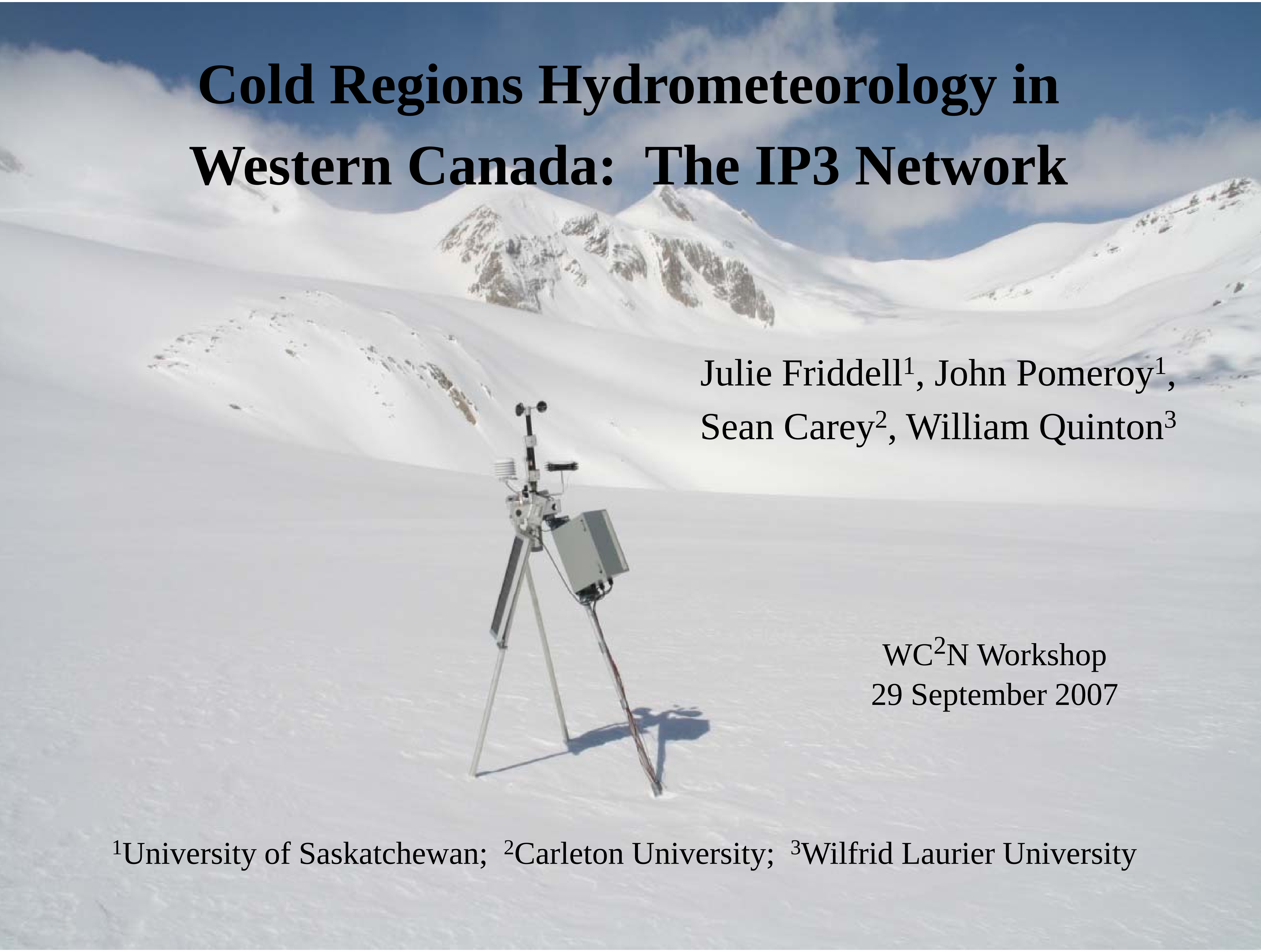
Cold Regions Hydrometeorology in Western Canada: The IP3 Network



Julie Friddell[1], John Pomeroy[1], Sean Carey[2], William Quinton[3]

WC²N Workshop
29 September 2007

[1]University of Saskatchewan; [2]Carleton University; [3]Wilfrid Laurier University

IP3...

- ...is devoted to understanding **water supply** and **weather systems** in cold regions (Rockies and western Arctic)

- ...will contribute to better prediction of regional and local **weather, climate, and water resources** in cold regions, including ungauged basin **streamflow,** changes in **snow and water supplies,** and calculation of **freshwater inputs** to the Arctic Ocean

- ...has organized a **Users' Advisory Committee** to guide development of relevant **data and model outputs**

IP3

Improved Processes & Parameterisation for Prediction in Cold Regions

Canadian Foundation for Climate and Atmospheric Sciences (CFCAS)

Fondation canadienne pour les sciences du climat et de l'atmosphère (FCSCA)

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- Hydrometeorology & Arctic Laboratory (HAL)
- Meteorological Research Branch (MRB)
- National Water Research Institute (NWRI)
- Water Survey of Canada

GEWEX/GLASS
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International Polar Year (IPY) - Cold Land Processes
Natural Resources Canada
Northwest Territories Power Corporation
Predictions in Ungauged Basins (PUB)
USDA Agricultural Research Service
Parks Canada
Saskatchewan Watershed Authority
Yukon Environment

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Dan Moore – University of
British Columbia

John Pomeroy (PI)

Bob Reid – Indian and Northern Affairs Canada, Yellowknife

Vincent Fortin – Environment Canada, Montreal

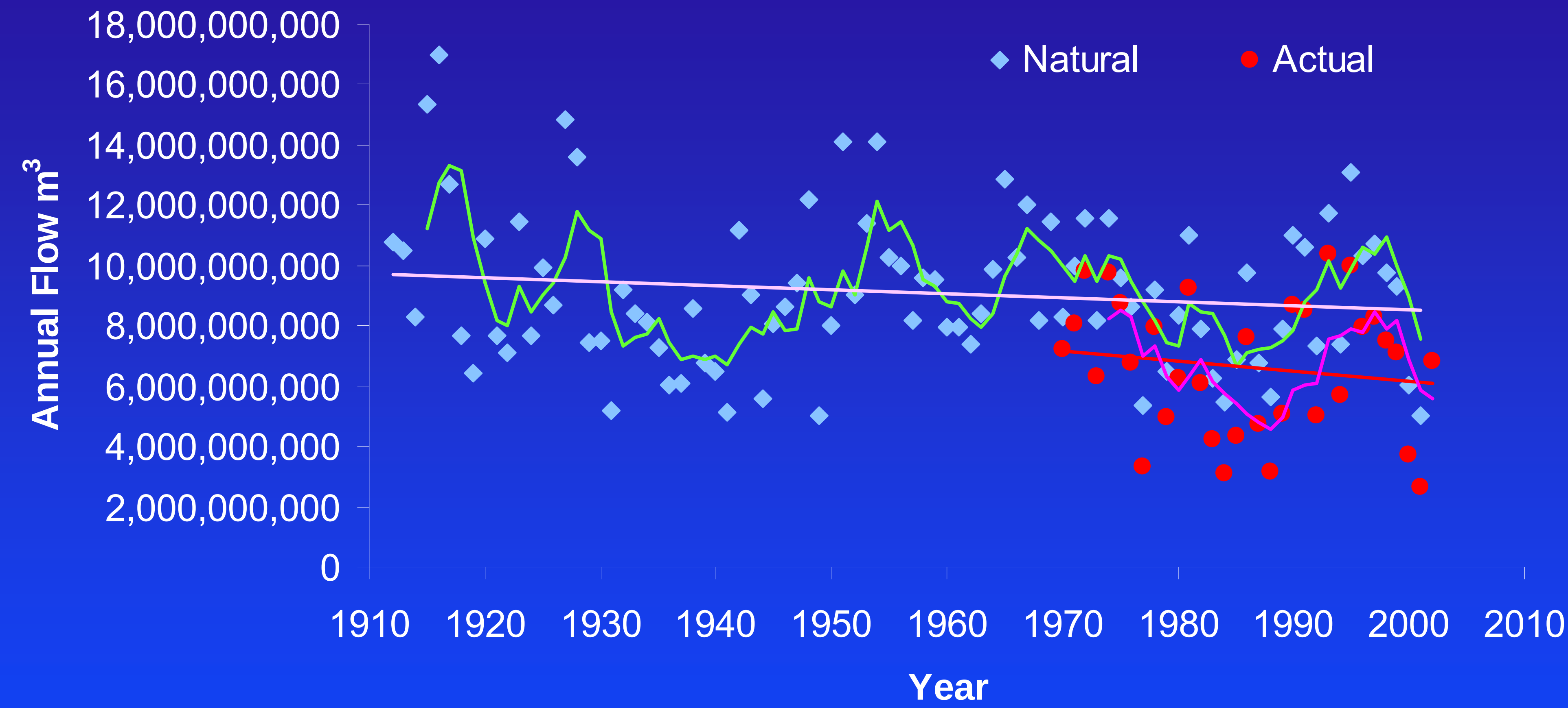
Julie Friddell (Network Manager, Secretary)

Why IP3?

- Need to forecast changing annual flow/ peak discharge in streams and rivers in the Rockies and North
- Increasing consumptive use of Rocky Mountain water in Prairie Provinces
- Uncertainty in engineering design for resource (oil & gas, diamond and other mines) development and restoration activities in small to medium size ‘ungauged’ basins
- Opportunity to include cold regions processes in coupled atmospheric-hydrological models to reduce uncertainty at small spatial scales in:

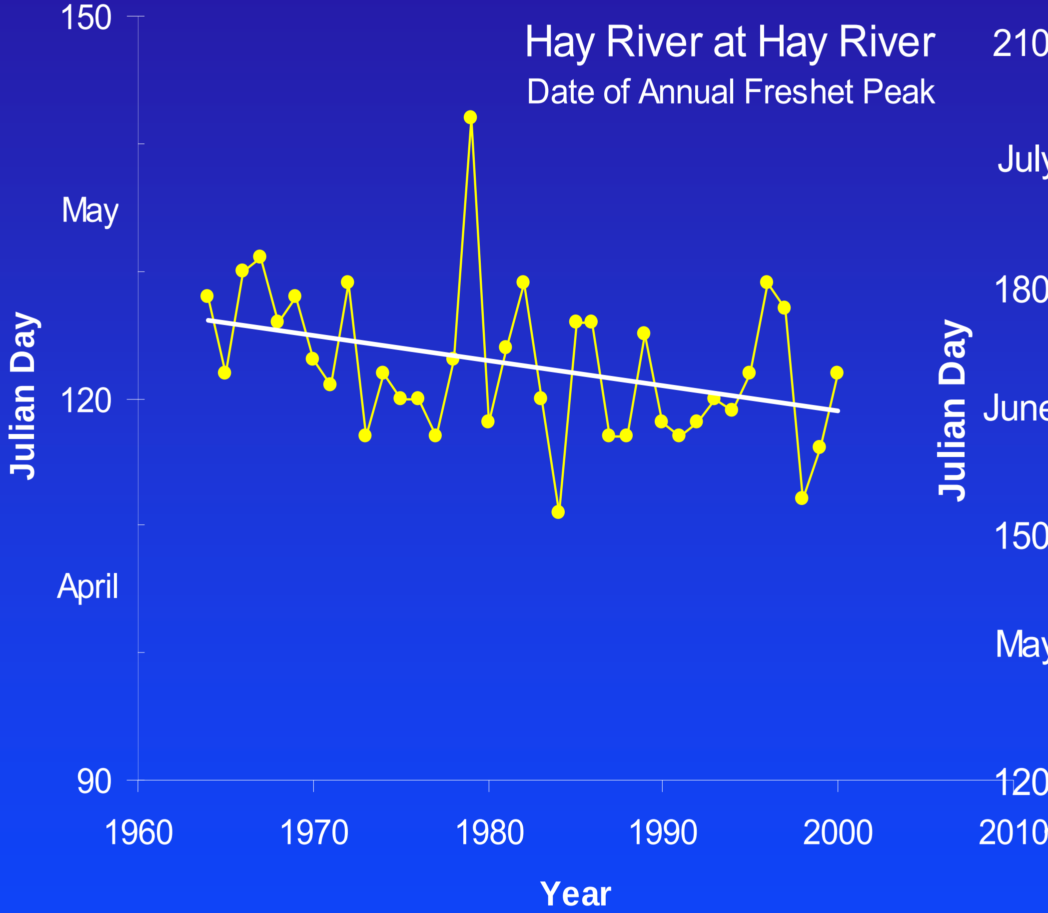
    Atmospheric impacts on water resources
    Simulation of land-atmosphere interaction
    Cycling and storage of water
    Prediction of future climate change

