The Functionally Assembled Terrestrial Ecosystem Simulator (FATES) tutorial

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and others

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National Center for Atmospheric Research, Boulder, Colorado

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Agenda

Morning Lectures (The Main Seminar Room)

8:30: Introductions.

8:45: Theory of FATES introduction lectures

- Introduction to Ecosystem Demography
- FATES in Earth System Models.
- Information flow in FATES
- Fast timescale processes
- Carbon Allocation
- Demographic processes
    - Recruitment, mortality, fire

9:45 - 10:15: Coffee break

- Patch and Cohort Dynamics
- Different modes for running FATES
- Plant Functional Types
- Example PFT experiments
- FATES-HYDRO
- Future Plans (nutrients, land use, etc.)

12.00: Lunch (NCAR cafeteria, on your own)

Afternoon Practical Sessions

(Main Seminar Room for lecture)

1:15: Running FATES presentation

(Library for practical)

2:00: Running FATES practical session

3:00 Tea break (**Chapman room**)

4:45: General Discussion/Q&A session

5:15: Bus pickup

Slides here:

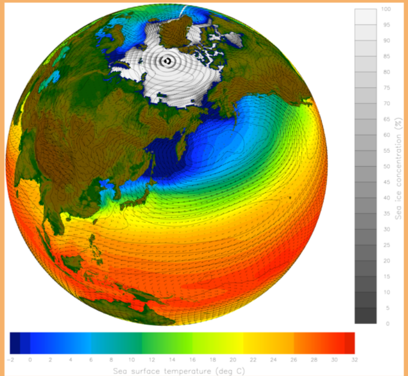
https://docs.google.com/presentation/d/1kztSENcOOw54XpjDCebcOLWciC8kqJegkMJGnuQKisI/edit?ts=5c48ed2a#slide=id.g309b6d9659_0_47

Two Useful Resources:

FATES Github PAGE:

https://github.com/NGEET/fates

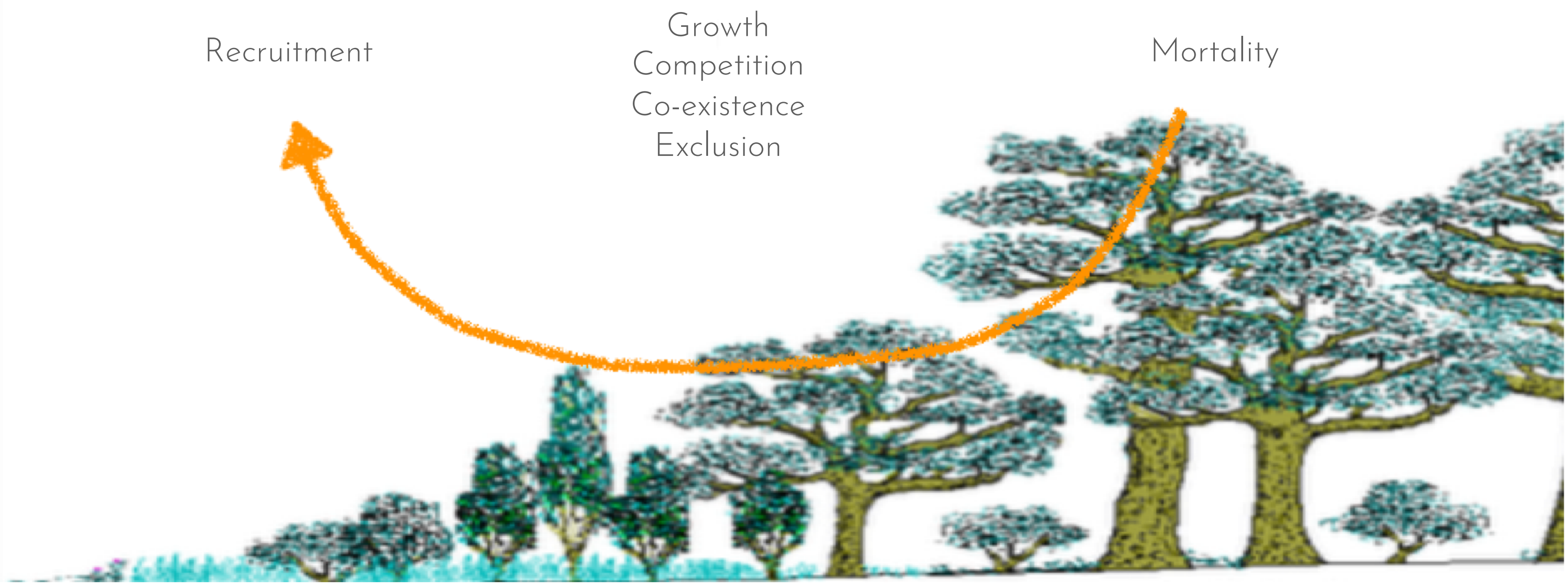
FATES Technical Documentation: https://fates-docs.readthedocs.io/en/latest/index.html



FATES is a **cohort-based** vegetation demographics model

What does that mean?

Basic Ecological Succession

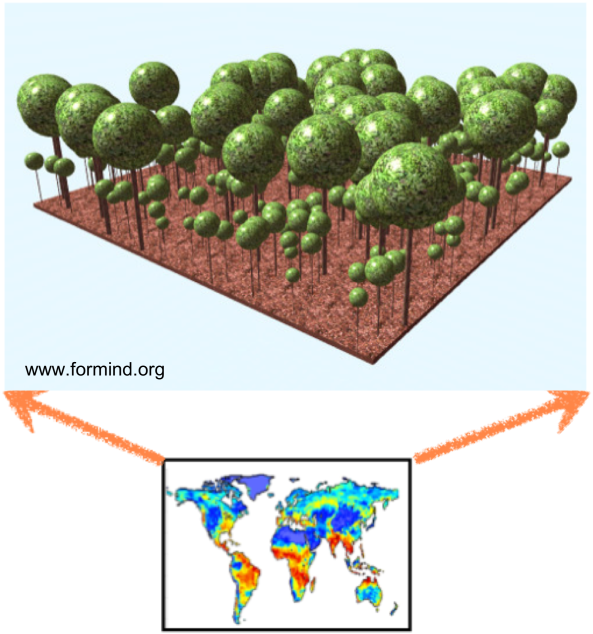


'Gap' Models

(e.g. SORTIE, LPJ-GUESS, SEIB, aDGVM, FORMIND)

Pros

- Individual Based
- 3D light environment
- Simulate competition recruitment & disturbance



Cons

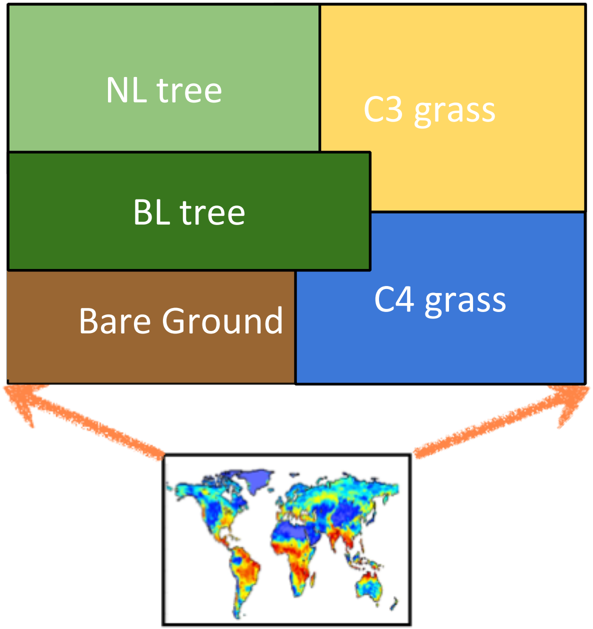
- Stochasticity
- Computational cost
- long timesteps, low sampling
- Inappropriate for climate simulations?

Area-based Models

(e.g. CLM, TRIFFID, LPJ, IBIS - models used in IPCC assessments))

Pros

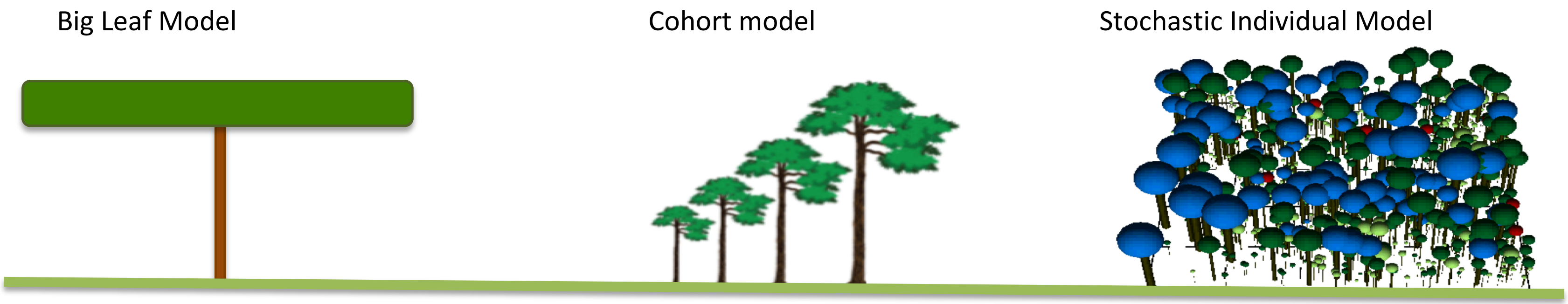
- Deterministic
- Efficient
- Default in ESMs



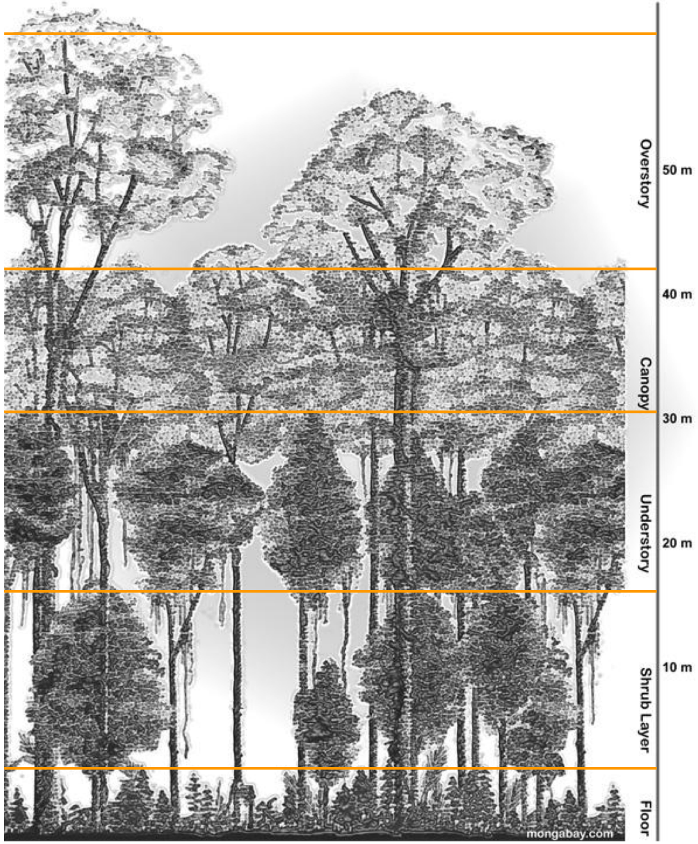
Cons

- One average tree per plant type.
- No height structure
- No light competition

‘Cohort-based’ Models as intermediate solutions

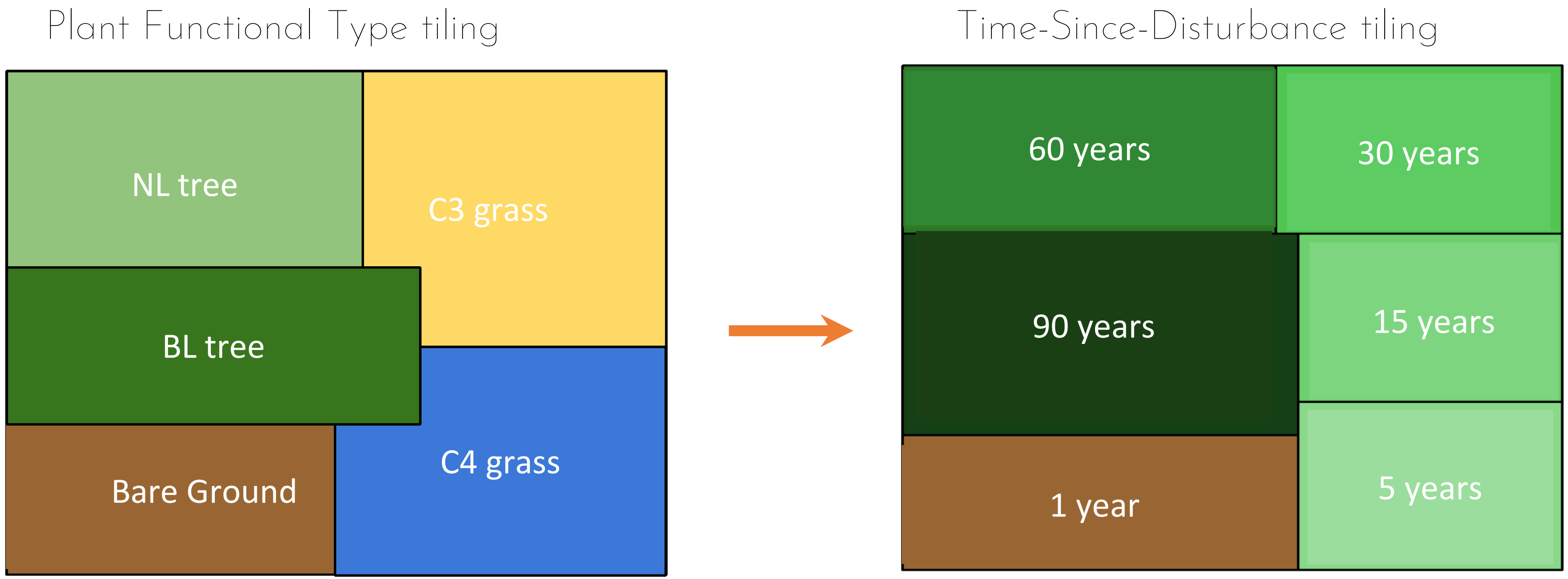


Ecosystem Demography Model (ED)
Moorcroft, Hurtt and Pacala. 2001



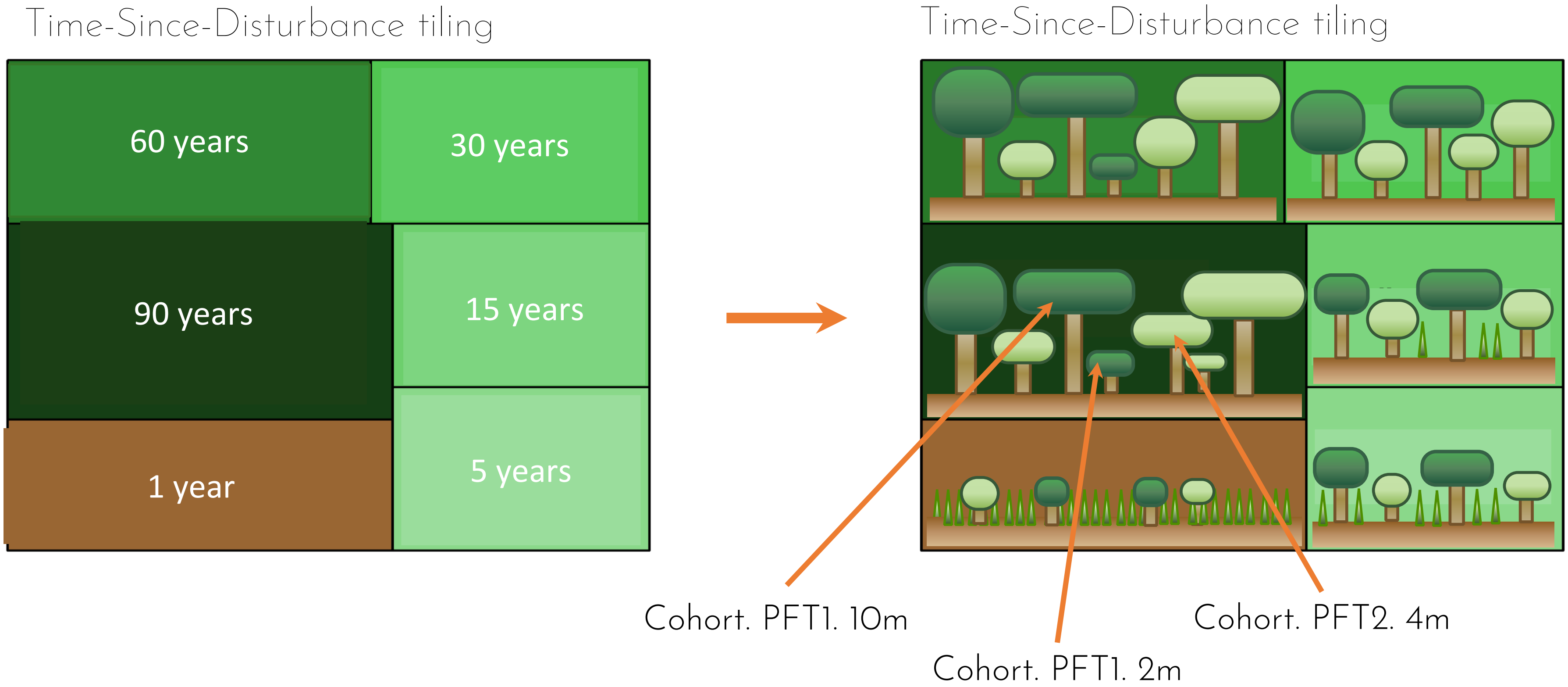
- 'Cohorts' of trees, grouped according to:
  - Plant type
  - Height
  - Successional stage

Vegetation structure: CLM/ELM vs ED models

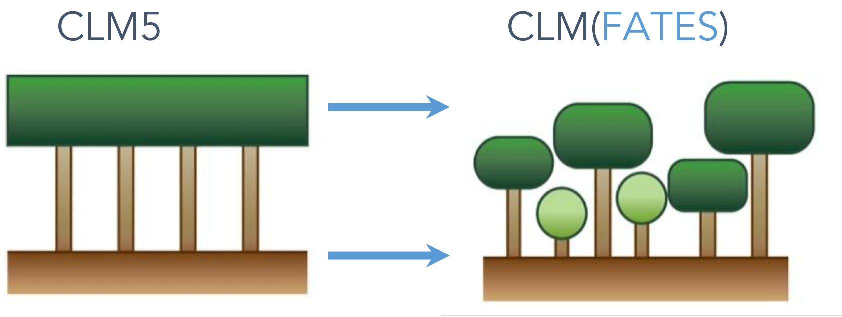


Vegetation structure in ED models

Each time-since-disturbance tile contains cohorts of plants, defined by PFT and size.



Benefits of Ecosystem Demography

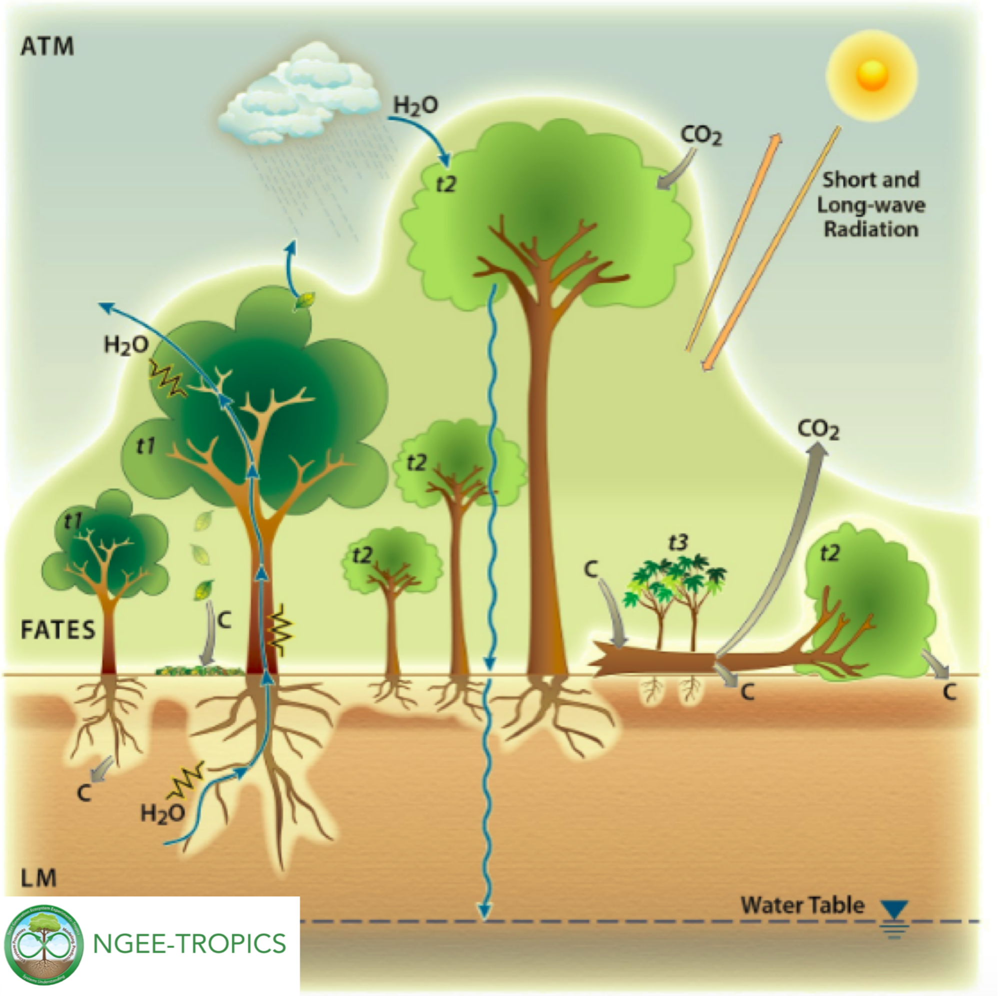


"Big-Leaf" vegetation

Demographic Vegetation

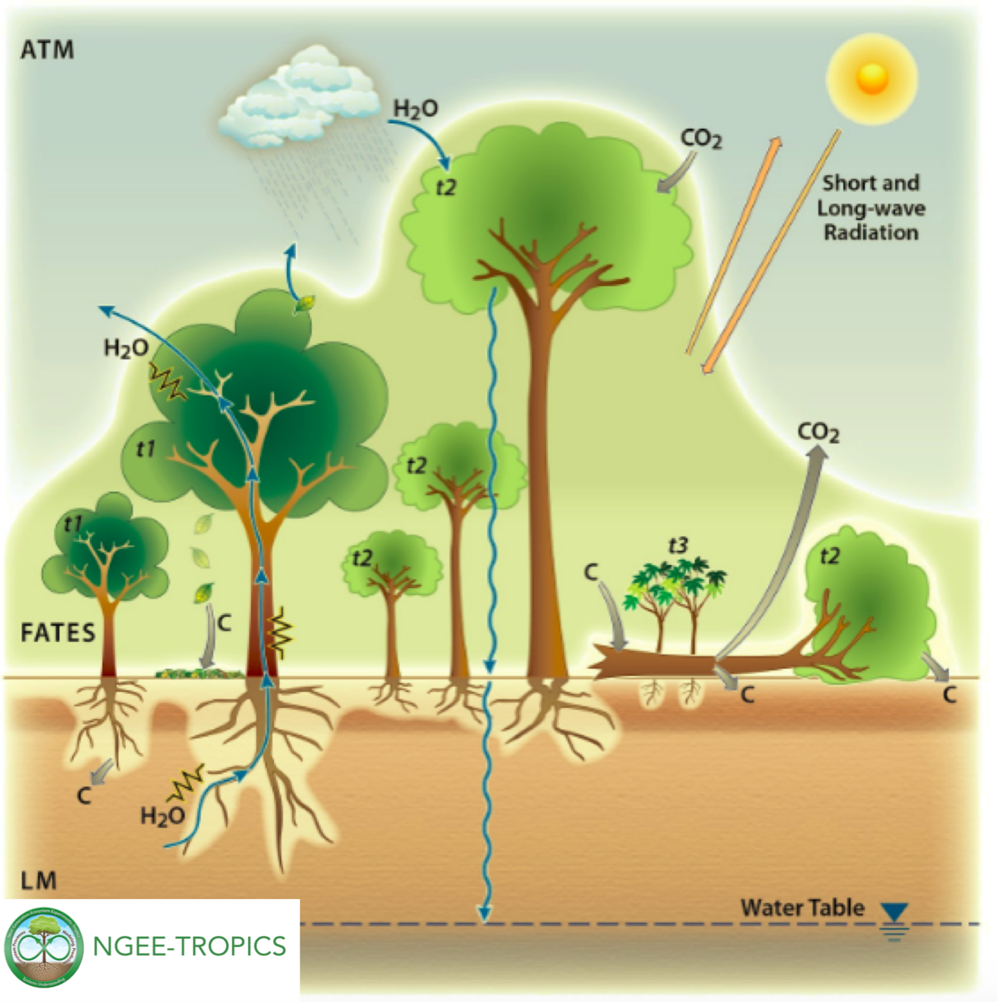
- Heterogeneity in light availability
- Competition (for light), exclusion & coexistence
- Mechanistic Ecosystem Assembly
- Recovery after Disturbance (fire, land use, mortality)
- Arbitrary PFT definition
- PFT distribution emerges from trait filtering

