



# Update on CLM5 progress

David Lawrence and the Land Model Working Group



# What's New for CLM5

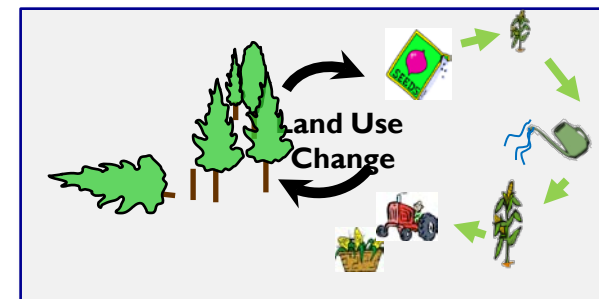
- Hydrology: dry surf. layer, var. soil depth w/ deeper (8.5m) max soil, revised GW and canopy interc
- Snow: canopy snow updates, wind effects, firn model (12 layers), glacier MEC, fresh snow dens.
- Rivers: MOSART(hillslope → tributary → main channel)
- Nitrogen: flexible leaf C:N ratio, leaf N optimization, C cost for N (FUN)
- Carbon: revisions to carbon allocation and decomposition
- Fire: updates, trace gas and aerosol emissions
- Vegetation: plant hydraulics, deep tropical tree rooting,  
Ecosystem Demography (FATES), prognostic roots, ozone damage
- Crops: global crop model with transient irrig. and fertilization (8 crop types), grain prod. pool
- Land cover/use: dynamic landunits, revised PFT-distribution, wood harvest by mass, shifting cultivation
- Isotopes: carbon and water isotope enabled

