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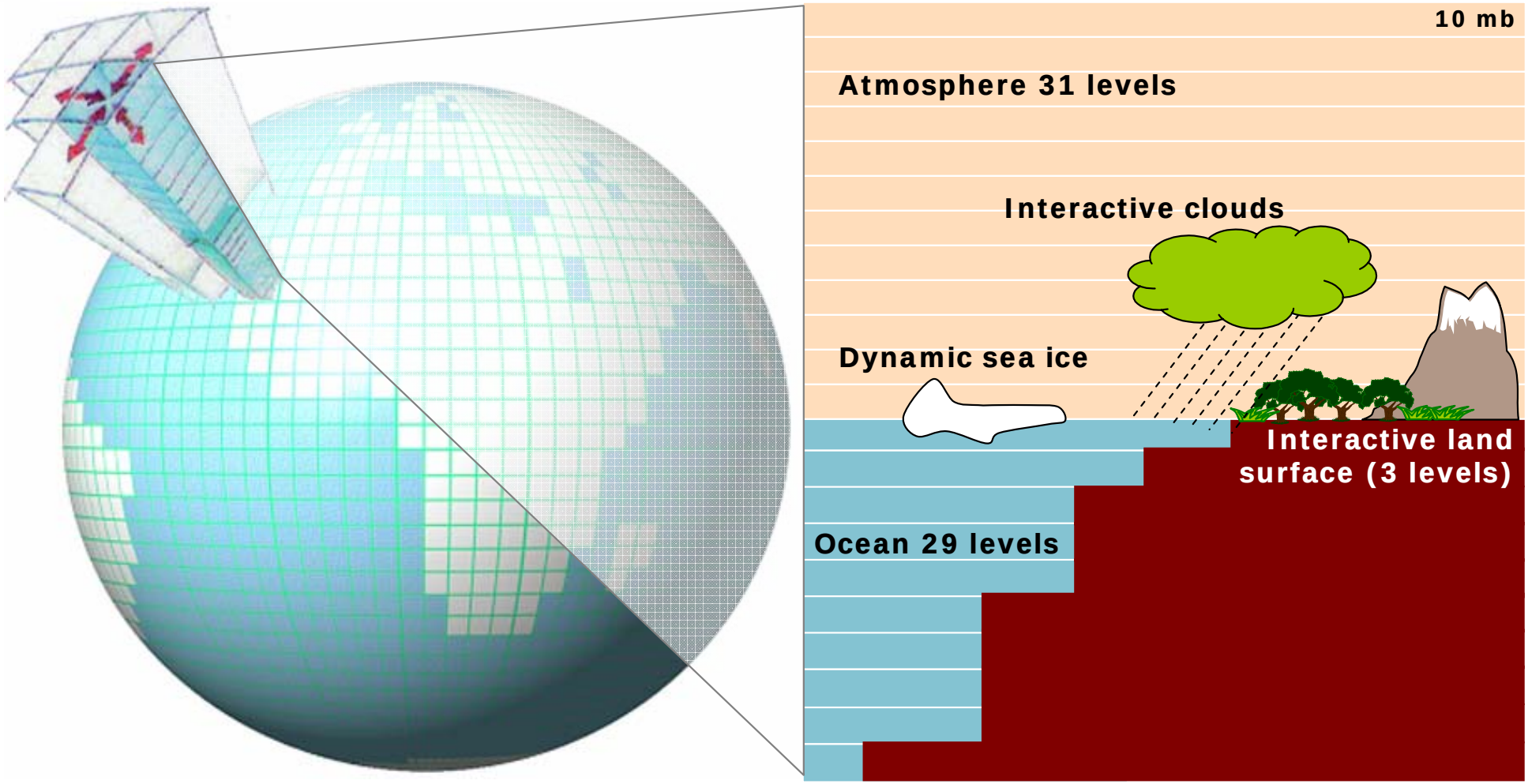
The role of soil moisture in influencing climate and terrestrial ecosystem processes

Vivek Arora
Canadian Centre for Climate Modelling and Analysis
Meteorological Service of Canada

Outline

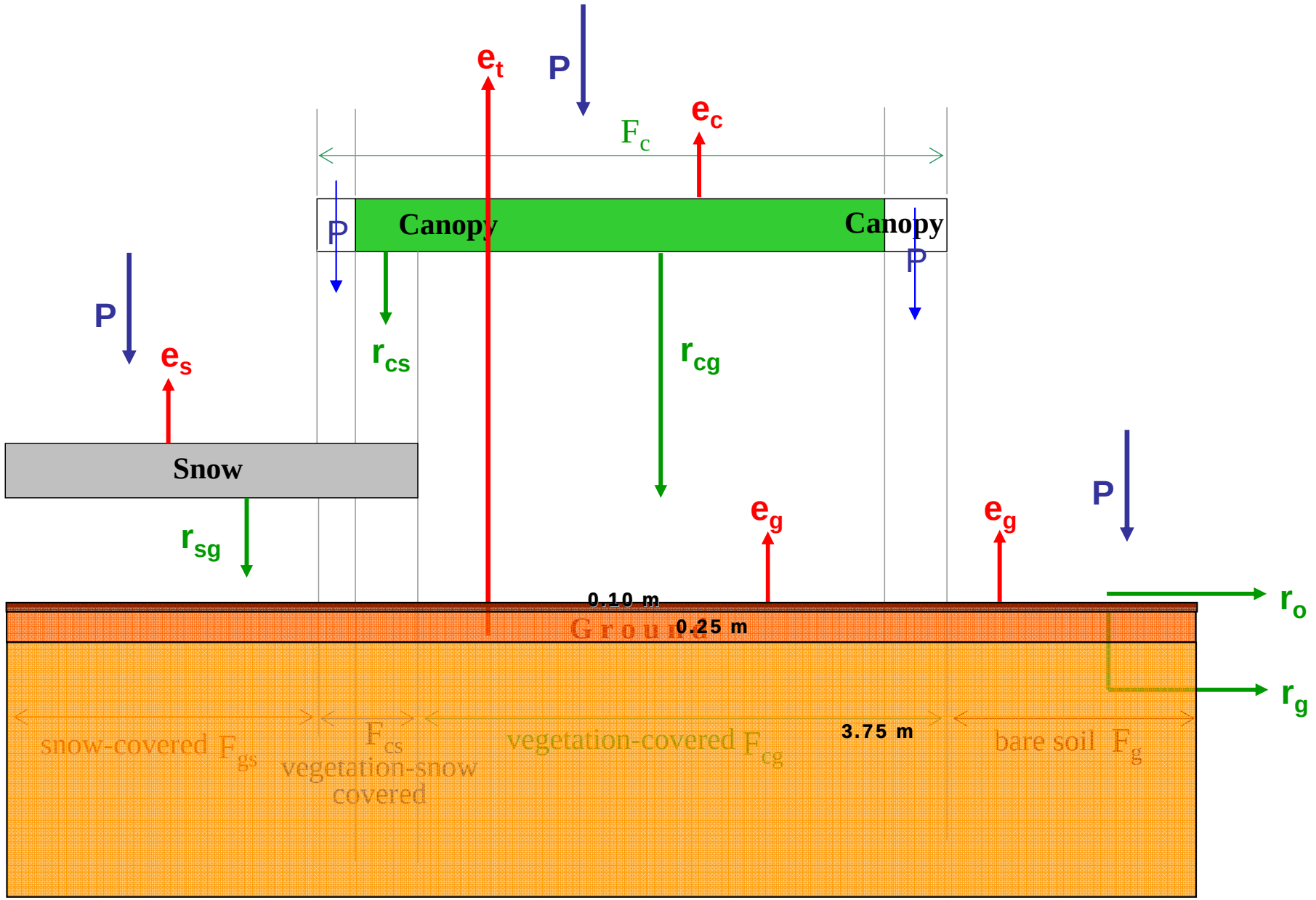
- The structure of the climate model.
- How soil moisture is modelled as a prognostic variable.
- The role of soil moisture in determining various climate system processes.
- Introduction of vegetation as a dynamic component of the climate system.
- Vegetation processes that are affected by soil moisture.
- Soil moisture requirements.

