Community Land Model existing and future capabilities relevant to SDWG

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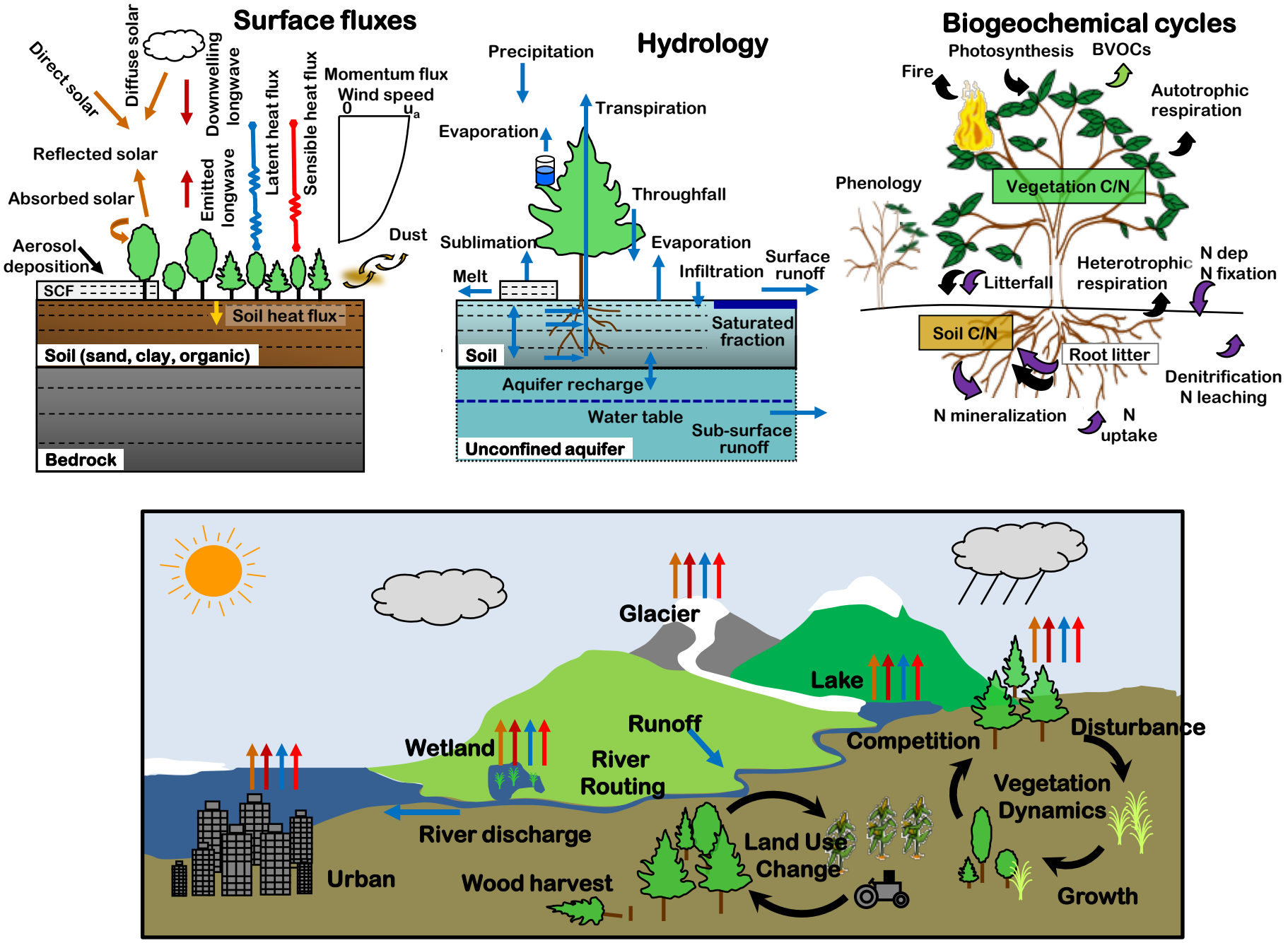
NCAR Earth System Laboratory

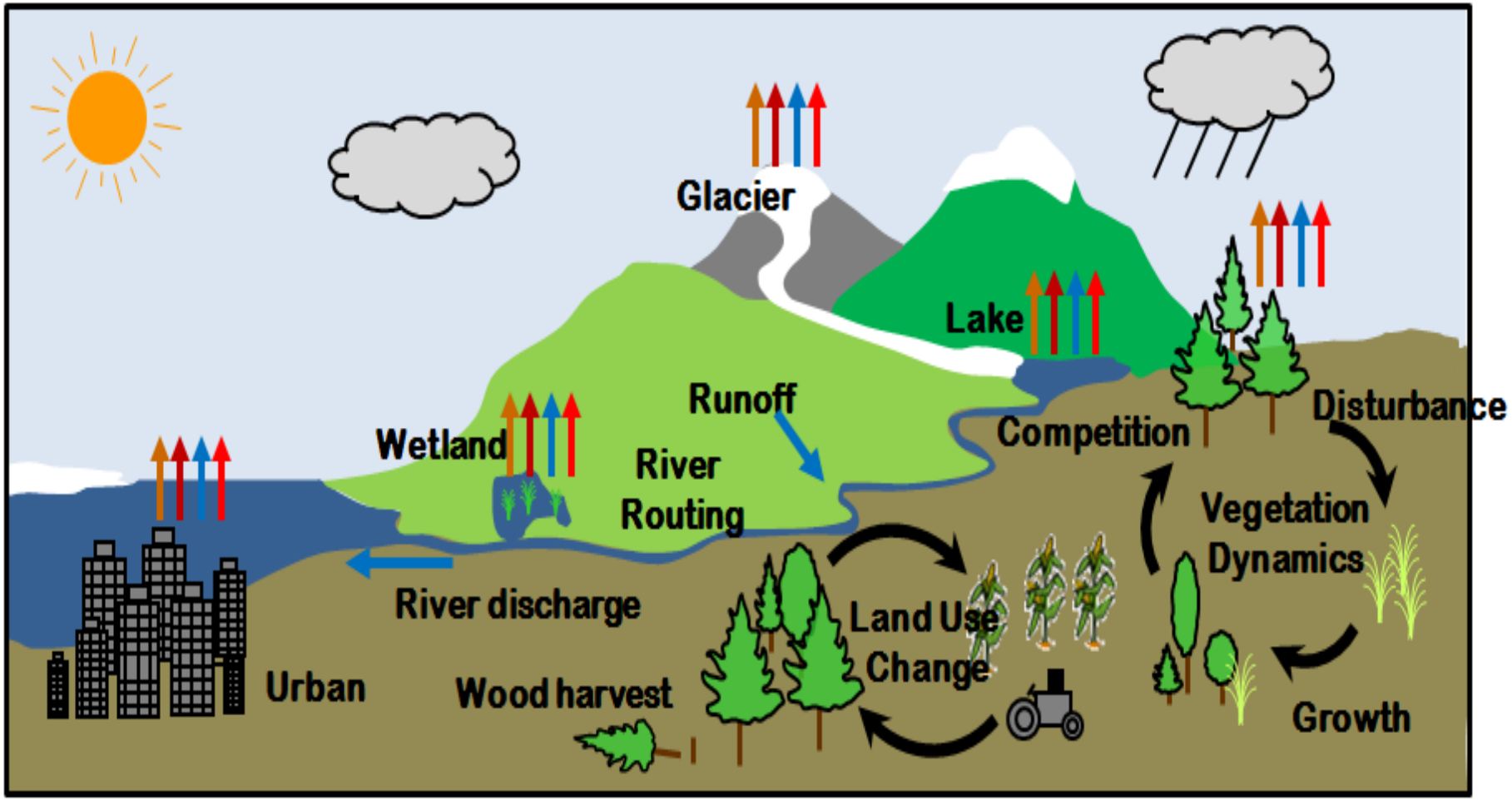
with input from members of LMWG and BGCWG

NCAR is sponsored by the National Science Foundation



Lawrence et al., Journal Advances Modeling Earth Systems, 2011

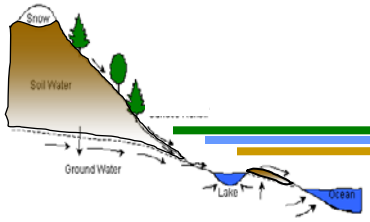
Landscape Dynamics



Humans in CLM

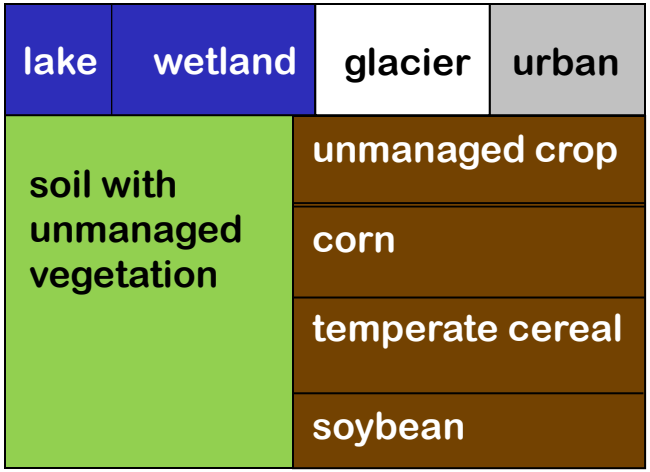
Crop and urban modeling, land cover and land use change

Emphasis on feedbacks of human activities onto climate system, but with an eye towards building a model that can be utilized for impacts studies

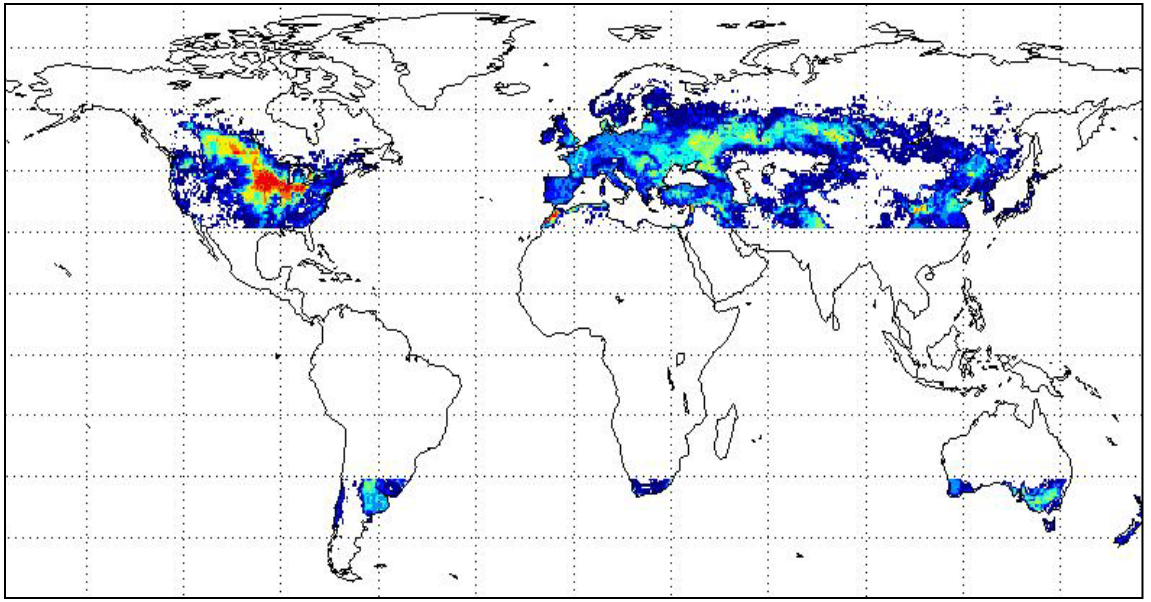


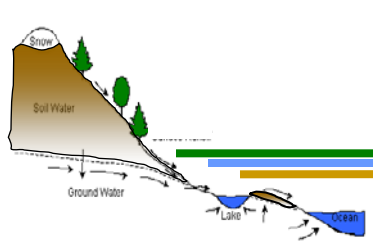
Crop modeling in CLM

- Crops (spring wheat, corn, soybean): planting, growth, harvesting; based on Agro-Ibis
- Irrigation: Area equipped for irrigation, water taken from runoff to maintain soil wetness above wilting point
- Crops and irrigation have demonstrable affects on climate



