NESL

High-latitude Hydrological Linkages between Surface Water, Frozen Soil, and Runoff in CLM4

Sean Swenson

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NCAR

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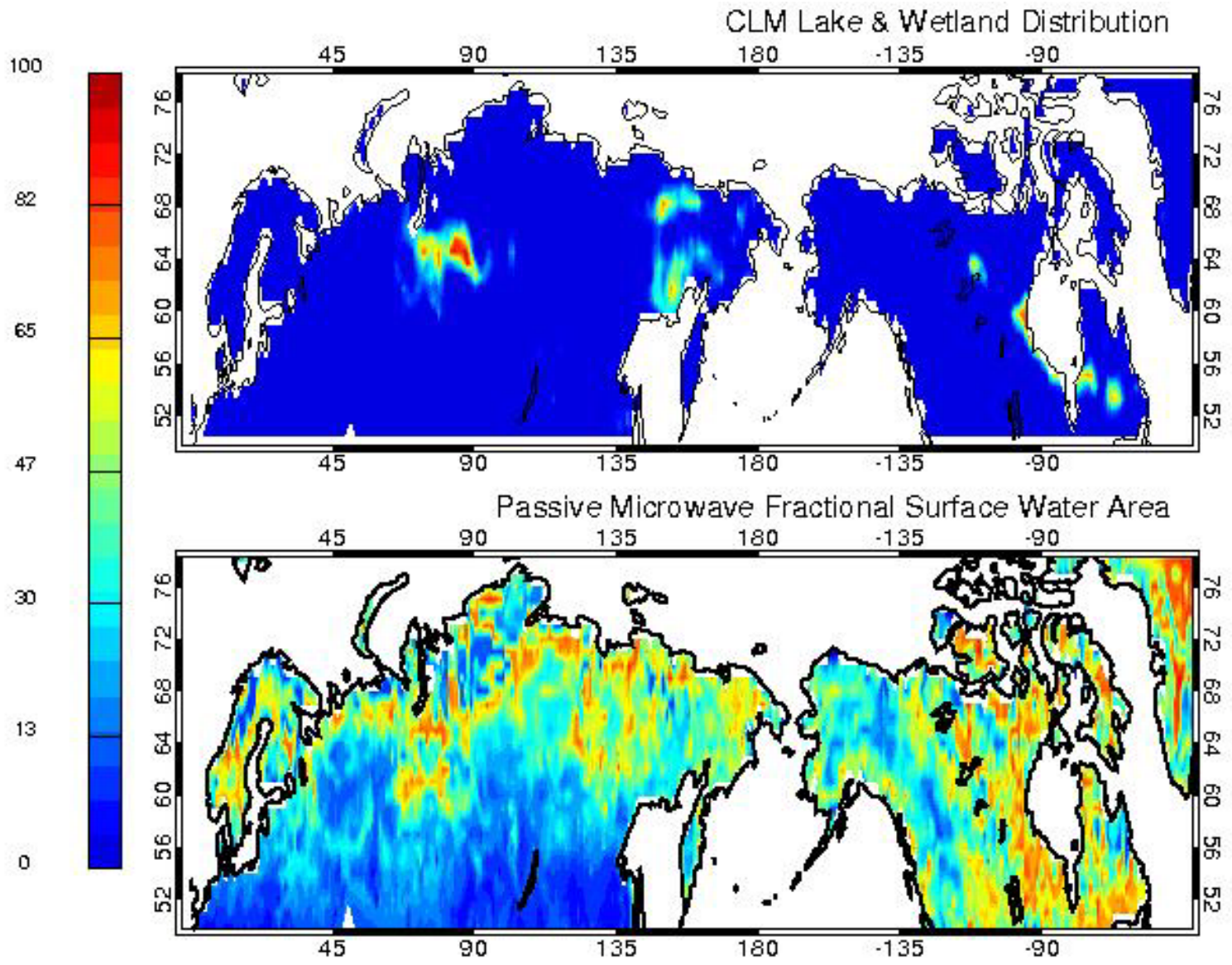
Role of Wetlands in the Control Model

