Processes and Parameterization: Runoff

IP3 Users/Stakeholders Community Workshop

18-19 March 2008, Canmore, Alberta

Runoff

Improved Processes & Parameterisation for Prediction in Cold Regions

- The “left over” hydrological process

Runoff

- 1) The total amount of liquid water leaving the region (Dingman, 1994)
- 2) Water precipitated into a catchment that is ultimately discharged to a stream channel (Hornberger et al., 1998)
- 3) i.Surface streams that appear after precipitation ii. The flow of water in a stream (McGraw-Hill Dictionary of Earth Science)
- 4) Runoff (or streamflow) comprises the gravity movement of water in channels which may vary in size from the one containing the smallest ill-defined trickle to ones containing the largest rivers such as the Amazon...(Ward and Robinson, 1990)
- 5) In hydrology, **runoff** is the combination of surface runoff and interflow. It also equivalent to quick flow. (Wikipedia)

Runoff in IP3

Improved Processes & Parameterisation for Prediction in Cold Regions

- We are particularly concerned with the influence of cold climate factors (snow, ice, frozen ground, permafrost, organic soils) on runoff generation and lateral redistribution of moisture.
- We study runoff at a variety of scales from the plot to the HRU to the entire basin, identifying *emergent properties* of the system.

Runoff and Global Change

Improved Processes & Parameterisation for Prediction in Cold Regions

From Walvoord and Striegl (GRL, 2007) showing changing winter flow regime. Increases in winter flow is most notable in permafrost regions.

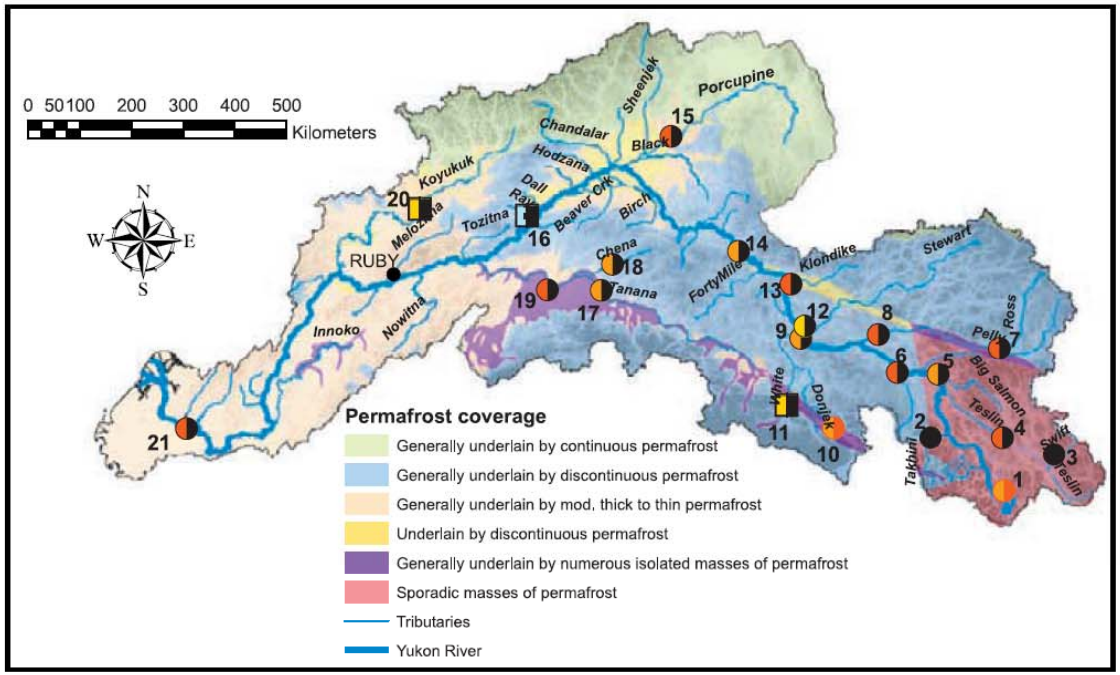
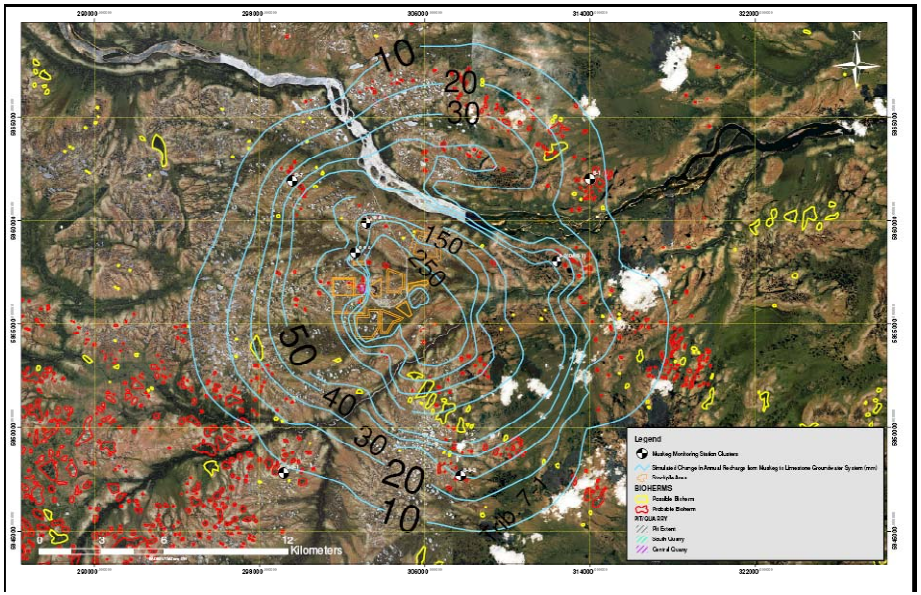


Figure 3. Observed trends in groundwater input (denoted by left side of marker) and annual flow (denoted by right side of marker) at YRB streamflow stations. Circle and square markers indicate flow records >30 years and <30 years, respectively. Marker color scheme indicates statistical significance of Mann-Kendall trend analysis: red, very highly significant ($P < 0.01$) upward trend; orange, highly significant ($0.01 < P < 0.05$) upward trend; yellow, moderately significant ($0.05 < P < 0.1$) upward trend; light blue, moderately significant ($0.05 < P < 0.1$) downward trend; and black, no significant ($0.1 < P$) trend.

Runoff and Development

Improved Processes & Parameterisation for Prediction in Cold Regions

There are strong practical implications of runoff generation from rapid expansion of development in the west and north.



Runoff - Plot and Hillslope (HRU) Studies

Improved Processes & Parameterisation for Prediction in Cold Regions

Detailed investigation of infiltration, redistribution and soil physics that operate to generate saturated conditions and runoff.

