Influence of Permafrost Plateau Thaw on Carbon Exchanges along a Fen-Plateau-Bog Transect within the Discontinuous Permafrost Zone, Northwest Territories

L. Chasmer, A. Kenward, R. Petrone, and W. Quinton

Cold Regions Research Centre, Wilfrid Laurier University, Waterloo, Ontario, Canada N2L 3C5

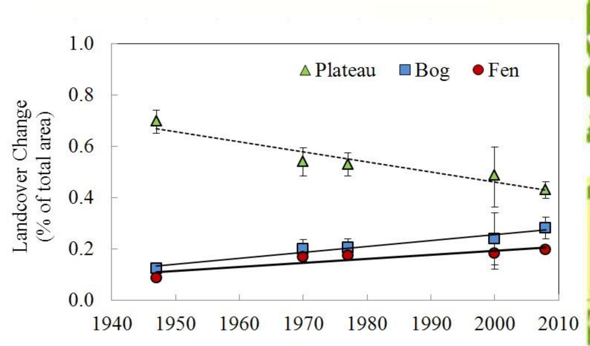
Email: lechasme@yahoo.ca

The southern boundary of the discontinuous permafrost zone of north-western Canada is dominated by peatlands (bogs, fens), and tree covered permafrost plateaus. Peatlands contain ~1/3 of the global soil C pool and are sensitive to changes in soil moisture and air temperature.

The thaw and conversion of plateaus to fen *or* bog ecosystems has unknown but potentially significant implications for net CO_2 exchange.

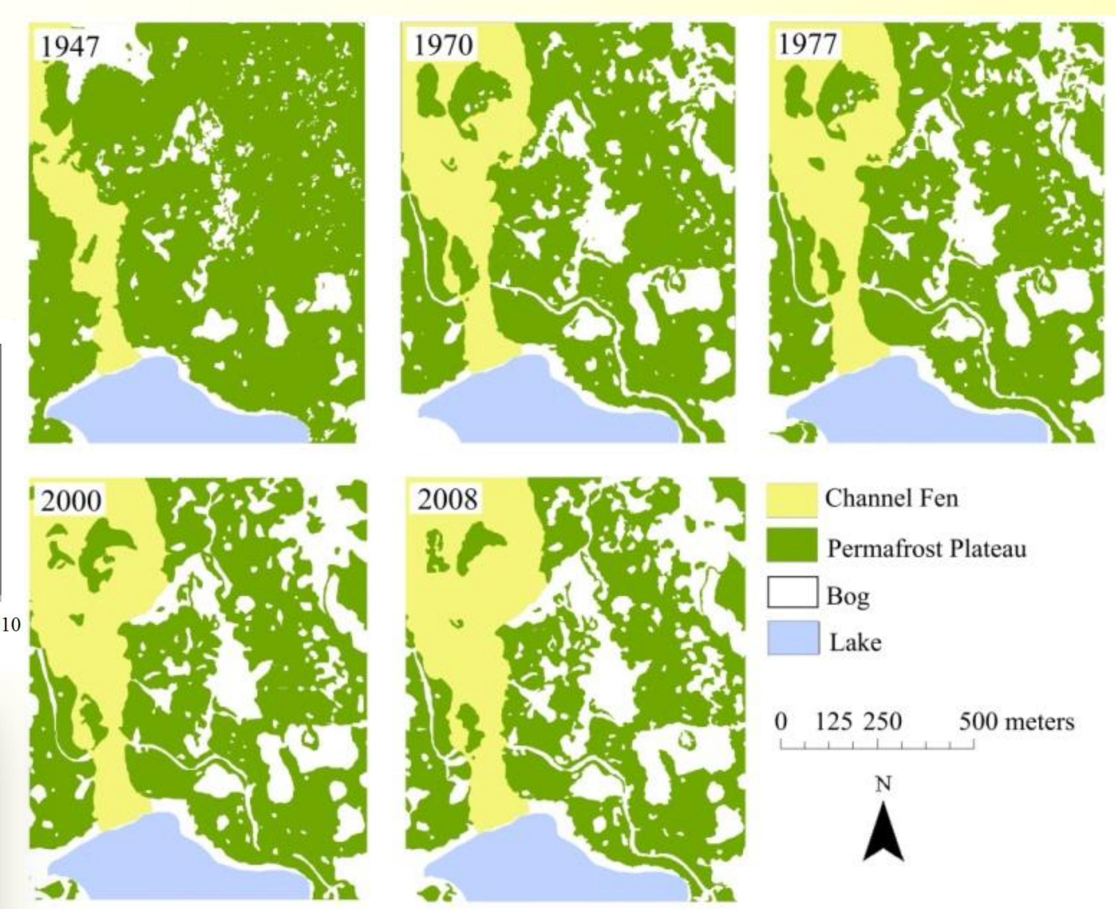
In this study, net ecosystem exchange (NEE) and total soil/ground cover respiration (R_{tot}) were measured during spring snow melt and green-up period (April 26 to June 6, 2008) using 9 soil chambers within bog, fen, and plateau land cover types.