- Occupy separate landunit

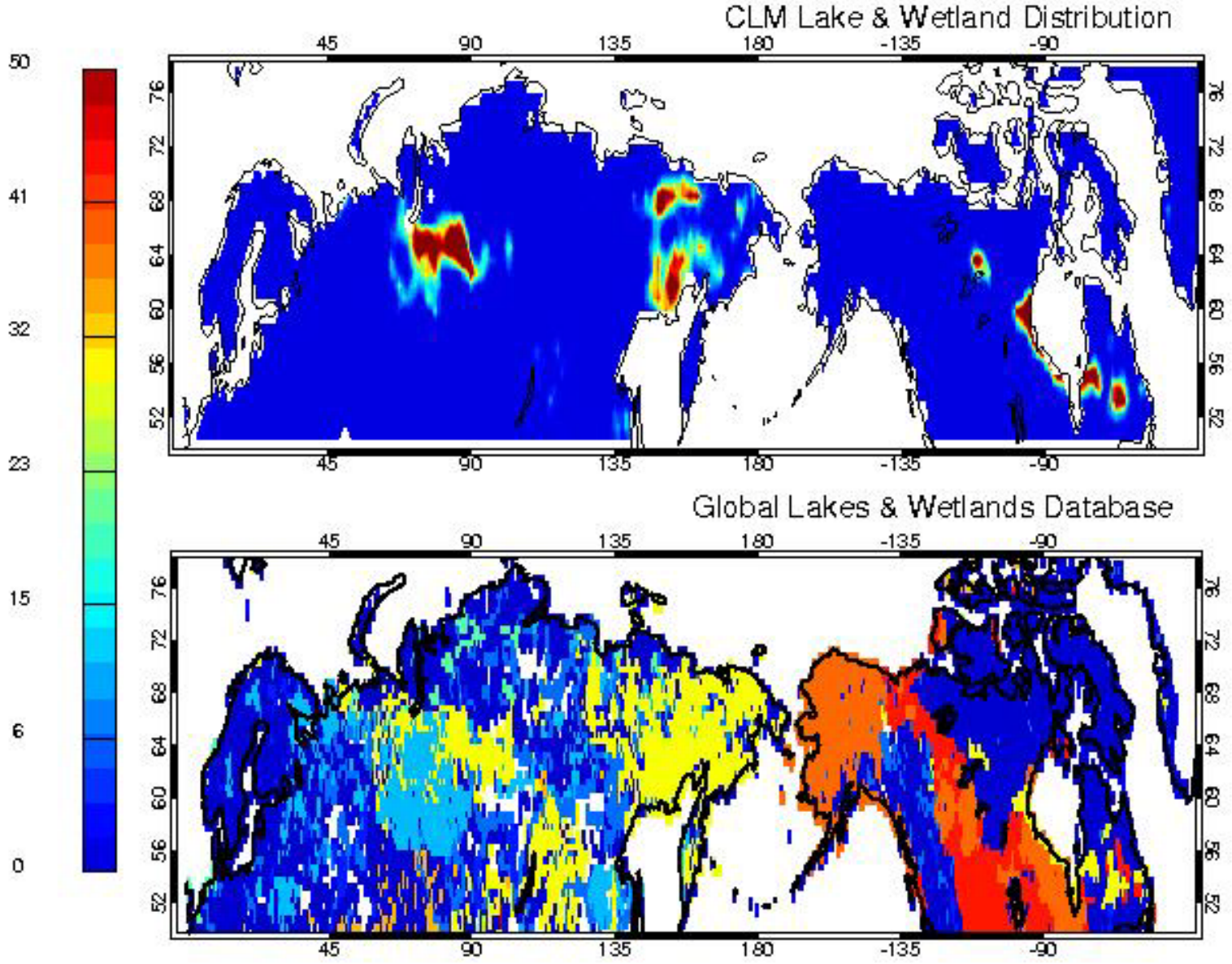
- Processes represented: albedo, sensible/latent heat flux from saturated surface, snow accumulation/ablation, runoff

- Processes not represented: vegetation dynamics, changes in water storage and area

Surface Water Distribution in Control Model Compared to Satellite Observations of FSW



Surface Water Distribution in Control Model Compared to Global Lakes & Wetlands Database



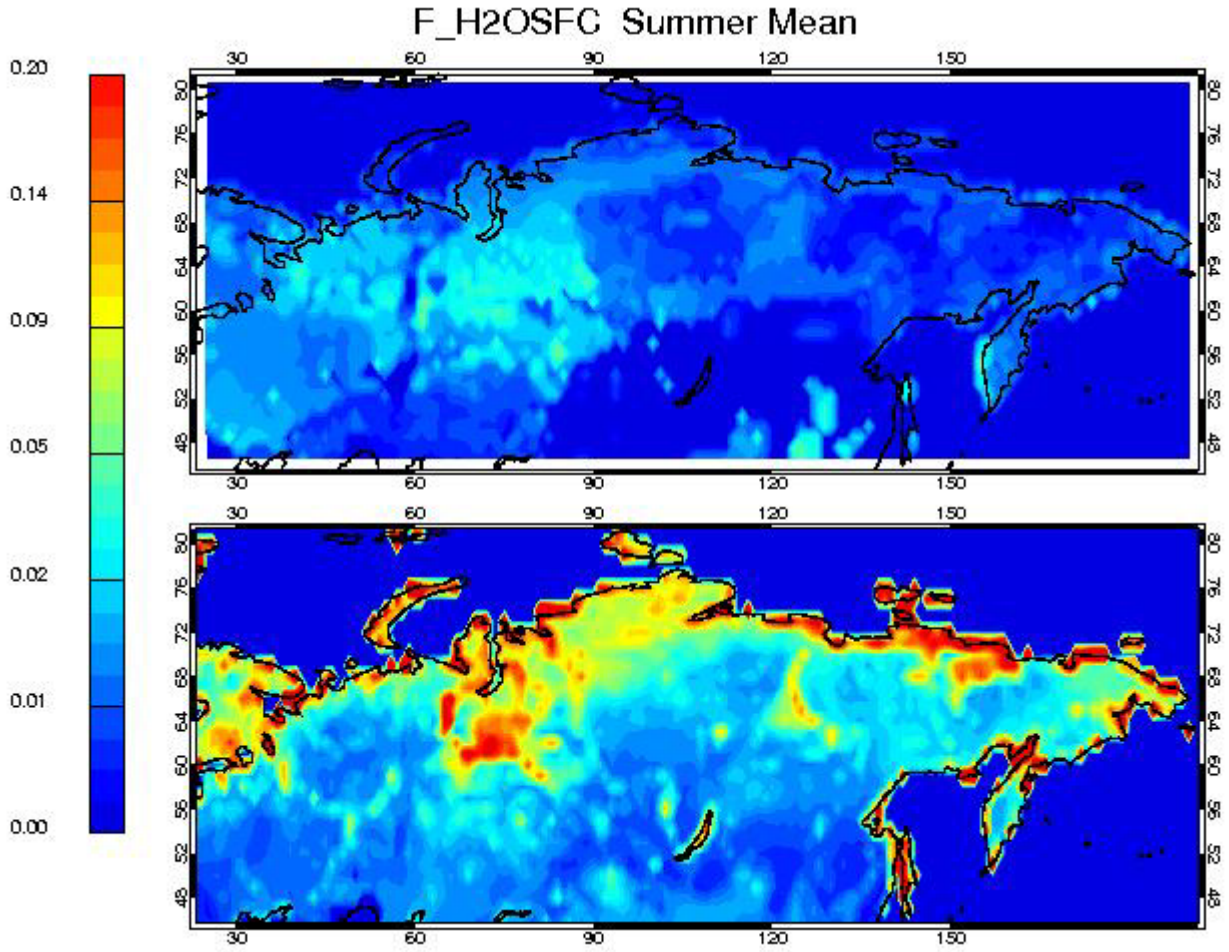
Adding a Prognostic Wetland (Surface Water) Component

