Community Land Model overview focus on ecosystem modeling

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CESM Tutorial 2012

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 basics

- 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)

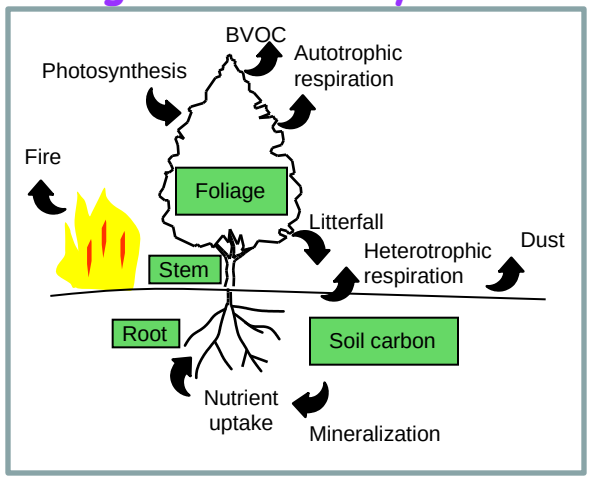
➢OUTPUT: *H*, *E*, *G* heat fluxes
reflected & emitted radiation fluxes
soil, snow, plant *T* and *W* …river flow
C & N fluxes…BVOC & dust emissions

} the energy and mass exchange at the interface

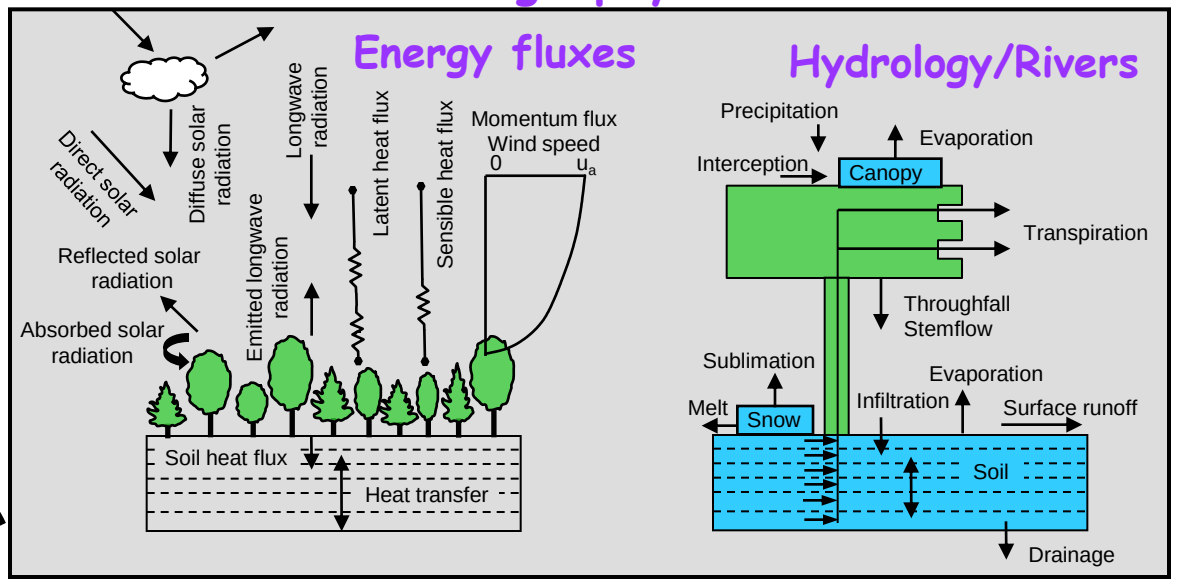
- Coupler passes information to atm. and ocn. models making the CLM a source of climate system feedbacks

