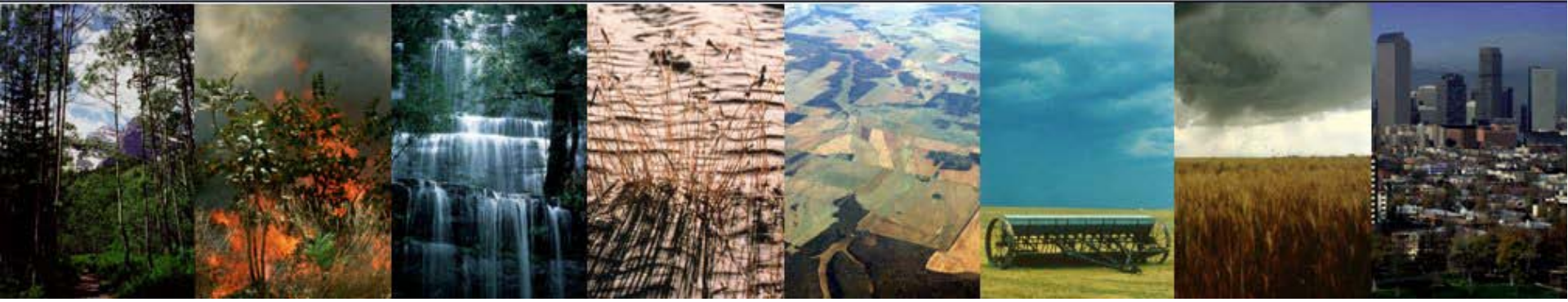


Community Land Model overview
Focus on ecosystem modeling

Samuel Levis
CLM Science Liaison
Terrestrial Sciences Section, CGD, NCAR

3rd Aug 2011 CESM Tutorial

NSF
NCAR
NATIONAL CENTER FOR ATMOSPHERIC RESEARCH
U.S. DEPARTMENT OF ENERGY
Office of Science

CLM overview: outline

- CLM basics
- Sample input and output
- Application: climate-veg interactions

CLM…
land component of the CESM

- source code: /models/lnd/clm/src
- input data: atm + sfc
- output data
- cesm scripts: can run just clm
- documentation: on the web site

What the CLM does in 100 words or less

✓INPUT: - near-surface atmosphere data (sim/obs)
S, *L*, *T*, *q*, *u*, *v*, *p*, *P*, [CO_2]
- surface data (sim/obs)
veg., soil, other data (eg, %lake)

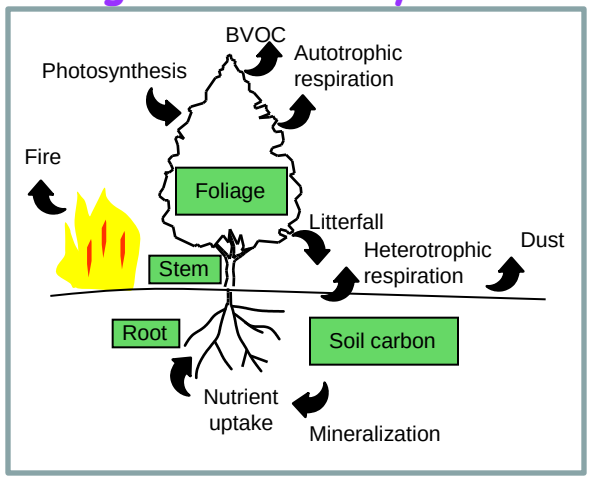
➢OUTPUT: *H*, λE, *G* heat fluxes
reflected & emitted radiation fluxes
soil, snow, plant *T* and *W* …river flow
C & N fluxes …BVOC & dust emissions

} the energy and mass exchange at the interface

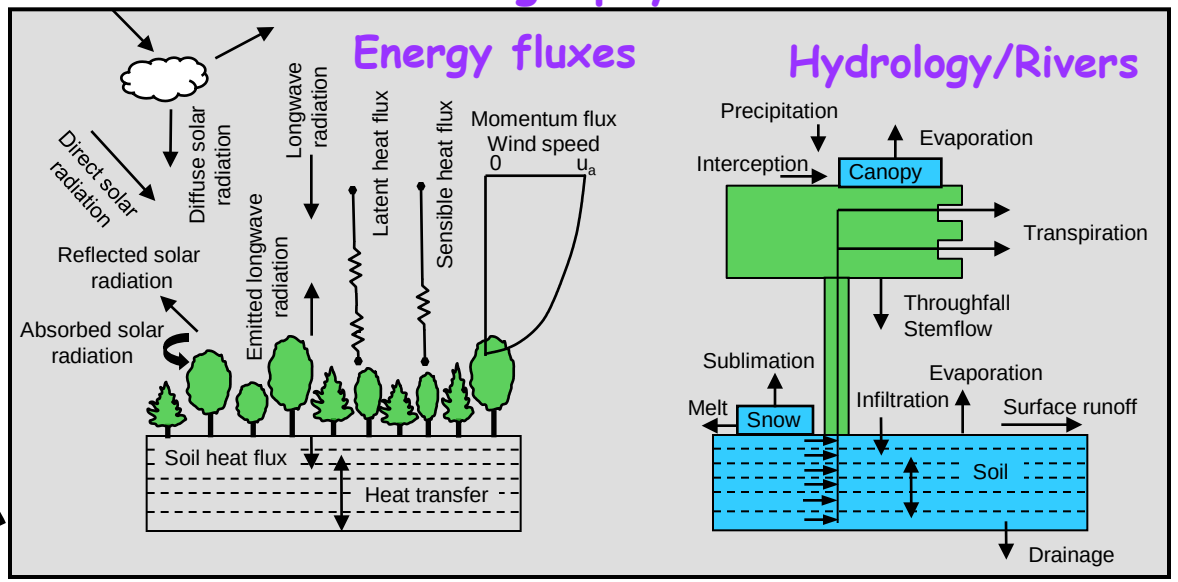
- Coupler passes information to atm. and ocn. models making the CLM a source of climate system feedbacks

