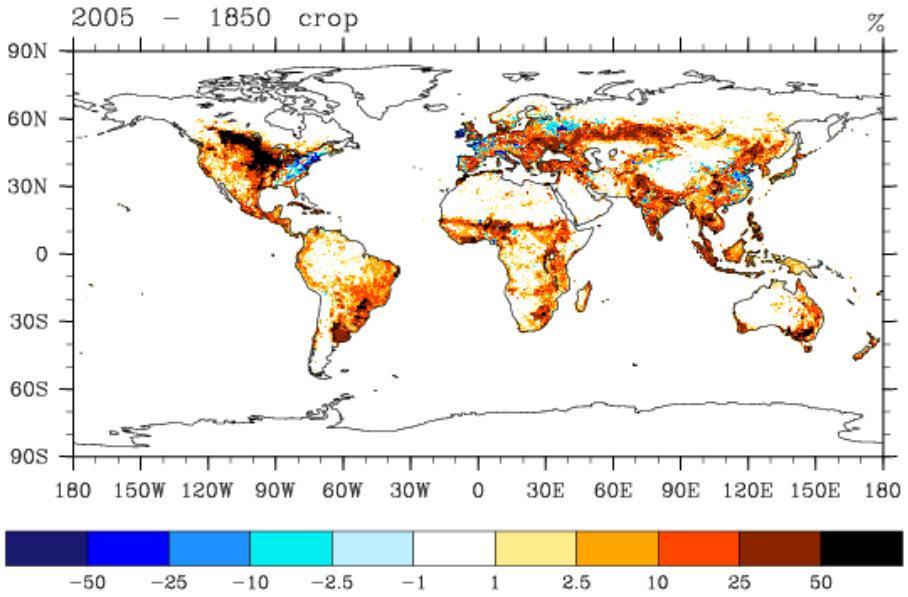
Present-day climate
Cities have more hot days and warm nights than rural land

21st century climate change
Cities increase more in hot days and warm nights than rural land

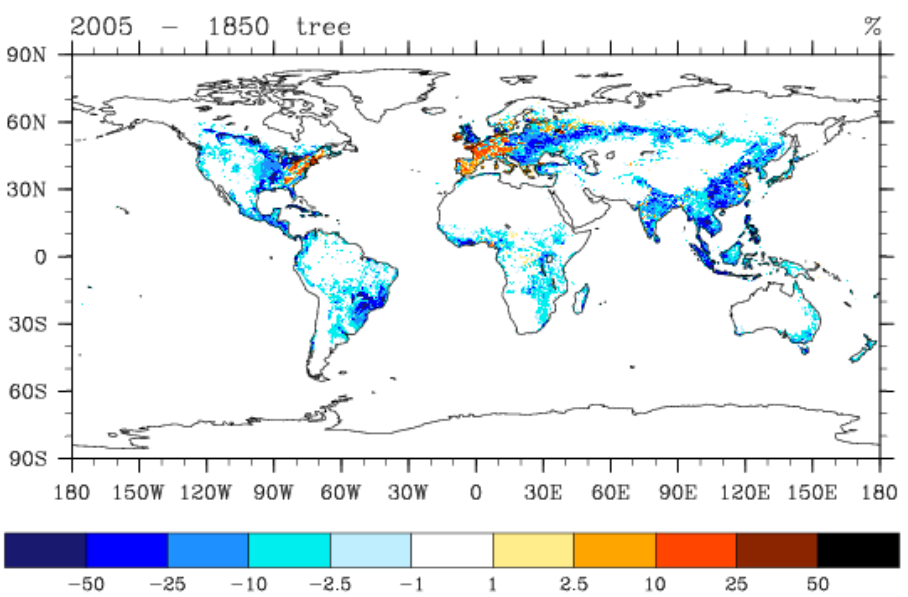
(Keith Oleson, NCAR)

