LMWG Activities

David Lawrence

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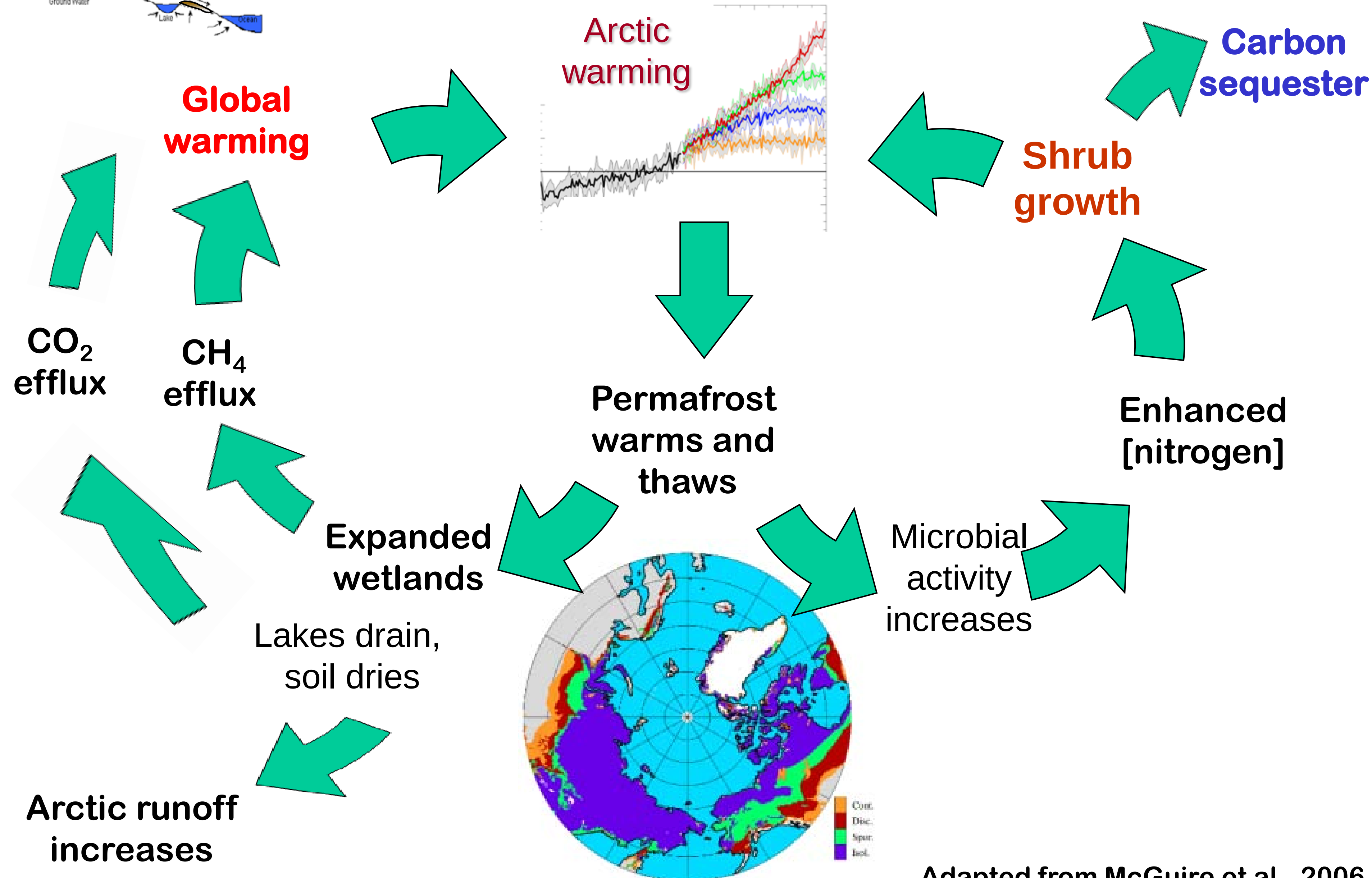
with input from members of LMWG and BGCWG

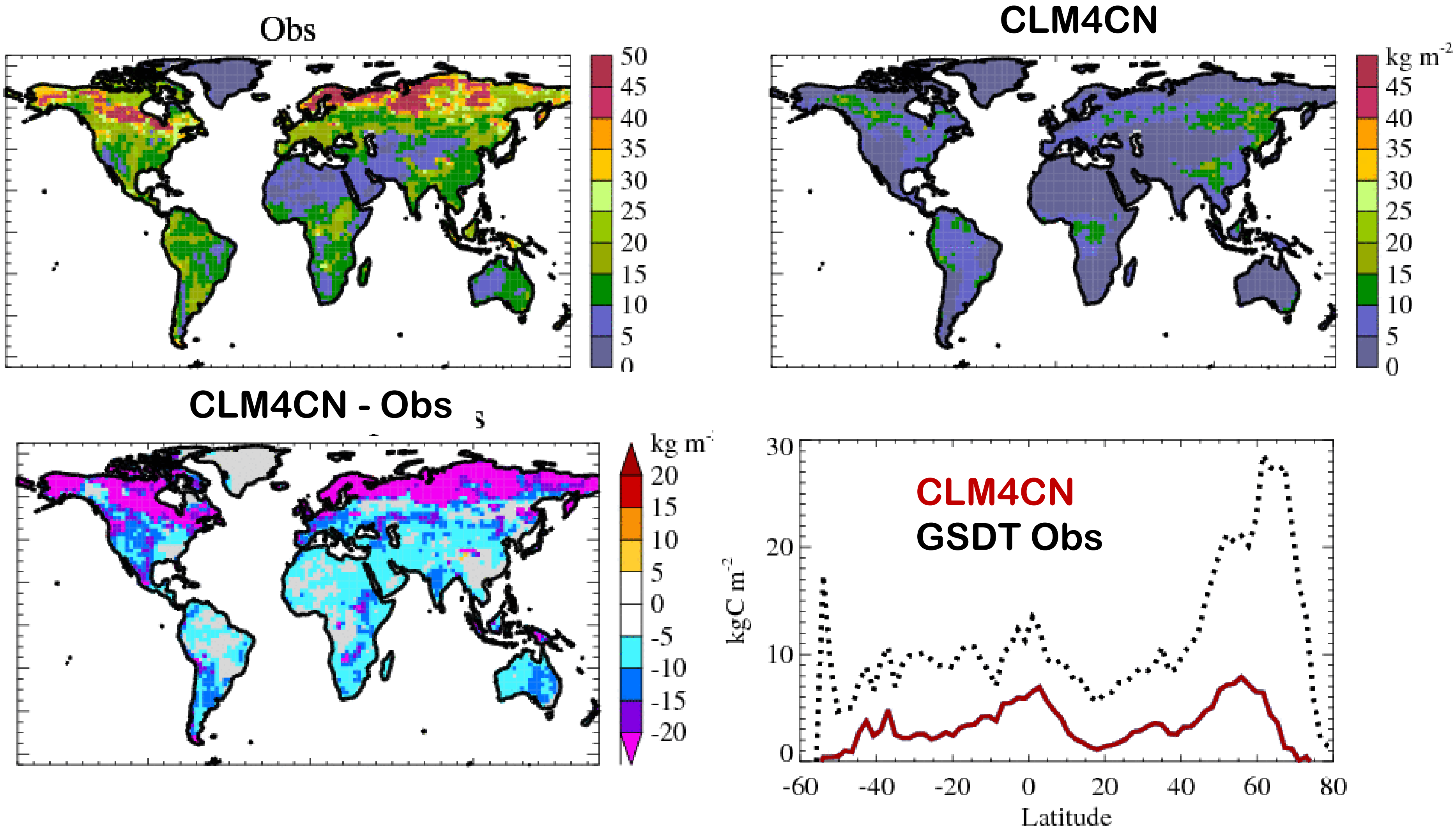
NCAR is sponsored by the National Science Foundation