Techniques

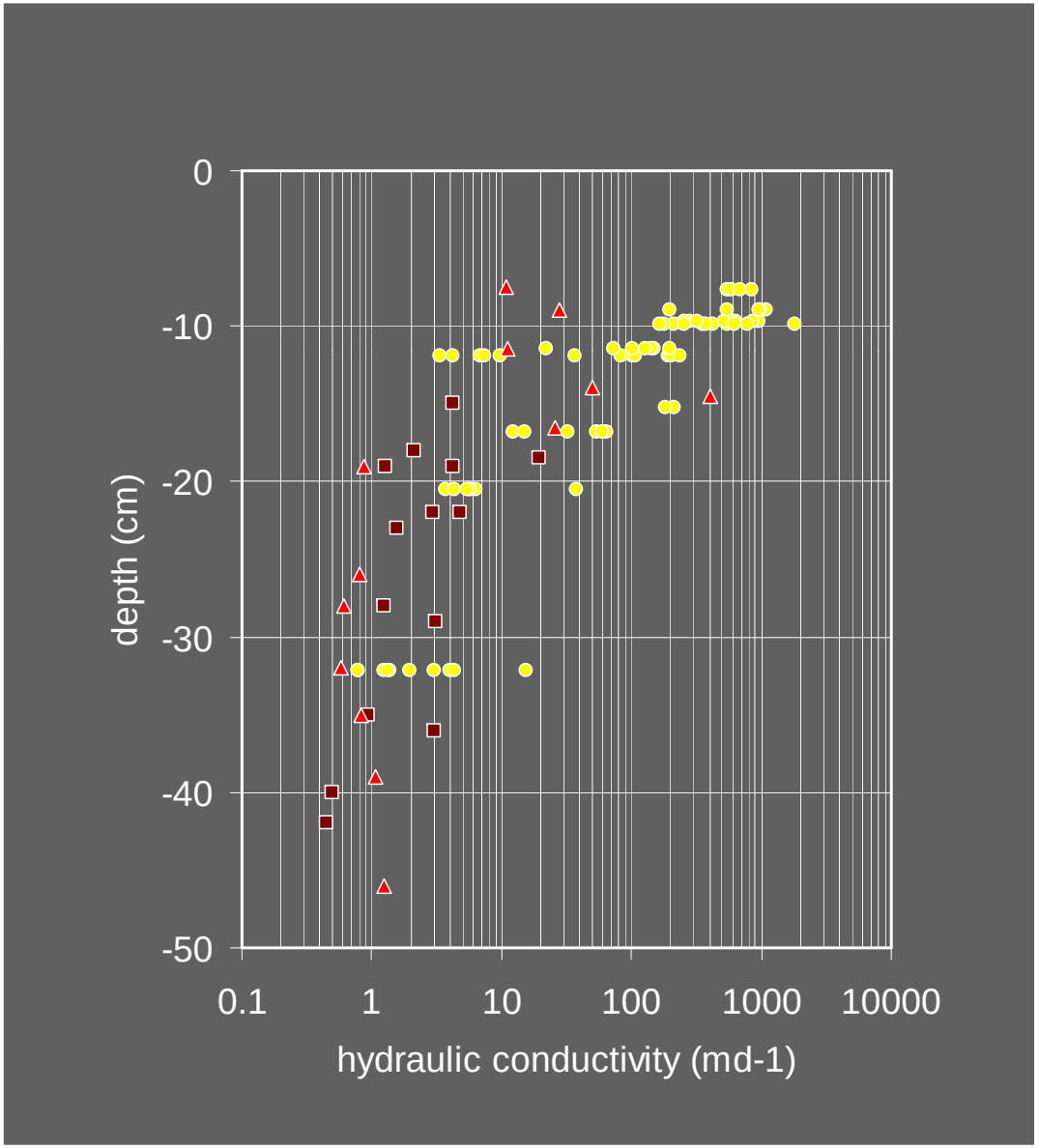
Improved Processes & Parameterisation

-High-frequency Sampling
-Synoptic Sampling
-Hydrometric
-Hydrochemical

Runoff – Plot and Hillslope (HRU) Studies

Improved Processes & Parameterisation for Prediction in Cold Regions

- Organic Soils

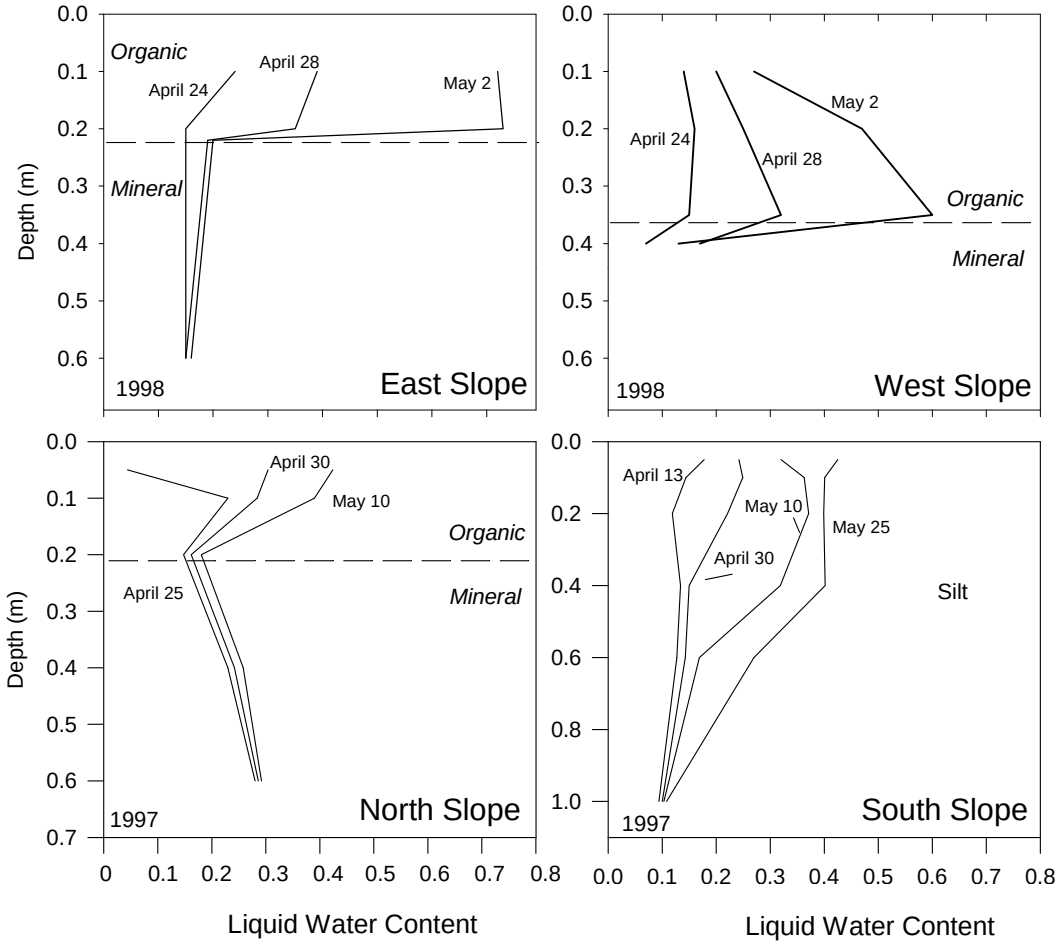


Runoff – Plot and Hillslope (HRU) Studies

Improved Processes & Parameterisation for Prediction in Cold Regions

Infiltration and percolation is restricted when soils are ice-rich (typical of permafrost soils), enhancing runoff generation.

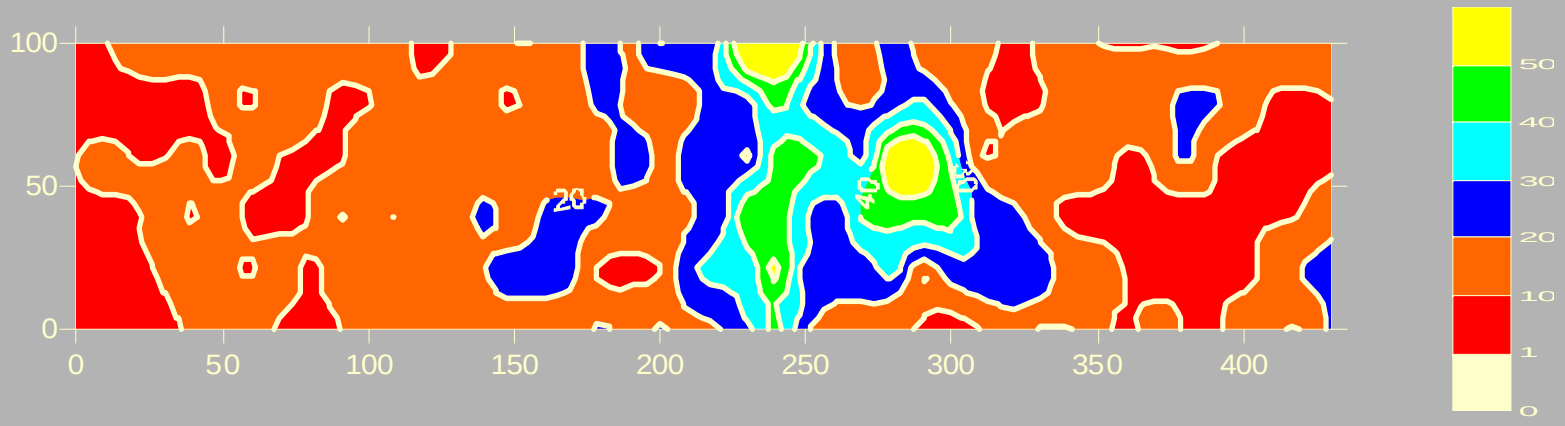
In contrast, infiltration and percolation is unimpeded at dry well drained sites, even when frozen.



Runoff – Plot and Hillslope (HRU) Studies

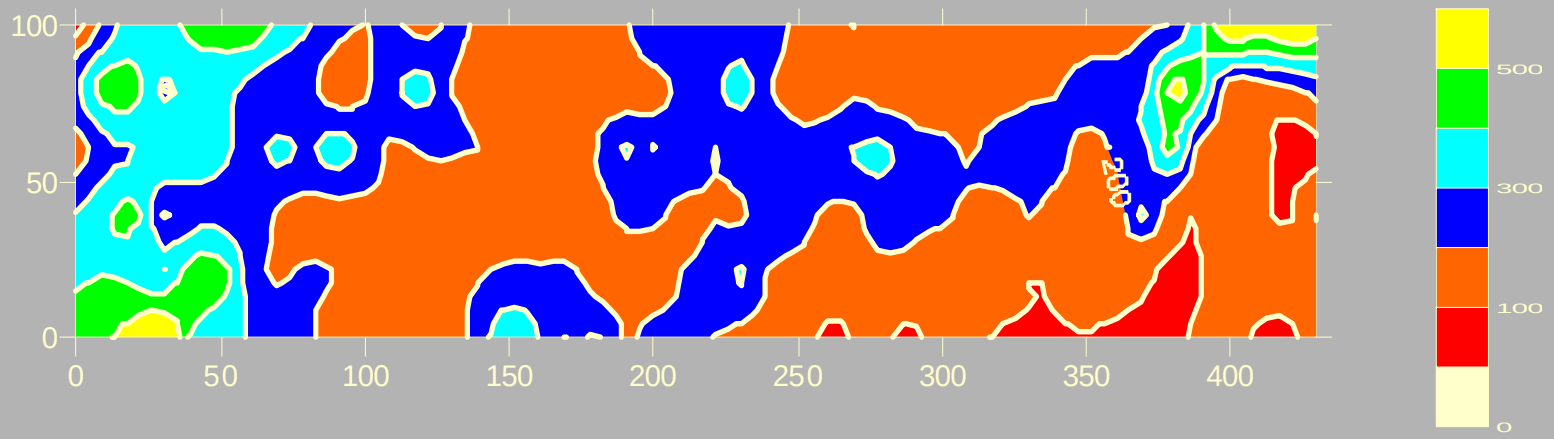
Improved Processes & Parameterisation for Prediction in Cold Regions

Fall soil moisture (percent)



North Face Valley Bottom South Face

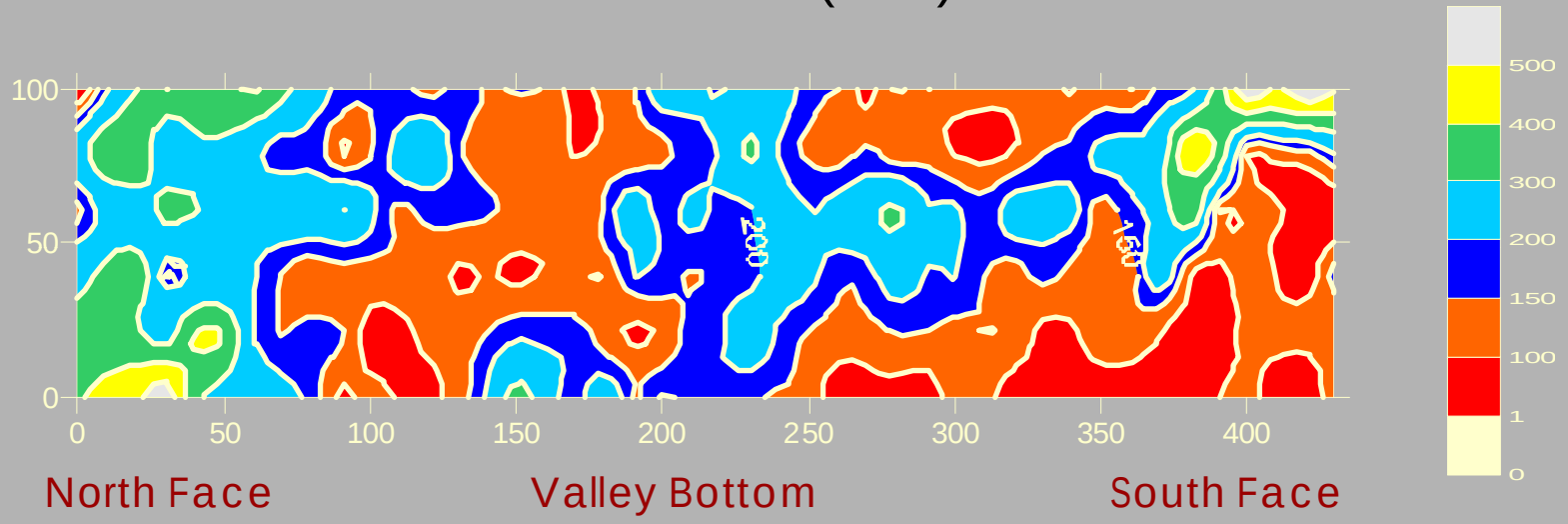
Spring Snow Water Equivalent (mm)



