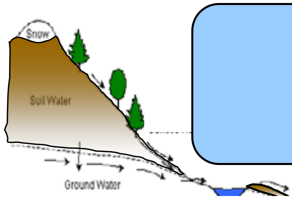
LMWG Activities Relevant to Polar Climate Working Group

1. **Snow model**
2. **Permafrost**
3. **Cold region hydrology**
4. **Soil Carbon**

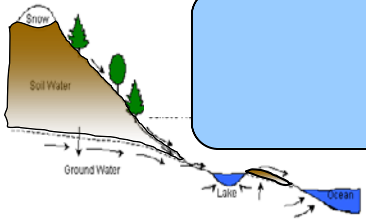
- Change to freezing temperature constant
- forcing height at atm plus z0+d on each tile
- Effective porosity divide by zero fix
- X. Zeng sparse/dense canopy aerodynamic parameters
- Stability formulations
- ground/snow emissivity
- organic soil
- init h2osoi=0.3
- snow compaction fix
- snow T profile 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 vcmax
- SAI and get_rad_dtime fix



CLM3.5 → CLM4

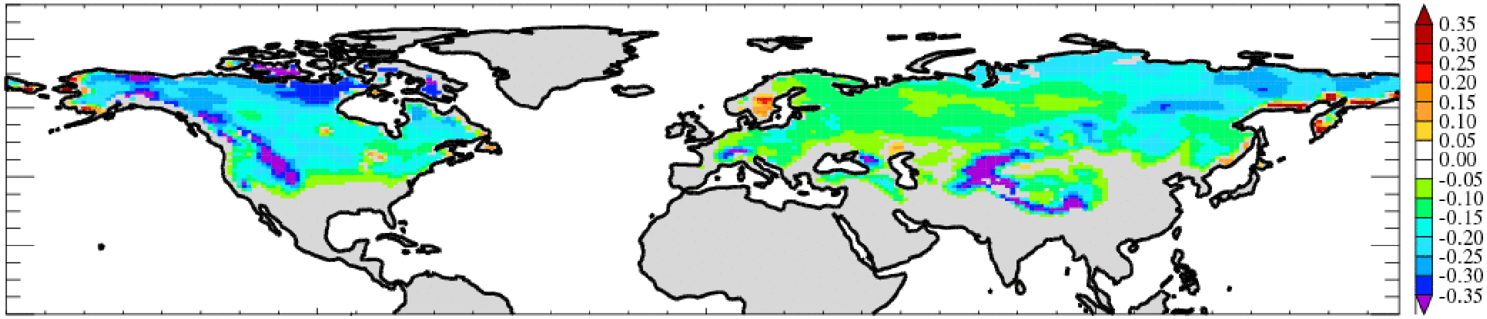
– **Snow model** (Flanner, Zender, Niu, Yang, Lawrence, Zeng)

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

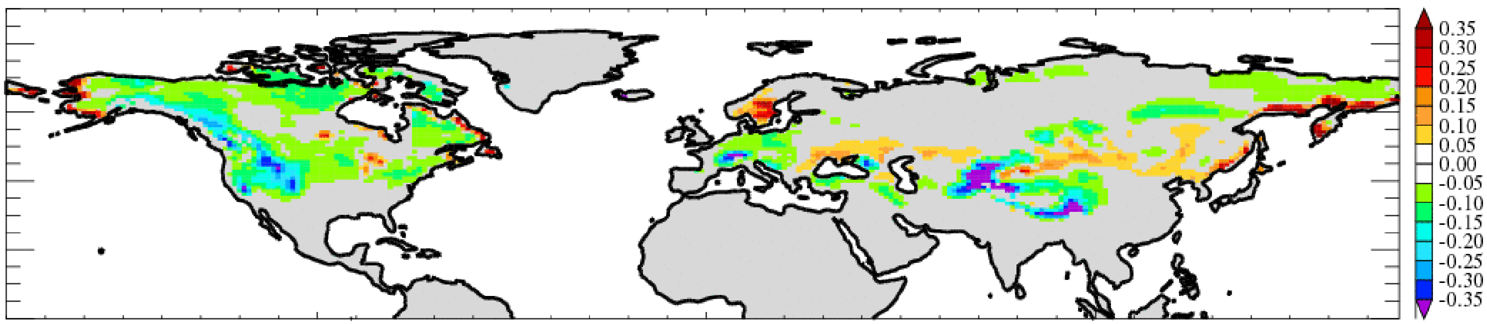


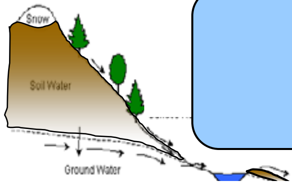
Snow cover fraction

Snow cover fraction: CLM3.5 – Obs



Snow cover fraction: CLM4SP – Obs





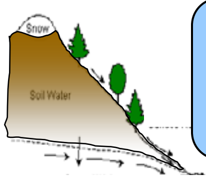
CLM3.5 → CLM4

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

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

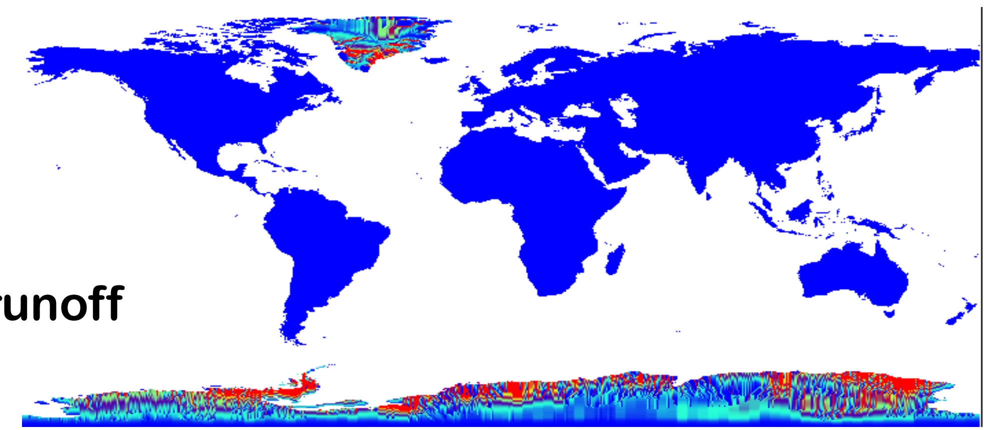
~ +0.13° C to CCSM4 climate sensitivity

- adopt SNICAR
  - 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

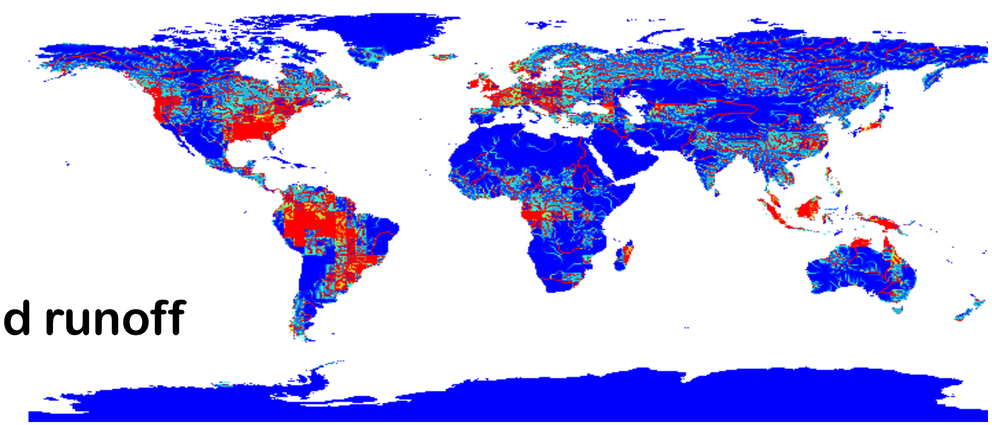


CLM3.5 → CLM4

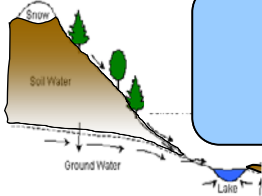
- **Ice stream in River Transport Model (Lawrence, Craig)**
  - For snow capped regions send excess water to ice stream (poor man's ice sheet calving)
  - Reduces CCSM energy imbalance by ~0.15-0.2 W/m^2
  - Unrealistic high sea-ice thickness in semi-closed bays