**CLM5 default configuration**

**CLM5 optional feature**

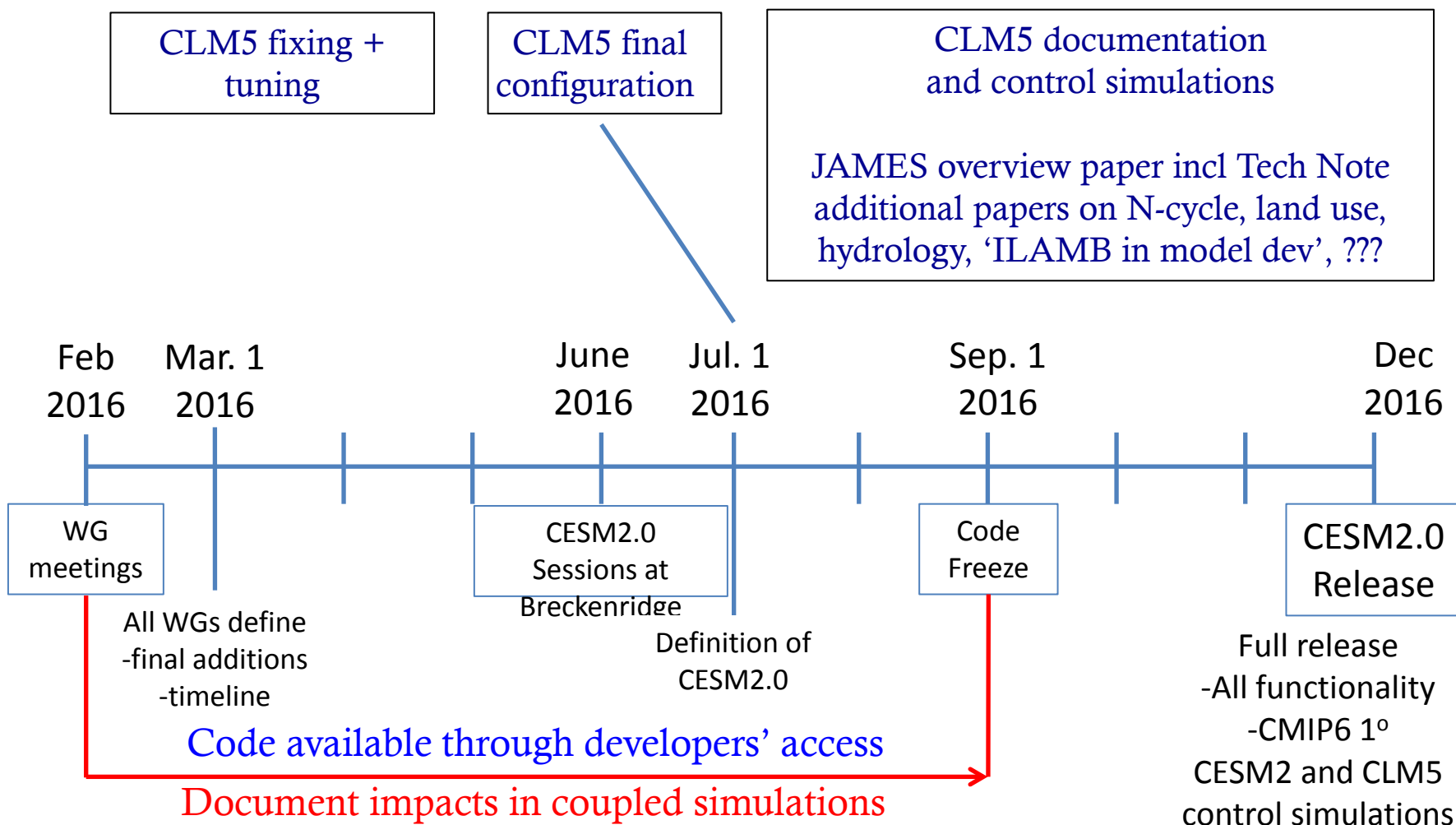
**Included in CESM1.5 (79)**

**Included by July 1**



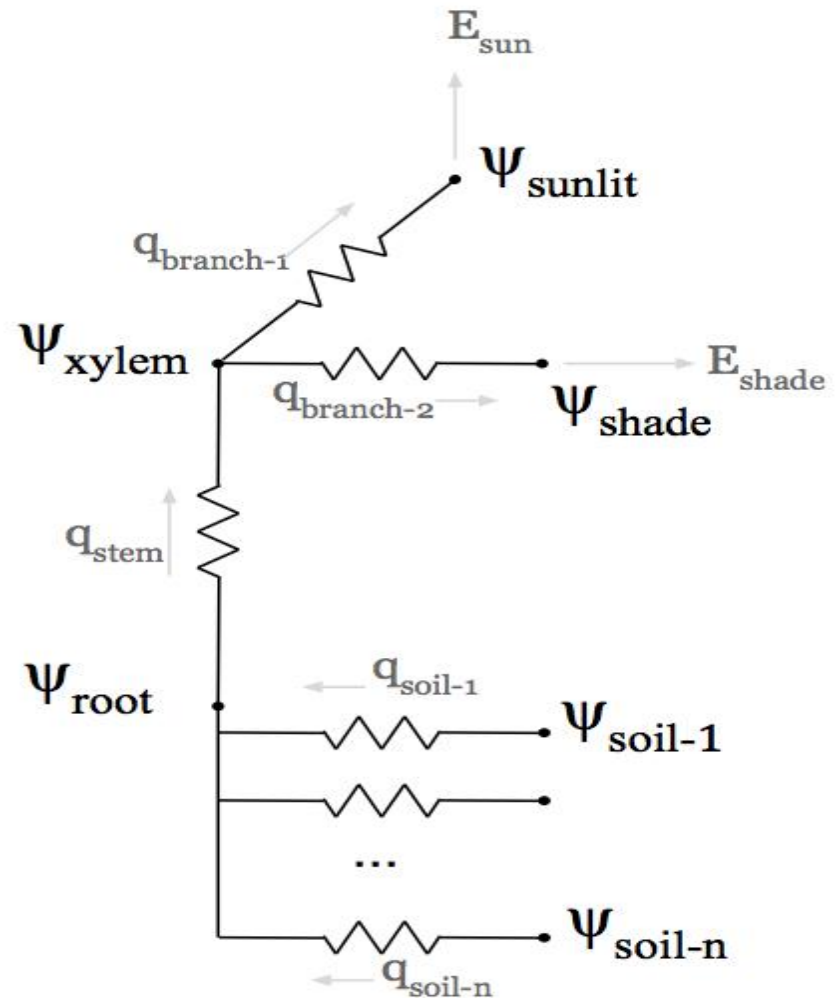


# Timeline



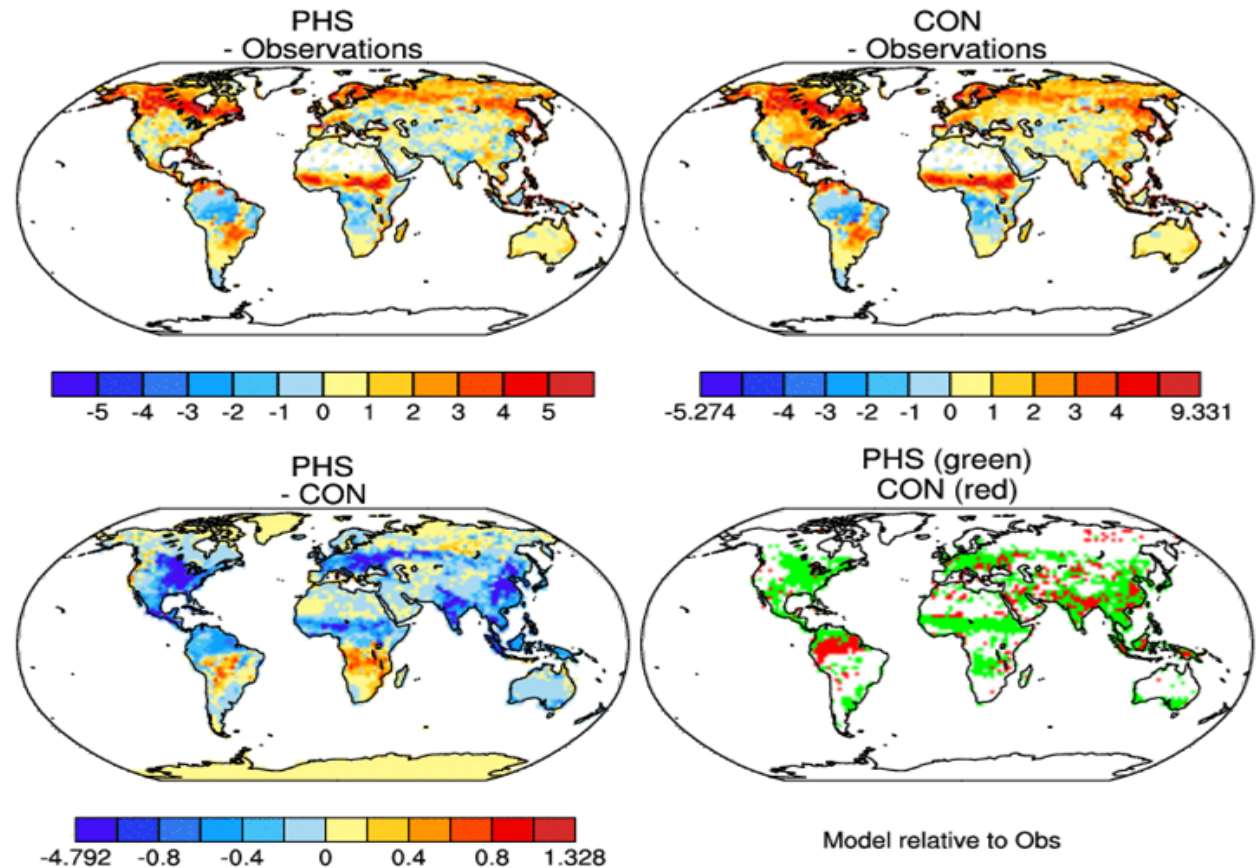
# Plant Hydraulic Stress

- Simple model to resolve water transport through the Soil Plant Atmosphere Continuum
- Water supply modeled via simple hydraulic framework
- Loss relative to unstressed transpiration modeled based on leaf-level water potential
- Water stress function used to calculate conductance, photosynthesis, and respiration



# Plant Hydraulic Stress - Recent Simulations

- Small improvements in many areas
- ~8% reduction in GPP RMSE in CLM5SP



# To do list: Scientific development

## Update surface dataset tool to ingest CMIP6 land use dataset

### New History

- Hyde 3.2 based
- Landsat F/NF
- Multiple crop types (5)
- Multiple pasture types (2)
- Updated Forest Cover/B
- Updated Wood harvest
- Updated Shifting Cultivation
- Extended time domain (850-2015)

### New Mgt. Layers

#### Agriculture

- Fraction of cropland irrigated
- Fraction of cropland flooded
- Fraction of cropland fertilized
- Fertilizer application rates
- Fraction of cropland tilled
- Fraction of cropland for biofuels

#### Crop rotations

#### Wood Harvest

- Fraction used for industrial products
- Fraction used for commercial biofuels
- Fraction used for fuelwood

