“Ancillary Fields” in the Community Land Model

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CICERO Center for International Climate Research

ECMWF Workshop on ancillary data for land surface and Earth system modelling. 9th Aptil 2025

Thanks to:

Charlie Koven

LBNL

Will Wieder

NCAR

Dave Lawrence

NCAR

Peter Lawrence

NCAR

Kjetil Aas

CICERO

Sean Swenson

NCAR

…& the CLM and FATES development and software engineering teams.

Evaluating climatic and soil water controls on evapotranspiration at two Amazonian rainforest sites

Rosie A. Fisher [a], Mathew Williams [a], Maria de Lourdes Ruivo [b], Antonio Lola de Costa [c], Patrick Meir [a]

- 2008: Amazonian soils have hugely different hydraulic properties than the standard pedo-transfer functions imply… (meaning they store **quite a lot less water**)

- AFAIK this is still true!

2002: Caxiuana, Brazil.

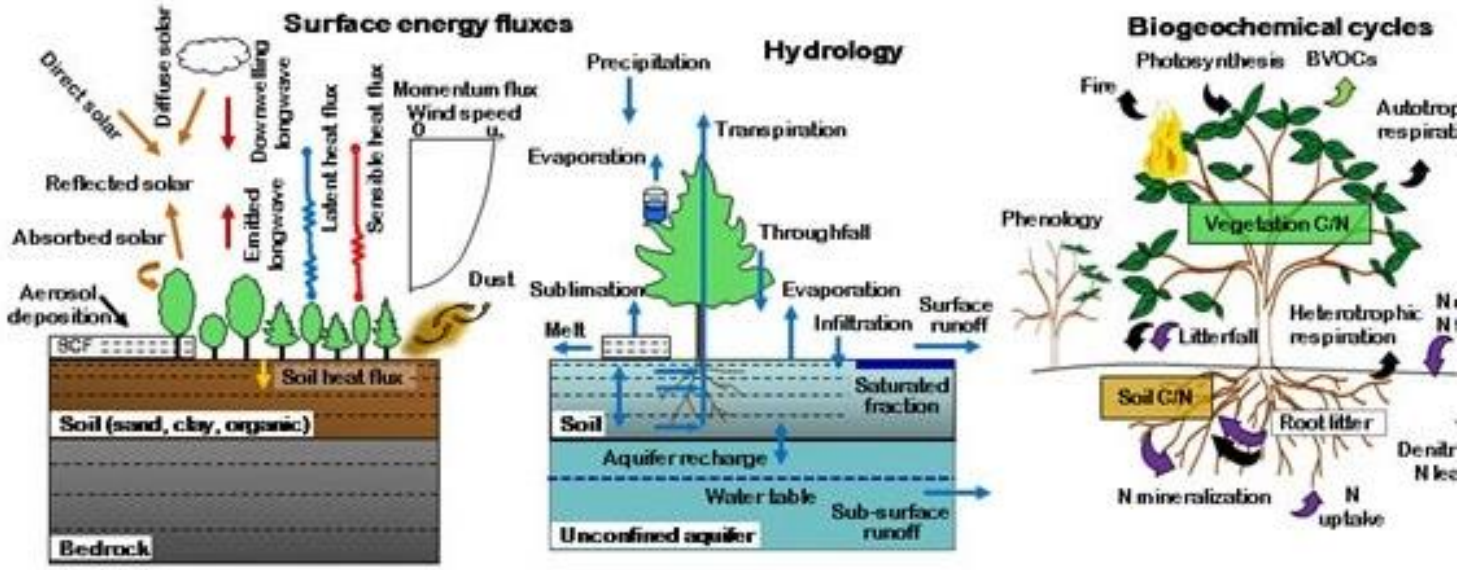
What is the Community Land Model?

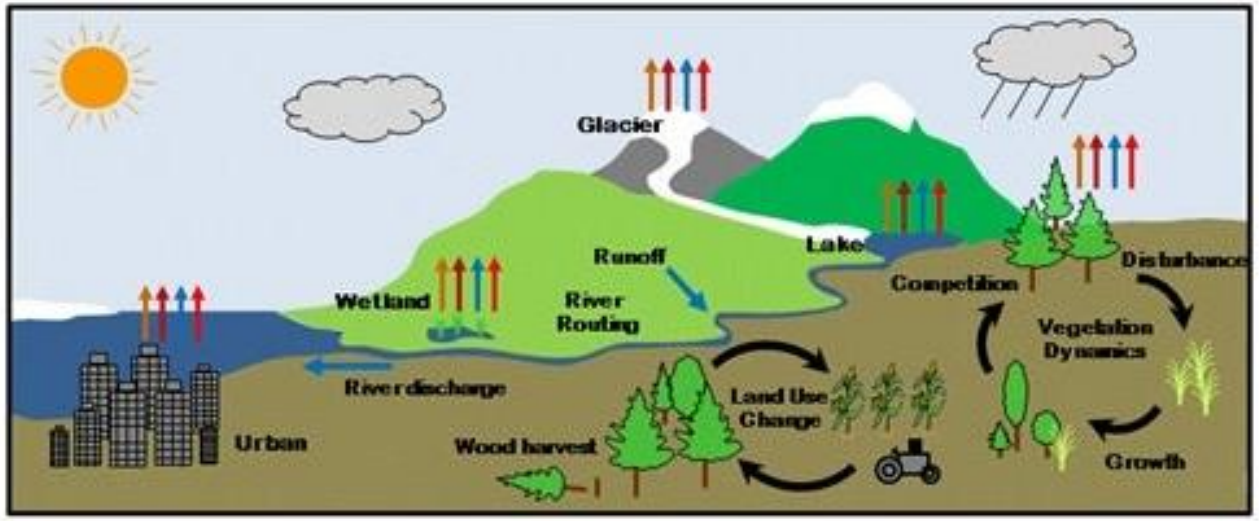
The land surface of numerous **Earth System Models**

CESM, **NorESM**, CMCC, E3SM

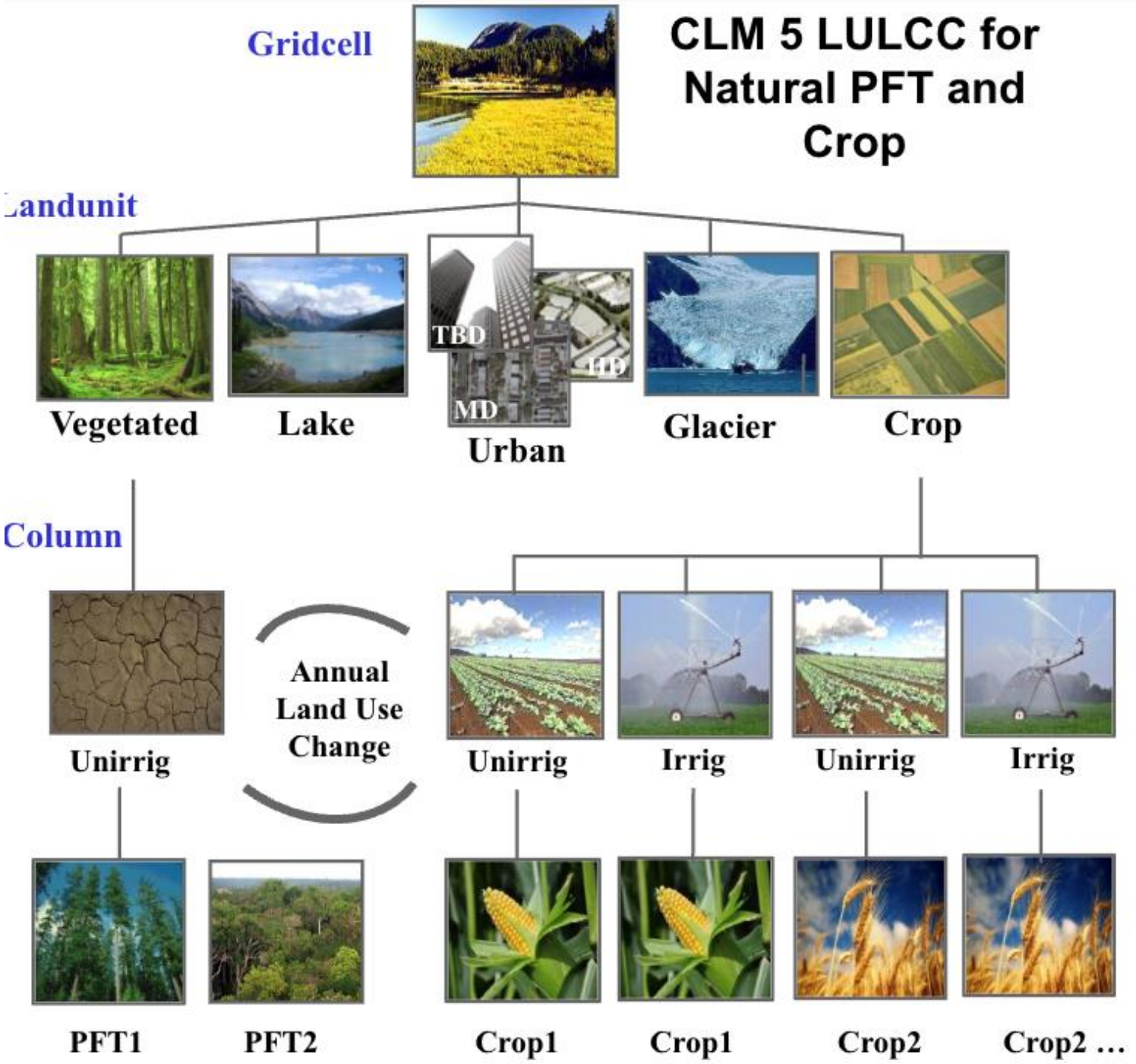
Open source, open development, ‘bottom-up’

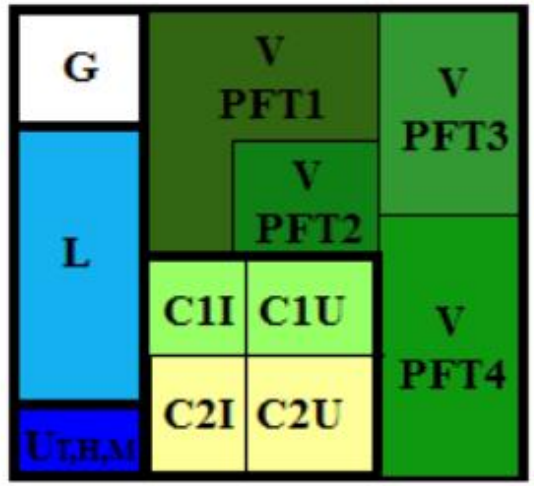
Relatively advanced **process representation** (for a LSM)

