Land Surface Models

ZL Yang

References:
Pitman (2003)
Yang (2004)
Bonan (2008) Ecological Climatology

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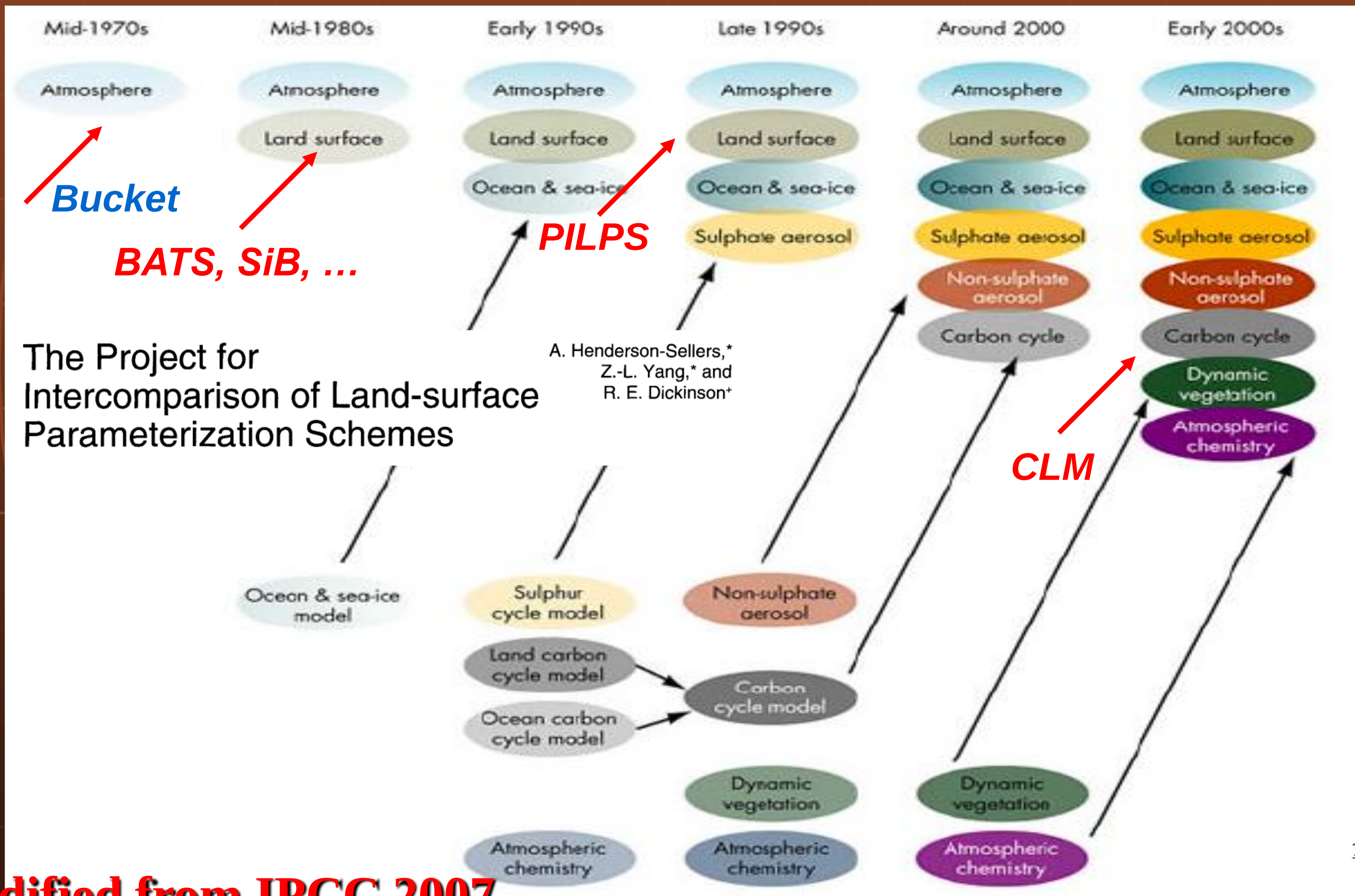
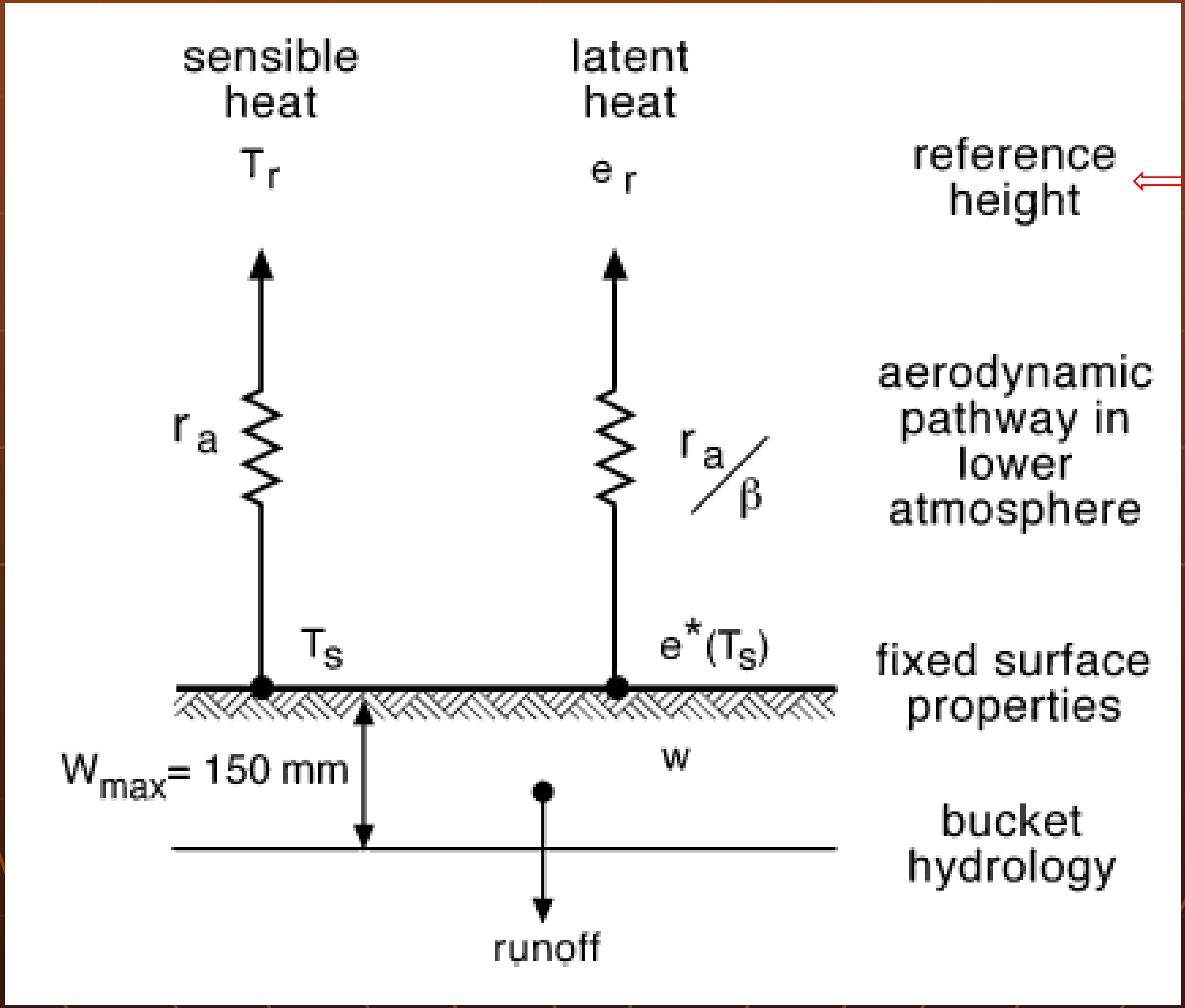
Land is an important component in weather and climate models



Modified from IPCC 2007

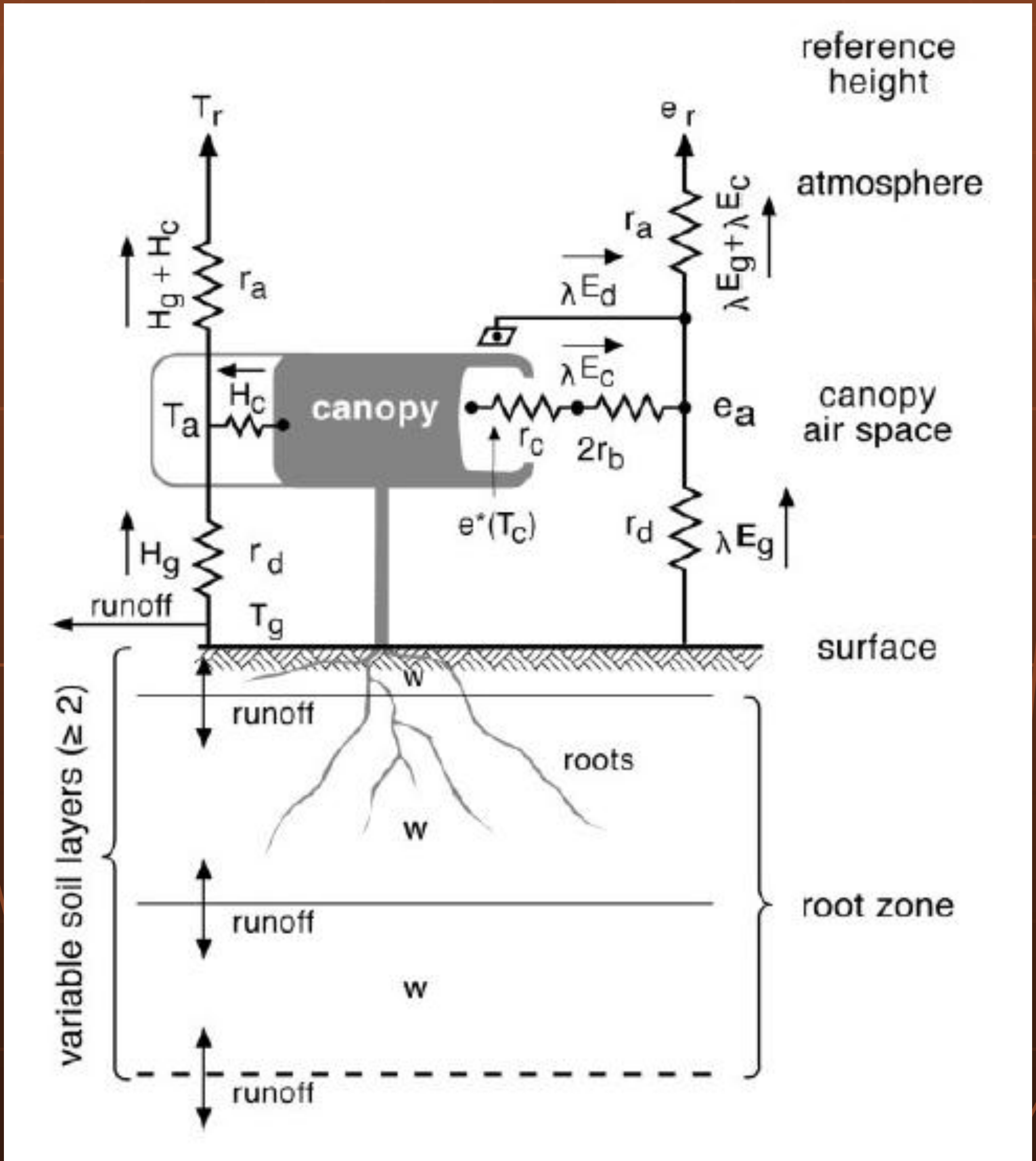
1^{st} Generation LSMs



The lowest model level in the host atmospheric model, typically ~50 m above the surface.