The structure of the climate model



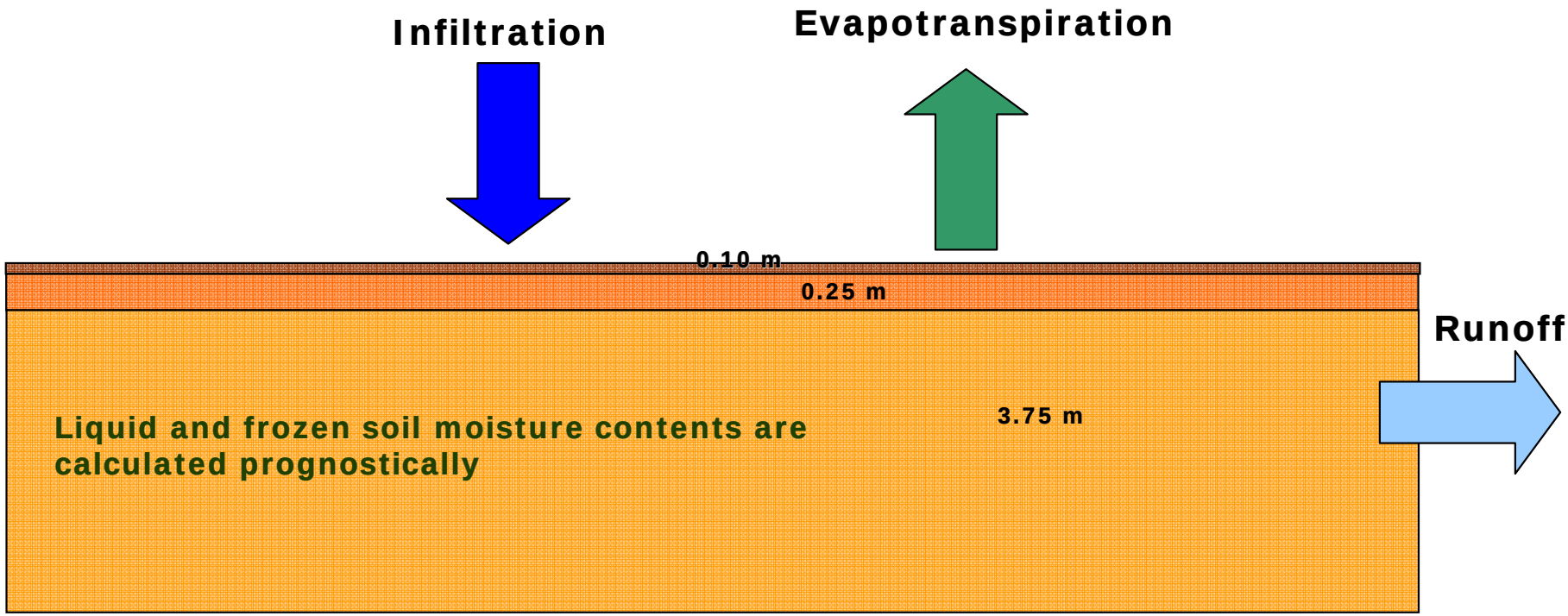
Global climate models (GCMs) solve mathematical equations describing the complex coupling of atmosphere, land surface and the oceans.

Structure of the Canadian land surface scheme (CLASS)

