Community Land Model Overview

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7/30/09 CAM Tutorial

CLM overview
outline

- CLM basics
- Sample output (of interest to me)
- Applications (land-atm interactions)

CLM…
land component of the CCSM

- source code (/models/lnd/clm/src)
- input data (atm + sfc)
- output data
- ccsm's scripts (can run just clm)
- documentation (on web site)

What the CLM does in 100 words or less

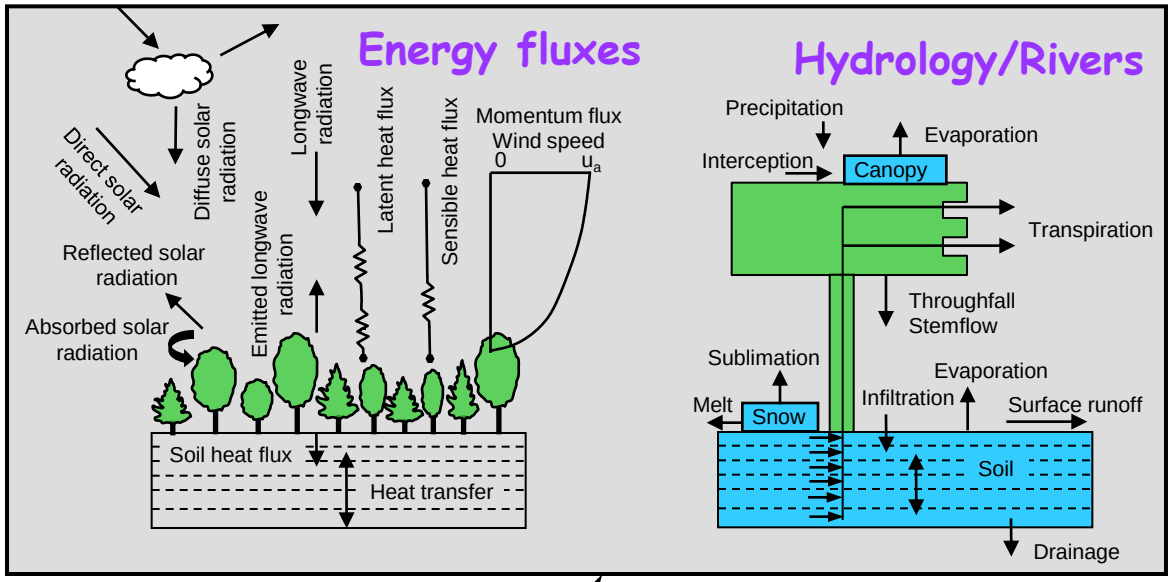
✓INPUT: - near-surface atmosphere data (sim/obs)
S, *L*, *T*, *q*, *u*, *v*, *p*, *P*, [CO_2]
- surface data (sim/obs)
veg., soil, other data (eg, %lake)

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

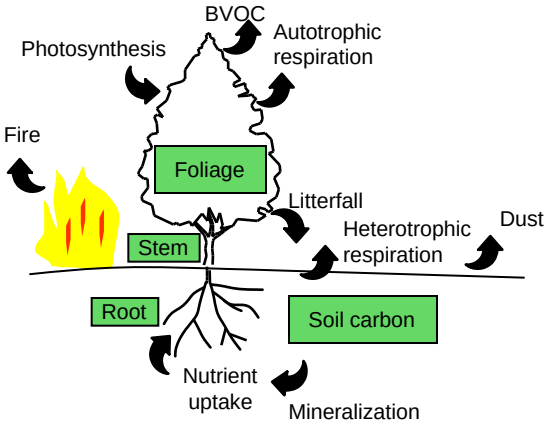
} the energy and mass exchange at the interface

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

Current-generation land models



Biogeochemical Cycles



Climate change

Establishment

Climate change

Disturbance

Ice sheets

Vegetation dynamics

Competition

Growth

Deforestation

Land use

Reforestation

Land Mgmt

Urbanization

At the core of the CLM

are time stepping algorithms ensuring

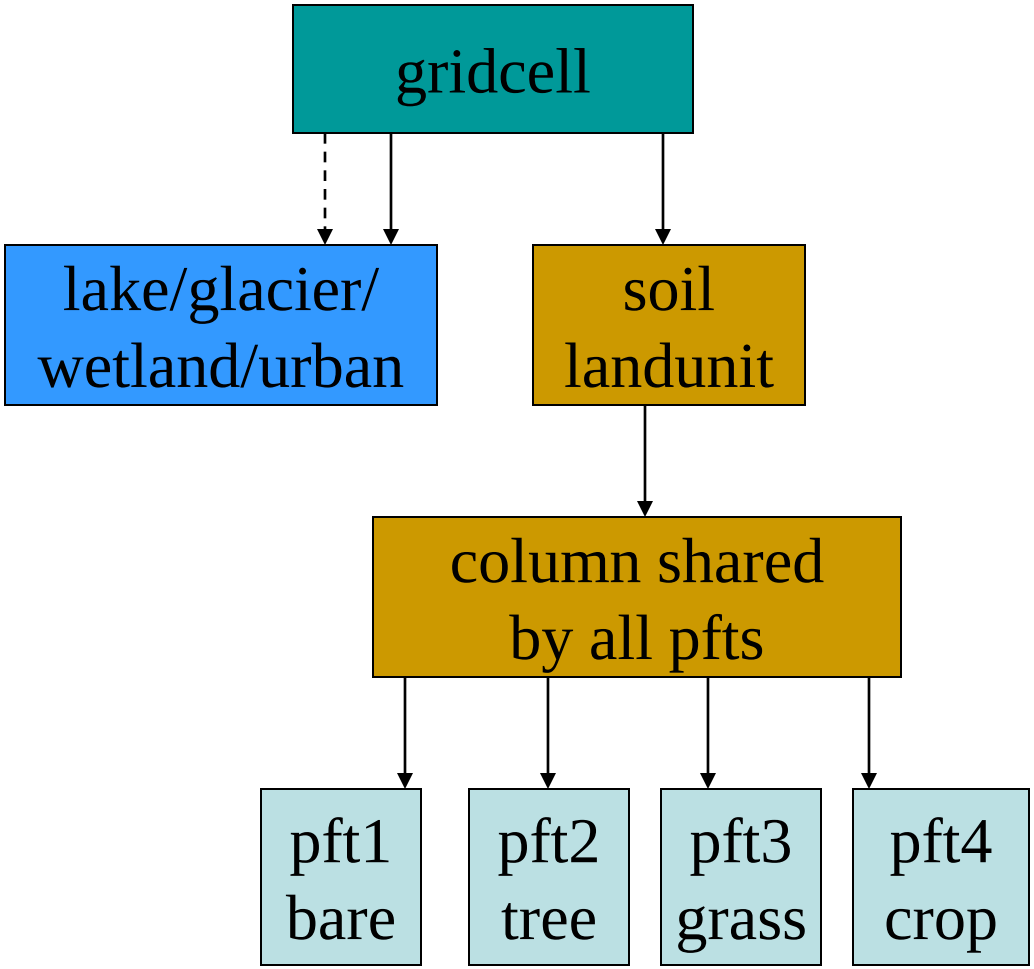
conservation of energy

$$S - L - \lambda E - H - G = 0$$

conservation of mass

$$P - E - R - \Delta\theta / \Delta t = 0$$

CLM Sub-Grid Hierarchy



Subroutine Tree

- Initialize
- Driver (in time stepping loop) →

Hydrology1	…Surface radiation
Biogeophysics1	…Soil fluxes
Canopy fluxes	…Lake fluxes
Dust emission	…VOC emission
Biogeophysics2	…Hydrology2
Lake hydrology	…Snow
Carbon cycle	…Balance check
Surface albedo	…River flux

