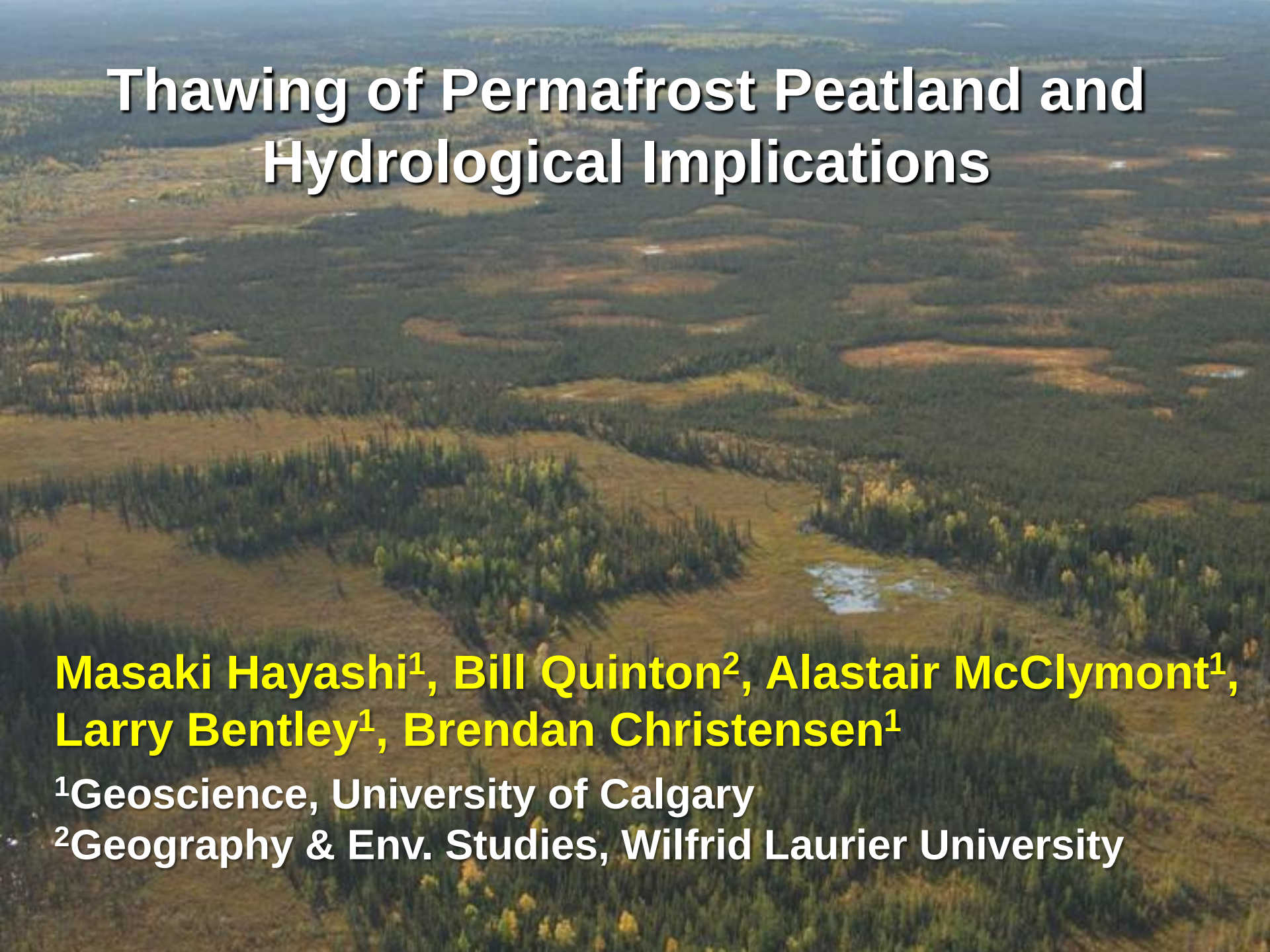
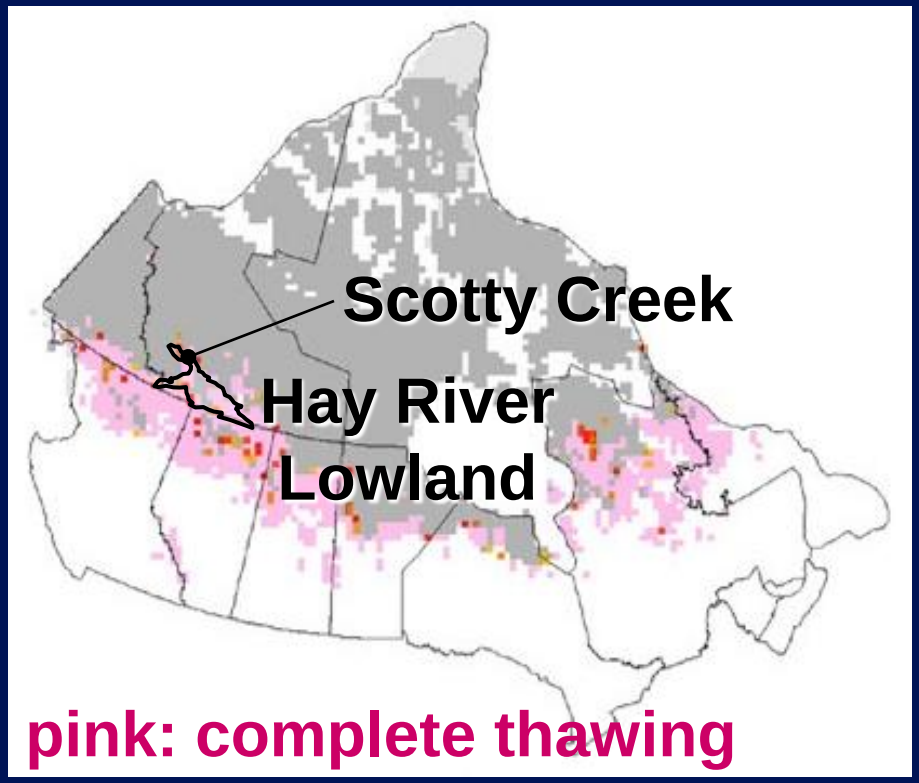
Thawing of Permafrost Peatland and Hydrological Implications



Masaki Hayashi[1], Bill Quinton[2], Alastair McClymont[1], Larry Bentley[1], Brendan Christensen[1]

[1]Geoscience, University of Calgary
[2]Geography & Env. Studies, Wilfrid Laurier University

