CLM Update

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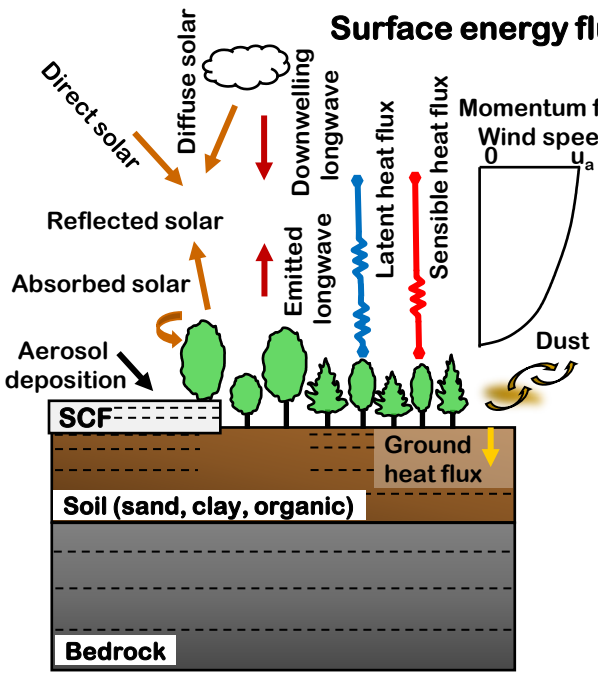
NCAR Earth System Laboratory

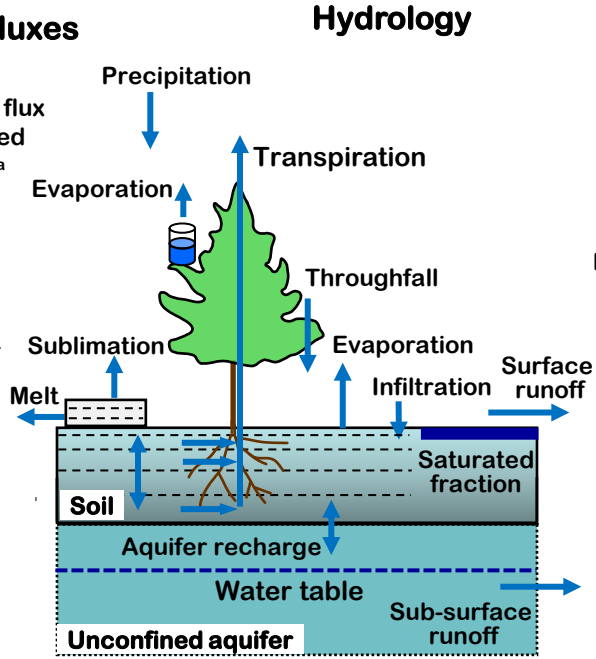
with input from members of LMWG and BGCWG