- Integrated into vegetated landunit
- Include mass (water), energy (heat), and variations in areal extent
- Based on concept of microtopography (O[10cm] variations)
- Microtopography parameter evolves with thermal state to represent rapid (decadal scale) geomorphological changes

CLM4 with Prognostic Surface Water

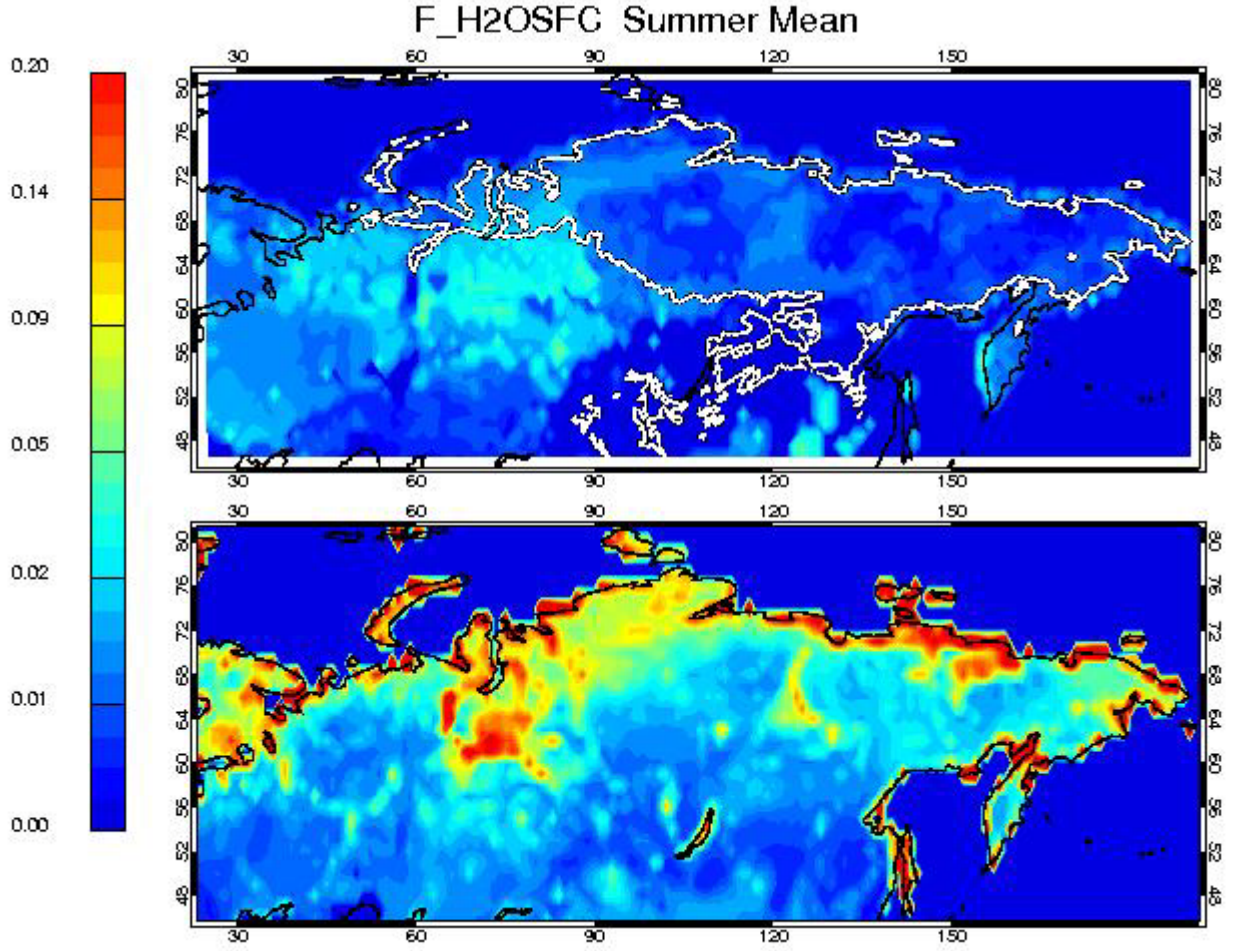
***Top Panel*: Modified CLM4**
***Bottom Panel*: Satellite Obs**