Prediction of Permafrost Thaw, 1990-2090

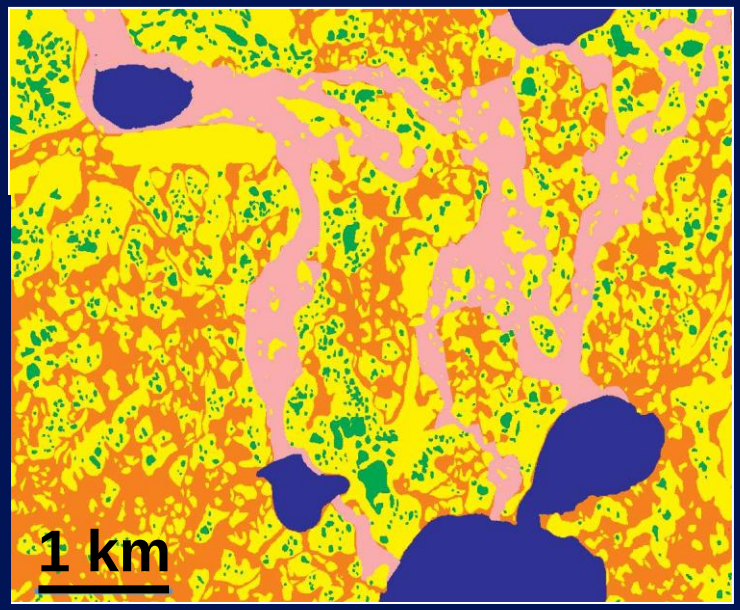


- lake
- peat plateau
- isolated bog
- connected bog
- channel fen

Model Assumptions

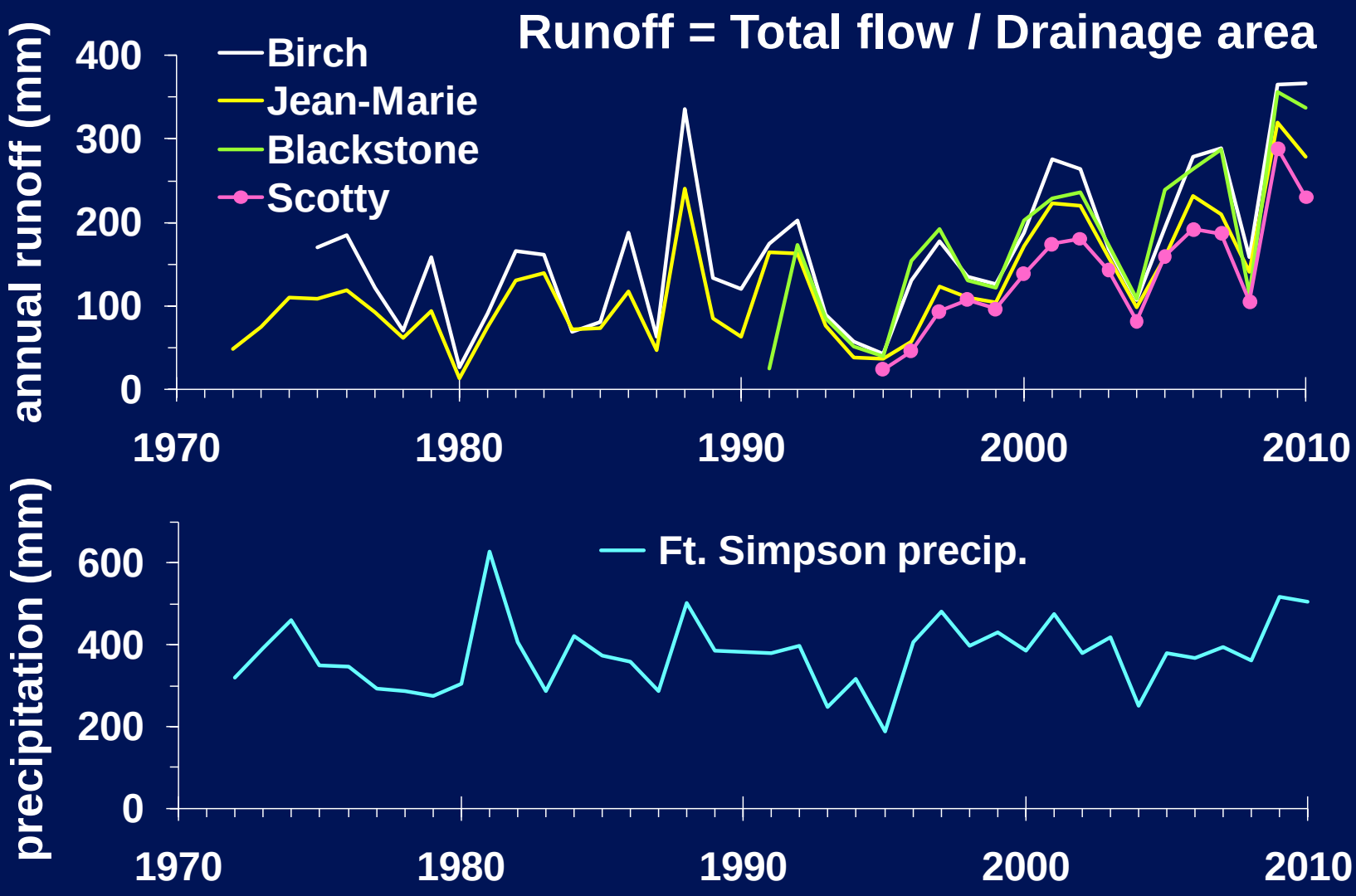
- Vertical energy transfer
- Large (~50 km) grids
- No lateral flow of water and energy

Reality (Scotty Creek)



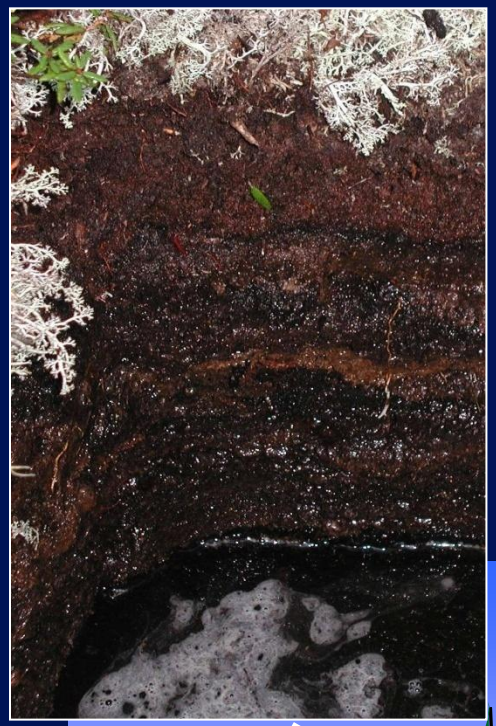
Annual Total Basin Runoff near Ft. Simpson