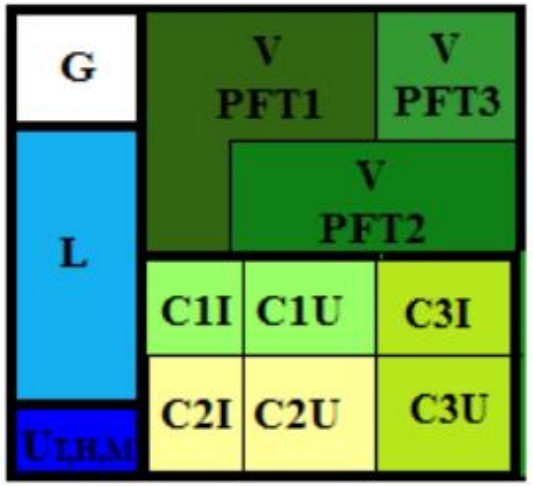




Land tiling in the ('big leaf') CLM5



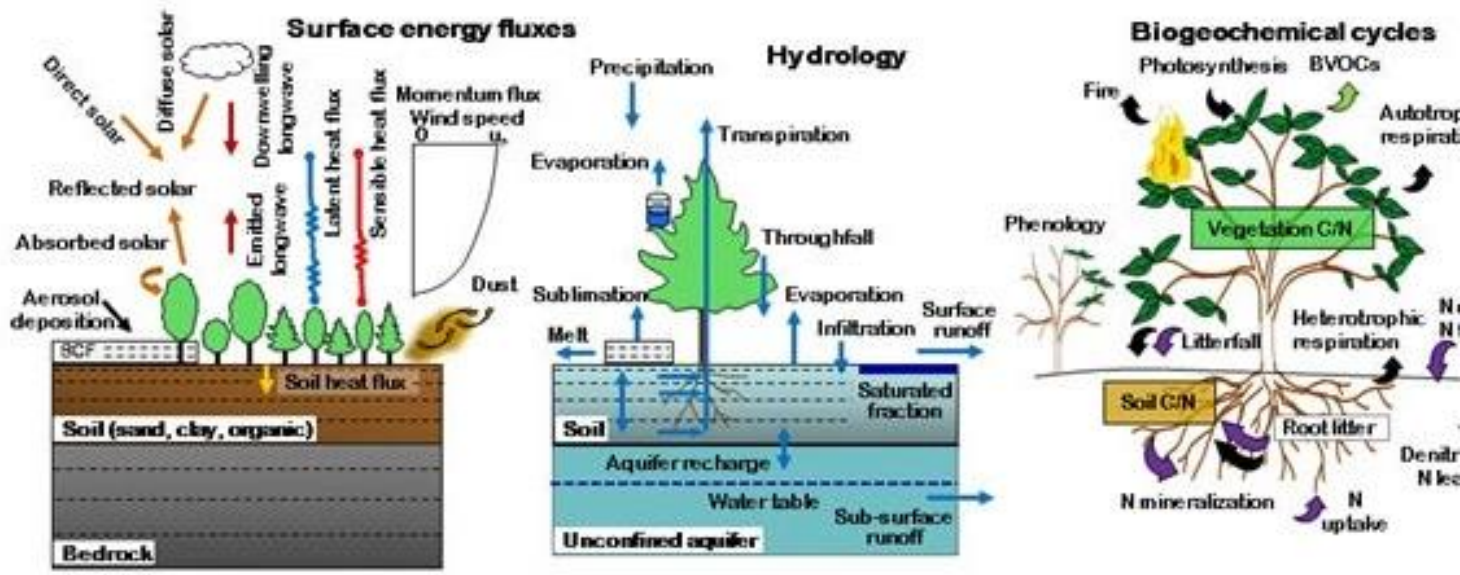




What are “ancillary fields”?

We call them “**surface datasets**”

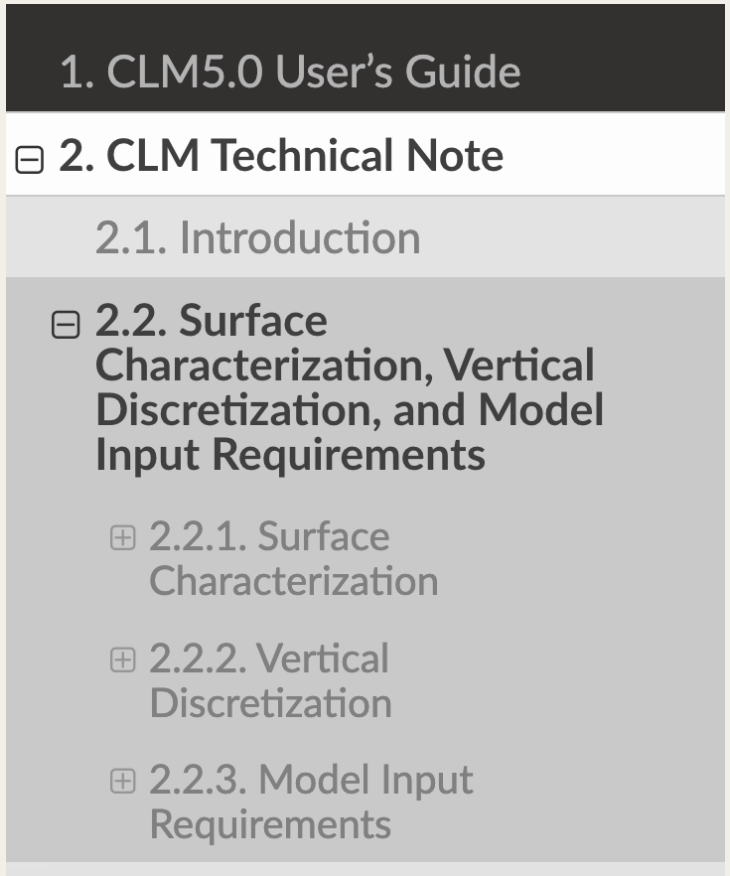
Used in CLM to provide information on properties of the land surface that are **prescribed** (input) to the model



Standard input maps

Details in CLM5 tech note:

https://escomp.github.io/ctsm-docs/



Surface Field	Resolution
Percent glacier	0.05°
Percent lake and lake depth	0.05°
Percent urban	0.05°
Percent plant functional types (PFTs)	0.05°
Monthly leaf and stem area index	0.5°
Canopy height (top, bottom)	0.5°
Soil color	0.5°
Percent sand, percent clay	0.083°
Soil organic matter density	0.083°
Maximum fractional saturated area	0.125°
Elevation	1km
Slope	1km
Biogenic Volatile Organic Compounds	0.5°
Crop Irrigation	0.083°
Managed crops	0.5°
Population density	0.5°
Gross domestic production	0.5°
Peat area fraction	0.5°
Peak month of agricultural waste burning	0.5°

Standard input maps

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Grid Cell Land Cover
(PFT distribution is an INPUT)

Used by 'Satellite Phenology' mode
With fixed LAI)

Soil/hydrology

Crop Management

Fire

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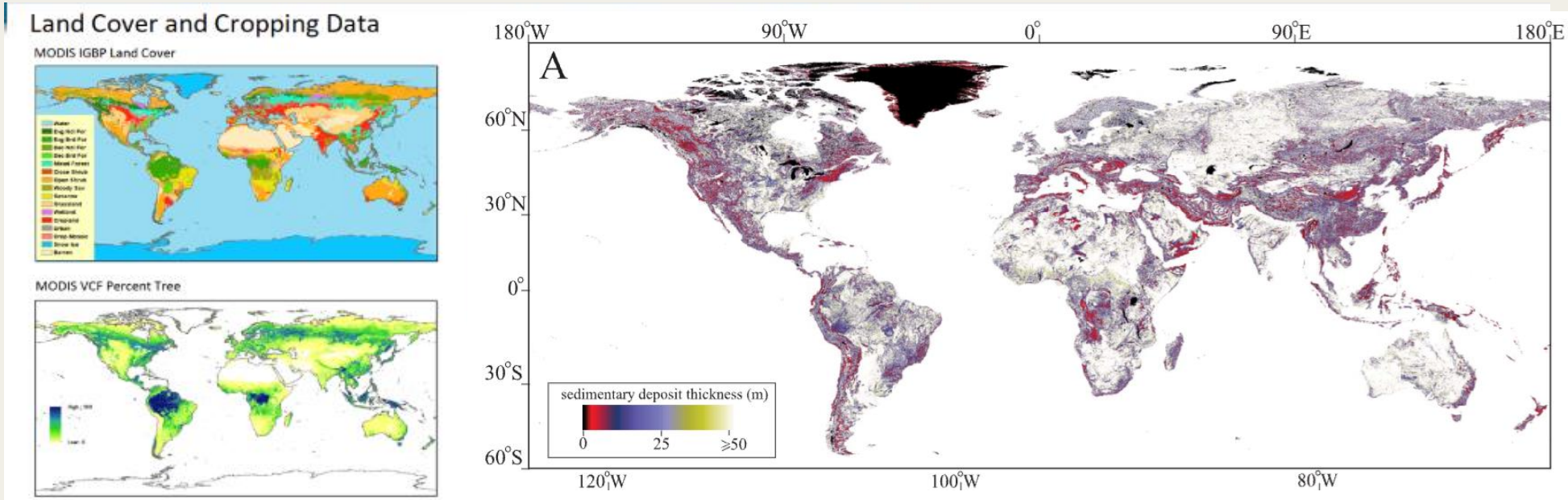
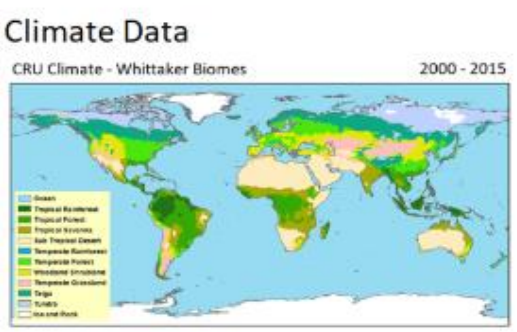
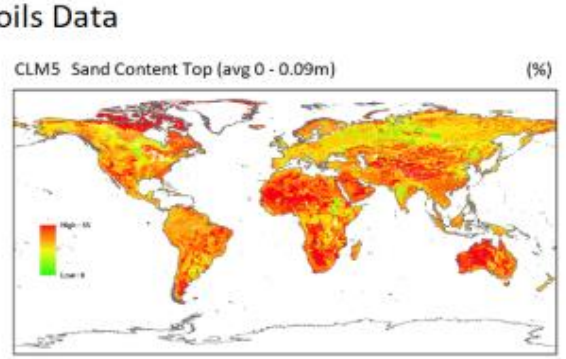
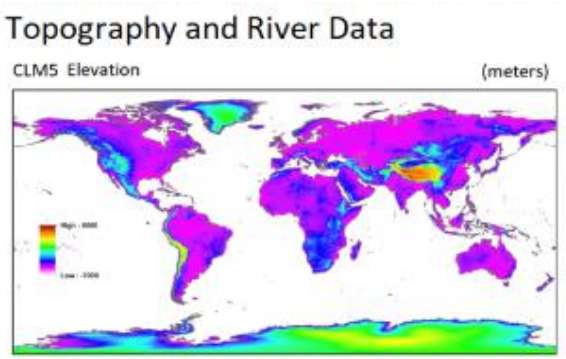
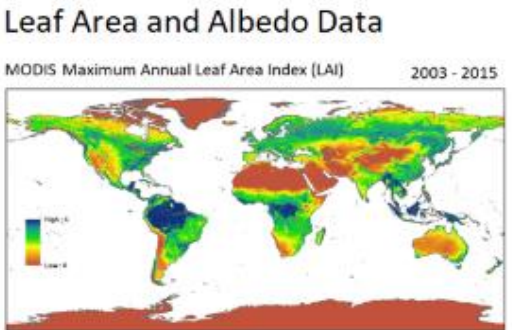
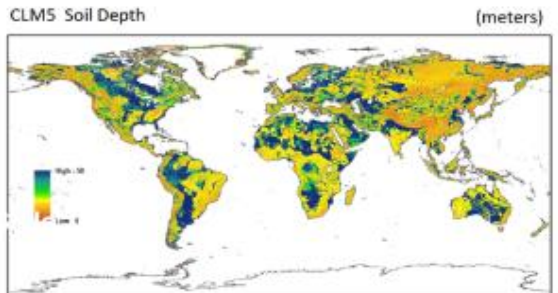