Instances where big-leaf models hinder realistic process representation

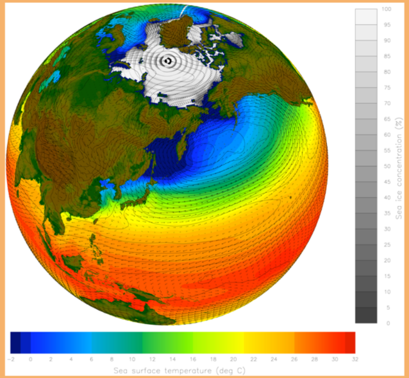


- Hydrodynamics
  - Need a representation of path length, rooting depth, with plant size
  - Need representations of canopy position to determine atmospheric demand
- Nutrients
  - N fixation only makes energetic sense early in succession
  - Allometric growth is necessary to provide sensible nutrient budgets
- Fire
  - Fire has lasting impacts on canopy structure, which in turn affect fire behavior
  - Tree-grass coexistence in fire regions is either along successional or vertical gradients, not captured by big leaf approach.
- Snow
  - Snow covers short vegetation early in succession but not older taller vegetation

Instances where big-leaf models hinder realistic process representation

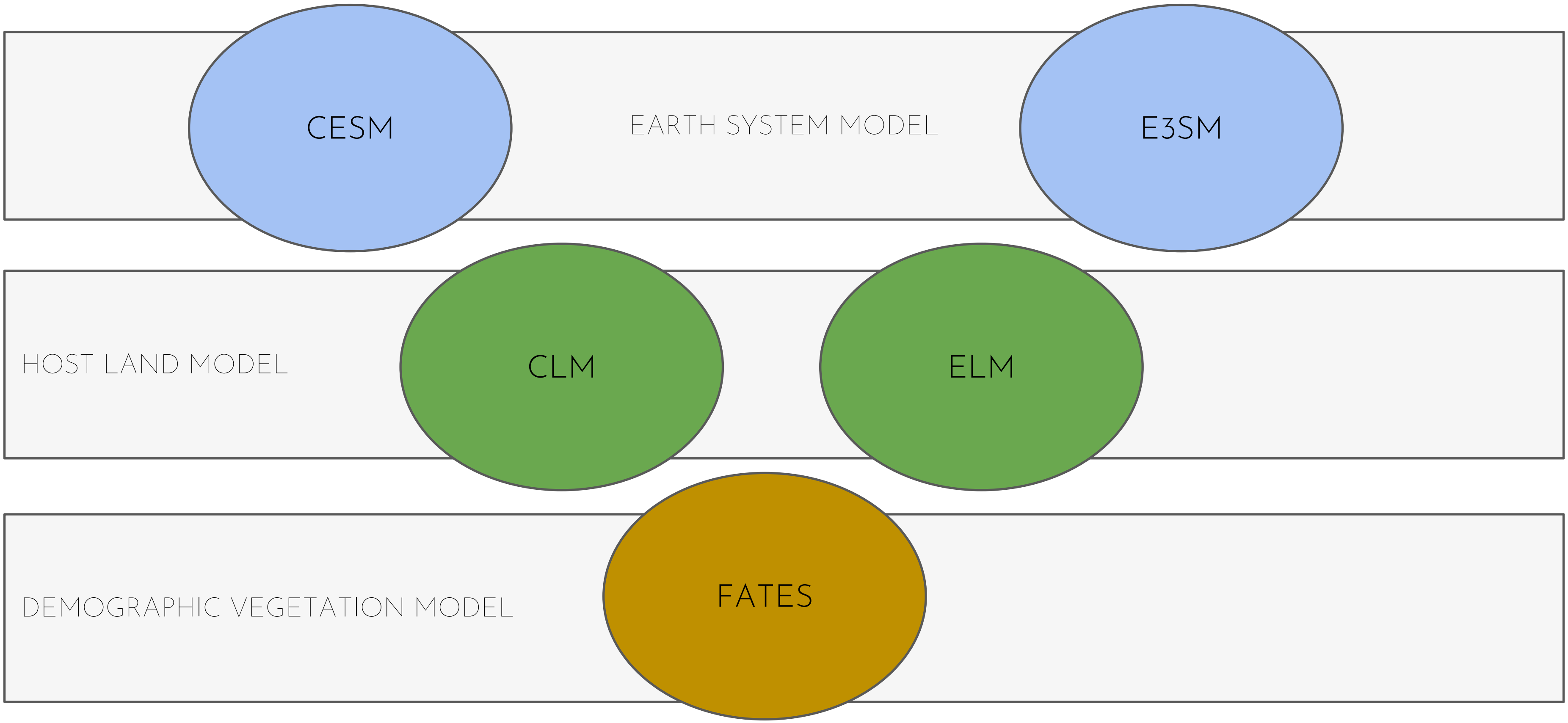


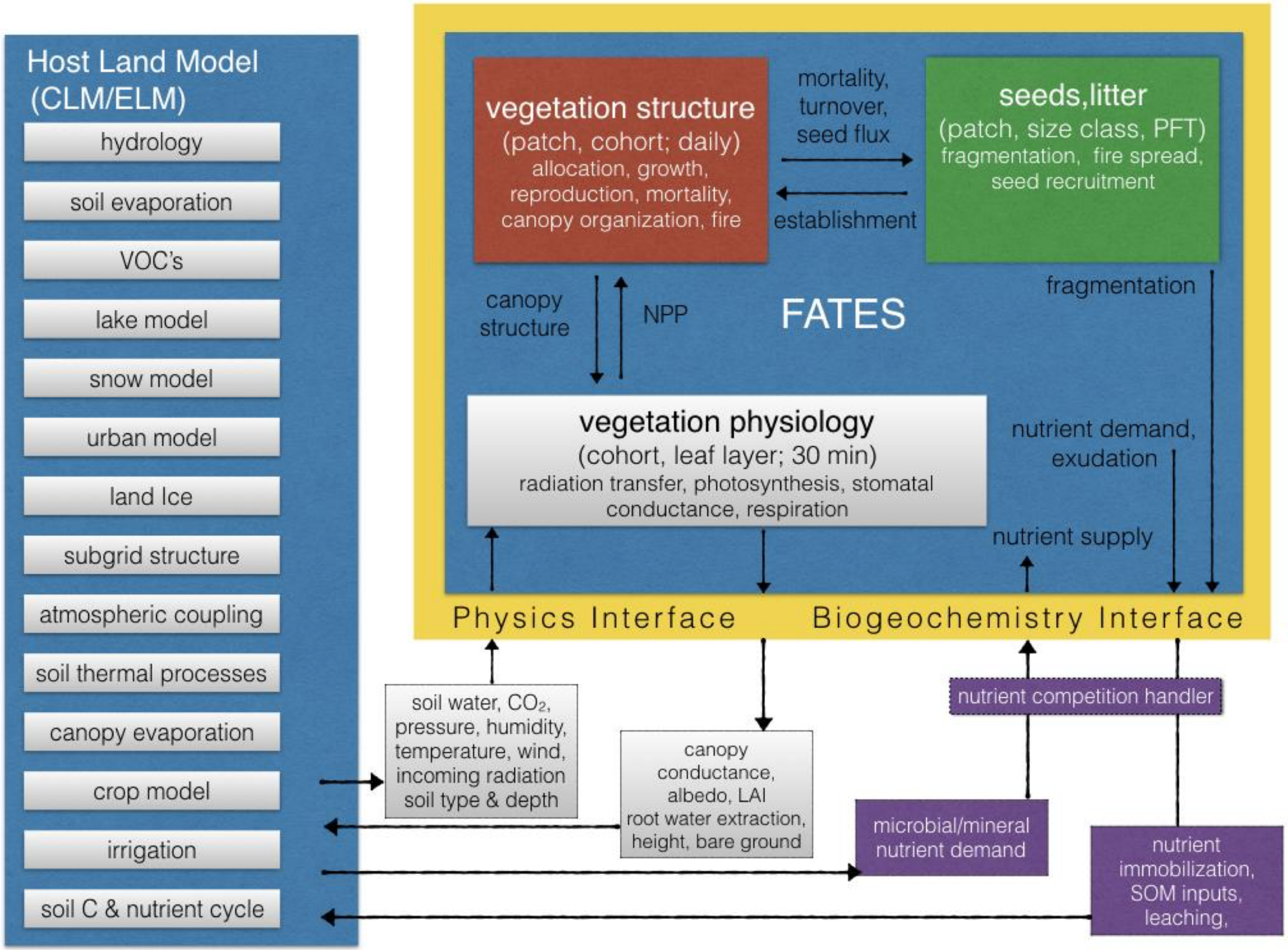
- Pests
  - Bark beetles preferentially attack larger trees
- Harvest
  - Selective logging only takes out large trees of particular functional classes.
  - Recovery alters biophysical properties
- Canopy turbulence
  - Simulation of internal canopy air space requires estimate of which leaves are where in canopy
- VOCs
  - Most major models critically dependant upon leaf age
- What about my favourite process? Is it affected (discussion..)



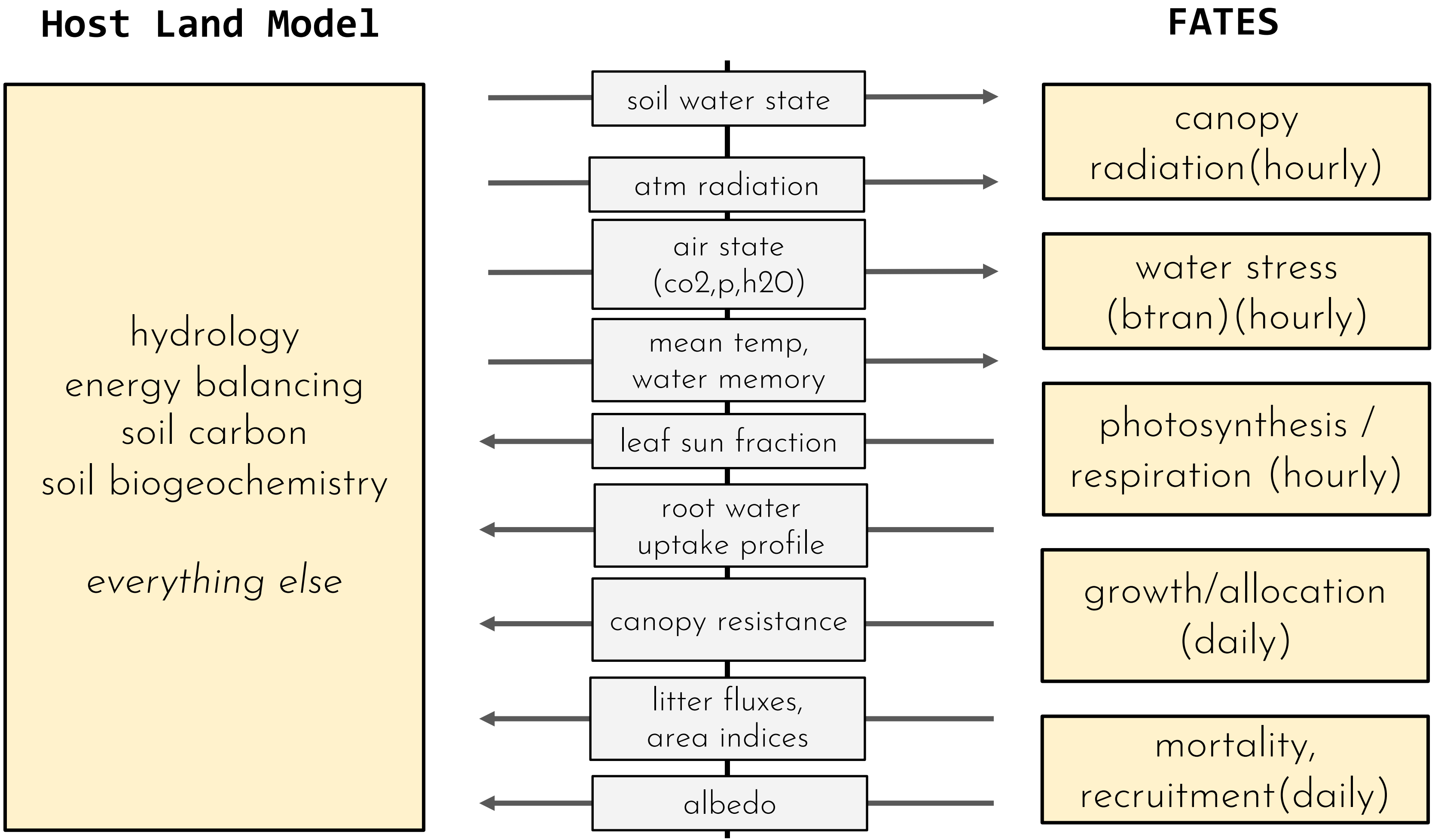
Where does FATES live within the ecosystem of earth system models?

FATES is a module and so must be associated with a “**Host Land Model**” (HLM)

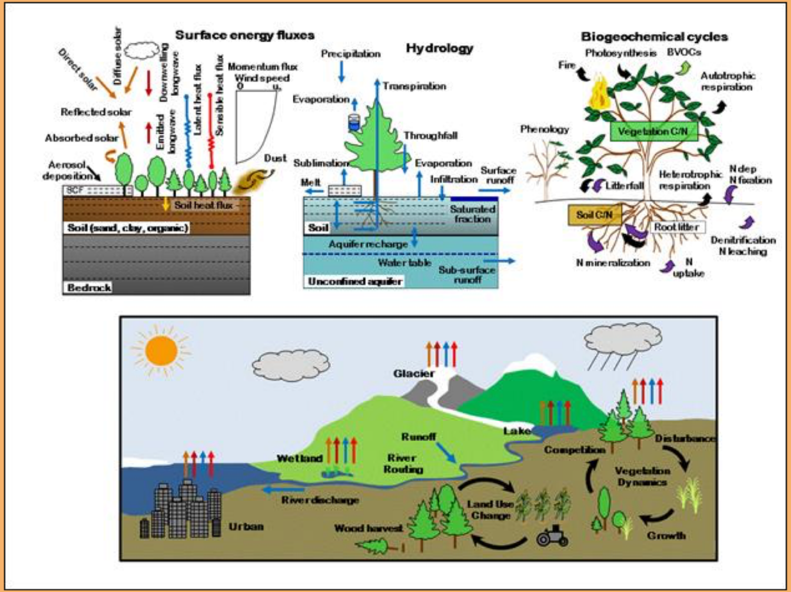

CESM
EARTH SYSTEM MODEL
E3SM
HOST LAND MODEL
CLM
ELM
DEMOGRAPHIC VEGETATION MODEL
FATES



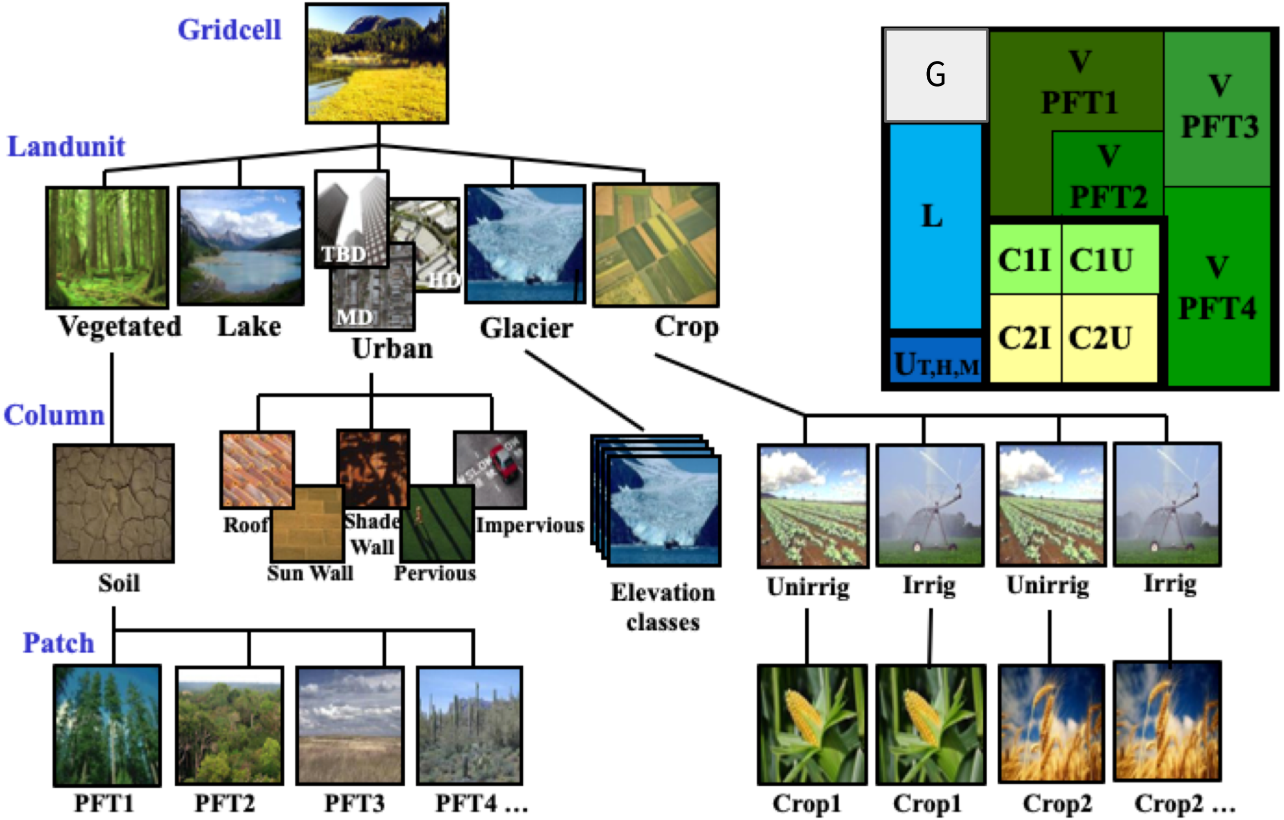
Host Land Model (CLM/ELM)
hydrology
soil evaporation
VOC's
lake model
snow model
urban model
land Ice
subgrid structure
atmospheric coupling
soil thermal processes
canopy evaporation
crop model
irrigation
soil C & nutrient cycle
vegetation structure
(patch, cohort; daily)
allocation, growth, reproduction, mortality, canopy organization, fire
mortality, turnover, seed flux
establishment
seeds,litter
(patch, size class, PFT)
fragmentation, fire spread, seed recruitment
canopy structure
NPP
FATES
fragmentation
vegetation physiology
(cohort, leaf layer; 30 min)
radiation transfer, photosynthesis, stomatal conductance, respiration
nutrient demand, exudation
nutrient supply
Physics Interface
Biogeochemistry Interface
soil water, CO2, pressure, humidity, temperature, wind, incoming radiation soil type & depth
canopy conductance, albedo, LAI root water extraction, height, bare ground
nutrient competition handler
microbial/mineral nutrient demand
nutrient immobilization, SOM inputs, leaching,


Host Land Model
FATES
hydrology
energy balancing
soil carbon
soil biogeochemistry
everything else
soil water state
atm radiation
air state
(co2,p,h2O)
mean temp,
water memory
leaf sun fraction
root water
uptake profile
canopy resistance
litter fluxes,
area indices
albedo
canopy
radiation(hourly)
water stress
(btran)(hourly)
photosynthesis /
respiration (hourly)
growth/allocation
(daily)
mortality,
recruitment(daily)

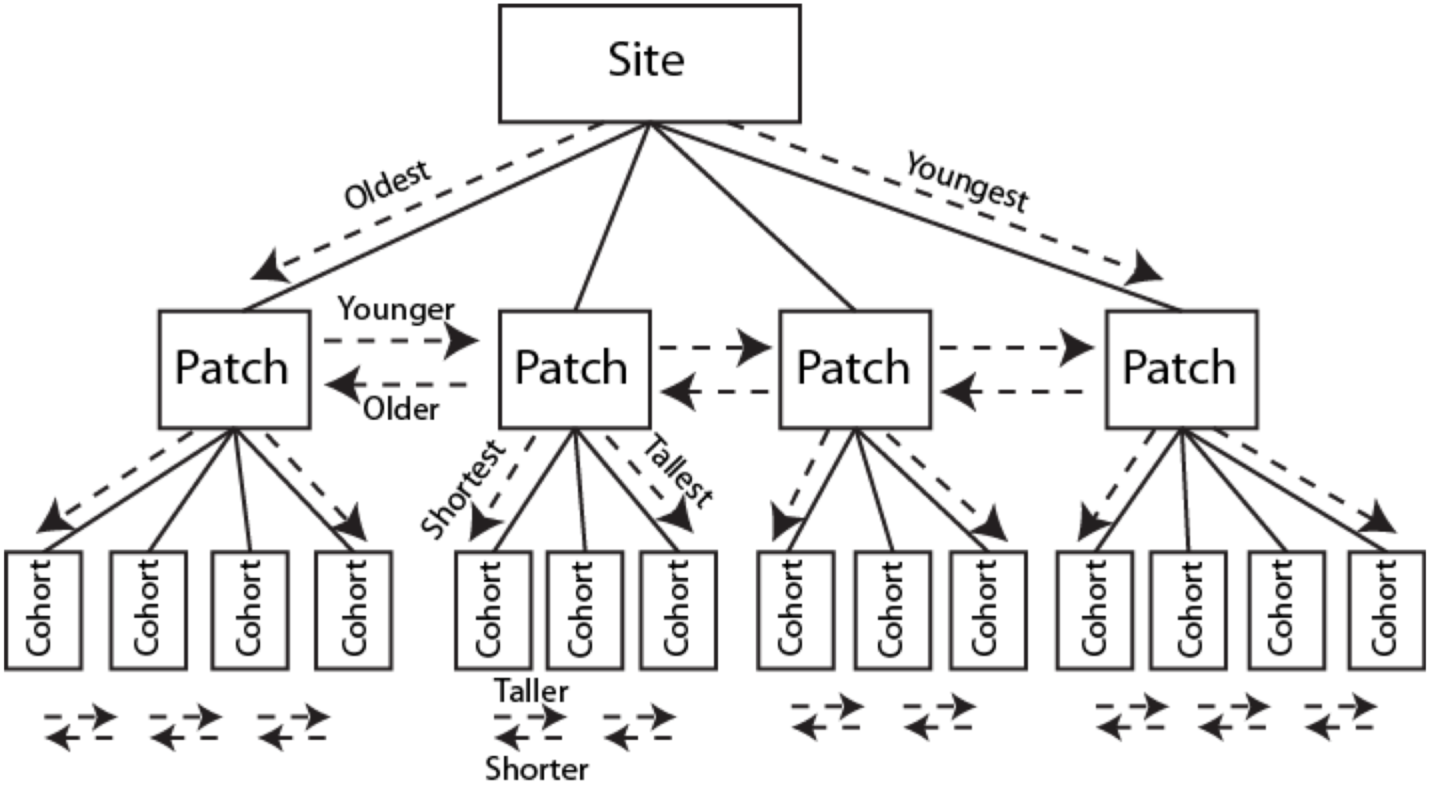
How is information organized in FATES



CLM and ELM: Normal Subgrid Hierarchy



The Structure of FATES: Linked Lists



List of example state variables at each level

Cohort variables

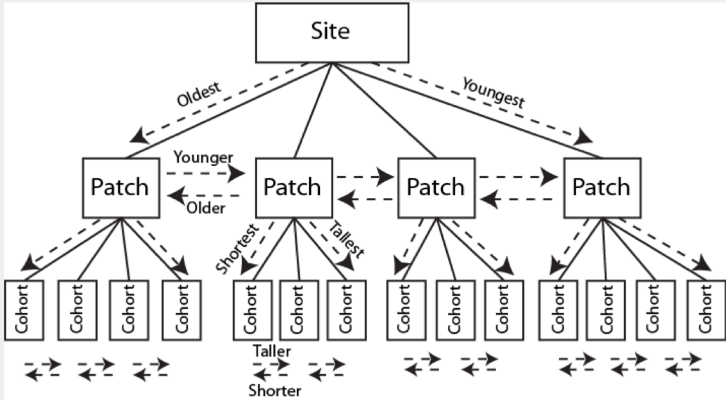
PFT, ‘N’, DBH, height, biomass: leaves, roots(c+f), stem(live+dead), storage, canopy layer.

Patch variables

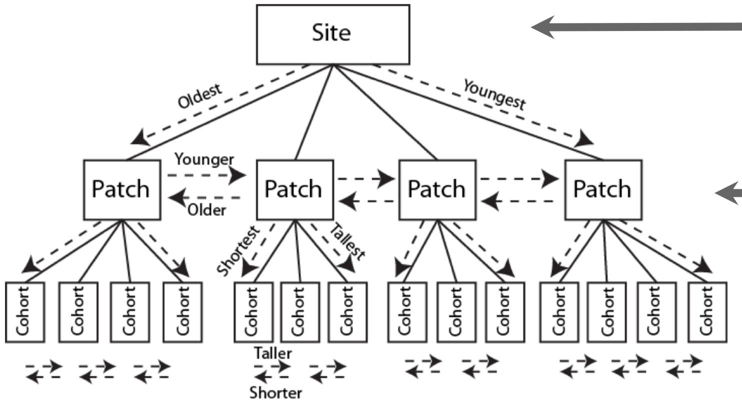
Area, age, CWD(size class (x4), leaf+froot litter, LAI profile, canopy height.

