The State of CLM
LMWG Activities

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with input from members of LMWG and BGCWG

NESL

U.S. DEPARTMENT OF ENERGY

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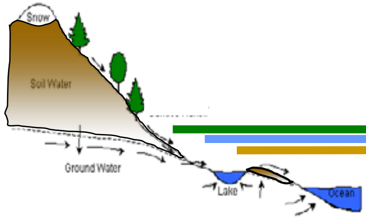
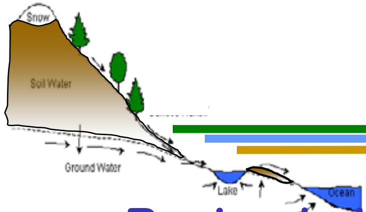
Progress with CLM4.5

to be released in May



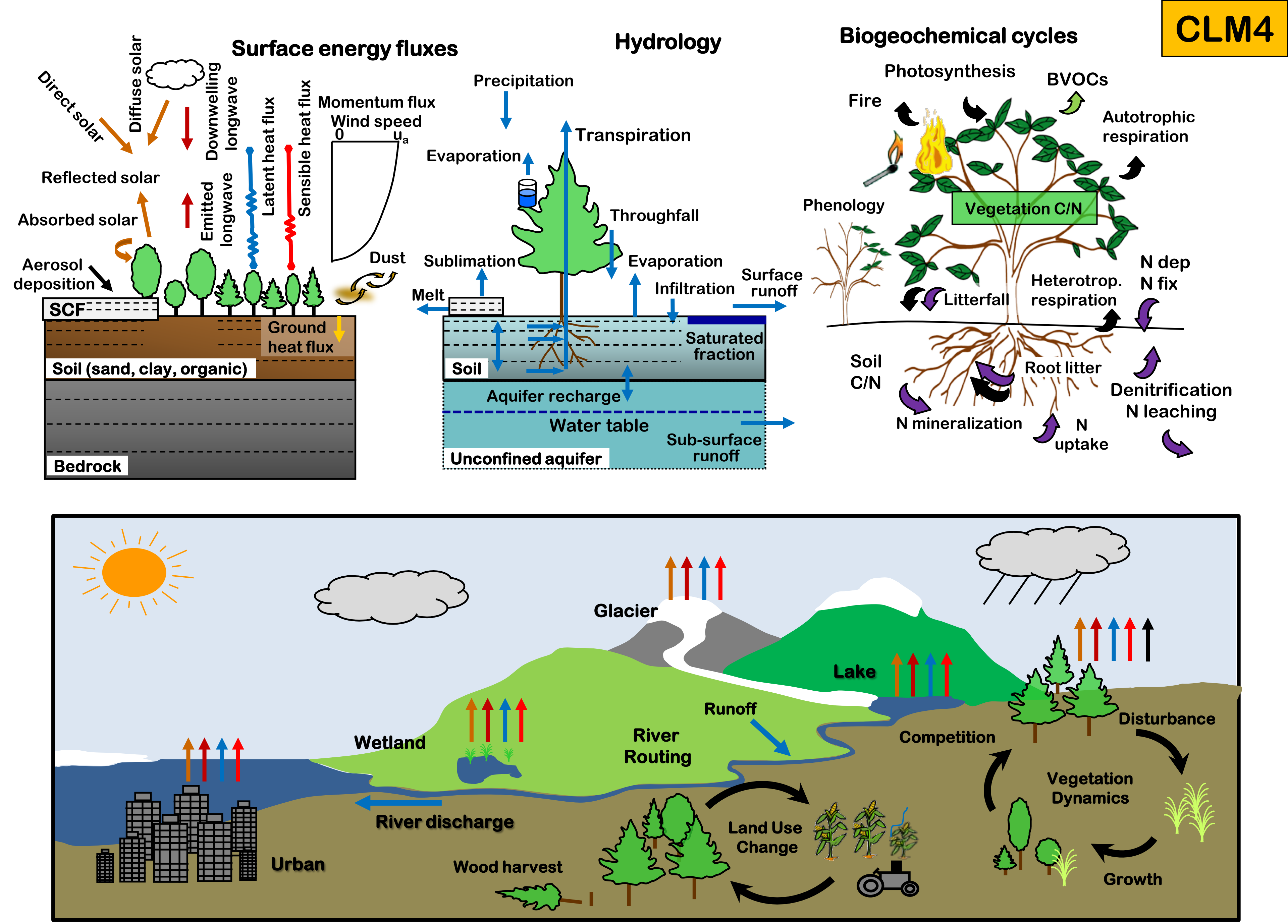
Changes for CLM4 (released in November)

- High resolution input datasets (PFTs, lake area, glacier area, etc)
- High resolution River Transport Model (0.1^{o}) with variable flow rates\
- MEGAN2.1 for BVOCs (Guenther et al., 2012)

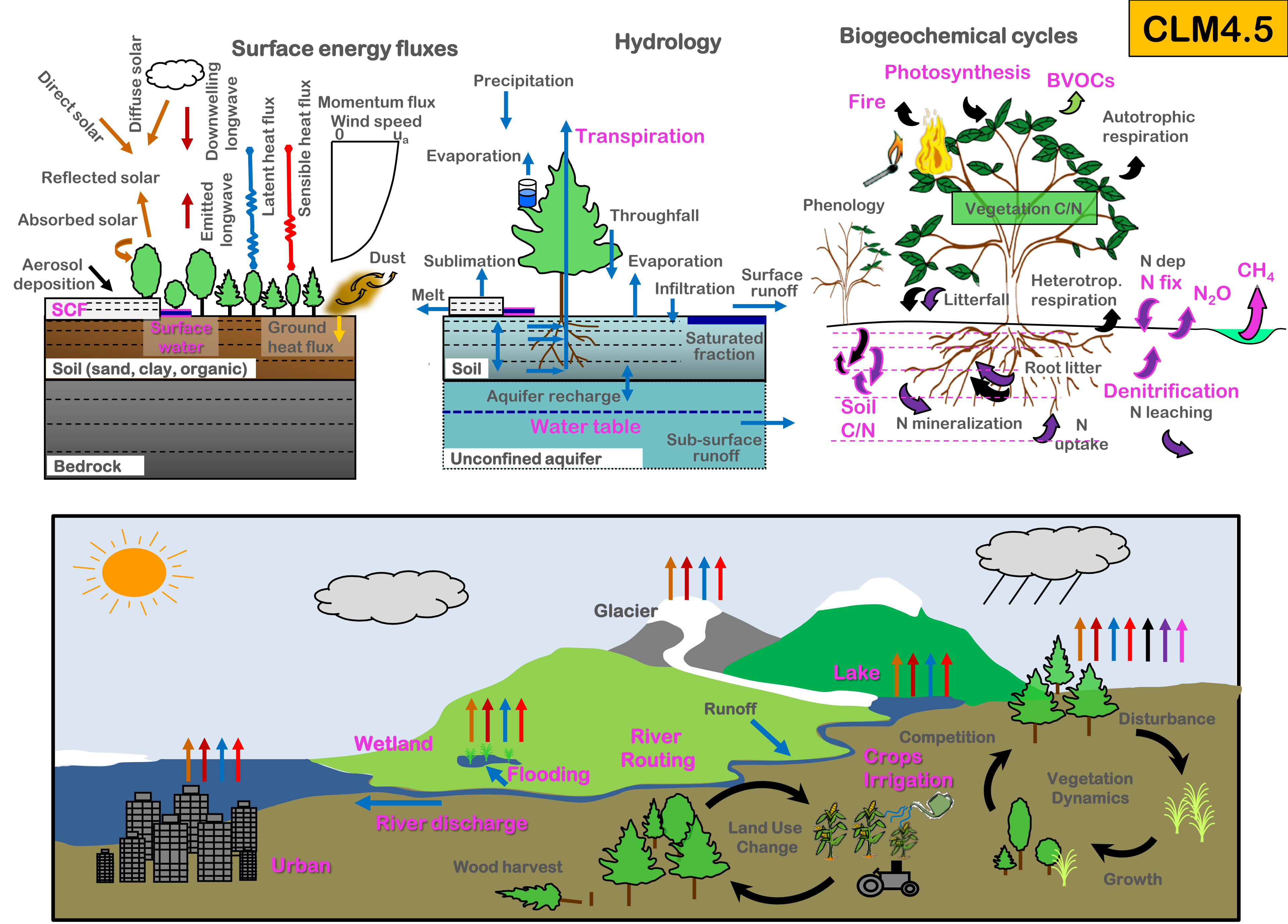


Changes for CLM4.5 (for release in May)

- Revised photosynthesis model, multilayer canopy, temperature acclimation, iterative calculation fix (Bonan et al., 2011, 2012; Sun et al., 2012)
- Cold region hydrology and snow model updates (Swenson et al. 2012, Swenson and Lawrence, 2012)
- CLM/RTM interactions, flooding (default off) (Swenson and Lawrence, in prep)
- CENTURY-like vertically resolved soil biogeochemistry (Koven et al., in prep)
- New lake model (Subin et al., 2012)
- CH_4 emissions (Riley et al., 2011; Meng et al. 2012)
- Prognostic wetland distribution model (Swenson and Lawrence, in prep)
- Revised fire model (Li et al., 2012; 2013)
- Fertilization, irrigation, organs pool, and other updates to crop model (Drewniak et al., 2013; Levis et al., 2012; Sacks et al. 2009)
- VIC hydrology (alternative hydrology) (Li et al., 2012)
- C_{13}/C_{14} enabled
- Multiple urban classes
- … and several minor and major bug fixes, speedup of BGC spinup



CLM4
Surface energy fluxes
Direct solar
Diffuse solar
Downwelling longwave
Reflected solar
Absorbed solar
Emitted longwave
Latent heat flux
Sensible heat flux
Momentum flux
Wind speed
0
u_a
Aerosol deposition
Dust
SCF
Ground heat flux
Soil (sand, clay, organic)
Bedrock
Hydrology
Precipitation
Transpiration
Evaporation
Throughfall
Sublimation
Evaporation
Melt
Infiltration
Surface runoff
Soil
Saturated fraction
Aquifer recharge
Water table
Sub-surface runoff
Unconfined aquifer
Biogeochemical cycles
Photosynthesis
BVOCs
Fire
Autotrophic respiration
Phenology
Vegetation C/N
Litterfall
Heterotrop. respiration
N dep
N fix
Soil C/N
Root litter
Denitrification
N leaching
N mineralization
N uptake
Glacier
Lake
Wetland
Runoff
River Routing
Competition
Disturbance
Vegetation Dynamics
Growth
River discharge
Land Use Change
Urban
Wood harvest



CLM4.5
Surface energy fluxes
Direct solar
Diffuse solar
Downwelling longwave
Latent heat flux
Sensible heat flux
Momentum flux
Wind speed
0
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Wood harvest
Land Use Change
Competition
Crops
Irrigation
Disturbance
Vegetation Dynamics
Growth

CLM configurations for May release

- **CLM4.5SP** Satellite phenology with new biogeophys
- **CLM4.5BGC** New biogeophysics + CENTURY-like vertically resolved soil BGC + CH_4 emissions
- **CLM4.5CN** New biogeophysics + CN soil BGC
- CLM4SP As in CCSM4 release
- CLM4CN As in CCSM4 release

Note: crop and irrigation model and VIC hydrology optional for all BGC configurations

CESM Release Strategy

- Annually in May, with firm deadlines
- Every release will include compsets with that fall into various categories:
  - **Scientifically vetted** – simulation output has been analyzed subject to a set of metrics, expert judgment (**CLM4.5SP and CLM4.5BGC**; no coupled compsets)
  - **Functionally vetted** – routine testing
  - **Development only** - no routine testing, "use at your own risk", still under development and could include known and unresolved problems
- Between releases, compsets can shift categories

Final steps towards CLM4.5/CESM1.2

- Feb 30 ☺ - All WGs provide and post list of developments
- March 30 - List of tests defined, computational platforms/compilers defined, supported compsets and resolutions defined, including necessary simulations
- April 15 - code frozen and branch release tags made
- April 30 - namelist and parameter settings frozen
- May 30 - documentation finalized (incl. CLM4.5 Tech Note) and model released
- Summer – CLM4.5 paper, focus on metrics, input from WG members appreciated

Water and Energy Benchmark (putting it together)

Class of Metric	Variable	Obs dataset	W (1-5)	CCSM4	CLM3.5 SP	CLM4 CN	CLM4 SP
Global (or regional) RMSE	LH	FLUXNET-MTE	4	0.68	0.71	0.63	0.71
	SCF	AVHRR	4	0.68	0.64	0.75	0.74
	Snow Depth	CMC	2	0.53	0.70	0.73	0.70
	Albedo	MODIS	5	0.44	0.35	0.52	0.55
	P	CMAP		0.48	0.93	0.93	0.93
	T_{air}	CRU		0.91	0.93	0.93	0.93
Basin Runoff (Top 20 biggest river basins)	R / P	riv discharge, CMAP	5	0.63	0.49	0.57	0.55
	R	river discharge	2	0.22	0.65	0.66	0.68
	P	CMAP		0.62	0.95	0.95	0.95
Total				18.54	21.38	22.80	23.17

Split weights into “quality of obs dataset” and “importance of variable”

Global spinup for CLM4.5 beta* ‘done’ at 0.5^{o} (~1500 years) using CRUNCEP forcing data

Preliminary analysis of CLM4.5SP and CLM4.5BGC is ongoing

Will need to extend spinup for final version of model

* Excluding new fire model and fix to numerical instability in stomatal conductance calc

A few preliminary plots and analyses

CLM4.5 plots
http://www.cgd.ucar.edu/tss/clm/diagnostics/clm4.5_dev/index.html

CLM4.5 Offline

clm4.5phys_1985-2004a-clm4CN_1985-2004a clm45sci12clm4054ctrl-i1860cnGCP clm45sci12clm4054ctrl-i2000cnGCP

Diagnostics	Test Case	Model Yrs	Comparison Model	Model Yrs	Trend Yrs	Created
LND	clm45scill_clm4_0_40_SP	1985-2004	clm4_SP	1985-2004	1948-2004	11/01/12
TEST	clm45scill_clm4_0_40_SP	1985-2004	clm4_SP	1985-2004	1948-2004	11/17/12
TEST	clm45scill_clm4_0_40_SP	1985-2004	OBS	1985-2004	-	11/17/12
TEST	clm4_CN	1985-2004	OBS	1985-2004	-	11/17/12
TEST	clm4_CN	1985-2004	clm4_CN	1985-2004	-	11/17/12
LND	clm45scill_clm4_0_40.btranalt	1950-1954	clm45scill_clm4_0_40	1990-1997	1990-1997	11/26/12
LND	CLM4SP2LGrh	1985-2004	clm4_SP	1985-2004	1948-2004	01/19/13
LND	CLM4SPMLkn_final	1985-2004	clm4_SP	1985-2004	1948-2004	01/19/13
LND	clm45scill_clm4_0_40_accl_SP	1985-2004	clm4_SP	1985-2004	1948-2004	11/28/12
LND	clm45scill_clm4_0_40_accl_SP	1985-2004	clm45scill_clm4_0_40_SP	1985-2004	1948-2004	11/28/12
LND	clm45scill_clm4_0_40_medlyn6_SP	1985-2004	clm45scill_clm4_0_40_accl_SP	1985-2004	1948-2004	01/16/13
LND	clm45scill_clm4_0_40_medlyn4_SP	1985-2004	clm45scill_clm4_0_40_accl_SP	1985-2004	1948-2004	01/16/13
LND	clm45scill_clm4_0_40_ceairsat_SP	1985-2004	clm45scill_clm4_0_40_accl_SP	1985-2004	1948-2004	12/03/12
LND	clm45scill_clm4_0_40.nopond	1990-1997	clm45scill_clm4_0_40	1990-1997	1990-1997	11/28/12
LND	clm45scill_clm4_0_40.specyield	1990-1997	clm45scill_clm4_0_40	1990-1997	1990-1997	12/21/12
LND	CLM4.5BGC(vertBGC,PFCMIP,HRsoil)	1985-2004	CLM4CN	1985-2004	1985-2004	12/11/12
LND	CLM4.5BGC(CN)	1985-2004	CLM4CN	1985-2004	1985-2004	12/11/12
LND	clm45sci12clm4054ctrl	50-72	i1860cnGCP	180-199	50-72 vs 180-199	2/11/13
LND	clm45sci12clm4054ctrl	50-72	i2000cnGCP	782-804	50-72 vs 782-804	2/12/13

CLAMP

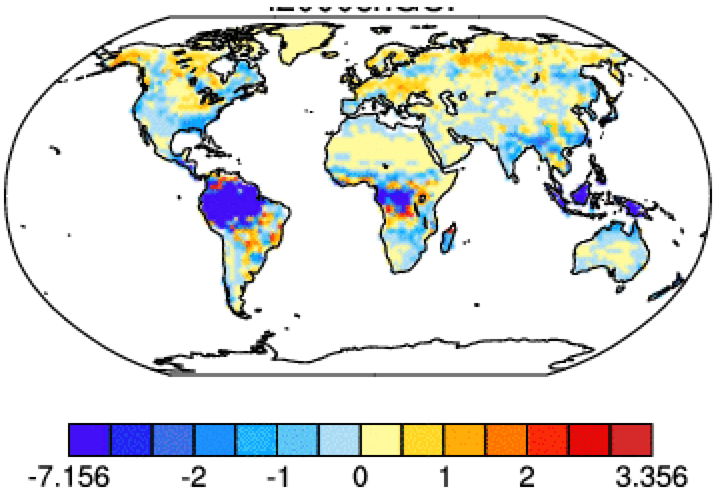
- CLM4.5BGC(vertBGC,PFCMIP,HRsoil)
- CLM4CN(TRENDY)

TOWER SIMULATIONS

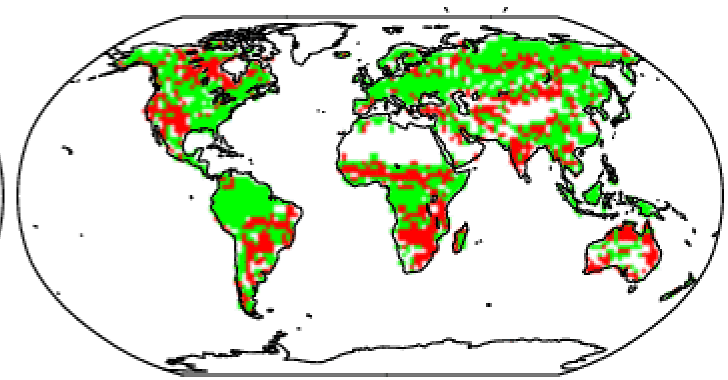
- clm4_0_40_SP SPINUP
- clm45scill_clm4_0_40_SP SPINUP
- clm4_0_40_CN SPINUP
- clm45scill_clm4_0_40_CN SPINUP
- clm45scill_clm4_0_40_SP and clm4_0_40_SP - COMPARE TO L2 DATA

GPP ($gC\ m^{-2}\ d^{-1}$) vs FLUXNET

CLM4.5BGC – CLM4CN



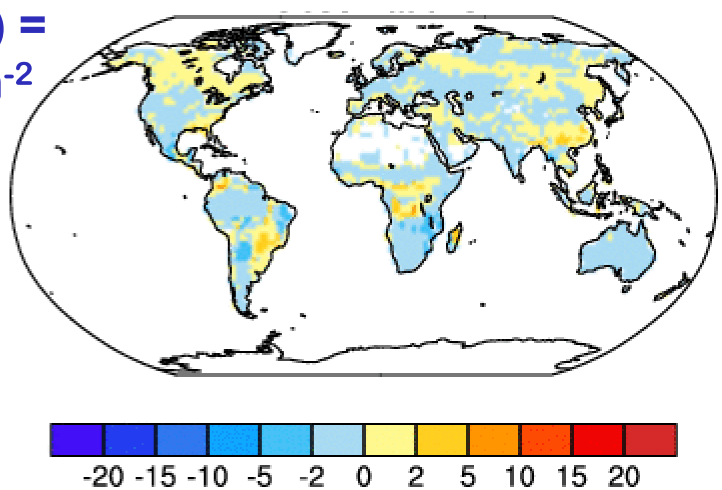
CLM4.5BGC (green), CLM4CN (red)



Model relative to Obs

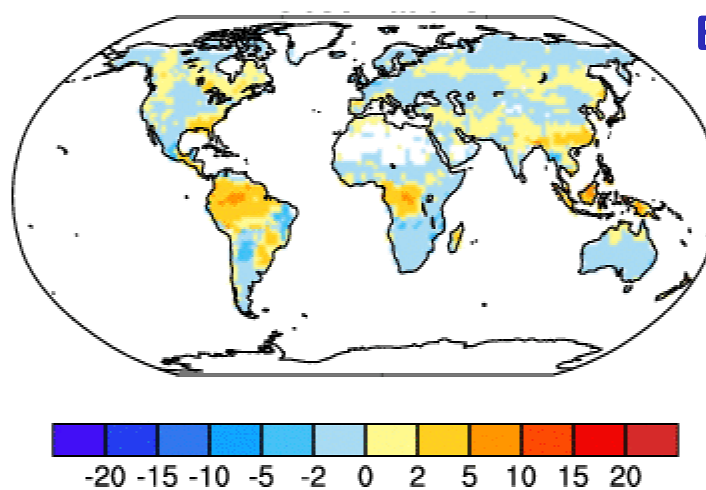
CLM4.5BGC – Obs

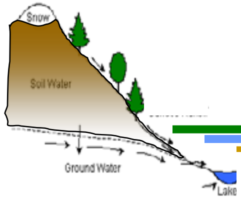
Bias (SP) = 0.8 W m^{-2}



CLM4CN - Obs

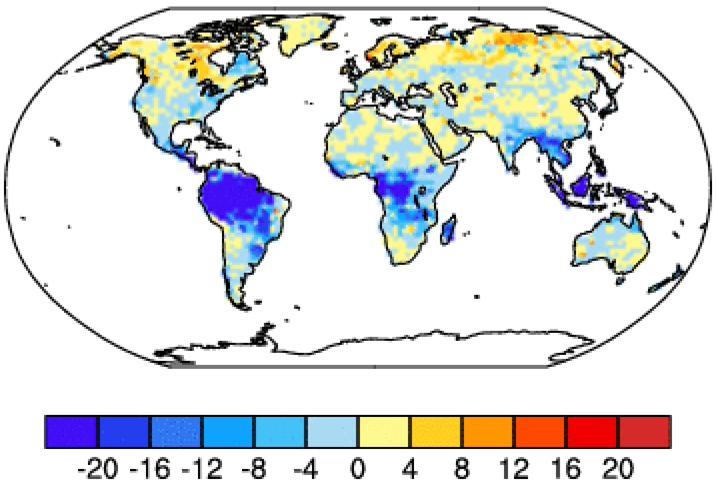
Bias (SP) = 1.2 W m^{-2}



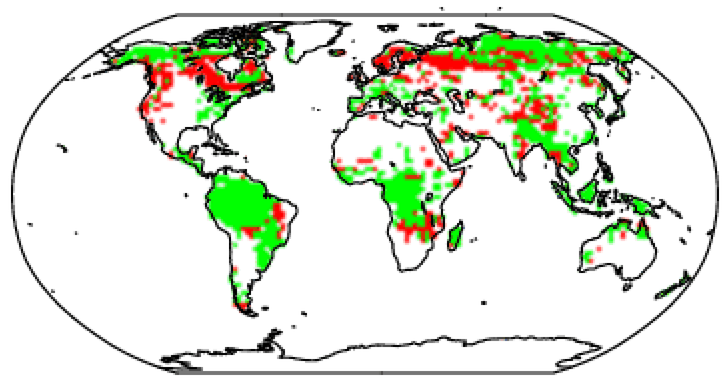


Latent Heat Flux (W m^{-2}) vs FLUXNET

CLM4.5BGC – CLM4CN

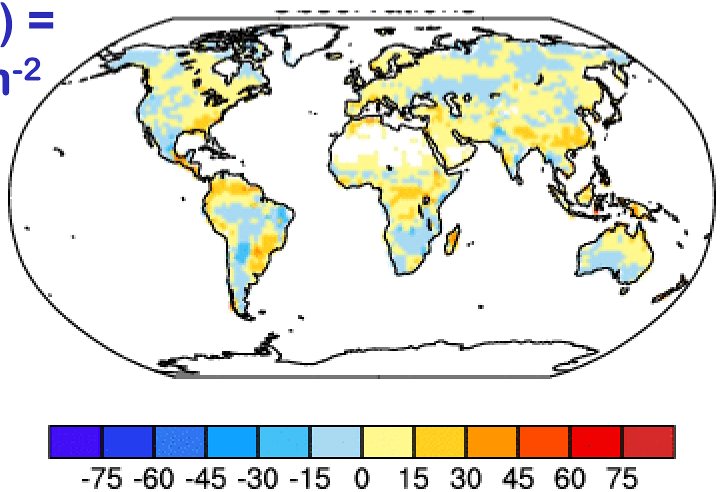


CLM4.5BGC (green), CLM4CN (red)