### New Future Scenarios

Six futures, SSP-based

### New Resolution

0.25°

### New Transition Matrix

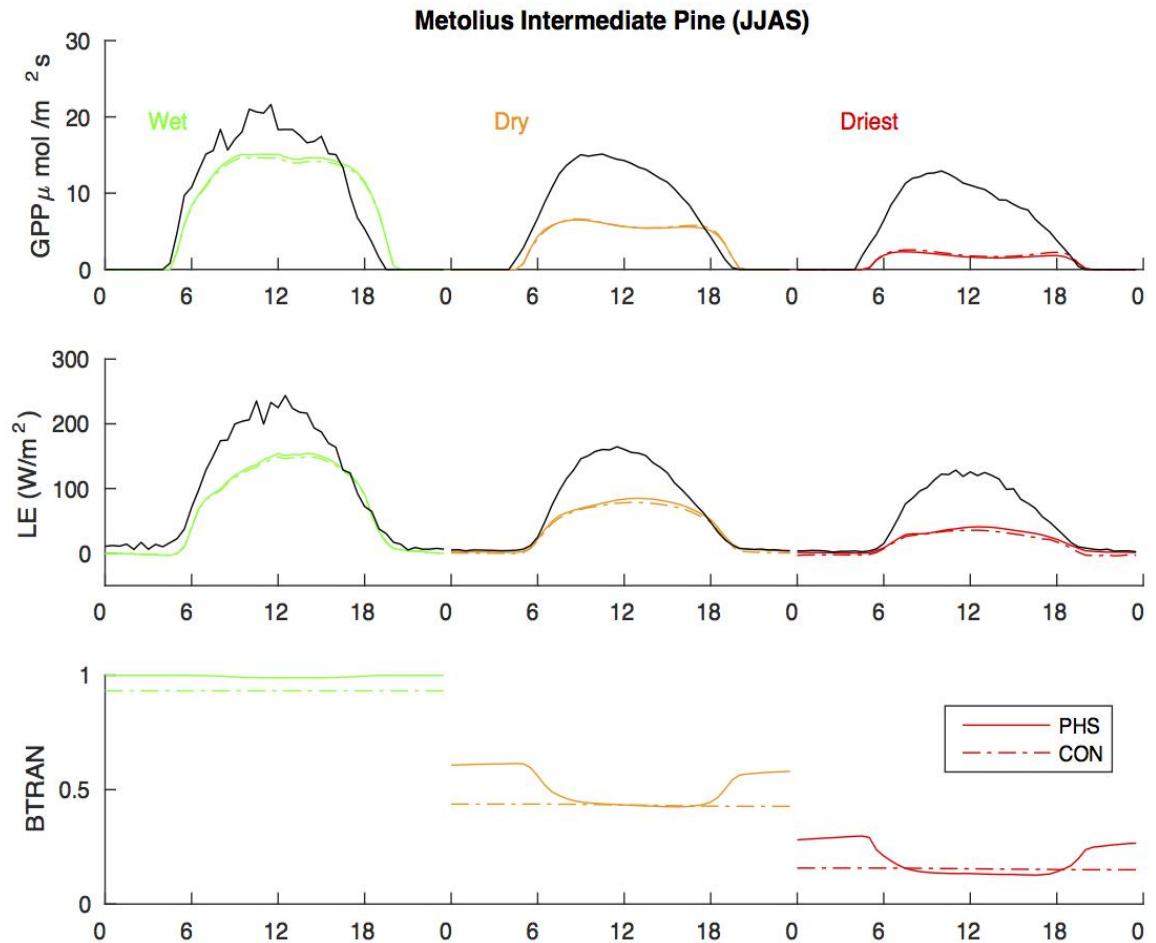
	Pri F	Pri NF	Sec F	Sec NF	C3 Ann	C4 Ann	C3 per	C4 per	C3 N-Fix	Pasture	Rangeland	Urban
Pri F	■											
Pri NF		■										
Sec F			■									
Sec NF				■								
C3 Ann					■							
C4 Ann						■						
C3 Per							■					
C4 Per								■				
C3 N-Fix									■			
Pasture										■	■	
Rangeland											■	■
Urban												■

~ 50x information content of CMIP5!



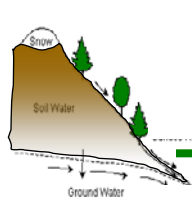
# PHS - Recent Simulations

- Using tower simulation analysis to understand and optimize parameterization for drought response



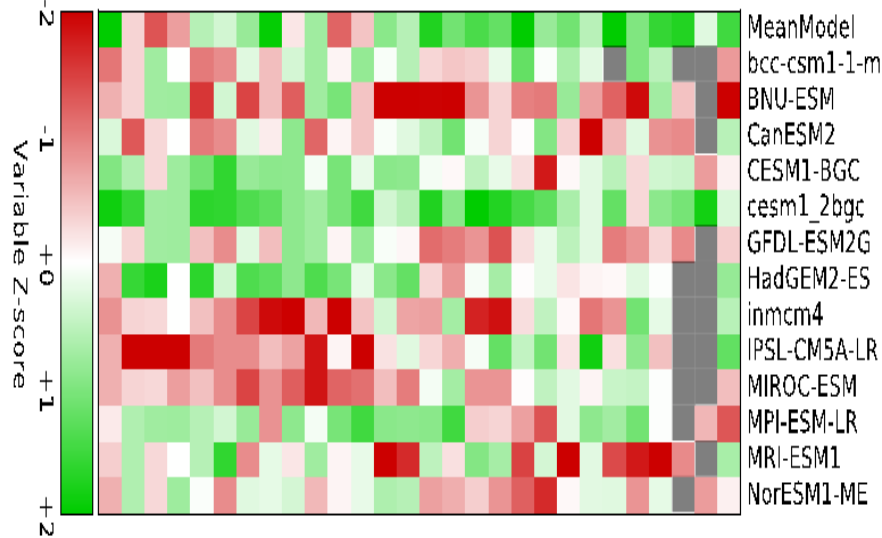
## 2<sup>nd</sup> CLM Tutorial scheduled for **September 12-16, 2016**

- **Lectures** on underlying model physics, hydrology, biogeochemistry, ecology, etc
- **Practical sessions** about how to run, modify, and analyze CLM simulations
- Will present science and software of **CLM5 / CESM2**
- More than **85** applicants, 46 accepted plus 8-10 auditors
- Tutorial will (likely) be webcast
- All tutorial material including lectures and practical sessions **will be available through a CLM tutorial website**