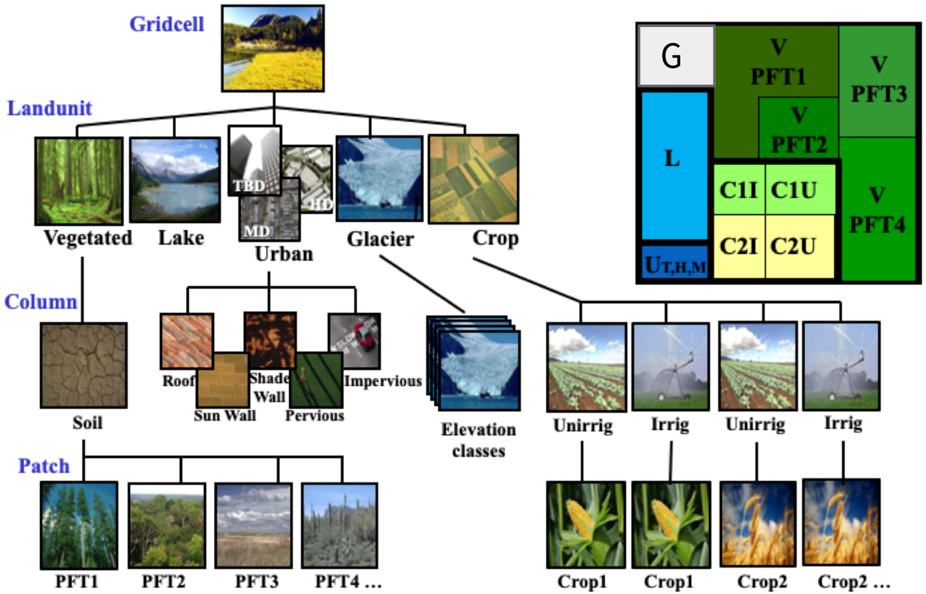
Site variables

Lat, long, seed bank(pft), phenology status & counters,
all HLM column properties



FATES and HLM: Connecting the Hierarchies

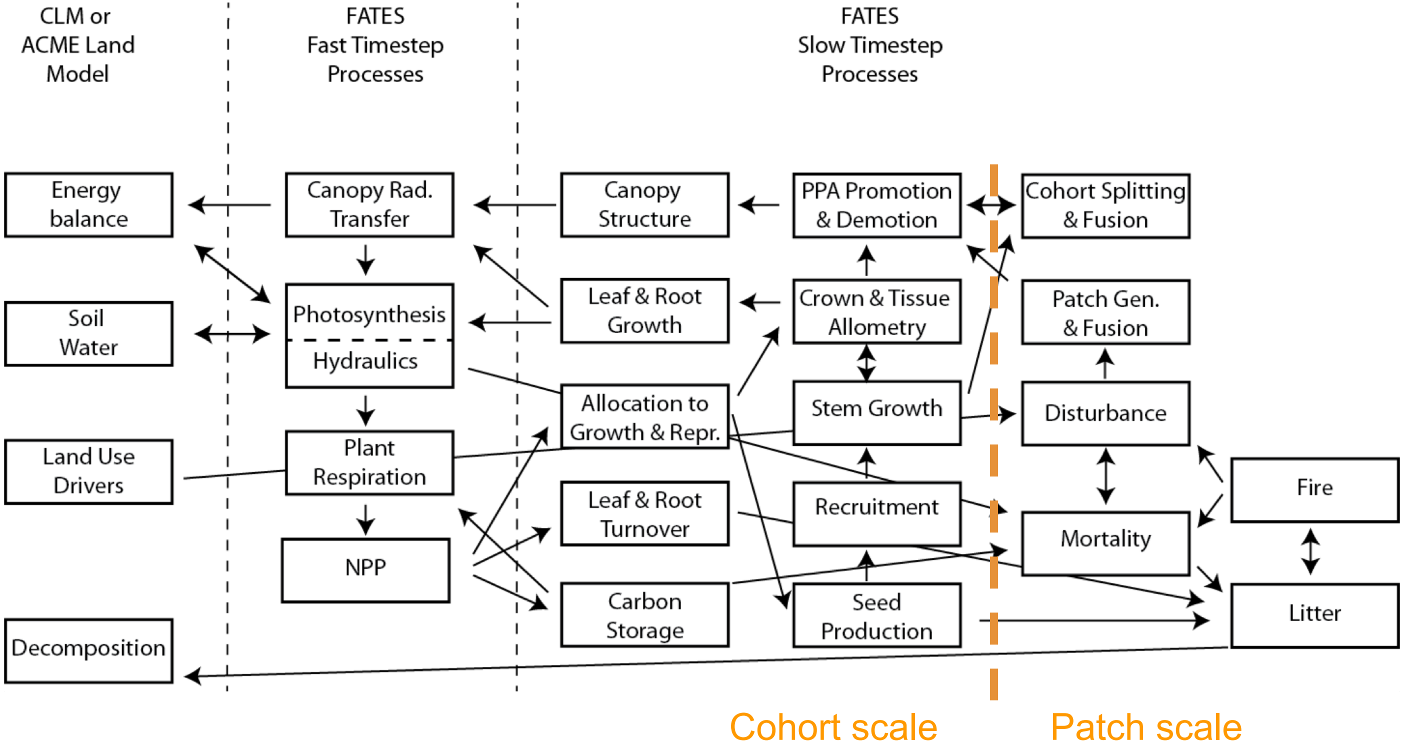




Fast timescale process in FATES

1. Radiation Transfer
2. Photosynthesis and Respiration
3. Stomatal Conductance
4. Boundary layer physics

An overview processes in FATES



Perfect **p**lasticity **a**pproximation

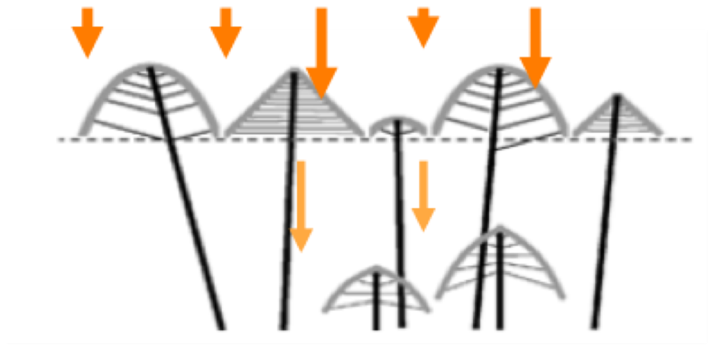
Canopy organization in fates

The ‘Perfect Plasticity Approximation’ (PPA)

- Tree canopies are ‘perfectly plastic’ and fill in all the gaps.
- The forest canopy splits into distinct layers.

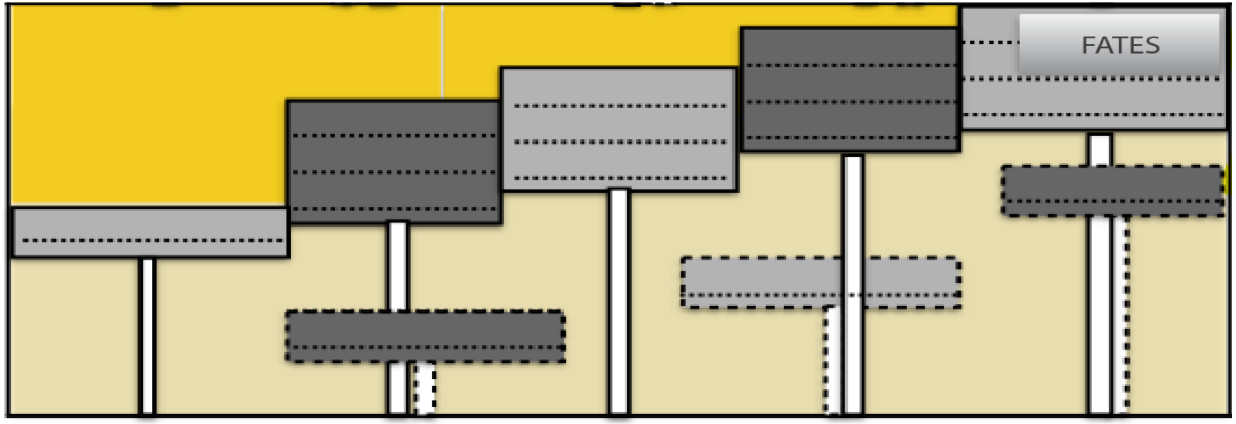
Canopy Layer : All plants receive 100% of incoming radiation on top leaf surface

Under-story Layer : All plants receive the same reduced incoming radiation light



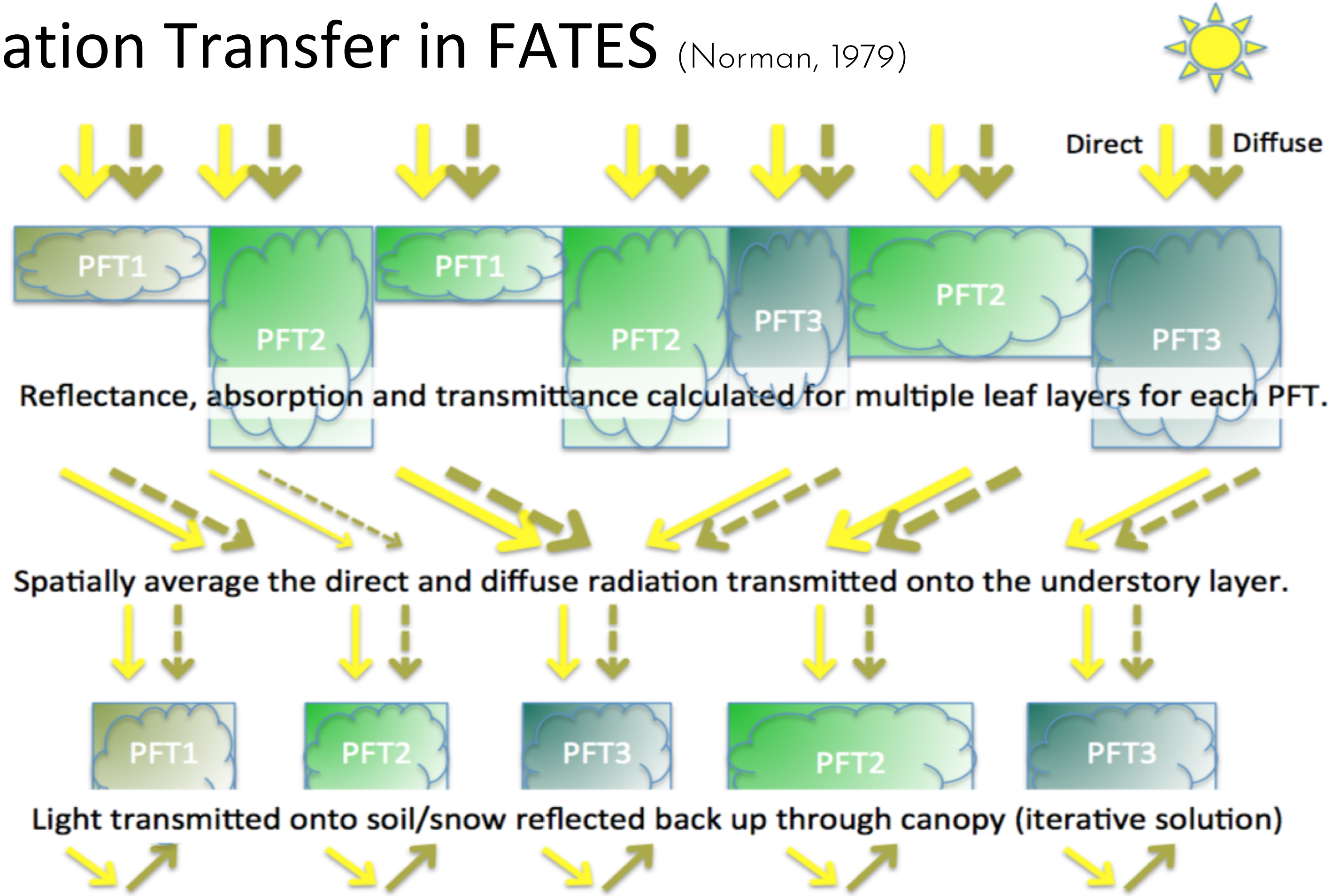
Purves et al. 2007

Canopy construction and vertical light environment:
The "PPA" simplifies the light environment into two regimes: **canopy** and **understory**



Fisher et al., GCB 2017

Radiation Transfer in FATES (Norman, 1979)



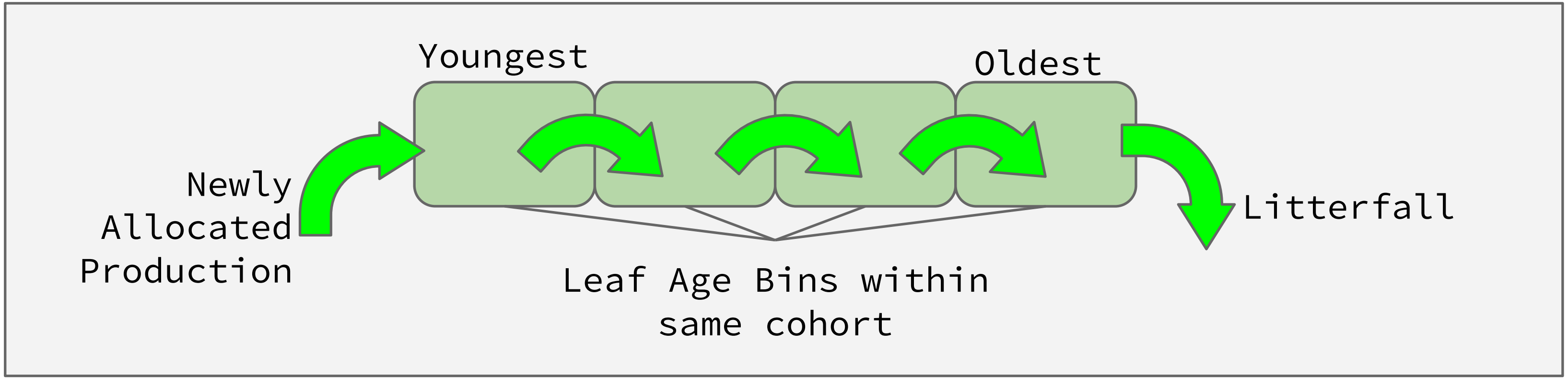
Photosynthesis

Photosynthesis, stomatal conductance etc. is mostly derived from ~CLM4.5

This, and much of the rest of this lecture, is documented the **FATES technical documentation**:
https://fates-docs.readthedocs.io/en/latest/index.html

The photosynthesis part is at:
https://fates-docs.readthedocs.io/en/latest/fates_tech_note.html#photosynthesis

New Feature 2019: Leaves Discretized by AGE!



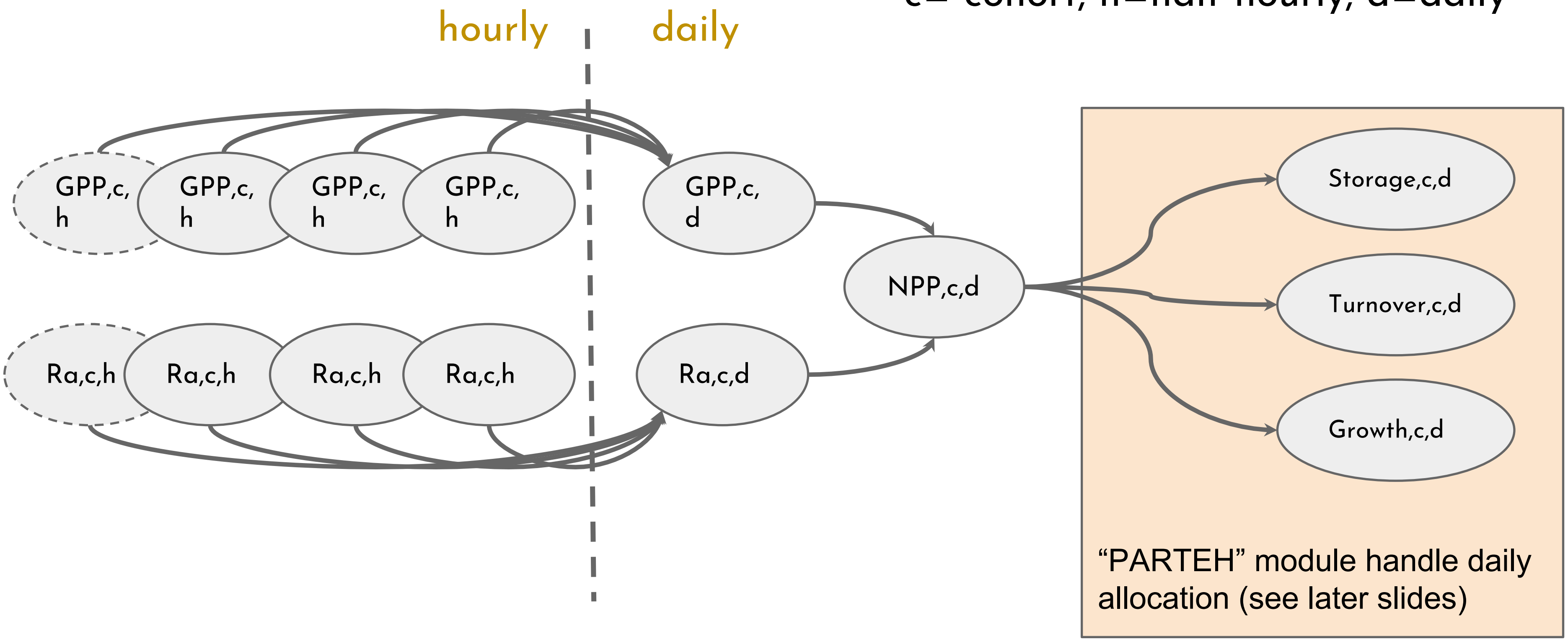
Each PFT has a user defined parameters "vcmax_25_top" and "longevity", which have an age dimension now.

Leaf carbon *(Cleaf)* flows from newer to older bins *(a)* based on longevity:

Flux Cleaf(a -> a+1) = Cleaf(a) * ΔT / longevity(a)

How FATES passes info from fast to slow timesteps

c= cohort, h=half-hourly, d=daily



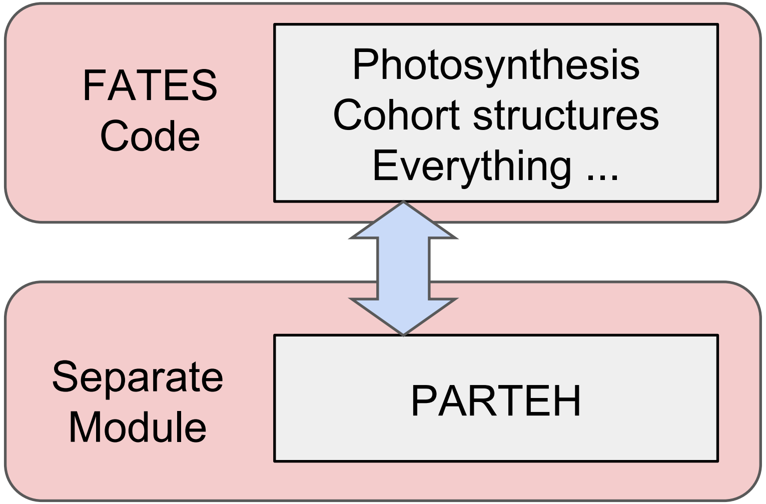
‘PARTEH’

Plant Allocation and Reactive Transport Extensible Hypotheses

Knox et al. (in prep)

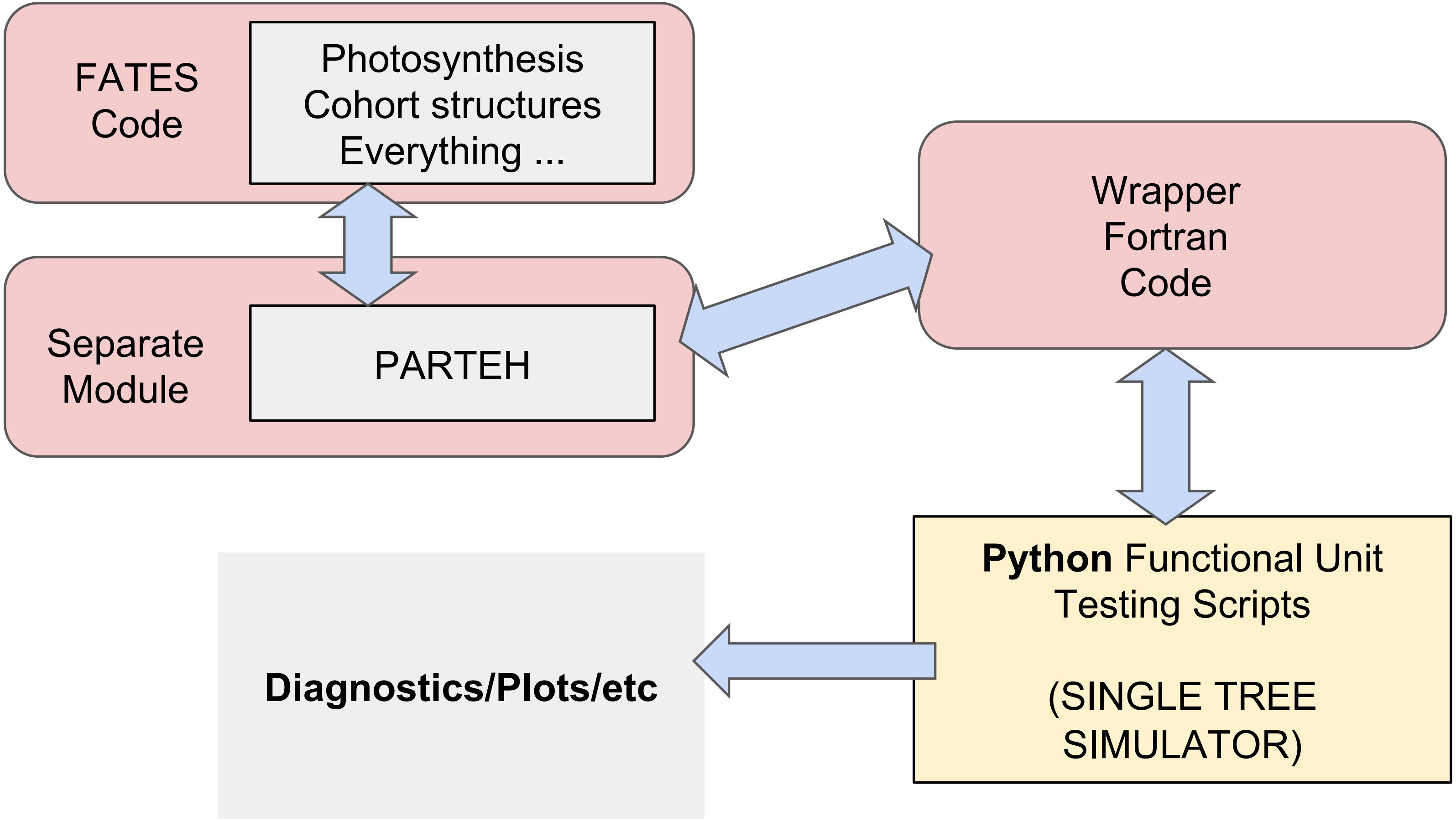
FATES’ new **allocation** scheme, and basis for planned nutrient cycling implementation

1) extensible and modular software, using robust numerical methods
2) changes in states are cast as fluxes
3) allows an arbitrary number of elements or pools
4) Modular options for alternative hypotheses

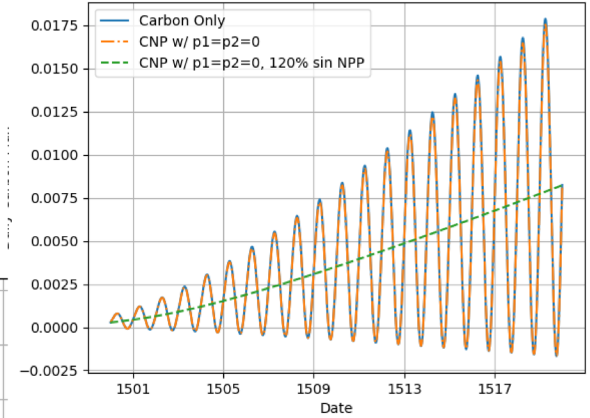


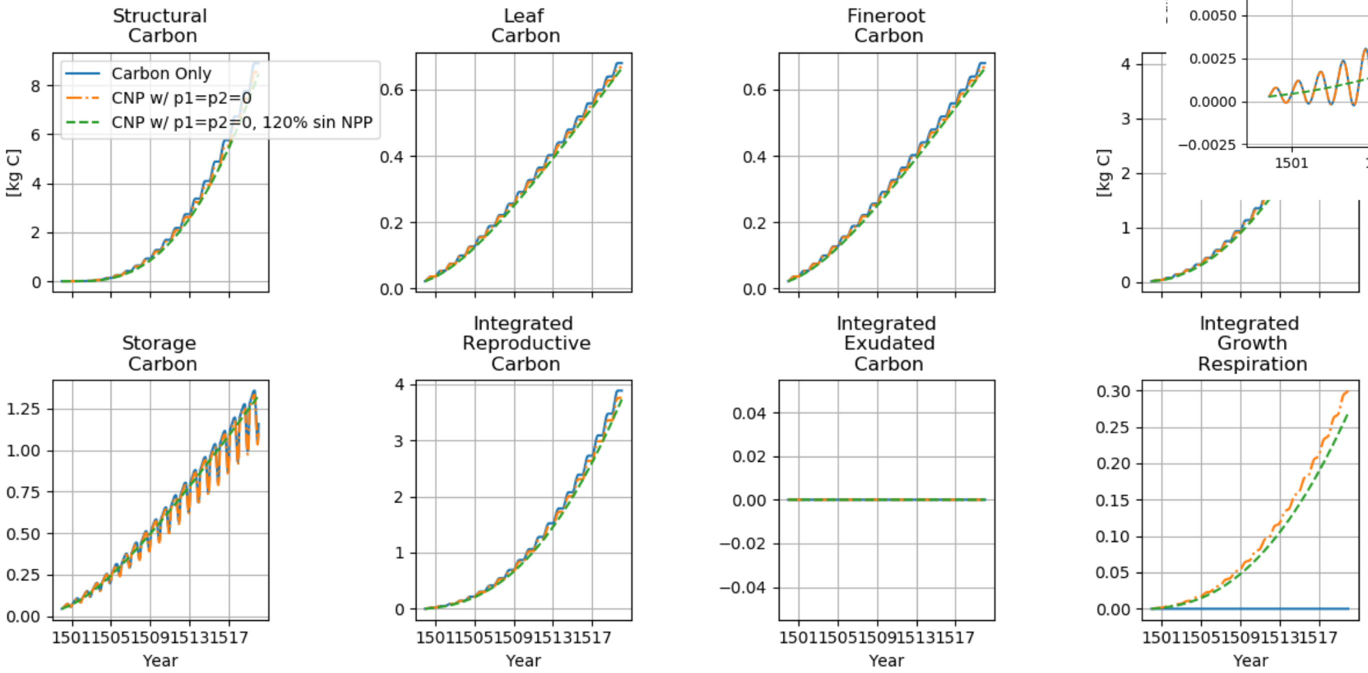
Modular structure:
PARTEH has a clean interface with the rest of the FATES code.

