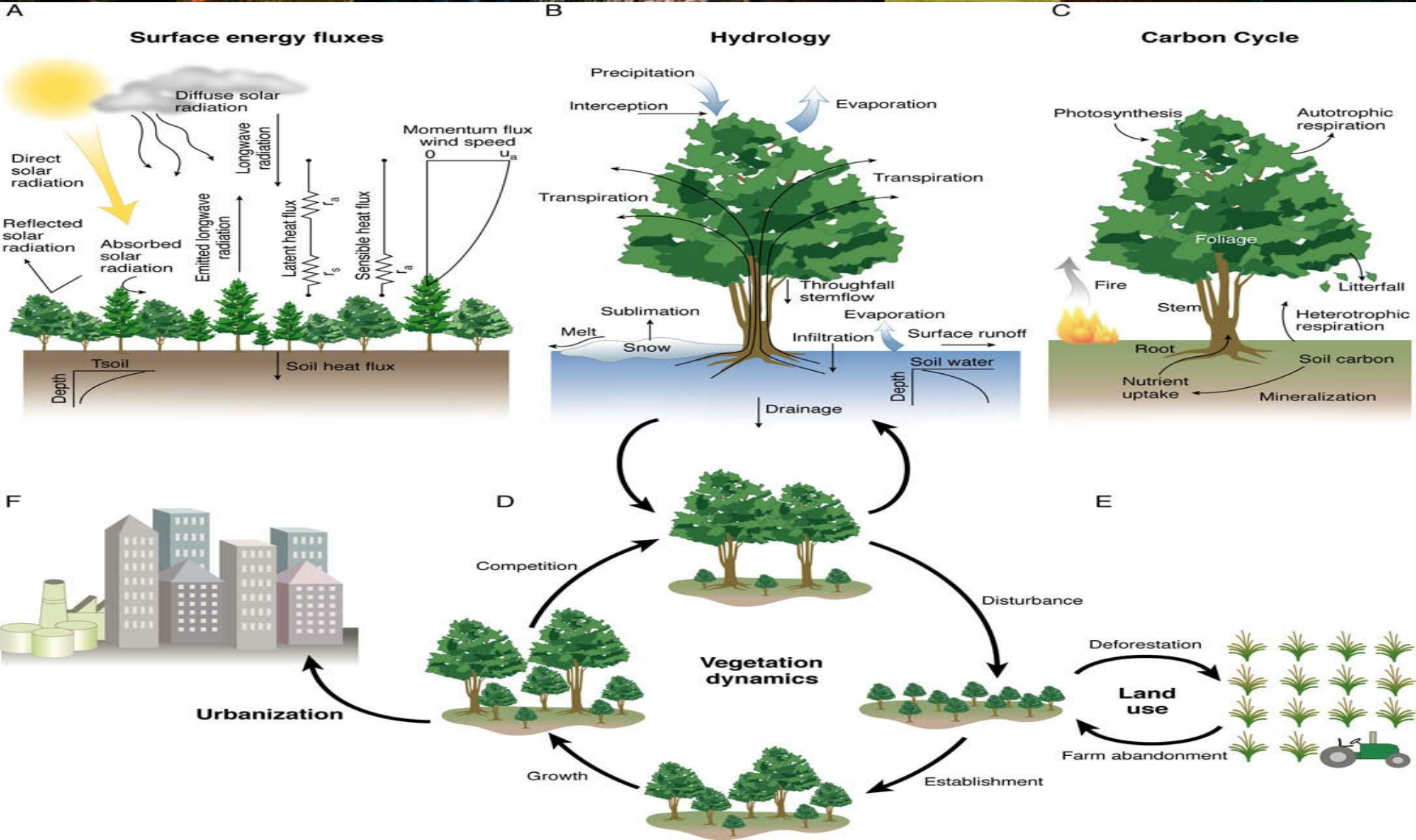
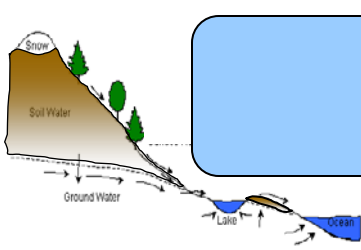


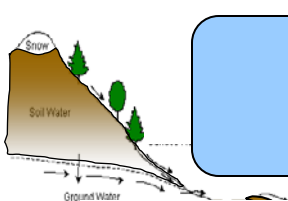
# The State of CLM4



- Change to freezing temperature constant
- forcing height at atm plus  $z_0+d$  on each tile
- Effective porosity divide by zero fix
- X. Zeng sparse/dense canopy aerodynamic parameters
- Stability formulations
- ground/snow emissivity
- organic soil
- init h2osoi=0.3
- snow compaction fix
- snow T profile during layer splitting fix
- new FGR12 diagnostic
- snow burial fraction
- snow cover fraction
- SNICAR (snow aging, black carbon and dust deposition, vertical distribution of solar energy)
- remove SNOWAGE, no longer used
- deep soil (15 layers), including changes for bed rock
- Koichi ground evap (beta), stability, and litter resistance
- Swenson organic/mineral soil hydraulic conductivity percolation theory
- Zeng/Decker Richards equation modifications
- normalization of frozen fraction of soil formulation
- Swenson one-step solution for soil moisture and qcharge
- changes to rsub\_max for drainage and decay factor for surface runoff
- back to old lakes and wetlands datasets
- changes to pft physiology file from CN
- possible changes to surface dataset due to CN?
- new grass optical properties
- new surface dataset from Peter Lawrence assuming no herbaceous understory
- direct versus diffuse radiation offline
- new VOC model (MEGAN)
- modification to solar radiation penetration through snow (no solar to soil if snowdp<0.1m)
- new RTM rdirc file and change to QCHANR definition
- snow-capped runoff goes to ice stream
- dust model always on, LAI threshold parameter change from 0.1 to 0.3
- daylength control on vcmx
- SAI and get\_rad\_dtime fix

# What's new for CLM4

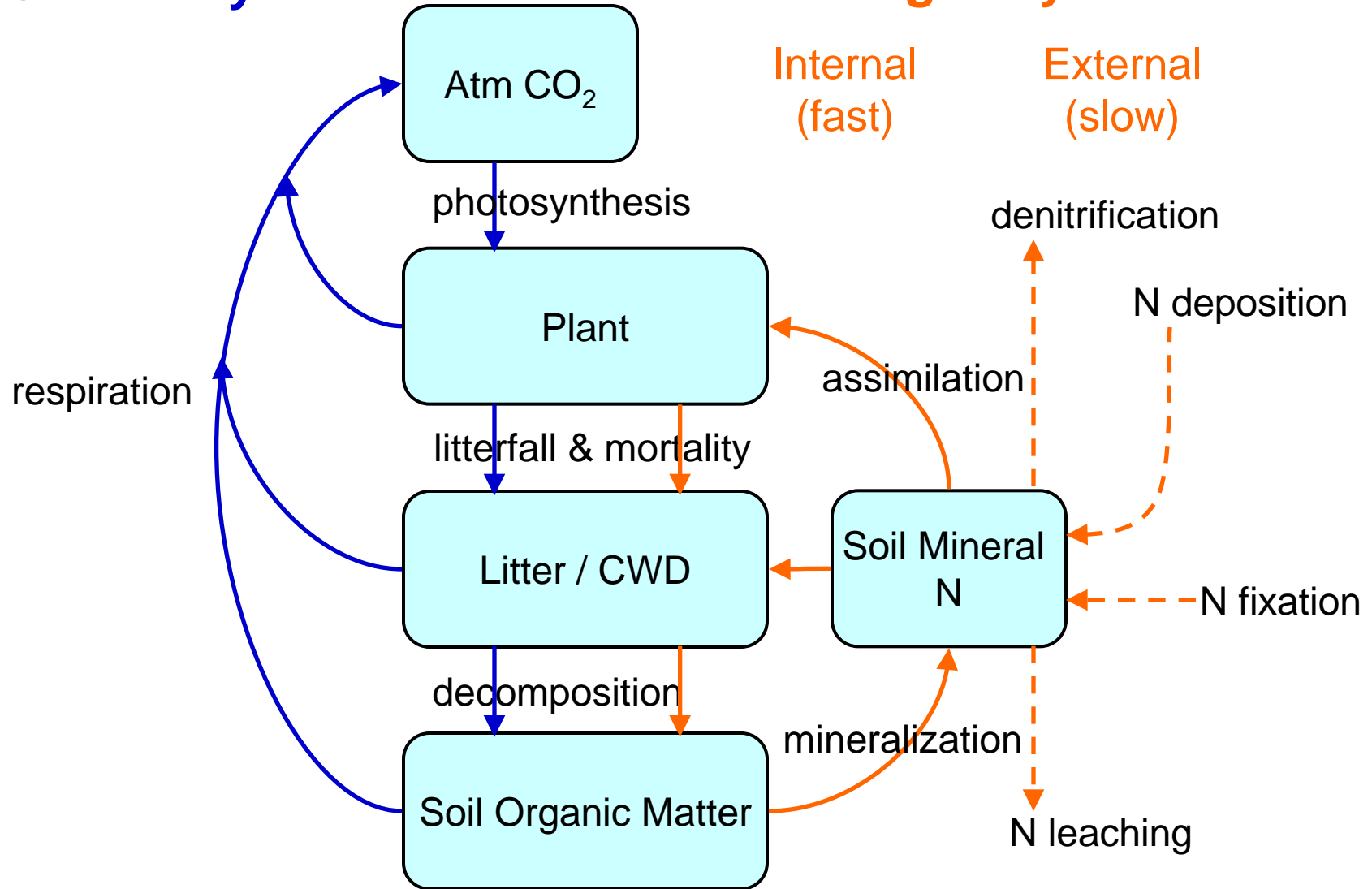




# CLM3.5 → CLM4 : Carbon and Nitrogen cycling

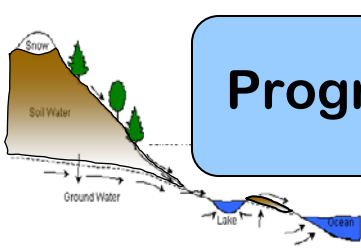
## Carbon cycle

## Nitrogen cycle



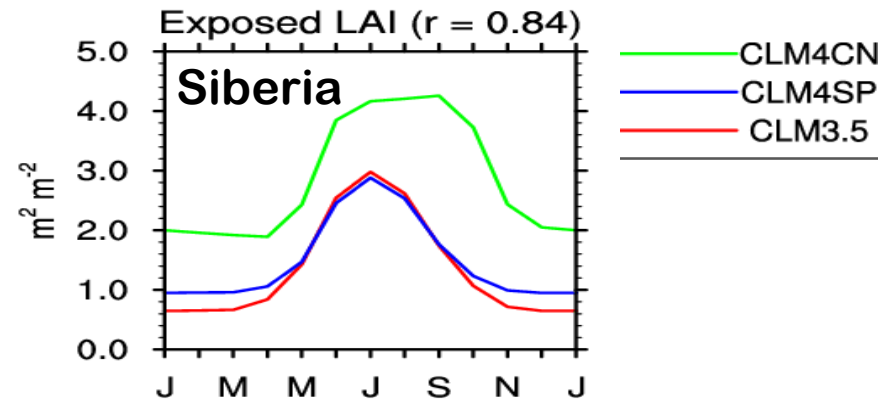
Based on Biome-BGC, Thornton et al., 2009

