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Land-Surface-Hydrological Models for Environmental Prediction – Case study – Wolf Creek

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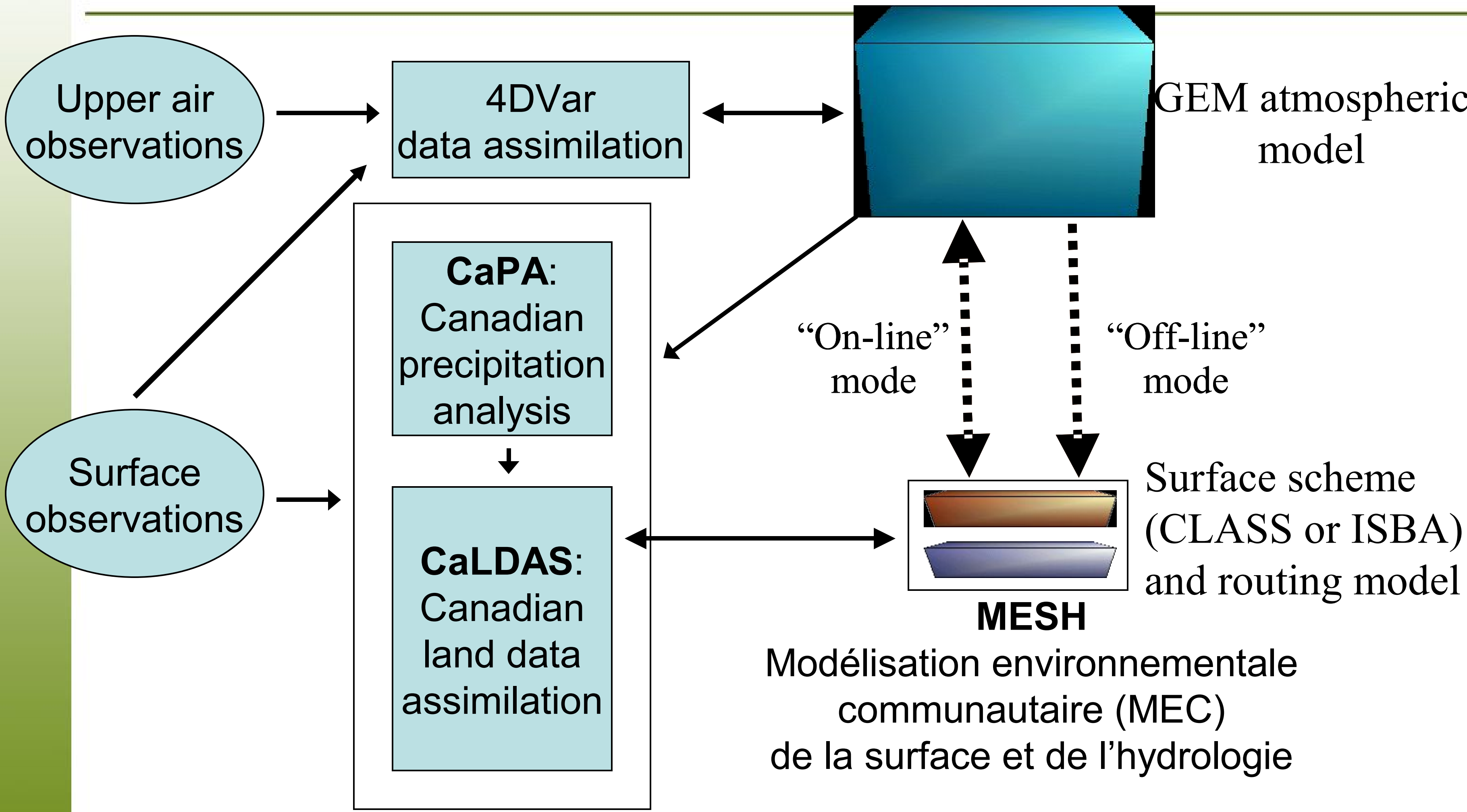
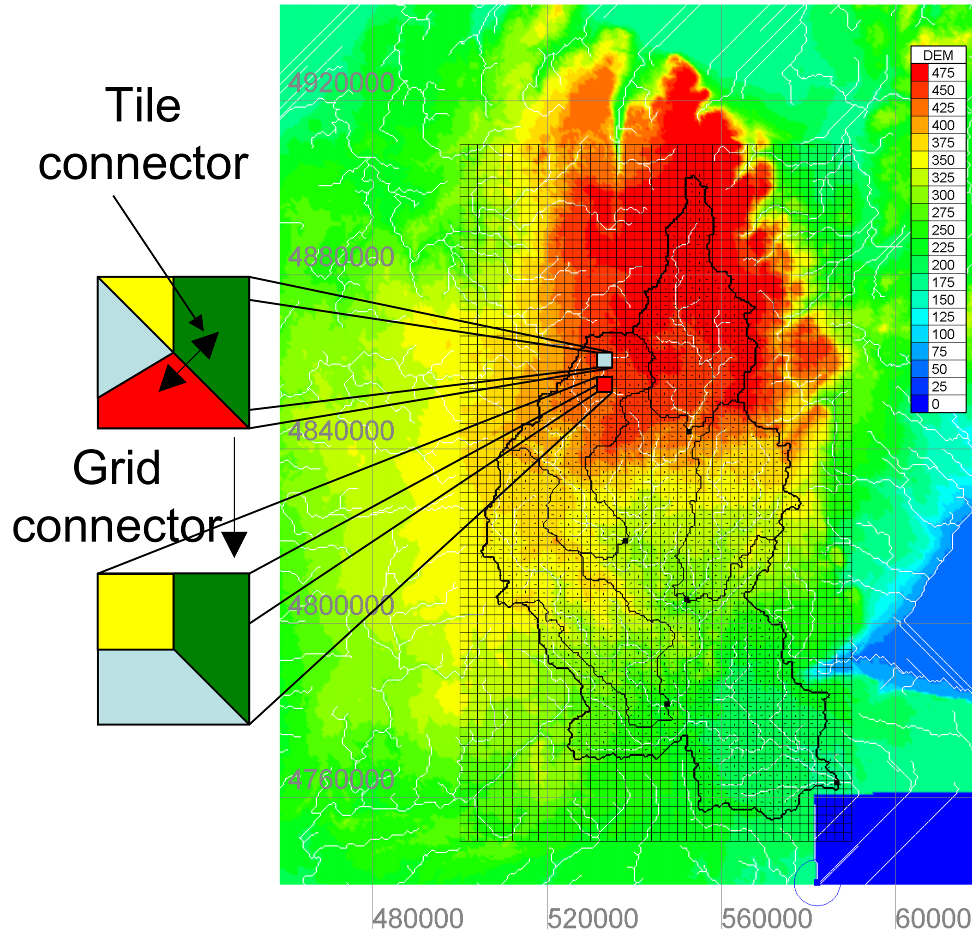
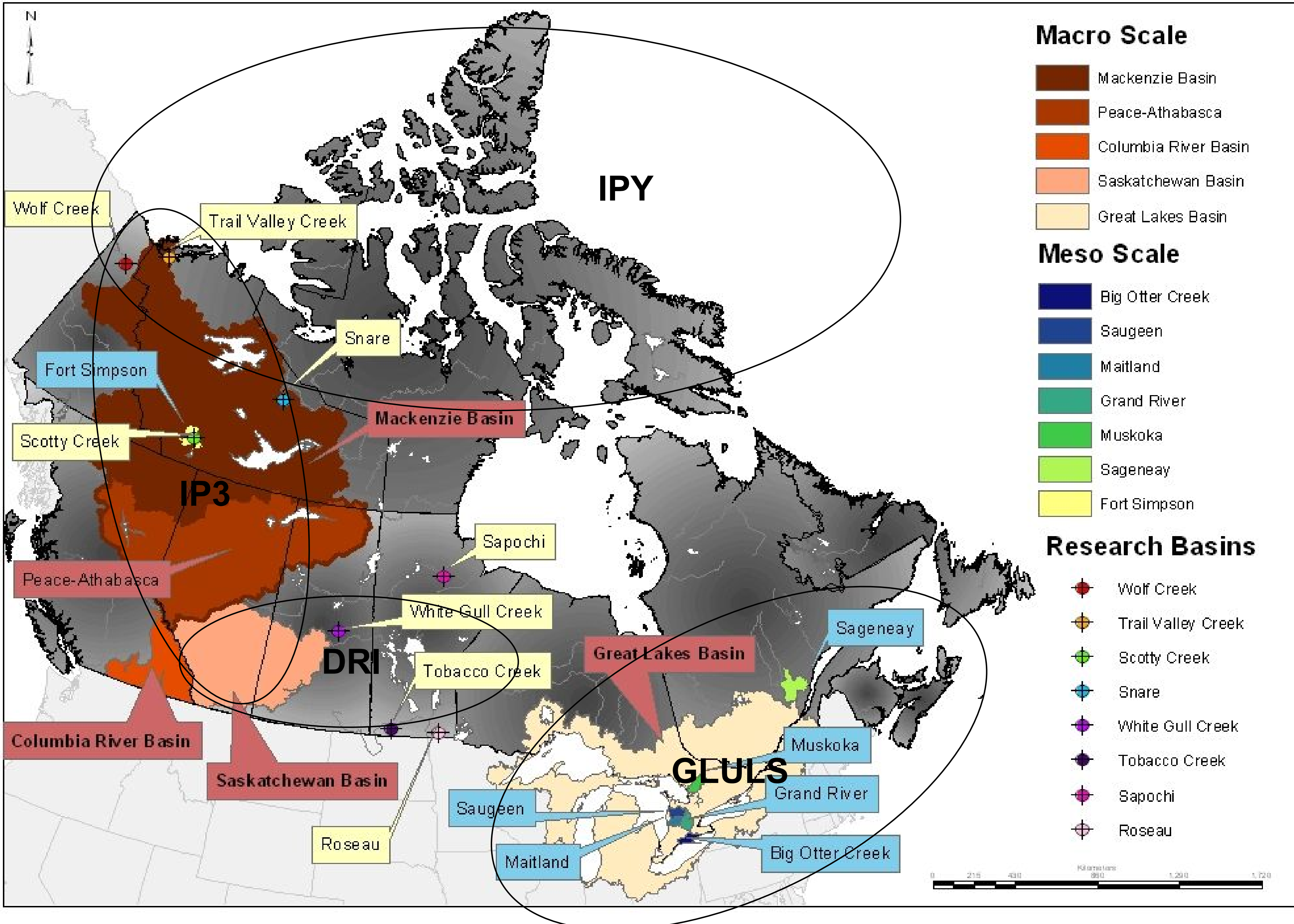
Environmental Prediction Framework