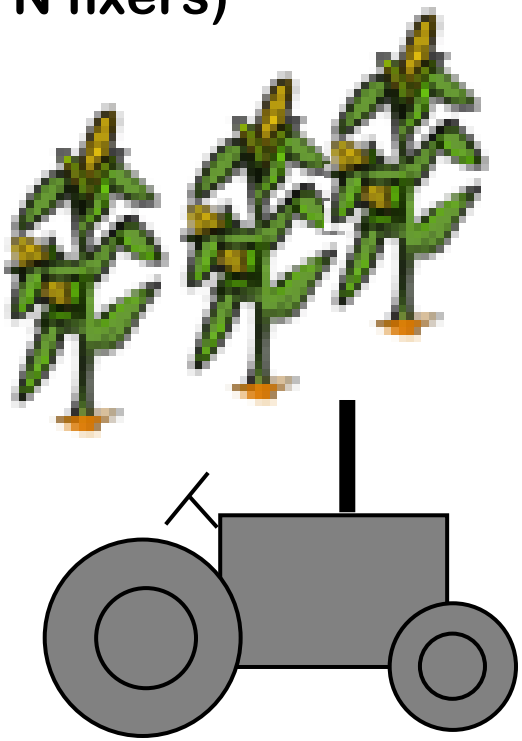
Managed crop area



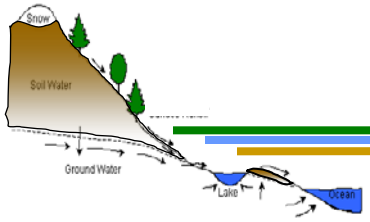


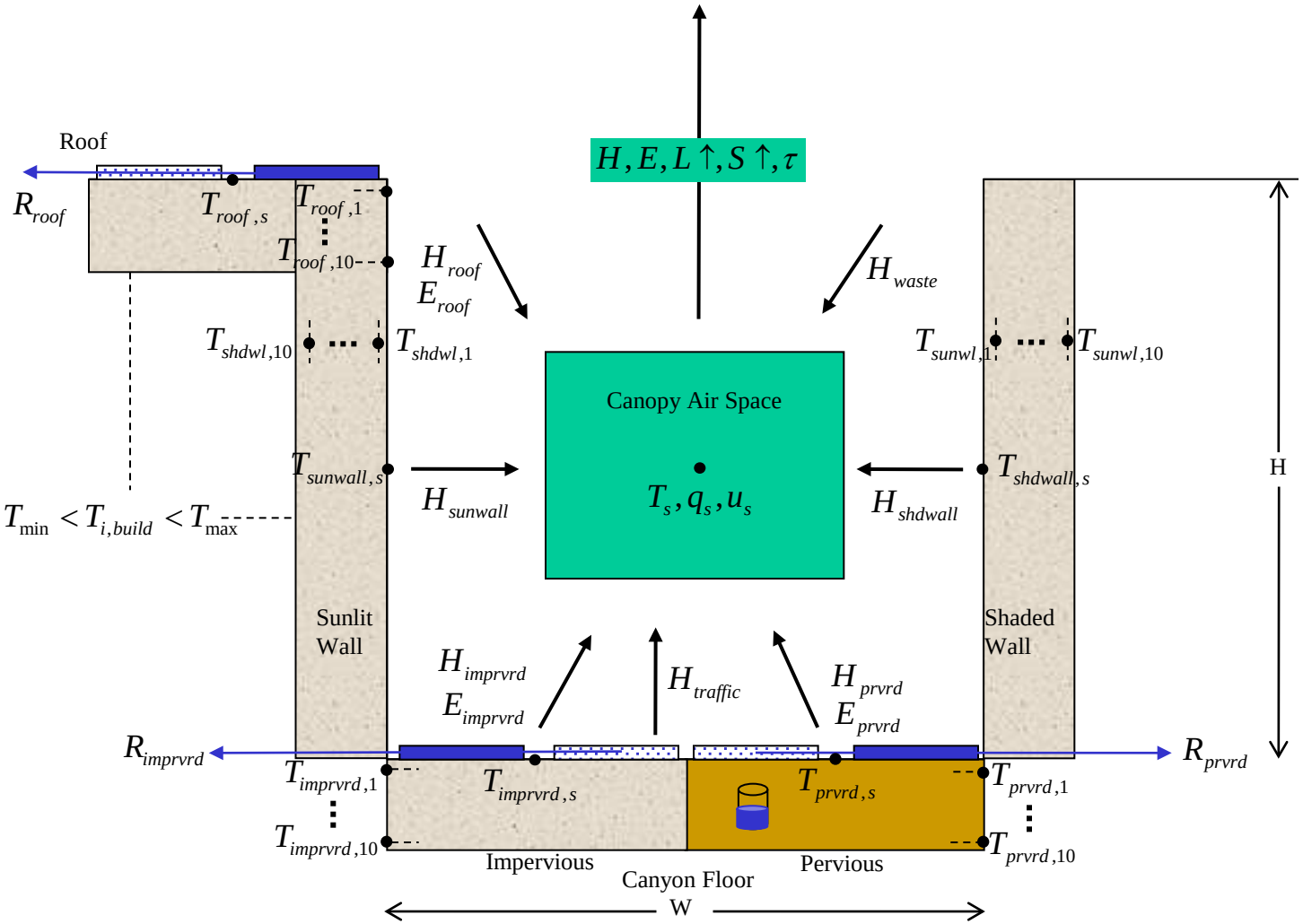
Planned crop model improvements

- 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



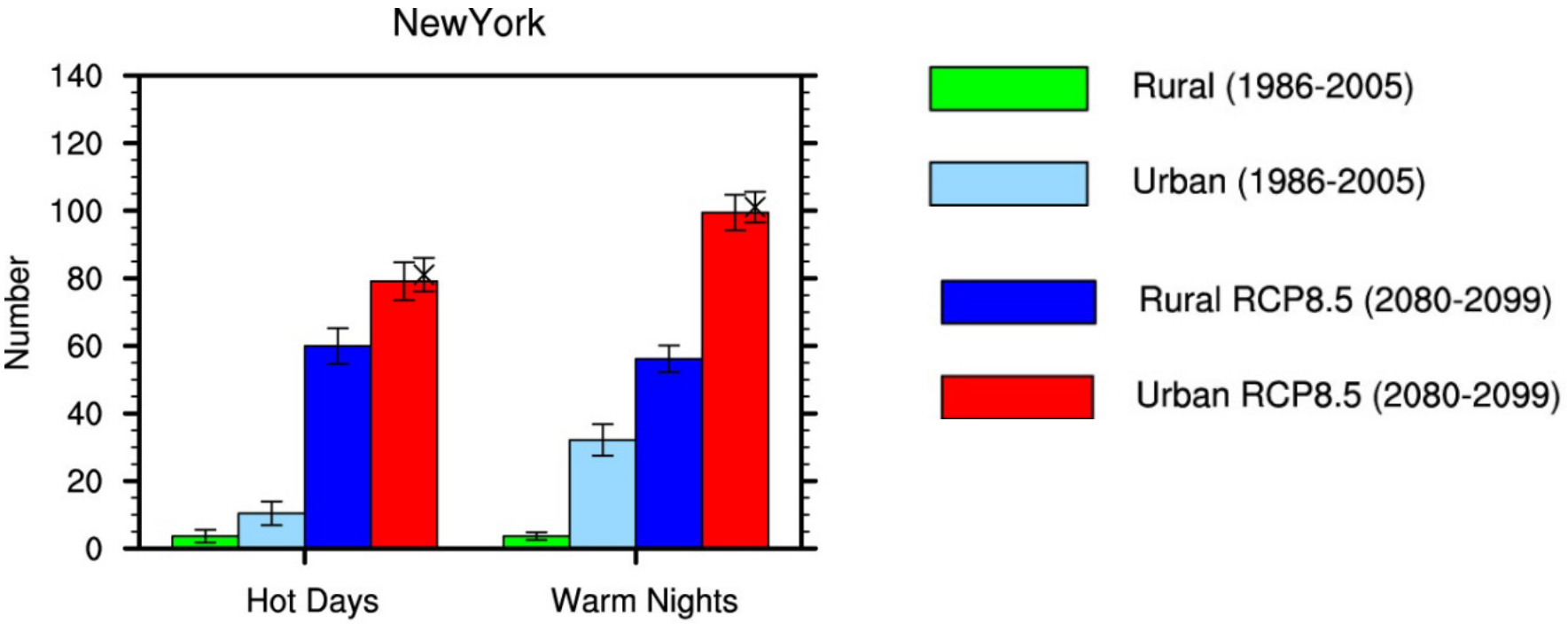
Urban model in CLM





Changes in hot days and warm nights – RCP8.5

Hot days (warm nights) – Number of days per year that daily TMAX (TMIN) exceeds 99th percentile of present day Rural daily TMAX (TMIN)



Present-day climate

Cities have more hot days and warm nights than rural land

21st century climate change

Cities increase more in hot days and warm nights than does rural land

Slide courtesy K. Oleson

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

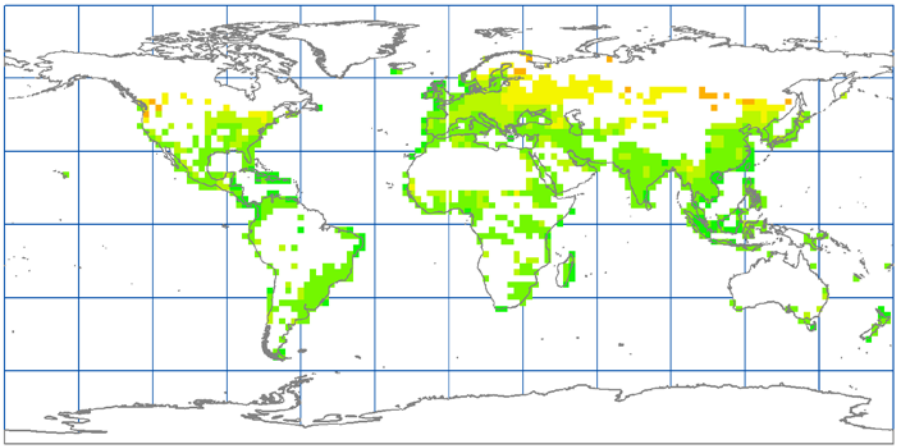
Road properties

Interior Tsettings

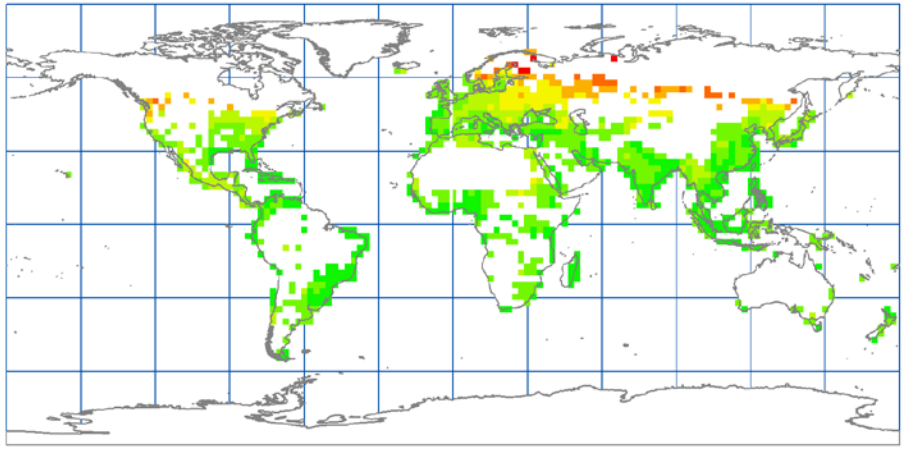
- Urban emissions (long term goal, but no active project)

Urban Heat Island Comparison: Parameterization Sensitivity

Vancouver Parameters Applied Globally



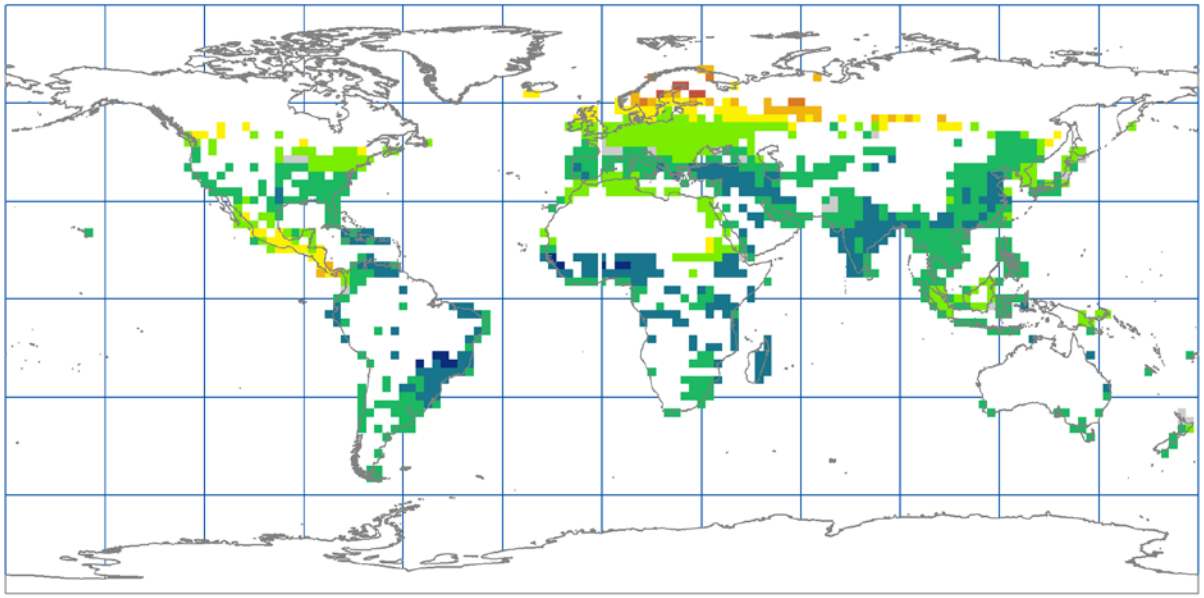
Global Parameter Set



Urban - Rural Temperature Difference (K)