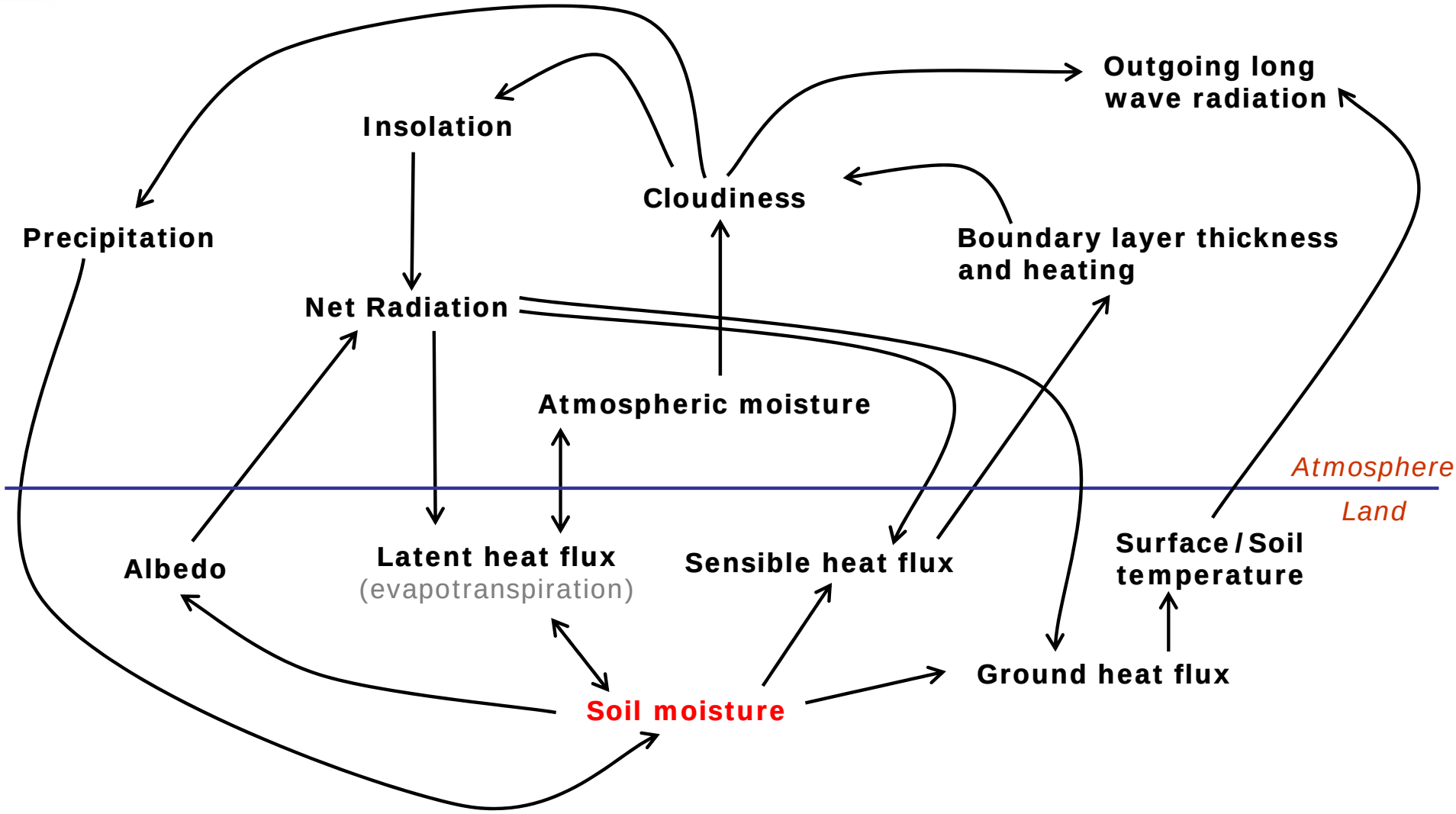


The structure of the land surface scheme

Both evapotranspiration and runoff are non-linear functions of soil moisture

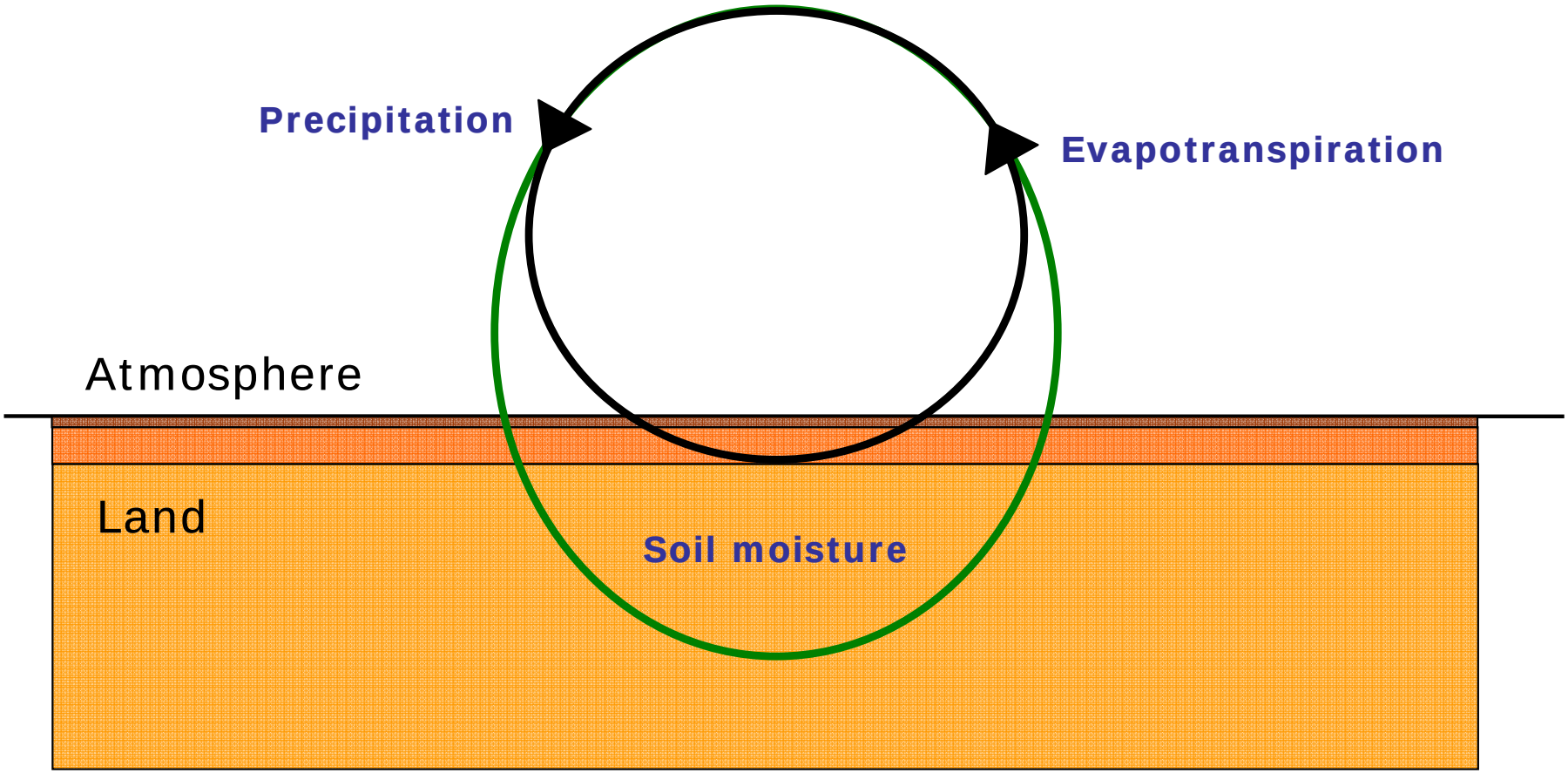


Land-atmosphere interactions and feedbacks

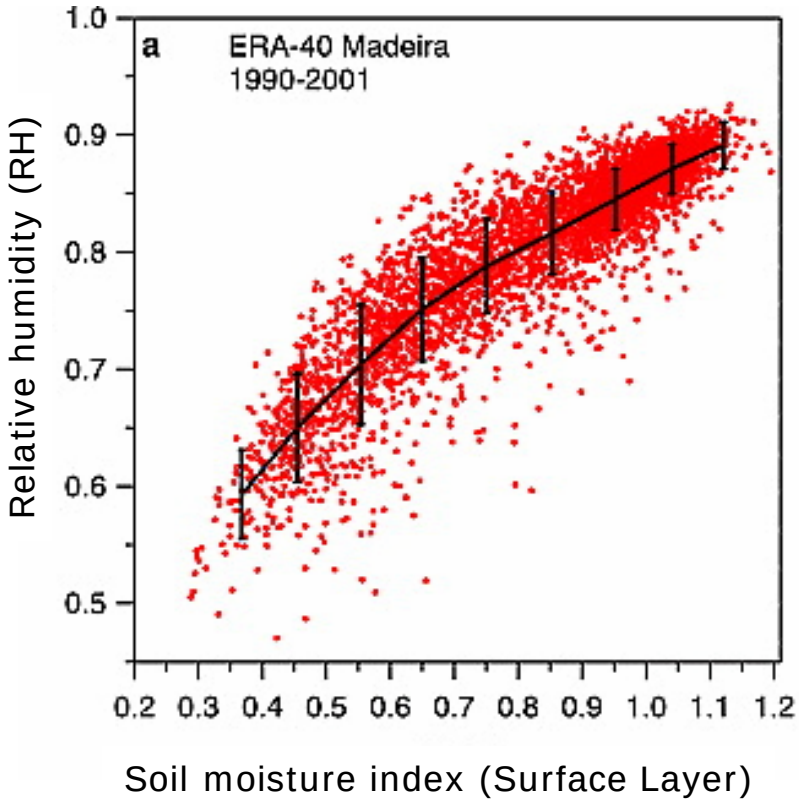


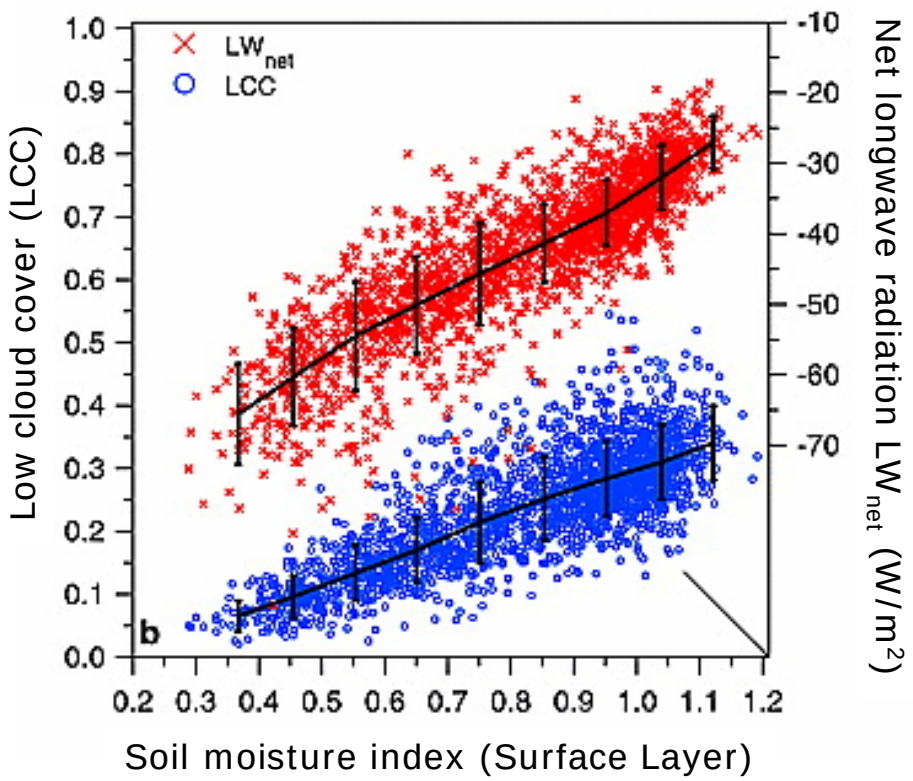
Land-atmosphere interactions and feedbacks

What is the strength of this feedback loop?
