www.cesm.ucar.edu/working_groups/Land/

LMWG | Land Model Working Group

The Community Land Model (CLM) is the land model component of the CESM. Information on the latest version of CLM, including technical descriptions, user guides, and download instructions can be found on the CLM web page.

LMWG Liaison Information

- Keith Oleson

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LMWG Information

Developers' Guidelines

CLM5 Release

Upcoming Meetings

Past Meetings

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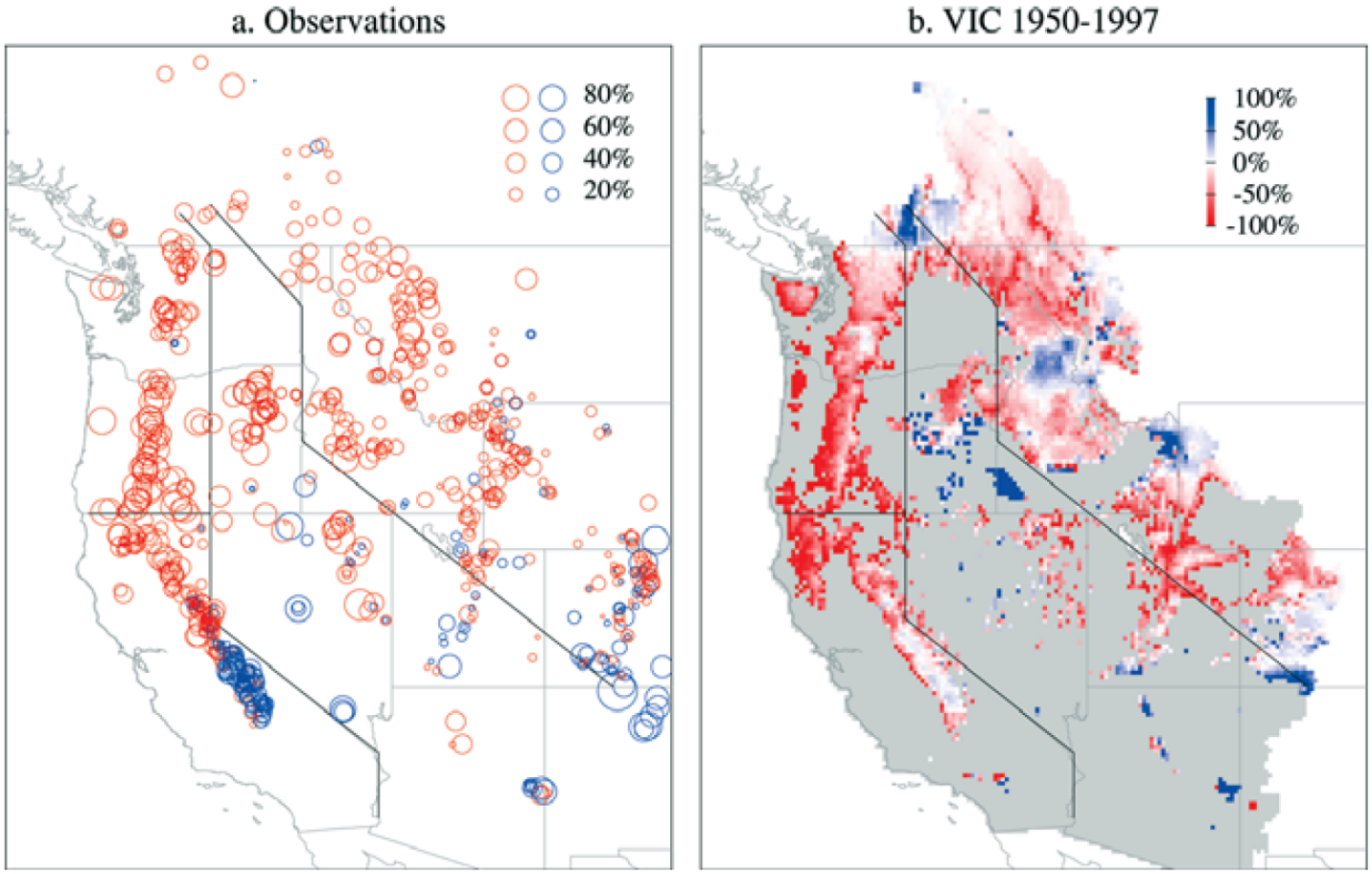
Snow processes in CLM

Dave Lawrence, Sean Swenson,
and Martyn Clark

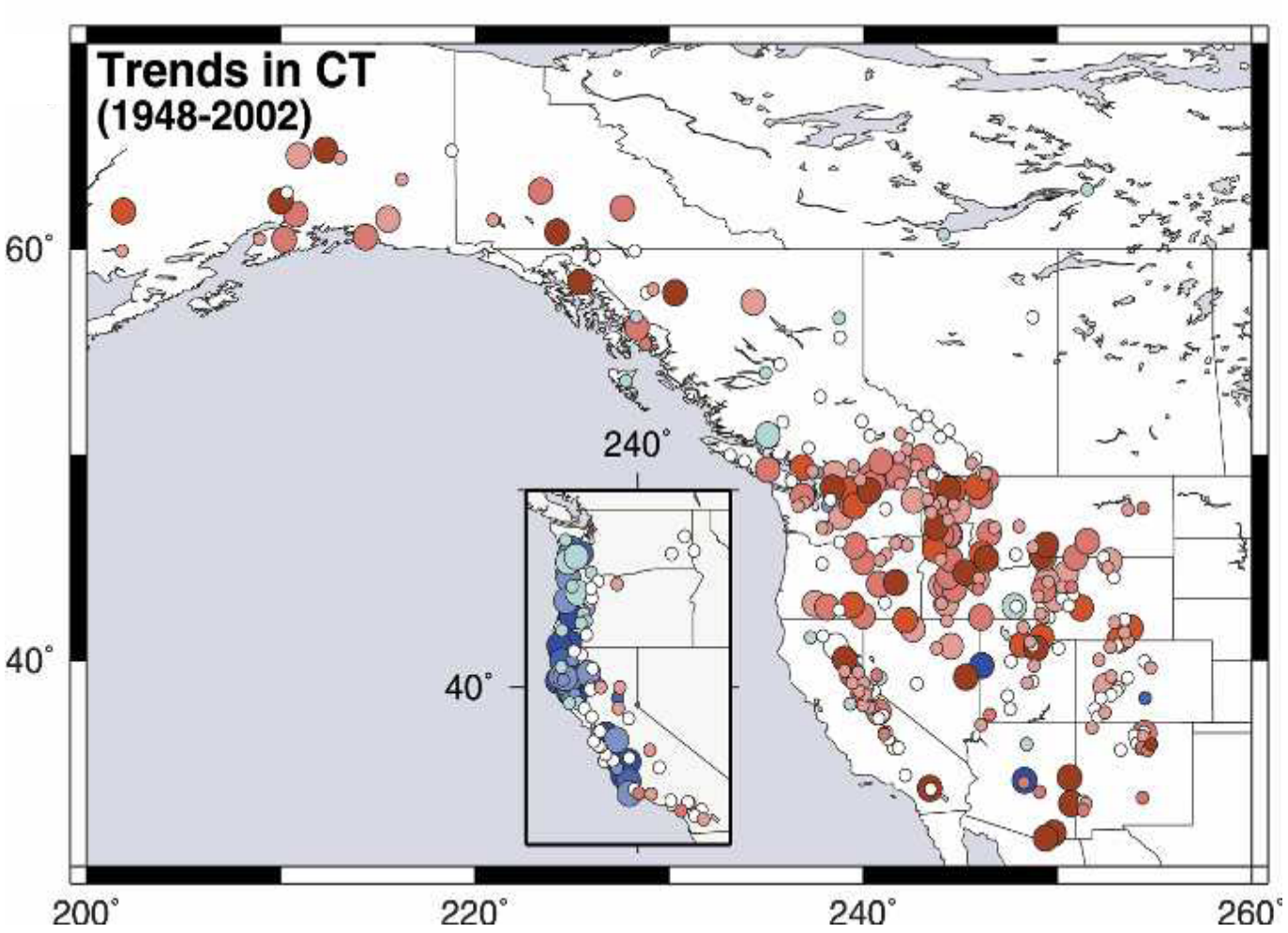
More than one-sixth of world's population dependent on water from seasonal snowpacks