Potential Arctic terrestrial climate-change feedbacks

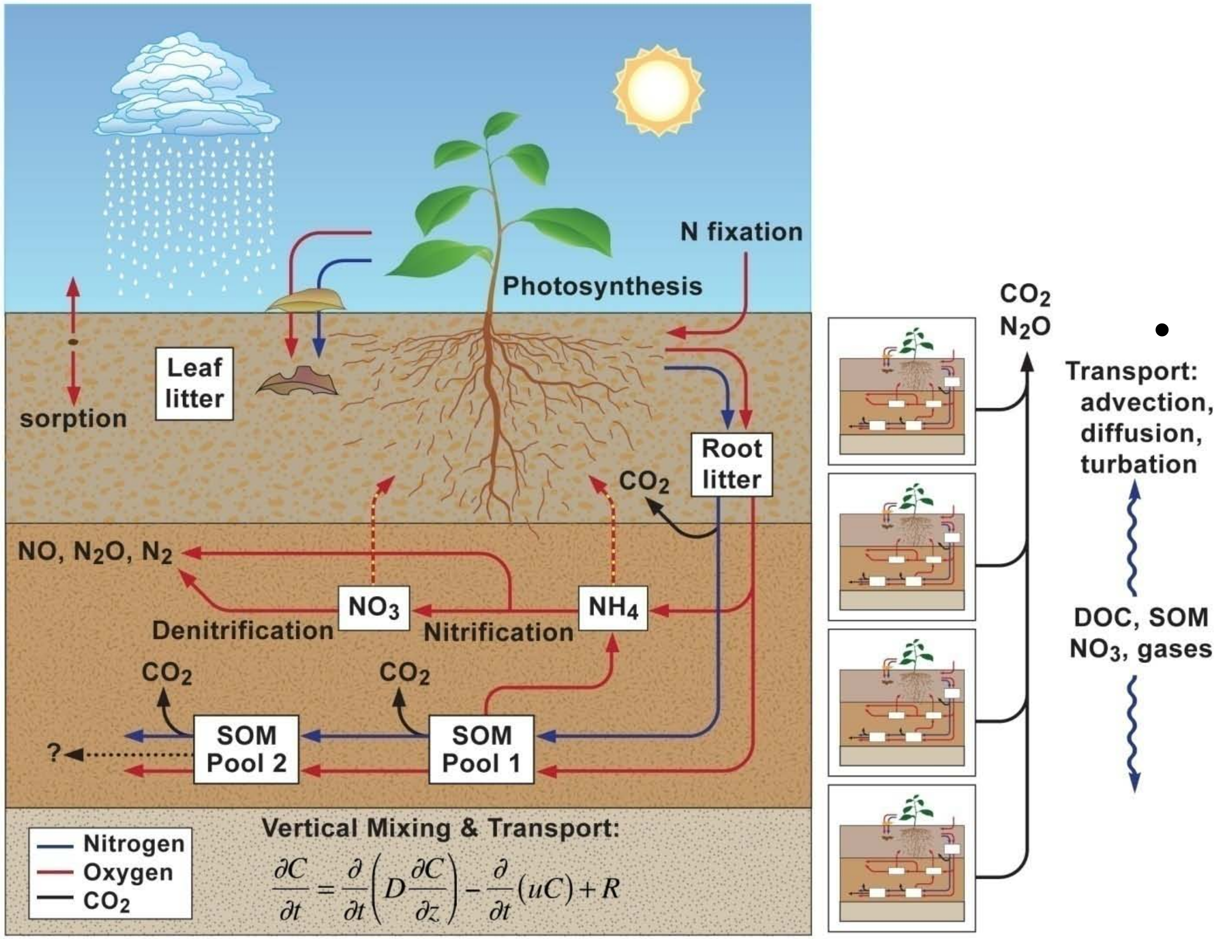


Adapted from McGuire et al., 2006

Biases in CLM4: Soil carbon stocks

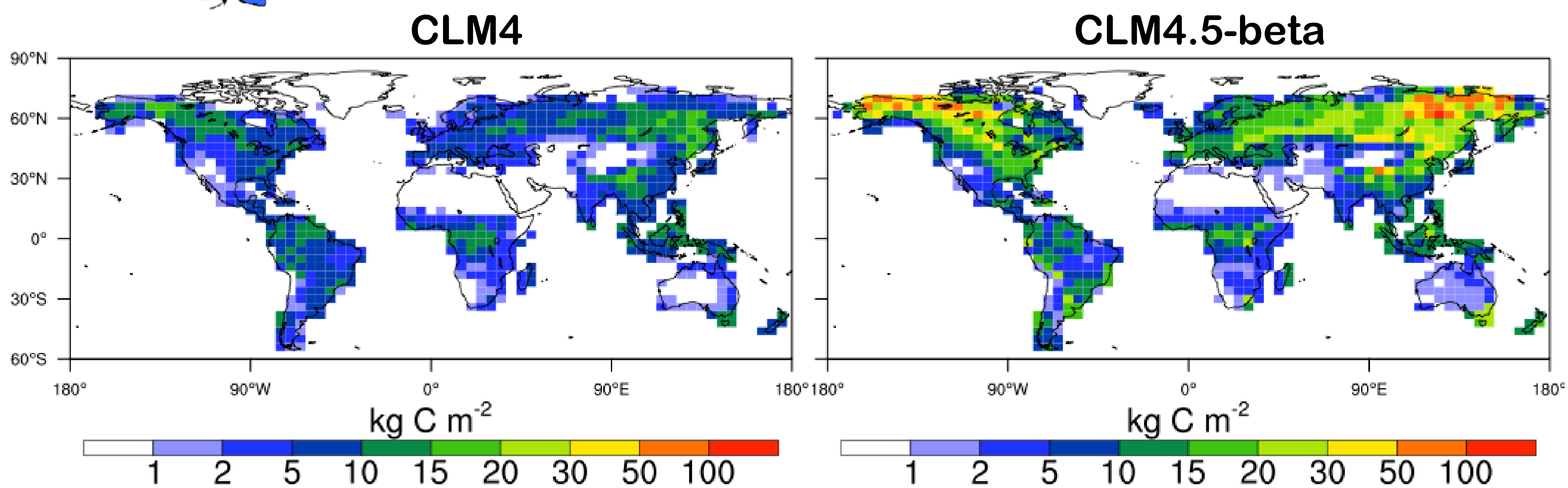


Vertically-Resolved C & N Cycle in CLM4.5



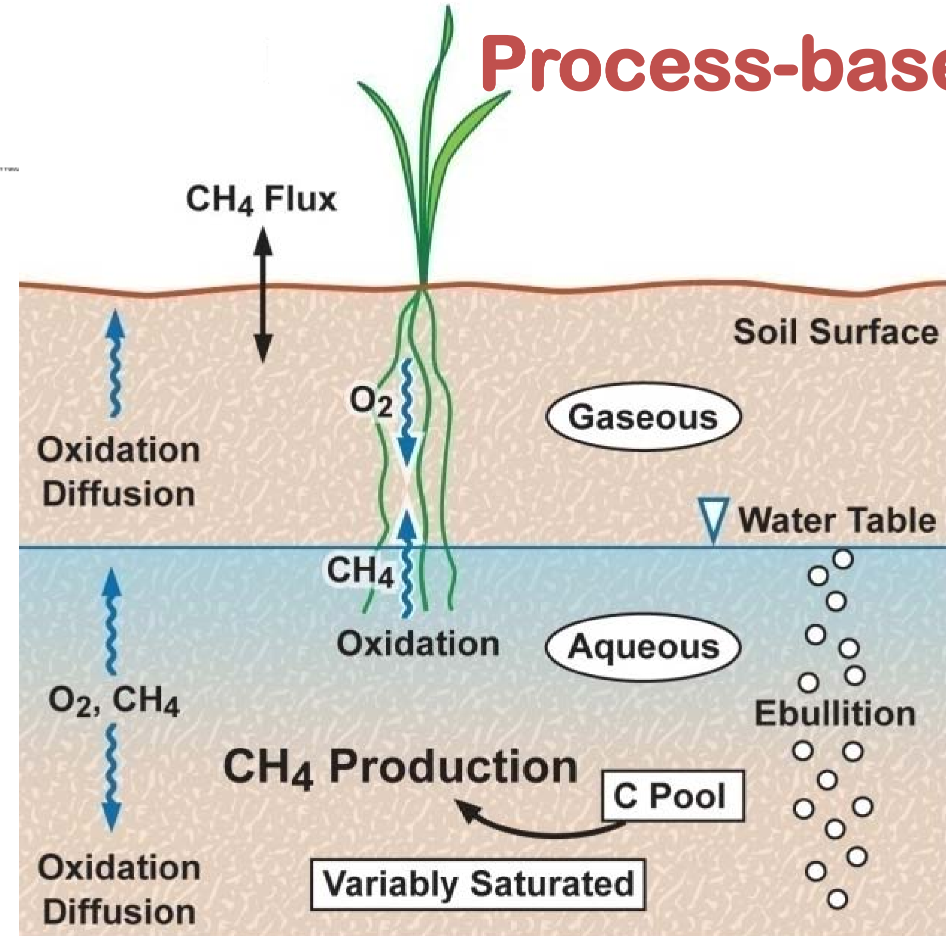
- CLM4
  - No vertical structure for C & N dynamics
  - Crude SOM N cycle representation
- For CLM4.5
  - Flexible first-order biogeochemistry, based on CENTURY-like soil BGC structure