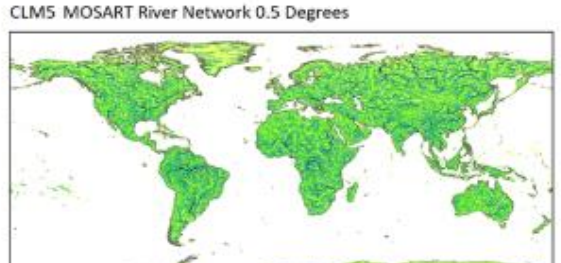








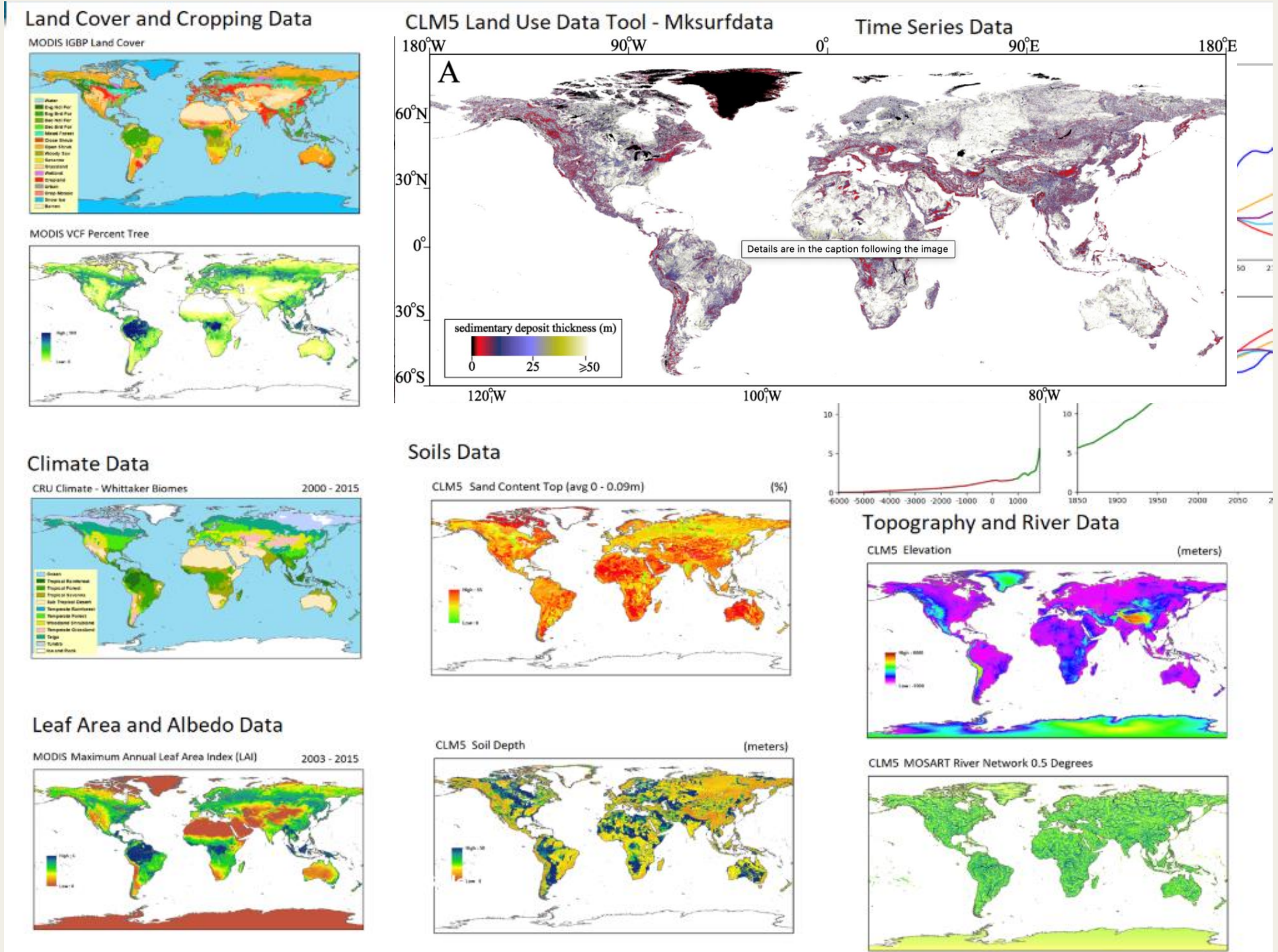




What is new since CLM5?

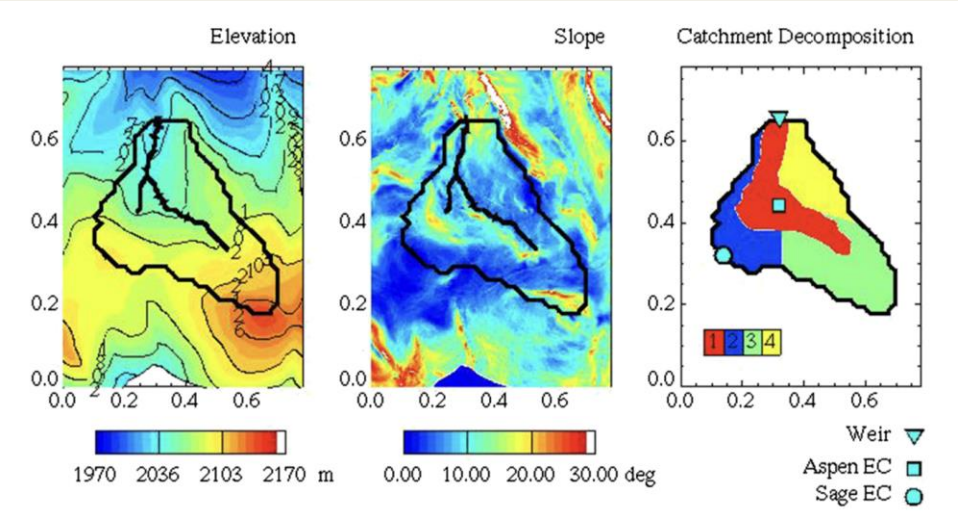
Standard input maps...?

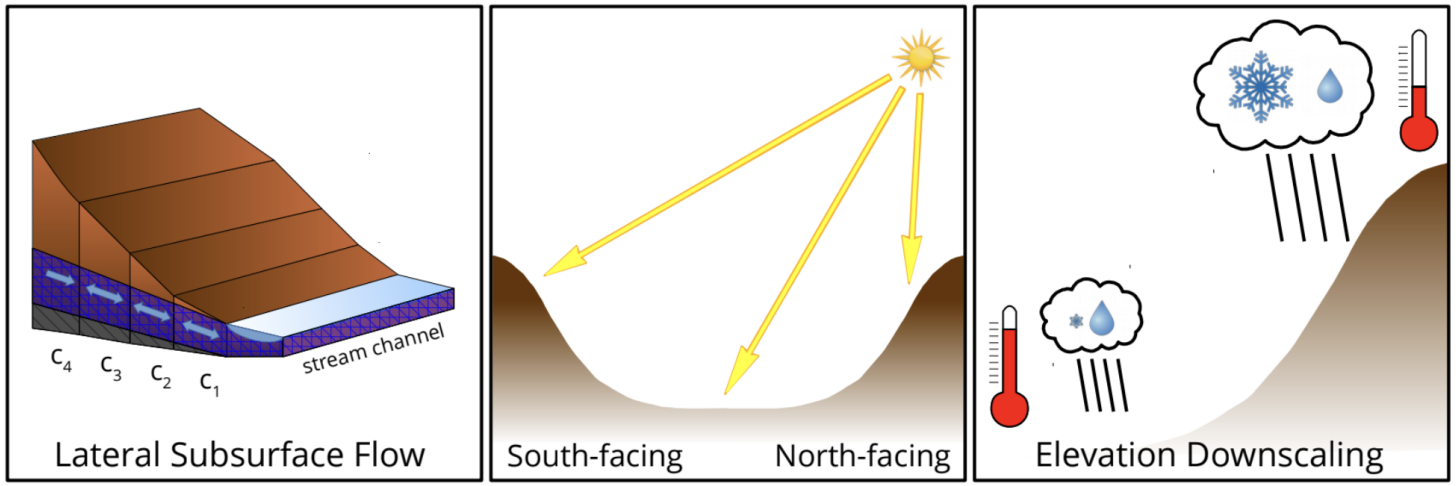
These are still mostly the same 🙃



What is new since CLM5?

