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Changing Northern Landscapes: New Challenges and Partnerships for NWT Water Resources

5th Annual IP3 Meeting and Workshop, 4-5 October, 2010, Yellowknife.

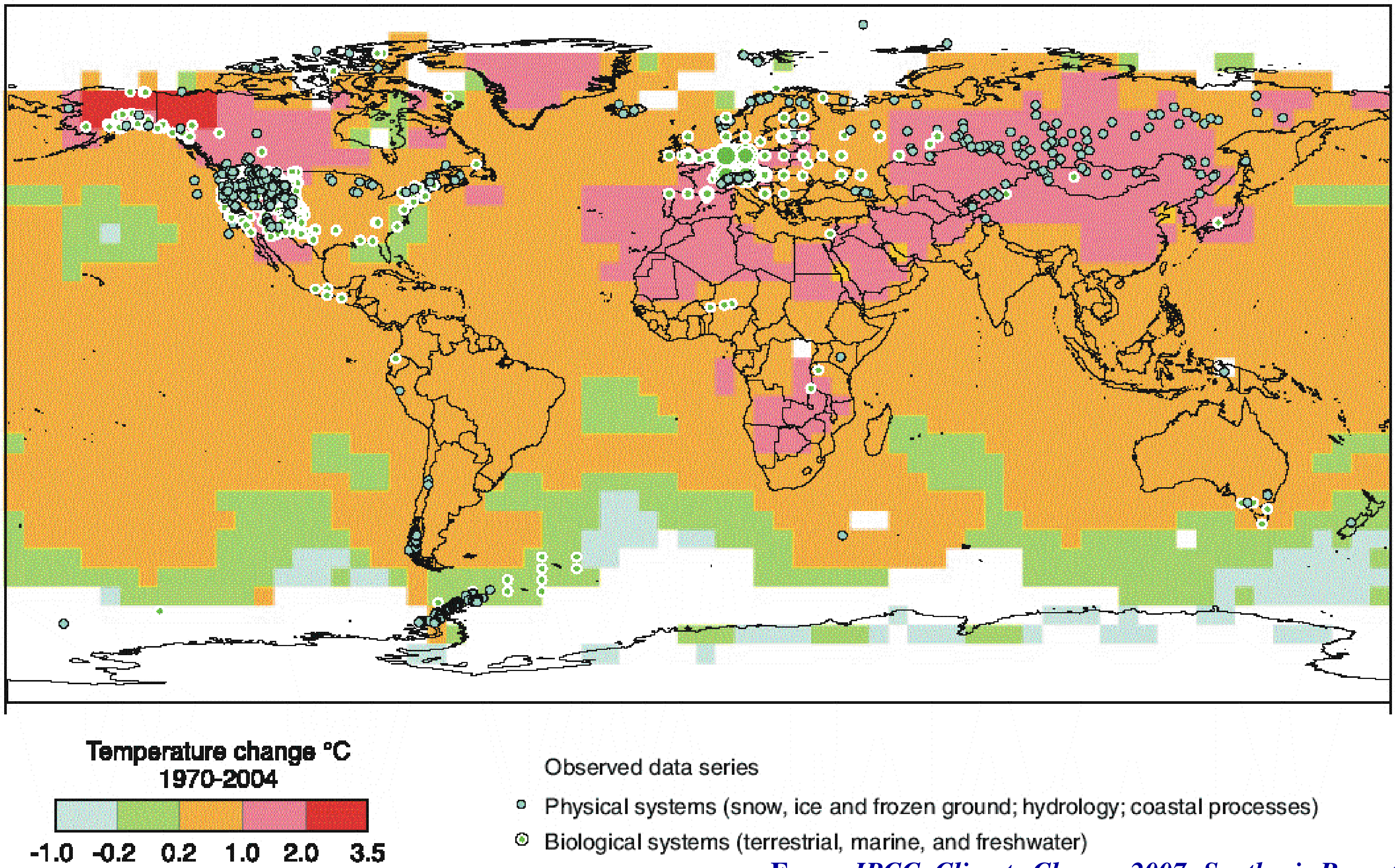
Cold Regions Research Centre

Acknowledgements:

- M. Hayashi, L. Chasmer, N. Wright, B. Christensen, A. MacLymont, T. Veness, A. Verma, R. Bemrose, Y. Zhang, C. Hpkinson, and many others.

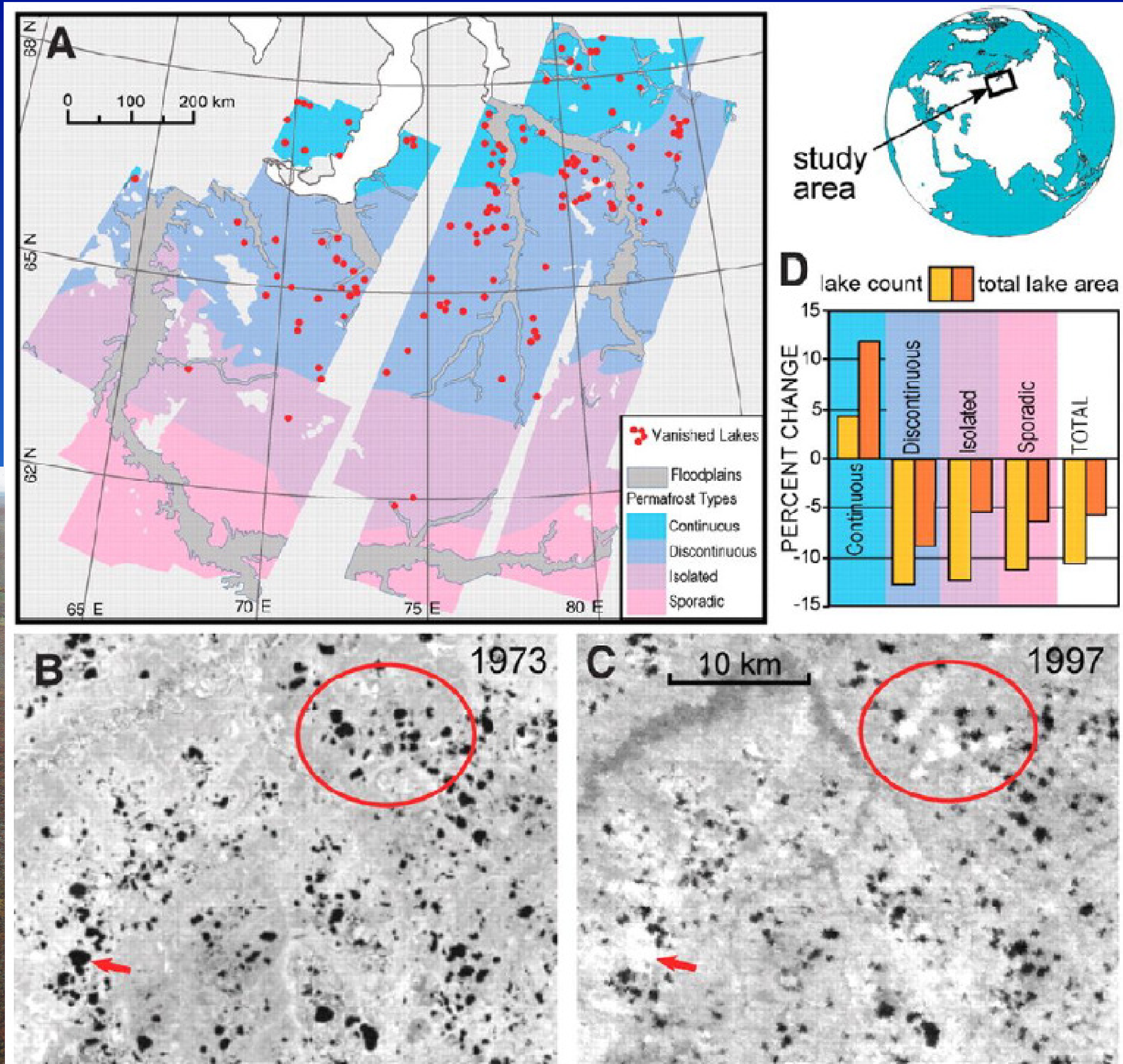
- Environment and Natural Resources (NWT), INAC, LKFN, JMFN, Water Survey of Canada, CFCAS, NSERC.

Air Temperature Change, 1970 - 2004:



From: ***IPCC, Climate Change 2007: Synthesis Report***

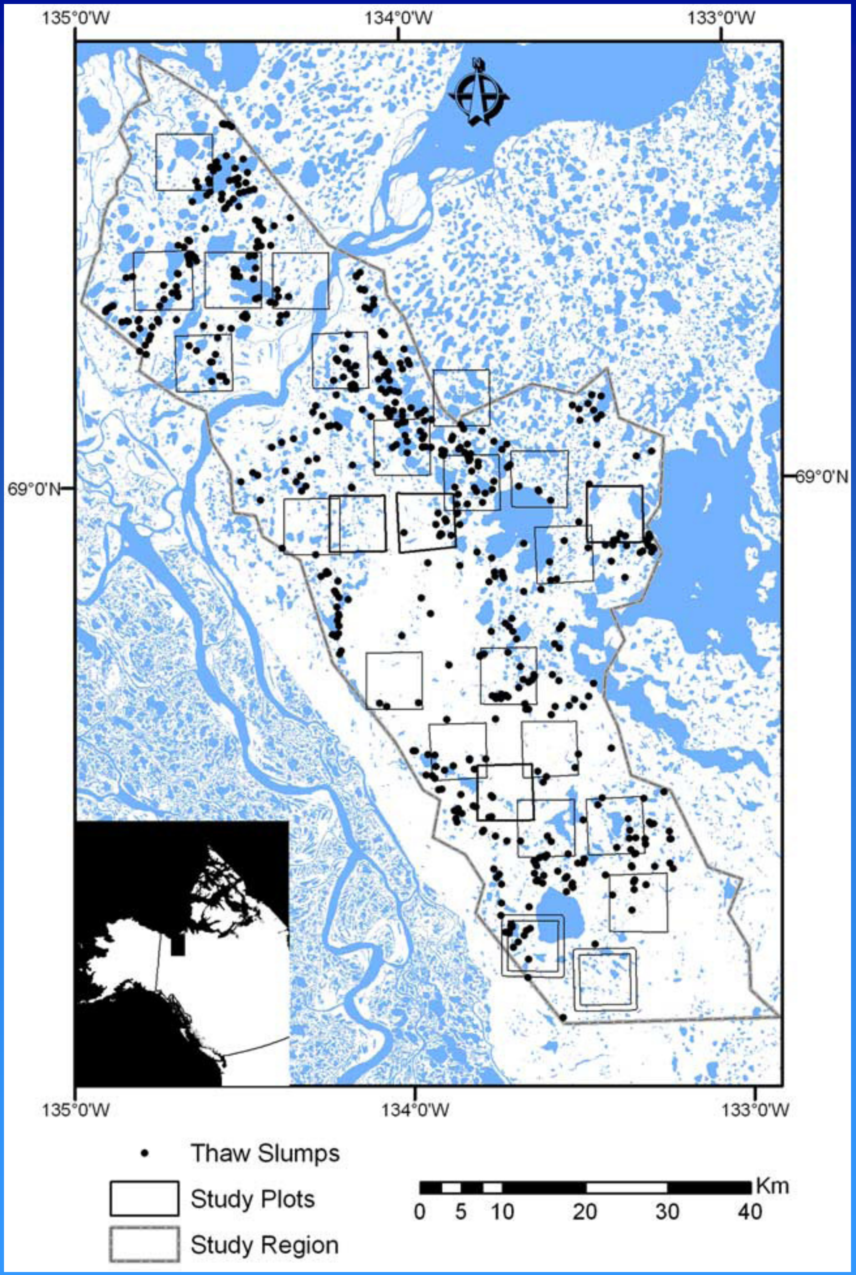
Draining lakes, ponds and wetlands.



From: Smith *et al.*, *Science*, 2005.

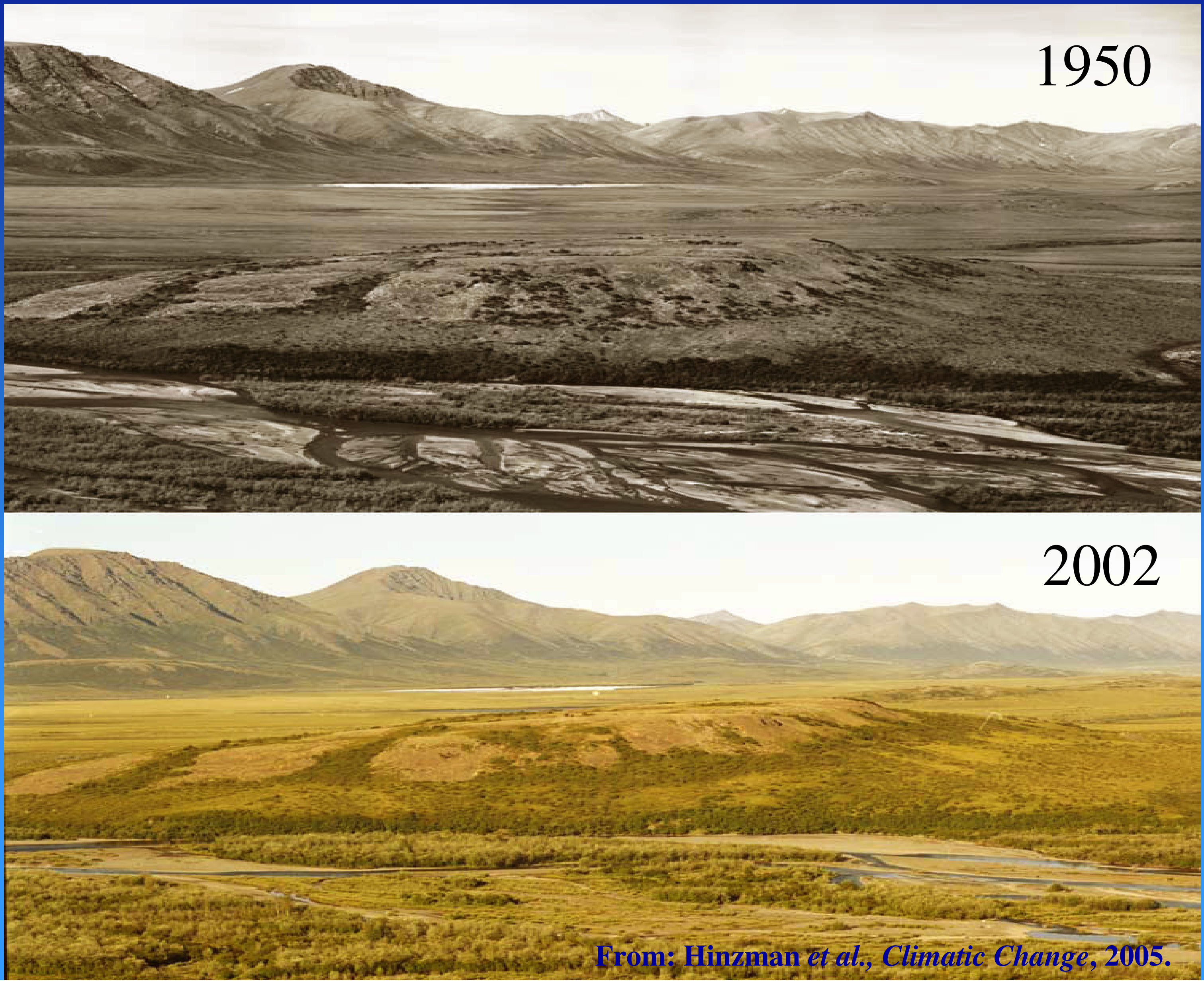
Thaw Slumps:

From: *NWT Climate Change Impacts and Adaptation Report.*



From: Lantz & Kokelj, *GRL*, 2008.