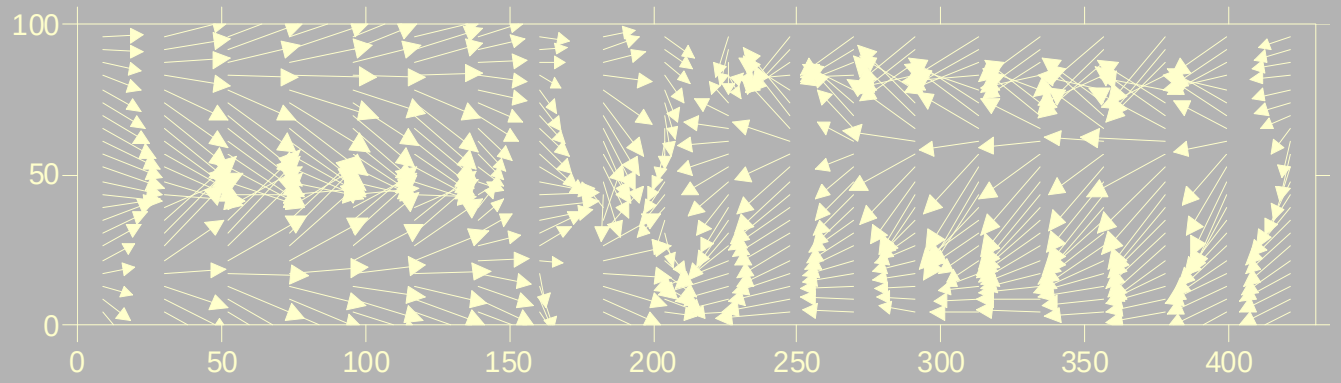
Runoff – Plot and Hillslope (HRU) Studies

Improved Processes & Parameterisation for Prediction in Cold Regions

Snowmelt Runoff (mm)

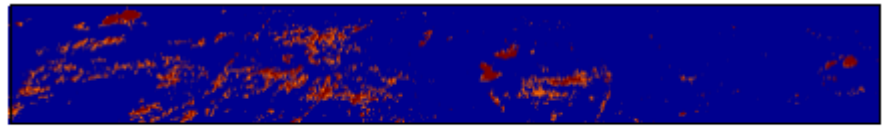


Flow Direction

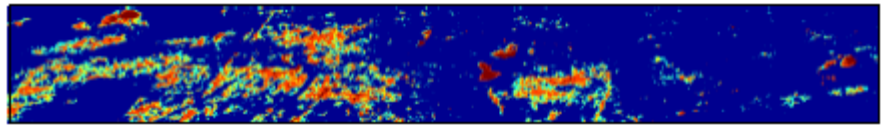


Runoff – Plot and Hillslope (HRU) Studies

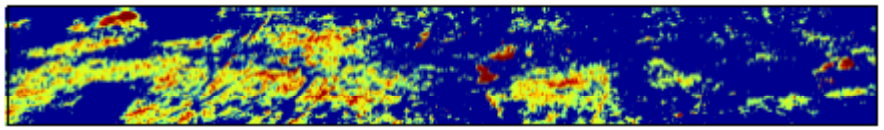
Improved Processes & Parameterisation for Prediction in Cold Regions



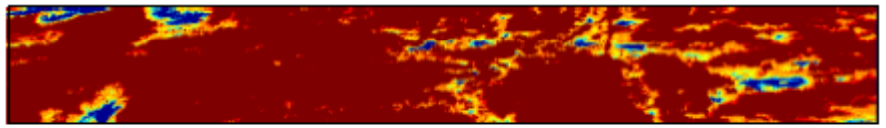
27 April



3 May



6 May



1 June

The position of the frost table has strong control on the delivery of water to the drainage network. In cold regions, appropriate consideration of ground thermal and moisture conditions is essential

Runoff – Basin Scale Interactions

Improved Processes & Parameterisation for Prediction in Cold Regions

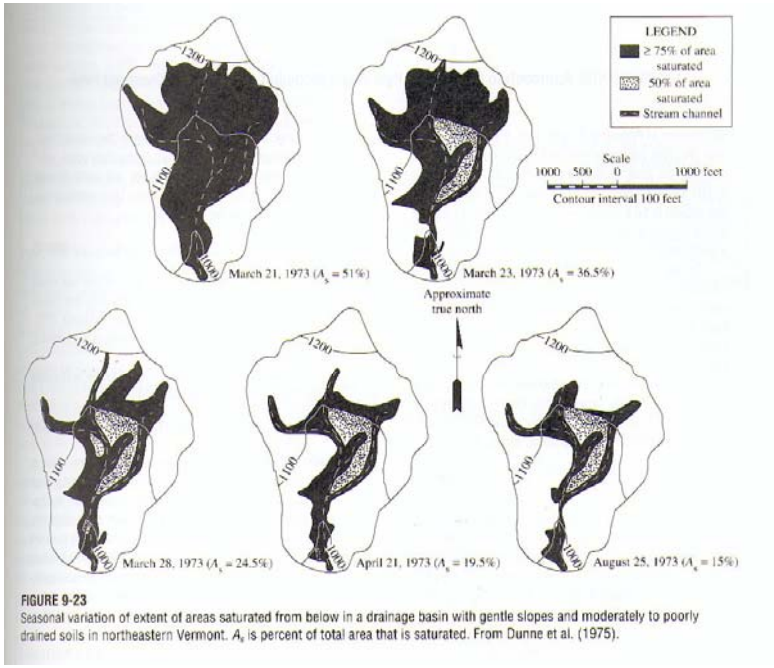
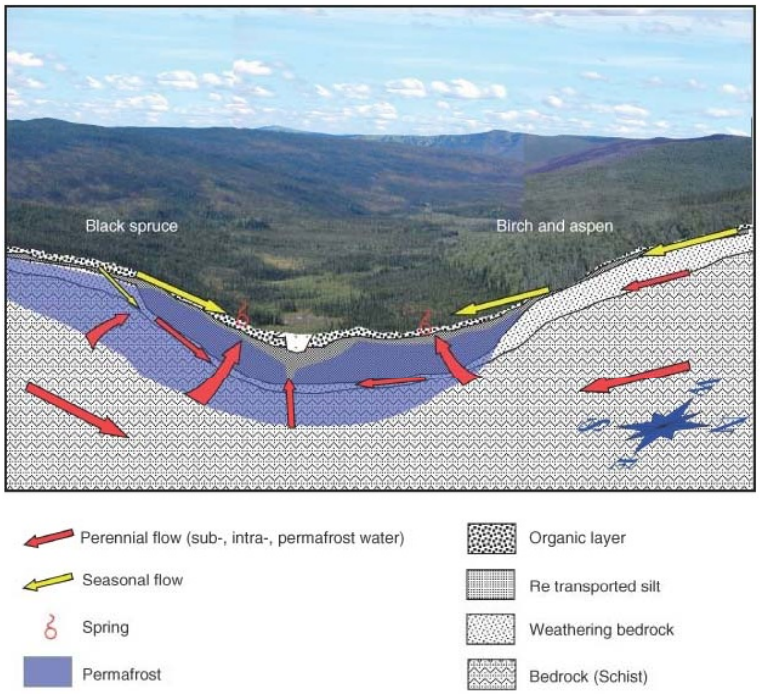
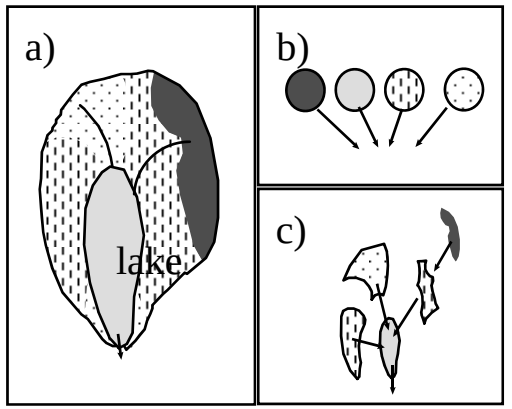


FIGURE 9-23
Seasonal variation of extent of areas saturated from below in a drainage basin with gentle slopes and moderately to poorly drained soils in northeastern Vermont. A_s is percent of total area that is saturated. From Dunne et al. (1975).



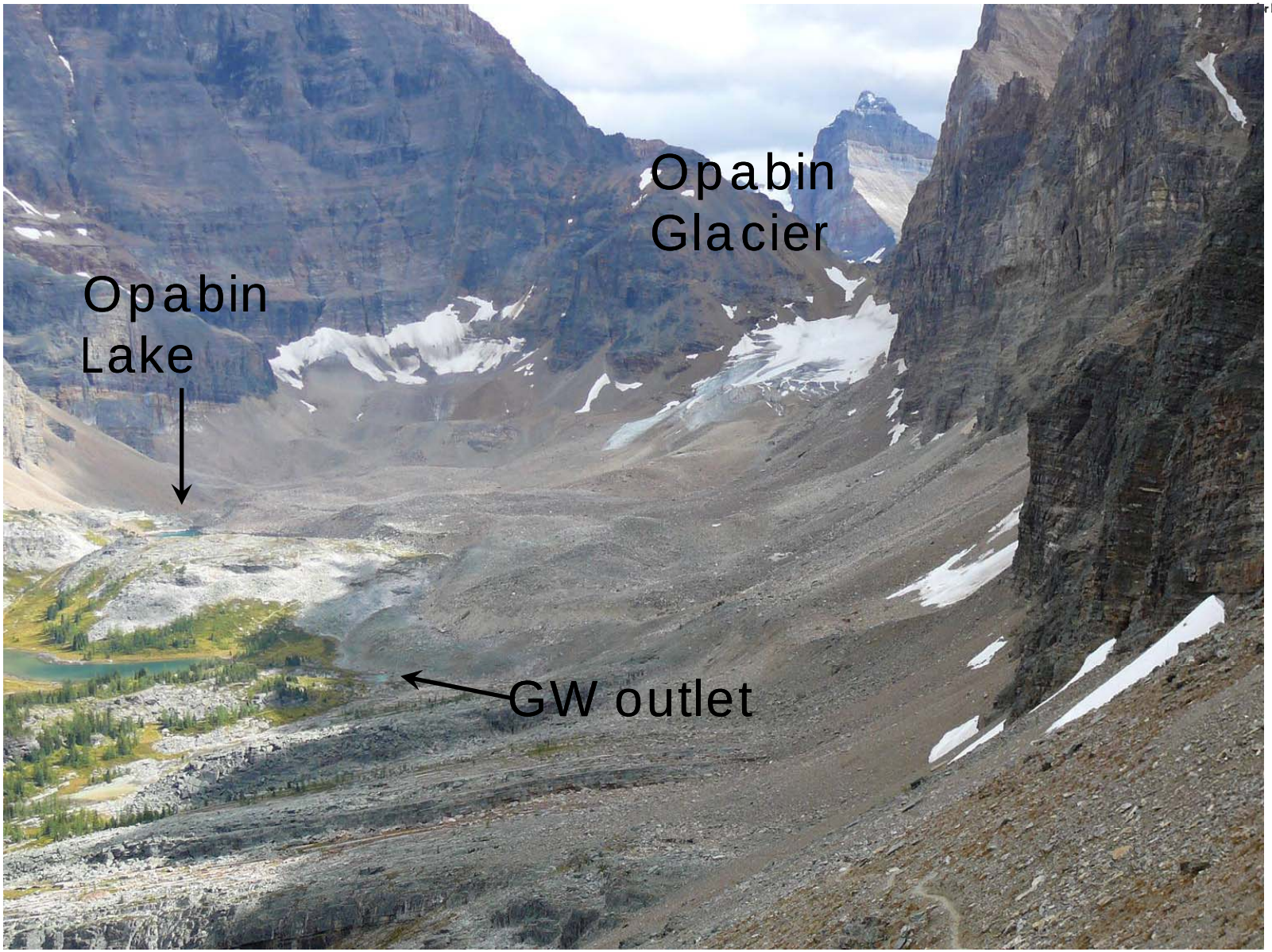
How do processes at the plot, hillslope/HRU scale "upscale" to the basin