1. Hillslope Hydrology

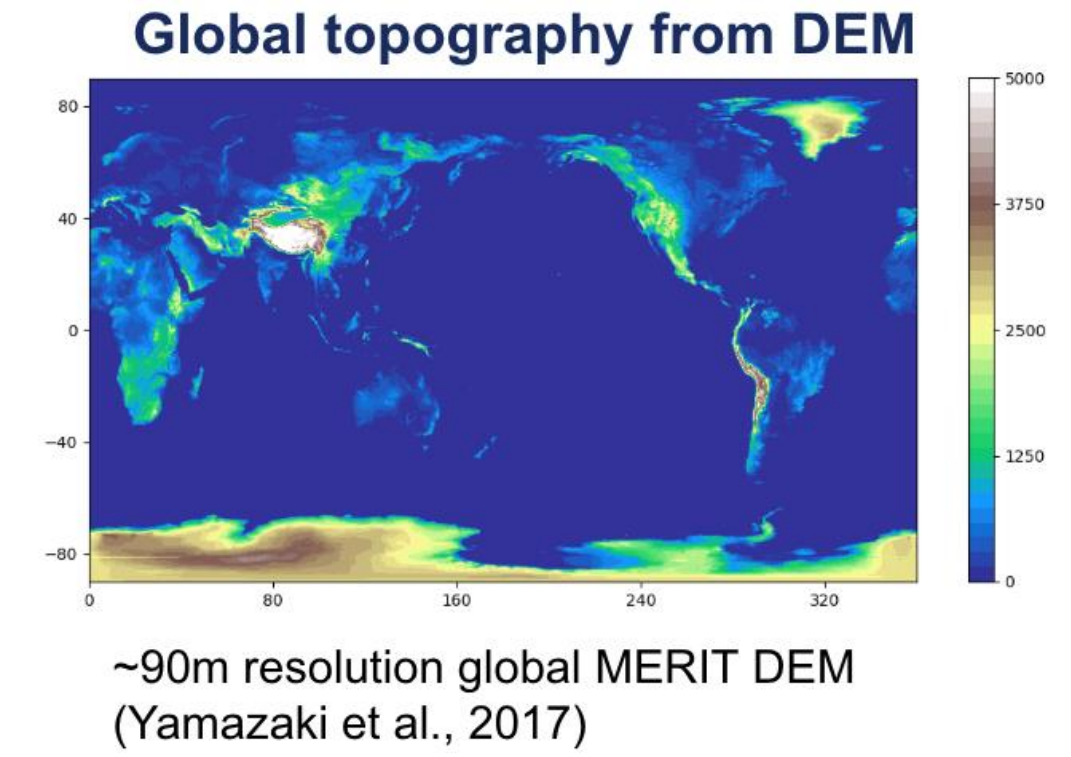




Representing Intrahillslope Lateral Subsurface Flow in the Community Land Model

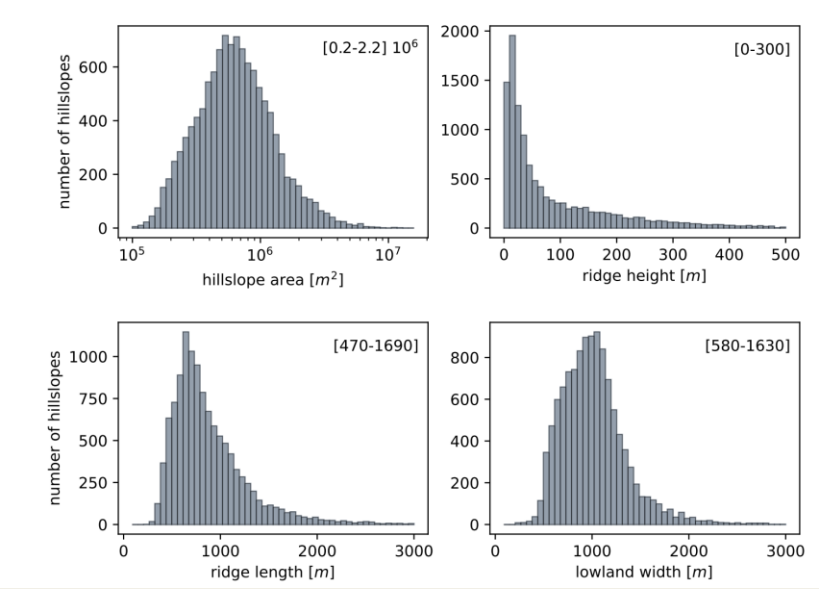
Sean C. Swenson[1], Martyn Clark[2], Ying Fan[3], David M. Lawrence[1], and Justin Perket[4]

What is new since CLM5?



Each hillslope element (column) is defined by 6 parameters

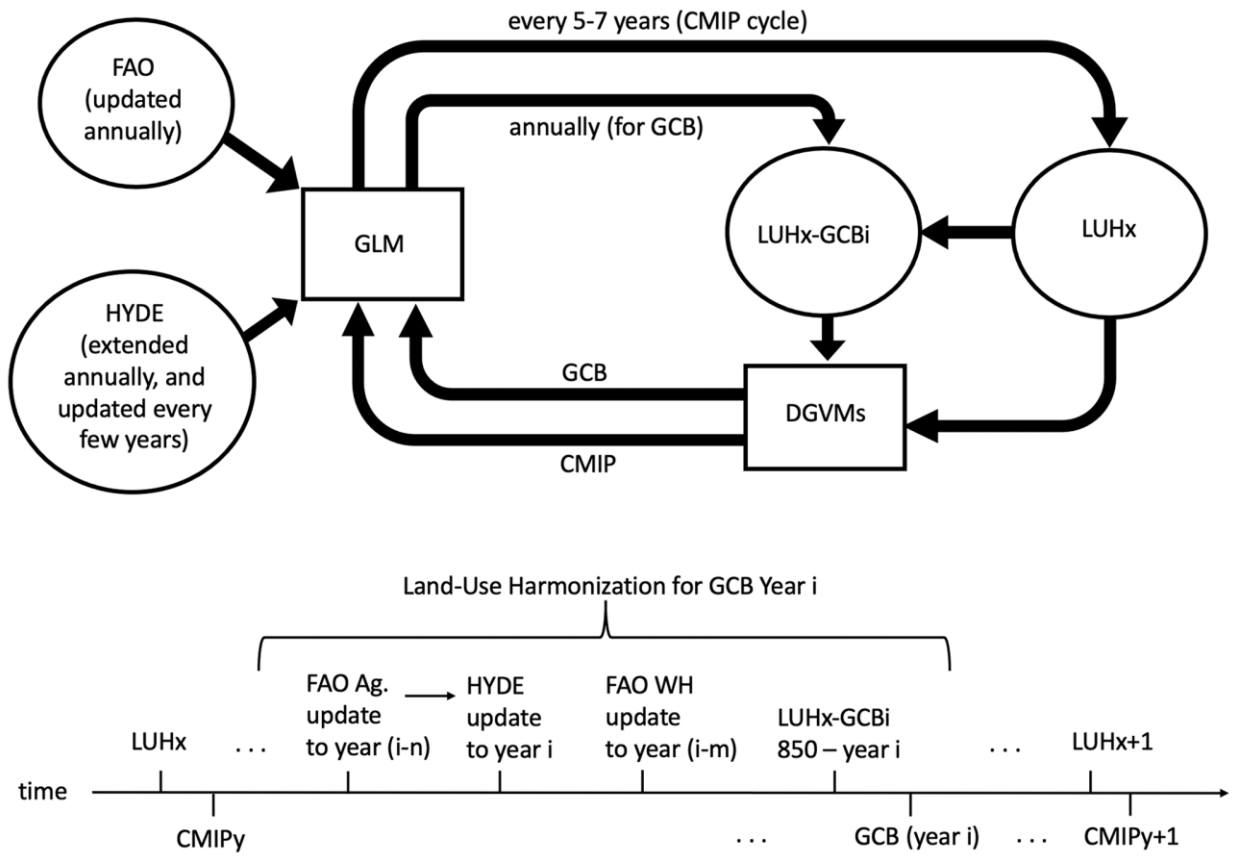
- Area (**a**)
- Width (**w**)
- Distance from channel (**d**)
- Height above nearest drainage (**h**)
- Slope (**α**)
- Aspect (**β**)



Swenson & Lawrence (in review) extract these parameters from DEM

What is new since CLM5?

1. Hillslope Hydrology
2. New LUH3 **land use drivers** for **CMIP7**
   - Plantations
   - Biofuels
     - -> switchgrass & miscanthus