Historical land cover change, 1850 to 2005

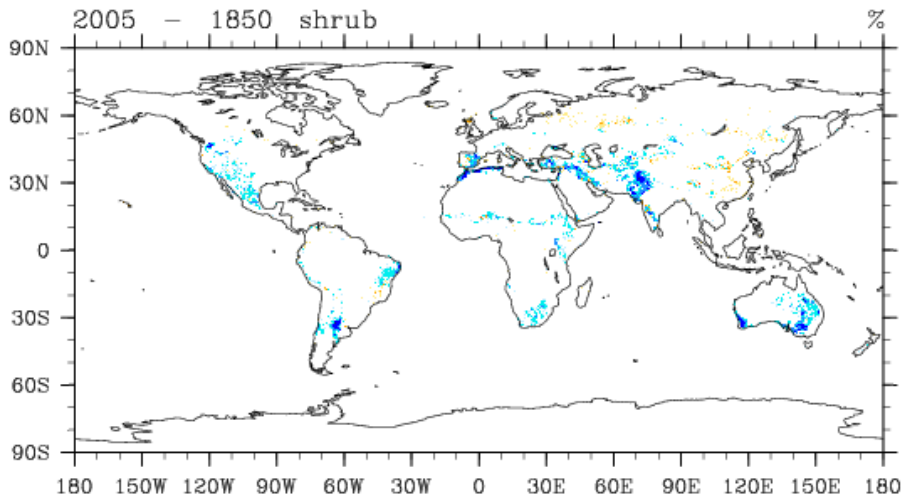
Crop PFT



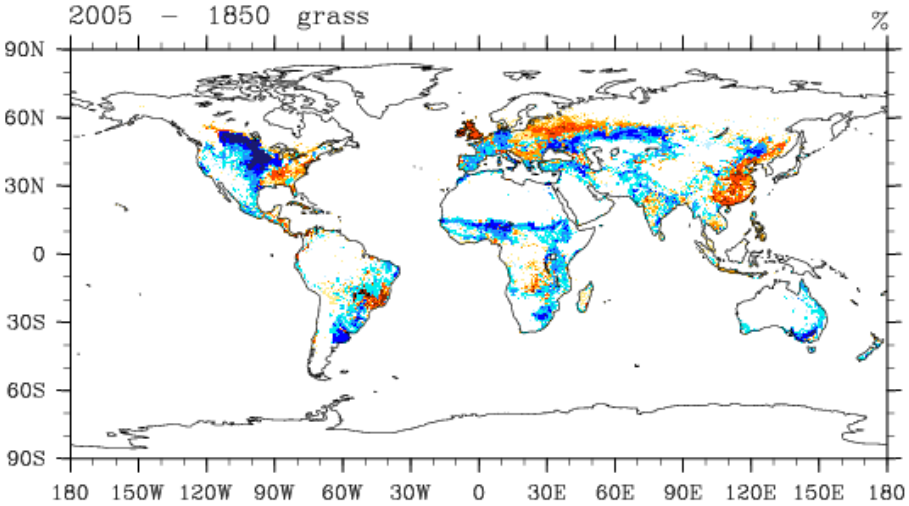
Tree PFTs



Shrub PFTs



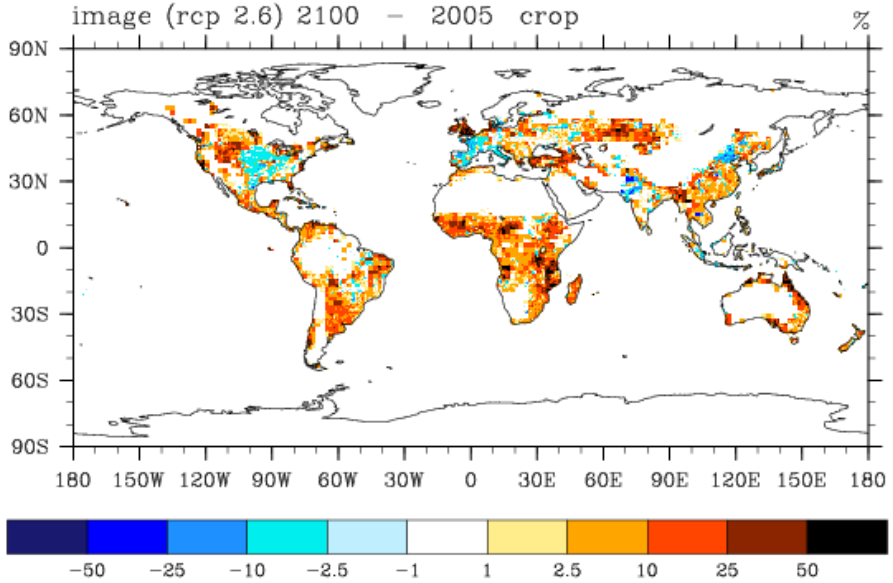
Grass PFTs



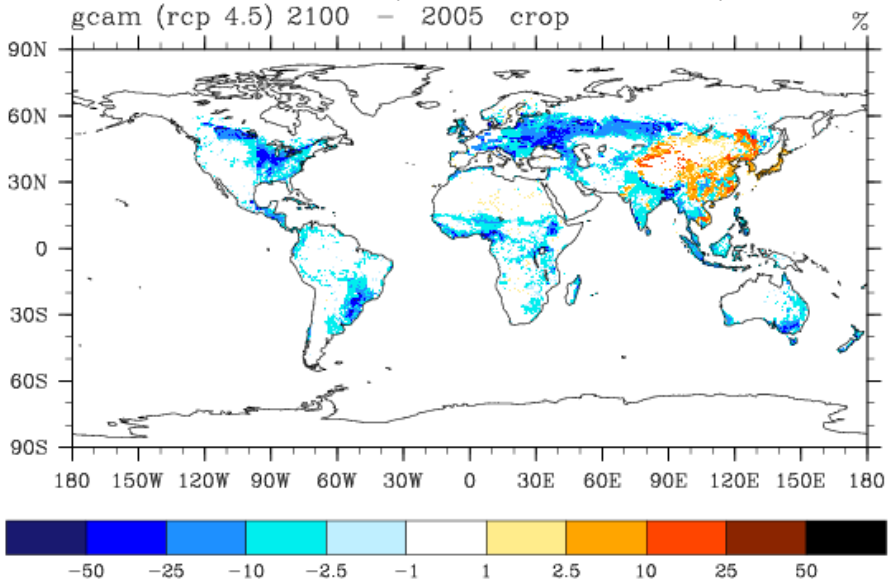
(datasets by Peter Lawrence & Johan Feddema)