Dynamic vegetation

write history and restart data

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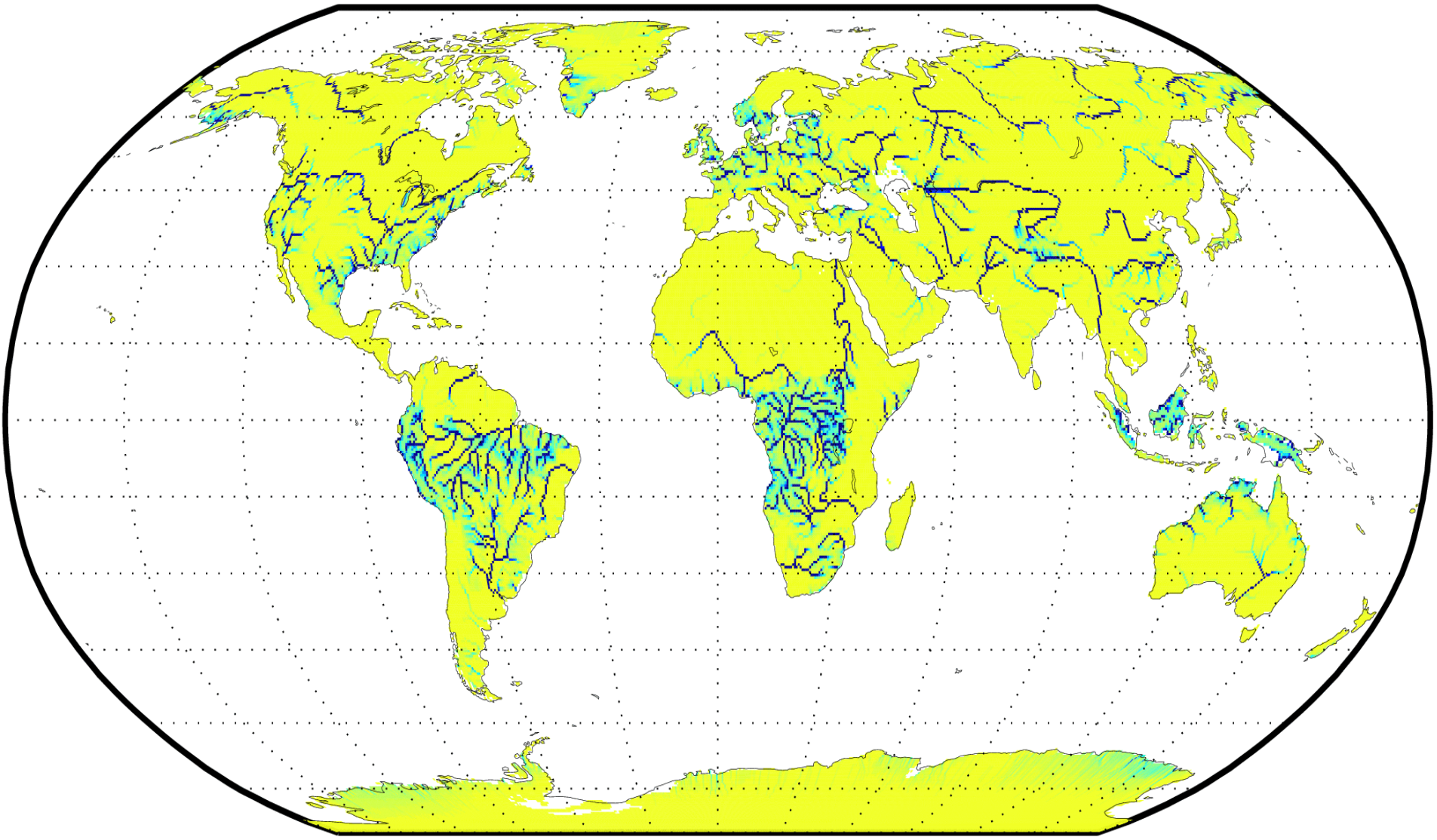
