Update on CLM BGC Component

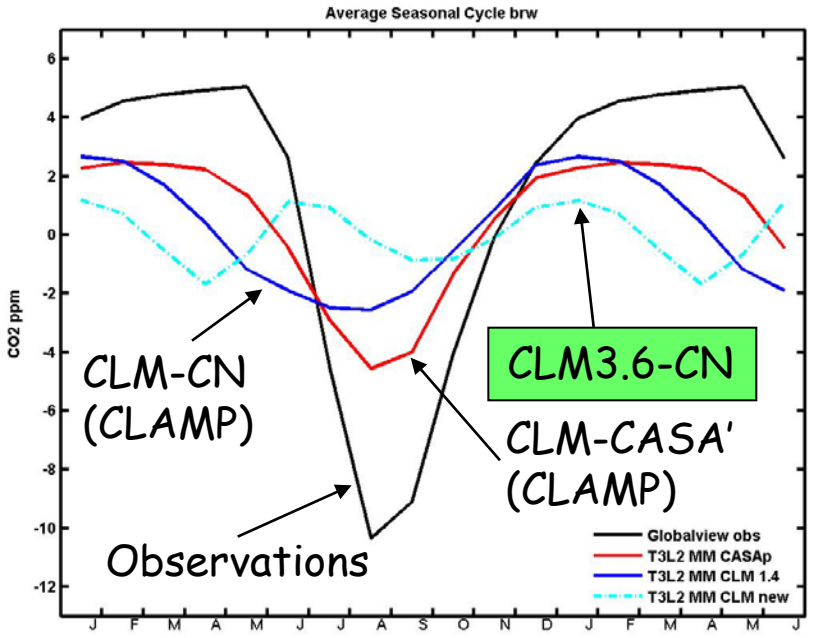
Gordon Bonan
NCAR

CCSM BGCWG
17 June 2009
Breckenridge, CO

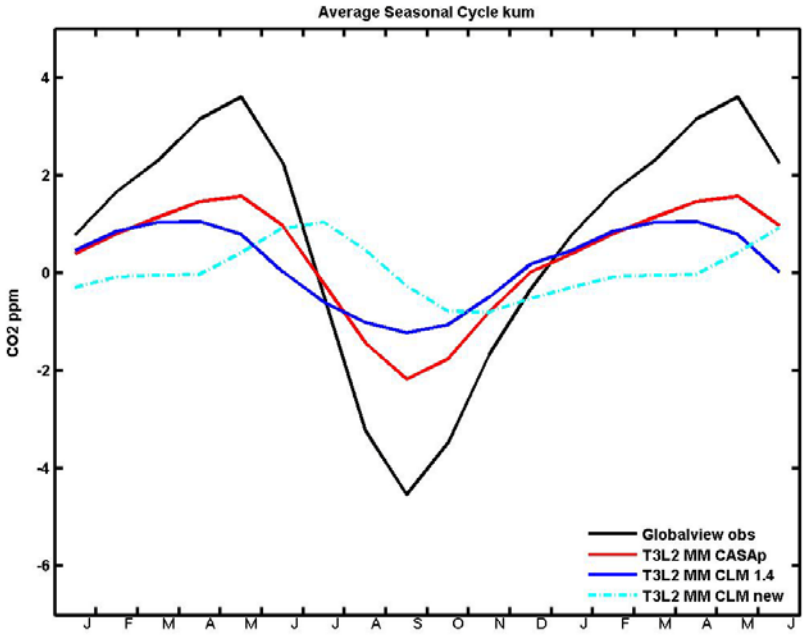
July 2008 – Poor annual cycle CO_2

13 July 2008: Cindy Nevison and Jim Randerson identified a deficiency in simulated CO_2 flux for CLM3.6-CN

Barrow (71N)

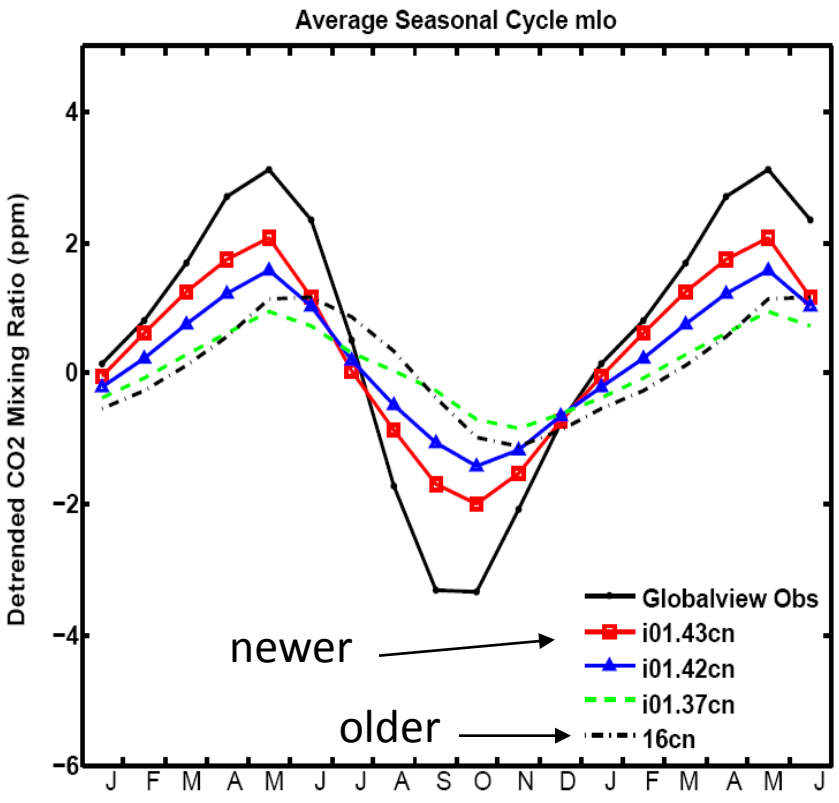


Kumukahi (19.5N)

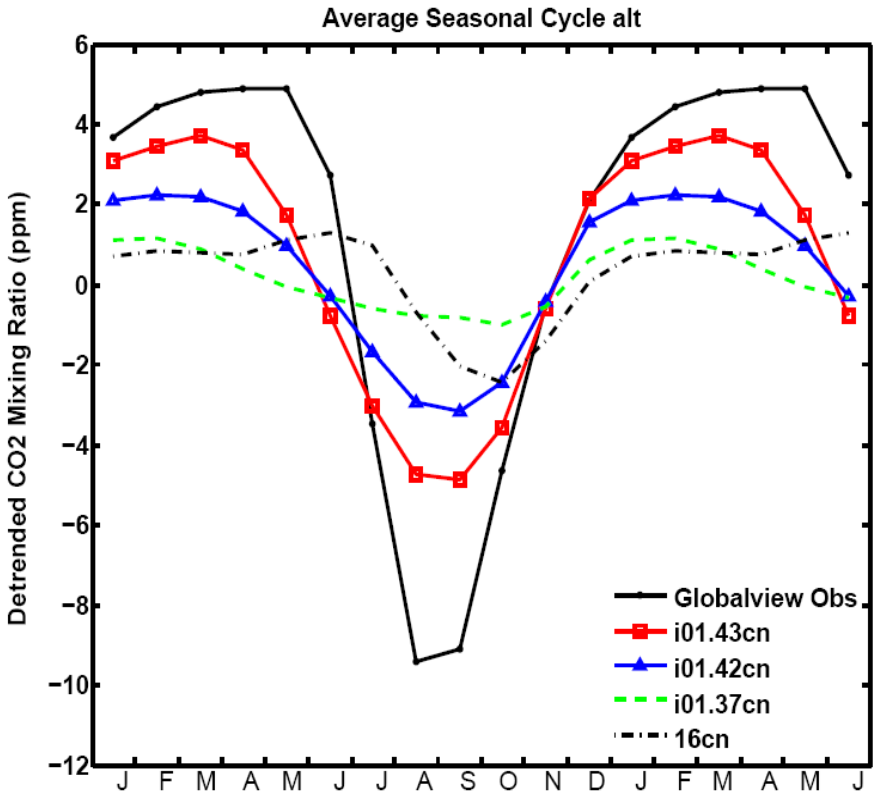


March 2009 - Improved annual cycle CO_2

Sequence of four modifications with progressive improvement



Mauna Loa



Alert

Heterotrophic respiration – switch to Q10 function, change Q10 parameter from 2.0 to 1.5
GPP – add daylength control
Maintenance respiration – change Q10 from 2.0 to 1.5

Peter Thornton (ORNL)
Sam Levis, Peter Lawrence, Brian Kauffman (NCAR)

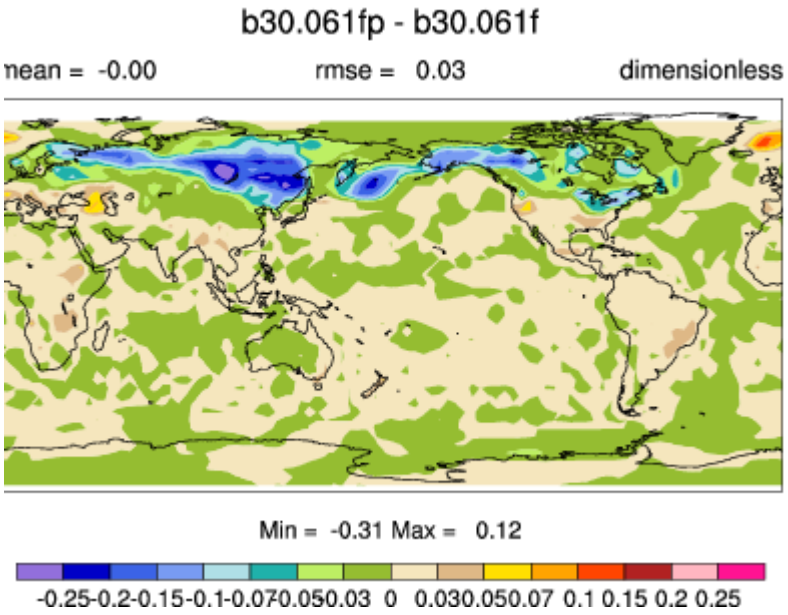
Biogeophysical coupling

The BGC model provides leaf area index, stem area index, and height to CLM, which affect surface fluxes. The impact of prognostic vegetation on climate must be evaluated in CAM/CLM simulations

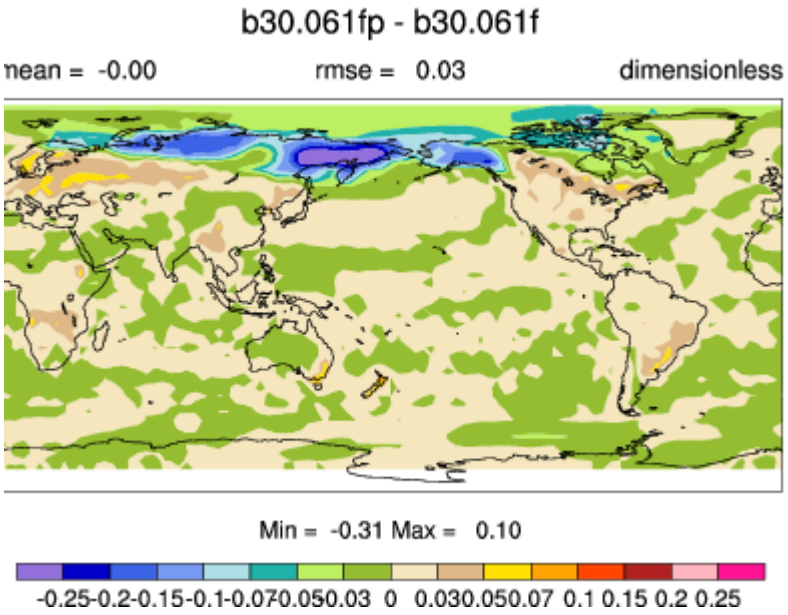
Previous analyses (**June-August 2006**) revealed low LAI and SAI, manifested in increased surface albedos when CN is active …