Modified model generates surface water storage in Western Siberia, but not in Eastern Siberia



CLM4 with Prognostic Surface Water

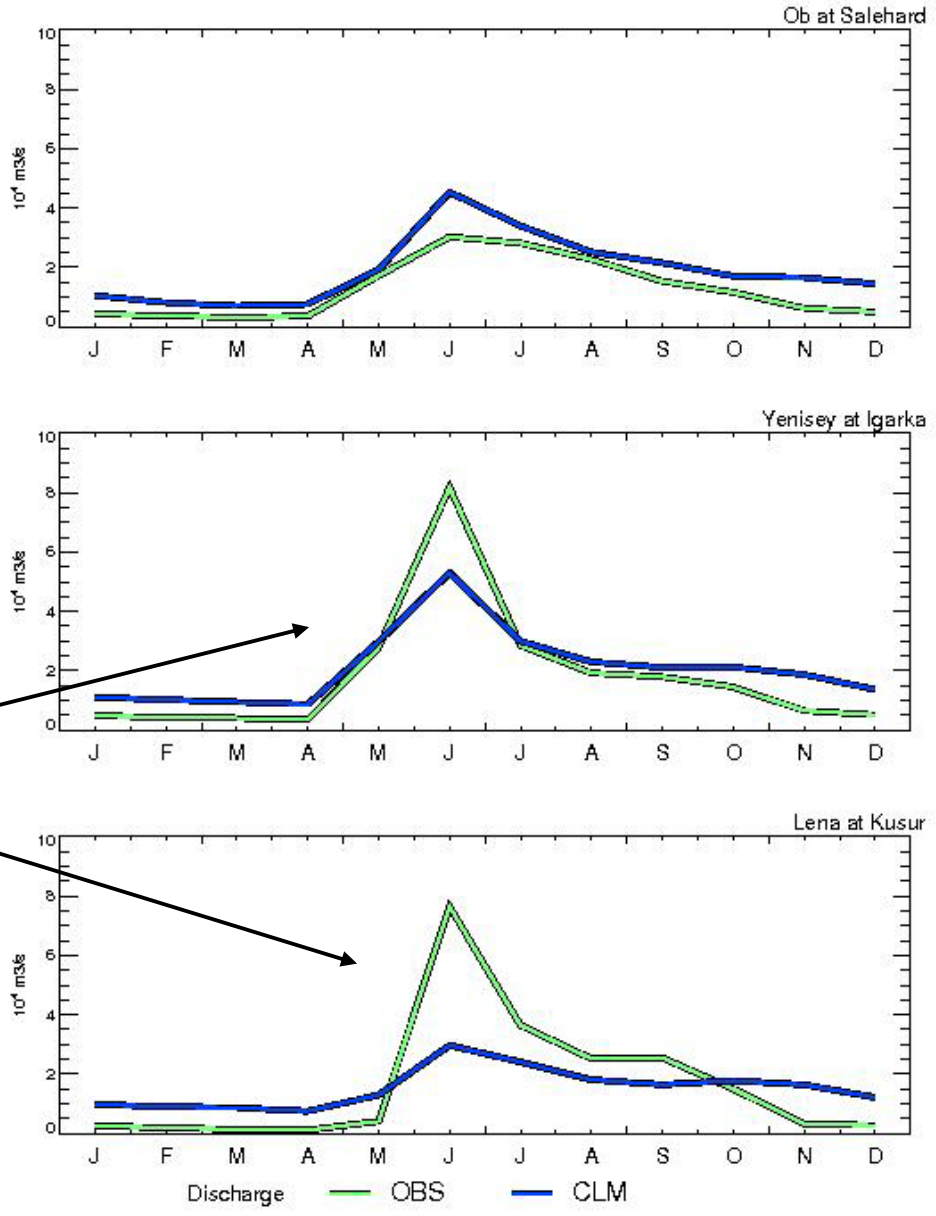
Is the spatial pattern related to the presence of permafrost?