Current-generation land models

Biogeochemical Cycles



Biogeophysics



Climate change

Establishment

Climate change

Disturbance

Vegetation dynamics

Competition

Growth

Deforestation

Land use

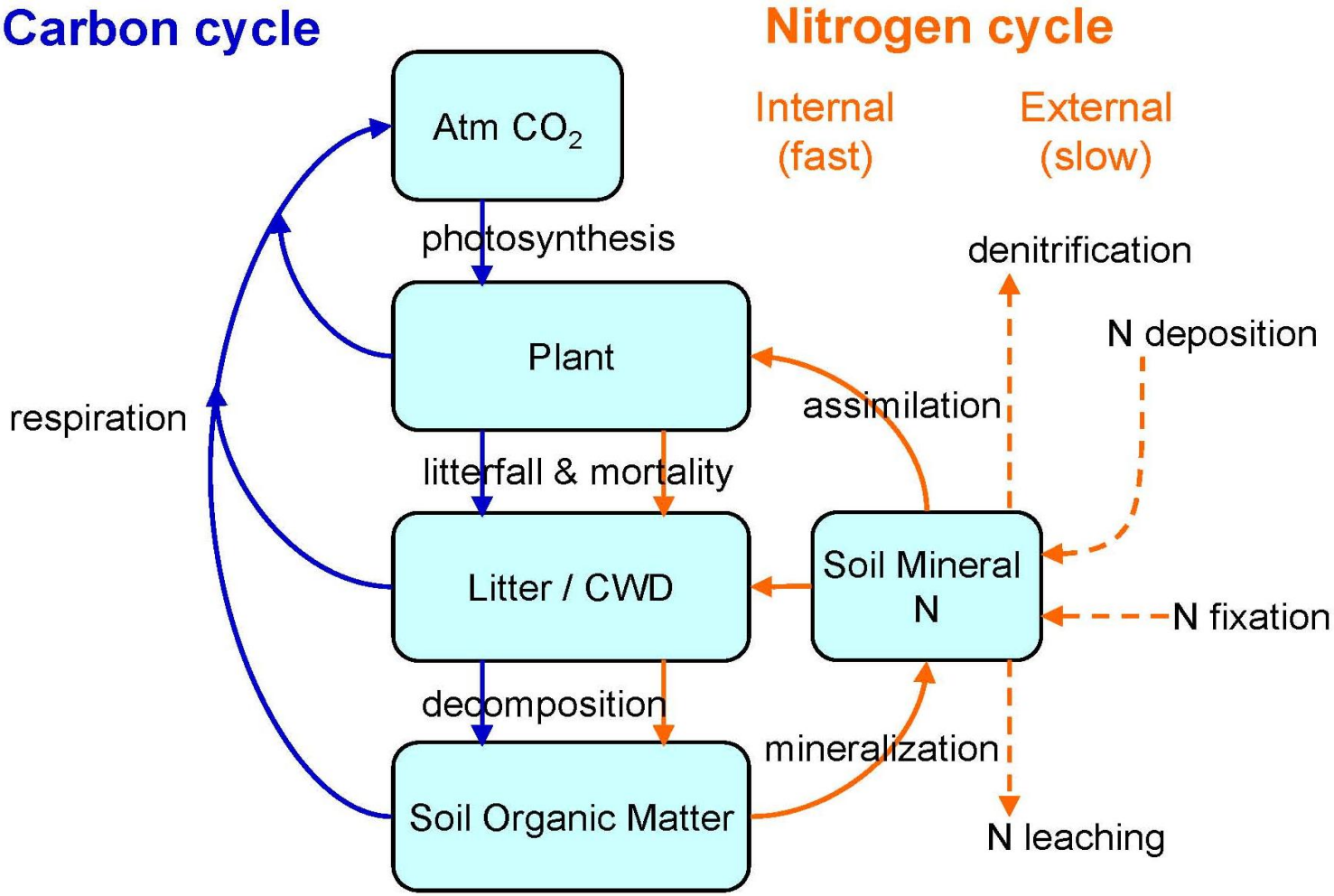
Afforestation

Urbanization

Land Management

Ice sheets

Beyond CLM4SP: Option CLM4CN
Biogeochemical Cycles in the CLM



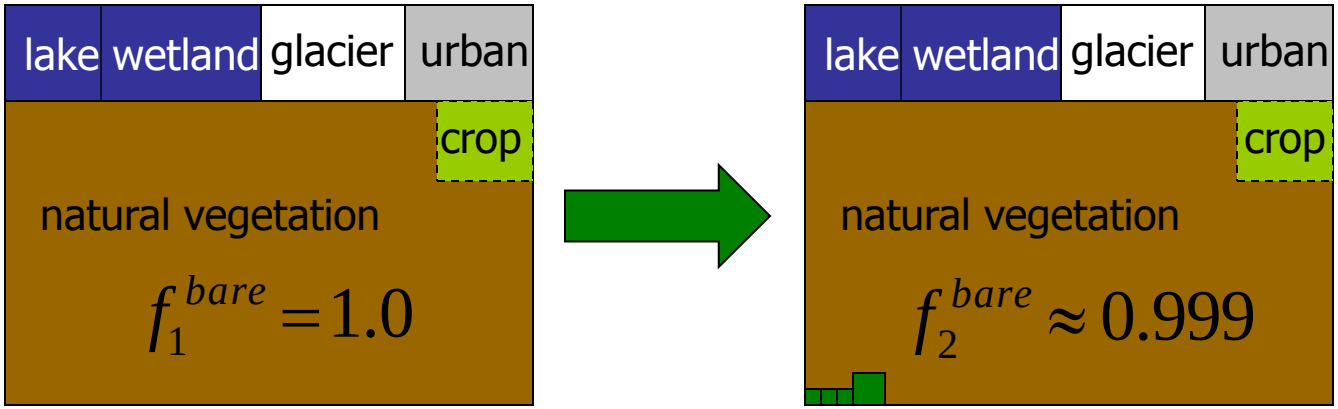
Thornton *et al.*

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



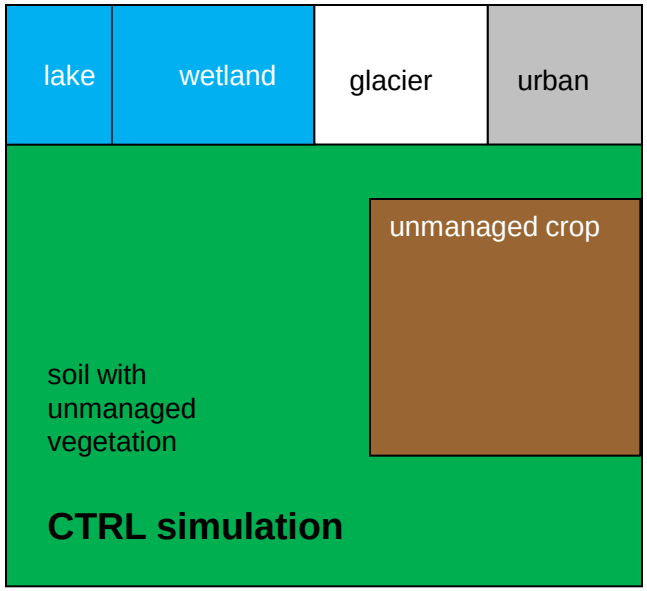
Year 2+:
Bioclimatology accumulators
Biogeochemistry:
Photosynth., respiration, growth, mortality

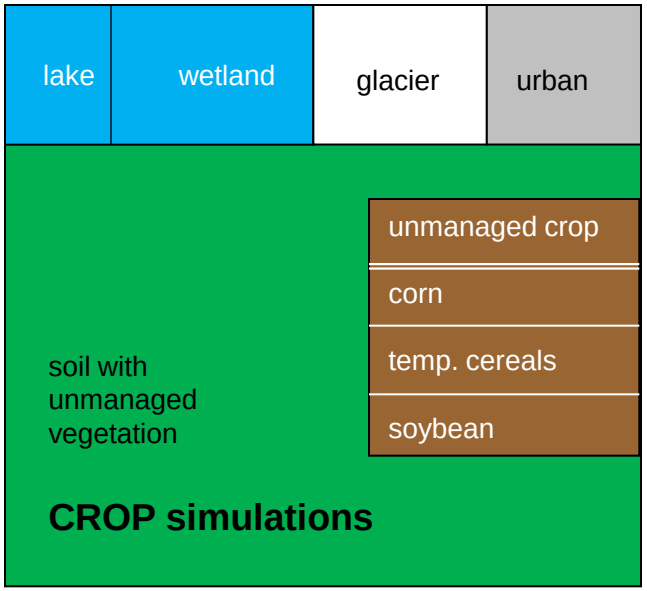
End of year 2+:
Establishment
Competition for Light (space)

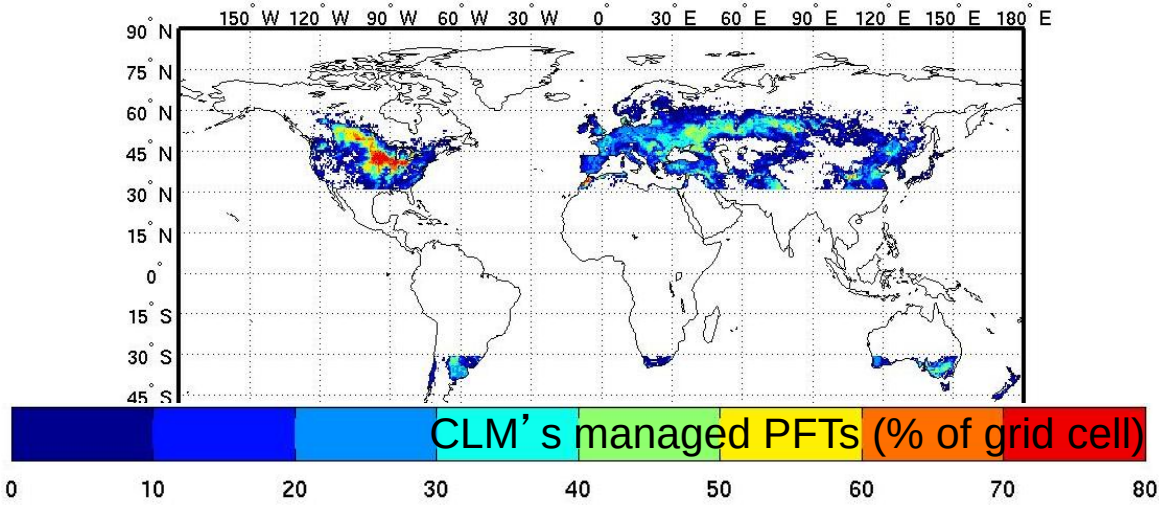
All these processes are affected by and may also affect the physics