Four Rivers (150-1,900 km^2), Similar Landcovers

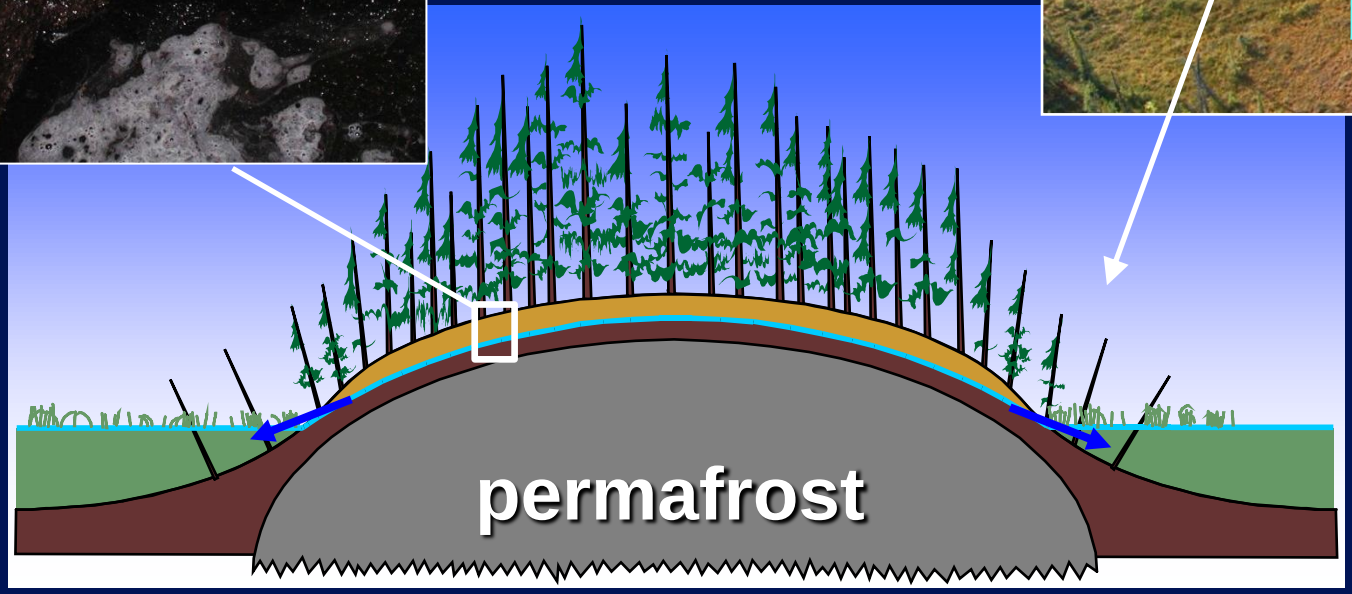



flat bog
peat plateau
channel fen

Peat Plateaus Have Permafrost Cores

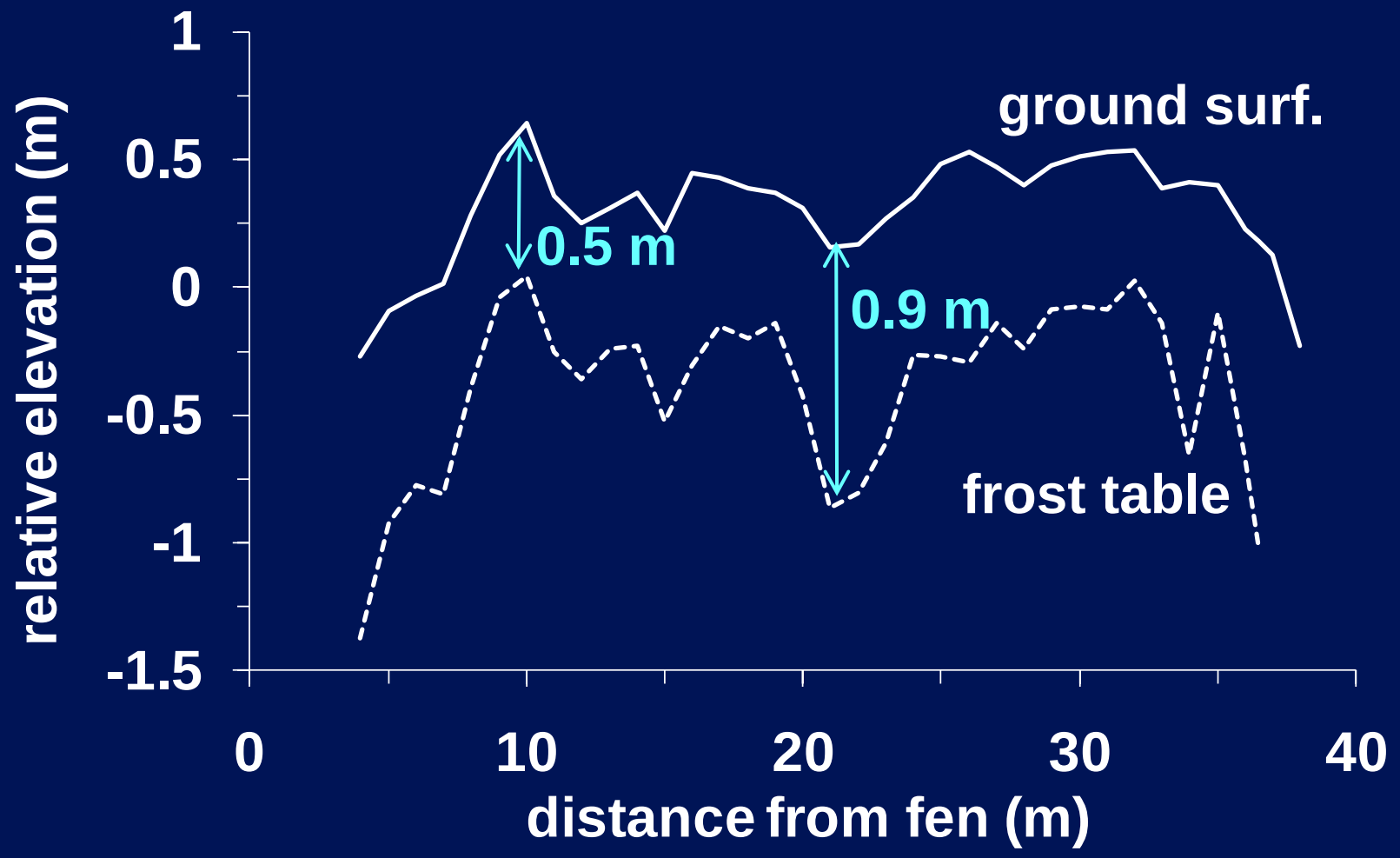


Water flows over frozen peat.

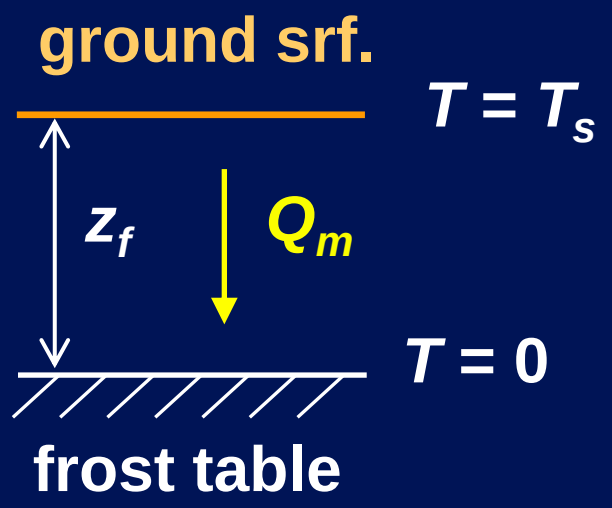


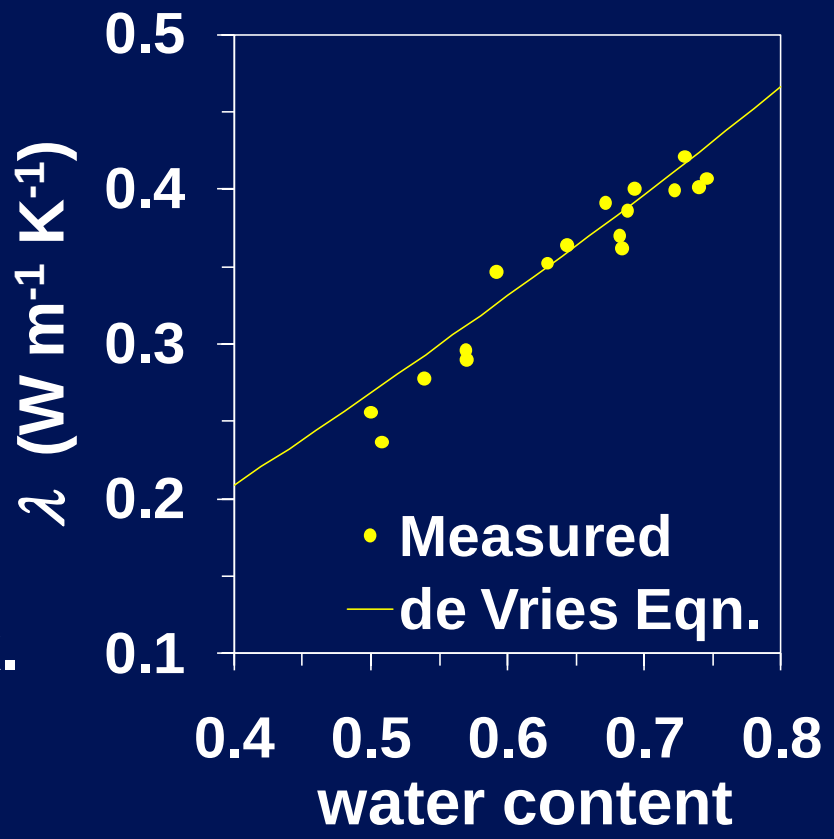
Frost Table in Late August 2006

GS: ground surface **FT: frost table**



Differential Thawing by Conduction





Conduction dominates heat flux.