Vegetation Change on the Tundra:



How shrubs influence water resources:

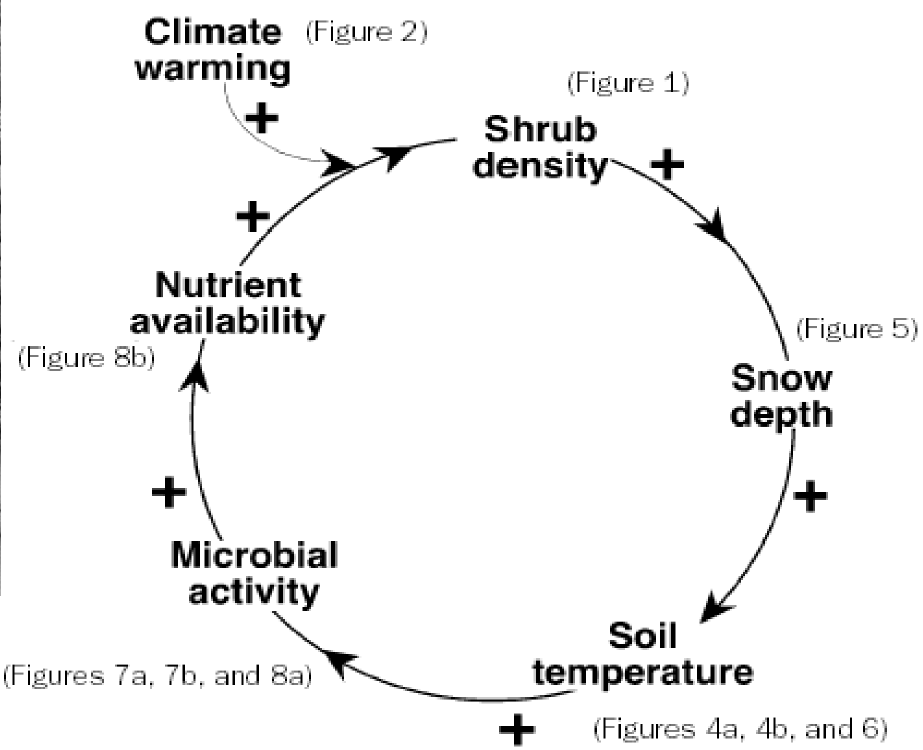
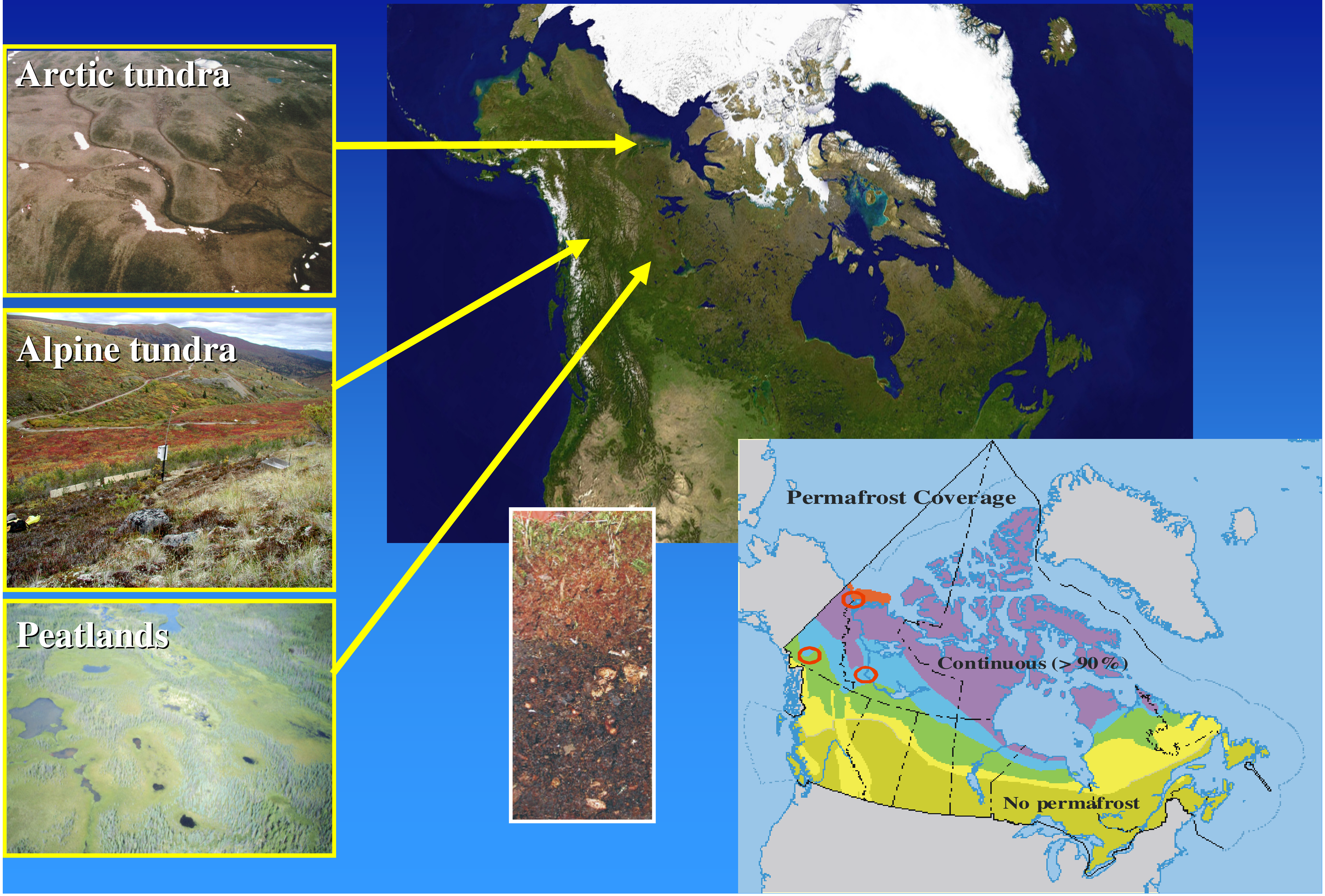


Figure 9. The snow–shrub–soil–microbe feedback loop (based on Sturm et al. 2001b).

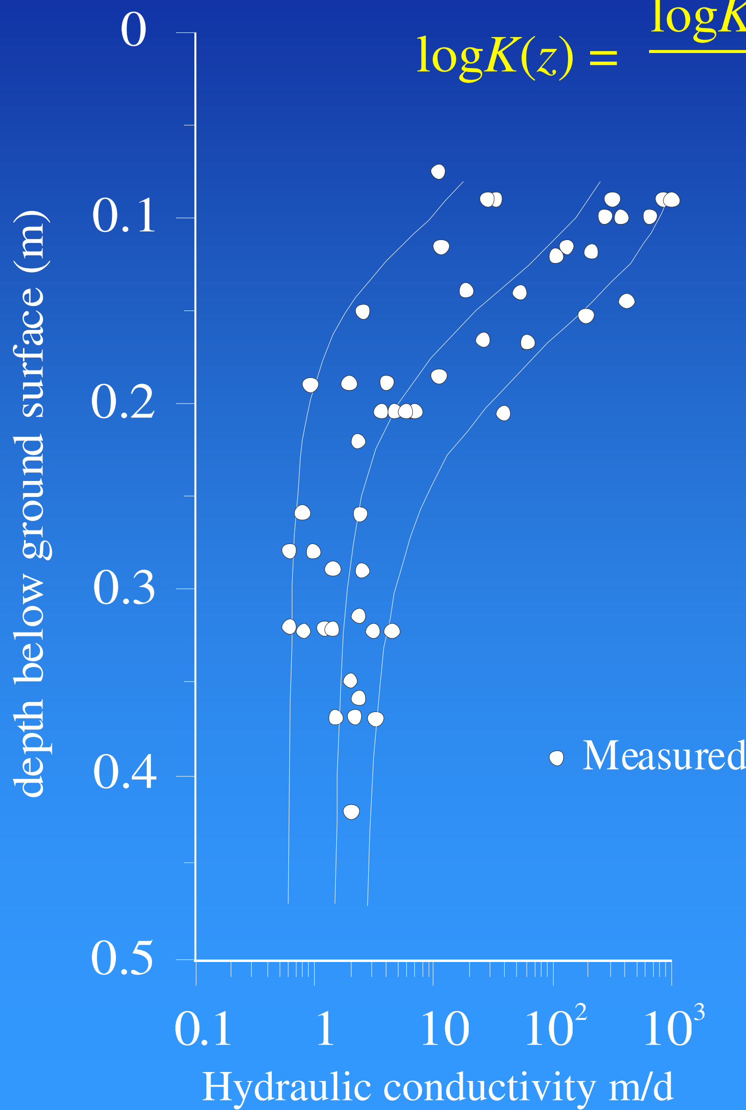
From: Sturm *et al.*, *Nature*, 2005.

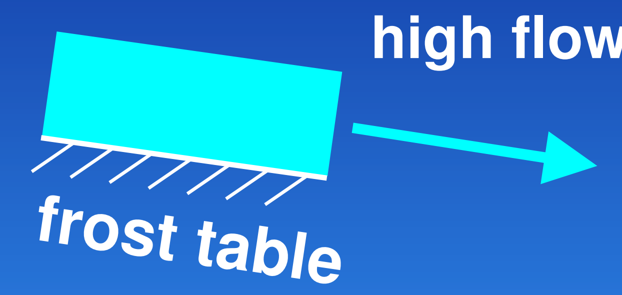
Changes to the active layer:

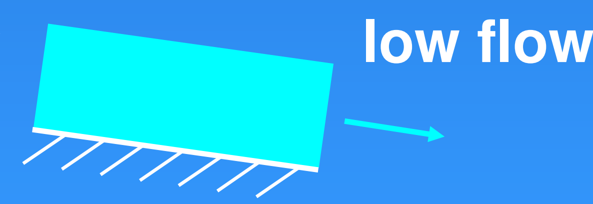


Changes to Subsurface drainage:

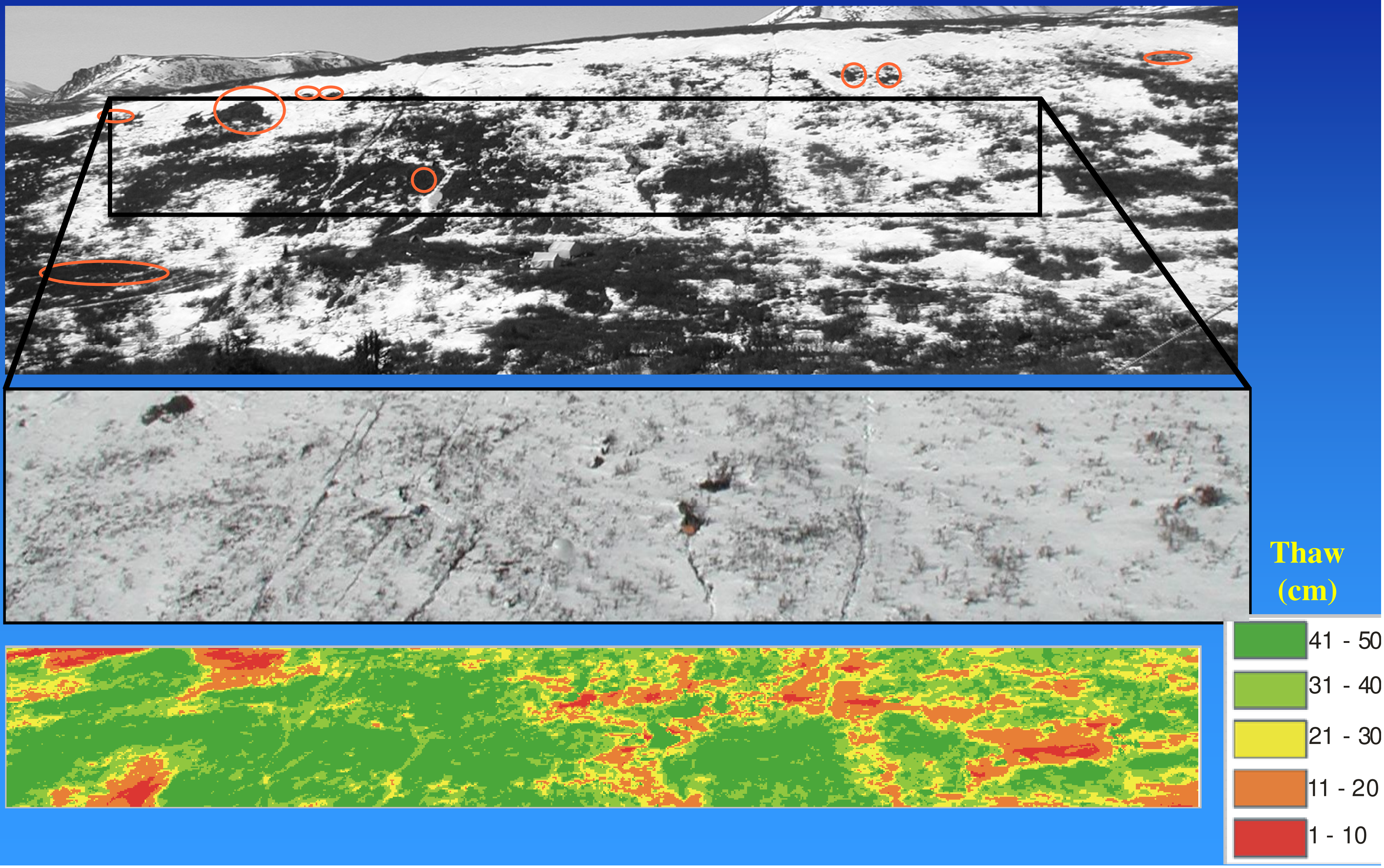
$$\log K(z) = \frac{\log K_{btm} + (\log K_{top} - \log K_{btm})}{[1 + (z/z_{trn})^{n}]}$$



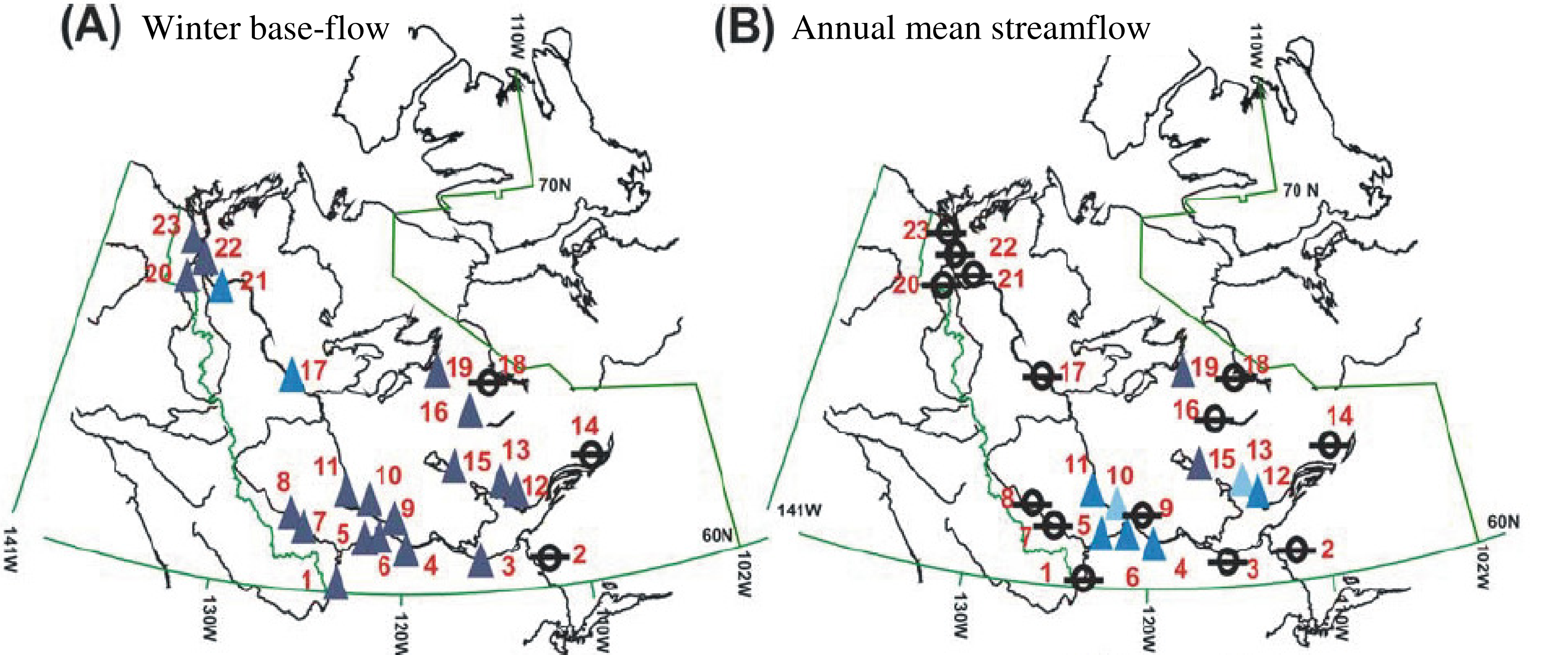




Changes to FT topography:



Changing River Flow in the NWT:



From: St. Jacques & Sauchyn, *GRL*, 2009.

System-wide response:

From: Rowland *et al*., *EOS*, 2010.

Human Activities:

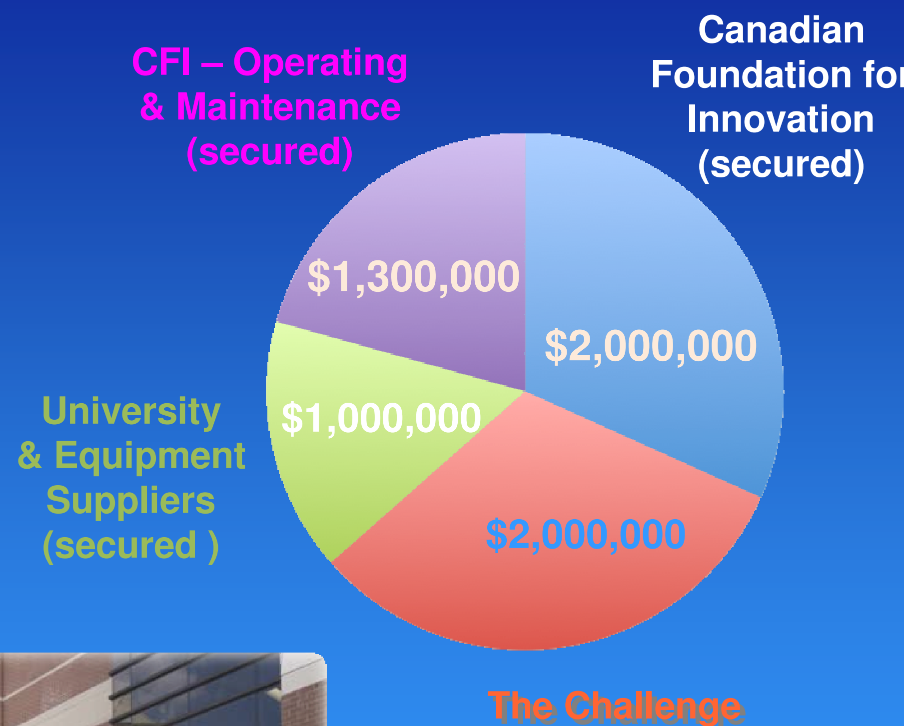
Partners in Problem-Solving:

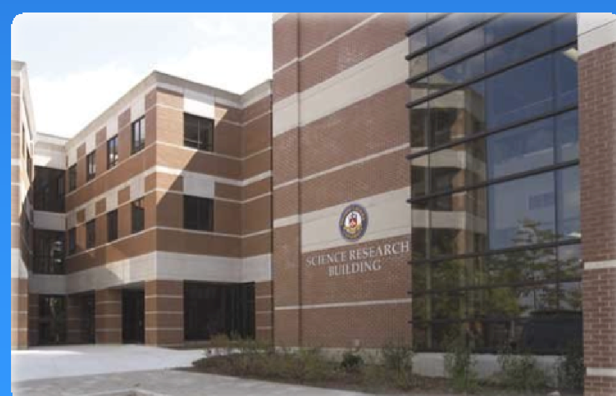
Funding Status

- funding secured for >60% of the project
  - CFI (100% of request)
  - Laurier
  - Equipment suppliers

CFI International Peer Review

"The Principal Users are a good mix of experienced senior researchers and promising early and mid-career faculty. This is an impressive research group of highly accomplished scientists who have garnered awards for research excellence, are productive, and whose publications are well cited. The group has broad and interdisciplinary expertise in all the requisite domains of the proposed project, including climatology, hydrology, ecology, geochemistry, physiology, toxicology, and modelling."