MESH: A MEC surface/hydrology configuration designed for regional hydrological modeling

- The tile connector (1D, scalable) redistributes mass and energy between tiles in a grid cell
  - e.g. snow drift
- The grid connector (2D) is responsible for routing runoff
  - can still be parallelized by grouping grid cells by subwatershed





Map created by Jackie Bronson

Hydrological Models

- **Plethora of models**
  - **Lumped and Conceptual Models**

    Operational - Simple hydrological models

    1D soil-vegetation–atmosphere transfer schemes, (numerical climate and weather forecast models)
  - **Distributed and Physically Based Models**

    Models based on process descriptions

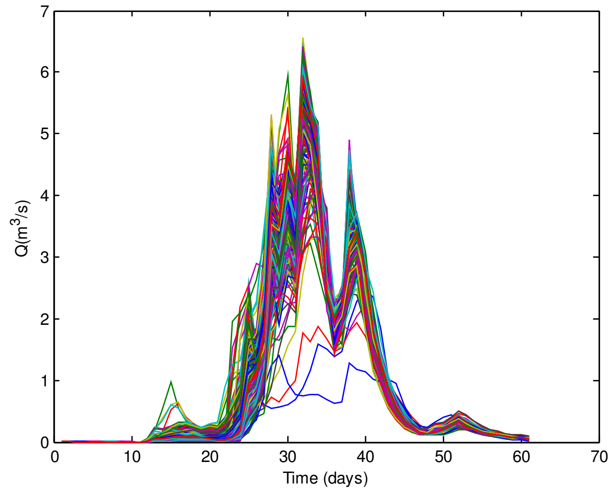
    Can account for spatial patterns of process response

Complexity more parameters

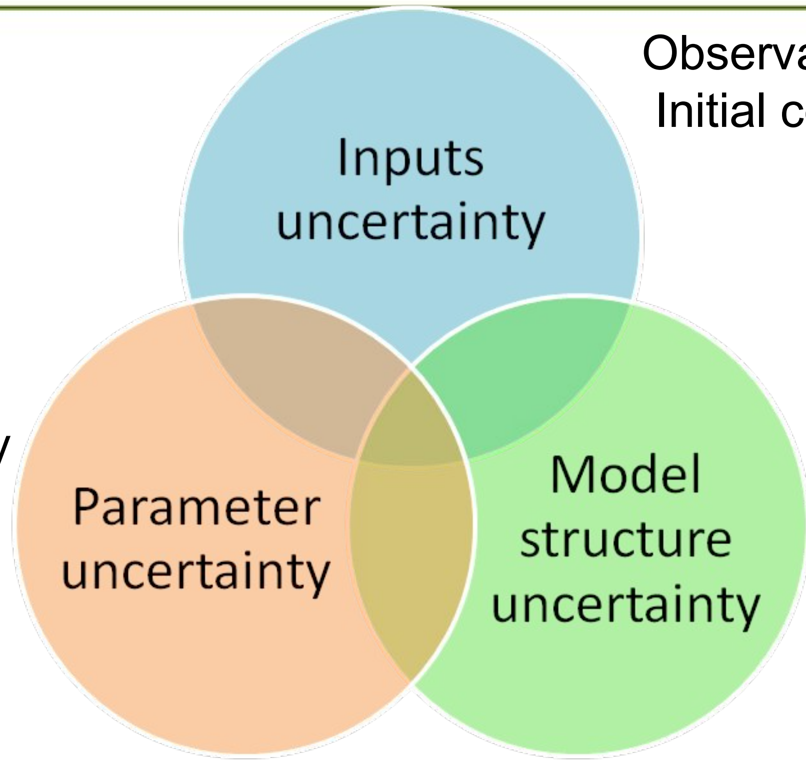
Not enough data

Some parameters still conceptual

Equifinality issues



Predictive uncertainty



- This situation becomes even more important in cold regions areas due the ungauged nature of arctic and subarctic environments.
- New strategies that combine detailed process understanding with an overall knowledge of the system are needed.

Modelling methodology

Inductive Approach

Deductive Approach

basin segmentation

process descriptions

Landscape based
Topography – vegetation

- Snow accumulation regimes
- Blowing snow transport
- Snowmelt energectics
- Snow interception
- Runoff generation/response

Detail process understanding
In cold regions research
basins
(e.g. WC, TVC, prairies)

Modelling Objectives

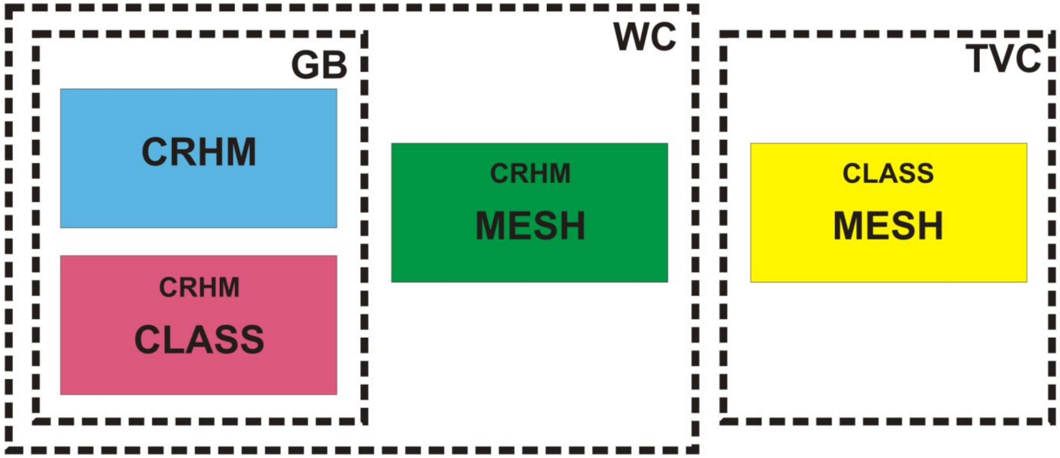
- Definition of an appropriate **modelling strategy** in complex subarctic environments.

- Definition of an optimum representation of the **spatial heterogeneity** that would allow the scaling from point scale observations to catchment scale models. in complex subarctic environments.

2.Effects of **spatially distributed solar forcing** and **initial snow conditions**.