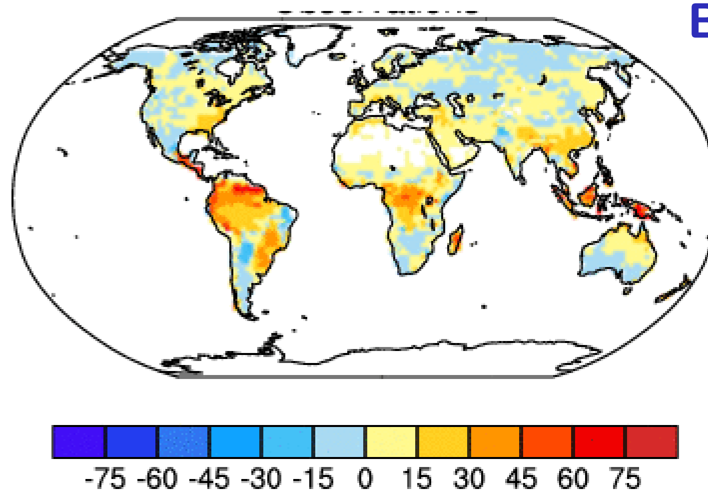
CLM4.5BGC – Obs

Bias (SP) = 1.6 W m^{-2}

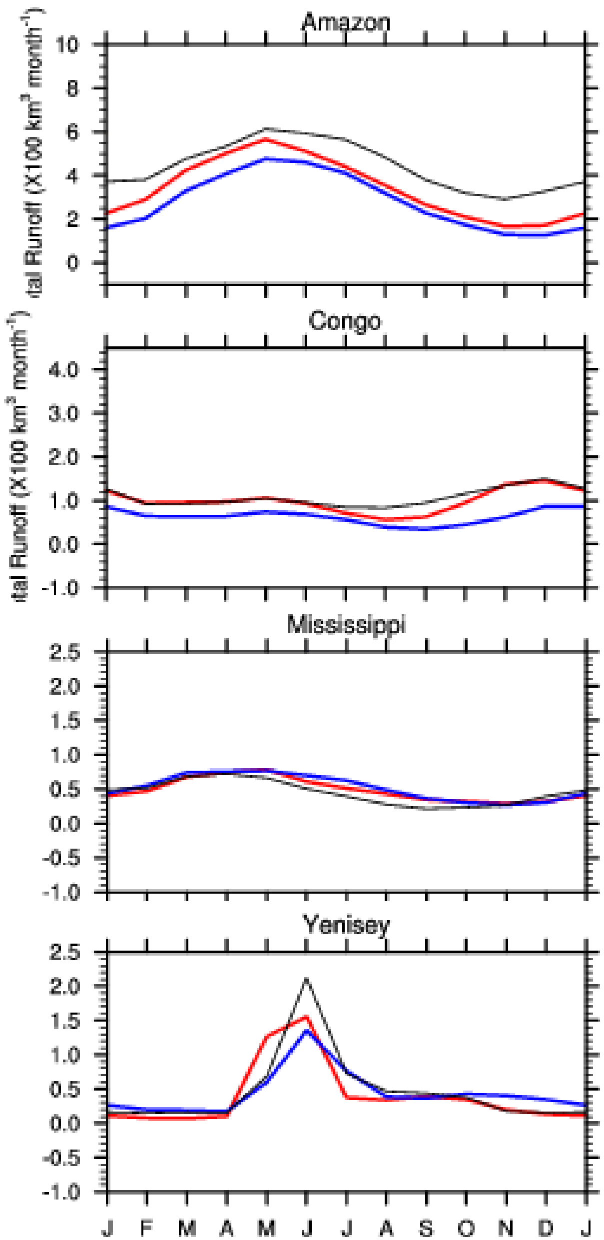


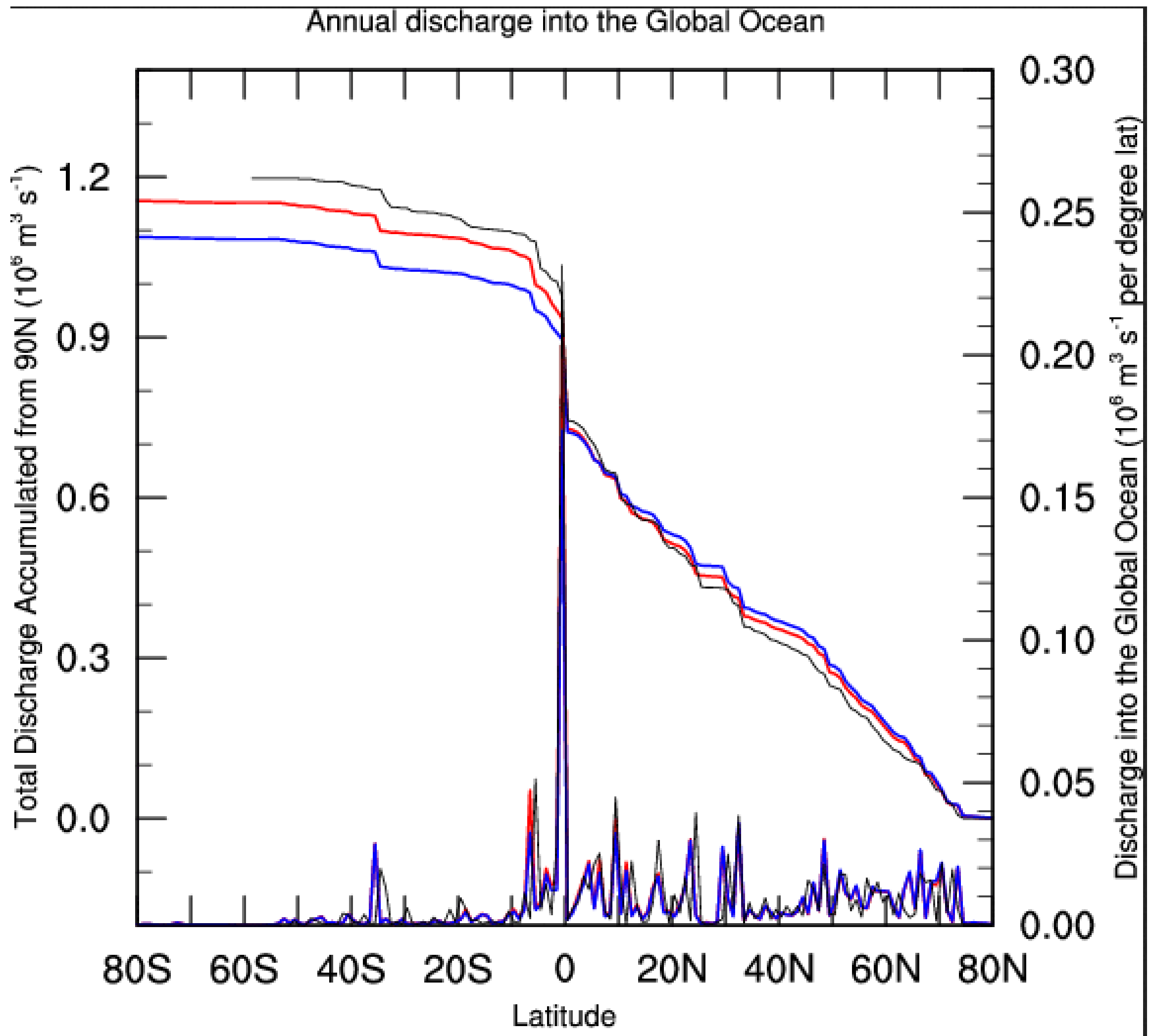
CLM4CN - Obs

Bias (SP) = 2.8 W m^{-2}



River discharge



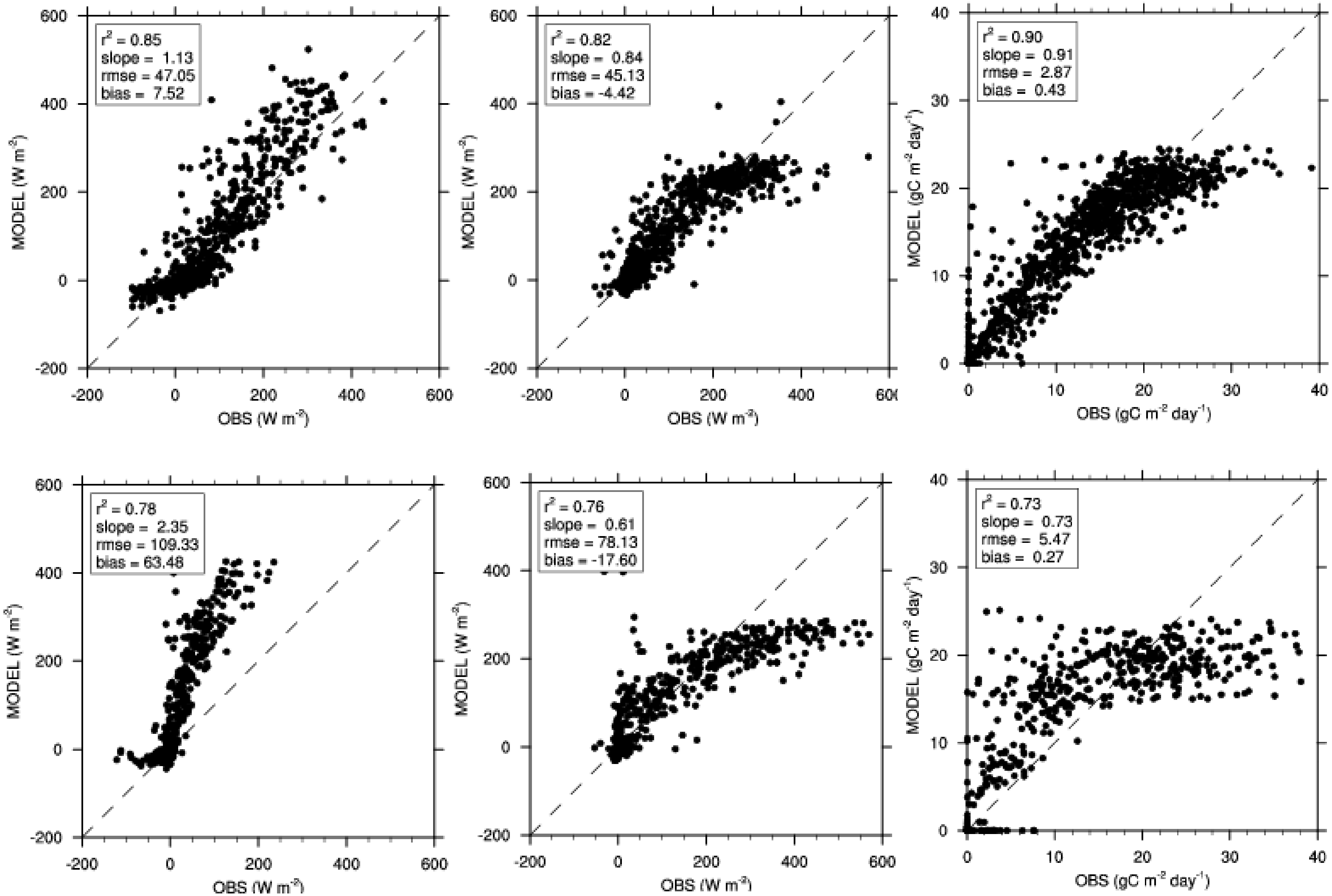


CLM4.5 Performance at Tower Sites

Sensible Heat | Latent Heat | GPP

Howland Forest Main July, 1996
NET-T

Morgan Monroe July, 2001
BDT-T



Thanks to D.M. Ricciuto, D. Wang, P.E.Thornton, W.M. Post, R.Q. Thomas, E. Kluzek for PTCLM!

Temperature Acclimation of Photosynthesis

Kattge and Knorr 2007

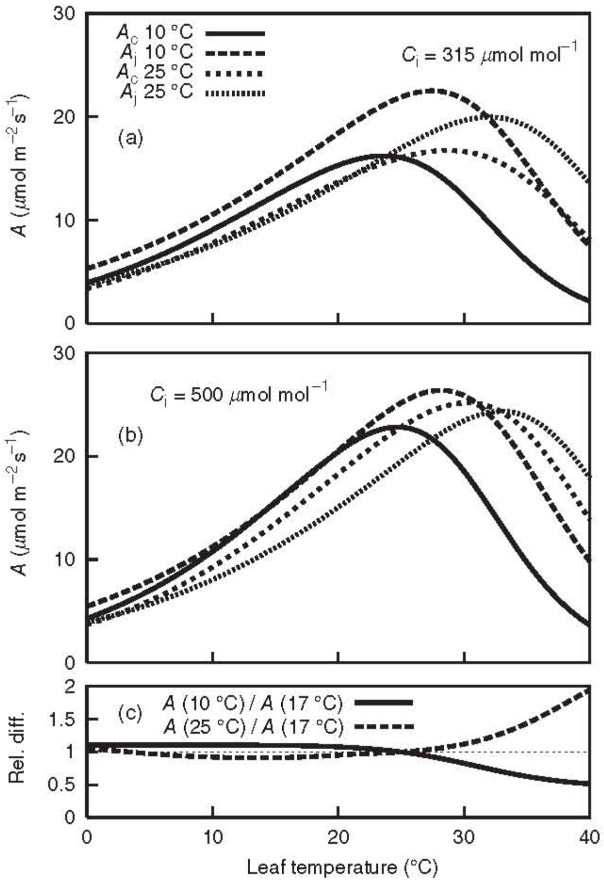
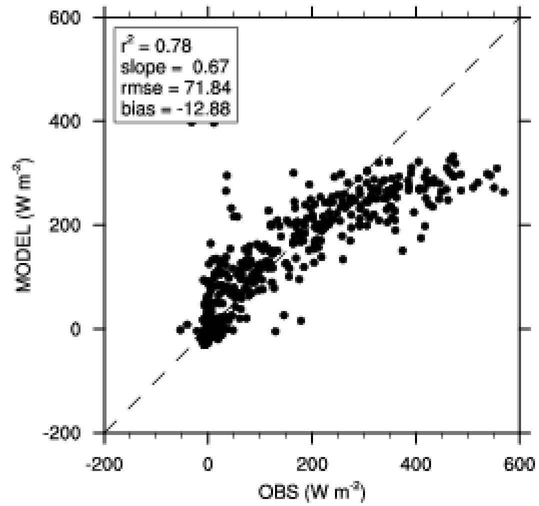


Figure 5. Impact of temperature acclimation on modelled photosynthesis. (a) Light-saturated ribulose-1,5-bisphosphate (RuBP) carboxylation (A_C) and RuBP regeneration (A_J) at intercellular CO_2 concentration (C_i) of 315 ppm (photosynthetically active irradiance = 1500 µmol m^{-2} s^{-1}, V_{cmax}^{25} = 60 µmol m^{-2} s^{-1}). (b) Same as (a) but for C_i of 500 ppm. (c) The ratio of modelled photosynthesis of plants grown at 10 and 25 °C to plants grown at 17 °C for C_i = 315 µmol mol^{-1}.