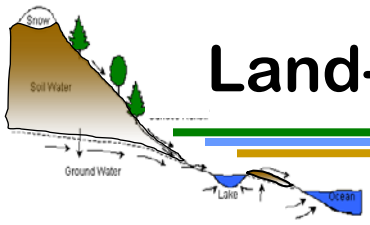
- 0.0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5

Difference: Global - Vancouver



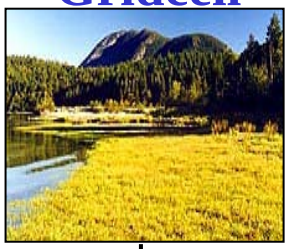
Global - Vancouver UHI Temperature Difference (K)

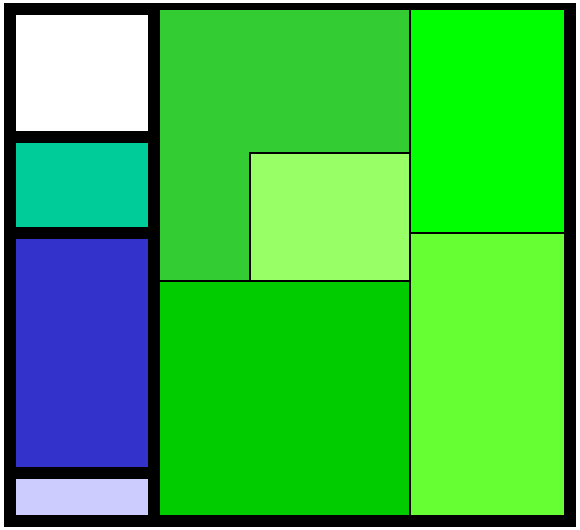
- -0.75 - -0.50
- -0.50 - -0.25
- -0.25 - -0.01
- -0.01 - 0.01
- 0.01 - 0.25
- 0.25 - 0.50
- 0.50 - 0.75
- 0.75 - 1.00
- 1.00 - 1.25



Land-surface heterogeneity: subgrid tiling structure

Gridcell





Landunit



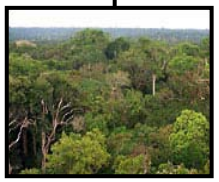


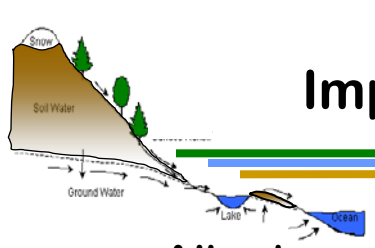
Glacier **Wetland** **Vegetated** **Lake** **Urban**

Columns

Soil Type 1

PFTs

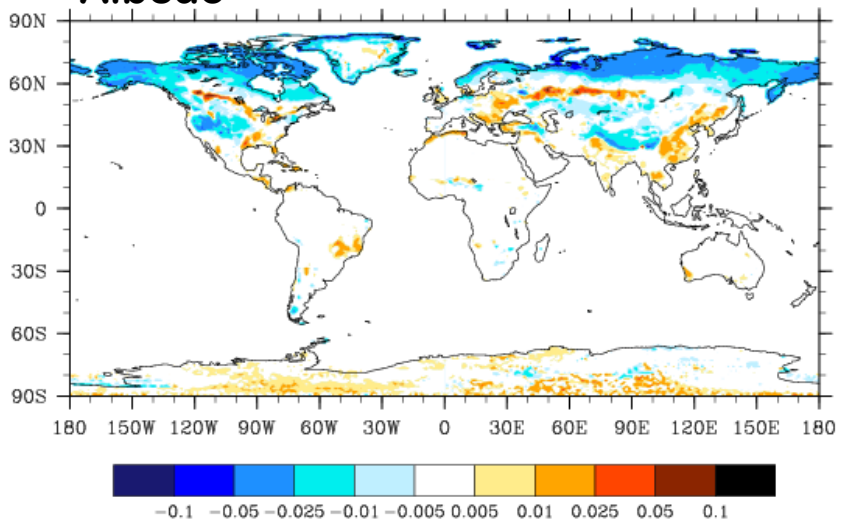





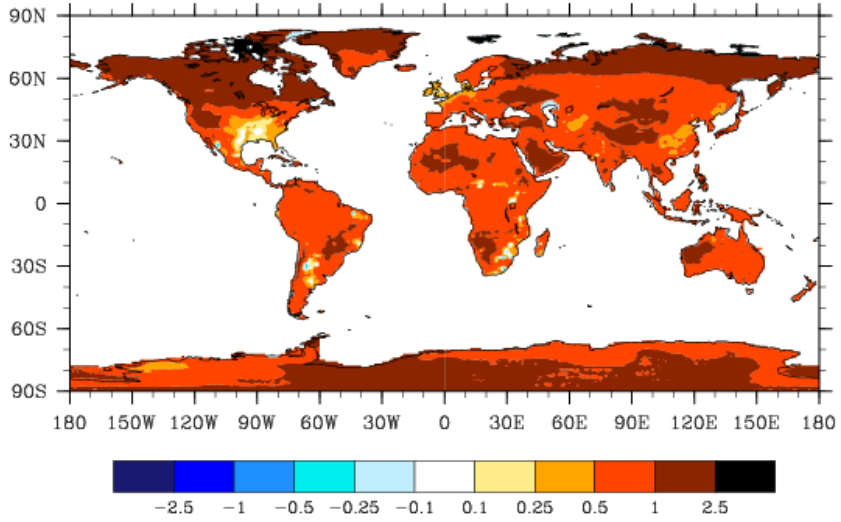
Impact of land cover change (1976-2005 minus 1850-1879)