How is it modulated by soil moisture?
How does vegetation affects this loop?



Relationship between soil moisture and the state of the atmosphere

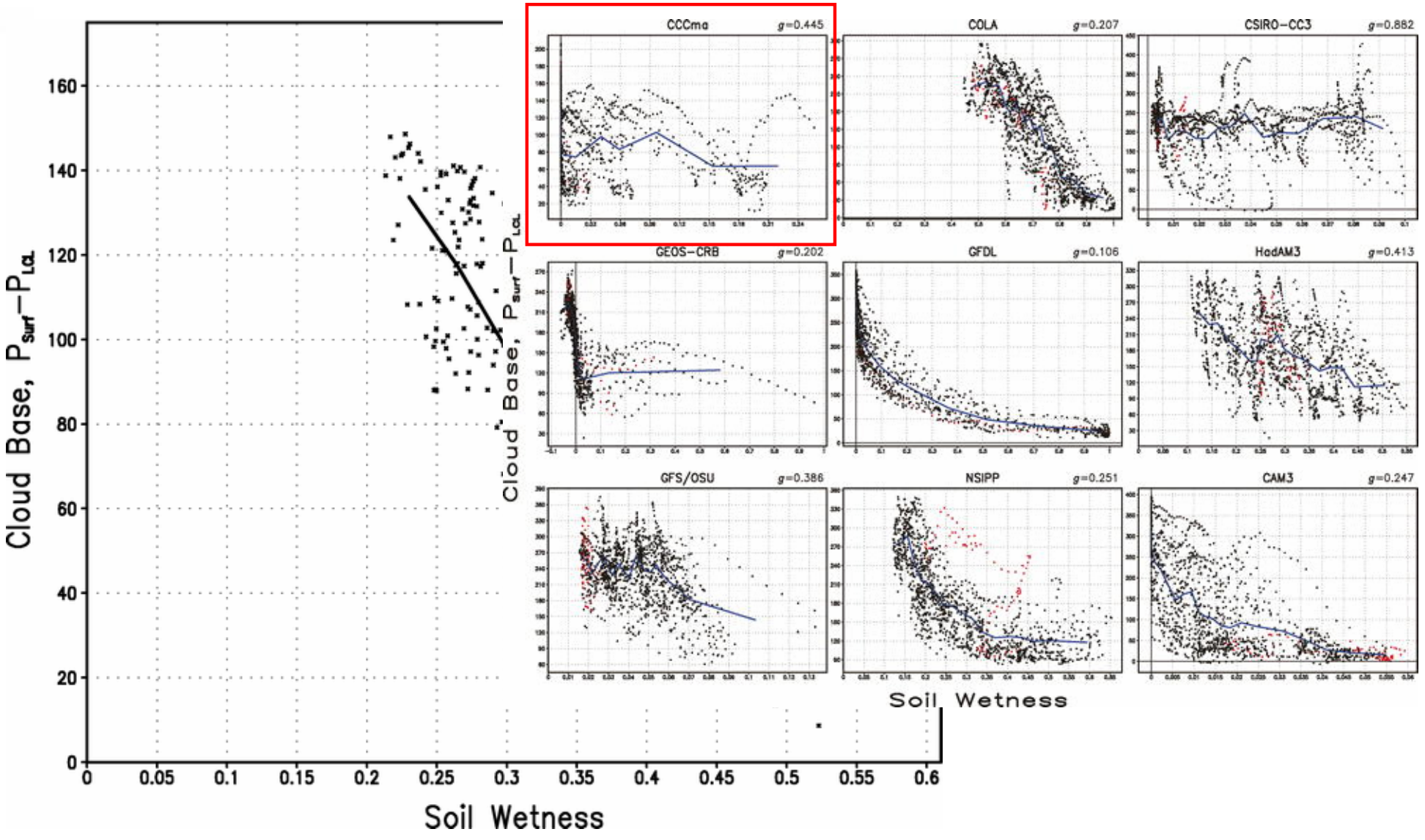




Results from ECMWF reanalysis over southwestern Amazon Basin

Betts A. K., P. Viterbo (2005), Land-surface, boundary layer, and cloud-field coupling over the southwestern Amazon in ERA-40, J. Geophys. Res., 110, D14108, doi:10.1029/2004JD005702.