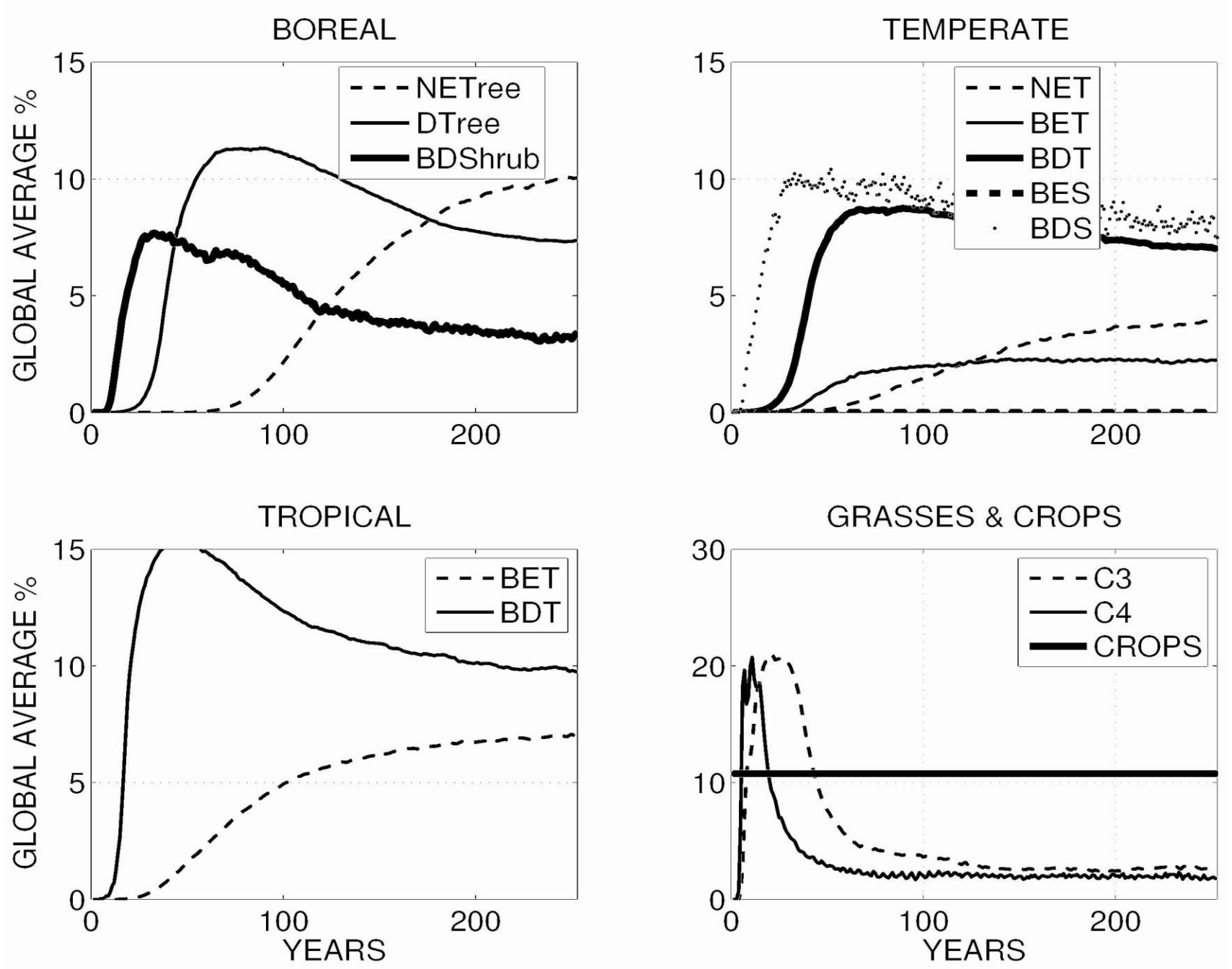
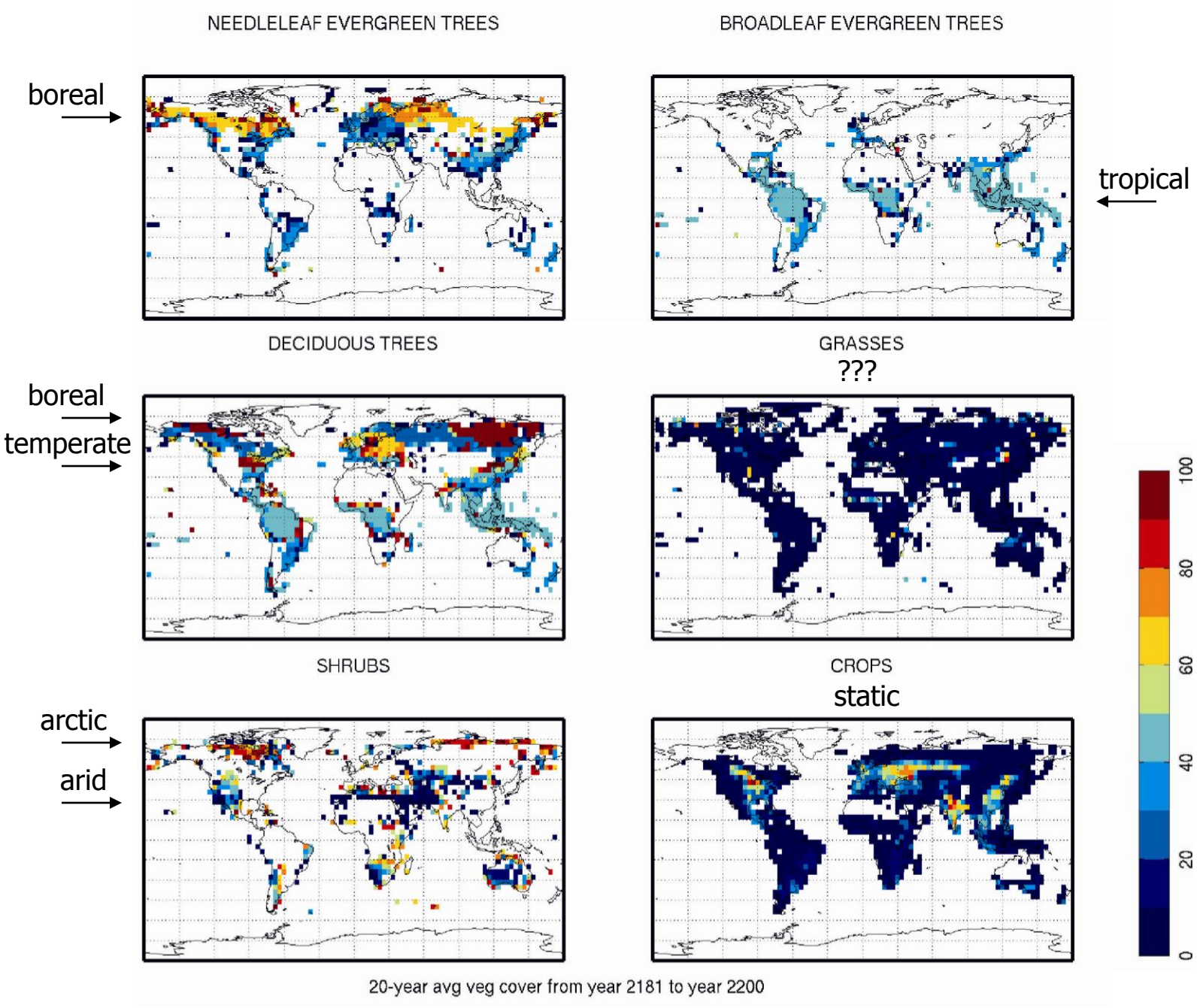
SIMULATED RIVER FLOW ($m^3\ s^{-1}$)