All forcings

Albedo

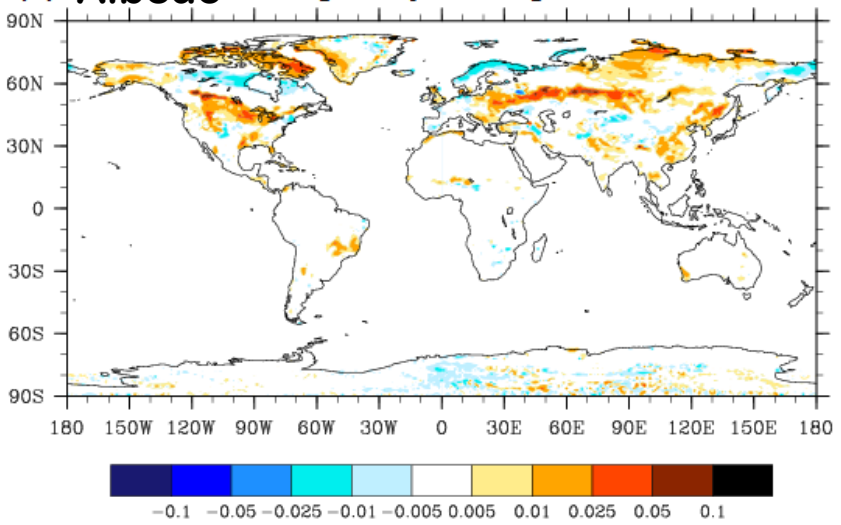


Air Temperature

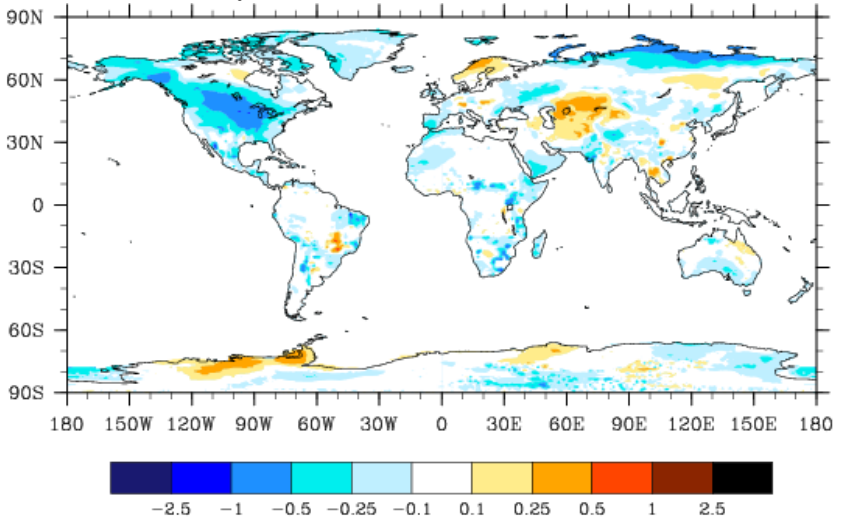


Land cover change only

Albedo

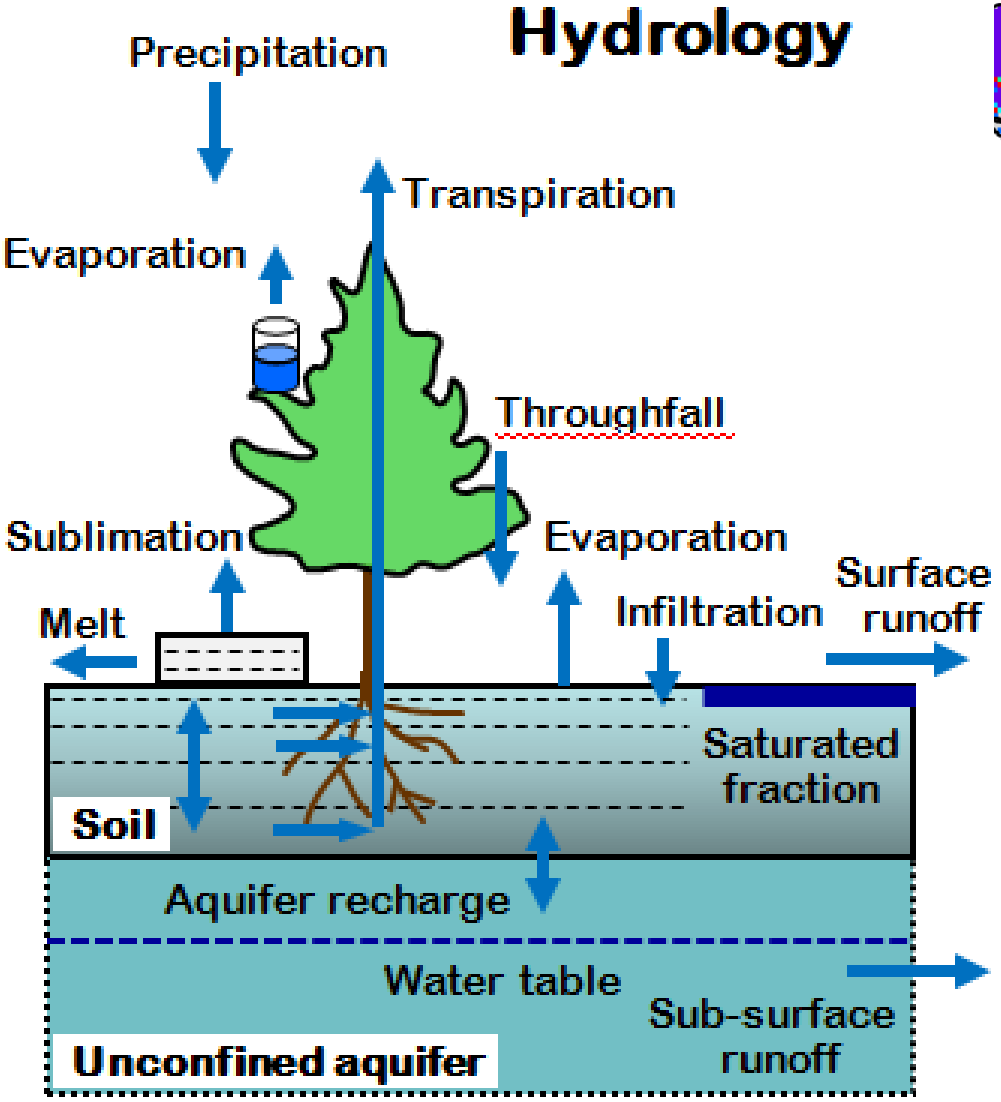


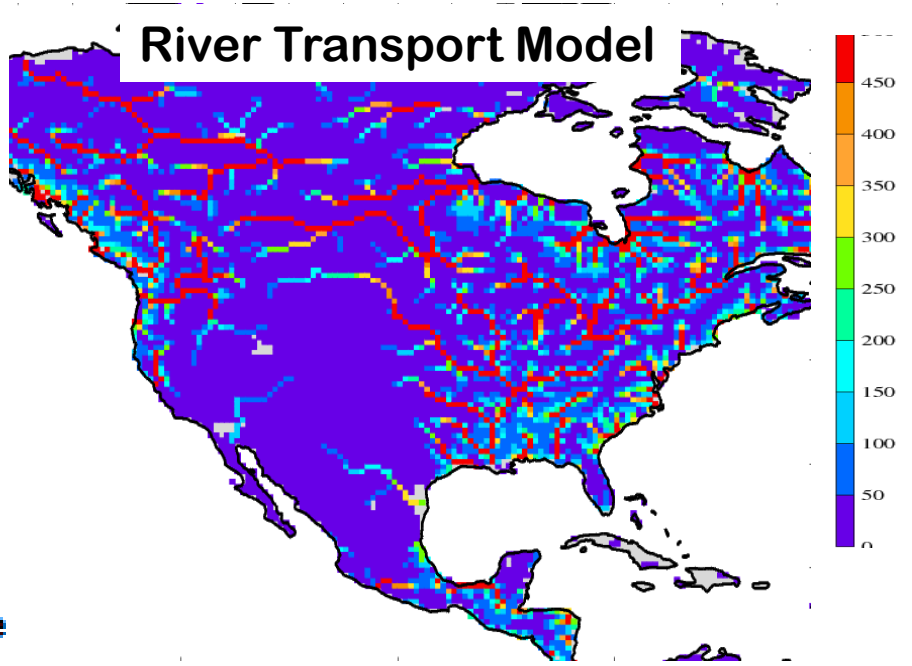
Air Temperature



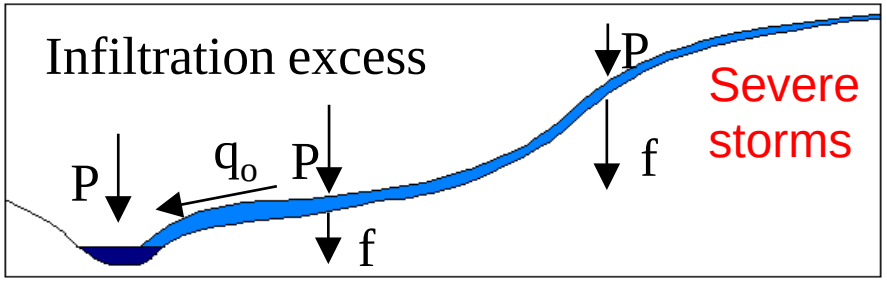
Lawrence, P. et al., 2011, J. Clim

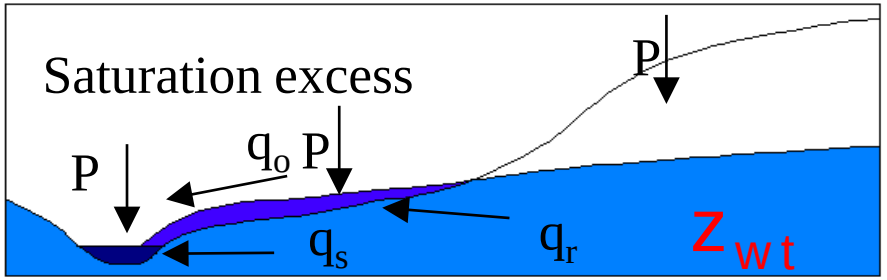
Water

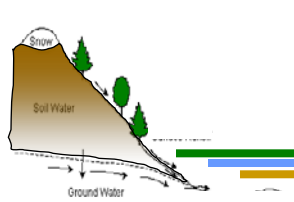




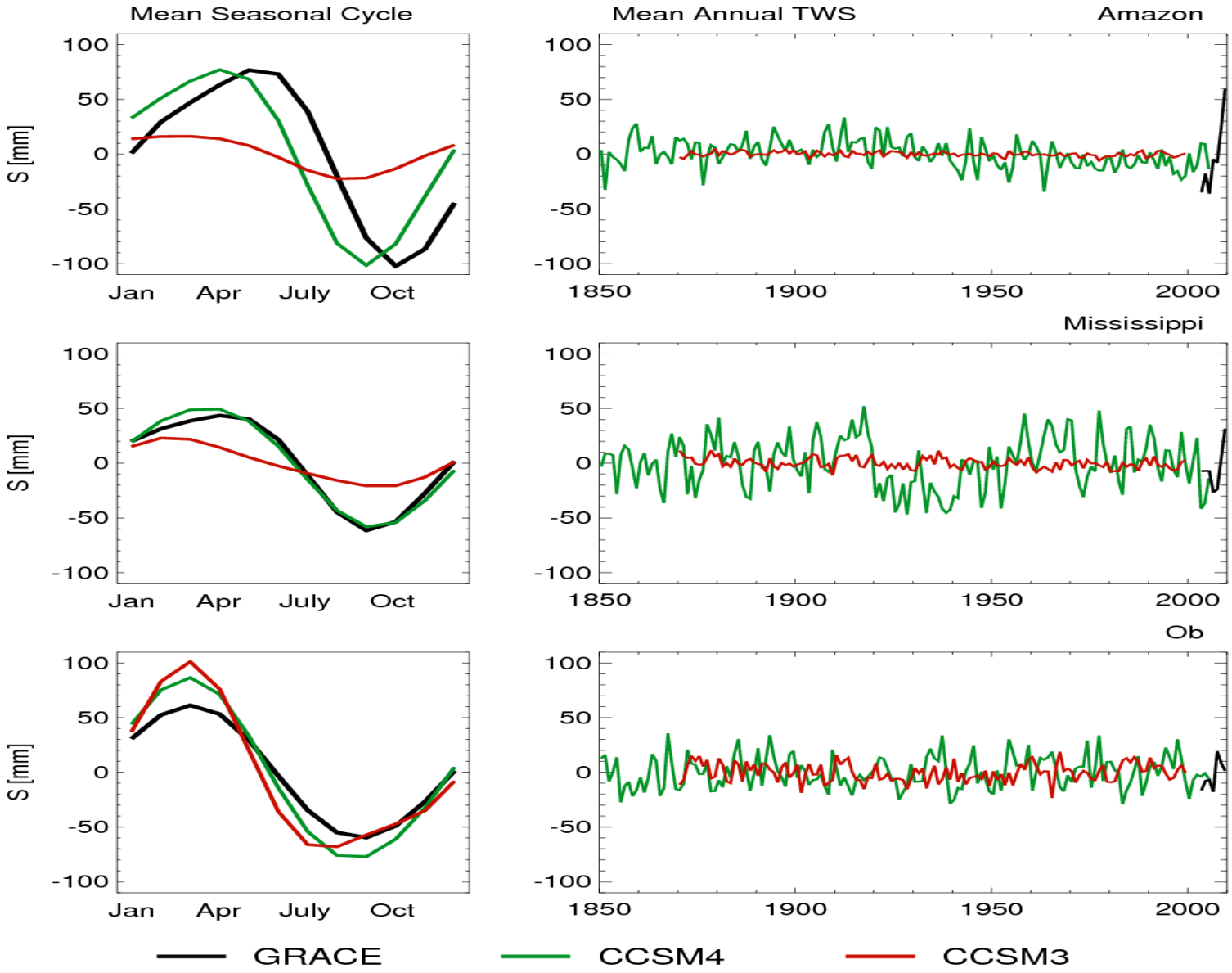
SIMTOP: TOPMODEL-based runoff

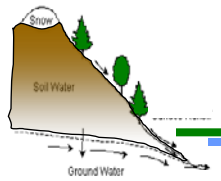




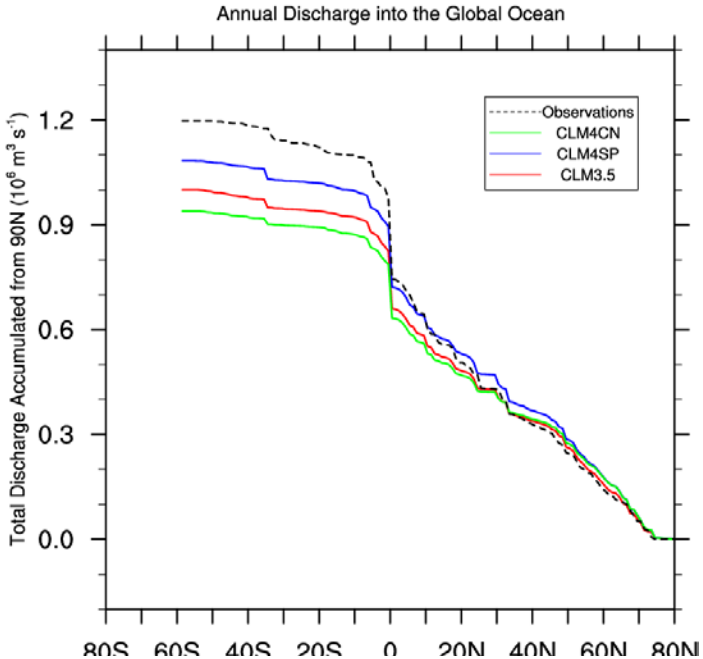


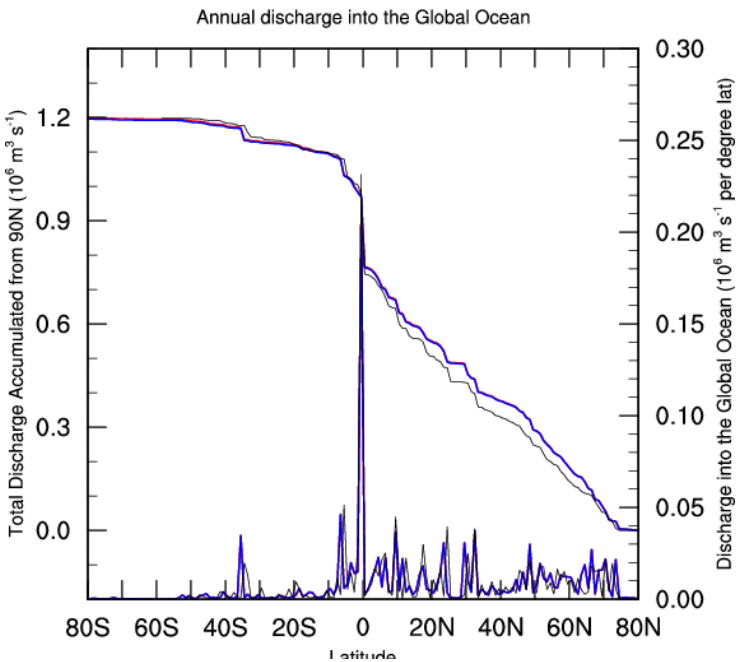
Total Land Water Storage (CCSM vs GRACE)