# Prognostic phenology and vegetation state (LAI, canopy height)

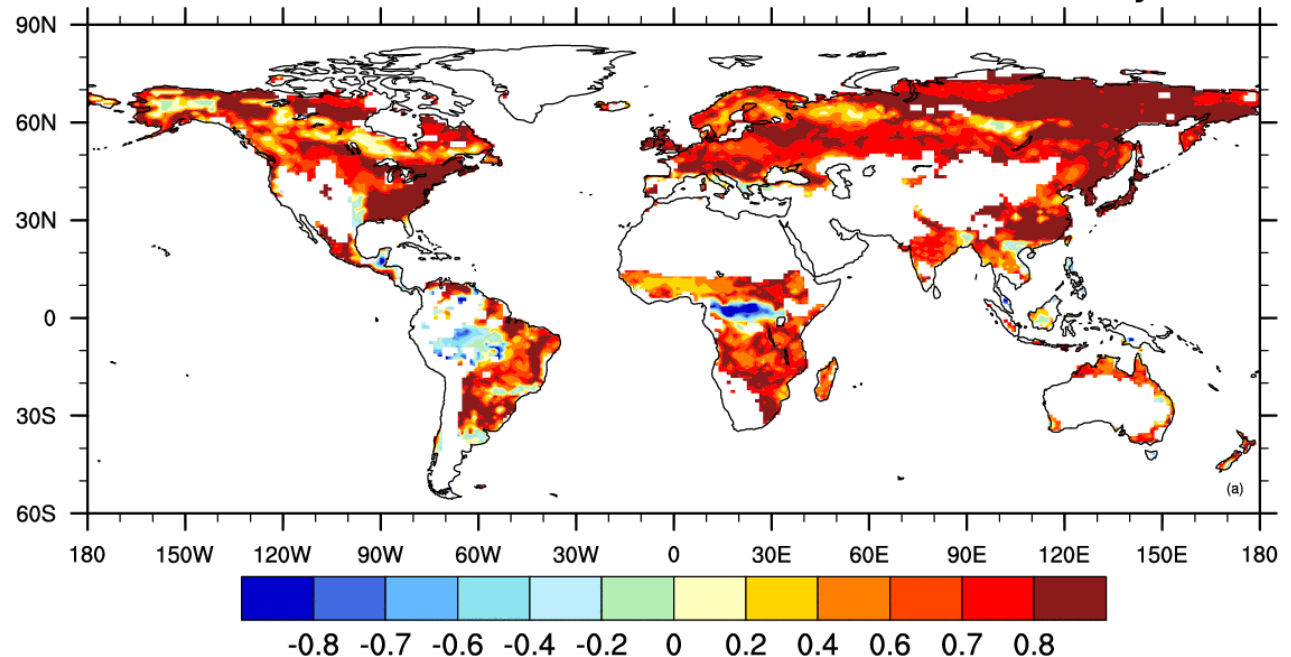


## CLM4

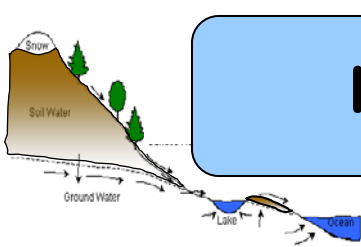
- CLM4SP: satellite phenology
- CLM4CN: carbon-nitrogen cycle phenology