Without CN vs With CN

DJF surface albedo

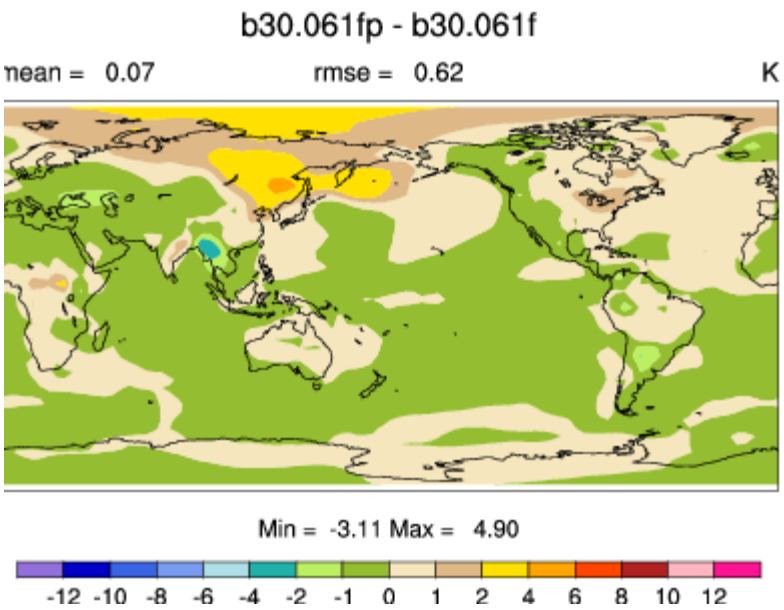


JJA surface albedo

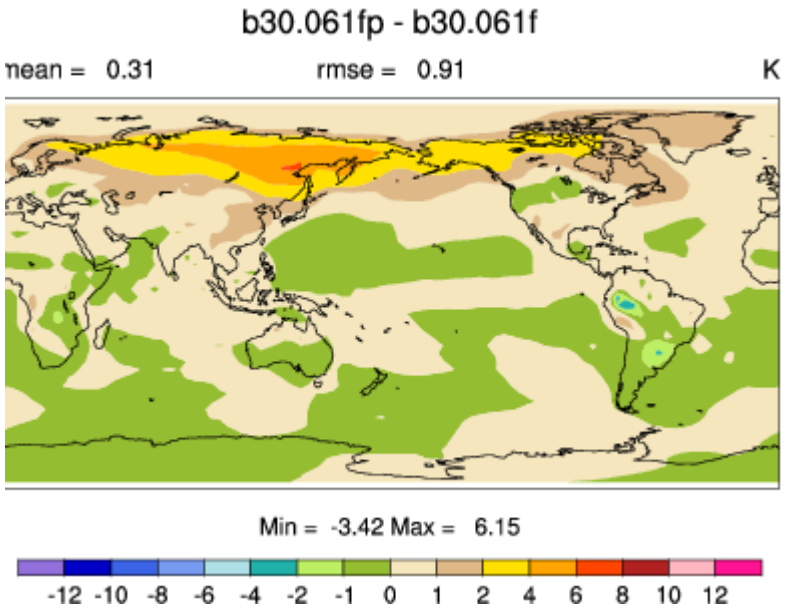


Biogeophysical coupling – temperature bias

DJF 2-m air temperature

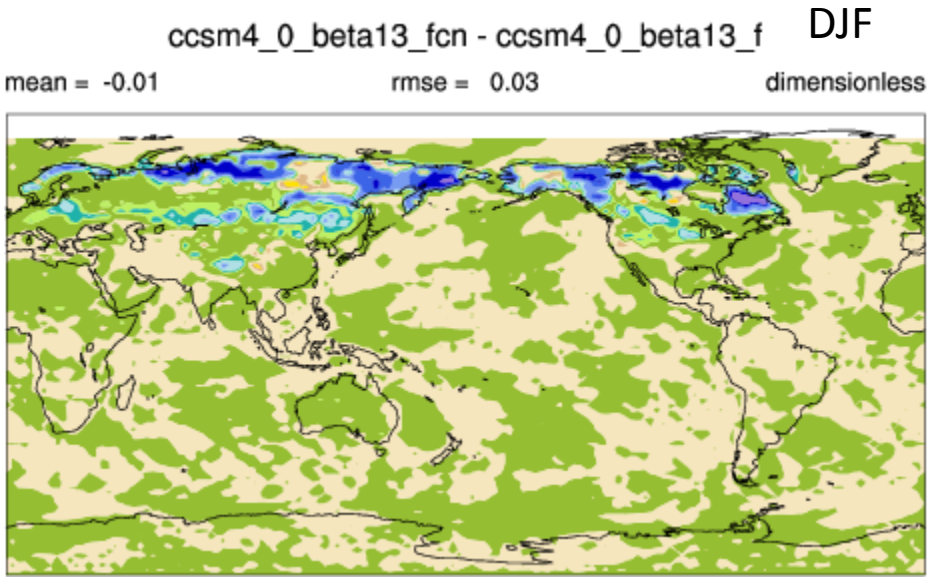


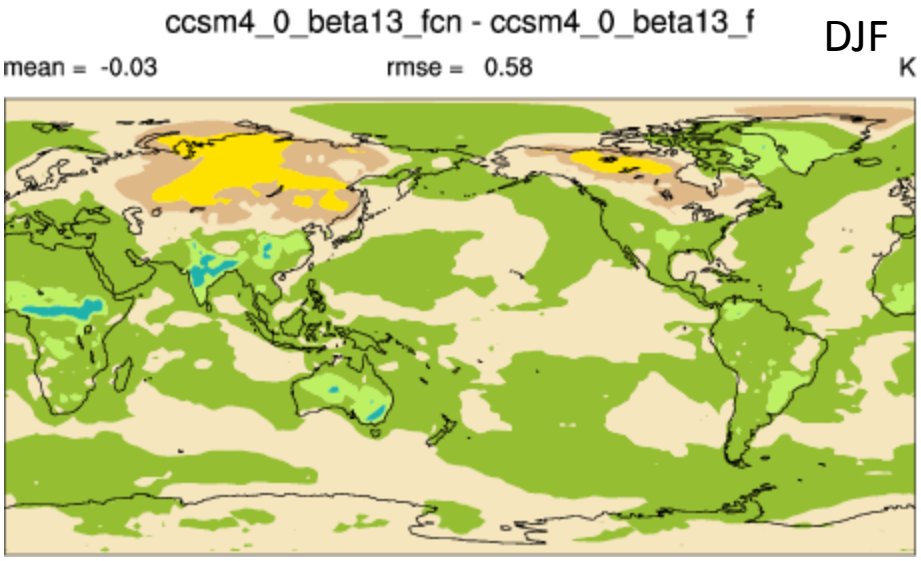
JJA 2-m air temperature



Biogeophysical coupling – Arctic shrubs

With CN vs Without CN





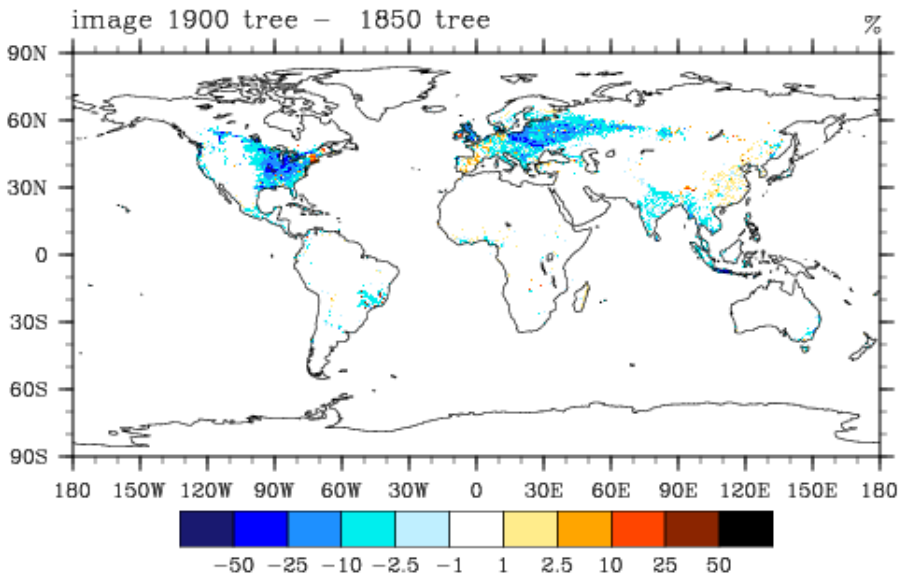
The BGC model provides leaf area index, stem area index, and height to CLM, which affect surface fluxes

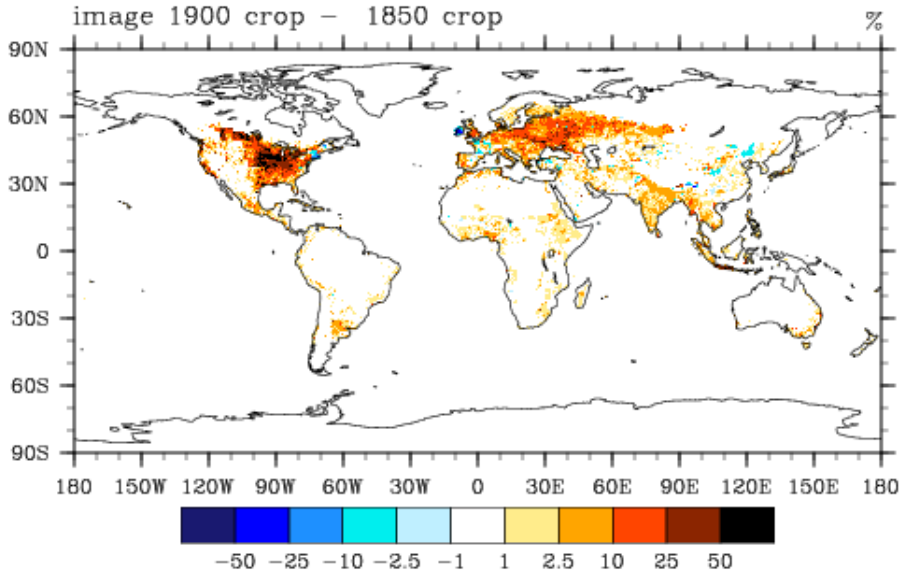
Added new SAI parameterization, but now CN has low albedo in the Arctic compared with non-CN simulation

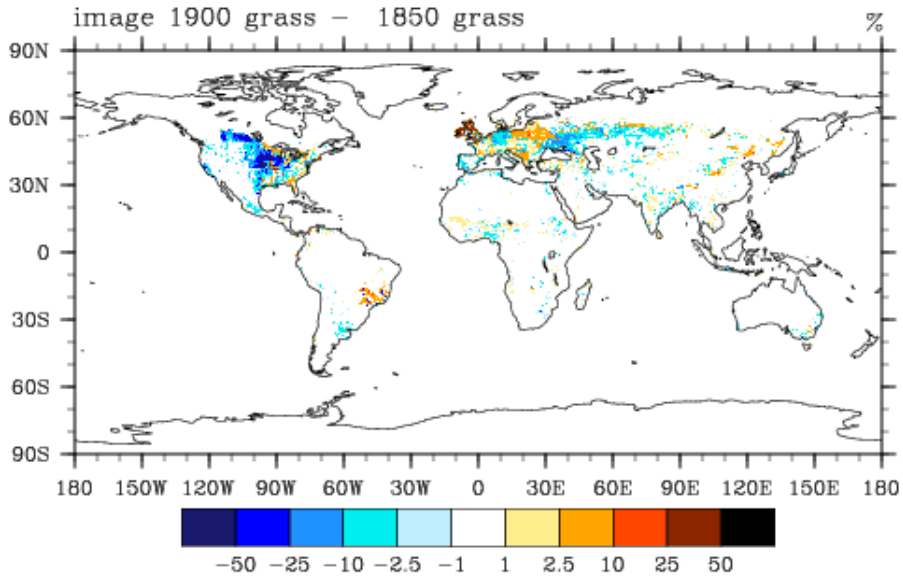
Shrubs are tall and protrude above the snow pack, masking the snow albedo

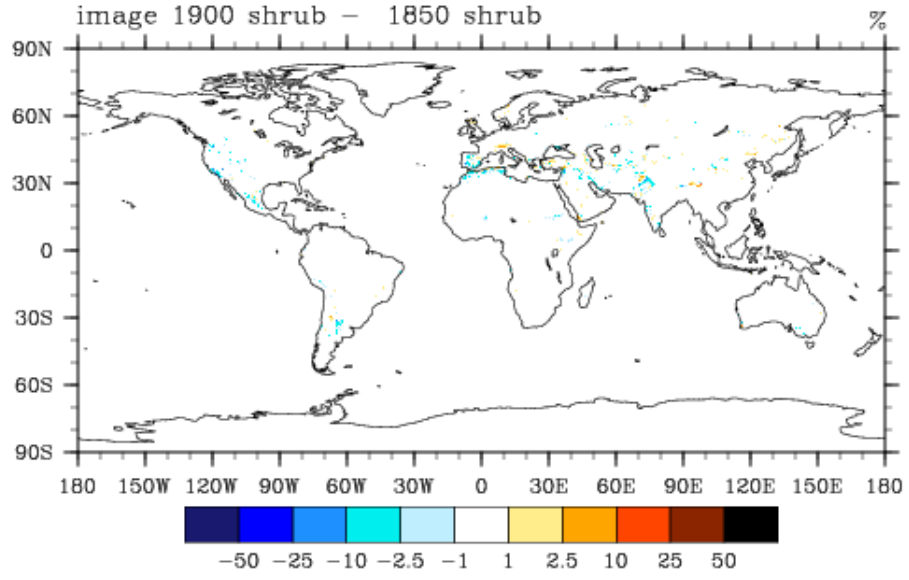
Dave Lawrence, Keith Oleson, Sam Levis (NCAR)