Pitman (2003); also Figs. 18.12, 25.1 in Bonan (2008)

2^{nd} Generation LSMs



Pitman (2003); also Figs. 18.12, 25.2 in Bonan (2008); note r_b is defined differently from that in Bonan, p. 231

Biosphere–Atmosphere Transfer Scheme (Dickinson et al., 1986)

Provides bottom boundary conditions over land for climate models.

Focuses on biophysics and hydrology.

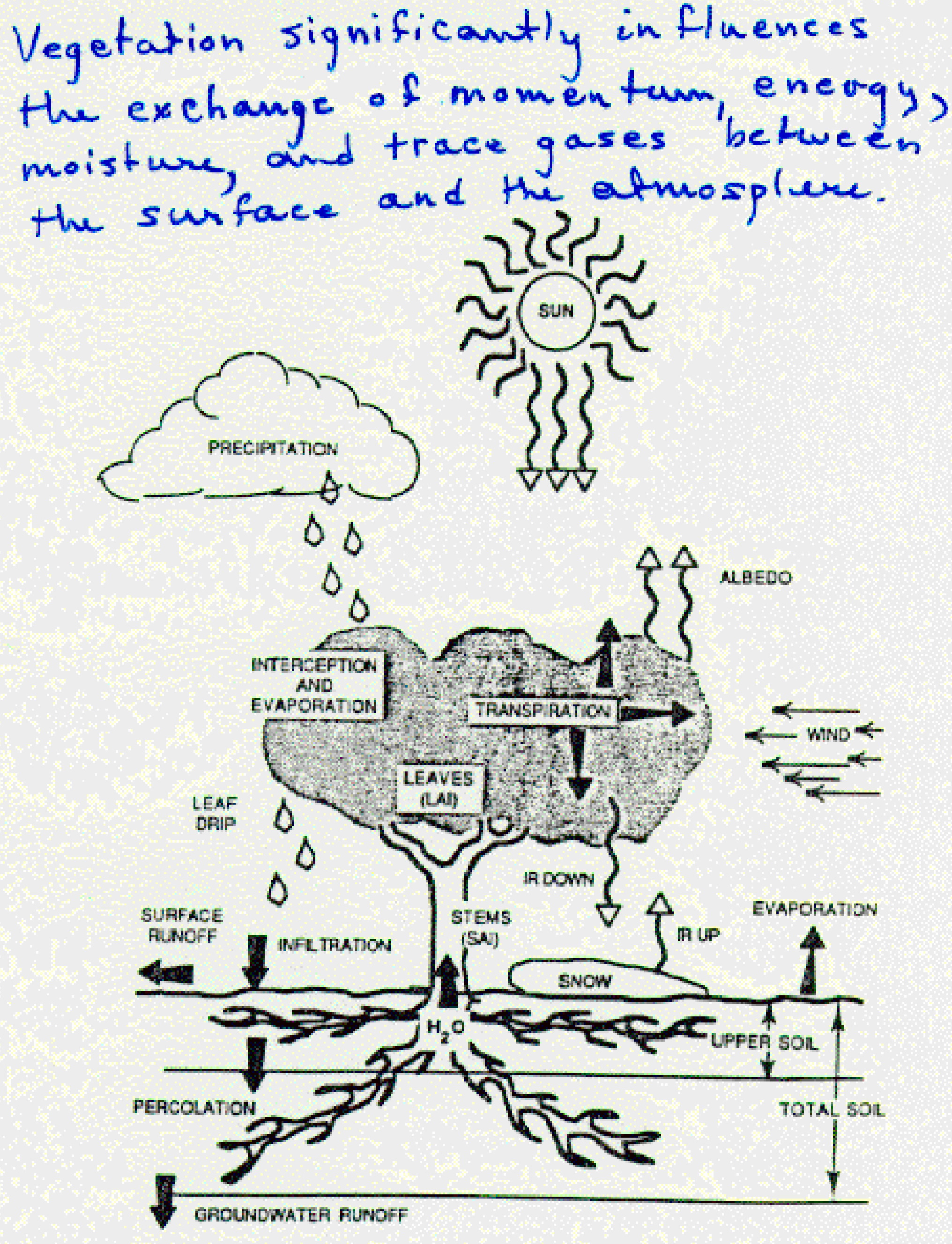
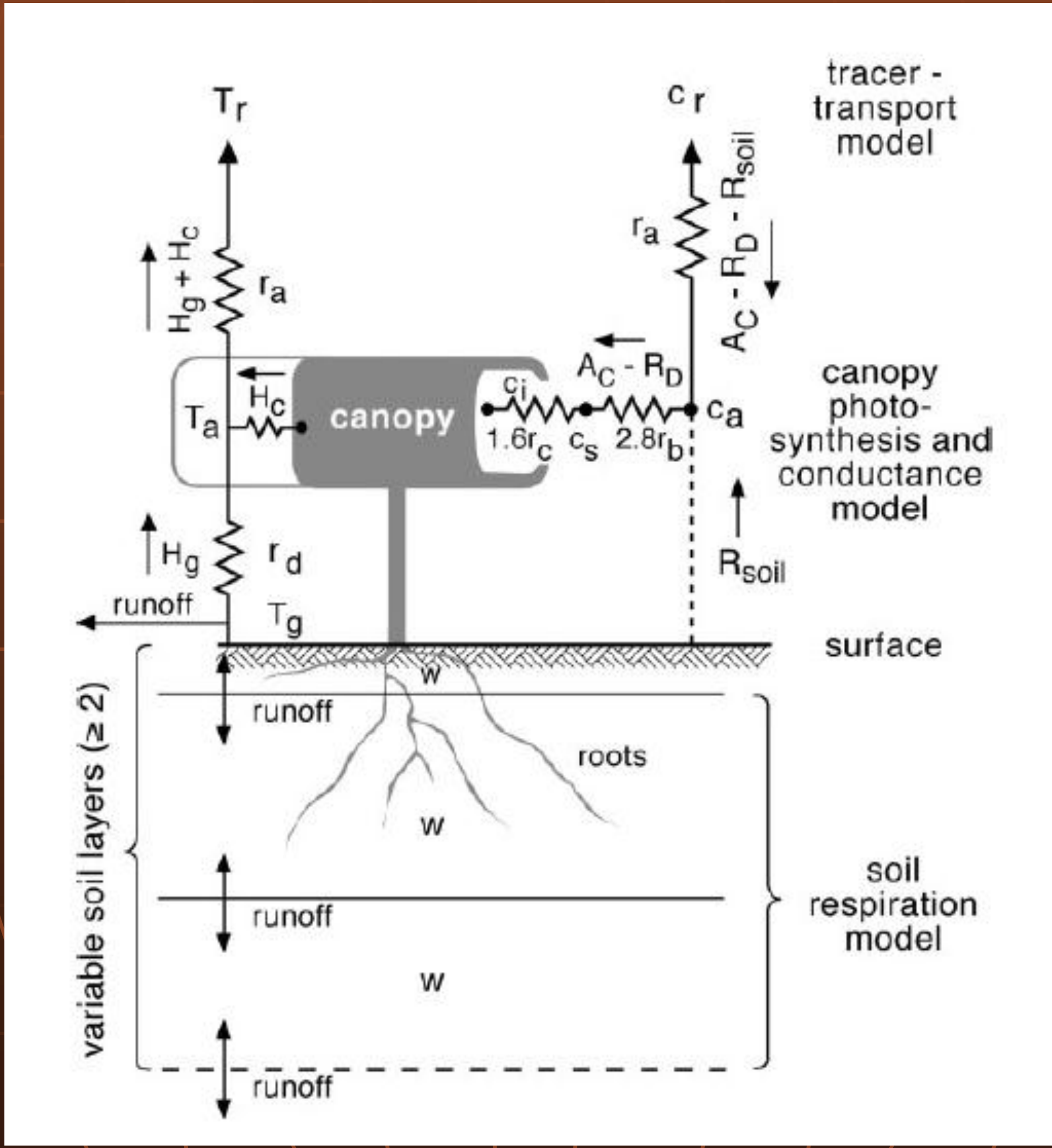


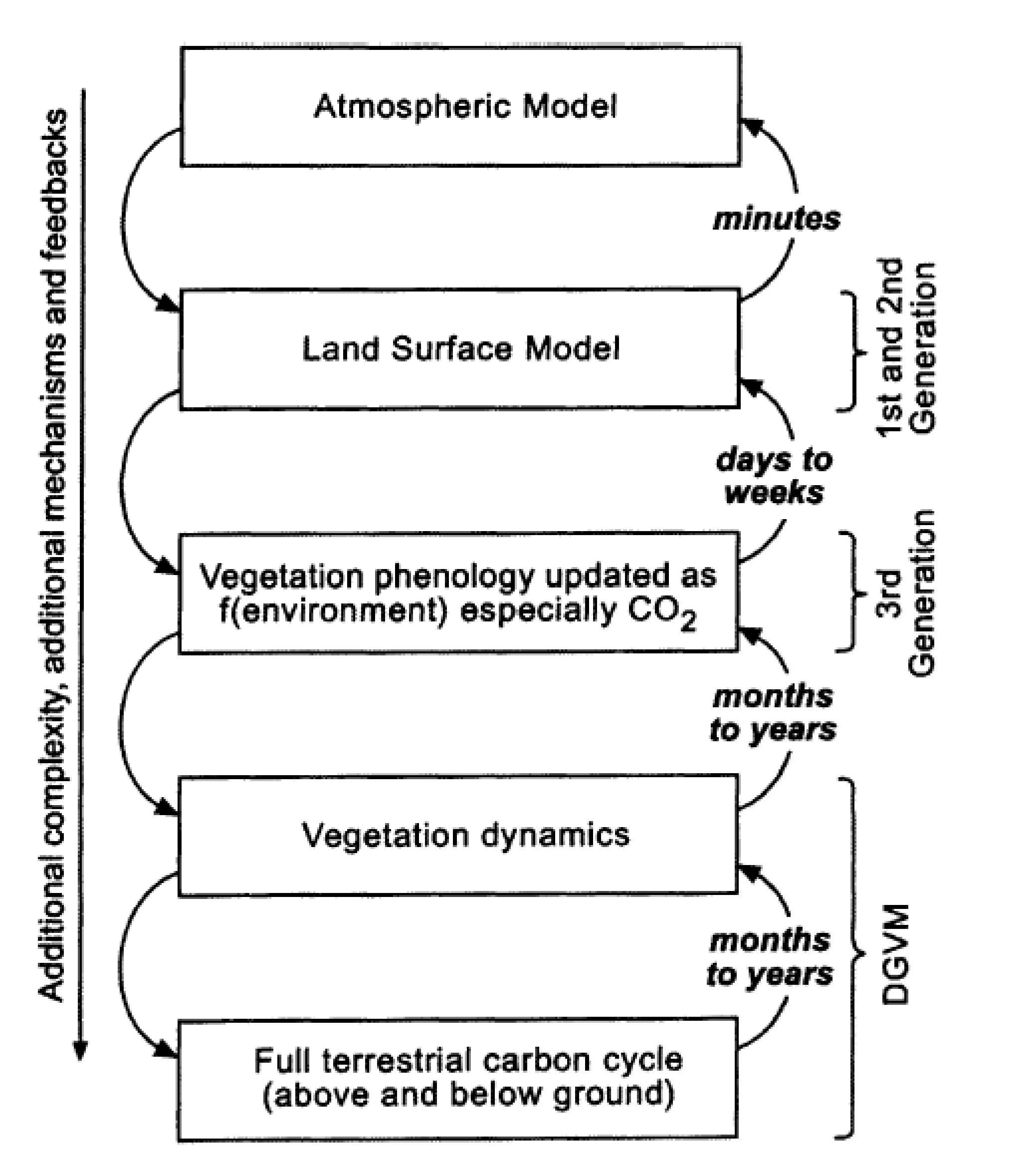
Figure 1. Schematic diagram illustrating the features included in the land-surface parameterization scheme used here.