Total Project
$6,300,000

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Institute *for* Water Science

Canadian Aquatic Laboratory for Interdisciplinary Boreal Ecosystem Research

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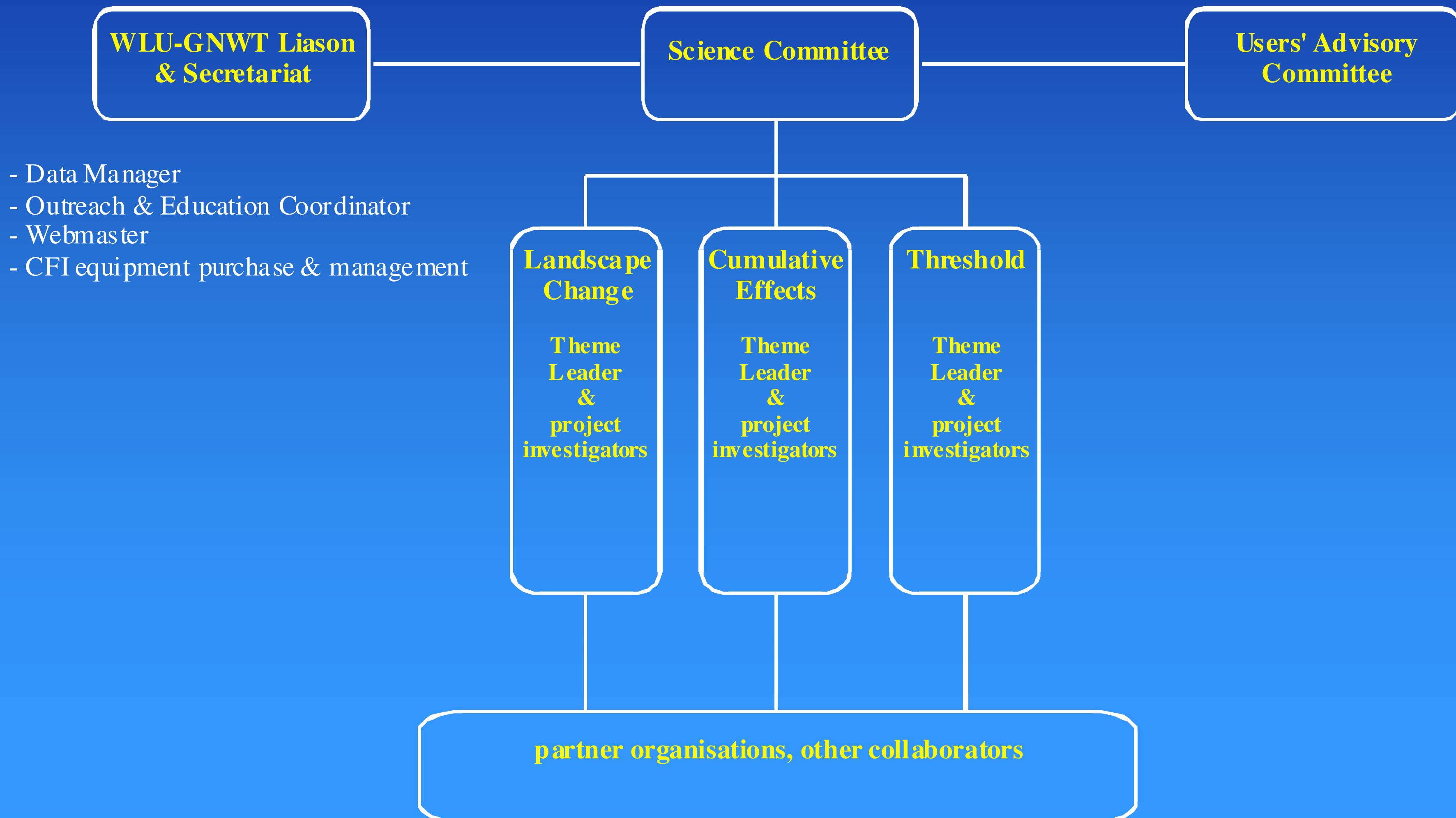
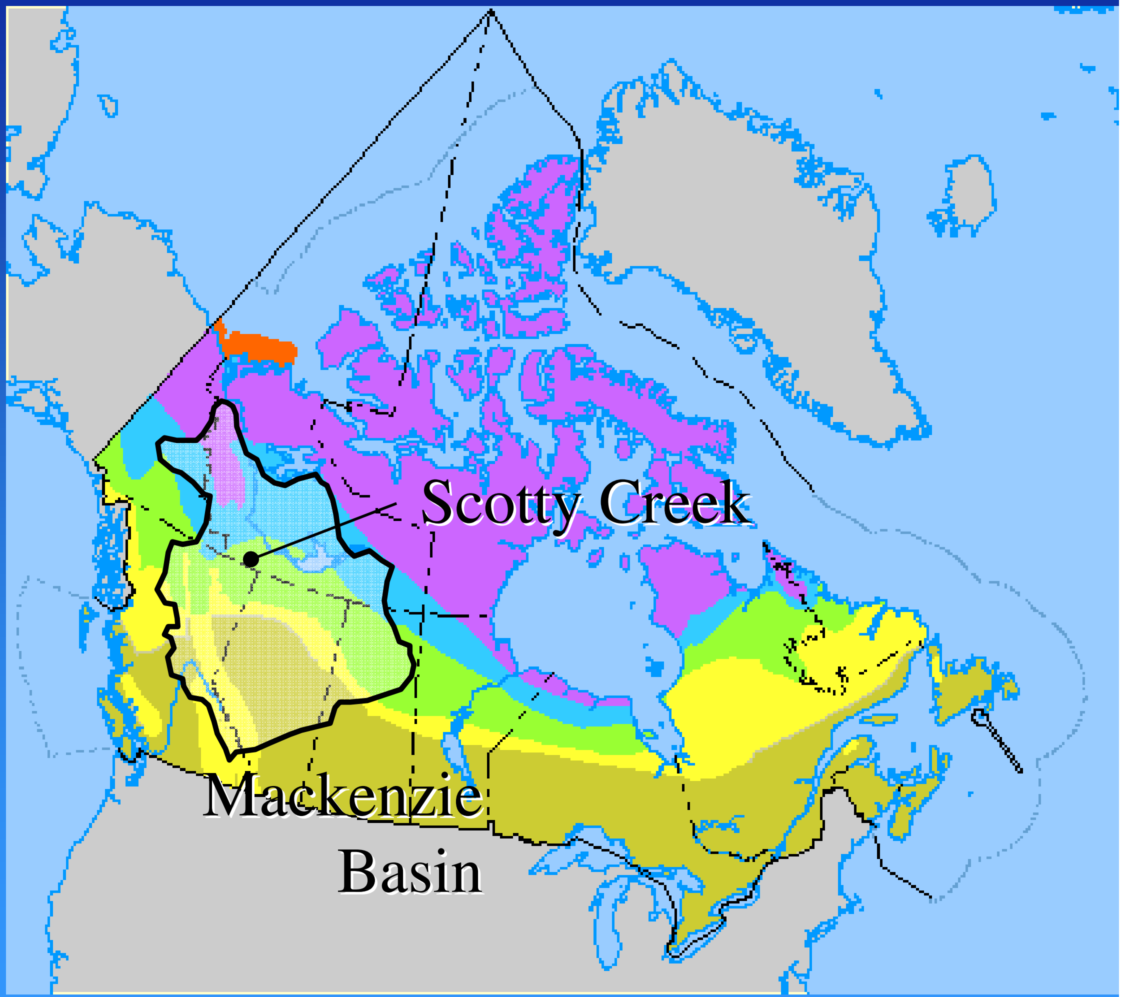
Framework for GNWT-Laurier Partnership:



Landscape changes in the southern margin of permafrost:

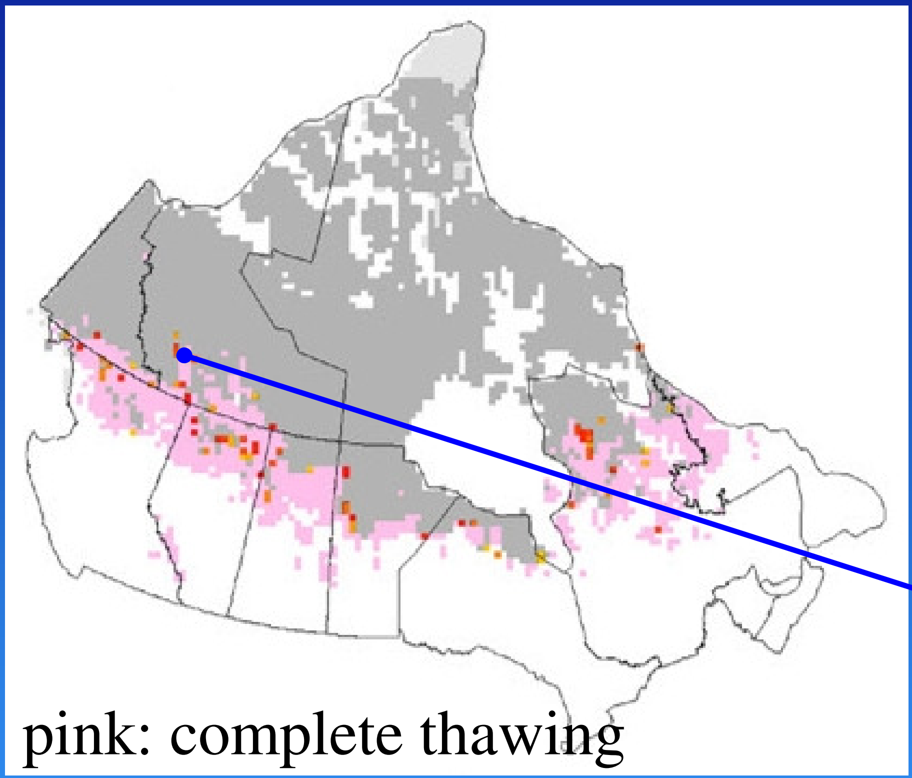
Permafrost Cover:

- Continuous (> 90%)
- Discontinuous (50-90%)
- Discontinuous (10-50%)
- Isolated patches (< 10%)
- No permafrost



Natural Resources Canada
(http://atlas.nrcan.gc.ca/site/english/maps/environment/land)

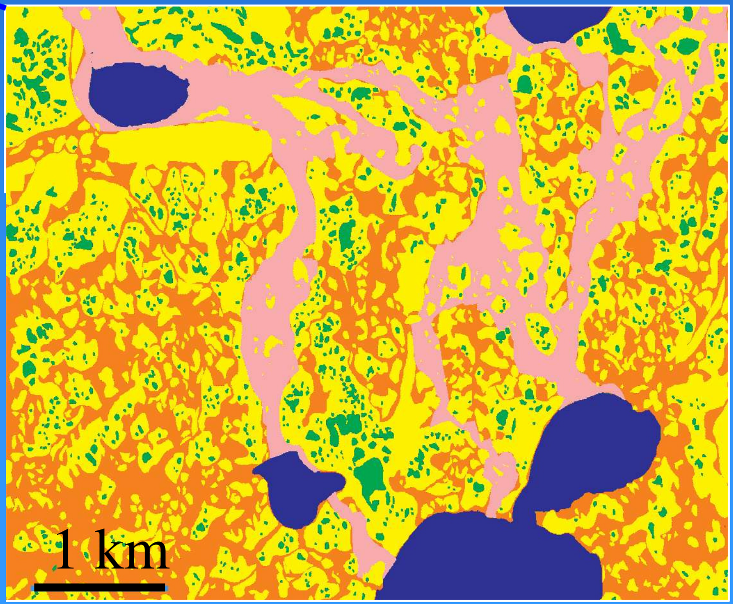
Prediction of Permafrost Thaw for 1990-2090:



Computer Model

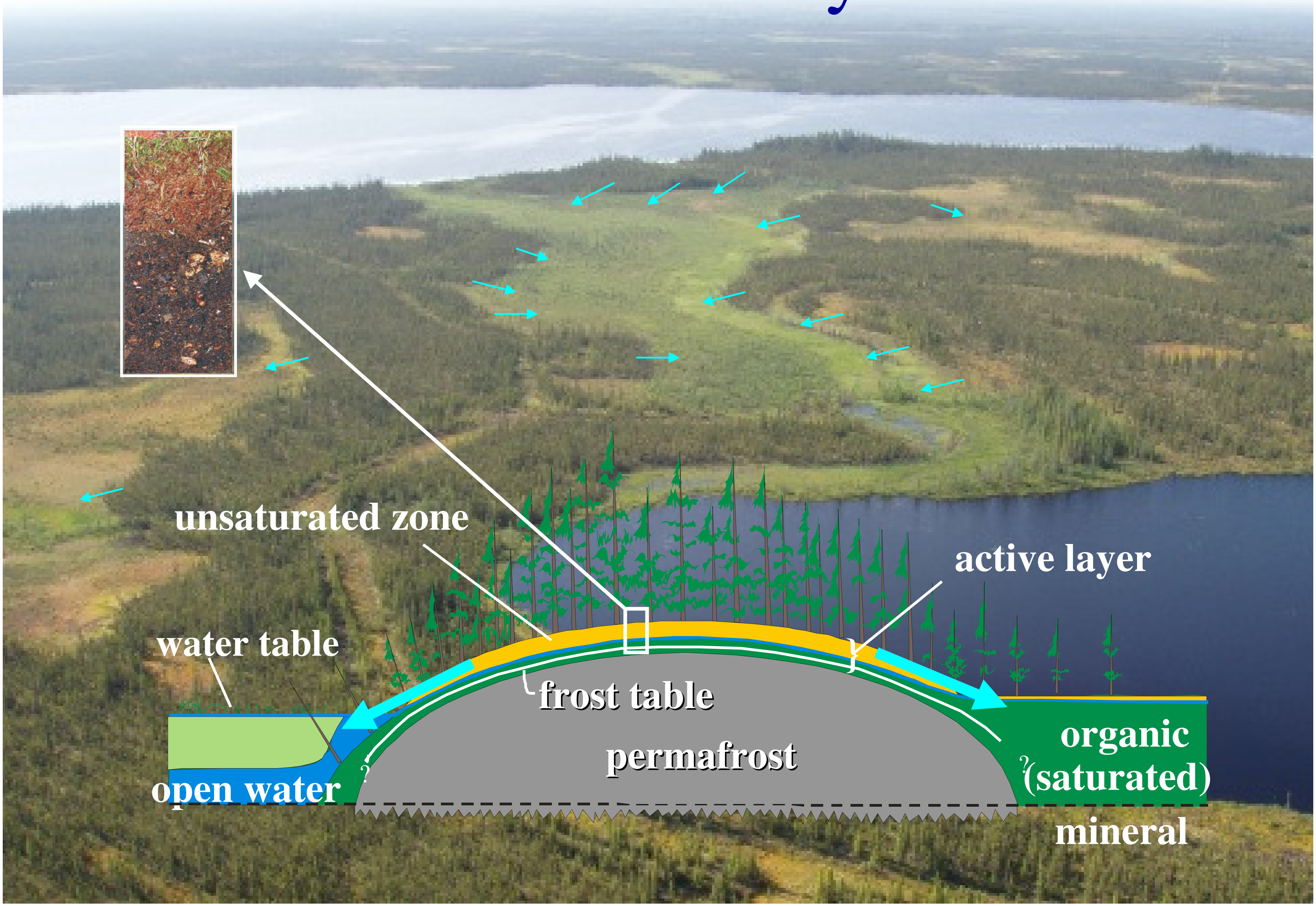
- Large scale (50 km grid).
- Each grid = uniform condition.

Reality (Scotty Creek)



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

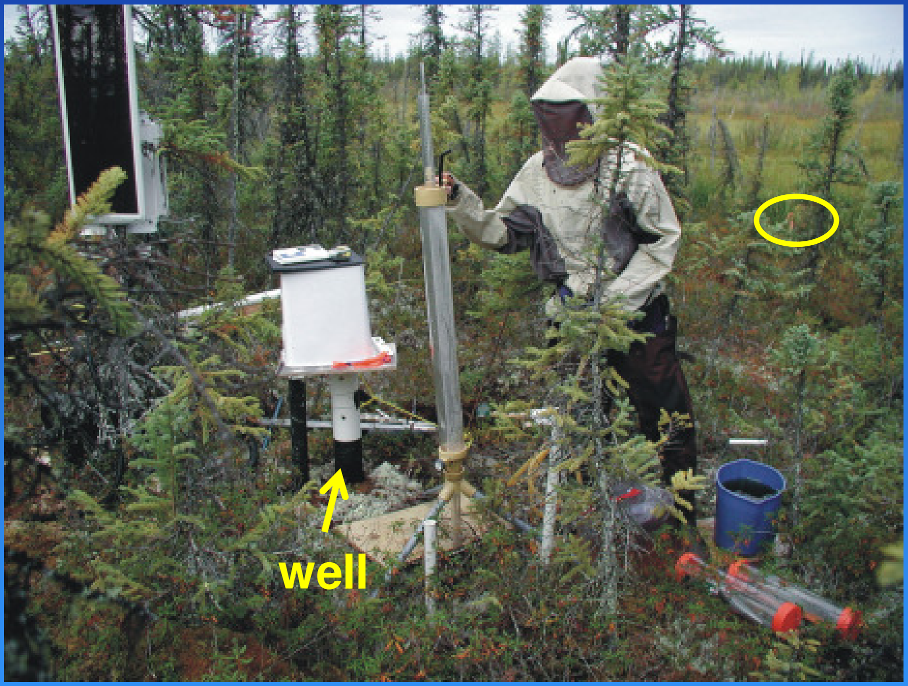
Basin Water Cycle



Shifting Edges:

Change Observed on the Ground:

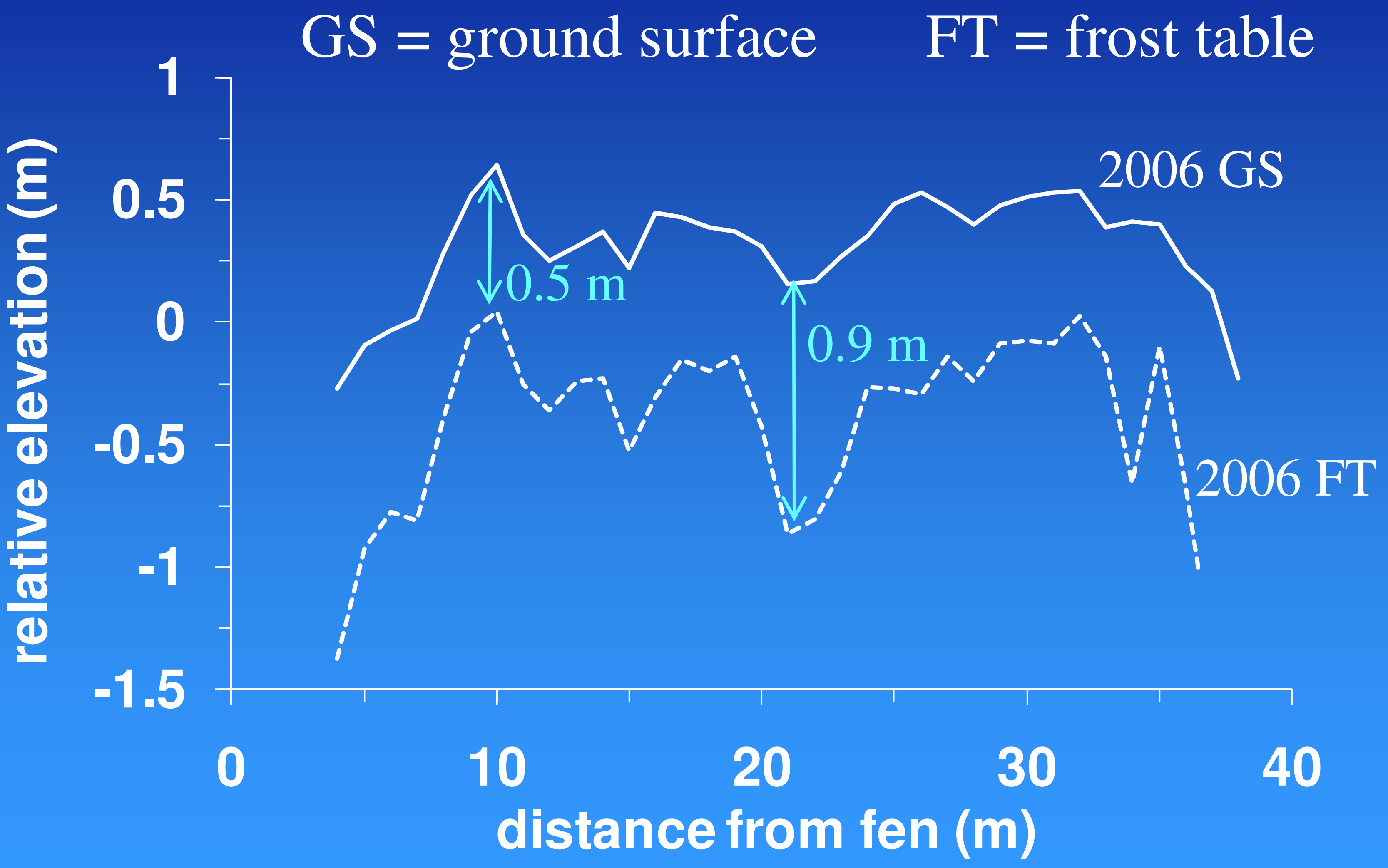
Aug., 2002



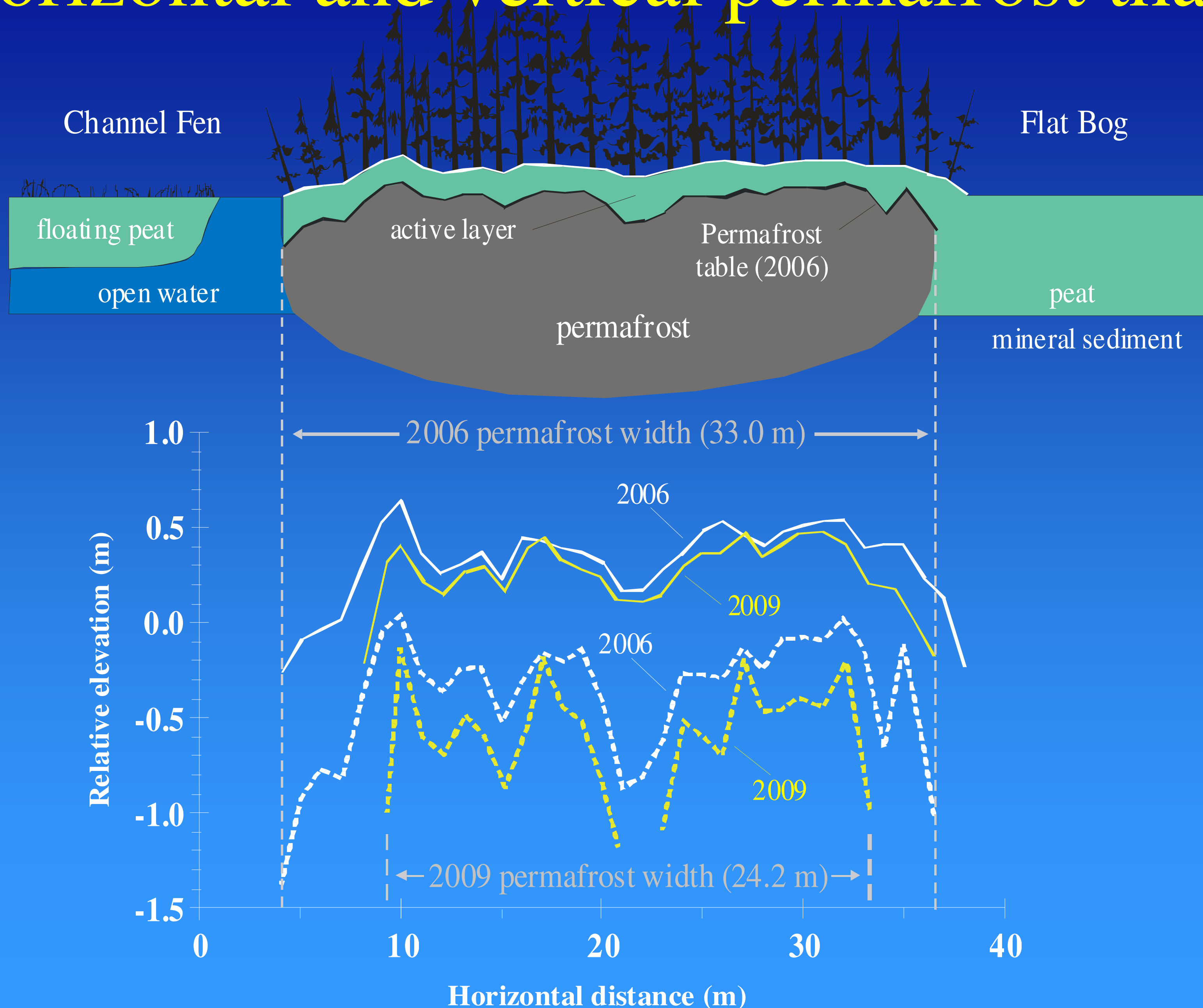
Aug., 2008

well

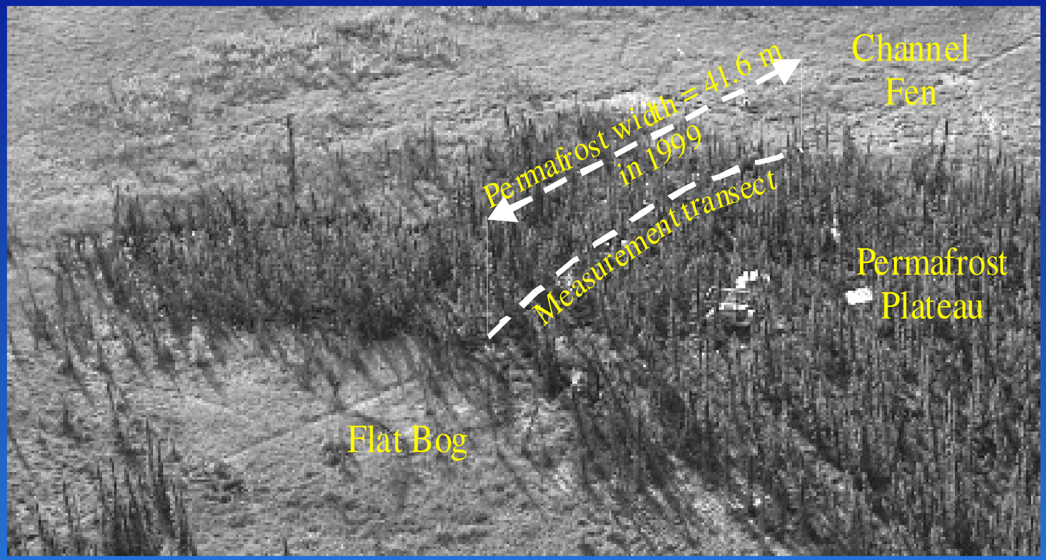
Seasonal thaw depth on a plateau:

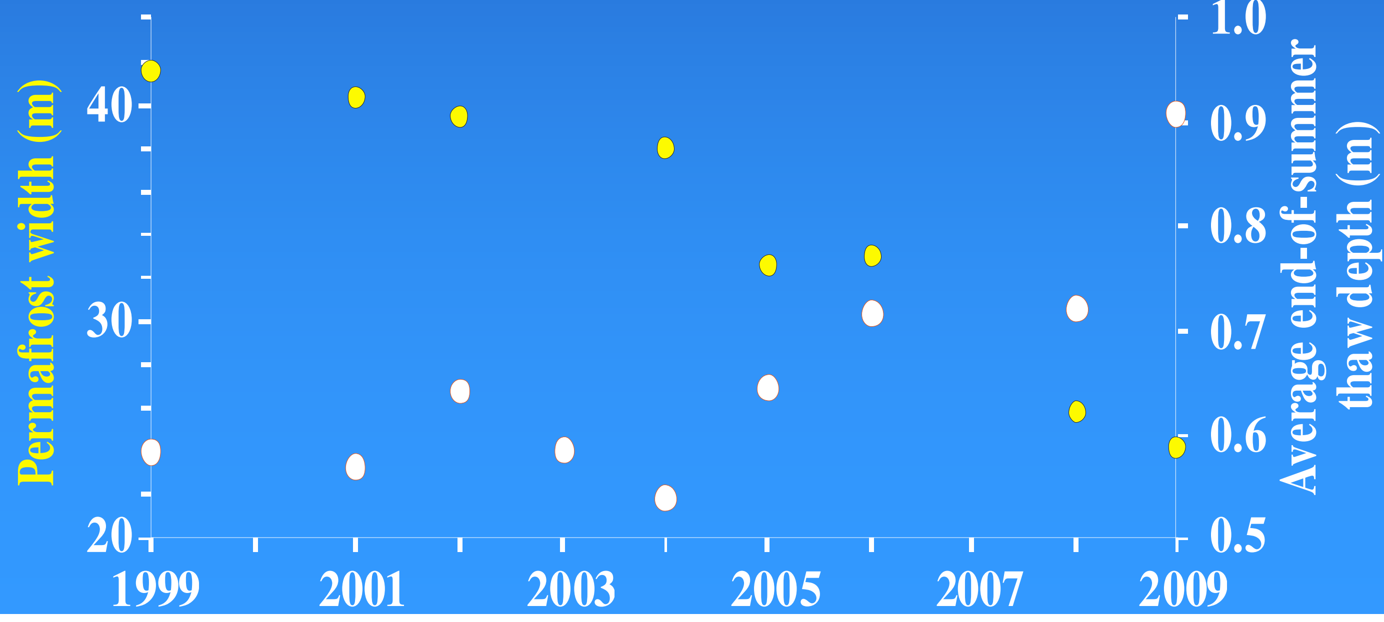


Horizontal and vertical permafrost thaw:

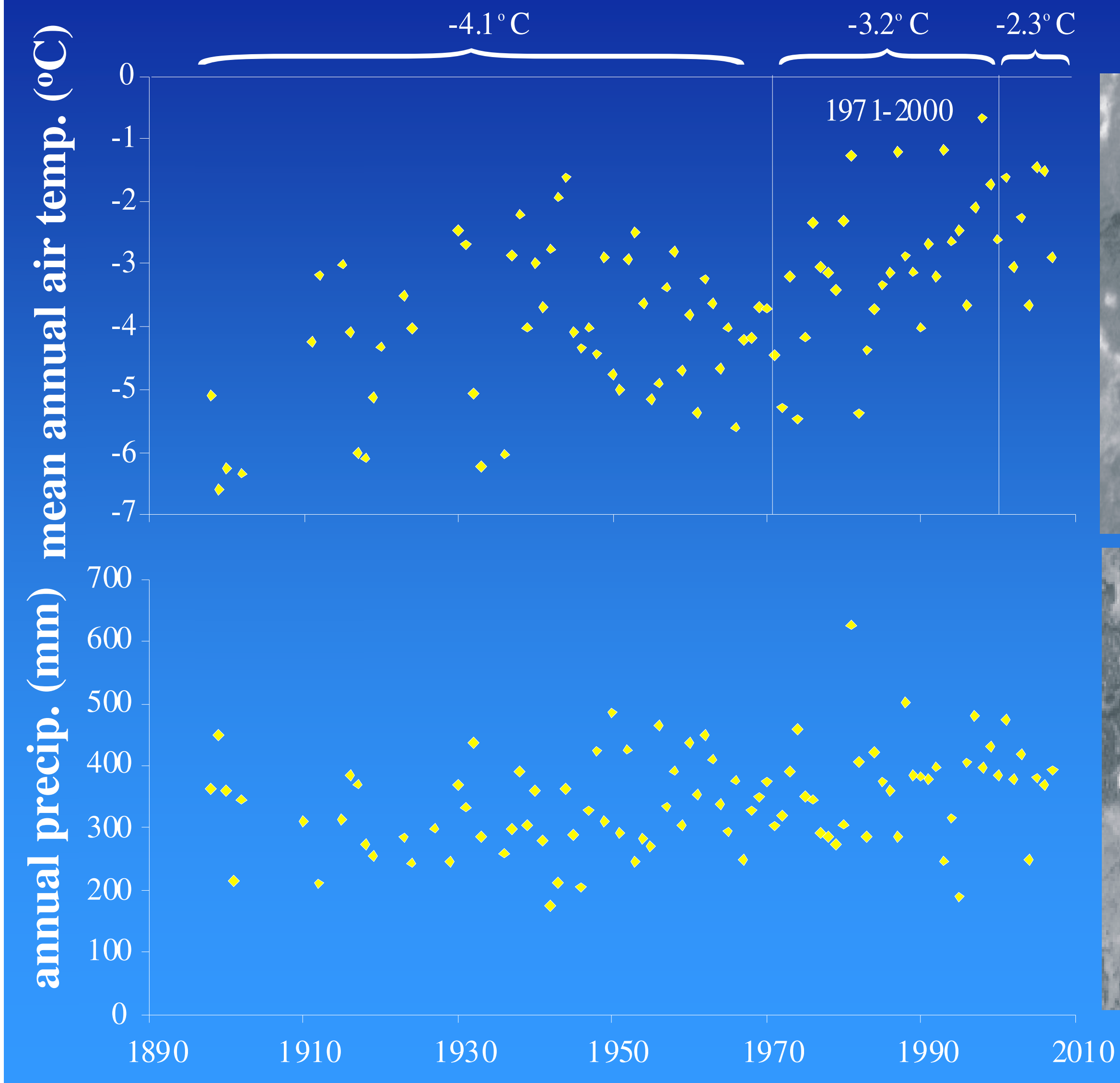


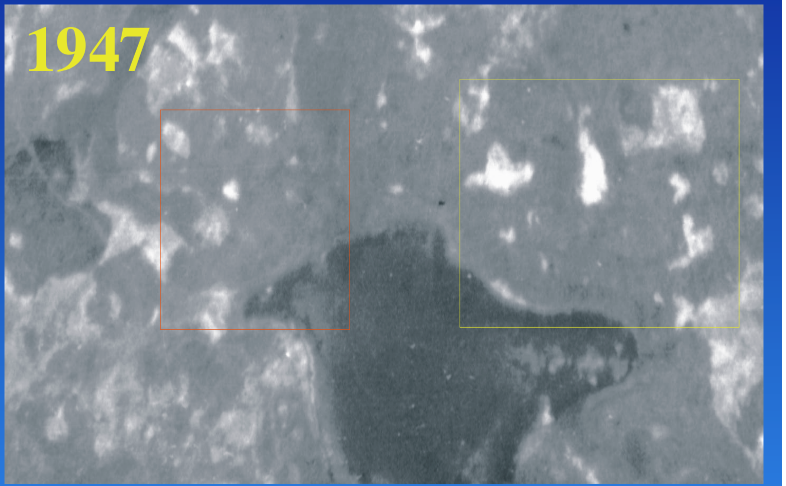
Changes to permafrost & seasonal thaw:

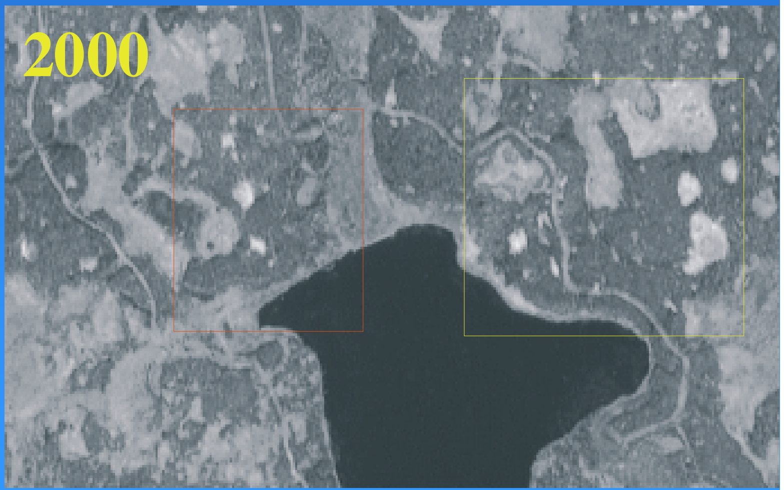




Air Photo Archive 1947 – 2000:







Questions for Research and Management:

- How will the permafrost distribution change?
- How fast will the change occur?
- What site factors control permafrost thaw?
- Is human disturbance contributing to permafrost thaw?
- How might water resources be affected?
- Could other resources be affected too?