Levis *et al.*

Newest option CLM4CNcrop
Interactive crop management



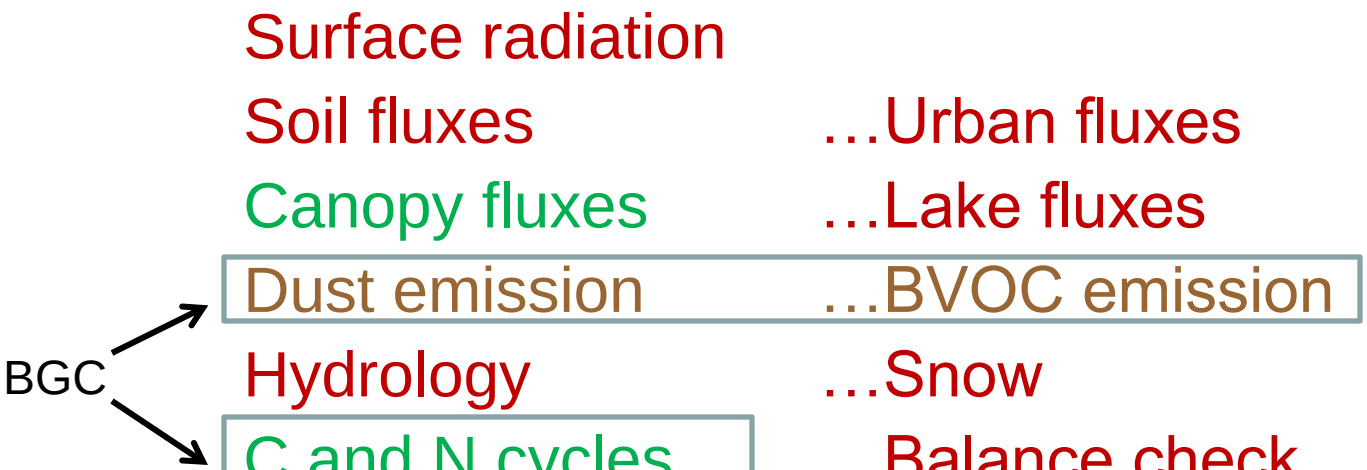




Levis *et al.*

Subroutine Tree

- Initialize
- Time stepping loop -



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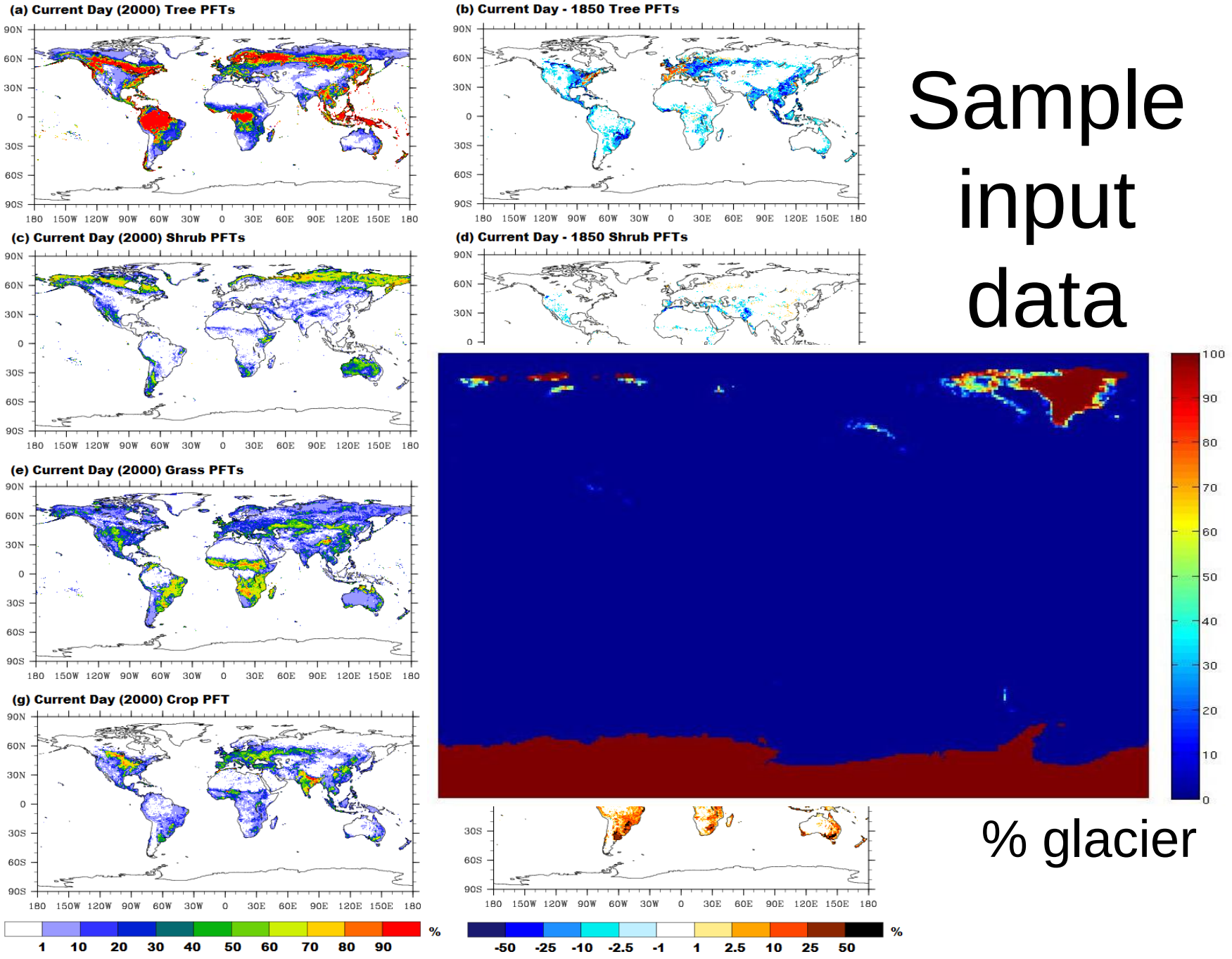
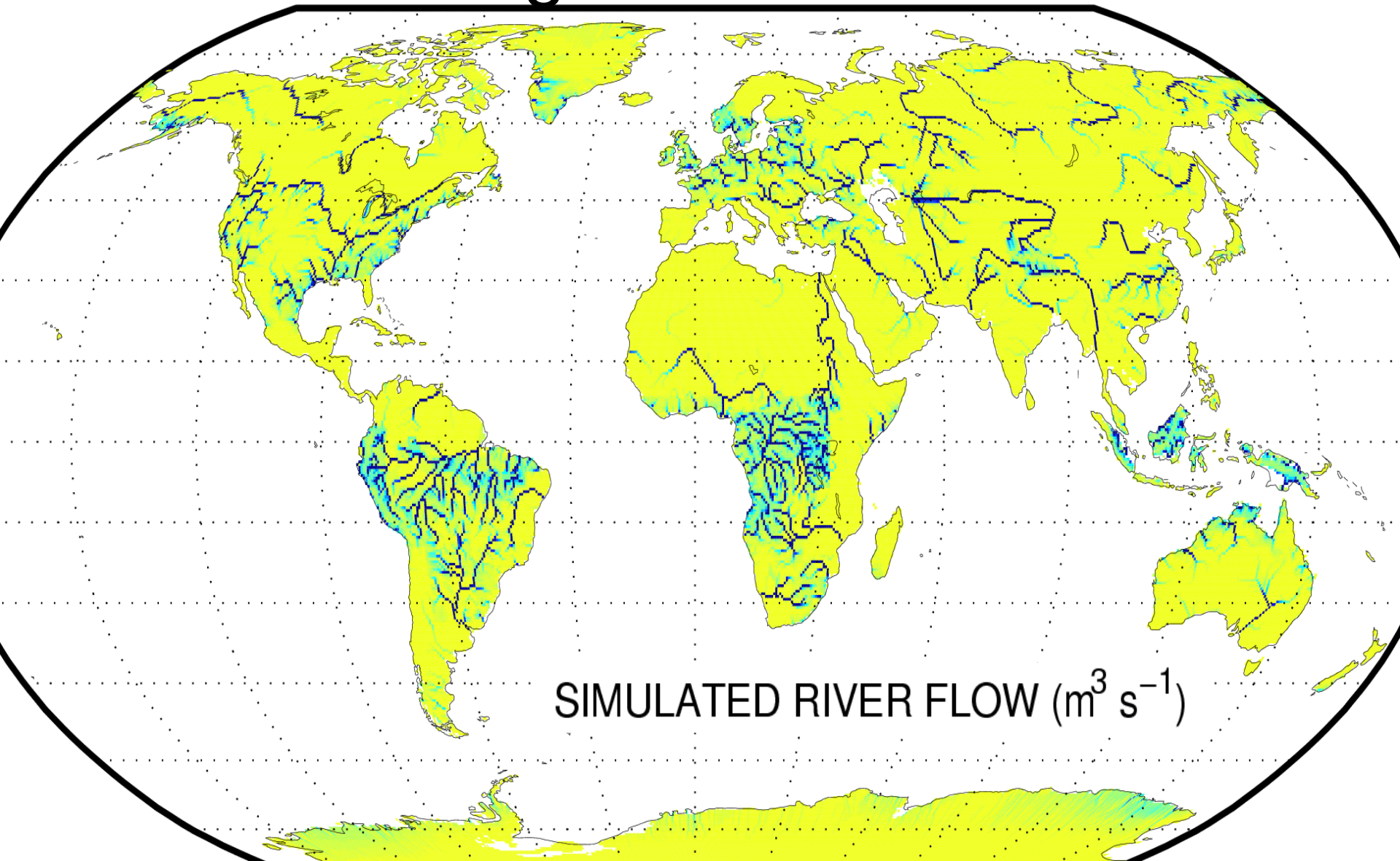
- CLM basics
- ➢ Sample input and output
- Climate-vegetation interactions