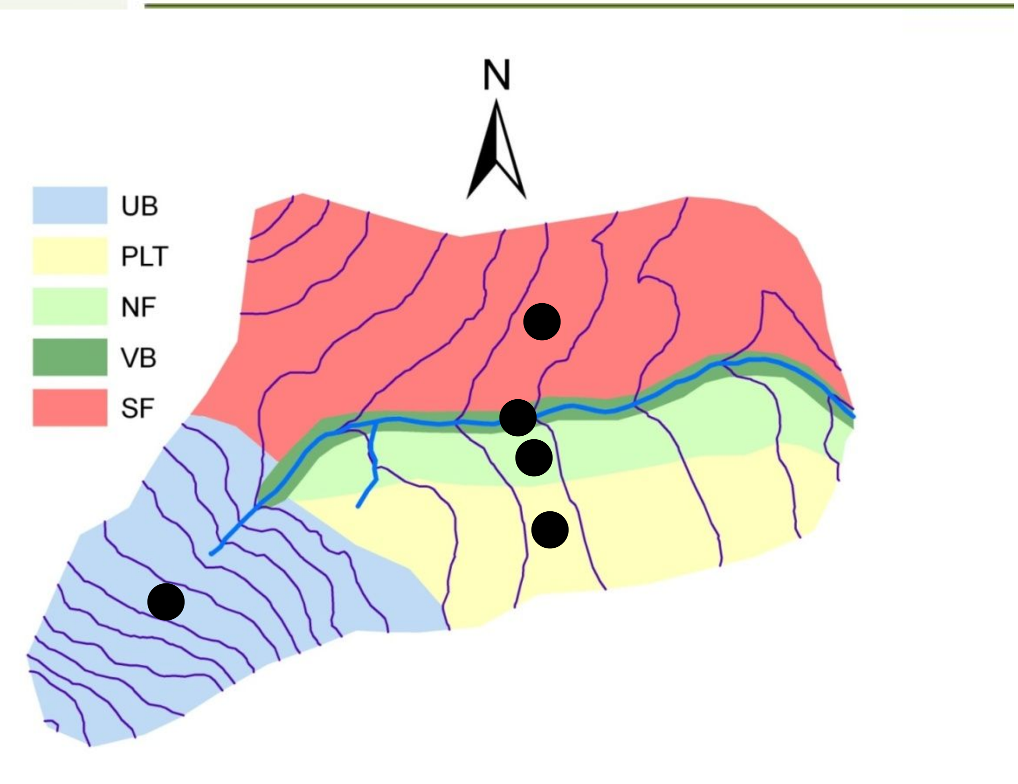
3. Identification of **stable model parameterisations** using a landscape-based approach.

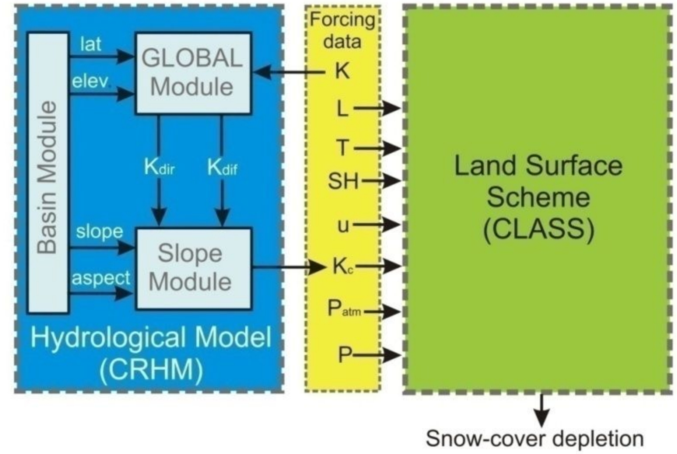
Modelling methodology

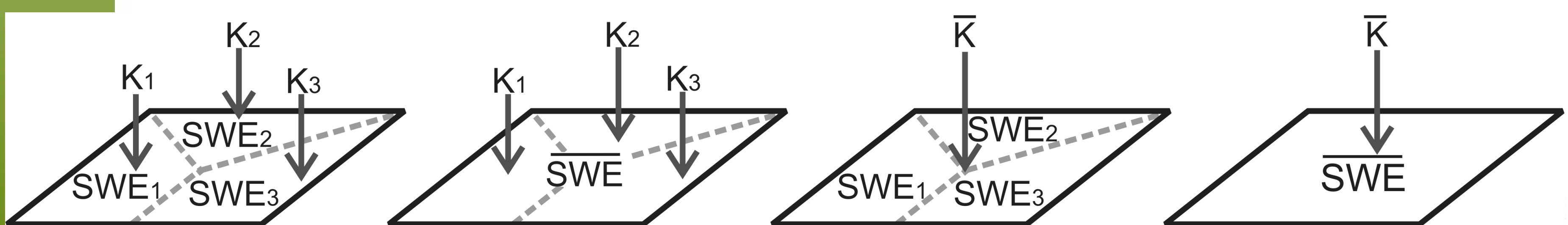


- **Point mode-landscape based** (Granger Basin): **CLASS**
    - Dynamically Dimensioned Search (DDS) global optimisation algorithm
    - □ Vegetation parameters governing snowmelt
- **Distributed mode** (Wolf Creek): **MESH modelling system**
    - Using DDS streamflow ▪ **Hydrology (routing parameters)**
- **Regionalisation** Trail Valley Creek:
    - Using DDS SCA-streamflow ▪ Hydrology parameters + snow-cover depletion parameter

