

**Land Model, Biogeochemistry, Chemistry
Climate, Societal Dimensions Working
Groups**



Understanding and Modeling Soil Hydrological Processes and Their Impacts on Carbon Dynamics in High-latitude Regions

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THE UNIVERSITY OF TEXAS AT AUSTIN
**CENTER FOR INTEGRATED
EARTH SYSTEM SCIENCE**



- **Snow cover in high-latitude regions is an excellent insulator.**
- **This study aims to improve our understanding of soil thermal and hydrological processes and biosphere–atmosphere interactions in snow-covered areas.**



<http://en.wikipedia.org/wiki/File:Storflaket.JPG>



<http://www.weather.com.cn/photo/gqt/02/1274797.shtml>

Model, Data, and Domain

2/17

- **Model:**

- The Community Land Model Version 4 (CLM4):
with satellite phenology – CLM4SP
with the explicit carbon and nitrogen balances – CLM4CN

- **Data:**

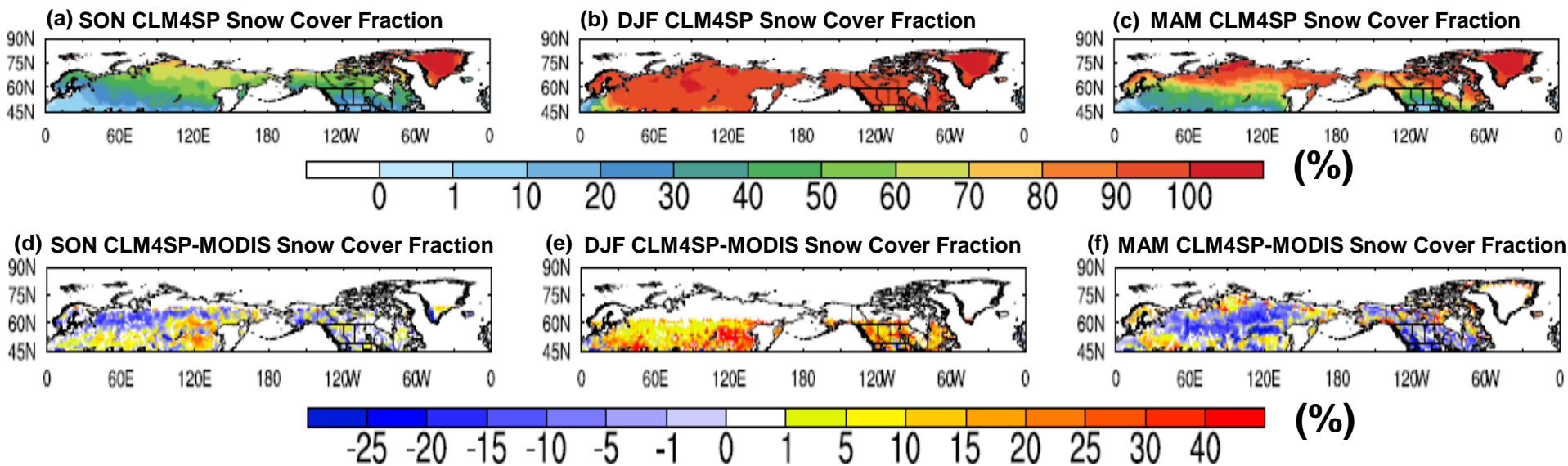
- Meteorological forcing: Qian et al. ([2006](#))
- Runoff data: New Hampshire – Global Runoff Data Center dataset (UNH-GRDC)
- Snow cover fraction data: MODIS snow-cover products
- Landscape freeze/thaw (FT) state: satellite microwave remote sensing ([Kim et al. 2011](#))

- **Domain:**

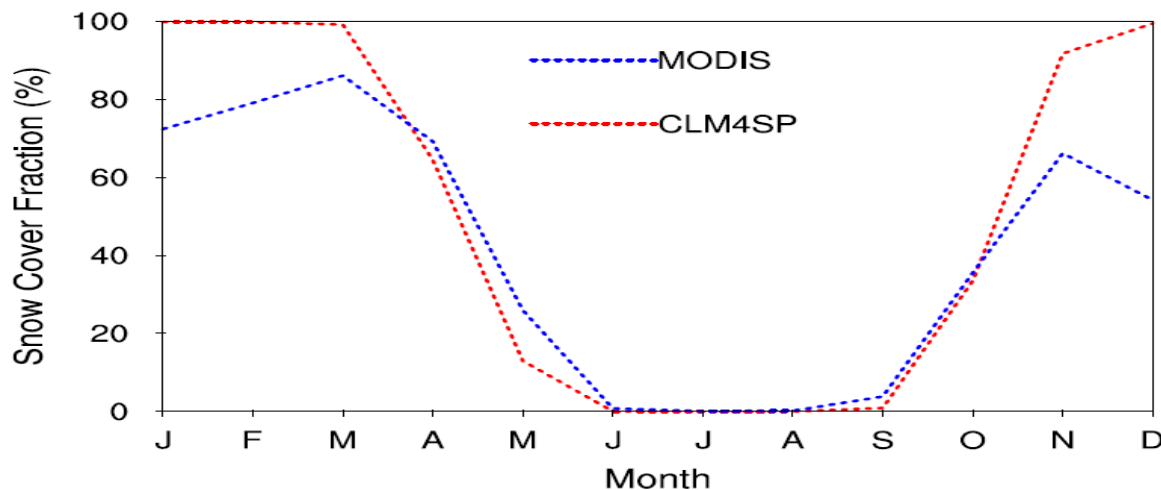
- 45°N – 90°N, 180°W – 180°E with the resolution 1° × 1°

CLM4 Reproduced Snow Areas

3/17



Siberia(50-66.5N,60-140E)