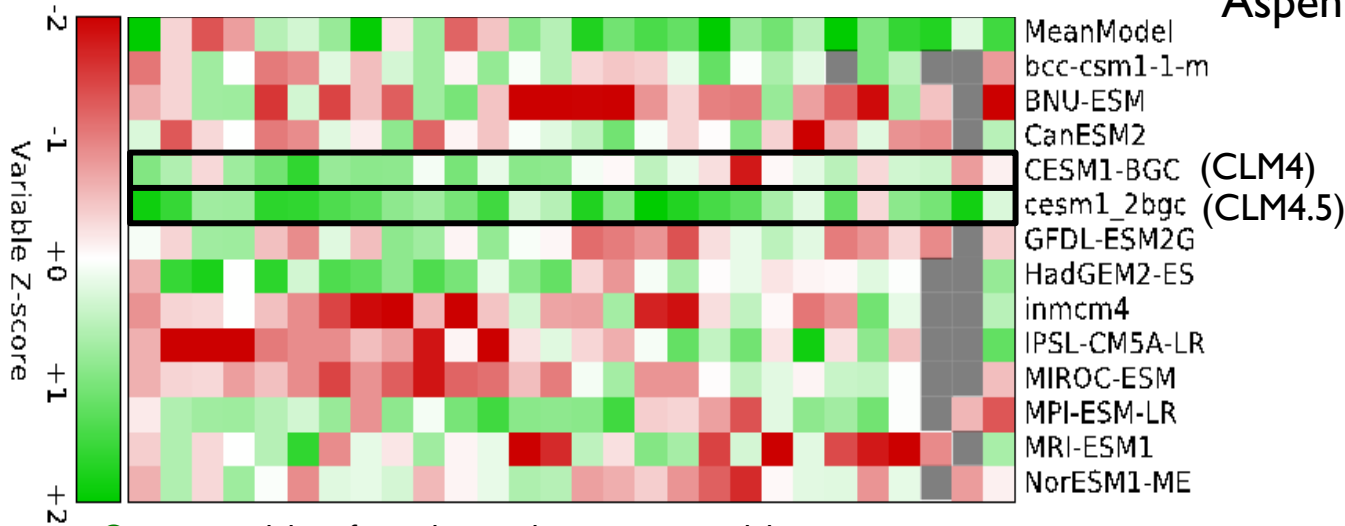


# International LAnd Model Benchmarking (ILAMB) project

scores for RMSE, interannual variability, pattern correlation, variable-to-variable comparisons, +



- 2<sup>nd</sup> International ILAMB meeting in May
- New variables: runoff, runoff ratio, evap fraction, updated biomass
- New diagnostics
- ILAMBV2 operational
- Tutorial on Wednesday at 5:30 in Aspen / Blue Spruce room



**Green:** model performs better than average model

**Red:** model performs worse than average model

# Beyond CLM5

- FATES
- Multilayer canopy
- Hillslope hydrology
- ...

... and the proliferation of models?



Can we move beyond “Shantytown” syndrome?



... and continue efforts to modularize and modernize the code and support tools?





# Development targets for CLM5

- Land cover and land use change

- Global / transient crop capability with irrigation, fertilization, and cultivation of crops (land management) as default for historical and projection runs

- More realistic land cover change impact on water and energy fluxes

- Carbon and nutrient cycles

- Improved 20<sup>th</sup>C land carbon stocks and carbon stock trends

- Address ecological stones thrown at CLM4 (plants don't get N for free, leaf N isn't static, photosynthetic capacity should respond to environment, stomatal conductance not linked to N-limitation)

- Hydrology

- Hydrology representation closer to state-of-art hydrology understanding

- Increase utility for use in water resource and water-carbon interaction research

- Land-atmosphere chemistry coupling

- Enhanced interactions, fire emissions, ozone damage to plants, CH<sub>4</sub> emissions

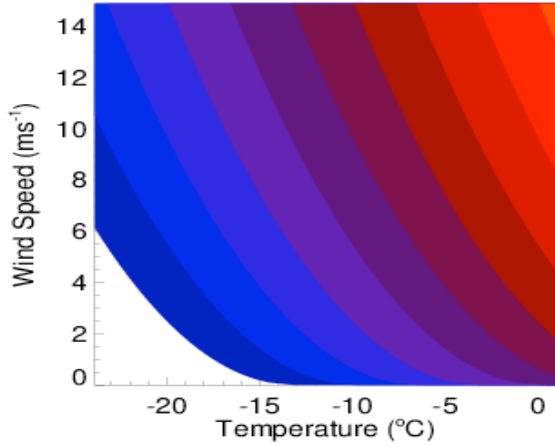
- Ecosystem Demography model – future biogeochemical core of CLM

- Functional CLM5(ED) for use in studies of biome boundaries, trait filtering, etc

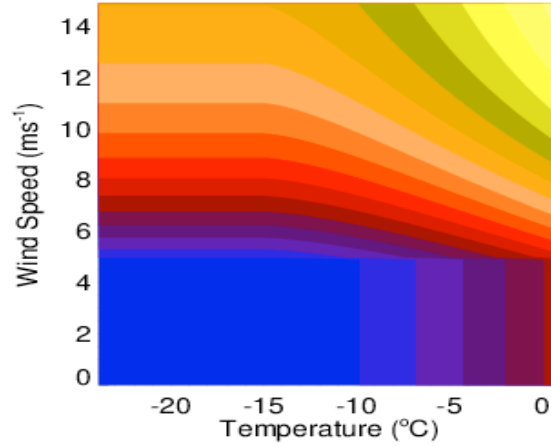
- CESM2 coupled runs with CLM(ED) within CMIP6 timeframe; will not be CESM2 default configuration