Current-generation land models

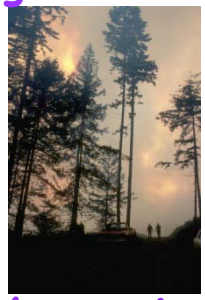
Biogeochemical Cycles



Biogeophysics



Climate change

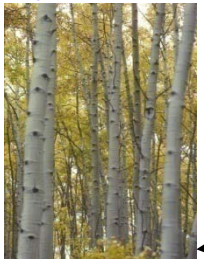


Establishment

Climate change

Disturbance

Vegetation dynamics



Competition

Growth

Ice sheets

Deforestation

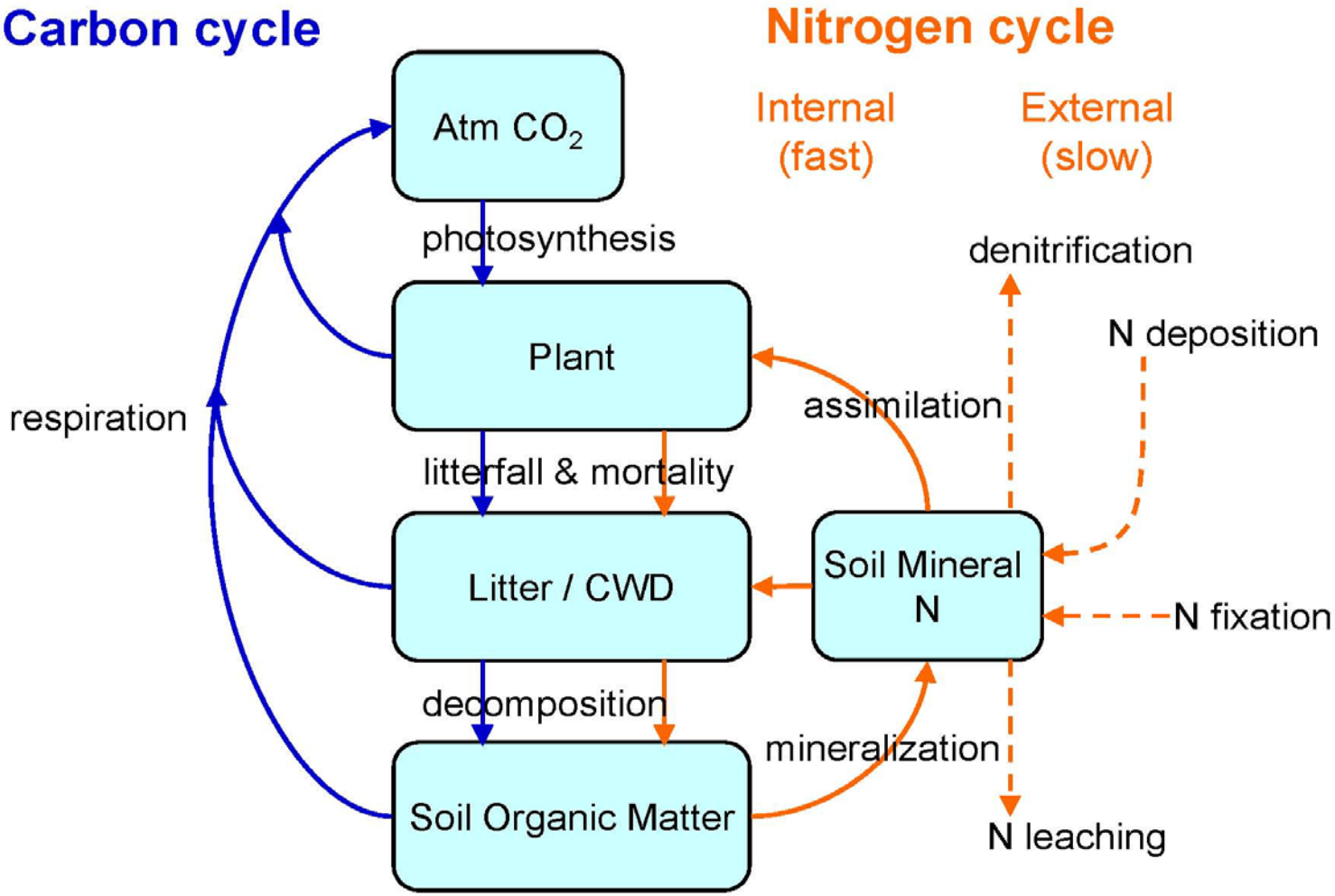
Land use

Afforestation

Urbanization

Land Management

Beyond CLM4SP: Option CLM4CN
Biogeochemical Cycles in the CLM



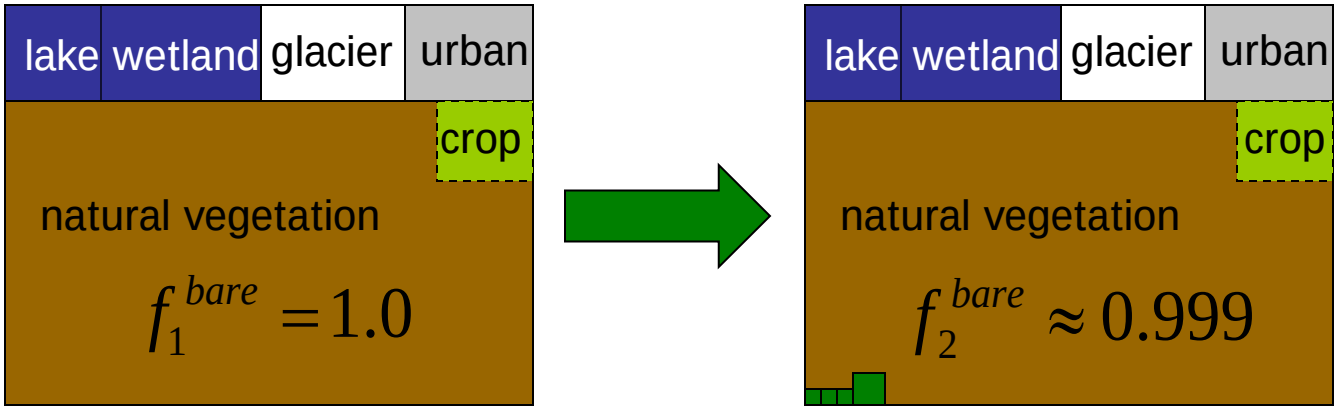
Thornton *et al.*

All these processes are affected by and may also affect the physics

Option CLM4CNDV
Dynamic Vegetation in the CLM

Year 1:
Bioclimatology accumulators

End of year 1:
Establishment



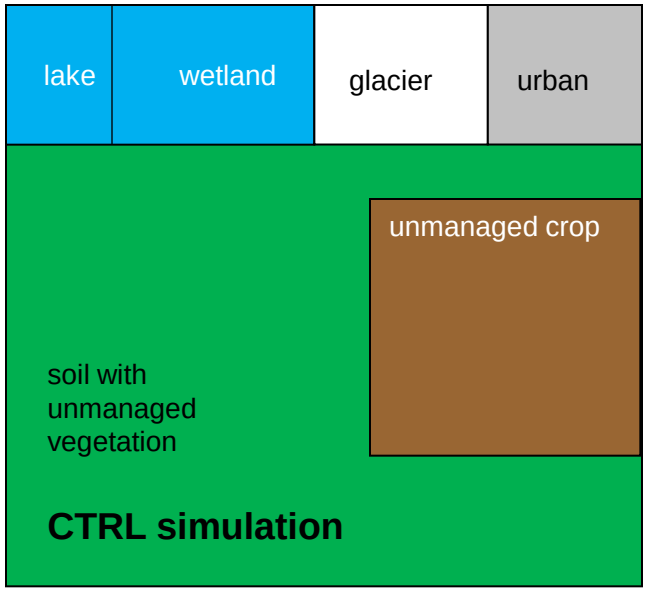
Year 2+:
Bioclimatology accumulators
Biogeochemistry:
Photosynth., respiration, growth, mortality

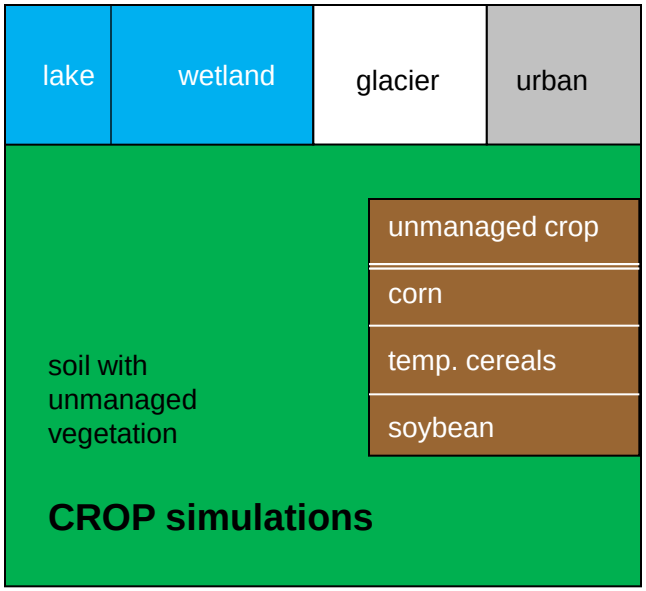
End of year 2+:
Establishment
Competition for Light (space)

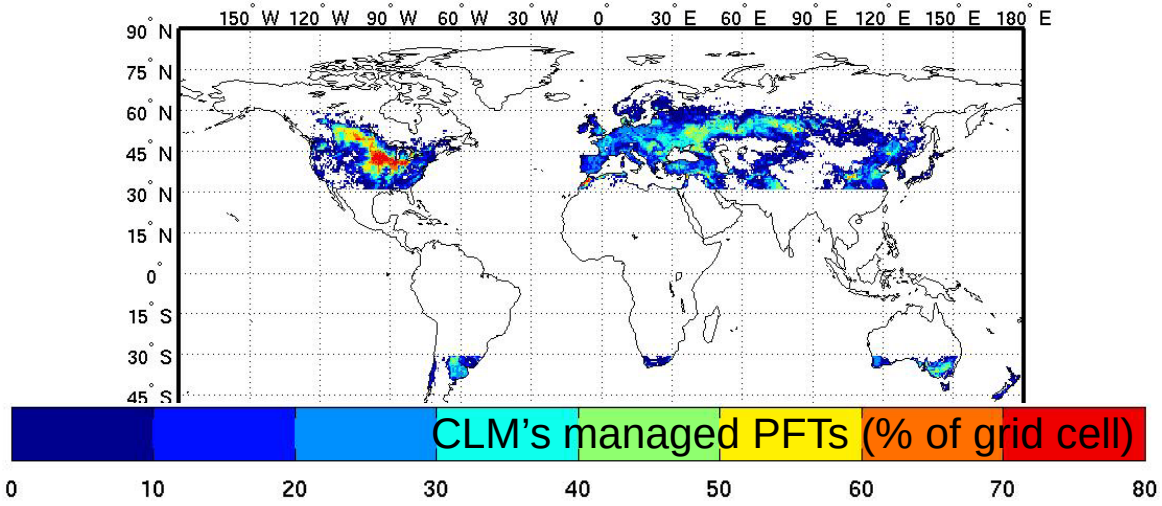
All these processes are affected by and may also affect the physics