## Correlation between CLM4CN and CLM4SP TLAI annual cycle

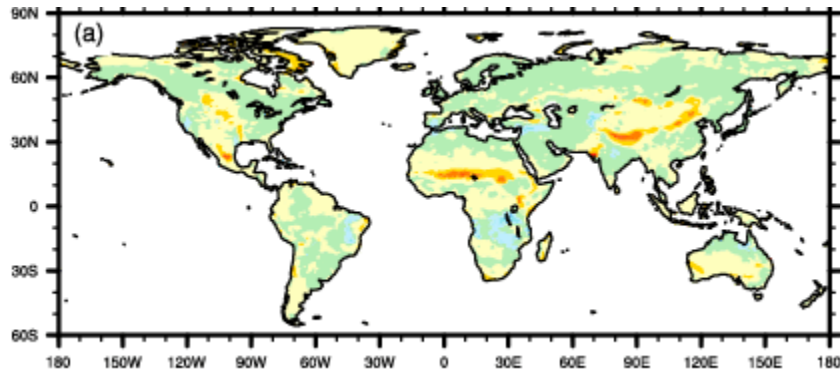


# Interannual variability (JJA): Latent Heat Flux

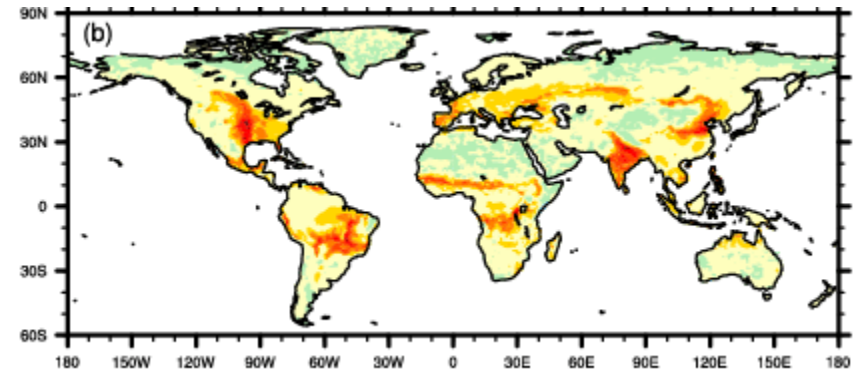


CLM4SP – CLM3.5

$$\sigma_2 - \sigma_1$$

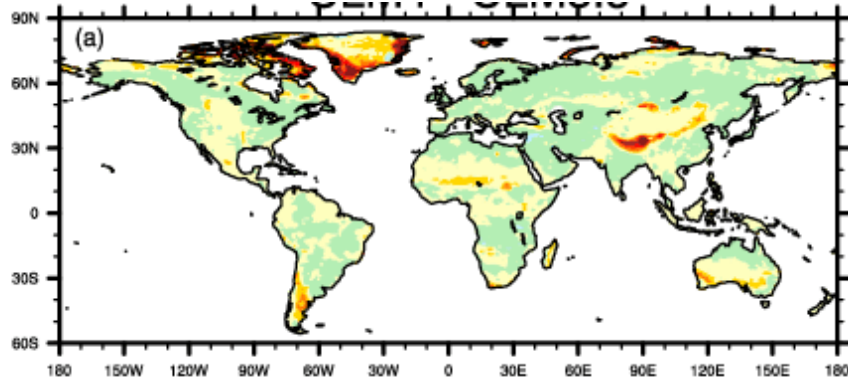


CLM4CN – CLM4SP

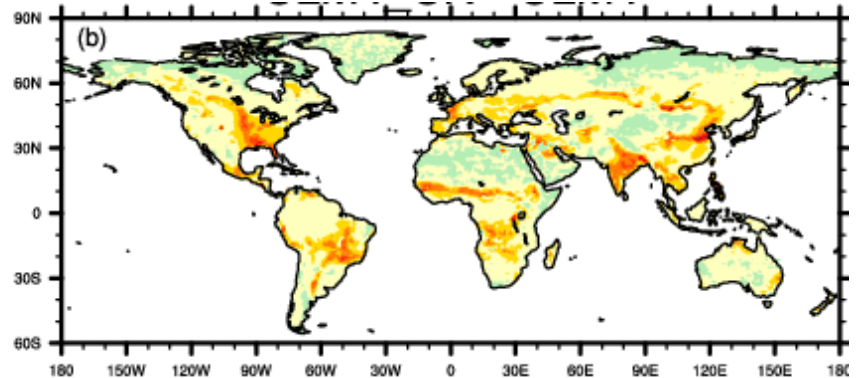


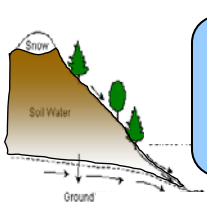
CLM4SP – CLM3.5

$$(\sigma_2 - \sigma_1) / \sigma_1$$



CLM4CN – CLM4SP

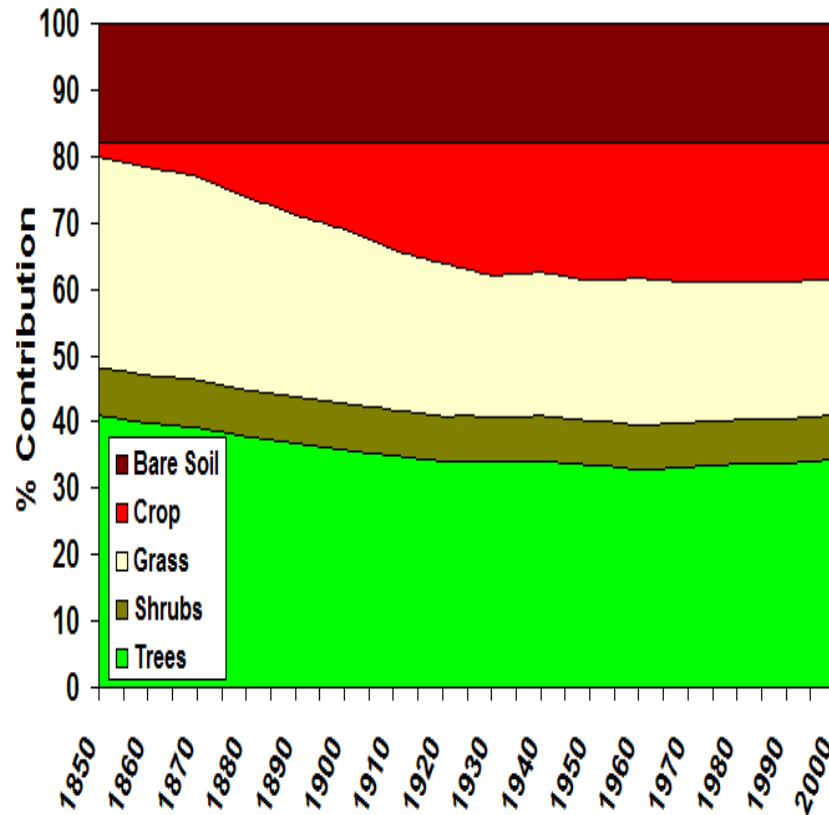




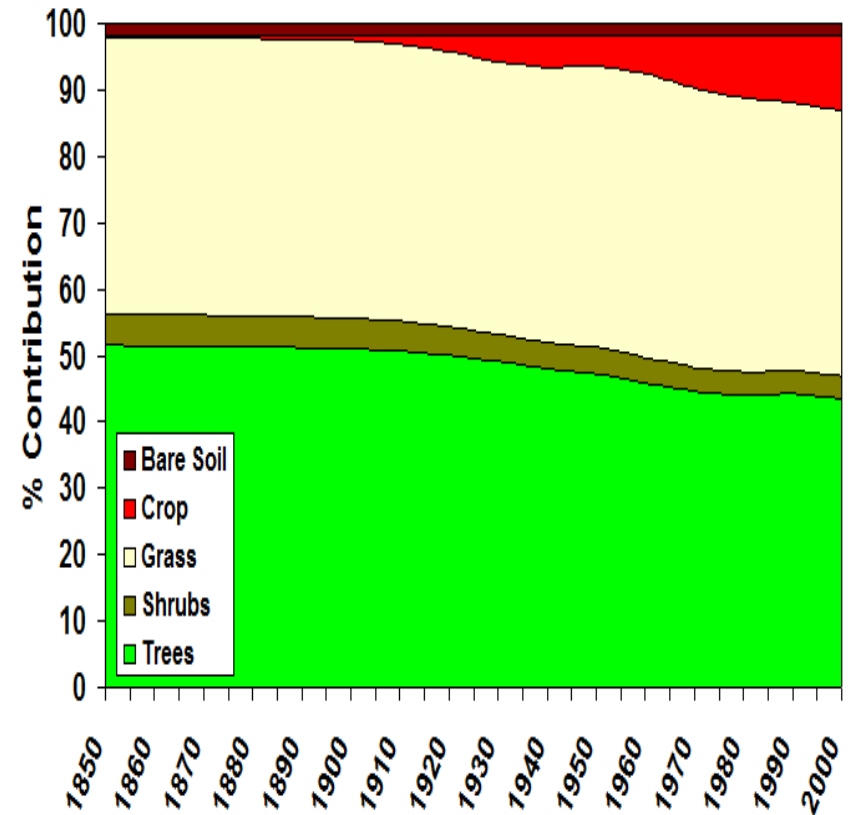
# CLM3.5 → CLM4

## Transient land cover/land use change including wood harvest

### a) Western North America Transient PFTs

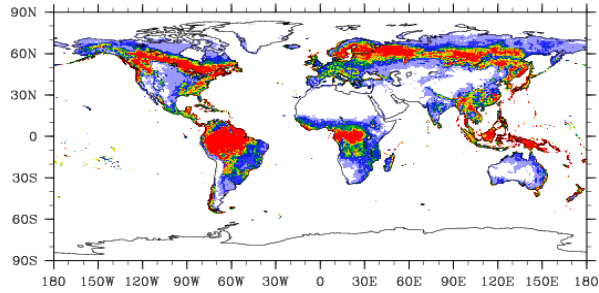


### b) Eastern South America Transient PFTs

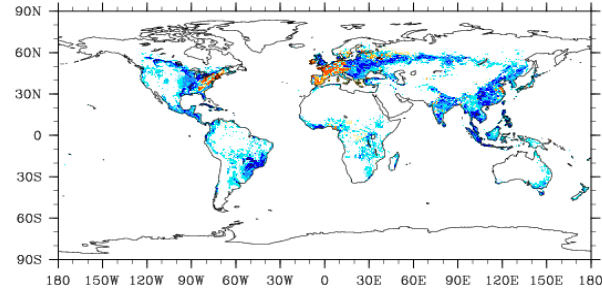


Working with CCWG to complete a set of LULC single forcing experiments

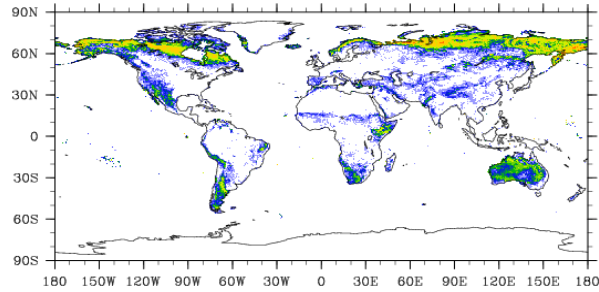
**(a) Current Day (2000) Tree PFTs**



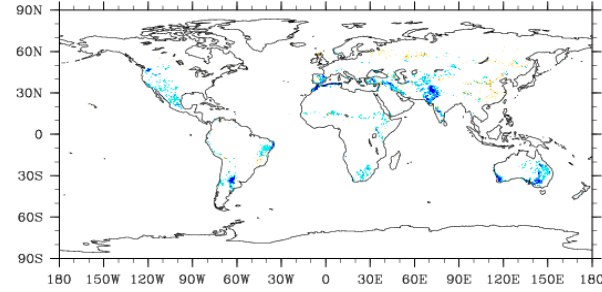
**(b) Current Day - 1850 Tree PFTs**



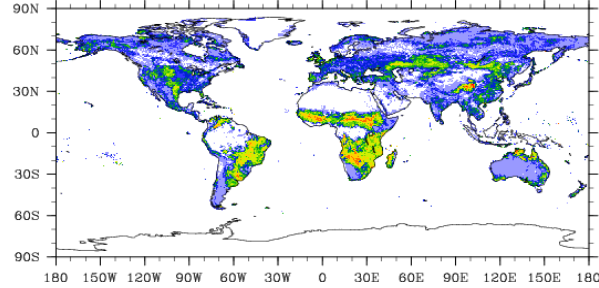
**(c) Current Day (2000) Shrub PFTs**



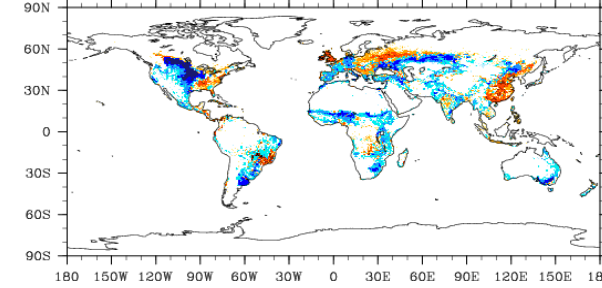
**(d) Current Day - 1850 Shrub PFTs**



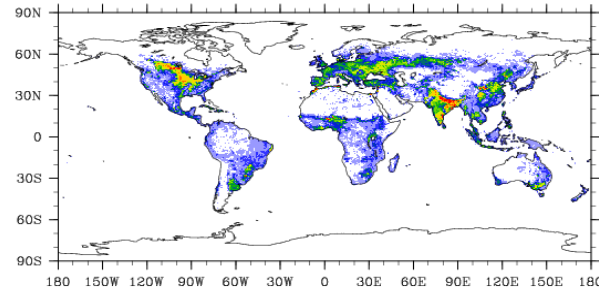
**(e) Current Day (2000) Grass PFTs**



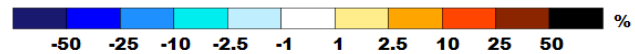
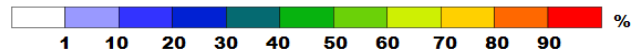
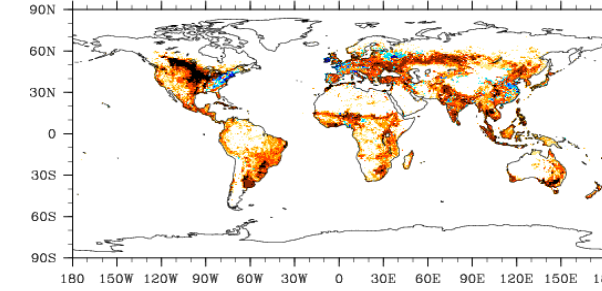
**(f) Current Day - 1850 Grass PFTs**



**(g) Current Day (2000) Crop PFT**



**(h) Current Day - 1850 Crop PFT**



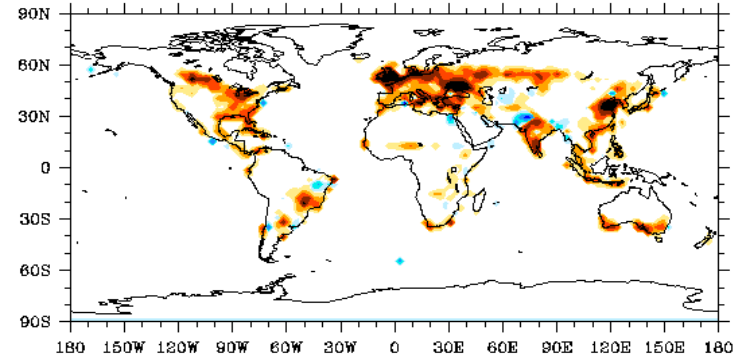
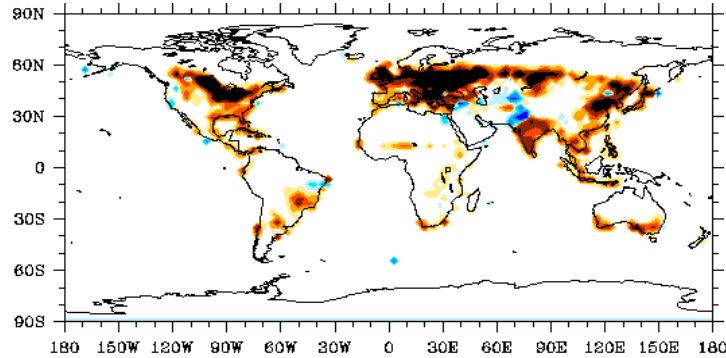


# Land cover change impact on albedo (present day minus 1850)

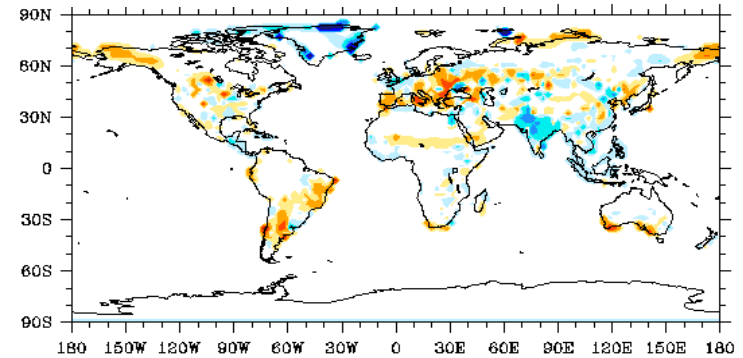
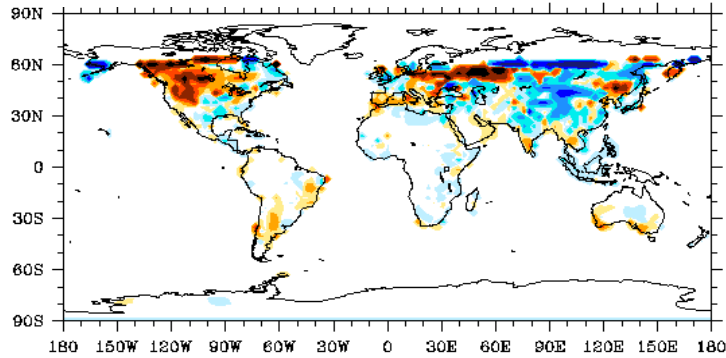
Obs estimate  
derived from  
potential  
veg vs present  
day albedo

DJF

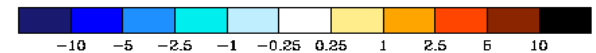
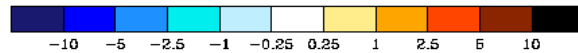
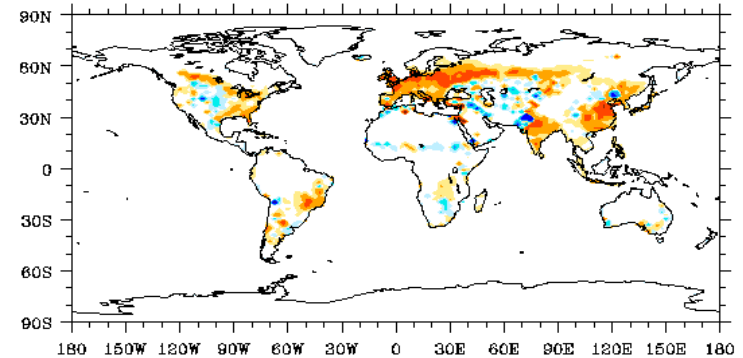
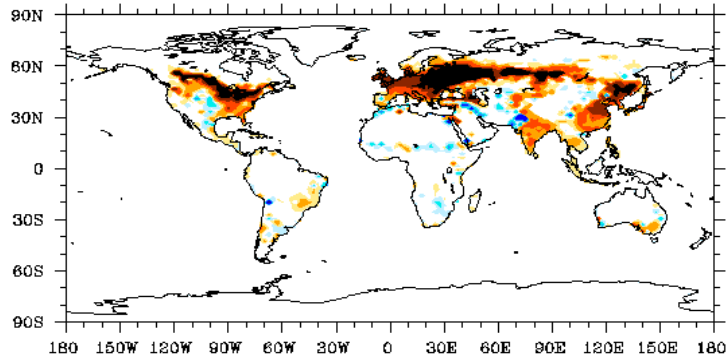
JJA

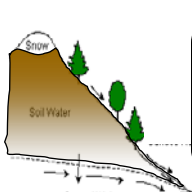


CLM3.5



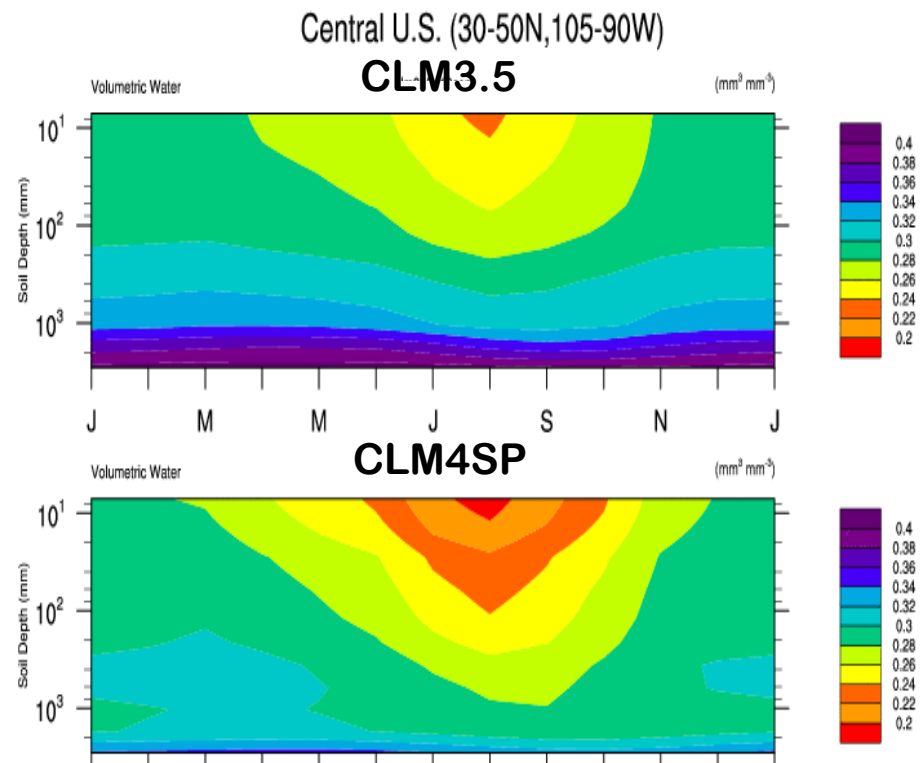
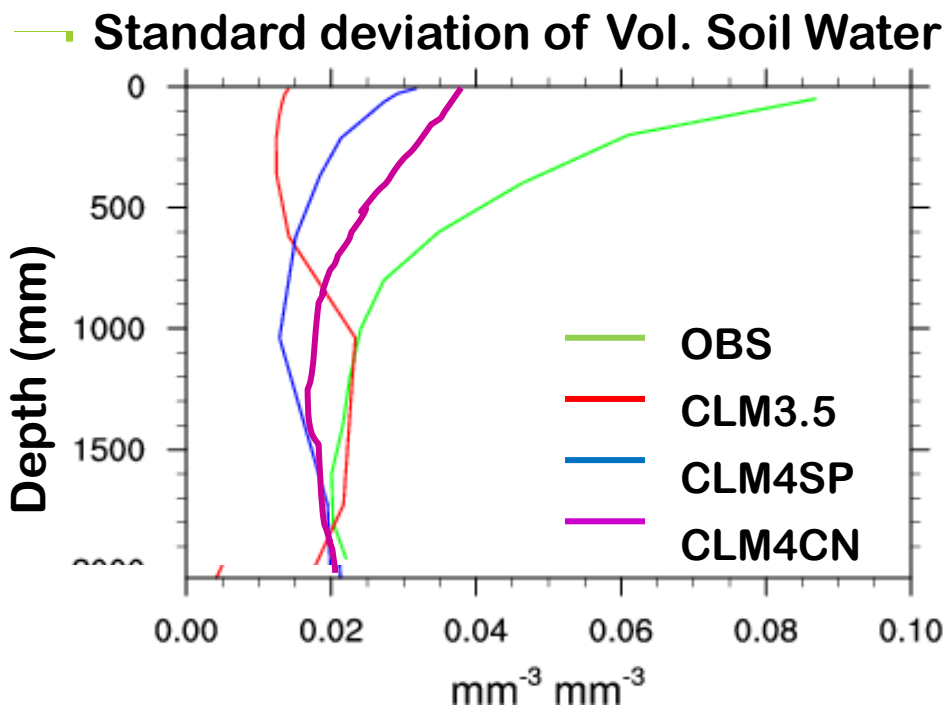
CLM4