Future land cover change, 2005 to 2100

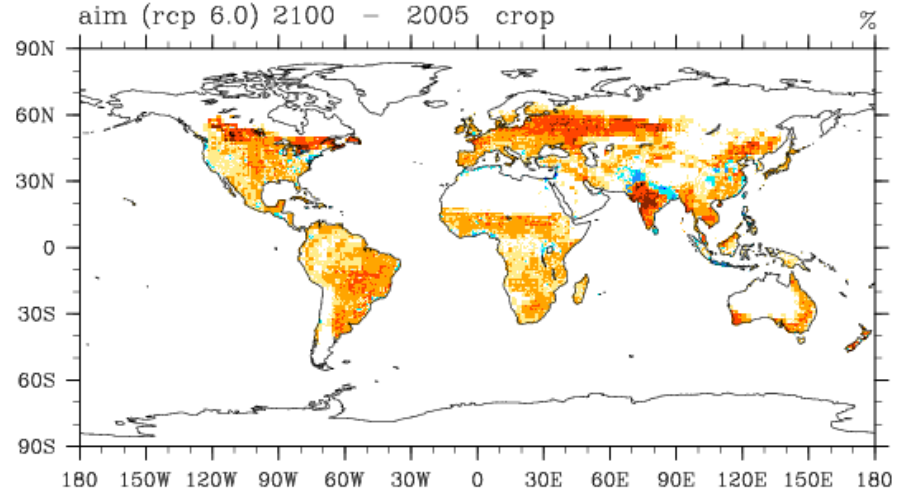
IMAGE (RCP 2.6 W m^{-2})



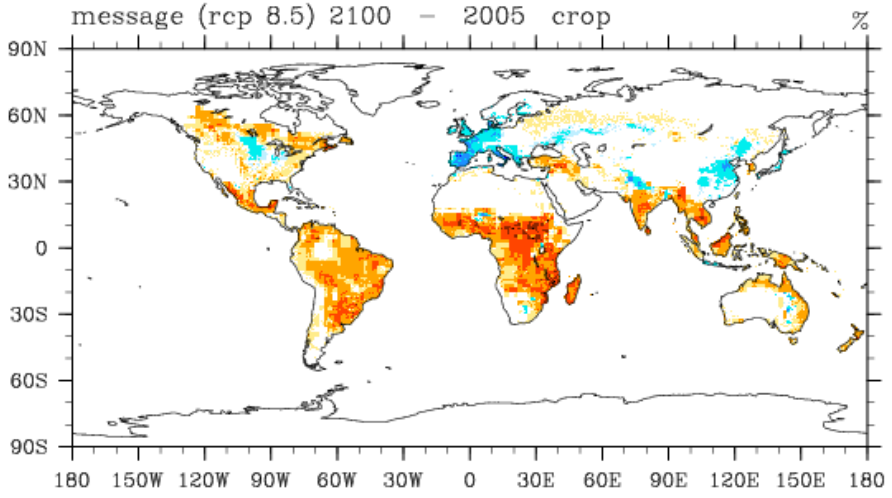
MINICAM (RCP 4.5 W m^{-2})



AIM (RCP 6.0 W m^{-2})



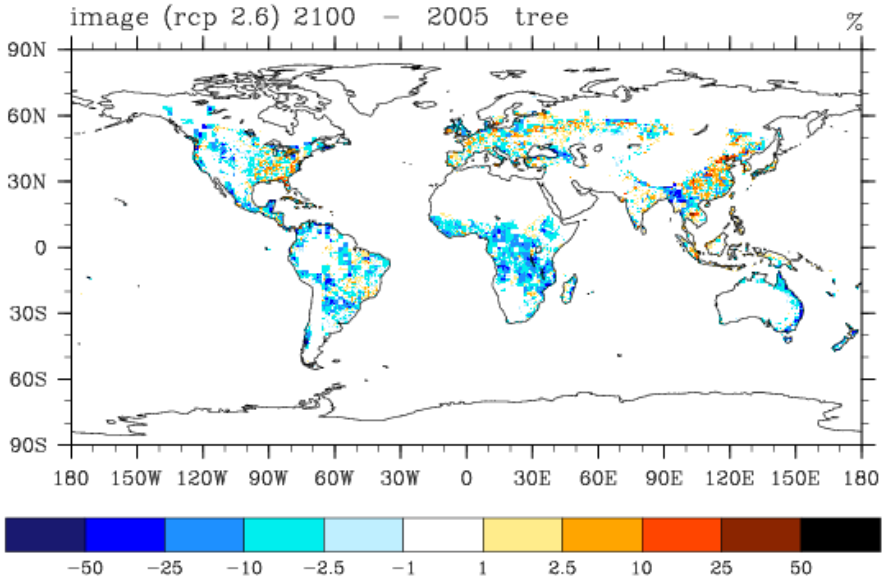
MESSAGE (RCP 8.5 W m^{-2})