Levis *et al.*

Newest option CLM4crop
Interactive crop management







Levis *et al.*

Subroutine Tree

- Initialize
- Time stepping loop →

Surface radiation

Soil fluxes …Urban fluxes

Canopy fluxes …Lake fluxes

Dust emission …BVOC emission

BGC

Hydrology …Snow

C and N cycles …Balance check

Surface albedo …River flux

Dynamic vegetation

write history and restart data

CLM overview: outline

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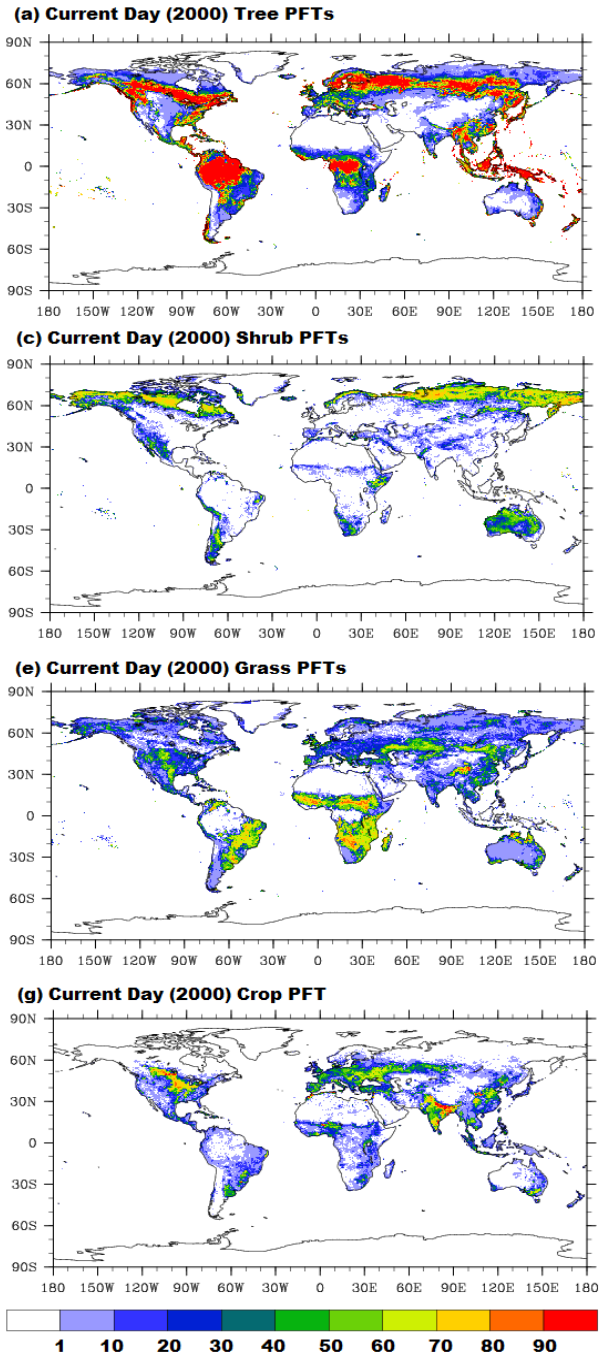
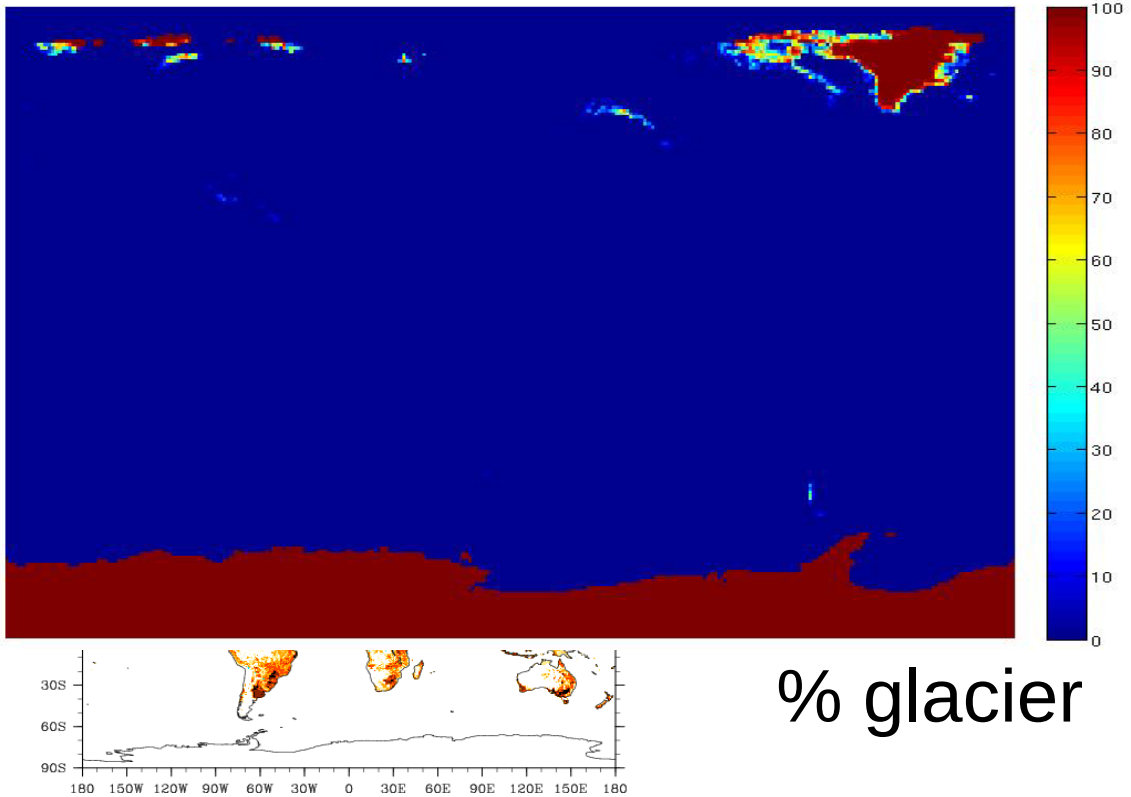
- Climate-vegetation interactions