Permafrost Thaw at Scotty Creek, NWT 1947 – 2008 (aerial photography)



Total change in land cover area 1947 – 2008:

Plateau = ↓ 27%
Bog = ↑ 16%
Fen = ↑ 11%



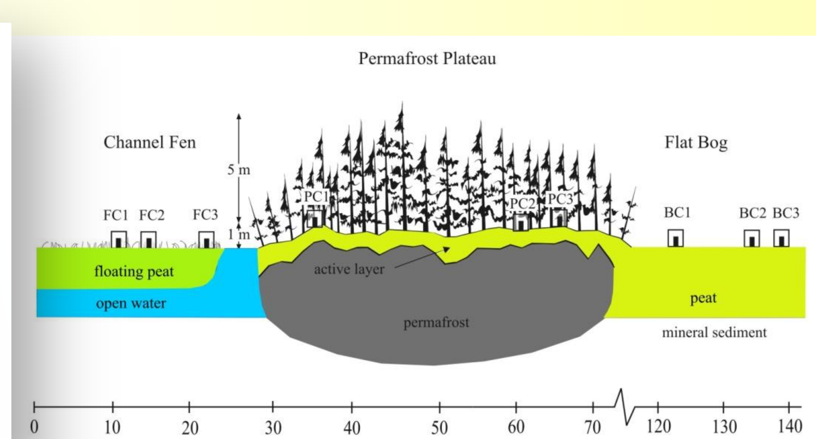
Permafrost plateaus have become increasingly fragmented, such that the perimeter:area ratio has increased linearly from 0.03 (1947) to 0.08 (2008).