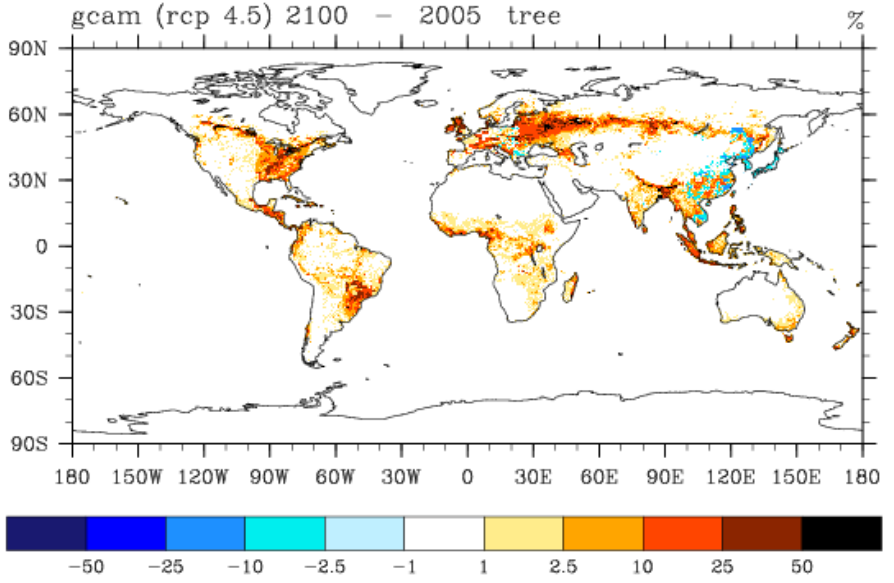
(datasets by Peter Lawrence & Johan Feddema)

Future land cover change, 2005 to 2100

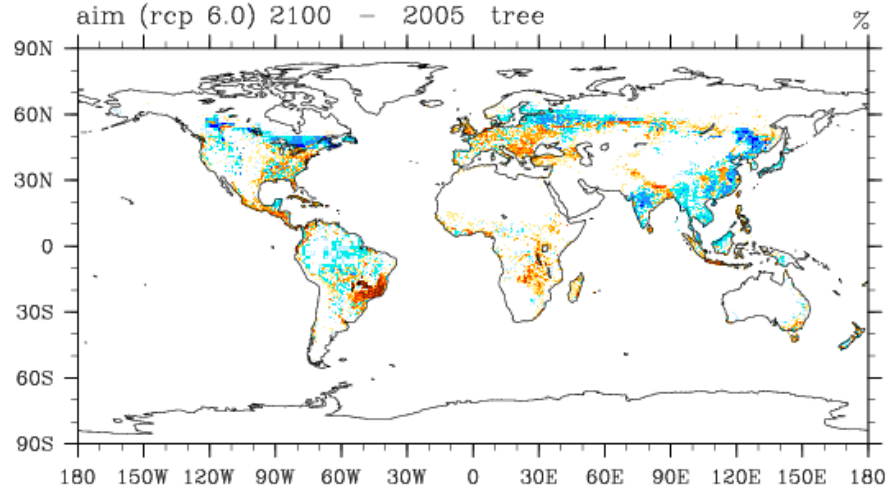
IMAGE (RCP 2.6 W m^{-2})



MINICAM (RCP 4.5 W m^{-2})



AIM (RCP 6.0 W m^{-2})