$Q_m = \lambda_b (T_s - 0) / z_f$

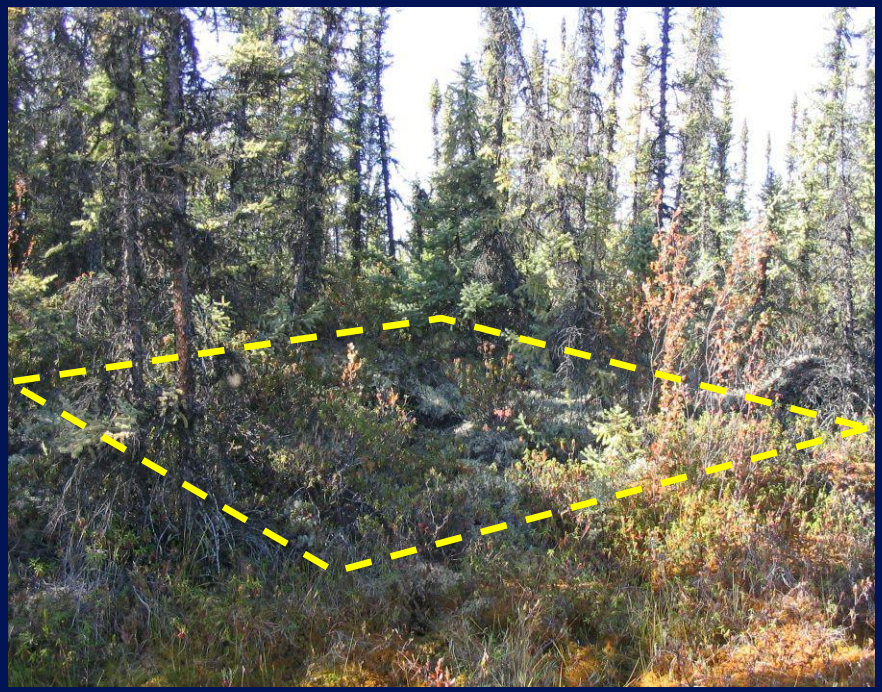
λ_b : bulk thermal conductivity

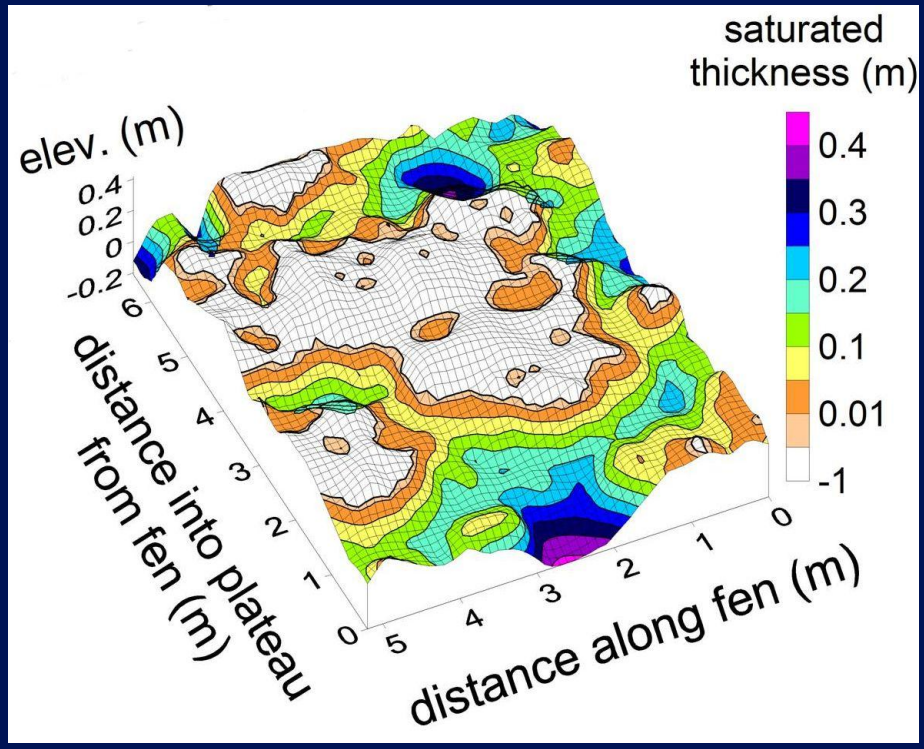
Wet spots thaw faster.

Hayashi *et al*. (2007, *Hydrol*. *Proces*. 21: 2610-2622)

2D Survey of Frost Table (FT)

June 12, 2006

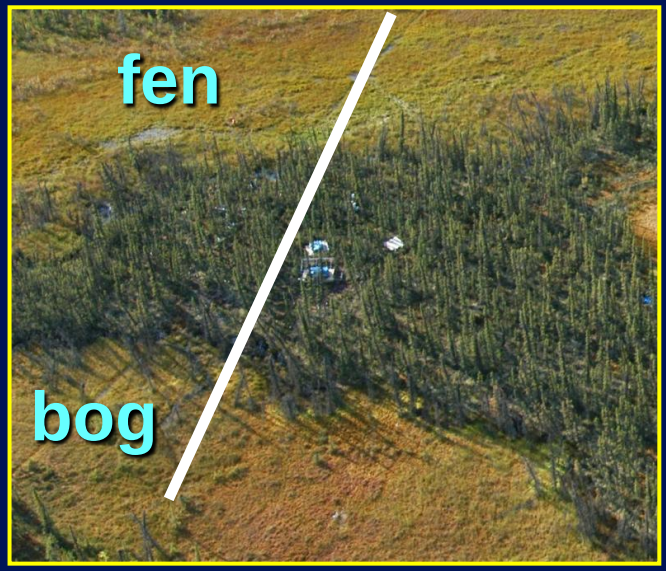


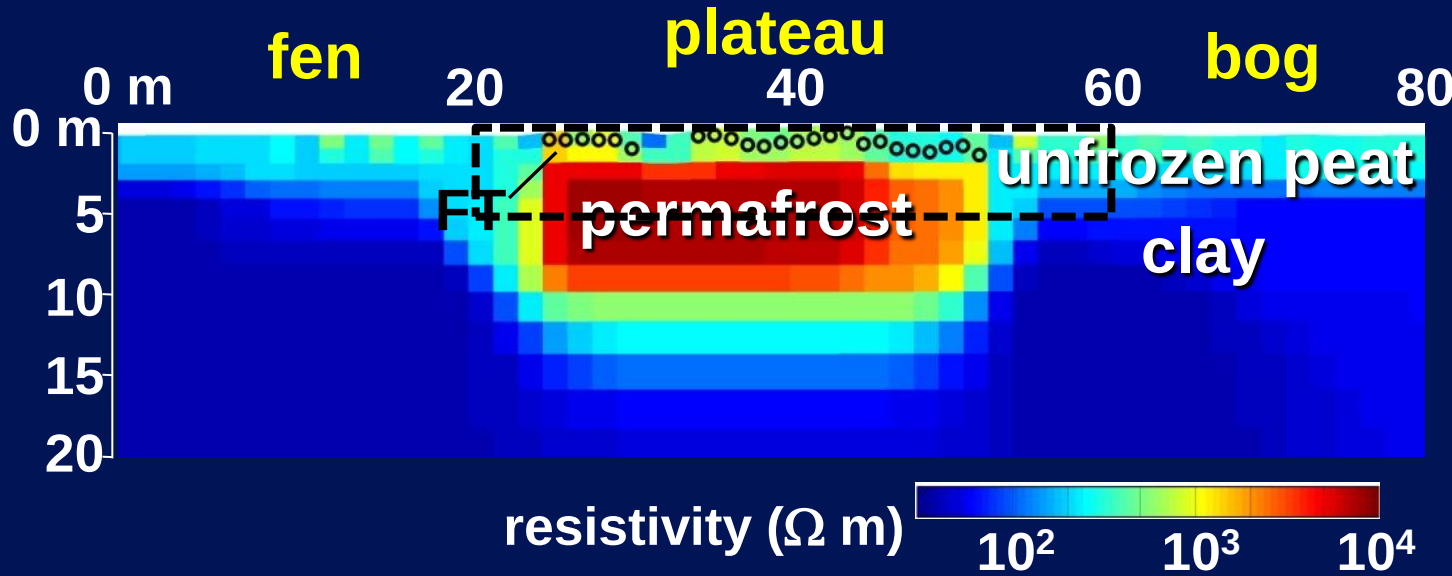


- **FT measured using FT probe on 0.25 m grids.**
- **Subsurface flow simulation: 15 mm of rain added. Boussinesq equation is numerically solved.**