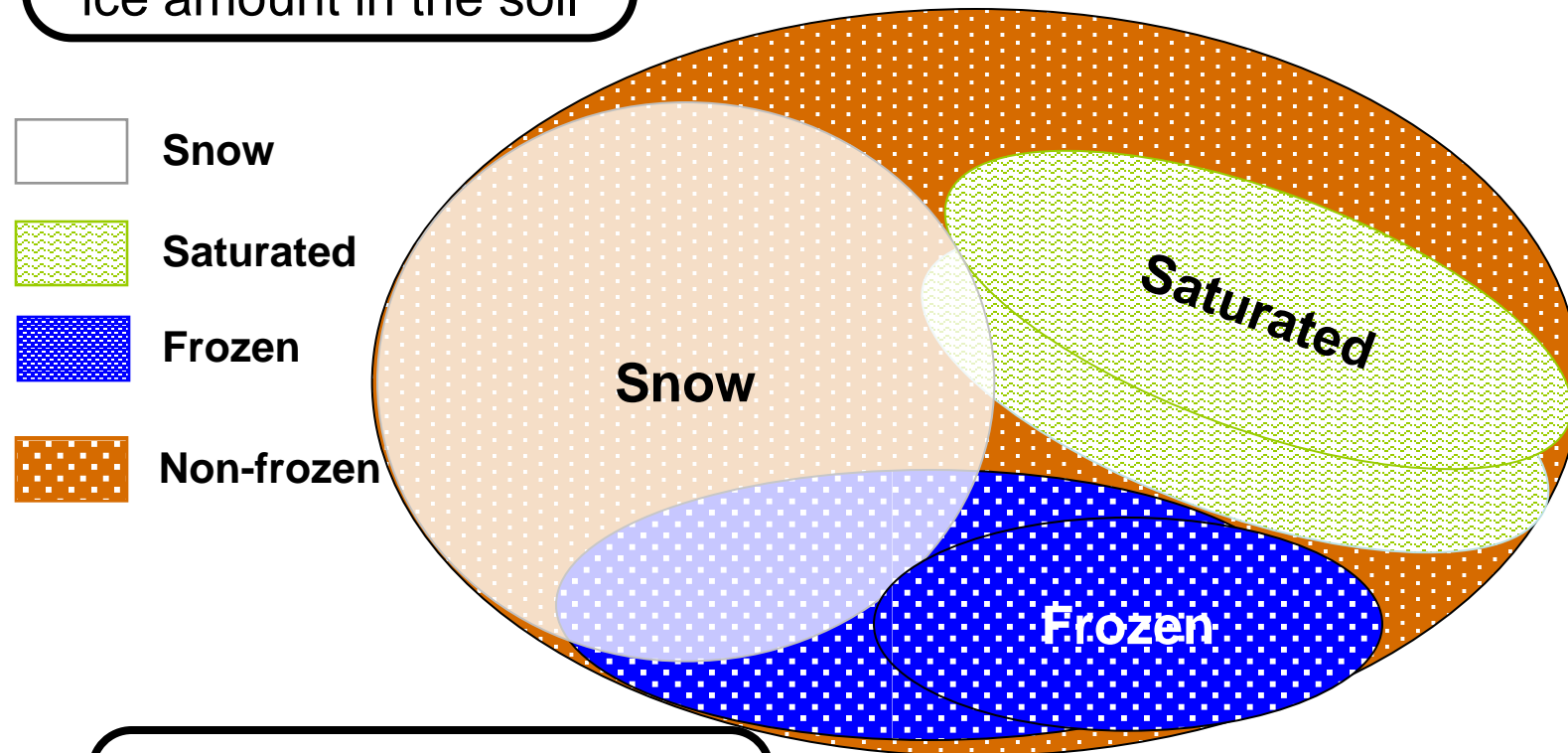
Experiment Design

4/17

CTL: In each grid cell, the fractional frozen area depends on the ice amount in the soil

MOD1: In each grid cell, soil under the snow cover is unfrozen

$$\Rightarrow f_{frz} = f_{frz} \times (1 - f_{sno})$$

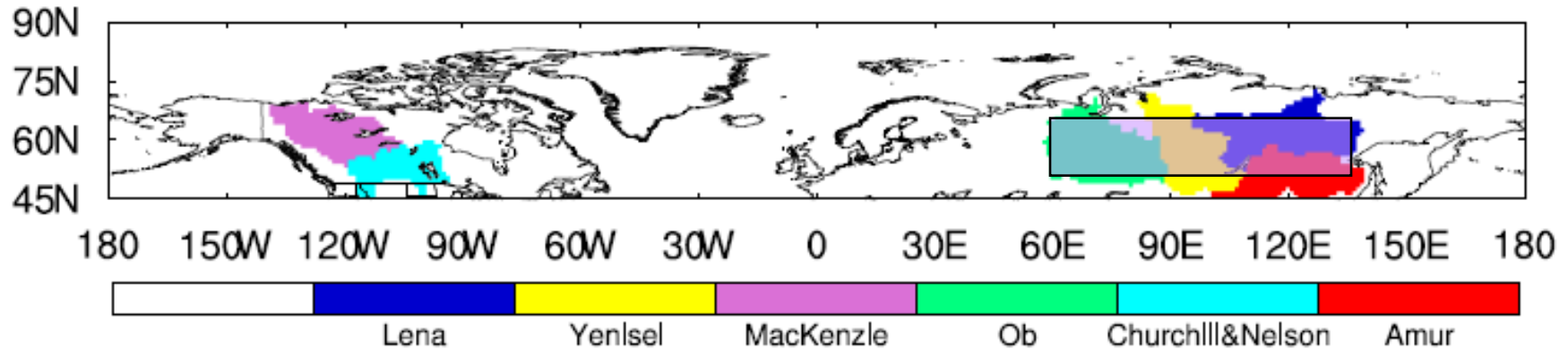


MOD2: Based on MOD1, but the saturated regions are snow free

$$\Rightarrow f_{sat} = f_{sat} \times (1 - f_{sno})$$

Research Domain

5/17

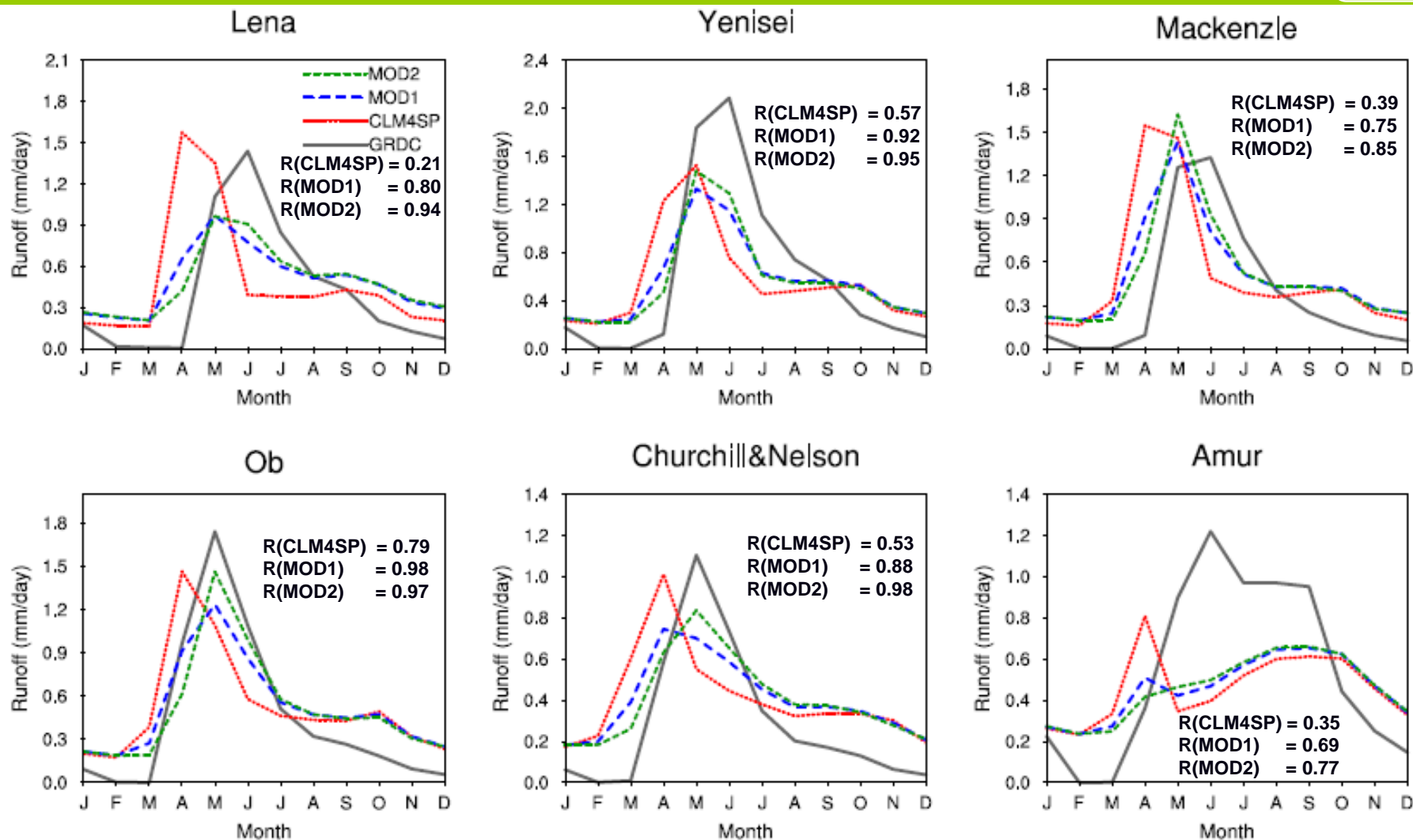


Research domain includes:

- ✓ Lena
- ✓ Yenisei
- ✓ Mackenzie
- ✓ Ob
- ✓ Churchill–Nelson
- ✓ Amur
- ✓ The Siberia region ($50 - 66.5^{\circ}\text{N}$, $60 - 140^{\circ}\text{E}$)