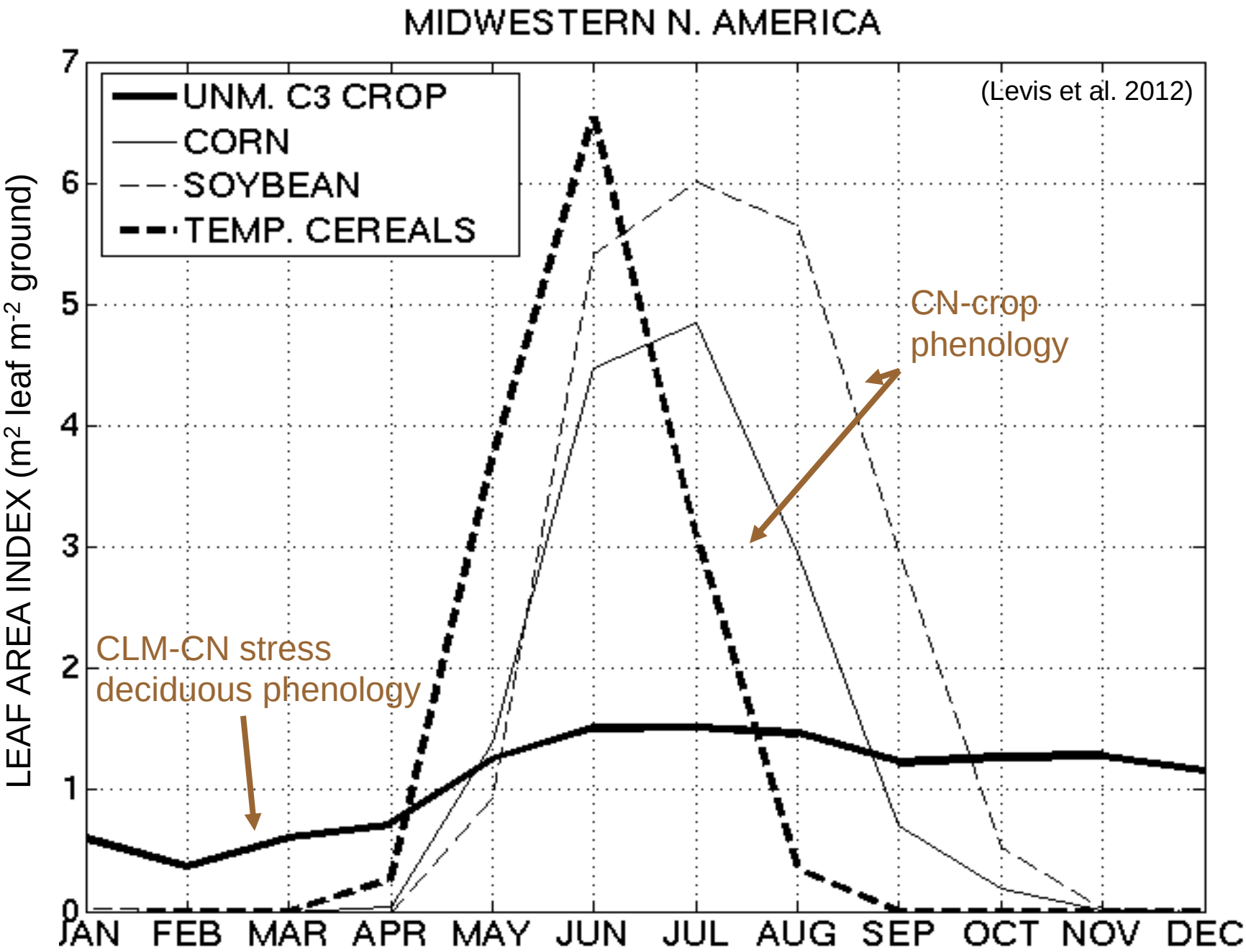


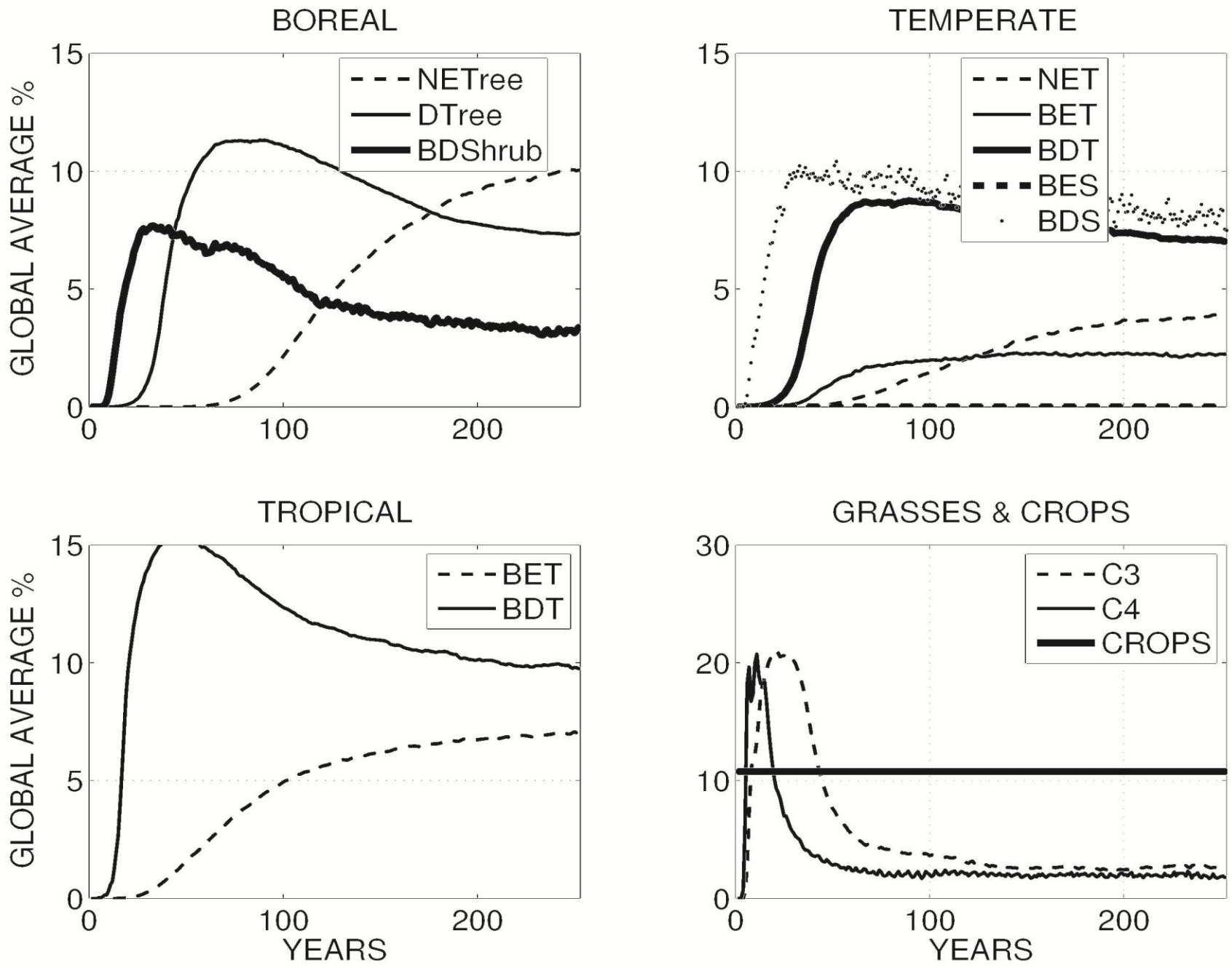
Sample input data

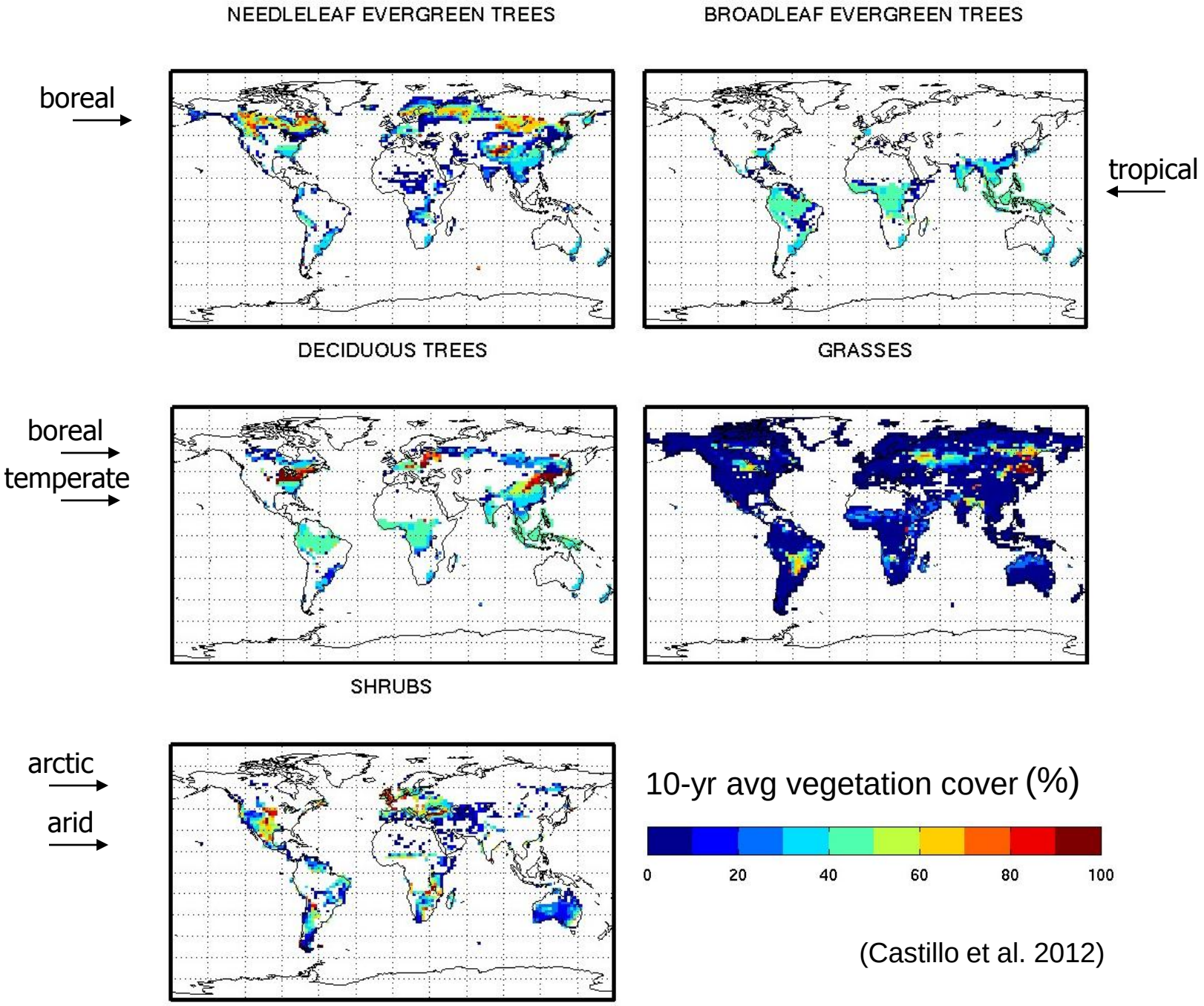
% glacier

Sample output: linking land to ocean




MIDWESTERN N. AMERICA
(Levis et al. 2012)
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 et al. 2012)