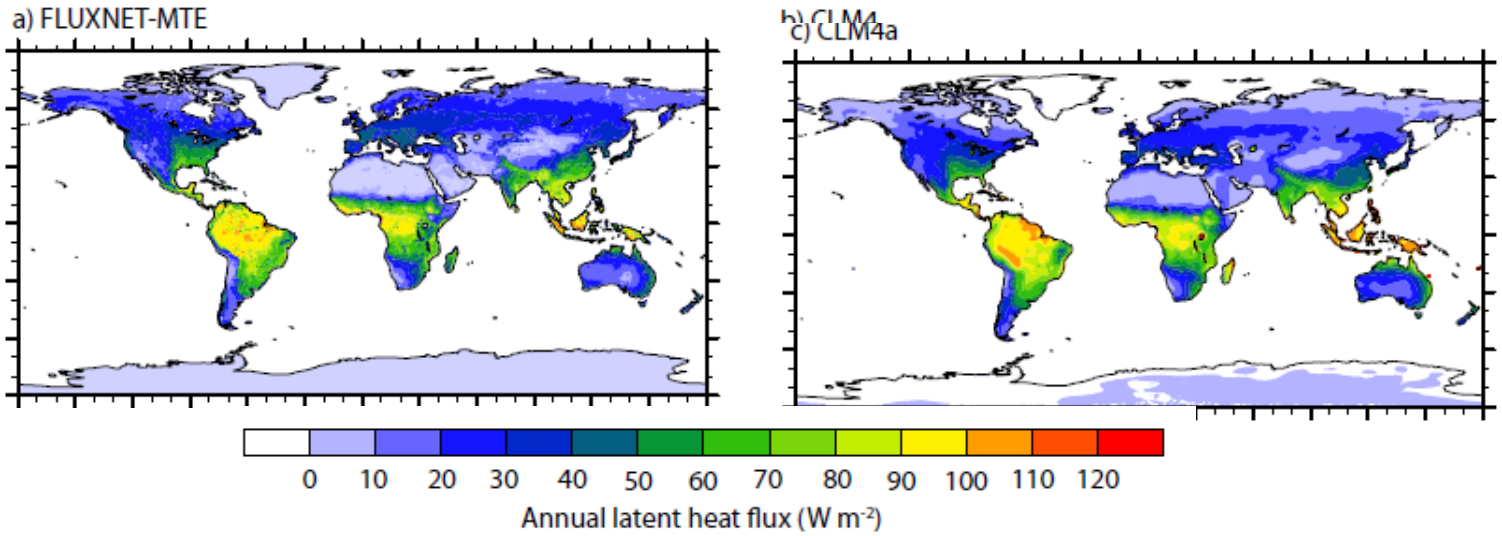




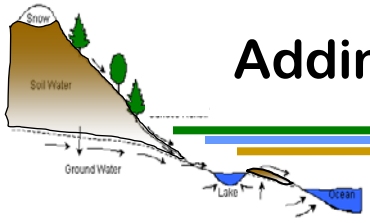
River discharge and evapotranspiration







Adding Flooding Capability / 2-way CLM-RTM interactions



CLM

Surface Runoff

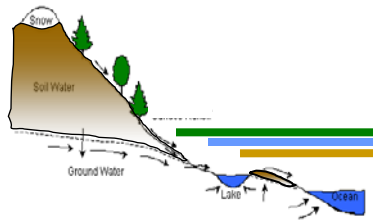
New Capability:
Flood Water Taken From
RTM is Sent to CLM

RTM

Baseflow

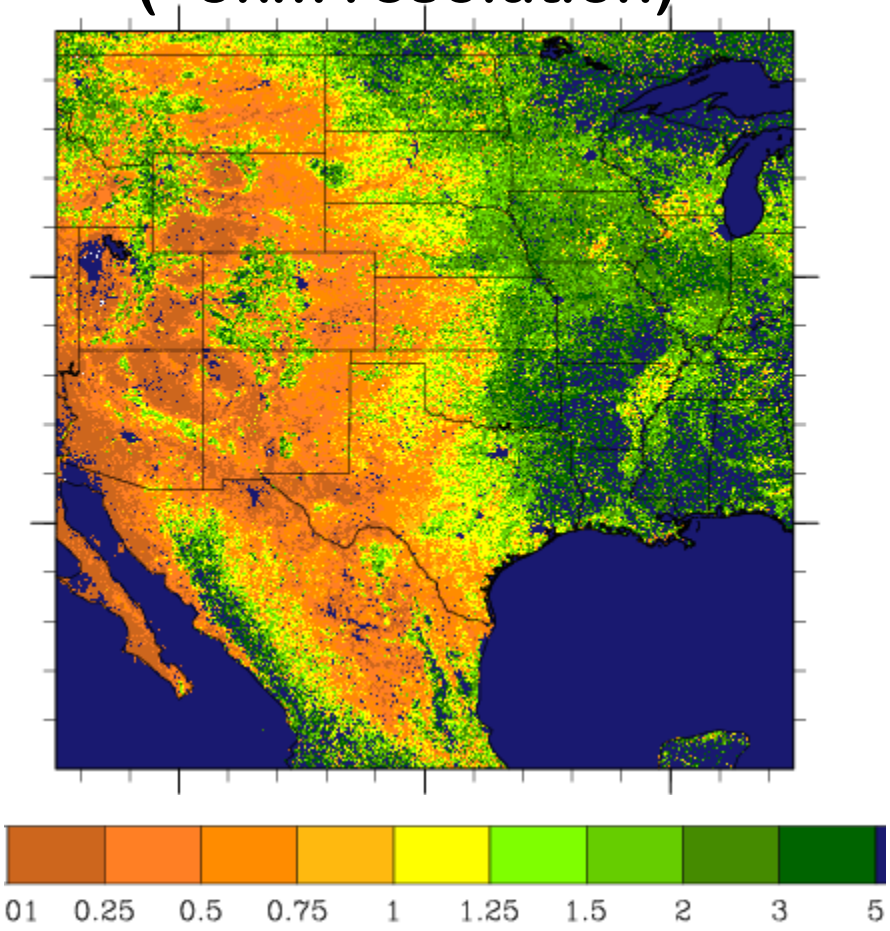
Ocean
(POP)

High resolution input datasets



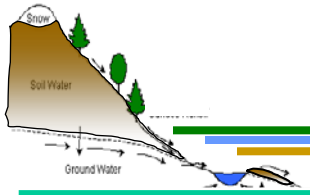
CESM1.1: High resolution input datasets

LAI July 2003 (~5km resolution)



Increasing emphasis and demand across CESM/CLM research communities for high resolution, but …

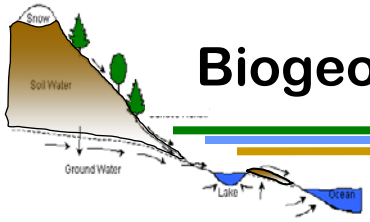
CLM input datasets mostly at ~0.5° and RTM fixed at 0.5°



CESM1.1: High resolution input datasets

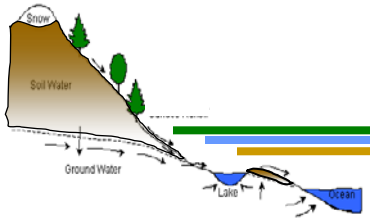
Input dataset	CLM4 resolution	Updated resolution
PFT distribution	0.5º (MODIS)	3' (MODIS)
LAI / SAI	0.5º (MODIS)	0.5º (MODIS)
% Glacier	0.5º (IGBP DISCover)	1km (Gardner, avail spring?) [Bill]
% Lake, Lake depth	0.5º (Cogley, 1991)	3' (GLWD)
% Wetland	0.5º (Cogley, 1991)	Prognostic
% Urban	0.5º (?)	1km (??) [Keith, aggregation issues?]
Soil texture (%sand, %clay)	5' (IGBP)	5' (IGBP for now; ISRIC-WISE for multiple soil classes) [Johann]
Soil organic matter	1.0º (IGBP)	5' (ISRIC-WISE) [Dave]
Soil color	0.5º (MODIS)	0.5º (MODIS)
Fmax	0.5º	??? [Guo-Yue?]
RTM Directional Map	0.5º	0.1º (coupled to CESM?)
Irrigation/Crop types	5'	5' (Navin) [Sam]
Topography (for GLCMEC)	10' (USGS)	1km ?? (USGS)

Building CLM4.5



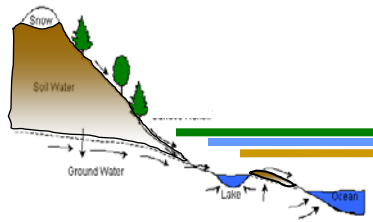
Biogeophysics and biogeochemistry updates planned for CLM4.5

- Revised Soil Biogeochemistry
- Wetland methane emissions model (CLM4Me)
- Revised lake model and lake dataset
- Revised canopy physiology (GPP, ET)
- Revised cold region hydrology
- Improved fire algorithm incl. human triggers and suppression
- Faster carbon/nitrogen pool spinup process
- WRF / CLM



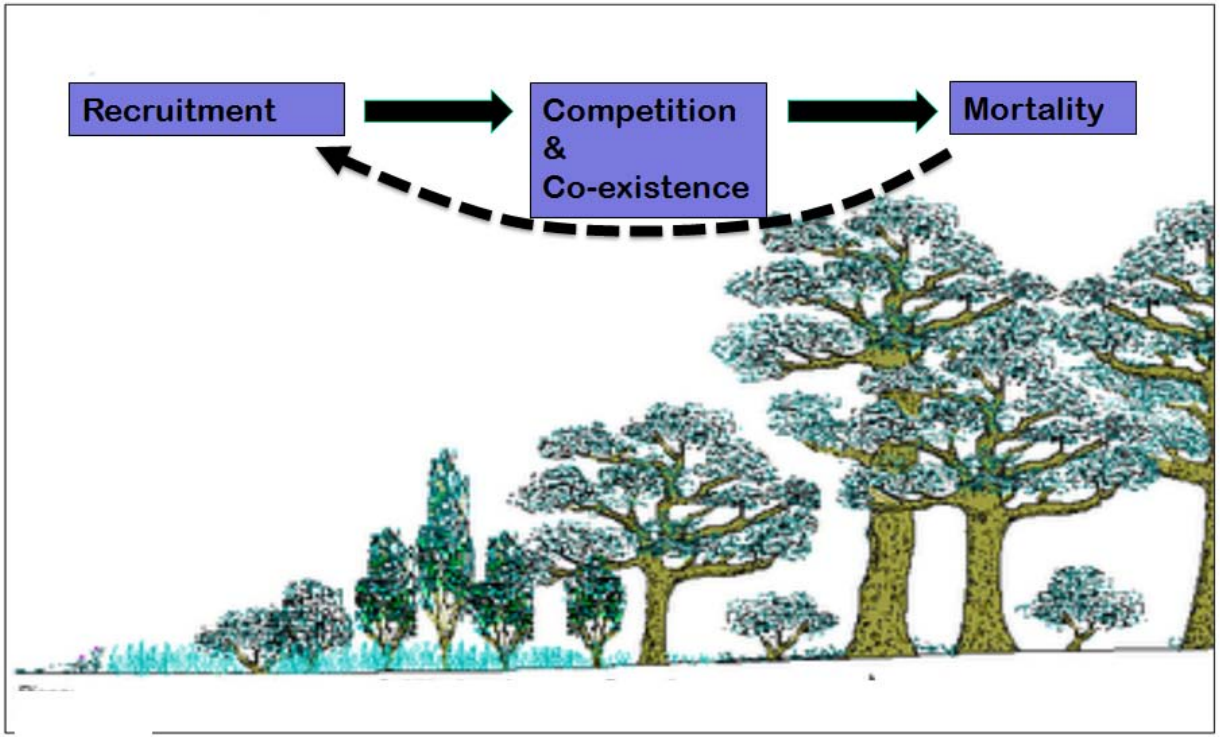
Development plans relevant to SDWG for CLM4.5

- Crops and irrigation
  - Connect crops and irrigation, fertilization, grain-fill, etc.
- Dynamic landunits
  - Prescribed and/or prognostic land unit transitions: e.g., glacier to vegetated, vegetated to crop, vegetated to urban
- Flooding (2-way CLM/RTM interactions)
- Reconsider soil evaporation and under canopy turbulence parameterizations from water cycle response to land cover change perspective
- Unstructured grids (e.g., catchment grid capability, regionally refined)



Longer term development plans relevant to SDWG

- Ecosystem demography option (forest response to disturbance)
- VIC hydrology option
- Lateral groundwater flow / 3-D subsurface hydrology
- IAM-ESM coupling
- Soil N_2O emissions



WEDNESDAY, 29 February – Land Model Working Group Session

IAMs

8:30 Dave Lawrence – Welcome and Introduction

8:40 Peter Thornton – First results from coupled IAM-ESM (iESM): Influence of model coupling through land use and land cover change

8:55 Andrew Jones – Greenhouse gas policies influence climate via direct effects of land use change

9:10 Adam Schlosser – Assessing climate impacts of linked econometric-based land-use projections

9:25 Discussion

Hydrology

9:30 Hongyi Li – A physically based runoff routing model for land surface and earth system models

9:45 Maoyi Huang – On the application of CLM-VIC at multiple scales

10:00 Gautam Bisht – A proposed model development strategy to incorporate 3-D subsurface hydrologic and thermal processes in CLM

10:15 Discussion

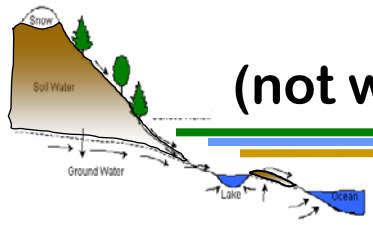
10:30 Break

11:00 Zhenghui Xie – A quasi three-dimensional variably saturated groundwater flow model for climate modeling