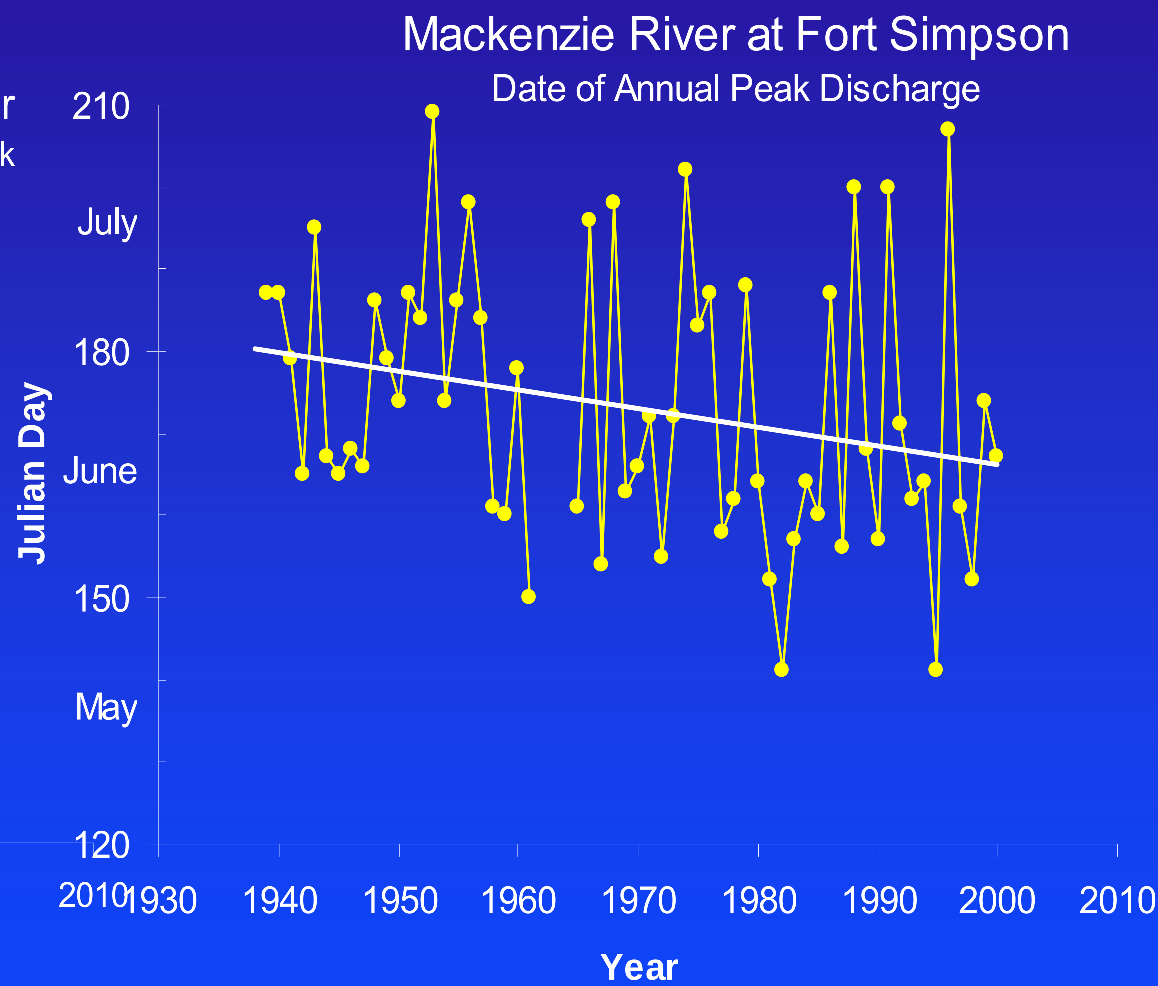
Naturalized Flow of South Saskatchewan River entering Lake Diefenbaker



Natural flow: Decline of 1.2 billion m^3 over 90 years (-12%)
Actual flow: Decline of 1.1 billion m^3 over 30 years (-15%)
Decline of 4 billion m^3 over 90 years (-40%)
Note: 70% of decline due to consumption, 30% due to hydrology
Upstream consumption: 7%-42% of naturalized flows in last 15 years

Date of Spring Freshet

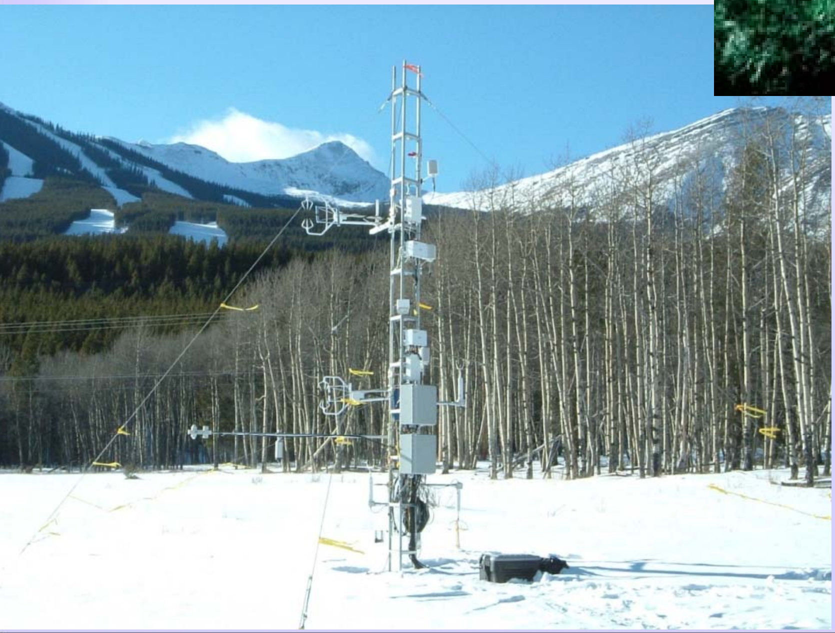


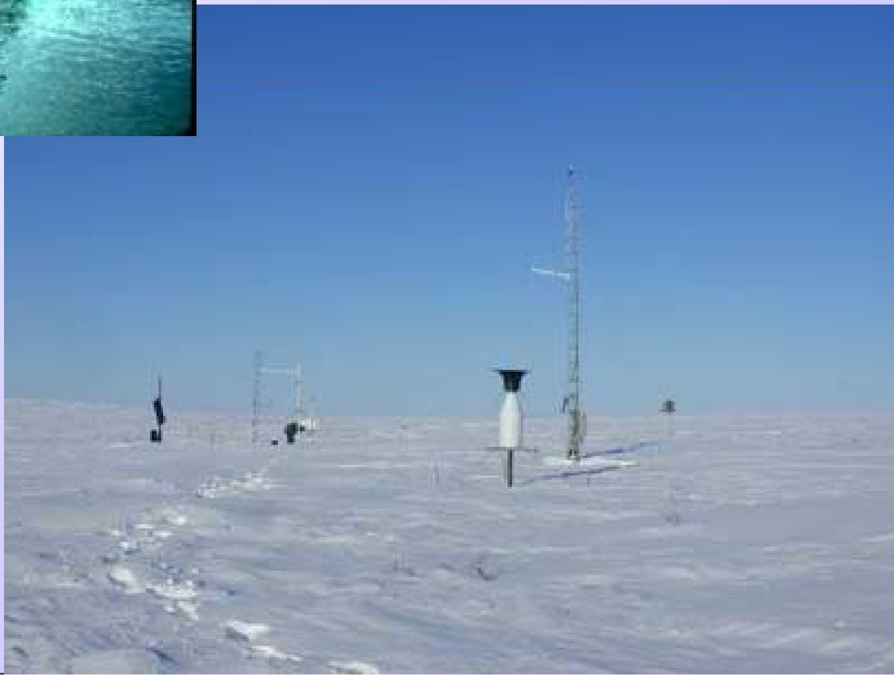


Courtesy Derek Faria, INAC

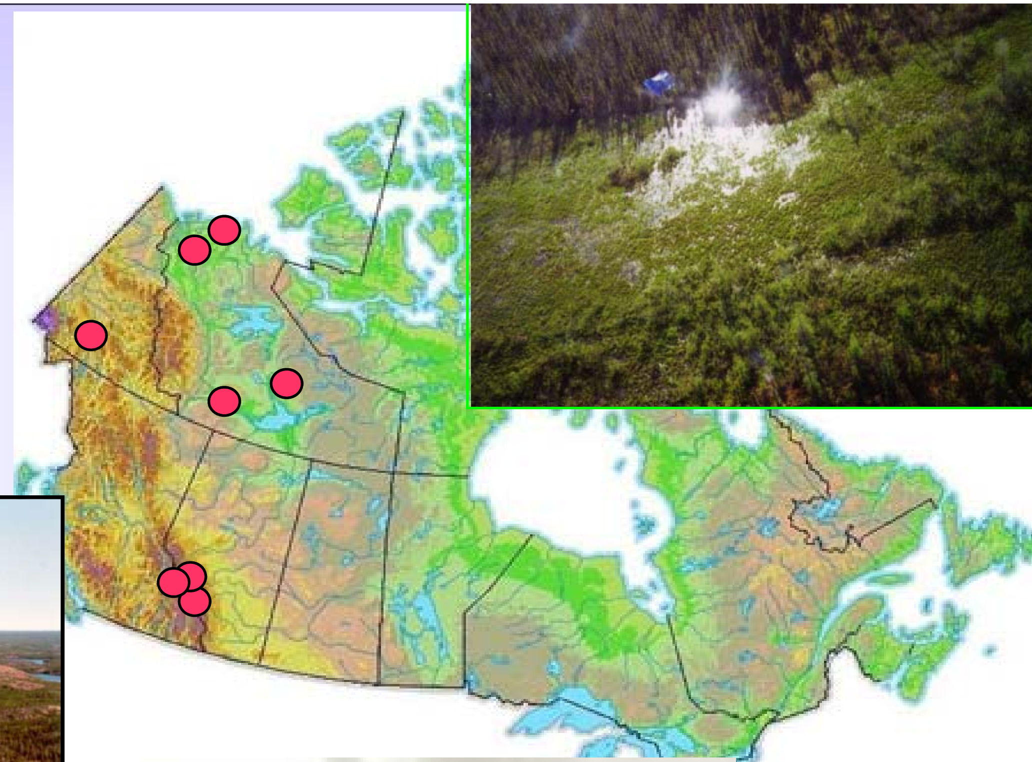
Processes

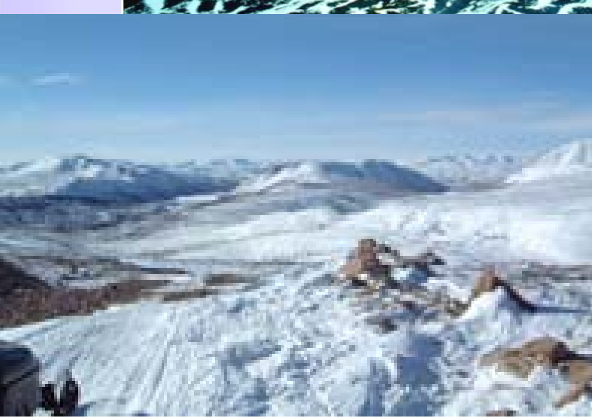
→ Multi-scale observations of effect of radiation, wind, vegetation, and topography on the interaction between snow, water, soil, and air





IP3 Research Basins





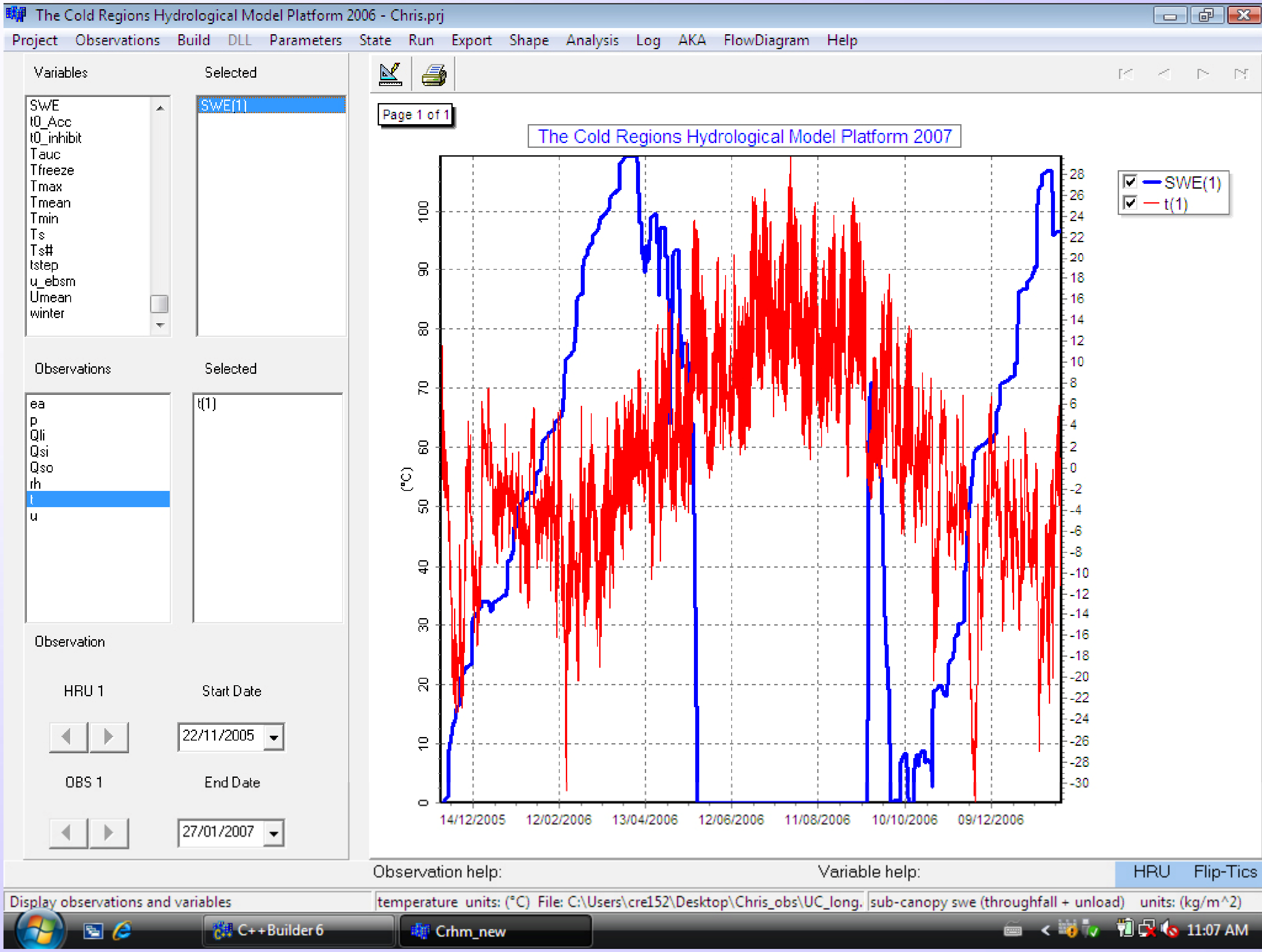
Anticipated Results: Processes

- New soil physics parameters for organic and frozen soils
- Control of lateral flow established for various cold regions environments
- Improved turbulent transfer relationships over snow and glacier ice in complex terrain
- Improved short- and long-wave radiation relationships for vegetation canopies on snow-covered slopes