Trends in snow accumulation



Mote et al., BAMS, 2005

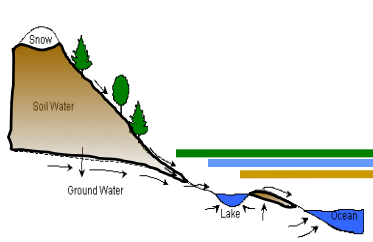
Trends in timing of snowmelt runoff



Red - Earlier runoff

Blue - Later runoff

Stewart et al., J. Climate, 2005



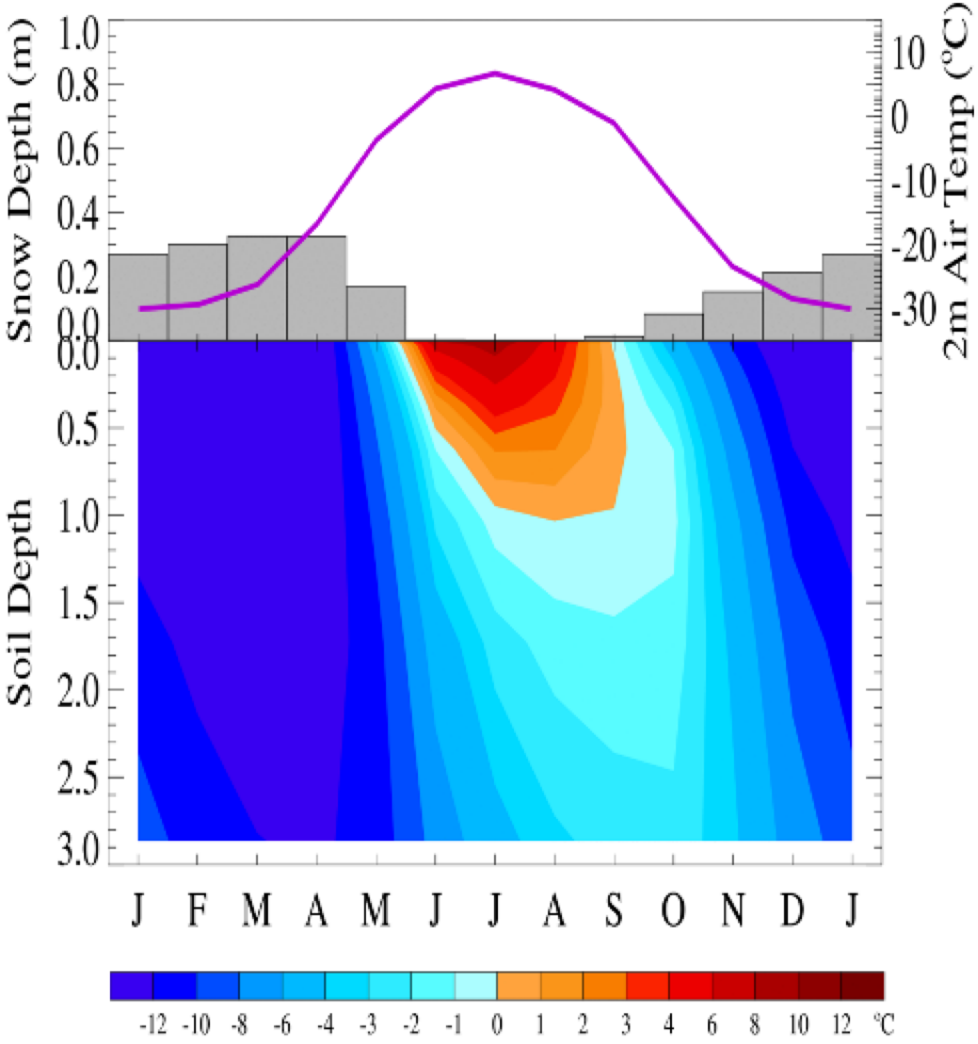
Snow/Soil thermodynamics

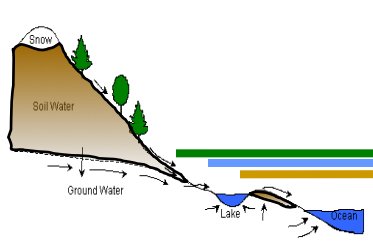
Solve the heat diffusion equation for multi-layer snow and soil model

$$C_p \frac{\partial T}{\partial t} = \frac{\partial}{\partial z}\left(K \frac{\partial T}{\partial z} \right)$$

where C_p (heat capacity) and K (thermal conductivity) are functions of:

- temperature
- total soil moisture
- soil texture
- ice/liquid content





Key requirements / decisions in snow modeling

Water balance

Precipitation

(partitioning)

Rain Snow

Energy balance

Turbulent fluxes

Longwave radiation

Solar radiation

(stability)

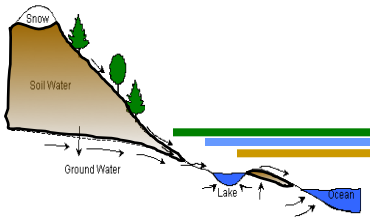
(thermal conductivity)

(albedo)

Snowpack

(drainage parameterization)