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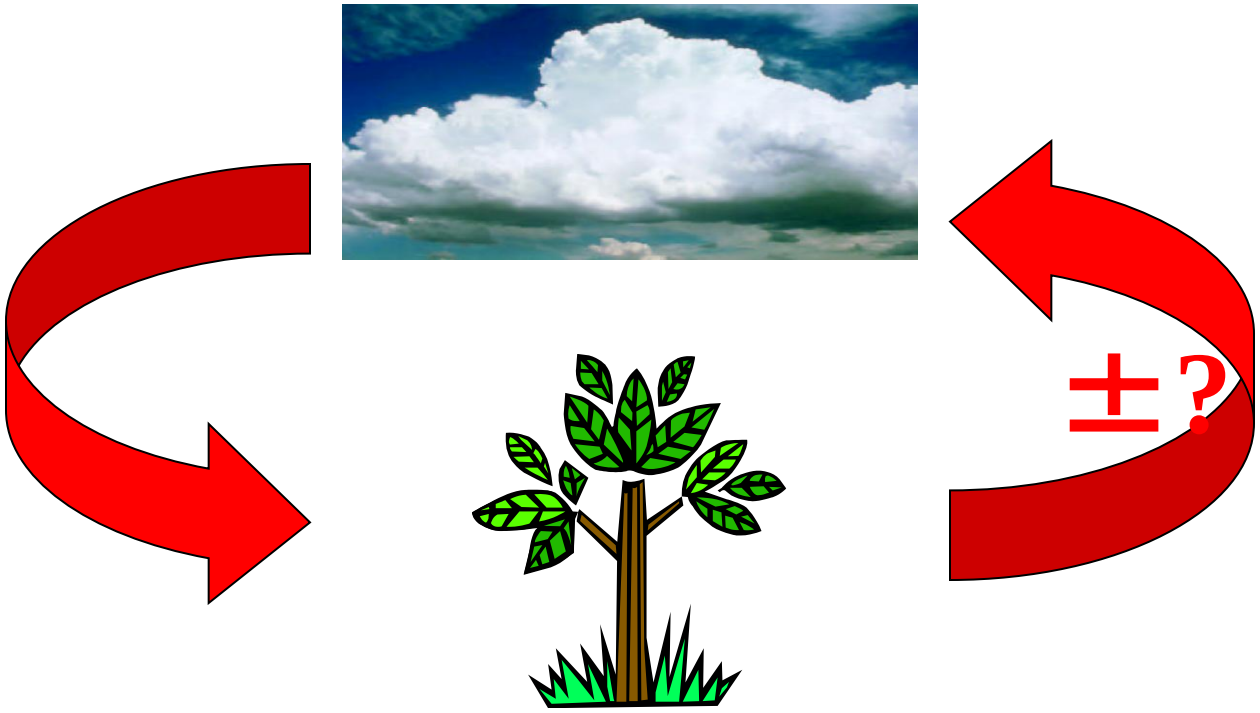
Climate-Vegetation Interactions

CLIMATE-VEGETATION FEEDBACKS



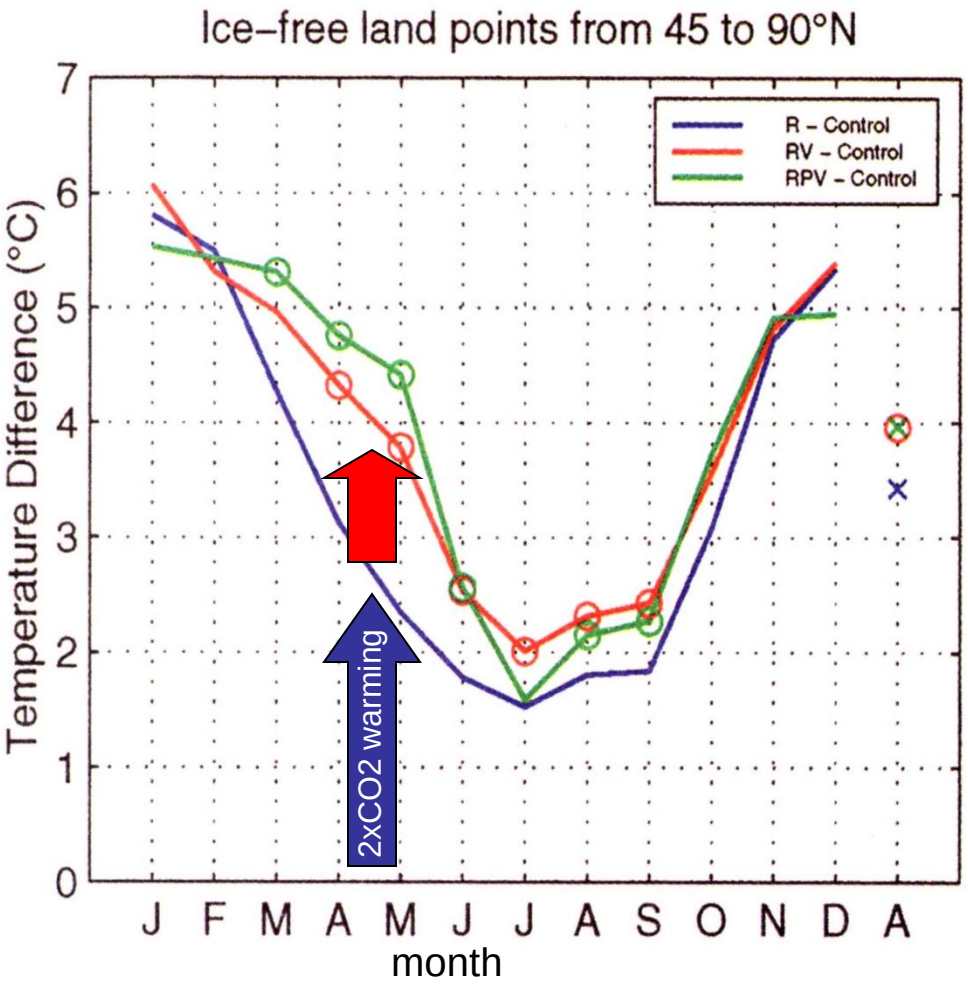
Climate-Vegetation Interactions
CLIMATE-VEGETATION FEEDBACKS

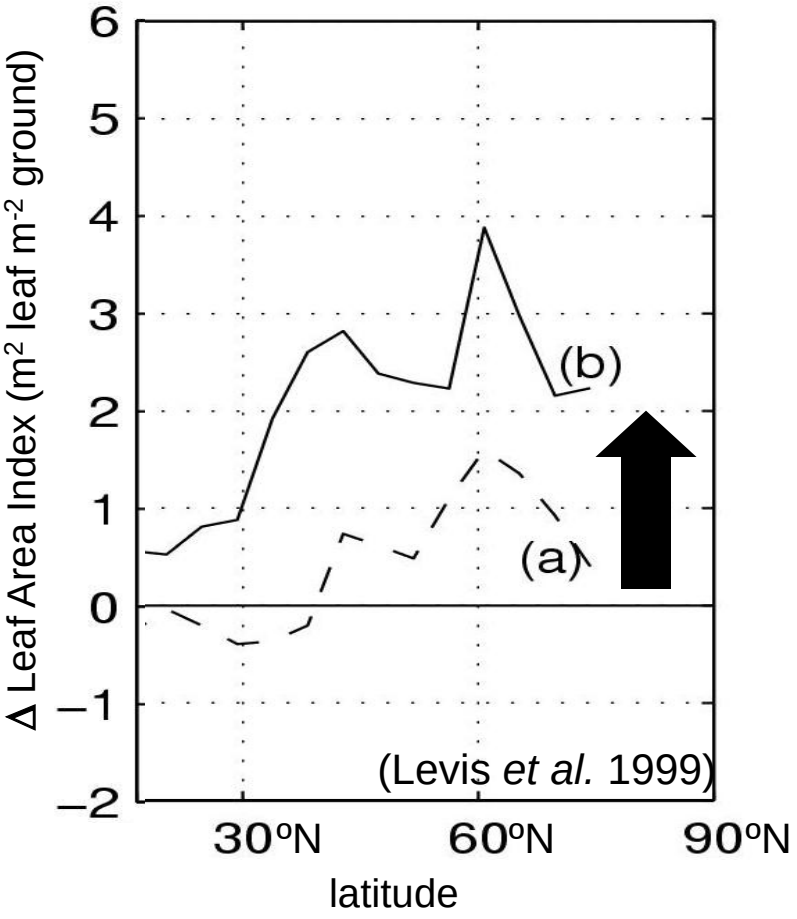
- Climate changes → vegetation responds
- Vegetation changes → climate responds:

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

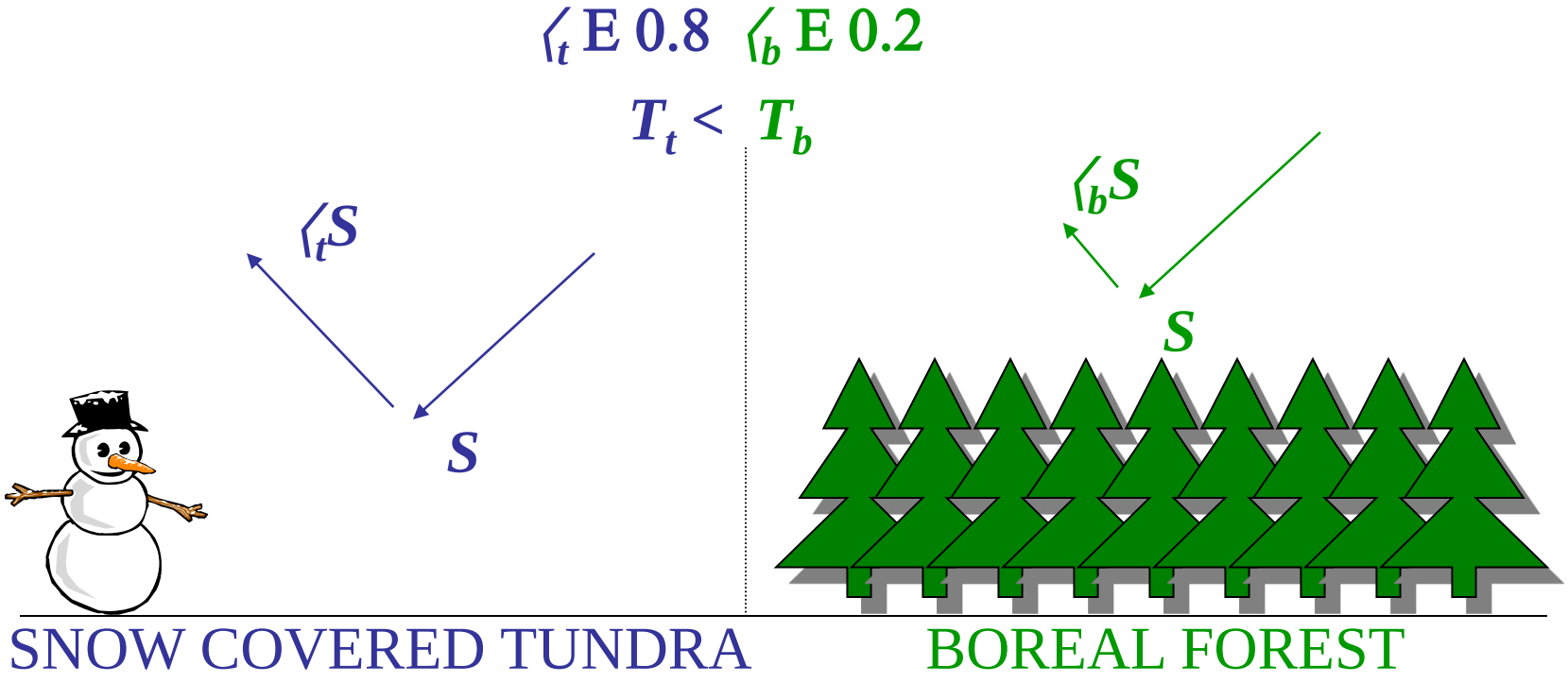




Biogeophysical feedbacks

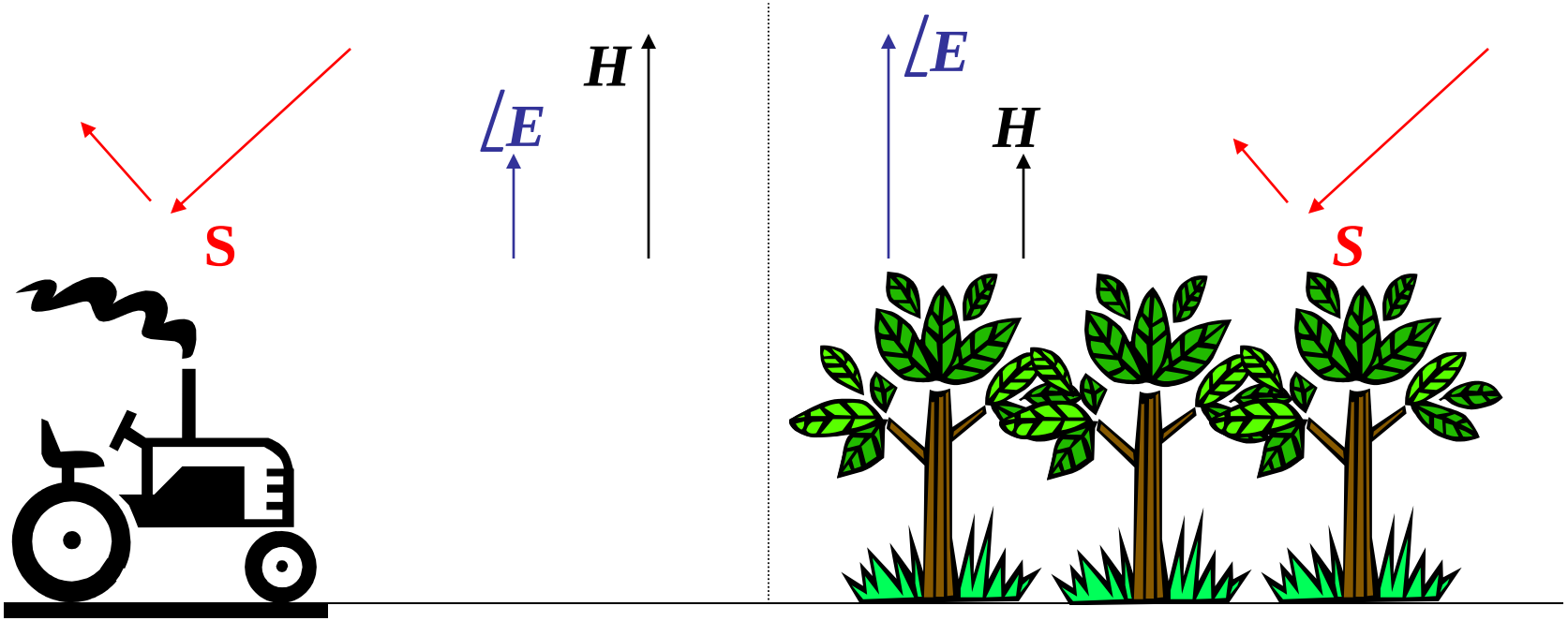
1. Surface radiation balance:

   Trees darken snow-covered surfaces



Biogeophysical feedbacks

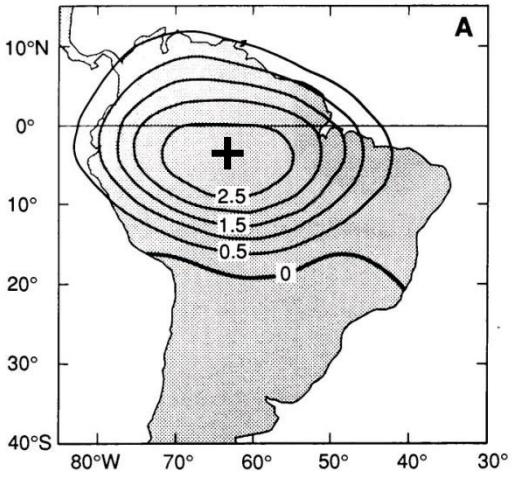
1. Surface radiation balance
   Trees darken snow-covered surfaces
2. Surface heat balance $R_n = H + \lambda E$
   Vegetation increases the latent heat flux



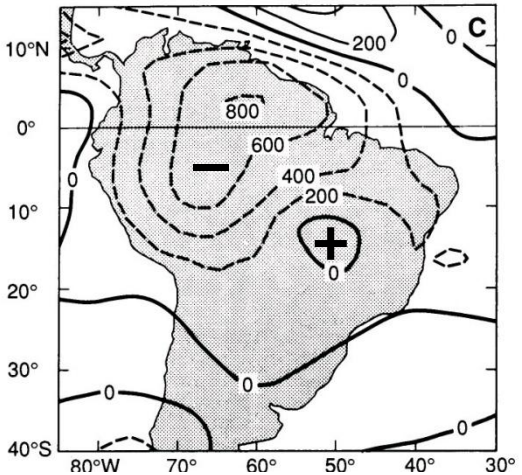
AMAZON BASIN

Trees increase evapotranspiration …deforestation decreases it

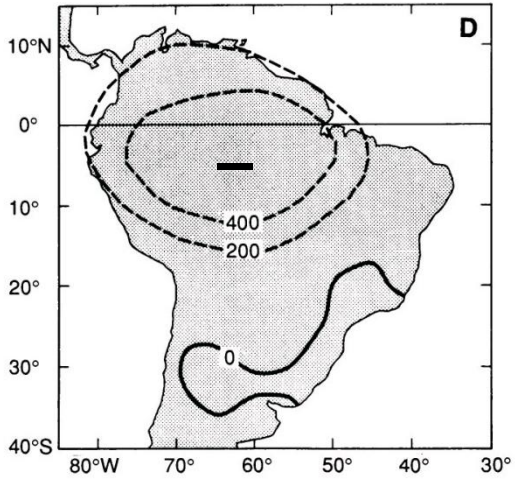
Temperature (K)



Precipitation (mm yr^{-1})