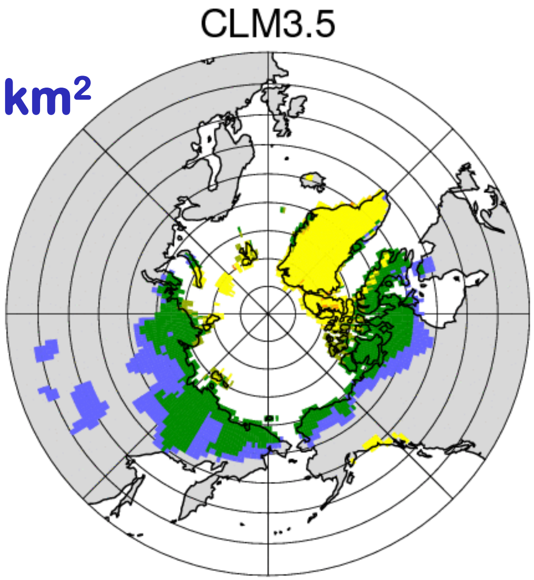
Ice runoff



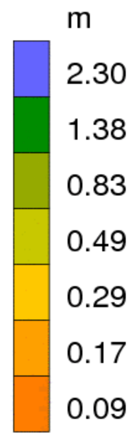
Liquid runoff

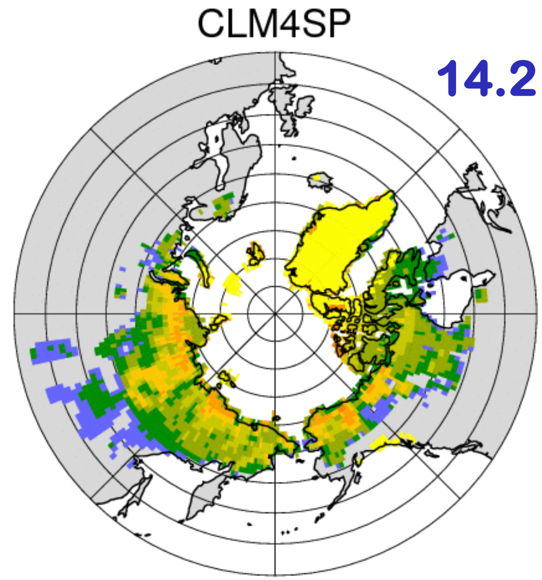


Near-surface Permafrost Extent and Active Layer Thickness



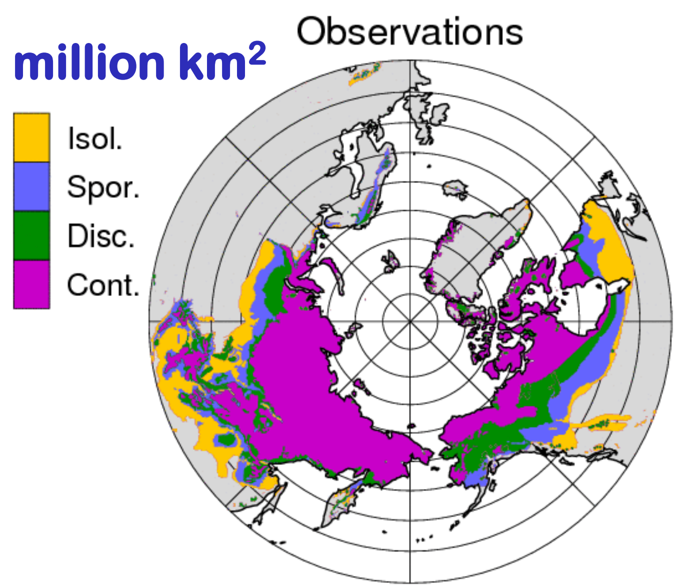
8.2 million km²





14.2 million km²

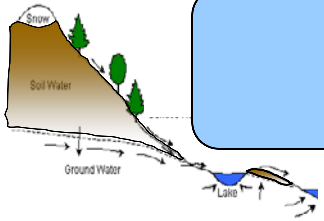
11.3 – 14.3 million km²



Organic soil

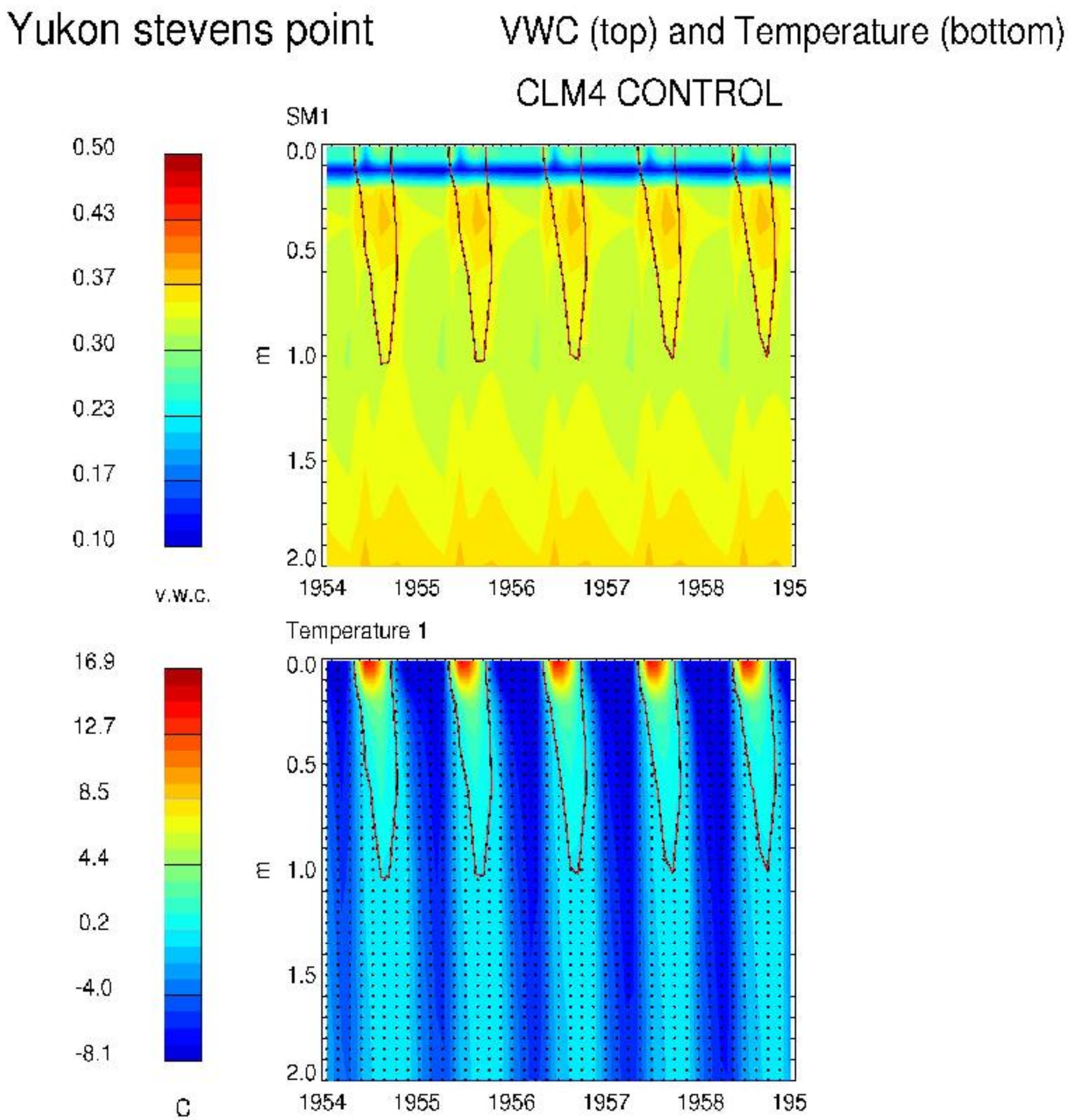
thermal and hydraulic prop

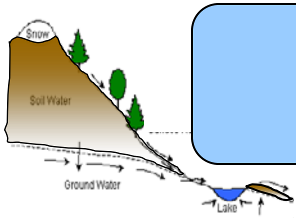
Deep soil column (~50m deep)



Cold region hydrology problem in CLM4

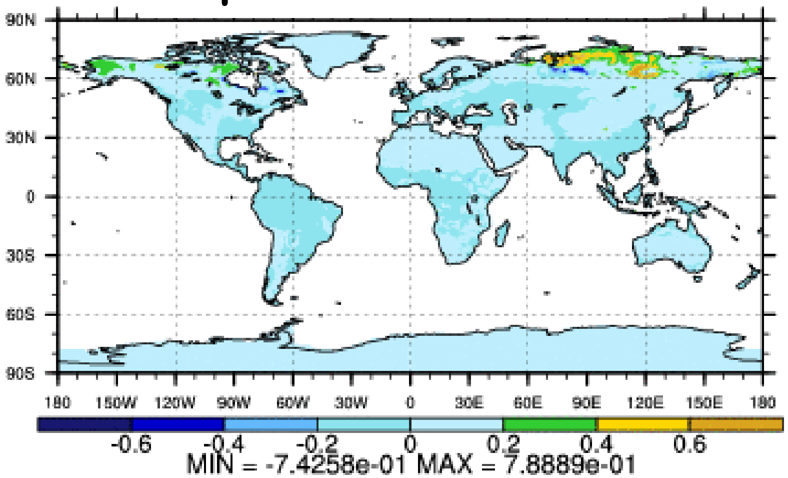
Slow leak of ~+3.5 mm yr^{-1} to Arctic Ocean in early part of CCSM4 1850 control