→ Scientific basis for adaptation to climate change

Permafrost Distribution 1947 – 2000:

1 km^2

Peat Plateau Area

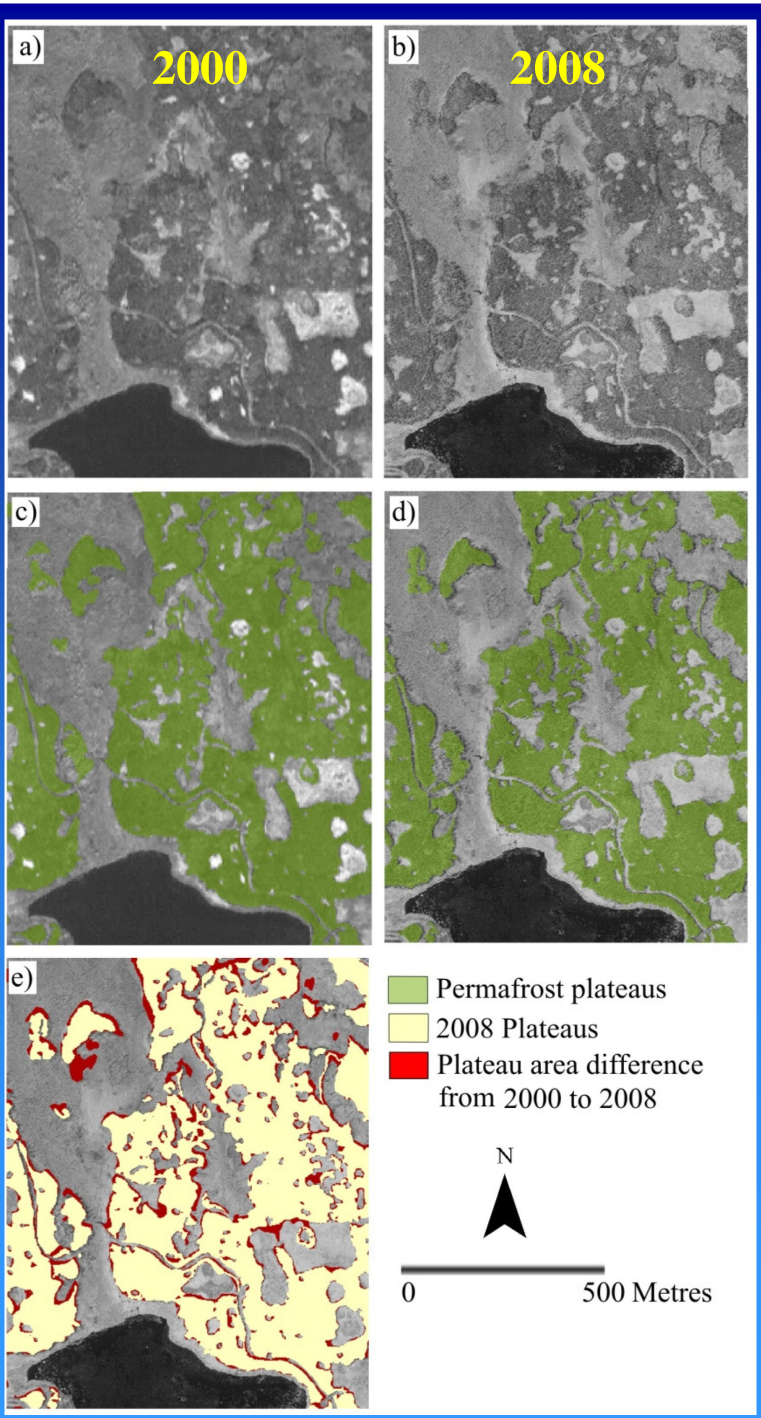
1947: 70%

1970: 54%

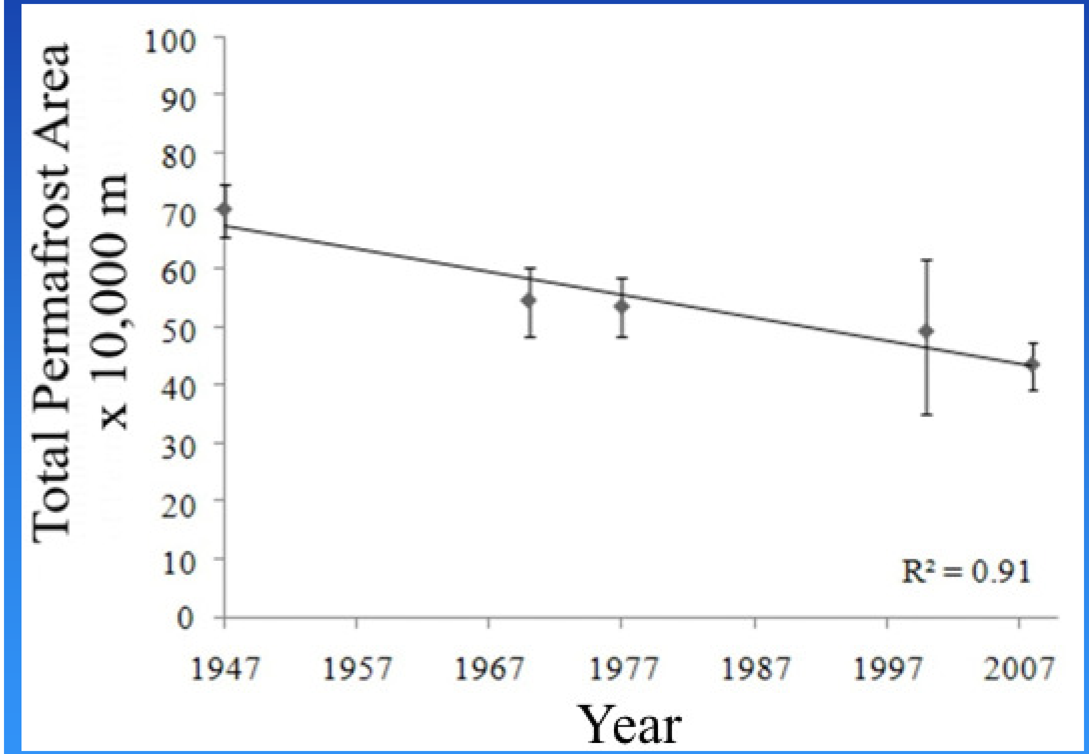
1977: 53%

2000: 49%

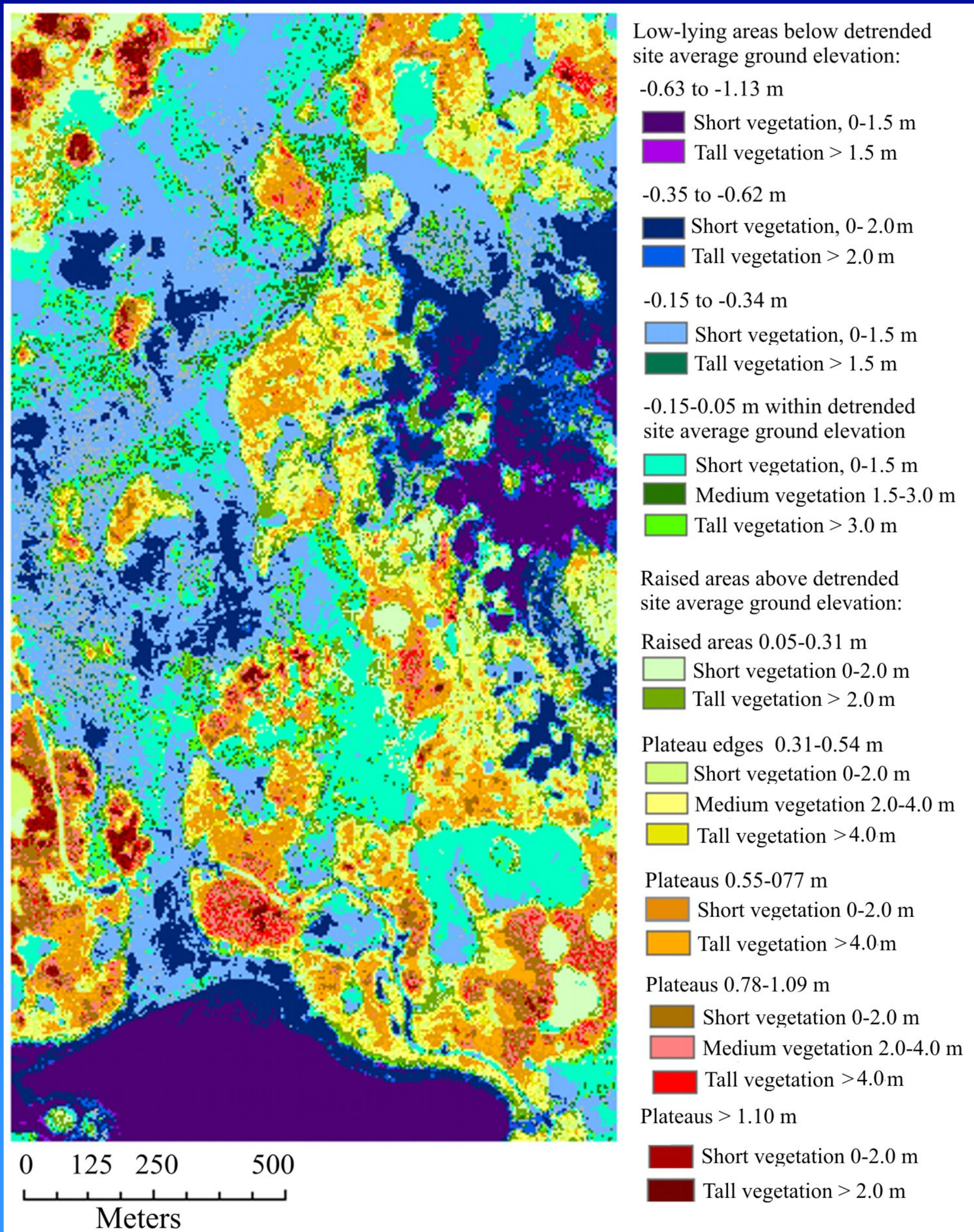
2008: 43%



Where is permafrost thaw occurring?



Above: Historical change in permafrost plateau area from 1947 to present using aerial photography and satellite imagery



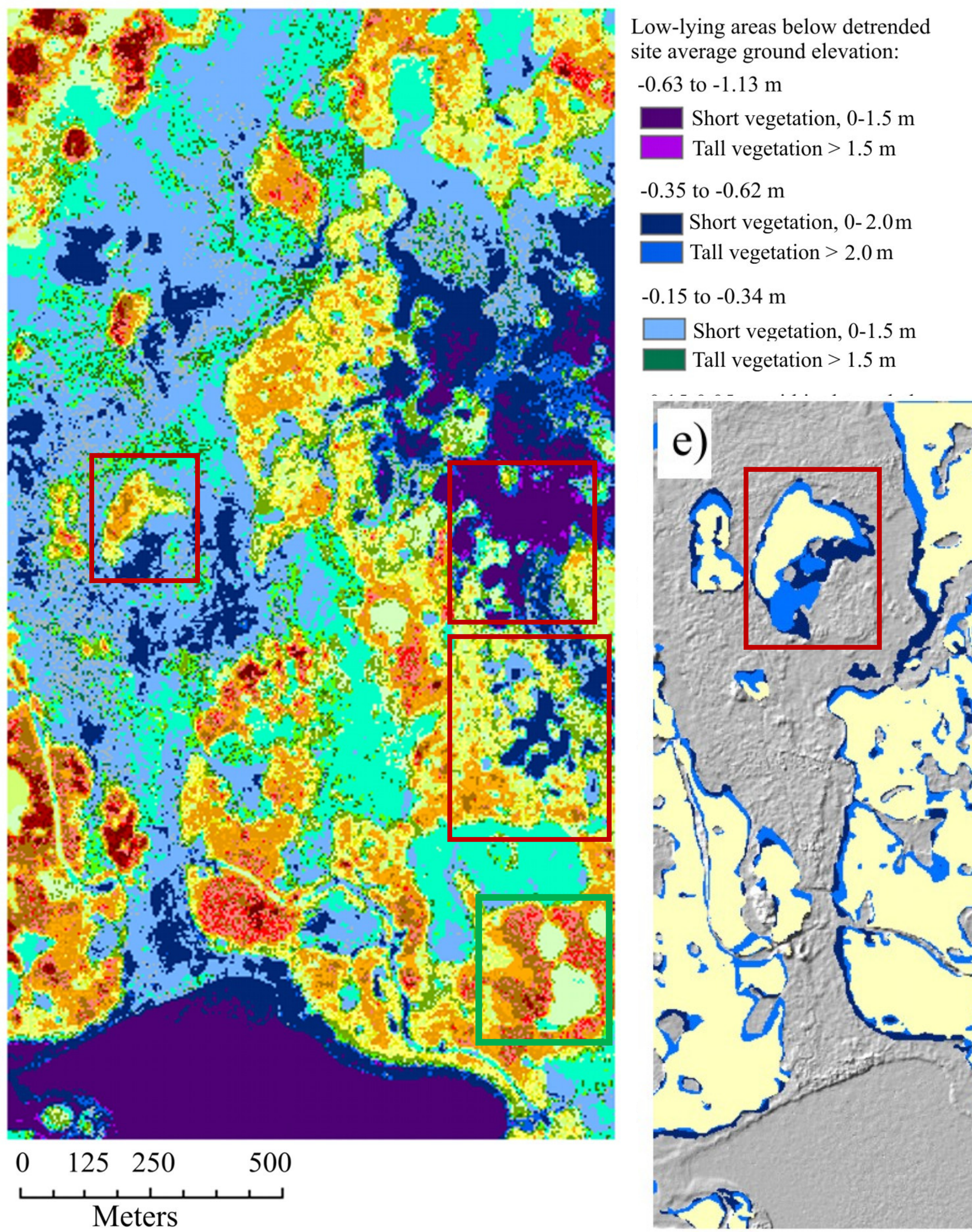
Land cover characteristics at Scotty Creek determined from 3-D airborne LiDAR data.

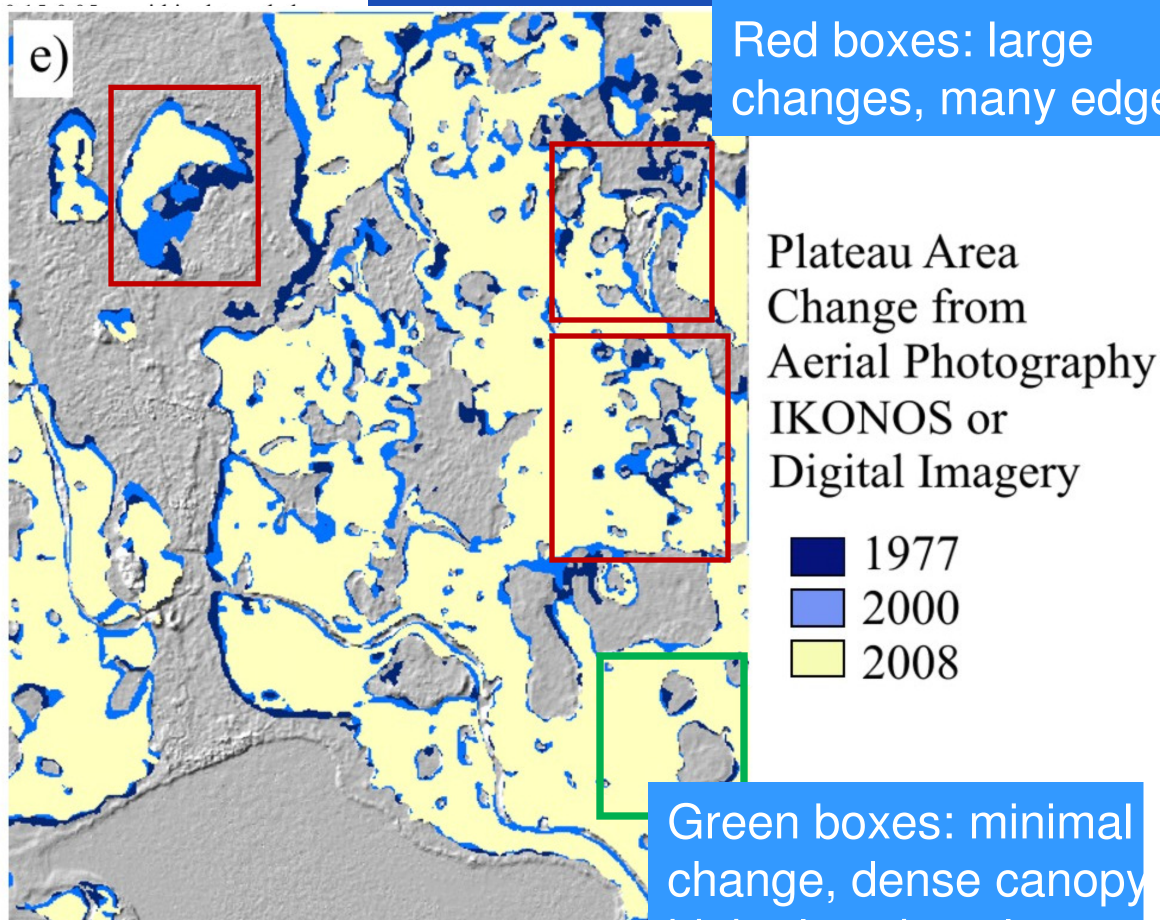
Warm colours represent plateaus of varying elevations and canopy characteristics

Cool colours represent low-lying areas: fens and bogs.

Low-lying areas with short vegetation with adjacent plateaus are likely to undergo most rapid thaw in the future: Evidence from historical change.

Edge properties are important.