Land use – cropland and pastureland



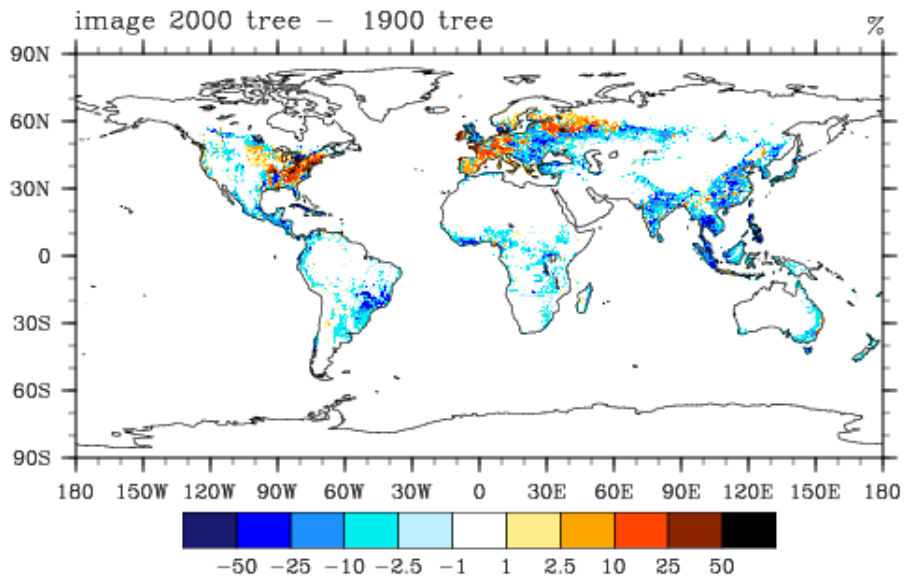


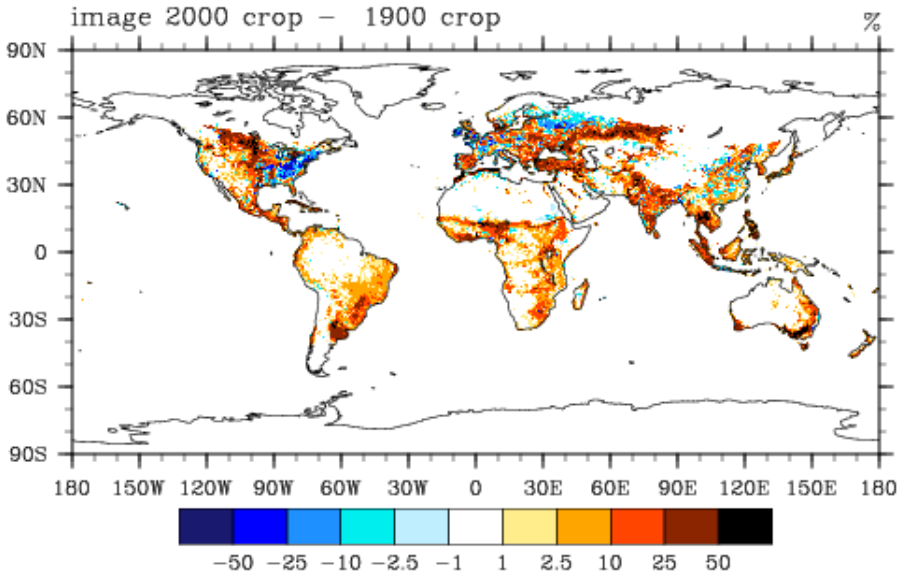


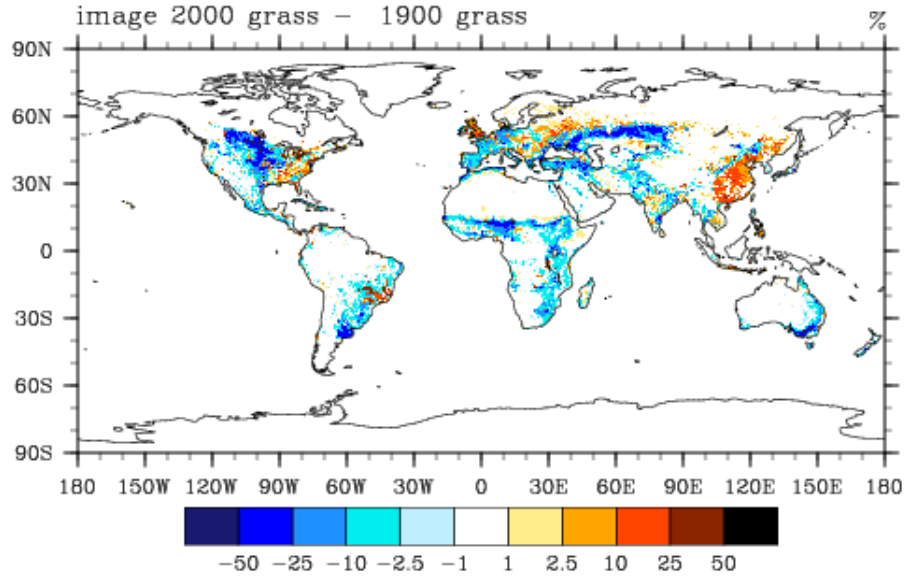


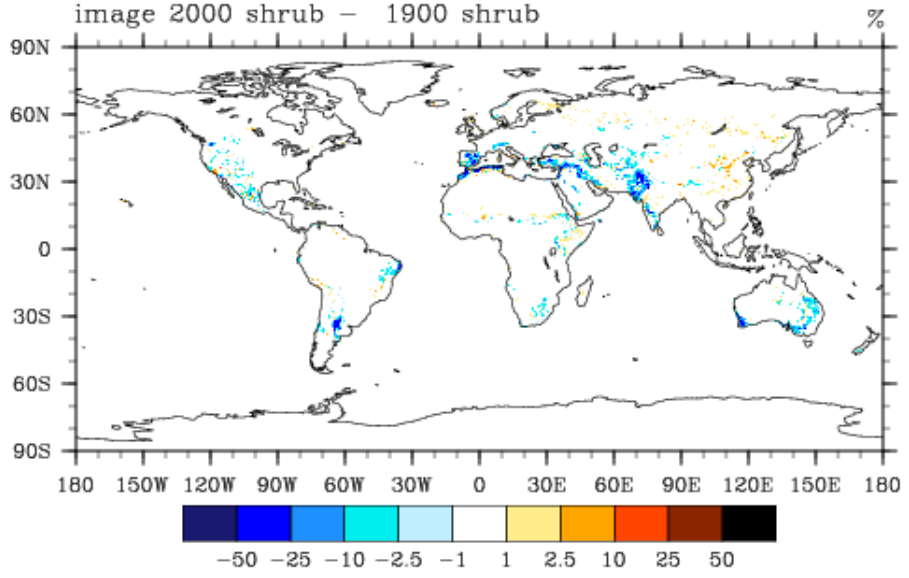
Peter Lawrence (NCAR) , Johan Feddema (Kansas)

Land use – cropland and pastureland



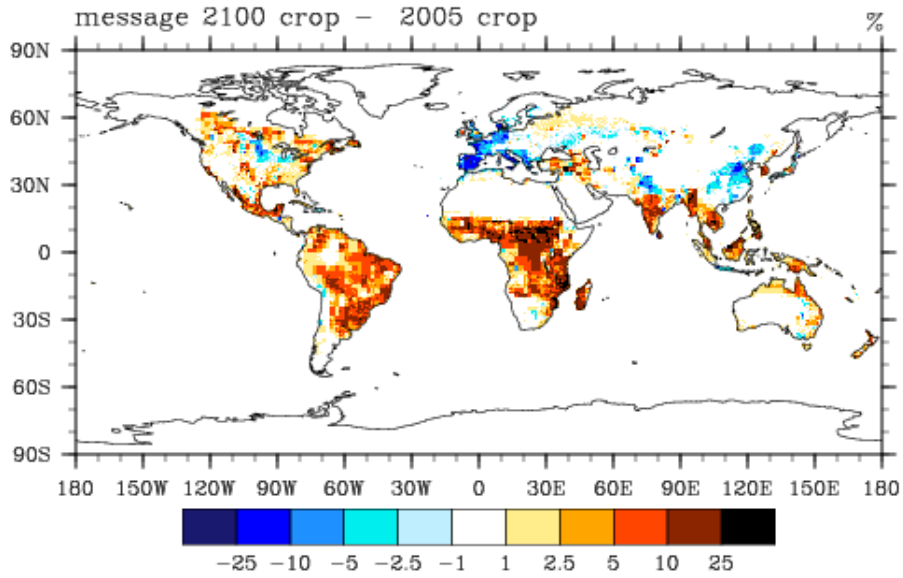


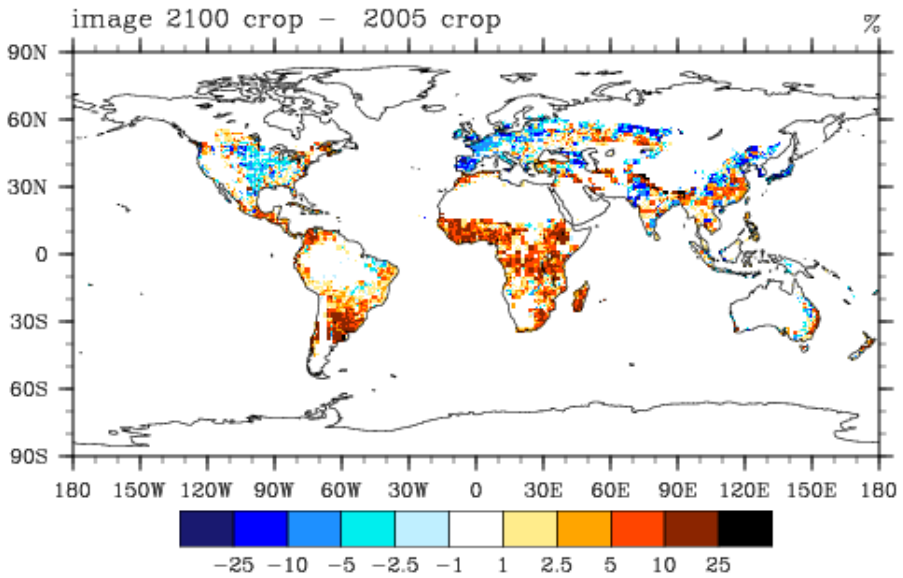




Peter Lawrence (NCAR) , Johan Feddema (Kansas)

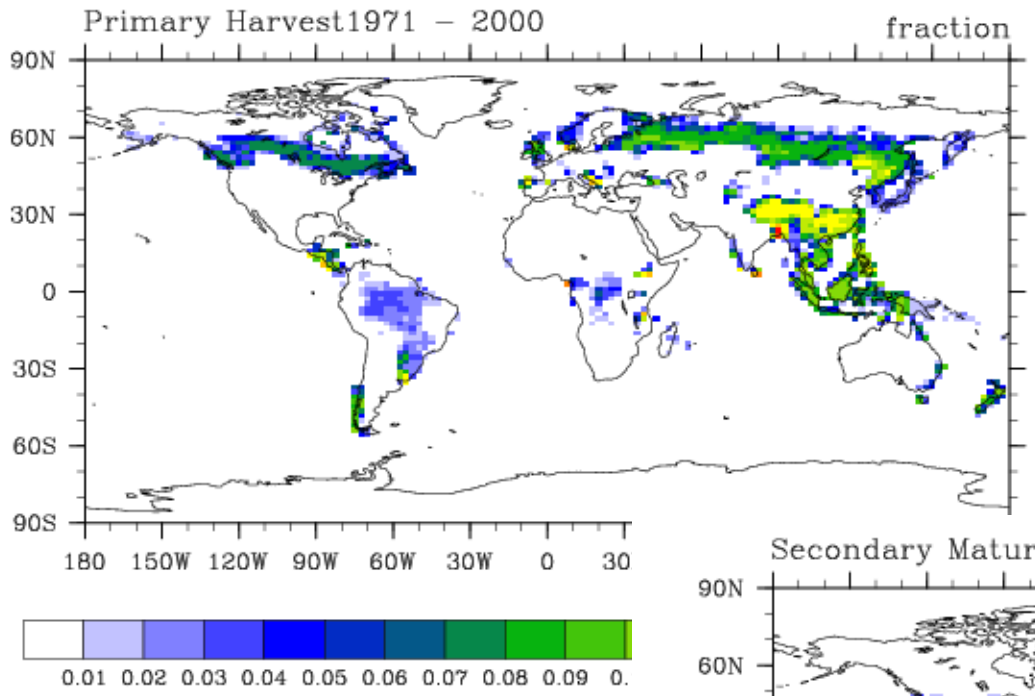
MESSAGE (RCP 8.5) vs IMAGE (RCP 3.0)



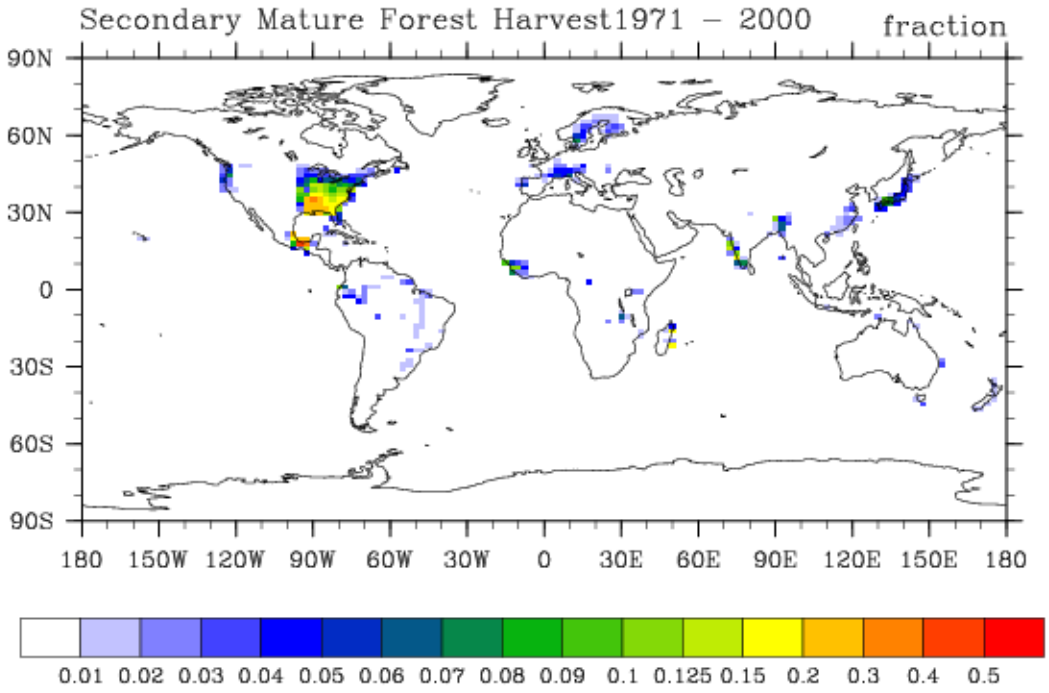


Peter Lawrence (NCAR) , Johan Feddema (Kansas)