- Does not use FATES globals
- Clearly defined initialization of states and fluxes
- Clearly defined boundary conditions with FATES


FATES
Code
Photosynthesis
Cohort structures
Everything ...
Separate
Module
PARTEH
Wrapper
Fortran
Code
Python Functional Unit
Testing Scripts
(SINGLE TREE
SIMULATOR)
Diagnostics/Plots/etc

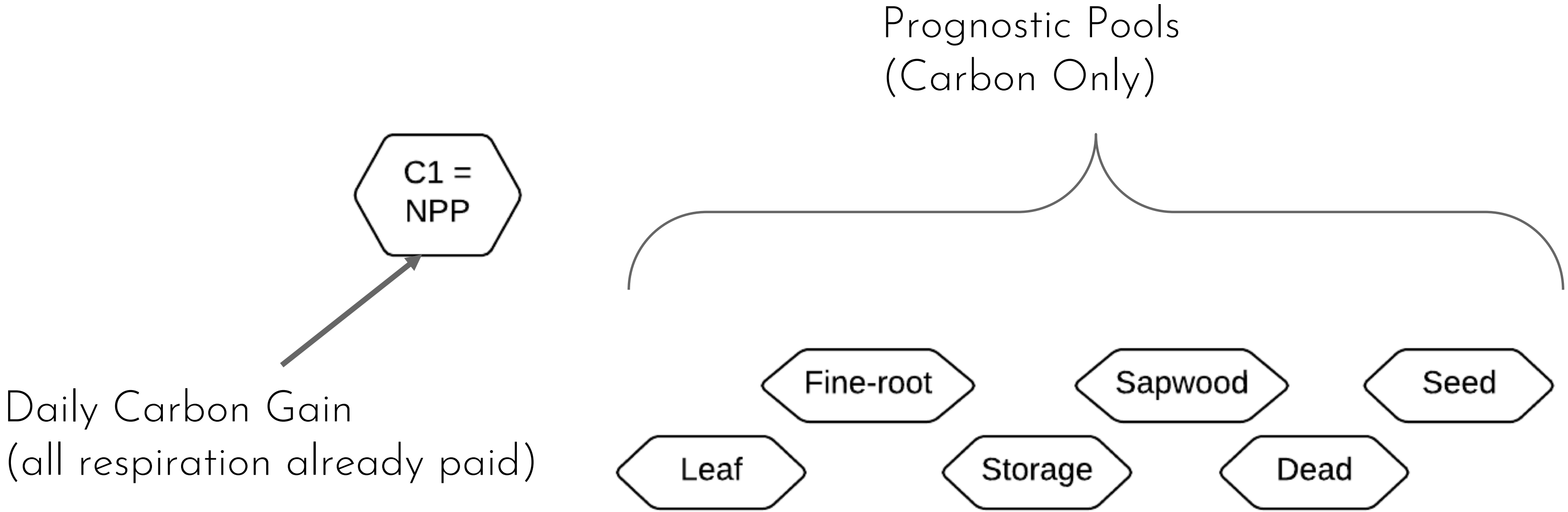
Example of Single Tree Simulator:
20 year “smoke test”: 3 different parameterizations, 1 carbon only case with seasonal oscillation, 1 C+N+P case with seasonal oscillation and 1 C+N+P case without oscillation

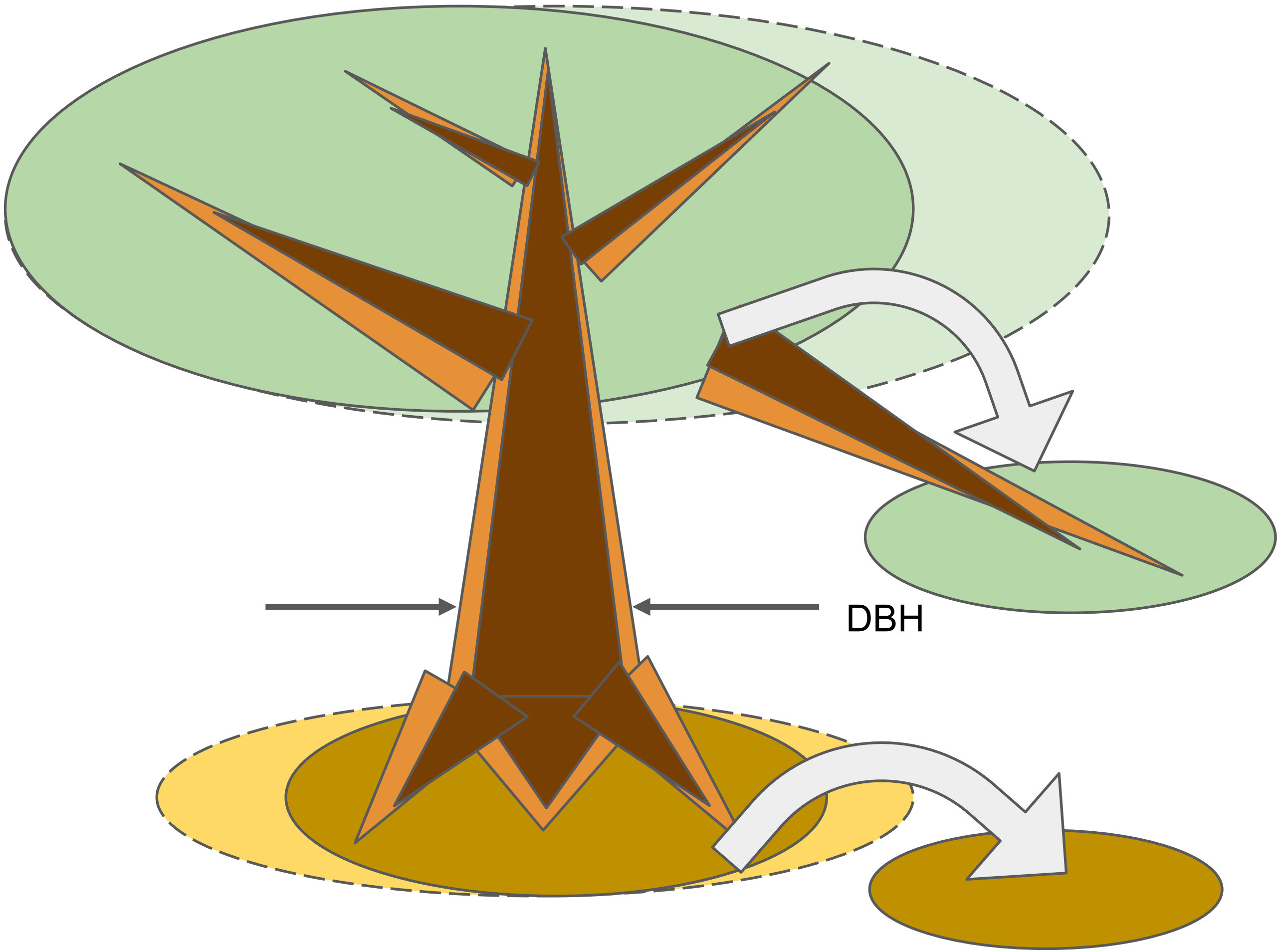




Default allocation/ hypothesis #1:
Carbon Allocation along allometric trajectories

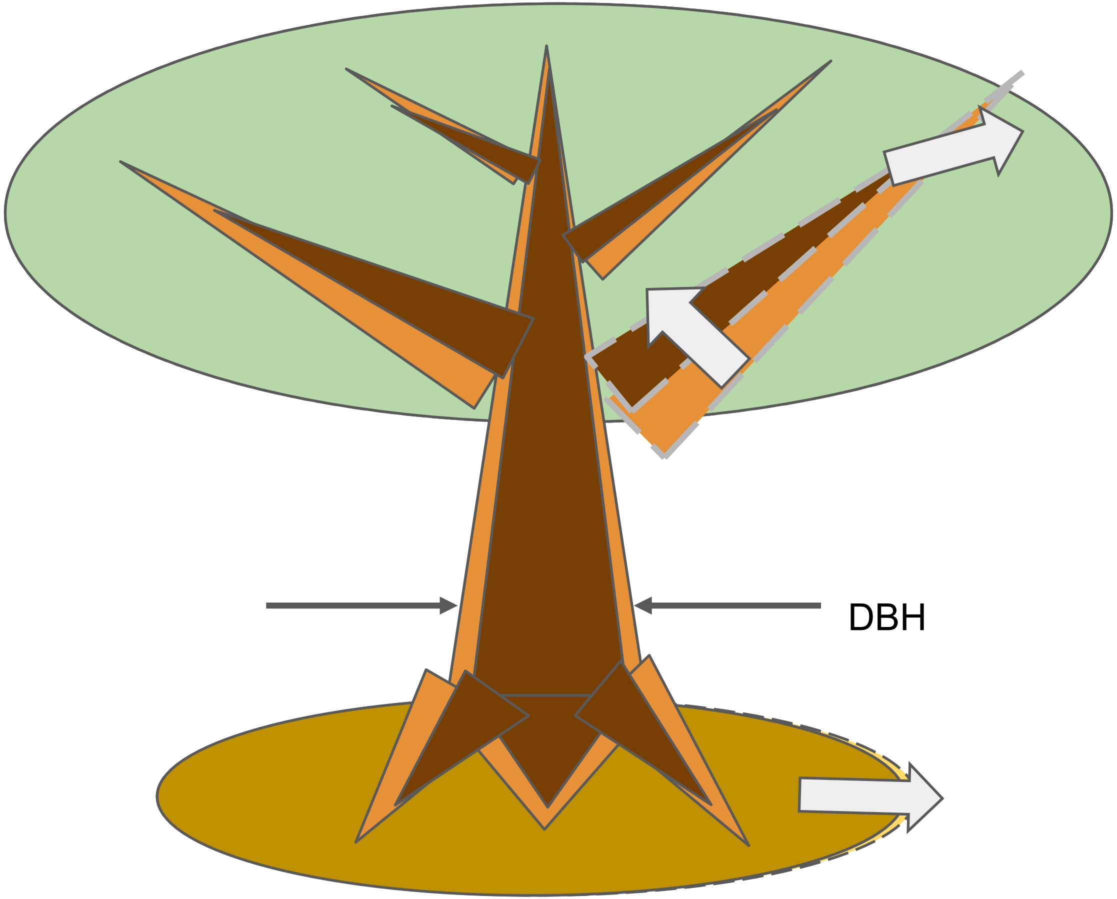
Allocation


Prognostic Pools
(Carbon Only)
C1 =
NPP
Daily Carbon Gain
(all respiration already paid)
Fine-root
Sapwood
Seed
Leaf
Storage
Dead



Step 1:
Remove turnover from live pools

Assumption: "stature" (dbh) of plant stays same, and so do the target pool sizes

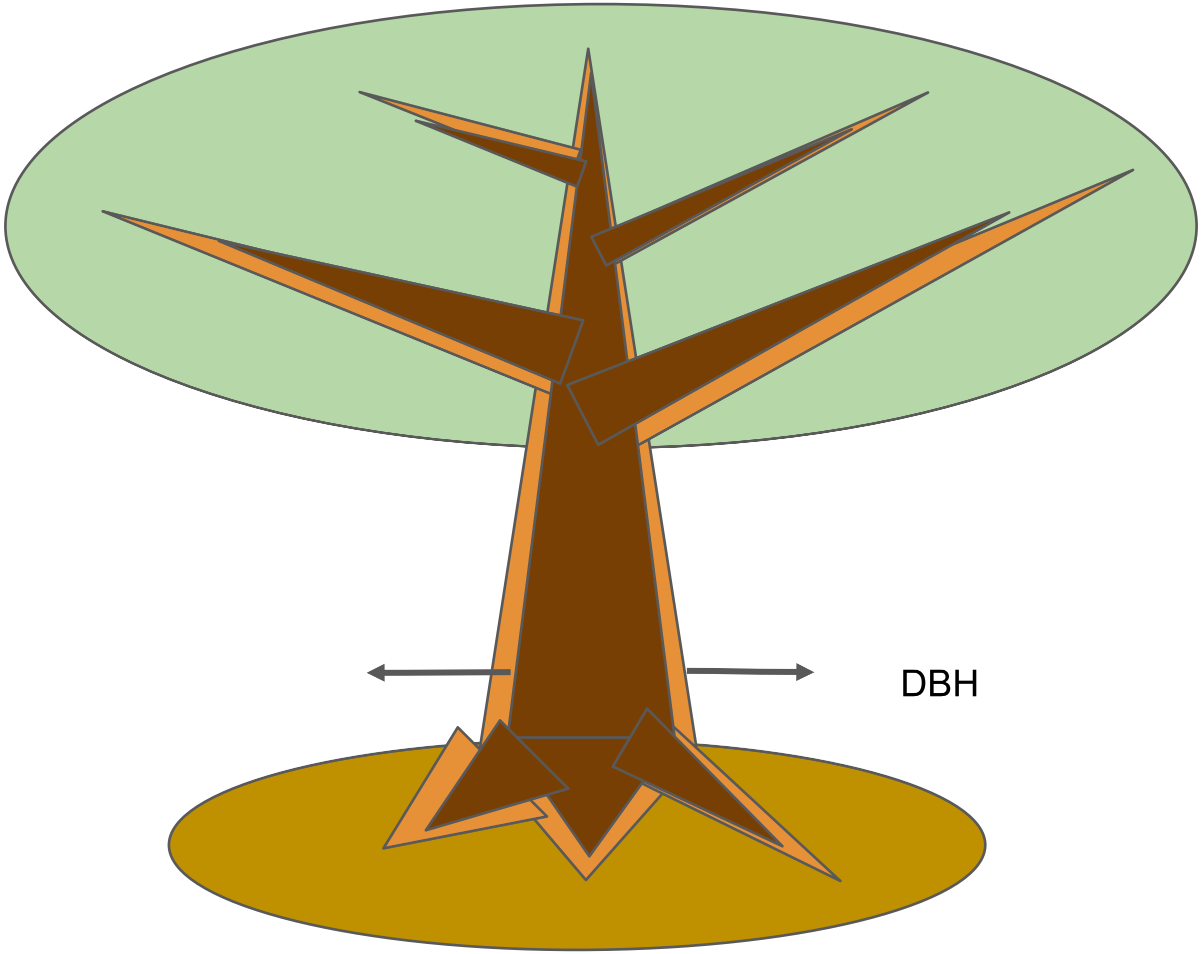


Step 2:
Replenish Pools towards allometry

*Each organ is given a priority level.

Replenish pools in priority order based on availability and relative distance to target

*Same principal for C & N & P



Step 3:
Stature Growth

Grow all pools concurrently.

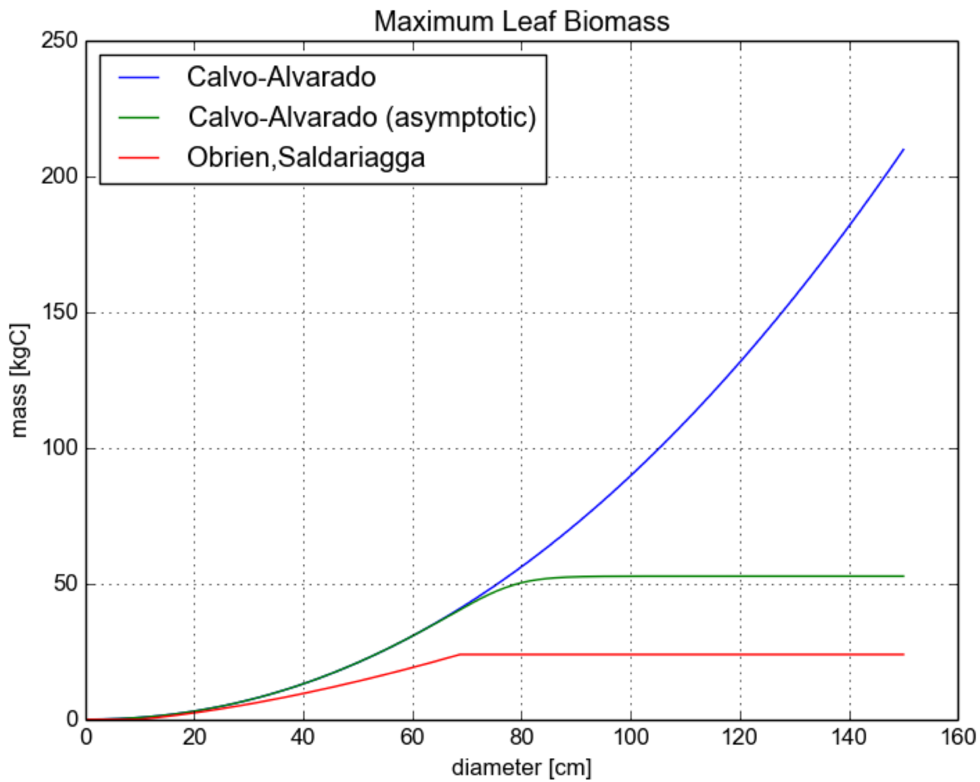
Integrate along the derivative of the allometric curves for each carbon pool.

The amount of concurrent growth is limited by whichever C or N or P would generate the least amount of equivalent C growth

Stature Growth Follows Allometry

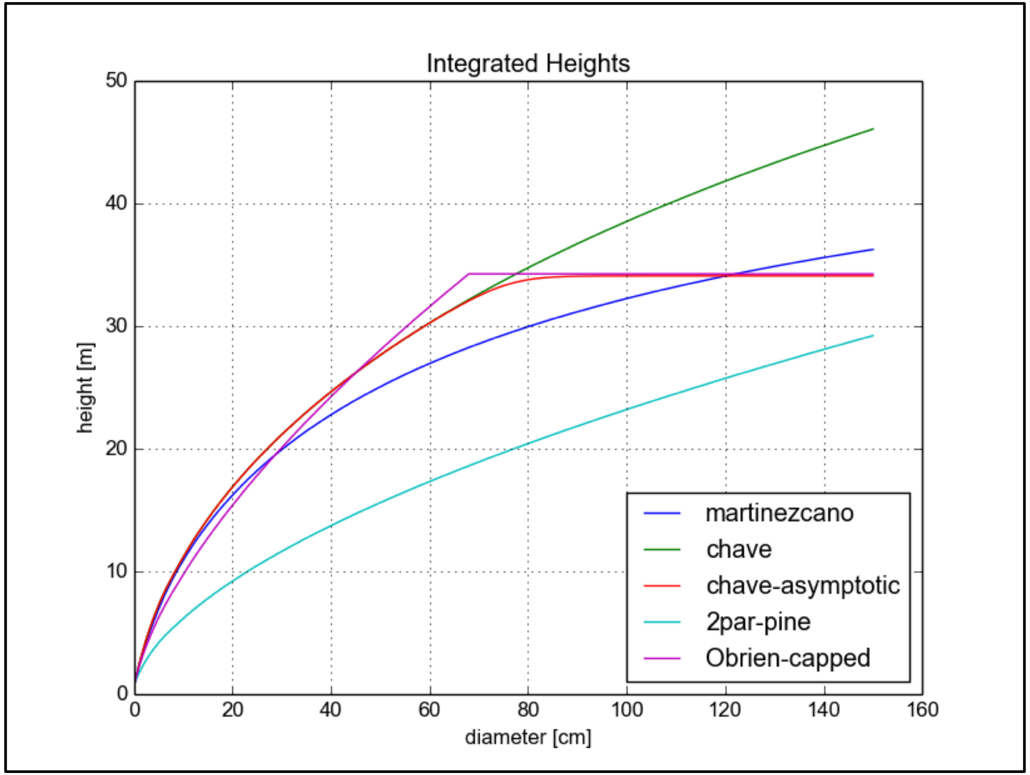
Take home points:

- Allometry governs proportionality
- Allometry equations are either trivial or dependent on diameter
- Allometry of tissue pools describe the ideal or maximum carrying capacity for the stature
- Code allows for new functional forms to be added



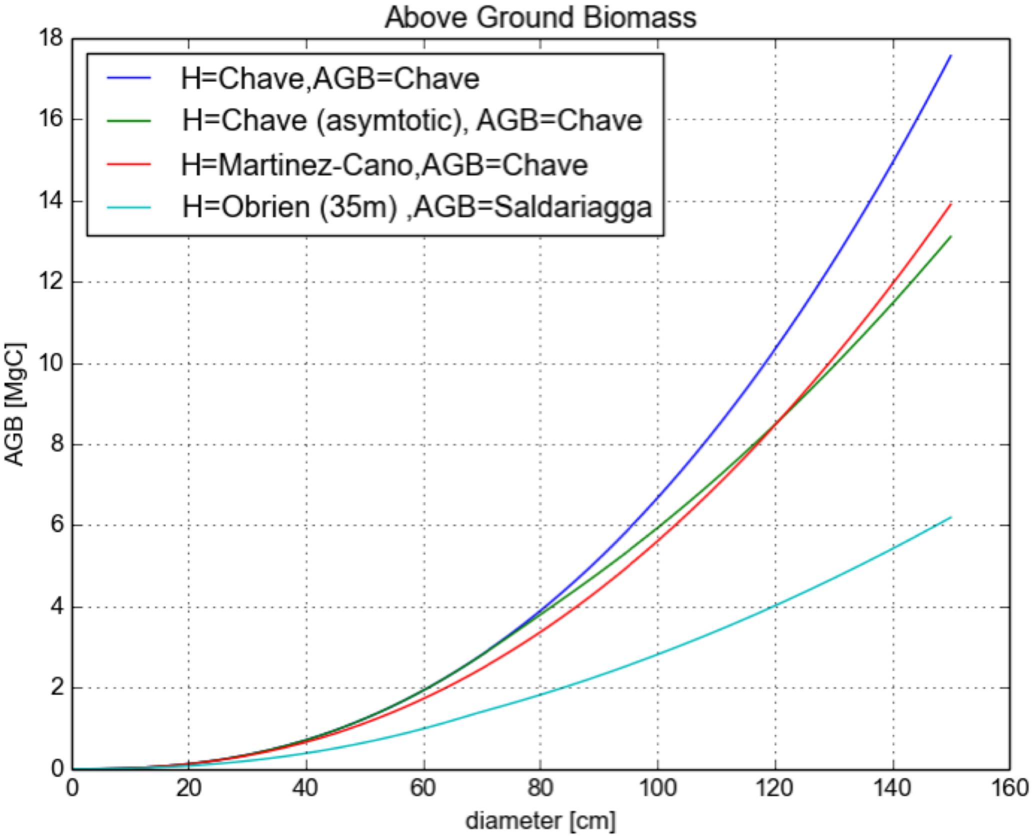
Stature Growth Follows Allometry

Height - Diameter Allometry



Stature Growth Follows Allometry

AGB - Diameter Allometry



Phenology (Abridged Edition)

Phenology - very similar to phenology in CLM

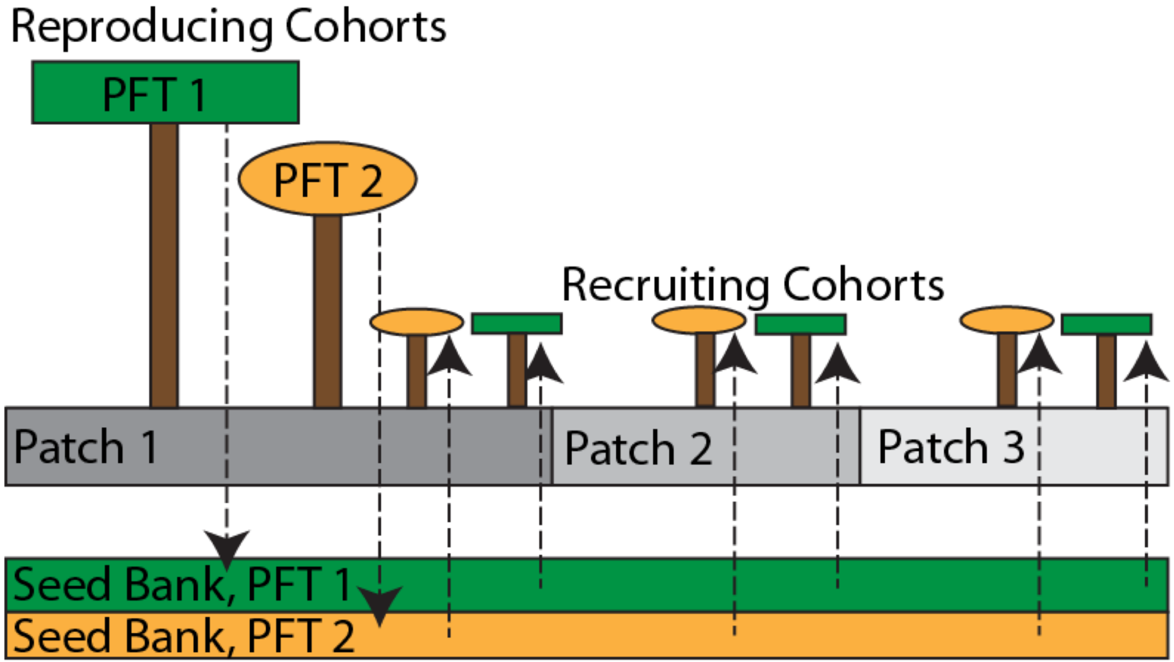
- Timing of cold deciduous leaf-on and leaf-off is governed by integrating growing degree days, and counting cold days (respectively) (Botta et al.)
- Timing of stress deciduous leaf-on and leaf-off is governed by mean soil moisture and thresholds
- On/Off status is a site (column) scale variable, not a plant scale variable (but it should be…?)
- A plant must be one of evergreen, stress deciduous or cold deciduous
- Leaf-on and leaf-off status has minimum window requirements to prevent flickering
- Triggering “leaf-on” will flush a fraction of the plants carrying capacity
- Triggering “leaf-off” will drop all leaves instantaneously