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1. Hillslope Hydrology
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   - Plantations
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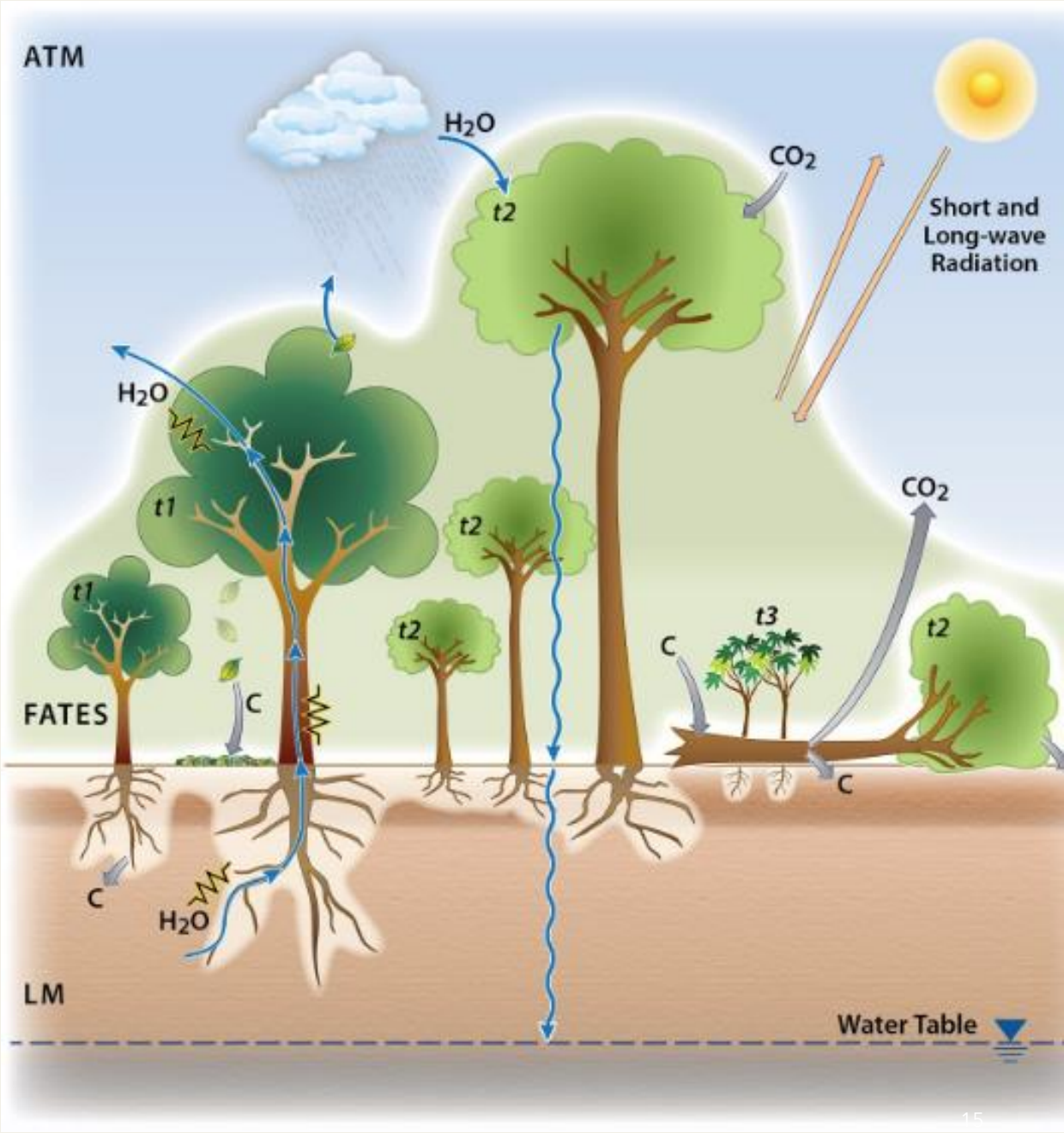
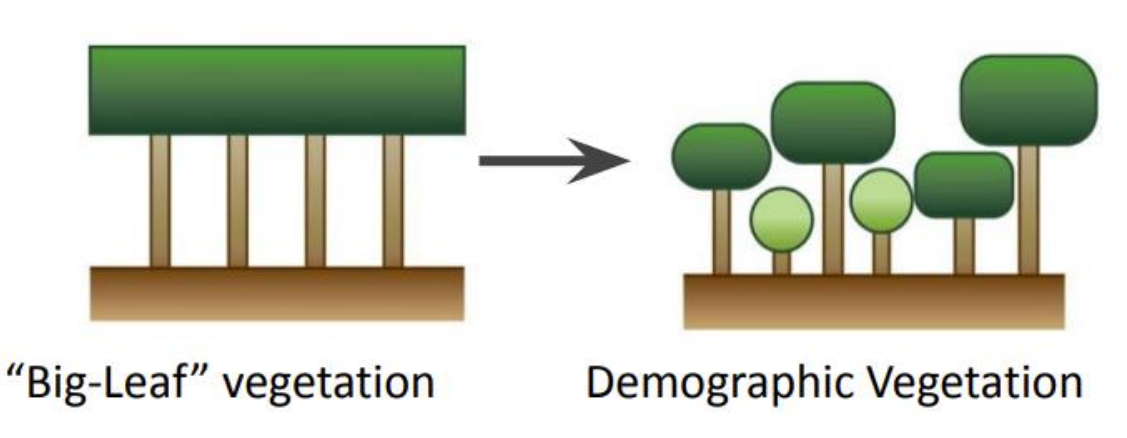
3. **FATES**!

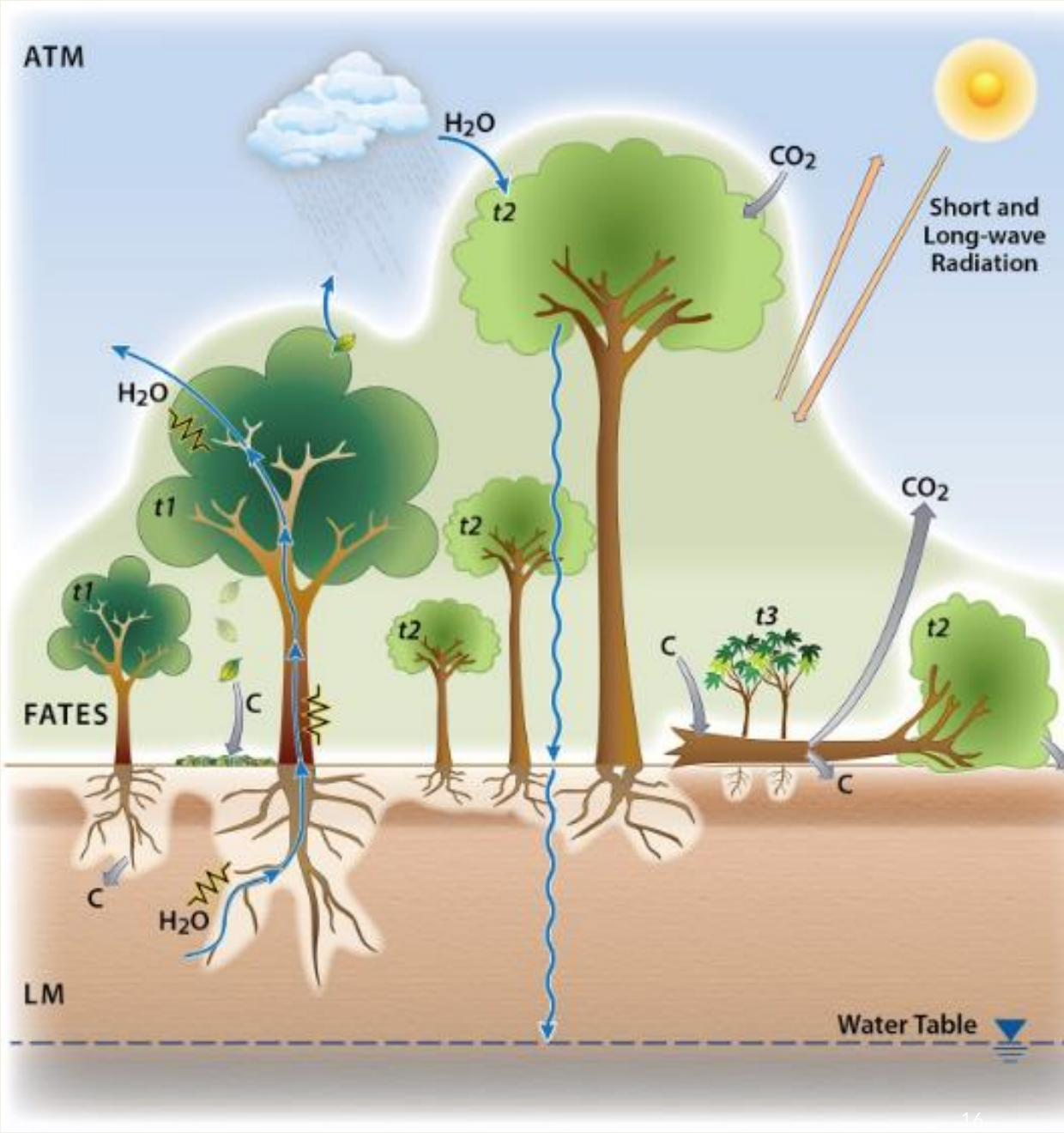


What is new since CLM5?

FATES (**F**unctionally **A**ssembled **T**errestrial **E**cosystem **S**imulator

https://github.com/NGEET/fates





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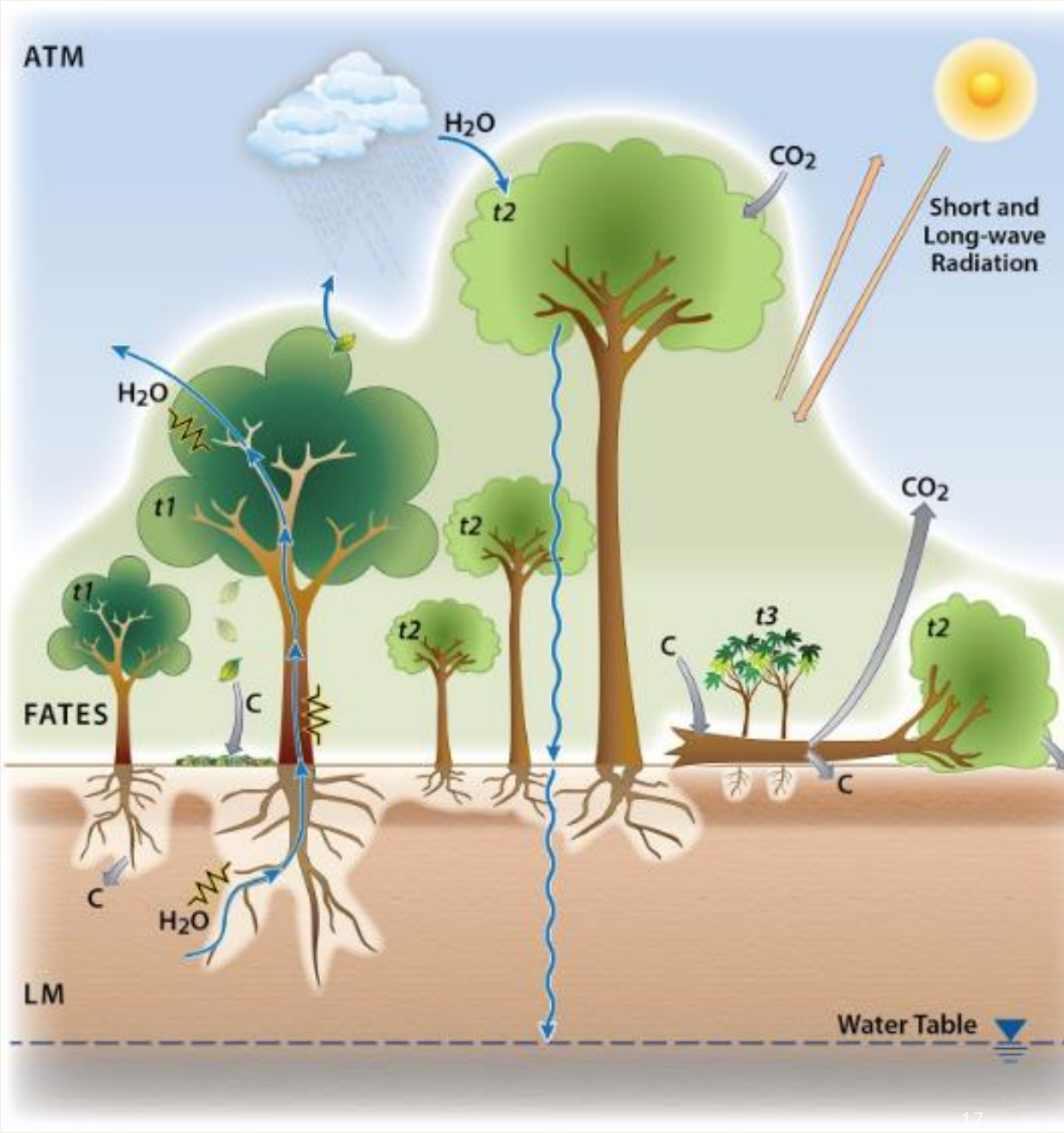
What is new since CLM5?