Land use – wood harvest



Harvest from primary forest

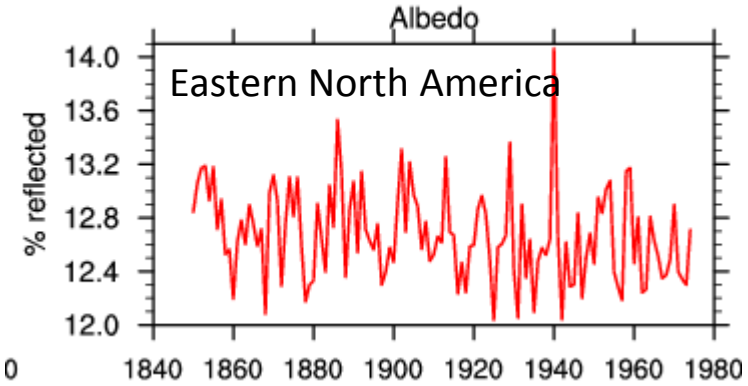


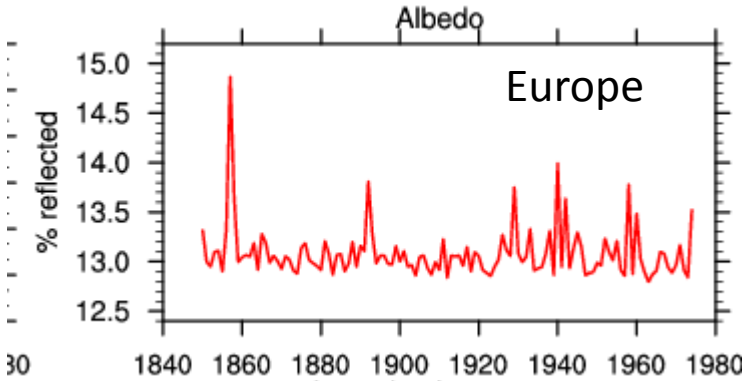
Harvest from secondary mature forest

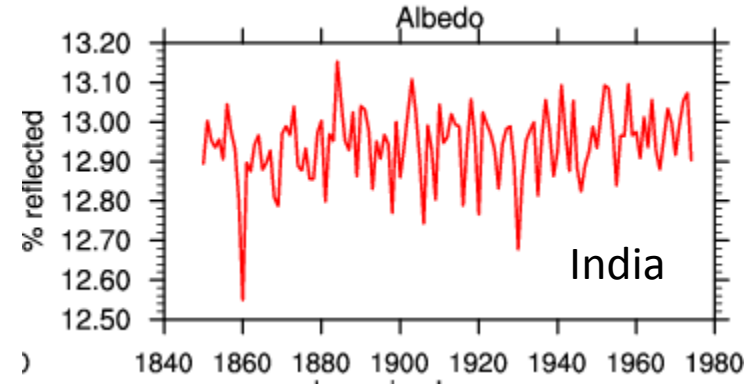
Peter Thornton (ORNL)
Peter Lawrence, Sam Levis (NCAR)

Land use – biogeophysics

b40.20th.track1.004







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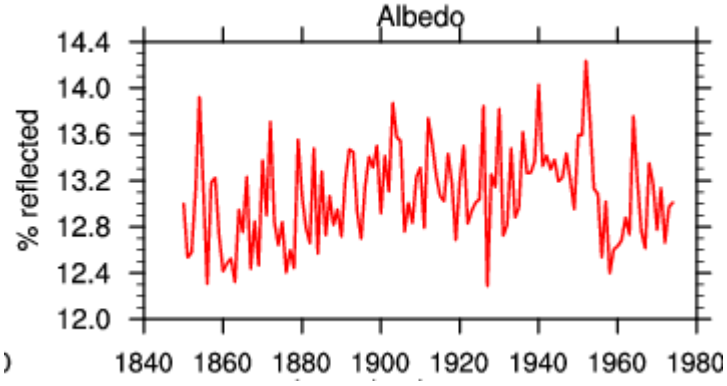
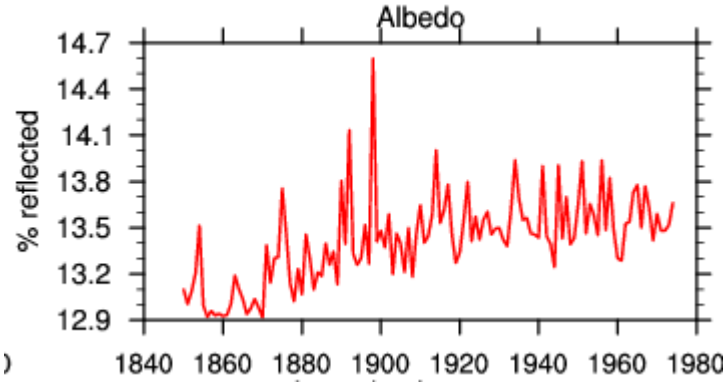
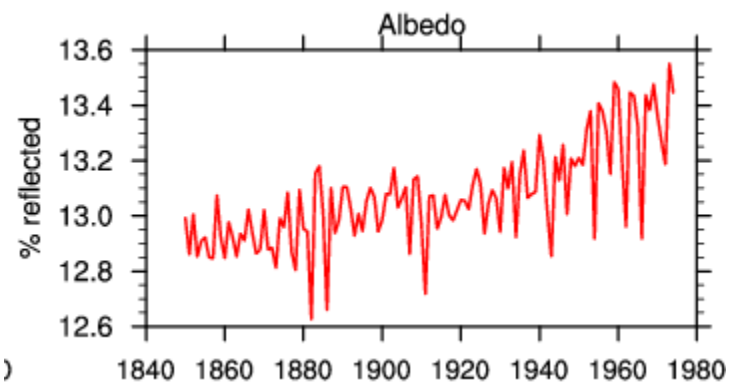
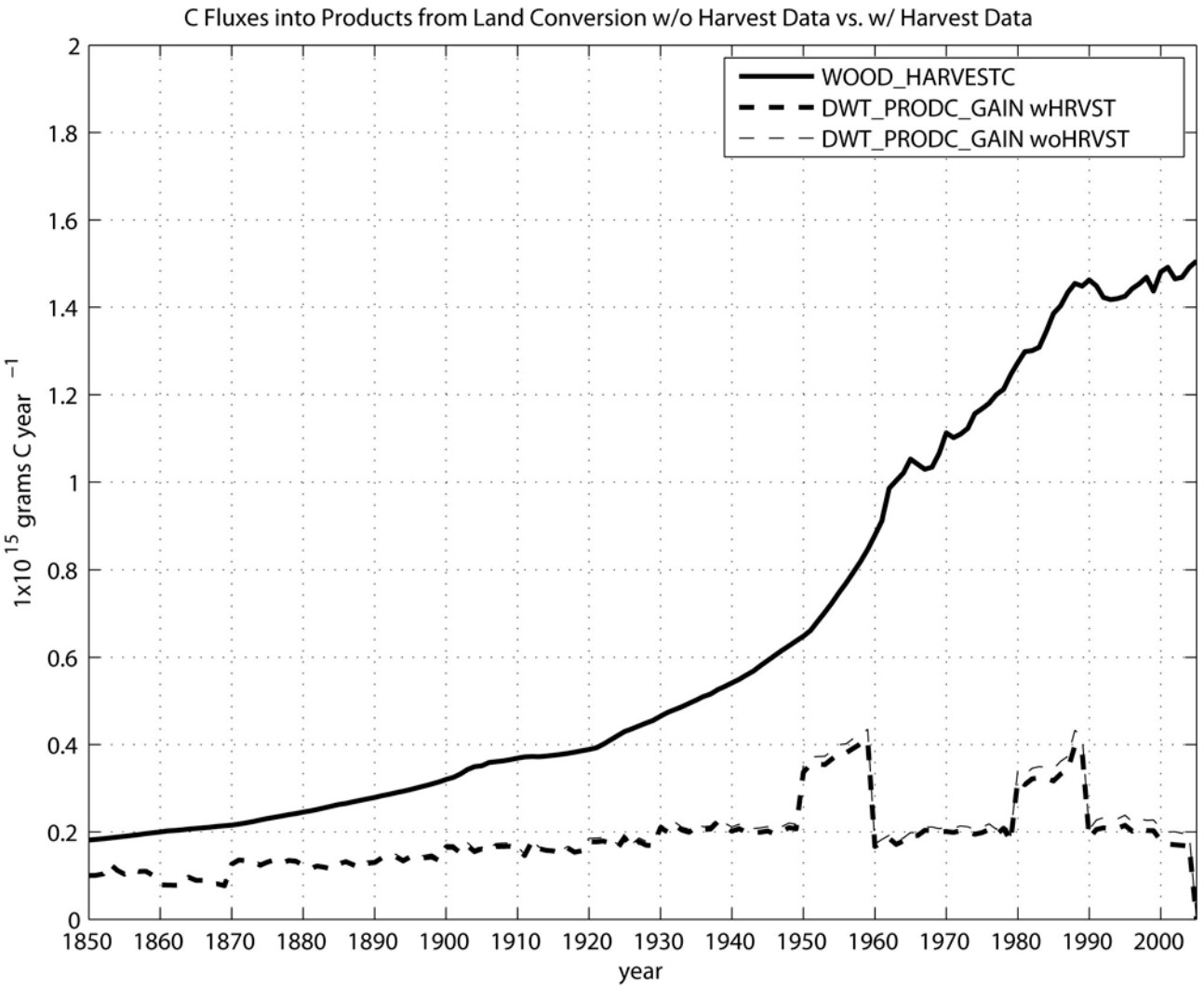






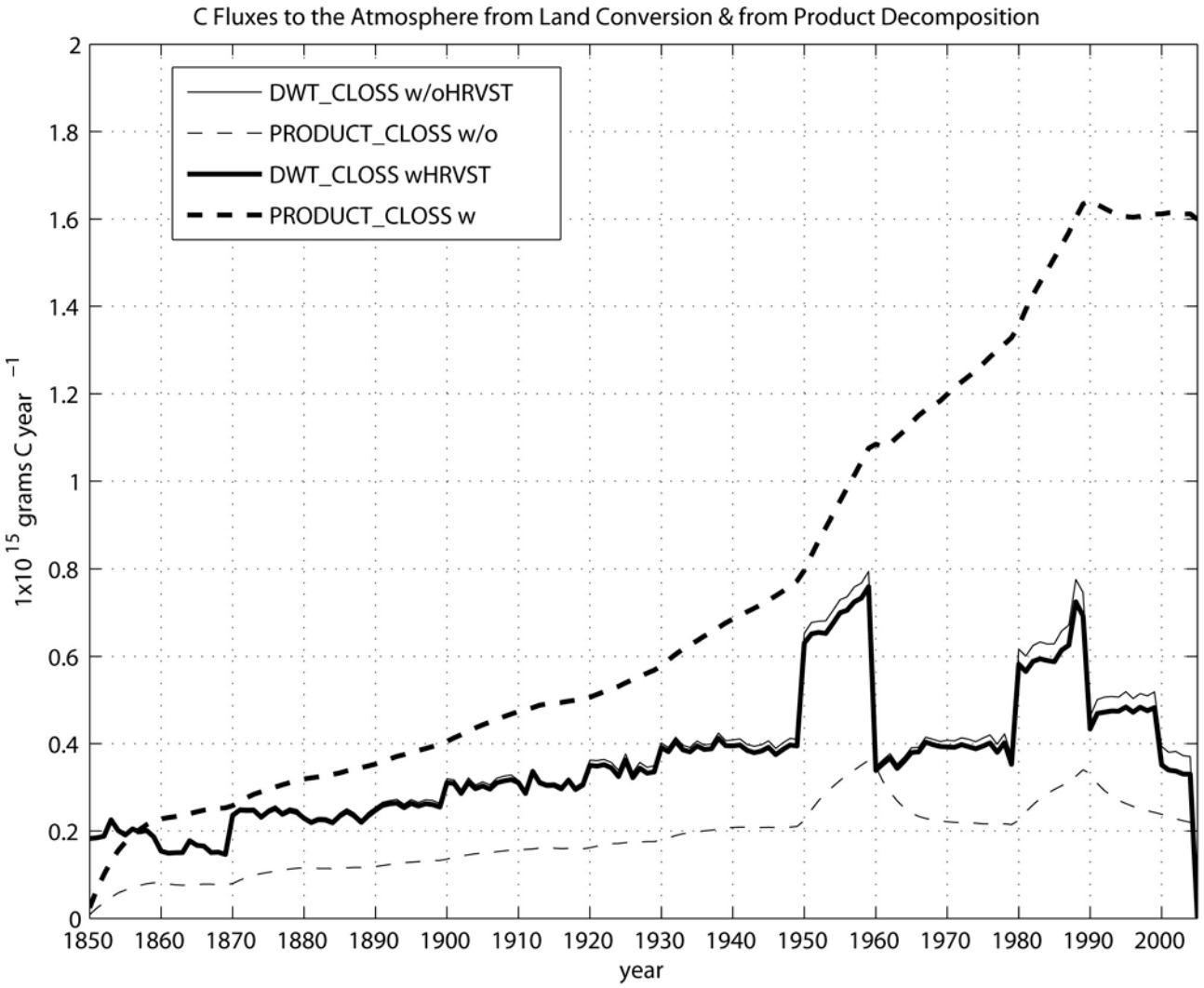
Land use – biogeochemistry



Offline CLM simulations
Repeating NCEP forcing
Historical atmospheric CO_2
Transient N deposition

Sam Levis (NCAR)
Forrest Hoffman (ORNL)

Land use – biogeochemistry



Offline CLM simulations
Repeating NCEP forcing
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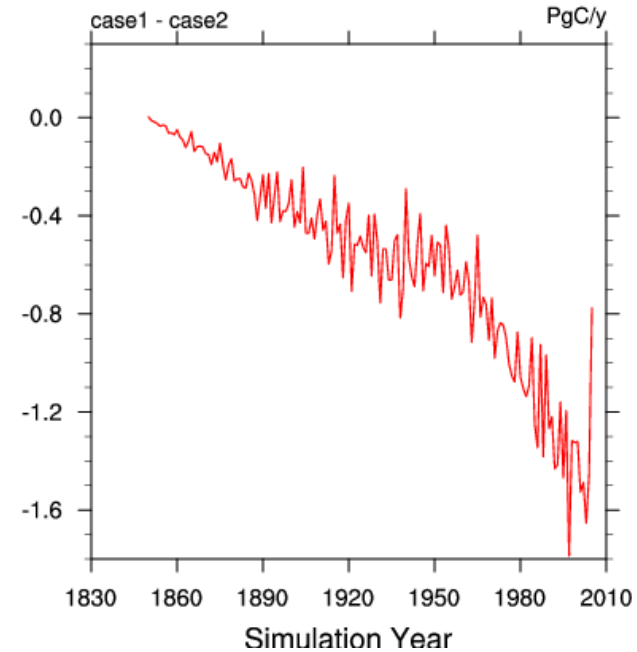
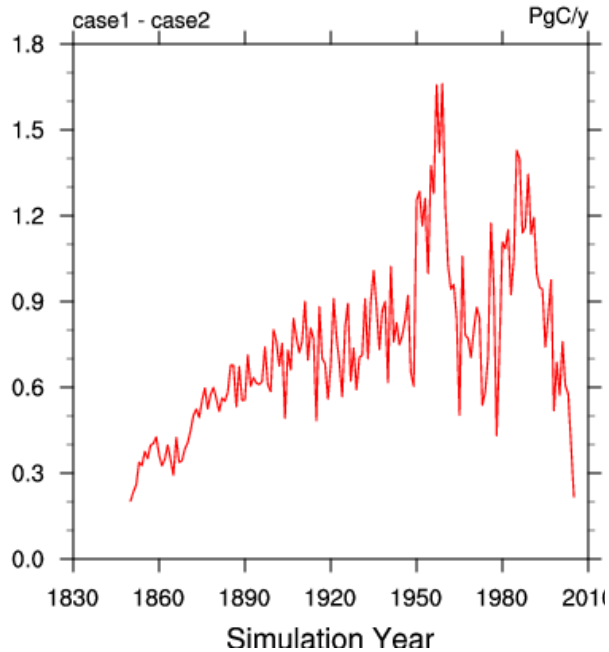
Land use – biogeochemistry