Improved Soil Carbon Stocks



- Improvement in steady-state C stocks (note quasi-log scale)
- Large improvement in high latitude C stocks
- Improvement in predicted soil C radiocarbon and age distribution

Process-based CH_4 emissions model

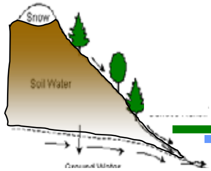


Coupling to atmosphere model and atmospheric chemistry ongoing

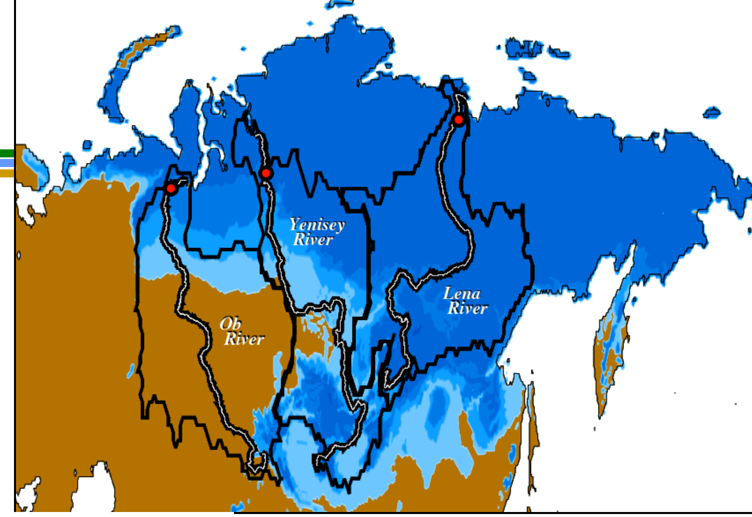
$$\frac{\partial (RC)}{\partial t} = \frac{\partial F_D}{\partial z} + P(z,t) - E(z,t) - A(z,t) - O(z,t)$$

- Net change: $\frac{\partial (RC)}{\partial t}$
- Diffusion: $\frac{\partial F_D}{\partial z}$
- Production: $P(z,t)$
- Ebullition (bubbling): $E(z,t)$
- Aerenchyma (tissue): $A(z,t)$
- Oxidation: $O(z,t)$

Riley et al., 2011, JGR-Biogeosciences

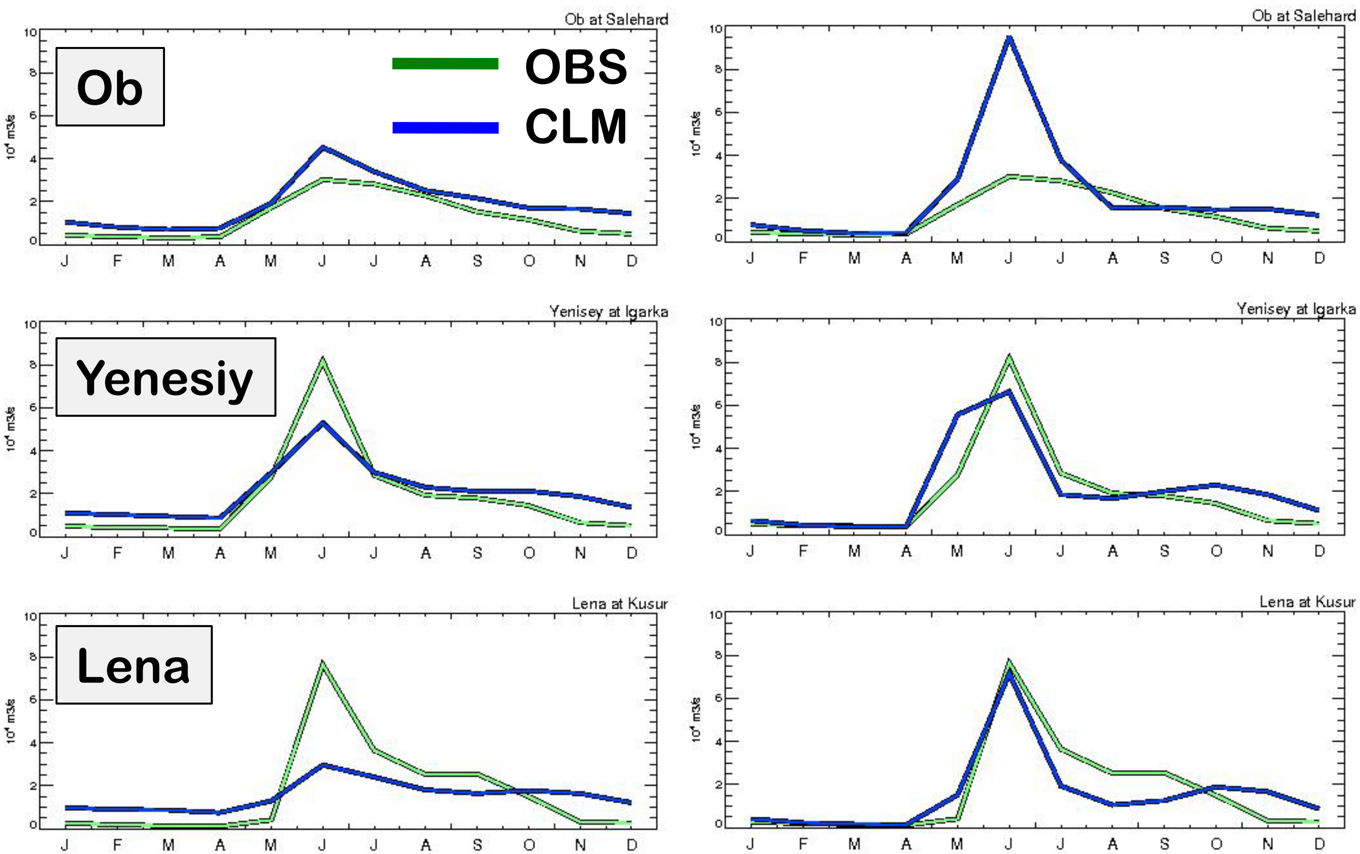


Cold region hydrology



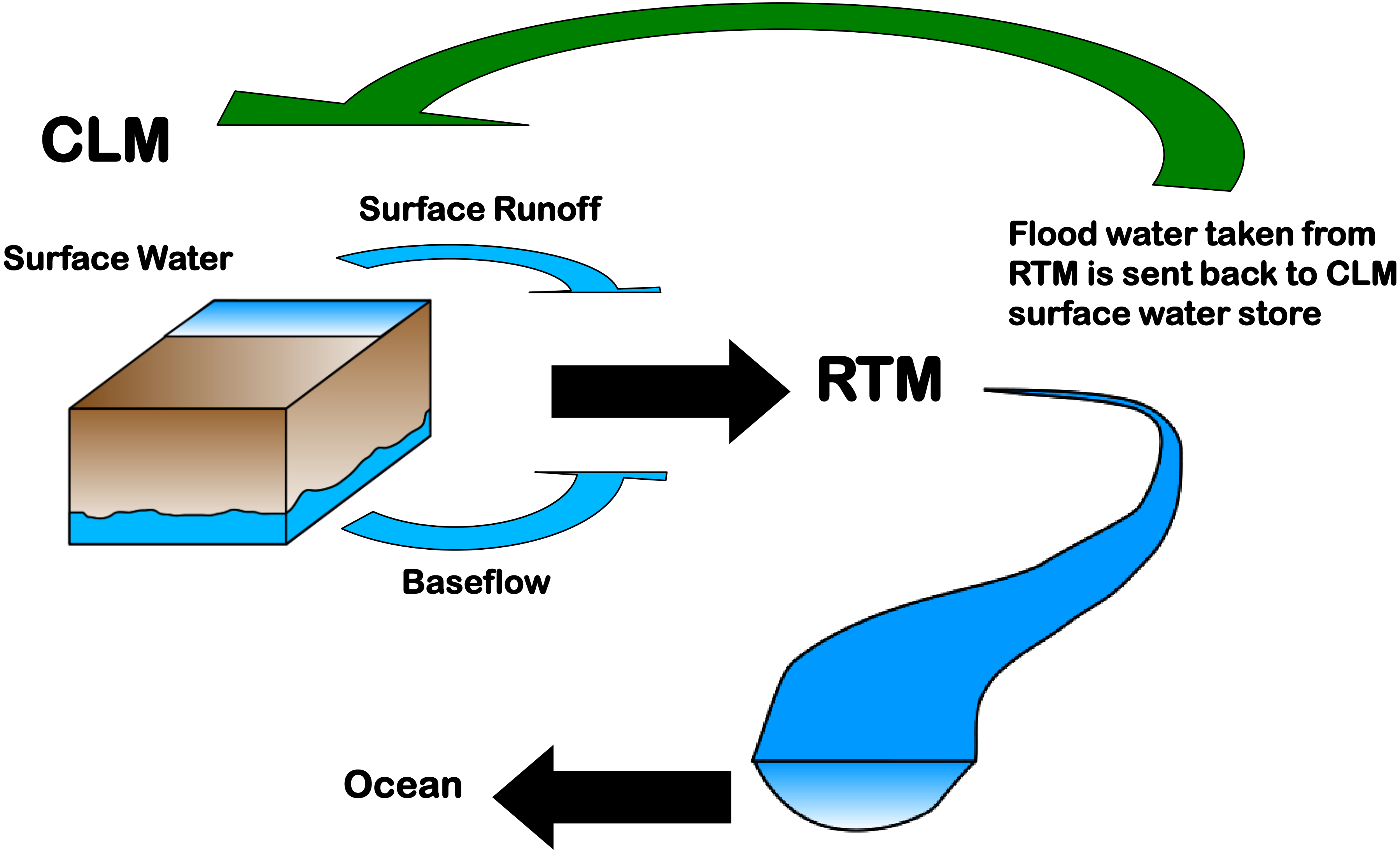
Problems: Water permeates icy soil too easily, dry active layer, vegetation grows poorly, river discharge hydrograph poor in permafrost basins