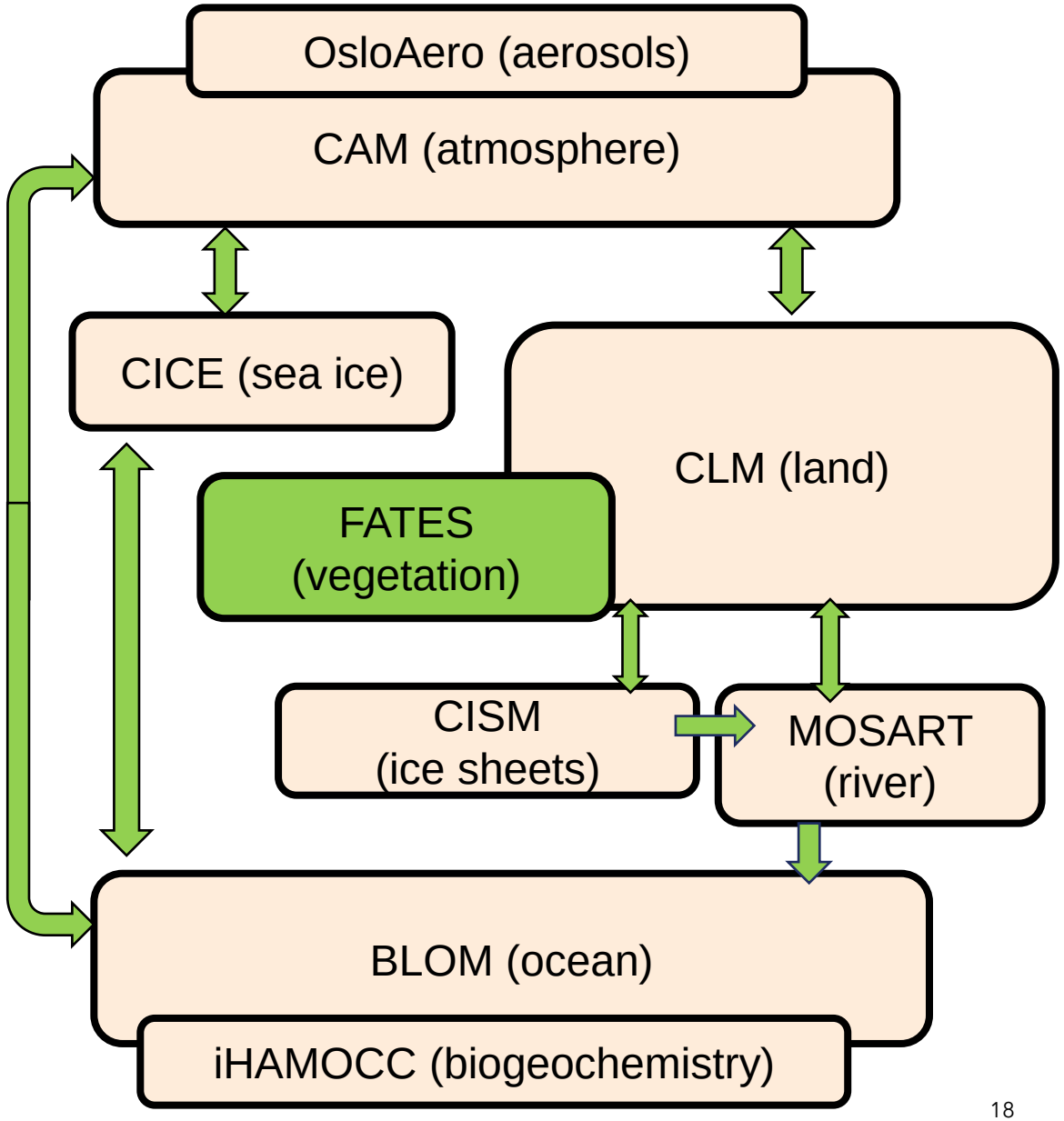
FATES includes:

- **Demographic** vegetation (size and age–structured) including **allometric growth**
- Plant **hydraulics**
- Plant **mortality** drivers (x7)
- **Nitrogen** and **Phosphorus** cycles
- Direct **land use change,** regrowth & **grazing**
- Multi-layer leaf **gas exchange**
- Flexible **PFT** representation
- **Multi-physic**s representation of most things
- Multiple **reduced complexity** modes