Wright *et al*. (2009, *Water Resour*. *Res.* 45: W05414)

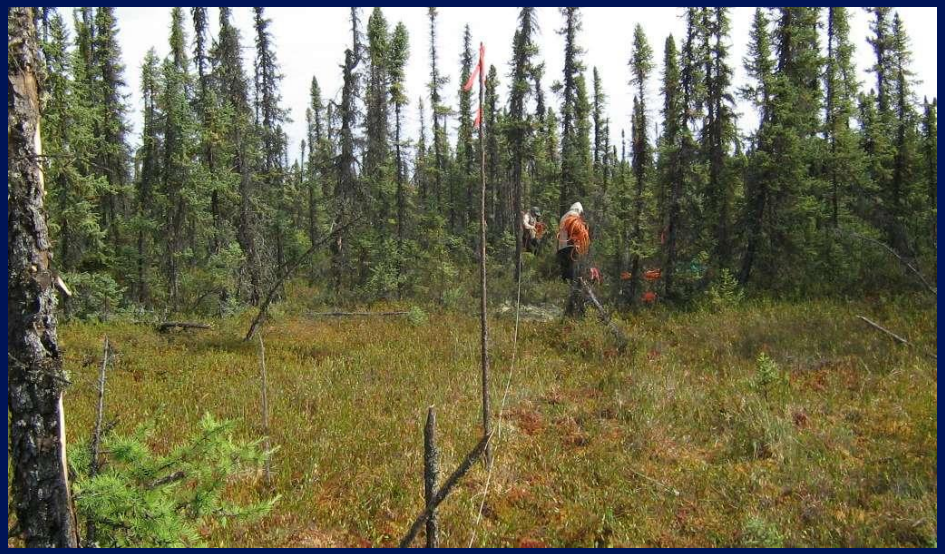
Electrical Resistivity Imaging (ERI)