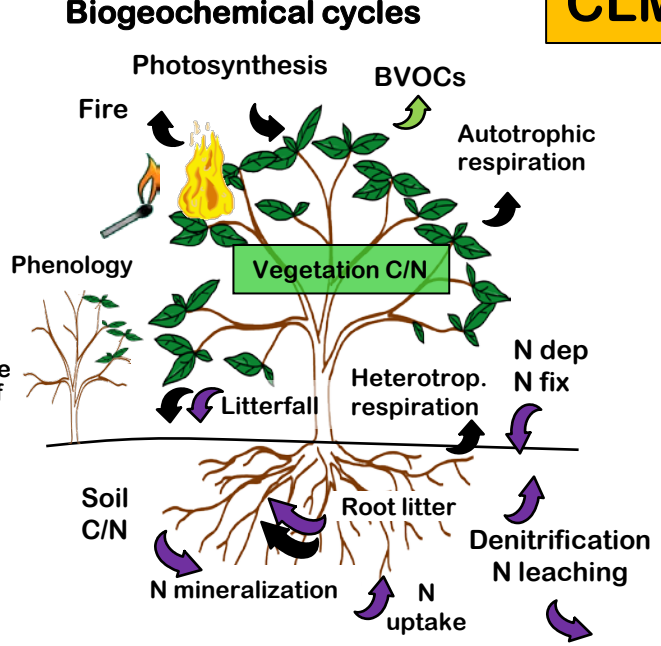
U.S. DEPARTMENT OF ENERGY

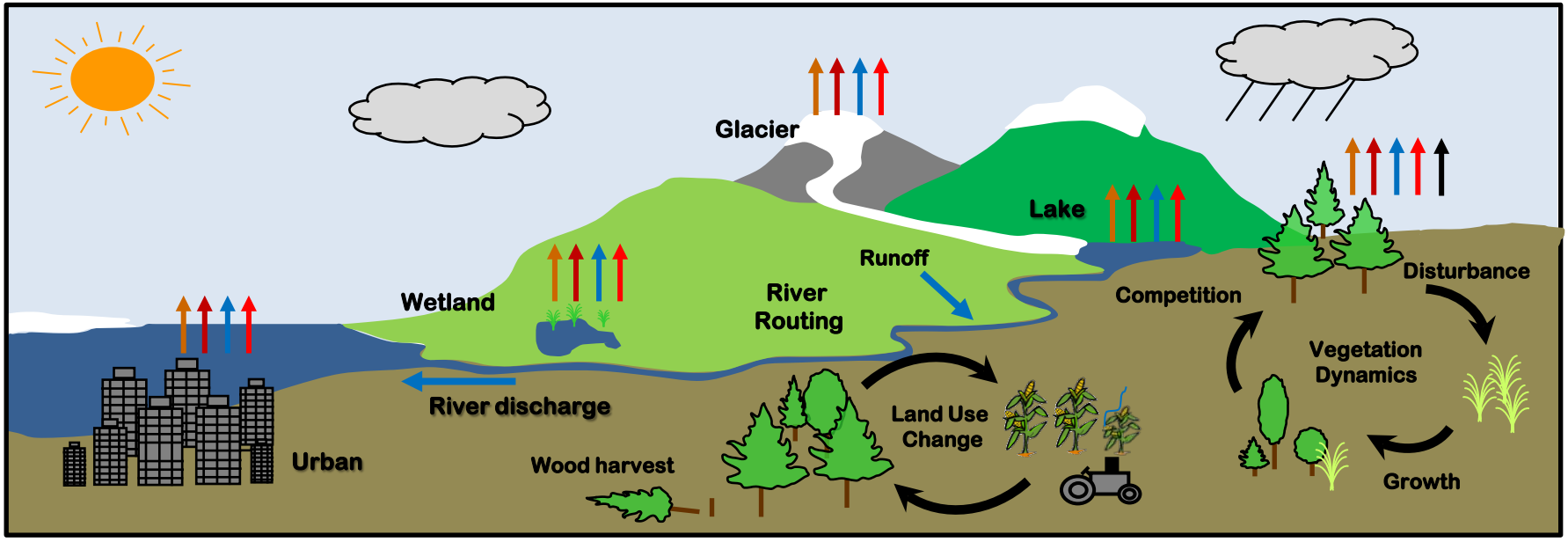
NSF

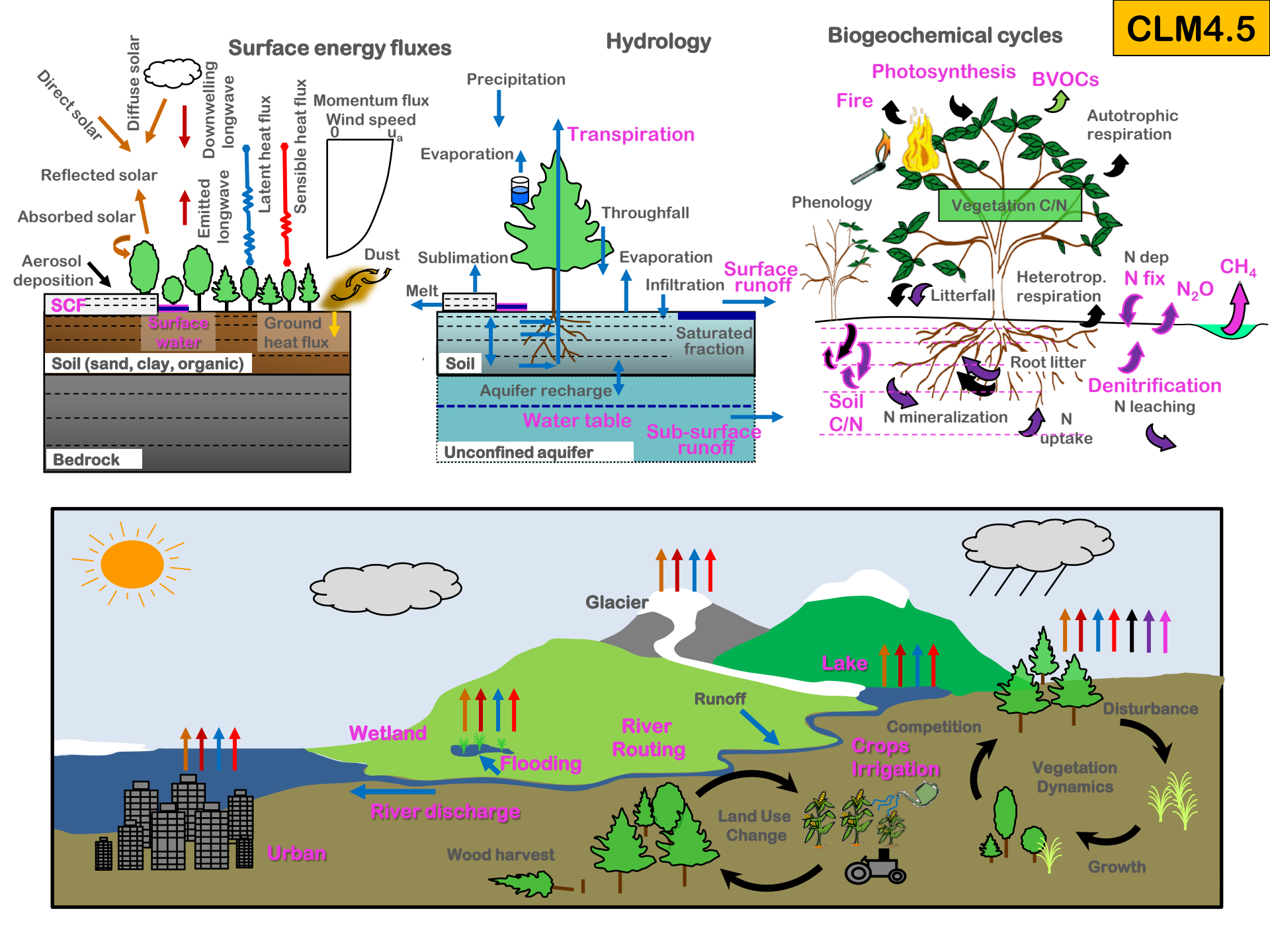
CLM4


Surface energy fluxes
Direct solar
Diffuse solar
Downwelling longwave
Latent heat flux
Sensible heat flux
Momentum flux
Wind speed
0
u_a
Reflected solar
Absorbed solar
Emitted longwave
Aerosol deposition
Dust
SCF
Ground heat flux
Soil (sand, clay, organic)
Bedrock


Hydrology
Precipitation
Transpiration
Evaporation
Throughfall
Sublimation
Evaporation
Melt
Infiltration
Surface runoff
Saturated fraction
Soil
Aquifer recharge
Water table
Sub-surface runoff
Unconfined aquifer


Biogeochemical cycles
Photosynthesis
BVOCs
Fire
Autotrophic respiration
Phenology
Vegetation C/N
N dep
N fix
Heterotrop. respiration
Litterfall
Soil C/N
Root litter
Denitrification
N leaching
N mineralization
N uptake


Glacier
Lake
Runoff
Wetland
River Routing
Disturbance
Competition
Vegetation Dynamics
River discharge
Land Use Change
Urban
Wood harvest
Growth


CLM4.5
Surface energy fluxes
Direct solar
Diffuse solar
Downwelling longwave
Latent heat flux
Sensible heat flux
Momentum flux
Wind speed
0
u_a
Reflected solar
Absorbed solar
Emitted longwave
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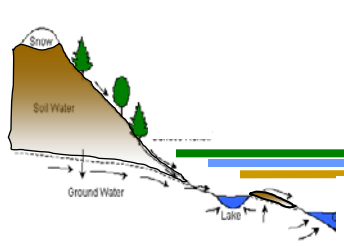

June 2013

Technical Description of version 4.5 of the Community Land Model (CLM)

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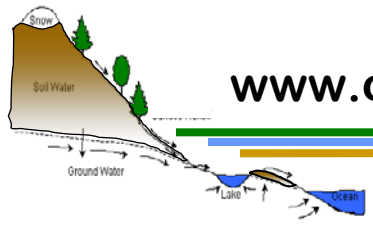
CLM configurations in CESM1.2

- **CLM4.5SP** Satellite phenology with new biogeophys
- **CLM4.5BGC** New biogeophys + CENTURY-like vertically resolved soil BGC + CH_4 emissions, nitrogen upates
- **CLM4.5CN** New biogeophys + CN soil BGC, nitrogen
- CLM4SP As in CCSM4/CESM1 release
- CLM4CN As in CCSM4/CESM1 release

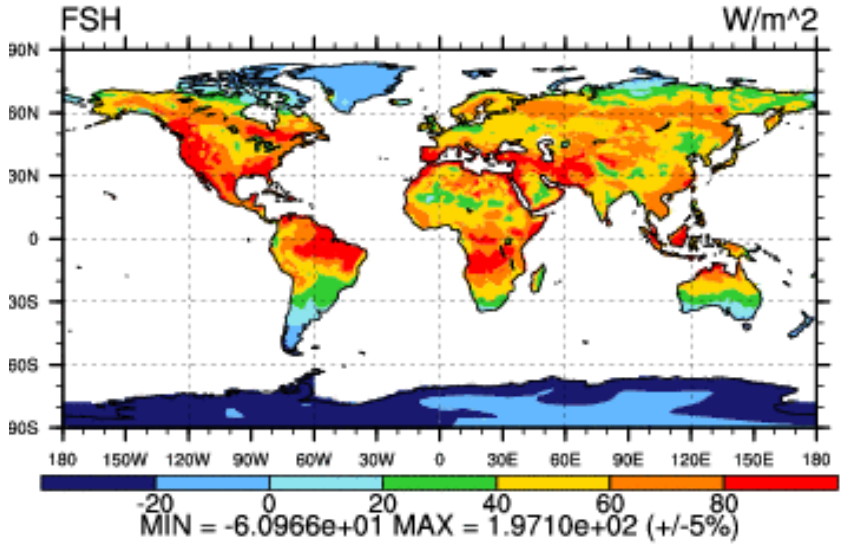
Note: crop and irrigation, VIC hydrology, and DGVM all optional for all BGC configurations

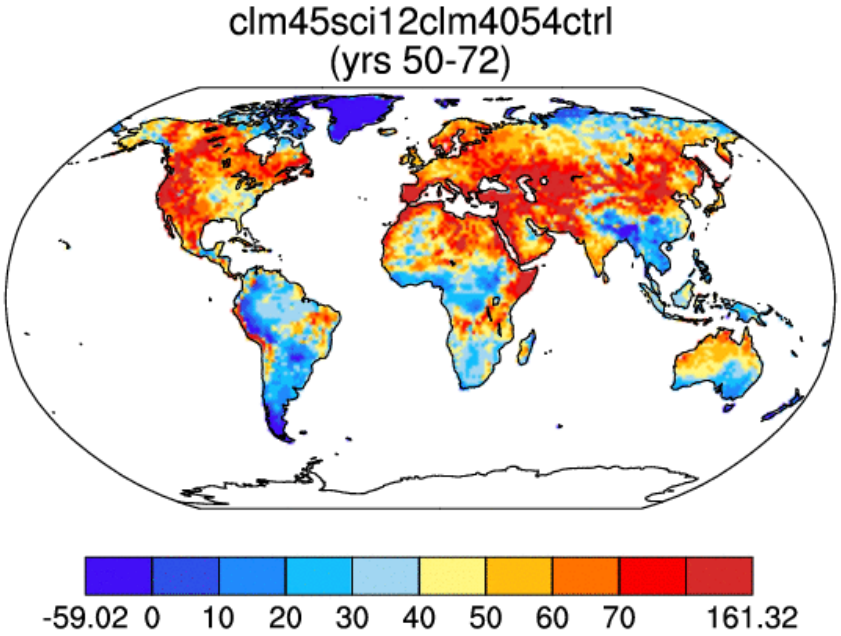


CLM Diagnostics Package

www.cesm.ucar.edu/experiments/cesm1.2/diagnostics/clm_diag.html

- Up to 5x faster
- Better plots
- New fields
- C-LAMP
- thanks to Sheri Mickelson, Adam Phillips, Keith Oleson, and Nan Rosenbloom





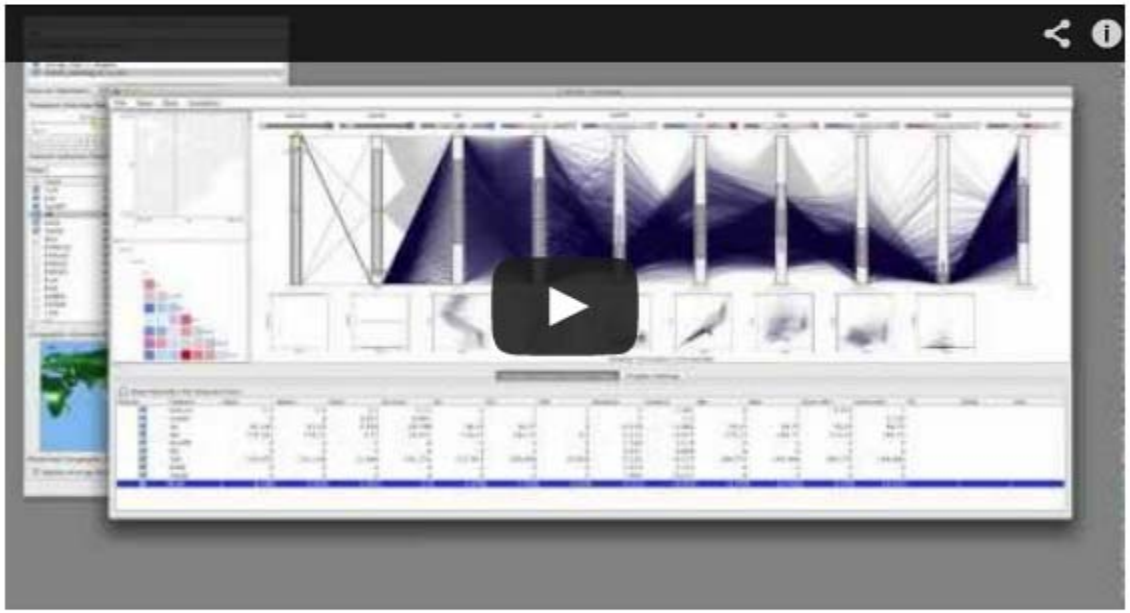
Exploratory Data analysis Environment (EDEN)

EDEN

Exploratory Data analysis ENvironment

EDEN is a visual analytics tool for exploring multivariate data sets. EDEN helps you see the associations among variables for guided analysis.