Parameterisation

→ Scaling of hydrological processes

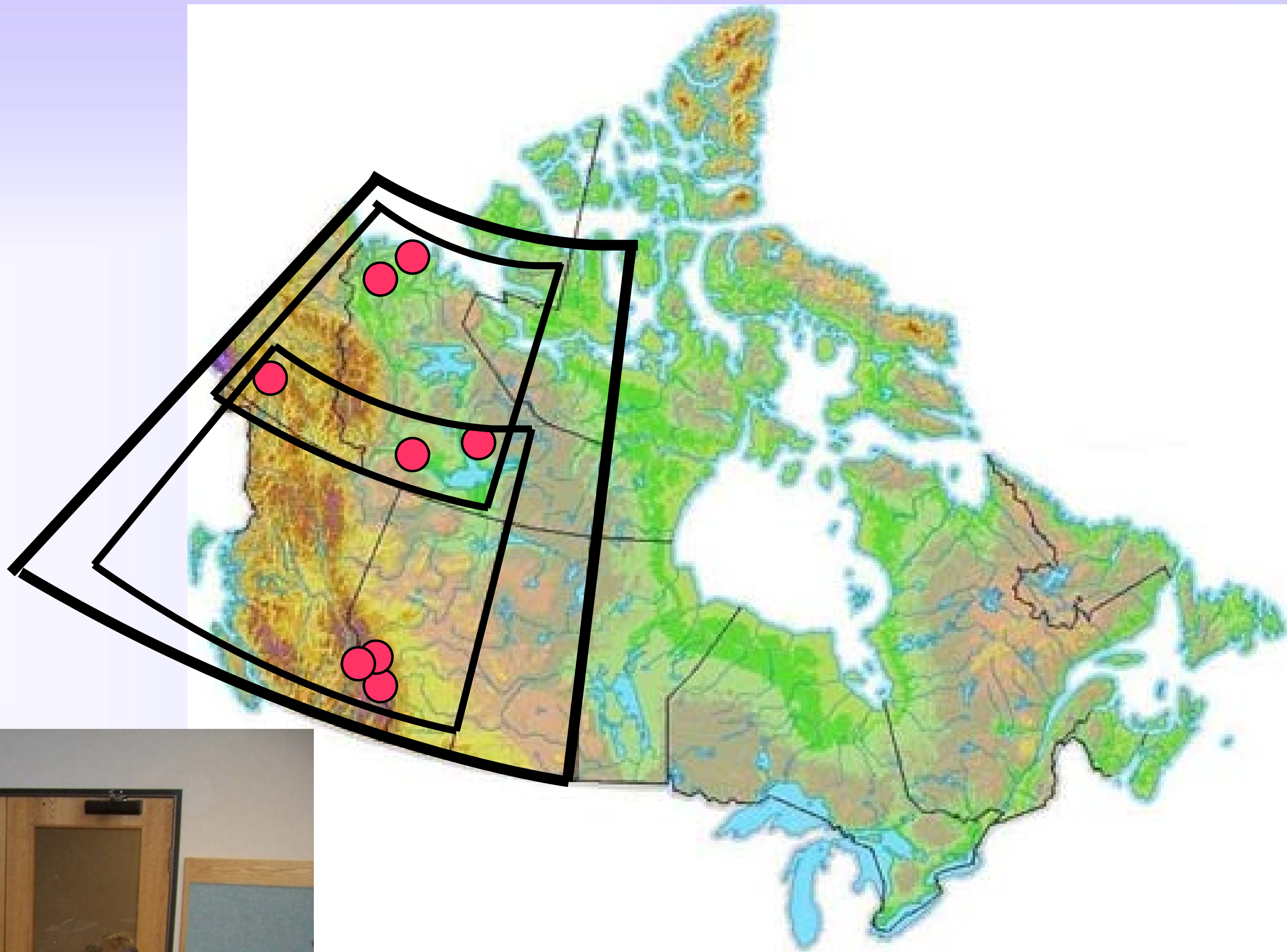
→ Minimize model complexity while reproducing the essential behaviour of the system



Anticipated Results: Parameterisation

- Runoff and streamflow, including 'fill and spill' method
- Advection, evaporation, and ice on small lakes
- Blowing snow redistribution and other mass, phase, and radiation changes in snow
- Upscaled radiation and turbulent fluxes from snow, snow-covered area depletion

Prediction

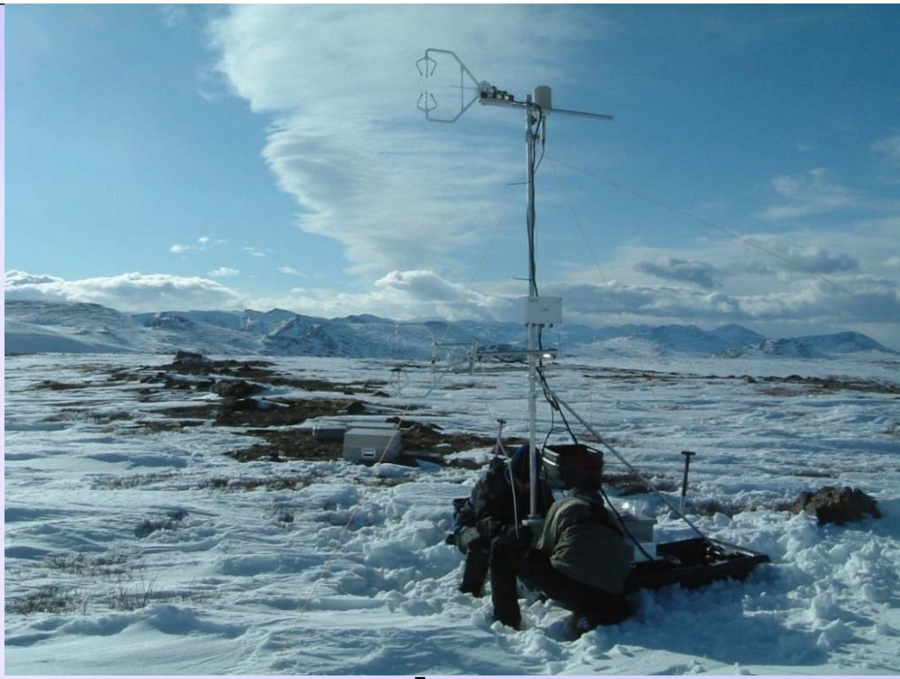


→ Water resources (storage, discharge, snow cover, soil moisture), atmosphere-ground interaction (evaporation), and weather and climate

Anticipated Results: Prediction

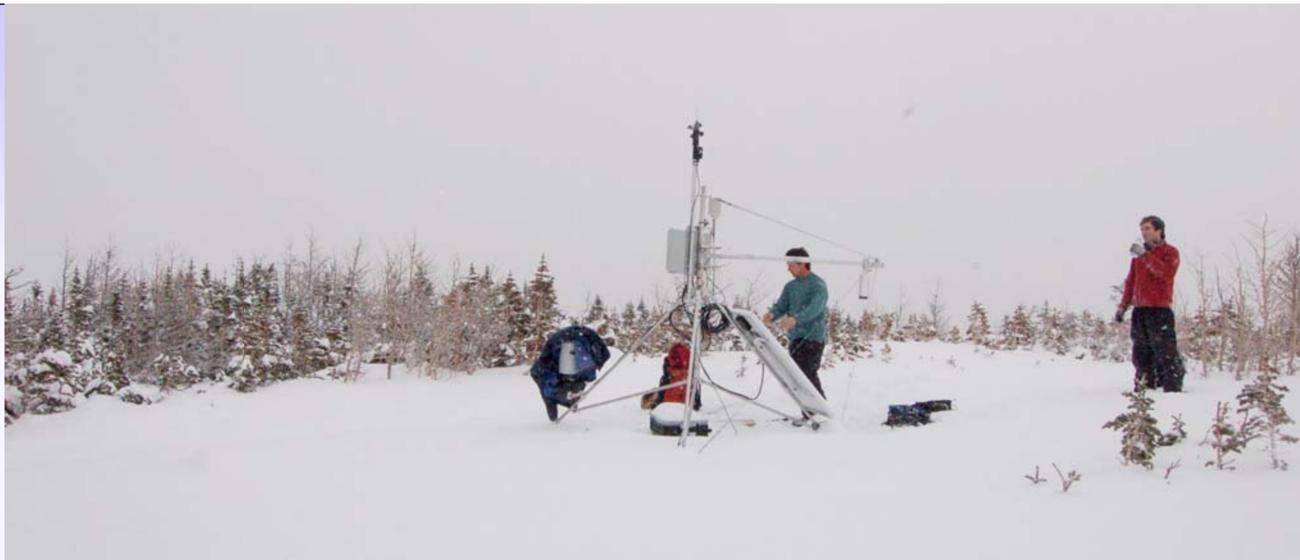
- MEC/MESH for cold regions – developed and tested
- CRHM for small northern and mountain basins
- Improved prediction in ungauged basins – streamflow prediction with less calibration of model parameters from gauged flows
- Improved weather prediction – quantify importance of land-atmosphere feedback in cold regions
- Improved climate prediction – benefits from improved land surface scheme physics and parameterisation

IP3 Final Outputs



- Improved understanding of cold regions hydrological processes at multiple scales
- Unique observational archive of research basin data
- More effective incorporation of cold regions processes and parameterisations into hydrological and meteorological models at regional and smaller scales
- Improved environmental predictive capability in cold regions in response to greater water resource demands:
  - → Enhanced hydrological and atmospheric model performance at multiple spatial scales *and at scales requested by users*
  - → Improved streamflow prediction in ungauged basins with less calibration of model parameters from gauged flows
  - → Improved weather and climate prediction due to rigorous model development and testing

Users' Advisory Committee



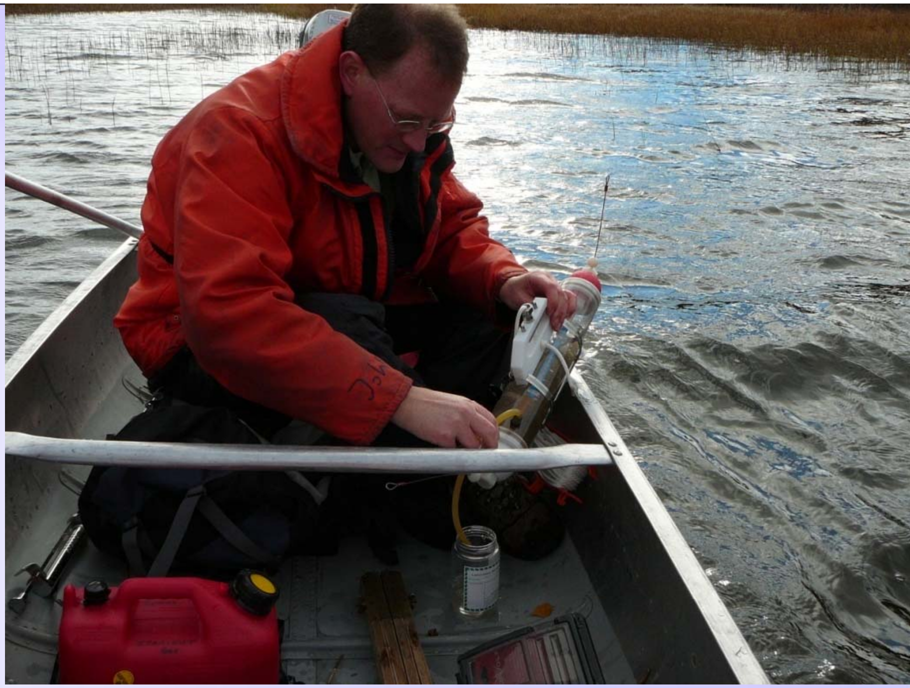
- Public and private:

community, government, industry,…

- Goal is to provide information that can be used in regional planning/policy making, streamflow/flood forecasting, water management, environmental conservation, and northern development

- Interactive workshops for outreach to practitioners and feedback on applicability of research

Recent Activities



- Field work began in spring in all basins, new field equipment installed
- Model development:
  - CLASS 3.3 finalized
  - CRHM – initialized for most basins, participated in SnowMIP2, many new parameterisations added
  - MEC/MESH – initialized for several basins, training workshop
- GEM Modeller, several students and postdocs started summer 2007
- LiDAR surveys of all 8 basins completed August 2007
- Lake O'Hara and Peyto Glacier – coming up!
- Scotty Creek (NWT) – parameterising wetland frost table depth, runoff
- Wolf Creek (Yukon) – tests of freeze/thaw soil simulation algorithms
- Marmot Creek (Rockies) – blowing snow model, etc.