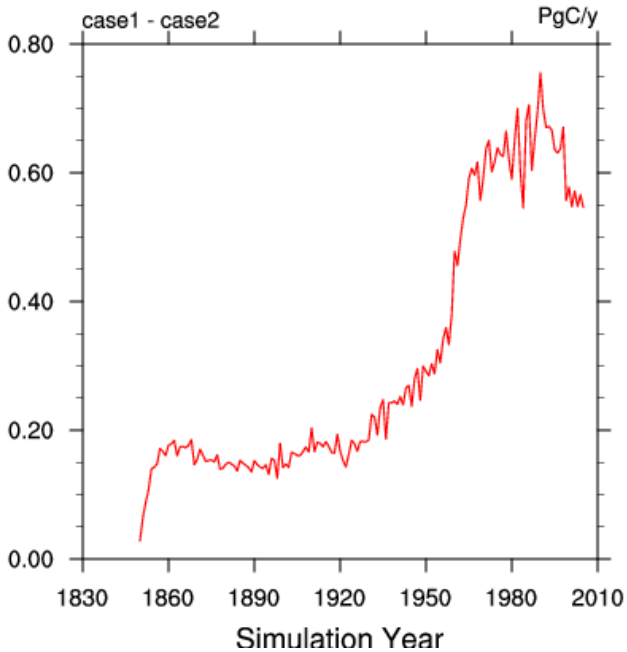
(a) Change in NEE due to CO2 and N deposition



(b) Change in NEE from (a) due to land cover change

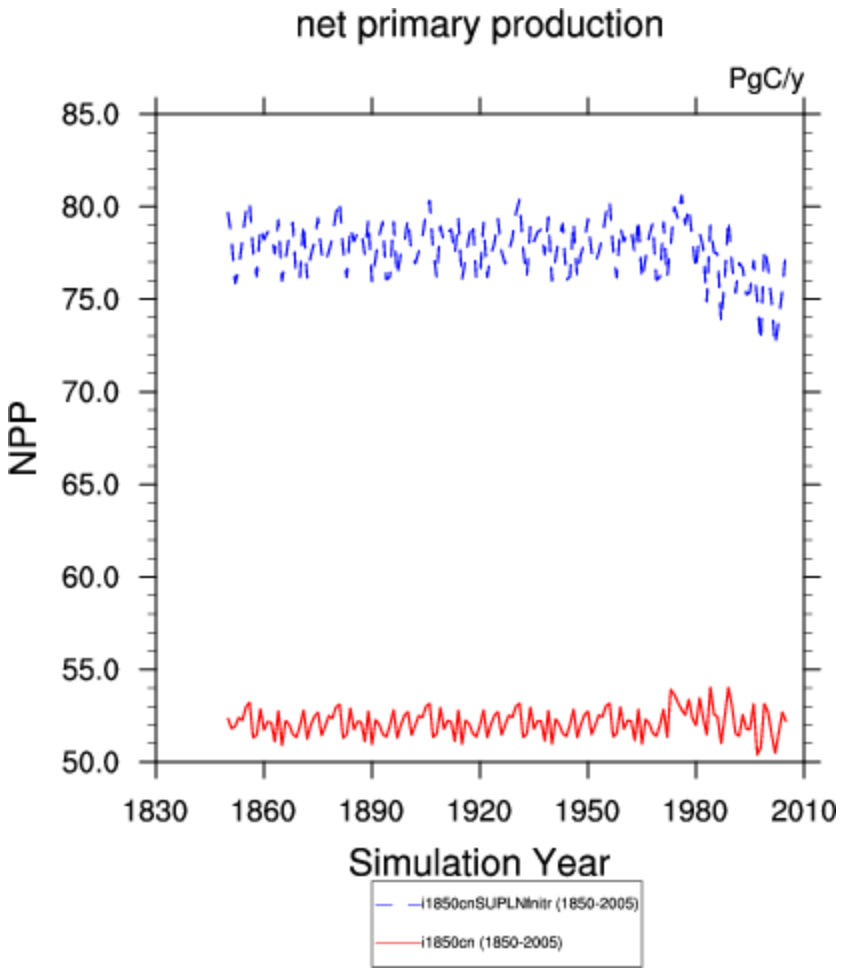


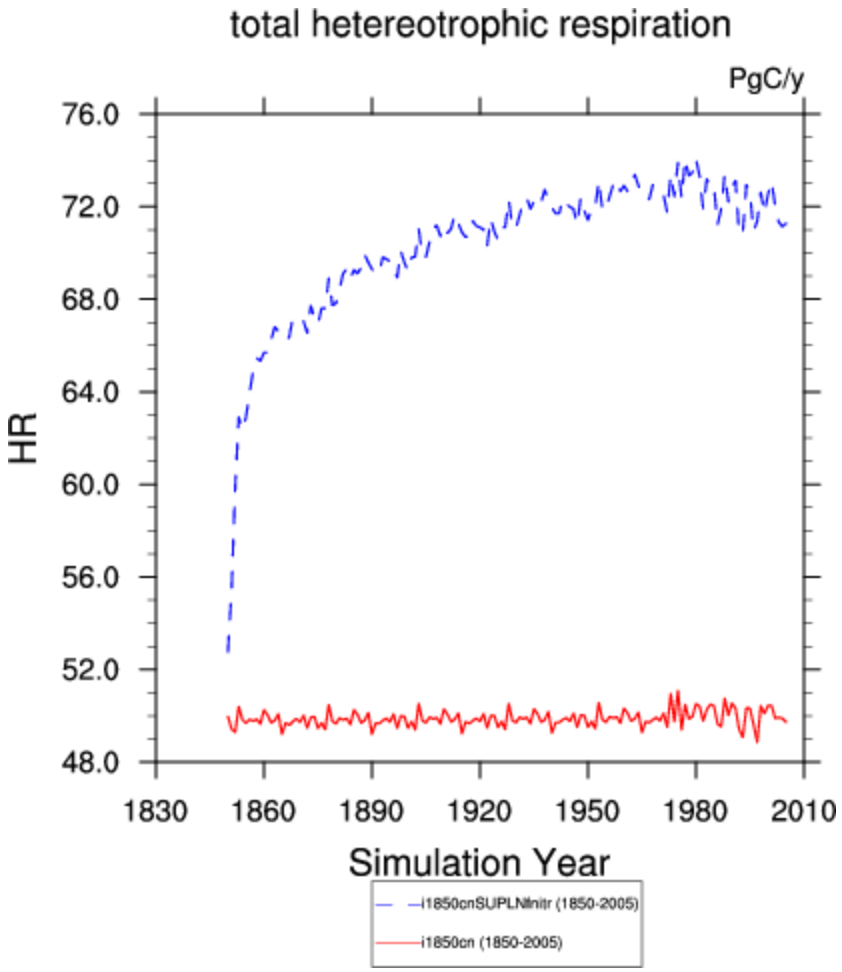
(c) Additional change in NEE from wood harvest



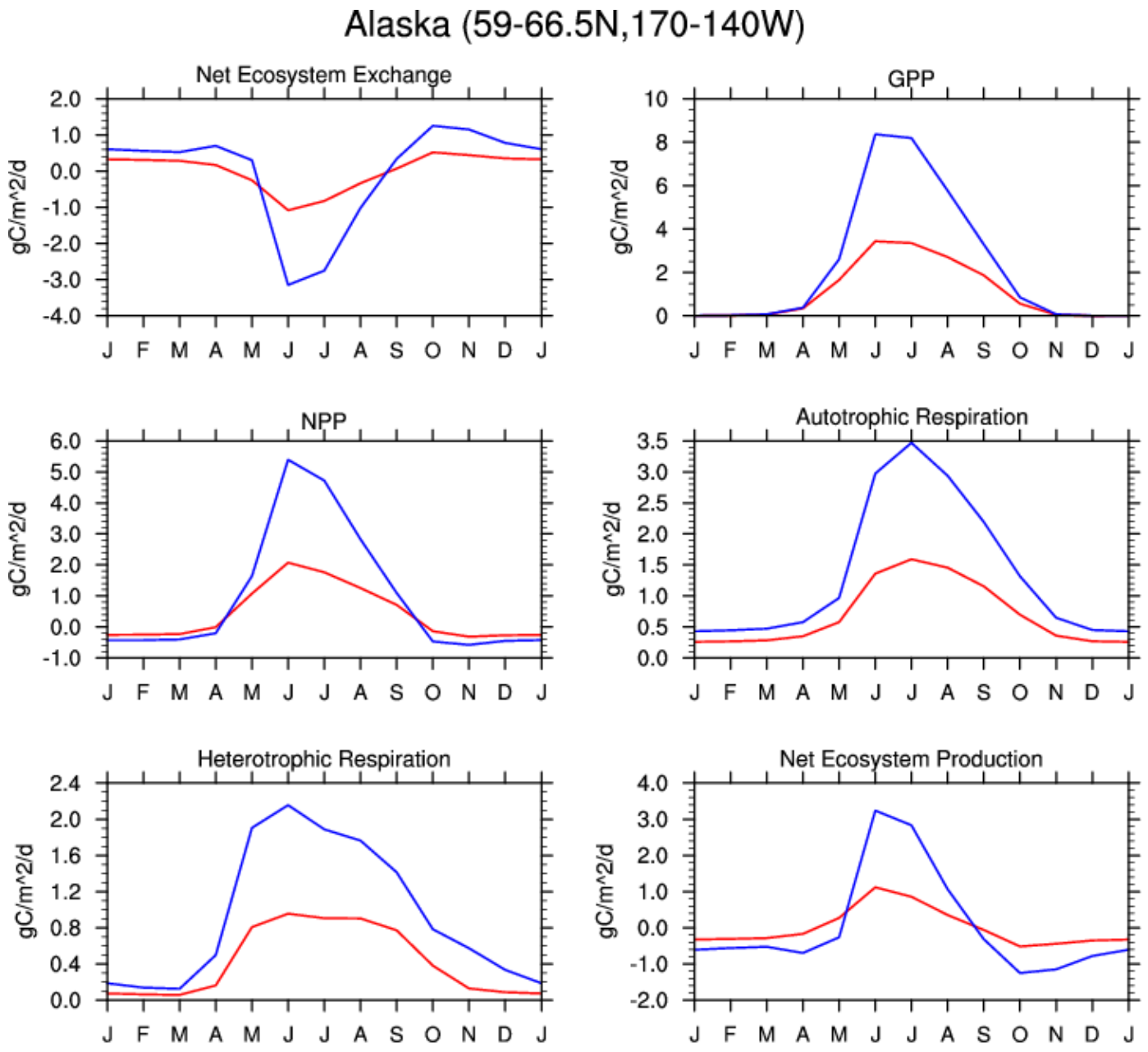
Sam Levis (NCAR)
Forrest Hoffman (ORNL)

Carbon-only BGC model





Carbon-only annual cycle



CLM BGC software engineering

Code is complex and challenging

1. Restart files – Addressing issues with restart capabilities involved deleting 7533 lines of code and 602 fields
   (Peter Thornton, Forrest Hoffman, ORNL)
1. History files – 211 single-level C/N fields. For comparison there are 216 single-level equivalent CLM fields (many of these are multi-level)

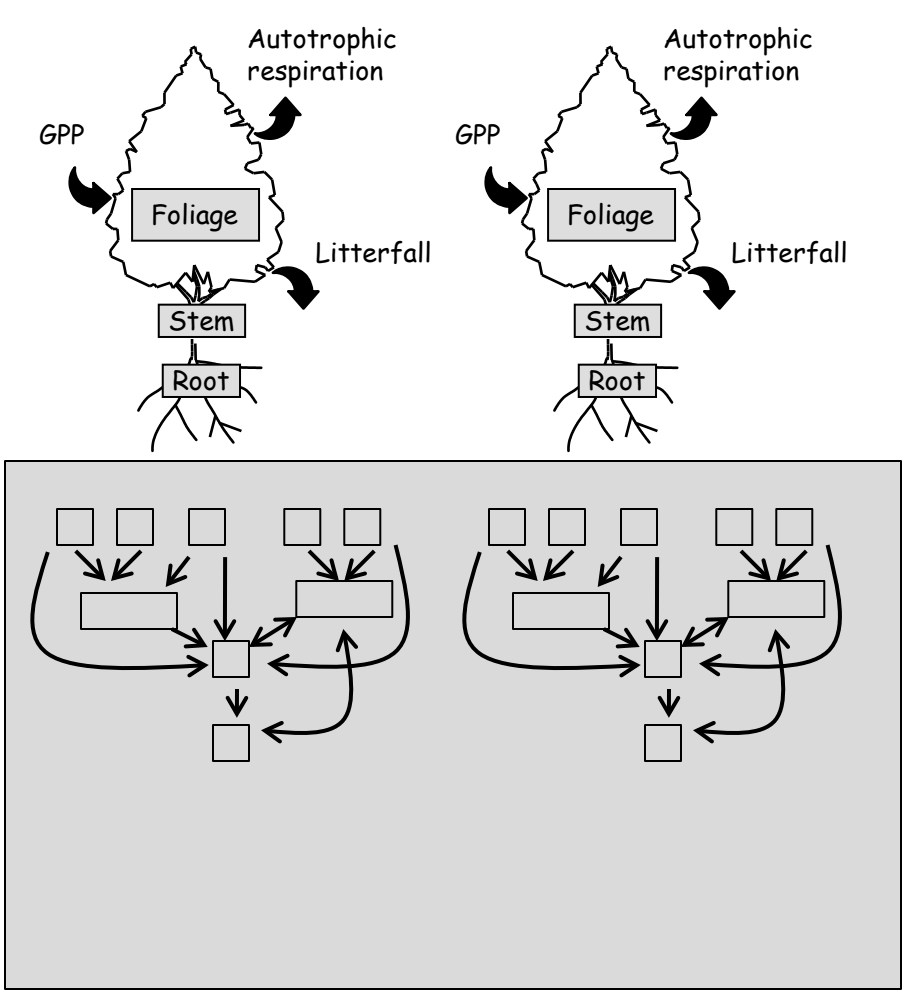
Code needs to be better modularized to allow for alternative parameterizations