3^{rd} Generation LSMs



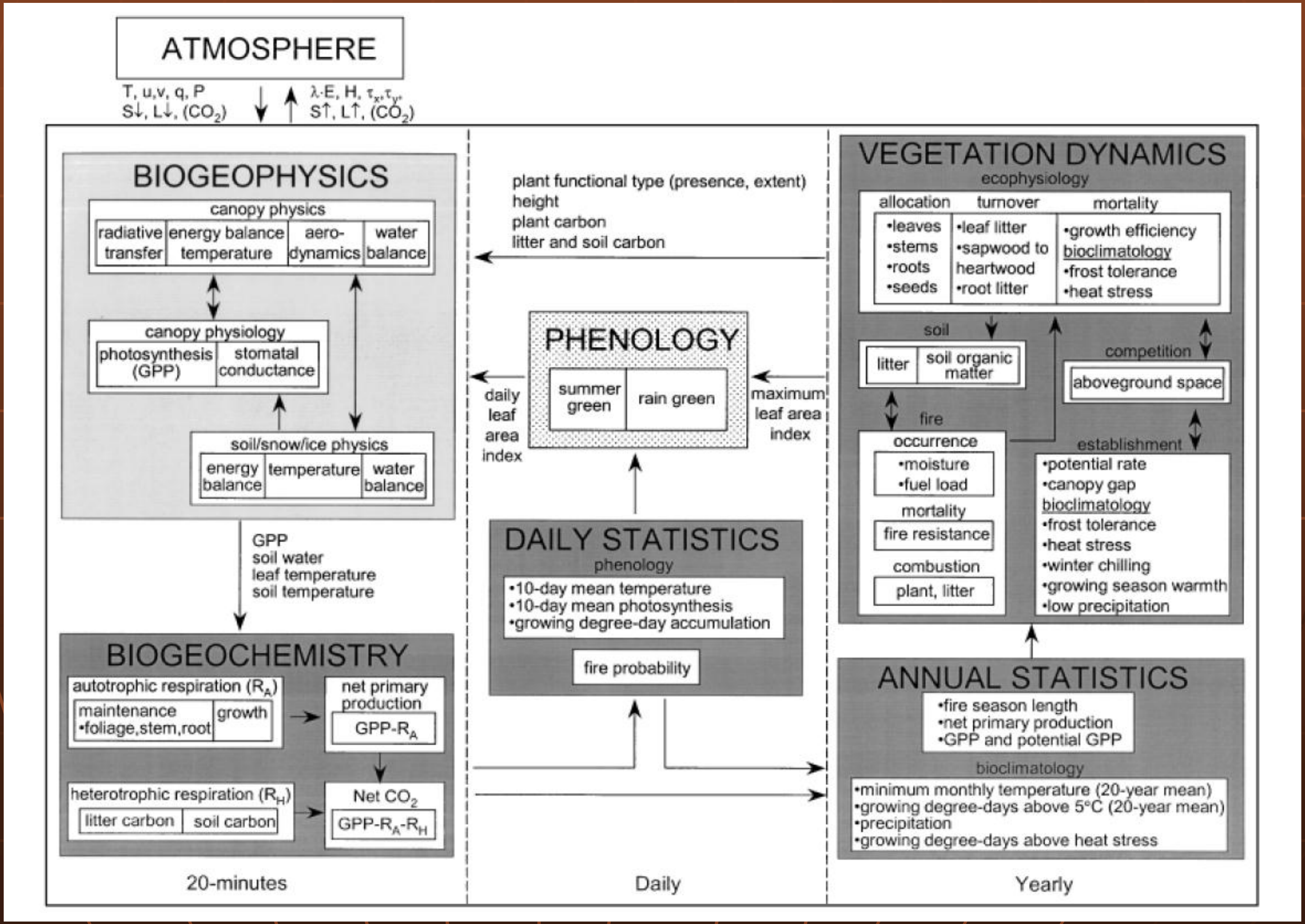
Pitman (2003); also Figs. 16.2, Eqn (17.2), Section 17.8, Section 25.2.3 in Bonan (2008); note r_b is defined differently from that in Bonan, p. 231

4th Generation LSMs (1)



Pitman (2003); also Section 25.2.4 in Bonan (2008)

4th Generation LSMs (2)

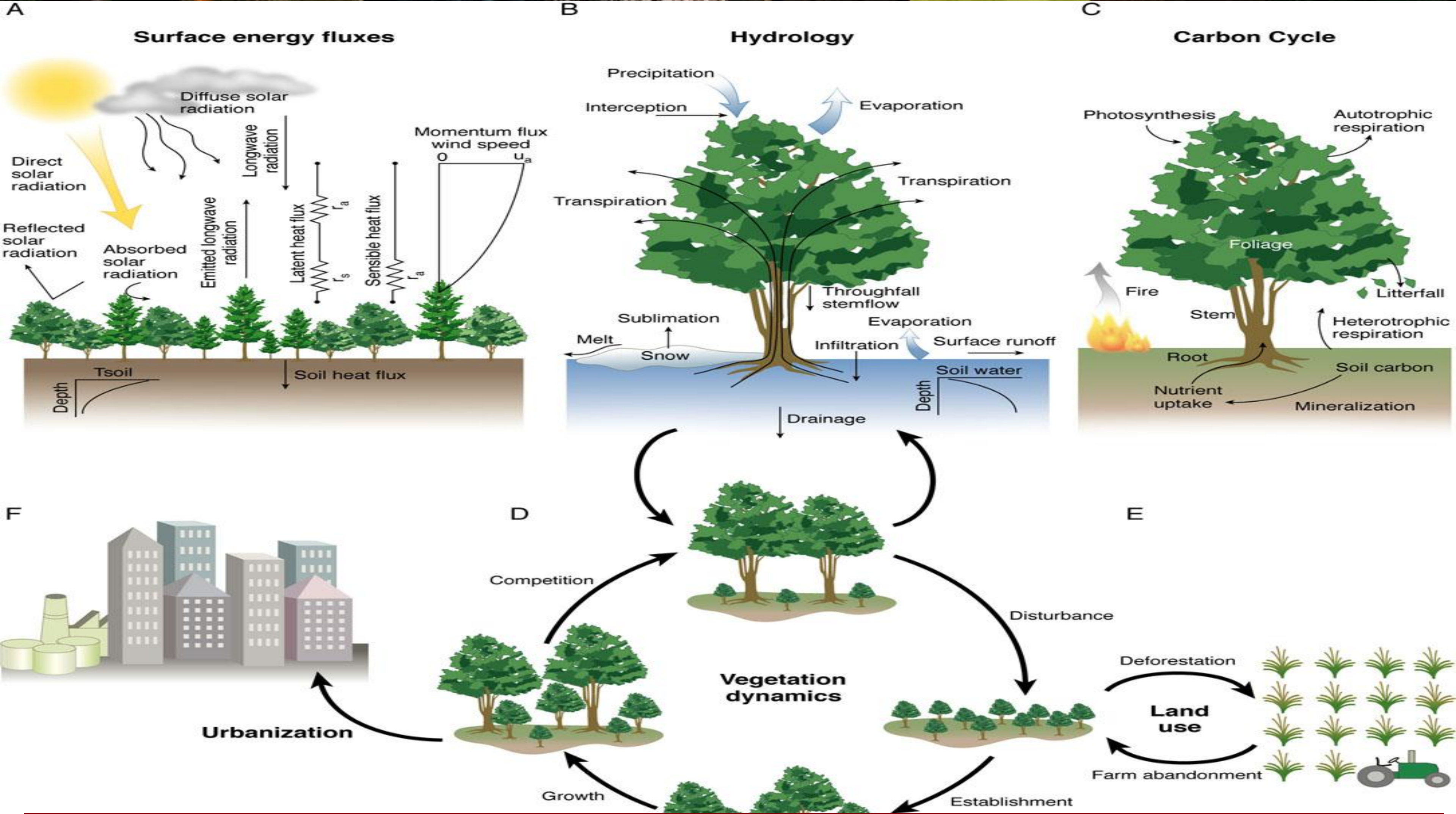


Pitman (2003); also Section 25.2.4, Fig. 25.14 in Bonan (2008)

4th Generation LSMs (3)

NCAR CLM4

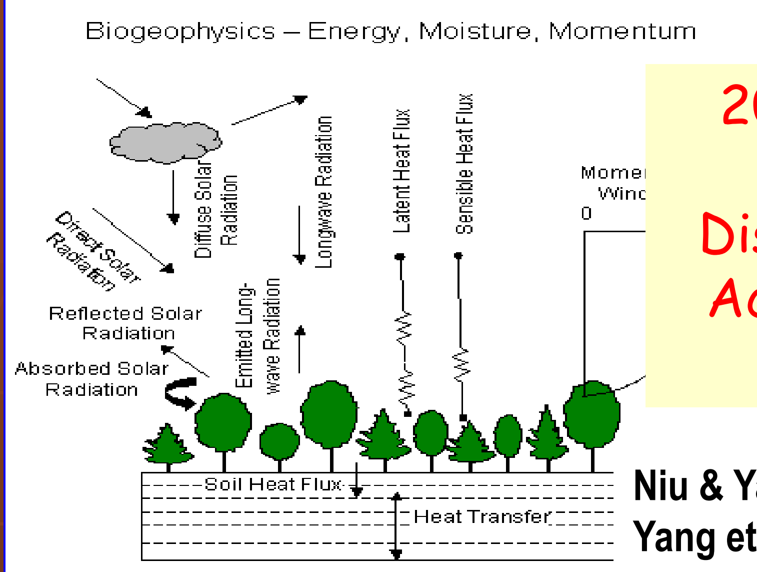
NCAR Community Land Model (CLM4) for Climate Models in 2010



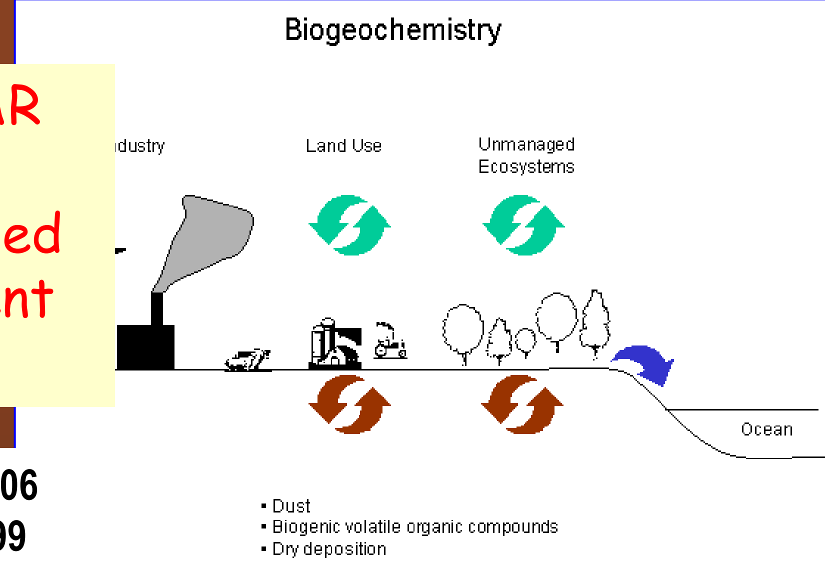
Co-Chairs: David Lawrence (NCAR), Zong-Liang Yang (Univ of Texas at Austin)