Interaction between Subsurface Water Flow and Heat Transfer in a Subarctic Permafrost Peatland

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Acknowledgement:

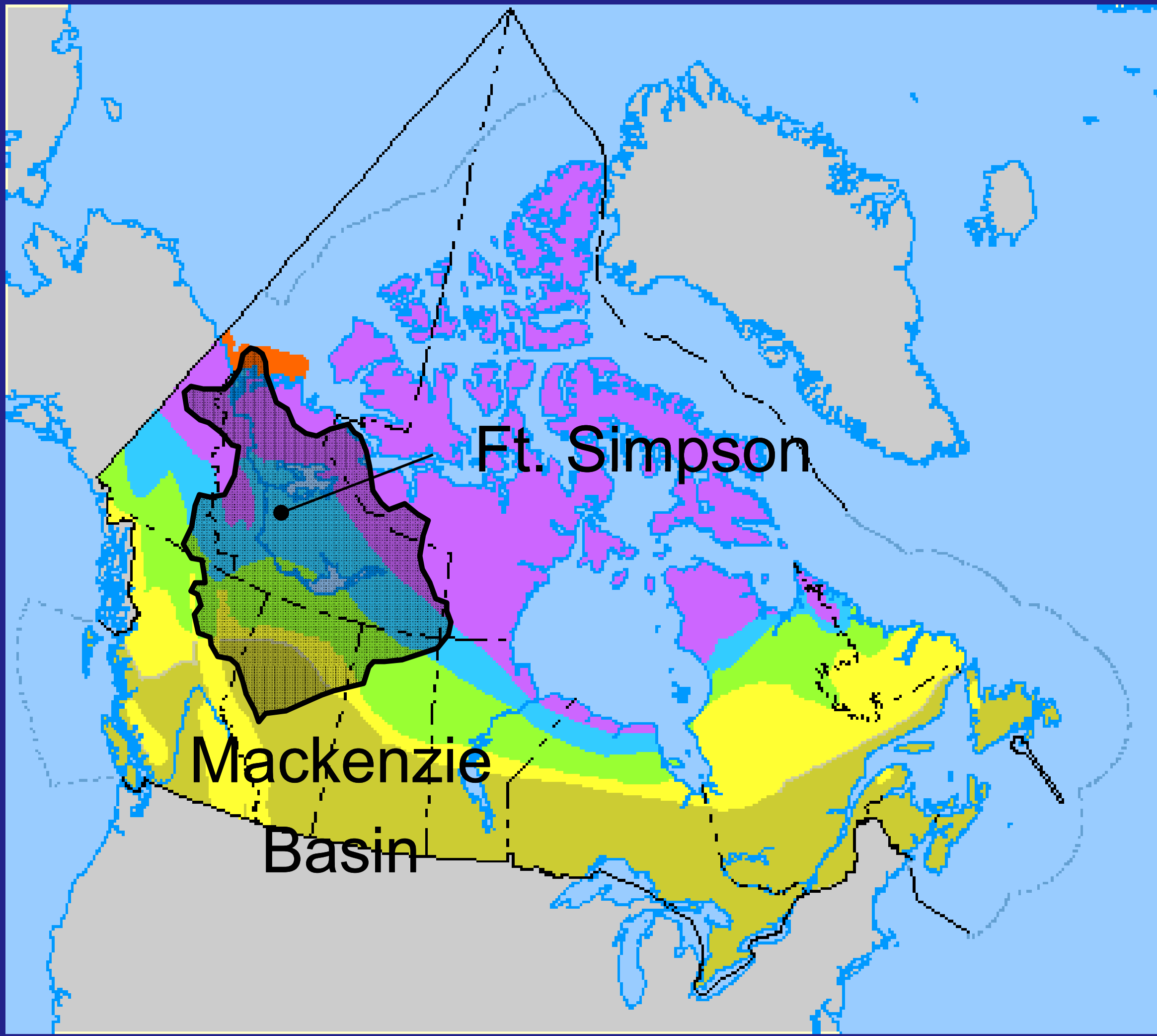
Water Survey of Canada, Ft. Simpson

Canadian Foundation of Climate and Atmospheric Sci.