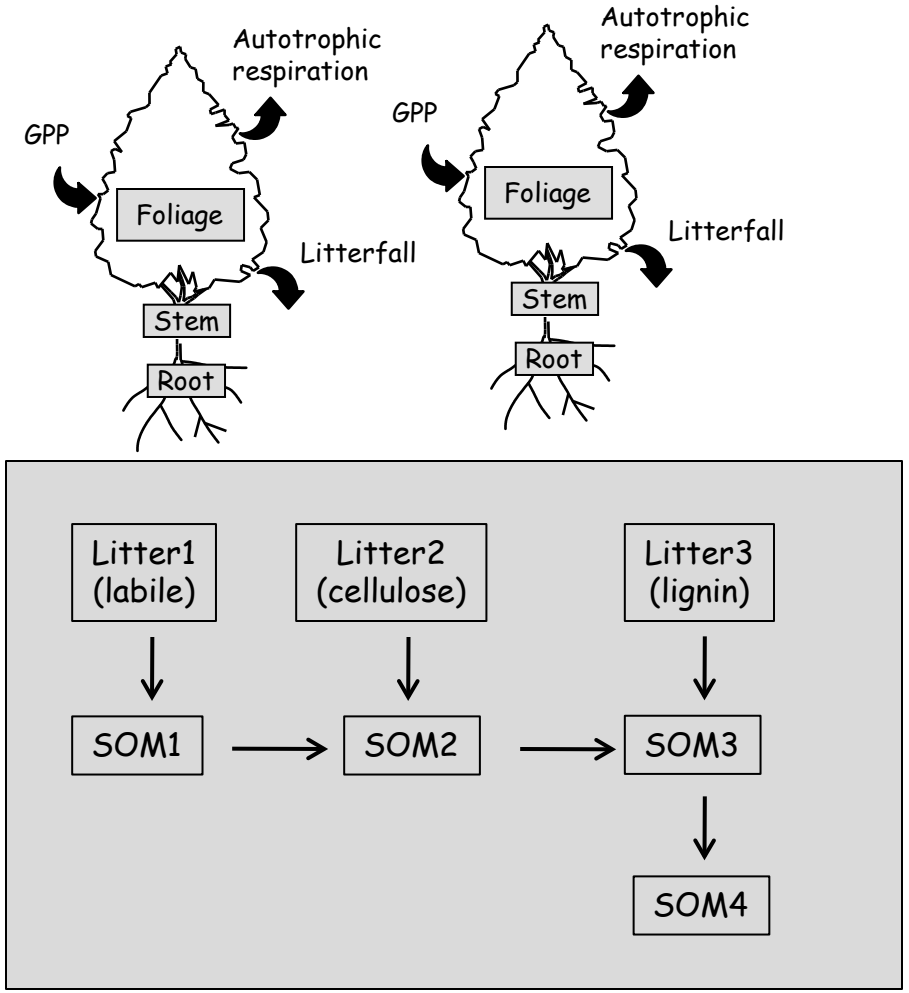
1. Clean interface between plant (aboveground) and soil (belowground) modules – Thanks Peter Thornton (in advance)!!!
2. Carbon-only version of model
3. Capability to add alternative and/or additional BGC cycles

Path forward to community BGC for CLM4

CASA' – each PFT has own soil bgc

CN – PFTs share common soil bgc on a single soil column



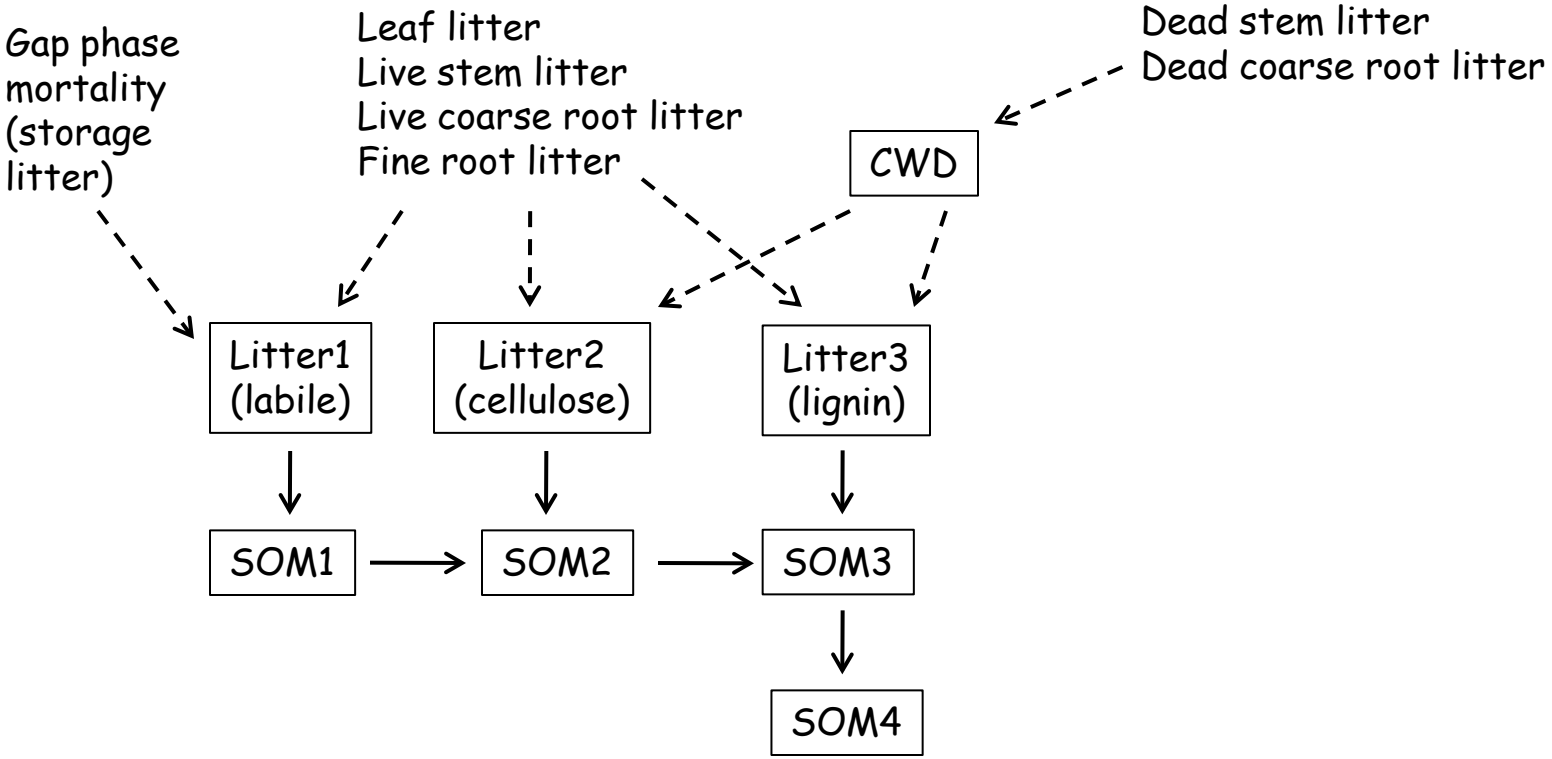


Path forward to a community model

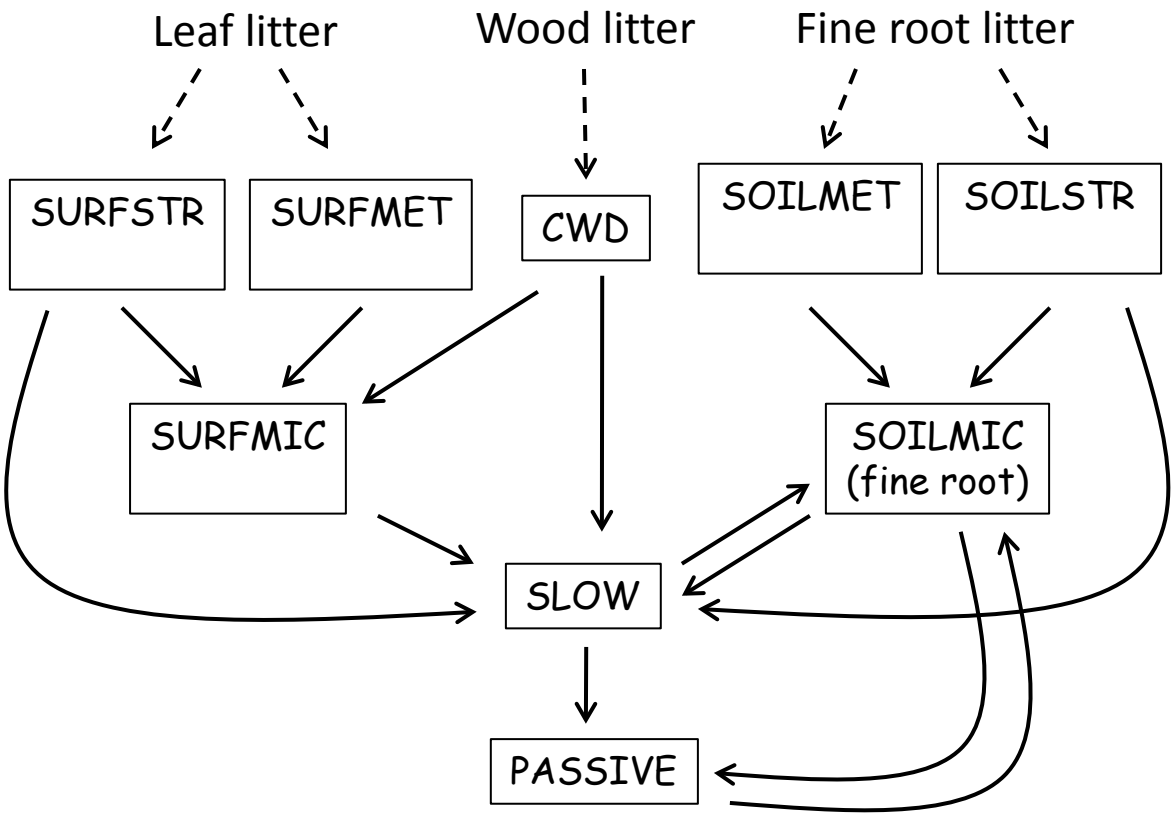
CN aboveground (plant) code

- GPP
- Autotrophic respiration
  - Maintenance
  - Growth
- Allocation (displayed, storage, transfer)
  - Leaf
  - Live stem → dead stem
  - Live coarse root → dead coarse root
  - Fine root
- Phenology
  - Evergreen
  - Seasonal deciduous (temperature, daylength)
  - Stress deciduous (temperature, soil water)
- Litterfall (leaf, fine roots)
  - Evergreen (background)
  - Seasonal deciduous (offset period)
  - Stress deciduous (offset period, background)
- Mortality (woody plants, 2% per year)
  - Leaf and fine roots (displayed, storage)
  - Live stem, dead stem
  - Live coarse root, dead coarse root

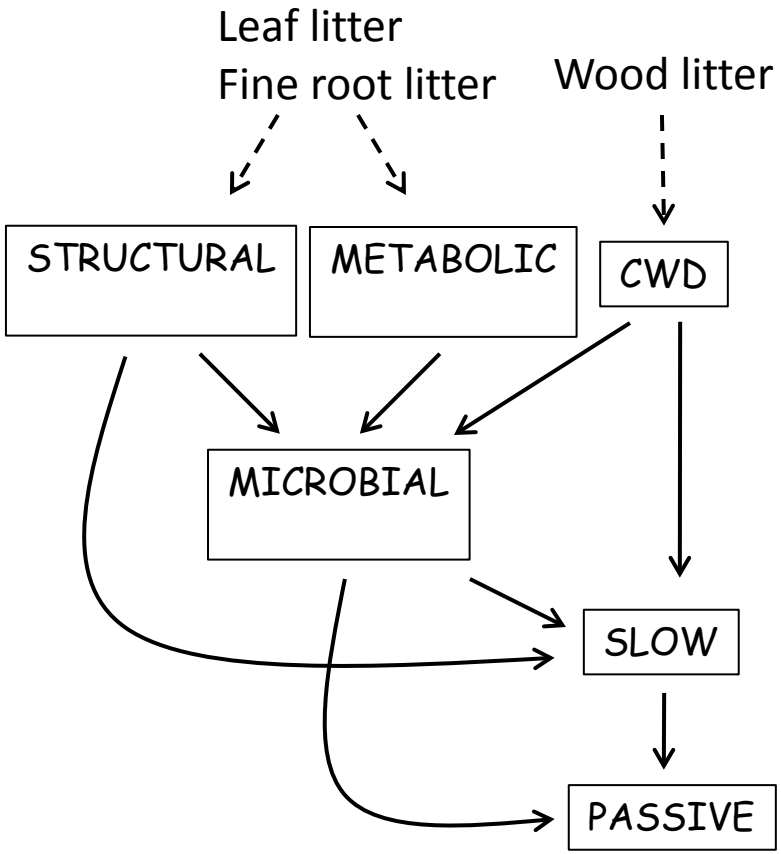
CN soil bgc (soil column-based, C-N)



CASA' soil bgc (PFT-based, C-only)



CASA-CNP soil bgc (PFT-based, C-N-P)