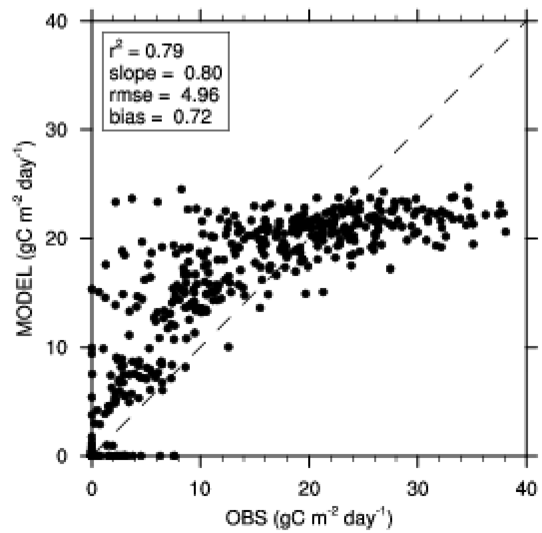
Morgan Monroe July, 2001

CLM4.5 + Acclimation

Latent Heat

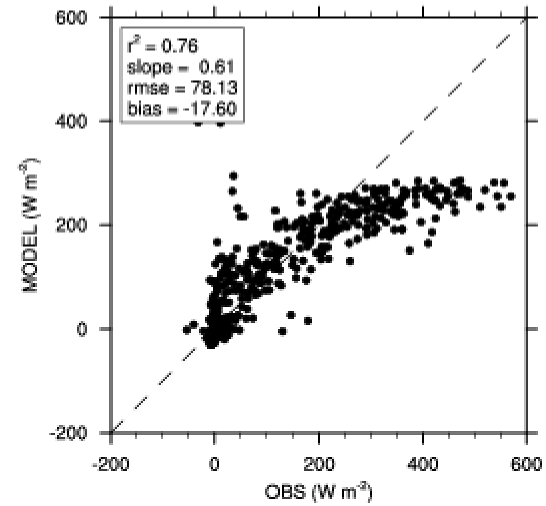


GPP

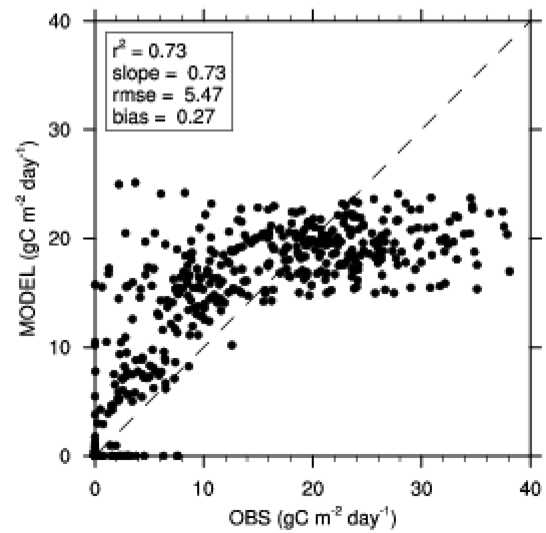


CLM4.5

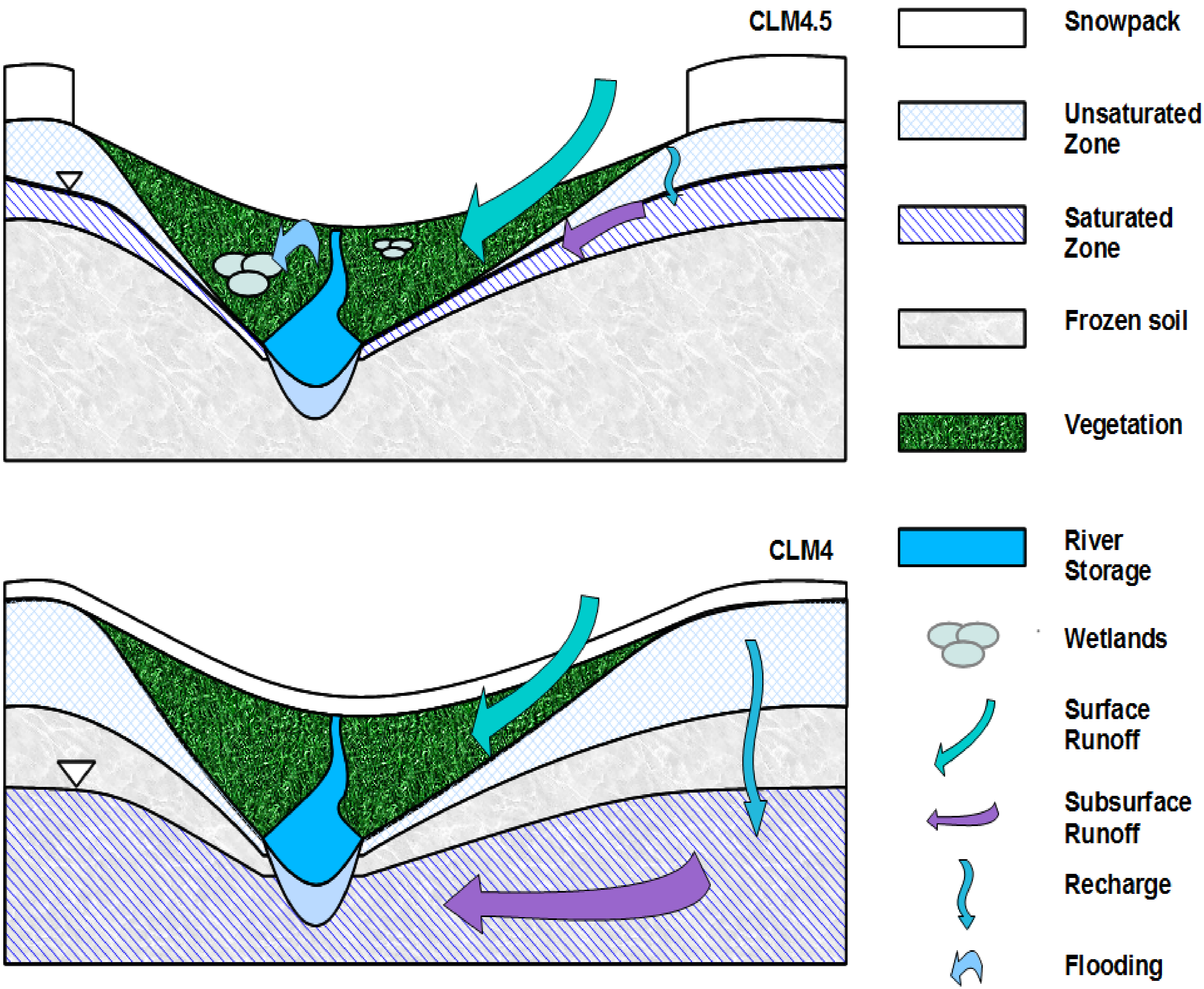
Latent Heat

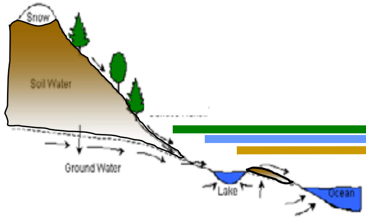


GPP

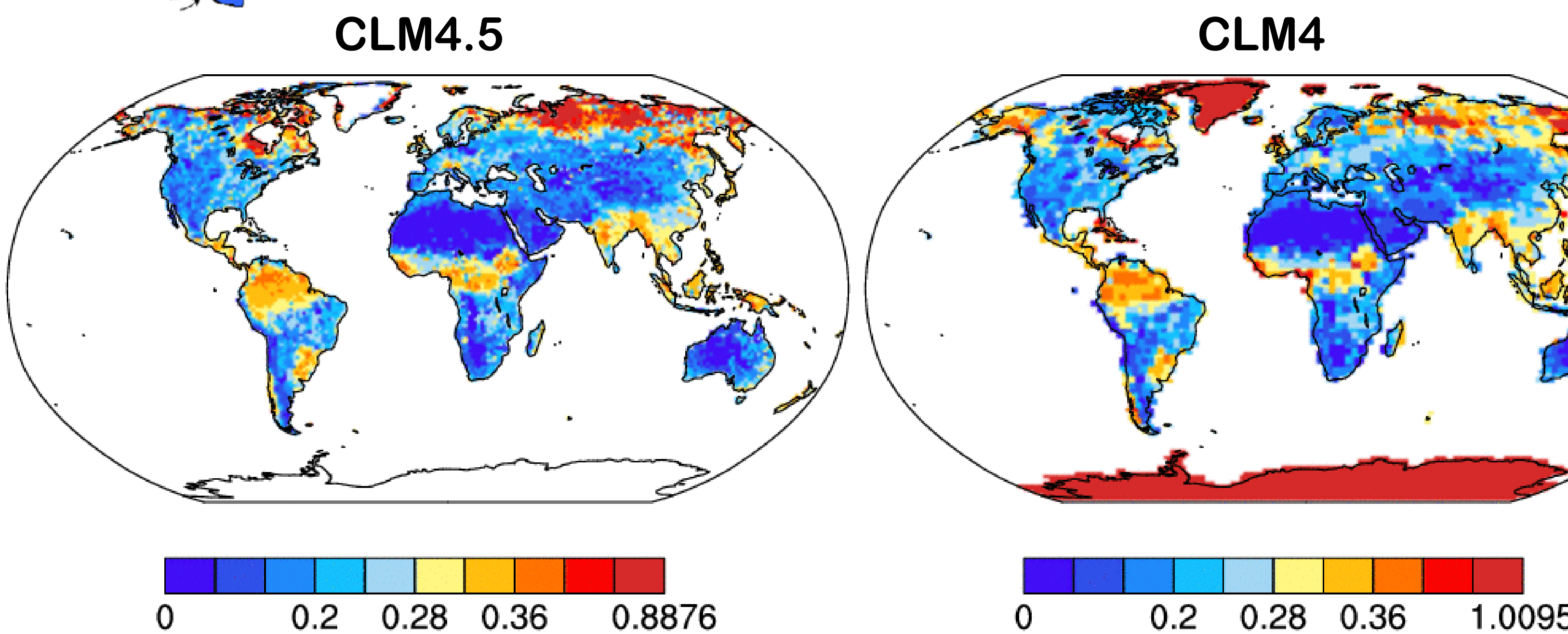


Cold region hydrology





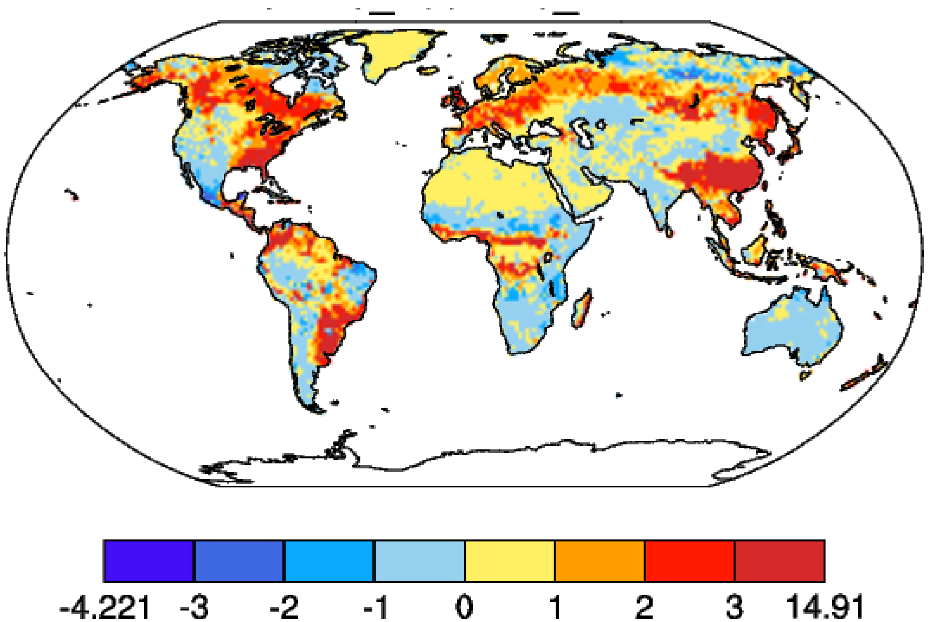
Soil Water (0.5m, JJA, $mm^3\ mm^{-3}$)



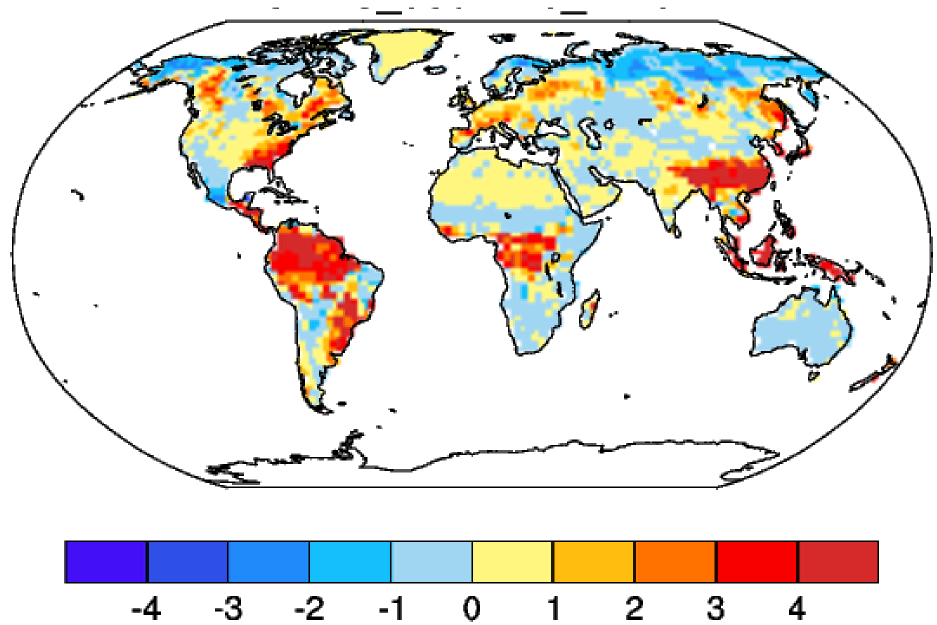
- **More realistically saturated Arctic soils**
- **Prognostic wetland distribution (especially with flooding on) 'reasonably' simulates Arctic and tropical wetlands (depending on precipitation forcing dataset used)**
- **Water table tracks soil moisture much better**

Leaf Area Index(JJA) vs MODIS

CLM4.5BGC – Obs

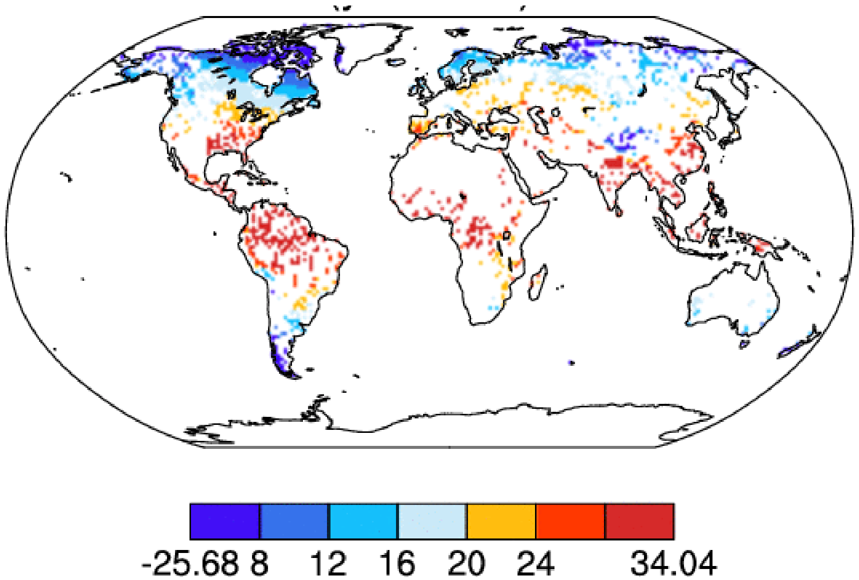


CLM4CN - Obs

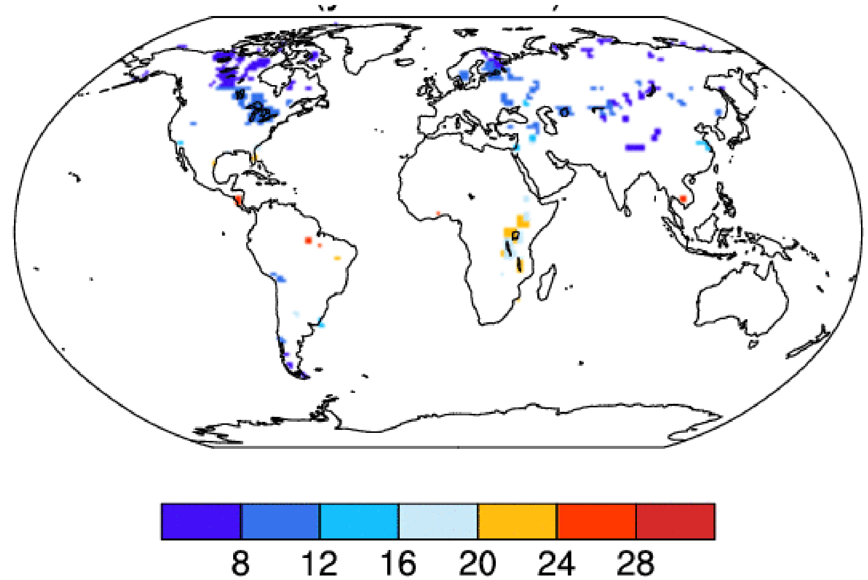


Lake Temperature (JJA, surface)

CLM4.5

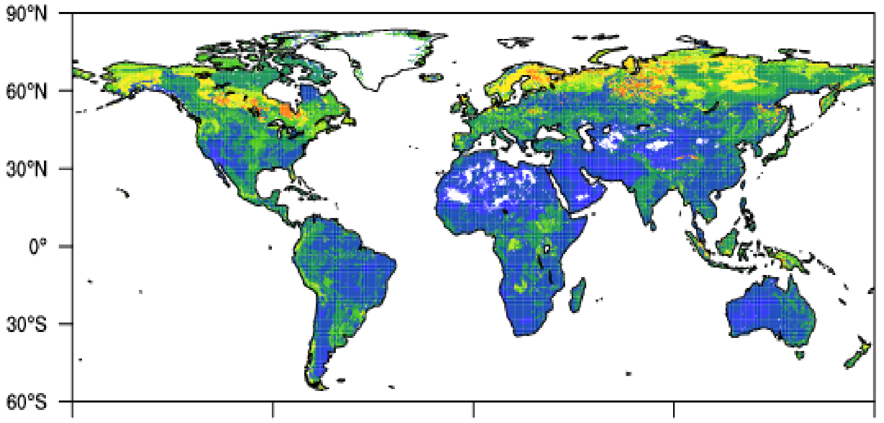


CLM4

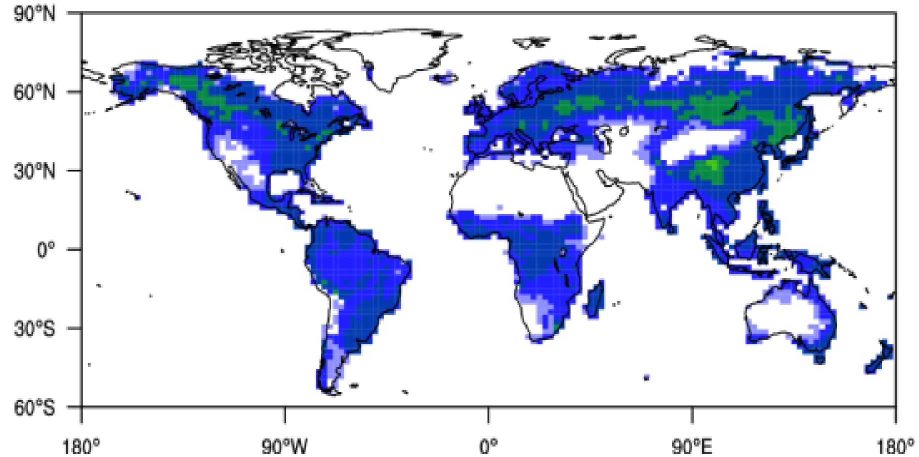


Soil carbon

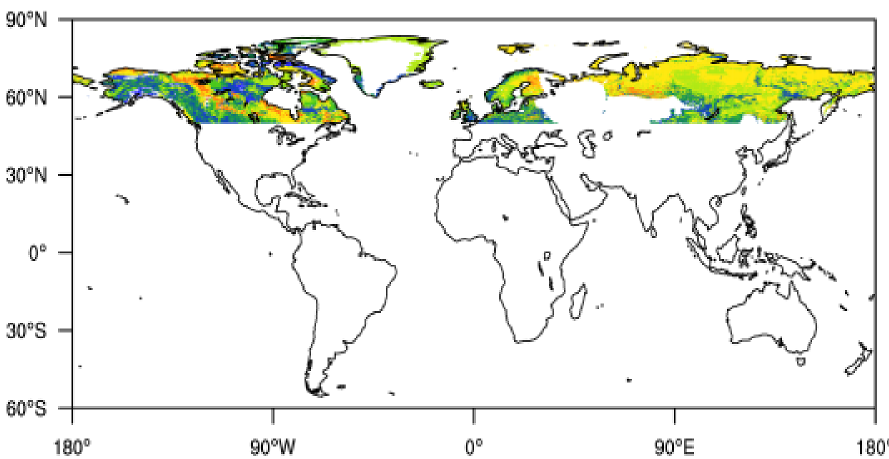
IGBP 900-1650 PgC, to 1m



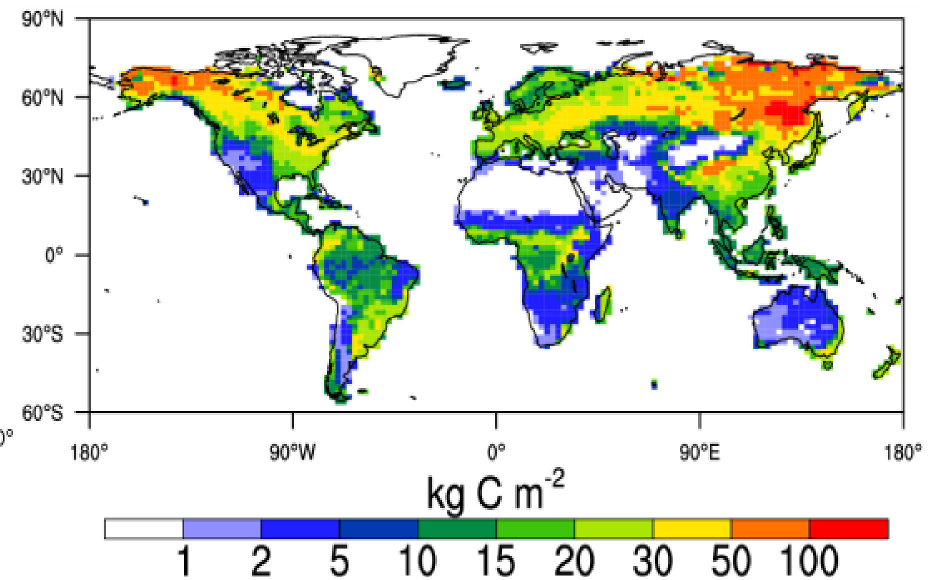
CLM4CN (650 PgC)



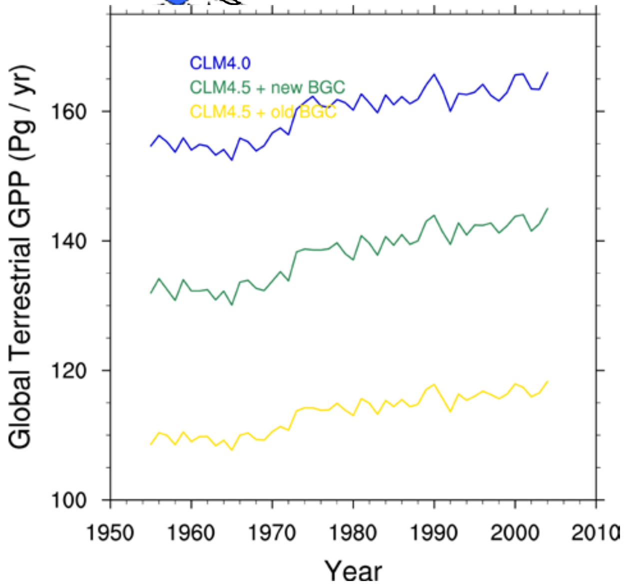
NCSCD soil carbon

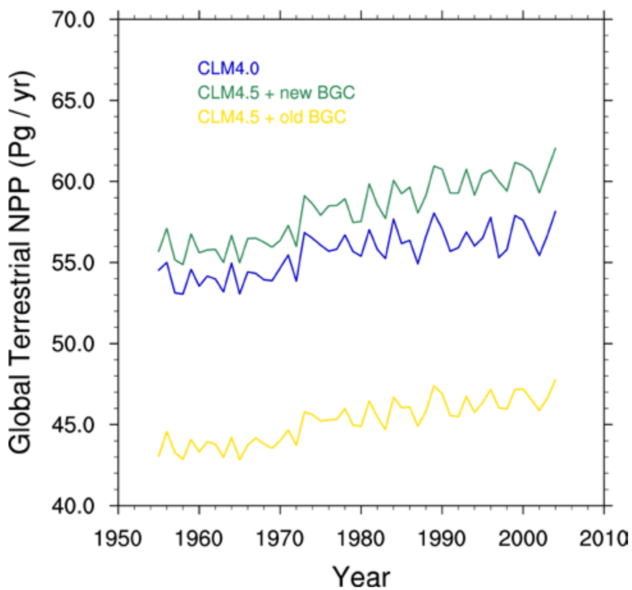


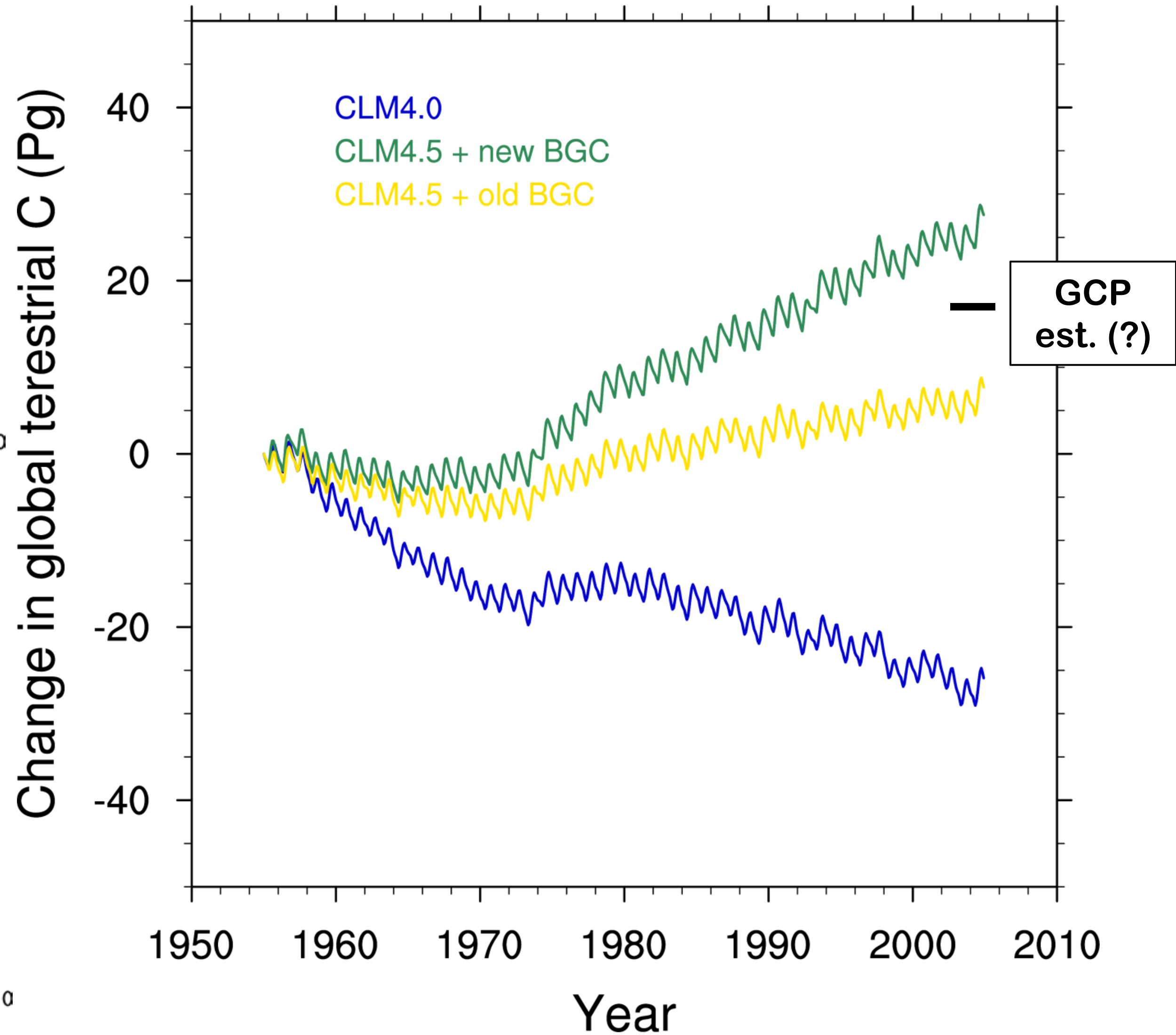
CLM4.5BGC (to 1m; 1900 PgC)