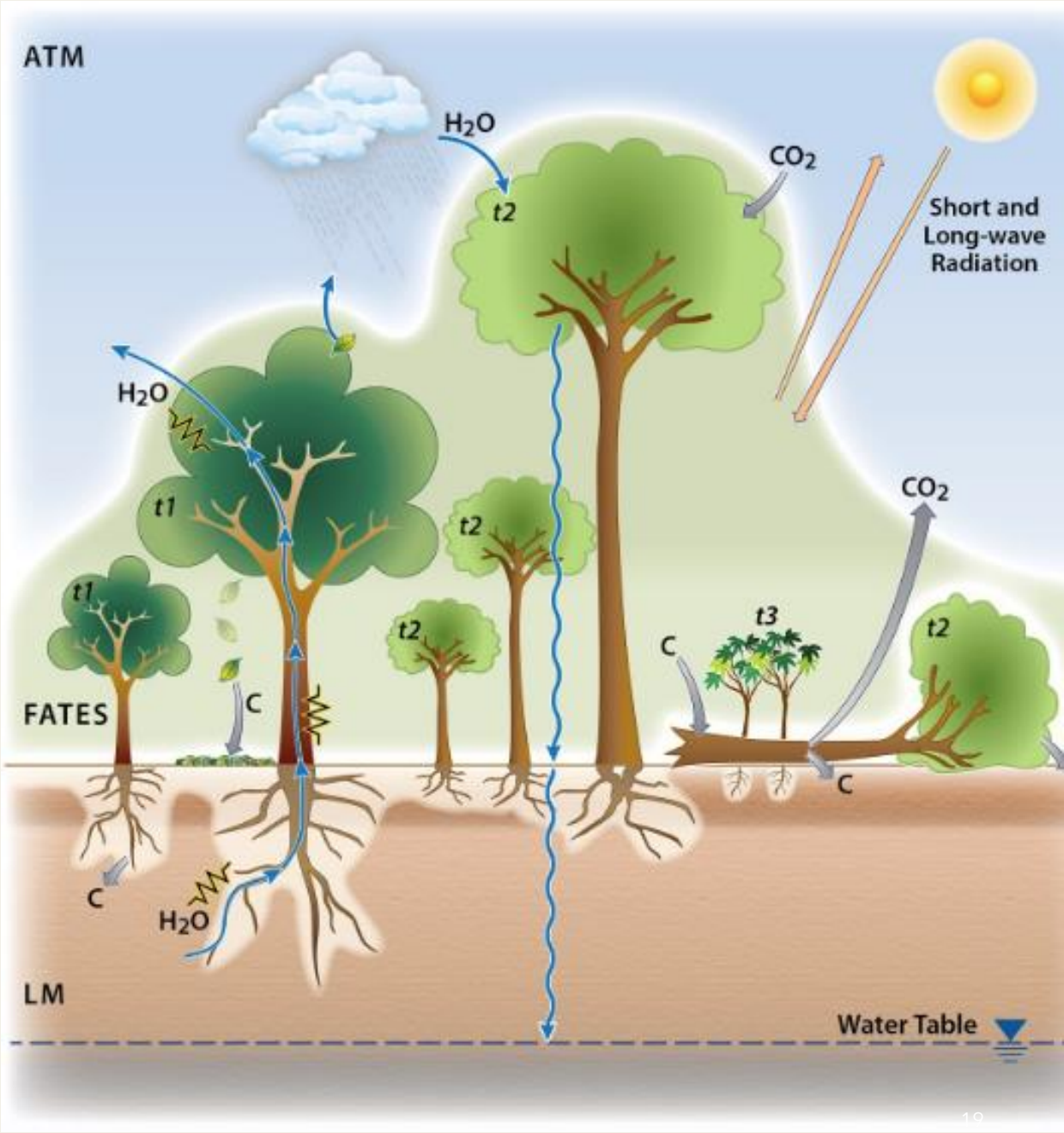
The Norwegian Earth System Model

NorESM =

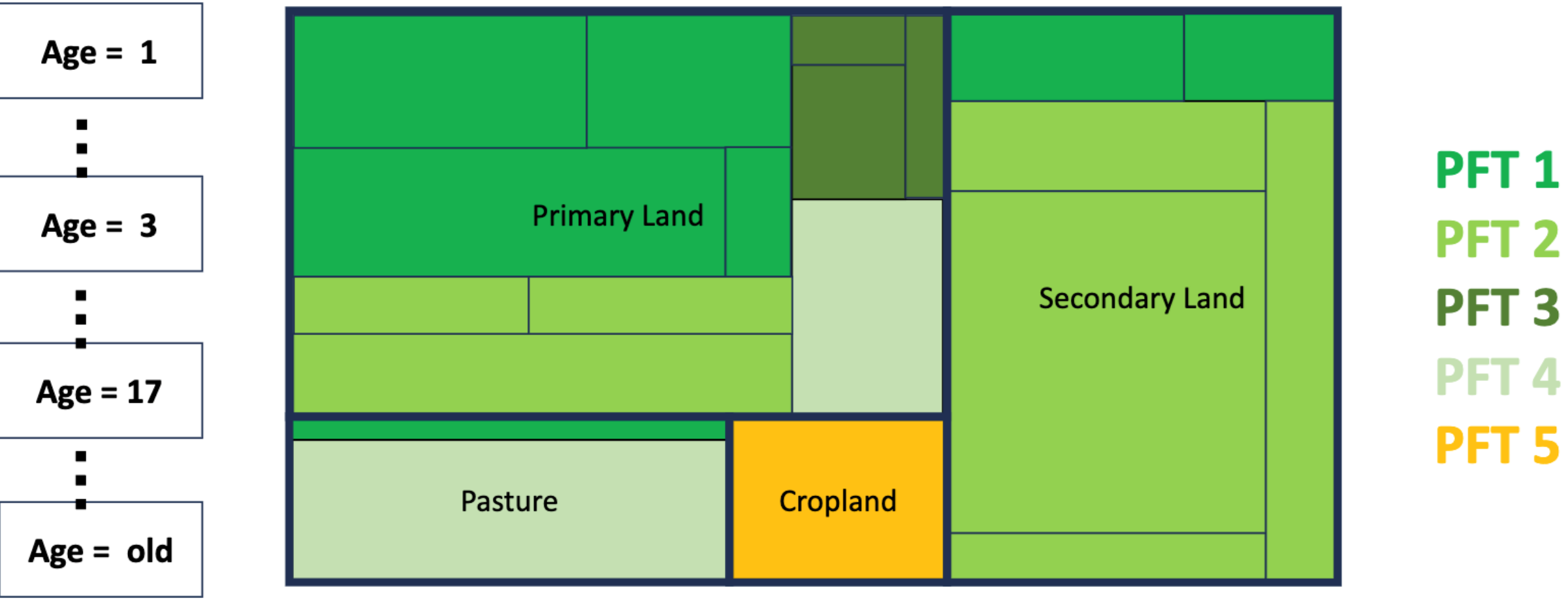


Does FATES need extra ancillaries?

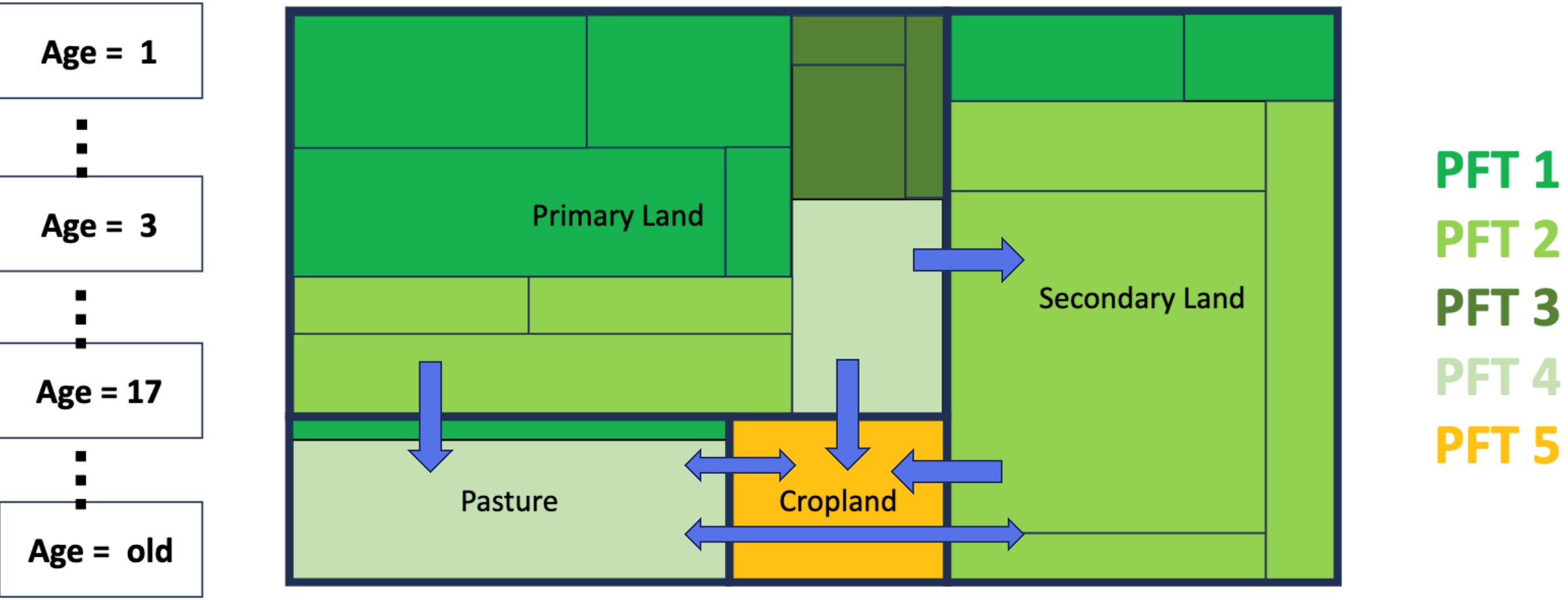
1. FATES can use same PFT maps as CLM (but can **add extraplant diversity** if drivers permit)
2. It can **represent direct land use transitions** from LUH2/3 (harvest, deforestation, abandonment)
3. We have made **new tools** to directly ingest these data into FATES