Download EDEN

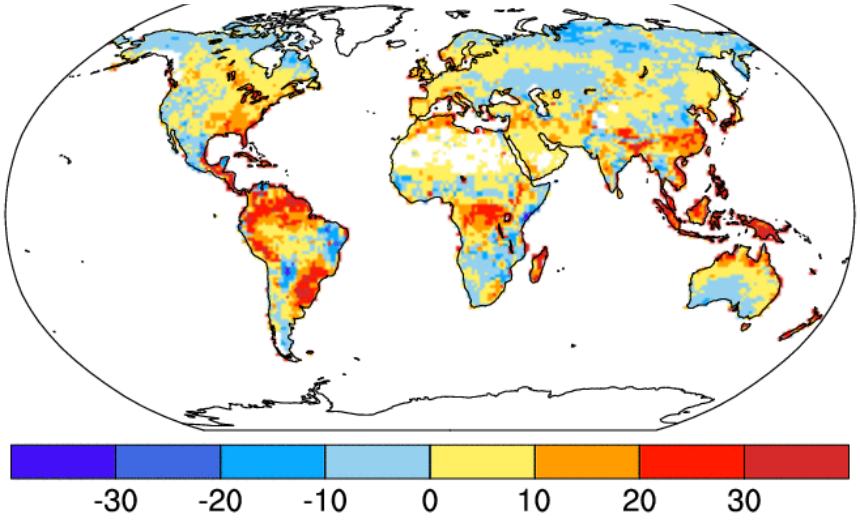


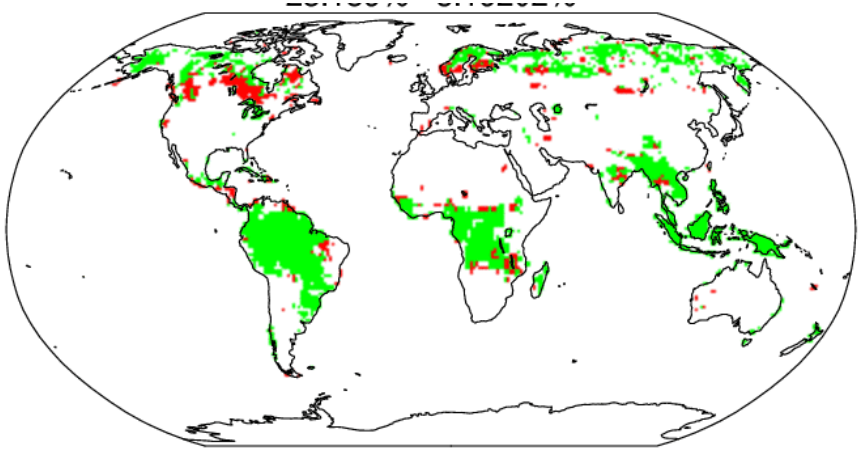
Reduced biases in CLM4.5

ANN Latent Heat bias (obs: FLUXNET MTE)

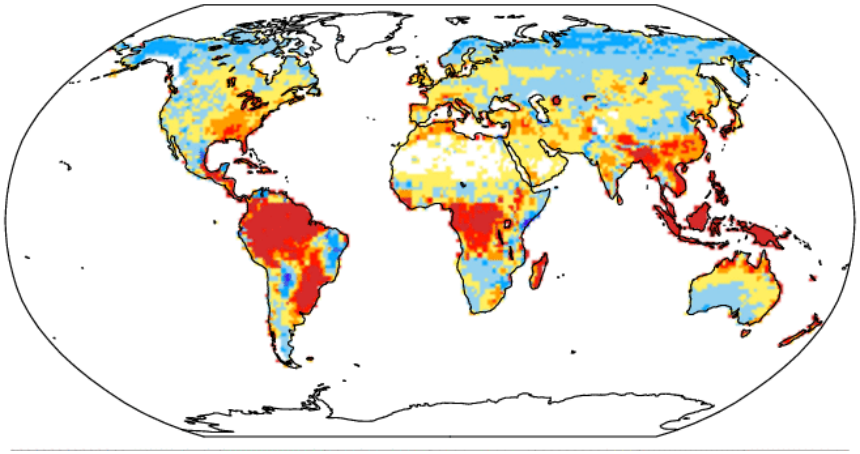
Green: Improved in CLM4.5
Red: Degraded in CLM4.5

CLM4.5BGC



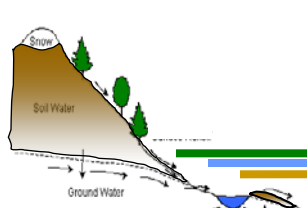


CLM4CN

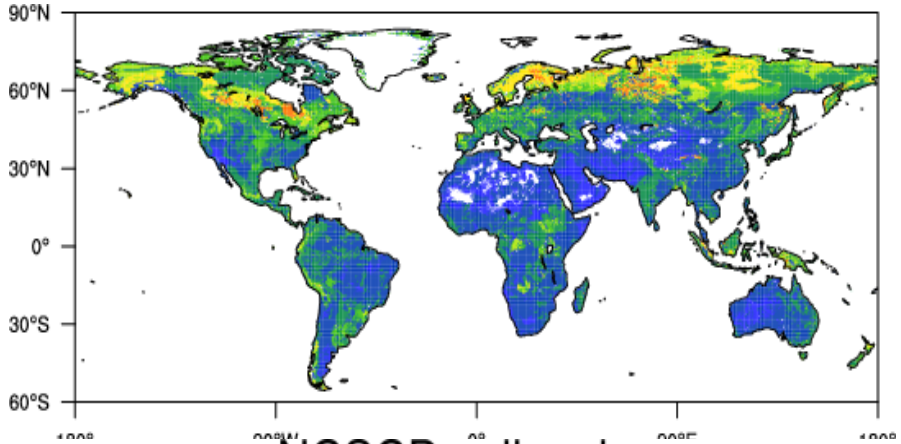


	CLM4	CLM4.5
LH (W m^{-2})	8.9	5.9
GPP (gC m^{-2} d^{-1})	0.41	0.07
Albedo (%)	-0.41	-0.52