Transient historical run

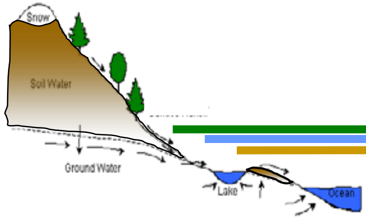






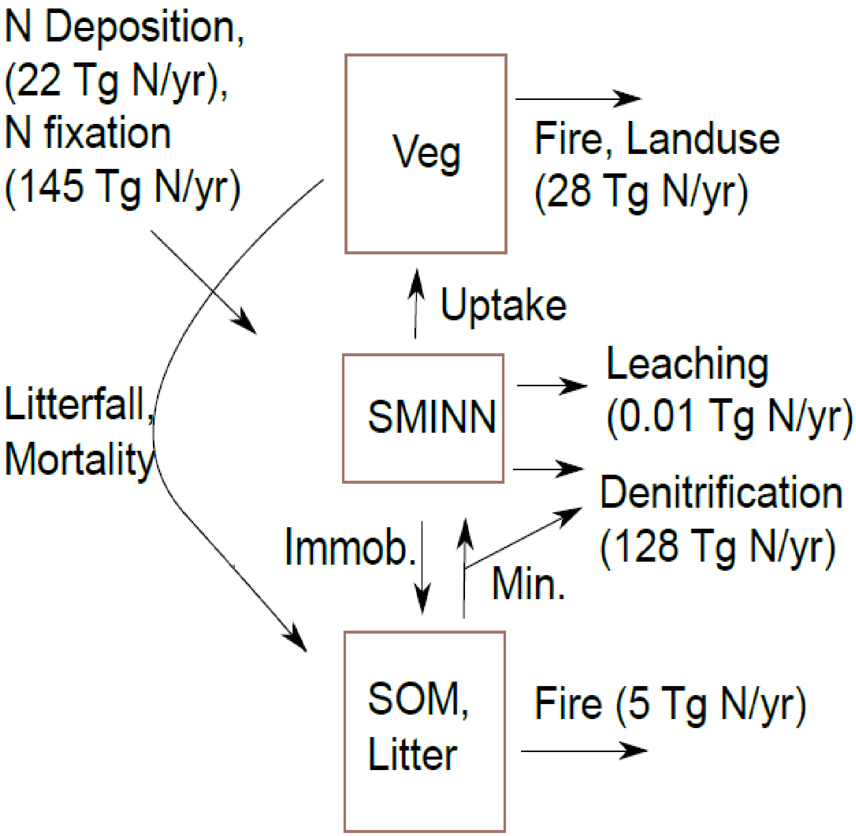
What won't be in this release?

- Improved hydrologic response to land cover change (?)
- Ecosystem Demography option
- Comprehensive improvement to N-cycle
- Riverine transport of nutrients
- Dynamic landunits
- Separation of above and below ground C and N pools and fluxes

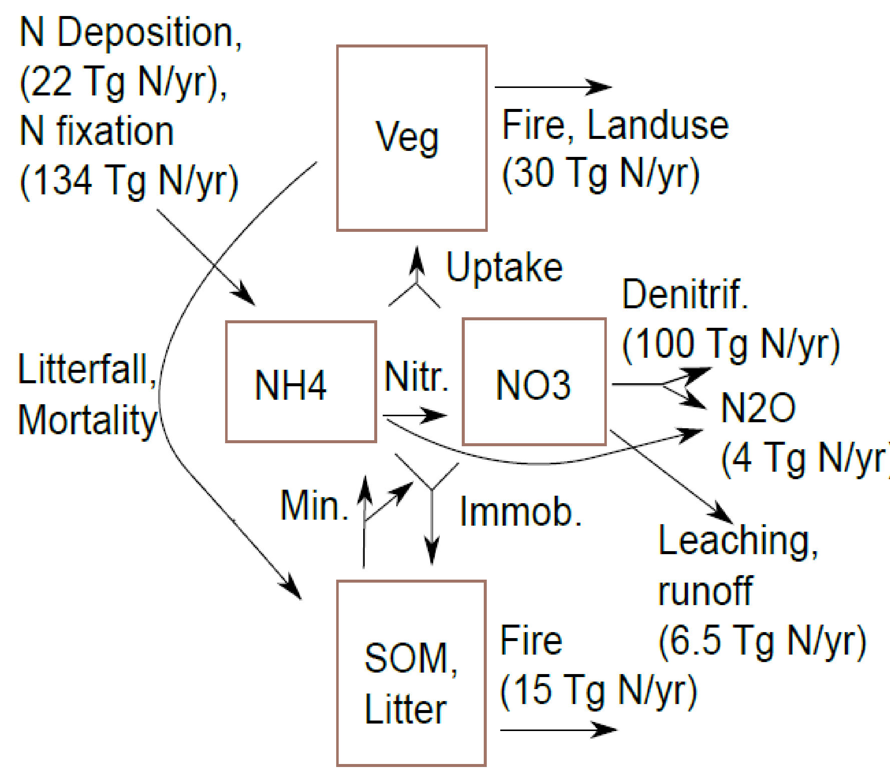


N-cycle

CLM4CN

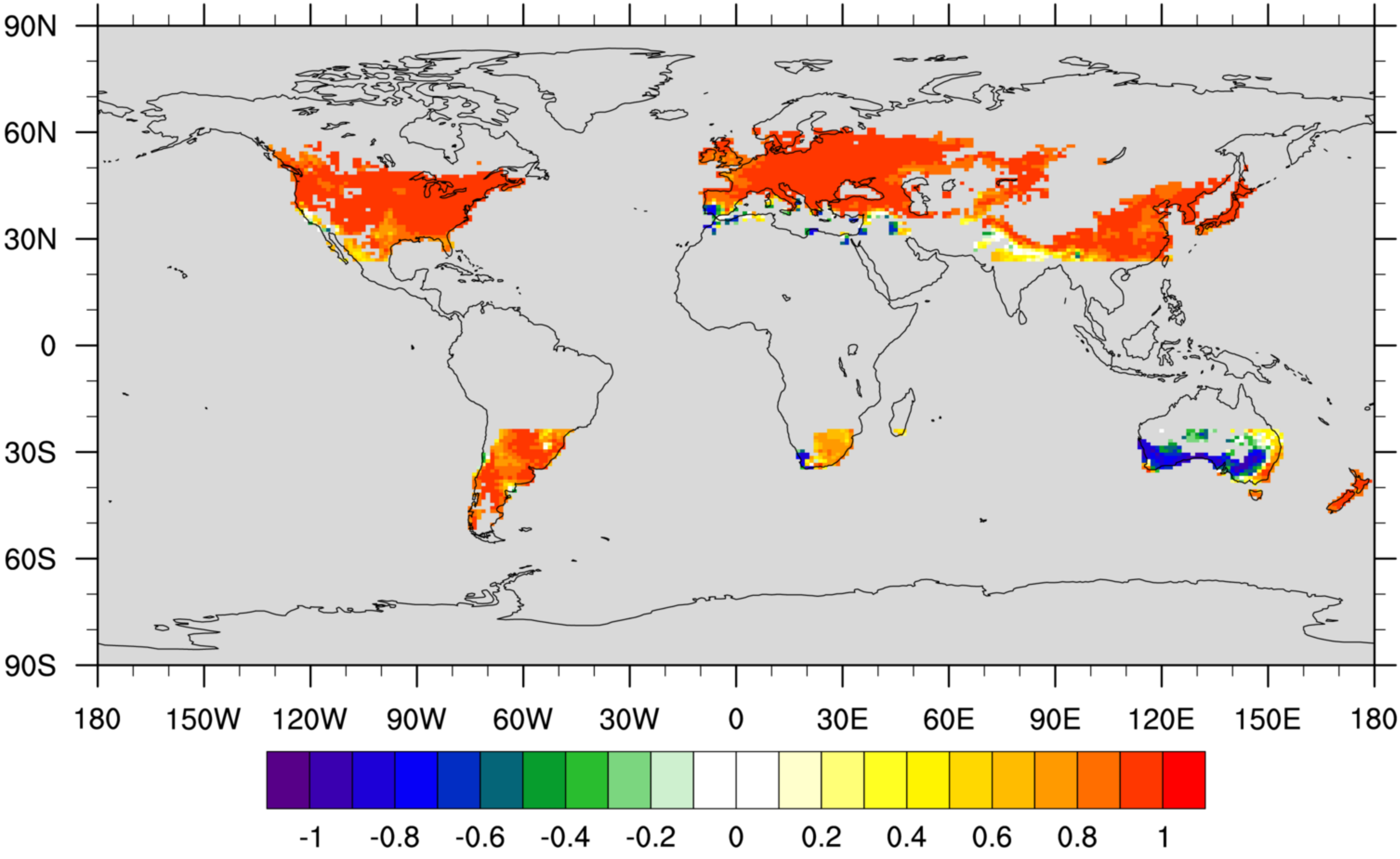


CLM4.5BGC

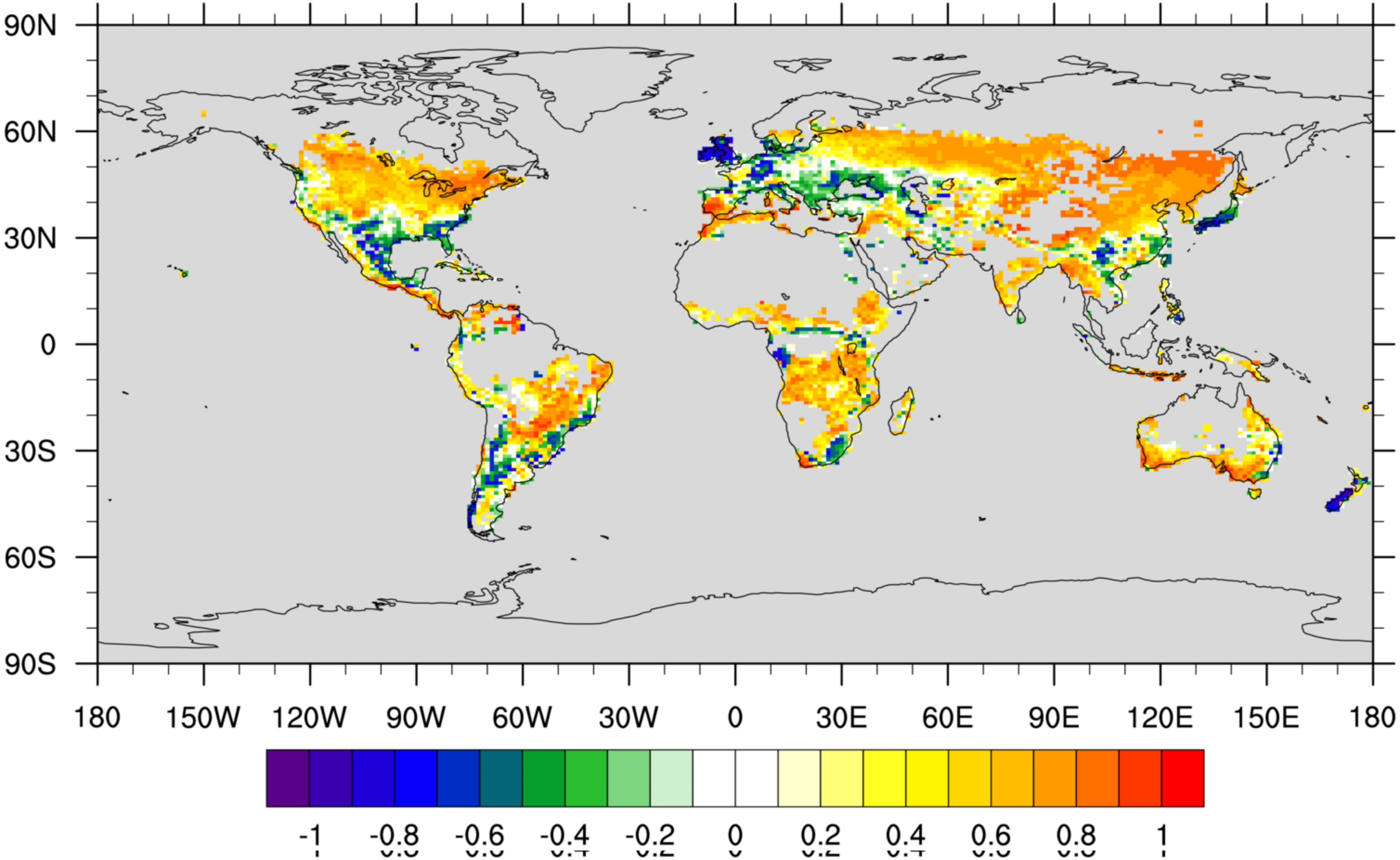


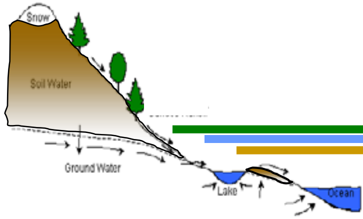
Obs (preindustrial, Galloway et al. 2004)
Deposition 17; BNF 120; Denitrification 98; Export to Rivers 70; N_2O 6

Phenology: Broadleaf deciduous tree, annual correlation



Phenology: non-arctic C3 grass, annual correlation





Vexing Issue: Forcing Datasets

- **For CLM4.5, current plan is to include support for Qian, CRUNCEP, and CESM MOAR**
  - **Answers are substantially different between Qian and CRUNCEP; e.g. high lat soil carbon and river discharge**
  - **Tune for which forcing dataset**
  - **Will GSWP3 forcing dataset be better?**

Other Activities

CLM-DART developments

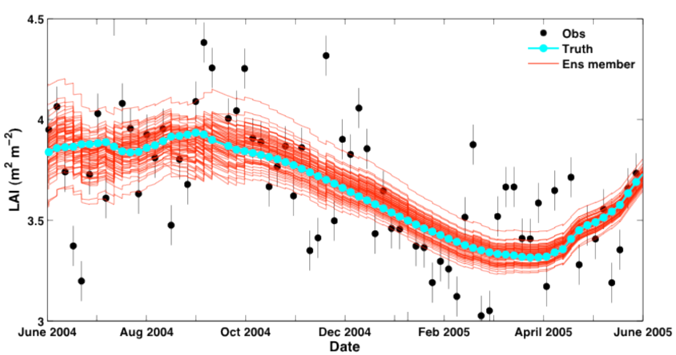
Current capabilities

- The Data Assimilation Research Testbed (DART) is a tool for ensemble DA maintained by members of IMAGe at NCAR
- DART is coupled to multiple instances of CLM in a CESM executable and updates state variables in restart files for each instance dependent on observation values and their uncertainty at daily time steps
- Developed the capability to assimilate FLUXNET observations of NEP, LE and H and satellite observations of LAI and snow covered area
- Investigated the impacts of assimilation on temporal forecasts and spatial extrapolation using both synthetic and real observations in both global and point runs
- Updating support for latest model releases with preliminary testing completed for CLM-DART coupling using CESM 1.1 on Yellowstone

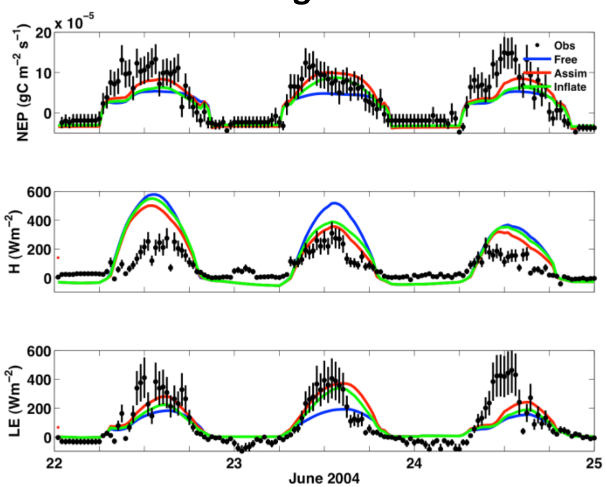
Future Plans

- Add PFT-specificity to observation operators to allow multiple observations of different PFT-types in a single grid cell
- Add observation operators for addition observation types, including hyperspectrally derived foliar N, Lidar/Radar derived biomass, soil respiration, soil moisture from COSMOS probes
- Test implementation at finer grid resolutions (currently 2° for global runs)

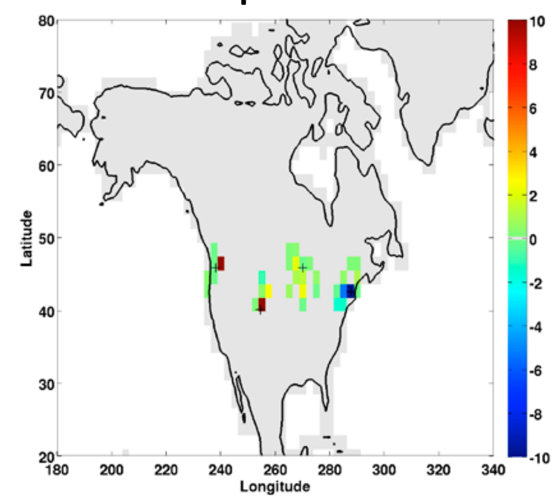
Assimilating 72 LAI obs over 12 months



Assimilating FLUXNET obs

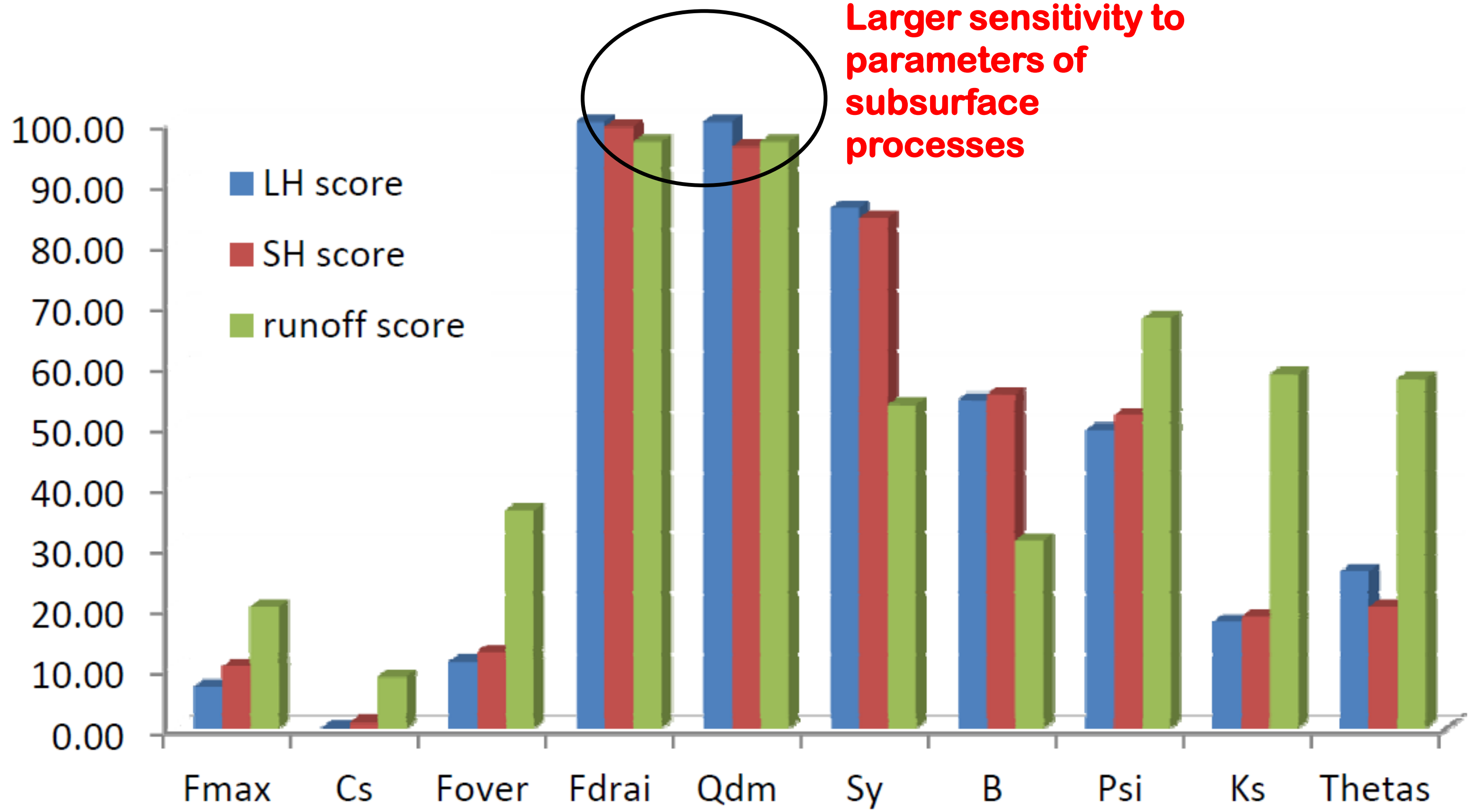


Mean update in leaf C



Tools: Land Uncertainty Quantification (UQ)