Model spinup

Incrementally couple BGC models and physical models…

(1) Initial conditions for 1850 “physics only” CCSM control simulation

a. Offline spinup - Use NCEP atmospheric forcing to spinup land BGC with 1850 atmospheric CO_2 (2000-3000 years)
b. Offline spinup - Use CCSM atmospheric forcing to spinup land BGC with 1850 atmospheric CO_2 and climate. Requirement: 50 years of atmospheric forcing at every model timestep (30-minutes)

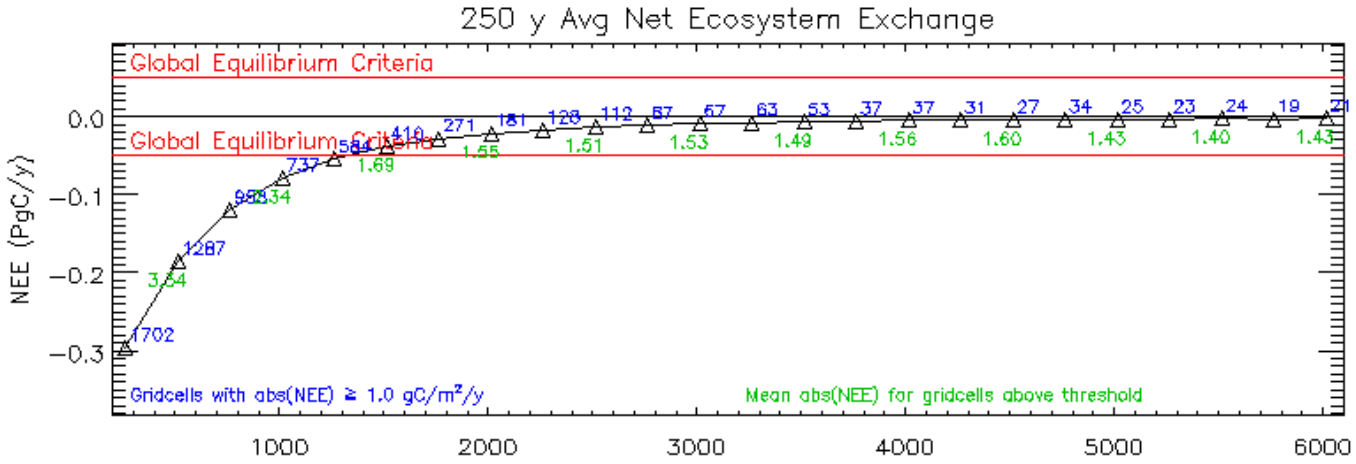
(2) Using output of 1850 “physics only” CCSM control simulation

a. Offline spinup ocean BGC (2000-3000 years)
b. Offline spinup land BGC with atmospheric CO_2 of (a) (2000-3000 years)

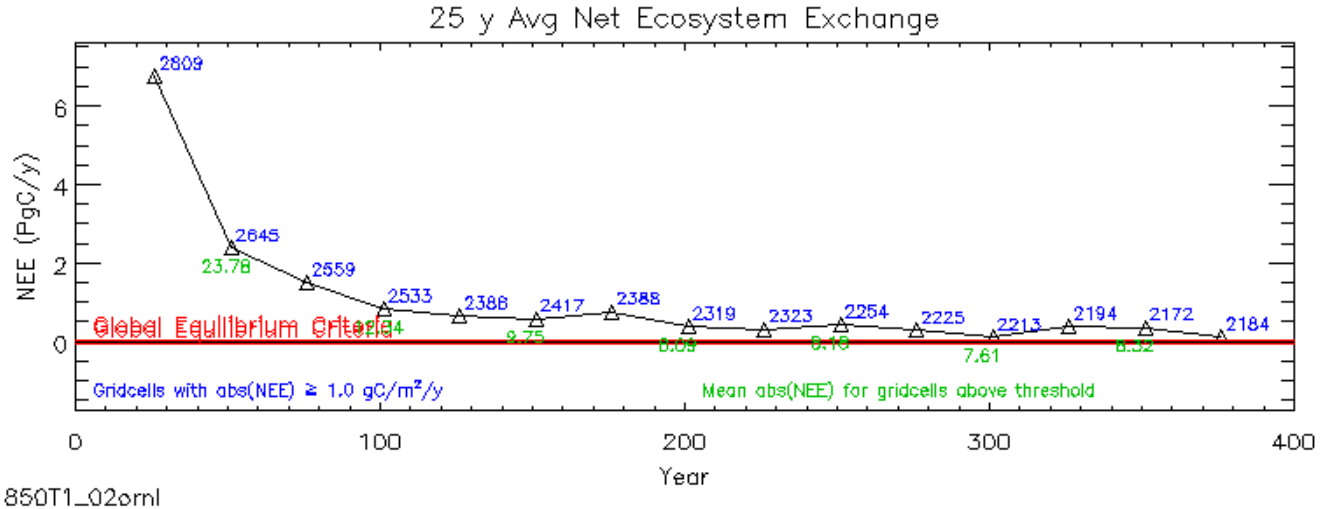
(3) Couple ocean/land BGC models and physical models and spinup coupled model

Land model spinup

Case i01.48cn: 250 Year Average Net Ecosystem Exchange



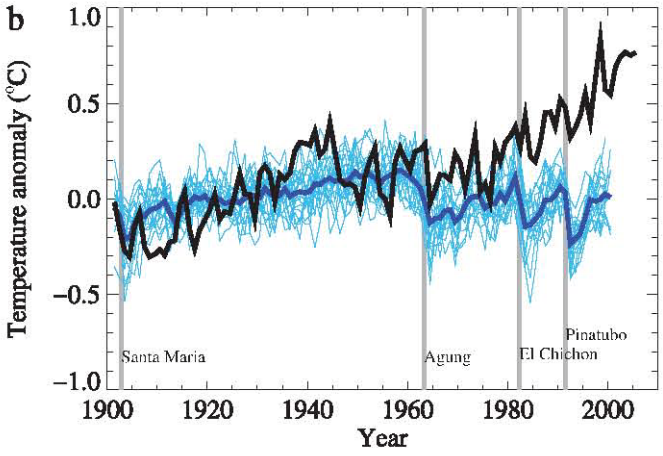
Case b40.1850T1_02ornl: 25 Year Average Net Ecosystem Exchange



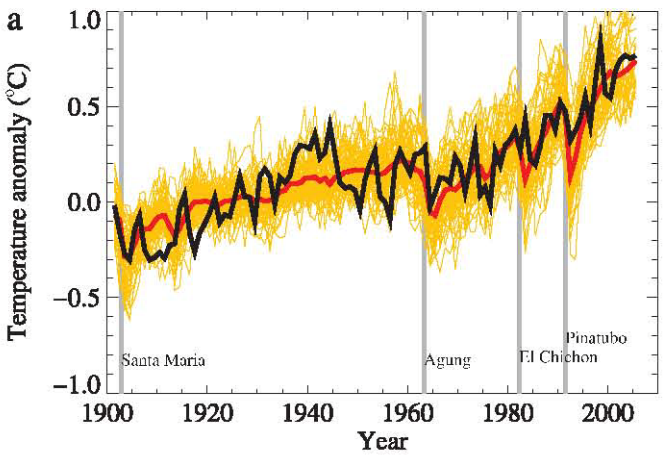
Forrest Hoffman (ORNL)

Biogeophysical and biogeochemical feedbacks

Natural forcings



Anthropogenic and natural forcings



Natural ecosystem feedbacks

Biogeophysical – Vegetation-climate feedback (LAI/SAI/Height)

Biogeochemical – Carbon cycle-climate feedback

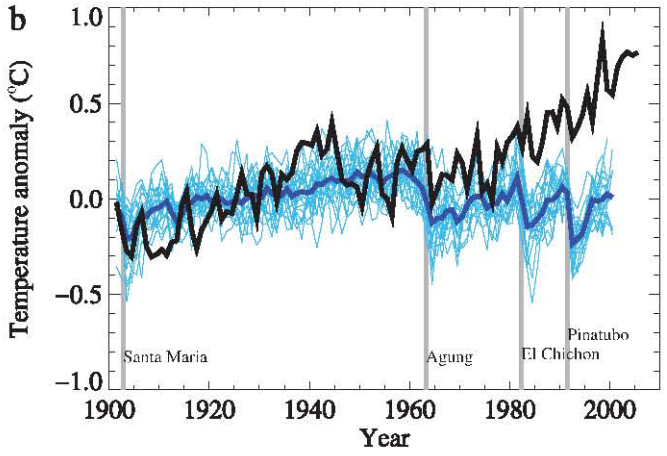
Anthropogenic ecosystem feedbacks (land use)

Biogeophsyical – Albedo and evapotranspiration

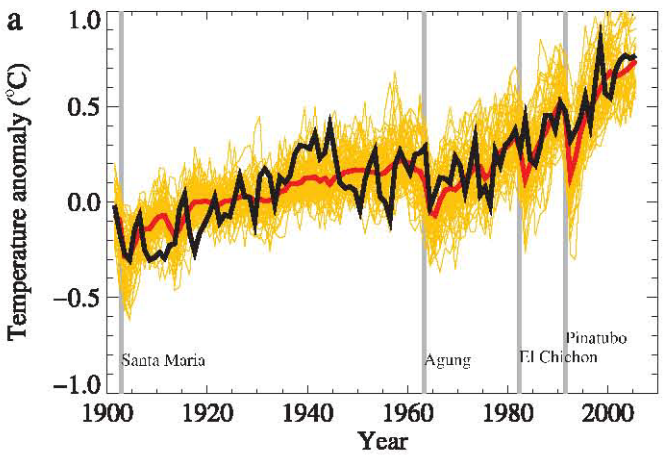
Biogeochemical – Carbon cycle

Biogeophysical and biogeochemical feedbacks

Natural forcings



Anthropogenic and natural forcings

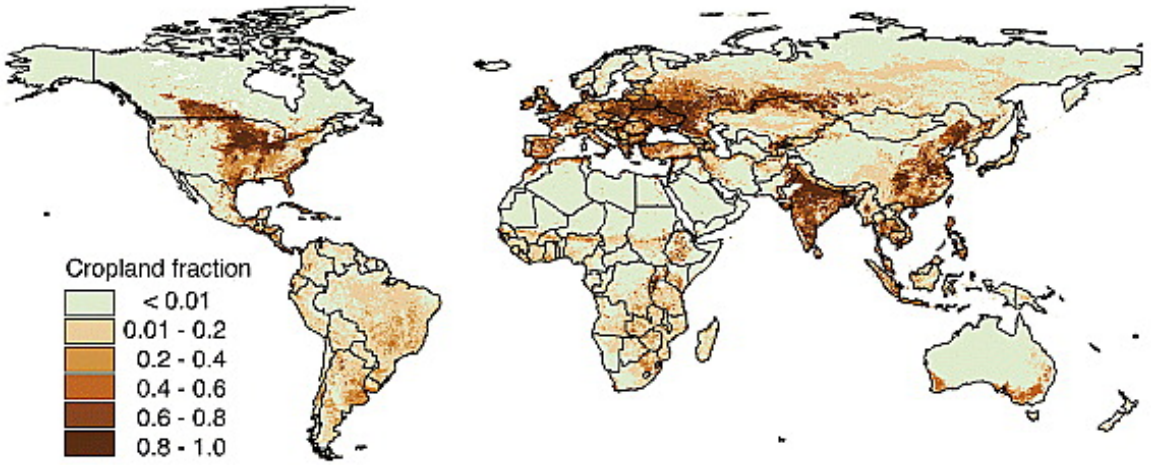


Transient Climate Simulations

	Control	Natural	Natural and anthropogenic
Biogeophysical	**1850 Control**	**Time-invariant vegetation**	**Vegetation-climate feedback (LAI/SAI/height, wildfire)**	**Vegetation feedback and land use**
Biogeochemical	**1850 Control**	**Radiatively uncoupled**	**Carbon cycle-climate feedback**	**Carbon cycle feedback and land use**

Challenge – Biogeochemical feedback also includes biogeophysical feedback

Multi-model ensemble of global land use climate forcing



The LUCID inter-comparison study of the land use forcing (1992-1870)

Models

Atmosphere - CAM3.5

Land - CLM3.5 + new datasets for present-day vegetation + grass optical properties

Ocean - Prescribed SSTs and sea ice

Experiments

30-year simulations (CO_2 = 375 ppm, SSTs = 1972-2001)

- PD – 1992 vegetation
- PDv - 1870 vegetation

30-year simulations (CO_2 = 280 ppm, SSTs = 1871-1900)