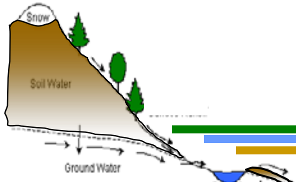
Control | **Ice Impedance**



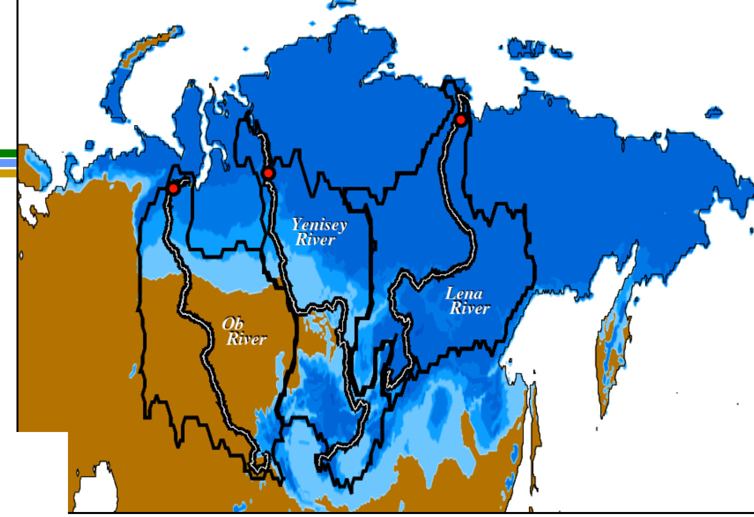
Swenson and Lawrence, in prep

Flooding Capability (2-way CLM-RTM interactions) and Surface Water (wetlands)



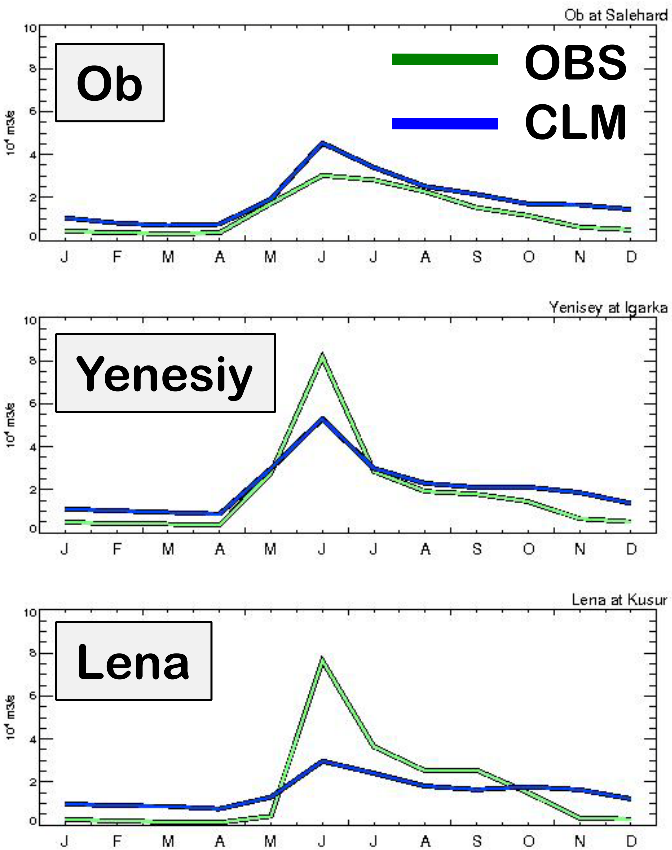


Cold region hydrology

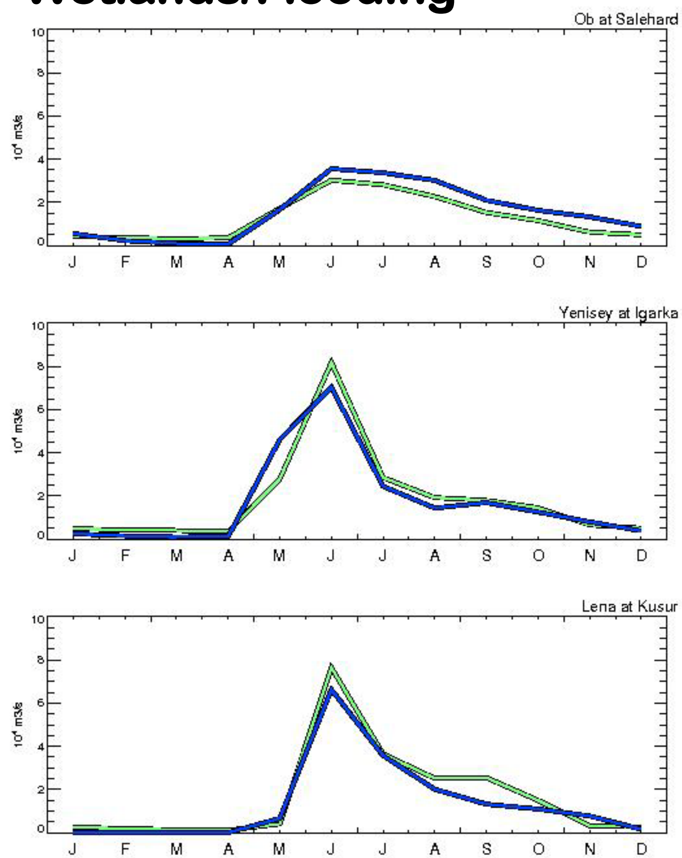


Results: Good hydrographs for both permafrost basins and non-permafrost basins, better active layer hydrology and veg?

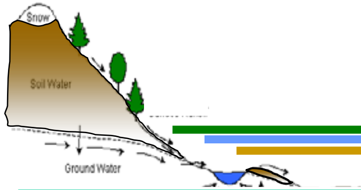
Control



Ice Impedance + Wetlands/Flooding

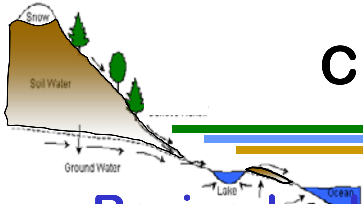


Swenson and Lawrence, in prep



CESM1.1: High resolution input datasets

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



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

- Revised cold region hydrology
  - Impedance factor, perched water table
  - Surface water store (prognostic wetlands)
  - New snow cover fraction param; separate surface energy calc for snow covered, surface water, and bare ground surfaces
  - 2-way CLM grid cell – RTM interactions (flooding)
- Soil Biogeochemistry
  - Vertically resolved soil C/N pools, CENTURY-like pool structure
- Methane emissions model (CLM4Me)
  - Based on Riley et al. 2011; with options from Meng et al. 2011
- Revised lake model
  - New lake physics and lake area dataset, sub-lake soil (Subin et al. 2012)
- Dynamic Landunits
  - Glacier to vegetated transitions and vice versa
- VIC Hydrology option (???)

Will a large-scale expansion of Arctic shrub extent increase or decrease permafrost vulnerability to climate change?