# Improvements to fresh snow density and snow compaction

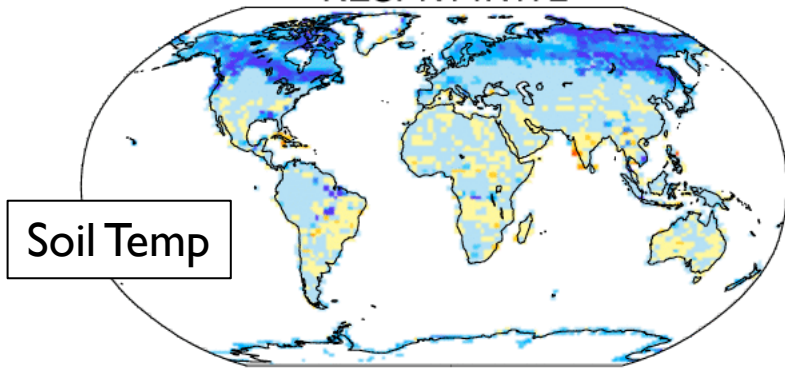
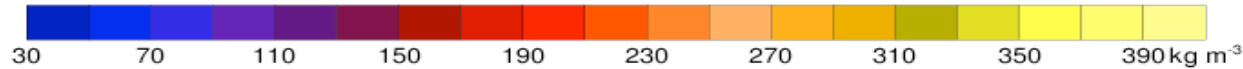
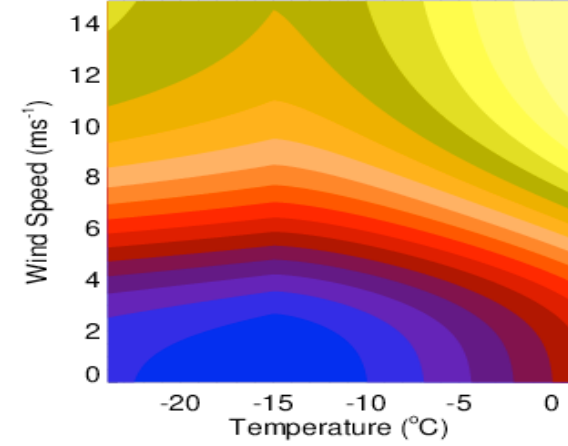
**CLM4/CLM4.5**  
**Pahaut (1976)**



**CLM5 (Feb)**  
**Liston et al.(2007)**



**CLM5 (May)**  
**Slater**



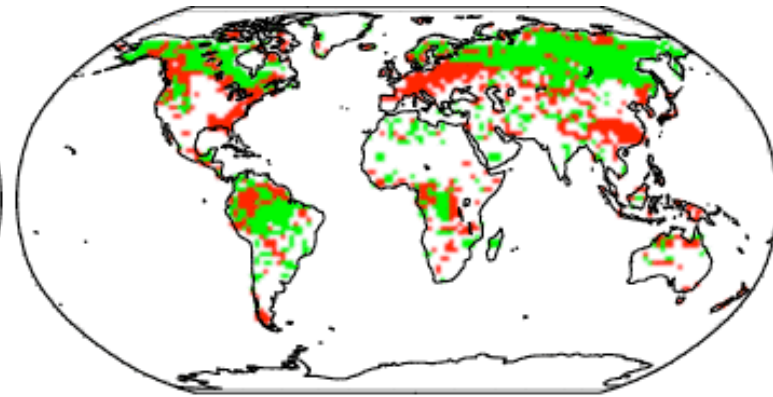
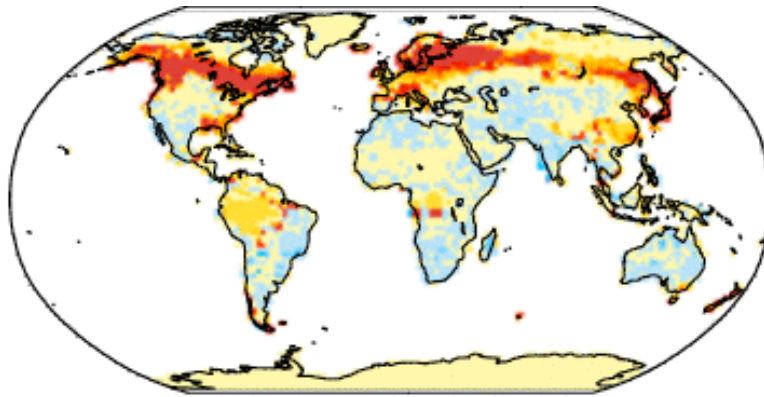
- Improved snow densities
- Cooler soil temperatures
- Eliminates spurious Antarctica snow melt