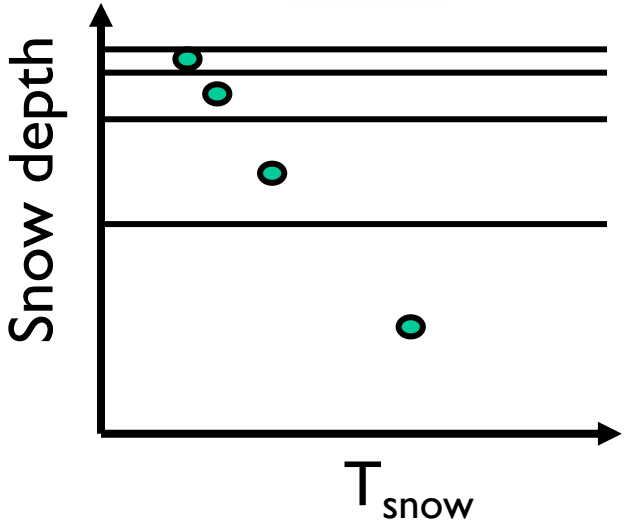
Snowpack outflow



Features of CLM snow model

State Variables

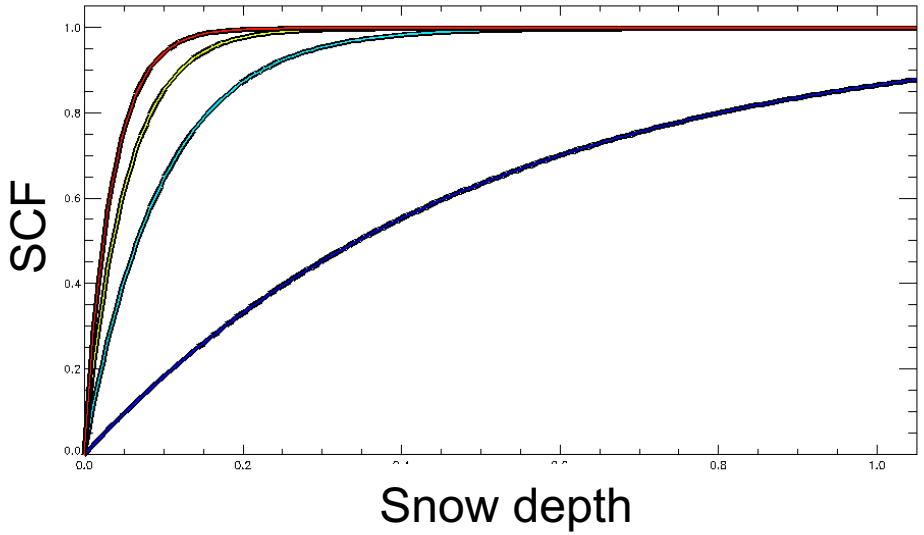
$$N, w_{liq,i}, w_{ice,i}, \Delta z_i, T_i$$

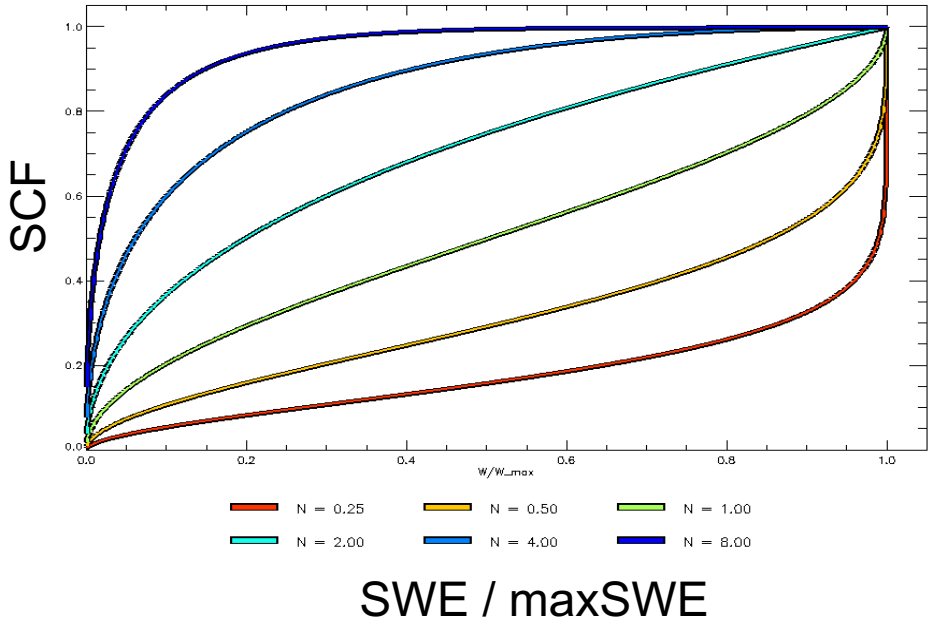


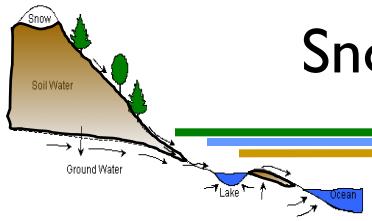
- Up to 12-layers of varying thickness
- Represented processes
  - Accumulation and fresh snow density *f* (T, wind)
  - Snow melt and refreezing
  - Snow aging
  - Water and energy transfer across snow layers
  - Snow compaction
    - destructive metamorphism due to temperature and wind
    - overburden
    - melt-freeze cycles
  - Sublimation
  - Aerosol (black carbon, dust) deposition
  - Canopy snow storage and unloading
  - Canopy snow radiation
  - Snow burial of vegetation
  - Snow cover fraction
- Unrepresented processes
  - Blowing snow
  - Subgrid variations in snow depths
  - Depth hoar

Snow Covered Fraction (SCF)

- Fraction of grid cell covered by snow for a given snow depth
- Based on snow water equivalent (SWE)
- Dependent on snow history
- Dependent on snow trajectory