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
CROPS
static
arctic
arid
100
80
60
40
20
0
20-year avg veg cover from year 2181 to year 2200

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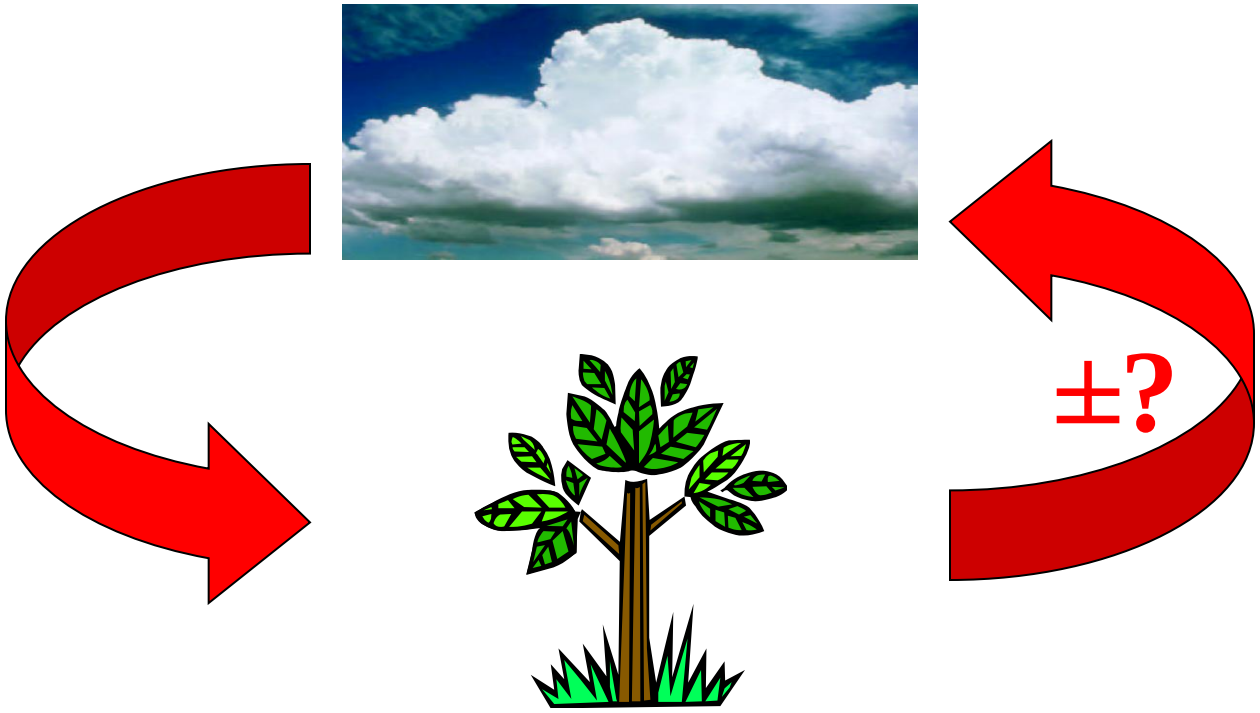
Land-Atmosphere Interactions

LAND-ATMOSPHERE FEEDBACKS



Land-Atmosphere Interactions
LAND-ATMOSPHERE FEEDBACKS

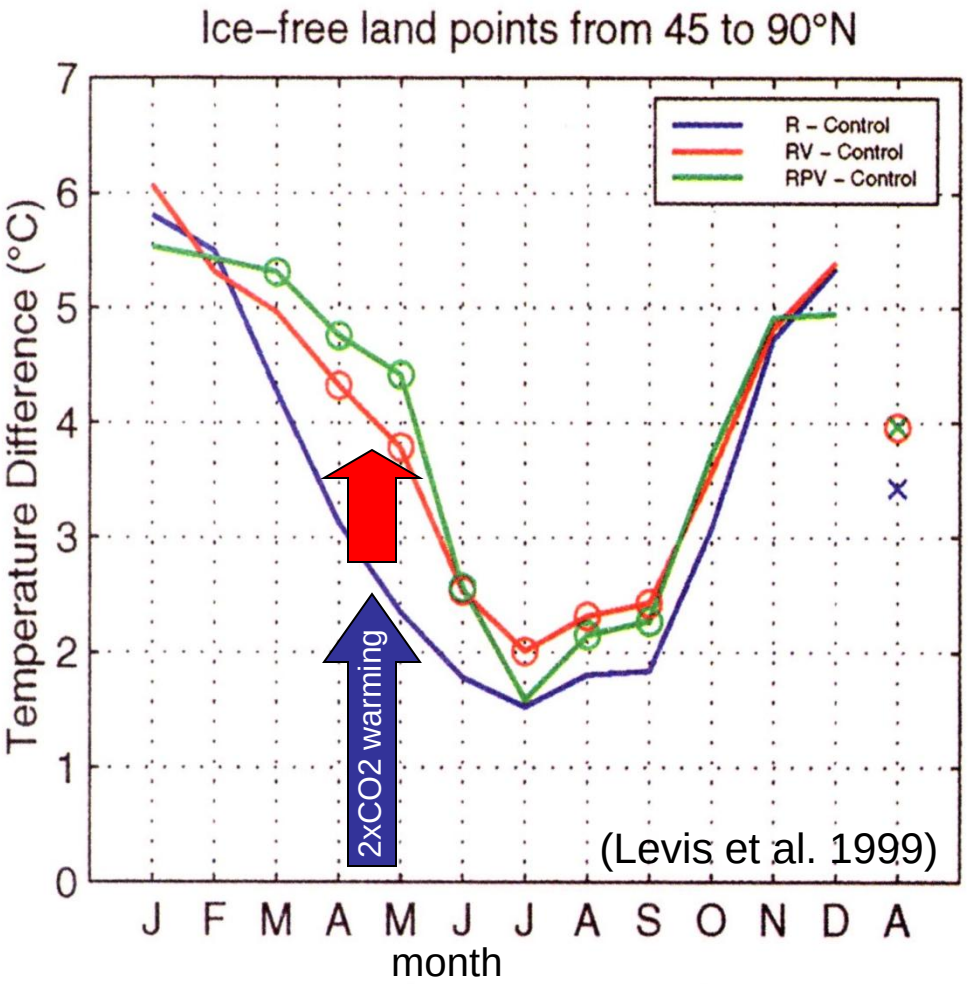
- Climate changes → vegetation responds
- Vegetation changes → climate responds:

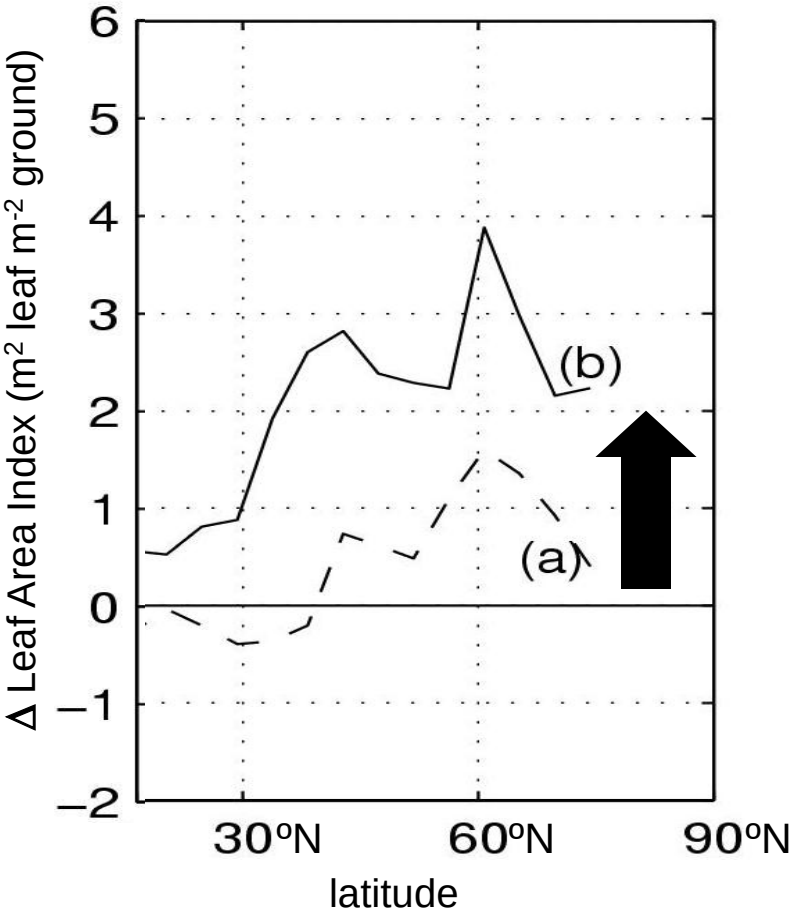
A. Biogeophysical feedbacks:

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

B. Biogeochemical feedbacks (e.g. carbon cycle)

2 x CO_2 climate and vegetation

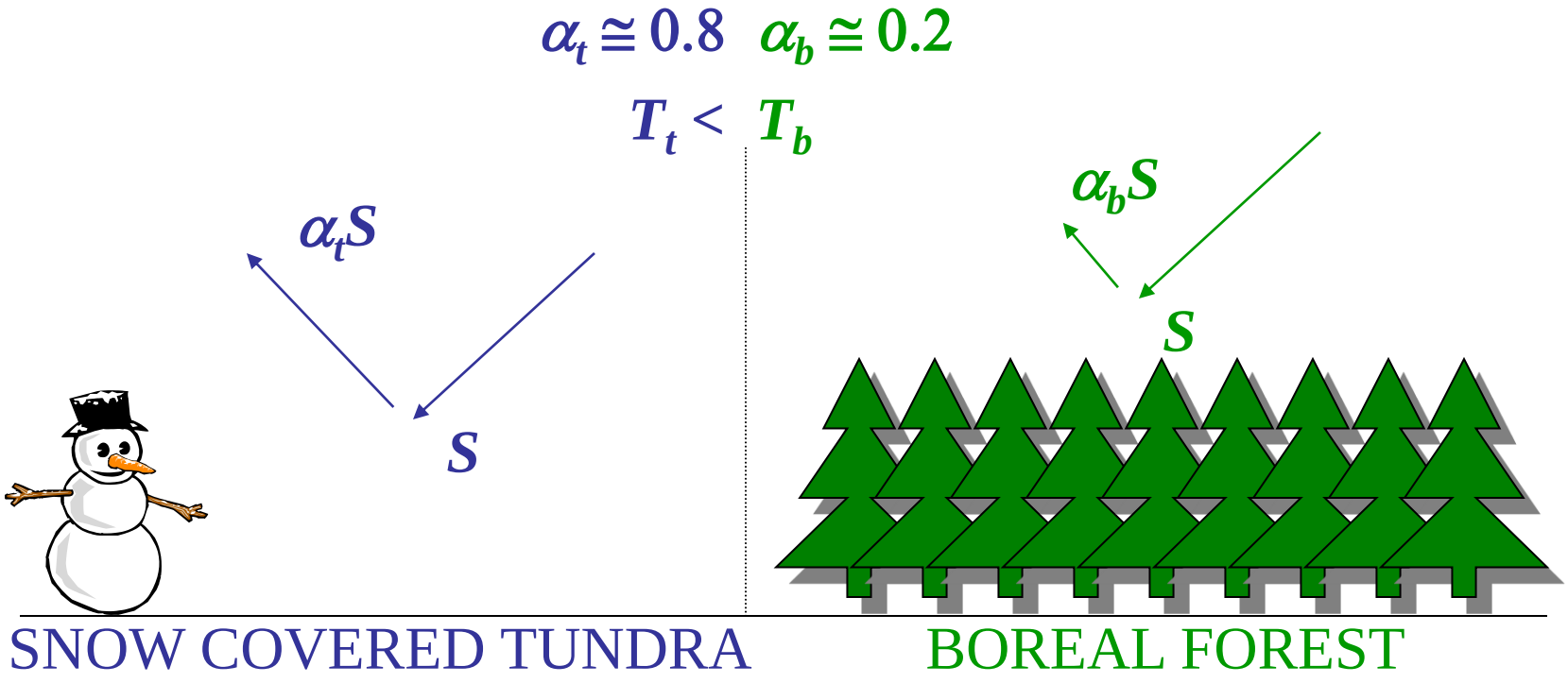




Biogeophysical feedbacks

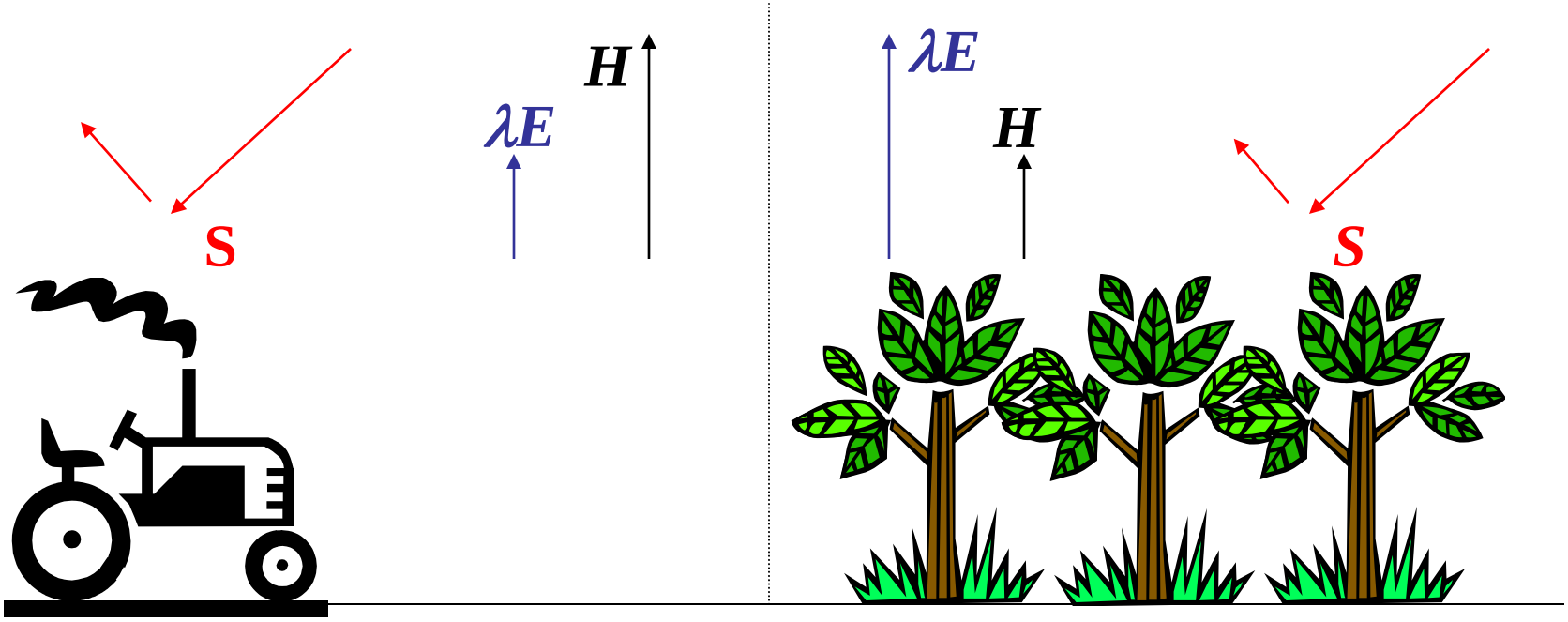
1. Surface radiation balance:

   Trees darken snow-covered surfaces



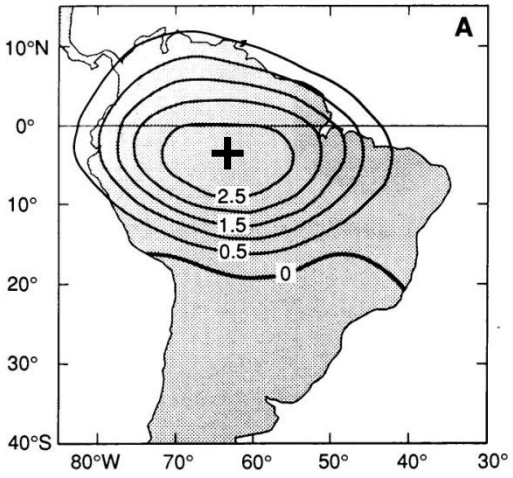
Biogeophysical feedbacks

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

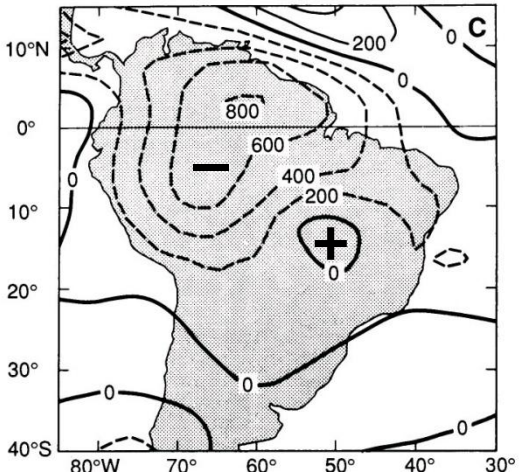


Trees increase evapotranspiration …deforestation decreases it

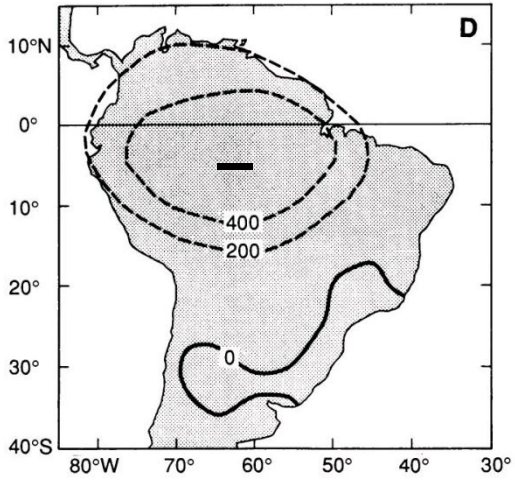
Temperature (K)



Precipitation (mm yr^{-1})

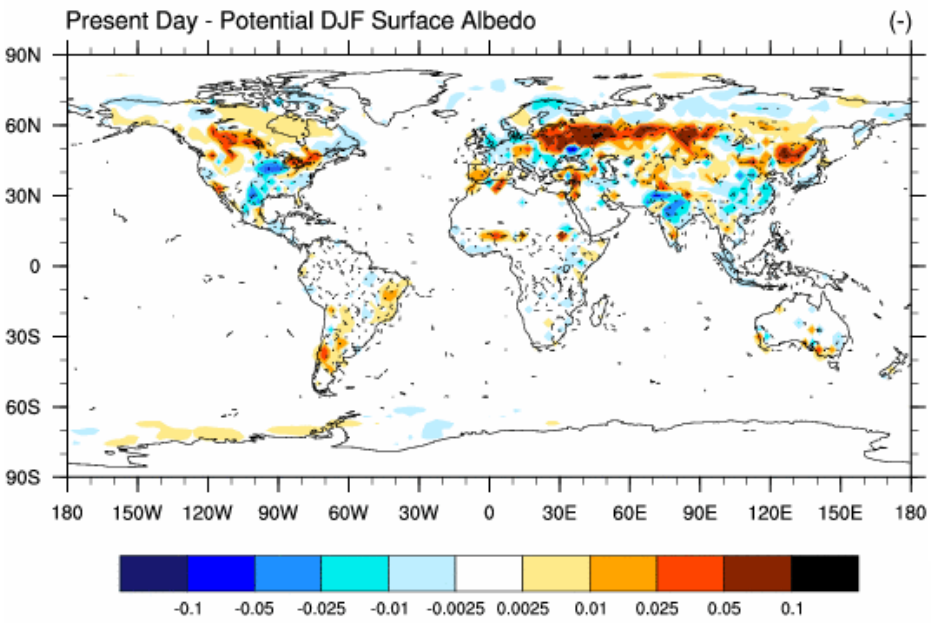


Evapotranspiration (mm yr^{-1})



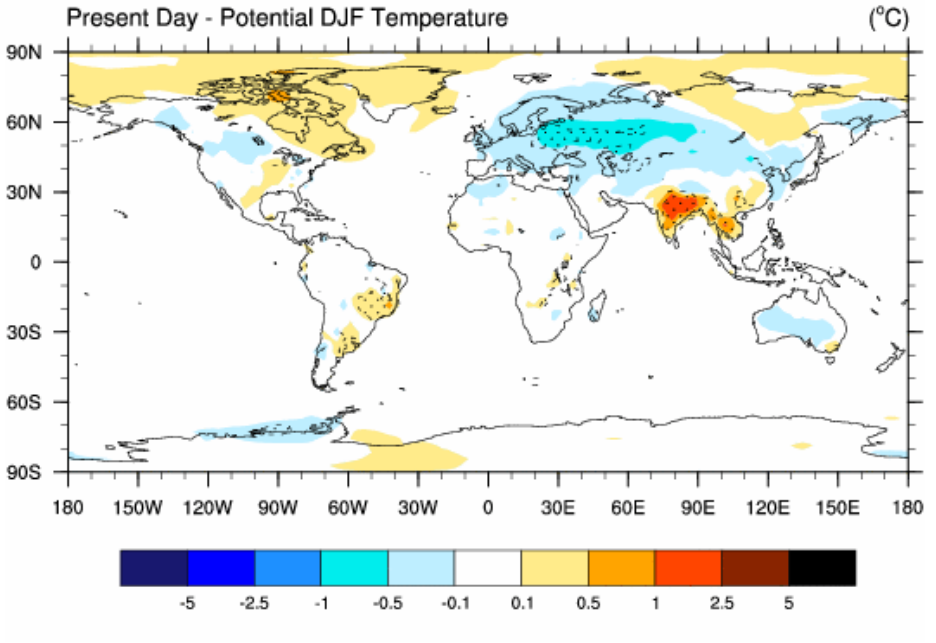
(Shukla et al. 1990)