# Community Nitrogen Cycle Project

## Bug fixes and parameter adjustments

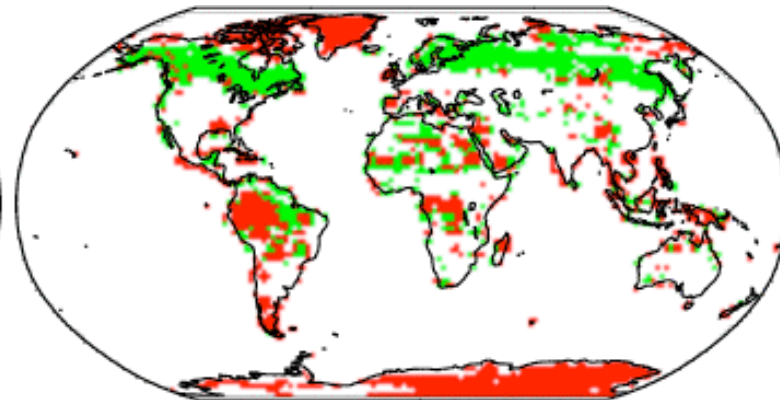
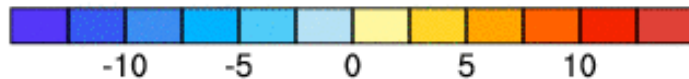
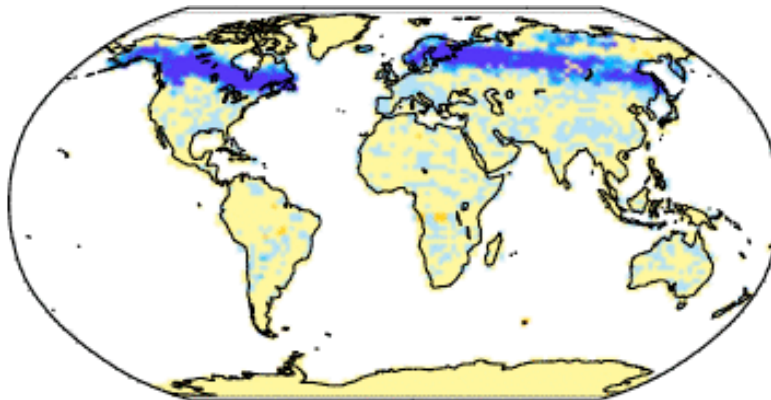
CLM5 (May version) – CLM5 (Feb version)

Leaf Area Index



Model relative to Obs

Albedo (MAM)



Model relative to Obs



# Community Nitrogen Cycle Project

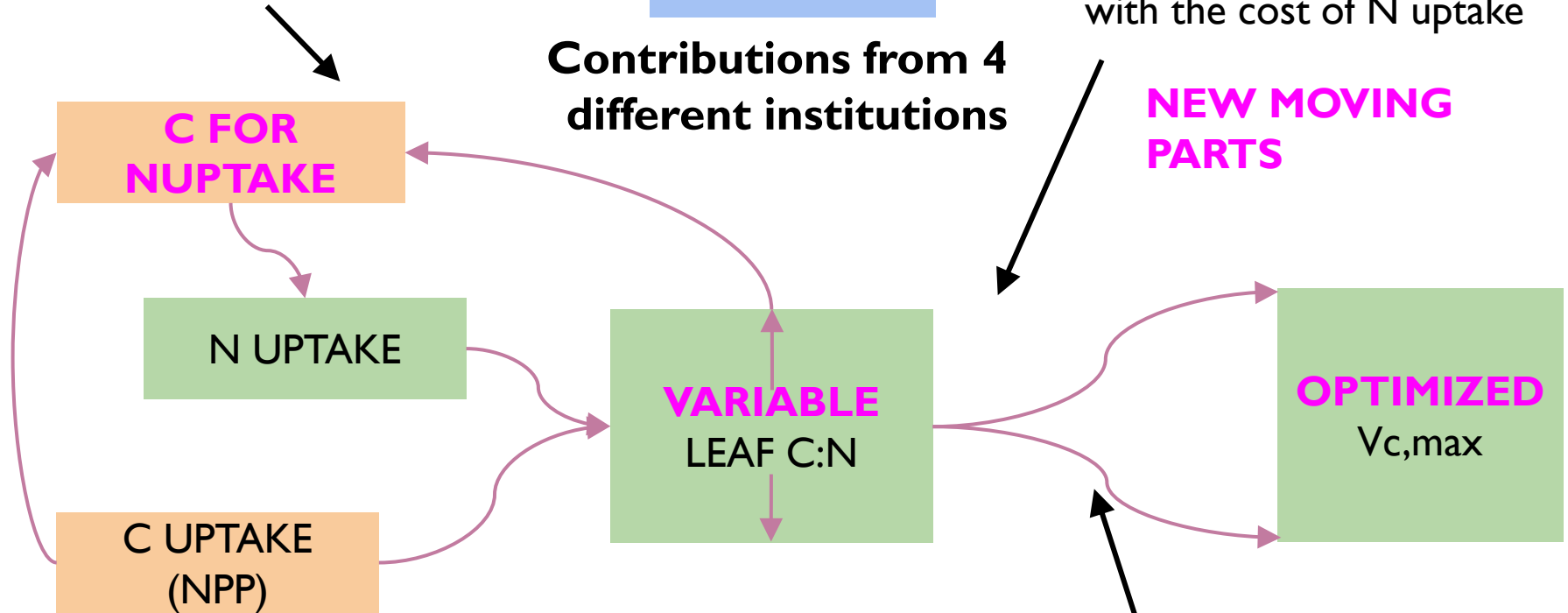
Plants pay for fixed & active Nitrogen uptake (in Carbon)