Objectives

1. Quantify soil CO_2 exchanges and drivers within bog, fen, and plateau land cover types.

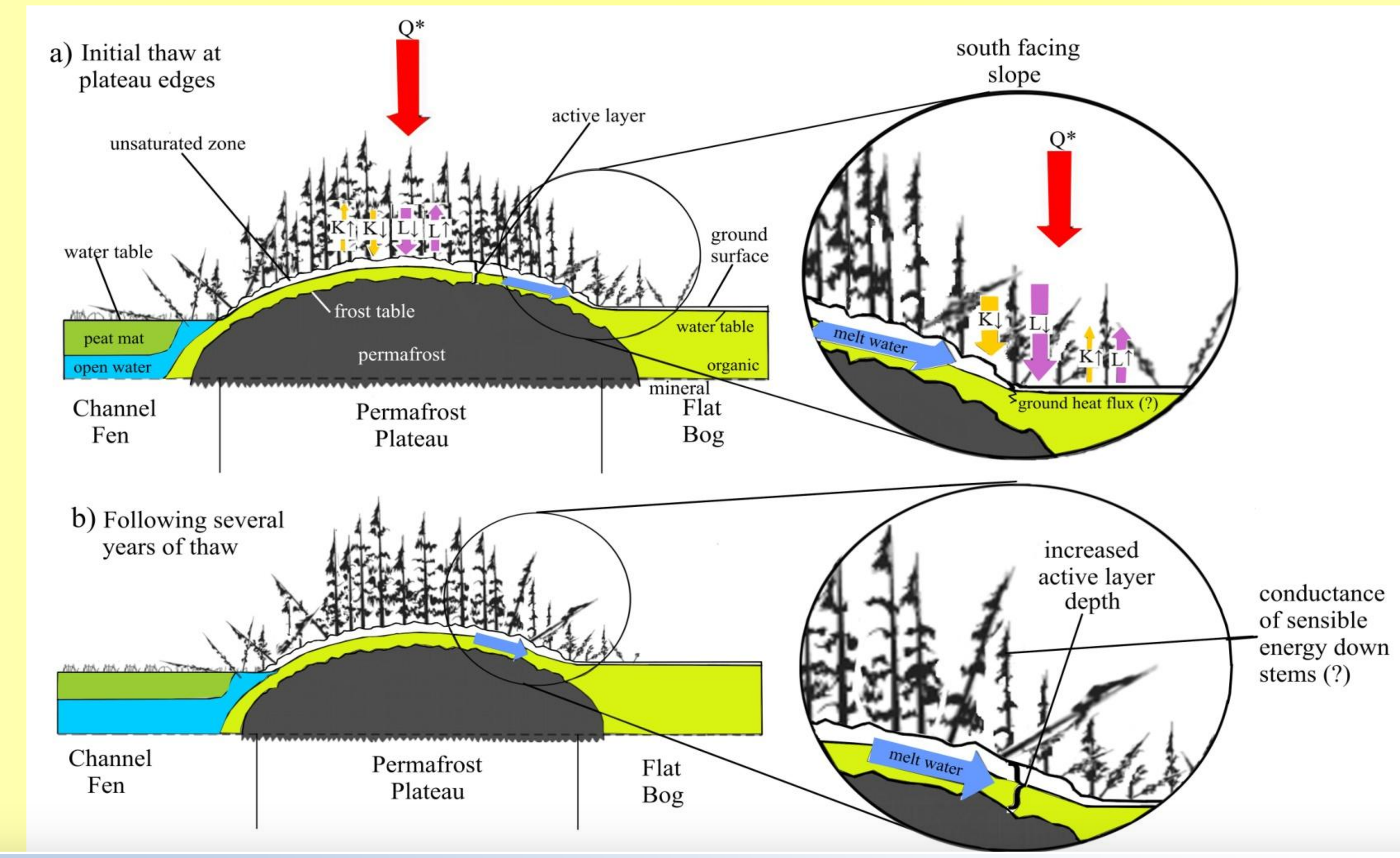
Cross section of CO_2 flux chambers along ~140 m transect at Scotty Creek. FC = Fen chambers, PC = plateau chambers, and BC = bog chambers

Based on a classification of vegetation structural and topographic characteristics within 2 m of each chamber, chambers represented 53%, 72%, and 59% of total plateau, bog, and fen areas within the study basin