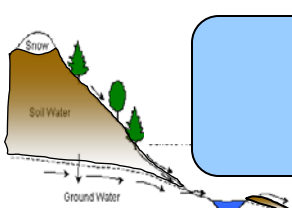




# CLM3.5 → CLM4: Soil Hydrology (Sakaguchi, Zeng, Decker, Swenson, Oleson, Lawrence, Niu, Yang)

- replaced soil evap resistance term with so-called  $\beta$  formation
- litter resistance
- under canopy turbulent stability
- modified Richard's equation – maintains steady state
- simplified bottom boundary condition for soil water equations





# CLM3.5 → CLM4

## – Snow model (Flanner, Zender, Niu, Yang, Lawrence, Zeng)

- snow density dependent snow cover fraction parameterization
- snow burial fraction for short vegetation
- adopt SNICAR

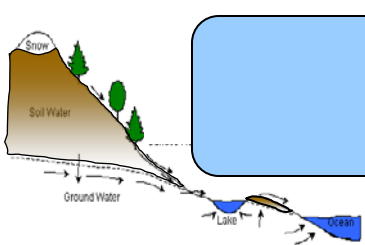
} ~ +0.13° C to  
CCSM4 climate  
sensitivity

snow age

vertically resolved heating in snowpack (snowdp > 0.1m)

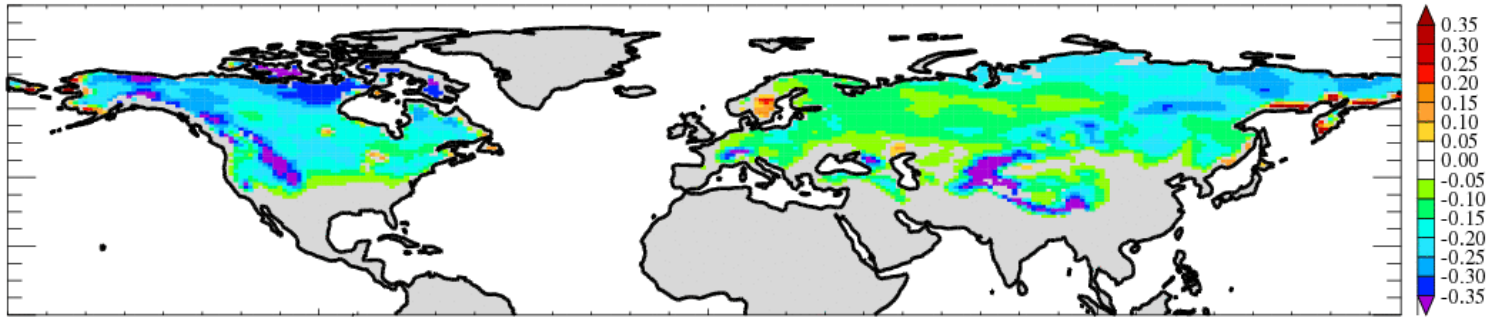
aerosol deposition (dust, black carbon, organic carbon) –  
works with bulk or modal aerosols

- snow compaction
- snow layer splitting
- (bug) – energy not always conserved during snow layer combination

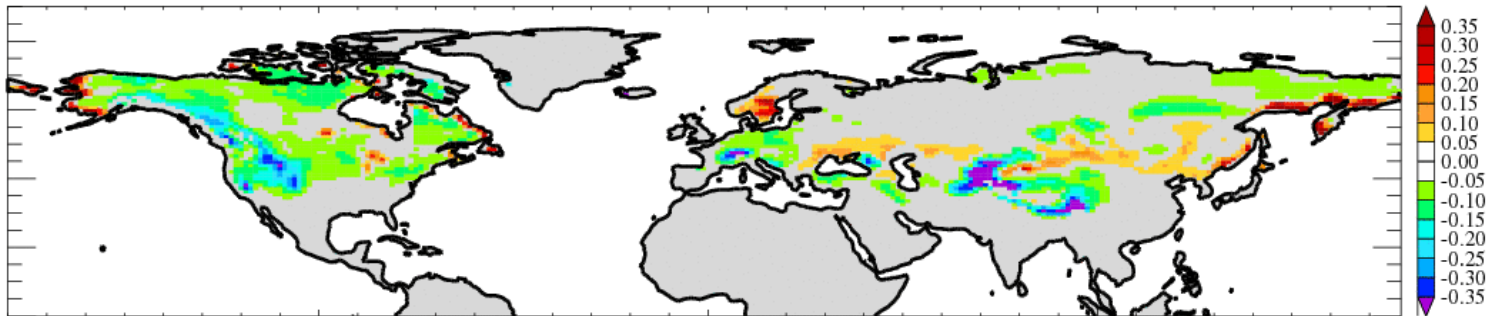


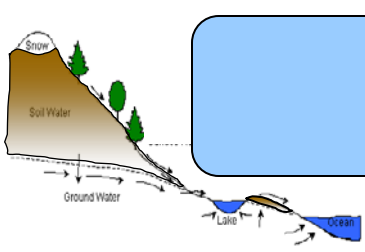
# Snow cover fraction

Snow cover fraction: CLM3.5 – Obs



Snow cover fraction: CLM4SP – Obs

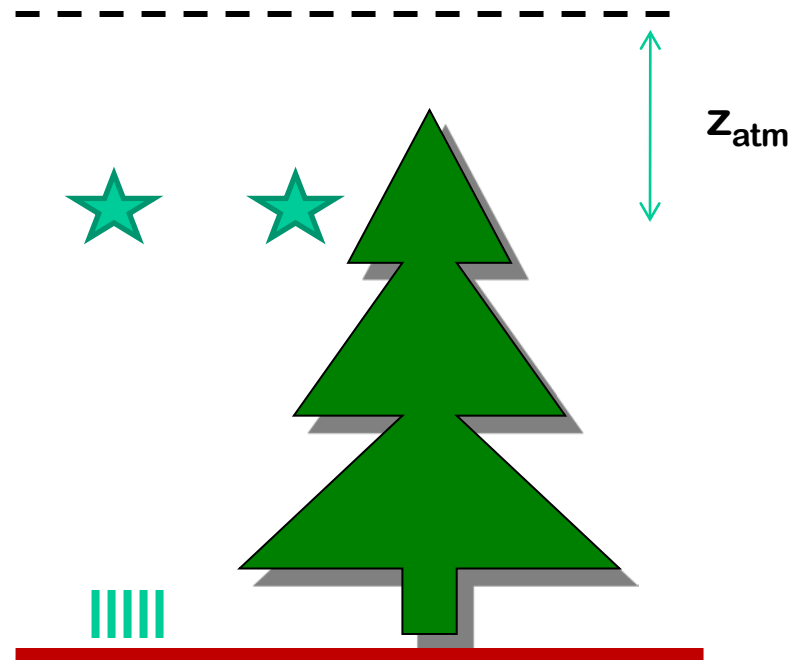
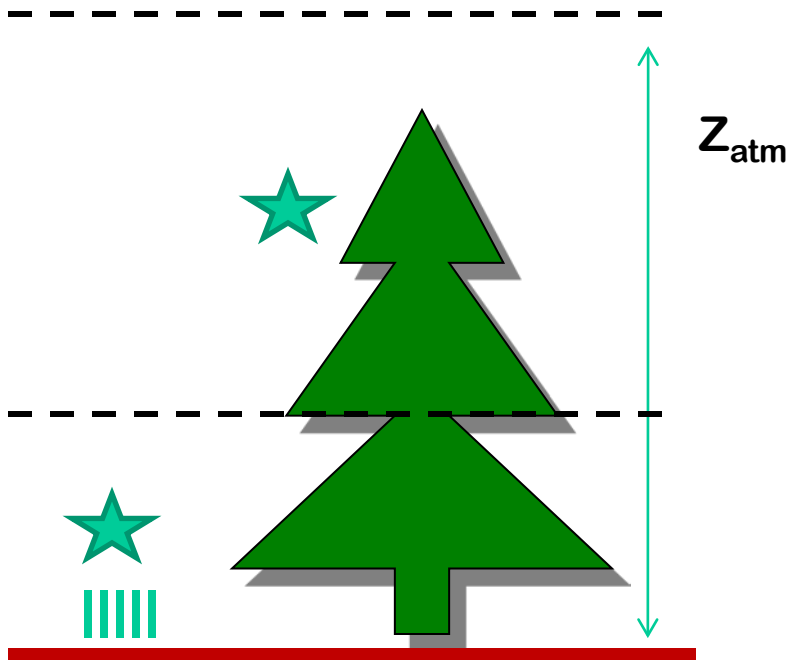
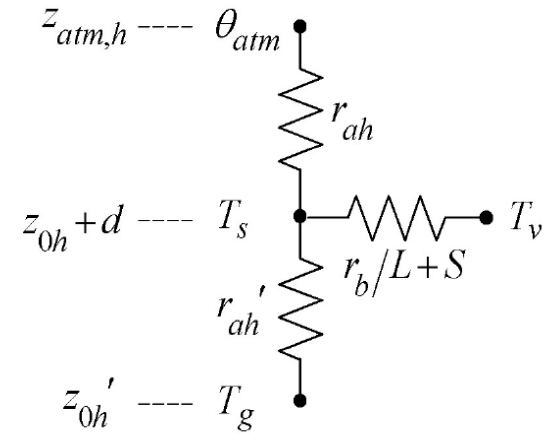


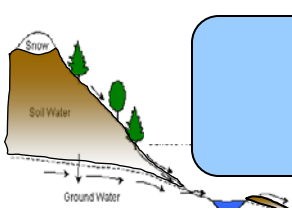


# CLM3.5 → CLM4

## – Reference height (Oleson, Svensson)

Distance between reference height ( $z_0+d$ ) and lowest atmospheric level is same for all land tiles

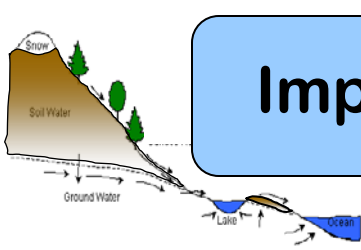


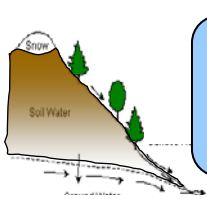


## CLM3.5 → CLM4

- Urban model
- Organic soil – thermal and hydrologic properties (Lawrence, Slater)
- Deeper soil column (~50 m, 15 soil levels, layers 11-15 are bedrock) (Lawrence, Slater)
- Integration of CN and DGVM (CNDV)
- Ice stream in River Transport Model
- New VOC model (MEGAN model) (Heald, Levis)
- Fixed diurnal cycle of solar radiation (offline) (Kluzek, Oleson, Swenson)
- Partitioning of direct vs diffuse radiation (offline) (Lawrence)

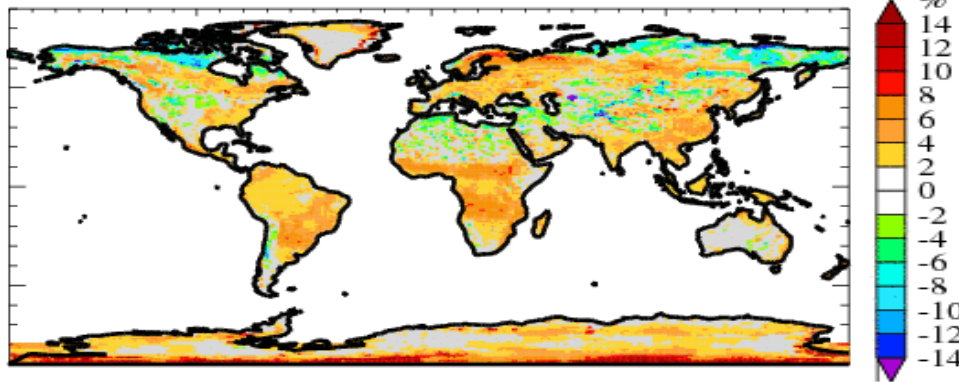
# Impact of integrated changes on offline simulations