CLM4

- Evolved from CLM3.5 (released in 2008). CLM3.5 improves over CLM3 (released in 2004)
  - Surface runoff (Niu, Yang et al., 2005)
  - Groundwater (Niu, Yang, et al., 2007)
  - Frozen soil (Niu and Yang, 2006)
  - Canopy integration, canopy interception scaling, and pft-dependency of the soil stress function
- CLM4 (released in 2010) improves over CLM3.5
  - Prognostic in carbon and nitrogen (CN) as well as vegetation phenology; the dynamic global vegetation model is merged with CN
  - Transient landcover and land use change capability
  - Urban component
  - BVOC component (MEGAN2)
  - Dust emissions
  - Updated hydrology and ground evaporation
  - New density-based snow cover fraction, snow burial fraction, snow compaction
  - Improved permafrost scheme: organic soils, 50-m depth (5 bedrock layers)
  - Conserving global energy by separating river discharge into liquid and ice water streams



2008 NCAR CCSM Distinguished Achievement Award



Niu & Yang, 2003, 2006
Yang et al., 1997, 1999

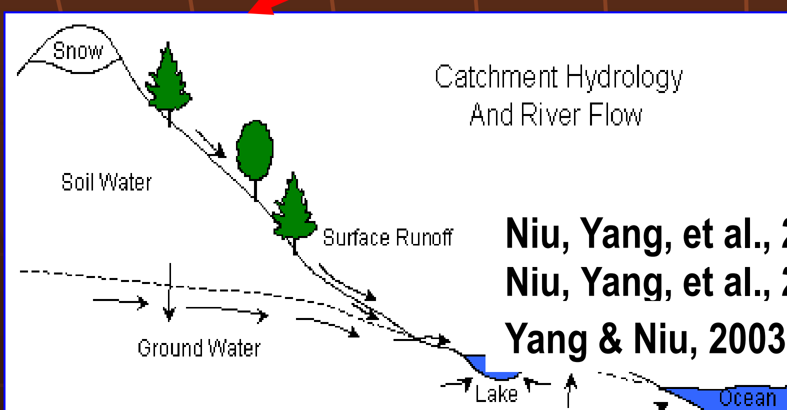
Biogeophysics

Biogeochemistry

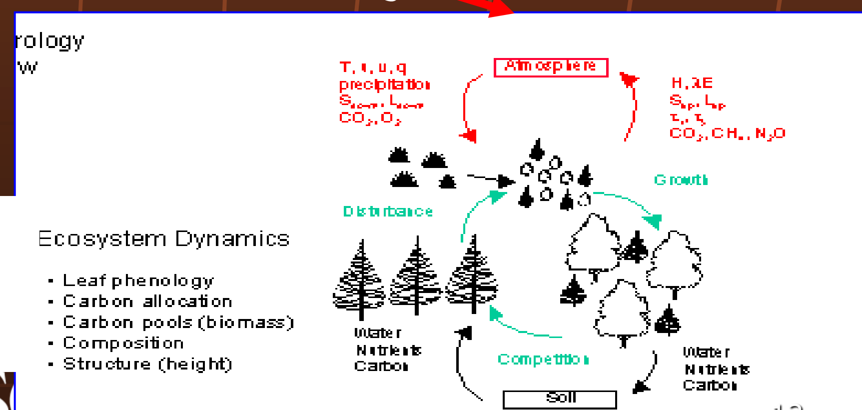
NCAR CLM 3.5/4.0

Hydrology

Ecosystem Dynamics



Niu, Yang, et al., 2005
Niu, Yang, et al., 2007
Yang & Niu, 2003



Collaborators: UT (Yang, Niu, Dickinson), NCAR (Bonan, Oleson, Lawrence) and others

Model Validation

- Local scale (comparison with flux tower data)
- Regional scale (comparison with satellite and other gridded datasets)
- Global scale (comparison with satellite and other gridded datasets)
- Offline model evaluations (standalone, detached from the host atmospheric model): useful to assess the realism of LSMs (evaluation, calibration, validation), assess sensitivity (to forcing, parameters, and LULCC), improve parameterizations, provide initial (soil moisture) data for coupled runs. and develop new methods
- Coupled model evaluations (comprehensive): useful to study land–atmosphere interactions and feedbacks (e.g. soil moisture-precipitation coupling strength, predictability, carbon-nitrogen-climate feedbacks), evaluate sensitivity to perturbations (e.g., land use and land cover change), and sort out cause–effects

Observations: FLUXNET, a global network

USED SITES IN OUR STUDY:

- Morgan Monroe (1999-2005)
- Fort Peck (2000-2005)
- Harvard Forest (1994-2003)
- Niwot Ridge (1999-2004)
- Boreas (1994-2005)
- Lethbridge (1998-2004)

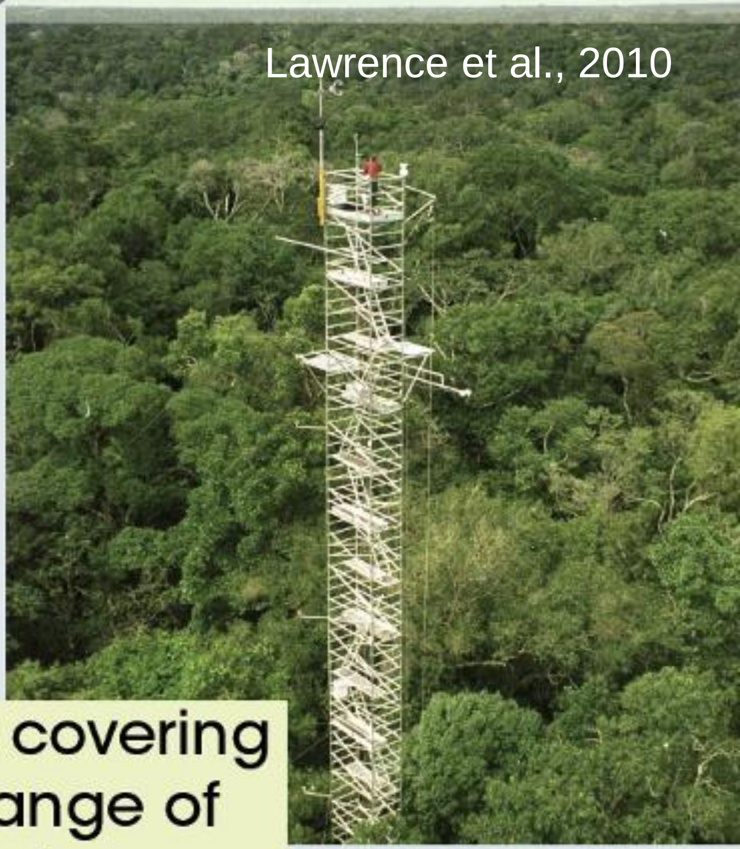
- Santarem KM83 (2001-2003)
- Tapajos KM67 (2002-2005)

- Castelporziano (2000-2005)
- Collelongo (1999-2003)
- El Saler (1999-2005)
- Kaamanen (2000-2005)
- Hyytiälä (1997-2005)
- Tharandt (1998-2003)
- Vielsalm (1997-2005)

Color Legend:

temperate
tropical
boreal
sub-alpine
north-boreal
mediterranean

Lawrence et al., 2010



300+ sites covering global range of climates & ecosystems

Tower flux statistics (15 sites, hourly)

	Latent Heat Flux		Sensible Heat Flux	
	r	RMSE (W/m^2)	r	RMSE (W/m^2)
CLM3	0.54	72	0.73	91
CLM3.5	**0.80**	50	0.79	65
CLM4SP	**0.80**	**48**	**0.84**	**58**

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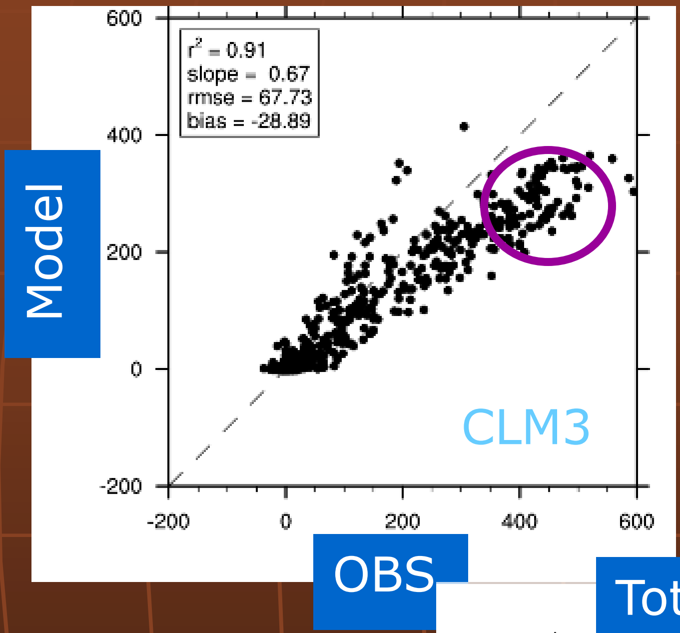
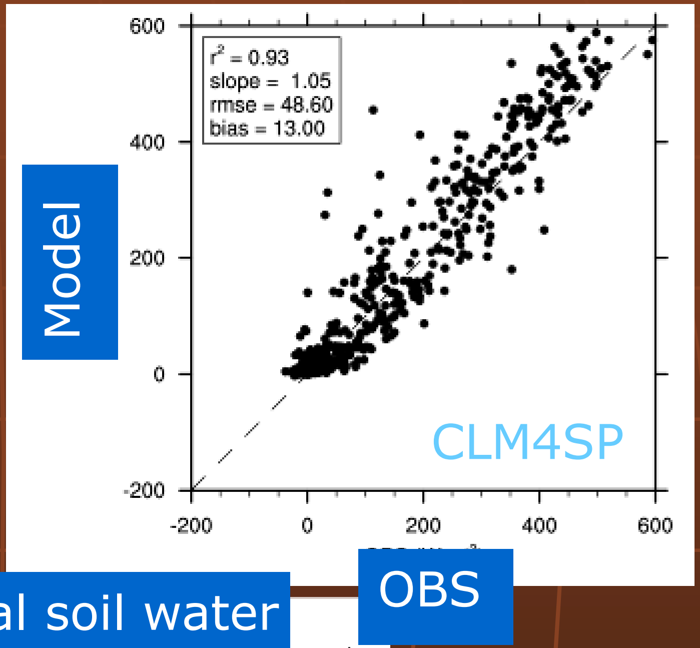
Lawrence et al., 2010

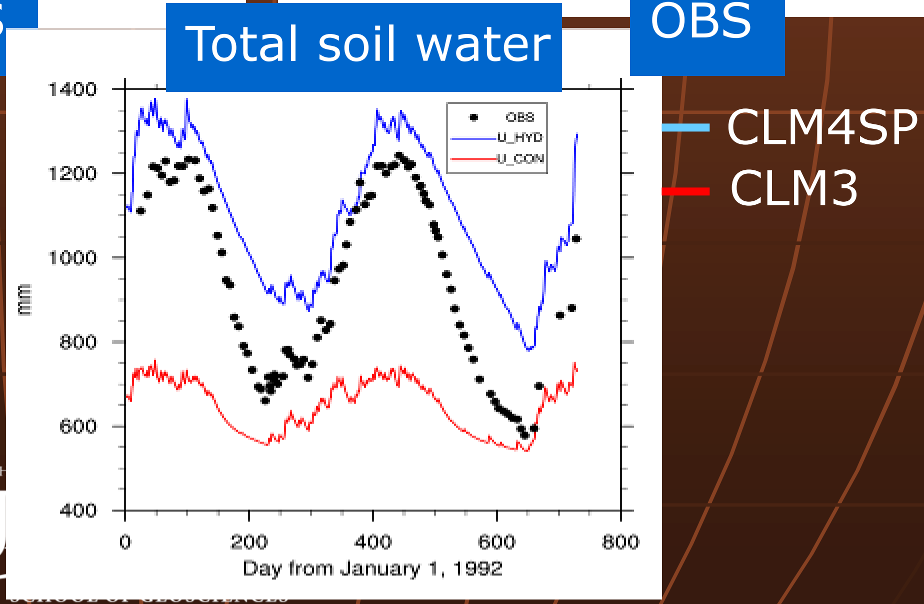
Abracos tower site (Amazon)