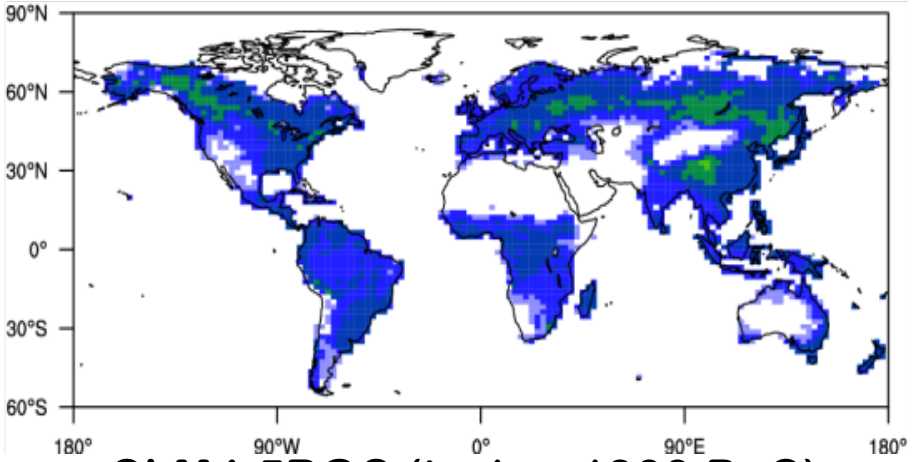
Soil carbon



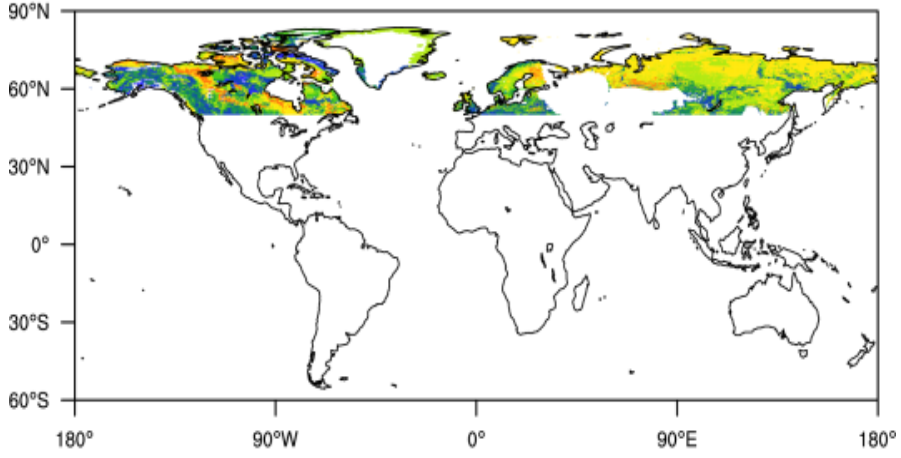
IGBP 900-1650 PgC, to 1m



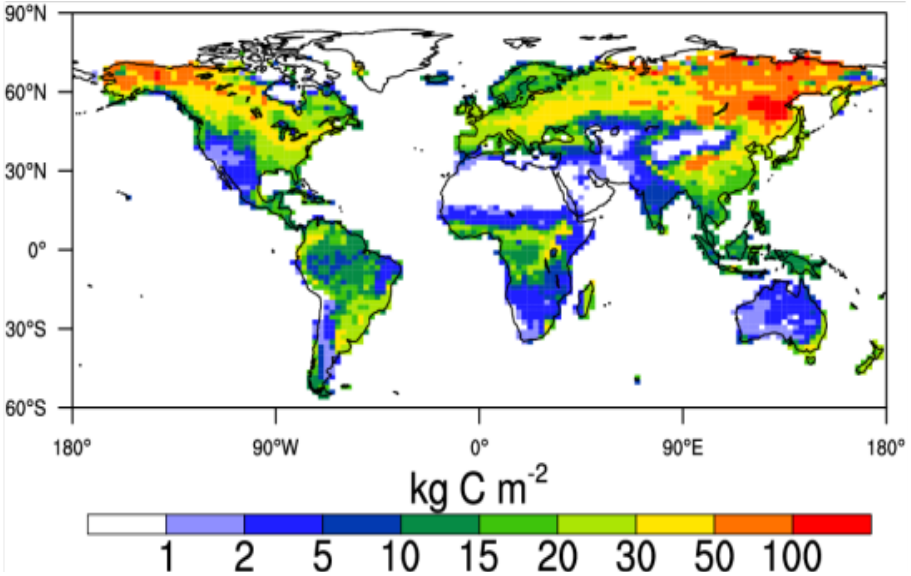
CLM4CN (650 PgC)



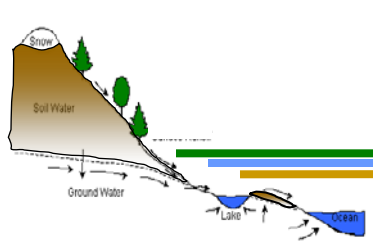
NCSCD soil carbon

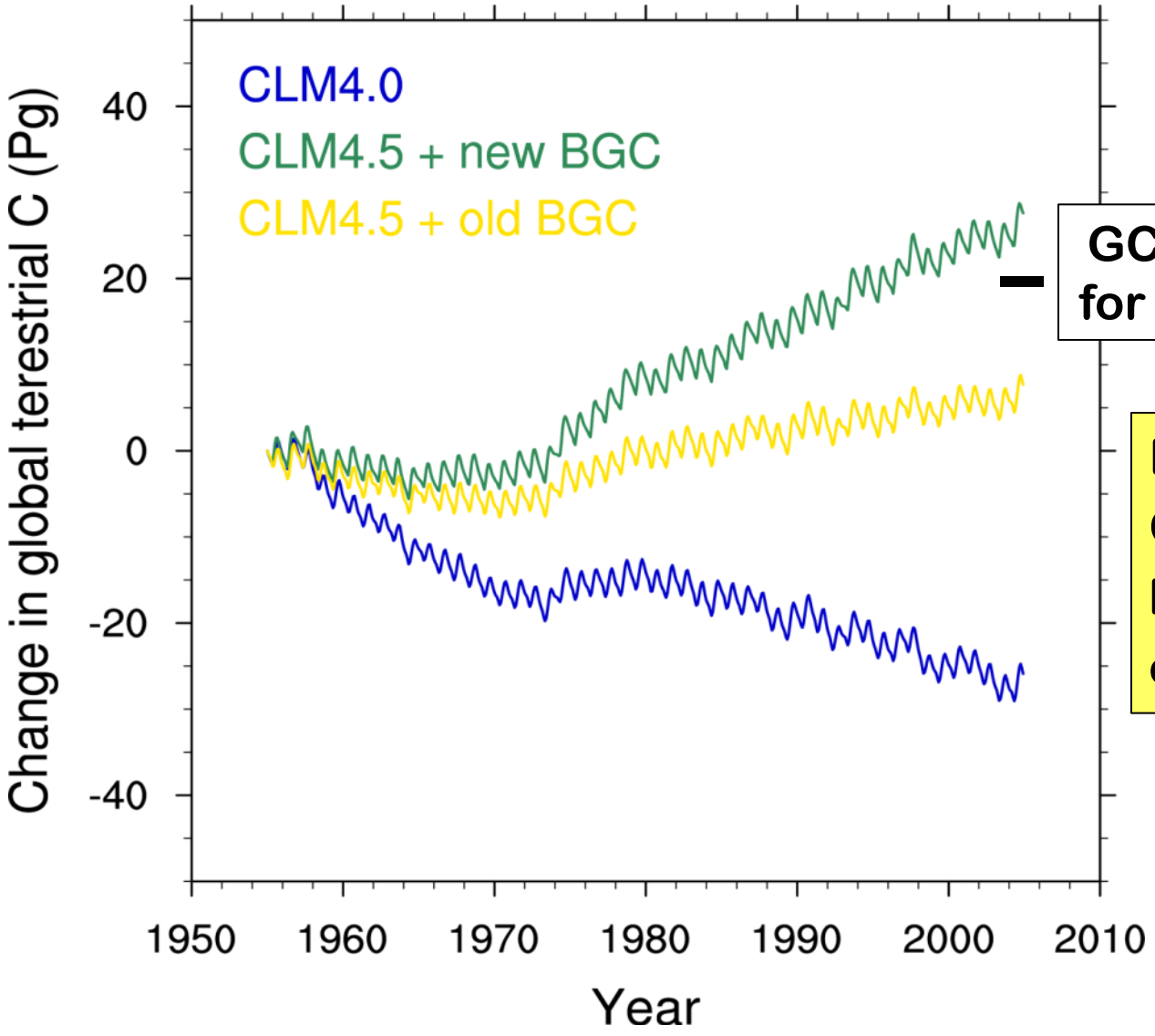


CLM4.5BGC (to 1m; 1900 PgC)



Impact of CLM4.5 model changes on global terrestrial carbon trajectory



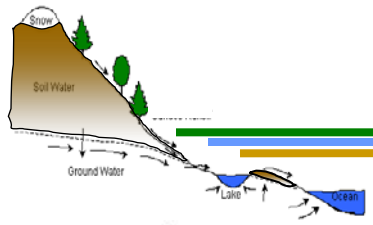


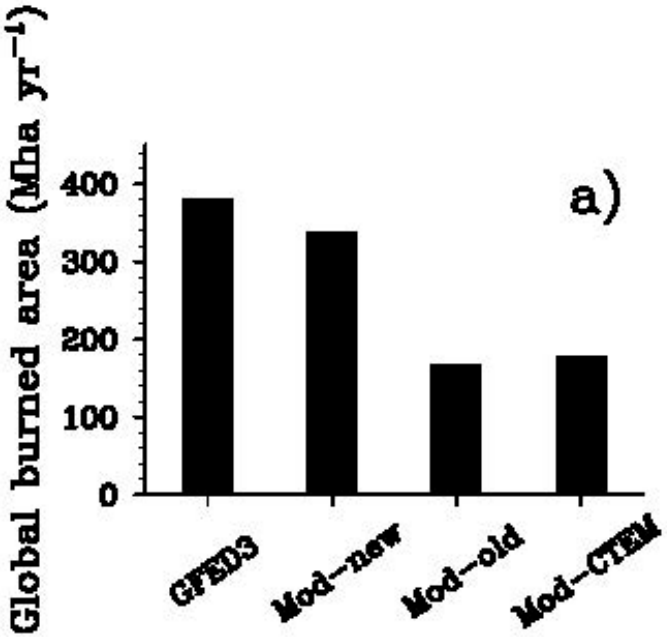
GCP estimate for land C sink

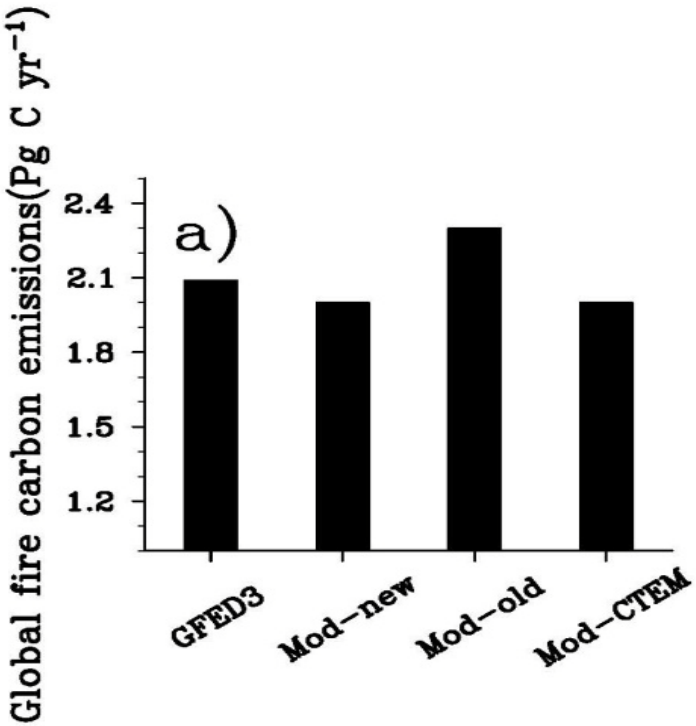
In CLM4.5, land is a C sink over latter half of 20thC, as observed