David Lawrence

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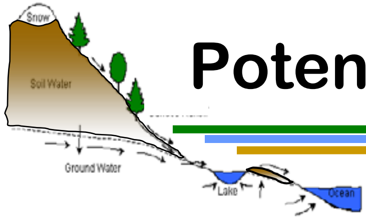
Boulder, CO

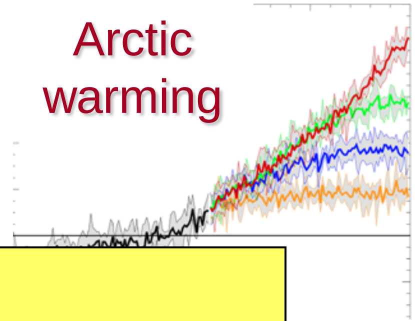
NCAR is sponsored by the National Science Foundation



Potential Arctic terrestrial climate-change feedbacks

Global warming

Arctic warming

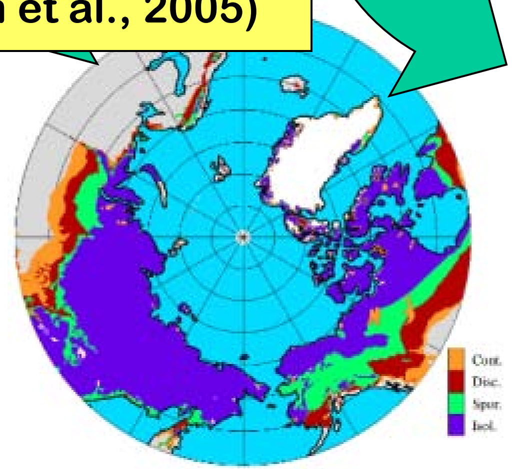


Carbon sequester

Shrub growth

Enhanced [nitrogen]

Microbial activity increases



Lakes drain, soil dries

Arctic runoff increases

Vegetation

Radiative forcing of complete conversion tundra to shrubland

+8.9W m^{-2} (4.2W m^{-2} GHG)

(Chapin et al., 2005)

Since 1950, 13% to 20% cover

(Sturm et al., 2005)

Adapted from McGuire et al., 2006

Shrub cover increasing in Arctic

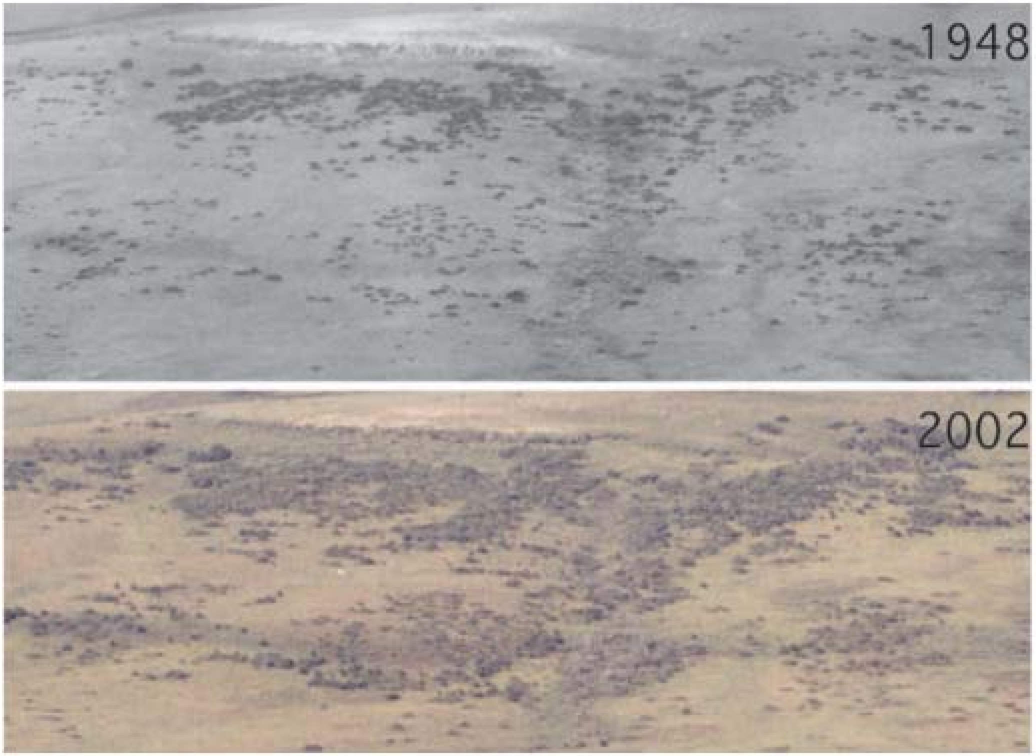
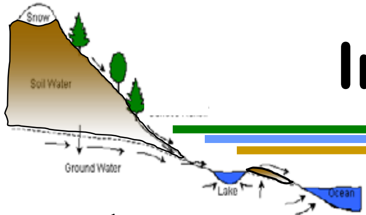
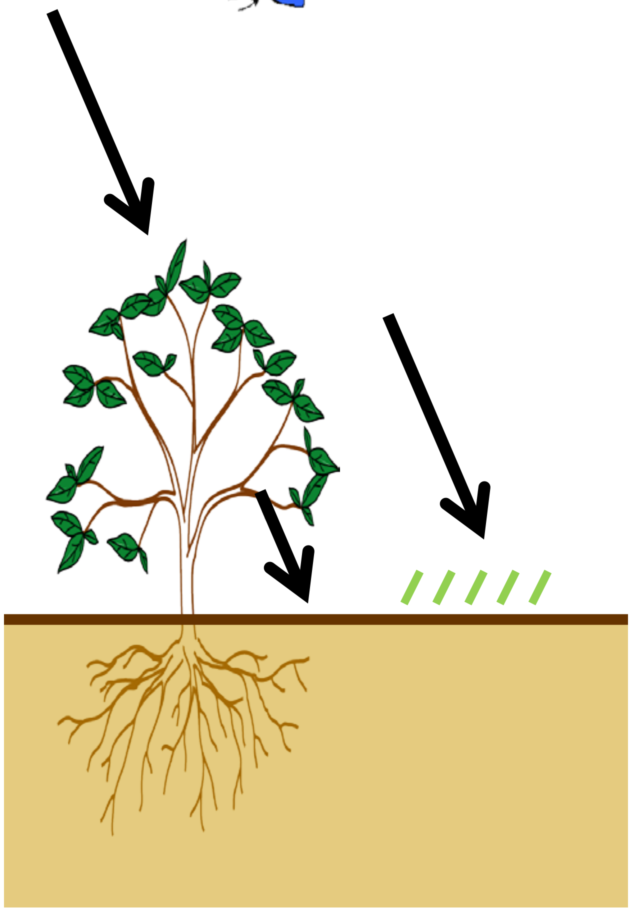


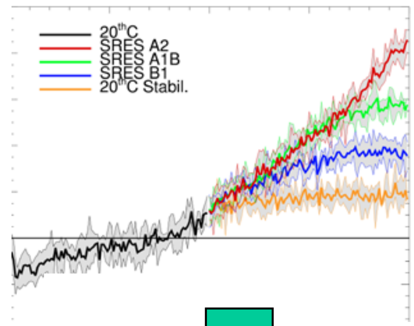
Figure 1. Increasing abundance of shrubs in arctic Alaska. The photographs were taken in 1948 and 2002 at identical locations on the Colville River (68° 57.9' north, 155° 47.4' west). Dark objects are individual shrubs 1 to 2 meters high and several meters in diameter. Similar changes have been detected at more than 200 other locations across arctic Alaska where comparative photographs are available. Photographs: (1948) US Navy, (2002) Ken Tape.