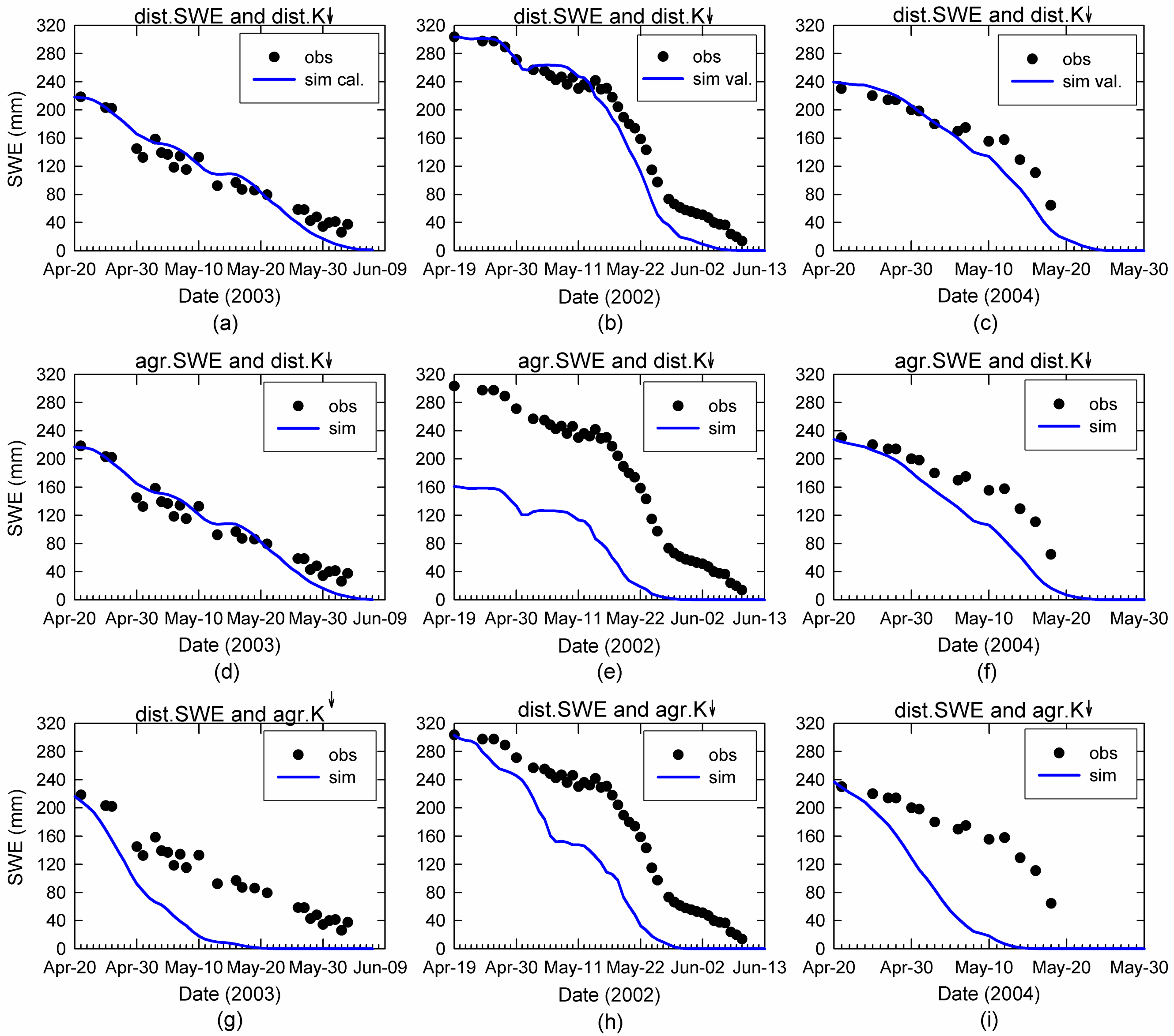
Snow-cover ablation - CLASS

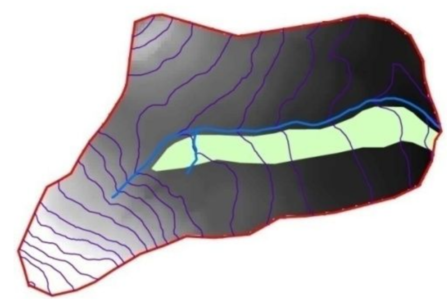






NF - Snow-cover ablation





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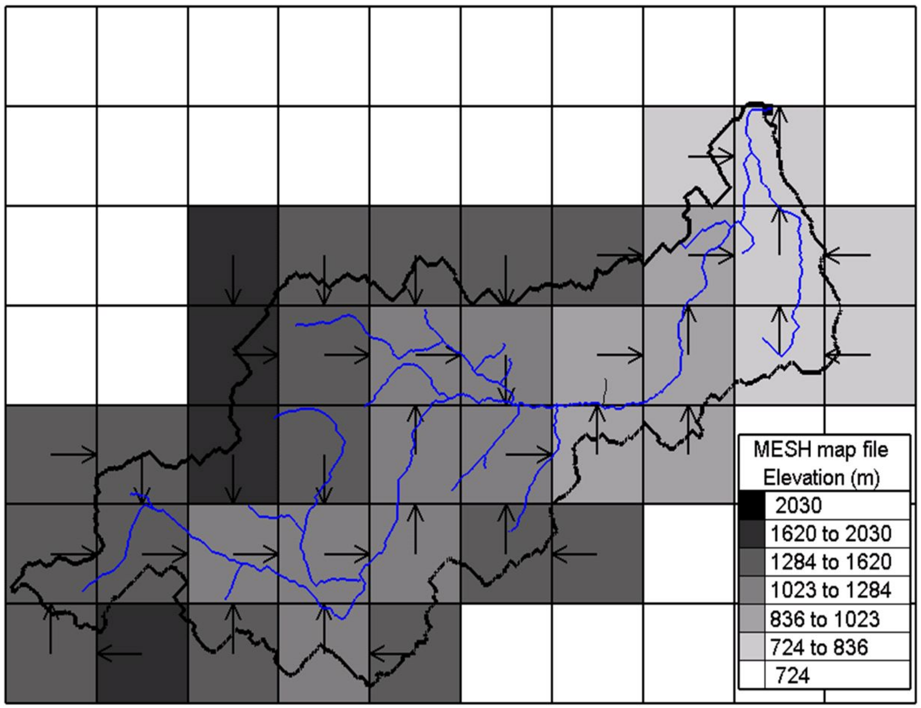
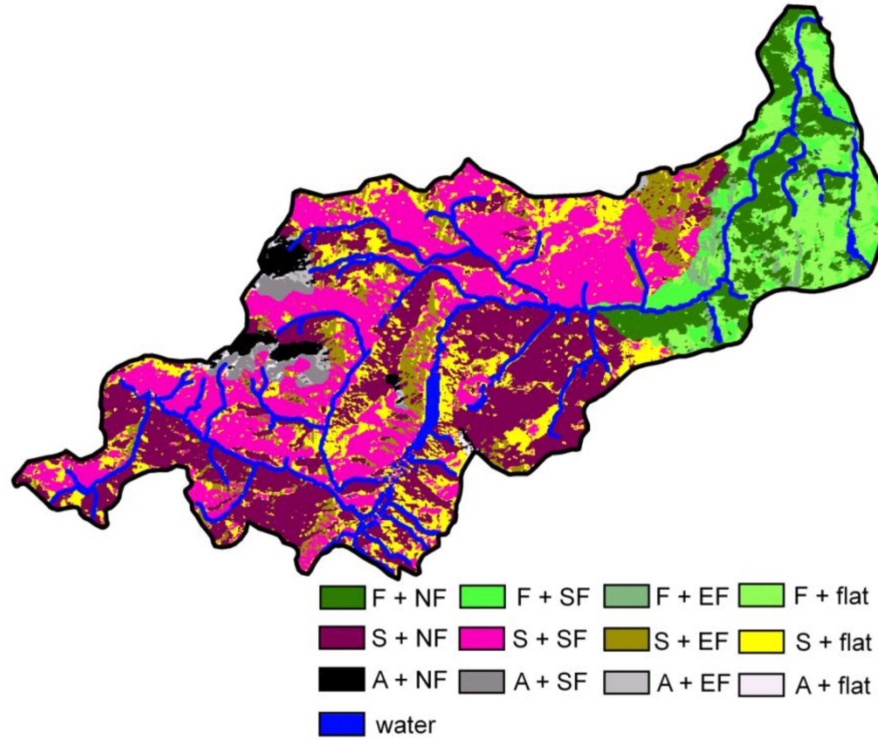
MESH - GRU approach
Wolf Creek