Discharge Bias in Permafrost Regions

Model simulates well the Ob River, which has limited permafrost, but simulates poorly the Yenisey and Lena Rivers, which are largely underlain by permafrost

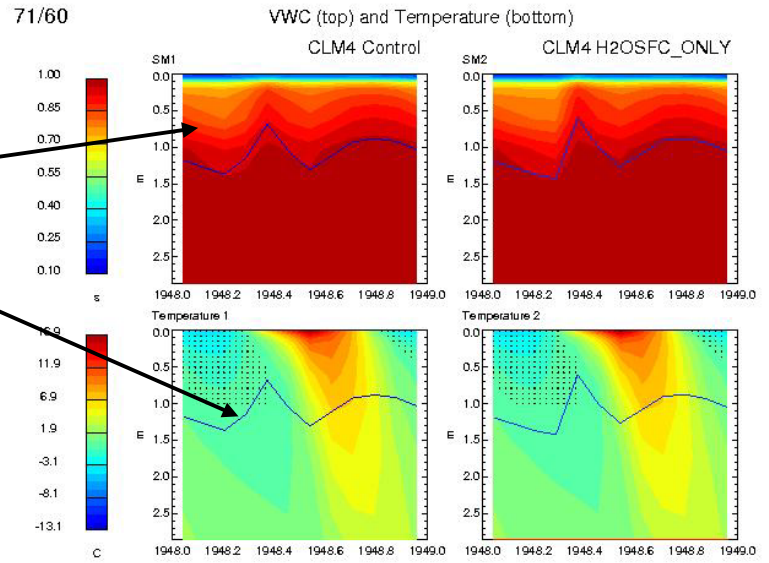
Regions of high permafrost occurrence exhibit “flashier” hydrographs



Soil Moisture Bias in Permafrost Regions

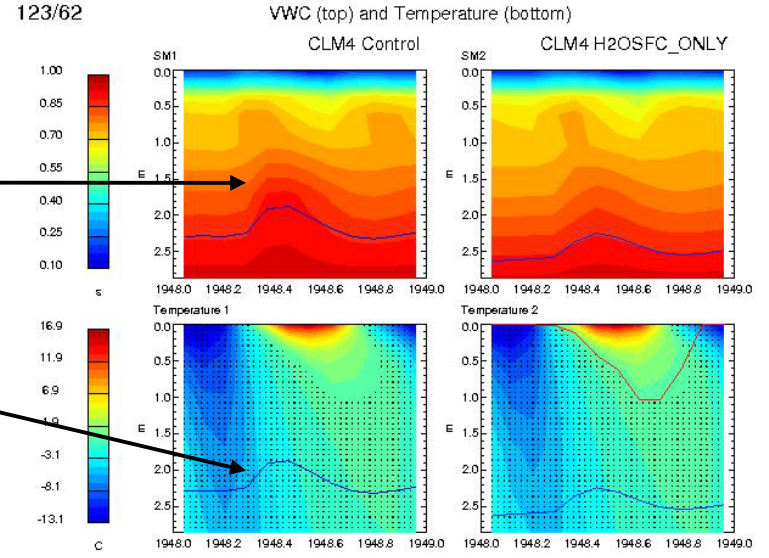
Non-Permafrost Location:

- **High soil moisture due to shallow water table**
- **Degree of saturation increases when melt begins**



Permafrost Location:

- **Near-surface is relatively dry, wetter conditions supported by groundwater**
- **Water table varies despite frozen soil**



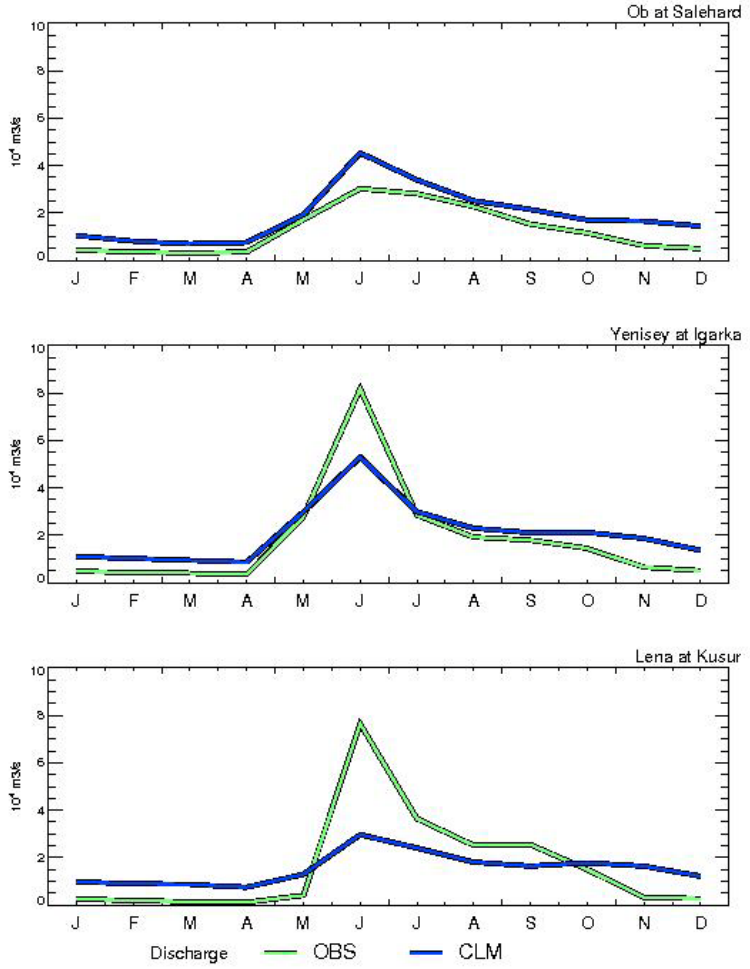
Reducing Permeability of Frozen Soil

- Use ice impermeability formulation of Lundin [1990]
- Represents increase in tortuosity of pore space due to presence of ice
- Provides a solution to **both** problems:
    - discharge increases during melt season
    - near-surface soil moisture increases due to reduced drainage