- **Shrub cover increasing in N. Alaska at 1.2% per decade since 1950, 15% to 20% cover (Sturm et al. 2001)**
- **Similar increases seen in Canada**
- **No studies for Siberia, but satellite NDVI data indicates that Siberia is getting ‘greener’ and one explanation for this is increasing shrub cover**



Impact of shrubs on climate and permafrost





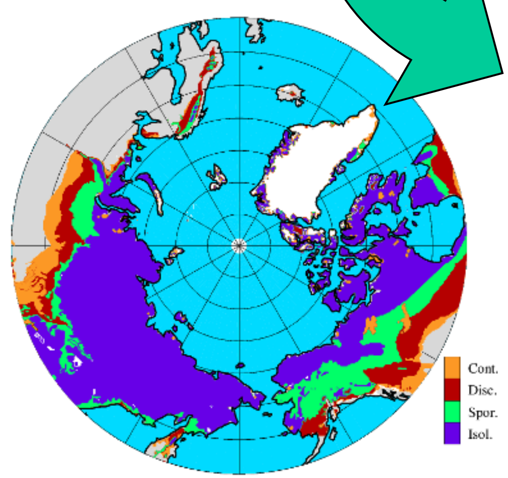
Carbon sequester

Shrub growth

Permafrost warms and thaws

Enhanced [nitrogen]

Microbial activity increases



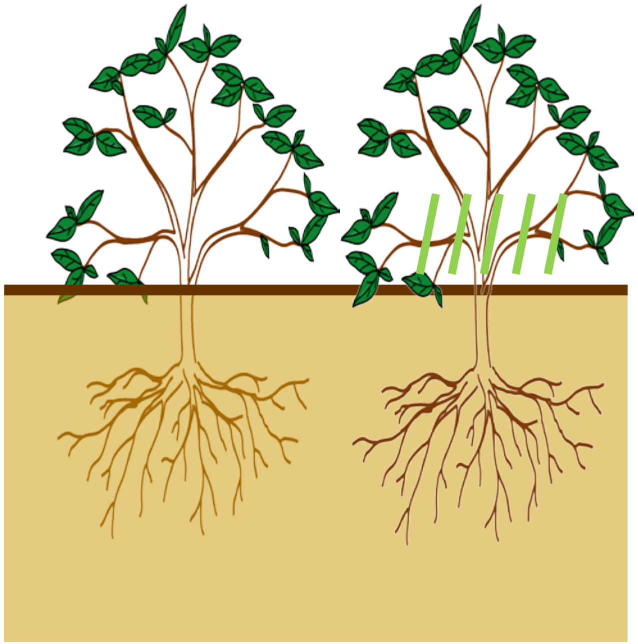
Adapted from McGuire et al., 2006

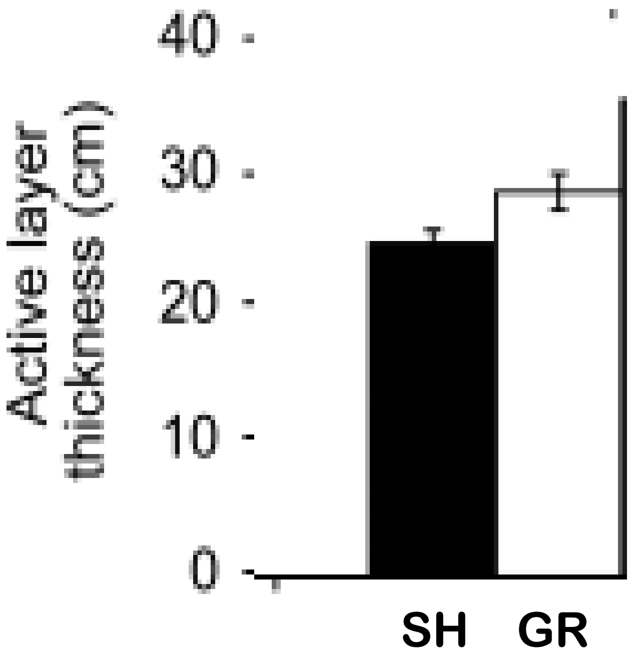
Global Change Biology

Global Change Biology (2010) 16, 1296–1305, doi: 10.1111/j.1365-2486.2009.02110.x

Shrub expansion may reduce summer permafrost thaw in Siberian tundra

D. BLOK*, M. M. P. D. HEIJMANS*, G. SCHAEPMAN-STRUB*†, A. V. KONONOV‡, T. C. MAXIMOV‡ and F. BERENDSE*

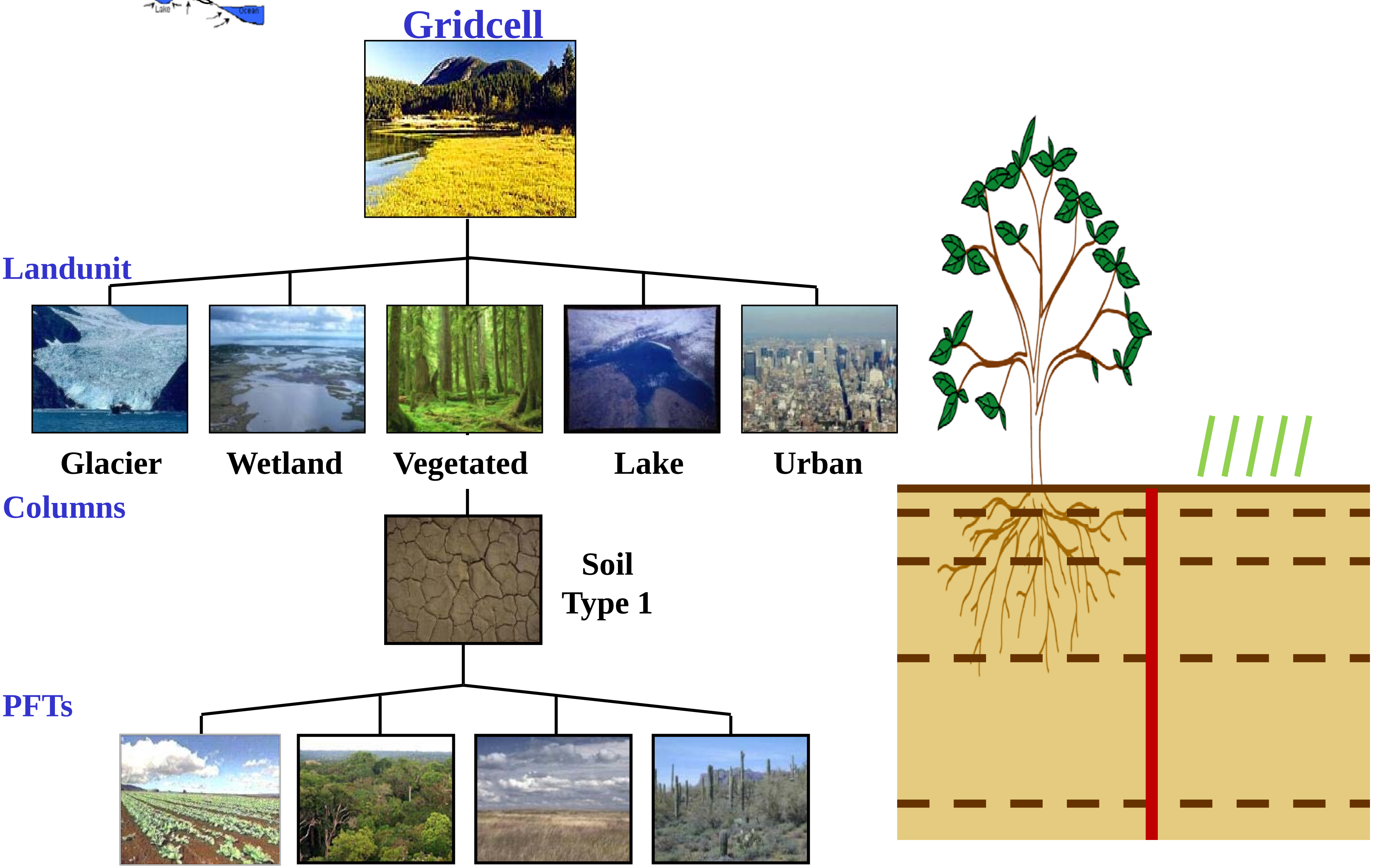


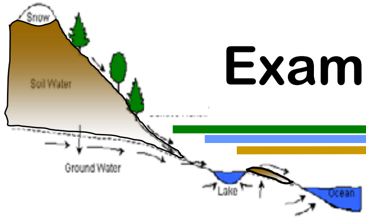


"These results suggest that the expected expansion of deciduous shrubs in the Arctic region, triggered by climate warming, may reduce summer permafrost thaw."