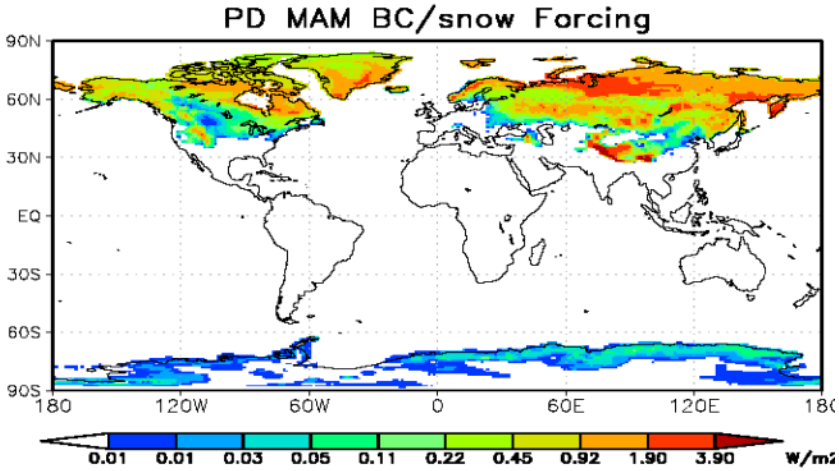


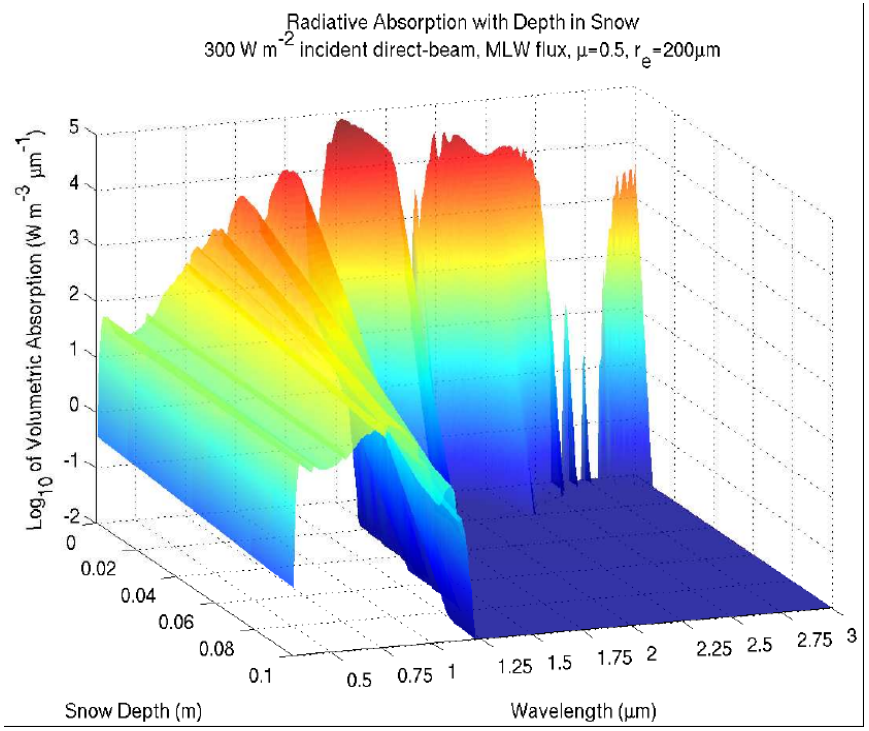




Snow, Ice, and Aerosol Radiative Model (SNICAR)

- Snow darkening from deposited black carbon, mineral dust, and organic matter
- Vertically-resolved solar heating in the snowpack
- Snow aging (evolution of effective grain size) based on:
  - Snow temperature and temperature gradient
  - Snow density
  - Liquid water content and
  - Melt/freeze cycling

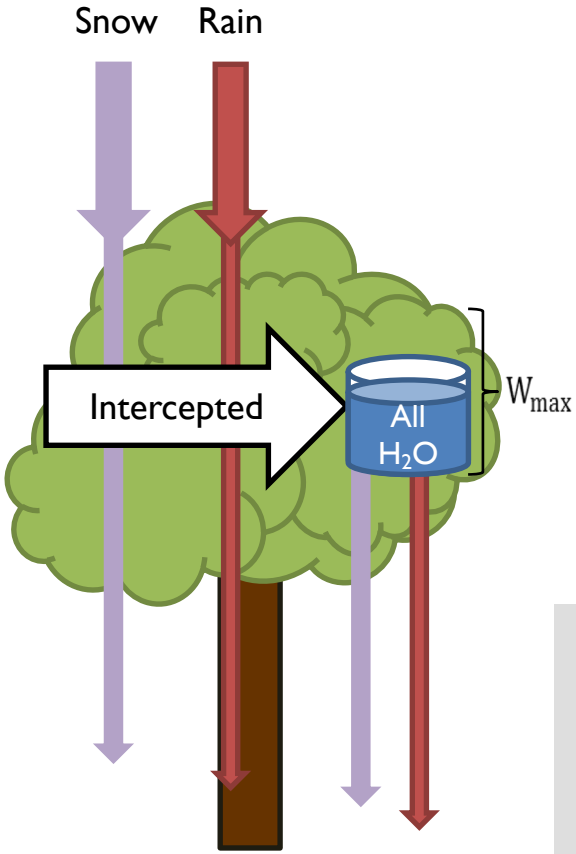


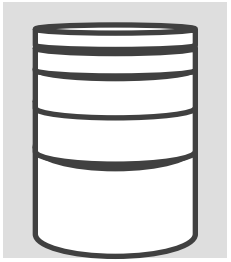


Flanner et al (2007), *JGR*
Flanner and Zender (2006), *JGR*
Flanner and Zender (2005), *GRL*