Is what we observe at larger scales explainable by our small scale observations



Runoff – The Influence of Glaciers

Improved Processes & Parameterisation
r Prediction in Cold Regions



Runoff – The Influence of Glaciers

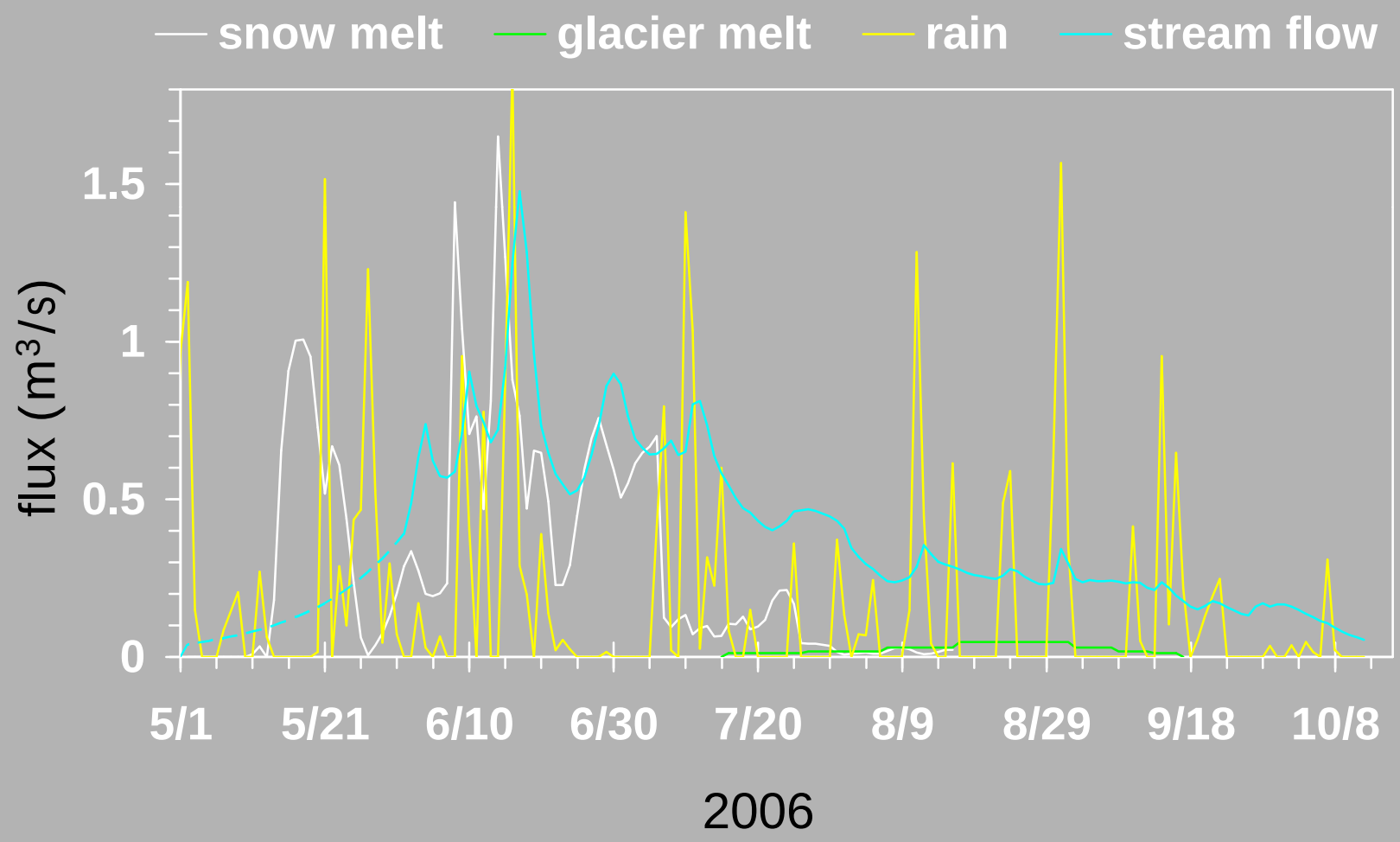
Improved Processes & Parameterisation for Prediction in Cold Regions