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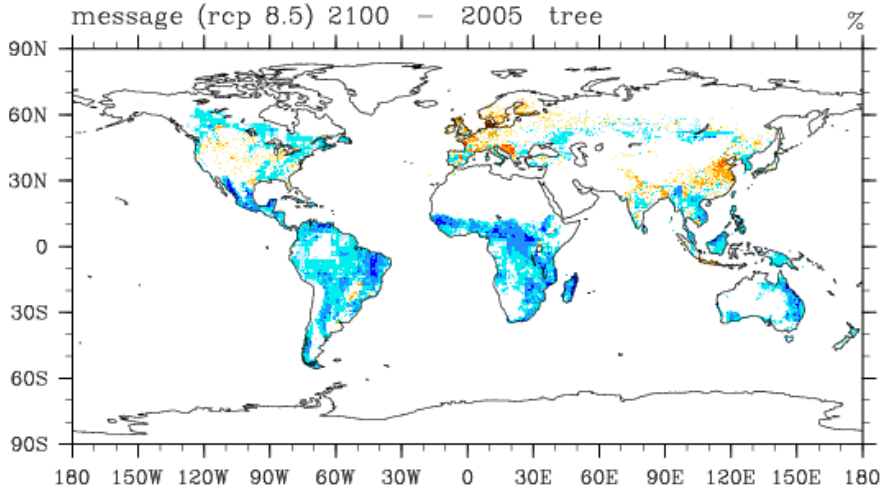
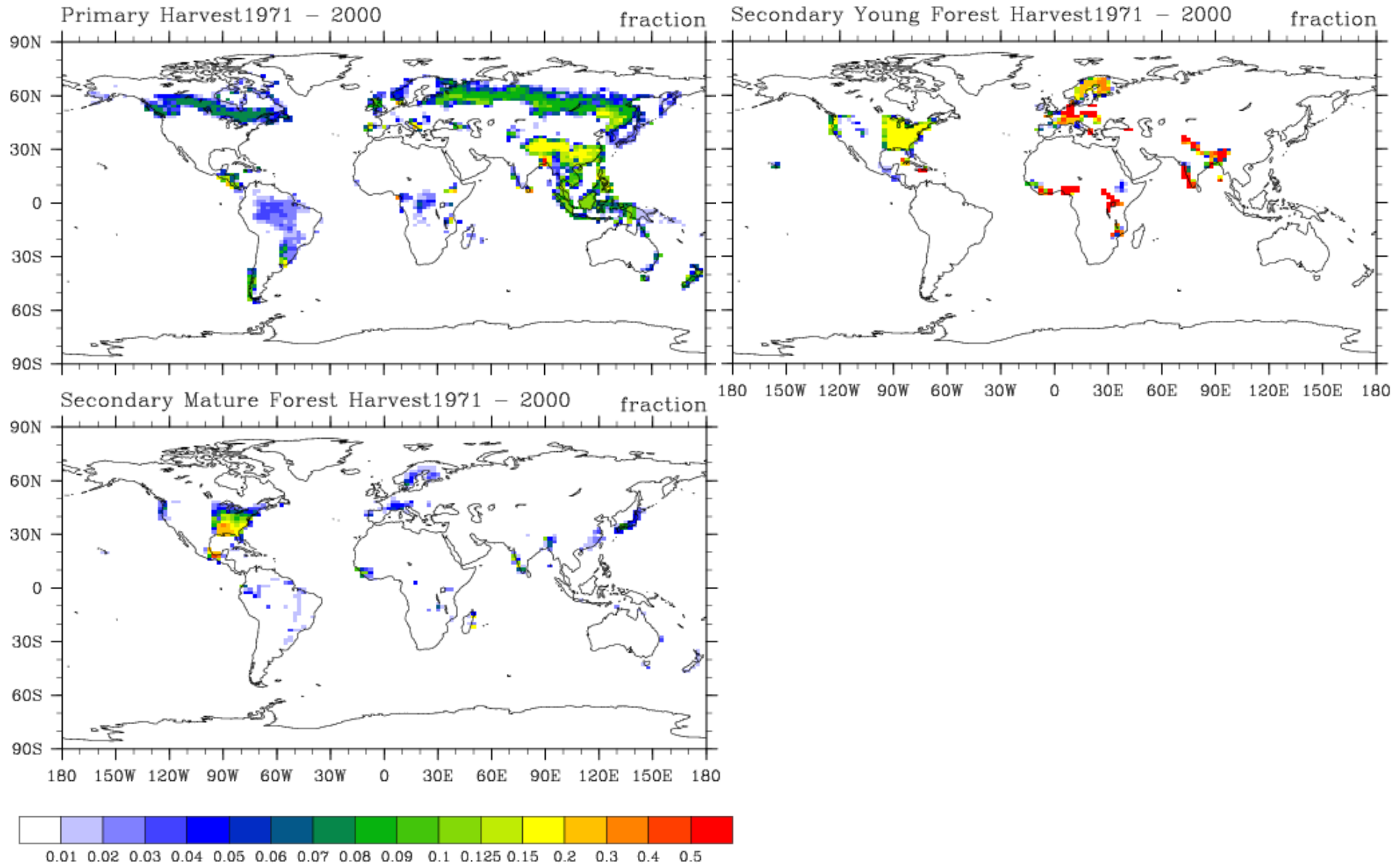