CLM5: Snow updates

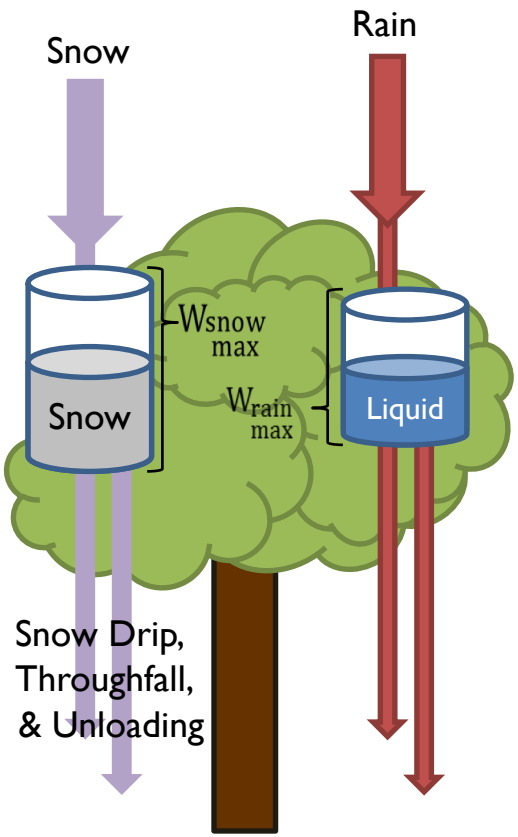
CLM4.5

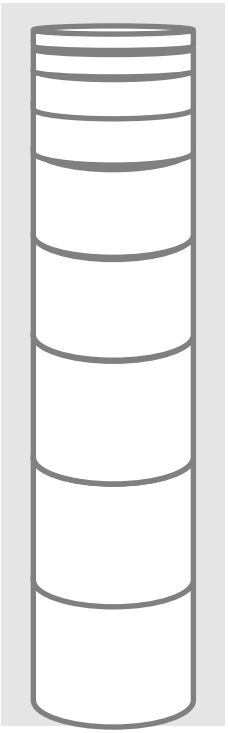




1m max SWE
up to 5 layers

CLM5

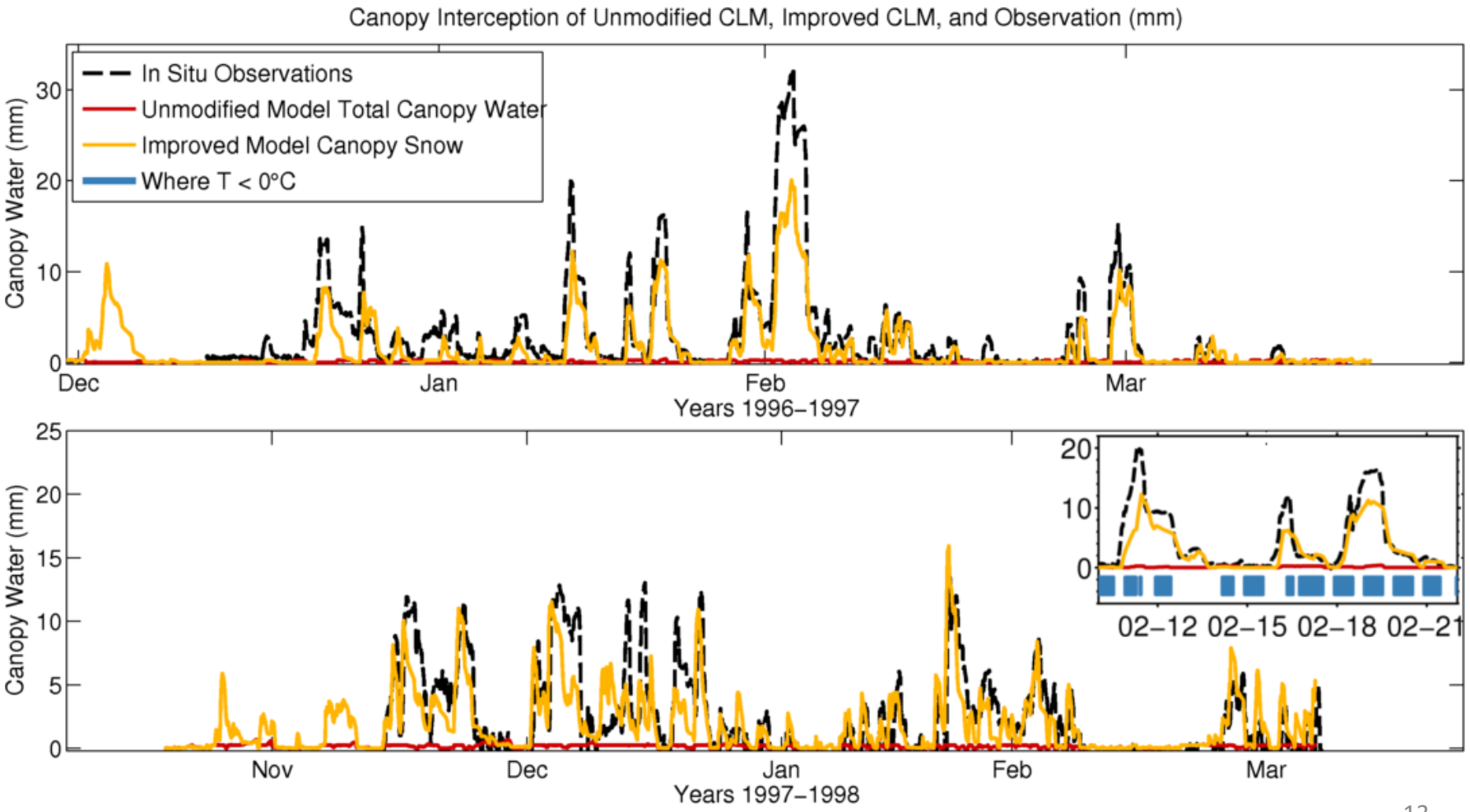




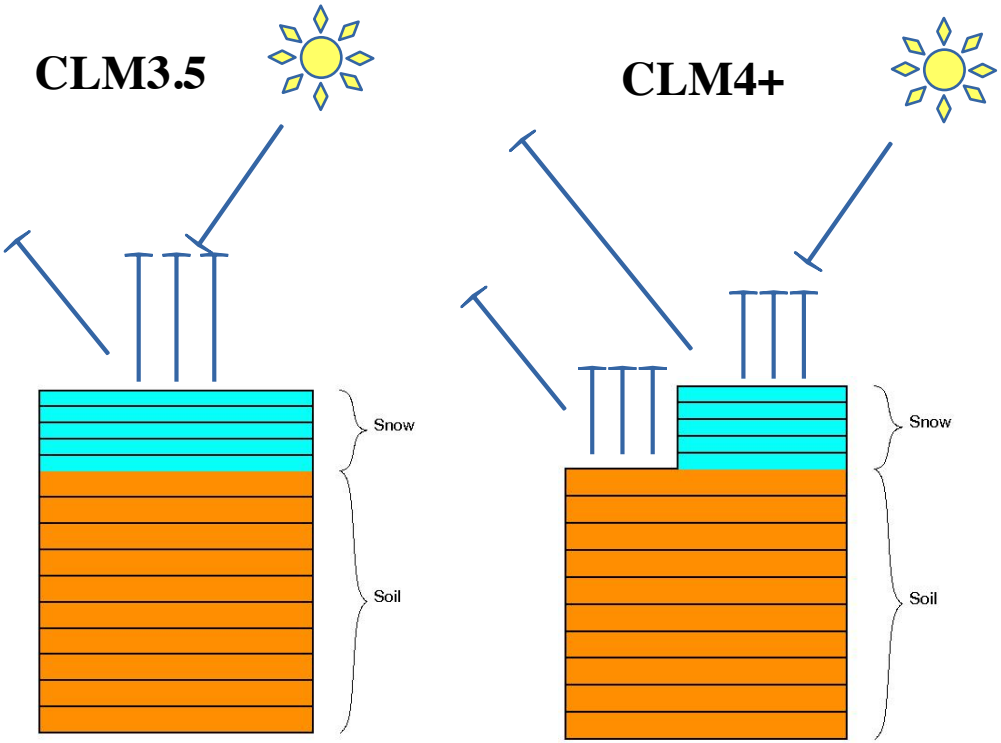
20m max SWE
up to12 layers

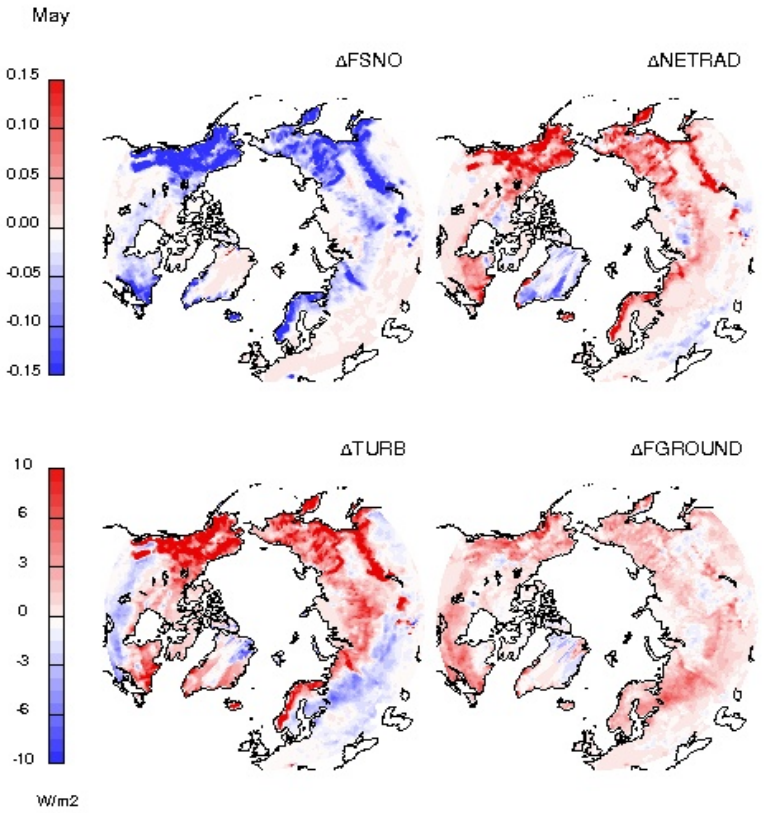
Evergreen Snow Interception Measurements