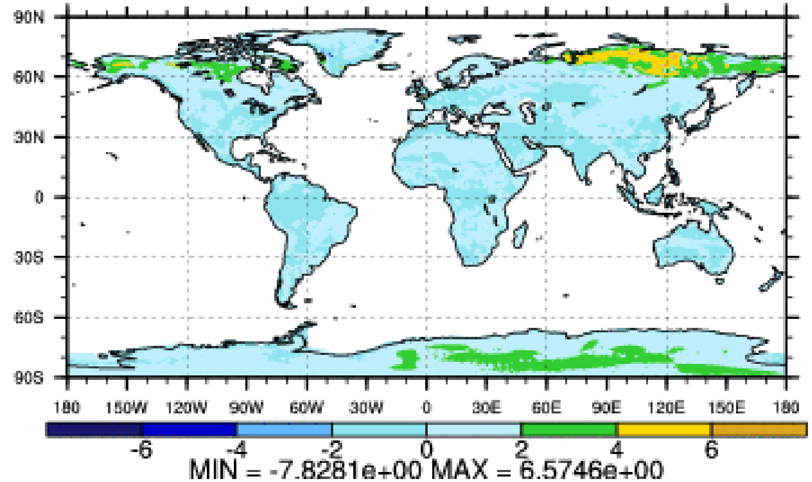


Cold region hydrology: impact of impedance factor for icy soil

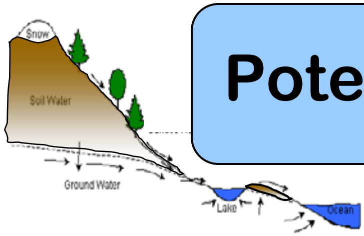
Soil Moisture (0.4m) Impedance – Control