- PI – 1870 vegetation
- PIv – 1992 vegetation

No irrigation

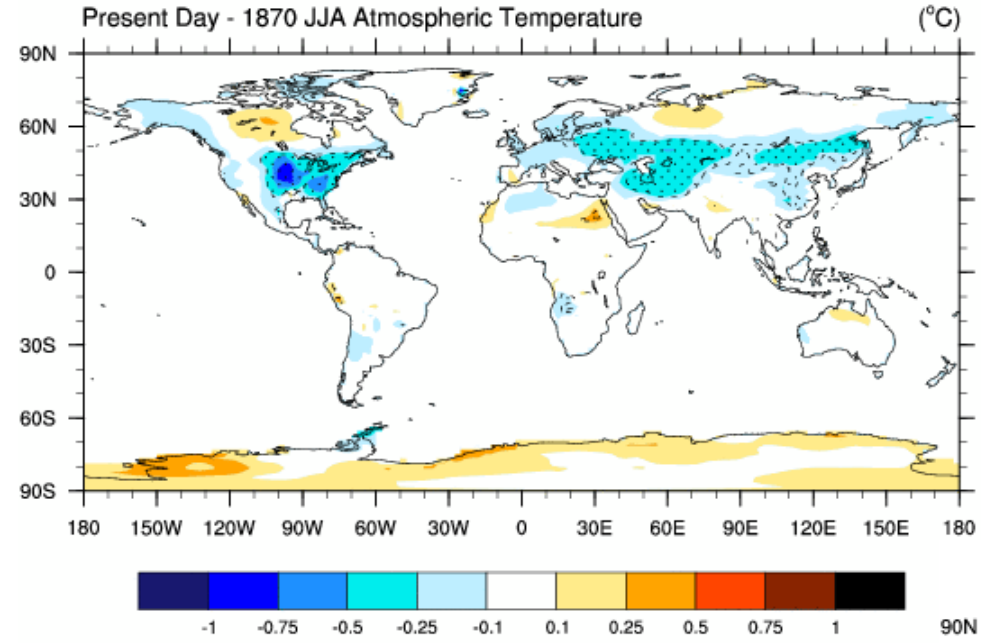
5-member ensembles each

Total of 20 simulations and 600 model years

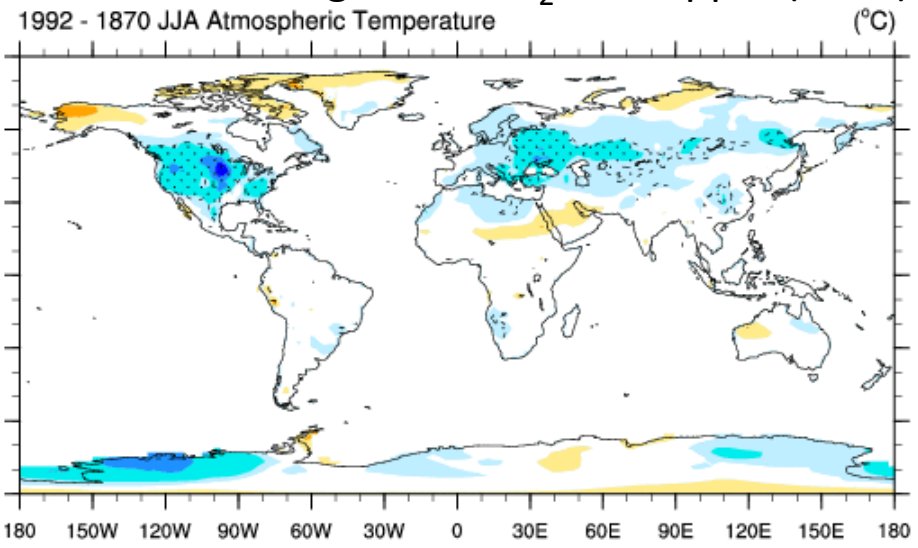
Pitman et al. (2009) Land use and climate via the LUCID intercomparison study: Implications for experimental design in AR5. Geophysical Research Letters, in press

Land cover change offsets greenhouse gas warming

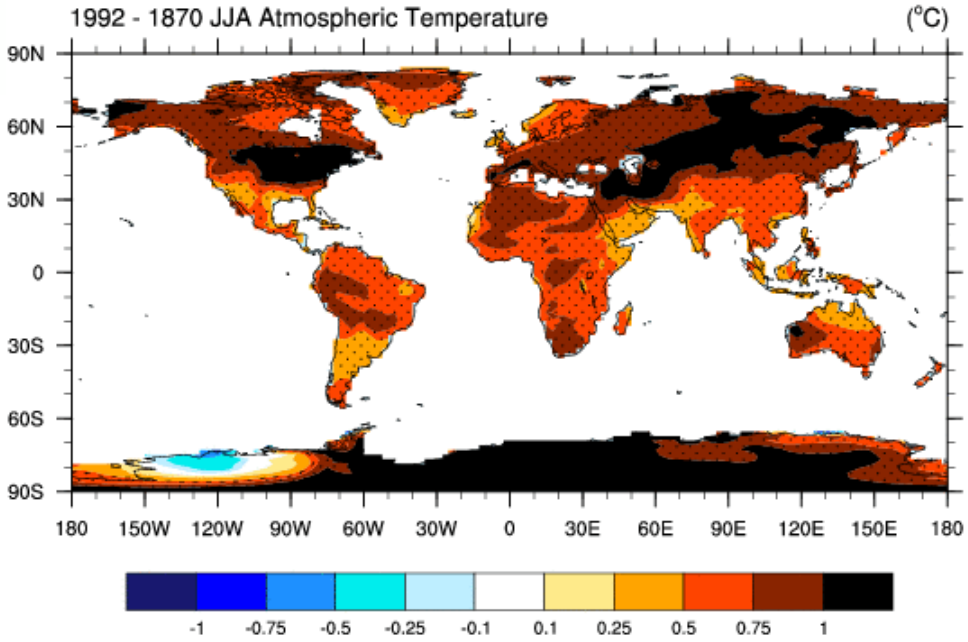
Land cover change with CO_2 = 375 ppm (1992)



Land cover change with CO_2 = 280 ppm (1870)



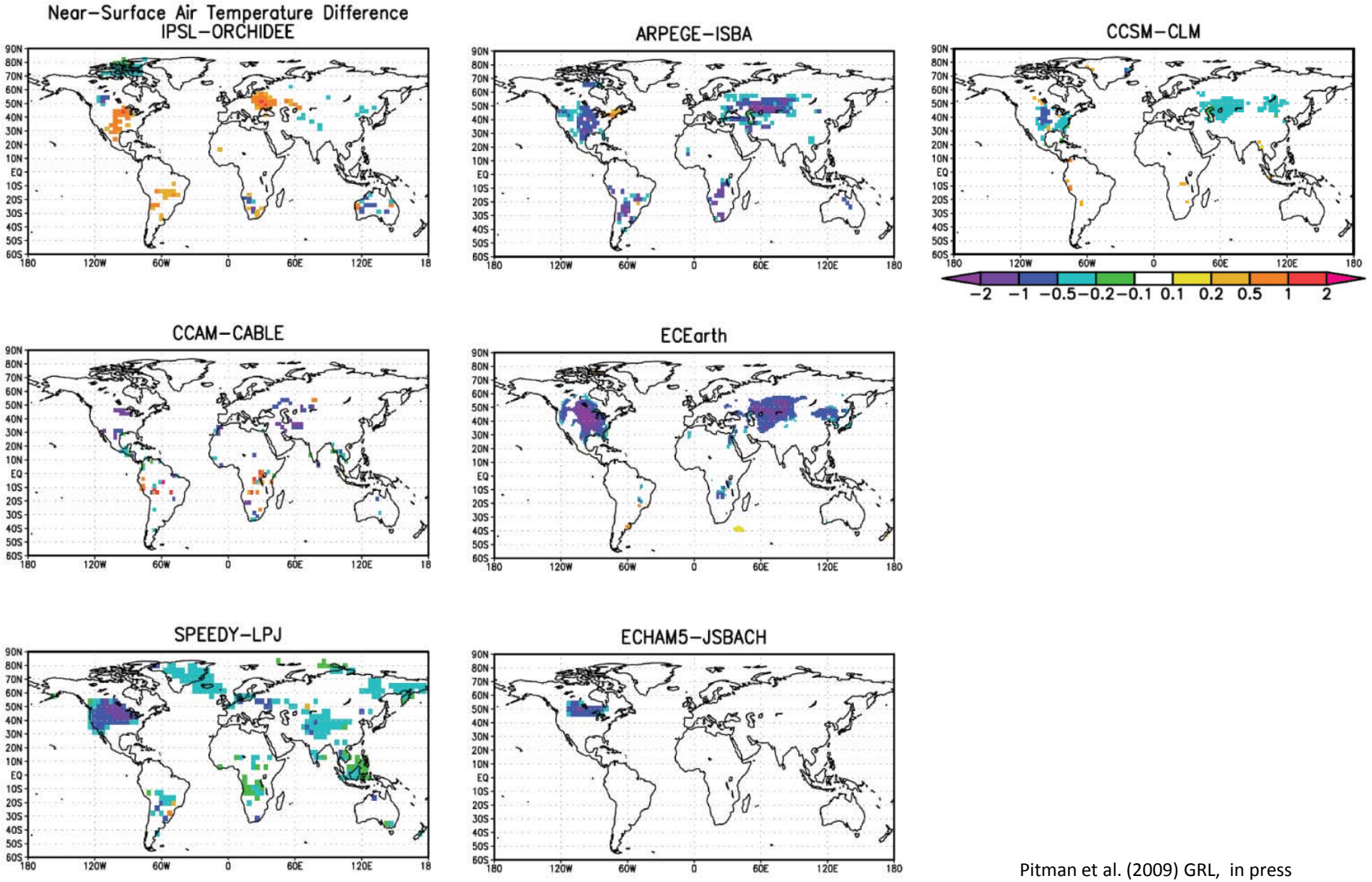
CO_2 forcing with 1870 land cover



CAM3.5/CLM3.5 simulations

The LUCID intercomparison study

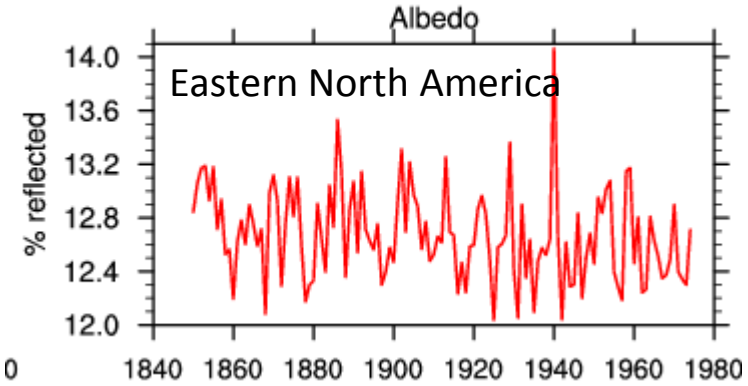
Change in JJA near-surface air temperature (PD – PDv)

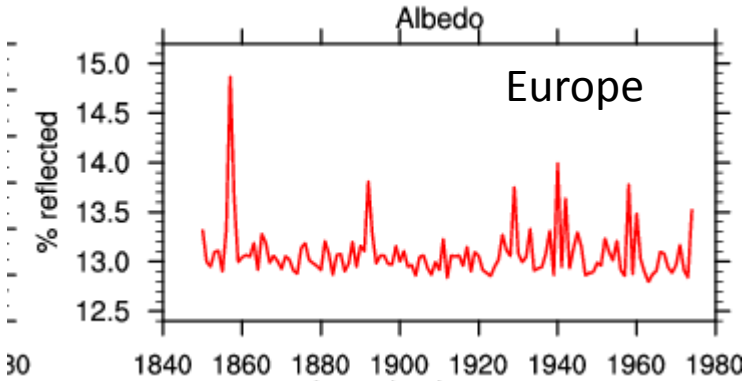


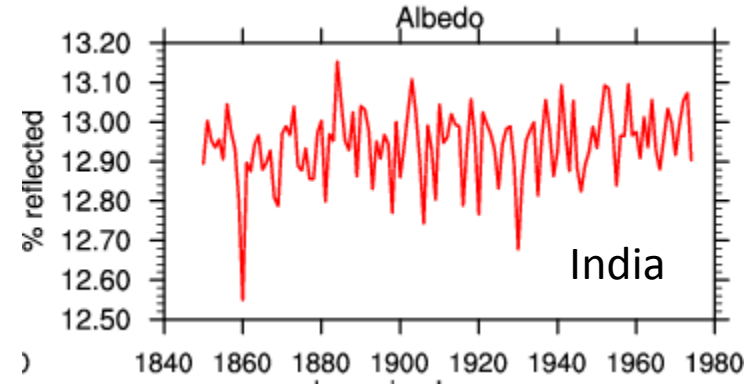
Pitman et al. (2009) GRL, in press

CCSM4 transient climate simulations

b40.20th.track1.004







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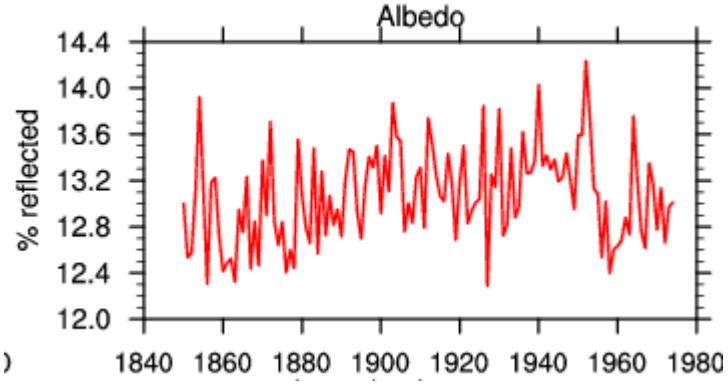

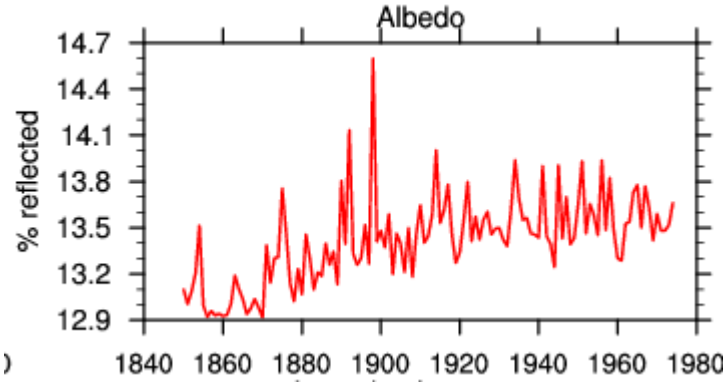

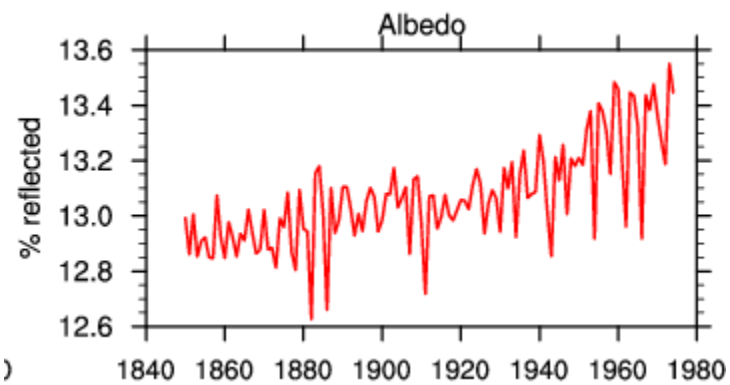

CCSM4 transient climate simulations