Patch-scale
Demographic processes

Recruitment, Mortality, Fire

1. Reproduction & Recruitment

- Seed flux is in mass units as a fraction of NPP
- Seeds from all patches mixed at site level => perfectly efficient dispersal within sites
- Population of recruits is function of carbon flux out of seed pool and recruit size



Plant Mortality

Plant Mortality

1. Background mortality

```
bmort =bmort(pft)
```

1. Carbon starvation mortality

```
frac = bstore/b_leaf

cmort =ED_val_stress_mort*(1.0_r8 - frac)
```

1. 'Hydraulic failure' mortality

```
if(btran_ft(pft) <= hf_sm_threshold)then
hmort = mort_scalar_hydrfailure
```

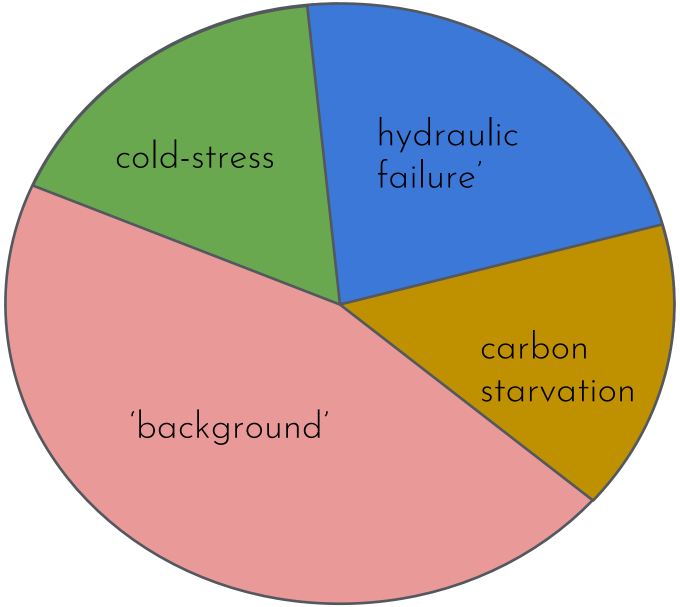
If hydro is on:

```
hmort = (flc-hf_flc_threshold)/(1.0_r8-hf_flc_threshold)
       *mort_scalar_hydrfailure
```

1. Cold-stress mortality

```
temp_dep = max(0.0,min(1.0,1.0 - (temp-
freezetol(pft))/frost_mort_buffer))

frmort = frost_mort_scaler * temp_dep
```

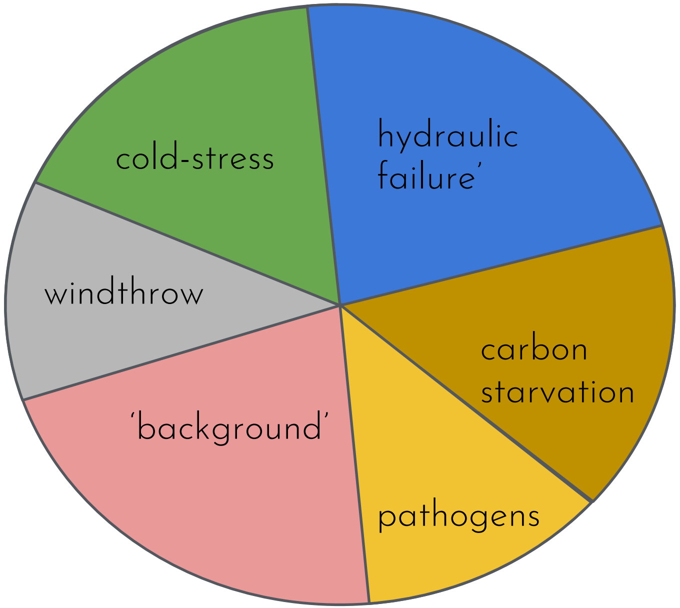


Plant Mortality

n.b. In principle 'background' is all the as-yet unexplained mortality

As well add more mechanisms of mortality, 'background' should decline

e.g.
windthrow
insects/fungi
phloem failure
heat stress



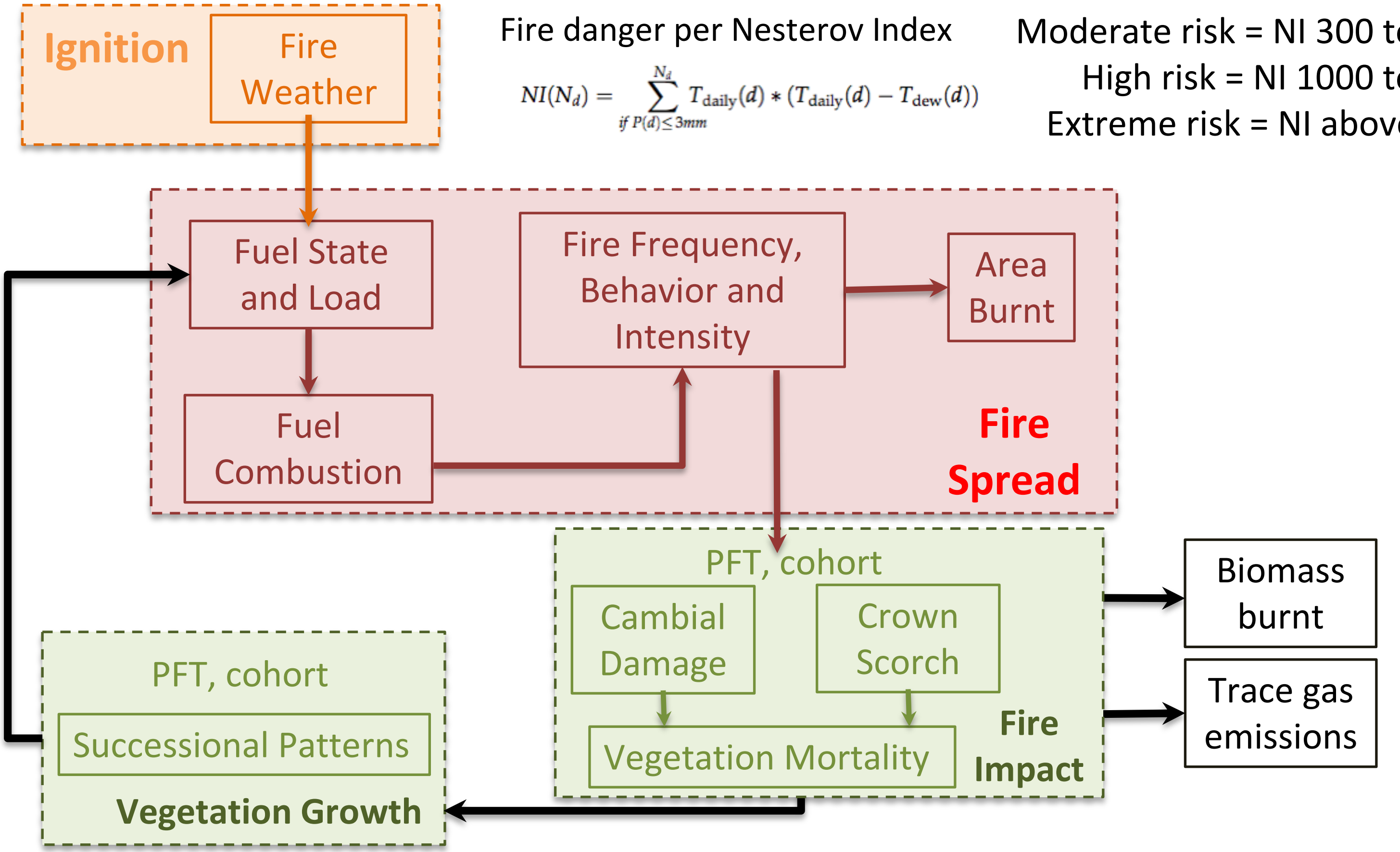
FIRE

FATES-SPITFIRE

Fire danger per Nesterov Index

$$NI(N_d) = \sum_{if\ P(d) \leq 3mm}^{N_d} T_{\text{daily}}(d) * (T_{\text{daily}}(d) - T_{\text{dew}}(d))$$

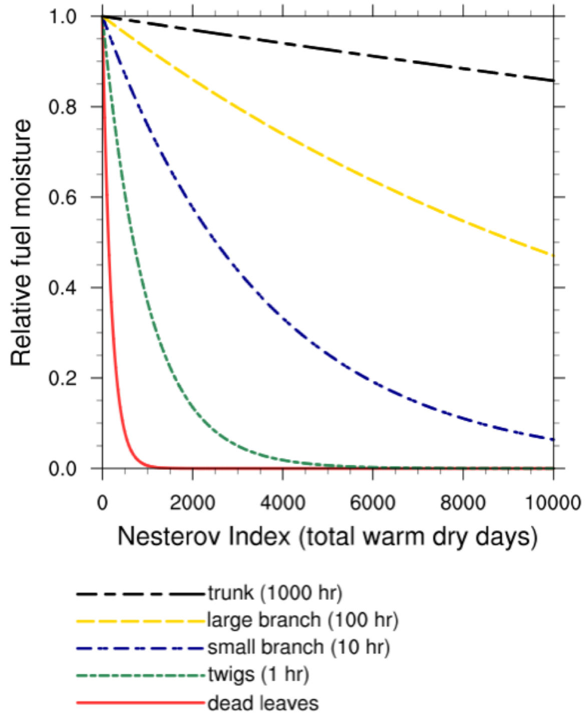
Moderate risk = NI 300 to 1000
High risk = NI 1000 to 4000
Extreme risk = NI above 4000



Adapted from Thonicke *et al.* 2010 *Biogeosciences*

LITTER and FIRE

FATES fuel moisture changes with climate



FATES tracks six fuel classes

Trunks
Large branches
Small branches
Twigs
Leaves
Live grass

These gradually 'fragment' into soil organic matter pools, and are passed into the host land model decomposition routines.

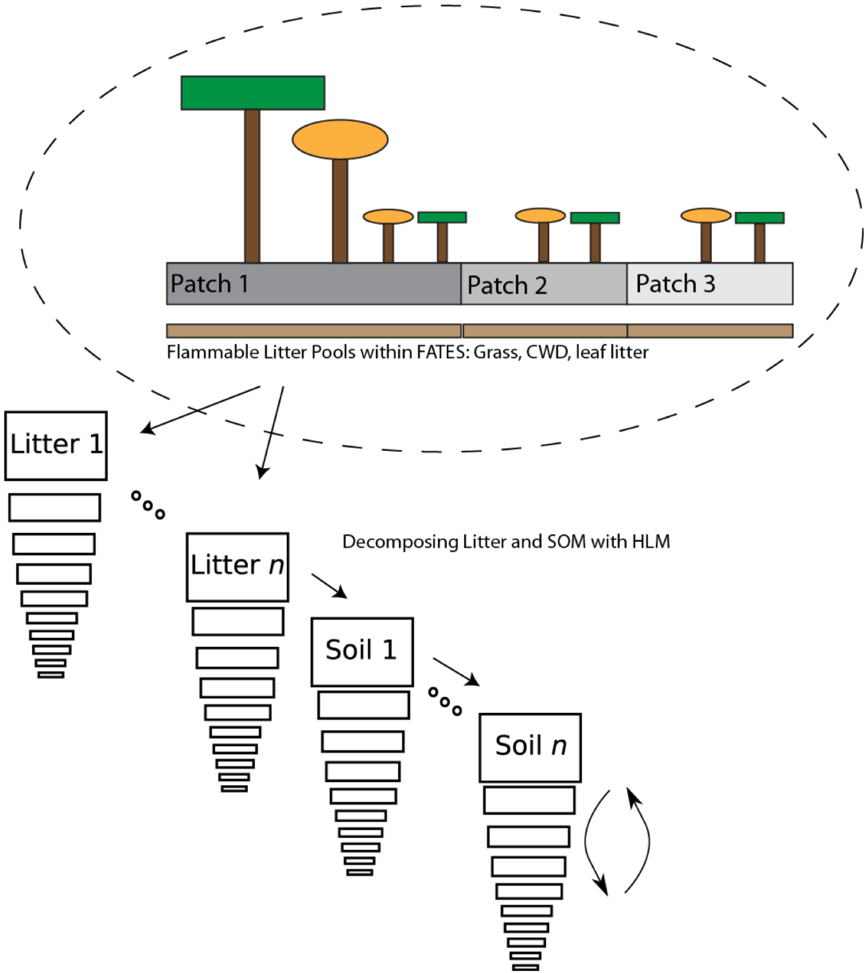
Cellulose
Lignin
Labile

FATES-HLM Transfer of Litter

Flammable CWD and litter held on FATES patches

Mechanically breaks down to decomposable litter and passed to HLM for decomposition routines

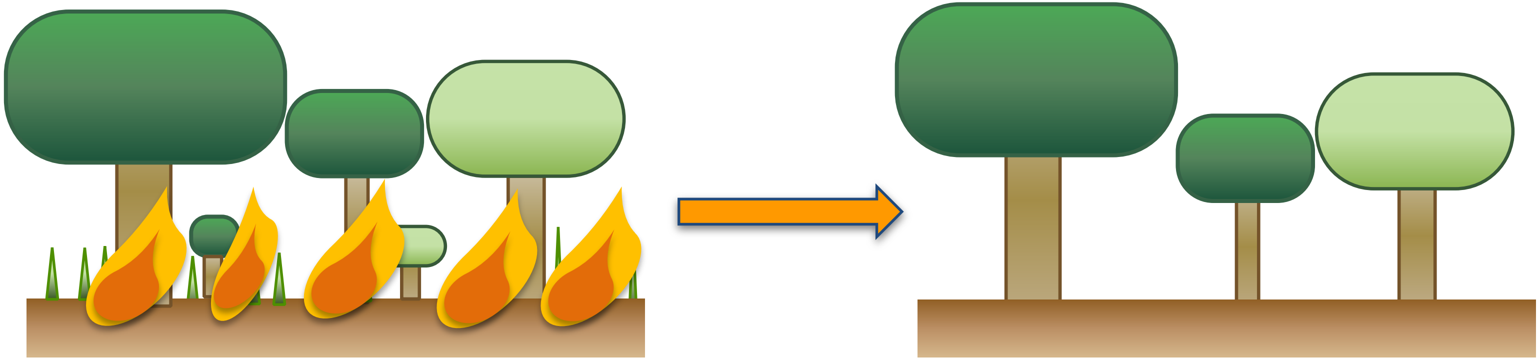
Vertical profiles of belowground litter outputs defined by root profiles



VEGETATION and FIRE

Mortality for trees depends on:
Flame height (relative to canopy height)
Bark thickness (varies by age and PFT)
Fire intensity and residence time

Grasses are not protected, and burn with fire



FATES retains the fire-affected canopy structure, e.g. altering future fire behavior

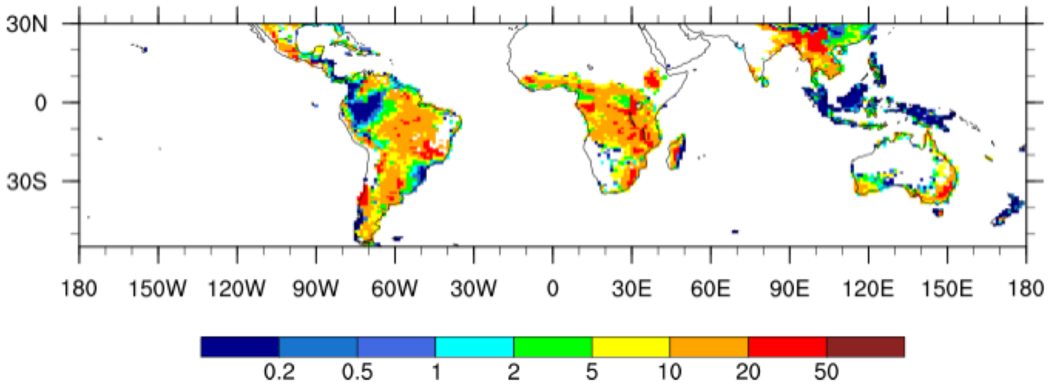
Impact of initial conditions

Challenge in Forest/Savanna areas:

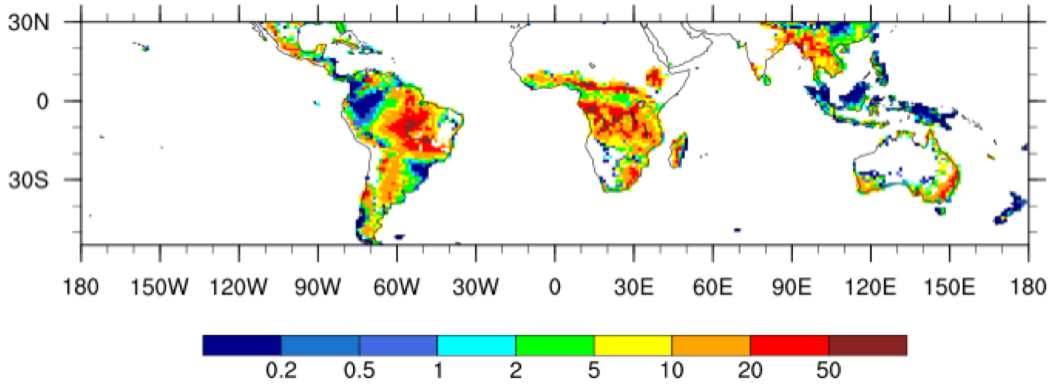
- Climate
- Seasonality (# dry months)
- Vegetation state/ Species Traits

Burned fraction (% $year^{-1}$)

Bare ground, 150 yrs Fire

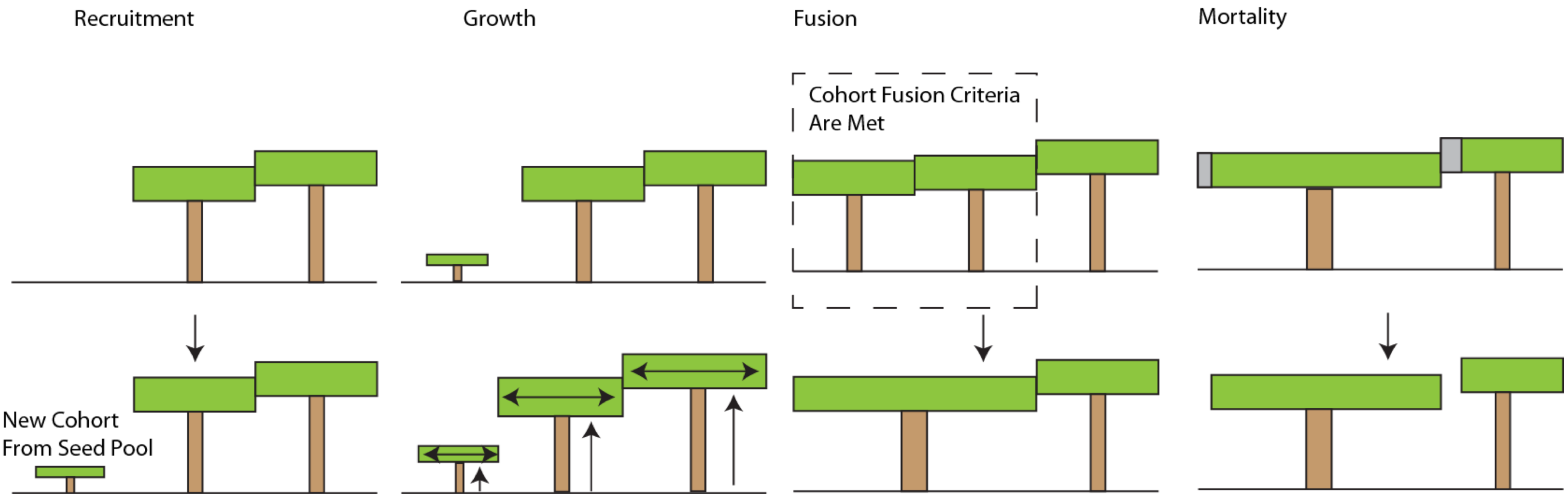


50 yrs no Fire, 150 yrs Fire



FATES patch and cohort dynamics

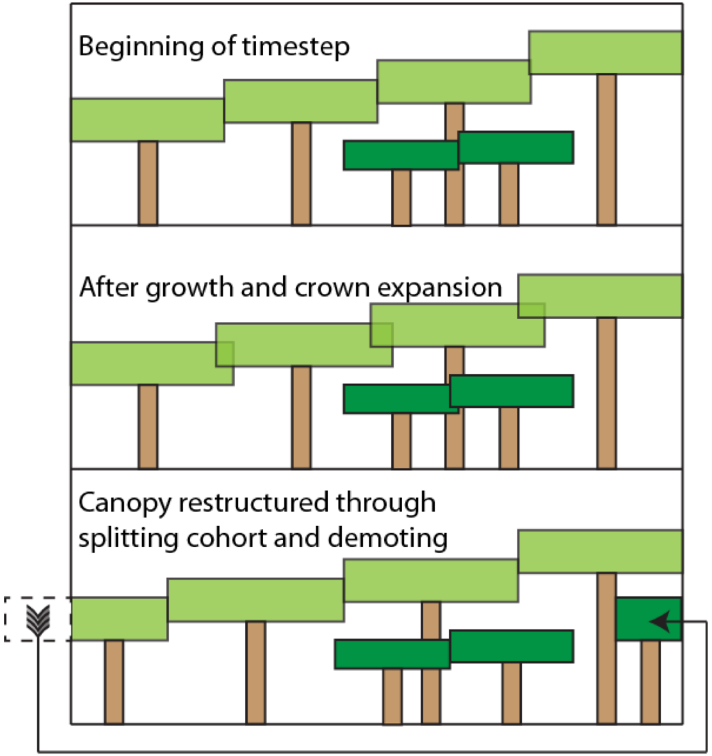
The life of a cohort



FATES Cohort organization within the Patch

- Cohort organization by PPA-based rank organization
- As cohorts grow their crown areas expand via allometry, overfilling canopy. This leads to a constant demotion of cohorts into the understory
- Competitive exclusion parameter allows changes to efficiency of sorting from deterministic PPA to a degree of stochasticity

Deterministic PPA Sorting



FATES Cohort organization within the Patch

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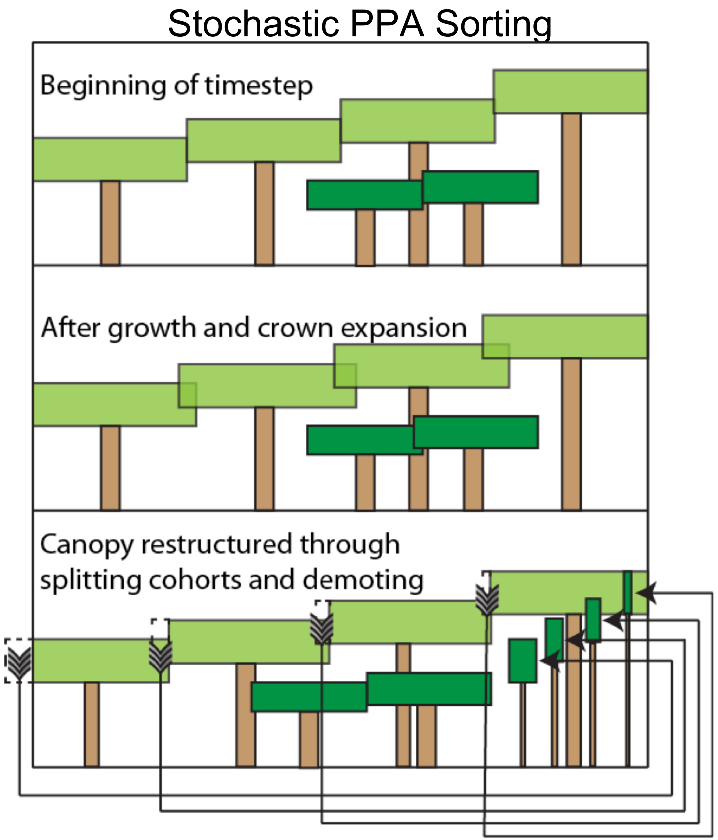