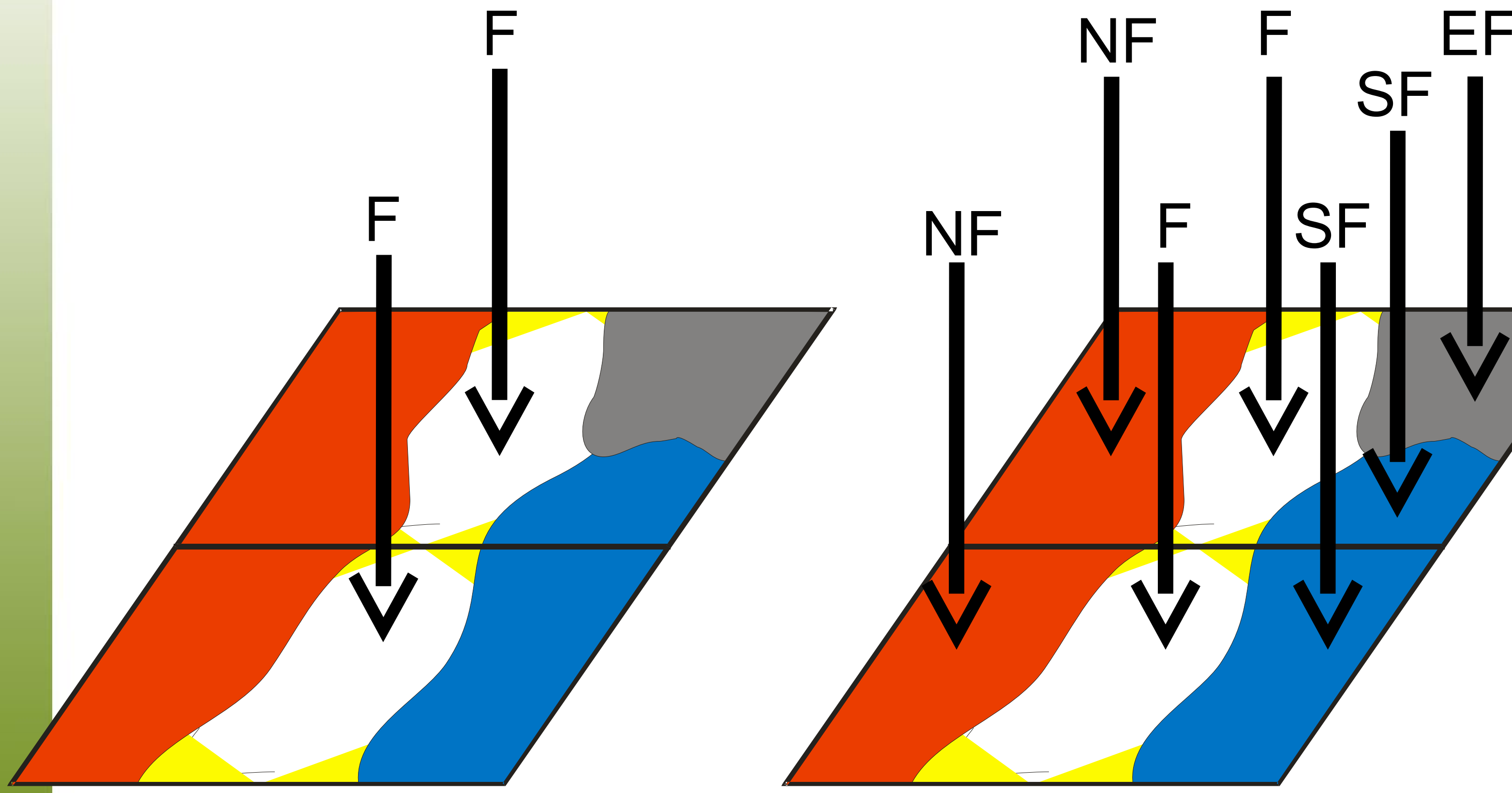


Grid model
spatial discretisation
3 km x 3 km

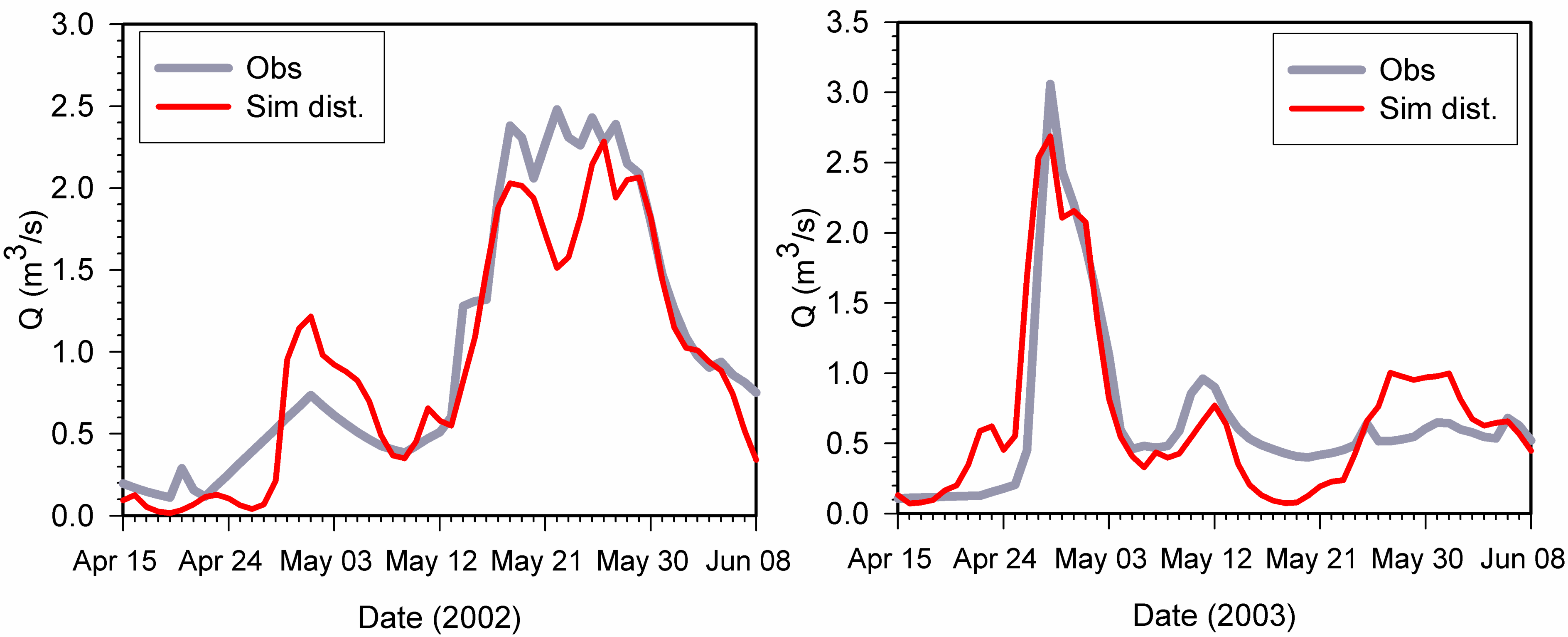


Landscape
representation
topography + land-
cover

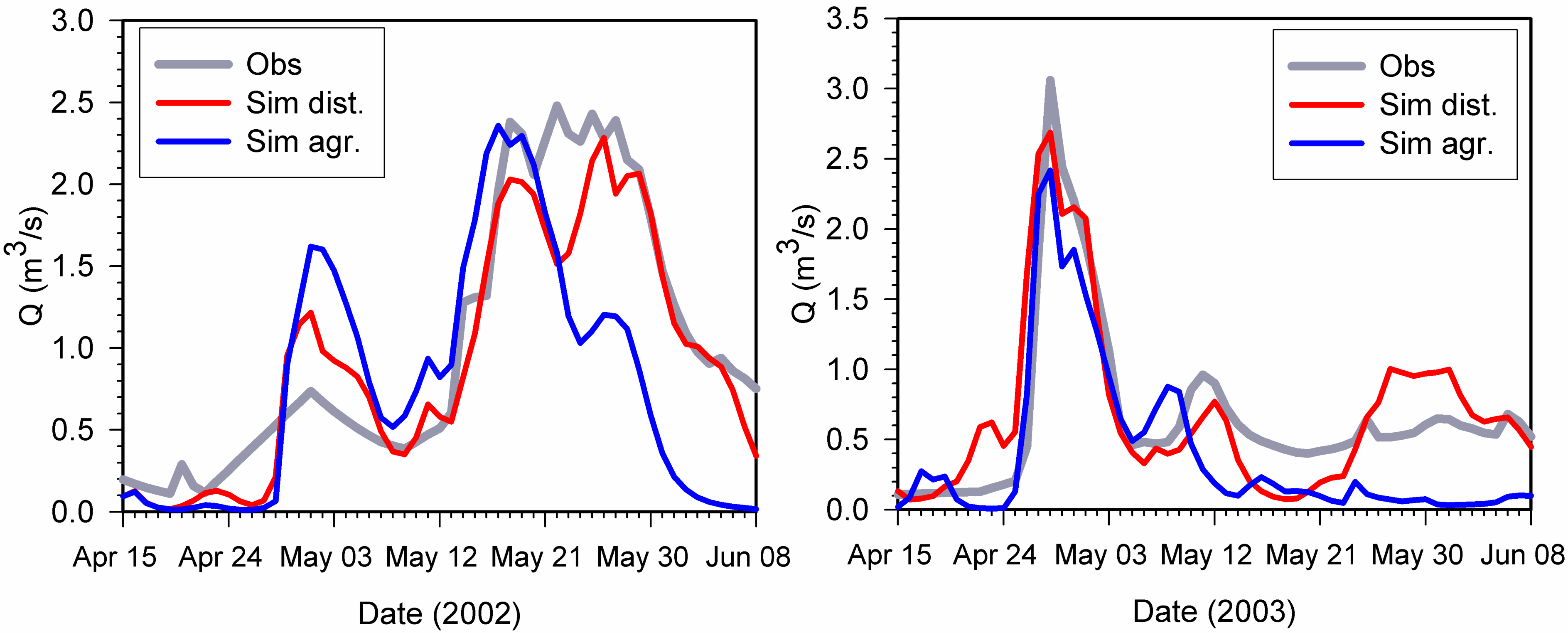
GRU – distributed solar forcing



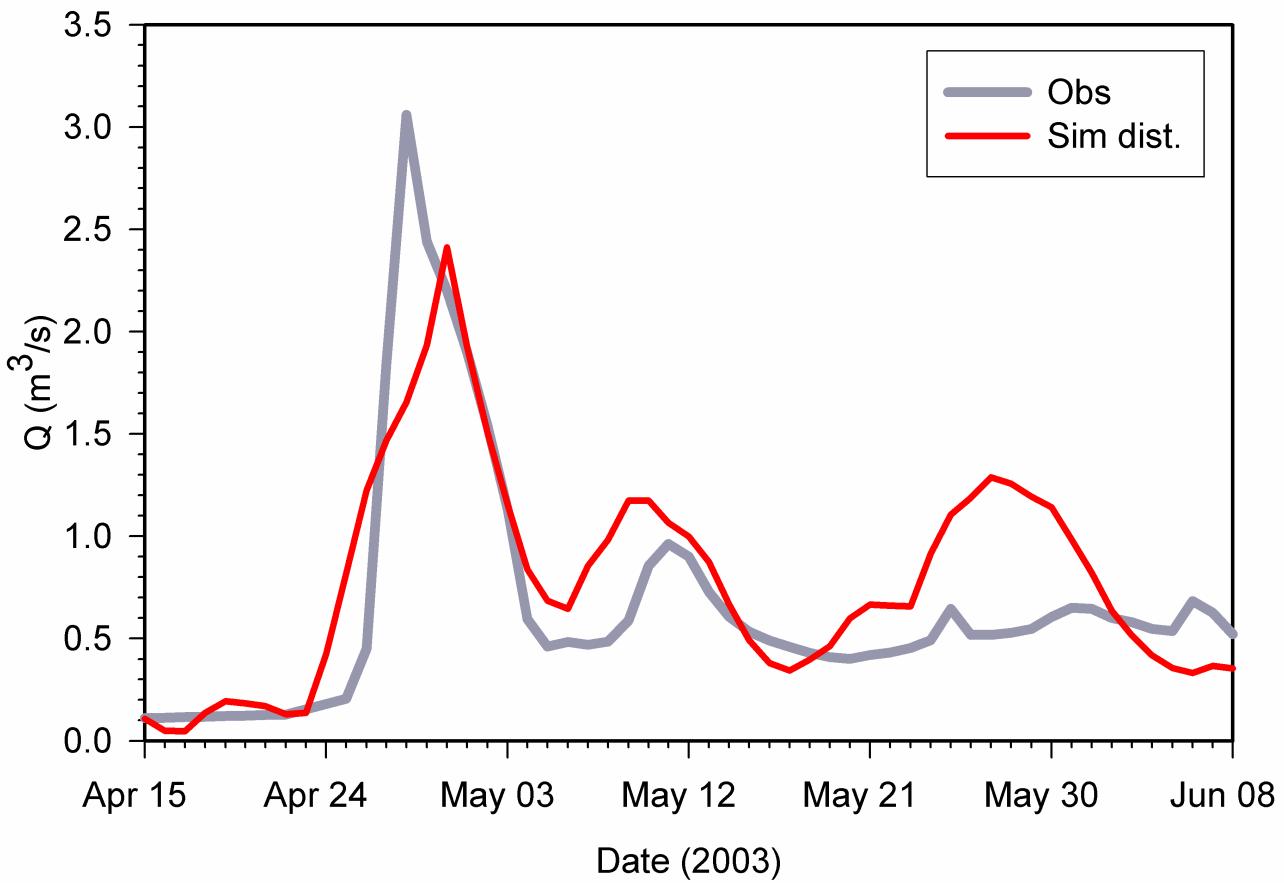
Wolf Creek- discharges (calib.)