Natural Sciences and Engineering Research Council

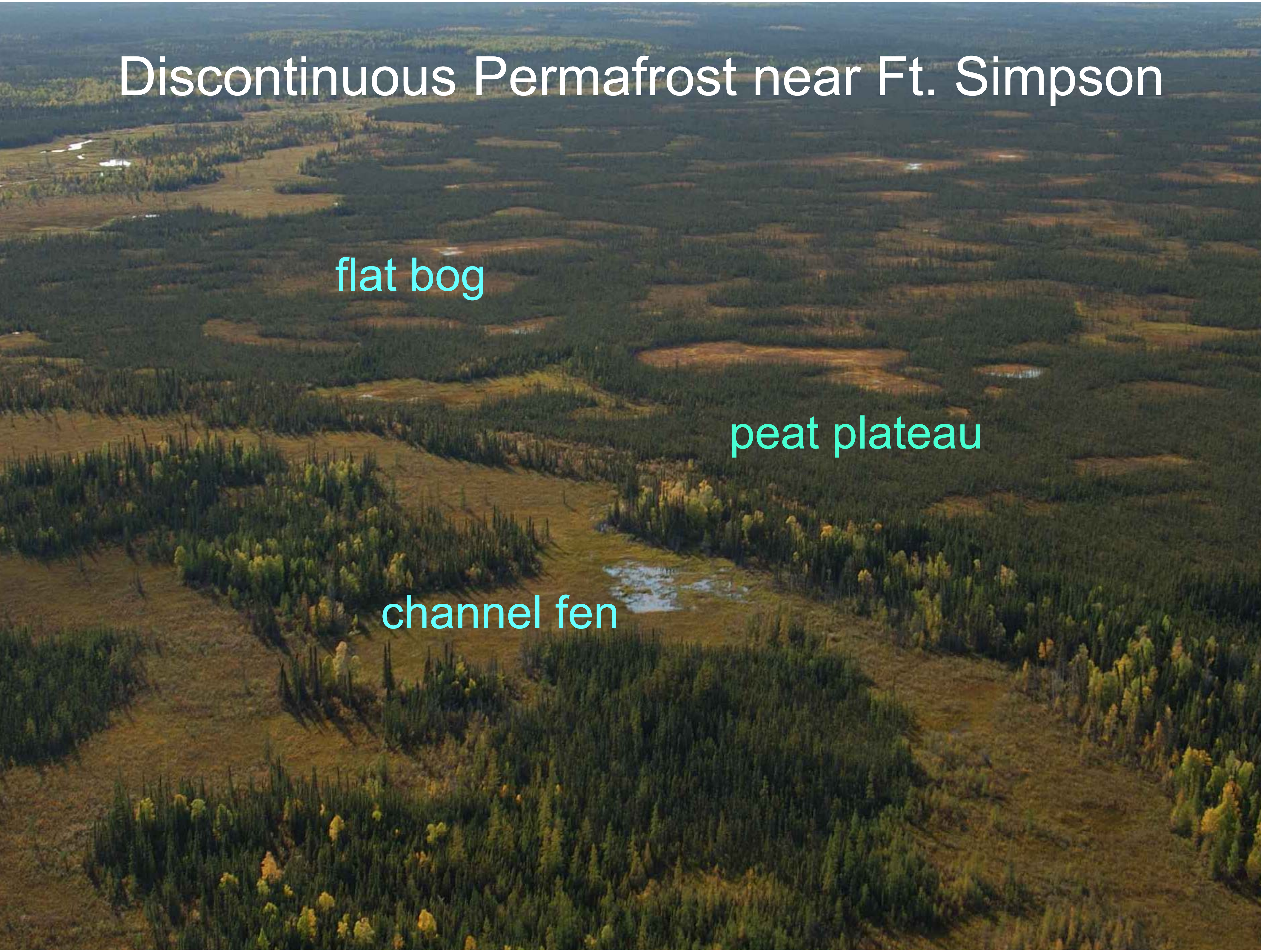
Permafrost Area

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

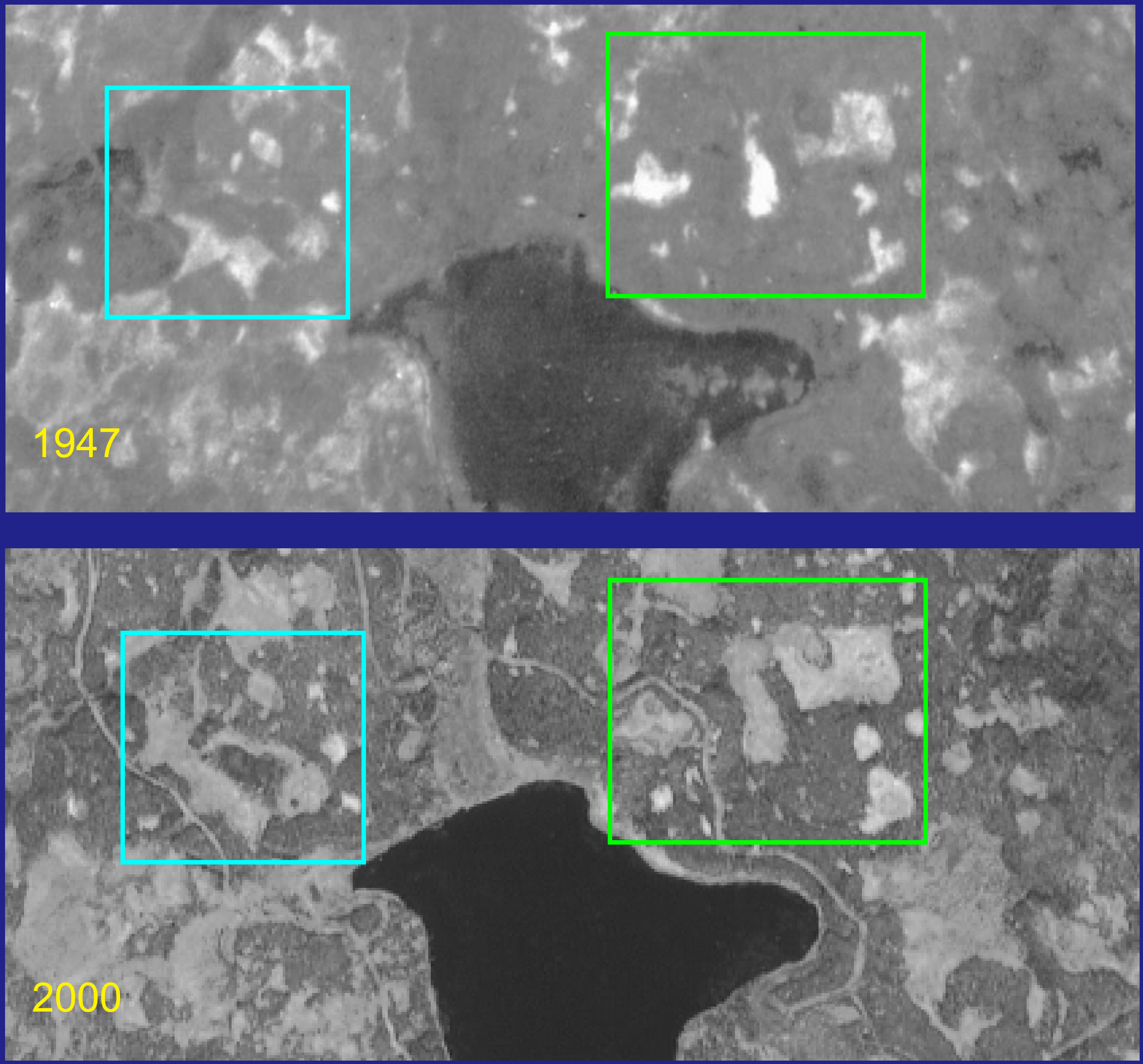


The Atlas of Canada

Natural Resources Canada
Ressources naturelles Canada
Canada

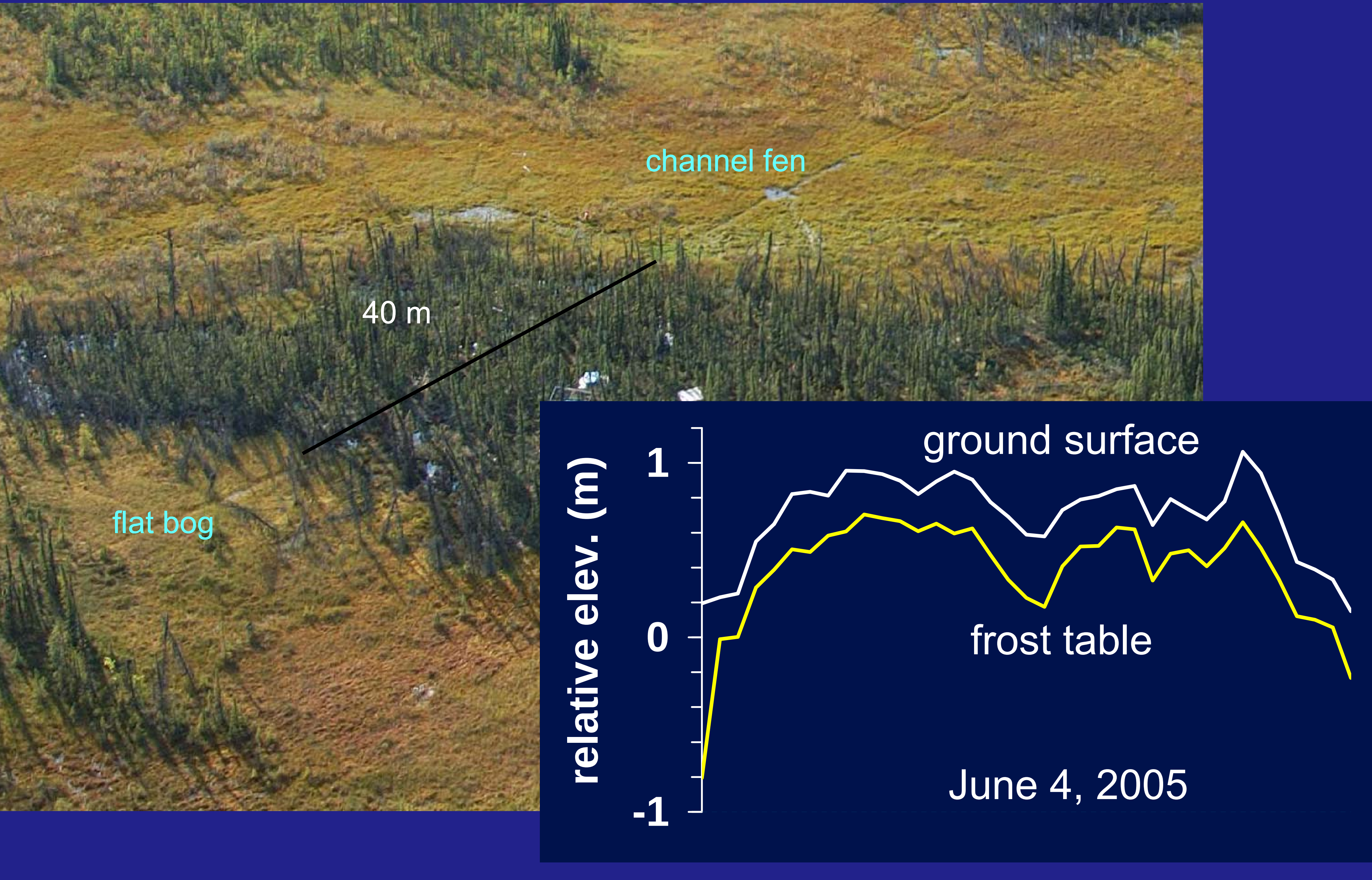

Discontinuous Permafrost near Ft. Simpson
flat bog
peat plateau
channel fen

Increasing Size of Wetlands with Warming

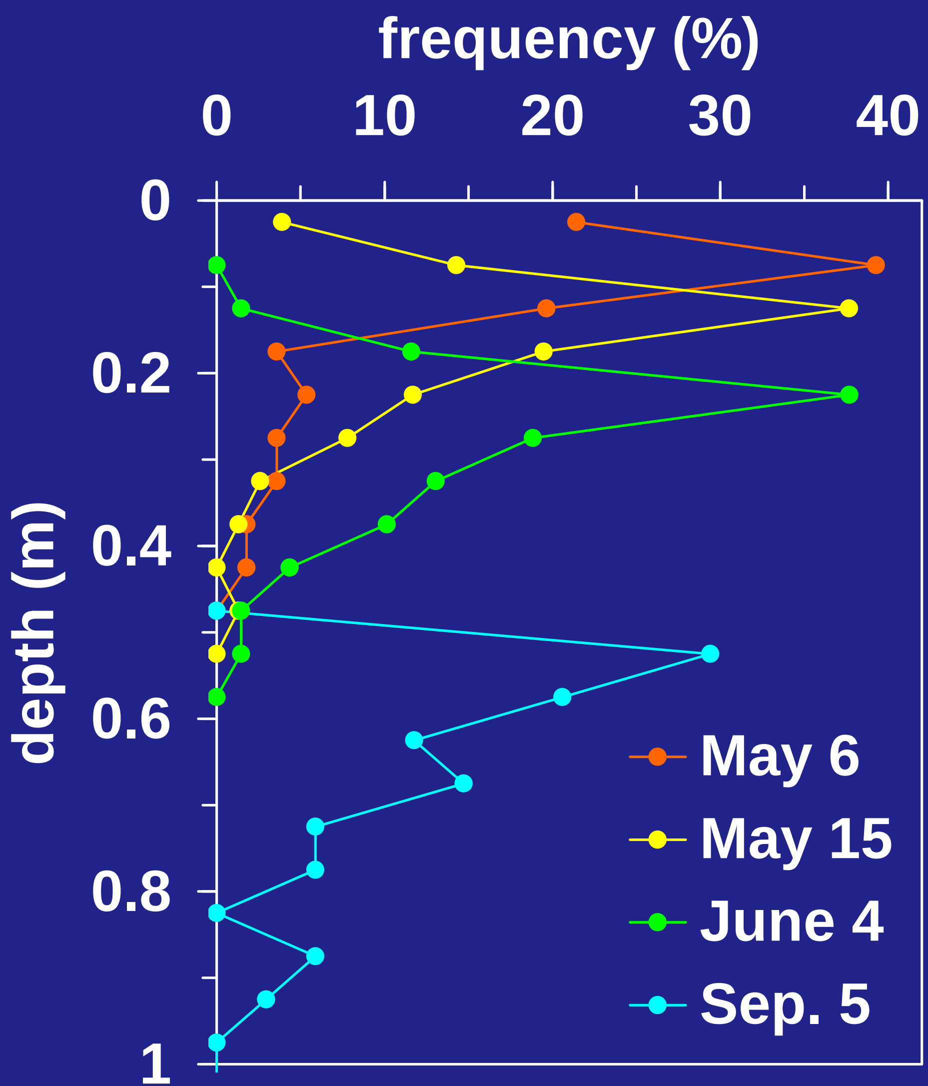


250 m

Frost Table Survey on a Peat Plateau



Frost Table Depth Distribution in 2005



Number of points = 40 to 80

Skewed distribution with a tail extending deeper.

Non-linear feedback causes the skewness?

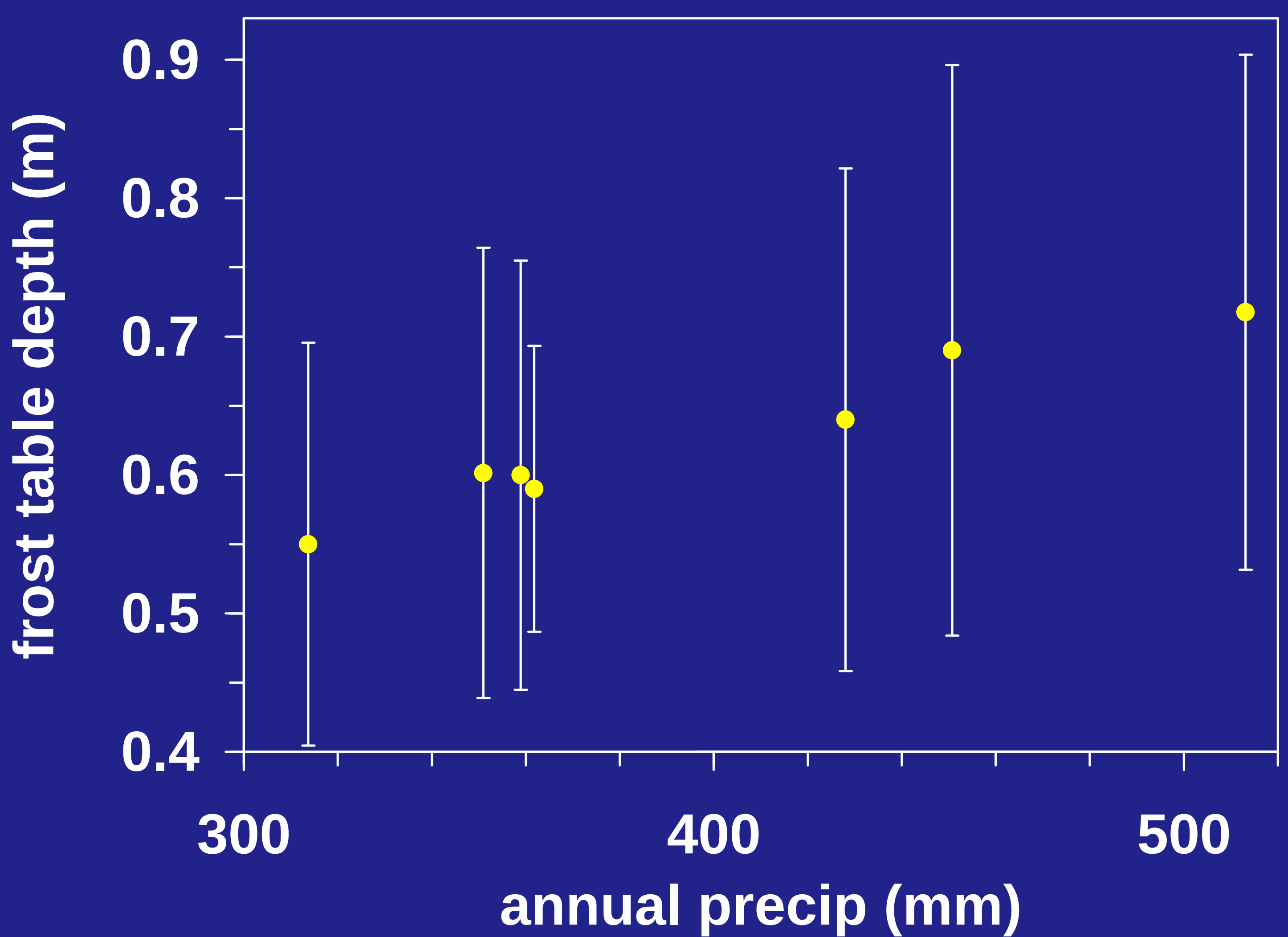
HYPOTHESIS:

Frost-table depth is controlled by the soil moisture distribution.

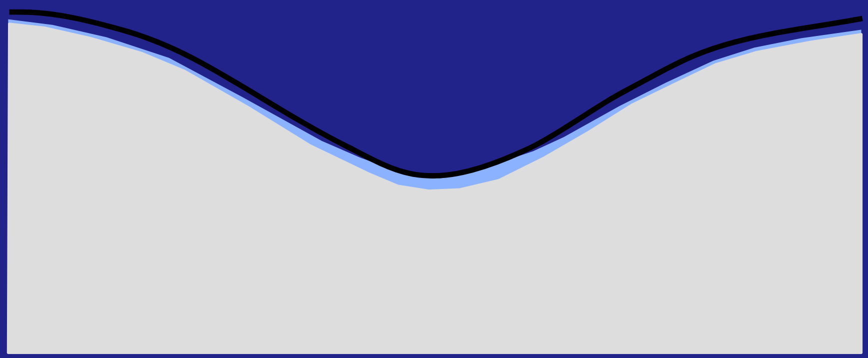
Frost Table Depth in the Summer End

Surveyed in late August or early September

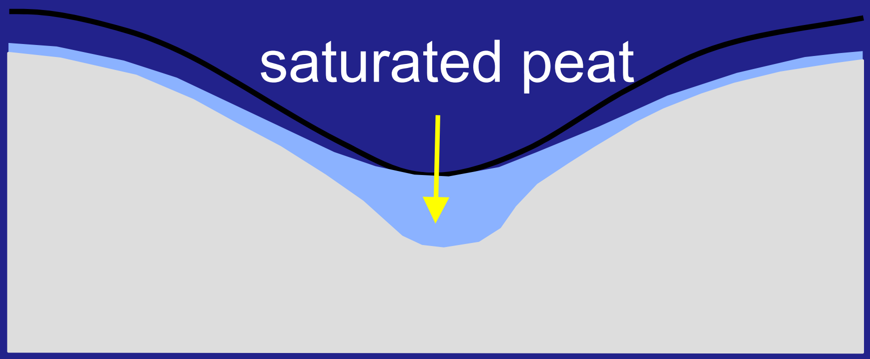
Bars indicate one standard deviation.



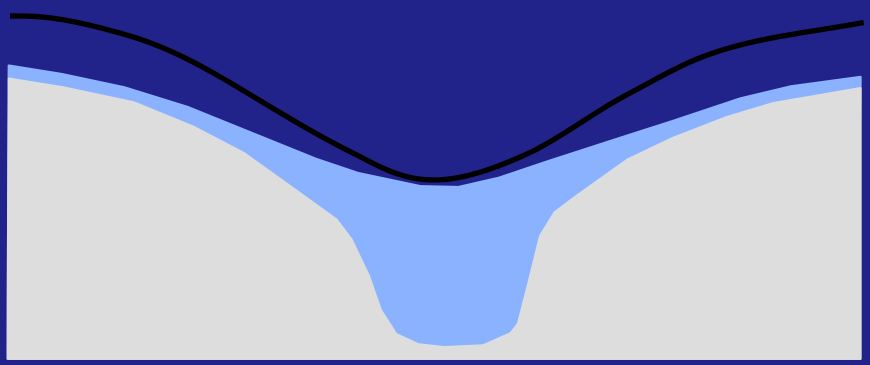
Conclusions



Melt water converges to depressions by subsurface flow.



Wet peat has high thermal conductivity → enhances heat conduction.



Depression continue to receive subsurface runoff, frost table gets deeper.

Parameterization Objectives: Thermal Modelling (Sean Carey, Carleton University)

Evaluate the performance of commonly used simulation algorithms in permafrost regions:

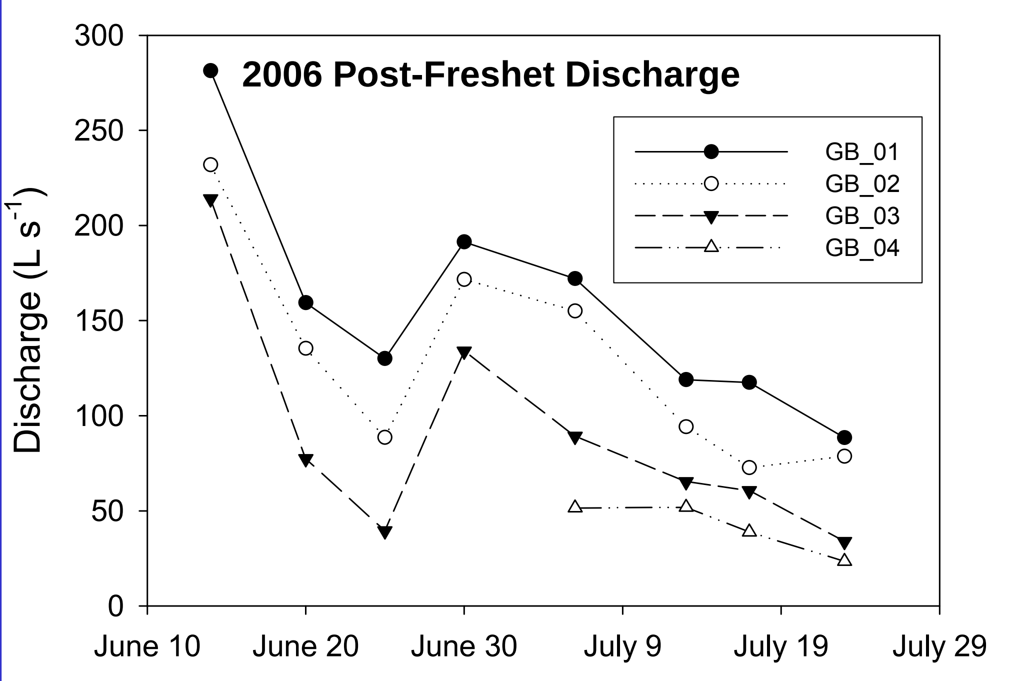
Freeze-Thaw algorithm to test Soil parameterizations for mineral and organic soils

Tested algorithms are Semi-empirical (1), Analytical (2), and Numerical (3)

Selected Results:

1. Selection of parameterisation more important for organic soils than mineral soils
2. Semi-empirical algorithms not recommended (due to large spatial and temporal variations in the parameter values)
3. Numerical algorithms performed best – traced ground freezing and thawing most precisely, but require very high temporal resolution and assimilation of soil moisture data

Process Objective: Explore downstream changes in flow and hydrochemistry to elucidate changes in streamflow sources