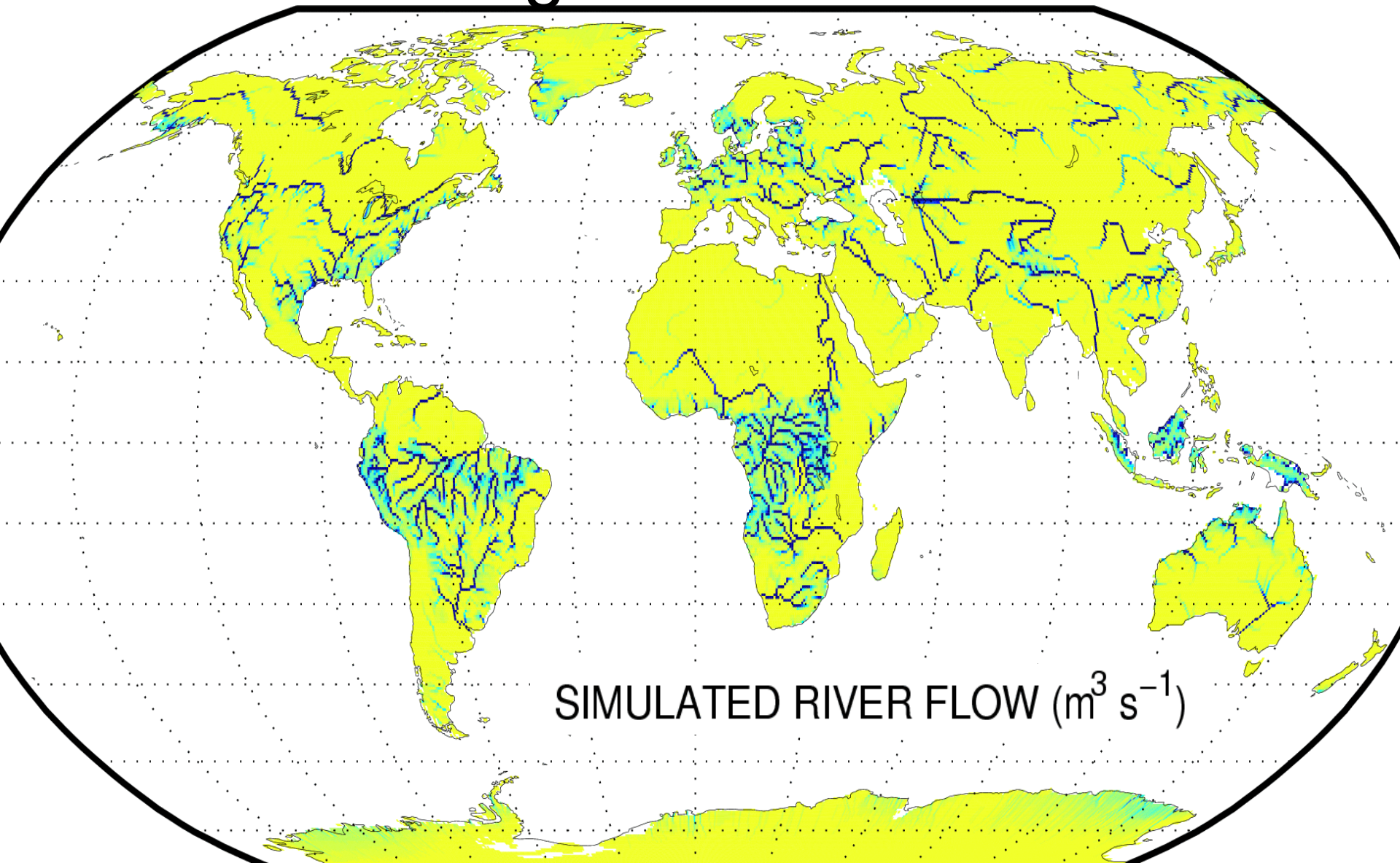


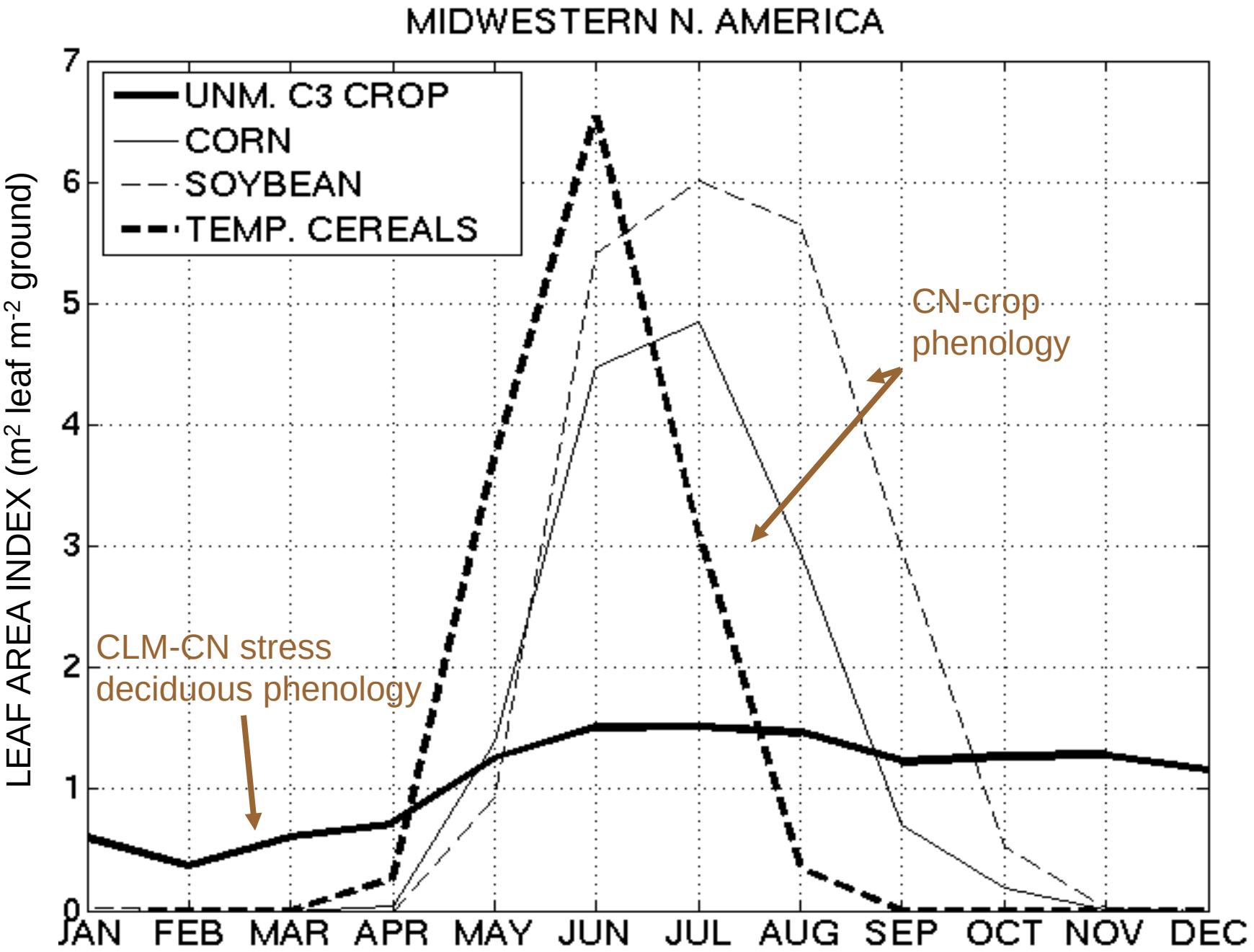
Sample input data

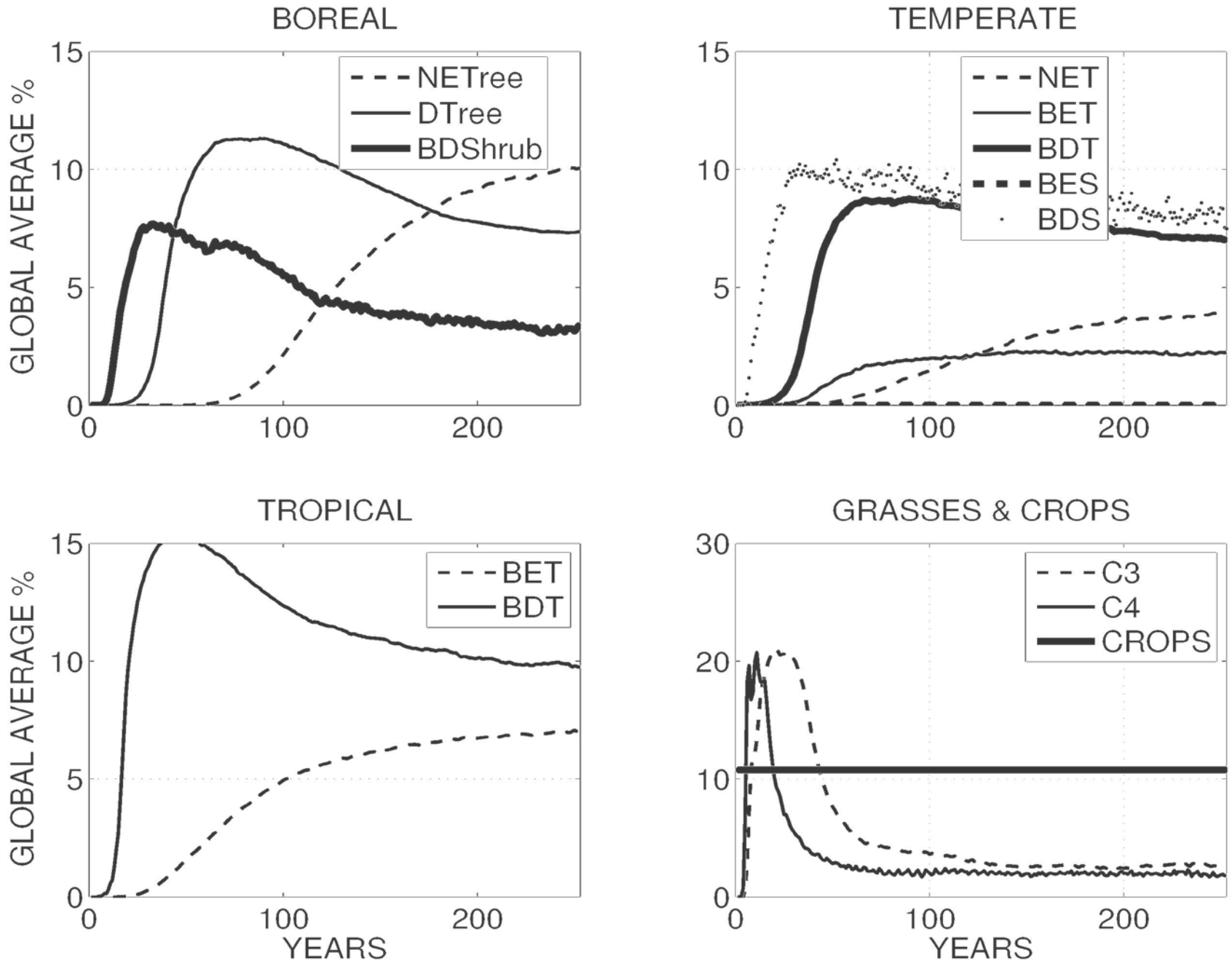


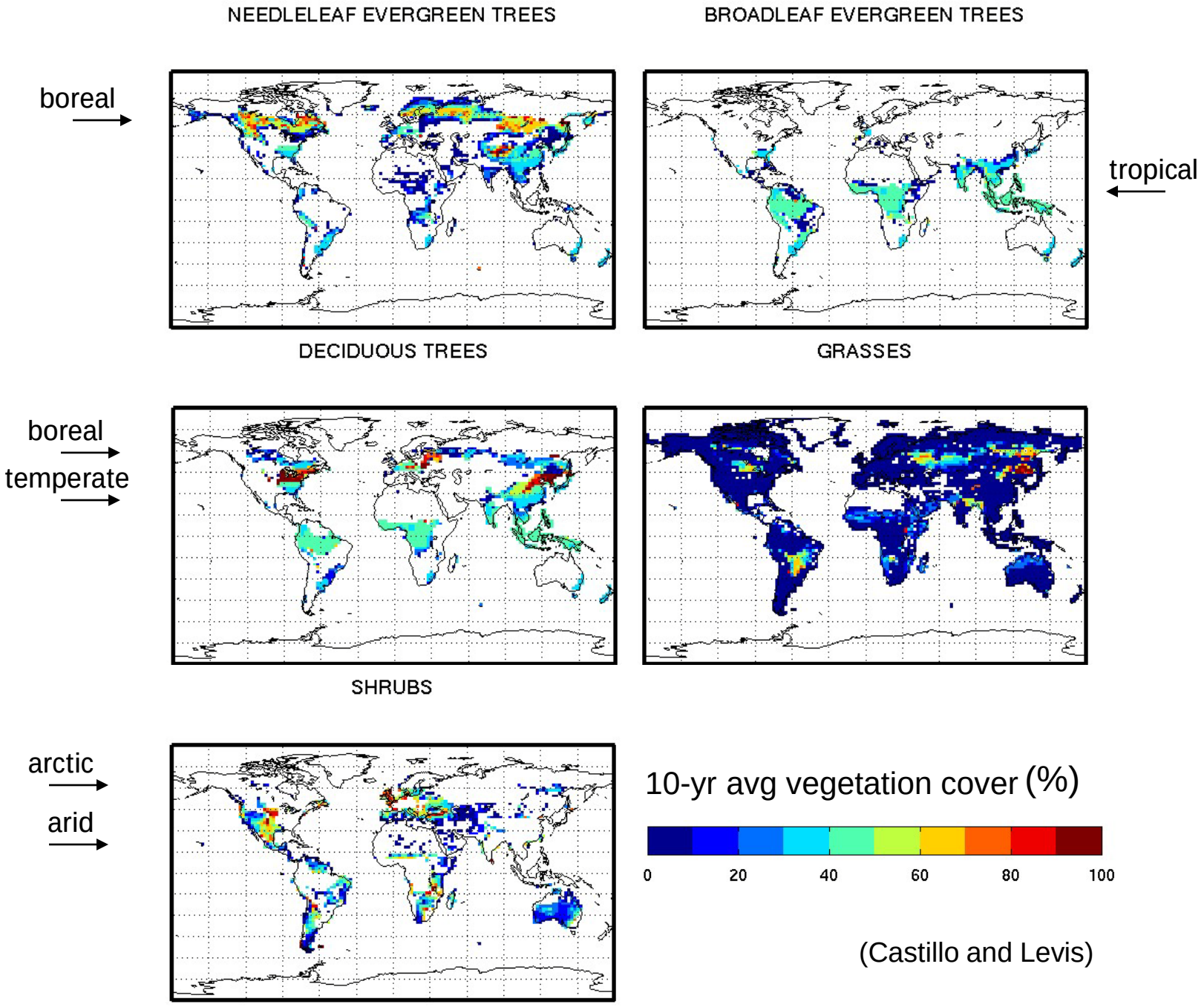
% glacier

Sample output: linking land to ocean




MIDWESTERN N. AMERICA
UNM. C3 CROP
CORN
SOYBEAN
TEMP. CEREALS
LEAF AREA INDEX (m2 leaf m-2 ground)
0
1
2
3
4
5
6
7
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
CN-crop
phenology
CLM-CN stress
deciduous phenology


BOREAL
GLOBAL AVERAGE %
NETree
DTree
BDShrub
TEMPERATE
NET
BET
BDT
BES
BDS
TROPICAL
BET
BDT
YEARS
GRASSES & CROPS
C3
C4
CROPS
YEARS