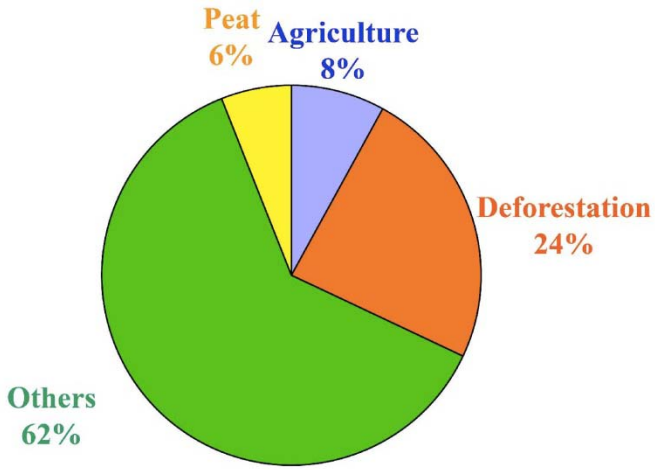
Koven et al., 2013

Fire model results



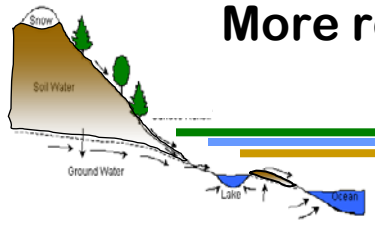






Li et al. 2013

More realistic active layer hydrology and soil hydrologic response to permafrost thaw (RCP8.5)



CLM4.5

CLM4

Soil water

ΔSoil water

mm³/mm³

Depth (m)

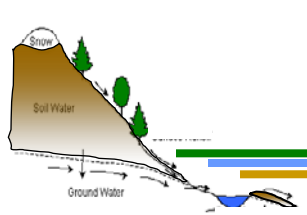
0
1
2
3

1850
1900
1950
2000
2050
2100

0.41
0.39
0.37
0.35
0.33
0.31
0.29
0.27
0.25

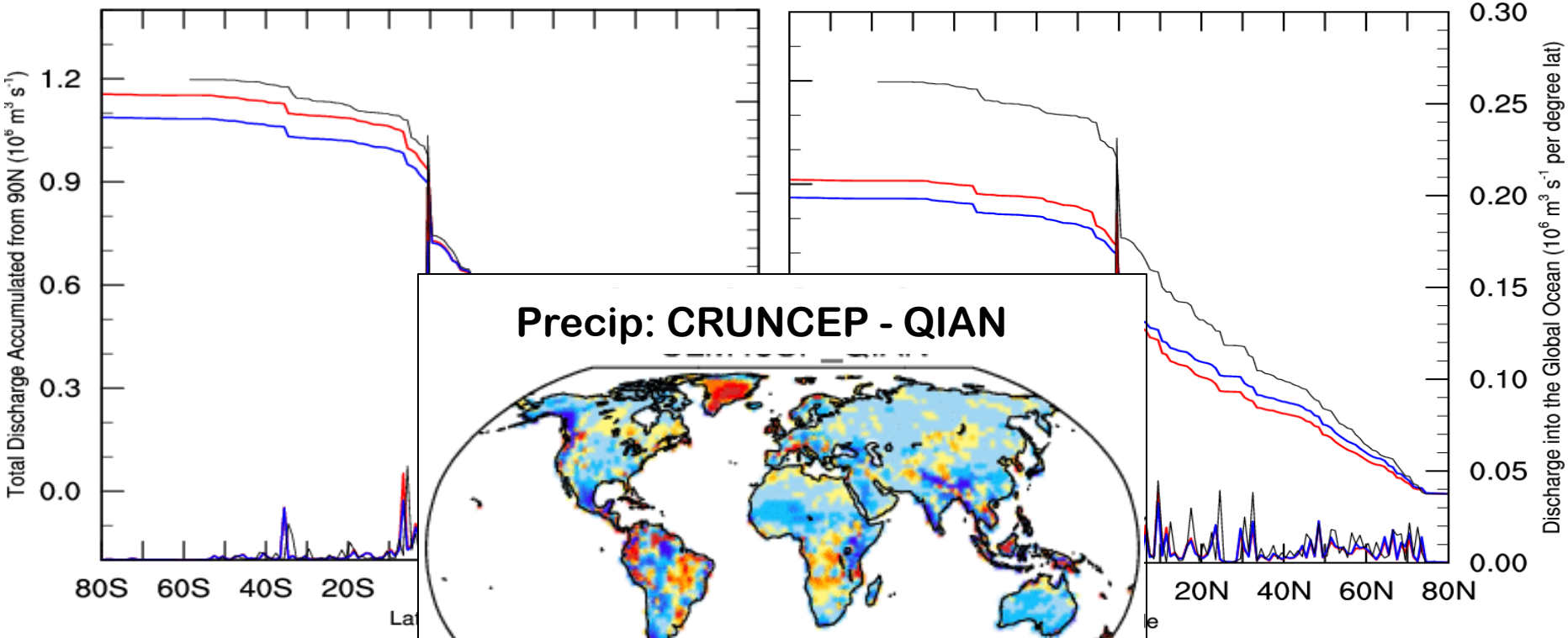
0.08
0.06
0.04
0.02
0.00
-0.02
-0.04
-0.06
-0.08

Uncertainties in atmospheric forcing
Annual river discharge into global ocean

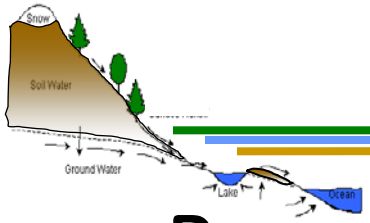


Forced with Qian (GPCP)

Forced with CRUNCEP (CRU)

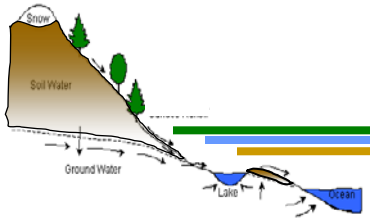


Precip: CRUNCEP - QIAN



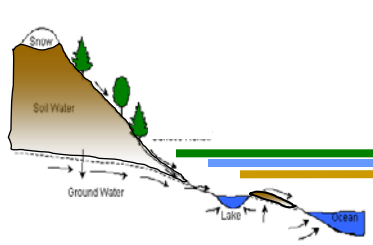
What next?

- Document CLM4.5 in a paper (or series of papers)
  - Model description
  - Metrics / benchmarks including experimental data - model comparisons
  - Atmospheric forcing uncertainty
- Code refactoring
  - Pull parameters out of code into external files, remove CPPs, pointers into associates, rationalize filters, multiple data output levels
- Refine developer protocol
- Bring Ecosystem Demography model to trunk



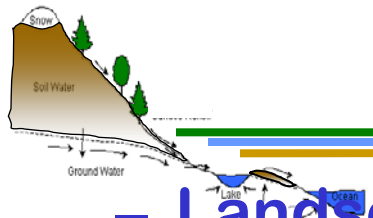
Science Questions

- "Charge to the working groups"
  - What science topics do we want to be able to address with CLM5/CESM2?
  - What missing (or poorly represented) processes or biases need to be addressed to enable these studies?



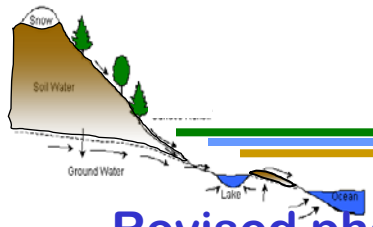
Potential development targets for CLM5

- **Nutrient dynamics**
  - Plant nitrogen uptake and allocation
  - N-gas emissions
  - Leaching and riverine transport
  - Phosphorous dynamics
- **Ecosystem disturbance**
  - Ecosystem Demography model
  - Trace gas emissions from fire
- **Evapotranspiration, partitioning of ET**
  - Unrealistic hydrologic response to land cover change
  - Soil evap, canopy turbulence, canopy evap
  - Water isotopes



Potential development targets for CLM5

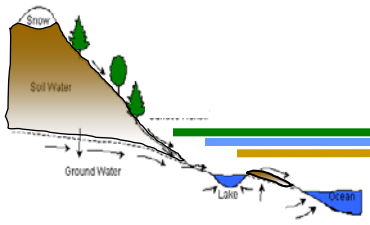
- **Landscape dynamics**
  - Dynamic landunits
  - iESM infrastructure
- **Hydrology**
  - Assess TOPMODEL-based vs VIC-based hydrology
  - MOSART routing model
  - Progress on lateral flow processes
  - Human management and withdrawals
- **Canopy processes**
  - Multi-layer, turbulence, optimization
- **Agriculture**
  - Extend crops to global
  - Additional crop management processes