The life of a patch

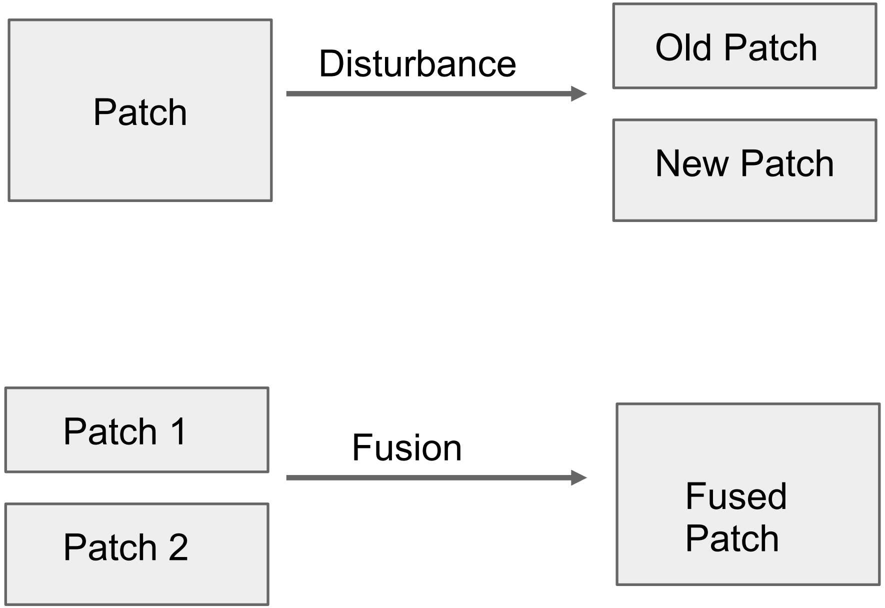
1. Patches made from disturbance
2. Fused to similar patches
3. Reduced by subsequent disturbances
4. Terminated when too small/old
5. Age

Patch Generation and Fusion

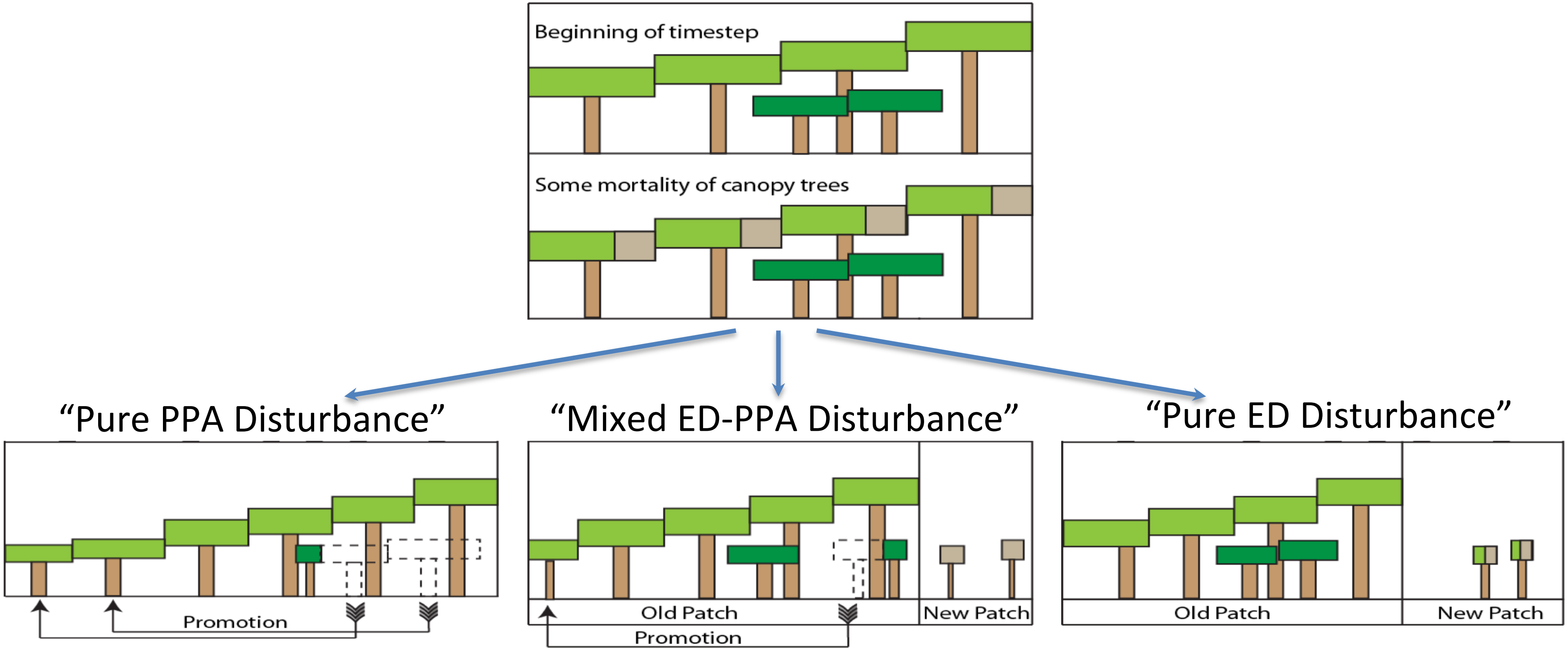
Disturbance occurs when canopy trees die.

Disturbance generates new zero-aged patches.

Patches fuse when they become sufficiently similar



Sensitivity to Patch heterogeneity



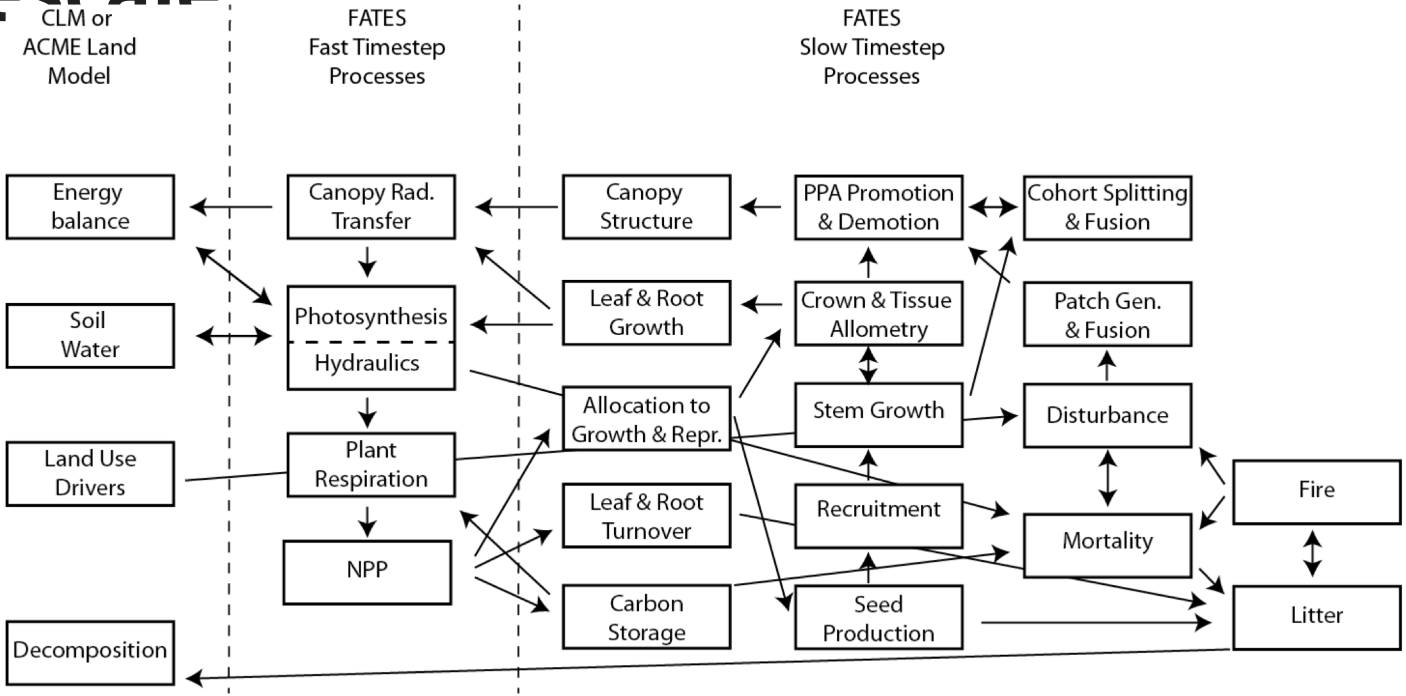
Accommodate all disturbance by rearranging within patch

Create smaller amount of unoccupied patch area

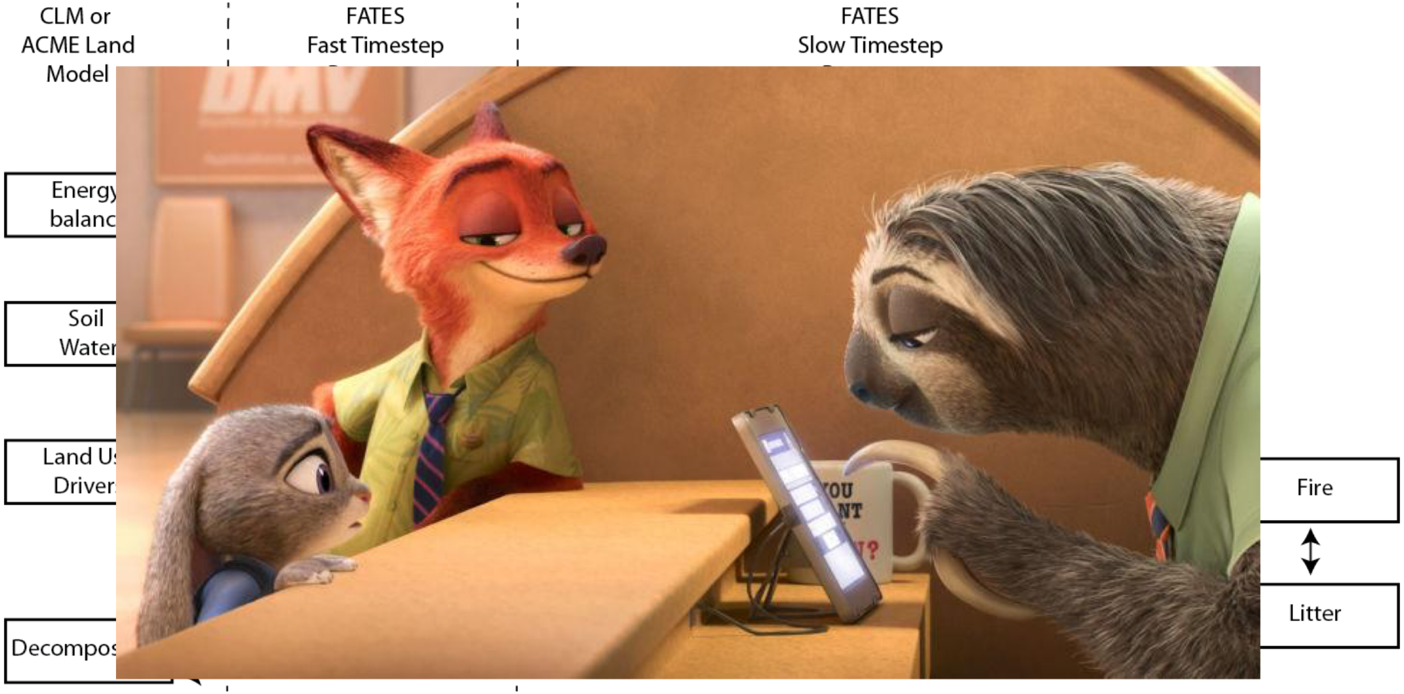
Resolve disturbance by creating new (occupied) patch area

Different ‘modes’ for running fates

Simplified FATES Versions: Separate Along Timescale



Simplified FATES Versions: Separate Along Timescale



Simplified FATES Modes: ST3 and PPM

Static Stand Structure (ST3) :

Holds the slow processes constant and **calculates only biophysics** (can be initialized from inventory data)

Prescribed Physiology Mode (PPM) :

Overwrites NPP, mortality, and (optionally) recruitment with **specified rates** (set in FATES parameter file).

Why would one want to use ST3 Mode?

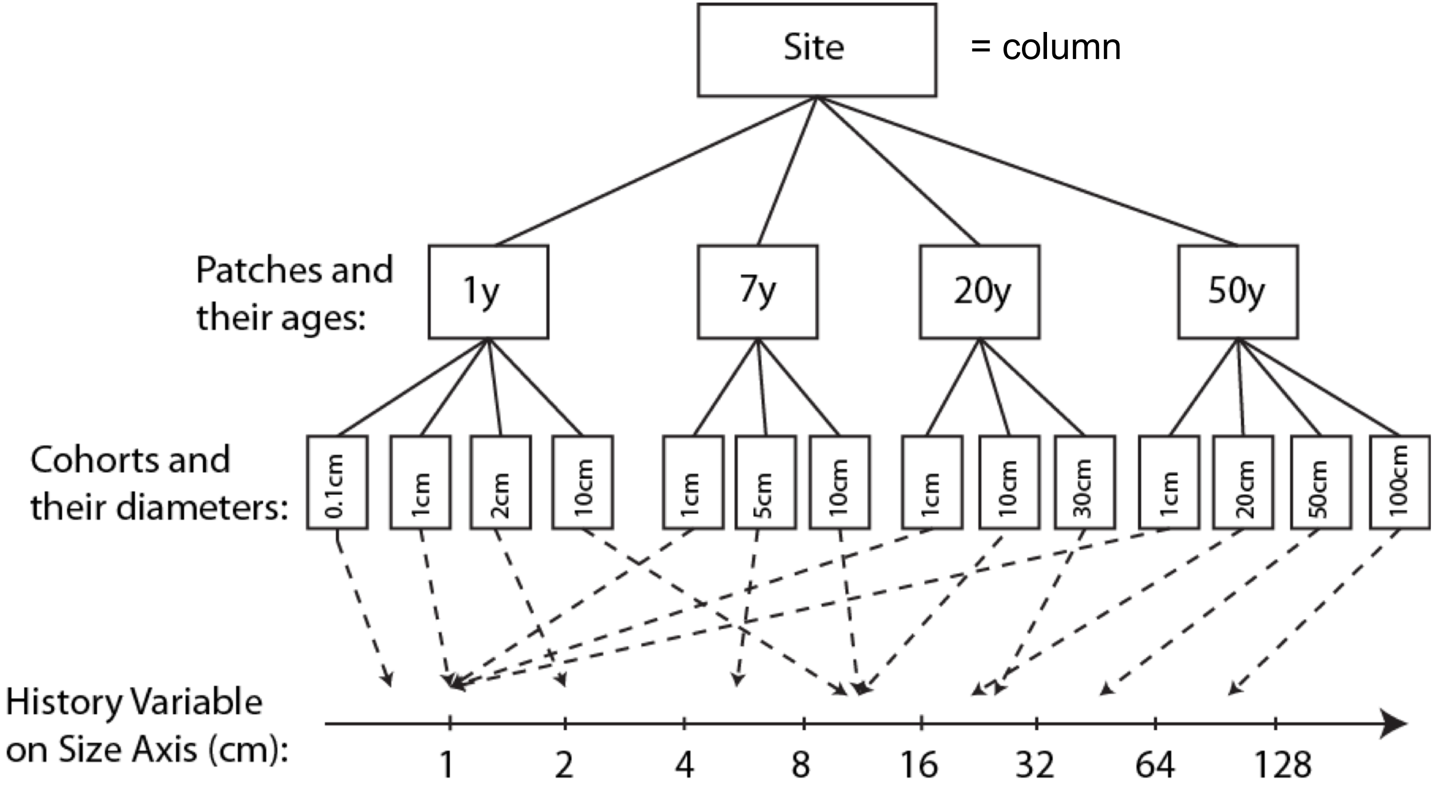
- Breaks feedback loop between ecosystem structure and function.
- Allows cleaner experimental design to look at changes to a given parameter or structure directly rather than the effects of those changes as propagated through ecosystem structure.
- If initialized from inventory, allows understanding of physiological rates conditional on the observed forest structure.
- Analogous to CLM's SP mode, except that, for now at least, there is no phenology. (Which should change.)

Why would one want to use PPM?

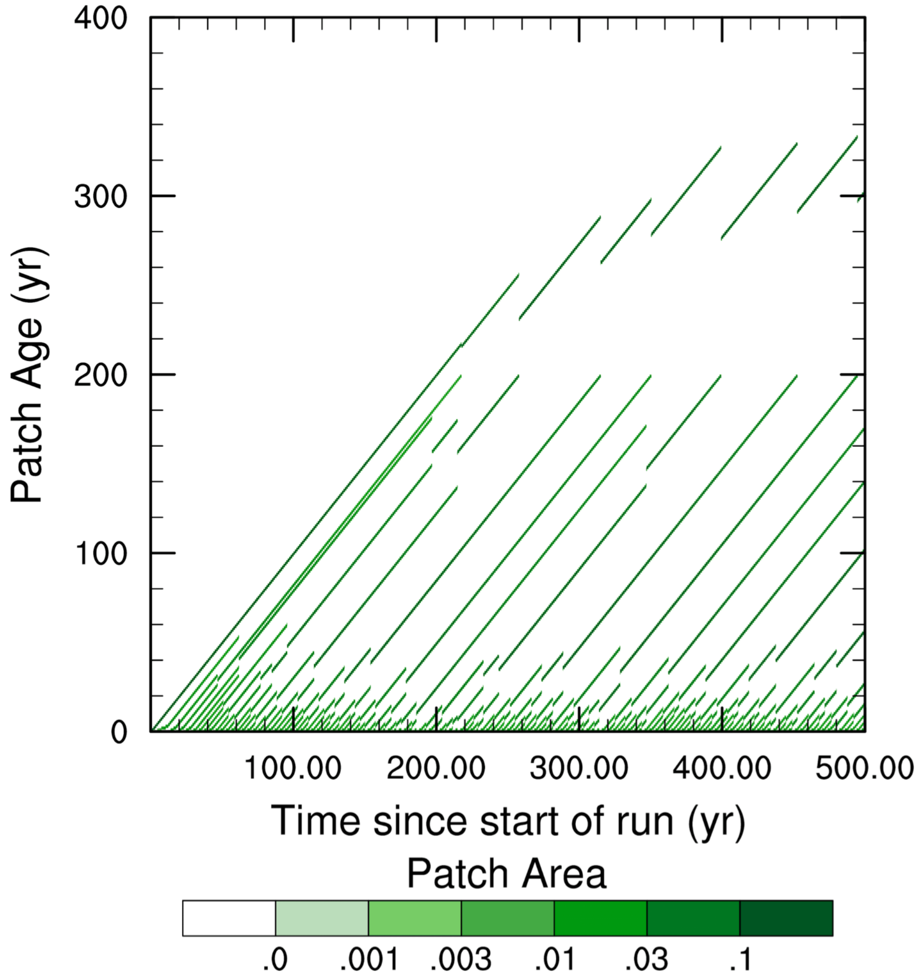
- Allows a direct assessment of how vital rates—which have much lower dimensionality than physiological traits—govern ecosystem structure.
- Allows testing of model structure and parameters that govern slow vegetation dynamical processes given a known set of vital rates.
- Possible to sample different / larger physiological rate parameter spaces than might be possible using full model.
- Separation of forced from internal modes of variability (which, in ecology language, means an ability to isolate things like a storage effect on coexistence)
- Ability to test generality of behavior by applying it in reduced-complexity model.

FATES History File Structures

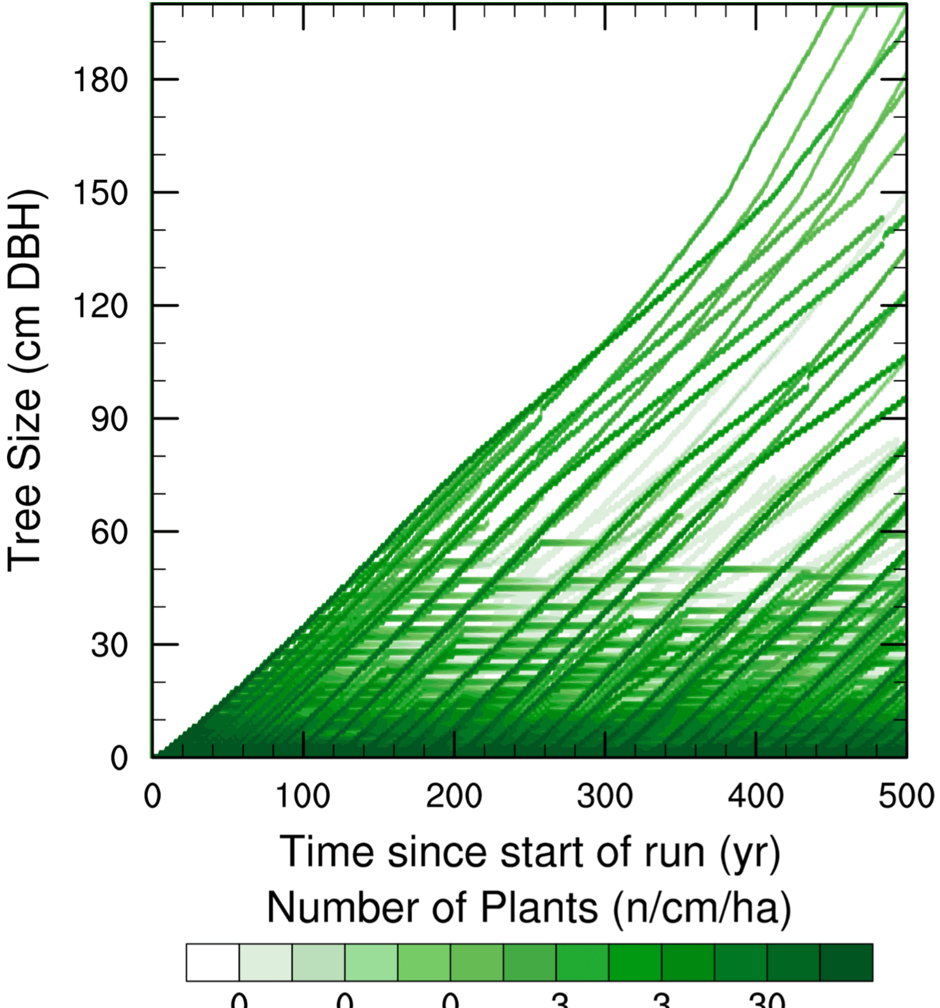
How FATES Passes Info to History Files:



Example of Patch Age Dynamics in a Tropical Forest Simulation

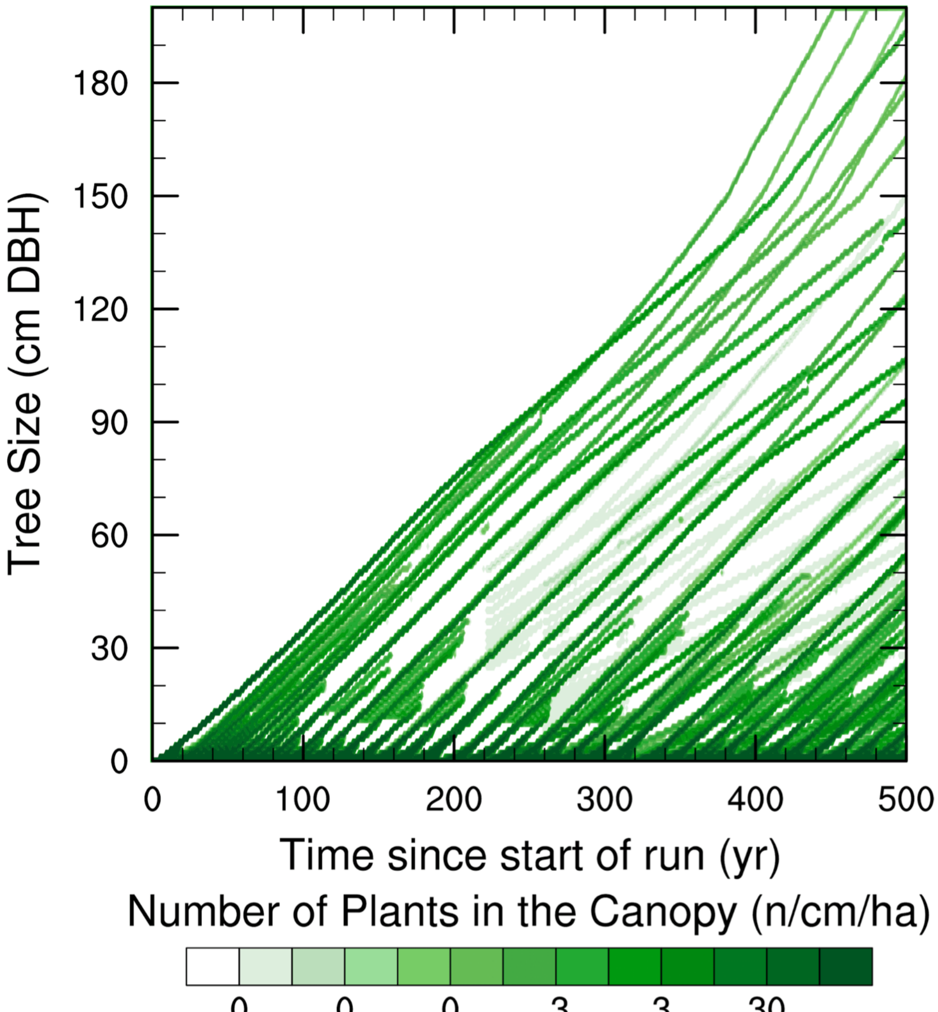


Cohort Dynamics

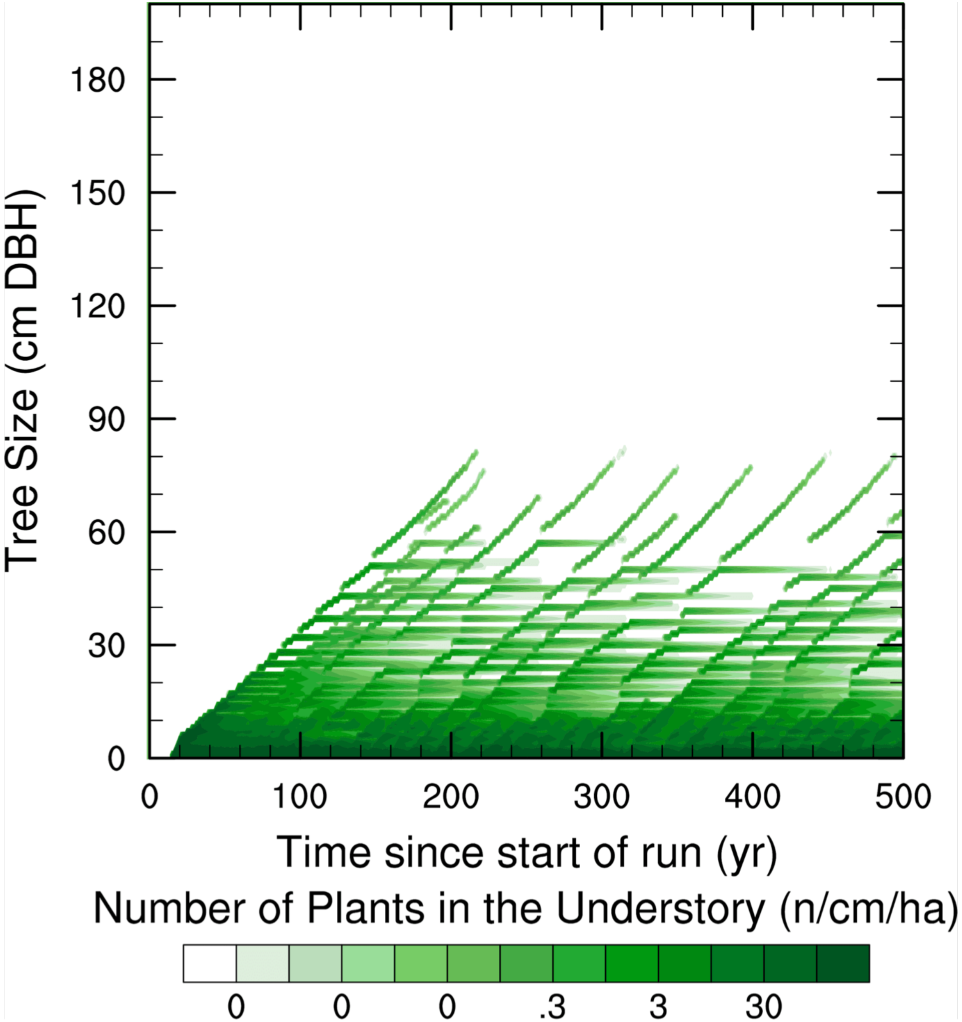


Cohort Dynamics

(Canopy Trees Only)