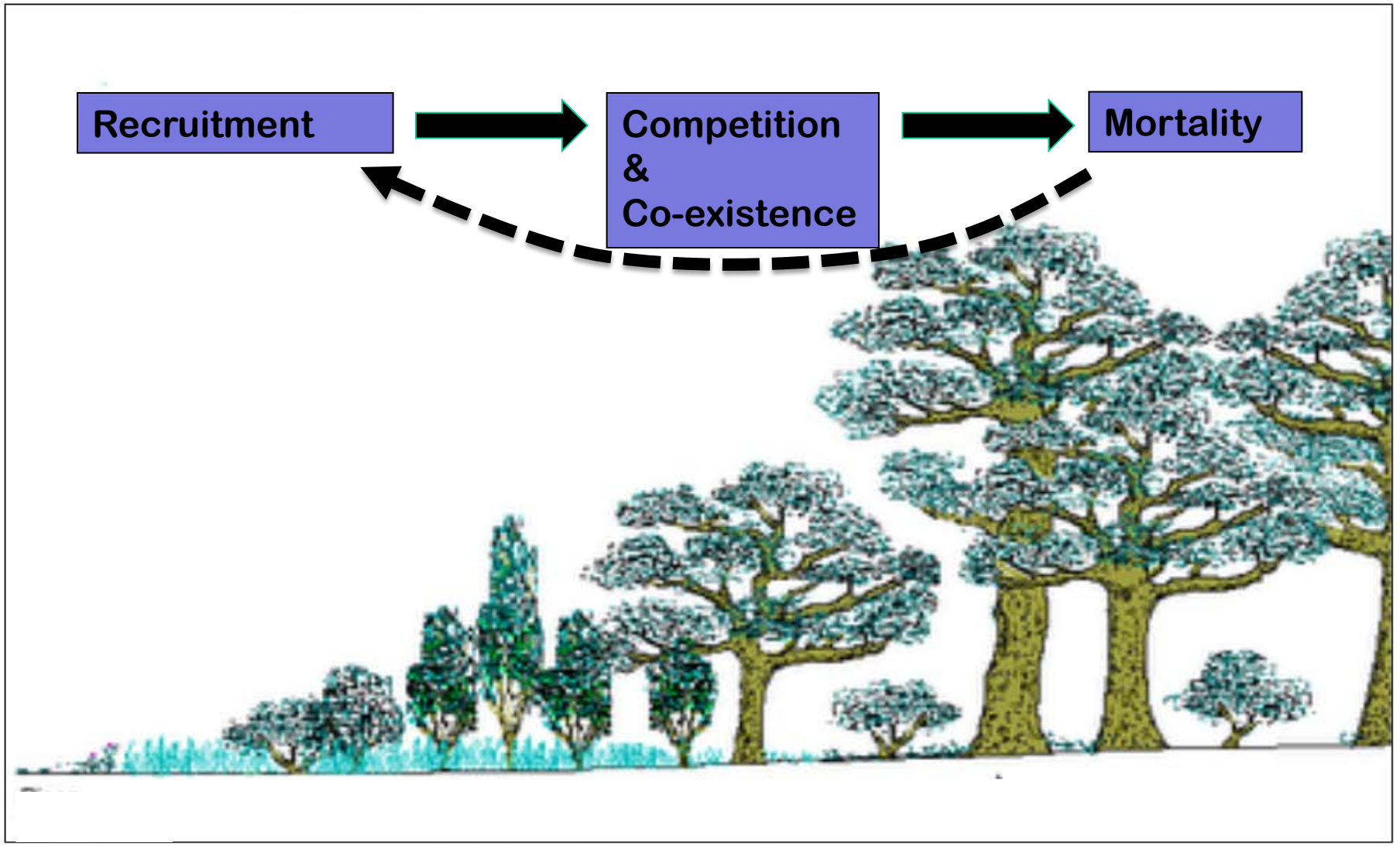
11:15 Min-Hui Lo – Irrigation in California's Central Valley Strengthens the Regional Hydrological Cycle

Land-atmosphere interactions

12:10 Peter Lawrence – Investigating the Biogeophysical impacts of land cover change in CLM4

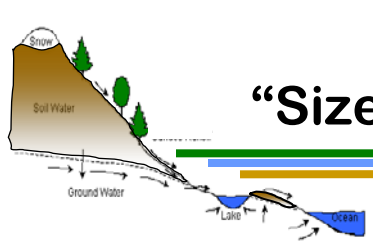


Forest succession
(not well simulated in most large-scale ecosystem models)



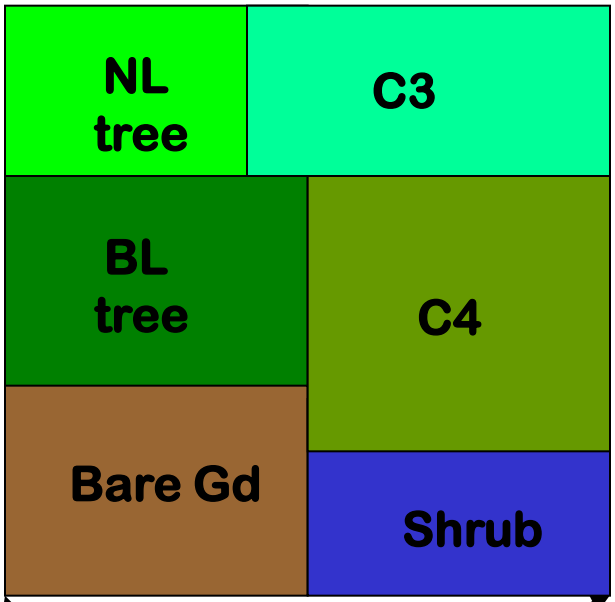
Slide courtesy Rosie Fisher

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

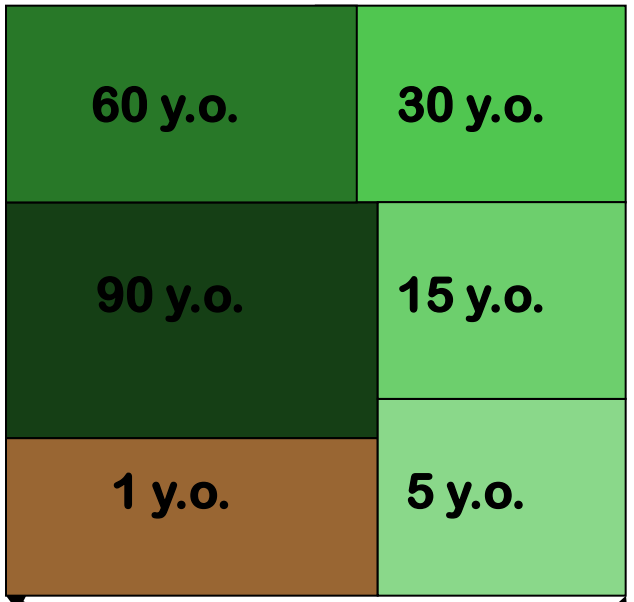


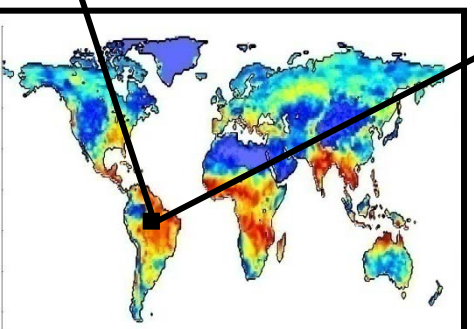
PFT-based tile structure.

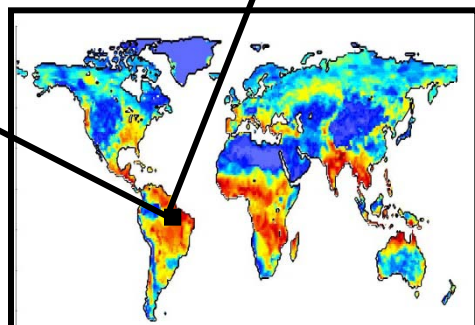
Time since disturbance-based tile structure.



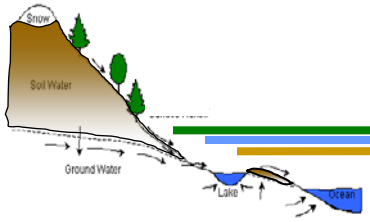
ED





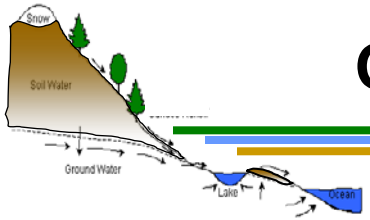


Slide courtesy Rosie Fisher



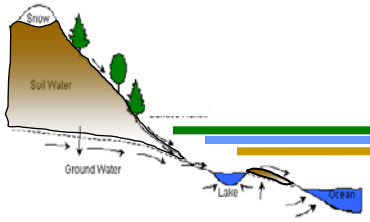
Why bother with ED?

- Co-existence = resilience to climate change.
- Re-growth post disturbance (insects, drought).
- Post-fire succession – track burnt and unburnt areas.
- Simulate savanna ecosystems – tree-grass co-existence.
- Explicit simulation = explicit parameter constraints.
- Variable vegetation complexity = efficiency.
  - Areas with no light competition only have one patch…



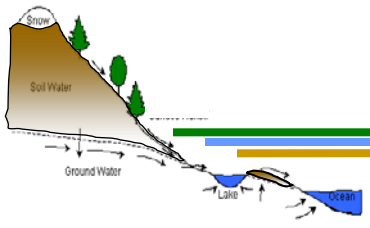
Other ongoing CLM development activities

- Sub-surface hydrological processes – lateral redistribution of water
- Sub-grid PFT distribution (elevation dependence)
- Sub-grid soil moisture and snow heterogeneity
- Online Integrated Assessment Modeling
- Soil microbial dynamics, multi-phase transport, multiple tracers in soil (CLM4-BeTR)
- Water isotopes
- Vegetation phenology improvements
- Peatlands
- Other nutrient cycles (e.g., phosphorous)
- Ozone poisoning of vegetation
- Data assimilation
- 3-D canopy radiation

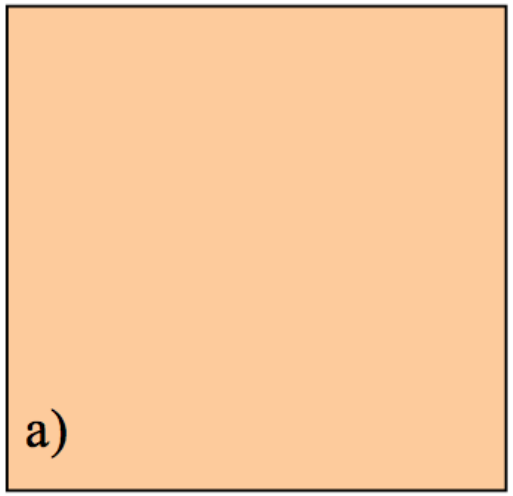


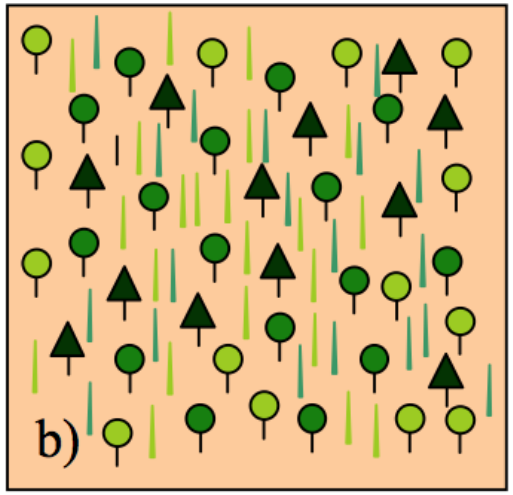
Model Intercomparison Projects

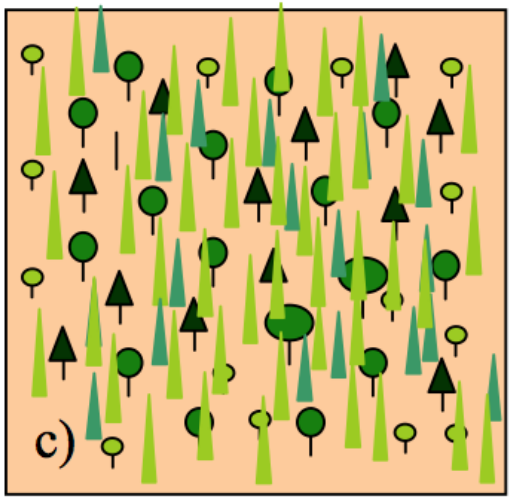
- TRENDY
  - Historic carbon cycle simulations with revised CRUNCEP data
- GSWP3
  - 20th century water (and carbon cycles)
- GLACE-CMIP5
  - How do projected changes in soil moisture feedback onto future climate change and carbon cycle
- Permafrost-carbon
  - Historic and future permafrost loss and permafrost-carbon feedback
- Land use / land cover change
- PILDAS