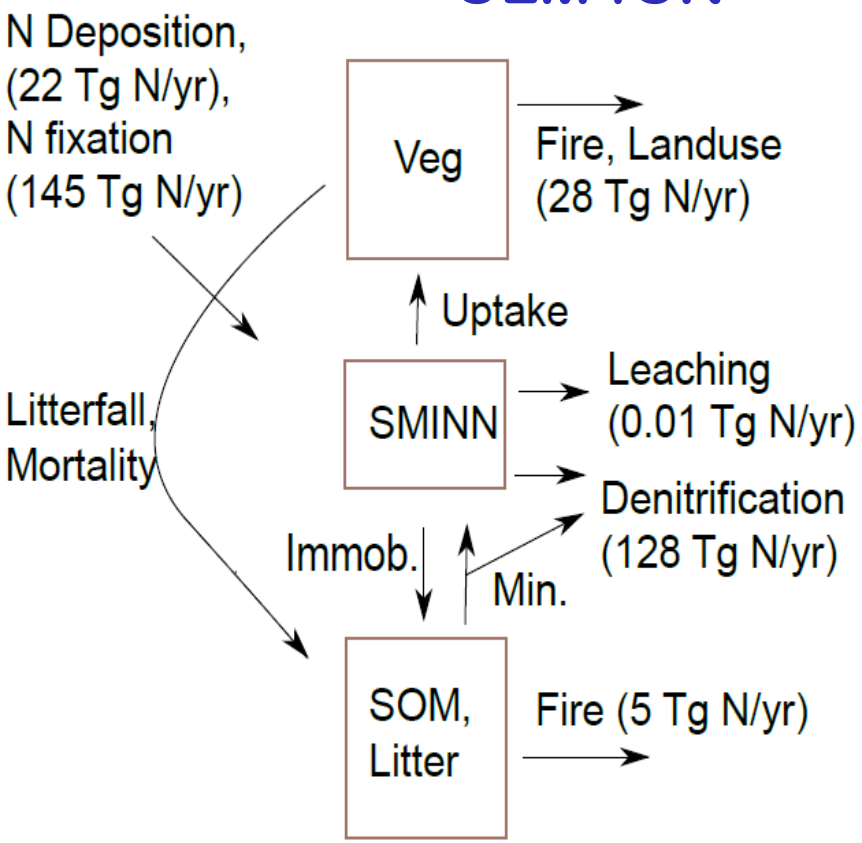
Changes for CLM4.5 for CESM1.2

- Revised photosynthesis model, multilayer canopy, temperature acclimation, iterative calculation fix (Bonan et al., 2011, 2012; Sun et al., 2012)
- Cold region hydrology and snow fix (Swenson et al. 2012, Swenson and Lawrence, 2012)
- CENTURY-like vertically resolved soil biogeochemistry with nitrogen updates (Koven et al., in prep)
- New lake model (Subin et al., 2012)
- CH_4 emissions (Riley et al., 2011; Meng et al. 2012)
- 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)
- Prognostic wetland distribution model (Swenson and Lawrence, in prep)
- CLM/RTM interactions, flooding (default off) (Swenson and Lawrence, in prep)
- 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

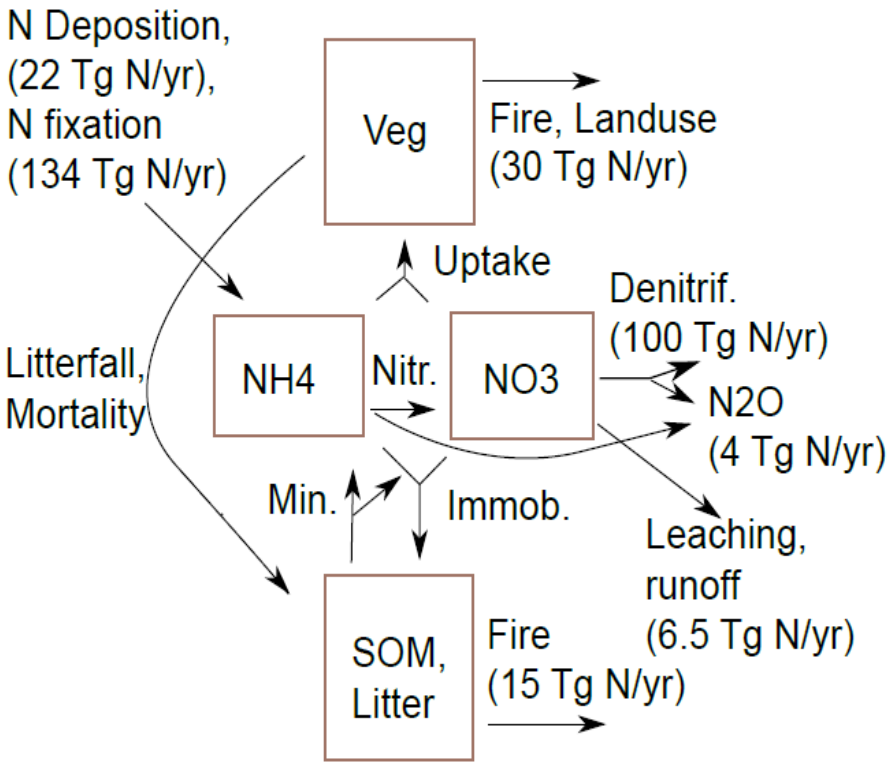
Nitrogen-cycle



CLM4CN



CLM4.5BGC

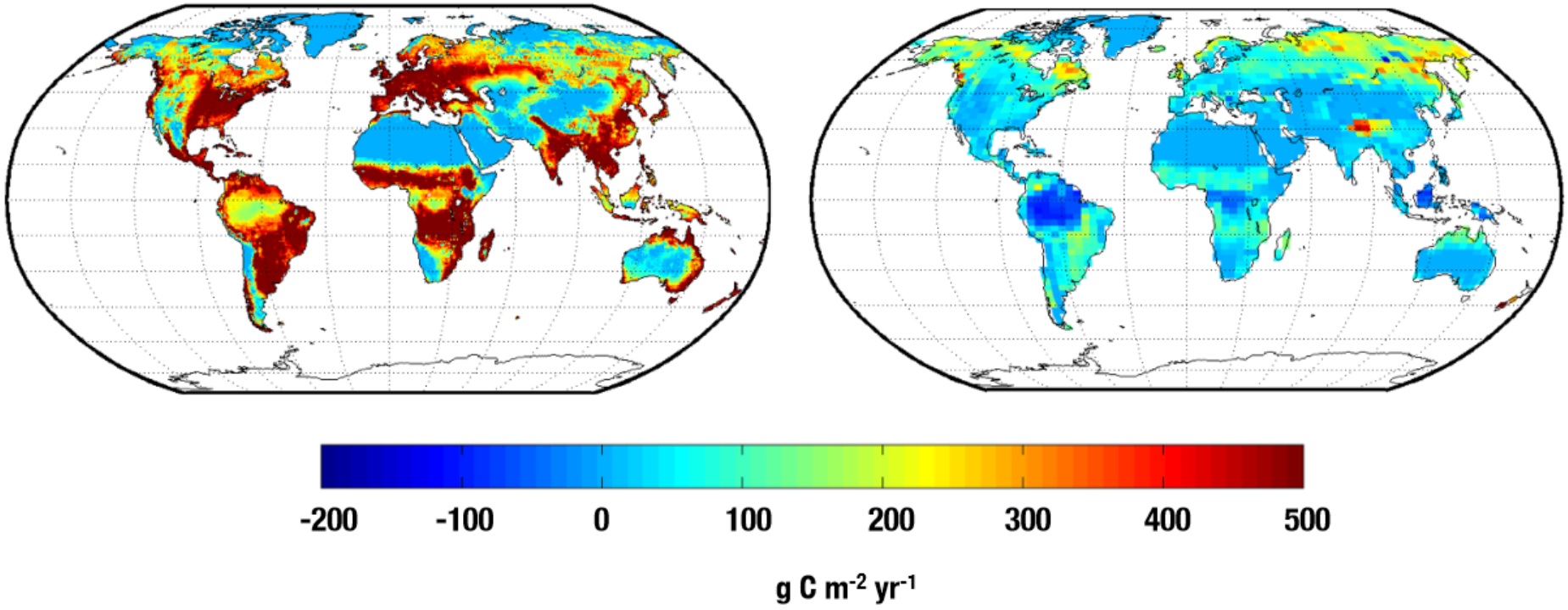


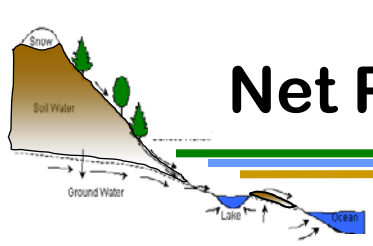
Obs (preindustrial, Galloway et al. 2004)
Deposition 17; BNF 120; Denitrification 98; Export to Rivers 70; N_2O 6