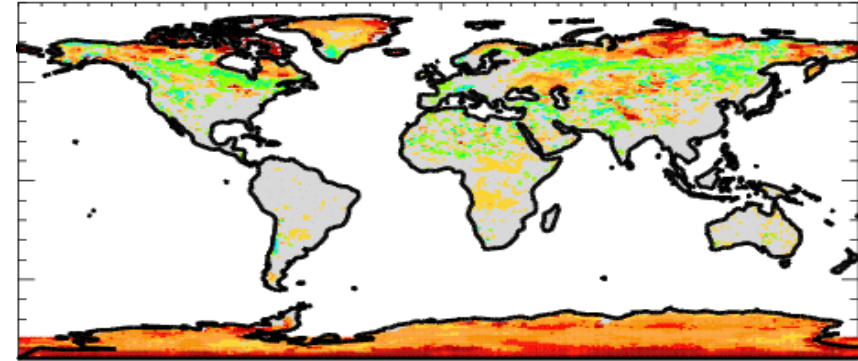


# Albedo

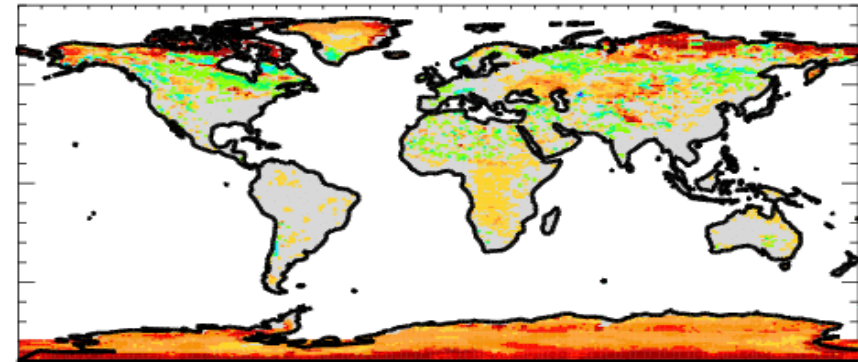
CLM3.5 – Obs



CLM4SP – Obs

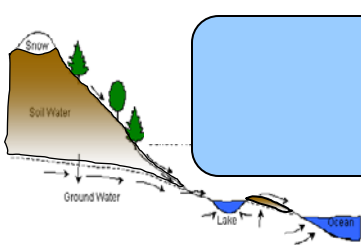


CLM4CN – Obs



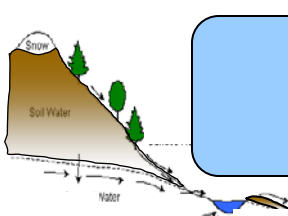
Model	Bias (%)		RMSE (%)	
	Snow-free	Snow depth > 0.2m	Snow-free	Snow depth > 0.2m
CLM3.5	2.7	-5.0	4.1	11.9
CLM4SP	0.4	2.9	2.0	13.2
CLM4CN	0.7	1.3	2.2	13.9





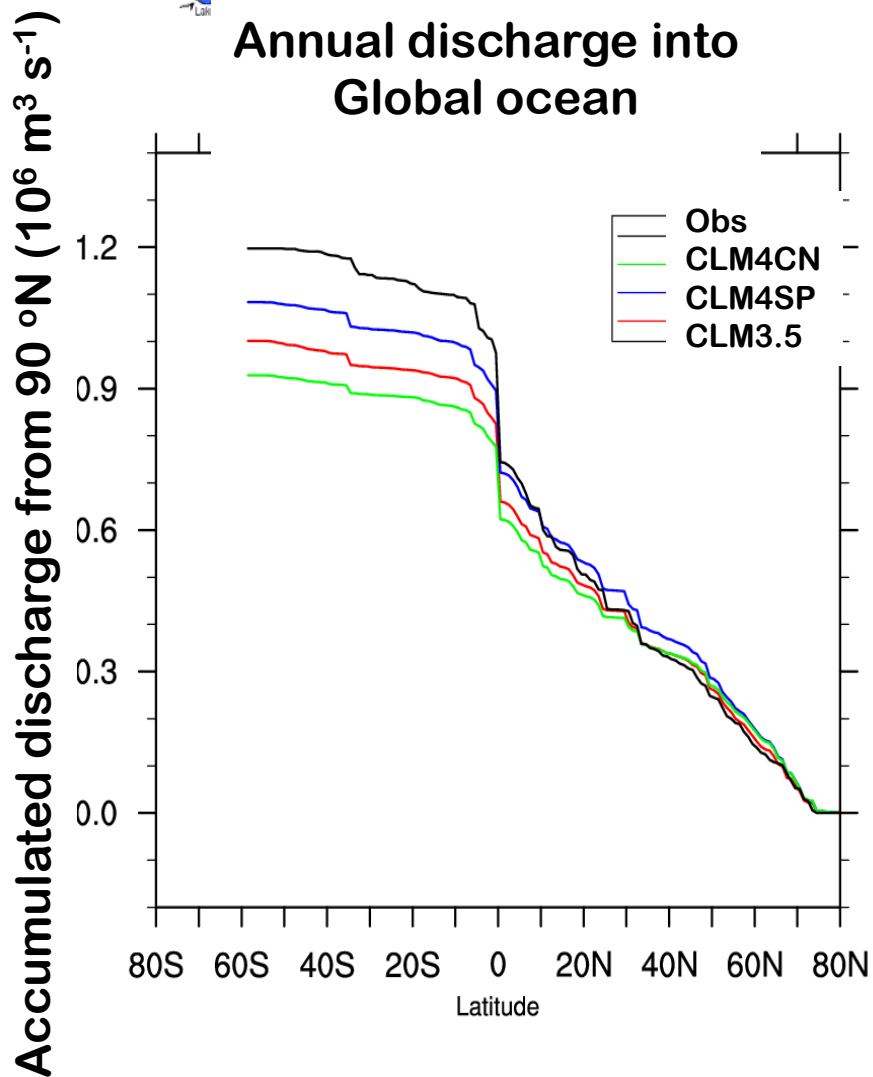
# Tower flux statistics (15 sites, hourly)

	Latent Heat Flux		Sensible Heat Flux	
	r	RMSE (W/m <sup>2</sup> )	r	RMSE (W/m <sup>2</sup> )
CLM3	0.54	72	0.73	91
CLM3.5	0.80	50	0.79	65
CLM4SP	0.80	48	0.84	58

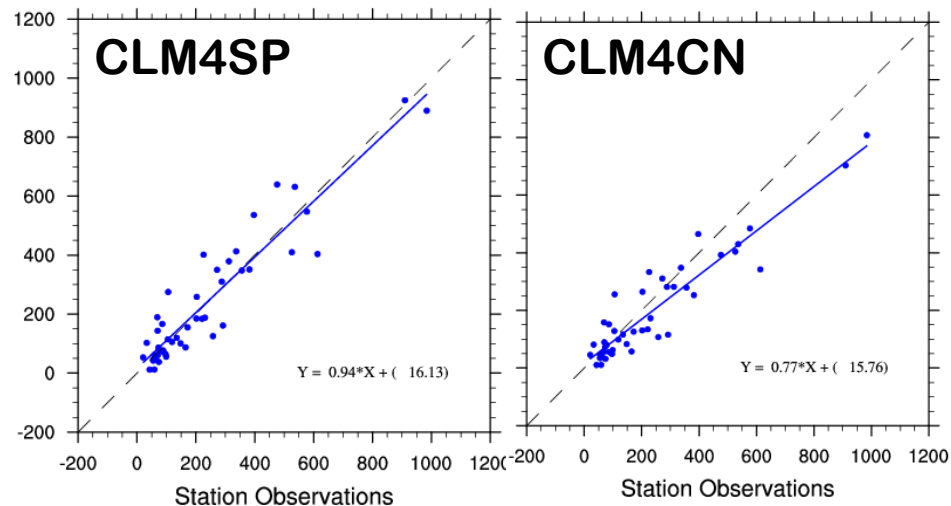


# River Discharge

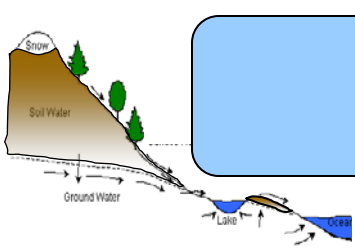
Annual discharge into Global ocean



River flow at outlet  
Top 50 rivers ( $\text{km}^3 \text{ yr}^{-1}$ )



**CLM3:  $r = 0.86$**   
**CLM3.5:  $r = 0.87$**   
**CLM4SP:  $r = 0.94$**   
**CLM4CN:  $r = 0.77$**

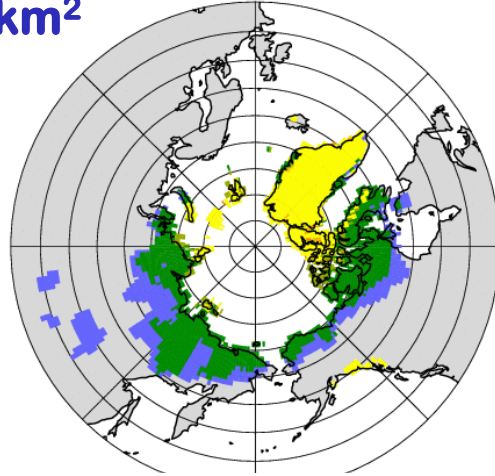


# Permafrost

Near-Surface Permafrost Extent and Active Layer Thickness

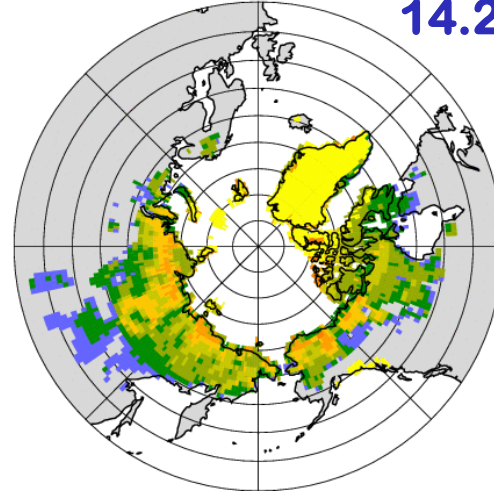
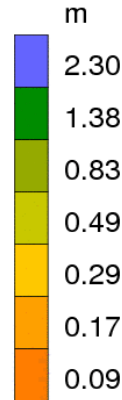
**8.2 million km<sup>2</sup>**