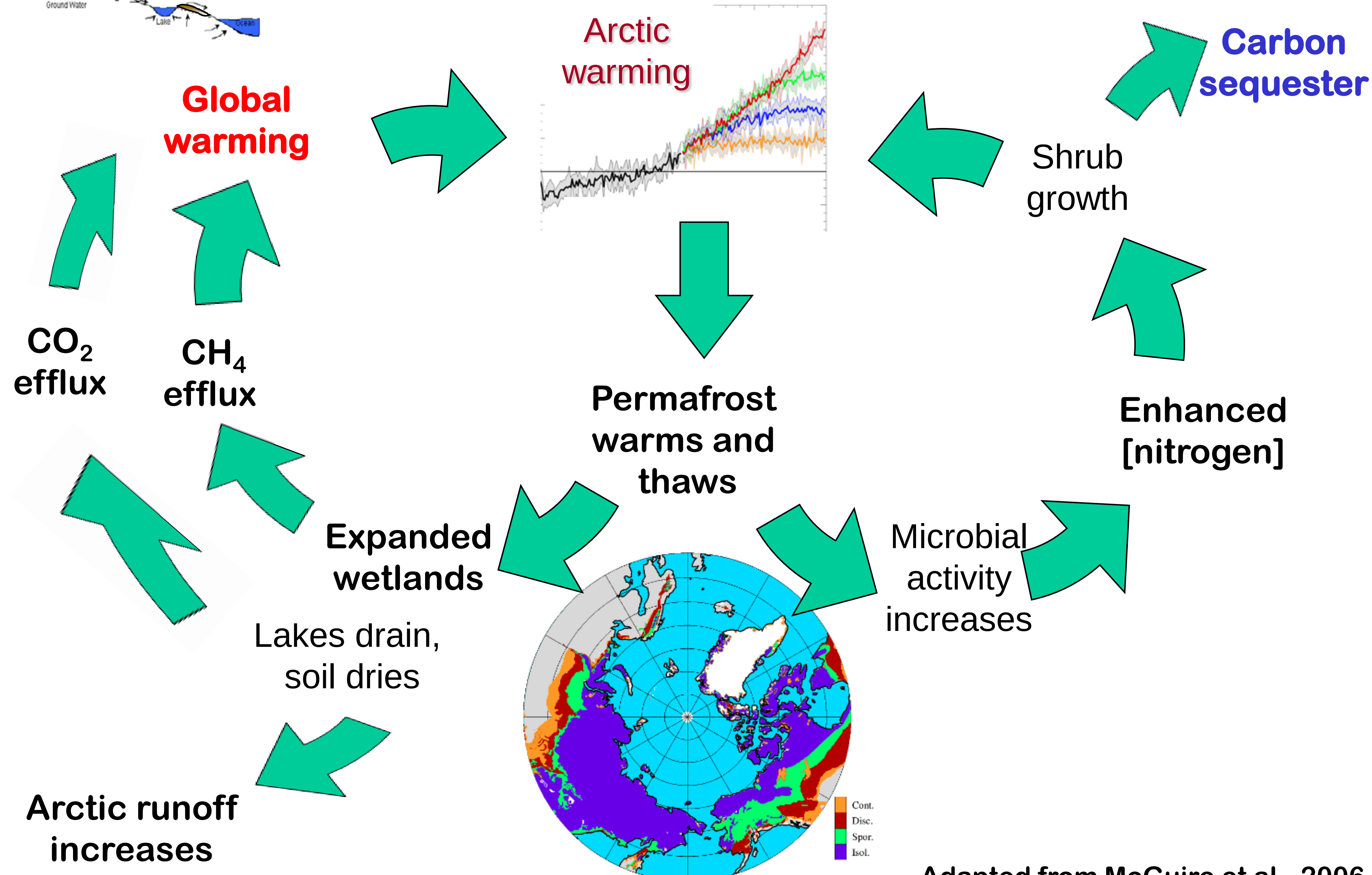


Soil Temperature (0.4m) Impedance – Control

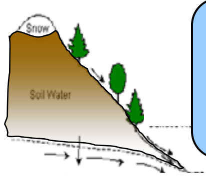


Potential Arctic terrestrial climate-change feedbacks

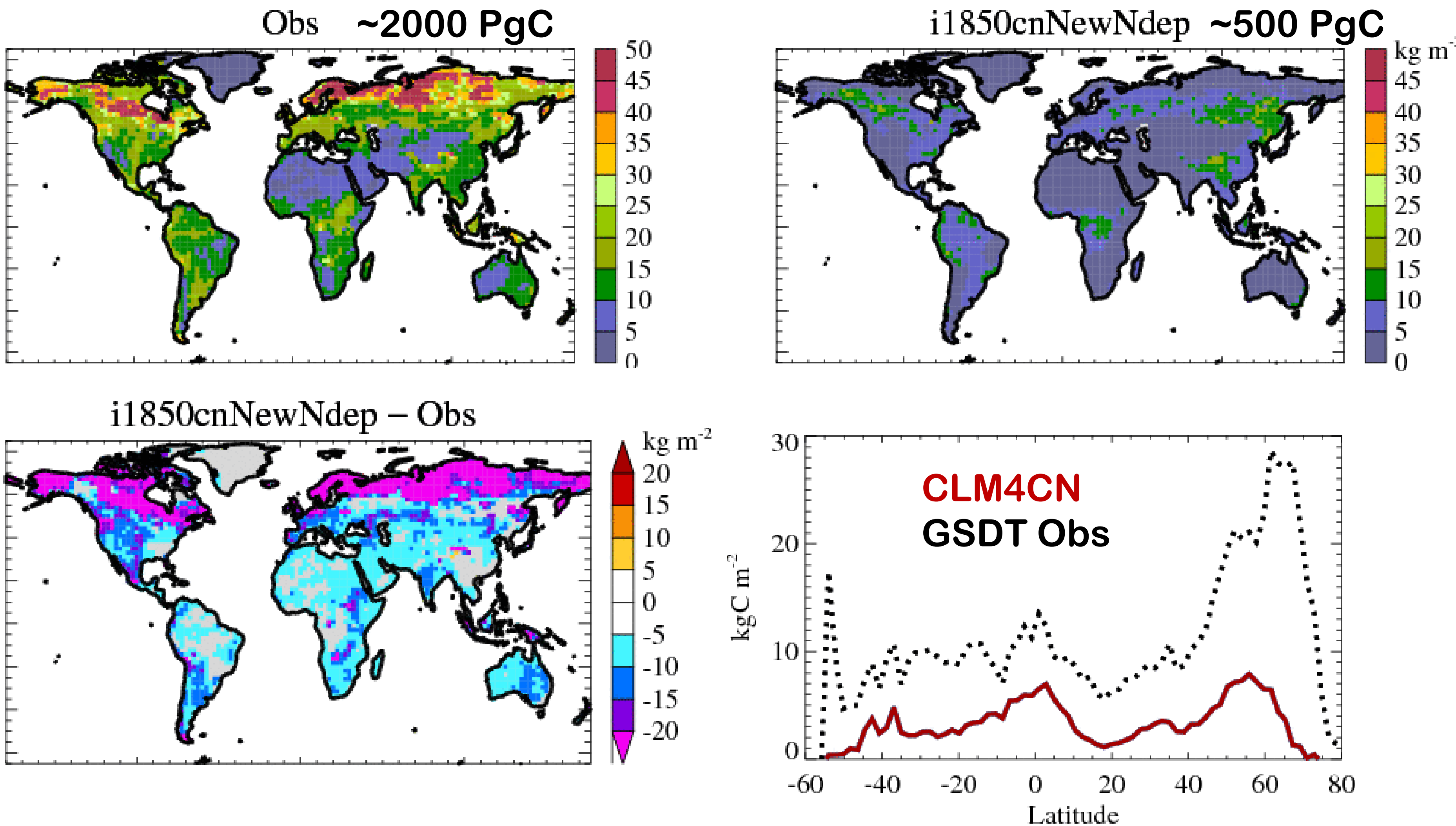


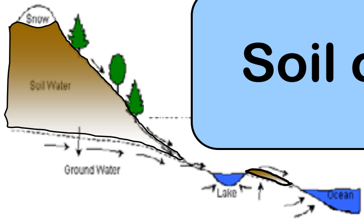


Adapted from McGuire et al., 2006



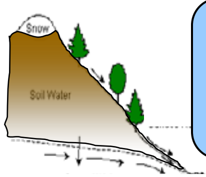
CN Soil carbon compared to Global Soil Data Task obs



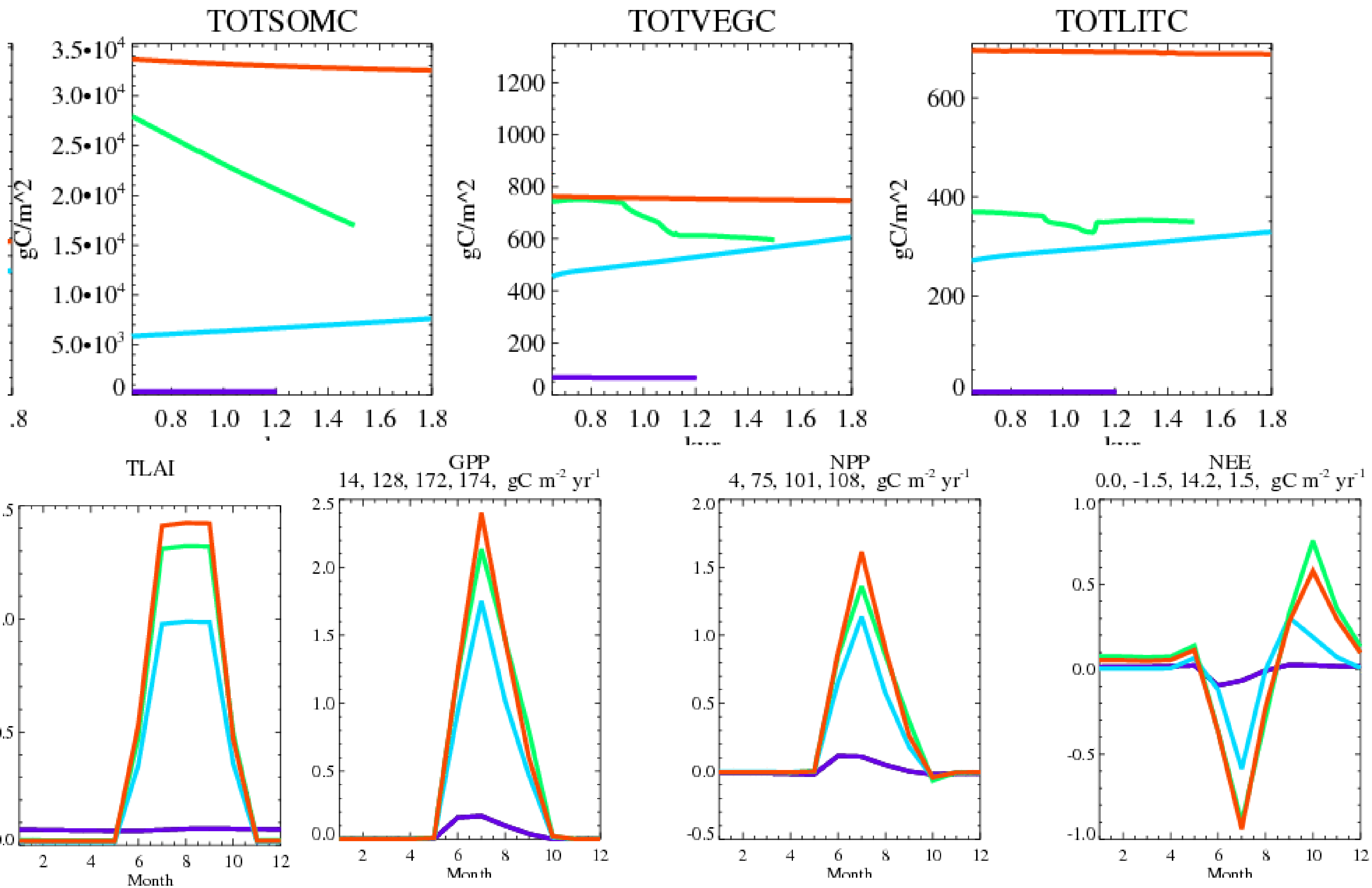


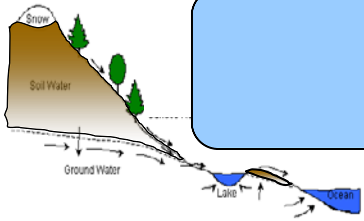
Soil carbon: Issues from perspective of northern high latitudes

- In tundra zones, very low vegetation growth CLM4CN (at least partly due to hydrology problem)
- Soil decomposition rates
  - No limits due to anoxia at high saturation levels
  - Soil carbon is assumed to be in top ~0.5m, no frozen carbon
- Large carbon stores result of thousands of years of accumulation (with differing initiation dates) in peatlands or similar systems
- Not representing unique biogeochemistry of peatlands