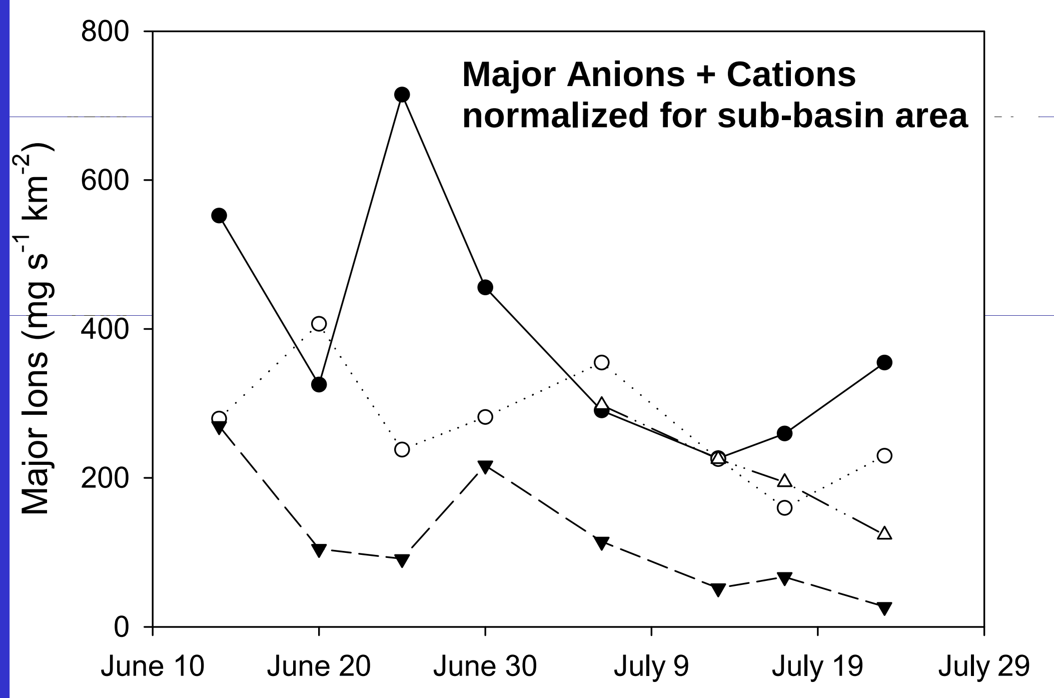


Sources of water in discontinuous alpine catchments remains unclear

Distributed hydrometric and hydrochemical sampling approach used to assess areas of basins that contribute water during different times of the year.

Unlike previous research, deep groundwater sources are identified as an important source of streamflow, whereas previous studies have emphasized supra-permafrost water

Deep groundwater contribution increases as summer progresses, whereas supra-permafrost water declines.



Snow Processes and Modelling

John Pomeroy

Centre for Hydrology
University of Saskatchewan, Saskatoon

and collaborators

Richard Essery (U Edinburgh), Kevin Shook (U Saskatchewan)

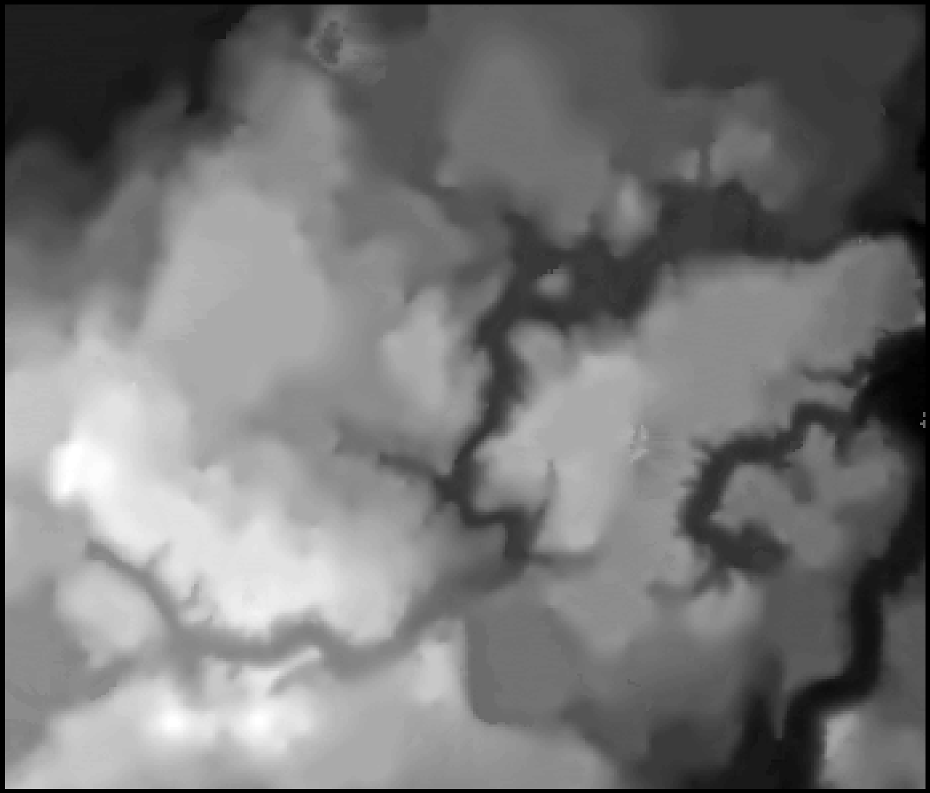
and students

Dan Bewley, Pablo Dornes, Xing Fang, Rick Janowicz,
Warren Helgason, Nicholas Kinar

Blowing Snow: Transport (Saltation), Redistribution, and Sublimation of Snow

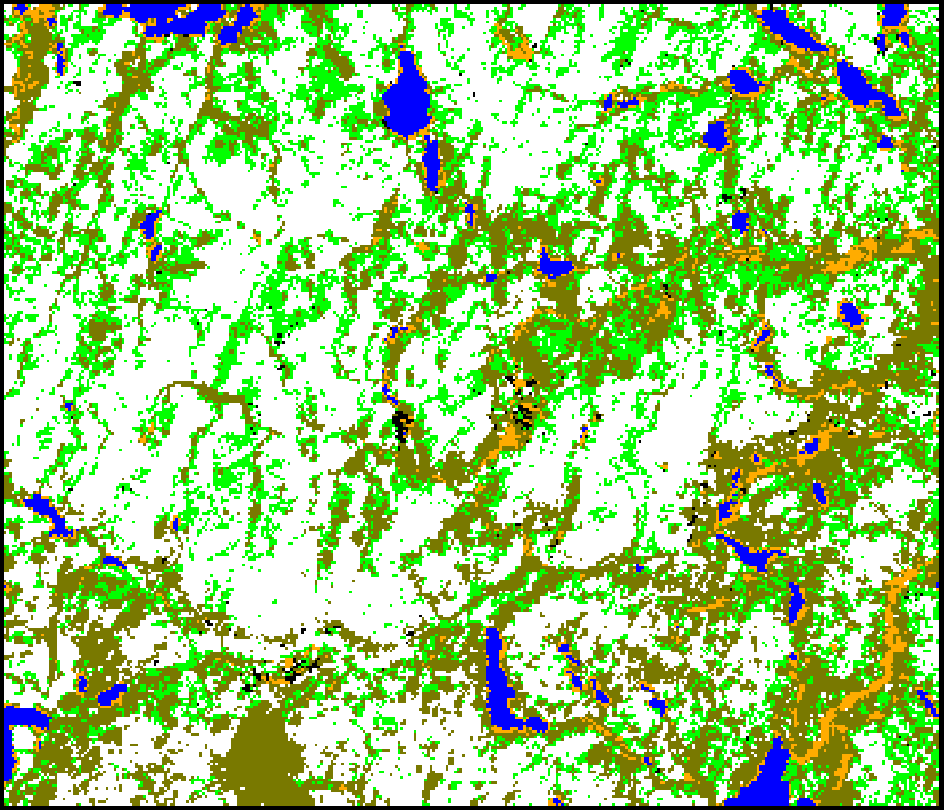
How to Model Blowing Snow over Complex Landscapes?