Opabin Creek in June 2005

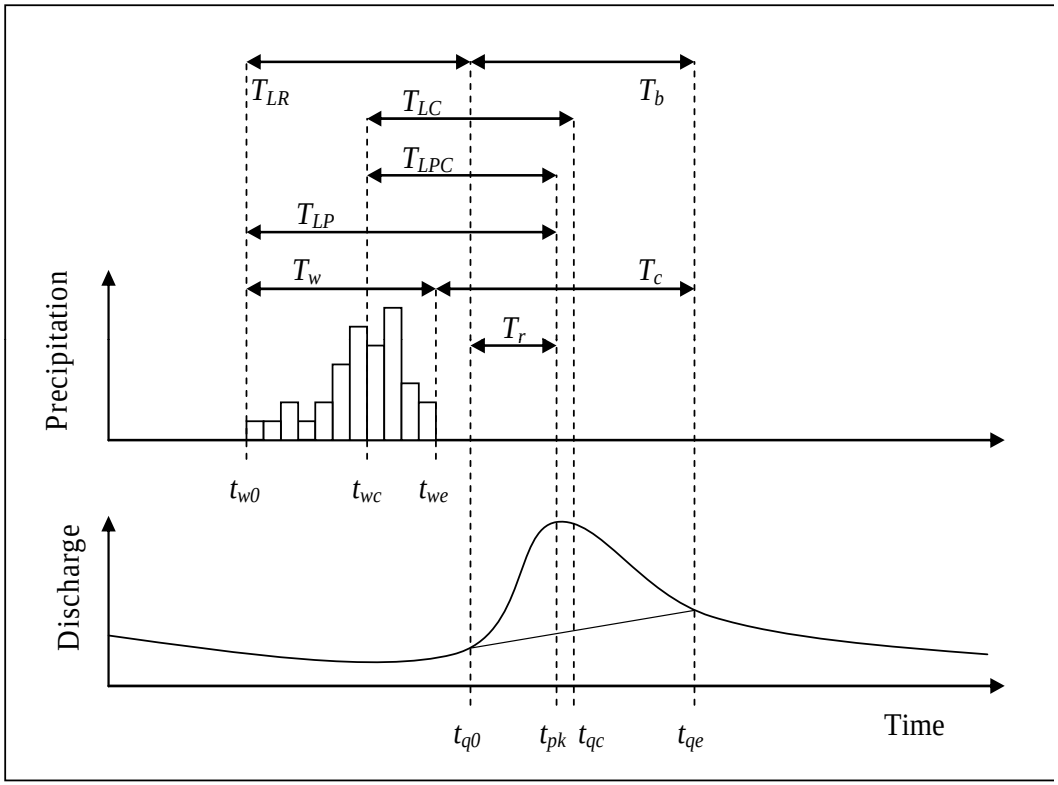
Runoff – The Influence of Glaciers

Improved Processes & Parameterisation for Prediction in Cold Regions

Water Inputs and Output

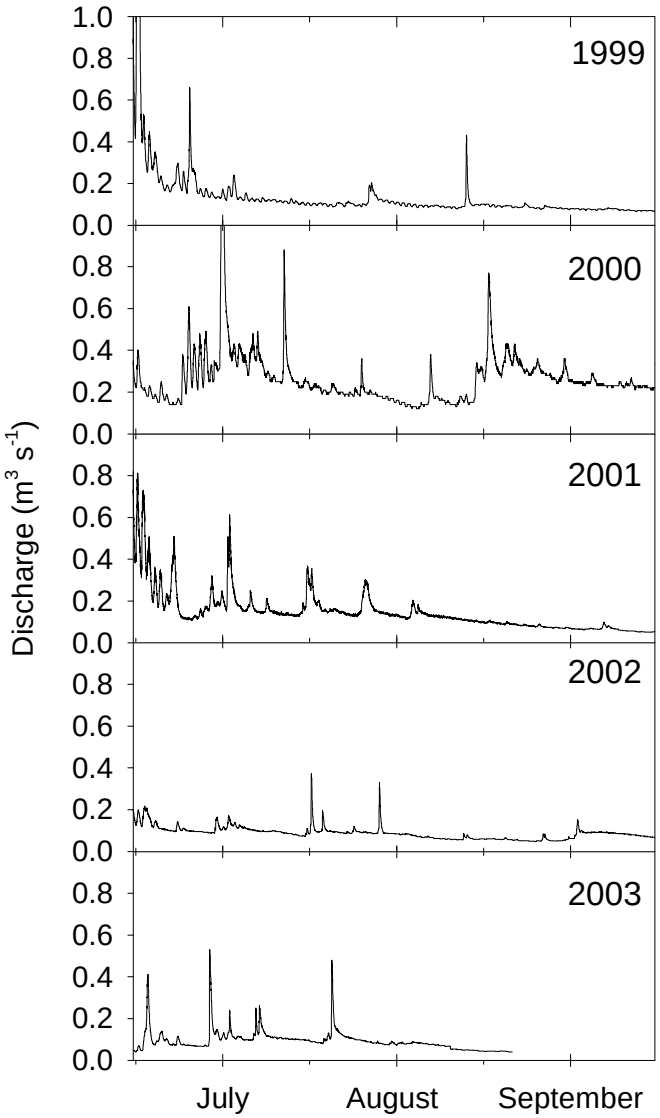


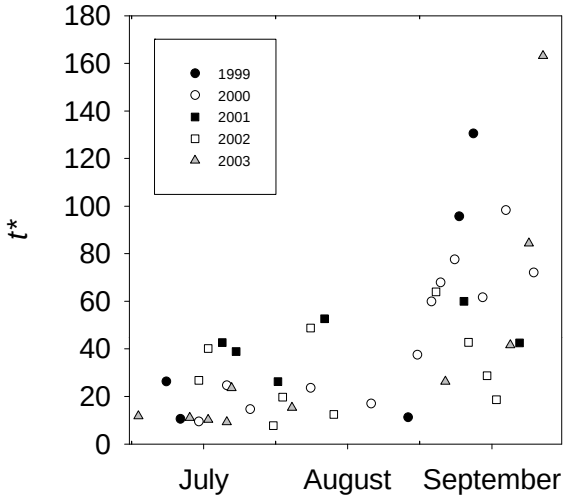
Runoff – the hydrograph

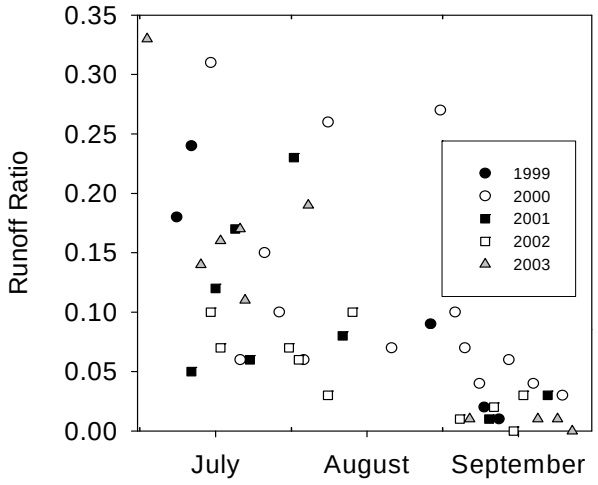


The hydrograph remains an important element of the analysis of runoff processes, particularly at larger spatial scales.

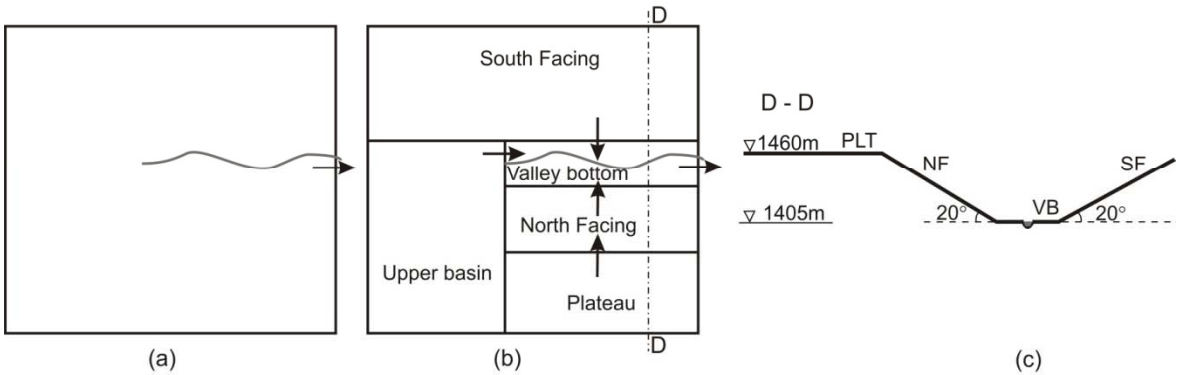
Runoff – the hydrograph







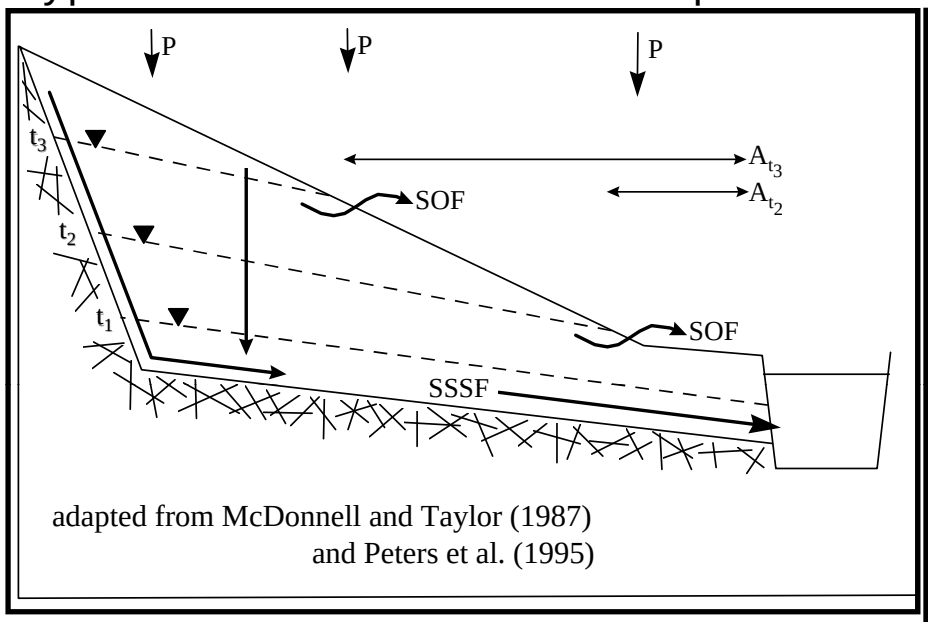
Changes in simple parameters such as the runoff ratio and recession slope indicate strong seasonal controls in runoff response.



Runoff - Thresholds

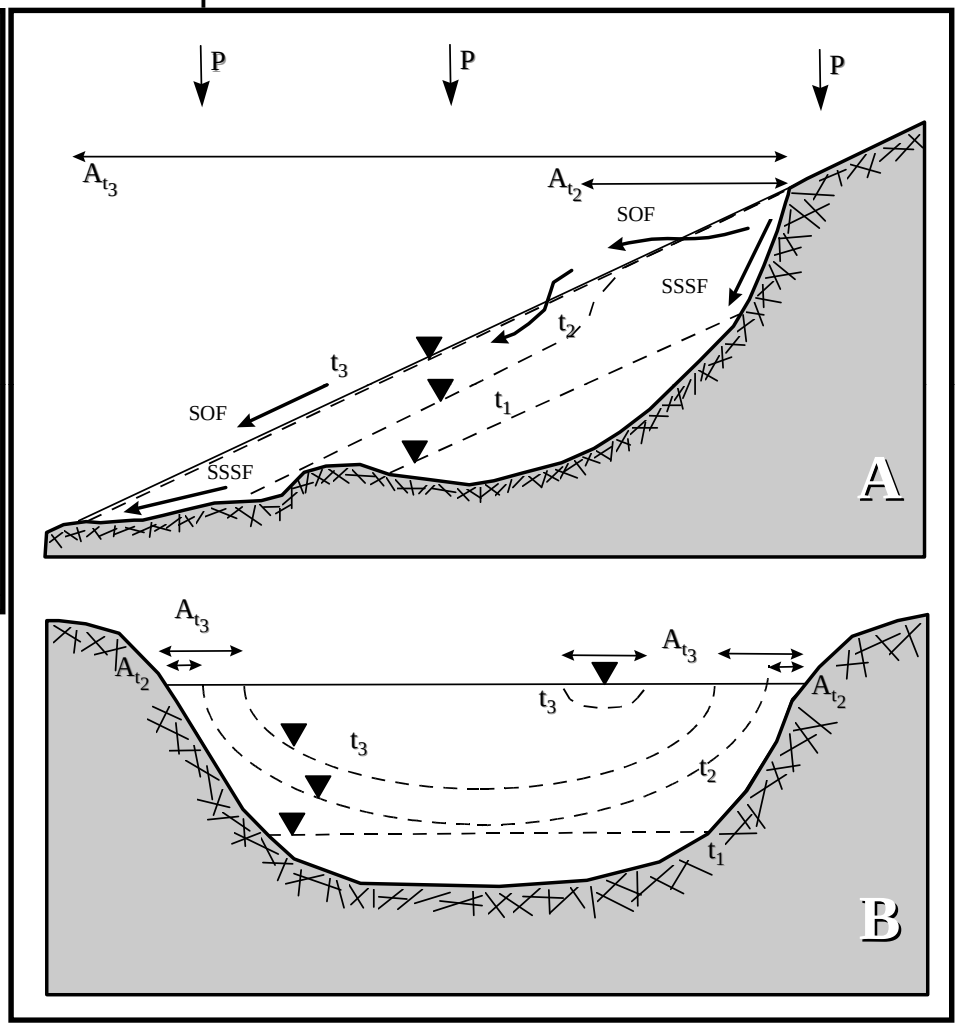
Improved Processes & Parameterisation for Prediction in Cold Regions

Typical saturation overland flow process



adapted from McDonnell and Taylor (1987) and Peters et al. (1995)

Fill-and-spill flow mechanism

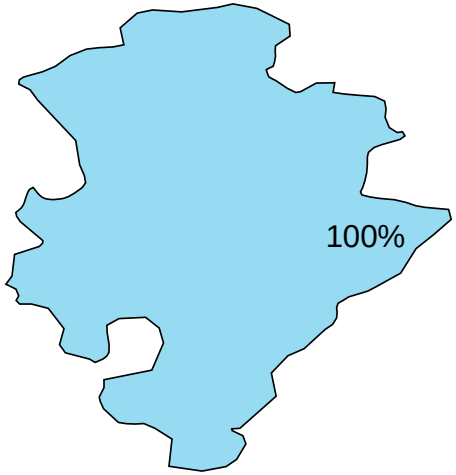


P = precipitation
A = contributing area
t = time
SOF = saturation overland flow
SSSF = subsurface storm flow