Runoff

6/17

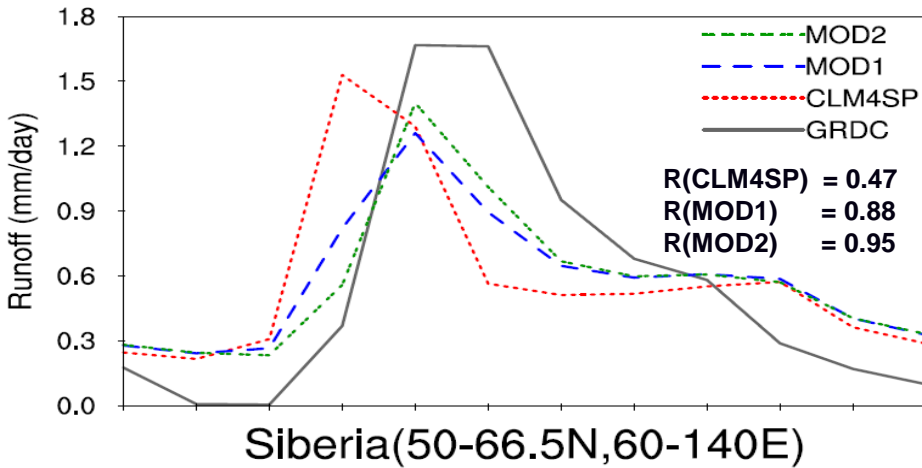


Climatological (1985–2004) monthly runoff in the six largest river basins in cold regions.

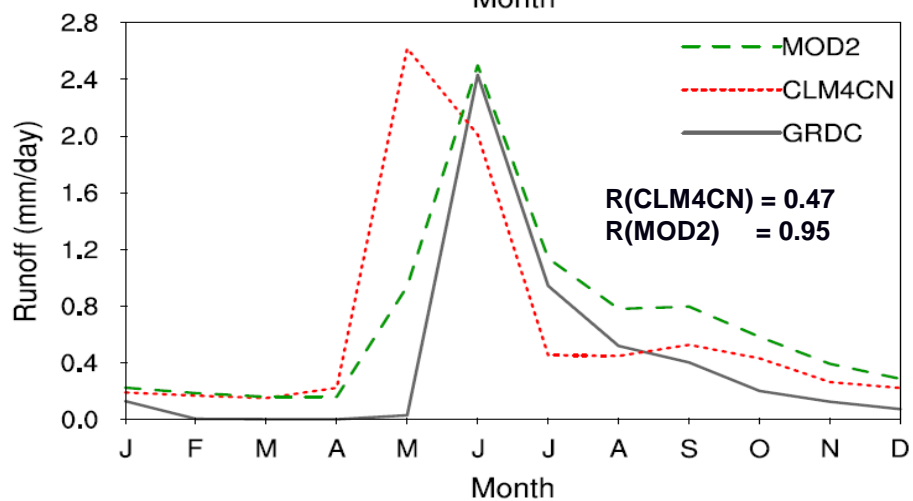
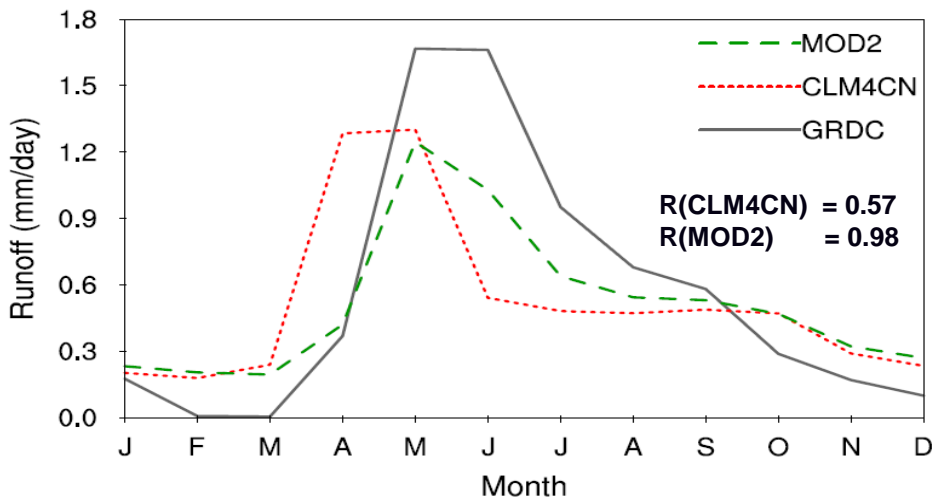
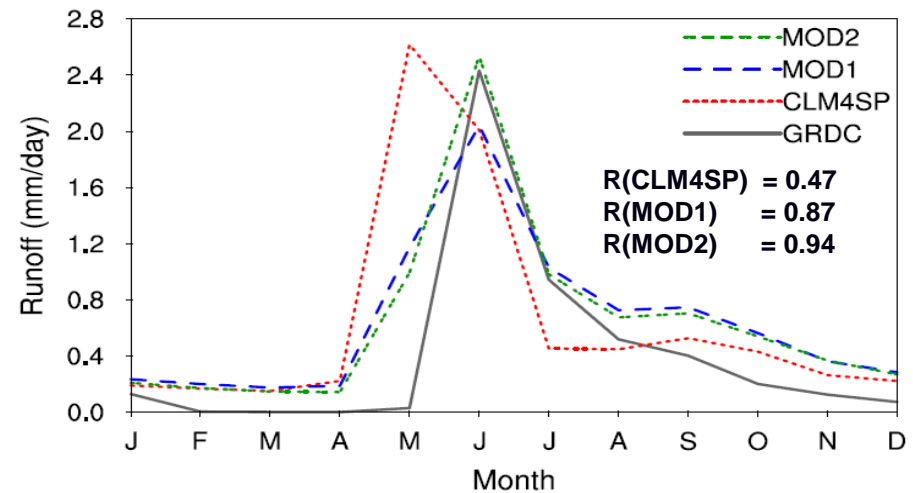
Runoff

7/17

Siberia(50-66.5N,60-140E)