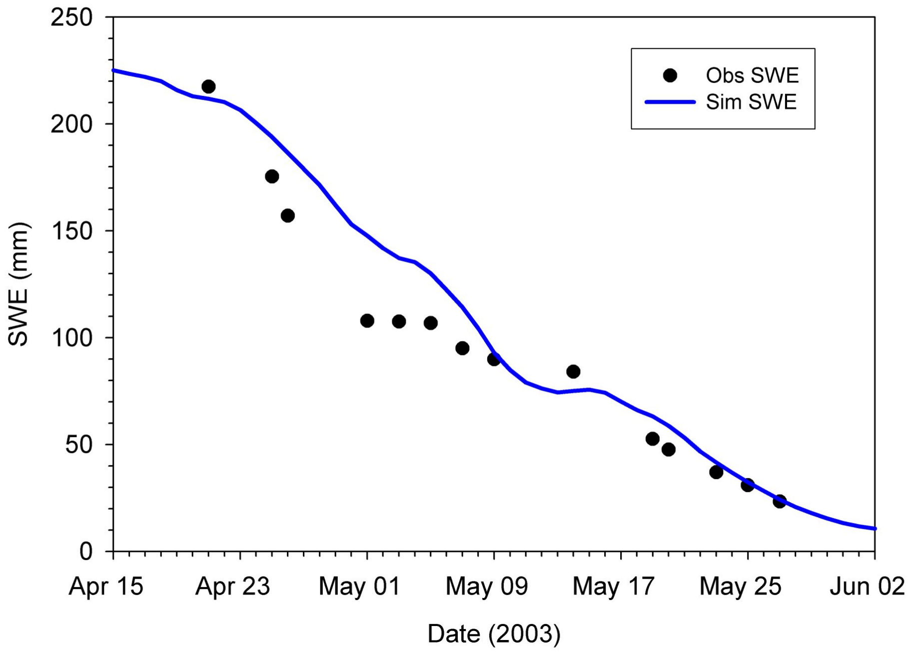
Wolf Creek- discharges (calib.)

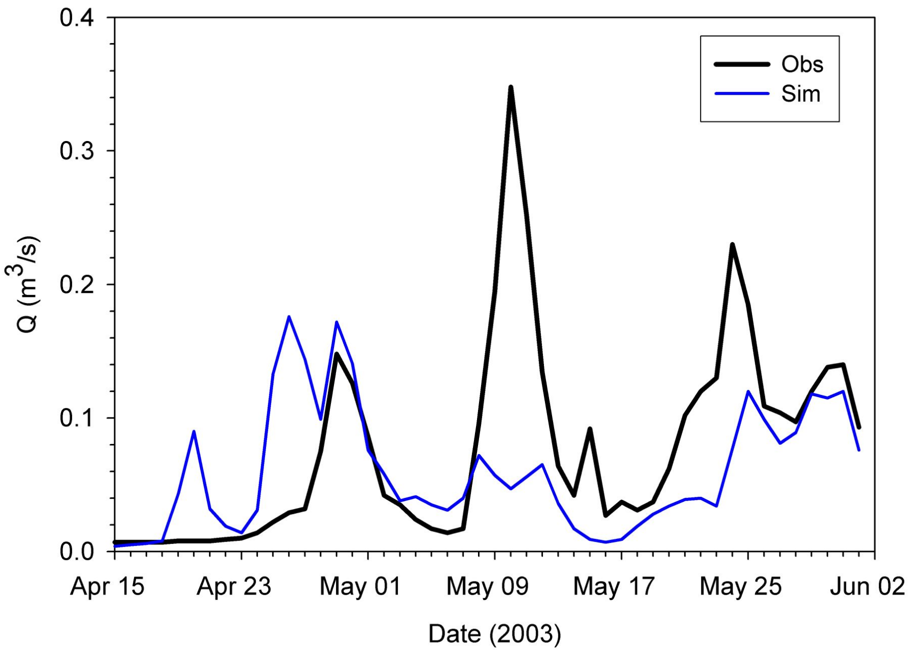


Wolf Creek- discharges (valid.)



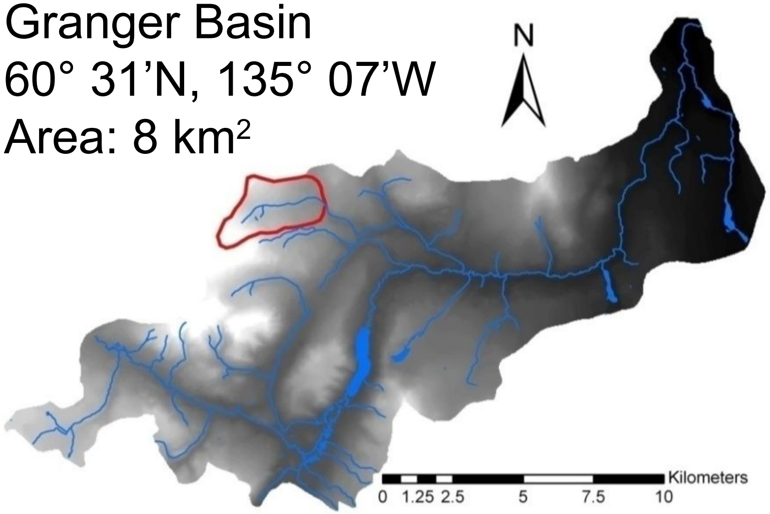
Granger Basin SWE – streamflow





Wolf Creek – Trail Valley Creek

Granger Basin
60° 31’N, 135° 07’W
Area: 8 km²



TVC Basin
68° 45’N, 133° 30’W
Area: 63 km²

Model Regionalisation

- Typically Regionalisation is based on:
  1) regression approach (parameters and basin characteristics).
  2) transference based on similarity/spatial proximity
  3) regional calibration

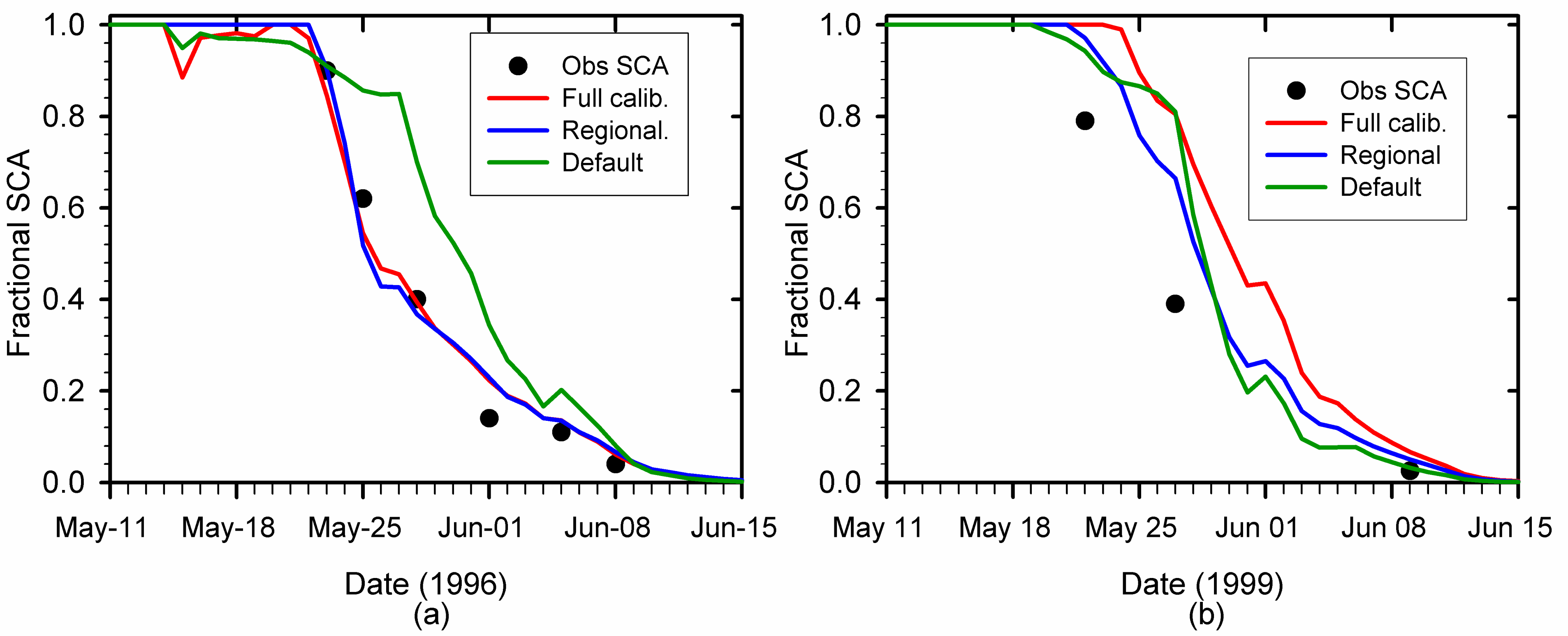
Good for conceptual models – Inappropriate for Physically Based Models