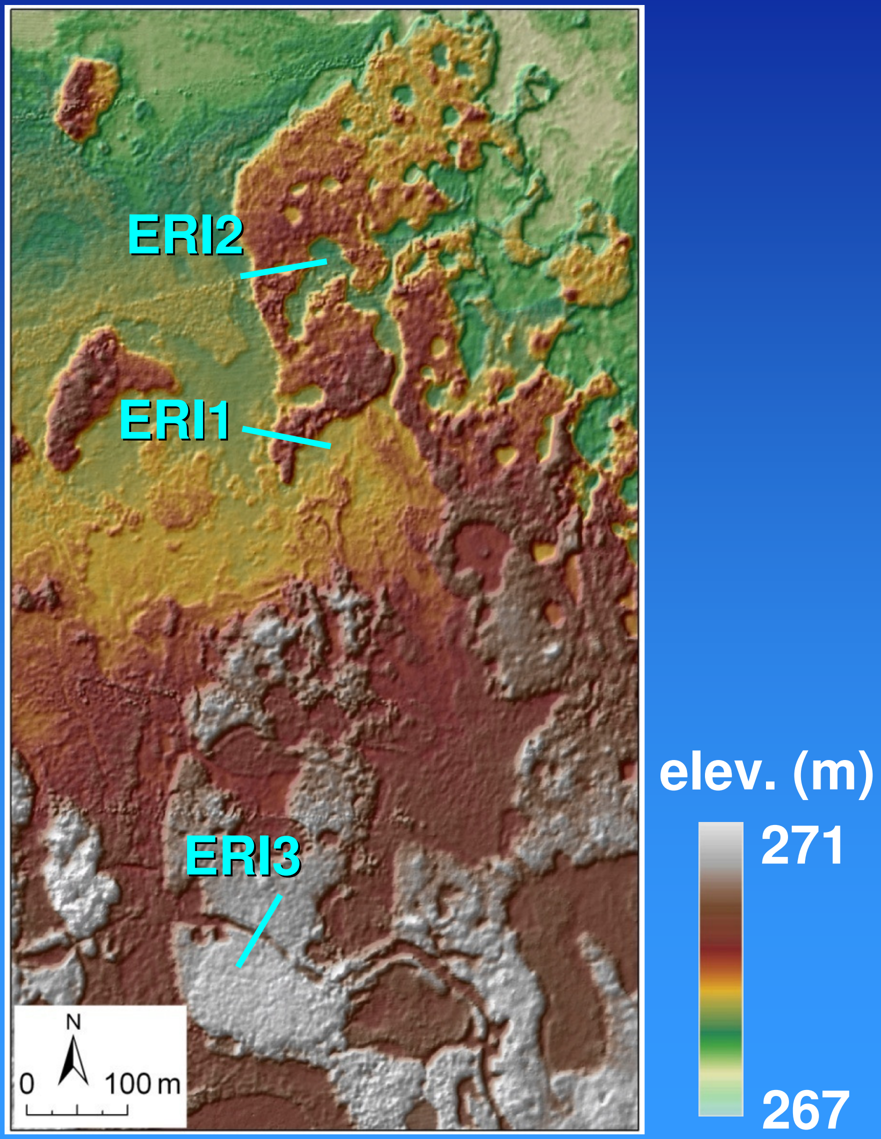




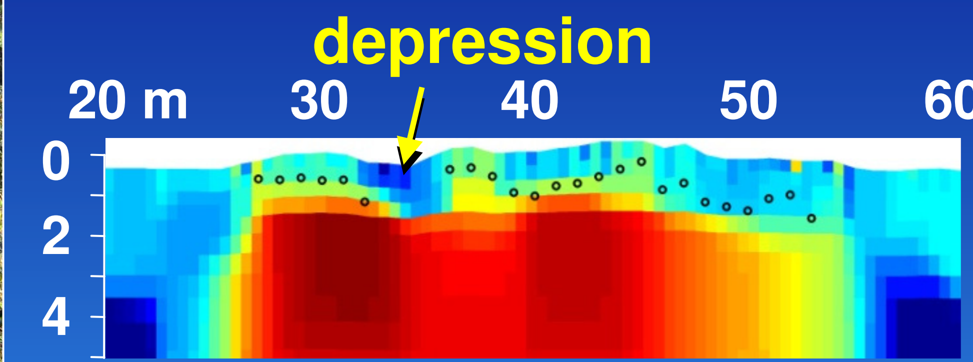
Red boxes: large changes, many edge

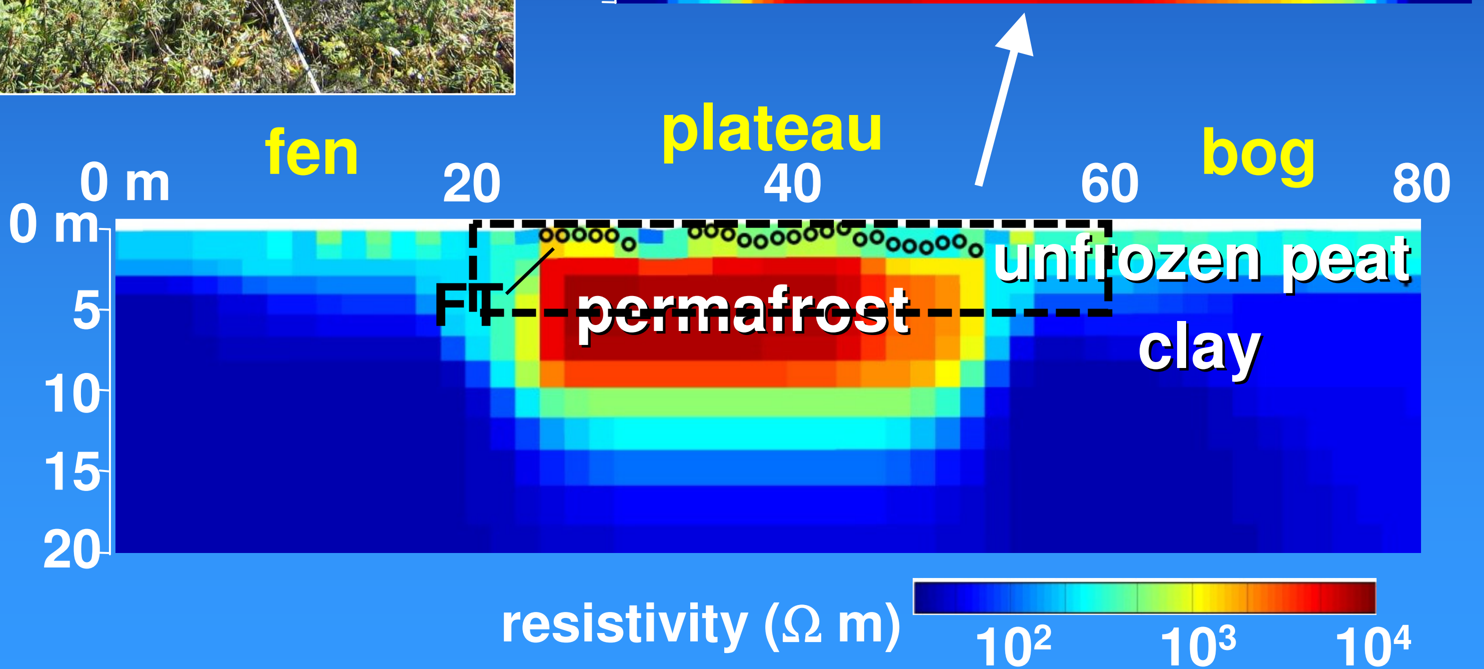
Green boxes: minimal change, dense canopy high elevation plateaus

Characterising permafrost edges with ERI



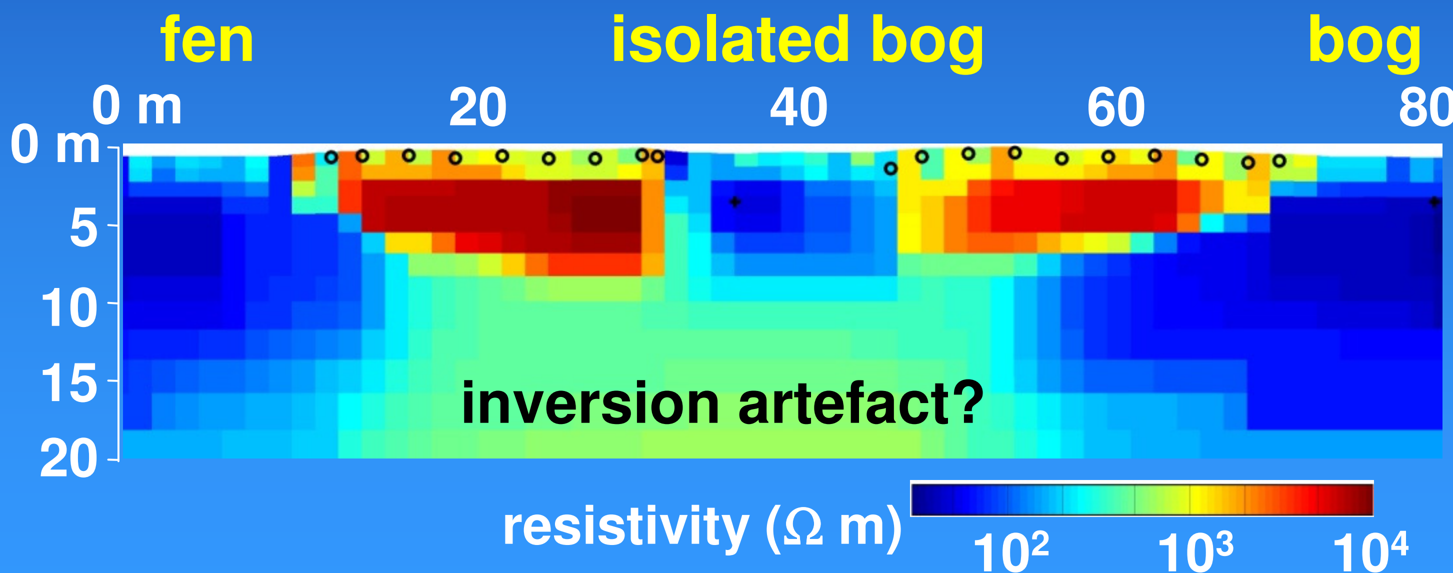
ERI Line 1: Peat Plateau Transect



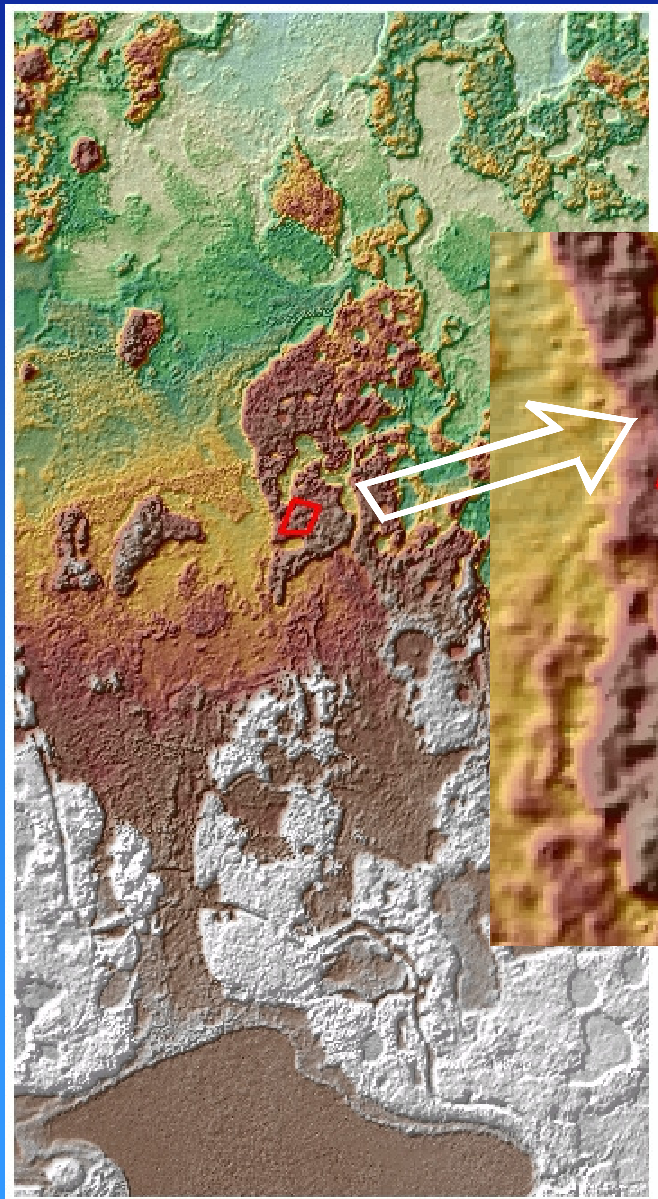


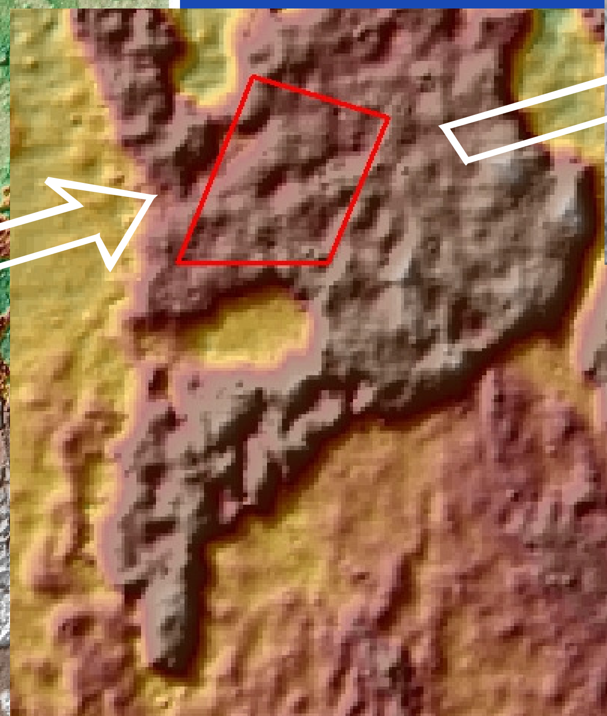
ERI Line 2: Cross-Bog Transect

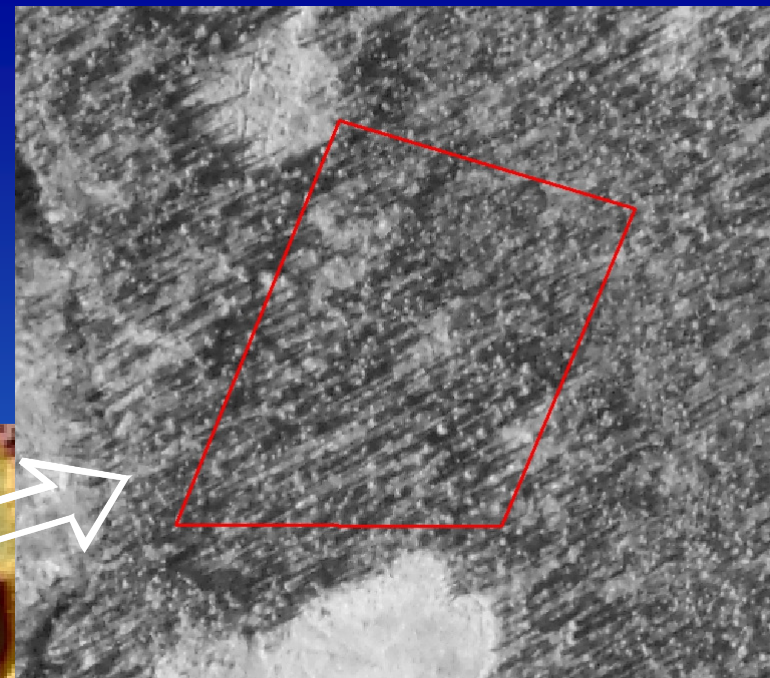
- Permafrost under the isolated bog has been "broken through".
- Possibility of groundwater recharge.
- It may become connected to larger bogs.



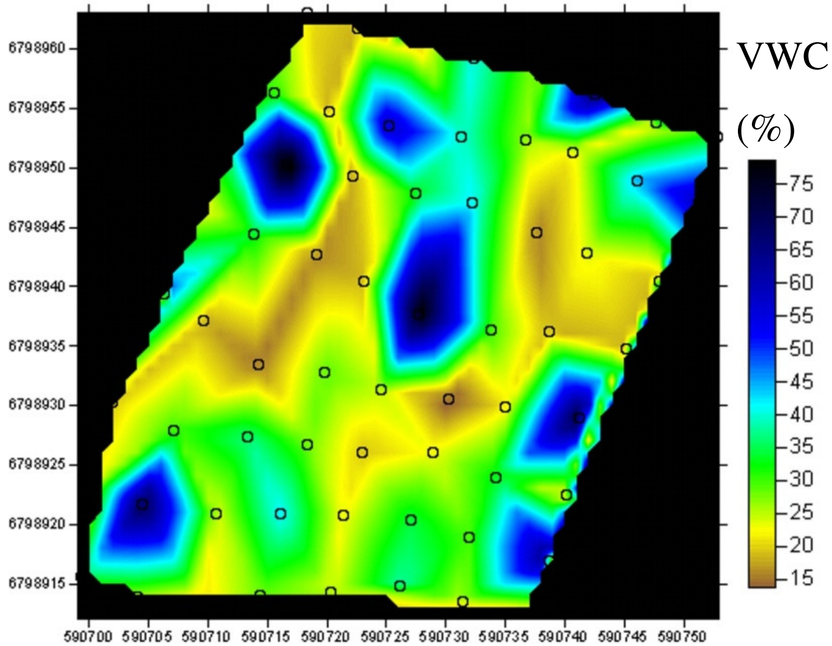
Away from the edges:

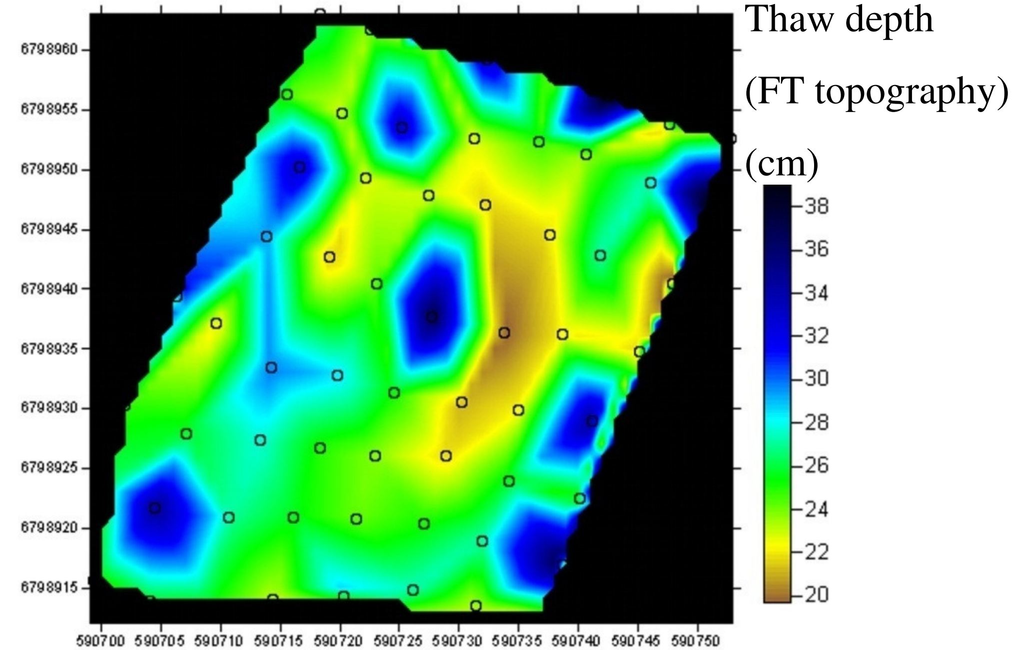


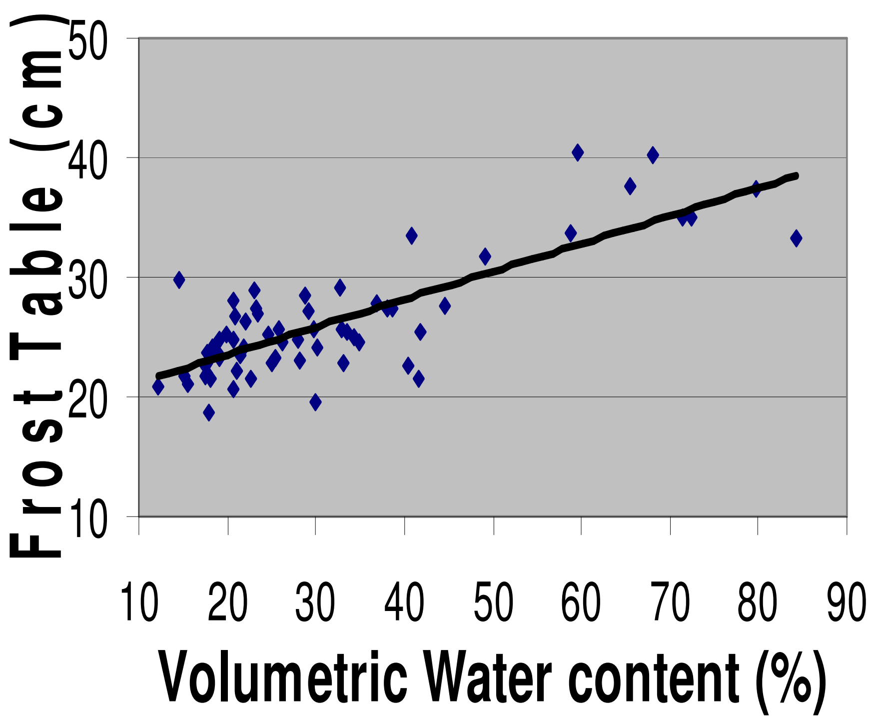


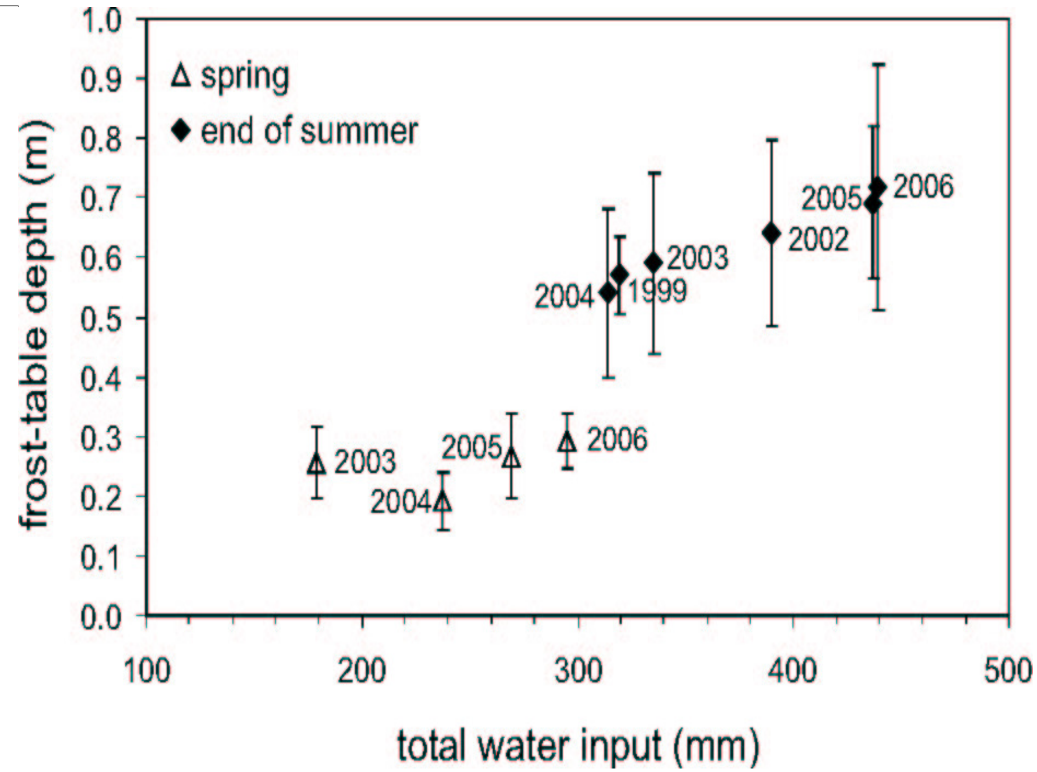


Site factors controlling seasonal thaw.

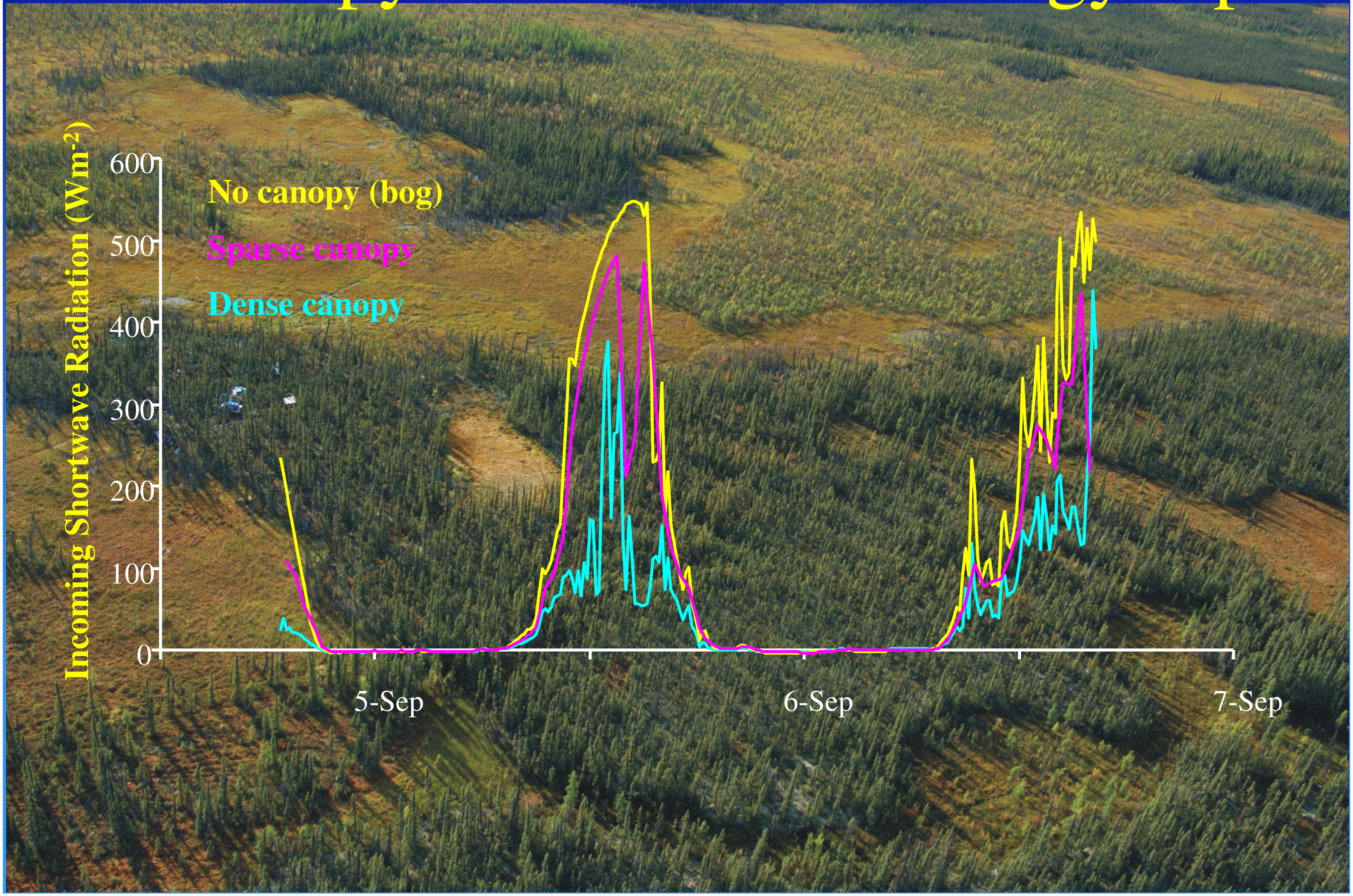

VWC
(%)
75
70
65
60
55
50
45
40
35
30
25
20
15


Thaw depth
(FT topography)
(cm)
38
36
34
32
30
28
26
24
22
20


Frost Table (cm)
Volumetric Water content (%)
10
20
30
40
50
60
70
80
90


Δ spring
◆ end of summer
frost-table depth (m)
total water input (mm)
2003
2004
2005
2006
1999
2002
100
200
300
400
500

Tree canopy controls thaw energy input:



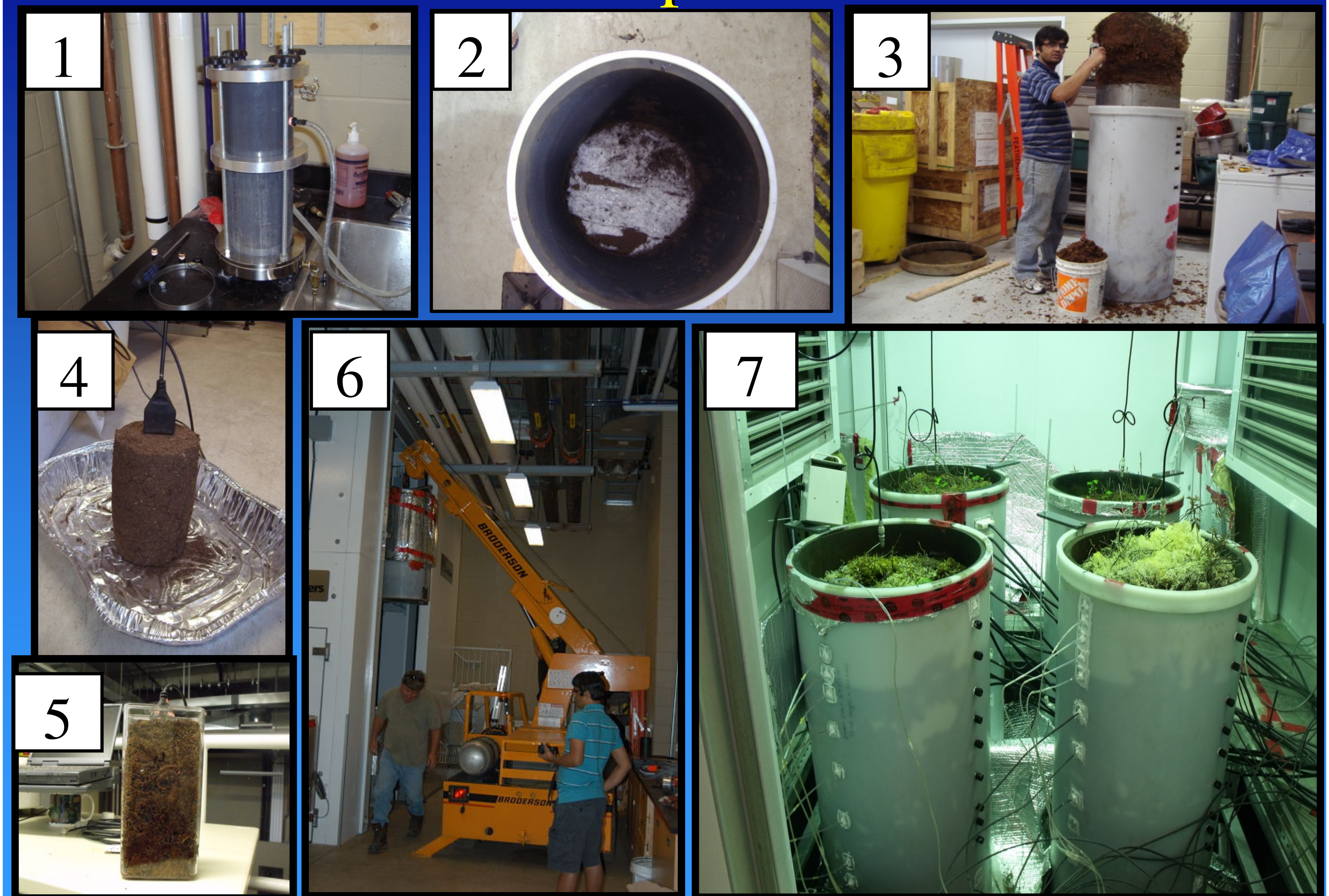
Lichen,
Labrador Tea

Moss,
Labrador Tea

bandsaw
blade

clean
undisturbed
break on
bottom

Soil Mesocosm Experiments:



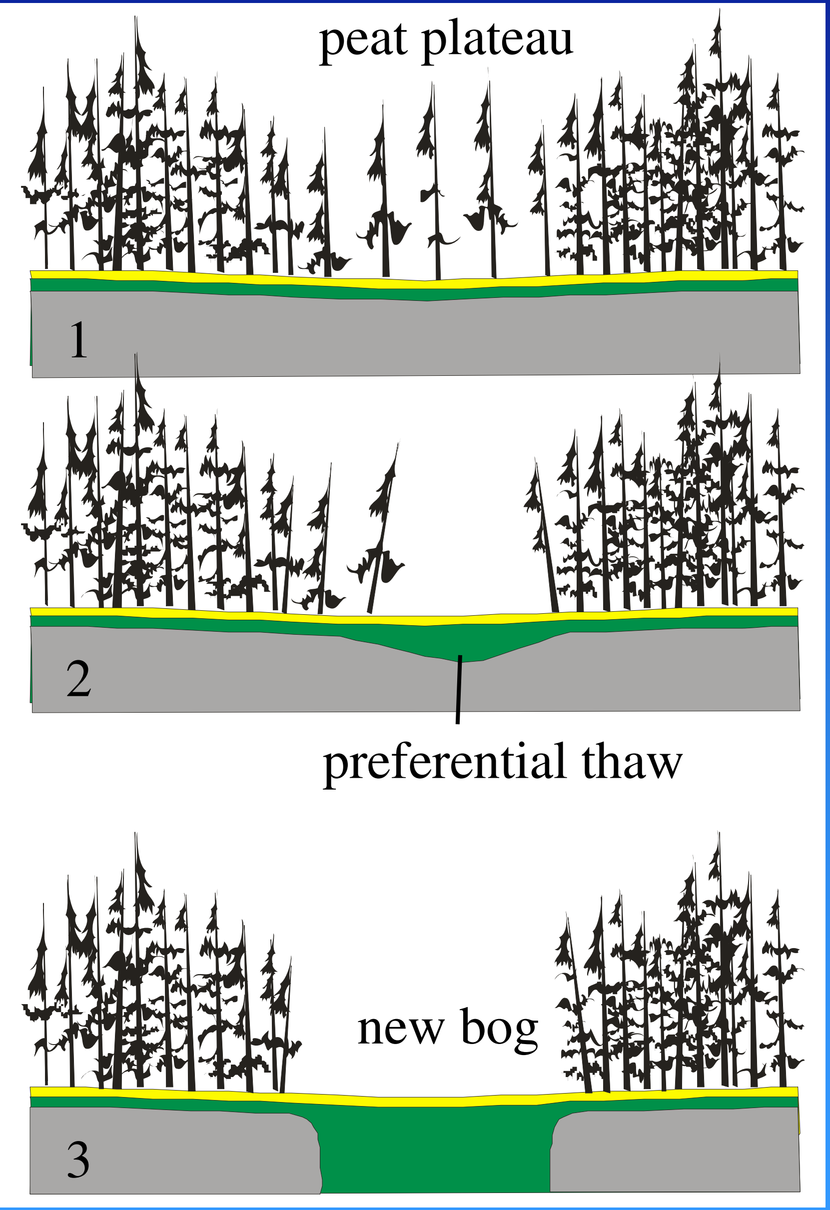
Factors controlling permafrost thaw:

1. Thinning of canopy.
   → Increase in solar energy input.
2. Local thawing.
   → Wet areas thaw faster and deeper.
3. Wet condition prevents trees from growing back.
   → New bog forms.