Latent Heat Flux



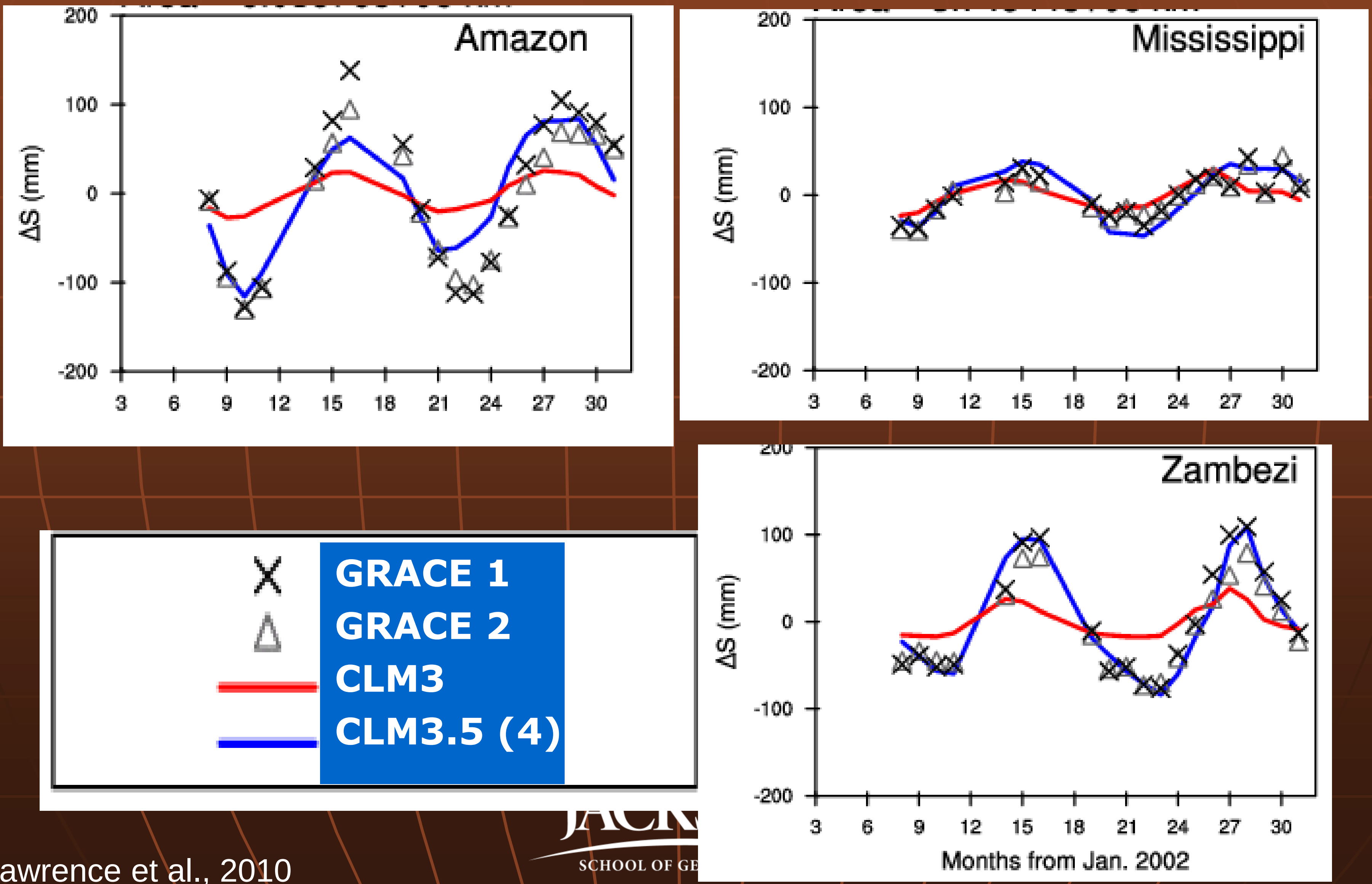
Latent Heat Flux





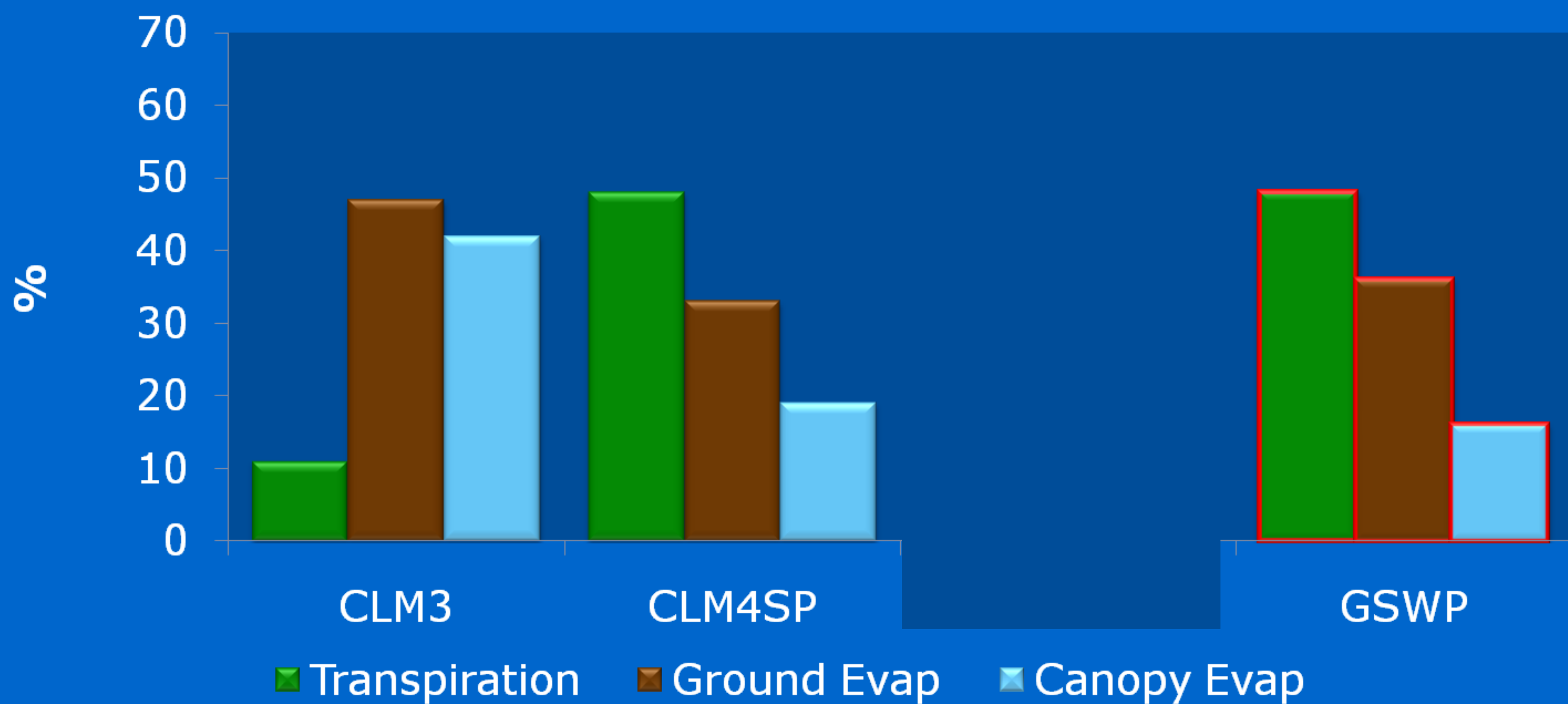
Lawrence et al., 2010

Water storage



Lawrence et al., 2010

Global Partitioning of Evapotranspiration



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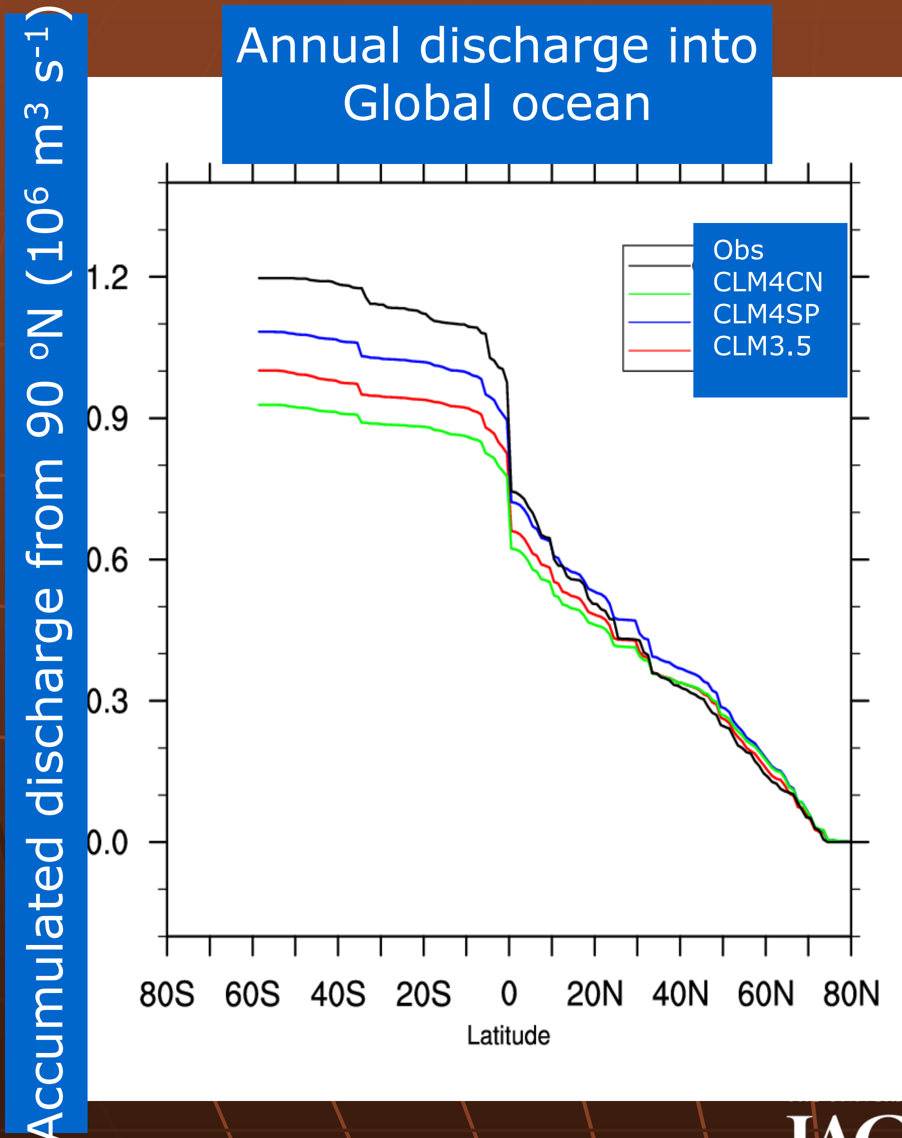
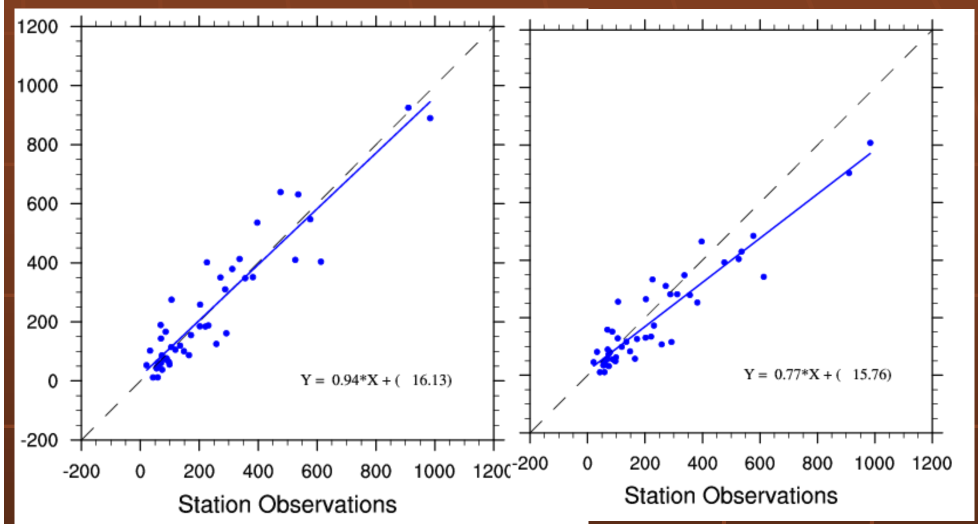
Lawrence et al., 2010