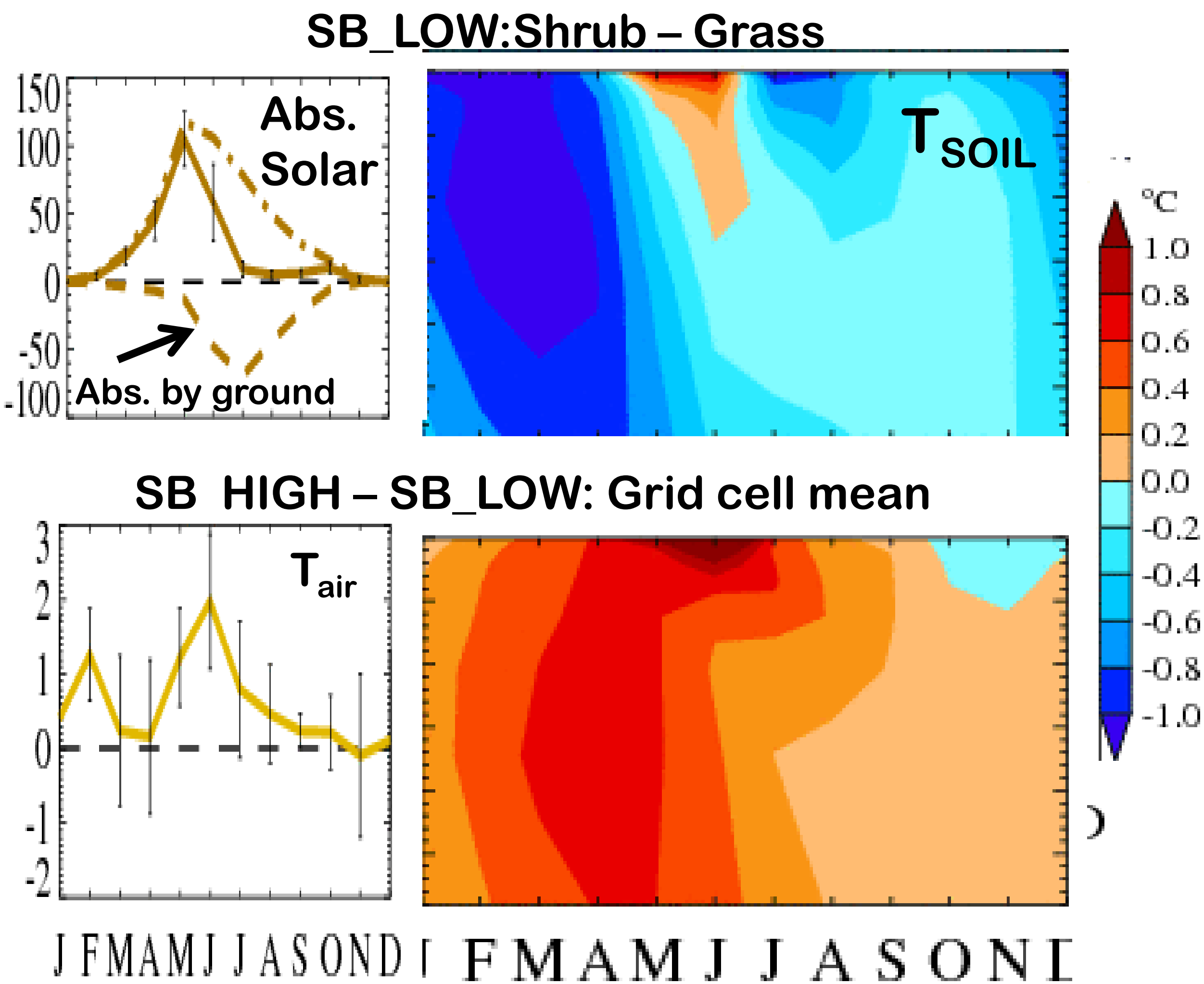
Evaluate this hypothesis using CAM4/CLM4

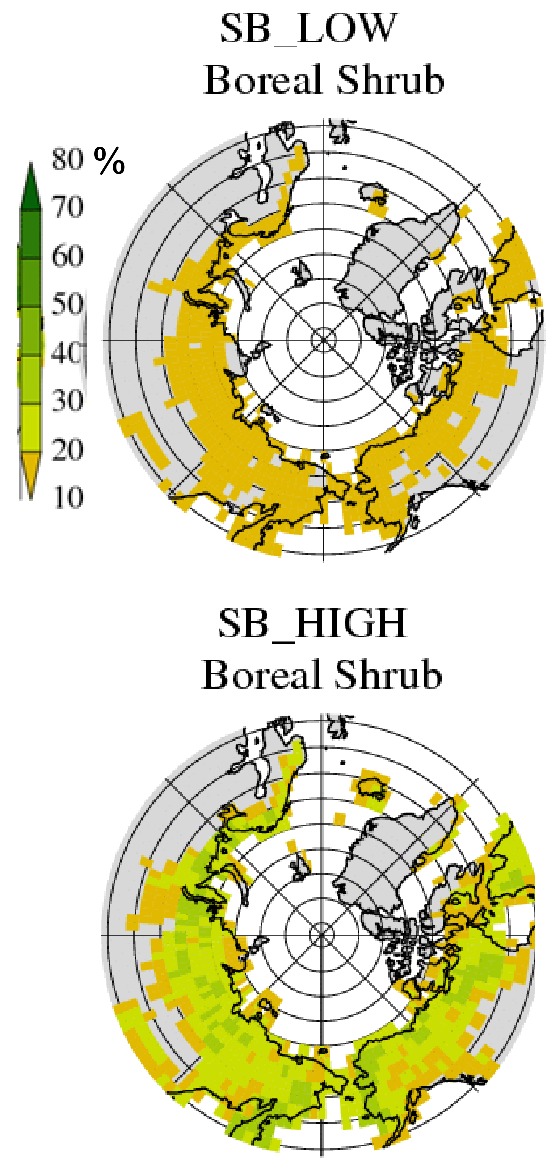
Community Land Model subgrid tiling structure