Nitrogen fertilization response

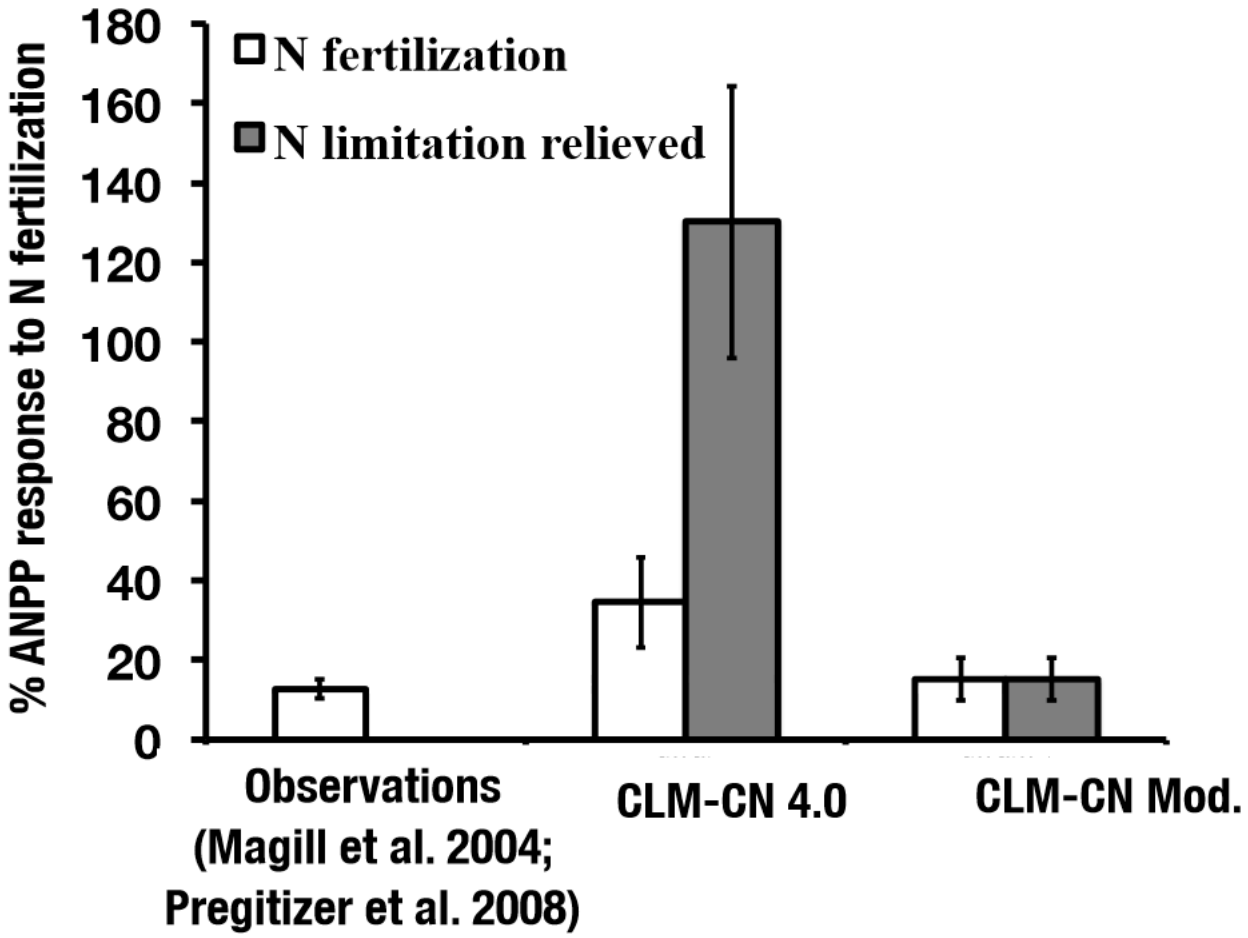
CLM-CN ΔNet Primary Productivity

O-CN ΔNet Primary Productivity



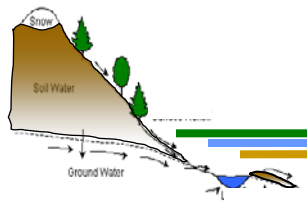


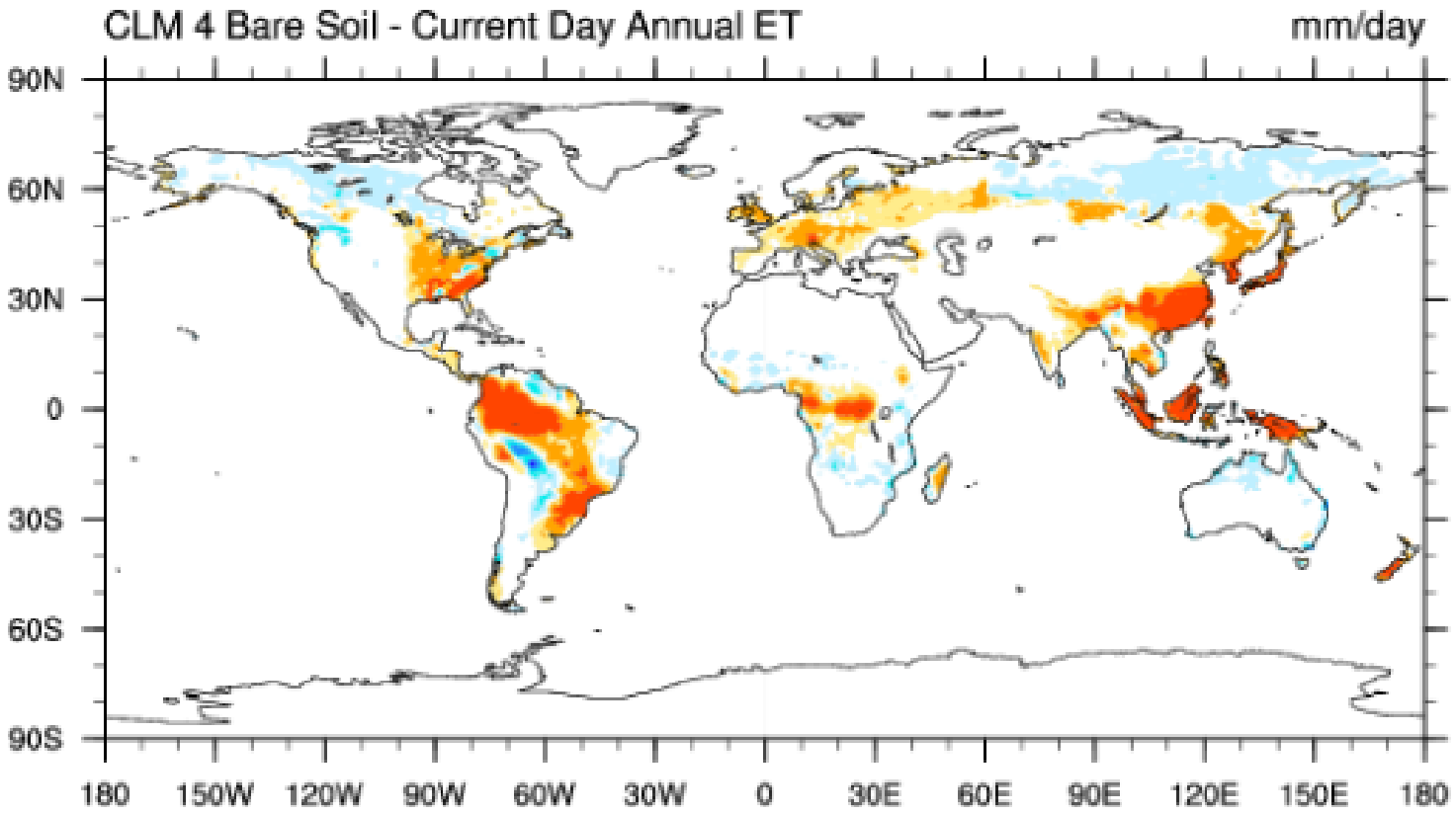
Net Primary Productivity response to N fertilization