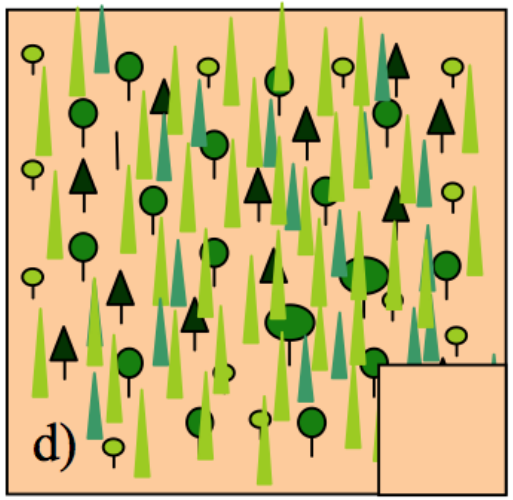


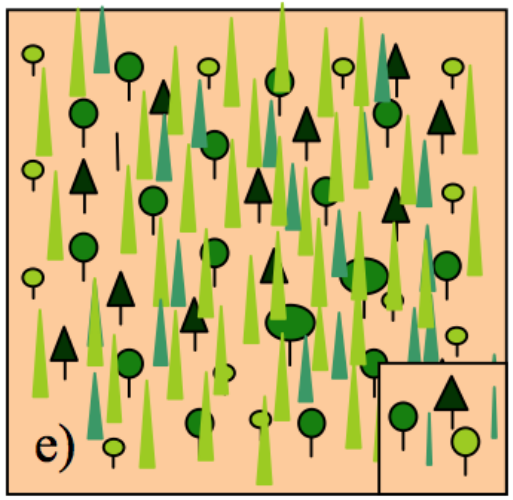
Light competition succession in ED.

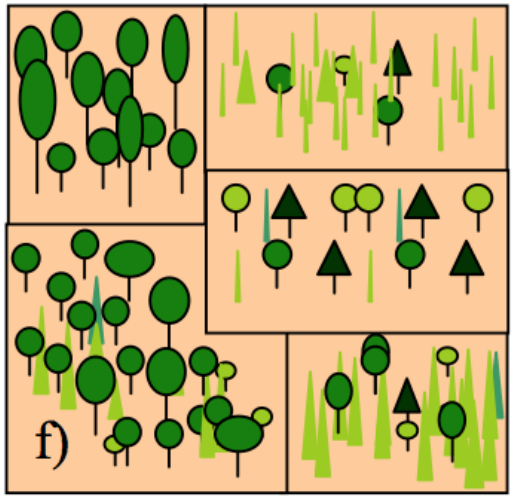




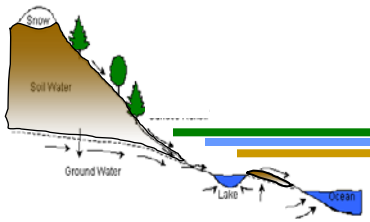






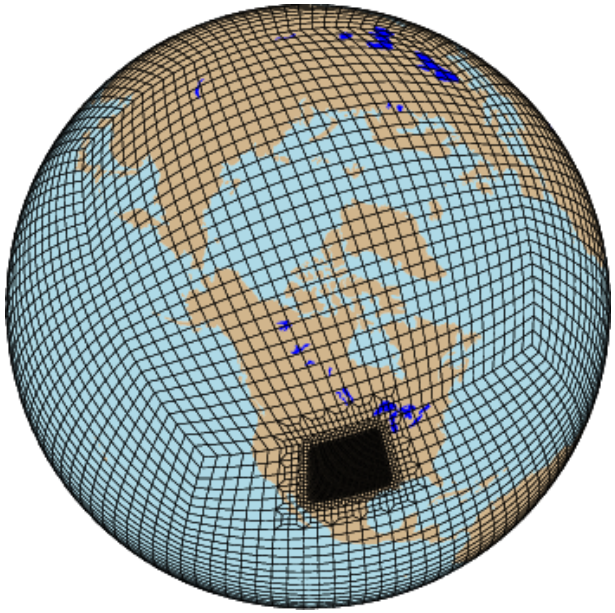


Slide courtesy Rosie Fisher



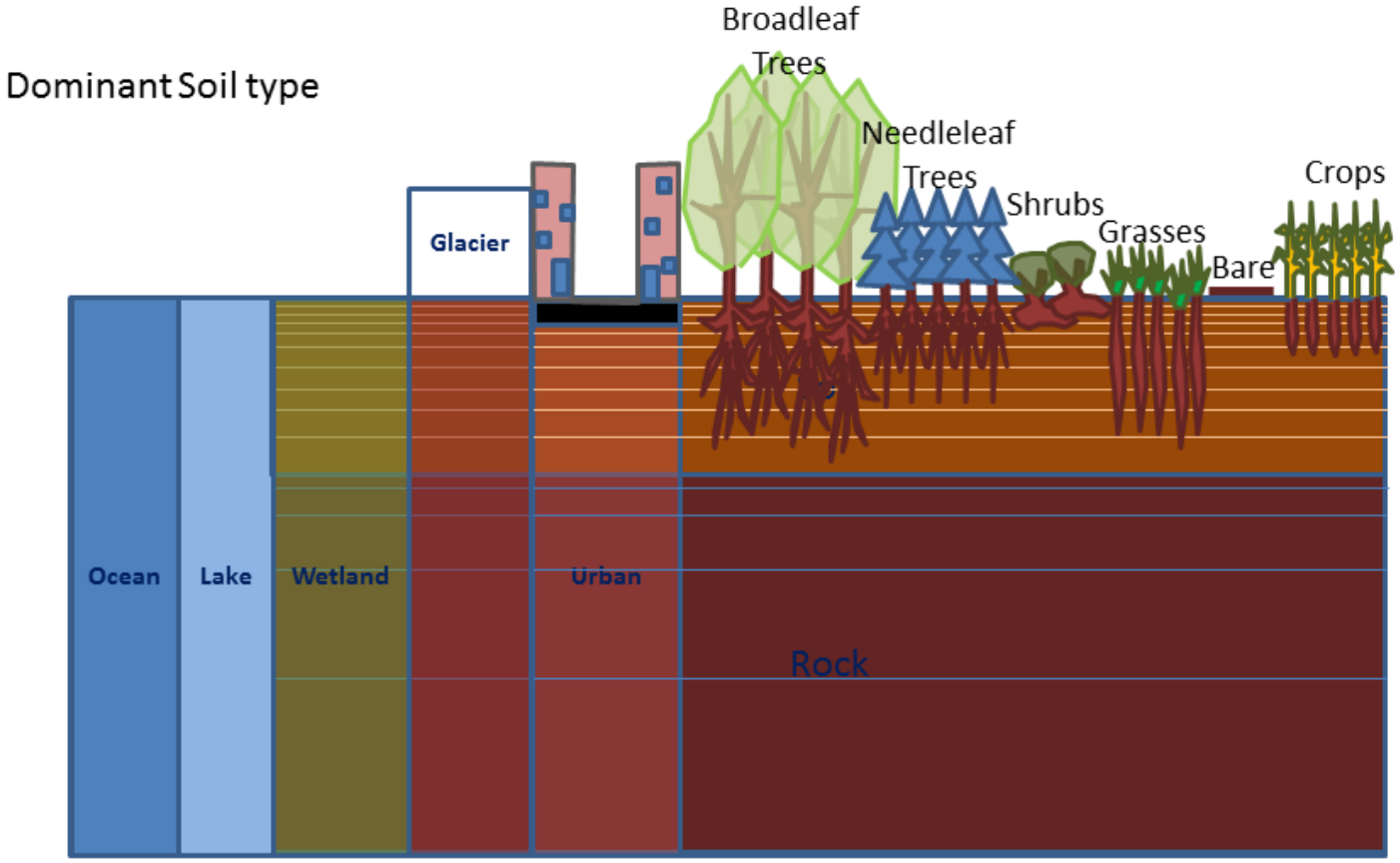
CESM1.1: Unstructured Grids in CLM

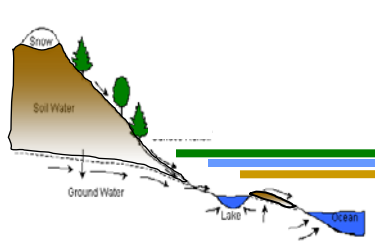
- Capability to run with non lat/lon or logically rectangular grids
  - Surface dataset generation tool for non lat/lon grids
  - CLM code support to deal with non lat/lon surface datasets and generate appropriate history files
  - Post-processing utility to map non lat/lon history files to 2d for visualization/analysis
- New ways to run CLM
  - Cubed sphere and regionally refined grids
  - Collection of tower sites in parallel
  - Catchment grid