Topography

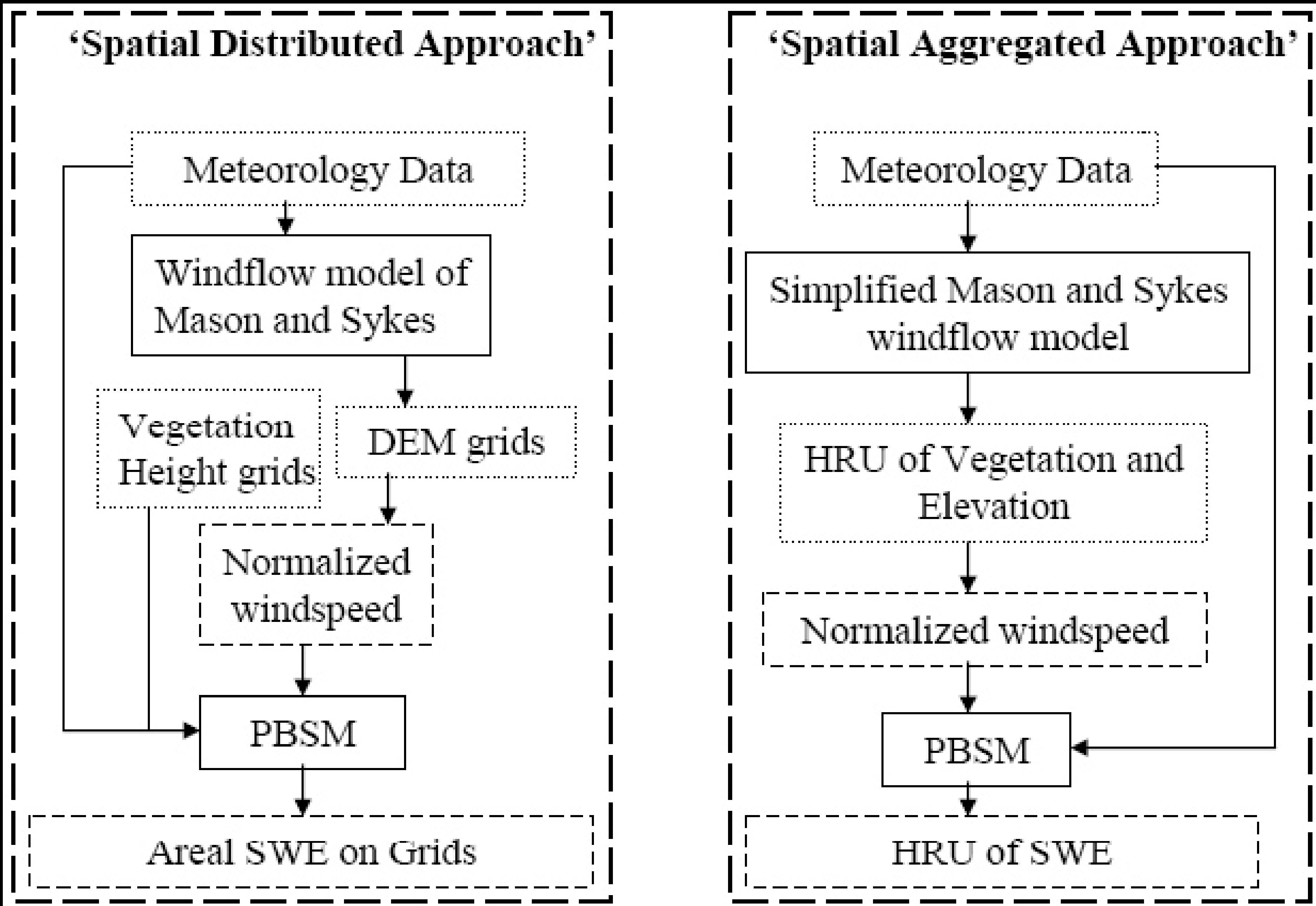


2 km

Vegetation



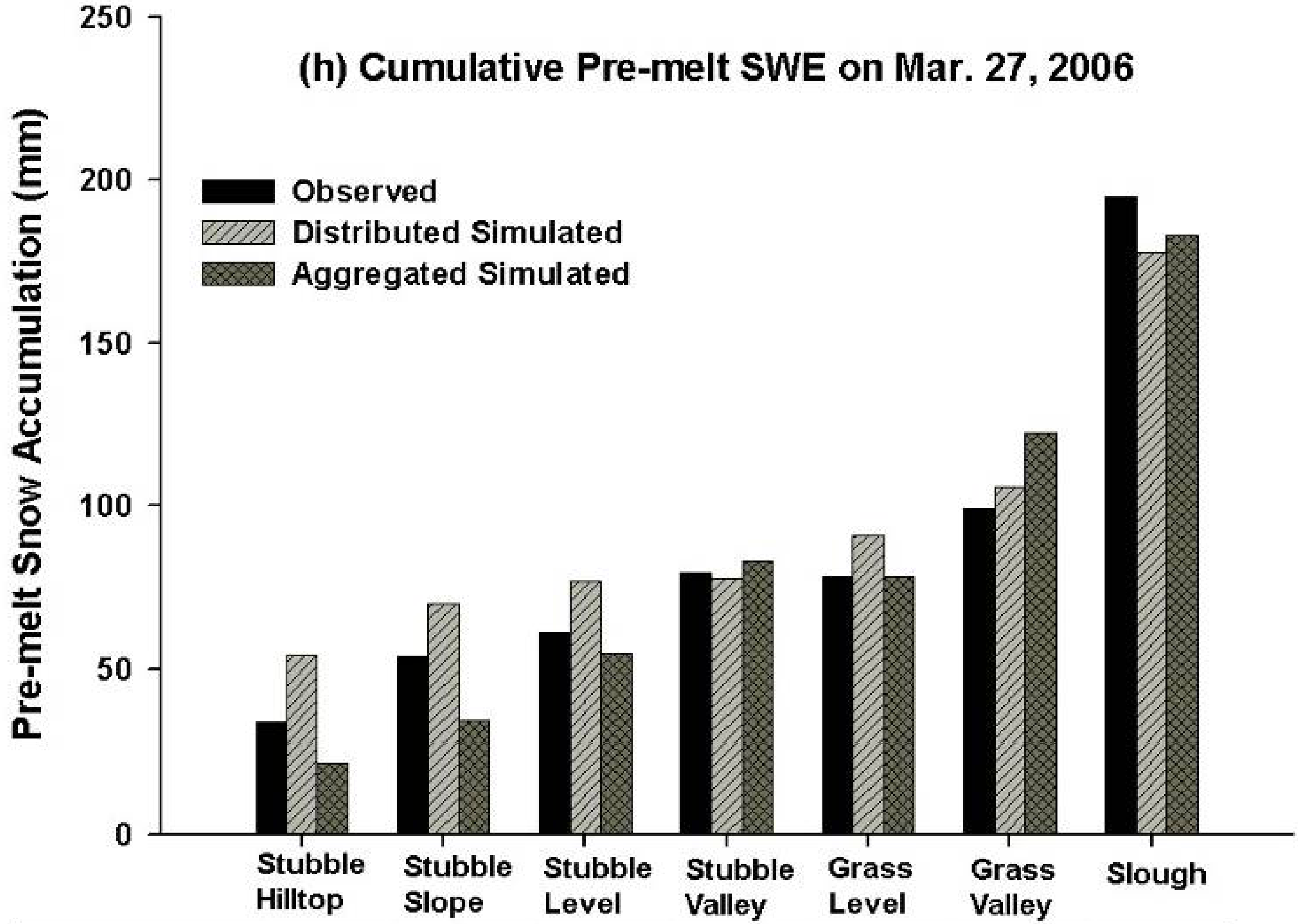
Dual Scale Approach



~250,000 grid cells

7 HRU

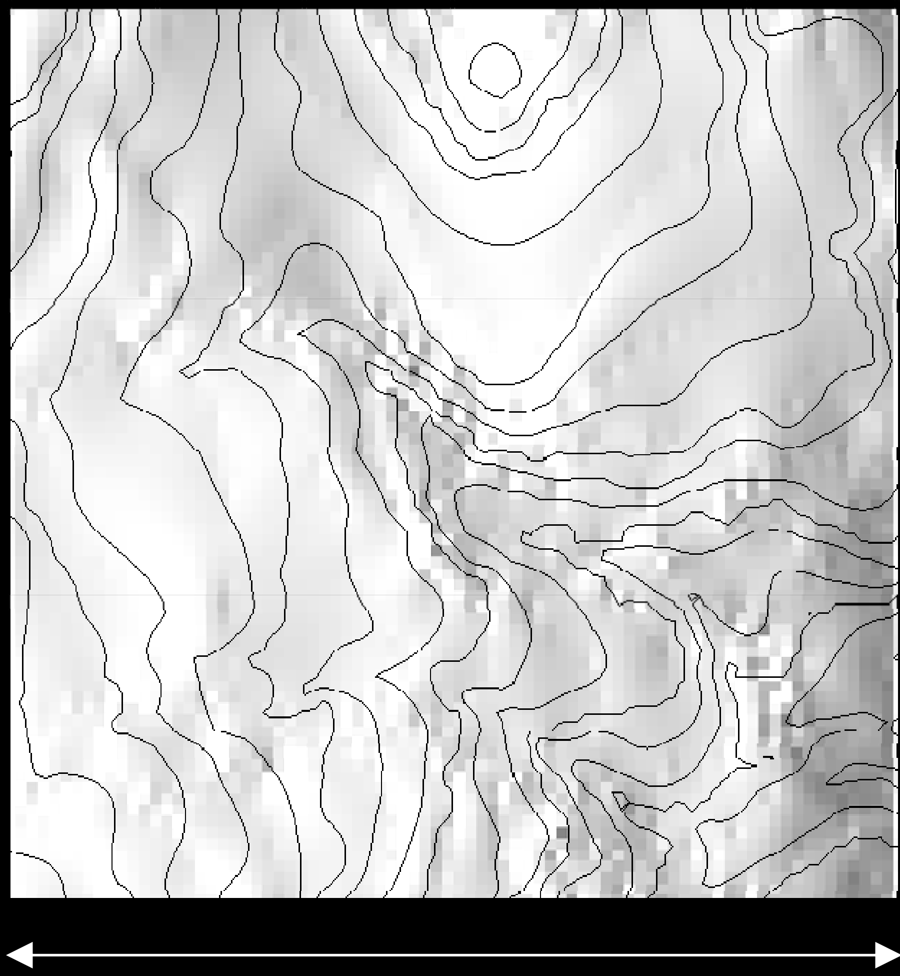
Comparison of Model to Observations



	Stubble Hilltop	Stubble Slope	Stubble Level	Stubble Valley	Grass Level	Grass Valley	Slough
MB (Distributed)	0.6	0.31	0.26	-0.02	0.16	0.07	-0.09
MB (Aggregated)	-0.37	-0.36	-0.11	0.05	-0.003	0.23	-0.06

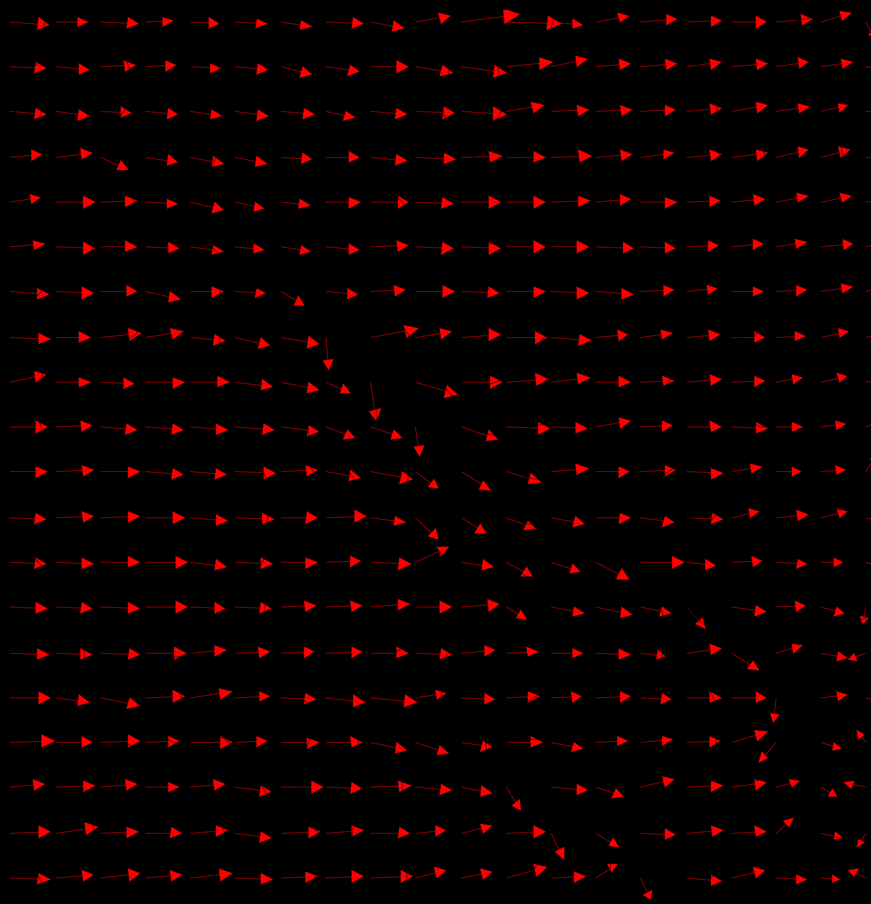
Linear simulation of westerly flow over Wolf Creek, Yukon

Windspeed



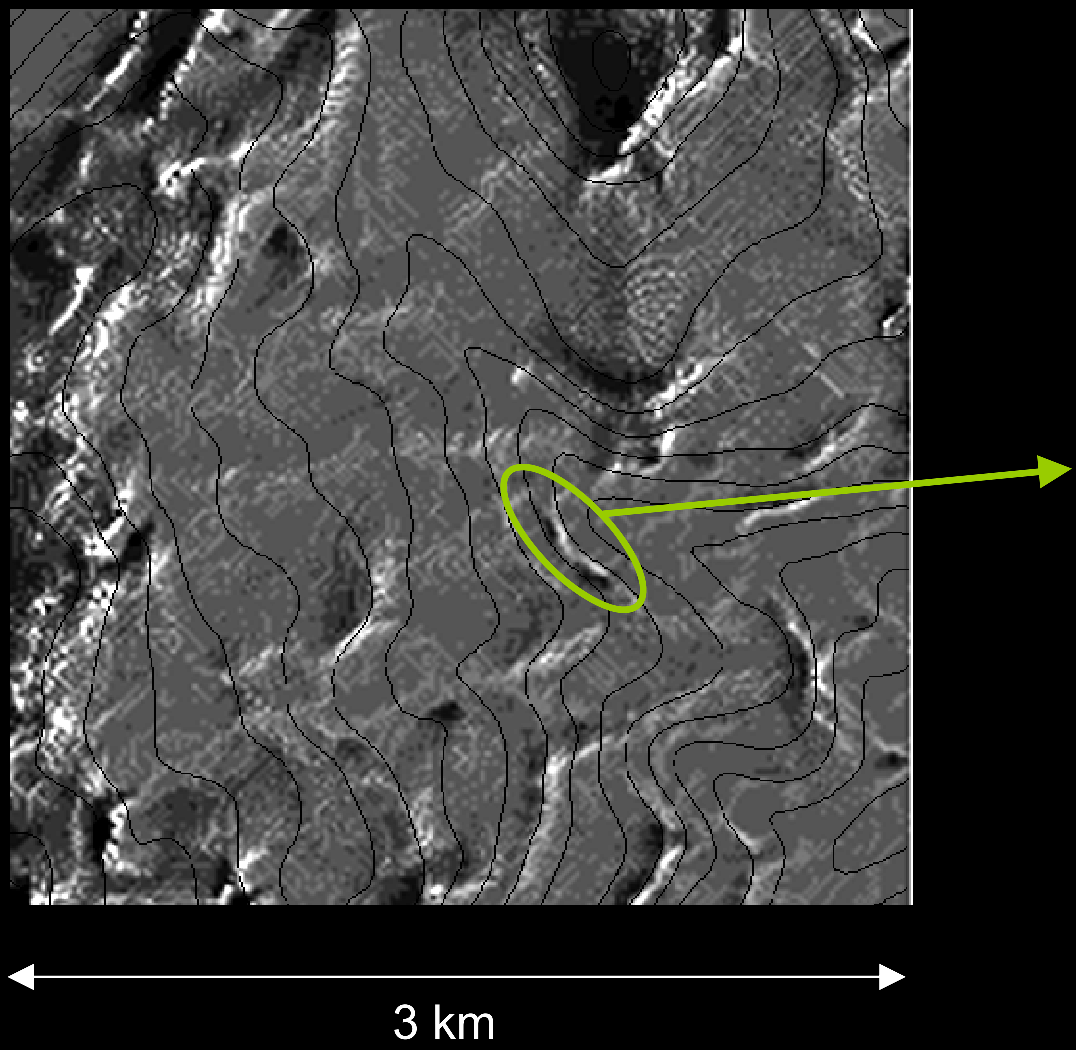
3 km

Direction



Essery and Pomeroy, *in preparation*

Simulation of Hillslope Snowdrift

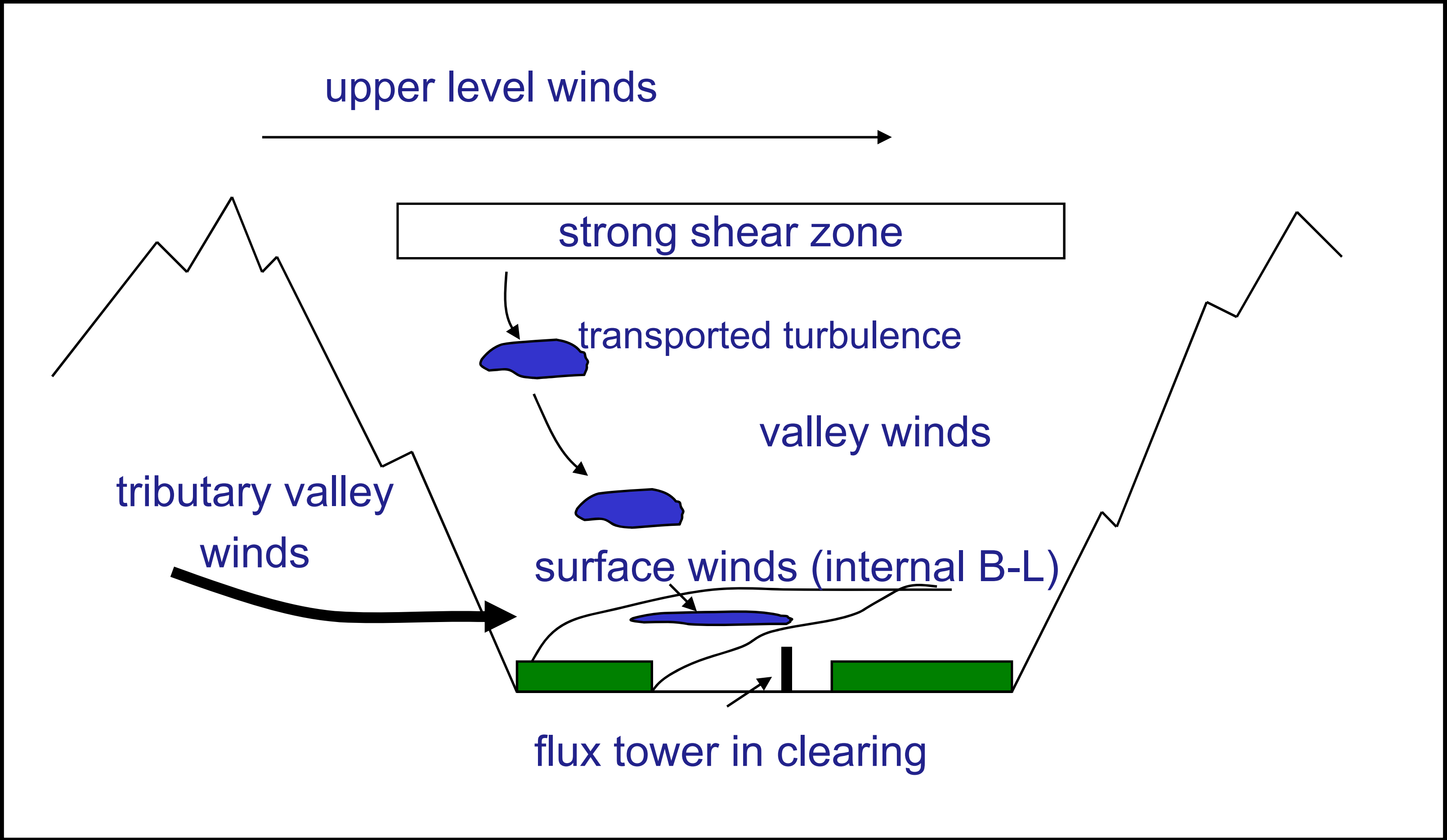


Distributed Blowing Snow Model

Distributed Blowing Snow Model Seasonal Snow Accumulation Trail Valley Creek, NWT