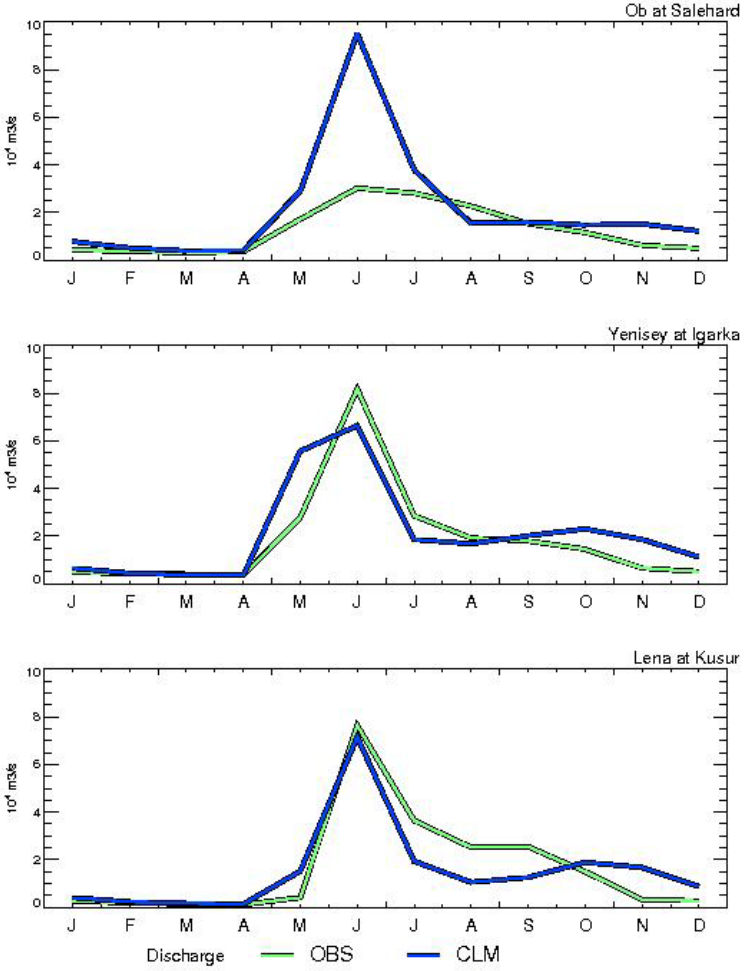
River Discharge in Modified CLM4

Results are mixed: better hydrographs for permafrost basins, but degraded simulation in non-permafrost basin