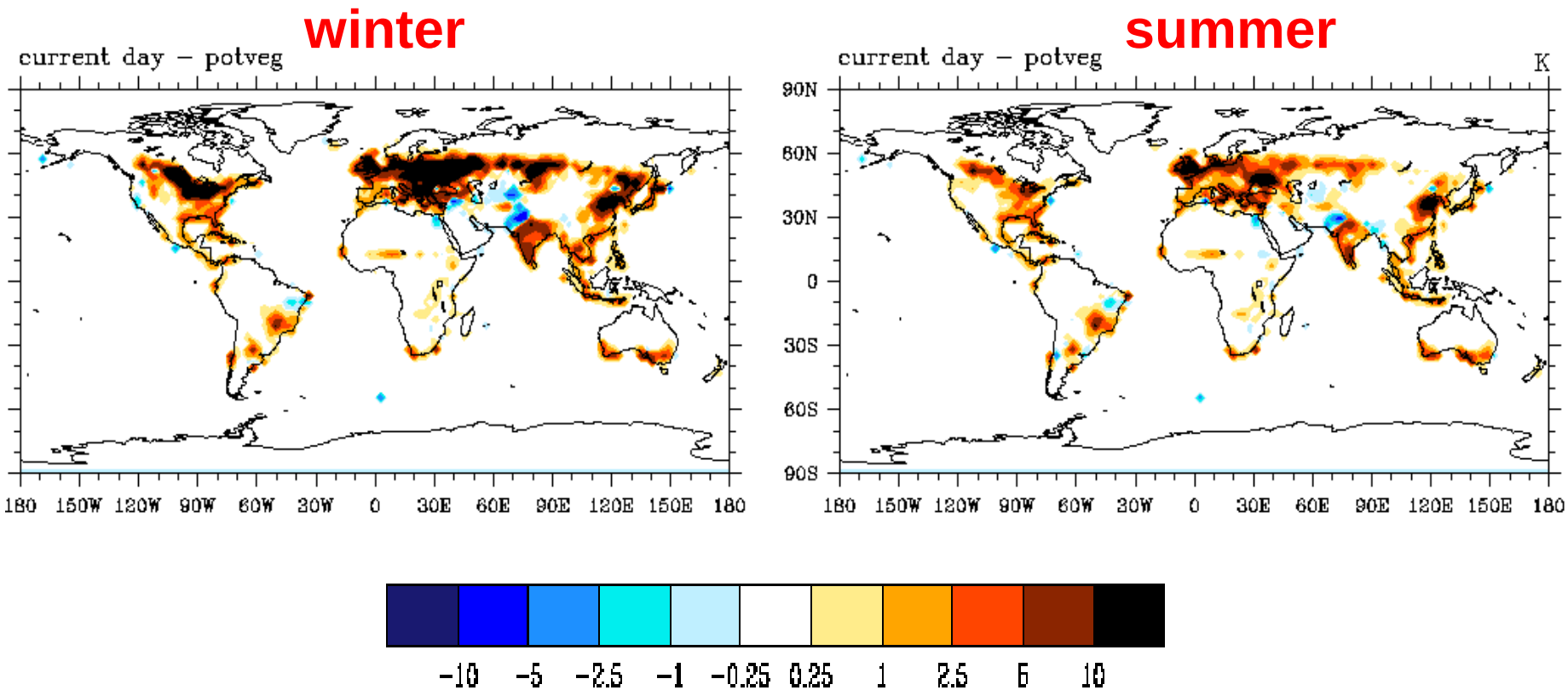


Evapotranspiration (mm yr^{-1})

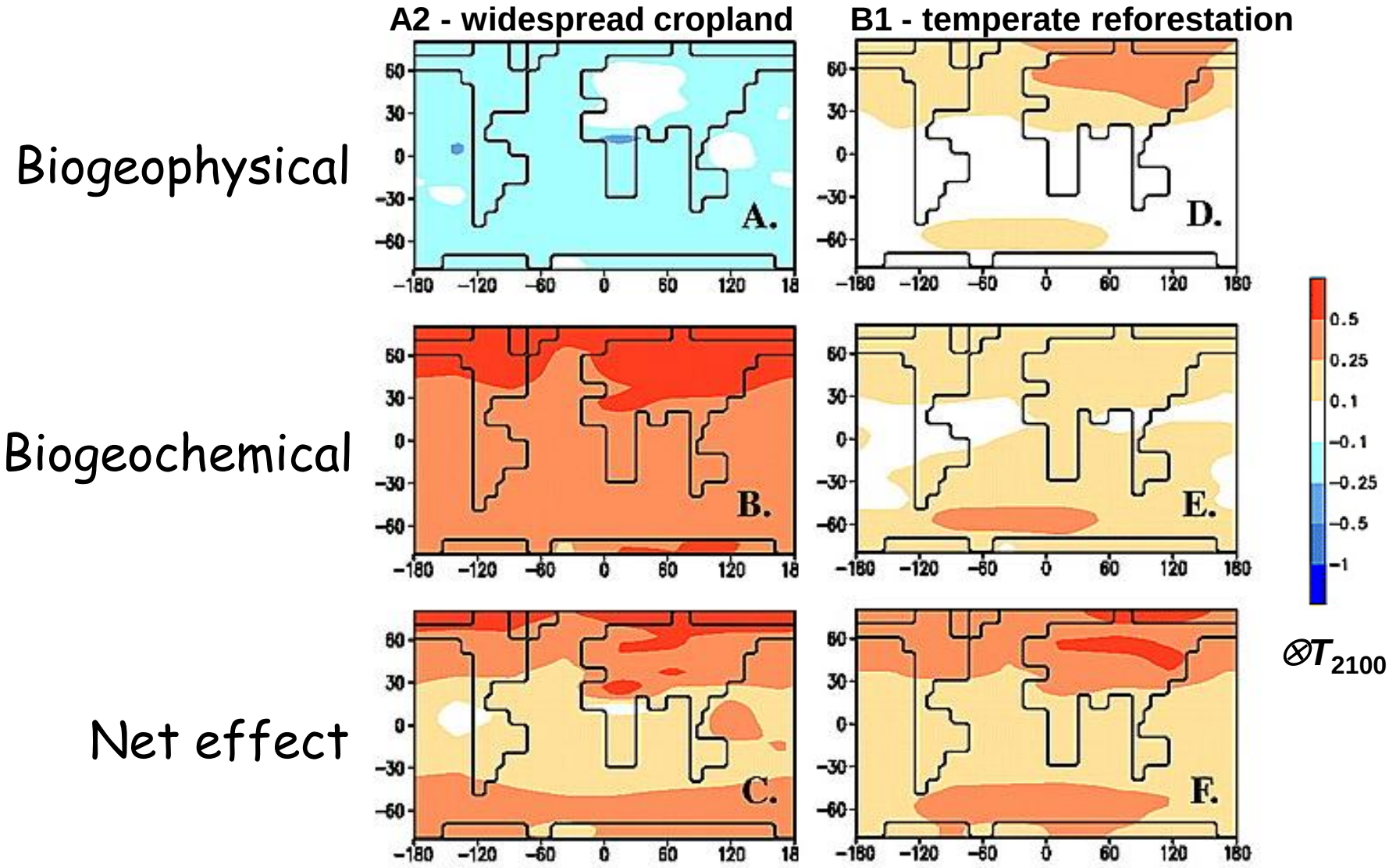


(Shukla *et al.* 1990)