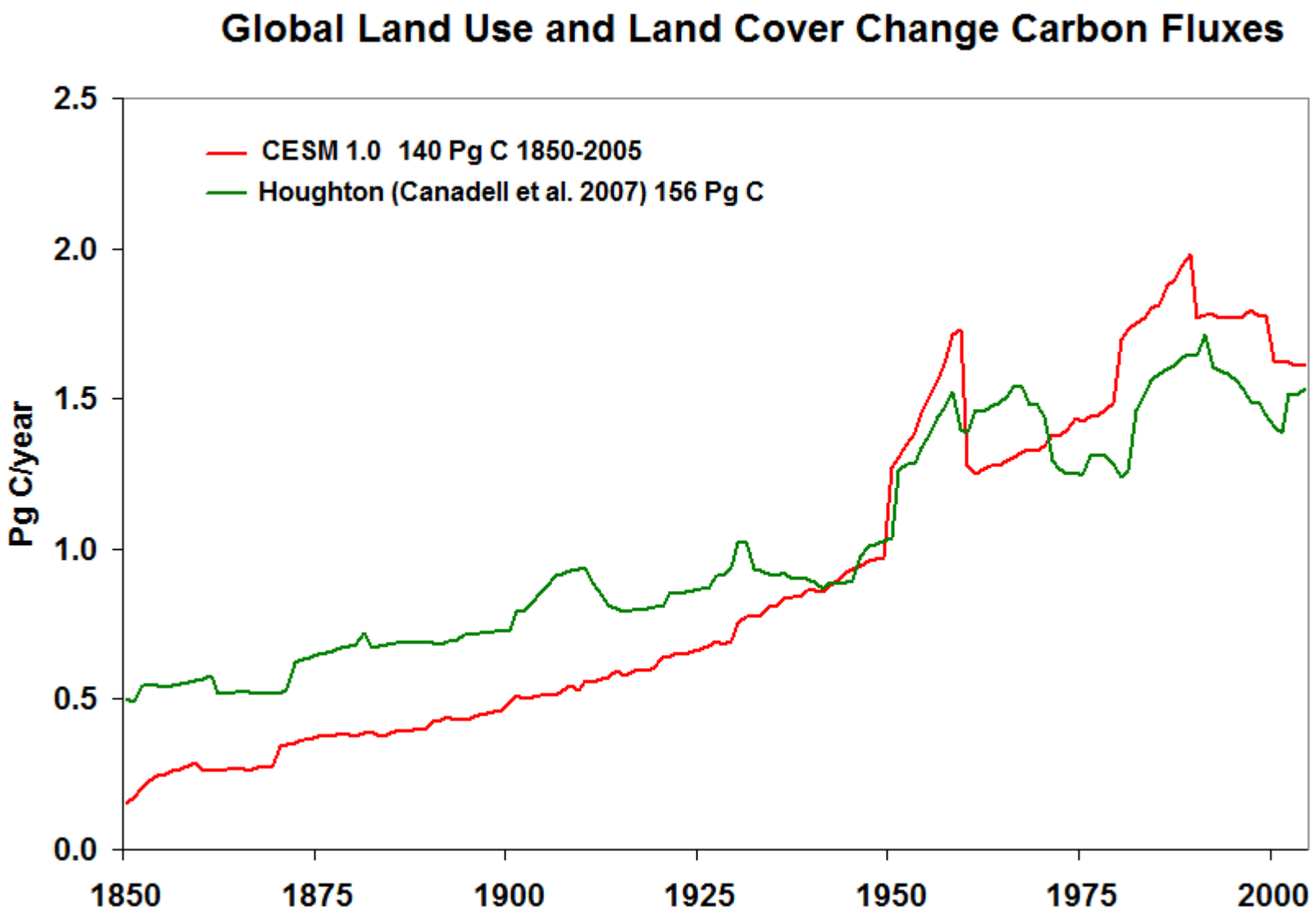
(datasets by Peter Lawrence & Johan Feddema)

Land use - wood harvest



(datasets by Peter Lawrence & Johan Feddema)

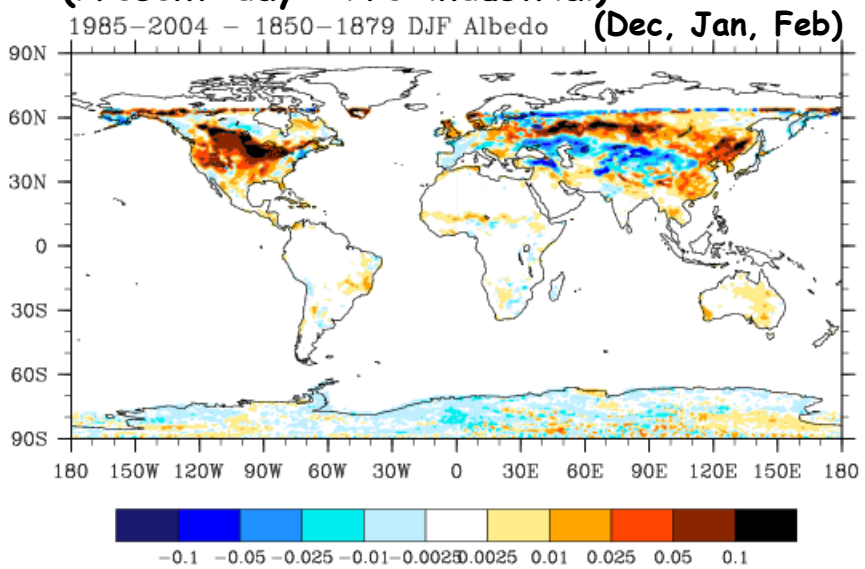
Land use carbon emission is prominent feedback