FATES land use representation

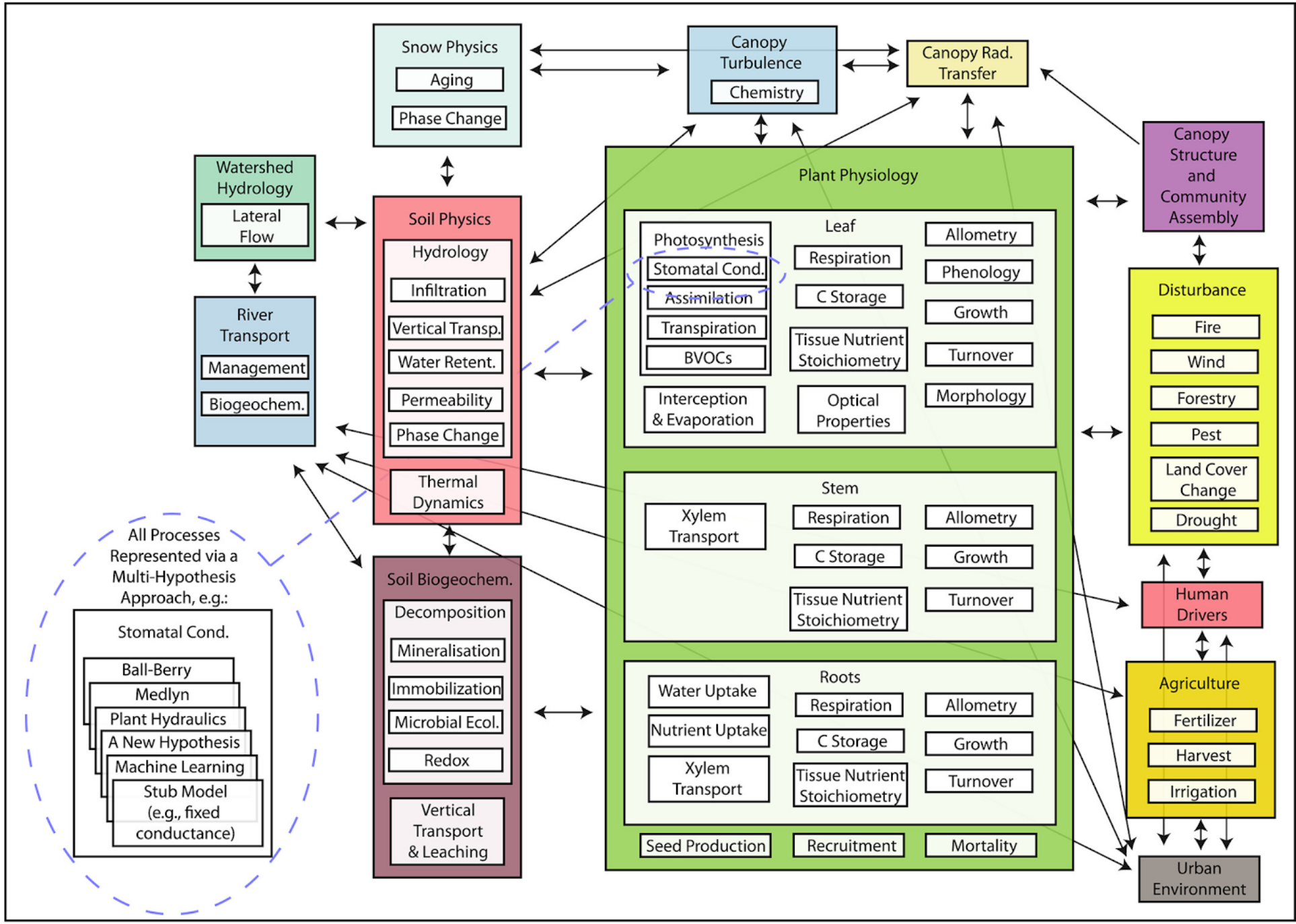


FATES land use transitions



Land surface models are **tremendously complex**

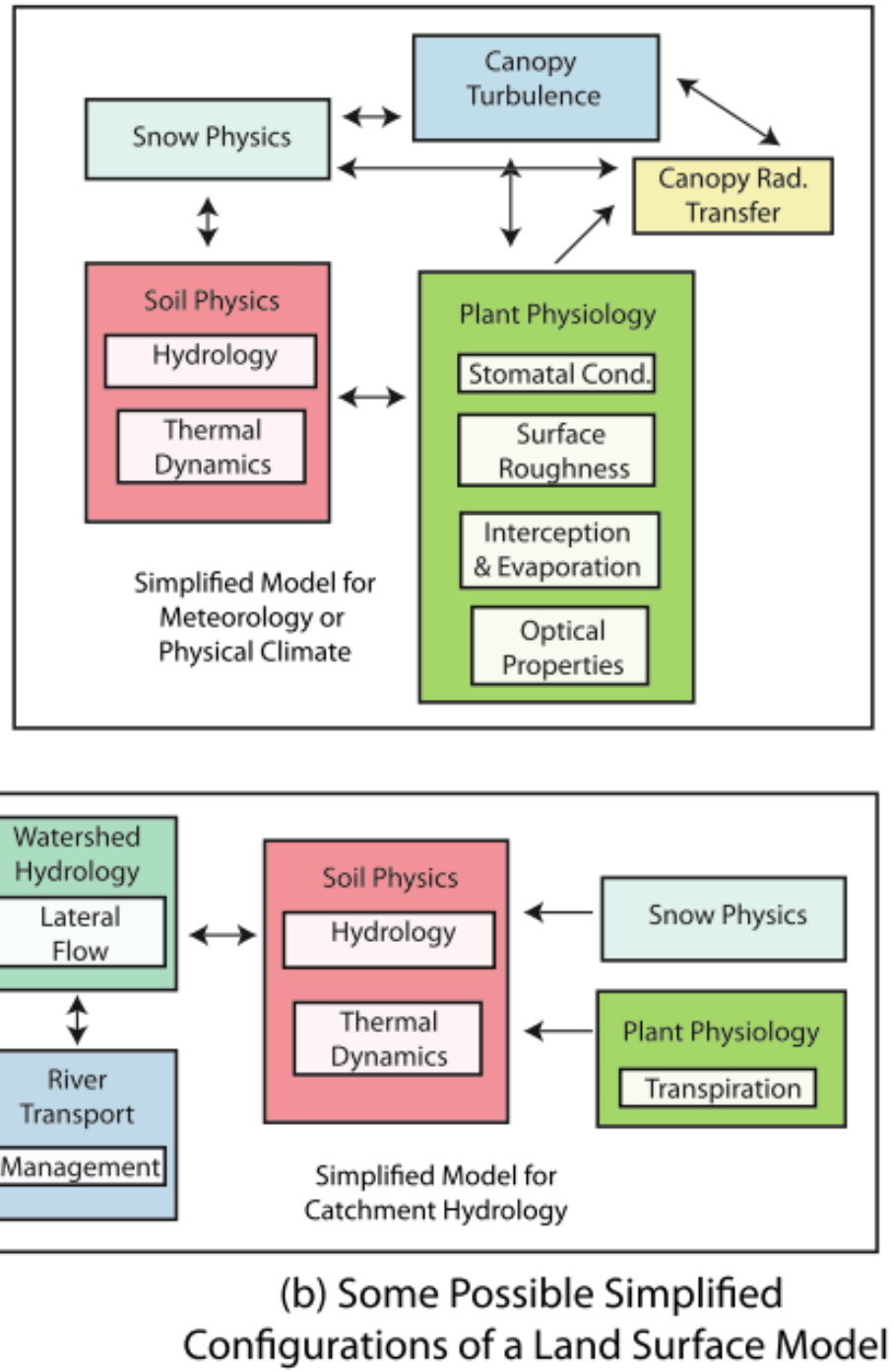
This makes **calibration** (i.e. emulator-based calibration efforts) **hard/ uninformative**.

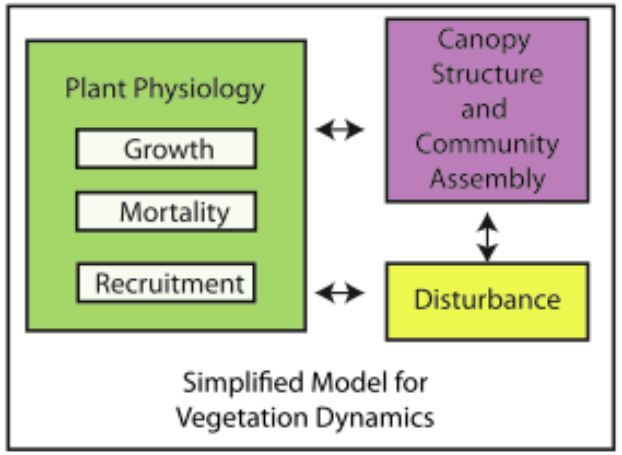


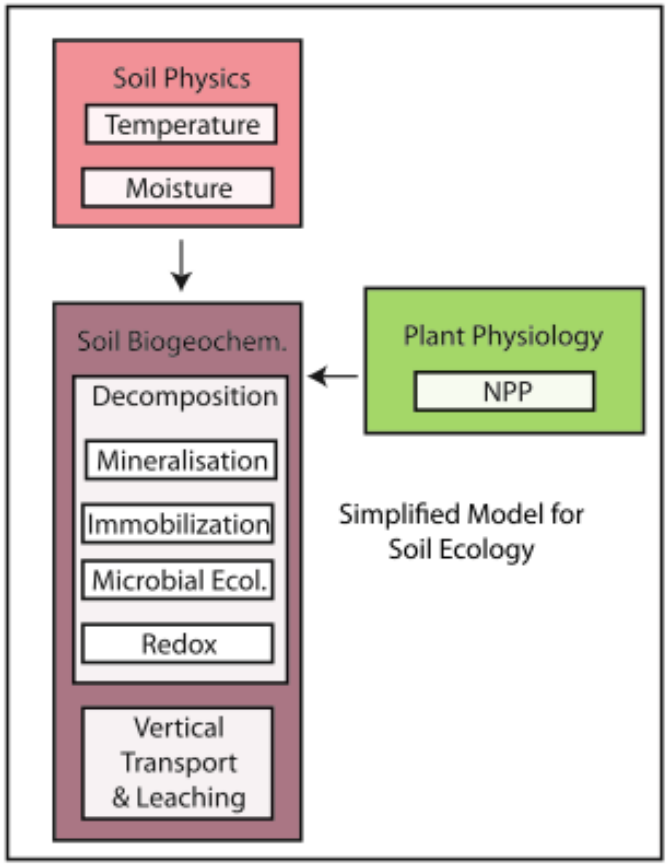
(a) Process Schematic of a Possible Full-Complexity Configuration of a Land Surface Model

A '**modular complexity**' approach to reducing dimensionality…

Driving the model with additional observations (ancillaries?) to **reduce complexity**.



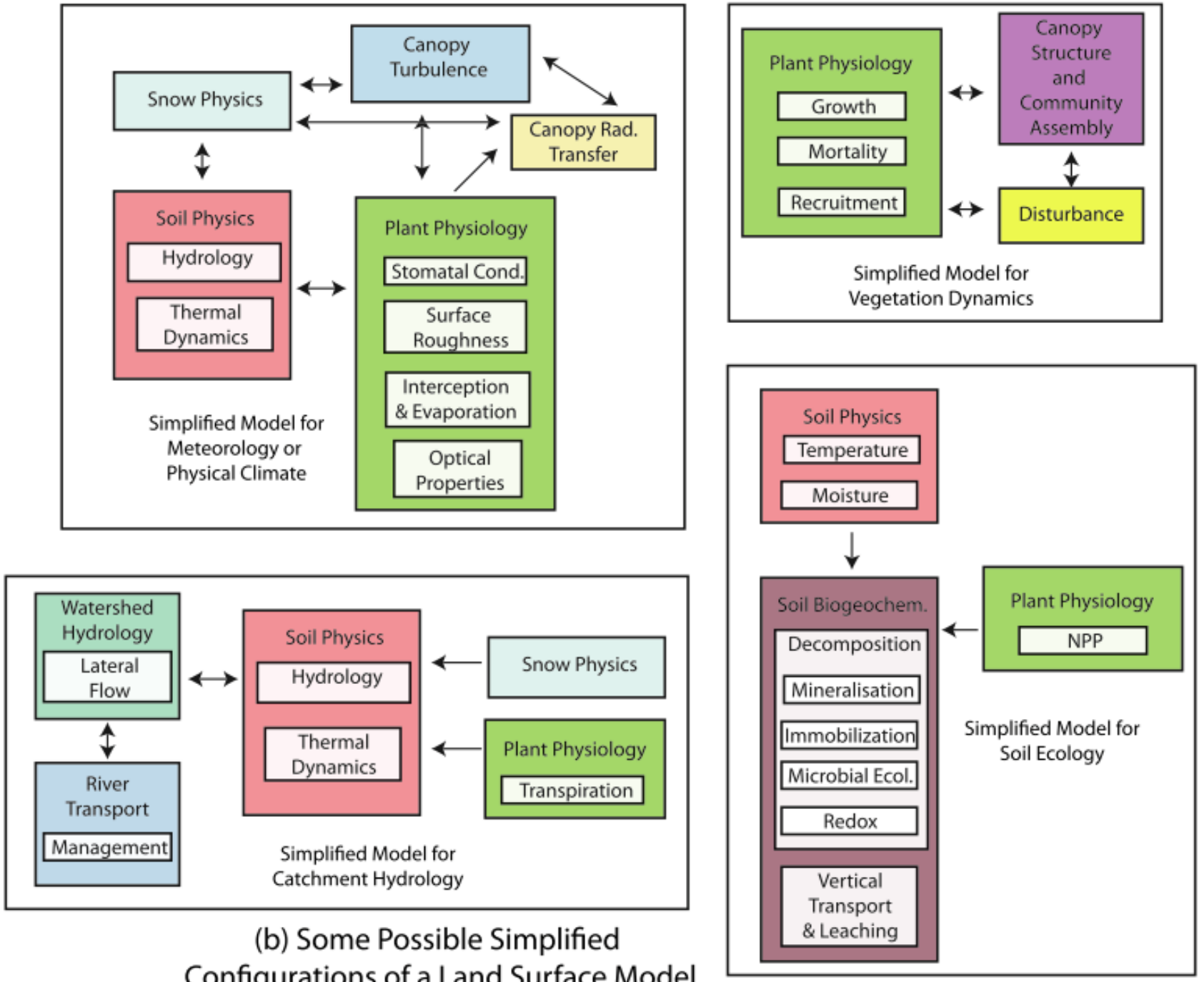




A '**modular complexity**' approach to reducing dimensionality…

Possible extra ancillaries

Leaf Area Index
Canopy Structure
Burned Area/fire emissions
Tree growth & mortality
Soil moisture



(b) Some Possible Simplified Configurations of a Land Surface Model

SUMMARY

1. Considerable **effort** gone into representation of **land use** and **hydrological** heterogeneity in CLM
2. **Not much work** on the more standard input fields, esp **soils**
3. **Introduction of**

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esm Earth System Models for the future 2025

GC GenCarbon

Thank you

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https://github.com/ESCOMP/CTSM
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