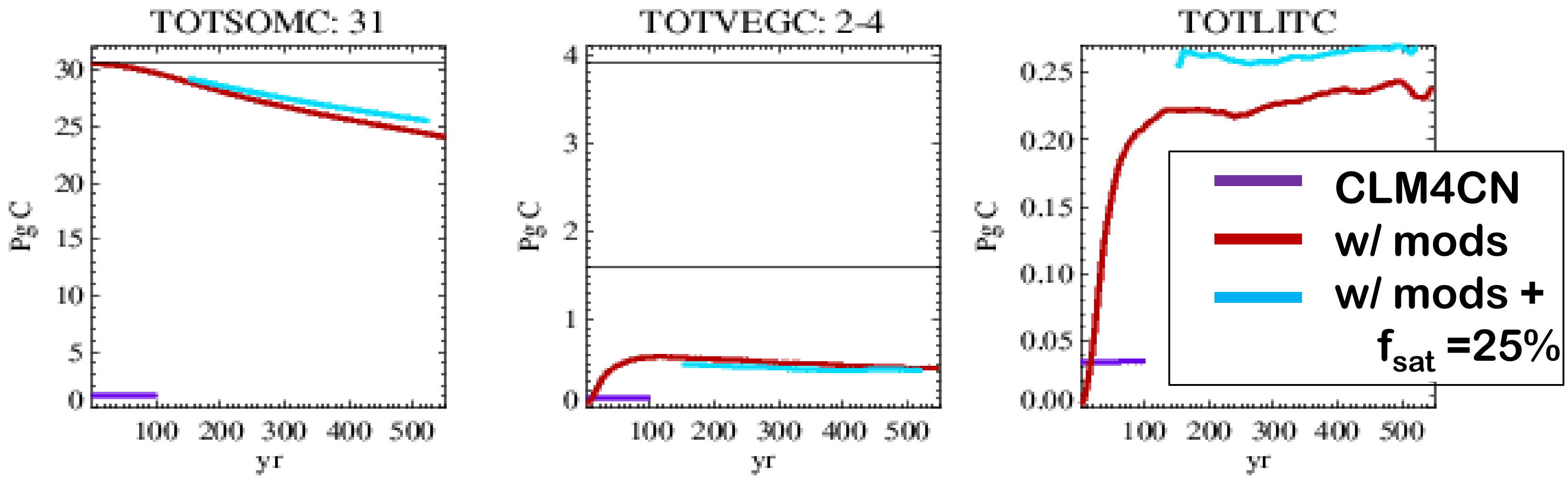
Arbitrary point in Alaska Arctic



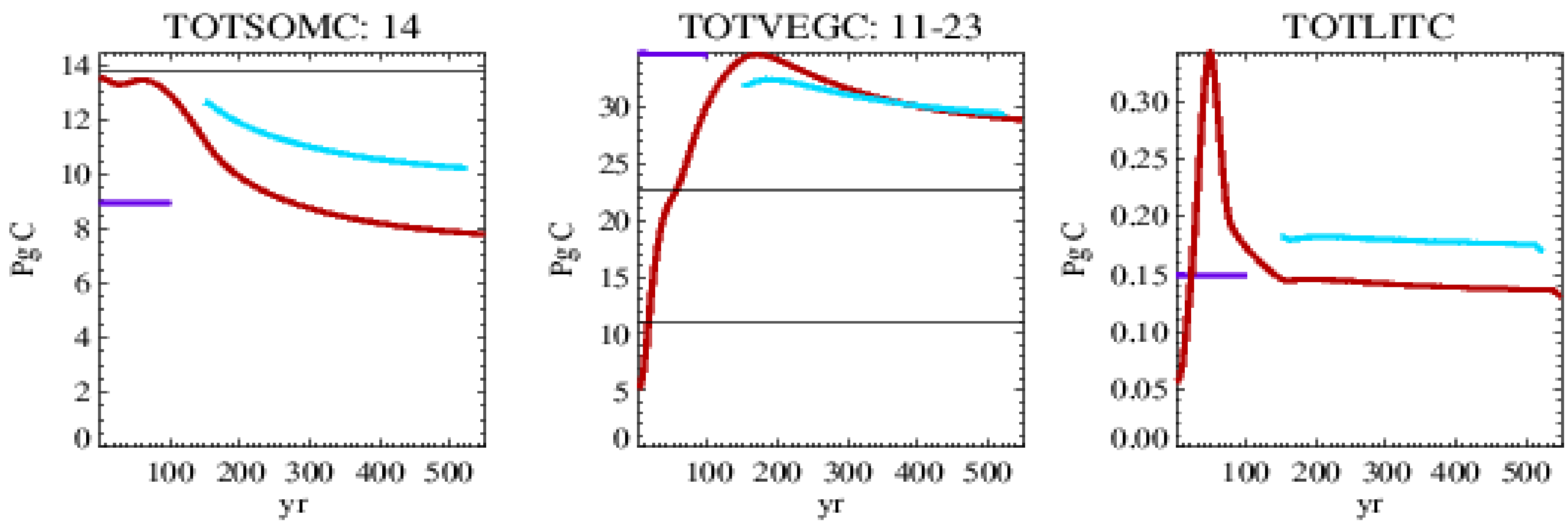


Results from global runs

Alaska Arctic



Amazonia



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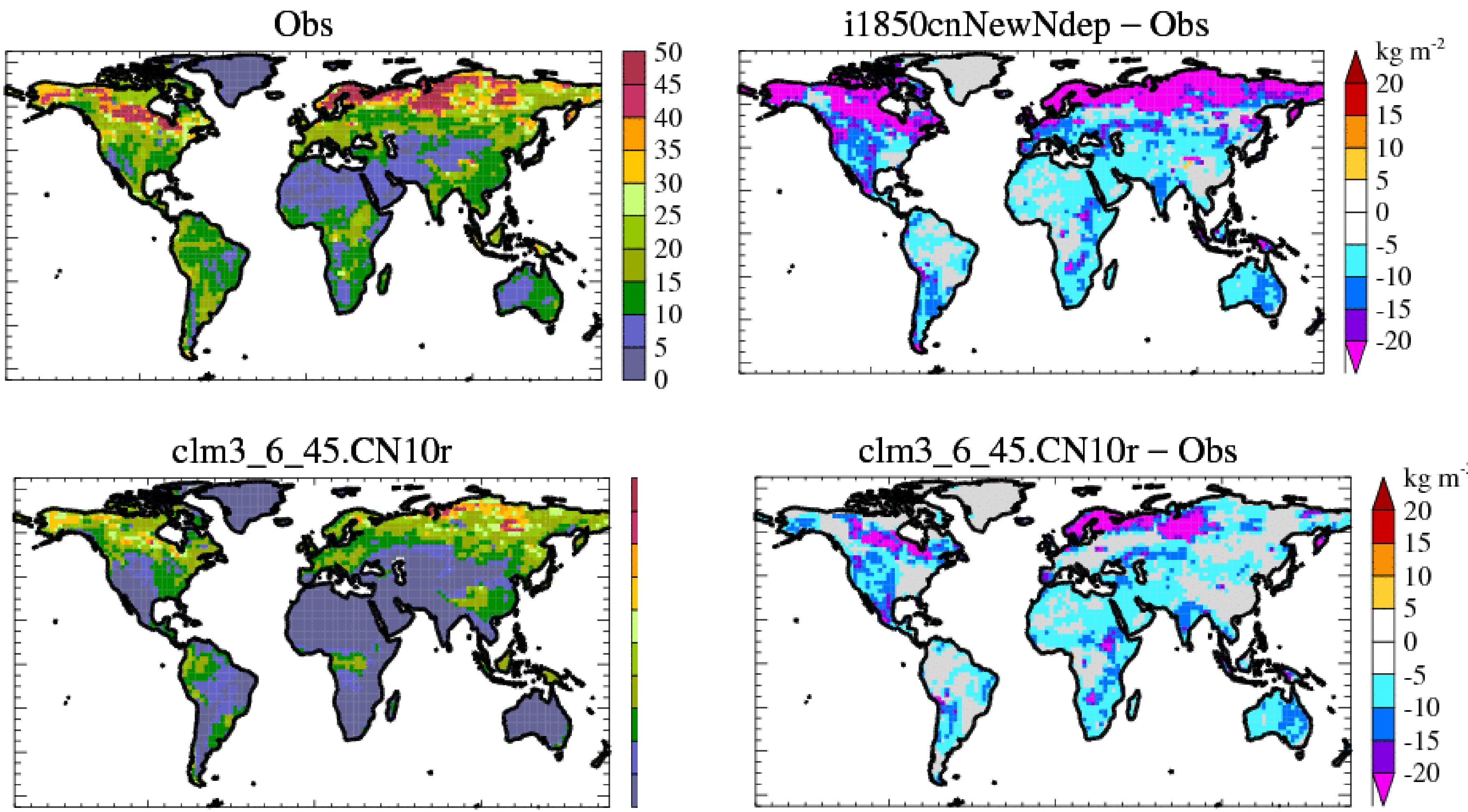
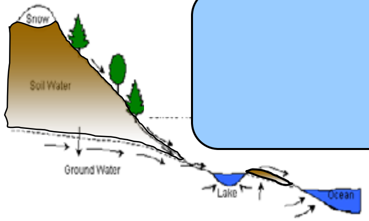
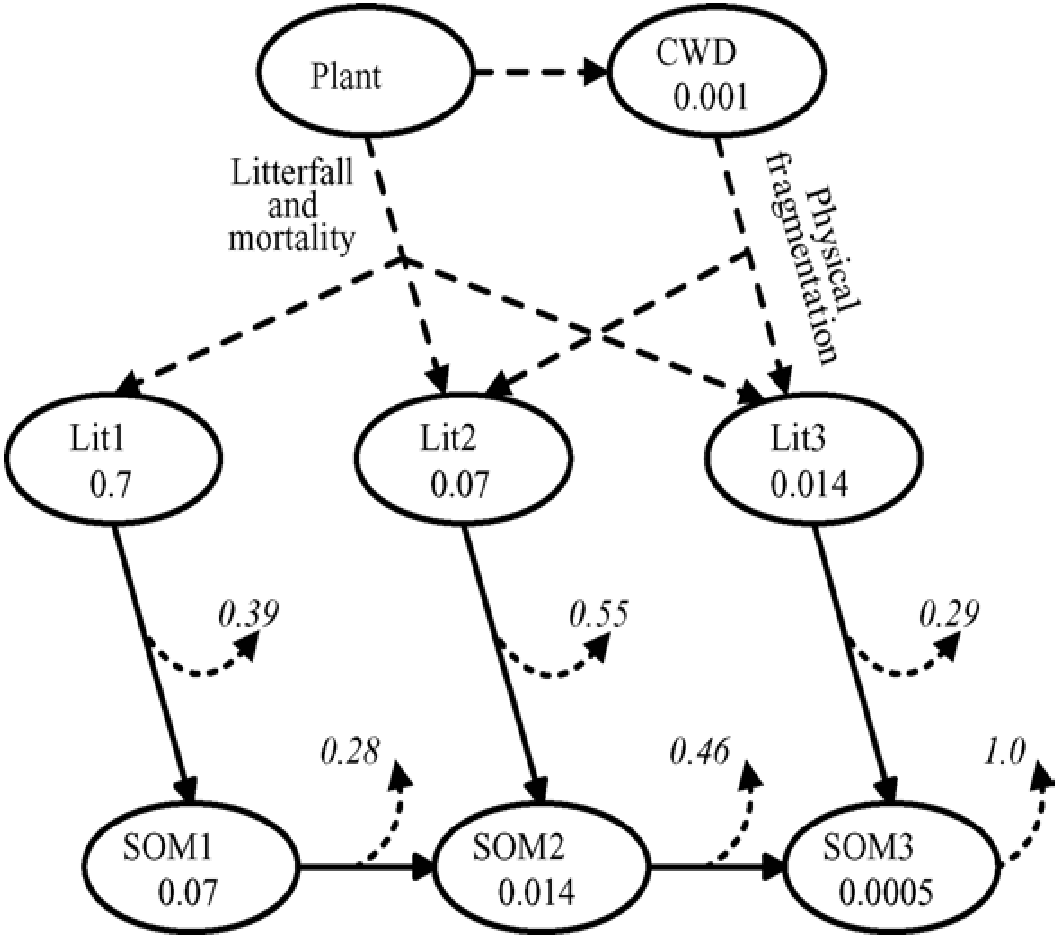