CLM3.5



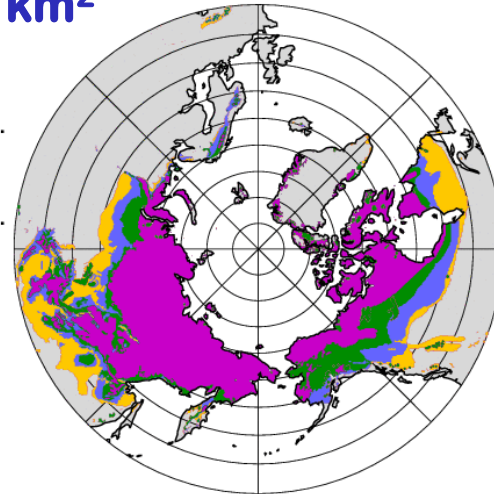
CLM4SP

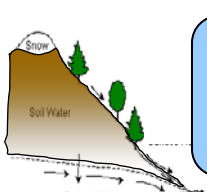
**14.2 million km<sup>2</sup>**



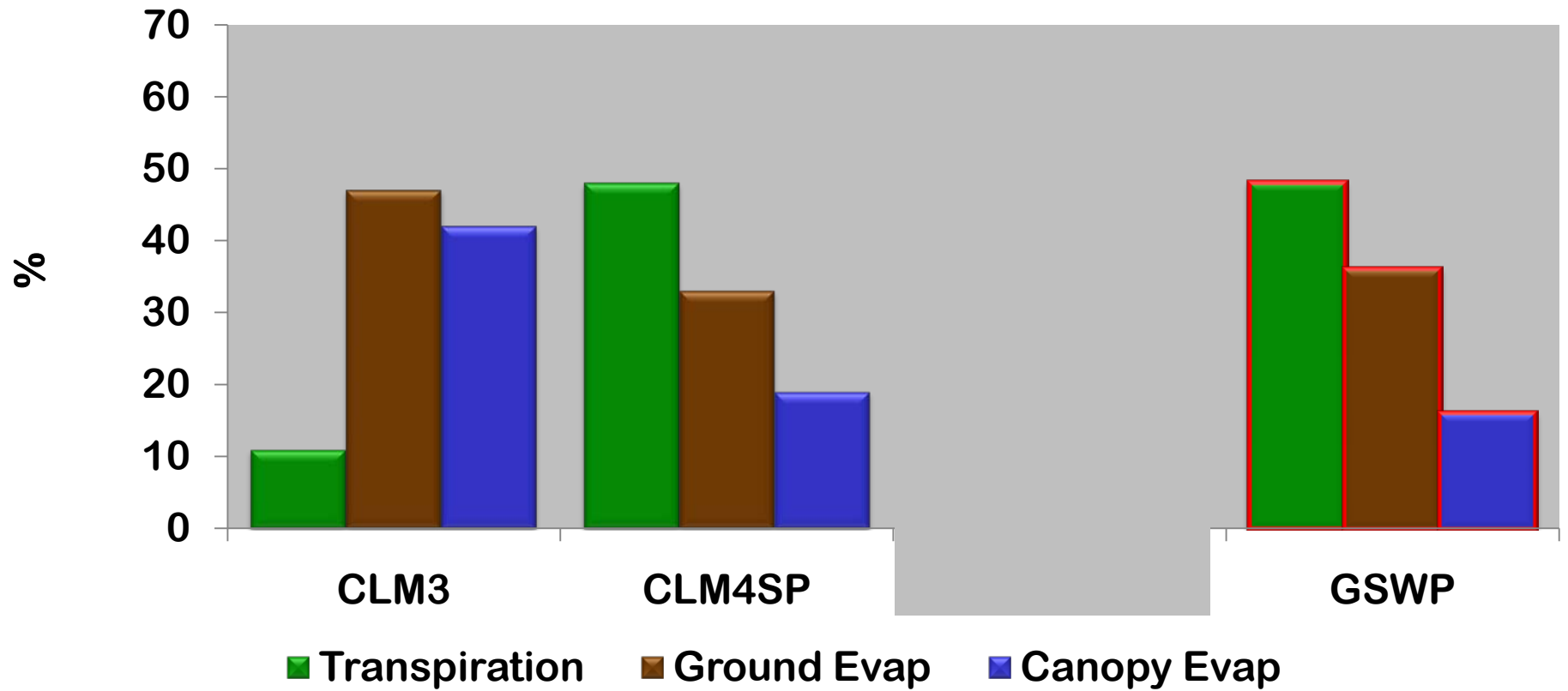
**11.3 – 14.3 million km<sup>2</sup>**

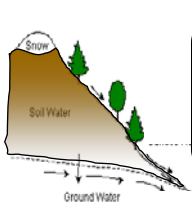
Observations



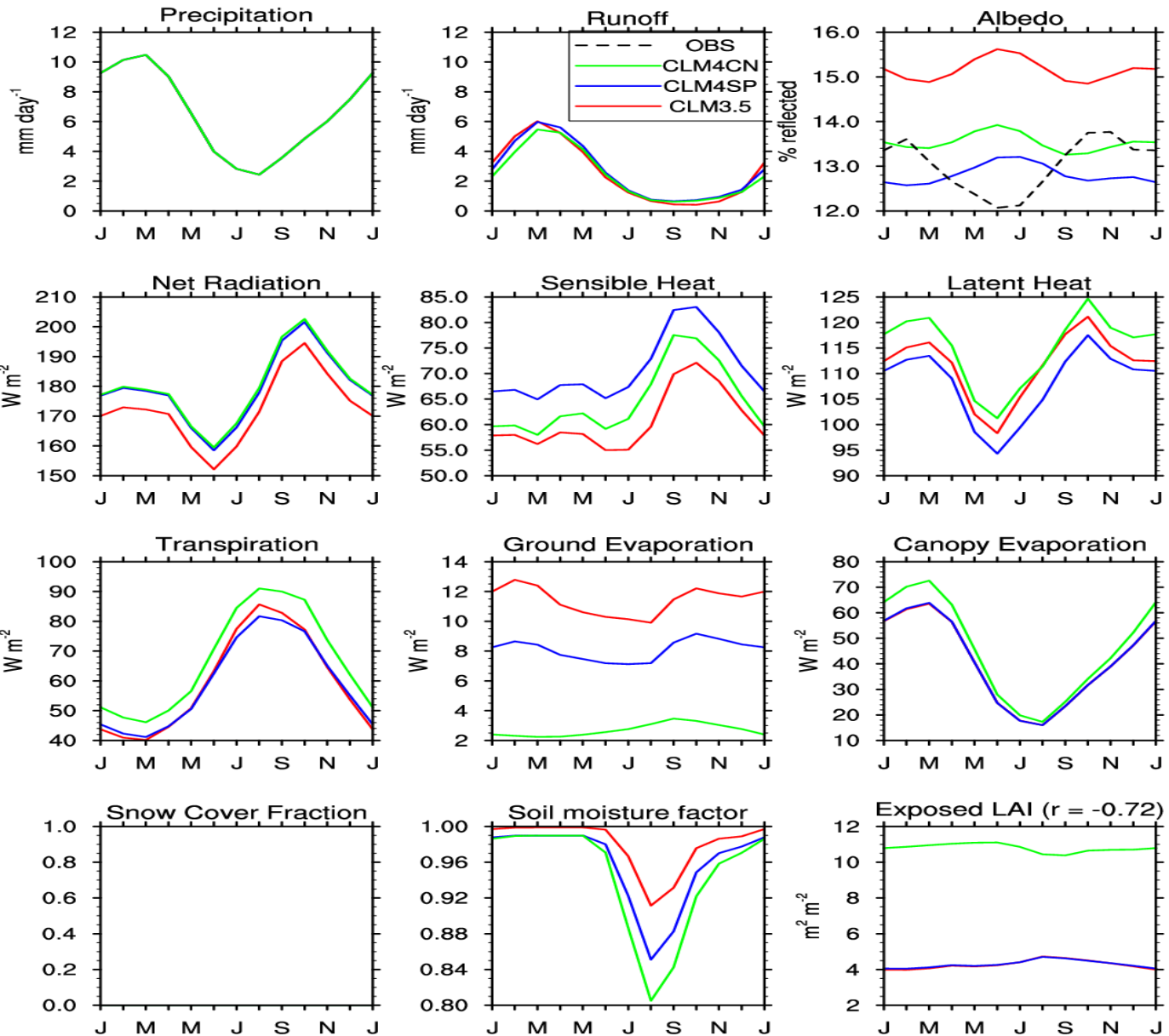


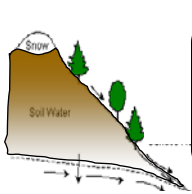
# Global Partitioning of Evapotranspiration



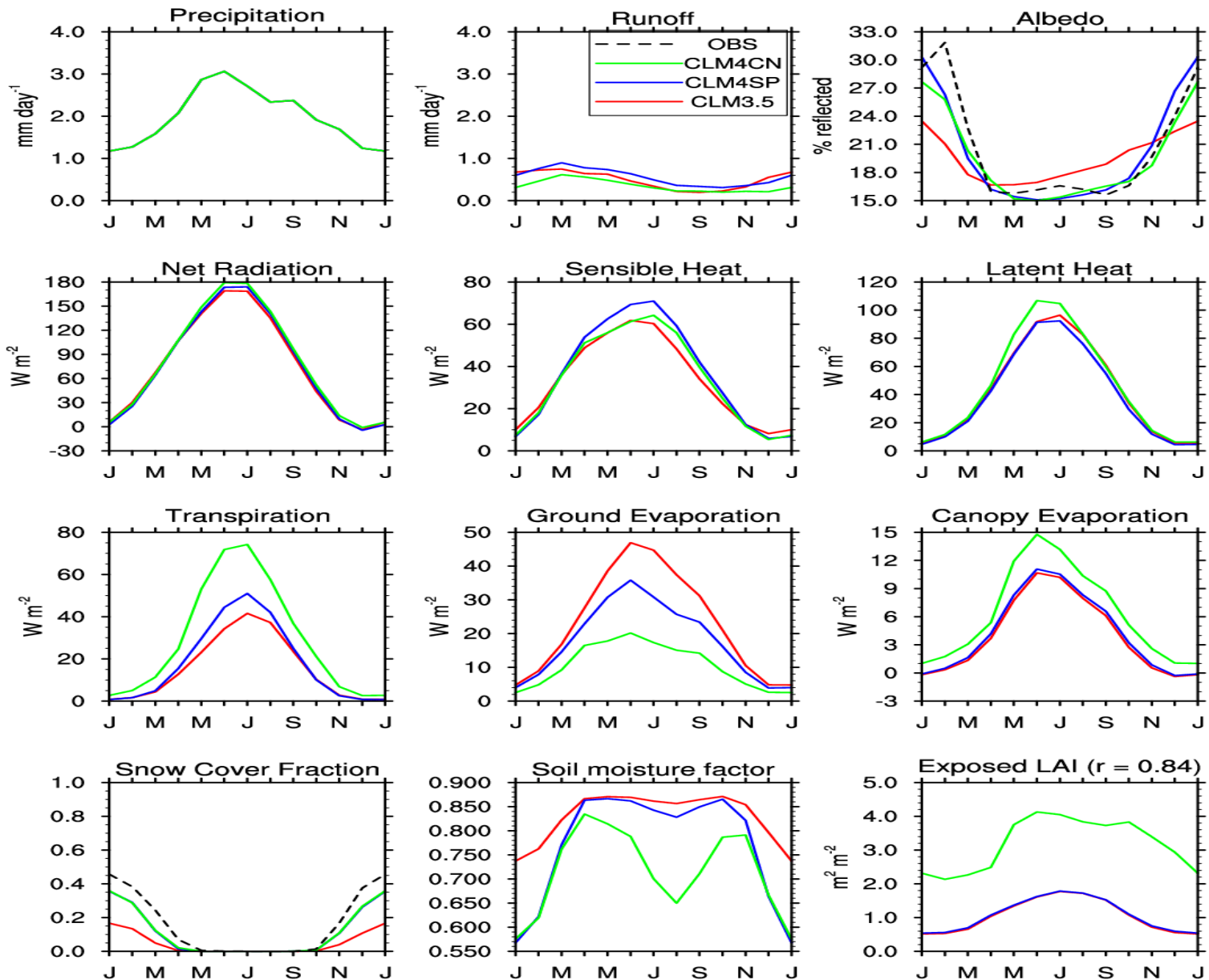


# Climatological annual cycle: Amazonia

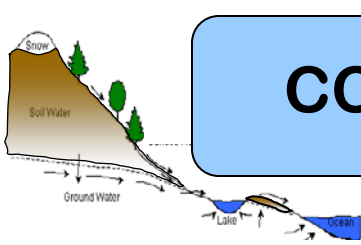




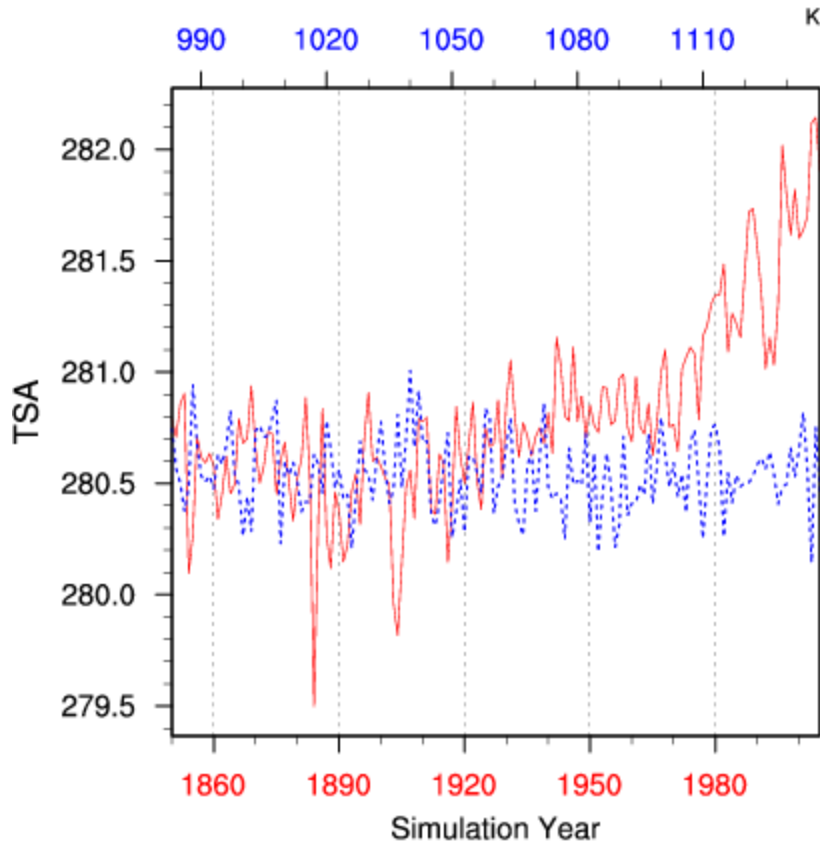
# Climatological annual cycle: Central US