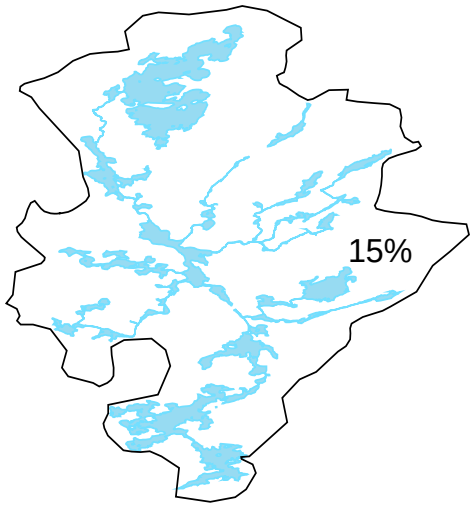
Runoff - Thresholds

Improved Processes & Parameterisation for Prediction in Cold Regions

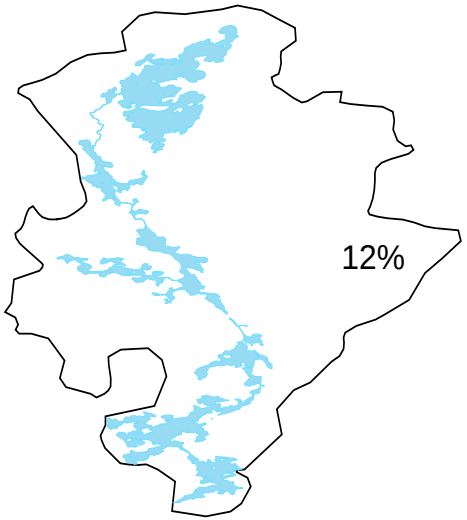
May



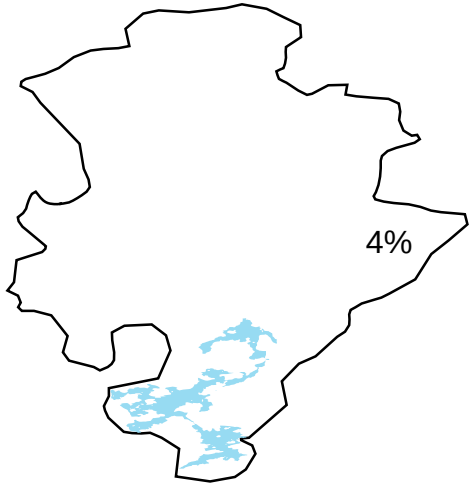
June



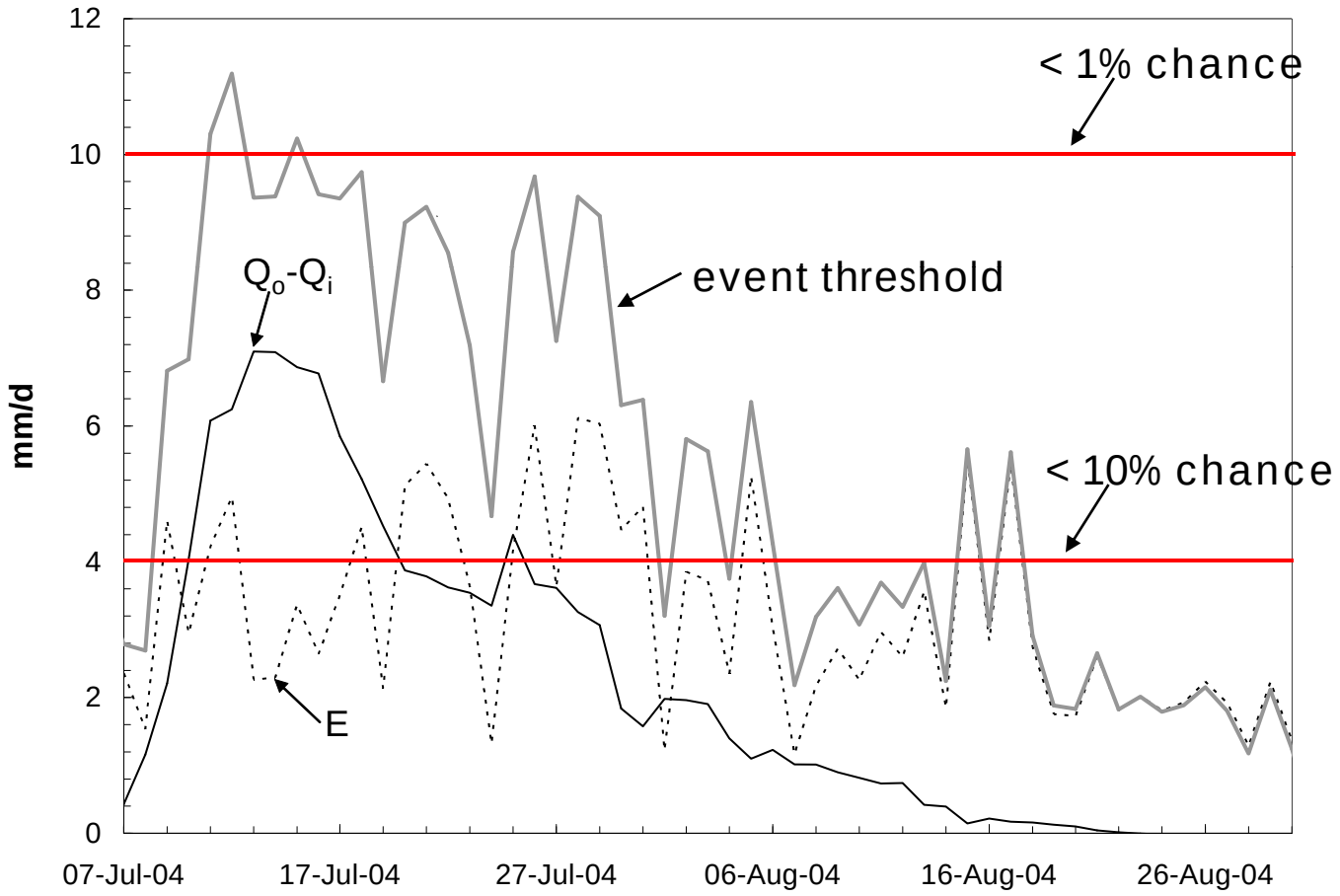
July



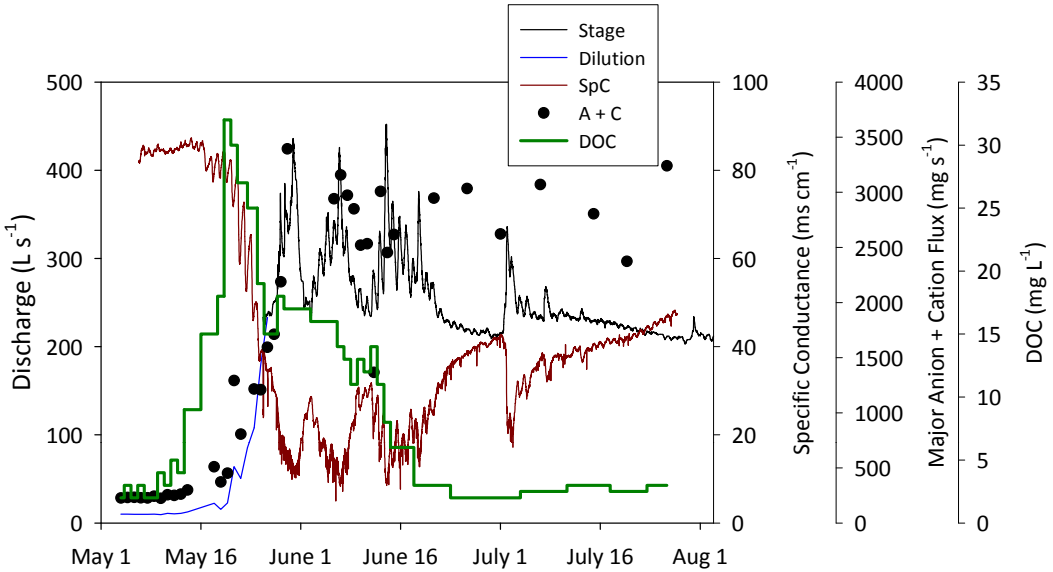
August - September



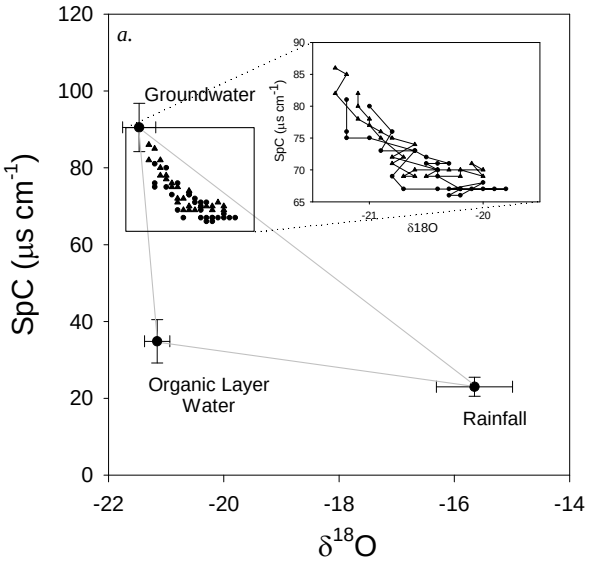
Runoff - Thresholds



Runoff - Tracers

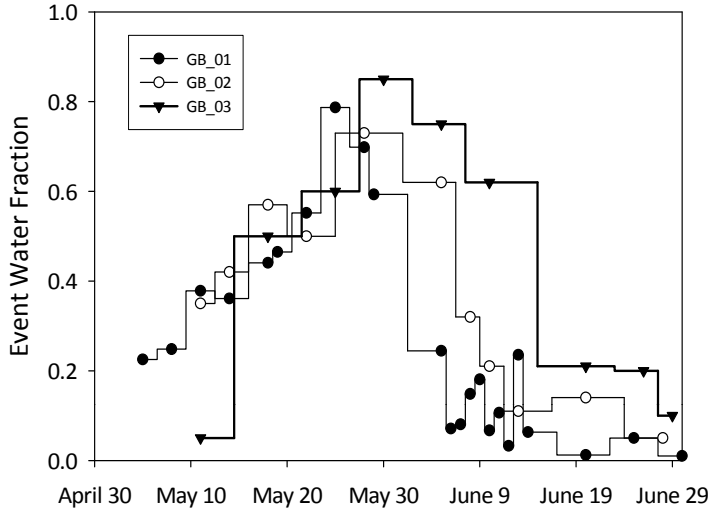


The IP3 network is strongly engaged in using tracers as a means to identify sources of water and interactions, particularly as scale increases.