- **Physiographic approach**

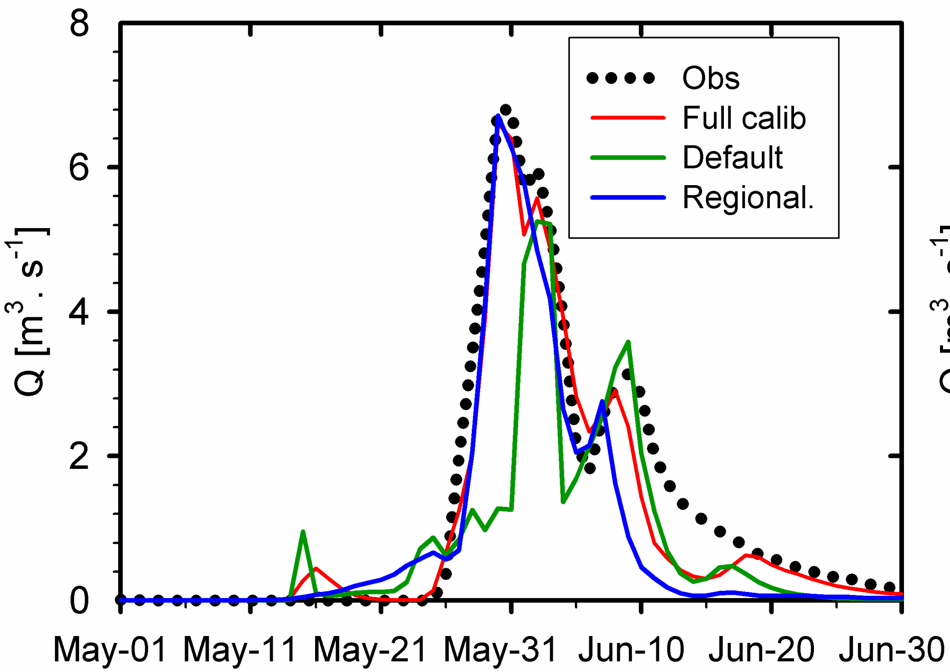
Based on **Self similarity** concept of landscape units: topography, vegetation.

- **Transference of landcover based parameters**

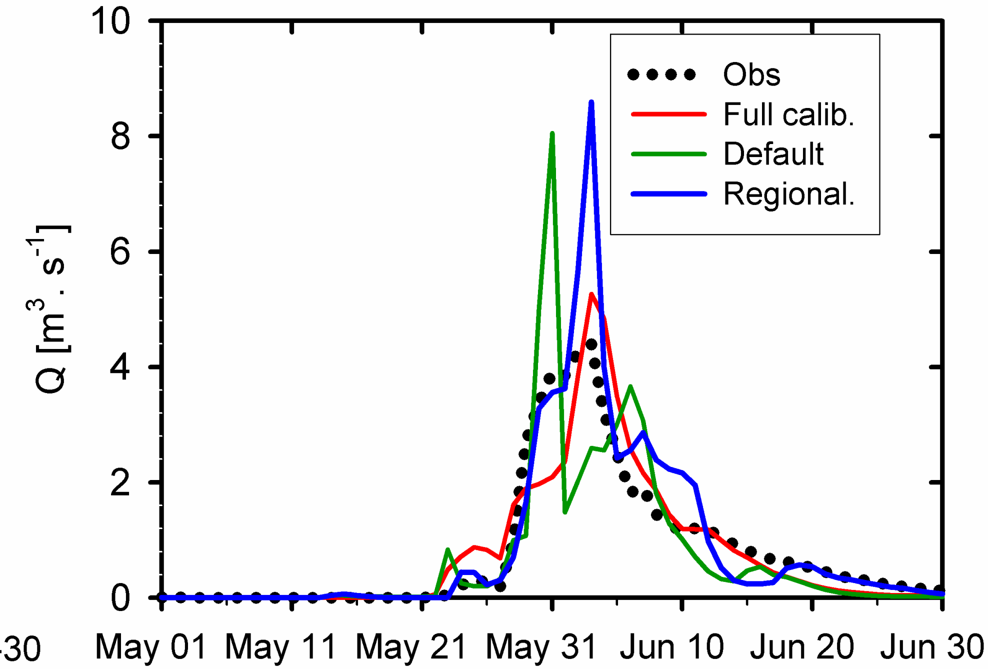
Model Regionalisation TVC - SCA



Model Regionalisation TVC - streamflow



Date (1996)
(a)



Date (1999)
(b)

Conclusions

- From a conceptual perspective, the combination of deductive and inductive modelling approaches proved to be an appropriate methodology for representing and conceptualising landscape heterogeneity in sub-arctic mountain environments.

- The use of a basin-average initial snow-cover proved to have a negative influence in distributed model descriptions.

- Inadequate or unrepresentative forcing data showed also to have unfavourable effects on model predictions.

- Definition of landscape-based parameters appear to be an appropriate methodology for transferring parameters to similar basins, therefore reducing the predictive uncertainty of hydrological and LSS models in ungauged basins.

UNIVERSITY OF SASKATCHEWAN

Canadian Foundation for Climate and Atmospheric Sciences (CFCAS)
Fondation canadienne pour les sciences du climat et de l'atmosphère (FCSCA)

IP3
Improved Processes & Parameterisation for Prediction in Cold Regions

Glacier contribution to the North and South Saskatchewan Rivers

Laura Comeau

Dirk de Boer, Alain Pietroniro, John Pomeroy, Xulin Guo

Environnement Canada   Environment Canada

Canada

Methods

Wastage contribution to streamflow

- Volume-Area scaling relationship
- Net total wastage from 1975 to 1998

$$V = 28.5\,A^{1.357}$$

Chen and Ohmura (1990)

and Bahr *et al.* (1997)

Peyto Glacier contribution to streamflow

- WATFLOOD
- Hydrologic-hypsometric comparison (Silverhorn basin)
- Summer mass balance below the ELA

- Volume-Area scaling
- Net mass balance
- Previous published research results

- Streamflow data available 1967 to 1977

Results: Glacier Wastage and Melt

WATFLOOD results

- Glacier contribution is strongly correlated with % basin glacier cover
- Glacier wastage and Melt (combined) contributes >25% to streamflow in July-Sept for basins with above 1% glacier cover

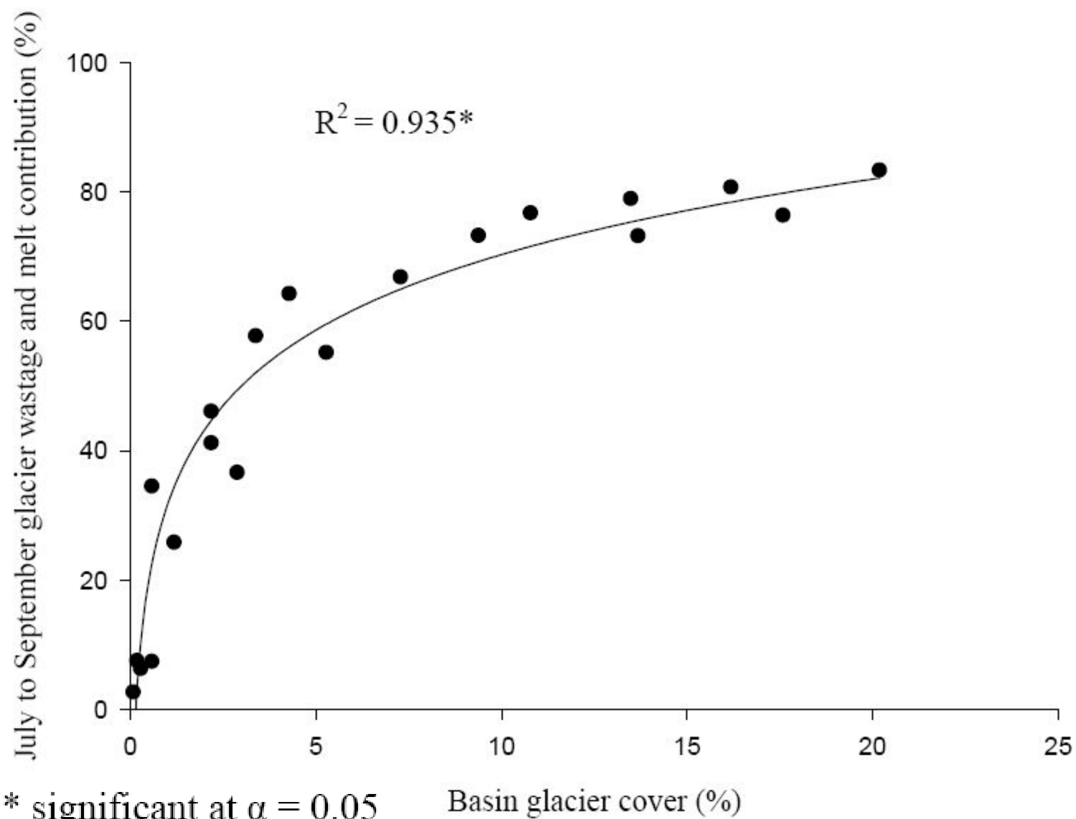
Glacier basin cover	Glacier contribution
>10% (NSRB only	70-80%
1 - 10%	25-70%
< 1%	<10%