Current Soil Representation in CLM

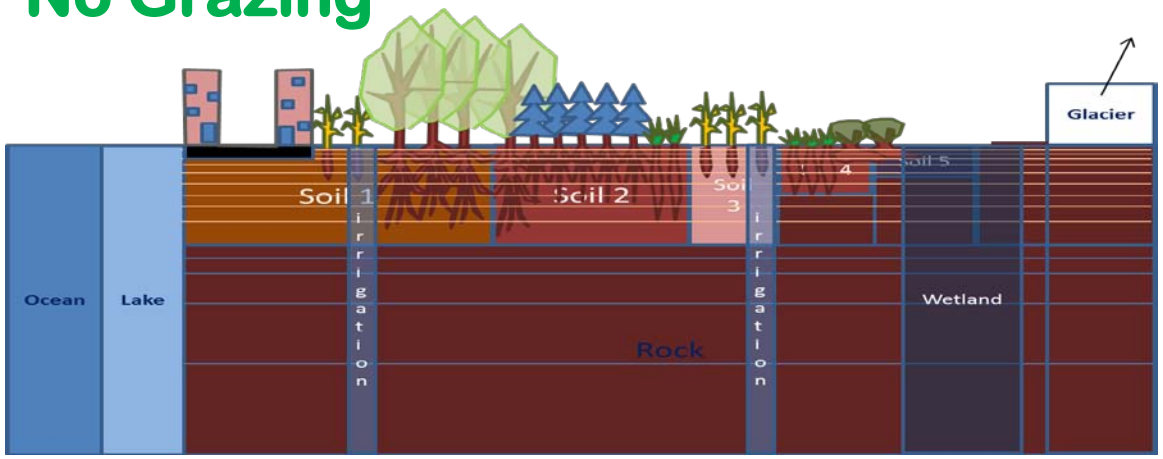
Current Configuration



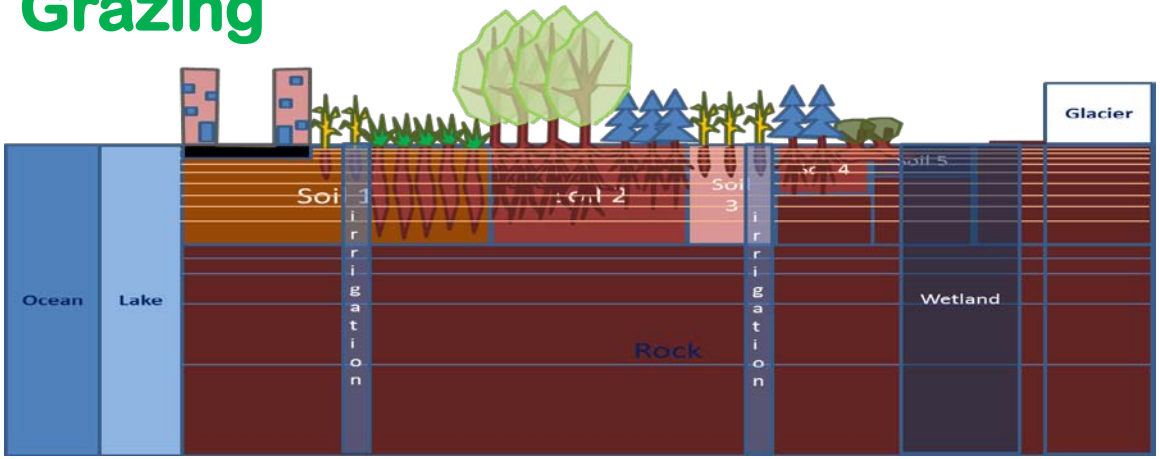


Proposed Configuration

No Grazing



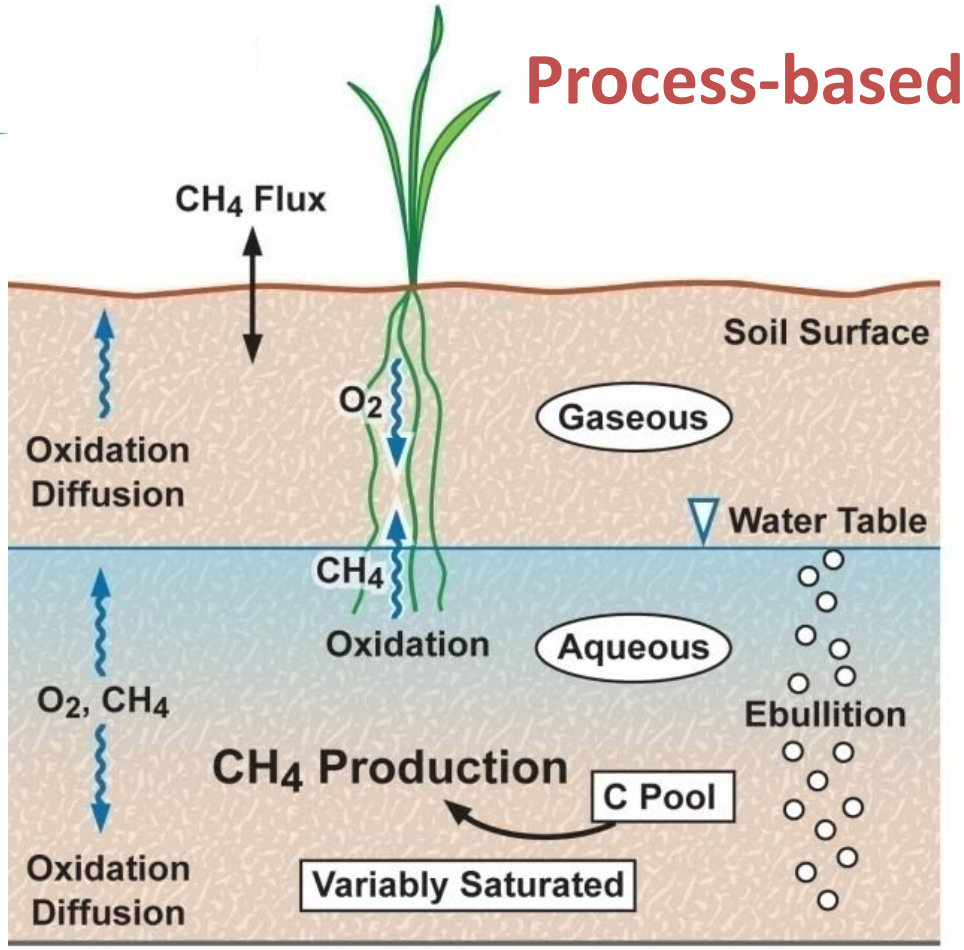
Grazing



Agricultural Suitability

- Excellent
- High
- Medium
- Poor
- Rock

Process-based CH_4 emissions model



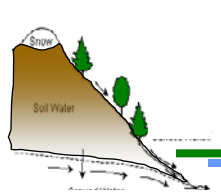
Coupling to atmosphere model and atmospheric chemistry ongoing

$$\underbrace{\frac{\partial(RC)}{\partial t}}_{\text{Net change}} = \underbrace{\frac{\partial F_D}{\partial z}}_{\text{Diffusion}} + P(z,t) - \underbrace{E(z,t)}_{\text{Ebullition (bubbling)}} - A(z,t) - \underbrace{O(z,t)}_{\text{Oxidation}}$$

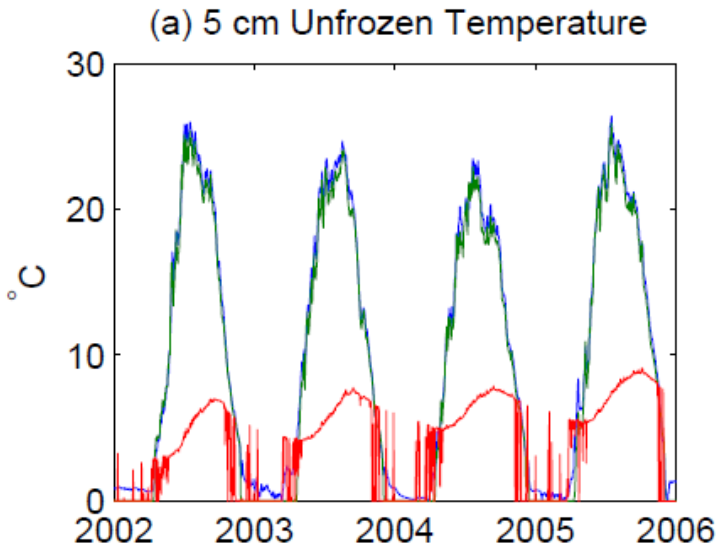
Production

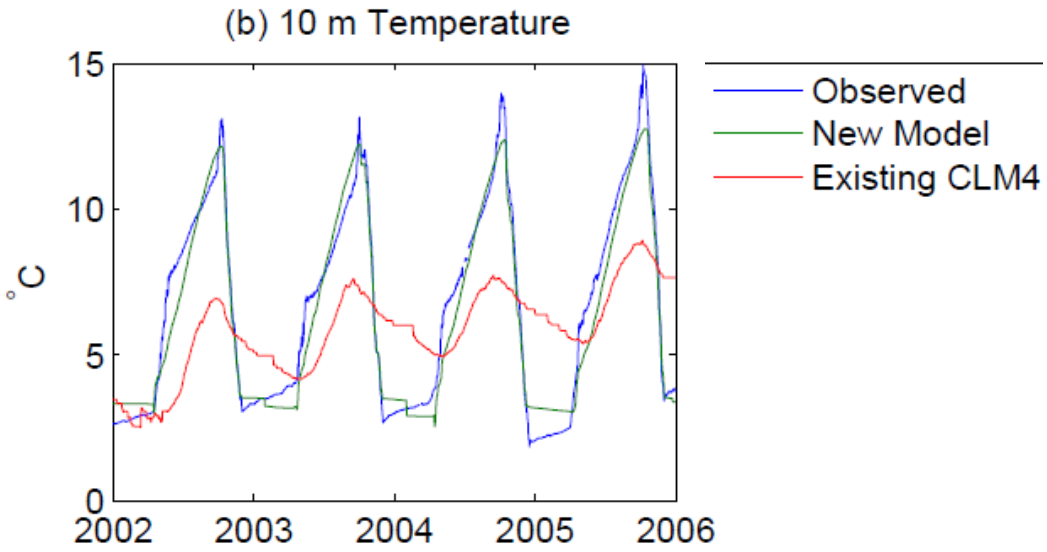
Aerenchyma (tissue)

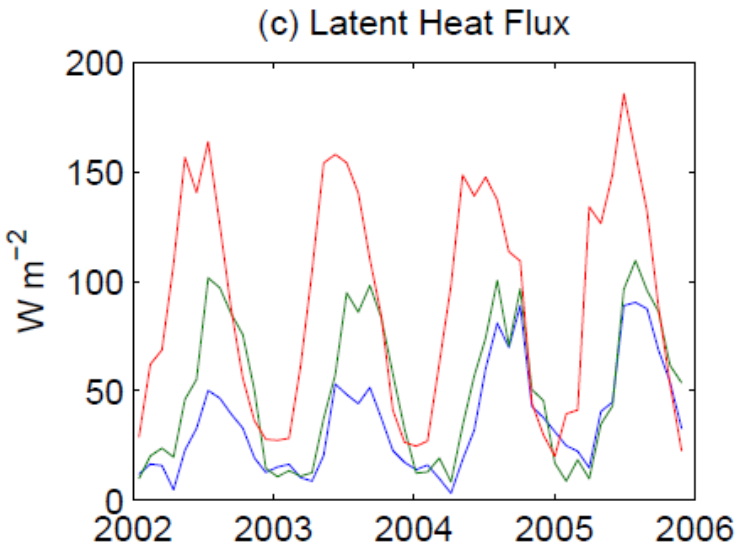
Riley et al., 2011, JGR-Biogeosciences

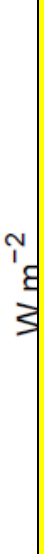


Revised lake model: Sparkling Lake (WI)









Revised model includes

(1) a treatment of snow

(2) freezing, melting, and ice physics

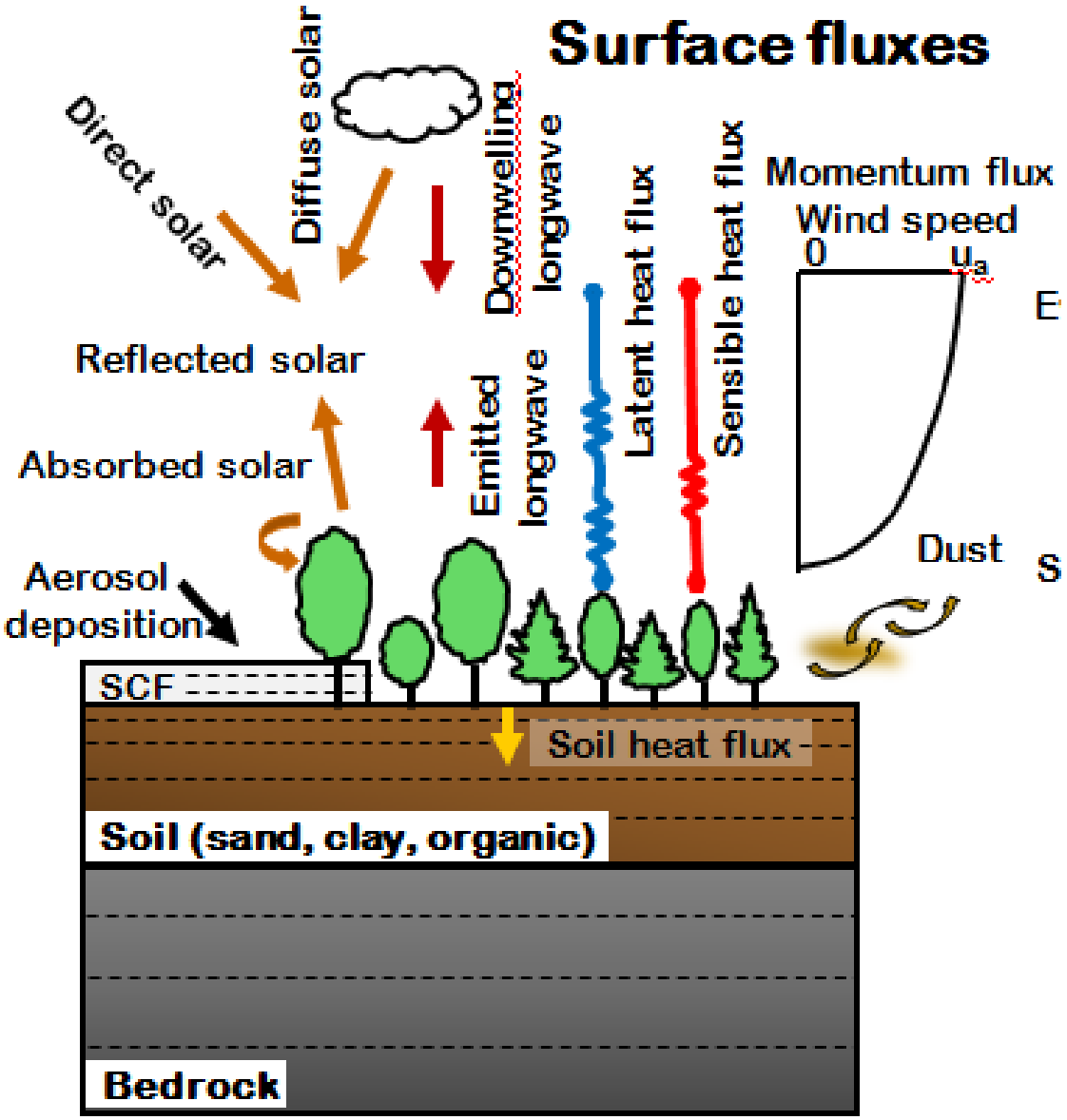
(3) a sediment thermal submodel

(4) spatially variable prescribed lake depth

(5) improved params of lake surface properties;

(6) increased mixing under ice and in deep lakes

(7) new lake datasets (3x total lake area)


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

Biogeochemical cycles