- More representative of in-situ snow canopy storage
- (previously canopy snow albedo present only in freezing temps).



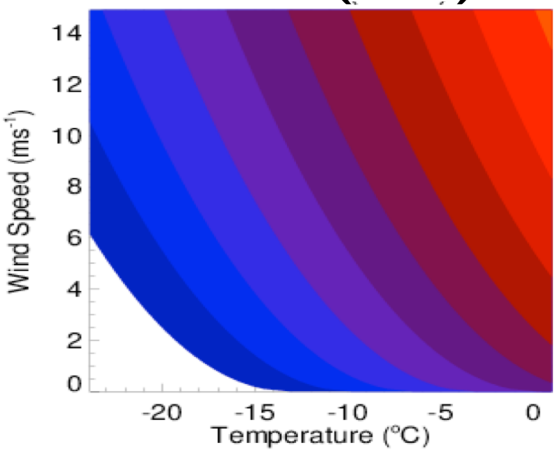
Subgrid Snowpack and Surface Fluxes



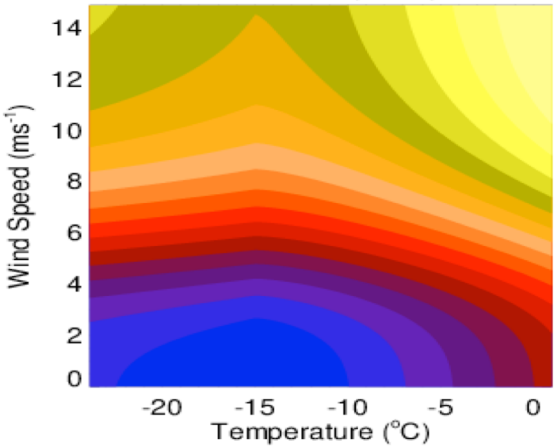


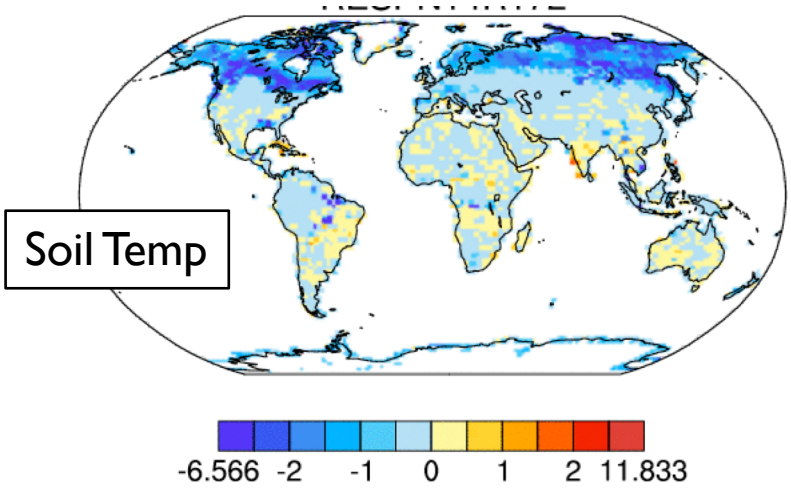
Improvements to fresh snow density and snow compaction

CLM4/CLM4.5
Pahaut (1976)