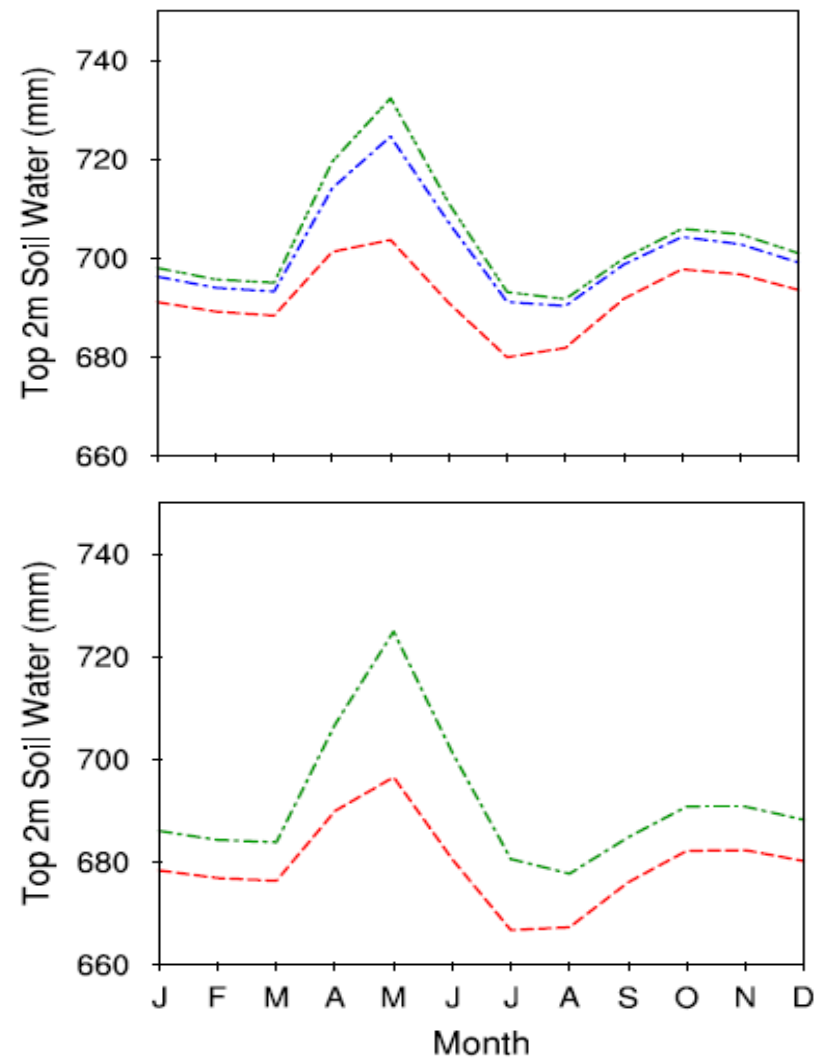
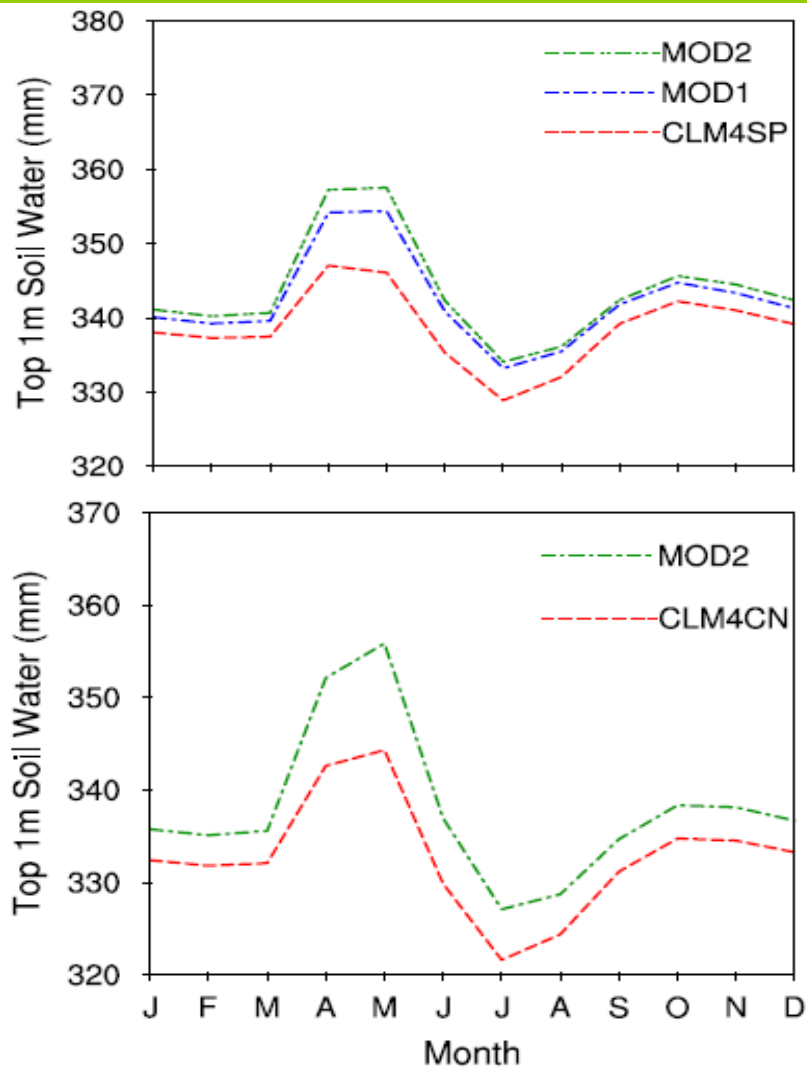
Further North of Siberia (66-74.5N,60-140E)



Climatological (1985–2004) monthly runoff in the Siberia region and in the 8° further north region.

Soil Moisture

8/17

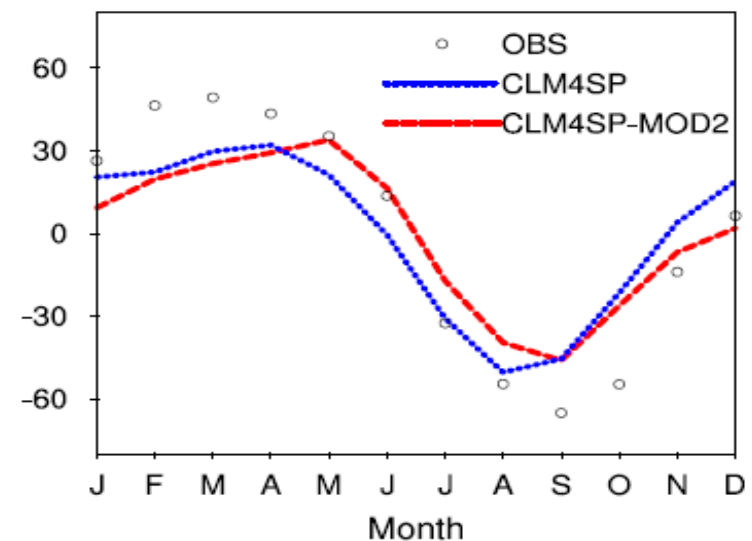
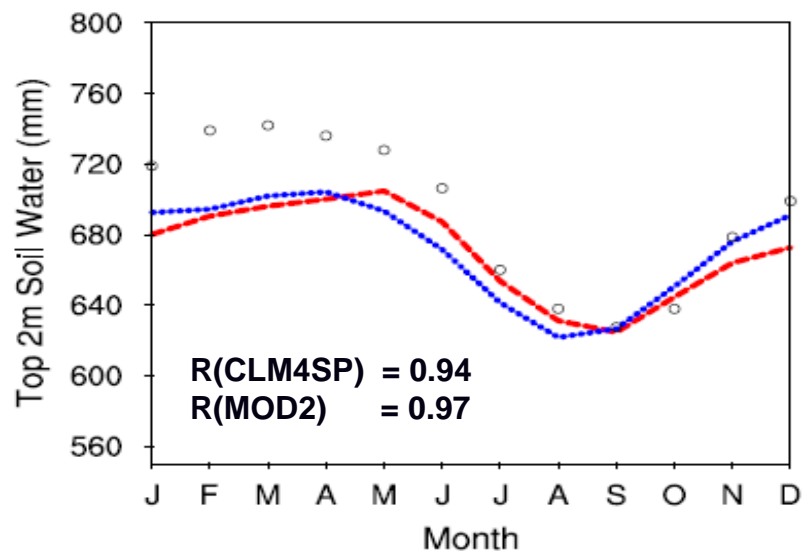
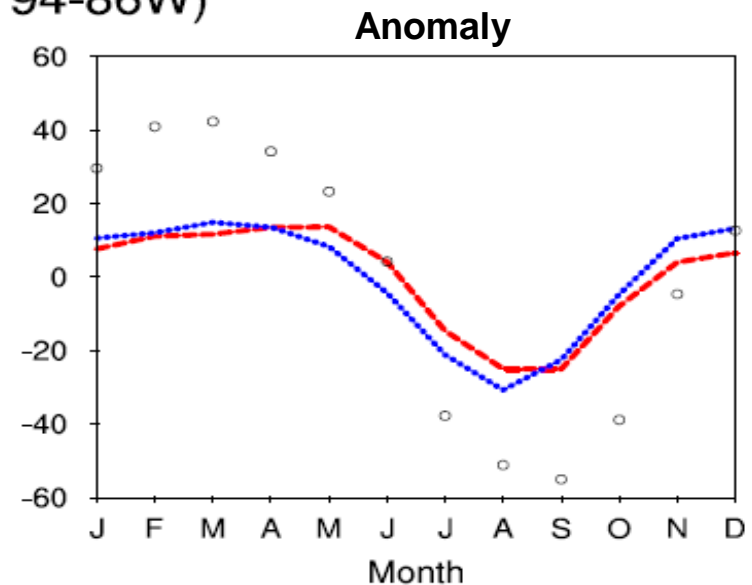
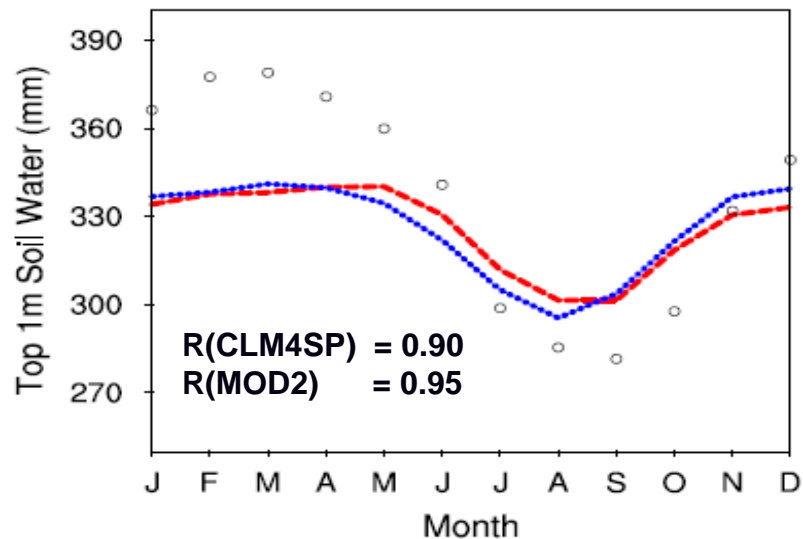