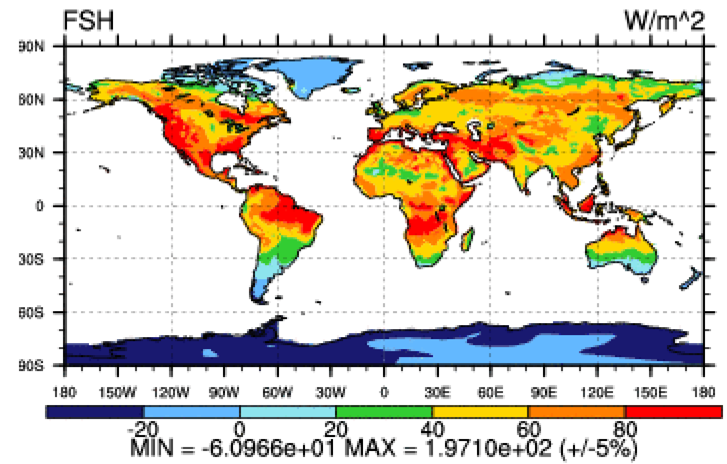
- CLM parameter sensitivity analysis (CSSEF)
    - BGC, Hydrology, Crops
- Goal is for capability to do global CLM parameter calibration/optimization

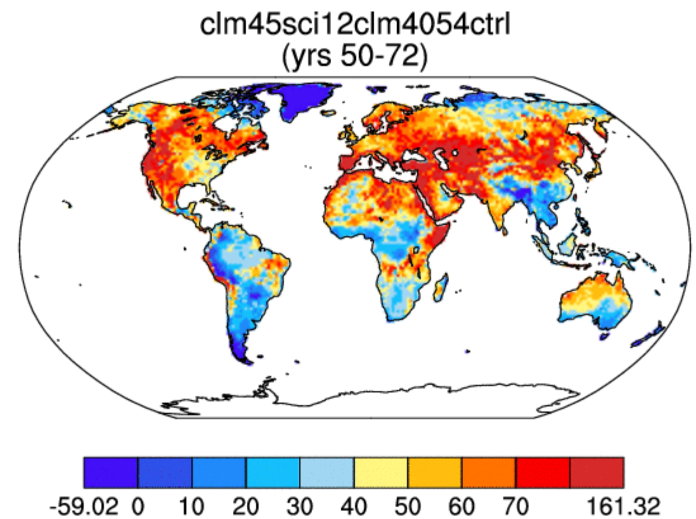


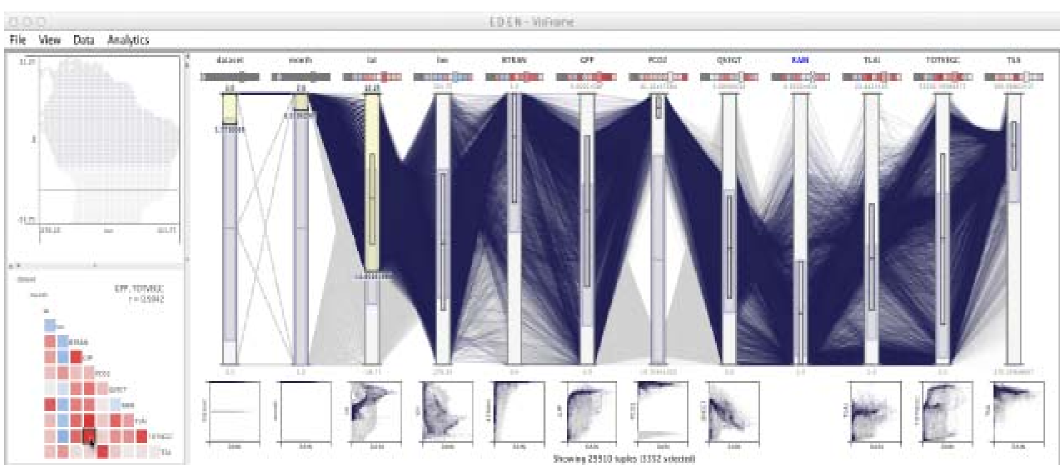
Larger sensitivity to parameters of subsurface processes

CLM Diagnostics

- **CLM Diagnostics Package**
  - Up to 5x faster (thanks to Sheri Mickelson, Nan Rosenbloom, and Keith Oleson)
  - Better plots (Adam Phillips)
  - C-LAMP, Metrics (coming soon)
- **EDEN (Exploratory Data analysis ENvironment)**
  - Chad Steed at ORNL (see poster)







Community Integrations - Large Ensemble

- 30 members (perhaps more)
- 1900-2080 with RCP8.5 forcing scenario
- CESM-CAM5-BGC (1-degree) with prescribed CO2.
- Spin-up runs underway; long control will be available
- Initial state will vary by a round-off level change
- High-frequency output to be saved
  - Timeslice output for decades in 1850s, 1910s, 1990s, 2070s for downscaling runs
  - Smaller set of continuous daily fields for analysis

Thanks to Clara Deser and Jen Kay for leading the planning effort

https://wiki.ucar.edu/display/ccsm/CESM+Large+Ensemble+Planning+Page

Marika Holland
mholland@ucar.edu

Community Integrations – High Resolution Control

- 25km atmosphere coupled to 1-degree ocean
- Multi-century integration (200-300 yrs)
- Requires CAM-SE configuration
  - Developments still underway
  - Hopeful that CAM-SE with new vertical advection will be released in May, 2013
- Integrations unlikely to start until later this year
- Community input on experiment design/desired output is welcome
- Planning will begin after the May release

Marika Holland
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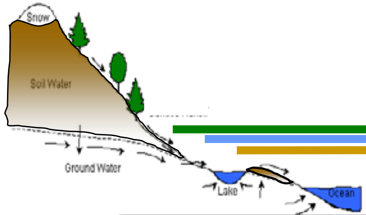
Beyond CLM4.5

Information request from SSC

- Short-term (next year) model development priorities, including scientific motivation (annually in March)
- Documentation on model development process/protocols (by June)
- Description of metrics/diagnostics for model assessment (by June)



Model Development Process

Model release (CESM1/CLM4)

Use model for scientific studies

Detailed model assessment (identify strengths and weaknesses)

LMWG members develop parameterizations or add features

Present ideas/results at LMWG meetings

Publish papers

Evaluate competing parameterizations

Plans for next (and next next) model version discussed at LMWG meetings

Build and test beta version of offline model

Finalize and test within CESM

Document; Control integrations

Developer's Guide

https://wiki.ucar.edu/display/ccsm/Community+Land+Model+Developers+Guide

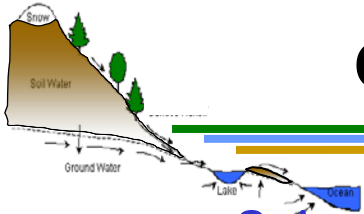
Steps in the Collaborative process:

Initial development may be done outside the CLM repository, but for changes to make it on the CLM trunk a collaborat management team at NCAR will take place. Both the developer and the CLM code management team will be involved make it to the CLM trunk and in a timely manner. Note that all code development needs to be approved by the LMWG

1. A branch is created for the work (usually by the CLM gatekeeper).
2. Changes are checked in for the work on the branch by the developer. We recommend that the developer revie undertaking their model development. See Using SVN to Work with CLM Development Branches for instructior
3. Code is reviewed by the CLM code management team. As a result of the code review, improvements to the coc should be checked into the branch by the developer. Note that the more discussion and collaboration that take approved.
4. Note that we highly recommend that during the development process, the developer's branch should be update to Work with CLM Development Branches for instructions on how to update code to the trunk or main developm
5. As noted in the guidelines below, new datasets will need to be added to the models/lnd/clm/bld/namelist_files X Users Guide Chapter 3 for information on how to do this.
6. Any CLM tools that need to be modified to create new datasets will need to be updated as well.
7. Tests for the new features will need to be added to the standard CLM testing (in general this is done by the CLN
8. At this stage, the developer should run the test suite to ensure that the revised code passes both old and new t with the test systems for CLM. If possible, the test suites should be run on more than one machine (three mach accomplish that).
9. Once the testing is complete and the results are satisfactory, the code is ready to be brought onto the trunk or n identifying the tag in which the CLM code management team will attempt to bring the code onto the trunk or ma (see CLM Upcoming Tags). Note that especially for major code changes, we recommend that testing is done fr
10. At this point, the developer's branch will need to be updated to the latest CLM trunk or main development branc
11. At this stage, depending on several factors with respect to timing of tags, other development activities, resource conducted by either the CLM code management team or the developer until the developer's branch can be mov

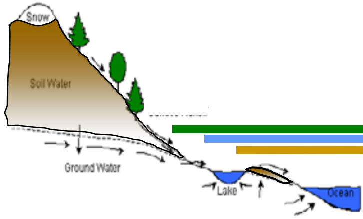
Possible priorities for CLM code development for next year

- Dynamic landunits
  - Prescribed and prognostic land unit transitions: e.g., glacier to vegetated, vegetated to crop, vegetated to urban, etc.
  - Transient land cover change with crop model / CNDV
- Code refactoring
  - Remove CPPs, rationalize filters, multiple data output levels, etc.
- Bring Ecosystem Demography option to trunk
- Infrastructure for riverine transport of nutrients
- iESM infrastructure



Other ongoing CLM development activities

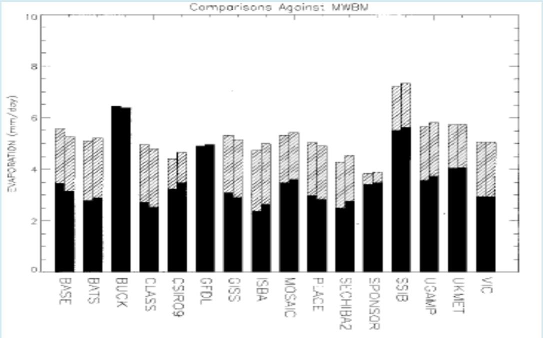
- Sub-surface hydrological processes – lateral redistribution of water
- Sub-grid PFT distribution (elevation dependence)
- Sub-grid soil moisture and snow heterogeneity
- IAM-ESM coupling (iESM) (SDWG)
- Soil microbial dynamics, multi-phase transport, multiple tracers in soil (CLM4-BeTR)
- Spatially explicit soil depth
- Water isotopes
- Peatlands
- Excess soil ice in permafrost / thermokarst
- Other nutrient cycles (e.g., phosphorous)
- Ozone poisoning of vegetation
- Data assimilation
- 3-D canopy radiation
- Prognostic canopy air space and canopy turbulence



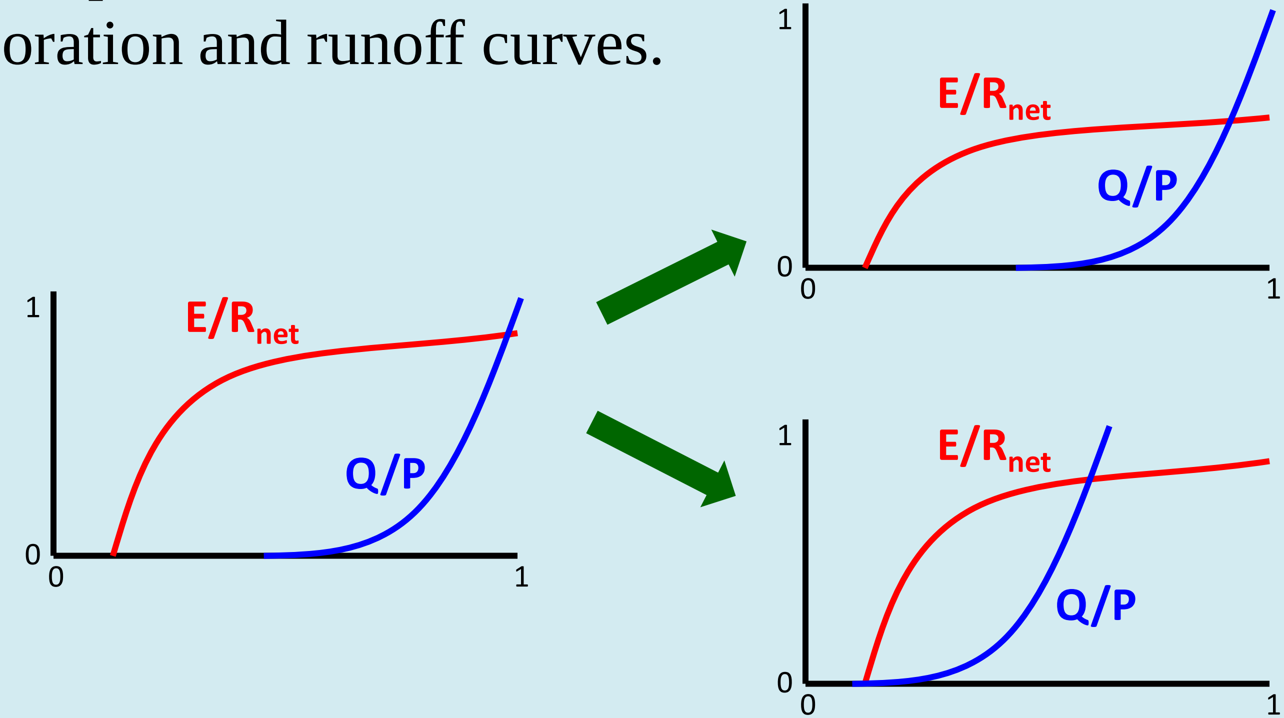
Priorities for model development and analysis

- Extend crop model to include more crops, esp. tropical
- Nitrogen cycle improvement, phosphorous
- Hydrologic response to land cover change
- Ecosystem Demography; vegetation mortality
- Photosynthesis
- iESM (Integrated Assessment Model coupled to CESM)
- Human management of water (?)
- Develop capability to do routine parameter calibration

The comparison was a success…



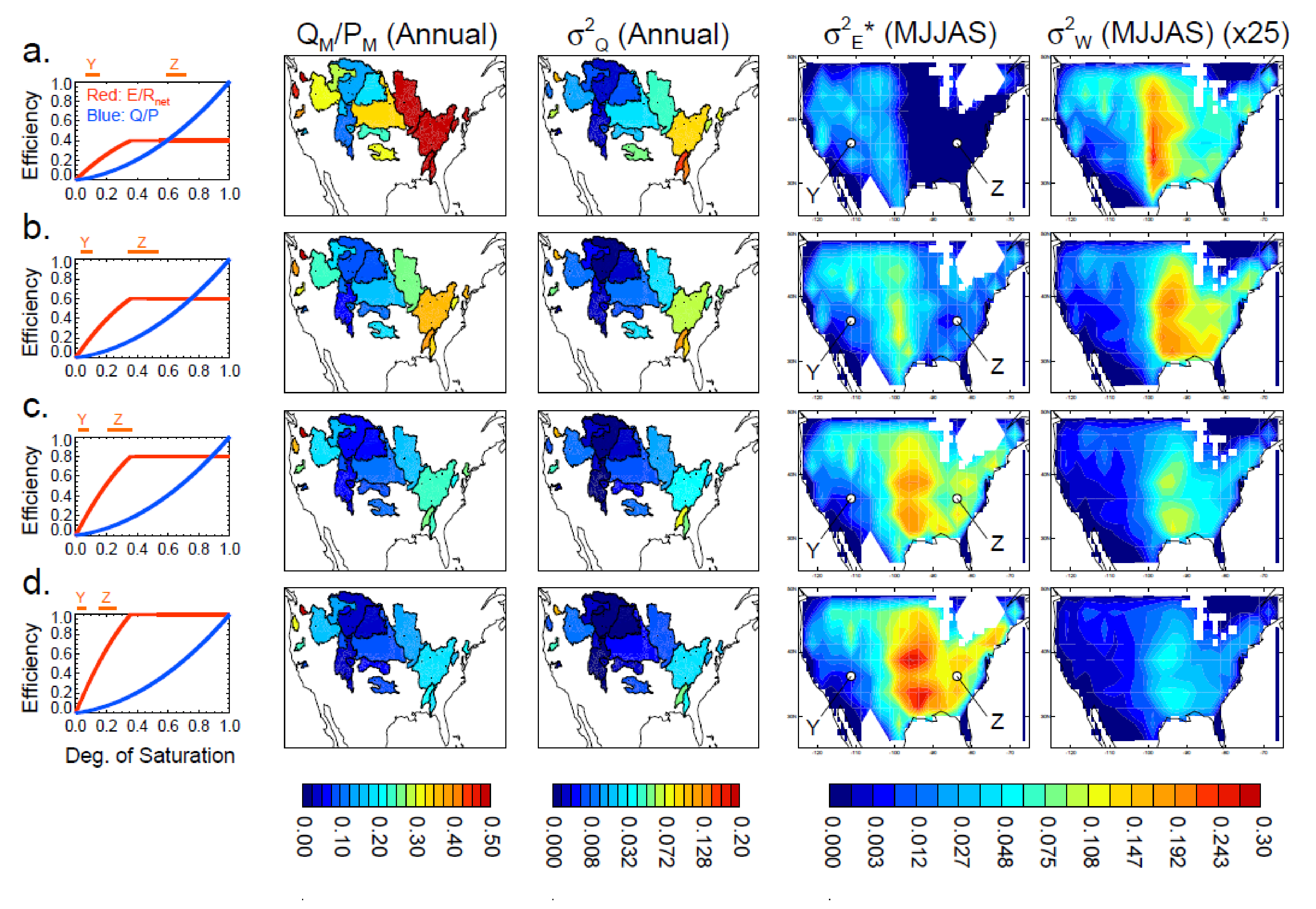
… demonstrating that, to first order, simulated evaporation totals are explained by the <u>relative positions</u> of the evaporation and runoff curves.



Shift evaporation curve down
⇨ reduce annual evaporation

Shift runoff curve to the left
⇨ reduce annual evaporation

Sensitivity study with WBM: Vary "height" of evaporation function.

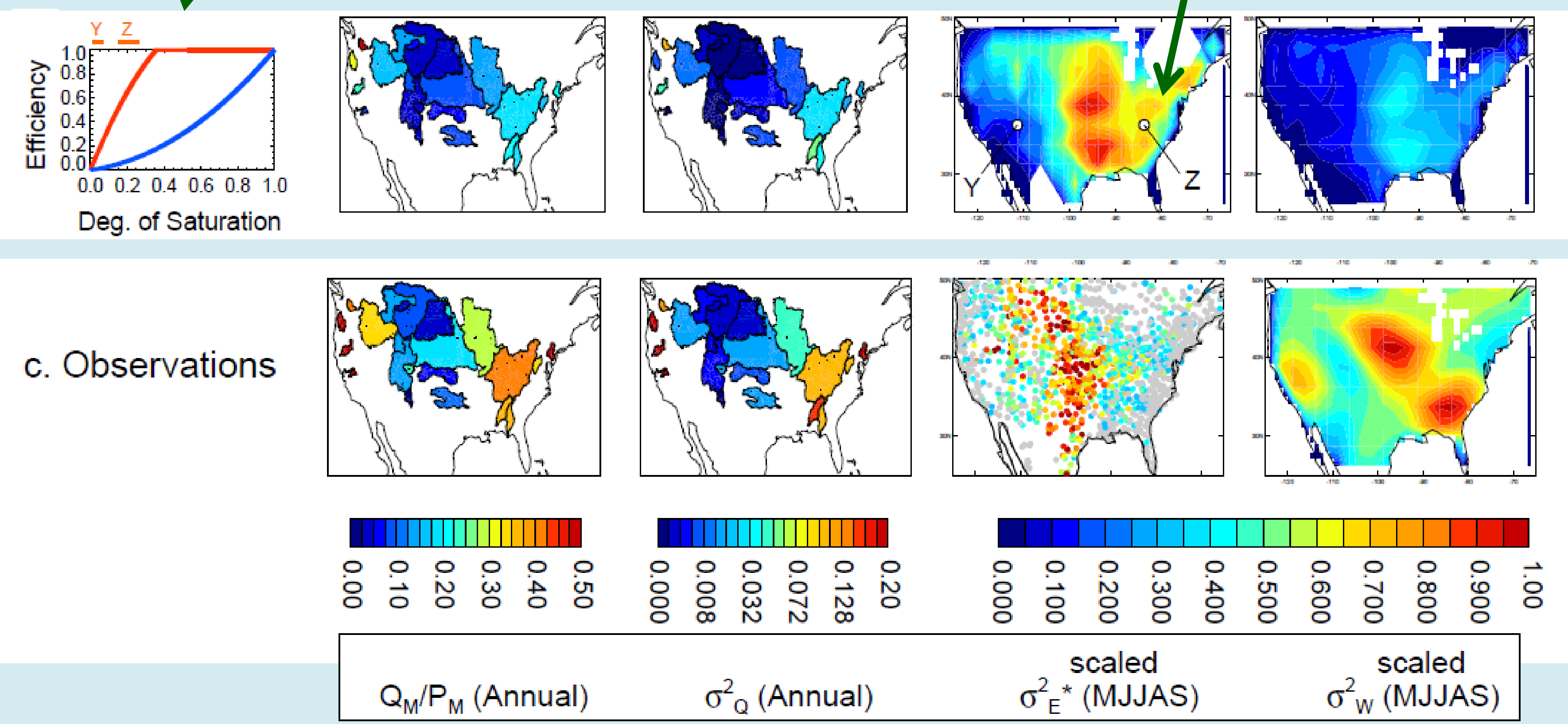


Sample comparison: WBM results (selected arbitrarily from sensitivity experiments above) versus observations

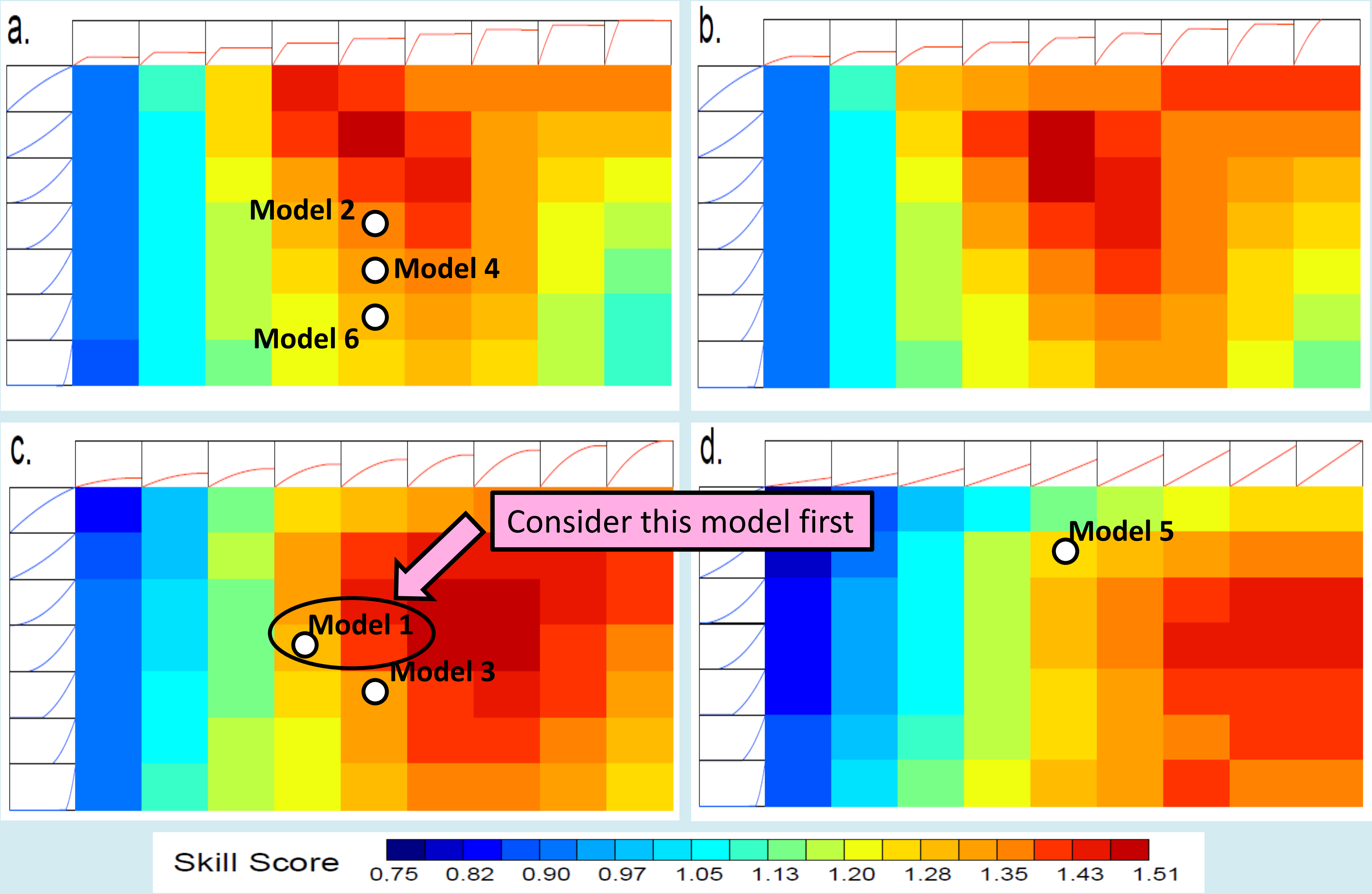
With this pairing of evaporation and runoff functions, …

… we get underestimated runoff means and variances…

… and excessive σ^2_E* in the east.