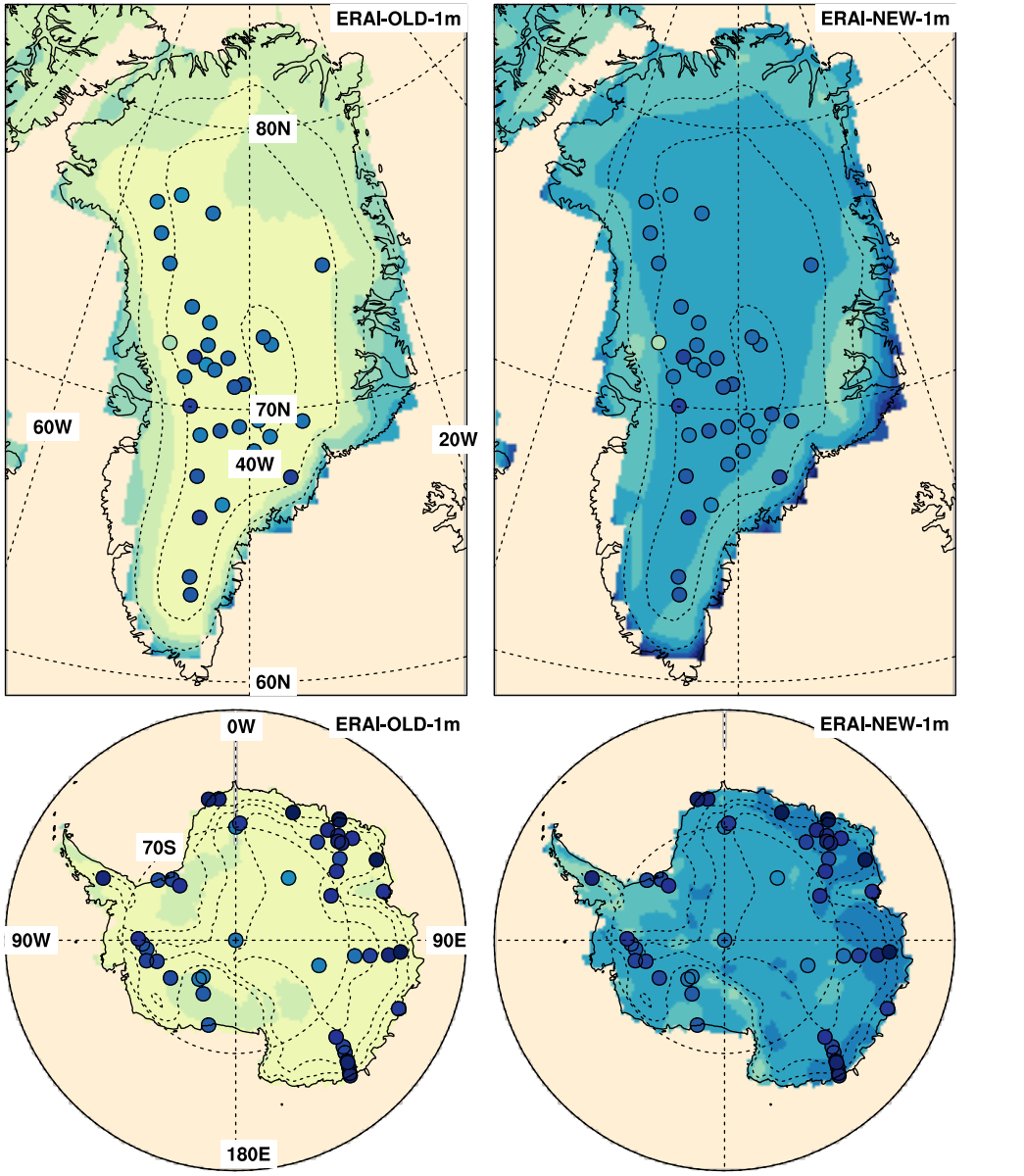


CLM5
Slater





- Improved snow densities
- Cooler soil temperatures
- Eliminates spurious Antarctica snow melt

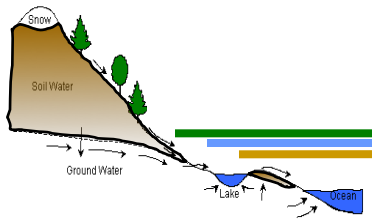


CLM5 snow density

Revised fresh snow density with improved temperature and wind effects
Lead to increased and more realistic snow density and less thermal insulation

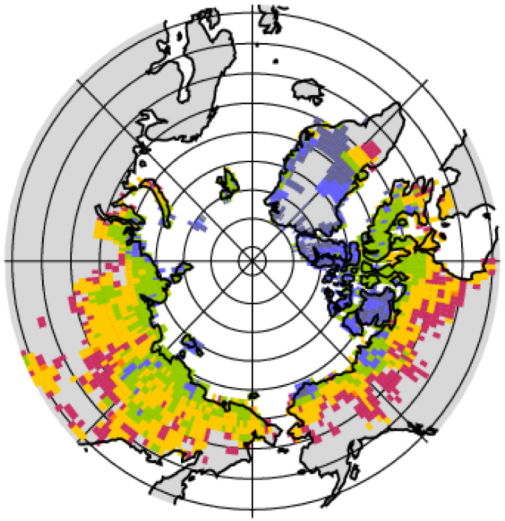
Figure courtesy L. Van Kampenhout

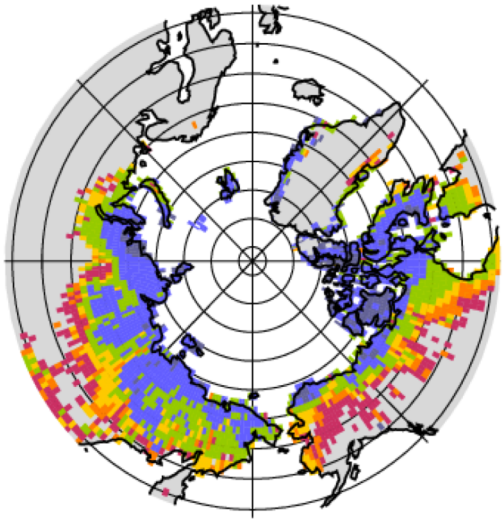
Snow insulation and permafrost distribution