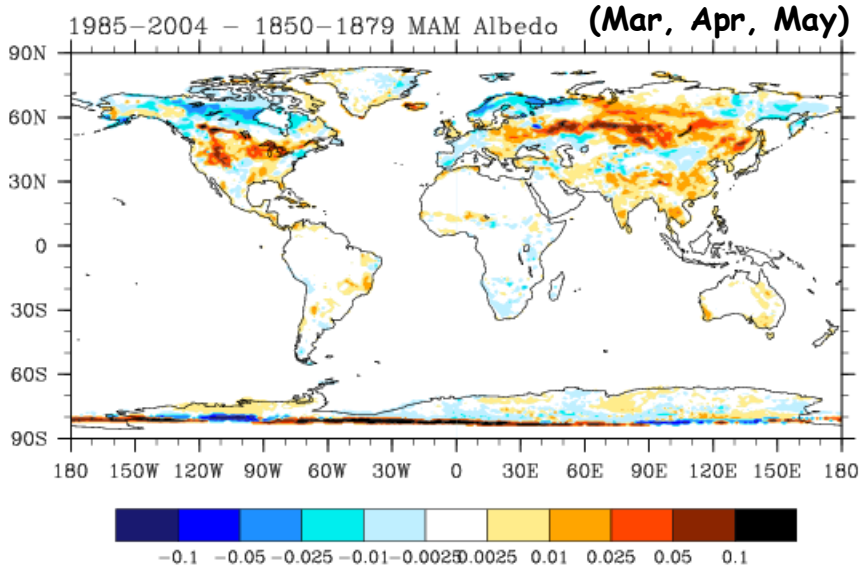


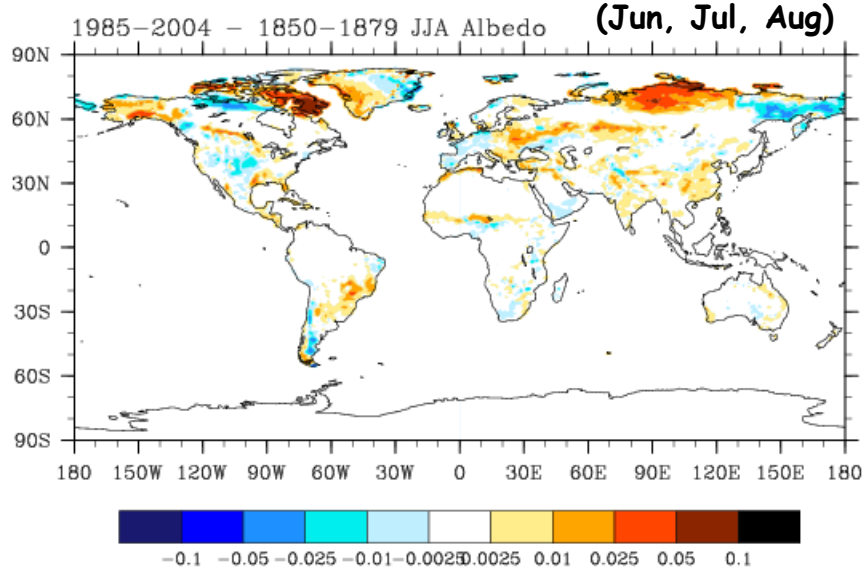
(Peter Lawrence, NCAR)

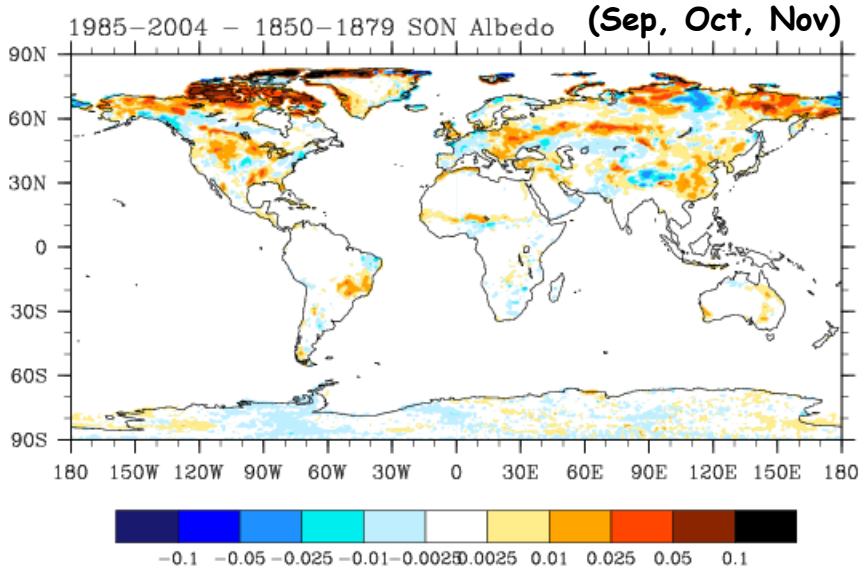
Surface albedo increases

(Present-day – Pre-industrial)