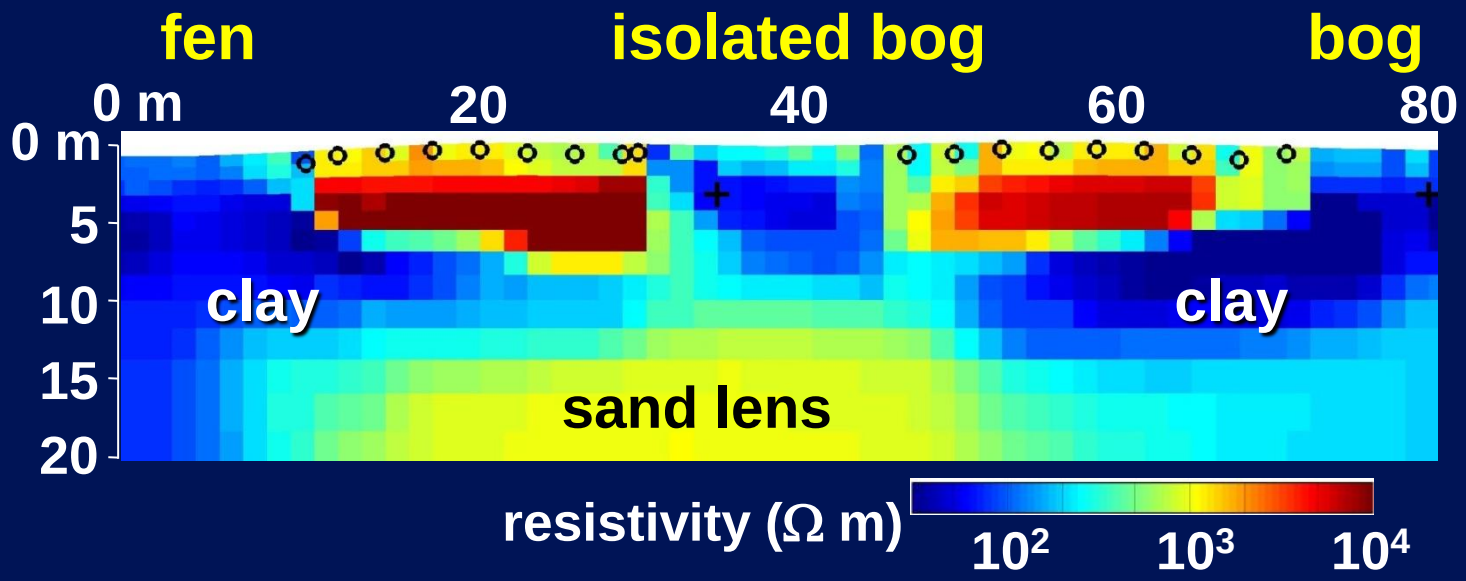




ERI Line 1: Peat Plateau Transect

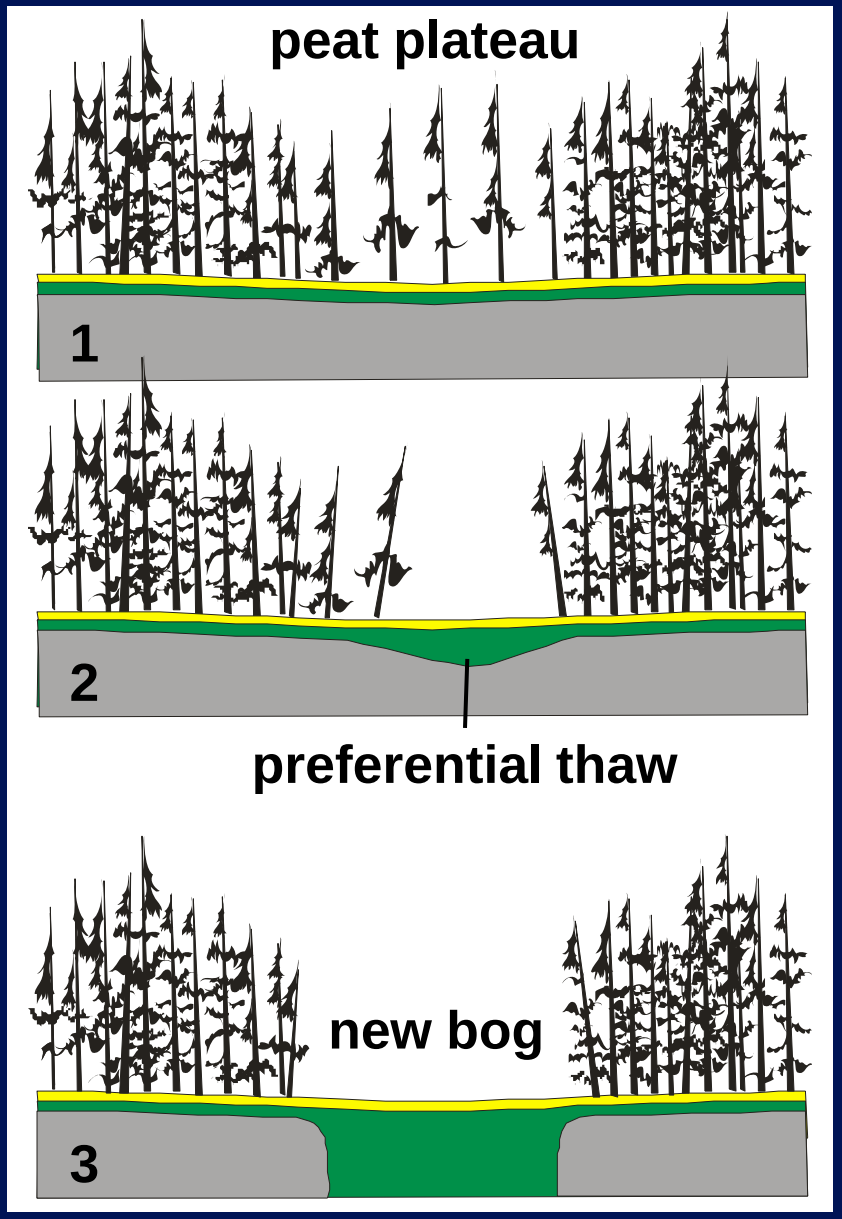
ERI Line 2: Cross-Bog Transect





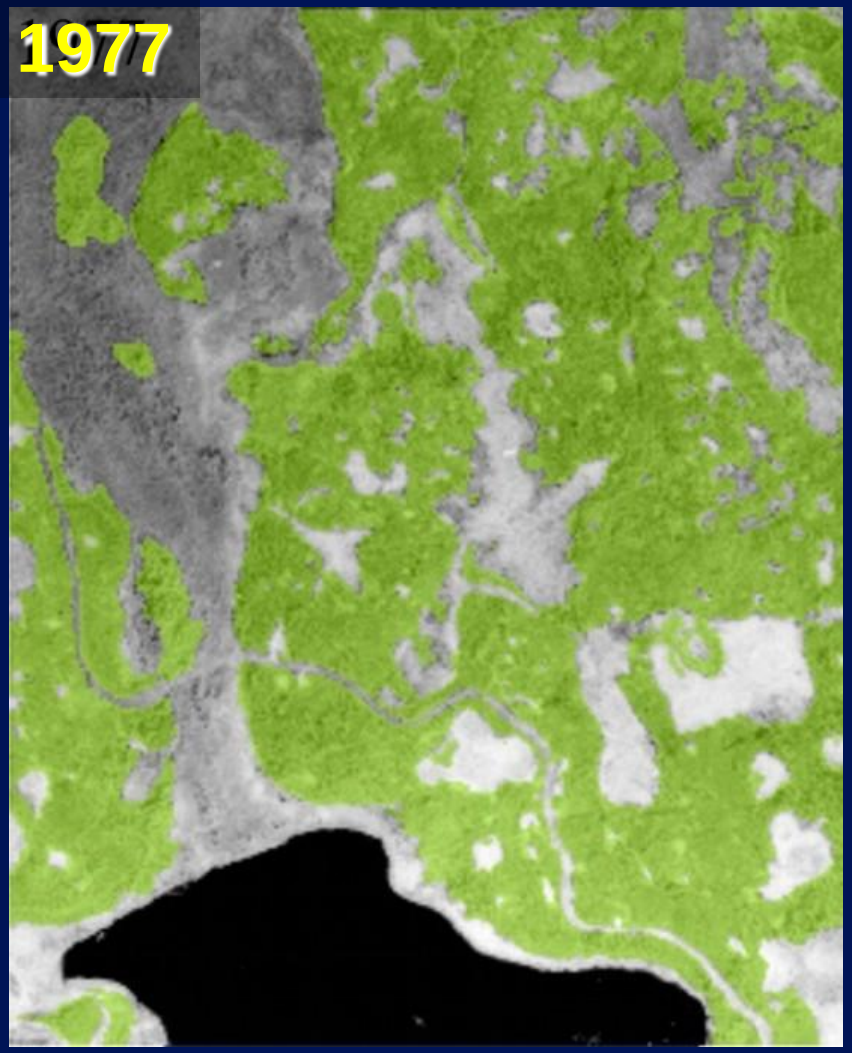
Conceptual Model of Permafrost Thaw

1. Thinning of canopy.
   → Increase in radiation energy input.
2. Local thawing.
   → Water-energy feedback causes further thawing.
3. Wet condition prevents trees from growing back.
   → New bog forms.



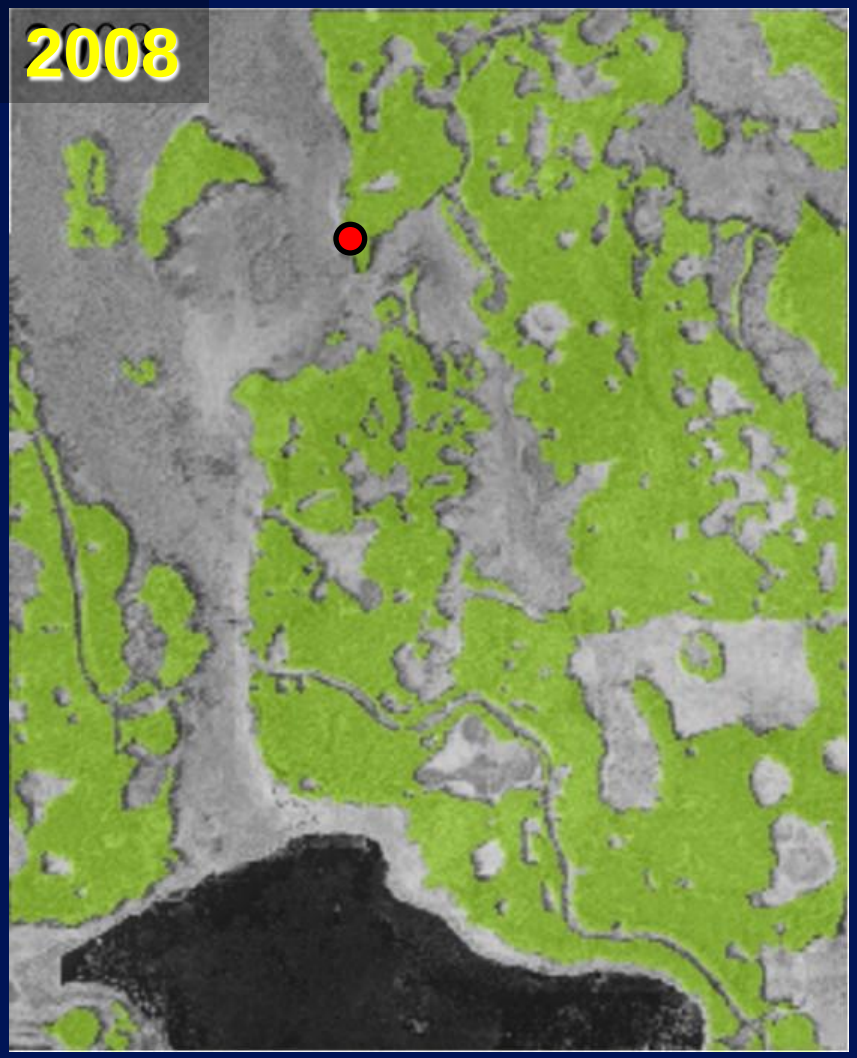
unsaturated, thawed peat
saturated, thawed peat
saturated, frozen peat

Delineation of Peat Plateau on Aerial Images



Quinton *et al*. (2011, *Hydrol*. *Proces*., 25: 152)