Relationship between soil moisture and the state of the atmosphere

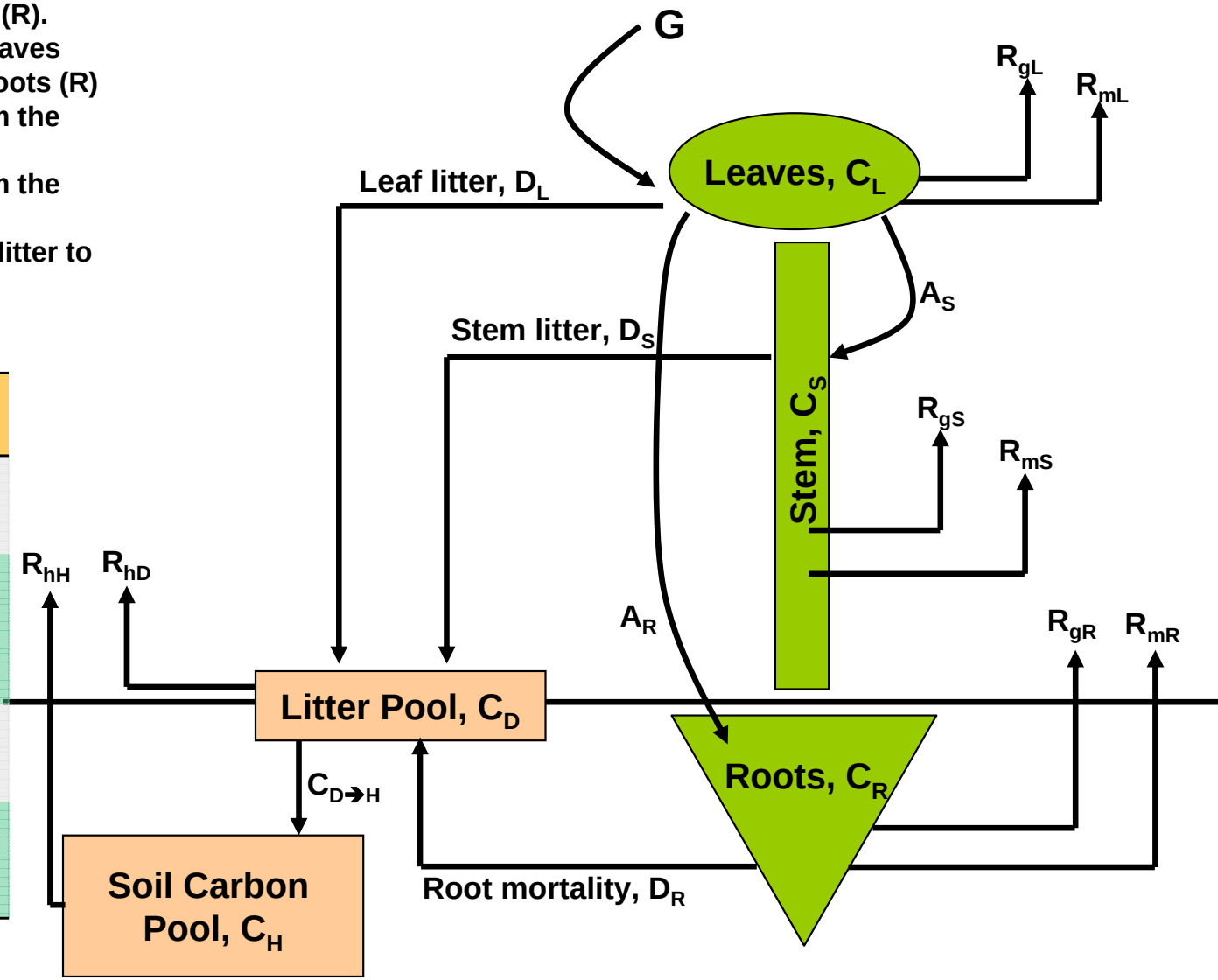


Dirmeyer, P.A., R.D. Koster, and Z. Guo, Do Global Models Properly Represent the Feedback between Land and Atmosphere? J. Hydrometeorology, 7(6), 1177–1198.

Structure of the Canadian Terrestrial Ecosystem Model (CTEM)

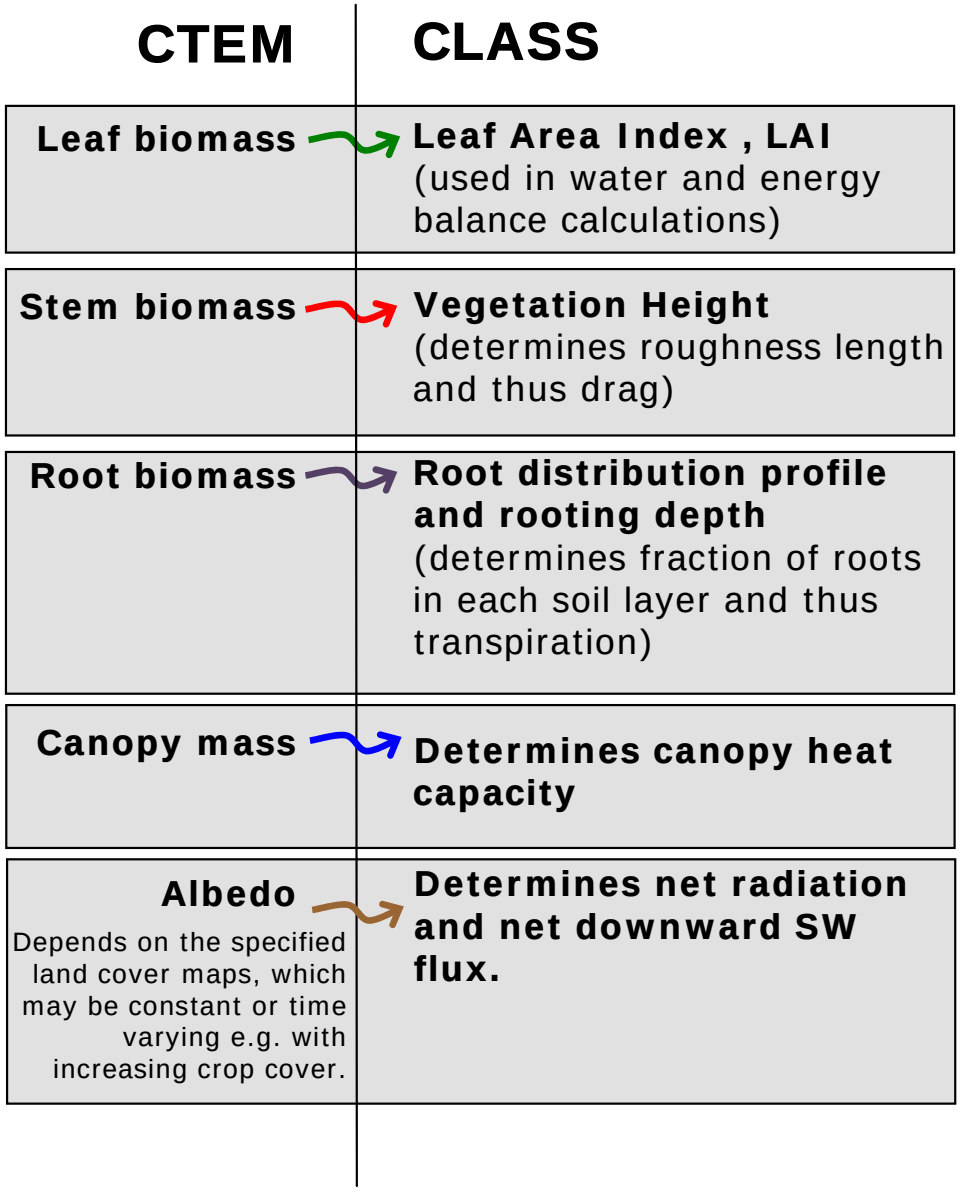
G = photosynthesis, GPP
A_S = carbon allocated to stem from leaves
A_R = carbon allocated to roots from leaves
R_{gL} = Growth respiration for leaves, and similarly for stem (S) and roots (R).
R_{mL} = Maintenance respiration for leaves and similarly for stem (S) and roots (R)
R_{hD} = Heterotrophic respiration from the litter or debris pool
R_{hH} = Heterotrophic respiration from the soil carbon (humus) pool
$C_{D\rightarrow H}$ = carbon transferred from the litter to the soil carbon pool