River Discharge



River flow at outlet
Top 50 rivers (km^3 yr^{-1})



CLM3: r = 0.86
CLM3.5: r = 0.87
CLM4SP: r = 0.94
CLM4CN: r = 0.77

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Lawrence et al., 2010

Model Validation

- East Canada (50–60N, 80–55W)

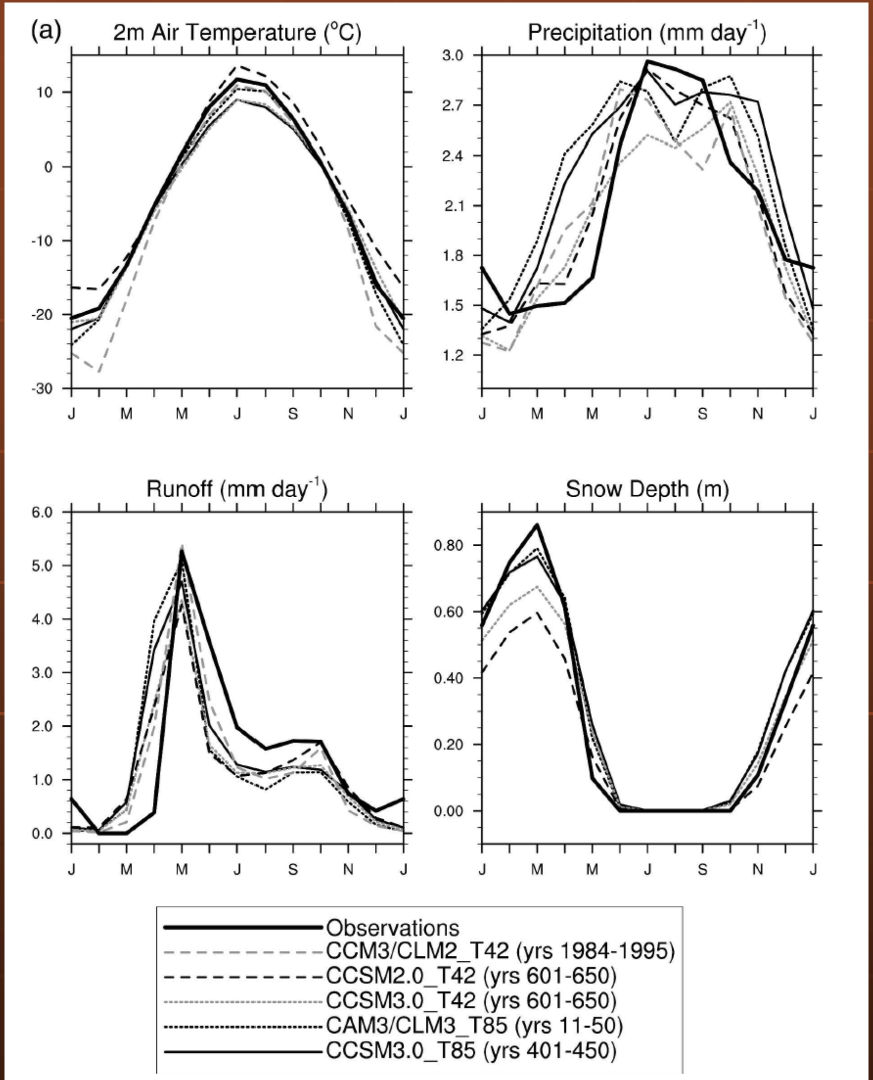


FIG. 8. Seasonal cycle of 2-m air temperature (°C), precipitation (mm day^{-1}), total runoff (mm day^{-1}), and snow depth (m) compared to observations in (a) eastern Canada (50°–60°N, 80°–55°W), (b) northern Europe (60°–70°N, 5°–45°E), and (c) eastern Siberia (50°–66.5°N, 90°–140°E) for the ensemble of simulations described in the text. Observations are from Willmott and Matsuura (2000; air temperature and precipitation), Fekete et al. (2002; runoff), and Foster and Davy (1988; snow depth). Model grid cells containing glaciers were masked out. Snow depth was not available from CCM3/CLM2_T42.

Dickinson et al. (2006)

Model Validation

- Amazonia (10S–0, 70–50W)

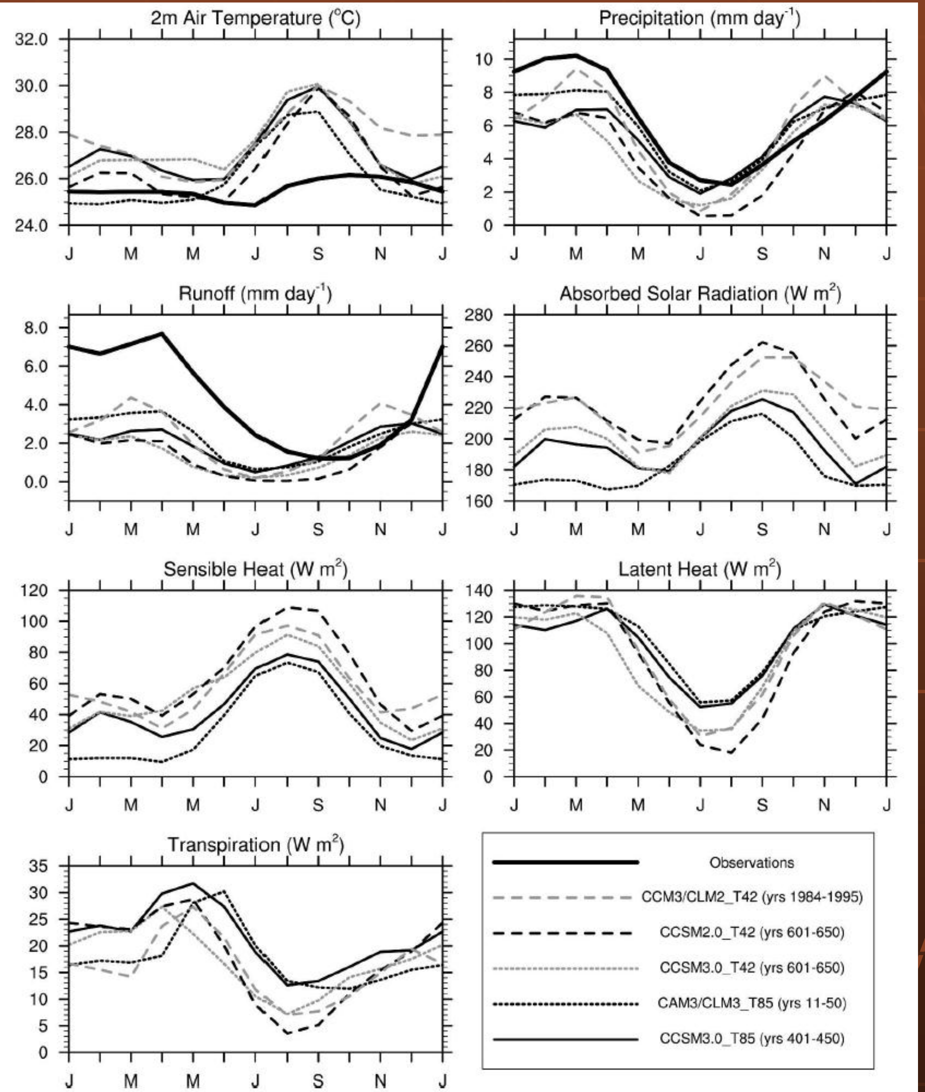
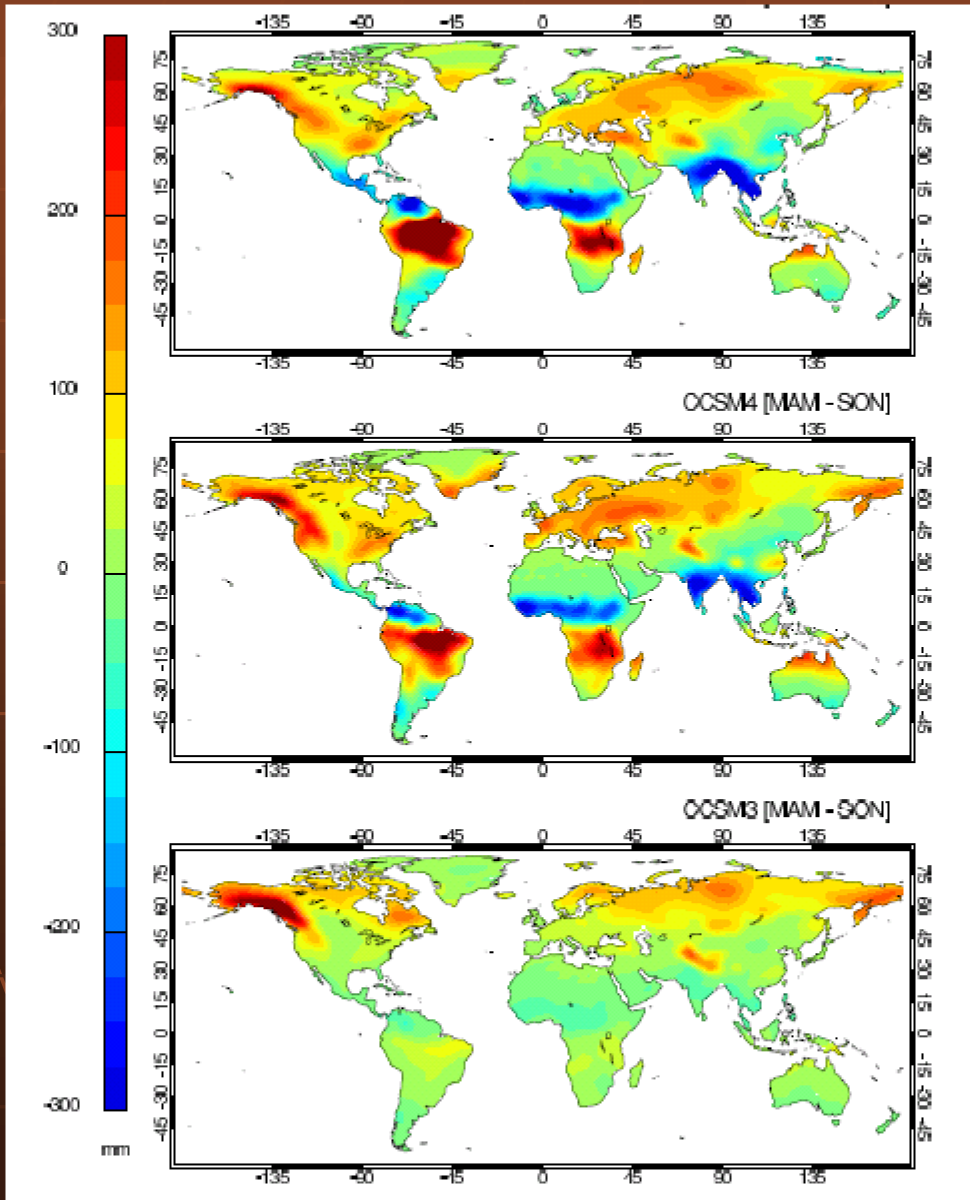


FIG. 13. Seasonal cycle of 2-m air temperature (°C), precipitation (mm day^{-1}), total runoff (mm day^{-1}), absorbed solar radiation (W m^{-2}), sensible and latent heat (W m^{-2}), and transpiration (W m^{-2}) in Amazonia (10°S–0°, 70°–50°W) for the ensemble of simulations described in the text.