Delineation of Peat Plateau on Aerial Images



Peat Plateau Area

1977: 53%

2008: 43%

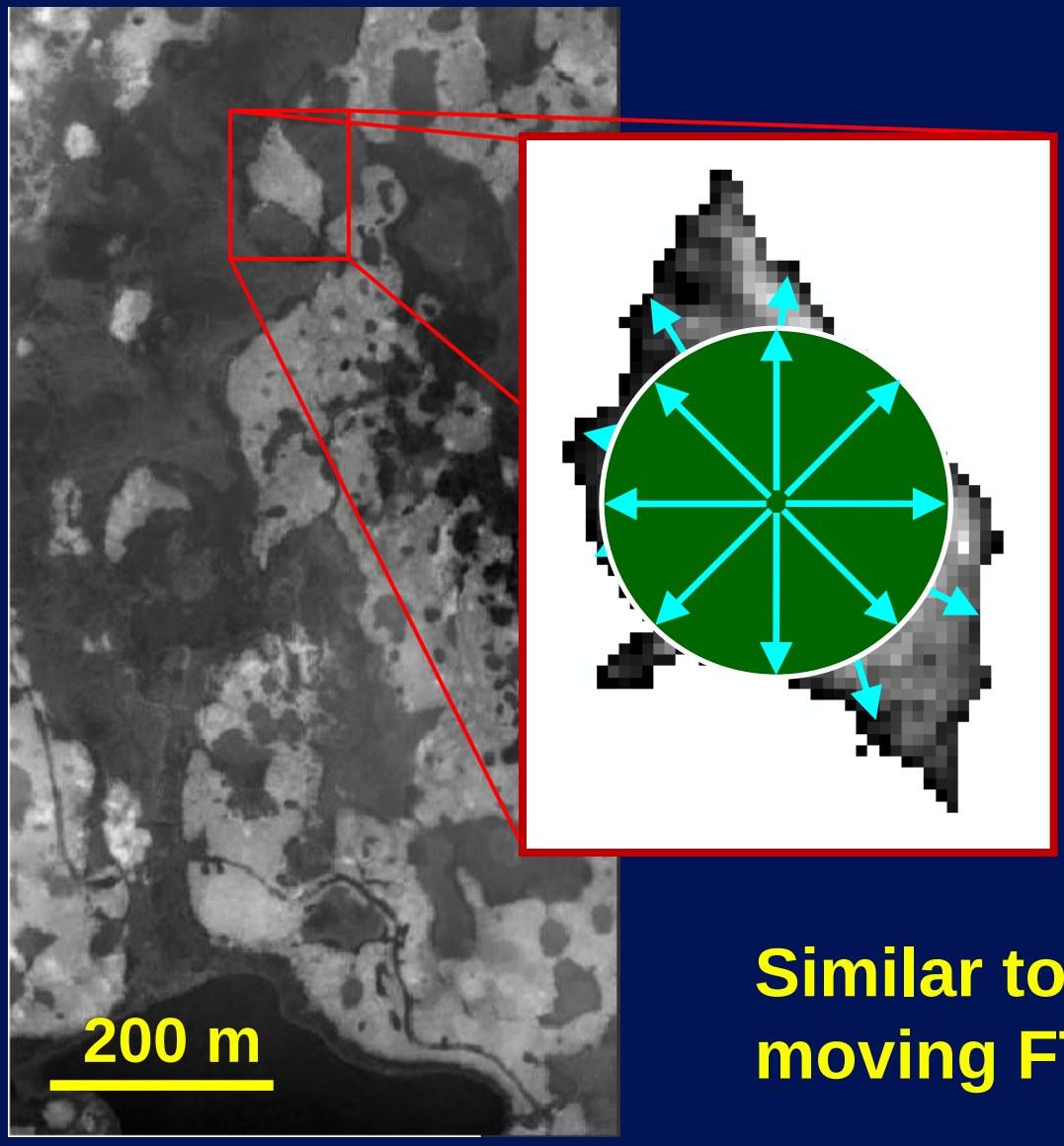
Quinton *et al*. (2011, *Hydrol*. *Proces*., 25: 152)

Changes Evident on the Ground

Aug. 2002

July 2010

Modelling Peat Plateau Runoff



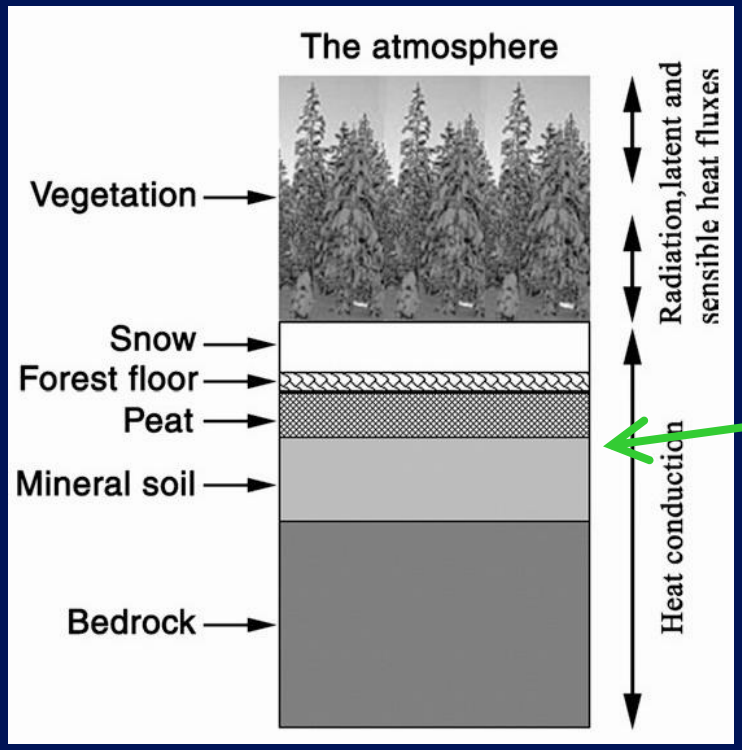
Hydraulically equivalent plateau

Drainage of ground-water controlled by:
- Radius
- Gradient
- K_{sat} distribution
- **Frost-table depth**

Similar to MESH, but the moving FT is the challenge.

Coupled Permafrost-Hydrology Model for Circular Peat Plateau

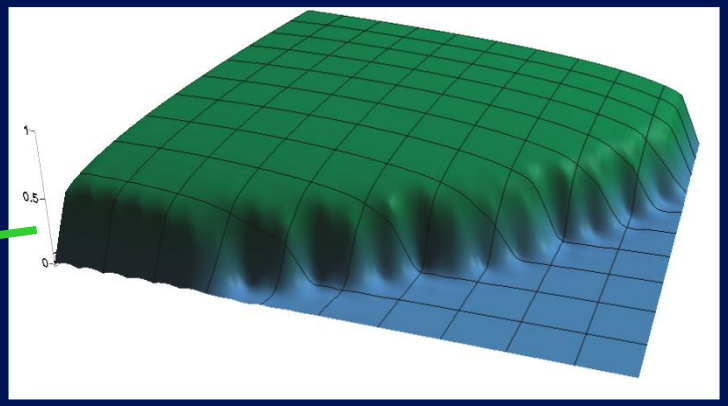
vertical transfer



Northern Ecosystem Soil Temperature (NEST) model

Zhang et al. (2008)