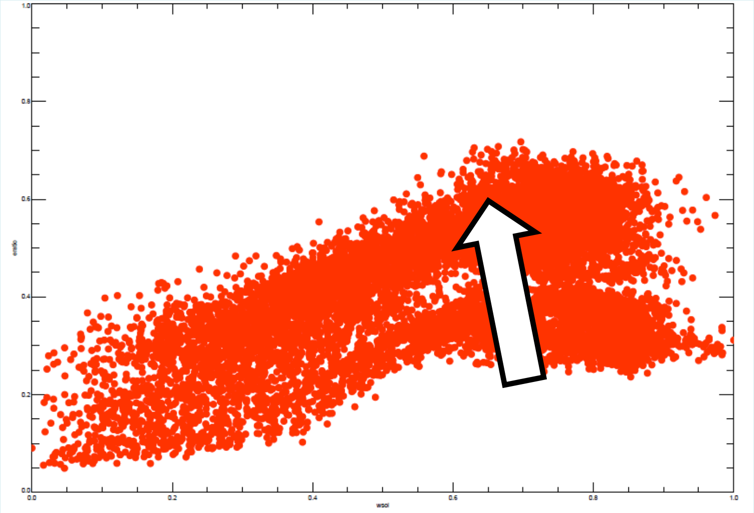


More comprehensive look at the skill scores

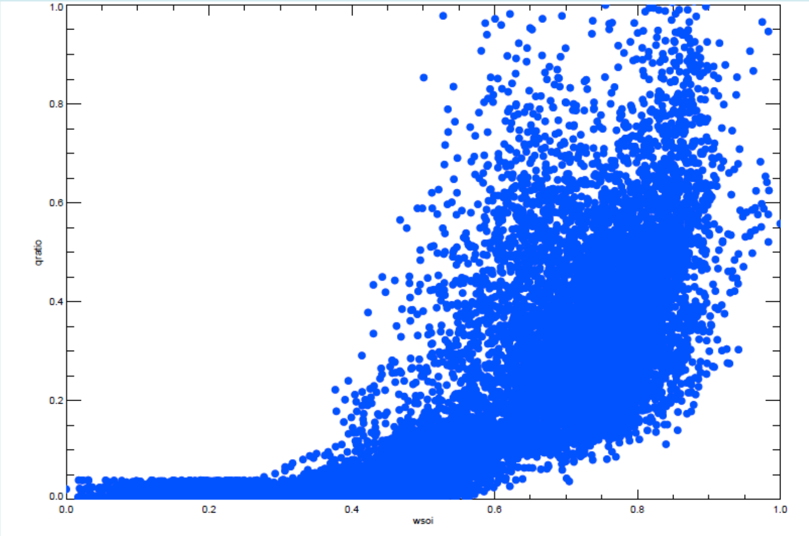


Model 1

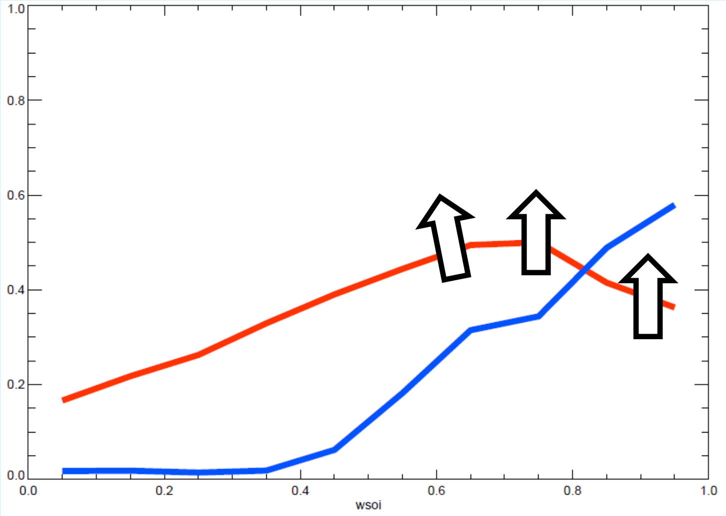
$\frac{E}{R_{net}}$



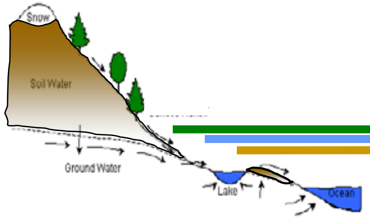
$\frac{Q}{P}$



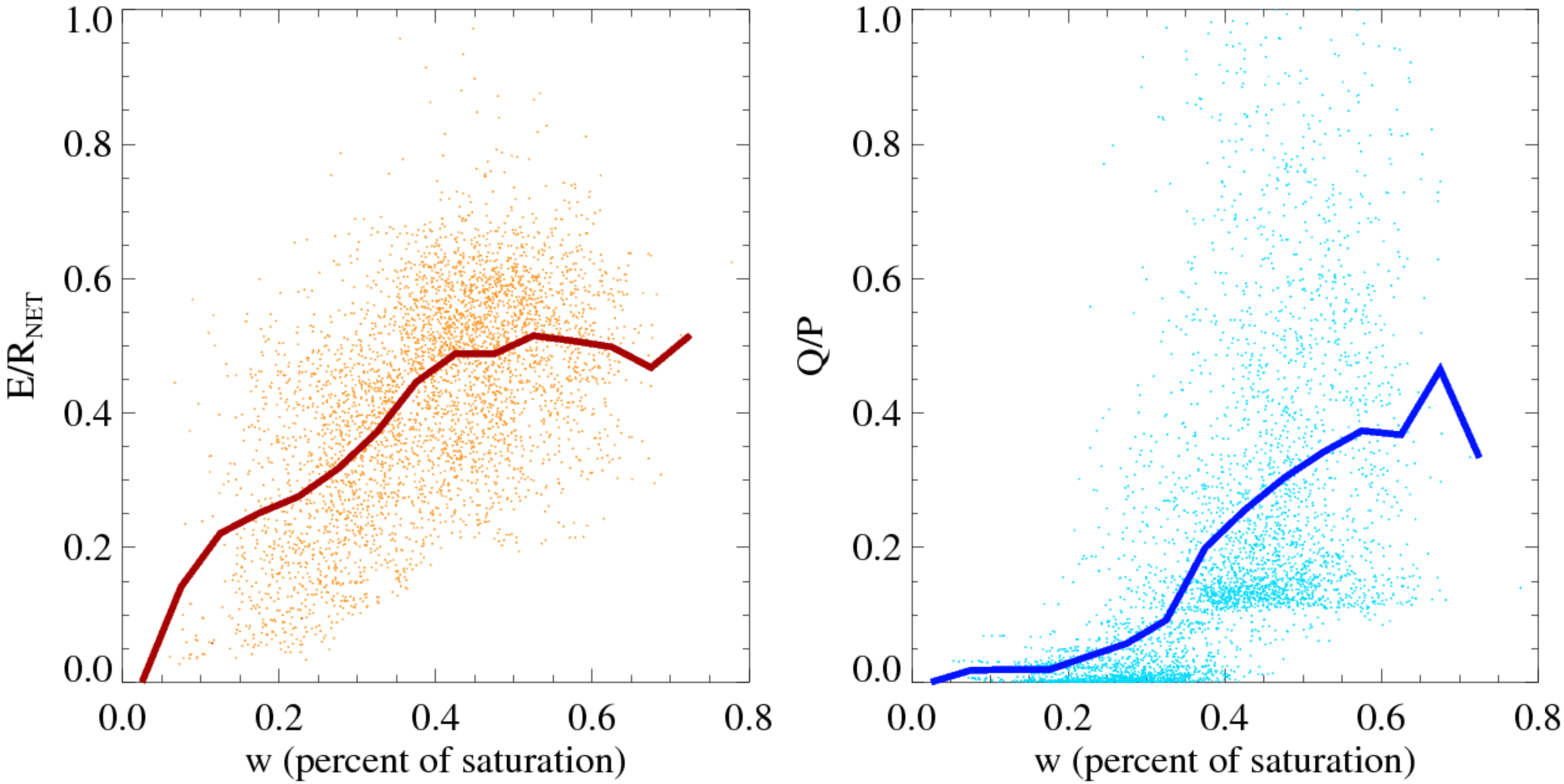
Binned functions



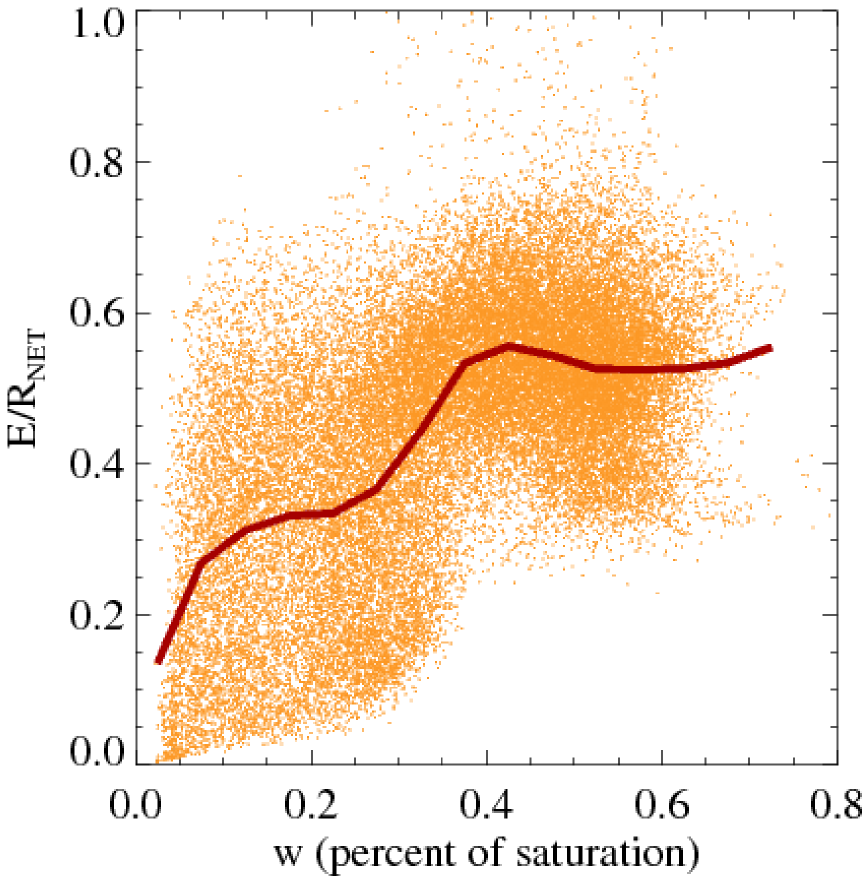
The WBM thus suggests that Model 1 developers should modify their code to increase the evaporative fractions at mid- to high-level soil moistures.


Snow
Soil Water
Ground Water
Lake
Ocean

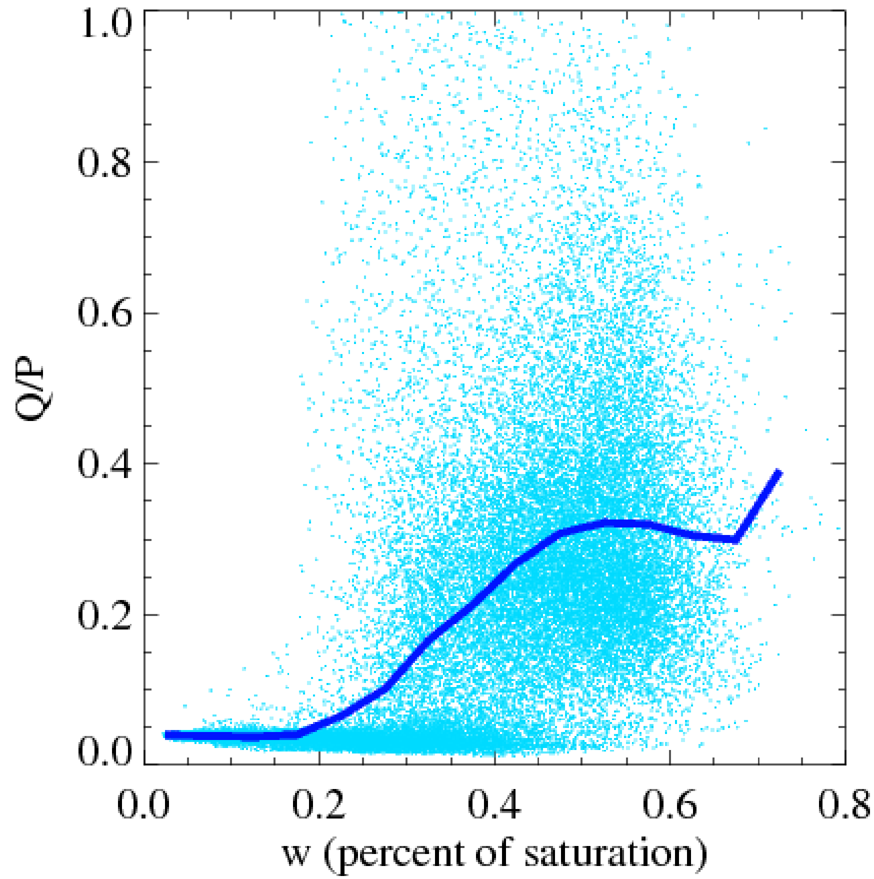
CLM4


1.0
0.8
0.6
0.4
0.2
0.0
E/R_{NET}
0.0
0.2
0.4
0.6
0.8
w (percent of saturation)
1.0
0.8
0.6
0.4
0.2
0.0
Q/P
0.0
0.2
0.4
0.6
0.8
w (percent of saturation)

CLM4.5



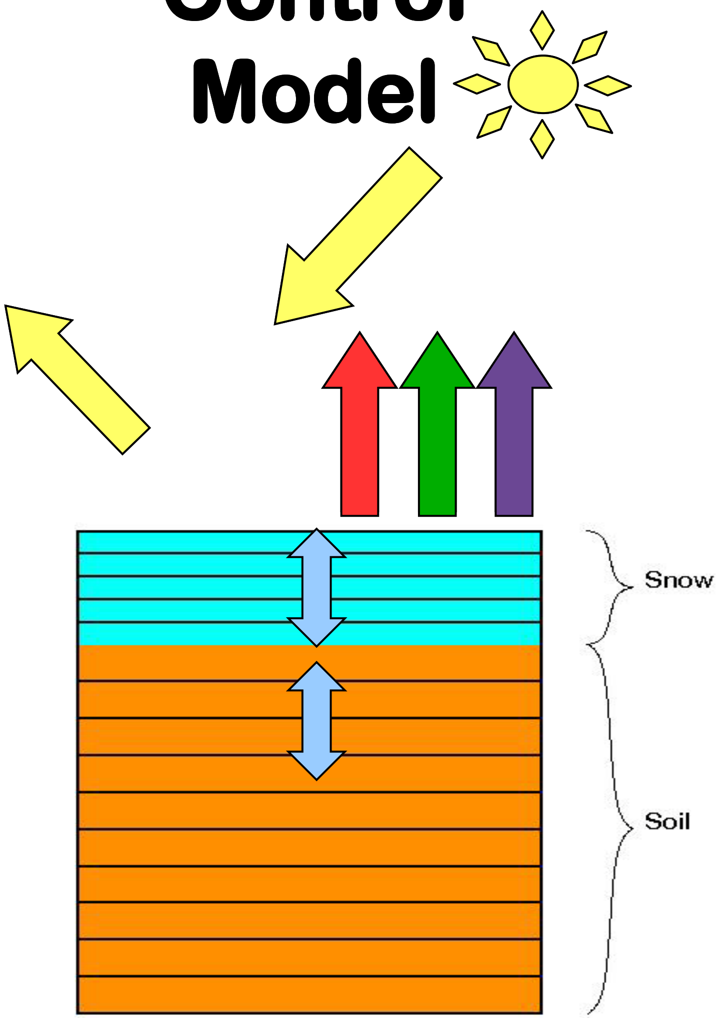
1.0
0.8
0.6
0.4
0.2
0.0
E/R_{NET}
0.0
0.2
0.4
0.6
0.8
w (percent of saturation)



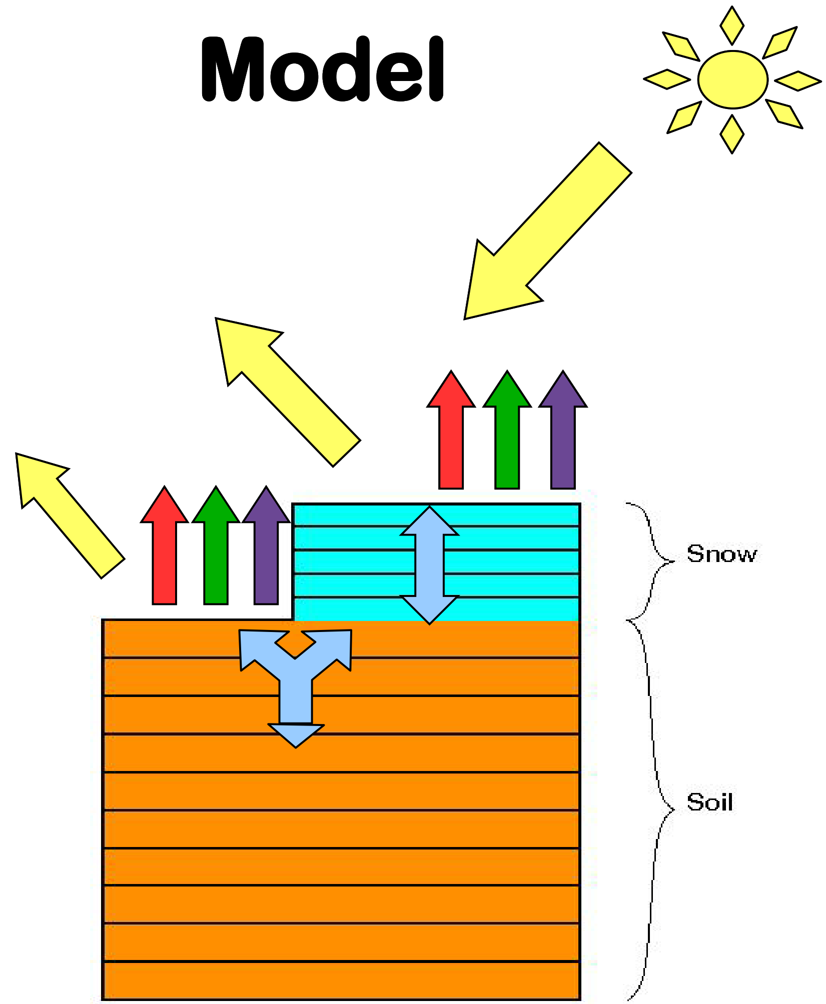
1.0
0.8
0.6
0.4
0.2
0.0
Q/P
0.0
0.2
0.4
0.6
0.8
w (percent of saturation)