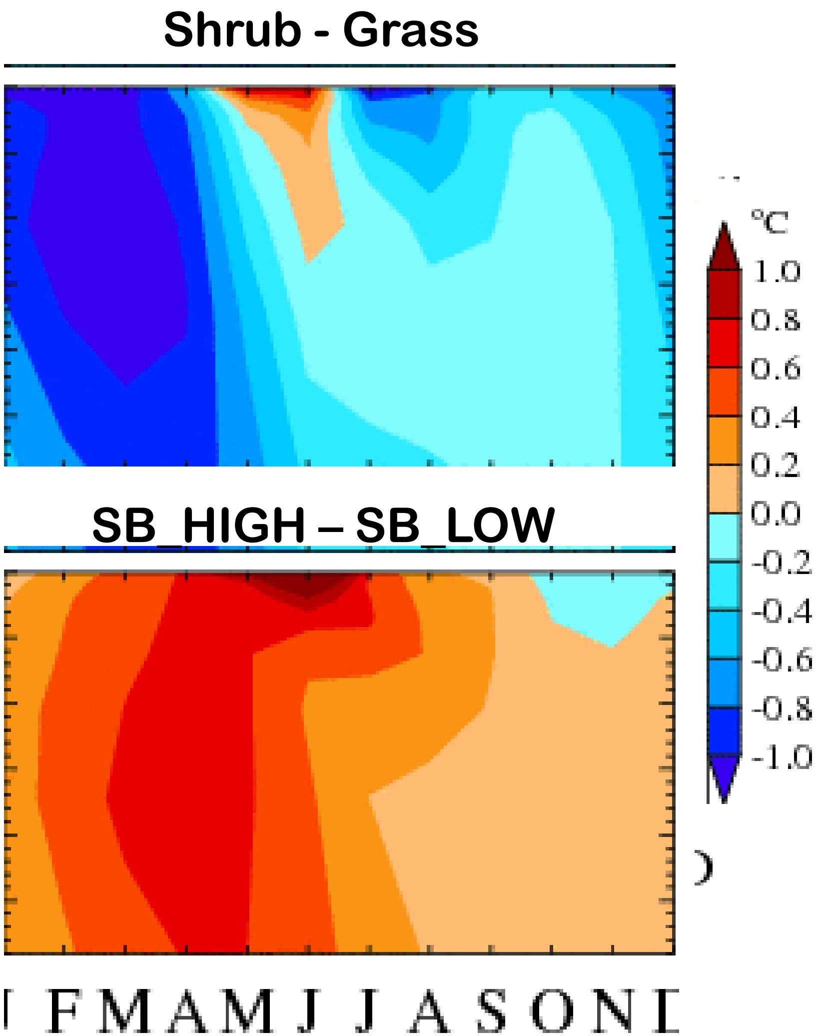


Examining impact of shrubs on permafrost using CAM4/CLM4



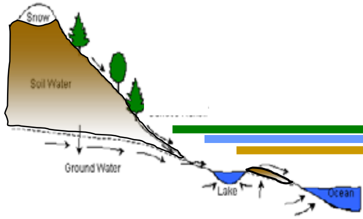


Impact of shrubs on permafrost



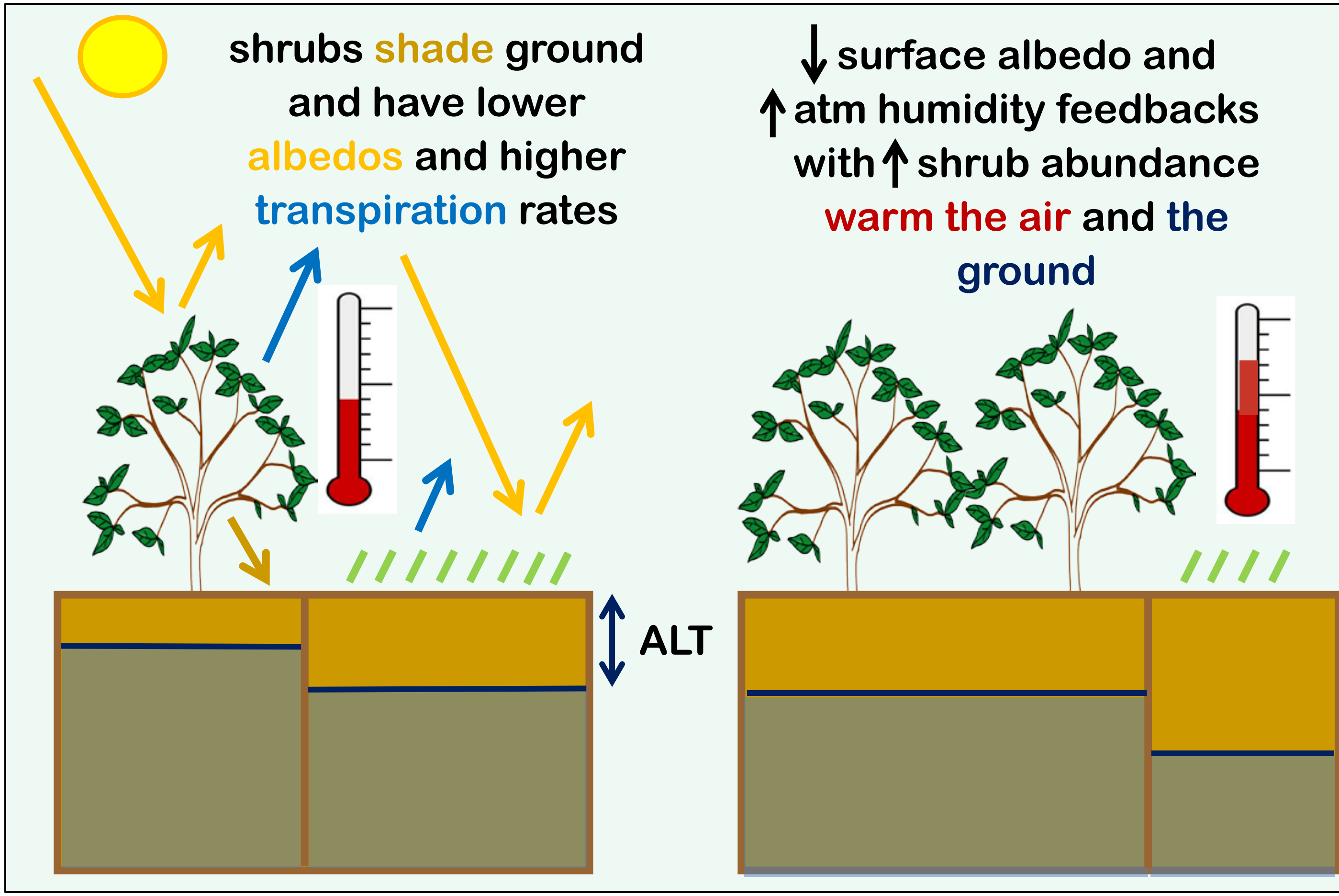
Model replicates results from field manipulation study (Blok et al. 2010)

But, if climate feedbacks are considered, ground actually gets warmer, suggesting that shrub area expansion may increase rather than decrease permafrost vulnerability.



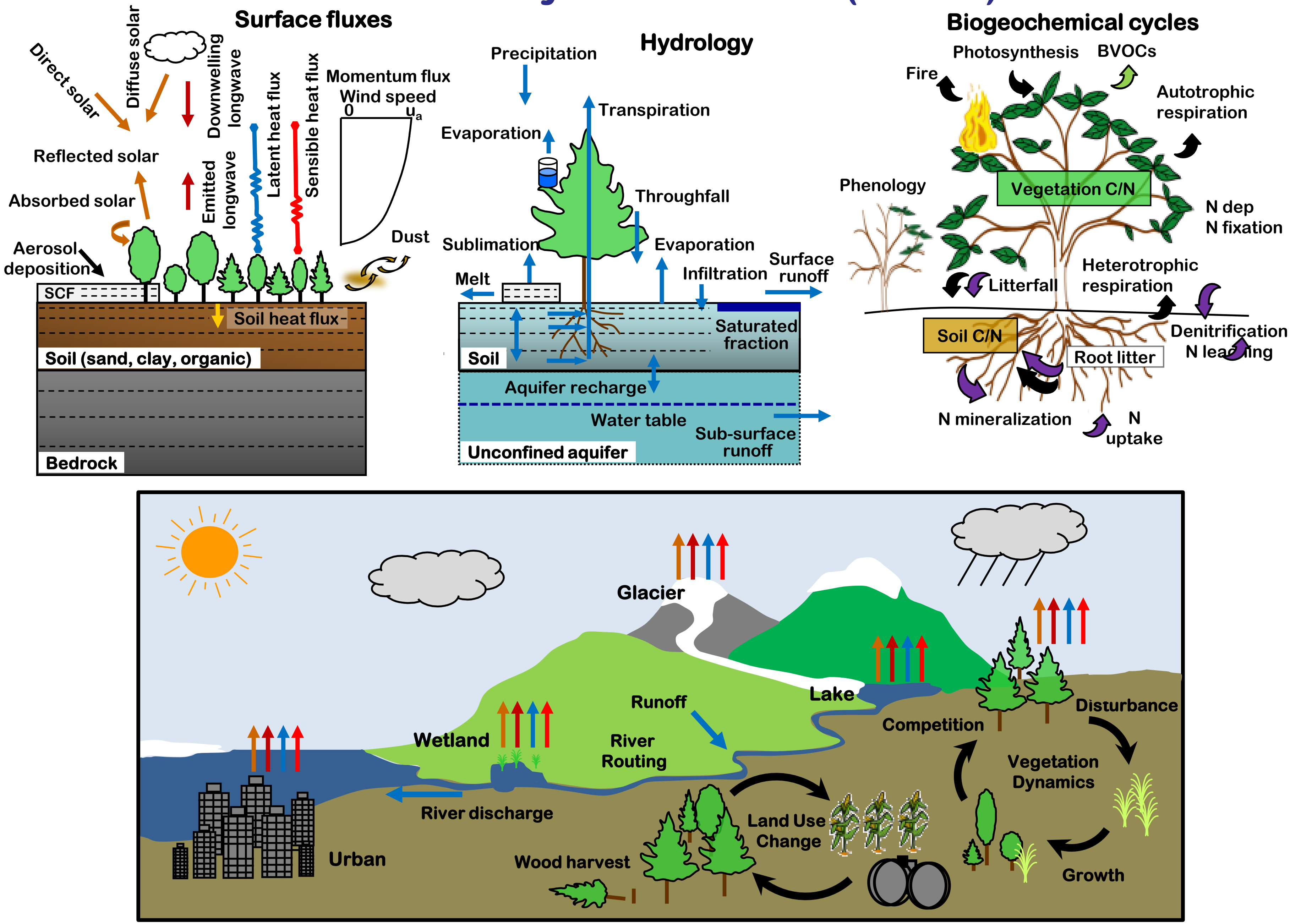
Summary (Lawrence and Swenson, ERL, 2011)

Will expanding Arctic shrub cover decrease permafrost vulnerability to climate change?

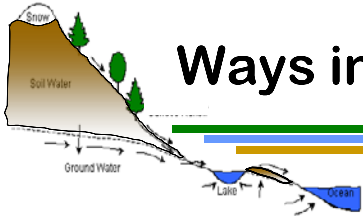


A. Not necessarily. Depends on whether the direct local cooling or the indirect climate warming dominates. Our results indicate that shrub expansion may increase rather than decrease permafrost vulnerability to climate change.

Community Land Model (CLM4)



Lawrence et al. 2011, JAMES



Ways in which shrubs can affect above and belowground climate

Shrubs compared to tundra

- absorb more solar
- earlier snowmelt
- shade the ground
- deeper snow drifts (insulation)
- higher transpiration

(Sturm et al. 2005)

Radiative forcing of complete conversion tundra to shrubland

+8.9W m^{-2} (4.2W m^{-2} GHG)

(Chapin et al., 2005)

Photo by M. Sturm