Thomas et al. 2012

Complete removal of vegetation experiments



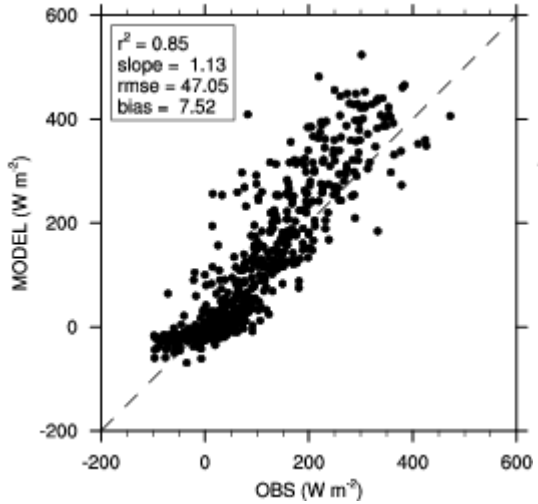


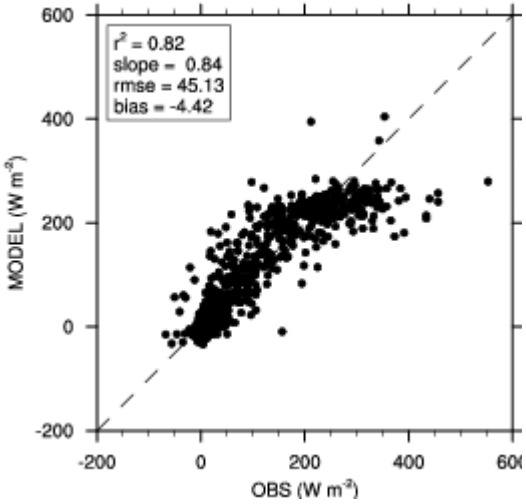
Bare soil has higher ET than forests

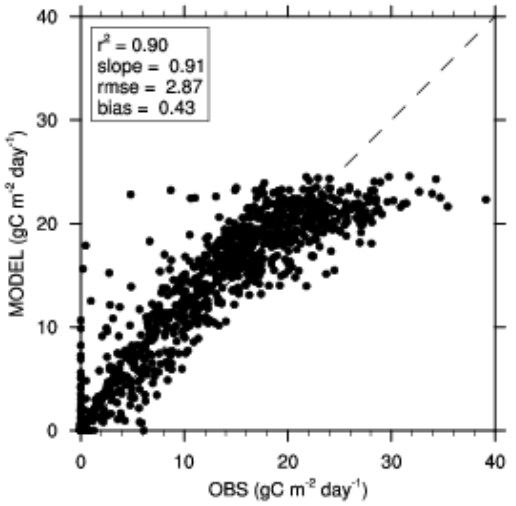
CLM4.5 Performance at Tower Sites

Sensible Heat | Latent Heat | GPP

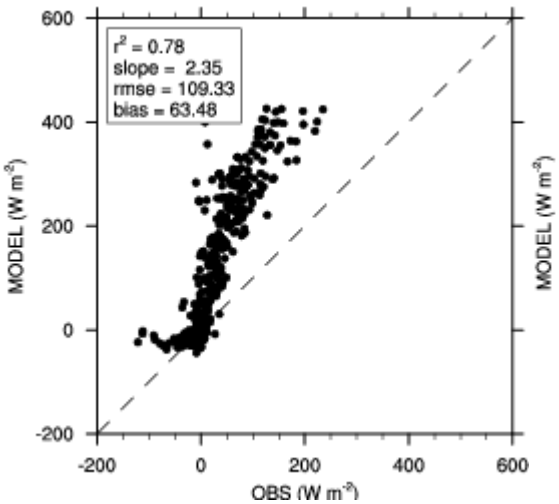
Howland Forest Main July, 1996 NET-T

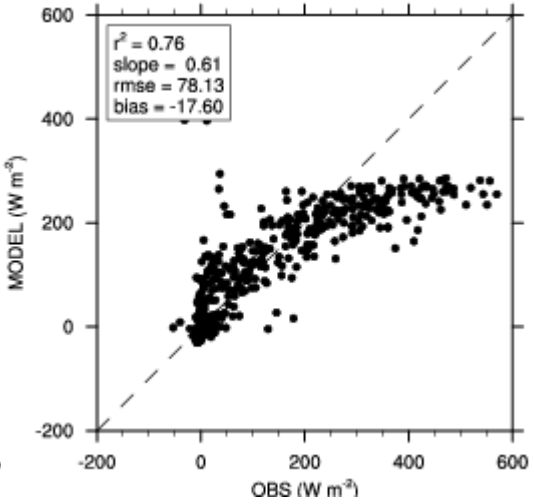


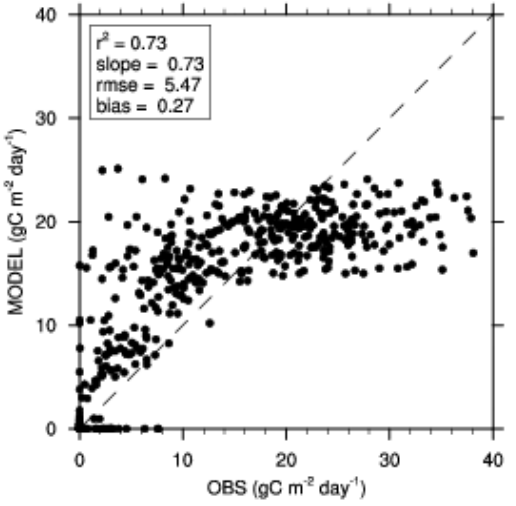




Morgan Monroe July, 2001 BDT-T







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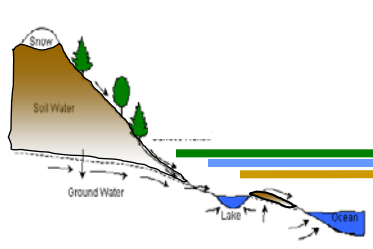
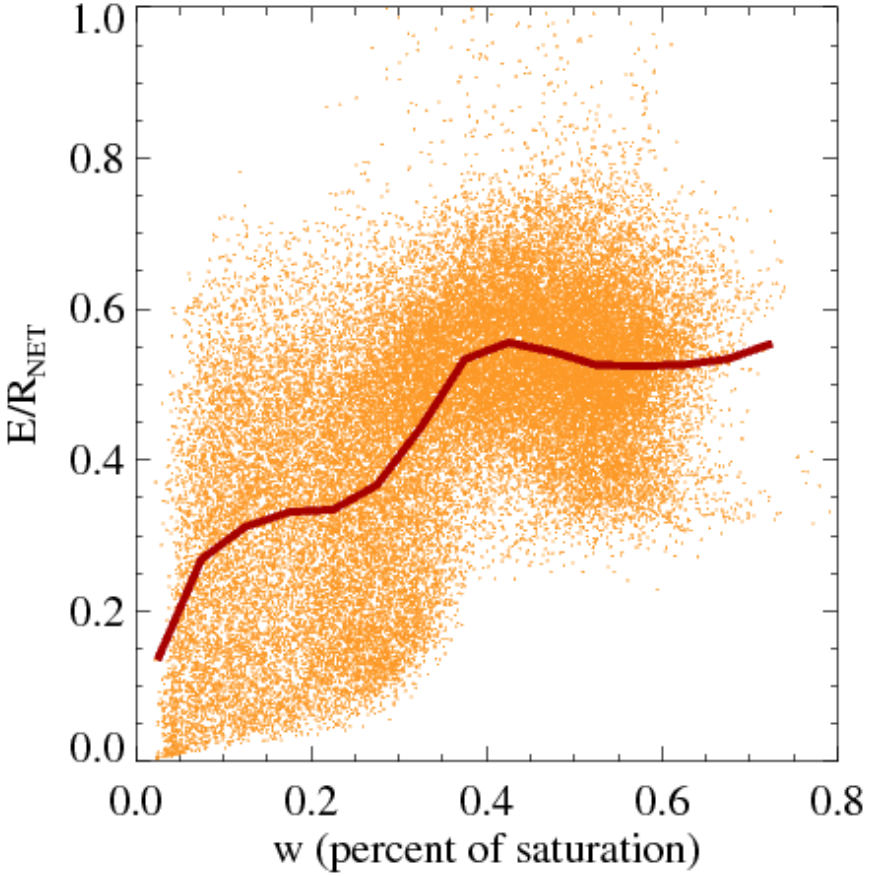
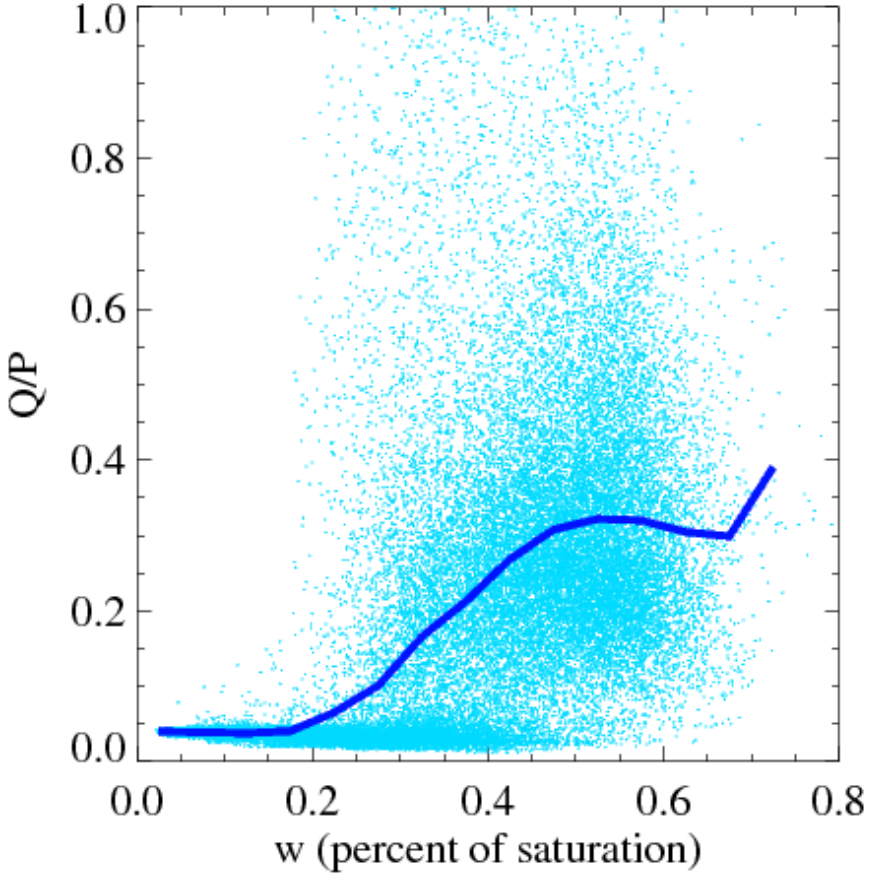
CLM4.5


Snow
Soil Water
Ground Water
Lake
Ocean


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)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Q/P
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0.8
w (percent of saturation)