NEEDLELEAF EVERGREEN TREES
BROADLEAF EVERGREEN TREES
boreal
tropical
DECIDUOUS TREES
GRASSES
boreal
temperate
SHRUBS
arctic
arid
10-yr avg vegetation cover (%)
0
20
40
60
80
100
(Castillo and Levis)

CLM overview: outline

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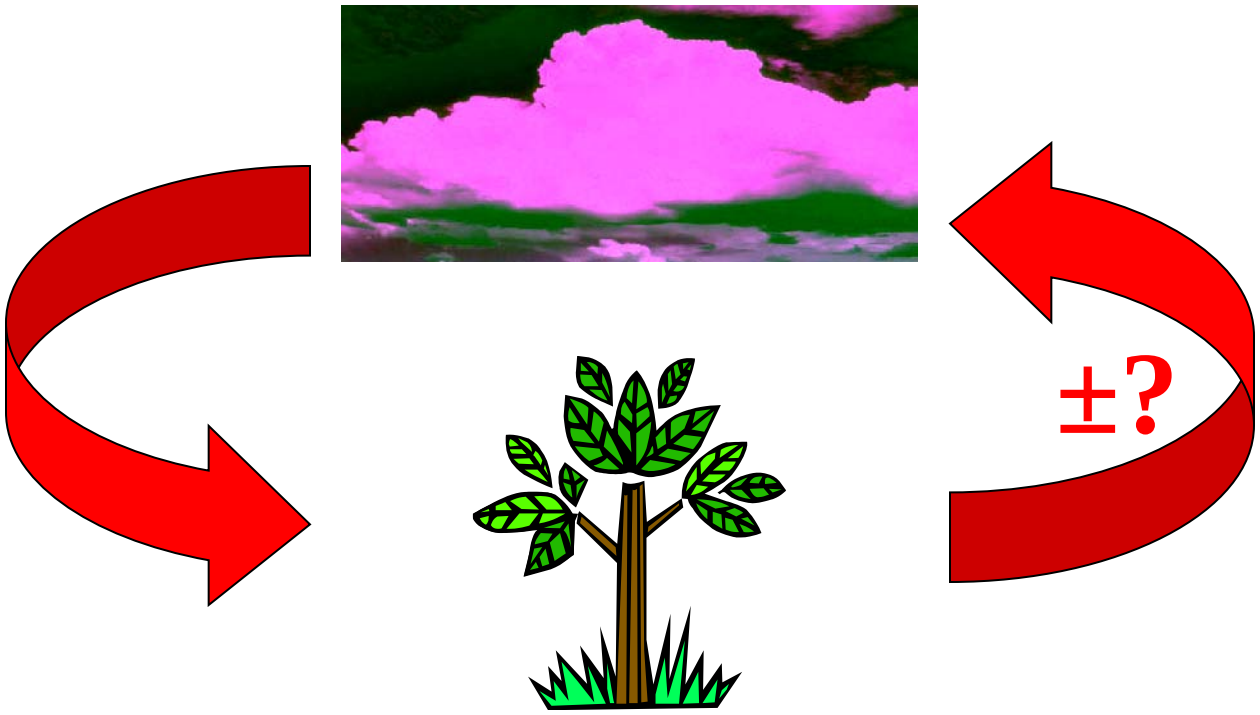
Climate-Vegetation Interactions

CLIMATE-VEGETATION FEEDBACKS



Climate-Vegetation Interactions
CLIMATE-VEGETATION FEEDBACKS

- Climate changes → vegetation responds
- Vegetation changes → climate responds:

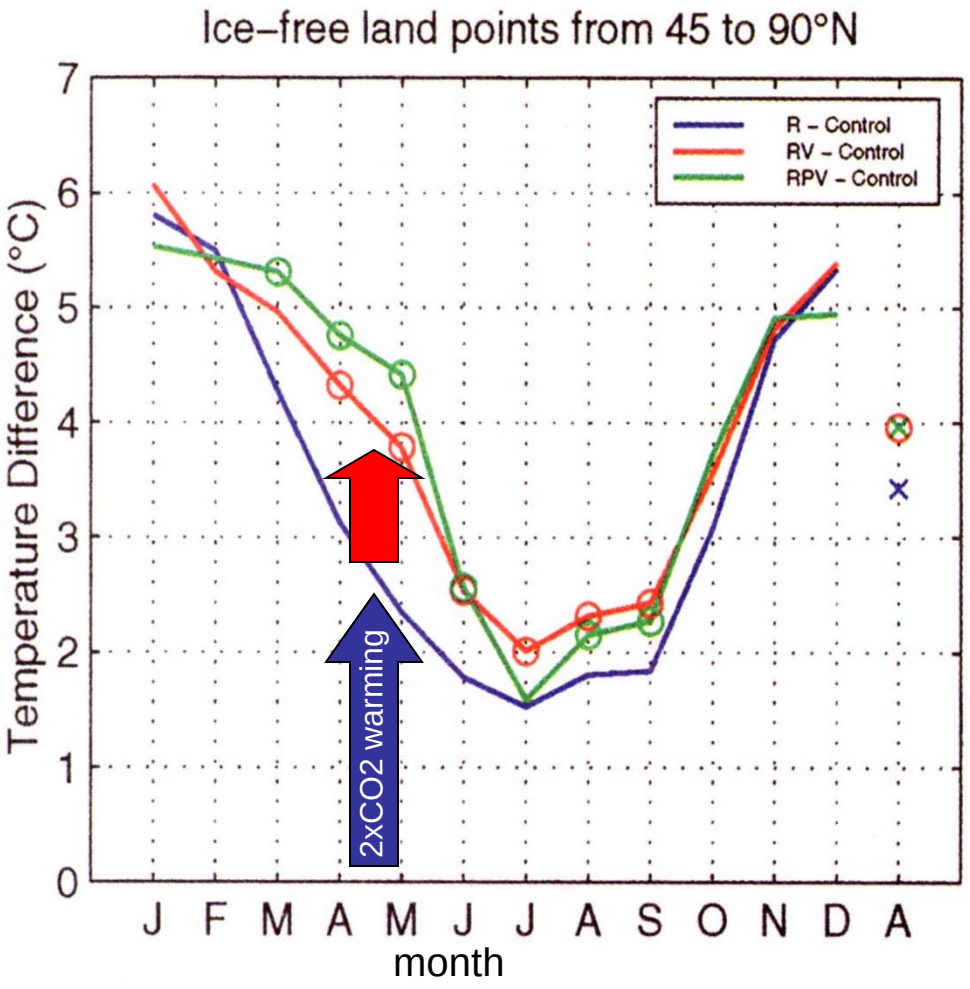
A. Biogeophysical feedbacks:

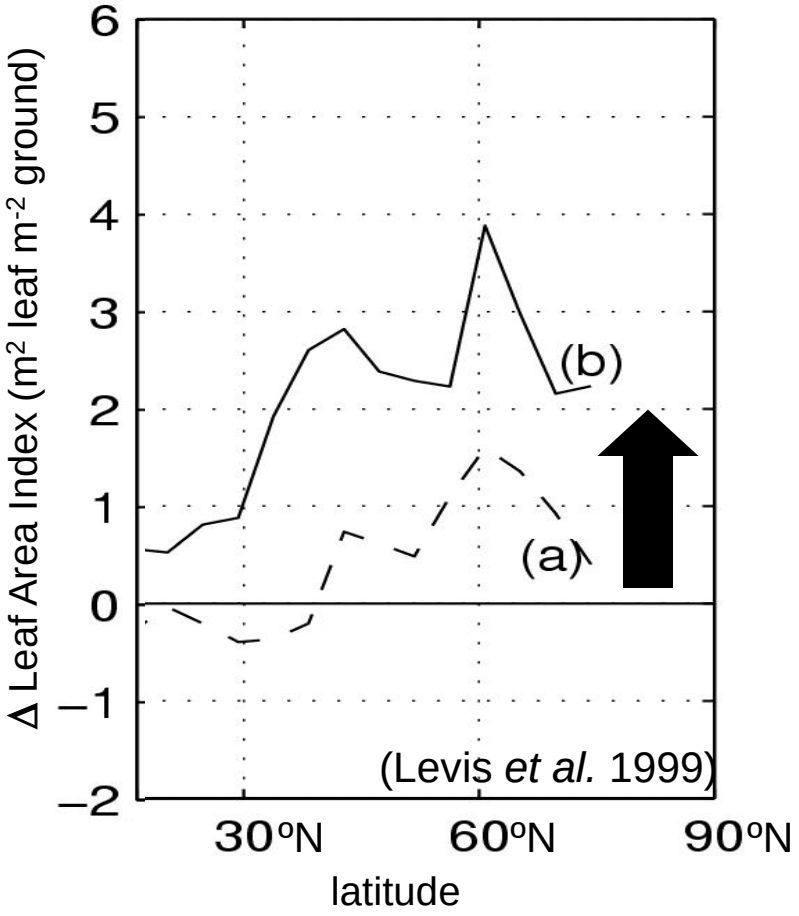
1. **Surface radiation balance** $R_n = S + L$
2. **Surface heat balance** $R_n = H + \lambda E$