2. Determine impact of land cover change on aerially weighted fluxes from 1947 to 2008.

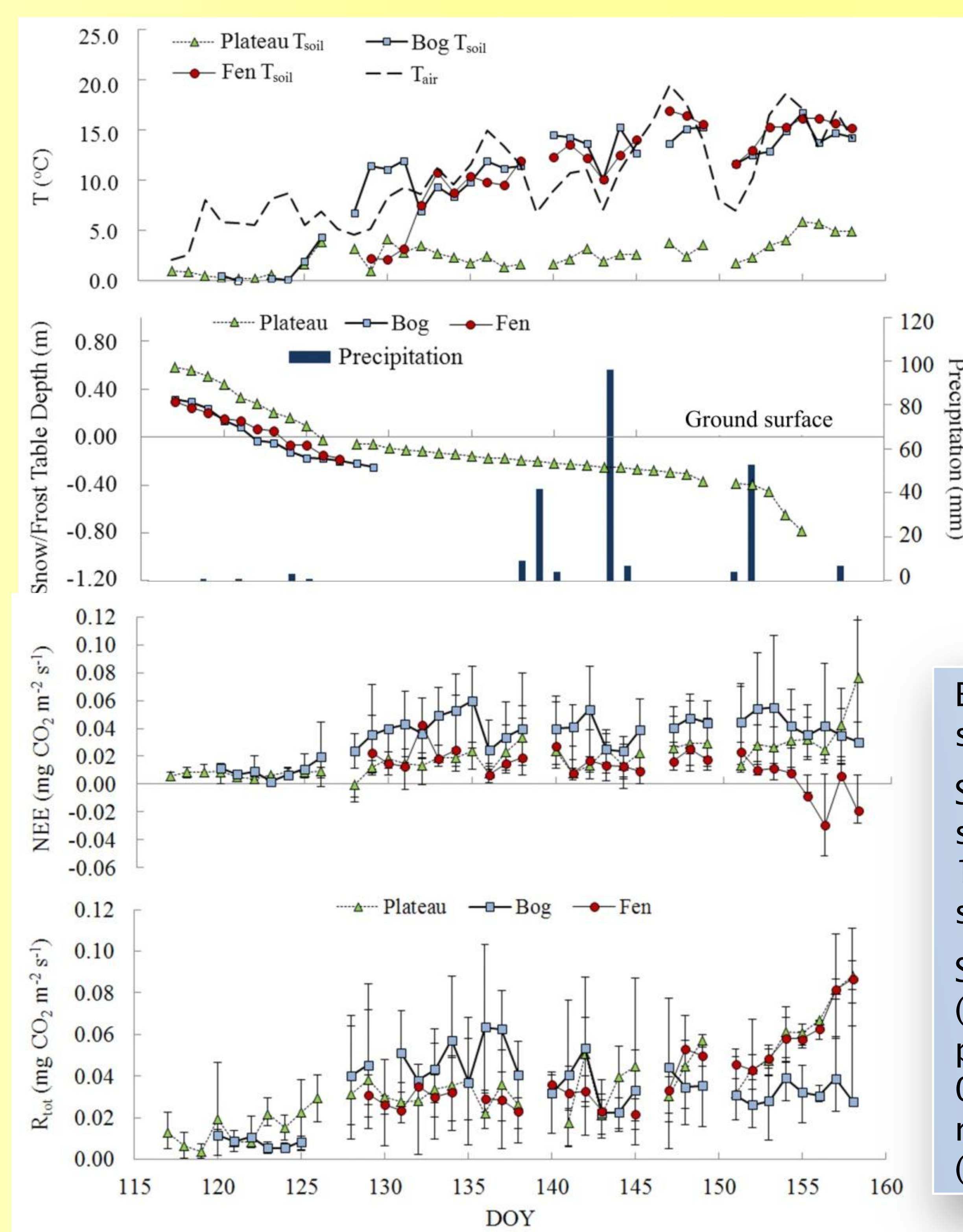
Impacts of Plateau Land Cover Change

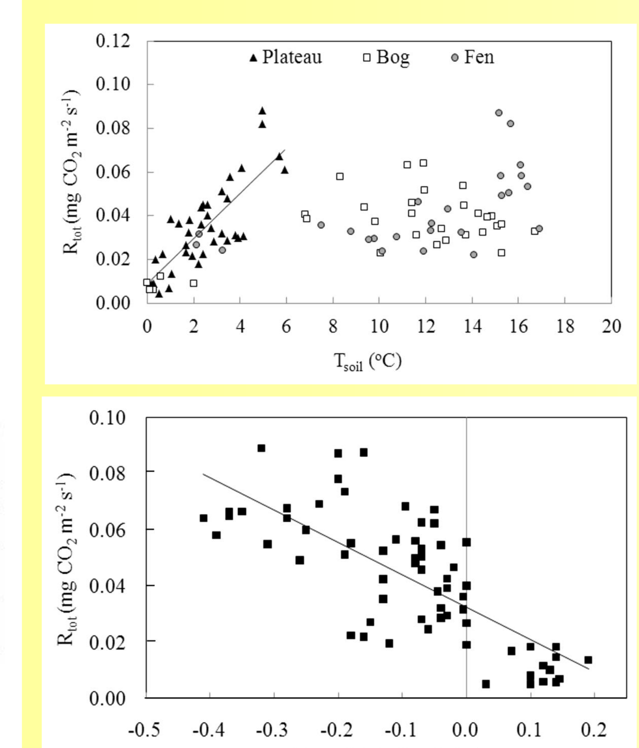


Schematic of radiation influences on permafrost thaw during the growing season. Magnitudes of energy (Q* net radiation, K shortwave, L long wave) and melt water transfer are shown based on width of arrows. a) Warming of ground surface = increased melt water runoff and tree mortality. b) After several years of thaw, radiation incident on tree stems increases long wave fluxes and thaw of active layer.