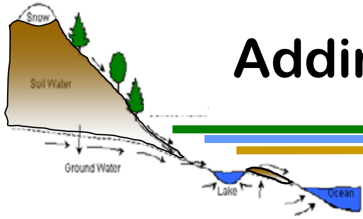
Revised surface flux calculations

Control Model

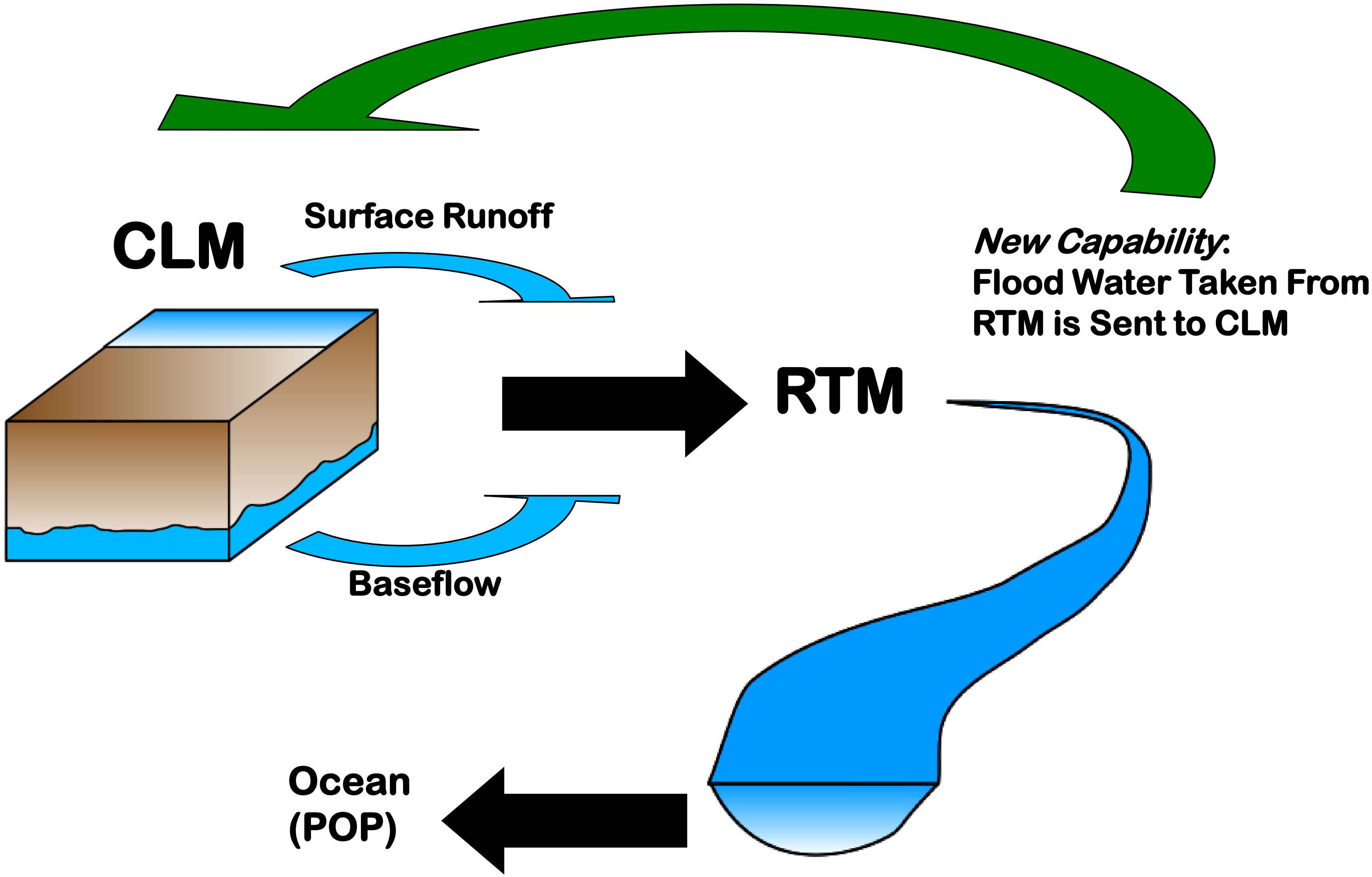


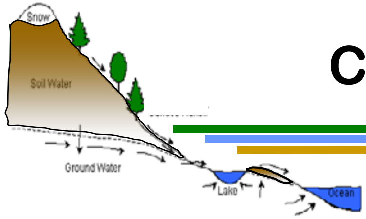
Modified Model





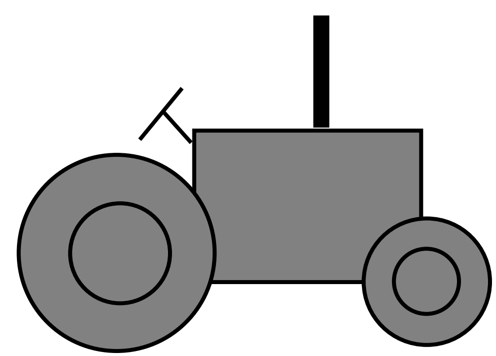
Adding Flooding Capability / 2-way CLM-RTM interactions





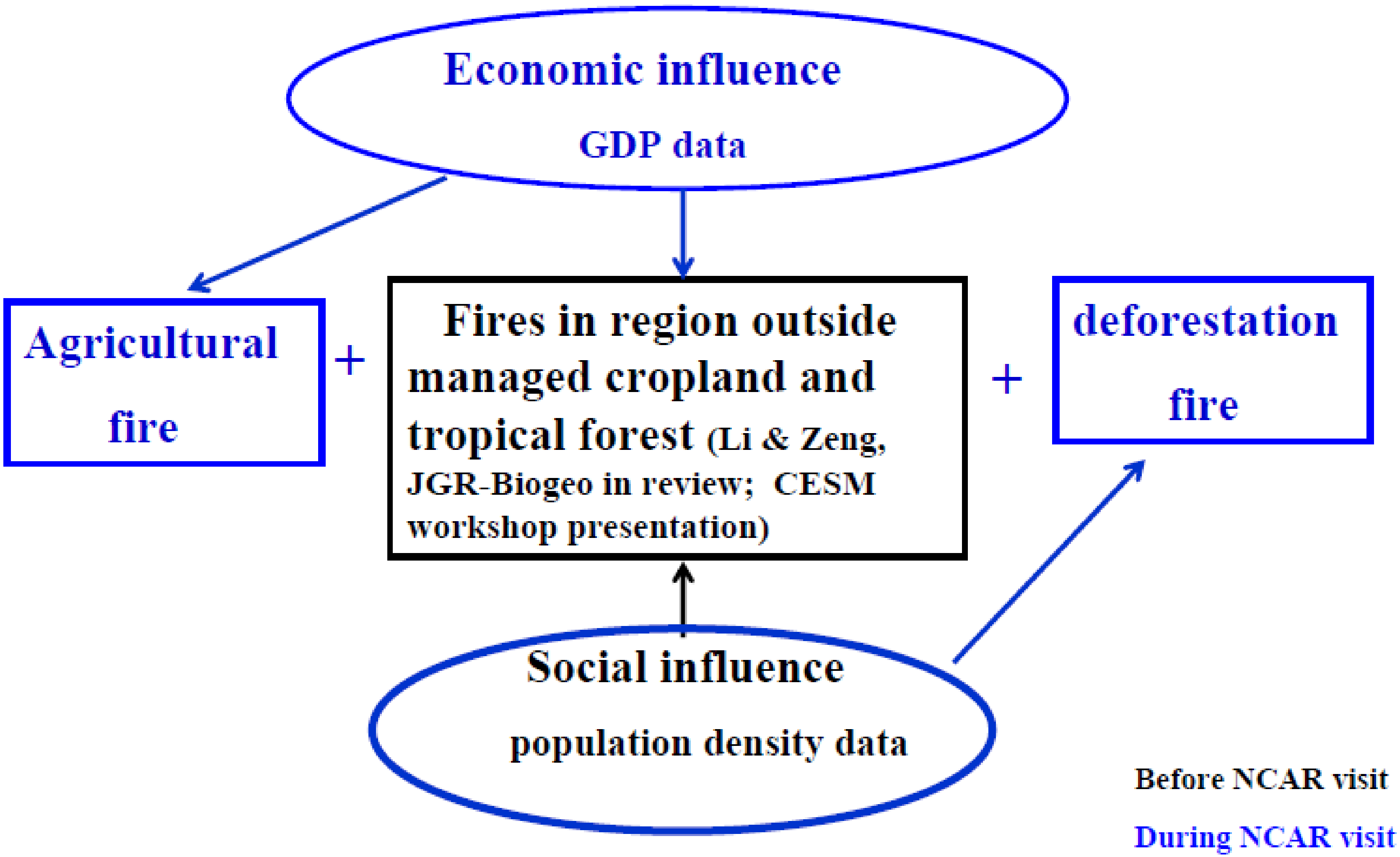
CLM4.5 (potential release with CESM update late 2012)

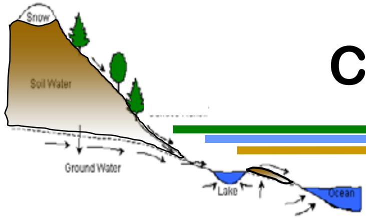
- Crop model and irrigation
  - Connect crops and irrigation
  - Interactive fertilization based on N demand
  - Separate organs/grains pool
  - New planting date dataset and phenological heat units
  - Biological N fixation for soy (legumes are N fixers)
  - Crop C:N ratios
  - N retranslocation



Newer fire parameterization scheme

(Li and Zeng, 2011; Li et al., 2012)

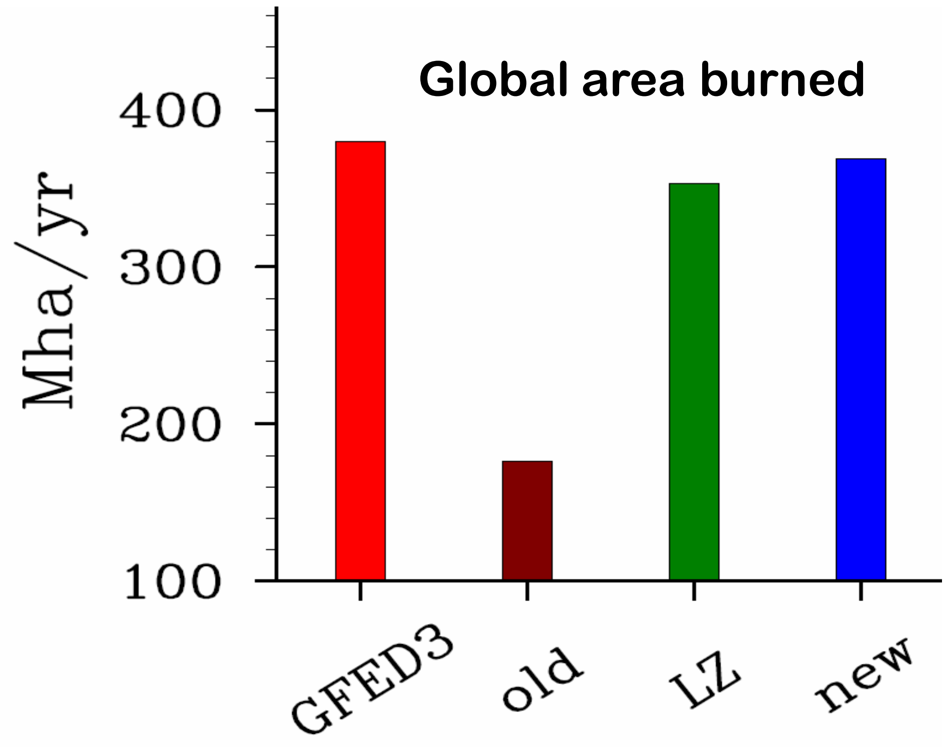




CLM4.5 (potential release with CESM update late 2012)

– Improved improved fire algorithm

- Includes human triggers and suppression (Kloster et al., 2010)
- Agricultural, deforestation fires, economic influence (Li and Zeng, 2011; Li et al, 2012)



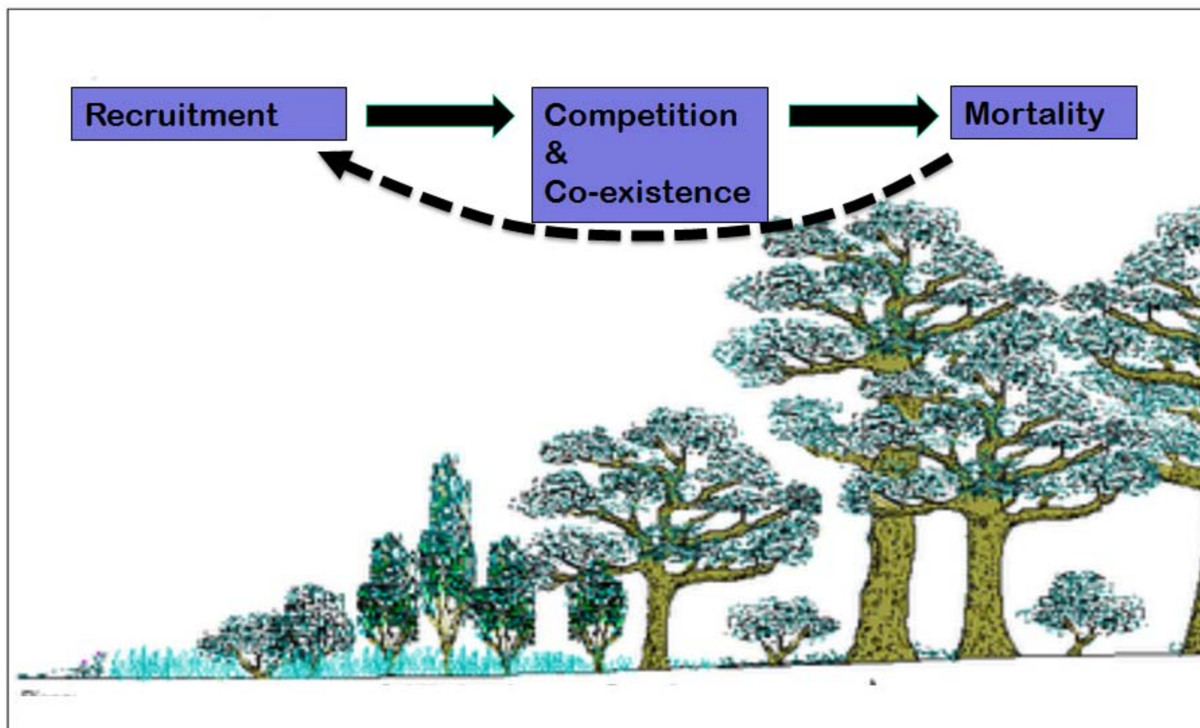
Spatial correlation
R = 0.52 Kloster
R= 0.65 Li

Carbon emissions
GFED3 = 2.1 PgC/yr
Kloster = 2.0 PgC/yr
Li = 2.1 PgC/yr

CLM4.5 (potential release with CESM update late 2012)

Additional potential options (depending on how much we can get done)

- Ecosystem demography option
- VIC hydrology option
- Infrastructure for riverine transport of nutrients, carbon, and sediments
- N_2O emissions



Planned urban model developments

- Dataset development
  - Enable multiple urban classes
  - Improved spatially-explicit representation of present-day and future urban characteristics

Low Density

Medium Density

High Density

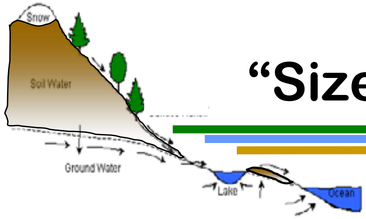
CBD

Urban Properties
- *Height*
- *H/W ratio*
- *Vegetated fraction*
- *Roof fraction*

Wall properties
- *Albedo*
- *Thermal properties*
- *Radiative properties*

Roof properties
Road properties
Interior Tsettings

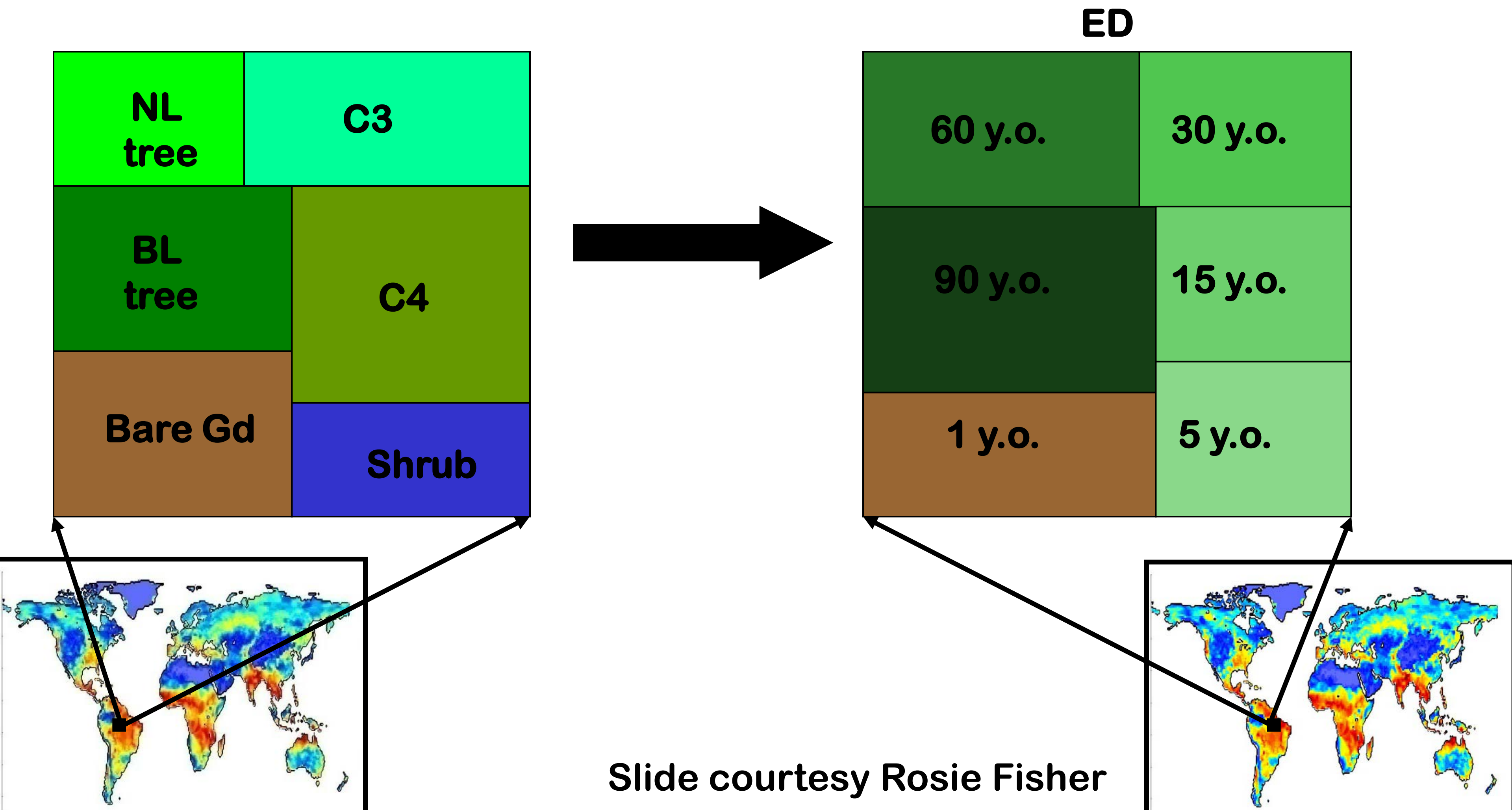
- Urban emissions (long term goal, but no active project)



Ecosystem Demography Model (ED)
"Size-and-age structured approximation of a gap model"

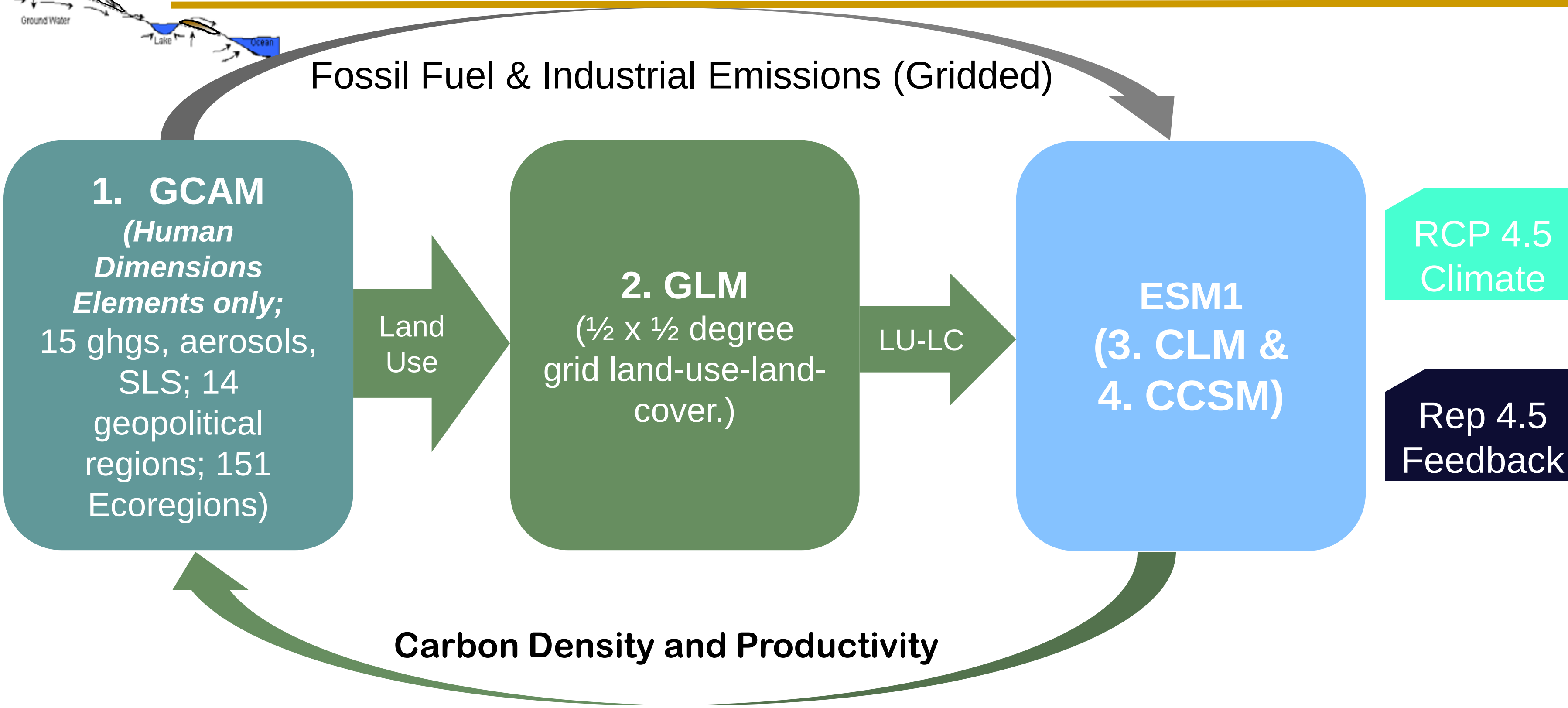
PFT-based tile structure.

Time since disturbance-based tile structure.