B. Biogeochemical feedbacks

1. **Carbon cycle**

2 x CO_2 climate and vegetation

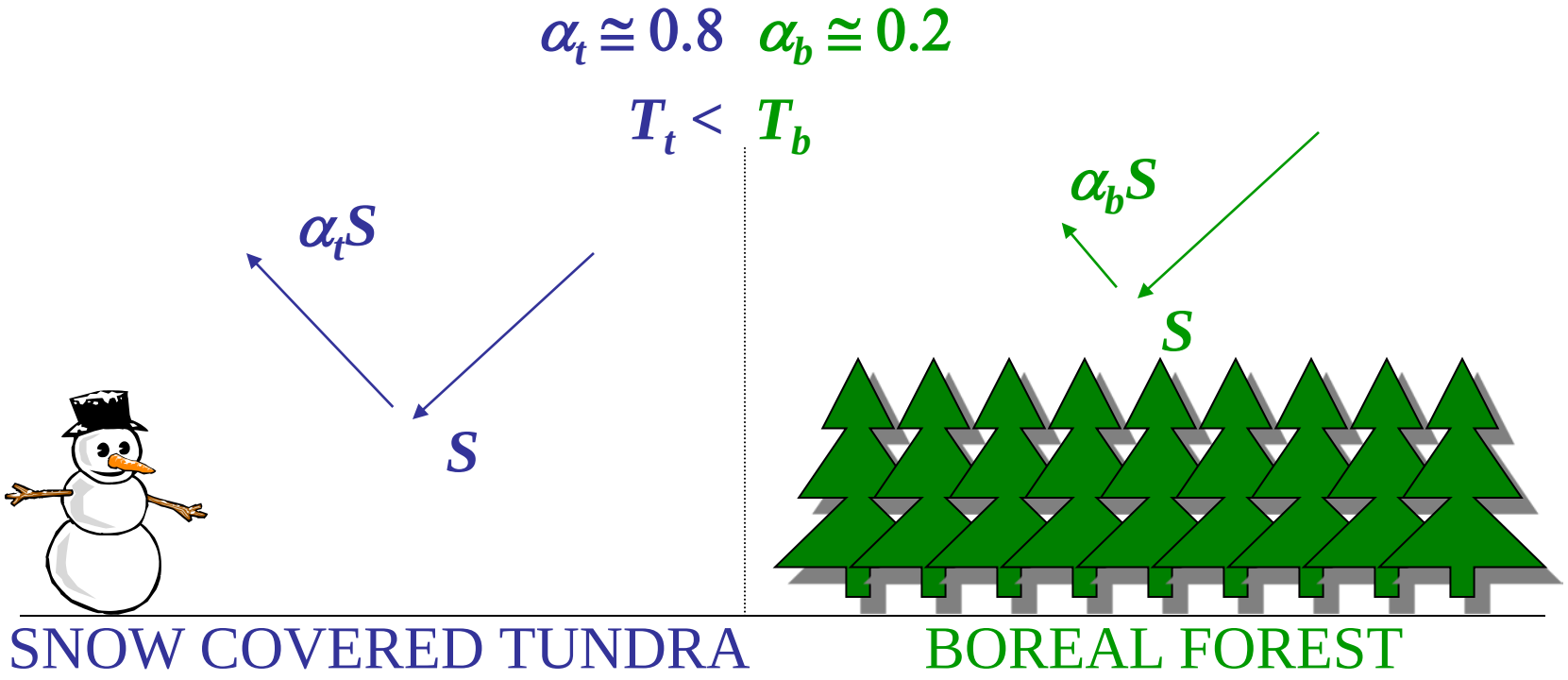




Biogeophysical feedbacks

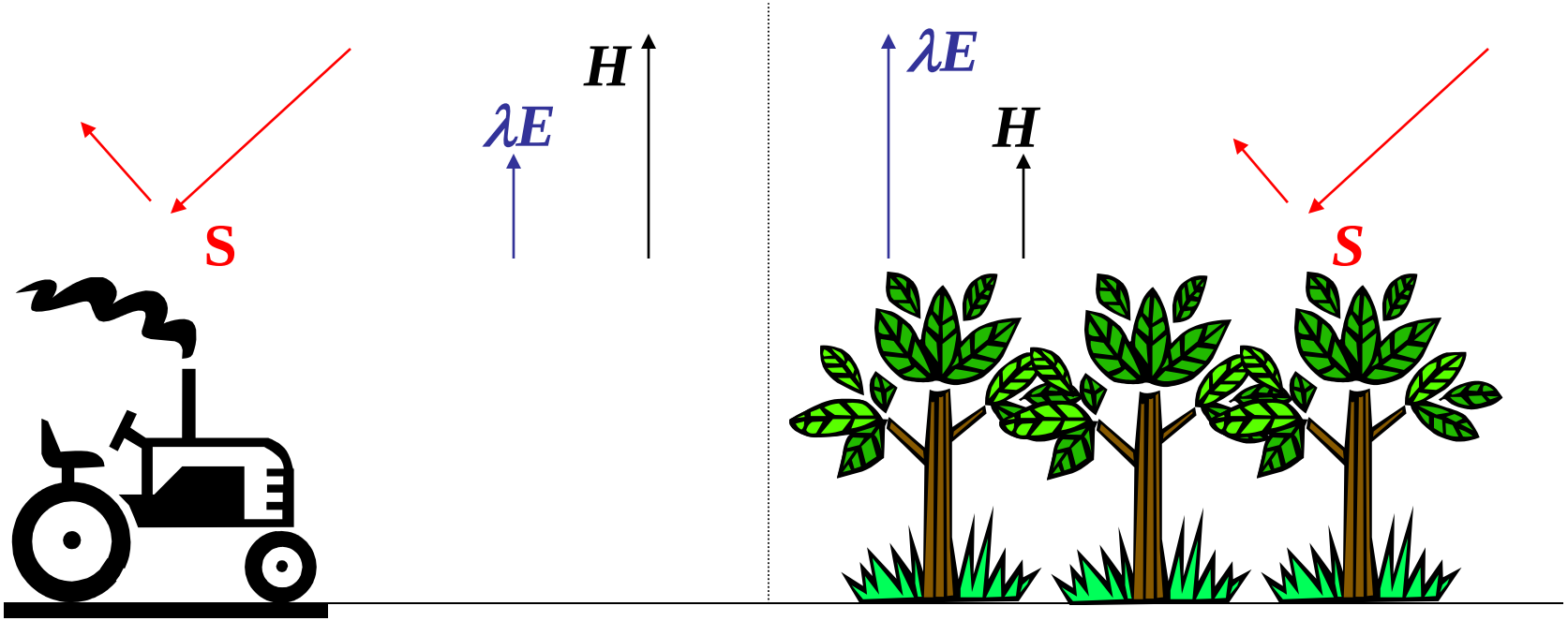
1. Surface radiation balance:

   Trees darken snow-covered surfaces



Biogeophysical feedbacks

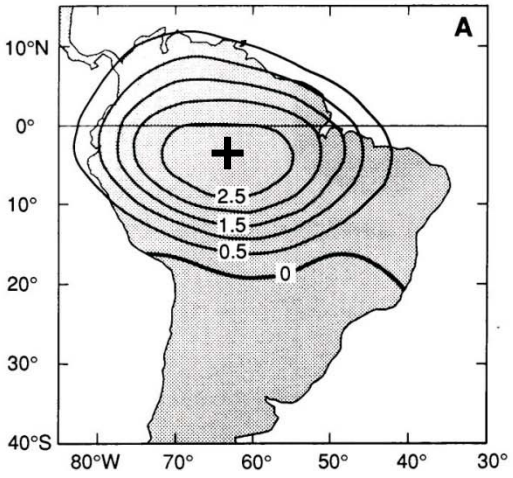
1. Surface radiation balance
   Trees darken snow-covered surfaces
2. Surface heat balance $R_n = H + \lambda E$
   Vegetation increases the latent heat flux



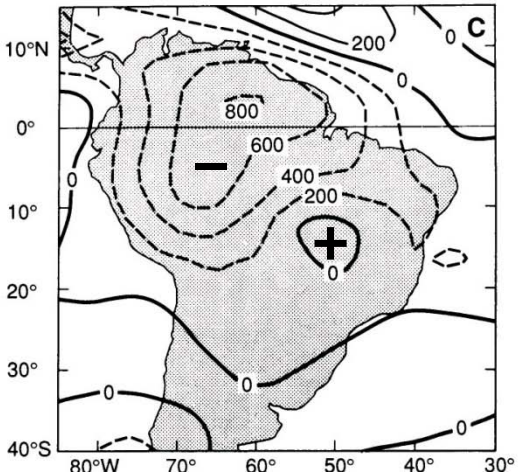
AMAZON BASIN

Trees increase evapotranspiration …deforestation decreases it

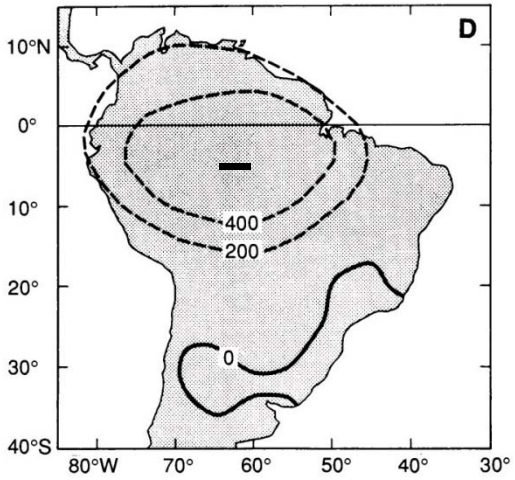
Temperature (K)



Precipitation (mm yr^{-1})