Climatological (1985–2004) monthly top 1m and top 2m soil water in the Siberia region.

Soil Moisture

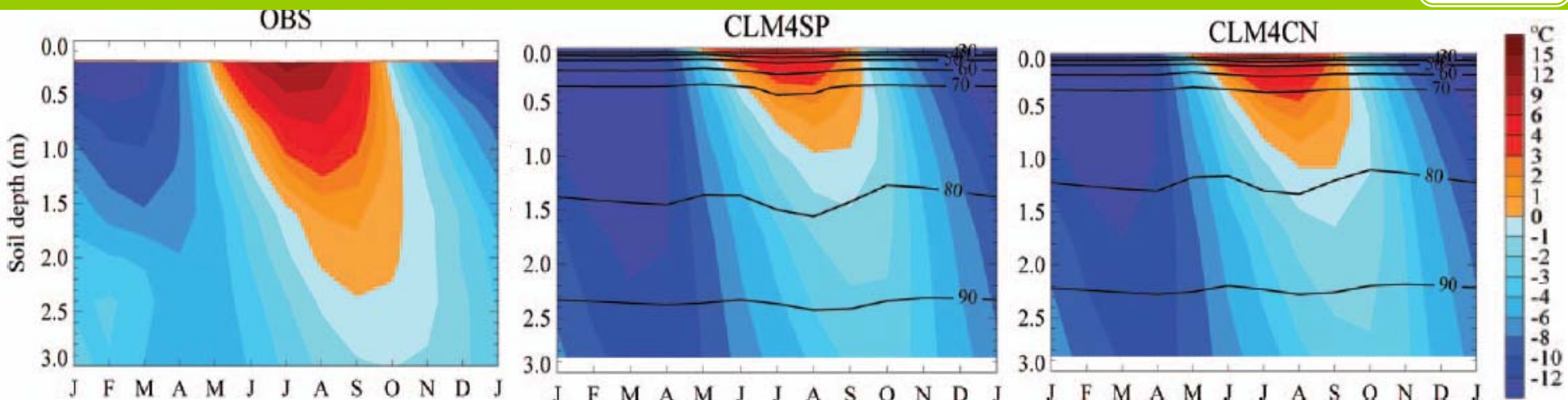
9/17

Illinois (37-44N, 94-86W)

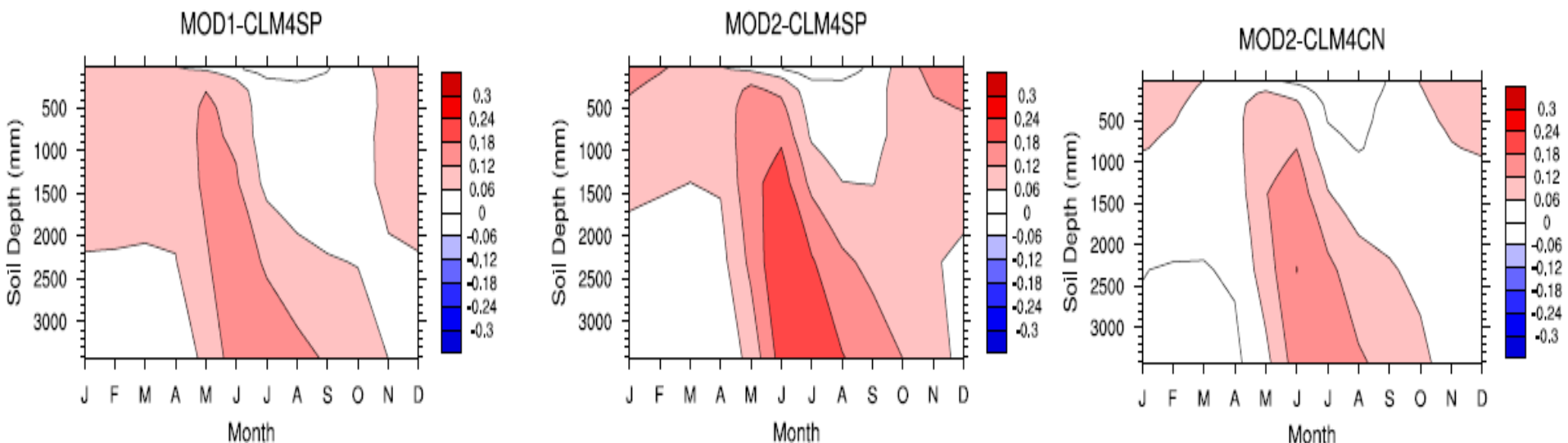


Soil Temperature

10/17



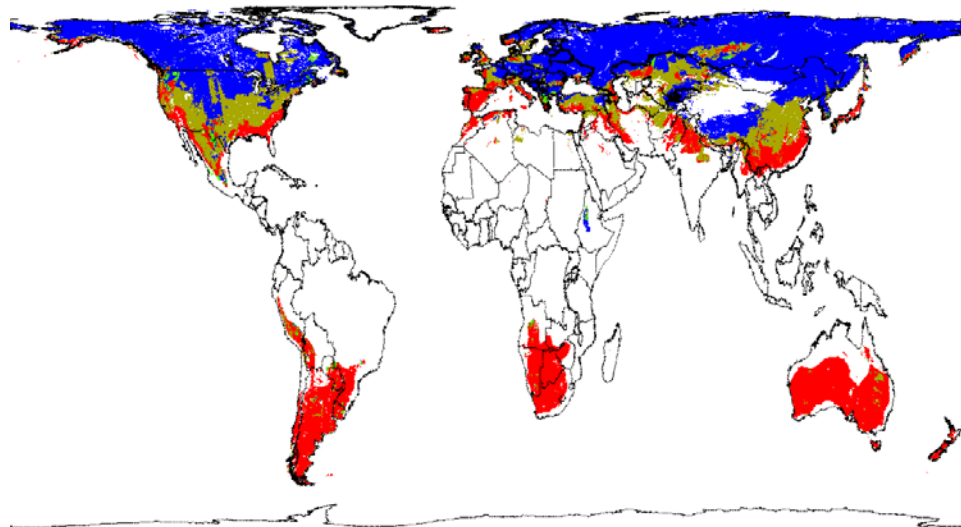
(Lawrence et al. 2011)



Climatological (1985–2000) annual cycle-depth plots of soil temperature in the Siberia region.