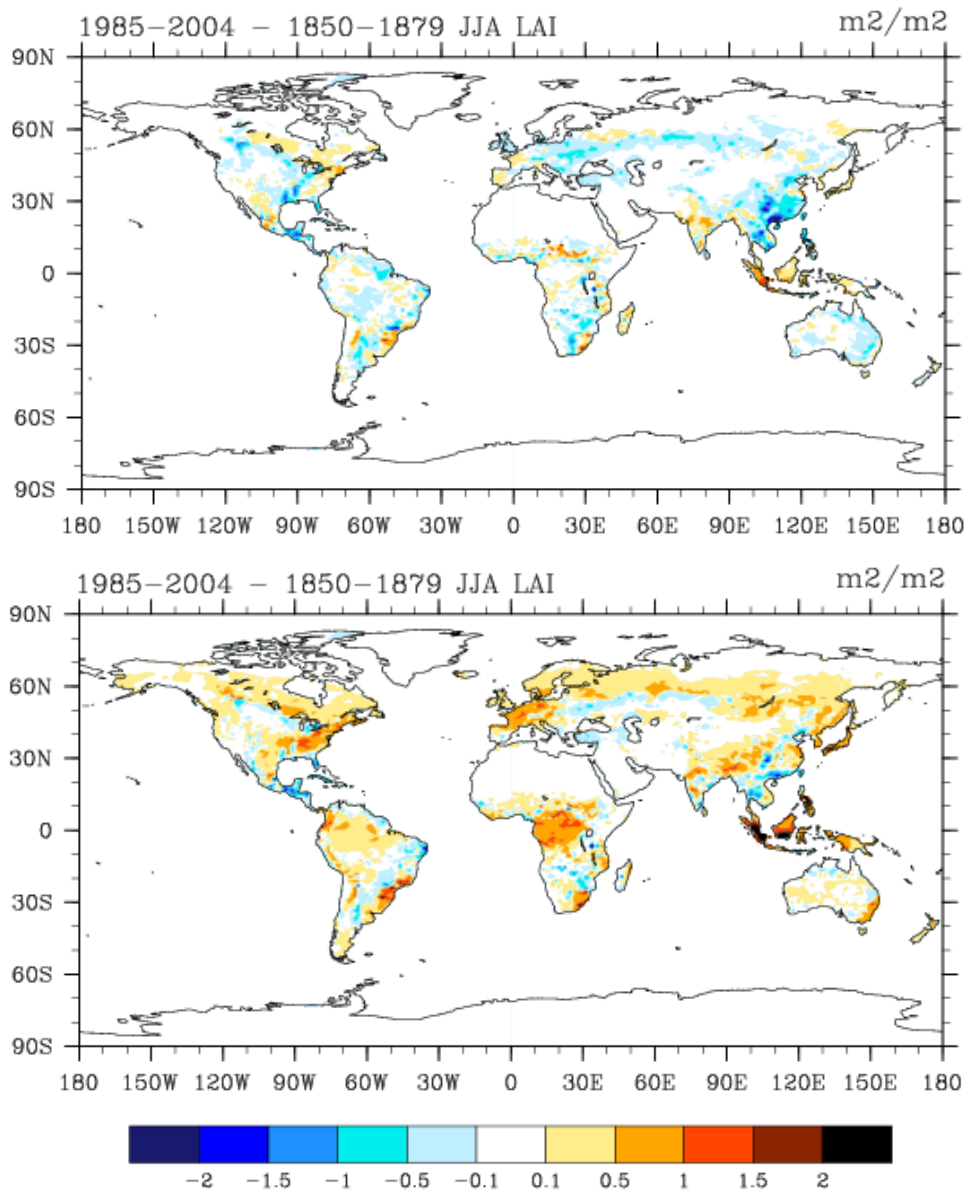






(Peter Lawrence, NCAR)

Opposing trends in vegetation



Leaf area index (Jun, Jul, Aug)

(Present-day – Pre-industrial)

Single forcing simulation
Land cover change only

Loss of leaf area, except where reforestation

All forcing simulation
CO_2
Climate
Nitrogen deposition
Land cover change

Increase in leaf area, except where agricultural expansion

Conclusions

Earth system models

Now represent human modification of the biosphere from land use and land cover change (e.g., agriculture, deforestation) and urbanization

Agroecosystems

- Representation of agricultural systems improves simulation

Cities

- Cities respond differently to climate change than do other land cover types

Anthropogenic land cover change

- Land use carbon emission is prominent
- Higher albedo of croplands cools climate
- Less certainty about role of evapotranspiration
- Implementation of land cover change (spatial extent, crop parameterization) matters, as does the simulation of natural vegetation