Dickinson et al. (2006)

Terrestrial Water Storage Change



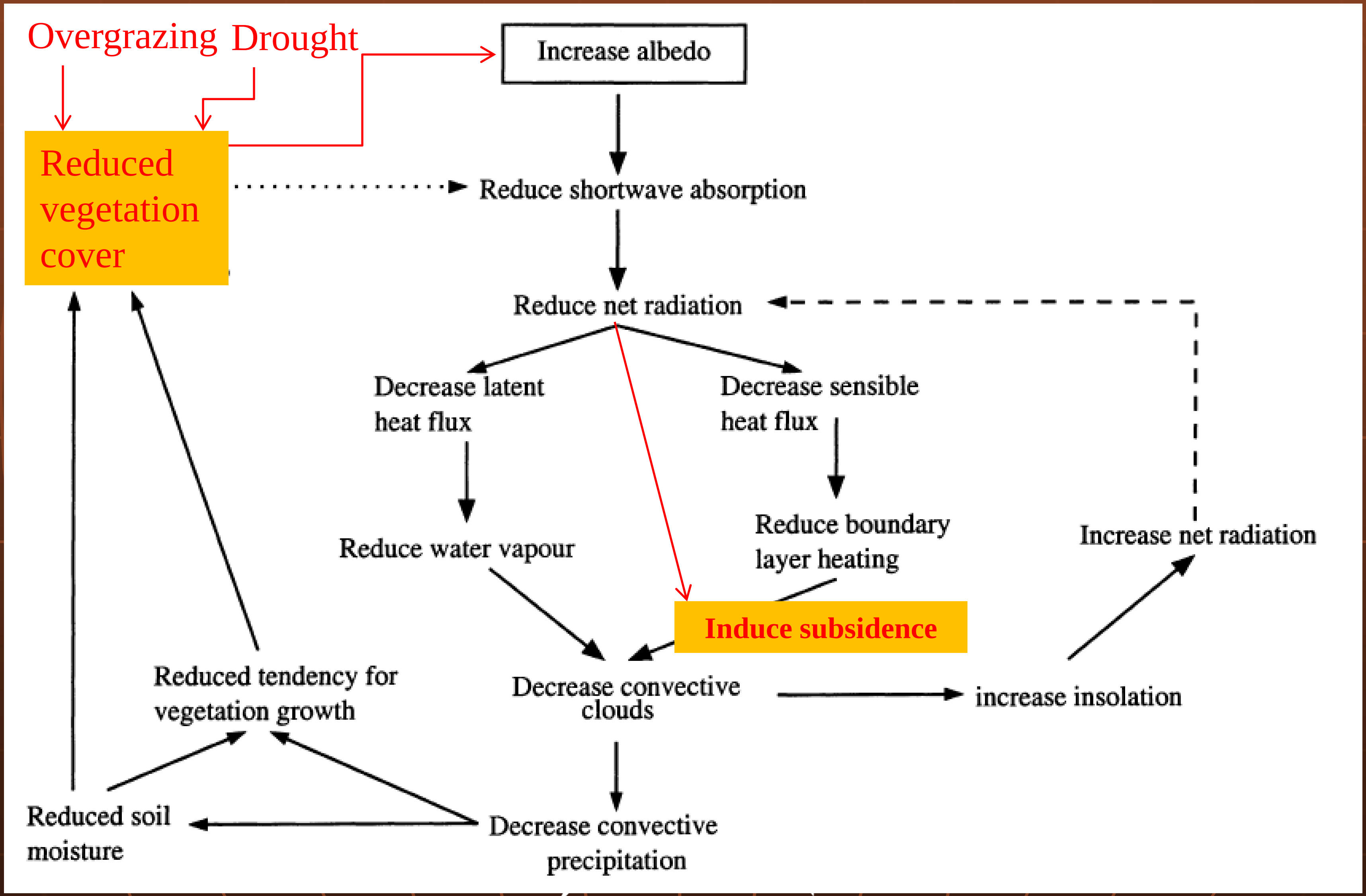
GRACE (MAM – SON)

CCSM4 (MAM – SON)

CCSM3 (MAM – SON)

Gent et al., 2010

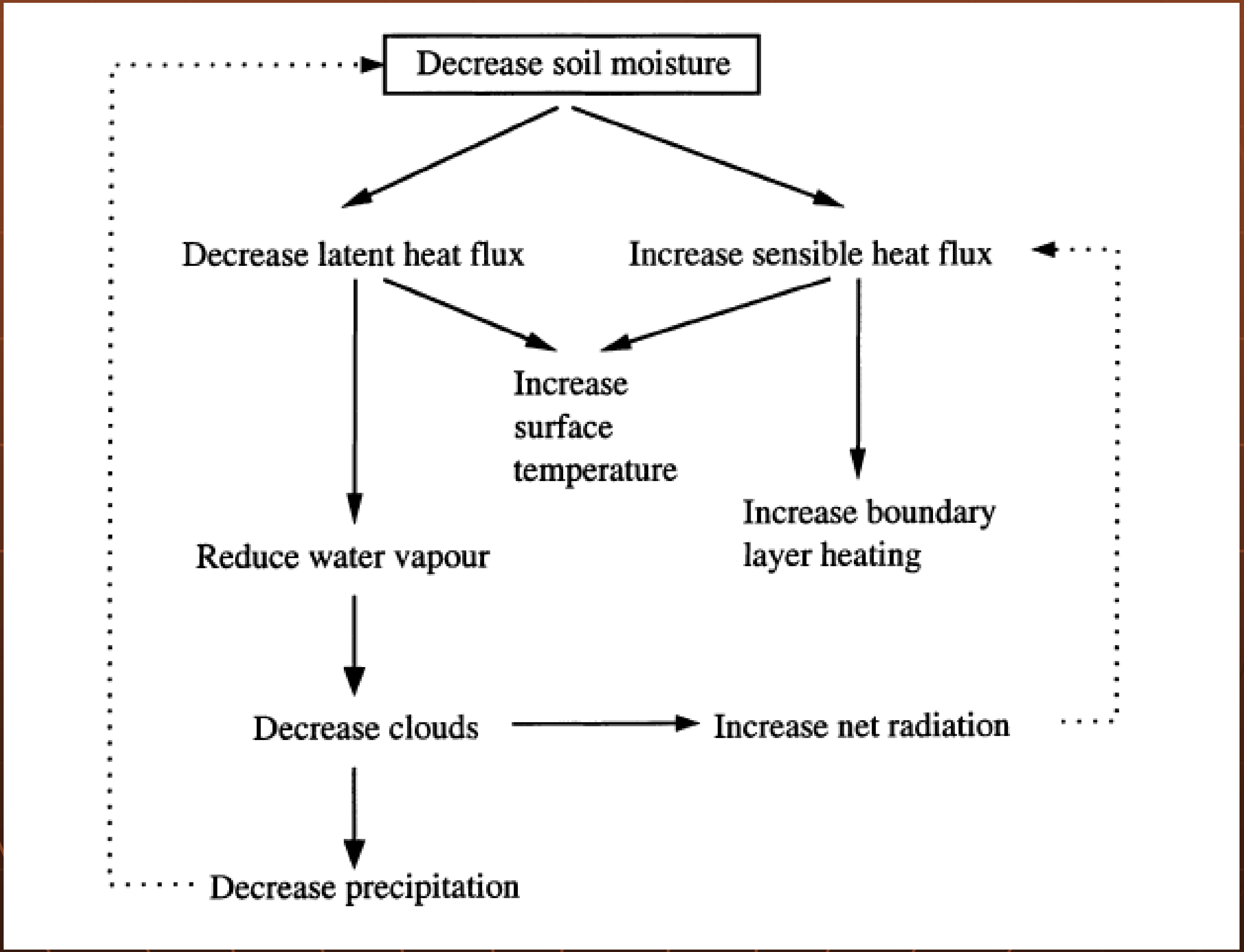
Land–Atmosphere Feedback Loops (1)



Pitman (2003); also Fig. 27.1 in Bonan (2008)

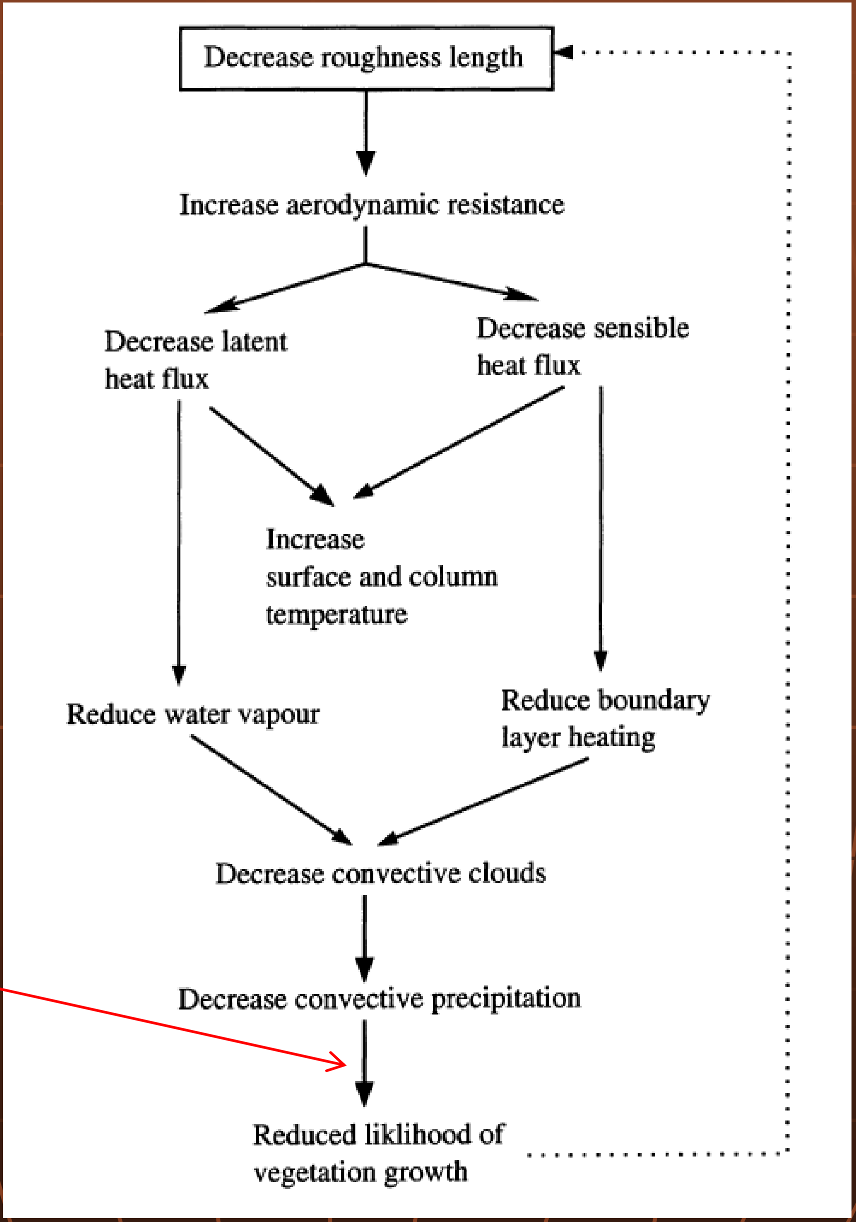
Fig. 27.7 in Bonan (2008)

Land–Atmosphere Feedback Loops (2)



Pitman (2003)