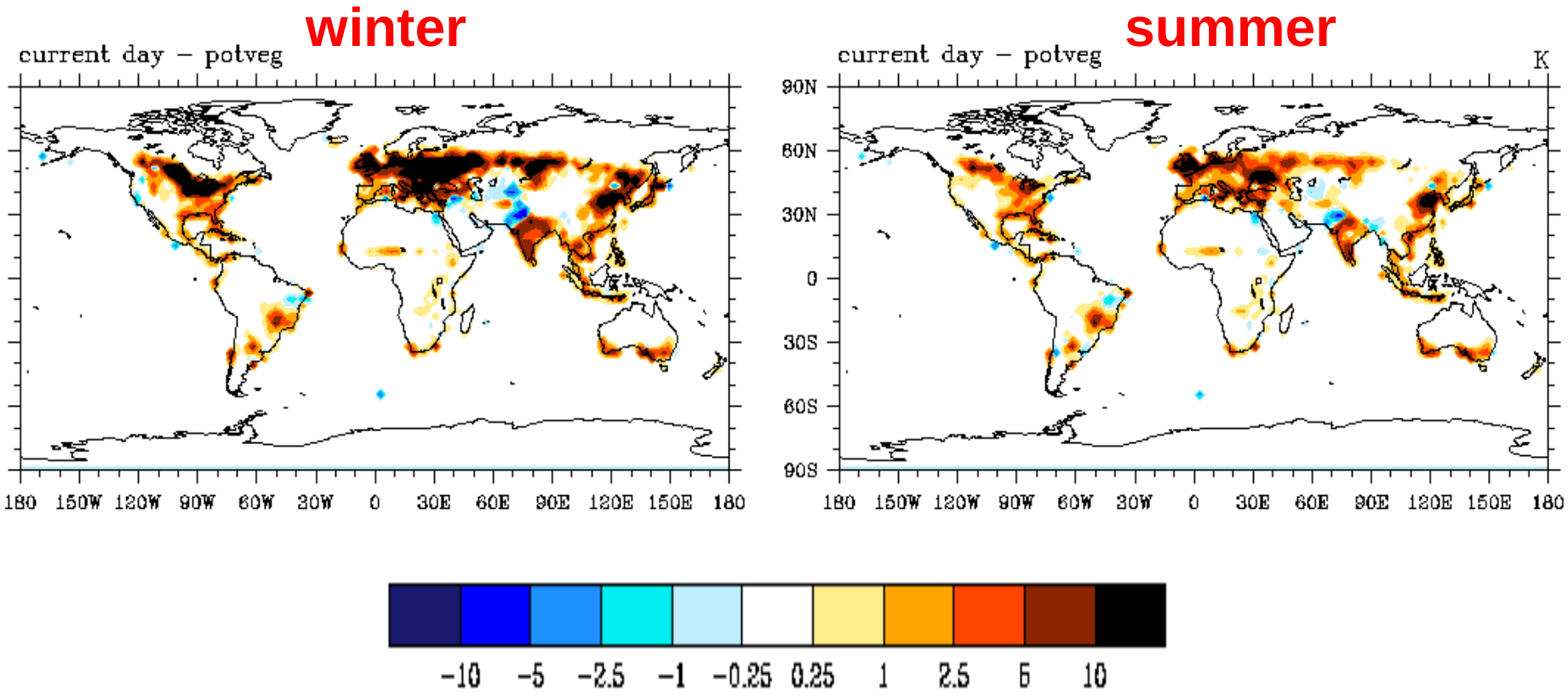


Evapotranspiration (mm yr^{-1})

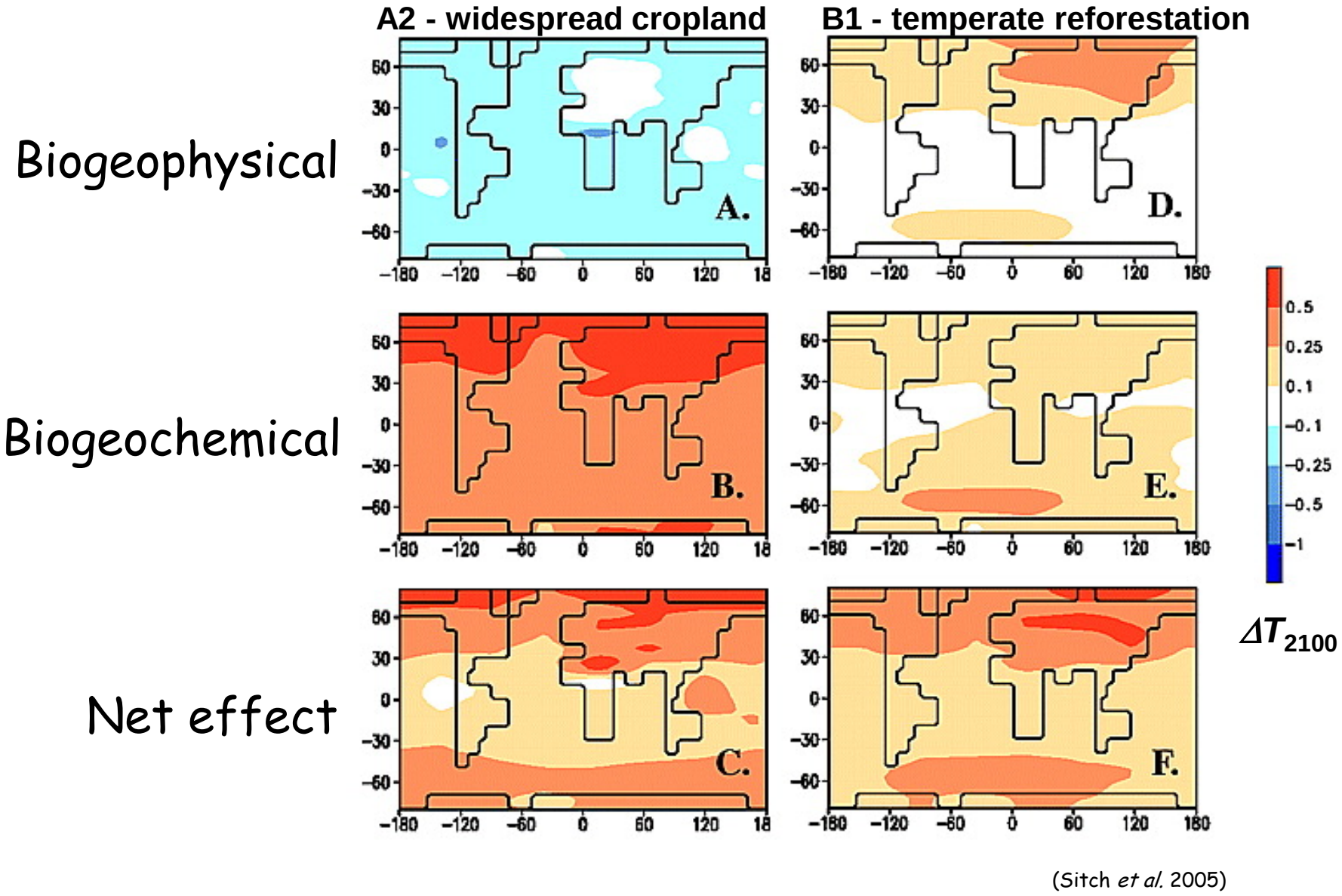


(Shukla *et al.* 1990)

Effect of deforestation on albedo

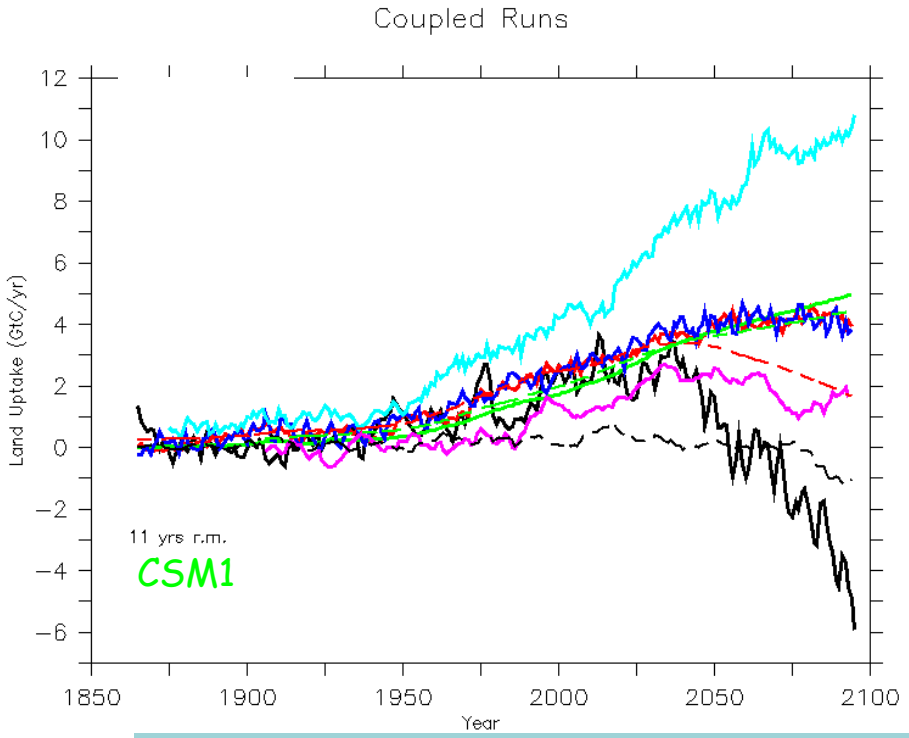


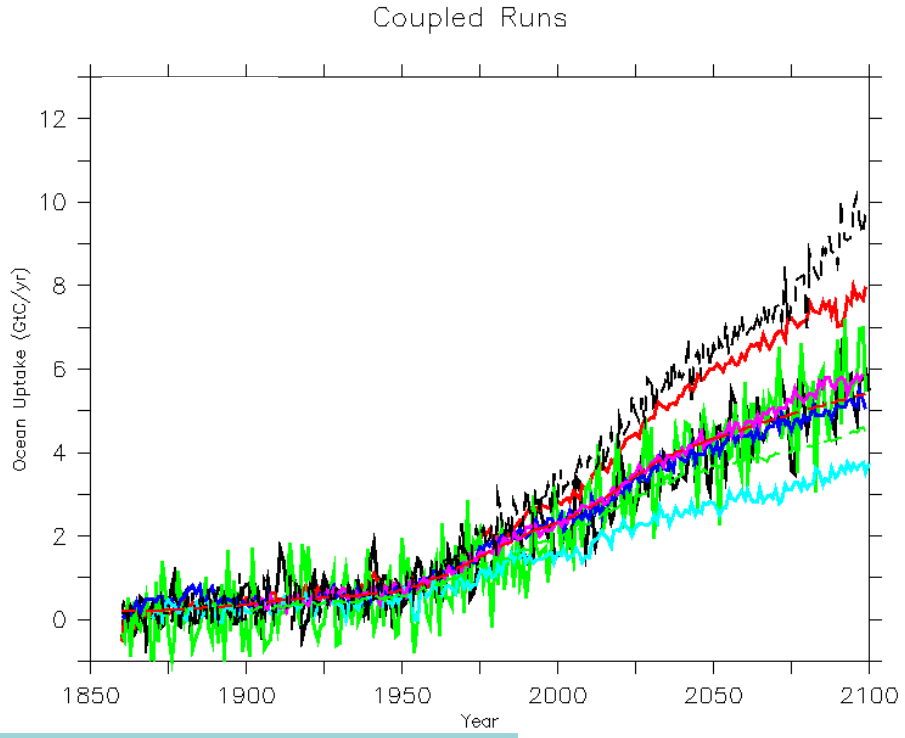
Future land use effect on temperature



(Sitch *et al.* 2005)