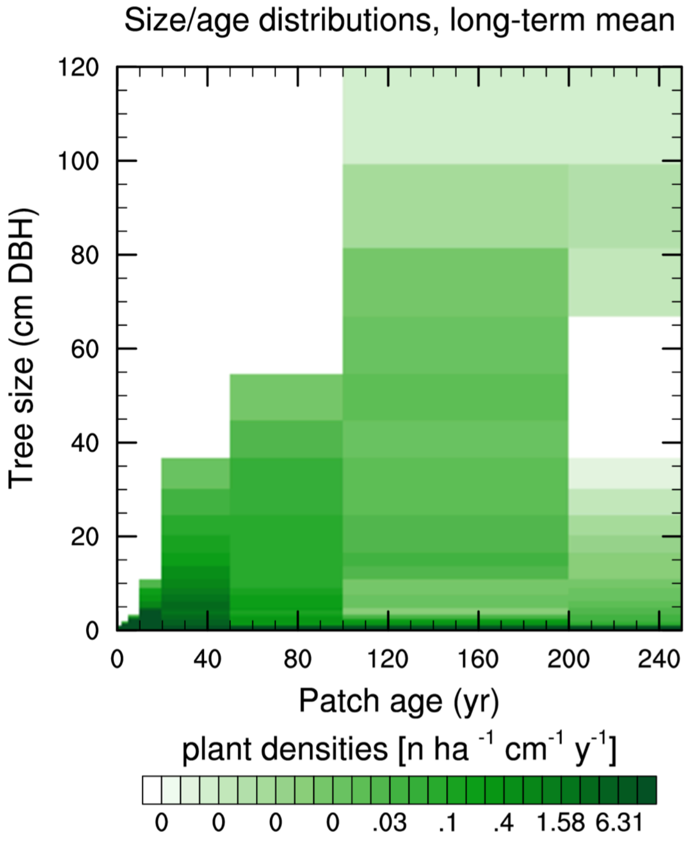


Cohort Dynamics
(Under-Canopy Trees Only)



More Complex, multi-dimensional output:

- Multiple dimensions available for output:
    - Cohort Size,
    - Patch Age,
    - Cohort Canopy Position,
    - Leaf Layer,
    - Cohort PFT, &
    - time since start of run.
- E.g: number of plants as binned along axes of size and age:



Plant Functional types

Plant Functional Types in CLM/ALM

Typically, land surface model PFTs are defined by:

- Phenology (evergreen, cold dec, stress dec)
- Growth Form (tree, shrub, grass)
- Leaf Habit (broadleaf, needleleaf)
- Photosynthesis (C3, C4)

These are unambiguous traits, mostly identifiable from space

But they don't tell us much about ecosystem function or responses to change.

A note on climate envelopes

Paradigm: Vegetation climate limits are a function of simple climate variables, defined from current vegetation distributions

Climate envelope parameterization from Lund-Potsdam-Jena (LPJ) DGVM (vegetation cannot survive outside limits)

Used in:
ORCHIDEE (IPSL), CTEM (CanESM)
SEIB (MIROC-ESM), CLM-DV (CESM)

Plant Functional Type	Temp coldest month (°C)	Temp hottest month (°C)	Growing Degree Days
Tropical broad-leaved evergreen	15.5	–	–
Tropical broad-leaved raingreen	15.5	–	–
Temperate needle-leaved evergreen	−2.0	22.0	900
Temperate broad-leaved evergreen	3.0	18.8	1200
Temperate broad-leaved summergreen	−17.0	15.5	1200
Boreal needle-leaved evergreen	−32.5	−2.0	600
Boreal needle-leaved summergreen	–	−2.0	350
Boreal broad-leaved summergreen	–	−2.0	350
Temperate herbaceous (TeH)	–	15.5	–
Tropical herbaceous (TrH)	15.5	–	–

Sitch et al. 2003

PFTs in FATES

The idea of FATES is that PFT definitions are flexible.

Fundamentally, a plant functional type is a vector of plant traits.

In FATES, this vector can be configured however you want.

n.b. the EDv1 and EDv2 PFTS (early, mid-late successional tropical trees) are not the default in FATES.

As yet, none of these traits are climate envelopes... (tbc)

Representation of plant trait vector

specific leaf area				
leaf C:N				
wood density				
root:leaf ratio				
bark thickness				
root lifespan				
etc.				

PFTs in FATES - Special Case (vcmax and leaf lifespan)

VCMAX and leaf lifespan are dimensioned by PFT and "age bin".

User can specify any number of each

1 age bin is allowed.

Representation of plant trait vector

specific leaf area				
leaf C:N				
wood density				
root:leaf ratio				
bark thickness				
root lifespan				
Leaf lifespan				

FATES parameters in CLM/ALM

FATES has **187** parameters, but you have options.

Hydro (18), Fire (23), Nitrogen/Phos (6), Special Modes (14), Obvious/Developer (23), Special Modes (i.e. logging, prescribed physiology, etc.) (14)

Allometry (leaf, height, aboveground biomass, sapwood, root) (27)

Now you only have **66** other parameters to calibrate

For regional/site calibration **start here:**

*Allometric relationships (DBH to H, DBH to biomass, DBH to crown area)

*Wood Density

Vcmax

Specific Leaf Area

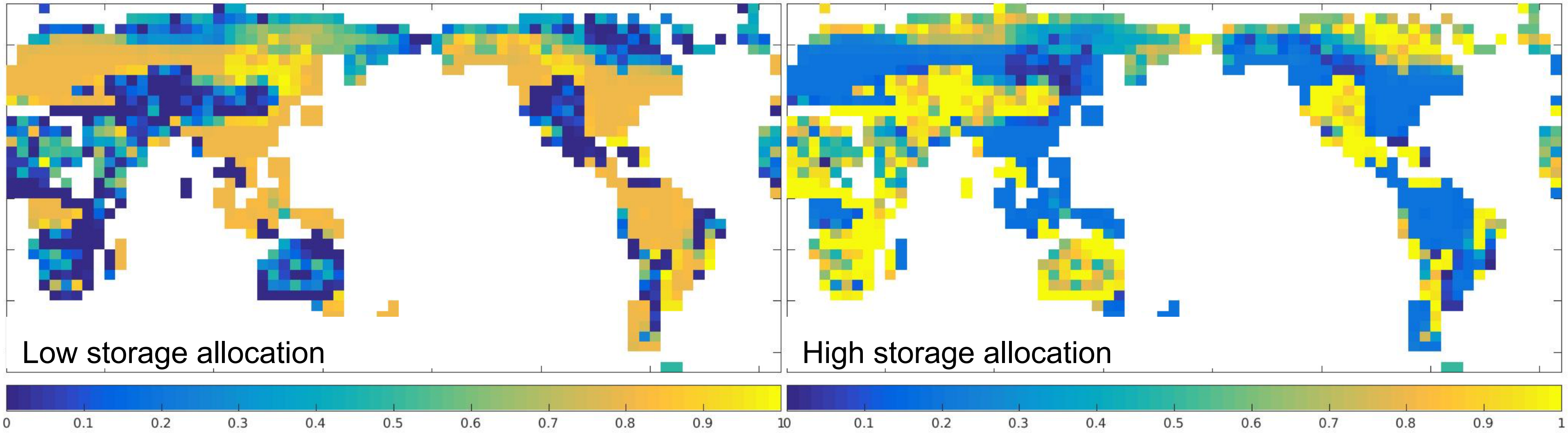
Leaf C:N ratio

Leaf Longevity

Example plant functional types experiments in fates

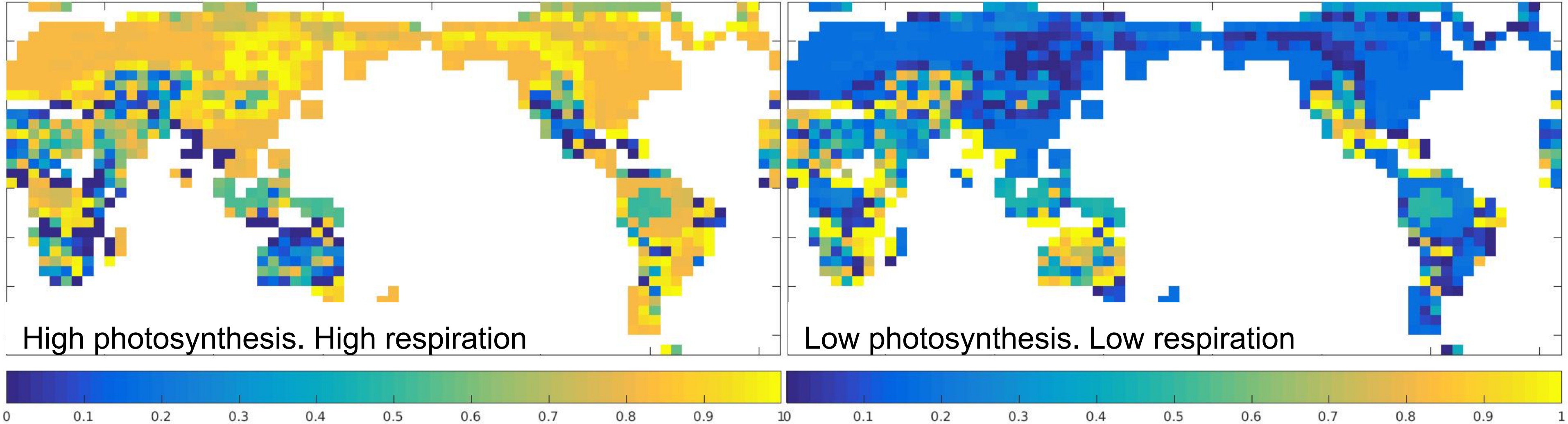
Example single trait competition experiments in FATES

Allocation to storage



Growing, rather than storing, is a good idea whereever there is closed canopy forest.

LeafCN & Vc,max



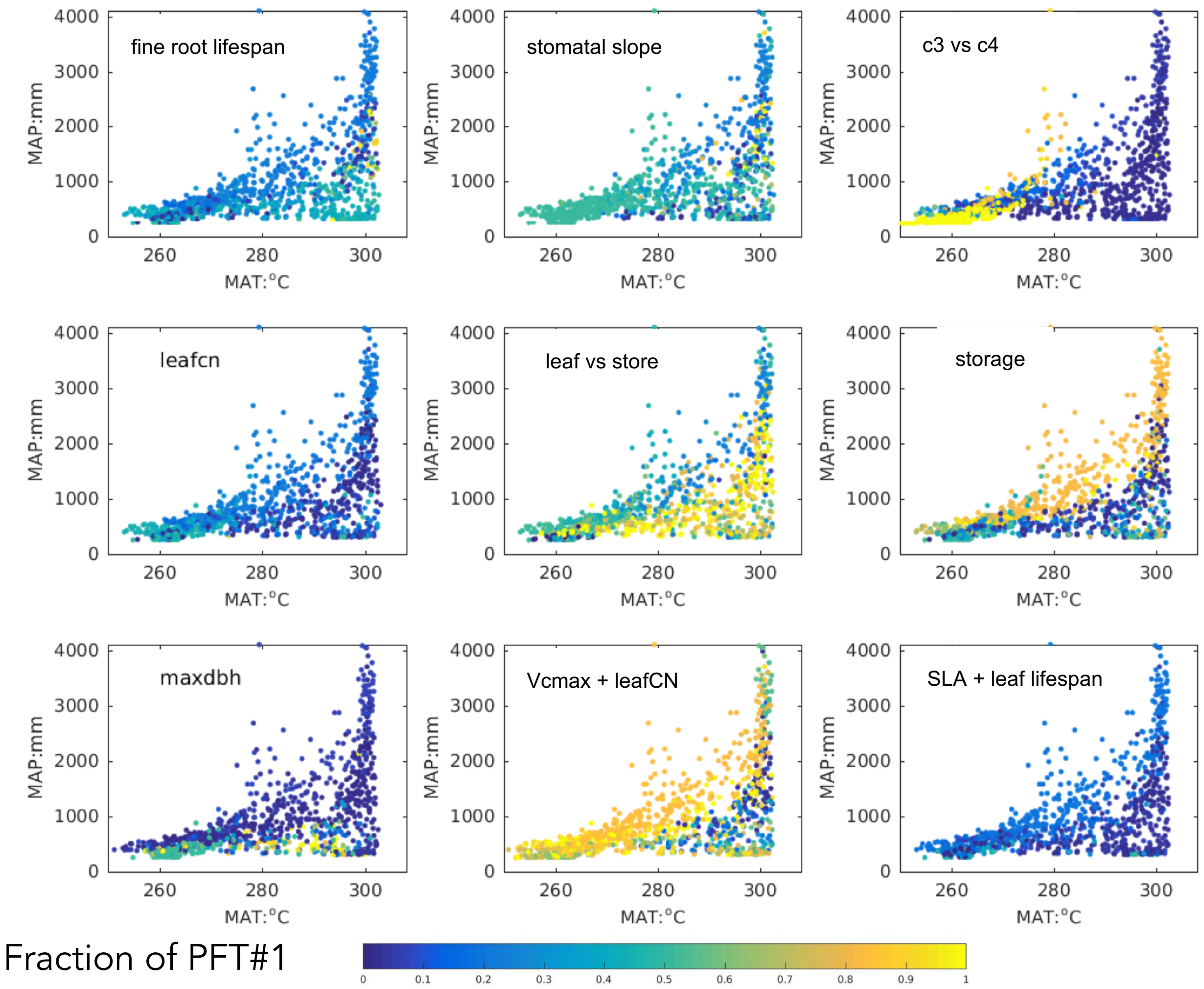
High leaf N is beneficial in high resource environments. In dry environments it is sub-optimal

Climate envelopes

-Selection is typically not only along temperature or precip gradients.

-Most trait filtering is related to light competition intensity

-Are we missing processes/traits that allow filtering by temperature, or drought?



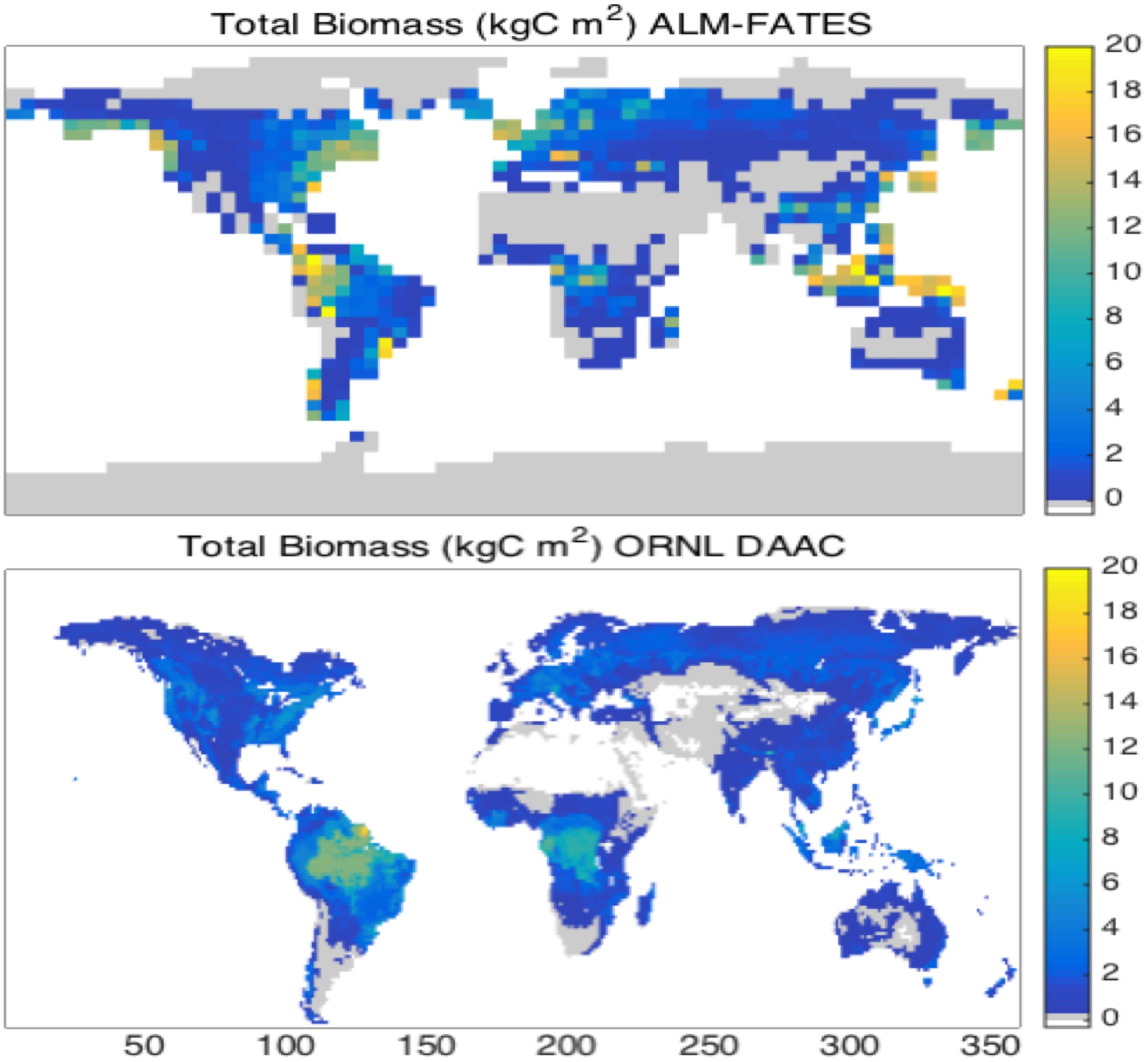
What happens if we put the CLM parameters into FATES?

Global PFT distribution status (jennifer Holm)

- Global simulations of FATES
- One approach to FATES globalization (other simpler representations are possible and planned)
- Coupled to E3SM Land Model (ELM)

- 13 PFTs:
  - Default FATES specific parameters
  - Non-FATES parameters based on CLM4.5 values

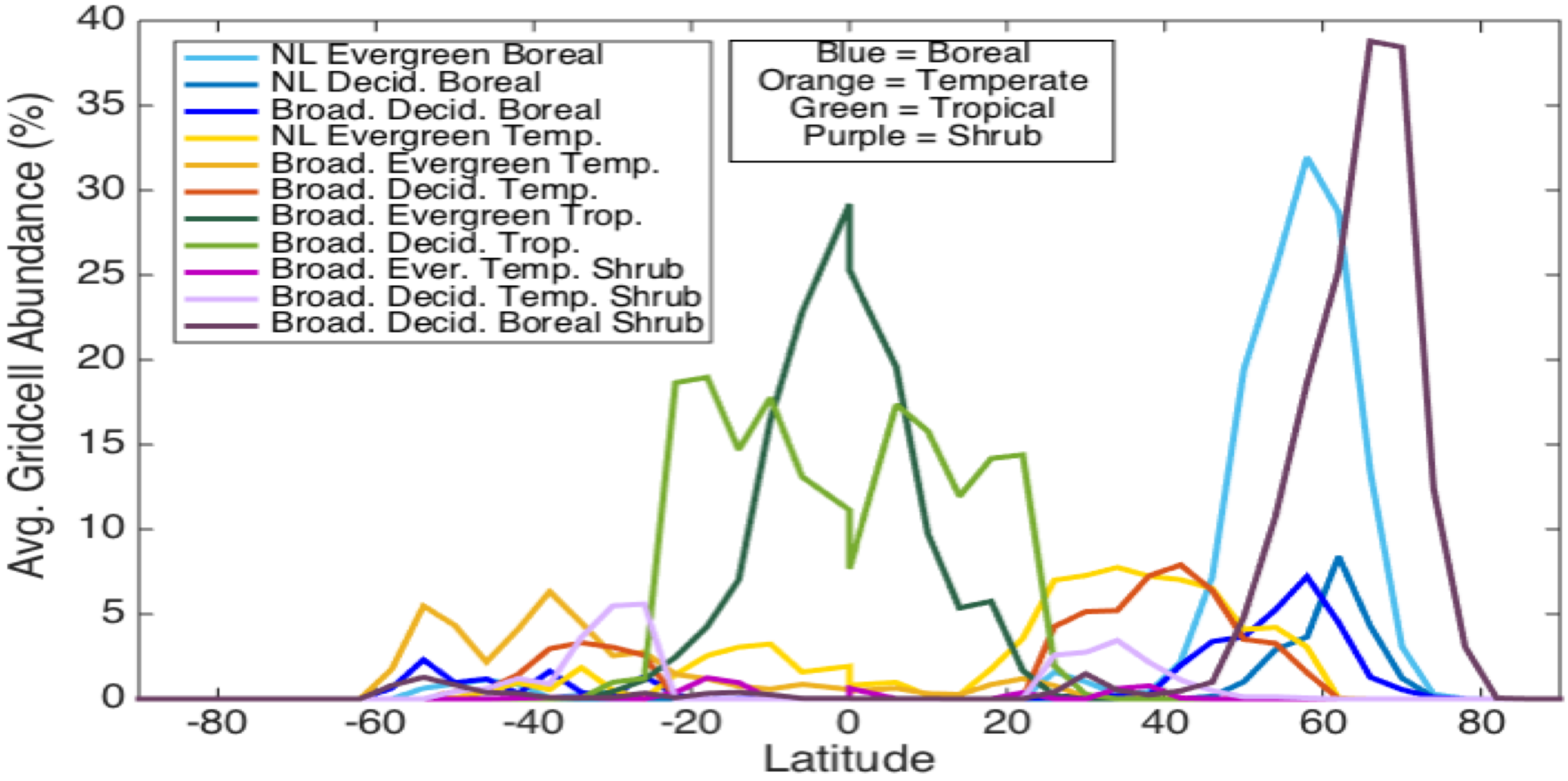
- Goal with global simulations:
  - Latitudinal gradient of plant distribution based on emergent dynamic vegetation processes
  - With FATES, no climate envelopes boundaries (i.e. no pre-defined climate tolerances for recruitment and survival).
  - BUT some climate tolerances are real (i.e. freezing tolerances)



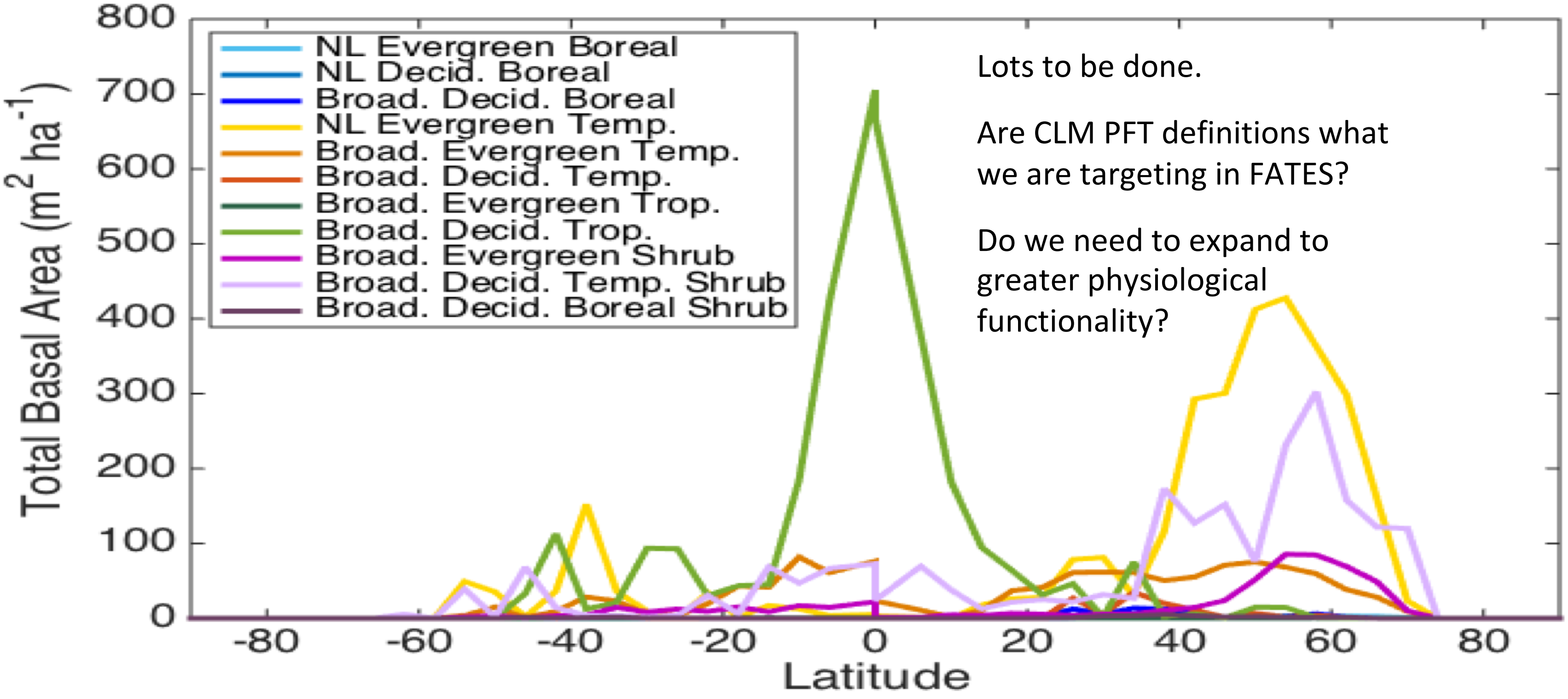
4x5 degree resolution simulations

FATES has reasonable biomass, etc.