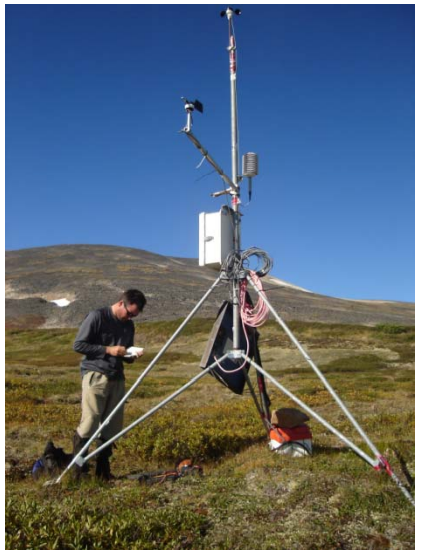


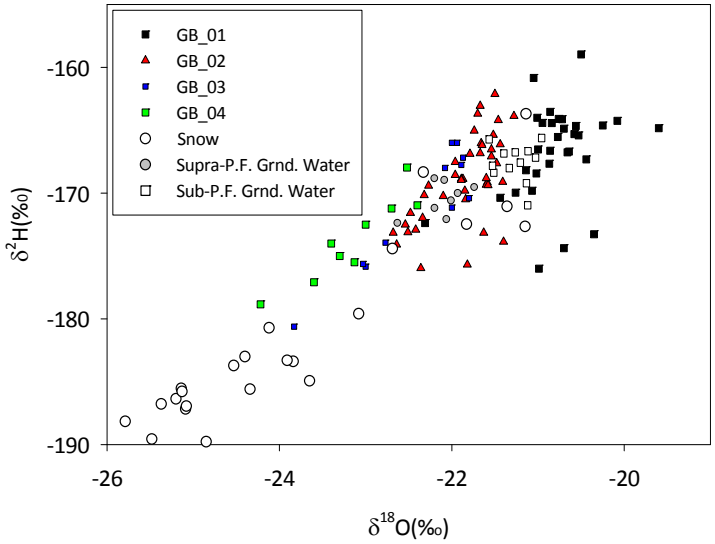
Tracers can be used in combination with hydrometric data to validate both our conceptual and numerical models of the system in question.

Runoff - Tracers



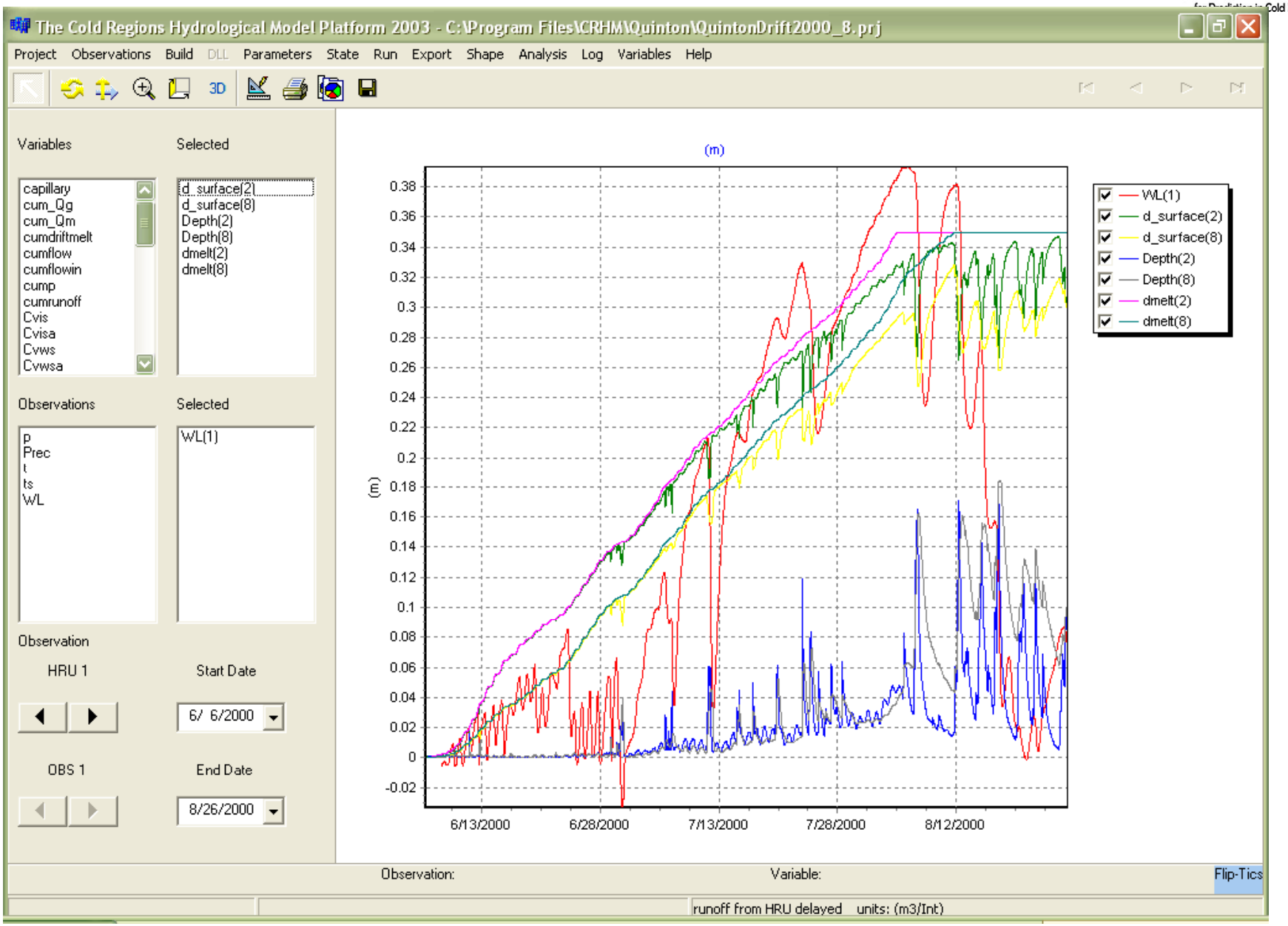
HRUs can be identified based on their unique geochemical signature, which is a particularly useful tool for identifying contributing areas in ungauged basins.





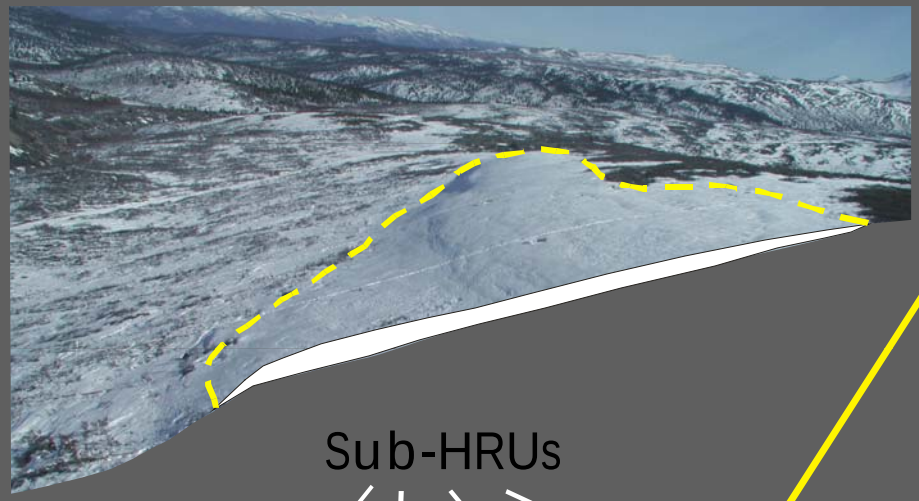
Stable isotopes of water can be used to assess ecosystem cycling of water, and how changes in climate, soils and runoff processes affect that cycling.