CTEM 1.0 Plant Functional Types	
1	Needleleaf Evergreen
2	Needleleaf Deciduous
3	Broadleaf Evergreen
4	Broadleaf Cold Deciduous
5	Broadleaf Dry Deciduous
6	C_3 Crop
7	C_4 Crop
8	C_3 Grass
9	C_4 Grass



CTEM provides CLASS all vegetation related attributes

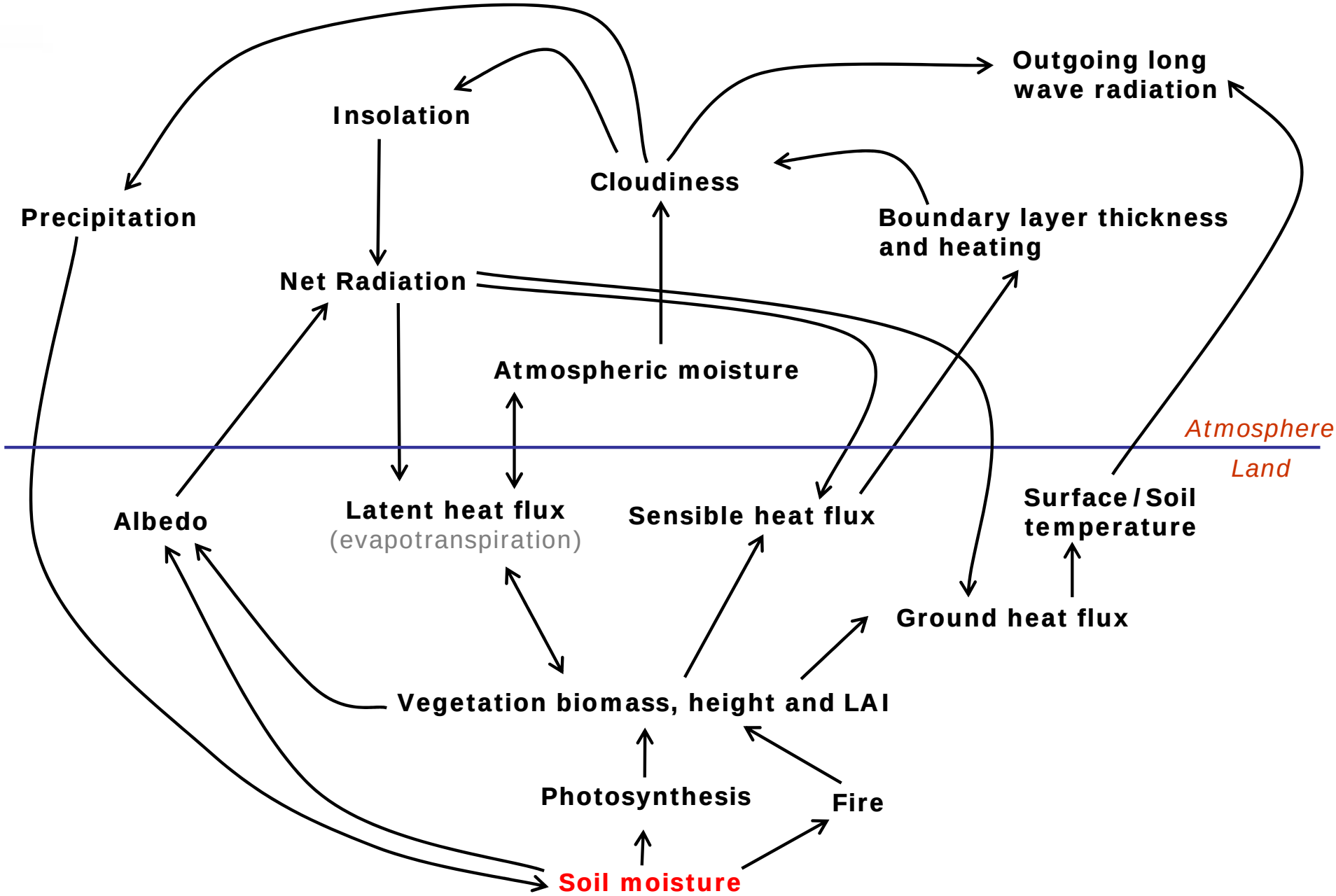
Since vegetation biomass is time variant and model climate dependent



All these vegetation attributes also become time variant and climate dependent (except for the land cover which has to be specified).

CTEM 1 doesn't model the competition between PFTs and thus the fractional coverages of PFTs in a grid cell has to be specified.