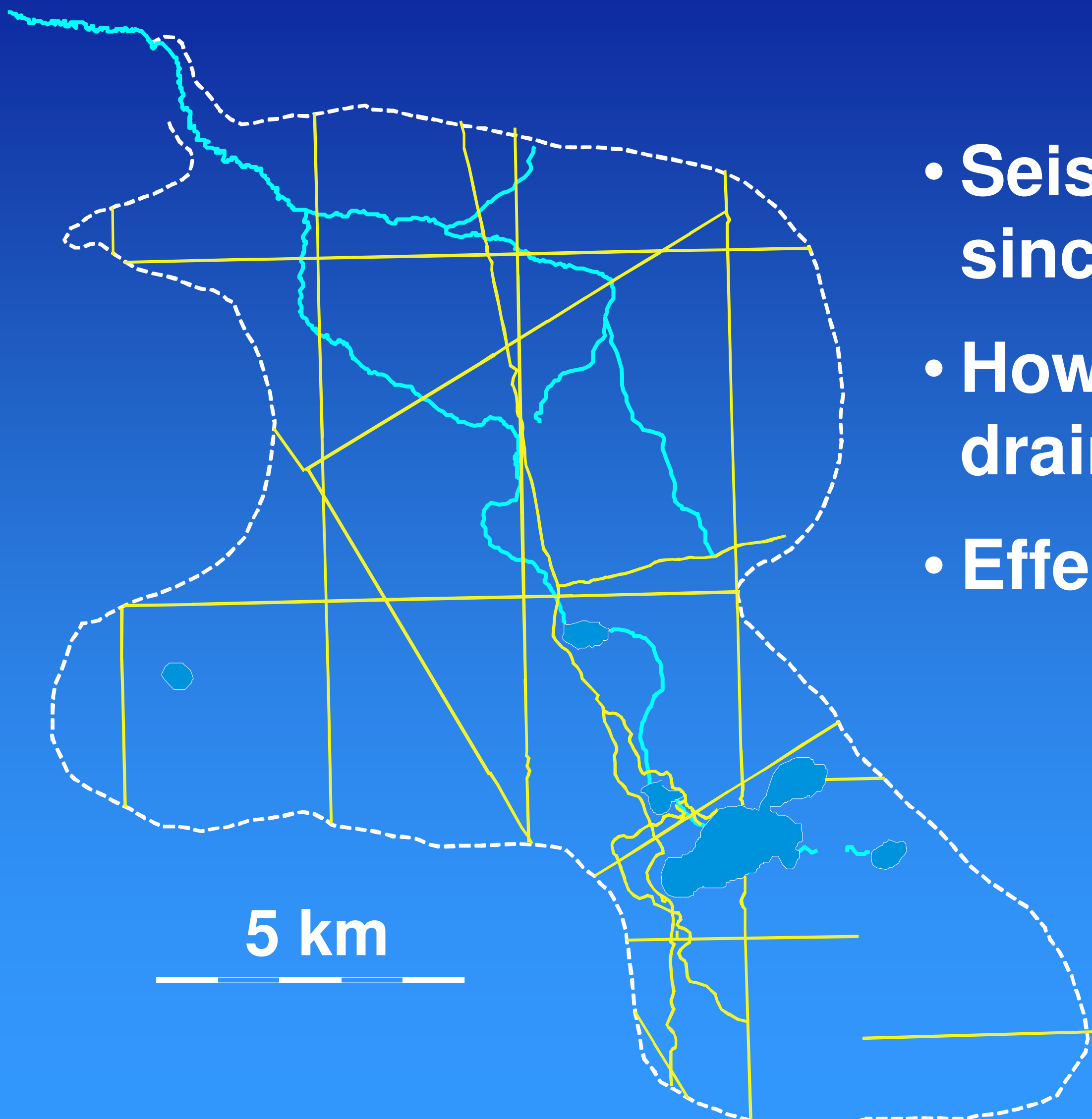
Unsaturated, thawed peat

Saturated, thawed peat

Saturated, frozen peat

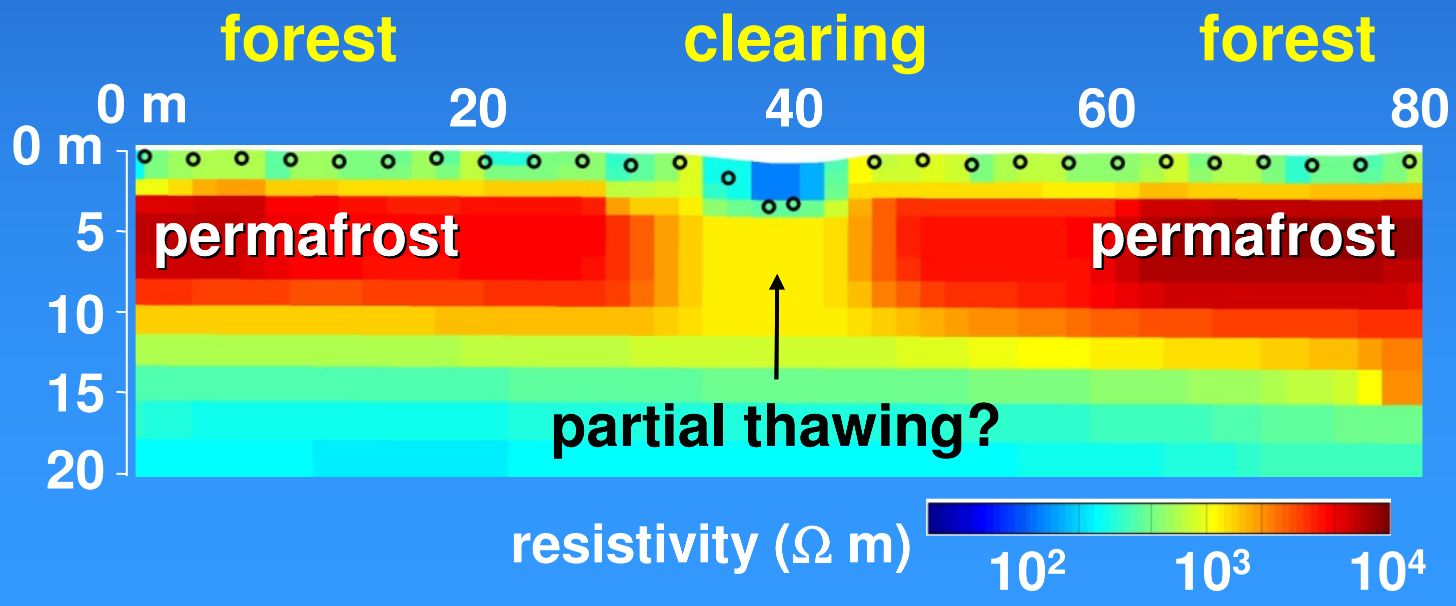


Linear Wetlands in Scotty Creek Watershed

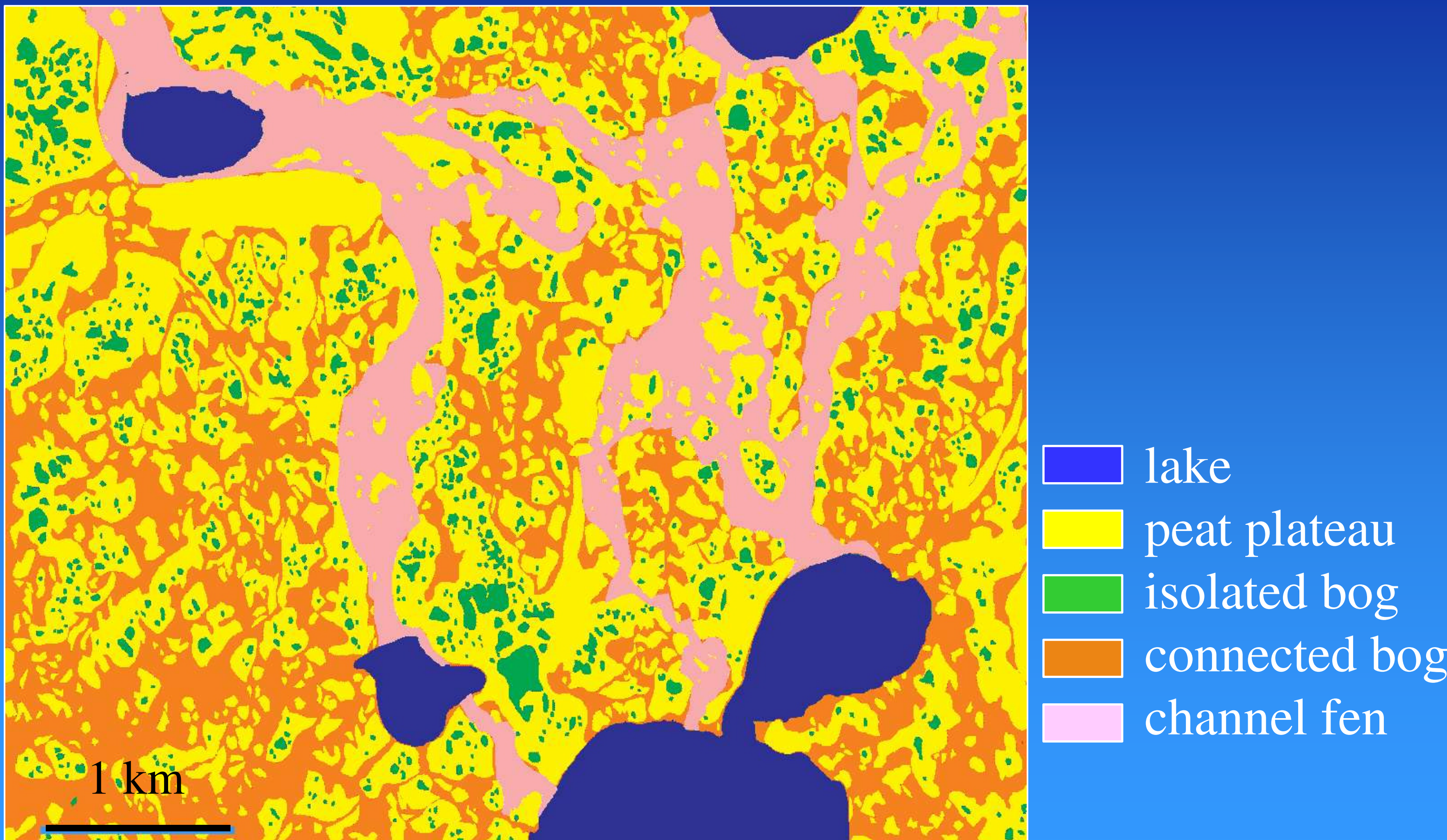


- Seismic exploration since the 1960s.
- How do they affect the drainage pattern?
- Effects of warming?

ERI Line 3: Winter Road (~45 yrs old)



Does Permafrost thaw influence streamflow?



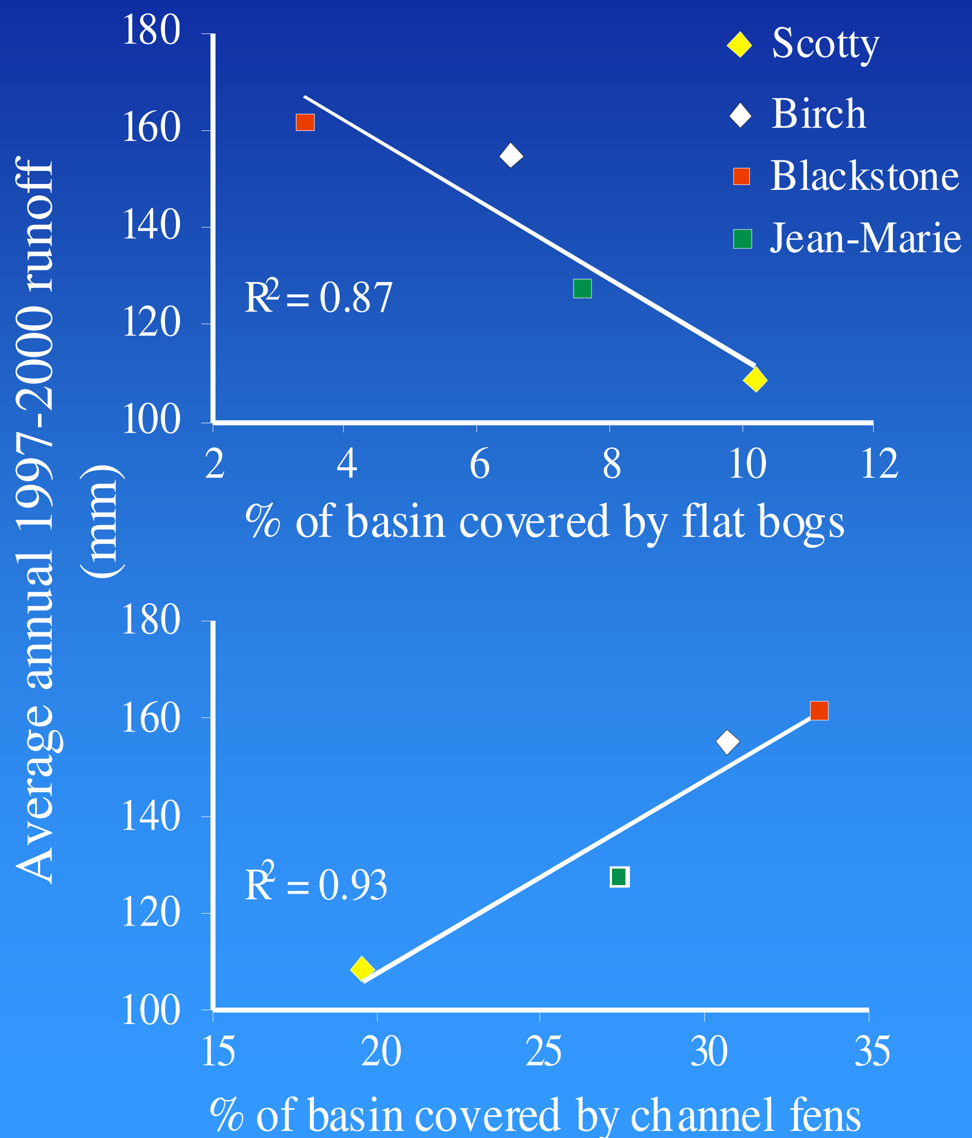
Basin Runoff Related to Cover Type

Four River Basins
(150-1300 km²)

- Scotty Creek
- Birch River
- Blackstone River
- Jean-Marie River

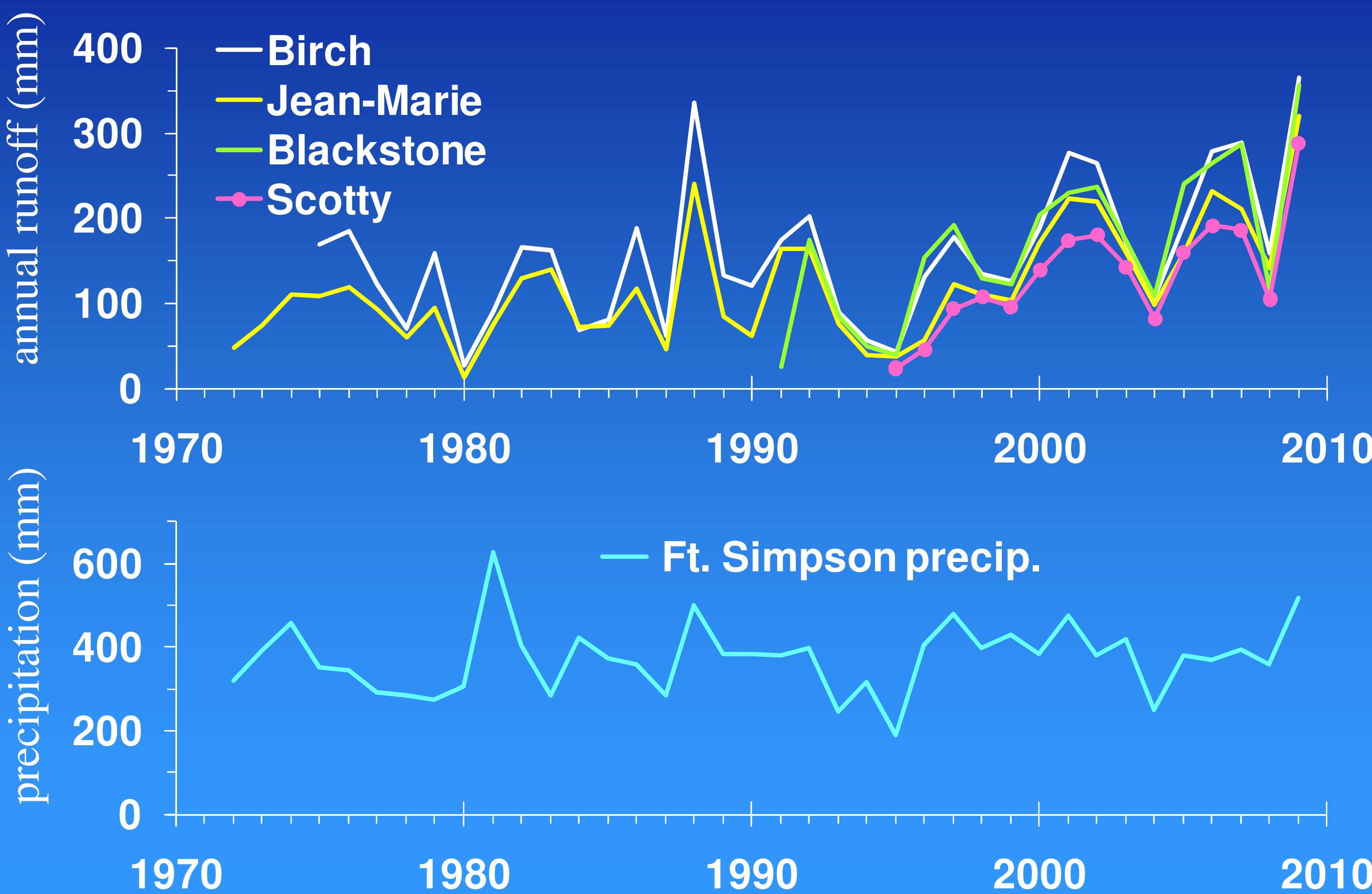
Different percentage of land-cover types

- bogs (storage)
- fens (drainage)



Annual Total Basin Runoff near Ft. Simpson:

Runoff = Total river flow / Drainage area



Approach & on-going work:

- The key to better prediction is improved process understanding.
- Link to other research themes - *e.g.* impact of permafrost thaw on water quality, wildlife, fisheries *etc*.
- Adaptation work – contribute to mitigation strategy development within the GNWT strategy/policy framework.
- Identify the key factors controlling the rates and patterns of preferential thaw leading to permafrost degradation,
- Develop a new model that simulates the permafrost response to climate warming and human disturbance,
- Develop conceptual & mathematical models of key hydrological processes, and
- Couple the hydrological and permafrost models to predict the spatial distribution of permafrost, and the river flow regime under scenarios of climate warming and human disturbance.