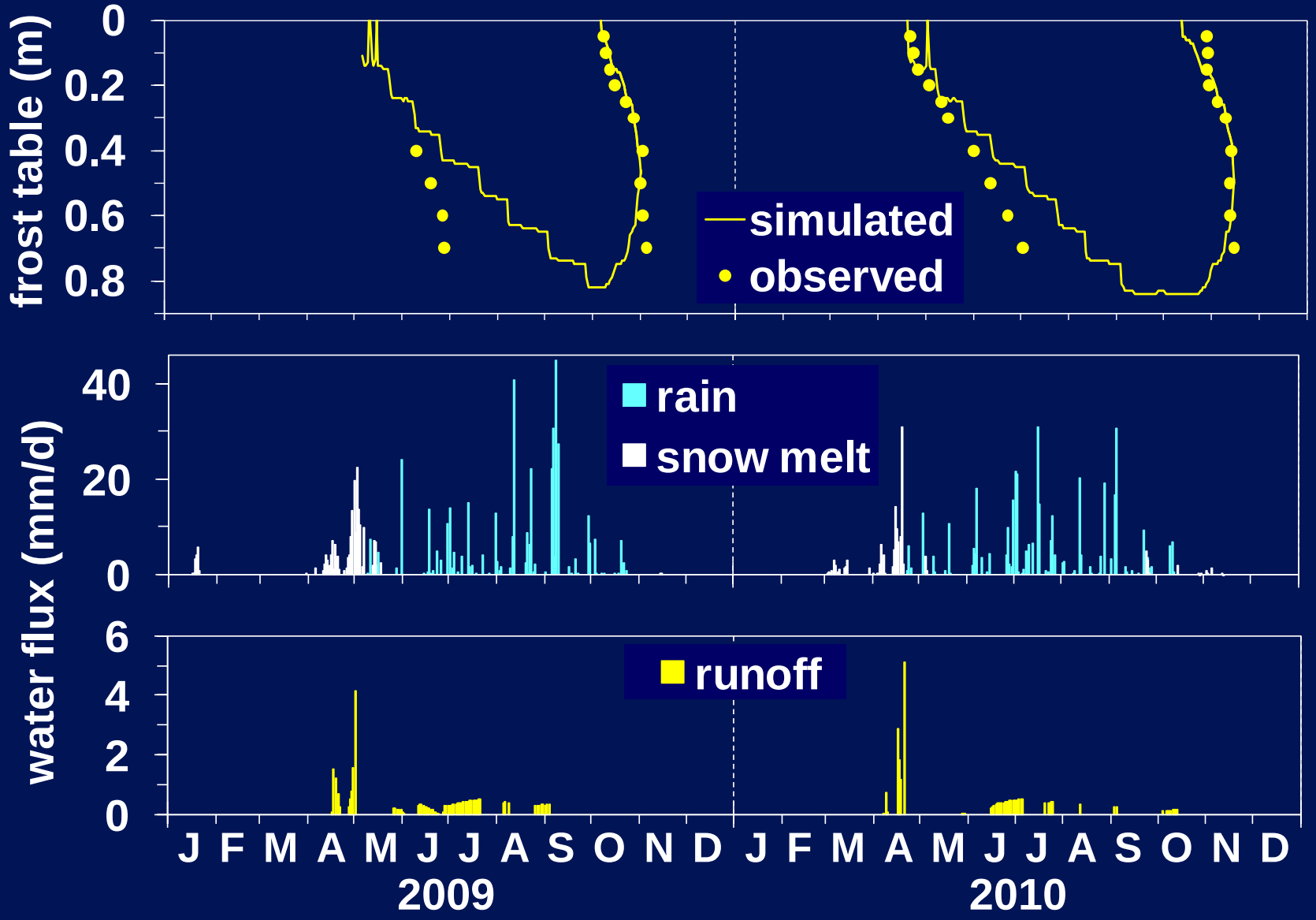
lateral drainage

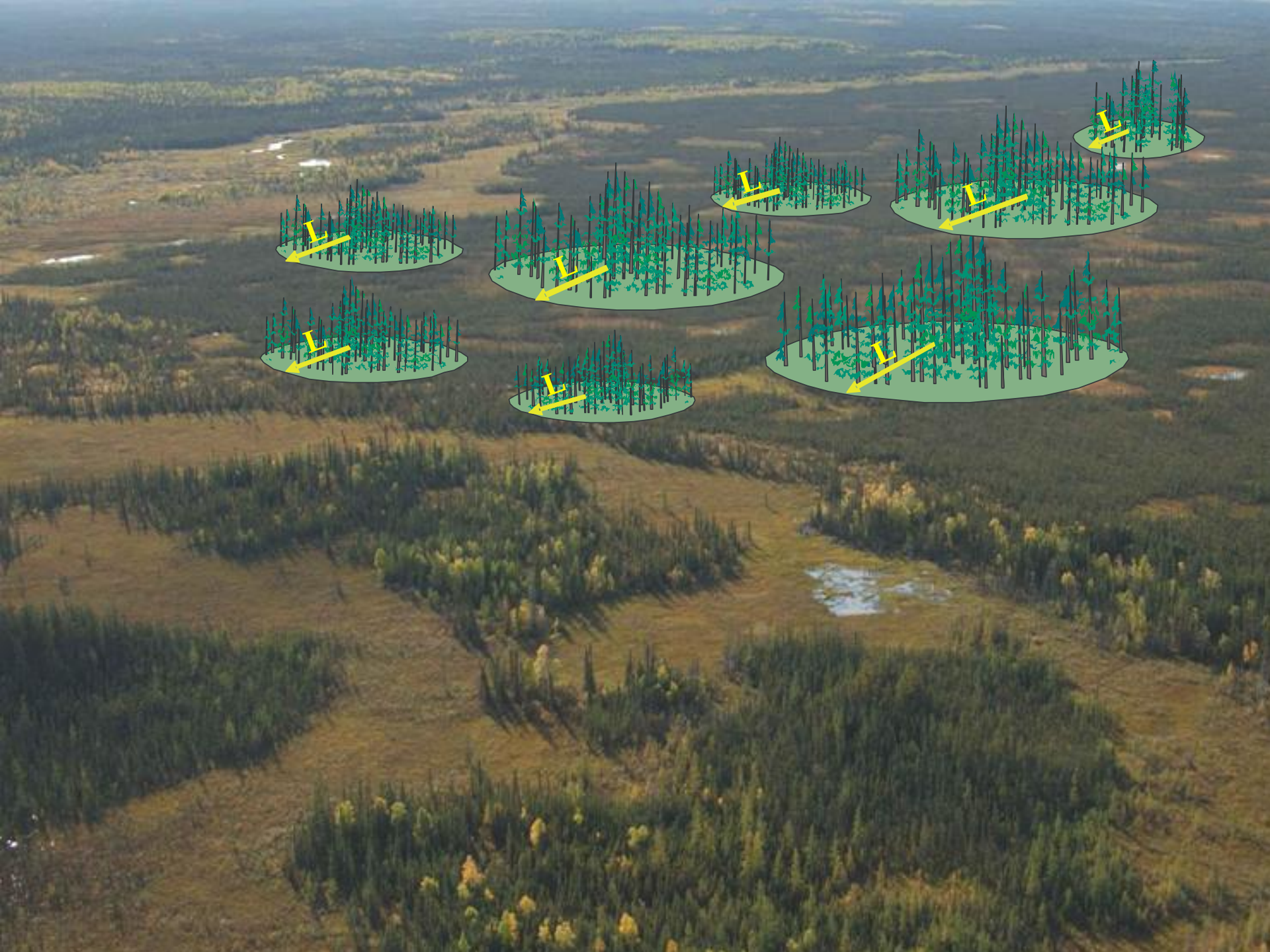


Simple Fill and Spill Hydrology (SFASH) model

Wright et al. (2009)

NEST-SFASH Preliminary Results




L
L
L
L
L
L
L
L

Challenges and the Way Forward

1. Storage and flow of runoff water in the fen-bog network → Basin-scale hydrological model.
2. Incorporate lateral thawing of permafrost in long-term model simulation (e.g. 50 years).
3. Ecology-hydrology feedback processes.

IP3 Legacy

1. Scotty Creek research basin
2. Close collaboration with the local First Nation.
3. WLU-Northwest Territories Partnership for Research and Training (2010-2020, $10M project).

Acknowledgements

People

Nicole Wright, Laura Chasmer, Chris Hopkinson, Tyler Veness, Rob Schincariol, and many others

Funding

IP3 Network
International Polar Year
Natural Sciences and Engineering Research Council
Canada Research Chair Program
Environment Canada Science Horizons Program

Logistical Support

Water Survey of Canada
Environment Canada (NWRI)
Liidlii Kue First Nations