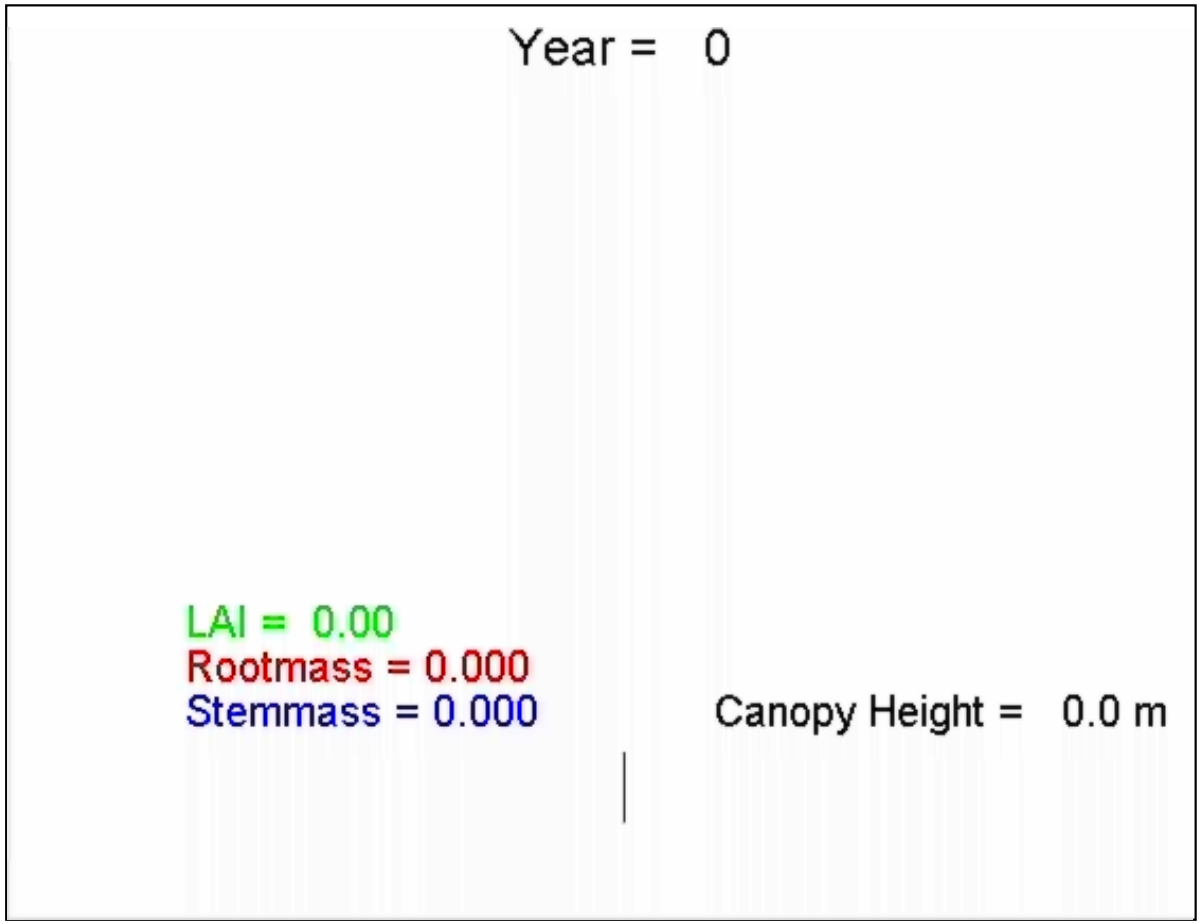
Land-atmosphere interactions and feedbacks



How CTEM grows vegetation?

Annual vegetation growth

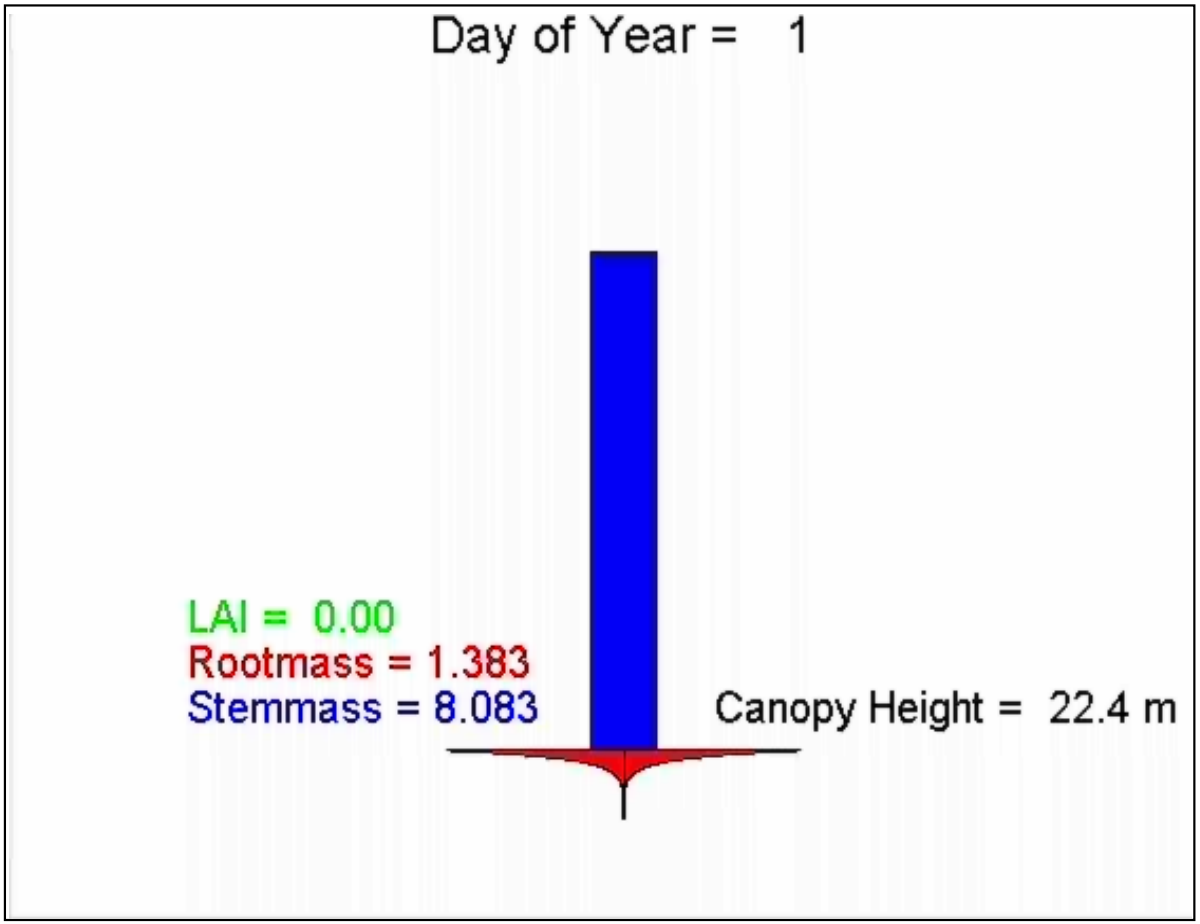
for a Broadleaf Cold Deciduous plant functional type in Germany



How CTEM grows vegetation?