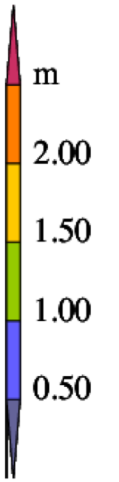


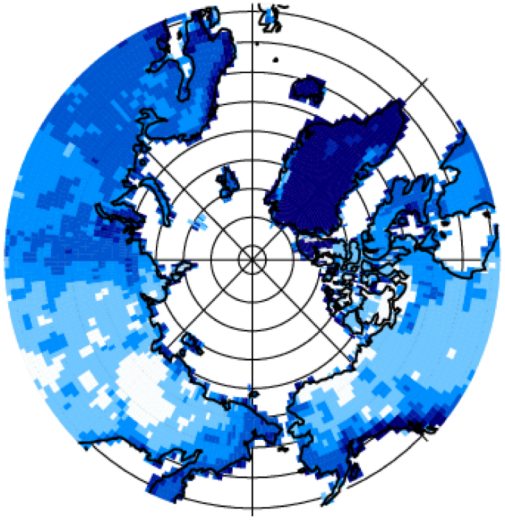
CLM4.5BGC (GSWP3)
11.5

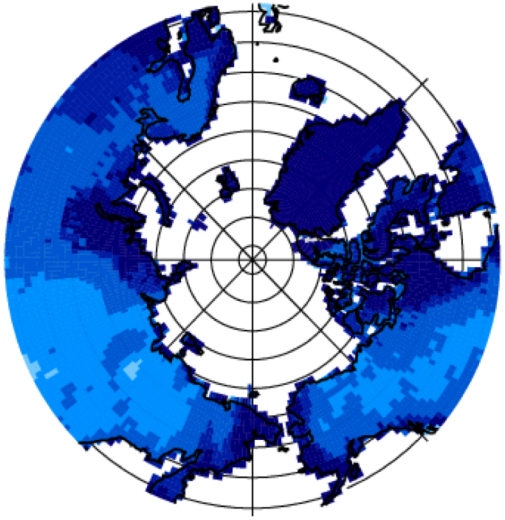
CLM5BGC (GSWP3)
13.1

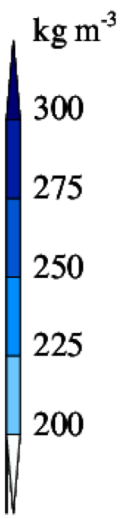






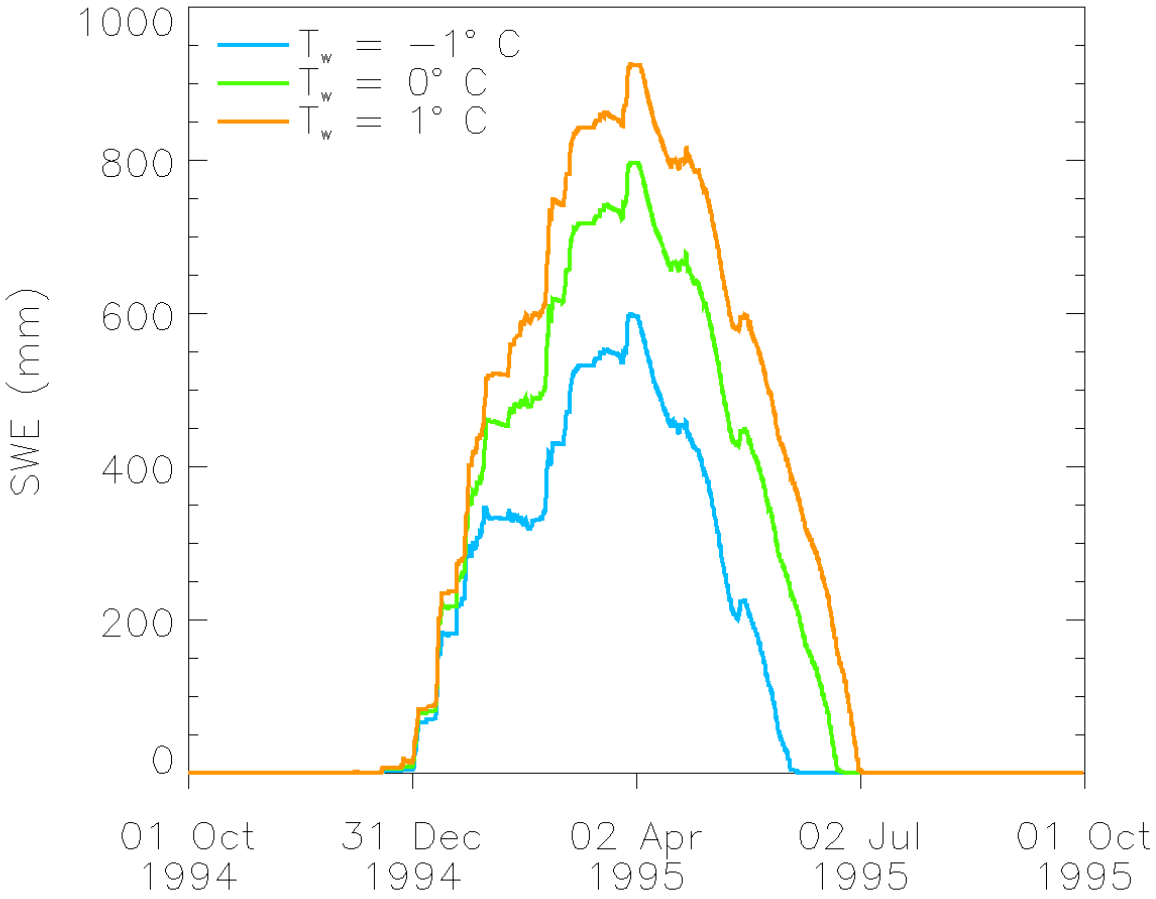






Uncertainties: Precipitation partitioning

- Partitioning of precip into rain and snow is based on temperature
- In CLM5, the atmosphere model partitioning into rain and snow is ignored. CLM repartitions total precipitation using a linear ramp. For most landunits, this ramp generates all snow below 0°C, all rain above 2°C (T=1°C), and a mix of rain and snow in between. For glaciers, the end points are minus 2°C and 0°C, respectively.
- Changes to the phase of precipitation are accompanied by a sensible heat flux (positive or negative) to conserve energy.



Uncertainties: Liquid water flow

- The storage and transmission of liquid water parameterized as gravity drainage (note: this is not the function used in CLM)

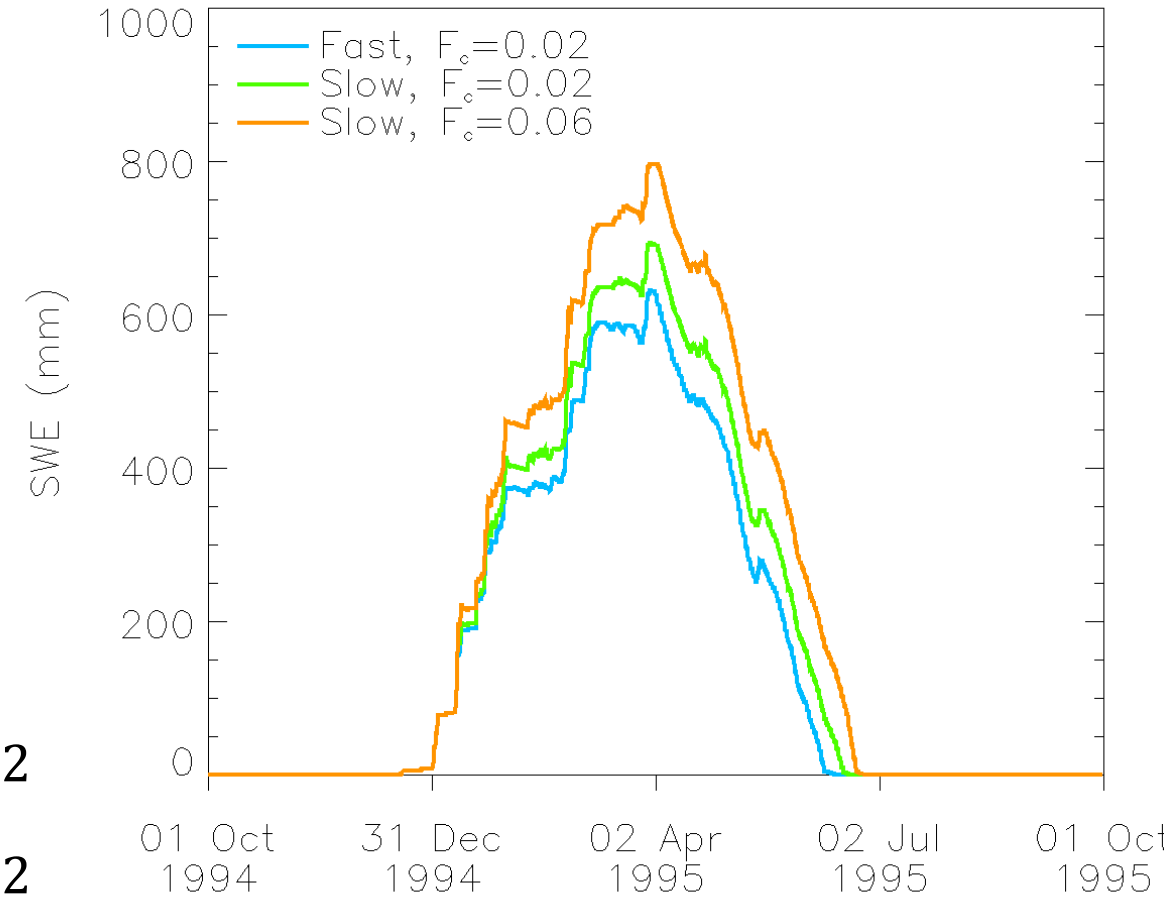
$$q = k\left(\frac{\theta_{liq} - \theta_{res}}{\phi - \theta_{res}}\right)^{c}$$

- Consider three parameter sets

$k = 10; \quad c = 1; \quad \theta_{res} = 0.02$

$k = 0.015; \quad c = 3; \quad \theta_{res} = 0.02$

$k = 0.015; \quad c = 3; \quad \theta_{res} = 0.06$



Thanks. Questions?