Results

Variability of CO_2 Exchanges, Drivers





Bog is greatest source, Fen is smallest source (positive NEE).

Sites become significant source of CO_2 to atmosphere 1-2 days following complete snowmelt.

Soil/ground cover respiration (R_{tot}) at plateau and fen sites is positively related to T_{soil} ($r^2 = 0.63$, $p < 0.01$) and negatively related to depth to water table ($r^2 = 0.56$, $p < 0.01$).

Results

Soil Characteristics

Table 1. Landcover type soil core analysis of averaged within the top 20 cm of the soil column.

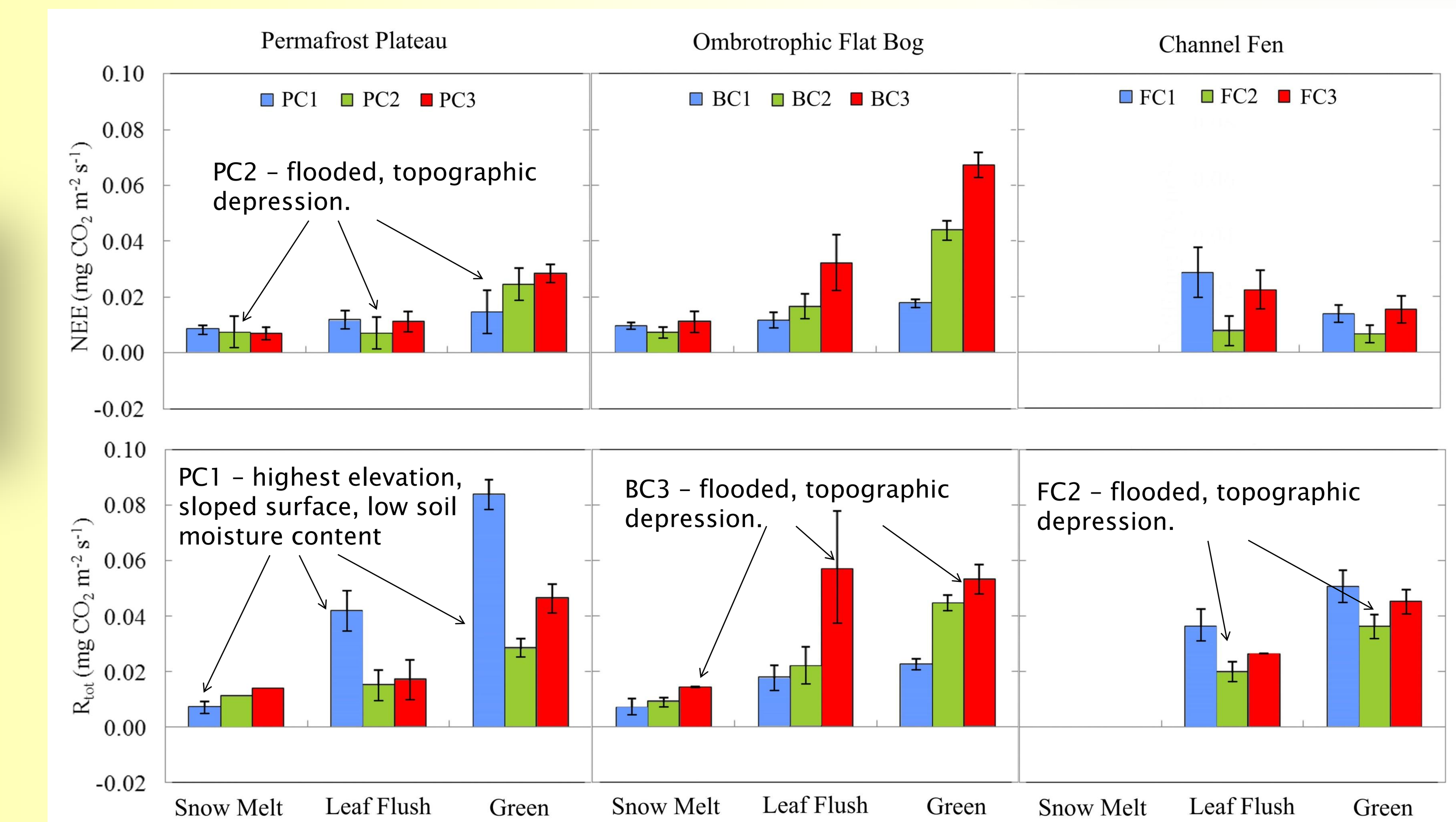
Landcover Type	ρ_b (g/cm³)	Φ (%)	Φ_d (%)	VonPost decomposition	LOI (%)	TC (%)	TN (%)	C:N
Permafrost Plateau	0.10	80.6	0.20	H1-H3	96.5	44.7	0.80	55.9
Flat Bog	0.04	41.9	0.42	H1-H4	97.2	47.4	0.91	52.1
Channel Fen	0.04	32.5	0.39	H2-H4	94.1	48.7	1.2	40.6