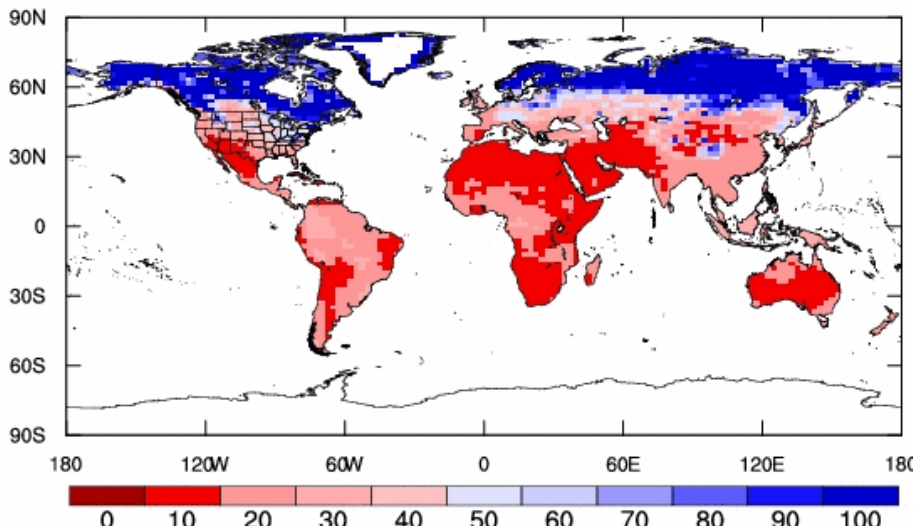
Landscape Freeze/Thaw State

Landscape Freeze/Thaw (FT) Status from Special Sensor Microwave Imager (SSM/I)



- Frozen
- Transitional
- Non-frozen
- Inv-transitional

CLM4 day 001 Fractional Impermeable Area (%)



Landscape Freeze/Thaw State

Day 001 (Jan 1st)

Day 081 (Mar 22nd)

Day 151 (May 31st)

- Frozen
- Non-frozen
- Transitional
- Inv-transitional

CTL

Fractional Impermeable Area

day 001

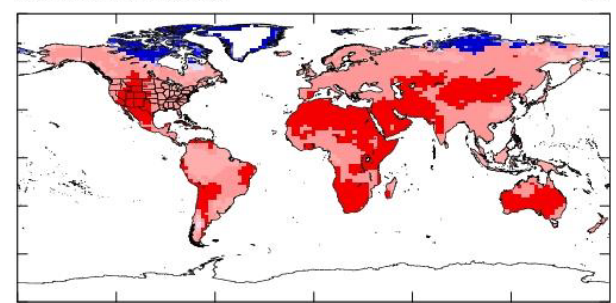
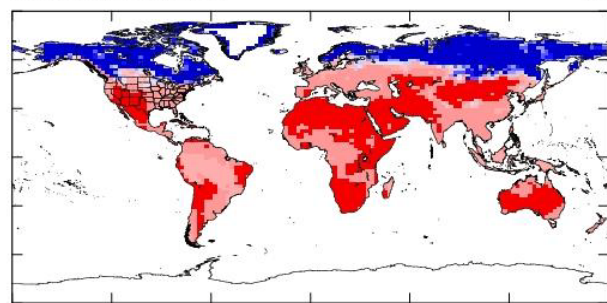
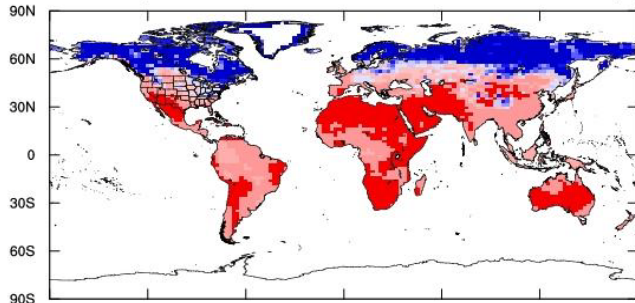
(%)

day 081

(%)

day 151

(%)



MOD2

Fractional Impermeable Area

day 001

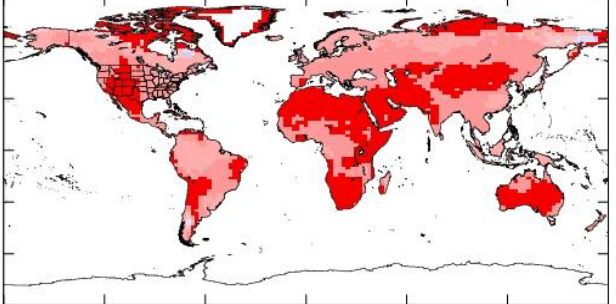
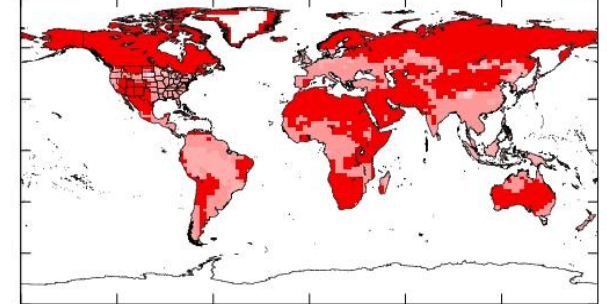
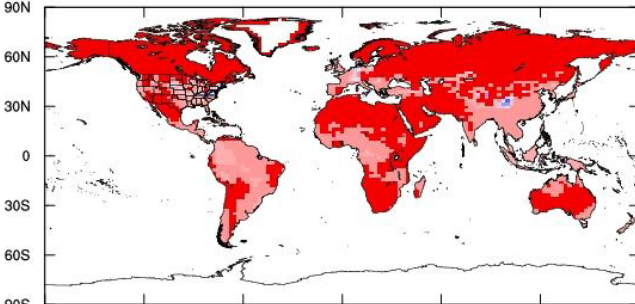
(%)

day 081

(%)

day 151

(%)



Experiment Design

13/17

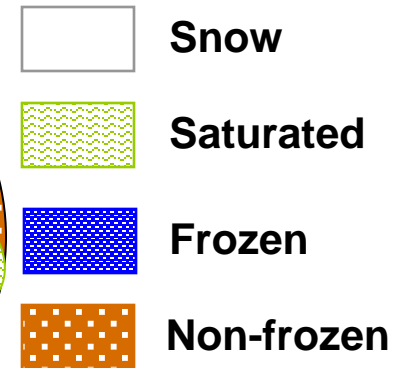
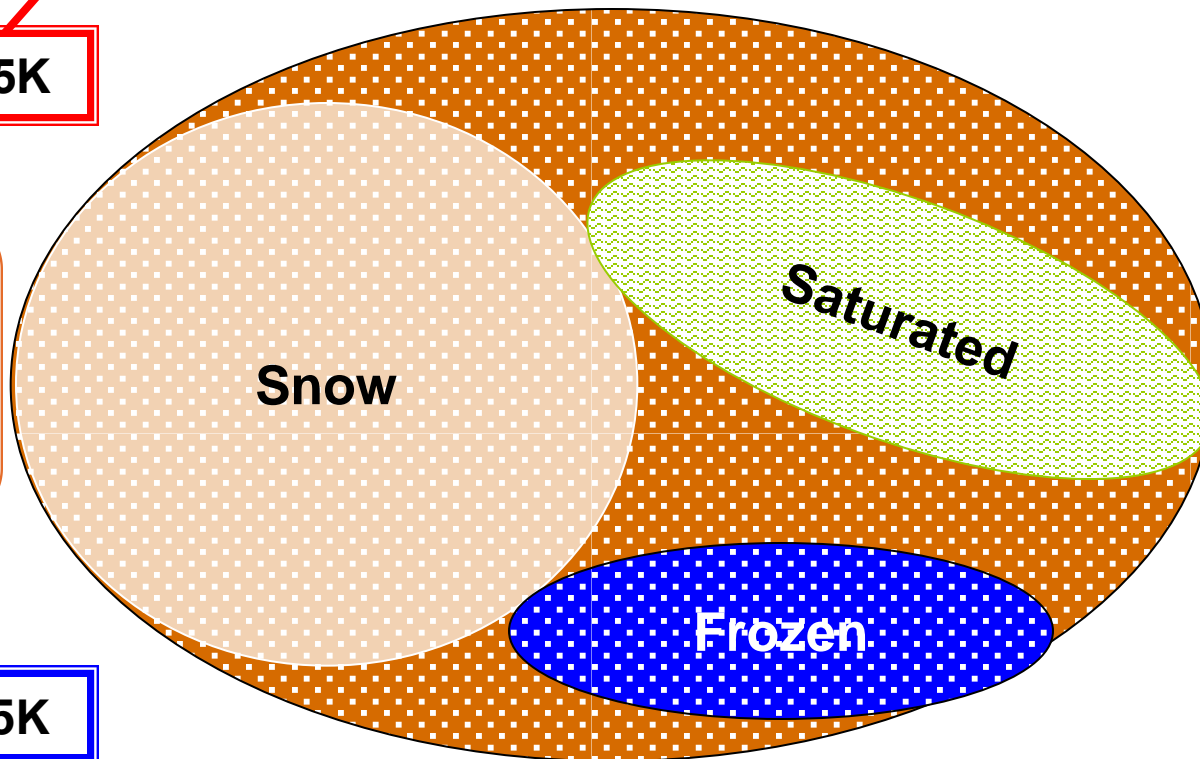
MOD2: Based on MOD1, but the saturated regions are snow free