Slide courtesy Rosie Fisher

iESM Experiment – first approach to full coupling



- **Experiment 1: RCP 4.5, with feedback from the CLM-CCSM calculations**
  - **15-year time steps;**
  - **Lagged adjustment:**

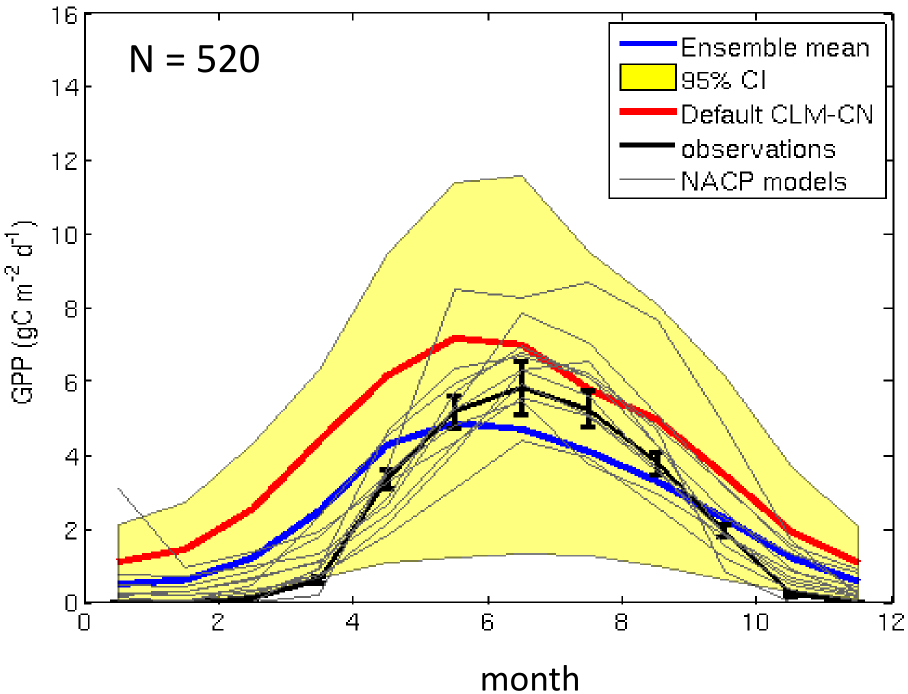
CLM-CN parameter sensitivity analysis (DOE CSSEF)

Parameter samples

mp
leafcn
flnr
froot_leaf
leaf_long
rc_npool
br_mr
q10_mr
r_mort

→ Point CLM Ensemble (1000) members

↓ Post-processing (2M files)



- Ensemble capability developed for CLM-CN point version
- Up to 1000 simultaneous point ensembles varying pft-physiology and surface data
- Nearly 50% of runs do not produce any vegetation (parameters incompatible with growth)
- Will eventually be used for model parameter calibration

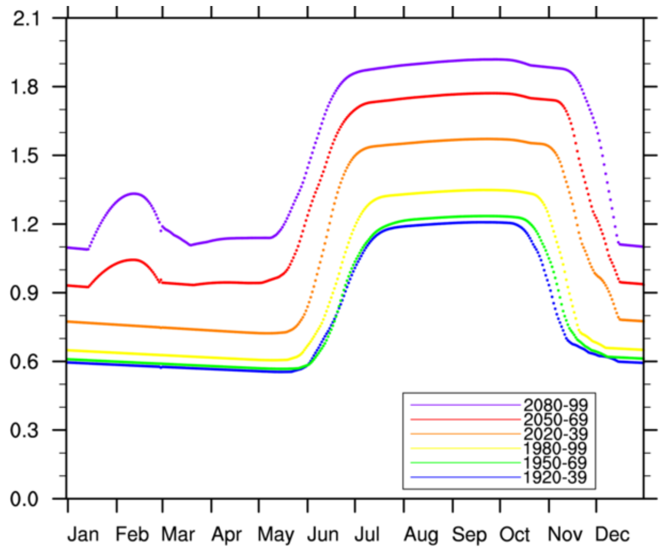
← 1000 member ensemble run at Niwot Ridge flux site, full spinup and transient simulations for each simulation

- 9 parameters varied over ranges determined by literature survey
- Comparing observations against full model uncertainty range useful for validation
- Observations suggest model has too much cold-season GPP

Slide courtesy Dan Ricciuto

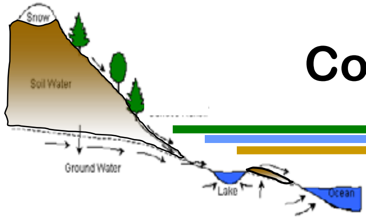
Problem with high-latitude Arctic C3 grass and boreal shrub phenology

Grid cell averaged TLAI – CLM4



stress deciduous
6 broadleaf_evergreen_temperate_tree
10 broadleaf_deciduous_temperate_shrub
~~11, broadleaf_deciduous_boreal_shrub~~
~~12 c3_arctic_grass~~
13 c3_non-arctic_grass
14 c4_grass
15 c3_crop
16 c3_irrigated

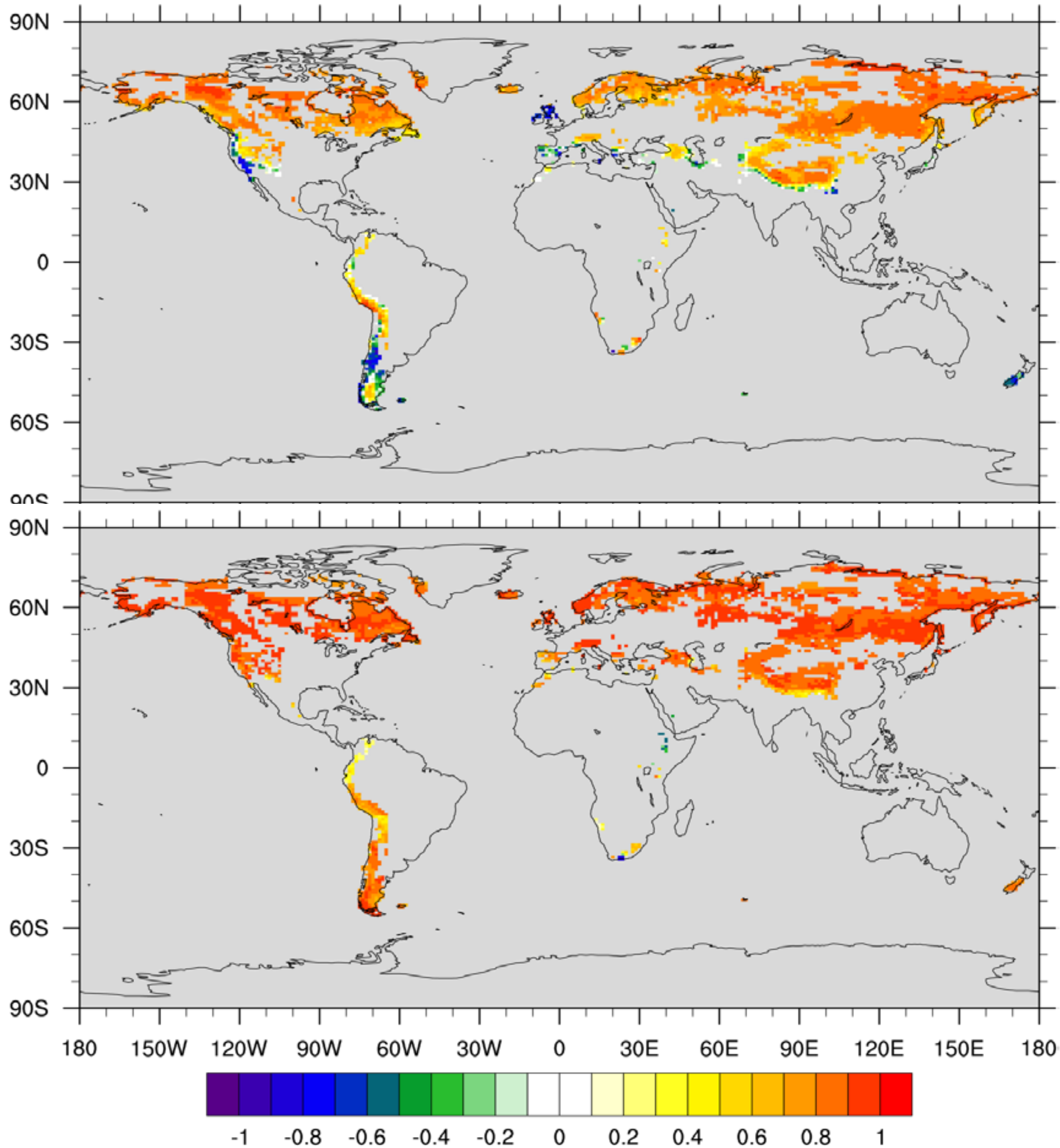
seasonal deciduous
3 needleleaf deciduous_boreal_tree
7 broadleaf_deciduous_temperate_tree
8 broadleaf_deciduous_boreal_tree
11 broadleaf_deciduous_boreal_shrub
12 c3_arctic_grass

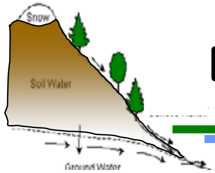


Correlation of simulated TLAI vs MODIS TLAI: boreal shrub

CLM4

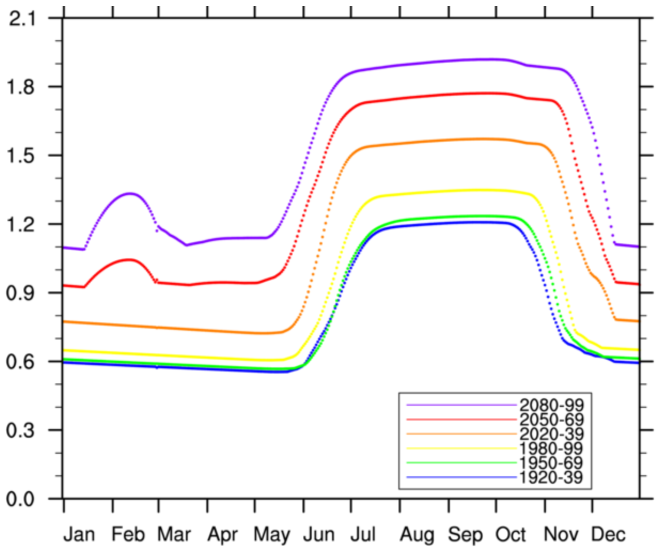
Phenology fix



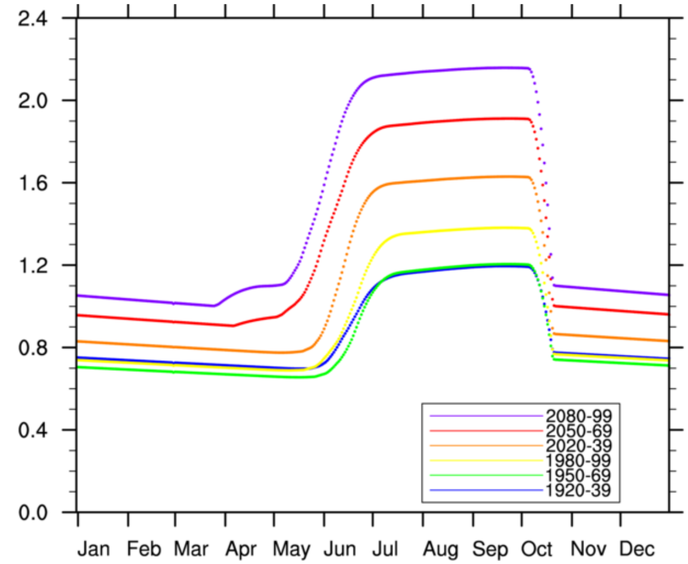


Problem with high-latitude Arctic C3 grass and boreal shrub phenology

Grid cell averaged TLAI – CLM4

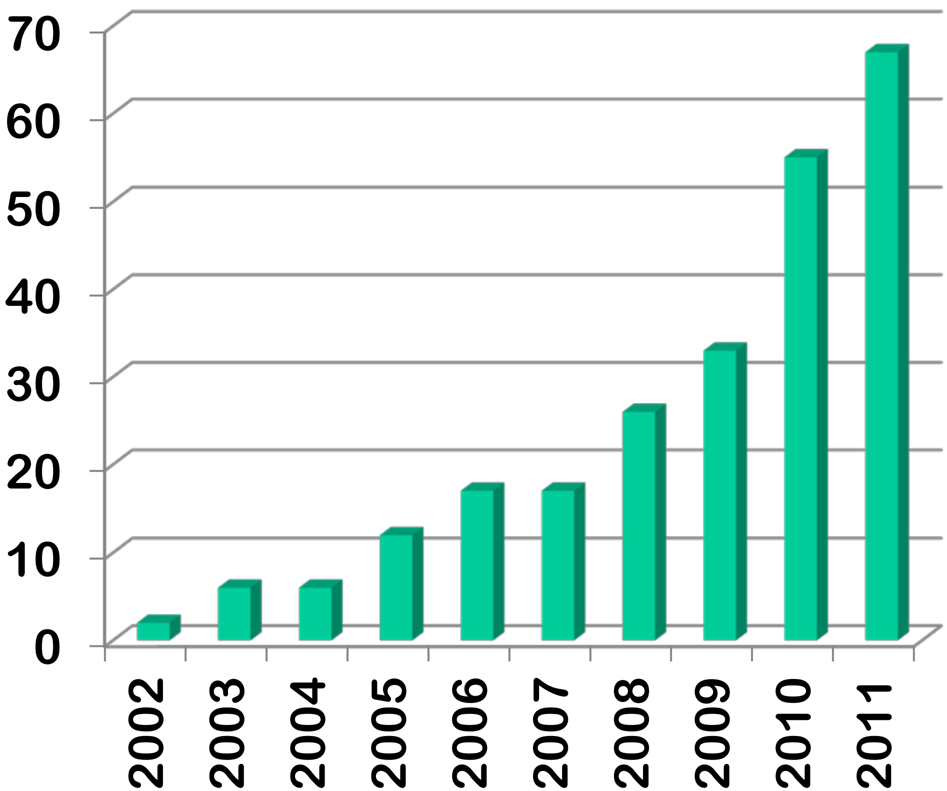


Grid cell averaged TLAI - Revised

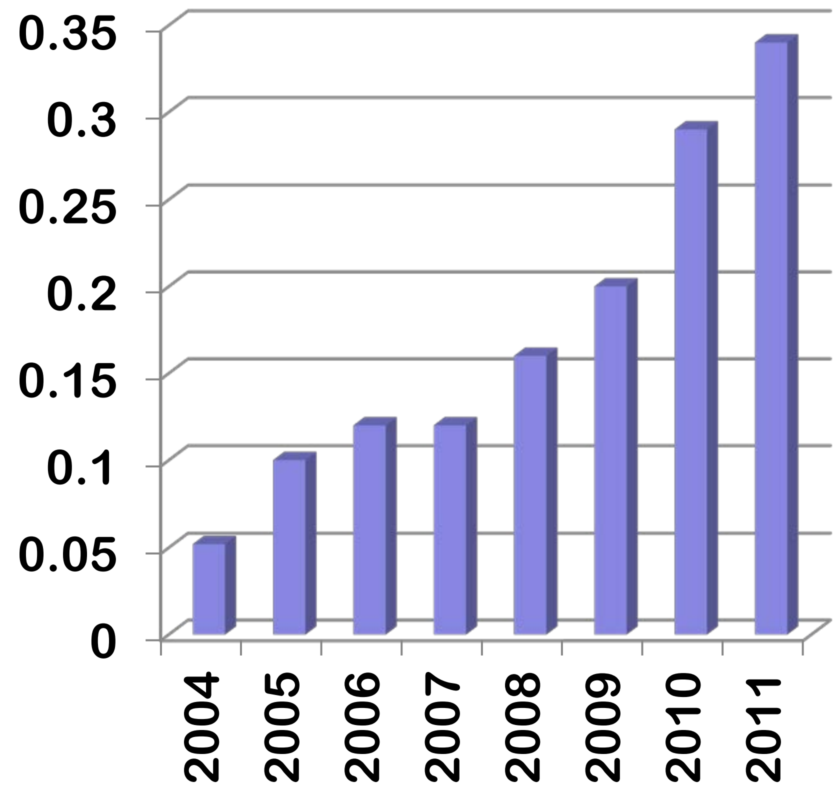


CLM at AGU

Presentations with CLM in abstract or title



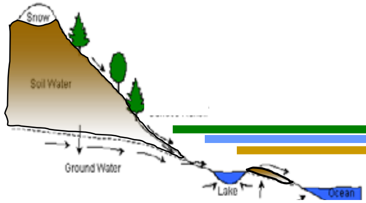
% of AGU presentations that included CLM

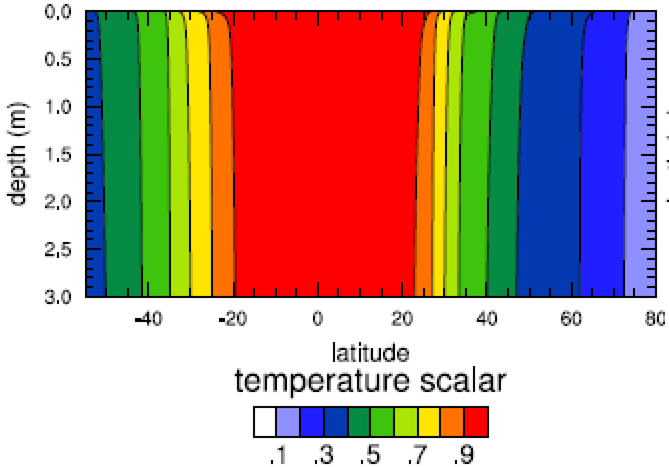


CESM1.1: High resolution input datasets

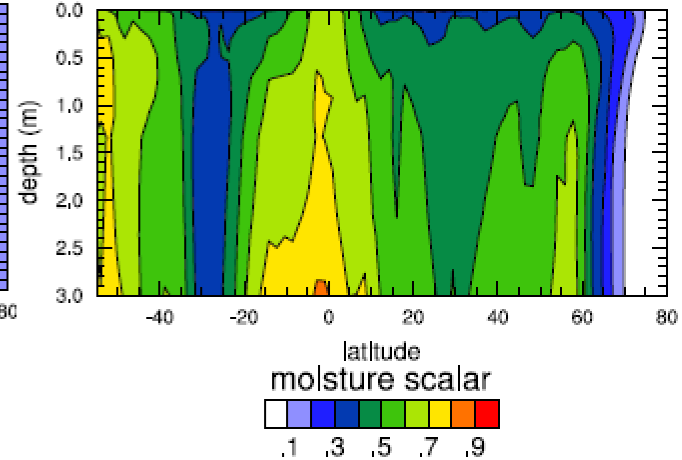
(-hires option in mksrfdat.pl)

Input dataset	CLM4 resolution	Updated resolution	Status
PFT distribution	0.5^{o} (MODIS)	3’ (MODIS)	x
LAI / SAI	0.5^{o} (MODIS)	0.5^{o} (MODIS)	x (?)
% Glacier	0.5^{o} (IGBP DISCover)	1km (Gardner) [Bill]	?
% Lake, Lake depth	0.5^{o} (Cogley, 1991)	3’ (GLWD)	x
% Wetland	0.5^{o} (Cogley, 1991)	Prognostic	x
% Urban	0.5^{o} (?)	3’ Jackson et al. 2010	x
Soil texture (%sand, %clay)	5’ (IGBP)	5’ (IGBP for now; ISRIC-WISE for multiple soil classes) [Johann]	x
Soil organic matter	1.0^{o} (IGBP)	5’ (ISRIC-WISE/NCSCD) [Dave]	x (meta)
Soil color	0.5^{o} (MODIS)	0.5^{o} (MODIS)	x
Fmax	0.5^{o}	0.125^{o} calc from HydroSHEDS	x
RTM Directional Map	0.5^{o}	0.1^{o}	x (coupling?)
Irrigation/Crop types	5’	5’ (Navin) [Sam]	X
Topography (GLCMEC)	10’ (USGS)	1km ?? (USGS)	x


Snow
Soil Water
Ground Water
Lake
Ocean


depth (m)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
-40
-20
0
20
40
60
80
latitude
temperature scalar
.1
.3
.5
.7
.9

(a)


depth (m)
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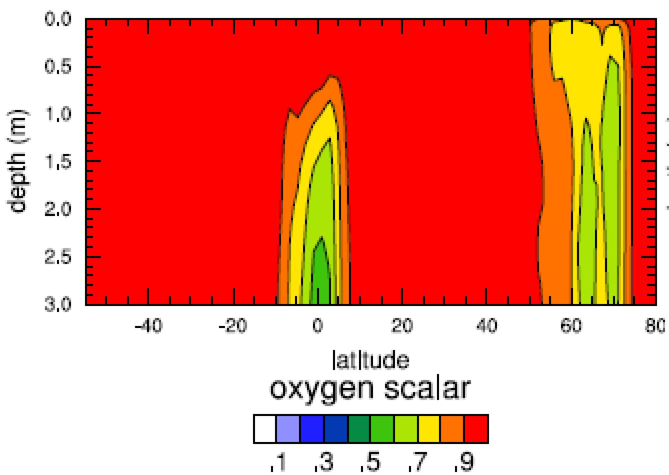
1.0
1.5
2.0
2.5
3.0
-40
-20
0
20
40
60
80
latitude
moisture scalar
.1
.3
.5
.7
.9

(b)


depth (m)
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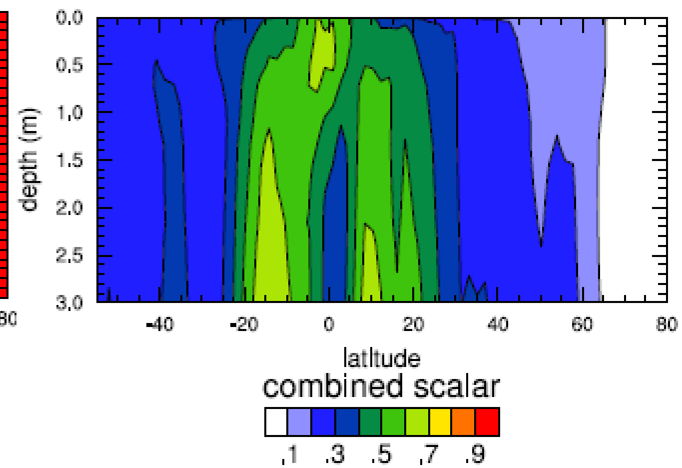
0.5
1.0
1.5
2.0
2.5
3.0
-40
-20
0
20
40
60
80
latitude
oxygen scalar
.1
.3
.5
.7
.9


depth (m)
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0.5
1.0
1.5
2.0
2.5
3.0
-40
-20
0
20
40
60
80
latitude
combined scalar
.1
.3
.5
.7
.9