Effect of deforestation on albedo

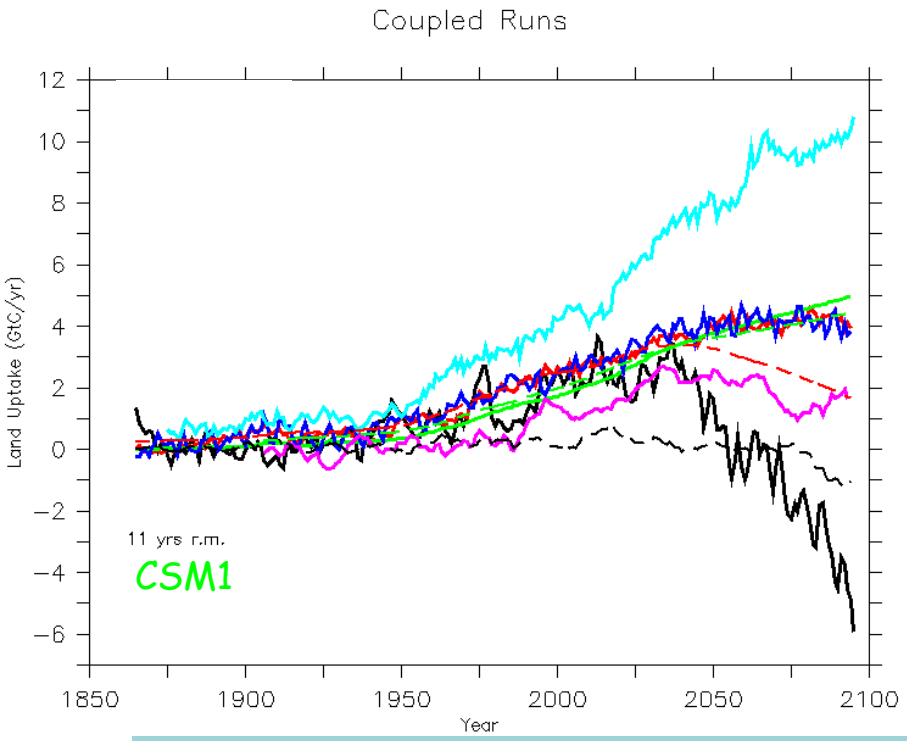


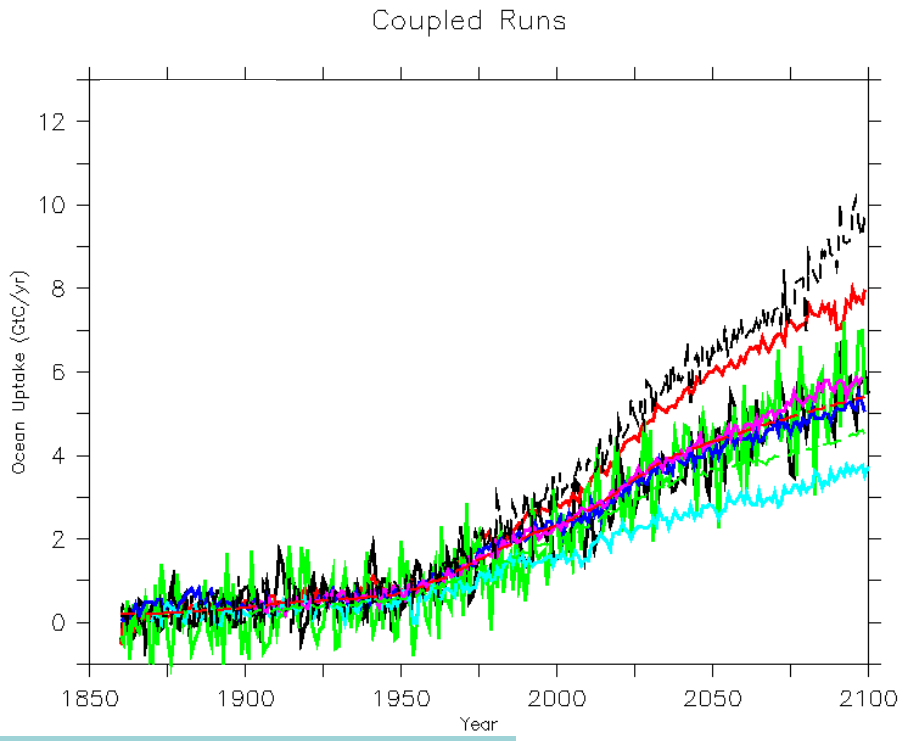
Future land use effect on temperature



(Sitch *et al.* 2005)

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



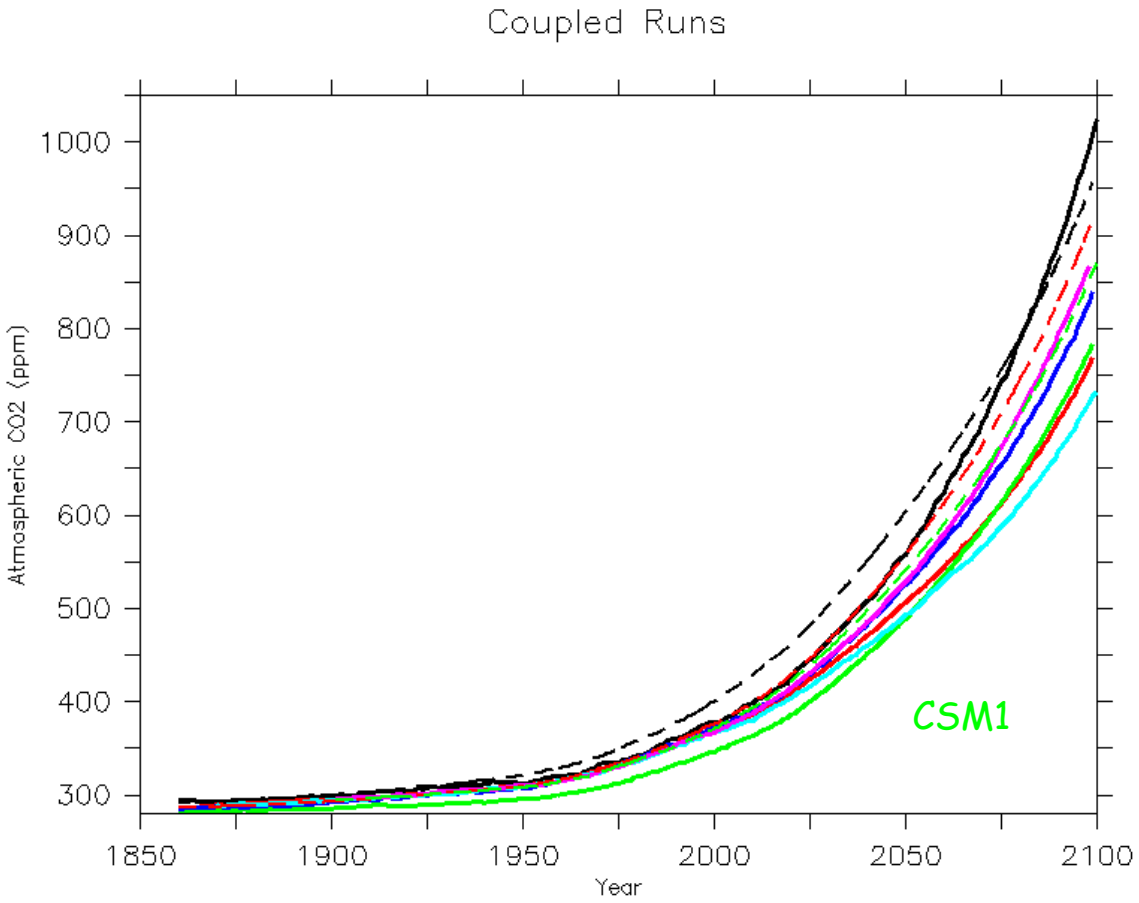


Uncertainty arises from differences in terrestrial fluxes

- 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

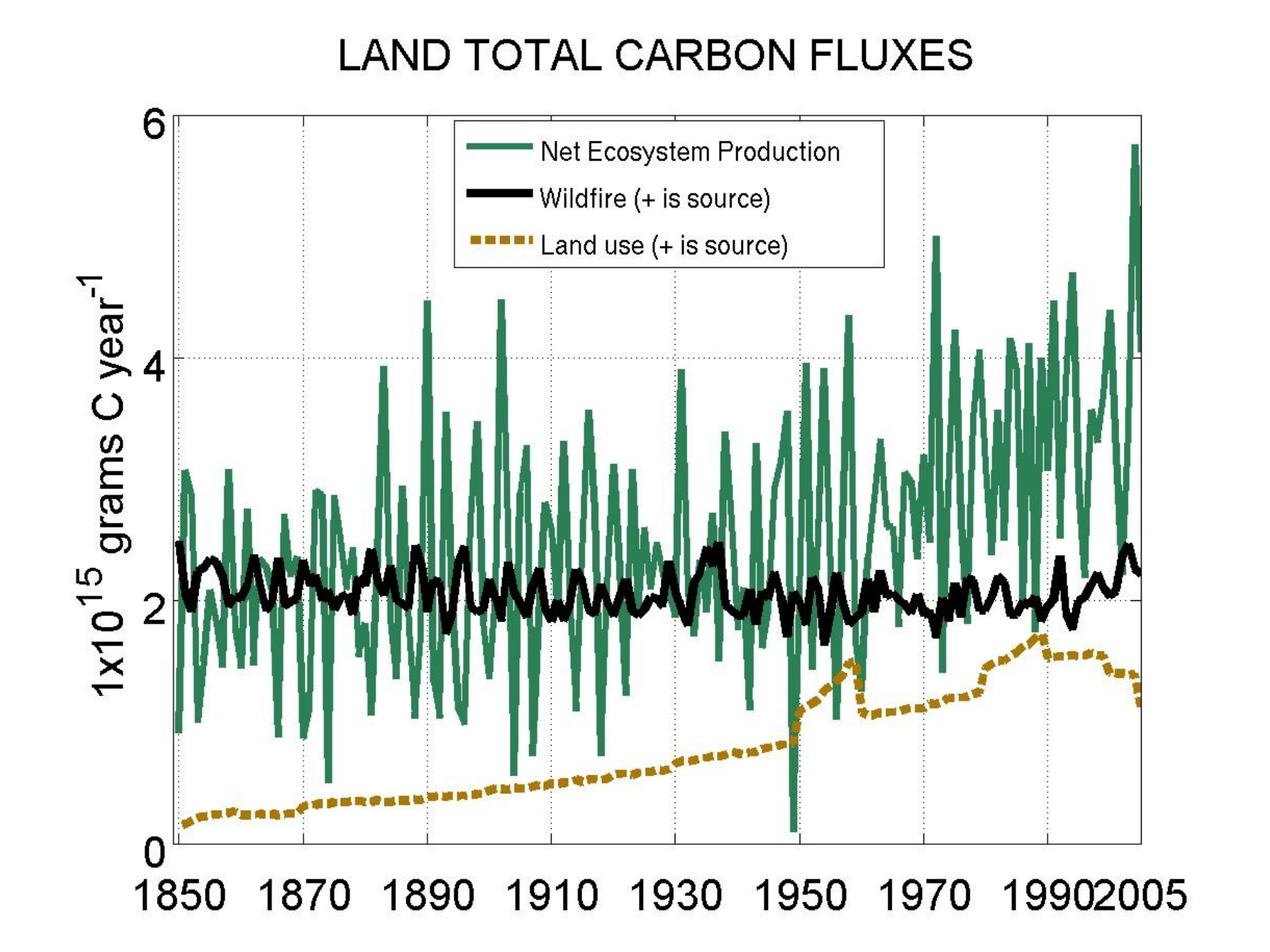
Carbon model intercomparison:
Nine climate models of varying complexity with active carbon cycle



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 w/ examples of 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?