$$\Rightarrow f_{sat} = f_{sat} \times (1 - f_{sno})$$

$\geq 273.15K$

MOD3:
Soil
temperature
in the first
soil layer

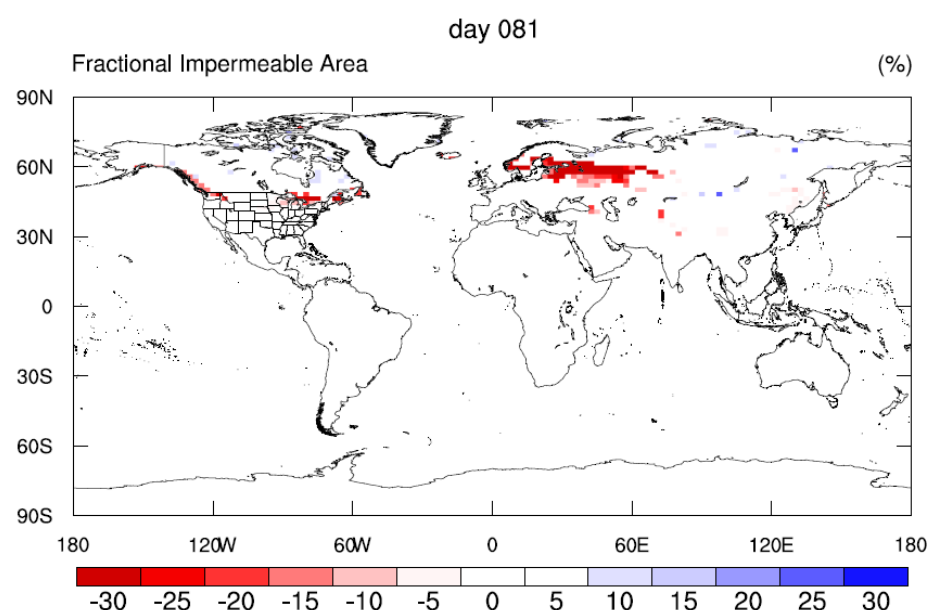
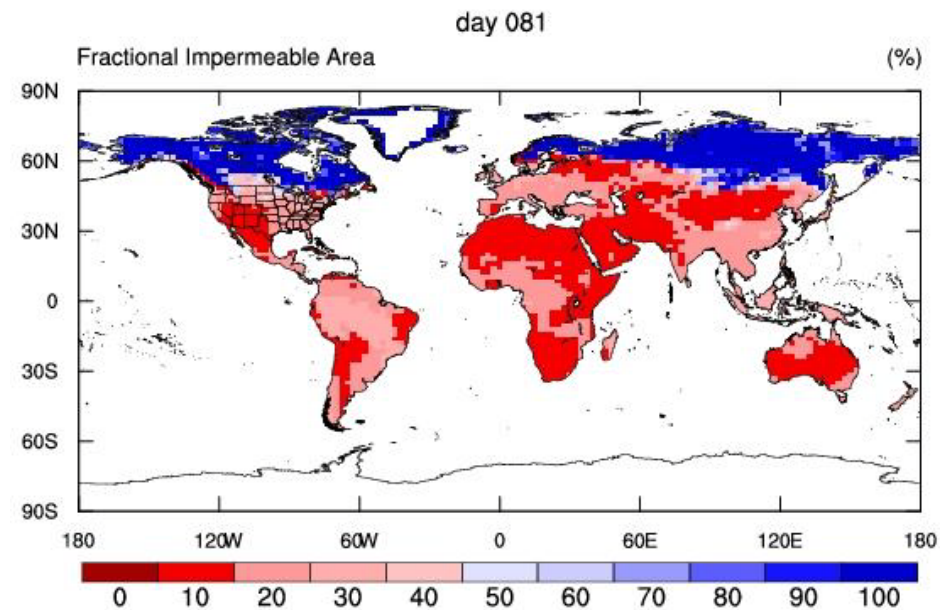
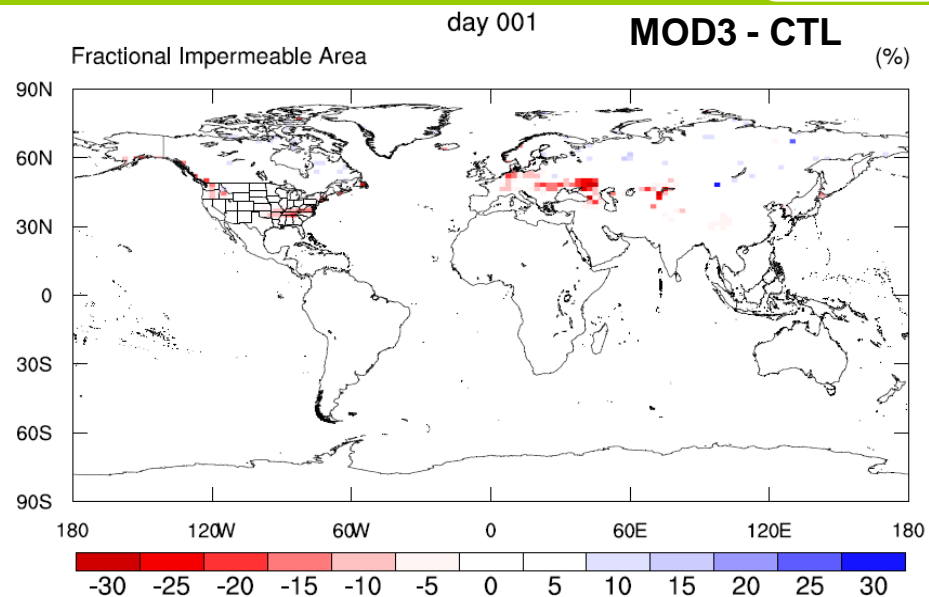
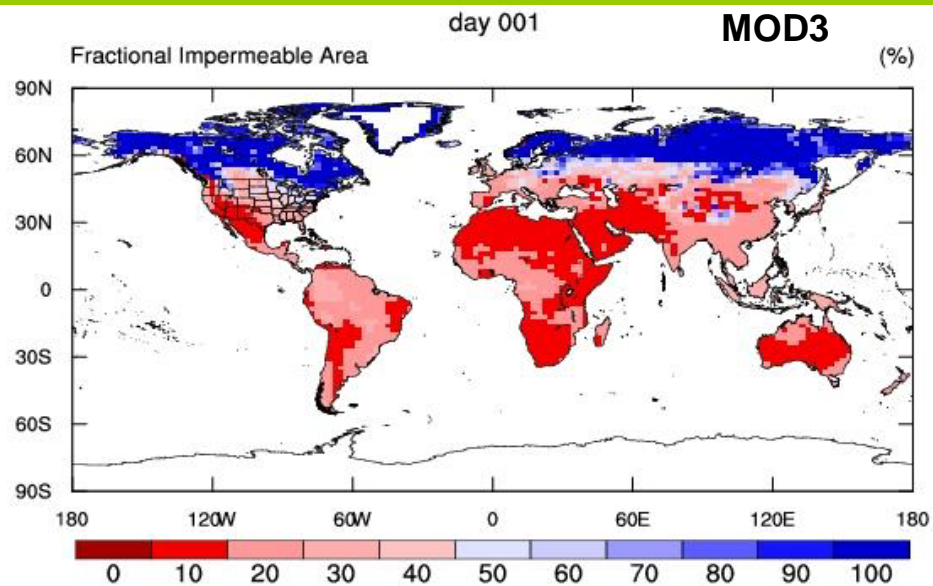
$< 273.15K$