- Average % glacier wastage and Melt contribution to July to Sept streamflow for basins of

  N and SSRB:

  1975 51%

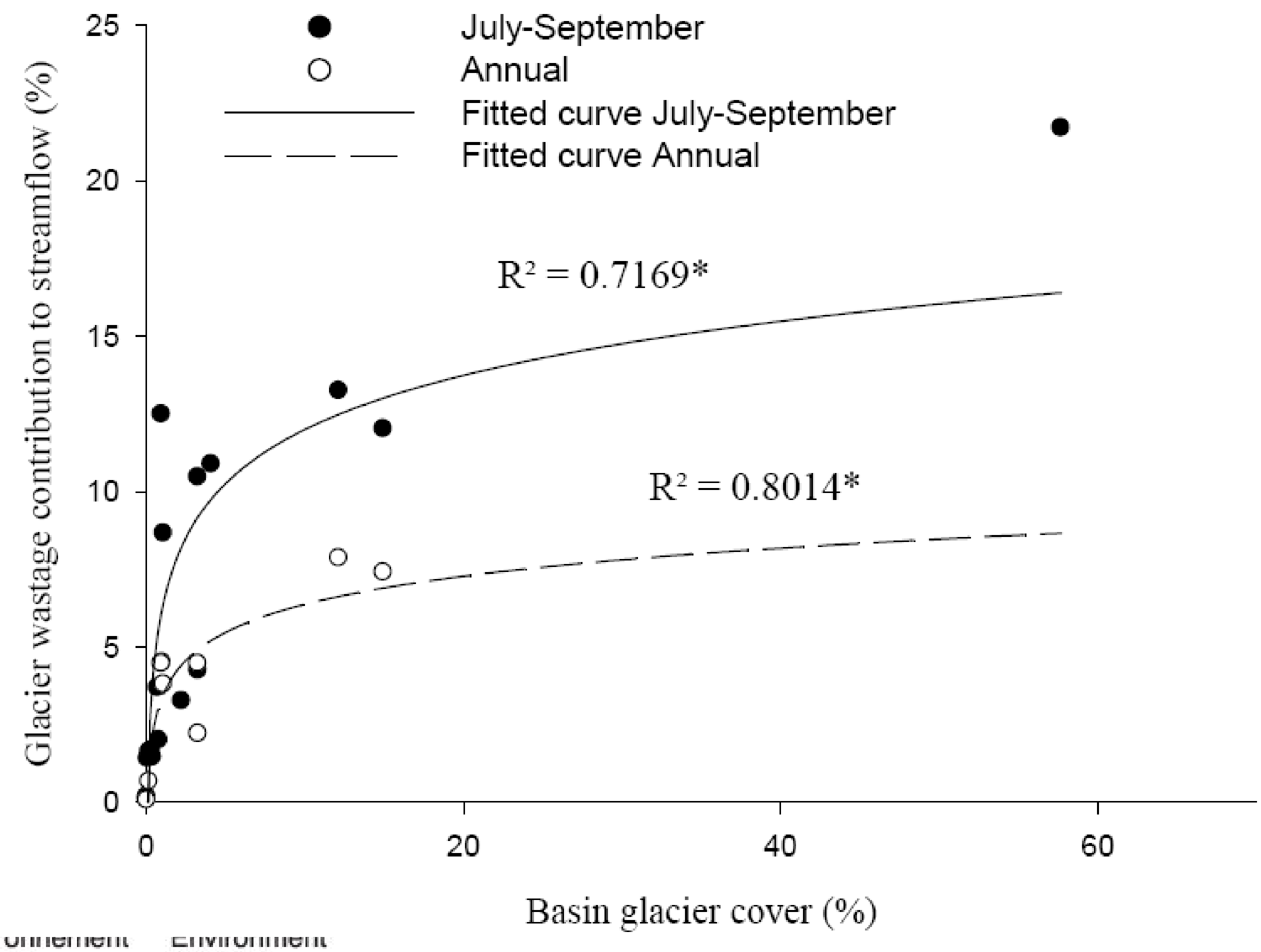
  1998 39%



Results: Wastage (1975-1998)

Wastage contribution to streamflow:

- Ranges from 1 – 22% July-Sept, 1 – 8% annually
- Percentage basin glacier cover ranges from 0.02% - 58%

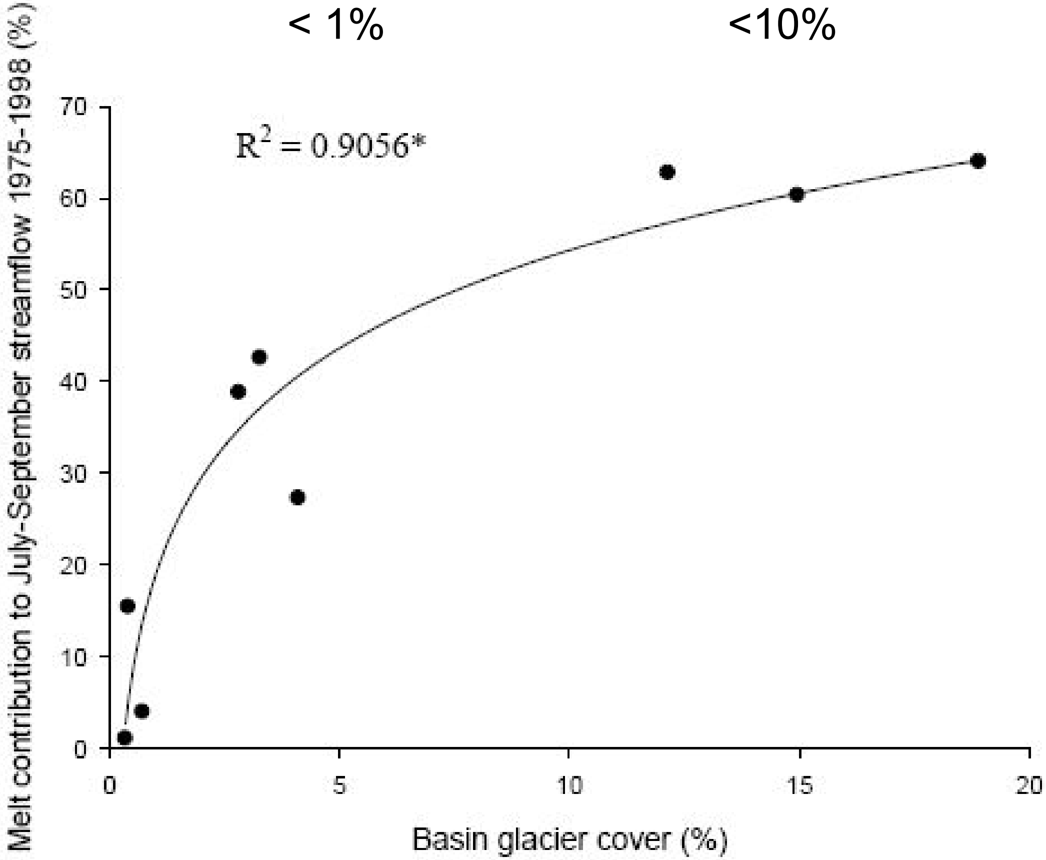


* significant at $\alpha = 0.05$

Results: Melt

- Compare WATFLOOD and Volume-Area glacier contribution results to estimate Melt contribution from 1975 to 1998

Glacier basin cover	Glacier contribution
>10% (NSRB only	60-65%
1 - 10%	25-45%
< 1%	<10%



* significant at α = 0.05

Glacier Contribution Downstream

Edmonton and Calgary 1975 to 1998

Bow River, Calgary

- Wastage (Volume-Area relationship)
- NSRB at N.Sask at Edmonton = 4 000 x10^6 m^3
  2.6% annually
- SSRB at Bow River at Calgary = 1 800 x10^6 m^3
  2.8% annually

- Melt (WATFLOOD and Volume-Area difference)
- NSRB at N.Sask at Edmonton = 14 000 x10^6 m^3
- SSRB at Bow River at Calgary = 4 000 x10^6 m^3

North Saskatchewan River, Edmonton

  - Melt is over double the volume of wastage
  - Regulated streamflow
  - Main direct impact of glacier decline will be the advance of Melt volume towards the spring snowmelt peak timing

Publications

- Comeau, L., A. Pietroniro, M. Demuth, "Glacier Contribution to the North and South Saskatchewan Rivers", Hydrological Processes, CGU Special Edition, (submitted).
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- Dornes, P.F., B. Tolson, B. Davison, A. Pietroniro and J.W. Pomeroy, 2008. "Regionalisation of Land Surface Hydrological Model Parameters in Subarctic and Arctic Environments", Physics and Chemistry of the Earth. Special Issue: From Measurement and Calibration to Understanding and Predictions in Hydrological Modelling, doi:10.1016/j.pce.2008.07.007.

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