Control



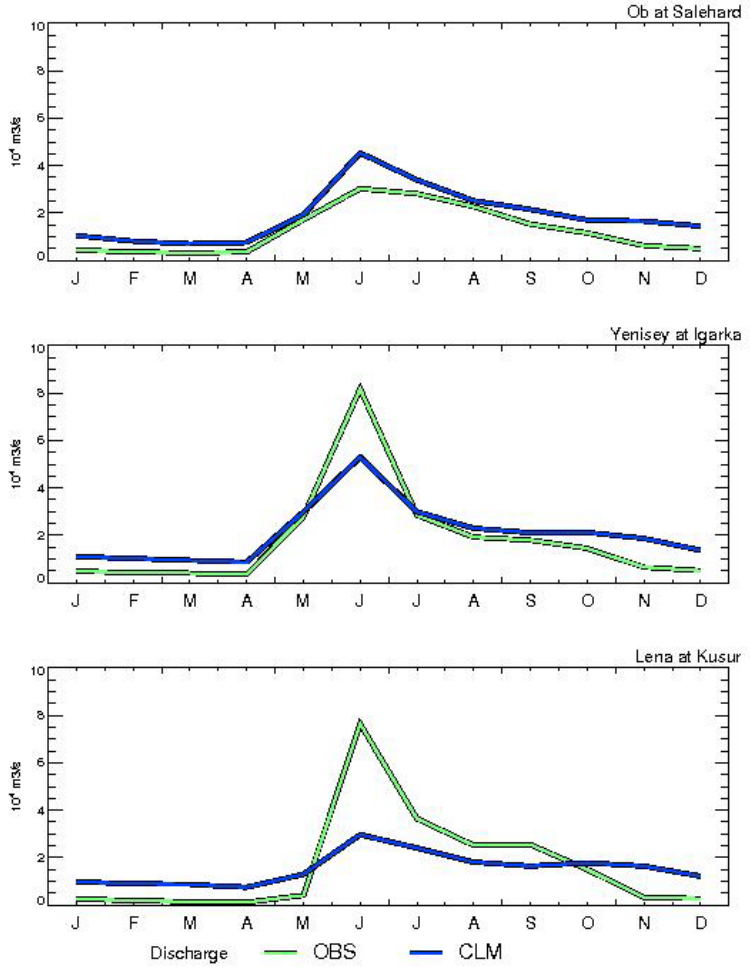
Ice Impedance



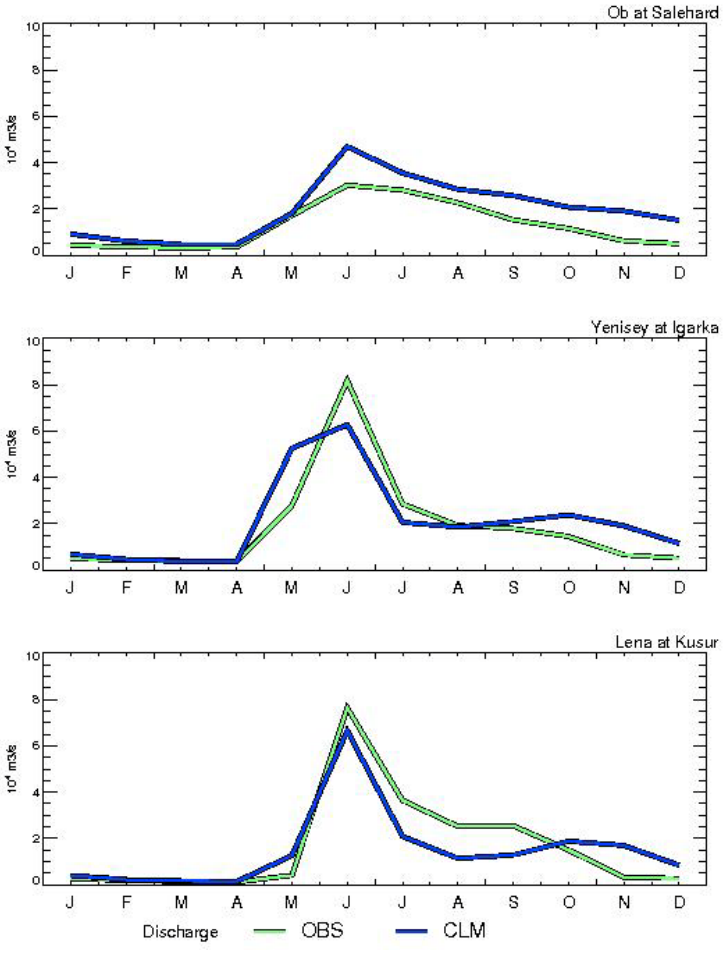
River Discharge (Impedance + Surface Water)

Results: better hydrographs for both permafrost basins and non-permafrost basins

Control



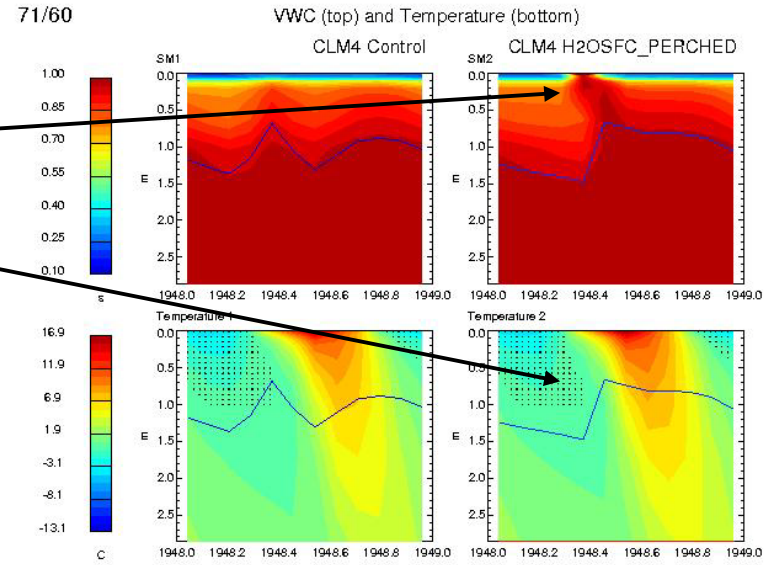
Surface Water + Impedance



Soil Moisture Improvements in Permafrost Regions

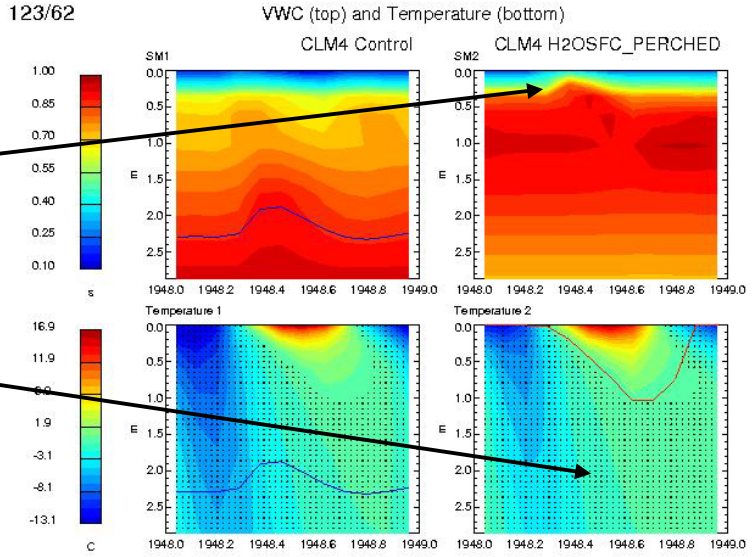
Non-Permafrost Location:

- **Active layer saturated in early summer**
- **Saturation increase delayed until soil thaws**



Permafrost Location:

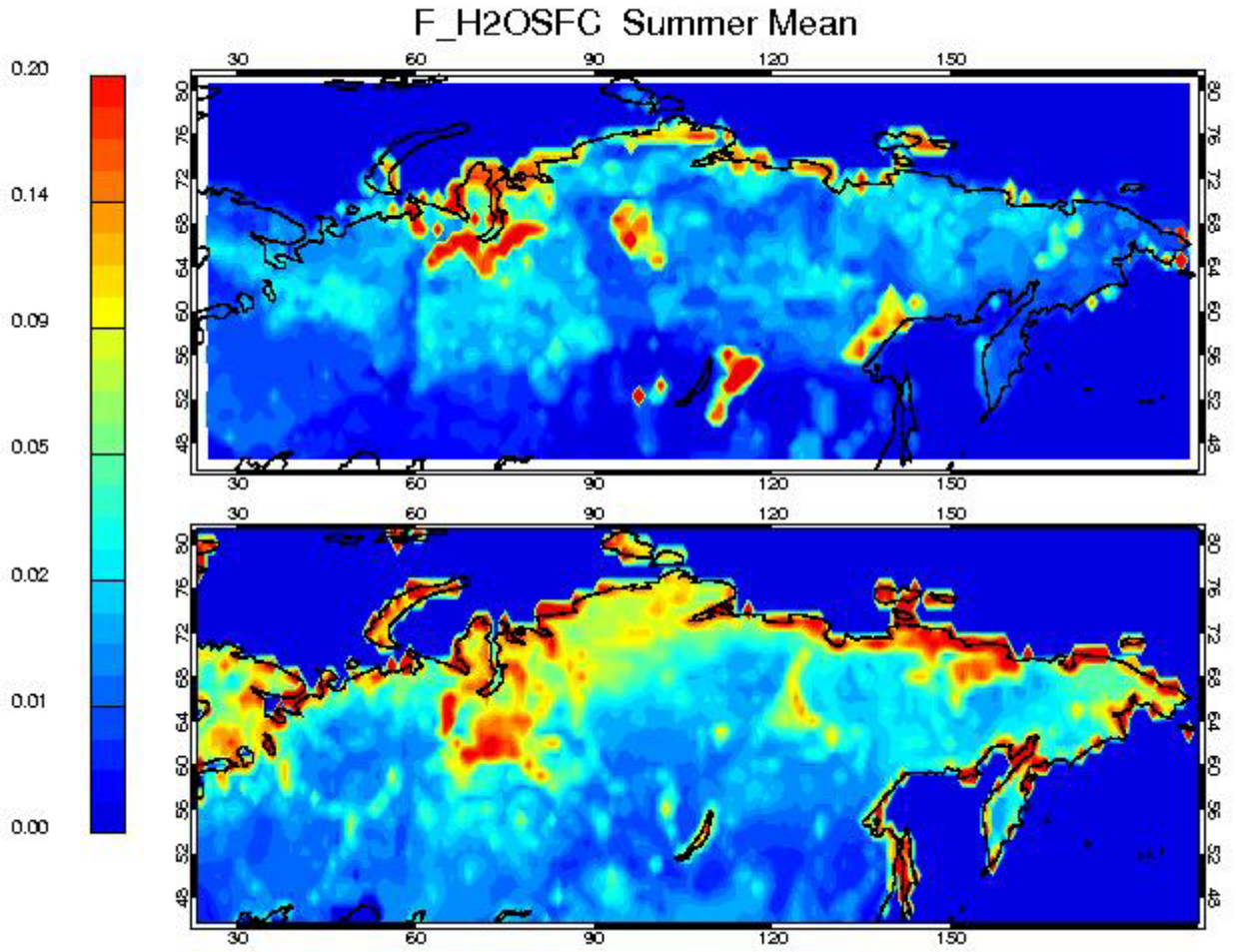
- **Near-surface is relatively wet, conditions supported by ice content below active layers**
- **Water table not present in frozen soil**



Surface Water Distribution w/ Ice Impedance

Top Panel: Modified CLM4
Bottom Panel: Satellite Obs

More surface water storage across Eurasia



Summary

• Correct simulation of Arctic hydrology depends on linkages between thermal and hydrologic states

• Biases in discharge and soil moisture in high-latitude regions exist in CLM4

• Changes to both ice impedance and surface water storage are required to correct these biases

• Modified model agrees better with multiple observations: river discharge, soil moisture, and surface water fractional area

Current/Future Work

- Sensitivity studies on impedance and microtopography parameters
- Offline simulations to assess ability to reproduce observations
- Coupled simulations to examine climate impact
- Development of thermokarst evolution parameterization to look at future changes in wetland distribution