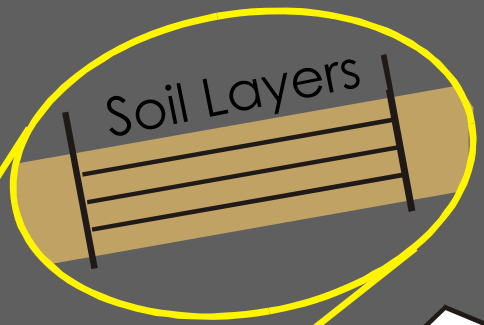
Runoff Modelling

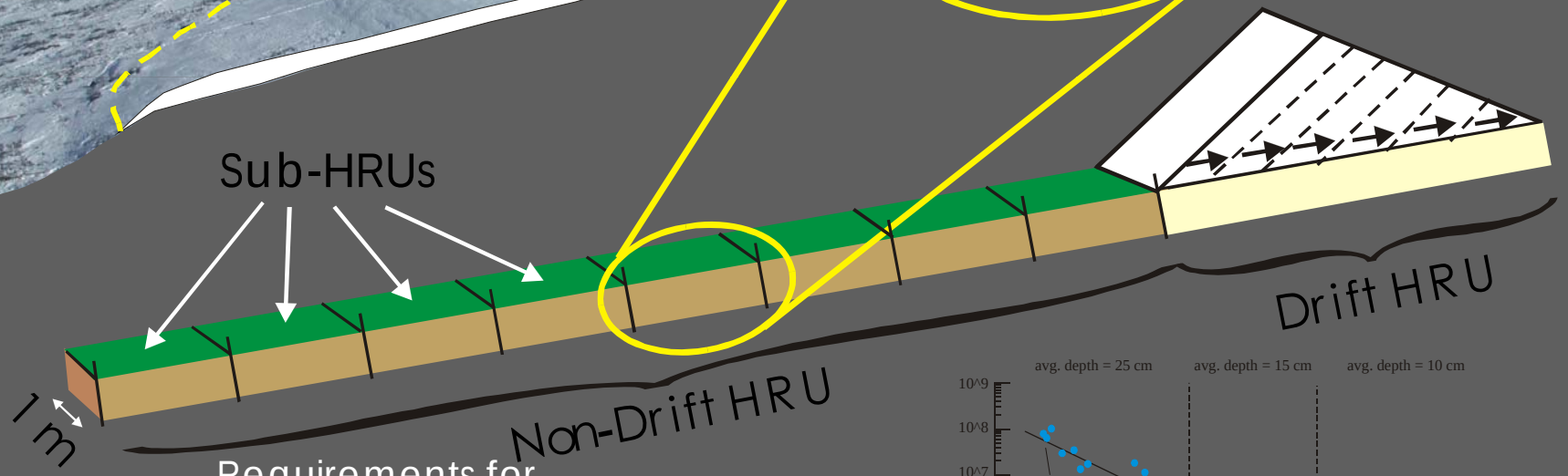


Runoff Modelling

Improved Processes & Parameterisation for Prediction in Cold Regions

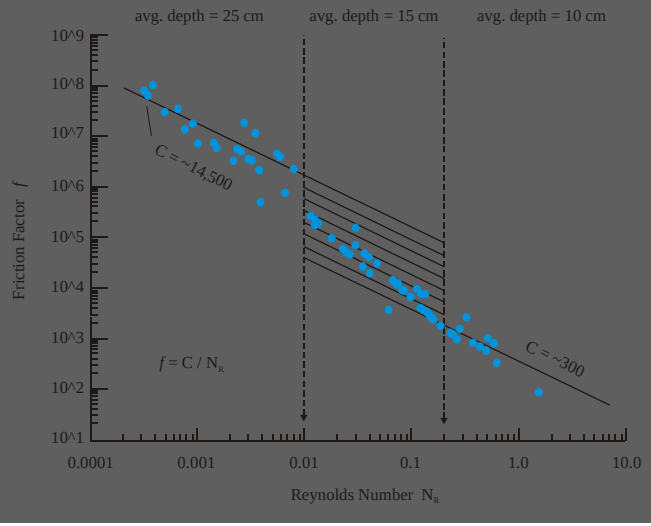






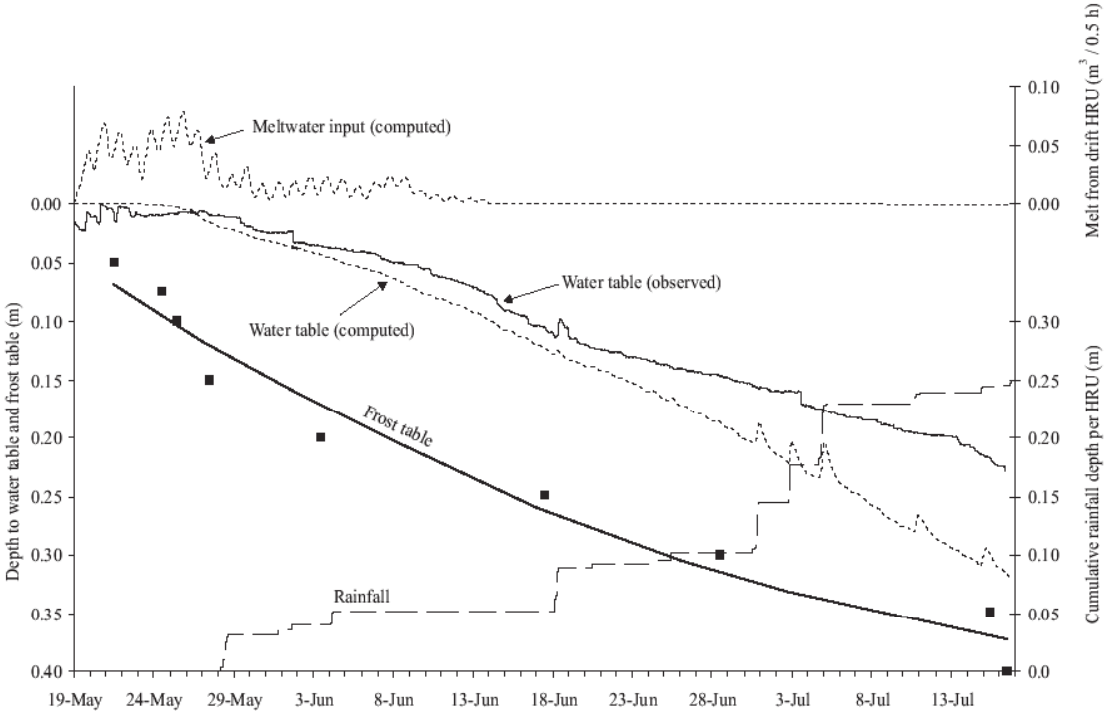
Requirements for each layer:

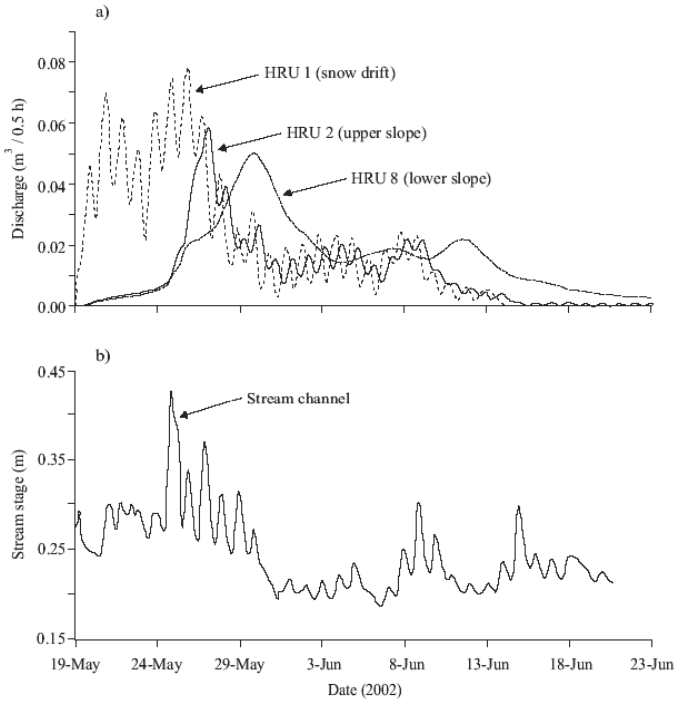
- Thickness
- Porosity
- Specific Retention
- Soil Type
- Lag and Storage
- Slope



Runoff Modelling

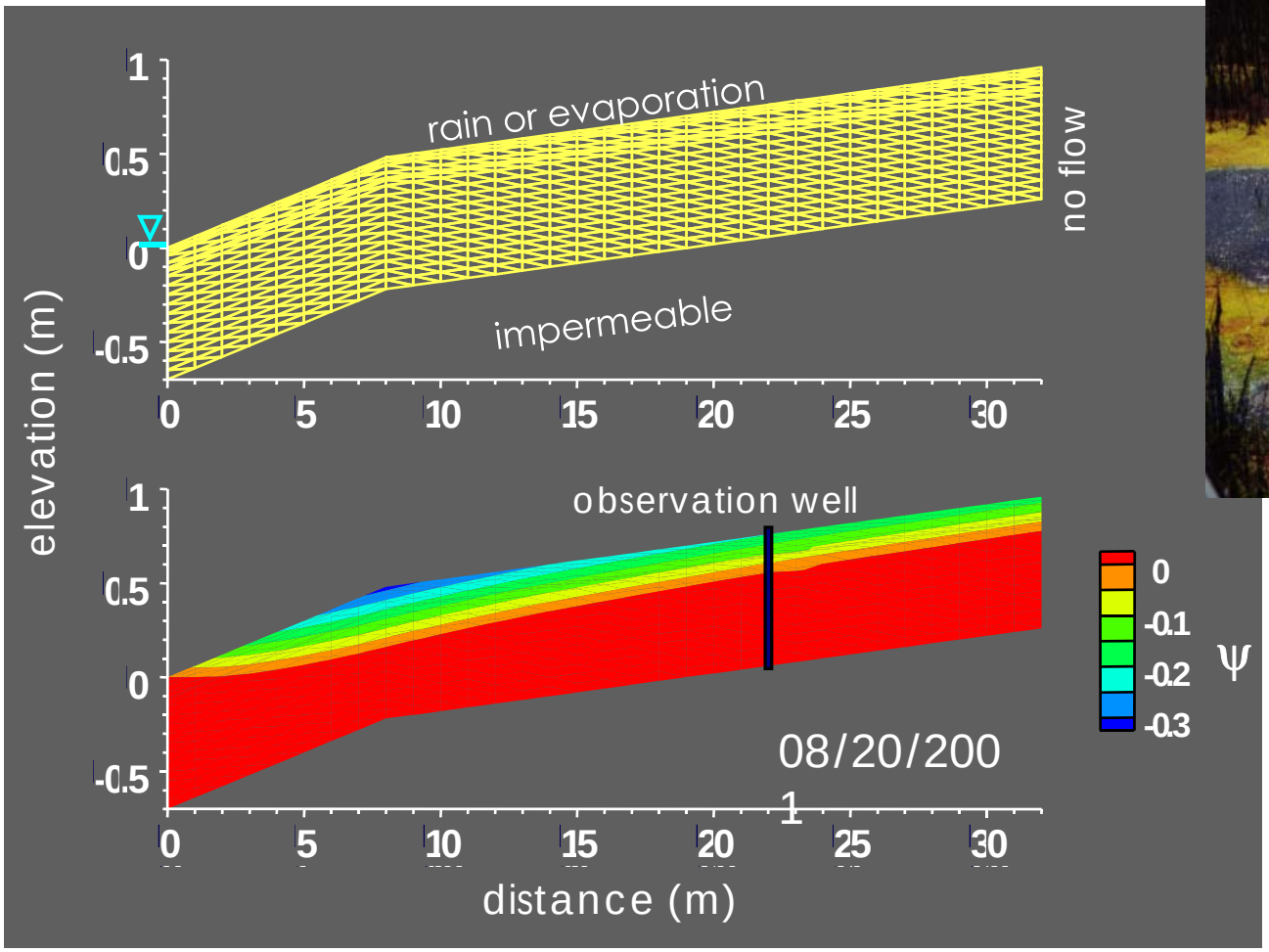
Improved Processes & Parameterisation for Prediction in Cold Regions

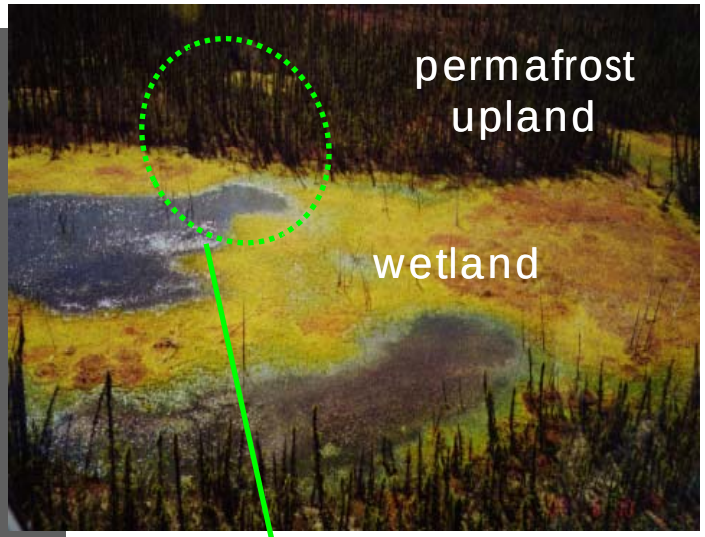


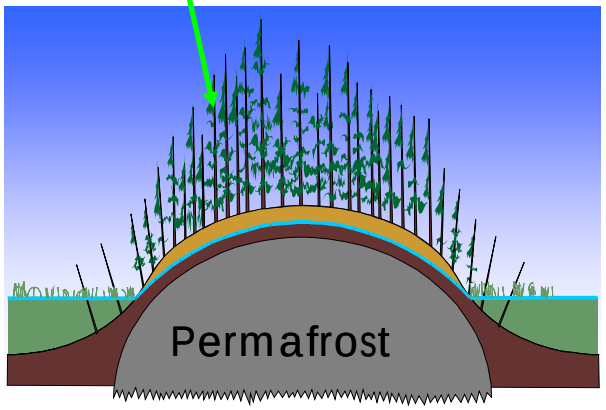


Basic element of runoff and storage can be modelled, and shortcomings point to areas where future research is needed.

Runoff Modelling







Hayashi et al. (2005, IAHS Proceedings)

Thank You

Improved Processes & Parameterisation for Prediction in Cold Regions