Annual cycle of leaf area index

for a Broadleaf Cold Deciduous plant functional type in Germany



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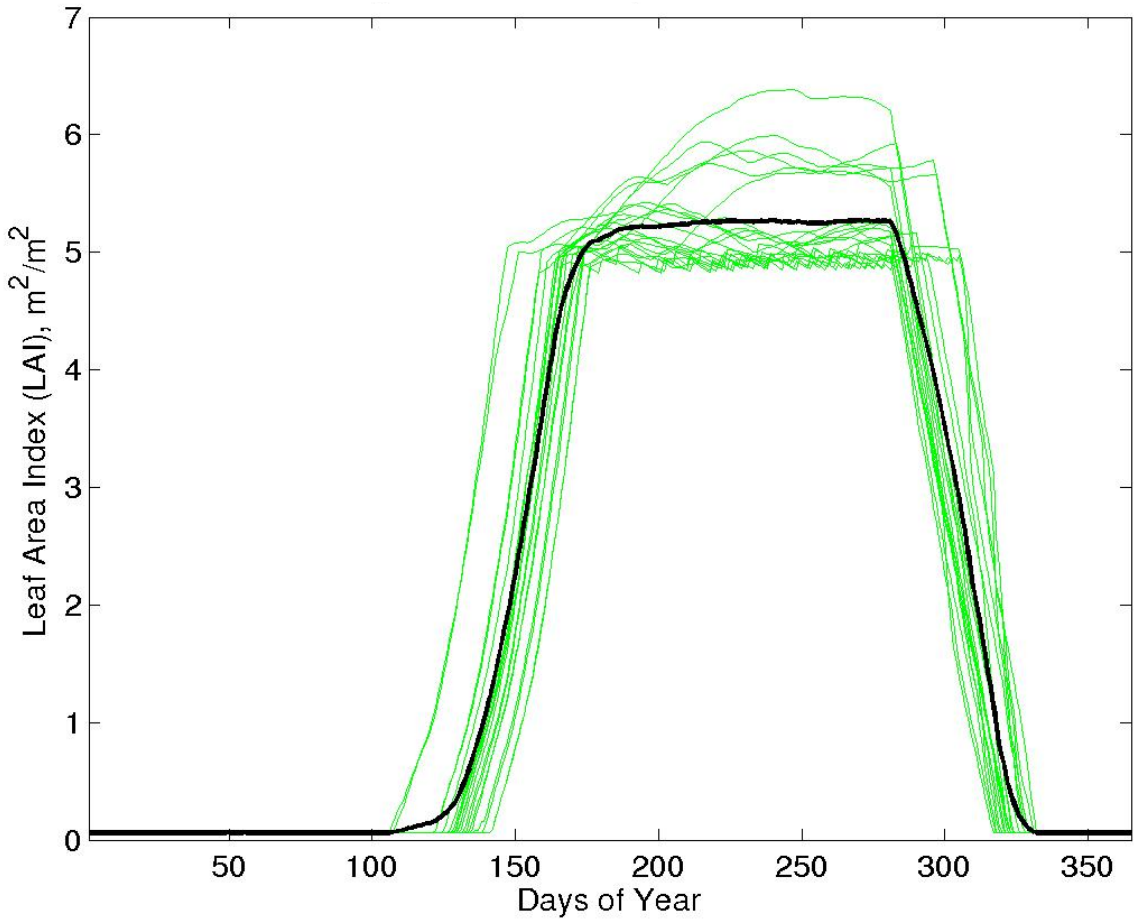
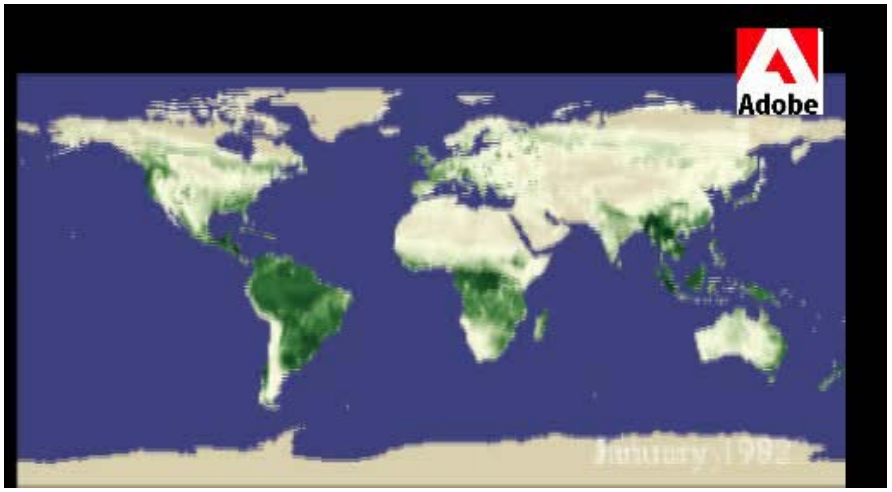
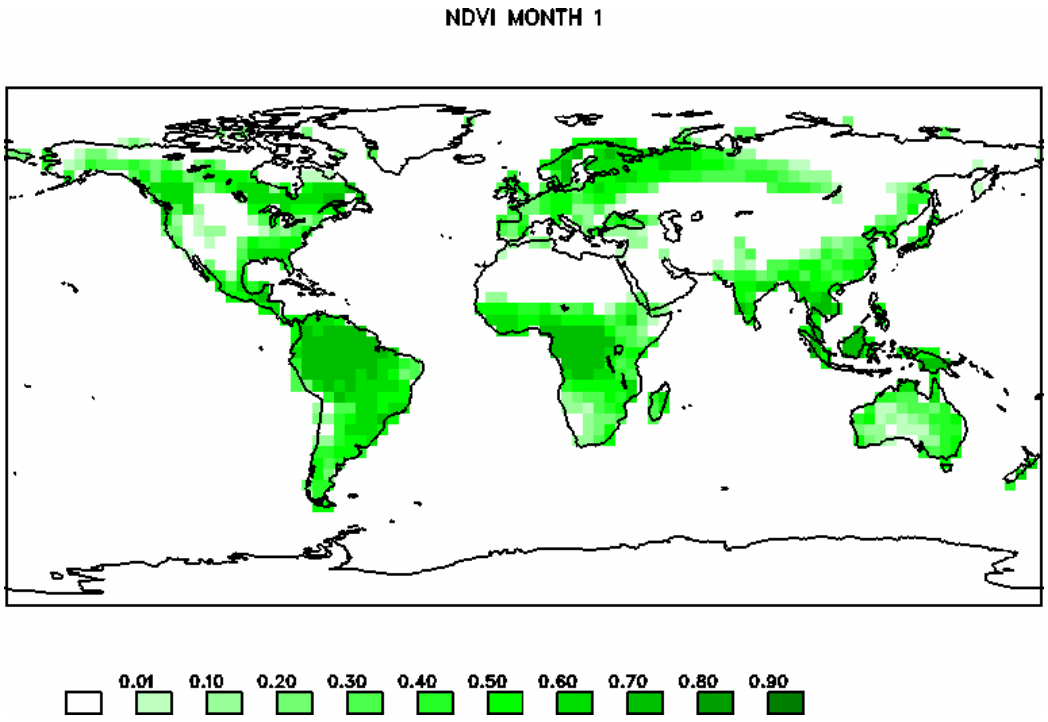


How CTEM grows vegetation?

Simulated annual cycle of leaf area index



Annual cycle of satellite-derived normalized difference vegetation index (NDVI)



Model-simulated annual cycle of NDVI (derived from grid-averaged LAI, m^2/m^2)

NDVI-LAI relationship from Buermann, W., et al. (2002): Analysis of a multi-year global vegetation leaf area index data set, J. Geophys. Res., 107(D22), 10.1029/2001JD000975.

In near future, combined analysis of soil moisture and states of vegetation and atmosphere is planned

- Compare model simulated and observation-based behaviour of and relationship between …
  - Soil moisture,
  - Vegetation state defined in terms of LAI or NDVI, and
  - State of the atmosphere
- Observation-based information about states of vegetation (satellite-based NDVI) and atmosphere (reanalysis) is available.
- But no information is available for root zone soil moisture at large spatial scales.

Summary

- Soil moisture affects the state of the atmospheric boundary layer (ABL) by influencing the partitioning of net radiation into latent and sensible heat fluxes.
- In a coupled vegetation-climate model, soil moisture additionally influences the state of vegetation and in particular the LAI which also interacts with the ABL.
- Quantification of soil-vegetation-atmosphere feedbacks is important to understanding the behaviour of coupled models, but hindered by the lack of observation-based root zone soil moisture data.