Carbon model intercomparison:
Nine climate models of varying complexity with active carbon cycle



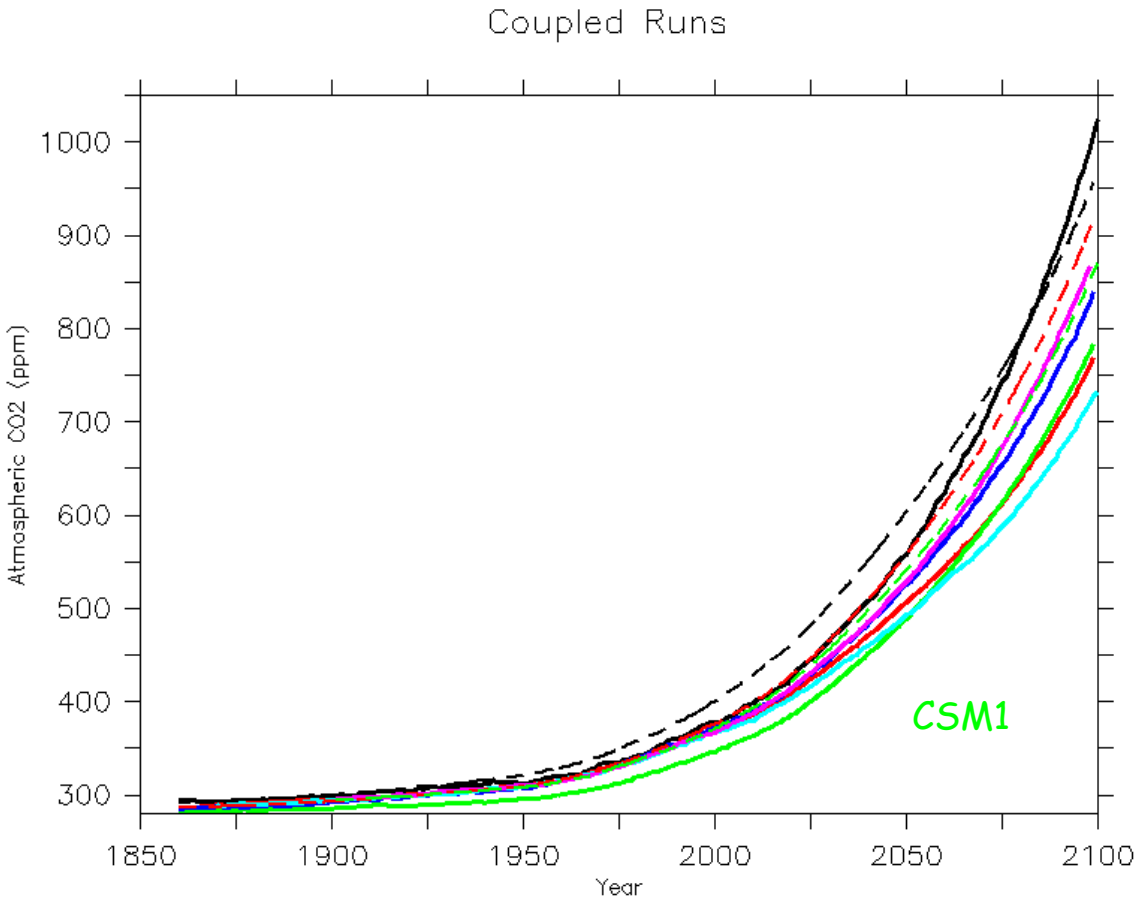


Uncertainty arises from differences in terrestrial fluxes

- One model simulates a large source of carbon from the land
- Another simulates a large terrestrial carbon sink
- Most models simulate modest terrestrial carbon uptake
- Terrestrial carbon cycle can be a large climate feedback
- Considerable more work is needed to understand this feedback

Figures courtesy of Pierre Friedlingstein

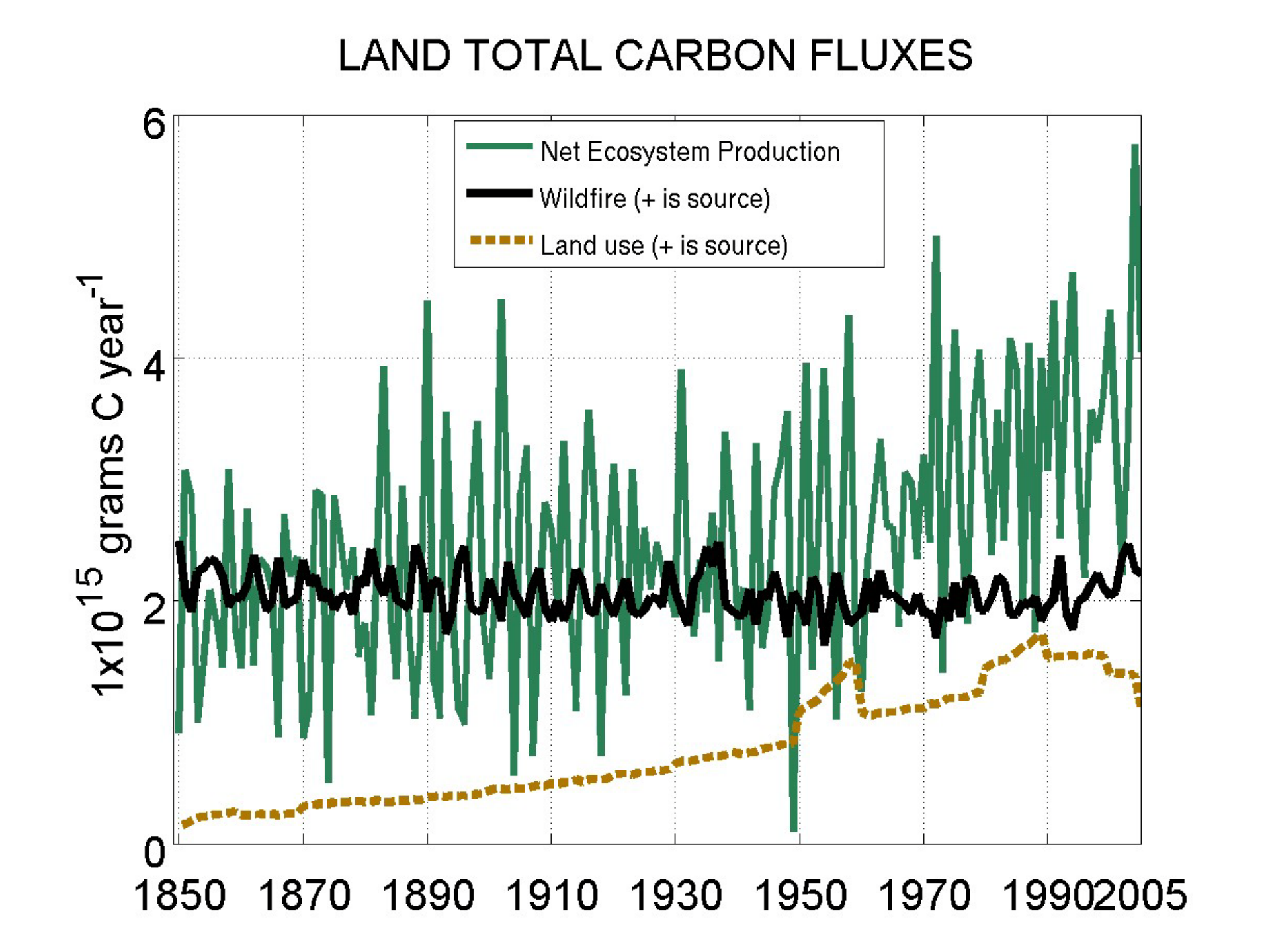
Carbon model intercomparison:
Nine climate models of varying complexity with active carbon cycle



Large uncertainty in simulated atmospheric CO_2 at 2100

max is > 1000 ppm
min is < 750 ppm

Courtesy of Pierre Friedlingstein


LAND TOTAL CARBON FLUXES
Net Ecosystem Production
Wildfire (+ is source)
Land use (+ is source)
1x10^15 grams C year^-1
6
4
2
0
1850
1870
1890
1910
1930
1950
1970
1990
2005

Summary & Conclusions

- CLM basics and Sample input/output
- Climate-vegetation interactions
  - First order effect seems to be land use
    - Biogeochemical effect
    - Human behavior our greatest uncertainty
  - From natural vegetation
    - Snow-vegetation-albedo feedback

QUESTIONS?