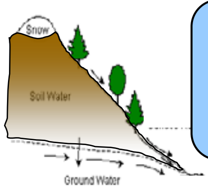


Heterotrophic soil respiration in CLM-CN



Base decomposition rates for each SOM pool are modified by functions of water and temperature

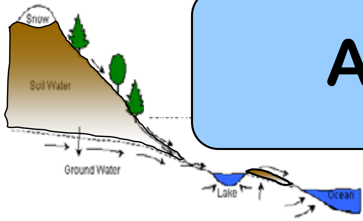
Thornton and Zimmerman, 2005

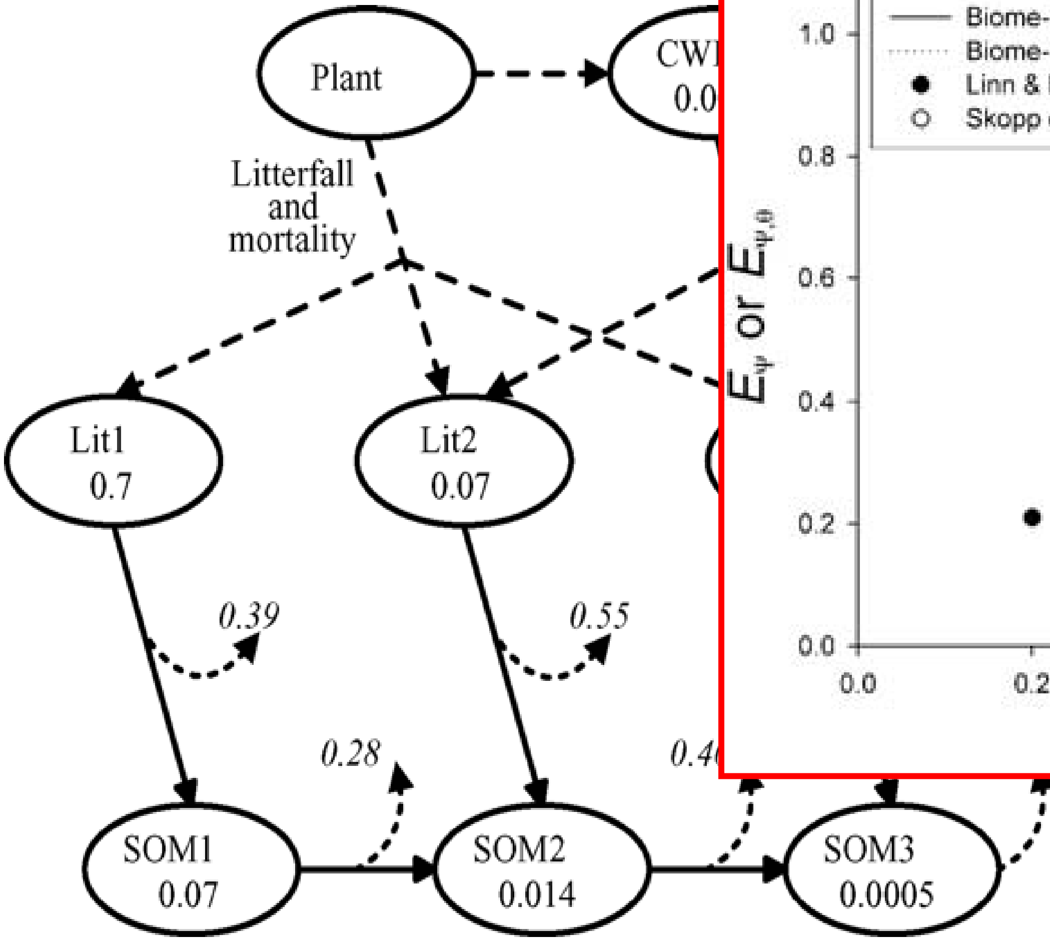


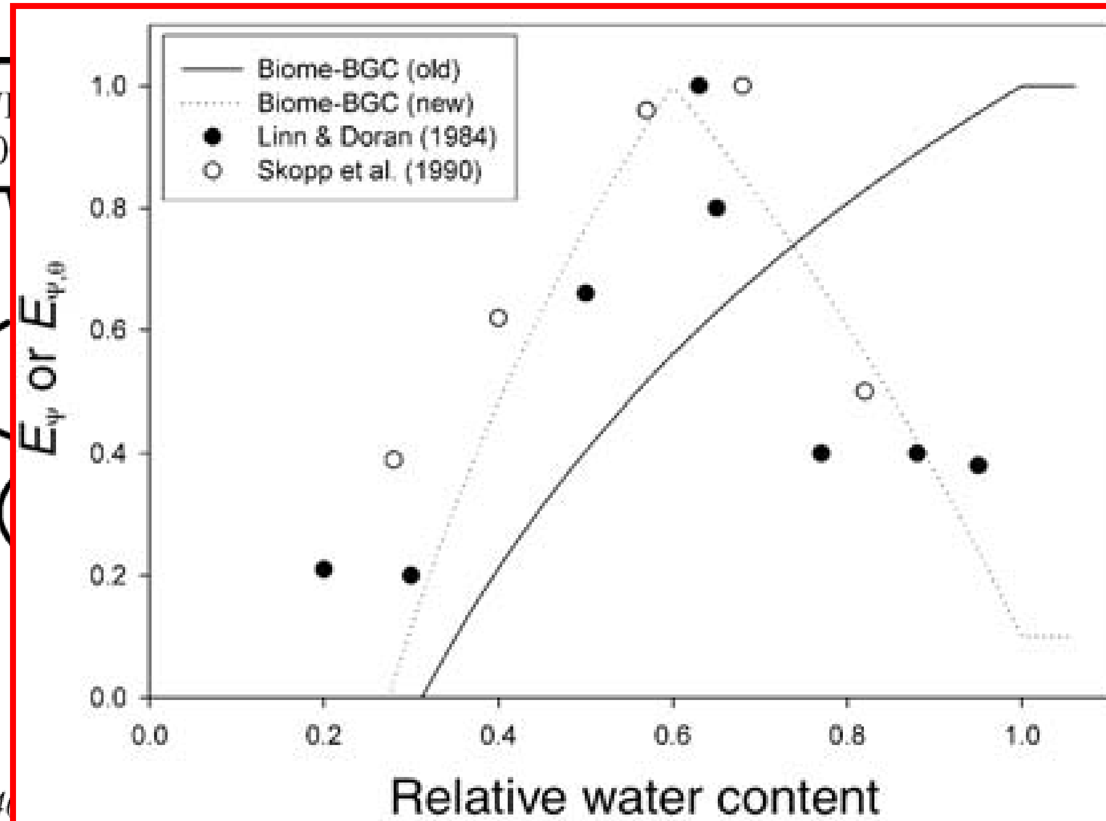
Proposed modifications

- Cold region hydrology modifications from Sean
- Connect organic soil thermal and hydrologic properties (Lawrence and Slater, 2008) with prognostic CN soil carbon
  - Represent vertical decrease in hyd. conductivity from fabric to sapric peat - wetter soil in organic rich regions
- Incorporate anoxia limitation on decomposition rates
  - Sync up CLM soil suction with CN soil suction
- Account for impact of vertical distribution of soil carbon on decomposition rates
- Change Q10 from 1.5 to 2 or ???
- Assume that Arctic C3 grass more like moss – grows in nutrient-limited environs
- Initialize model with ‘observed’ soil carbon and slowly turn on carbon pool transfers