MODIS PFT distribution



ELM-FATES



Lots to be done.

Are CLM PFT definitions what we are targeting in FATES?

Do we need to expand to greater physiological functionality?

Fates-Hydro

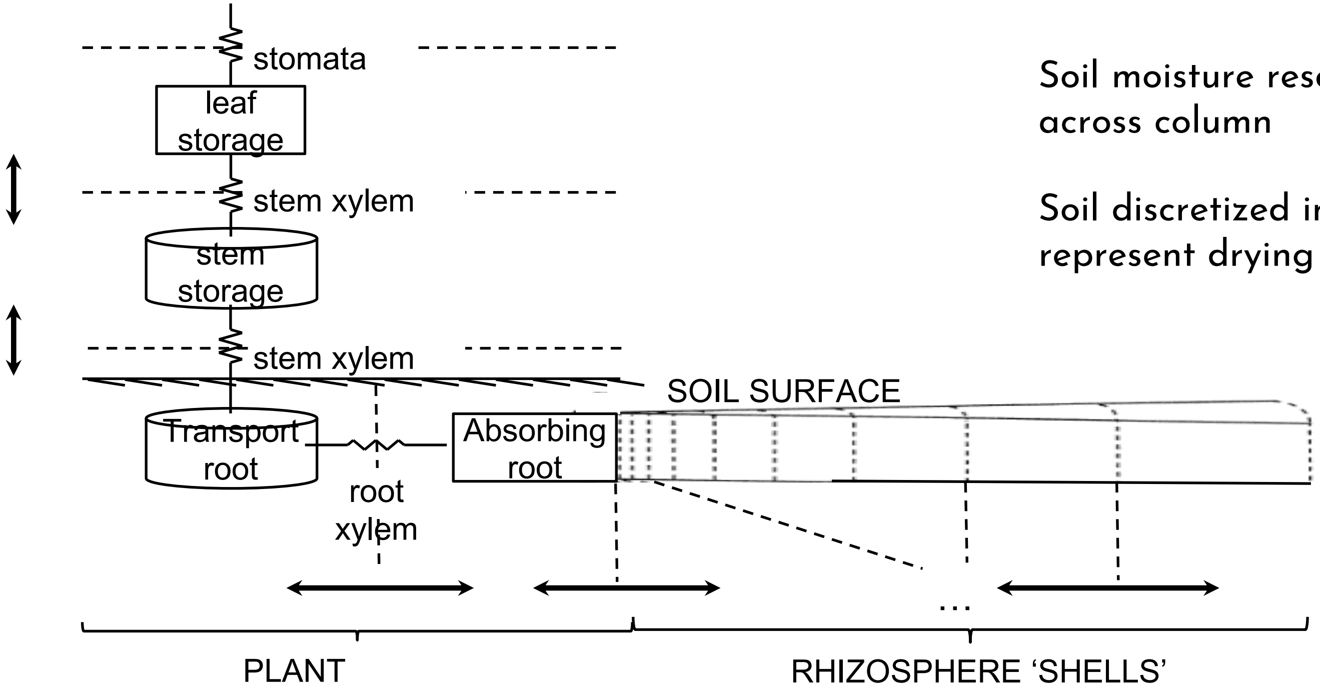
Plant hydrodynamics

BRAD CHRISTOFFERSEN, *CHONGGANG XU, NATE MCDOWELL* &
THE NGEE-TROPICS MODELING TEAM

NGEE–TROPICS
NEXT-GENERATION ECOSYSTEM EXPERIMENTS

U.S. DEPARTMENT OF ENERGY | Office of Science

FATES-HYDRO

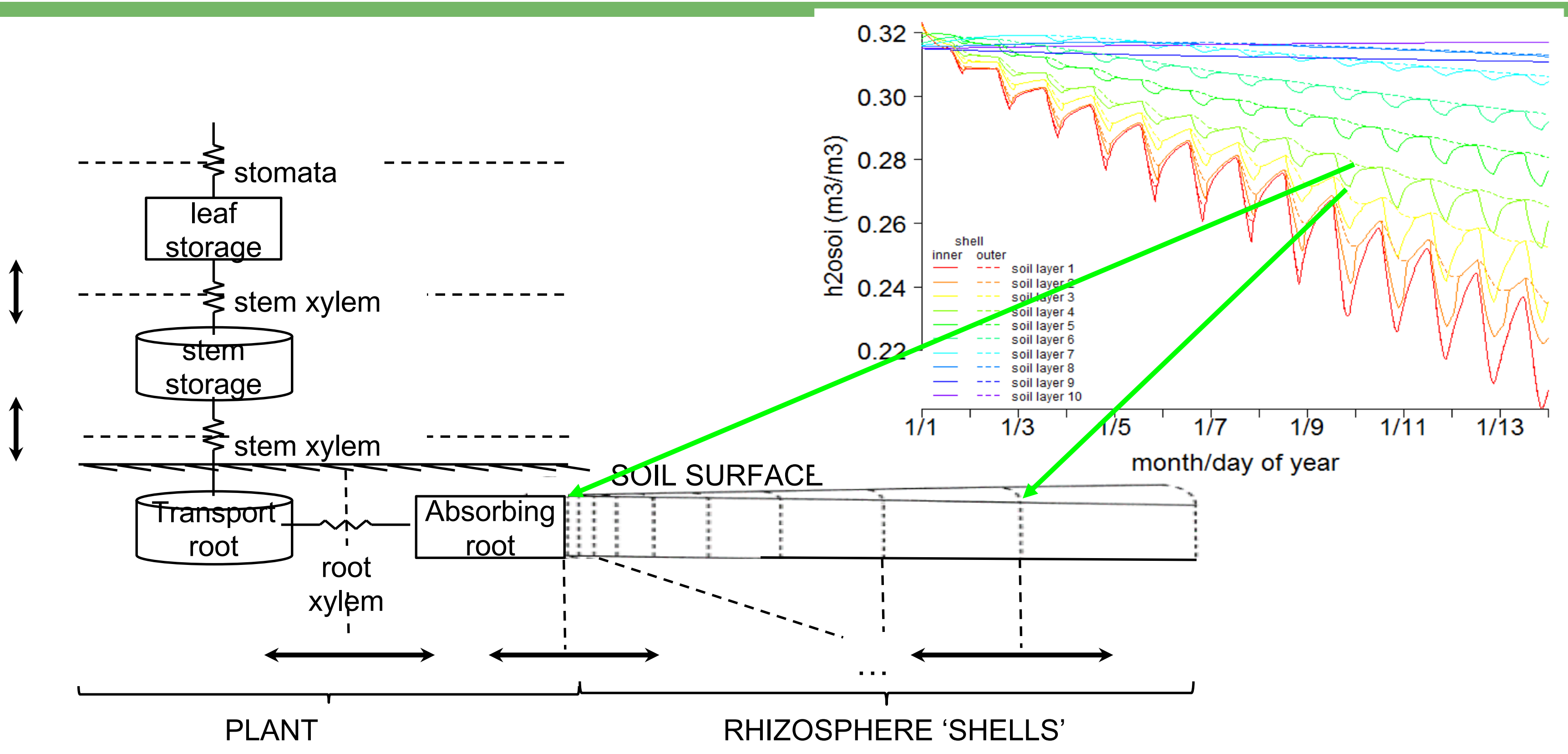


Plant hydraulic status represented for each cohort

Soil moisture resources pooled across column

Soil discretized into ‘shells’ to represent drying at root surface

FATES-HYDRO



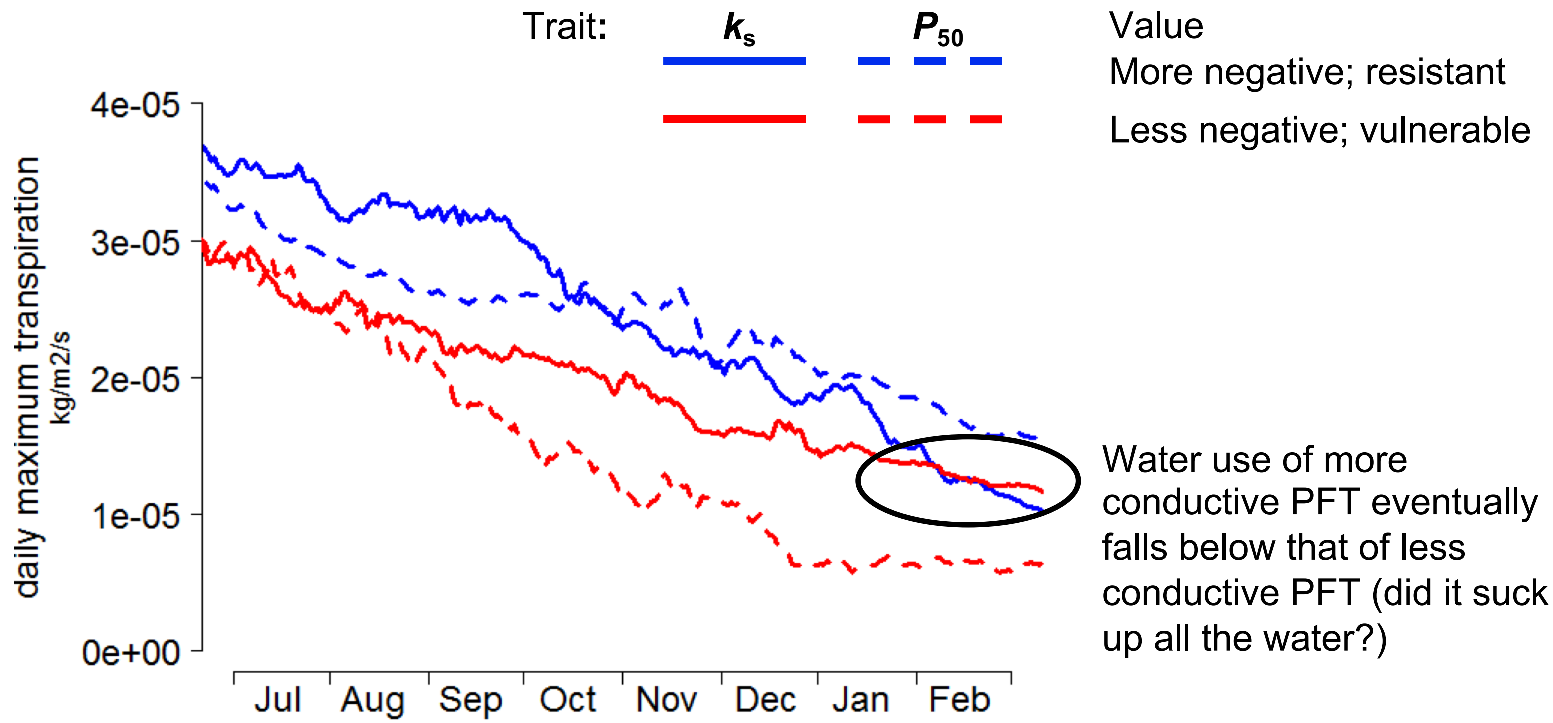
stomata
leaf storage
stem xylem
stem storage
stem xylem
SOIL SURFACE
Transport root
root xylem
Absorbing root
…
PLANT
RHIZOSPHERE 'SHELLS'
0.32
0.30
0.28
0.26
0.24
0.22
h2osoi (m3/m3)
shell
inner
outer
soil layer 1
soil layer 2
soil layer 3
soil layer 4
soil layer 5
soil layer 6
soil layer 7
soil layer 8
soil layer 9
soil layer 10
1/1
1/3
1/5
1/7
1/9
1/11
1/13
month/day of year

FATES-HYDRO: key hydraulic parameters

Parameter	Symbol	Units
Pressure-Volume (PV) curve (water content – water potential relationship)		
saturated water content	θ_s	$cm^3\ cm^{-3}$
turgor loss point	π_{tlp}	MPa
bulk elastic modulus	ε	MPa
residual fraction	RWC_r	unitless
fraction of water in capillary reserve	f_{cap}	unitless
Xylem Vulnerability Curve (water potential – hydraulic conductivity relationship)		
xylem water potential at 50% loss of max conductivity	$P_{50,x}$	MPa
xylem vulnerability curve shape parameter	a_x	unitless
maximum xylem conductivity per unit sapwood area	$k_{s,max}$	
Stomatal Vulnerability Curve (new Btran formulation)		
leaf water potential at 50% loss of max gs	$P_{50,gs}$	
stomatal vulnerability shape parameter	a_{gs}	

Plant Hydraulic Architecture		
Xylem taper exponent	p	(-)
Leaf to sapwood area ratio	$A_l{:}A_s$	$m^2\ cm^{-2}$
Root/shoot Architecture		
specific root length (converts biomass to root length)	SRL	$m\ g^{-1}$
absorbing root radius (sets length scale for soil-root water flux)	r	mm
Leaf mass per unit area	lma	g/m^2
root tissue density (controls root PV parameters)	RTD	$g\ cm^{-1}$
Fine root to leaf ratio	a	unitless
fraction of total tree resistance that is aboveground	$frac$	Unitless

Example FATES-HYDRO output



Water use of more conductive PFT eventually falls below that of less conductive PFT (did it suck up all the water?)

Future development plans

1. Nutrients
2. Land use
3. Static vegetation mode

Simple Allocative Case for nutrients within PARTEH:

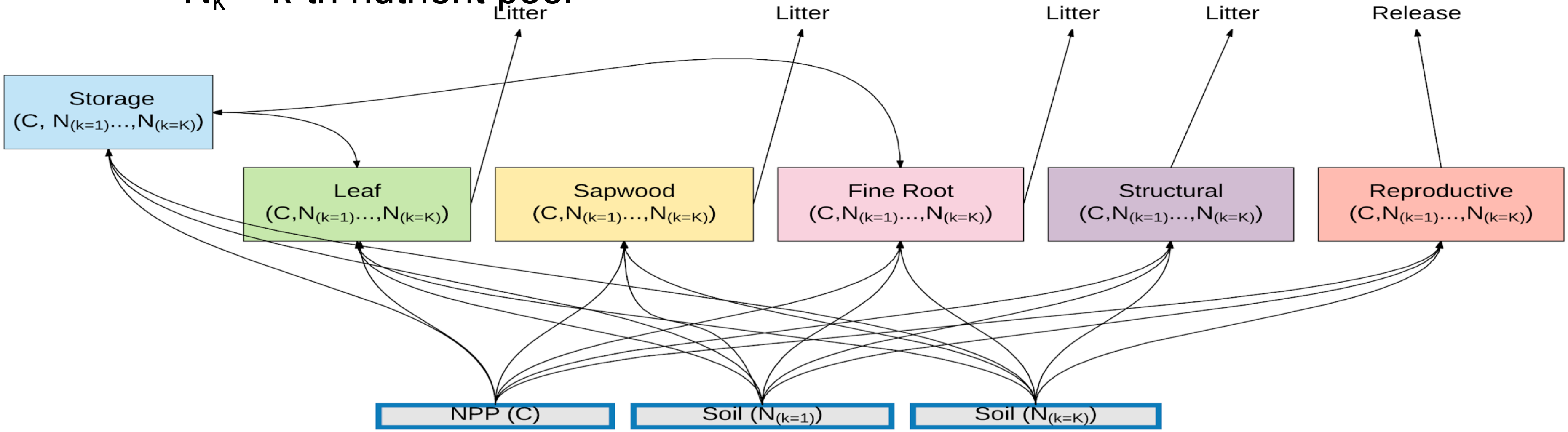
Instantaneous Allocation of NPP

Reaction Costs paid by the NPP pool

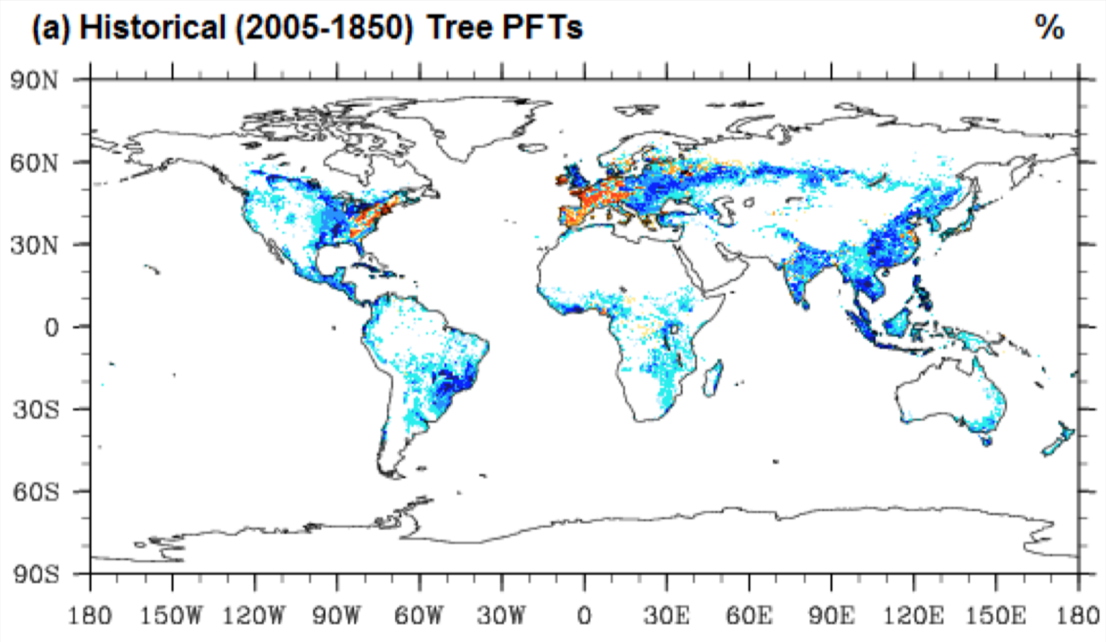
Single Pools for each tissue type

C = single carbon pool

N_k = k-th nutrient pool



FATES-fvd (fixed vegetation distribution). Tbd.

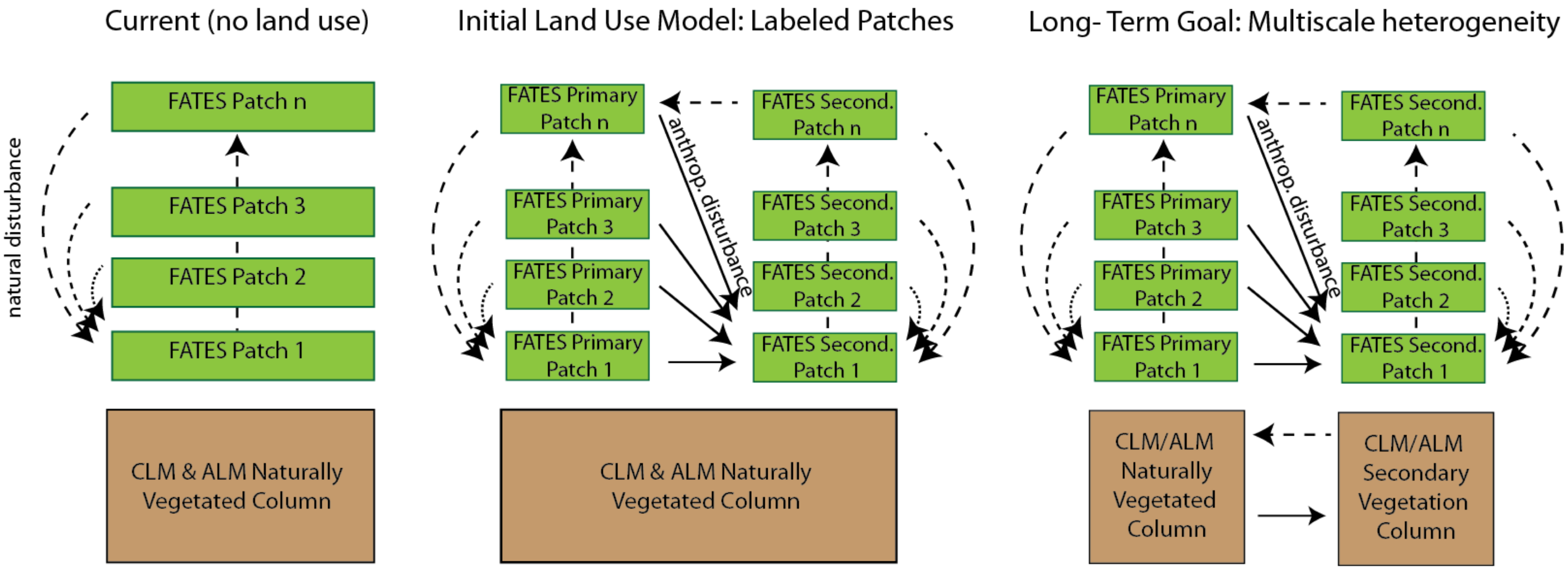


We need a mode to turn off the DGVM capability

1. Read in a PFT map from the surface dataset
2. Discover which PFTs are 'allowed' in each grid cell
3. Only allow seeding/recruitment with those PFTs

Could we mask parts of the globe and test dynamics in certain regions??

Some Shorter- and Longer-term Development Plans
1: Land-Use



Future FATES

Open Code Development

FATES is at https://github.com/NGEET/FATES

+ More eyes on code better
+ Better coordination of development/overlaps
+ Forum for collaboration: questions can be directed to whole community

This requires

+ Solid funding for maintenance of system (add software support to your proposals!)
+ Community ethical guidelines:

https://github.com/NGEET/fates/blob/master/CODE_OF_CONDUCT.md

Benchmarking phenological status discussion help wanted
#465 opened 23 days ago by rgknox

Fire Branch consumption
#463 opened 25 days ago by jkshuman

number of trees changed for static stand structure mode
#461 opened on Jan 8 by pnlfang

reduce loop sizes during history diagnostics of productivity enhancement
#460 opened on Jan 7 by rgknox

drought phenology timing uses 10th day of year, instead of 10th day of simulation
bug - software engineering
#452 opened on Dec 19, 2018 by rgknox

Towards FATES w/ land use
#450 opened on Dec 18, 2018 by ckoven

can we get a CAM in here?
#449 opened on Dec 17, 2018 by rgknox

The quadratic calculation of stomatal conductance in FATES
#446 opened on Nov 29, 2018 by youwasha

Update soil layer for drought phenology
#445 opened on Nov 28, 2018 by jkshuman

how to maintain multiple "default" parameter files? discussion enhancement
#444 opened on Nov 28, 2018 by rgknox

optimizing photosynthesis
#443 opened on Nov 12, 2018 by rgknox

Ongoing and planned FATES projects (non-exhaustive!)

- NGEE-tropics (DoE/LBL -led tropics-focused project. Phase II proposal ongoing)
  - Nutrient cycling, allocation
  - Fire, Gas Exchange,ysiology testbeds
  - Tropical forest testbeds
  - Coexistence & trait filtering
  - FATES-Hydro testing & calibration
  - Tropical phenology
  - Radiation transfer
- E3SM (DoE ESM)
  - Land-use implementation (LUH2)
  - Global PFT calibrations
- California/LBL proposals
  - Parameters for Western US forests
  - Wildfire simulation & benchmarking
  - FATES x Hillslope model
  - Regeneration parameterization
- Emerald (NorESM/University of Oslo-boreal focused project)
  - High latitude PFTs & processes
  - Moss PFTs
- LANL
  - Insect dynamics, wetlands, fire-atmosphere interactions

NGEE–TROPICS
NEXT-GENERATION ECOSYSTEM EXPERIMENTS

Biweekly FATES teleconferences
starting soon
+Thurs, 11am Pacific; 12am MDT, 8pm CET:
+Sign up for alerts at:
fates_model@googlegroups.com