# CCSM4 20<sup>th</sup> century CMIP5 simulations underway

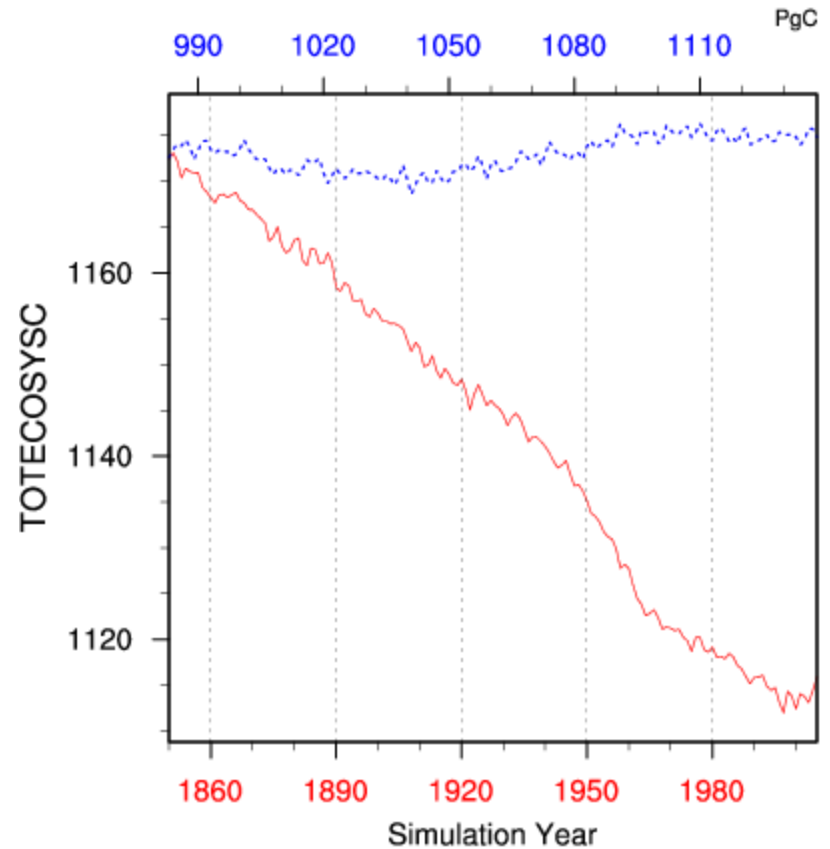


2m air temperature



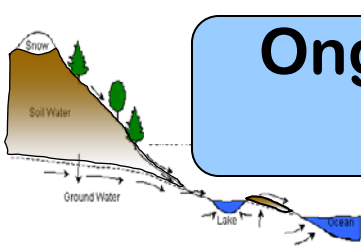
- b40.1850.track1.1deg.006 (1883-1138)  
- b40.20th.track1.1deg.007 (1850-2006)

total ecosystem C, incl veg but excl cpool



- b40.1850.track1.1deg.006 (1883-1138)  
- b40.20th.track1.1deg.007 (1850-2006)

# Ongoing and future development projects 'beyond' CLM4



- Crop model / irrigation
- Updated lake model / thermokarst lakes
- Cold region hydrology fixes
- Prognostic wetlands
- Methane emission model
- Integration with Integrated Assessment Models
- Spatially variable soil depth
- Insect outbreaks
- Implementing the Ecosystem Demography (ED) model
- Ozone and vegetation
- (Riverine carbon/nutrient fluxes)



January 2010

Technical Description of version 4.0 of  
the Community Land Model (CLM)

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Climate and Global Dynamics Division

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NATIONAL CENTER FOR ATMOSPHERIC RESEARCH  
BOULDER, COLORADO

**CLM4 Tech Note**

**257 pages**

**18 chapters**

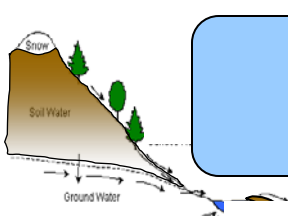
**643 equations**

**Separate Urban and CN  
Tech Notes**

**CLM4 paper in preparation,  
to be submitted to JAMES  
or GMD**

**Over 200,000 lines of code  
in CLM4**

**Over 1.5 million in CCSM4**

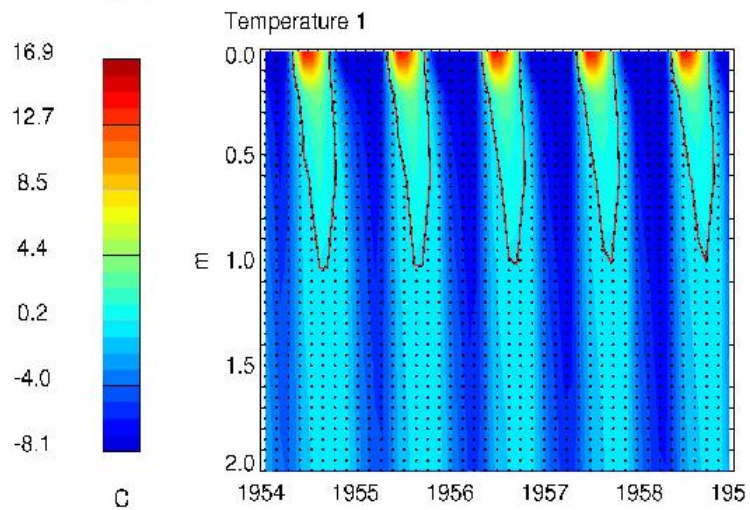
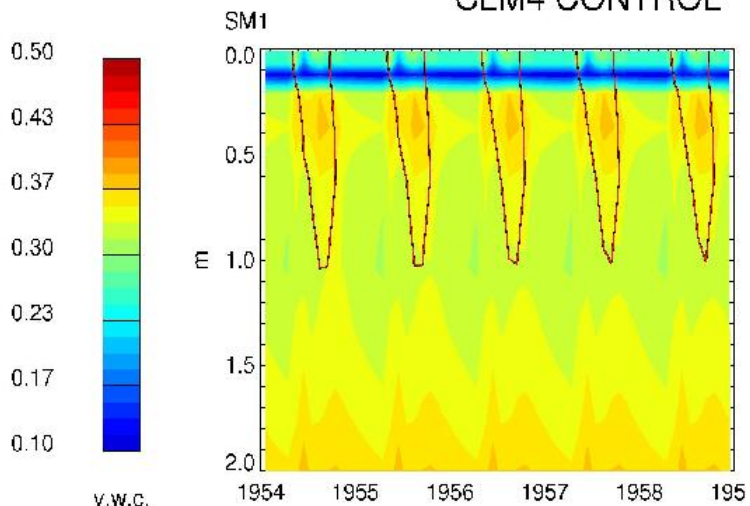


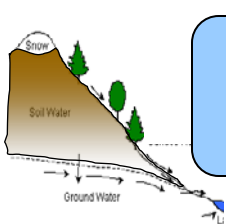
# Cold region hydrology problem

Yukon stevens point

VWC (top) and Temperature (bottom)

CLM4 CONTROL

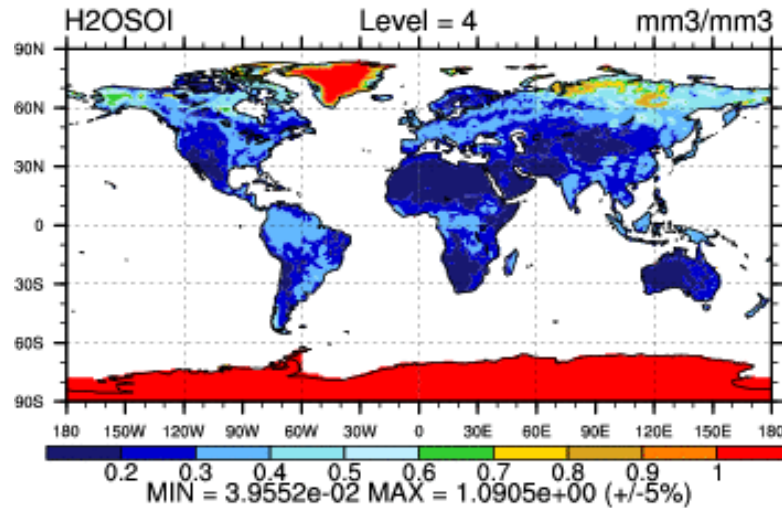




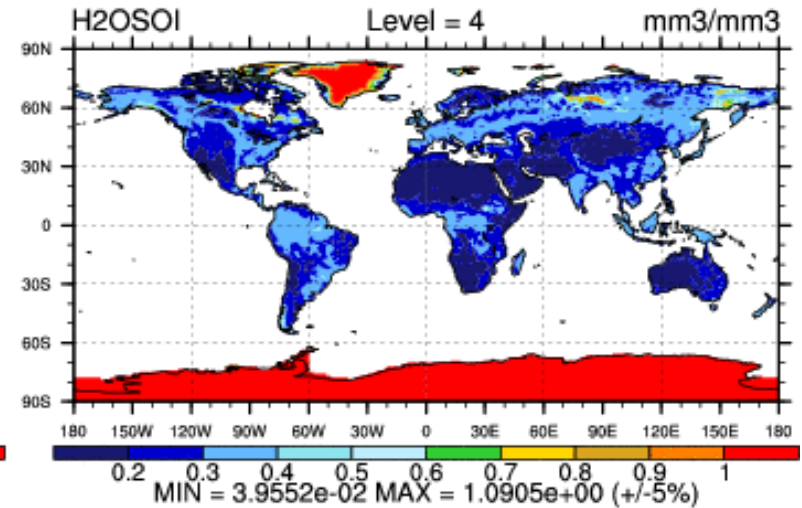
# Soil Moisture

ANN

DRAINAGE (yrs 1979-2003)

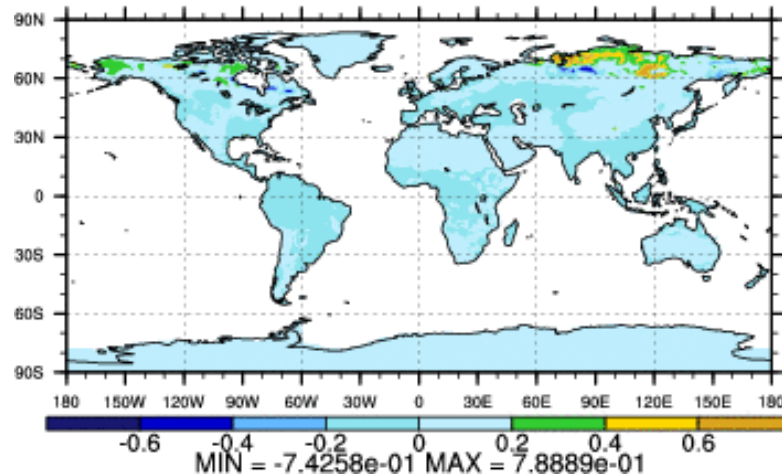


CONTROL (yrs 1979-2003)

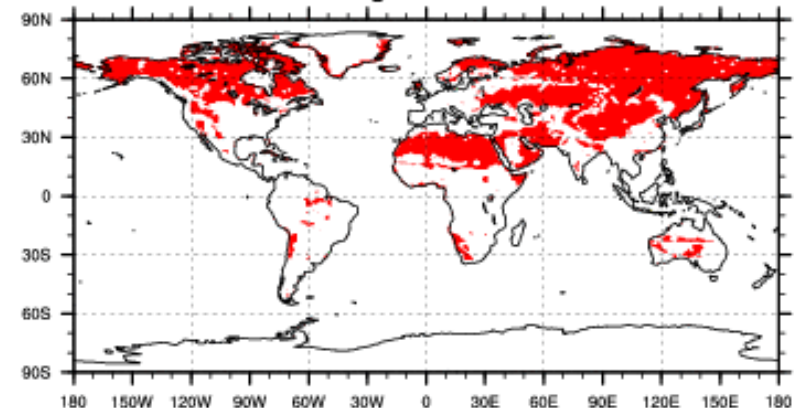


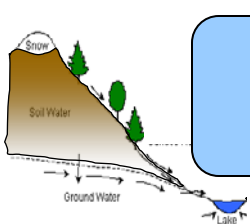
T-Test of two Case means at each grid point