light tones are deeper snow

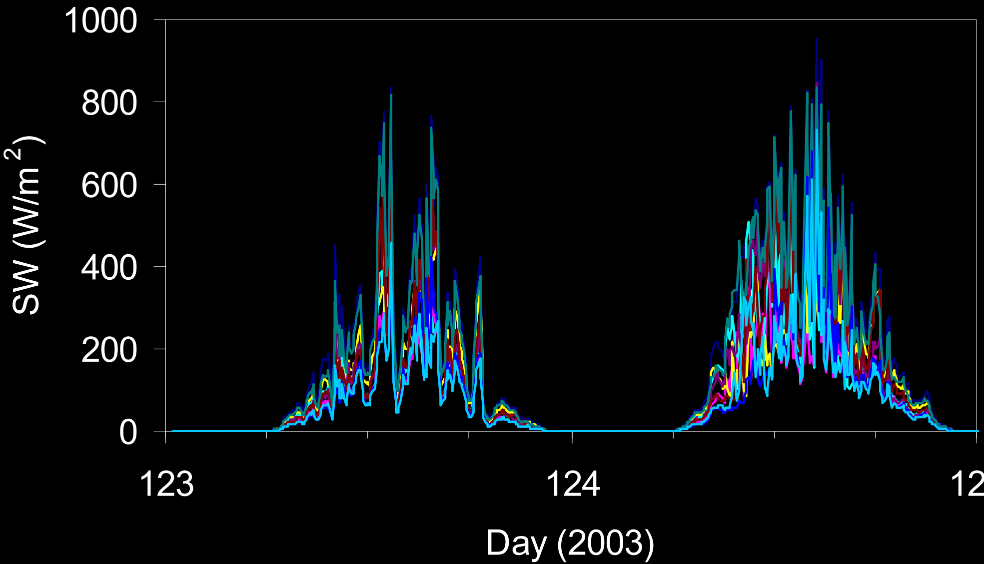
Turbulence generation mechanisms in mountains

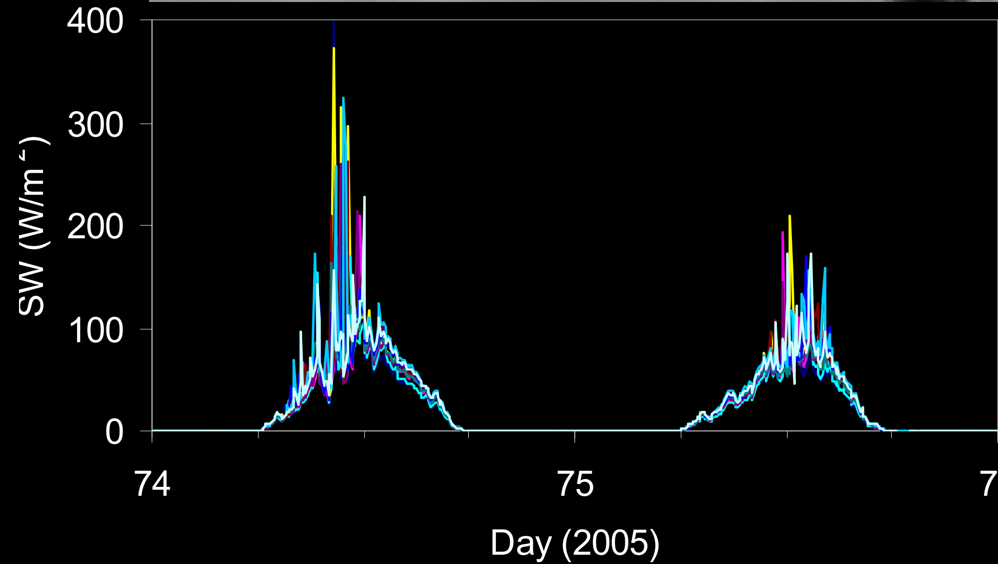


Solar radiation to snow beneath shrubs and trees

Wolf Creek shrubs

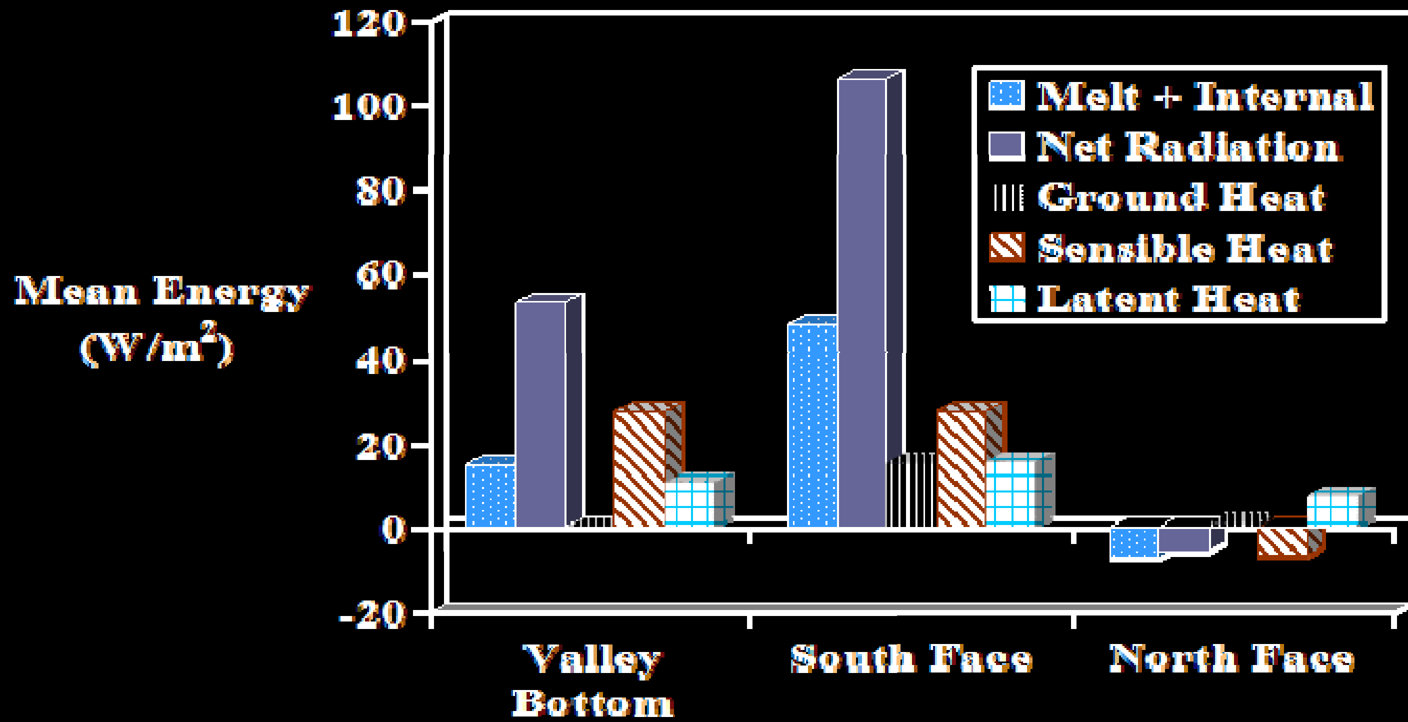
Marmot Creek level forest



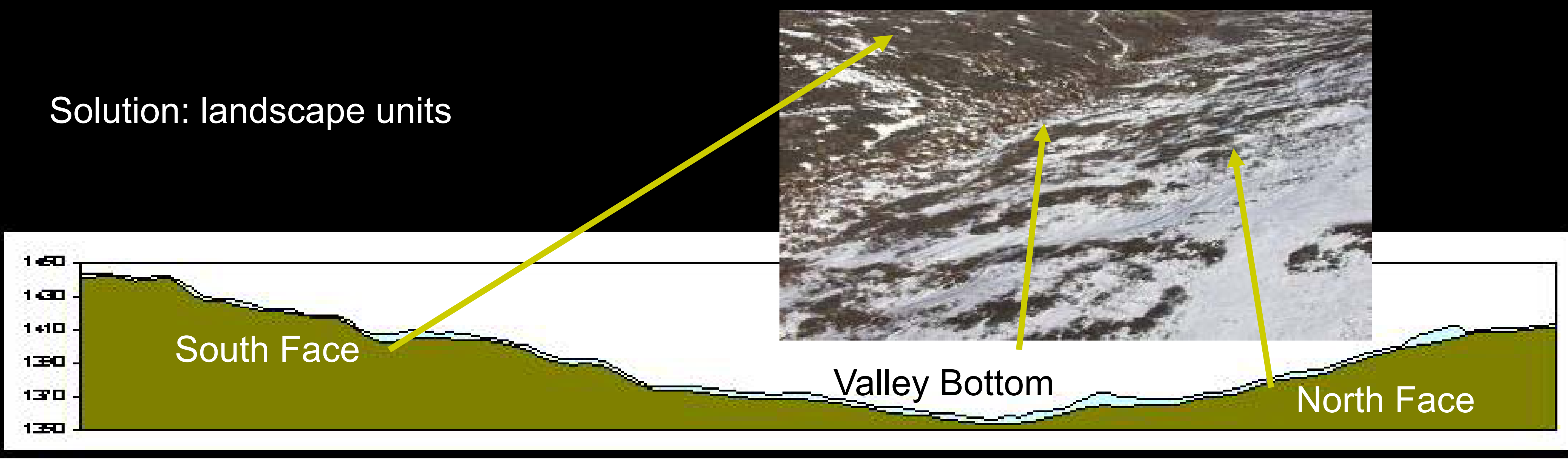


Pomeroy et al., *J Hydrometeorol*, submitted

Complex Terrain Snowmelt

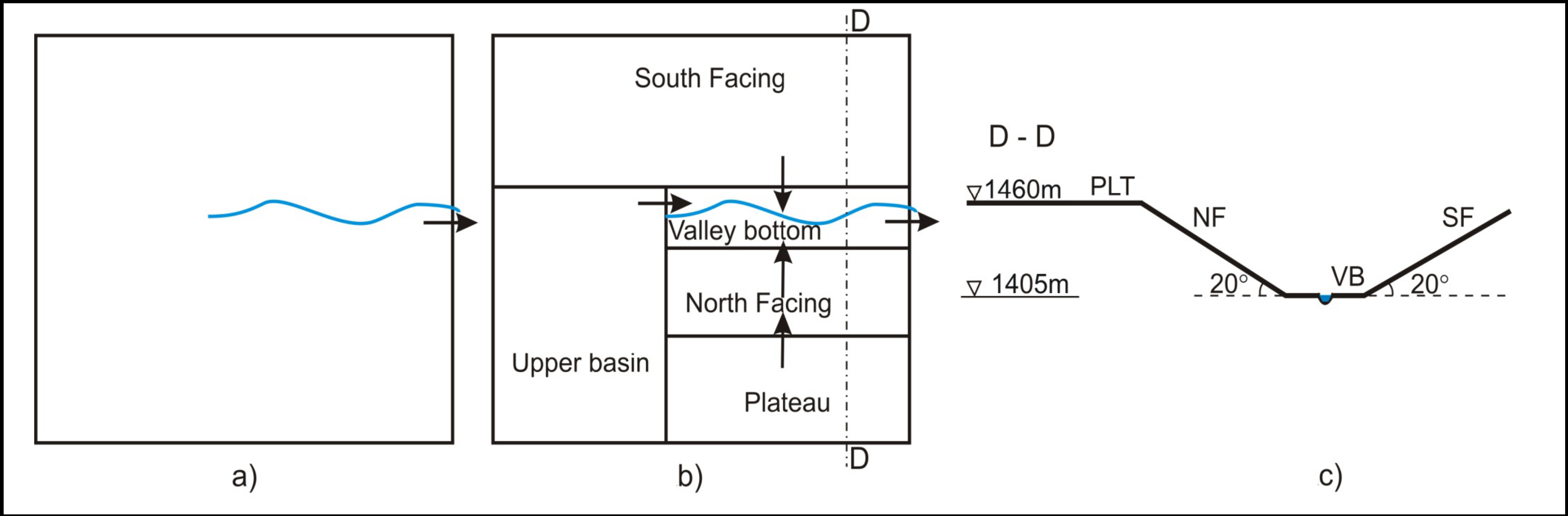


Solution: landscape units



Modelling Approach

Aggregated vs. Distributed



Distributed models can capture snowmelt synchronicity effects

Distributed models better reproduce Snowmelt and Streamflow in complex terrain than aggregated models

Upcoming Meetings

- IP3 2nd Workshop to be held at Cold Regions Research Centre, Wilfrid Laurier University, Waterloo, ON, 8-10 November 2007
- Other meetings to be planned:
  - Themes 2 and 3 Workshop (Parameterisation/Prediction)
  - CRHM training Workshop (possibly January)
  - Users' Advisory Workshop

Thank you!

Please visit us at www.usask.ca/ip3

Thank you to IP3 participants for providing photos!