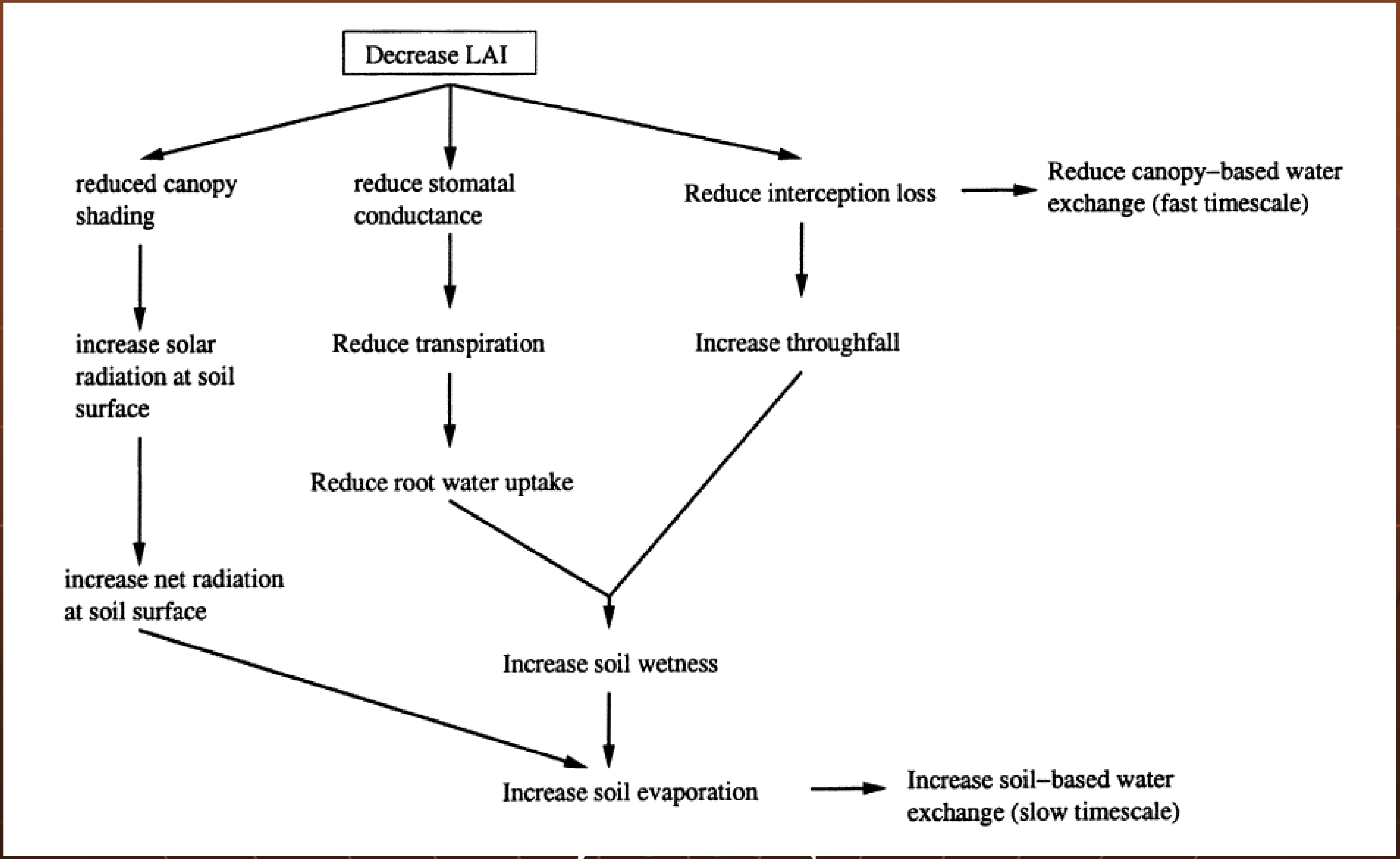
Land–Atmosphere Feedback Loops (3)



Reduced soil water

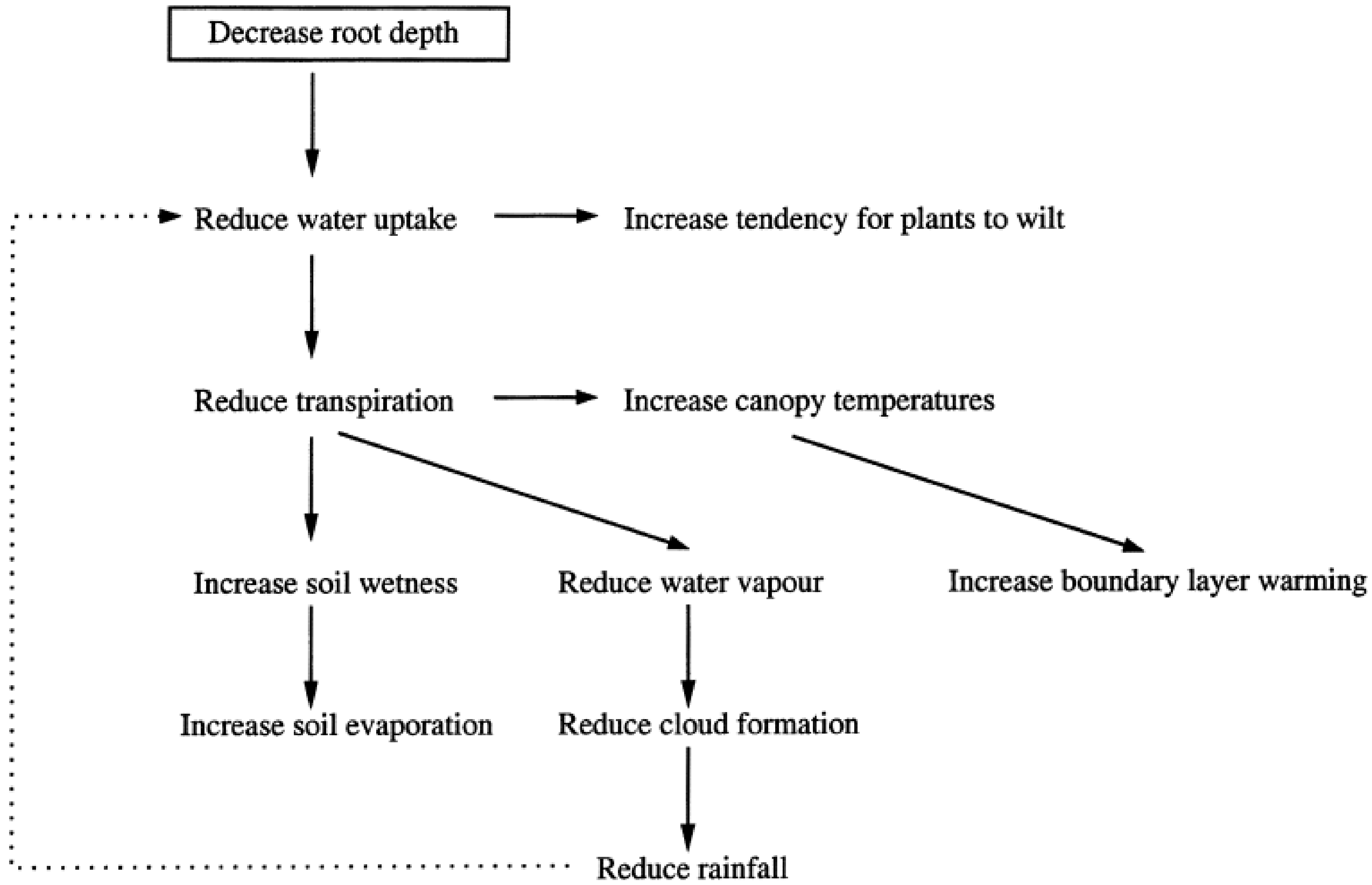
Pitman (2003); also
Fig. 27.2 in Bonan (2008)

Land–Atmosphere Feedback Loops (4)



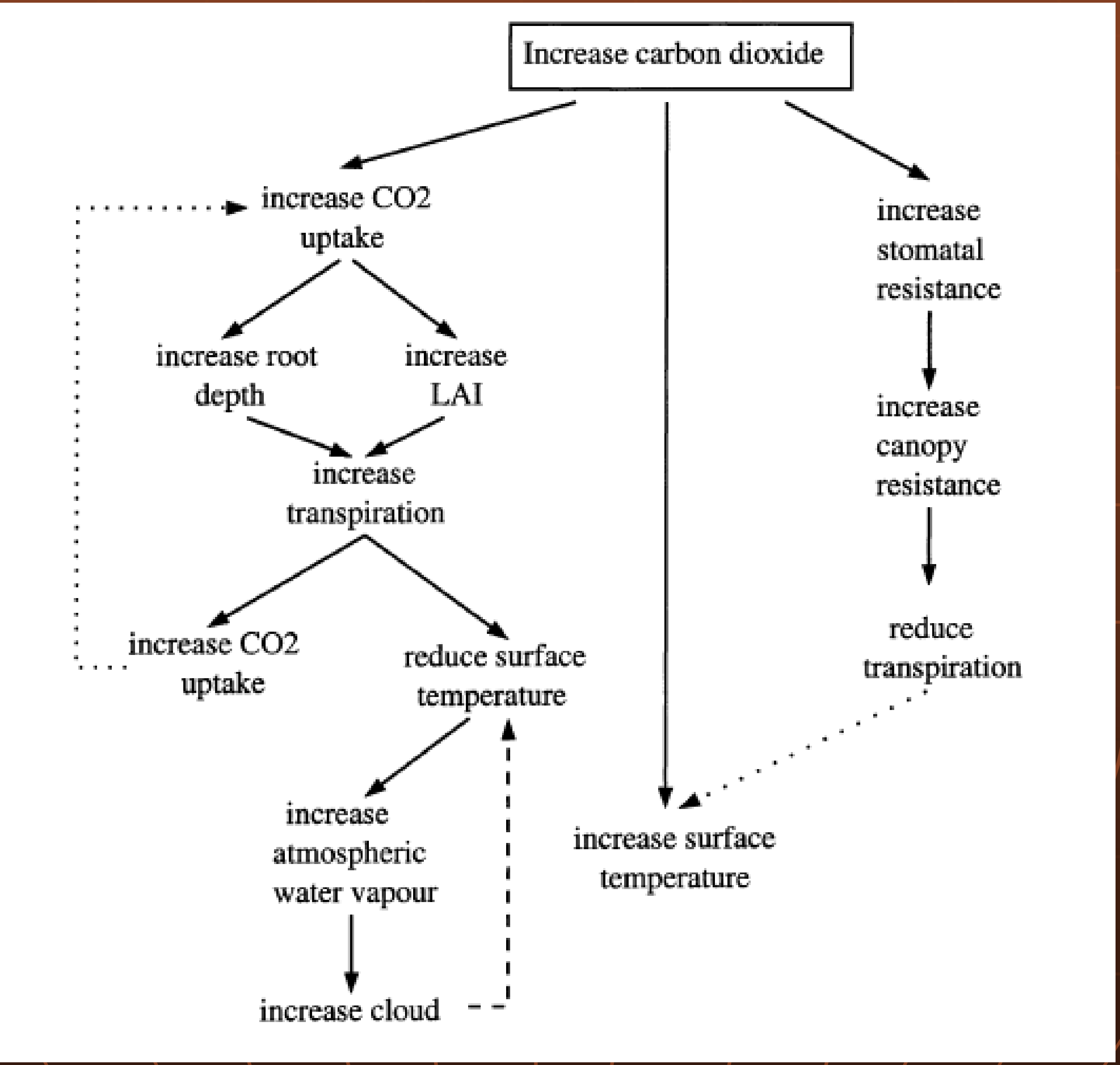
Pitman (2003)

Land–Atmosphere Feedback Loops (5)



Pitman (2003)

Land–Atmosphere Feedback Loops (6)



Pitman (2003)