P_b = bulk density, Φ = porosity, Φ_d = specific yield, VonPost = degree of decomposition (H1 not decomposed, H10 fully decomposed). LOI = Loss on ignition (% of organic material), TC = total carbon, TN = total nitrogen , C:N = ratio of carbon to nitrogen

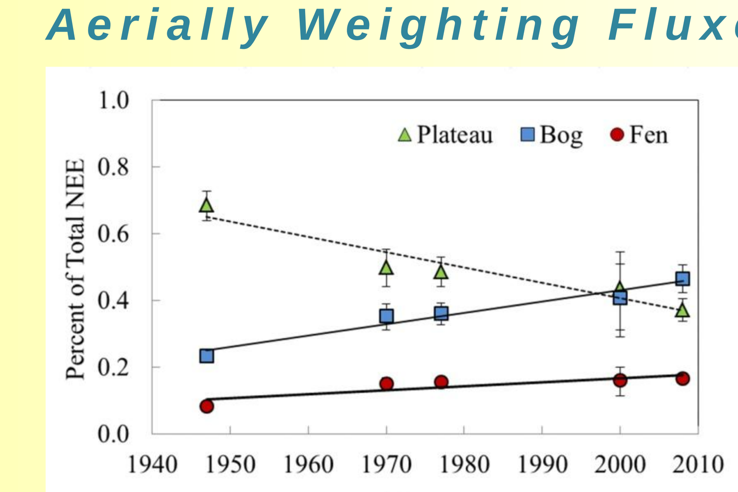
High N and C:N ratio often related to decomposition of organic matter and greater rates of respiration.

Porous, dry soils found at plateau site (average = 80.6% ±4.1%) may have aided in CO_2 diffusion to atmosphere.

Micro-topographic Influences on Fluxes



Aerially Weighting Fluxes: Historic Change



NEE Cumulative Change

Plateau = ↓ 45%
Bog = ↑ 98%
Fen = ↑ 99%

73% of the thawed plateau area (since 1970) converted into bog.

Take Home Message:

1. Conversion of plateaus to bog or fen land cover types with warming could have significant influences on soil CO_2 exchanges.
2. Plateaus are converting more rapidly into bog than fen.
3. Micro-topography has a significant and opposite influence on fluxes, depending on land cover type (e.g. Sulman *et al.* (2010), *GRL*).
4. Based on aerial weighting, area has become a greater source of CO_2 (↑14%) over the last 60 years during the spring thaw period (all else being equal to 2008).

Acknowledgements: IP3 network, including Drs. Masaki Hayashi, John Pomeroy, Nicole Wright, and field help from Tyler Veness. LiDAR and digital aerial photography provided in collaboration with Dr. Chris Hopkinson at the Applied Geomatics Research Group. Also thanks to Liidlii Kue First Nation. Funding provided by CFCAS, NSERC. Discussions with Dr. Oliver Sonnentag also appreciated.