Anoxia limitation on soil carbon decomposition

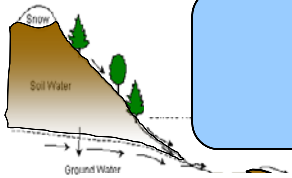






Bond-Lamberty et al., 2007

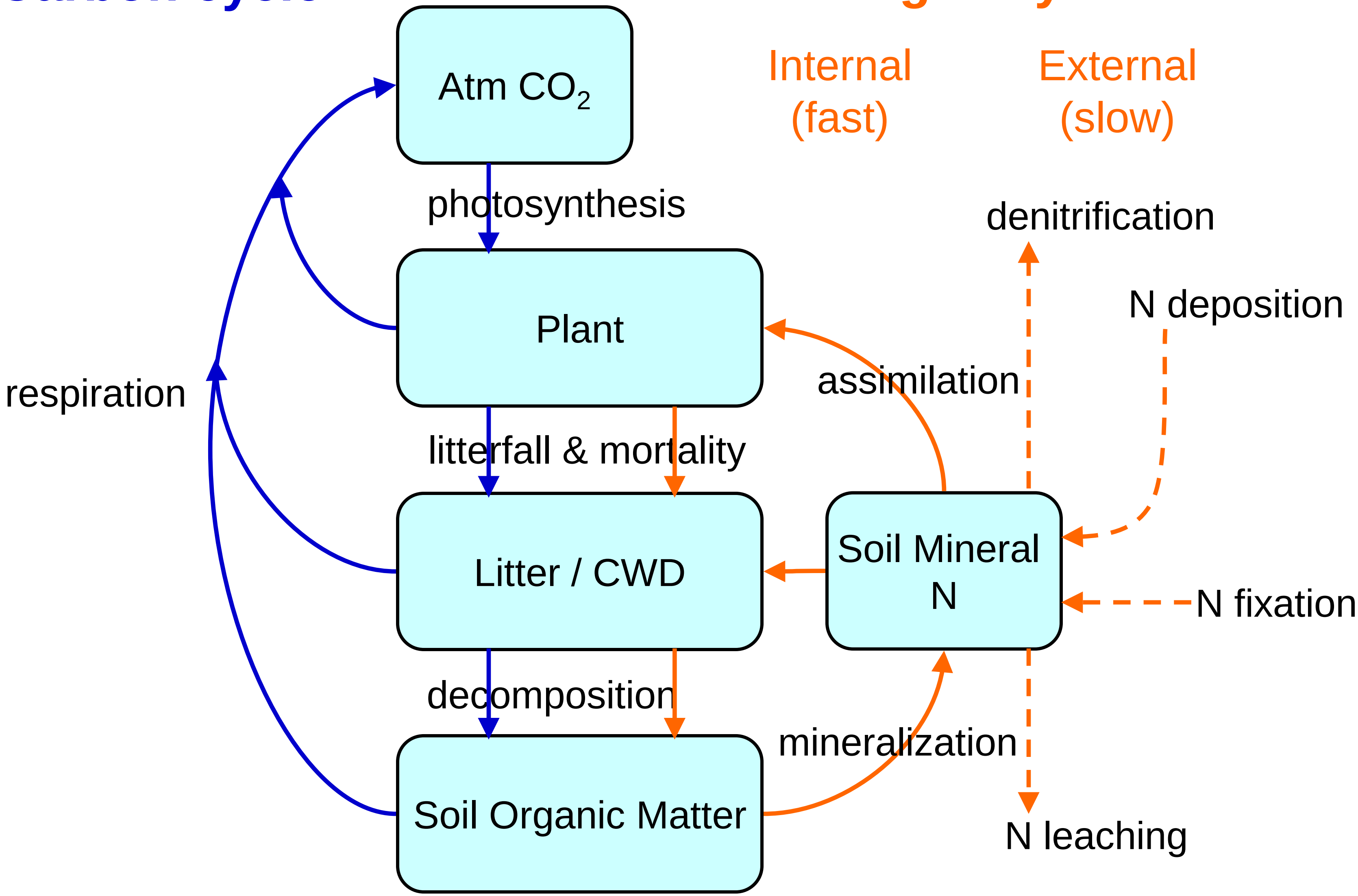
Thornton and Zimmerman, 2005



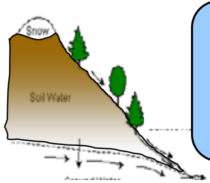
CLM3.5 → CLM4 : Carbon and Nitrogen cycling

Carbon cycle

Nitrogen cycle

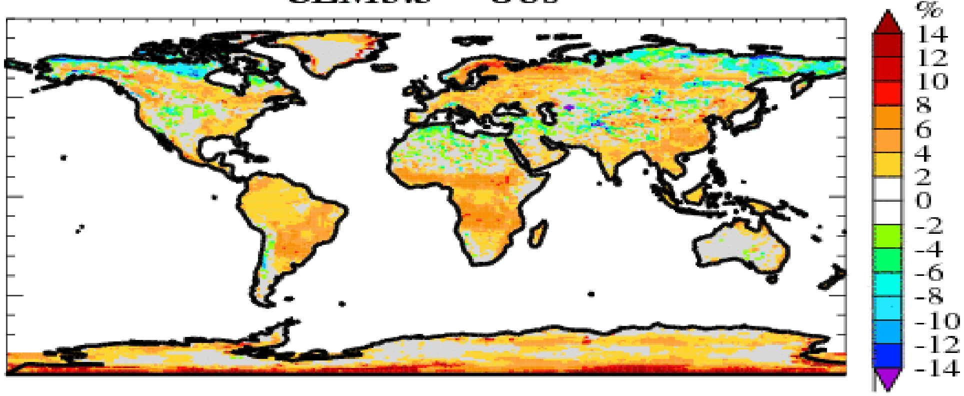


Based on Biome-BGC, Thornton et al., 2009

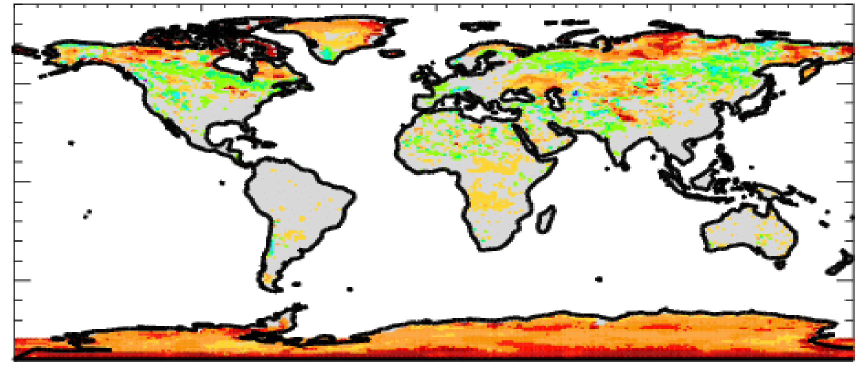


Albedo

CLM3.5 – Obs

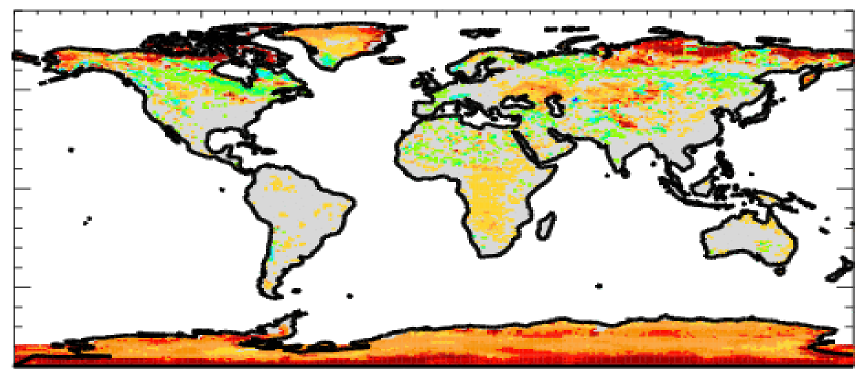


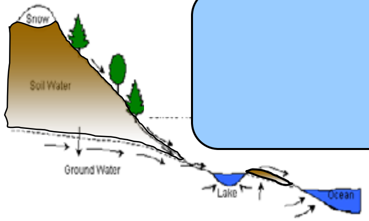
CLM4SP – Obs



	Bias (%)		RMSE (%)	
Model	**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**