CLM5.0

Leaf Nitrogen content varies with the cost of N uptake

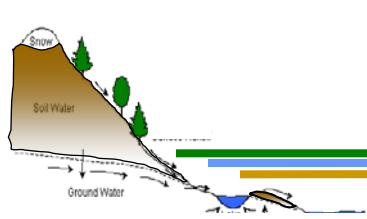
Contributions from 4 different institutions

NEW MOVING PARTS



Stomatal Conductance is based on N-limited photosynthesis

Photosynthetic Capacity is optimized wrt environmental drivers



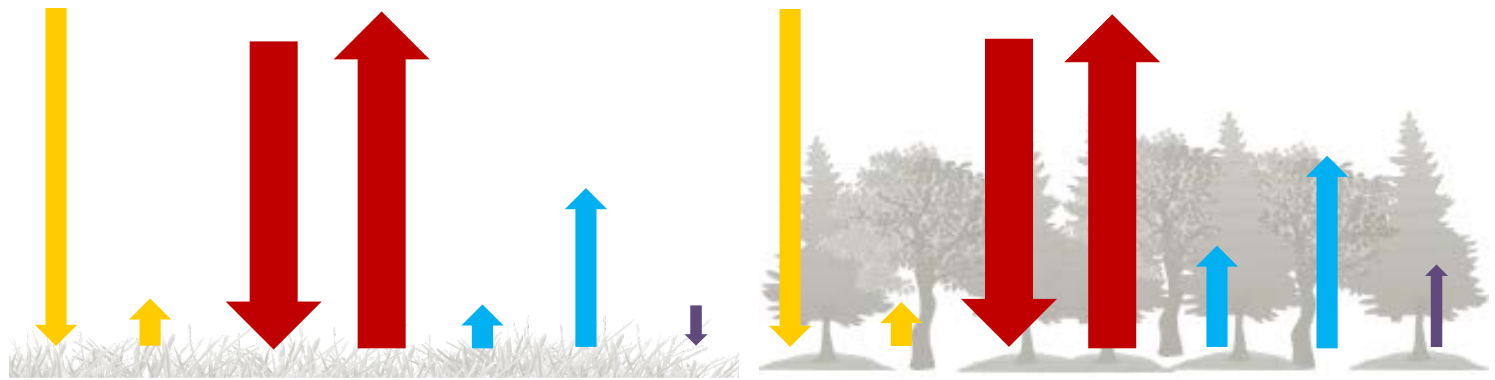
# To do list: Software development

- Integrate “loose-end” projects
  - Carbon / nitrogen conservation for dynamic landunits
  - Plant hydraulics
  - Dynamic roots
  - Water isotopes (BeTR)
  - Winter wheat
  - Crop tilling
  - Dynamic local river flood stage
  - Permafrost excess ice
  - Switch for PFTs on own column
  - Prescribed soil moisture code
  - ....
- Code cleanup
  - Rapid code integration for science has lead to accumulation of lots of “Technical Debt”
- Performance
  - CLM5BGC-crop costs ~5-10x over CLM4CN
- Model output rationalization
  - Over 550 fields archived by default

# Tropical grid [6.13°N, 288.75°E]

## 20 year annual mean

**CTRL**



	SW↓	SW↑	LW↓	LW↑	H	λE	G	SW↓	SW↑	LW↓	LW↑	H	λE	G
[Wm <sup>-2</sup> ]	207.3	30.7	429.2	468.4	26.2	96.5	14.7	207.3	26.4	429.2	463.0	61.2	117.7	-31.8

**PFT-COL**



	SW↓	SW↑	LW↓	LW↑	H	λE	G	SW↓	SW↑	LW↓	LW↑	H	λE	G
[Wm <sup>-2</sup> ]	207.3	30.7	429.2	470.8	31.7	103.3	-0.04	207.3	26.4	429.2	459.3	45.2	105.6	-0.03
<b>DIFF</b>	--	<b>0</b>	--	<b>2.4</b>	<b>5.5</b>	<b>6.8</b>	<b>14.74</b>	--	<b>0</b>	--	<b>3.7</b>	<b>16</b>	<b>12.1</b>	<b>31.77</b>