Vegetation-snow albedo feedback



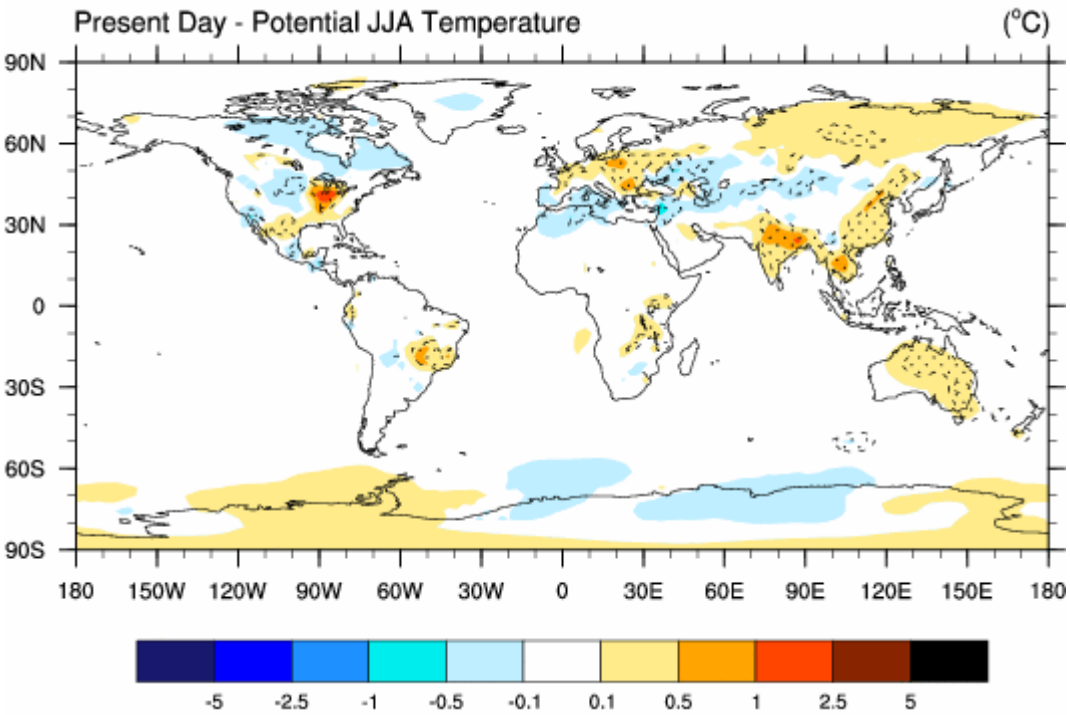
CAM3/CLM3.5 ensemble average

Increased surface albedo
➔ cooling



Bonan et al., unpublished

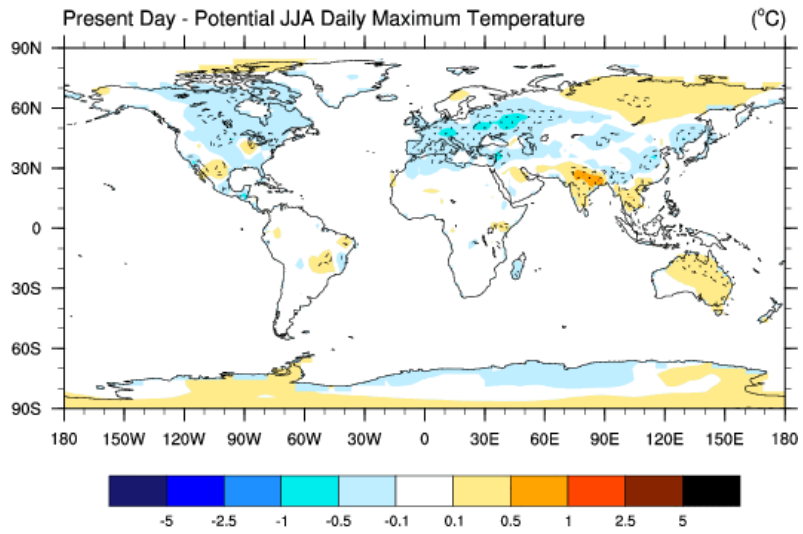
Mid-latitude summer

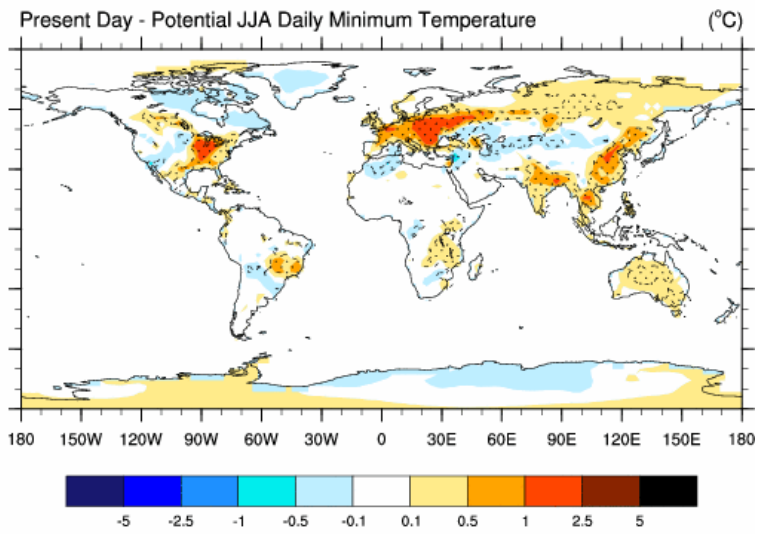


CAM3/CLM3.5 ensemble average

Decrease in daily maximum is offset by increase in daily minimum temperature

Feedbacks with clouds & precip





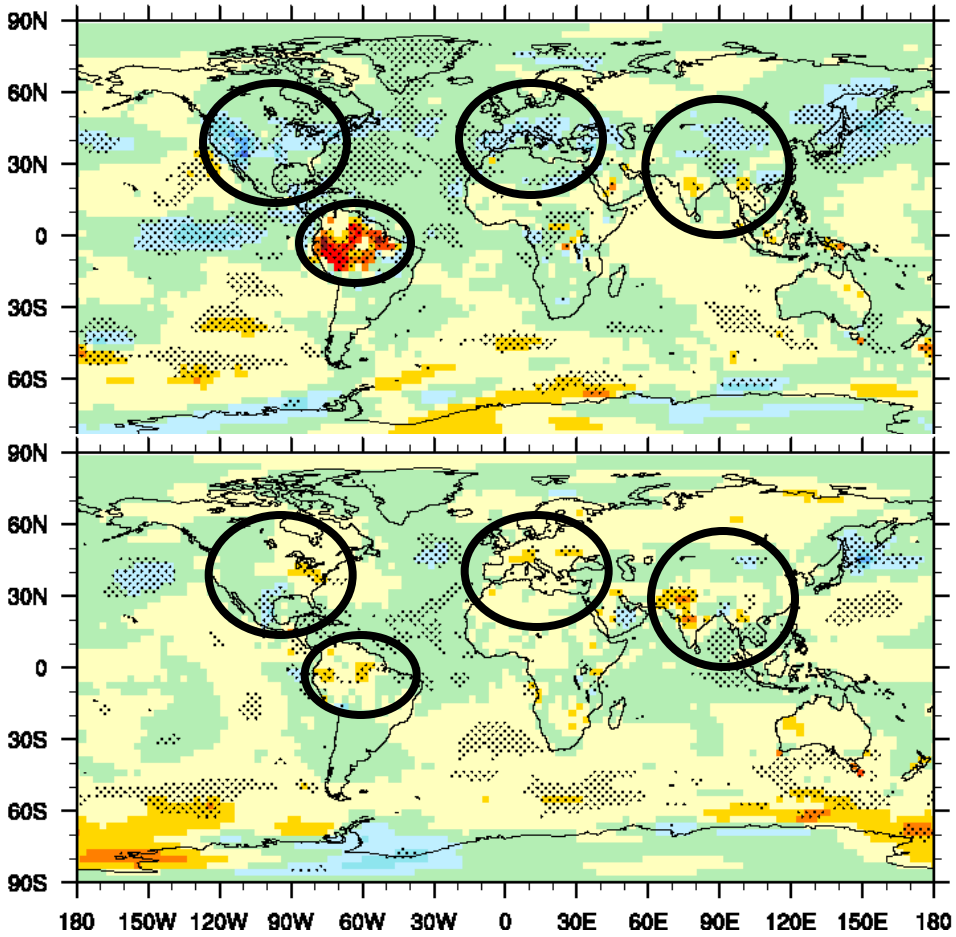
Bonan et al., unpublished

Future land use effect on temperature

(SRES land cover + SRES atmospheric forcing) - SRES atmospheric forcing

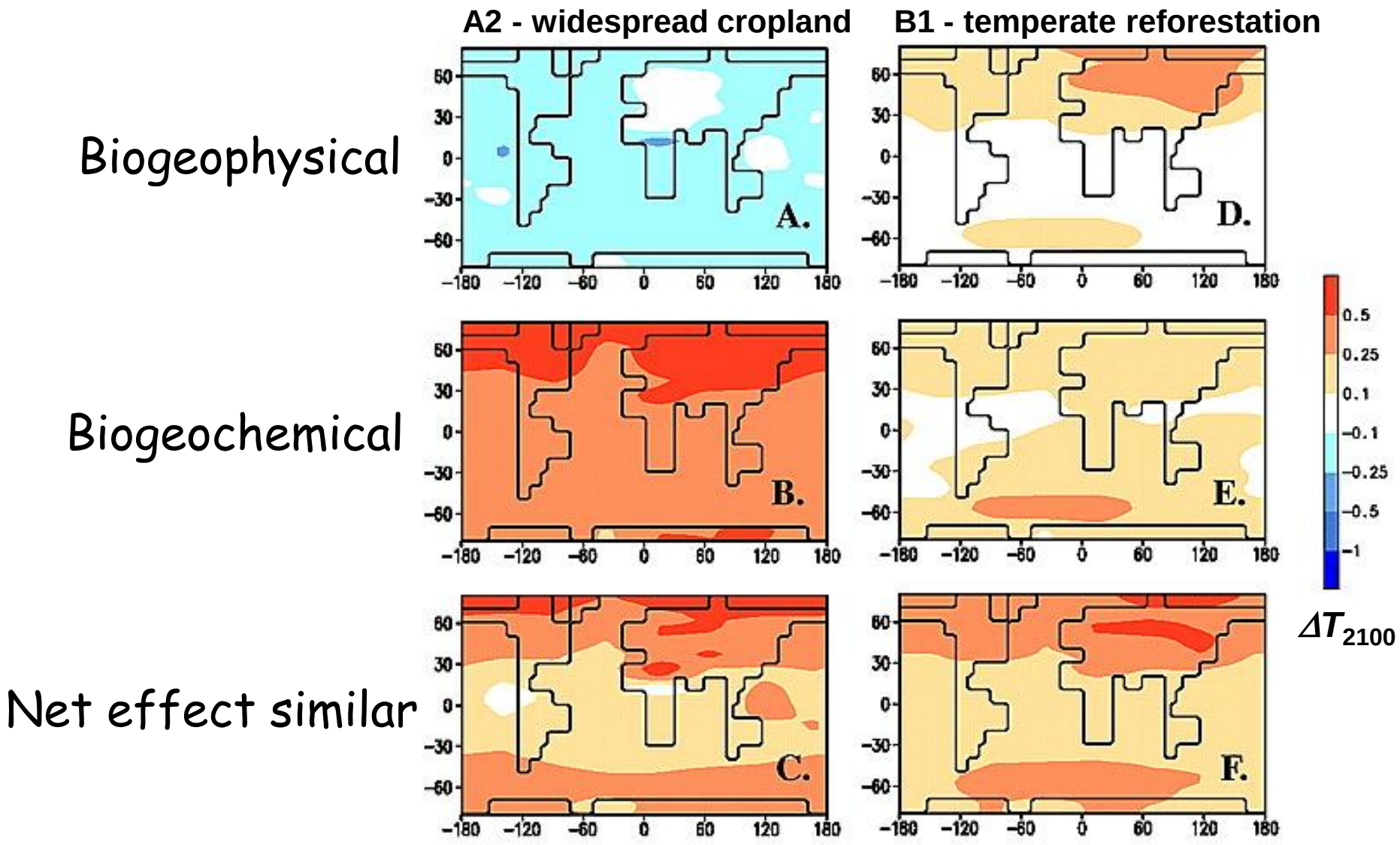
A2 - Most arable land used for farming by 2100 to support a large global population

B1 - Temperate reforestation due to declining population and farm abandonment in the latter part of the century



Feddema et al. (2005) Science 310:1674-1678

Future land use effect on temperature



Sitch et al. (2005) *GBC*, doi:10.1029/2004GB002311

Summary

The land surface can affect local to regional climate, often through feedback mechanisms

Examples I discussed

boreal forest ↔ tundra in the high latitudes

tropical and temperate deforestation

Other examples

desert ↔ savanna in North Africa

soil moisture, irrigation

urbanization

BGC