CLM4CN – Obs

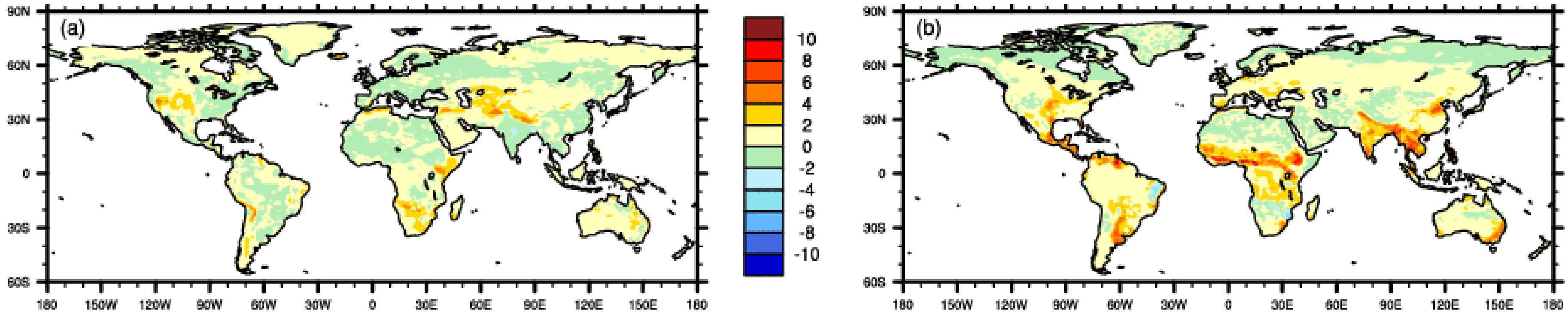




Interannual variability (MAM)

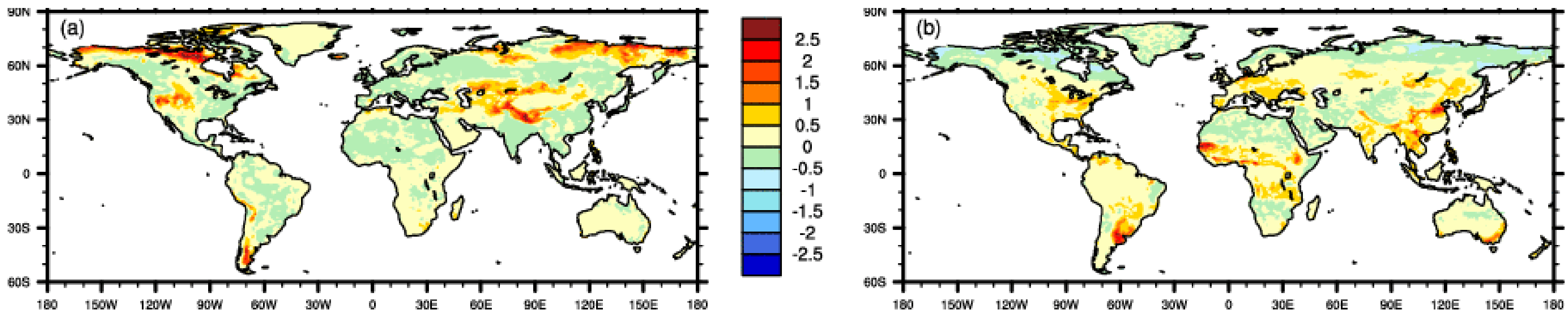
$\sigma_2 - \sigma_1$

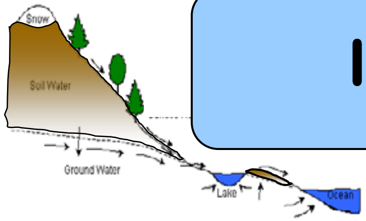
CLM4SP – CLM3.5 | **CLM4CN – CLM4SP**



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

CLM4SP – CLM3.5 | **CLM4CN – CLM4SP**

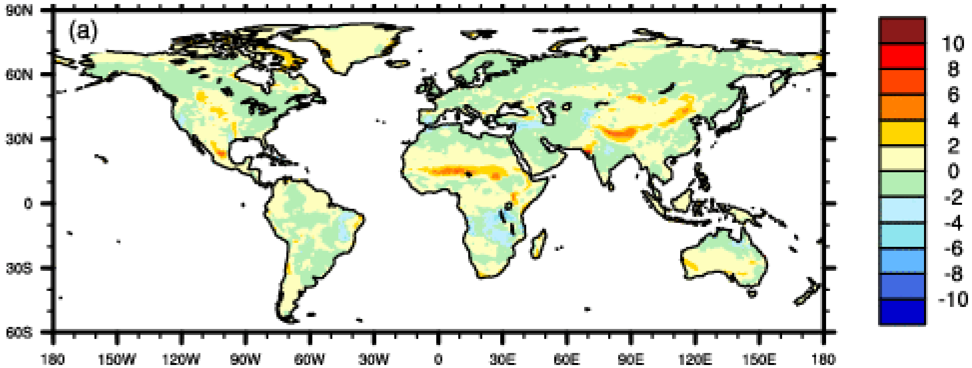




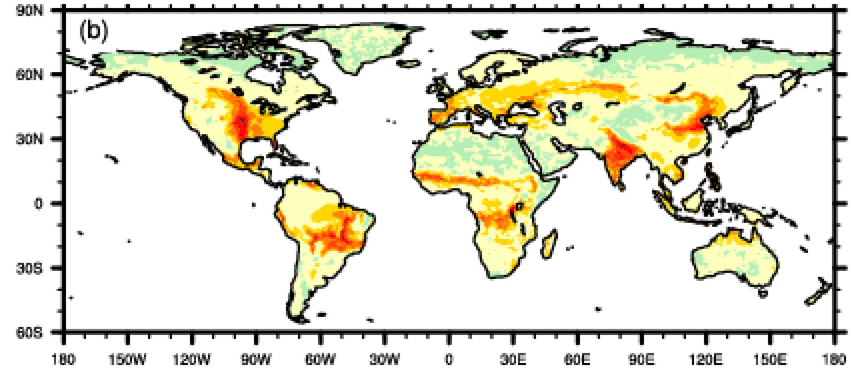
Interannual variability (JJA): Latent Heat Flux

$\sigma_2 - \sigma_1$

CLM4SP – CLM3.5

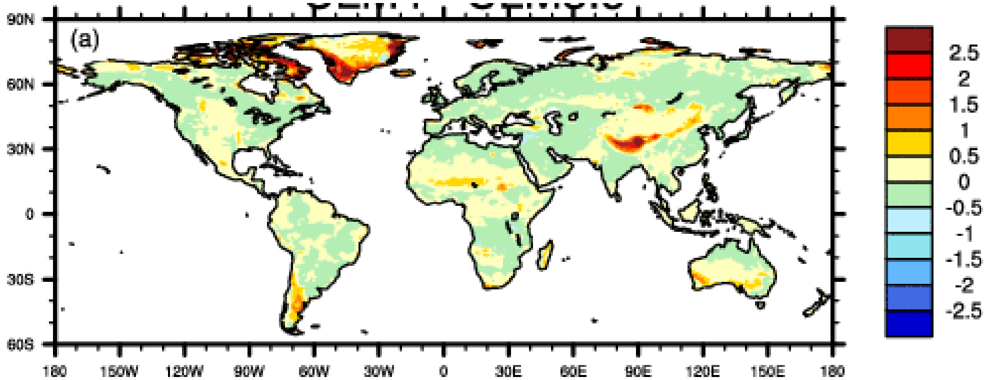


CLM4CN – CLM4SP

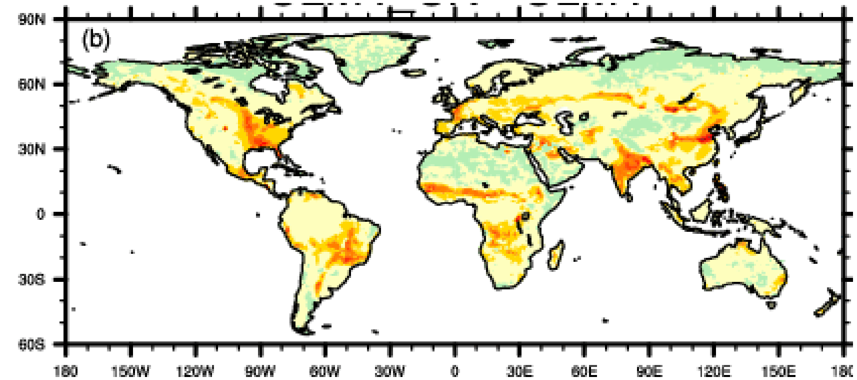


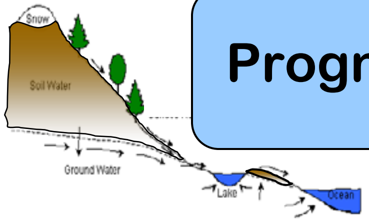
$(\sigma_2 - \sigma_1)/\sigma_1$

CLM4SP – CLM3.5



CLM4CN – CLM4SP





Prognostic phenology and vegetation state (LAI, canopy height)

CLM4
- CLM4SP: satellite phenology
- CLM4CN: carbon-nitrogen cycle phenology