$$f_{sat} = f_{sat} \times e^{\frac{1}{T(c,1)-273.15} \times (1-f_{sno})}$$

Landscape Freeze/Thaw State

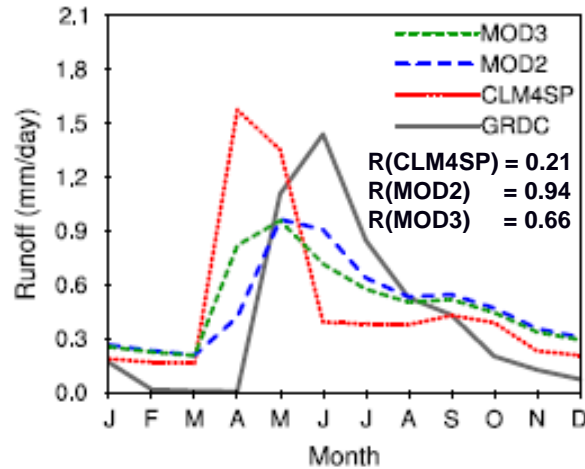
14/17



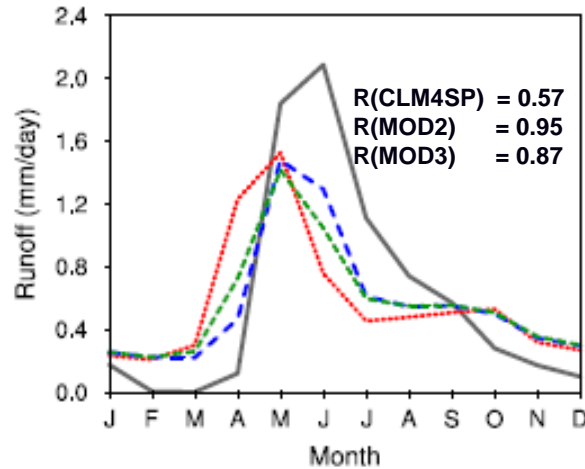
Runoff

15/17

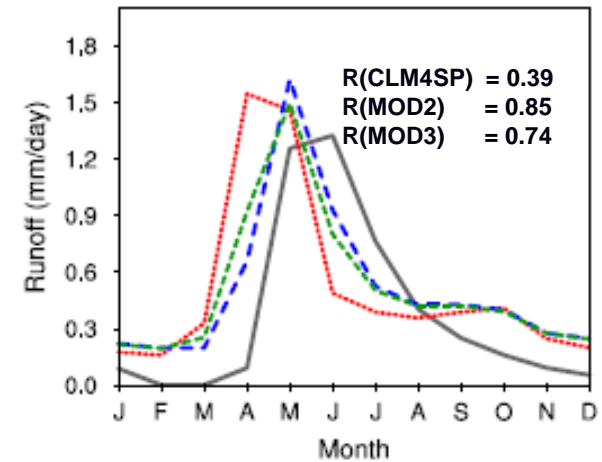
Lena



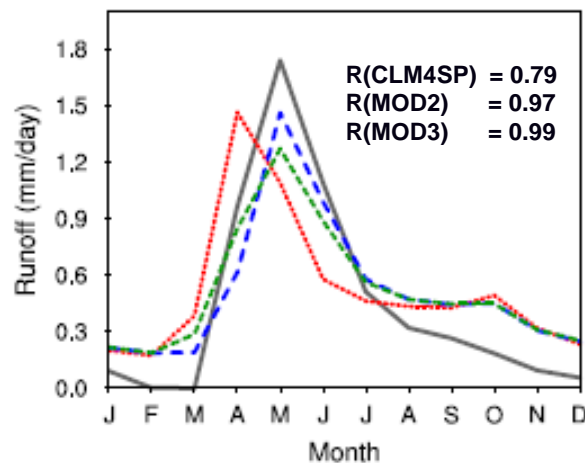
Yenisei



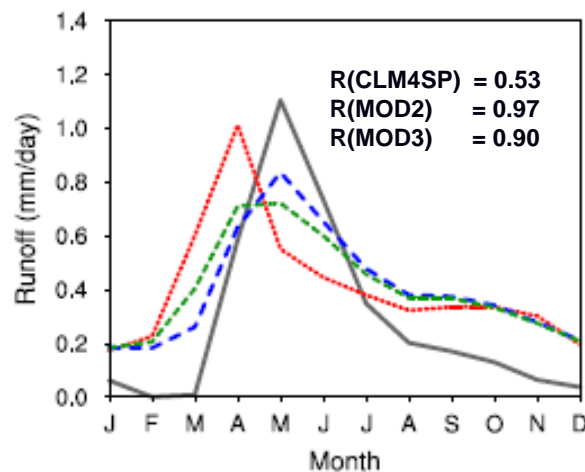
Mackenzie



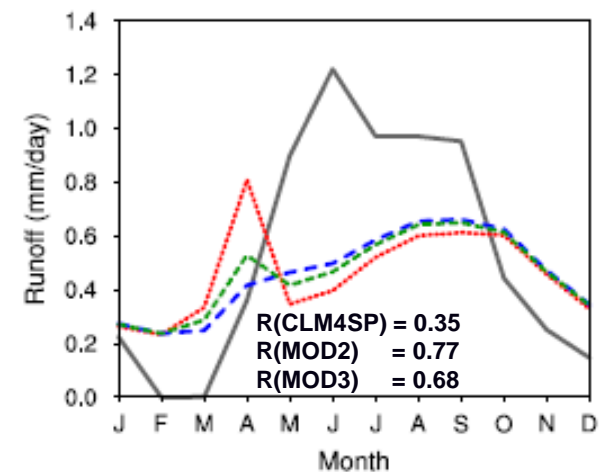
Ob



Churchill&Nelson



Amur



Climatological (1985–2004) monthly runoff in the six largest river basins in cold regions.

Conclusion

16/17

- Reducing or removing the impermeable area underneath the snowpack improves the timing of the spring runoff simulations.
- Soil moisture in Illinois was reasonably reproduced by MOD1 and MOD2.
- Both MOD1 and MOD2 result in favorable increases in deep soil temperature in the Siberia region, especially in late boreal springs and summers.
- MOD1, MOD2, and MOD3 show that the impermeable area and runoff are closely related in high-latitude regions.

- Validate the freeze/thaw state using SSM/I products.
- Validate soil moisture simulations with GRACE data.
- Evaluate how carbon dynamics will be influenced by soil moisture changes.
- Investigate how upward soil water fluxes from the groundwater driven by capillarity influence hydrological processes in high-latitude regions.

Thank you for your attention!
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liang@jsg.utexas.edu



<http://www.freefoto.com/preview/16-08-25/Snow-Scene>



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