Case 1 - Case 2



Cells are significant at 0.1 level



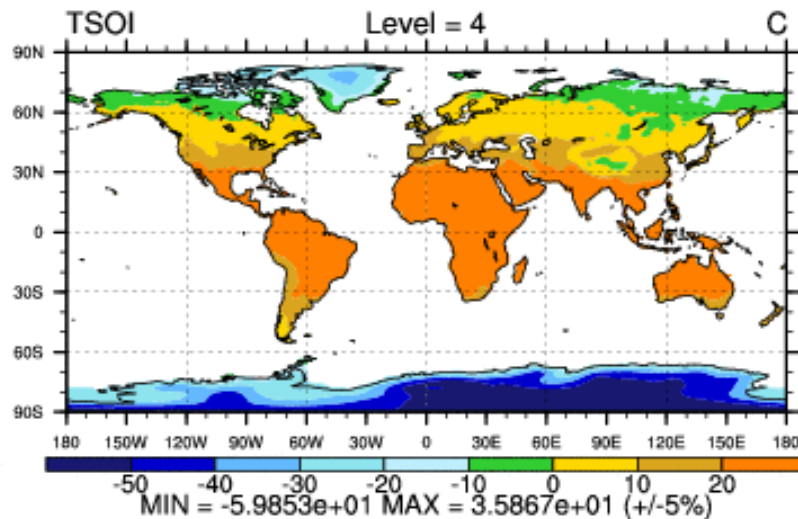
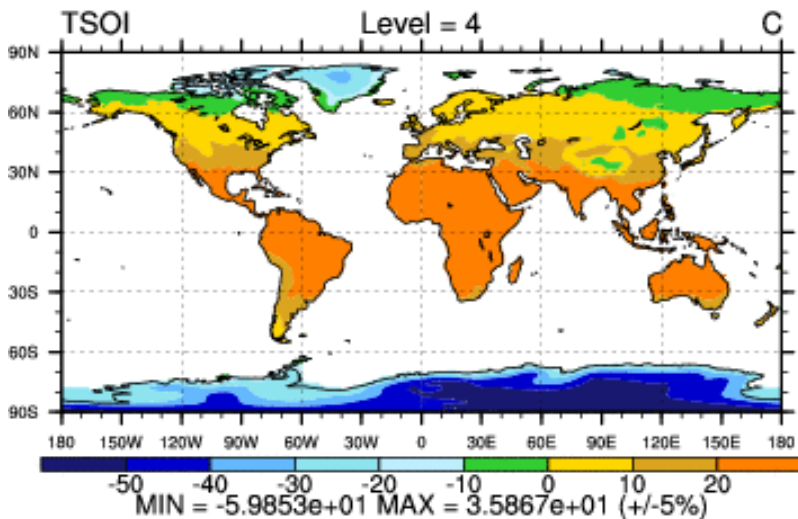


# Soil Temperature

ANN

DRAINAGE (yrs 1979-2003)

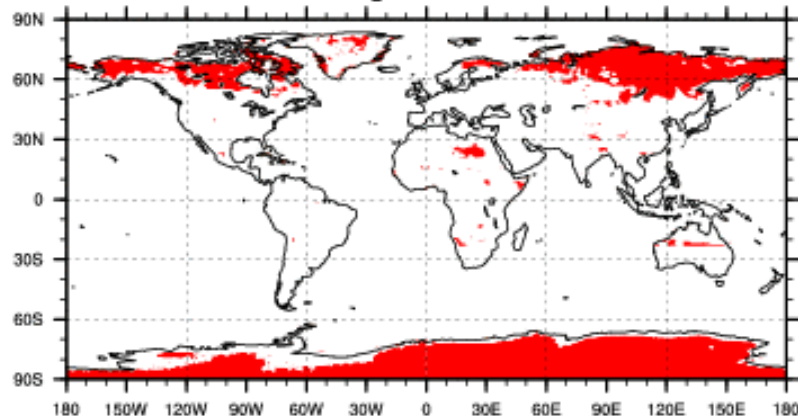
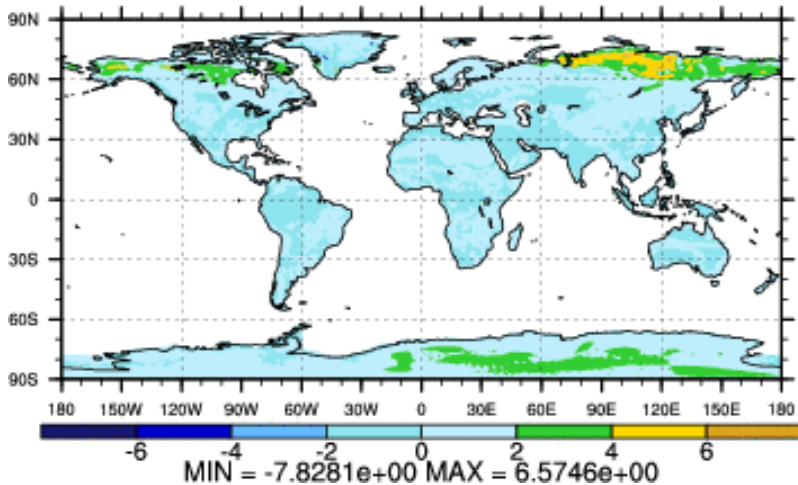
CONTROL (yrs 1979-2003)

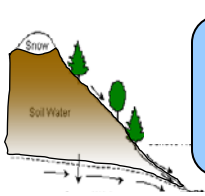


T-Test of two Case means at each grid point

Case 1 - Case 2

Cells are significant at 0.1 level



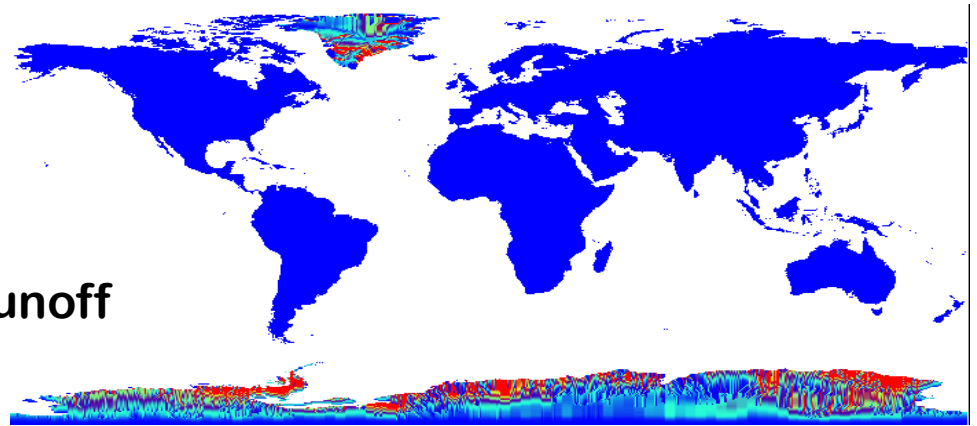


# CLM3.5 → CLM4

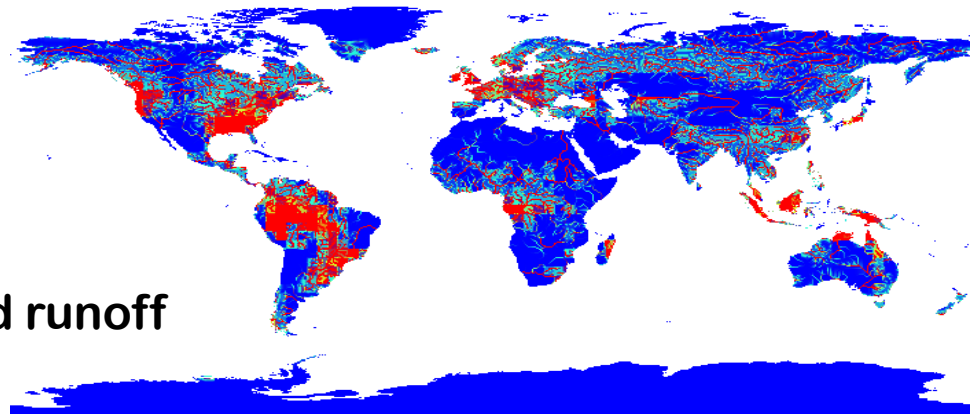
## – Ice stream in River Transport Model (Lawrence, Craig)

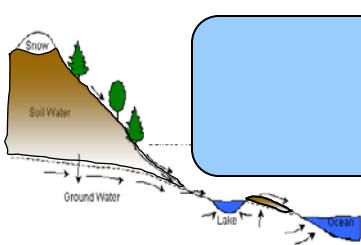
- For snow capped regions send excess water to ice stream (poor man's ice sheet calving)
- Reduces CCSM energy imbalance by  $\sim 0.15\text{-}0.2 \text{ W/m}^2$
- Unrealistic high sea-ice thickness in semi-closed bays

Ice runoff



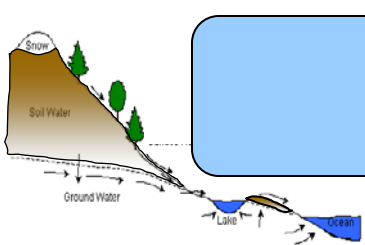
Liquid runoff





# Tower flux statistics (15 sites, monthly)

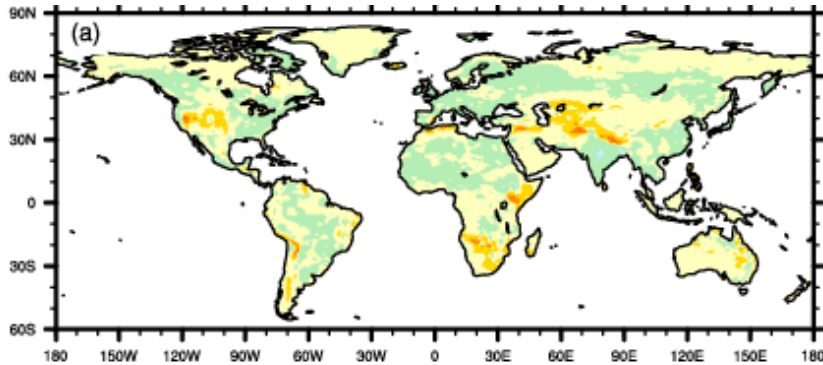
	Latent Heat Flux		Sensible Heat Flux	
	r	RMSE (W/m <sup>2</sup> )	r	RMSE (W/m <sup>2</sup> )
CLM3	0.58	33	0.73	40
CLM3.5	0.83	22	0.67	29
CLM4SP	0.82	23	0.69	26



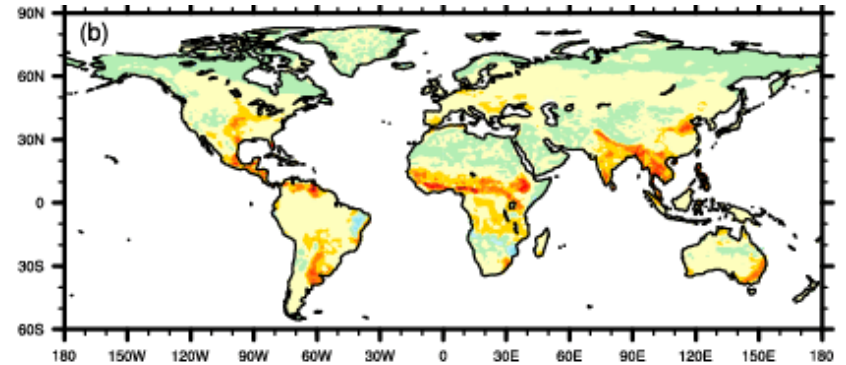
# Interannual variability (MAM)

$$\sigma_2 - \sigma_1$$

CLM4SP – CLM3.5

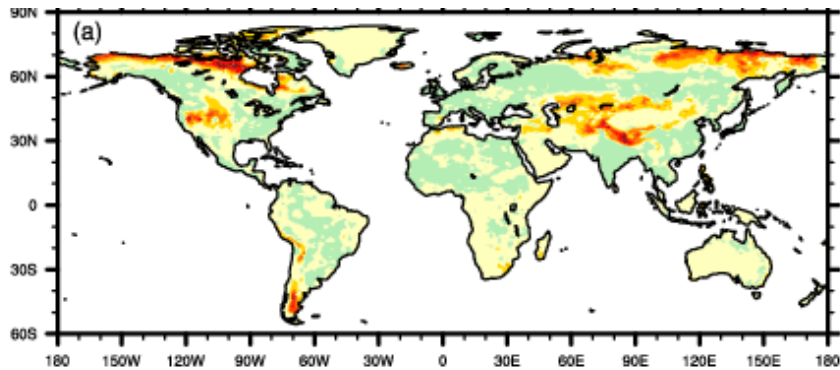


CLM4CN – CLM4SP



$$(\sigma_2 - \sigma_1) / \sigma_1$$

CLM4SP – CLM3.5



CLM4CN – CLM4SP

